Scenarios for a ROB system built with SHARC processors

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1 October 1999
Updated and corrected : 6 , 7 October 1999

Abstract

Two main scenarios are studied. In both scenarios point-to-point links play an essential role. In this note it is assumed that these links are the 40 MByte/s links of the ADSP-21060 SHARC processor. However, similar scenarios will apply for other types of hardware with point-to-point links with sufficient bandwidth.

In the first scenario 4 or 6 ADSP-21060 SHARC based ROBIns are grouped on 6U VME cards. These connect via PCI to "RIO2" like VME CPU cards with interfaces either to the LVL2 or to the Event Builder networks. This scenario follows the "standard model" for the readout system. Several configurations in combination with either 80 or 15 MByte/s links are studied and paper model results with respect to the number of ROBIn cards, number of "RIO2" like VME CPU cards, number of network interfaces, number of crates, utilization of links and message frequencies on the links are presented. With 80 MByte/s links 75 kHz LVL1 trigger rates can be handled, with 15 MByte/s links this is not possible for the grouping factors used. An important difference with other PCI-based designs is that only a single PCI interface on a single PCI segment is used. Hence the message frequency on the PCI bus can be considerably lower than in a system where the ROBIns connect directly to the PCI bus.

In the second scenario 6 or 8 ROBIns are grouped on 9U VME cards. They connect via SHARC links to S-link outputs, which in turn may connect to PCs connecting to the LVL2 and EB networks. Two configurations are studied and paper model results are presented. The second configuration provides support for full RoI fragment building and full event building, but is also more complex. In terms of the amount of hardware needed both configurations form an attractive alternative to the first scenario and are expected to provide sufficient throughput to handle 75 kHz LVL1 trigger rates, with further spare throughput capacity available.

1. Introduction

Two main scenarios are studied. In the first one ADSP-21060 SHARC based ROBIns are grouped on 6U VME cards, which connect to "RIO2" like VME CPU cards (for brevity these cards are referred to as "RIO2" cards) with interfaces either to the LVL2 or to the Event Builder networks. In the second scenario ROBIns are grouped on 9U VME cards. They connect via SHARC links to S-link outputs, which in turn may connect to PCs connecting to the LVL2 and EB networks. All SHARC links are assumed to have a throughput of 40 MByte/s. In both scenarios the Read-Out Links (input S-links) are assumed to connect via the front-panel to S-link daughter boards that each can connect to two S-links.

The ADSP-21160 SHARC-II DSP is a 2.5 times faster alternative for the ADSP-21060 SHARC and has links capable of transferring 100 MByte/s over 10 wires per link (the 21060 links use 6 wires each). As the 21160 is not yet readily available and as current hardware studies are based on the 21060 the scenarios discussed here are mainly for the 21060.

The numbers used are either for a LVL1 trigger rate of 75 kHz or for the nominal rate of about 40 kHz. For a LVL1 rate of 75 kHz the rates for the various trigger menu items were obtained by scaling their exclusive rates with a factor of 75 / nominal rate (~ 40 kHz). However, for low luminosity the frequency for the inner tracker scan was kept at the nominal value (~ 10 kHz). The accept fraction is assumed to be 5 % . Only average rates are considered, it is assumed that ROBIns with high access rates are combined with ROBIns with low access rates in the same groups. In this note RoI requests and LVL2 accepts and rejects at some places are referred to as "control data".

In both scenarios SHARCs that receive data from the ROBIns wait until all fragments from an event have arrived, and next build a single larger fragment for that event which is output. An important property of SHARC links is that all communication via these links is handshaked, giving automatic synchronization between sender and receiver. In some cases event or control data is passed from one SHARC to another SHARC via the SHARC external bus. This is possible, as up to six SHARCs can be connected to a single shared bus without glue logic, while each SHARC is able to write to and read from the internal memory of any of the other SHARCs.

2. Scenario 1, 6U VME, direct connection to LVL2 and EB networks

2.1 Configuration 1, 80 MByte/s LVL2 and EB links, groups of 6 ROBIns

The use of Gigabit Ethernet with an available bandwidth of 80 MByte/s is assumed. A ROB card is assumed to have the structure shown in fig. 1. The card connects via the PCI extension connector of a neighbouring RIO2 to the PCI bus of that card.

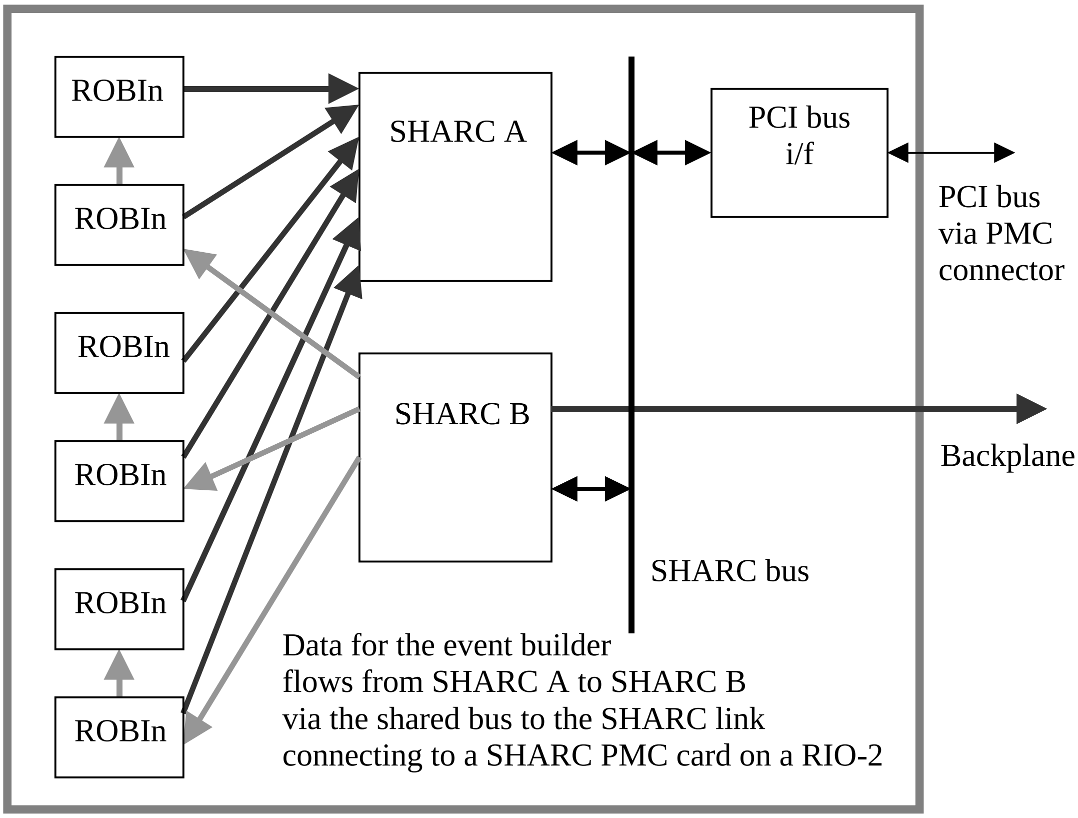


Fig. 1 Structure of a ROB card for configuration 1. Grey arrows pointing to the left and up refer to SHARC links carrying requests, arrows pointing to the right refer to SHARC links carrying event fragment data. All links are used uni-directionally.

A PMC card on this RIO2 is assumed to connect to the LVL2 network. Interfacing to the EB network is done with another RIO2 with a Gigabit Ethernet PMC interface. The other PMC slot of this RIO2 is used for a PMC SHARC card connecting to at maximum 8 SHARC links on a dedicated back plane.

The structure of the ROB card shown in fig. 1 is somewhat arbitrary and may not be optimal. In particular adding a SHARC also connecting to the SHARC bus would allow to have a configuration without the links between the ROBIns carrying requests for data. In view of the desire to minimize cost here we look at a configuration with a minimum number of SHARCs.

Tables 1 to 4 show paper model results for this configuration. In all cases the amount of data can be handled. The message frequency in the ROBIN card becomes high for the low luminosity trigger for the inner tracker, but it is expected that this can be handled by the SHARCs. The utilization of the links to the EB is high. With 80 MByte/s bandwidth the data has to be copied directly from SHARC memory to the network interface, otherwise the PCI bus bandwidth will limit the throughput to about 66 MByte/s at maximum. The number of EB links has to be increased if this is a problem, for the LVL2 links there is no problem. The number of crates is at maximum 43, the number of EB links varies between 64 and 180, the number of LVL2 links is always 257, as a LVL2 link is always coupled to a group of 6 ROBIns.

Discussion : this seems to be a feasible configuration if 50 MByte/s can be transferred via a single LVL2 link (needed for the TRT for the TRT scan). For the EB more data may need to be transferred via a single EB link, however the links with the highest utilization (TRT, muon detectors) receive data from more than 1 ROB card, thus in principle more EB links can be used. The accept rate of 5 % at 75 kHz LVL1 rate could also be regarded as being unrealistically high. Notice that passing the data via the RIO2 with the LVL2 interface and via the VME-bus to the RIO2 with the EB interface is an option. However, this will be problematic if there is more than 1 EB interface per crate, as data transfers to the EB interfaces have to share the VME bus.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	6	6	6	
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	2	1	24	6	27	4	2	66
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	8	1	127	17	11	2	2	168
# of crates (max. 18 slots per crate used)	4	1	22	3	6	2	2	40
Total RoI fragm. rate in ROBIn card (kHz)	3	7	8	13	64	68	72	
Total RoI fragm. rate per LVL2 link (kHz)	3.4	7.1	4.7	6.5	11.7	15.2	19.3	
Utilization of LVL2 link bandwidth (%)	3.5	3.6	19	29	62	23	10	
Number of ROBIn cards per EB link	4	8	1	1	4	8	7	
Total EB fragment rate in ROBIn card	23	23	23	23	23	23	23	
Utilization of EB link bandwidth (%)	90	86	50	49	82	54	16	

Table 1. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 1 ROBin card per LVL2 link, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	6	6	6	
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	4	1	35	5	5	1	1	52
Number of EB links	4	1	43	6	6	2	2	64
# of crates (max. 18 slots per crate used)	4	1	22	3	6	2	2	40
Total RoI fragm. rate in ROBIn card (kHz)	2	4	4	7	62	64	66	
Total RoI fragm. rate per LVL2 link (kHz)	1.8	3.8	2.5	2.8	10.9	12.7	14.9	
Utilization of LVL2 link bandwidth (%)	1.9	1.9	10	16	60	22	9	
Number of ROBIn cards per EB link	8	8	3	3	7	8	7	
Total EB fragment rate in ROBIn card	12	12	12	12	12	12	12	
Utilization of EB link bandwidth (%)	96	46	80	74	80	29	8	

Table 2. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 1 ROBin card per LVL2 link, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	6	6	6	
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	33	5	2	2	2	46
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	8	1	127	17	15	8	4	180
# of crates (max. 18 slots per crate used)	4	1	22	3	8	3	2	43
Total RoI fragm. rate in ROBIn card (kHz)	2	4	11	11	3	5	8	
Total RoI fragm. rate per LVL2 link (kHz)	1.7	3.6	6.5	5.7	1.1	3.3	5.9	
Utilization of LVL2 link bandwidth (%)	1.8	1.8	26	24	4	10	8	
Number of ROBIn cards per EB link	4	8	1	1	3	2	4	
Total EB fragment rate in ROBIn card	23	23	23	23	23	23	23	
Utilization of EB link bandwidth (%)	90	86	50	49	80	86	79	

Table 3. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 1 ROBin card per LVL2 link, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	6	6	6	
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	18	3	1	1	1	26
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	4	1	43	6	8	4	2	68
# of crates (max. 18 slots per crate used)	4	1	22	3	8	2	2	42
Total RoI fragm. rate in ROBIn card (kHz)	1	2	6	6	2	3	4	
Total RoI fragm. rate per LVL2 link (kHz)	0.9	1.9	3.4	2.2	0.6	1.7	3.1	
Utilization of LVL2 link bandwidth (%)	0.9	1.0	14	13	2	5	4	
Number of ROBIn cards per EB link	8	8	3	3	5	4	7	
Total EB fragment rate in ROBIn card	12	12	12	12	12	12	12	
Utilization of EB link bandwidth (%)	95	45	78	72	79	91	83	

Table 4. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 1 ROBin card per LVL2 link, 80 MByte/s output links.

2.2 Configuration 2, 80 MByte/s LVL2 and EB links, groups of 6 ROBIns

Again 80 MByte/s LVL2 and EB links (Gigabit Ethernet) are used, but for interfacing to the LVL2 interface now SHARC links are used that connect via a backplane to a of SHARC on a PMC on a RIO2 card with the LVL2 interface in the other PMC slot. At maximum 8 ROBIn cards can connect to a single LVL2 link. The interfacing to the EB links is done in the same way. The configuration of the ROBIn card is shown in figure 2. One ROBIn card connects only with 2 SHARC links to the backplane as only a limited number of links can be connected, at maximum 10 in the case of 64 free pins on the VME P2 connector. As at maximum 8 * 2 = 16 links in this case connect in groups of 8 to different RIO2 boards this is not a problem for this configuration.

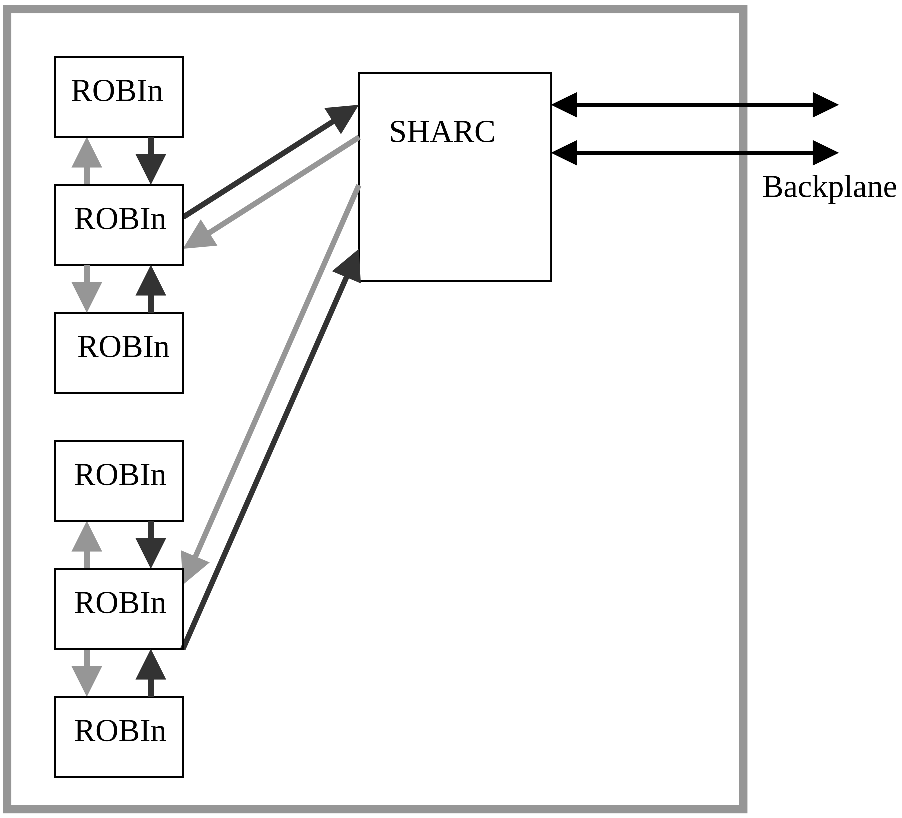


Fig. 2 Structure of ROB card for configuration 2. Grey arrows pointing to the left and between ROBIns refer to SHARC links carrying requests, other arrows refer to SHARC links carrying event fragment data. The two links connecting to the backplane are used bi-directionally.

For the TRT one SHARC link cannot transfer all the data from 6 ROBIns, with 4 ROBIns per ROBIN card there should be no problem, so this is the number used for the TRT.

Tables 5 - 8 show paper model results for this configuration. The number of LVL2 interfaces is considerably less than for the first configuration (75 in stead of 275), the number of crates is again about 40 - 45. Many links run at high utilization, requiring direct transfer from SHARC memory (SHARCs on the PMCs) to network interface. The bi-directional use of the SHARC links in the backplane may give rise to inefficiencies. Furthermore the high message rate in the ROB cards for the inner tracker for the low luminosity trigger in combination with its architecture may prove to be problematic with the 21060 type SHARCs. It is expected that an implementation using the new 21160 SHARC can handle the message rates without problems

Discussion : this configuration may be feasible and is attractive in view of the considerably smaller number of LVL2 interfaces than required for the first configuration. Another argument in favor of this configuration is the absence of direct connections between a PMC connector on a RIO2 board and a ROBIn card : all connections are made with SHARC link connections via a backplane. The new 21160 SHARC may need to be used in view of architecture of the card.

Detector	muoL -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	4	6	6	
Number of cards with ROBIns	32	8	127	17	64	16	14	278
Minimum number of LVL2 links required	2	1	24	6	27	4	2	66
Number of LVL2 links	6	2	32	6	37	6	2	91
Minimum number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	11	2	127	17	10	3	2	172
# of crates (max. 18 slots per crate used)	3	1	16	3	10	2	1	40
Number of ROBin cards per LVL2 link	6	4	4	3	2	3	7	
Total RoI fragm. rate in ROBIn card (kHz)	3.4	7.1	8.2	13.4	42.9	67.5	71.8	
Utilization of LVL2 link bandwidth (%)	18.7	14.6	75	83	73	61	70	
Number of ROBIn cards per EB link	3	4	1	1	6	5	7	
Total EB fragment rate in ROBIn card	23	23	23	23	15	23	23	
Utilization of EB link bandwidth (%)	65	43	50	49	90	36	16	

Table 5. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	4	6	6	
Number of cards with ROBIns	32	8	127	17	64	16	14	278
Minimum number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	5	2	16	3	32	6	2	66
Minimum number of EB links required	4	1	35	5	5	1	1	52
Number of EB links	5	2	48	6	8	3	2	74
# of crates (max. 18 slots per crate used)	3	1	16	2	8	2	1	33
Number of ROBIn cards per LVL2 link	7	4	8	6	2	3	7	
Total RoI fragm. rate in ROBIn card (kHz)	1.8	3.8	4.4	7.2	41.3	63.7	66.0	
Utilization of LVL2 link bandwidth (%)	12.0	7.8	80	89	81	57	65	
Number of ROBIn cards per EB link	7	4	3	3	8	5	7	
Total EB fragment rate in ROBIn card	12	12	12	12	8	12	12	
Utilization of EB link bandwidth (%)	77	23	72	74	60	19	8	

Table 6. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	4	6	6	
Number of cards with ROBIns	32	8	127	17	64	16	14	278
Minimum number of LVL2 links required	1	1	33	5	2	2	2	46
Number of LVL2 links	6	2	43	5	11	2	3	72
Minimum number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	11	2	127	17	22	8	5	192
# of crates (max. 18 slots per crate used)	3	1	22	3	6	2	2	39
Number of ROBIn cards per LVL2 link	6	4	3	3	6	8	5	
Total RoI fragm. rate in ROBIn card (kHz)	1.7	3.6	11.3	10.8	2.0	5.1	7.8	
Utilization of LVL2 link bandwidth (%)	9.5	7.4	76	81	15	79	38	
Number of ROBIn cards per EB link	3	4	1	1	3	2	3	
Total EB fragment rate in ROBIn card	23	23	23	23	15	23	23	
Utilization of EB link bandwidth (%)	65	43	50	49	55	86	63	

Table 7. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	6	6	6	6	4	6	6	
Number of cards with ROBIns	32	8	127	17	64	16	14	278
Minimum number of LVL2 links required	1	1	18	3	1	1	1	26
Number of LVL2 links	5	2	26	5	10	3	2	57
Minimum number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	5	2	77	11	10	6	2	113
# of crates (max. 18 slots per crate used)	3	1	16	3	5	2	1	27
Number of ROBIn cards per LVL2 link	7	4	5	4	6	5	7	
Total RoI fragm. rate in ROBIn card (kHz)	0.9	1.9	5.9	5.7	1.1	2.7	4.1	
Utilization of LVL2 link bandwidth (%)	6.0	3.9	66	53	9	28	30	
Number of ROBIn cards per EB link	7	4	1	1	6	3	7	
Total EB fragment rate in ROBIn card	12	12	12	12	8	12	12	
Utilization of EB link bandwidth (%)	76	22	44	40	63	60	83	

Table 8. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s output links.

2.3 Configuration 3, 15 MByte/s LVL2 and EB links, groups of 4 ROBIns

This configuration is built from VME cards with 4 ROBIns each. The ROB card is assumed to contain the PCI interface chip and to connect to the PCI extension connector of a RIO2 card with the LVL2 interface. The second PMC slot on the RIO2 is used for a PMC card with a PVIC bus interface. The interfacing to the EB interface is via the PVIC bus, at maximum 8 ROB cards are connected to a single EB interface.

The LVL2 and EB links are assumed to be 15 MByte/s (ATM) links. The bandwidth of the links and the grouping chosen does not allow operation at a LVL1 rate of 75 kHz. For the TRT in any case there need to be 1 LVL2 link per ROBIn. Tables 9 - 10 contain paper model results for this configuration. From the tables it is seen that using groups of 4 ROBIns per EB link for the calorimeter results in almost full utilization of these links. Tables 11 - 12 contain results for the case that the PVIC bus is used for connecting to the RIO2 card with the LVL2 interface, while the ROB card connects via PCI to the RIO2 card with the EB interface.

This configuration is inspired by the current implementation of the DAQ-1 project of the Read-Out Crate. It is costly in terms of number of RIO2 cards and PVIC interfaces needed and also does not provide the bandwidth required for event building at 3.75 kHz (5 % of 75 kHz). However, this may be an unrealistic high rate. The LVL2 links can support the traffic generated for a LVL1 rate higher than 40 kHz in the case that the ROB cards connect to the RIO2s with the LVL2 interfaces and if the number of ROBIns per card for the SCT is decreased.

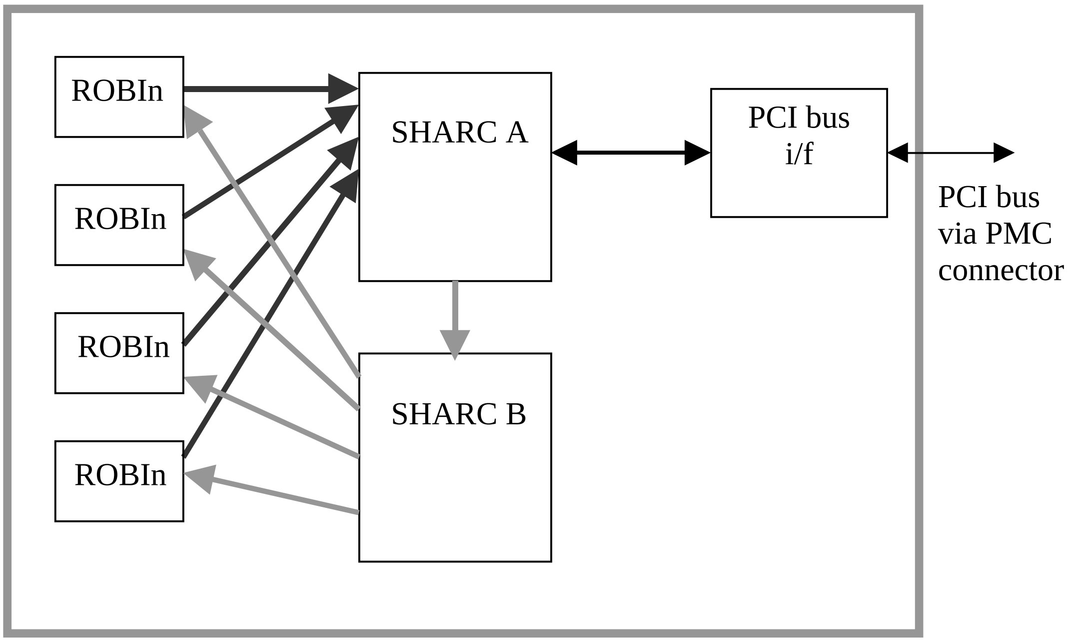


Figure 3. Structure of ROB card for configuration 3. Grey arrows pointing to the left and from SHARC A to SHARC B refer to SHARC links carrying requests, uni-directional arrows pointing to the right refer to SHARC links carrying event fragment data. Only SHARC A is connected to the PCI bus.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	4	4	4	4	1	4	4	
Number of cards with ROBIns	48	12	190	25	256	23	21	575
Minimum number of LVL2 links required	4	1	69	15	138	19	7	253
Number of LVL2 links	48	12	190	25	256	23	21	575
Minimum number of EB links required	21	3	184	24	26	4	1	263
Number of EB links	24	3	190	25	32	4	3	281
# of crates (max. 18 slots per crate used)	8	2	32	5	32	4	3	86
Total RoI fragm. rate in ROBIn card (kHz)	1.2	2.5	2.9	4.8	10.3	42.5	44.0	
Total RoI fragm. rate per LVL2 link (kHz)	1.2	2.5	1.9	2.4	10.3	11.9	13.4	
Utilization of LVL2 link bandwidth (%)	6.7	6.9	36	57	54	80	33	
Number of ROBIn cards per EB link	2	4	1	1	8	6	7	
Total EB fragment rate in ROBIn card	8	8	8	8	2	8	8	
Utilization of EB link bandwidth (%)	86	81	96	94	80	77	30	

Table 9. Low luminosity, nominal LVL1 rate, 1 ROBin card per LVL2 link, LVL2 accept rate = 2.0 kHz, 6 ROBIns per card, 15 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	4	4	4	4	1	4	4	
Number of cards with ROBIns	48	12	190	25	256	23	21	575
Minimum number of LVL2 links required	2	1	92	12	5	5	4	121
Number of LVL2 links	48	12	190	25	256	23	21	575
Minimum number of EB links required	21	3	180	24	34	20	9	291
Number of EB links	24	4	190	25	37	23	11	313
# of crates (max. 18 slots per crate used)	8	2	32	5	37	4	4	92
Total RoI fragm. rate in ROBIn card (kHz)	0.6	1.3	4.0	3.8	0.3	1.8	2.7	
Total RoI fragm. rate per LVL2 link (kHz)	0.6	1.3	2.5	1.9	0.3	1.2	2.1	
Utilization of LVL2 link bandwidth (%)	3.3	3.4	48	45	2	19	15	
Number of ROBIn cards per EB link	2	4	1	1	7	1	2	
Total EB fragment rate in ROBIn card	8	8	8	8	2	8	8	
Utilization of EB link bandwidth (%)	84	60	95	93	91	84	80	

Table 10. High luminosity, nominal LVL1 rate, 1 ROBin card per LVL2 link, LVL2 accept rate = 2.0 kHz, 6 ROBIns per card, 15 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	4	4	4	4	1	4	4	
Number of cards with ROBIns	48	12	190	25	256	23	21	575
Minimum number of LVL2 links required	4	1	69	15	138	19	7	253
Number of LVL2 links	6	2	95	25	256	23	7	414
Minimum number of EB links required	21	3	184	24	26	4	1	263
Number of EB links	48	12	190	25	256	23	21	575
# of crates (max. 18 slots per crate used)	6	2	32	5	43	4	4	96
Number of ROBIn cards per LVL2 link	8	6	2	1	1	1	3	
Total RoI fragm. rate in ROBIn card (kHz)	1.2	2.5	2.9	4.8	10.3	42.5	44.0	
Total RoI fragm. rate per LVL2 link (kHz)	6.8	13.1	3.0	2.4	10.3	11.9	18.2	
Utilization of LVL2 link bandwidth (%)	53.4	41.6	72	57	54	80	99	
Total EB fragment rate in ROBIn card	8	8	8	8	2	8	8	
Utilization of EB link bandwidth (%)	43	20	96	94	10	13	4	

Table 11. Low luminosity, nominal LVL1 rate, 1 ROB card per EB link, LVL2 accept rate = 2.0 kHz, 6 ROBIns per card, 15 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	4	4	4	4	1	4	4	
Number of cards with ROBIns	48	12	190	25	256	23	21	575
Minimum number of LVL2 links required	2	1	92	12	5	5	4	121
Number of LVL2 links	6	2	95	13	32	6	4	158
Minimum number of EB links required	21	3	180	24	34	20	9	291
Number of EB links	48	12	190	25	256	23	21	575
# of crates (max. 18 slots per crate used)	6	2	32	5	32	3	4	84
Number of ROBIn cards per LVL2 link	8	6	2	2	8	4	5	
Total RoI fragm. rate in ROBIn card (kHz)	0.6	1.3	4.0	3.8	0.3	1.8	2.7	
Total RoI fragm. rate per LVL2 link (kHz)	3.4	6.5	4.1	2.6	0.7	3.6	6.4	
Utilization of LVL2 link bandwidth (%)	26.6	20.7	97	87	15	74	80	
Total EB fragment rate in ROBIn card	8	8	8	8	2	8	8	
Utilization of EB link bandwidth (%)	42	20	95	93	13	84	42	

Table 12. High luminosity, nominal LVL1 rate, 1 ROB card per EB link, LVL2 accept rate = 2.0 kHz, 6 ROBIns per card, 15 MByte/s output links.

3. Scenario 2, 9U VME, S-link output

3.1 Introduction

This scenario is motivated by the realization that in the previous scenario connecting to the LVL2 and EB networks requires many RIO2s + network interfaces on PMC cards. These tend to be costly items, while PC hardware with the same type of functionality may be considerably cheaper. However, using crate mechanics for the ROB system is desirable in view of reliability, easy access, cooling, etc. . To reduce the number of RIO2s there seem to be three different possibilities :

- provide each ROB card with its own network interface(s). This is an interesting possibility, but it is not at all clear that this can be done in a cost-effective way in the high-energy physics community,
- use PC motherboards with standard network interfacing in a crate environment and connect ROB cards to the PCI bus. This requires special mechanics, i.e. non-standard crates,
- use unidirectional point-to-point links for output of the ROB data to standard PCs that connect to the LVL2 and EB networks (see figure 4). These PCs then need to have PCI cards connecting to these point-to-point links. The S-link would be a suitable candidate for such a link. It is well known in our community how to design S-link hardware, while also a probably suitable commercial PCI S-link destination card is available. RoI requests and LVL2 accepts/rejects will have to be passed to the ROBs via a separate network connection.

The last possibility, although different from the "standard model" of the read-out organization, seems to be of interest and can be implemented in a straightforward way with SHARCs (or comparable combinations of processors and point-to-point links). To distinguish this scenario from the conventional one the ROBs could be referred to

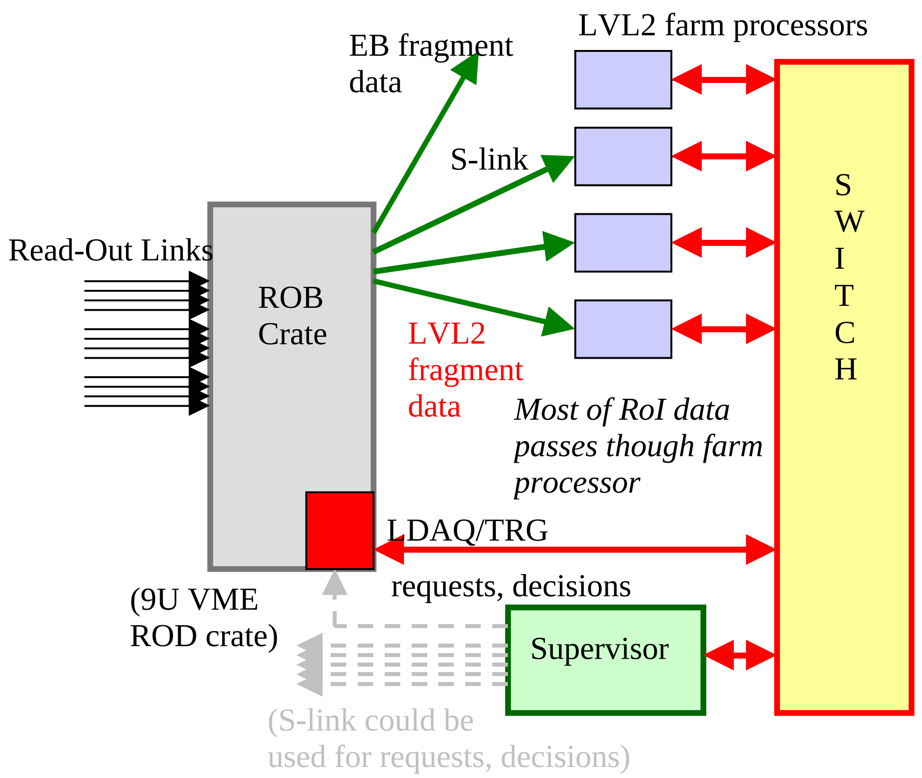


Figure 4. A system in which the event data is output via S-links directly to the LVL2 farm processors and to the Event Builder (or to Event Filter processors connecting to the Event Builder network). In the figure it is suggested that S-links could be used for transmitting control data from the supervisor to the ROB crates. This is a possibility, but in this note it is assumed that control data is sent to the ROB crate via a standard network.

as "intermediate ROBs" or "iROBs", as this system could be inserted between the RODs and the ROBs in the conventional architecture. Obviously, the latter scheme is non-optimal but not impossible.

For crate mechanics a larger format than the 6U format is attractive in view of increasing the number of ROBIns per ROB card. A possibility is to 9U VME crates, which probably also will be used for the RODs. On a single 9U card 8 S-link interfaces could be mounted, again assuming that 2 S-links can connect to a single PMC card size daughterboard. Two possible configurations are discussed :

- identical cards, each with 6 ROBIns and 2 output S-links,
- separate input and output cards with 8 ROBIns and 8 output S-links each.

In both cases it is assumed that each crate contains one general-purpose CPU card connected to the same network as the PCs and running LynxOS or Linux. This CPU is to be used for setting up the system (including booting of the SHARCs either via VME-bus or via SHARC links) and for receiving and passing RoI requests and LVL2 accepts/rejects.

3.2 Configuration 1, 6 ROBIns and 2 output S-links per card

For this configuration 9U cards may not be necessary, if the S-link outputs can be located at the back of a 6U crate and as 6 ROBIns probably can be placed on a normal 6U VME card. However, if this is possible in a 9U environment one could have 8 ROBIns per 9U VME card. Here we will assume that there are 6 ROBIns per card. A possible architecture of the card is presented in figure 5. Figure 6 shows how the control tree of SHARCs (SHARCs D of figure 5) can be organized if 5 SHARC link connections via the backplane are available. The idea here is that RoI requests and accepts/rejects are passed via VME to the SHARC at the root of the tree, which passes and replicates these as needed. The VME interface on each card can provide support for booting, monitoring and debugging of the system. Requests for data and rejects are passed via the tree of SHARCs of figure 6, as otherwise the host CPU has to pass the requests and rejects for each card individually via the VME bus.

The tables 13 – 16 contain paper model results for the average utilization of the S-links, assuming that a single S-link can transfer 80 MByte/s. As can be seen in all cases the 514 S-links would provide sufficient bandwidth for transporting the data. The message frequencies in each card for the inner tracker are relatively high, but can probably be handled by the SHARCs. The total number of ROB cards is 257, with 20 cards per crate 13 crates would be needed. If it is required that the data passed to a single crate all comes from the same subdetector 15 crates are needed (the muon trigger and precision detectors are considered as a single subdetector). The tables show that in all cases one S-link per board (i.e. per 6 ROBIns) could transport the data for the LVL2 system as well as the data for the Event Builder, so that 257 links would be needed in stead of 514.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	2	1	24	6	27	4	2	66
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	32	8	127	17	43	16	14	257
Total RoI fragm. rate in ROBIn card (kHz)	3	7	8	13	64	68	72	
Total RoI fragm. rate per LVL2 link (kHz)	3.4	7.1	4.7	6.5	11.7	15.2	19.3	
Utilization of LVL2 link bandwidth (%)	3.5	3.6	19	29	62	23	10	
Total EB fragment rate in ROBIn card	23	23	23	23	23	23	23	
Utilization of EB link bandwidth (%)	23	11	50	49	21	7	2	

Table 13. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 6 ROBIns per card, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	4	1	35	5	5	1	1	52
Number of EB links	32	8	127	17	43	16	14	257
Total RoI fragm. rate in ROBIn card (kHz)	2	4	4	7	62	64	66	
Total RoI fragm. rate per LVL2 link (kHz)	1.8	3.8	2.5	2.8	10.9	12.7	14.9	
Utilization of LVL2 link bandwidth (%)	1.9	1.9	10	16	60	22	9	
Total EB fragment rate in ROBIn card	12	12	12	12	12	12	12	
Utilization of EB link bandwidth (%)	12	6	27	26	11	4	1	

Table 14. Low luminosity, nominal LVl1 rate, LVL2 accept rate = 3.75 kHz, 6 ROBIns per card, 80 MByte/s output links.

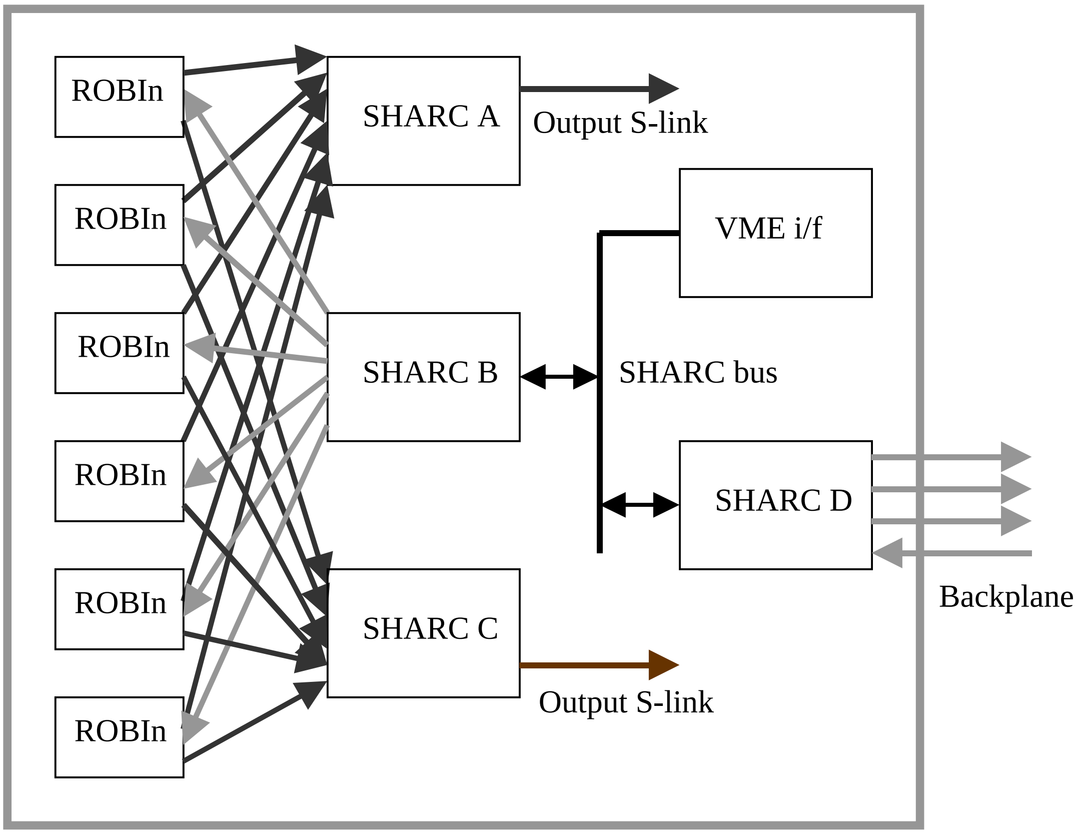


Figure 5. ROB card with 6 ROBIns and 2 S-link outputs, one for LVL2 data and the other for EB data. Arrows pointing to the right refer to SHARC links used for transferring event data. The grey arrows pointing to the left and from and to SHARC D refer to SHARC links transferring requests.

From tables 13 - 16 one sees that also 8 ROBIns per card would be possible, if in a 9U crate the output S-links can be connected at the rear of the crates. The total number of S-links (assuming again separate links for data for the LVL2 system and for the Event Builder) would then reduce to 386, the total number of cards to 193 and the minimal number of crates to 10.

With 120 or 160 ROBIns per crate the frequency of RoI requests sent to each crate can become high. In the following discussion it is assumed that the ROBs in one crate receive data only from one subdetector. The RoI request rate per crate cannot exceed the total RoI request rate for the subdetector mapped onto the ROBs in the crate. The paper model provides the rates per subdetector, see tables 17 - 20. The highest rate occurs for the em calorimeter for high luminosity at a LVL1 rate of 75 kHz. The ROBs for this detector need to occupy about 7 crates. If the ROBs in one crate are receiving data from a segment (a "tower") of the calorimeter the input message rate per crate can be expected to be well below 50 kHz. For all detectors the upper limit for the RoI request rate is then 50 kHz per crate for a LVL1 trigger rate of 75 kHz or 32 kHz for a LVL1 trigger rate of 40 kHz. The input message rates per crate can be reduced if RoI requests for different events are grouped. This could be done in the farm processors by maintaining for each crate a queue of RoI requests, which are sent together as soon as for example 2 or 3 requests for a crate are ready for transmission. Another possibility consists of sending the RoI requests first to a subset of the farm processors which group the requests before passing them to the ROB crates.

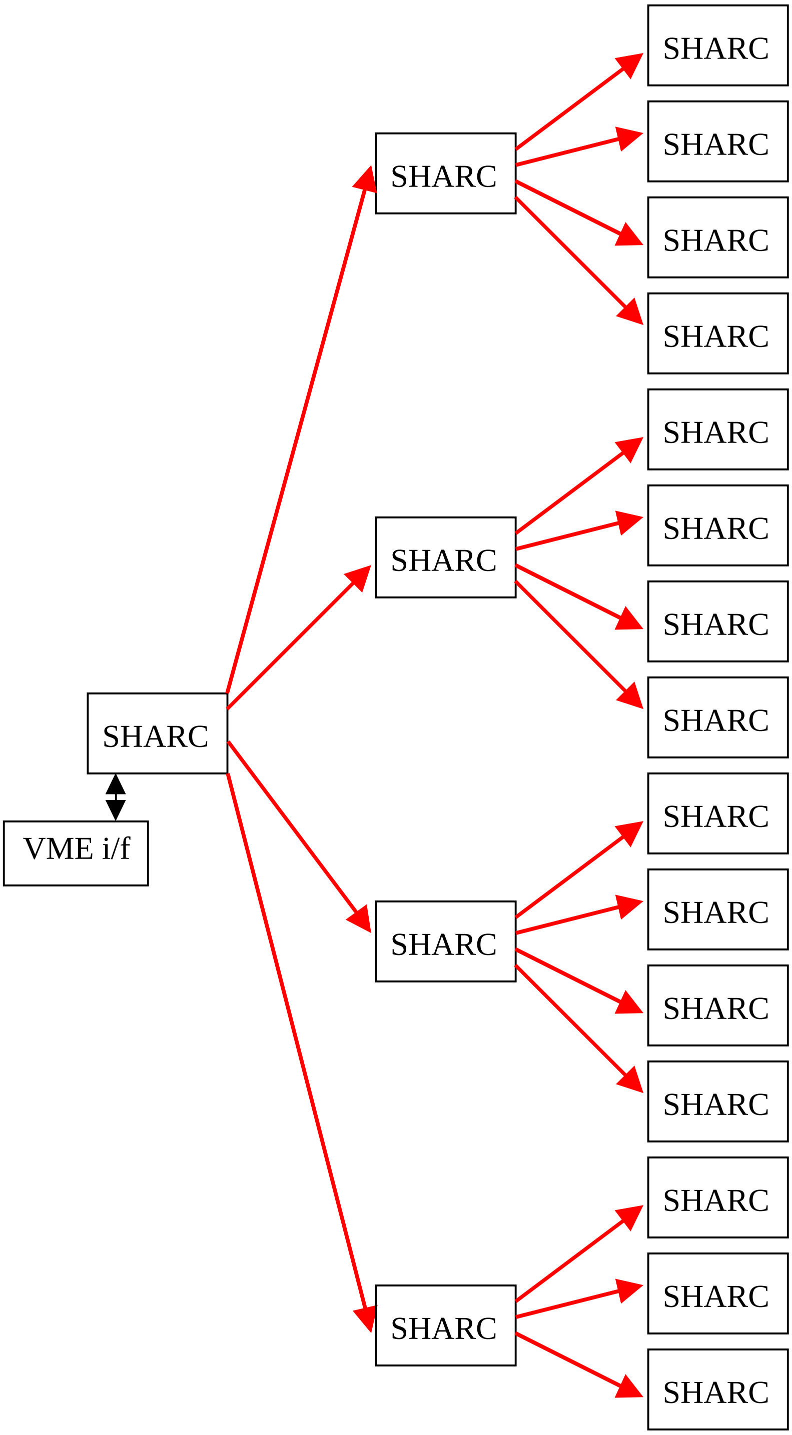


Figure 6. Tree of SHARCs built from the SHARC D processors of figure 5. The arrows refer to SHARC links providing connections between the cards via a dedicated backplane. RoI requests and accept/ rejects are passed via the VME bus to the SHARC at the left of the figure, which replicates these if needed and passes the information to via the SHARC bus to SHARC B on the same card and via the SHARC links to the SHARCs connected to it. These in turn replicate the requests and accept/rejects if needed and pass the information to the SHARCs B on the cards they are residing on and via the SHARC links to the SHARCs at the right of the figure. These SHARCs pass the information to the SHARCs B on the cards they are residing on. With the tree shown 20 cards can be serviced.

Mapping towers of the complete experiment onto the ROB crates in stead of mapping single subdetectors could also result in lower input message rates per crate. However, for sequential triggers then several requests per RoI may need to be sent to a single crate. As the average number of steps is small (1.8 for low luminosity and 1.5 for high luminosity) this may still be acceptable.

The average event fragment output rate per link to the LVL2 system can also be read from tables 13 - 16. Only for low luminosity for the subdetectors for the inner tracker the rates exceed 10 kHz.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	33	5	2	2	2	46
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	32	8	127	17	43	16	14	257
Total RoI fragm. rate in ROBIn card (kHz)	2	4	11	11	3	5	8	
Total RoI fragm. rate per LVL2 link (kHz)	1.7	3.6	6.5	5.7	1.1	3.3	5.9	
Utilization of LVL2 link bandwidth (%)	1.8	1.8	26	24	4	10	8	
Total EB fragment rate in ROBIn card	23	23	23	23	23	23	23	
Utilization of EB link bandwidth (%)	23	11	50	49	28	43	23	

Table 15. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, 6 ROBIns per card, 80 MByte/s output links.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of cards with ROBIns	32	8	127	17	43	16	14	257
Minimum number of LVL2 links required	1	1	18	3	1	1	1	26
Number of LVL2 links	32	8	127	17	43	16	14	257
Minimum number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	32	8	127	17	43	16	14	257
Total RoI fragm. rate in ROBIn card (kHz)	1	2	6	6	2	3	4	
Total RoI fragm. rate per LVL2 link (kHz)	0.9	1.9	3.4	2.2	0.6	1.7	3.1	
Utilization of LVL2 link bandwidth (%)	0.9	1.0	14	13	2	5	4	
Total EB fragment rate in ROBIn card	12	12	12	12	12	12	12	
Utilization of EB link bandwidth (%)	12	6	27	26	15	23	12	

Table 16. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 6 ROBIns per card, 80 MByte/s output links.

RoI type (rates in kHz)	em	had	mu	jet	scan	Total
muon detector	0.0	0.0	46.9	0	0.0	46.9
em calorimeter	28.4	5.0	18.8	6.4	0	58.6
hadron calorimeter	4.7	5.0	18.8	6.4	0.0	34.9
TRT	2.6	1.0	35.2	0.0	9.9	48.6
SCT, pixels	2.6	1.0	35.2	0.0	9.9	48.6

Table 17. RoI request rates per subdetector, low luminosity, LVL1 rate = 75 kHz.

RoI type (rates in kHz)	em	had	mu	jet	scan	Total
muon detector	0.0	0.0	25.1	0	0.0	25.1
em calorimeter	15.2	2.7	10.0	3.4	0	31.3
hadron calorimeter	2.5	2.7	10.0	3.4	0.0	18.7
TRT	1.4	0.5	18.8	0.0	9.9	30.6
SCT, pixels	1.4	0.5	18.8	0.0	9.9	30.6

Table 18. RoI request rates per subdetector, low luminosity, nominal LVL1 rate.

RoI type (rates in kHz)	em	had	mu	jet	Total
muon detector	0.0	0.0	23.8	0	23.8
em calorimeter	64.9	1.4	9.5	4.7	81.8
hadron calorimeter	10.8	1.4	9.5	4.7	27.7
TRT	5.8	0.3	17.8	0.0	24.2
SCT, pixels	5.8	0.3	17.8	0.0	24.2

Table 19. RoI request rates per subdetector, high luminosity, LVL1 rate = 75 kHz.

RoI type (rates in kHz)	em	had	mu	jet	Total
muon detector	0.0	0.0	12.5	0	12.5
em calorimeter	34.1	1.4	5.0	2.5	42.9
hadron calorimeter	5.7	1.4	5.0	2.5	14.5
TRT	3.1	0.3	9.4	0.0	12.7
SCT, pixels	3.1	0.3	9.4	0.0	12.7

Table 20. RoI request rates per subdetector, high luminosity, nominal LVL1 rate.

3.3 Configuration 2, 9U VME, 8 ROBIns per card, S-link outputs on separate cards

With S-link outputs and ROBIns implemented together on a single board the number of output S-links is fixed by the number of ROBIns per group. With 6 or 8 ROBIns per group many more S-links are needed than dictated by the bandwidth requirements. By using separate cards with ROBIns and S-link outputs the number of S-links can be optimized with respect to the bandwidth requirements and to the data volume that can be passed from S-link interface to network interface in the PCs taking care of transferring data from the S-links to the LVL2 and EB networks.

A possible choice for the organization in a 9U VME crate consists of using 16 slots for boards with ROBIns and the rest of the slots for at maximum 4 boards with output S-links and for one general purpose CPU board with network connection as in the configuration of section 3.2. A single crate would then contain 128 ROBIns and at maximum 32 S-link sources. The connections between ROBIns and S-link sources can be made with SHARC links implemented on a backplane. With 4 output SHARC links per ROBIn card this seems to be feasible, giving 64 links in the backplane with a total bandwidth of 2.56 GByte/s, i.e. a maximum output bandwidth of 80 MByte/s per S-link. This is also the maximum throughput of a SHARC receiving data via its links and passing this data to a S-link due to internal bandwidth limitations of the SHARC for this type of traffic (the data has to be transferred twice over an internal bus with 160 MByte/s bandwidth).

Figure 7 shows a possible architecture of the input card. The SHARCs on the card are connected such that data from each ROBIn can be passed to any of the 4 output links. With the SHARCs G a tree for passing control data can be constructed as shown in figure 8. Event fragment data and control data are passed only via SHARC links, which are all used uni-directionally, with the exception of the input board containing the SHARC at the root of the tree of figure 8. Control data is passed via the VME and SHARC bus to SHARC G on this board. On the other boards the SHARC bus is only used for booting and for monitoring / debugging. From the VME bus each SHARC on the input board can be reached directly or via at most one intermediate SHARC.

Figure 9 shows a possible architecture of the output board. The 16 input links are via a backplane connected to the 16 input boards. Data arriving on one of the input links can be routed to any of the output S-links. Event fragment data only flows via SHARC links, which all are used uni-directionally. The SHARC bus is only used for booting and for monitoring / debugging. From the VME bus each SHARC on the output board can be reached directly or via at most one intermediate SHARC. As the size of the event fragments can be of the same order as the size of the SHARCs internal memory (512 kByte) external memory may be needed for the SHARCs interfacing to S-links connected to the Event Builder. There is probably no need for external memory if data of an event can be sent to the destination in a number of small chunks that will be ordered by the destination. RoI fragments are much smaller with the exception of data from the inner tracker scan, but these could be handled in the same way as event data for the Event Builder.

In the figures 10 and 11 it is shown how the connections between the input and output boards and for the control tree between the SHARCs on the boards in different slots of a crate can be made with a dedicated backplane.

The tables 21 - 24 contain paper model results for the minimum number of output S-links required. The "maximum fragment rate per LVL2 link" in the tables was calculated by dividing the RoI request rate for the complete subdetector by the number of LVL2 links per crate. The tables show that the complete ROB system could be implemented in 14 9U crates. For the muon precision chambers and trigger detector together 2 crates would be sufficient, hence it would be possible to reduce this number to 13 crates. In that case the maximum number of output S-links is 13 * 32 = 416, considerably above the number required at 75 kHz for low and high luminosity. If 3 crates in stead of 2 crates for the TRT are used (2 with 11 input cards, 1 with 10 input cards) and with a sufficient number of S-links per crate (but not more than 32) the total output bandwidth of the system can be such that all rates or all data volumes can be doubled with respect to the requirements for the low luminosity trigger at a LVL1 rate of 75 kHz.

In this scenario the ROBIns in a crate share the same set of output S-links. In combination with the fragment building inside a crate this results in an event fragment rate per output S-link used for connecting to the LVL2 system which is equal to the RoI request rate for the crate divided by the number of these output links. Hence the fragment rate can be reduced by using more S-links for outputting to the LVL2 system. The same is true for the rate of event fragments to be passed to the Event Builder. From the tables 21 - 24 it is seen that by adding a relative small number of output S-links the highest fragment rates for links connecting to the LVL2 system can be reduced considerably. The tables 25 - 28 illustrate this. The same number of links to the LVL2 and EB systems is used in these tables. Finally the tables 29 - 32 show a possible choice for the number of links resulting in a maximum event fragment rate of 4 kHz for output S-links connecting to the LVL2 system and of 1 kHz for output S-links connecting to the EB system, in combination with less than 50 % occupation of the output S-links connecting to the LVL2 system. For the TRT 3 crates in stead of 2 are used. Also in these tables the same number of links is used. The maximum LVL2 fragment rate is a pessimistic estimate and in particular will be lower for the muon detectors and for the electromagnetic calorimeter with appropriate mapping of the detector onto the ROB crates.

The type of hardware described probably could also be used for further fragment and event building (see figure 12). Crates with input boards only partially populated with components (see figure 13) could have 32 inputs (i.e. only 2 ROBIns per input board) and 32 outputs, would have a throughput of at maximum 2.56 GByte/s and can be expected to be capable of doing full event or RoI fragment building at that speed (the SHARCs in these "builder" crates may need to have additional external memory, see also previous page). Six additional "builder" crates can handle all necessary event and fragment building for a LVL1 trigger rate of 75 kHz at low luminosity if this expectation is correct and as can be seen from table 33. The table shows that with the choices made for number of output links per ROB crate each ROB crate can be connected with 1 or more S-links to each of the builder crates. As complete RoI fragment building and event building is done the message rate per output S-link would be 3.75 kHz / 116 = 0.032 kHz for the links connecting to the Event Builder and 188.9 kHz / 68 = 2.8 kHz for the links connecting to the LVL2 processor farm. The rate of 188.9 kHz is the sum of the request rates for the muon detectors (46.9 kHz), the electromagnetic calorimeter (58.6 kHz), the hadron calorimeter (34.9 kHz) and the inner tracker (48.6 kHz).

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	2	1	24	6	27	4	2	67
Number of LVL2 links	2	1	24	6	28	4	2	67
Max. fragment rate per LVL2 link (kHz)	46.9	46.9	14.7	5.8	3.5	12.2	24.3	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	8	1	66	9	10	2	1	97
Fragment rate per EB link	0.9	3.8	0.3	0.4	0.8	1.9	3.8	
Number of output links per crate	5	2	15	15	19	6	3	164

Table 21. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	2	1	18	3	26	4	2	56
Max. fragment rate per LVL2 link (kHz)	25.1	25.1	10.4	6.2	2.4	7.7	15.3	
Number of EB links required	4	1	35	5	5	1	1	52
Number of EB links	4	1	36	5	6	1	1	54
Fragment rate per EB link	1.0	2.0	0.3	0.4	0.7	2.0	2.0	
Number of output links per crate	3	2	9	8	16	5	3	110

Table 22. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz.

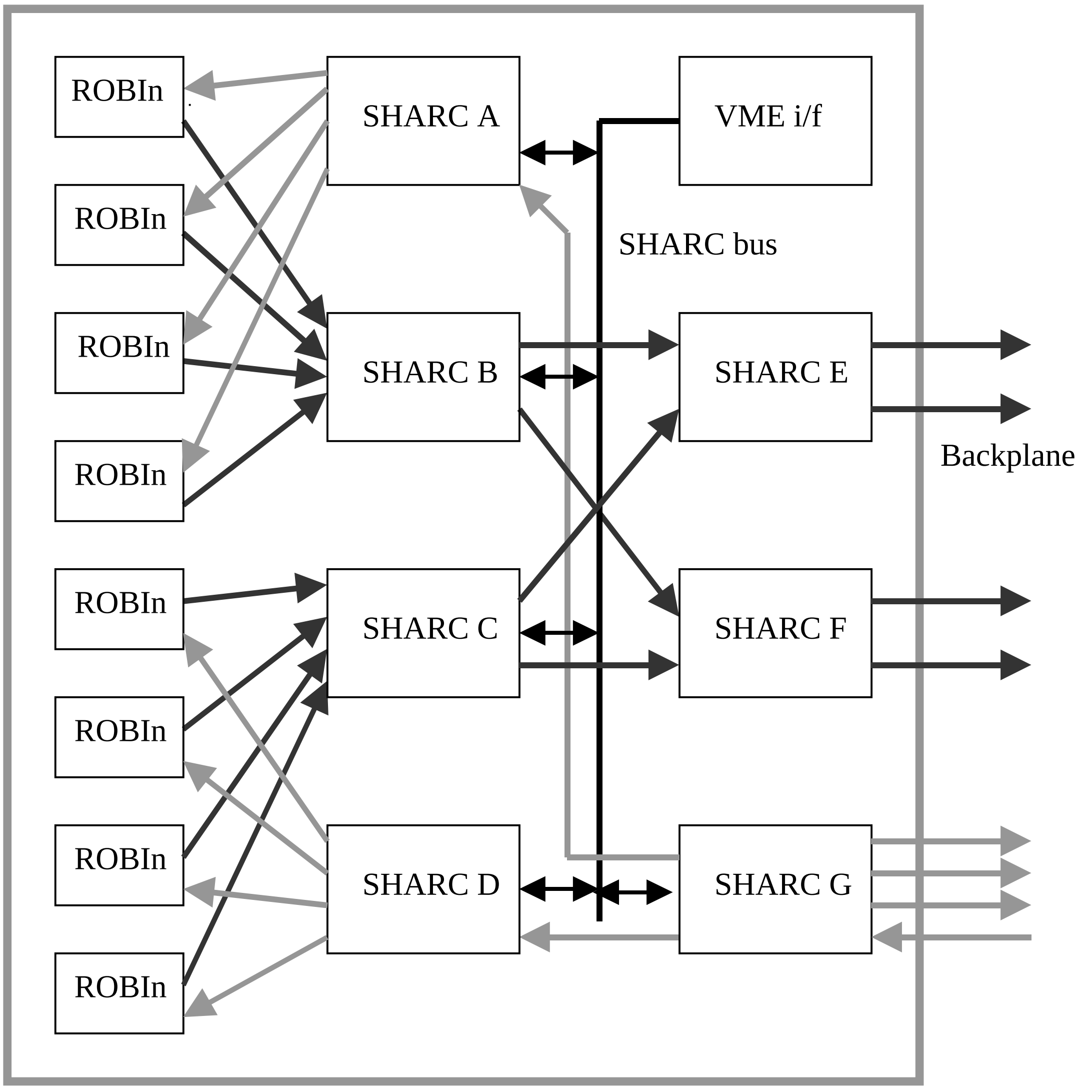


Figure 7. Structure of ROB crate input board. Red arrows pointing to the left refer to SHARC links carrying control data, red arrows at the right of SHARC G refer to SHARC links connecting to the backplane transferring control data, blue arrows pointing to the right refer to SHARC links carrying event fragment data. The VME interface is a simple 32-bits slave interface. The SHARC bus is used for booting SHARCs A, B, C, D and G and for control. SHARCs B, C, E and F build event fragments from the data received. Each SHARC link used for outputting event data to the backplane can receive data from all ROBIns. Additional SHARC link connections between 2 ROBIns and SHARCs E and F could be present (see figure 13). The ROBins cannot connect to a SHARC bus unless each ROBIn can be isolated from it, as otherwise communication between SHARCs and associated FPGAs in different ROBIns would interfere with each other.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	1	1	33	6	2	2	2	47
Number of LVL2 links	2	1	36	6	2	2	2	51
Max. fragment rate per LVL2 link (kHz)	23.8	23.8	13.6	4.6	24.2	12.1	12.1	
Number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	8	1	66	9	14	7	4	109
Fragment rate per EB link	0.9	3.8	0.3	0.4	0.5	0.5	0.9	
Number of output links per crate	5	2	17	15	8	9	6	160

Table 23. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz.

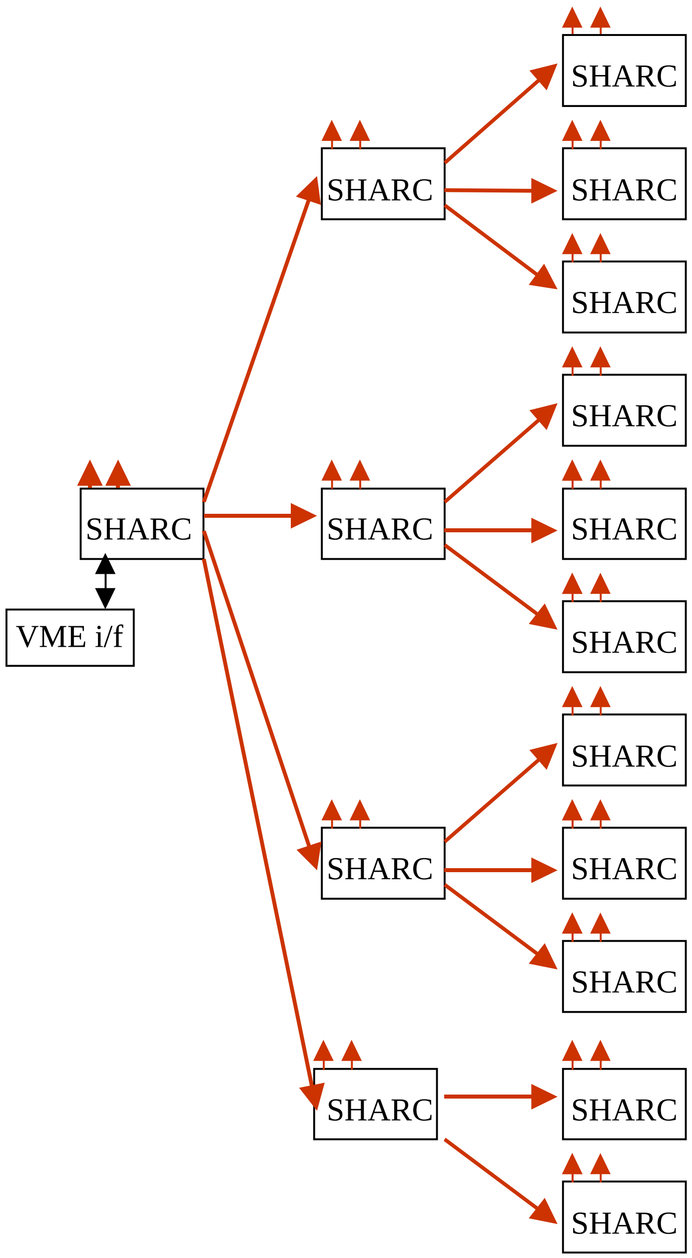


Figure 8. Structure of tree built with the SHARCs G (see figure 7) of the 16 input boards. The small verical arrows refer to the SHARC links to SHARCs A and D on each input board, the other arrows refer to SHARC links that connect SHARCs via the backplane (see also figures 10 and 11). All control information arrives via VME bus in the memory of the SHARC at the left.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	1	1	18	3	1	1	1	26
Number of LVL2 links	2	1	18	3	2	1	1	28
Max. fragment rate per LVL2 link (kHz)	12.5	12.5	14.3	4.8	12.7	12.7	12.7	
Number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	4	1	36	5	8	4	2	60
Fragment rate per EB link	1.0	2.0	0.3	0.4	0.5	0.5	1.0	
Number of output links per crate	3	2	9	8	5	5	3	88

Table 24. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz.

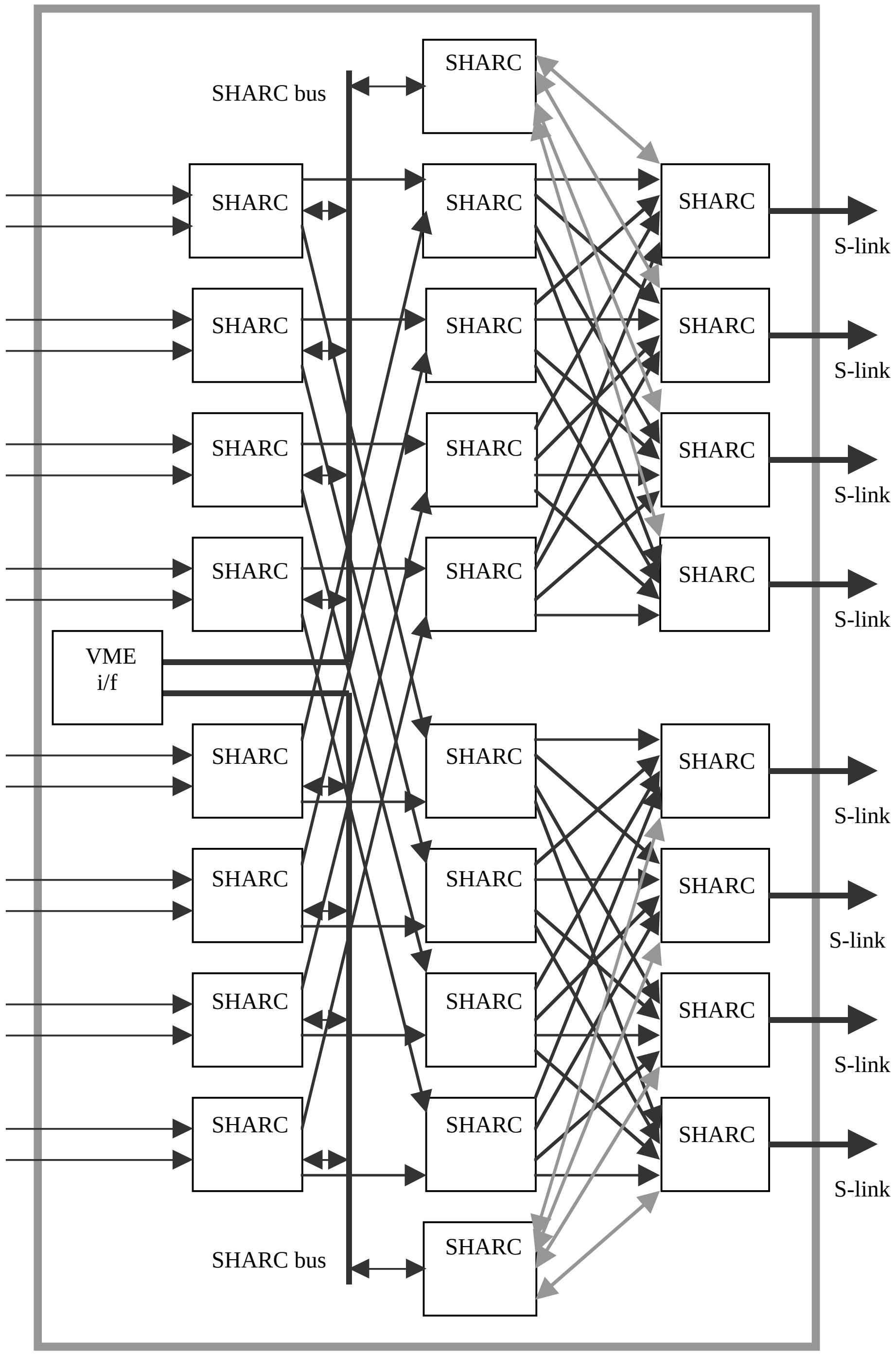


Figure 9. Structure of the output board. Grey bi-directional arrows refer to SHARC links used for booting and control, uni-directional arrows pointing to the right refer to SHARC links carrying event fragment data. The SHARC busses are used for booting the left column of SHARCs and the top and bottom SHARC in the middel column. The other SHARCs in the middle column need to be booted by the SHARCs in the left column. The VME interface is a simple 32-bits slave interface. All SHARCs build event fragments from the data received. The SHARCs with S-link interfaces cannot connect to a common SHARC bus unless each SHARC can be isolated from it, as otherwise communication between different SHARCs and associated S-link interfaces would interfere with each other.

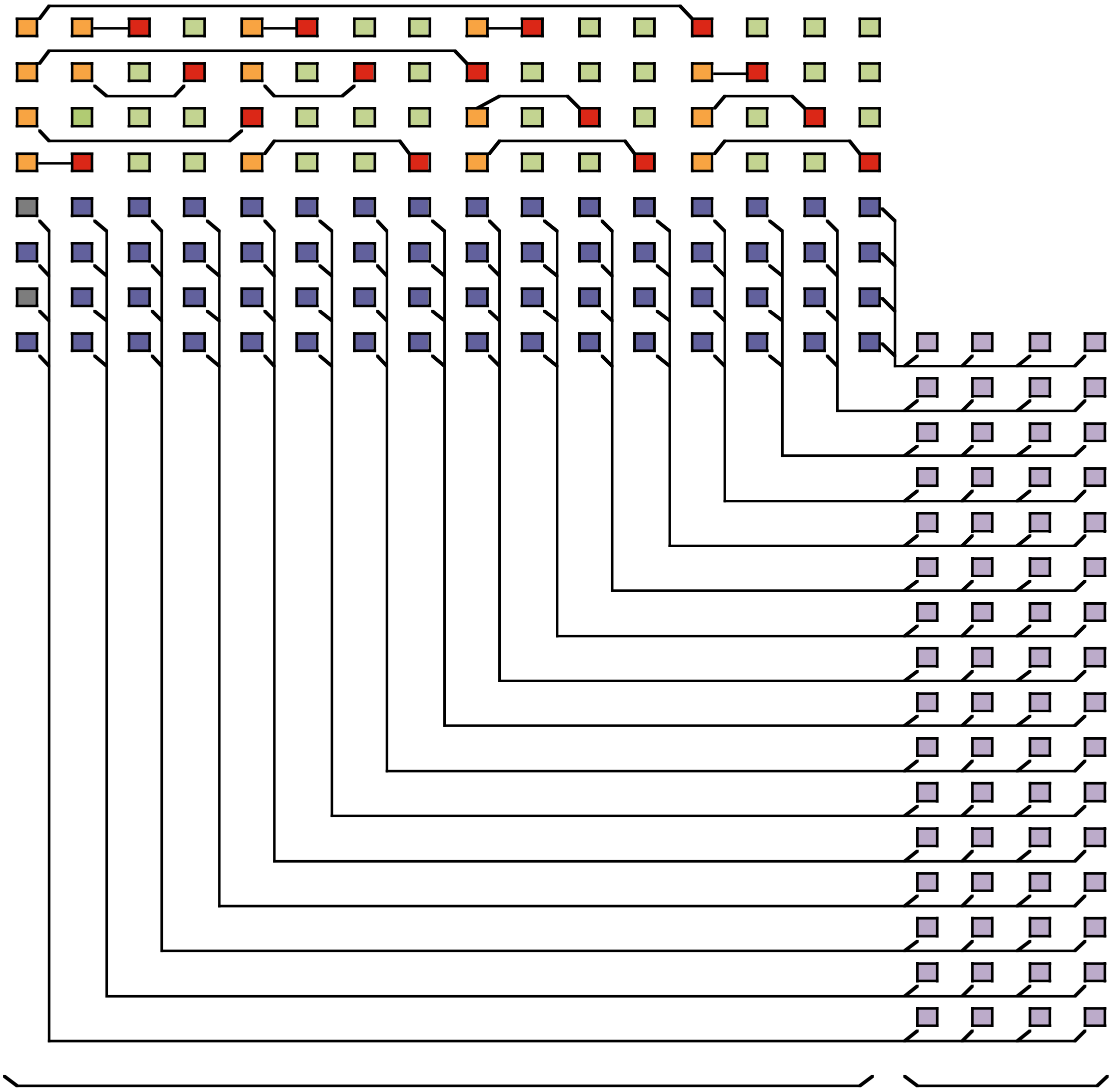
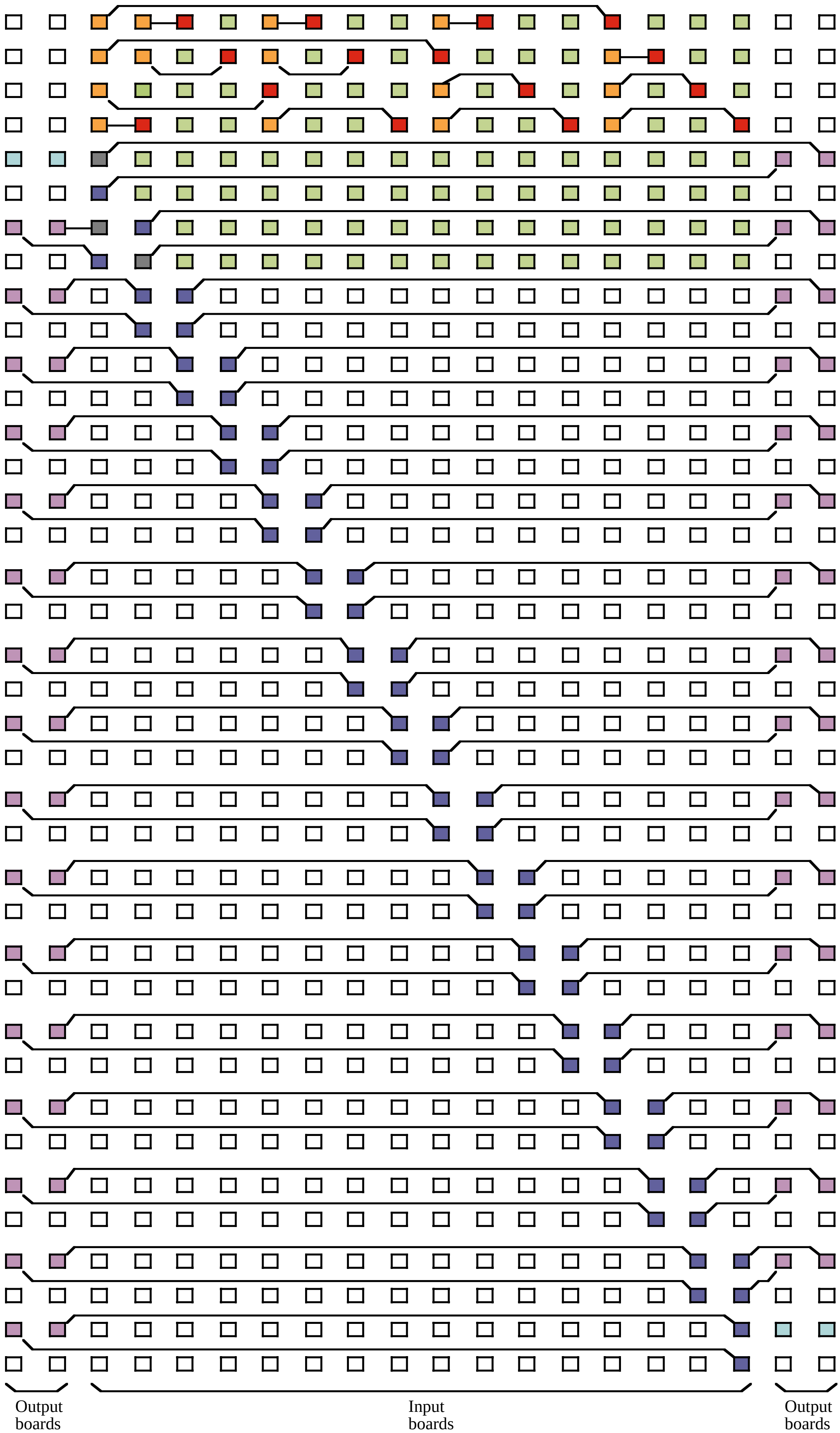


Figure 10. Connectivity required in backplane. Each square represents the six connections needed for a single SHARC link. Each column corresponds to a single slot in the crate. For each input board 8 links = 48 signals and for each output board 16 links = 96 signals need to be connected. The upper 4 rows are used for transfers of control data (see also figure 8). Using different connectors for the input and output boards in combination with a multi-layer backplane may allow a lay-out of the backplane as suggested by this figure.

Next page : figure 11. Possible structure of backplane if the input and output boards use the same connectors and assuming that between rows only a single horizontal connection is possible. Vertical connections not shown should allow for all input boards and all output boards to have the same lay-out. Empty boxes indicate that no SHARC link is connected. The blue boxes for the input boards in most cases need to be connected to the input board via a vertical connection to the green boxes in the 5th to 8th row.



Output boards
Input boards
Output boards

Detector	muon -MDT	muoni -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	2	1	24	7	27	10	10	67
Number of LVL2 links	8	4	30	7	28	10	10	97
Max. fragment rate per LVL2 link (kHz)	11.7	11.7	11.7	5.0	3.5	4.9	4.9	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	8	4	66	9	10	4	4	105
Fragment rate per EB link	0.9	0.9	0.3	0.4	0.8	0.9	0.9	
Number of output links per crate	8	8	16	16	19	14	14	202

Table 25. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, reduced fragment rates for larger number of S-links than in table 21.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	2	1	24	7	27	10	10	50
Number of LVL2 links	8	4	30	7	28	10	10	97
Max. fragment rate per LVL2 link (kHz)	6.3	6.3	6.3	2.7	2.2	3.1	3.1	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	8	4	66	9	10	4	4	105
Fragment rate per EB link	0.5	0.5	0.2	0.2	0.4	0.5	0.5	
Number of output links per crate	8	8	16	16	19	14	14	202

Table 26. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, number of S-links same as in table 25.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	2	1	24	7	27	10	10	47
Number of LVL2 links	8	4	30	7	28	10	10	97
Max. fragment rate per LVL2 link (kHz)	6.0	6.0	16.4	4.0	1.7	2.4	2.4	
Number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	8	4	66	9	10	4	4	105
Fragment rate per EB link	0.9	0.9	0.3	0.4	0.8	0.9	0.9	
Number of output links per crate	8	8	16	16	19	14	14	202

Table 27. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, number of S-links same as in table 25.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	2	1	24	7	27	10	10	26
Number of LVL2 links	8	4	30	7	28	10	10	97
Max. fragment rate per LVL2 link (kHz)	3.1	3.1	8.6	2.1	0.9	1.3	1.3	
Number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	8	4	66	9	10	4	4	105
Fragment rate per EB link	0.5	0.5	0.2	0.2	0.4	0.5	0.5	
Number of output links per crate	8	8	16	16	19	14	14	202

Table 28. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, number of S-links same as in table 25.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	3	1	1	14
Number of LVL2 links required	2	1	24	7	27	10	10	67
Number of LVL2 links	32	16	120	14	60	20	20	282
Max. fragment rate per LVL2 link (kHz)	2.9	2.9	2.9	2.5	2.4	2.4	2.4	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	16	8	72	10	12	4	4	126
Fragment rate per EB link	0.5	0.5	0.3	0.4	0.9	0.9	0.9	
Number of output links per crate	24	24	32	24	24	24	24	408

Table 29. Low luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, reduced fragment rates and utilization of LVL2 links lower than 50 % for larger number of S-links than in table 21.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	3	1	1	14
Number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	32	16	120	14	60	20	20	282
Max. fragment rate per LVL2 link (kHz)	1.6	1.6	1.6	1.3	1.5	1.5	1.5	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	16	8	72	10	12	4	4	126
Fragment rate per EB link	0.3	0.3	0.2	0.2	0.5	0.5	0.5	
Number of output links per crate	24	24	32	24	24	24	24	408

Table 30. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, number of S-links same as in table 29.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	3	1	1	14
Number of LVL2 links required	1	1	33	6	2	2	2	47
Number of LVL2 links	32	16	120	14	60	20	20	282
Max. fragment rate per LVL2 link (kHz)	1.5	1.5	4.1	2.0	1.2	1.2	1.2	
Number of EB links required	8	1	65	9	13	7	4	107
Number of EB links	16	8	72	10	12	4	4	126
Fragment rate per EB link	0.5	0.5	0.3	0.4	0.9	0.9	0.9	
Number of output links per crate	24	24	32	24	24	24	24	408

Table 31. High luminosity, LVL1 rate = 75 kHz, LVL2 accept rate = 3.75 kHz, number of S-links same as in table 25.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of crates	2	1	6	1	3	1	1	14
Number of LVL2 links required	1	1	18	3	1	1	1	26
Number of LVL2 links	32	16	120	14	60	20	20	282
Max. fragment rate per LVL2 link (kHz)	0.8	0.8	2.1	1.0	0.6	0.6	0.6	
Number of EB links required	4	1	34	5	7	4	2	57
Number of EB links	16	8	72	10	12	4	4	126
Fragment rate per EB link	0.2	0.2	0.2	0.2	0.5	0.5	0.5	
Number of output links per crate	24	24	32	24	24	24	24	408

Table 32. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, number of S-links same as in table 25.

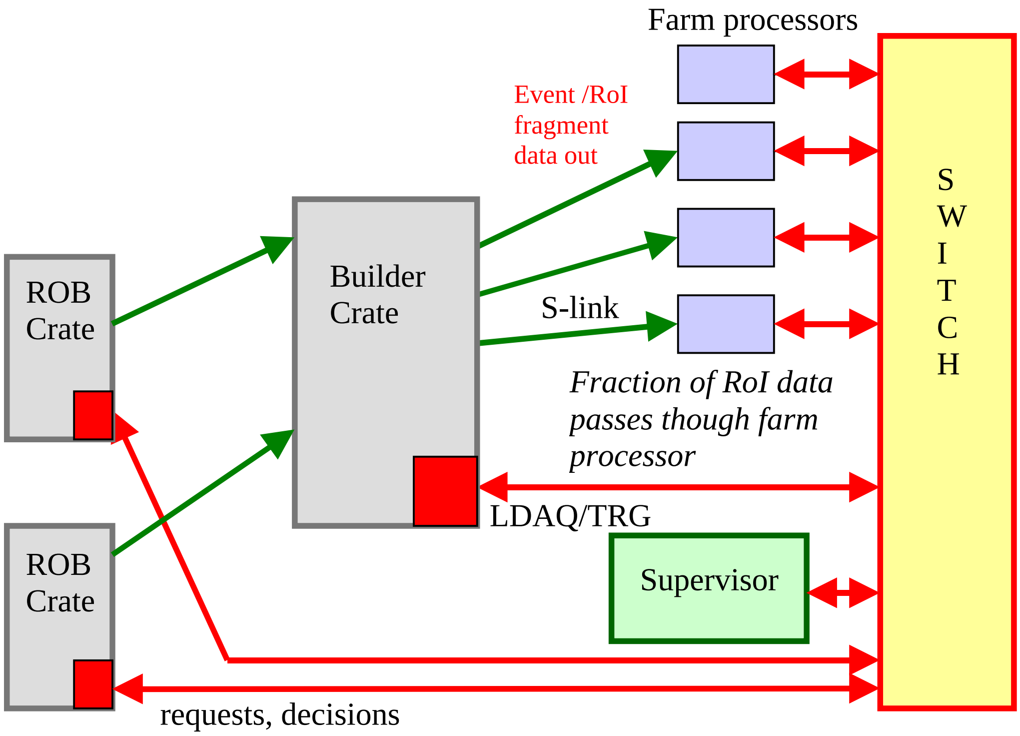


Figure 12. Event / RoI fragment building with “builder” crates equipped with the same hardware as the ROB crates.

As full RoI fragments can be passed to the processors in the LVL2 farm probably a configuration can be found in which the LVL2 network mainly is used for transporting control traffic (RoI requests, decisions) to the ROB crates, resulting in considerably reduced requirements for this network. Multi-CPU PCs may fit very well in this picture.

The message frequencies per output link are relatively low, while the request rate per ROB crate can be as high as about 50 kHz (see section 3.2). If bi-directional point-to-point links with sufficient bandwidth are used in stead of S-links the requests could be send (with a much lower frequency per link) via these links to the builder crate. The requests then have to be send to the ROB crates via bi-directional links connecting ROB and builder crates.

Detector	muon -MDT	muon -trig	e.m. cal	had. cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROB crates	2	1	6	1	2	1	1	14
Number of LVL2 links required	1	1	13	3	26	4	2	50
Number of LVL2 links	3	4	21	6	26	4	4	68
Max. fragment rate per LVL2 link (kHz)	31.3	11.7	16.7	5.8	3.7	12.2	12.2	
Number of EB links required	8	1	65	9	10	2	1	96
Number of EB links	8	2	80	12	10	2	2	116
Fragment rate per EB link	0.5	1.0	0.2	0.2	0.4	1.0	1.0	
Number of output links per ROB crate	6	6	18	18	18	6	6	192
Number of input links per builder crate	2	1	18	3	6	1	1	32

Table 33. Low luminosity, 75 kHz LVL1 rate, LVL2 accept rate = 3.75 kHz, 6 “builder” crates.

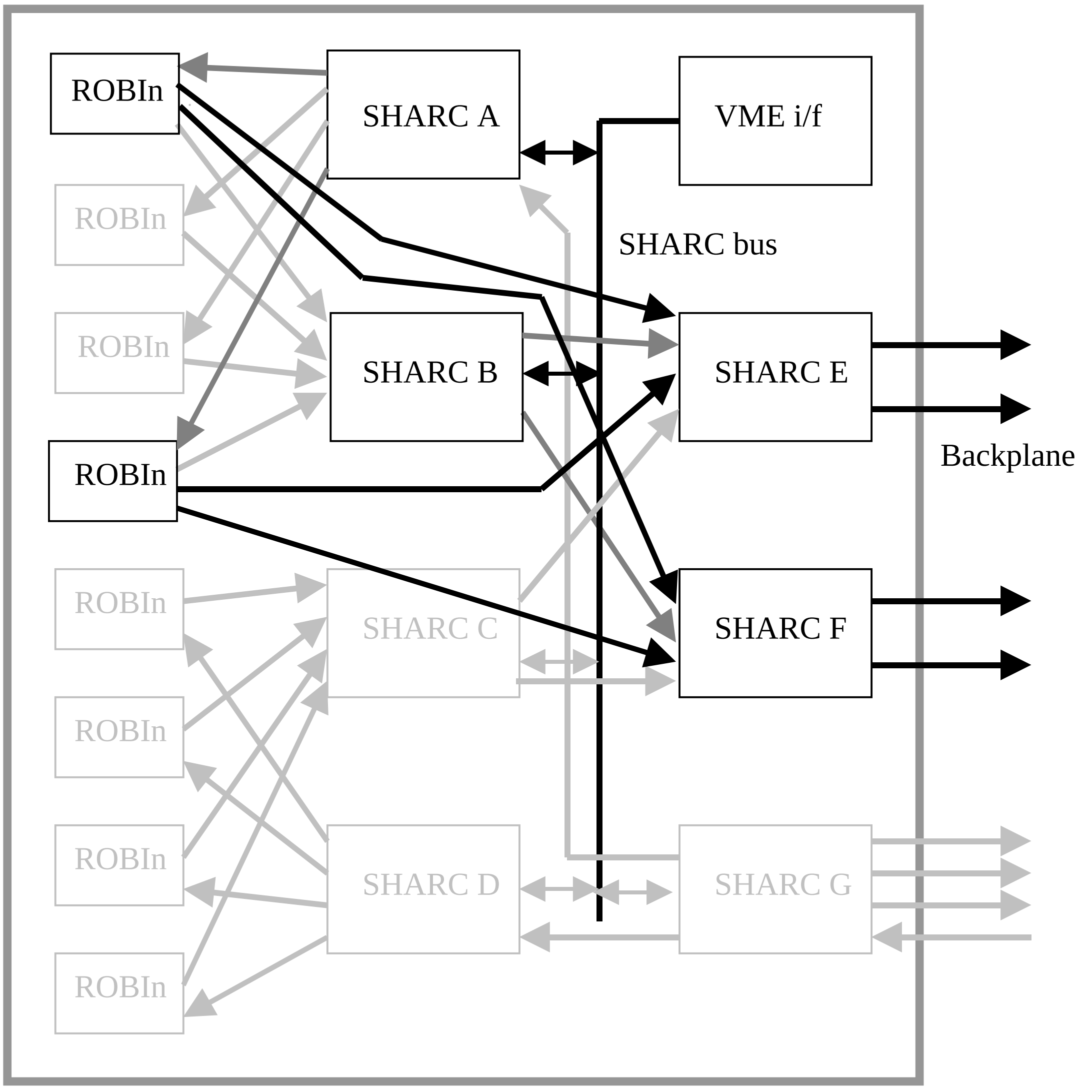


Figure 13. With additional SHARC link connections between 2 ROBIns and SHARCs E and F (uni-directional arrows pointing to the right) the input board of figure 7 can be used as input board in a crate for fragment building or event building. The configuration of the FPGAs of the "ROBIns" may need to be different from the configuration used for the ROBIn function. The grey arrows between SHARC A and the ROBIns and between SHARC B and SHARCs E and F refer to SHARC links used for booting the ROBIns and SHARCs E and F. Components for the six unused ROBIns and SHARC C, SHARC D and SHARC G need not to be present.

As the SHARC links inside the crates can be used bi-directionally and as the required bandwidth for transferring the requests is relatively small it is in principle possible to pass requests from the farm processors via the builder crates to the ROB crates with the internal architecture of the crates as described in this section. For the technology of the links between the crates SHARC-II links (100 MByte/s links) would be a possibility, but these links lack CRC error checking, which is a desirable feature (notice that inside a crate by implementing SHARC links only on multi-layer boards and backplanes these links can function very reliably). Perhaps a future version of FireWire with higher bandwidth and allowing cables longer than about 4 m could be used.

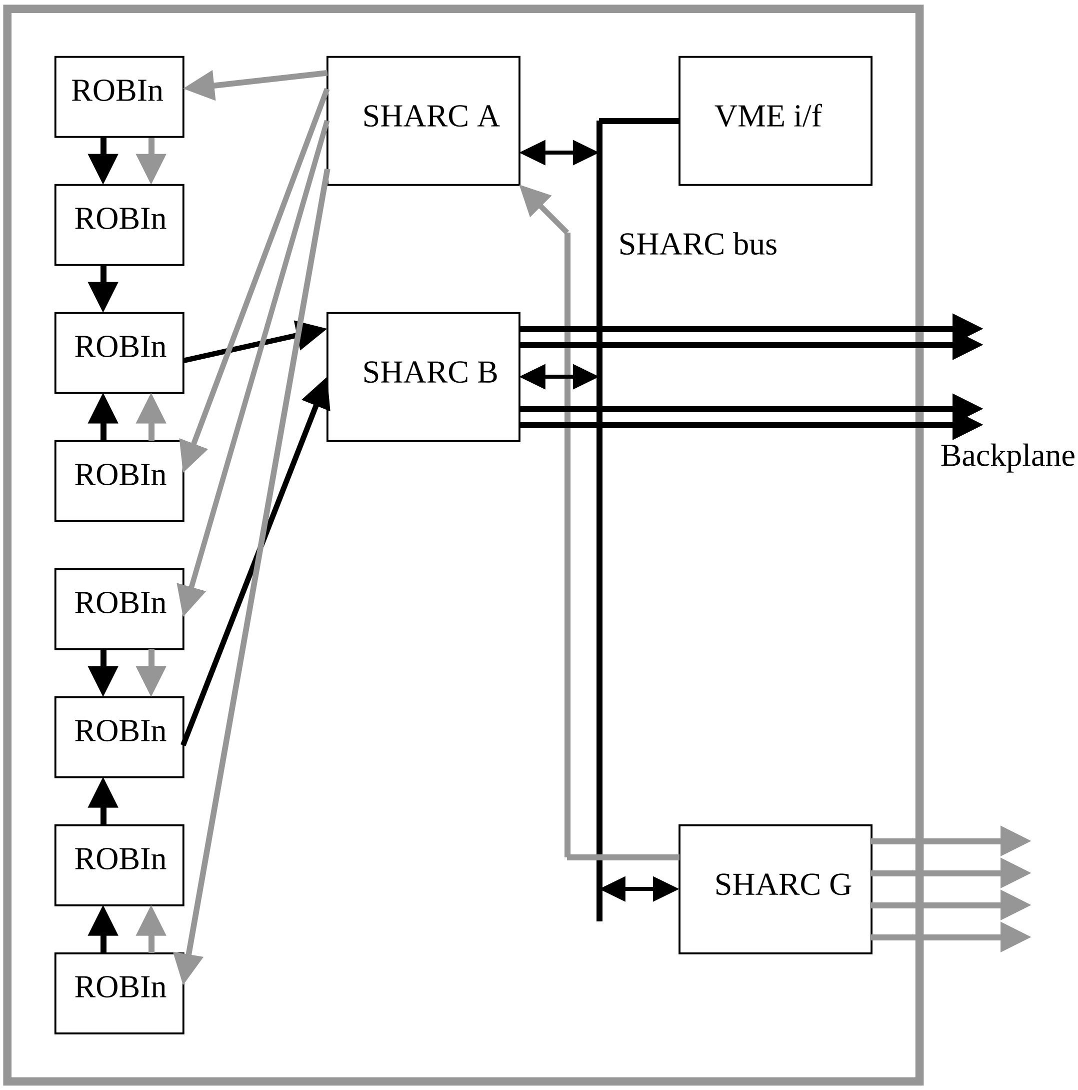


Figure 14. ROB crate input board with less SHARCs than in figure 7, but with connections between the SHARCs for transferring event and control data. This may be a possible configuration if the 21160 SHARC is applied in stead of the 21060.

The scenario discussed in this section has assumed the use of the SHARC 21060 in the ROB and builder crates if these are also used, as experience with the 21060 exists and can be used for extrapolation. In the ROB crates each fragment has to pass through 6 different SHARCs before it reaches an output S-link and another 5 SHARCs if it also has to pass through a builder crate. These numbers are dictated by the number of links of a single SHARC processor and will also be found when the 21160 is used, as it has also 6 links and as shown in the following discussion. The link bandwidth of 21160 links is a factor of 2.5 higher than for the 21060. It is assumed that the number of 128 ROBIns and 32 S-link outputs per crate is determined by the physical dimensions of the S-link cards. In view of the bandwidth requirements the number of output SHARC links per input card could be reduced from 4 to 2. However, then it is only possible to connect to 2 output cards, so still 4 output links are needed and the architecture of the input board is not modifed. The architecture of the output board is also dictated by the connectivity required. Hence also with the 21160 in the ROB crates each fragment will have to pass through 6 different SHARCs.

The 21060 has also a 2.5 times faster processor and 2.5 times faster internal memory access as the 21160. These properties could be exploited for reducing the total number of SHARCs required. In particular by allowing links connecting ROBIns to each other so that event and control data can be transported from one ROBIn to another ROBIn the architecture of the input board could be simplified as shown in figure 14. The architecture of the output board is dictated by the number of links of the SHARC and it is not obvious how to simplify its architecture.

4. Discussion

Several variations of two different scenarios are discussed in this document. Other variations not considered here are possible and could be more cost effective or provide better performance. The SHARC has several facilities not mentioned in this note which potentially are of interest. For example it is possible to broadcast over the SHARC bus from one SHARC to the other SHARCs connected to the bus. Each SHARC also has 2 40 Mbit/s serial links that could be used for monitoring and control. However, it is believed that the possibilities considered are representative for ROBComplexes based on SHARCs and exploiting in particular the data movement capabilities of the SHARC in combination with its compactness (allowing to use a considerable number on a single board) and in combination with the available communication links. Although the scenarios in this note are based on the use of the SHARC 21060 processor, they could also apply to other hardware. In particular a combination of a DSP, fast memory and an FPGA implementing point-to-point links similar to the SHARC links could be used as alternative for the SHARC, although it may not be straightforward to obtain the performance made possible by the SHARCs integrated architecture.

Scenario	1.1	1.2	1.3	1.3"	2.1	2.1'	2.2
Number of ROBIn cards	257	278	--	383	257	193	193
Number of SHARCs	2056	1818	--	2298	2570	2895	3545
Number of LVL2 interfaces	257	91	--	383	13	10	14
Number of EB interfaces	168	172	--	151	*)	*)	*)
Number of S-links to LVL2 system	None	None	--	None	257	193	68
Number of S-links to EB system	None	None	--	None	257	193	97
Number of output cards (for S-link)	None	None	--	None	None	None	25
Number of "RIO2s"	425	263	--	534	13	10	14
Number of PMC SHARC cards	168	263	--	None	None	None	None
Number of PVIC interfaces	None	None	--	534	None	None	None
Number of backplanes with SHARC links	168	72	--	None	13	10	14
Number of crates	40	36	--	59	13	10	14

*) Same as LVL2 interface, used only for control data **) see appendix

Table 34. Hardware needed for the different scenarios for the low luminosity trigger at a LVL1 rate of 75 kHz. The number of SHARCs specified for scenarios 1.1 and 1.2 does not contain the SHARCs on PMC boards. Scenario 1.3 cannot handle a LVL1 rate of 75 kHz (due to the use of 15 MByte/s links). Scenario 1.3' is the same as scenario 1.3 but with 80 MByte/s links, for the TRT 4 ROBIns per card in stead of 1 and at maximum 4 ROBIn cards per EB interface. Scenario 2.1' is the same as scenario 2.1 but with 8 ROBIns in stead of 6 ROBIns per board.

Scenario	1.1	1.2	1.3	1.3'	2.1	2.1'	2.2
Number of ROBIn cards	257	278	575	383	257	193	193
Number of SHARCs	2056	1818	2682	2298	2570	2895	3467
Number of LVL2 interfaces	257	66	575	383	13	10	14
Number of EB interfaces	64	74	281	98	*)	*)	*)
Number of S-links to LVL2 system	None	None	None	None	257	193	56
Number of S-links to EB system	None	None	None	None	257	193	54
Number of output cards (for S-link)	None	None	None	None	None	None	22
Number of "RIO2s"	321	140	856	481	13	10	14
Number of PMC SHARC cards	64	140	None	None	None	None	None
Number of PVIC interfaces	None	None	856	481	None	None	None
Number of backplanes with SHARC links	64	74	None	None	13	10	14
Number of crates	40	33	86	50	13	10	14

*) Same as LVL2 interface, used only for control data

Table 35. Hardware needed for the different scenarios for the low luminosity trigger at the nominal LVL1 rate. The number of SHARCs specified for scenarios 1.1 and 1.2 does not contain the SHARCs on PMC boards. Scenario 1.3' is the same as scenario 1.3 but with 80 MByte/s in stead of 15 MByte/s links and at maximum 4 ROBIn cards per EB interface. Scenario 2.1' is the same as scenario 2.1 but with 8 ROBIns in stead of 6 ROBIns per board.

Table 34 contains for the low luminosity trigger at a LVL1 rate of 75 kHz a comparison of the amount of hardware required for the different possibilities considered. For a comparison for the low luminosity trigger at the nominal LVL1 rate see table 35.

For scenario 1 it is clear that using 15 MByte/s LVL2 and EB links is problematic with respect to LVL1 trigger rates of 75 kHz and in view of the number of network interfaces needed. Making a direct connection between ROBIn card and RIO2 with the LVL2 interface (scenario 1.1) or with the EB interface has two disadvantages : (i) the number of network interfaces is determined by the number of ROBIn cards and not by the bandwidth requirements, (ii) RIO2 and ROBIn card have to be connected mechanically. Scenario 1.2 gives most flexibility and the smallest number of RIO2s, but it may be necessary to modify the structure of the ROBIn card and to avoid the bi-directional use of SHARC links by using more SHARCs and more SHARC links in the backplanes connecting the ROBIn cards to the RIO2s.

An important difference of the SHARC based ROBComplexes described with other PCI-based designs is that the SHARC based ROBComplex only has a single PCI interface on a single PCI segment. Requests can be passed to a SHARC in the ROBComplex that replicates the requests as needed and also builds event or RoI fragments from the data of the ROBIns. Hence the message frequency on the PCI bus can be considerably lower than in a system where the ROBIns are connected directly to the PCI bus.

When using 80 MByte/s links in scenario 1 the number of link interfaces and RIO2s could be reduced if data for the Event Builder and data for the LVL2 system can be transferred over the same link. Paper model results are provided in the appendix.

For scenario 2 the RIO2s and the network interfaces are essentially replaced by the SHARCs with S-link source interfaces. This replacement also results in a considerably smaller number of crates.

Scenario 2.1 and 2.1' (8 ROBIns in stead of 6 ROBIns per card) have a simpler architecture than scenario 2.2. However, the number of output S-links is large and fixed for scenario 2.1. Combination of event data for the Event Builder and of RoI fragment data for the LVL2 farm on the same link is possible and could reduce the number of links with a factor of 2. In this case the PC connecting to a S-link could in principle have two network interfaces, one connecting to the Event Builder network and the other connecting to the LVL2 network.

The output cards of scenario 2.2 are relatively complex and are responsible for the increased number of SHARCs relative to the number of SHARCs needed for scenario 2.1. However, these cards make a next level of complete event and RoI fragment building possible, resulting in reduced message frequencies on the output S-links. Furthermore, in combination with a small number of "builder" crates complete event and RoI fragment building could be possible with as consequence a considerable reduction of the requirements for the Event Builder and LVL2 networks. It is expected that no major problems will be found with respect to this scenario, but this expectation needs to be justified.

Test measurements with the hardware currently available and additional computer modelling will be necessary to study the scenarios in more detail. This work is going on, but in particular scenario 2.2 may require a considerable amount of work with respect to computer modelling.

5. Conclusion

In terms of the amount of hardware needed scenario 2 forms an attractive alternative to the standard model for the readout system and is expected to provide sufficient throughput to handle 75 kHz LVL1 trigger rates, with further spare throughput capacity available and for scenario 2.2 the possibility to tailor the output capacity. In scenario 1 also the 75 kHz rate can be handled, but network connections of sufficient bandwidth have to be used. Different design choices are possible and may have a large impact on the amount of hardware required.

Appendix

This appendix contains paper model results for scenario 1.1 and 1.2 for LVL2 and EB interfaces sharing the same slot and for combined LVL2 and EB links. If EB and LVL2 interface share the same slot (and the same RIO2) PMC cards with SHARCs cannot be used and the structure of the ROBIN cards need to be changed to allow for communication between cards connected to the same RIO2. For comparison the results for the case that LVL2 and EB interfaces do not share the same slot are also included.

Scenario 1.1

80 MByte/s links, 6 ROBins per card, 1 LVL2 interface per ROBIn card, at maximum 8 ROBIn cards per EB interface or per combined EB+LVL2 link, see tables 36 - 39.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**6**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	2	1	24	6	27	4	2	66
Min # of EB links required	8	1	65	9	10	2	1	96
Min # of combined links required	9	2	88	14	36	5	2	156
# of LVL2 links after grouping, LVL2 i/f slot not shared	32	8	127	17	43	16	14	257
# of EB links after grouping, EB i/f slot not shared	8	1	127	17	11	2	2	168
# of LVL2 = # of EB links after grouping, i/f slot shared	32	8	127	17	43	16	14	257
# of combined LVL2+EB links after grouping	11	2	127	17	43	6	2	208
Number of crates, LVL2 and EB i/f in different slots	4	1	22	3	6	2	2	40
Number of crates, LVL2 and EB i/f share same slot	4	1	15	2	5	2	2	31
Number of crates, combined LVL2+EB link	3	1	15	2	5	2	1	29
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	1	1	1	1	1	1	1	
# of ROBin cards per EB link, EB i/f slot not shared	4	8	1	1	4	8	7	
Utilization of LVL2 link bandwidth (%)	3.5	3.6	18.8	29.4	62.4	22.8	10.1	
Utilization of EB link bandwidth (%)	90.0	85.5	50.5	48.6	81.8	53.9	15.8	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	1	1	1	1	1	1	1	
Utilization of LVL2 link bandwidth (%)	3.5	3.6	18.8	29.4	62.4	22.8	10.1	
Utilization of EB link bandwidth (%)	22.5	10.7	50.5	48.6	20.9	6.7	2.3	
# of ROBin cards per combined LVL2+EB link	3	6	1	1	1	3	8	
Utilization of link bandwidth (%)	75.7	57.3	69.3	78.1	83.4	78.8	86.2	
Fraction of link bandwidth used for LVL2 data (%)	10.2	14.6	18.8	29.4	62.4	60.8	70.4	
Fraction of link bandwidth used for EB data (%)	65.5	42.8	50.5	48.6	20.9	18.0	15.8	

Table 36. Low luminosity, 75 kHz LVL1 rate, LVL2 accept rate = 3.75 kHz, 80 MByte/s links, 6 ROBins per card, 1 LVL2 interface per ROBIn card, at maximum 8 ROBIn cards per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**6**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	13	3	26	4	2	50
Min # of EB links required	4	1	35	5	5	1	1	52
Min # of combined links required	5	1	48	8	31	5	2	100
# of LVL2 links after grouping, LVL2 i/f slot not shared	32	8	127	17	43	16	14	257
# of EB links after grouping, EB i/f slot not shared	4	1	43	6	6	2	2	64
# of LVL2 = # of EB links after grouping, i/f slot shared	32	8	127	17	43	16	14	257
# of combined LVL2+EB links after grouping	5	1	64	9	43	6	2	130
Number of crates, LVL2 and EB i/f in different slots	4	1	22	3	6	2	2	40
Number of crates, LVL2 and EB i/f share same slot	4	1	15	2	5	2	2	31
Number of crates, combined LVL2+EB link	3	1	11	2	5	2	1	25
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	1	1	1	1	1	1	1	
# of ROBin cards per EB link, EB i/f slot not shared	8	8	3	3	7	8	7	
Utilization of LVL2 link bandwidth (%)	1.9	1.9	10.0	15.8	60.1	21.5	9.2	
Utilization of EB link bandwidth (%)	96.4	45.8	79.8	73.8	80.3	28.9	8.4	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	1	1	1	1	1	1	1	
Utilization of LVL2 link bandwidth (%)	1.9	1.9	10.0	15.8	60.1	21.5	9.2	
Utilization of EB link bandwidth (%)	12.0	5.7	27.0	26.0	11.2	3.6	1.2	
# of ROBin cards per combined LVL2+EB link	7	8	2	2	1	3	8	
Utilization of link bandwidth (%)	89.1	61.4	73.6	79.0	71.3	67.0	73.1	
Fraction of link bandwidth used for LVL2 data (%)	12.0	15.6	19.9	29.8	60.1	57.4	64.7	
Fraction of link bandwidth used for EB data (%)	77.1	45.8	53.6	49.2	11.2	9.6	8.4	

Table 37. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s links, 6 ROBins per card, 1 LVL2 interface per ROBIn card, at maximum 8 ROBIn cards per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**6**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	33	5	2	2	2	46
Min # of EB links required	8	1	65	9	13	7	4	107
Min # of combined links required	8	2	97	13	14	9	5	148
# of LVL2 links after grouping, LVL2 i/f slot not shared	32	8	127	17	43	16	14	257
# of EB links after grouping, EB i/f slot not shared	8	1	127	17	15	8	4	180
# of LVL2 = # of EB links after grouping, i/f slot shared	32	8	127	17	43	16	14	257
# of combined LVL2+EB links after grouping	8	2	127	17	15	16	5	190
Number of crates, LVL2 and EB i/f in different slots	4	1	22	3	8	3	2	43
Number of crates, LVL2 and EB i/f share same slot	4	1	15	2	5	2	2	31
Number of crates, combined LVL2+EB link	3	1	15	2	4	2	2	29
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	1	1	1	1	1	1	1	
# of ROBin cards per EB link, EB i/f slot not shared	4	8	1	1	3	2	4	
Utilization of LVL2 link bandwidth (%)	1.8	1.8	25.8	23.8	3.9	9.9	8.1	
Utilization of EB link bandwidth (%)	90.0	85.5	50.5	48.6	80.0	86.3	78.8	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	1	1	1	1	1	1	1	
Utilization of LVL2 link bandwidth (%)	1.8	1.8	25.8	23.8	3.9	9.9	8.1	
Utilization of EB link bandwidth (%)	22.5	10.7	50.5	48.6	27.9	43.1	22.5	
# of ROBin cards per combined LVL2+EB link	4	7	1	1	3	1	3	
Utilization of link bandwidth (%)	97.1	50.1	76.3	72.4	91.1	53.0	85.7	
Fraction of link bandwidth used for LVL2 data (%)	7.1	7.4	25.8	23.8	11.1	9.9	22.7	
Fraction of link bandwidth used for EB data (%)	90.0	42.8	50.5	48.6	80.0	43.1	63.0	

Table 38. High luminosity, 75 kHz LVL1 rate, LVL2 accept rate = 3.75 kHz, 80 MByte/s links, 6 ROBins per card, 1 LVL2 interface per ROBIn card, at maximum 8 ROBIn cards per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**6**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	18	3	1	1	1	26
Min # of EB links required	4	1	34	5	7	4	2	57
Min # of combined links required	5	1	51	7	8	5	3	80
# of LVL2 links after grouping, LVL2 i/f slot not shared	32	8	127	17	43	16	14	257
# of EB links after grouping, EB i/f slot not shared	4	1	43	6	8	4	2	68
# of LVL2 = # of EB links after grouping, i/f slot shared	32	8	127	17	43	16	14	257
# of combined LVL2+EB links after grouping	5	1	64	9	9	6	3	97
Number of crates, LVL2 and EB i/f in different slots	4	1	22	3	8	2	2	42
Number of crates, LVL2 and EB i/f share same slot	4	1	15	2	5	2	2	31
Number of crates, combined LVL2+EB link	3	1	11	2	3	2	2	24
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	1	1	1	1	1	1	1	
# of ROBin cards per EB link, EB i/f slot not shared	8	8	3	3	5	4	7	
Utilization of LVL2 link bandwidth (%)	0.9	1.0	13.6	12.5	2.0	5.2	4.3	
Utilization of EB link bandwidth (%)	94.5	44.9	78.3	72.4	78.8	90.6	82.7	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	1	1	1	1	1	1	1	
Utilization of LVL2 link bandwidth (%)	0.9	1.0	13.6	12.5	2.0	5.2	4.3	
Utilization of EB link bandwidth (%)	11.8	5.6	26.5	25.5	14.7	22.7	11.8	
# of ROBin cards per combined LVL2+EB link	7	8	2	2	5	3	6	
Utilization of link bandwidth (%)	81.6	52.7	79.6	71.9	79.7	74.3	75.1	
Fraction of link bandwidth used for LVL2 data (%)	6.0	7.8	26.9	23.6	9.7	13.9	19.9	
Fraction of link bandwidth used for EB data (%)	75.6	44.9	52.6	48.3	70.0	60.4	55.2	

Table 39. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s links, 6 ROBins per card, 1 LVL2 interface per ROBIn card, at maximum 8 ROBIn cards per EB interface or per combined EB+LVL2 link.

Scenario 1.2

80 MByte/s links, 6 ROBins per card, for TRT 4 ROBins per card, at maximum 8 ROBIn card, at maximum 8 ROBIn cards per LVL2 interfaces or per EB interface or per combined EB+LVL2 link, see tables 40 - 43.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**4**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	2	1	24	6	27	4	2	66
Min # of EB links required	8	1	65	9	10	2	1	96
Min # of combined links required	9	2	88	14	36	5	2	156
# of LVL2 links after grouping, LVL2 i/f slot not shared	6	2	32	6	37	6	2	91
# of EB links after grouping, EB i/f slot not shared	11	2	127	17	10	3	2	172
# of LVL2 = # of EB links after grouping, i/f slot shared	8	1	127	17	32	4	2	191
# of combined LVL2+EB links after grouping	11	2	127	17	64	6	2	229
Number of crates, LVL2 and EB i/f in different slots	3	1	16	3	10	2	1	36
Number of crates, LVL2 and EB i/f share same slot	3	1	15	2	6	2	1	30
Number of crates, combined LVL2+EB link	3	1	15	2	8	2	1	32
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	6	4	4	3	2	3	7	
# of ROBin cards per EB link, EB i/f slot not shared	3	4	1	1	6	5	7	
Utilization of LVL2 link bandwidth (%)	18.7	14.6	74.5	83.4	72.5	60.8	70.4	
Utilization of EB link bandwidth (%)	65.5	42.8	50.5	48.6	90.0	35.9	15.8	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	4	8	1	1	2	4	8	
Utilization of LVL2 link bandwidth (%)	14.0	29.1	18.8	29.4	83.9	91.3	70.4	
Utilization of EB link bandwidth (%)	90.0	85.5	50.5	48.6	28.1	27.0	15.8	
# of ROBin cards per combined LVL2+EB link	3	6	1	1	1	3	8	
Utilization of link bandwidth (%)	75.7	57.3	69.3	78.1	56.0	78.8	86.2	
Fraction of link bandwidth used for LVL2 data (%)	10.2	14.6	18.8	29.4	41.9	60.8	70.4	
Fraction of link bandwidth used for EB data (%)	65.5	42.8	50.5	48.6	14.1	18.0	15.8	

Table 40. Low luminosity, 75 kHz LVL1 rate, LVL2 accept rate = 3.75 kHz, 80 MByte/s links, 6 ROBins per card, for TRT 4 ROBins per card, at maximum 8 ROBIn cards per LVL2 interfaces or per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**4**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	13	3	26	4	2	50
Min # of EB links required	4	1	35	5	5	1	1	52
Min # of combined links required	5	1	48	8	31	5	2	100
# of LVL2 links after grouping, LVL2 i/f slot not shared	5	2	16	3.0	32	6	2	66
# of EB links after grouping, EB i/f slot not shared	5	2	48	6.0	8	3	2	74
# of LVL2 = # of EB links after grouping, i/f slot shared	4	1	43	6.0	32	4	2	92
# of combined LVL2+EB links after grouping	5	1	64	9.0	32	6	2	119
Number of crates, LVL2 and EB i/f in different slots	3	1	16	2	8	2	1	33
Number of crates, LVL2 and EB i/f share same slot	2	1	11	2	6	2	1	25
Number of crates, combined LVL2+EB link	3	1	11	2	6	2	1	26
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	7	4	8	6	2	3	7	
# of ROBin cards per EB link, EB i/f slot not shared	7	4	3	3	8	5	7	
Utilization of LVL2 link bandwidth (%)	12.0	7.8	79.8	89.3	80.8	57.4	64.7	
Utilization of EB link bandwidth (%)	77.1	22.9	71.5	73.8	60.2	19.2	8.4	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	8	8	3	3	2	4	8	
Utilization of LVL2 link bandwidth (%)	15.0	15.6	29.7	44.7	80.8	86.1	64.7	
Utilization of EB link bandwidth (%)	96.4	45.8	79.8	73.8	15.1	14.4	8.4	
# of ROBin cards per combined LVL2+EB link	7	8	2	2	2	3	8	
Utilization of link bandwidth (%)	89.1	61.4	73.6	79.0	95.9	67.0	73.1	
Fraction of link bandwidth used for LVL2 data (%)	12.0	15.6	19.9	29.8	80.8	57.4	64.7	
Fraction of link bandwidth used for EB data (%)	77.1	45.8	53.6	49.2	15.1	9.6	8.4	

Table 41. Low luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s links, 6 ROBins per card, for TRT 4 ROBins per card, at maximum 8 ROBIn cards per LVL2 interfaces or per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**4**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	33	5	2	2	2	46
Min # of EB links required	8	1	65	9	13	7	4	107
Min # of combined links required	8	2	97	13	14	9	5	148
# of LVL2 links after grouping, LVL2 i/f slot not shared	6	2	43	5.0	11	2	3	72
# of EB links after grouping, EB i/f slot not shared	11	2	127	17.0	22	8	5	192
# of LVL2 = # of EB links after grouping, i/f slot shared	8	1	127	17.0	13	8	4	178
# of combined LVL2+EB links after grouping	8	2	127	17.0	16	16	5	191
Number of crates, LVL2 and EB i/f in different slots	3	1	22	3	6	2	2	39
Number of crates, LVL2 and EB i/f share same slot	3	1	15	2	5	2	2	30
Number of crates, combined LVL2+EB link	3	1	15	2	6	2	2	31
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	6	4	3	3	6	8	5	
# of ROBin cards per EB link, EB i/f slot not shared	3	4	1	1	3	2	3	
Utilization of LVL2 link bandwidth (%)	9.5	7.4	76.3	80.9	15.1	79.2	37.9	
Utilization of EB link bandwidth (%)	65.5	42.8	50.5	48.6	54.5	86.3	63.0	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	4	8	1	1	5	2	4	
Utilization of LVL2 link bandwidth (%)	7.1	14.8	25.8	23.8	12.8	19.8	28.4	
Utilization of EB link bandwidth (%)	90.0	85.5	50.5	48.6	92.3	86.3	78.8	
# of ROBin cards per combined LVL2+EB link	4	7	1	1	4	1	3	
Utilization of link bandwidth (%)	97.1	50.1	76.3	72.4	85.4	53.0	85.7	
Fraction of link bandwidth used for LVL2 data (%)	7.1	7.4	25.8	23.8	10.4	9.9	22.7	
Fraction of link bandwidth used for EB data (%)	90.0	42.8	50.5	48.6	75.0	43.1	63.0	

Table 42. High luminosity, 75 kHz LVL1 rate, LVL2 accept rate = 3.75 kHz, 80 MByte/s links, 6 ROBins per card, for TRT 4 ROBins per card, at maximum 8 ROBIn cards per LVL2 interfaces or per EB interface or per combined EB+LVL2 link.

Detector	muon-MDT	muon-trig	e.m. cal	hadron cal	TRT	SCT	pixels	Total
Total number of ROBIns	192	48	760	98	256	92	84	1530
Number of ROBIns per card	**6**	**6**	**6**	**6**	**4**	**6**	**6**	
Number of cards with ROBins	32	8	127	17	43	16	14	257
Min # of LVL2 links required	1	1	18	3	1	1	1	26
Min # of EB links required	4	1	34	5	7	4	2	57
Min # of combined links required	5	1	51	7	8	5	3	80
# of LVL2 links after grouping, LVL2 i/f slot not shared	5	2	26	4	10	3	2	52
# of EB links after grouping, EB i/f slot not shared	5	2	77	11	10	6	2	113
# of LVL2 = # of EB links after grouping, i/f slot shared	4	1	43	6	8	4	2	68
# of combined LVL2+EB links after grouping	5	1	64	9	8	6	3	96
Number of crates, LVL2 and EB i/f in different slots	3	1	13	2	5	2	1	27
Number of crates, LVL2 and EB i/f share same slot	2	1	11	2	4	2	1	23
Number of crates, combined LVL2+EB link	3	1	11	2	4	2	2	25
# of ROBin cards per LVL2 link, LVL2 i/f slot not shared	7	4	5	4	6	5	7	
# of ROBin cards per EB link, EB i/f slot not shared	7	4	2	2	6	3	7	
Utilization of LVL2 link bandwidth (%)	6.0	3.9	66.3	53.1	8.7	27.7	29.9	
Utilization of EB link bandwidth (%)	75.6	22.5	43.7	39.5	63.0	60.4	82.7	
# of ROBin cards per LVL2 and per EB link, i/f slot shared	8	8	3	3	8	4	8	
Utilization of LVL2 link bandwidth (%)	7.5	7.8	40.1	35.4	10.9	20.8	29.9	
Utilization of EB link bandwidth (%)	94.5	44.9	78.3	72.4	78.8	90.6	82.7	
# of ROBin cards per combined LVL2+EB link	7	8	2	2	8	3	6	
Utilization of link bandwidth (%)	81.6	52.7	79.6	71.9	89.7	74.3	75.1	
Fraction of link bandwidth used for LVL2 data (%)	6.0	7.8	26.9	23.6	10.9	13.9	19.9	
Fraction of link bandwidth used for EB data (%)	75.6	44.9	52.6	48.3	78.8	60.4	55.2	

Table 43. High luminosity, nominal LVL1 rate, LVL2 accept rate = 2.0 kHz, 80 MByte/s links, 6 ROBins per card, for TRT 4 ROBins per card, at maximum 8 ROBIn cards per LVL2 interfaces or per EB interface or per combined EB+LVL2 link.

Overview of hardware needed for scenarios 1.1 and 1.2

Table 44 and 45 provide an overview of the number of RIO2s, number of network interfaces and number of crates needed for the low luminosity trigger.

Scenario	1.1	1.2
Number of ROBIn cards	257	278
Number of LVL2 interfaces, LVL2 and EB interface do not share slot	257	91
Number of EB interfaces, LVL2 and EB interface do not share slot	168	172
Number of LVL2 interfaces sharing slot with EB interface	257	191
Number of EB interfaces sharing slot with LVL2 interface	257	191
Number of combined LVL2+EB interfaces	208	229
Number of "RIO2s", LVL2 and EB interface do not share slot	425	274
Number of "RIO2s", LVL2 and EB interface share slot	257	191
Number of "RIO2s", combined LVL2+EB link	208	229
Number of crates, LVL2 and EB interface do not share slot	40	36
Number of crates, LVL2 and EB interface share slot	31	30
Number of crates, combined LVL2+EB link	29	32

Table 44. Hardware needed for scenario 1.1 and 1.2 for the low luminosity trigger at a LVL1 rate of 75 kHz and different options for network interfacing.

Scenario	1.1	1.2
Number of ROBIn cards	257	278
Number of LVL2 interfaces, LVL2 and EB interface do not share slot	257	66
Number of EB interfaces, LVL2 and EB interface do not share slot	64	74
Number of LVL2 interfaces sharing slot with EB interface	257	92
Number of EB interfaces sharing slot with LVL2 interface	257	92
Number of combined LVL2+EB interfaces	130	119
Number of "RIO2s", LVL2 and EB interface do not share slot	321	140
Number of "RIO2s", LVL2 and EB interface share slot	257	182
Number of "RIO2s", combined LVL2+EB link	130	119
Number of crates, LVL2 and EB interface do not share slot	40	33
Number of crates, LVL2 and EB interface share slot	31	25
Number of crates, combined LVL2+EB link	25	26

Table 45. Hardware needed for scenario 1.1 and 1.2 for the low luminosity trigger at nominal LVL1 rate and different options for network interfacing.