BTeV Silicon Pixel Detector

Test Beam Results 1999-2000

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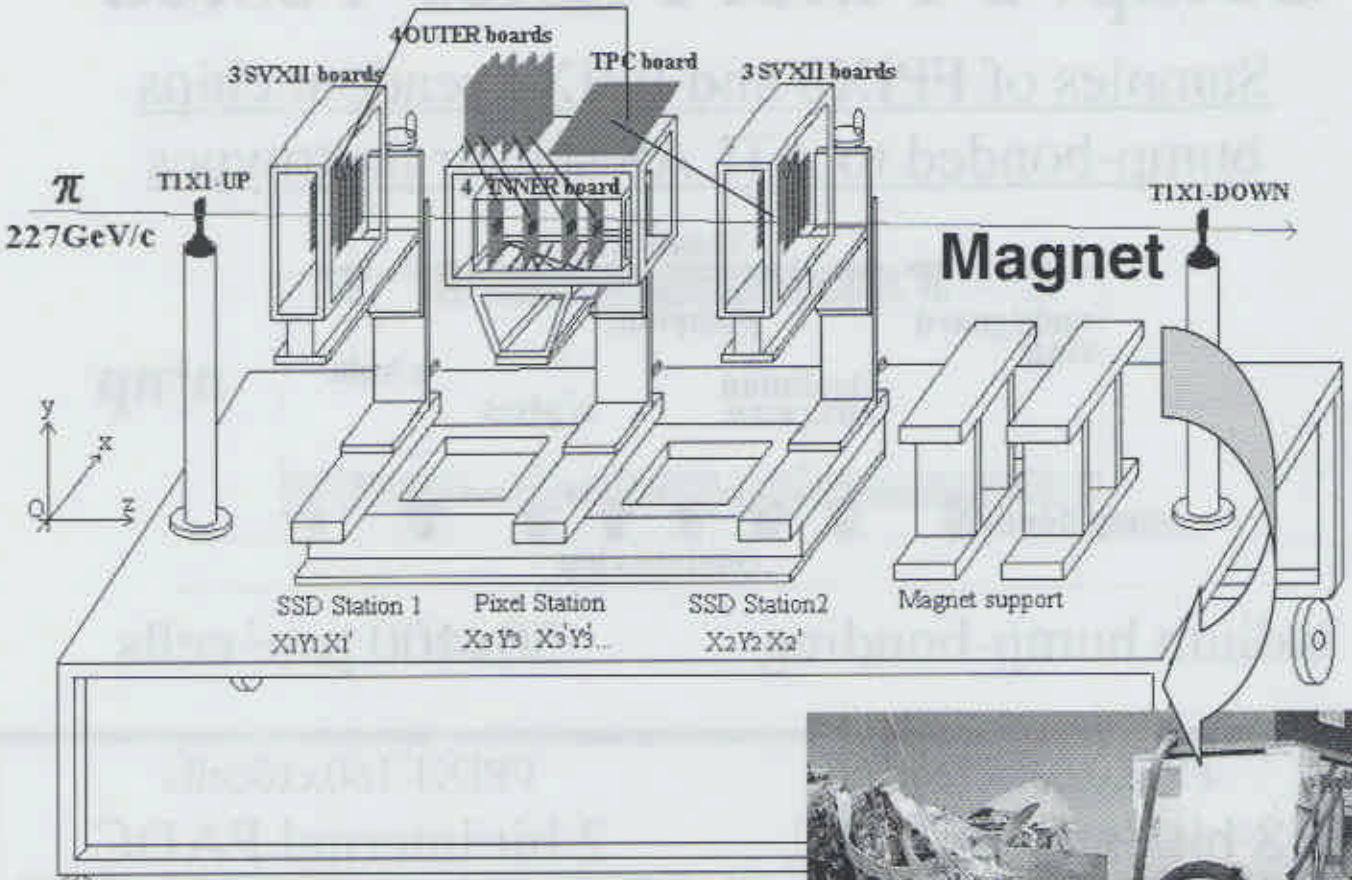
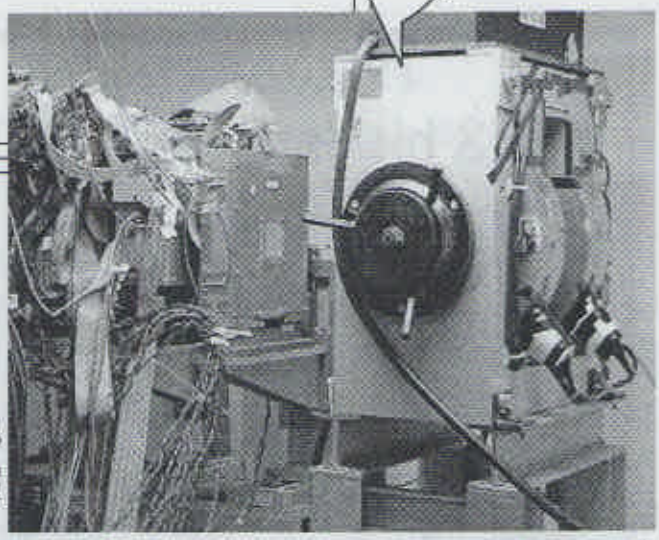
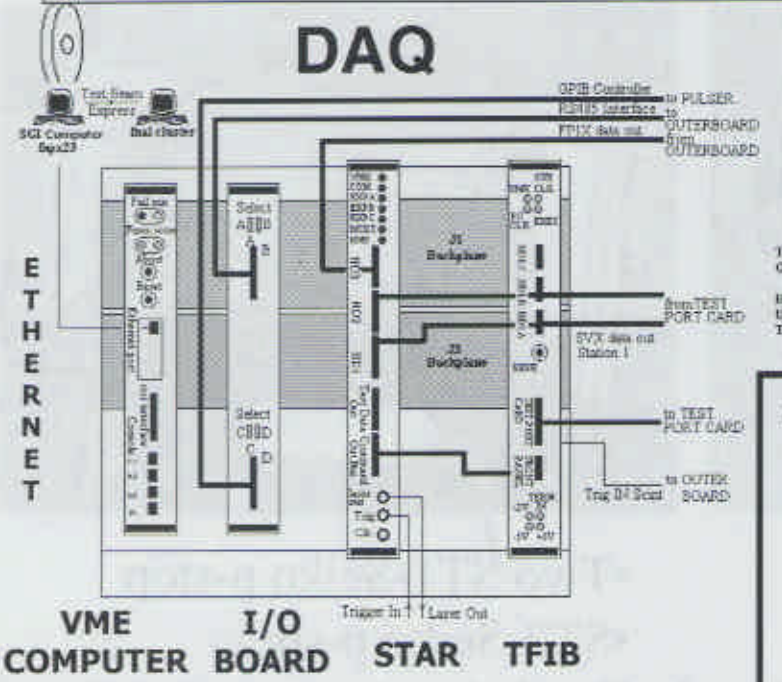
Overview

1. Test Beam Setup
   - SSD Telescope and DAQ
   - 5 Pixel Planes Tested
2. Test Beam Results
   - Pixel Calibration
   - Charge Collection
   - Charge-Sharing
   - Spatial Resolution
3. Four-Plane Pixel Telescope
4. Conclusions

Setup: SSD Telescope and DAQ



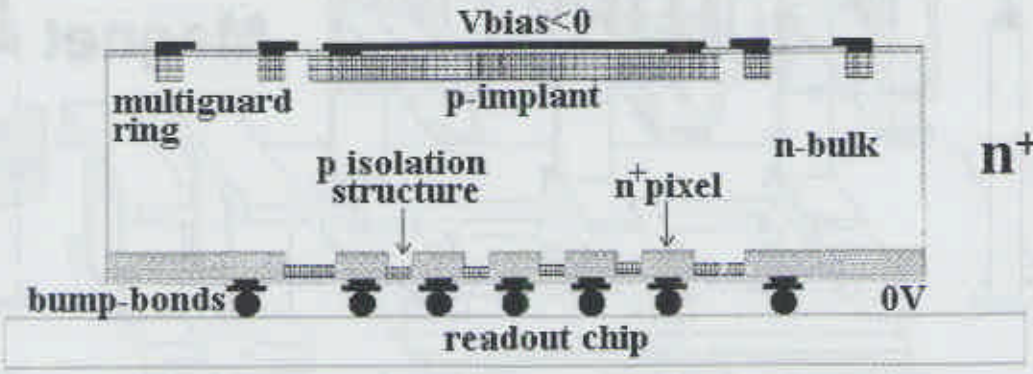




- I/O Board
  - Controls and Initializes 4 pixel readout chips
  - GPIB controller: HV, thresholds and pulser
- Automatic pixel calibration

Setup: 5 Pixel Planes Tested

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

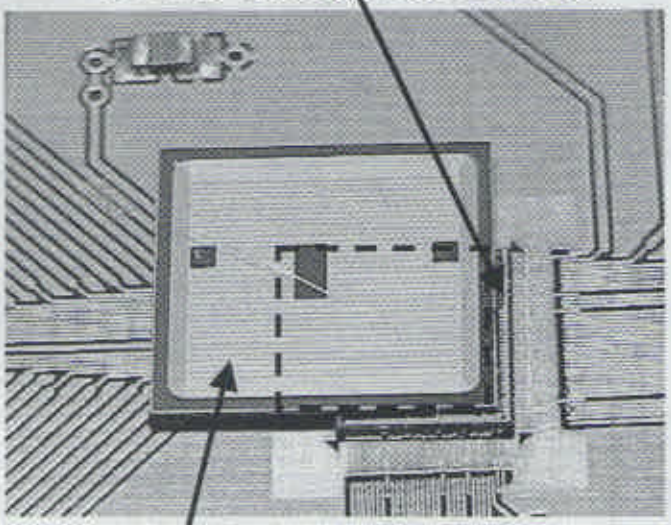


n^+np

indium bump-bonding 50x400 μm^2 cells

FPIX0 64x12cells

8 bit external ADC

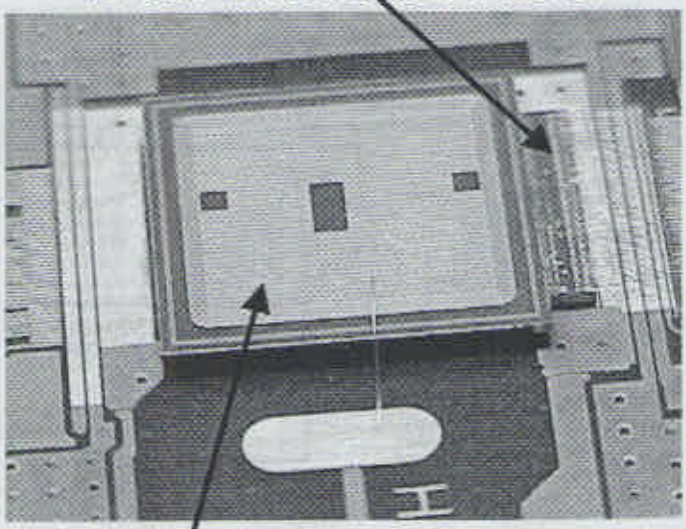


- ST1-CiS p-stop
- ST2-CiS p-spray

Bonded active area 3.2x4.4mm^2

FPIX1 160x18cells

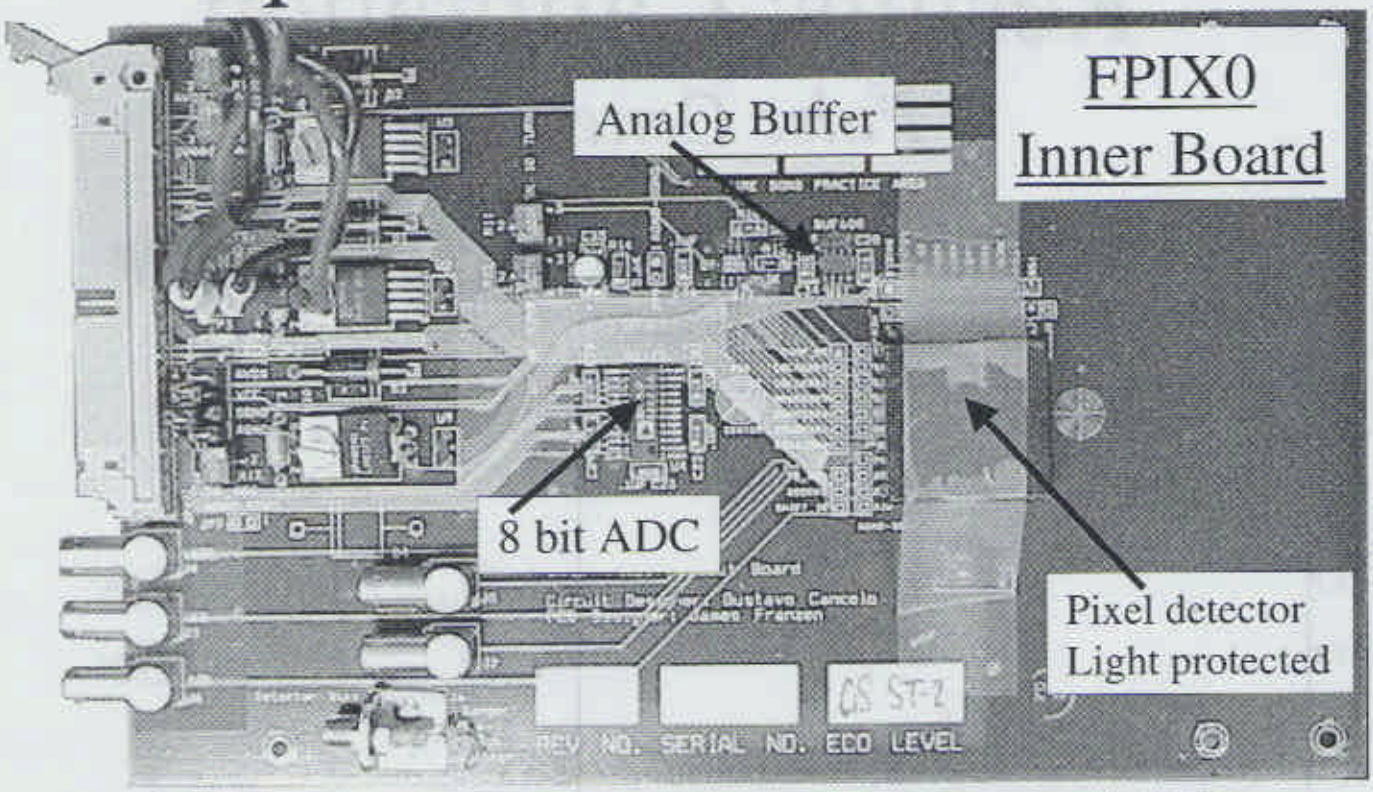
2 bit internal FADC

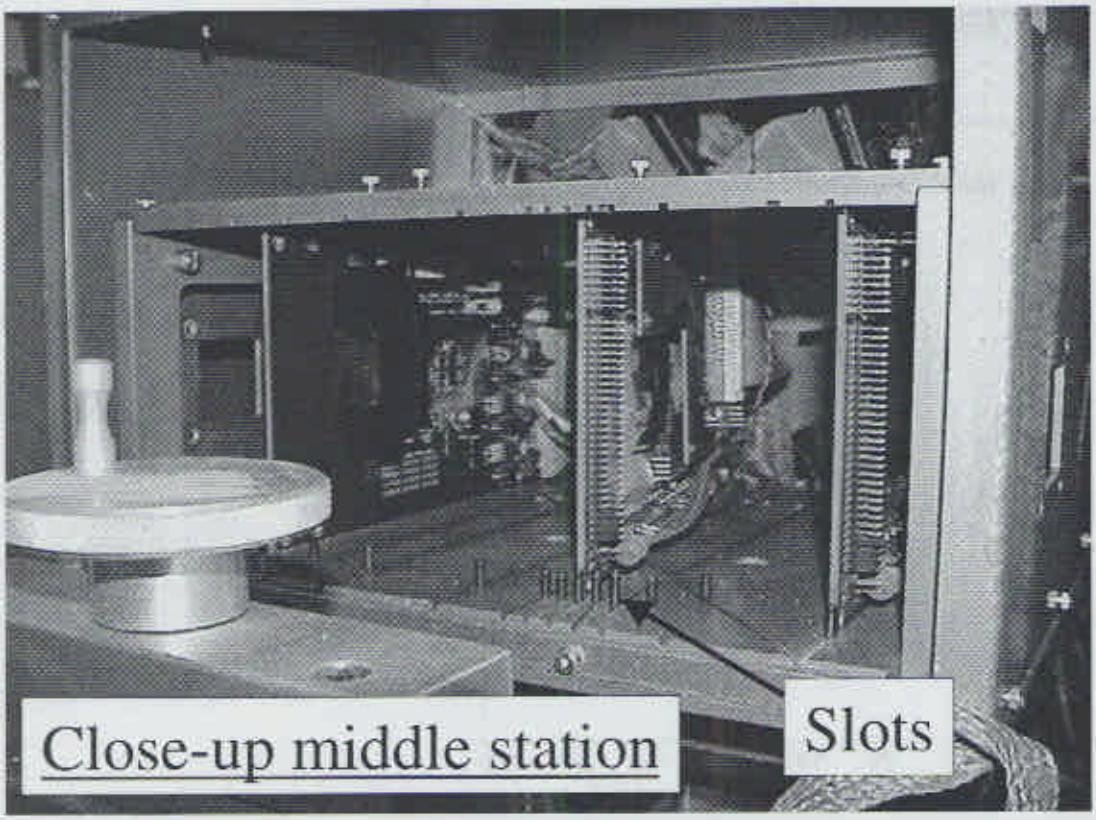


- Two ST1-Seiko p-stop
- ST2-Seiko p-spray

Bonded active area 8x6.8mm^2

Setup: 5 Pixel Planes Tested

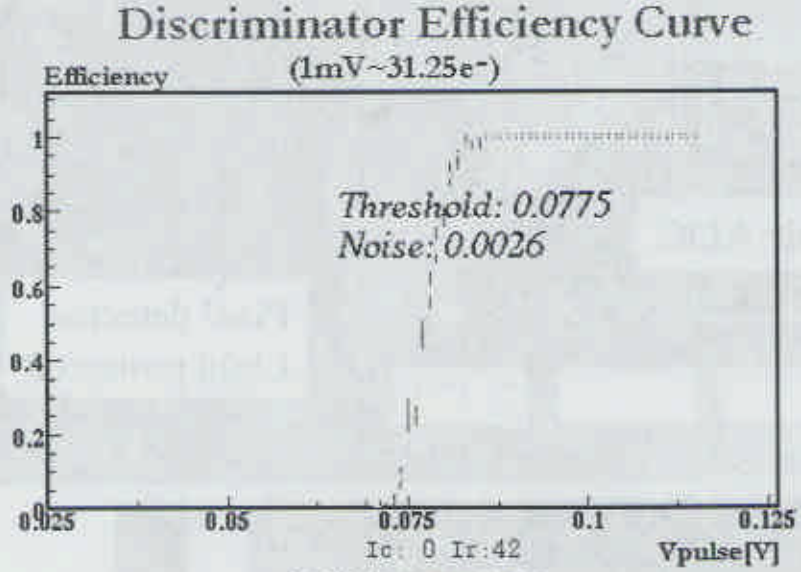




Results: Calibration

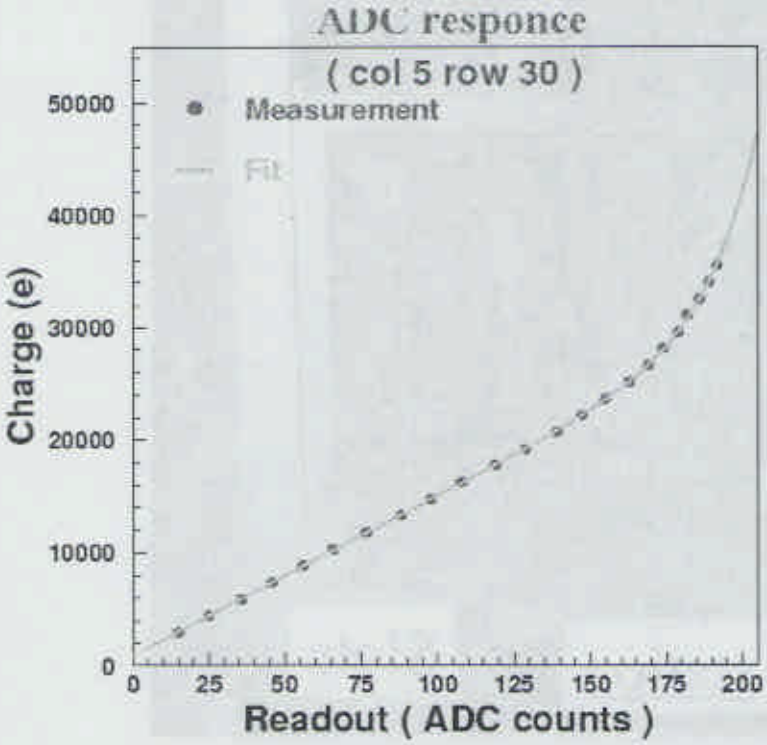
Pulse Generator

FPIX0 bump-bonded to ST1 CiS p-stop



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

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



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

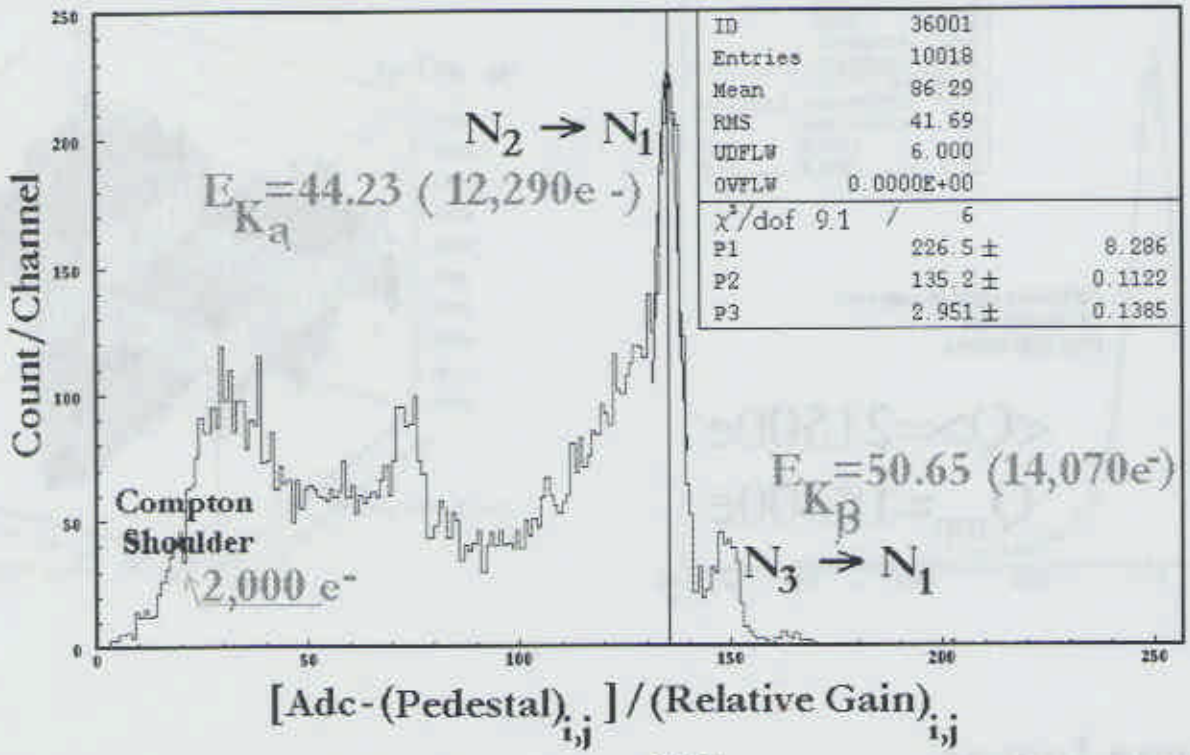
Dynamic range $\leq$1.5MIP

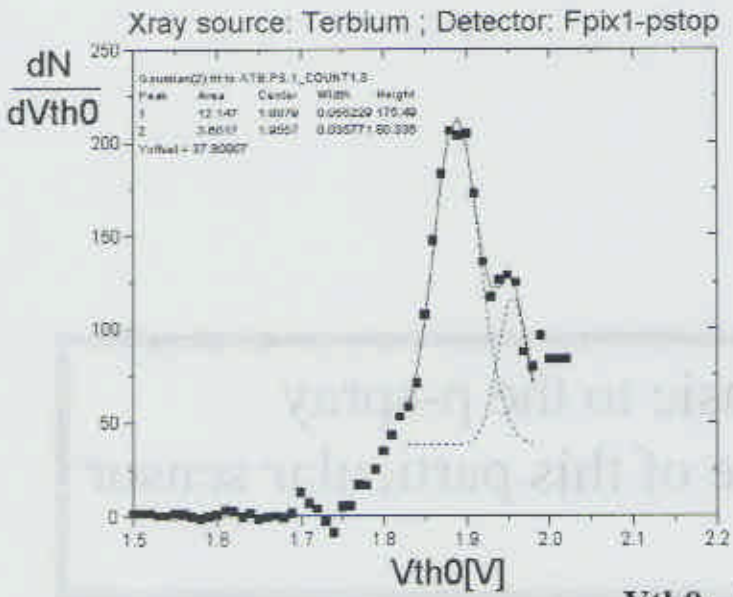
Results: Calibration

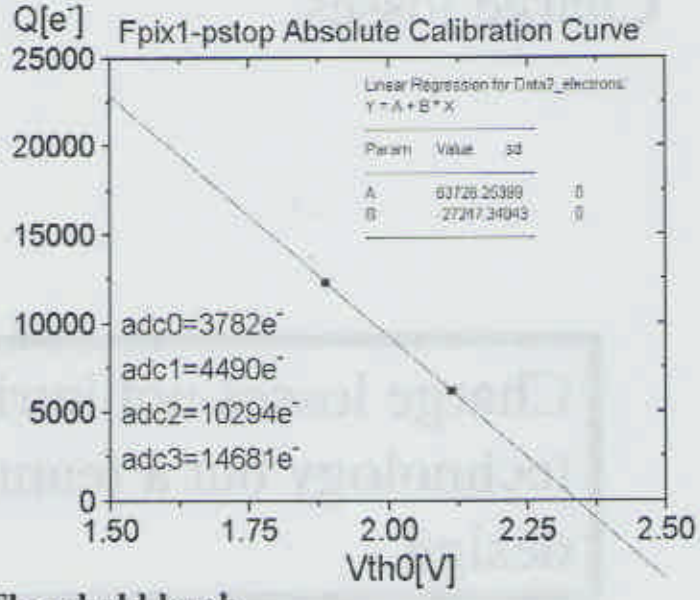
X-Ray Sources

Xray Peaks of an Activated Terbium Foil

FPIX0 bump bonded to a p_spray sensor





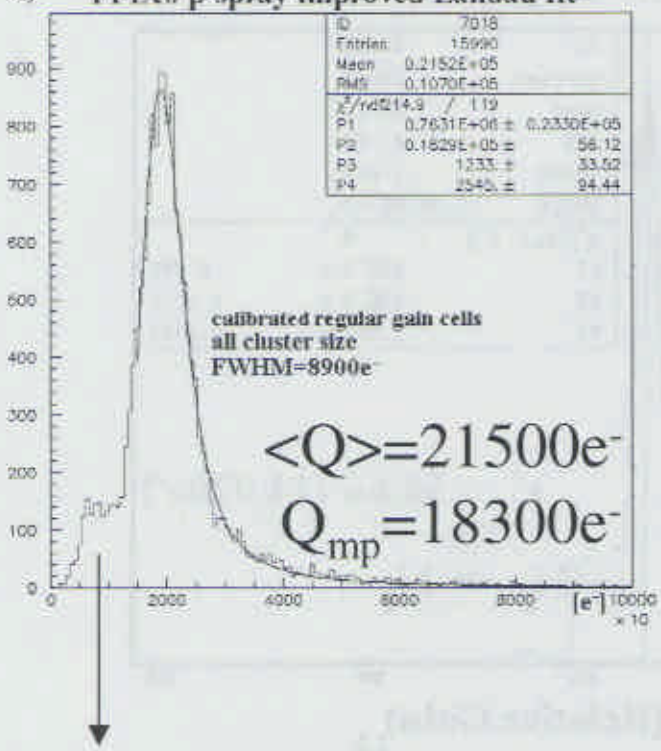


Vth0 = Threshold knob

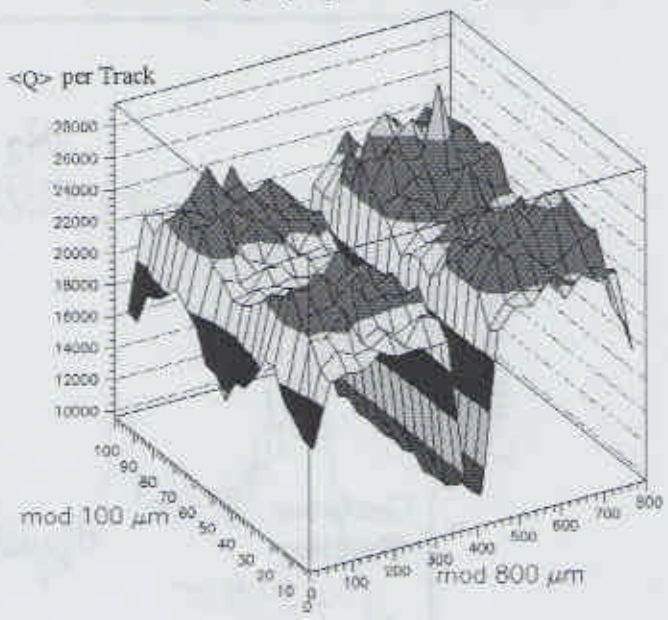
Results: Charge Collection

Single Chip CiS p-spray

a) FPIX0 p-spray improved Landau fit



b) FPIX0 p-spray spatial charge collection



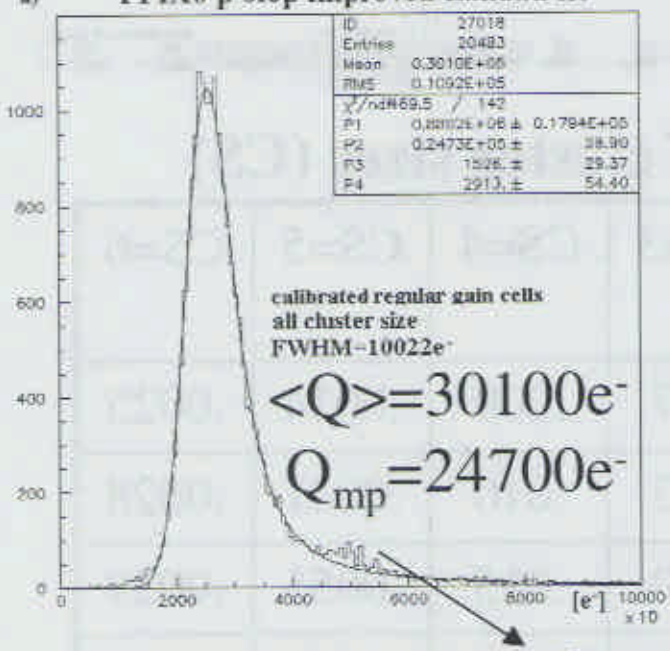
Charge losses

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

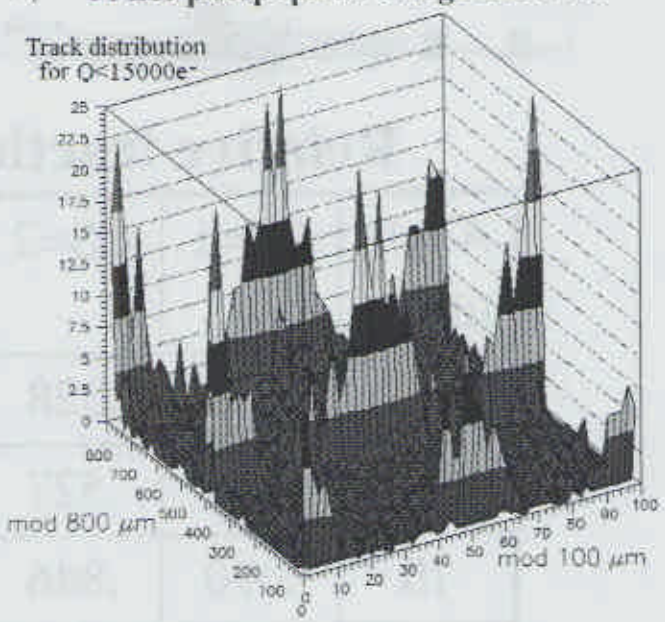
Results: Charge Collection

Single Chip CiS p-stop

a) **FPIX0 p-stop improved Landau fit**



b) **FPIX0 p-stop spatial charge collection**



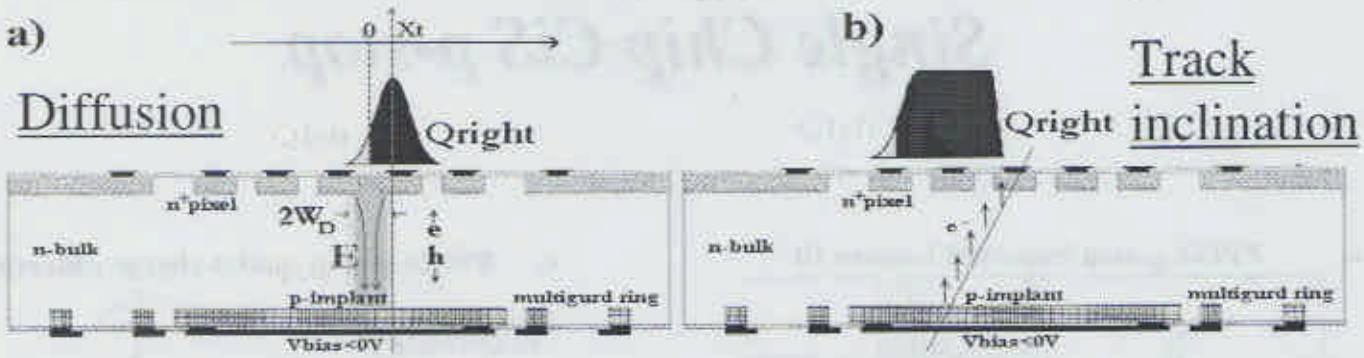
Saturation bump for all charge in single pixel.

- 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

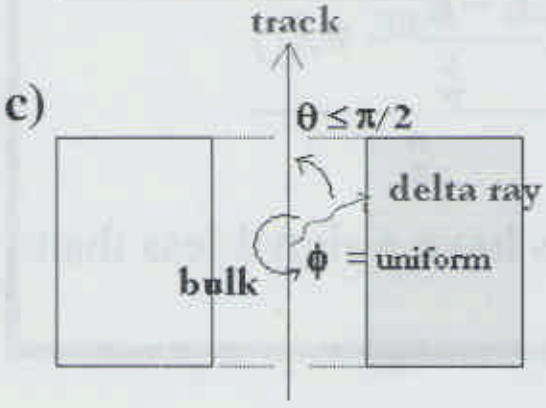


Relative fraction of cluster sizes (CS)

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

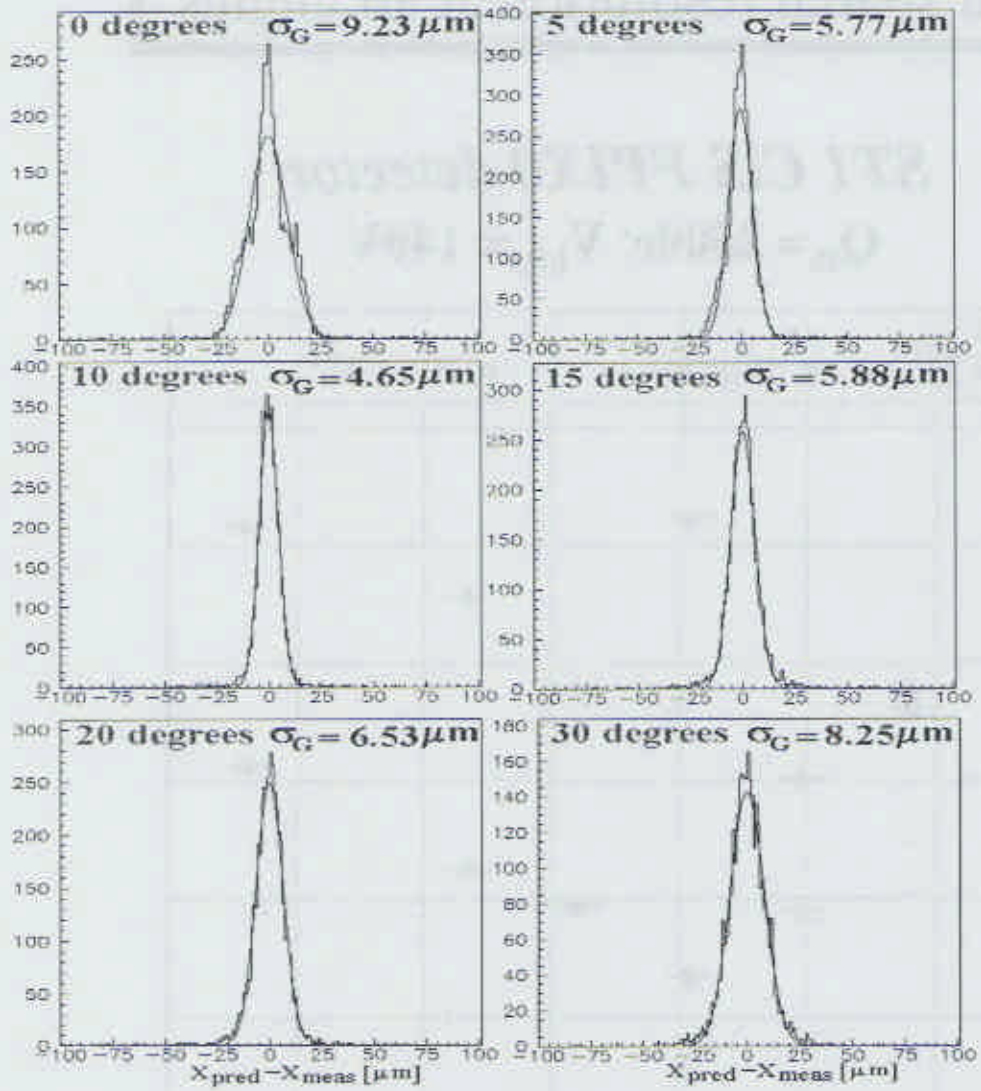


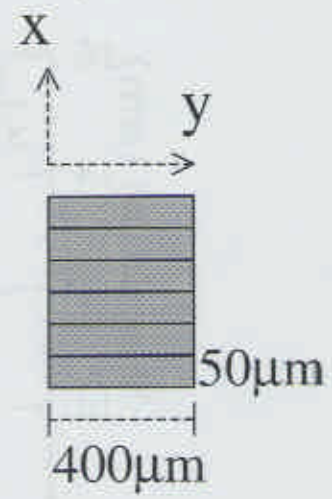
delta ray emission

Results: Spatial Resolution

Gaussian Fits to Residual Distributions

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.

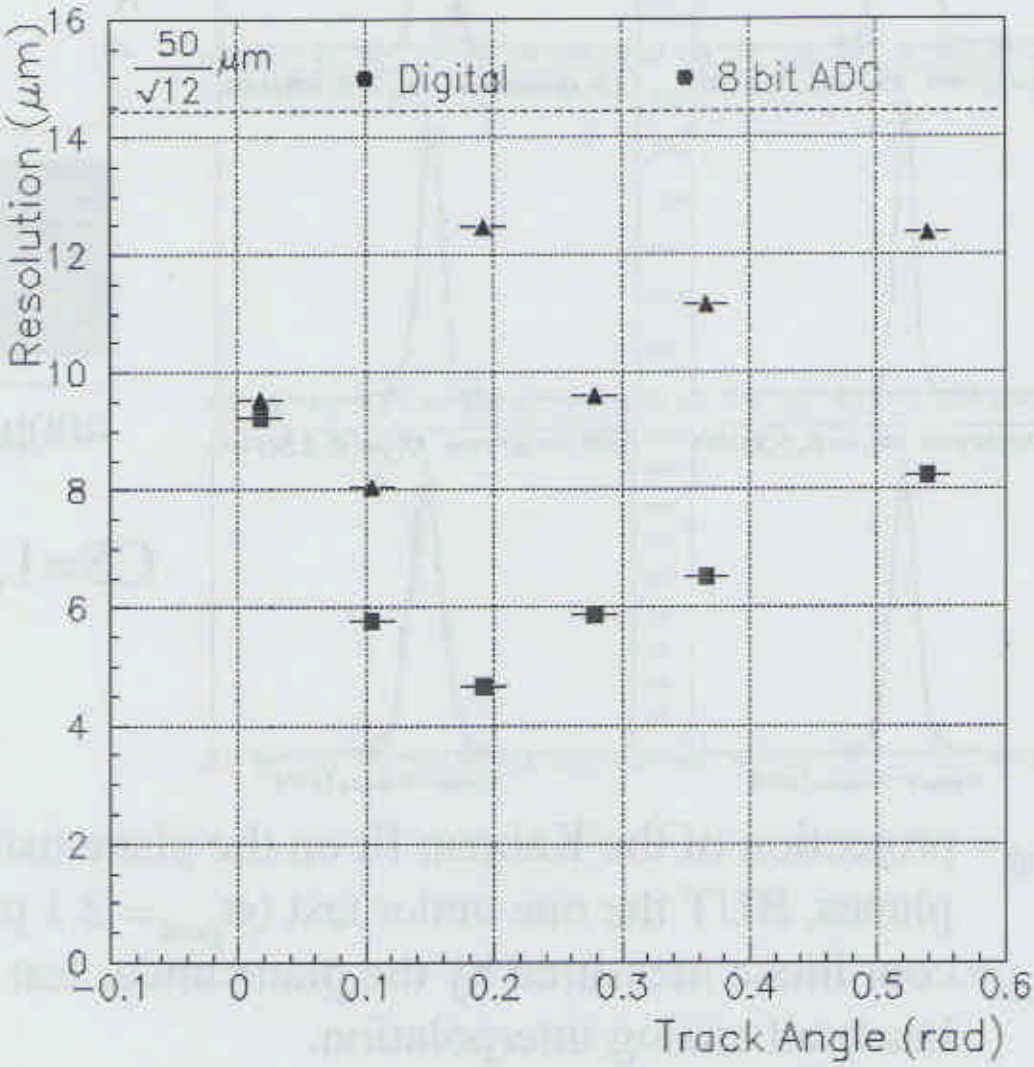
Results: Spatial Resolution

Spatial Resolution vs Angle

Good spatial resolution at all angles

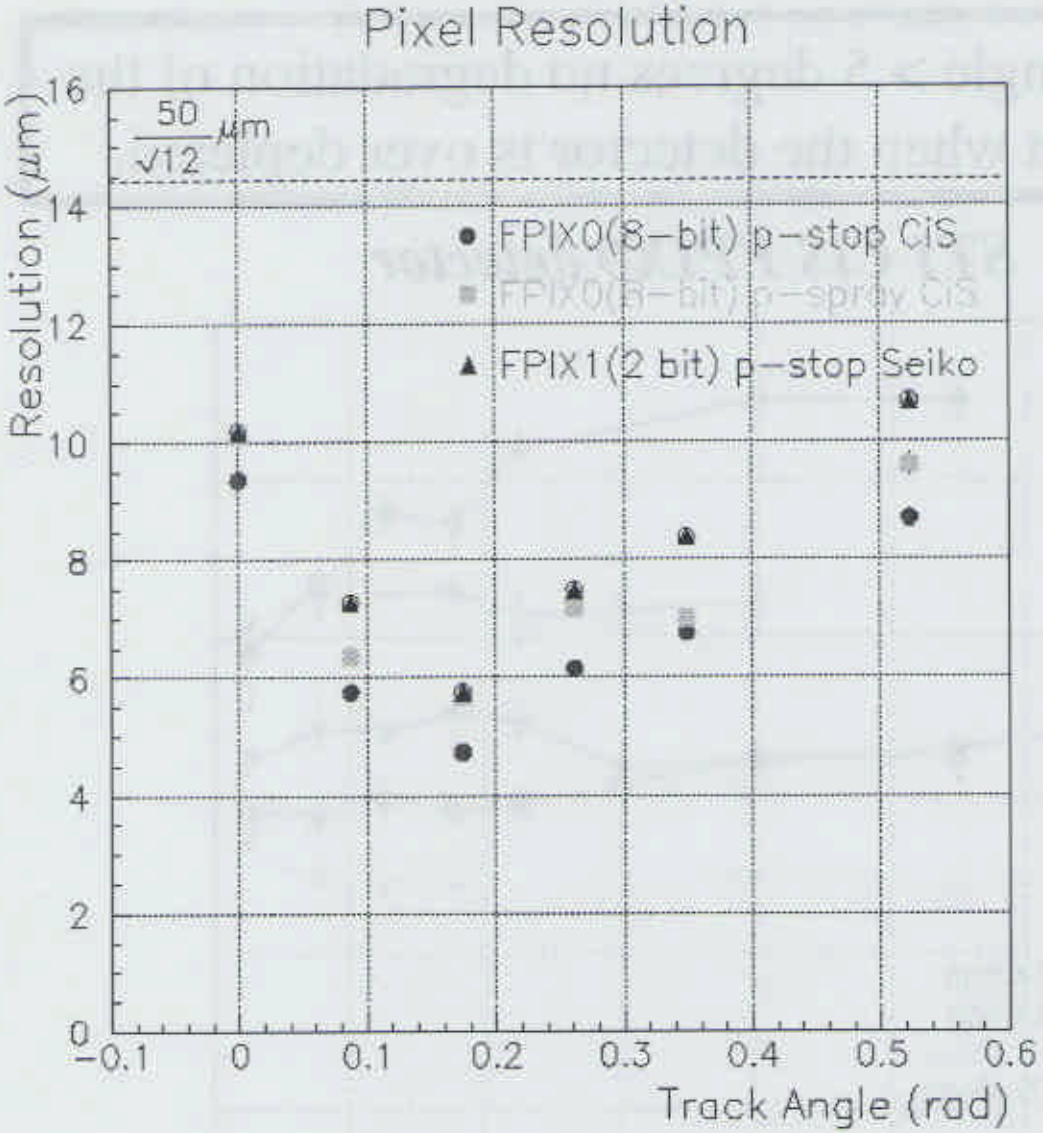
ST1 CiS FPIX0 detector

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



Results: Spatial Resolution

Comparison of Detectors



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

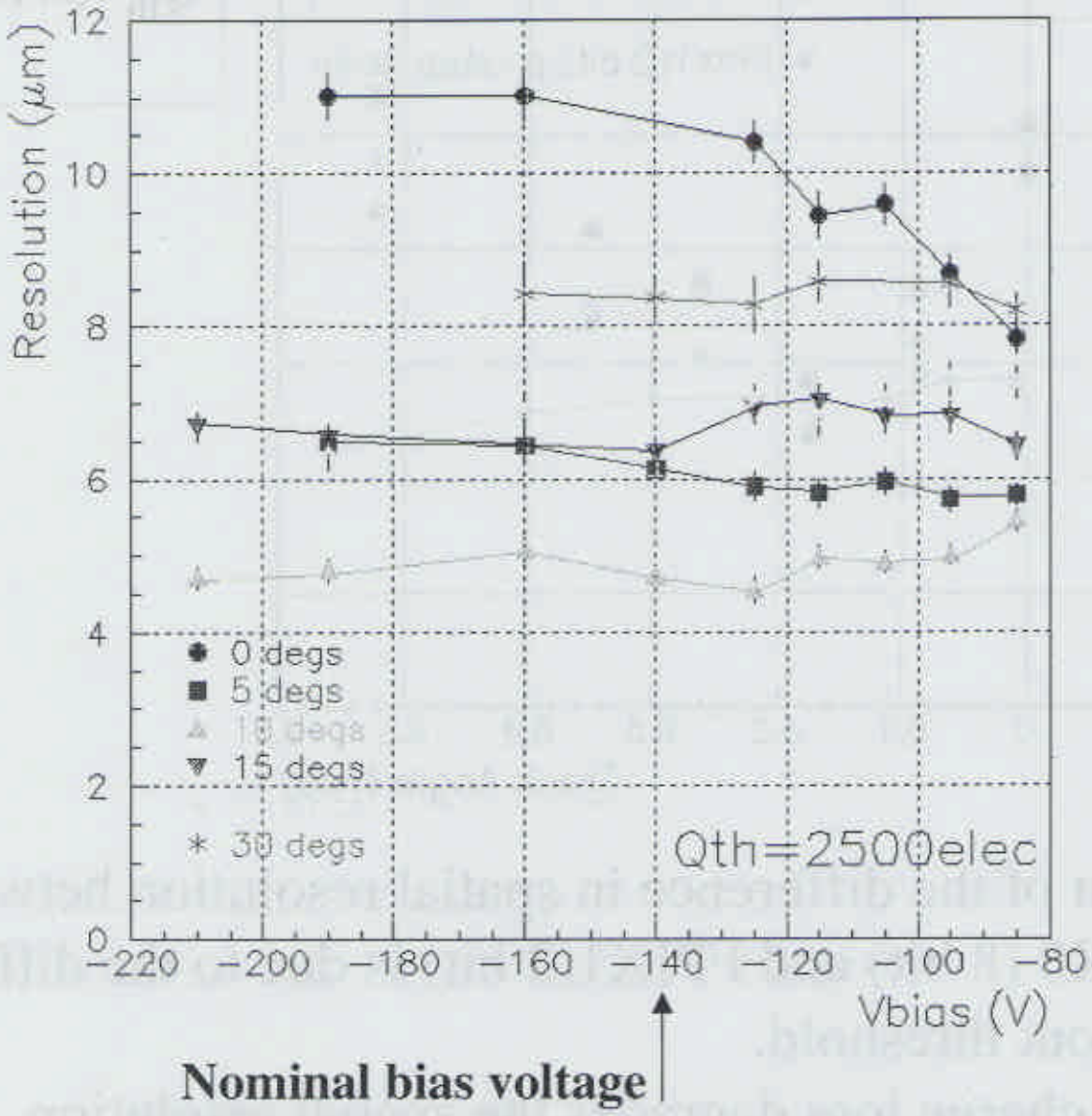
- Most of the difference in spatial resolution between FPIX0 (8 bit) and FPIX1(2 bit) is due to the different readout threshold.
- The charge loss degrades the spatial resolution

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



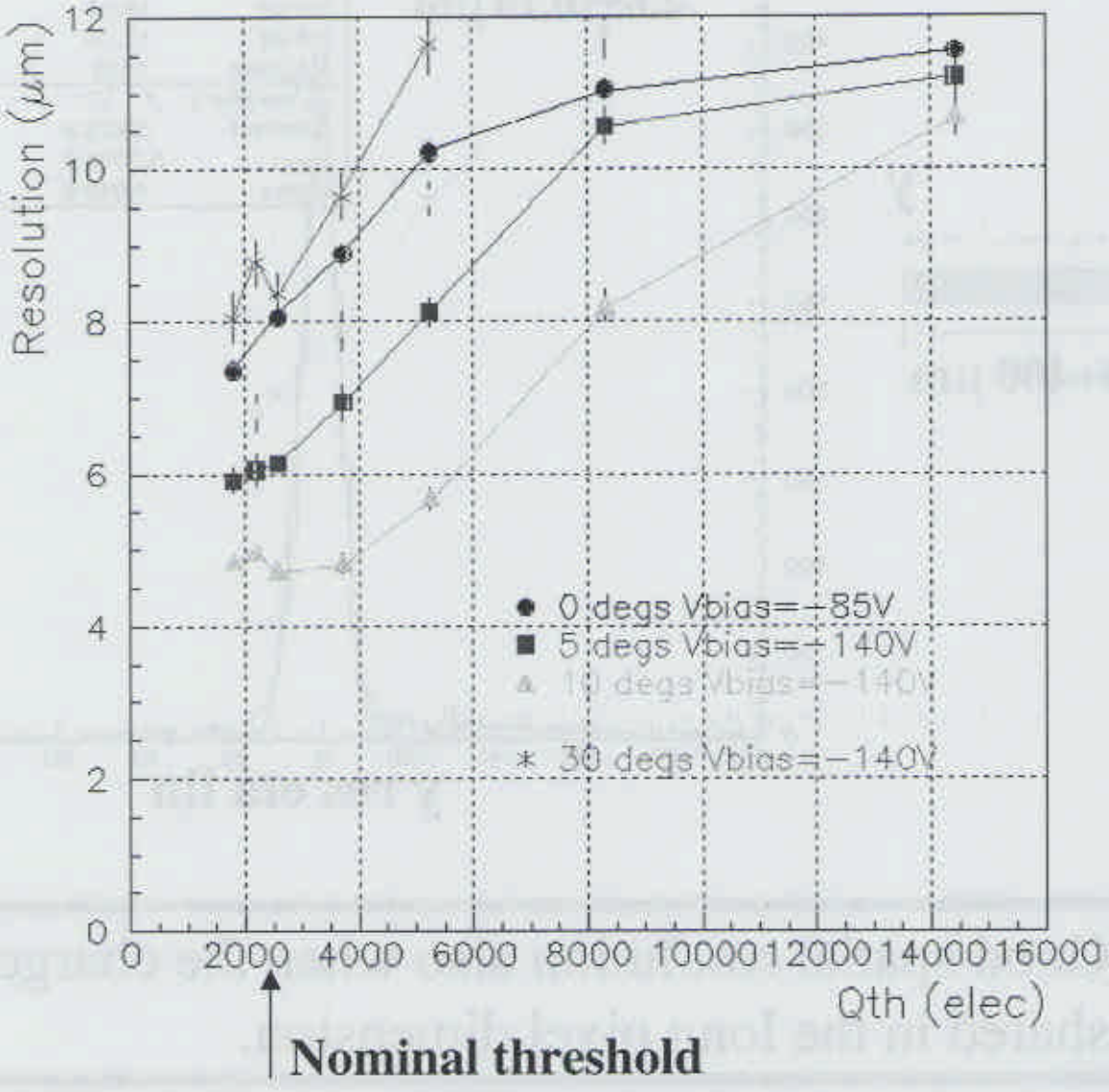
Nominal bias voltage

Results: Spatial Resolution

Threshold Dependence

Higher readout threshold degrades the spatial resolution.

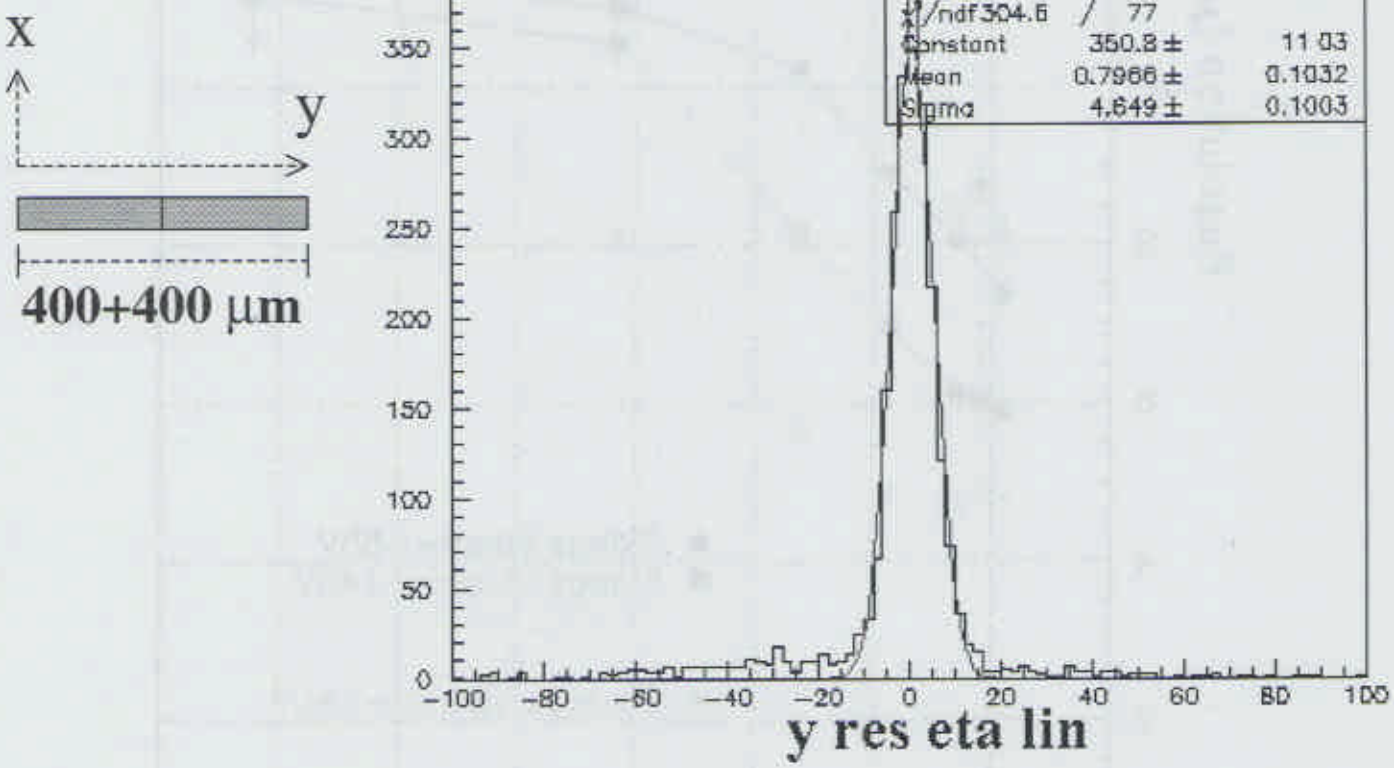
ST1 CiS FPIX0 detector



Results: Spatial Resolution

2D Spatial Resolution

ST1 CiS FPIX0 detector

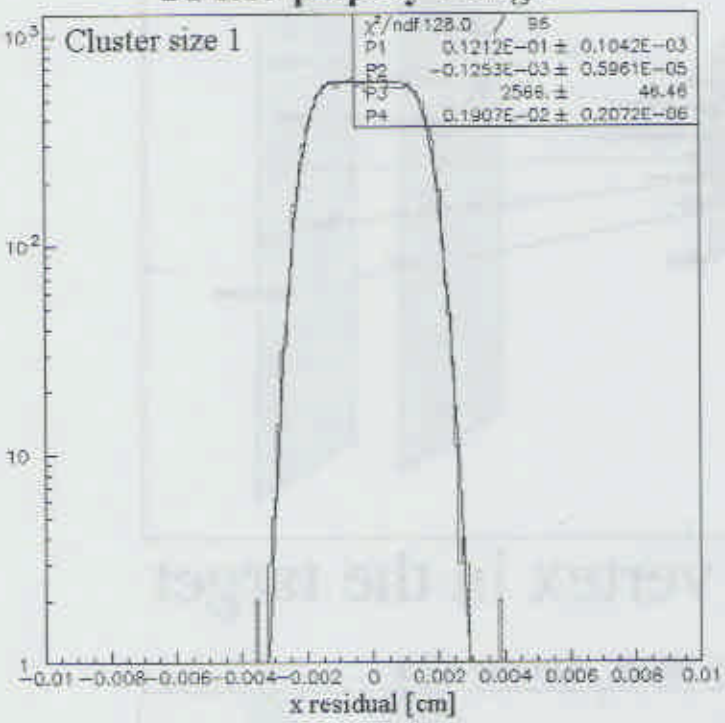


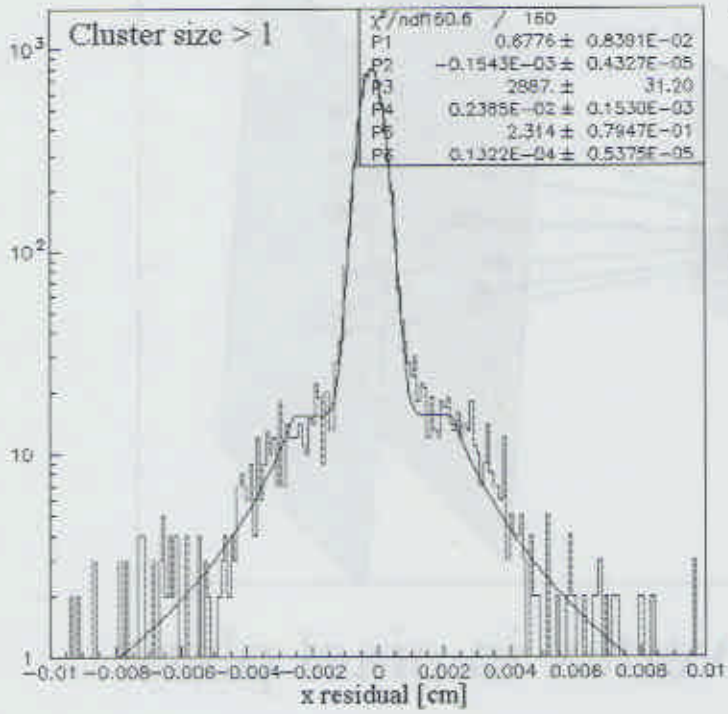
Good spatial resolution also when the charge is shared in the long pixel dimension.

Results: Spatial Resolution

Non-Gaussian Resolution Function

FPIX0 p-spray 0 degs





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

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

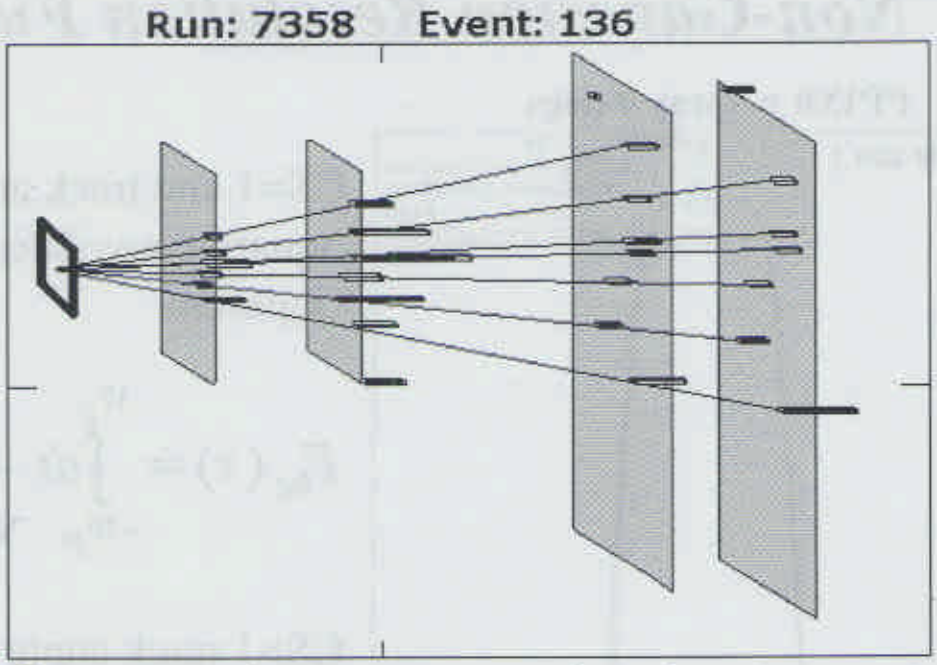
$$F_{pl}(x) = \begin{cases} \dfrac{A_{pl}}{|r_{cut-off}|^{\gamma}} & |x| < r_{cut-off} \\ \dfrac{A_{pl}}{|x|^{\gamma}} & |x| > r_{cut-off} \end{cases}$$

Non-Gaussian part:

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

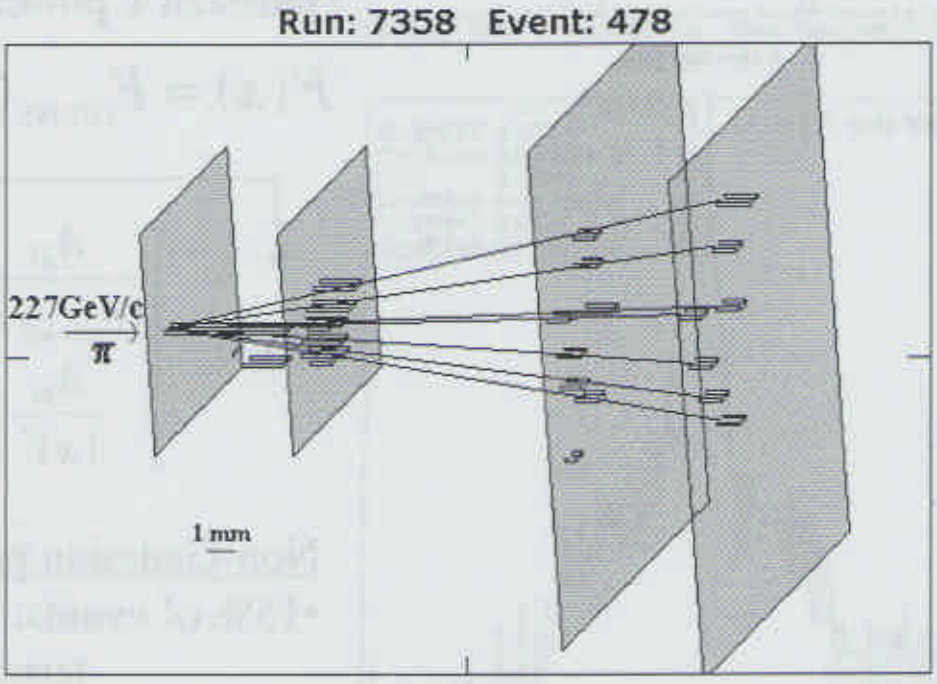
Four Plane Pixel Telescope

2.2mm thick diamond target



Interaction vertex in the target

Thousands of triggered multiple-track interactions



Interaction vertex in pixel plane

Conclusions

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