# Report on the HERMES Recoil Detector

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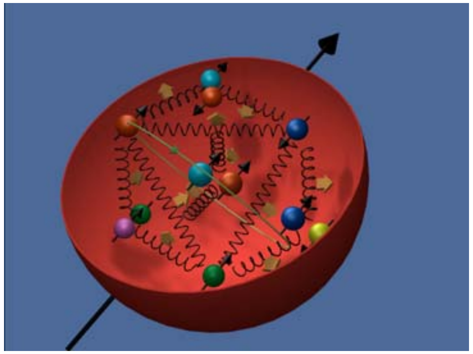
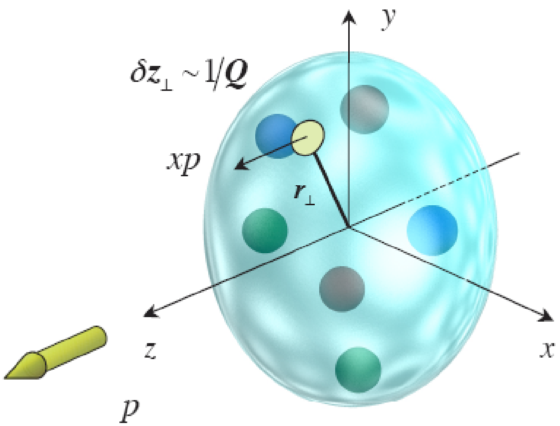
on behalf of the hermes collaboration

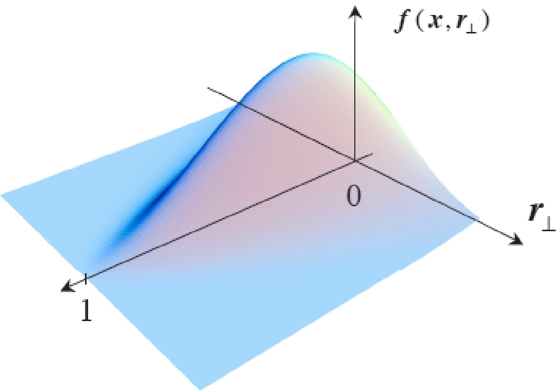
HELMHOLTZ
ASSOCIATION

DESY

# Spin structure of the nucleon






- Nucleon spin decomposition

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

$$\approx 30\%$$

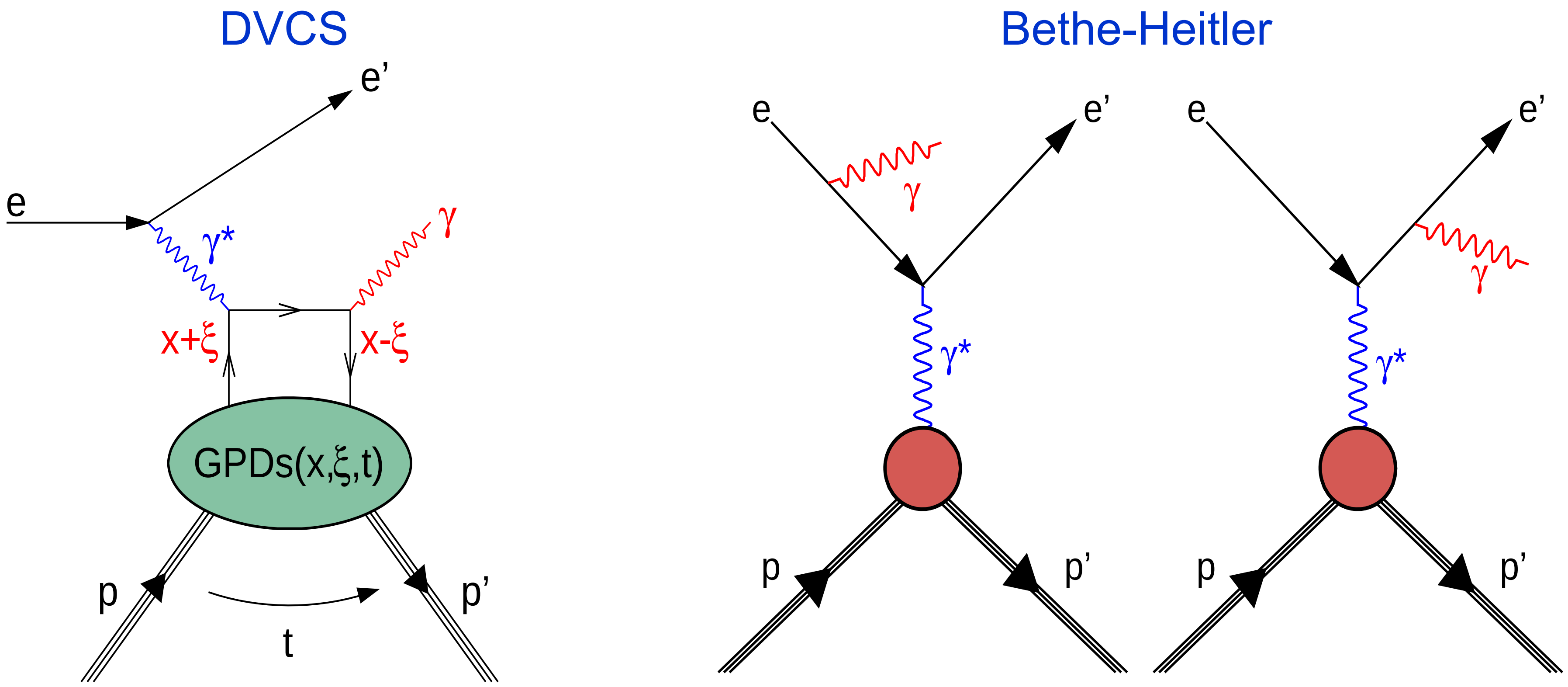
- Generalized Parton Distributions (GPDs)
  - access to quark orbithal angular momentum via Ji relation

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

  - Multidimensional representation of structure of the nucleon in longitudinal momentum – transverse coordinate space

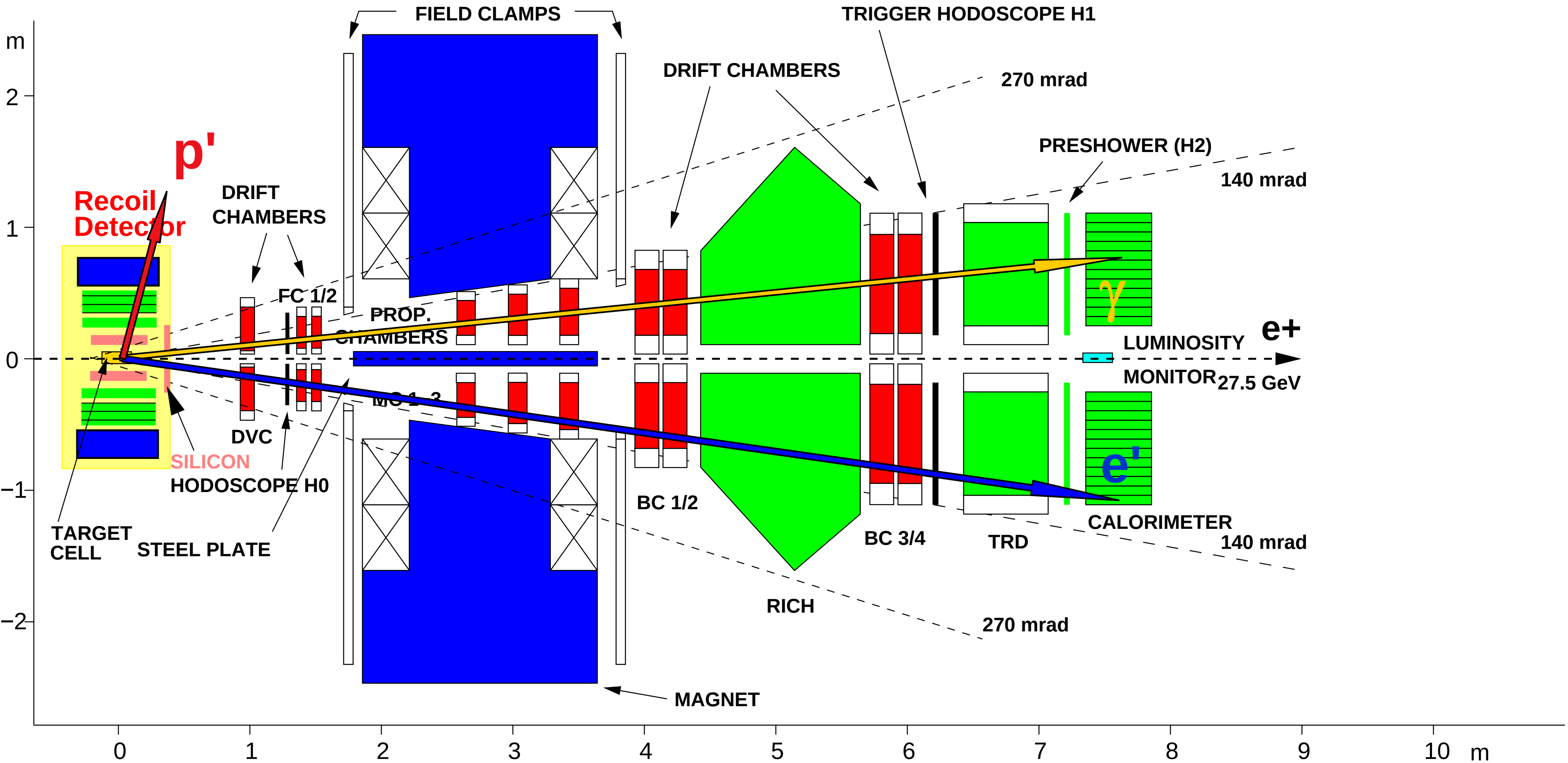
- Access to GPDs → Deeply Virtual Compton Scattering (DVCS)

# Deeply virtual Compton scattering (DVCS)



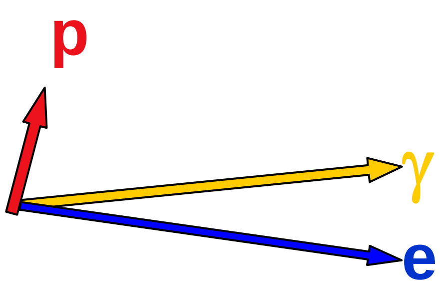

- DVCS and Bethe-Heitler: the same initial and final state
- Bethe-Heitler dominates at HERMES kinematics
- GPDs accessible through cross section differences and azimuthal asymmetries via interference term

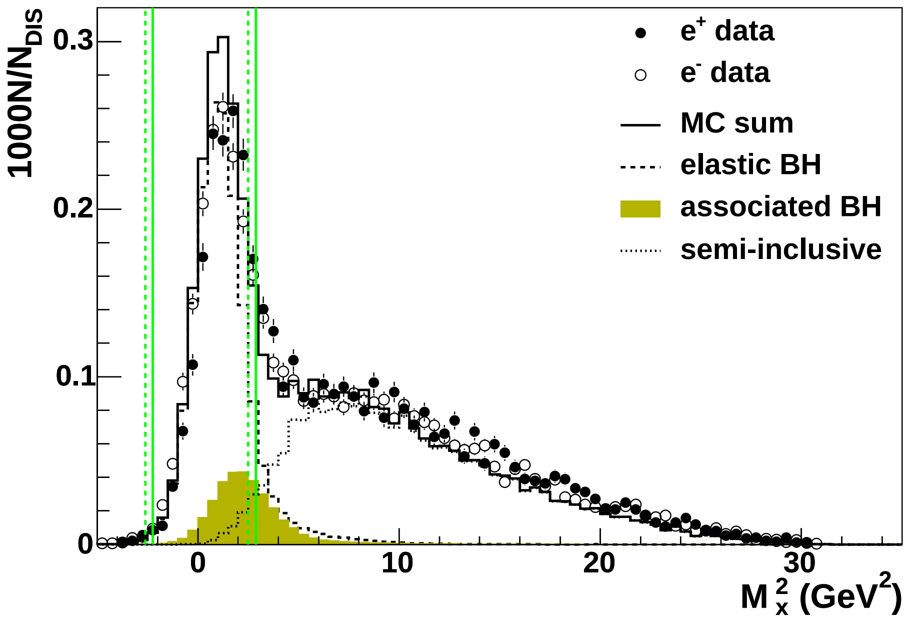
# HERMES spectrometer




- Unpolarized hydrogen target: 38 Mio DIS (41.000 DVCS)
- Unpolarized deuterium target: 10 Mio DIS (7.500 DVCS)
- Two beam helicities, 27.57 GeV electron and positron beams

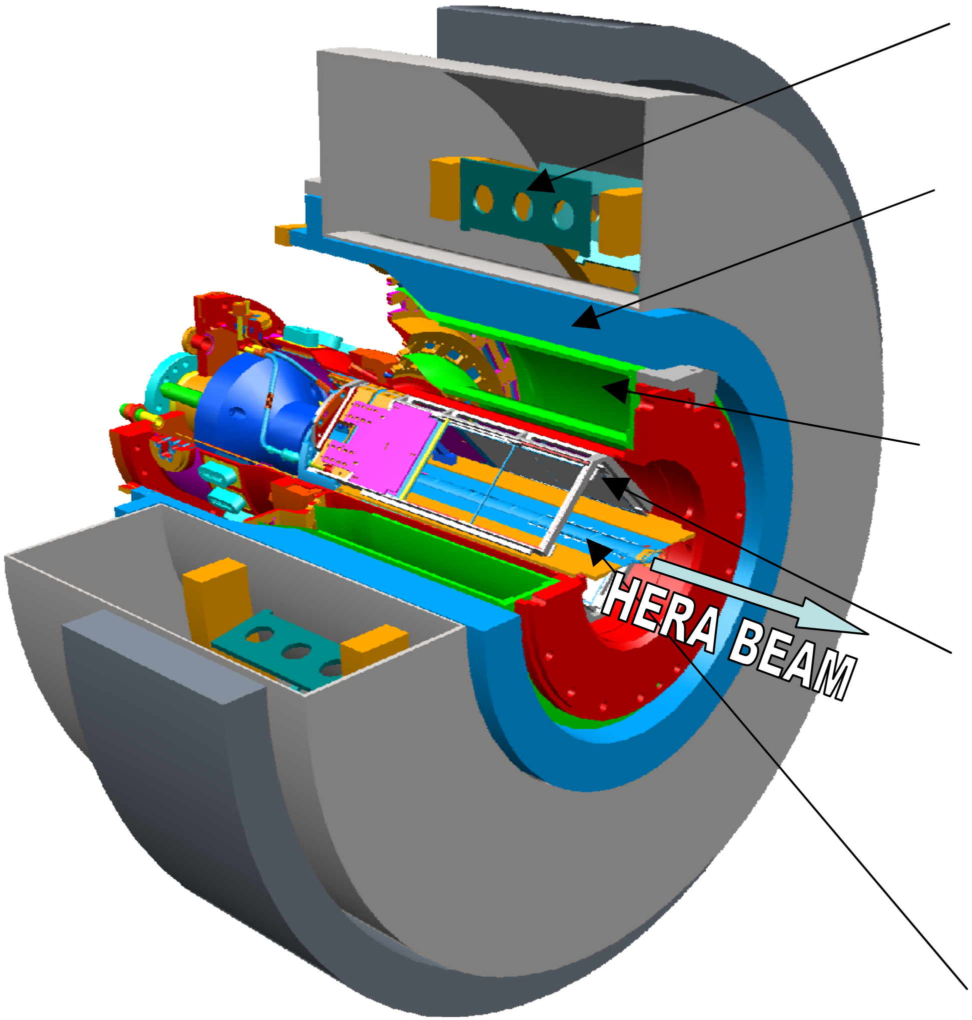
# DVCS measurement with the Recoil Detector




- Pre-Recoil data
  - Scattered lepton and photon detected in the forward spectrometer
  - Recoil proton not detected
  - Exclusivity achieved via missing mass technique
  - Associated processes not resolved (12% contribution in the signal) $ep \rightarrow e\Delta^+\gamma$
- Recoil data
  - Detection of recoil proton, pions and photons
  - Suppression of the background to <1% level
  - Important to measure as low-momentum protons as possible

# Recoil Detector




1 Tesla superconducting solenoid

Photon Detector (PD)

- detect gammas
- p/π PID for momentum > 600 MeV/c

Scintillating Fiber Tracker (SFT)

Momentum reconstruction by bending in magnetic field

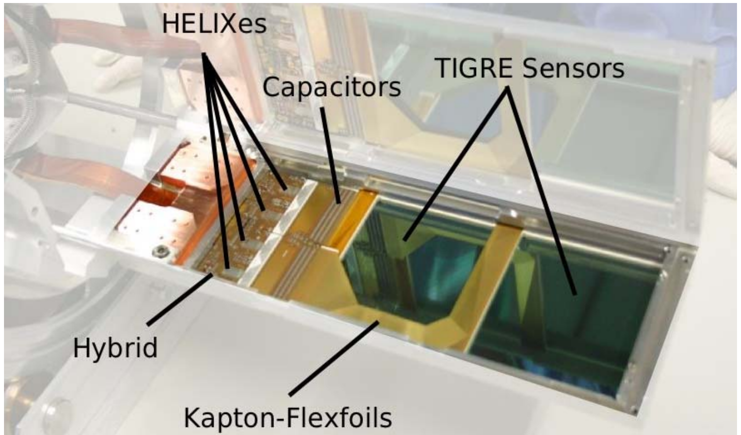
Silicon Strip Detector (SSD)

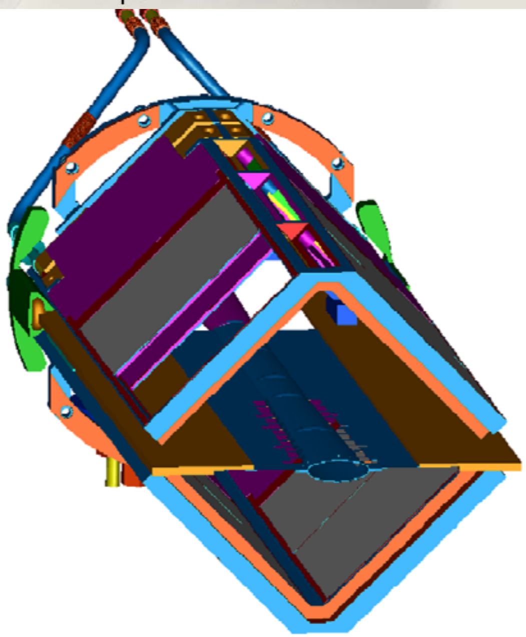
- Inside the HERA vacuum
- 5 cm close to the beam
- Momentum reconstruction by energy deposit for protons and deuterons

Target cell

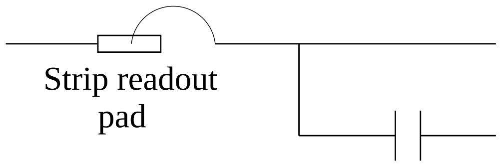
- Unpolarized hydrogen and deuterium targets

# Silicon Strip Detector

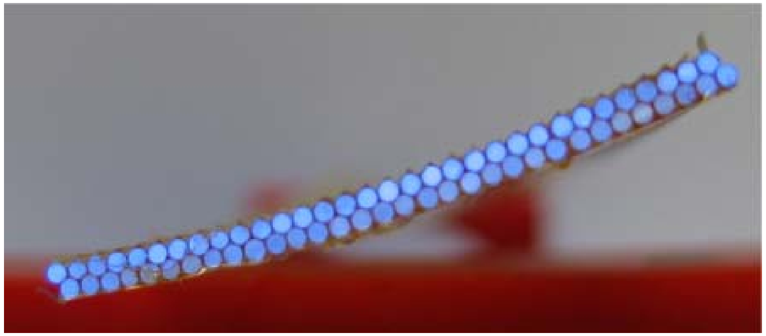


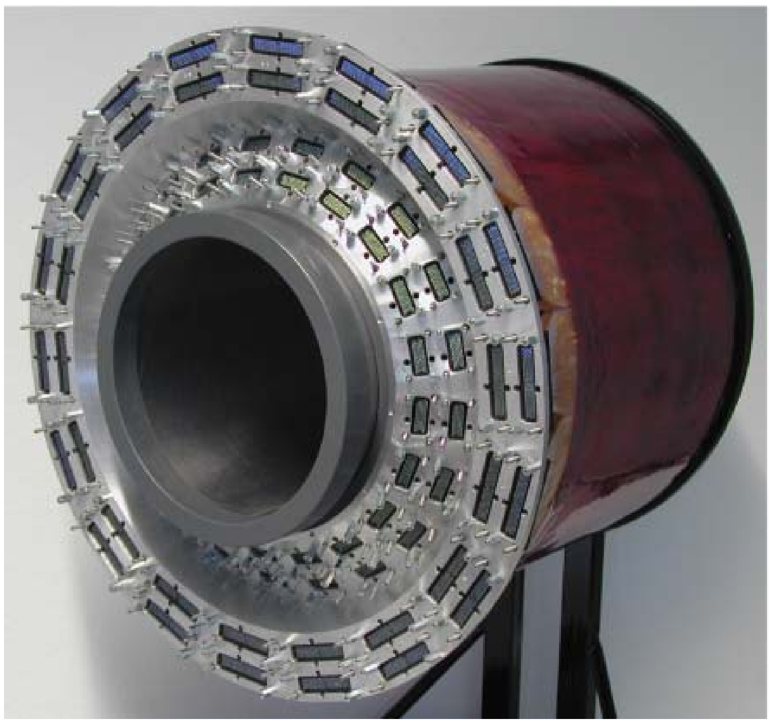



- 2 layers of double-sided silicon strip sensors located in beam vacuum
- Strips: pitch=758 μm, 300μm thick
- Readout by HELIX 3.0 chips: high and low gain to increase dynamic range



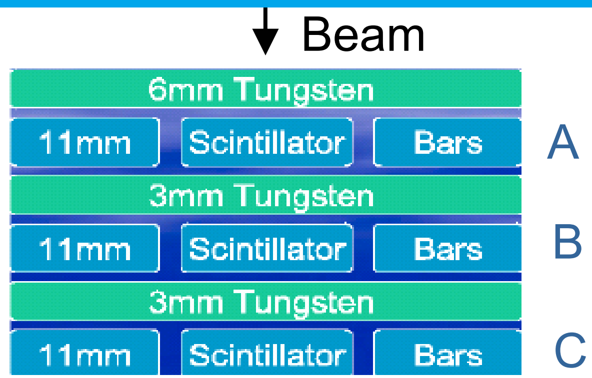
# Scintillating Fiber Tracker





- 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

# Photon Detector

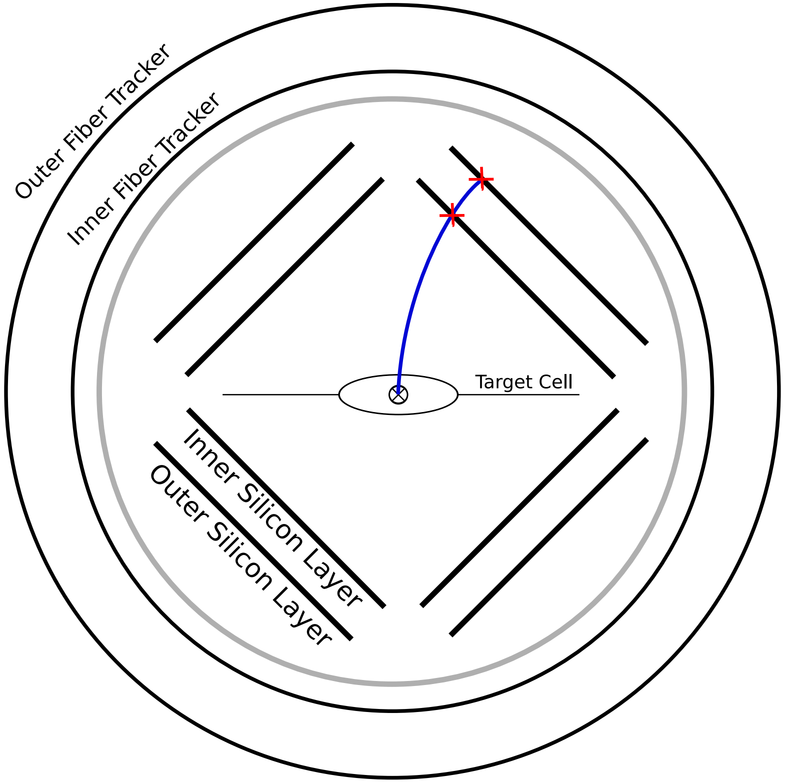


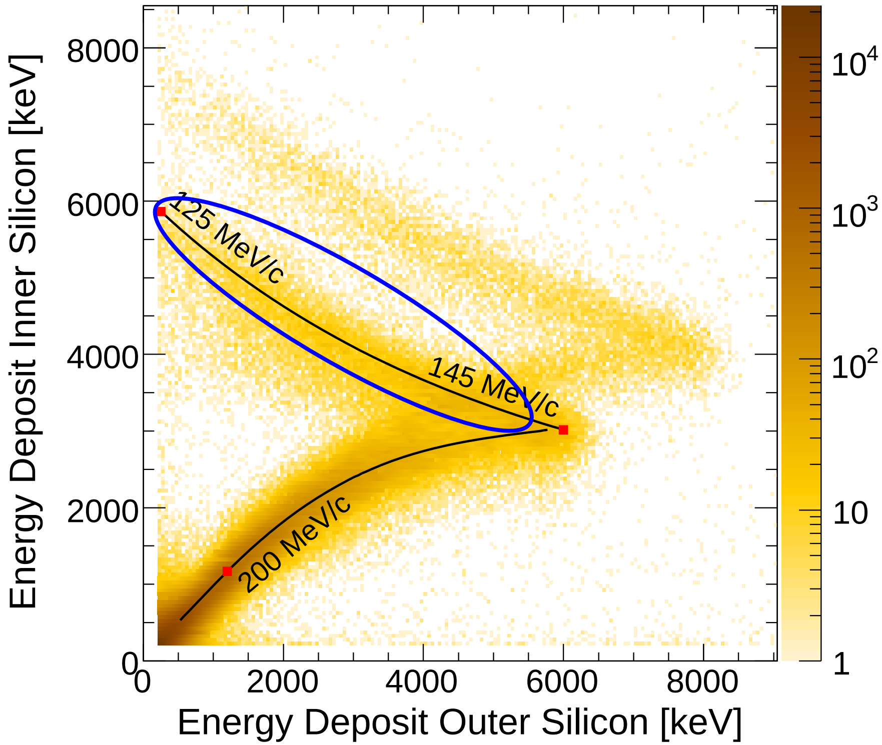

- Sandwich of 3 layers of tungsten-scintillator:
  - A-layer parallel to the beam axis
  - B/C: under +45/-45 degree angle
- Strips: $2\text{x}1\text{x}28\ \text{cm}^3$
- Read out by multi-anode PMTs
- Detect $\gamma$ from $\pi^0$ decay
- p/π PID for momentum > 600 MeV/c

# Recoil Detector analysis

- Raw data processing
  - Pedestal and noise studies
  - Crosstalk corrections
  - Signal processing algorithms to hit detection
- Alignment and calibration
  - Alignment and calibration of each subdetector
  - Efficiencies studies
- Event reconstruction
  - Momentum reconstruction taking energy deposits into account
  - Particle Identification
  - Kinematic fitting
  - Tagging of spectator proton

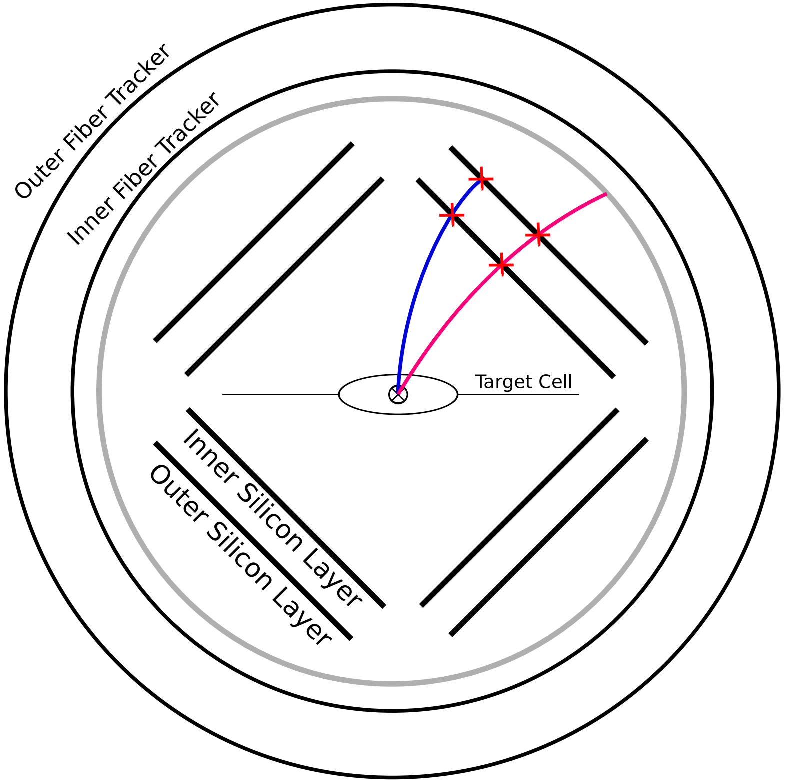
# Momentum reconstruction

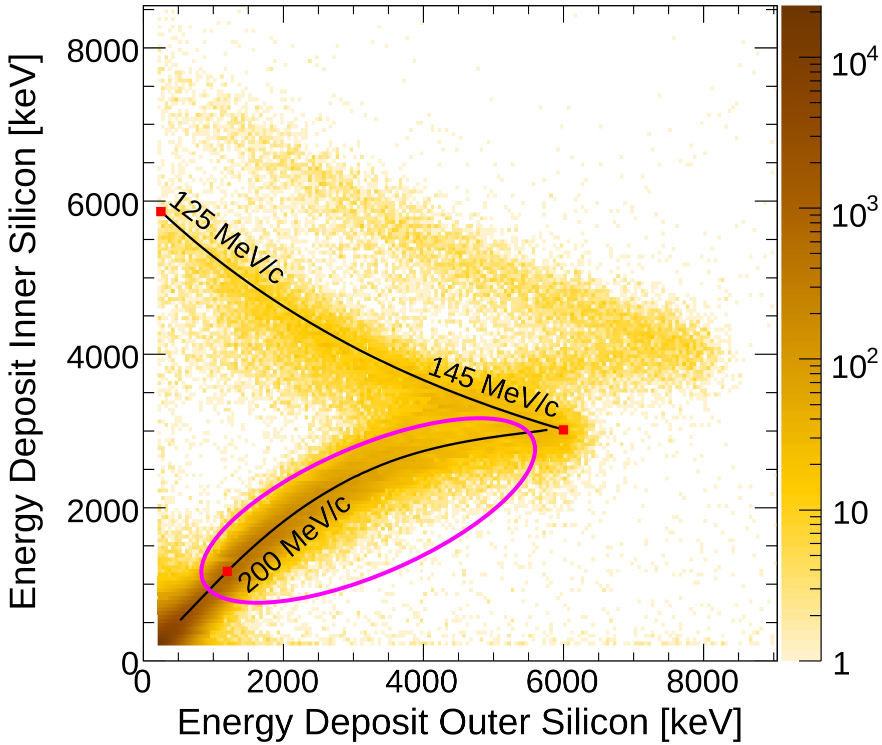



- Protons with momenta of 125-145 MeV/c are stopped in the outer silicon layer
- Momentum reconstructed by sum of energy deposits
- Passive material corrections

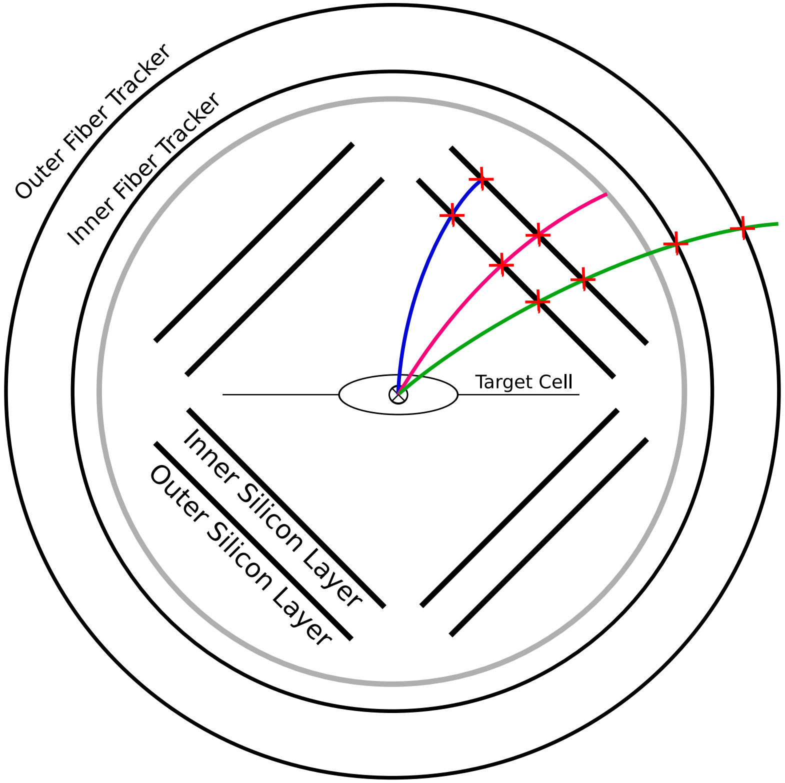
# Momentum reconstruction

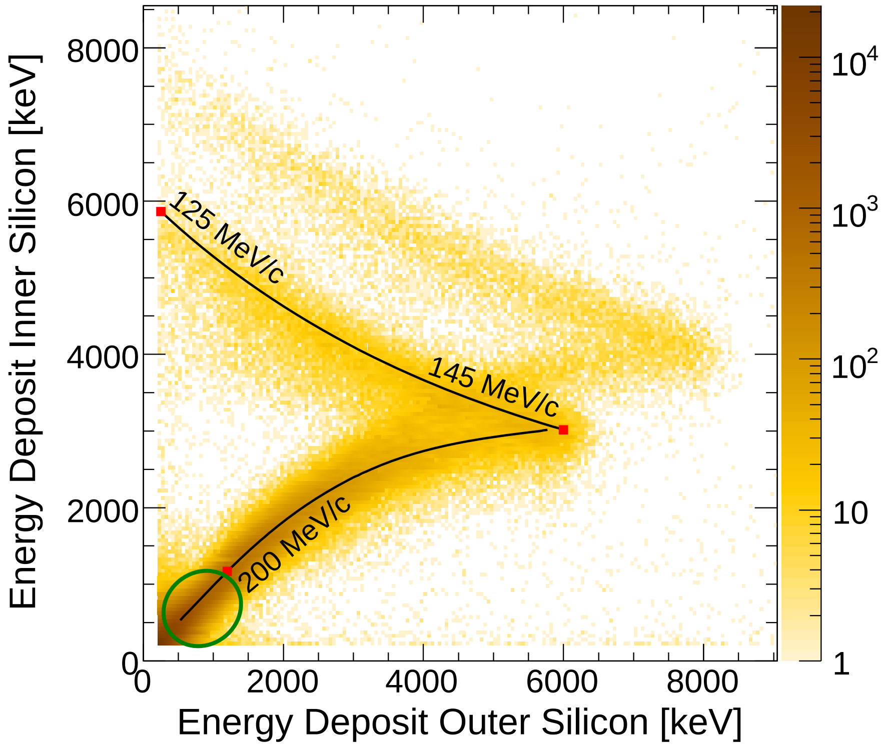



- Protons with momenta of 145-250 MeV/c path through both silicon layers
- Momentum reconstruction by dE/dX
- Passive material corrections

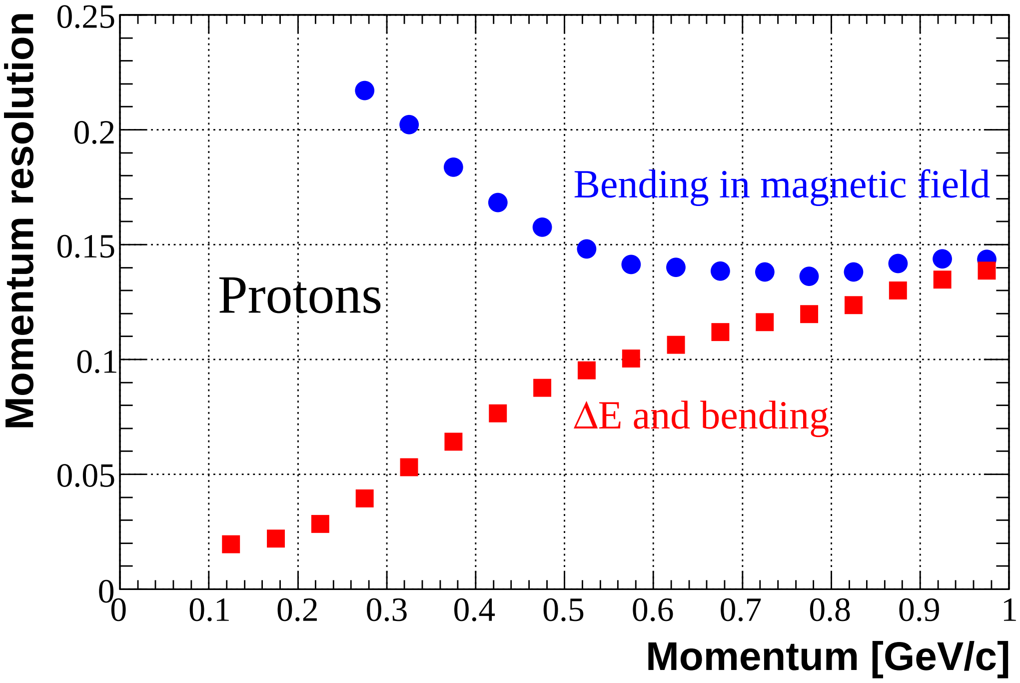
# Momentum reconstruction

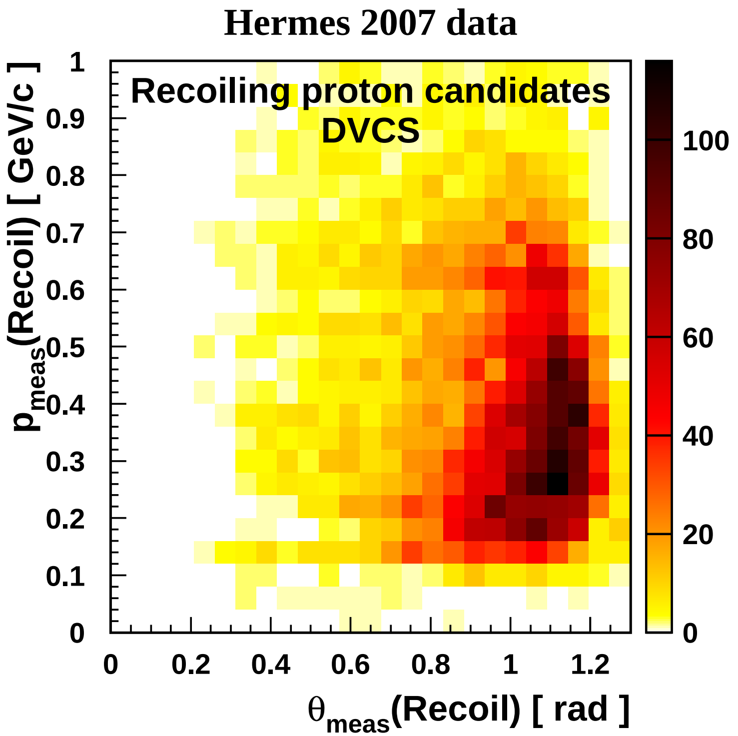



- Protons and pions with momenta above 250 MeV/c reach the outer layer of scintillating fiber tracker
- Momentum reconstruction by bending in the magnetic field
- Improved momentum reconstruction for protons using bending in the magnetic field and energy deposits in both silicon layers

# Momentum resolution

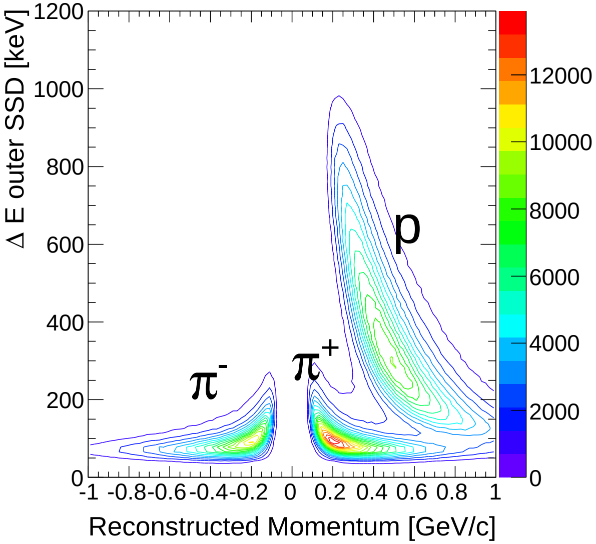


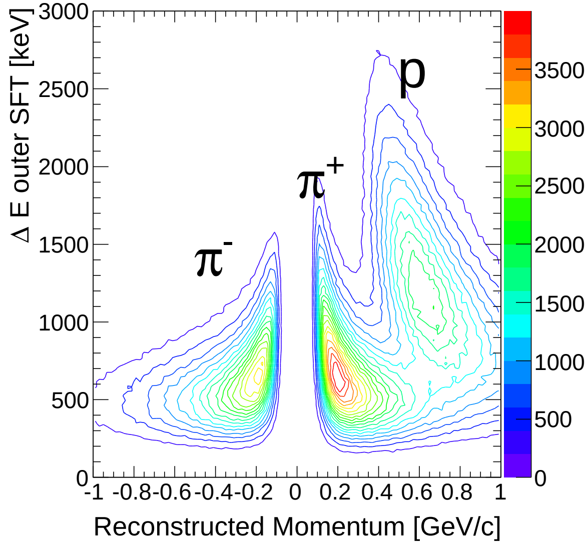

- Use of energy deposit in silicon layer improves momentum resolution for low-momentum protons
- Important for DVCS analysis

# Particle identification

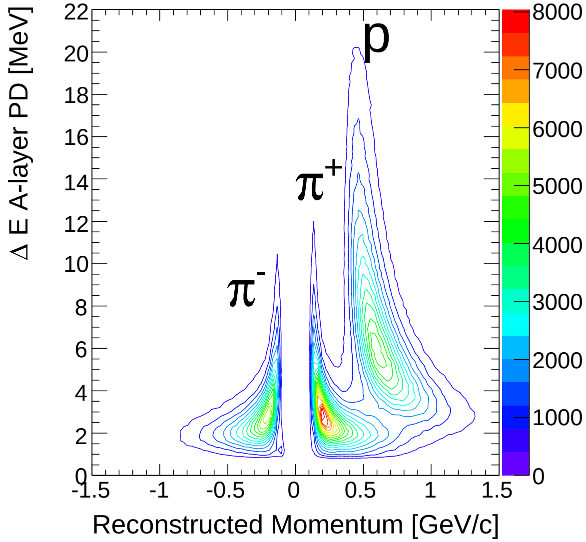
## Silicon Strip Detector

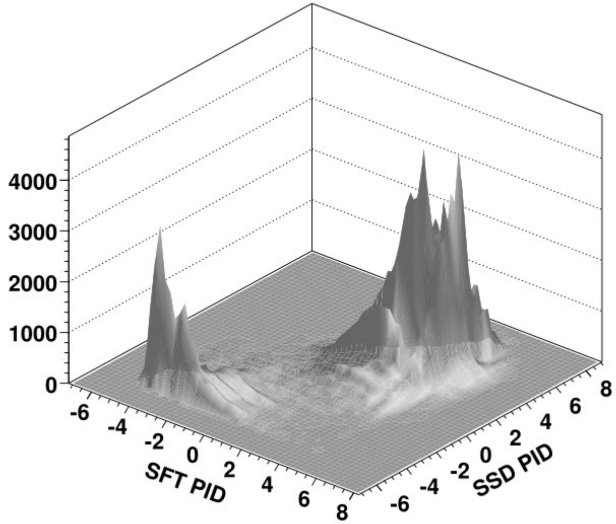



## Scintillating Fiber Tracker




## Photon Detector




- Particle identification in all subdetectors
- Likelihood formalism to combine all PIDs

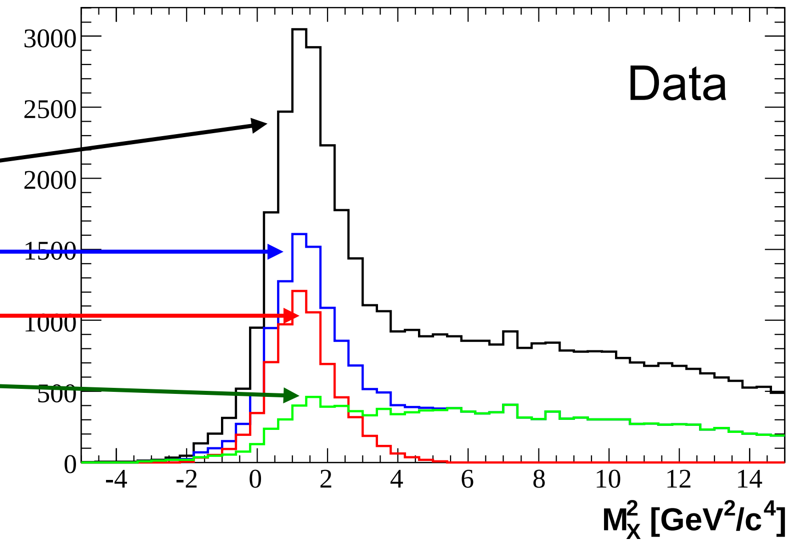
$$PID_{tot} = \sum_i PID_i = \sum_i \log \frac{P_p(\Delta E_i, p)}{P_{\pi^+}(\Delta E_i, p)}$$

# DVCS event selection with the Recoil Detector

- Kinematic fitting technique is developed and tested on Monte-Carlo
  - 3 particles detected → 4 constraints from energy-momentum conservation
  - Allows to suppress the associated Bethe-Heitler and semi-inclusive background to negligible level

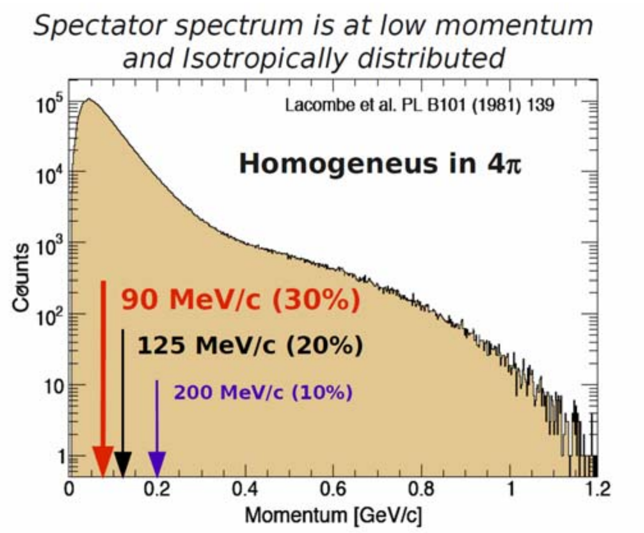
- Applied for data for physics analysis
  - Systematic studies in progress
  - First physics results expected soon

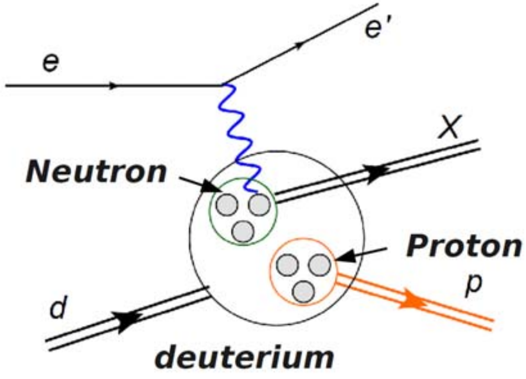
- Missing mass distribution
  - No requirement for Recoil
  - Positively charged Recoil track
  - Kinematic fit probability > 1%
  - Kinematic fit probability < 1%

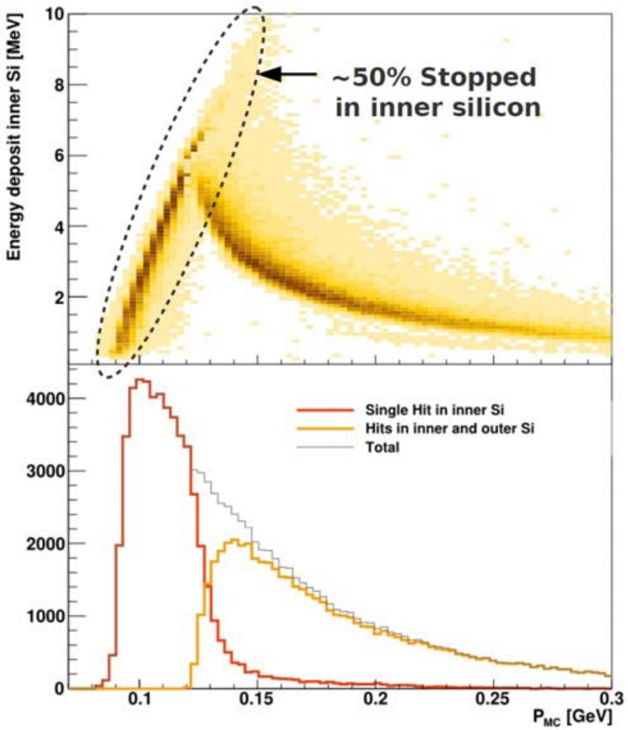


# 'Tagged' neutron structure function and spectator protons in the Recoil

- Effective structure function of the neutron by 'tagging' spectator protons on deuterium target
- Reconstruct as low momentum of spectator protons as possible




- Background from fragmentation and DIS, mostly in forward direction
- Use region without non-spectator protons, select protons on backward hemisphere
- Alternatively try to use more sophisticated selection methods (neural networks, …)

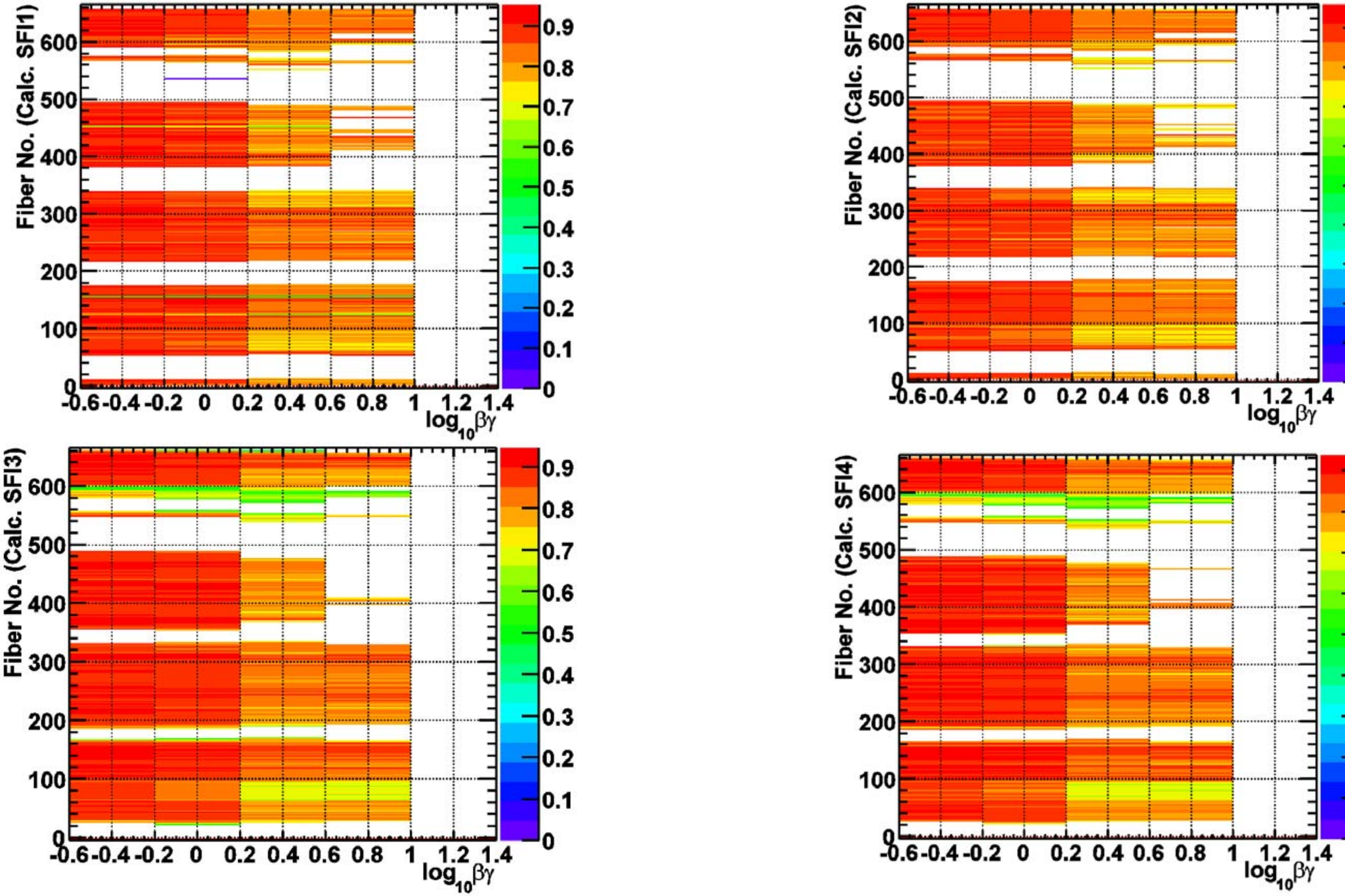
# Summary and Outlook

- Data with the Recoil Detector prepared for physics analysis
  - All subdetectors aligned and calibrated
  - Detector efficiencies studied
  - Momentum reconstruction by bending in magnetic field and energy deposit in both silicon layers
  - Particle identification for all subdetectors
  - Kinematic fitting for exclusive processes
  - Selection of spectator protons in preparation

- First physics results expected soon

# Backup slides

# SFT efficiency (inner layers)



# SFT efficiency (outer layers)