Polarized Electron Footprint at JLab

Positron

P. Adderley, J. Clark, J. Dumas[‡], A. Freyberger, J. Hansknecht, J. Grames, M. Poelker, K. Surles-Law, M. Stutzman, R. Suleiman, E. Voutier[‡]

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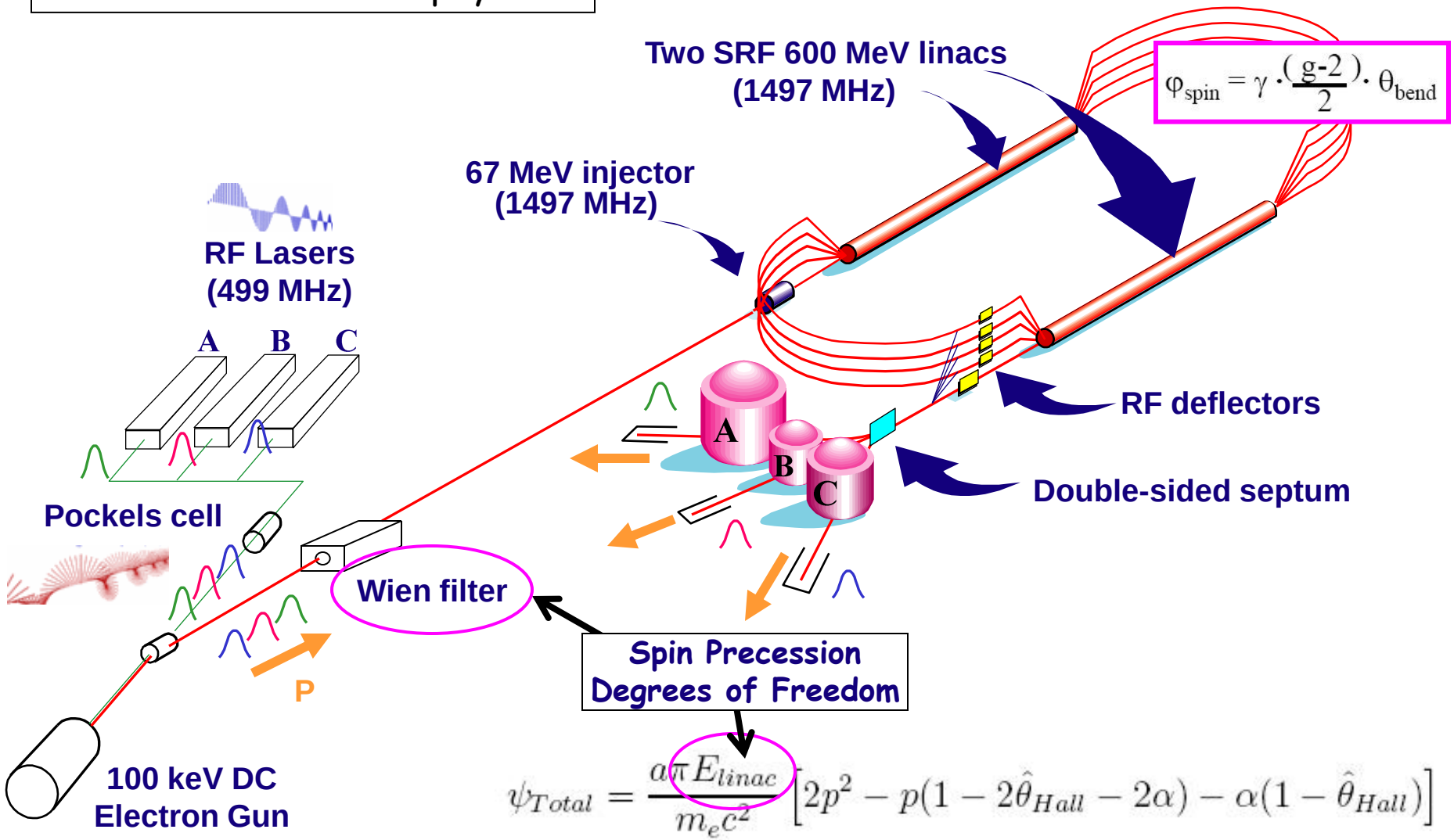
Grenoble, France

Continuous Electron Beam Accelerator Facility

- Recirculating SRF LINACs
- Three Halls; 3x the physics

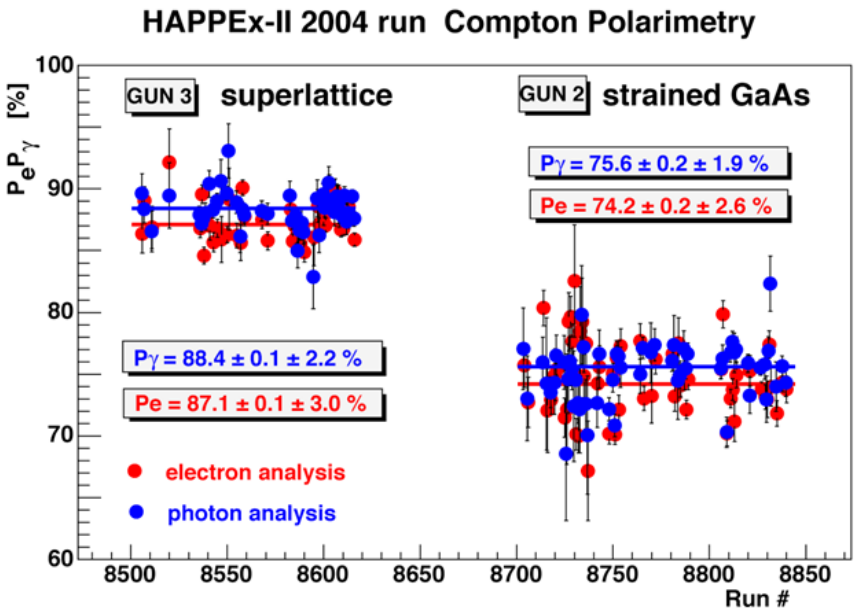


Spin Precession
Degrees of Freedom

$$\psi_{Total} = \frac{a\pi E_{linac}}{m_e c^2}\left[2p^2 - p(1 - 2\hat{\theta}_{Hall} - 2\alpha) - \alpha(1 - \hat{\theta}_{Hall})\right]$$

Everyone Gets Polarized Electrons !

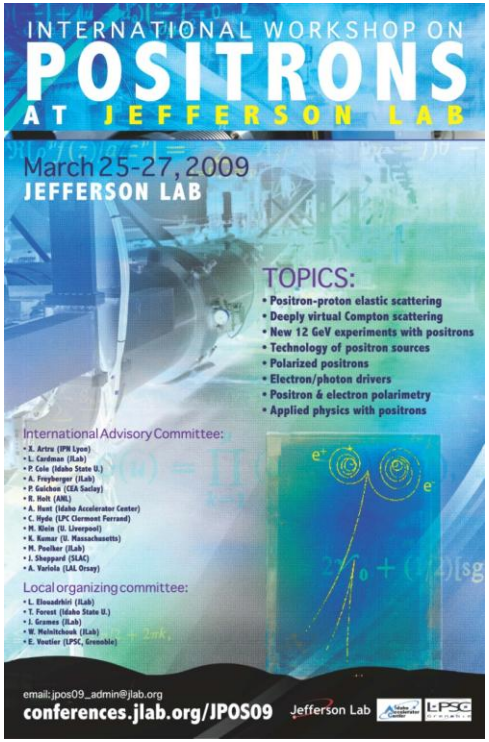
- CEBAF's first polarized e-beam experiment 1995
- Now polarized beam experiments comprise ~ 80% of our physics program, in fact, we *only* deliver polarized electrons
- All beam originates via photoemission from a strained superlattice GaAs crystal inside a 100kV DC photogun
- Three experimental areas may *simultaneously* receive:
  - high polarization (~85%)
  - continuous wave (499 MHz)
  - independent intensity (50 pA to 200 μA)
  - energy selection (6 GeV now, 12 GeV 2012)



- What about positron physics ?
  - Lepton charge degree of freedom
  - But, costly endeavor…
  - But, rich e- program keeps us busy…

JPOS'09

Recent workshop to discuss e+ @ Jlab … identified **"old"** & **new** physics motivations…



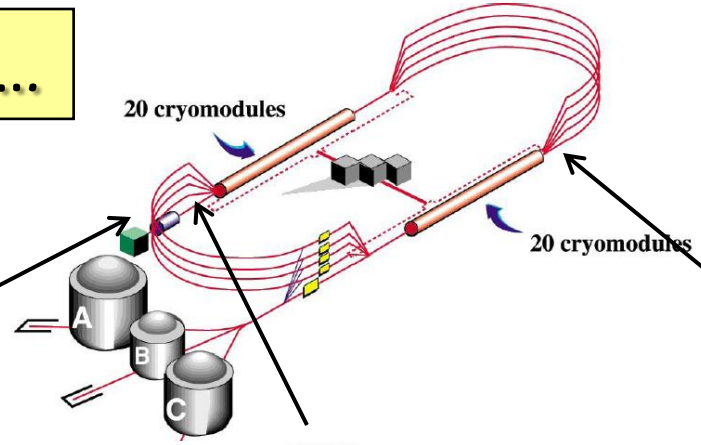
- **G**eneralized **P**arton **D**istributions
- Investigation of **2g exchange** in elastic scattering
- Study of **Coulomb distortion** in the inelastic regime
- Search for a light dark matter gauge **U-boson**
- Measurement of the C_{3q} **neutral weak coupling**
- **P**ositron **A**nnihilation **S**pectroscopy

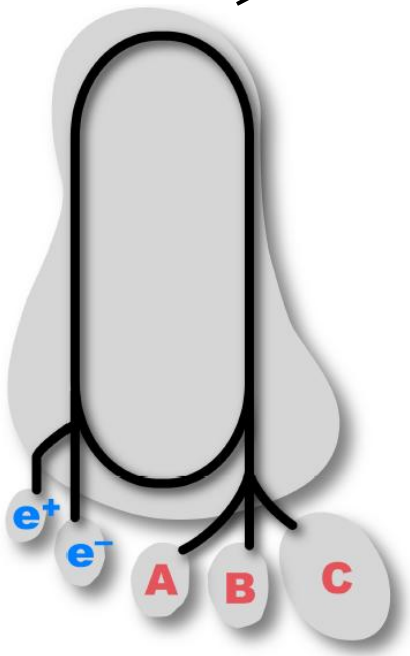
- **e^+** beam current > **100 nA** in **CW** mode
- As **large** as possible **e^+** beam **polarization**

New interest from the source & accelerator community working at JLab …

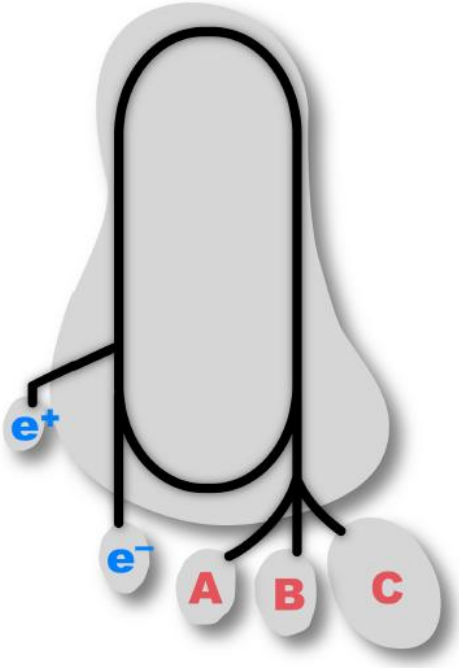
If the shoe fits …

…then wear it !

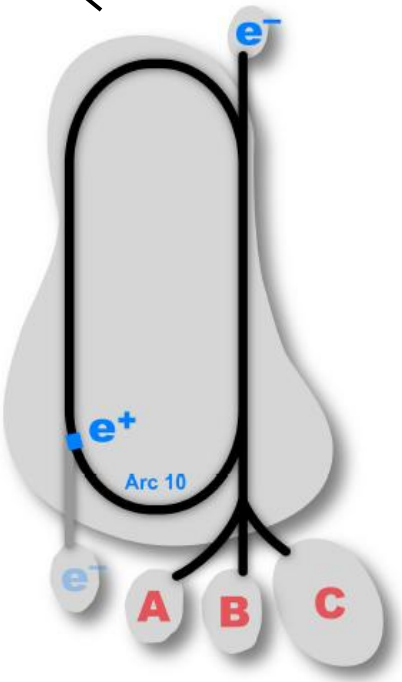




10 MeV/10 mA
Power loss/scattering
Compact, low rad



100 MeV/10 mA
Better divergence
Worse energy spread



1000 MeV/1 mA
Easier source
Bigger "driver"

A. Freyberger, Proc. of the International Workshop on Positrons at Jefferson Lab, Newport News (VA, USA), March 25-27, 2009

R&D Effort for a continuous wave [polarized] positron source at JLab for fixed target experiments to take place in the 12 GeV era.

J. Dumas, C. Hyde, T. Forest, A. Freyberger, S. Golge, J. Grames, R. Kazimi, E. Voutier

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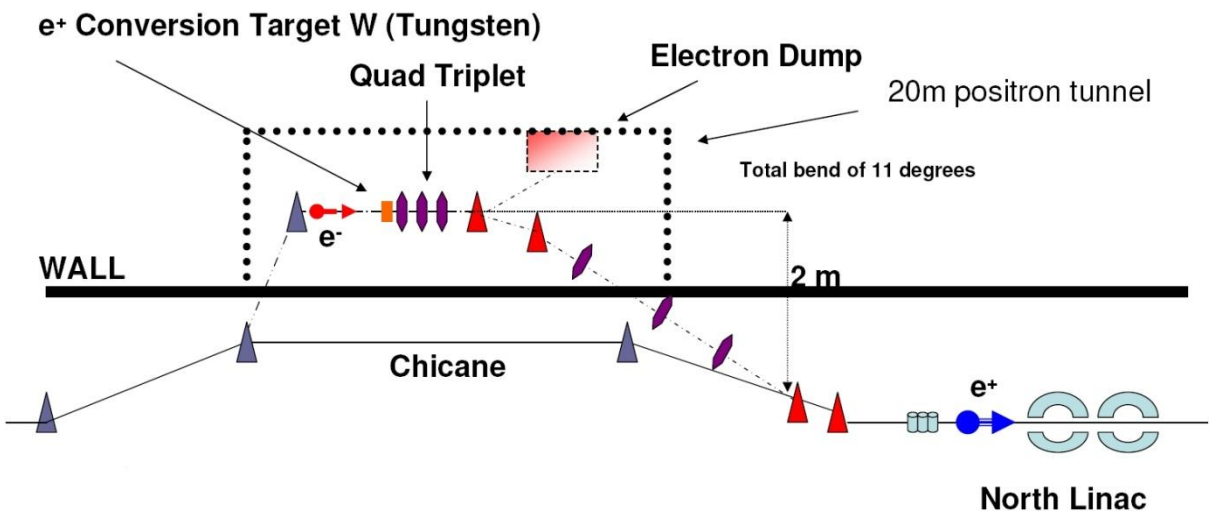
S. Golge et al., Proc. of the International Workshop on Positrons at Jefferson Lab, Newport News (VA, USA), March 25-27, 2009

- A **possible concept** involves the construction of a **dedicated e^+ tunnel** at the end of the injector and parallel to the north linac.
- Positrons would be produced with **120 MeV e^-** (JLab 12 GeV) incident on a tungsten target.
  - **e^+**'s are **selected** with a **quadrupole triplet** and **transported** to the accelerator section.

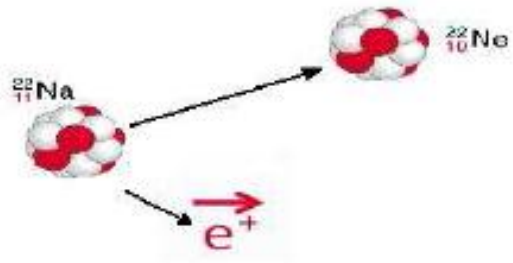


G4beamline simulations indicate a global efficiency of **10^{-5} e^+/e^-** for 120 MeV e^- off a 3 mm W target.

10 mA e^- → 100 nA e^+

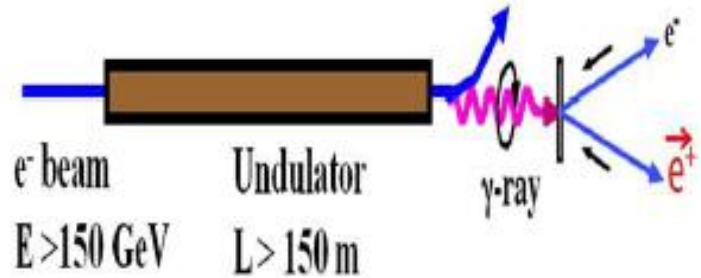
What about polarized e+ ?

- Polarized beta-plus decay: used in material science



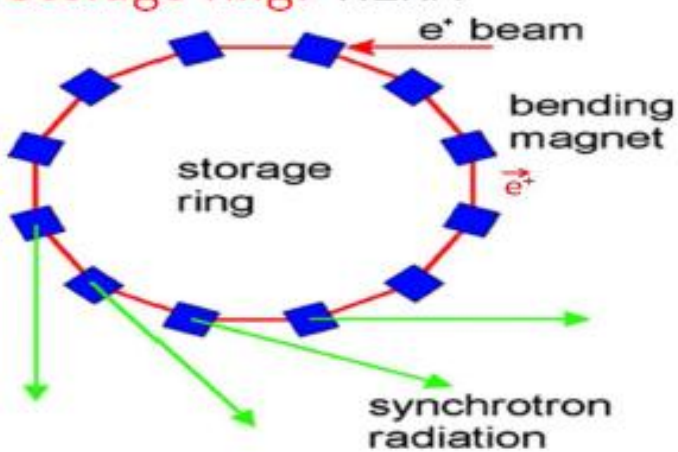
A. Kawasuso, M. Maekawa, ASS 255 (2008) 108

- Helical undulator: colliders

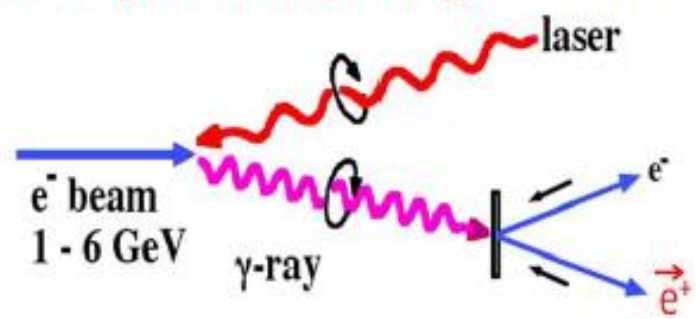


G. Alexander et al. PRL 100 (2008) 210801

- Storage ring: HERA



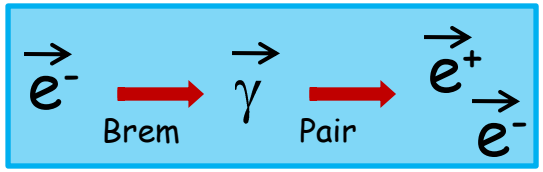
- Compton scattering: colliders



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

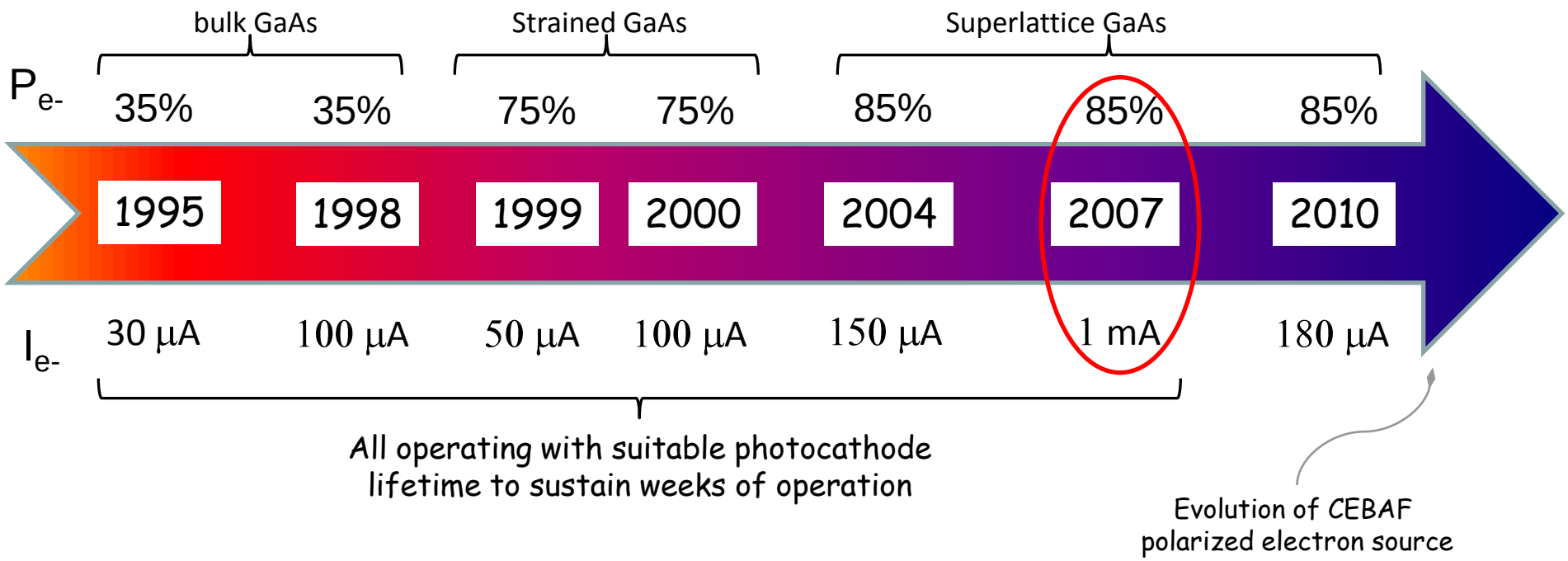
Polarized Bremsstrahlung/Pair Creation

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



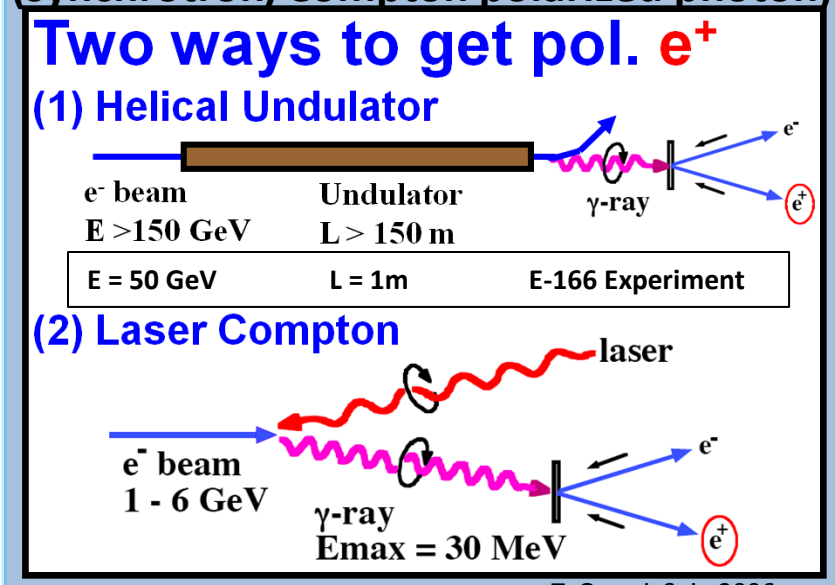
- Within a high Z target, **longitudinally polarized e^-'s** radiate **circularly polarized γ's**.
- Within the same/different target, **circularly polarized γ's** create **longitudinally polarized e^+'s**.

So, why not pursued so far … ?



PhD Thesis: *Polarized Positrons for JLab*, Jonathan DUMAS
Advisors: Eric Voutier, LPSC and Joe Grames, JLab

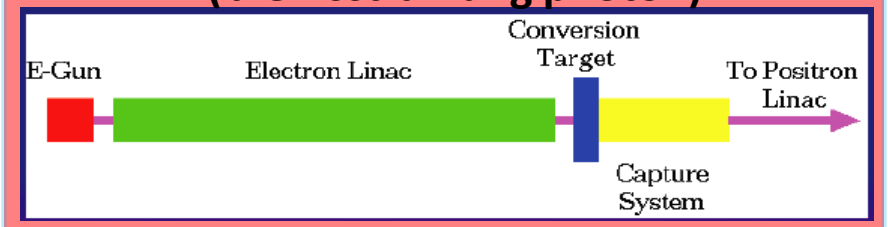
ILC Polarized e+ Schemes/Demos (synchrotron/Compton polarized photon)



T. Omori, Spin 2006

OR

Conventional un-polarized e+ Scheme (bremsstrahlung photon)



+

High Polarization, High Current e- Gun (*polarized bremsstrahlung* photon)

LIFETIME MEASUREMENTS OF HIGH POLARIZATION STRAINED-SUPERLATTICE GALLIUM ARSENIDE AT BEAM CURRENT >1 MILLIAMP USING A NEW 100kV LOAD LOCK PHOTOGUN*

J. Grames#, P. Adderley, J. Brittian, J. Clark, J. Hansknecht, D. Machie, M.Poelker, M.L. Stutzman, R. Suleiman, K. Surles-Law, Jefferson Laboratory, Newport News, VA 23606, U.S.A.

Source Property	E-166 Experiment PRL 100, 210801 (2008)	J. Dumas et al. Proc. Spin 2008
Electron beam energy	50 GeV - Undulator	10 MeV - Conversion
Electron beam polarization	Unpolarized	85%
Photo Production	Synchrotron	Bremsstrahlung
Converter Target	Tungsten Foil	Tungsten Foil
Positron Polarization	80% (measured)	40% (Simulation)

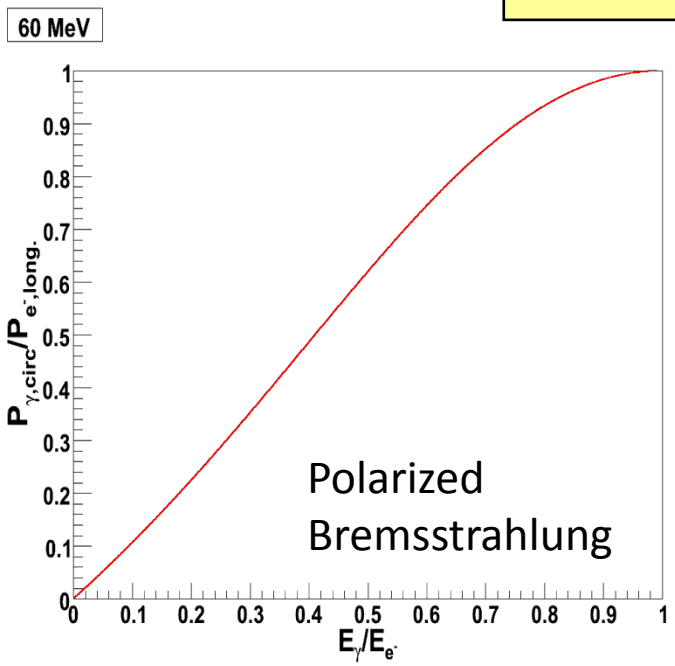
Positron Yield scales with Beam Power
- Replace GeV-pulsed with MeV-CW

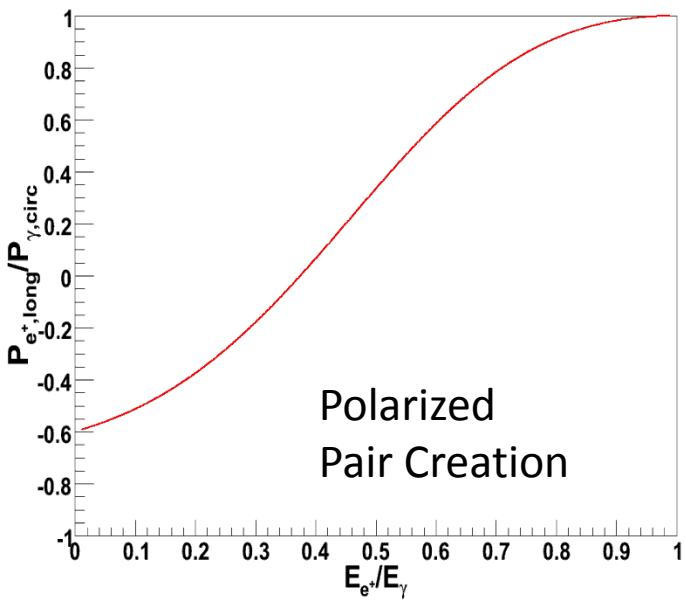
Reduce radiation budget
- Remain below photo-neutron threshold

Bunch/Capture to SRF linac
- Compact source vs. Damping Ring

Unique capabilities
- First CW source with helicity reversal

e^+ Source Polarization



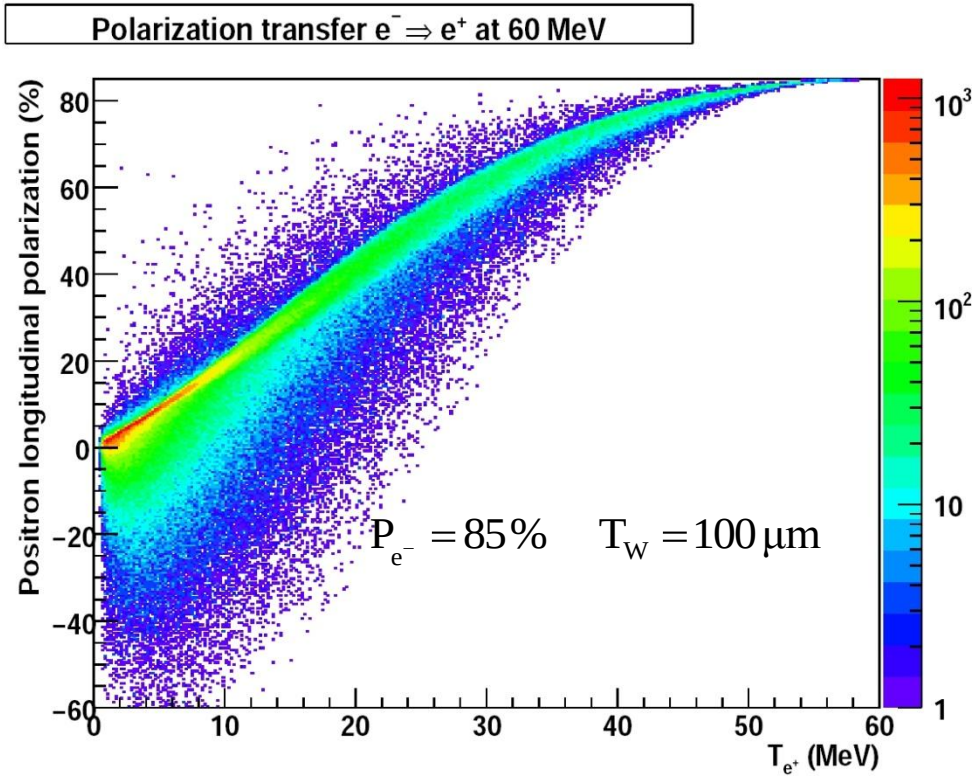


H.A. Olsen, L.C. Maximon, *Phys. Rev.* **114** (1959) 887.

- Simulation are performed within the **GEANT4** framework, taking advantage of the **polarization capabilities** developed by the **E166 Collaboration**.

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

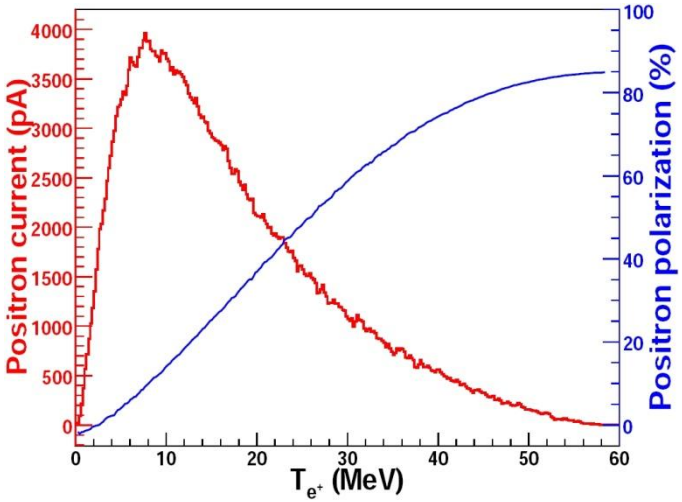
- The **source** files are **modified** to select complete screening (where T~0 or T~60 MeV)

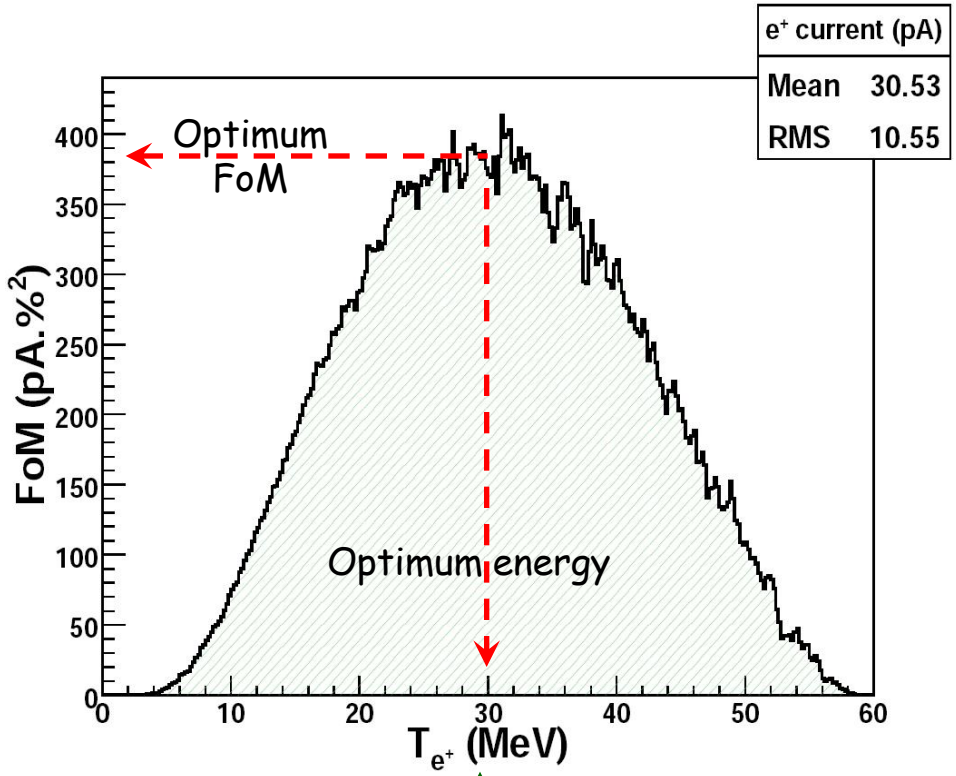


e^+ Figure of Merit (FOM)

- The **Figure of Merit** is the quantity of interest for the accuracy of a measurement which combines the **incident flux** of particles and its **polarization**.

$\Delta\theta_{e^+} = \pm 10^\circ \qquad \Delta E_{e^+} = \pm 0.25\ \mathrm{MeV}$



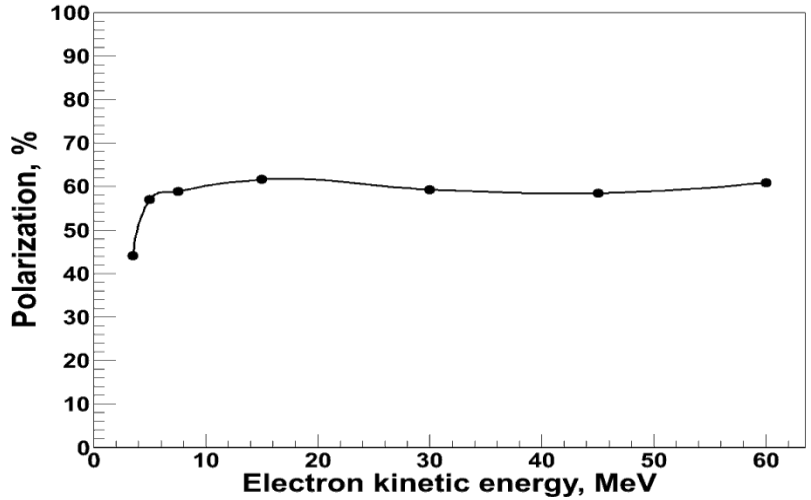


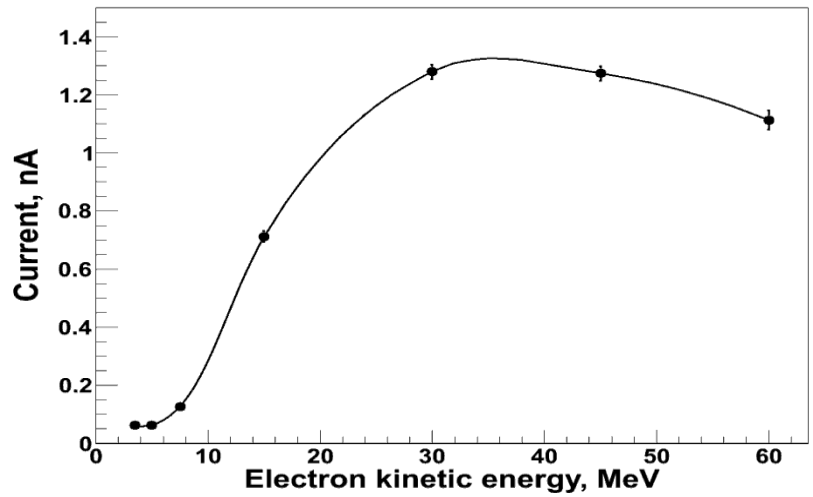
$$\mathrm{FoM} = I_{e^+} \times P_{e^+}^2$$

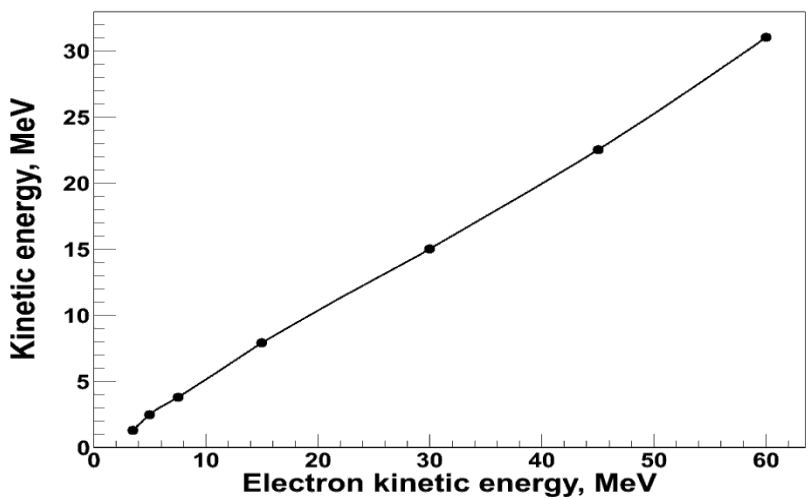
$$I_{e^-} = 1\,\mathrm{mA}$$

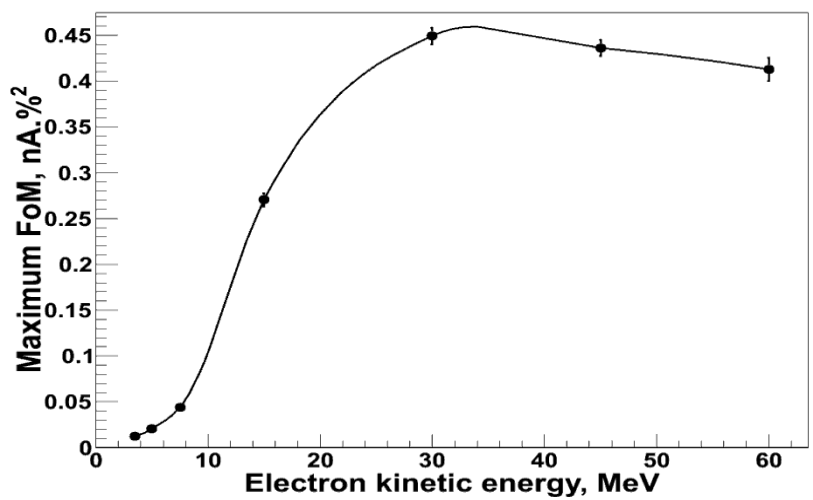
FOM Evolution vs. e- Energy (0 to 60 MeV)

- ***Simplistic*** *cuts are applied to mimic a* ***capture system*** *and the* ***accelerator acceptance****.*









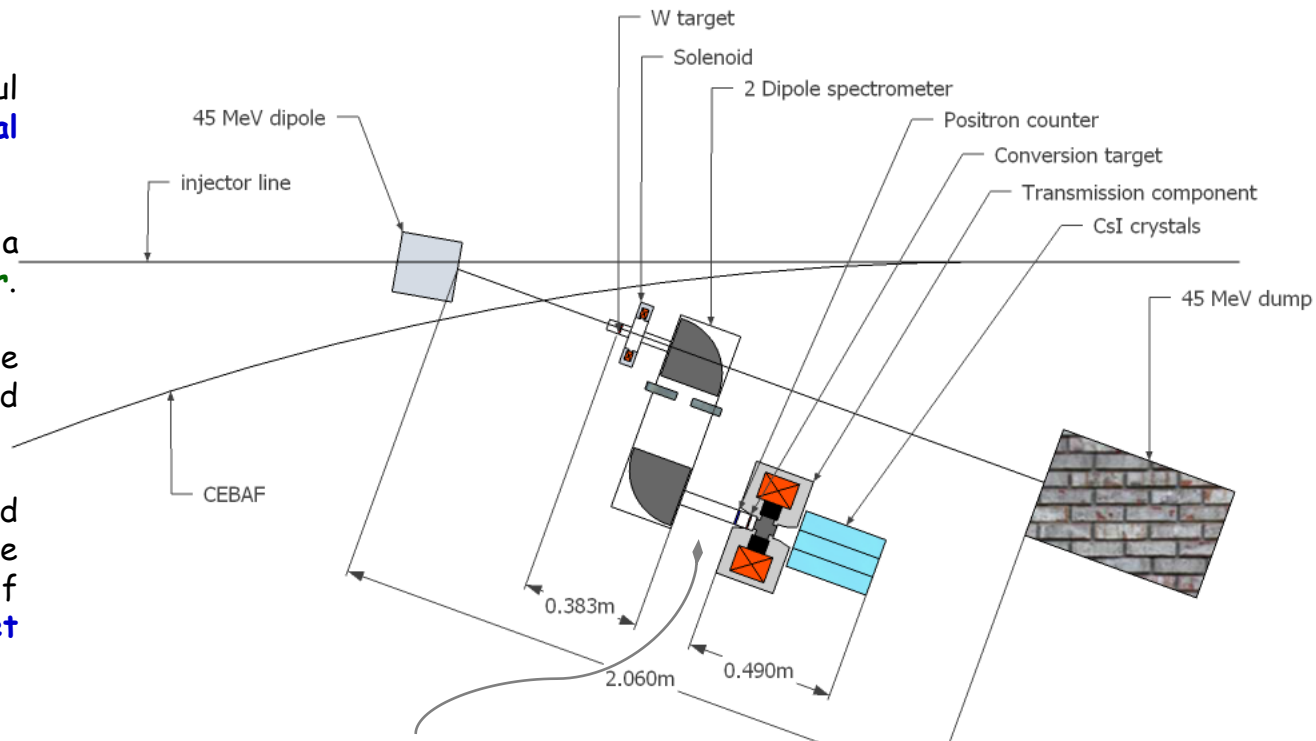
Thickness sensitivity is under study…

Demonstration Experiment

- An experiment to test the production of polarized positrons is currently designed.

The **goals** are to measure the **yield** and **polarization distributrions** as a function of the **beam energy**.

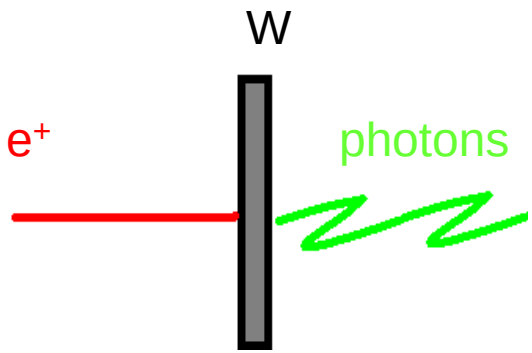
- The **ATF/KEK** & **E166** successful set-up serves as a **conceptual guidance** towards the final design.
- Polarimetry would consist of a **Compton transmission polarimeter**.
- **Calibration** and check of the analyzing power can be performed with the **polarized electron** beam.
- The **Compton asymmetry** would be measured by **reversing** the **beam** (up to 1 kHz frequency of random change) **and/or** the **target polarization**.

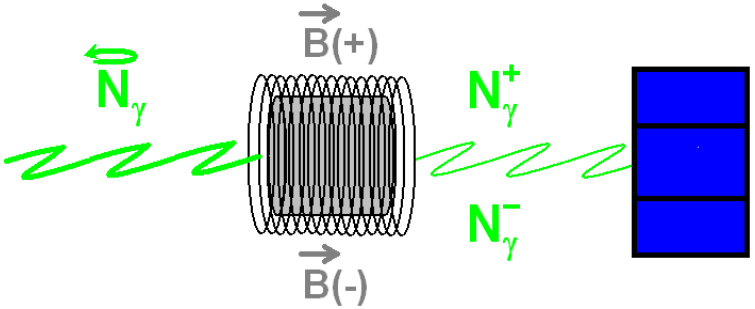


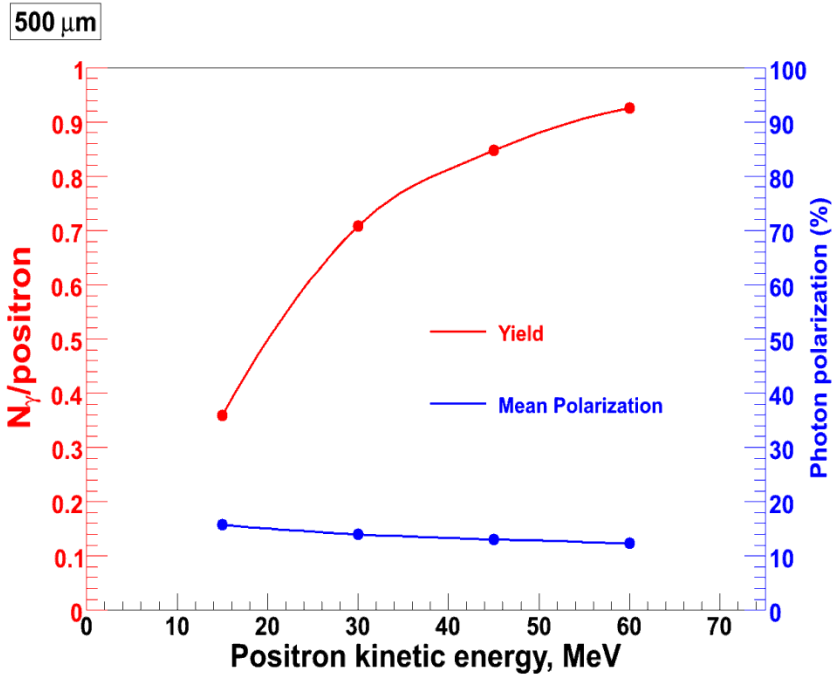
G. Alexander et al, PRL 100 (2008) 210801
G. Alexander et al, physics.ins-det:0905.3066

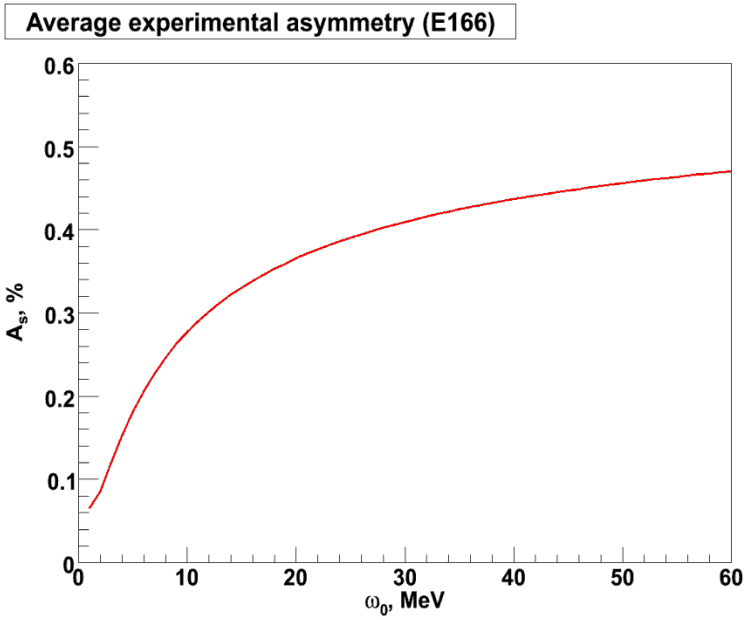
ATF/KEK: M. Fukuda et al. PRL 91 (2003) 164801 T. Omori et al. PRL 96 (2006) 114801

Compton Transmission Polarimeter





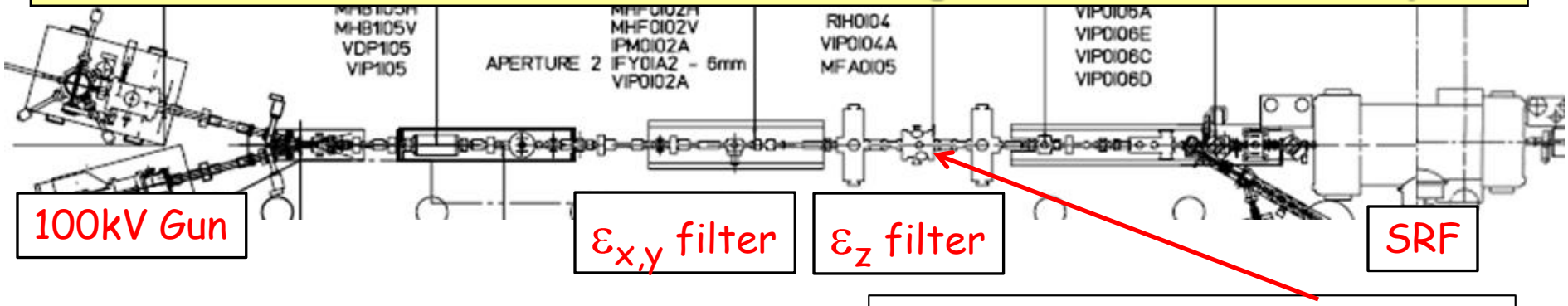




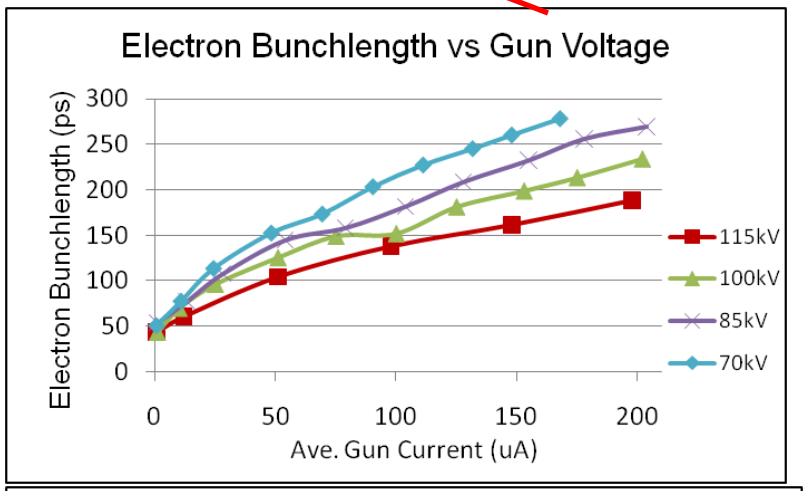
Detector solid angle = +/- 8°

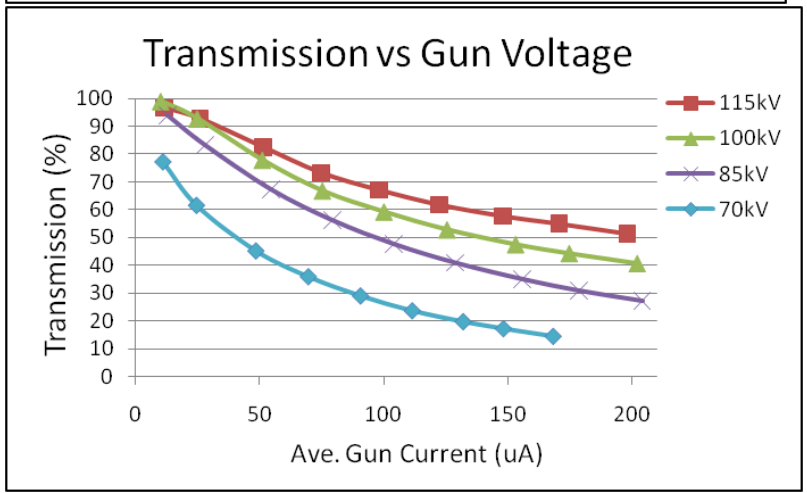
Average asymmetry for $P_{\gamma,circ}$=10%

What about CEBAF 10 MeV injector at milliamps?



Condition	Repetition Rate	Bunch Charge	Current
Typical	499 MHz	0.2 pC	100 uA
G0 (2003)	31 MHz	1.25 pC	40 uA
G0-like	1497 MHz	1.25 pC	1900 uA





Operating at higher gun voltage…

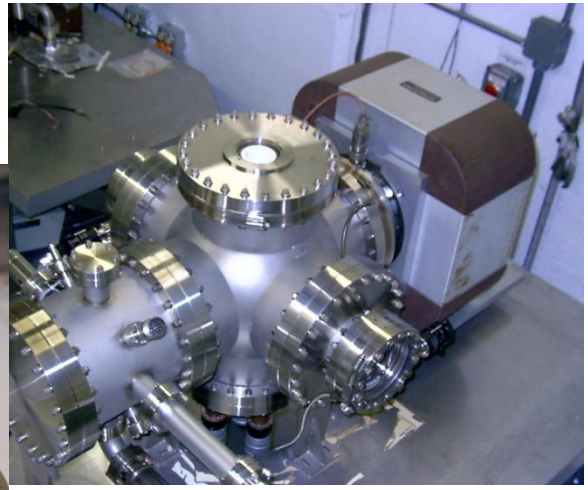
- Improves transmission (stiffer beam)
- May improve photocathode lifetime

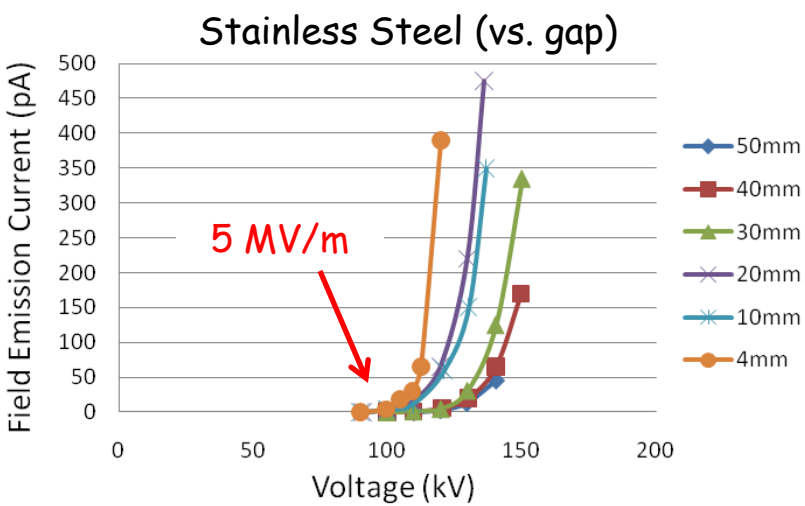
For high bunch charge guns (like ILC/CLIC)
Essential to overcome photoemission limit

Field Emission – Critical Issue for Higher Voltage

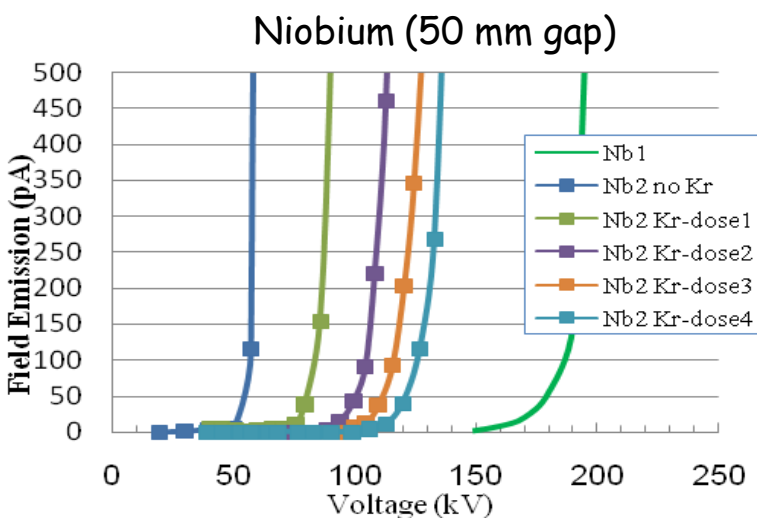
"Conventional" cathode electrode mounted on metal support structure

"Inverted" no SF6 and no HV breakdown outside chamber



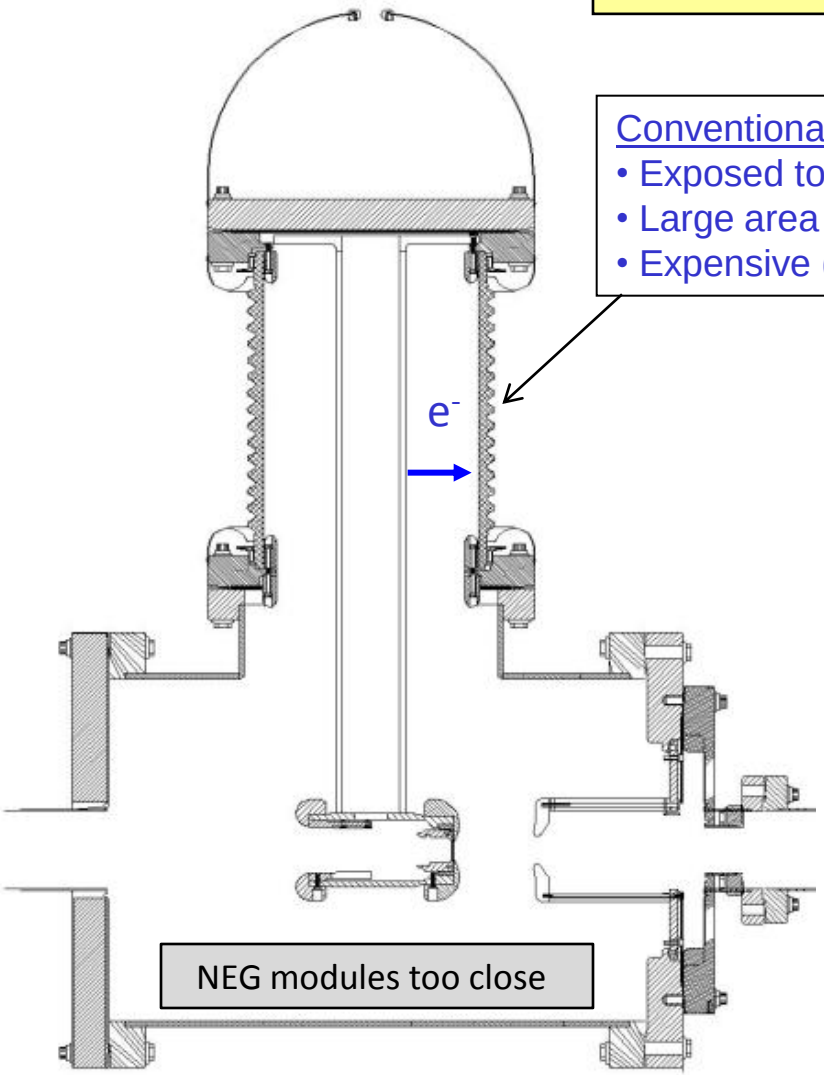


Work of Ken Surles-Law, Jefferson Lab



Thanks to P. Kneisel, L. Turlington, G. Myneni

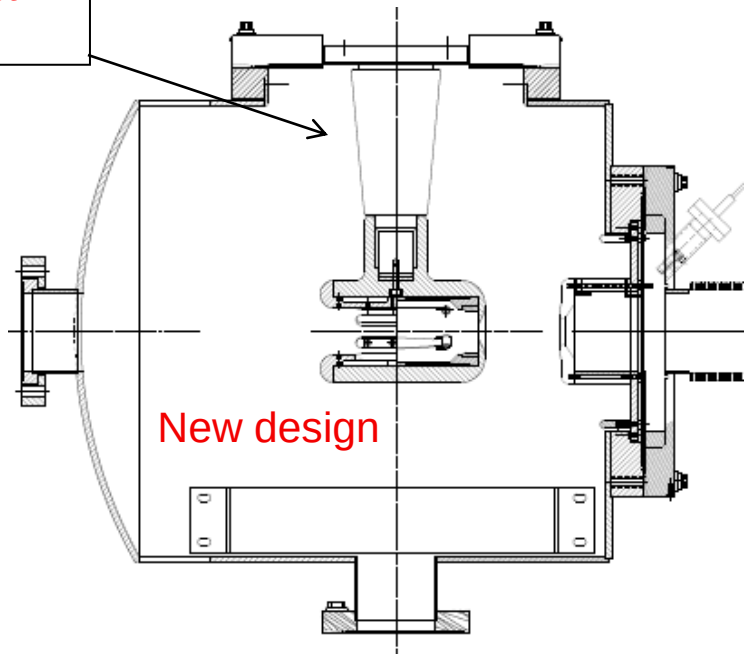
"Inverted" Gun



Conventional Ceramic
- Exposed to field emission
- Large area
- Expensive (~$50k)

Medical x-ray technology

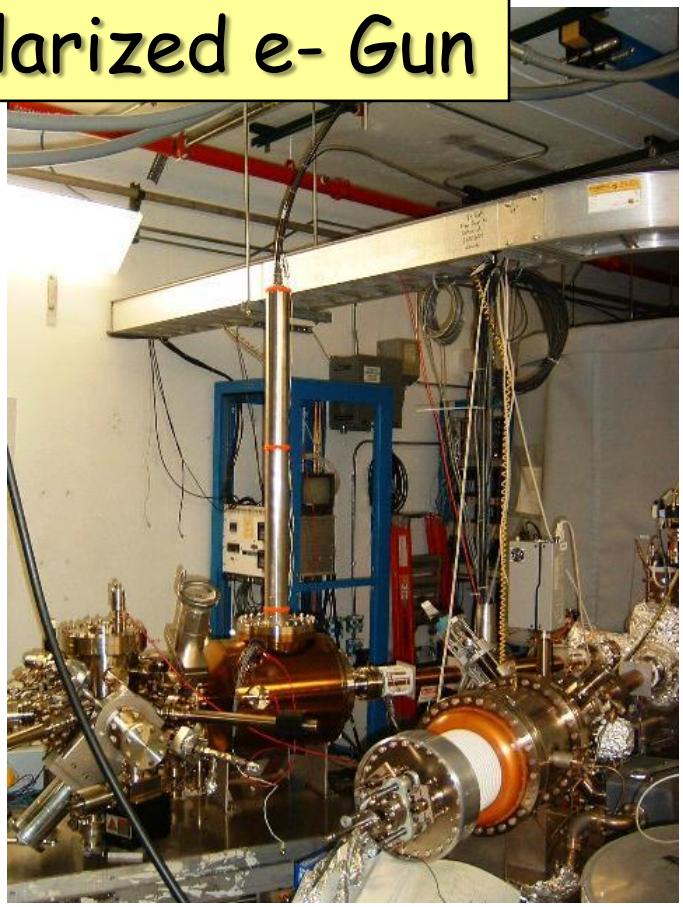
New Ceramic
- Compact
- ~$5k



Want to move away from "conventional" insulator used on **all** GaAs photoguns today – expensive, months to build, prone to damage from field emission.

July 2009 – Assembling the inverted gun chamber

New CEBAF "Inverted" Polarized e- Gun



Installed July-August:

✓Vacuum => extractor ~3E-12 Torr, IP ~20pA

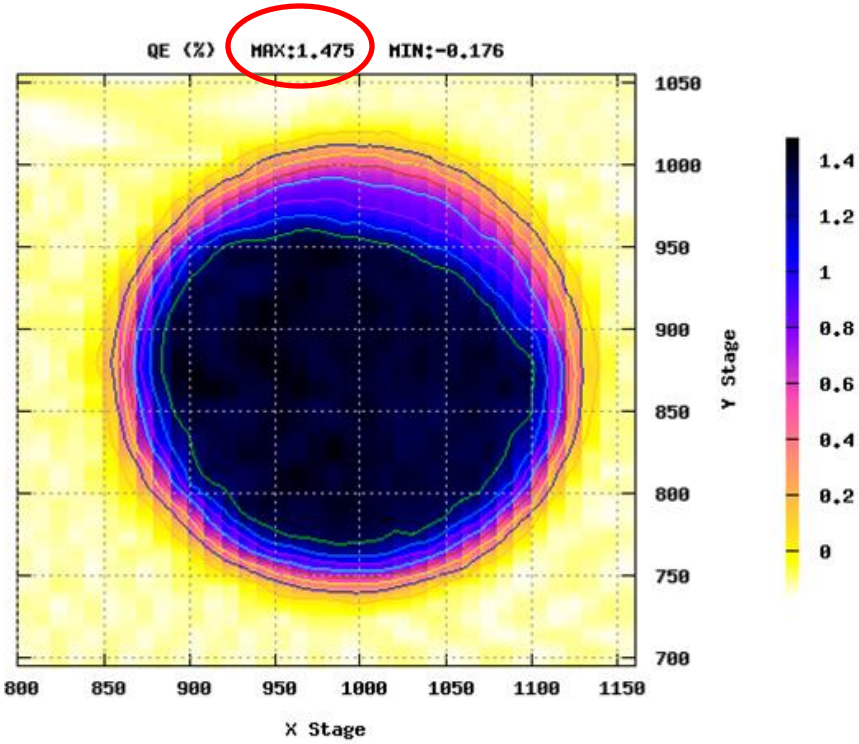
✓HV Process to 110kV => no FE or VAC activity

✓New HVPS => Increased to 150kV supply

✓New Photocathode => QE>1% and P~85%

Just began running about a week ago.

We'll begin characterizing lifetime & photocathode…




```
to 90.24, very easy keeping Wien quads OFF.
 Polarization: (85.54 +/- 1.09stat +/- 1.03sys) %
, Polarization: (84.98 +/- 1.07stat +/- 1.02sys) %

ott.  Turned off prebuncher.  Helped.  Adjusted Hal
 after the measurement. In brief, Hall B needs some

, Polarization: (85.77 +/- 1.23stat +/- 1.03sys) %
 Polarization: (84.38 +/- 1.28stat +/- 1.01sys) %

 off, very nice spectra, no changes required.
 Polarization: (85.32 +/- 1.11stat +/- 1.02sys) %
, Polarization: (85.07 +/- 1.05stat +/- 1.02sys) %
```