SPiDeR (Silicon Pixel Detector Research) at EUDET Telescope

- Sensor overview with lab results
  - TPAC
  - FORTIS
- Beam test 09

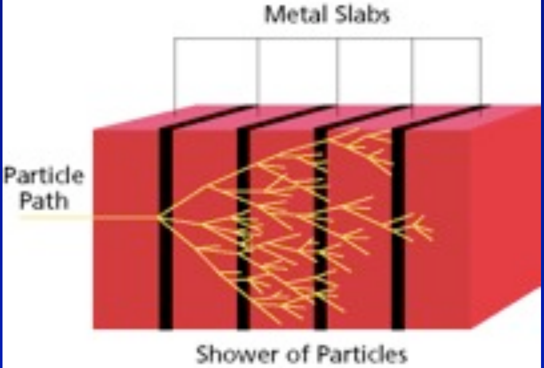
D. Cussans on behalf of
J.J. Velthuis, A. Caldarone
for the
SPIDER collaboration

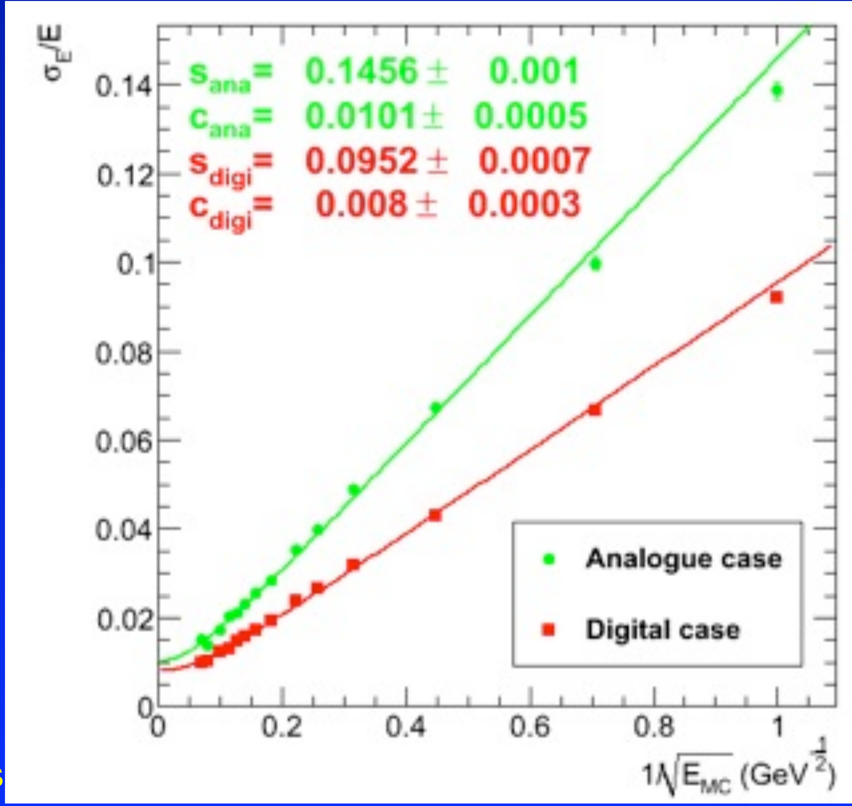
Sensors…

- TPAC is the sensor aimed at digital calorimetry
  - Tests with Fe55 and beam test
- FORTIS aimed at tracking
  - Tests with light, Fe55 and beam tests
- Cherwell:
  - The future

TPAC: Digital Calorimetry

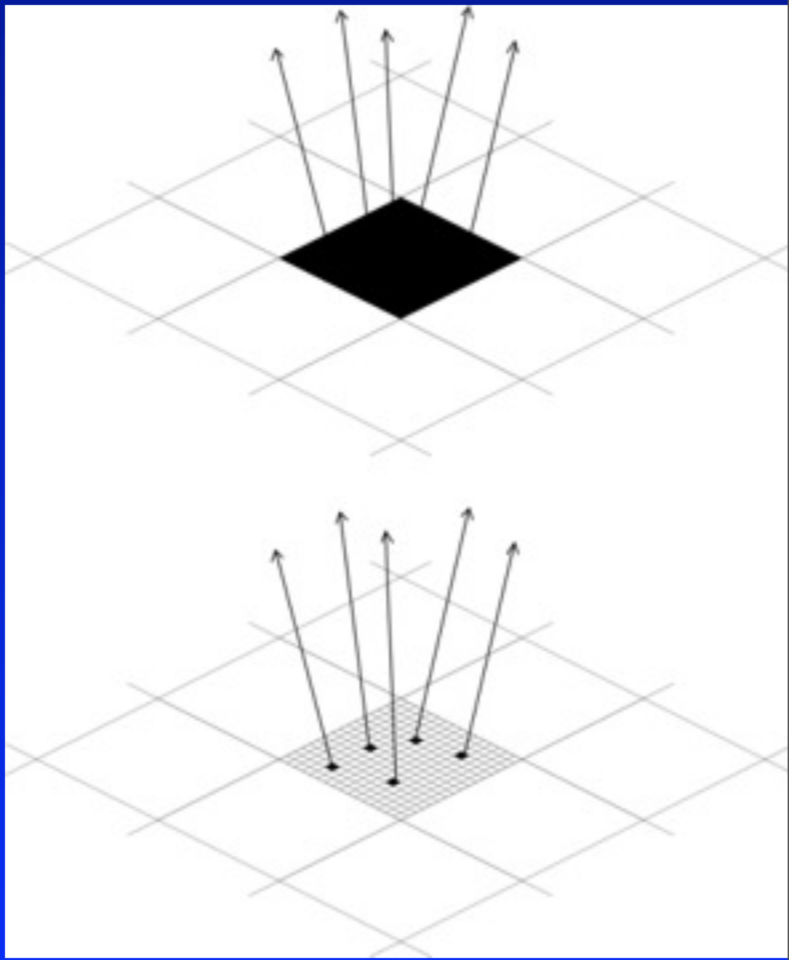
- Average number of charged particles in EM shower ∝ incident energy
  - Fluctuations due to statistical nature of shower
- Average energy in sensitive layers ∝ number of charged particles
  - Fluctuations due to angle of incidence, velocity and Landau spread
- Hence, number of charged particles is an intrinsically better measure than the energy deposited
  - Clearest with ideal calorimeter; no experimental effects
  - Energy deposited ("analogue"



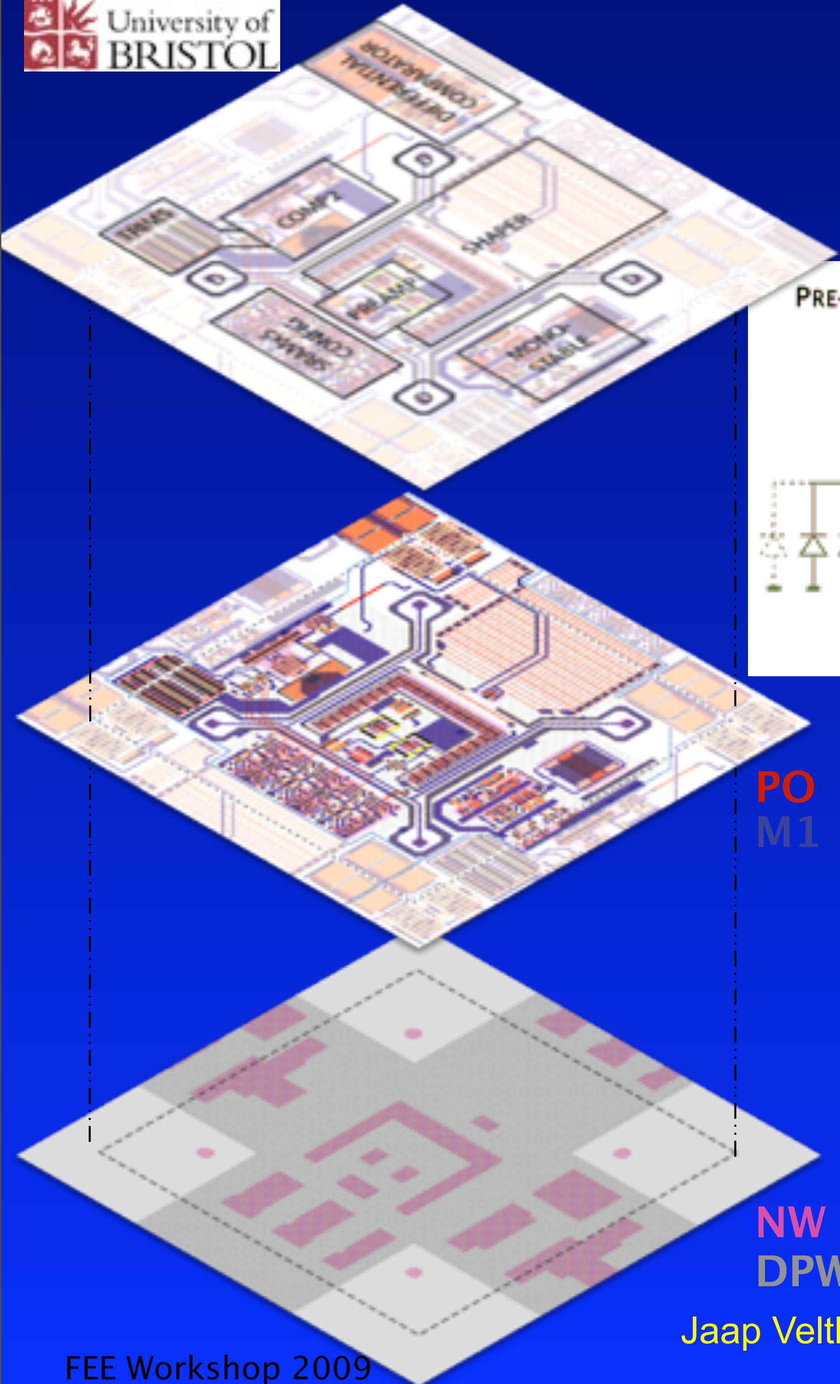


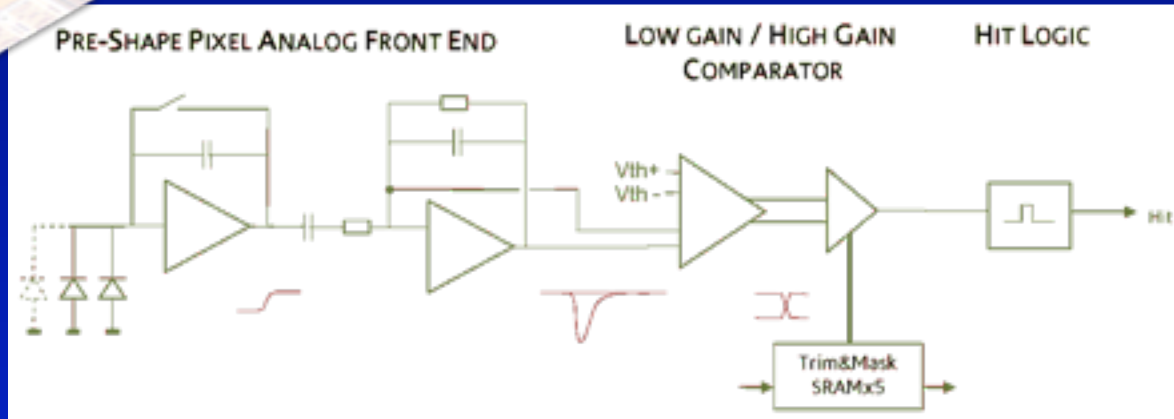
Digital Calorimetry: Concept

- Can we measure the number of charged particles?
  - Possible to get close to the analogue ideal resolution with low noise electronics
- Can we get anywhere near the ideal resolution for the digital case?
  - Make pixellated detector with small pixels
    - Probability of more than one charged particle per pixel can be made small
    - Allows binary readout = hit/no hit
- EM shower density ~100/mm^2 in core
  - Need pixels ~ 50μm
  - Results in huge number of pixels in a real ECAL ~ 10^{12} pixels



TPAC Pixel

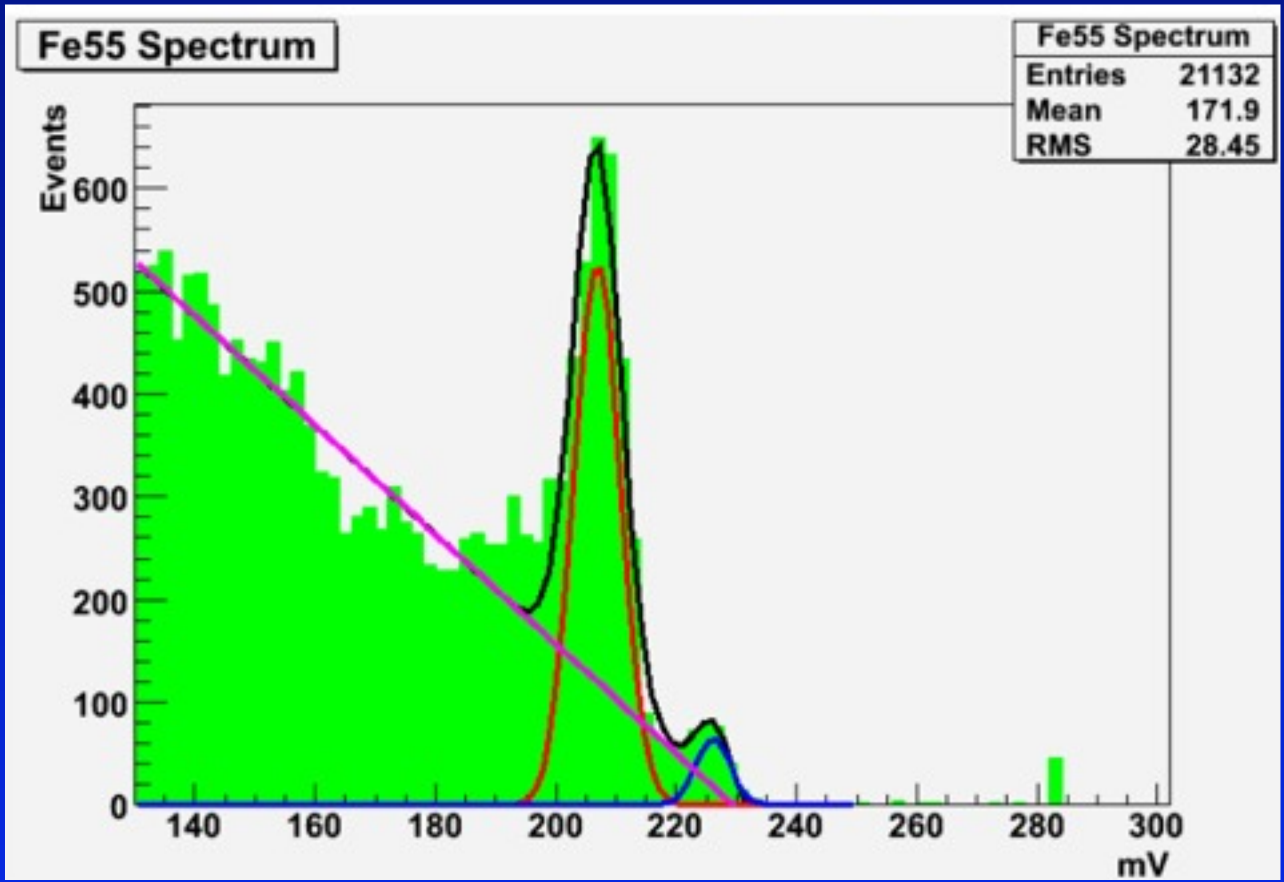




- Gain 136uV/e
- Noise 23e-
- Power 8.9uW
- 150ns "hit" pulse wired to row logic
- Shaped pulses return to baseline

- 50um pixel
- 4 diodes
- 160 transistors
- 27 unit capacitors
- 1 resistor (4Mohm)
- Configuration SRAM
  - Per Pixel Mask
  - Comparator trim (6 bits)

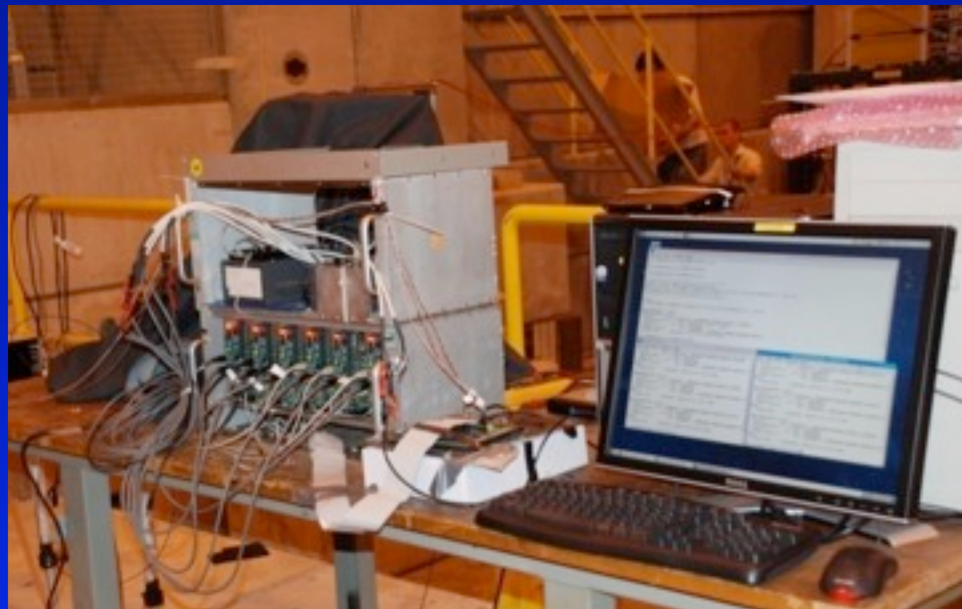
TPAC Fe55



- Primary 55Fe peak gives calibrated gain of 128μV/e−
- Width of 55Fe peak gives noise of 27e−
- See Kα and Kβ clearly separated

TPAC beam test

- TPAC in beam tests
  - 120 GeV π & 20–120 GeV e^-
  - 6 TPAC sensors (layers) in stack
  - 170k pixels in total
  - 1cm x 1cm active area
  - Three scintillators/PMTs installed
    - Used to tag time of particles within bunch trains
- Data seems good
  - Scintillators/PMTs give good time tags for particles
  - Events were seen in all layers



USB-based DAQ setup on H6B beam line at CERN

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SPiDeR

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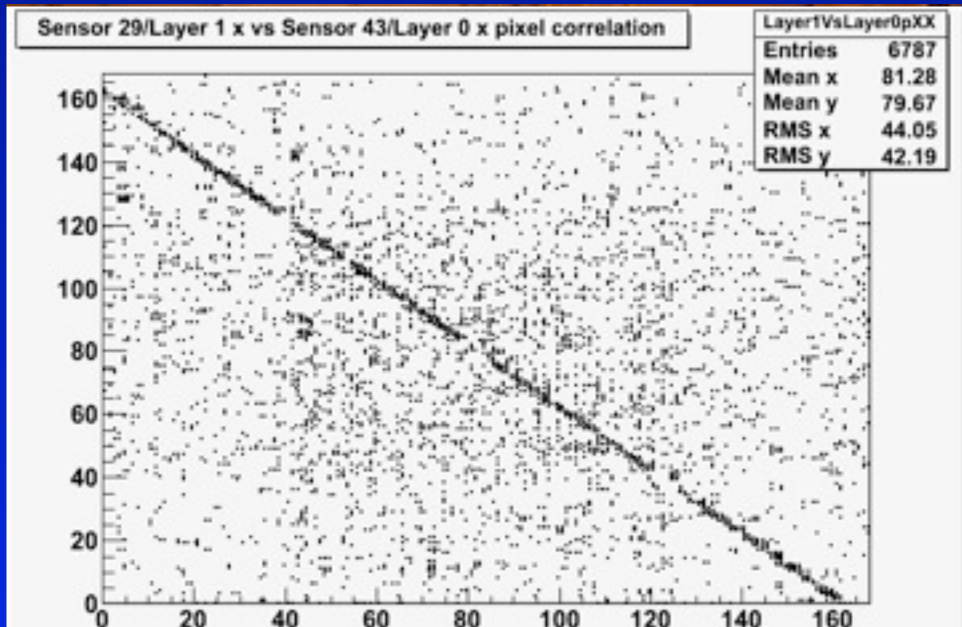

X–X correlation plot for two layers (back-to-back)

Jaap Velthuis, University of Bristol

FORTIS

- FORTIS is the first 4T MAPS for Particle Physics
  - 3T CMOS
    - Simple architecture
    - Readout and charge collection area are the same
  - 4T CMOS
    - Three additional elements
    - Readout and charge collection area are at different points

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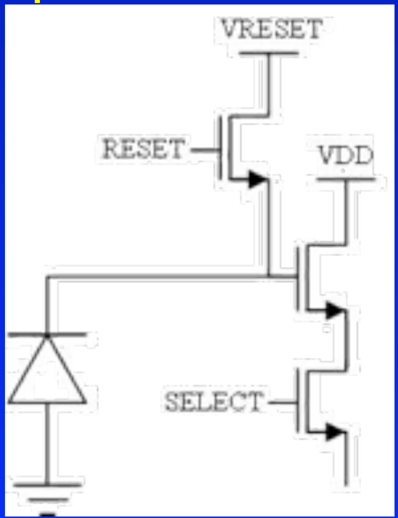

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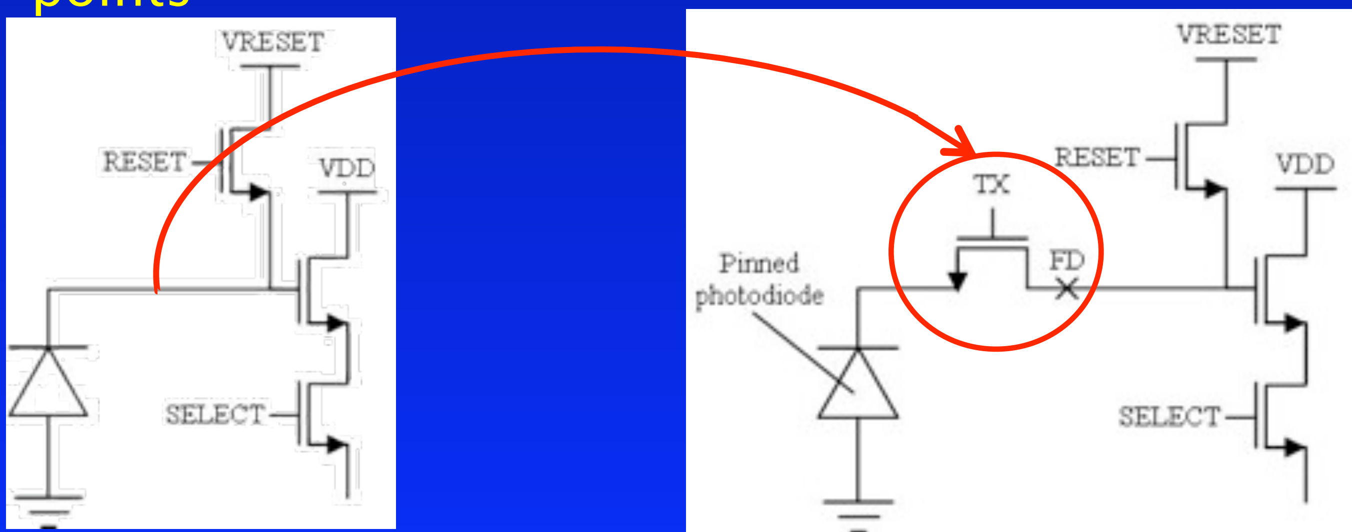

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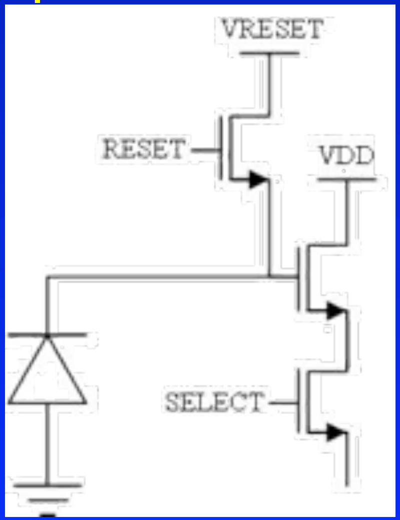
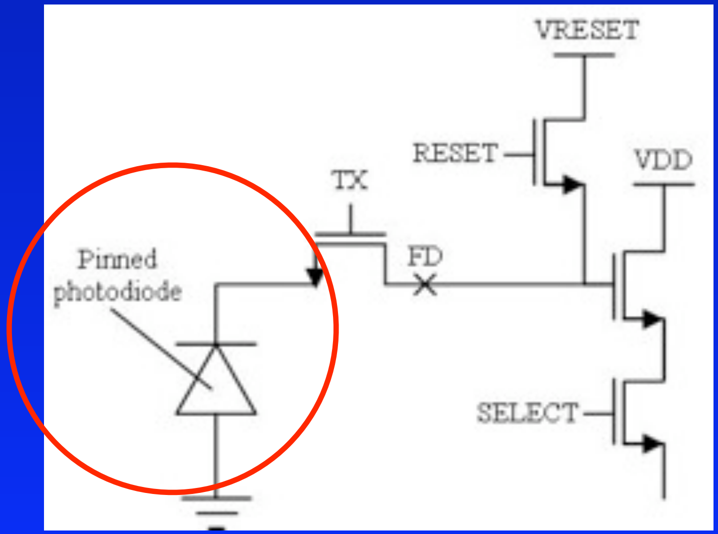
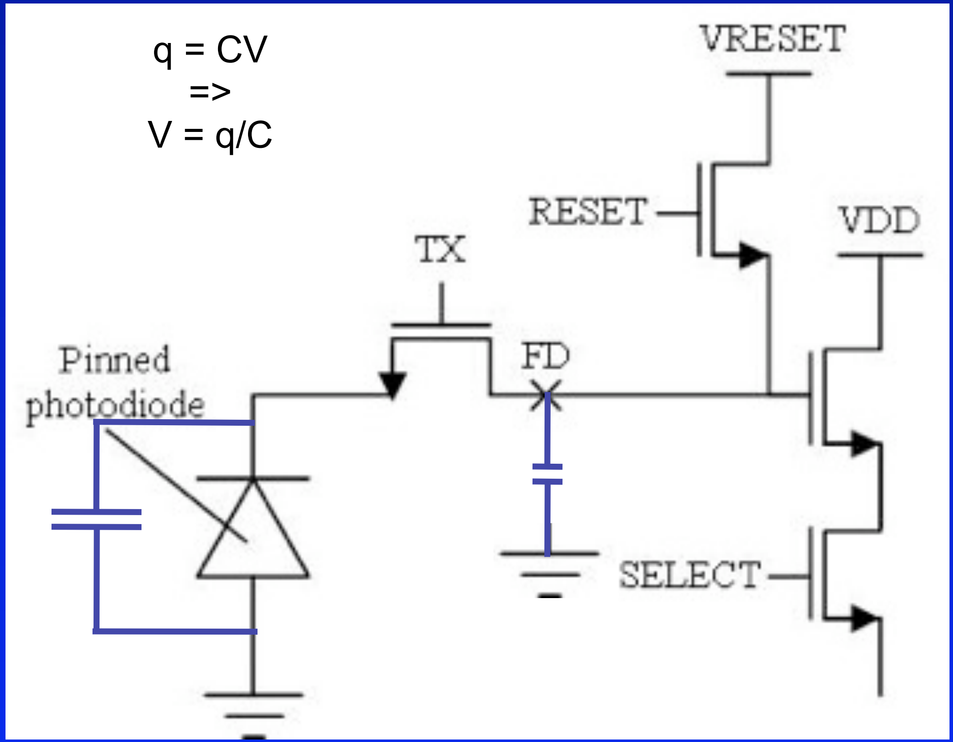




4T Pixel Advantages

- Low Noise
  - readout node separated from charge collection area
  - The reset noise and fixed pattern noise (FPN) can be removed by in-pixel correlated double sampling (CDS)
- High Conversion Gain
  - Charge is collected on large diode then transferred to the floating diffusion
  - Large C gives fast and complete charge collection
  - Small C yields large gain



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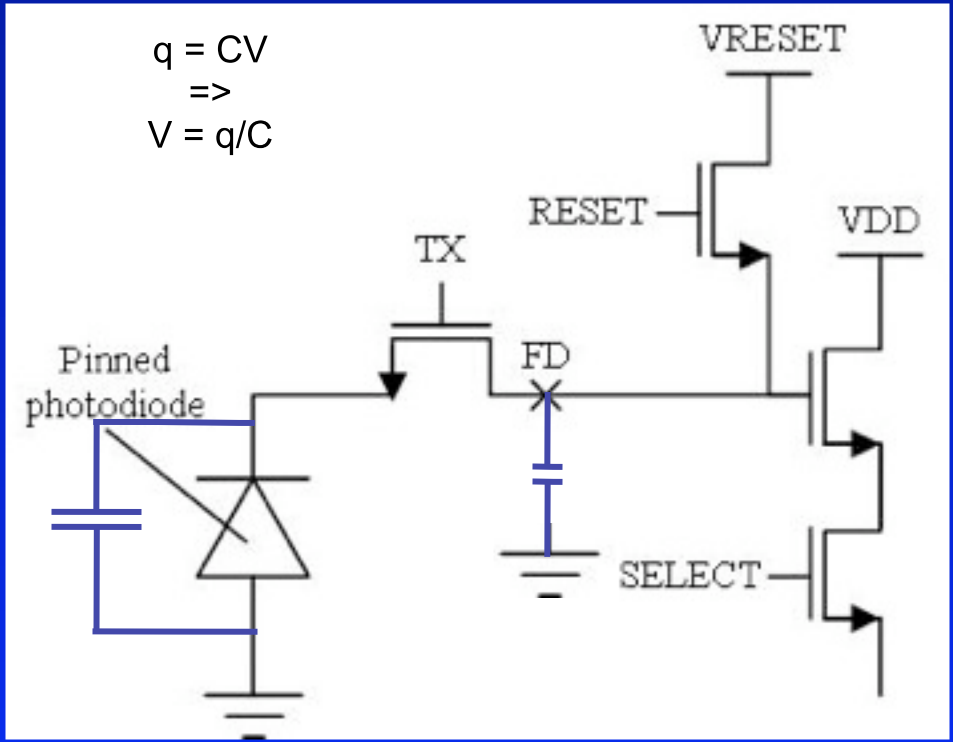

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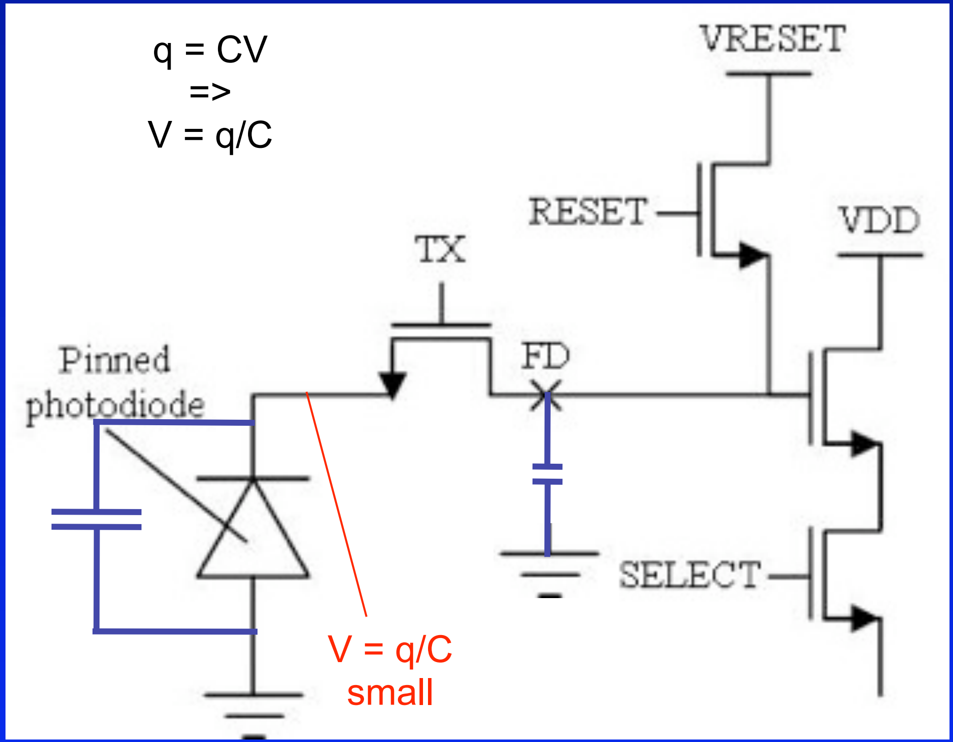

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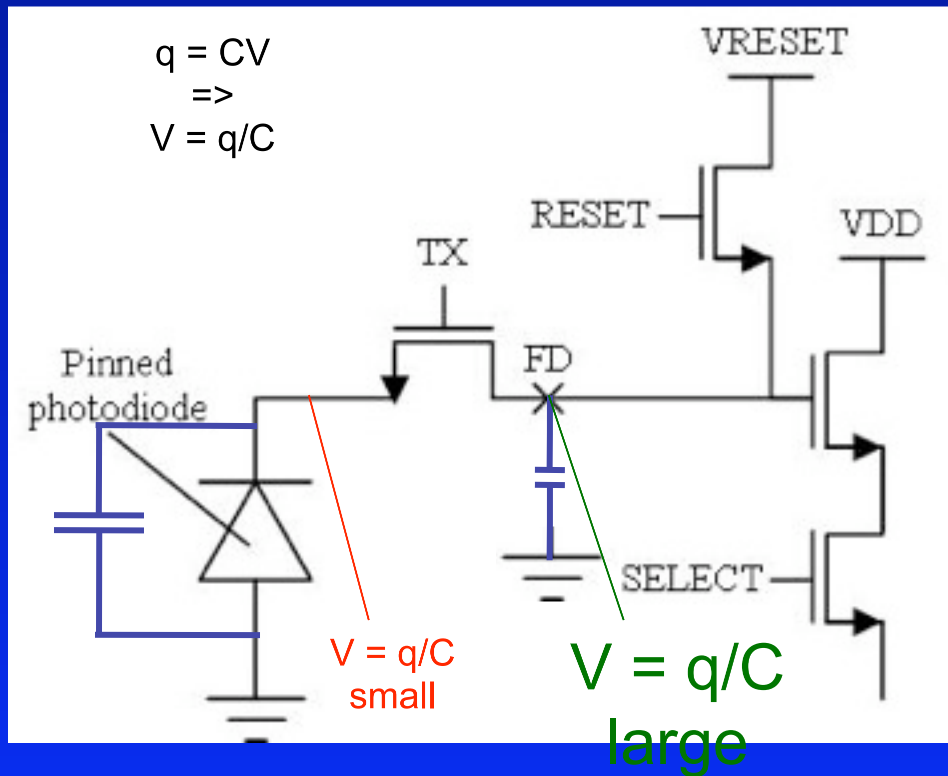

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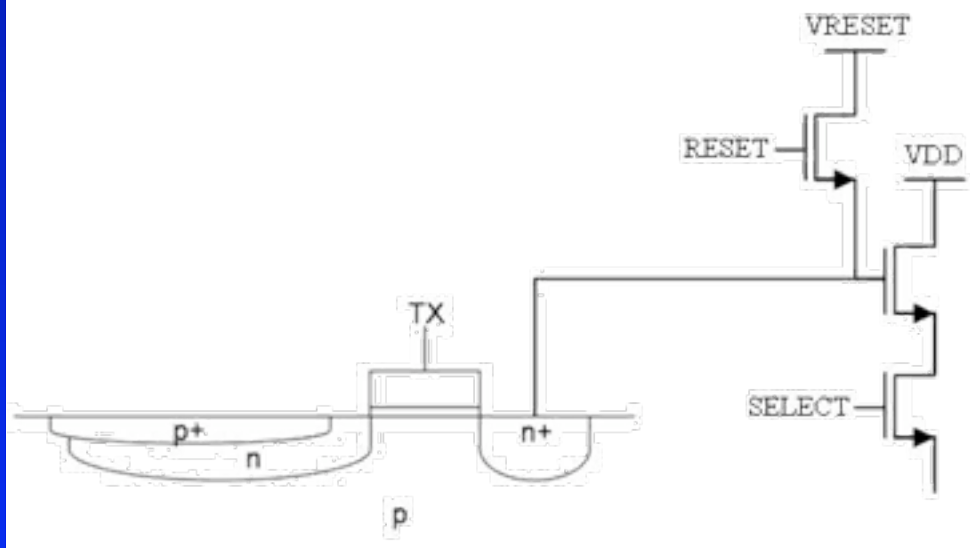

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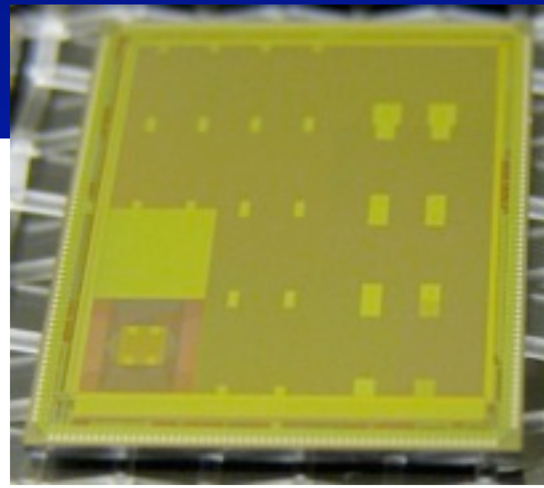
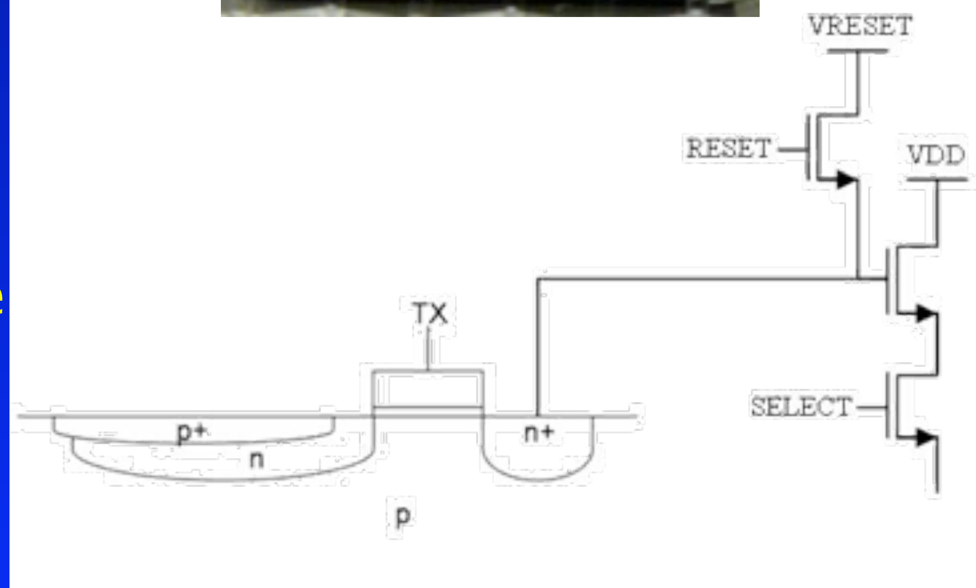
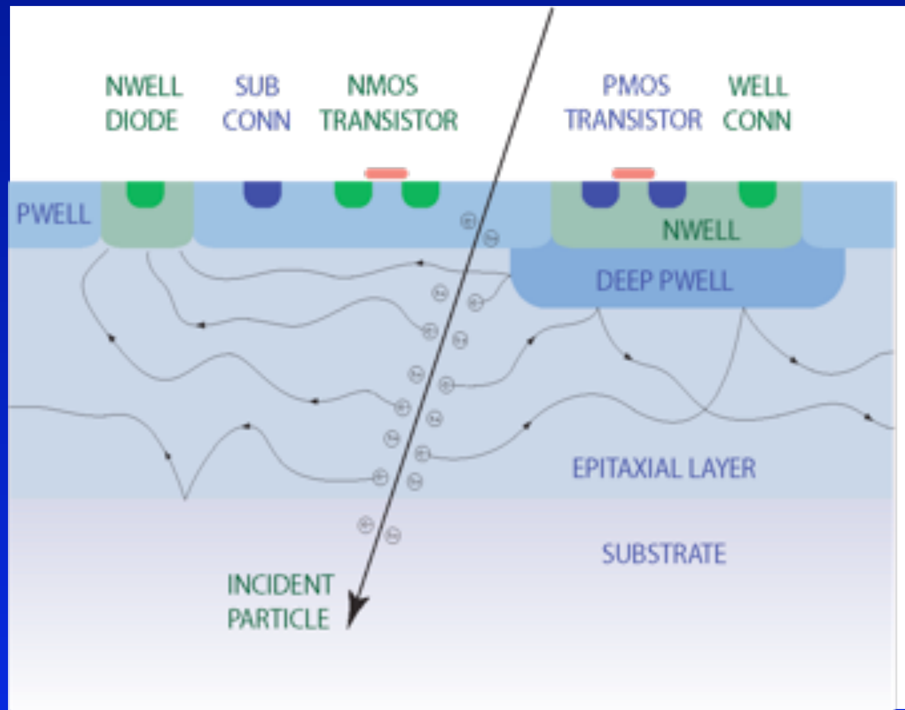


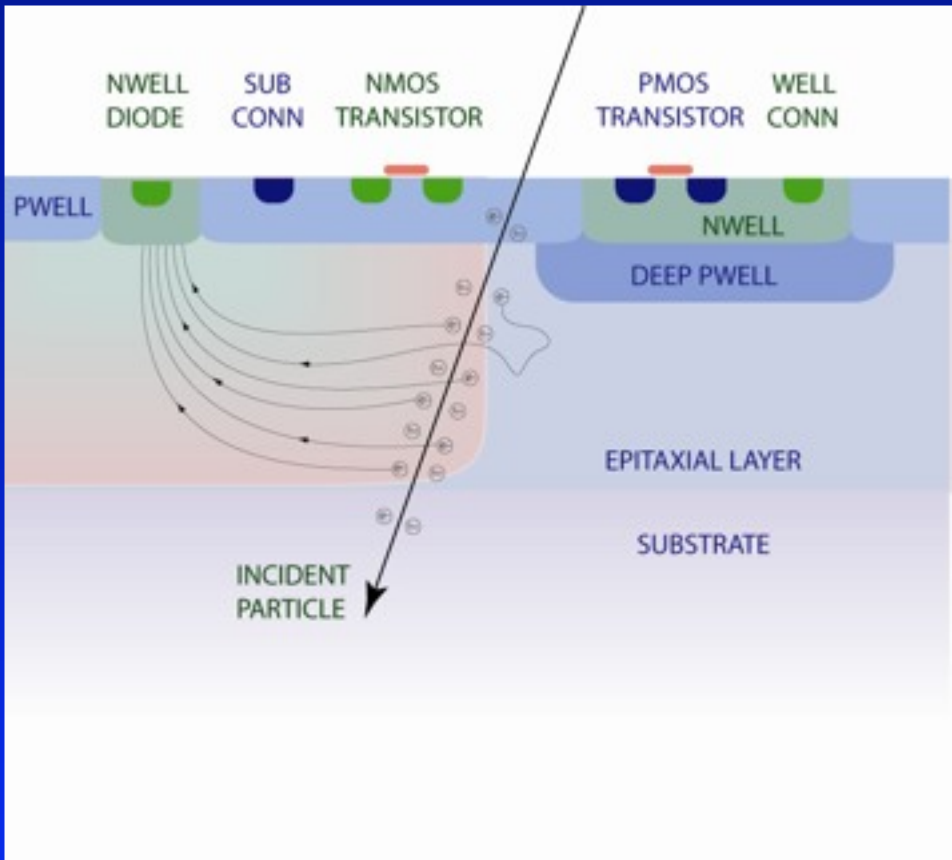


Deep Pwell

- Problem in MAPS:
  - PMOS electronics need Nwell
  - Nwell acts as charge collection diode
  - So can't make PMOS without losing huge amount of Q
- New development: make deep pwell with Nwell inside → can do CMOS
  - Road to data processing in pixel

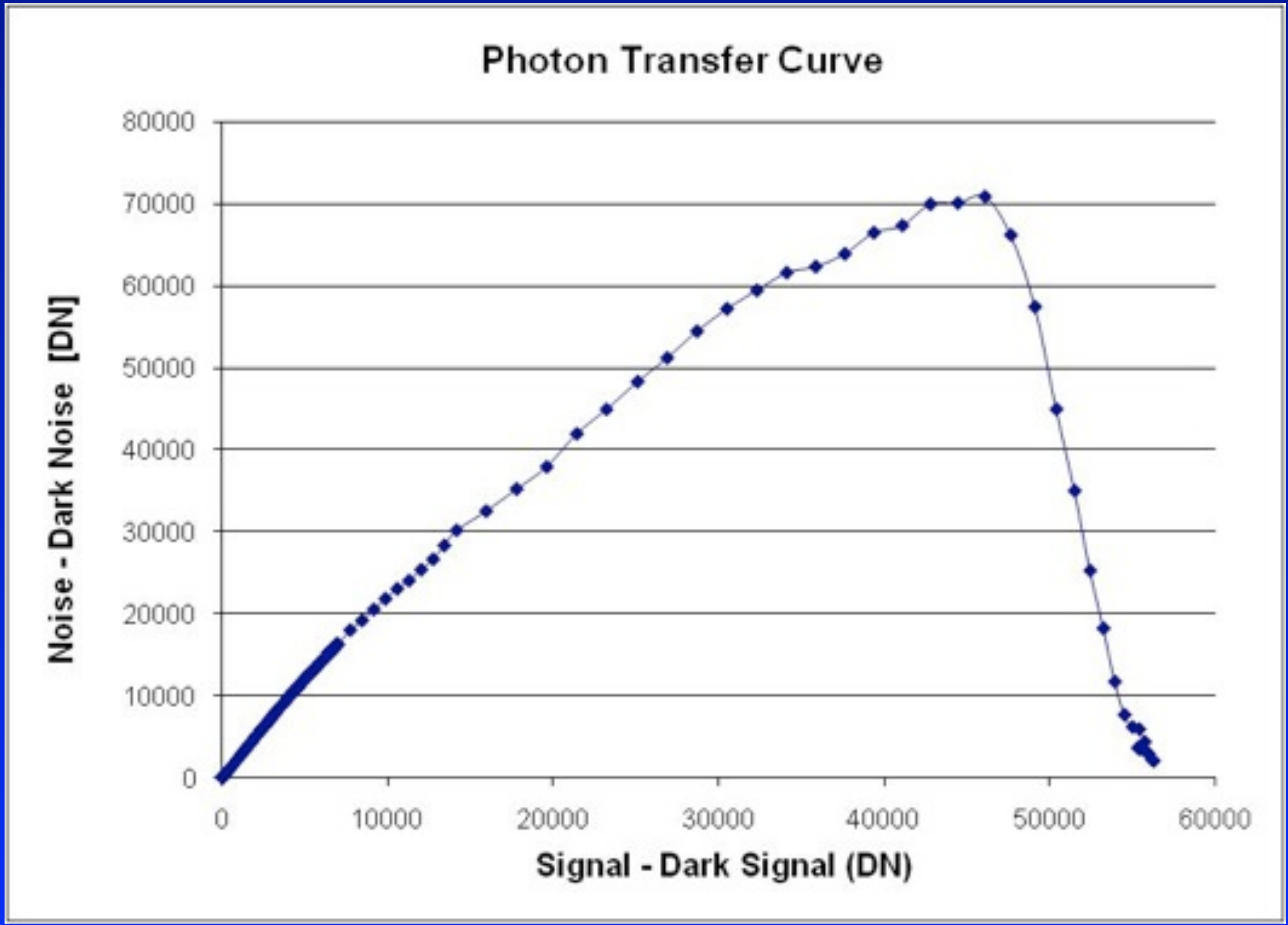


Substrate Resistivity



- High resistivity (intrinsic) silicon enlarges the depletion region to fully occupy the pixel
  - Majority of deposited charge now falls in a depletion region and is collected by electric field
  - Improved charge collection efficiency
  - Faster charge collection (drift vs diffusion)
- Some FORTIS have high res

FORTIS Results



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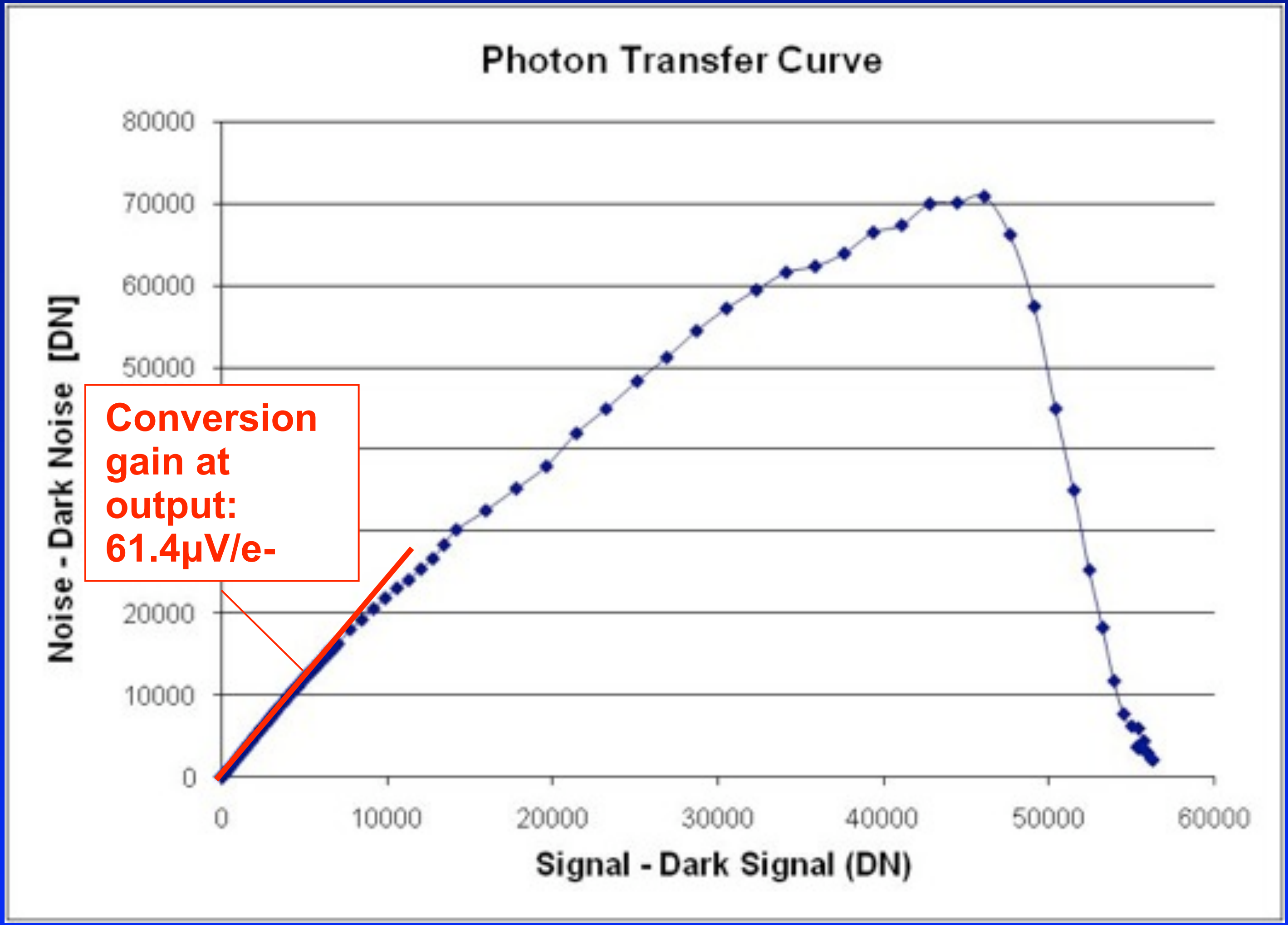

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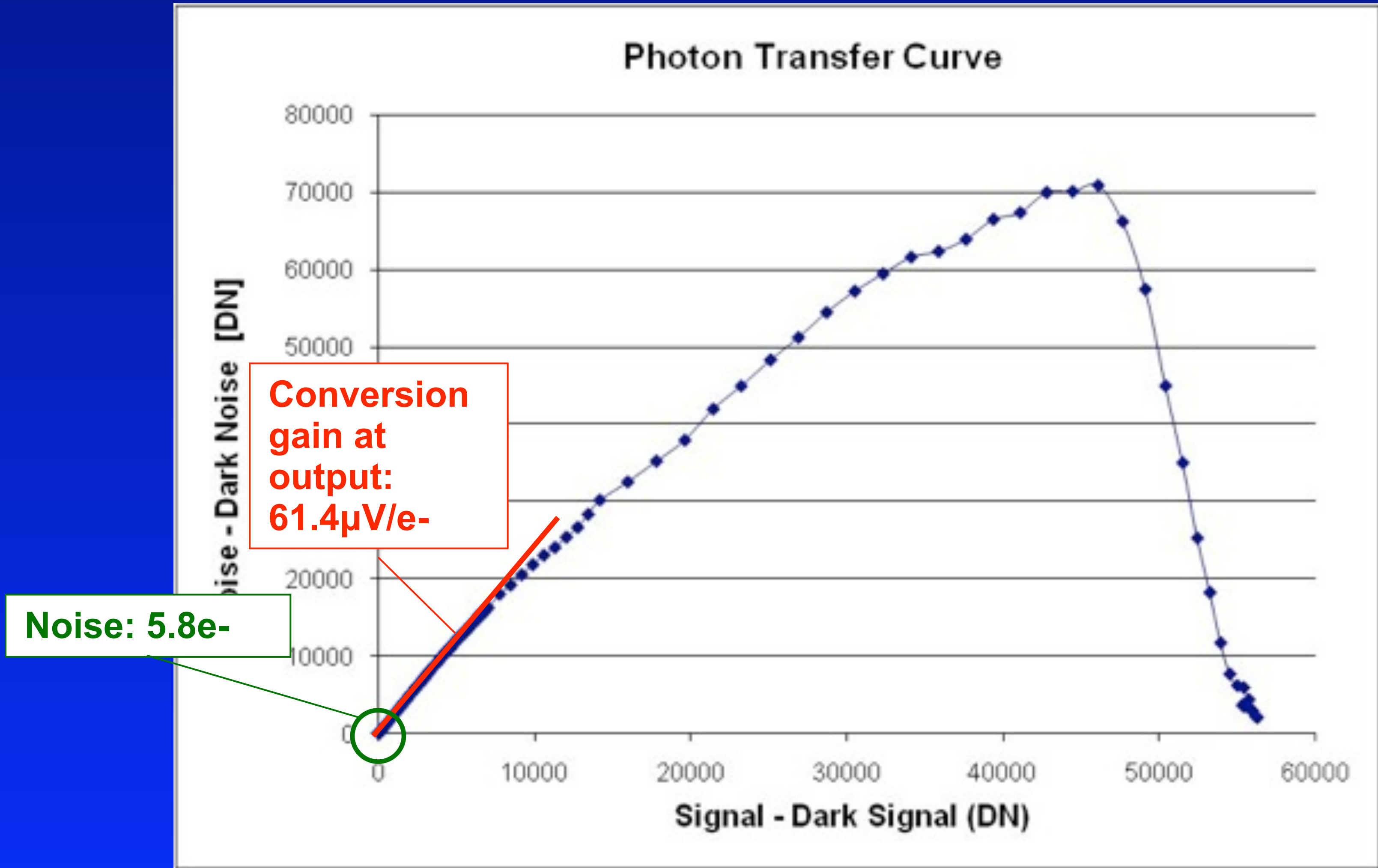

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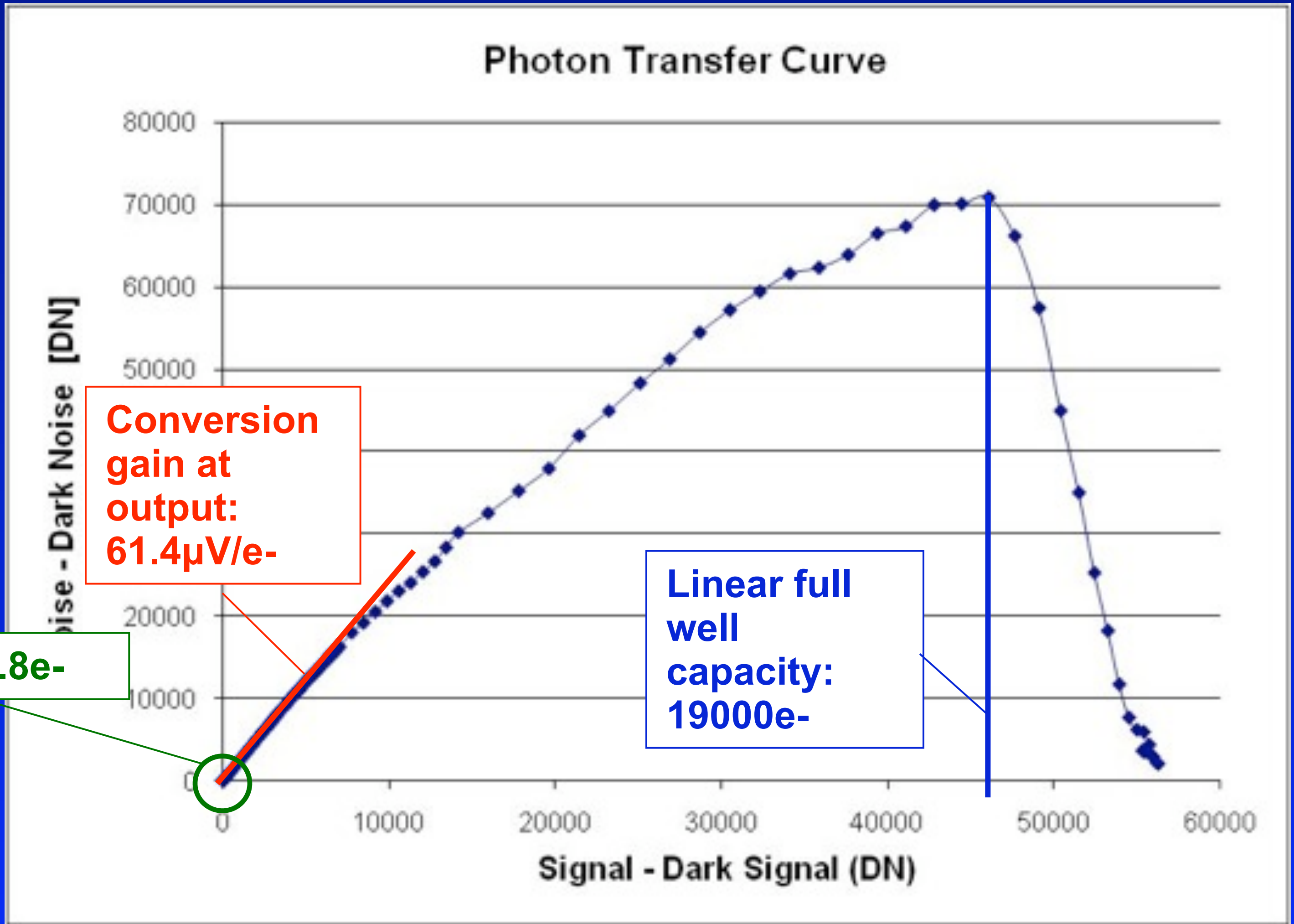

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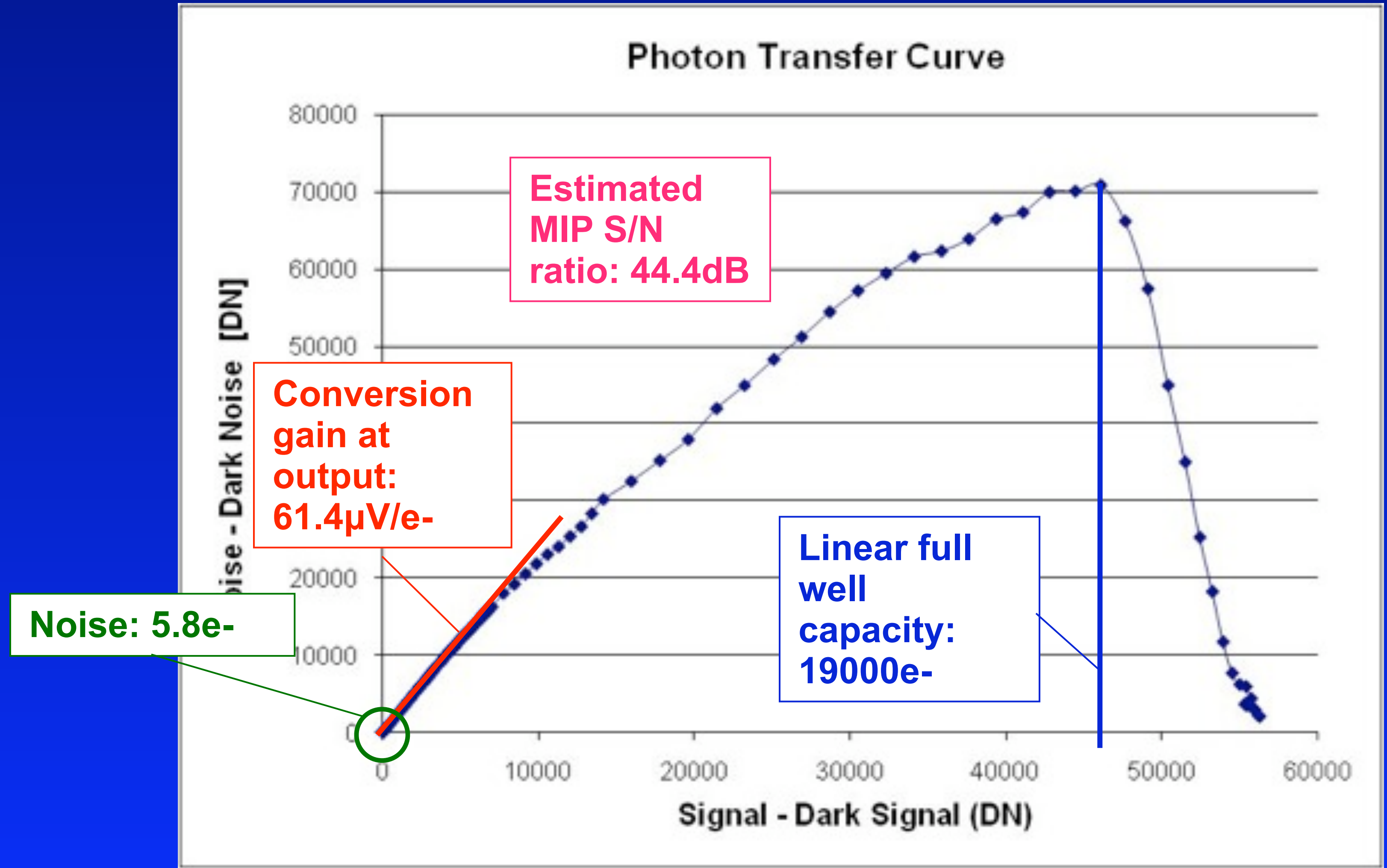

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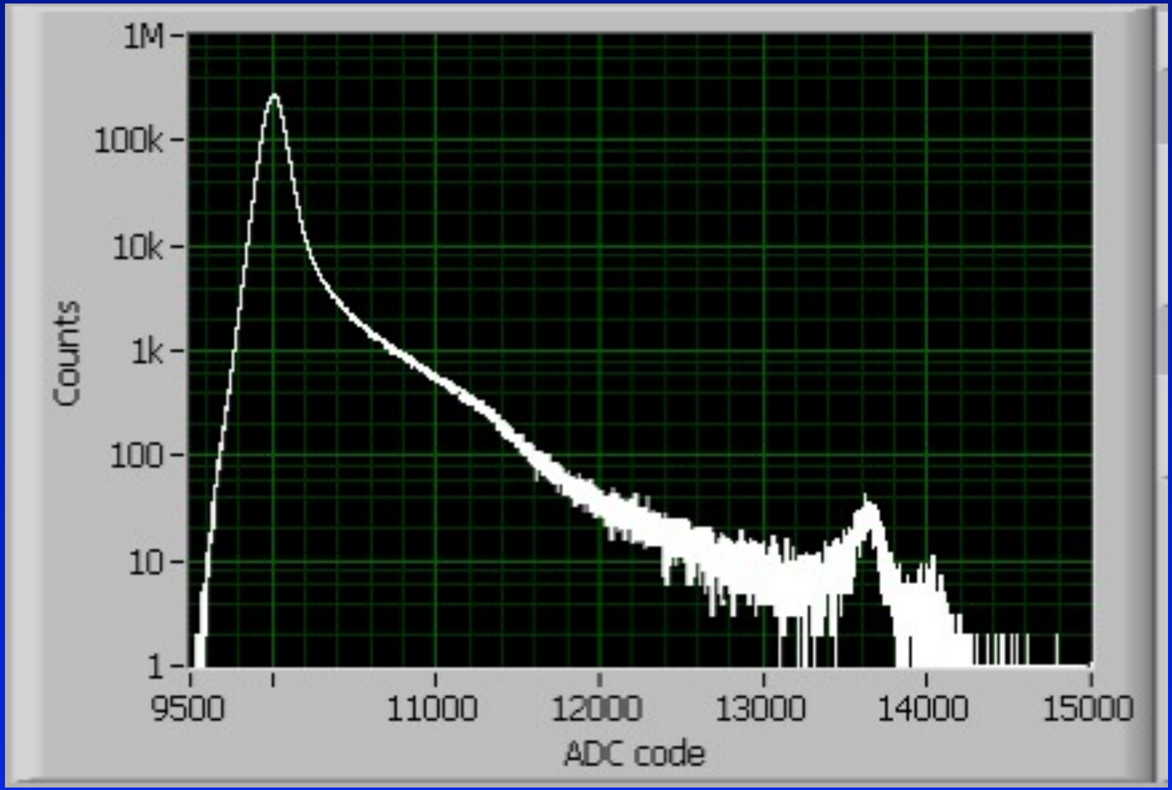
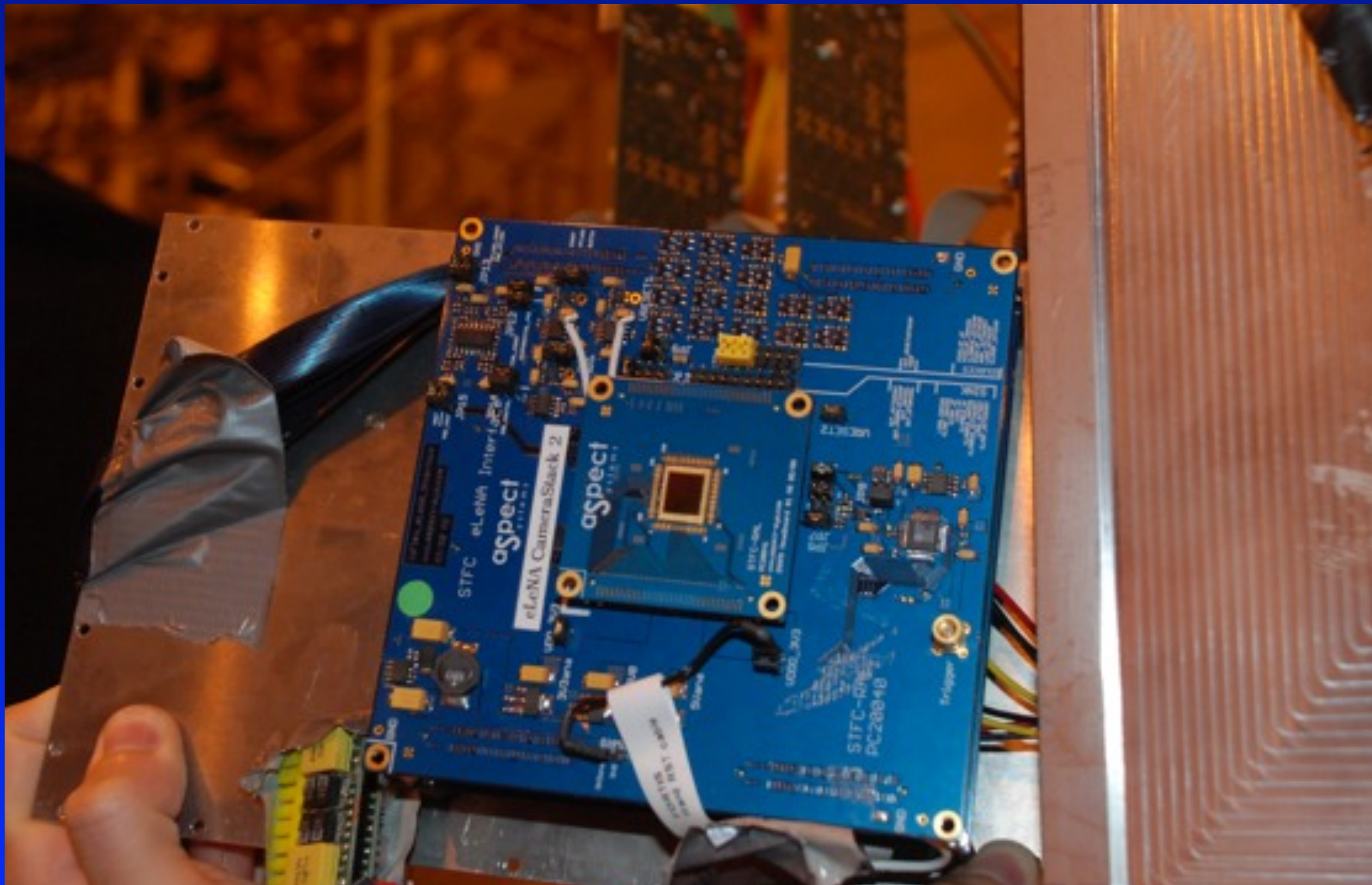


- ^{55}Fe Photons (preliminary)
  - Conversion gain = 56 μV/e⁻
  - Noise (from dark fwhm) = 7.7e⁻

Some test beam pictures



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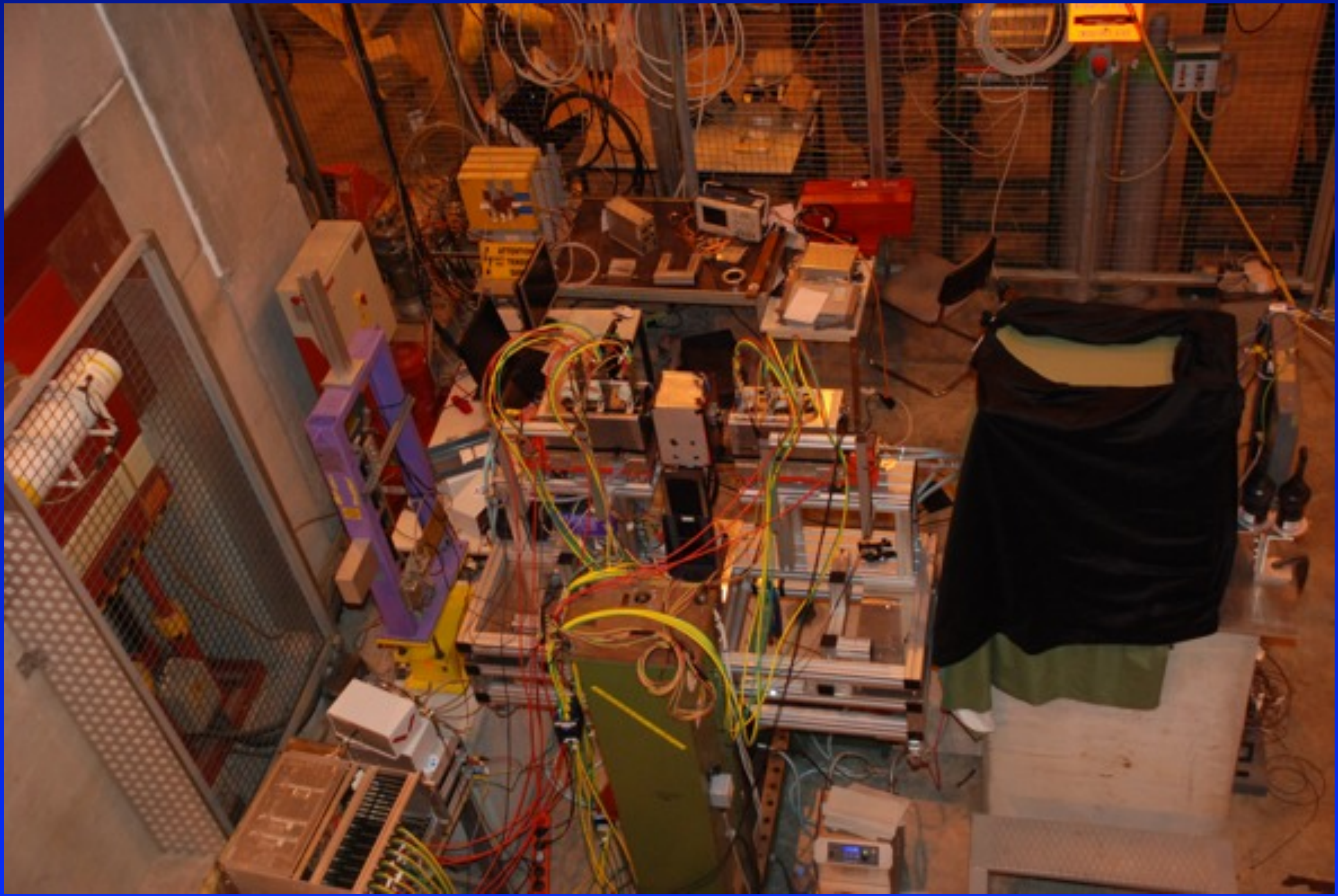
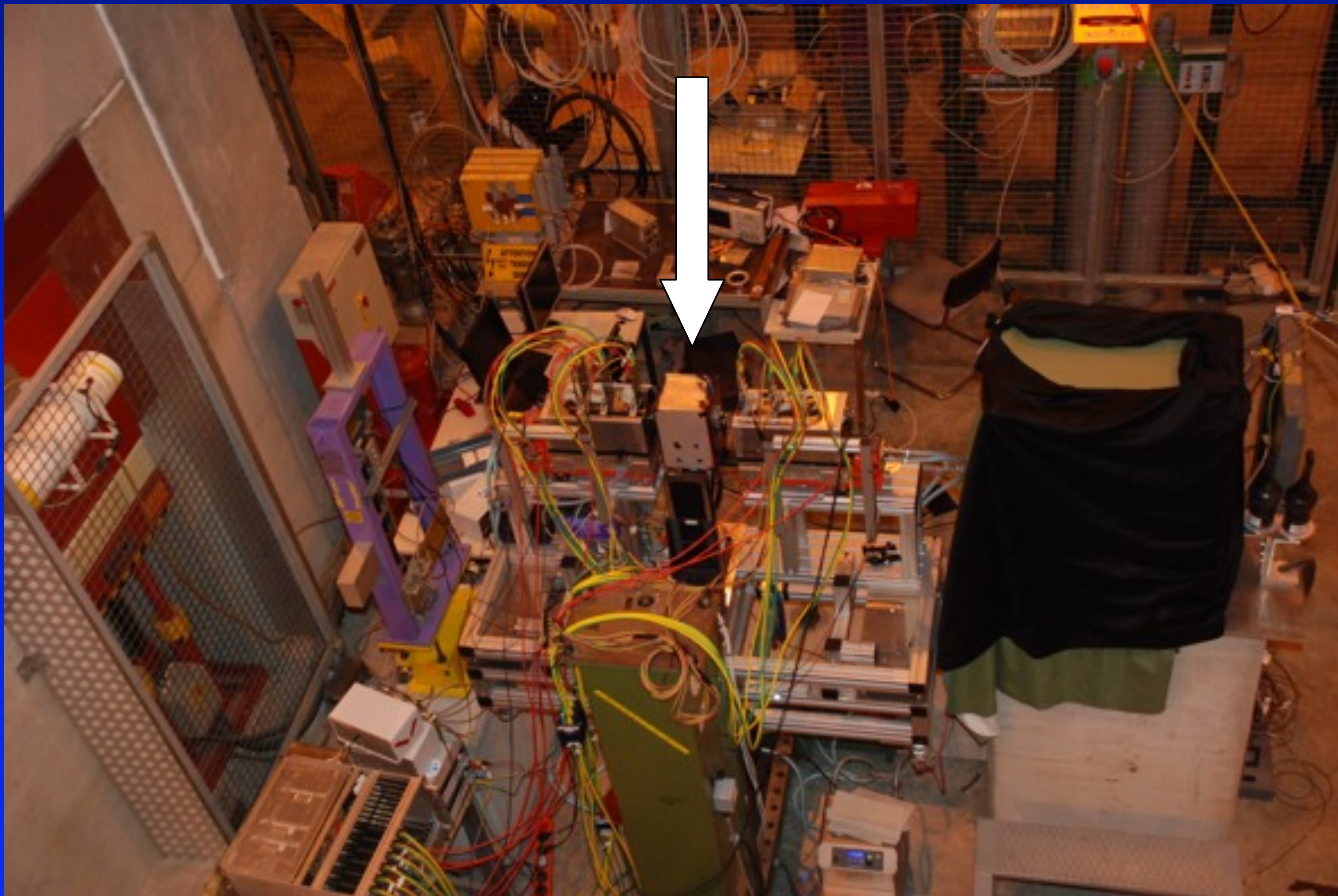
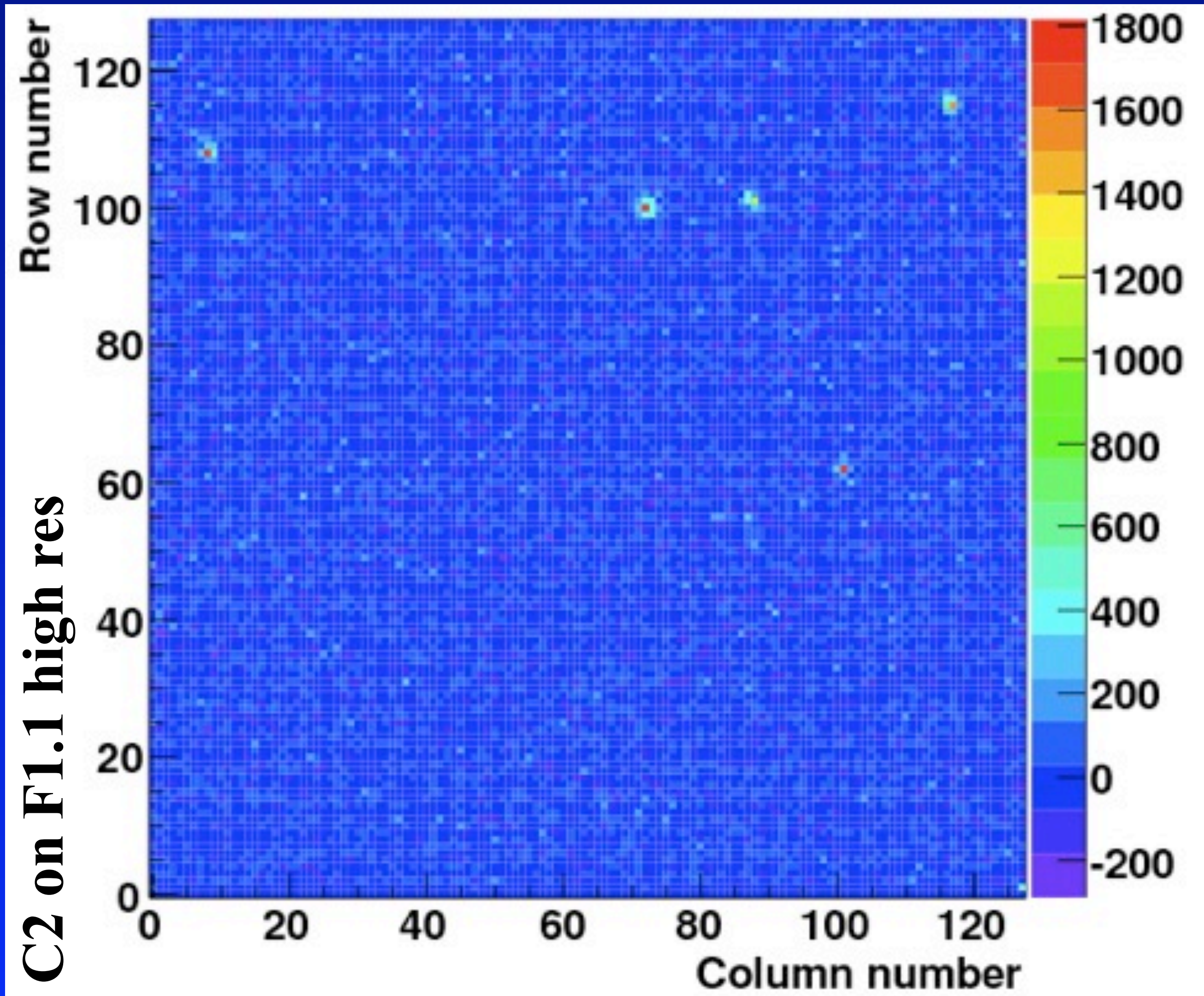
Some test beam pictures



Some test beam pictures



We see hits...



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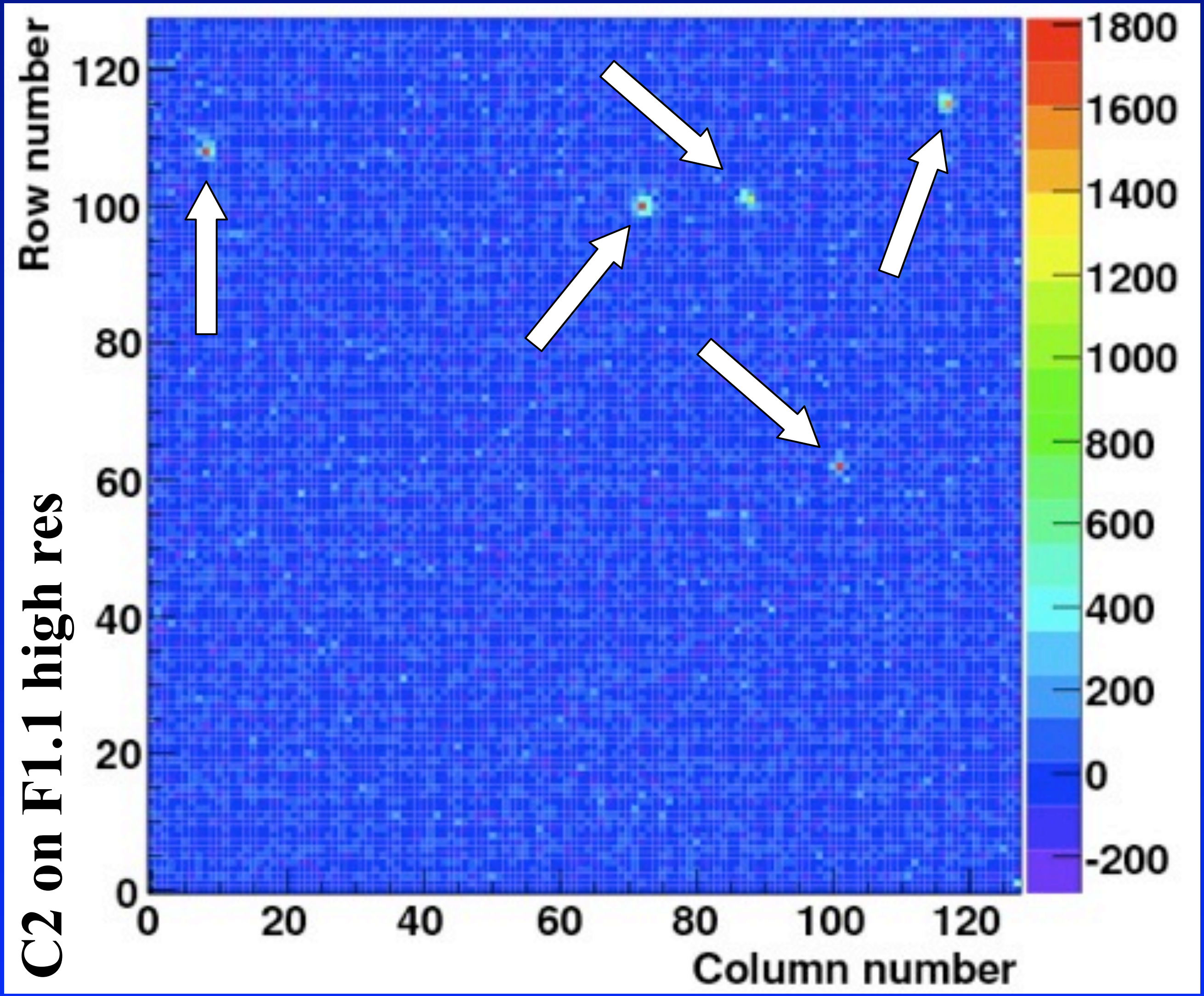

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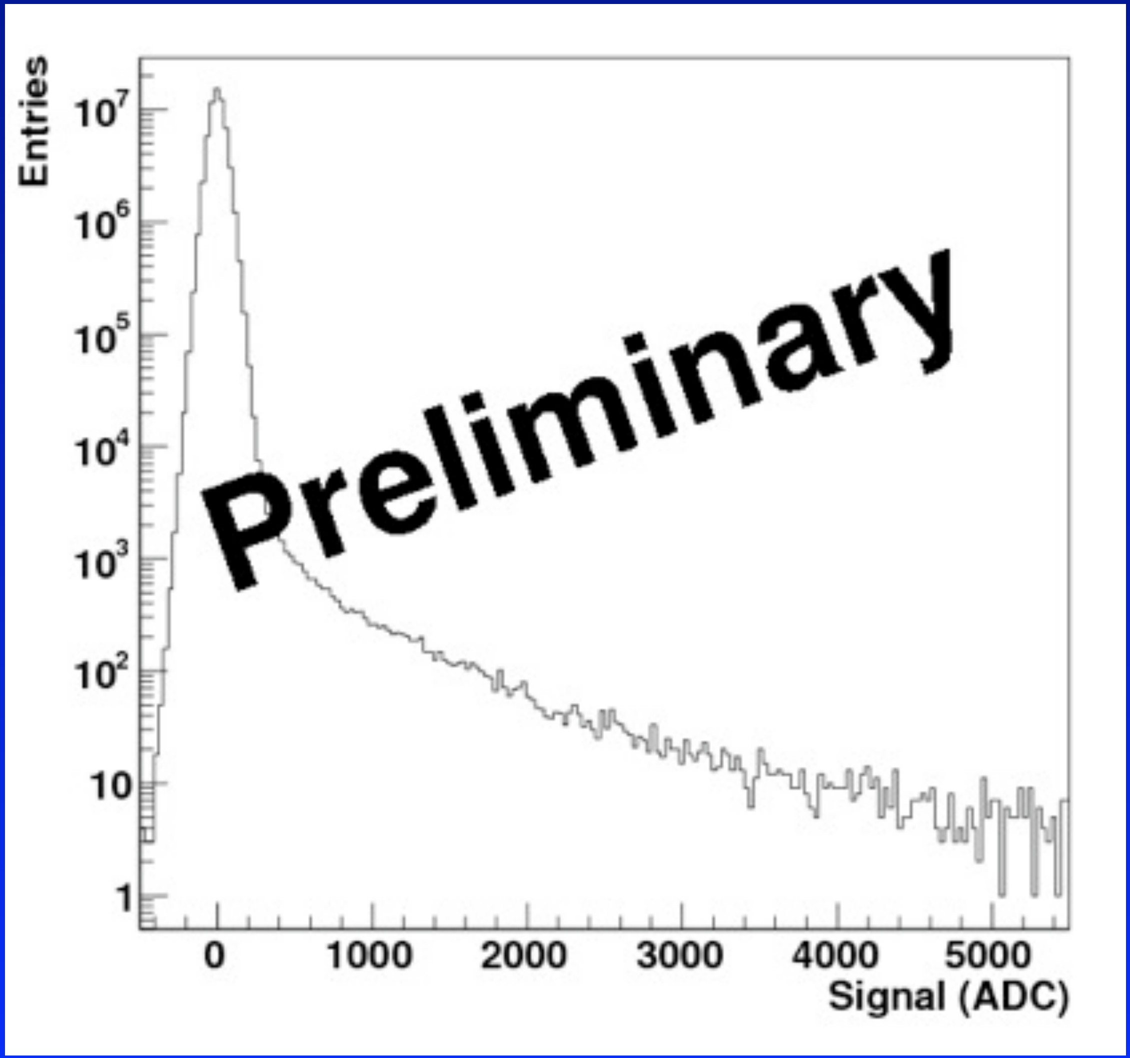
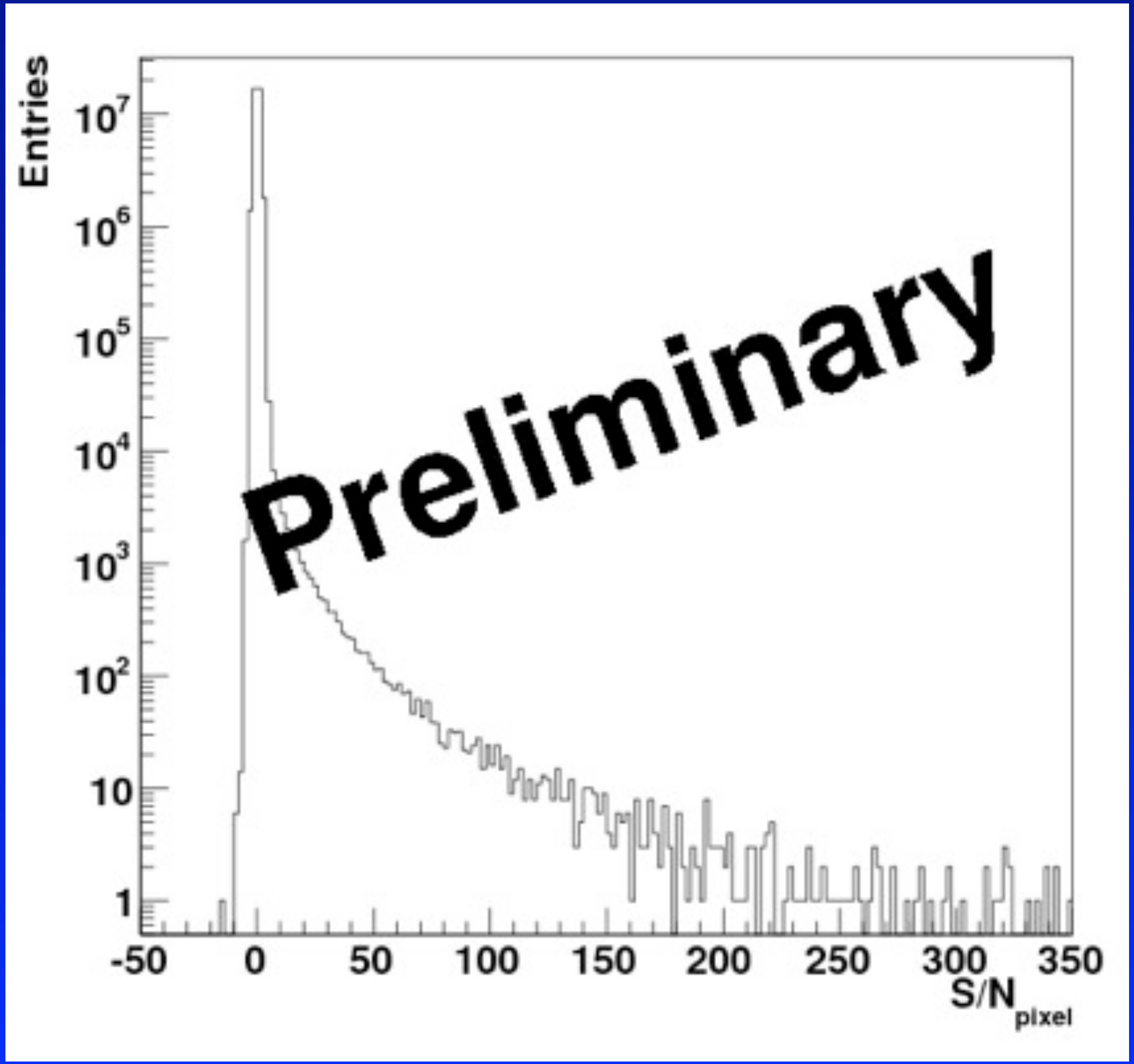
Raw signals



Entries
10^7
10^6
10^5
10^4
10^3
10^2
10
1
0
1000
2000
3000
4000
5000
Signal (ADC)
Preliminary

Raw S/N for each pixel



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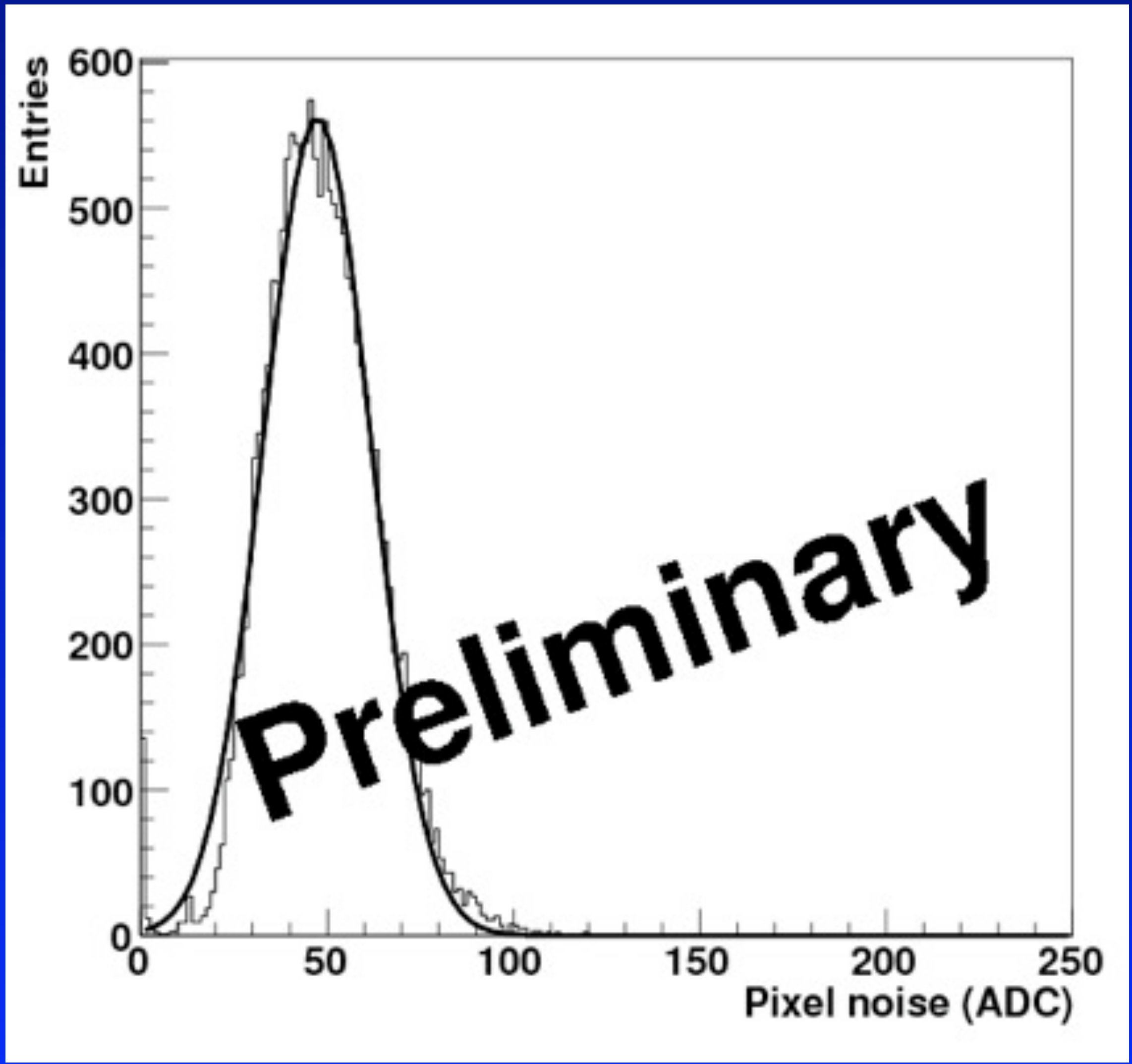
Pixel Noise



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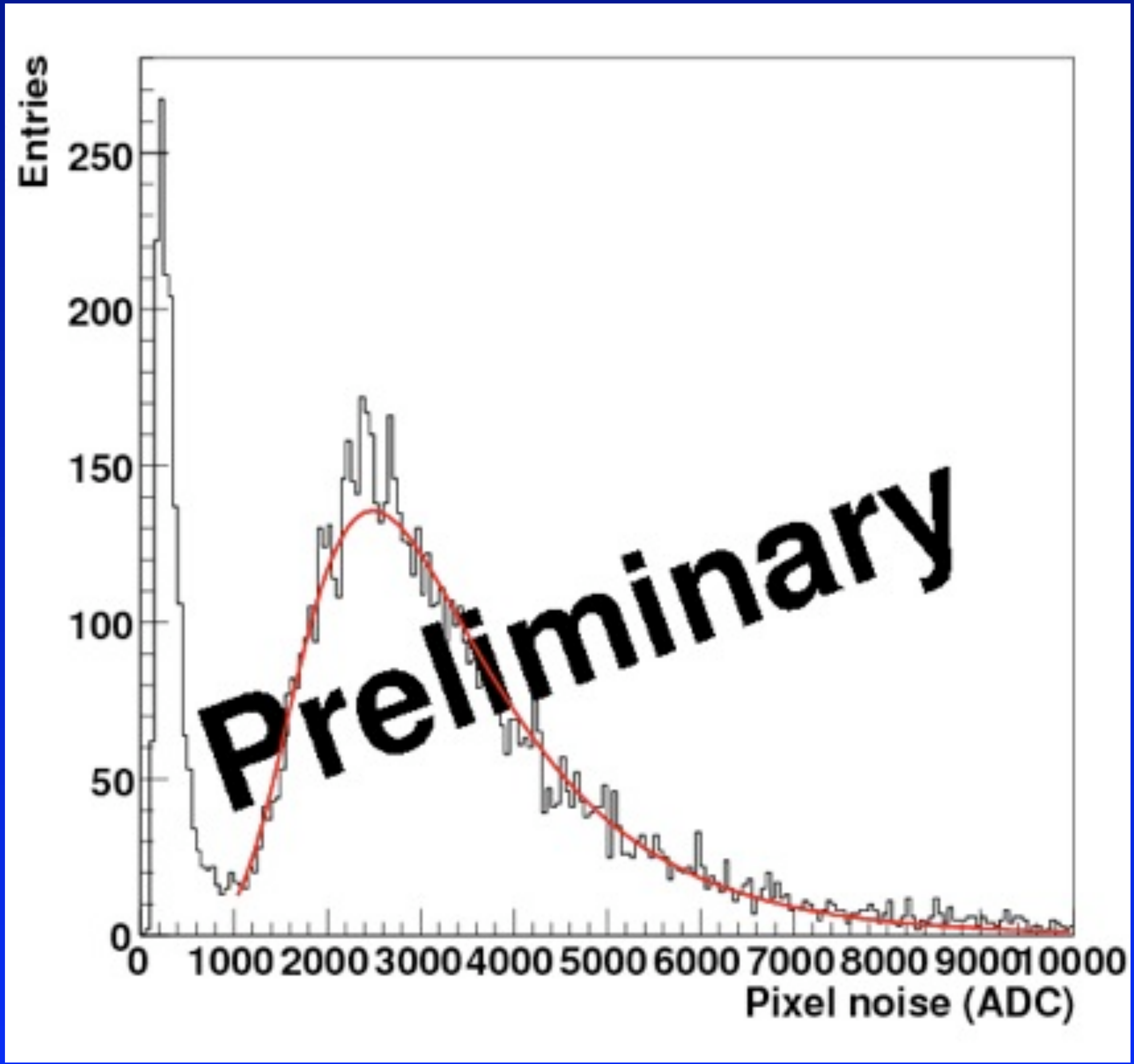
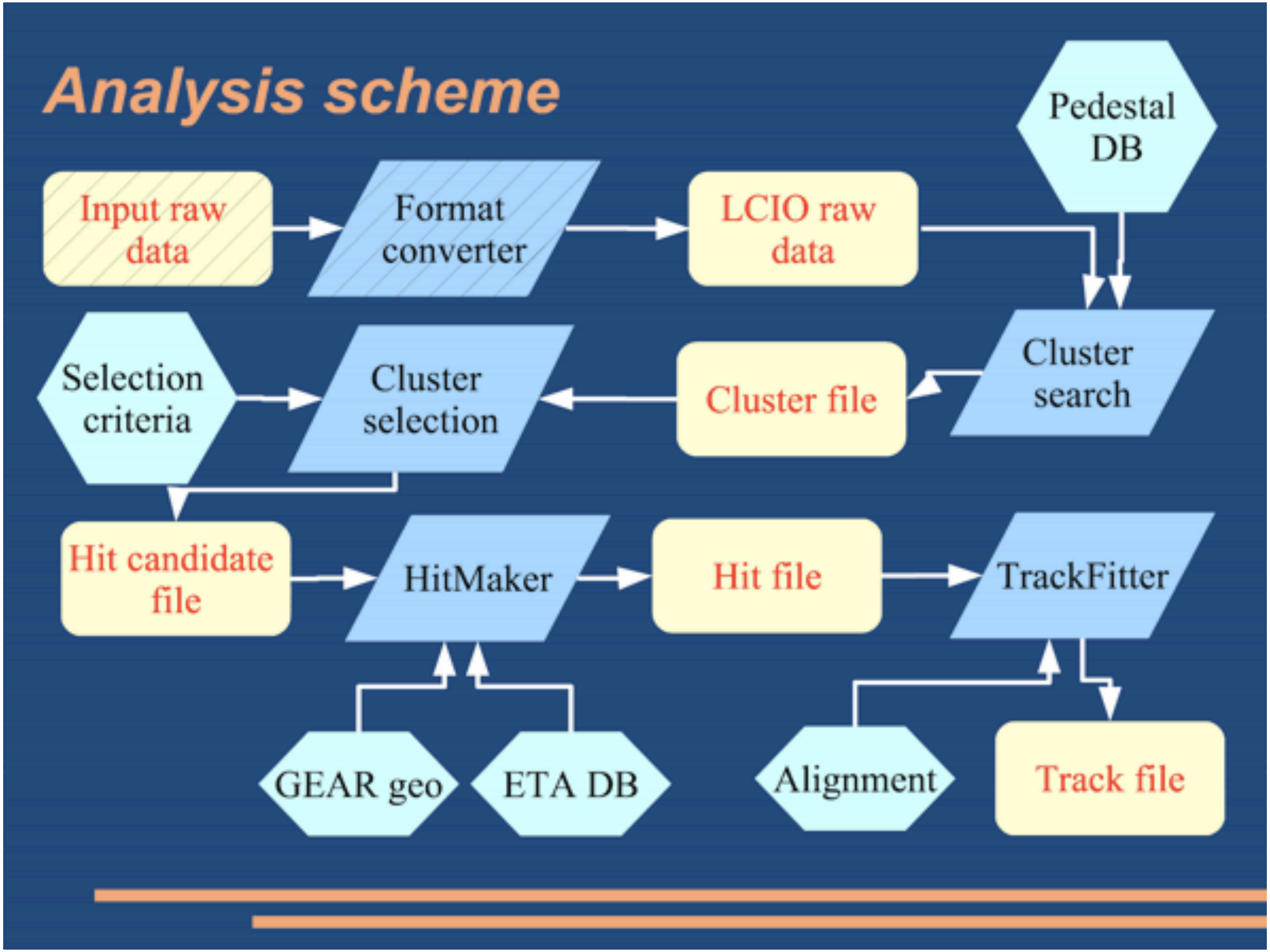
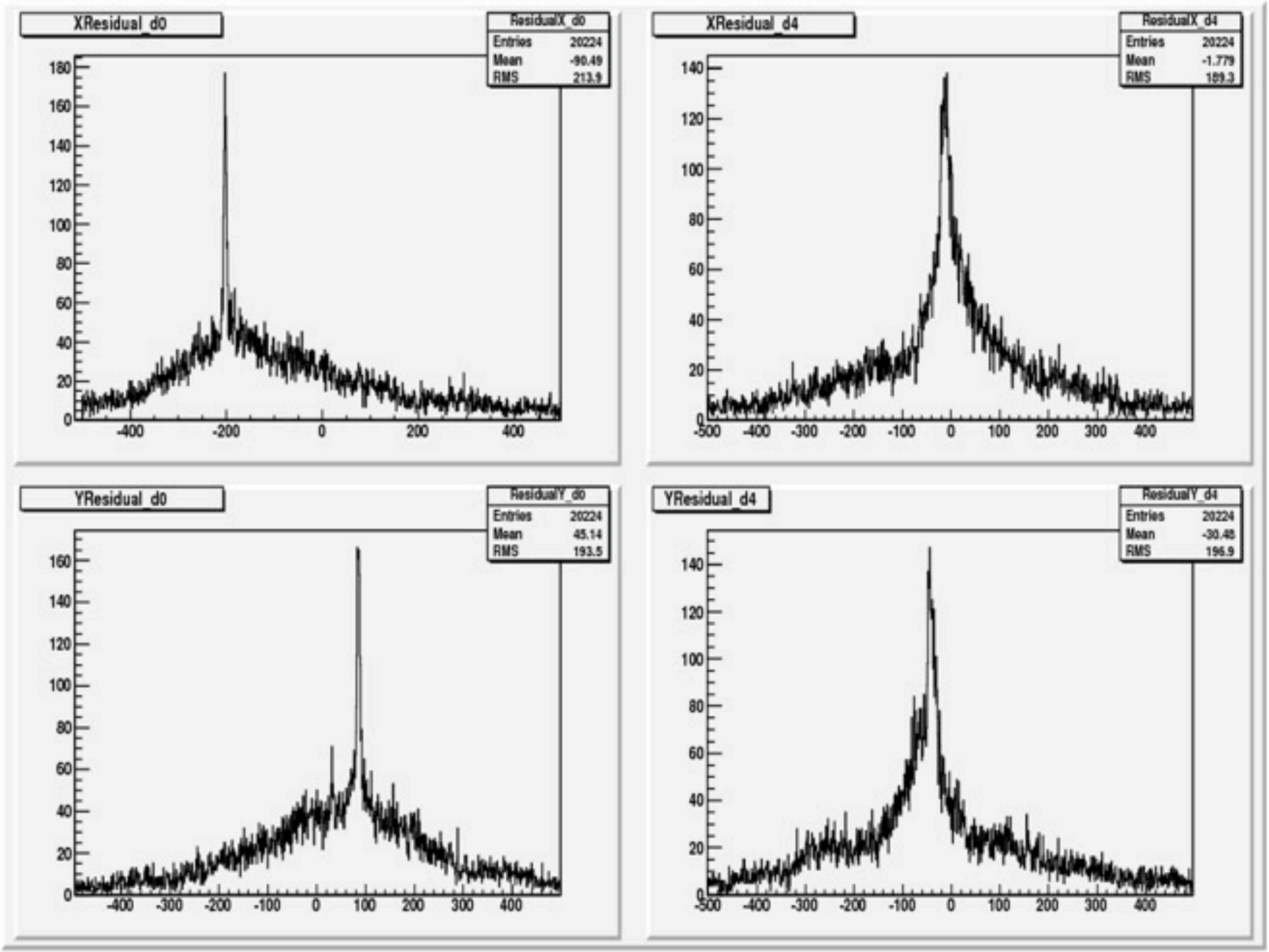
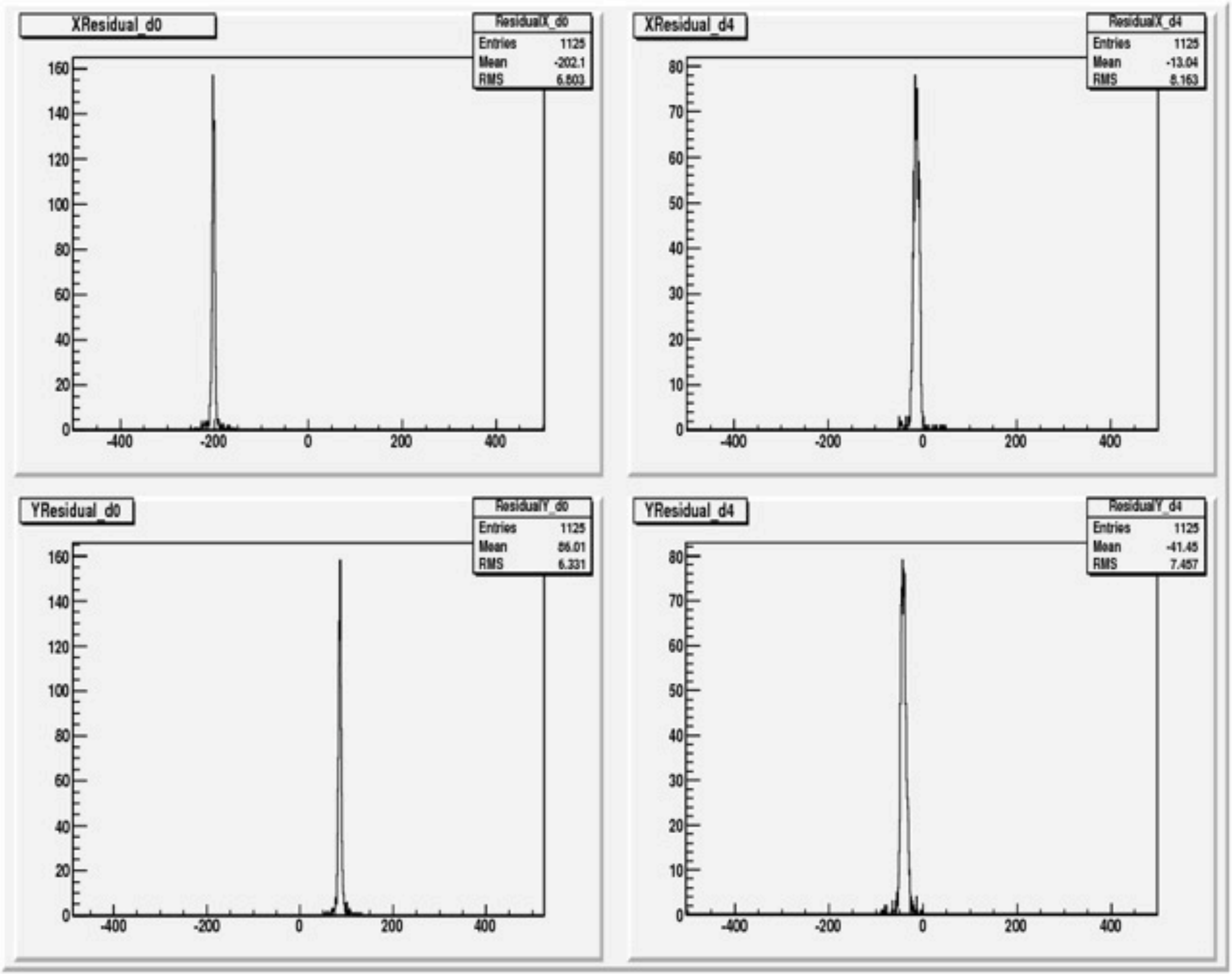
Cluster signal

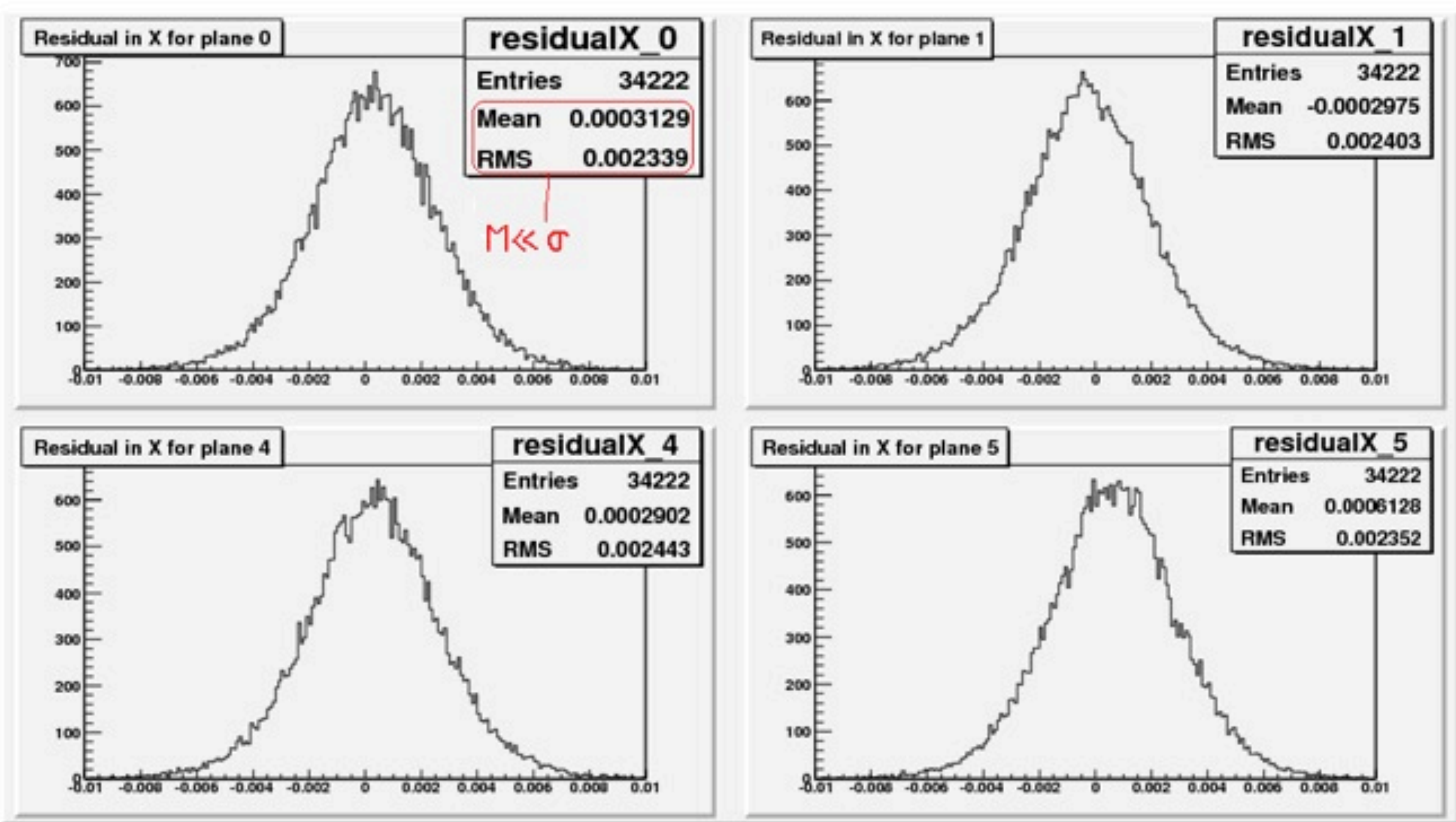


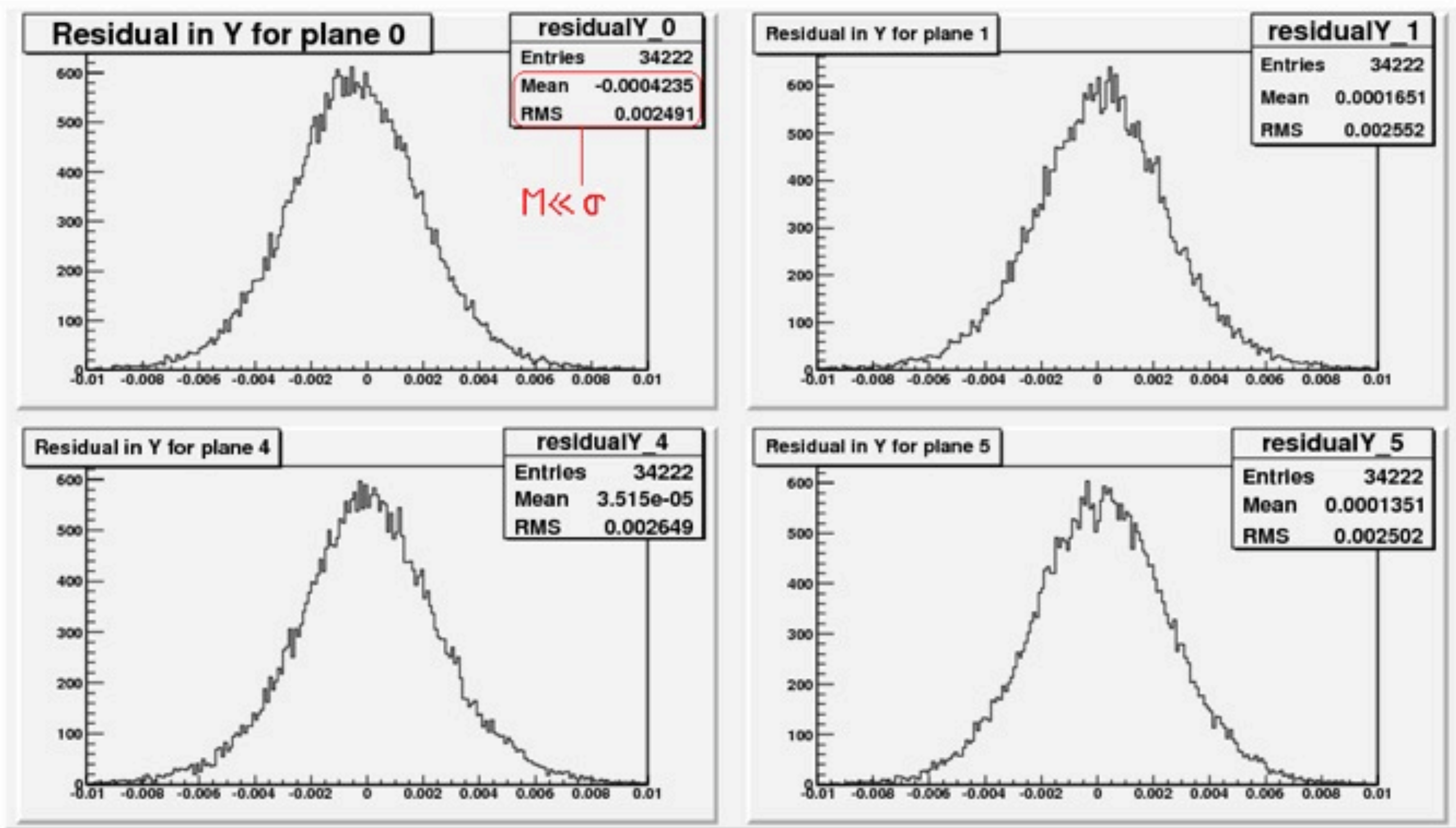
- Corresponds to S/N~50
- Data analysis just started
- Still need to match up with telescope

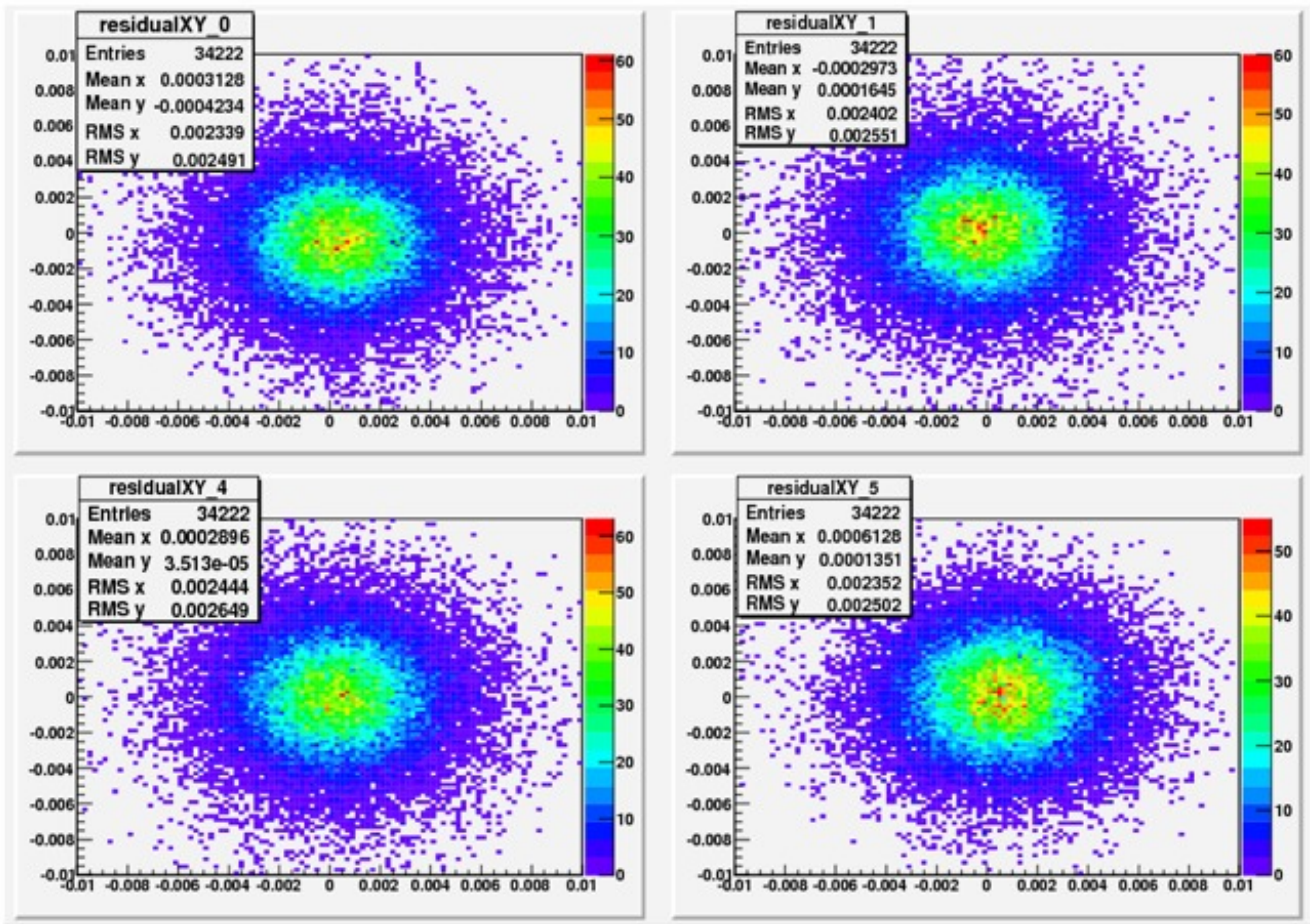

Analysis scheme
Pedestal DB
Input raw data
Format converter
LCIO raw data
Selection criteria
Cluster selection
Cluster file
Cluster search
Hit candidate file
HitMaker
Hit file
TrackFitter
GEAR geo
ETA DB
Alignment
Track file


XResidual_d0
ResidualX_d0
Entries 20224
Mean -90.49
RMS 213.9
XResidual_d4
ResidualX_d4
Entries 20224
Mean -1.779
RMS 189.3
YResidual_d0
ResidualY_d0
Entries 20224
Mean 45.14
RMS 193.5
YResidual_d4
ResidualY_d4
Entries 20224
Mean -30.48
RMS 196.9


XResidual_d0
ResidualX_d0
Entries 1125
Mean -202.1
RMS 6.803
XResidual_d4
ResidualX_d4
Entries 1125
Mean -13.04
RMS 8.163
YResidual_d0
ResidualY_d0
Entries 1125
Mean 86.01
RMS 6.331
YResidual_d4
ResidualY_d4
Entries 1125
Mean -41.45
RMS 7.457

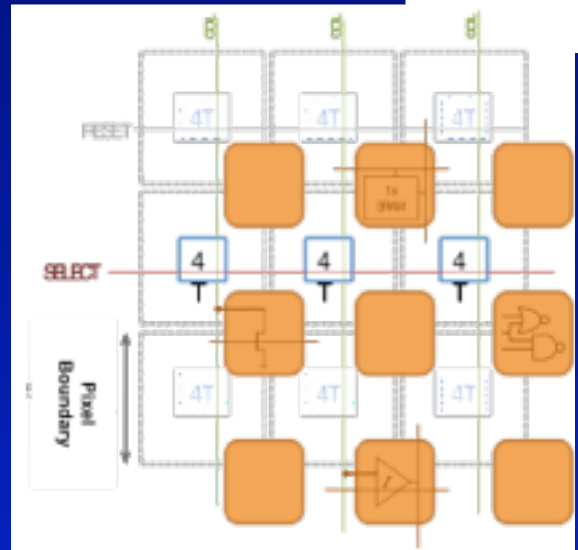

Residual in X for plane 0
residualX_0
Entries 34222
Mean 0.0003129
RMS 0.002339
M≪σ
Residual in X for plane 1
residualX_1
Entries 34222
Mean -0.0002975
RMS 0.002403
Residual in X for plane 4
residualX_4
Entries 34222
Mean 0.0002902
RMS 0.002443
Residual in X for plane 5
residualX_5
Entries 34222
Mean 0.0006128
RMS 0.002352

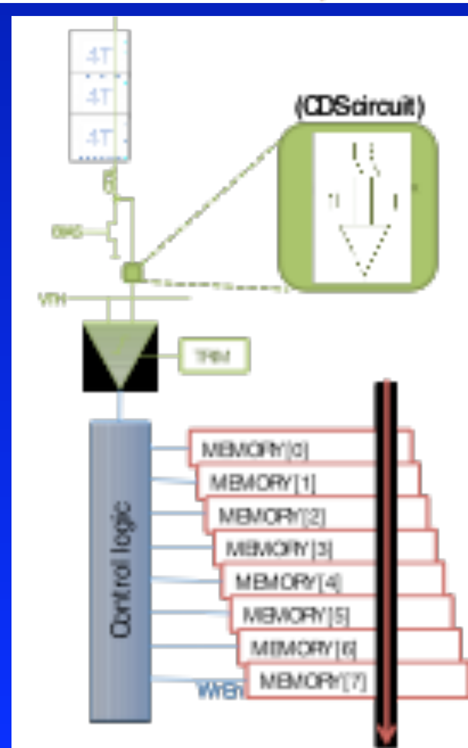

Residual in Y for plane 0
residualY_0
Entries 34222
Mean -0.0004235
RMS 0.002491
M≪σ
Residual in Y for plane 1
residualY_1
Entries 34222
Mean 0.0001651
RMS 0.002552
Residual in Y for plane 4
residualY_4
Entries 34222
Mean 3.515e-05
RMS 0.002649
Residual in Y for plane 5
residualY_5
Entries 34222
Mean 0.0001351
RMS 0.002502


residualXY_0
Entries 34222
Mean x 0.0003128
Mean y -0.0004234
RMS x 0.002339
RMS y 0.002491
residualXY_1
Entries 34222
Mean x -0.0002973
Mean y 0.0001645
RMS x 0.002402
RMS y 0.002551
residualXY_4
Entries 34222
Mean x 0.0002896
Mean y 3.513e-05
RMS x 0.002444
RMS y 0.002649
residualXY_5
Entries 34222
Mean x 0.0006128
Mean y 0.0001351
RMS x 0.002352
RMS y 0.002502

The future: Cherwell

- Uses INMAPS plus 4T to achieve
  - 100% fill factor with integrated sensor and readout electronics
    - Incorporation of complex logic within a pixel
    - Investigation of data reduction/clustering
  - Low noise using transfer gate, CDS and in-pixel amplification





Future plans

- Complete beam test analysis for FORTIS and TPAC
- Test all FORTIS and TPAC variants in the lab
- Test results will drive DECAL and CHERWELL architectures
- Perform beam test at DESY with TPAC

- Waiting for next April fools day...