Polarized Positron Source at JLab

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JPOS09, March 25-27, 2009

1. Motivations for a $\vec{e}^+$ source at JLab
2. Polarization transfer from $\vec{e}^-$ to $\vec{e}^+$
3. Source considerations
4. Demonstration experiment at CEBAF

$\vec{e}^+$ uses

Material science

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

CEBAF

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

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

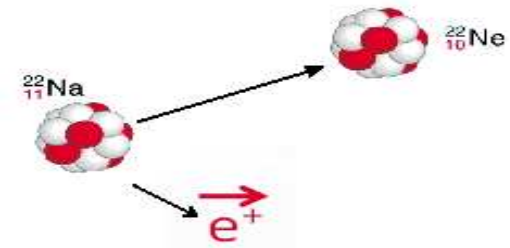
Colliders

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

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

$\vec{e}^+$ sources

- Polarized beta-plus decay:
  used in material science



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

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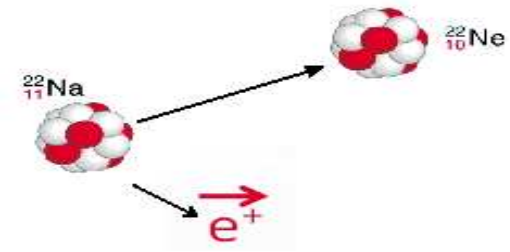

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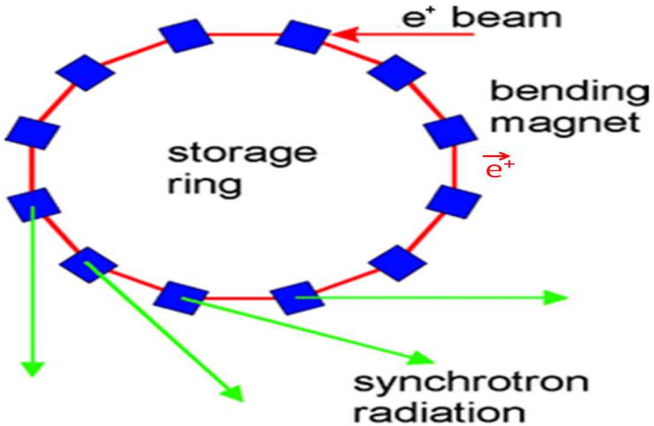
- Storage ring: HERA



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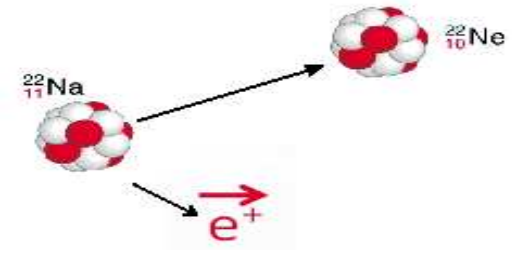

A. Kawasuso, M. Maekawa, ASS 255 (2008) 108

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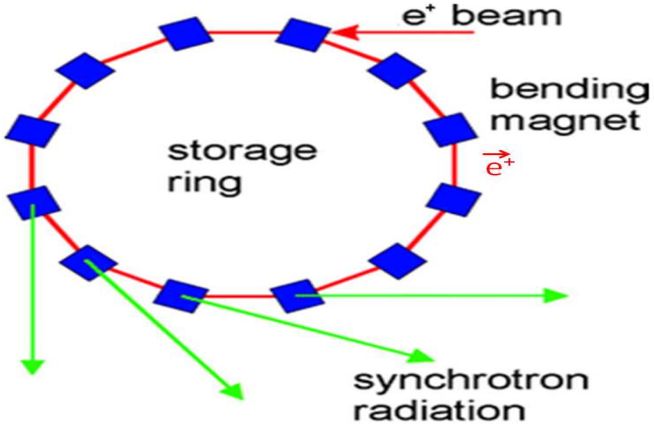
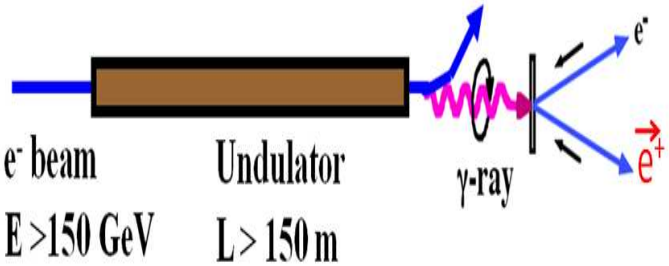


- Helical undulator: colliders



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

$\vec{e}^+$ sources

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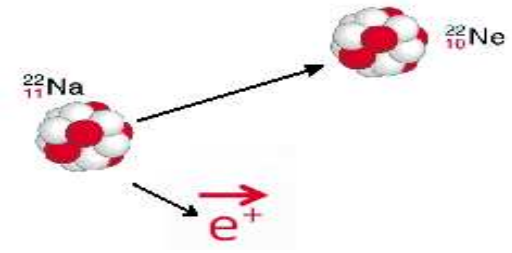
  used in material science



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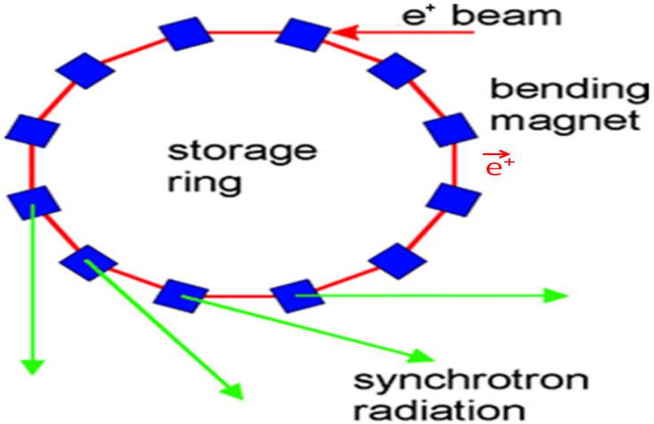

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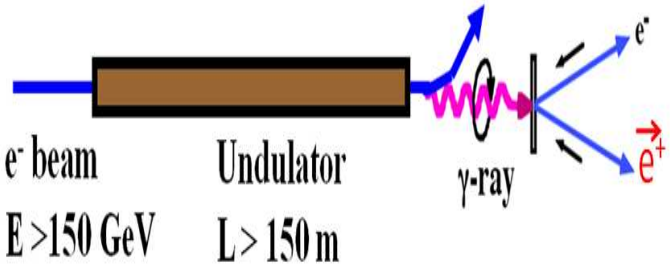
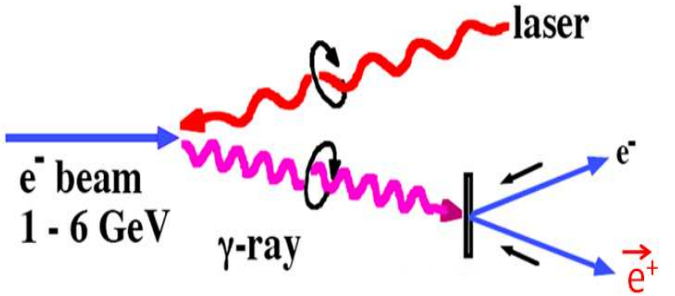


G. Alexander et al. PRL 100 (2008) 210801

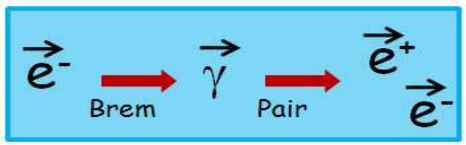
- Compton scattering: colliders



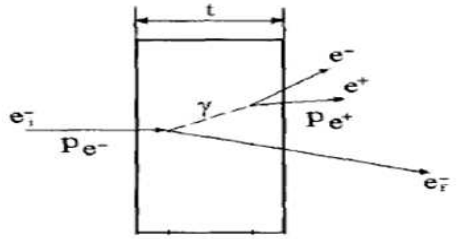
A. Kuriki et al. AIP Conf. Proc. 980(2008) 92

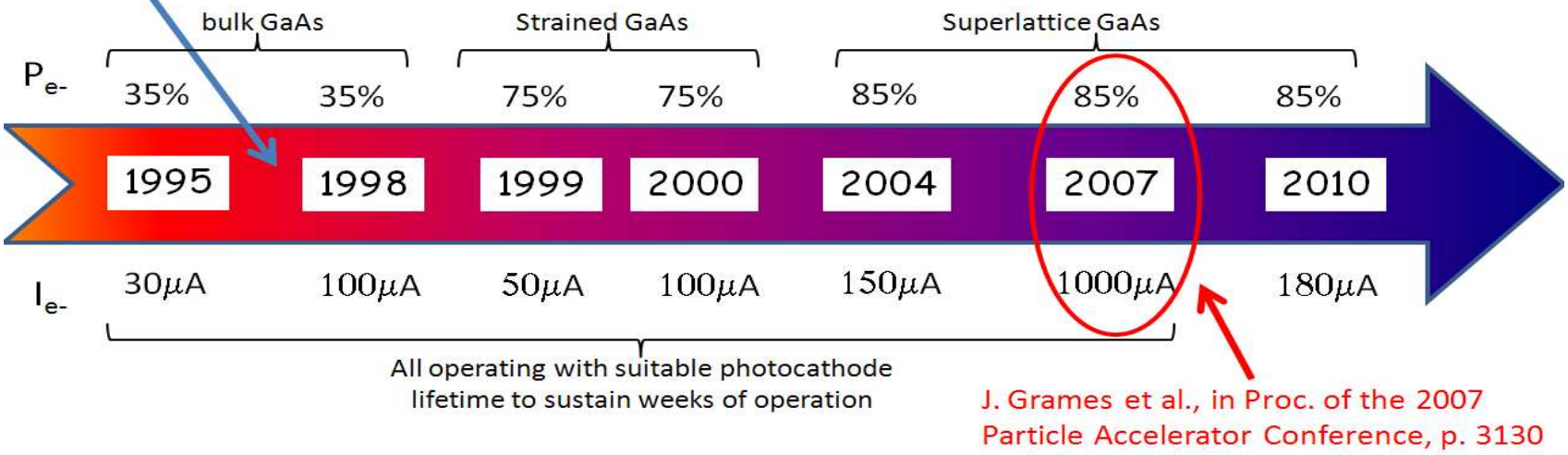
$\vec{e}^+$ source based on $\vec{e}^-$ beam

e+ source based on longitudinally polarized electron source



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





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)

Polarization transfers

Polarized positron production:

Polarization transfers for bremsstrahlung and pair creation were calculated by Olsen & Maximon in 1959.

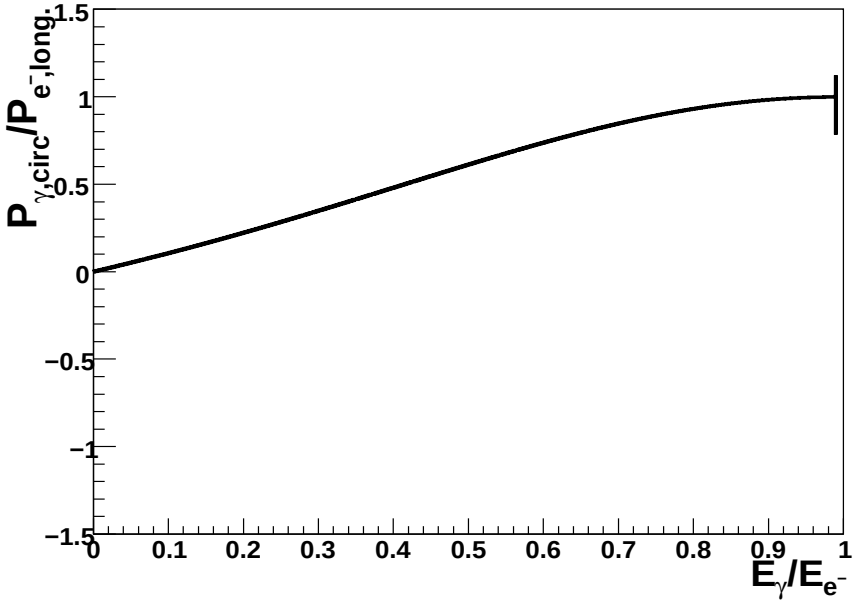
$$\Delta = \frac{Z^{1/3}}{121}\frac{12\epsilon_1\epsilon_2}{k}\frac{1}{1+k\sin(\theta)} \begin{cases} \Delta < 0.5 & \text{No nucl. screening} \\ 0.5 \leq \Delta < 120 & \text{Intermediate screening} \\ 120 \leq \Delta & \text{Complete screening} \end{cases}$$

H. Olsen, L. Maximon, PR 114 (1959) 887

O&M calculations @ 60 MeV

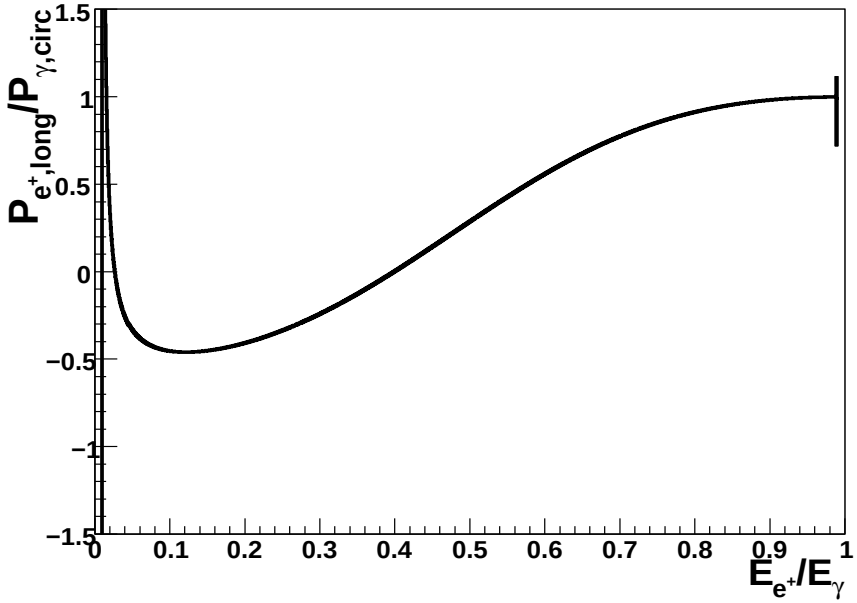
Bremsstrahlung

$\theta_\gamma = 0.41$ mrad



Pair creation

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



$\Rightarrow$ Some features of O&M calculations
are not valid for fractional energy ~ 0 and ~ 1
(Coulomb corrections ? Screening ? Relativistic approximation ? ...)

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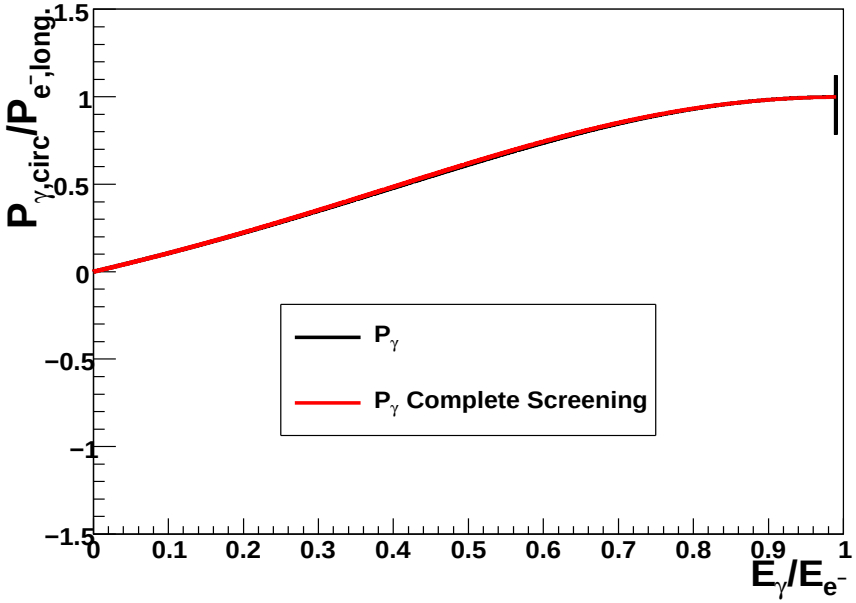

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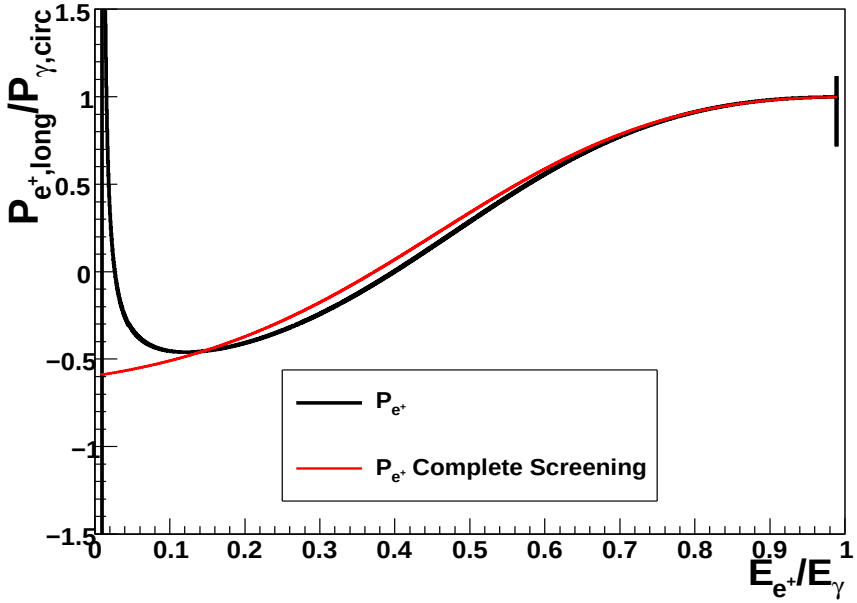

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$\Rightarrow$ Selecting complete screening

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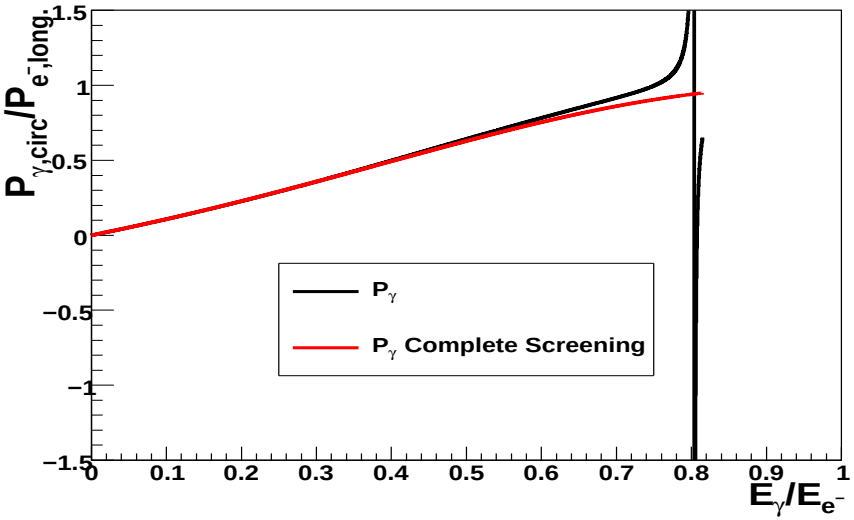
O&M calculations @ 3 MeV

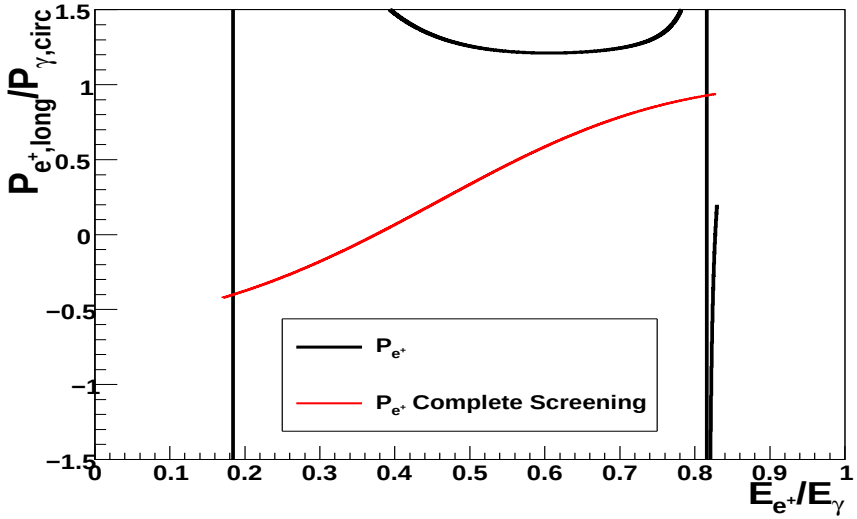
Bremsstrahlung

$\theta_\gamma = 0.41$ mrad



Pair creation

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



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

Polarization transfers are currently re-visted

E. Tomasi-Gustafsson, E. Kuraev, in progress

Simulations are performed in the complete screening case.

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

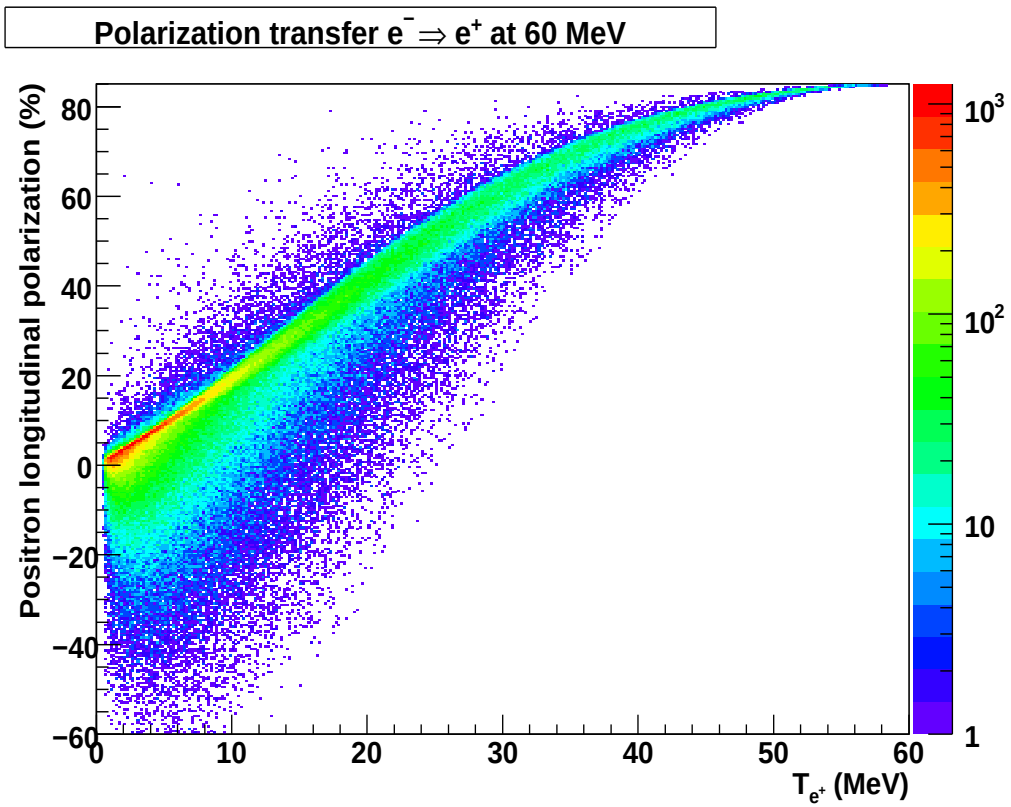
$\Rightarrow$ Study of the source properties

e^+ yield
e^+ polarization
FoM

e^+ polarization / yield distribution

CEBAF:

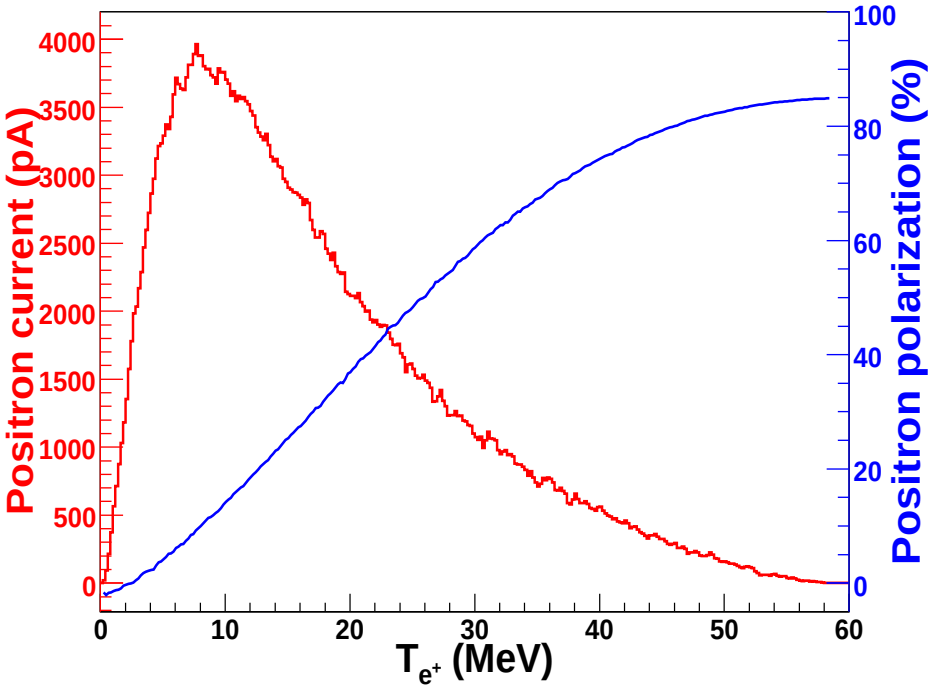
- $E_{e^-} = 60$ MeV
- $I_{e^-} = 1$ mA
- Polarization= 85%
- Target: W, 100 μm

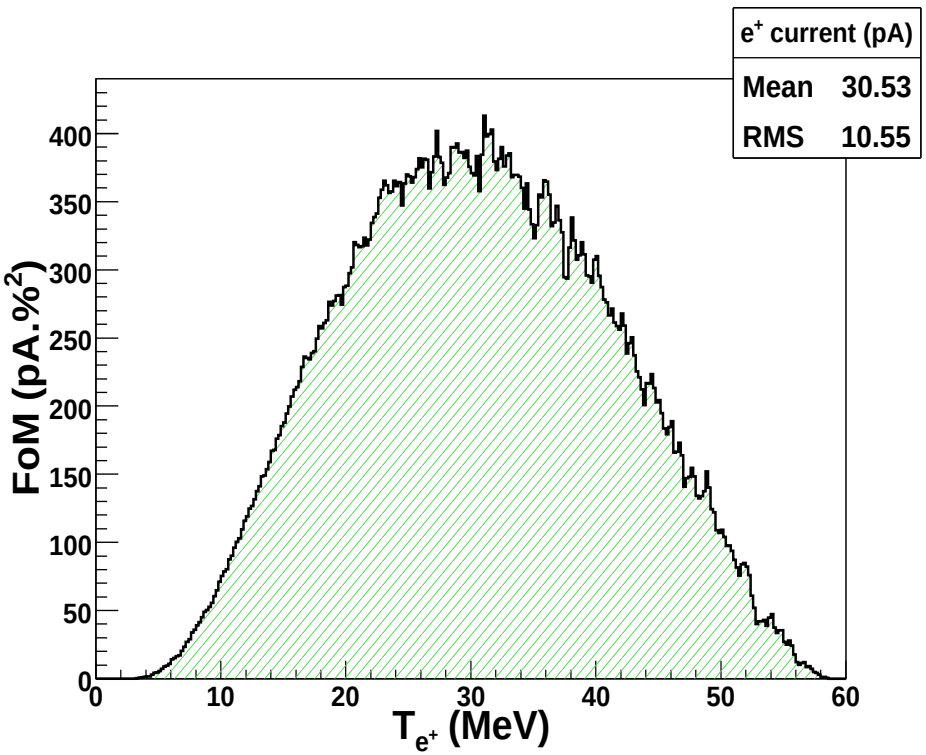


"source" characteristics for E_{e^-}=60 MeV

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

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





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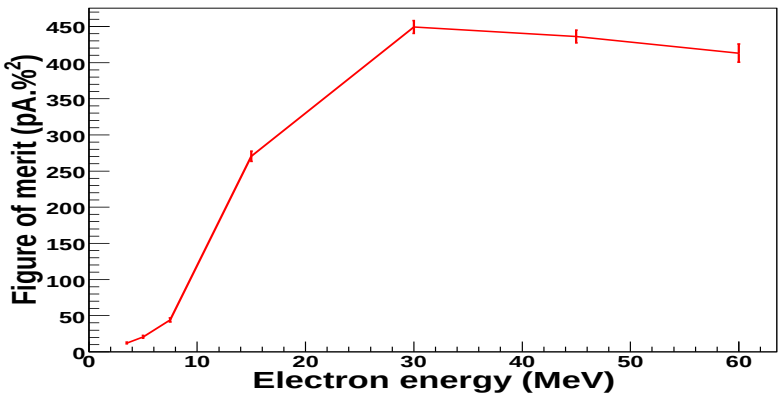
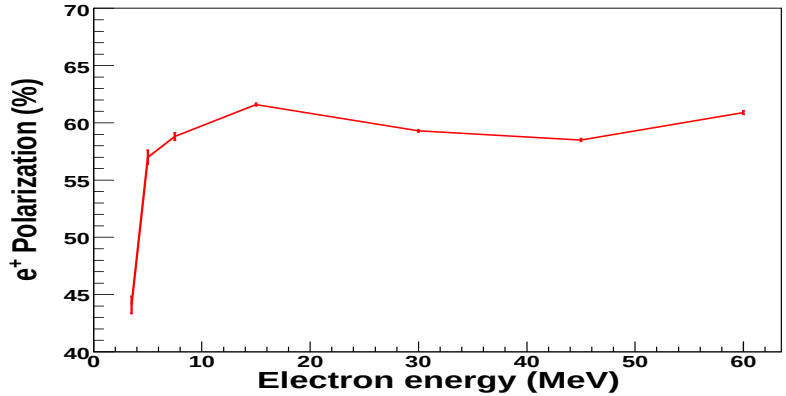
Source characteristics vs E_{e^-}

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

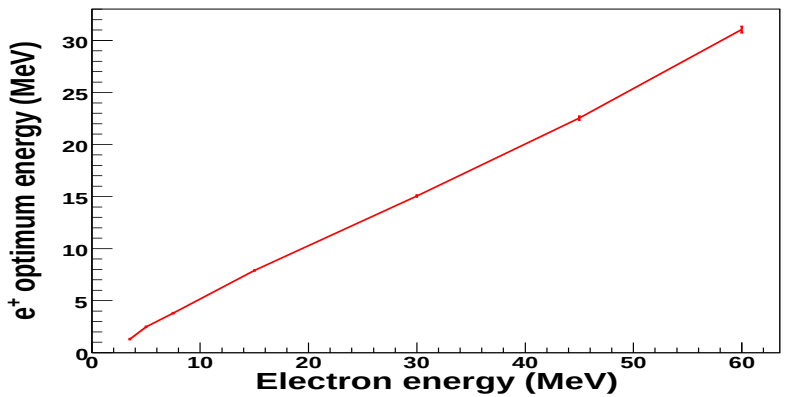
FoM_{e^+}



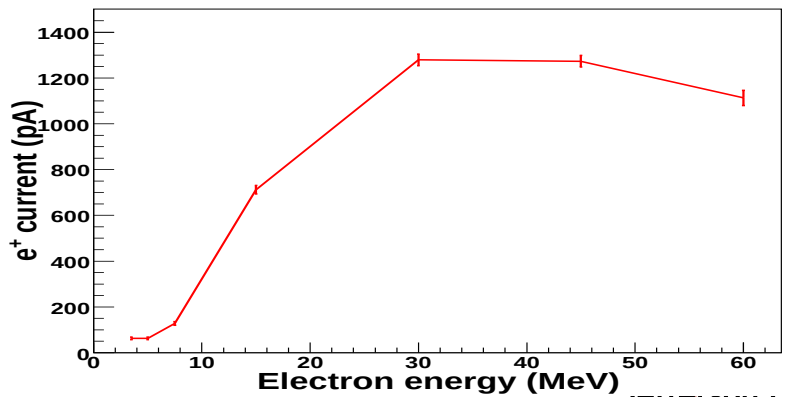
P_{e^+}



E_{e^+}



I_{e^+}

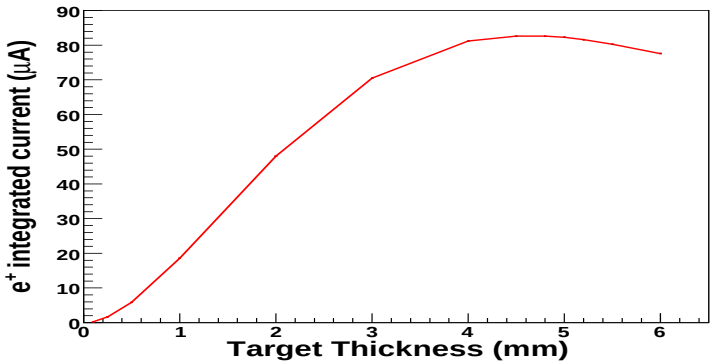


Target thickness

Target thickness for positron production:

- too small, EM shower is limited
- too large, the positrons are stopped in the target

50 MeV



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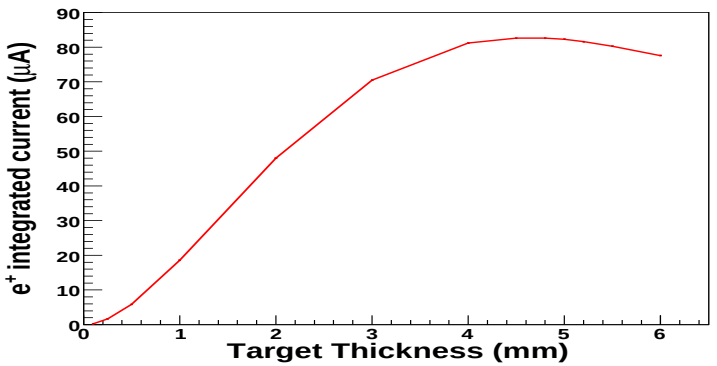


Depolarization effects: significant for thicknesses above 0.2 X_0

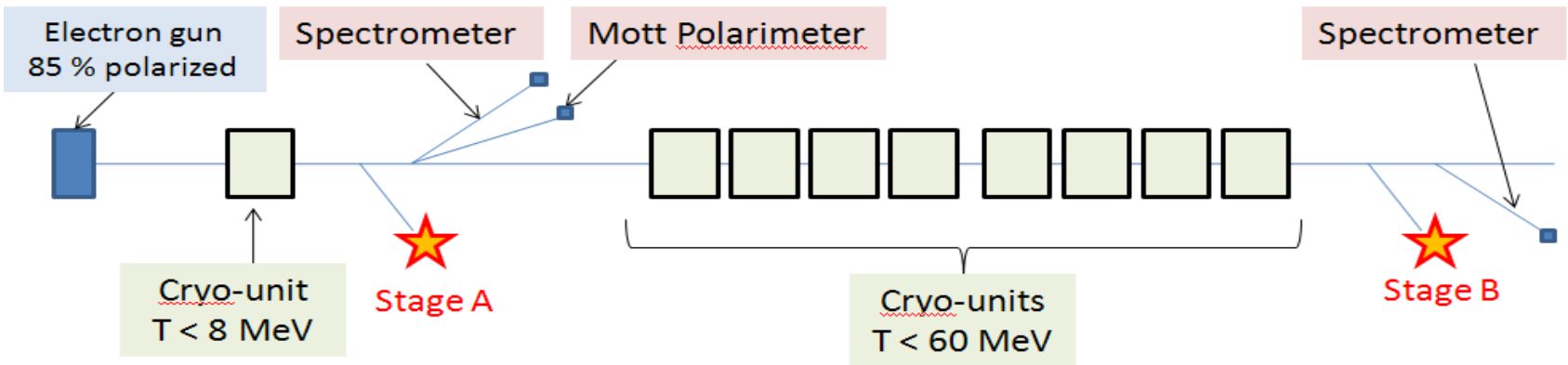
A.P. Potylitsin, NIM A398 (1997) 395

Work in progress

Demonstration experiment

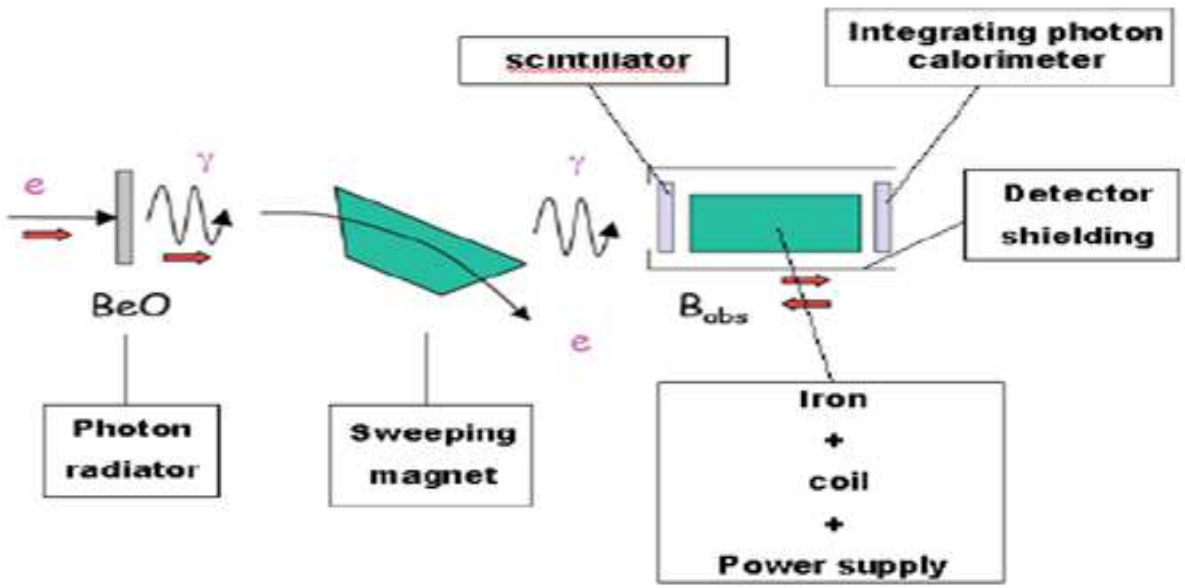
An experiment to test this concept of polarized positron production:

- A polarized electron beam (high-P, high-I)
- CW-SRF accel: $\sim 3 - 60$ MeV
- A positron beamline with conversion target + e^- dump
- Diagnostics for e^+/e^- polarization and yield



Compton transmission polarimetry

- Polarized bremsstrahlung $\vec{e}^{\pm} \rightarrow \vec{\gamma}$
- Magnet removes leptons
- Photon transmission through a magnetized iron target
- Asymmetry ($\sim$1%) due to the polarization sensitivity of Compton scattering
- Calibration against the Mott polarimeter

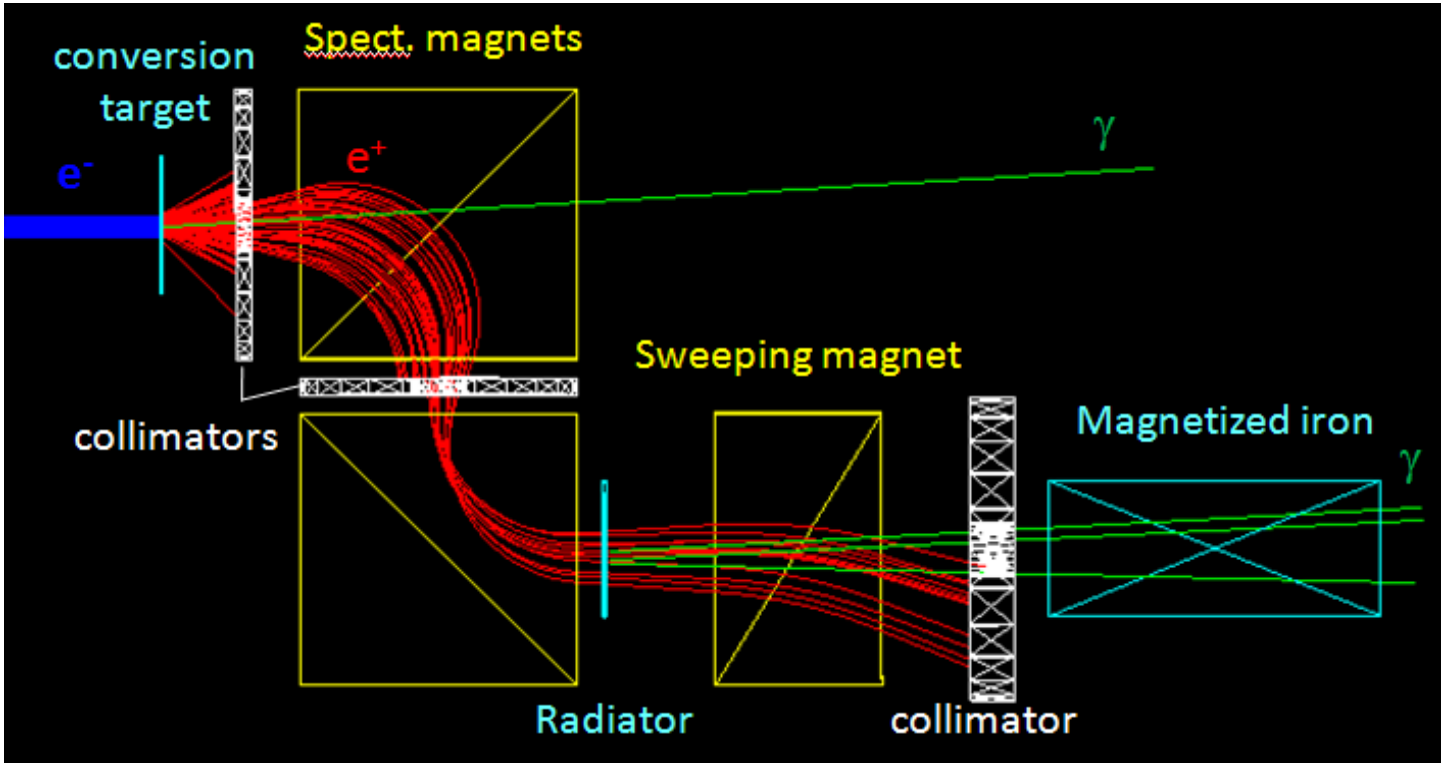


T. Zwart et al., in Proc. of the 2002 AIP Conference CP675, p. 1011

Experiment layout

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

- $e^{\pm}$ and energy selection: dipoles + collimators
- Compton transmission polarimeter



G4Beamline picture

Conclusion

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- Simulations: e^+ yield ~ 1 nA and $P_{e^+} \sim 60\%$
- Simulations continue for beamline + polarimetry $\rightarrow$ test at CEBAF injector, install e^+ beamline, polarimetry from MIT-Bates.