First results from the HERMES Recoil Detector

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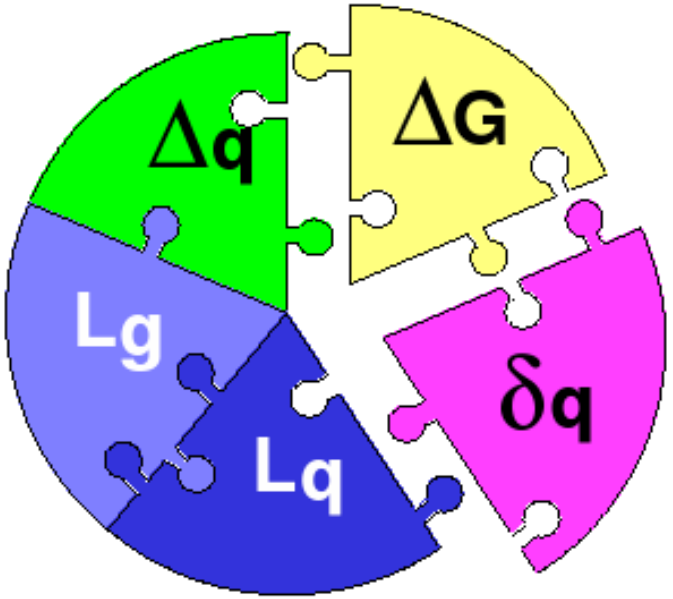
The Spin Structure of the Nucleon



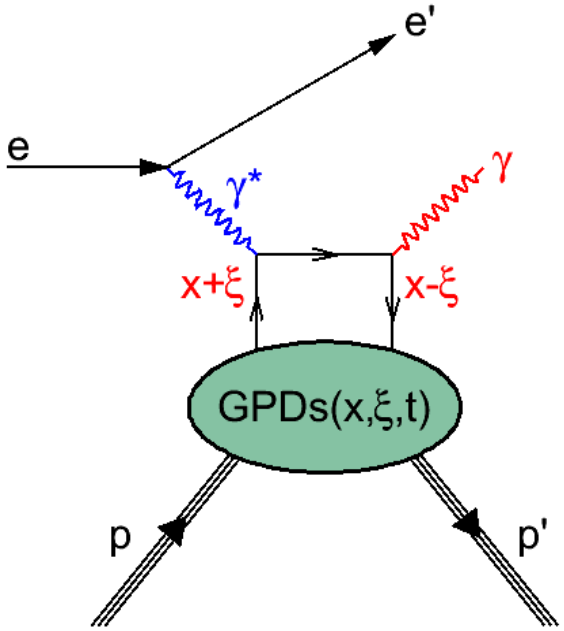
Nucleon Spin:

$$\frac{1}{2} = \underbrace{\frac{1}{2}\overbrace{(\Delta u + \Delta d + \Delta s)}^{\Delta\Sigma} + L_q}_{J_q} + \underbrace{\Delta G + L_g}_{J_g}$$

$\Delta\Sigma \approx 30-35\,\%$ measured in DIS

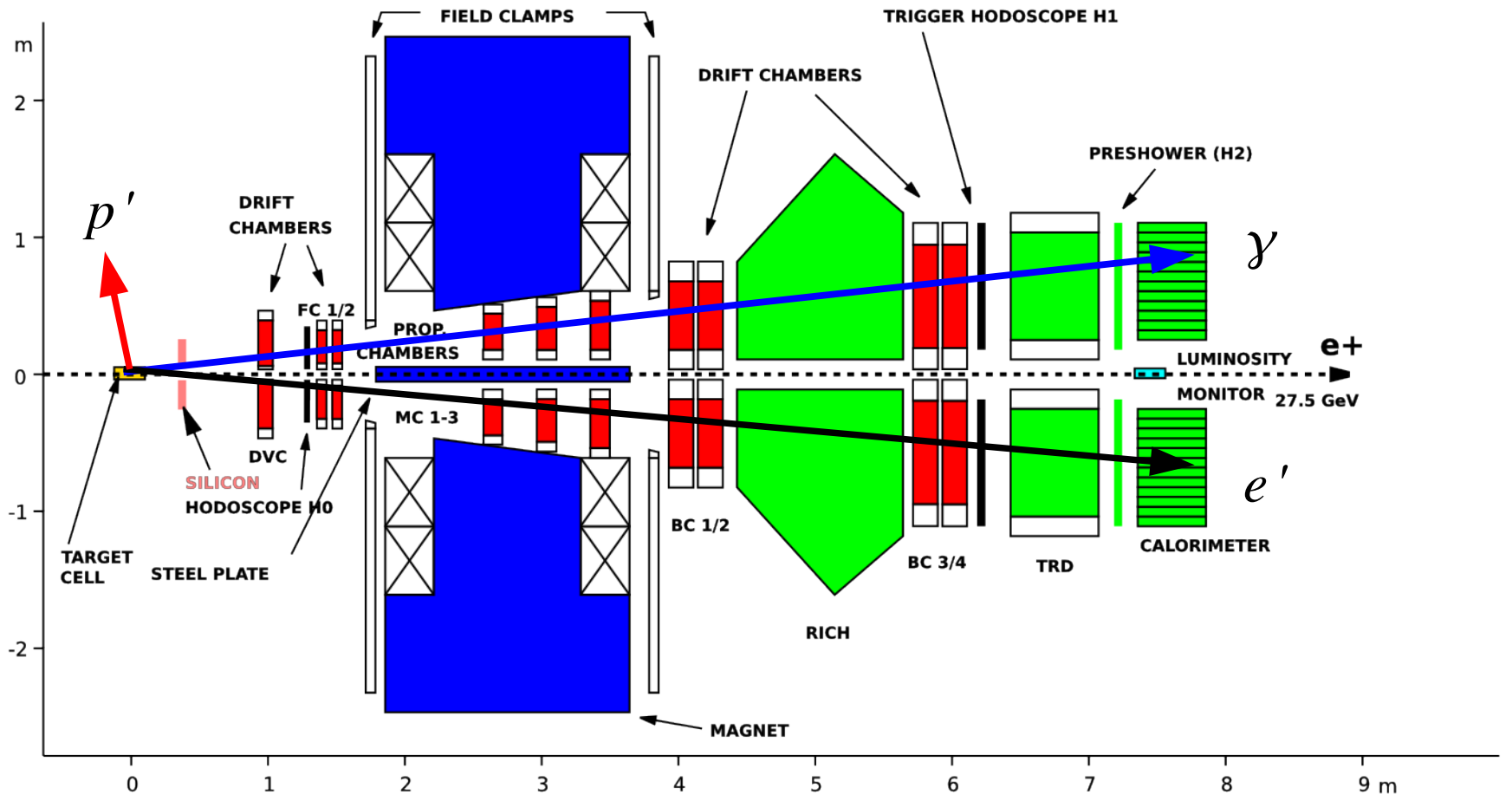
L_q, L_g and ΔG unknown

Access to J_q via Deeply Virtual Compton Scattering (DVCS)



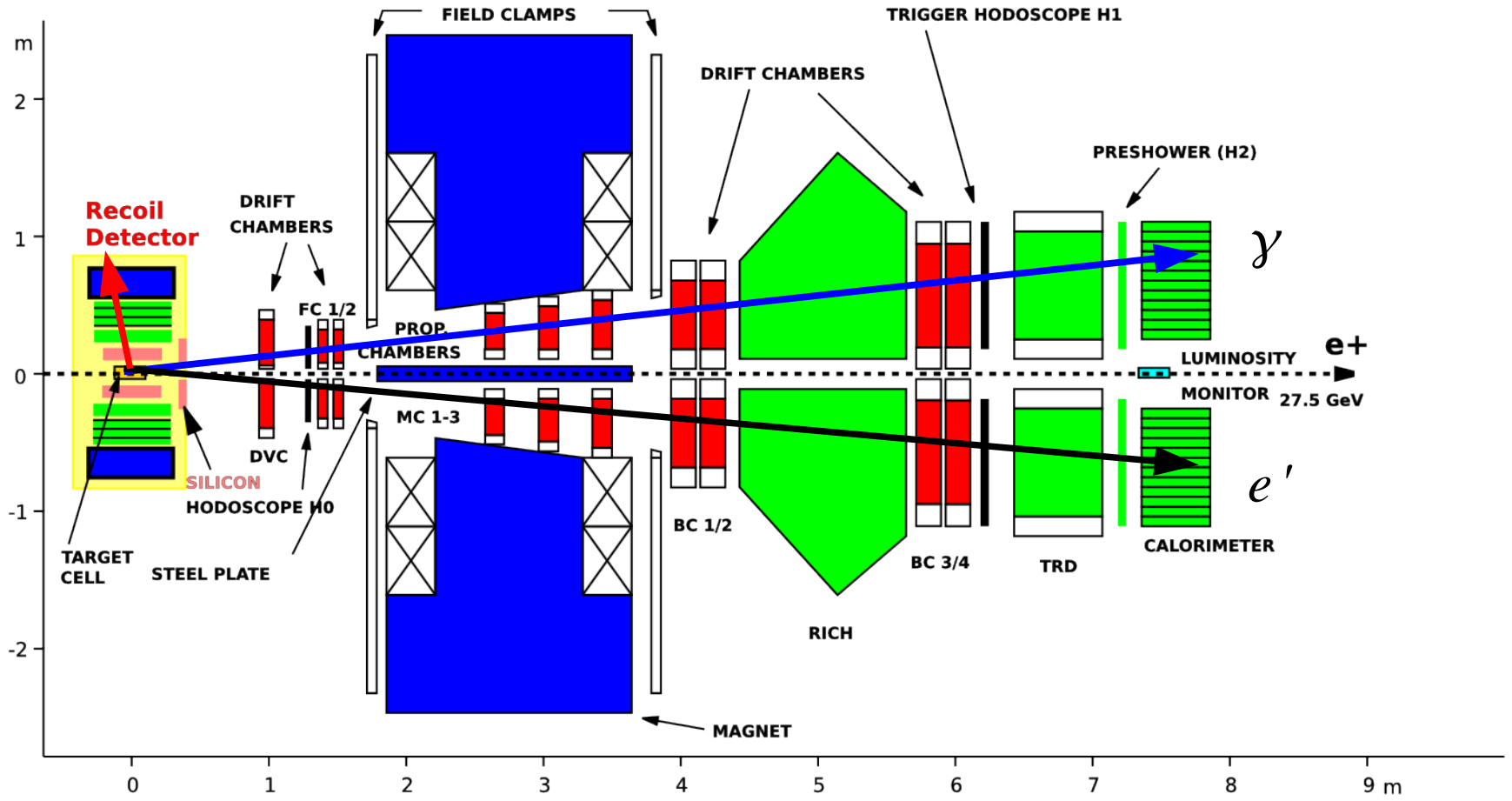
- Scattered beam lepton e'
- Real photon γ
- Recoiling proton p'

The HERMES Spectrometer (before 2006)



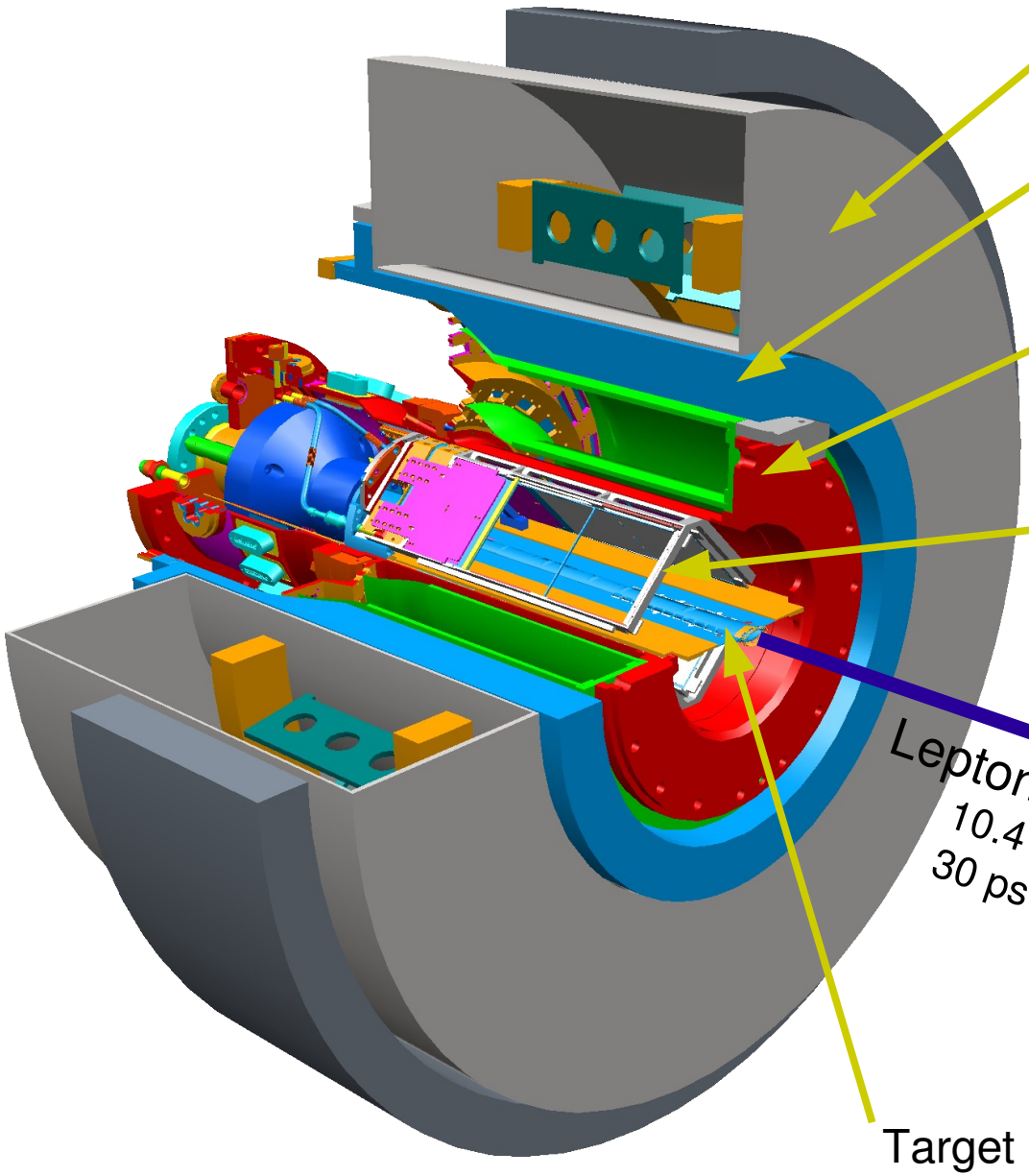
- Fixed target experiment (uses 27.6 GeV/c HERA lepton beam)
- Storage cell target
- Various tracking and PID detectors
- DVCS: recoiling proton undetected ⇒ large background contamination (15%)

The HERMES Spectrometer (2006 - 2007)



- Recoil detector installed for the last two years of data taking
- DVCS: recoiling proton detected ⇒ background contamination <1%

The HERMES Recoil Detector



Superconducting Solenoid (1T)

Photon Detector
- 3 layers of Tungsten/Scintillator sandwich

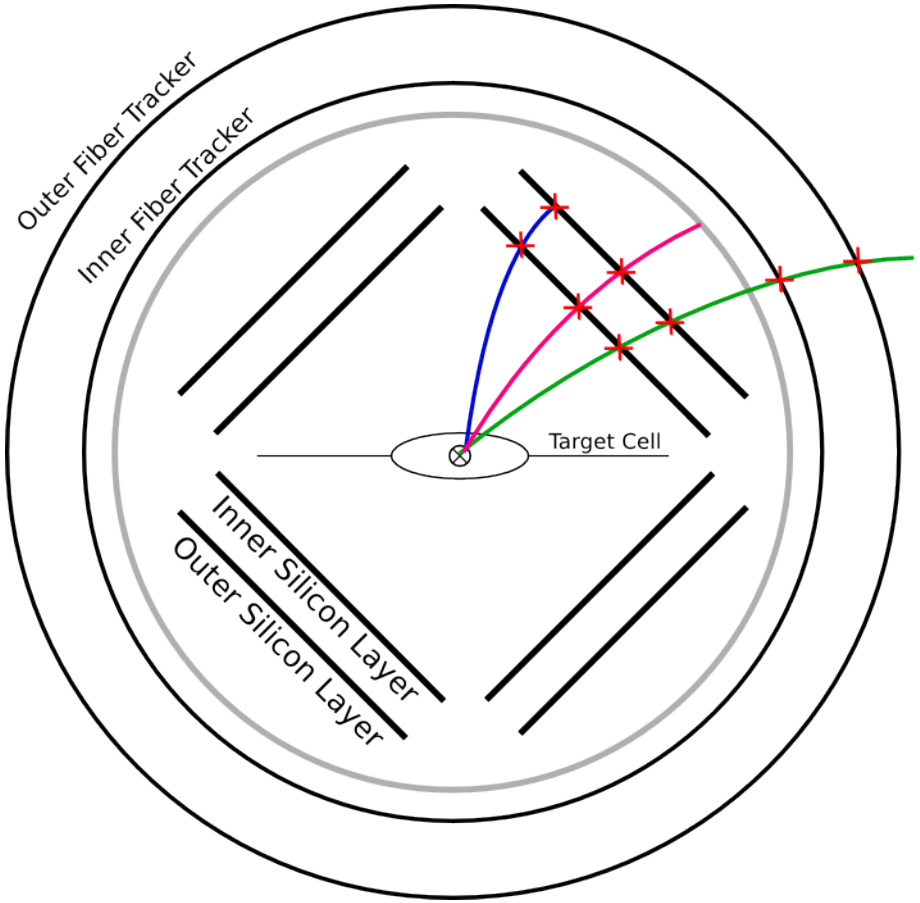
Fiber Detector
- 2 barrels with 4 layers of scintillating fibers
- 2 parallel and 2 stereo layers per barrel

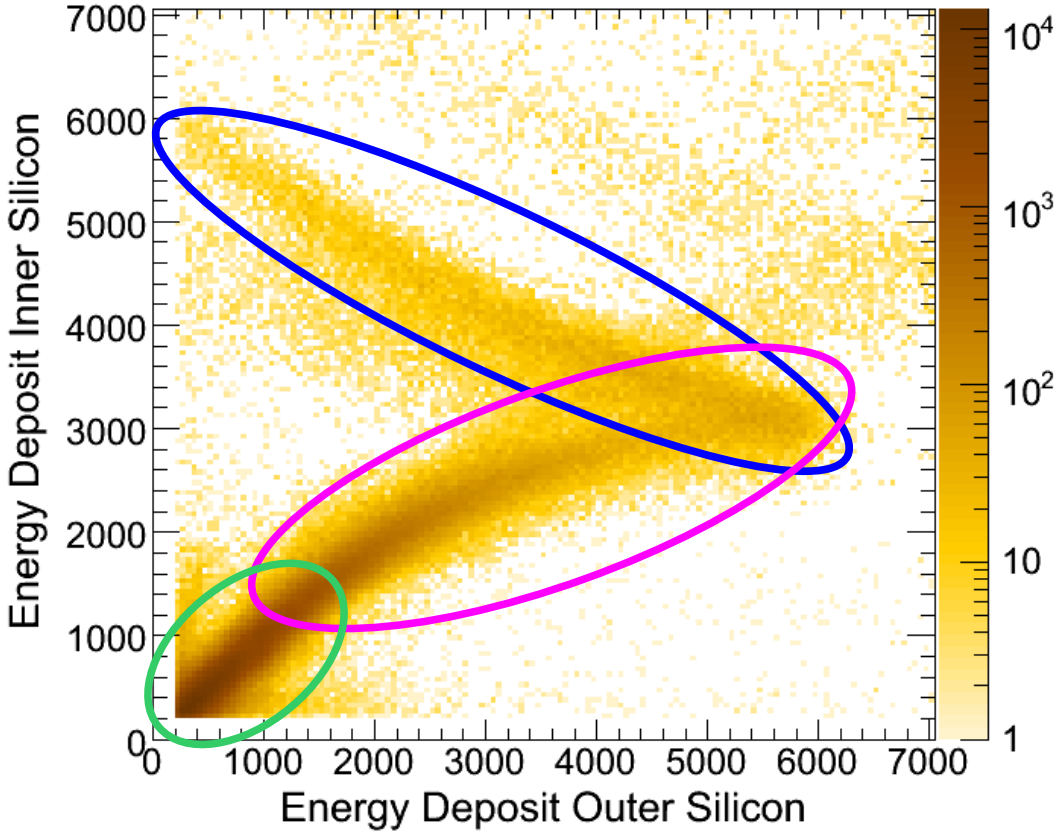
Silicon Detector
- 16 sensors
- Inside HERA vacuum
- 5 cm close to beam

Lepton beam
10.4 MHz bunch frequency
30 ps bunch length

Target cell

Momentum Reconstruction





- Low-energy protons
  - ➔ Momentum via sum of deposited energies
- Medium-energy protons
  - ➔ Momentum via dE/dx
- High-energy particles (protons/pions)
  - ➔ Momentum via bending in magnetic field

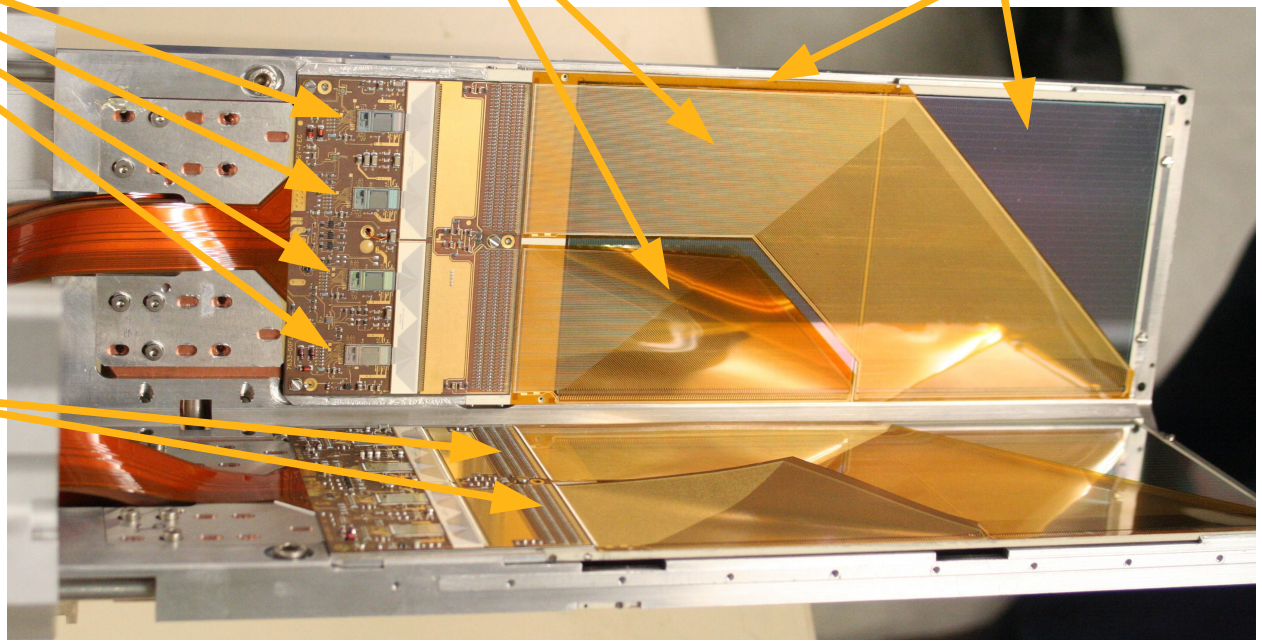
} Precise energy measurement in Silicon detectors

Silicon Modules

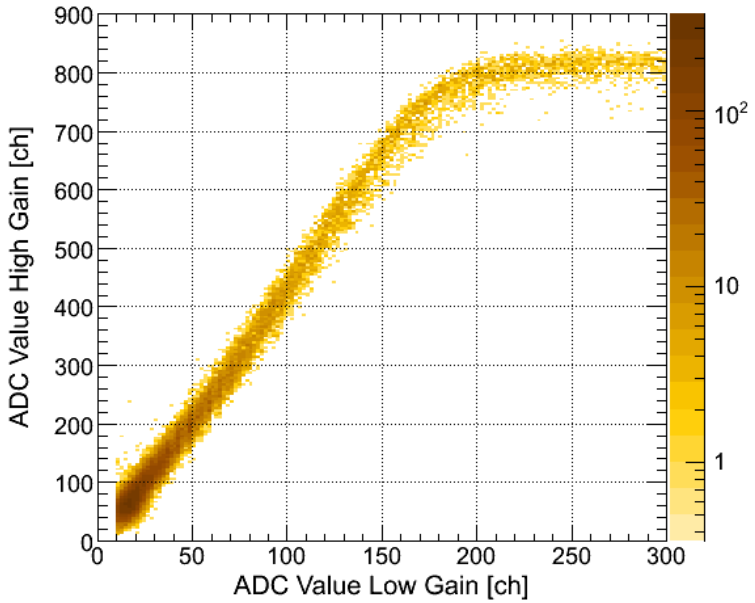
HELIX chips
- 128 channels
- 10.4 MHz

FLEX foils
- 70 µm Kapton
- 20 µm Copper

Sensors
- TIGRE design
- 300 µm
- 10 cm x 10 cm
- 128 x 128 strips
- 758 µm pitch



Charge divider (1 : 5)



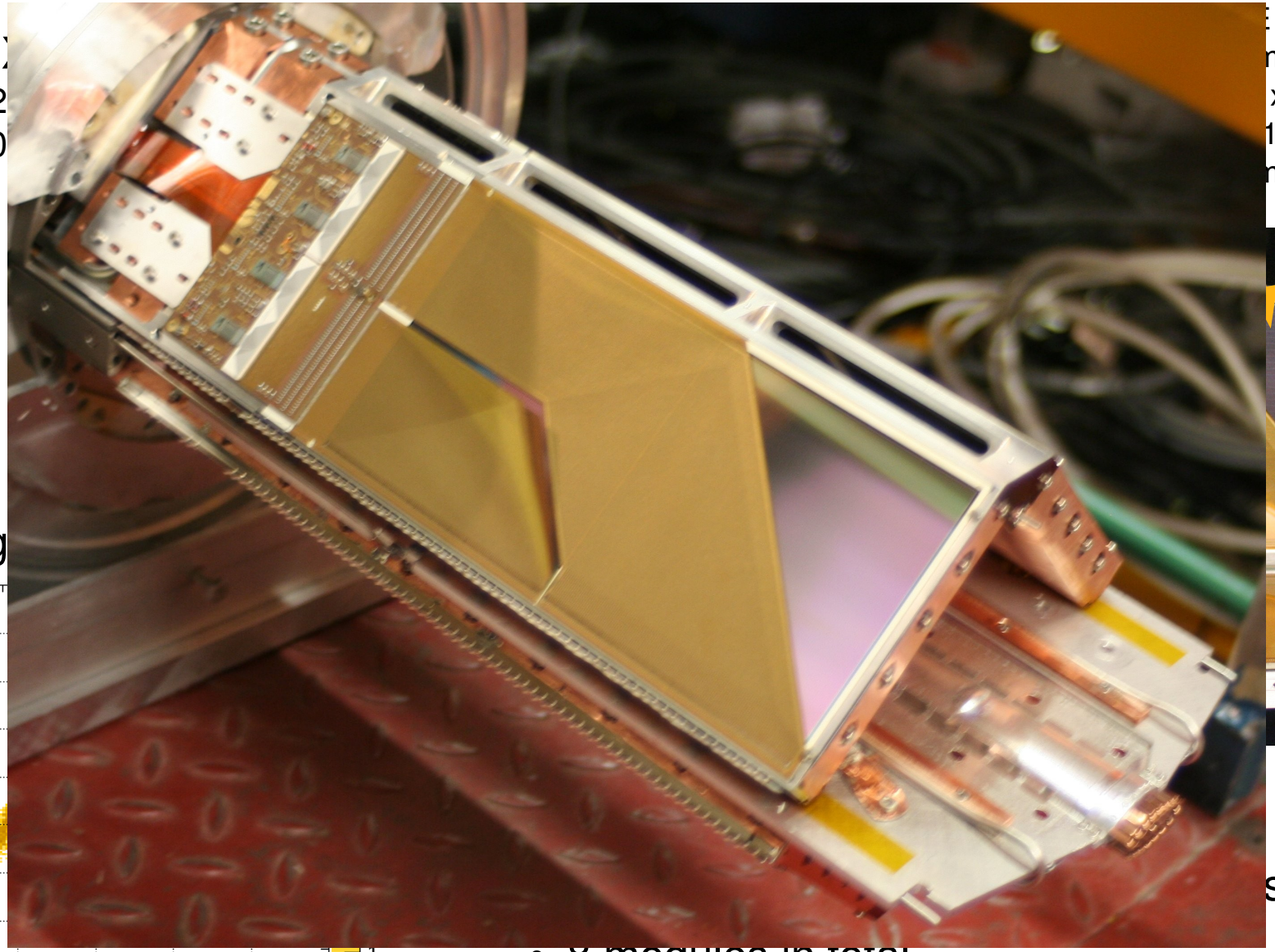
- 2 sensors per module
- 2 HELIX chips attached to each sensor side
- 8 modules in total

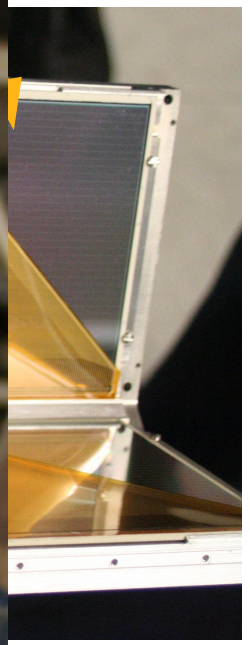
Silicon Modules

Sensors

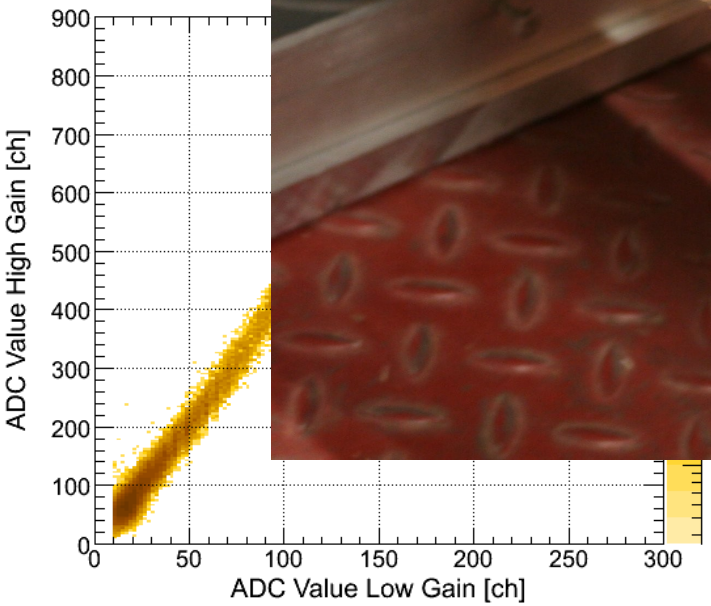
HELI
- 12
- 10

design
m
x 10 cm
128 strips
n pitch





Charg

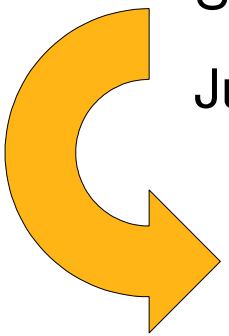


sor side

- 8 modules in total

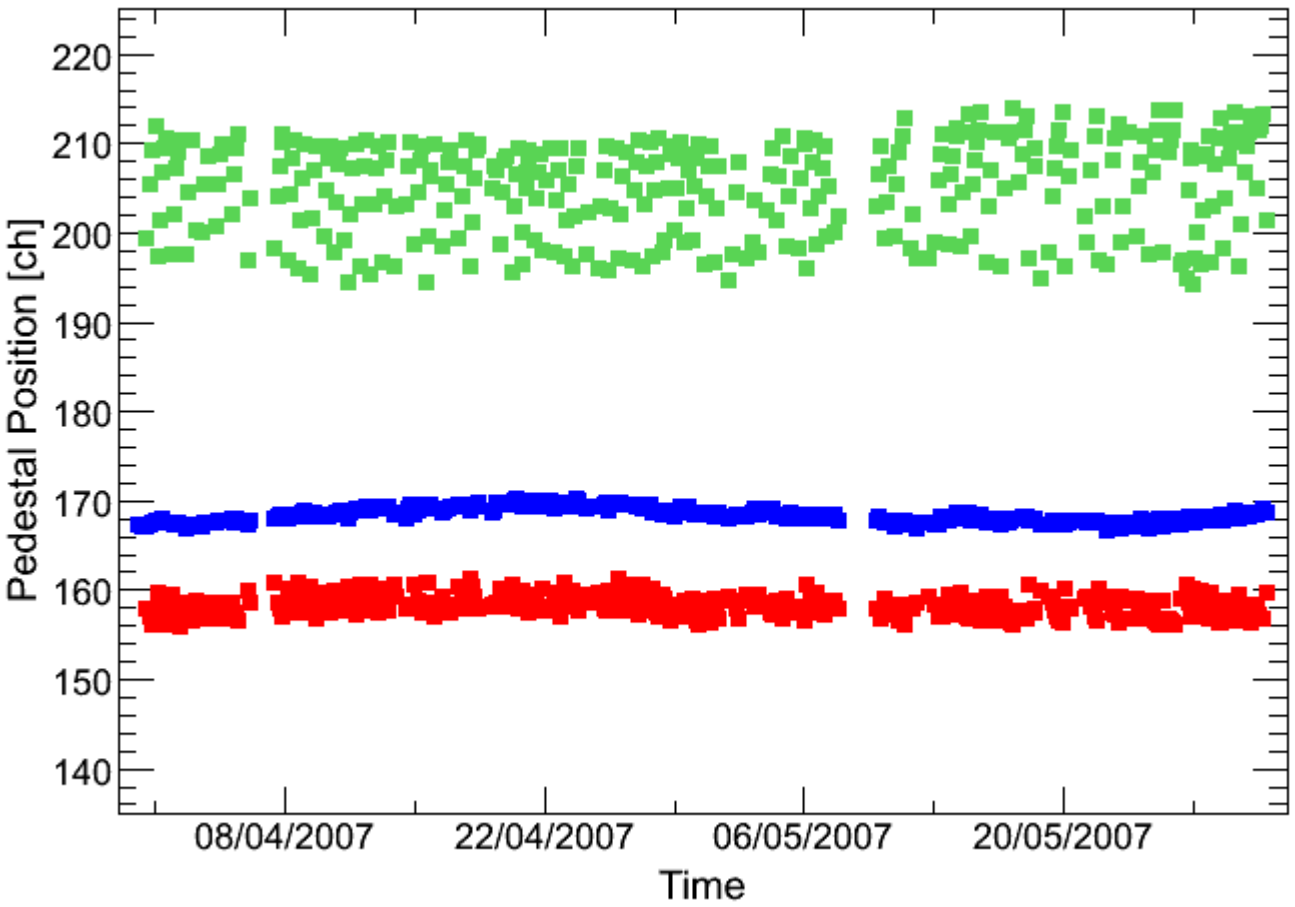
Timeline

Dec. 2005	Installation of the Recoil Detector at HERMES
Feb. 2006	Start of data taking and commissioning
Mar. 2006	Problems with target cell
May 2006	Deinstallation and repair of Silicon modules
June 2006	Installation of Silicon detector
Sep. 2006	Finished commissioning
June 2007	End of data taking



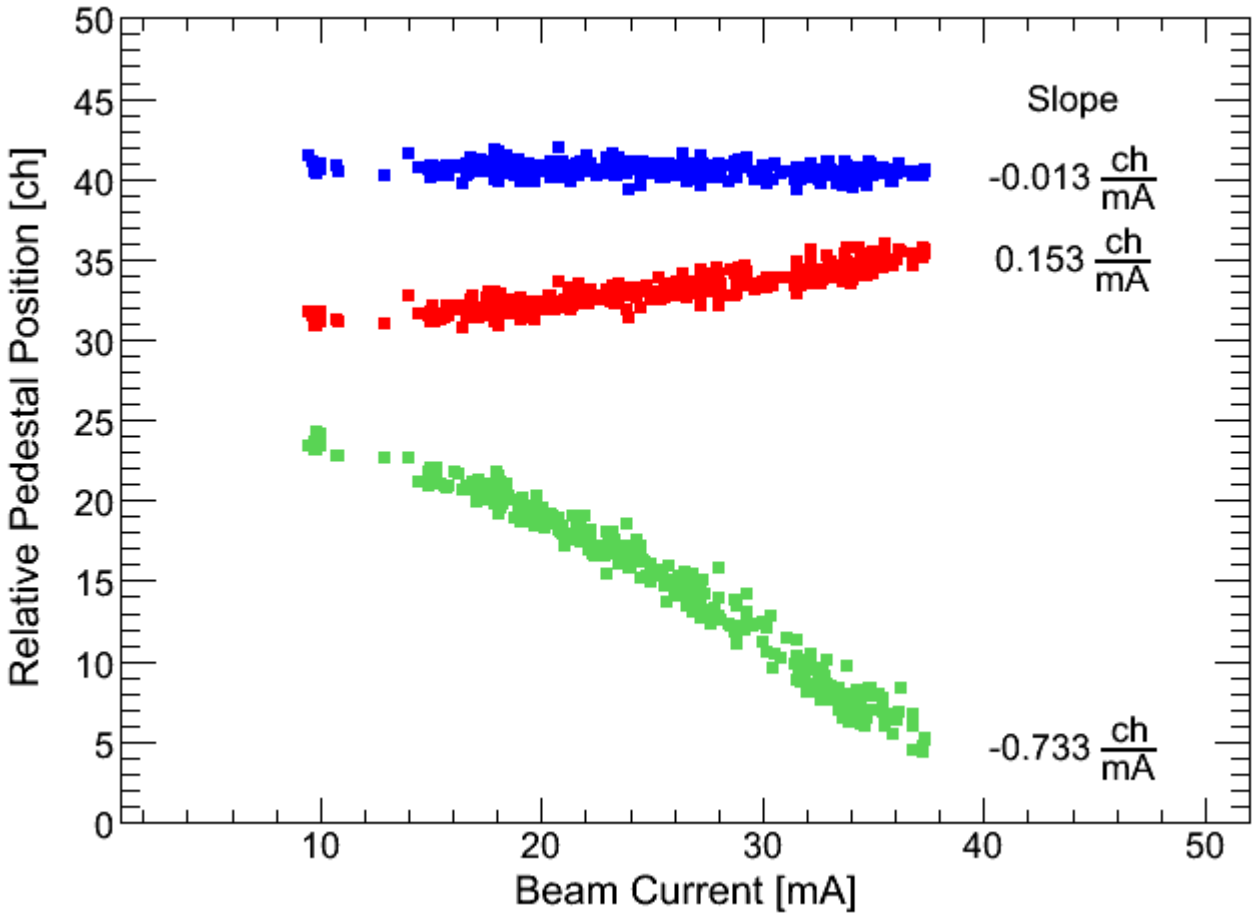
- Running stable over full data taking period
- ~ 95 % data taking efficiency

Pedestal Stability



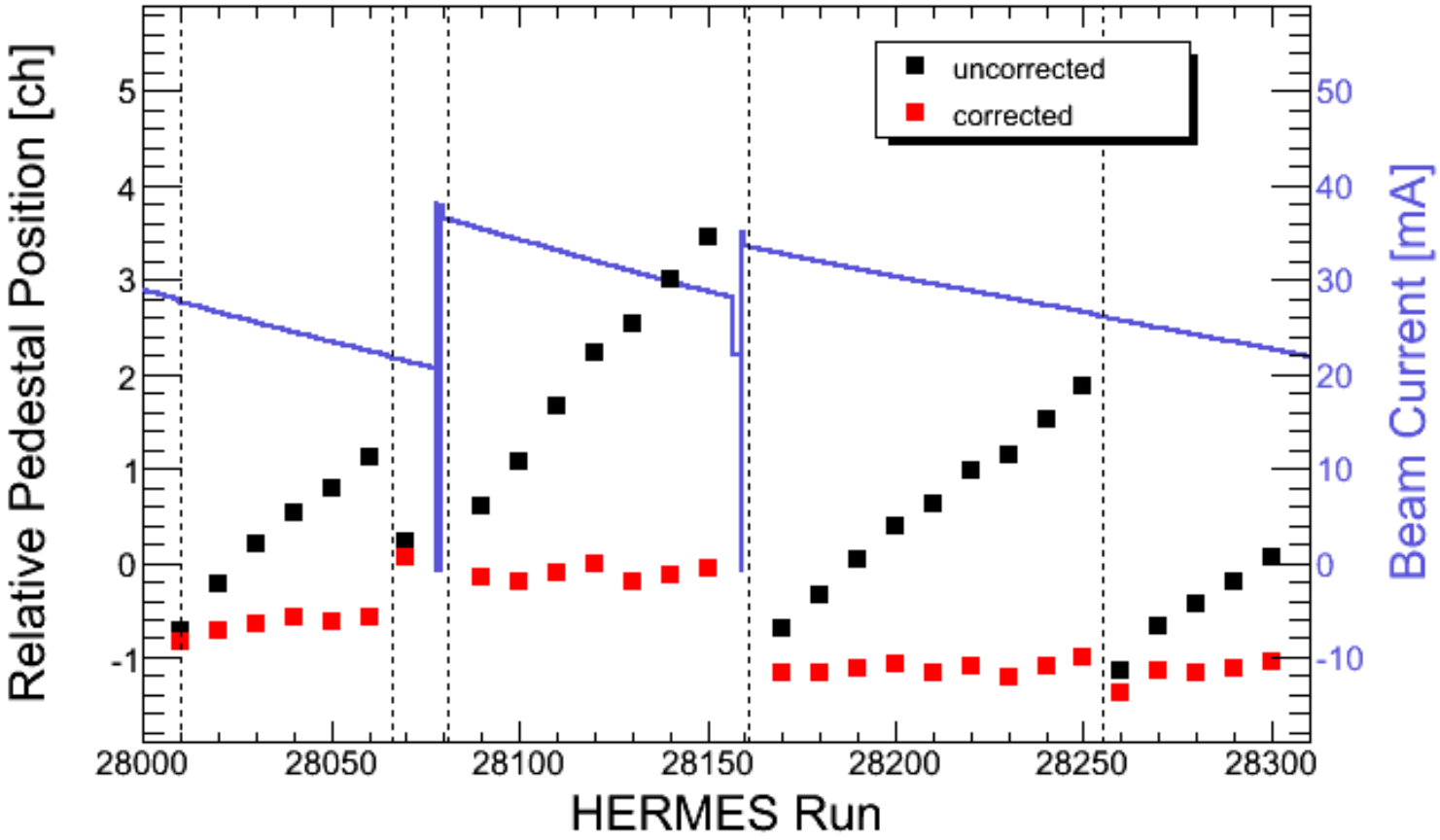
- Pedestal run every 3 – 4 hours (1588 pedestal runs in total)
- ~ 85 % of channels are stable
- Remaining channels show medium or strong variations

Pedestal Drift



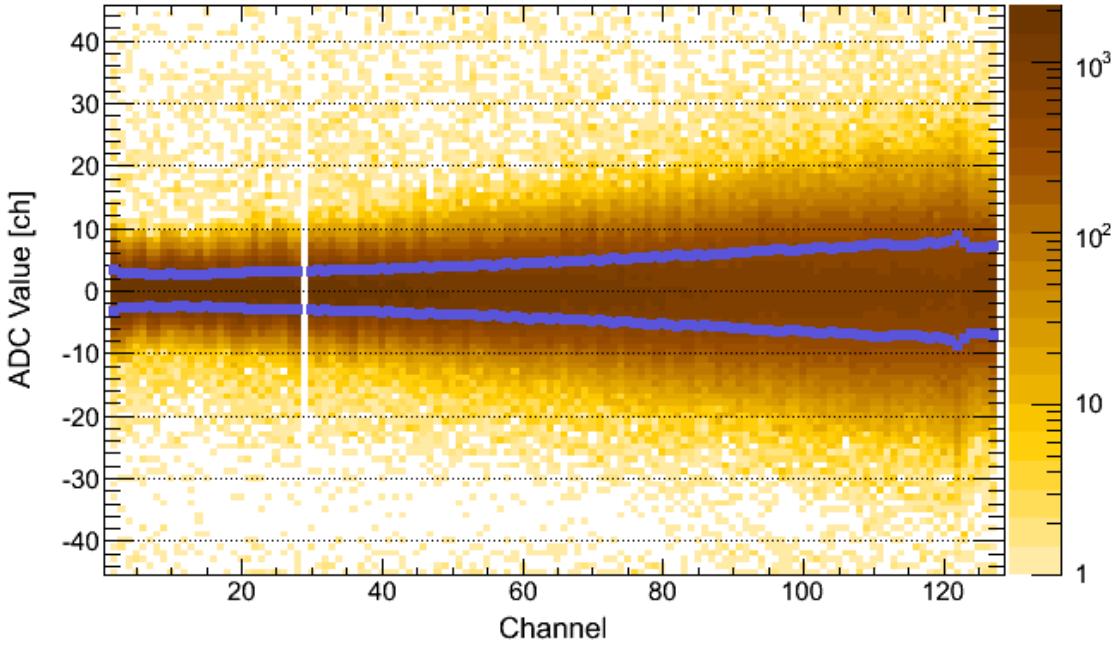
- Variations caused by beam current dependent pedestal position
- ~ 10 mA change in beam current between pedestal runs
- No systematics or symmetries seen

Pedestal Drift Correction



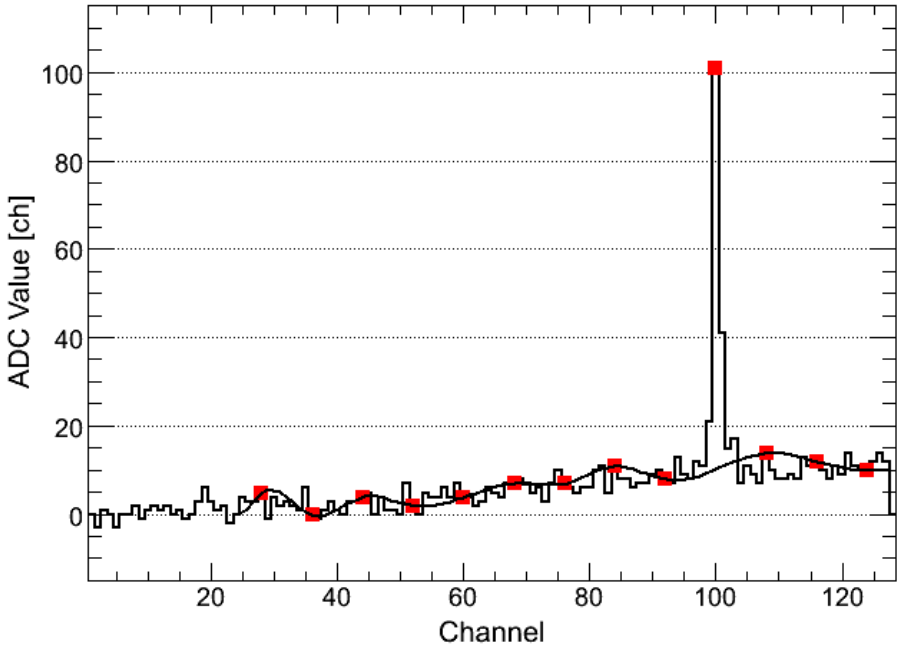
- After correction: pedestal drift < 1 ADC channel
- Remaining “jumps” are random and can't be corrected

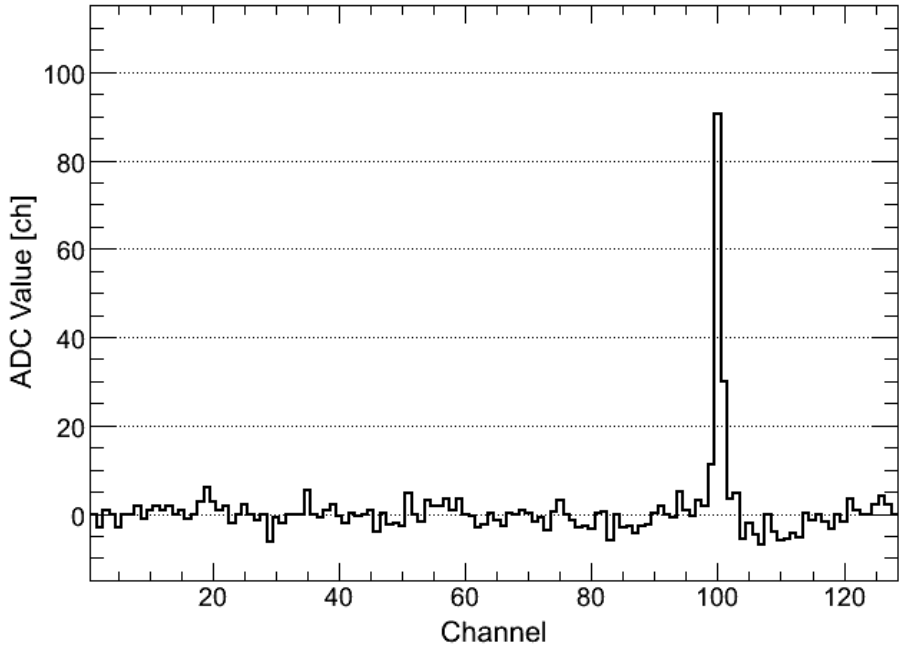
Correlated Noise

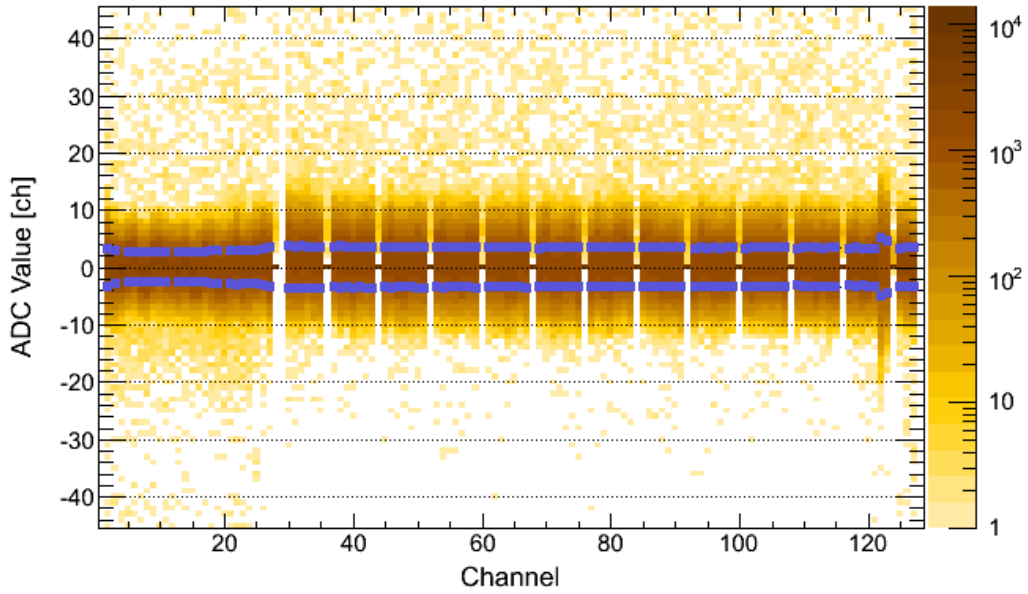


- Pedestal after common mode (CM) correction in hardware
  - CM correction uses only first 16 channels of each chip
  - 3 – 4 ADC channels pedestal width
- Pedestal width increases with increasing channel number
- Correction via spline interpolation
  - Every 8th channel always read out (no threshold)
  - About 90% of data written to tape is just for this correction

Correlated Noise

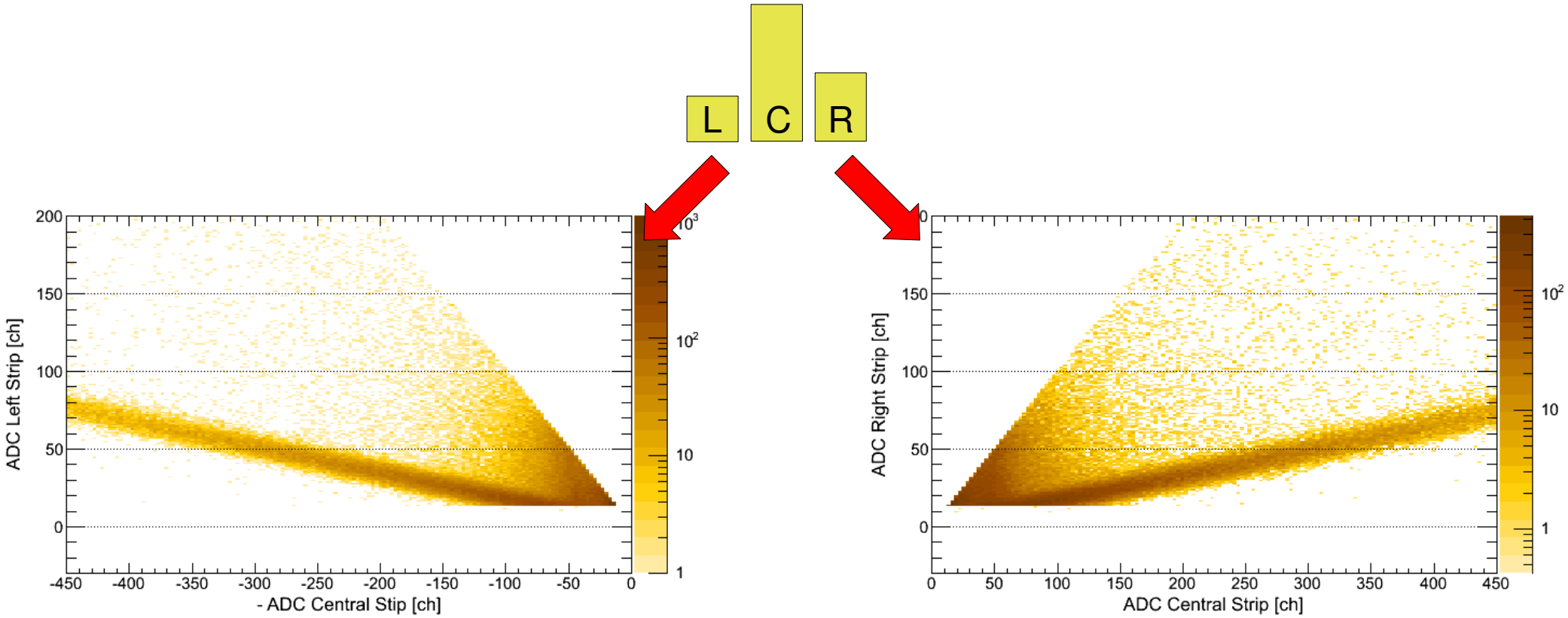






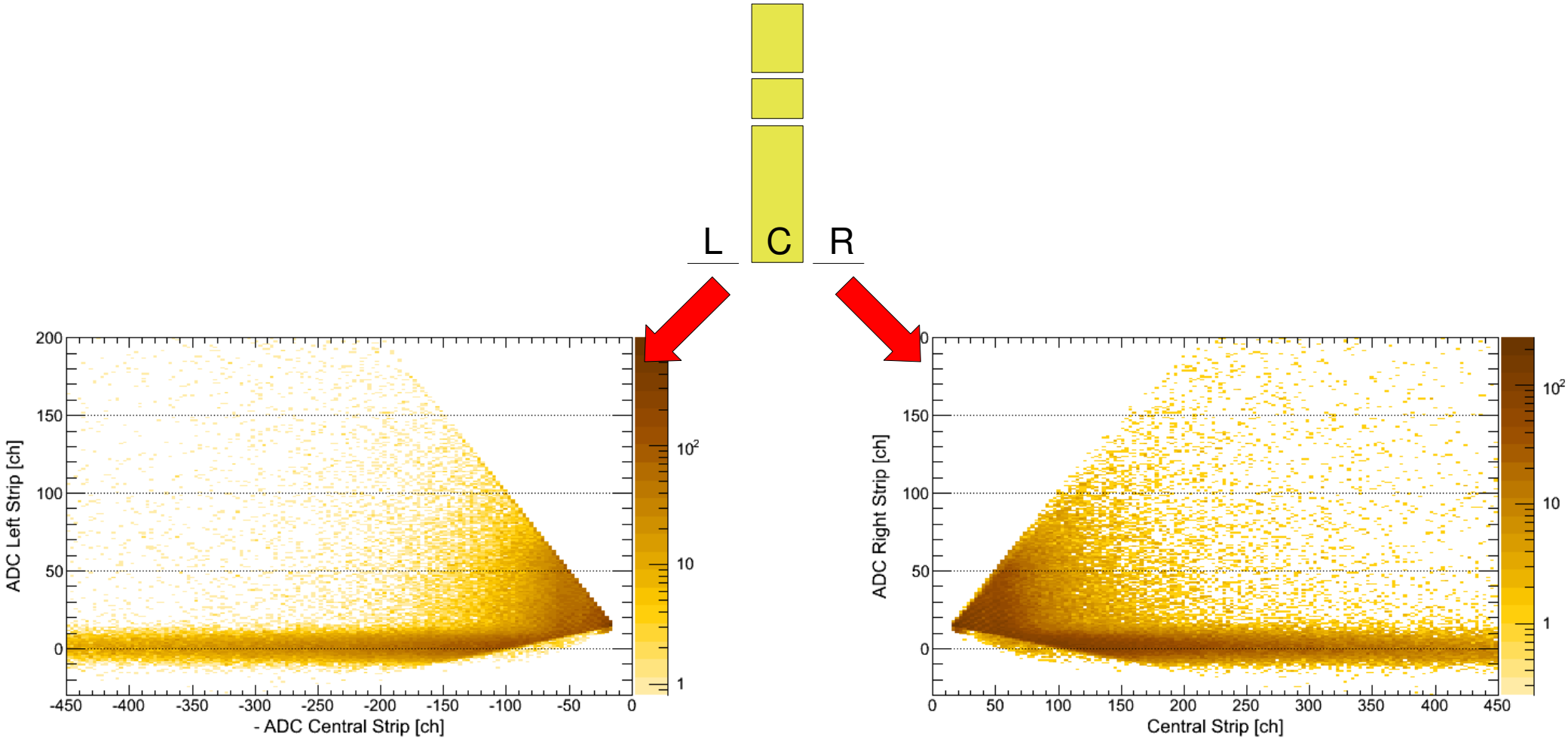
- Remove actual hits from basepoints
- After correction: 3 – 4 ADC channels pedestal width over full chip

Crosstalk



- ~ 11 – 16 % crosstalk to left neighbour
- ~ 15 – 21 % crosstalk to right neighbour
- Crosstalk different for even and odd channels

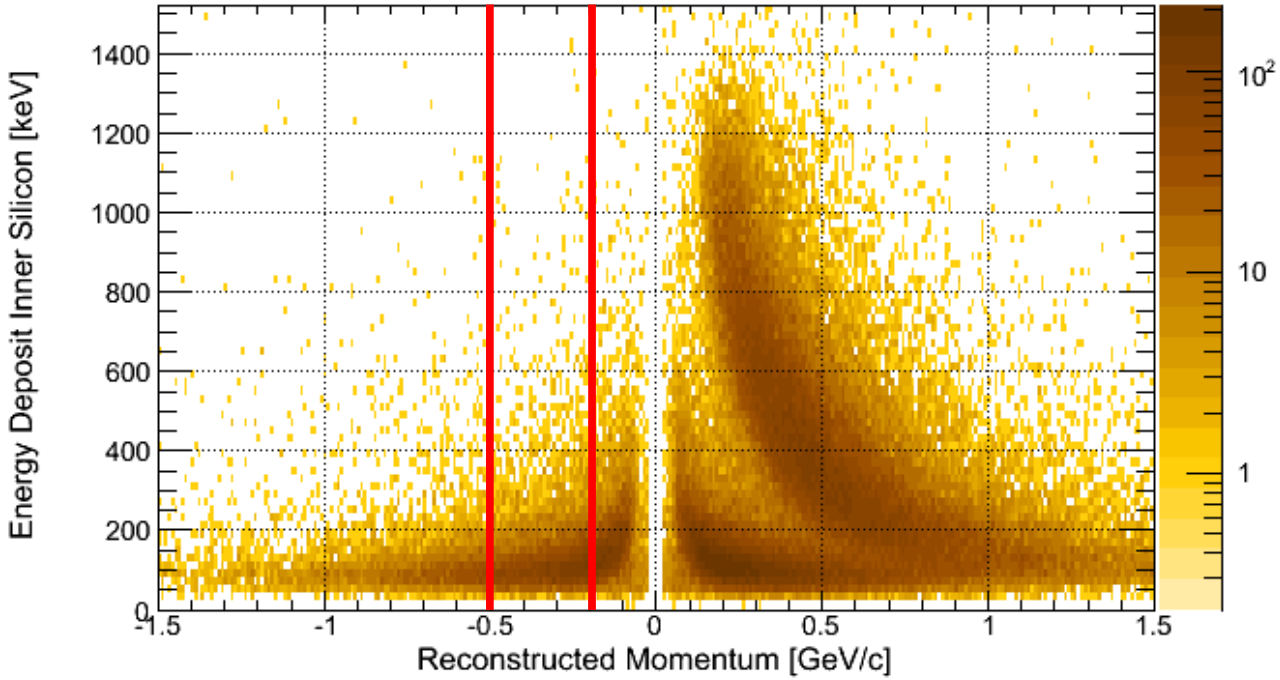
Crosstalk Correction



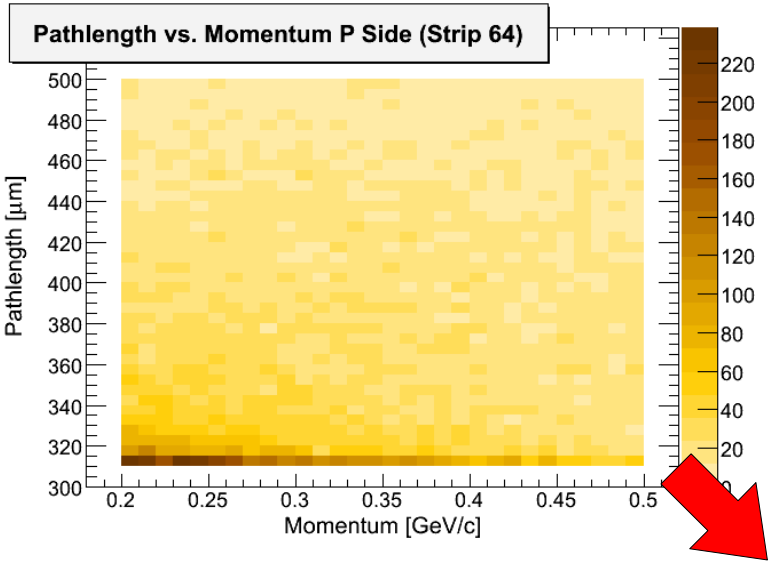
- Correction coefficients stable over full data taking period
- Algorithm can recover signals in neighbouring channels even if below threshold

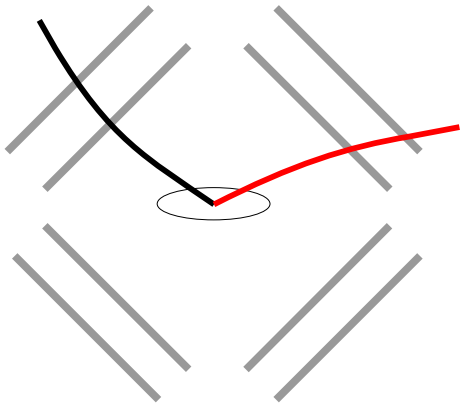
Calibration

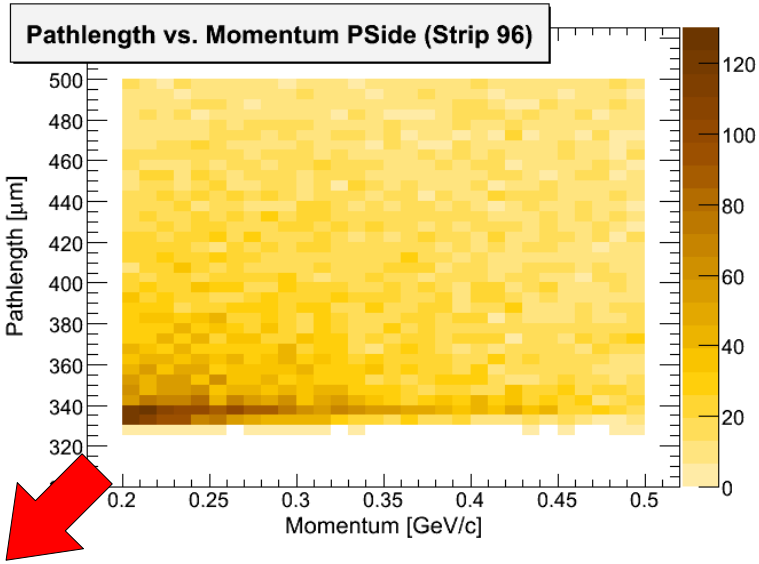
- All modules calibrated at Erlangen Tandem
  - with protons of 3.5, 4.0, 6.0 and 9.0 MeV kinetic energy
- Calibration from HERMES data
  - Use negative pions: 0.2 GeV/c < p < 0.5 GeV/c
  - Enough statistics to calibrate individual channels
  - Calibrate high-gain chips
  - Extrapolate to range of interest
- Each strip “sees” different
  - Momentum and
  - Path length distribution



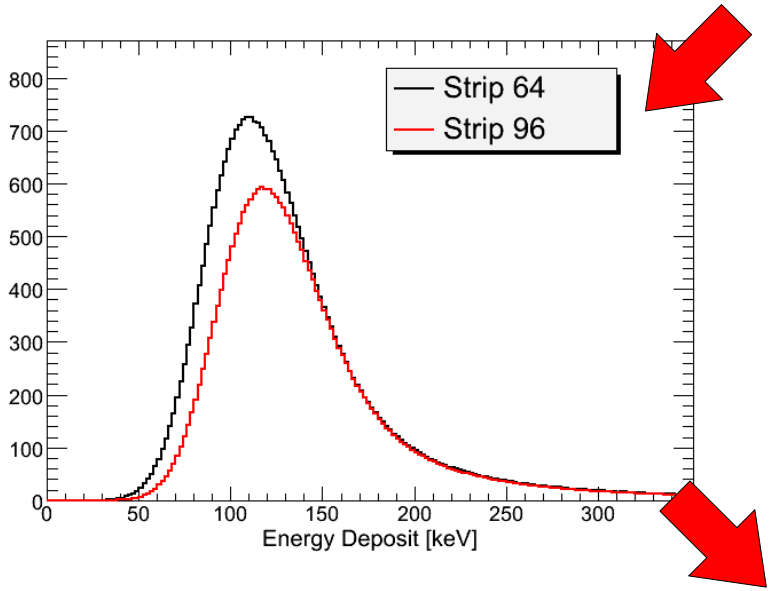
Calibration using MIPs

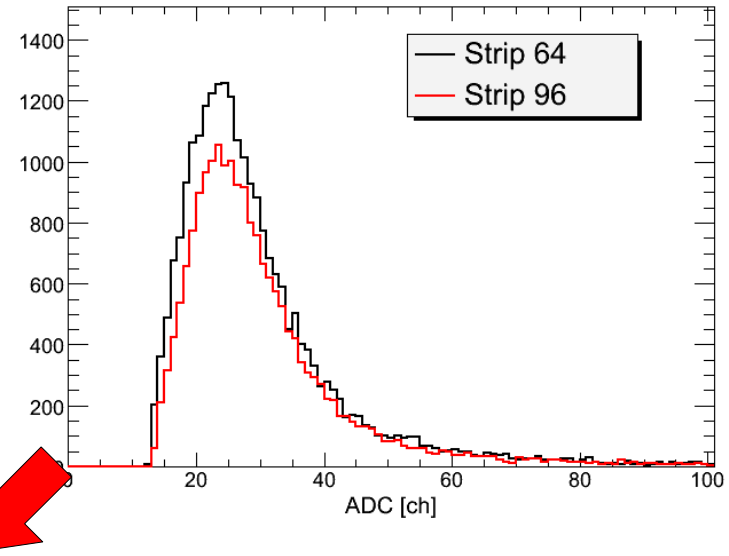






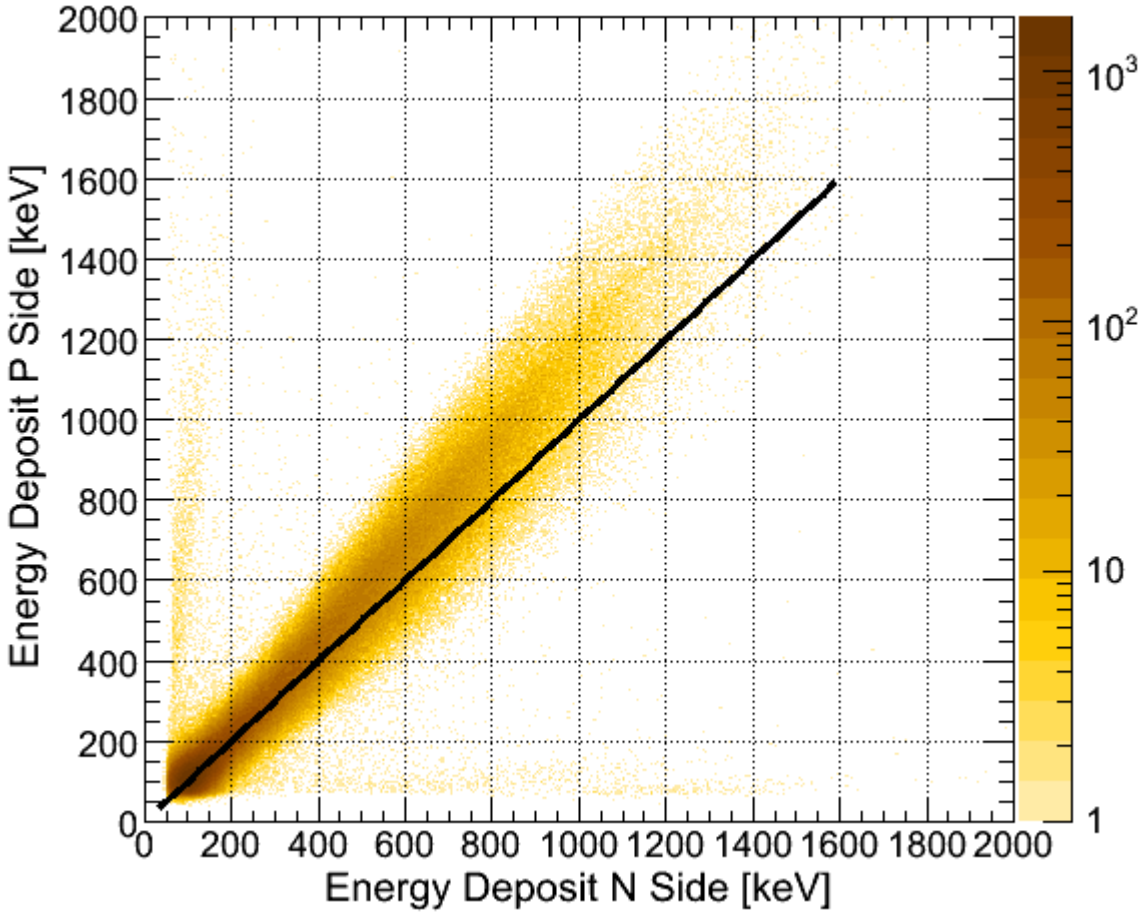
Geant4 Lookup Table





Calibration

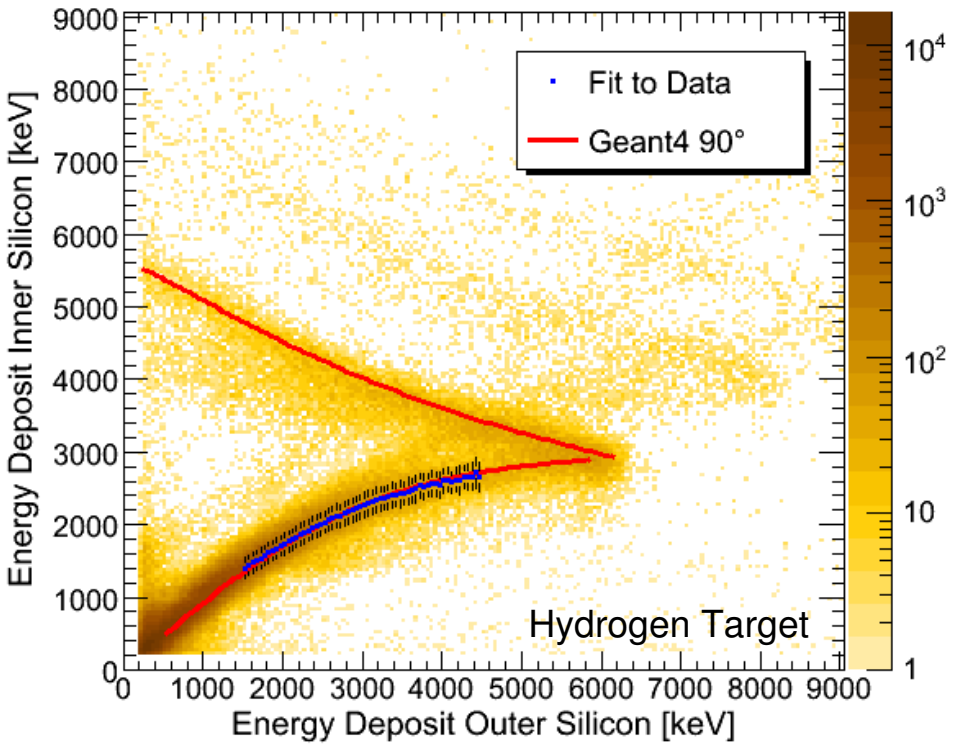
Calibration using MIPs

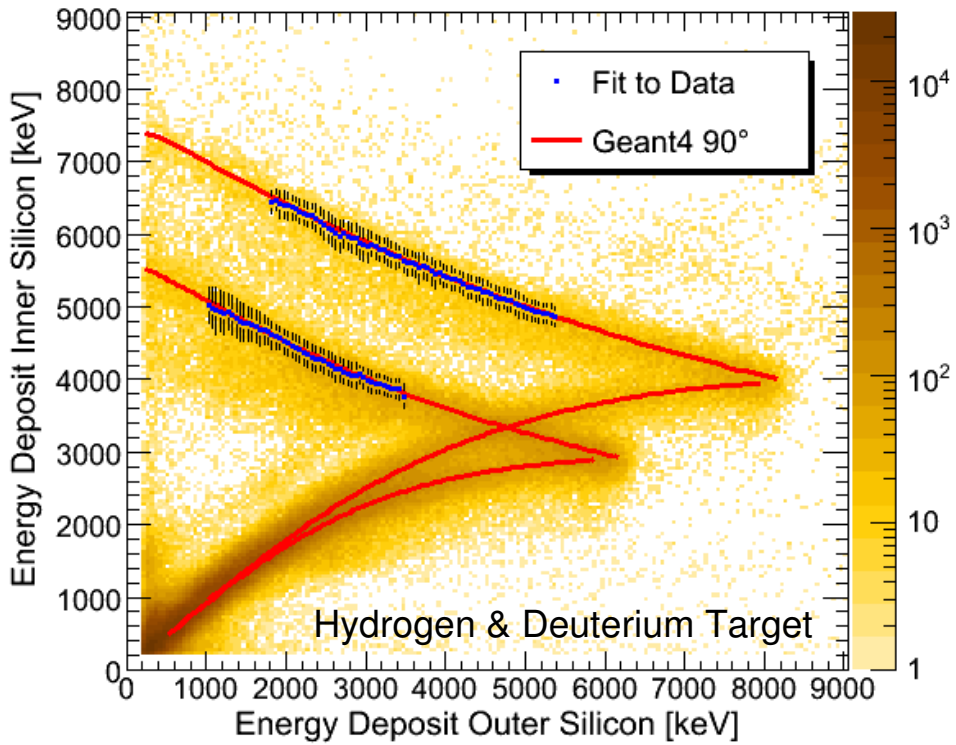


- Extrapolation to large energy deposits does not work
- ~ 5% channel to channel gain variation
- Will use this information in next iteration

Calibration using Protons

- Calibrate low gain chips in region of interest

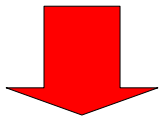




- After correction for incident angle
- Substitute $E_{Dep}^{*Inner} = c_I \cdot E_{Dep}^{Inner}$ and $E_{Dep}^{*Outer} = c_O \cdot E_{Dep}^{Outer}$
- Fit Geant4 calculation to data points (2 free parameters)
- Works well but ...
- Not enough statistics to calibrate individual channels

Summary and Outlook

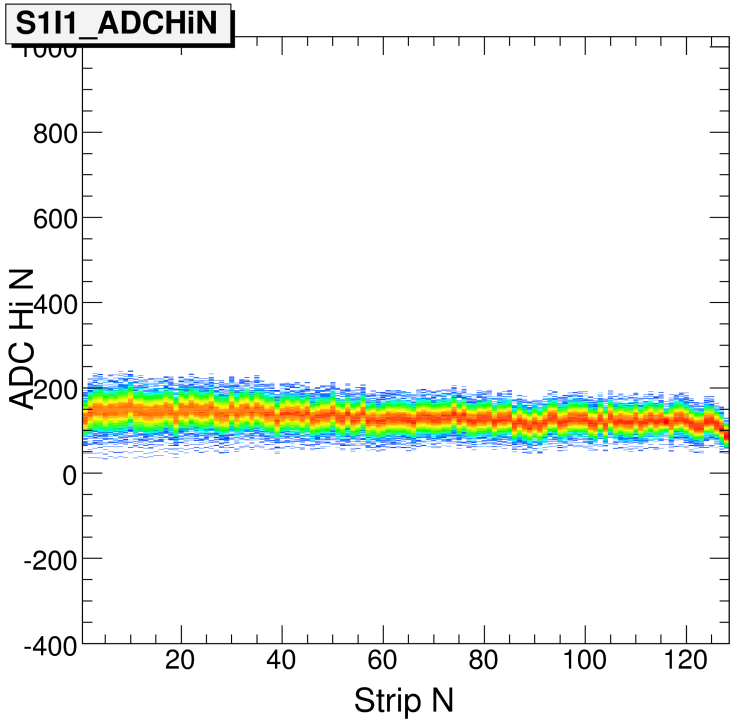
- All raw data correction algorithms implemented
- First iteration of calibration done
  - Channel by channel calibration needs understanding of MIP calibration
  - Feedback from momentum reconstruction improves incident angle correction
- New data production in progress
  - All subdetectors calibrated

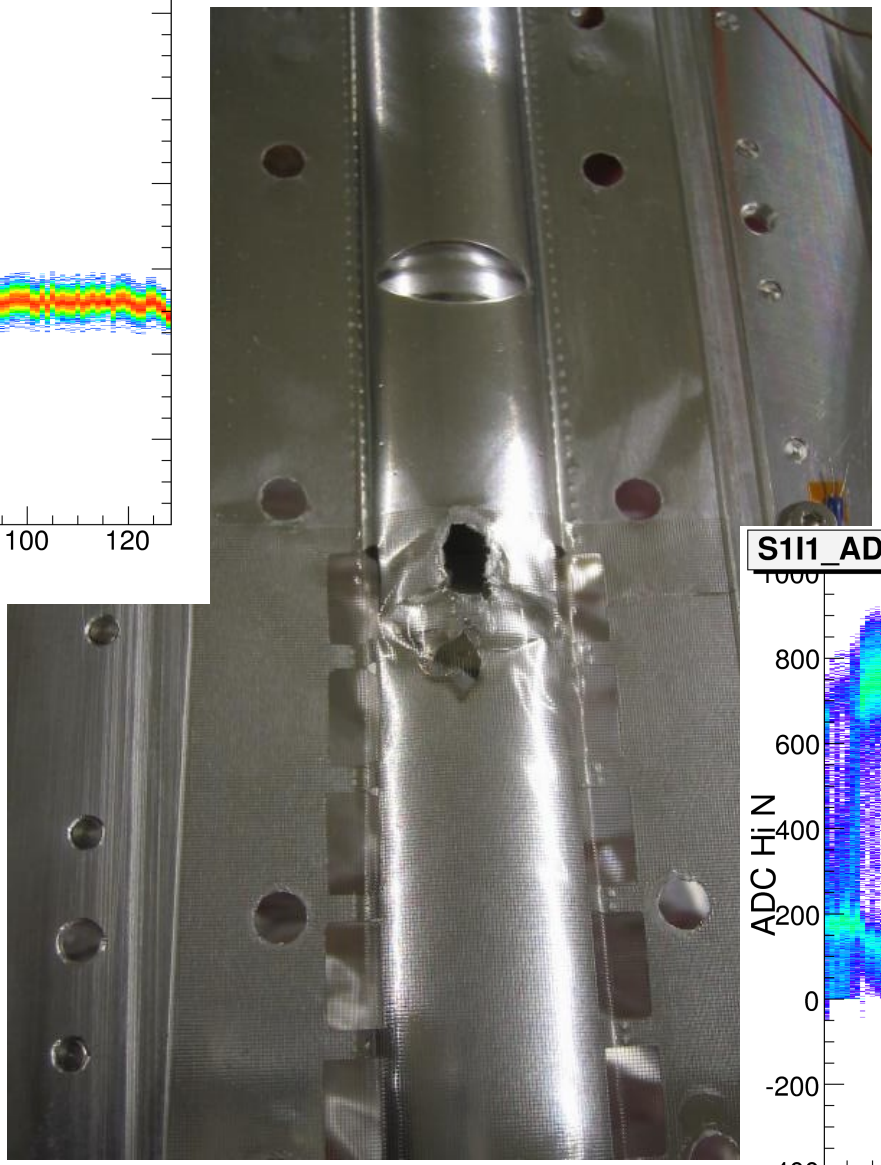


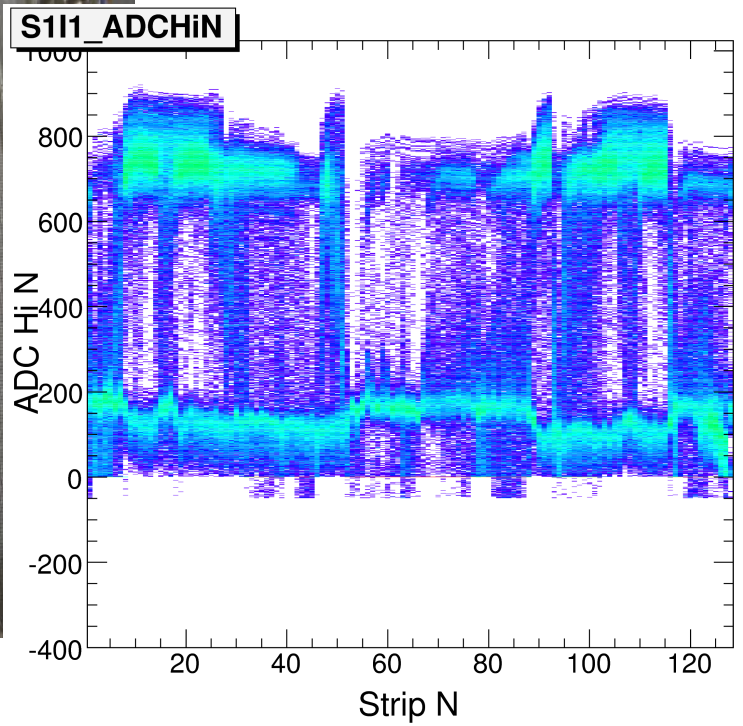
- Physics Analysis
  - 38 Mio DIS events off Hydrogen; 10 Mio DIS events off Deuterium
  - 2002 – 2005: 9 Mio DIS events off Hydrogen
- Efficiency studies
  - In advanced stage for fiber tracker
  - Started for Silicon detector
- Energyresolution
  - Studies in progress

Backups

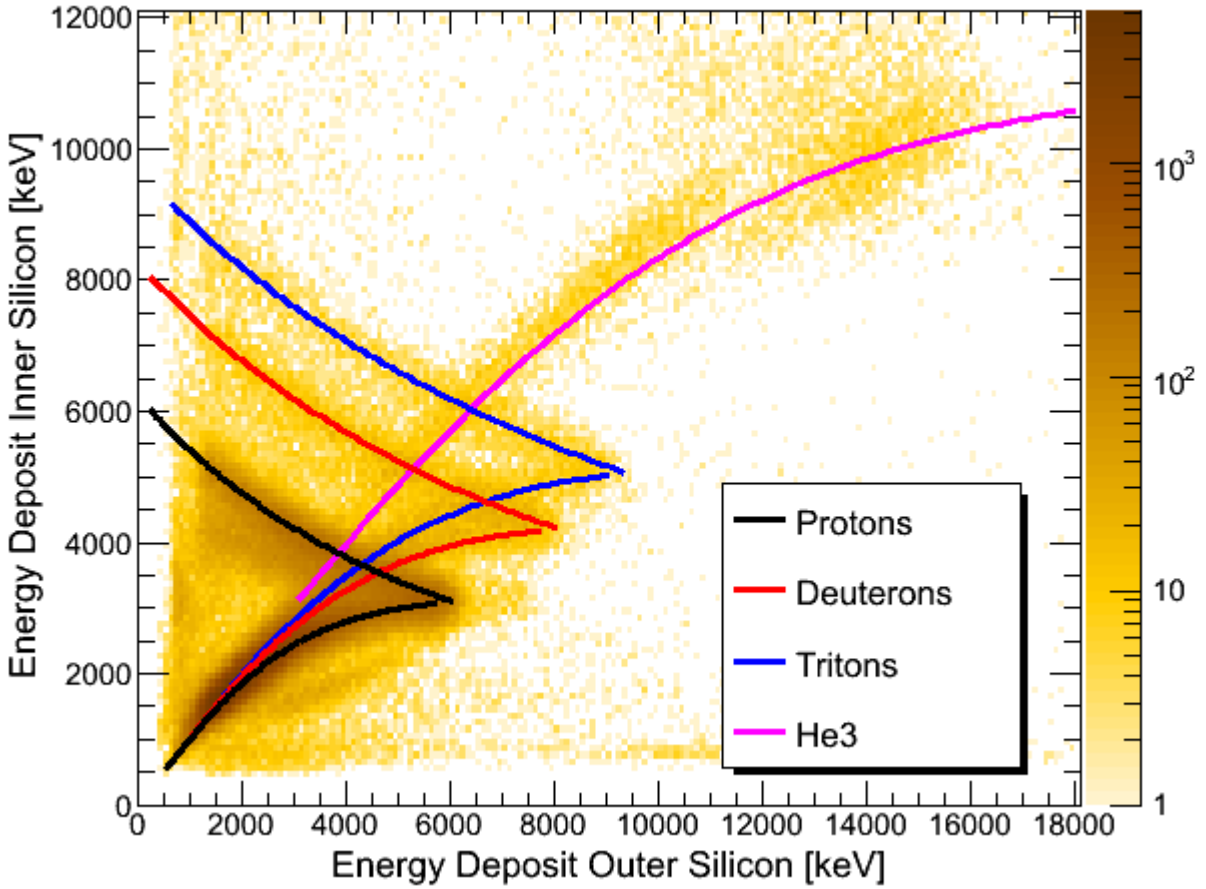
Target Cell Problems



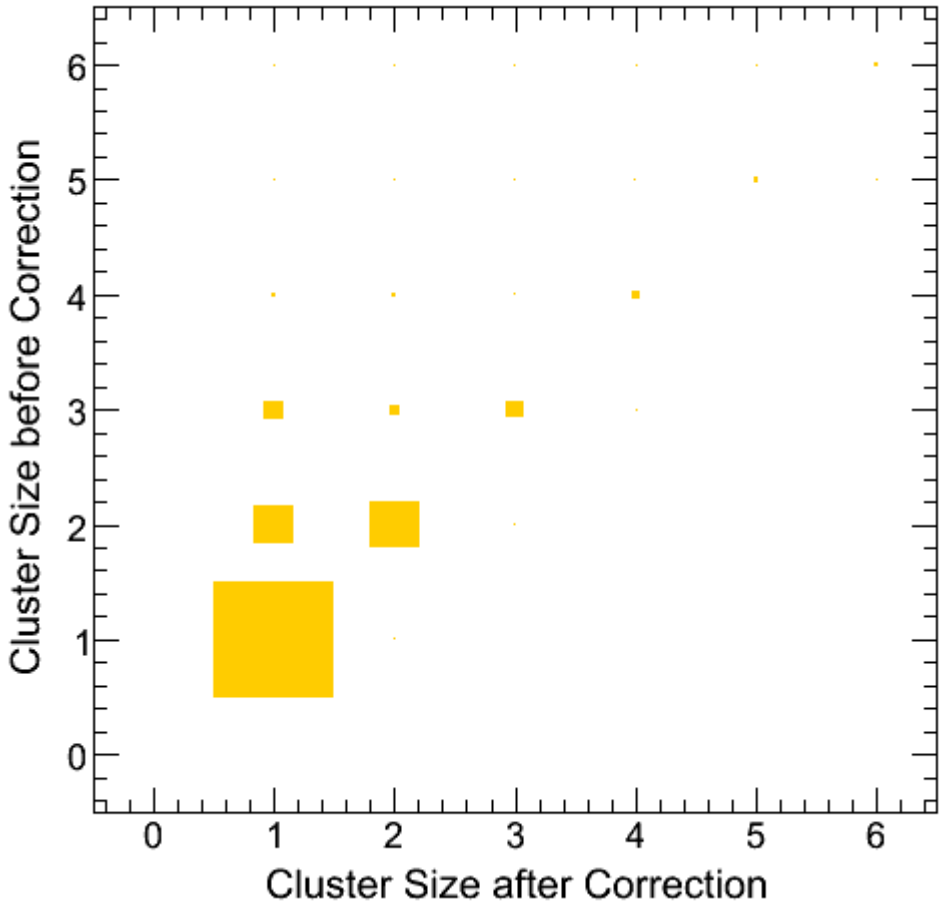




Heavy Particles from Hydrogen Target

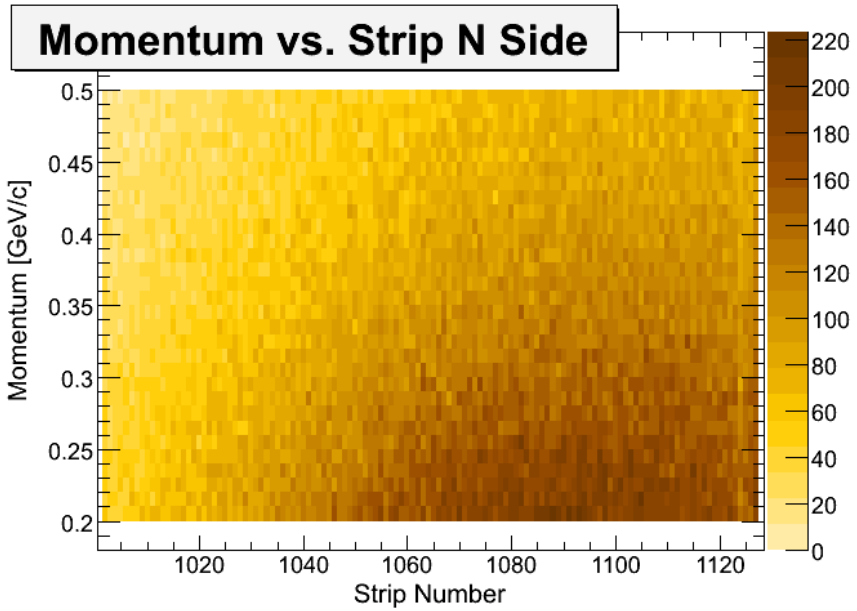


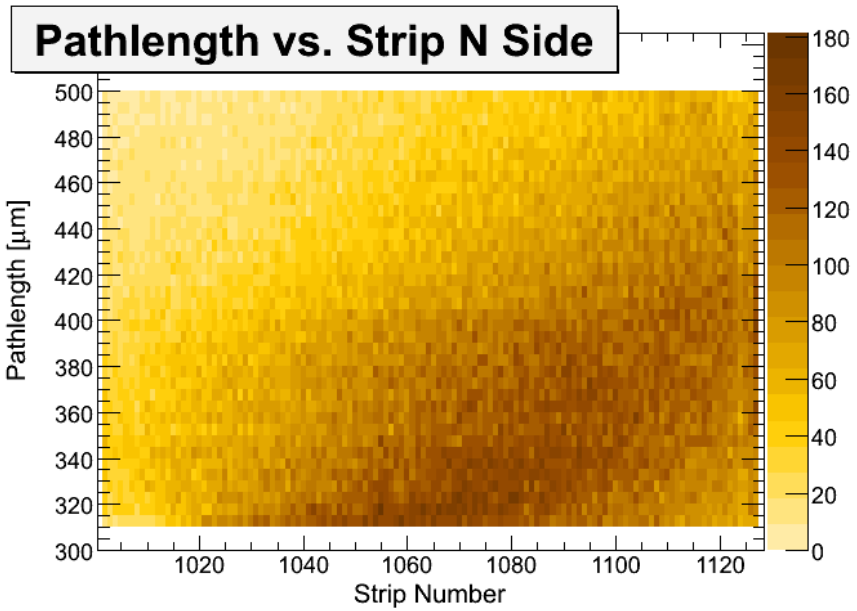
Crosstalk Correction – Clustersize



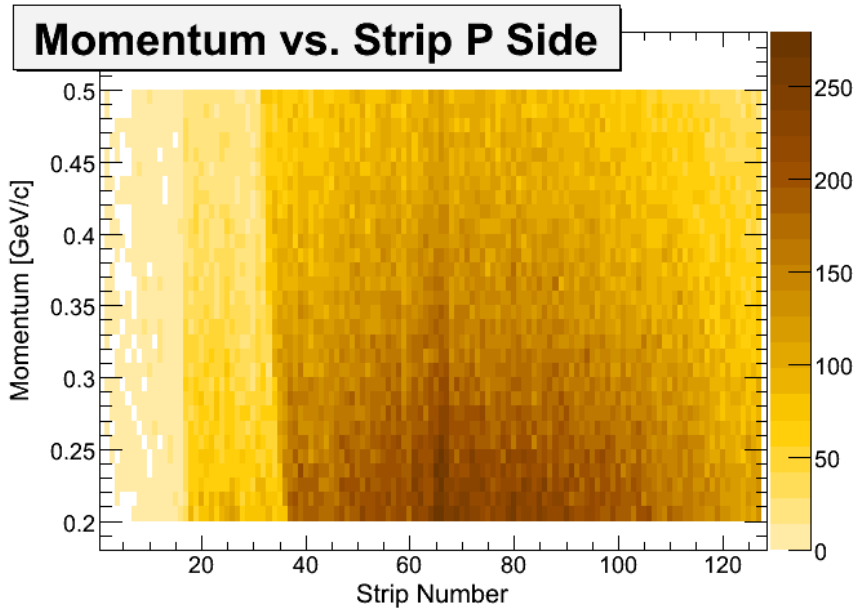
Calibration – Momentum and Pathlength Distributions

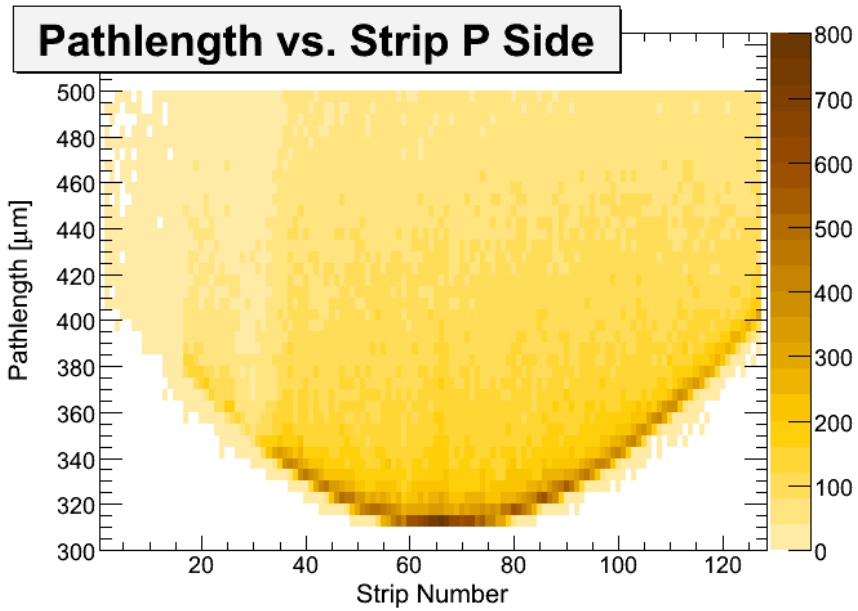
Perpendicular to beam



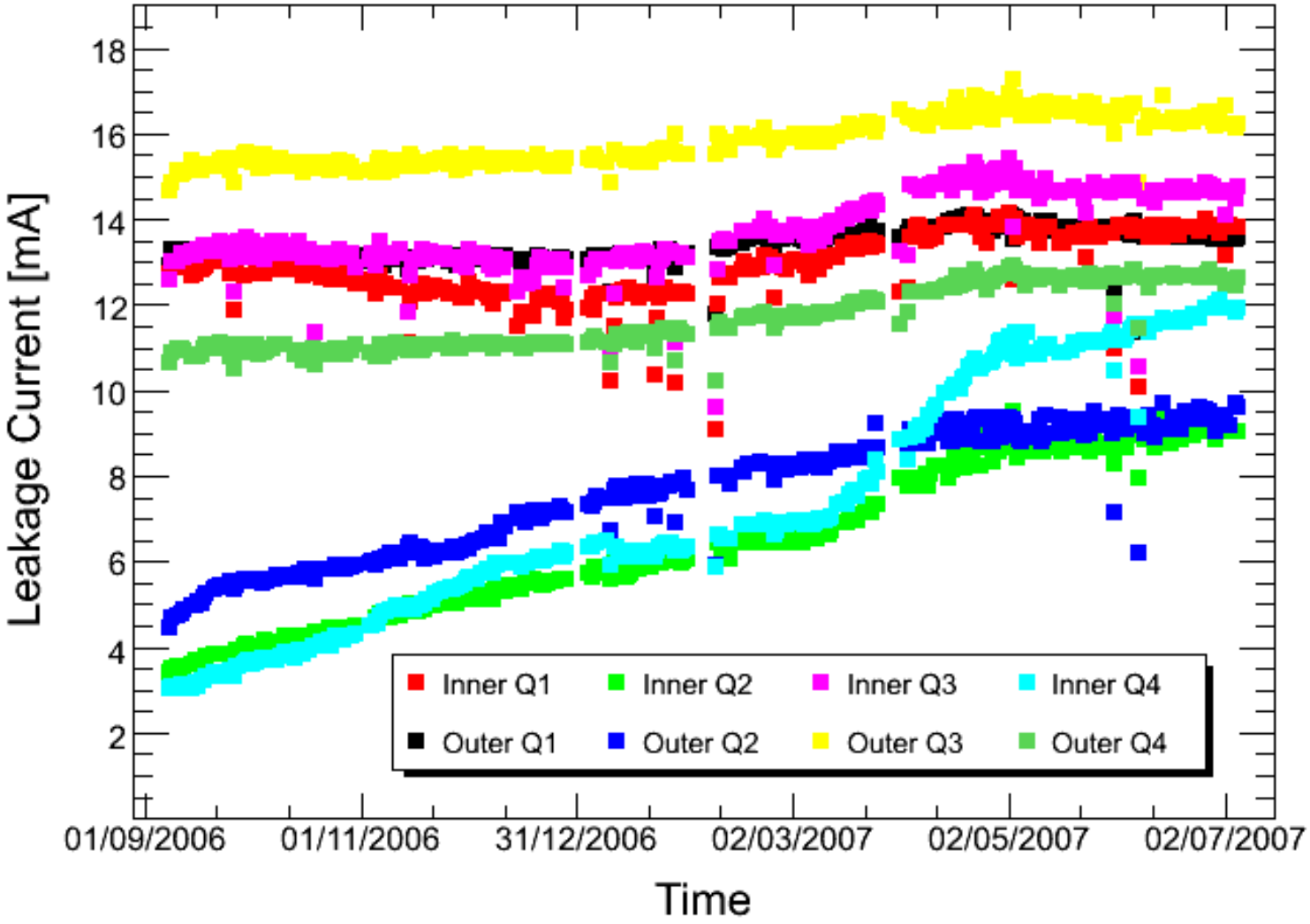


Parallel to beam

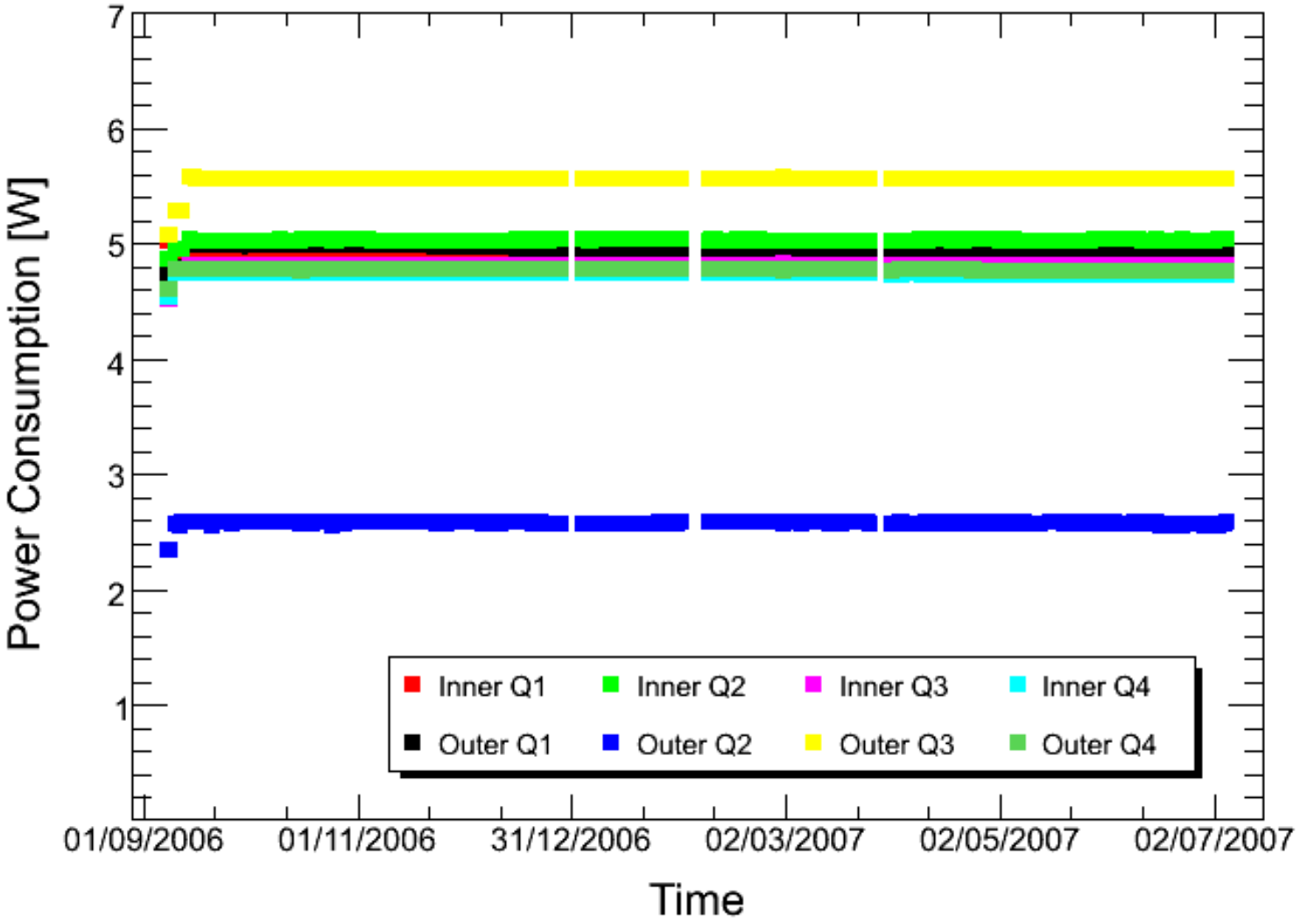




Leakage Currents

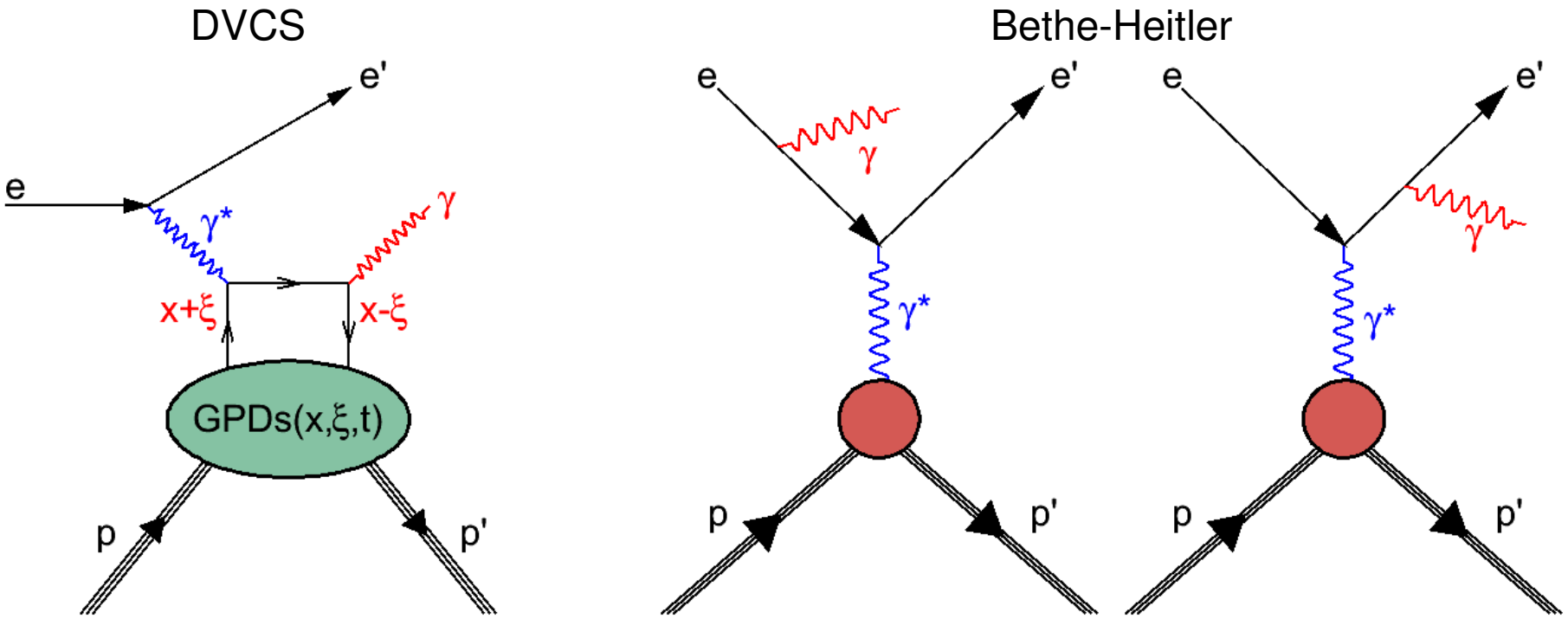


Power Consumption



- 8 HELIX chips per module (8 x 300 mW)

Deeply Virtual Compton Scattering - DVCS



- GPDs: Probabilityfunction to take a parton with momentum fraction $x+\xi$ from the nucleon and put it back with momentum fraction $x-\xi$
- Same final state in DVCS and Bethe-Heitler
- Access to DVCS via interferance term and azimuthal asymetries:

$$A_C, A_{LU}, A_{UT} \quad \text{and} \quad A_{UL}$$