

Progress in the Gossip/GridPix development

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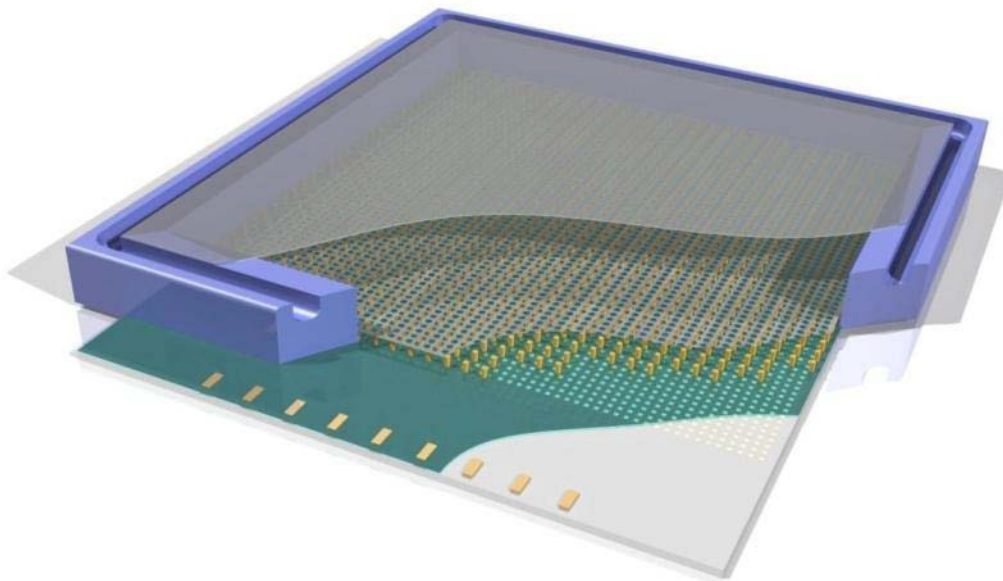
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Some analysis results from the
August 2010 testbeam

Reference in EDMS
Gossip backup document
ATL-P-MN-0016 v.1



On Sept 3, 2010, Gossip/GridPix have been approved as Atlas R&D projects

(original EB text in blue)

■ **Baseline inner tracker remains silicon**

- “The baseline ATLAS inner tracker upgrade is an all- silicon detector”

■ GridPix and Gossip are now considered as candidates for **new** detector technology

- “New technologies such as GridPix and the Gossip version of it could become an alternative sensor technology to pursue for part of the detector. “

■ But at the end Gossip and GridPix **have to be very advantageous over silicon**

- “They would only be adopted in case of major performance or cost advantages over silicon technology, or if technical issues are found in the silicon projects in the next 2-3 years. “

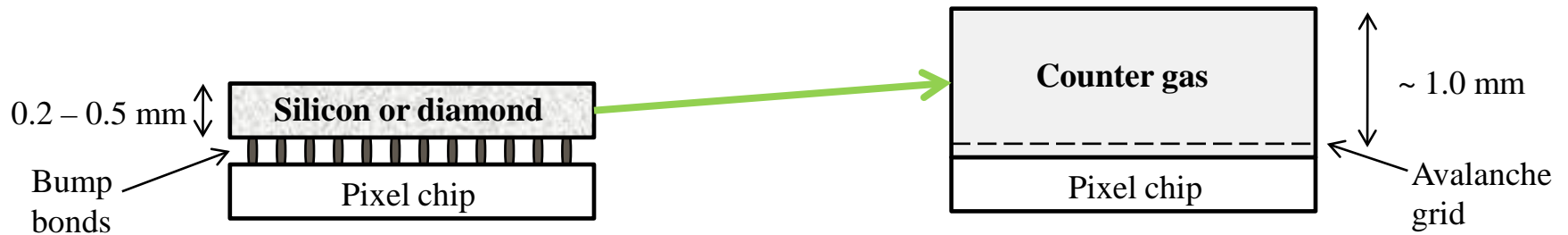
■ Only approved for **three years** => **evaluation** of Gossip/GridPix in **2013**

- “The EB has considered the Gossip R&D proposal, and supports this R&D for a limited duration of 3 years to demonstrate and quantify performance, cost and reliability. In 2013, ATLAS will review the results and consider if there are sufficient elements for further pursuance of this technology for ATLAS. “

Principle of Gossip

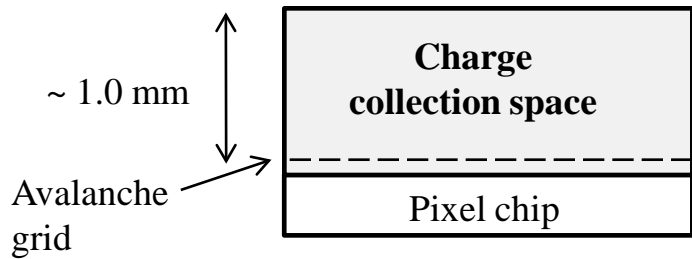
■ Gaseous pixel detector

Solid state (silicon/diamond) → gas

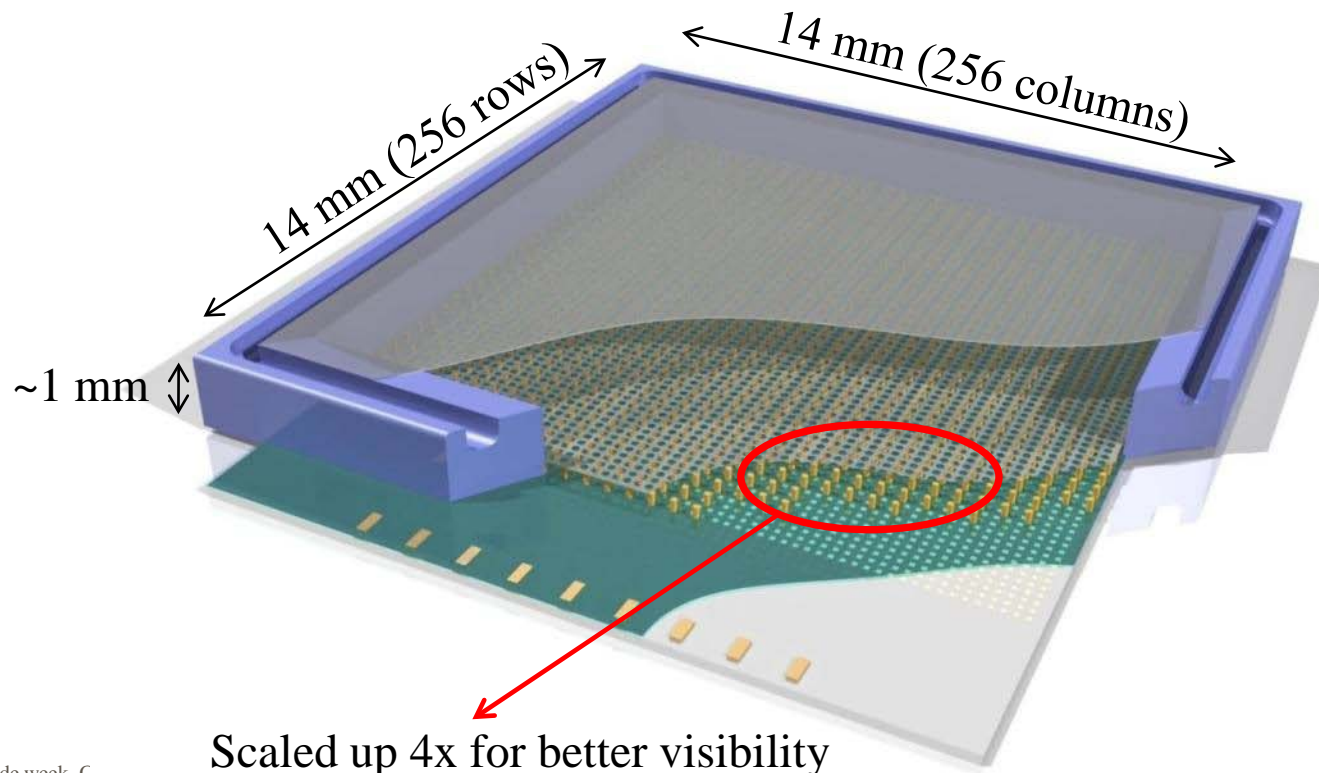


Bump bonds → Avalanche grid

The three components of Gossip

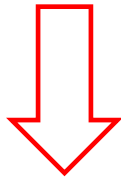


- **Charge collection space**, about 1 mm high
- **Amplification grid** inducing gas avalanche
- **Pixel chip** with a **high granularity** (55 – 60 μm)



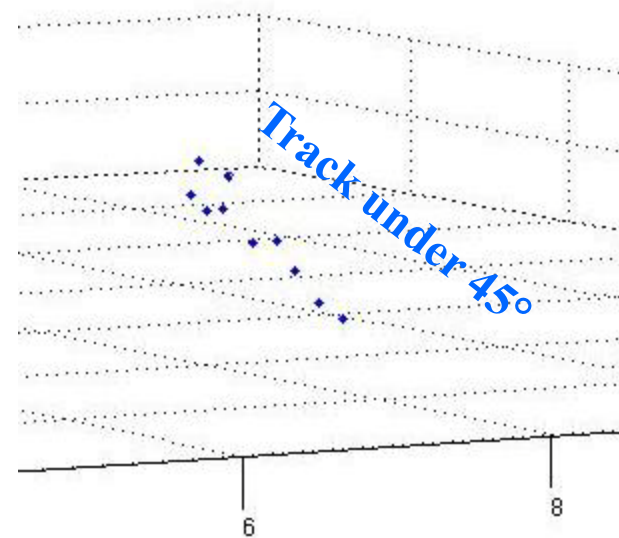
Ionization in Gossip

- **Ref:** Solid state $\sim 5000 - 25000$ primary electron-hole pairs
- **Gossip:** only 1 mm of gas
- $\Rightarrow \sim 1 - 20$ electrons per track crossing
- \Rightarrow **electrons** in Gossip are **precious**



● We detect them **individually**

Typical event from August 2010 testbeam



Detecting individual electrons

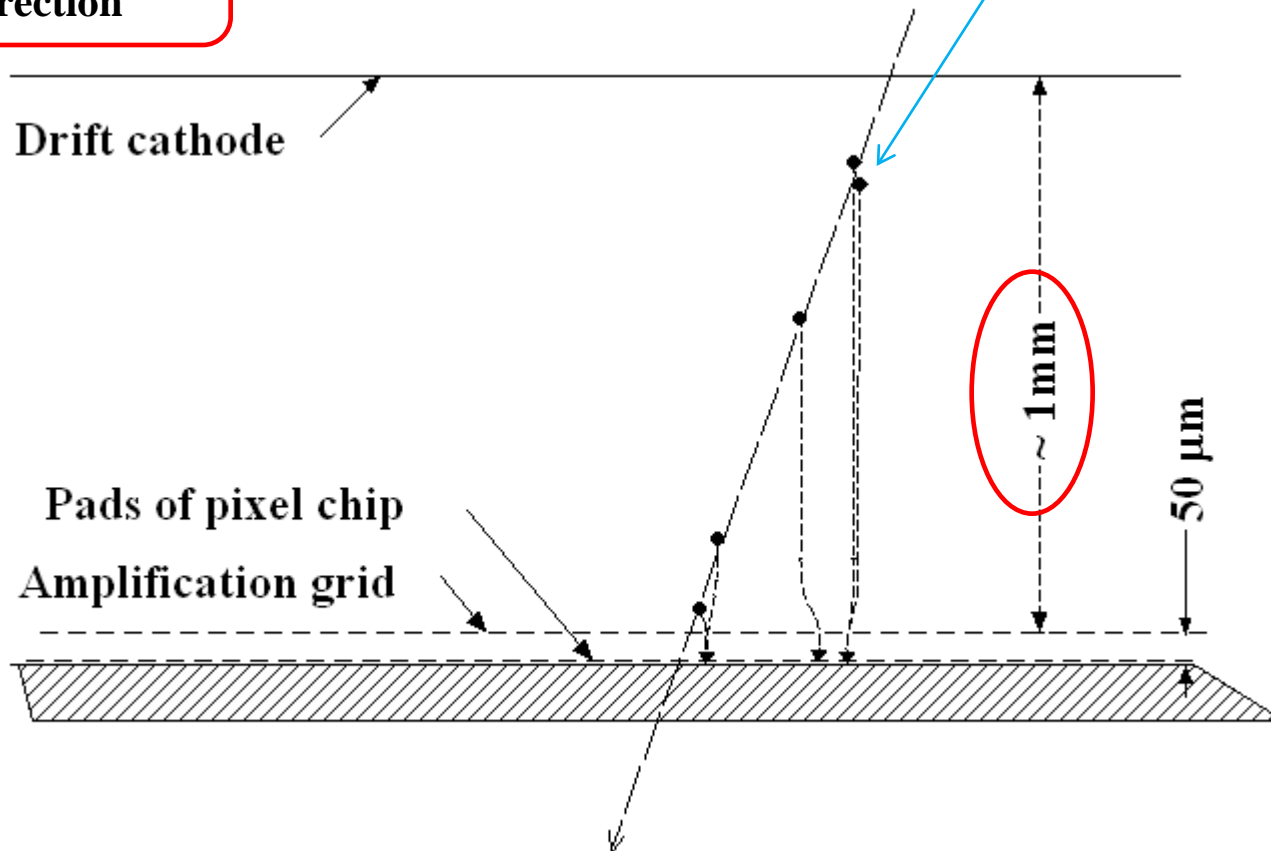
- **Arrival time** of individual electrons registered by pixels

- Track segment is reconstructed, characterized by

- **Crossing point**

- **Direction**

Two electrons share a pixel pad
(Pile up effect)

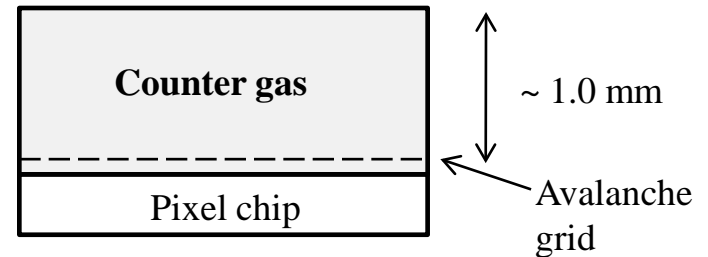


Gossip versus GridPix

Gossip

- **Gossip: ~ 1 mm gas**

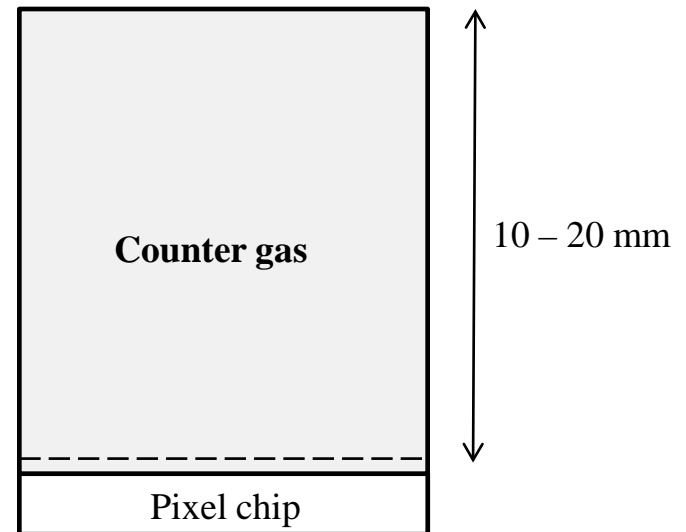
- Short drift time (20 ns)
- => **high rate performance**
- Expected to operate at **B-layer of sLHC**
(0.9 GHz/cm²)



GridPix

- **GridPix: 10 – 20 mm gas**

- Drift time 200 – 400 ns
- => **very good angular resolution**
- Well suited for **L1 trigger**

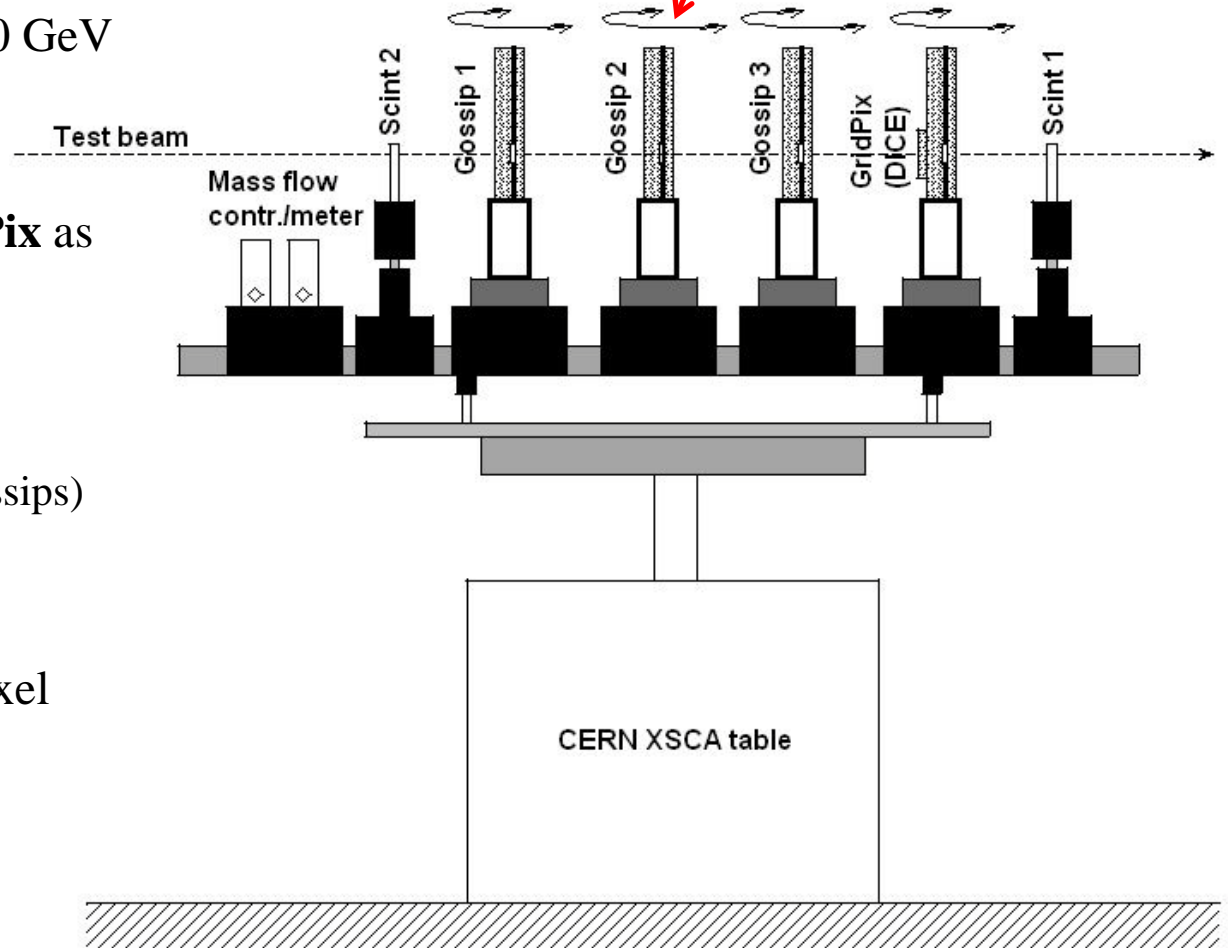


Preliminary analysis of the August 2010 testbeam

Testbeam set-up

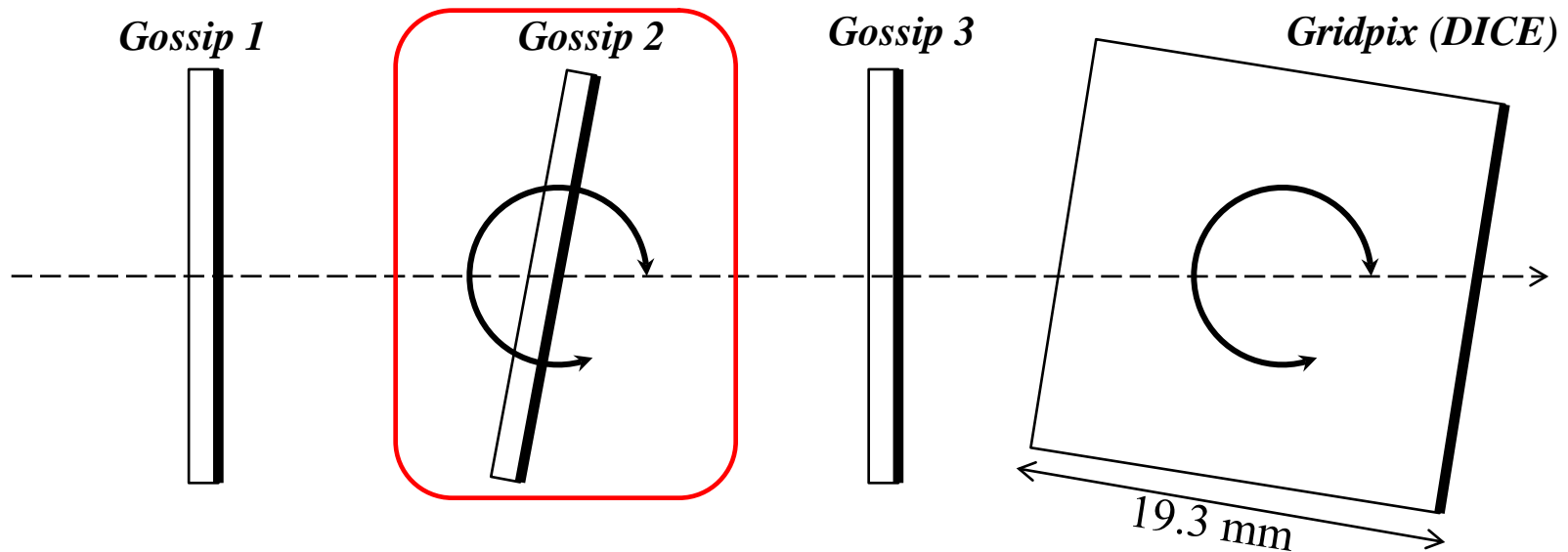
Angular adjustment
in X-Z plane

- In CERN SPS, H4 (150 GeV muons)
- 3 **Gossips** and a **GridPix** as a telescope
- **Drift space**
 - 0.94 – 0.98 mm (Gossips)
 - 19.3 mm (GridPix)
- Using **TimePix** as a pixel chip



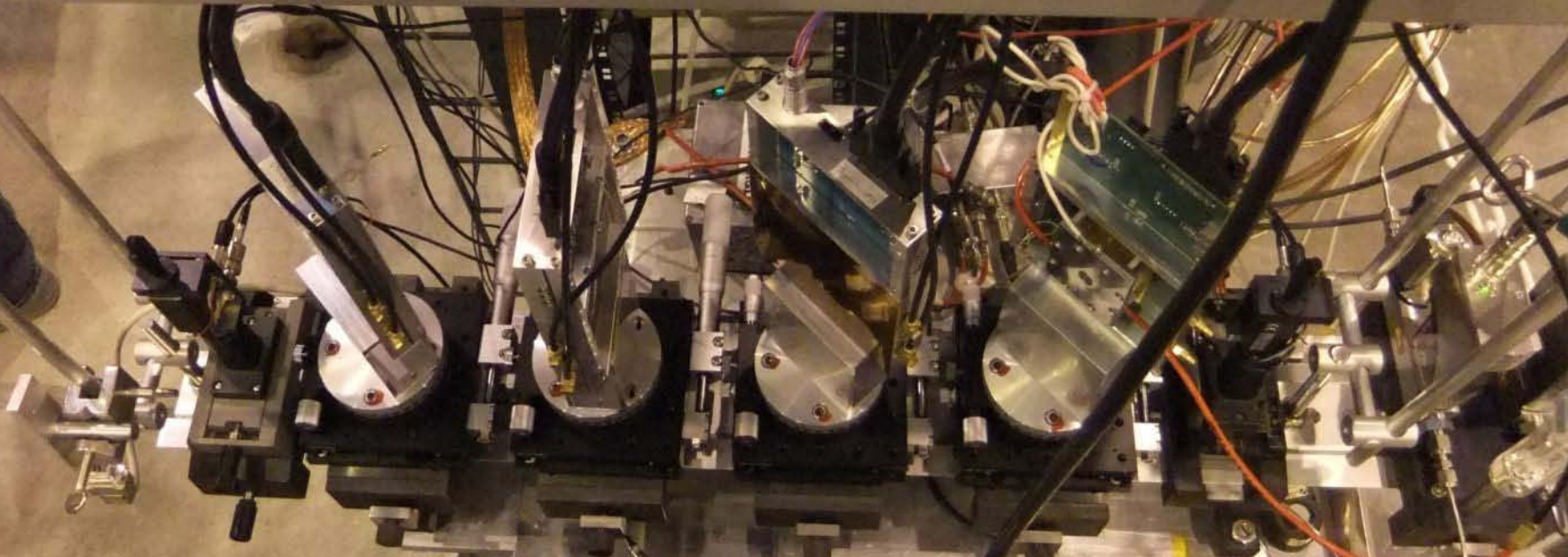
Using Gossip/GridPix telescope as a reference

- Measurements done with **Gossip 2**
- Define track with Gossip 1 and 3
- Reject bad events using the Gridpix detector (19.3 mm drift gap)
 - Wrong angle (background tracks)
 - Outside fiducial volume
 - Multiple tracks (showers)





Nikhef
detector R&D



Counter gas at testbeam

DME/CO₂ 50/50

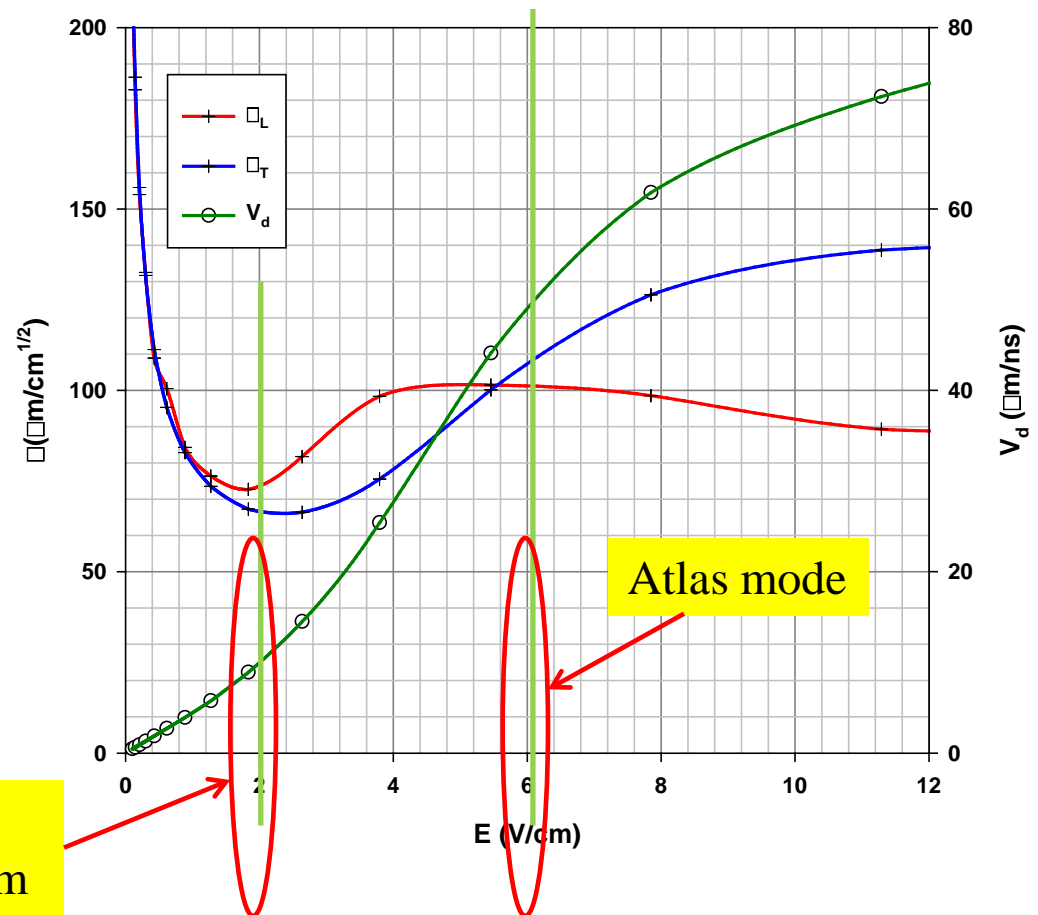
Calculated diffusion (\square) and drift velocity (V_d) of DME/CO₂ 50/50 vs electrical field (E)

■ DME/CO₂ 50/50

- Very slow and “cool” gas
- High drift field required
- ✓ **Very low diffusion**
- Suited for TPC

■ Drift fields used in Gossips

- **2 kV/cm** (lowest diffusion)
- **6 kV/cm** ($V_d = 50 \mu\text{m/ns}$)
 - LHC tracking



Working point during testbeam

Atlas mode

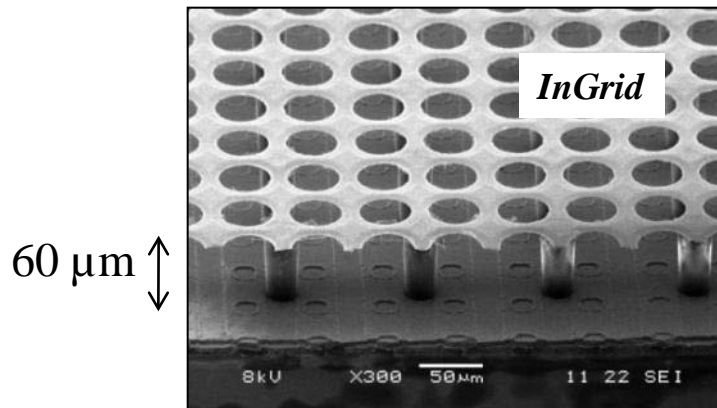
Using Timepix as a pixel chip

■ TimePix

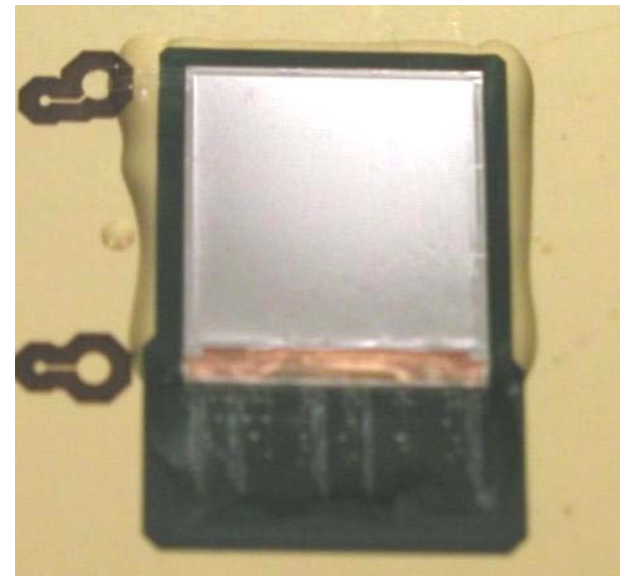
- Derived from MediPix (X-ray detection)
- Matrix of 256 x 256 pixels
- 55 x 55 μm pitch
- \Rightarrow 14.08 x 14.08 mm^2 sensitive area
- Common clock **(10 ns period)** to measure drift time for each pixel

■ Grid by wafer postprocessing

- 7 μm Si doped Si_3N_4 for **spark protection**
- **Amplification grid (InGrid) on TimePix**



TimePix with InGrid on carrier PCB



Measuring conditions at August 2010 test beam

- We produced **four** Gossips for the August testbeam (one spare)
 - Drift gap 0.94 – 0.98 mm
 - **Three** were put in the testbeam, they all have worked **reliably** at high single electron efficiency
- In the “**Atlas mode**” at 6 kV/cm we couldn’t get much sensible time info
 - $V_d = 50 \mu\text{m/ns} \Rightarrow$ only **two time bins** over the full drift height of **1 mm**
 - But we still did a number of runs in Atlas mode
- \Rightarrow most measurements done at 2 kV/cm $\Rightarrow V_d = \sim 11 \mu\text{m/ns}$

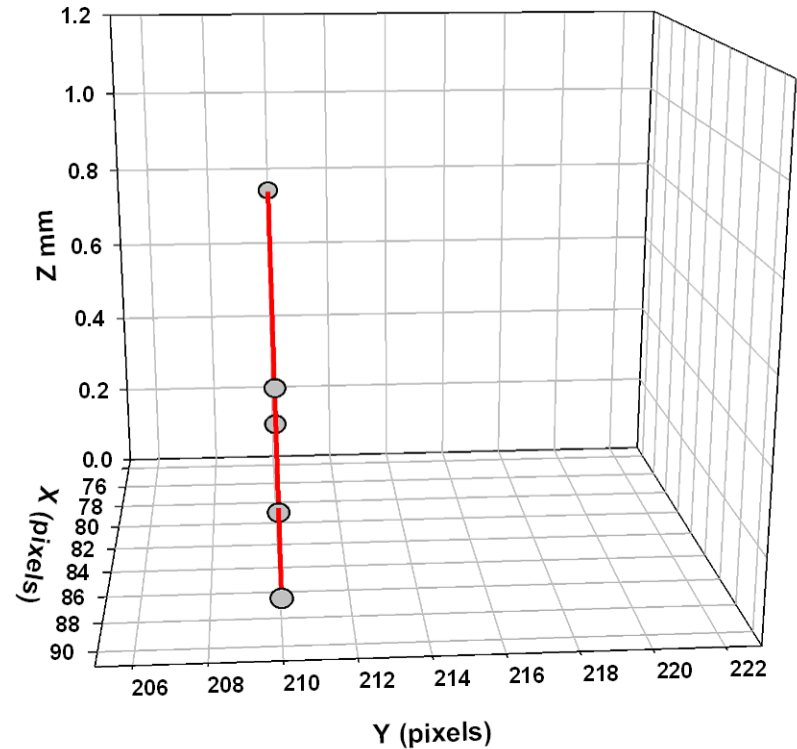
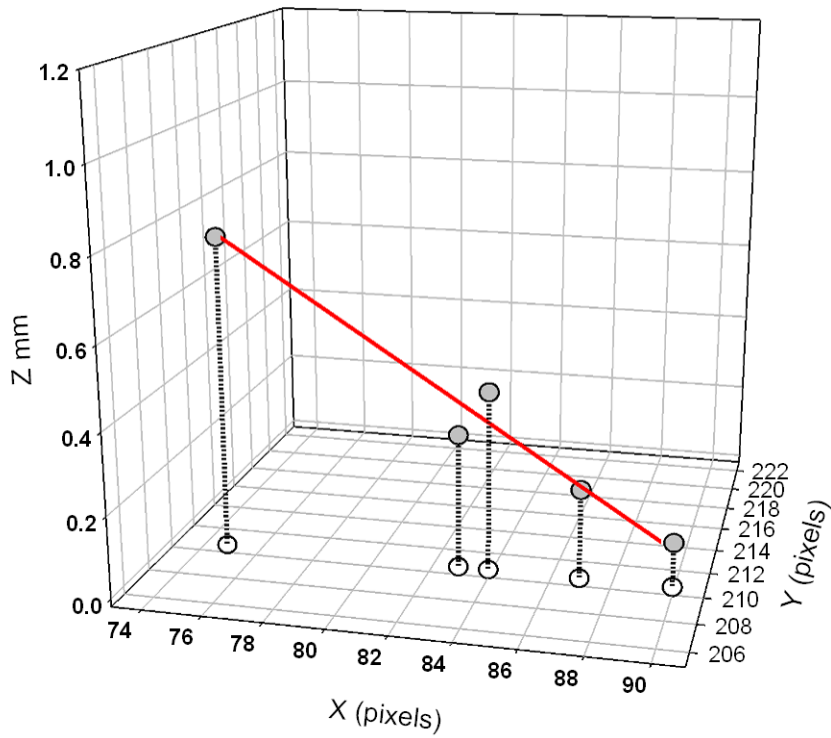
The same track in Gossip 2

45° in X-Z plane

55 x 55 μm
pitch

Event 124run32_4
detector 2

Event 124run32_4
detector 2



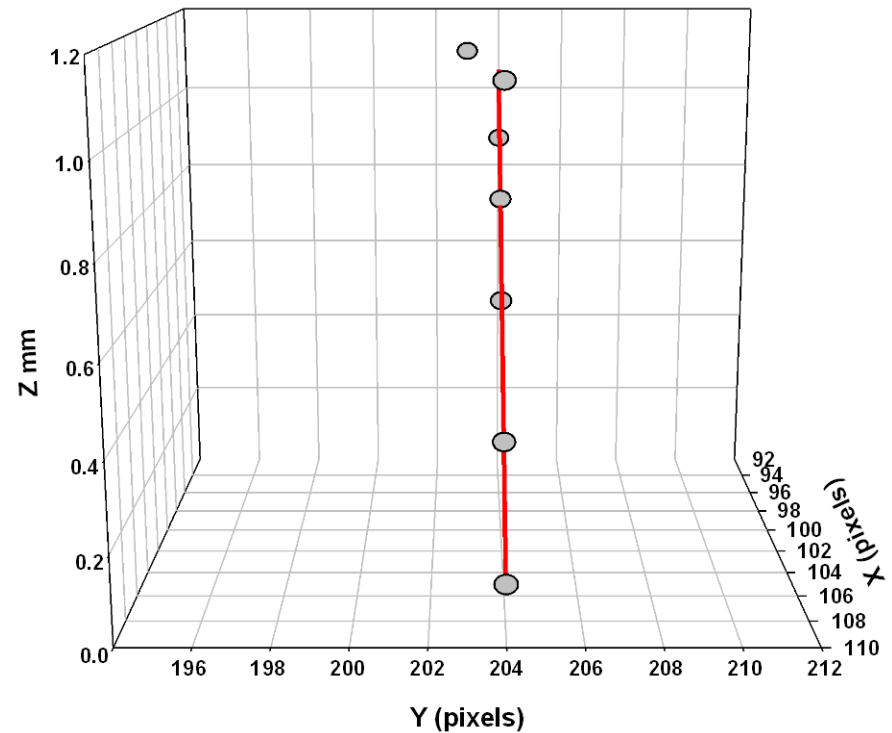
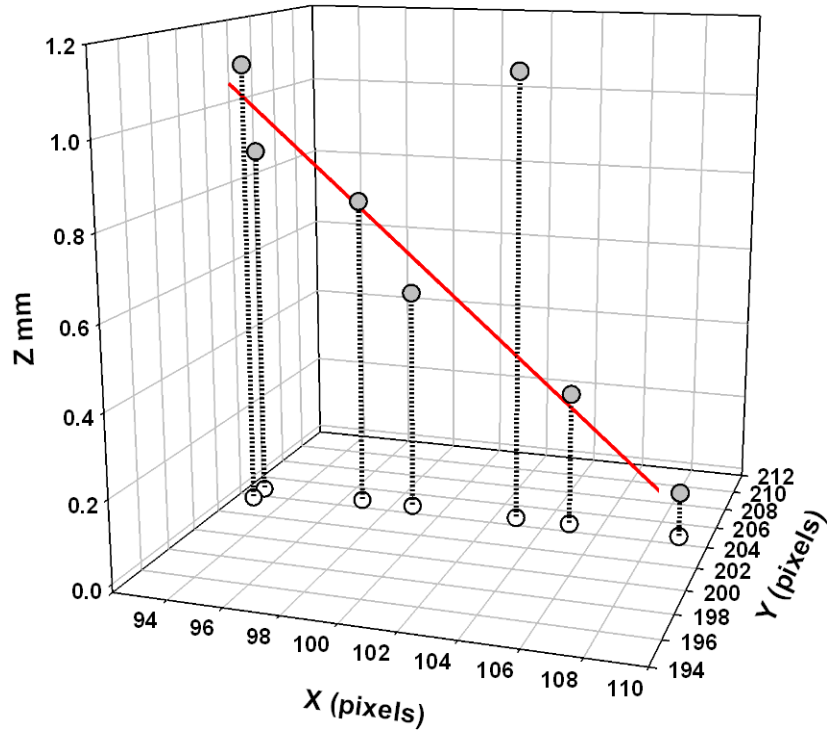
The same track in Gossip 3

45° in X-Z plane

55 x 55 μm
pitch

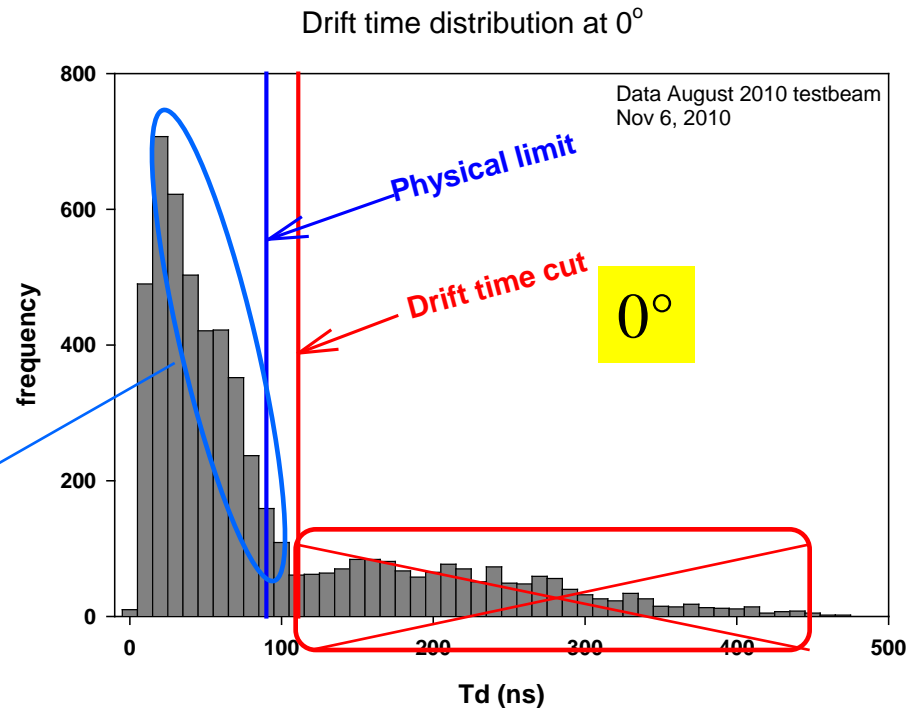
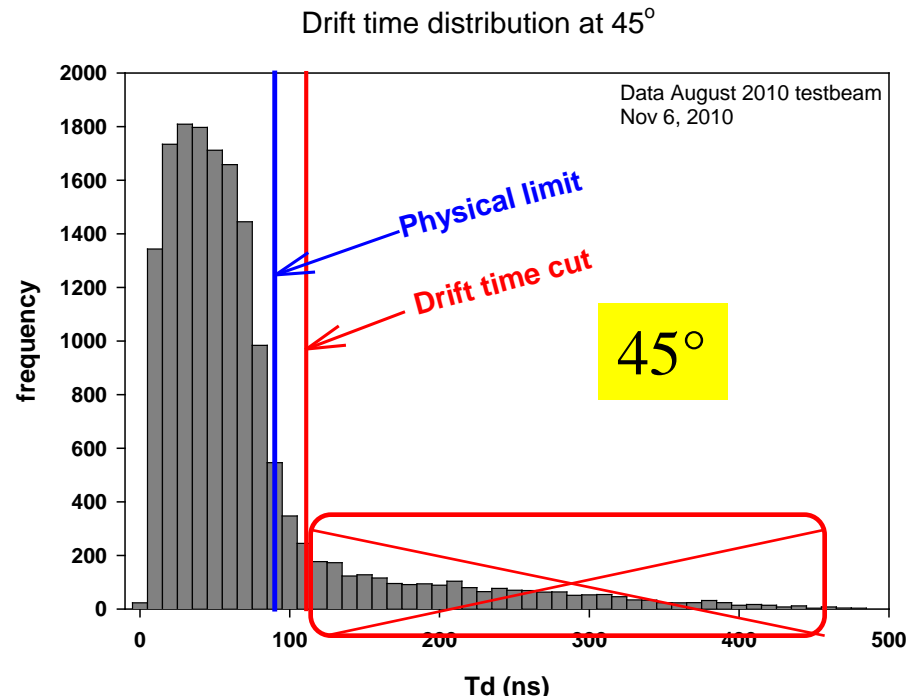
Event 124run32_4
detector 3

Event 124run32_4
detector 3



Drift time spectra

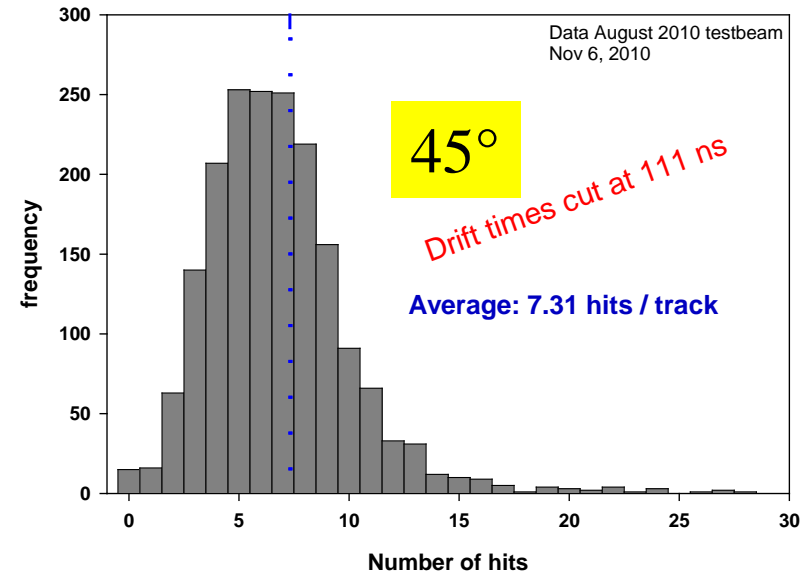
- **Tail** with drift times longer than given by drift space
 - Origin not yet clear
 - Possibly an electronic effect (cross talk signal just passing the threshold) in combination with poor time slewing properties of TimePix chip
- => out of range drift times removed in analysis
 - **drift time cut at 111 ns**
- **Pile up effect** => Two or more electrons collected by the same pixel
- => at 0° longer drift times are under populated



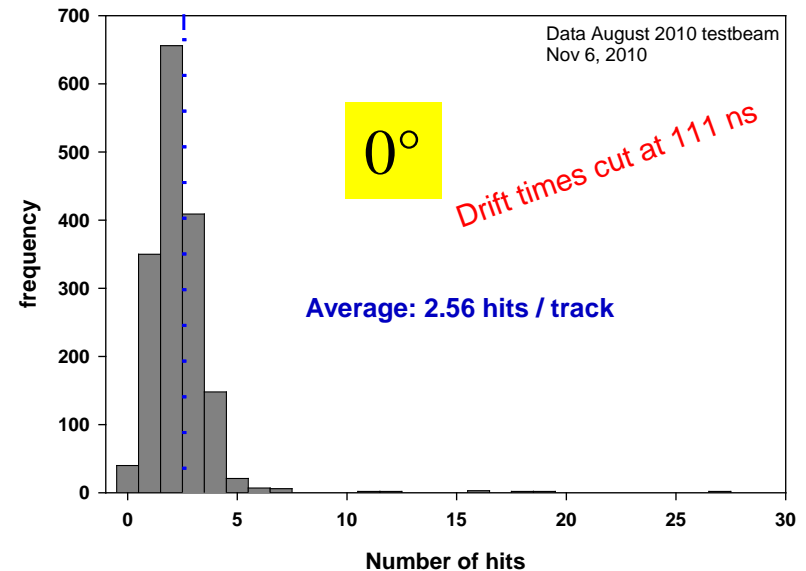
Number of hits per track

- **Pile up** effect at 0° causing factor 2 decrease of hit pixels

Distribution of the number of hits per track at 45°



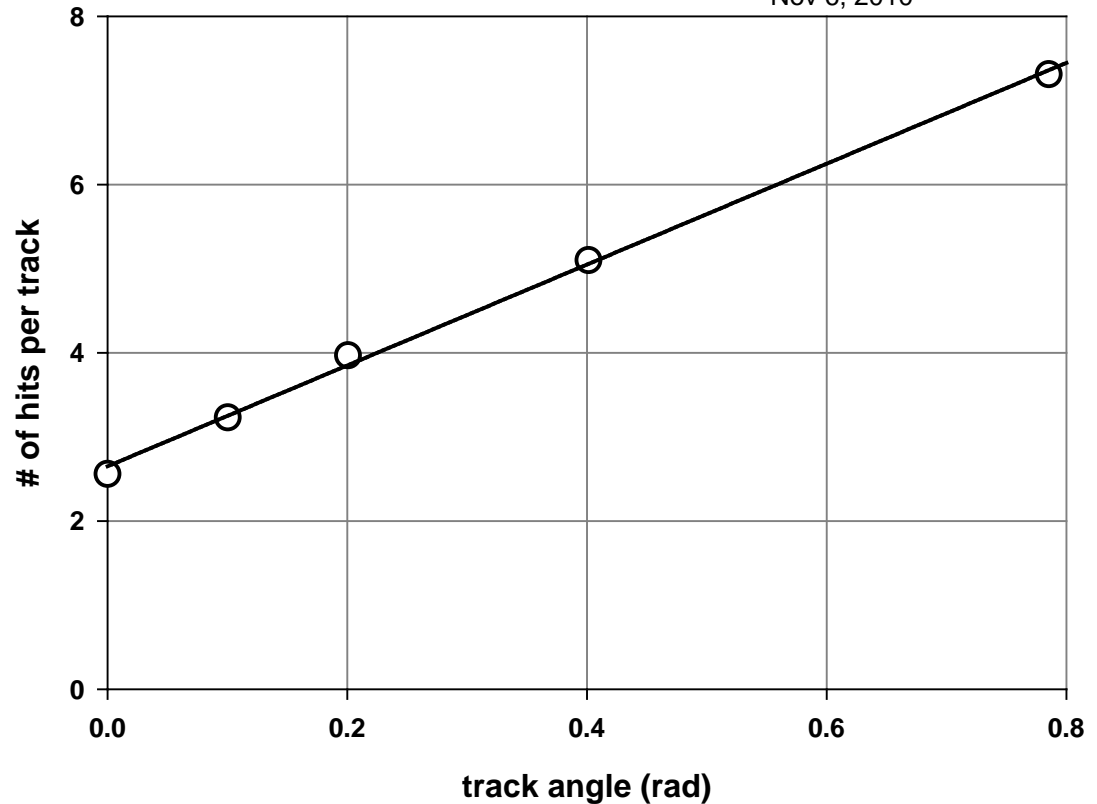
Number of hits per track at 0°



Number of hits per track versus angle of incidence

Number of hit pixels per track versus the track angle

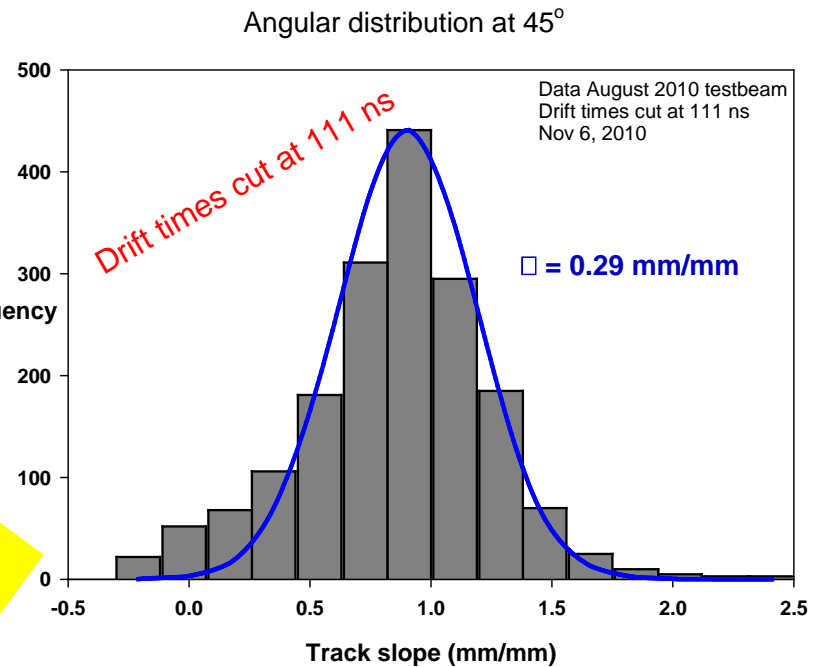
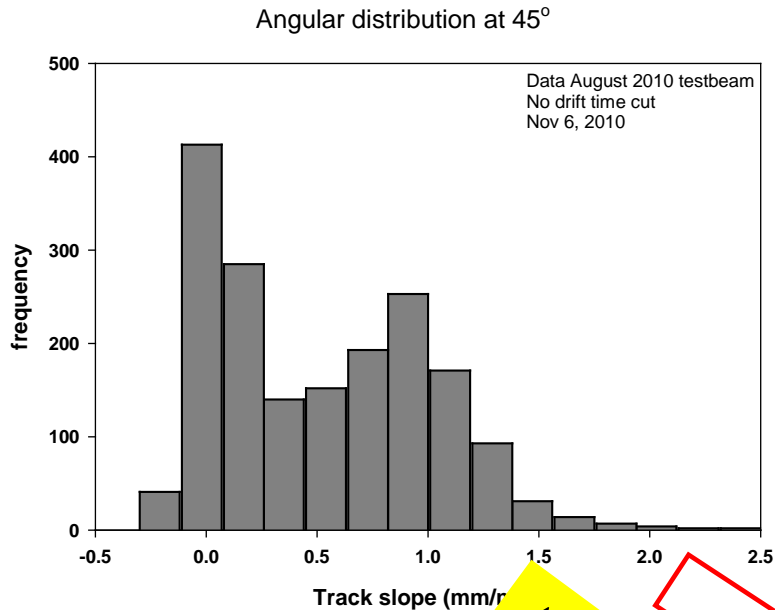
Data August 2010 testbeam
Drift times cut at 111 ns
Nov 6, 2010



■ Steady rise from decrease of **pile up**

■ Cannot explained by the increase of the ionization

Angular resolution at 45°



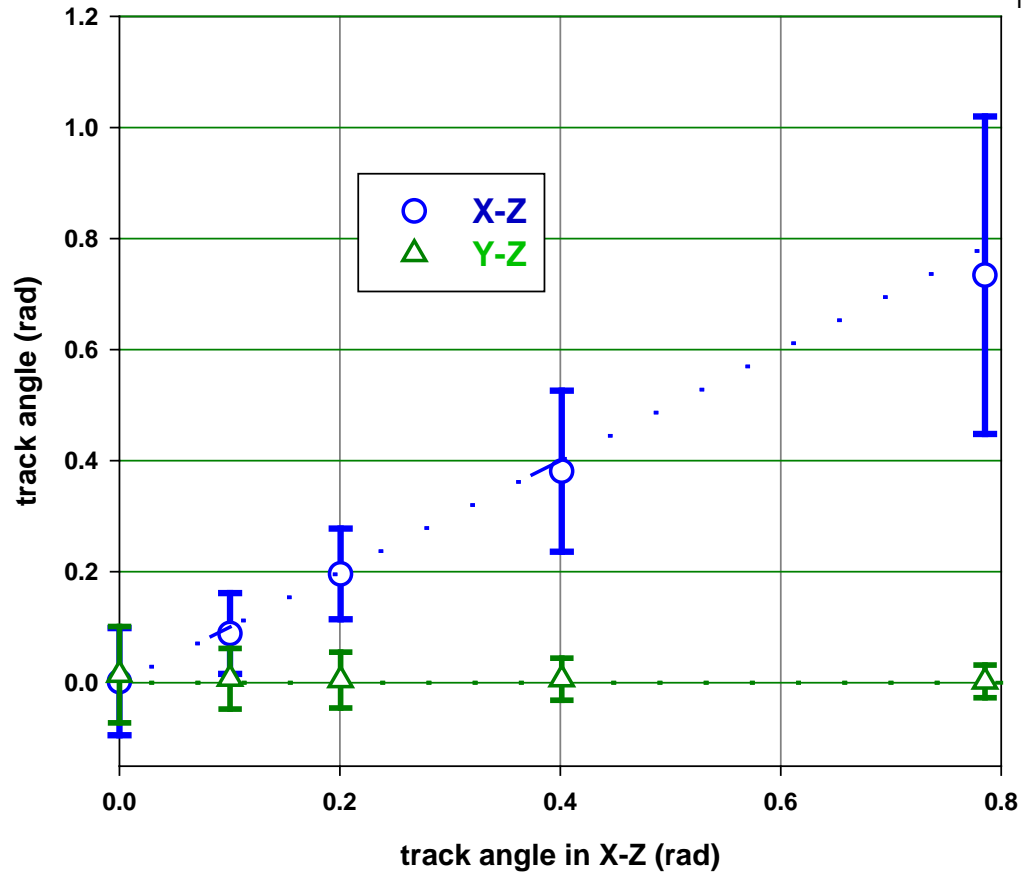
Angular resolution improved by drift time cut

Measured track angle versus angle of incidence

- Angular resolution in X-Z plane still limited by minor ionization and lever arm
- In Y-Z plane accuracy gets better with increasing X-Z angle (better statistics)
- Increasing the drift gap 1.2 mm would give better performance

Measured track angle versus actual track angle

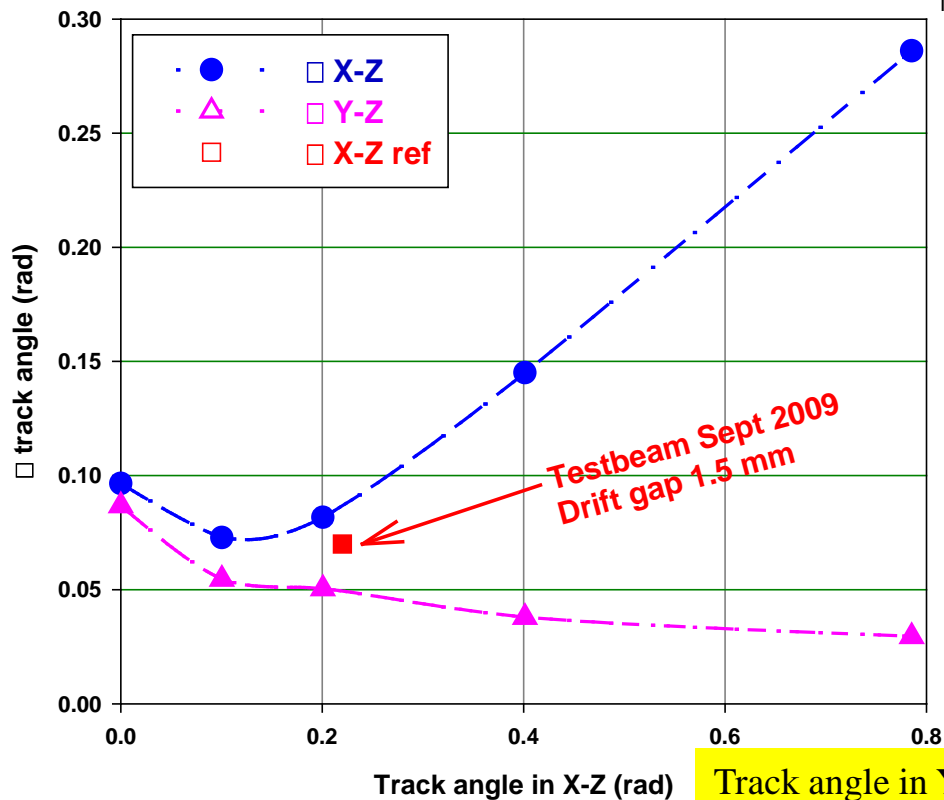
August 2010 testbeam
Drift times cut at 111 ns
Error bars given by the
□ of the Gaussian fit
Nov 6, 2010



Angular resolution versus angle of incidence

- Angular resolution in X-Z plane deteriorated by **limited timing properties** of the TimePix chip
- In Y-Z plane accuracy gets better with increasing X-Z angle (better statistics)
- Increasing the drift gap to **1.2 mm** would give better performance

Measured width (σ) of track angle distribution



August 2010 testbeam
Drift times cut at 111 ns
Error bars given by the
 σ of the Gaussian fit
Nov 6, 2010

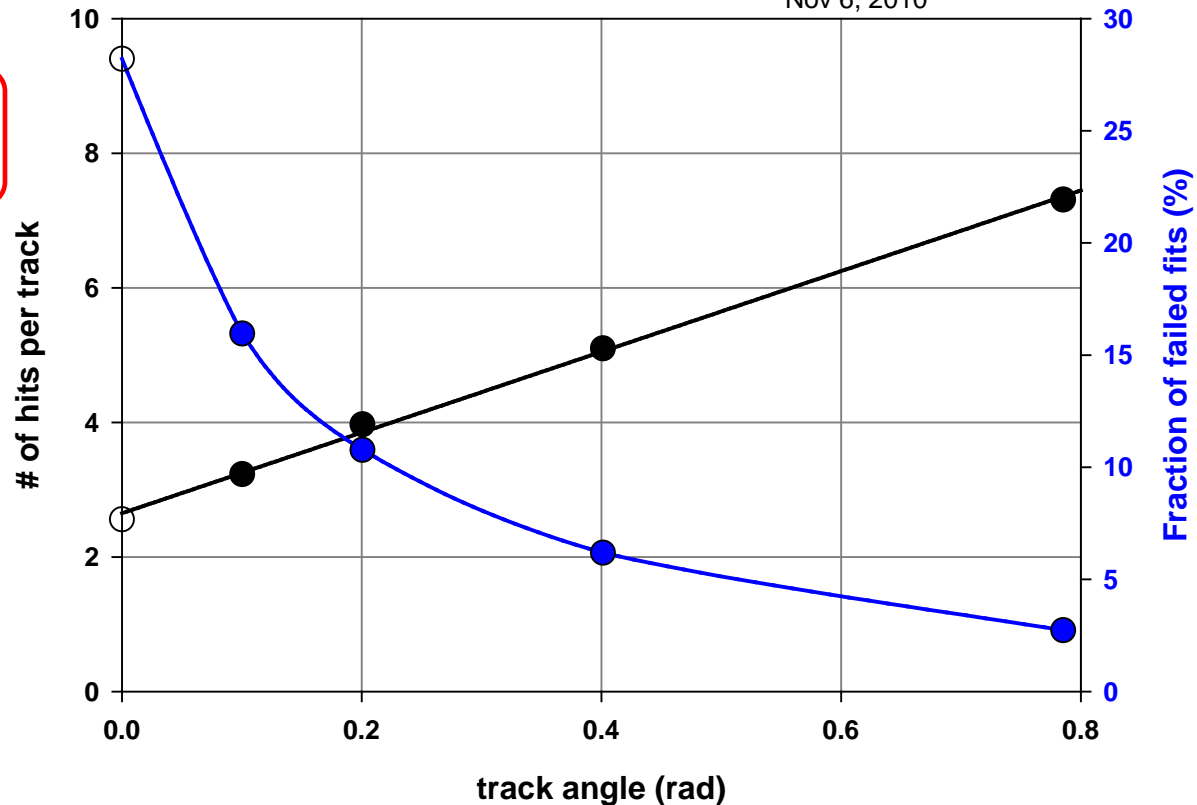
ref: *Y. Bilevych et al., submitted to the proceedings of the 12th Topical Seminar on Innovative Particle and Radiation Detectors, Siena, Italy, June 7 -10, 2010*

Track fitting sometimes fails

- Strong correlation with number of hits per event
 - => One hit events have no angle
- Frequently at small angle of incidence
- Rare at 45°

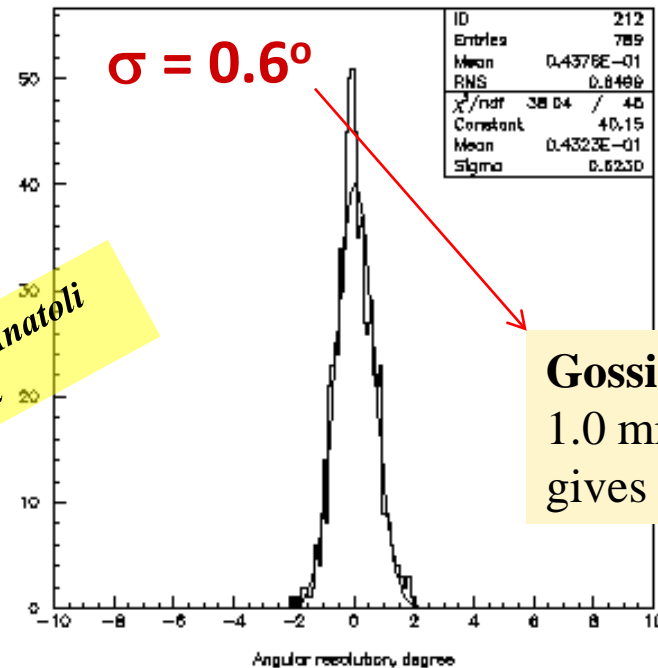
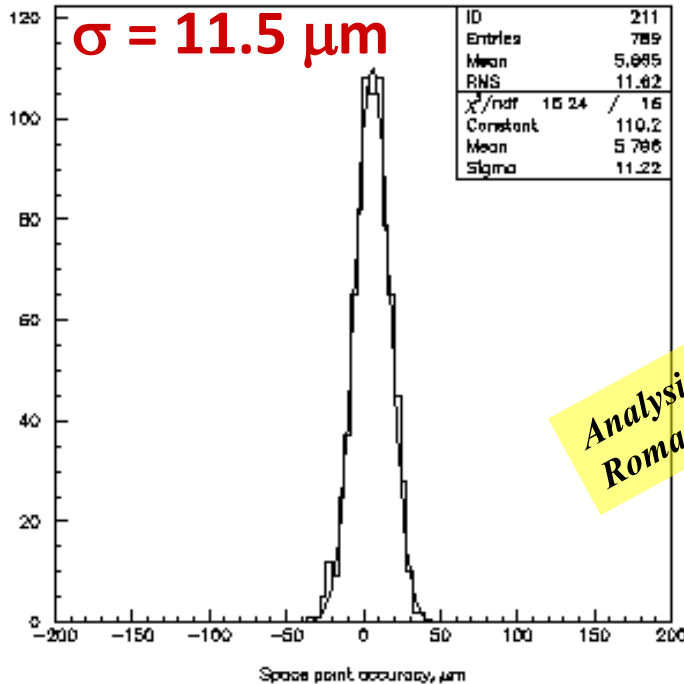
Number of hit pixels per track versus the track angle

Data August 2010 testbeam
Drift times cut at 111 ns
Nov 6, 2010



GridPix Tracking: Low diffusion gas (test beam result).

DME/CO₂ (50/50), 20 mm drift,
Incident angle of **11.5°**.



Analysis by Anatoli
Romaniouk

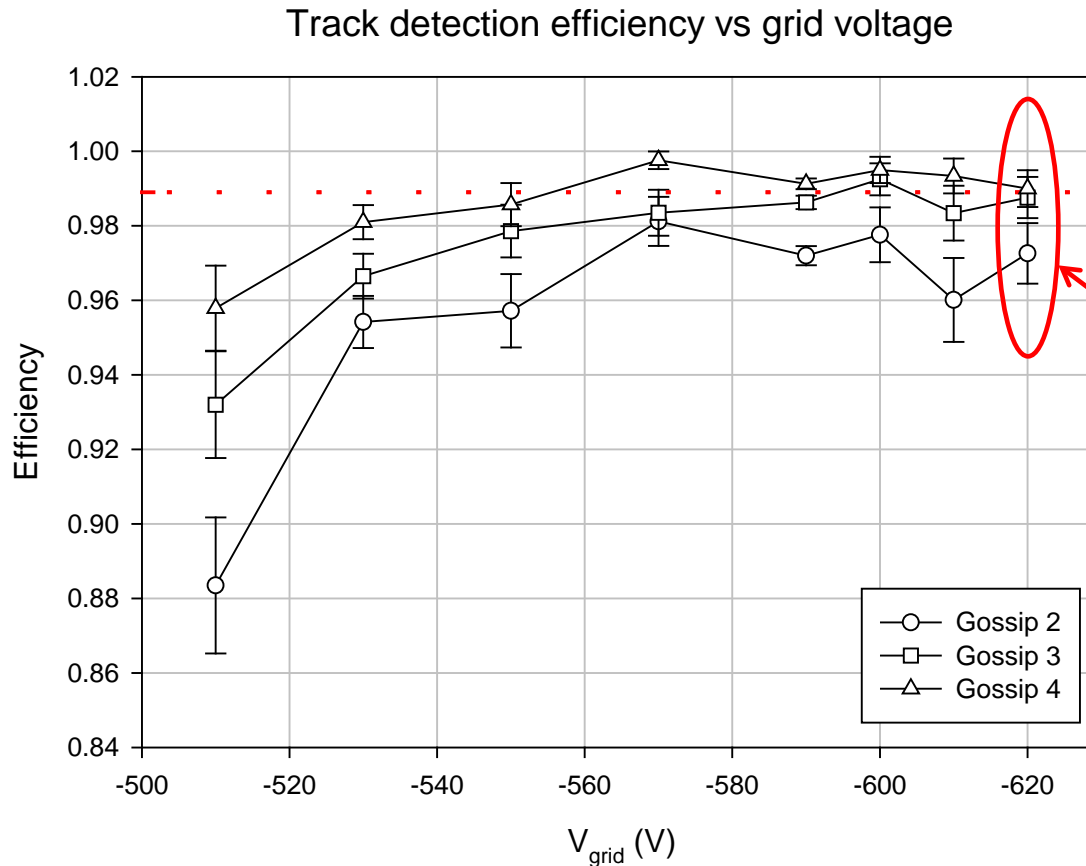
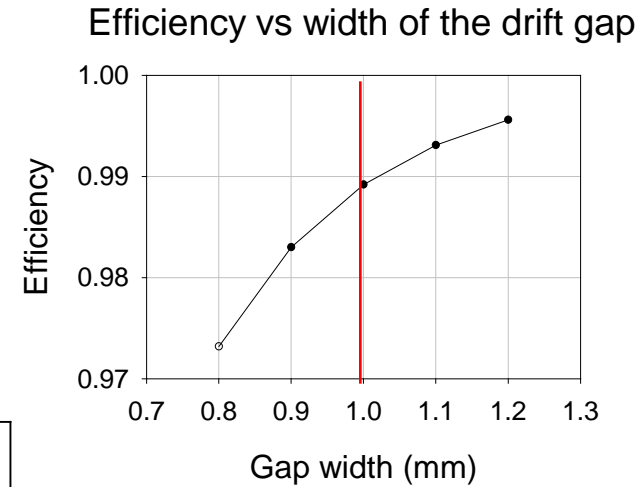
Gossip:
1.0 mm of gas
gives $\sigma = 4.6^\circ$

At **11.5°** incident angle an angle measurement accuracy
of **0.6°** for the track projection would mean:

15% momentum measurement accuracy for P_t of **40 GeV**
with one layer of the GasPixel tracker/L1 trigger!

Track detection efficiency versus grid voltage

- Tracks selected by GridPix detector
- Completely flat plateau from ~ -570 V on
- Expected for 1.0 mm DME/CO₂: 98.9%

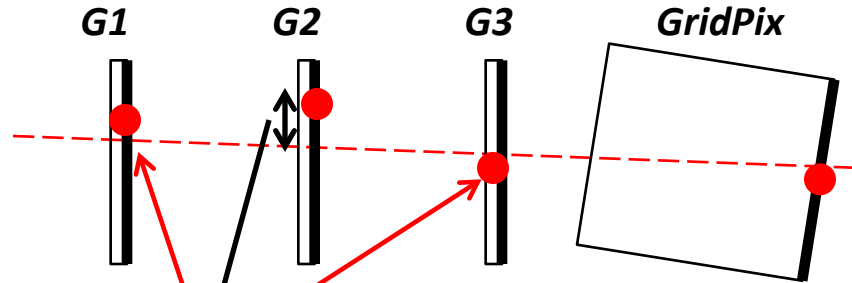


Expected for 1.0 mm gas gap

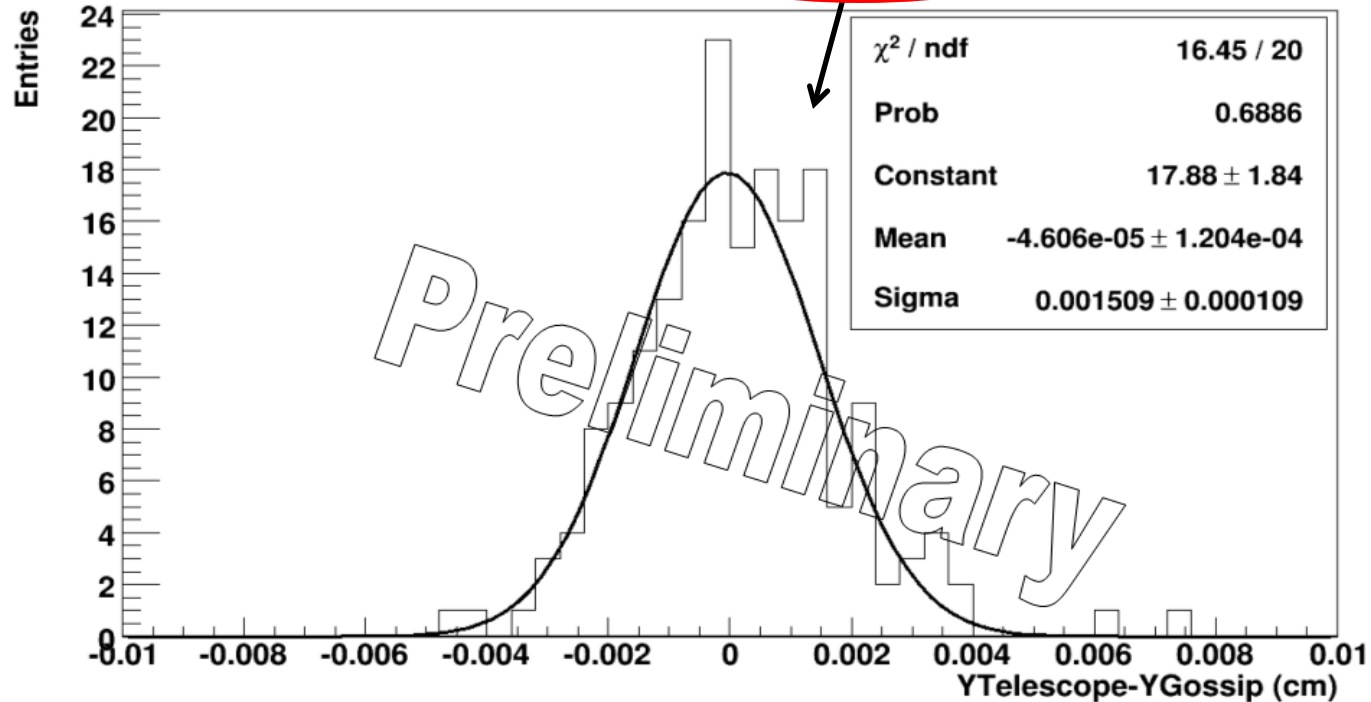
Working point
During testbeam

Position resolution

- Fit through G1, G3 and GridPix → residuals G2
- 0 degrees → **~15 μ m**
- Other angles to be analyzed



Y-Residual Gossip 2, fitted with **>2 electrons, constrained angles**



Conclusions and discussion

- Gossip detectors can now be produced **reliably and stable** on a small scale
 - No operational problems during testbeam
 - The spare detector had not to be used
- Track detection efficiency **~ 99%**
- Principle of 3D track fitting demonstrated
 - Gas diffusion hardly visible on 1.0 mm scale

Track angle can be reconstructed

Conclusions and discussion cntd

- **Angular information** is very **useful** for tracking in a dense environment like the pixel tracker at the sLHC

- Y-Z plane => good resolution **78 to 30 mrad**
- But X-Z resolution (**100 to 300 mrad**) limited by
 - **Low clock frequency** of TimePix (10 ns period)
 - **Poor time slewing** of present TimePix chip
 - **Short drift height** (1.0 mm)

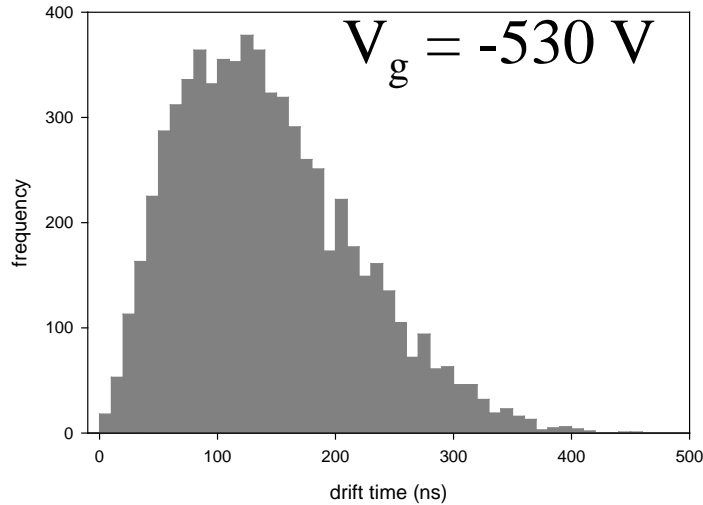
- **Greatly improved time performance** expected when using **TimePix-2** which is now being designed
 - **~1.6 ns** clock
 - Greatly improved time slewing
 - Correction for time slewing

- In addition **1.0 → 1.2 mm** drift gap would give significant improvement

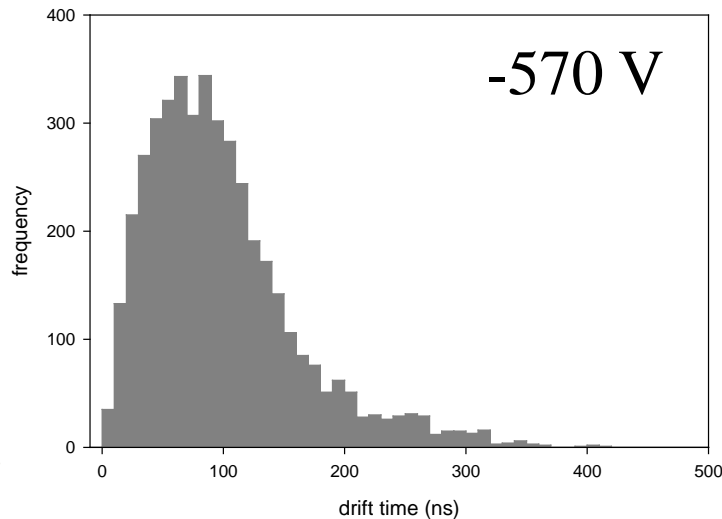
Spare

Drift time spectrum of a Gossip

- TimePix chip suffering from time slewing
- Less dominant at high gain

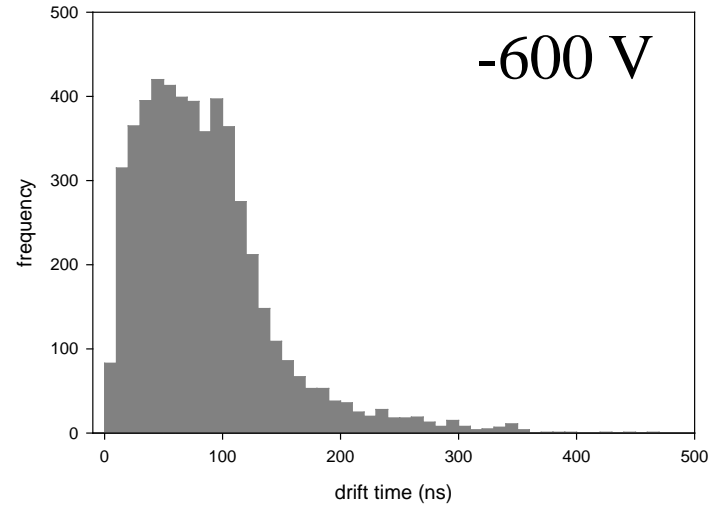


Drift time spectrum
 $V_g = 570 \text{ V}$ run 24

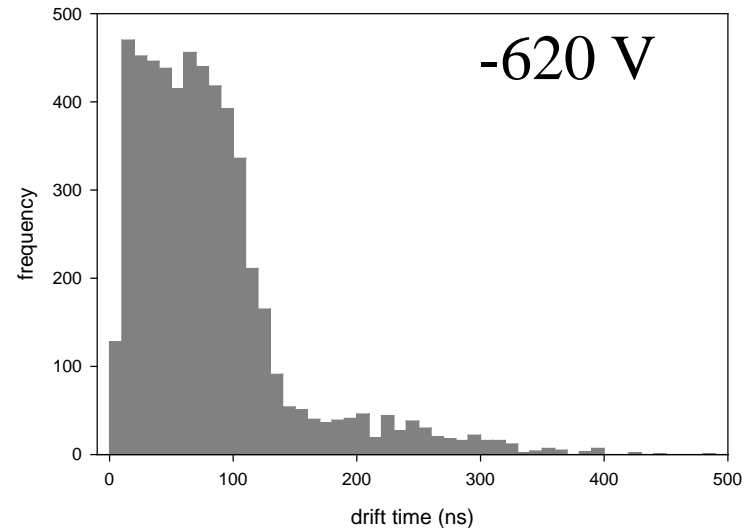


Atlas

Drift time spectrum
 $V_g = 600 \text{ V}$ run 28



Drift time spectrum
 $V_g = 620 \text{ V}$ run 32



Fred Hartjes

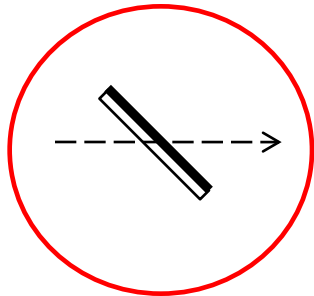
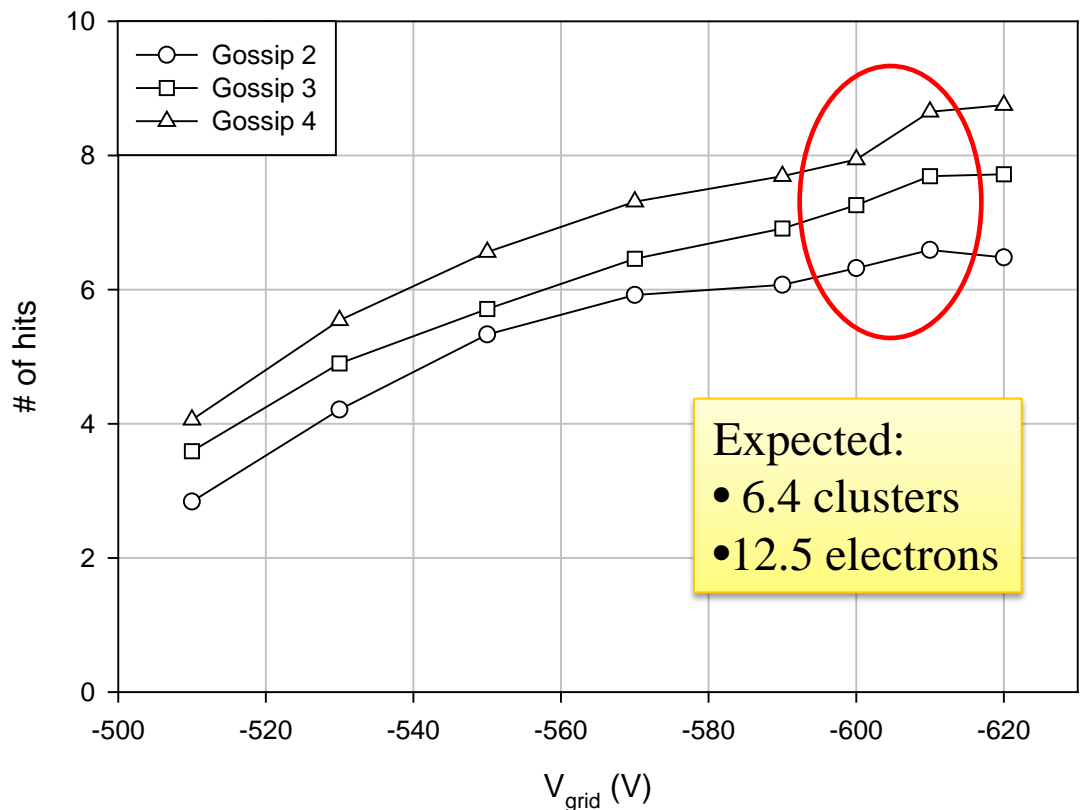
Number of hits per track in Gossip vs grid voltage

■ Unexpected difference between the three Gossips

- If drift gap of Gossip 3 were 1.0 mm, then Gossip 4 => 1.13 mm and Gossip 2 => 0.84
- => not consistent with metrology (differences of 40 μm)

Tracks under 45°

Number of hits per track vs grid voltage



Expected:
• 6.4 clusters
• 12.5 electrons