Update on the Polarized Electrons for Polarized Positrons (PEPPo) Experiment

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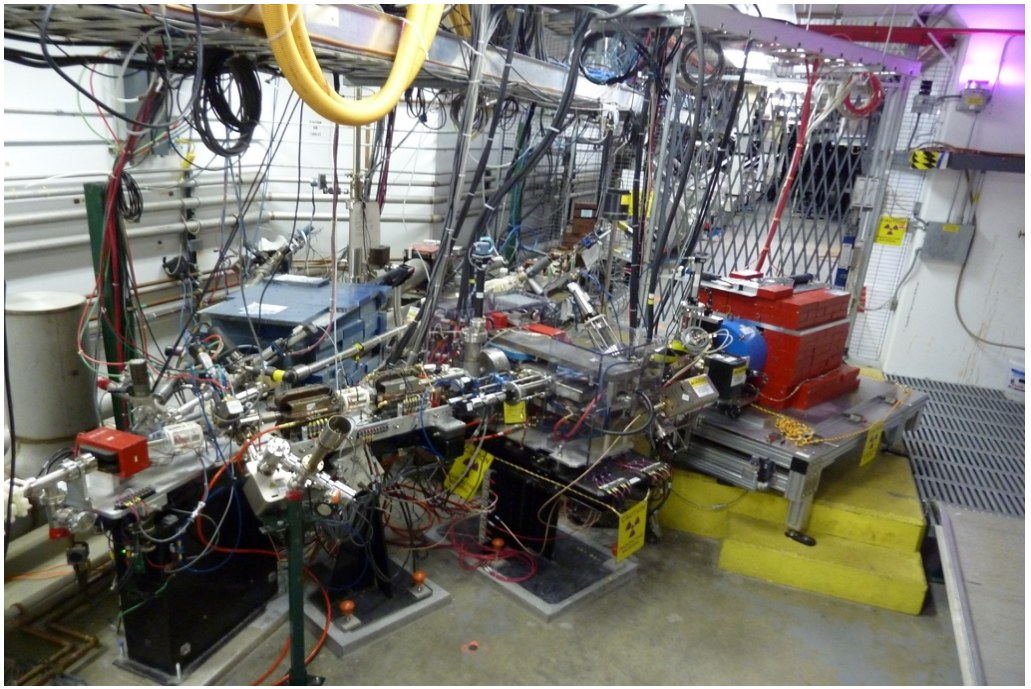
The PEPPo Concept

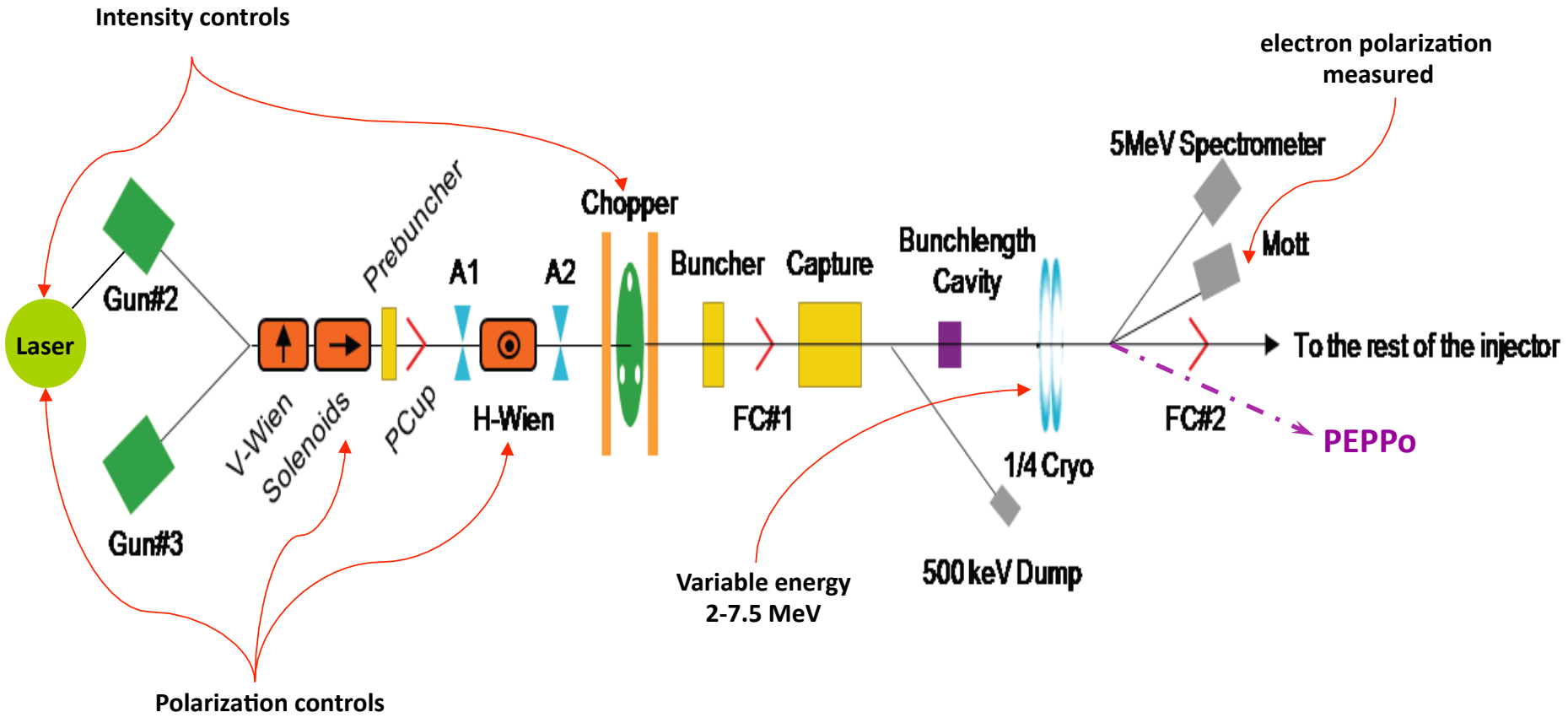
- The PEPPo experiment was conducted in the injector of the CEBAF accelerator at JLab to demonstrate a new technique for the production of polarized positrons.



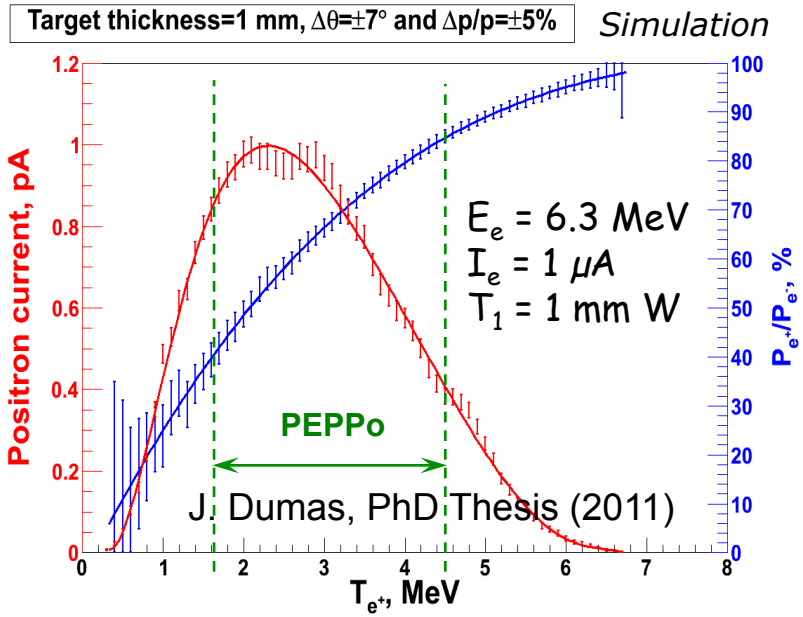
- It involves a two-step processes :
  - Creation of circularly polarized photons from the bremsstrahlung interaction of longitudinally polarized electrons in a target
  - Followed by the creation of polarized e+e- pairs via the pair production from the photons, within the same target.

JLab CEBAF

PEPPo took advantage of the existing experimental capabilities that uniquely define with precision the CEBAF polarized electron beam at creation.

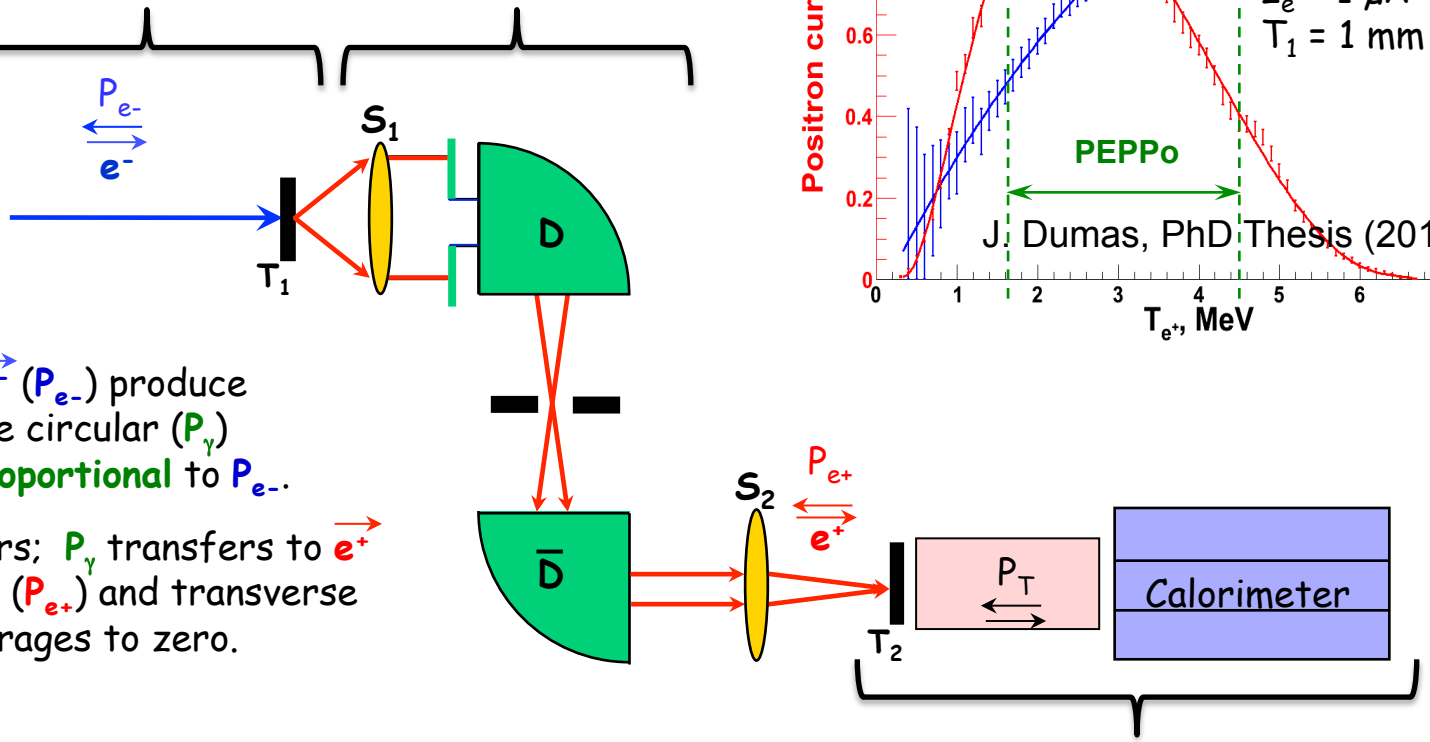


Principle of Operation



Polarized Electrons (<10 MeV) strike production target

Positron Transverse and Momentum Phase Space Selection

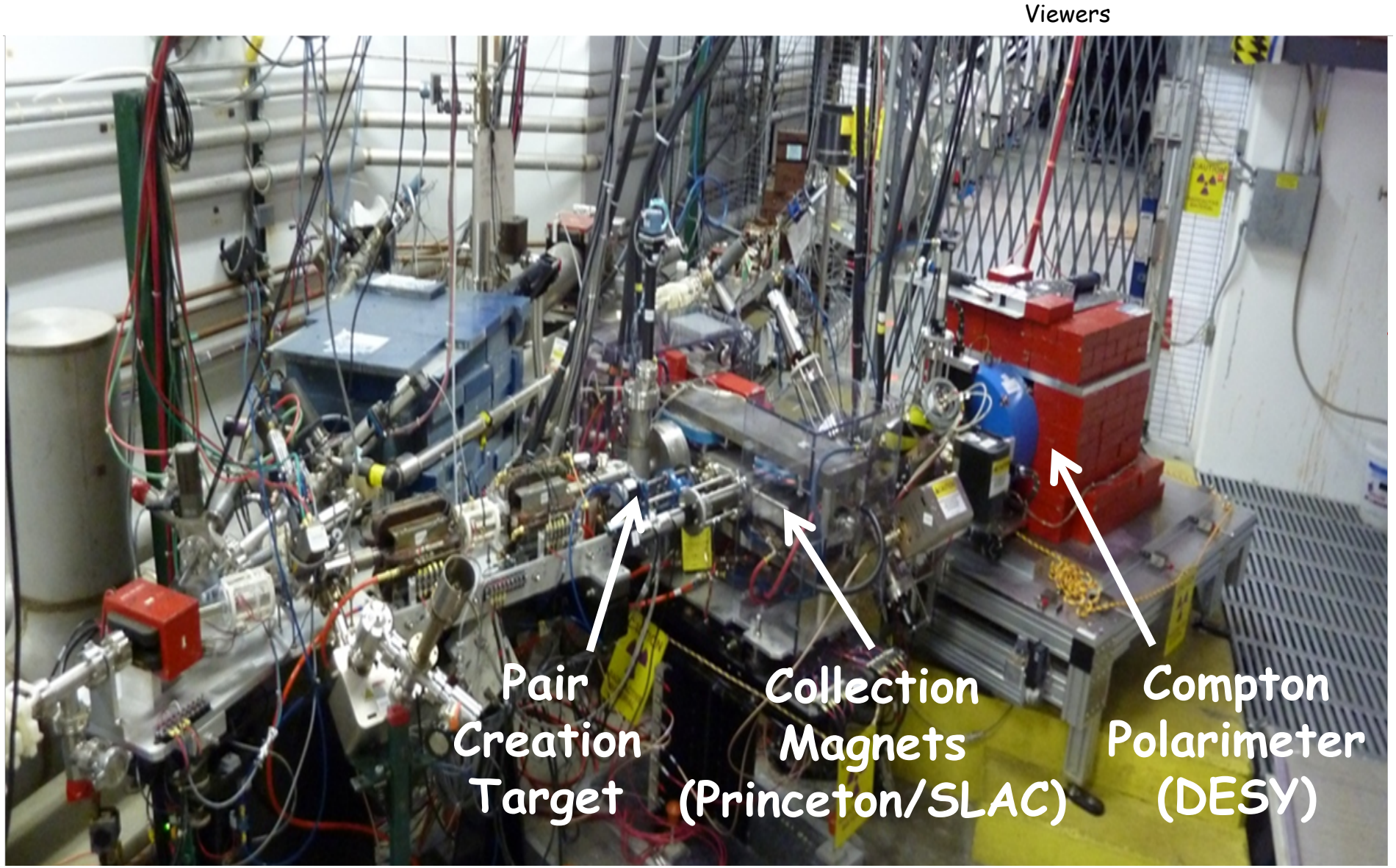


Compton Transmission Polarimeter

- Longitudinal $\vec{e^-}$ (P_{e^-}) produce elliptical γ whose circular (P_γ) component is **proportional** to P_{e^-}.
- γ produces pairs; P_γ transfers to $\vec{e^+}$ into longitudinal (P_{e^+}) and transverse polarization averages to zero.

PEPPo measured the **polarization transfer** from **8.2 MeV/c longitudinal electrons** to longitudinal positrons in the **3.1-6.2 MeV/c momentum range.**

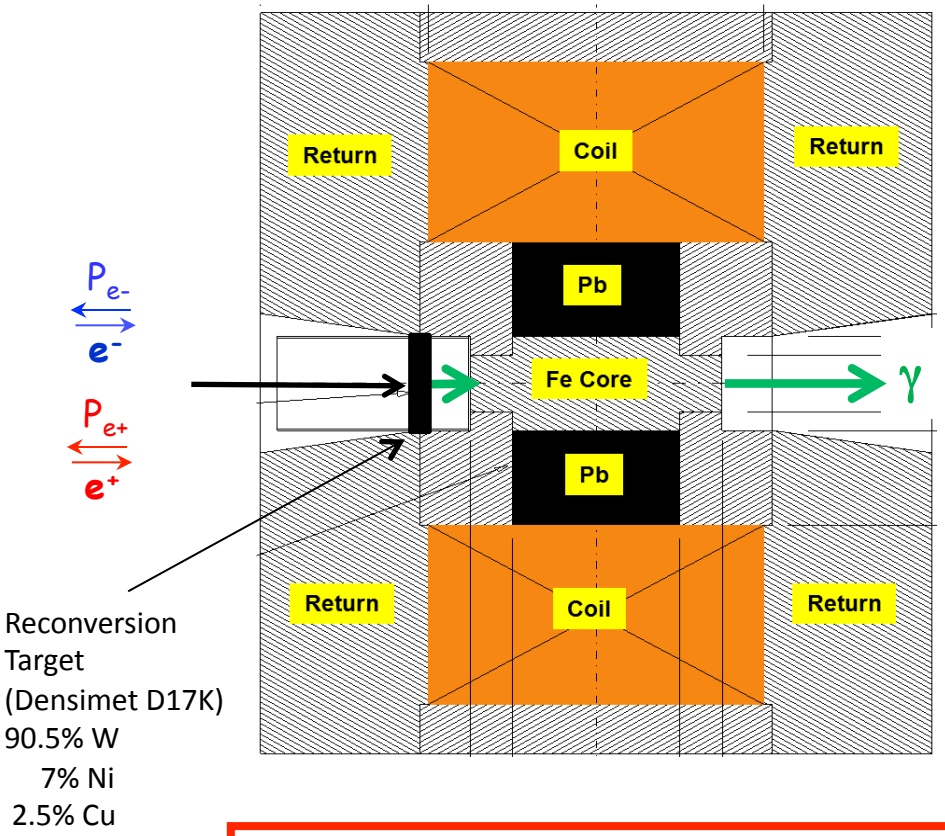
Experiment Layout



Compton Transmission Polarimeter

Electrons or **Positrons** radiate **polarized photons** by Bremsstrahlung in reconversion target

Energy dependent Compton scattering of **photons transmitted** through **polarized target** is proportional to polarization of incoming **Electrons** or **Positrons** (aligned or anti-aligned).



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

μ1 - Compton absorption coefficient
L - target length
P_3 - photon polarization (long.)

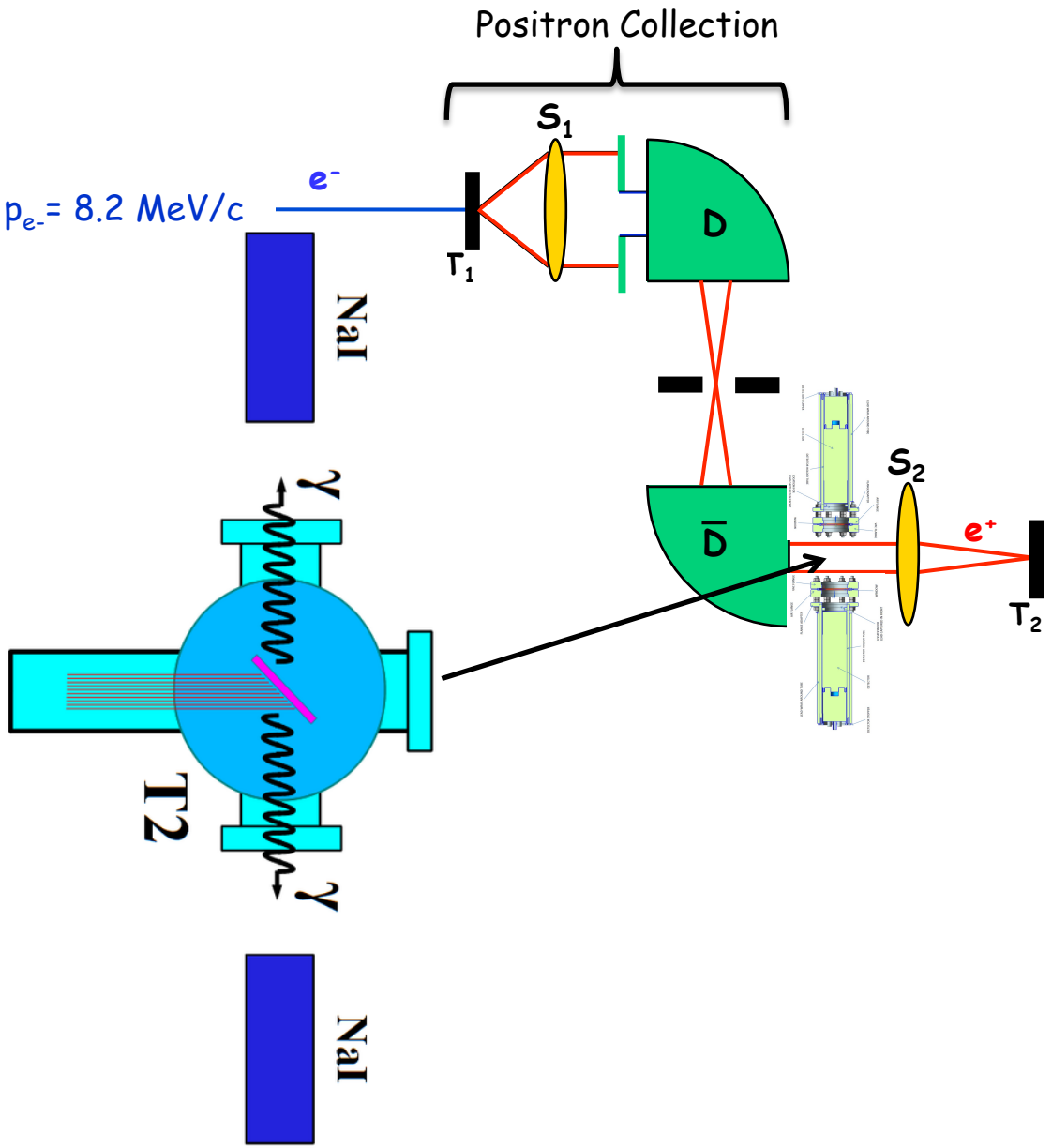
$$A_T = P_e P_T A_e$$

P_e - electron/positron polarization
P_T - target polarization
A_e - analyzing power

Bremmstrahlung photon spectrum requires energy-dependent analyses

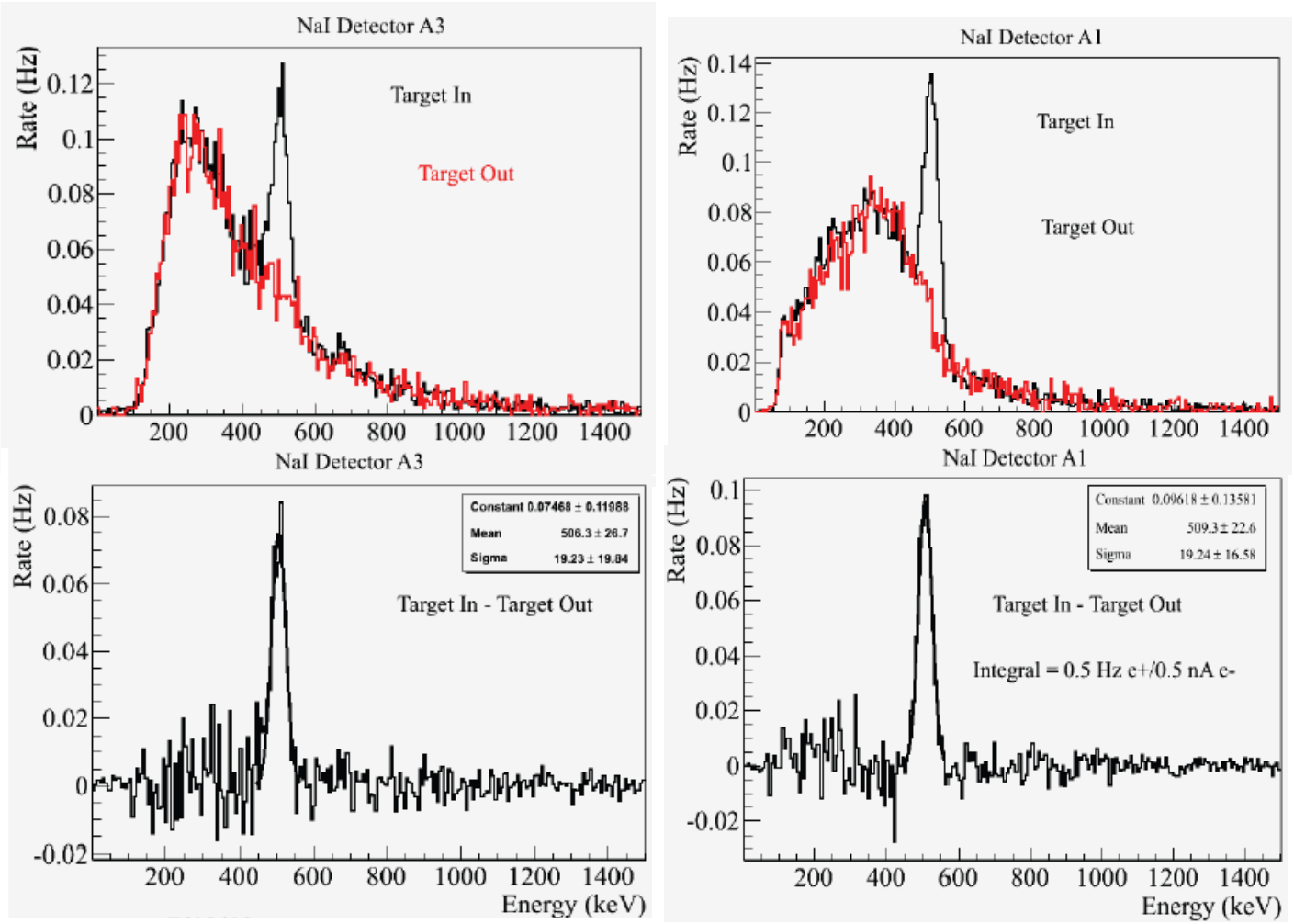
- Energy binning
- Energy integration

Positron Detection



The positrons produced in the PEPPo experiment are detected using a set of two annihilation counters. The positrons stopped in an insertable 0.011" chromox target and the corresponding 511keV photons detected in coincidence with two NaI detectors.

Coincidence Signal and Positron "Beam" Yield



Detected e+ rate (1 e^+ per 10^{10} e^-)
Solid Angle (0.1 sr)
GEANT annihilation probability (1/400)
Coincidence detector efficiency (0.49 @ 511keV)

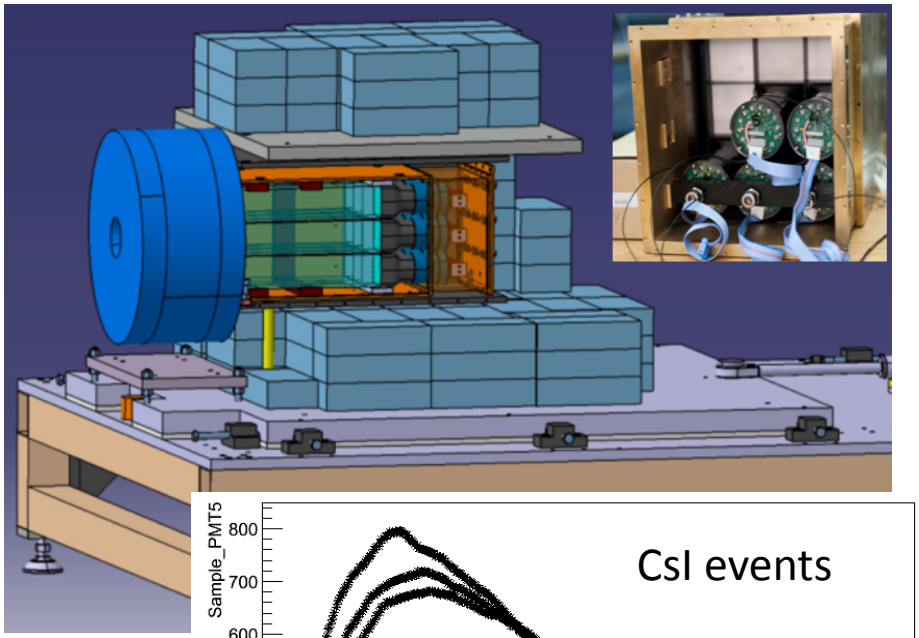
1 e^+ per 10^6 e^-
(consistent with proposal)

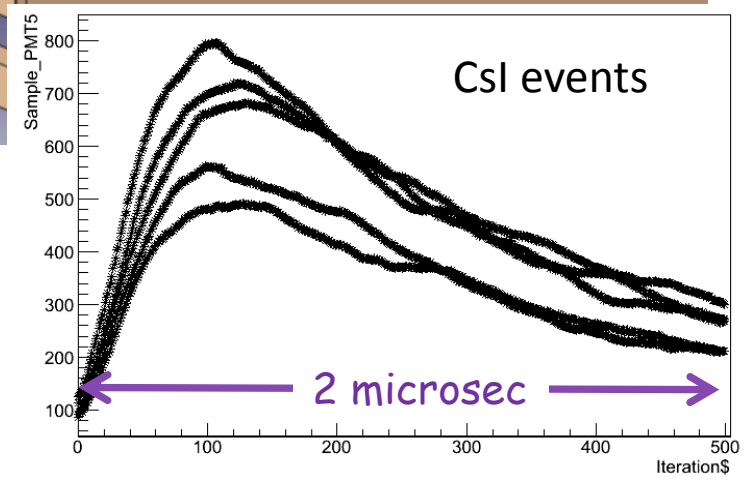
Photon Calorimeter and DAQ

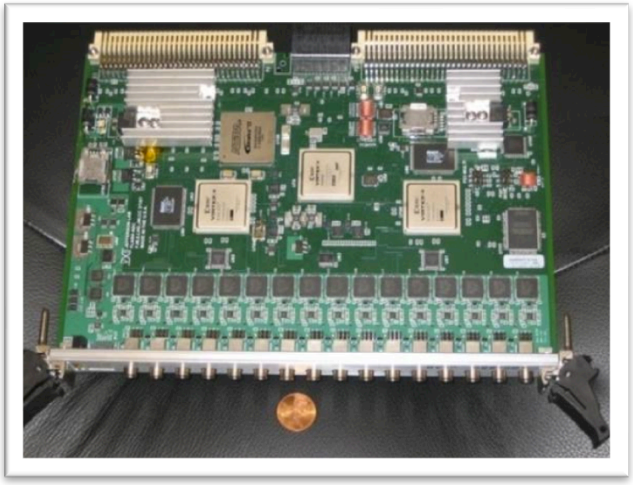
- **CsI(Tl) crystals (28cm)** are coupled to **PMTs** equipped with LPSC custom amplified basis to extend the **PMT life-time** in the high rate environment of PEPPo.

- The **~2 μs** long and **2 V** optimized signal is fed into the JLab custom **FADC250** that sampled the signal at **250 MHz**.

Hamamatsu R6236-100



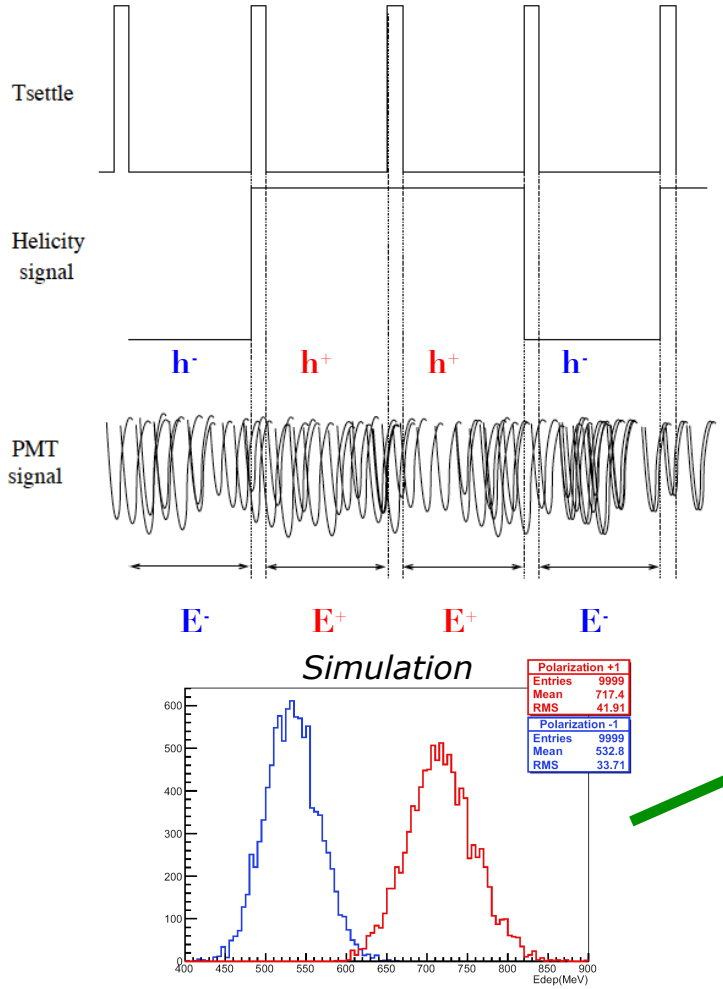




FADC250 allows for 3 data taking modes :

- **Sample** (**500 samples** /2 micro-sec)
- **Semi-integrated** (**1 integral** / 2 micro-sec)
- **Integrated** (**1 integral** /33 milli-sec)

Electron Data Analysis



➢ The **integrated mode** operates for **high rate** conditions by **integration** of the **PMT signal** over the duration of an **helicity gate** (PEPPo firmware devoped by JLab).

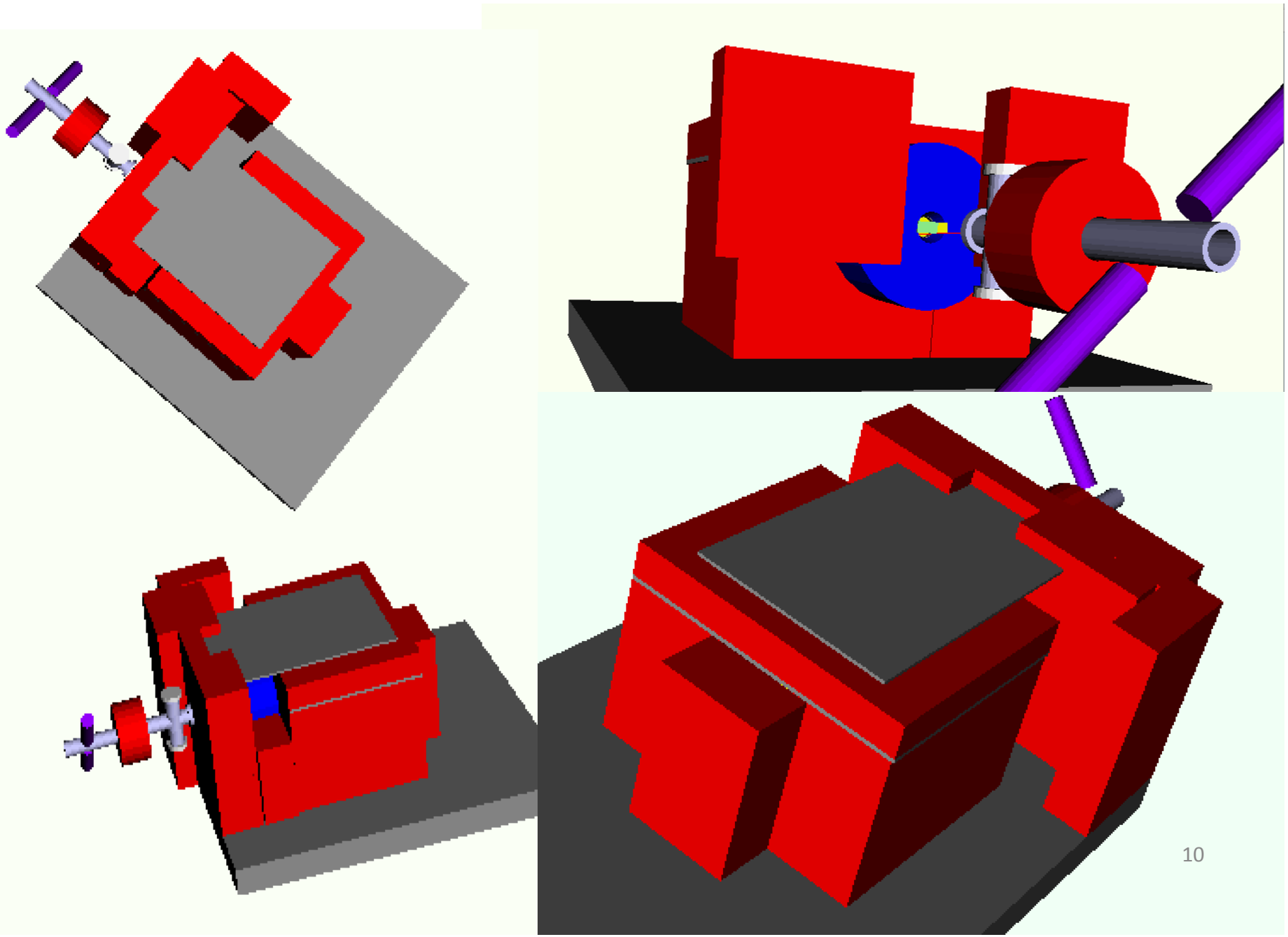
Helicity frequency = **30 Hz**
Helicity delay = **8 windows**
Helicity pattern = quartet (**+−−+** or **−++−**)

$$A_T = \frac{E^+ - E^-}{E^+ + E^-} = \frac{\sum_i E_i^+ - \sum_i E_i^-}{\sum_i E_i^+ + \sum_i E_i^-} = P_{e^\pm} P_T A_{e^\pm}$$

Analysis:

- ✓ Cuts on beam trips
- ✓ Pedestal subtraction for beam energy and PMT HV
- ✓ Asymmetry calculations (global, false)

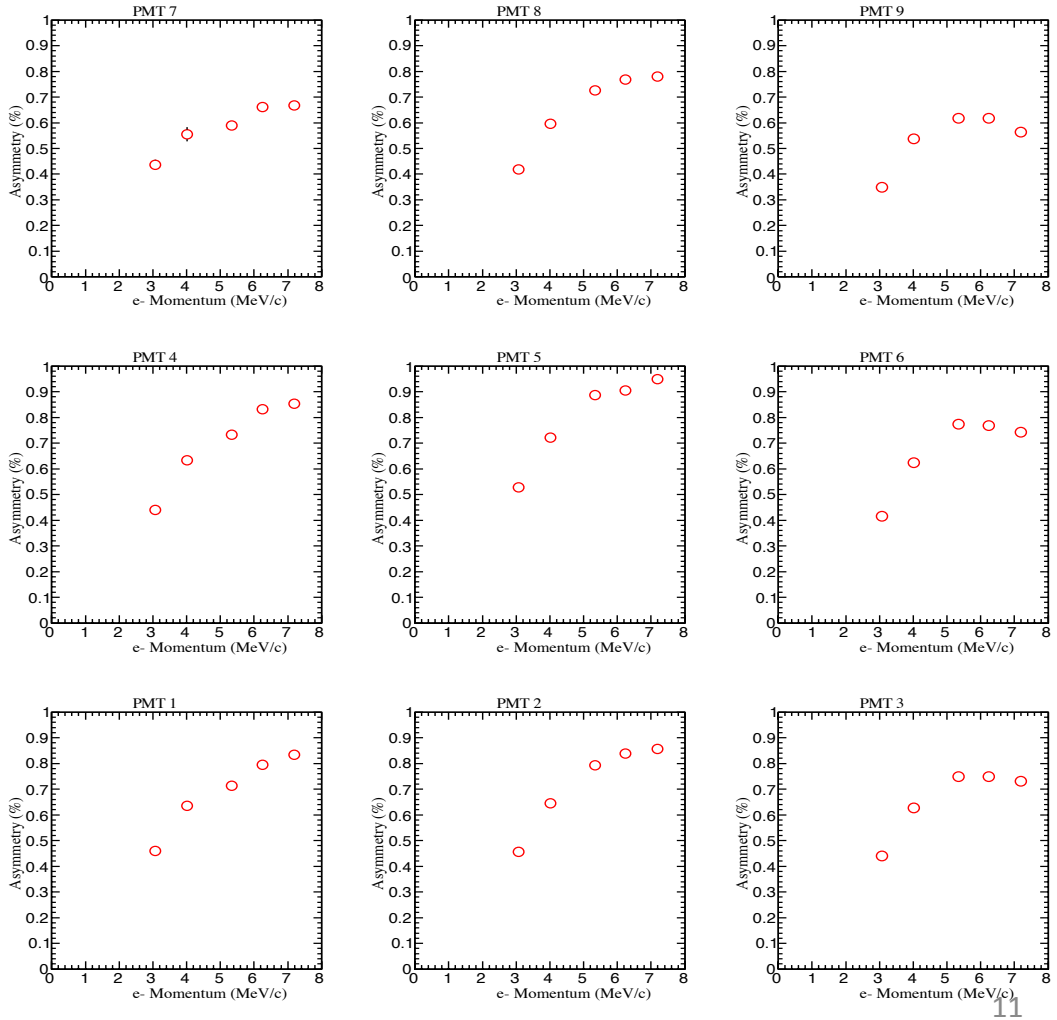
G4PEPPo



Asymmetry measurements

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

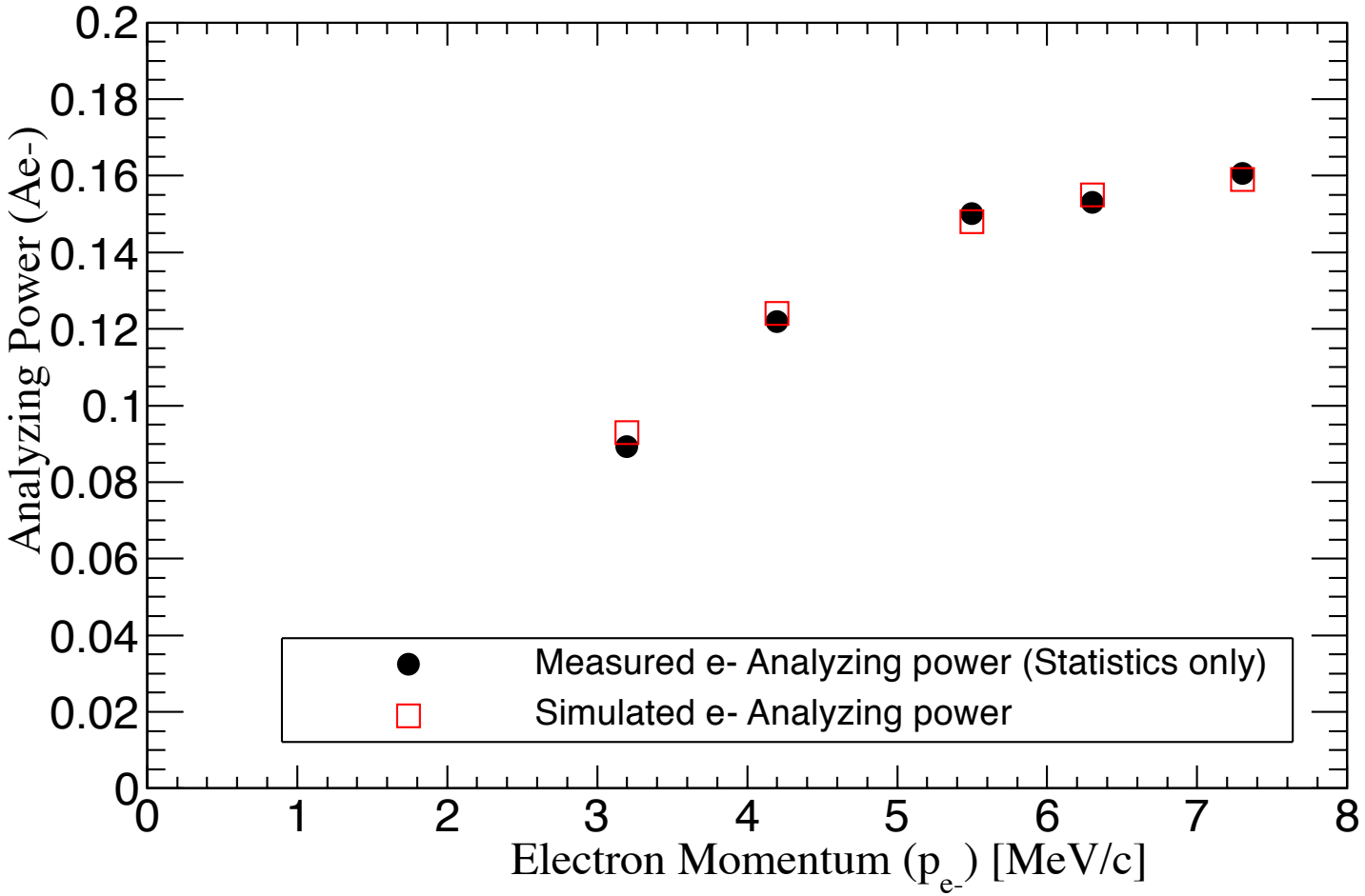
P_{e^-} (MeV/c)	Mode	I_{e^-} @ T2
3.08	Int.	60 pA
4.02	Int.	23 pA
5.34	Int.	25 pA
6.25	Int.	10 pA
7.19	Int.	10 pA



Electron Analyzing power

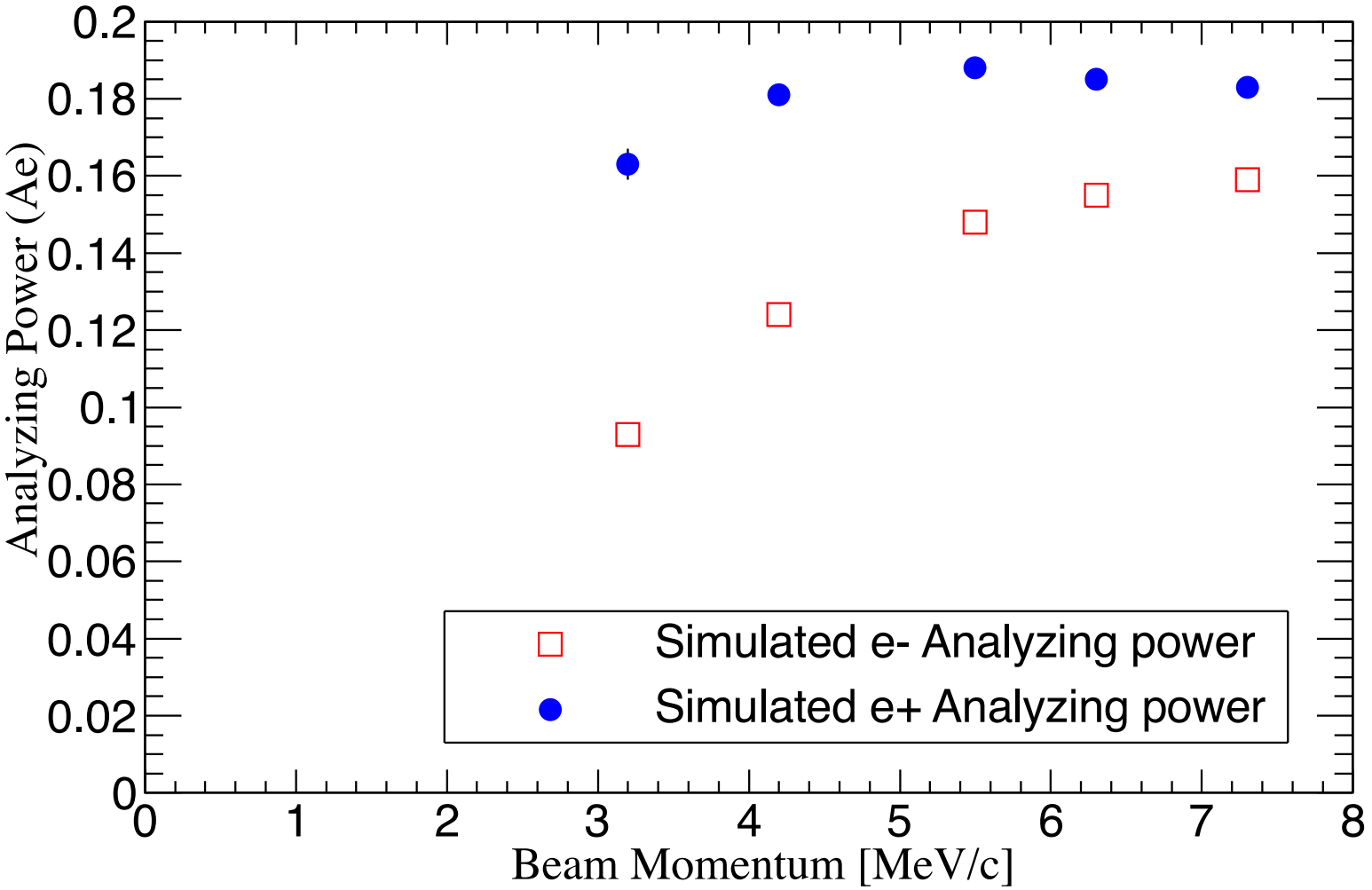
The calibration of the analyzing power for the PEPPo experiment relies on electron experimental data and the positron analyzing power is obtained directly from the simulations.

- Electron beam polarization
  $P_{e^-} = 83.7\% \pm 0.6\%_{(stat)} \pm 2.8\%_{(sys)}$
- Target polarization
  $P_T = 7.53\% \pm 0.06\%_{(Opera)} \pm 0.04\%_{(Coil)}$



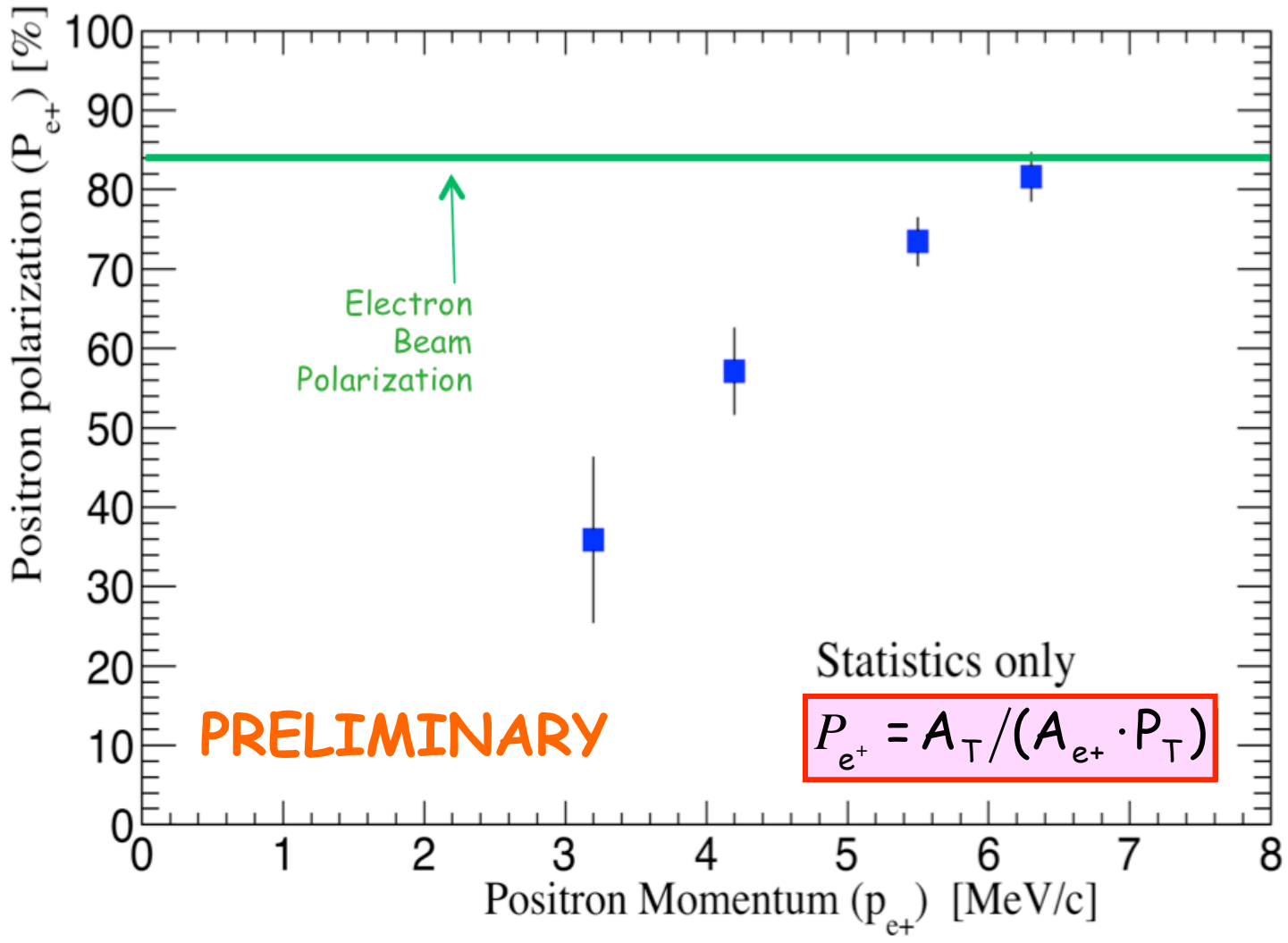
Simulated Analyzing power

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



Positron Polarization

With the measured asymmetry of positrons (A_T) the target polarization (P_T) and the simulated positron analyzing power (Ae+),the positron polarization is calculated.



Conclusion

- Used an 8.2 MeV/c electron beam with polarization 84% to generate positrons by successive polarized bremsstrahlung and polarized pair production in a 1mm tungsten foil.
- Detected and estimated positron yield with an annihilation detector.
- Used a Compton transmission polarimeter and benchmarked a Geant4 model of polarimeter with a known electron polarization in order to calculated the analyzing power for positrons.
- Collected positrons in the range of 3.1-6.2 MeV/c and measured their polarization as high as 80%.