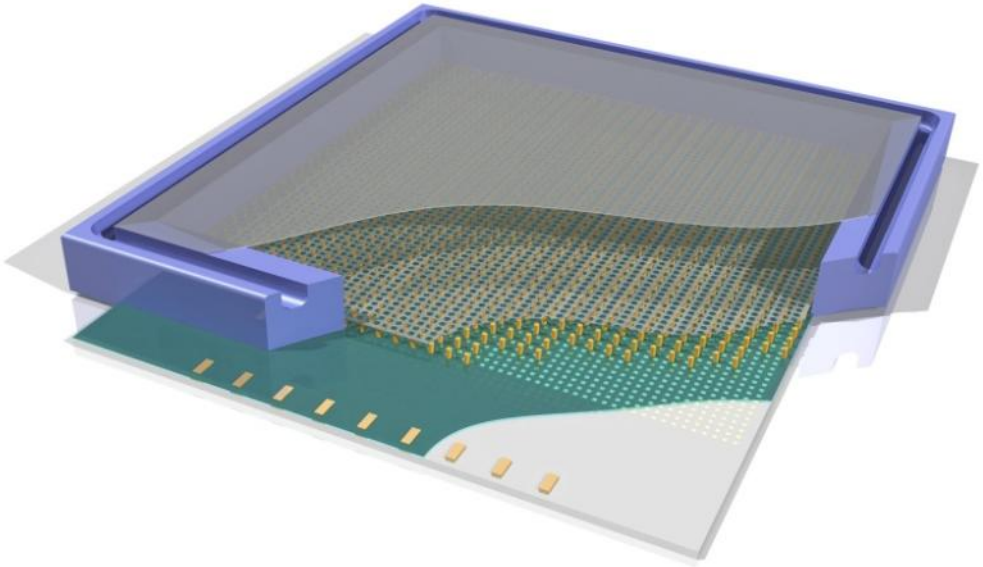
Concept and operation of the high resolution gaseous micro-pixel detector Gossip



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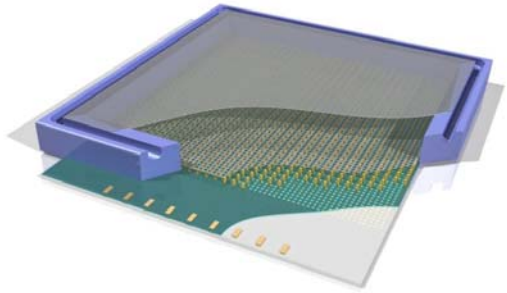
12th Topical Seminar on Innovative Particle and Radiation Detectors
Siena, Italy, June 7 - 10, 2010

Overview

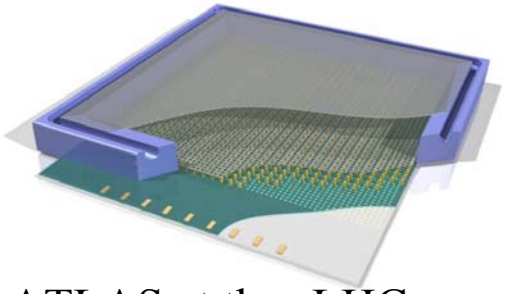
- **Introduction** of the **gaseous** detector Gossip
  - Functioning of Gossip
  - Pros and cons of Gossip
- **Testbeam results**
  - Angular resolution
  - Position resolution
- **Discussion and summary**



Many often relevant details about the Gossip concept had to be omitted from this presentation. They can be found in the backup note https://edms.cern.ch/file/808572/1/GossipBackupNoteV2-2.pdf.

More details about the testbeam measurement are found in the presentation at the 4th RD51 collaboration meeting: http://indico.cern.ch/getFile.py/access?contribId=0&sessionId=5&resId=0&materialId=slides&confId=72610.

Motivation and principle



- **Primary goal of the Gossip detector**
  - **Tracking of MIPs** in the pixel layers of experiments like ATLAS at the sLHC
    - sLHC luminosity is expected to reach about $\mathcal{L} = 10^{35}$ cm^{-2} s^{-1}
  - Assuming 3000 fb-1, 79 mb pp Xsec, 6.3 tracks/η /interaction
  - Safety factor of 2
  - => **extremely high rates** (up to 0.9 GHz/cm^2 for Atlas-b-layer)
  - => **extremely high radiative doses** (up to **2*10^{16} n$_{eq}$/cm^2** for Atlas-b-layer)
    - Corresponds to **3.4*10^{16} cm^{-2}** for charged hadrons

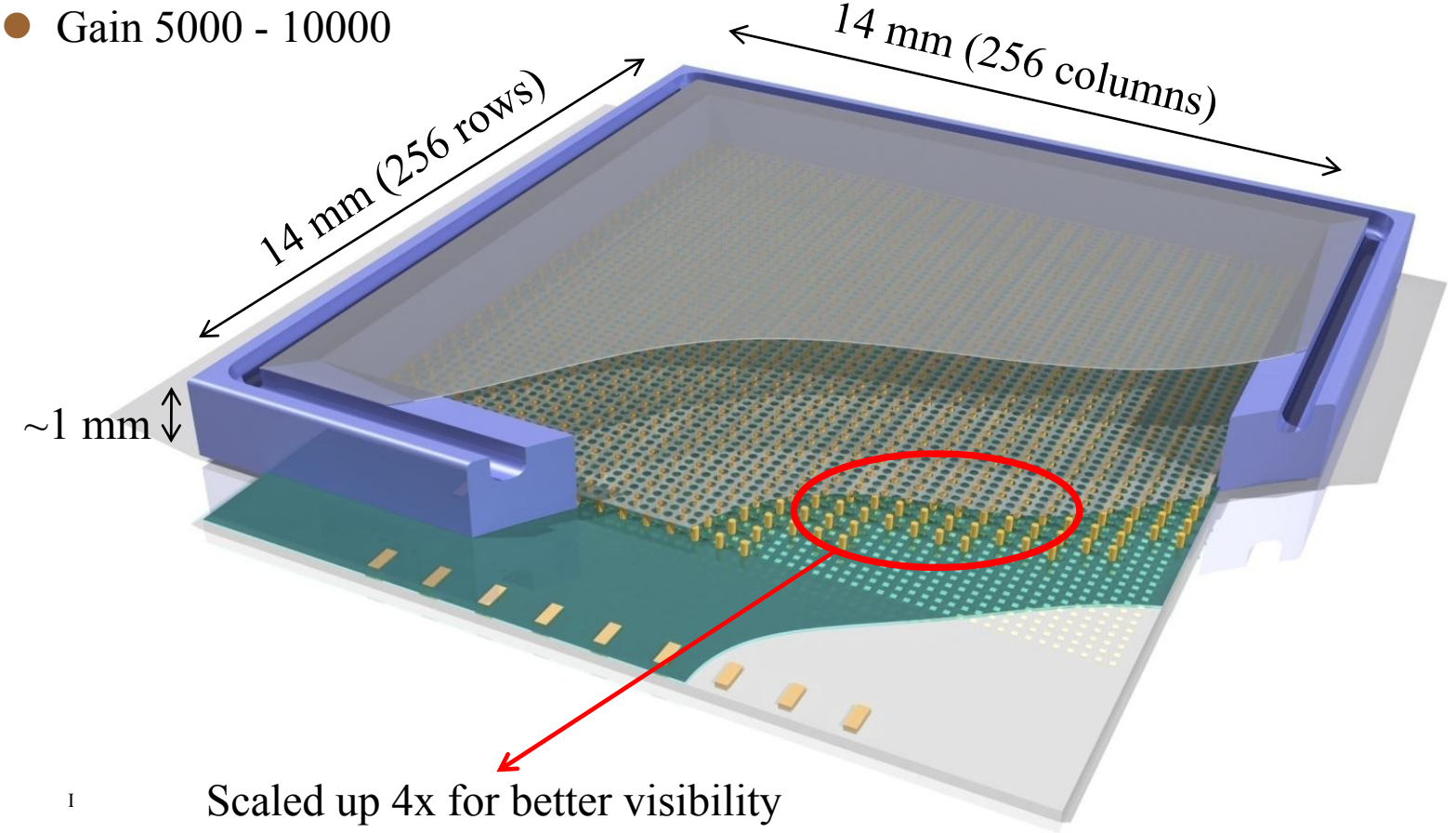
- **Gossip** is a **gaseous** micro pixel detector that is adapted for this environment

  - **Using high granularity pixel chip**
  - **Having a very short drift gap**

The Gossip proposal (ATLAS R&D Proposal ATL-P-MN-0016) has been approved by the Atlas Upgrade Steering Group as a meaningful R&D activity

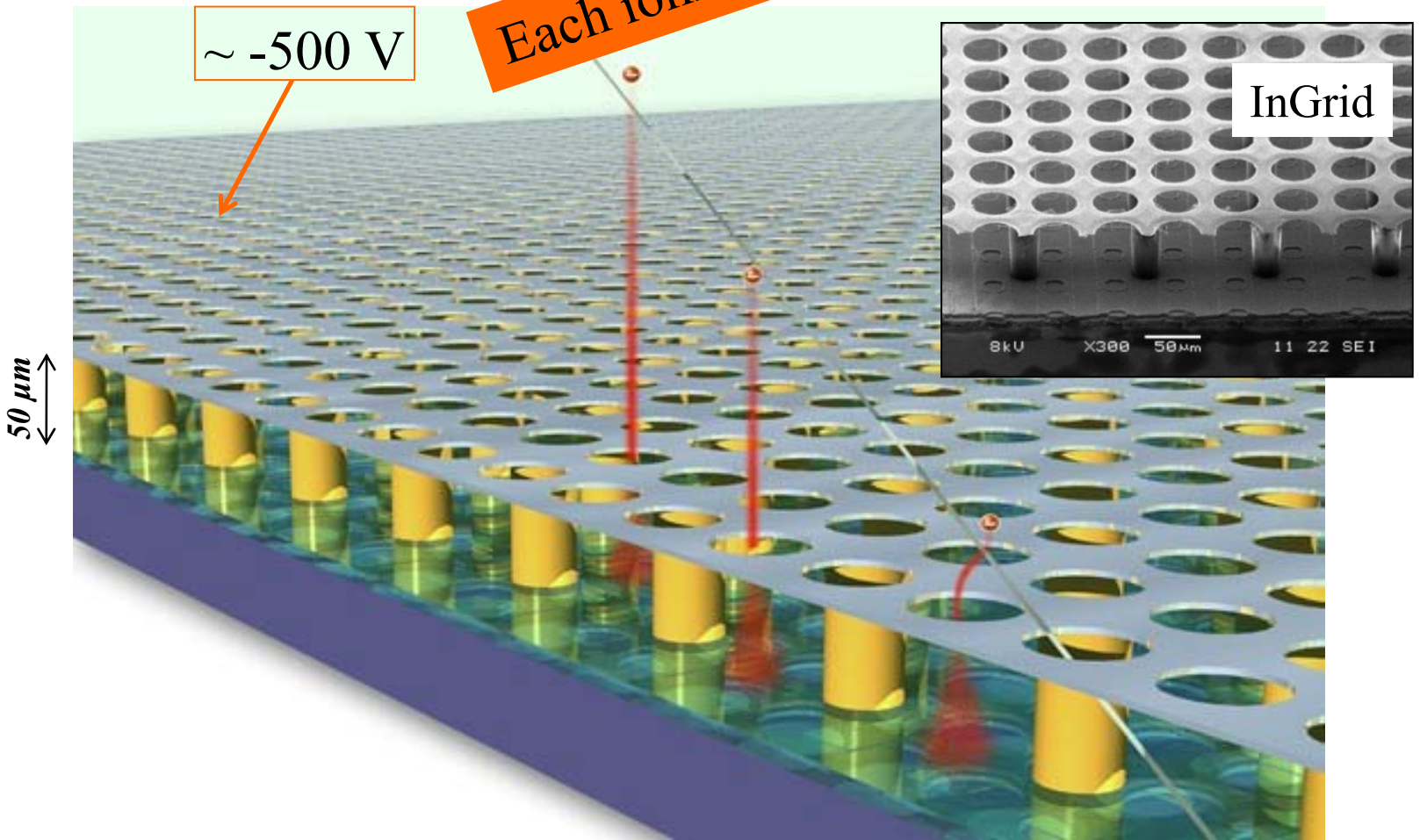
Principle of Gossip

- **High granularity** pixel chip
  - Cell pitch 55 – 60 μm in X and Y
  - Thinned to 50 – 100 μm
- Detection medium: **thin gas layer** instead of bulk semiconductor
  - Drift gap ~ 1 mm high
- Signal (average 6 electrons) enhanced by **gas avalanche** from a grid
  - Gain 5000 - 10000



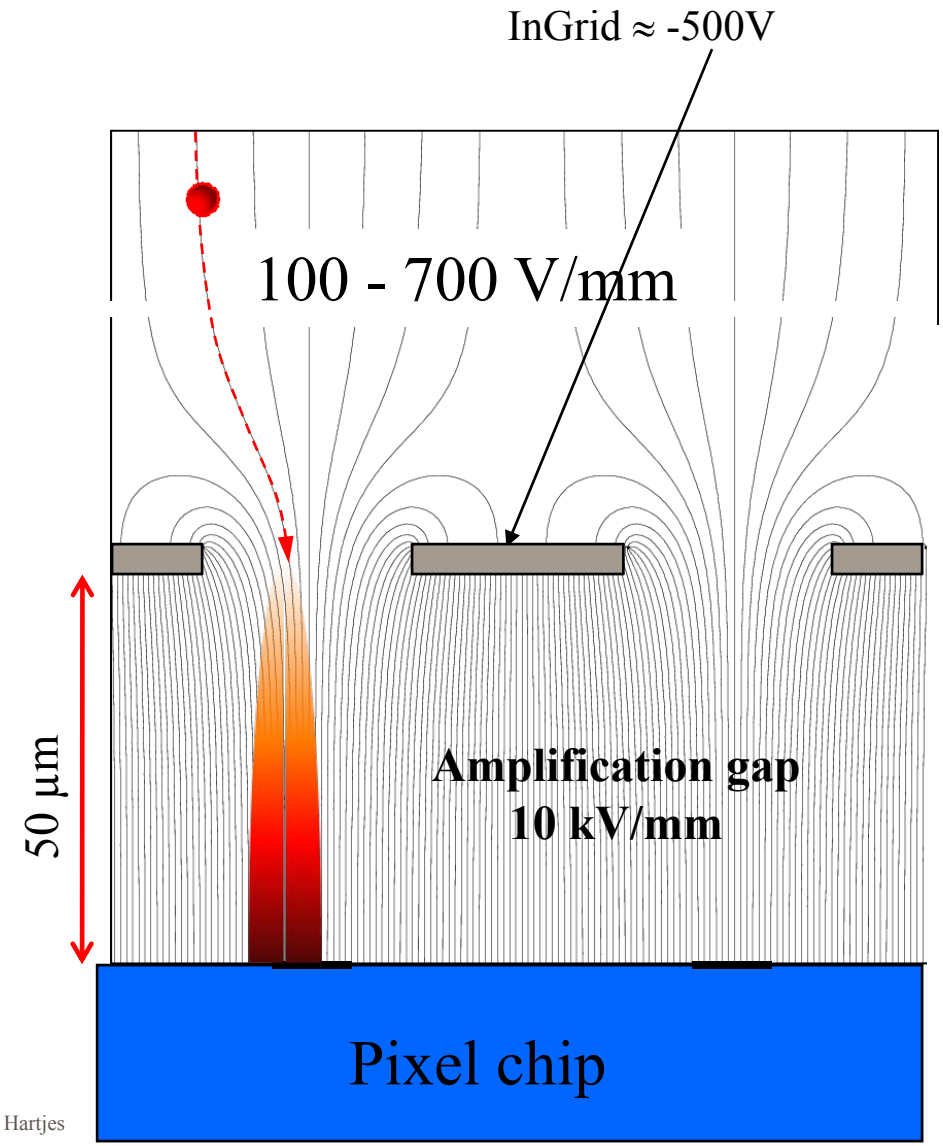
Gas avalanche in Gossip

- Ionization electron drifts towards grid (InGrid)
  - Focused into hole
- Gas avalanche towards anode pad of the pixel



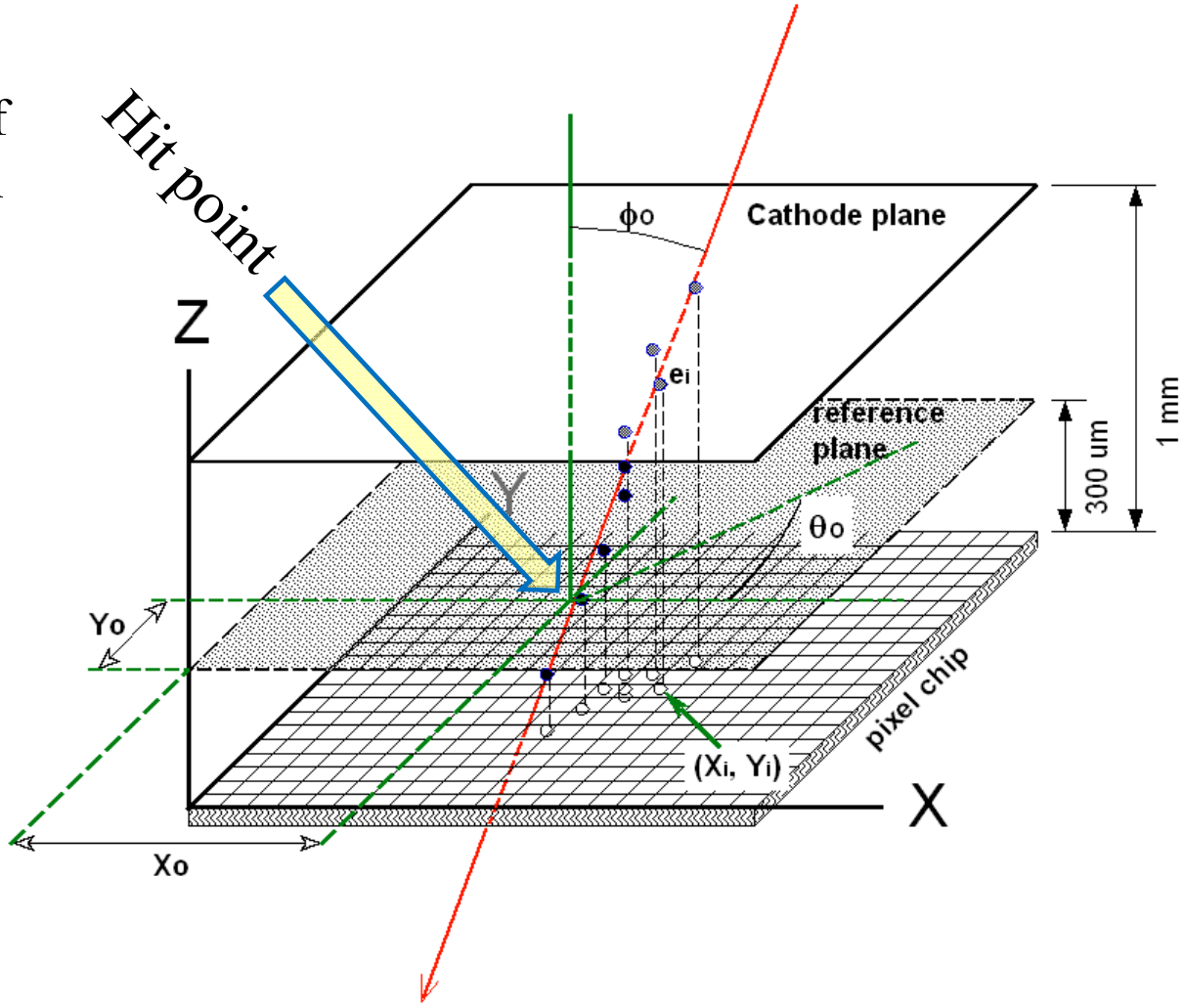
Field configuration of Gossip

- **Drift field** 100 -700 V/mm
- High **amplification field** under grid to induce gas avalanche
  - ~ 10 kV/mm
- Grid holes centred on pads pixel chip



Track reconstruction in space

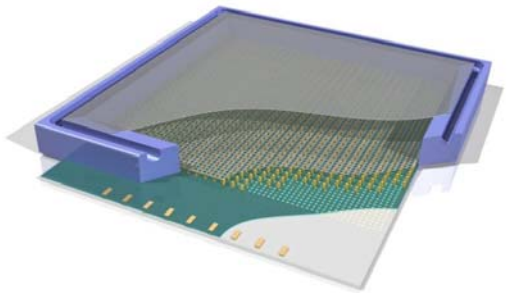
- **Space points** are reconstructed from the measured arrival time of the individual ionisation electrons
- **Track segment** is fitted through these space points
- => **Final outcome** is given by 4 parameters:
  - **Hit point (X, Y)**
    - Crossing point with the reference plane
  - **Track angle (φ, θ)**



Benefits of the Gossip concept

- **Very high radiation tolerance** possible
  - Solid state technologies are hard to operate after 10^{16} n_{eq}/cm^2
  - Gossip technology may operate well after this limit
    - See the backup document: https://edms.cern.ch/file/808572/1/GossipBackupNoteV2-2.pdf
- **Better tracking** in high track density environment
  - The Gossip detector yields vector => hit point (x, y) + angle (φ, θ)
- **Easier cooling**
  - Operation at room temperature
  - Heat only generated by electronics
- Almost insensitive for hard X-rays
- No bump bonding, no detector mass
  - **Smaller X/X_0**
- **No bias current**, only signal current
- Practically no detector capacity

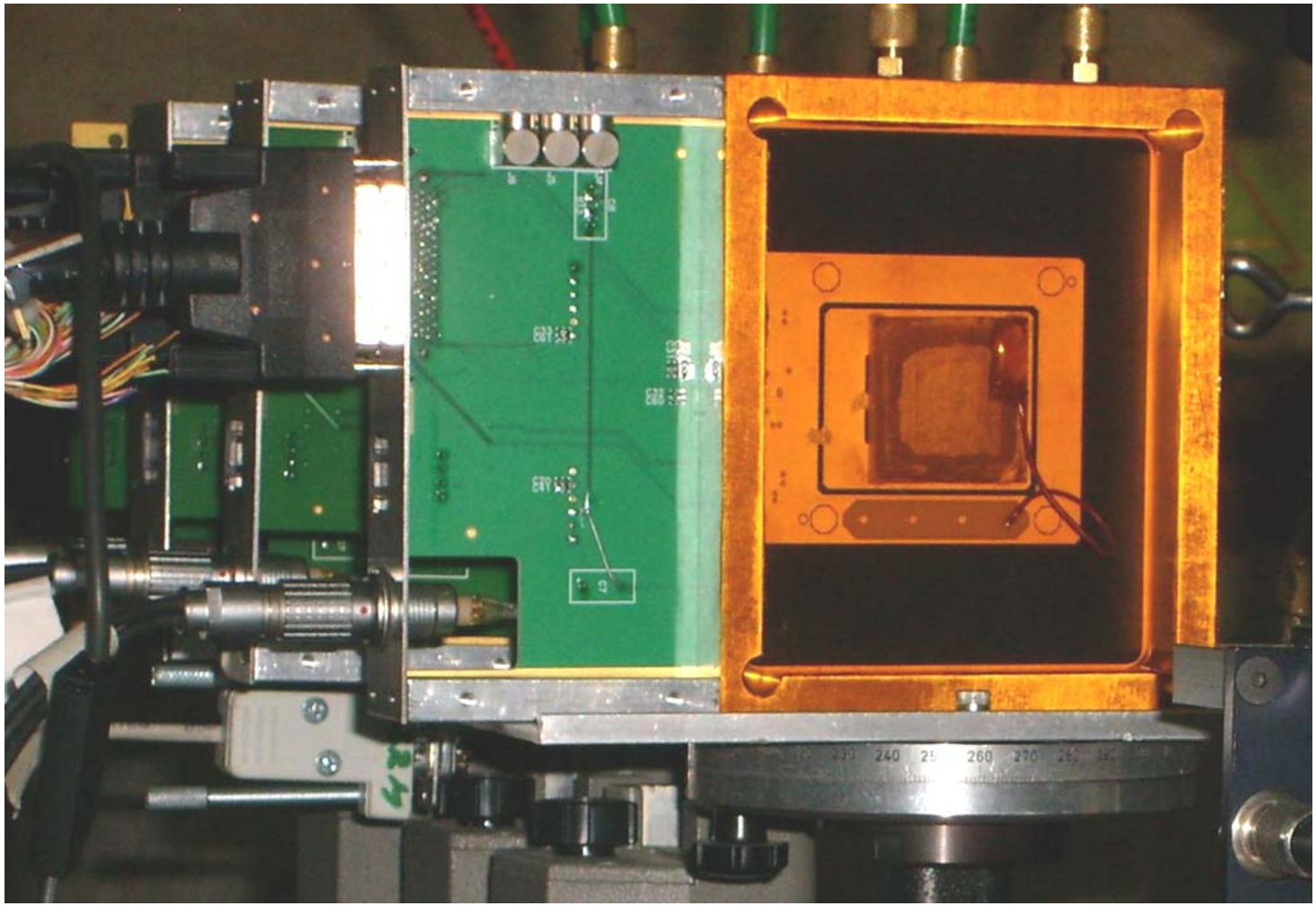
  => lower electronic noise



What does one have to sacrifice using Gossip technology?

- **Position resolution** ~factor 2 less good
  - ~ 15 µm (predicted) vs < 10 µm for solid state possible
- **Longer charge collection time**
  - ~ 2 LHC bunch crossings (50 ns) vs < 1 bunch crossing for silicon
    - But occupancy still very low (< 2 ‰)
- **Additional services** for Gossip technology
  - 2nd HV line for drift field voltage
  - 2 gas lines (one in, one out)
- **Less easy operation**
  - Operation Gossip more critical because of signal multiplication by avalanche
  - Example: grid voltage -400 → -430V => 2 x more gain
- **Larger data stream**: Gossip => ~ 3 x more hit pixels
  - => either increased data rate
  - => or local track fitting processor needed (in or near frontend chip)

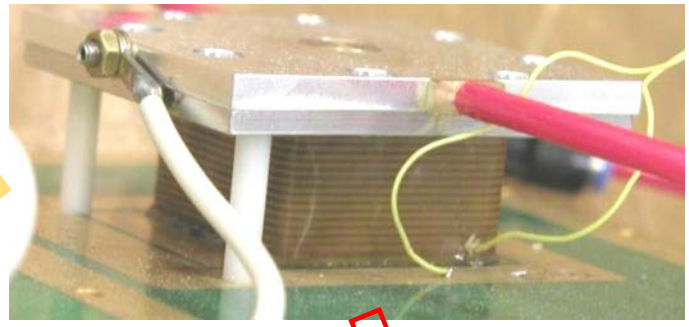
Results September 2009 testbeam at CERN PS



Telescope with 4 Gossip detectors

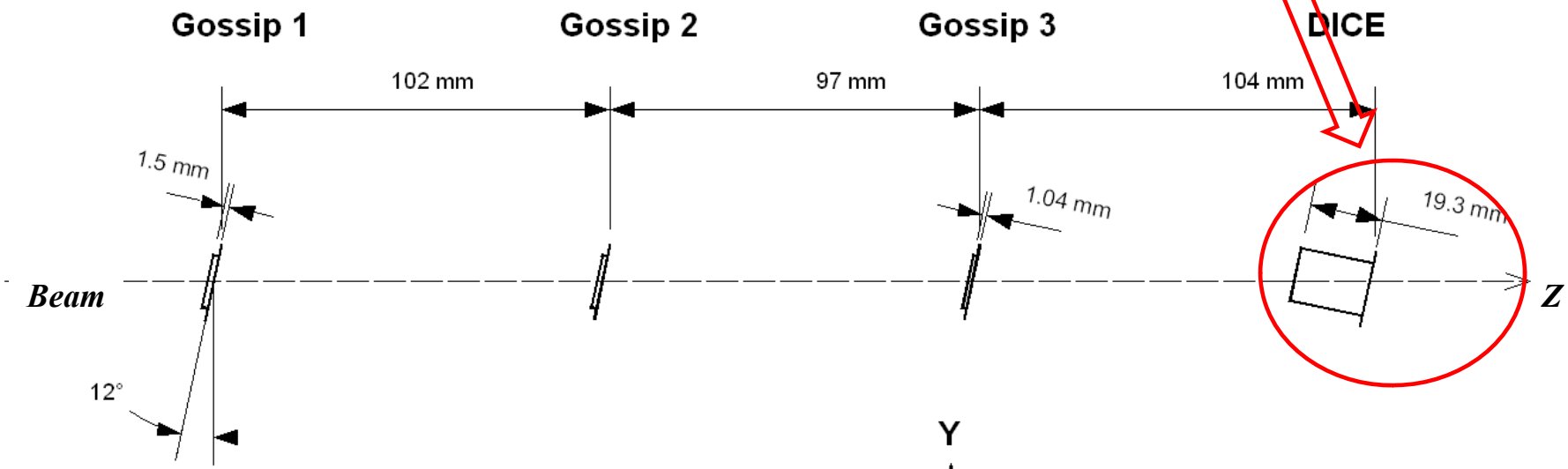
Set-up test beam experiment

- 4 TimePix† based Gossips ~ 10 cm apart
  - 3 Gossips with 1 – 1.5 mm drift gap
  - **1 Gossip with 19.3 mm drift gap**
    - Acting as a TPC
- Beam T10 (6 GeV π) at PS

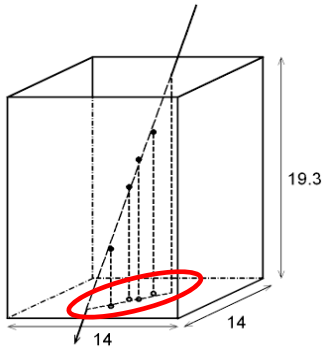


- **Gas CO_2/DME 50/50**

Top view



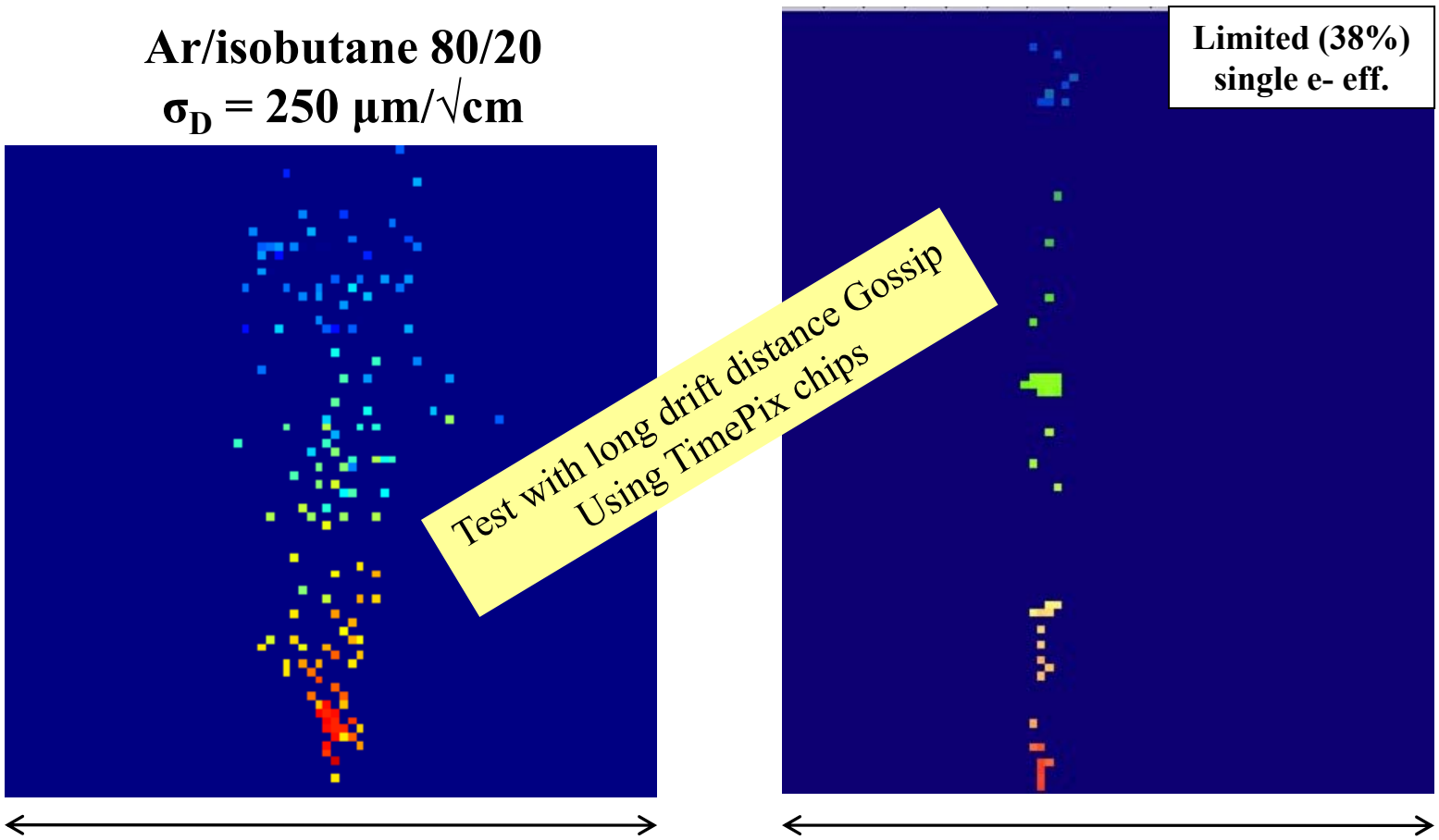
†TimePix DAQ by Pixelman software (IEAP Prague)



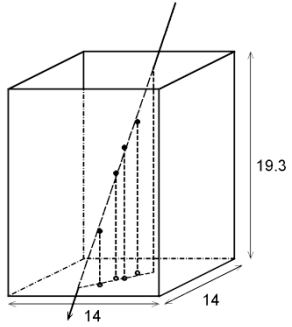
Choice of the detection medium (gas) very significant

CO_2/di-methyl-ether (DME) 50/50
σ_D = 70 µm/√cm

Ar/isobutane 80/20
σ_D = 250 µm/√cm

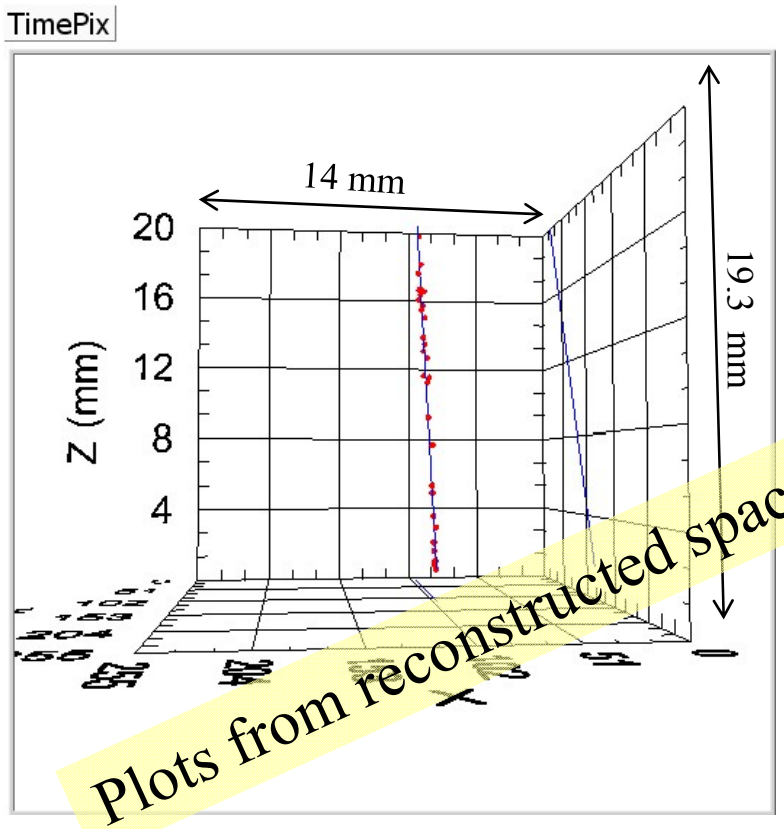


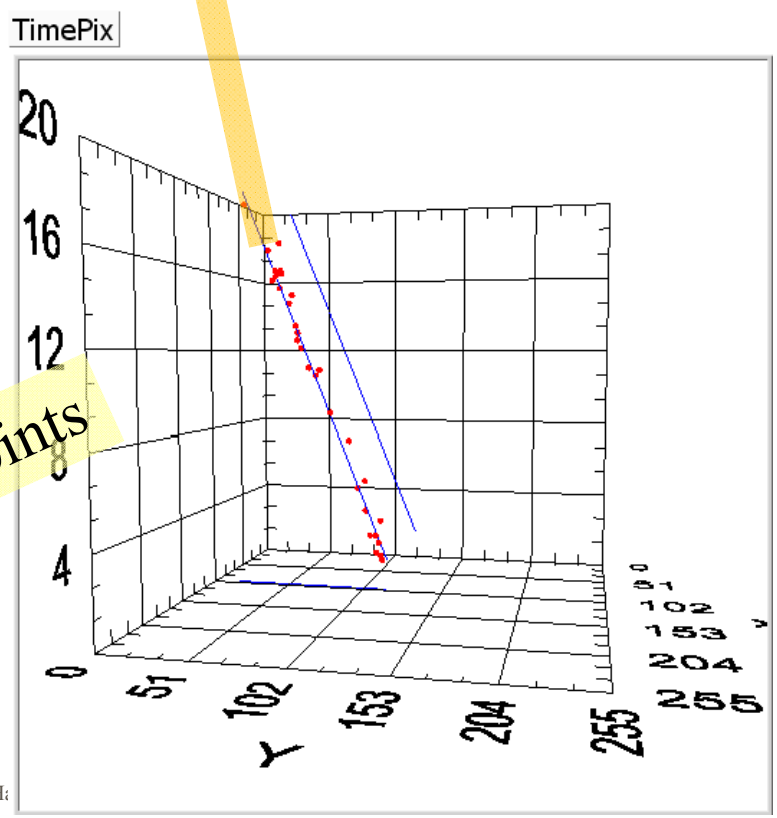
Example of event in 19.3 mm Gossip



- Angle of incidence: 12° in Y-Z plane, 0° in X-Z plane
- Drift velocity 10 µm/ns @ 2 kV/cm
- Limited single electron efficiency (~ 38%)

- X-Z plane shows **extremely low diffusion** in DME/CO_2 50/50
- Y-Z plane shows scattering in caused by **time slewing** of TimePix-1 chip

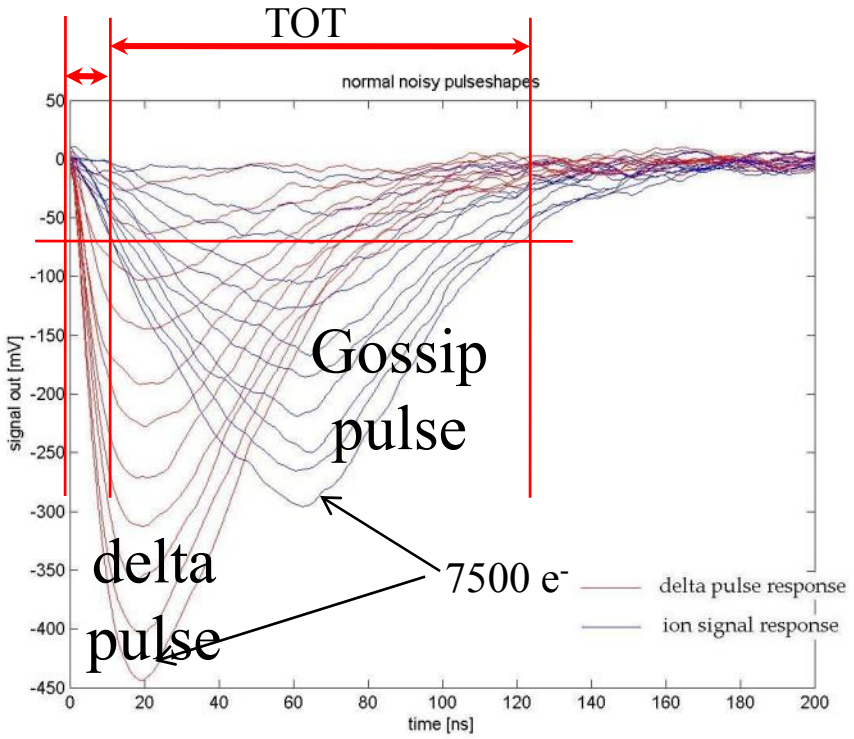




Plots from reconstructed space points

Time slewing

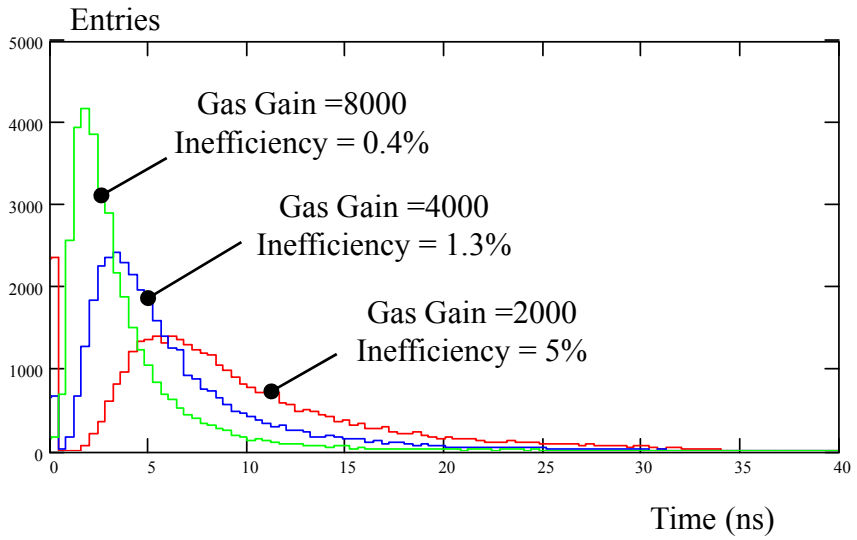
- Time slewing is the extra delay of the discriminator pulse caused by
  - **Finite rise time** of the shaped charge signal
  - **Response time** of the discriminator



Time slewing of Gossip using TimePix-1

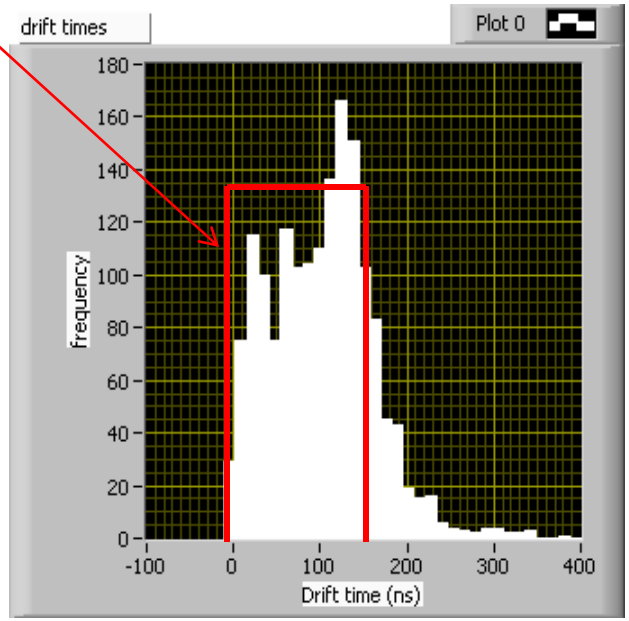
- Time slewing of the **TimePix-1** chip has shown to be a big problem
- For the measurements presented here the effect is less pronounced because of the low drift velocity (10 µm/ns vs 50 µm/ns intended)
- Effect will be much reduced at the **TimePix-2*** that is presently in development by the MediPix Collaboration
  - Time bin 1.7 ns (vs 12 ns for TimePix-1)
  - Slewing < 10 ns for almost all single electron hits
    - (TimePix-1: occasionally exceeding 200 ns)

Simulated time slewing for TimePix-2 frontend



Ideal time spectrum

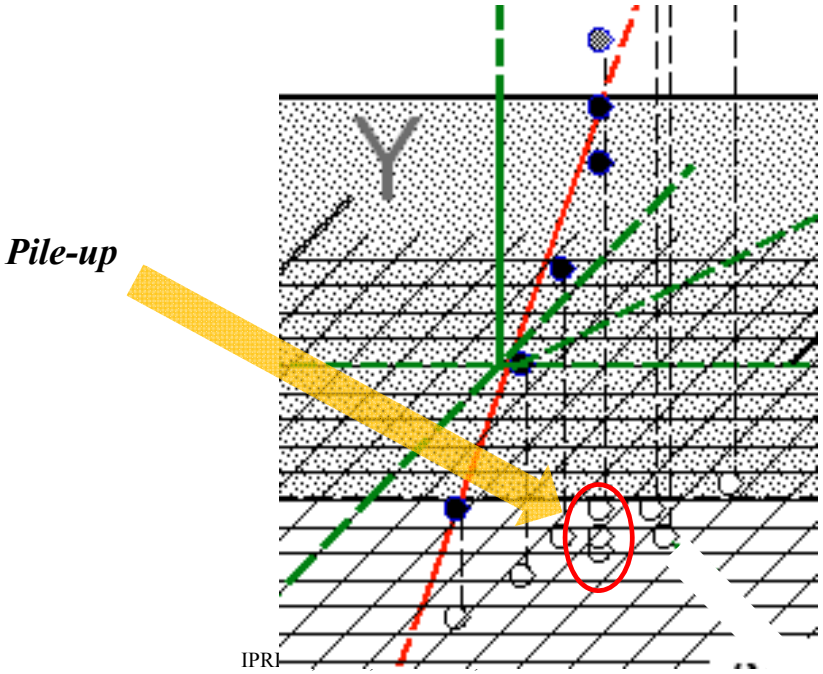
Measured drift time spectrum (1.5 mm drift gap)

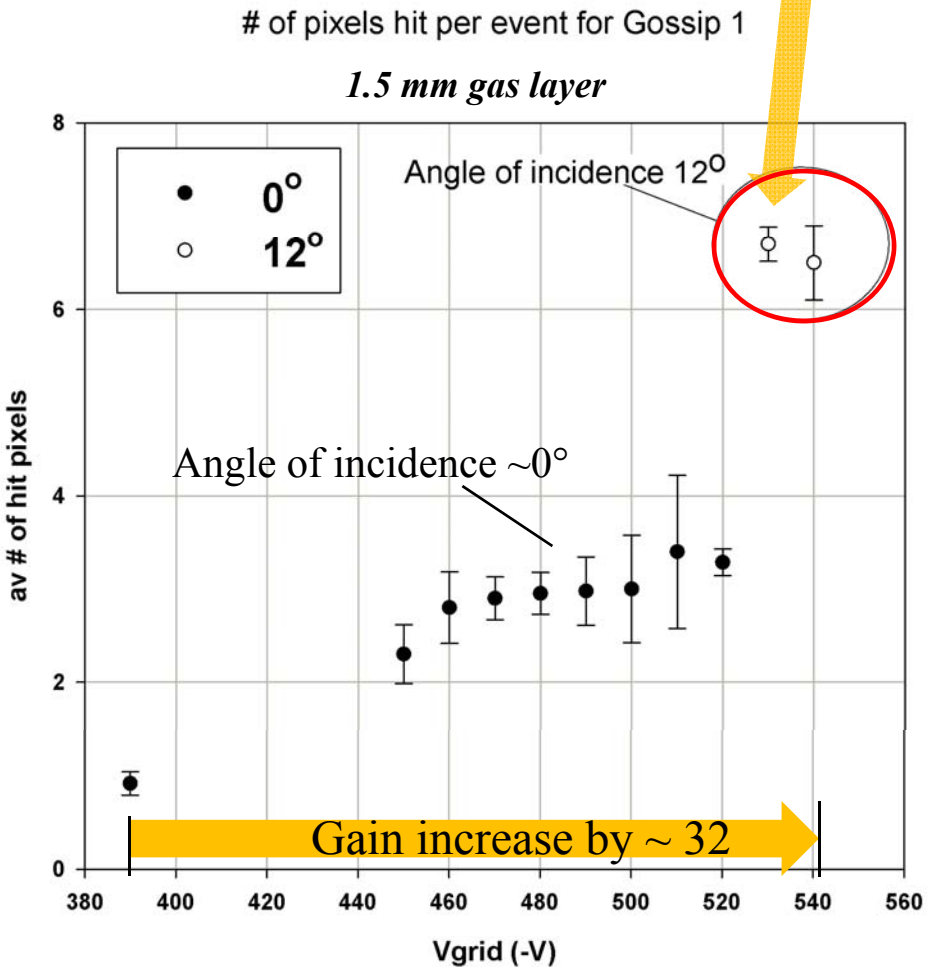


Pile-up effect

- **One pixel is hit by more than one electron**
- Angular dependence
  - **Strong pile-up** at small angles
- Pile-up larger for low diffusion gas

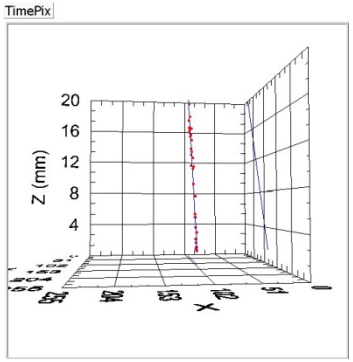
-530 V used for the resolution measurements. Single electron efficiency close to 100%.

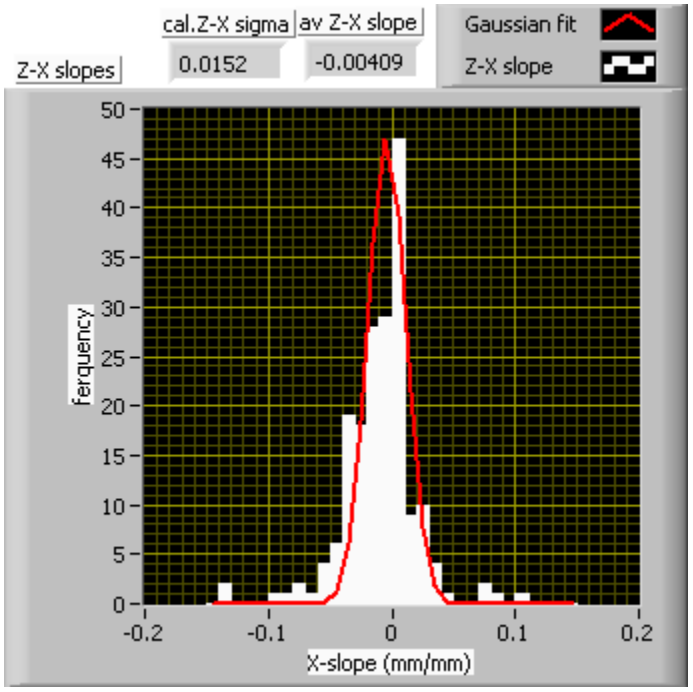




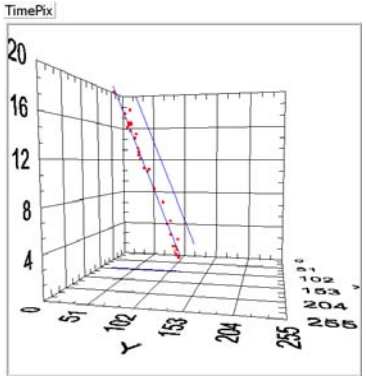
Track angle resolution in Gossip 1

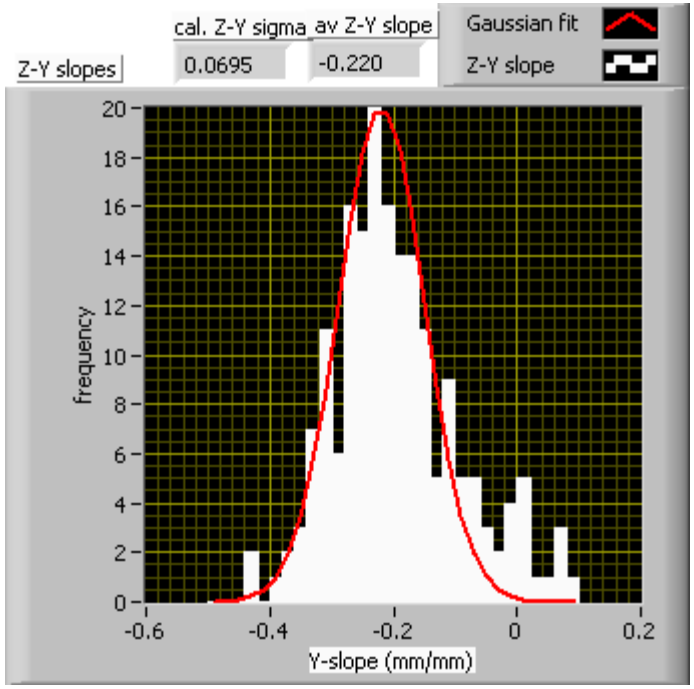
- X slope: 4.1 mrad (0.23°)
- Angular resolution **15 mrad (0.9°)** in X-Z plane
  - Surprisingly well for **1.5 mm of gas**





- Y slope: 220 mrad (12.6°)
- Angular resolution **70 mrad (4°)** in Y-Z plane
  - Deteriorated by slewing
    - Note the asymmetric distribution





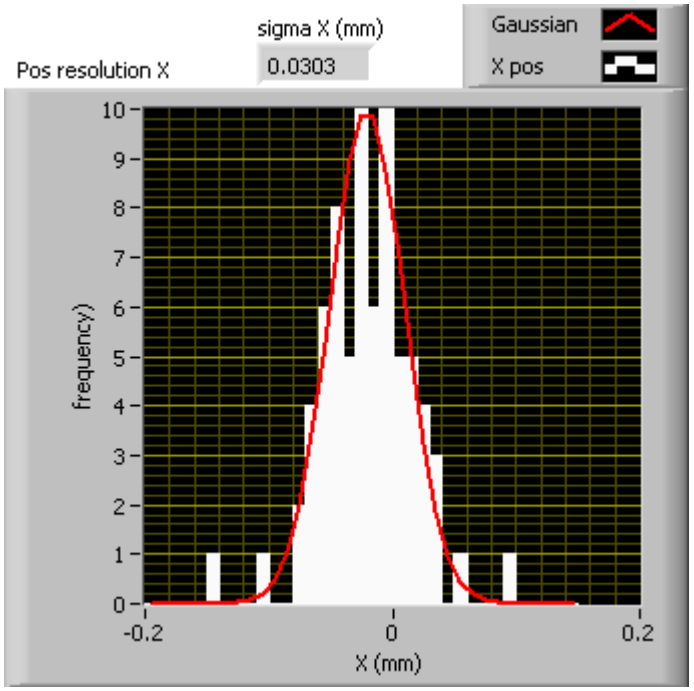
Position resolution

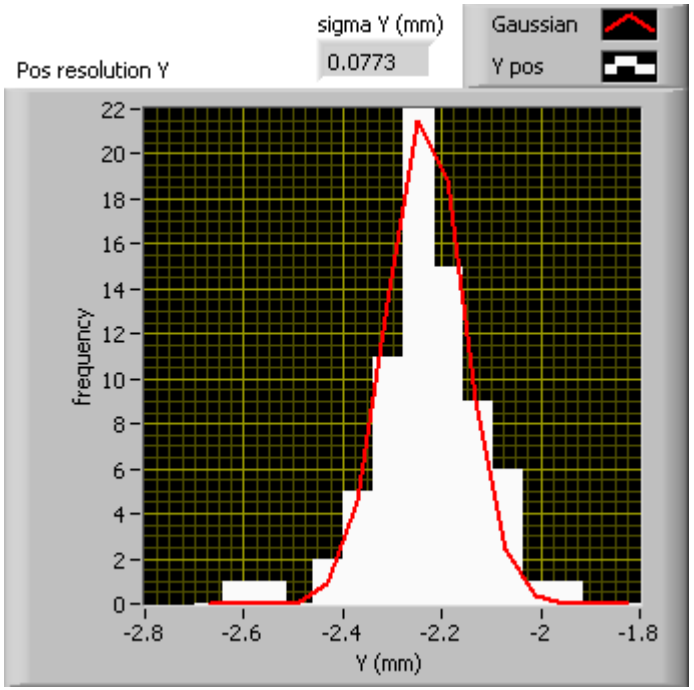
- Using two Gossips as a reference
  - 19.3 mm DICE and 1.5 mm Gossip 1
- Resolution determined on 1.0 mm **Gossip 3**

  X direction: **σ = 30 - 35 µm**

  Y direction: **σ = 70 - 80 µm**

- Obtained from simulations*
  - **σ = 12 and 15 µm resp.**
- Results are **deteriorated** by
  - **Poor single electron efficiency** of Gossip 3
    - 55% single pixel events
  - Accuracy of the fitted track (10 µm?)
  - Multiple scattering of 6 GeV beam (10 – 30 µm)
  - For Y direction: **large time slewing**
- **=> results do not contradict the simulations**



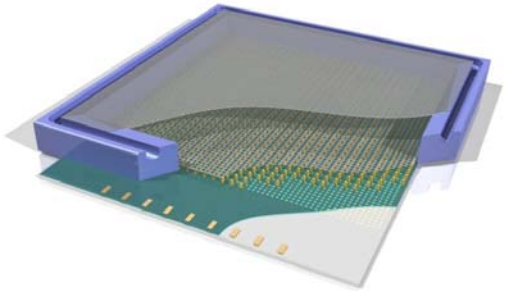


Ref.: ATLAS Note No: ATL-P-MN-0016 Backup document

Discussion and summary

- Using a low diffusion gas like DME/CO_2 in the Gossip detector, a high position resolution and angular resolution has been measured
  - Angular resolution better than **1°** with 1.5 mm of gas
  - ~ **30 µm** position resolution measured in X direction

- Better results **angular resolution** in Y-Z plane is likely if we improve the **time slewing** of TimePix-1 chip
- Better results **position resolution** if we improve
  - **Poor performance of the used detector**
  - **Time slewing** of TimePix-1 chip
  - Beam energy (for this test: 6 GeV)



- Using both the **hit point** and the **angular** information, the Gossip technology is a promising candidate for tracking at the hottest part of the sLHC