First Results from the HERMES Recoil Detector

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HK 11.1

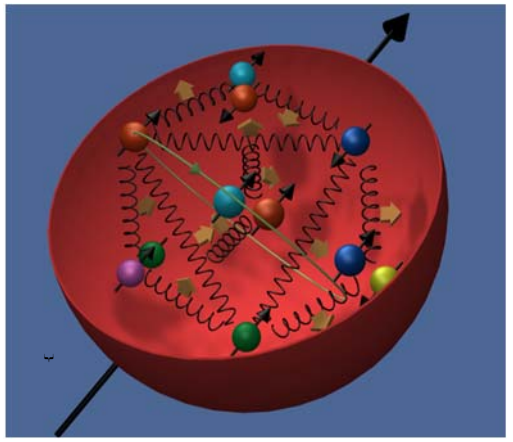
Outline

- Physics Motivation
  - Spin Structure of the Nucleon and GPD
  - DVCS and Exclusive Reactions at HERMES
  - HERMES at DESY
  - DVCS at HERMES without and with the Recoil Detector
- HERMES Recoil Detector
  - Silicon Strip Detector
  - Scintillating Fiber Tracker
  - Photon Detector
- First Results of Detector Performance
- Summary and Outlook

Spin Structure of the Nucleon

Nucleon spin:

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + J_g$$



- Quark spin: $\Delta\Sigma$ measured ~1/3 (HERMES, …)

  Phys. Rev. D 75, 012007 (2007)
- Quark orbital momentum: L_q unknown
- Gluon total angular momentum: J_g unknown

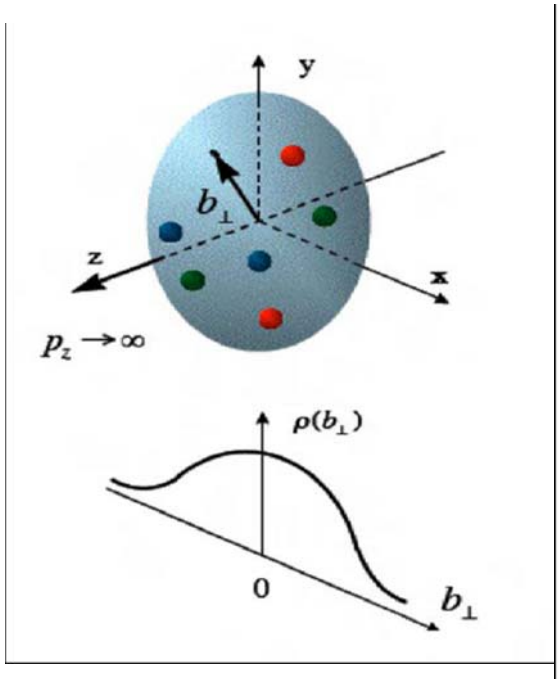
Ji's relation - PRL 78 (1997) 610

$$J_q = \lim_{t\to 0} \int_{-1}^{1} dx\, x \left[\underbrace{H_q(x,\xi,t) + E_q(x,\xi,t)}_{\text{GPDs}} \right]$$

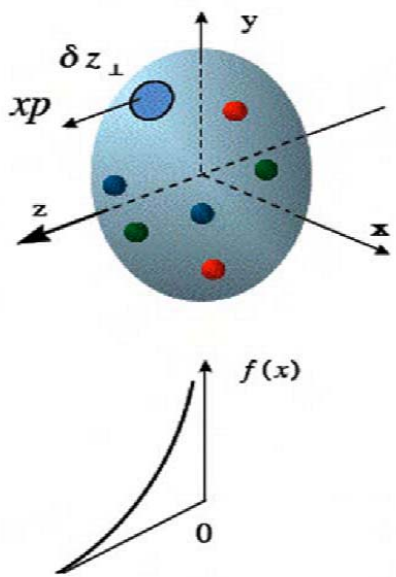
Generalized parton distributions: access the orbital angular momentum of quarks in nucleon

Generalized Parton Distributions

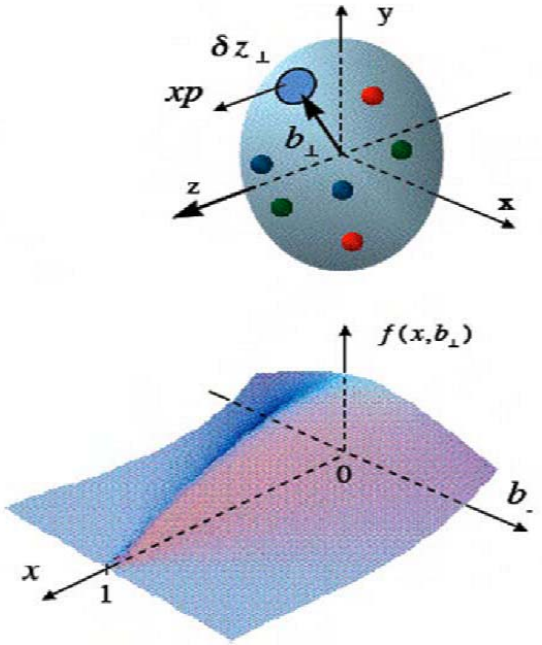
GPDs: incorporate regular parton distributions and form factors into a framework for phenomenological description of the nucleon



Form Factors



Parton Distribution Function



Generalized Parton Distributions

Generalized Parton Distributions

- GPDs → PDF

$$H_q(x,0,0) = q(x)$$

$$\tilde{H}_q(x,0,0) = \Delta q(x)$$

- GPD → FF

$$\int_{-1}^{1} dx H_q(x,\xi,t) = F_1^q(t)$$

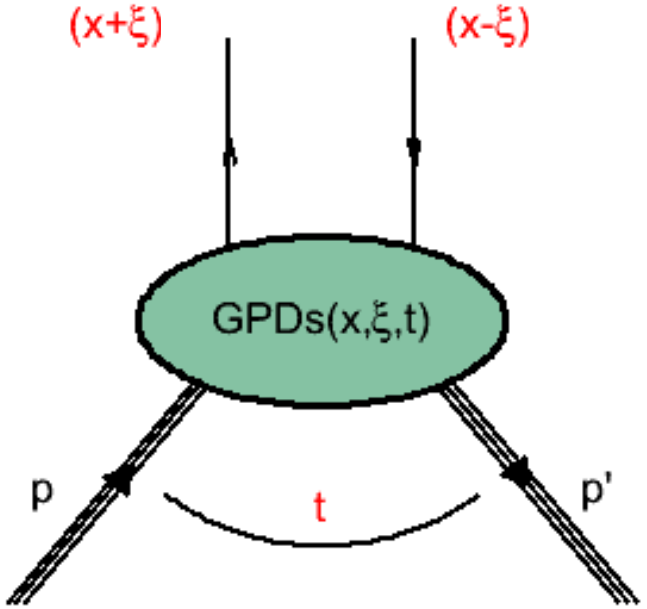
$$\int_{-1}^{1} dx E_q(x,\xi,t) = F_2^q(t)$$

- $H_q, \tilde{H}_q$ conserve nucleon helicity
- $E_q, \tilde{E}_q$ flip nucleon helicity

$x \pm \xi$ parton longitudinal momentum fractions

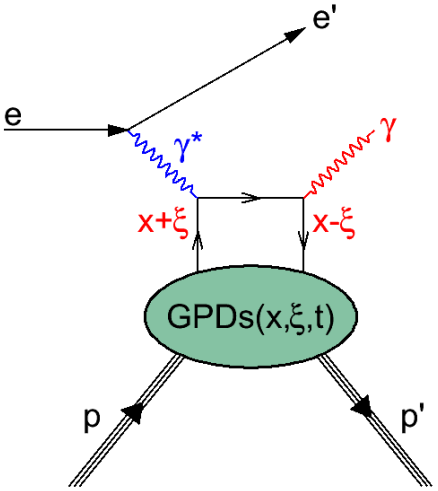
ξ fraction of the momentum transfer

t invariant momentum transfer to the nucleon

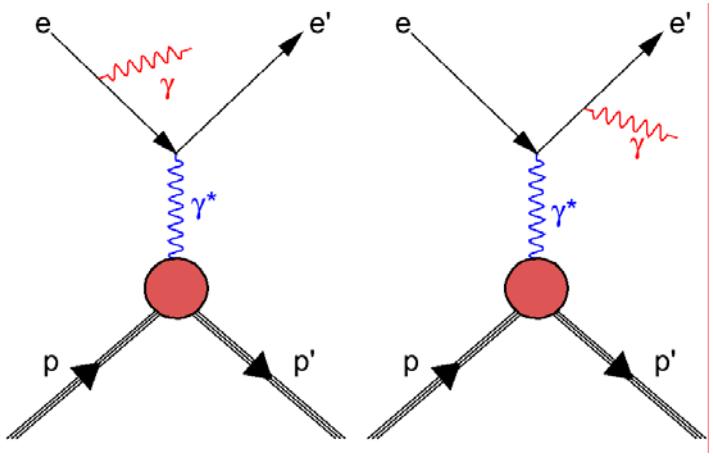


Access to GPD via Deeply Virtual Compton Scattering (DVCS)

Cleanest way to access GPDs: DVCS



Bethe-Heitler



$$d\sigma(eN \to eN\gamma) \propto \left|I_{BH}\right|^2 + \left|I_{DVCS}\right|^2 + \underbrace{I_{BH} I^*_{DVCS} + I^*_{BH} I_{DVCS}}_{\text{interference term}}$$

- DVCS and Bethe-Heitler: the same initial and final state
- Bethe-Heitler dominates at HERMES kinematics
- GPDs accessible through cross-section differences and azimuthal asymmetries via interference term

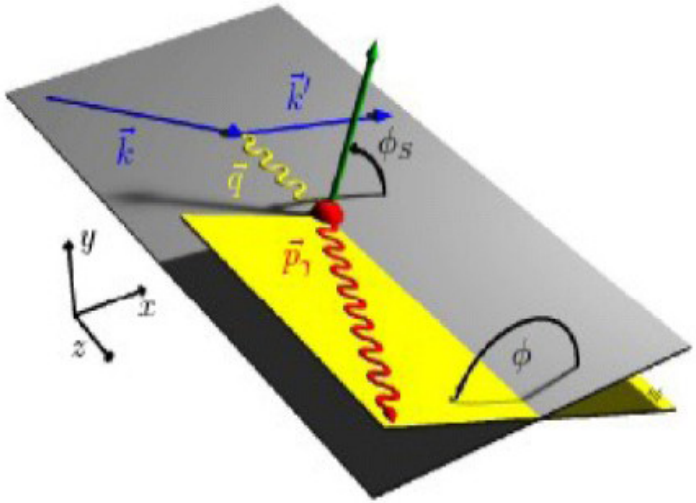
Asymmetries Measurable at HERMES

- Beam-Spin Asymmetry (BSA)

$$A_{LU} = \frac{d\sigma(e^{\rightarrow},\phi) - d\sigma(e^{\leftarrow},\phi)}{d\sigma(e^{\rightarrow},\phi) + d\sigma(e^{\leftarrow},\phi)} \propto \Im m(\mathcal{H}) \sin(\phi)$$

- Beam-Charge Asymmetry (BCA)

$$A_C = \frac{d\sigma(e^{+},\phi) - d\sigma(e^{-},\phi)}{d\sigma(e^{+},\phi) + d\sigma(e^{-},\phi)} \propto \Re e(\mathcal{H}) \cos(\phi)$$



- Longitudinal Target Spin Asymmetry (LTSA)

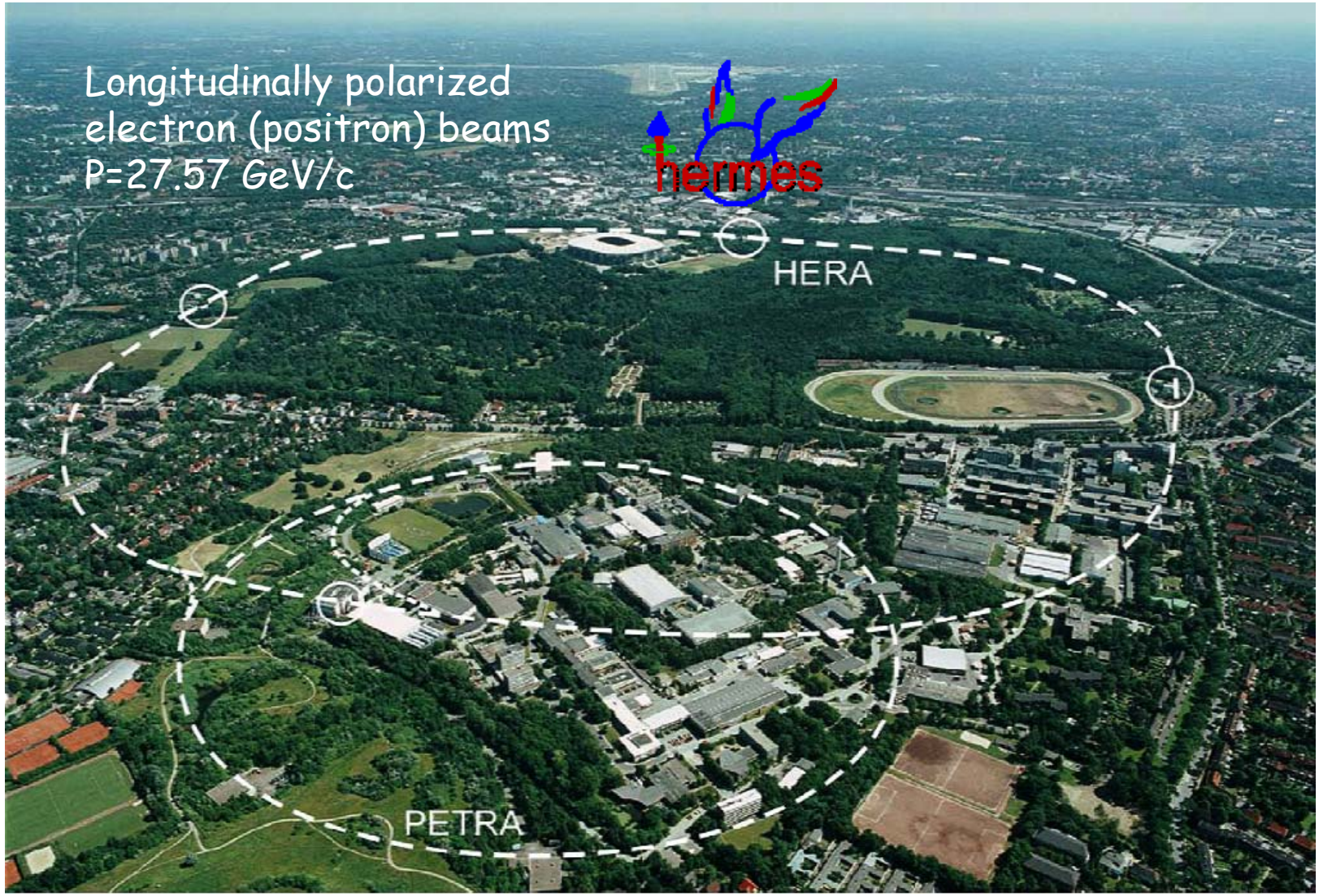
$$A_{UL} = \frac{d\sigma(p^{\rightarrow},\phi) - d\sigma(p^{\leftarrow},\phi)}{d\sigma(p^{\rightarrow},\phi) + d\sigma(p^{\leftarrow},\phi)} \propto \Im m(\widetilde{\mathcal{H}}) \sin(\phi)$$

- Transverse Target Spin Asymmetry (TTSA)

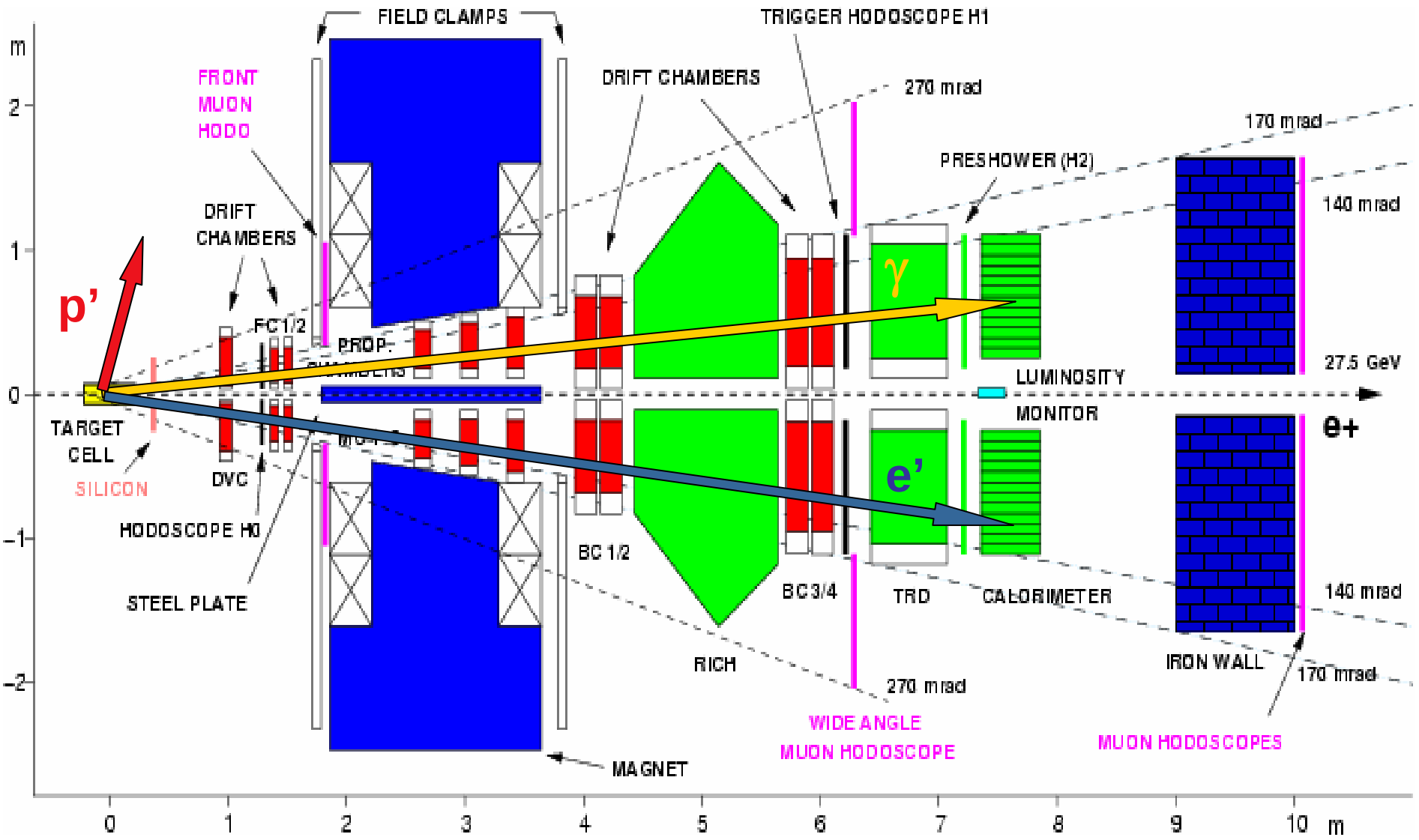
$$A_{UT} = \frac{d\sigma(p^{\uparrow},\phi) - d\sigma(p^{\downarrow},\phi)}{d\sigma(p^{\uparrow},\phi) + d\sigma(p^{\downarrow},\phi)} \propto f(\mathcal{H},\mathcal{E},\widetilde{\mathcal{H}},\widetilde{\mathcal{E}},\phi,\phi_S)$$

Talk: Dietmar Zeiler HK 16.3, 11.03 9.:15

HERA at DESY


Longitudinally polarized
electron (positron) beams
P=27.57 GeV/c
hermes
HERA
PETRA

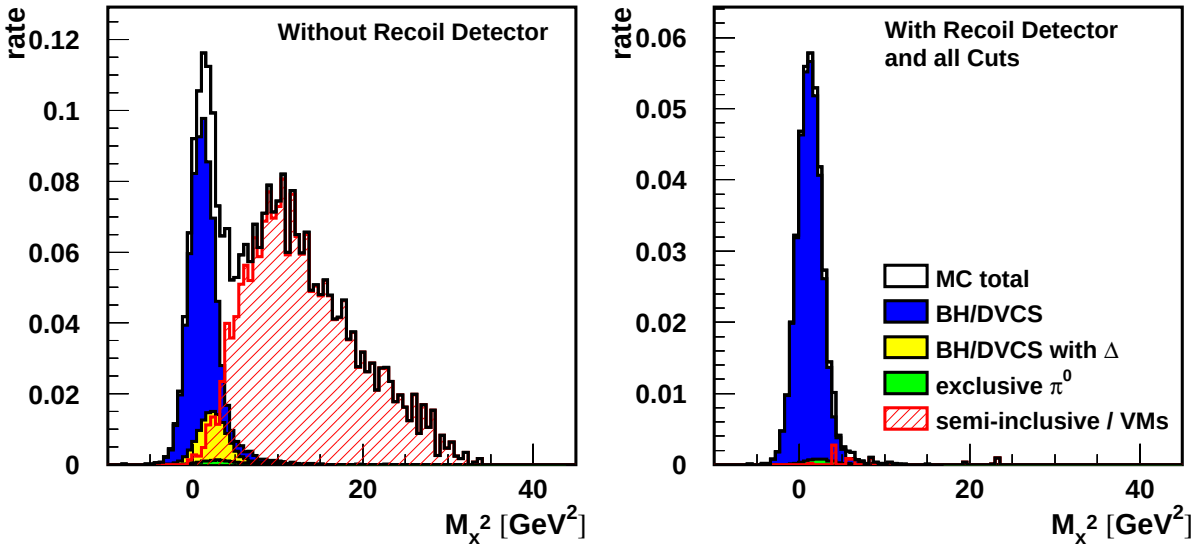
HERMES at DESY



DVCS Measurements at HERMES

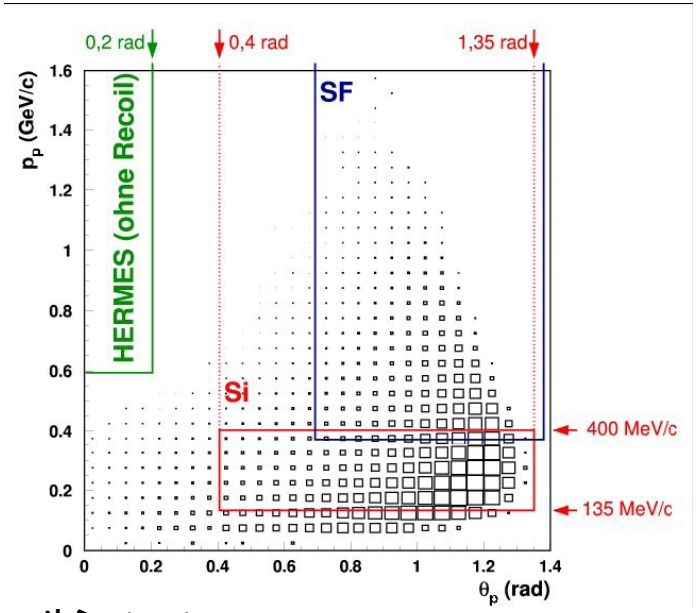
Before Recoil

- Reconstruct DVCS by measuring scattered electron and real photon
- Missing-mass method
- Background from
  - associated Bethe-Heitler $(ep \to e'\Delta^+\gamma)$ ~11%
  - semi-inclusive $(ep \to e'\pi^0 X)$ ~5%



With Recoil

- Improve exclusivity by measuring recoil protons, pions and photons
- Suppress background to the level below 1%
- Improve t-resolution



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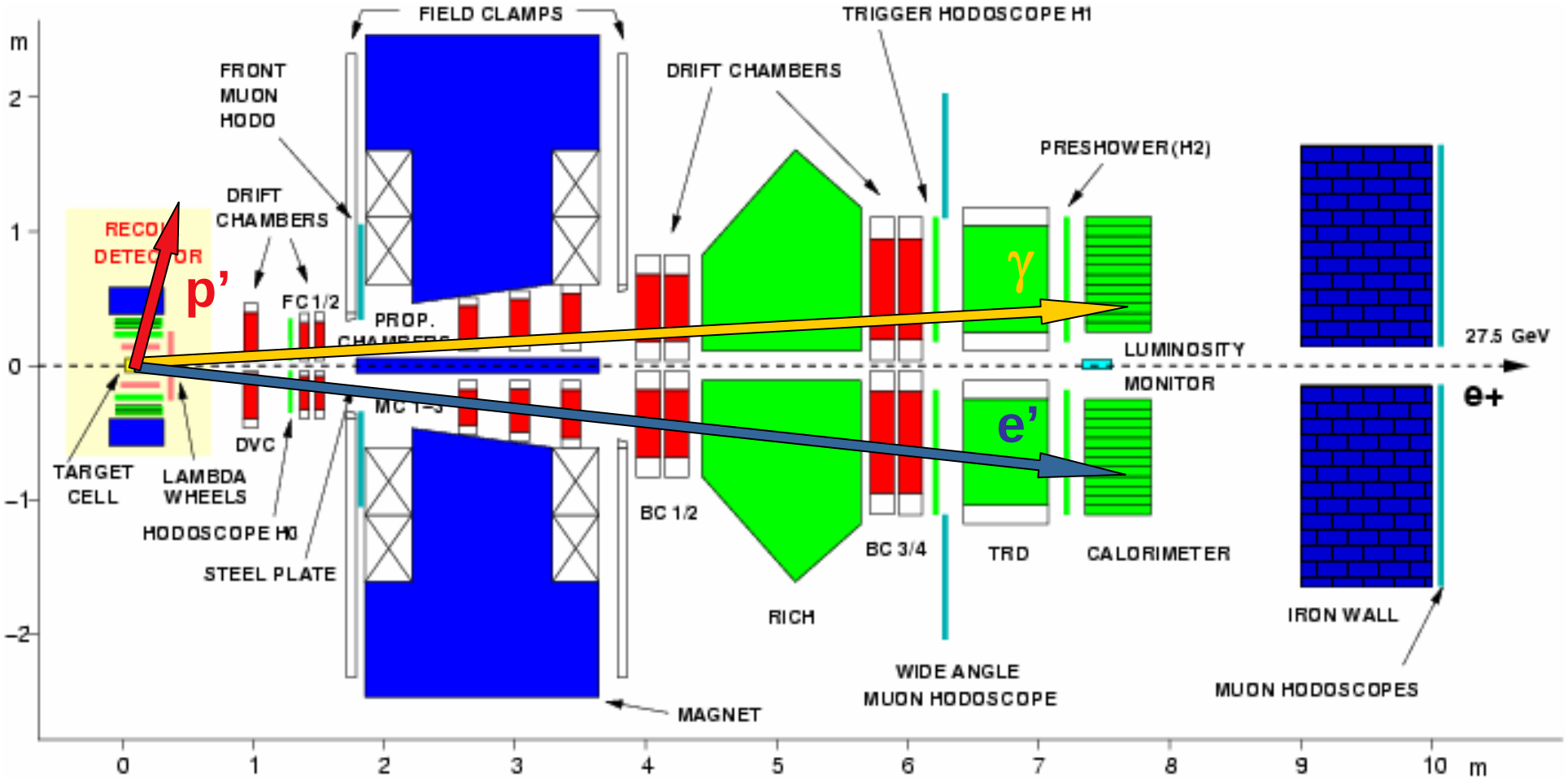
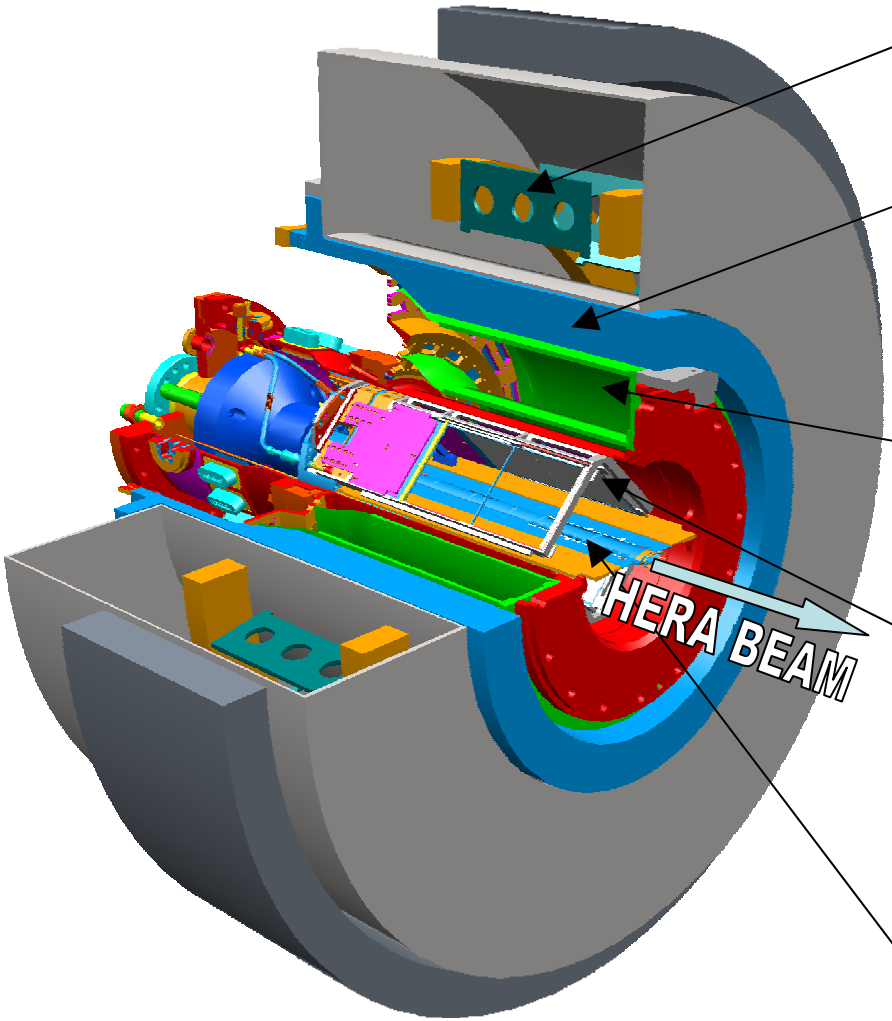
HERMES with Recoil



Recoil Detector



1 Tesla Superconducting Solenoid

Photon Detector (PD)

detect gammas

p/π PID for momentum > 650 MeV/c

Scintillating Fiber Tracker (SFT)

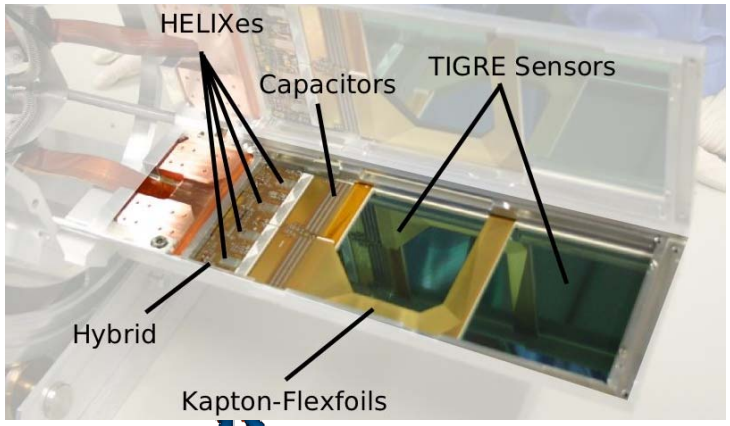
Momentum reconstruction by bending in magnetic field

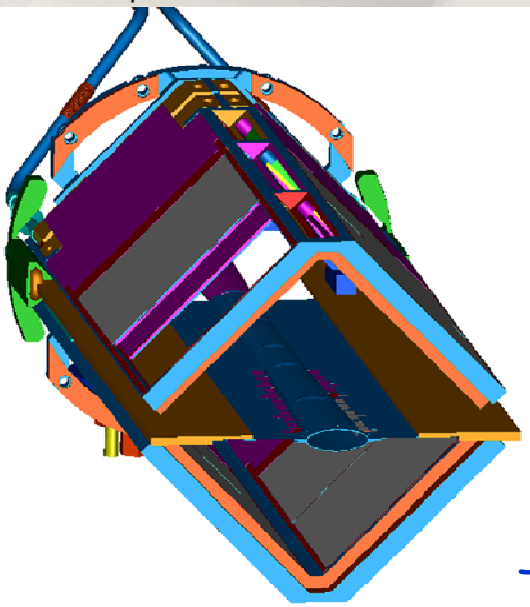
Silicon Strip Detector (SSD)

Momentum reconstruction by energy deposit for low-momentum protons and deuterons

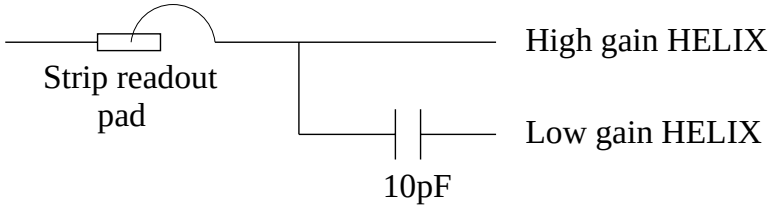
Unpolarized Target Cell

Silicon Strip Detector



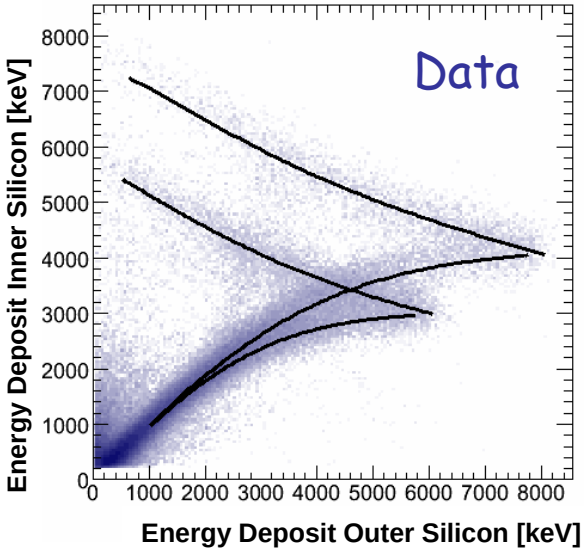


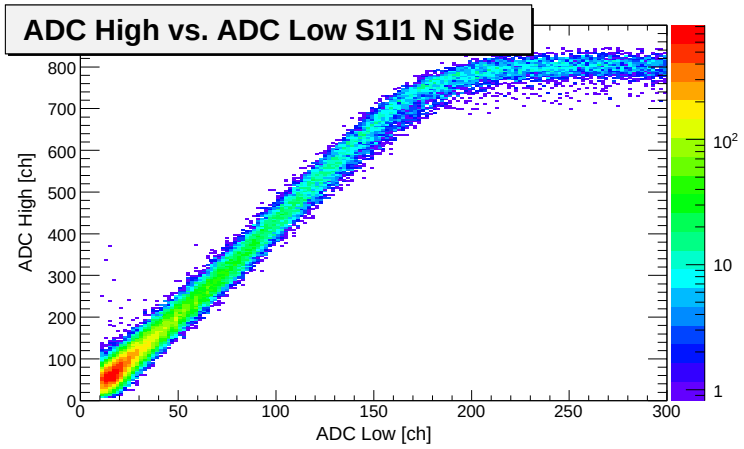
- 2 layers of double-sided silicon strip sensors located in beam vacuum
- Strips: pitch=758 μm, 300μm thick
- Readout by HELIX 3.0 chips: high and low gain to increase dynamic range



Talk: Andreas Mussgiller HK 25.6, 11.03 12:30

Silicon Strip Detector





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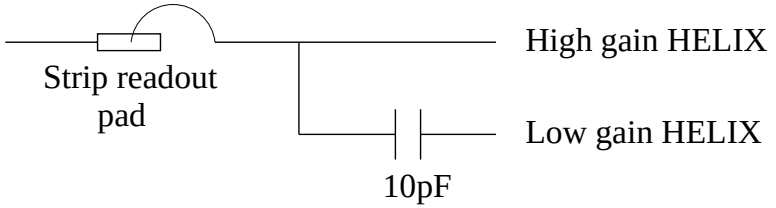
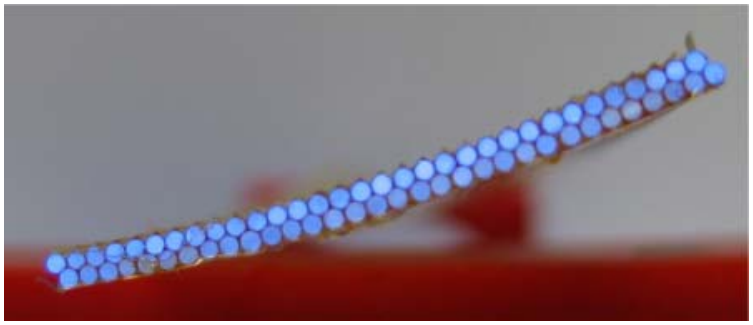
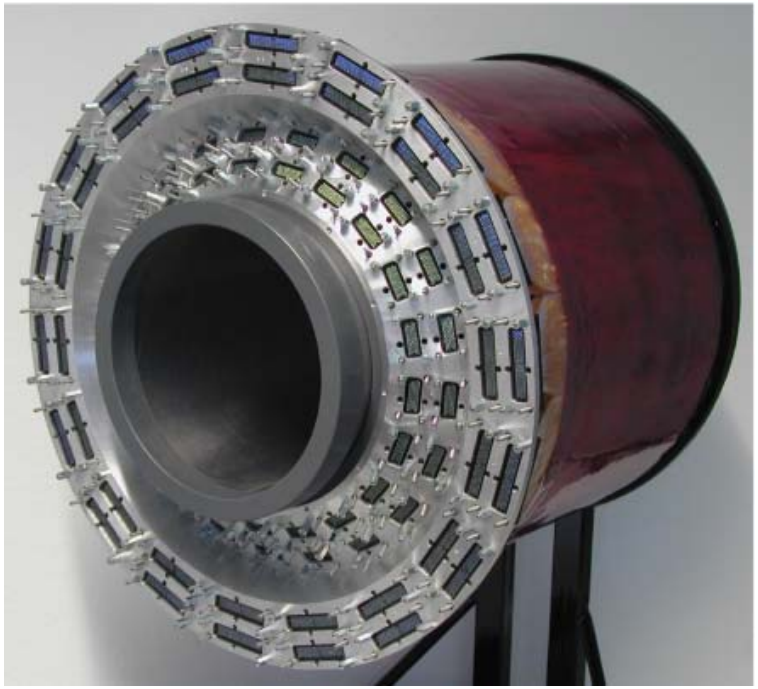


Talk: Andreas Mussgiller HK 25.6, 11.03 12:30

Scintillating Fiber Tracker

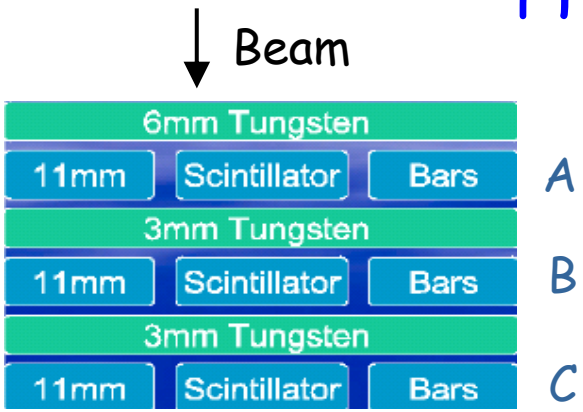




- 2 cylinders:
  - 2 parallel layers
  - 2 10 degree stereo layers
- KURARAY fibers: 1mm diameter
- Read out by multi-anode PMTs
- GASSIPLEX chips
- p_p: 250-1200 MeV/c from bending in magnetic field

Talk:Tibor Keri HK 11.5, 10.03 17:45

Photon Detector



- Sandwich of 3 layers of tungsten-scintillator:
  - A-layer parallel to the beam axis
  - B/C: under +45/-45 degree angle
- Strips: 2x1x28 cm^3
- Read out by multi-anode PMTs
- Detect γ from π^0 decay
- Reconstruct π^0 if 2 γ's detected

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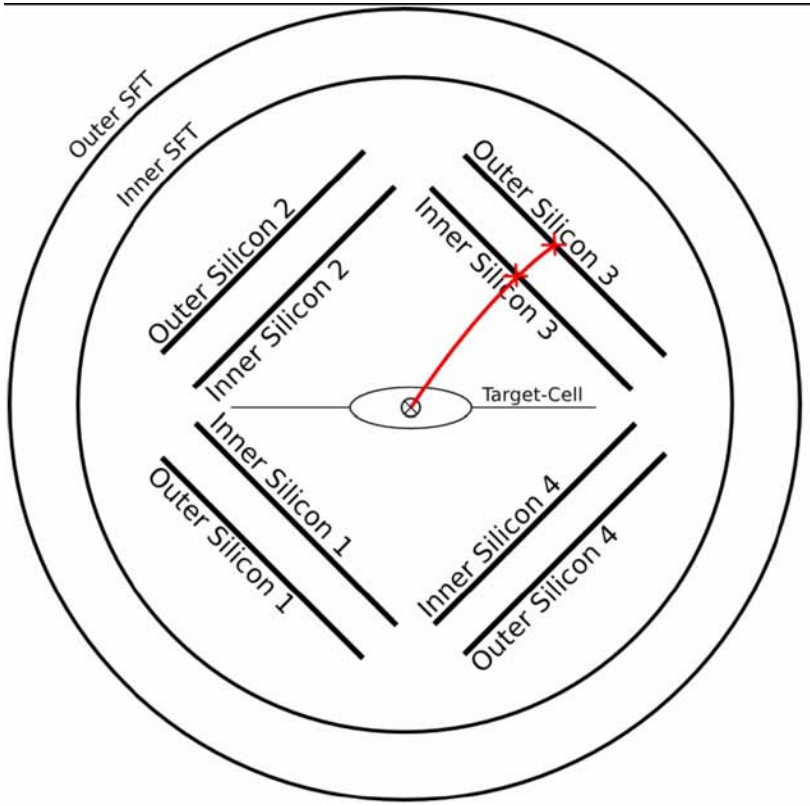
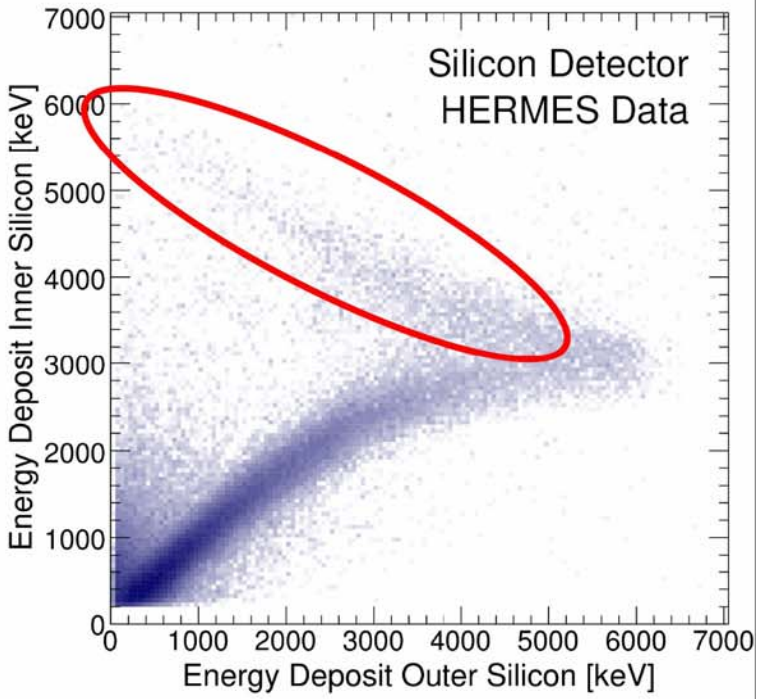
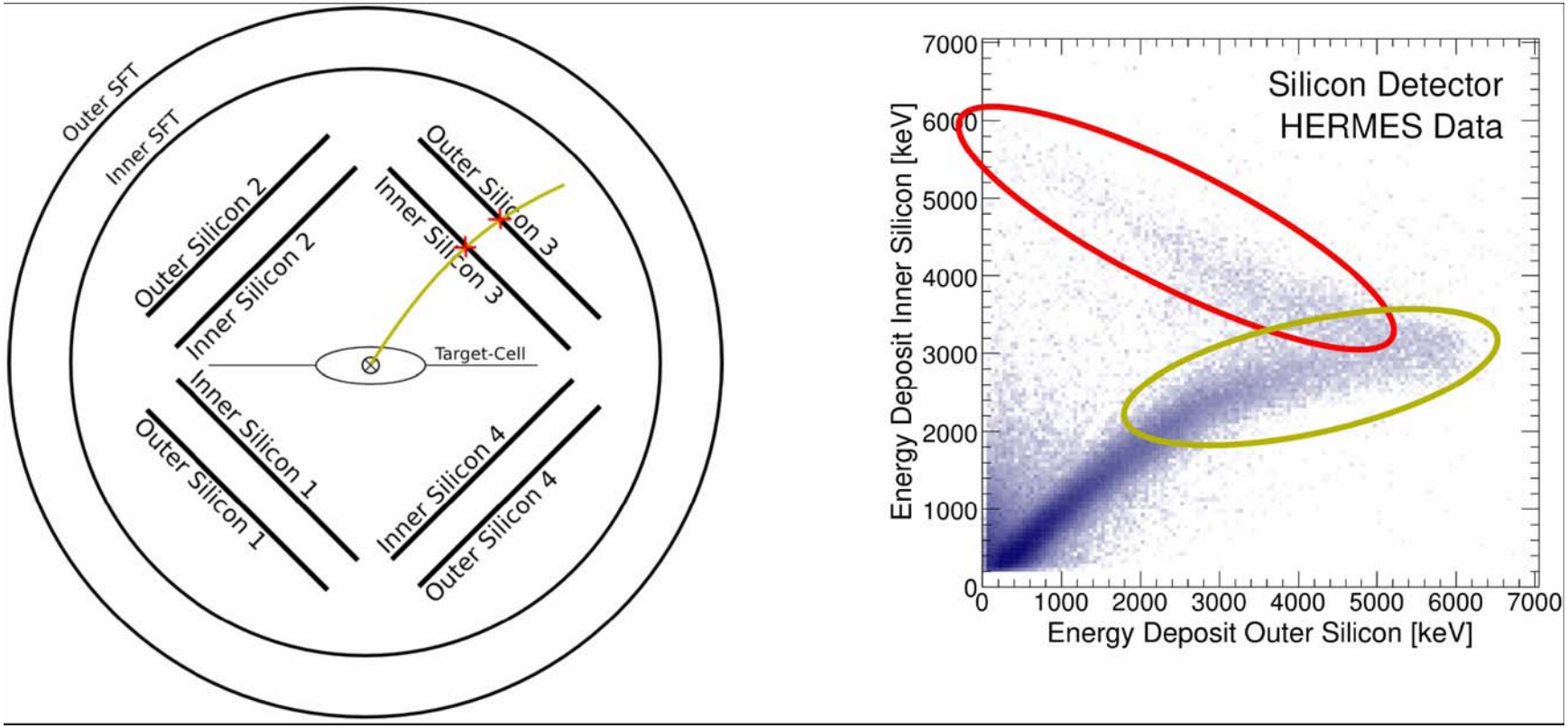
Momentum Reconstruction with Recoil

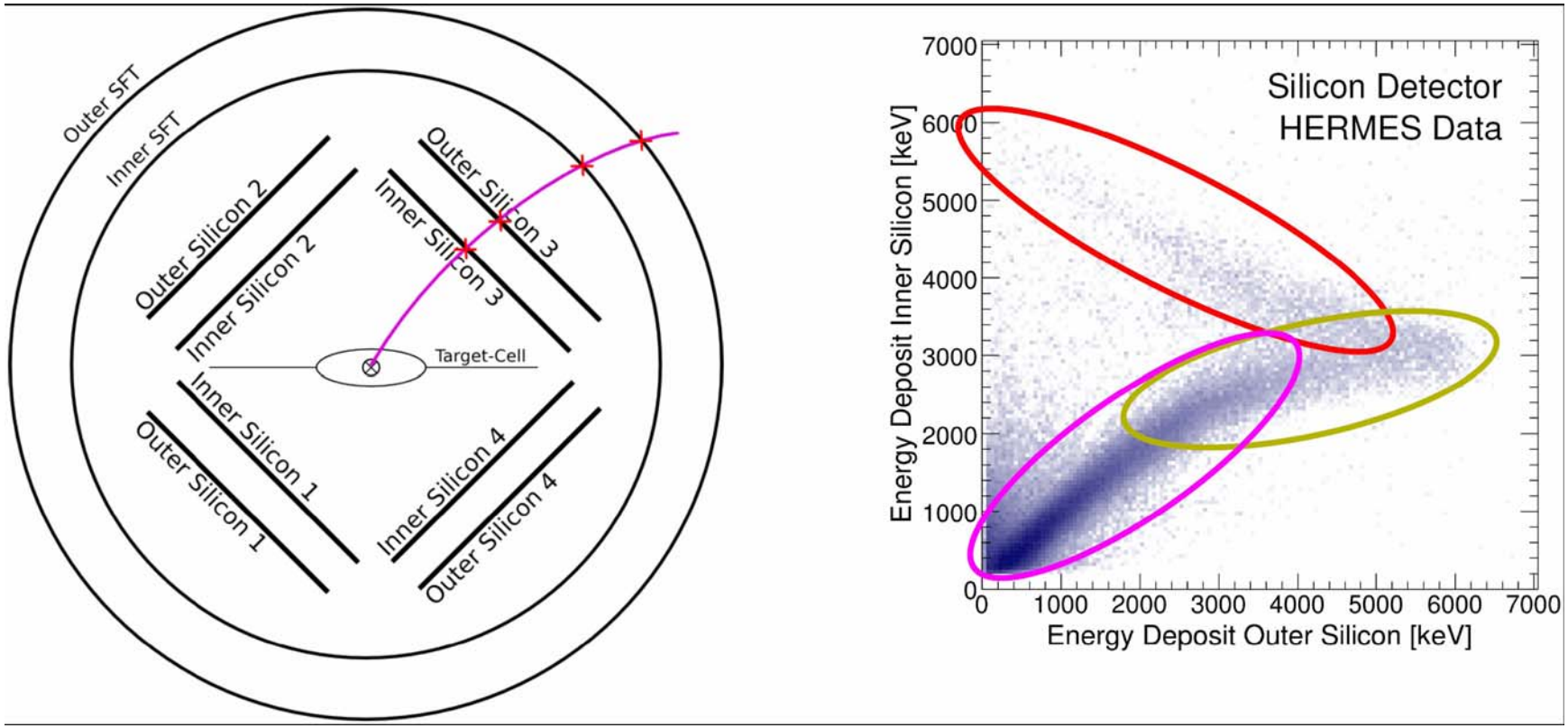




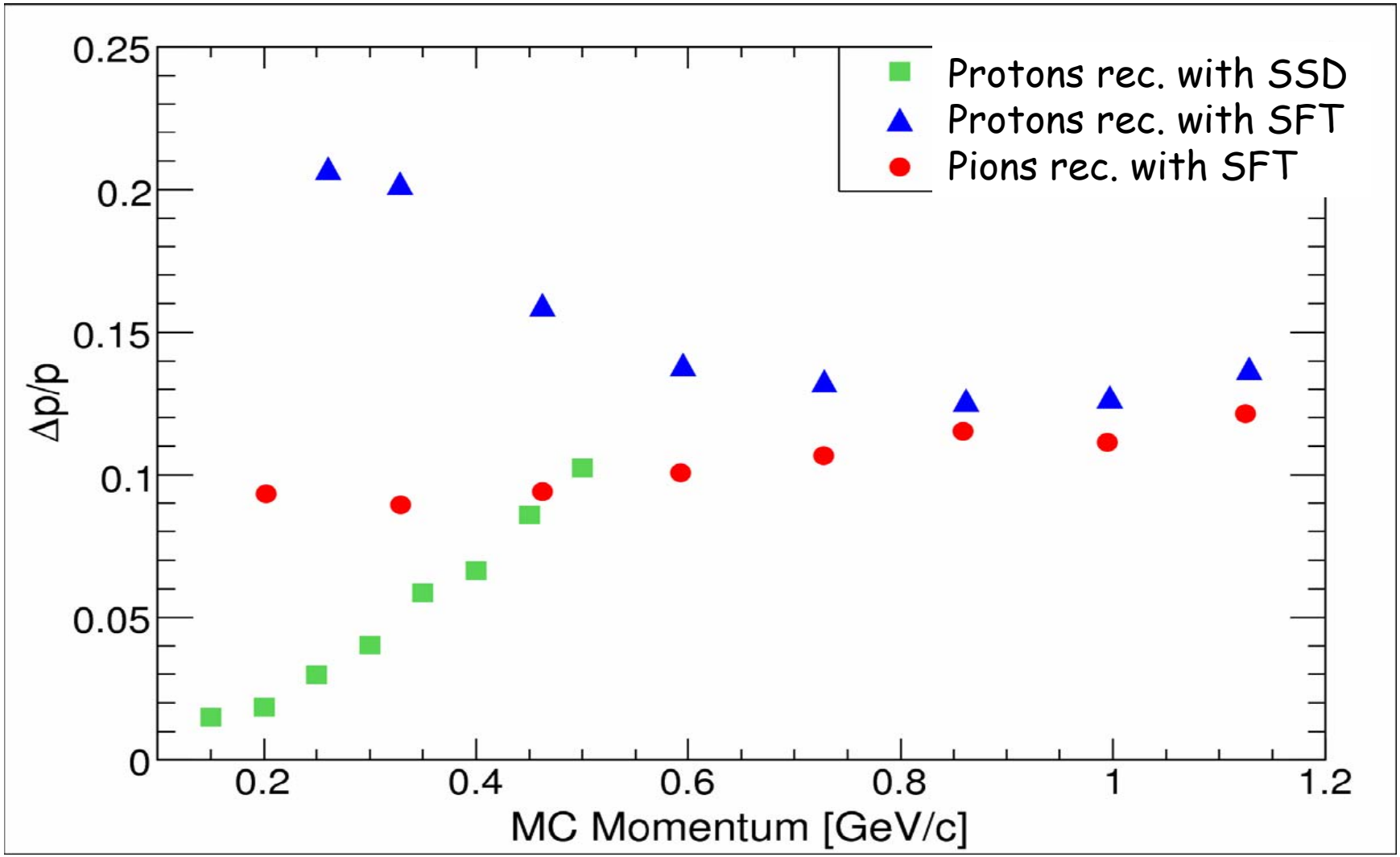
Momentum Reconstruction with Recoil



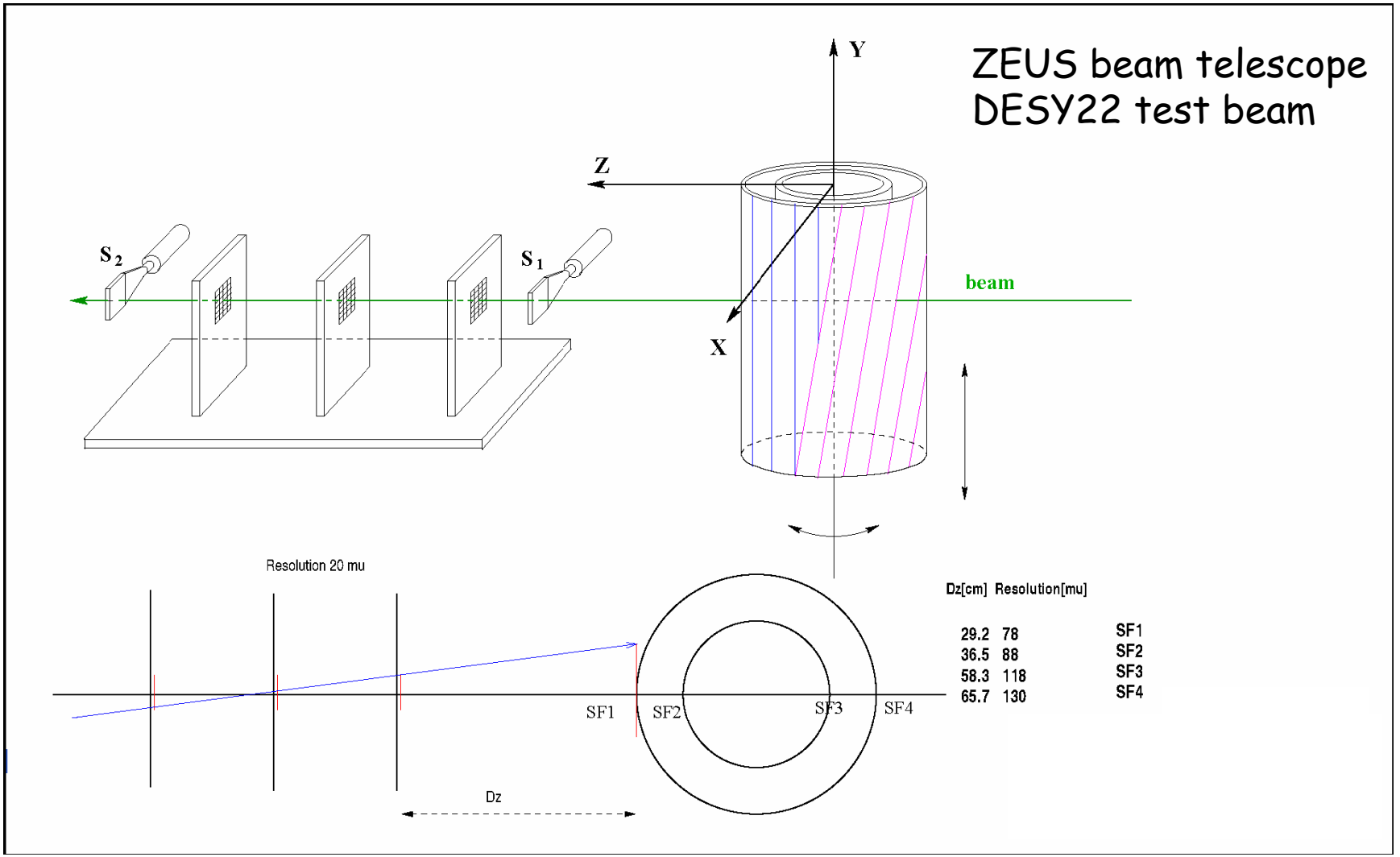
Momentum Reconstruction with Recoil



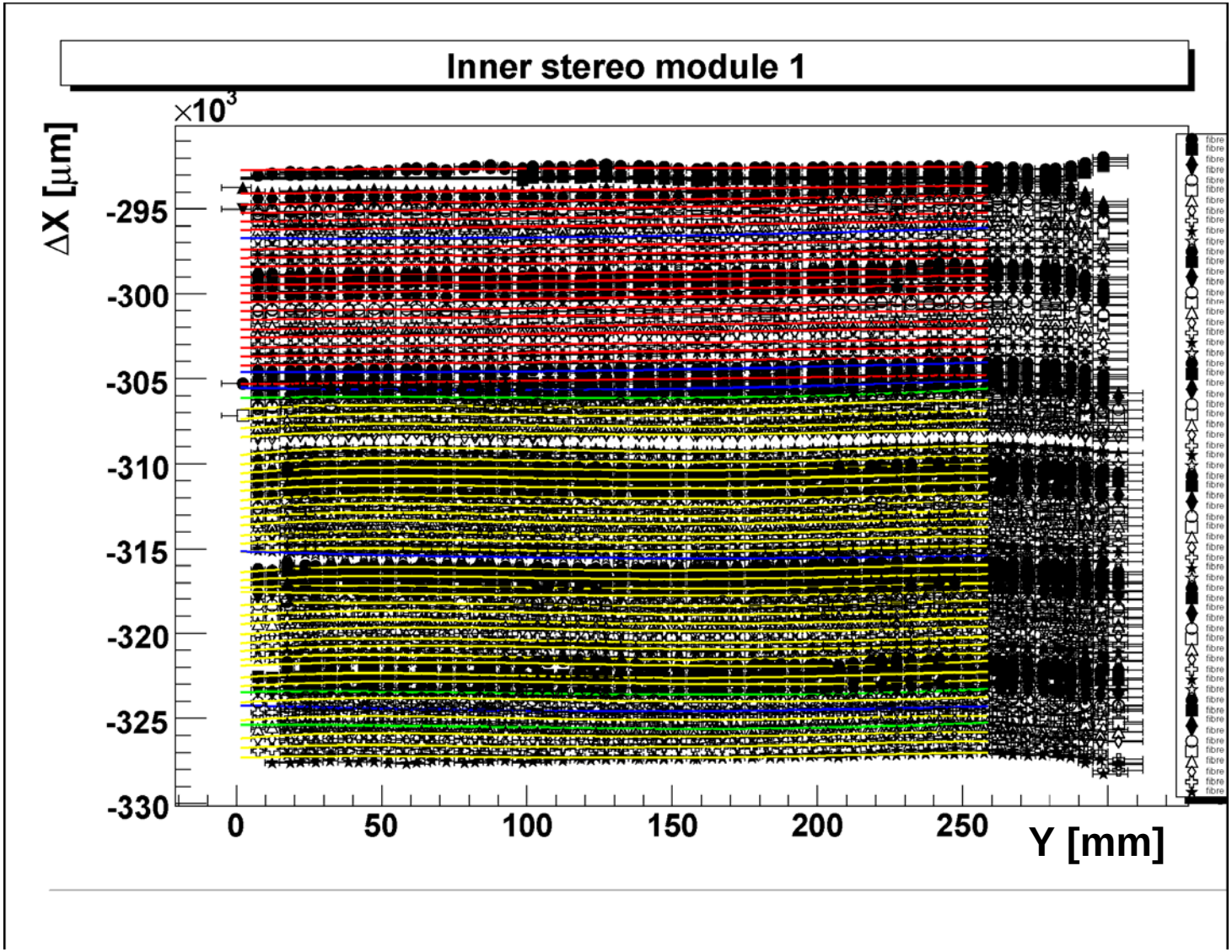
Accuracy of Momentum Reconstruction



Alignment of the SFT

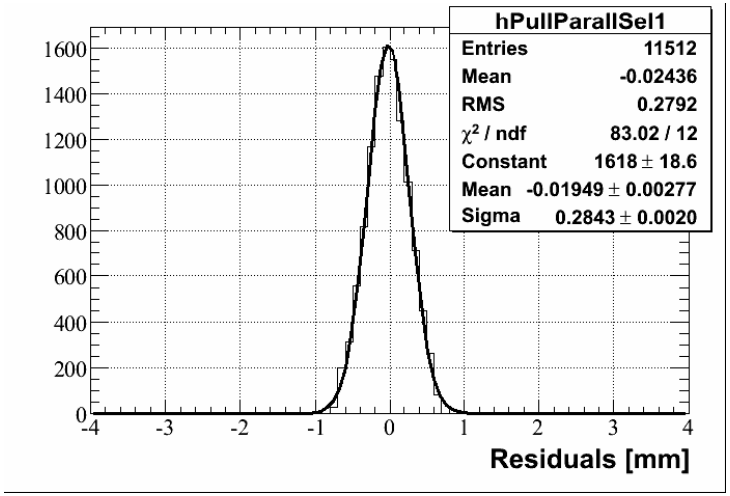


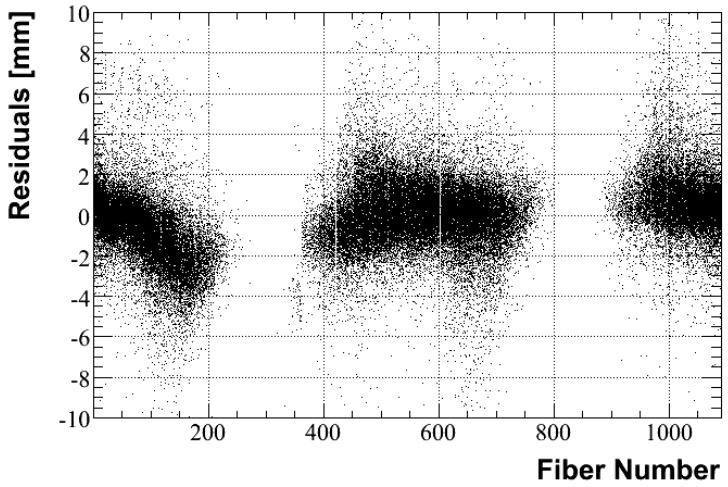
Measurements of Positions of SFT fibers

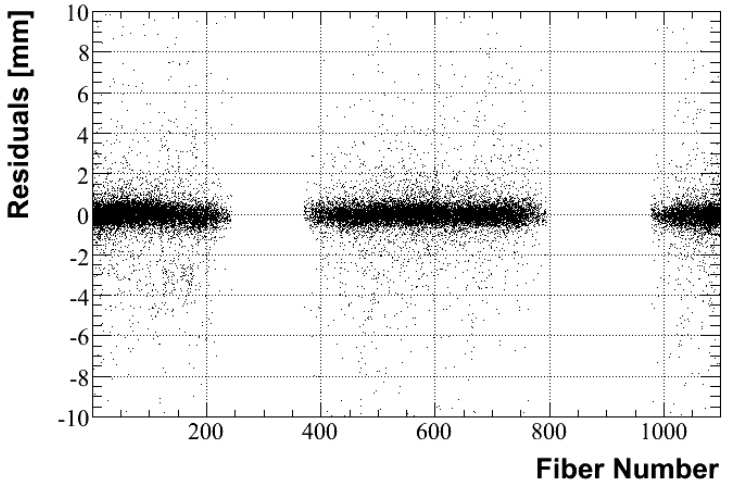


Results of Alignment of SFT

- Measurements of dedicated SFT run were used and tested on cosmic data collected with Recoil
- Residuals (280 μm) are in good agreement with expectations from ideally aligned Monte-Carlo (220 μm)

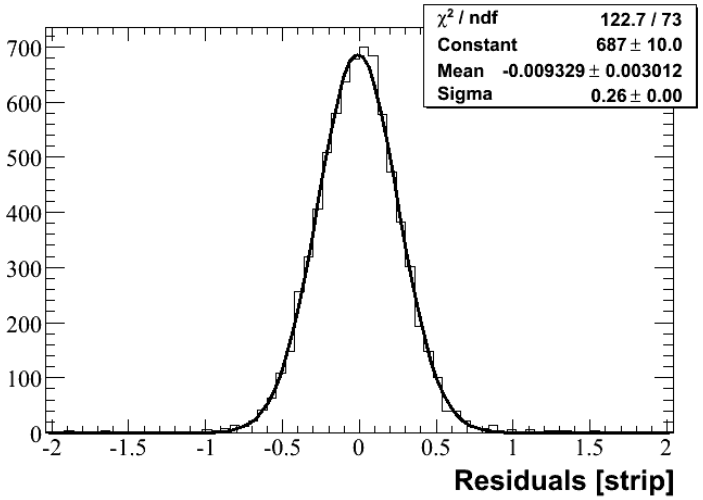


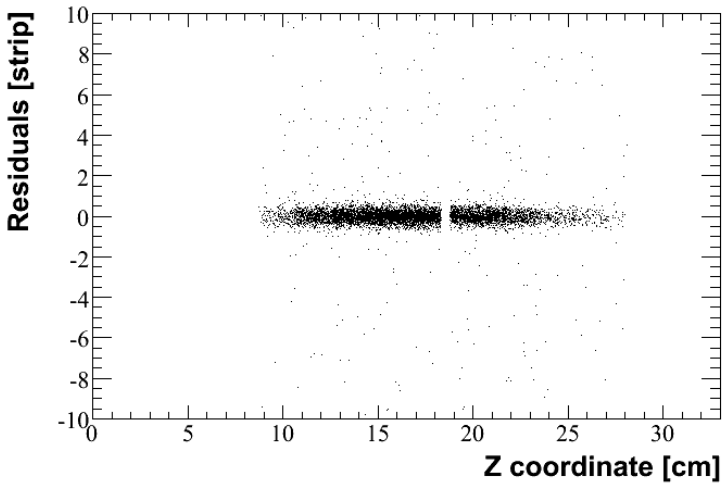


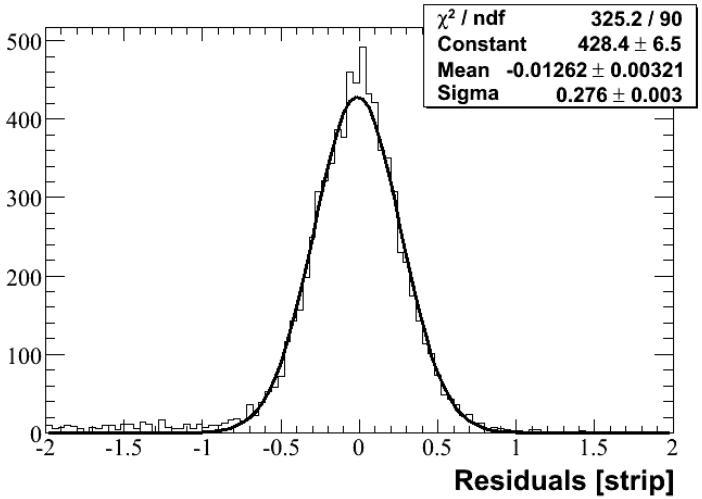


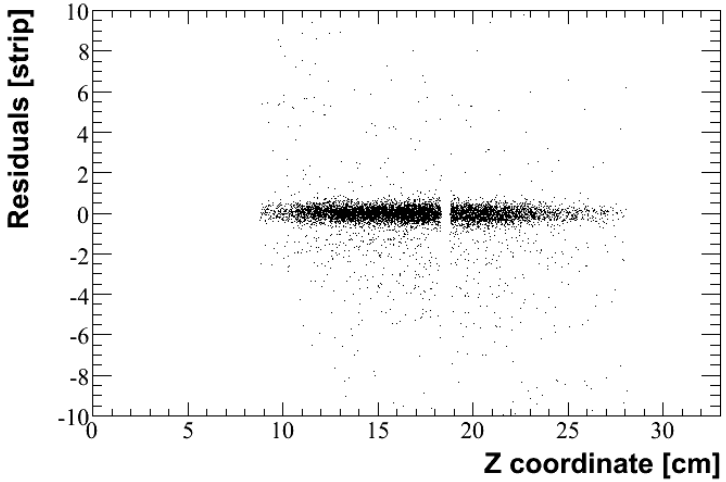
- SSD and PD aligned relative to the SFT

Silicon Strip Detector Alignment



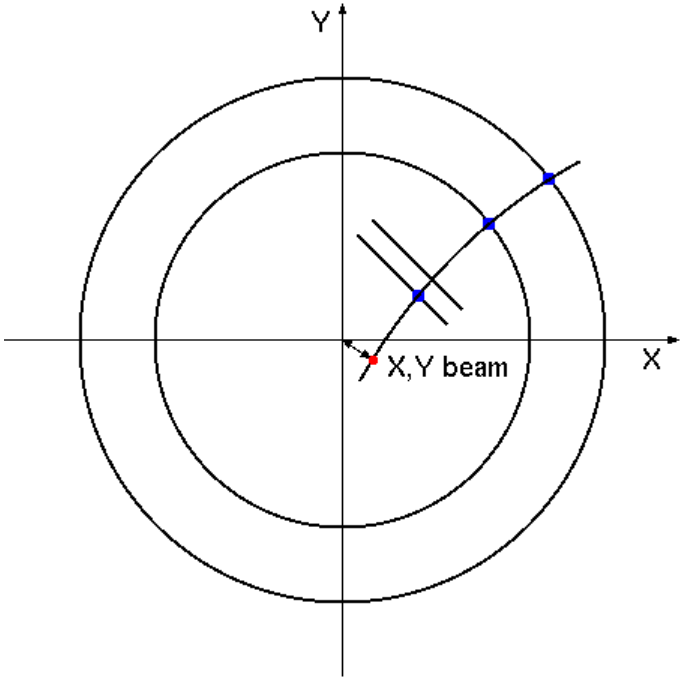


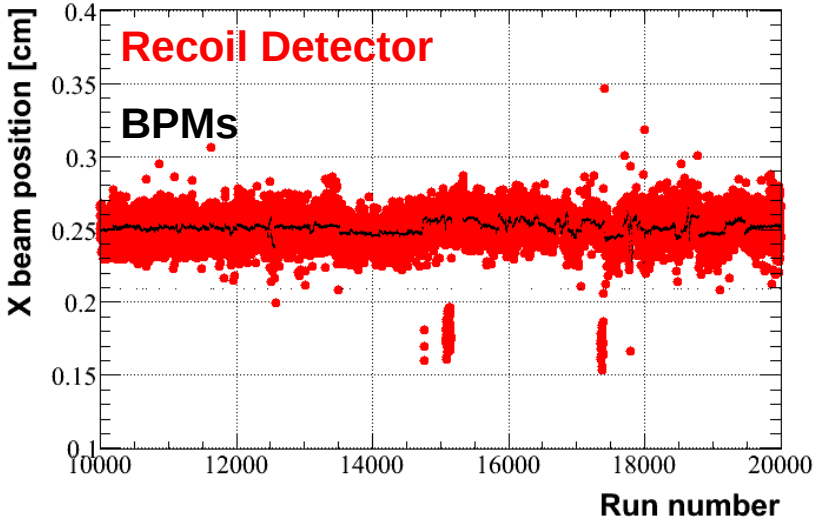


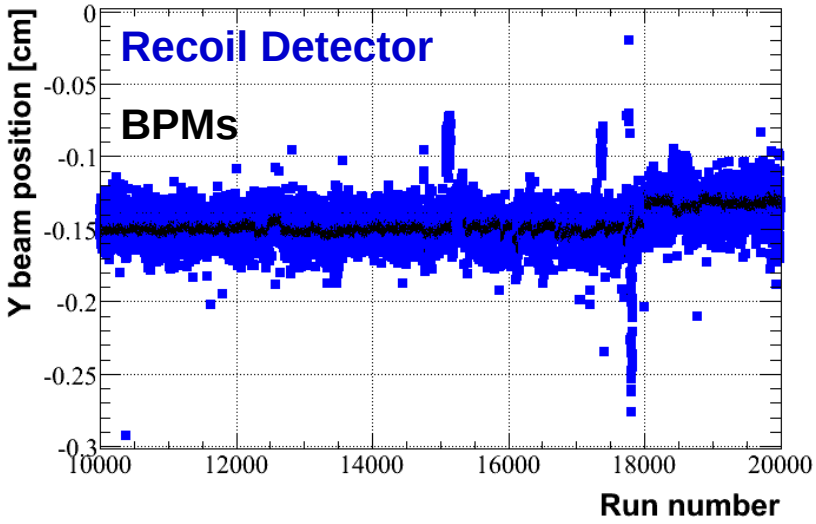


Beam Position Determination with Recoil

- Beam position from Recoil tracking and beam position monitors (BPM)
- Recoil beam finding for absolute normalization of beam position and alignment relative to the HERMES Forward spectrometer

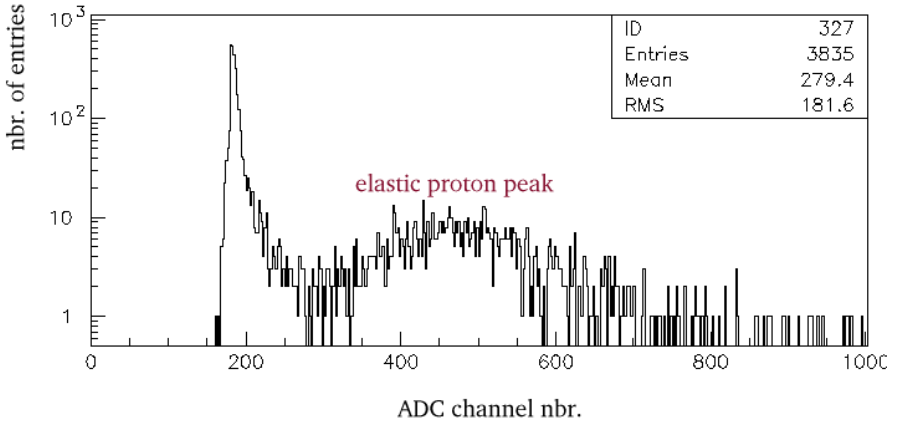


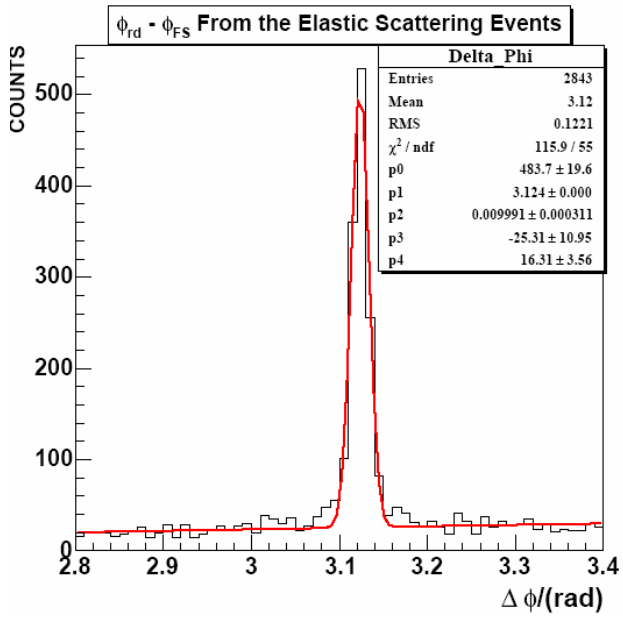




Ep Elastic Scattering

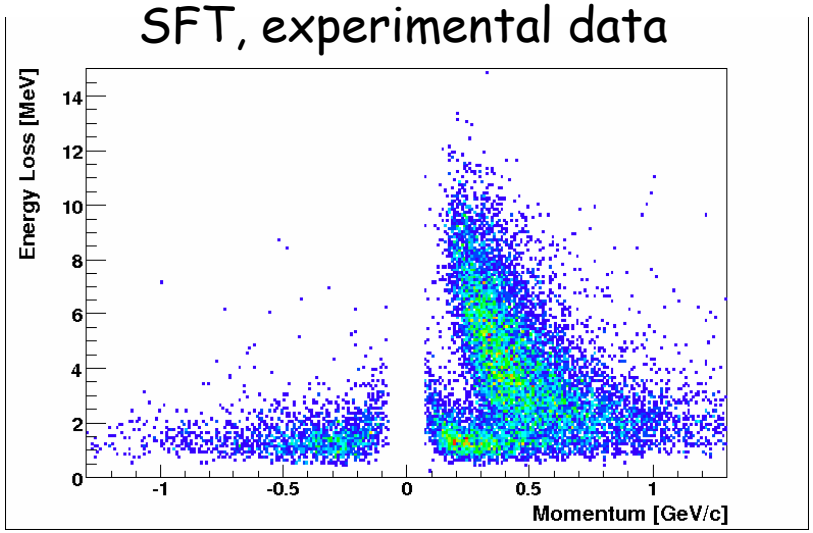
- Detect scattered electron in the Forward spectrometer and proton in the Recoil
- First observation of ep-elastic at HERMES by detecting protons in the Photon Detector
- Correlation of angles reconstructed in the Forward spectrometer and the Recoil Detector can be used for the relative alignment of these detector systems

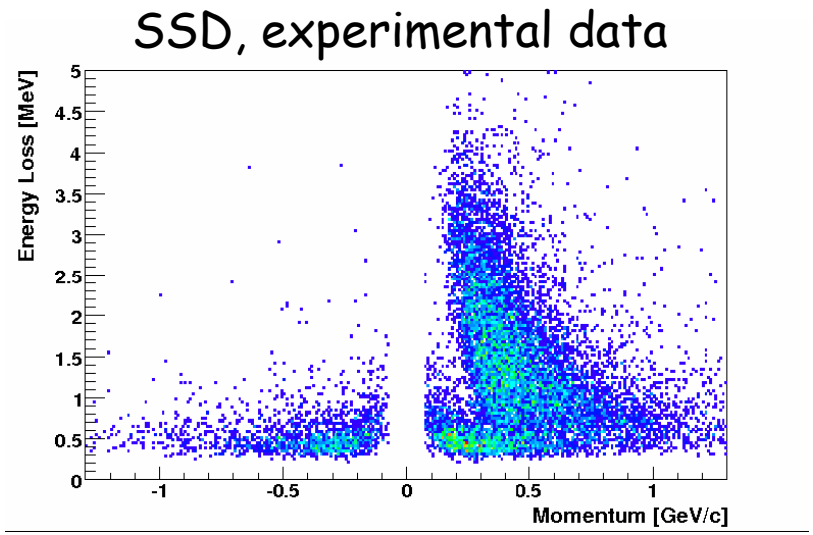




Particle Identification

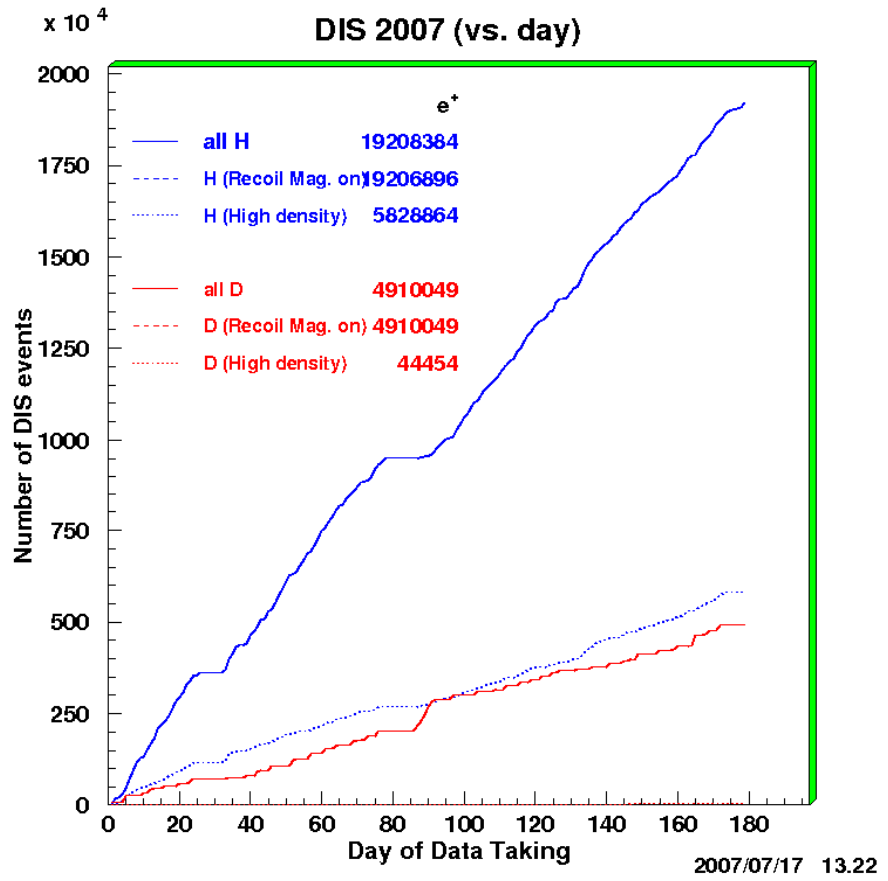
- Particle identification possible in all 3 subdetectors of the Recoil
- Proton-pion separation in momentum range below 700 MeV/c possible with the SSD and SFT
- Photon detector can be used for proton-pion separation at energies above 650 MeV/c





Data Taking in 2006 and 2007

- The recoil detector took data until the HERA shutdown – June, 2007
- Statistics collected with the recoil detector:
  - Electron beam 2006 (only SFT)
    - H2: 5K DVCS (3 Mil. DIS)
    - D2: 1K DVCS (0.8 Mil. DIS)
  - Positron beam 2006/07 (all subdetectors)
    - H2: 42K DVCS (28 Mil. DIS)
    - D2: 10K DVCS (7 Mil. DIS)



Summary and Outlook

- Recoil detector was installed at HERMES in winter 2005-2006 and was in operation until the end of HERA running in June 2007
- Experimental data on DVCS and other exclusive processes were collected with HERA electron and positron beams
- Physics analysis with Recoil will be possible after detector calibration is finished, tracking and PID are optimized
- Results of pre-Recoil DVCS analysis can be reevaluated after analysis of new data collected with the Recoil