7th Workshop on Polarized Positrons

POSIPOL 2012

4–6 September 2012, DESY, Zeuthen

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Conference topics:

- Generation of polarized positron beams
- High intensity positron sources
- Positron generation target issues
- Physics applications of polarized positrons
- Polarized gamma ray generation
- Channeling radiation and applications
- Physics applications of high quality X-rays and gamma-rays

Contact

The PEPPo e^- & e^+ polarization measurements

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On behalf of the PEPPo collaboration

POSIPOL 2012

Zeuthen 4-6 September

LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

Jefferson Lab
Thomas Jefferson National Accelerator Facility

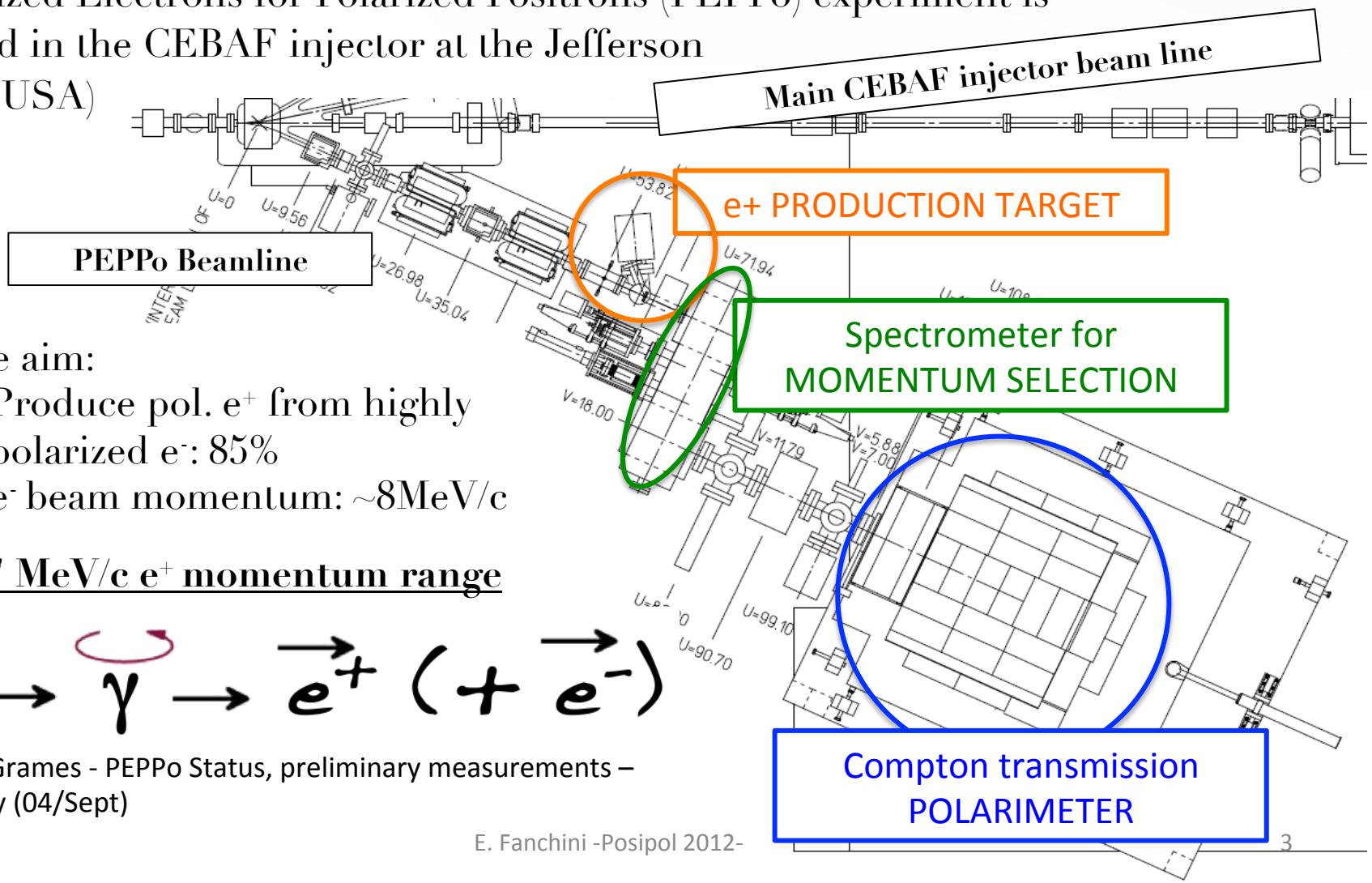
Université Joseph Fourier
Sciences Technologie Medecine

Outline

- ✧ The PEPPo experiment
- ✧ Polarization measurements with electrons and positrons
- ✧ The Compton transmission polarimeter
- ✧ PEPPo DAQ & data taking conditions
- ✧ Electron measurements
- ✧ Positron measurements
- ✧ Summary

The PEPPo experiment

Polarized Electrons for Polarized Positrons (PEPPo) experiment is placed in the CEBAF injector at the Jefferson Lab. (USA)



The aim:

- Produce pol. e^+ from highly polarized e^-: 85%
- e^- beam momentum: ~8MeV/c

3-7 MeV/c e^+ momentum range

$$\vec{e^-} \rightarrow \gamma \rightarrow \vec{e^+} (+ \vec{e^-})$$

Talk: J.Grames - PEPPo Status, preliminary measurements – Tuesday (04/Sept)

Compton polarization

Positron polarization is obtained with a 2-step analysis obtained with independent measurements:

Electron and Positron measurements

Physics processes:

- *Bremsstrahlung:* conversion of longitudinally polarized $e^{-/+}$ into polarized photons in the reconversion target
- *Compton:* transmission of polarized photons through a magnetized iron core

Detection: *Compton calorimeter*

The Compton absorption cross section:

Unpolarized Compton cross section

$$\frac{d^2\sigma}{d\theta d\phi} = \frac{d^2\sigma^0}{d\theta d\phi}\left[1 + P_3\, P_t A_3\right]$$

P_t Target polarization
P_3 longitudinally polarization contrib.
A_3 Analyzing power of the Compton scattering

Asymmetry

The Compton absorption is obtained counting the number of transmitted photons for opposite beam helicities ($N^{+/-}$) or polarized target orientations:

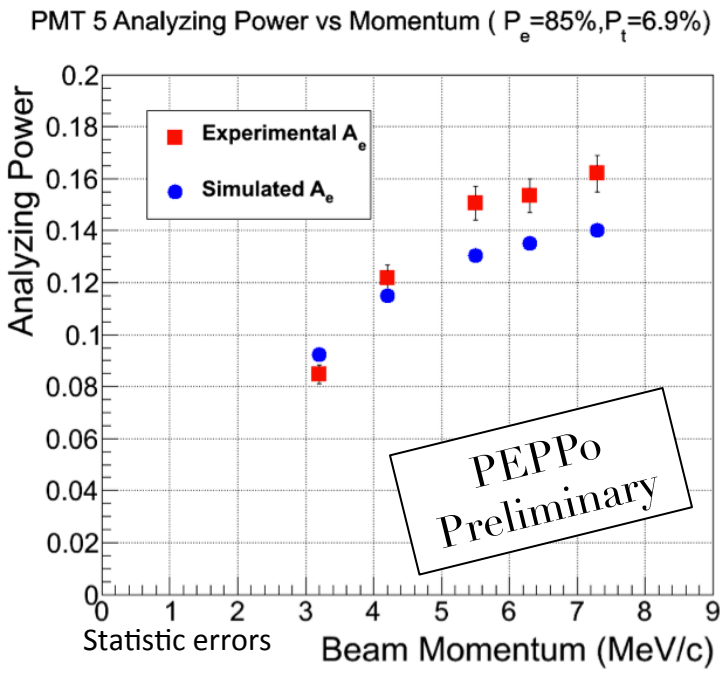
$$A_T = \frac{N^+ - N^-}{N^+ + N^-} = \tanh(-P_3\, P_t \mu_1 L)$$

μ1 Compton absorption coefficient
L target length

Experimentally:

$$A_T = P_e P_t A_e$$

P_e: polarization of the electron
P_t: polarization of the target
A_e: analyzing power of the polarimeter

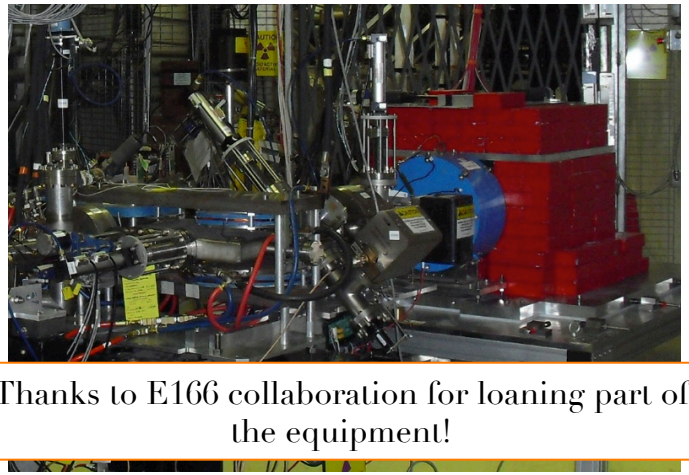


- Measurement with an e^- beam
- P_e beam pol. well known
- P_t of the target known

- Validation of the simulation
- Extraction of the A_e (e^- mode)

A.P. used for positron measurements

Compton transmission polarimeter

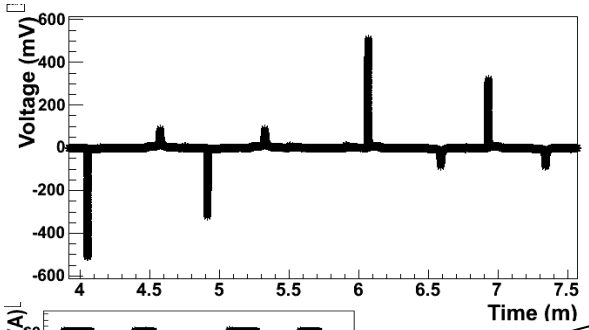


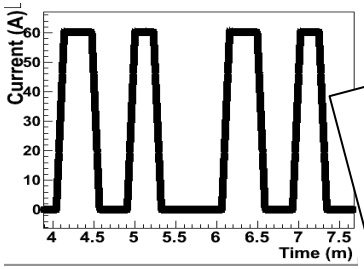
Thanks to E166 collaboration for loaning part of the equipment!

It determines the polarization of the $e^{+/-}$ beam by measuring the asymmetry of polarized photon absorption in a longitudinally polarized target

Polarization measurements obtained by reversing:

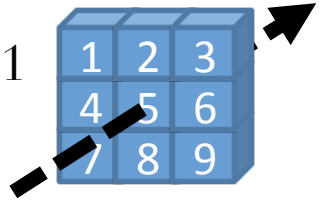
- Analyzing magnet polarization
- Beam polarization





Cycling procedure for systematic study of the magnetization

- **Reconversion target:** 2mm tungsten
- **Analyzing magnet:** 7.5cm iron with 7% polarization, working @$\pm$60A (saturation)
- **Photon detection:** 9 CsI crystals (28 cm long and 6 cm square sides) with optimized PMT readout chain
- **Charge particles selection** (TS1): 1 scintillator for e+ measurements

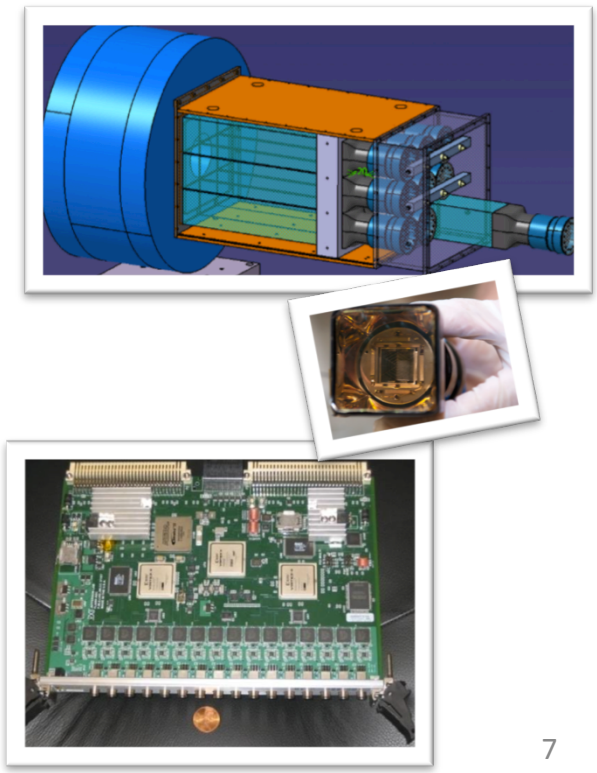


PEPPo DAQ

The signal from the crystal is a long (slightly larger that 2μs) and optimized pulse to have a maximum amplitude smaller than 2V.

The signal detection was done with a FlashADC board chosen to be compatible with the PMT signals and developed by the JLab electronic group

- 250 MHz sampling frequency of the detector ADC signals
- 2μs maximum read-out length
- 0->-2V maximum signal range



The advantage was the FADC versatility that allowed the 3 PEPPo data taking configurations :

- **Sample mode:** shape signal reconstruction with up to 500 samples per event (4ns resolution). Used for calibration measurements
- **Semi-Integrated mode (e^+):** 1 integral signal value per detector triggered event
- **Integrated mode (e^-):** 1 integral value per helicity gate

Data taking conditions

Electron measurement

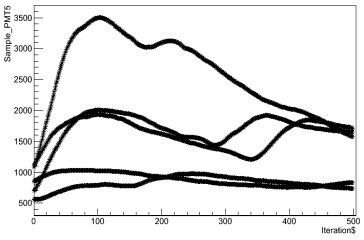
Mom (MeV/c)	Mode	Set	e⁻ beam current @T1	Det.Rate (kHz)	Target (mm)
3.2	e-	1	60pA	112	
4.2	e-	1	23pA	184	
5.5	e-	1	25pA	202	
6.3	e-	1	10pA	471	
7.3	e-	1	10pA	164	

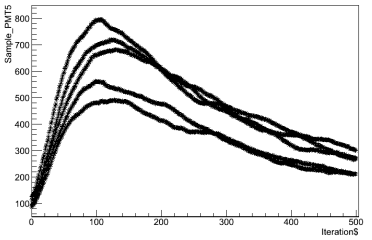
Positron measurement

Mom (MeV/c)	Mode	Set	Ie⁻ beam @T1	Det.Rate (kHz)	Target (mm)
3.2	e+	1	380nA	9	1
4.2	e+	1	25nA	7	1
5.5	e+	1	95nA	2	1
6.3	e+	1	380nA	8	1
3.2	e+	2	120nA	2	1
3.2	e+	2	380nA	3	0.1
4.2	e+	2	130nA	2	1
5.5	e+	2	200nA	3	1
6.3	e+	2	620nA	6	1

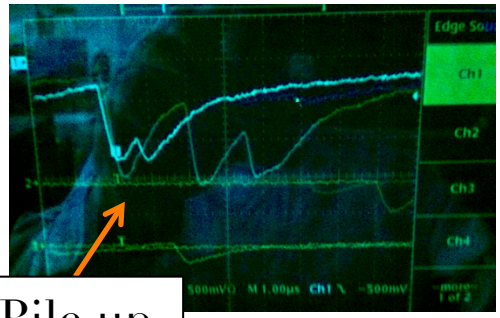
Same conditions
IHWP: IN
AM: -60A

FADC
Sum of few signals





Oscilloscope

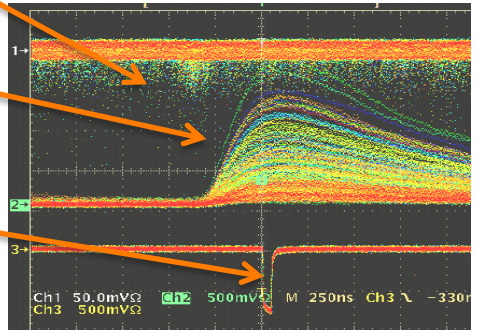


Pile up

TS1

$\overline{PMT5}$

Coincidence trigger



e- measurements

High rate measurements (@6.3MeV/c => ~500kHz rate).
Sample and Semi-Integrated mode neglected due to high dead time

Important aspect to consider: asymmetry measurement obtained by counting the number of transmitted photons

$$A_T = \frac{E^+ - E^-}{E^+ + E^-} = \frac{\sum_i E_i^+ - \sum_i E_i^-}{\sum_i E_i^+ - \sum_i E_i^-}$$

$$E_i^{\pm} = N_e^i \sum_j \varepsilon_j^{\pm} e_j$$

Integrated method

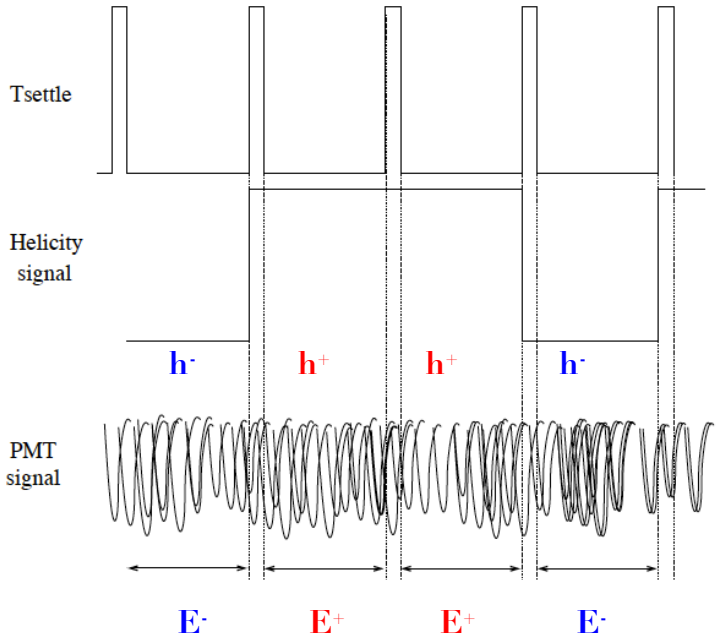
$E^{+/-}$: energy deposited per helicity state

N_e^i: N. of particles in a given time range

ε_j: Probability to produce and detect a photon of energy e_j

Detector signal integration during each helicity gate

Integrated mode

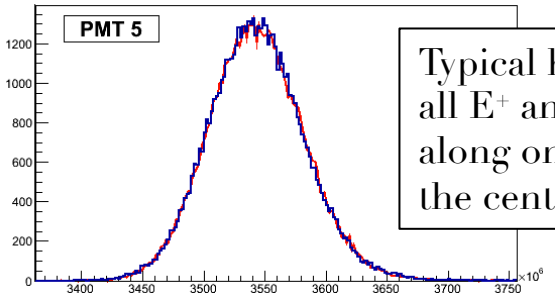


New FADC firmware developed by JLab for PEPPo

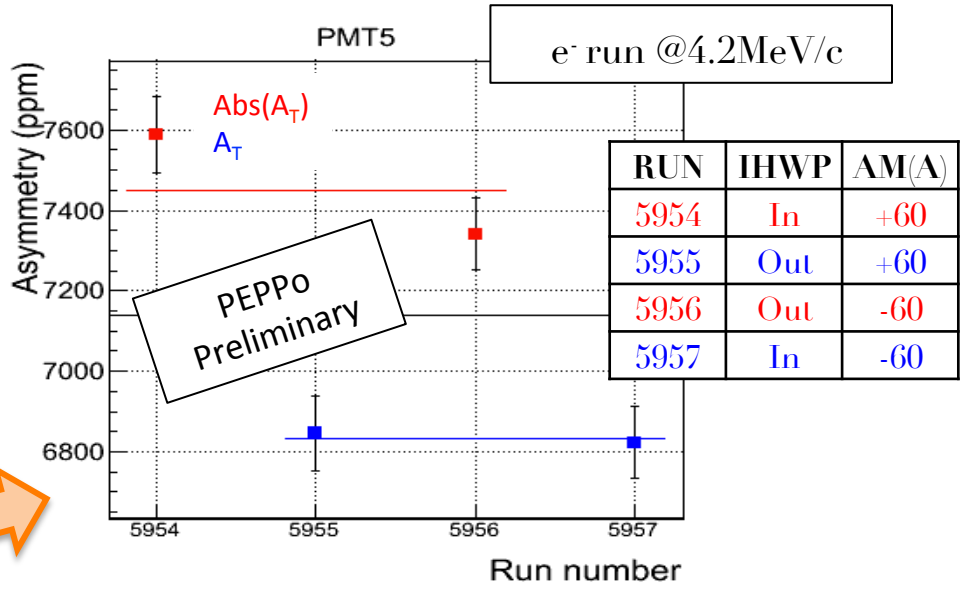
Setting used:

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

Sum over all the samples for ONE helicity gate



Typical histogram of all E^+ and E^- values along one e^- run for the central PMT



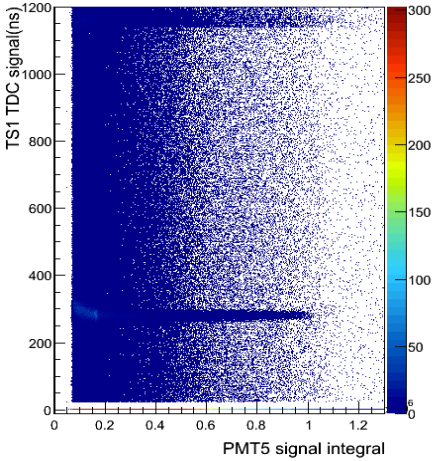
RUN	IHWP	AM(A)
5954	In	+60
5955	Out	+60
5956	Out	-60
5957	In	-60

e+ measurements

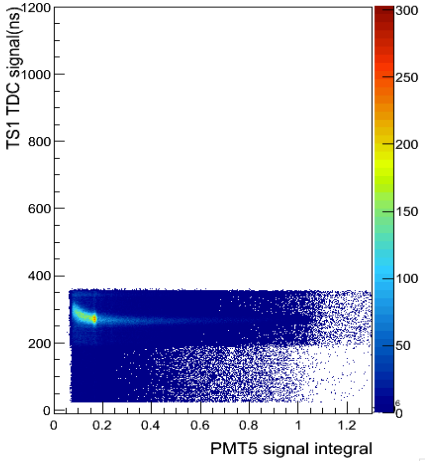
During the commissioning phase and the first week of data taking we learned how a better background reduction was important

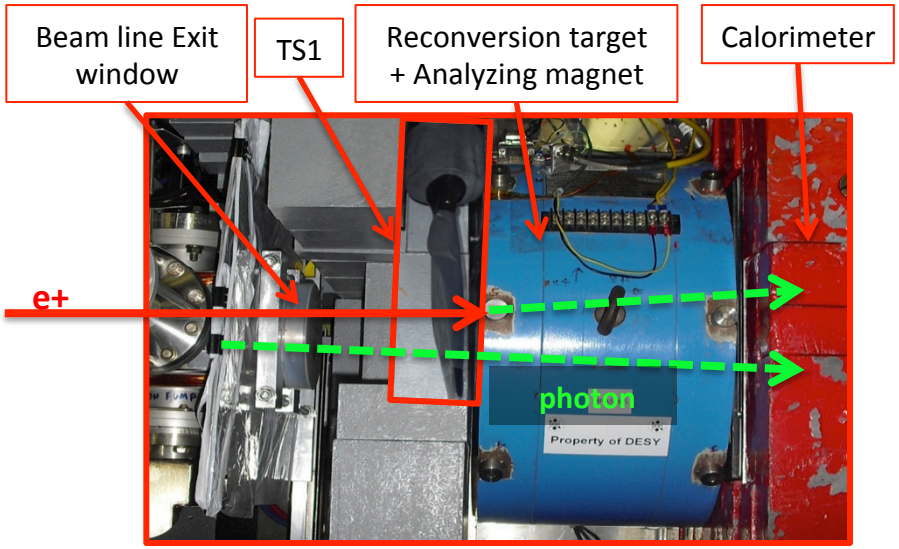
Data taking configuration obtained with the signal coincidence between a scintillator (TS1) and the signal of the central crystal (PMT5) of the calorimeter

e+ run with NO coincidence trigger



e+ run with TS1/PMT5 coincidence trigger

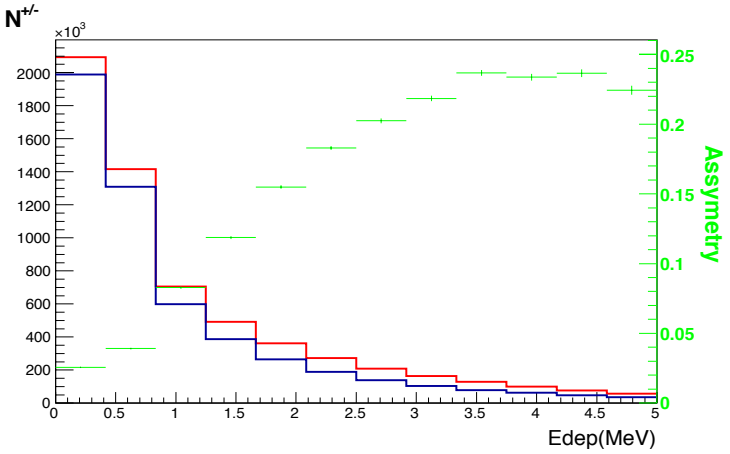




Semi-Integrated mode

Positrons are secondary particles generated by the main e^- beam hitting a tungsten target => Detection Rate drop (e^+ rate of the central crystal ~6kHz of 6.3MeV/c)

Semi-Integrated method: integral value of each triggered detector signal and asymmetry calculation as a function of energy



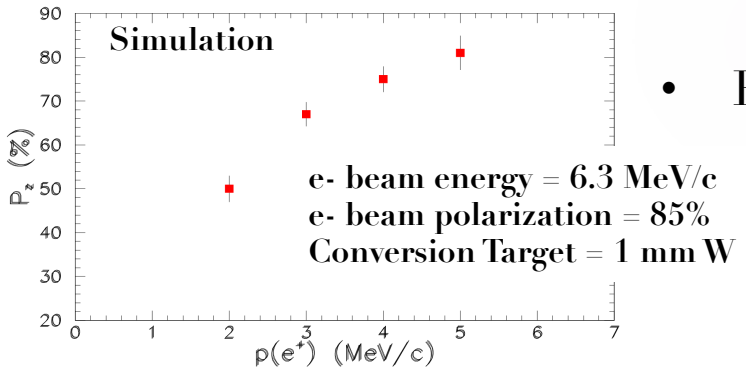
Simulated Energy spectra of a positron beam of 5MeV at the reconversion target, with opposite helicities (considering $P_T = P_{e^+} = 100\%$)

$$A_T^j = \frac{n_j^+ - n_j^-}{n_j^+ + n_j^-} = \left[\sum_i n_{ij}^+ - \sum_i n_{ij}^-\right] / \left[\sum_i n_{ij}^+ - \sum_i n_{ij}^-\right]$$

n^+_j and n^-_j: number of events for the energy bin j for different helicity status (+/-)

Energy distribution deposited for each helicity state and experimental asymmetry is built for each energy bin (A^j_T)

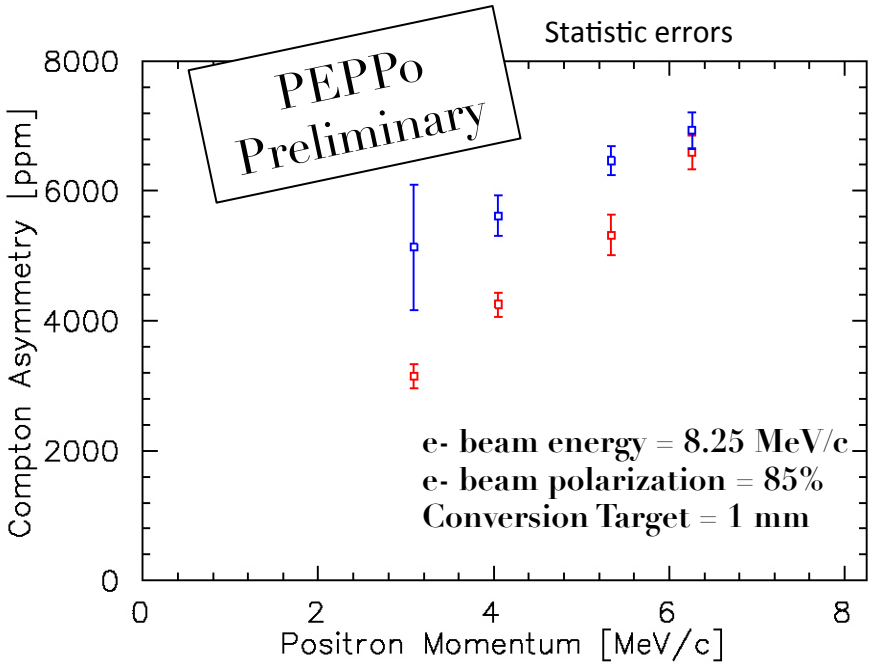
e+ asymmetries



- From the PEPPo proposal:
  - 4 momenta points for e-
  - 4 momenta points for e+ with 2 target production thickness (1.0 mm & 0.1mm)

After 5 weeks of data taking:

- 5 momenta points for e-
- 2 set at 4 momenta for e+ with 1.0mm target
- 1 momentum point for e+ with 0.1mm target



Online positron asymmetry calculation similar to the integrated mode

Data Set 1: Preliminary e+ collection momentum scan

Data Set 2

- Improved shielding of polarized background
- Improved stability of spectrometer
- Improved coincidence timing signal

Summary

Large (parts per thousand) asymmetries are observed suggesting the presence of polarized positrons

Good trend shown as a function of the momentum selection

All the preliminary results come from the online monitoring system and online fast analysis which drove us along all the data taking period

Preliminary results are encouraging

After a good data taking period the full analysis is now ongoing…
And we are finalizing the full GEANT4 simulation