Possibilities for Positron Beams at JLab

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e^+ historical ramblings

e^+ Discovery and Initial Science

1930 Postulated by P.A.M.Dirac† to avoid *negative energy* terms in his theory.

1932 Discovered in cloud chamber exposed to cosmic rays by Carl Anderson†

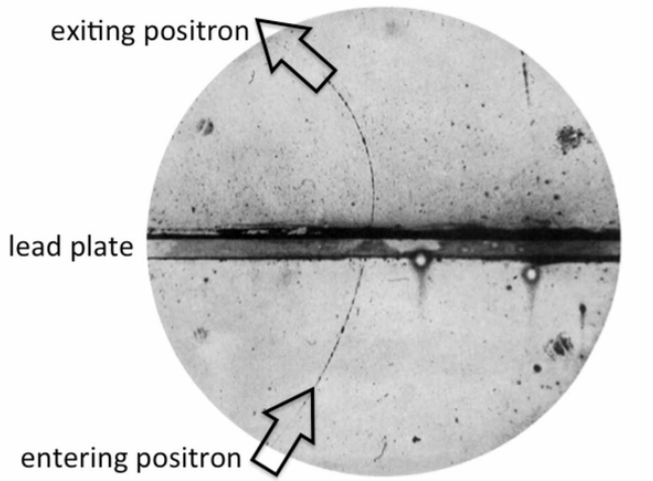
- e^+, ^{4}He (and Dark Matter?) examples of non-terrestrial discoveries of new types of stable matter.

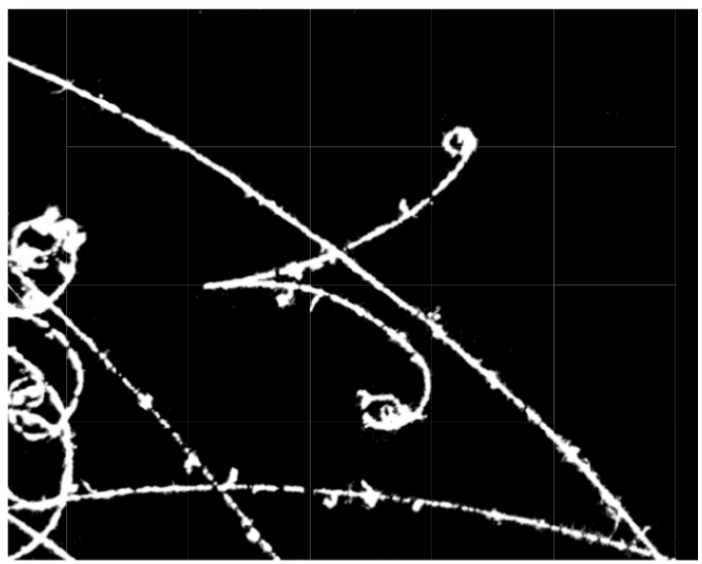
1933 Pair production discovered by Blackett† and Occhianlini

- Blackett's Nobel prize was for the development of the *trigger'd* cloud chamber used in the study of cosmic rays.

1934 Prediction of Positronium (*Ps*), Mohorovicic

1951 Discovery of *Ps*, Deutsch





e^+ Accelerators

1961 First e^-e^+ collider, AdA, Frascati, constructed

1963 AdA first 250 MeV e^-e^+ collisions

1964 VEPP-II 700 MeV e^-e^+ collisions, first physics results for e^-e^+ collisions in 1966.

1965 ACO, Orsay, 500 MeV e^-e^+, first results in 1996.

1972 SPEAR, SLAC e^-e^+ collisions for particle physics

- 1974 $\Psi(/J)$ discovery†
- 1975 τ lepton discovery†

1972... DORIS, PETRA, CESR, PEP, SLC, BEPC, LEP, **DAΦNE**, KEKB, PEP-II

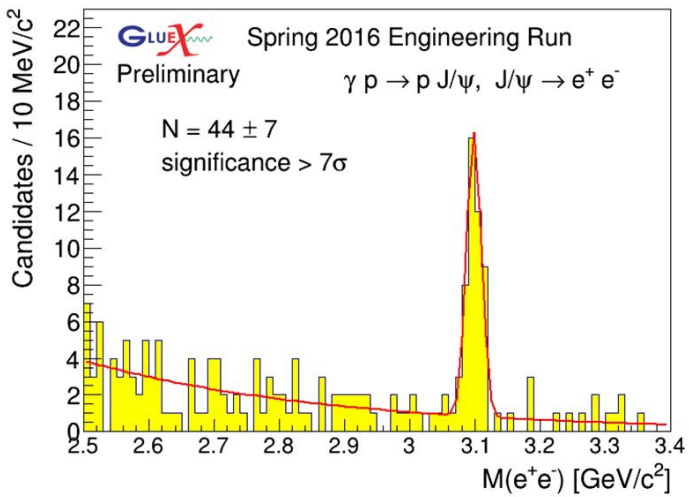
2003 **VEPP-2000**

2018 **Super-KEKB**

???? ILC

ADA on display in Frascati:

J/Ψ comes to JLAB!:



Summary of high energy e^+ accelerators to date

- Majority of e^+ accelerators have been developed for e^-e^+ collision with most being storage rings (SLC is a notable exception, includes a *damping ring* to reduce the positron beam emittance).
  - In a storage or damping ring the e^+ beam reaches an equilibrium which defines its parameters prior to collisions.
- Most (All?) of the e^+ beam experience has been with pulsed injectors into storage rings.
  - Initial target elements pulsed (sync'd) with beam repetition rate to reduce power deposition/cooling requirements.
  - Target element provides e^+ production, collection and initial transport.
- The number of e^-e^+ accelerators is shrinking, expertise might become scarce.

SLC e^+ target (circa 1988):

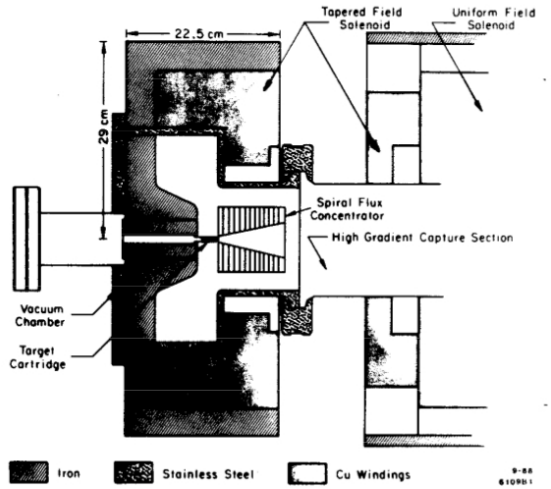
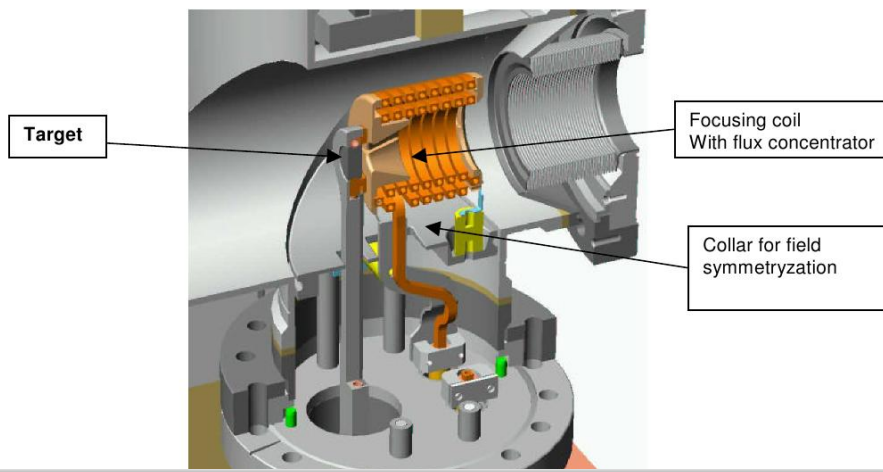


Fig. 1. Cross section of positron target assembly.

CESR e^+ target:



e^+ Activities at JLab

e^+ and JLab

1994 *Positrons at CEBAF*, W.J. Kossler, A.J. Greer and L.D. Hulett. Room temperature e^+ for materials science, using the FEL as a driver.

1999 Mini-workshop on e^+/e^- Physics at Jefferson Lab.

2000 LOI generated for PAC.

2004 μ-workshop on Positron Physics

2009 International Workshop on Positron at Jefferson Lab (JPOS09).

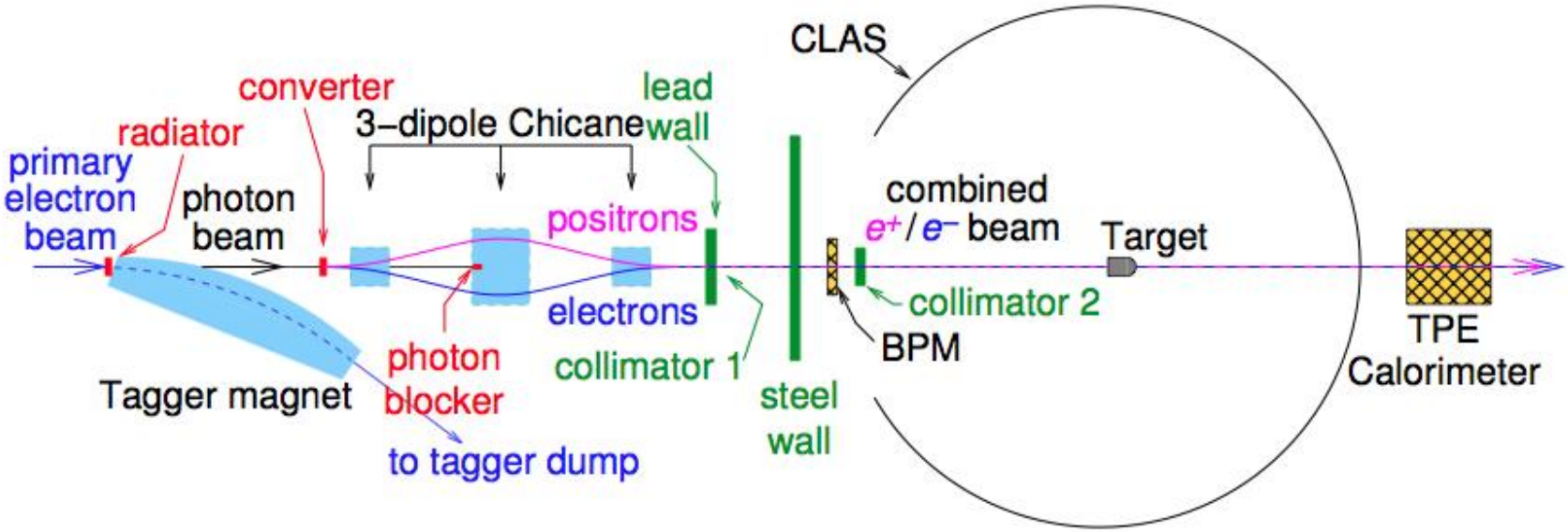
2010 E07-005, 2γ exchange experiment in Hall-B

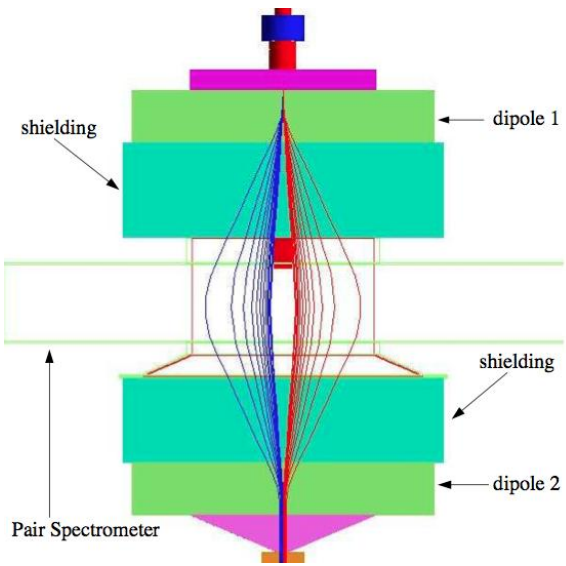
2011 Polarized Electrons for Polarized Positrons (PEPPo) experiment approved by PAC38.

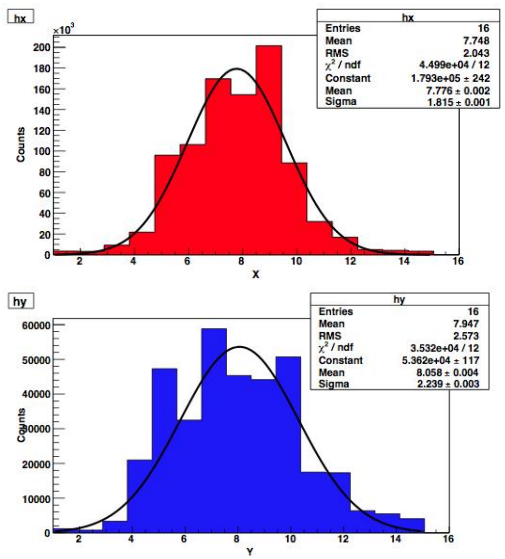
2017 International Workshop of **Physics** with Positrons and Jefferson Lab (JPOS17).

2018 LOI12-18-004, Physics with Positron Beams at Jefferson Lab 12 GeV submitted to PAC46

E07-005: 2γ exchange experiment







$e^{\pm}$ horizontal profile:
$RMS_x = 2$ mm
$e^{\pm}$ vertical profile:
$RMS_y = 2.6$ mm

- 770 W and 5.5 GeV primary e^- beam power and energy
- Production generated a bit of radiation

Recent e^+ at JLab

2004 *Feasibility and Conceptual Design of a C.W. Positron Source at CEBAF*, Serkan Golge, Ph.D. Thesis, Old Dominion University, USA.

2006 *Feasibility Studies of a Polarized Positron Source Based on Bremsstrahlung of Polarized Electrons*, J. Dumas, Ph.D. Thesis, University of Genoble, France.

2011 Polarized Electrons for Polarized Positrons (PEPPo) experiment approved by PAC38.

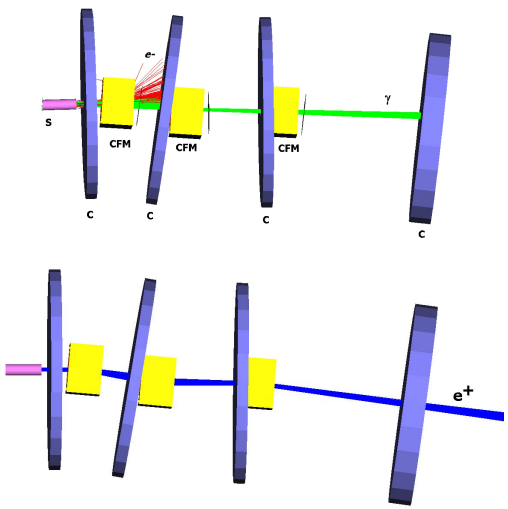
2012 PEPPo collects data during 12 GeV Upgrade installation.

2014 PEPPo publishes in Phys. Rev. Lett. 116 (2016) 214801

2014 SBIR Phase I for high power target approved (NIOWAVE), Phase IIa approved in 2015, **but Phase IIb not approved**.

2016 *Demonstration of Polarized Positrons Based on the Bremsstruhlung of an 8 MeV Polarized Electron Beam*, A. Adeyemi, Ph.D. Thesis Hampton University, USA.

Serkan's CW e^+ production and collection concept:



Dumas's simulation of $e^- \rightarrow e^+$ polarization transfer:

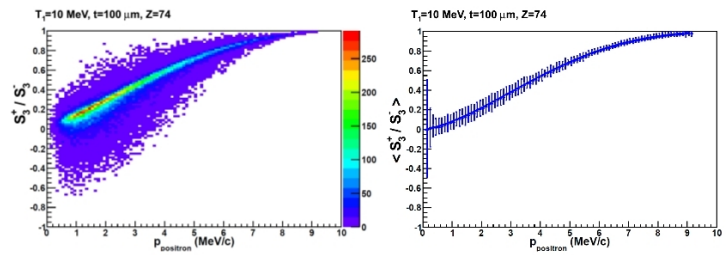
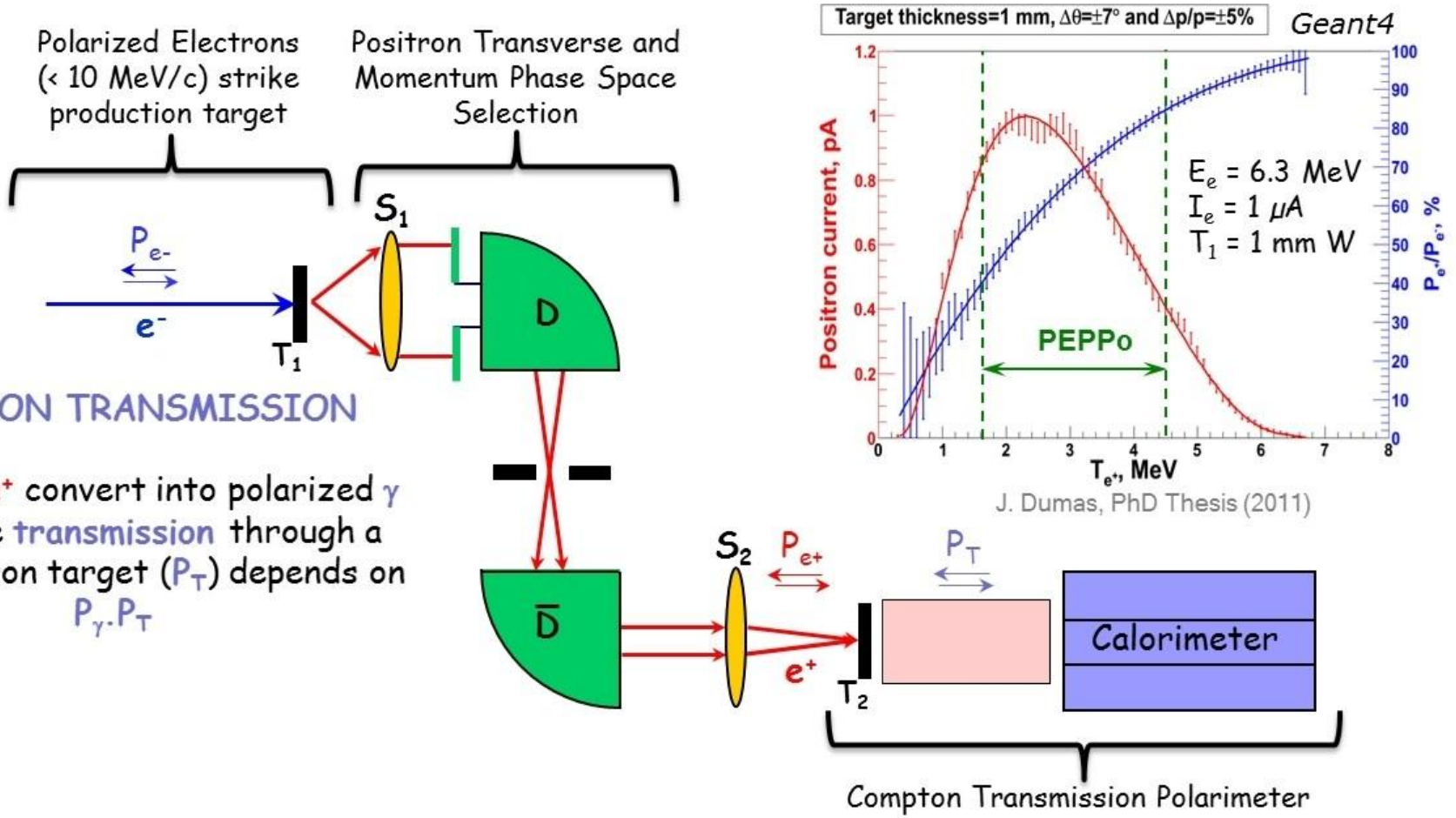


Figure 2.19: Distribution of the longitudinal polarization component of forward positrons from 10 MeV longitudinally polarized electrons off a 100 μm tungsten target (left) and average polarization distribution (right) as a function of the positron momentum.

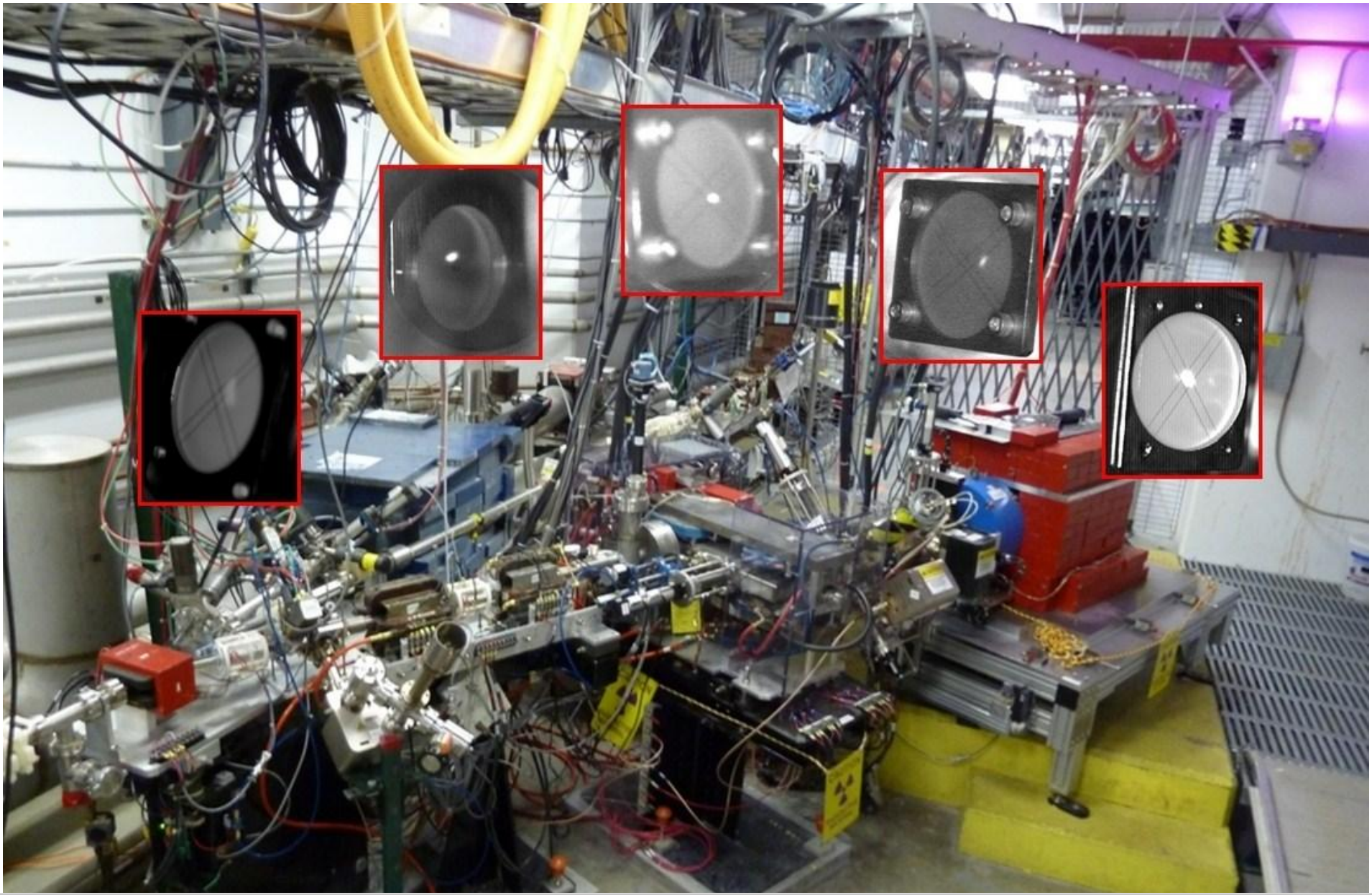
Principle of Operation



PEPPo measured the longitudinal polarization transfer in the 3.1-6.3 MeV/c momentum range.

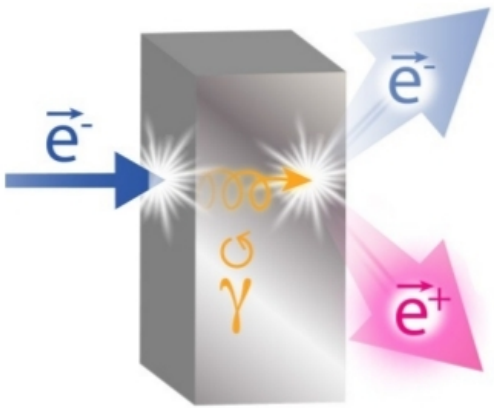
PEPPo!

Experiment ran early Summer 2012

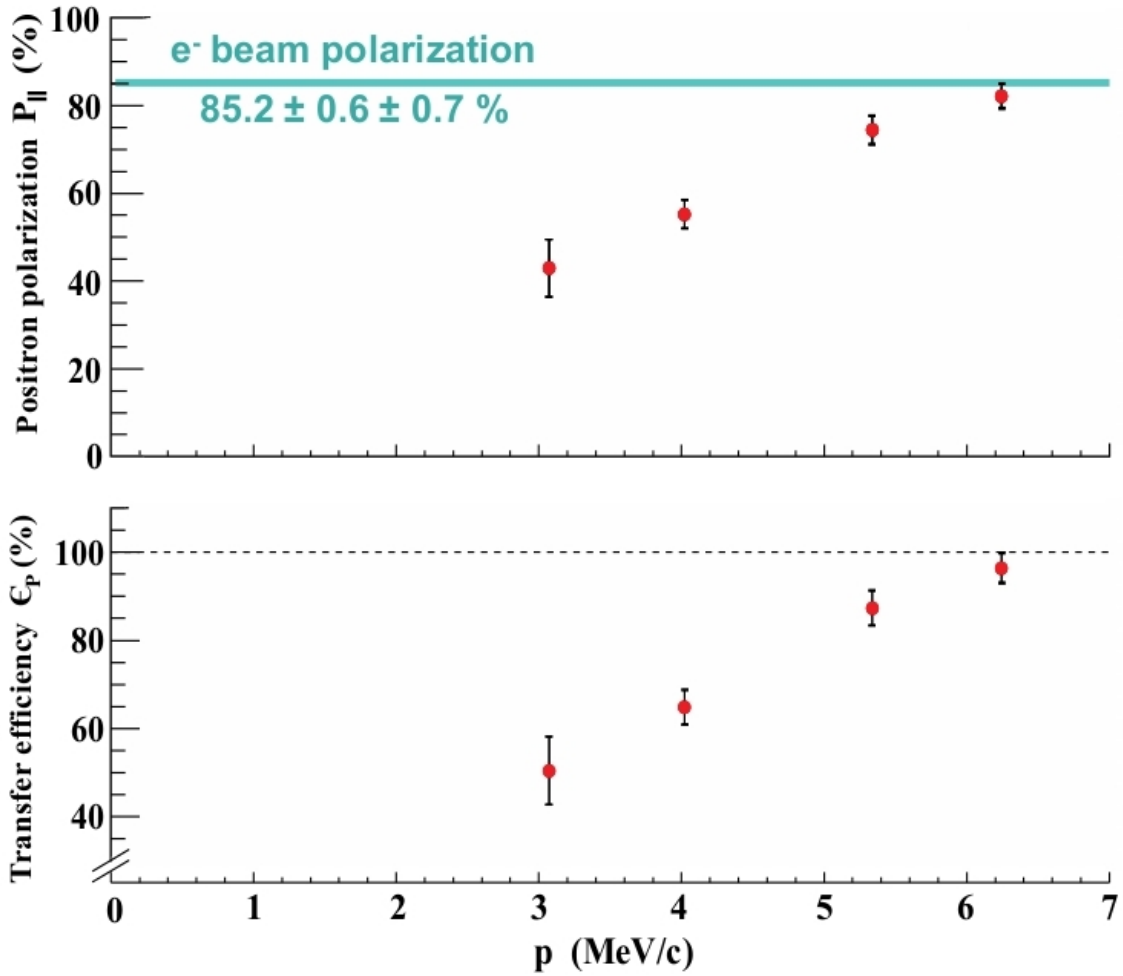


PEPPo!
Published in 2014

Electron polarization (~85%) efficiently transferred from 8.2 MeV/c electron beam to positrons (measured 3.2 – 6.7 MeV/c).



Whenever producing e^+ from e^-, polarization is coming for free if initial electrons are polarized.



(PEPPo Collaboration) D. Abbott et al., Phys. Rev. Lett. 116 (2016) 214801

If you would like to participate in the newly formed Jefferson Lab Positron Working Group please visit: wiki.jlab.org/pwg

e^+ at JLab Challenges

What makes e^+ CEBAF special?

Polarization Without the benefit of Ternov-Sokolov effect of a storage ring.

- **This has been resolved and demonstrated with the PEPPo experiment.**

CW CEBAF is a CW machine, tune-mode (60 Hz) available for tuning.

- This has an impact on the target collection design as the elements must be CW, not pulsed.

One-stage production Lack of accumulator rings and other stacking options, result in a very large incident beam flux to generate the desire e^+ yield. deposition in the target.

- This has implication on the e^- source, beam currents up to 1 mA (perhaps even 10 mA).
- Target must withstand high power (100 - 1000 kW). Existing designs are for $\approx$10 W average beam power.

SRF The positron beam parameters must be acceptable to the CEBAF SRF structures.

- Core of the beam must be cleanly transported through the SRF structures.
- Beam must be halo free enough so that any deposited energy in the SRF volume is acceptable.

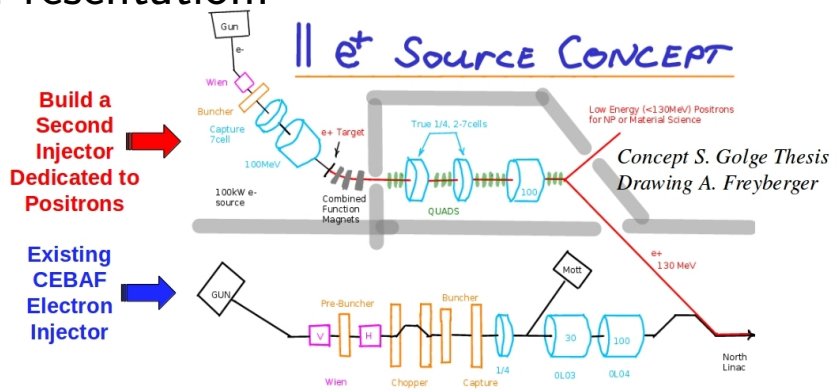
CEBAF Concepts are many

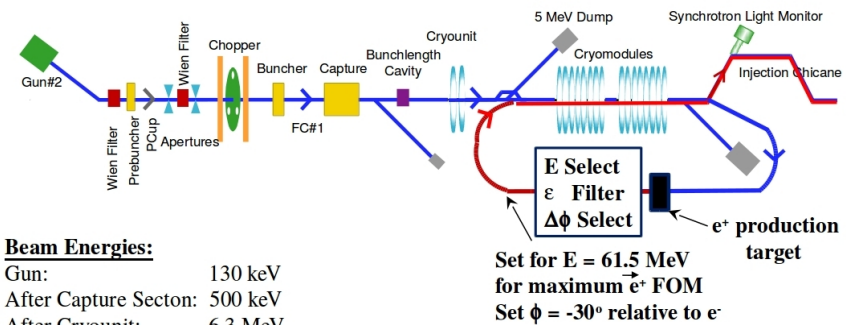
- No shortage of concepts:
  - Parallel e^- source and with e^+ production, capture and initial acceleration.
  - Injector recirculator to make use of existing e^- source.
  - Anti-parallel e^+ operation
- Simulations of the various concepts to date suggest that the CW polarized e^+ source can be built to meet the CEBAF requirements.

Some remaining questions are:

- What is the e^+ yield in an optimized CW target and captured system? Measurement and simulation!
- What is the E, ε and $\Delta\Phi$ filter design and how well does it work?
- Demonstrate the resulting e^+ beam is suitable for SRF acceleration.

From L. Cardman's JPOS17 Presentation:





Beam Energies:

Gun:	130 keV
After Capture Secton:	500 keV
After Cryounit:	6.3 MeV
After Cryomodules:	123 MeV

- Key apparatus (the **E Select, ε Filter, and Δϕ Select** in the figures above, the production target, and the associated electron beam dump) should be designed and built

Summary

Summary

- e^+ beams have been in use since 1964
- e^+ source driven by CEBAF or FEL e^- beam has been discussed since 1994
- Latest Physics case for e^+ has been submitted to PAC46 (LOI12-18-004)
- Conceptual designs and Ph.D theses on e^+ source for CEBAF have been developed and discussed at several workshops.
- $e^- \rightarrow e^+$ polarization transfer has been successfully demonstrated by the PEPPo experiment.
- The proposed e^+ source in CEBAF would be novel:
  - CW source of e^+
  - Longitudinally polarized e^+
  - High power incident target, x10-100 beyond nominal storage ring sources.
  - SRF linac post-creation acceleration.
  - mA current e^- polarized electrons

In order to push beyond conceptual design and simulations, a comprehensive R&D plan for the e^+ needs to be developed, supported by Lab Management and successfully executed. This R&D effort will require resources from the Acc. and Eng. (Physics is welcome as well) division, use of LERF (and CEBAF) beams.

Stop!

- Thanks to the graduate students, Golge, Dumas, Adeyemi, Adikaram whose theses provided the graphics for many of these slides.
- Thanks to Joe Grames for the opportunity and organization of JPOS09 and JPOS17
- Thanks to the JPOS09 and JPOS17 presenters for providing a rich resource to draw upon.