Two photon exchange and transverse spin asymmetries in the A4 experiment.

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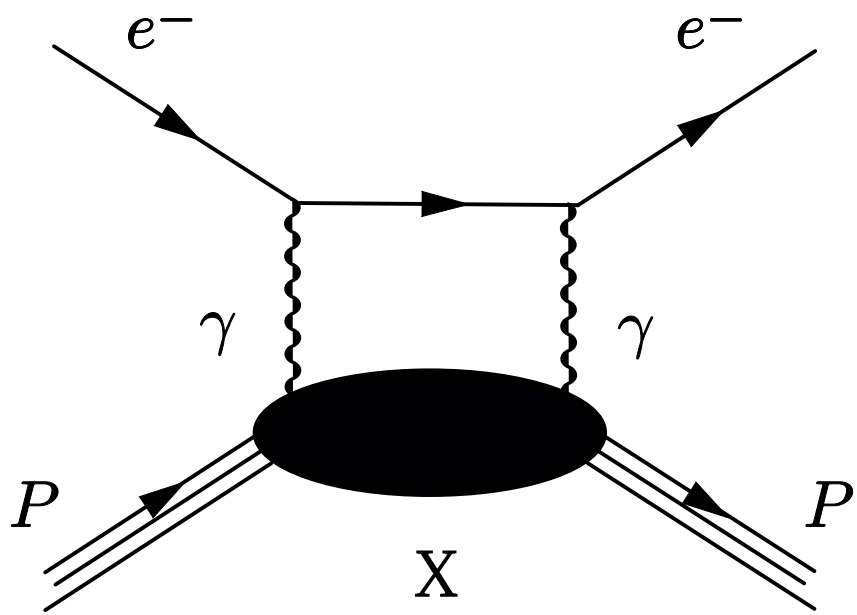
Outline

Introduction

Two photon exchange

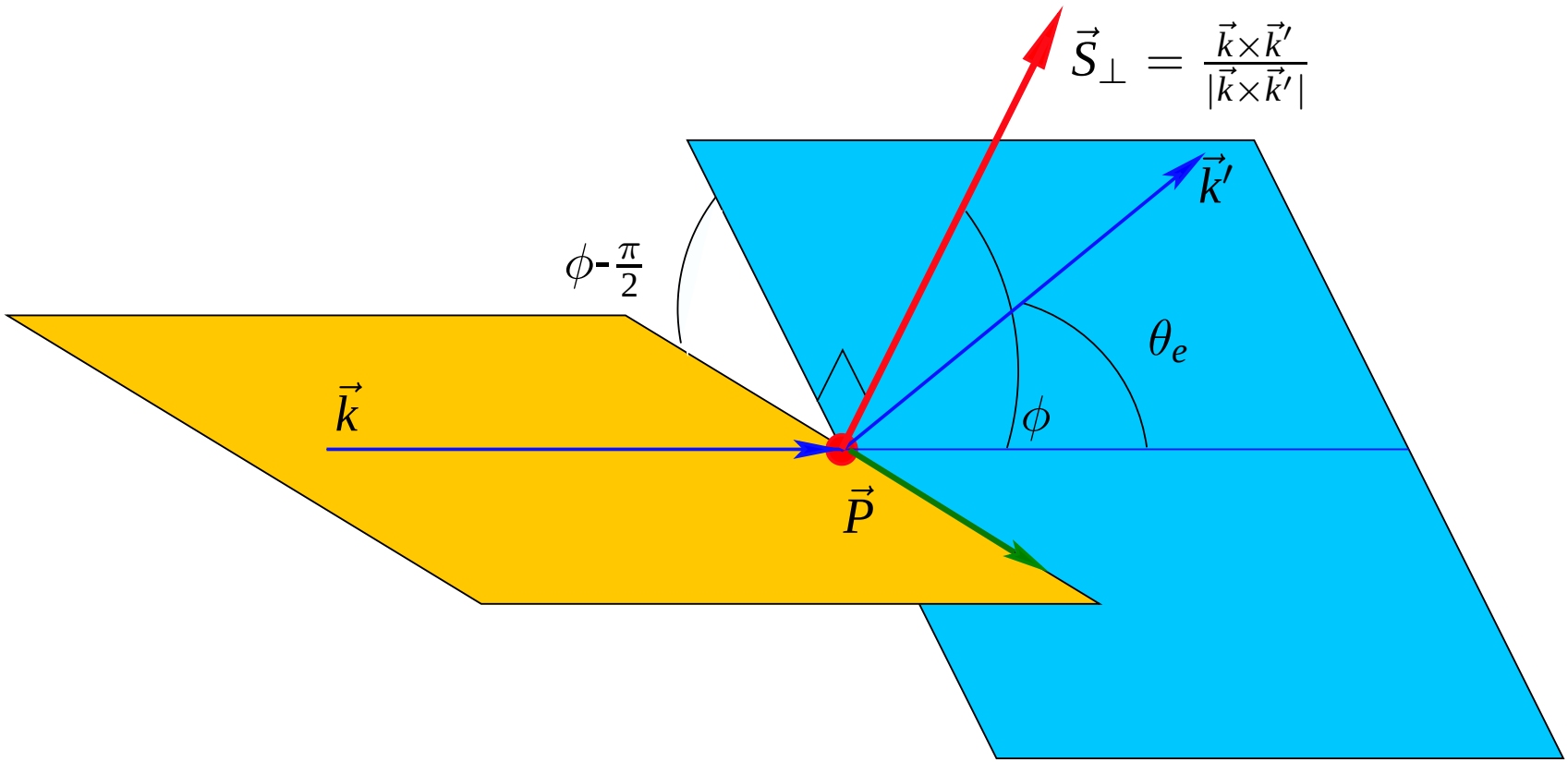
- $R = G_E^p / G_M^p$ discrepancy
- 2γ exchange amplitude $A_{2\gamma}$



- Target and beam normal SSA sensitive to $Im(A_{2\gamma})$.
- Dispersion relations between imaginary and real part.
- PVA experiments set up: transverse beam spin asymmetry $A_\perp$

Transverse spin asymmetry

$$A_{\perp}^{m} = \frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} = A_{\perp}(\theta)\vec{P}_e \cdot \vec{S} = A_{\perp} \cos\phi$$



Transverse spin asymmetry

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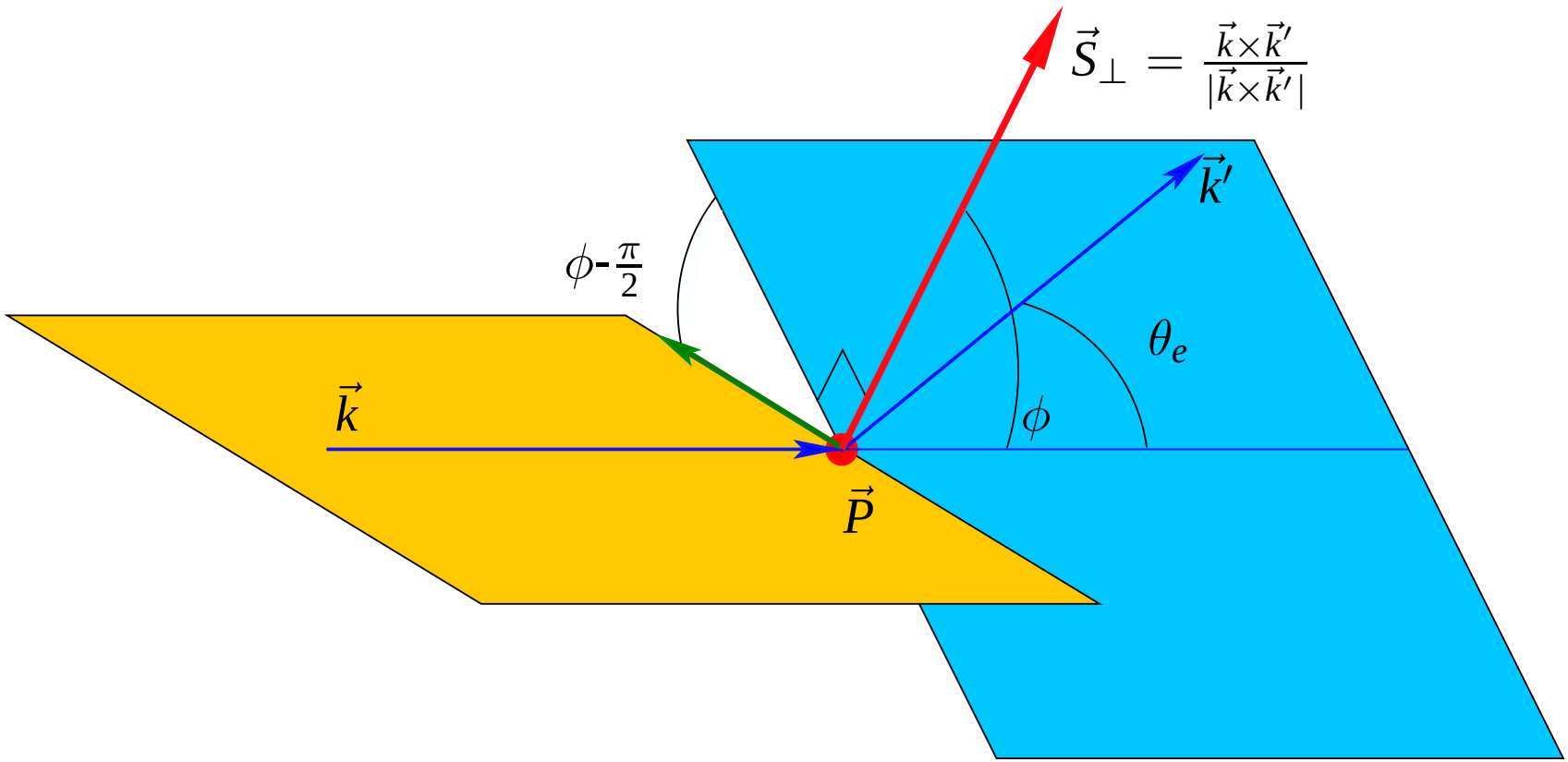
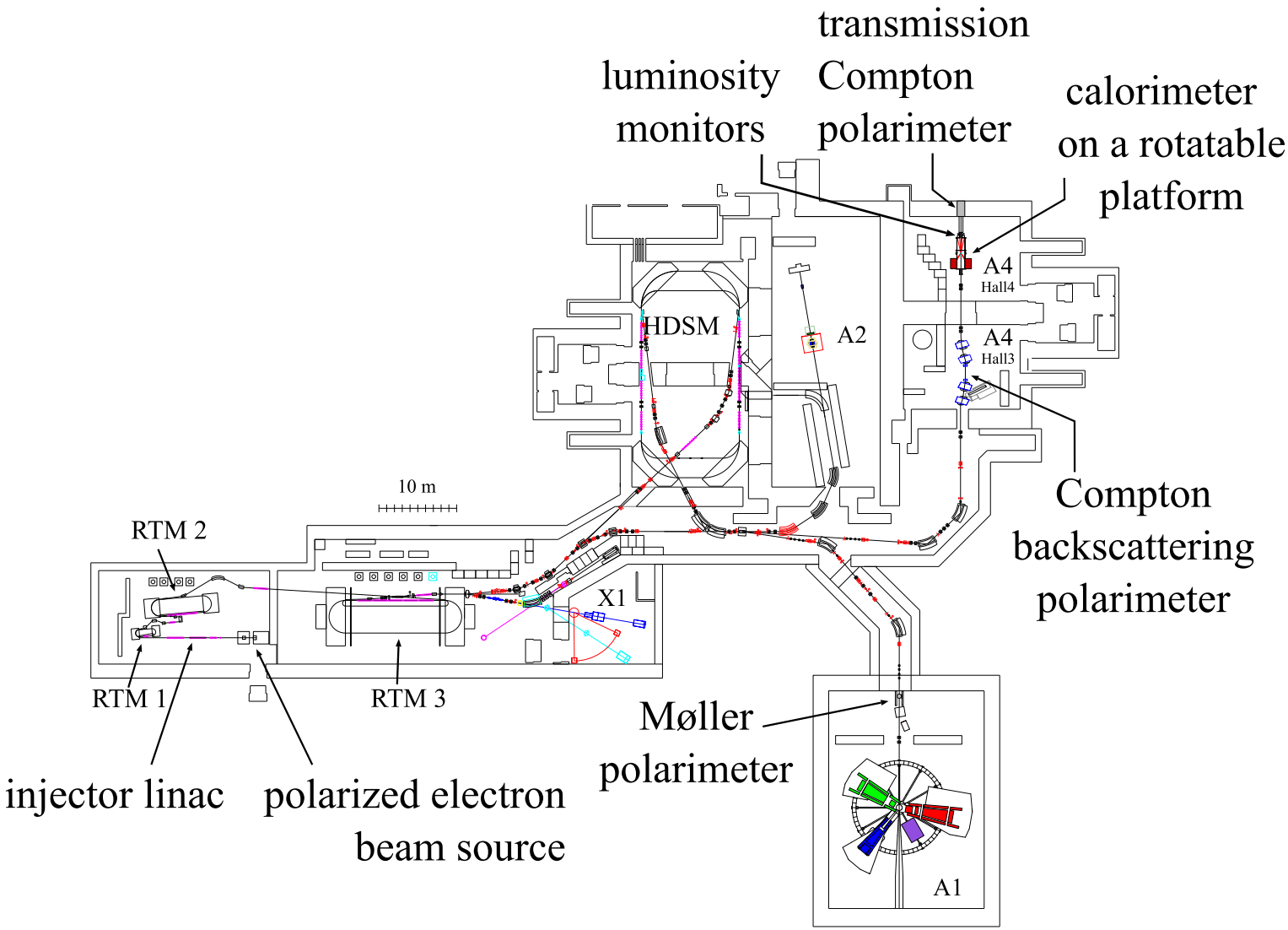
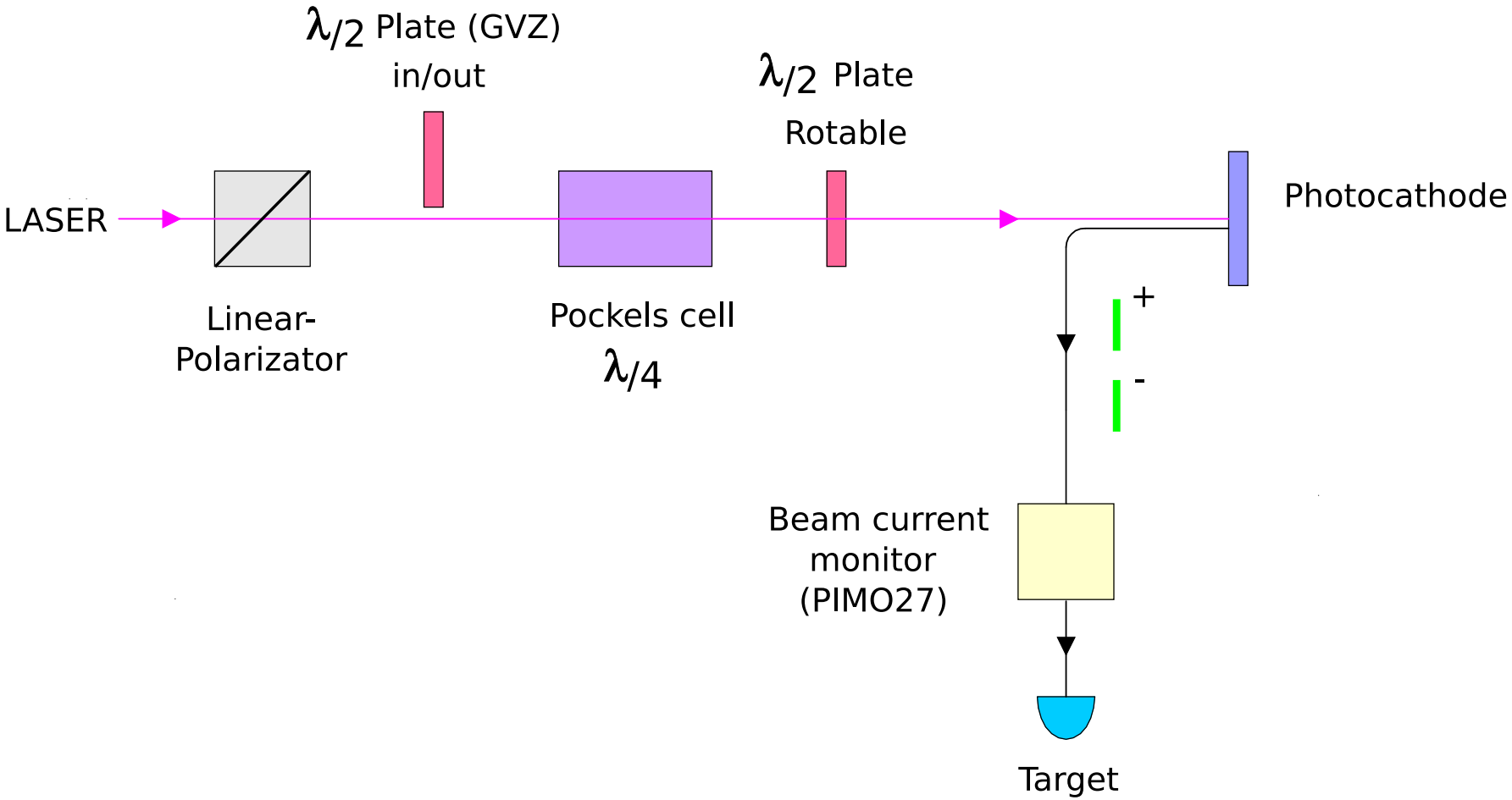


Experimental set up

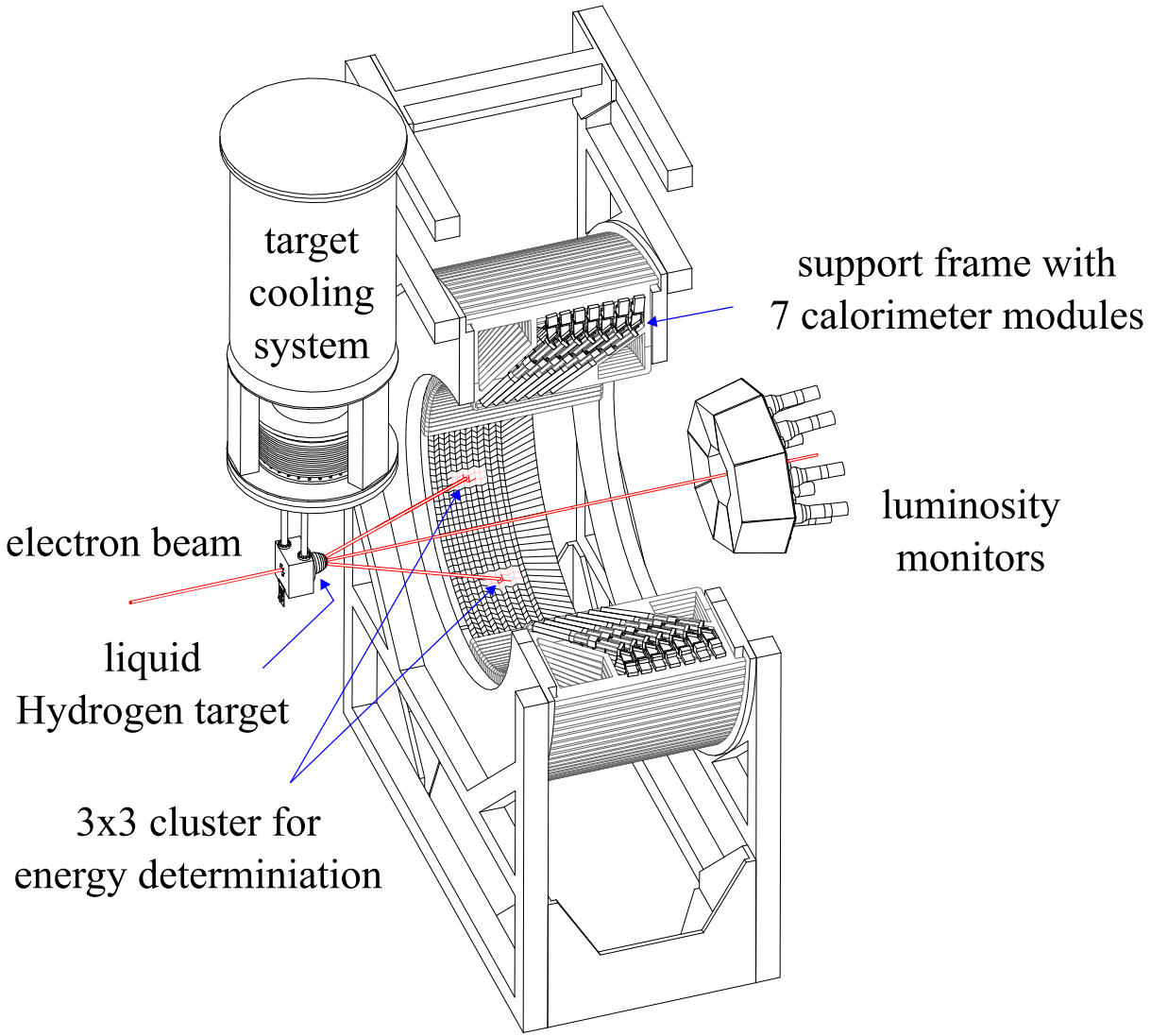
MAMI floor plan



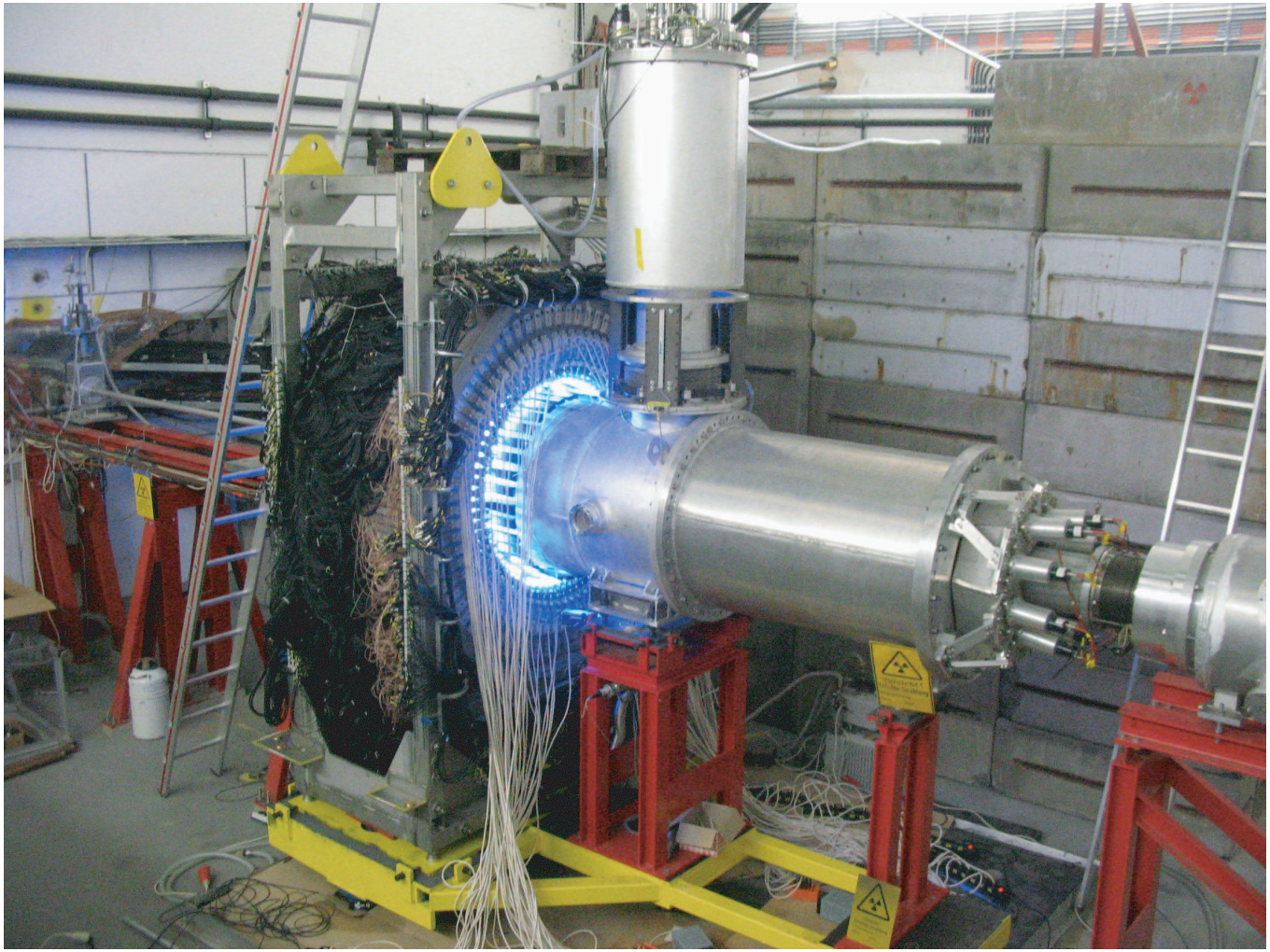
Polarized electron beam source

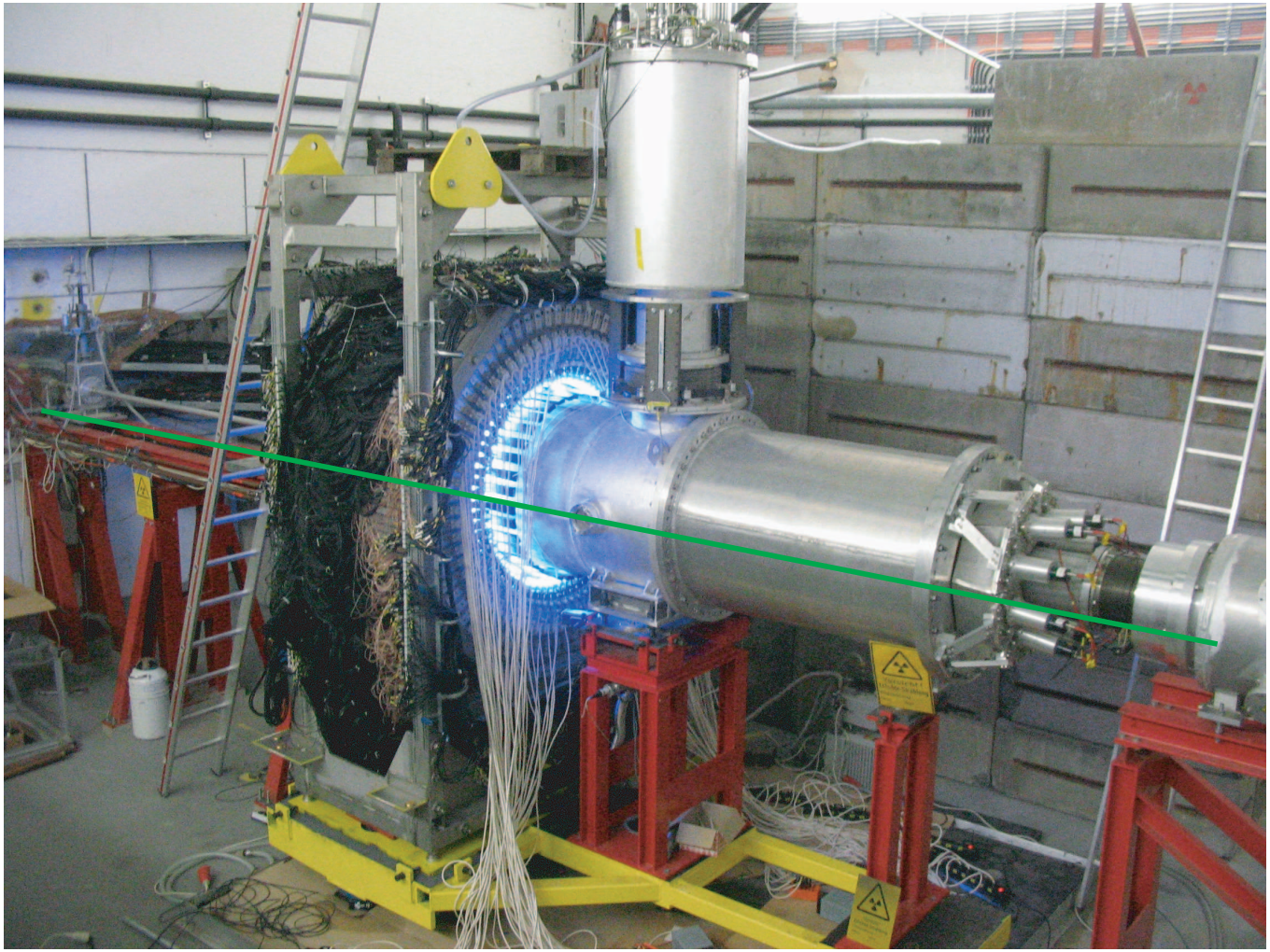


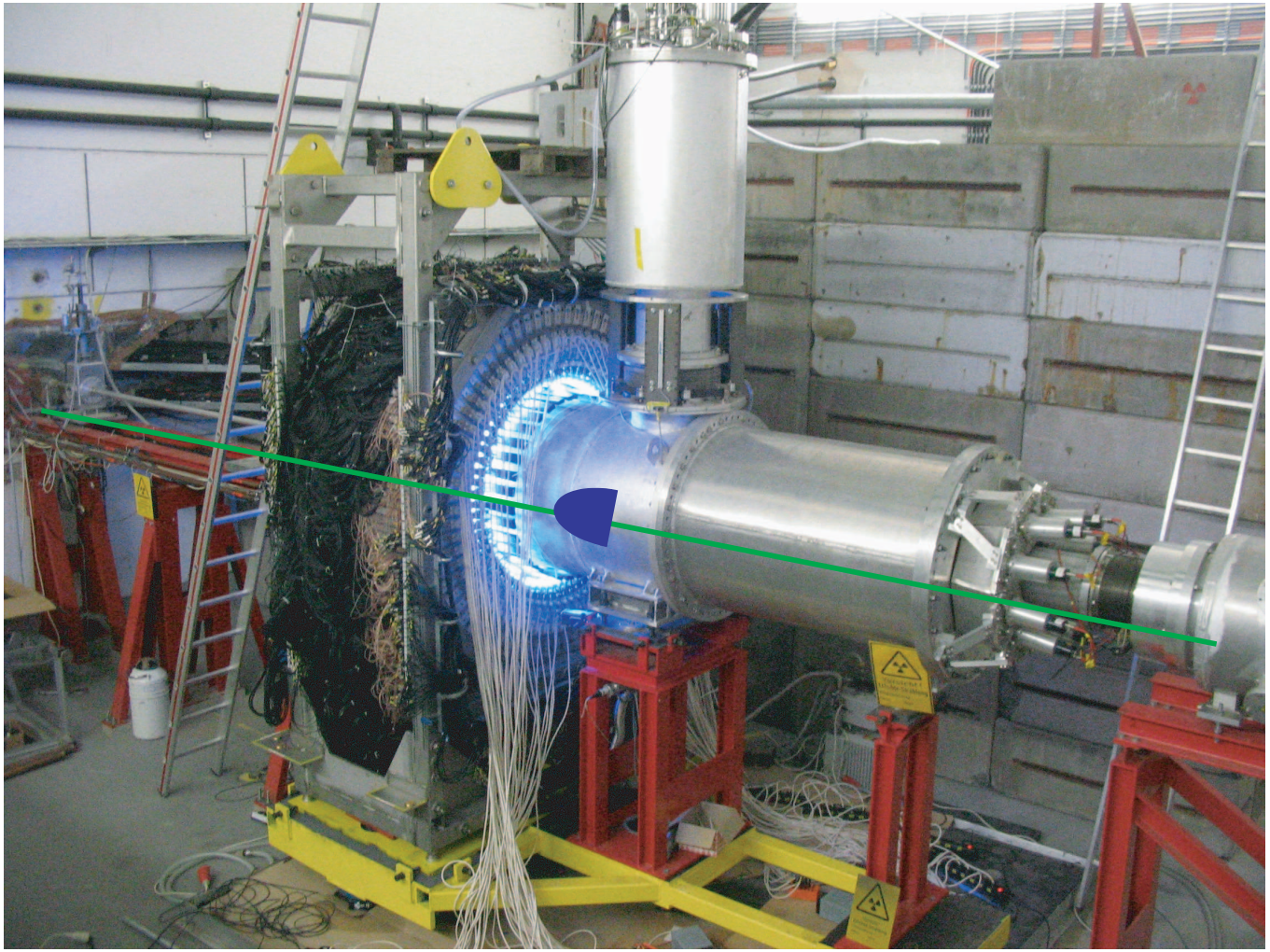
Calorimeter, target and luminosity monitors

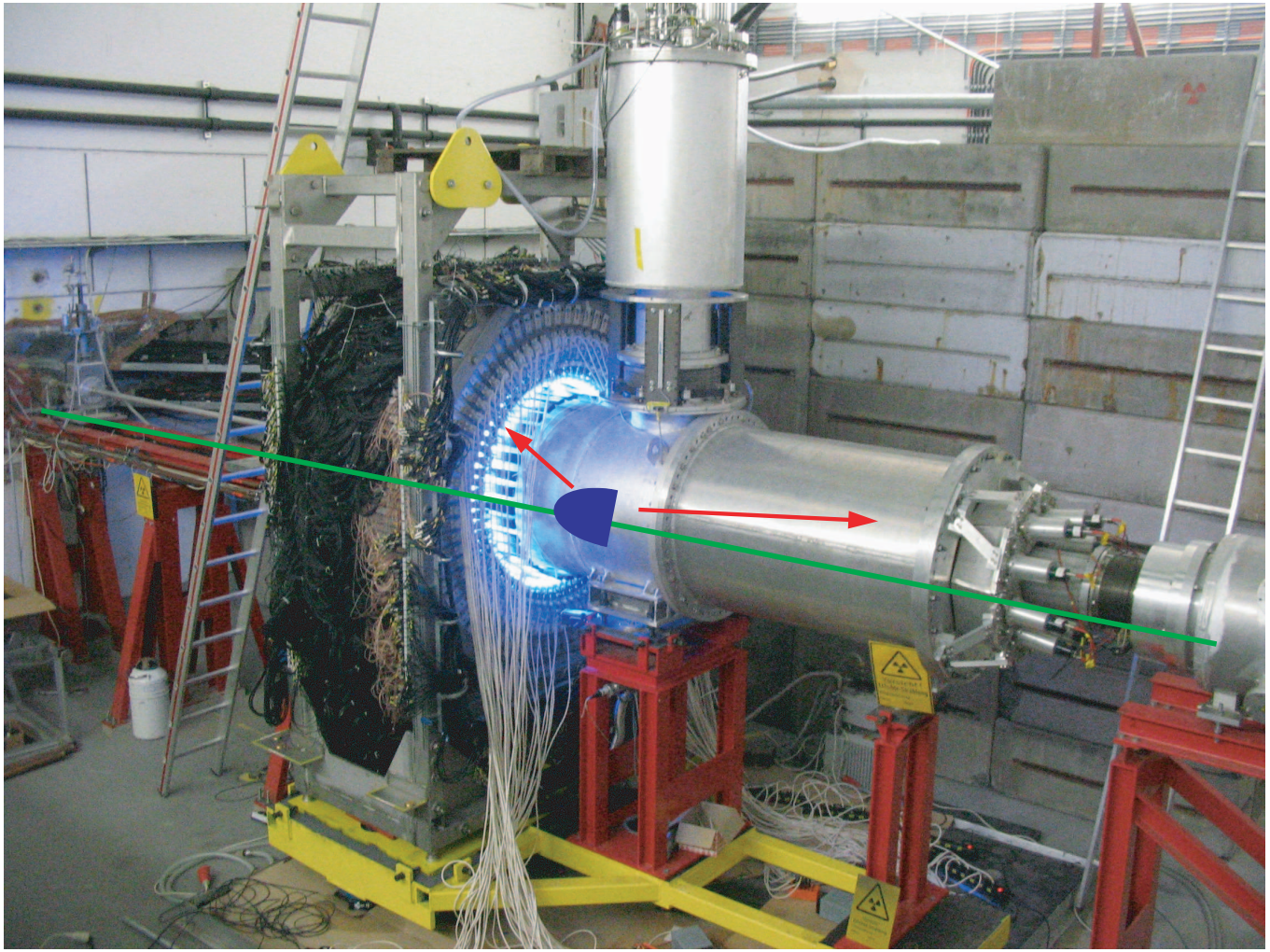


- Detector covers 2π ϕ.
- Counts single events and measures energy.
- Target of liquid hydrogen/deuterium.

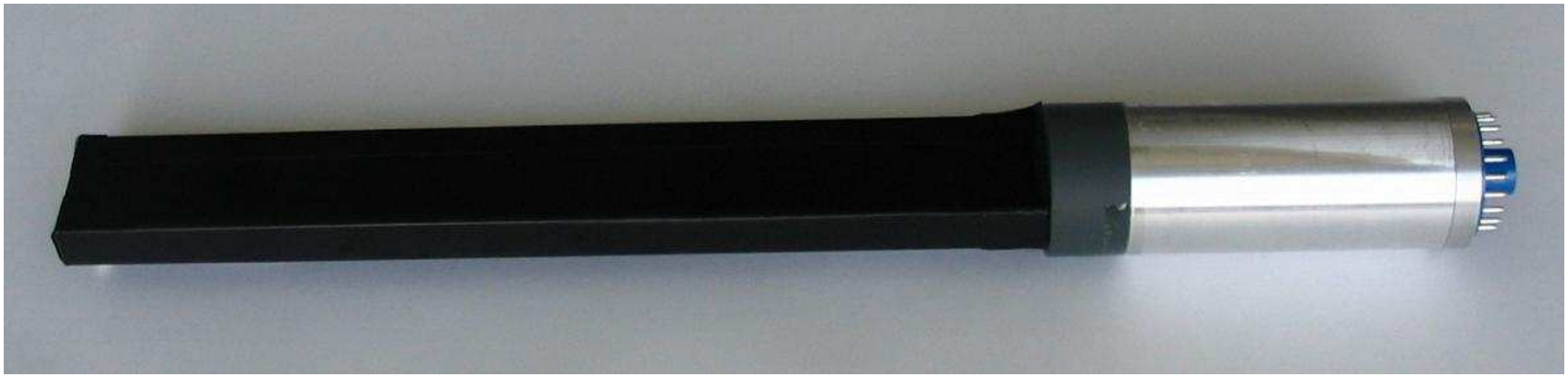




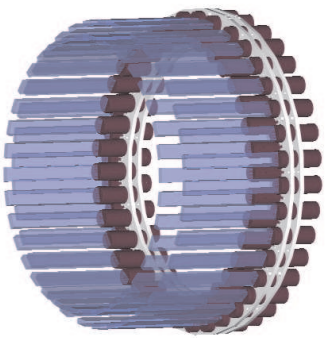




Plastic scintillators

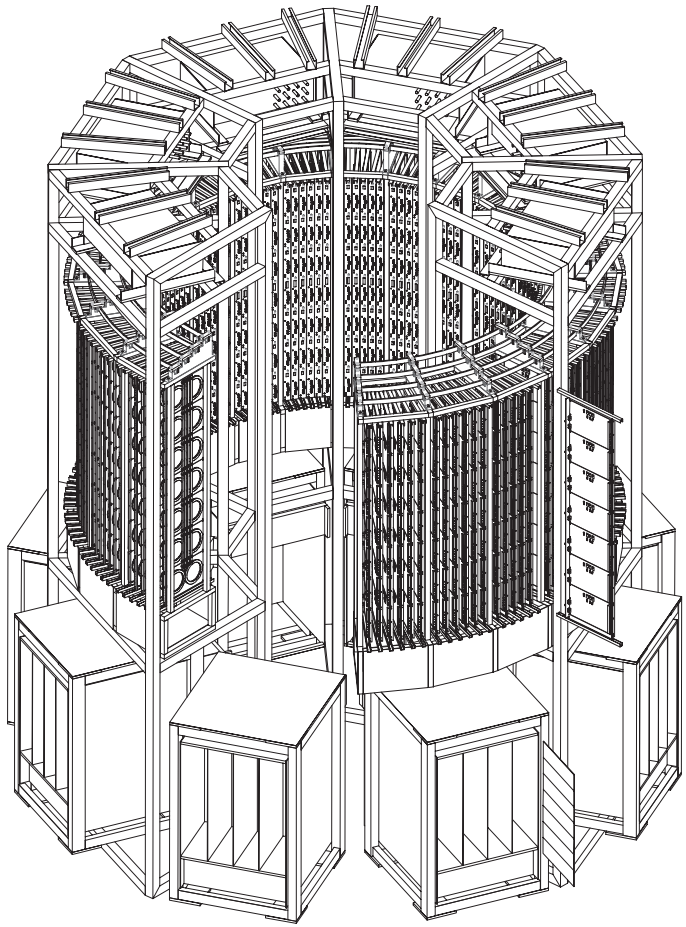


- Plastic scintillators detect charged particles. Neutral particles not detected.



- 72 plastic scintillators: two rings of 36 with overlap.
- One scintillator covers two frames: 14 modules.

Medusa

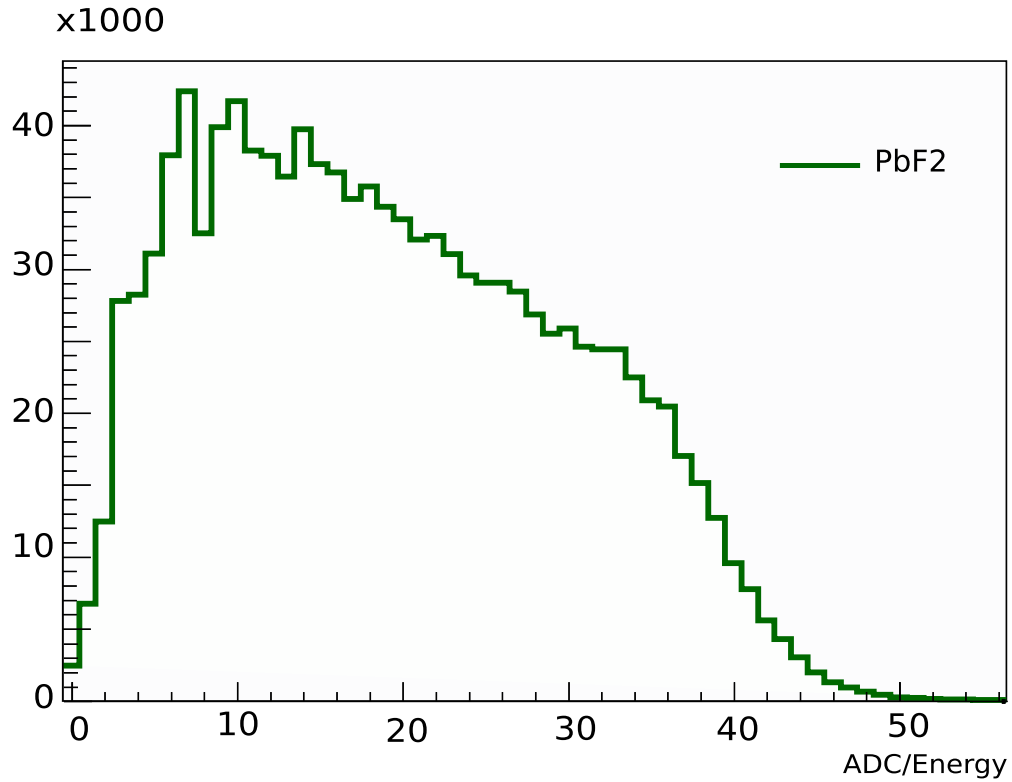


Measurements performed at backward angles

Target	Energy (MeV)	angle (deg)	Q^2 (GeV/c)^2
H_2	315.1 MeV	$140 - 150$	0.23
D_2	315.1 MeV	$140 - 150$	0.23

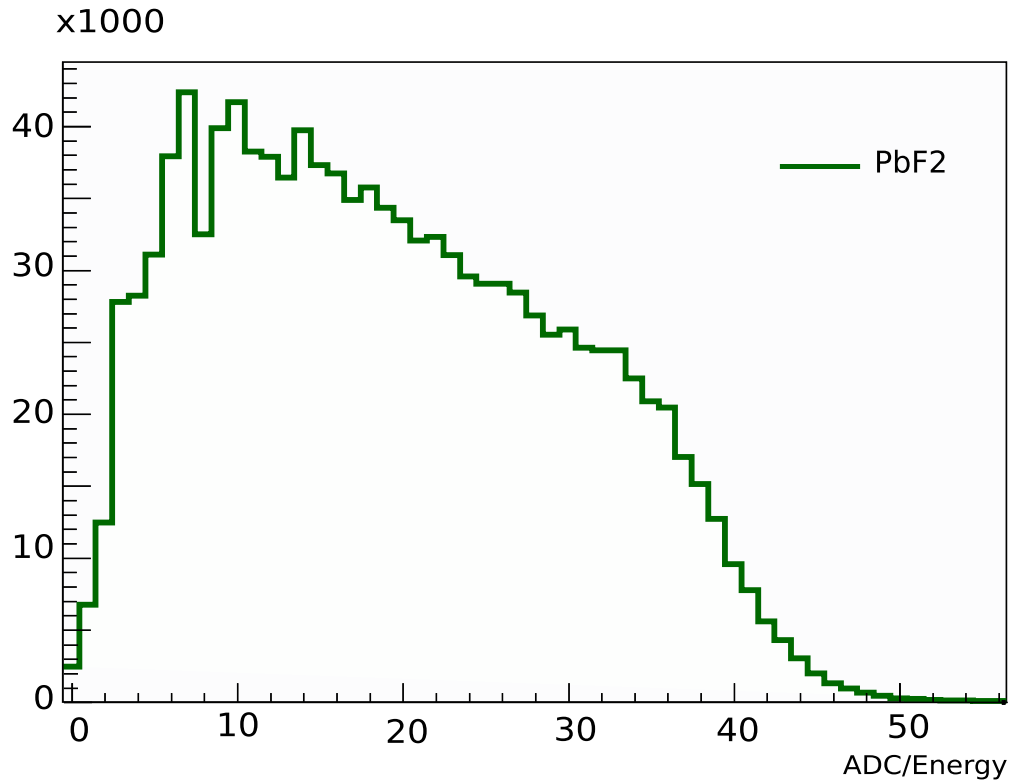
Data analysis

Energy spectra for H_2 target



- Counts and energy: energy spectrum histograms every 5 min.
- Two histograms for each polarization state.
- Scintillators: a histogram for charged particles and one for neutral paticles.

Energy spectra for H_2 target



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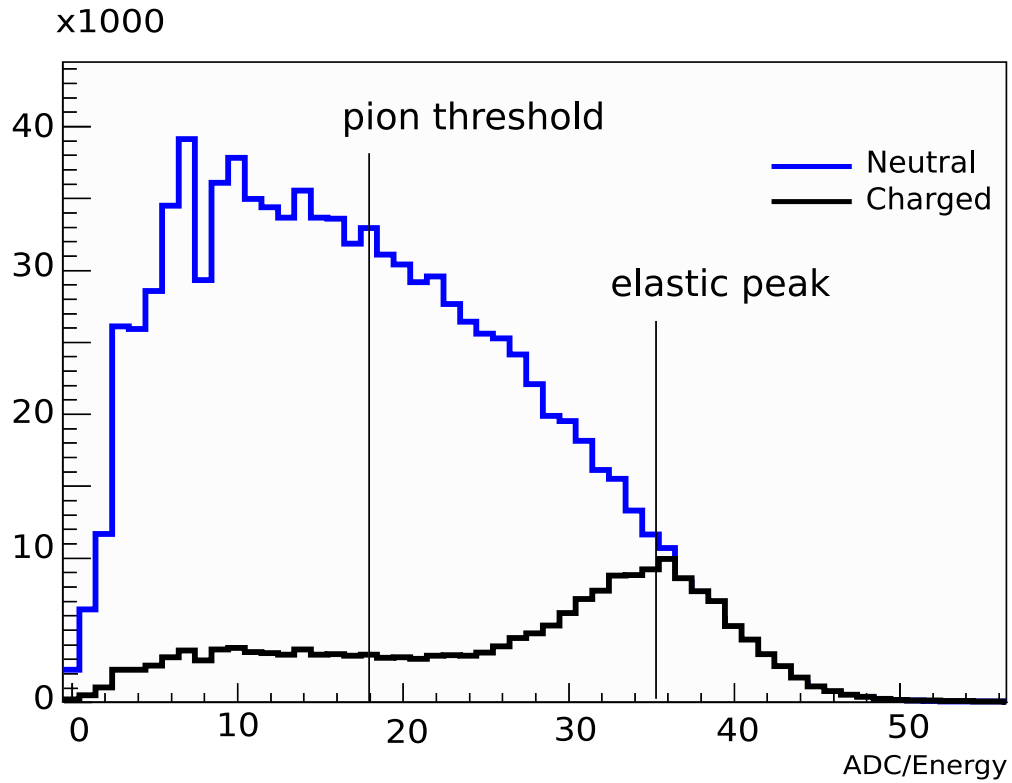

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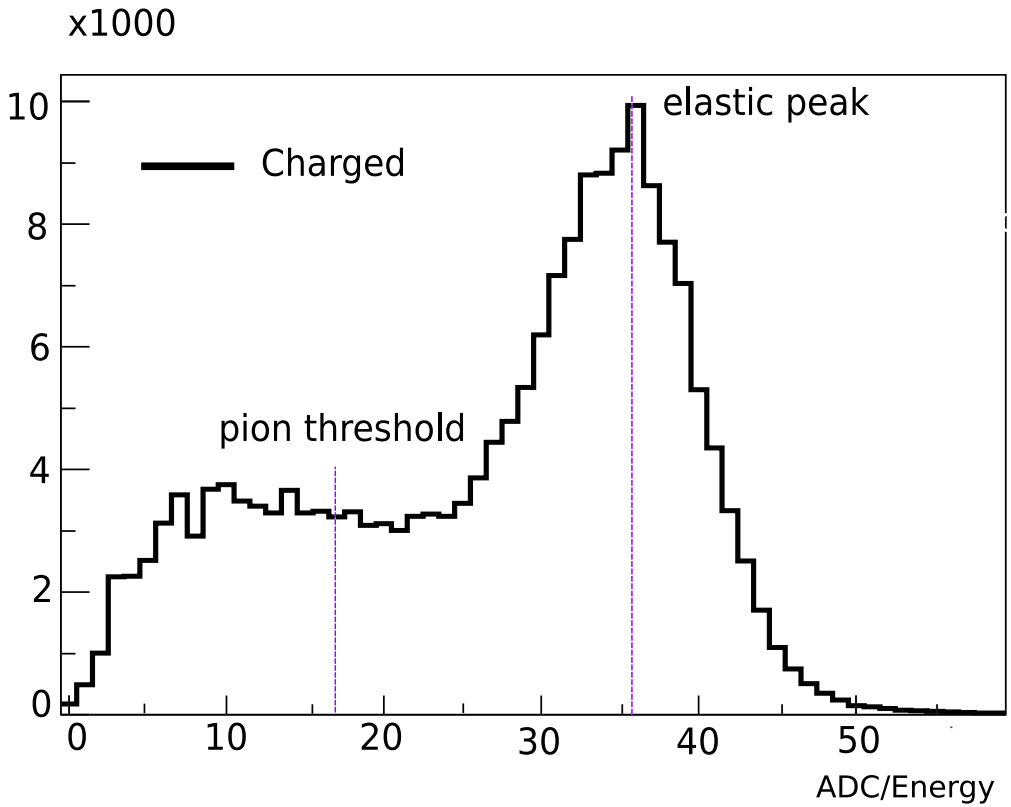
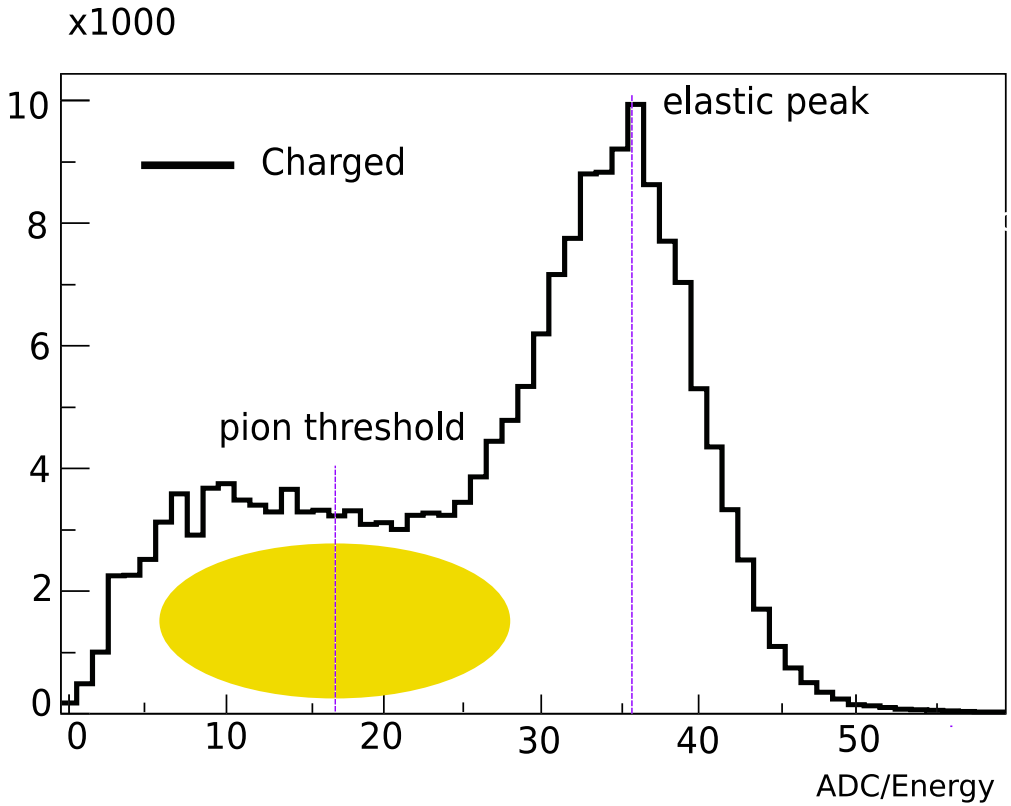


- Separation of the elastic peak in the charged particles spectrum
- Still neutral background from $\gamma \longrightarrow e^- e^+$

Energy spectra for H_2 target



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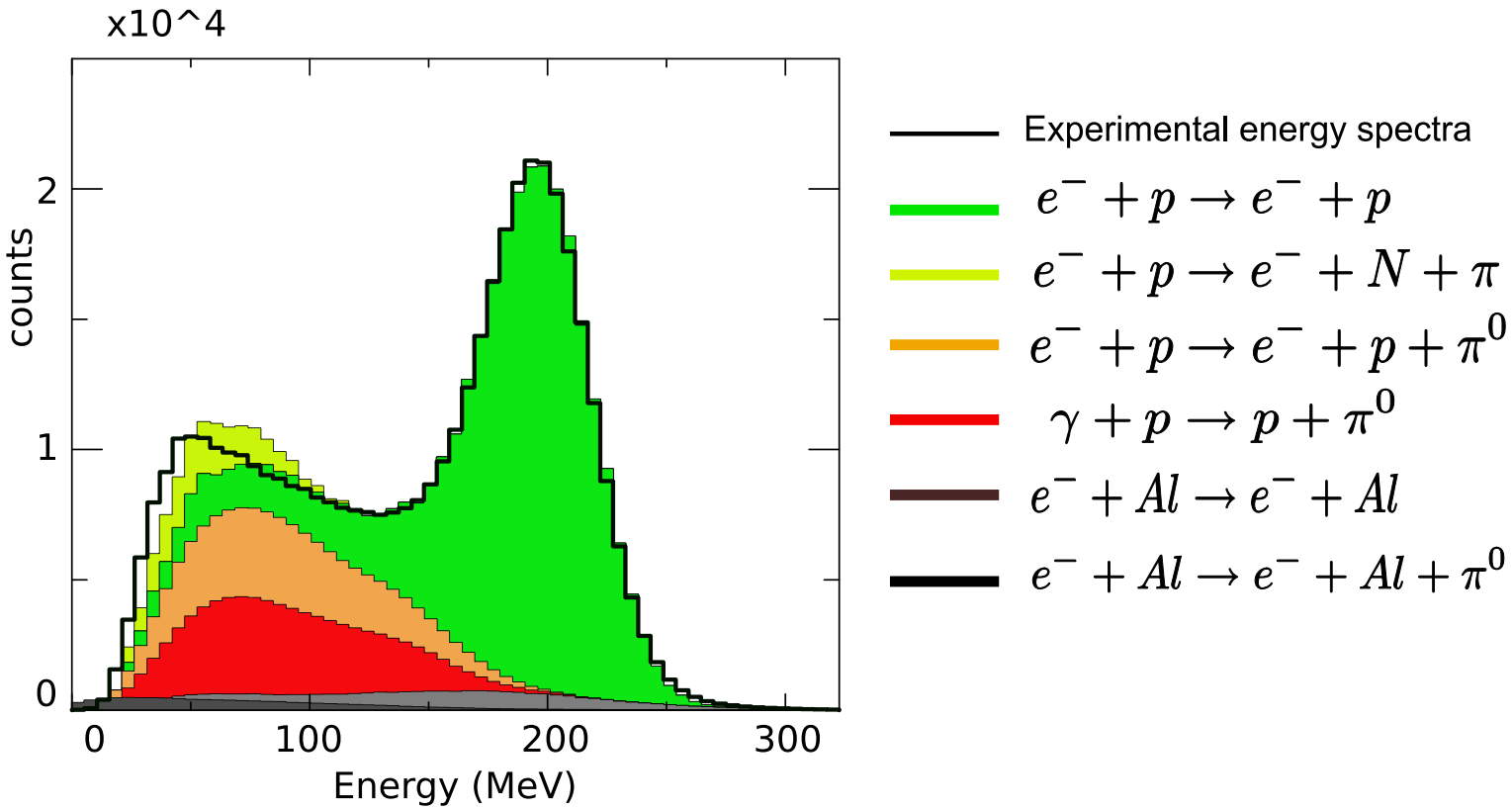
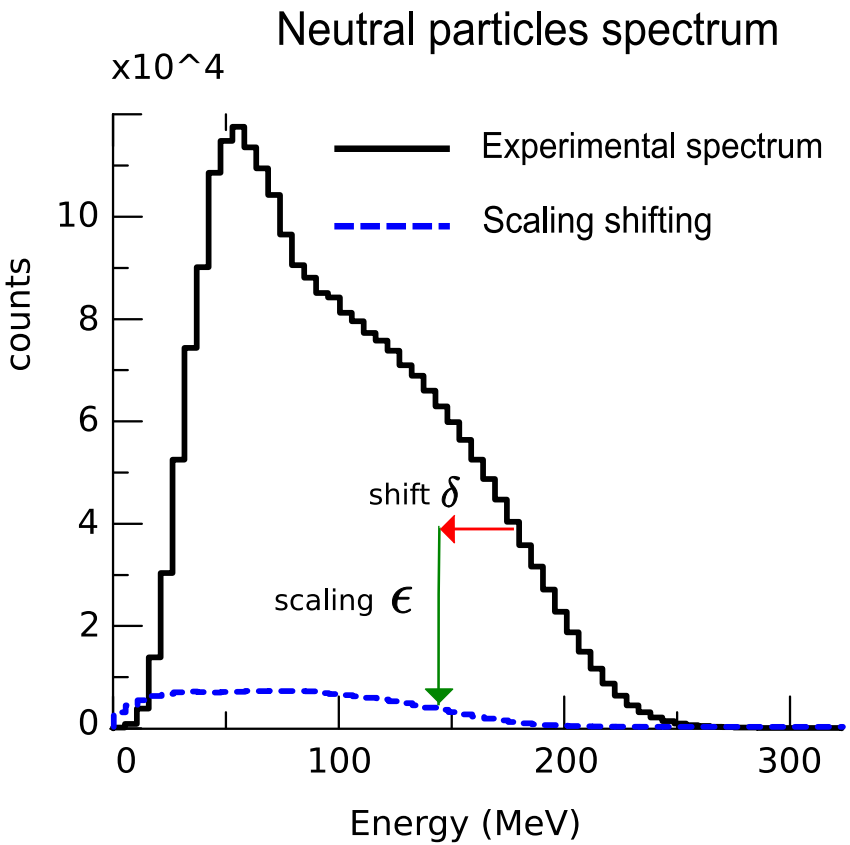
Understanding the energy spectrum



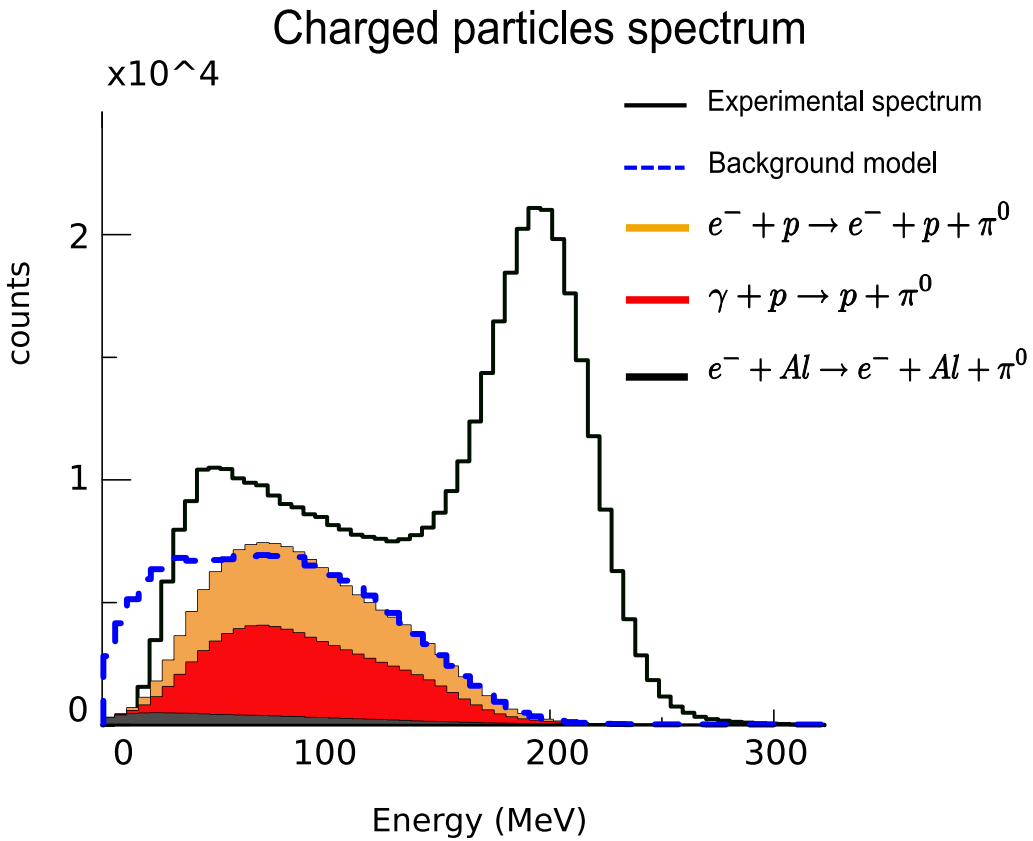
- Monte Carlo Geant4 simulation: e^- processes and γs
- Background from Al walls: measurement with empty target
- Agreement above 125 MeV

Background obtained from neutral spectrum



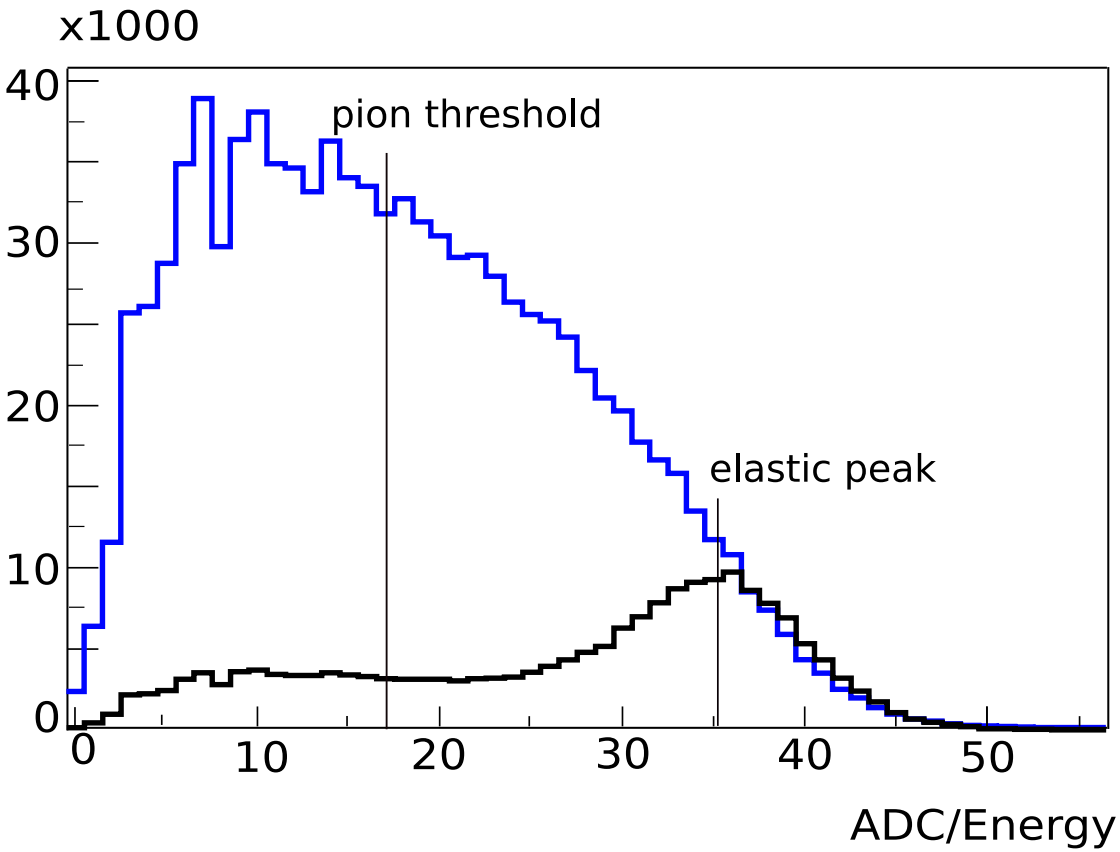
- γ background asymmetry?
- From experimental spectrum of neutral particles
- Model to obtain γ background
- Parameters
  - shift δ
  - scaling factor ϵ

Background obtained from neutral spectrum



- Scaling shifting model agrees with simulated background:
- above 125 MeV
- energy range of our interest

Extraction of the asymmetry from the spectra



- $f = \frac{N_e^{back}}{N_e^{back} + N_e^{el}}$
- Cuts applied $f = 5, 9, 16\%$
- $A_e = \frac{N_e^+ - N_e^-}{N_e^+ + N_e^-}$
- $A_\gamma = \frac{N_\gamma^+ - N_\gamma^-}{N_\gamma^+ + N_\gamma^-}$
- $A_{phys}^{raw} = \frac{A_e - f A_\gamma}{1 - f}$

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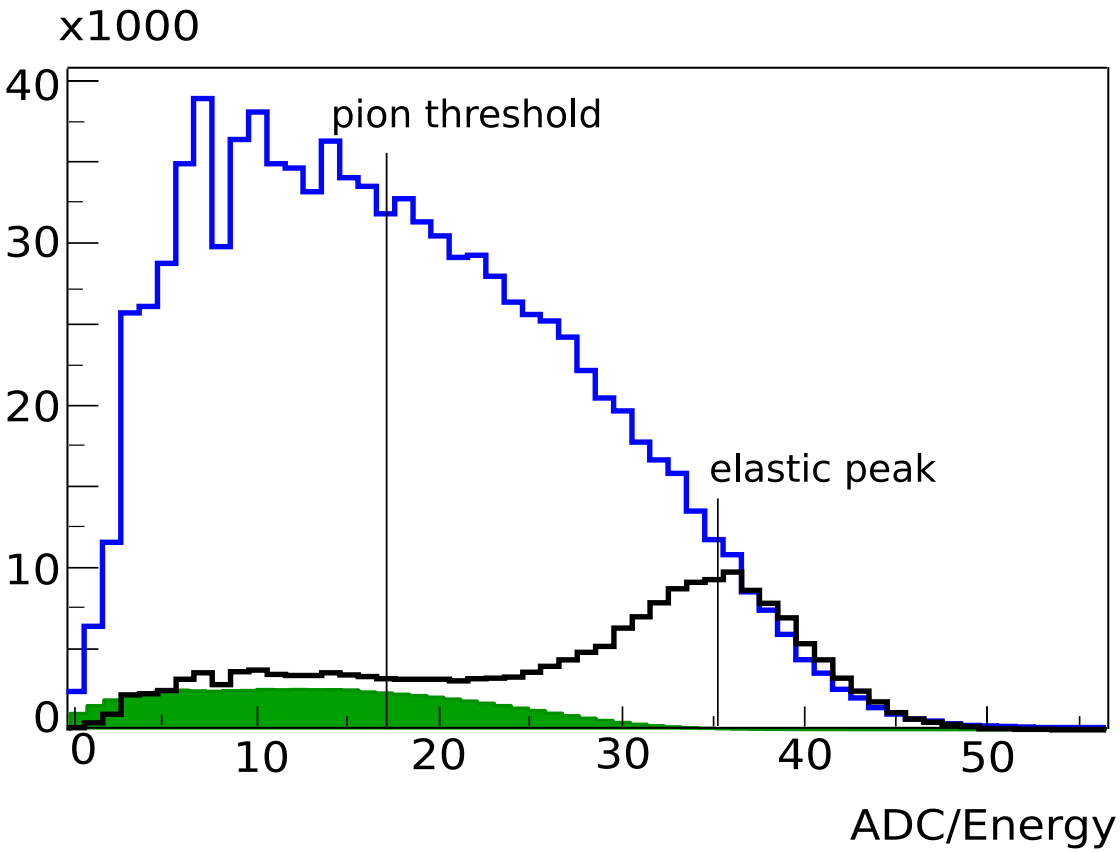

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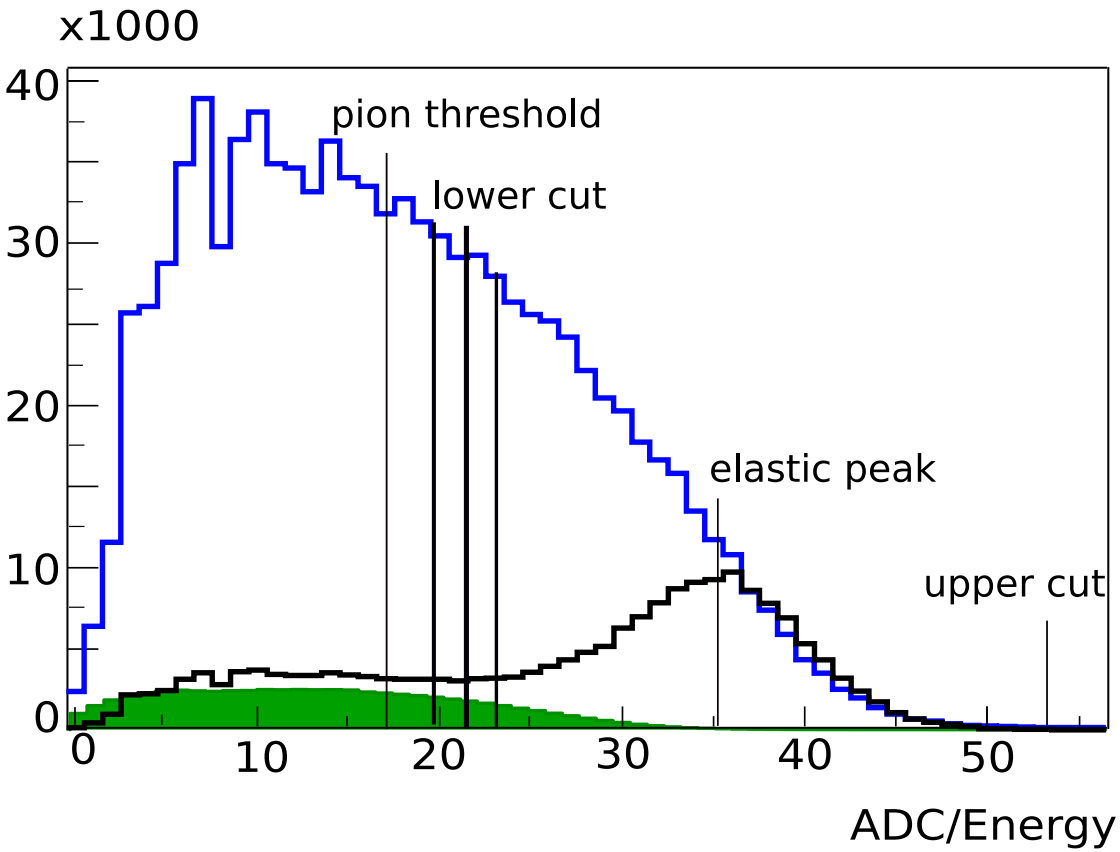

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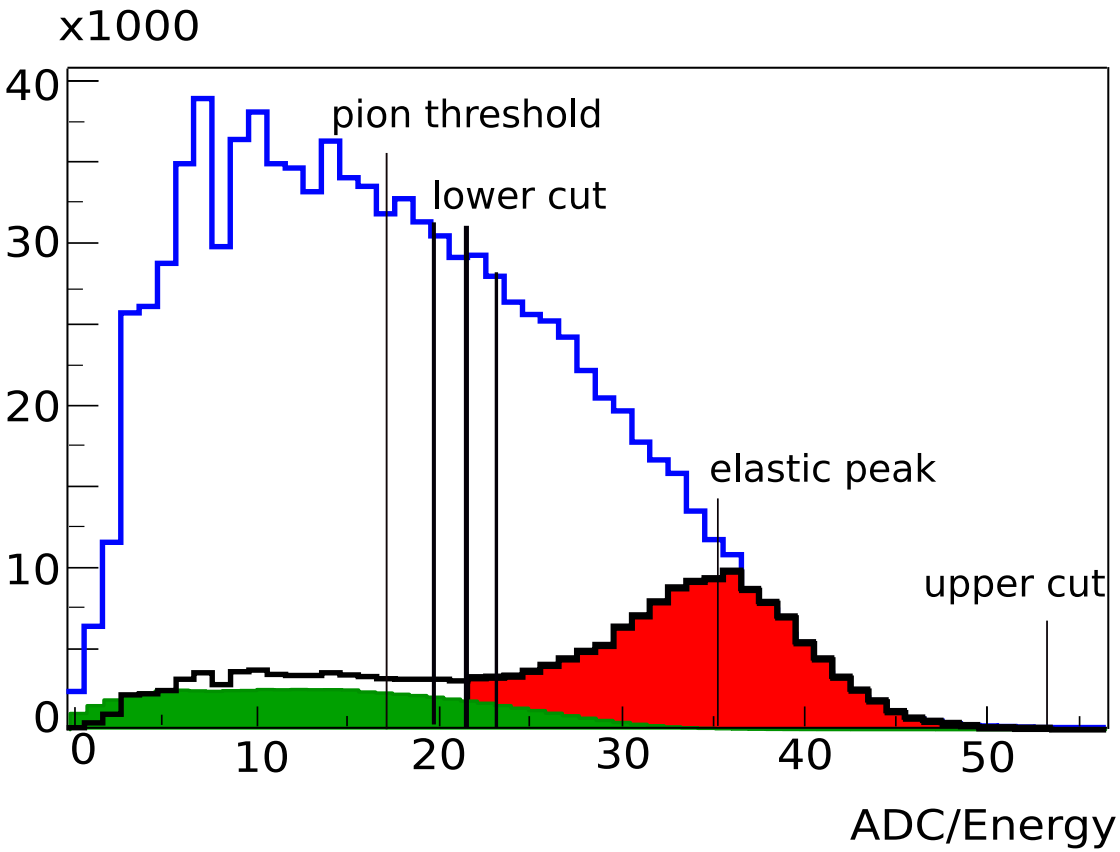

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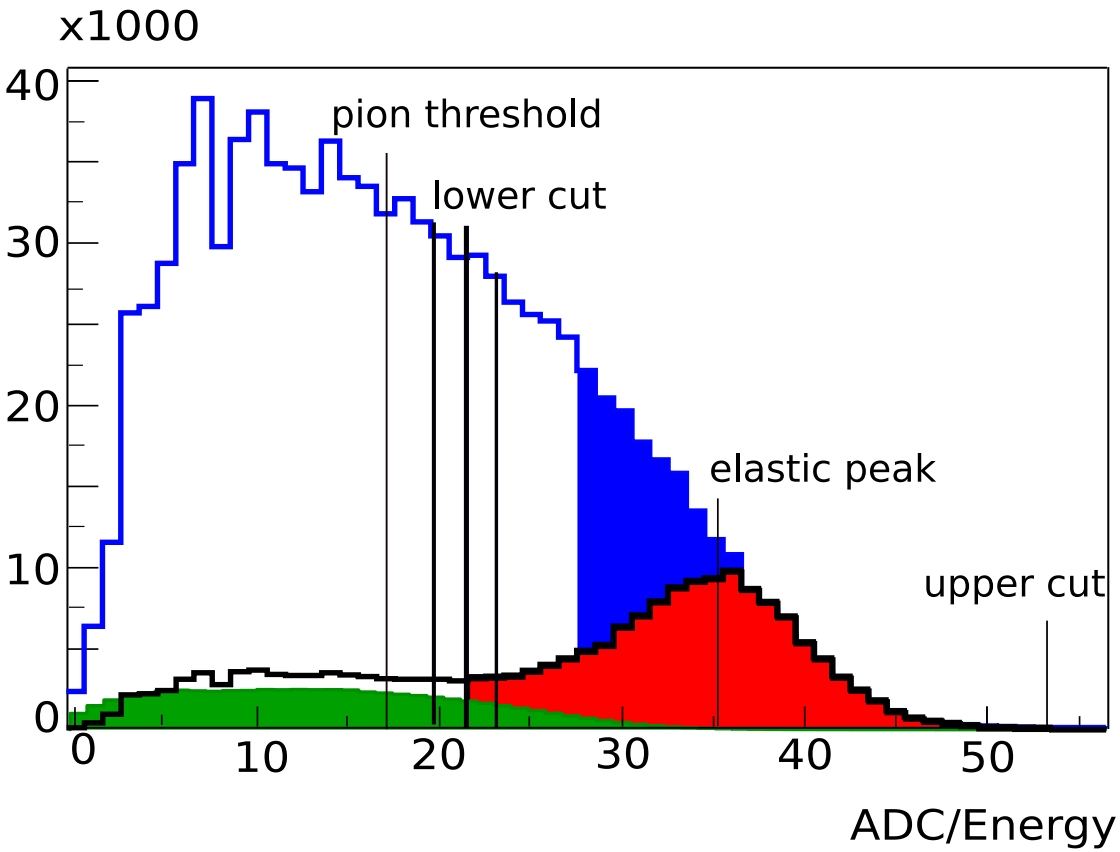

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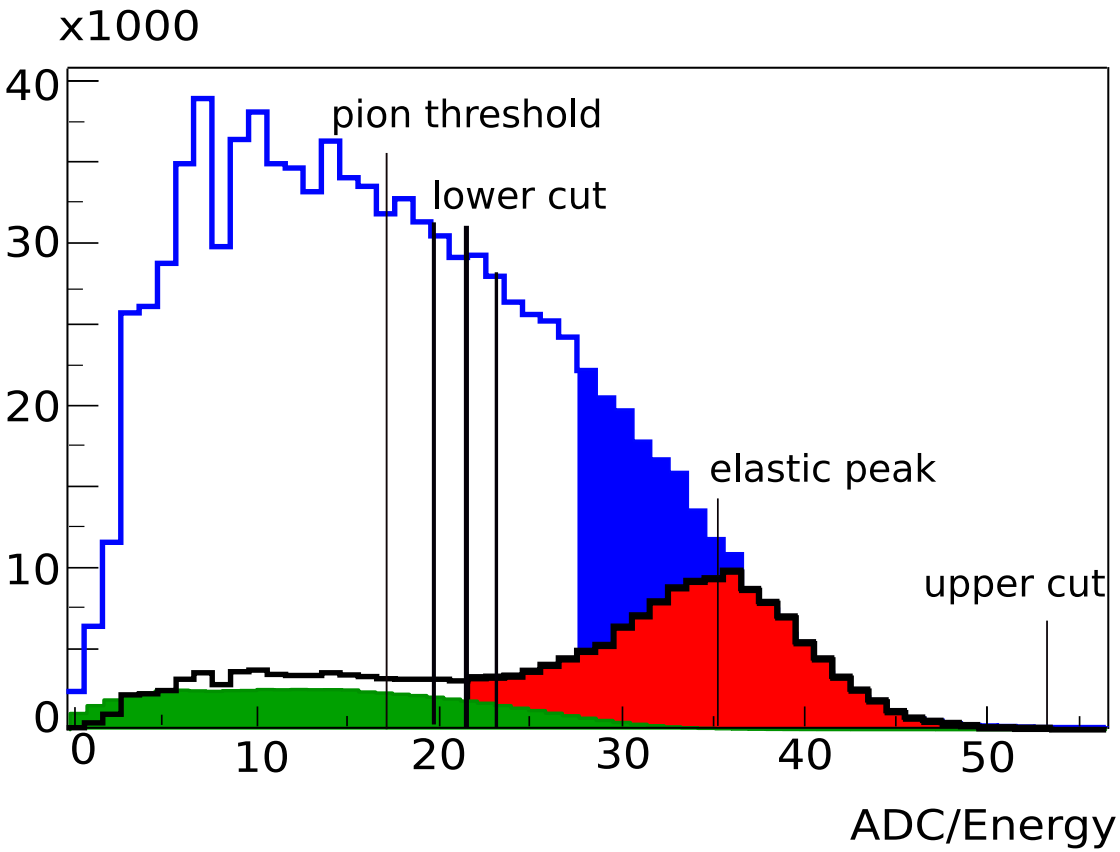

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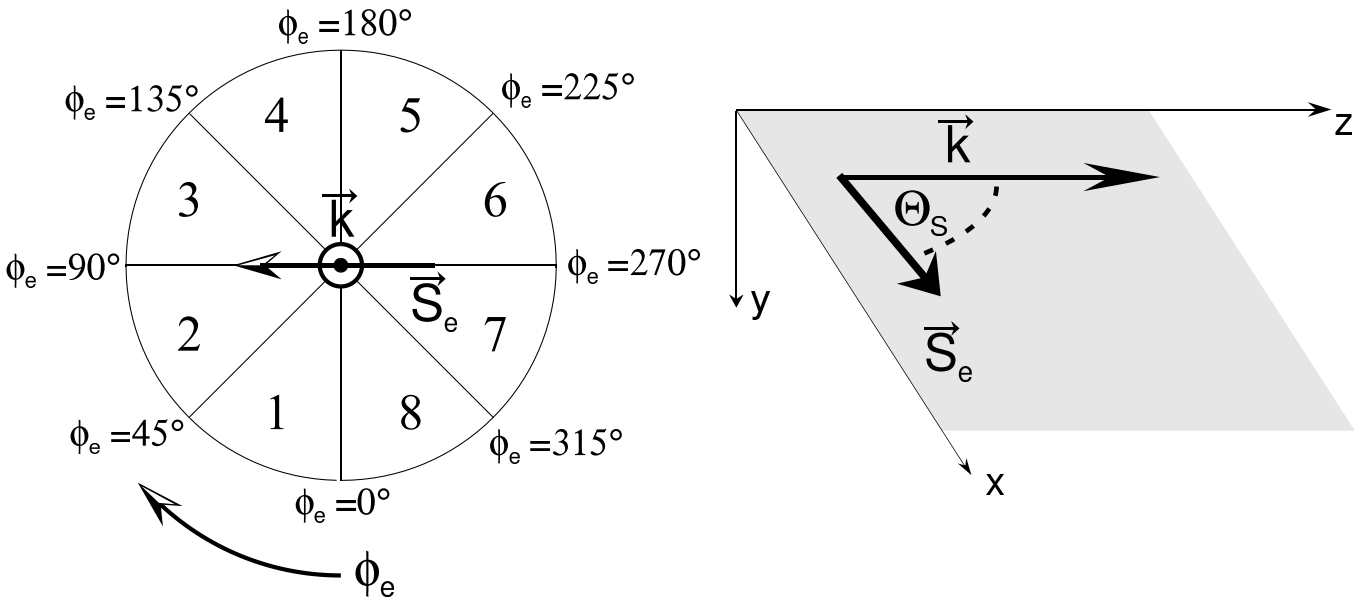
Combination of asymmetries



- Detector divided in sectors: azimuthal modulation of $A_\perp$
- $A_\perp$ averaged over the scattering angle θ

Outline

Results H_2 data

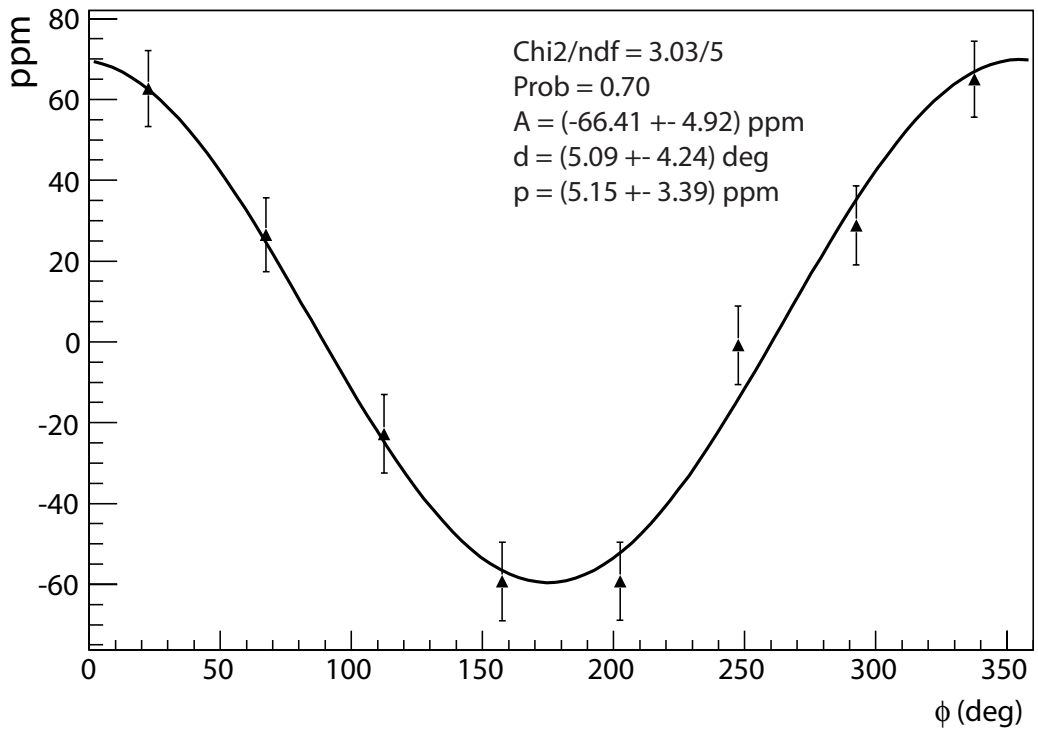
Raw asymmetry dependence on ϕ / H_2

$Q^2 = 0.23$ (GeV/c)^2

A4 backwards kinematics

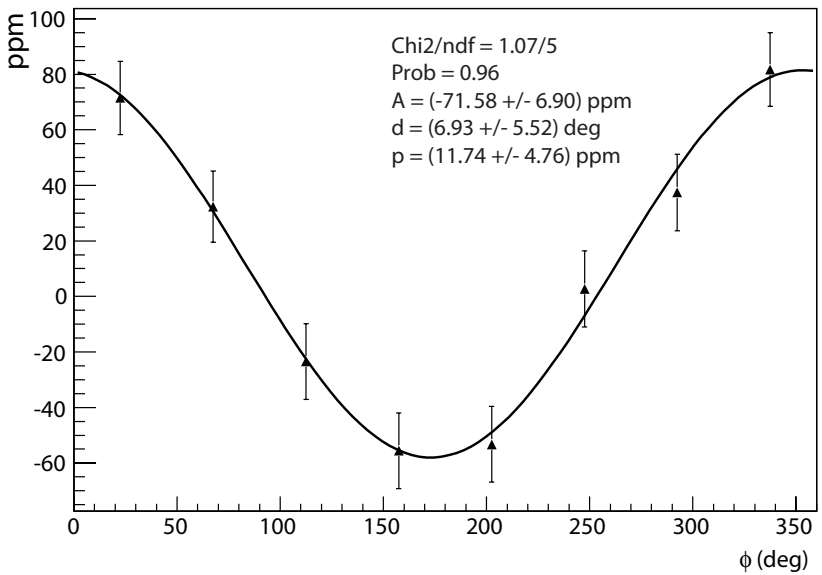
f = 9%

$$A_{exp} = A_{\perp} \cos(\phi + \delta) + p$$



GVZ test of systematics

GVZ = OUT



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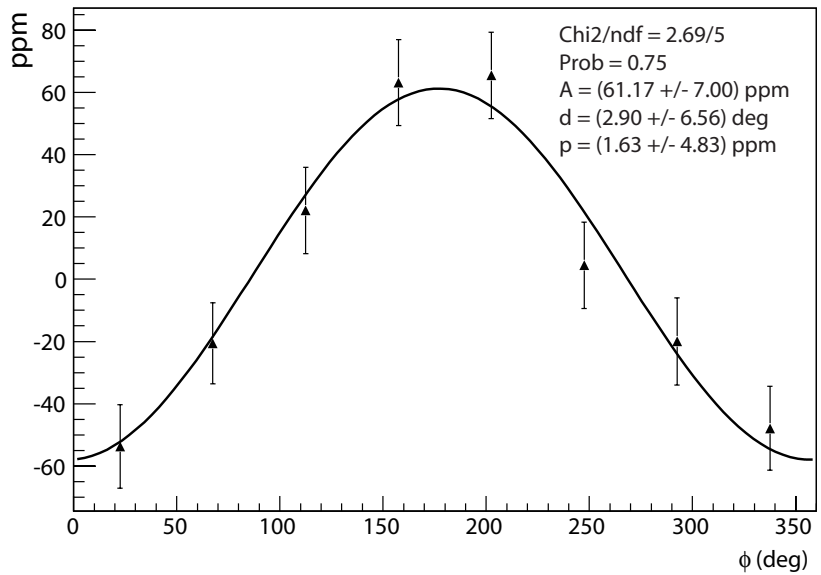


Preeliminary results for H_2 data

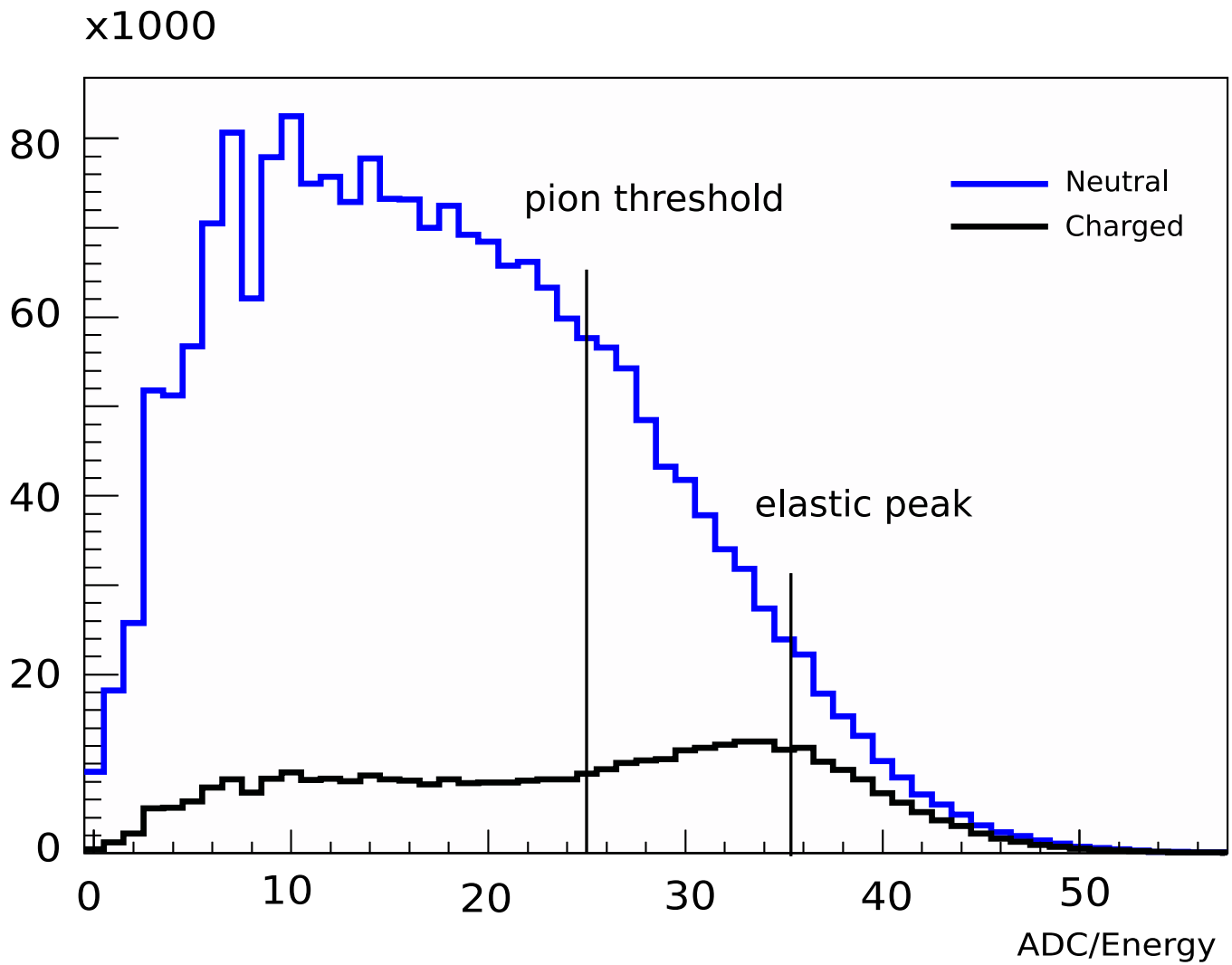
- 5 inner rings: 730 crystals.
- 50 h of data taking.
- Altogether $1.8 \cdot 10^{11}$ elastic events.
- Effective $P_e = 70.0\%$, error $\Delta(P_e) = 4\%$

At A4 Backward kinematics and $Q^2 = 0.23$ (GeV/c)^2
$A_\perp = (-86.65 \pm 3.35 \pm 3.46)$ ppm

Outline

Results D_2 data

Neutral and charged particles spectra for D_2



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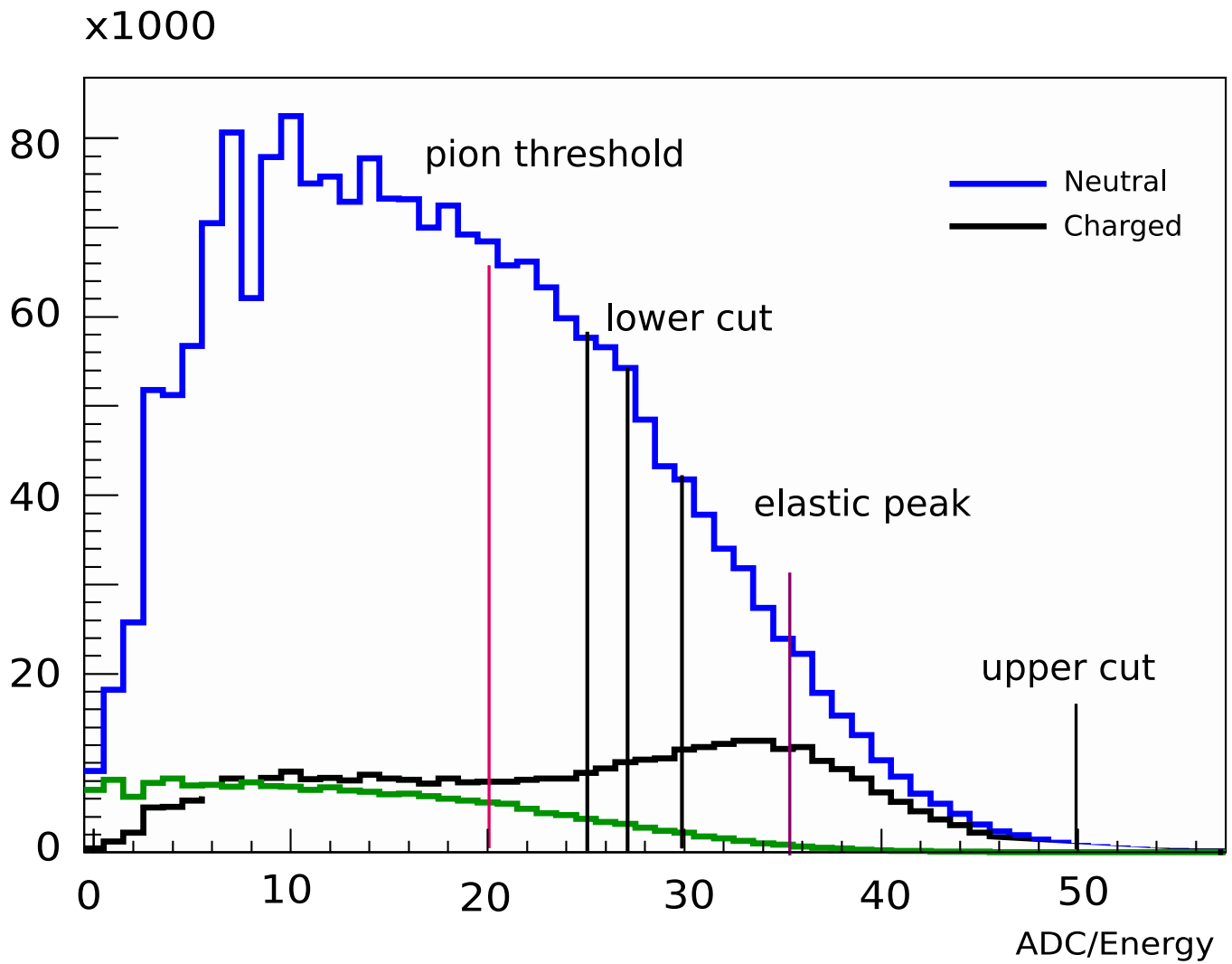

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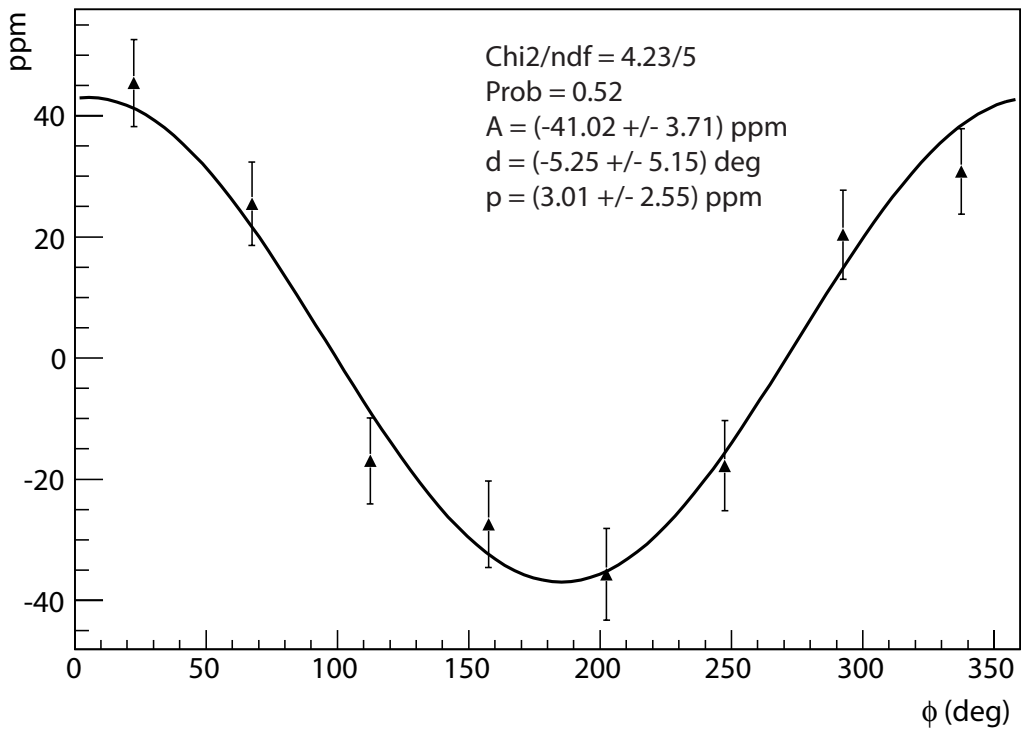

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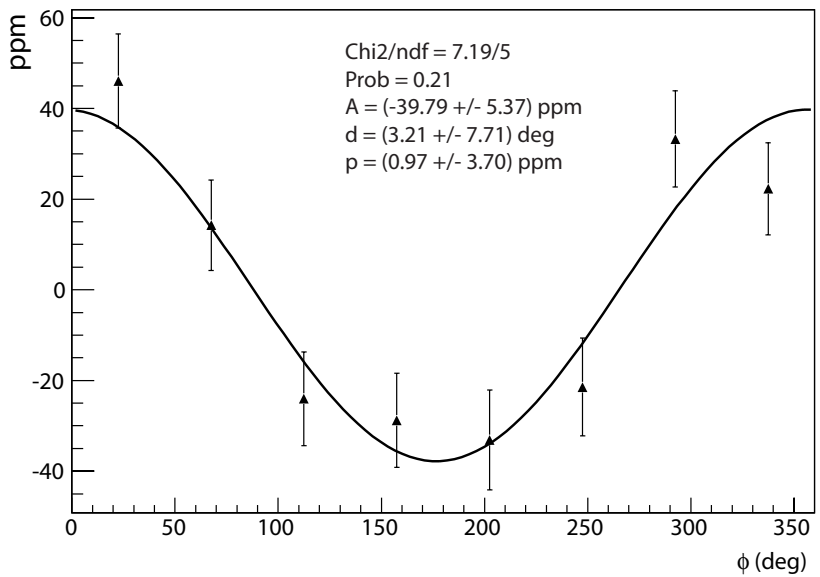

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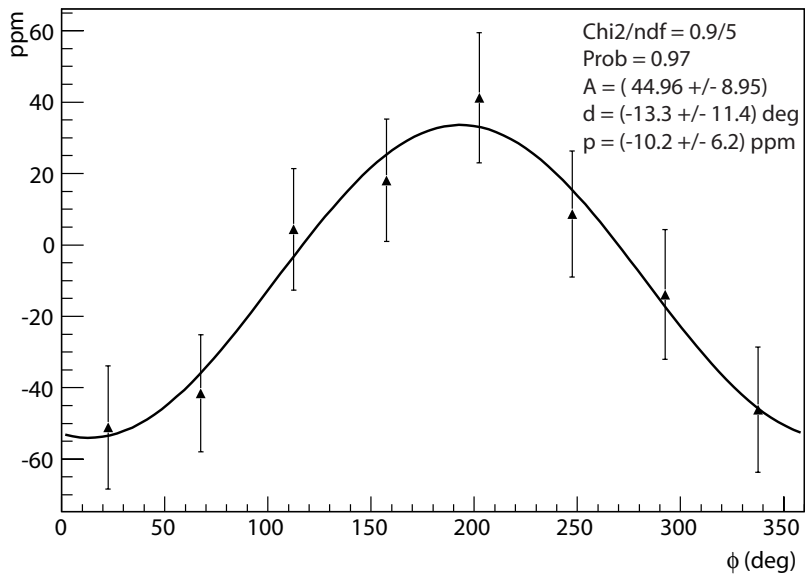


Preeliminary results for D_2 data

- 5 inner rings: 730 crystals.
- 60 h of data taking.
- Altogether $2.5 \cdot 10^{11}$ elastic events
- Effective $P_e = 78.4\%$, error $\Delta(P_e) = 4\%$

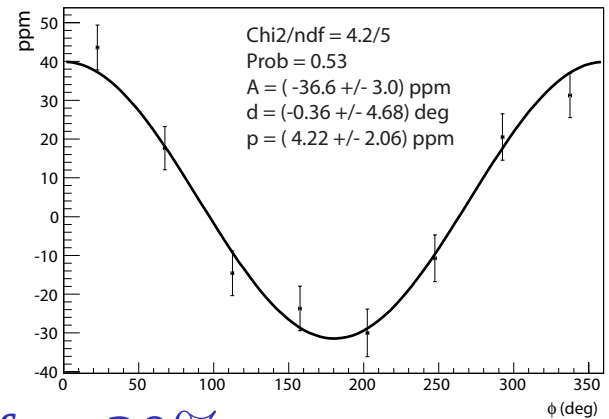
At A4 Backward kinematics and $Q^2 = 0.23$ (GeV/c)^2
$A_\perp = (-57.60 \pm 2.54 \pm 3.07)$ ppm

Systematic errors

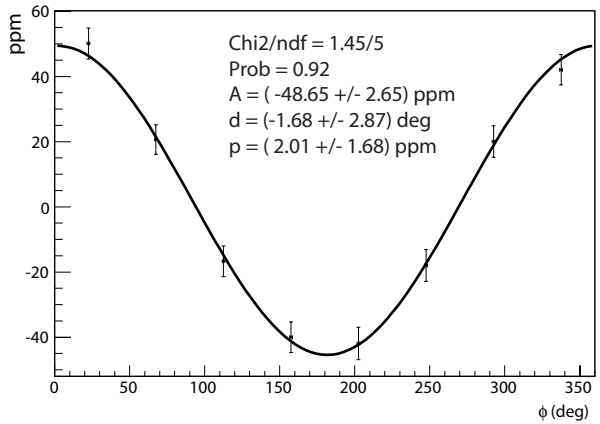
	Systematic error contribution
Polarization	2.30 ppm
False asymmetries	0.64 ppm
Model parameter δ	1.3 ppm
Model parameter ϵ	0.25 ppm
Target density	0.03 ppm
Spin deviation	1.4 ppm
Aluminium	—
Pile-up	—
Nonlinearity LuMo	—
Total	3.07 ppm

Transverse spin asymmetry in neutral background

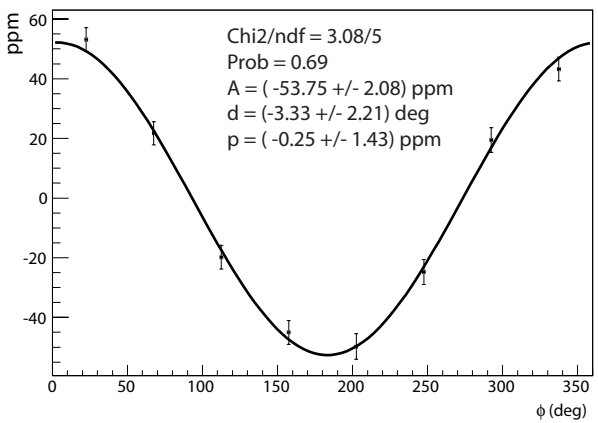
$f = 12\%$



$f = 16\%$



$f = 20\%$



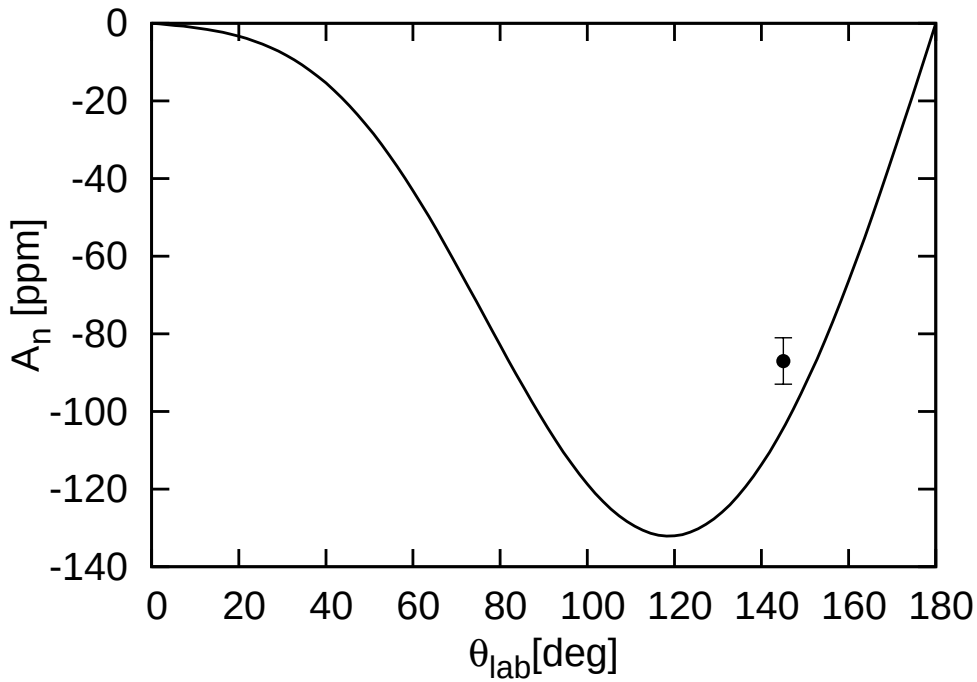
- $A_{\perp}^{\text{back}}$ is large and depends on the cut:
- $A_{\perp}$ sensitive to background subtraction

Summary of asymmetries

Target	elastic	background
H_2	-86.65 ± 3.35 ppm	-100.60 ± 2.78 ppm
D_2	-57.60 ± 2.54 ppm	-62.37 ± 2.28 ppm

Comparision of measured and calculated $A_\perp$

Calculation of $A_\perp$ for proton [1]



[1] Resonance estimates for single spin asymmetries in elastic electron-nucleon scattering. B. Pasquini et al. physical review c 70. 045206 (2004)

Summary and outlook

Summary

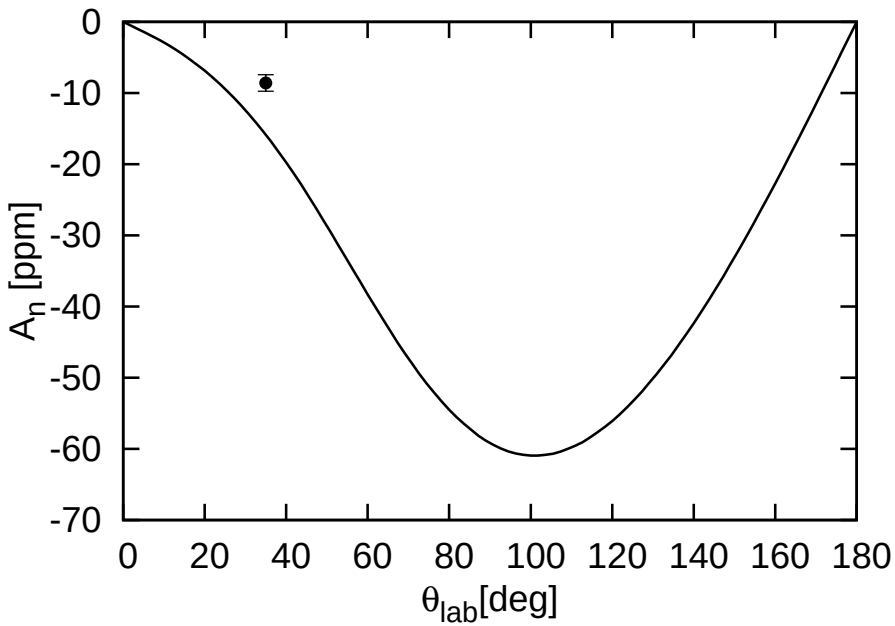
- Transverse spin asymmetry with H_2 and D_2 at $Q^2 = 0.23$ (GeV/c)^2 and backward angles.
- Detector of plastic scintillators to separate neutral background
- Understanding the energy spectrum and mixed γ background
- Modulation of the transverse spin asymmetry on $\cos\phi$
- Combination of whole data. Preliminary results
- Comparision of the measured transverse spin asymmetries with the calculations.

Outlook

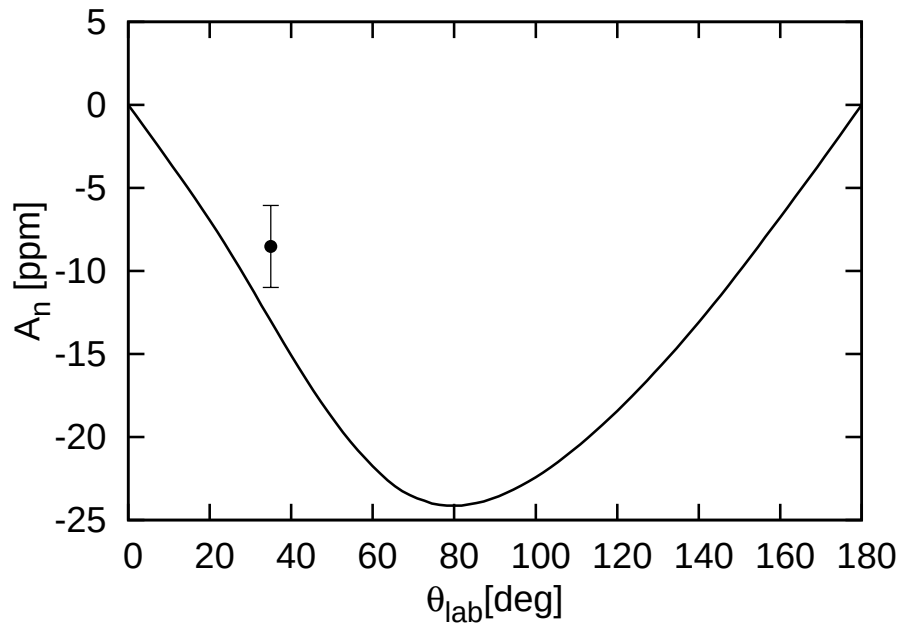
- Analysis in progress: sensitivity of $A_\perp$ to background subtraction.
- Investigation the transverse spin asymmetry in the neutral background.
- Analysis of data at backward angles with H_2 and D_2 and $Q^2 = 0.35$ (GeV/c)^2

Previous $A_\perp$ at A4 forward kinematics

570 MeV



855 MeV



Target l-H_2

$$A_\perp(Q^2 = 0.11(GeV/c)^2) = (-8.59 \pm 0.89 \pm 0.75) \text{ ppm}$$

$$A_\perp(Q^2 = 0.23(GeV/c)^2) = (-8.52 \pm 2.31 \pm 0.87) \text{ ppm}$$