BTeV Pixel Silicon Detector

Test beam results 1999-2000

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Talk given by G. Chiodini – Fermilab

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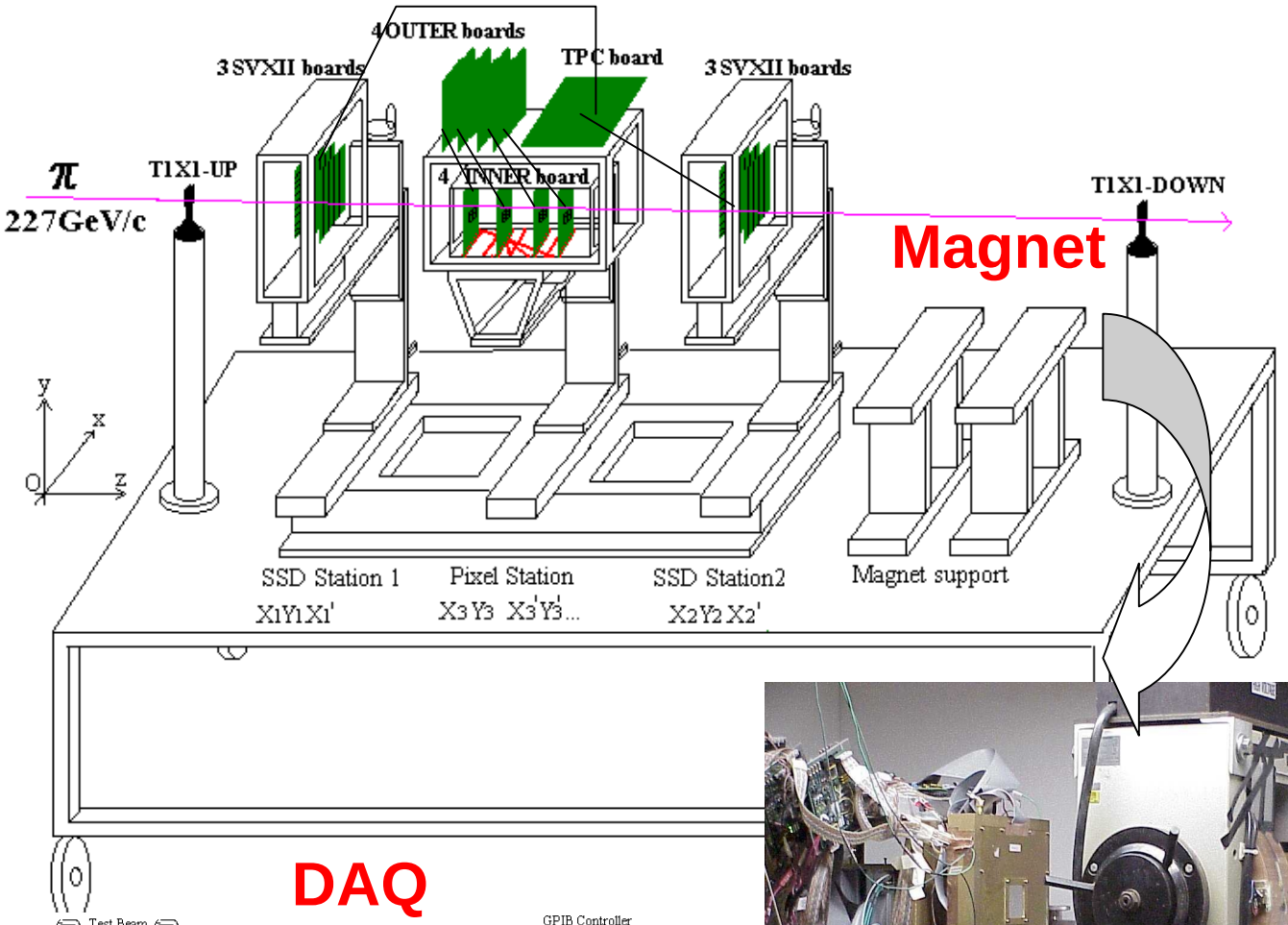
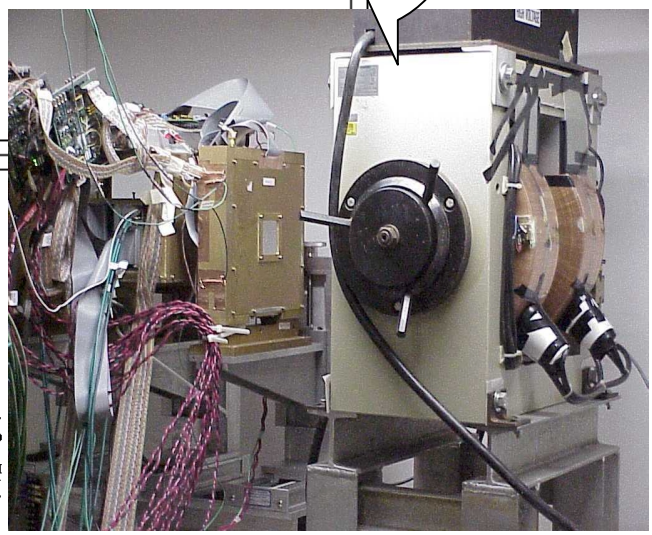
Overview

- Test beam setup
  - SSD telescope and DAQ
  - 5 pixel planes tested
- Test beam results
  - Pixel Calibration
  - Charge collection
  - Charge-sharing
  - Spatial resolution
- Four plane pixel telescope
- Conclusions

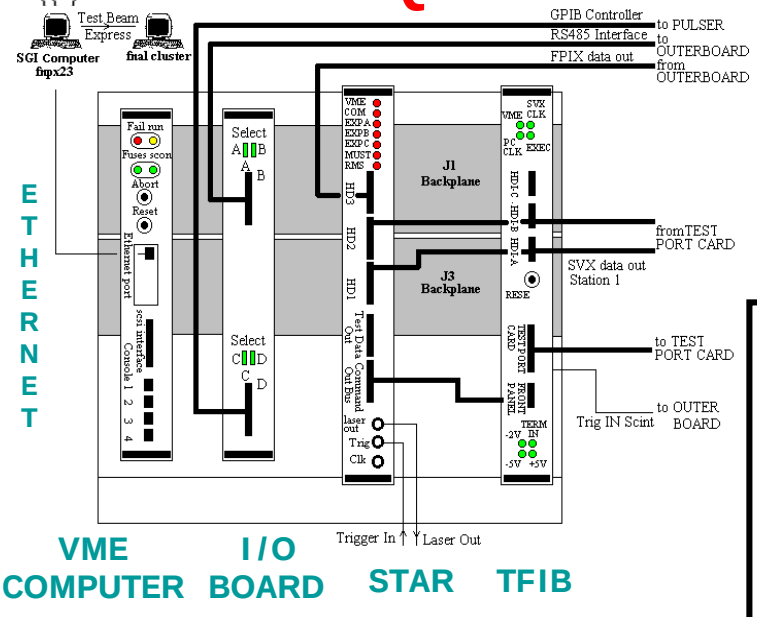
Setup: SSD telescope and DAQ





TO HUT

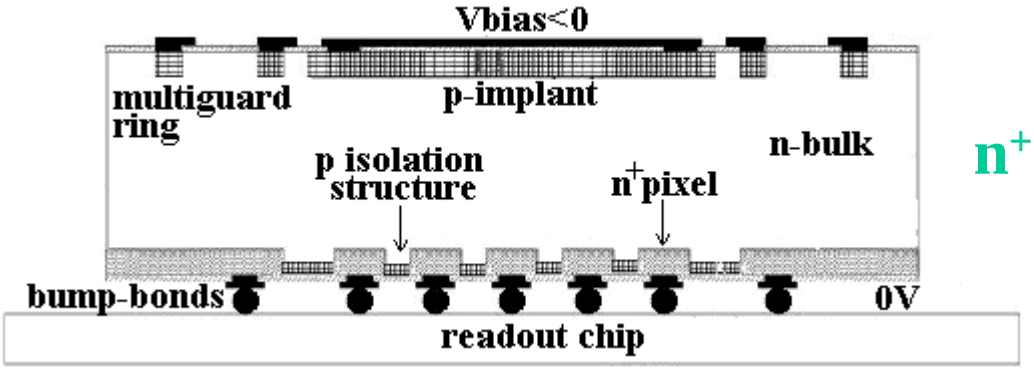
DAQ



- I/O Board
  - Controls and Initializes 4 pixel readout chips
  - GPIB controller: HV, thresholds and pulser
- Automatic pixel calibration

Setup: 5 pixel planes tested

Samples of FPIX0 and FPIX1 readout chips bump-bonded to ATLAS sensor prototypes



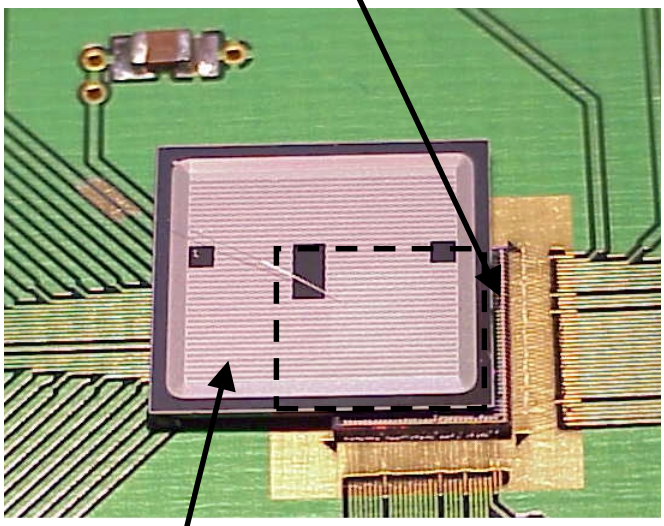
n^+np

indium bump-bonding

50x400 μm² cells

FPIX0 64x12cells

8 bit external ADC

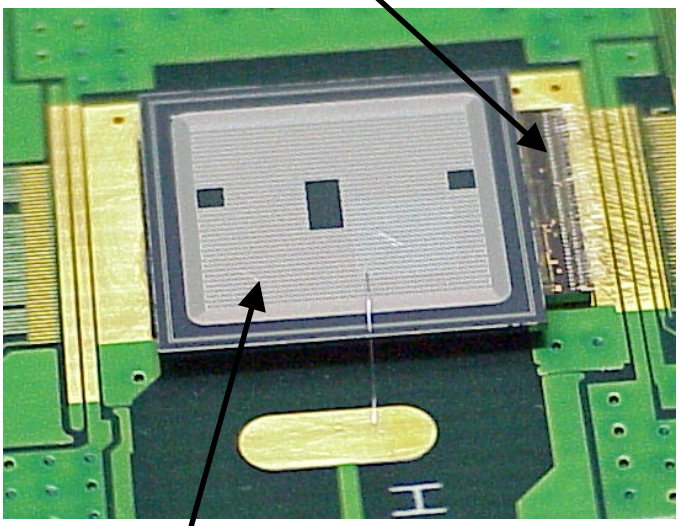


•ST1-CiS p-stop
•ST2-CiS p-spray

Bonded active area 3.2x4.4mm²

FPIX1 160x18cells

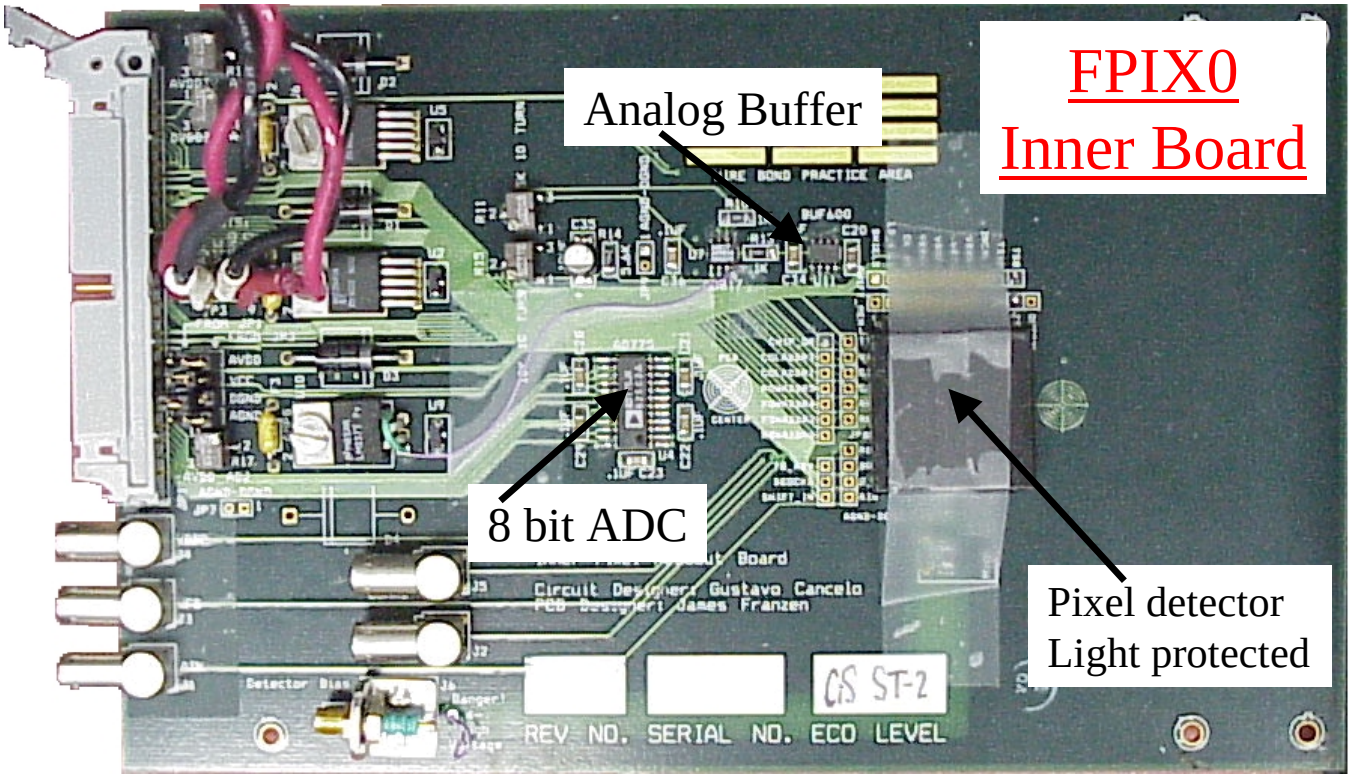
2 bit internal FADC



•Two ST1-Seiko p-stop
•ST2-Seiko p-spray

Bonded active area 8x6.8mm²

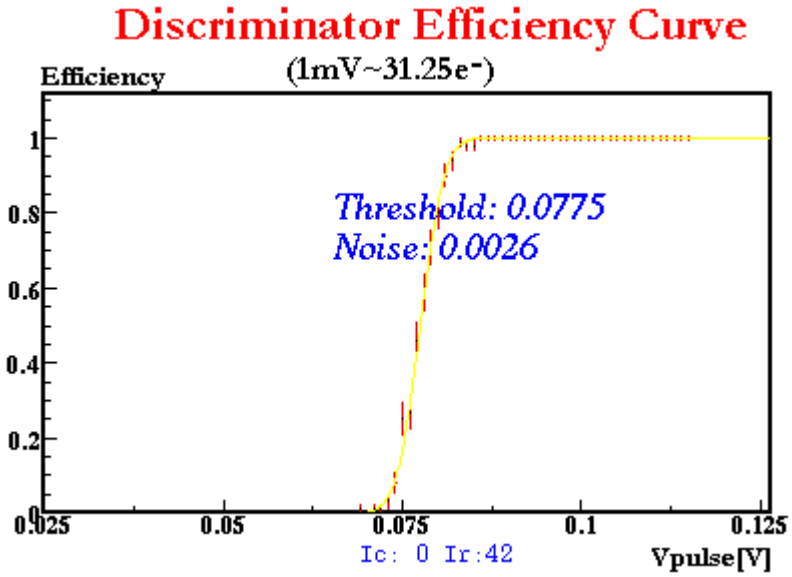
Setup: 5 pixel planes tested



Results:

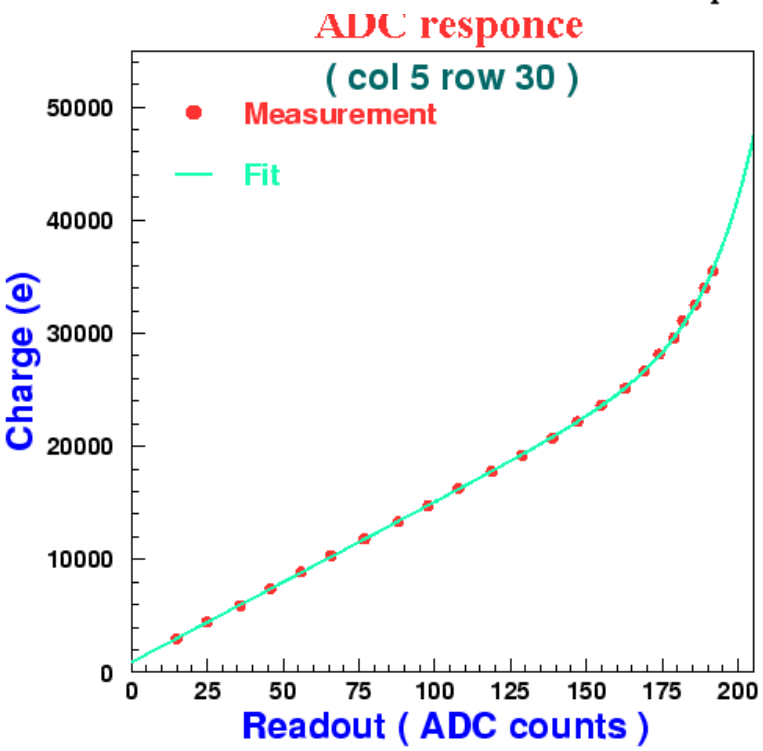
pixel calibration - *pulse generator*

FPIX0 bump-bonded to ST1 CiS p-stop



$Q_{th}=2500\pm400e^-$

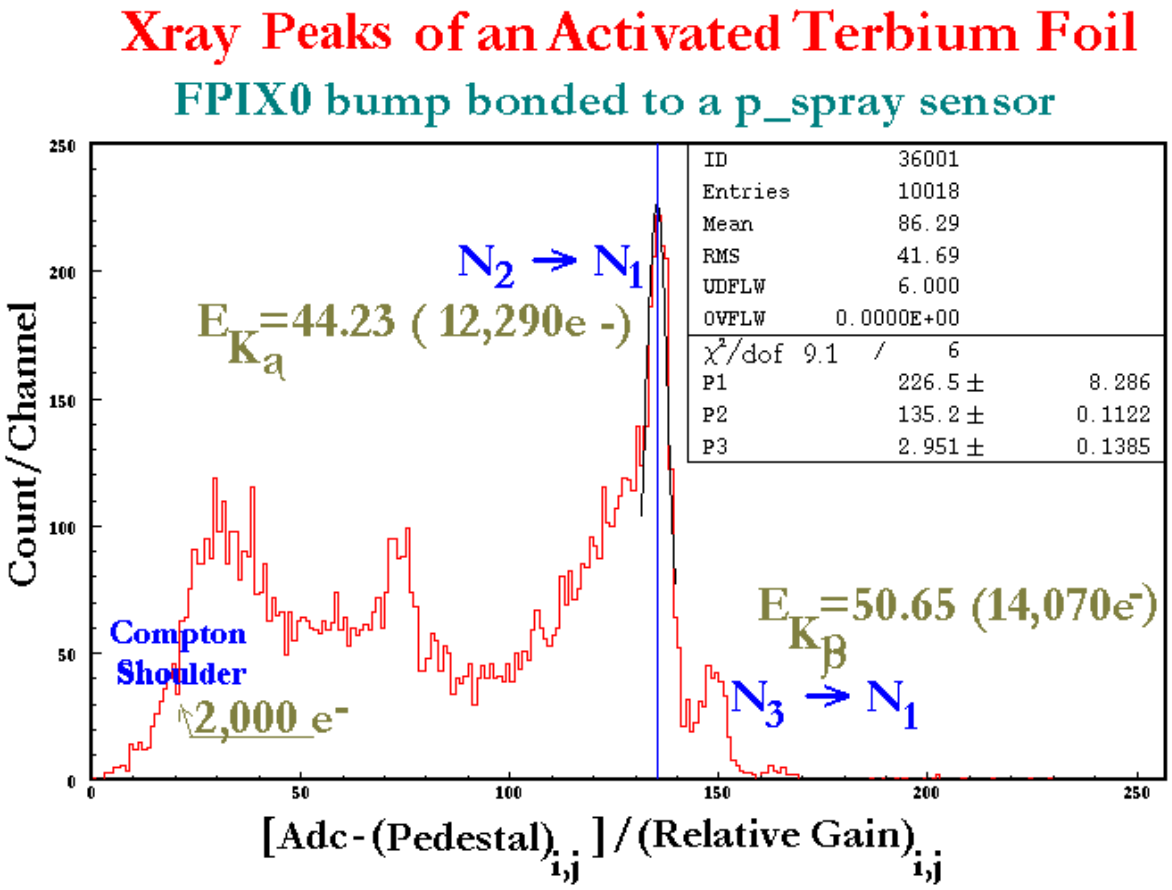
$Q_{noise}=106\pm13e^-$

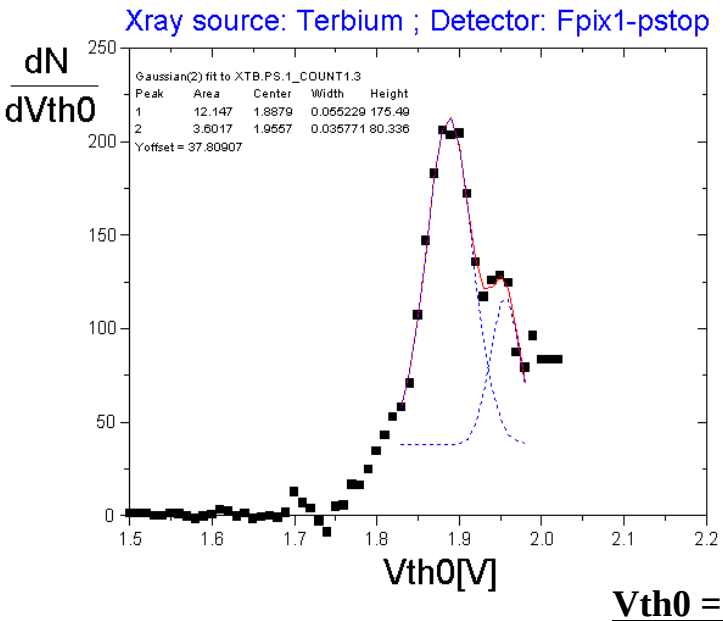


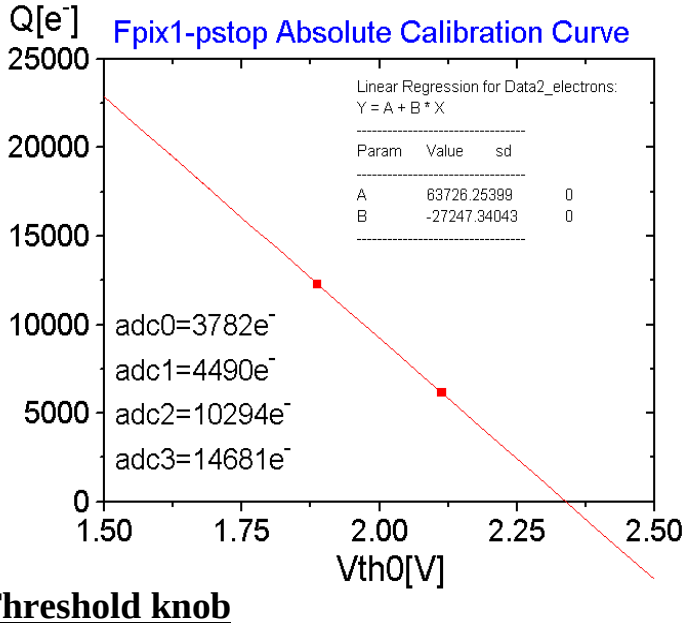
$Q_{noise,ADC}=400\pm96e^-$

Dynamic range ≤1.5MIP

Results: Pixel calibration - *X ray sources*



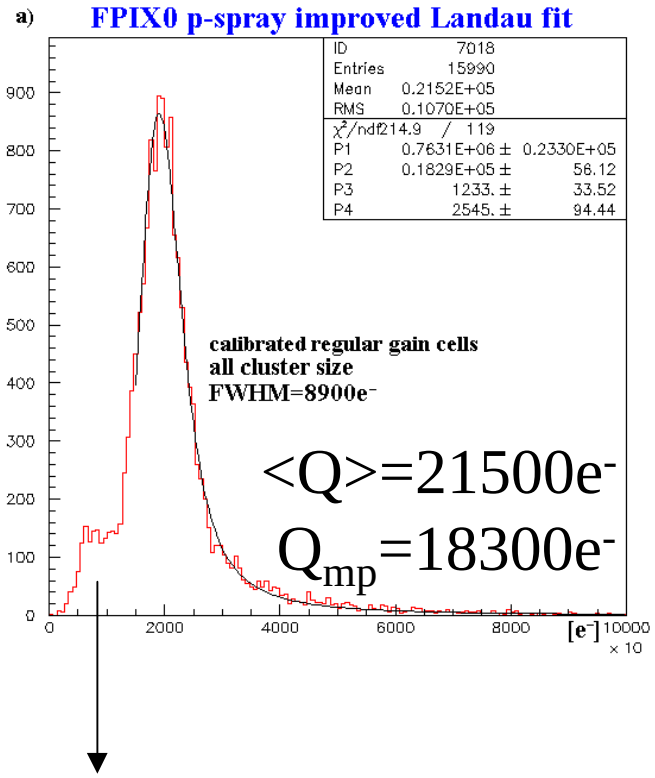


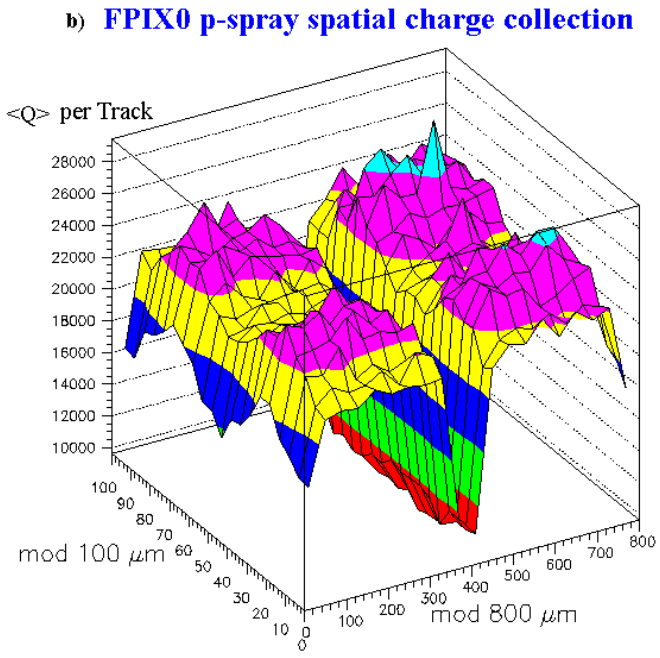


Vth0 = Threshold knob

Results: Charge collection

Single chip CiS p-spray



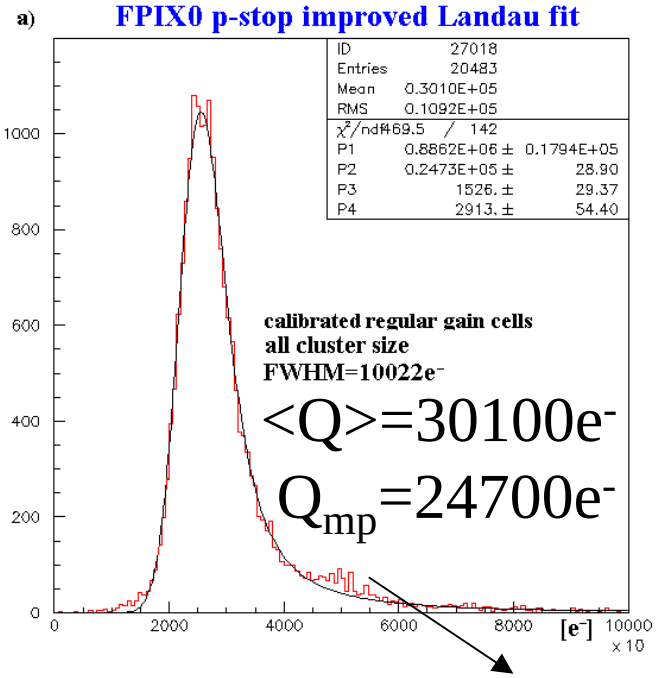


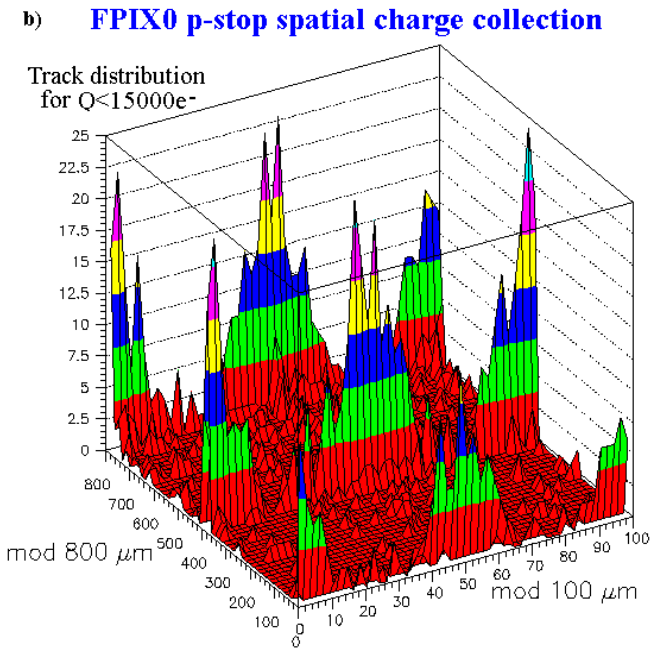
Charge losses

Charge losses not intrinsic to the p-spray technology but a feature of this particular sensor design.

Results: Charge collection

Single chip CiS p-stop





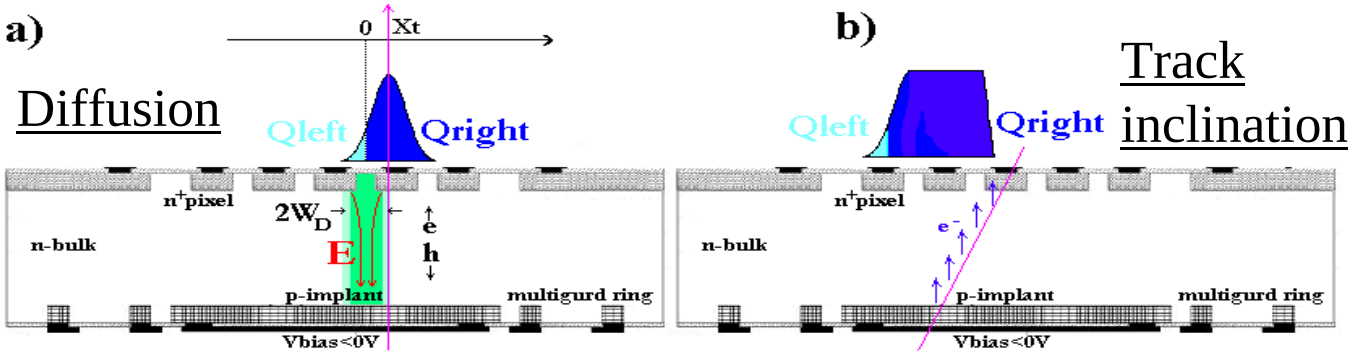
Saturation bump for CS=1

- The Landau distribution convoluted with a Gaussian function fit well the charge distribution.

$$f(E) = N \int dE' \frac{e^{-\frac{(E-E')^2}{2\sigma_g^2}}}{\sqrt{2\pi\sigma_g^2}} \frac{\phi\left(\frac{E'-E_{MP}}{\xi} + \lambda_0\right)}{\xi}$$

- Only less than 0.7 % of the events have a signal less than 15000 e⁻.

Results: charge-sharing

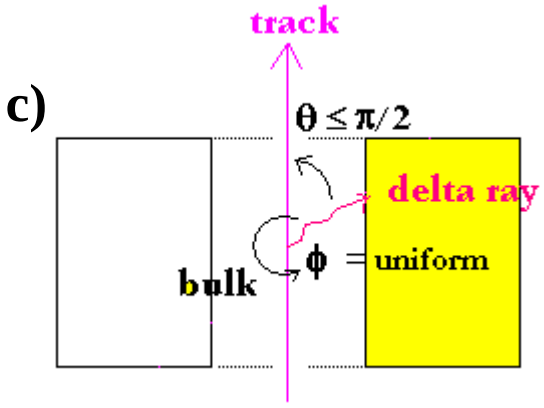


Relative fraction of cluster sizes (CS)

Angle [degs]	CS=1	CS=2	CS=3	CS=4	CS=5	CS=6
0	.639	.328	.017	.009	.0034	.0025
5	.433	.527	.022	.010	.0041	.0028
10	.090	.846	.040	.015	.0055	.0029
15	-	.635	.332	.022	.0080	.0034
20	-	.209	.741	.031	.0124	.0060
30	-	-	.178	.769	.041	.0115

FPIX0 CiS p-stop

Q_{th}=2500e$^-$ V_{bias}=-140V

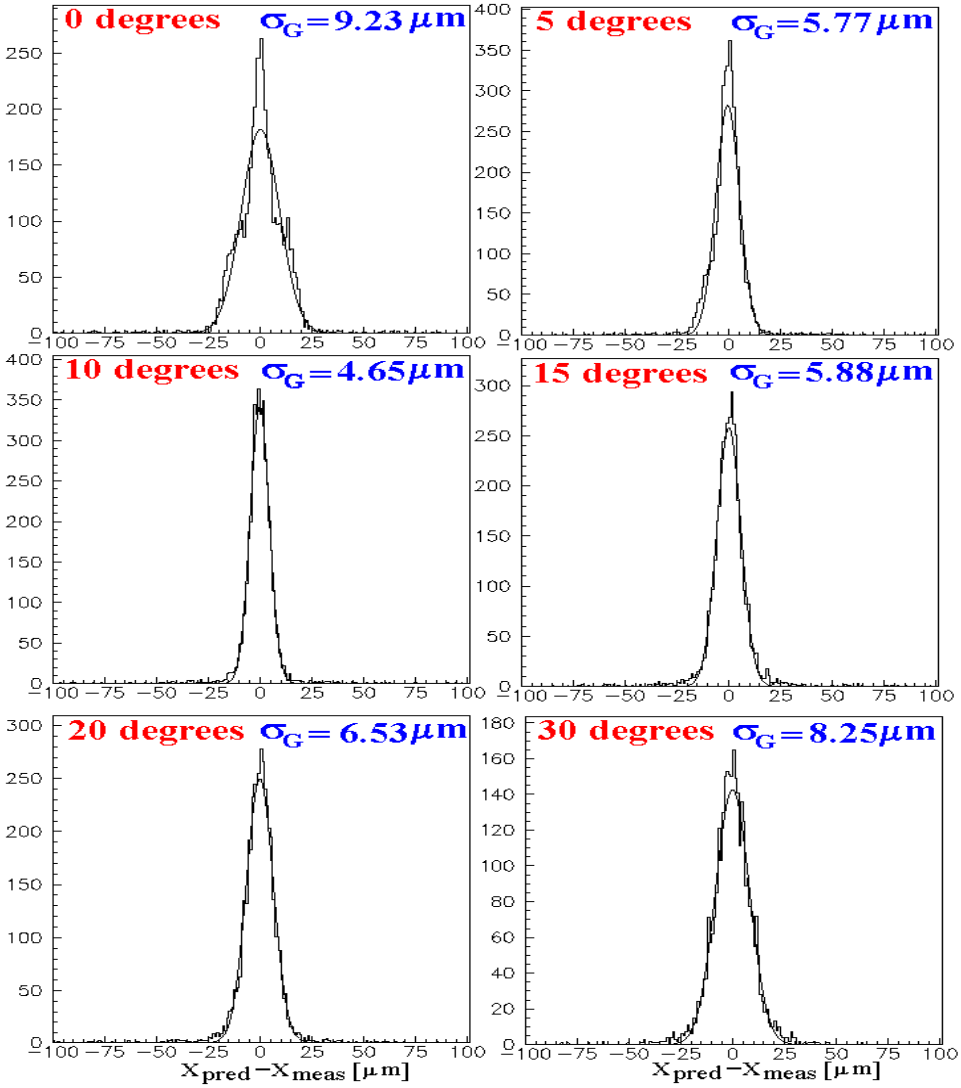


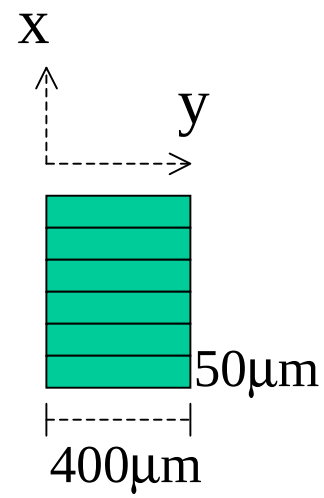
Delta rays emission

Results: spatial resolution

Gaussian fit residual distribution

ST1 CiS FPIX0 detector





CS=1,…,6

- X_{pred} = projection of the kalman fit on the plane using all the planes, BUT the one under test (σ_{pred} = 2.1 μm) .
- X_{meas}= coordinate measured by the plane under test using the head-tail analog interpolation.

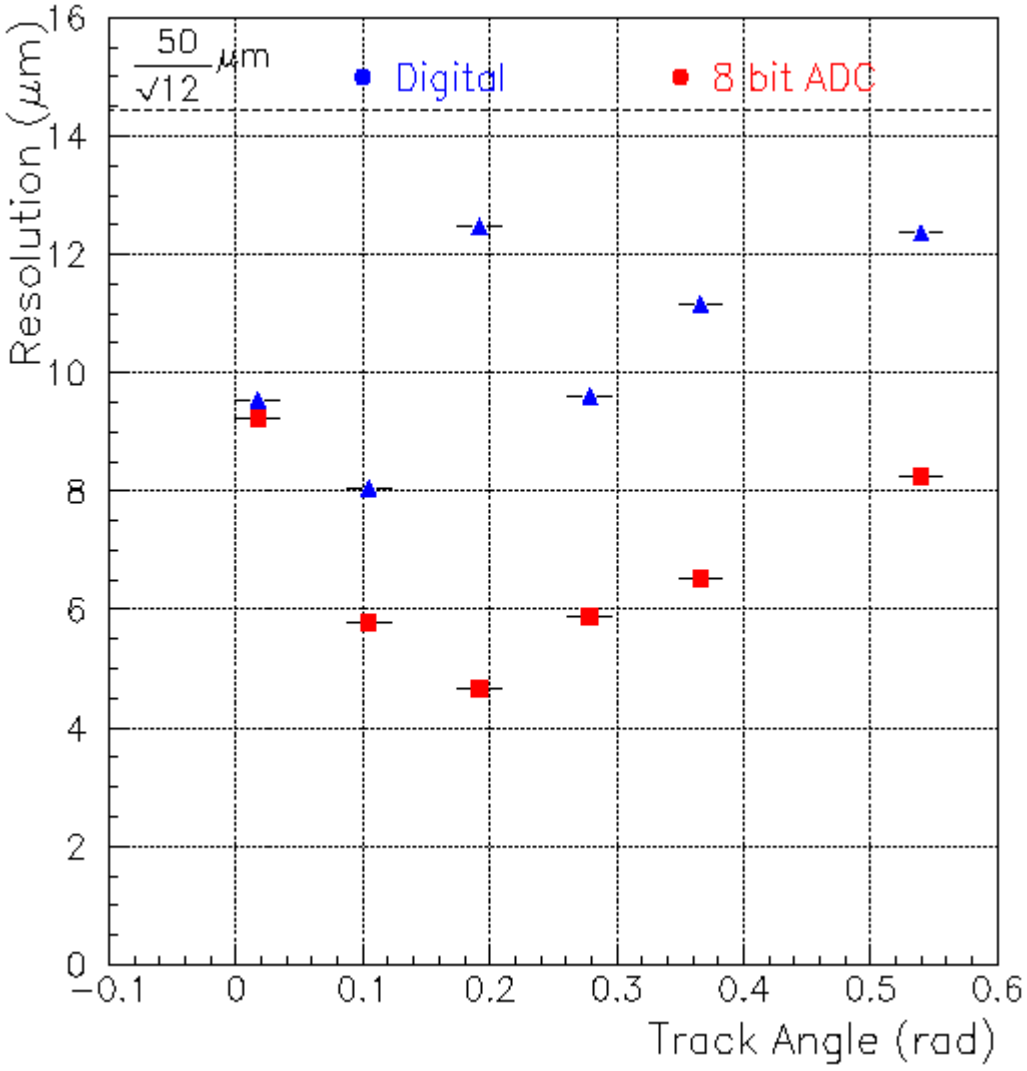
Results: spatial resolution

Spatial resolution vs angle

Good spatial resolution at all angles

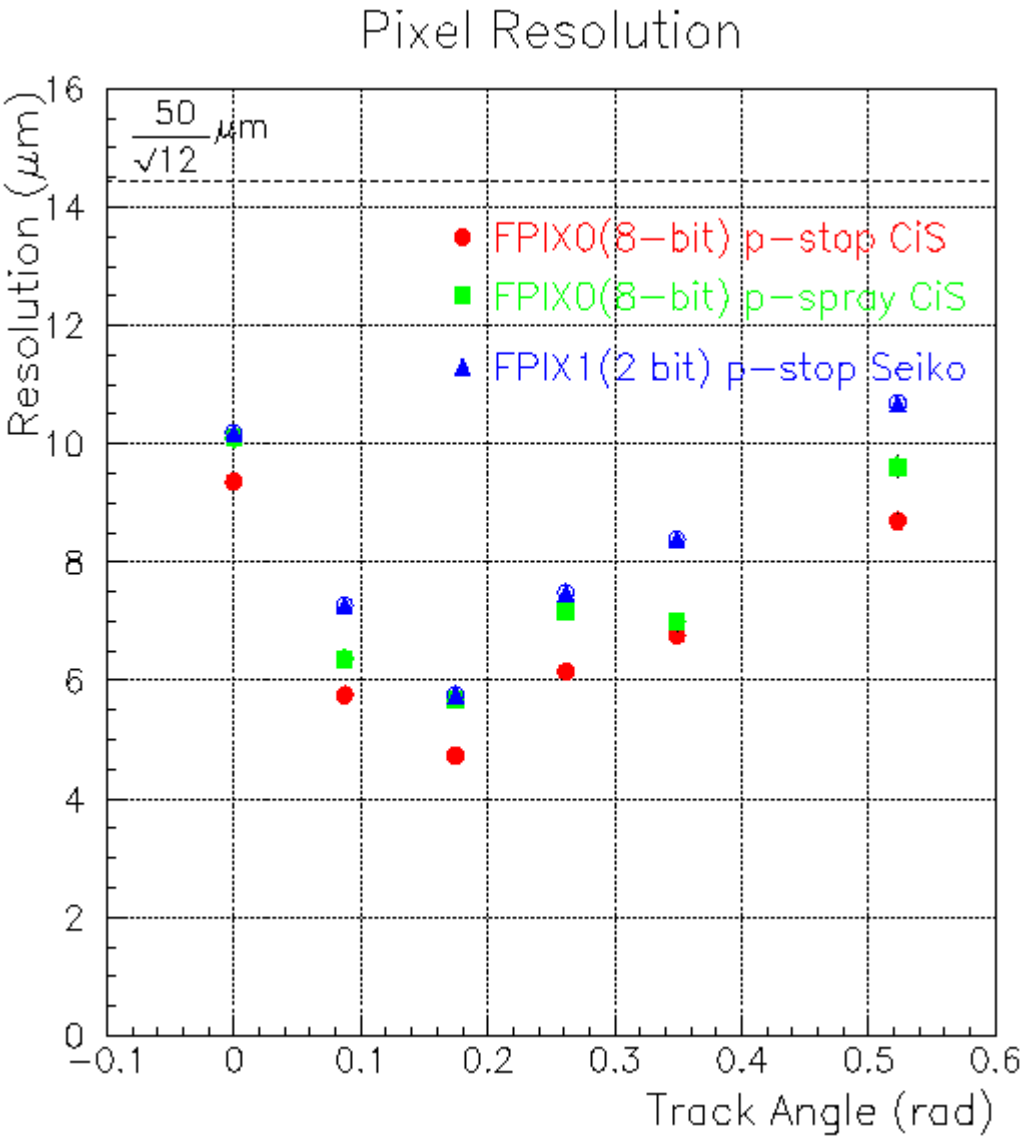
ST1 CiS FPIX0 detector

Q_{th}= 2500e$^-$ V_{bias}= 140V



Results: spatial resolution

Comparison between detectors



Q_{th}=2500e⁻
Q_{th}=2200e⁻
Q_{th}=3780e⁻

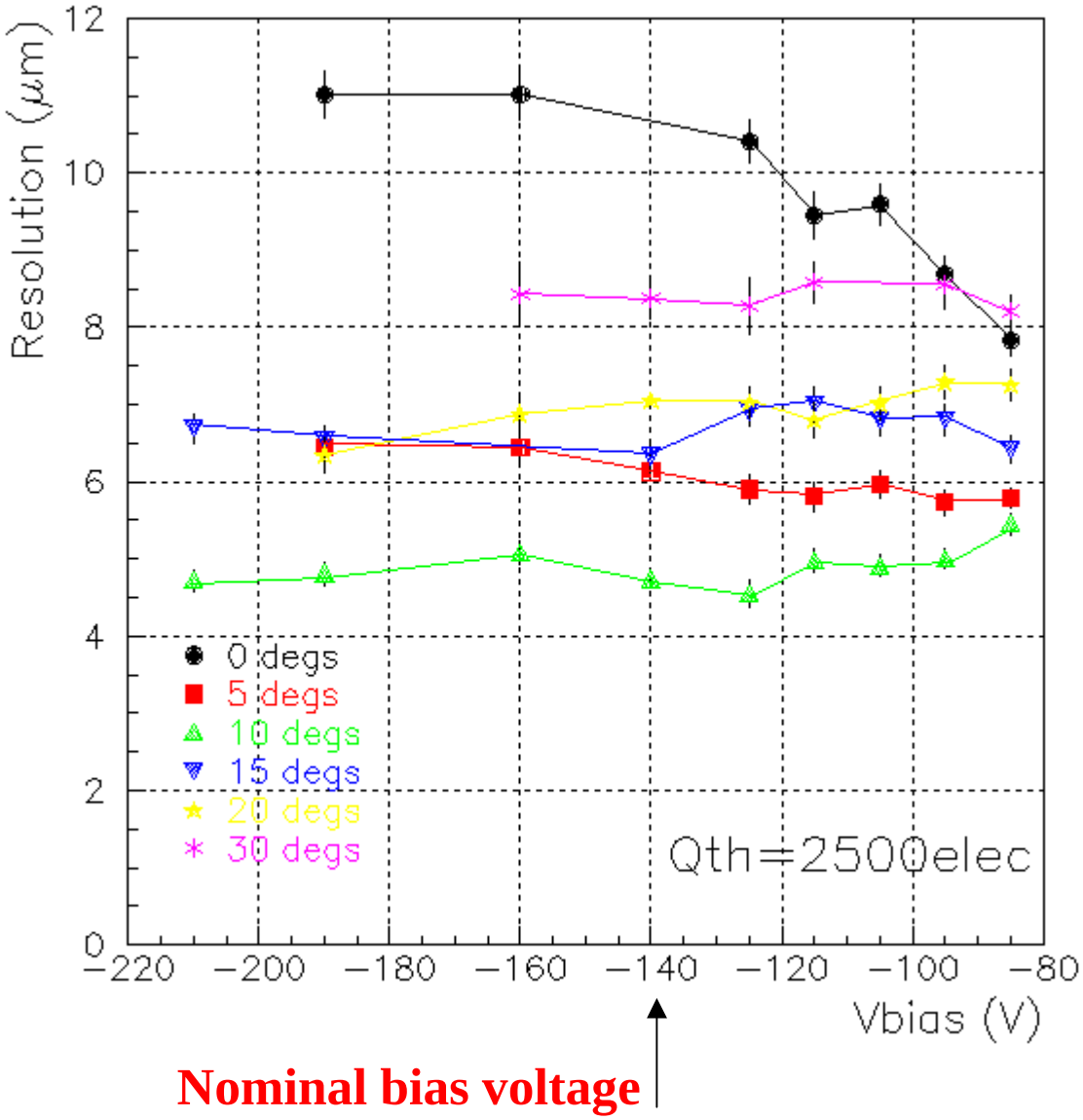
- Most of the difference in spatial resolution between FPIX0 (8 bit) and FPIX1(2 bit) is due to the different readout threshold.
- The charge losses degrades the spatial resolution

Results: spatial resolution

Bias voltage

For track angle > 5 degrees no degradation of the resolution when the detector is over depleted.

ST1 CiS FPIX0 detector

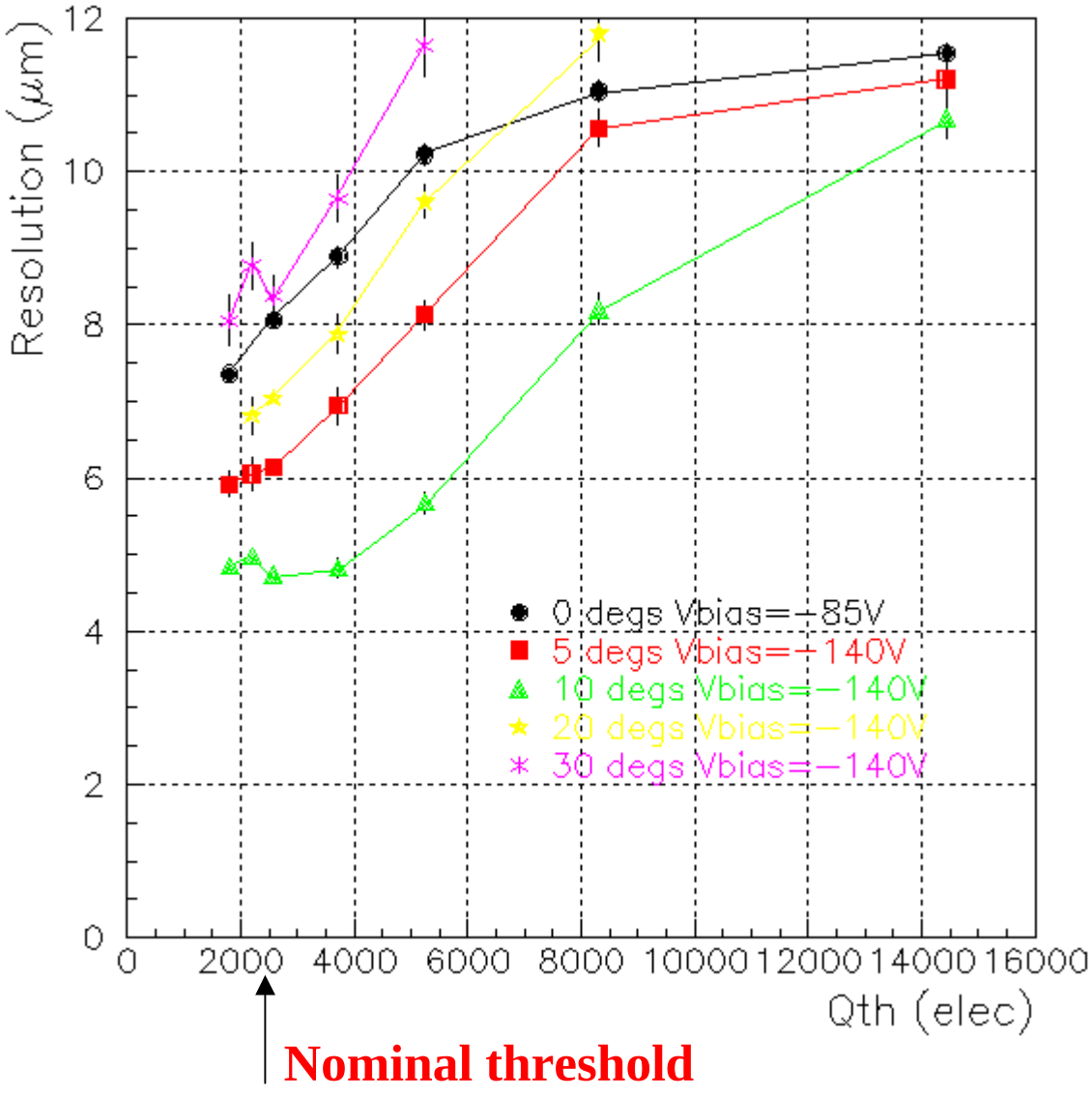


Results: spatial resolution

Threshold

As expected, larger readout threshold degrades the spatial resolution.

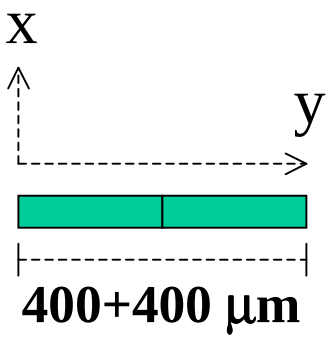
ST1 CiS FPIX0 detector

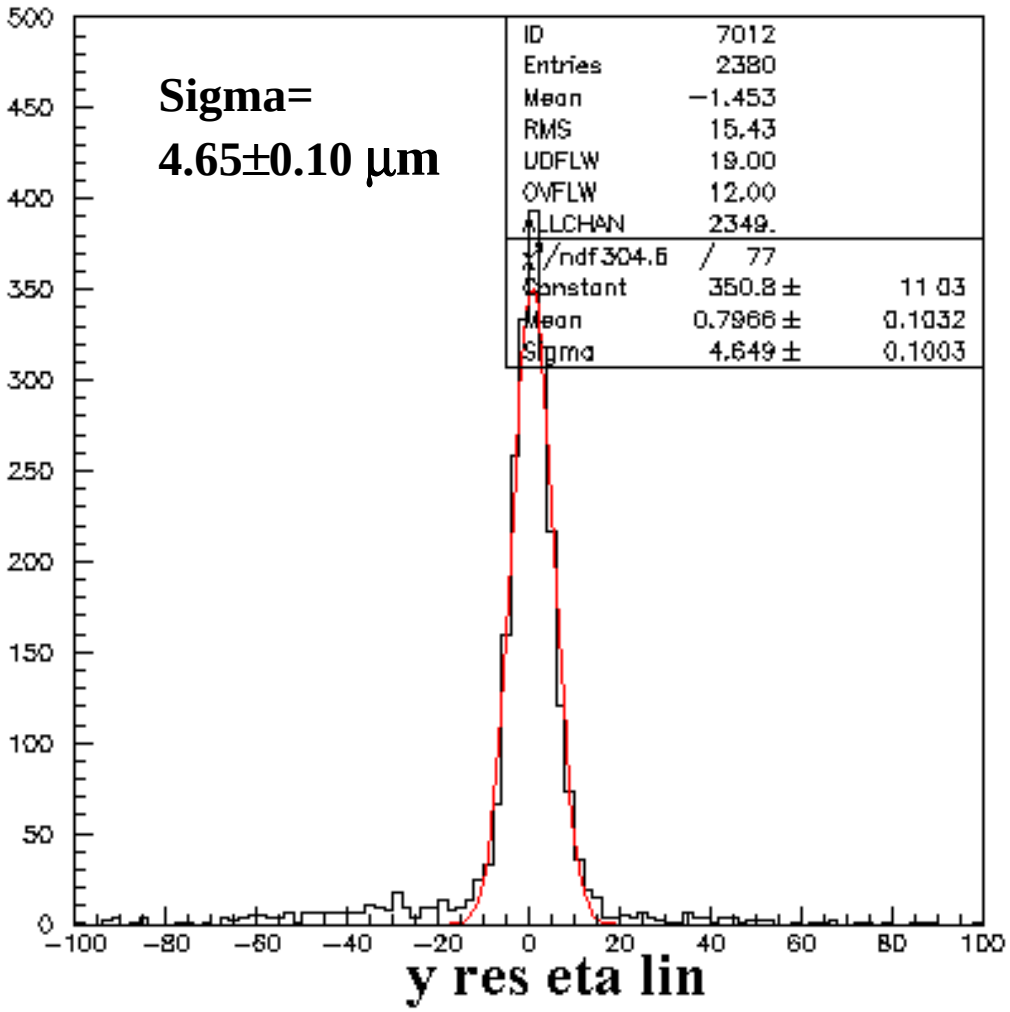


Results: spatial resolution

2D spatial resolution

ST1 CiS FPIX0 detector

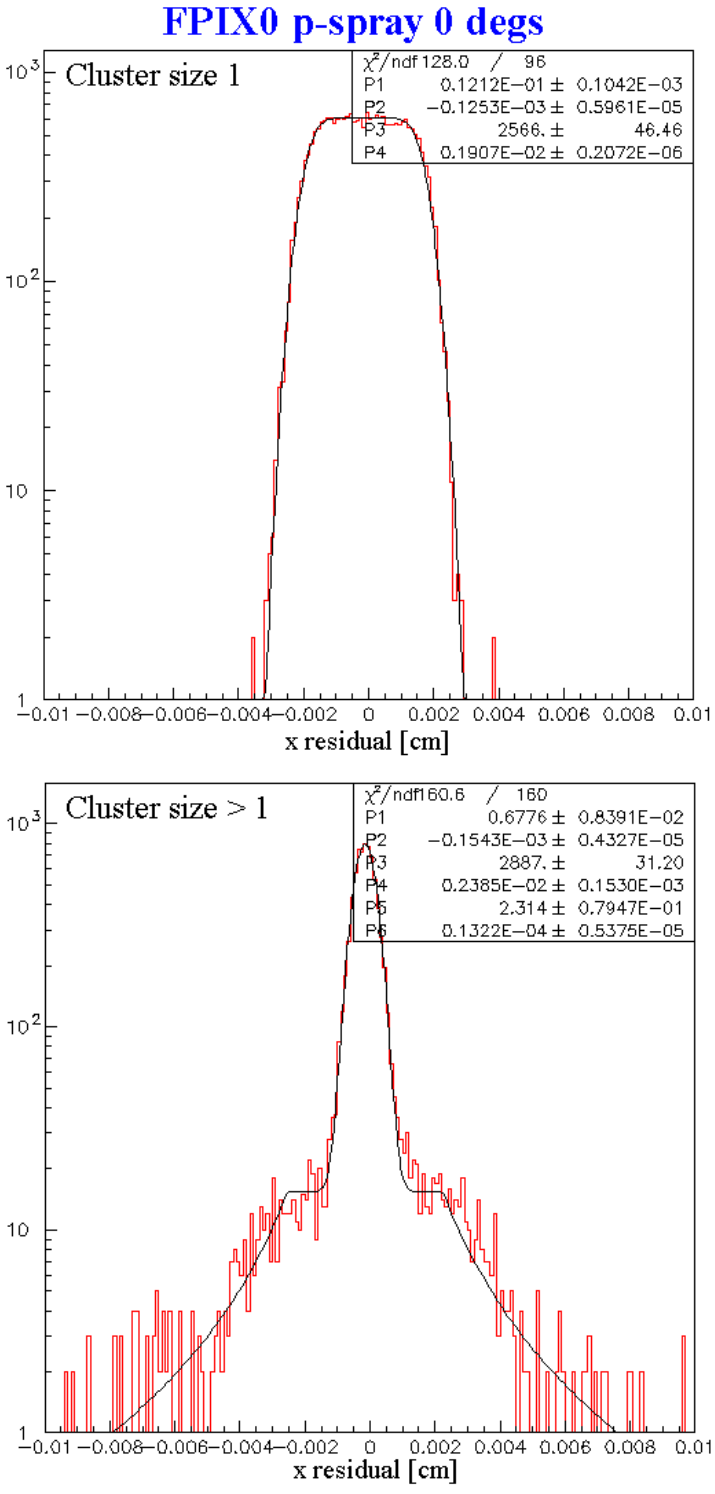




Good spatial resolution also when the charge is shared between the long pixel dimension.

Results: spatial resolution

Non-Gaussian resolution function



CS=1 and track angle < 10 degs: Square convoluted with a Gaussian

$$F_{bg}(x) = \int_{-W_p}^{W_p} dt \frac{A_{bg}}{\sqrt{2\pi\sigma_W}} e^{-\frac{(t-x)^2}{2\sigma_W}}$$

CS>1 track angle < 10 degs and all CS track angle > 10 degs: Gaussian + power law

$$F(x) = F_{Gauss}(x) + F_{pl}(x)$$

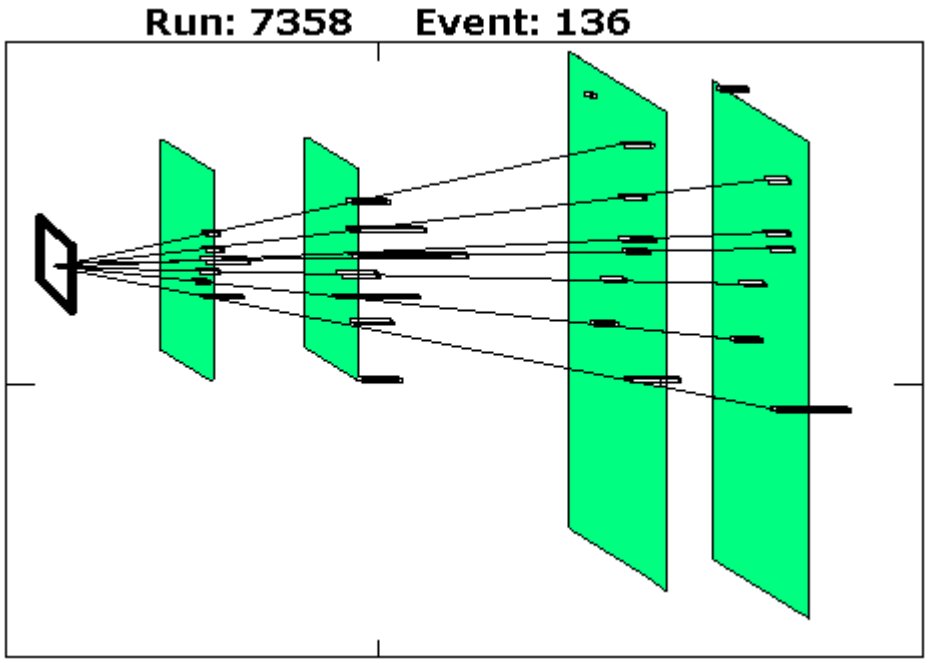
$$F_{pl}(x) = \begin{cases} \dfrac{A_{pl}}{|r_{cut-off}|^{\gamma}} & |x| < r_{cut-off} \\ \dfrac{A_{pl}}{|x|^{\gamma}} & |x| > r_{cut-off} \end{cases}$$

<u>Non-Gaussian part:</u>

- 15% of events: half in the constant term and half in the tails
- power law with an exponent ≥2

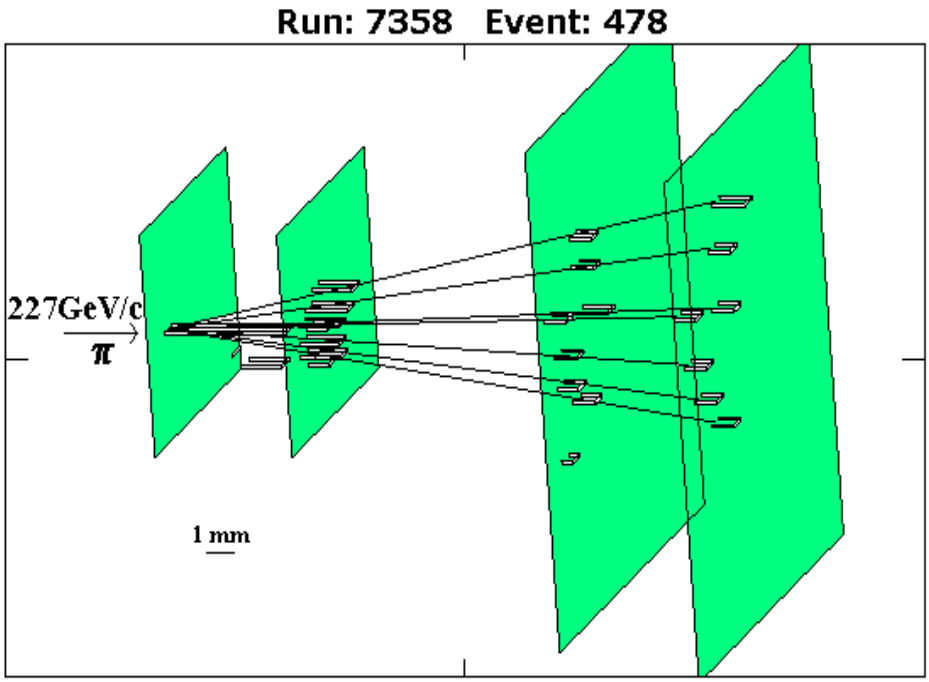
Four plane pixel telescope

2.2mm thick diamond target



Interaction vertex in the target

Thousands of triggered multiple interactions events



Interaction vertex in pixel plane

Conclusions

- The FPIX-type FE performs well as expected and needed
- GREAT data sample to gain operational experience with pixel silicon detectors (**3M useful events**)
- Primary features of results are clear:
  - Very good resolution at all angles
  - Little sensitivity to the bias voltage
  - Excellent tracking capability