Showing Real Big Data

Towards visualisation of data transfers with 'Big Data' analytics techniques

HvA induction session February 2016

David Groep, Nikhef

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Nikhef
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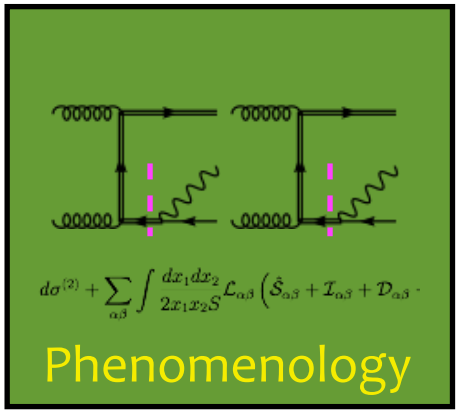
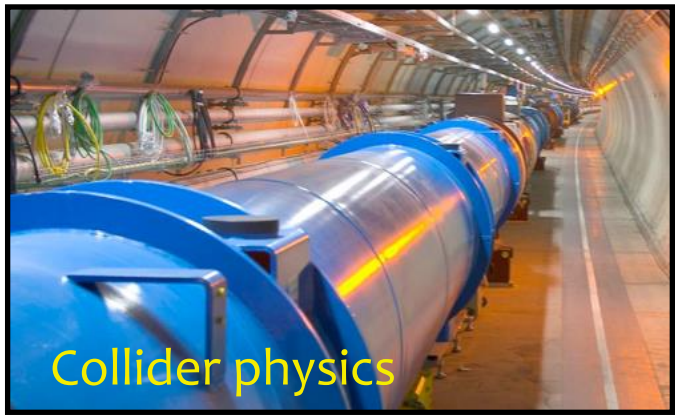
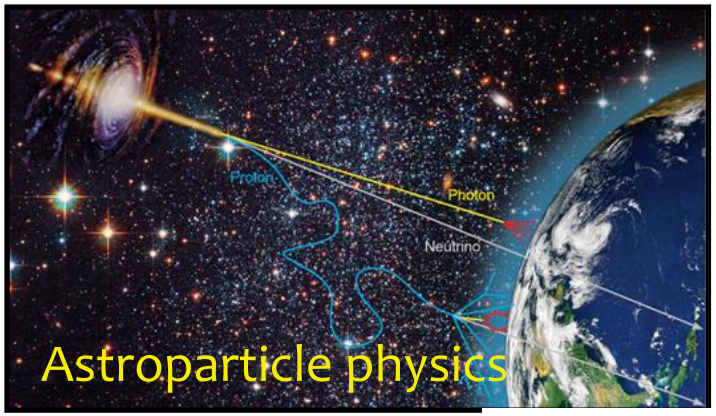
Nationaal instituut voor subatomaire fysica

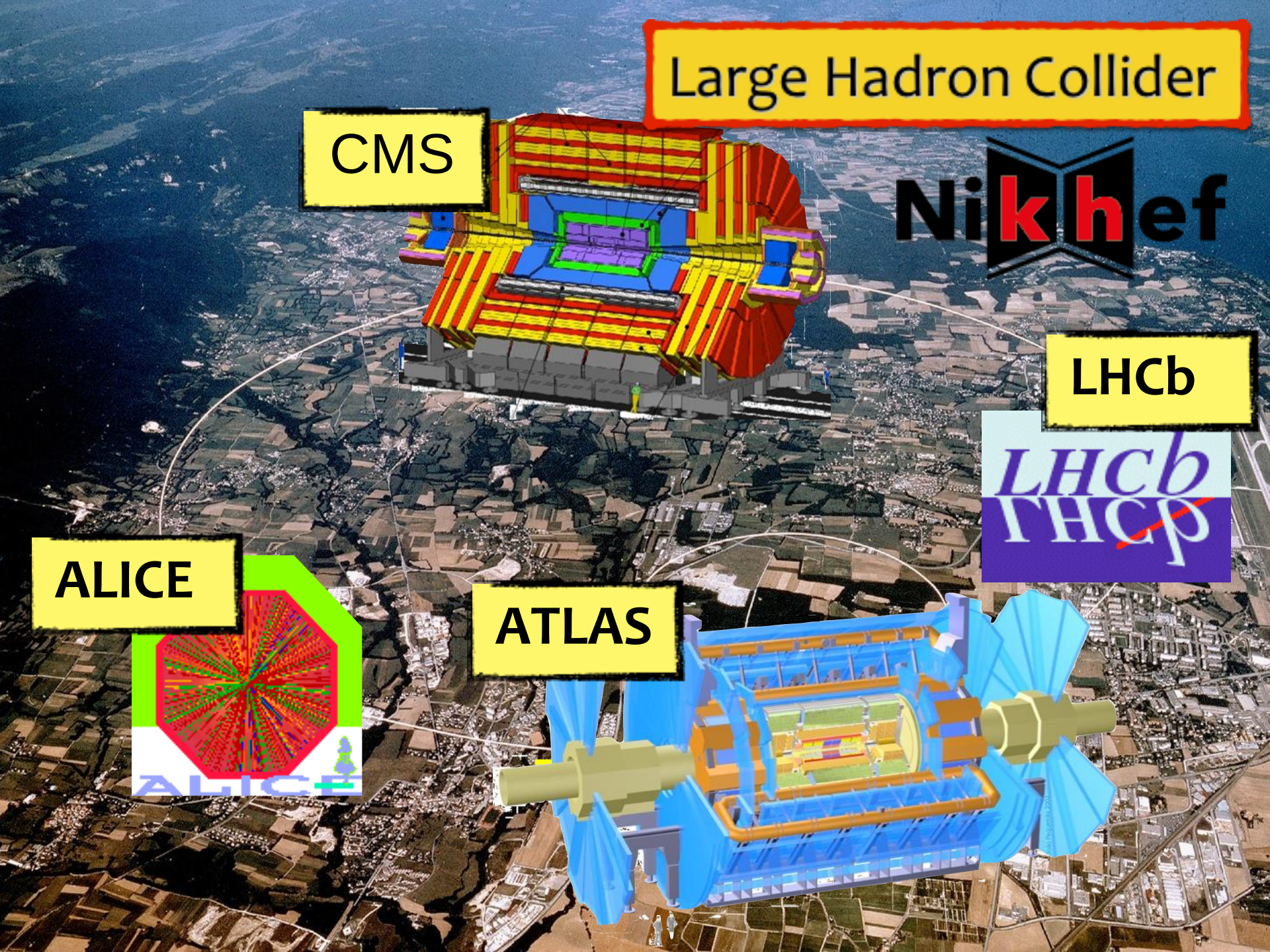
Verleggen van de grenzen van onze kennis

- **Accelerator-based particle physics**
  Experiments studying interactions in particle collision processes at particle accelerators, in particular at CERN;
- **Astroparticle physics**
  Experiments studying interactions of particles and radiation emanating from the Universe.

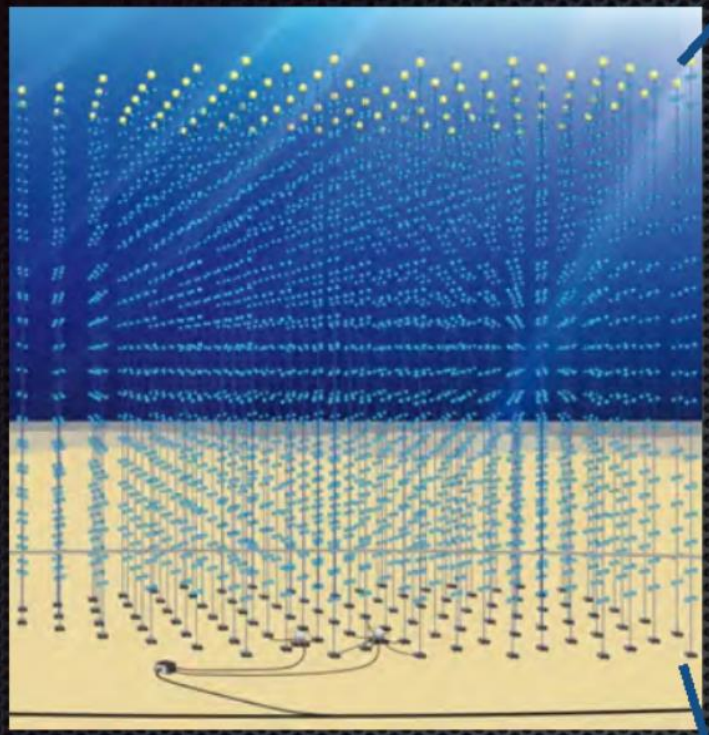


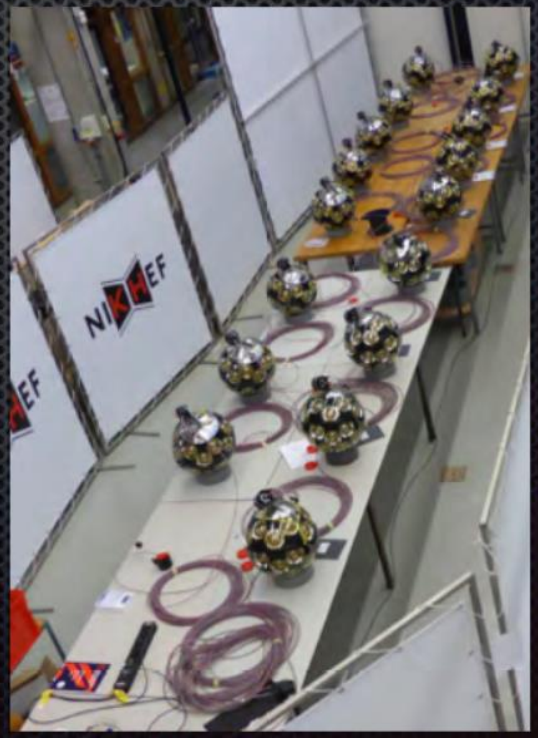





Large Hadron Collider
CMS
Nikhef
LHCb
LHCb
ALICE
ATLAS

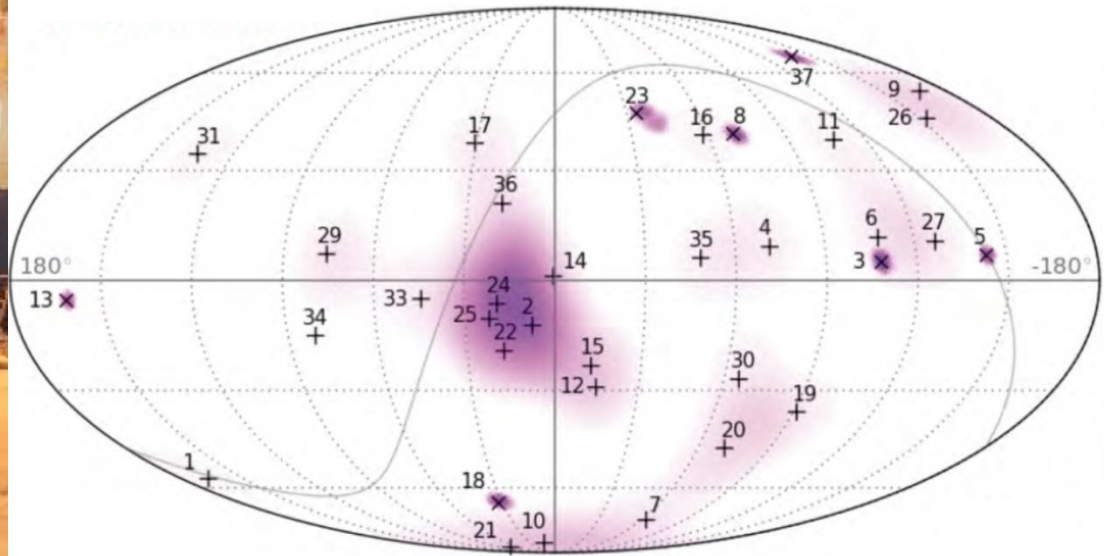
Nikhefs neutrino-detector: KM3NeT

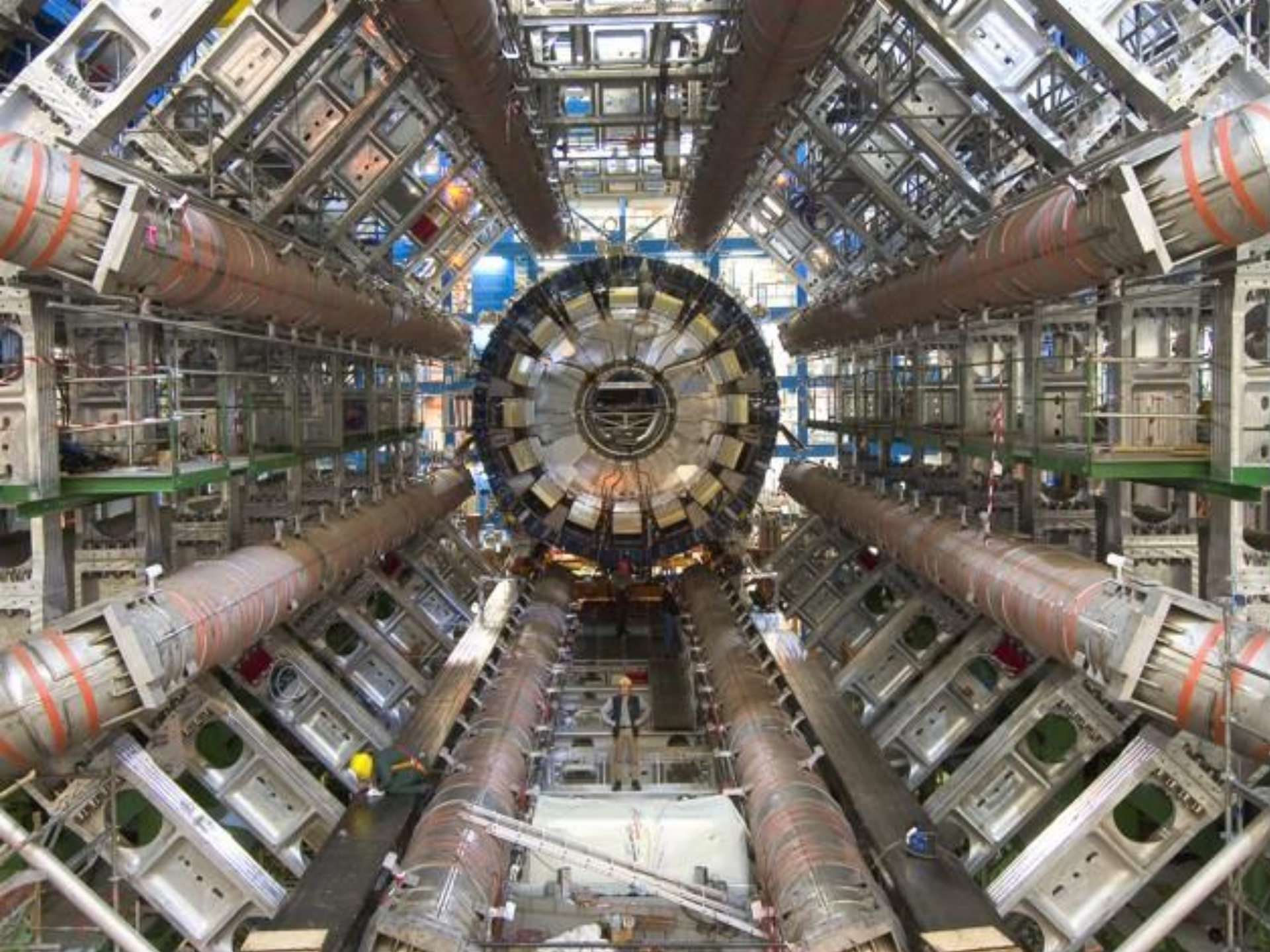




Little white structures prevent the HV bases and cables to touch each other

De Melkweg

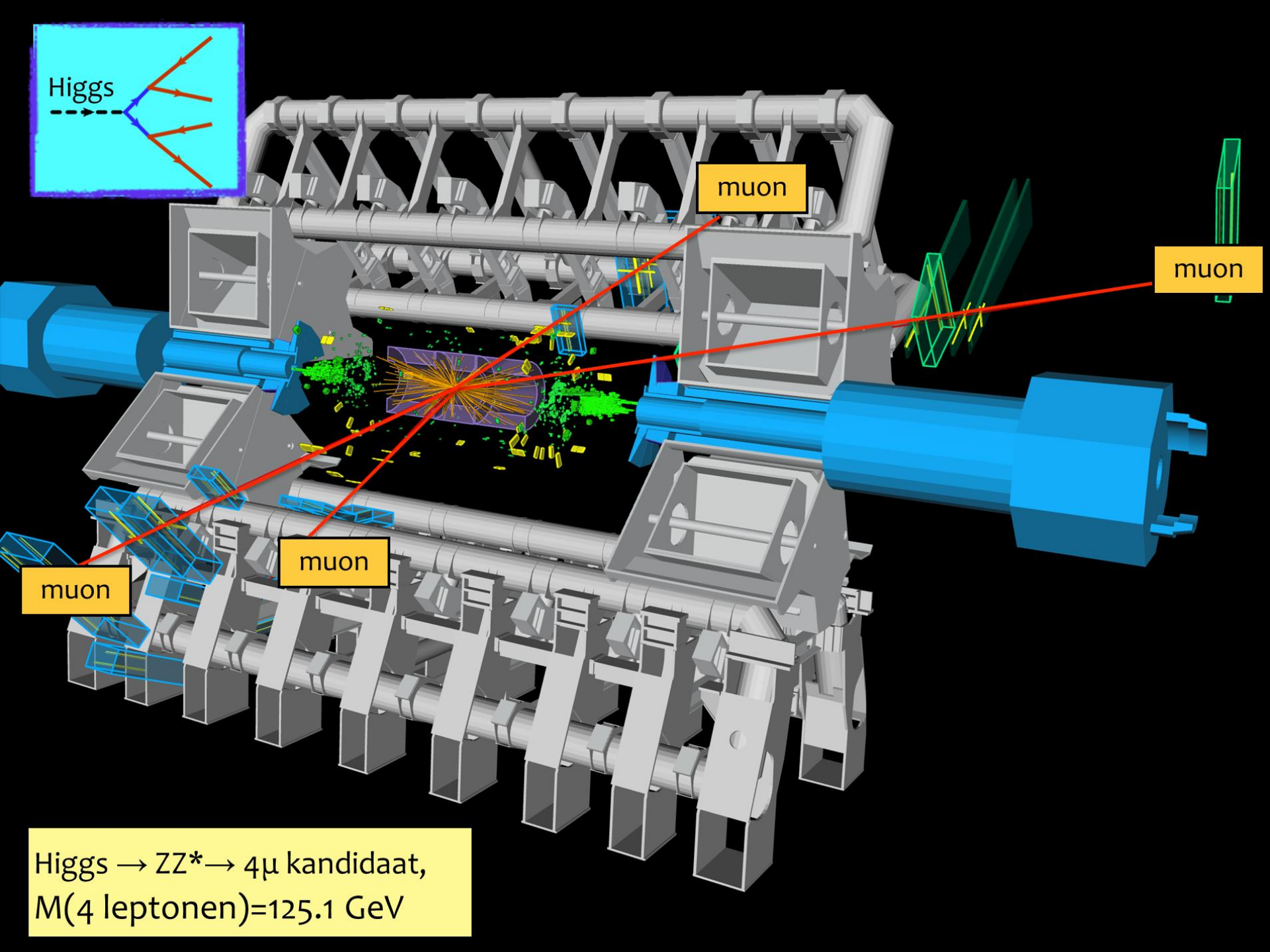




Kans Higgs deeltje:

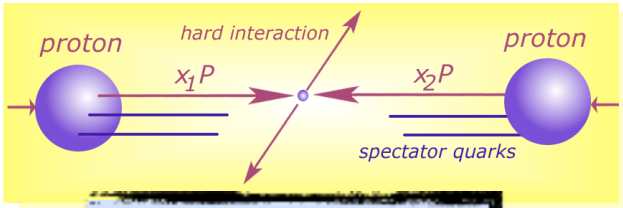
1 op de 1.000.000.000.000 bostingen

- Dit is equivalent met zoeken van 1 persoon op 1000 wereldpopulaties
- Oftewel één naald in 20 miljoen hooibergen

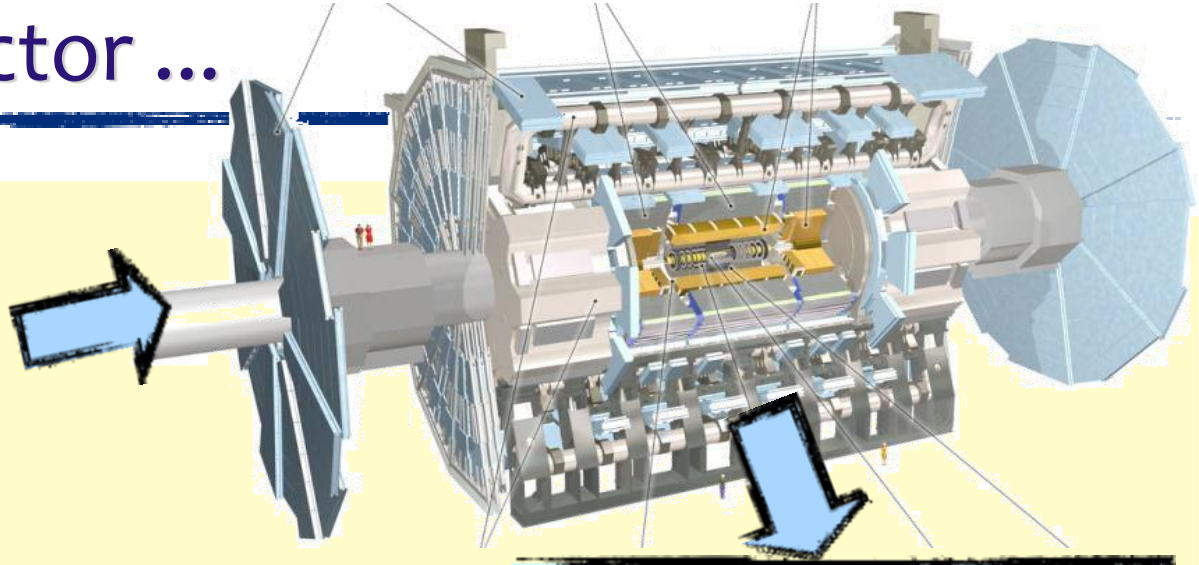


Higgs → ZZ*→ 4μ kandidaat,
M(4 leptonen)=125.1 GeV

Detector to doctor ...

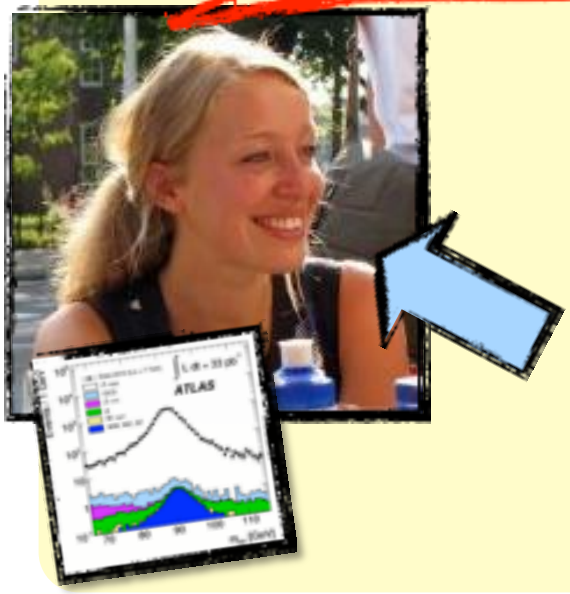


40 miljoen / seconde



Trigger systeem selecteert 600 Hz
~ 1 GB/s data

Analyse van botsingen door promovendi



and processing

Data distributie met GRID computers

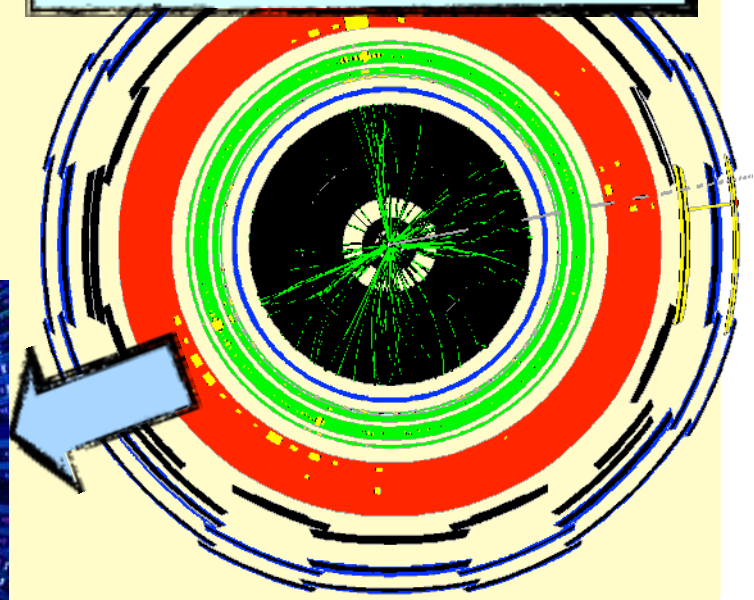


Image source: joint CERN (wLCG) and EGI

Organisations participating in the global collaboration of e-Infrastructures

Even just for wLCG, supporting the CERN LHC programme

More than 200 independent institutes with end-users
More than 50 countries & regions
More than 300 service centres
Handful regional 'service coordination organisations'
300 000 CPU cores, 200+PByte storage
One independent 'policy-bridge' PKI

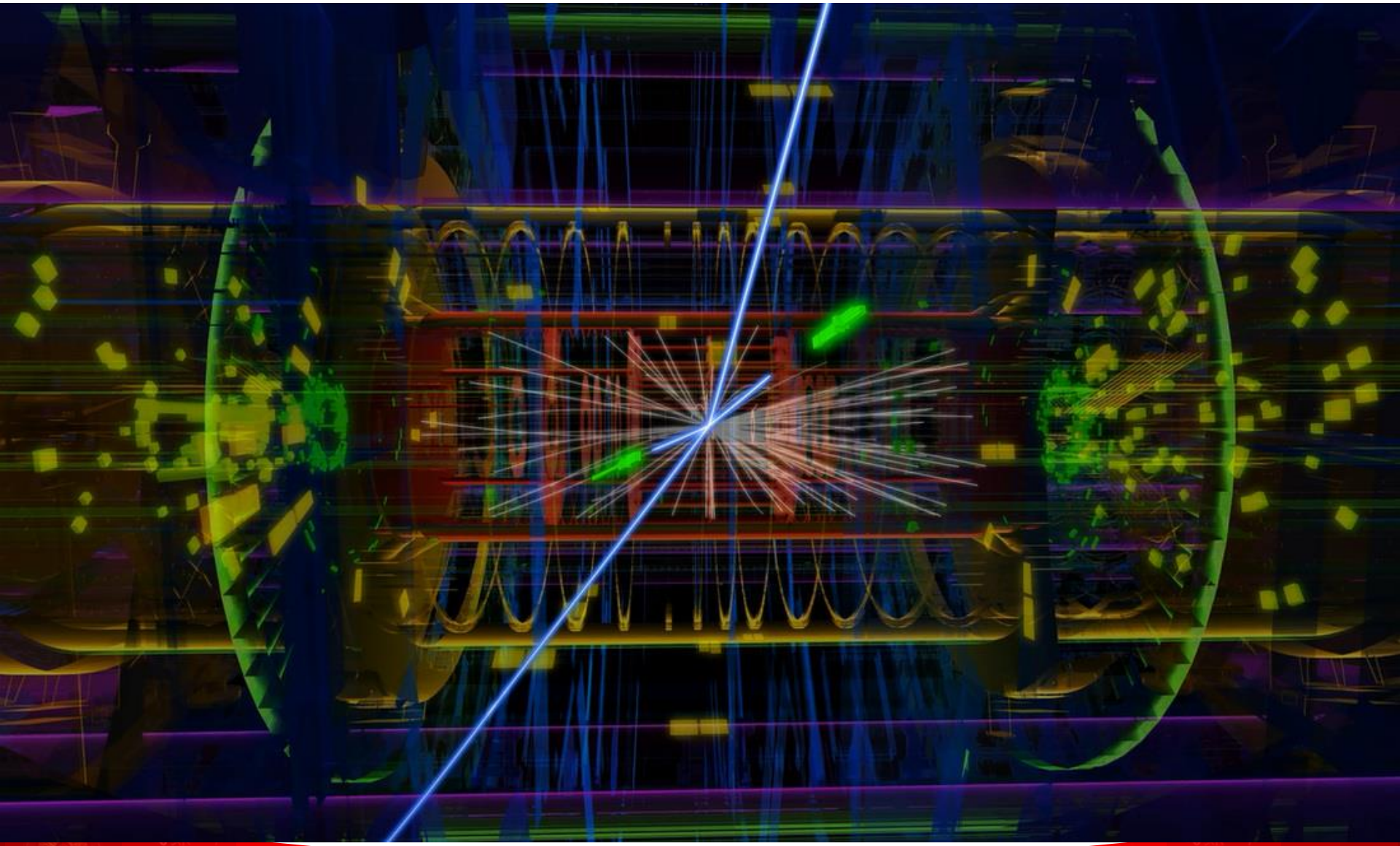
PRACE

Open Science Grid

EGI

XSEDE
Extreme Science and Engineering Discovery Environment

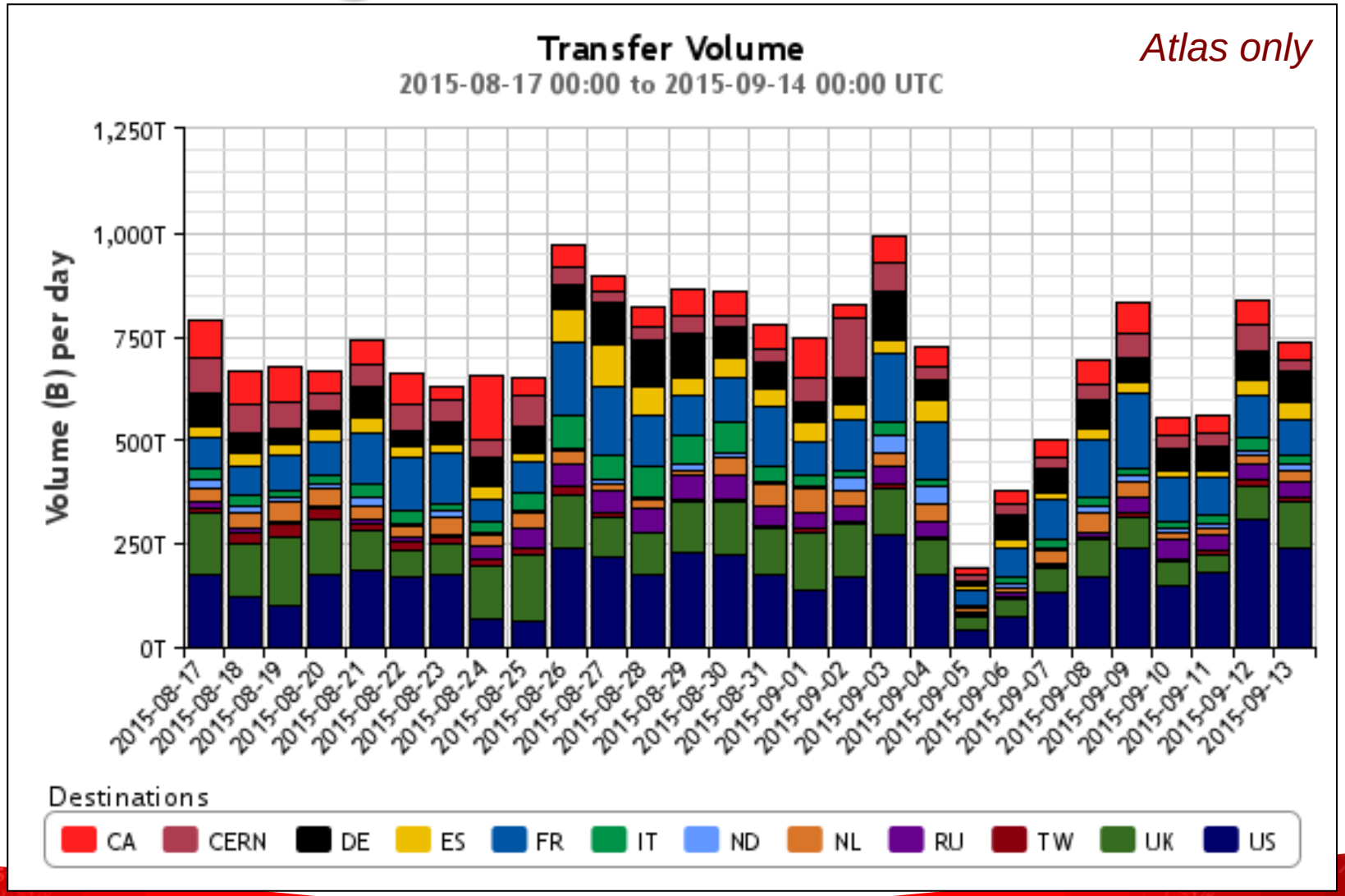
Atlas: ~50 TByte/day raw data to tape; 1000 TByte/day processed data transfers



Nikhef

Image source: CERN, Atlas

Big ‘as in Large’ Data



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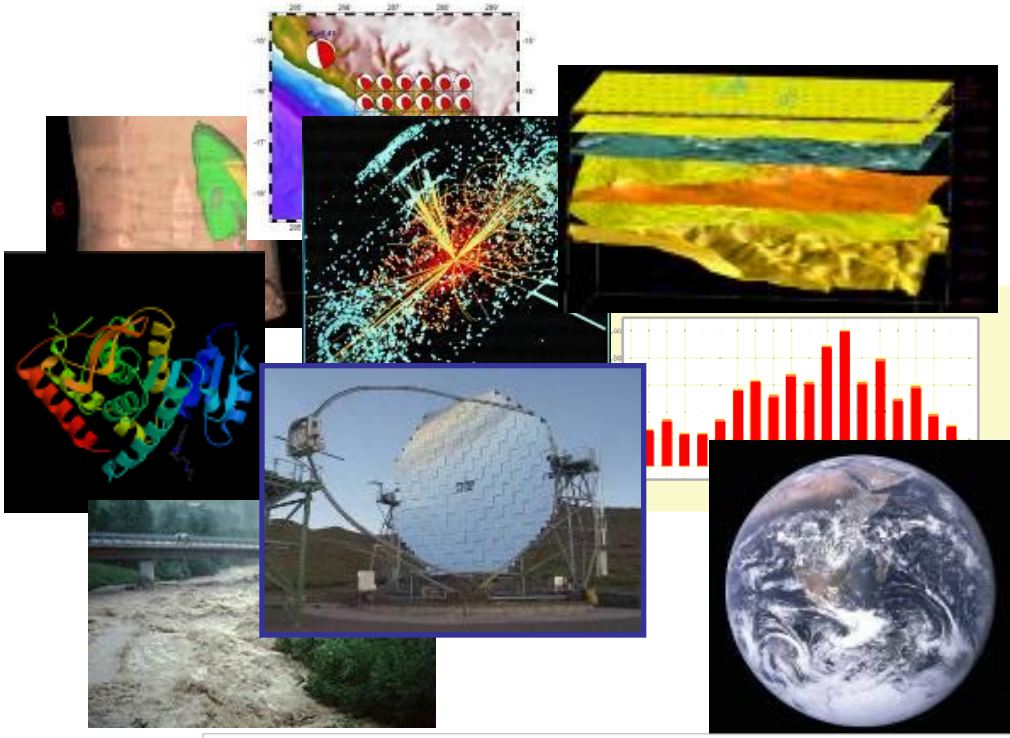
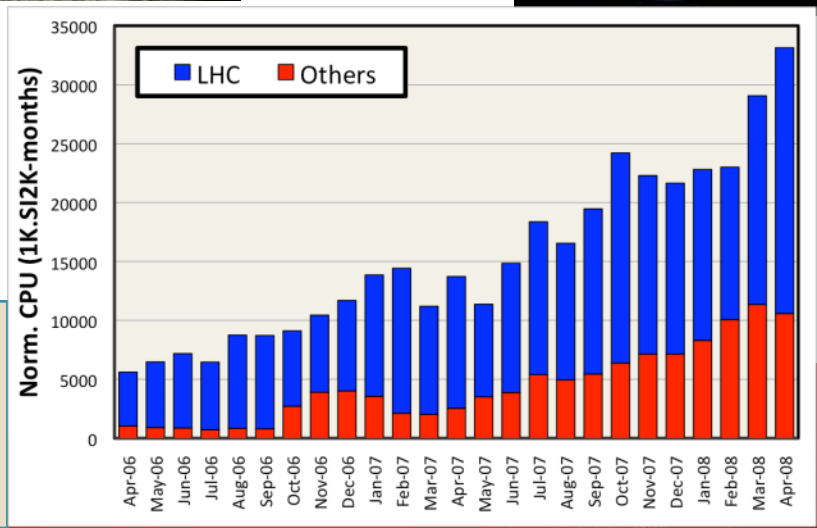
http://dashb-atlas-ddm.cern.ch/ddm2

Shared e-Infrastructure

- >270 communities from many different domains
  - Astronomy & Astrophysics
  - Civil Protection
  - Computational Chemistry
  - Comp. Fluid Dynamics
  - Computer Science/Tools
  - Condensed Matter Physics
  - Earth Sciences
  - Fusion
  - High Energy Physics
  - Life Sciences
  - …





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Applications have moved from testing to routine and daily usage

~80-95% efficiency

Global data flows

~150GByte, 12hrs
per (human) genome
per sequencer

But 1000+ sequencers…

50TByte from Shenzhen to NL is (still) done by rucksack

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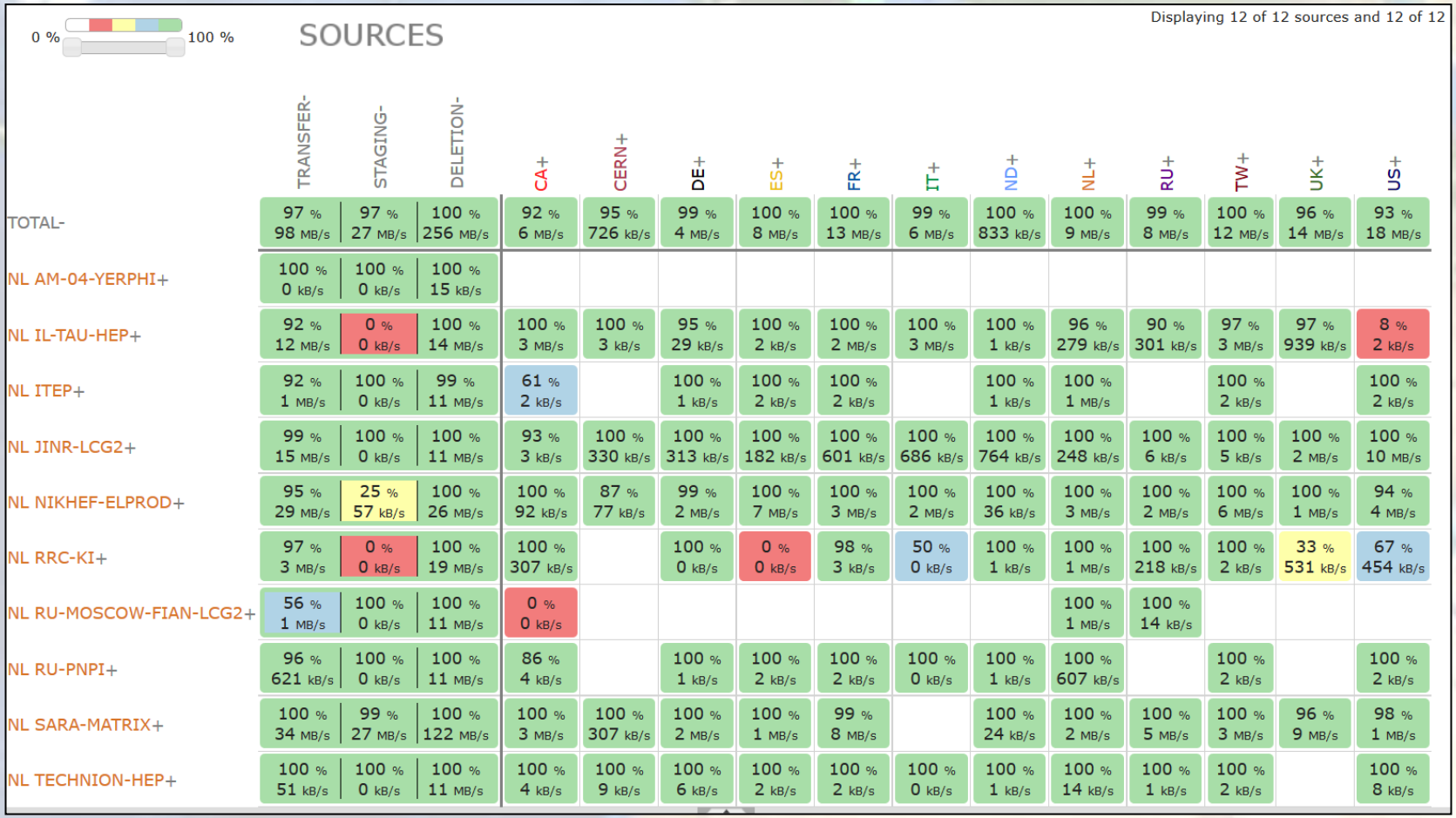
Genome sequencing at the Beijing Genomics Institute BGI
Photo: Scotted400, CC-BY-3.0

Distributed analysis – ‘Atlas neighbours’



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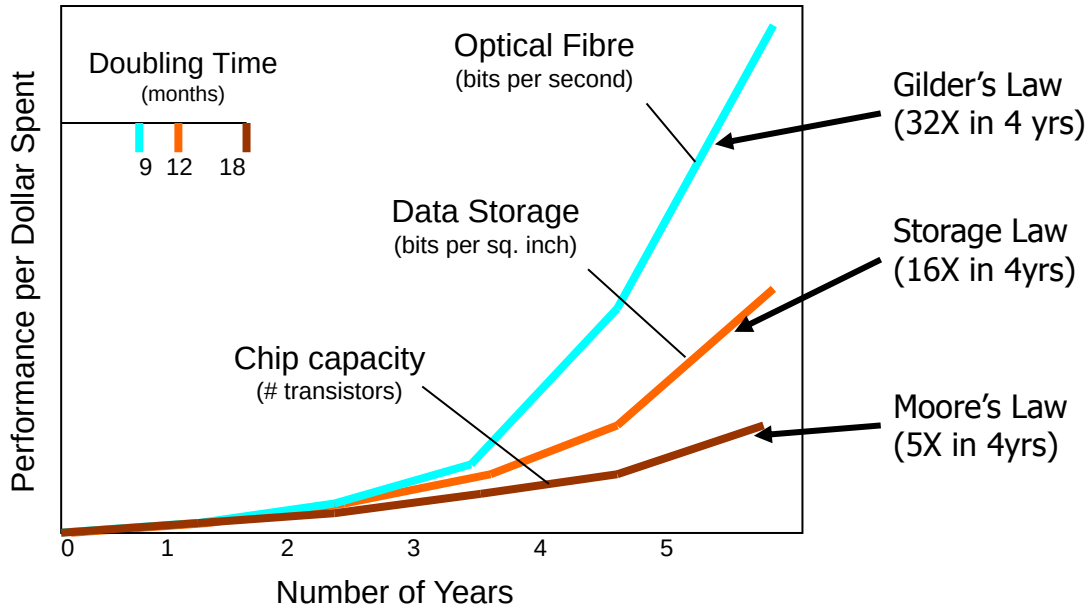
SOURCES

Displaying 12 of 12 sources and 12 of 12

	TRANSFER-	STAGING-	DELETION-	CA+	CERN+	DE+	ES+	FR+	IT+	ND+	NL+	RU+	TW+	UK+	US+
TOTAL-	97 % 98 MB/s	97 % 27 MB/s	100 % 256 MB/s	92 % 6 MB/s	95 % 726 kB/s	99 % 4 MB/s	100 % 8 MB/s	100 % 13 MB/s	99 % 6 MB/s	100 % 833 kB/s	100 % 9 MB/s	99 % 8 MB/s	100 % 12 MB/s	96 % 14 MB/s	93 % 18 MB/s
NL AM-04-YERPHI+	100 % 0 kB/s	100 % 0 kB/s	100 % 15 kB/s												
NL IL-TAU-HEP+	92 % 12 MB/s	0 % 0 kB/s	100 % 14 MB/s	100 % 3 MB/s	100 % 3 kB/s	95 % 29 kB/s	100 % 2 kB/s	100 % 2 MB/s	100 % 3 MB/s	100 % 1 kB/s	96 % 279 kB/s	90 % 301 kB/s	97 % 3 MB/s	97 % 939 kB/s	8 % 2 kB/s
NL ITEP+	92 % 1 MB/s	100 % 0 kB/s	99 % 11 MB/s	61 % 2 kB/s		100 % 1 kB/s	100 % 2 kB/s	100 % 2 MB/s		100 % 1 kB/s	100 % 1 MB/s		100 % 2 kB/s		100 % 2 kB/s
NL JINR-LCG2+	99 % 15 MB/s	100 % 0 kB/s	100 % 11 MB/s	93 % 3 kB/s	100 % 330 kB/s	100 % 313 kB/s	100 % 182 kB/s	100 % 601 kB/s	100 % 686 kB/s	100 % 764 kB/s	100 % 248 kB/s	100 % 6 kB/s	100 % 5 kB/s	100 % 2 MB/s	100 % 10 MB/s
NL NIKHEF-ELPROD+	95 % 29 MB/s	25 % 57 kB/s	100 % 26 MB/s	100 % 92 kB/s	87 % 77 kB/s	99 % 2 MB/s	100 % 7 MB/s	100 % 3 MB/s	100 % 2 MB/s	100 % 36 kB/s	100 % 3 MB/s	100 % 2 MB/s	100 % 6 MB/s	100 % 1 MB/s	94 % 4 MB/s
NL RRC-KI+	97 % 3 MB/s	0 % 0 kB/s	100 % 19 MB/s	100 % 307 kB/s		100 % 0 kB/s	0 % 0 kB/s	98 % 3 kB/s	50 % 0 kB/s	100 % 1 kB/s	100 % 1 MB/s	100 % 218 kB/s	100 % 2 kB/s	33 % 531 kB/s	67 % 454 kB/s
NL RU-MOSCOW-FIAN-LCG2+	56 % 1 MB/s	100 % 0 kB/s	100 % 11 MB/s	0 % 0 kB/s							100 % 1 MB/s	100 % 14 kB/s			
NL RU-PNPI+	96 % 621 kB/s	100 % 0 kB/s	100 % 11 MB/s	86 % 4 kB/s		100 % 1 kB/s	100 % 2 kB/s	100 % 2 kB/s	100 % 0 kB/s	100 % 1 kB/s	100 % 607 kB/s		100 % 2 kB/s		100 % 2 kB/s
NL SARA-MATRIX+	100 % 34 MB/s	99 % 27 MB/s	100 % 122 MB/s	100 % 3 MB/s	100 % 307 kB/s	100 % 2 MB/s	100 % 1 MB/s	99 % 8 MB/s		100 % 24 kB/s	100 % 2 MB/s	100 % 5 MB/s	100 % 3 MB/s	96 % 9 MB/s	98 % 1 MB/s
NL TECHNION-HEP+	100 % 51 kB/s	100 % 0 kB/s	100 % 11 MB/s	100 % 4 kB/s	100 % 9 kB/s	100 % 6 kB/s	100 % 2 kB/s	100 % 2 kB/s	100 % 0 kB/s	100 % 1 kB/s	100 % 14 kB/s	100 % 1 kB/s	100 % 2 kB/s		100 % 8 kB/s

http://dashb-atlas-ddm.cern.ch/ddm2

There's always a network close to you



NL Light

SURF NET

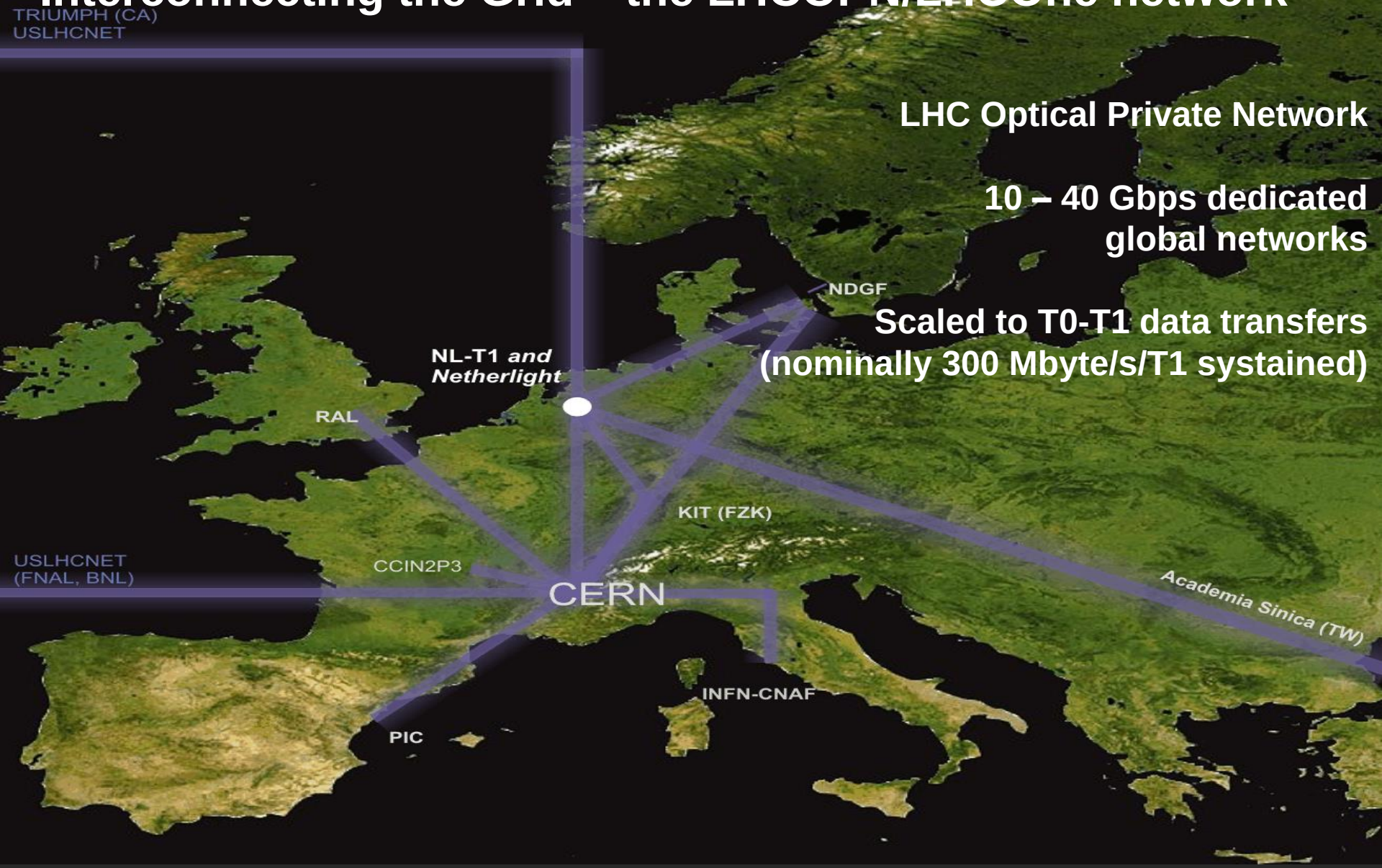
SURFnet pioneered 'lambda' and hybrid networks in the world

- and likely contributed to the creation of a market for 'dark fibre' in the Netherlands

There's always fibre within 2 miles from you – where ever you are!

(it's just that last mile to your home that's missing – and the business model of your telecom provider…)

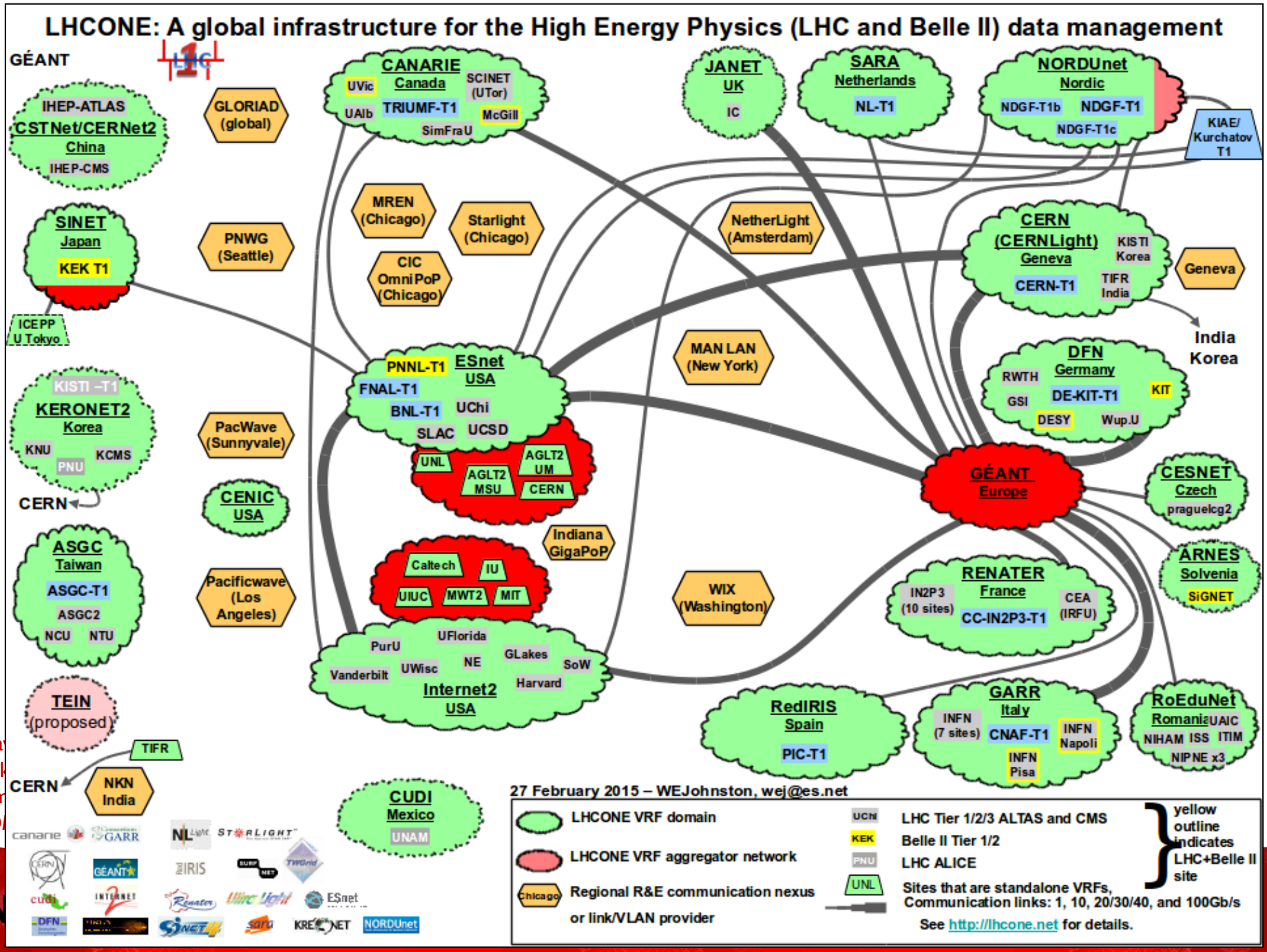
Interconnecting the Grid – the LHCOPN/LHCOne network



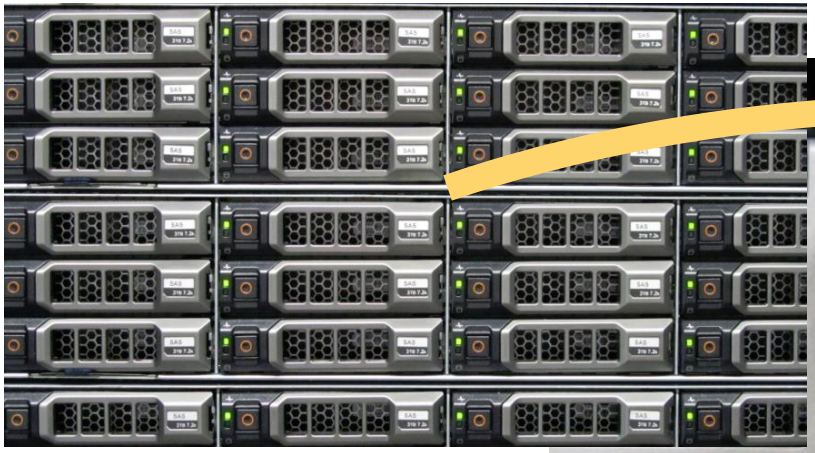
LHC Optical Private Network

10 – 40 Gbps dedicated global networks

Scaled to T0-T1 data transfers (nominally 300 Mbyte/s/T1 systained)


LHCONE: A global infrastructure for the High Energy Physics (LHC and Belle II) data management
GÉANT
IHEP-ATLAS
CSTNet/CERNet2
China
IHEP-CMS
GLORIAD (global)
CANARIE
Canada
UVic
SCINET (UTor)
UAlb
TRIUMF-T1
McGill
SimFraU
JANET
UK
IC
SARA
Netherlands
NL-T1
NORDUnet
Nordic
NDGF-T1b
NDGF-T1
NDGF-T1c
KIAE/ Kurchatov T1
SINET
Japan
KEK T1
PNWG (Seattle)
MREN (Chicago)
Starlight (Chicago)
CIC OmniPoP (Chicago)
NetherLight (Amsterdam)
CERN (CERNLight)
Geneva
CERN-T1
KISTI Korea
TIFR India
Geneva
India
Korea
ICEPP
U Tokyo
MAN LAN (New York)
DFN
Germany
RWTH
DE-KIT-T1
KIT
GSI
DESY
Wup.U
KISTI –T1
KERONET2
Korea
KNU
PNU
KCMS
CERN
PacWave (Sunnyvale)
PNNL-T1
ESnet
USA
FNAL-T1
BNL-T1
UChi
SLAC
UCSD
UNL
AGLT2 MSU
AGLT2 UM
CERN
GÉANT
Europe
CESNET
Czech
praguelcg2
CENIC
USA
Indiana GigaPoP
ASGC
Taiwan
ASGC-T1
ASGC2
NCU
NTU
Pacificwave (Los Angeles)
Caltech
IU
UIUC
MWT2
MIT
WIX (Washington)
RENATER
France
IN2P3 (10 sites)
CC-IN2P3-T1
CEA (IRFU)
ARNES
Solvenia
SiGNET
PurU
UFlorida
NE
GLakes
SoW
Vanderbilt
UWisc
Harvard
Internet2
USA
TEIN
(proposed)
TIFR
CERN
NKN
India
RedIRIS
Spain
PIC-T1
GARR
Italy
INFN (7 sites)
CNAF-T1
INFN Napoli
INFN Pisa
RoEduNet
Romania
UAIC
NIHAM
ISS
ITIM
NIPNE x3
CUDI
Mexico
UNAM
27 February 2015 – WEJohnston, wej@es.net
LHCONE VRF domain
LHCONE VRF aggregator network
Chicago
Regional R&E communication nexus or link/VLAN provider
UChi
LHC Tier 1/2/3 ALTAS and CMS
KEK
Belle II Tier 1/2
PNU
LHC ALICE
UNL
Sites that are standalone VRFs, Communication links: 1, 10, 20/30/40, and 100Gb/s
yellow outline indicates LHC+Belle II site
See http://lhcone.net for details.

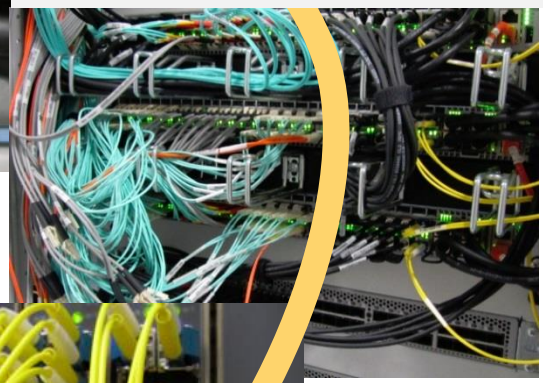
The Flow of Data at Nikhef



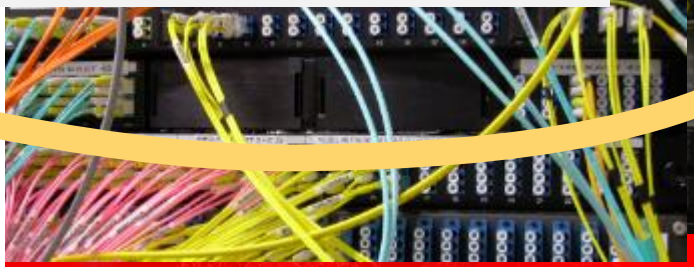
44 disk servers
~3 PiB (~3000 TByte)
2 control & DB nodes

10 – 40 Gbps per server

240 Gbps interconnect

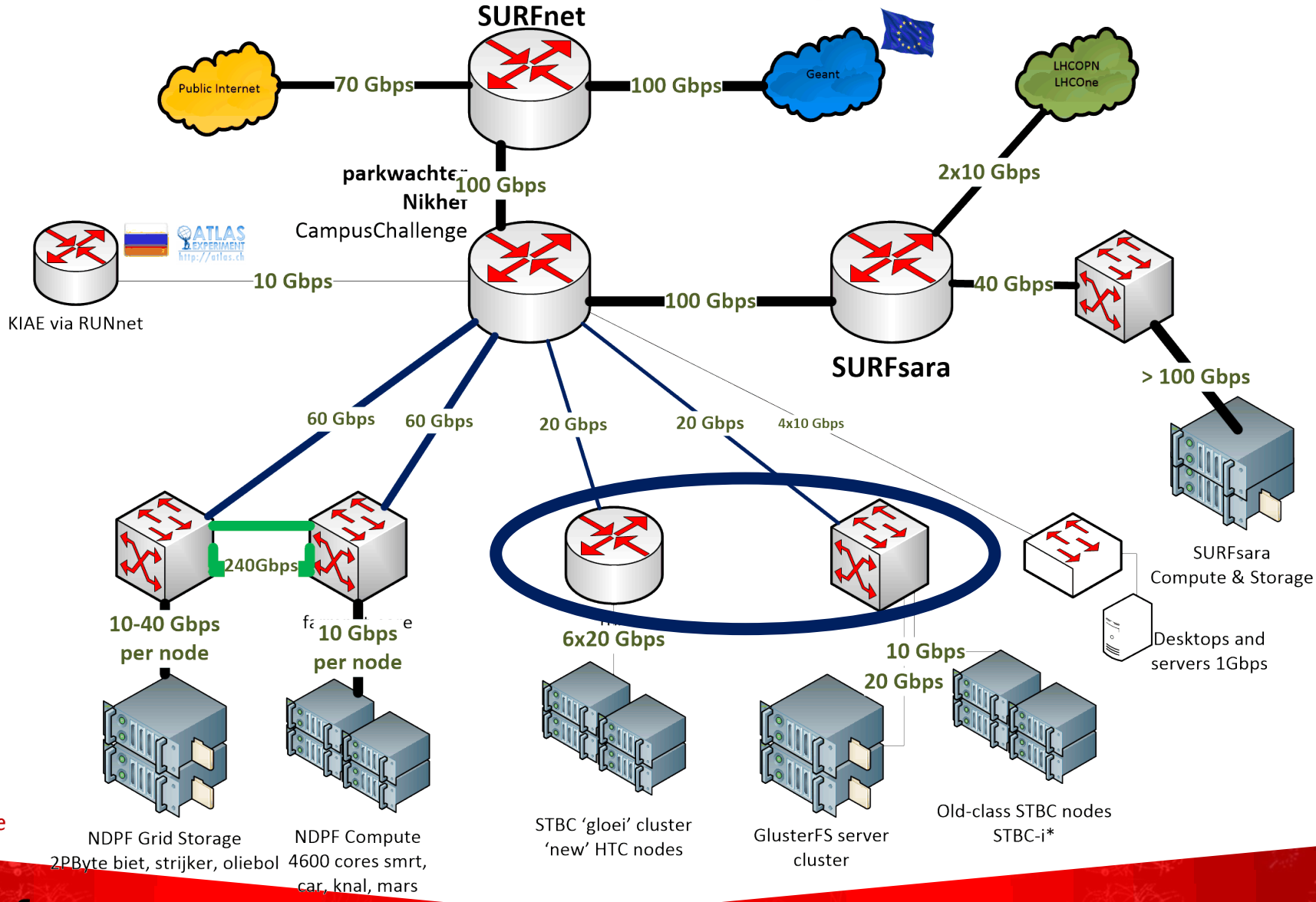


Peerings: SURFnet, SURFsara, Kurchatov, AMOLF, CWI, LHCOPN, LHCOne via SARA



>200 Gbps uplinks

Nikhef Data Processing network



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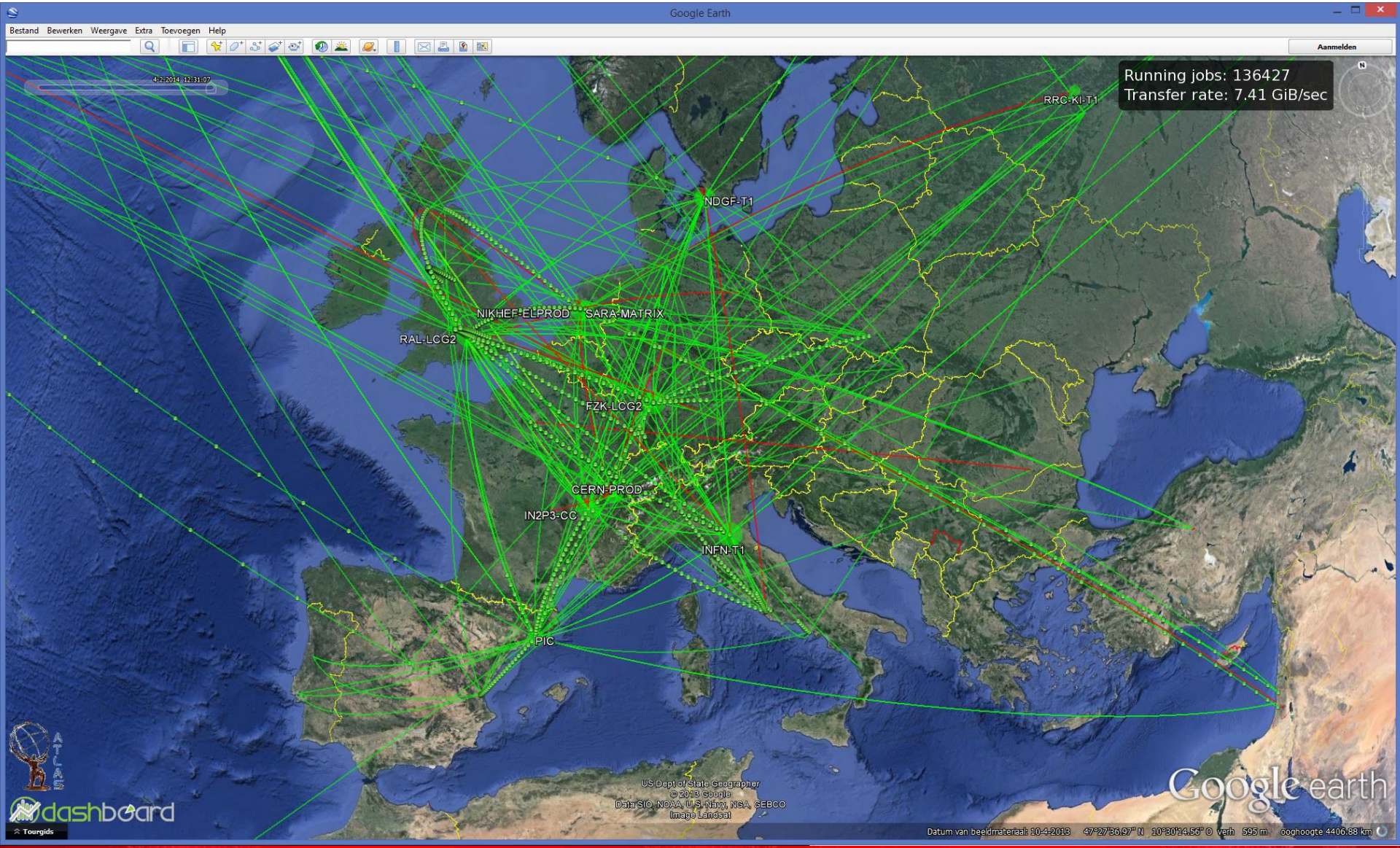
Data Flows in the LHC Computing Grid



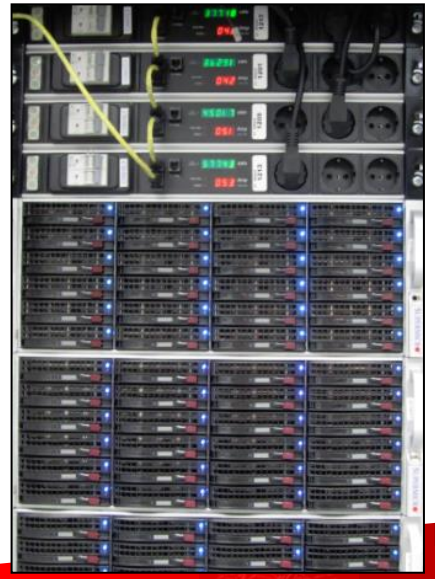
But that's only a small subset

LCG "FTS" visualisation sees but part of the data

- only shows the centrally managed data transfers
- sees only traffic from Atlas, CMS, and LHCb
- cannot show the quality, nor bandwidth used

But each of our nodes sees all its transfers

- server logging is in itself data
- we collect it all



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One day worth of logs … ~12GB/day

```
tbn18.nikhef.nl:/var/log/
 631M    dpm/log.1
 1.1G    dpns/log.1
 639M    srmv2.2/log.1
```

plus 44 disk server nodes @250 Mbyte/day

```
09/13 00:01:23.588 26759,79 dpm_srv_proc_put: calling dpm_selectfs
09/13 00:01:23.588 26759,79 dpm_selectfs: selected pool: BIOMED
09/13 00:01:23.588 26759,79 dpm_selectfs: selected file system: oliebol-02.nikhef.nl:/export/data/biomed
09/13 00:01:23.588 26759,79 dpm_selectfs: oliebol-02.nikhef.nl:/export/data/biomed reqsize=0, elemp->free=399976081749, poolp->free=399976081749
09/13 00:01:23.645 26759,79 dpm_srv_proc_put: calling Cns_creatx
09/13 00:01:23.712 26759,19 dpm_srv_getspacetoken: DP092 - getspacetoken request by /DC=ch/DC=cern/OU=Organic Units/OU=Users/CN=ddmadmin/CN=53149
09/13 00:01:23.712 26759,19 dpm_srv_getspacetoken: DP098 - getspacetoken ATLASDATADISK
09/13 00:01:23.713 26759,19 dpm_srv_getspacetoken: returns 0, status=DPM_SUCCESS
09/13 00:01:23.753 26759,78 dpm_srv_proc_get: TURL info: gsiftp oliebol-09.nikhef.nl oliebol-09.nikhef.nl:/export/data/atlasprd/atlas/2015-09-12/
09/13 00:01:23.755 26759,78 dpm_srv_proc_get: returns 0, status=DPM_SUCCESS
09/13 00:01:23.761 26759,79 dpm_srv_proc_put: TURL info: gsiftp oliebol-02.nikhef.nl oliebol-02.nikhef.nl:/export/data/biomed/biomed/2015-09-13/j
09/13 00:01:23.763 26759,79 dpm_srv_proc_put: returns 0, status=DPM_SUCCESS
09/13 00:01:23.881 26759,18 dpm_updfreespace: oliebol-02.nikhef.nl:/export/data/biomed incr=0, elemp->free=399976081749, poolp->free=399976081749
09/13 00:01:23.881 26759,18 dpm_srv_putdone: returns 0, status=DPM_SUCCESS
```

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And then our storage manager is still ‘decent’ …

CASTOR Logs

- ~2GB/day from the node I showed (highest volume)
- ~30GB/day collected overall
- ~200 source nodes
- ~70,000,000 log events/day

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Science & Technology Facilities Council

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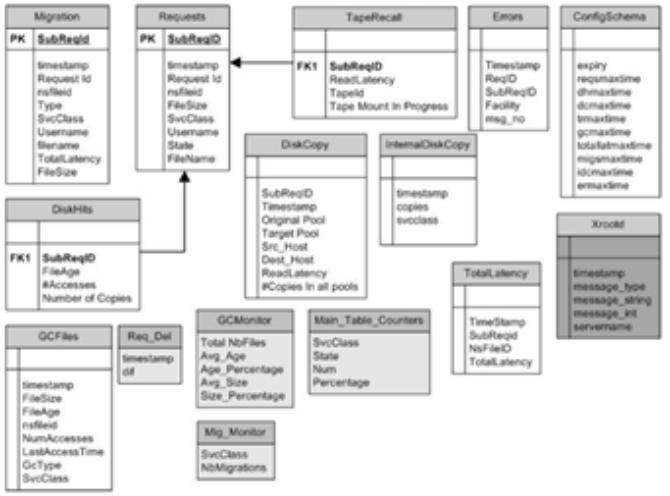
The First Solution - DLF

- DLF = 'Distributed Logging Facility'
- CERN-developed monitoring system for CASTOR
- Store all the log information in a big Oracle DB



Source: *CASTOR end-to-end monitoring*, by T Rekatsinas et al, URL: http://iopscience.iop.org/1742-6596/219/4/042052/pdf/1742-6596_219_4_042052.pdf

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Running DLF

- Scalability was a killer.
  - By 2013, simple queries were taking >1 hour.
  - Fundamental architecture couldn't cope.

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Big Data Analytics for log analysis

- Analysis of log data is typical 'big data' problem
  - CERN tried Hadoop ('map-reduce')
  - RAL went with … ELK*
- For logs specifically, it's mostly efficient search
  - ElasticSearch (www.elastic.co)
  - LogStash (collect and parse logs, import to ES)
  - Kibana – analysis based on Apache Lucene + graphing
- Integrated into a single 'stack': ELK

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*Appleyard et al., http://pos.sissa.it/archive/conferences/239/027/ISGC2015_027.pdf

LogStash

Data arrives in format A…
…process B occurs…
…data out in format C

e.g. convert syslog into json

plugin documentation

inputs	codecs	filters	outputs
collectd	cloudtrail	advisor	boundary
drupal_dblog	collectd	alter	circonus
elasticsearch	compress_spooler	anonymize	cloudwatch
eventlog	dots	checksum	csv
exec	edn	cidr	datadog
file	edn_lines	cipher	datadog_metrics
ganglia	fluent	clone	elasticsearch
gelf	graphite	collate	elasticsearch_http
gemfire	json	csv	elasticsearch_river
generator	json_lines	date	email
graphite	json_spooler	dns	exec
heroku	line	drop	file
imap	msgpack	elapsed	ganglia
invalid_input	multiline	elasticsearch	gelf
irc	netflow	environment	gemfire
jmx	noop	extractnumbers	google_bigquery
log4j	oldlogstashjson	fingerprint	google_cloud_storage
lumberjack	plain	gelfify	graphite
pipe	rubydebug	geoip	graphtastic
puppet_facter	spool	grep	hipchat
rabbitmq		grok	http
rackspace		grokdiscovery	irc
redis		i18n	jira
relp		json	juggernaut
s3		json_encode	librato
snmptrap		kv	loggly
sqlite		metaevent	lumberjack

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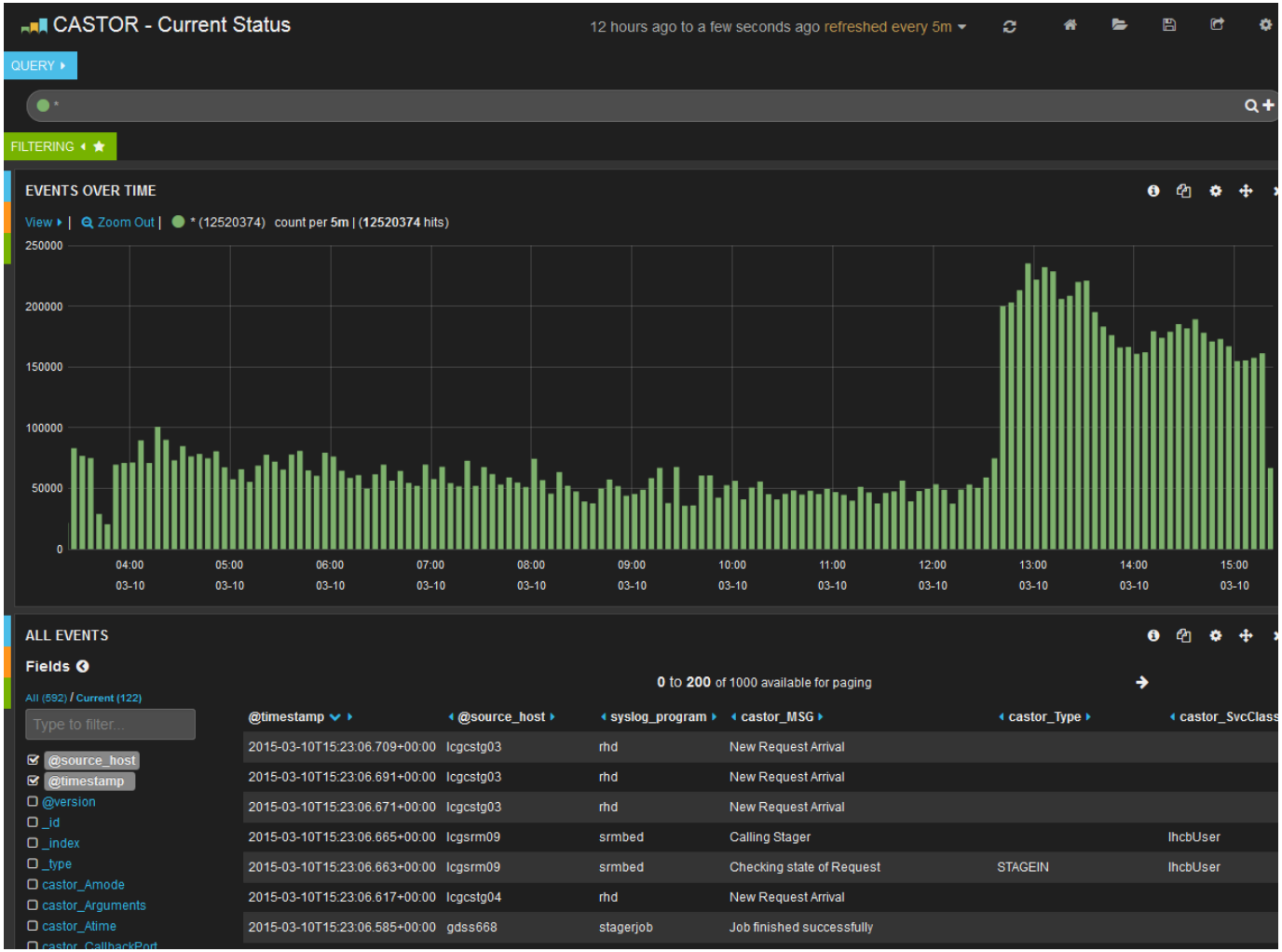
Analyse ‘by hand’: Kibana & Lucene



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Graphic from Rob Appleyard, RTFC RAL – at ISGC 2015

Challenges ahead!

At the start

- 44+ difference data sources, 240 Gbps of traffic
- 150+ different storage partners, 55 countries/regions
- public internet plus the LHCOPN/LHCOne
- 5000+ users, working 24x7

… and 'grep' for a tool … ☹

And phase I added

- setup of a big data analytics cluster (ELK)
- merge diverse data sources into a single system
- define queries and find some global anomalies ☺

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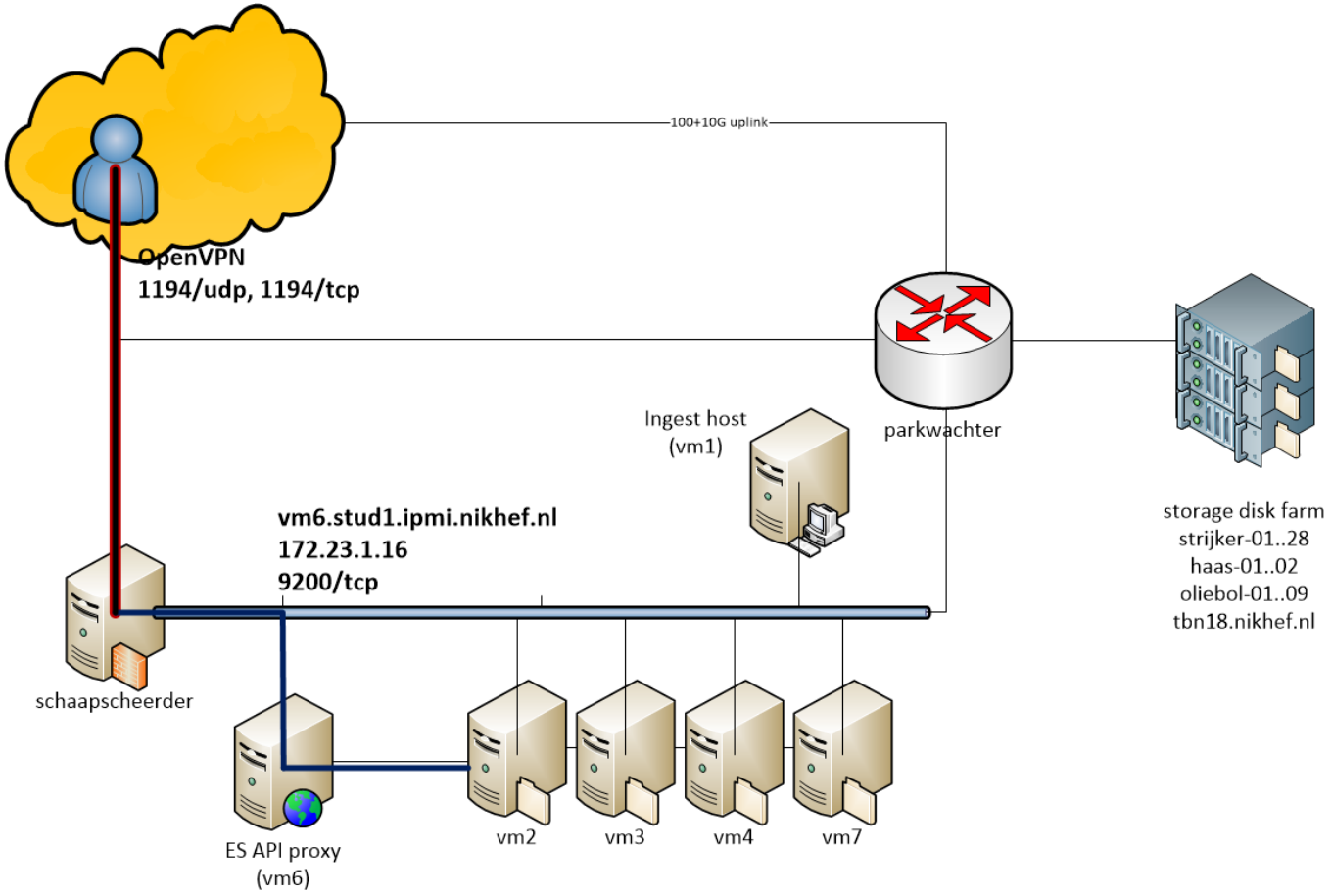
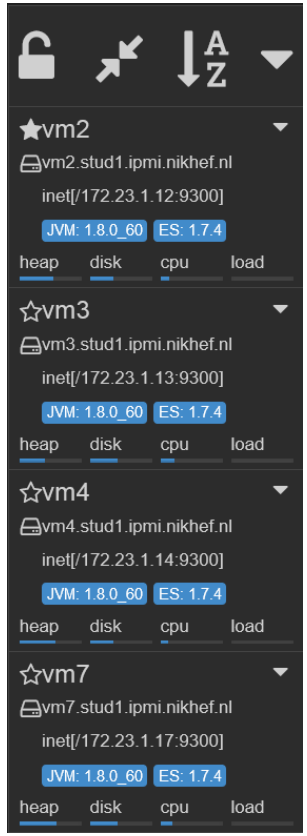
ELK Cluster and Interface





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Filled with data

filter nodes by name | master | data | client

name	load average	cpu %	heap usage %	disk usage %	uptime
logstash-vm5.stud1.ipmi.nikhef.nl-7420-... vm5.stud1.ipmi.nikhef.nl inet[/172.23.1.15:9300] JVM: 1.8.0_60 ES: 1.7.0	N/A		25.0 used: 126.69MB max: 491.69MB	*no disk info for client nodes*	3d.
vm2 vm2.stud1.ipmi.nikhef.nl inet[/172.23.1.12:9300] JVM: 1.8.0_60 ES: 1.7.4		22.0	59.0 used: 2.36GB max: 3.98GB	38.0 free: 121.55GB total: 196.74GB	9d.
vm3 vm3.stud1.ipmi.nikhef.nl inet[/172.23.1.13:9300] JVM: 1.8.0_60 ES: 1.7.4		18.0	58.0 used: 2.33GB max: 3.98GB	45.0 free: 107.77GB total: 196.74GB	7d.
vm4 vm4.stud1.ipmi.nikhef.nl inet[/172.23.1.14:9300] JVM: 1.8.0_60 ES: 1.7.4		15.0	73.0 used: 2.94GB max: 3.98GB	37.0 free: 123.51GB total: 196.74GB	7d.
vm7 vm7.stud1.ipmi.nikhef.nl inet[/172.23.1.17:9300] JVM: 1.8.0_60 ES: 1.7.4		20.0	59.0 used: 2.36GB max: 3.98GB	44.0 free: 109.89GB total: 196.74GB	9d.

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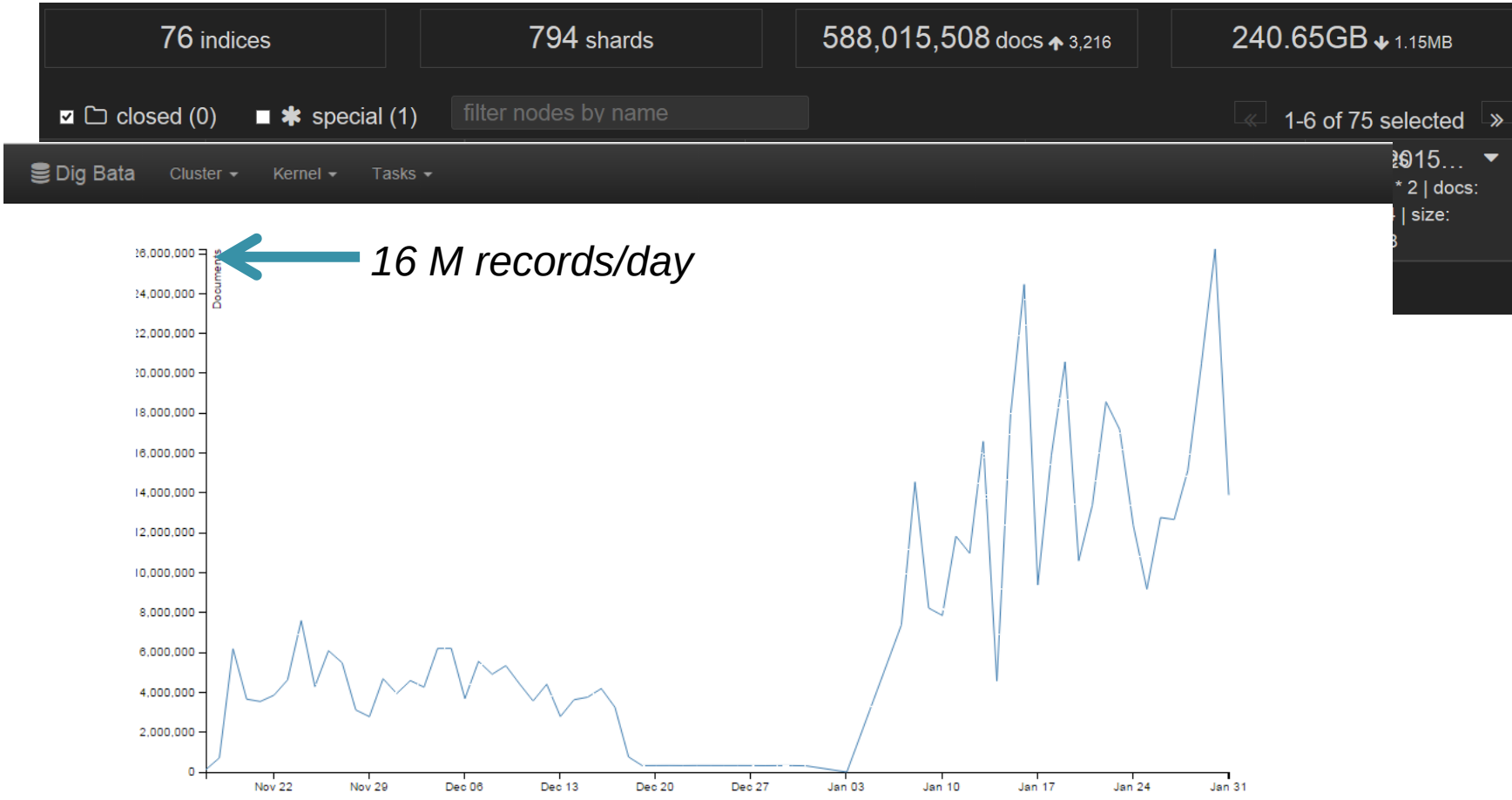
Filling it up: from 0 to ~ 500 million



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Graphics courtesy Jouke Roorda, Olivier Verbeek, Rens Visser

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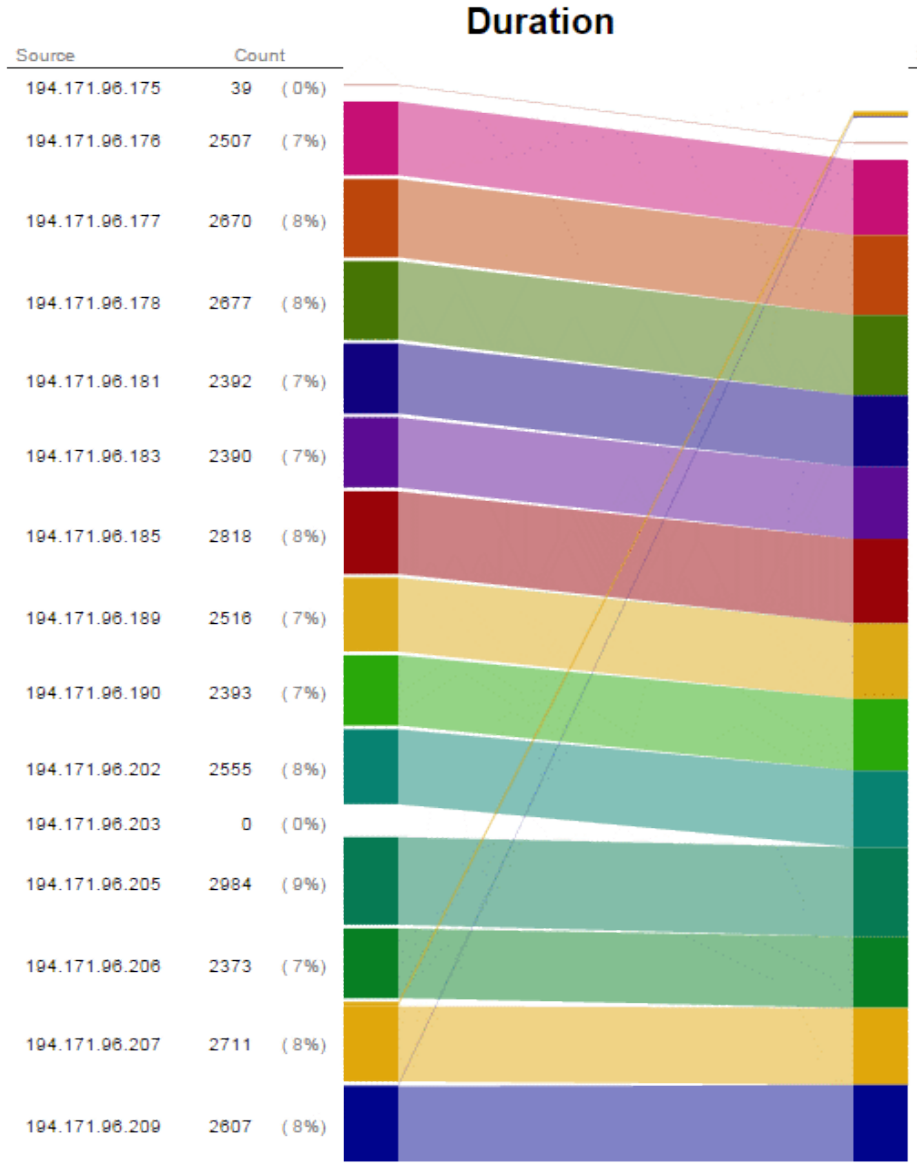

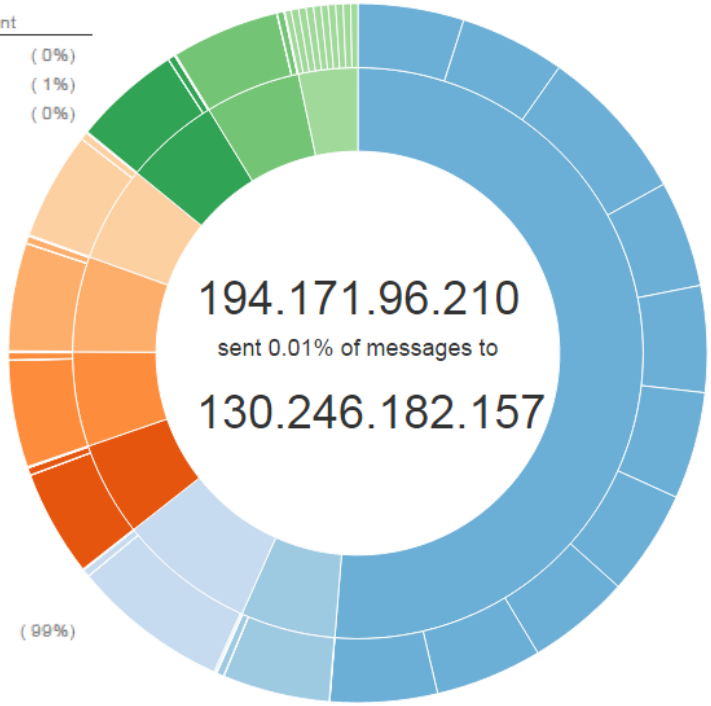

Data flows: a user at UC Irvine reading a data set from Nikhef, with some background from CERN and KIT Karlsruhe

Graphics courtesy Jouke Roorda, Olivier Verbeek, Rens Visser

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Building upon phase I …

Phase II

- How can global data flows be presented?
- Can one conceive visualisations for the general public? for users? or for both?
- Identifying troublesome inter-peer links (and local disk servers) via analytics techniques
- Identifying 'hot' (interesting) data by analysing usage
- Pro-active security incident detection:
  are there users 'behaving strangely'?

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Phase II: plenty to do!

…

- What's the way to explain WLCG data flows to the world?
- which systems (or group of systems) uses the most bandwidth (in and out separately)
- which systems (or group of systems) generates the most connections?
- what does the spectrum of transfers look like? mostly big, mostly small, ... ?
- what does the time distribution of transfers look like (bandwidth and also number)?

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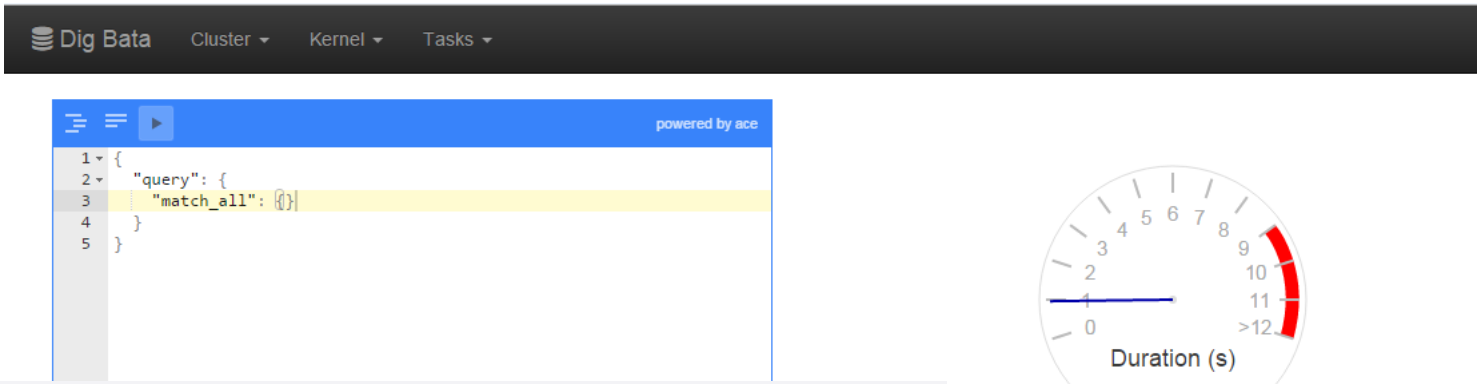
Queries and responses




```
{
    "Query_begin_structuur": {
        "type_query": {
            "field": "naam field aan te spreken"
        }
    }
}
```

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Graphics courtesy Jouke Roorda, Olivier Verbeek, Rens Visser

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Access services

https://wiki.nikhef.nl/grid/HvABigDataVisualisation

- OpenVPN configuration
- Access to full ES search API

- Please limit yourself to query methods
- Do not redistribute or copy records with PII
- Kindly observe the Nikhef AUP as well – and report any incidents to security@nikhef.nl

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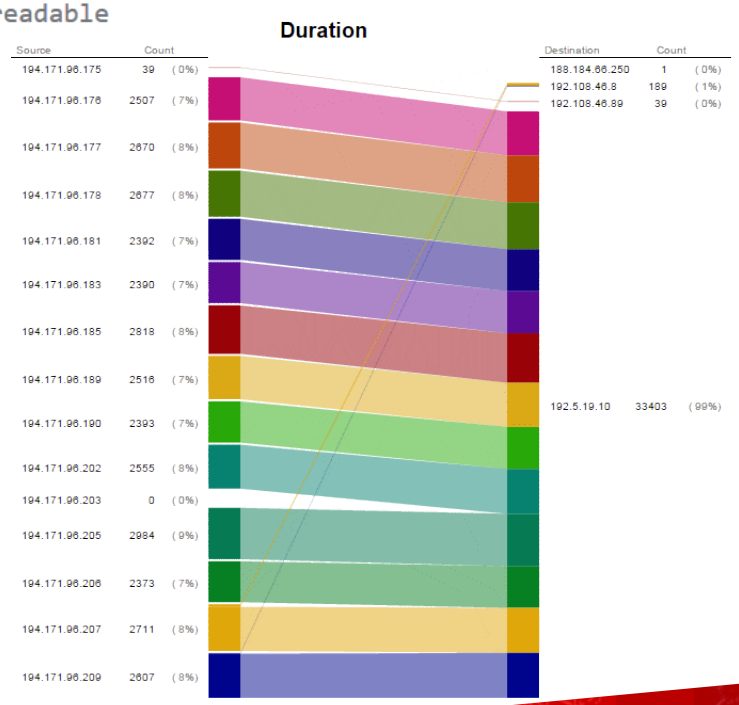
```
public List getDocsHistogram() throws IOException {
    return client.execute(
            new Search.Builder(new SearchSourceBuilder()
                    // This query searches for the right kind of log messages
                    .query(
                            QueryBuilders.boolQuery()
                                    .must(QueryBuilders.matchQuery("program", "dpm-gsiftp"))
                                    .must(QueryBuilders.matchQuery("msg_type", "transfer"))
                    )
                    // Newest results should be retrieved
                    .sort(SortBuilders.fieldSort("@timestamp").order(SortOrder.DESC))
                    // Get 25 entries to keep the graph readable
                    .size(25)
                    .toString()
            ).addIndex(logsIndex).build())
            .getHits(Map.class)
            // Java 8 streams because they're awesome :)
            .stream()
```

Your call!
Questions?



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Code sample: Jouke Roorda, PDP-sample-app