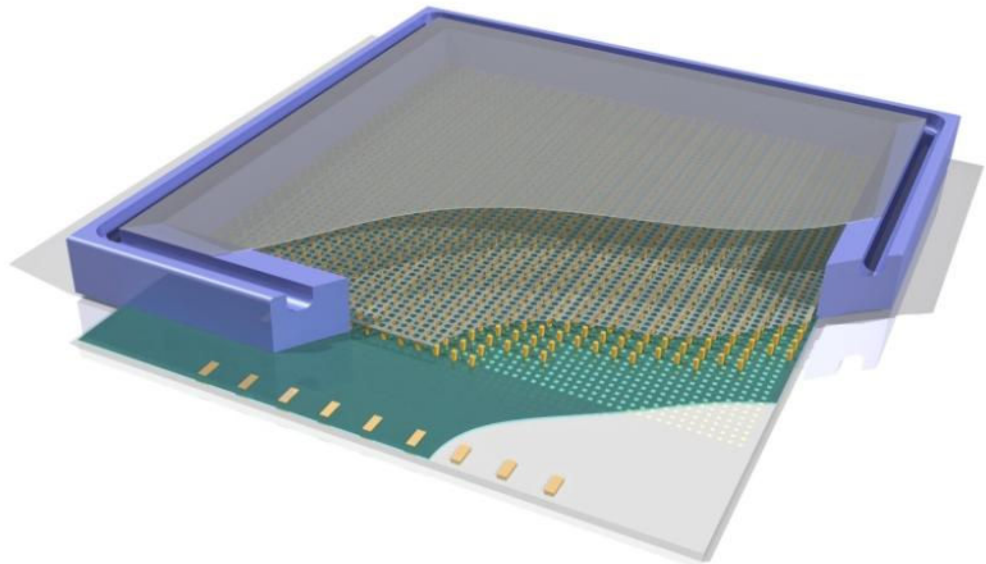
Operation of Gossip using DME/CO_2



- Introduction GridPix/Gossip
- Analysis September 2009 testbeam
  - CO_2/DME 50/50
- Conclusions

Yevgen Bilevych[1] ,Victor Blanco Carballo[1], Maarten van Dijk[1], Martin Fransen[1], Harry van der Graaf[1], Fred Hartjes[1], Nigel Hessey[1], Wilco Koppert[1], Sjoerd Nauta[1], Michael Rogers[2] , Anatoli Romaniouk[3], and Rob Veenhof[3]

[1] Nikhef

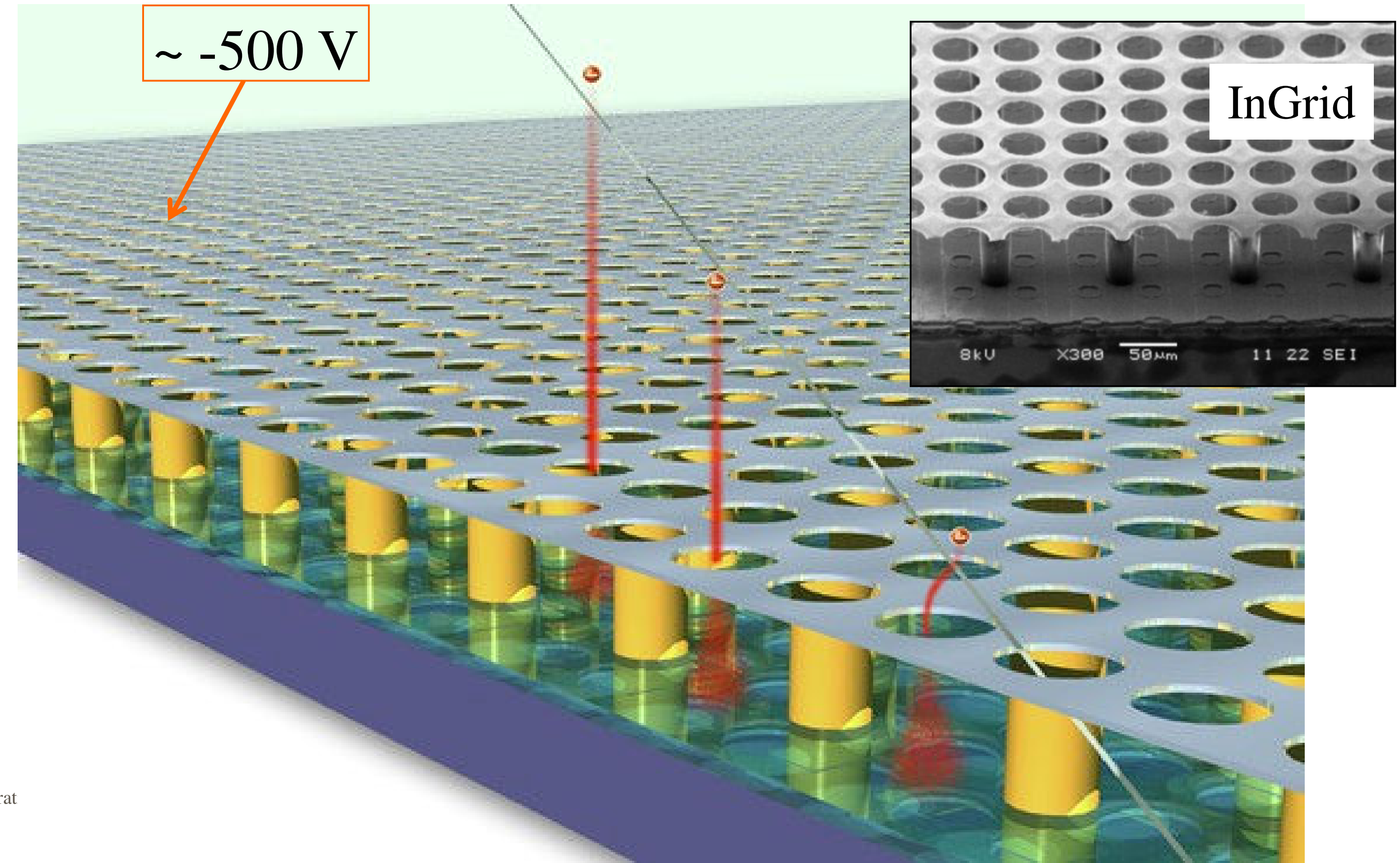
[2] Radboud University, Nijmegen

[3] CERN

4th RD51 Collaboration meeting
CERN, November 23 - 25, 2009

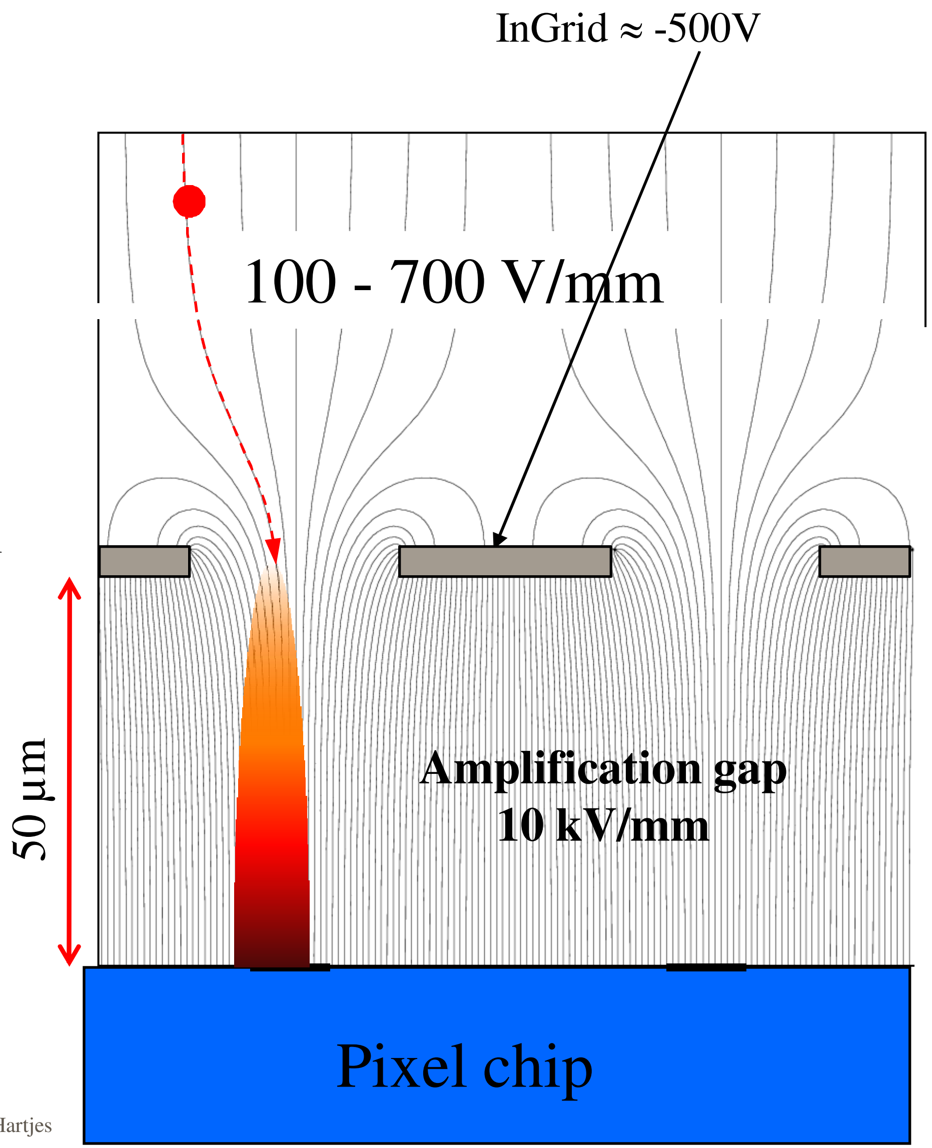
Functioning GridPix/Gossip

- Gaseous Pixel detector using a pixel chip
  - Using gas as a detecting medium
- Electron from traversing particle drifts towards Micromegas grid and is focused into one of the holes
- Thereafter a gas avalanche is induced ending at the anode pad of the pixel chip



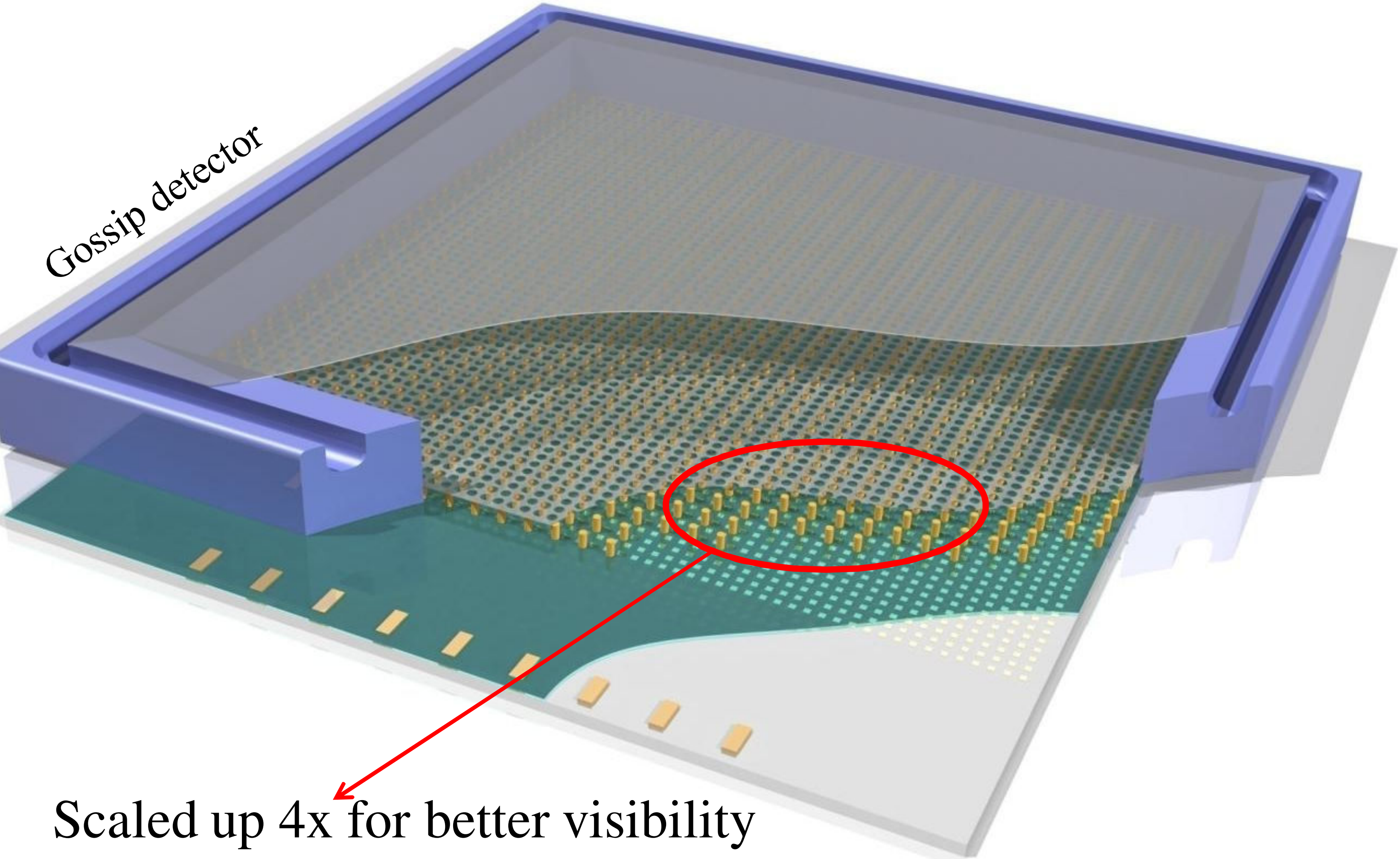
Field configuration of GridPix/Gossip

- Drift field 100 -700 V/mm
- High amplification field under grid to induce gas avalanche
  - ~ 10 kV/mm
- Micromegas holes centred on pads pixel chip
- Avalanche broadened by diffusion to 15 – 20 μm



Gossip vs GridPix

- GOSSIP is a speciality of GridPix
  - Minimal drift gap (1.0 - 1.2 mm) for short collection time (high rate application)
  - Actual gap height determined by required cluster density and efficiency
  - Example:
    - 1 mm gap and DME/CO_2 => 98.9% chance on detecting a track



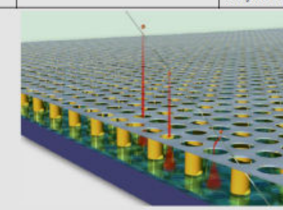
Scaled up 4x for better visibility

Organisation of Gossip R&D in ATLAS

- Gossip R&D proposal being reviewed: EDMS reference: ATL-P-MN-0016 v-1
  - ATLAS note (GossipBackupnoteV2-2, 52 pages)
  - RD51 Note Number: 2009-006
- Three ATLAS institutes involved
  - Nikhef (Amsterdam and Nijmegen)
  - Moscow State University
    - New concept L1 triggering
  - University of Bonn
    - RO of Gossipo-4
- More participants welcome

Performance and prospects of GridPix and Gossip detectors

ATLAS Note No: ATL-P-MN-0016	Institute Document No.	Created: **29/06/09**	Page: **1 of 52**
		Modified: **02/11/09**	Rev. No.: **2.2**



Abstract

This note gives an overview of the current research activities for the micropattern GridPix and Gossip detectors. As such it is intended as a technical backup document for the ATLAS R&D Proposal (ATL-P-MN-0016) on GridPix/ Gossip. In addition we present the new ideas we are developing or intend to develop.

The main advantages of GridPix/Gossip are treated: outlook for extremely high radiation tolerance and a very low material budget.

In addition we mention a number of applications for this technology: the ATLAS b-layer at the sLHC, an L1 trigger and TRT, a preshower tracker and a hadron calorimeter tracker.

We also treat the various technological steps that have to be taken: mechanical construction of the stave, services (powering, optical links).

Contact Persons: Harry van der Graaf (vdgraaf@nikhef.nl); Fred Hartjes (F.Hartjes@nikhef.nl)

Prepared by:	Checked by:	Approved by:
Harry van der Graaf (Nikhef) Fred Hartjes (Nikhef) Anatoli Romaniouk (Moskow MePhI, Russia/CERN)	Hans Band[a], Auke-Pieter Colijn[a], Martin Fransen[a], Vladimir Gromov[a], Nicolo de Groot[b], Nigel Hessey[a], Paul de Jong[a], Ruud Kluit[a], Wilco Koppert[a], Marco Kraan[a], Michael Rogers[b], Henk Schuijlenburg[a], Jan Timmermans[a], Rob Veenhof[c], Bart Verlaat[a] [a] Nikhef, Amsterdam, the Netherlands [b] Radboud University Nijmegen, the Netherlands [c] CERN, Geneva, Switzerland	

Distribution List

ATLAS High Luminosity Steering Group

Replacing silicon technology in Atlas ID with Gossip detectors brings a number of crucial benefits

- Outlook for extremely high radiation tolerance (>> 10^{16} MIPS/cm^2)
  - By far exceeding the range of most solid state detectors
- Almost insensitive for neutrons and hard X-rays
- No bias current, only signal current
  - b-layer @ sLHC: 3.5 μA/cm^2 @ 0.9 GHz/cm^2 (~30 pA/pixel of 55 x 55 μm)
  - → frontend with low power dissipation possible (**2 μW/pixel**)
- Operation at wide temperature range, relaxed cooling requirements
- → reduced material budget: 1.25 % estimated (services and support **included**)
- No bump bonding → major cost reduction
- No additional input capacity → very low threshold possible (350 e$^-$)

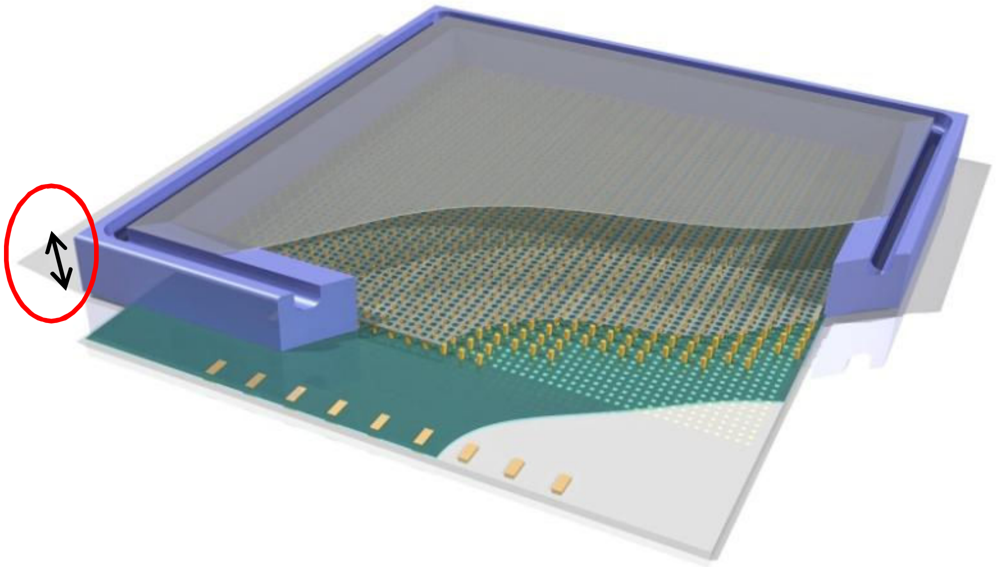
But everything has its drawbacks

- Additional services required
  - Gas pipes (may be thin: 0.8 mm or even 0.4 mm)
  - 2nd high voltage line for drift field (no critical regulation)
- Worse position resolution than is possible with solid state detectors
  - Limited ionization statistics (around 10 e^- , from one on)
  - Diffusion in the drift gap
  - → resolution does not quite meet the B-layer requirements (< 10 μm)
  - more layers needed, more data channels needed
- Critical regulation of grid voltage
  - Variation 30 V → factor 2 in gain
  - Many HV channels needed → local low power HV PS needed
- Tendency to sparking
  - Rate induced sparking, under investigation
  - FE chip should be made spark proof → problem basically solved
- Long charge collection time (30 – 70 ns, to be investigated)
- Risk on accelerated ageing (can be minimized)

September 2009 testbeam experiment using DME/CO_2

Three operating detectors at September 2009 test beam

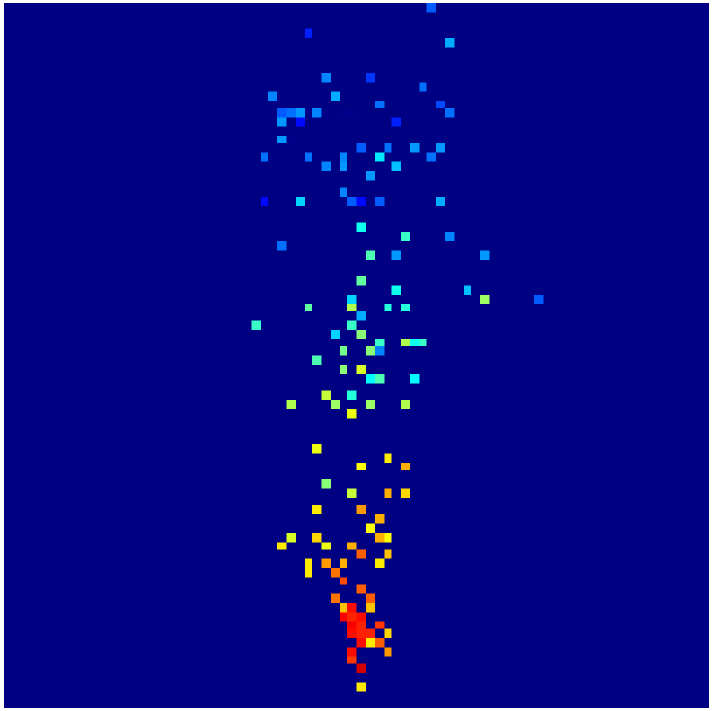
- Based on TimePix chip
  - Derived from the MediPix chip
  - 256 x 256 pixels
  - 55 x 55 μm pitch
  - TDC per pixel: 12.5 ns period
  - Threshold ~ 700 e^-
- Two Gossip detectors
  - Gossip 1: drift gap **1.5** mm high
  - Gossip 3: drift gap **1.0** mm high
- One GridPix detector
  - Drift gap **19.3 mm** high
  - Used as a reference to define tracks



Comparing DME/CO_2 with Ar/iC_4H_{10}

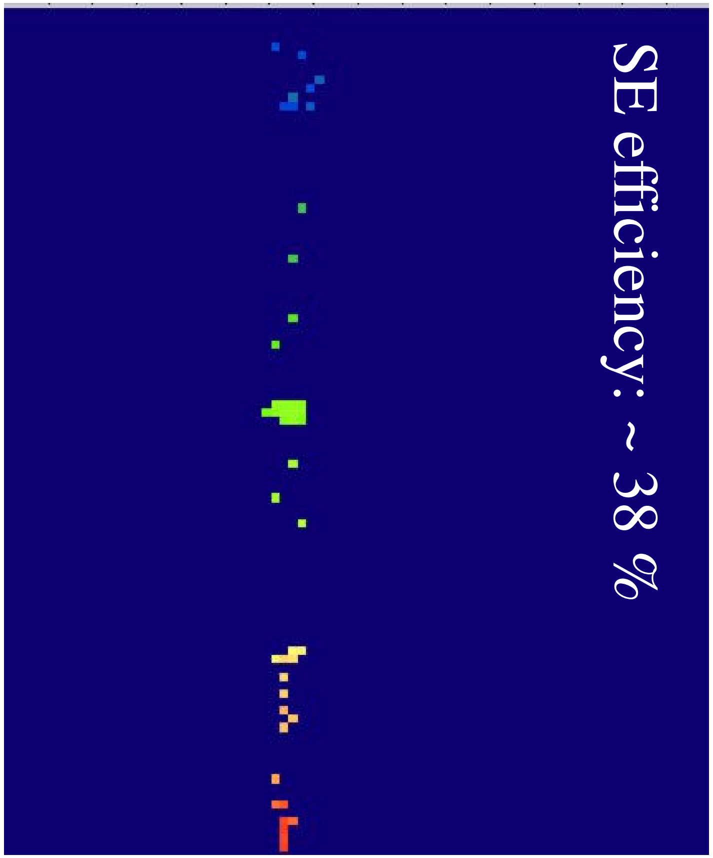
- Projected slanting tracks
- Measured in DICE detector: drift distance 19.3 mm
- Very low diffusion for CO_2/DME

Ar/iC_4H_{10} 80/20
(June 2009 testbeam)



80 pixels (440 μm)

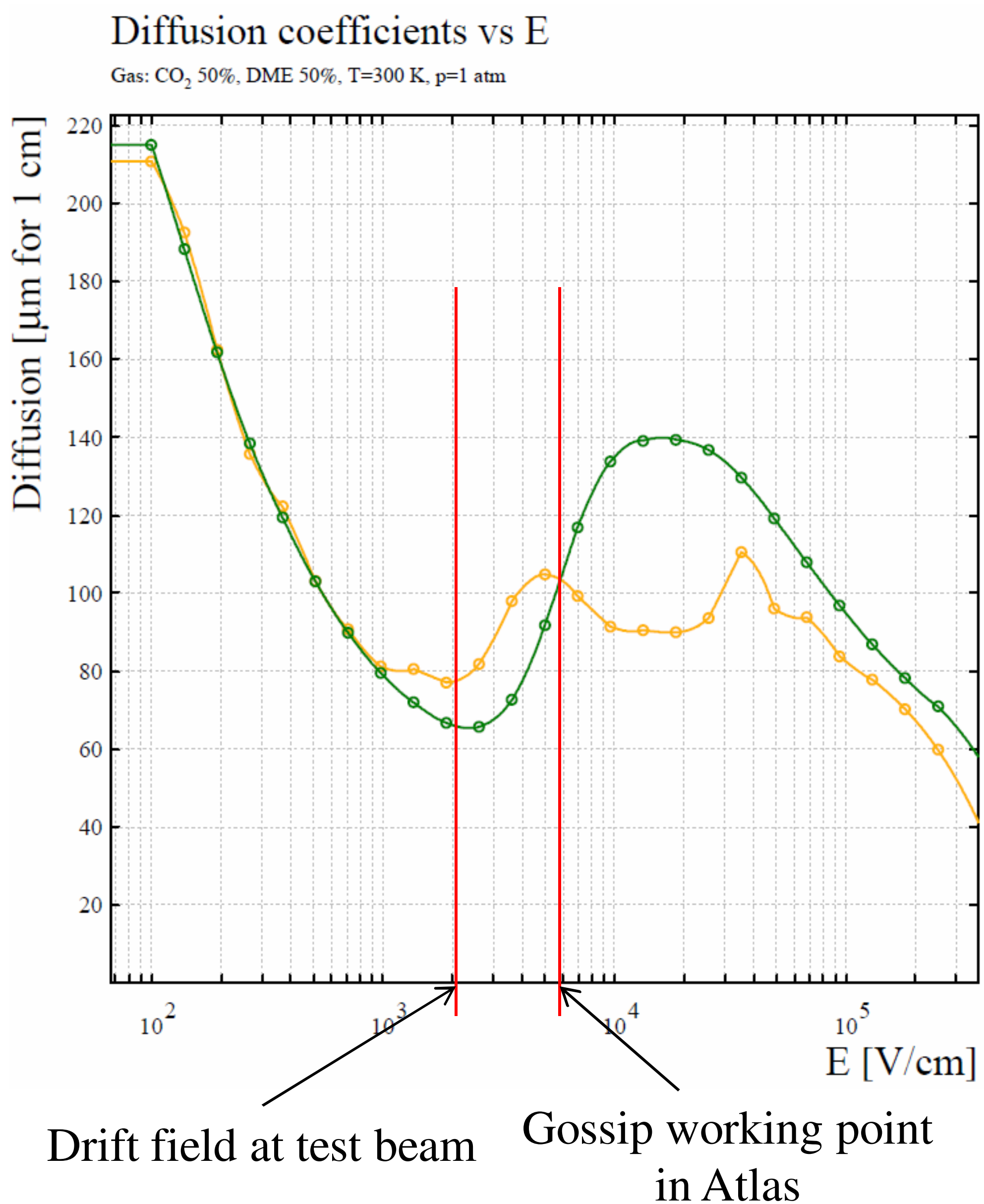
CO_2/DME 50/50



80 pixels (440 μm)

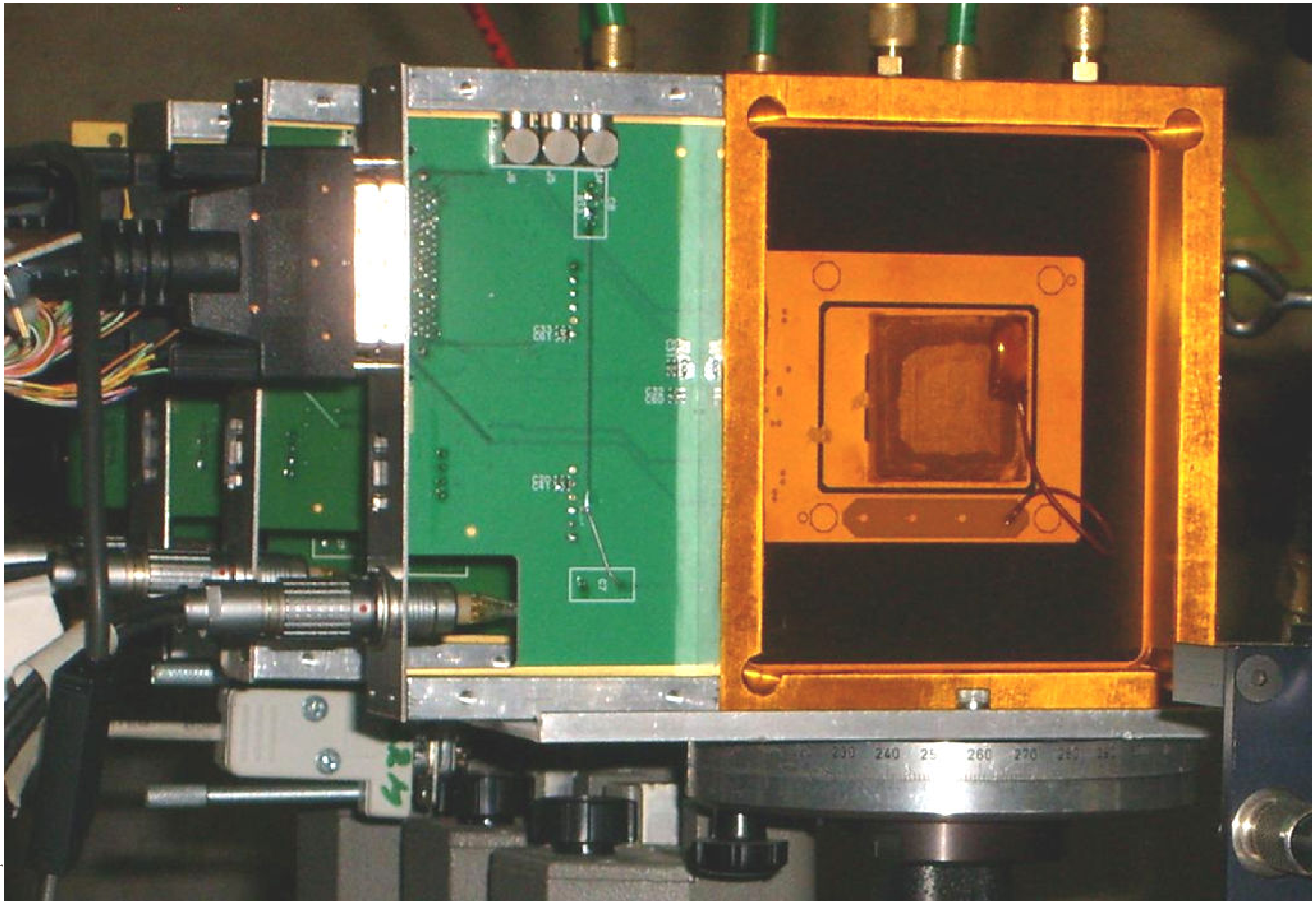
New chamber gas: CO_2/DME 50/50

- Used for first time with this type of detector
- "Cool gas"
  - Test beam:
    - $V_d \approx 10\ \mu m/ns$ @ 2 kV/cm
    - Very low diffusion: ~ 70 μm/√cm
  - Ref:
    - Ar/isobutane 80/20: ~ 250 μm/√cm
- We finally intend ~6 kV/cm for Atlas b-layer
  - $V_d \approx 50\ \mu m/ns$
  - Diffusion ≈ 100 μm/√cm
- High grid voltage needed to get sufficient gas gain
  - 400 V => 550 V
  - HV problems at edges (bond wires)

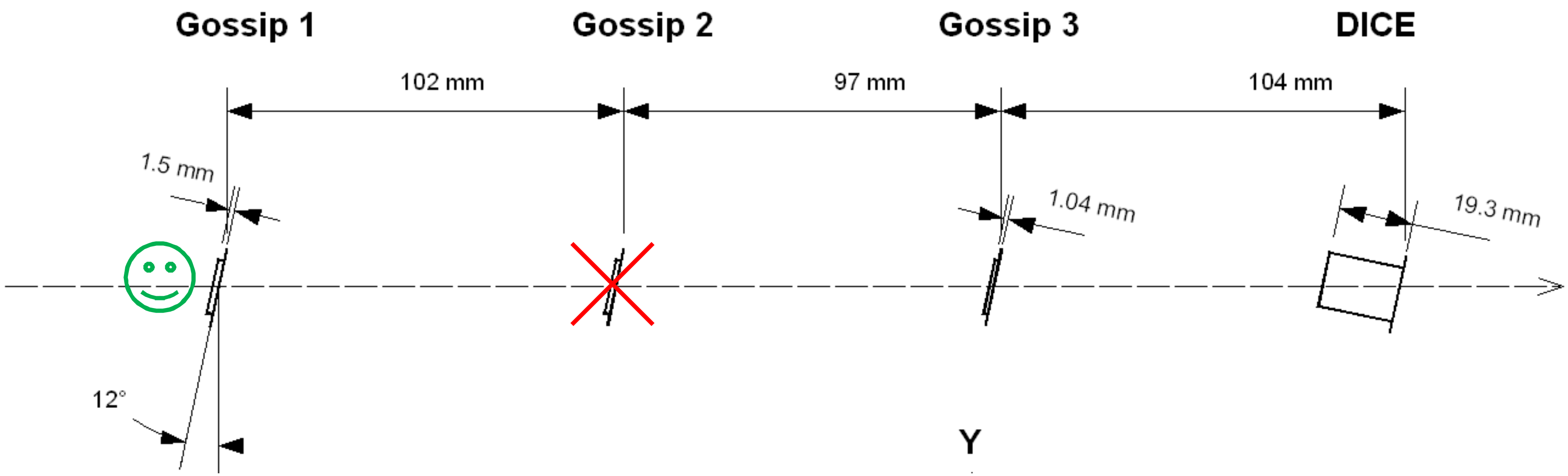


Testbeam setup in T10 (East hall)

- 3 Gossips and one GridPix
- ~ 10 cm apart



Test beam experiment using DME/CO_2



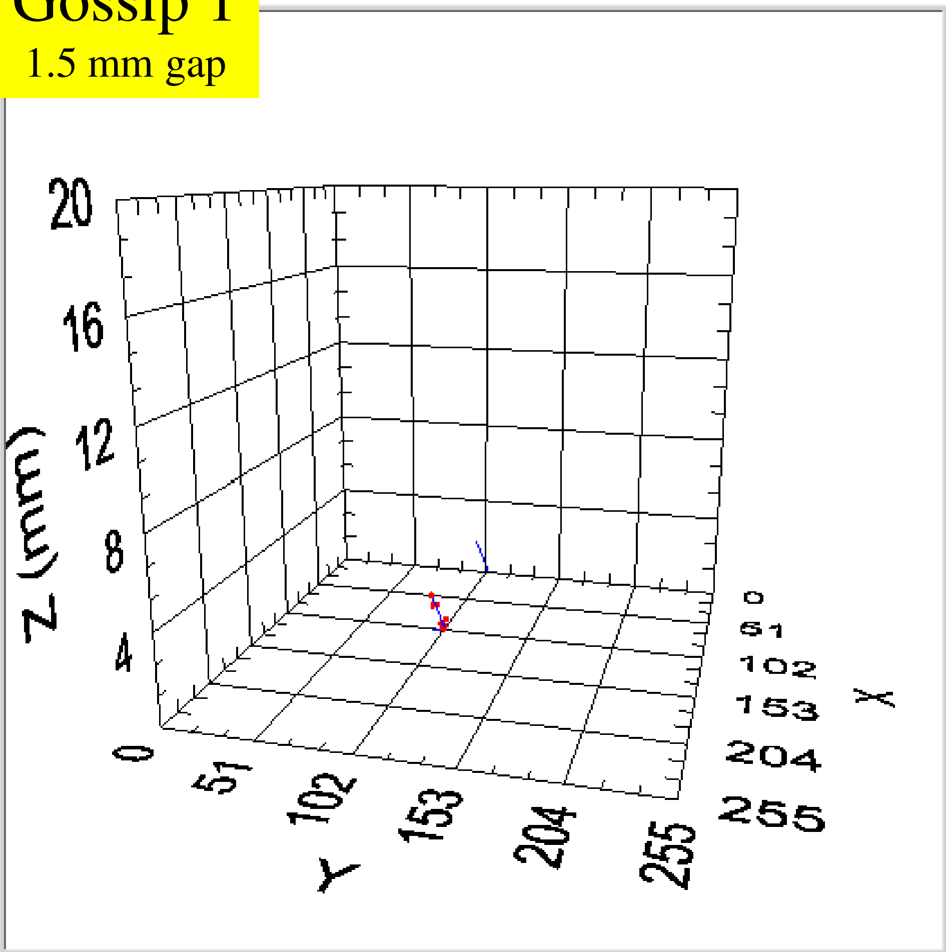
- Beam T10 (6 GeV π) at PS
- 4 detectors ~ 10 cm apart under 12 - 14^0 in Y and perpendicular in X

- HV problems (sparking)
  - Gossip 1: gas gap 1.5 mm, good single electron efficiency, protected with **GlobTop**
  - ~~Gossip 2: not useful~~ (HV problems)
  - Gossip 3: gas gap 1.04 mm, very small single electron efficiency (~ 16%)
  - DICE: gas gap 19.4 mm, single electron efficiency ~ 38%, but good for tracking
- Gas CO_2/DME 50/50

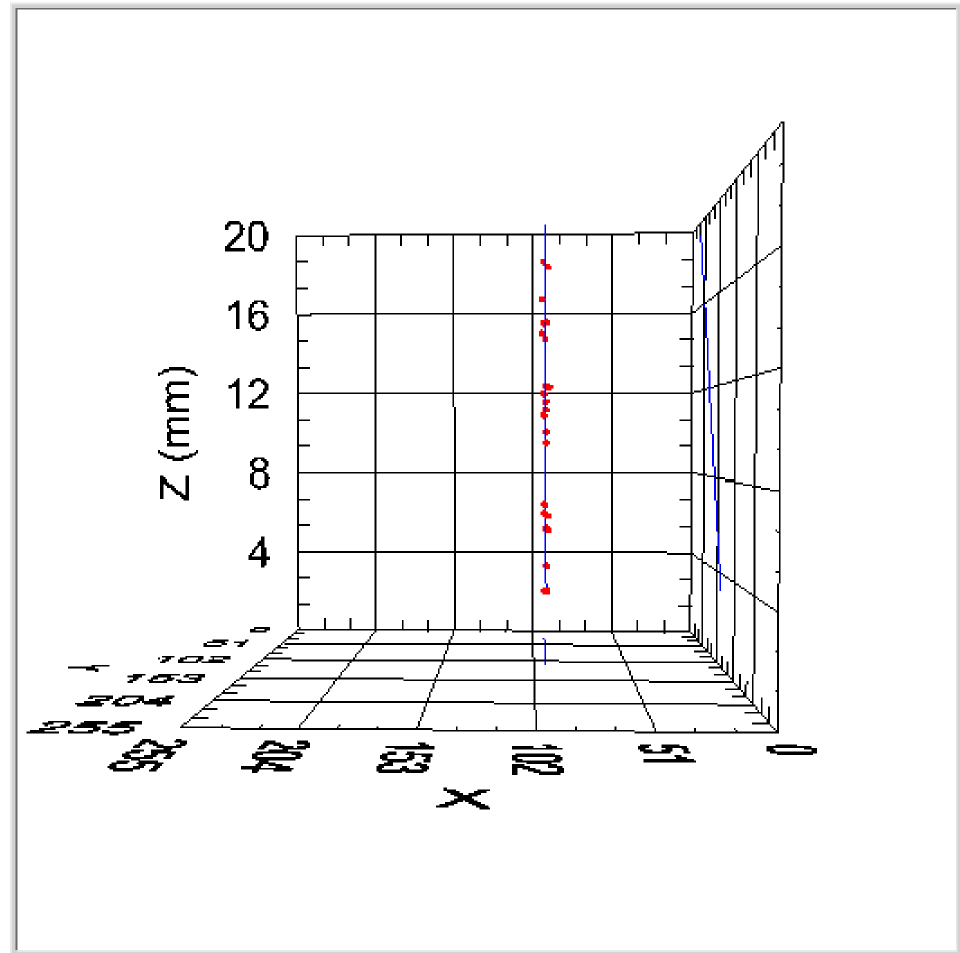
Example of events in Gossip 1 and DICE

- Pixel chip on X-Y plane

Gossip 1
1.5 mm gap

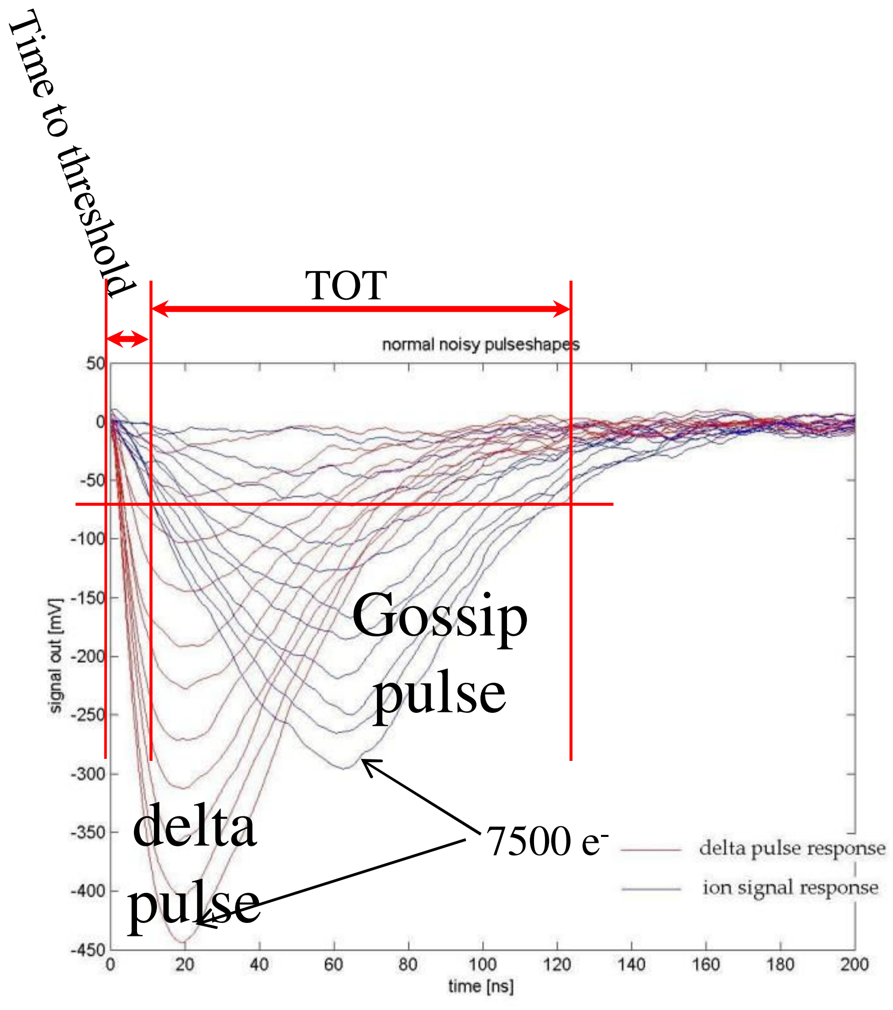


TimePix



Spoiling Z resolution by time slewing

- Simulation for Gossipo preamp
- State of the art frontend
  - 130 nm technology
  - 2 μW power
- Without any compensation, time slewing destroys Z resolution
  - 15 – 50 ns delay, exceeding range of drift time measurement (25 ns)
  - => Z errors ~300 μm rms
  - => compensation really required
- Possible compensation by
  - Time-over-threshold (TOT) measurement
  - => use this value to correct the measured arrival time
- Constant fraction discriminator

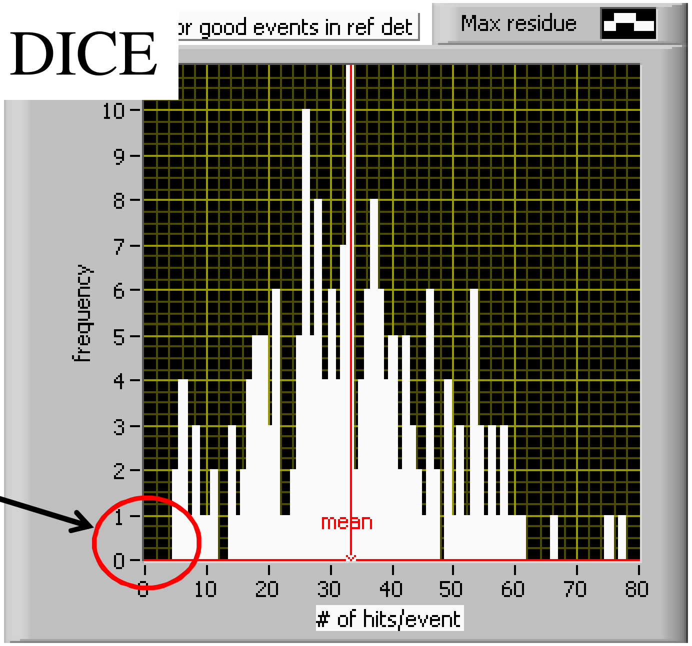


Cuts to the recorded events

- DICE (19.3 mm drift gap) used as a reference detector

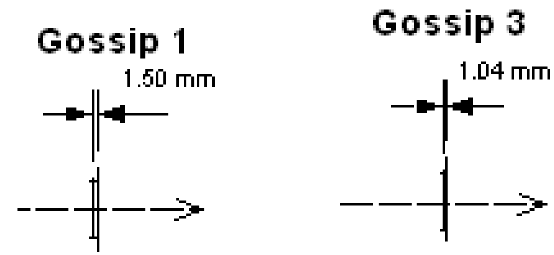
1. Noisy events removed (microdischarges)
   - > 400 kb instead of few kb
2. Noisy pixels masked (> 2% occurrence)
3. Empty events in DICE removed (< 3 hit pixels)
4. Tracks fitted in DICE with high slope residuals
   - Limit: > 0.1 rad
   - From double tracks, slow tracks, large deltas ....
5. Tracks having extreme slopes (> 10 mm/mm)
6. Tracks outside fiducial volume in X (3.6 – 9.1 mm)
   - Tracks at edge deformed by bad field shaping

DICE

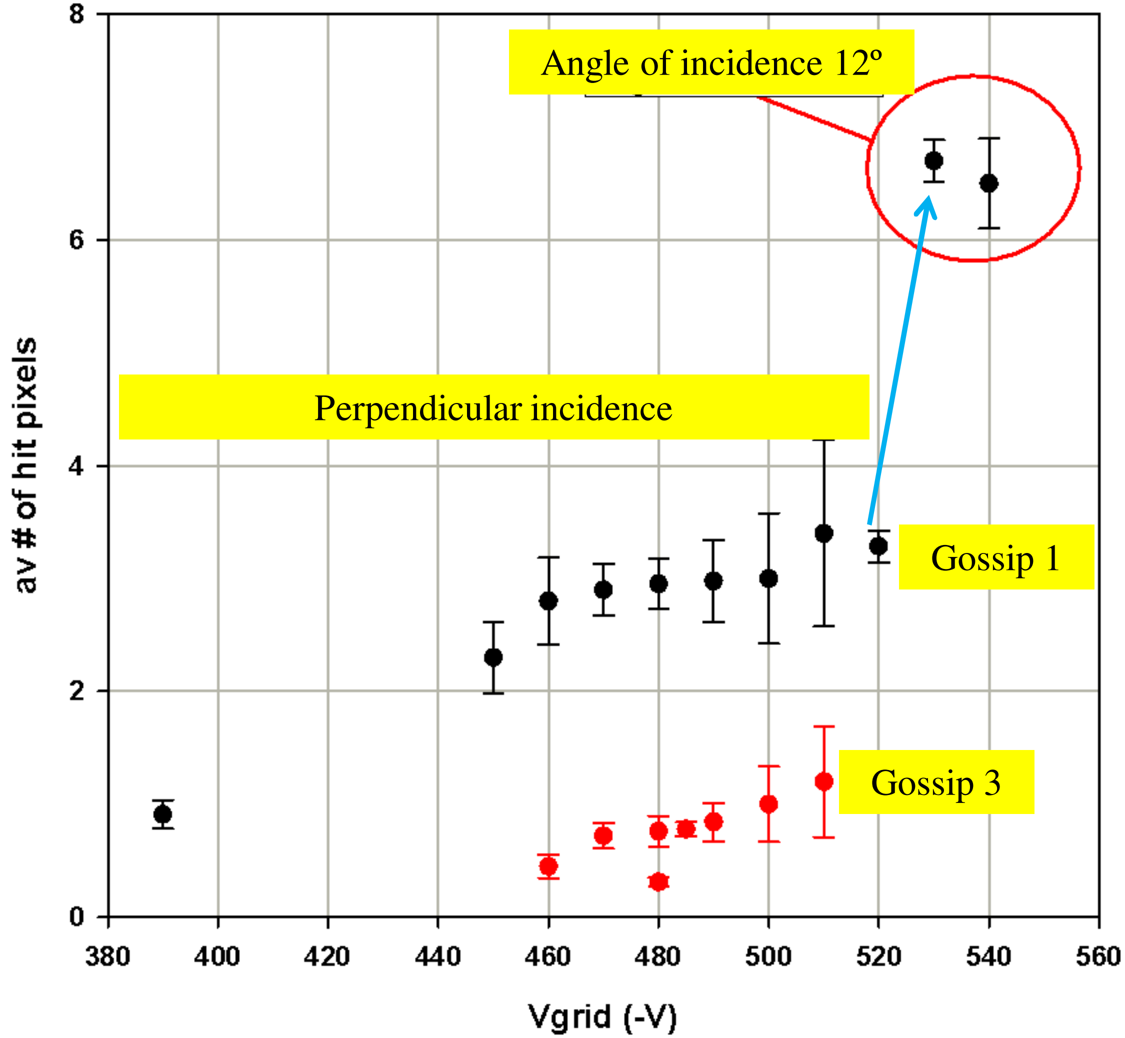


- Main run: => 197 out of 778 events seen in DICE accepted

of hit pixels vs grid voltage

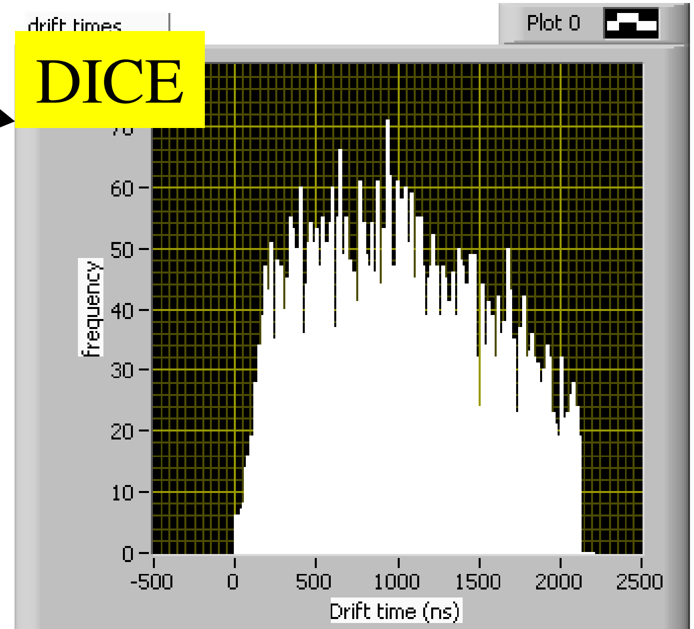


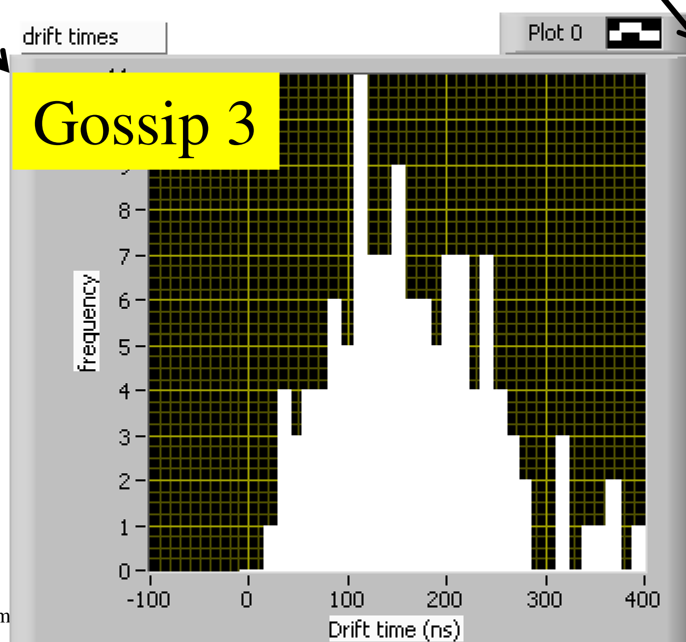
- Gossip 1 (1.5 mm drift gap)
  - well single electron efficient (plateau)
- Gossip 3 (1.0 mm drift gap)
  - No plateau
  - Poor single electron efficiency
- Much higher number of hits at 12º incidence
  - Avoiding pile-up effect

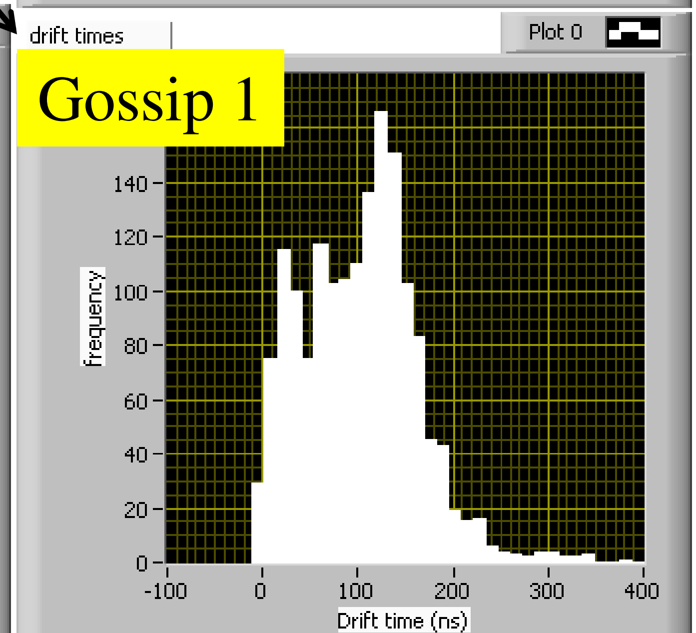


Drift time spectrum

- DICE: cut at 2.2 μs by common stop
  - About at end of drift region
  - Deviation from ideal shape (block) due to poor S.E. efficiency
- Gossip 1 (1.5 mm): basically ideal block shape
  - Deformed by convolution with slewing effect
- Gossip 3 (1.0 mm): broad distribution because of time slewing

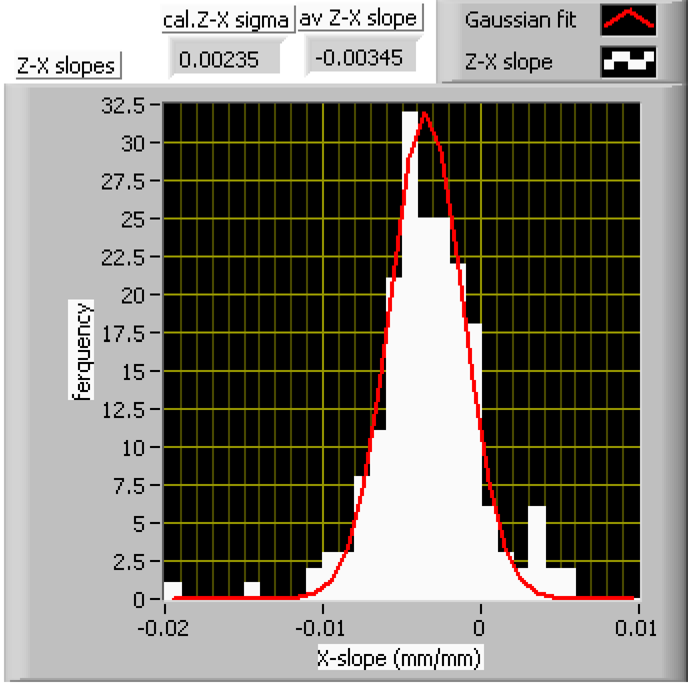


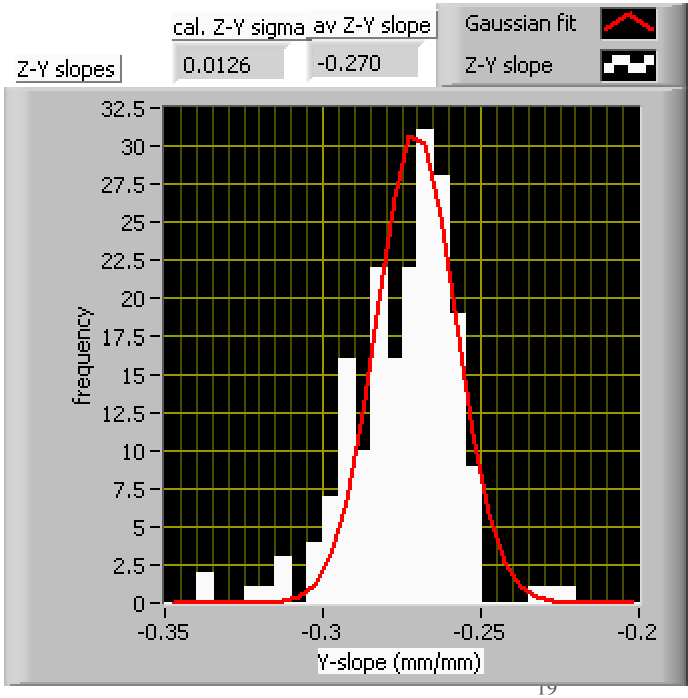




Measured track angle in DICE

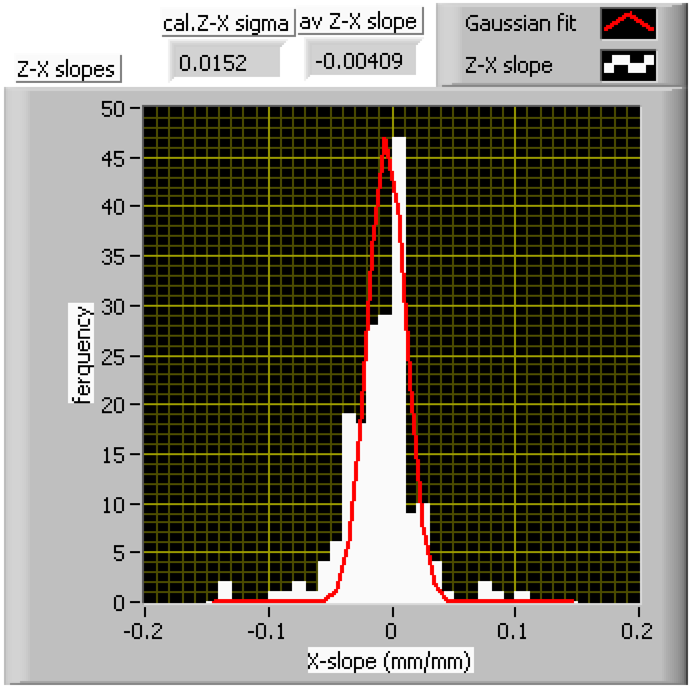
- Angles measured in projection of the track on X-Z plane and Y-Z plane respectively rather than in φ and θ
  - More practical for this analysis
- **X – Z plane**
  - Slope: -4.16 mrad (-0.24°)
  - **Resolution 2.35 mrad (0.13°) in X**
  - To be corrected for beam divergence (1 – 2 mrad)
  - "not bad for 2 cm of gas"
- **Y – Z plane**
  - Slope: - 270 mrad (-15,5°)
    - Correcting for 10% lower drift field => -14°
  - **Resolution 12.6 mrad (0.7°) in Y**
  - Worse because of slewing

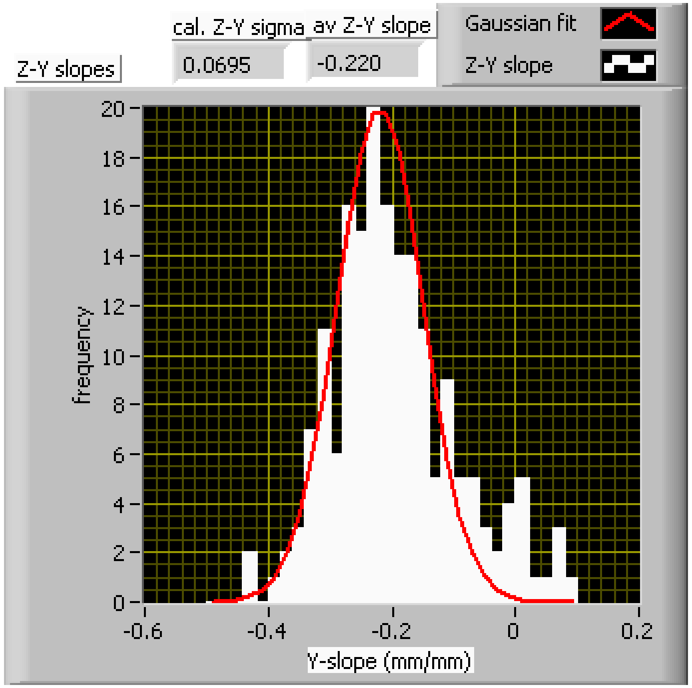




Measured track angle in Gossip 1

- **X – Z plane**
  - slope 4.1 mrad (0.23°)
  - **Resolution 15 mrad (0.9°) in X**
  - Also good for 1.5 mm of gas

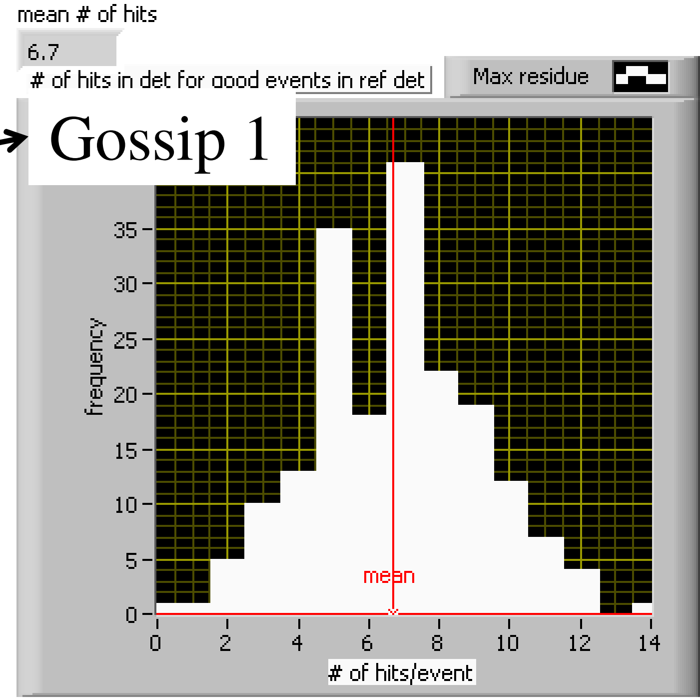


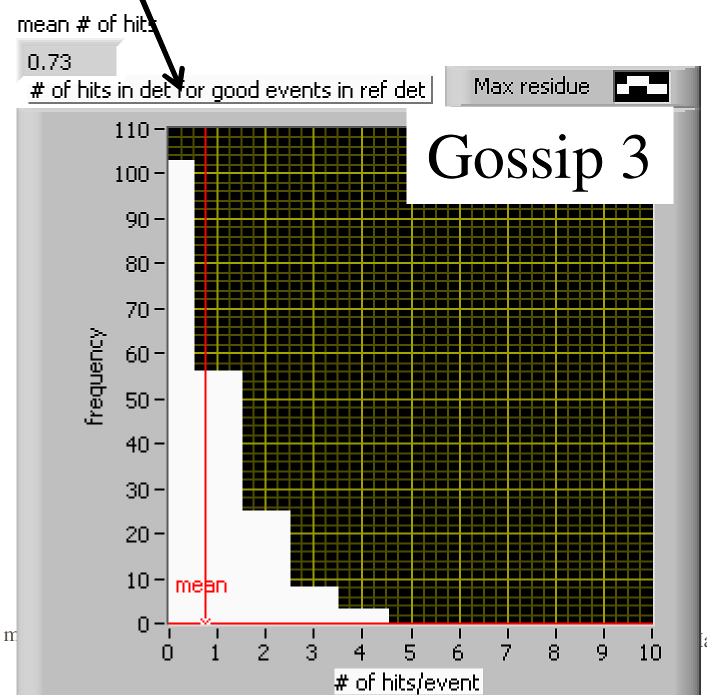


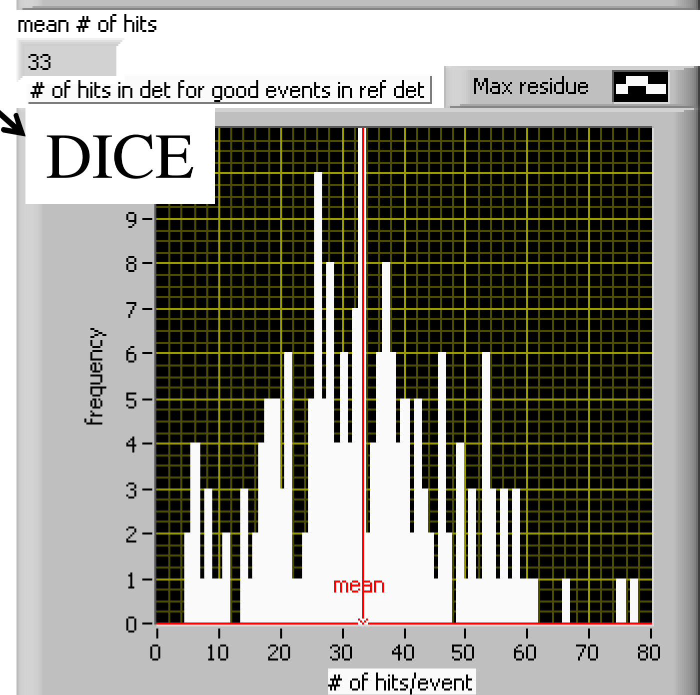
- **Y – Z plane**
  - Y – Z plane: slope 220 mrad (12.6°)
  - **Resolution 70 mrad (4°) in Y**
  - Again deteriorated by slewing
    - Note the asymmetric distribution

Hits per track

- Gossip 1: 6.7 hits/track across 1.5 mm
  - Single electron efficiency close to 100% expected
  - # of hits less than # of electrons (~19) (pile up)
- DICE: ~ 33 hits/track across 19.3 mm
  - => 38% single electron efficiency
- Gossip 3 (1.0 mm gap): 0.73 hits/track
  - 16% single electron efficiency
  - Poor track efficiency (48%)







Calculation of the position resolution
1. calculate the master point in Gossip 1 and DICE

1. Track fitted through reconstructed single electron hits
2. The **master point** is the crossing point of the fitted track with an intermediate plane
   - Intermediate plane about half way between the pixel chip and the cathode plane

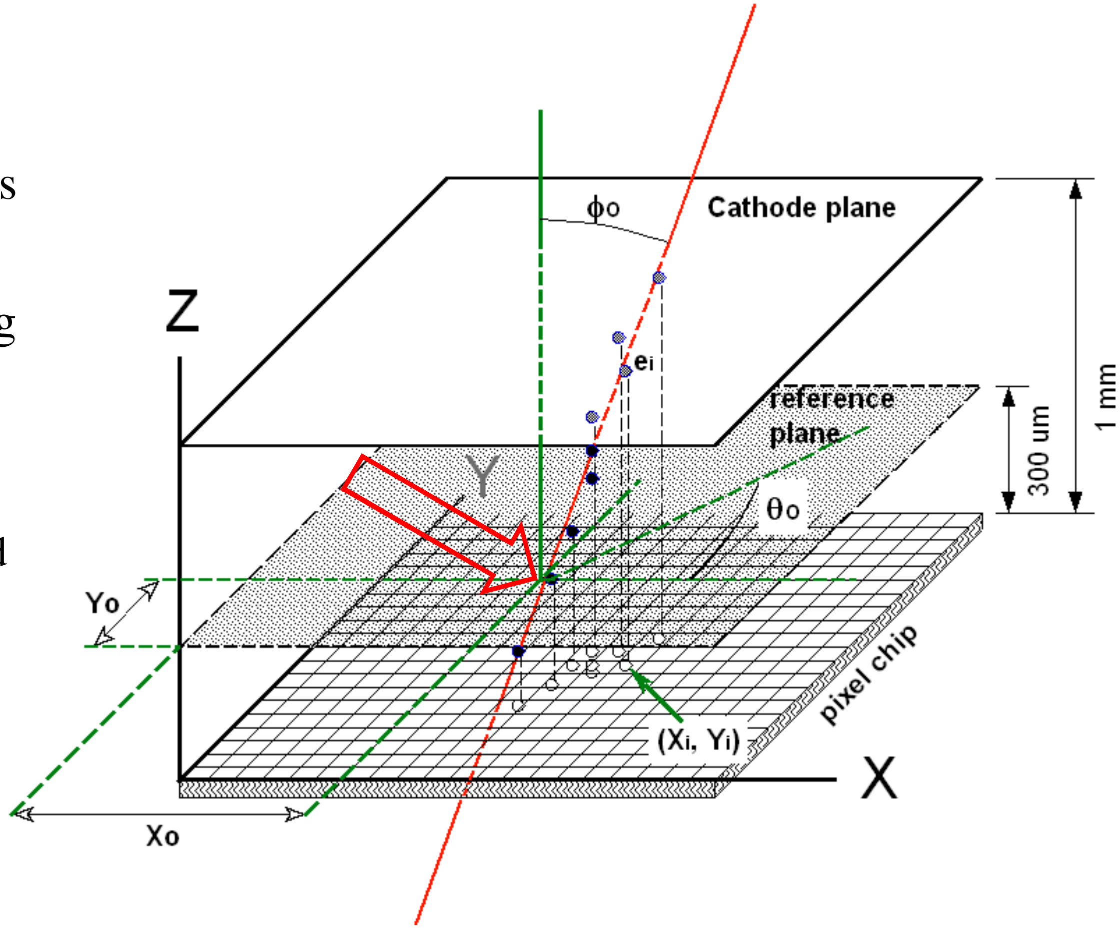
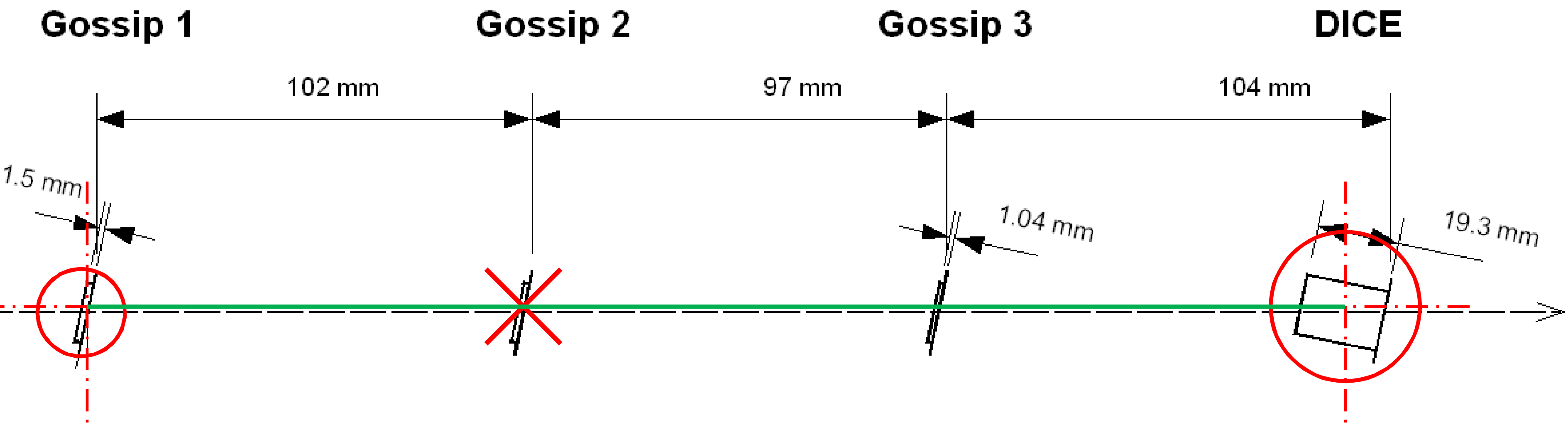


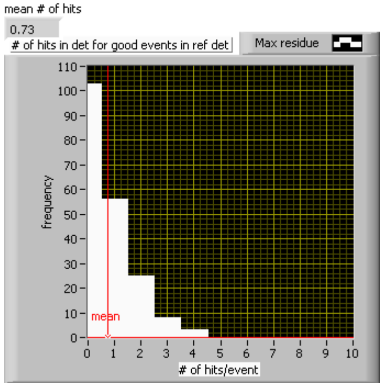
Fig. . Coordinate system and nomenclature of track parameters. The X-Y coordinate (X_0, Y_0) is given by the crossing point of the fitted track with the reference plane.



2. draw a straight line between both master points

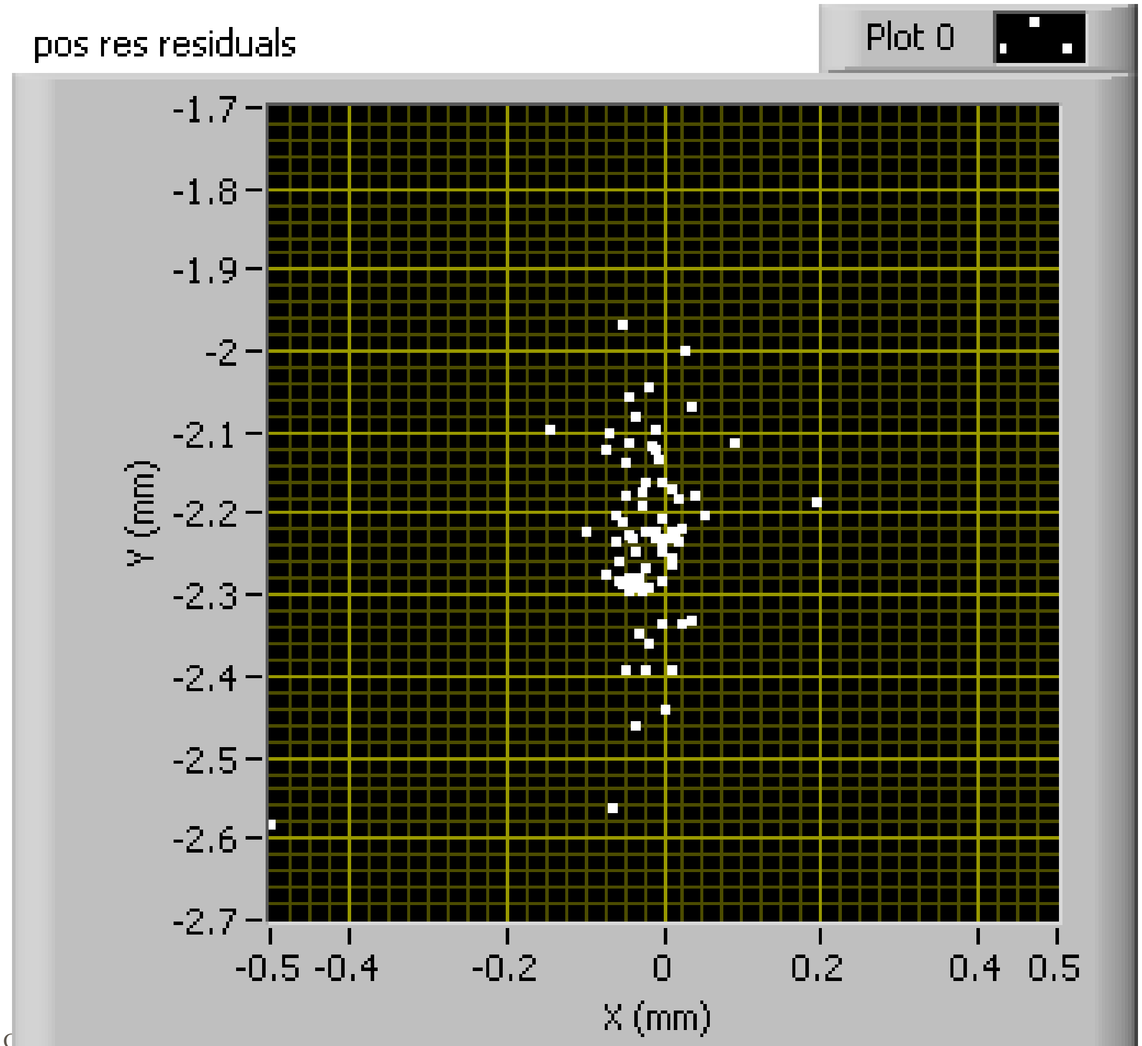
1. Calculate the **master point** in Gossip 3 as the simple average of all the pixel hits in X, Y and Z

2. Calculate the distance between the straight line and the Gossip 3 **master point**



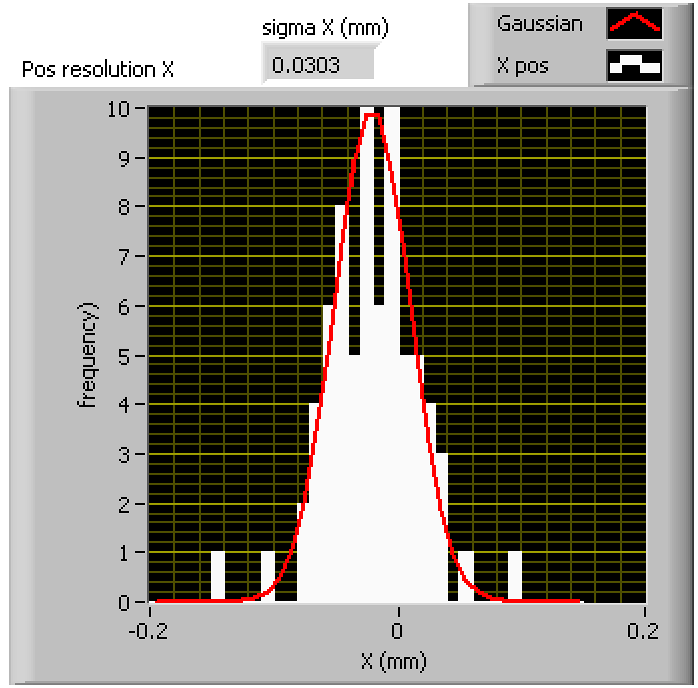
Measured X-Y residuals

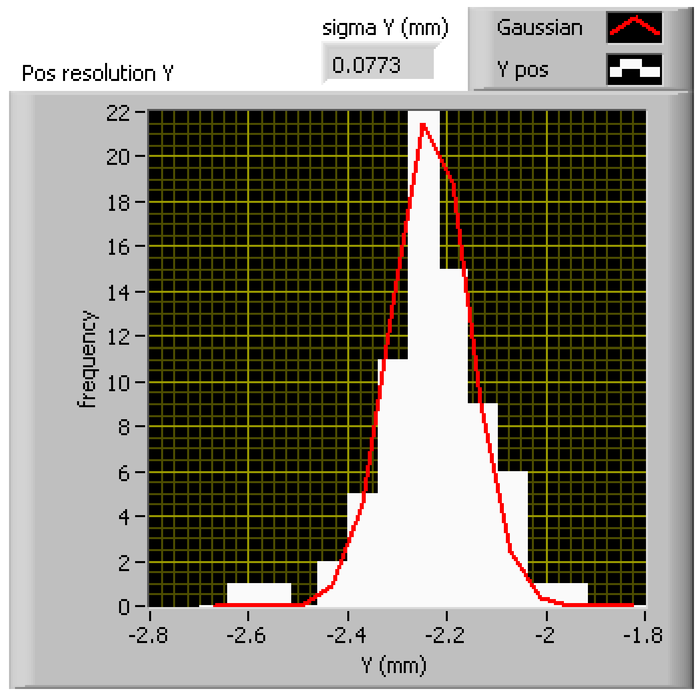
- Residues clustered in sub mm area
  - Deviating points from noisy pixels in Gossip 3



Gaussian fits through distributions

- 75 events
  - 40% track efficiency in Gossip 3
- Residuals in X: **σ = 30 - 35 μm**
- This number includes
  - Accuracy of the fitted track (10 μm?)
  - Multiple scattering in 6 GeV beam (10 – 30 μm)
  - Poor hit statistics
    - average **1.5** hit pixels instead of **4.5** in Gossip 3
  - => **σ ≈ 15 μm** expected for well operating Gossip
- Residuals in Y: **σ = 70 - 80 μm**
  - => same correction: **σ ≈ 45 μm** expected for well operating Gossip
- **Z info** used for all three detectors
  - Worse result if you don't use it





Conclusions on results September testbeam

- CO_2/DME 50/50 is very advantageous gas
  - Very low diffusion
  - High cluster density => good track efficiency (~99%) at 1 mm gap expected
  - But needs ~ 150 V higher grid potential
  - Drift field 6 kV/cm
  - (DME affects many plastics and rubbers)

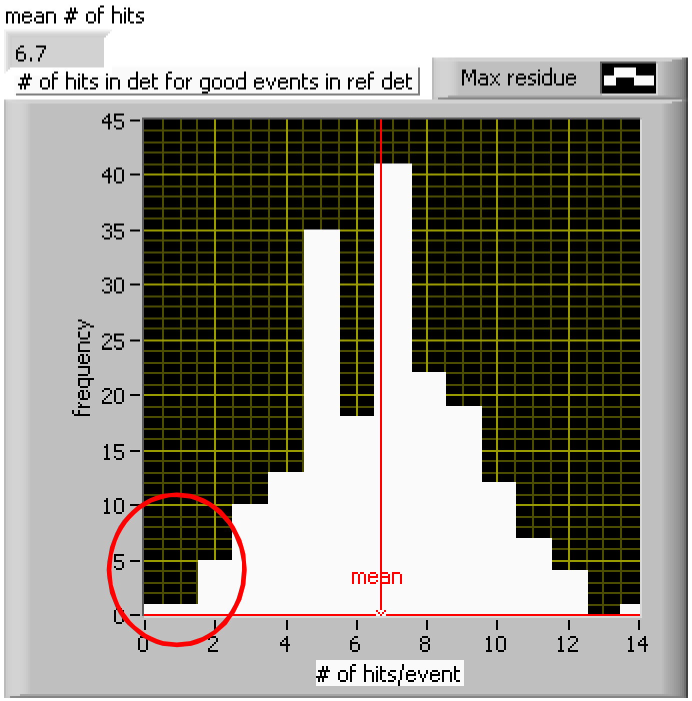
- Extrapolated position resolution in X (15 μm) corresponds well with simulations
  - But because of limited statistics this hypothesis is not firmly proved by this study

- Slewing is dominant effect, spoiling the resolution of tilted tracks in Y
  - Will be even much worse if v_d raised up from 10 to 40 μm/ns
  - Need dedicated frontend elecrtonics to solve this (TimePix not very suited for this)
  - MAJOR PROBLEM

- Discharge problem on grid area mostly solved
  - But detectors are frequently killed by discharges at the wire bonds
  - Applying GlobTop possibly helps

SPARE

Track efficiency



- Good track efficiency of Gossip 1 (1.5 mm gap)
  - One missing track for 197 good tracks in DICE
- But 1 event with 1 hit and 5 events with 2 hits
- If we would use a 1 mm drift gap instead, we would miss on the average:
  - 1/3 event from 1 event with one hit
  - 5/9 event from 5 events with two hits
  - => expected efficiency for 1 mm gap: **~99.1%**
  - But beware of limited statistics (197 events)
- Expected from known cluster density: **98.9%**

Variation of the gas gain

- Dominated by Poisson statistics
- Basically exponential distribution for single electron
- But in practice a bit less variation
  - Curve can be described by the (empirical) Pólya function
  - pdf = 1 → pure statistical avalanche growth

$$P\left(x, n_e = N\right) = \frac{x^{N-1}}{\left(N-1\right)!} \cdot e^{-x}$$

  - pdf = 2 → avalanche growth depending on its size

$$P\left(x, n_e = N\right) = \frac{2^{2N}}{\left(2N-1\right)!} \cdot x^{2N-1} e^{-2x}$$

- Experimental results: pdf ≅ 1.0 – 2.5