PEPPo

a Proof-of-Principle Experiment

Polarized Electrons for Polarized Positrons

Joe Grames (JLAB) for the PEPPo Collaboration

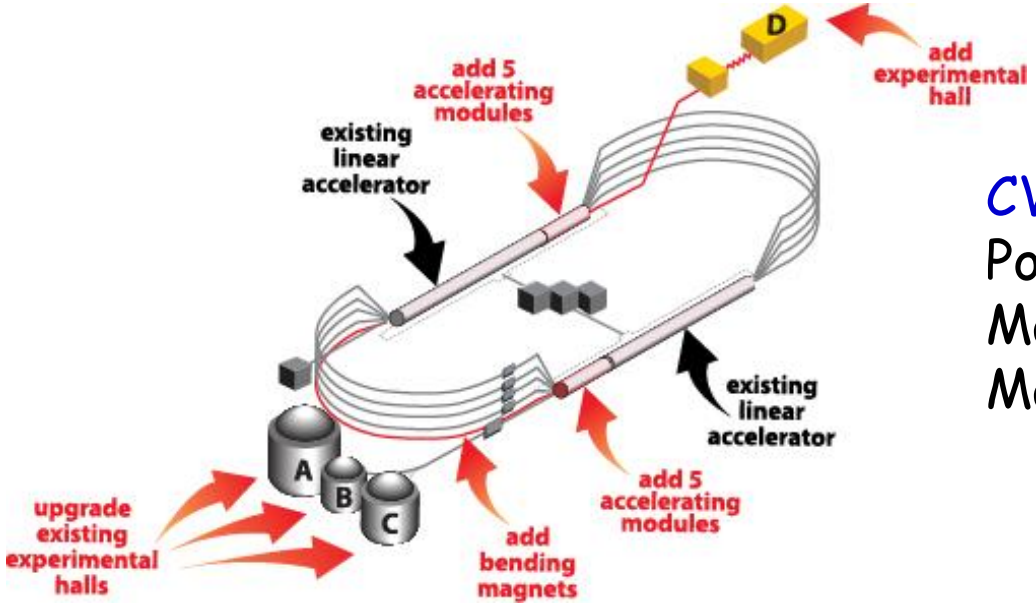
Many thanks for the good advice, equipment loans and funding:

SLAC E-166 Collaboration

International Linear Collider Project

Jefferson Science Association Initiatives Award

Continuous Electron Beam Accelerator Facility



CW Electron beam in all Halls
Polarization: 85-90%
Max Energy: 11GeV(ABC) / 12GeV(D)
Max Current: 200 μA

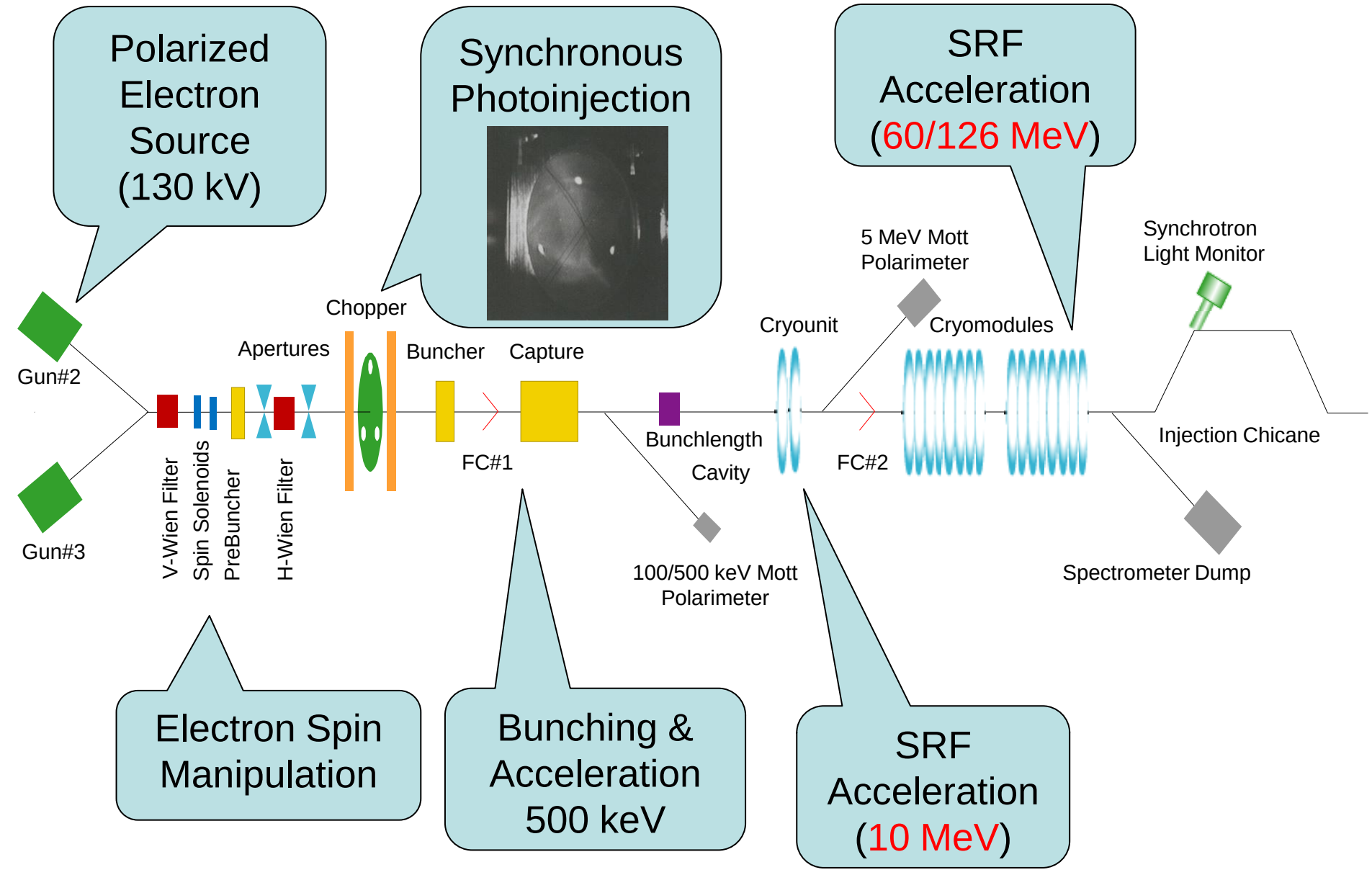
3 existing end stations for nuclear physics experiments would benefit from a beam of polarized positrons:

- Parton Imaging
- Deeply Virtual Compton Scattering
- Two Photon Exchange

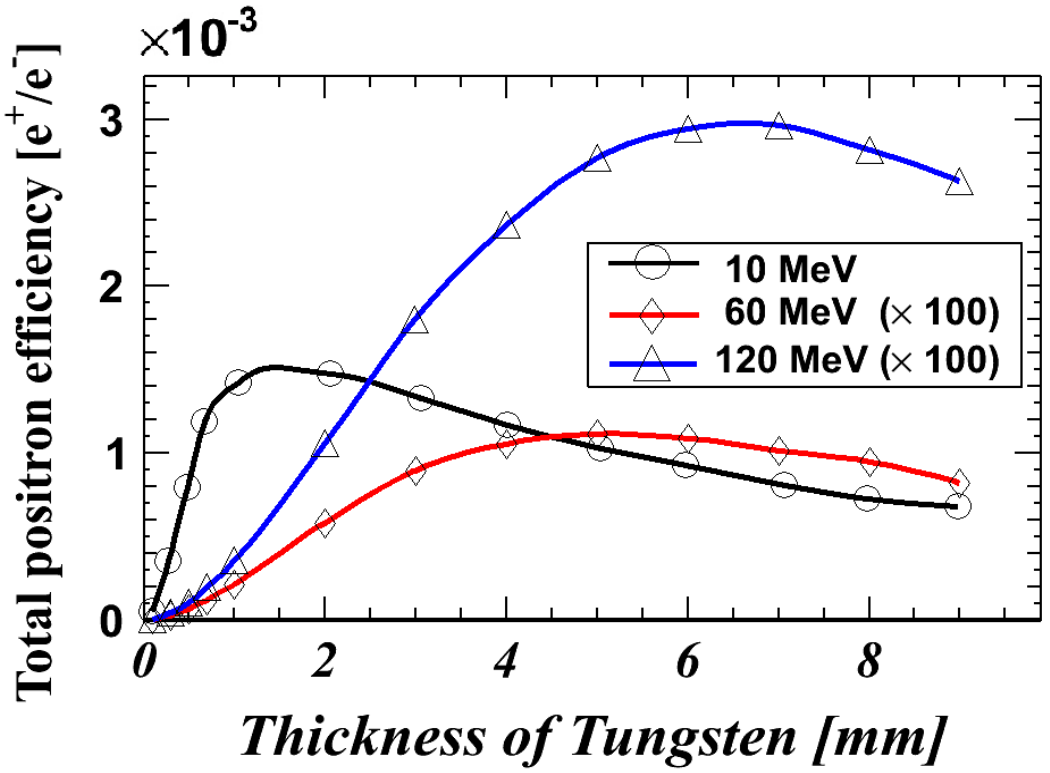
Other efforts may also benefit:

- Electron Ion Collider
- Materials Science Collaborations

CEBAF Polarized Electron Injector



CEBAF Energy Compatibilities



CEBAF Pre-Injector

CEBAF 6 GeV Injector

CEBAF 12 GeV Injector

Conversion efficiencies are low, but 100nA – 10μA sufficient for user requirements

Corresponding milliamp electron beams are challenging, yet possible (more later).

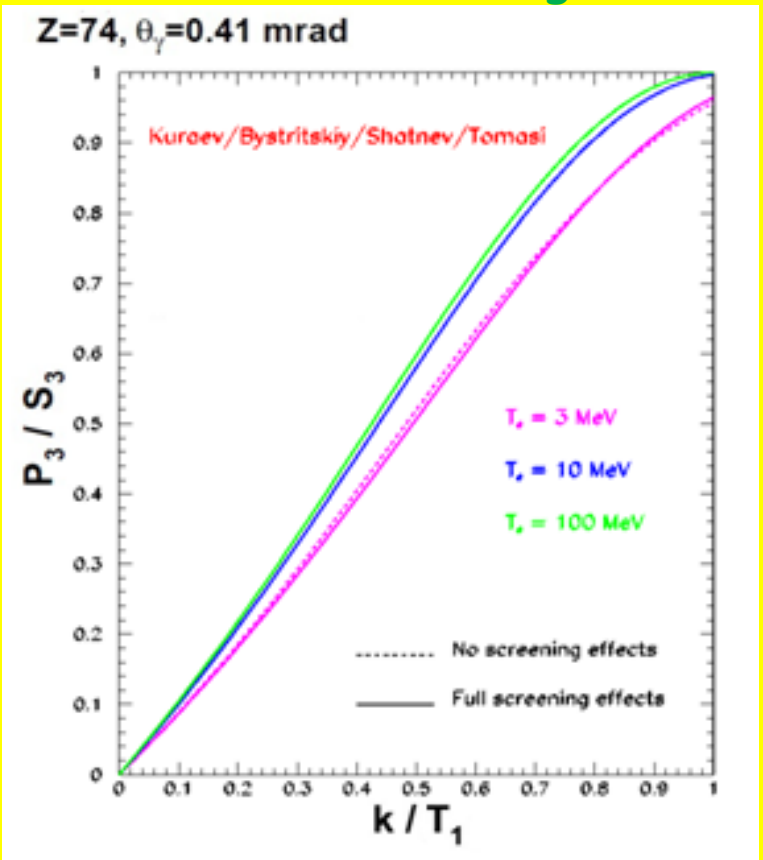
Polarized Bremsstrahlung & Pair Creation

E.G. Bessonov, A.A. Mikhailichenko, EPAC (1996) A.P. Potylitsin, NIM A398 (1997) 395

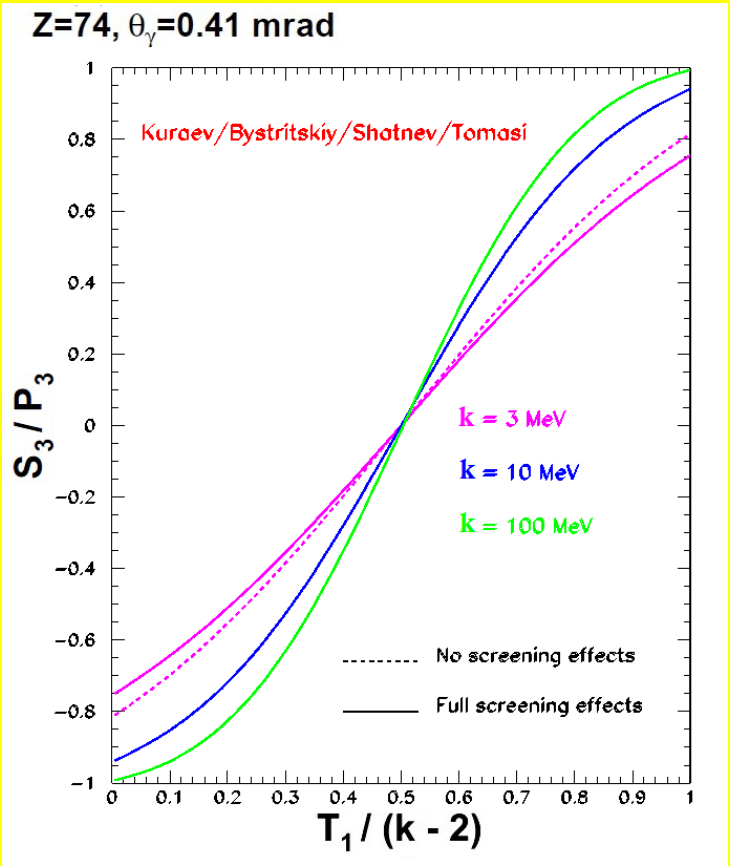
$\vec{e^-} \rightarrow \gamma \rightarrow \vec{e^+}$

E.A. Kuraev, Y.M. Bystritskiy, M. Shatnev, E.Tomasi-Gustafsson, PRC 81 (2010) 055208

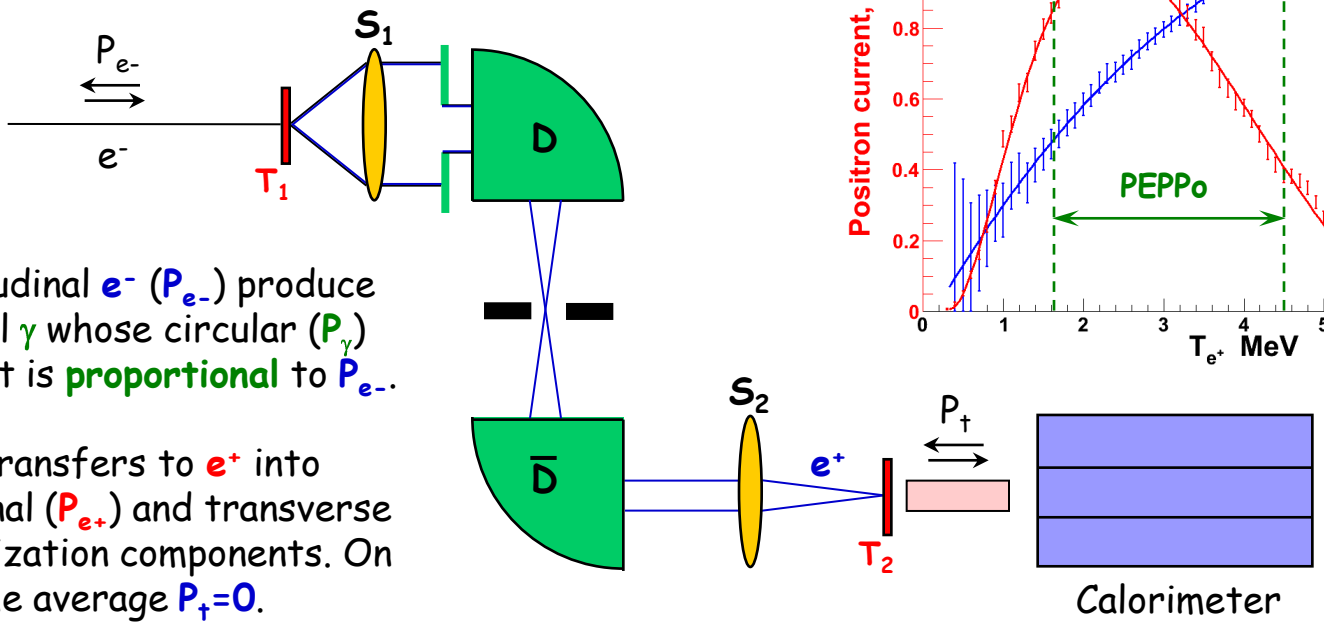
Bremsstrahlung



Pair Creation

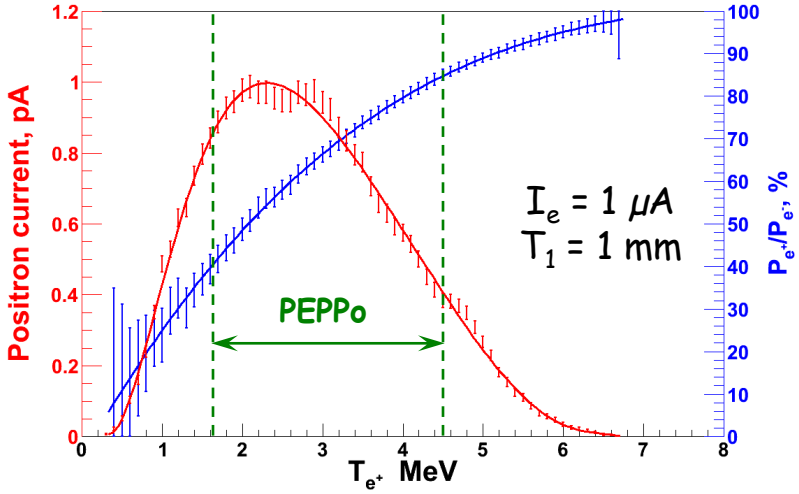


PEPPo Concept @ JLab



o Longitudinal e^- (P_{e^-}) produce elliptical γ whose circular (P_γ) component is **proportional** to P_{e^-}.

o P_γ transfers to e^+ into longitudinal (P_{e^+}) and transverse (P_t) polarization components. On the average P_t=0.

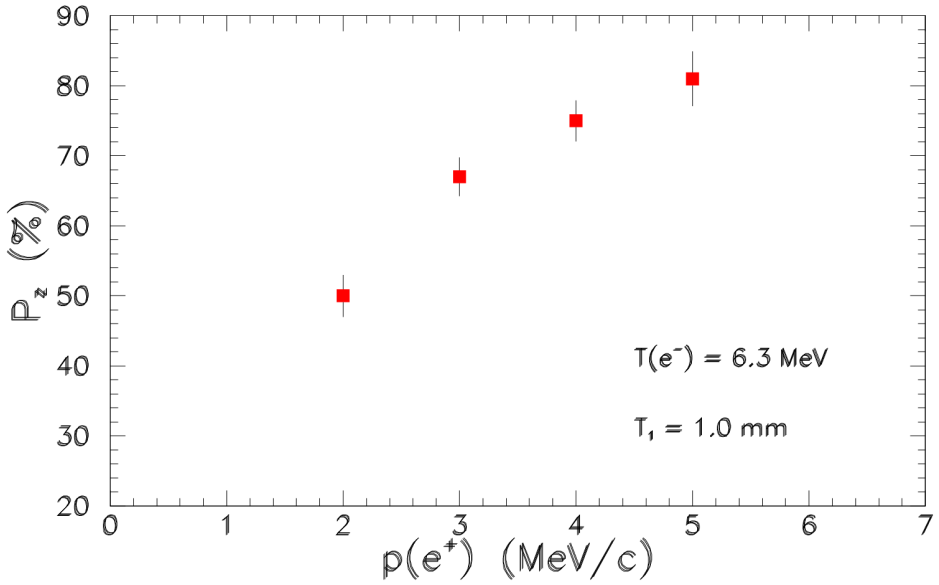


PEPPo is proposing to **measure** the **polarization transfer** from longitudinal electrons to longitudinal positrons in the **3-7 MeV/c momentum range**.

PEPPo Lobbying (2009-2011)

It followed PAC35's enthusiastic endorsement of LOI-10-010 which noted that

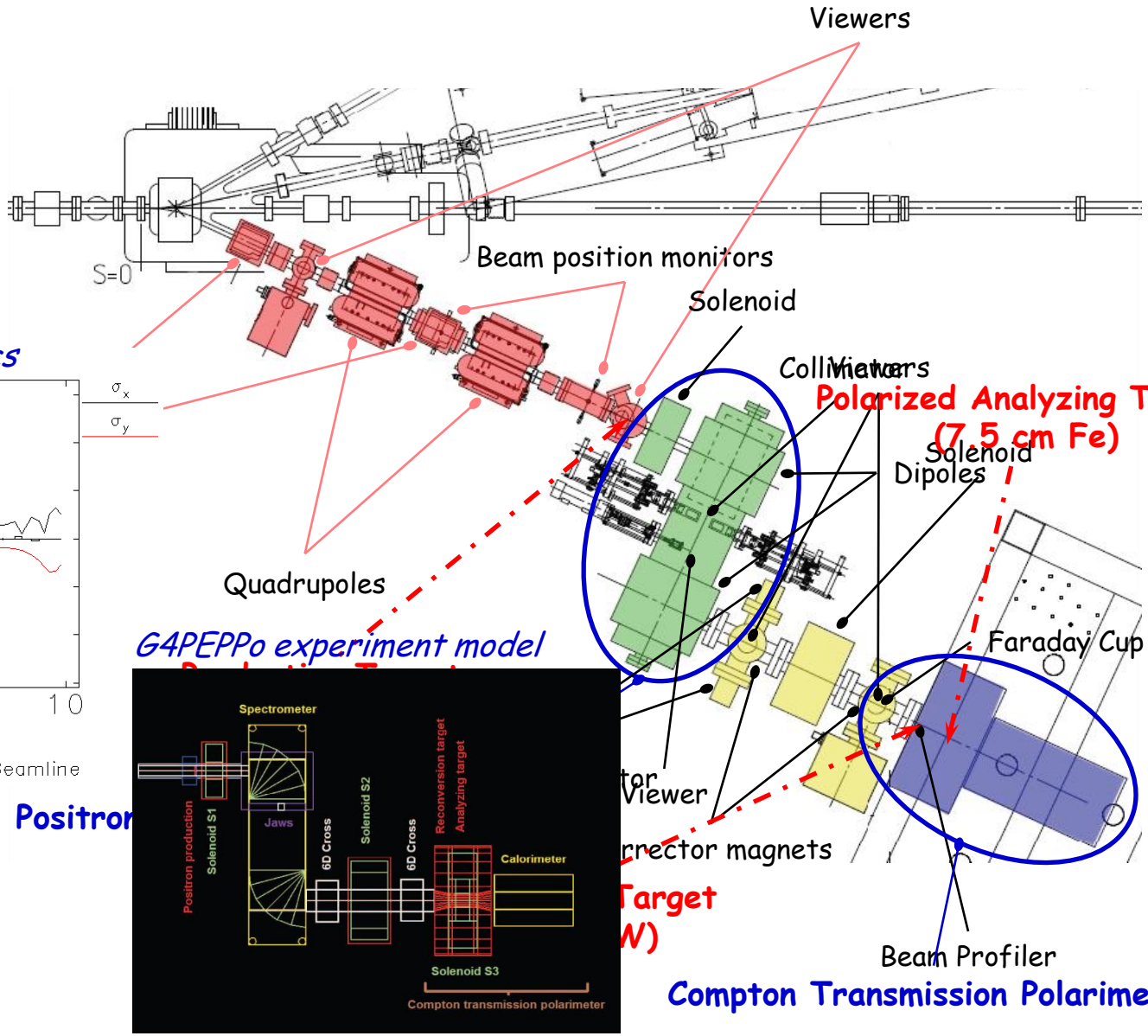
"Any accelerator facility, like JLab, using polarized electrons for its physics program would like an intense beam of polarized positrons. This Letter marks a proof of principle experiment that should become a full proposal."



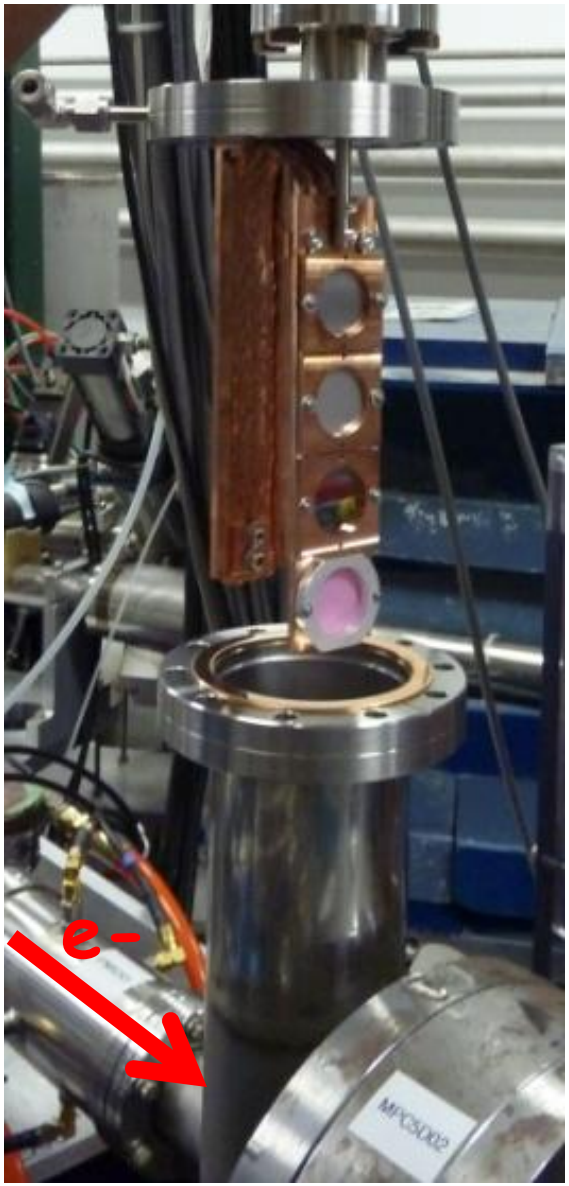
The **PEPPo** experiment (PR12-11-105) proposes to measure the **polarization transfer** from longitudinally polarized **electrons** to longitudinally polarized **positrons** as a **proof-of-principle** for a **new technique** for **polarized positron source**.

In August 2011 PAC38 recommended to run PEPPo with an "A" rating

The PEPPo experiment @ JLab

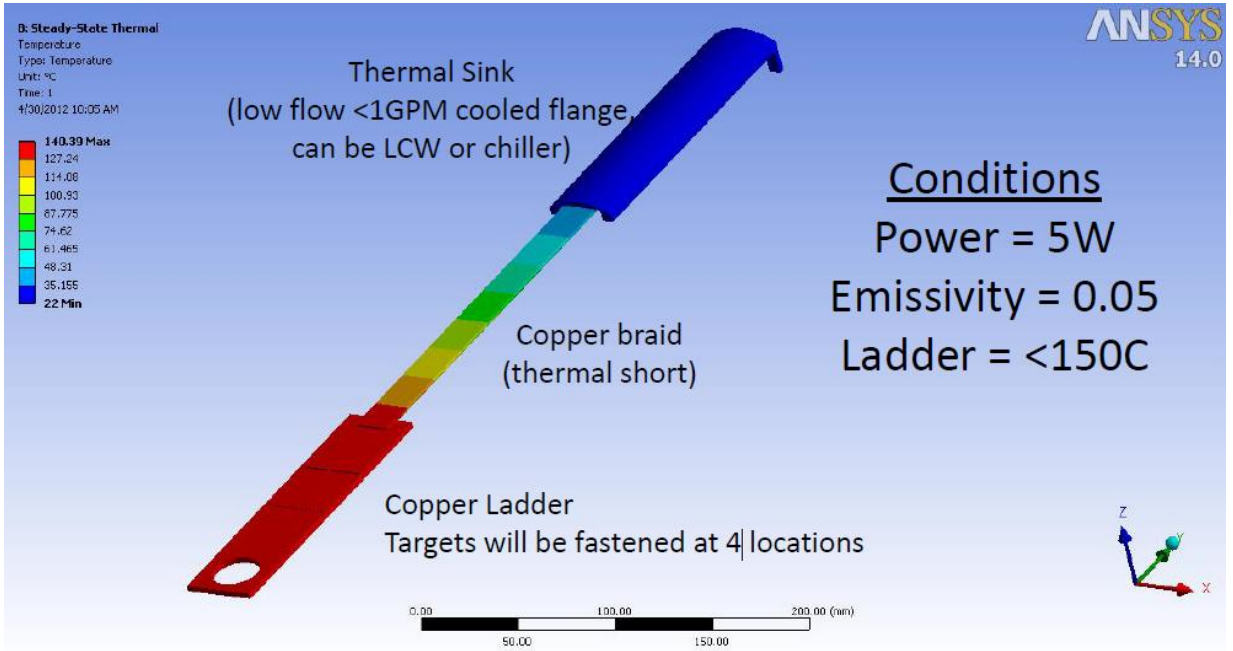


Positron Production Target Ladder

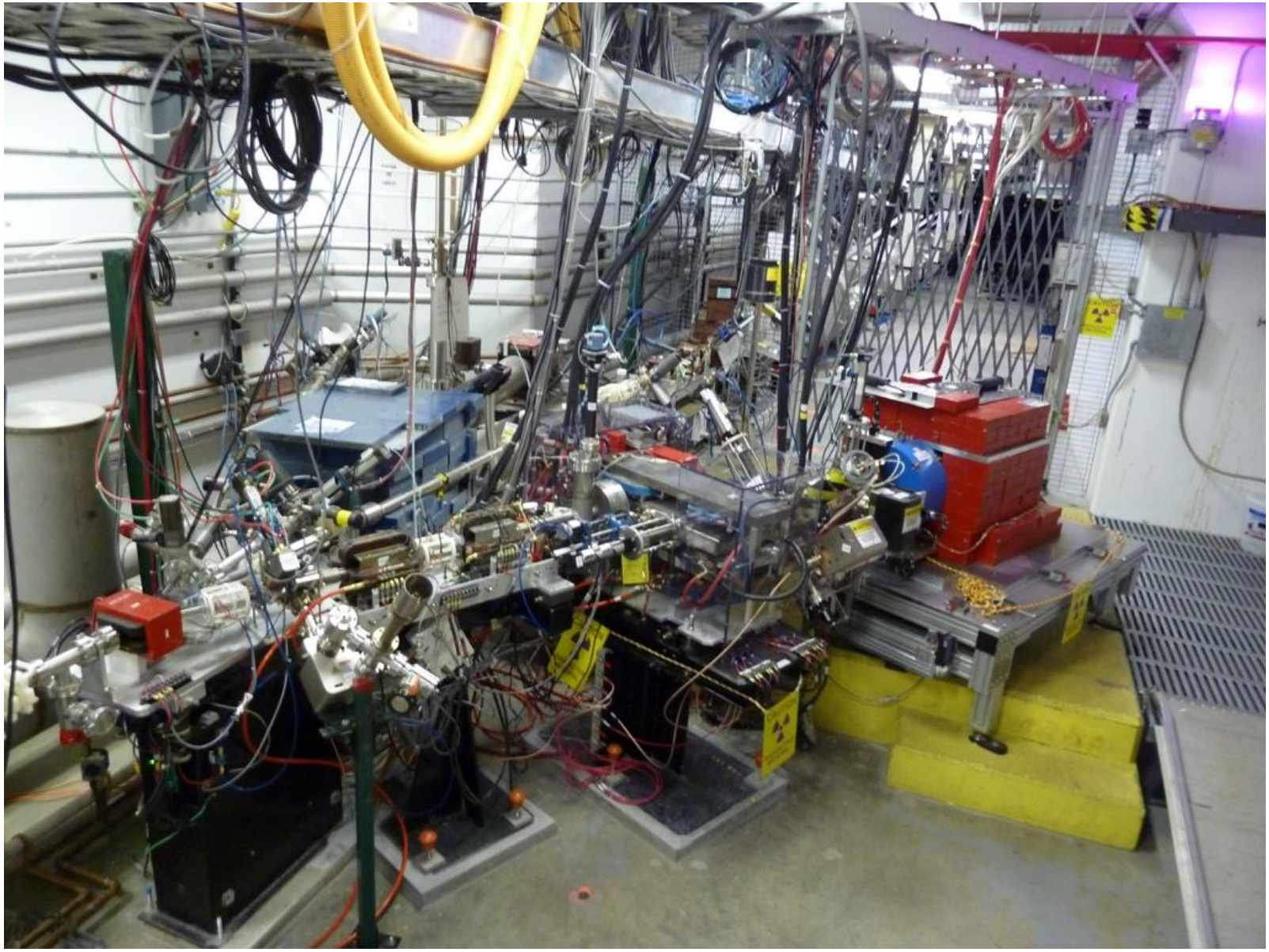


- Target ladder with viewer + 3 conversion targets

Incoming electron kinetic energy [MeV]		2	5	8	Necessary for Experiment [uA]
Target	Material	Max Current [uA] for 5W deposited			
Production Target = 0.1mm	Tungsten	15.9	27.6	30.1	4.0
Production Target = 0.5mm	Tungsten	5.0	3.0	3.7	n/a
Production Target = 1mm	Tungsten	4.9	2.0	1.6	0.4



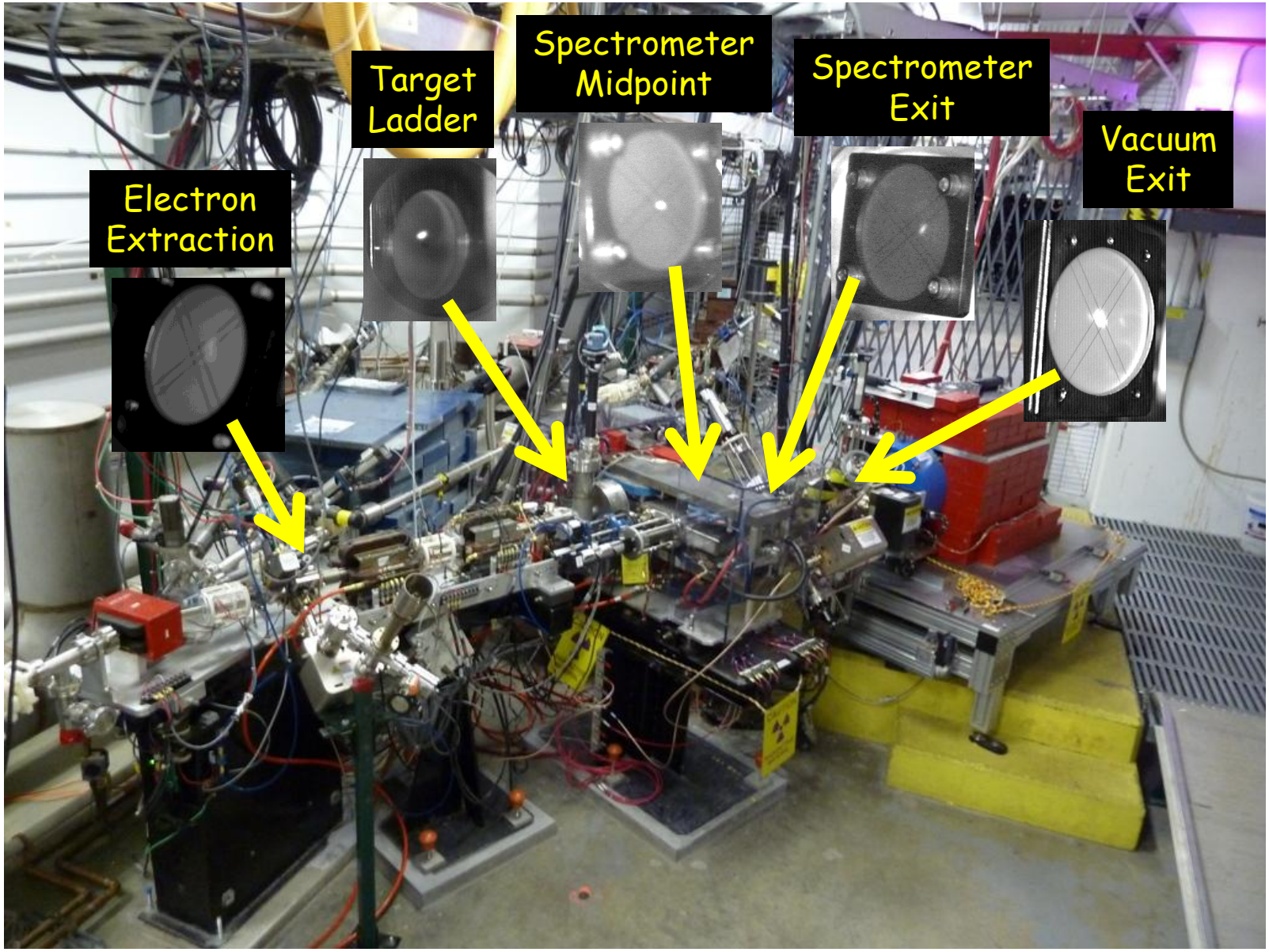
Installation Complete November, 2011



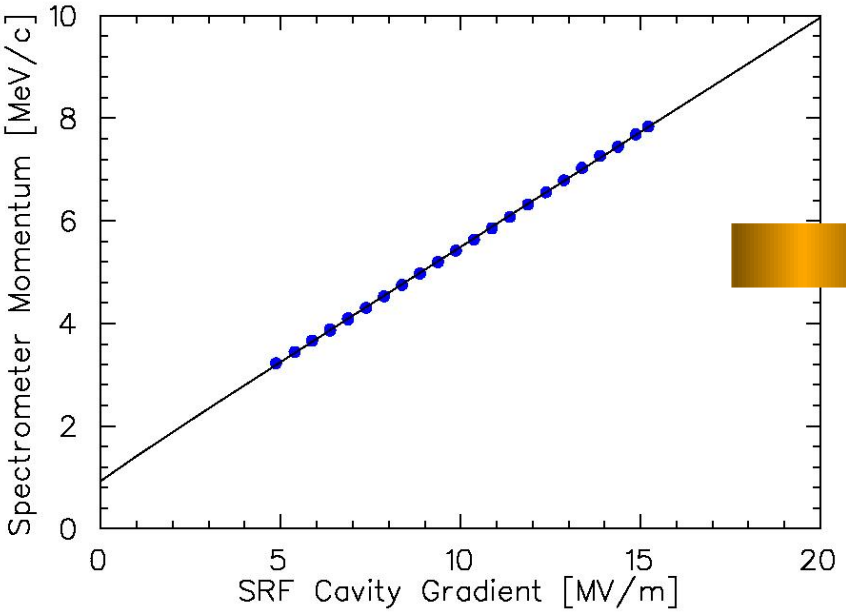
Experiment Strategy

- Beam line calibration, positron production & collection
- Calibrating Compton polarimeter with polarized electrons
- Measuring polarization of collected positrons

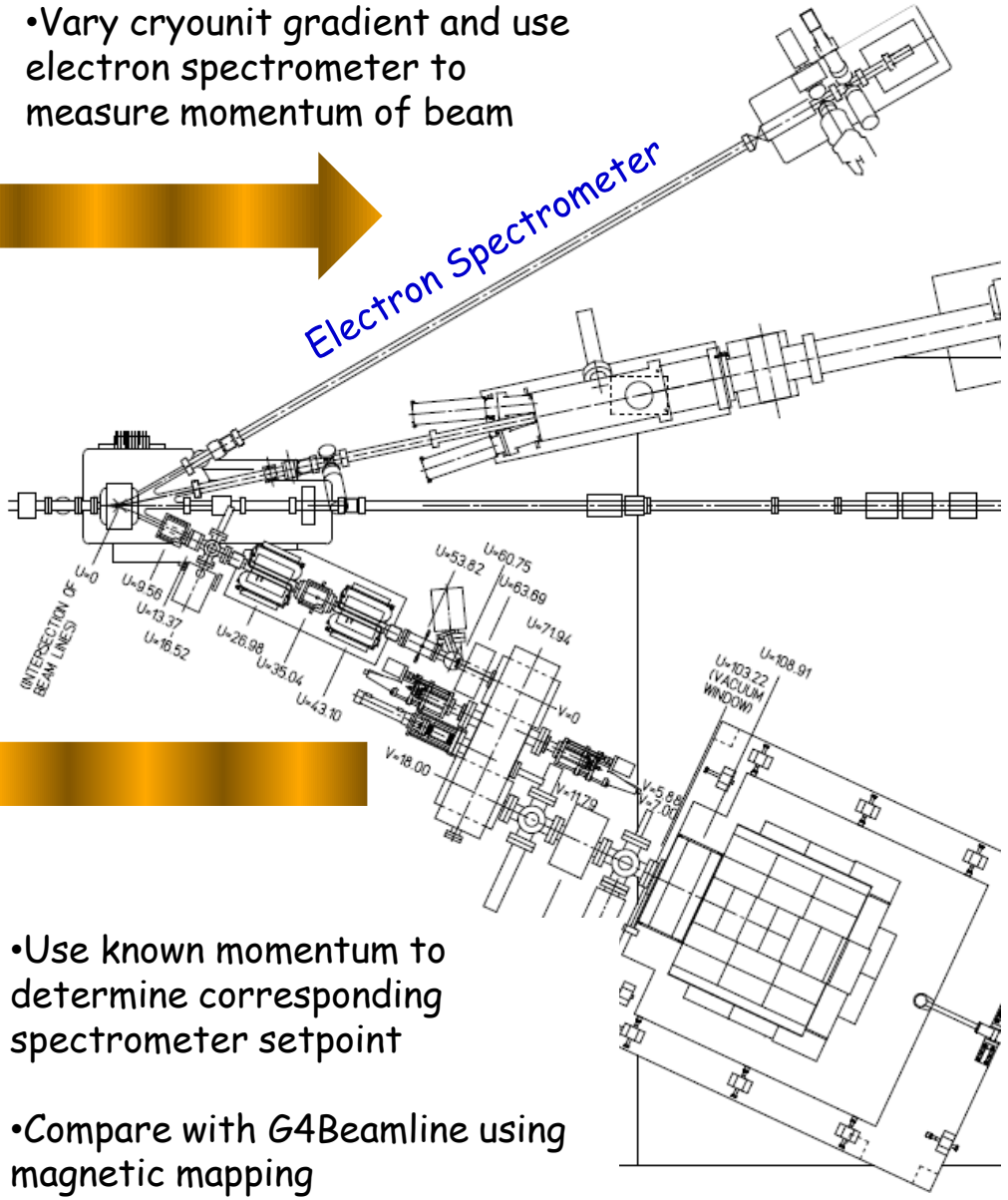
Beam line Tune-up & Check out

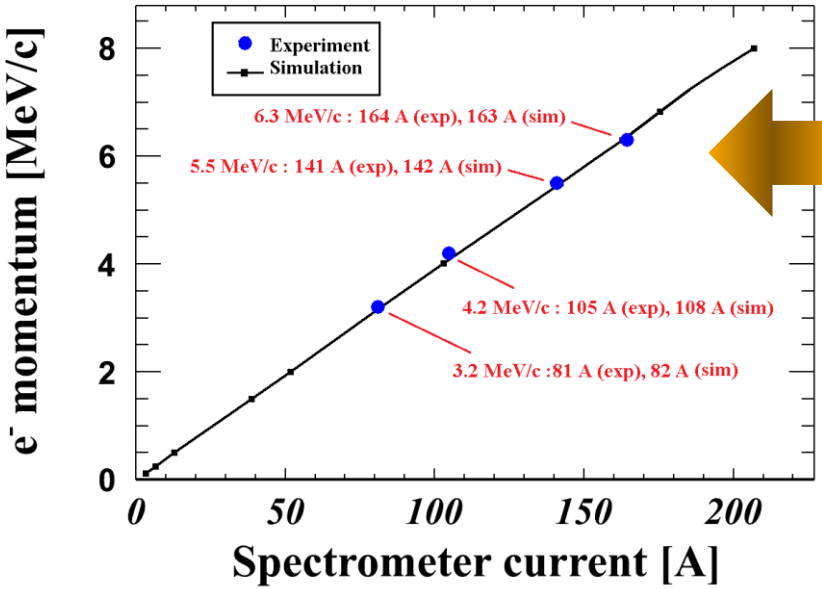


Electron Momentum Calibration



•Vary cryounit gradient and use electron spectrometer to measure momentum of beam

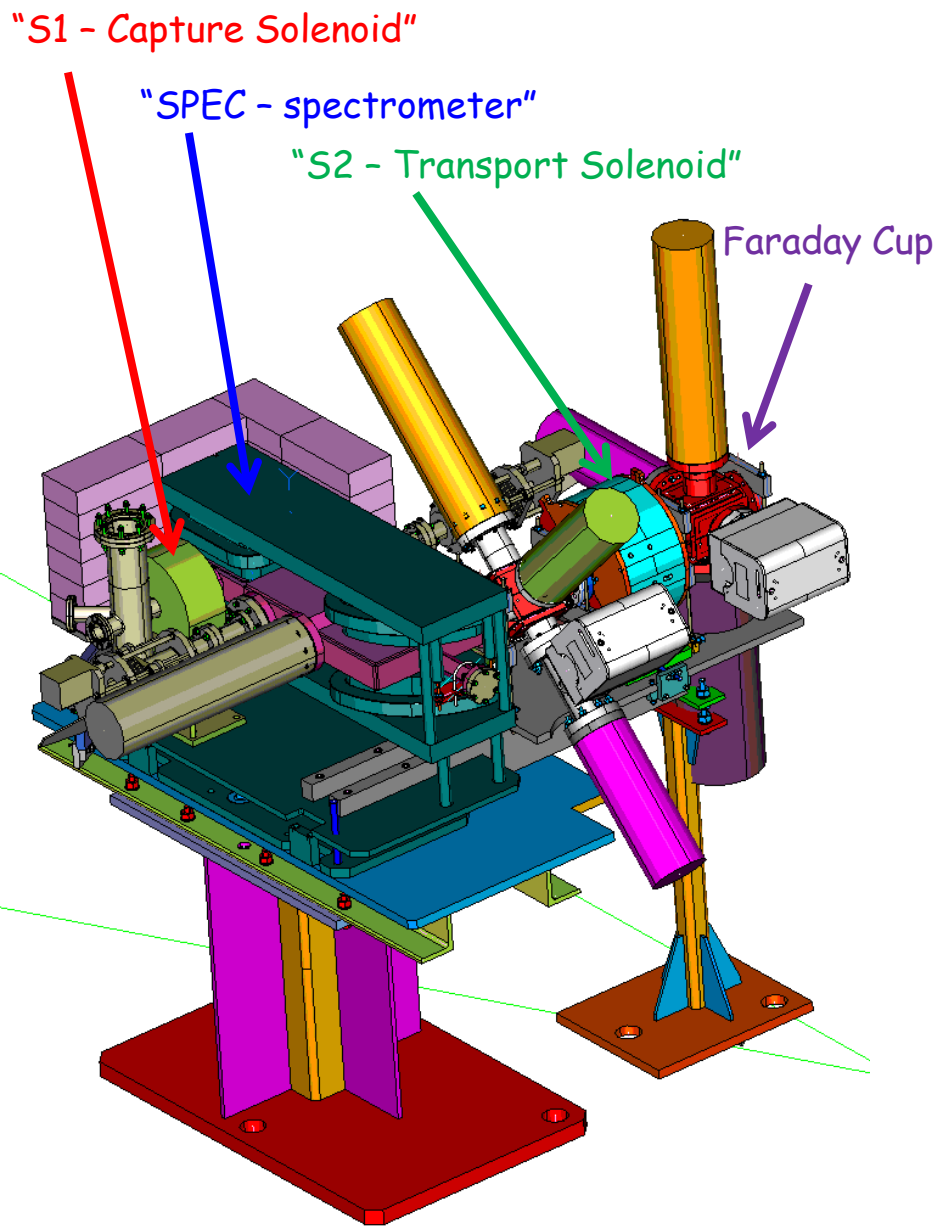


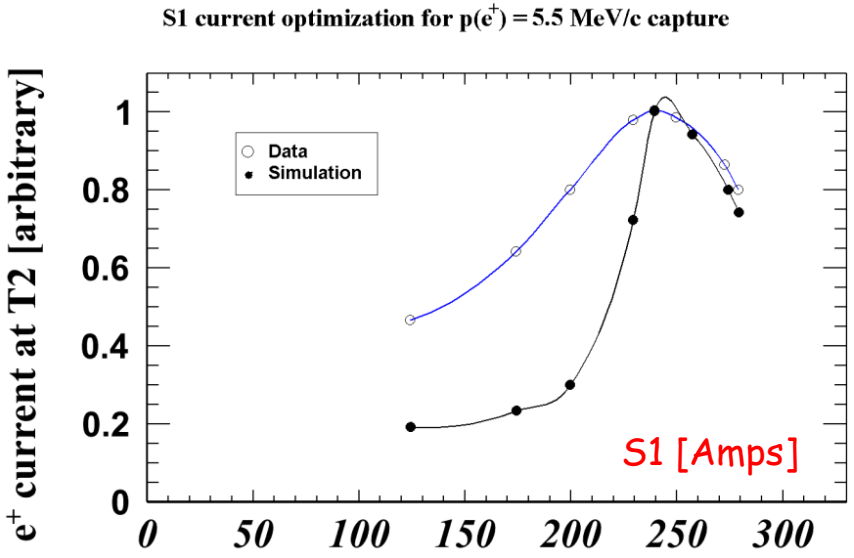


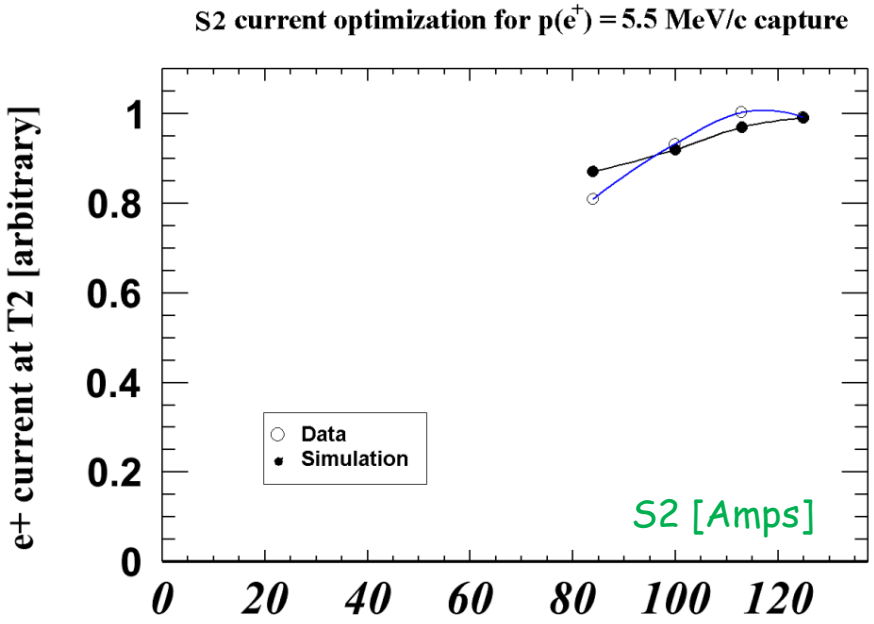
•Use known momentum to determine corresponding spectrometer setpoint

•Compare with G4Beamline using magnetic mapping

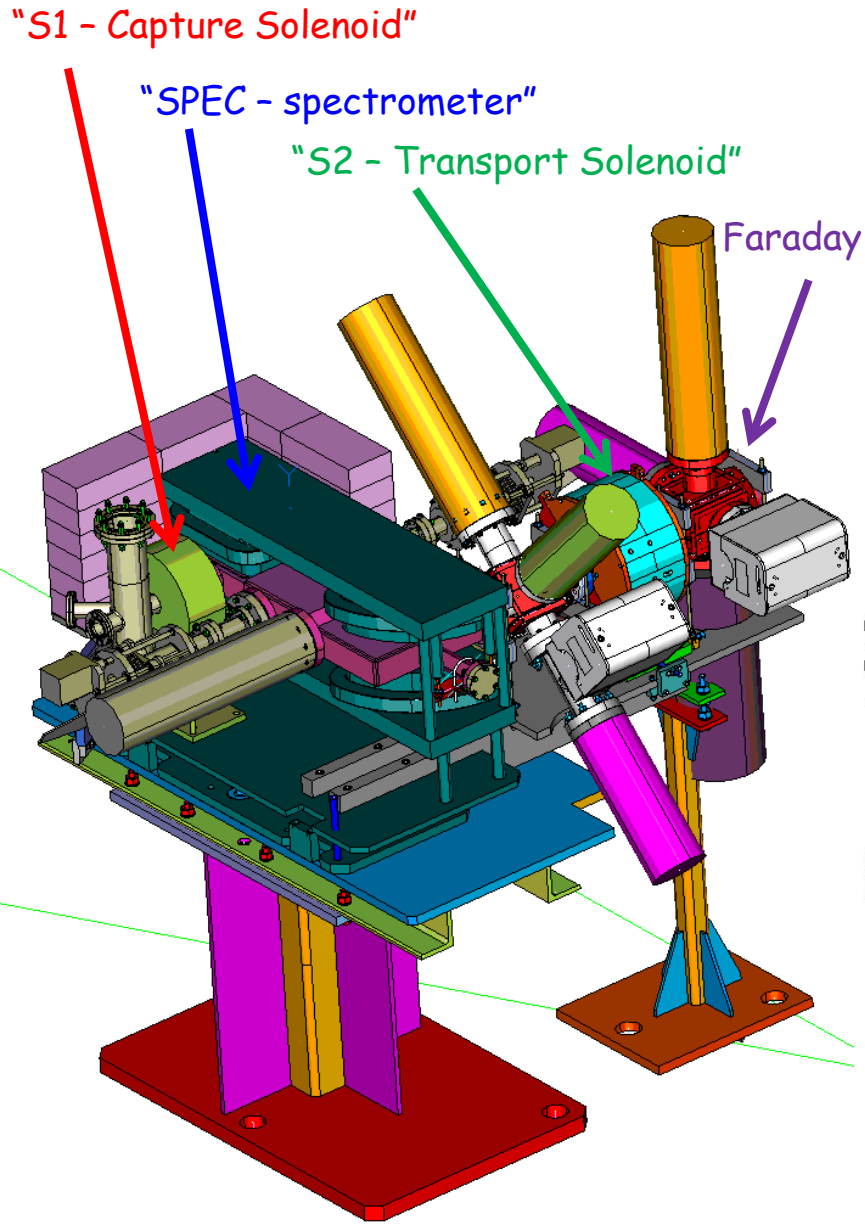
Collection of Degraded e- and Pair-Produced e+



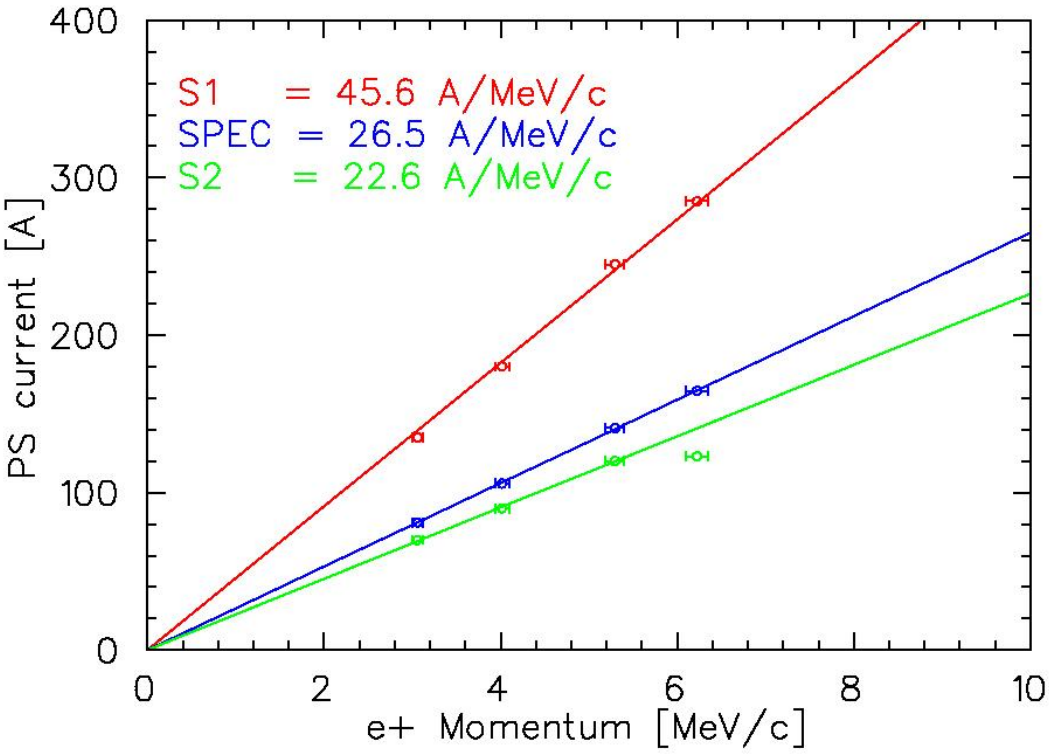




Collection: Degraded Electrons then Positrons

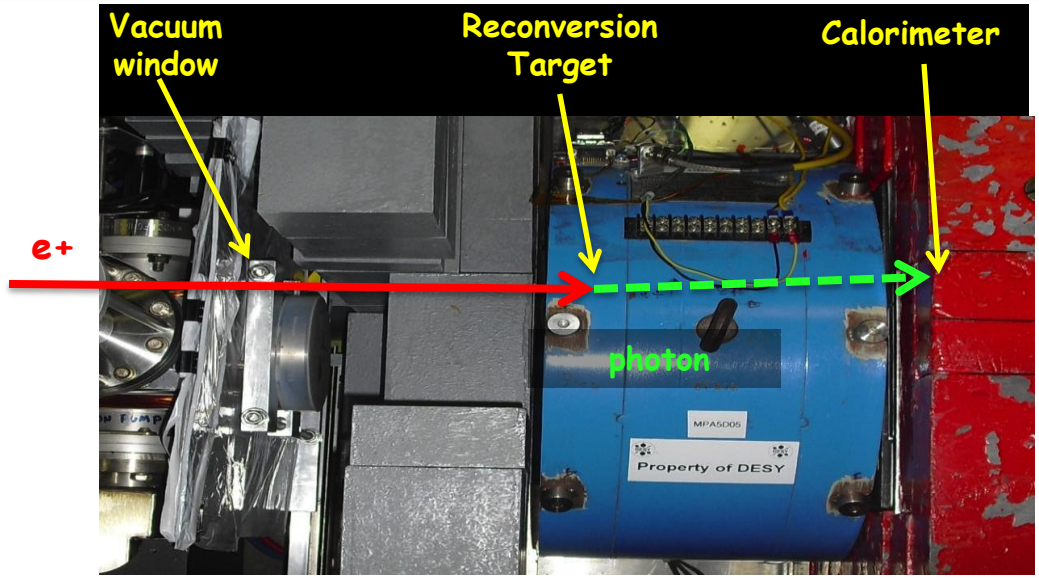


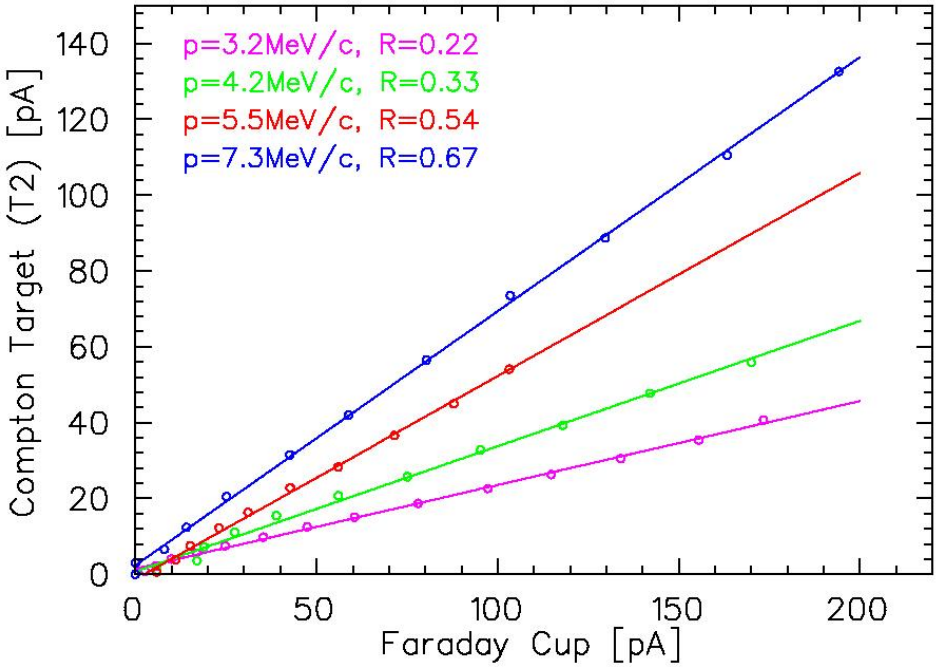
- Spectrometer setpoint determined from momentum calibration
- Capture (S1) and Transport (S2) setpoints determined from yield optimization

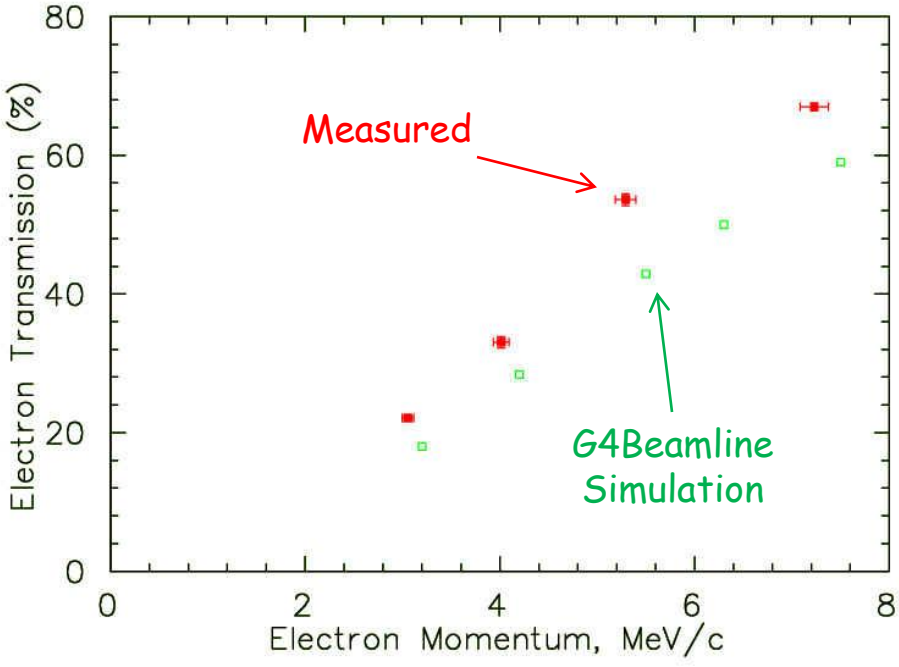


PositronYield

- Positron pass through 0.010" of Al and 25cm to reconversion target
- We recognized that some fraction of positrons (or electrons) were being lost in transit
- Comparison of simulations with data will be used to make corrections

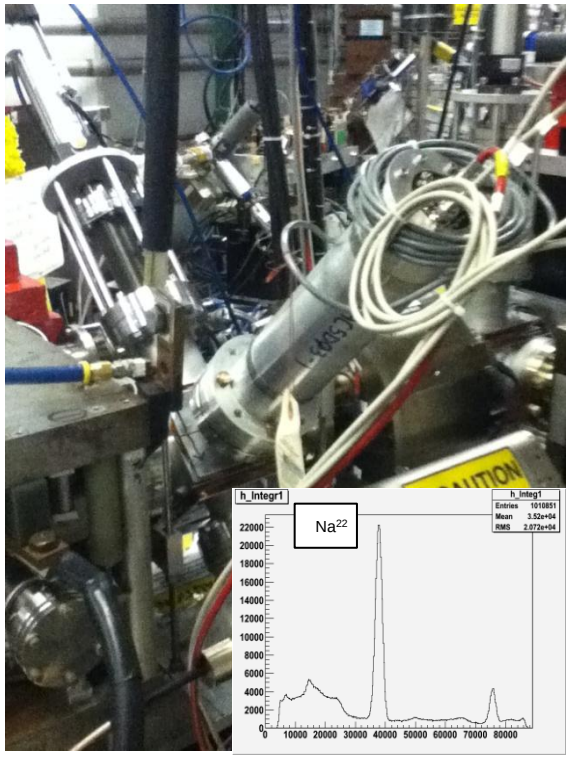


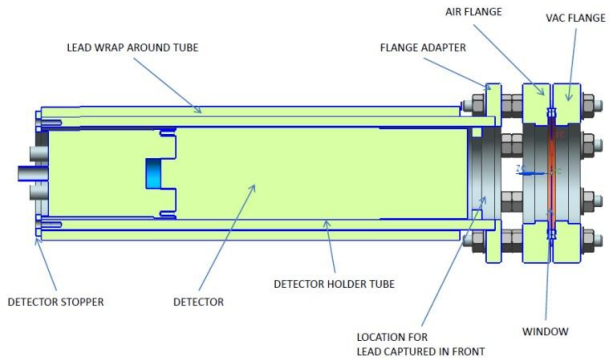




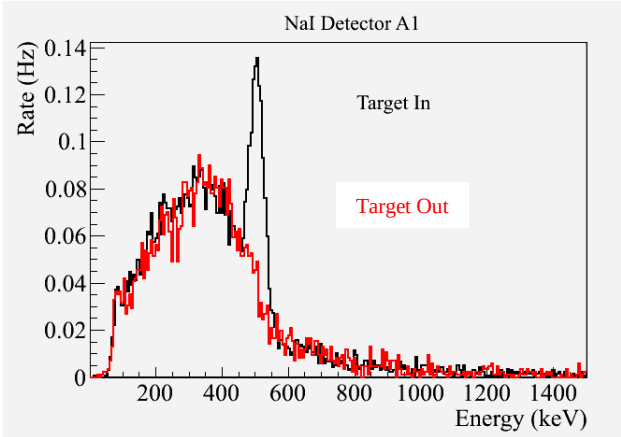
Positron Annihilation Counter

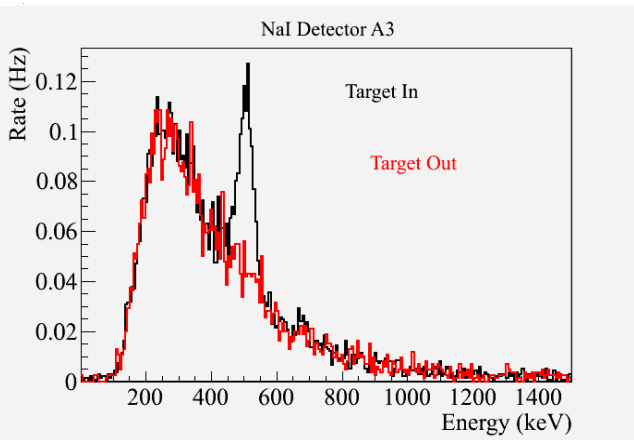
- Two **NaI** detectors are used to measure the **back-to-back photons** emitted by the **annihilation** of **positrons** in an insertable target.

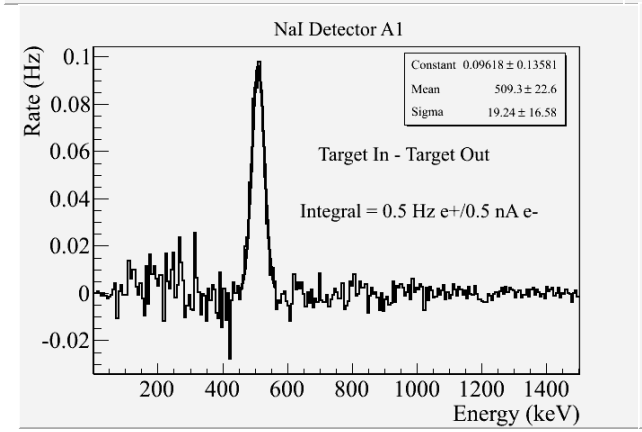


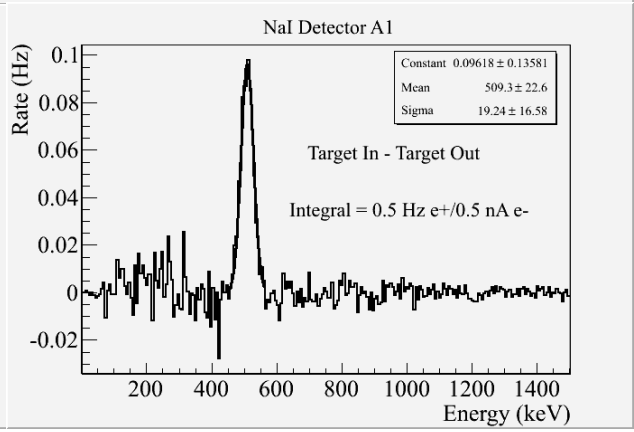


4MeV/c e+ collected from 0.5nA 7MeV/c e- on 1mm W target
Coincidence Cut < 8nS









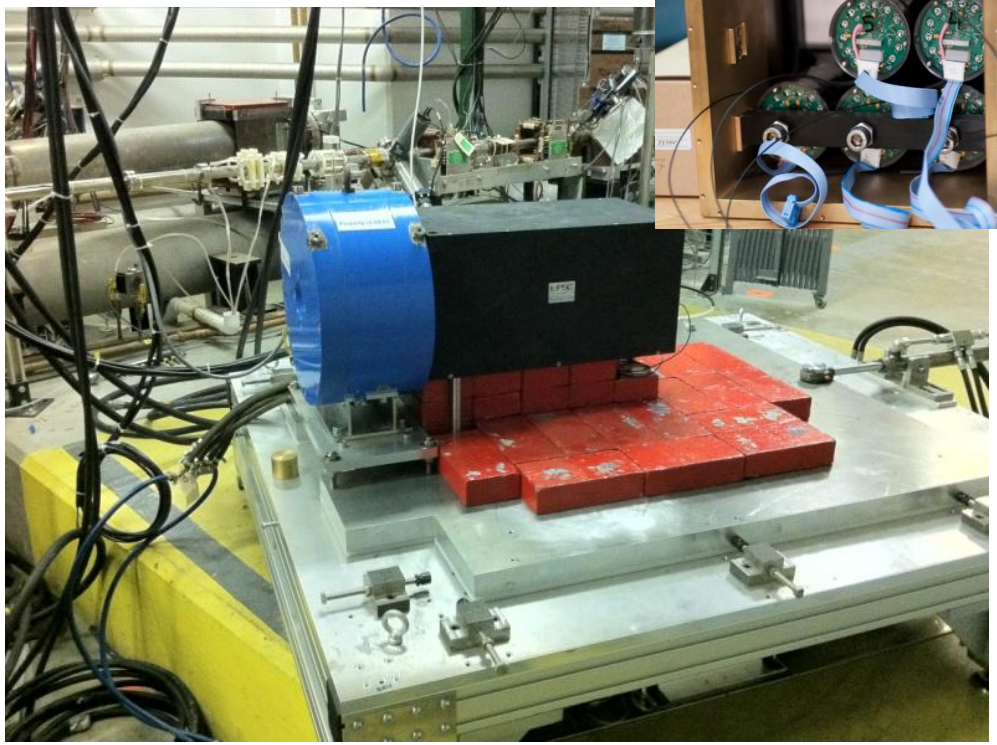
Experiment Strategy

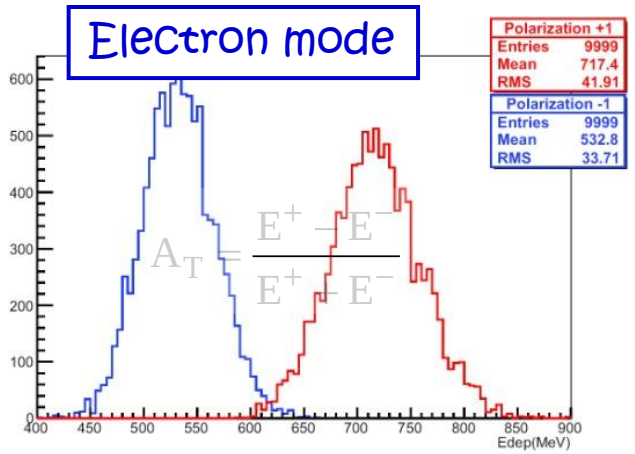
- Beam line calibration, positron production & collection
- Calibrating Compton polarimeter with polarized electrons
- Measuring polarization of collected positrons

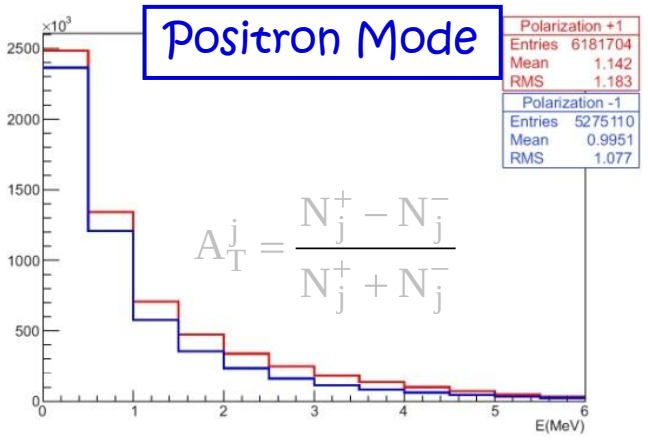
Compton Transmission Polarimeter (see E. Fanchini's talk on Thursday)

- PEPPo polarimetry relies on the **sensitivity** of the **Compton** process to the **polarization** of the **photons** generated in the T_2 target by the **interaction** of **incoming electrons/positrons**.

$$A_T = P_{e^\pm} P_T A_{e^\pm}$$



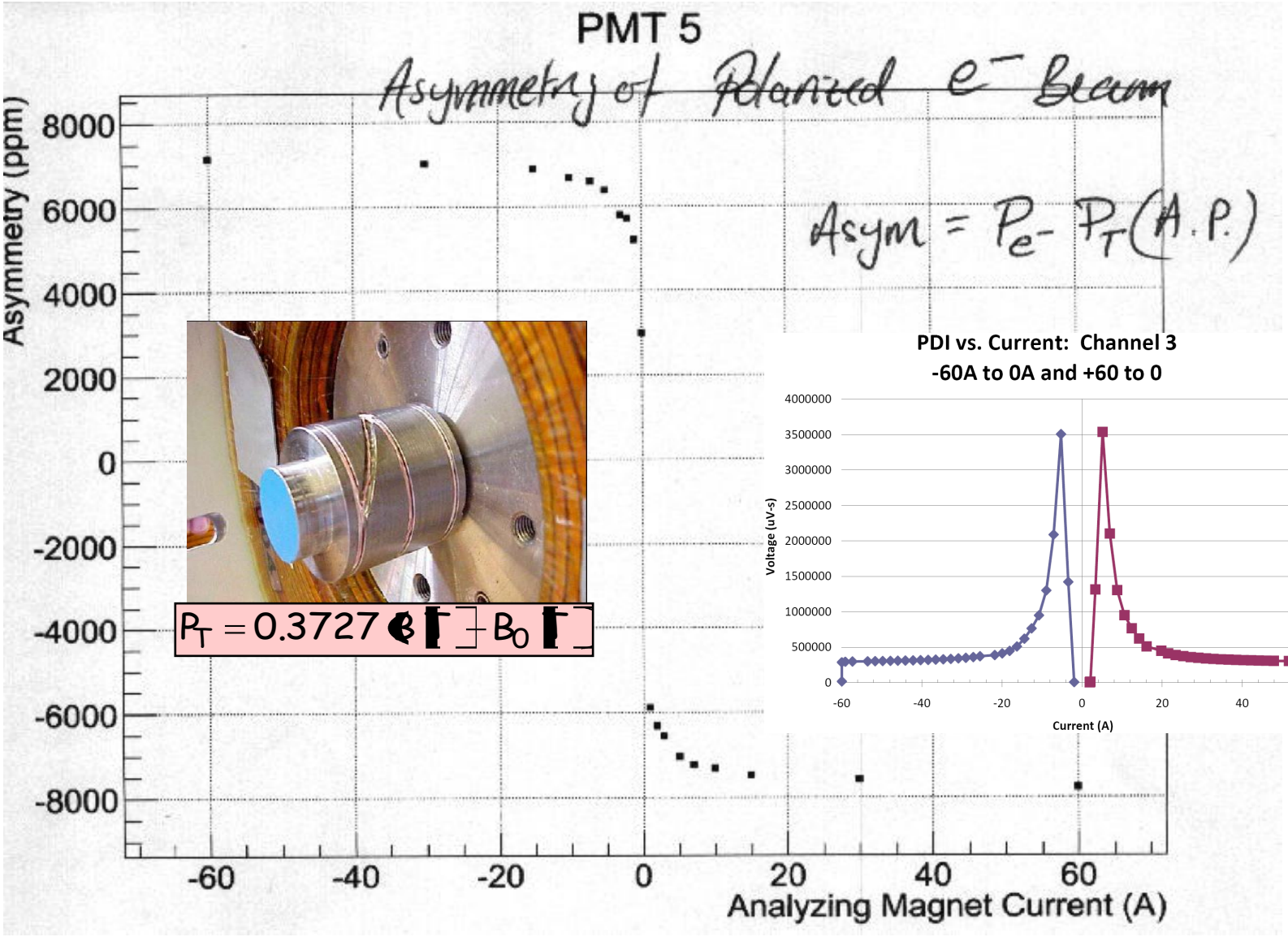




Expected experimental **asymmetries** are small (**1-8x10^{-3}**) and we will take advantage of the **current JLab practices** for the control of **helicity correlated systematics**.

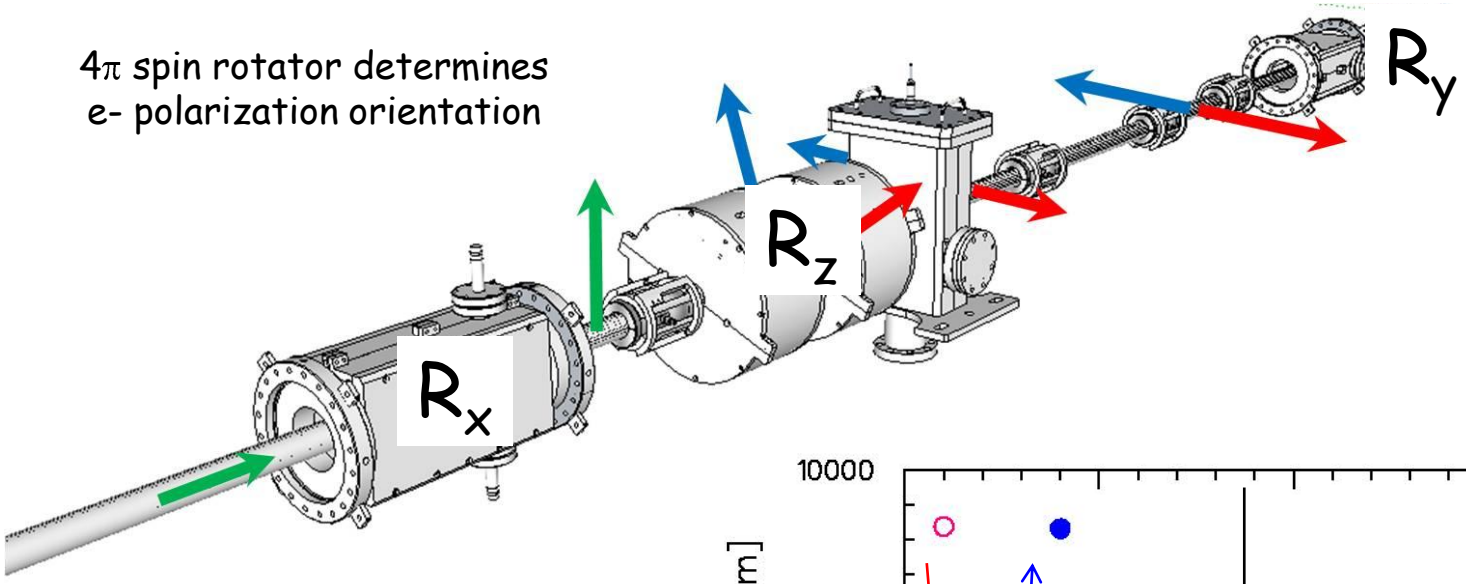
Compton Target Polarization (using e- @ 5.5 MeV/c)

One of our first commissioning tests while reversing polarity of analyzing magnet !

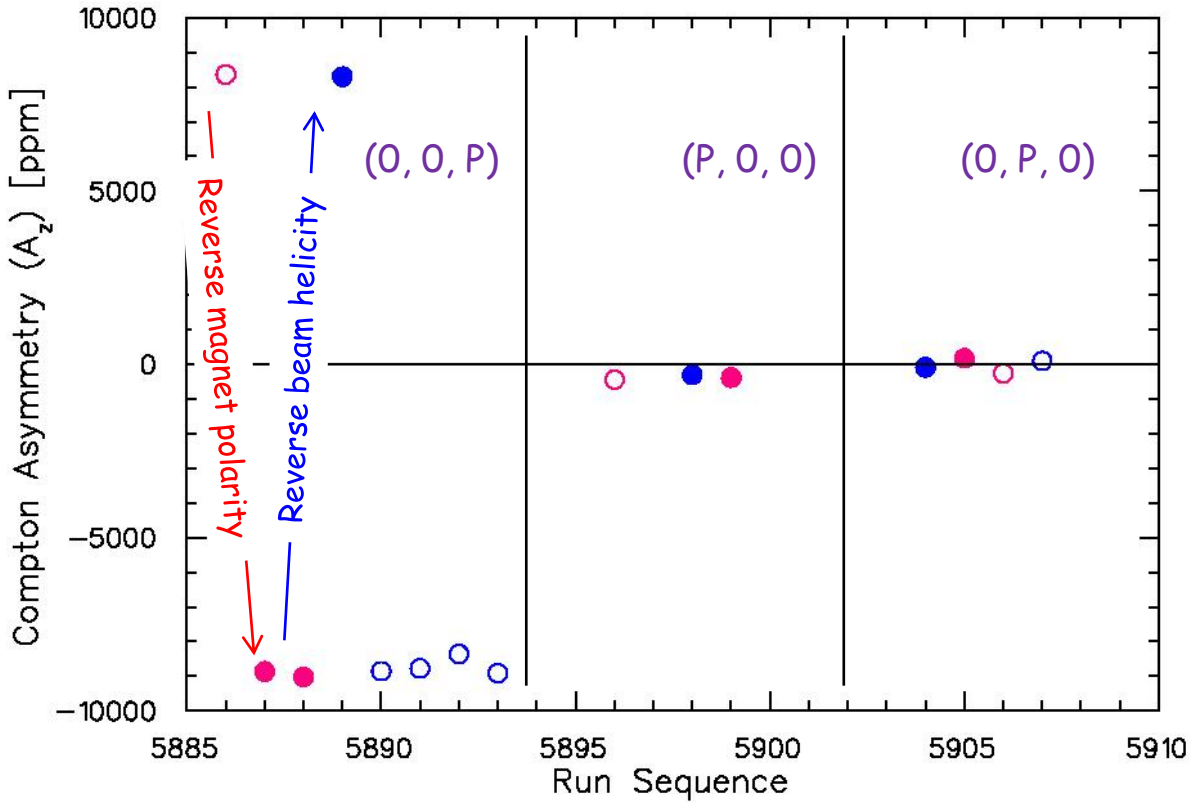


ComptonSystematic Studies

4π spin rotator determines
e- polarization orientation



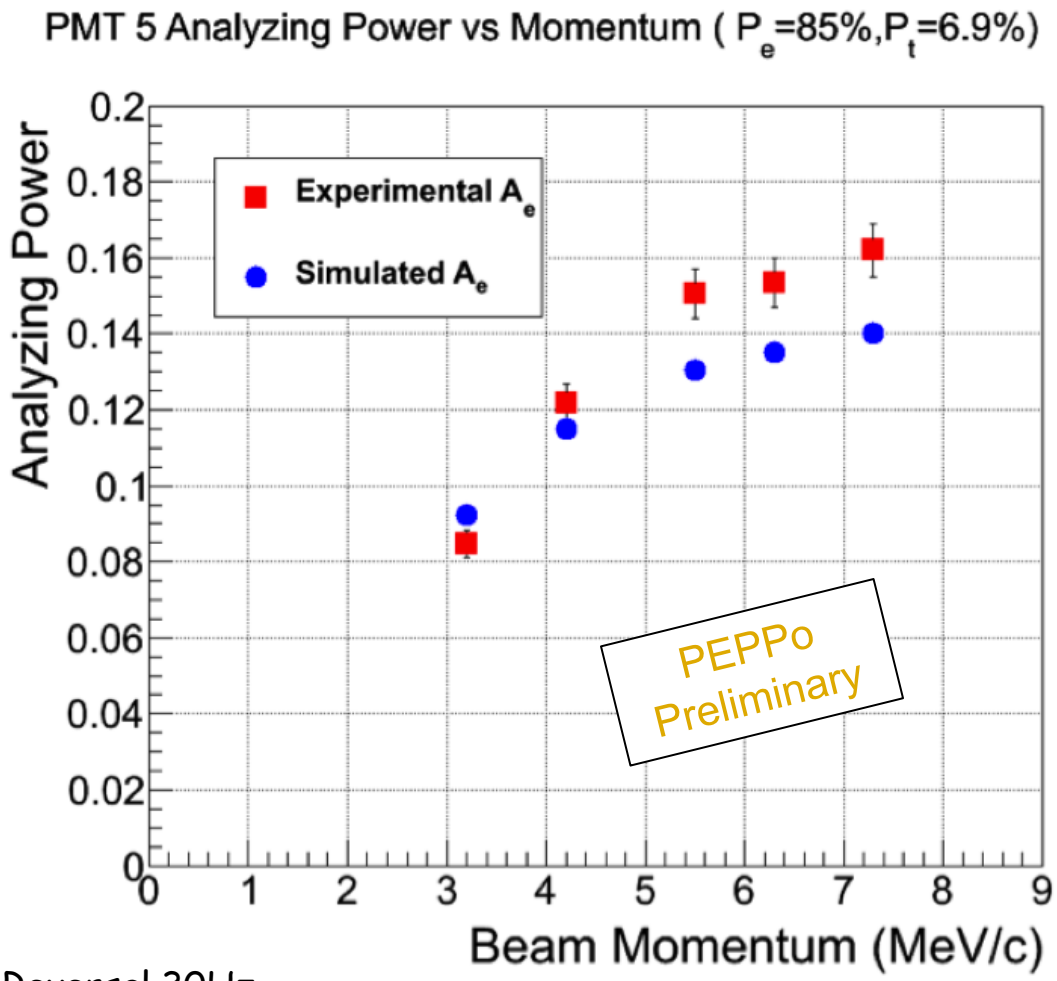
P ~ 85%



- Fast reversal of electron beam polarization at 30Hz through experiment
- Slow systematic reversal of electron polarization with optical waveplate (source) and target polarization (Compton)
- Orient polarization in x,y,z direction using 4π spin rotator

Electron Beam Analyzing Power Calibration

- Use Mott polarimeter to learn electron beam polarizatoin
- Use Compton polarimeter to measure experimental asymmetry
- Combine results to calculate analyzing power and benchmark model of polarimeter



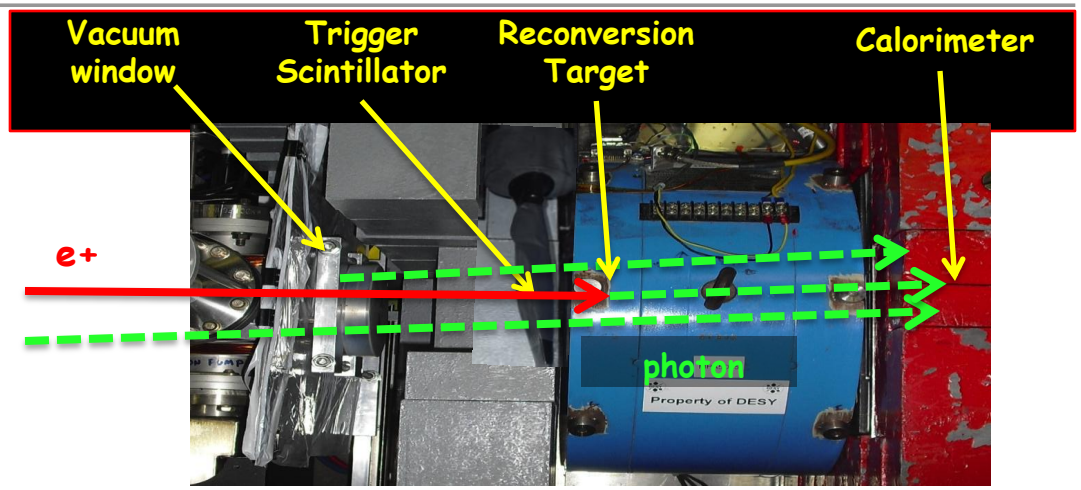
Helicity Reversal 30Hz
Reporting = delayed
Beam current 10-40pA
Asymmetries 5000-9000 ppm

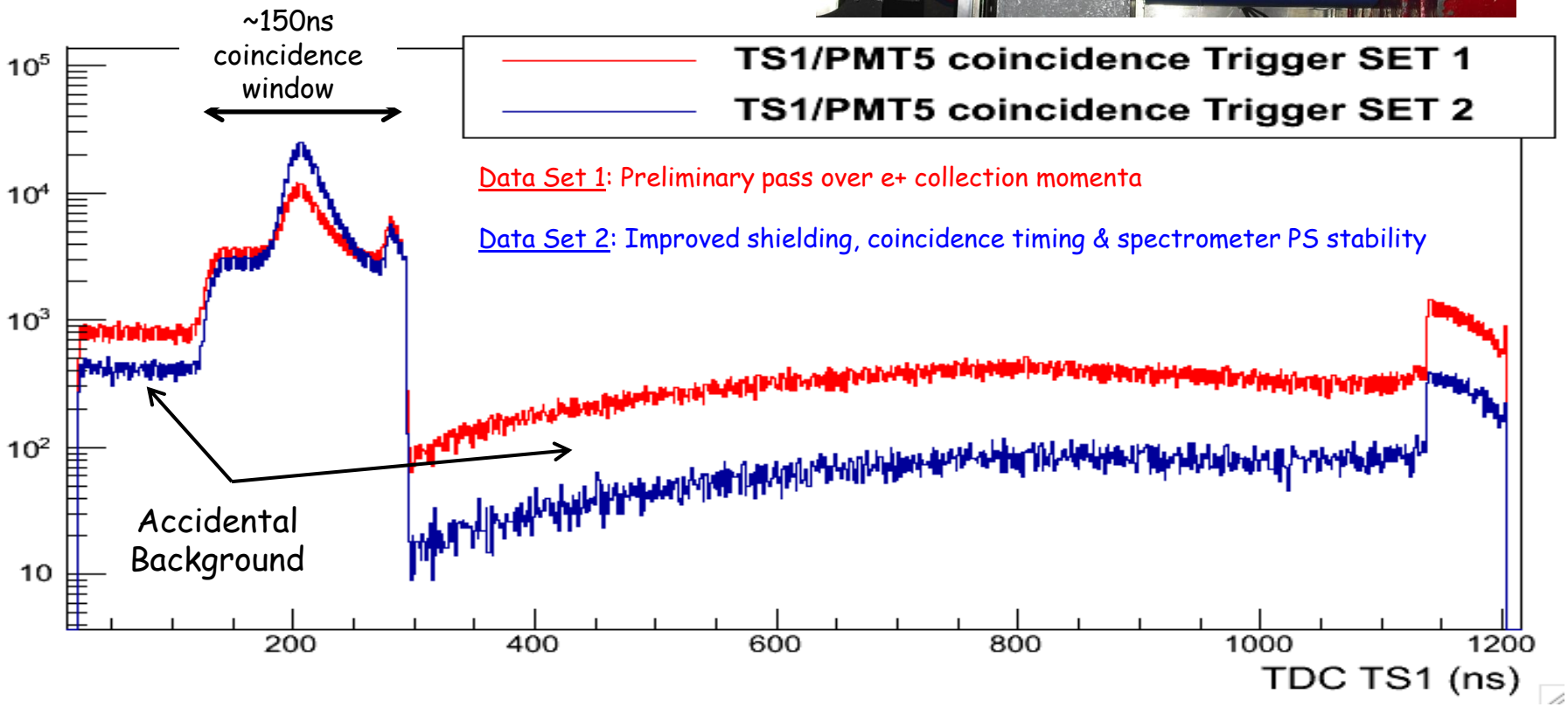
Experiment Strategy

- Beam line calibration, positron production & collection
- Calibrating Compton polarimeter with polarized electrons
- Measuring polarization of collected positrons

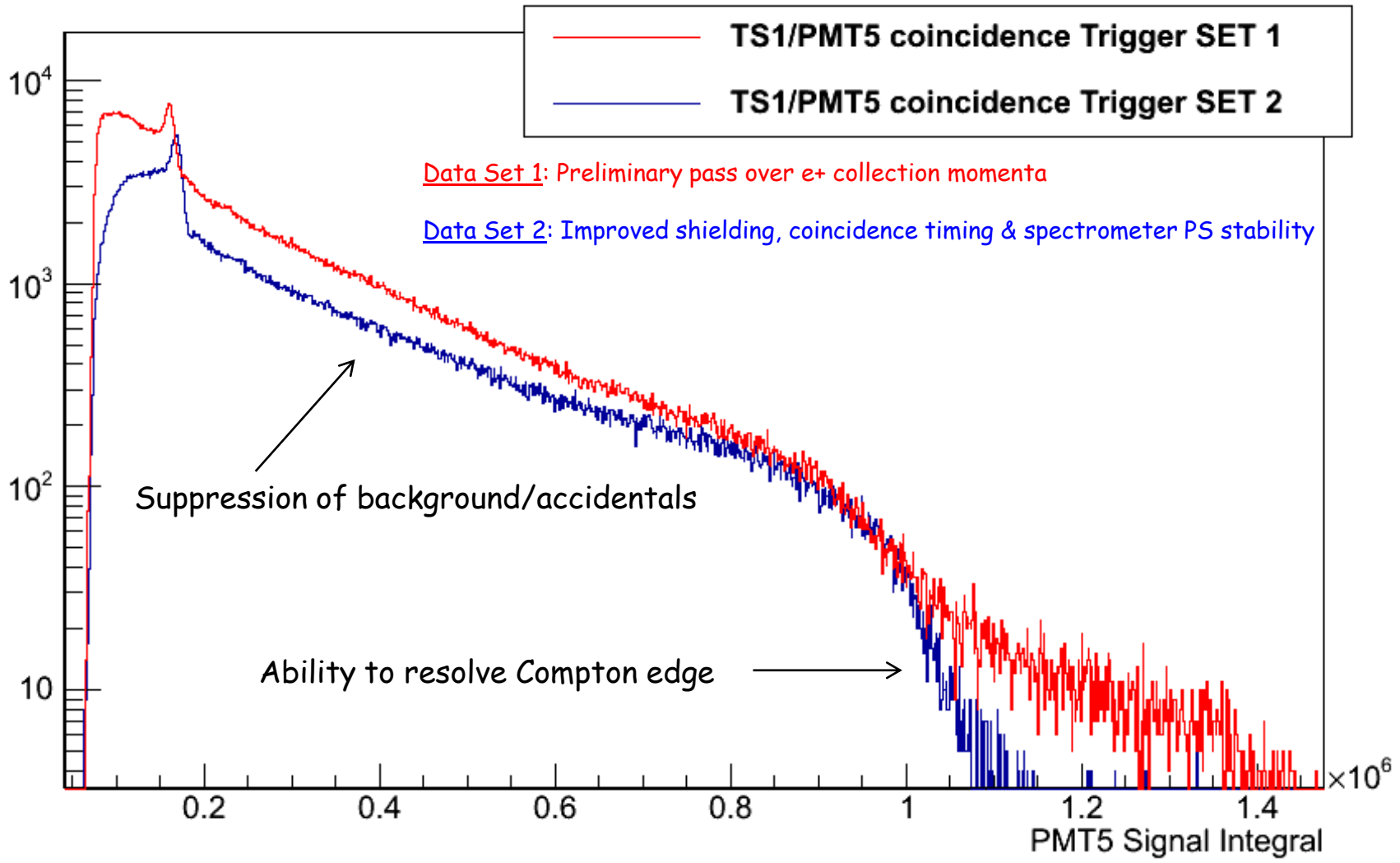
Compton Coincidence Spectrum (Set 1 v. Set 2)

"Good" positron events collected in coincidence of thin scintillator + Compton CsI calorimeter crystal

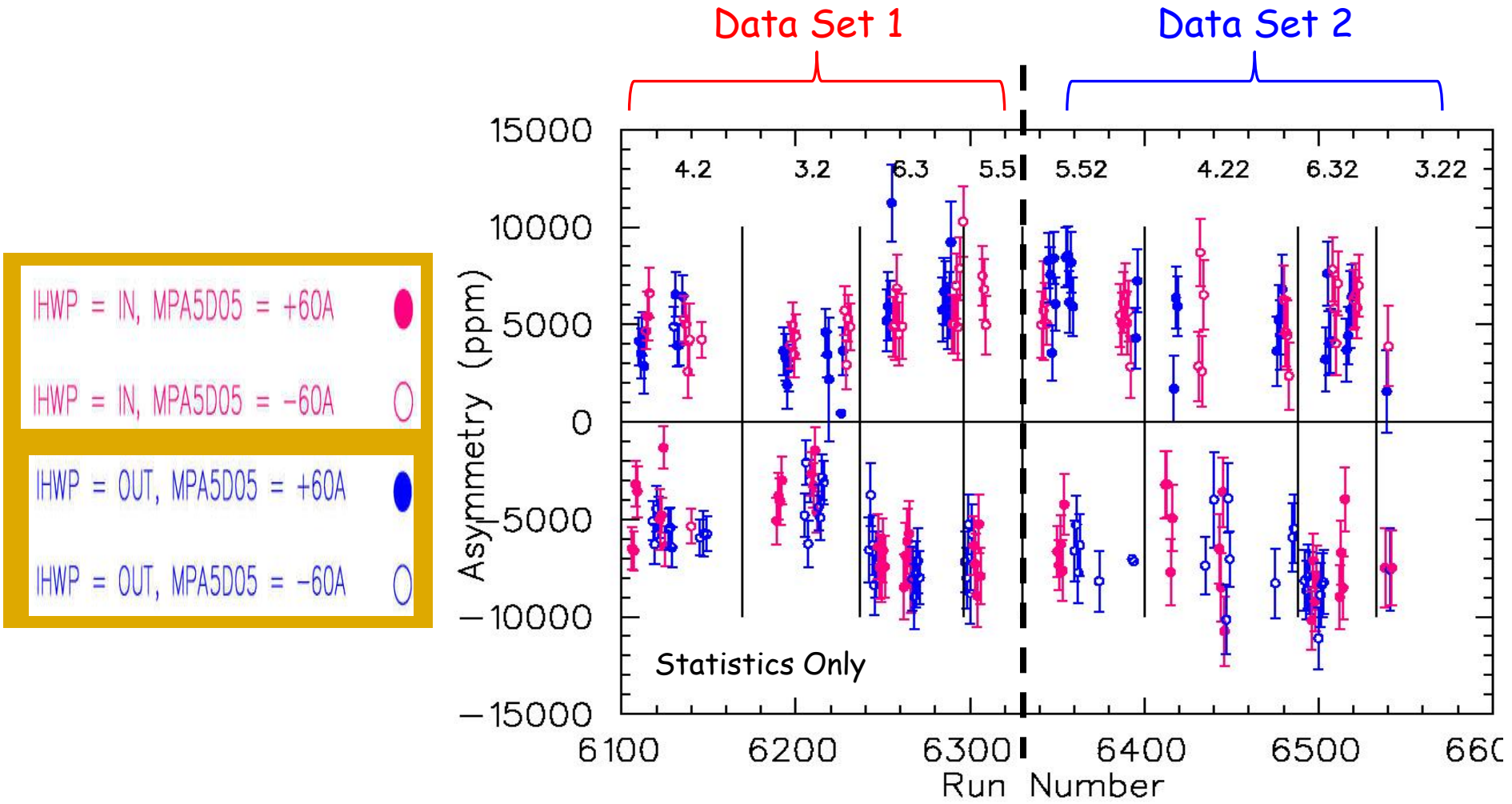




Compton Energy Spectrum (Set 1 v. Set 2)



Positron Compton Data in Two Acts…



Data Set 1: Preliminary pass over e+ collection momenta

Data Set 2: Improved shielding, coincidence timing & spectrometer PS stability

Preliminary Results of Positron Raw Asymmetry

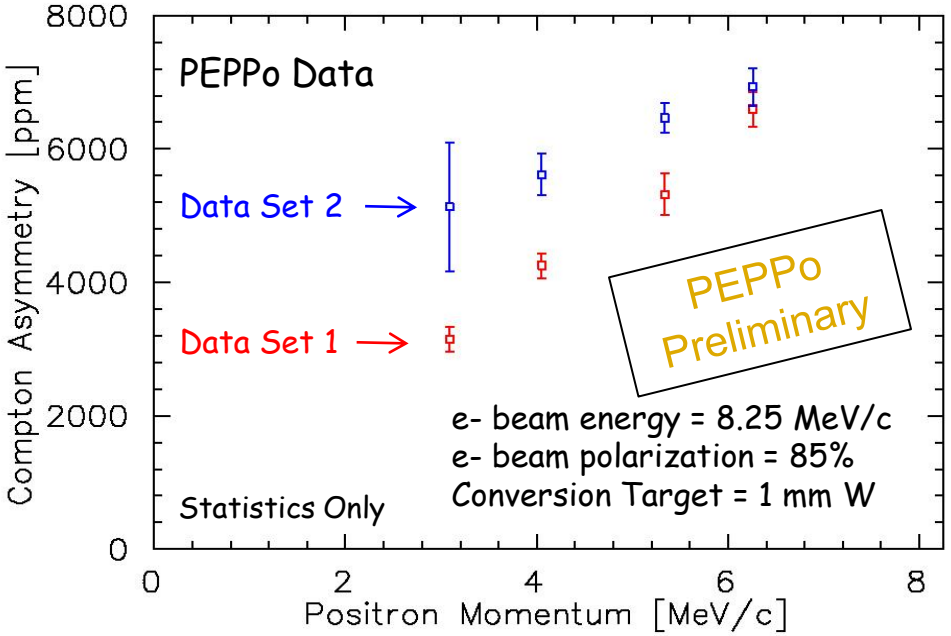
$$A_{Compton} = P_{e^+} \mathcal{P}_T \cdot A_{e^+}$$

Data Set 1

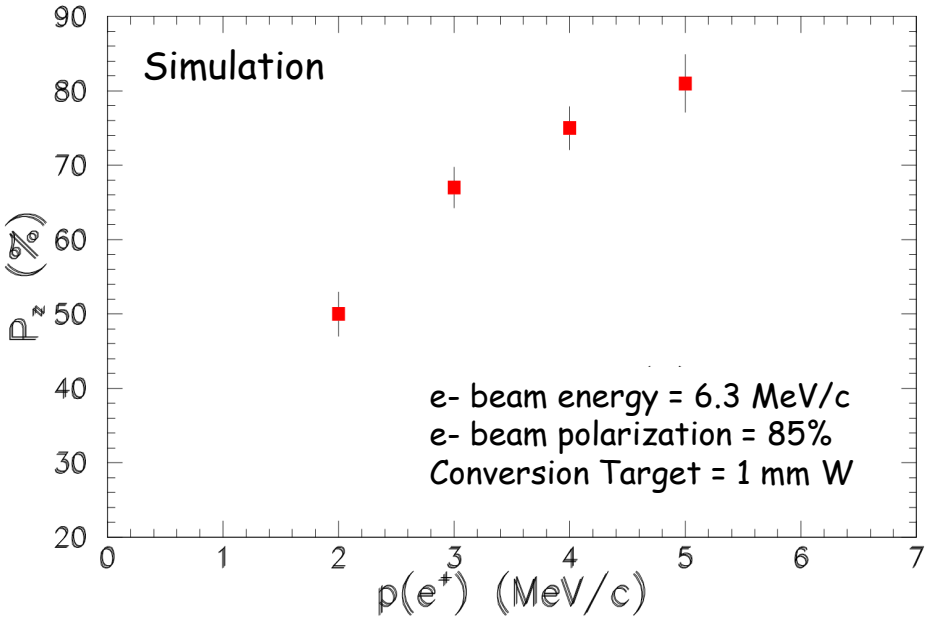
Preliminary pass over e+ collection momenta

Data Set 2

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



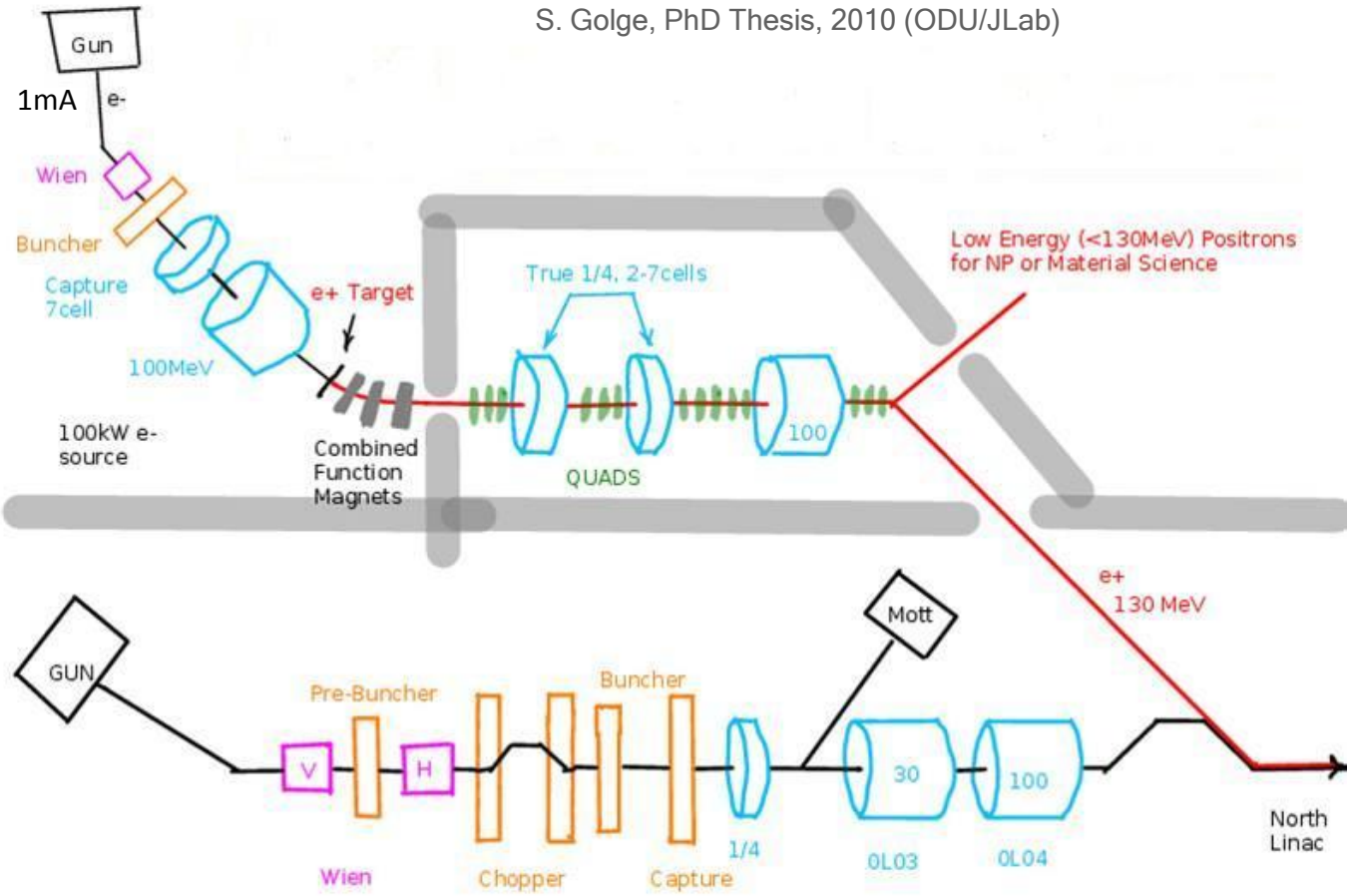
Operated experiment with somewhat higher electron beam momentum to improve yield



Positron Source Concept at CEBAF

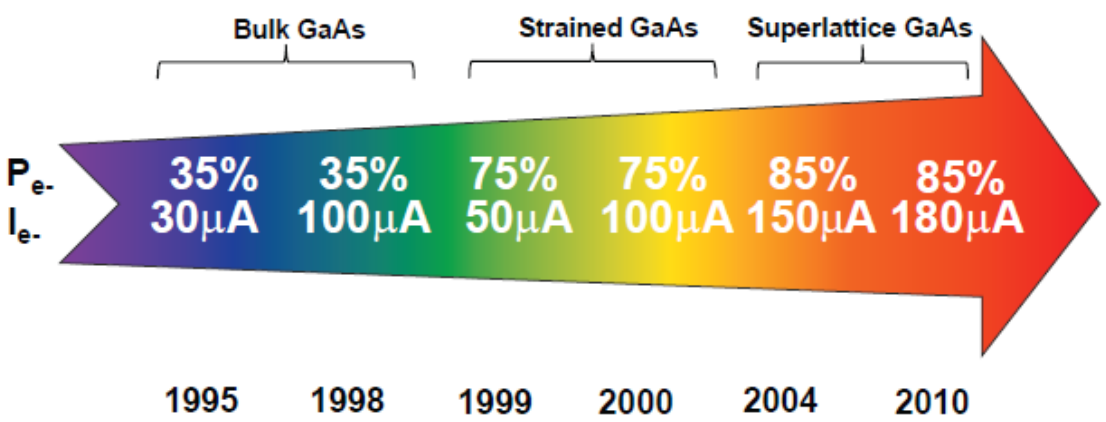
A. Freyberger at the Town Hall Meeting, JLab, 2011

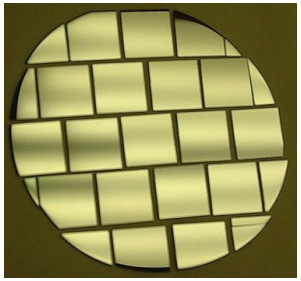
S. Golge, PhD Thesis, 2010 (ODU/JLab)

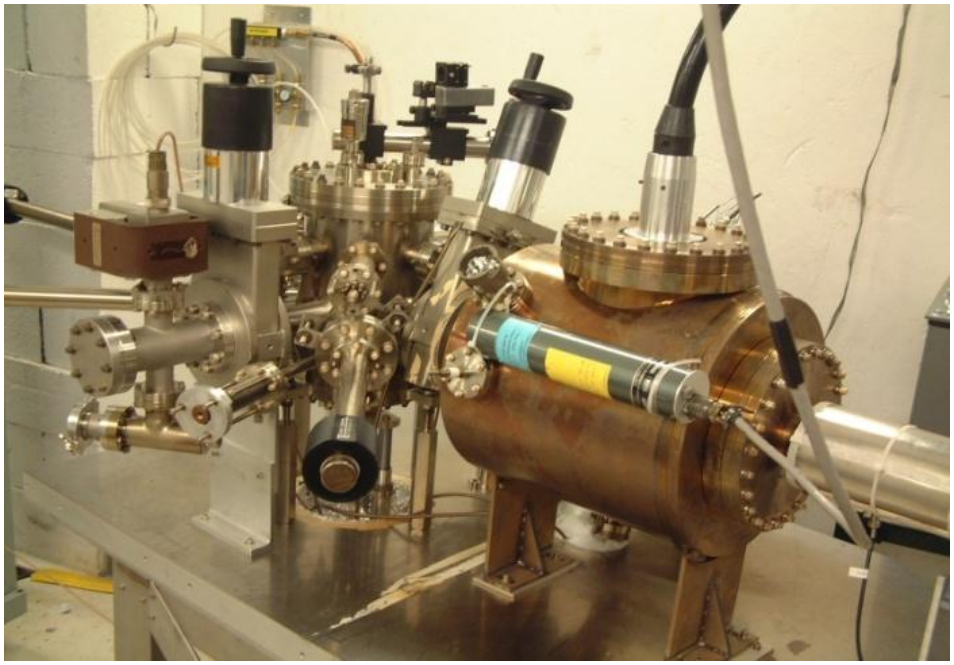


I = 300 nA
P_{e+} = 75%
$\delta p/p = 10^{-2}$
ε_x = 1.6 mm.mrad
ε_y = 1.7 mm.mrad

Suitable High Current Polarized Electron Source

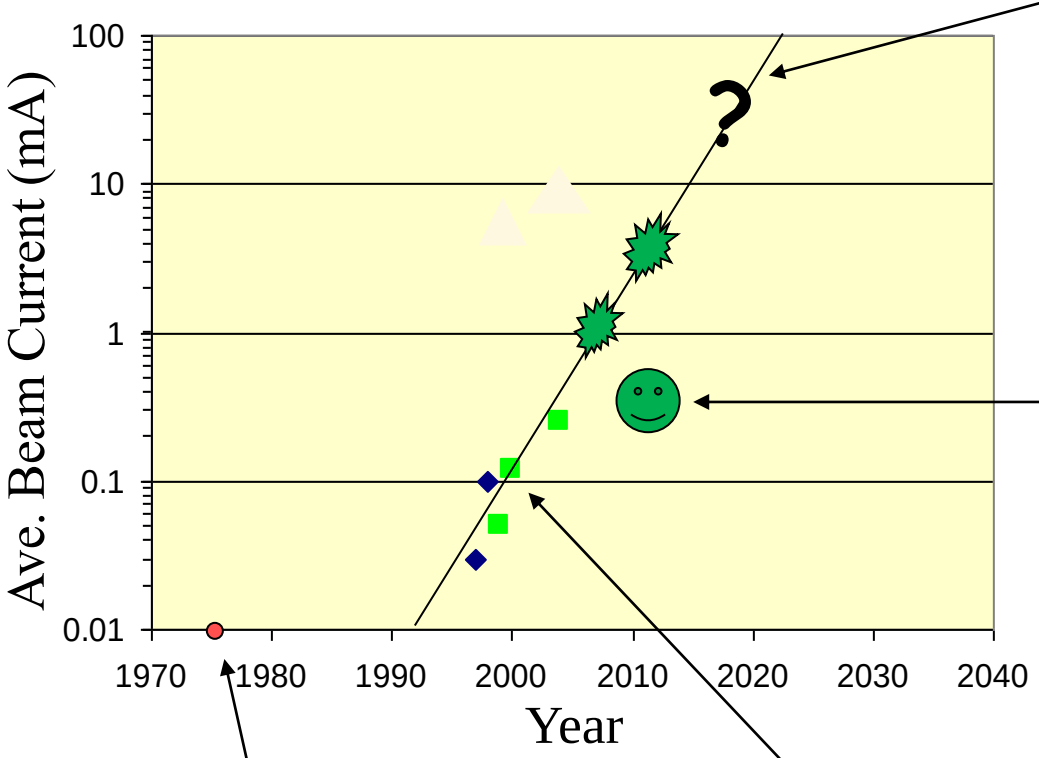


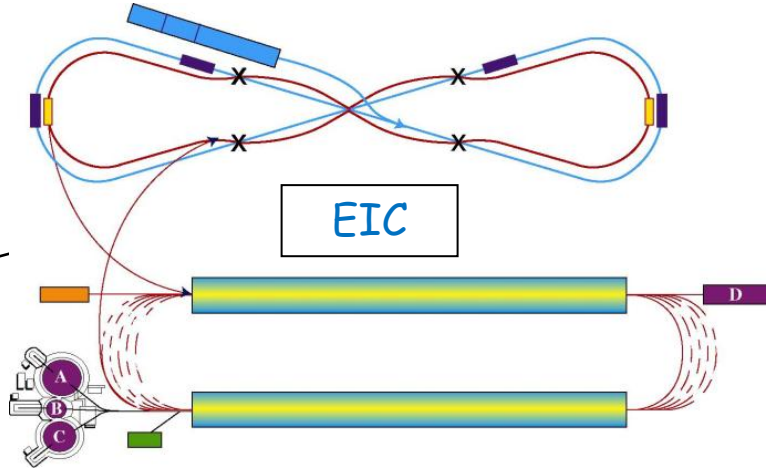


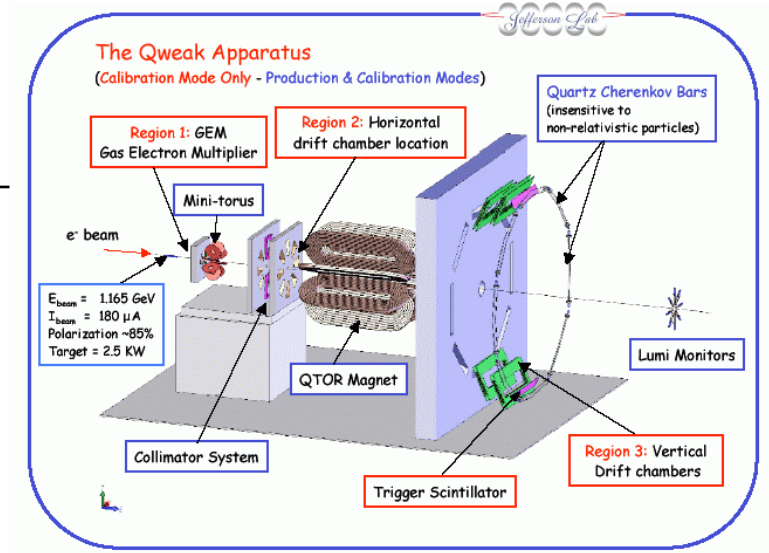


R. Suleiman et al., PAC'11, New York (NJ, USA), March 28 - April 1, 2011

Parameter	Value
Laser Rep Rate	1500 MHz
Laser Pulselength	50 ps
Laser Wavelength	780 nm
Laser Spot Size	350 μm FWHM
High-Pol Photocathode	SSL GaAs/GaAsP
Gun Voltage	200kV DC
CW Beam Current	**4 mA**
Run Duration	**1.4 hr**
Extracted Charge	20 C
1/e Charge Lifetime	85 C







First polarized beam from GaAs photogun

Trending @ JLAB
- Bulk GaAs
- Strained/Superlattice GaAs-GaAsP

Summary and Plans

✓We had a successful commissioning and run period (no show stoppers, few hiccups)

✓Used Compton polarimeter to measure polarization of electrons so that we may carefully prepare and develop model for positron analyzing power

✓Used 8MeV polarized e- beam to produce positrons and collected them with few percent momentum spread as a "beam" on polarimeter from 3-6 MeV/c

✓Used Compton polarimeter to measure experimental asymmetries while using helicity reversal (30Hz) and slow systematic reversal (laser waveplate & analyzer magnet for target polarization)

✓Lots of data "in the can"; aiming to publish results first half of 2013

A natural "next step" after PEPPo would be an experimental test of the **optimization** of a **positron collection** system and a scheme to **define the phase space** of the **positron beam** for **CEBAF acceleration**.