# Polarized positrons at JLab

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May 6, 2010

1. Motivations for a $\vec{e}^+$ source
2. Physics of polarization transfers
3. PEPPo experiment

# $\vec{e}^+$ uses

## JLab

DVCS (6-12 GeV): polarized beam charge asymmetry

$$d^5\vec{\sigma}^- - d^5\vec{\sigma}^+ = \mathcal{T}_{BH}\Re e[\mathcal{T}_{DVCS}] + P_l \times \mathcal{T}_{BH}\Im m[\mathcal{T}_{DVCS}]$$

## Colliders

ILC/CLIC (TeV): $\overrightarrow{e}^- \overrightarrow{e}^+$ affects effective luminosity.

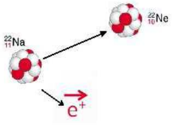
$$L_{eff} = (1 - P_{e^-}P_{e^+}) \times L_0$$

## Material science

Spin-polarized positron spectroscopy (eV-MeV): $\overrightarrow{e^+}$ annihilation to study the magnetic properties of ferromagnetic materials.

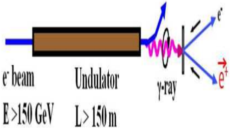
# $\vec{e}^+$ sources

Polarized beta-plus decay:
used in material science



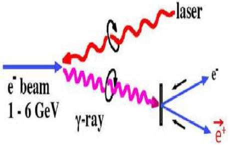

A. Kawasuso, M. Maekawa, ASS 255 (2008) 108

Helical undulator:




G. Alexander et al. PRL 100 (2008) 210801

Compton scattering:




A. Kuriki et al. AIP Conf. Proc. 980(2008) 92

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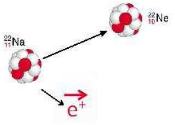


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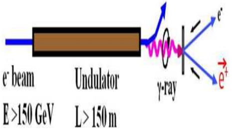


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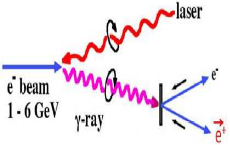



A. Kuriki et al. AIP Conf. Proc. 980(2008) 92

JLab: demonstration experiment for polarized positrons from polarized bremsstrahlung in a foil.

$$\vec{e}^- \xrightarrow{\text{Bremsstrahlung}} \vec{\gamma} \xrightarrow{\text{Pair production}} \vec{e}^+$$

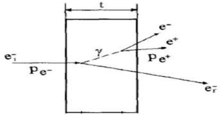
E.G. Bessonov, A.A. Mikhailichenko, EPAC96, 1516

# $\vec{e}^+$ source based on $\vec{e}^-$ beam

e+ source based on longitudinally polarized electron source

$\vec{e}^- \xrightarrow{\text{Brem}} \vec{\gamma} \xrightarrow{\text{Pair}} \vec{e}^+ \ \vec{e}^-$

E.G. Bessonov, A.A Mikhailichenko, EPAC96, p. 1516-1518





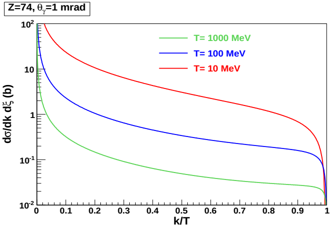
All operating with suitable photocathode lifetime to sustain weeks of operation

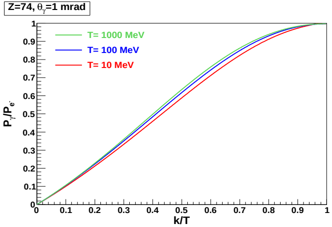
J. Grames et al., in Proc. of the 2007 Particle Accelerator Conference, p. 3130

Development of high-P, high-I e- sources over last 2 decades offer capability to be a ~1 MW beam driver for a polarized e+ source at CEBAF injector (10-100MeV)

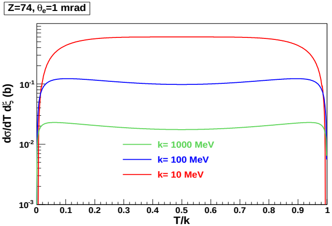
# Cross sections/Olsen & Maximon's polar. transfers in W

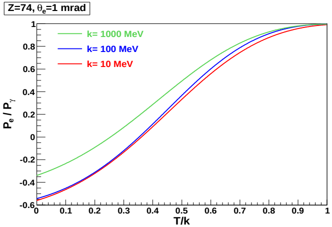
## Bremsstrahlung:




## Pair Creation:

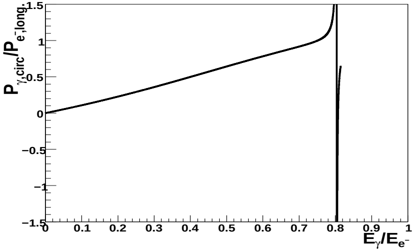


# Low energy polarization transfers (3 MeV)

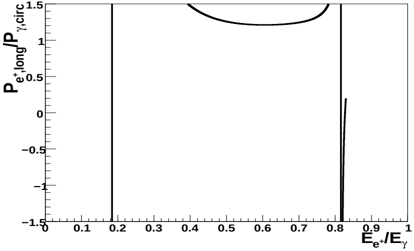
Bremsstrahlung

$\theta_\gamma = 0.41$ mrad




Pair Creation

$\theta_{e^+} = 0.41$ mrad




Unphysical results

Polarization transfers have recently been recalculated for low energies

E. Tomasi-Gustafsson, E. Kuraev

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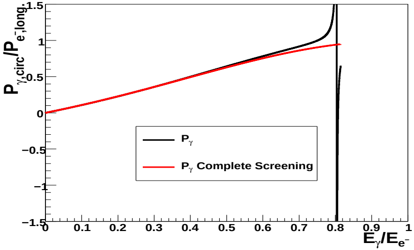


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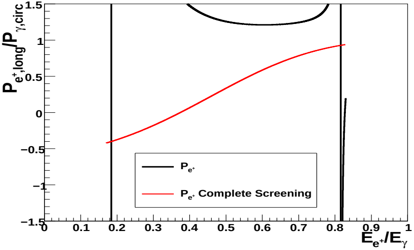


Unphysical results $\Rightarrow$ Correction: $-1 < P_{e^+,long} < 1$

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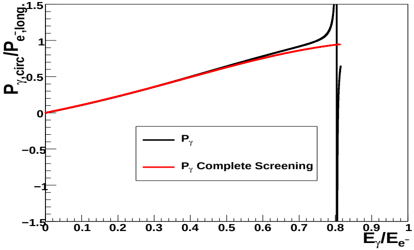


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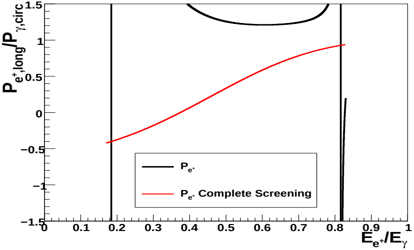


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Simulations are performed with a correction of the screening for low energy particles

# $\vec{e}^- \longrightarrow \vec{\gamma} \longrightarrow \vec{e}^+$ simulations

Positron production and polarization simulations with Geant4

Implementation of Olsen & Maximon's polarization transfers.
+ Cross-sections
+ Depolarization due to other processes
(Moller, Bhabha, Compton scattering, ionization ...)

R. Dollan, K. Laihem, A. Schälicke, NIM A559 (2006) 185

$\Rightarrow$ Study of polarization transfers

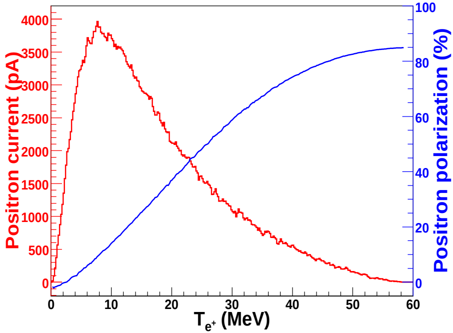
Thin target (100$\mu$m) to prevent depolarization

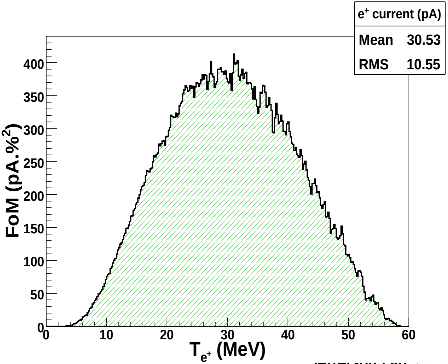
# $\vec{e}^- \longrightarrow \vec{e}^+$

$T_{e^-} = 60 MeV, \; P_{e^-} = 85\%, \; I_{e^-} = 1 mA$

Simplistic cuts: $\Delta\theta_{e^+} = \pm 10^\circ$ and $\Delta E_{e^+} = \pm 0.25$ MeV

$$\text{FoM} = I_{e^+}\ [\text{pA}] \times (P_{e^+,long})^2\ [\%^2]$$

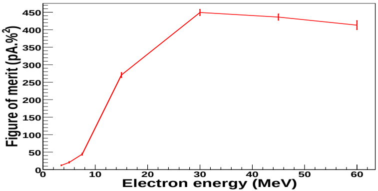


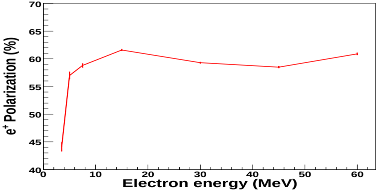
# Positron FoM vs $E_{e^-}$

Acceptance: $\Delta\theta_{e^+} = \pm 10^\circ$ and $\Delta E_{e^+} = \pm 0.25$ MeV

$FoM_{e^+}$




$P_{e^+}$

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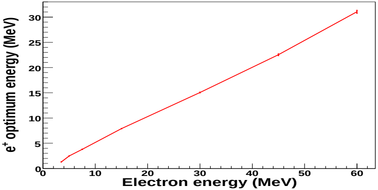
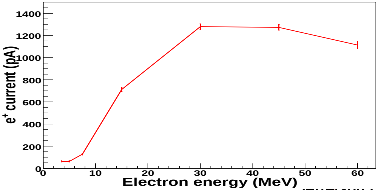


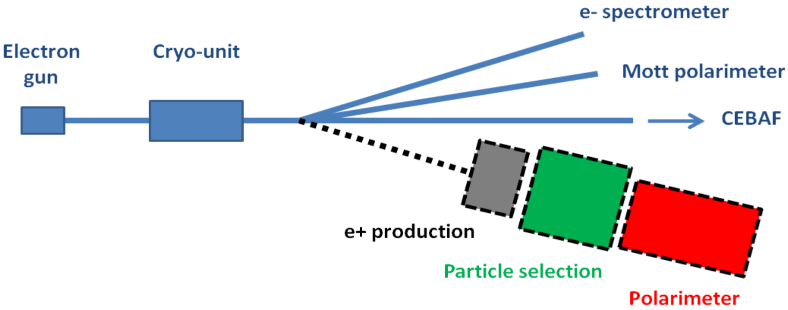

$I_{e^+}$



# PEPPo experiment

Proposal:

- Demonstration of $\vec{e}^+$ production with $\vec{e}^-$ at low energies.



# PEPPo experiment

## JLab injector:

- Momentum: 2-8 MeV/c
- Current: $\sim \mu$A
- Polarization: 85 %

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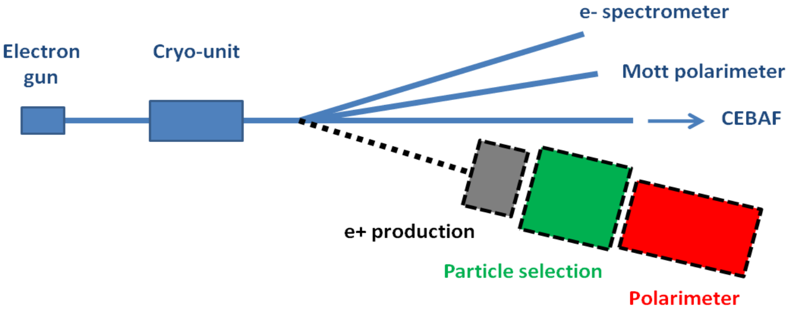
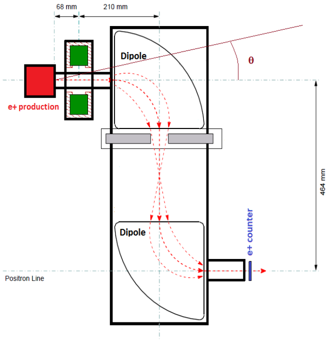


# Positron production and selection




Positron production:

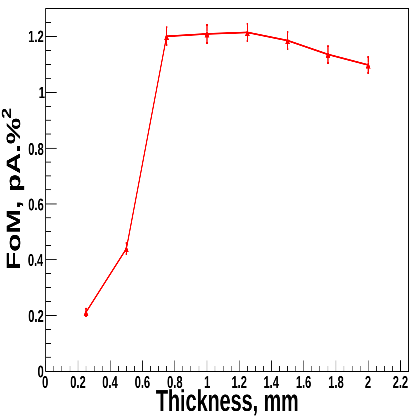
- W target thickness for optimized $e^+$ FoM

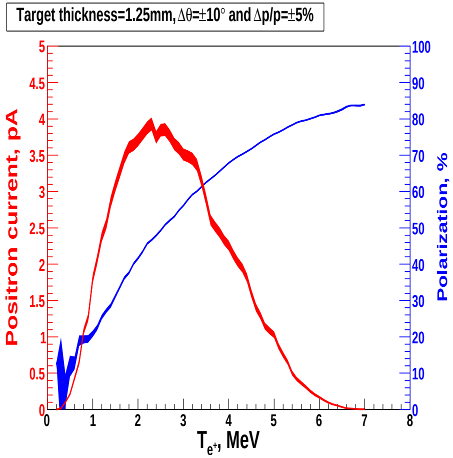
Positron selection:

- Solenoid for $e^+$ collection $\Delta\theta \ \pm 10\circ$
- Electrons and photons separated from positrons
- 2 dipole spectrometer to cancel spin precession
- $\pm 5\%$ energy bite

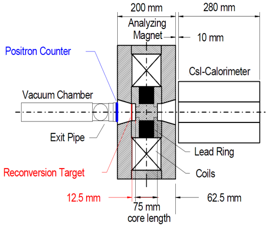
# Target thickness optimization at 8 MeV/c

$FoM_{e^+}$



# Polarimetry (1/2)




## Compton transmission:

- Reconversion target $\rightarrow \vec{\gamma}$
- $P_\gamma$ is a function of $P_e$
- $P_e = \frac{\delta}{P_t . A_e}$

## Compton cross section:

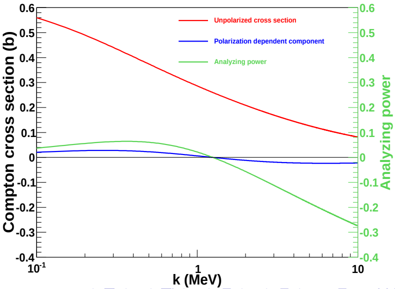
- $\sigma_{C.}(k) = \sigma_0(k) + P_\gamma P_t \sigma_{pol.}(k)$

## Transmission:

- $T^{\pm}(k) = e^{-nL\sigma_{C.}(k)}$

## Asymmetry:

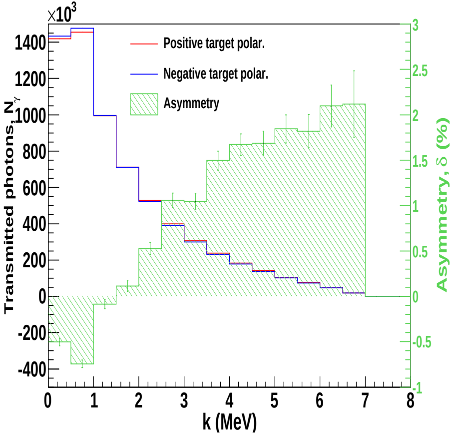
- $\delta = \frac{T^+ - T^-}{T^+ + T^-} = nLP_\gamma P_t \sigma_{pol.}(k)$



# Polarimetry (2/2)

Calibration: Geant 4 simulation to determine beam time necessary for precision measurement of $e^-$ beam polarization.

$I_{e^-}$ =1 pA, $p_{e^-}$ =8 MeV/c, $P_{e^-}$ =85% and t=100s




- $P_e^k = \frac{\delta}{P_t A_e^k}$
- $\partial P_e^k = \frac{\partial \delta}{P_t A_e^k}$
- $\Delta P_e = \sqrt{\frac{1}{\sum (1/\partial P_e^k)^2}}$

**Simulation says:**

$\Delta P_e = 2\%$ for t=100s

# Conclusion

- Polarized electrons for polarized positrons was perhaps not tested because of limited electron sources.
- Development of $\vec{e^-}$ sources offers $P = 85\%$ and sustainable mA currents possible.

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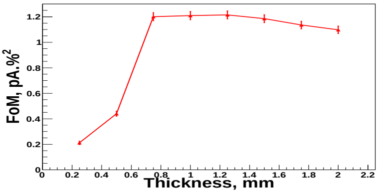
- Development of $\vec{e^-}$ sources offers $P = 85\%$ and sustainable mA currents possible.
- Simulations: $e^+$ yield $\sim$ pA and $P_{e^+} \sim 60\%$ for 1 $\mu$A of JLab electron beam
- Peppo for demonstration experiment

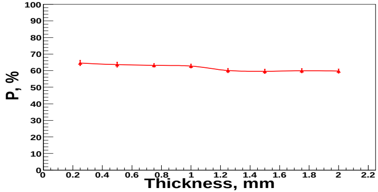
# Source characteristics vs target thickness

Acceptance: $\Delta\theta_{e^+} = \pm 10^\circ$ and $\Delta p/p = \pm 5\%$

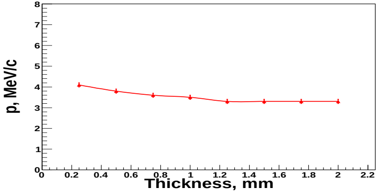
$FoM_{e^+}$




$P_{e^+}$




$p_{e^+}$

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