ATLAS and CVD Diamond Detectors

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LBL ATLAS Review
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Outline of Talk

- Introduction
- Charge Collection
- Diamond Pixel Detectors
- Summary
- Plans

Why Diamond

- Radiation hardness
- Low dielectric constant → low capacitance
- Low leakage current → low readout noise
- Fast signal collection time

LHC:

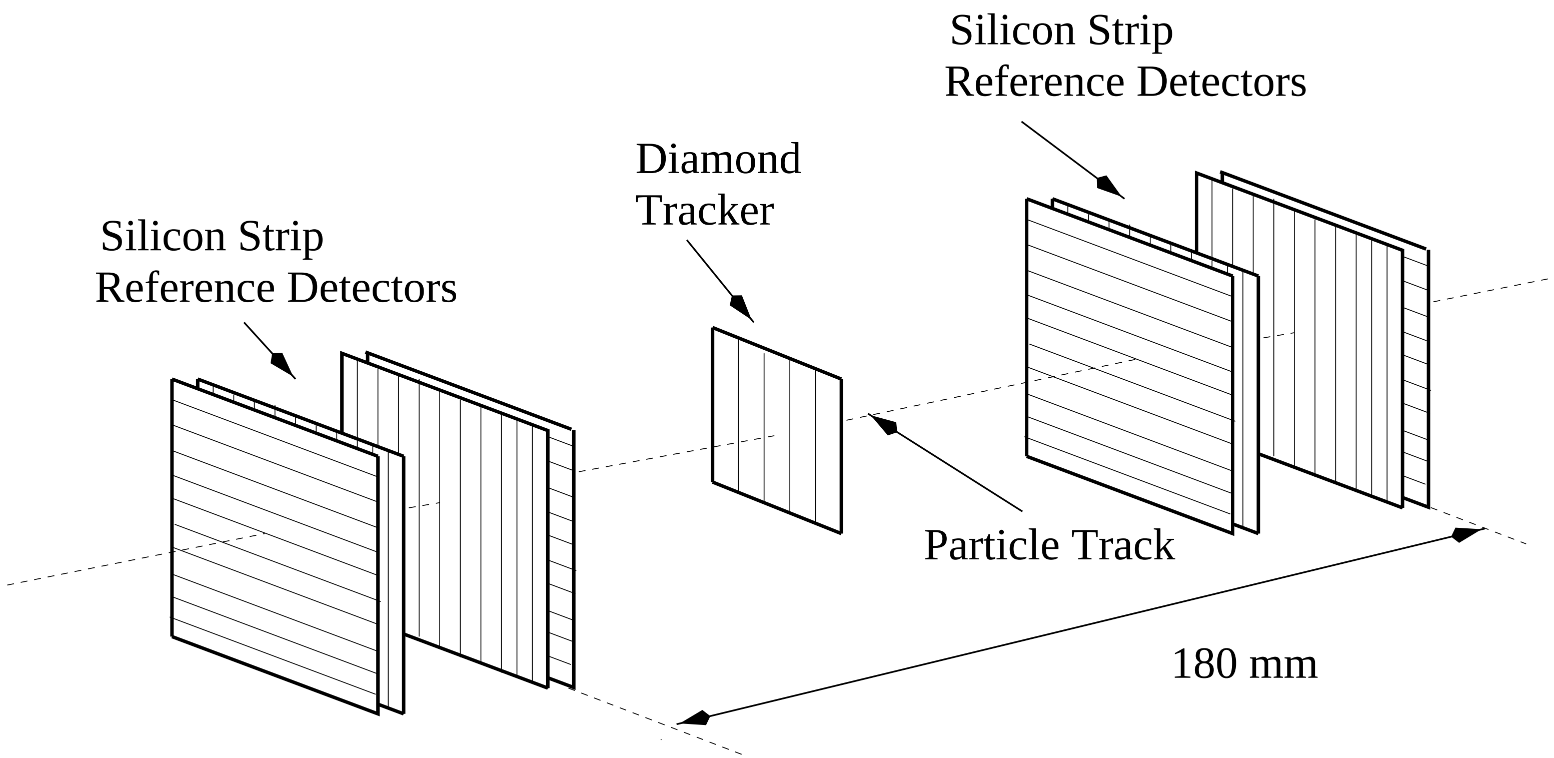
→ Annual replacement of B-layer perhaps?

→ Diamond can survive in this harsh environment

→ Provide high precision tracking to tag b, t, Higgs, . . .

But does it work as a pixel detector?

CERN Testbeam Setup



- 100 GeV/c pion beam
- External tracking with "Strassbourg Telescope"
- Tracking precision $\approx 2\ \mu$m

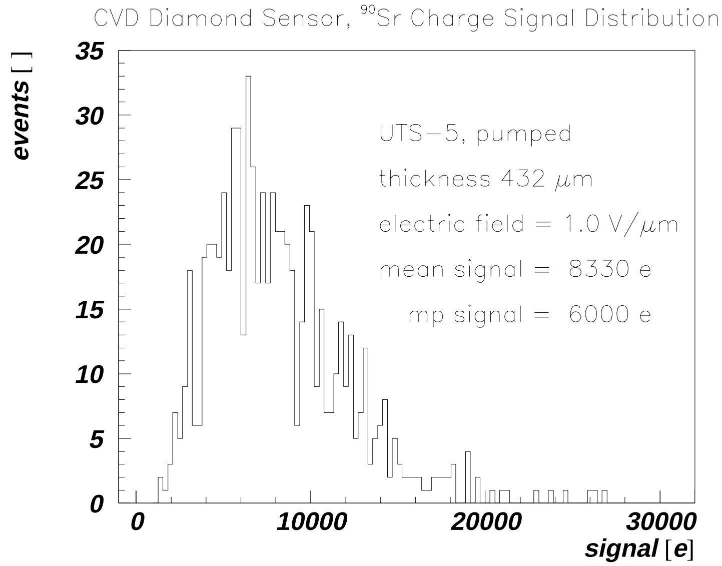
- Slow Electronics (2 μsec)

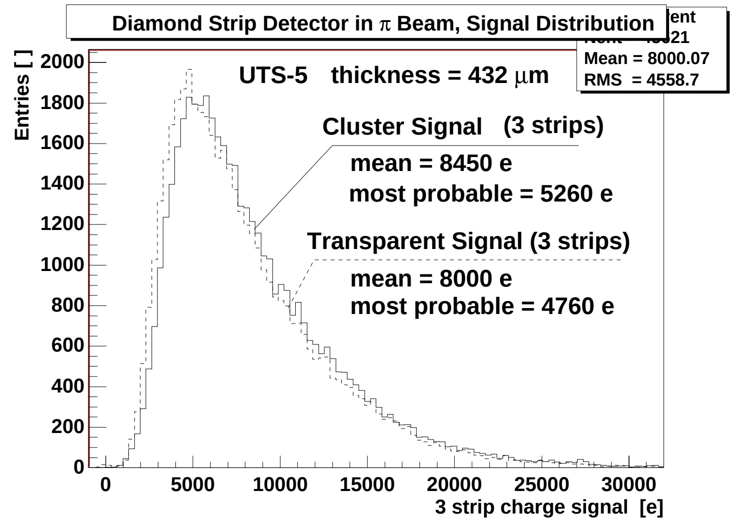
  ENC $\approx 100e + 14e/$pF

- Fast Electronics (25 nsec)

  ENC $\approx 600e + 70e/$pF

Charge Collection



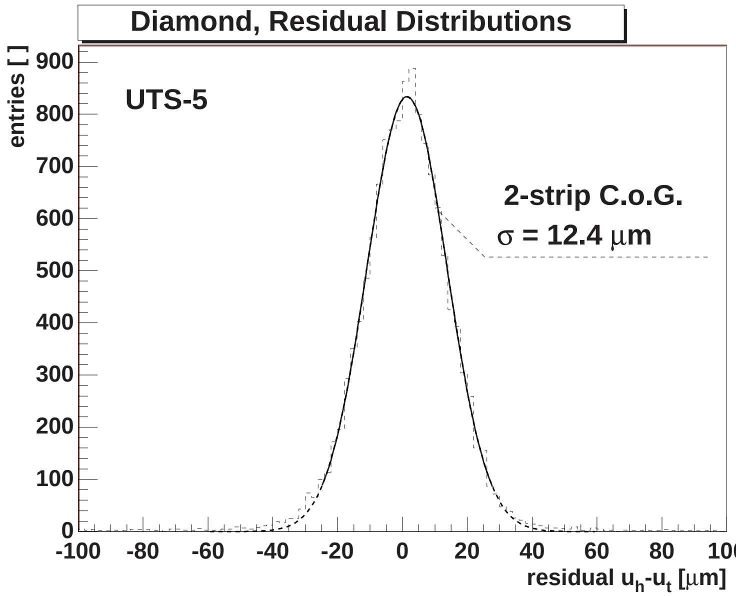


- Test Procedure: dot $\rightarrow$ strip $\rightarrow$ pixel
- Source data, test beam data well separated from 0
- FWHM/MP $\approx$ 1.1 (source) — Si has $\approx$ 0.5
- ENC $= 120\ e$, with 1.8 μs signal peaking time

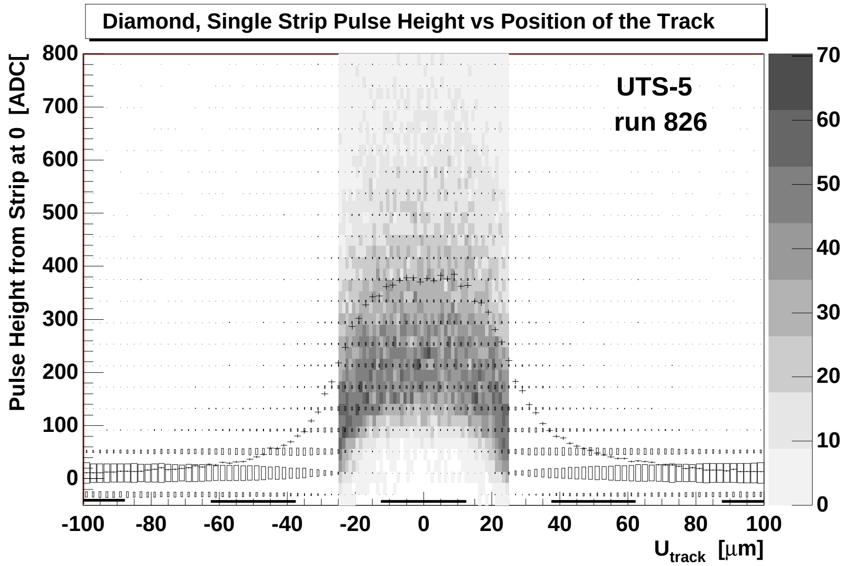
  $\Longrightarrow S_{\rm mp}$-to-$N$ = 40-to-1

Recent Results with Diamond Strip Detectors

Position Resolution

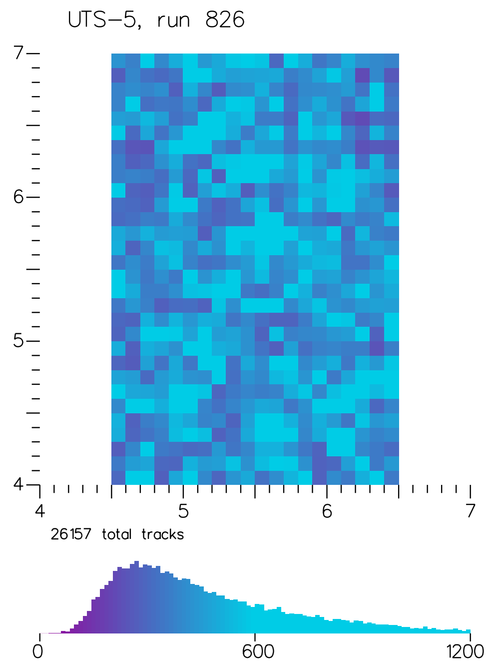


Pulse Height vs. Tracking Position



- Spatial resolution ≈ digital (Center-of-Gravity Method, 'CoG')
- Under strip, little charge sharing $\Longrightarrow$ constant pulse height
- Between strips, linear charge sharing
- Optimize strip width for strip detectors, pixel detectors
- Optimize position algorithm

First Uniformity Studies

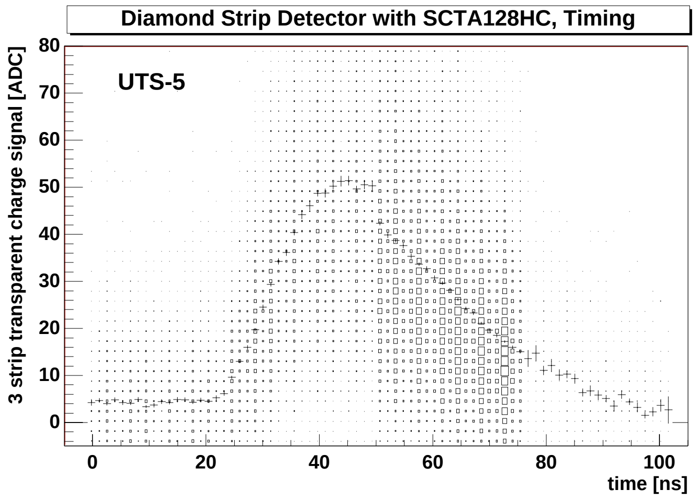


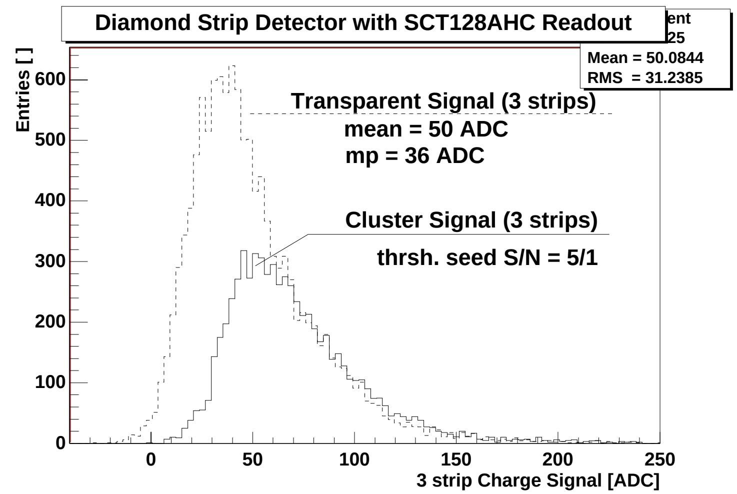
- $100\ \mu\mathrm{m} \times 100\ \mu\mathrm{m}$ bins
- Uniformity (RMS/mean) for 40 evt/bin

  Silicon $\approx$ 8 %

  Diamond $\approx$ 34 %
- Need finer binning, more data

Tracker with Fast Readout, SCTA128HC





- DMILL/SCTA128HC (high capacitance)
- Signal peaking time: 25 ns
- Analog pipeline, 40 MHz readout
- Preliminary results:

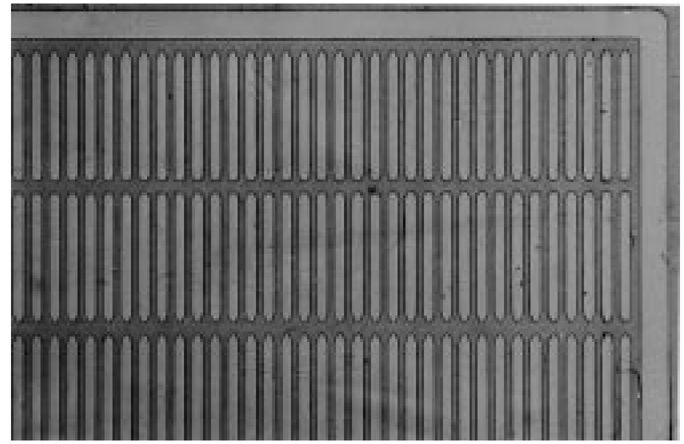
  $S_{\rm mean}/N$ = 10-to-1,

  $S_{\rm mp}/N$ = 7-to-1

- seed threshold around 3000 e

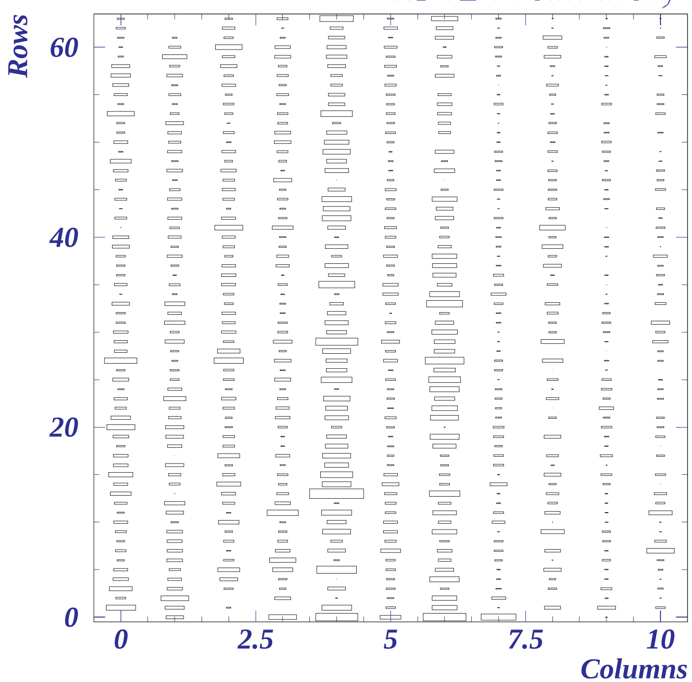
ATLAS/3 Pixels (Ti-W)

ATLAS FE/C Pixels (Ti-W)

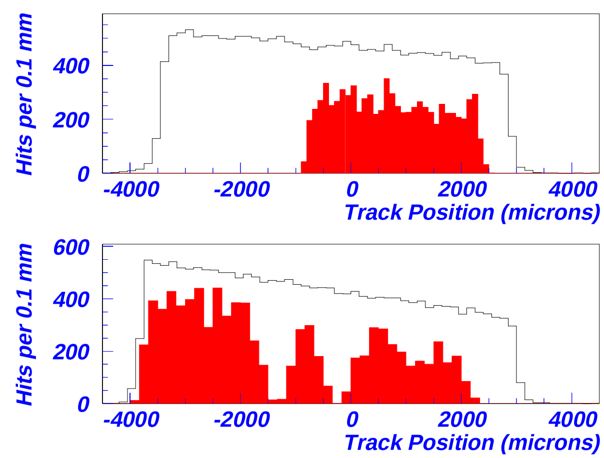


Results from ATLAS/3 Pixel Detector

Hit Pattern



Observed Beam Profile

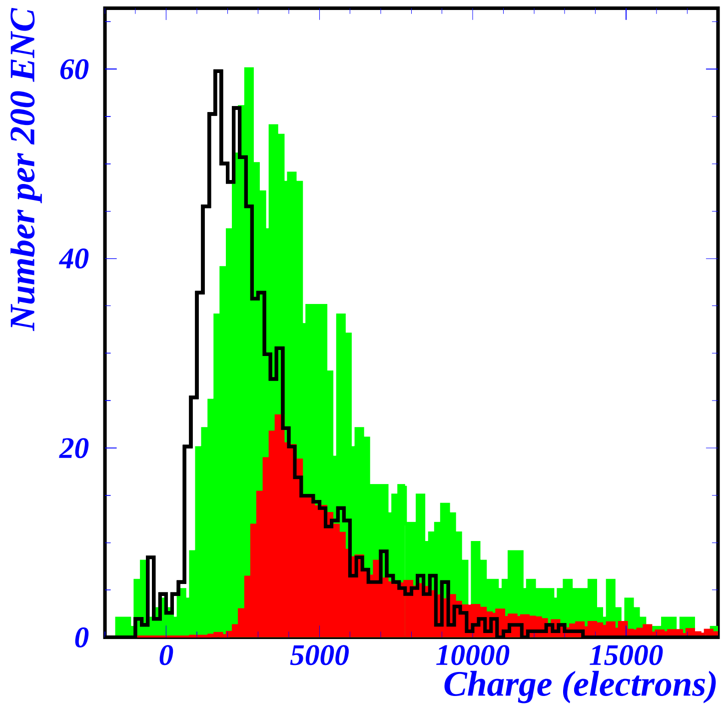


- Substrate size: 4.0 mm x 8.0 mm
- # Pixels: 12 x 64
- Pitch: 50 μm x 536 μm
- Readout chip: radsoft (HP)
- Bump bonding yield at Boeing: 100 %

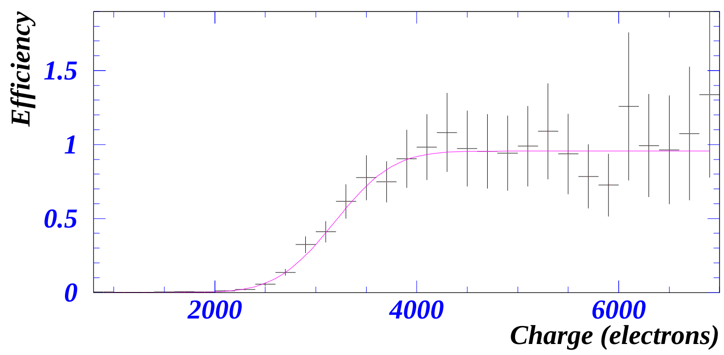
- 50 GeV/c π beam at CERN

Results from ATLAS/3 Pixel Detector

Observed Charge



Observed Efficiency



- Columns 4 & 6 excluded (low th)

  Red: pixel tracker — unpumped

  Green: strip tracker — pumped

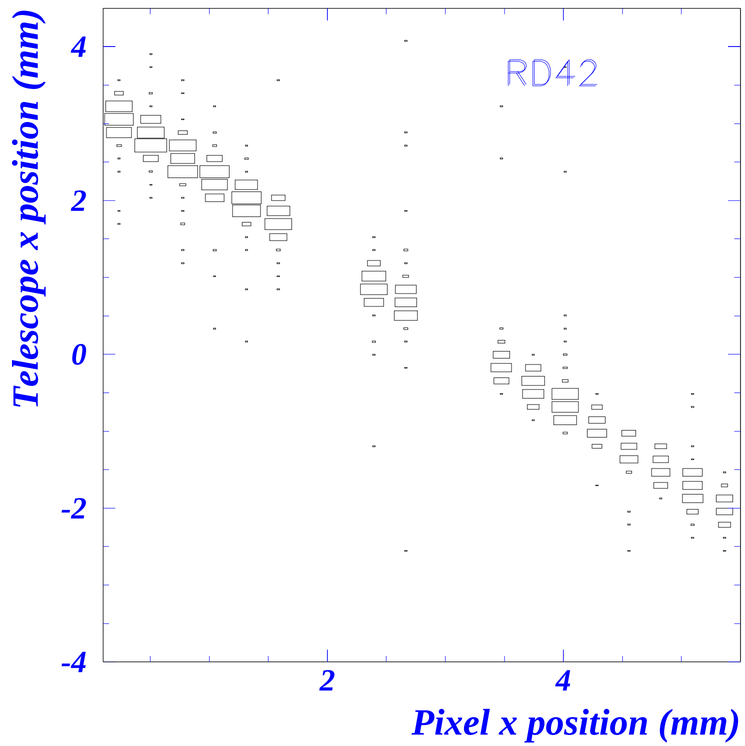
  Open: prediction — unpumped

- Threshold ≈ 3,500 e

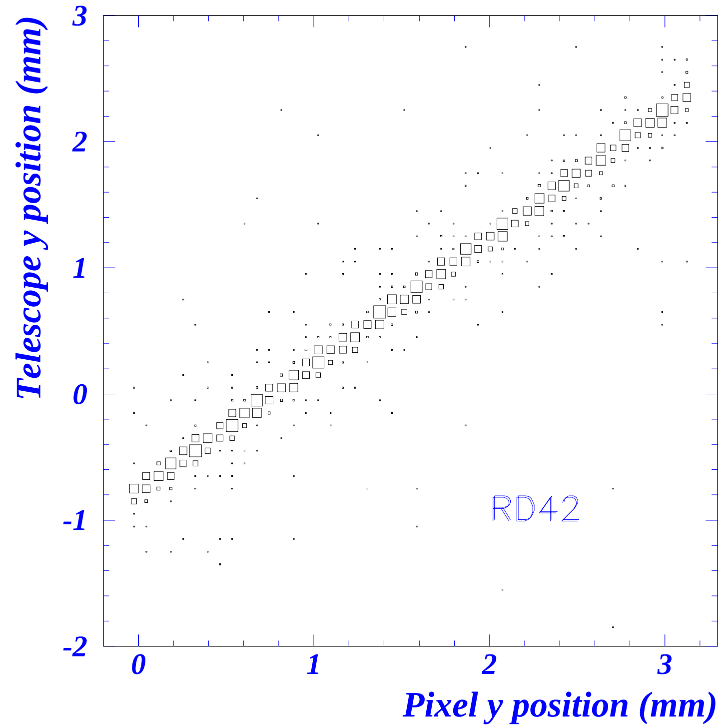
- consistent with 3500 e threshold

Results from ATLAS/3 Pixel Detector

Spatial Resolution – Long Pixels



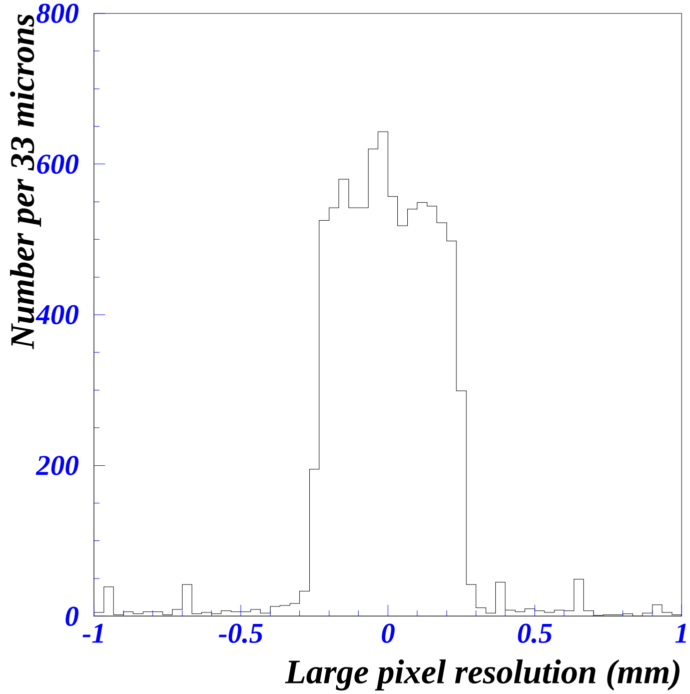
Spatial Resolution – Short Pixels



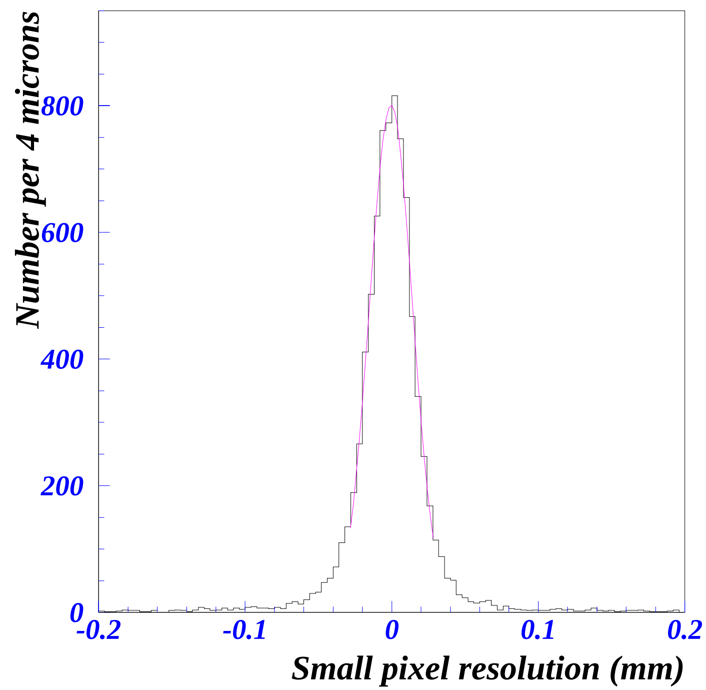
- Excellent correlation between beam telescope and pixel tracker data!

Results from ATLAS/3 Pixel Detector

Resolution – Long Pixels



Resolution – Short Pixels



- Pixel pitch: 536 μm
- FWHM $\approx$ 500 μm
- Minimal tails

- Pixel pitch: 50 μm
- Position resolution $=$ 14.8 μm (single hits)

Status Summary

- **Charge Collection**

  Mean signal $\approx$ 8,500 e

  MP signal $\approx$ 6,000 e

  Charge distribution starts at $\sim$ 1500 e

  FWHM/MP $\sim$ 1.1

  2-strip-efficiency 99% if threshold below $\approx$ 2,000 e

- **Radiation Hardness**

  40 % loss of charge occurs at

  - 5×10^{15} p/cm^2
  - 2×10^{15} π/cm^2
  - 1×10^{15} n/cm^2

- **Diamond Pixel Detectors**

  Successfully tested ATLAS pixel patterns

  - Bump bonding yield was 100 %
  - Excellent correlation between telescope and pixel data
  - Digital spatial resolution for 3500 e threshold

Future Plans

- **Charge Collection Goals - RD42**

  Mean signal 10,000 e with *MIP*

  MP signal 7,500 e

  Thickness $400\ \mu$m, area size $2 \times 4\ \mathrm{cm}^2$

It now seems reasonable to see if a diamond pixel device may be useful for ATLAS in the B-layer.

- **Pixel Studies**

  Reduction of readout thresholds to $\sim$ 2000 e

  Pixel detectors on FE/C (UT-S5 at IZM)

  Pixel detectors on FE/B (CD-S61, CD-S62 at AIT)

These studies should yield a definitive answer in the next six months and should be compared with oxygen treated silicon.