Calibration of the PEPPo Polarimetry
(a tale of two polarimeters)

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On behalf of PEPPo collaboration

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The PEPPo Concept

- The **PEPPo (Polarized Electrons for Polarized Positrons)** experiment was conducted in the injector of the **CEBAF** accelerator at JLab to demonstrate a new technique for the production of **polarized positrons**.

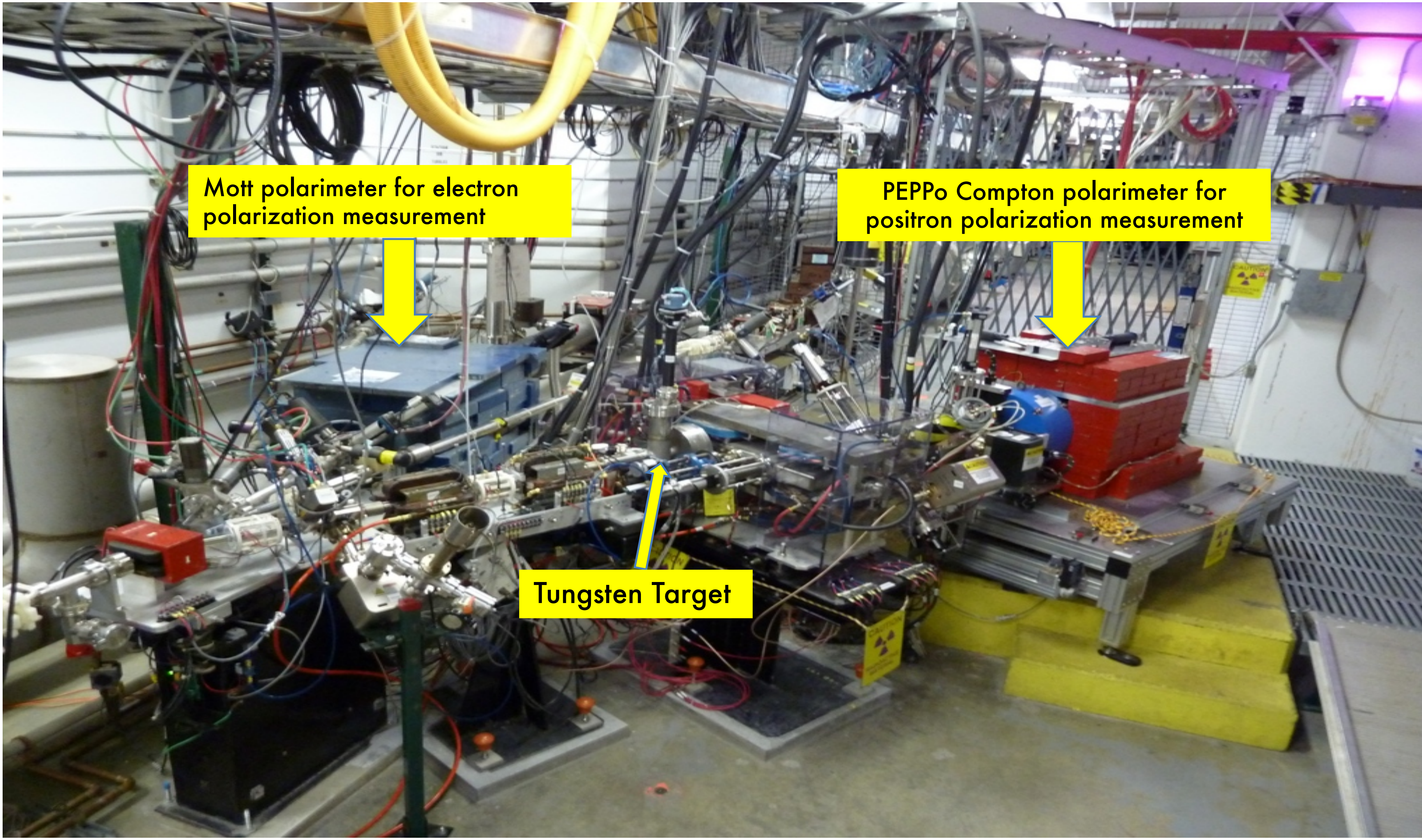
$$\overrightarrow{e^-} \longrightarrow \circlearrowleft\!\gamma \longrightarrow \overrightarrow{e^+}$$

- It involves a two-step process:

○ Creation of circularly polarized photons from the **bremsstrahlung** produced by longitudinally polarized electrons in a **hi-Z target**.

○ Followed by the creation of polarized e+e- pairs via the **pair production** from these circularly polarized photons within the same **target**.

PEPPo Experimental setup

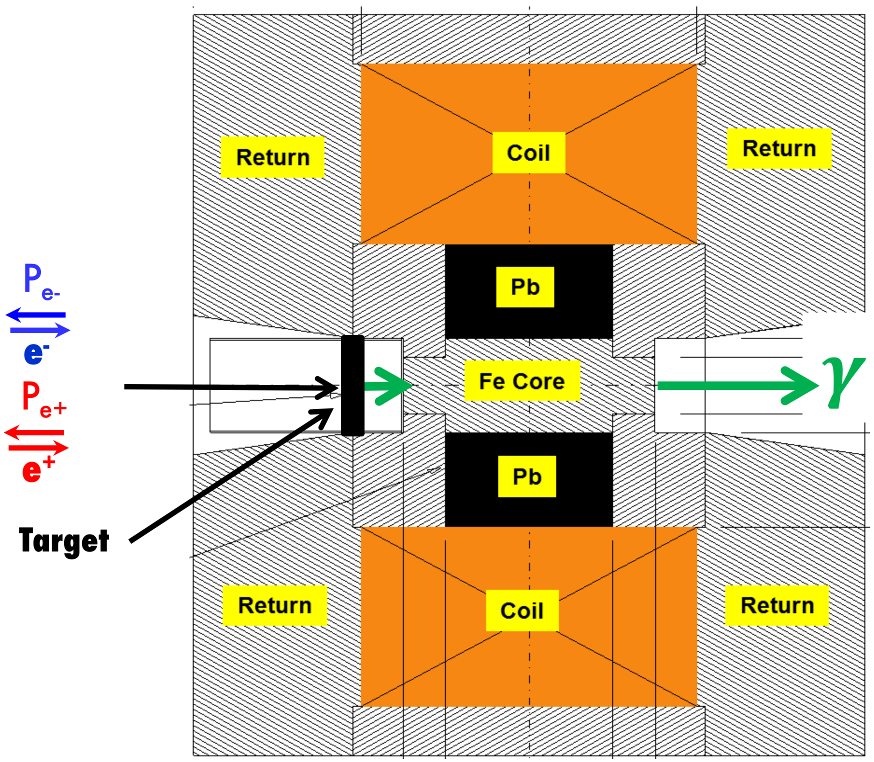


For more on the PEPPo experiment: See Grames talk on Thursday

Compton Transmission Polarimetry

- **Electrons** or **Positrons** radiate **polarized photons** by **Bremsstrahlung** in reconversion **target**. The photons **transmitted** by the magnetized **iron core** of the **analyzing magnet** are detected in 9 crystals of **photon calorimeter** and are **read by PMTs**

- The **measurement** of the **beam** (positron or electron) **polarization** is essentially obtained from the **transmission asymmetry (A_T)** of the **number** of transmitted **bremsstrahlung photons** for **oppositely polarized** target or **beam polarization orientations.**



$$A_T = \frac{N^+ - N^-}{N^+ + N^-} = \tanh(-P_3\, P_T\, \mu_1 L)$$

μ_1 - Compton absorption coefficient
L - target length
P_3 - photon polarization (long.)

$$A_T = P_e P_T A_e$$

P_e – e^-/e^+ polarization
P_T - target polarization
A_e - analyzing power

Electron beam polarization
P_{e-} = 83.7% ± 0.6% $_{(stat)}$ ± 0.7% $_{(sys)}$

Target polarization
P_T = 7.06% ± 0.05% $_{(sys1)}$ ± 0.07% $_{(sys2)}$

Compton Transmission Polarimeter

- Reconversion target

2 mm × 48 mm diameter **tungsten composite** (Densimet D17K) with 90.5% W,7% Ni and 2.5% Cu.

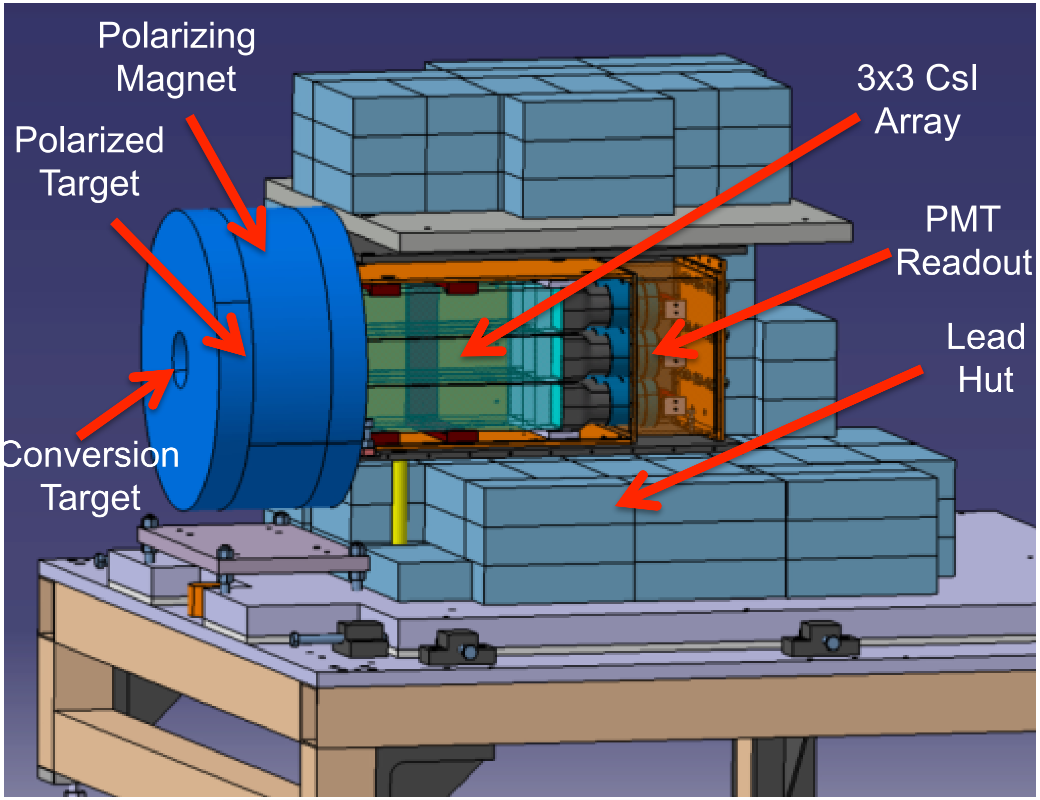
- Analyzing magnet

The core of the analyzing magnet is a **magnetized iron cylinder target** that is 7.5 cm long and 5 cm diameter

- Photon calorimeter

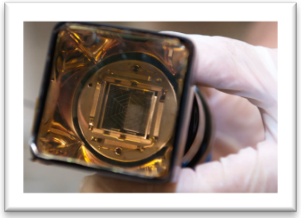
9 (60 x 60 x 280 mm) **Cesium Iodide** crystals doped with Thallium CsI(Tl) arranged in **3 × 3 array** configuration.

CsI(Tl) crystals are coupled to Hamamatsu R6236 PMTs operated at -1.5kV



FADC 250

Hamamatsu R6236



- The **signal** from the PMTs are fed into JLab custom made **FADC250** module which samples signals at **250 MHz**.

Analyzing magnet

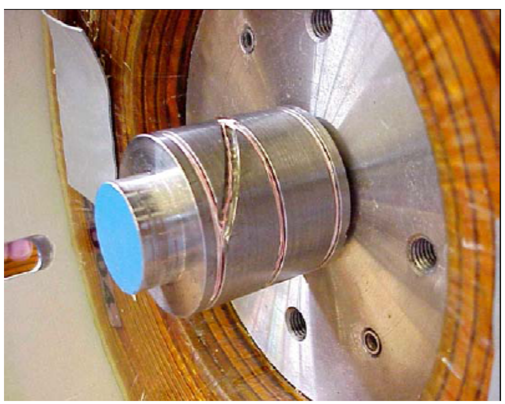
- The **iron core target** is equipped with **3 pick-up coils** measuring the **magnetic flux** generated by the magnet **current** variation (ramping-up, polarity reversal).

- Specific **cycling procedures** are used during the experiment to monitor the **target polarization.**

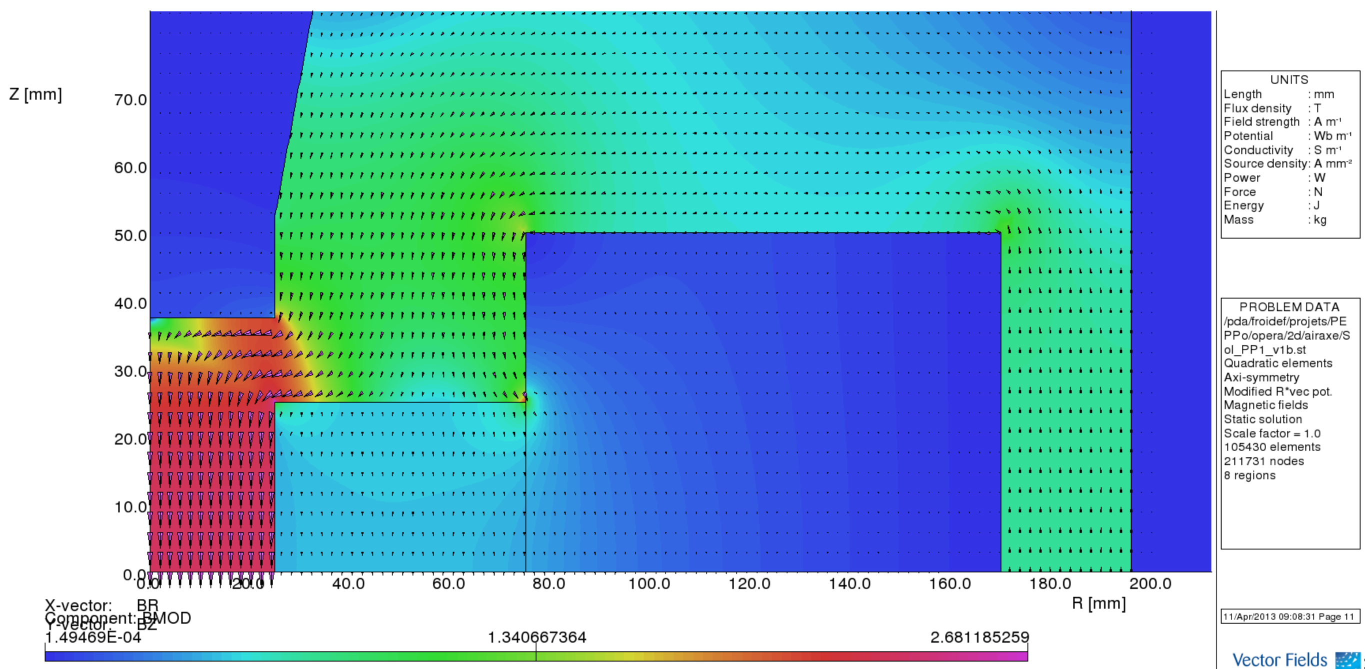
- The **magnetic field** of the analyzing magnet was **modeled** in OPERA 2D and **compared** to field values **measured experimentally** with the pick up coils.

$$P_T = 2\,\frac{g'-1}{g'}\,\frac{1}{\rho_e}\,\frac{1}{\mu_0\mu_b}\,(B-\mu_0 H)$$

P_T = 7.06% ± 0.05%$_{Stat.}$ ± 0.07%$_{Syst.}$



E. Froidefond, E. Voutier, PEPPo TN-14-02

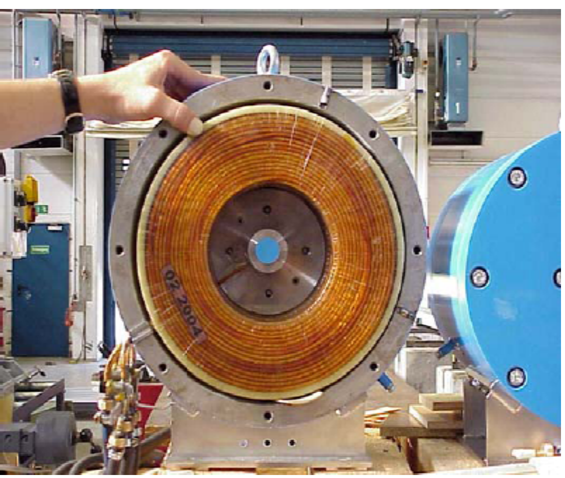


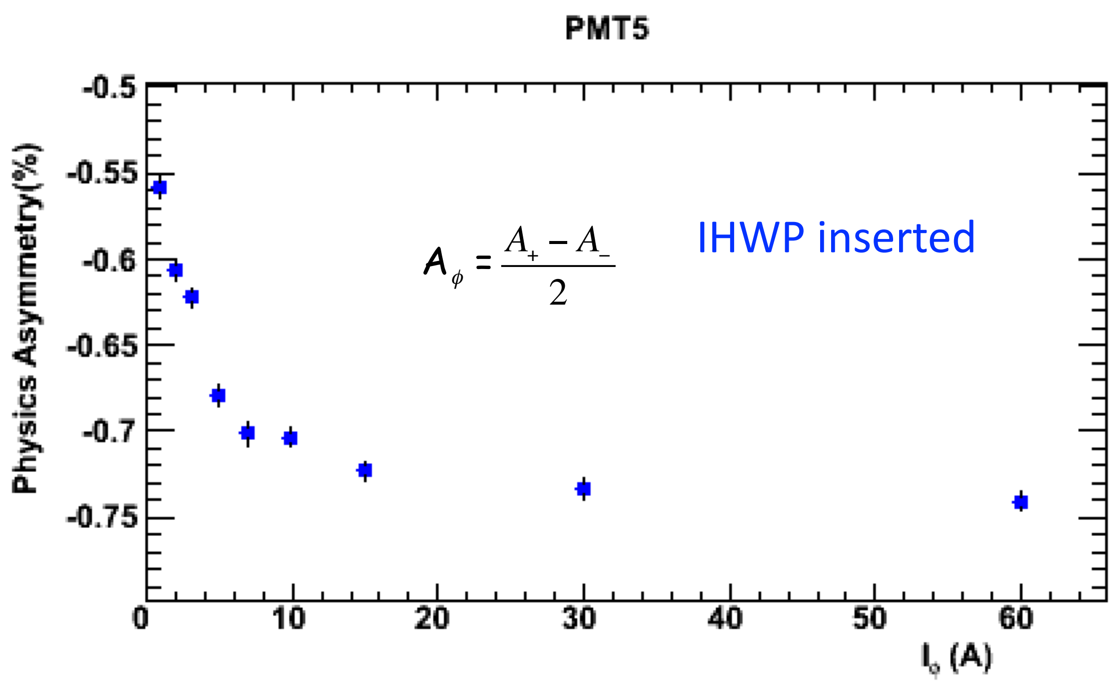
Analyzing magnet response

Experimental **asymmetries** are measured with respect to **beam helicity** ; they are linearly **proportional** to the **target polarization**, itself **proportional** to the **target magnetization**.

$$P_T = 2\,\frac{g'-1}{g'}\,\frac{1}{\rho_e}\,\frac{1}{\mu_0\mu_b}\,(B-\mu_0 H)$$

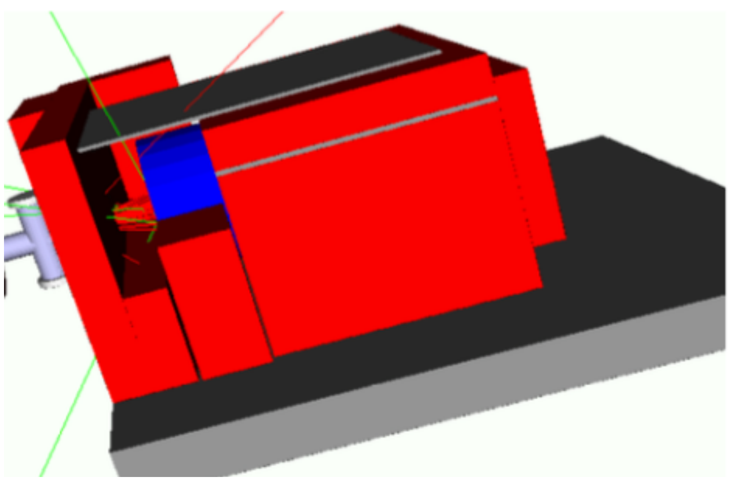
$$A_T = \frac{N^+ - N^-}{N^+ + N^-} = P_e P_T A_e$$



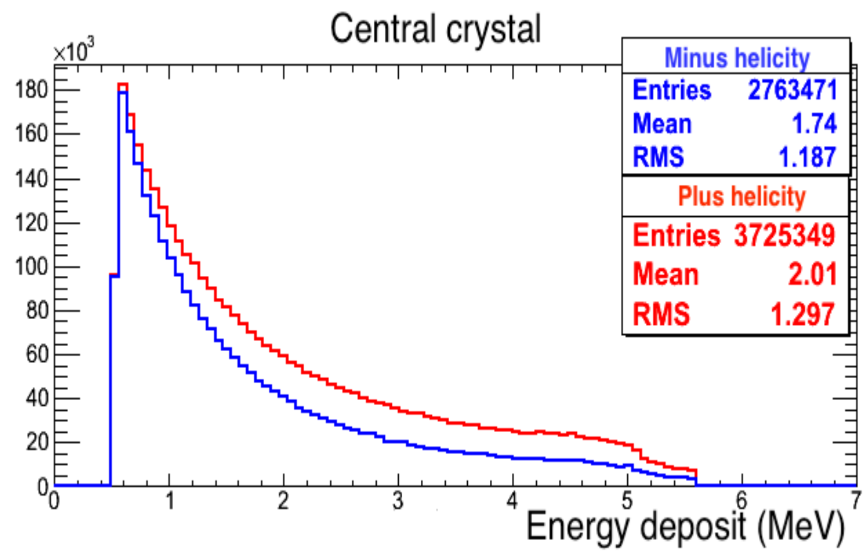


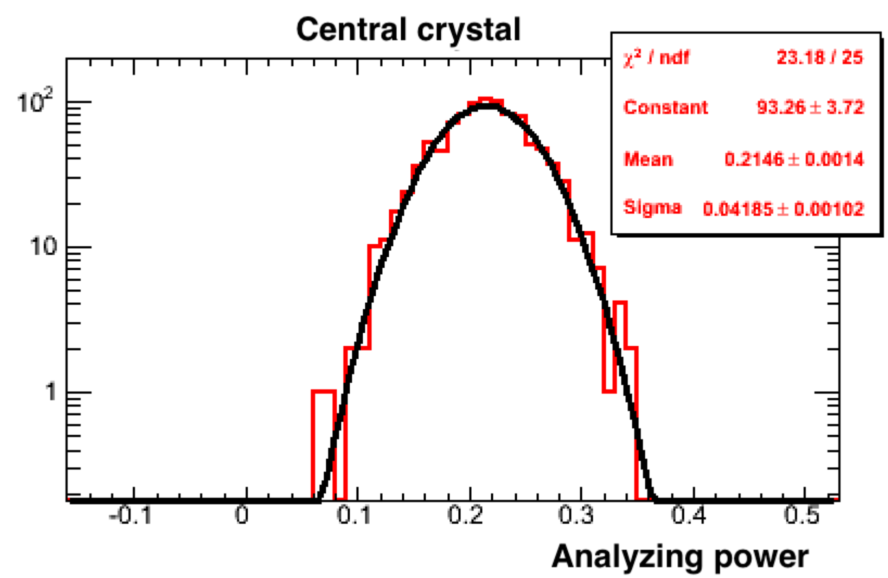
Analyzing power simulation

- The **analyzing power** of the polarimeter can be **experimentally measured** with a **known** polarized beam or **simulated** with GEANT4.
- A **model** of the **PEPPo polarimeter** has been developed within the GEANT4 framework, starting from **E-166 Collaboration** earlier work.
- The **simulated energy** deposited into each crystal is processed according to the **data read-out electronics** method



Simulation of 5.34MeV/c pencil beam e^+ beam

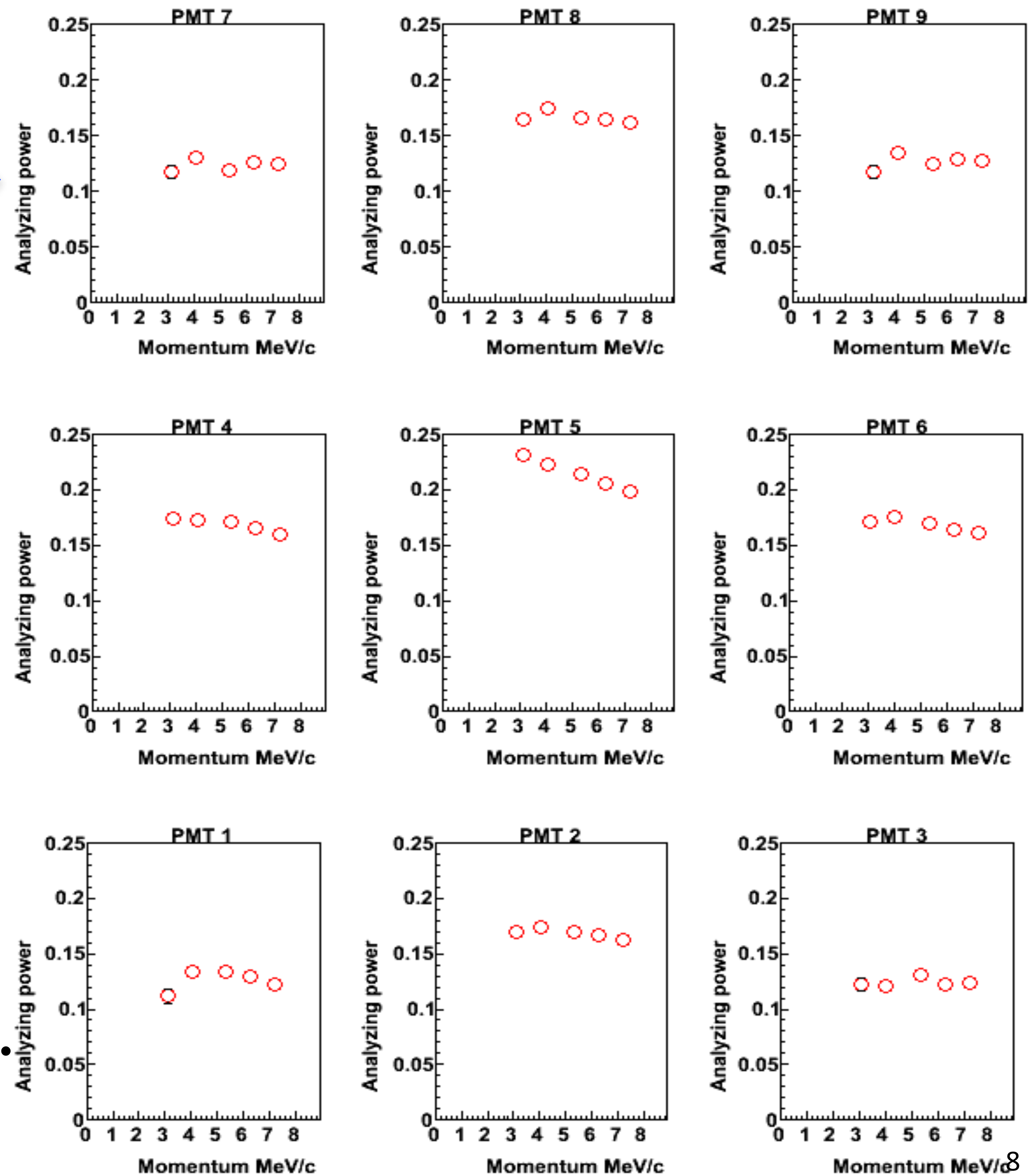




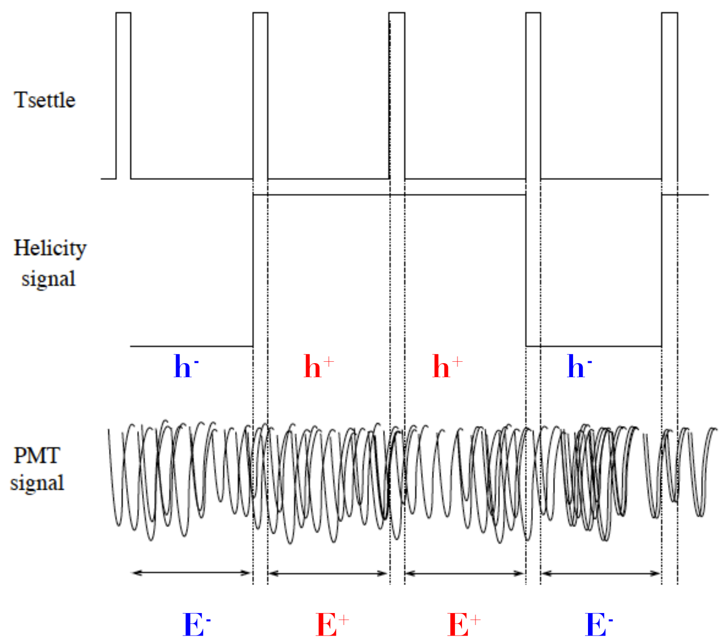
Simulated Positron Analyzing power

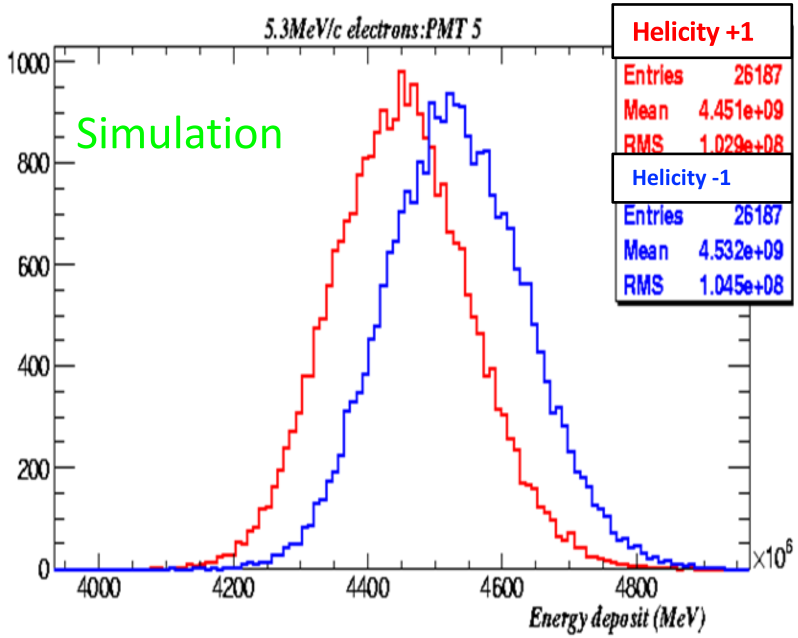
Positron analyzing power simulation: 3.08 - 7.19MeV/c.

- **Positron** analyzing power is obtained **directly** from **simulation**.
- The main **difference** between **electrons** and **positrons** is the **annihilation** reaction.



Energy Integrated Asymmetry



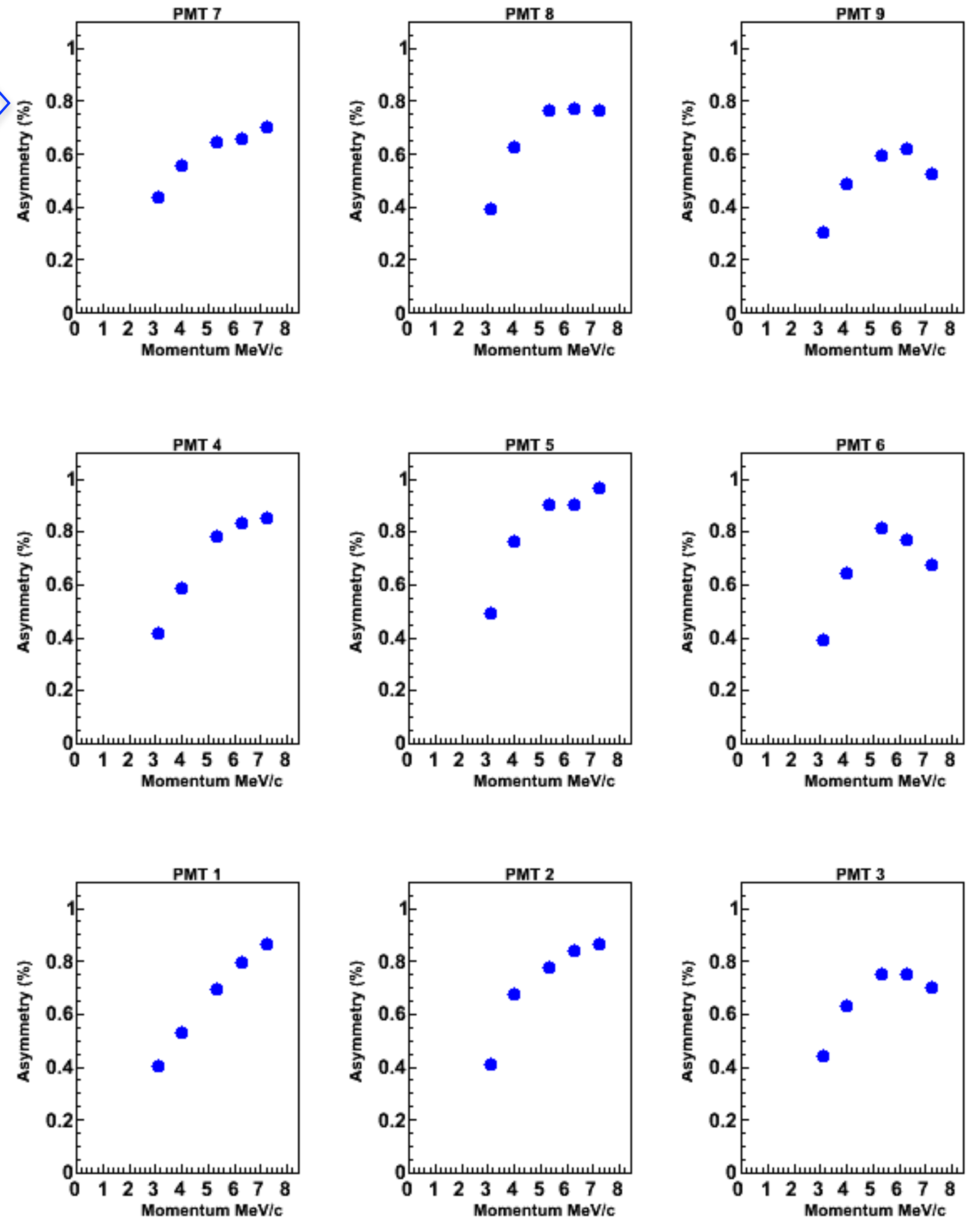


- Electron data are recorded in energy **integrated** mode.
- The energy integrated method is suitable for the **high rate** condition of the electron.
- The **total energy** deposited in each crystal during the time corresponding to a single **helicity state** of the initial electron beam is recorded.

Helicity frequency=30Hz
Helicity delay= 8windows
Helicity pattern=quartet
(+ - - + or - + + -)

Electron physics asymmetry measurement.

Combining **experimental asymmetries** measured for each **analyzing magnet polarity** and each **laser polarization orientation** allows to **cancel-out** eventual **false asymmetries** and isolate **physics asymmetries**.



P_{e-} (MeV/c)	I_{e-} @ T2
3.08	60 pA
4.02	23 pA
5.34	25 pA
6.25	10 pA
7.19	10 pA

$$A_e = \frac{A_T}{P_e P_T}$$

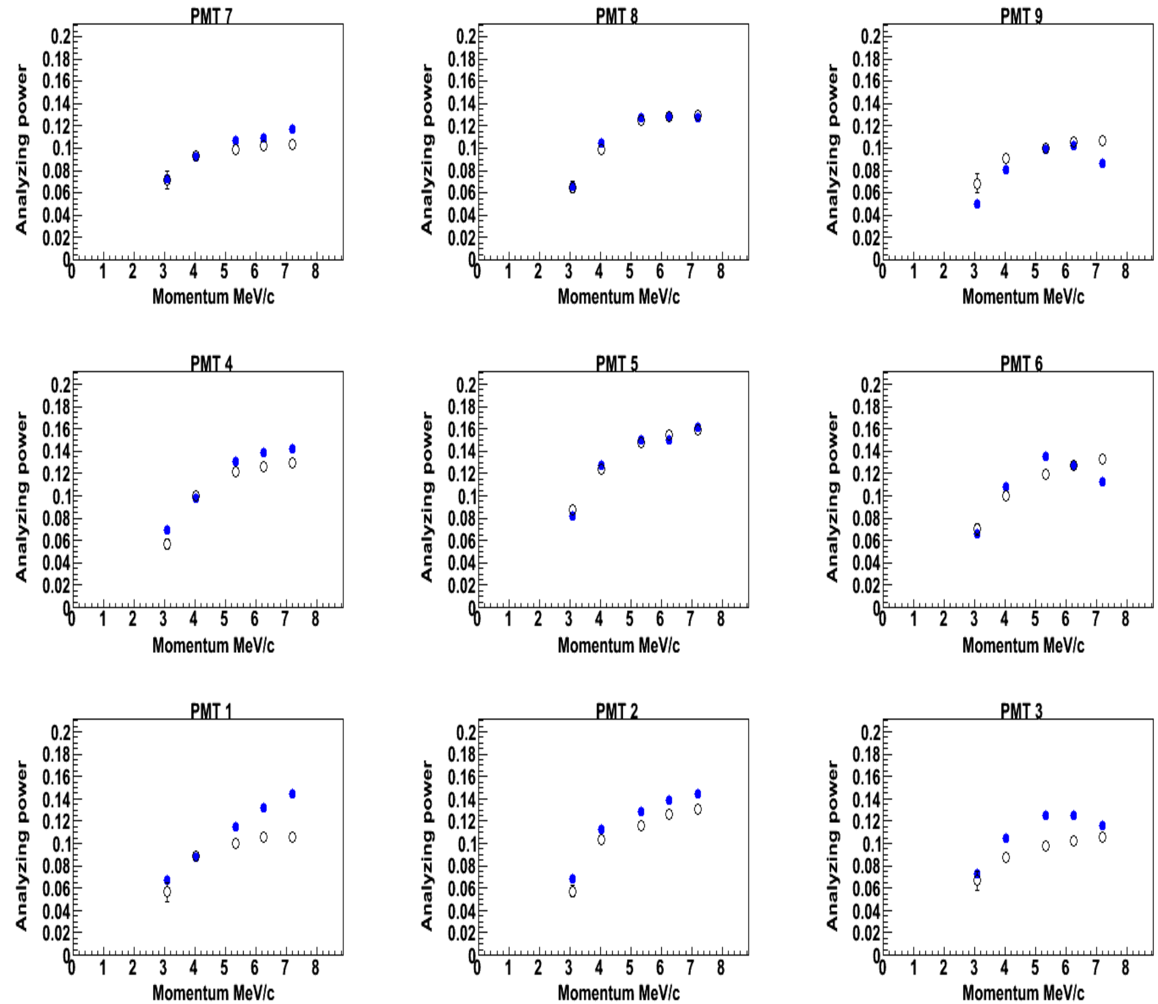
Electron Measured vs. Simulation

- The **calibration** of the **analyzing power** of the polarimeter relies on the comparison between **experimental** and **simulated** electron analyzing power.

- The comparison between experimental and simulated analyzing power allows to **benchmark** the GEANT4 physics packages

- **Agreement** between simulation and measurement is best for **central** crystal; outer crystals demonstrate greatest **difference** at **largest** energies

- Beam position was unknown during the experiment, thus simulation could not reproduce exact conditions



● Measured e- analyzing power ○ Simulated e- analyzing power

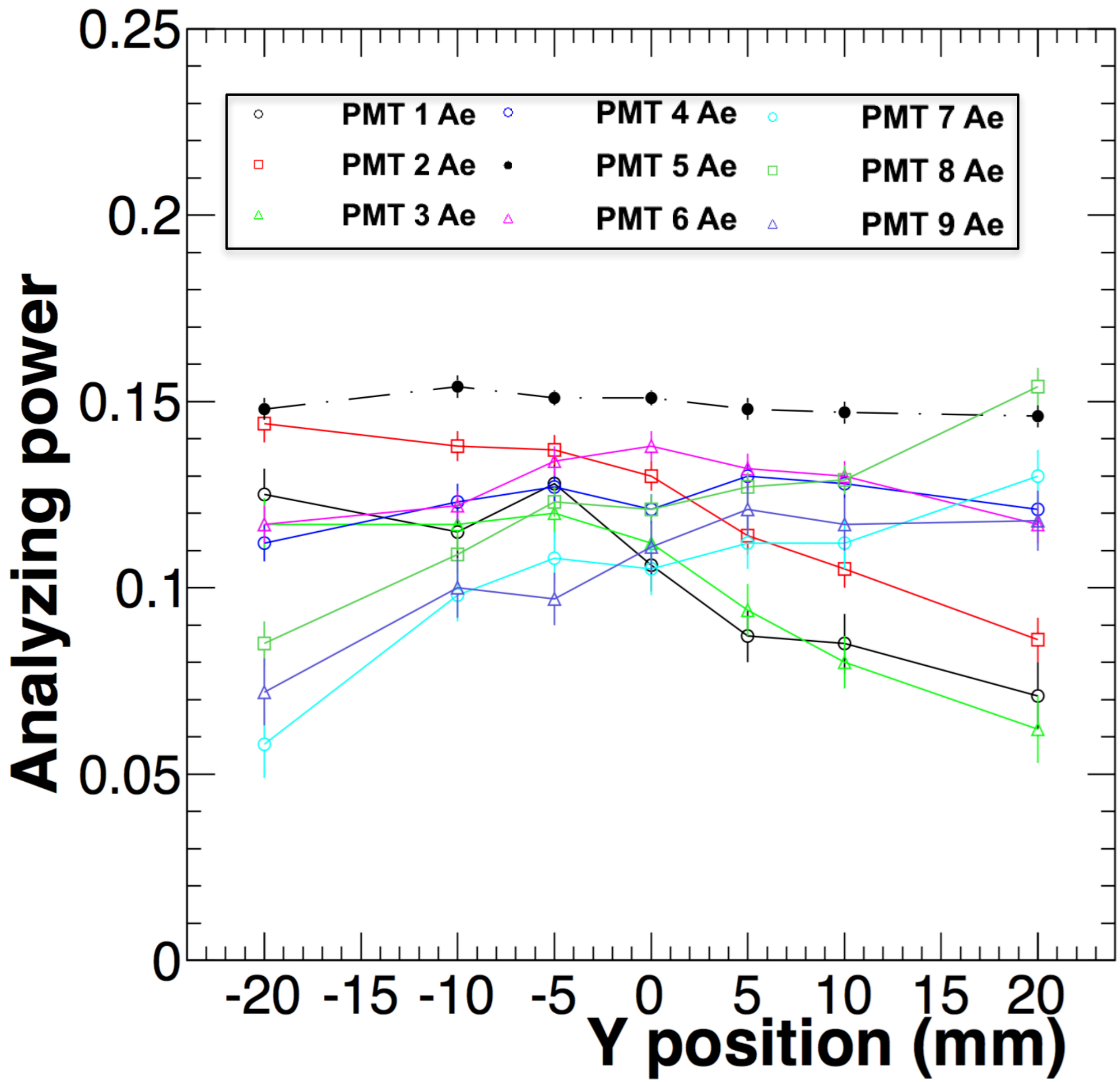
Beam position sensitivity

Simulation of 5.34MeV/c pencil beam e^- beam

7	8	9
4	5	6
1	2	3

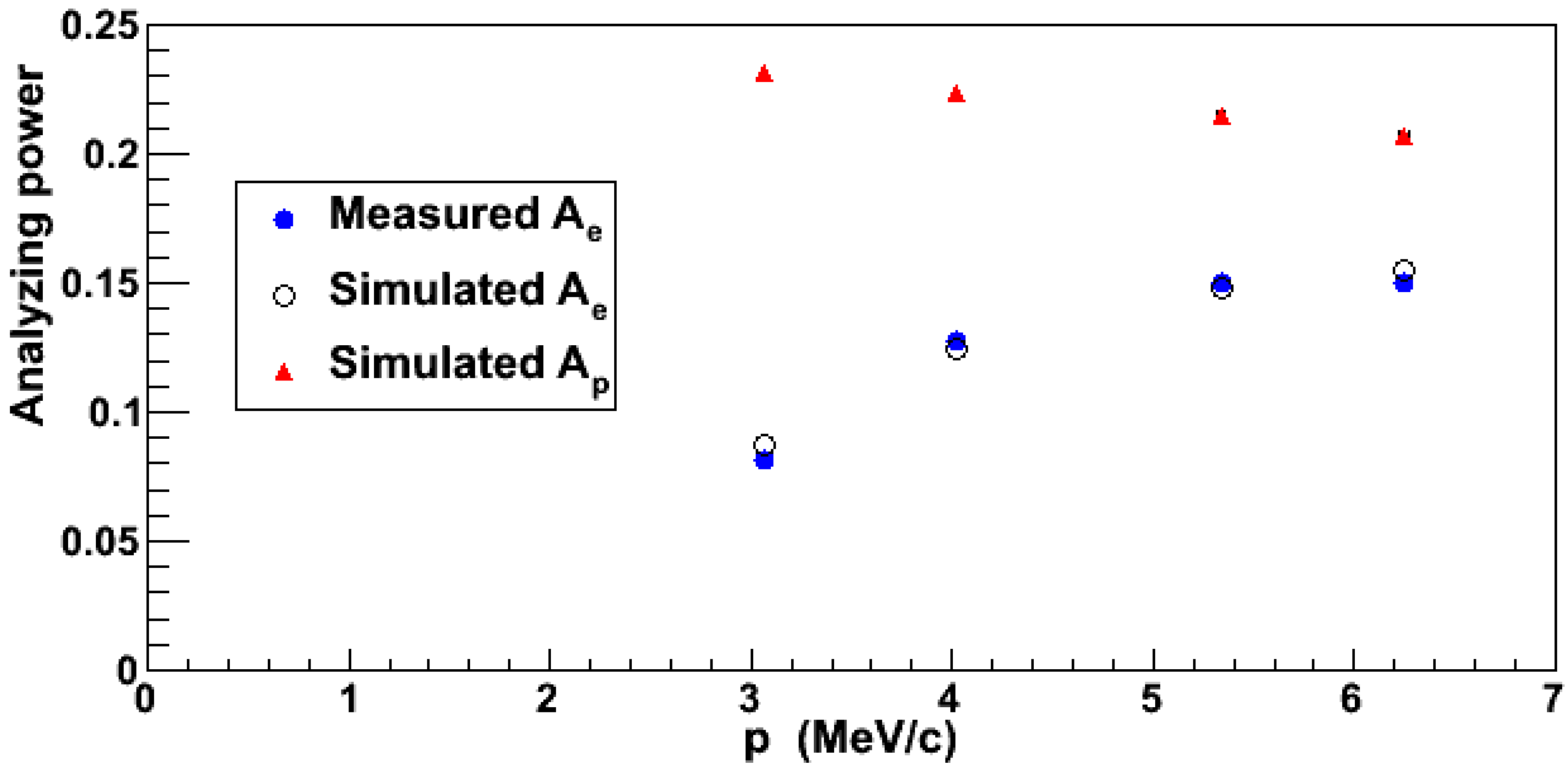
Simulating the analyzing power at **different positions** along the Y axis (fixed along X axis) **reveals** a **sensitivity** to beam position

While the analyzing power for the **central** crystal remain **steady** throughout the scan, the values **for other crystals varies** depending on the **position** of the **beam**



Simulated Positron Analyzing power

GEANT4 simulations allow to link the **measured electron** analyzing power to the **expected positron analyzing power** of the **PEPPo** Compton transmission polarimeter.



Summary

- The electron beam was used to study and calibrate the Compton transmission polarimeter analyzing power.

- Geant4 simulation of the central crystal agreed very well with measurements.

- Sensitivity of outer crystals in simulation may explain difference between measurement and model.

- The positron analyzing power was obtained directly from the simulation of the central crystal.

PEPPo Collaboration

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