Positron Sources, Applications and the PEPPo Experiment

Joe Grames

Center for Injectors and Sources

Jefferson Lab

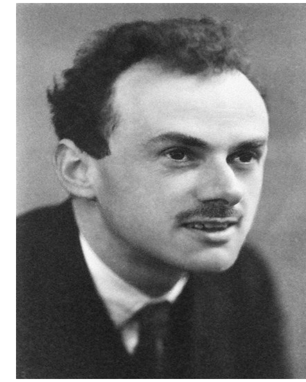
I would like to acknowledge those whose slides and images are incorporated into to this talk: D. Cassidy, S. Chemerisov, J. Dumas, A. Freyberger, W. Gai, S. Golge, J. Jonah, R. McKeown, A. Mikhailichenko, A. Mills, Y. Saquin, E. Voutier

CAS Seminar

Old Dominion University

February 26, 2015

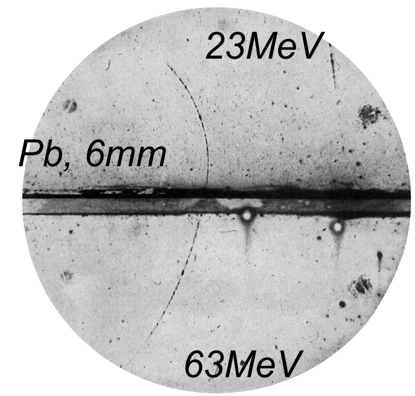
A Distinguished Field

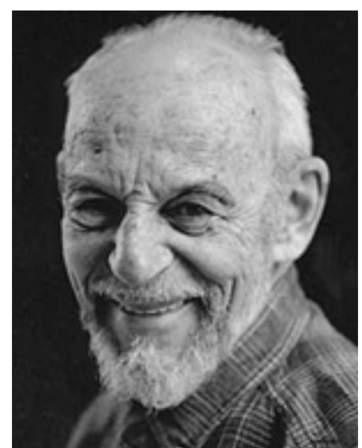


P.A.M. Dirac (1902 – 1984) shared 1933 Nobel prize (with Erwin Schrodinger) for relativistic wave equation of massive spin-1/2 particles. This theory predicted negative energy “holes” with properties identical to the electron, but with a positive charge !

$$\left[\frac{W^2}{c^2} - p_r^2 - m^2c^2\right]\psi = 0$$

Carl Anderson (1905 – 1991) awarded 1936 Nobel prize (with Victor Hess) for detecting the positron (March 15, 1933, PRL, V. 43, The Positive Electron). He later co-discovered the muon!

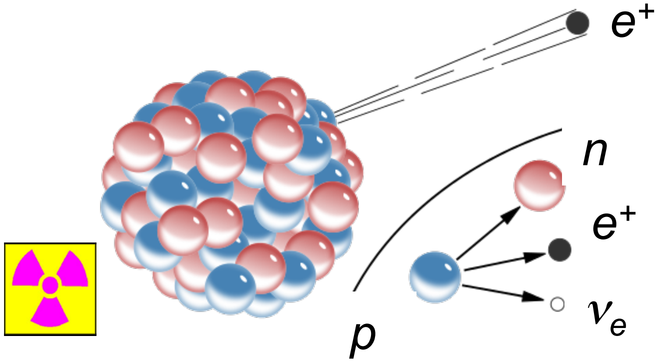




Martin Deutsch (1917 – 2002) awarded 1956 Nobel prize for discovery of Positronium (Ps), which had been predicted by Anderson.

30,000 foot view

β^+ emission by radioactive decay



Requires activating material

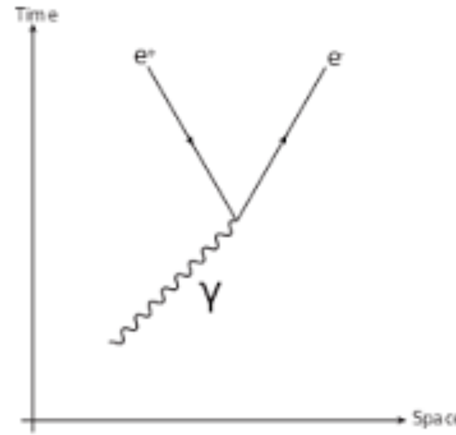
- Commercial sources
- Nuclear reactors

Suited for low energy

- Emission ~few MeV
- Random time structure

Intensity ~ 10^6-10^8 e^+/s

Pair Conversion by energetic photon



Requires high energy electron beam

- Bremsstrahlung
- Synchrotron/Undulator
- Compton scattering

Suited for high energy

- LINAC acceleration
- Timing set by “drive” beam

Intensity ~ 10^{10}-10^{12} e^+/s

Outline

Applications

- Diverse activities and energy requirements

Radioactive β^+ decay

- Source, moderation and examples

Pair production by gamma rays

- Suited for RF accelerators
- Technical challenges
- Positron facilities

Polarized Positrons

- Sources and demonstrations
- Newest method: Polarized Electrons for Polarized Positrons (PEPPo)

Outlook

- Positrons at Jefferson Lab (CEBAF, LERF, UITF)
- R&D Challenges

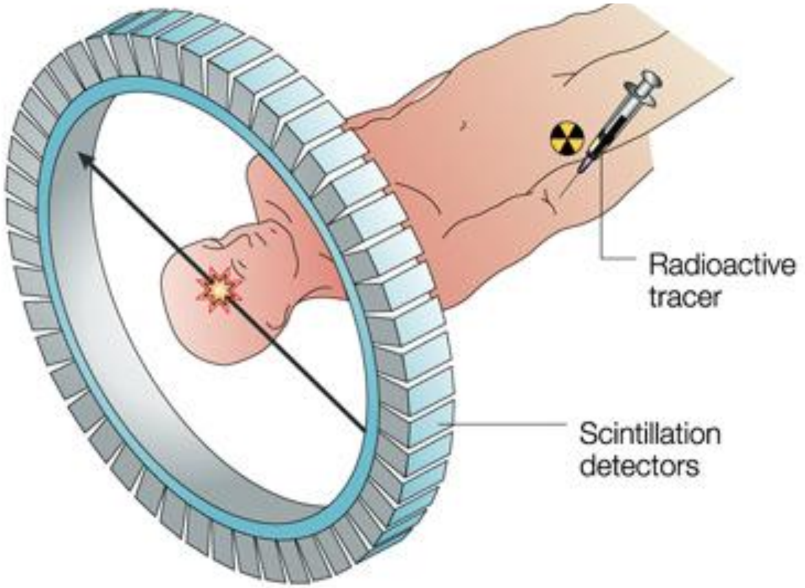
How are positrons used ?

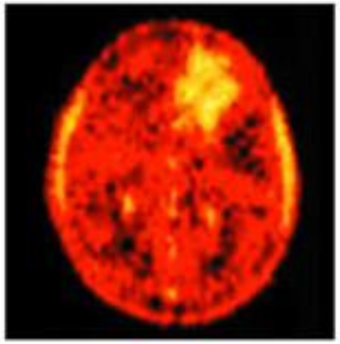
Many applications with energy scale from 1 eV to 1 TeV

- Medicine – positron emission tomography
- Materials Science – positron annihilation spectroscopy
- Anti-matter gravity – positronium formation
- Nuclear Physics – DVCS, GPD's, Dark Matter Searches
- Detectors – excellent source of annihilation photons
- Standard Model Tests – Higgs production

Positron Emission Tomography

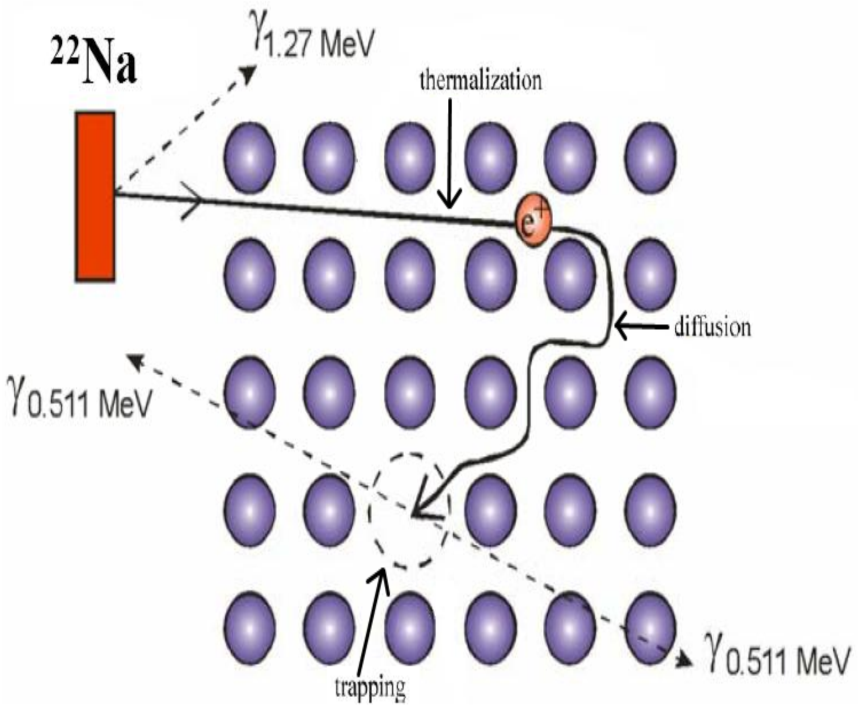
- Short-lived radioactive tracer is injector into the subject and becomes concentrated in tissue of interest
- After travelling up to a few millimeters the thermalized positron annihilates into a pair of oppositely moving gammas
- Technique depends upon high energy resolution of photons which arrive in pairs.





Positron Annihilation Spectroscopy (PAS)

- Probe for semiconductors, electronic structure of metals and alloys, radiation damage, surfaces and interfaces



e^+ annihilation rate $\propto$ e^- density

PAS Techniques and Observables

Positron Lifetime (PALS)

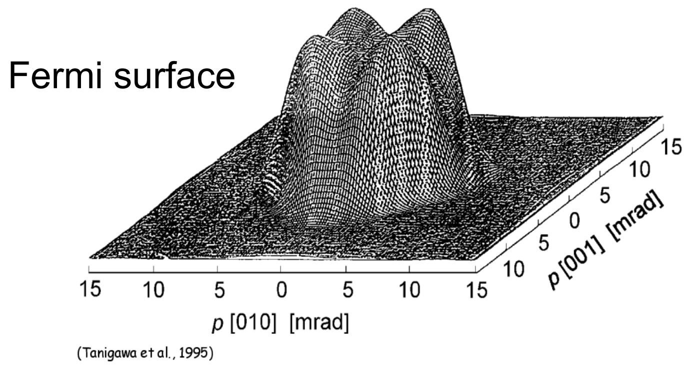
Time between trigger and annihilation photon depends on void size and defect density

- Silicon (bulk): 218 ps
- Defect (dopant): 260-330 ps

Angular Correlation (ACAR)

Angular deflection between annihilation photons due to transverse momentum of electrons

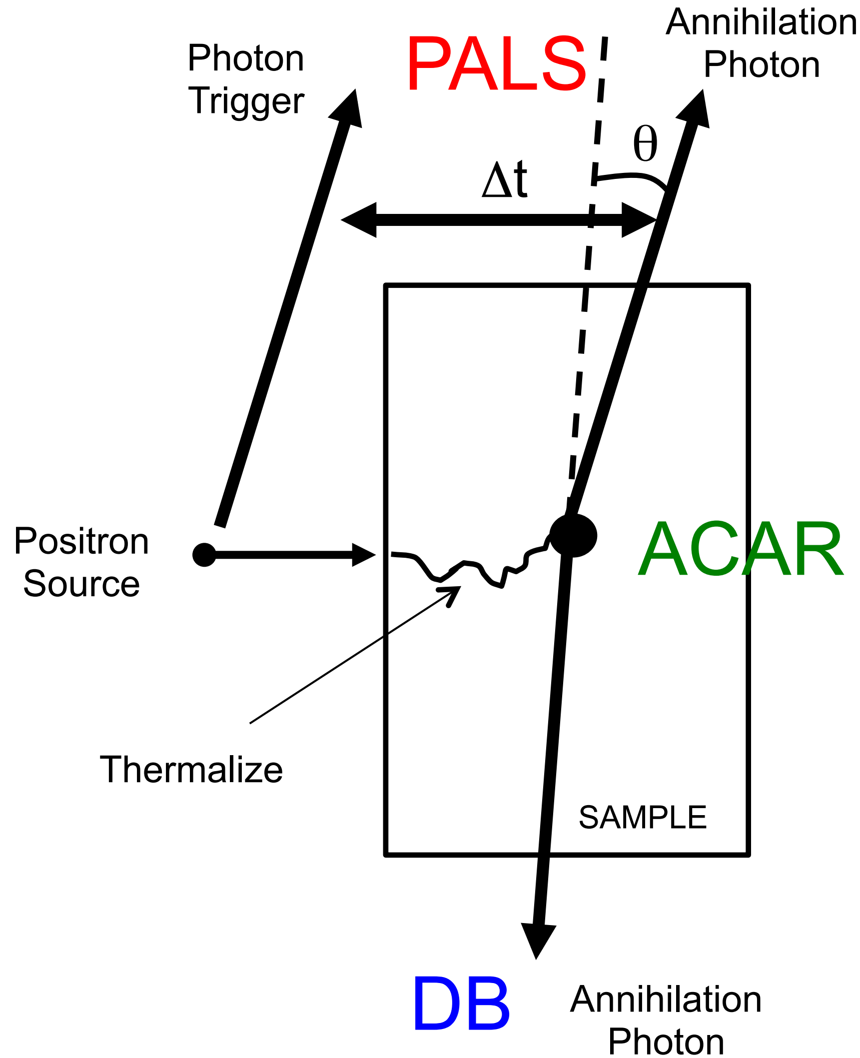
$\theta \propto p_{x,y}/m_{e-}$



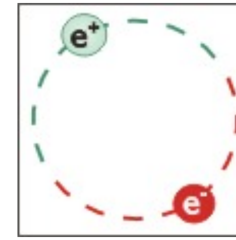
Doppler Broadening (DB)

Annihilation photon energy shift due to the longitudinal momentum of electrons

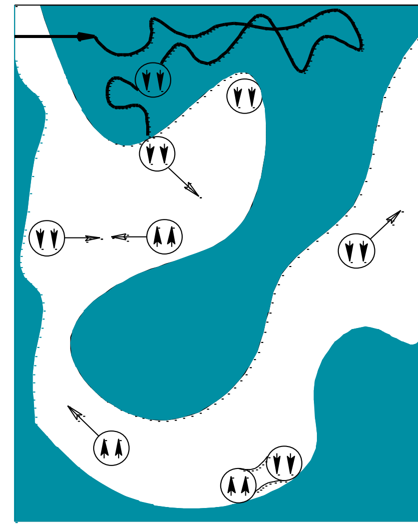
E_γ=0.511 MeV ± ΔE (ΔE ∝ p_z/2)



Positronium (Ps) Formation



- Although an electron/positron pair are doomed to annihilate they can briefly exist in a bound state described as a hydrogen atom with corresponding reduced mass of e^+/e^-



- Positrons directed into porous silica can pick up an electron to form Ps in the bulk and then diffuse to the surface or remain in internal voids
- Ps can also be become trapped on the surface to form Ps_2 molecules
- Ps provide tool for atomic physics (QED), astrophysiccal or production of anti-matter

Spin

$$|0,0\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle\right)$$

$$|1,0\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\downarrow\rangle + |\downarrow\uparrow\rangle\right)$$

$$|1,1\rangle = |\uparrow\uparrow\rangle$$

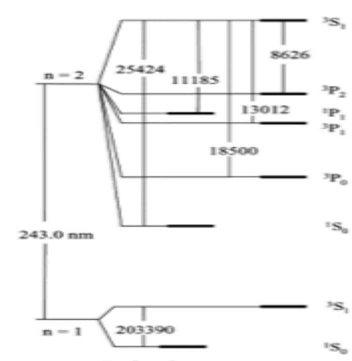
$$|1,-1\rangle = |\downarrow\downarrow\rangle$$

Lifetime

para-Ps (s=0) ~ 125 ps

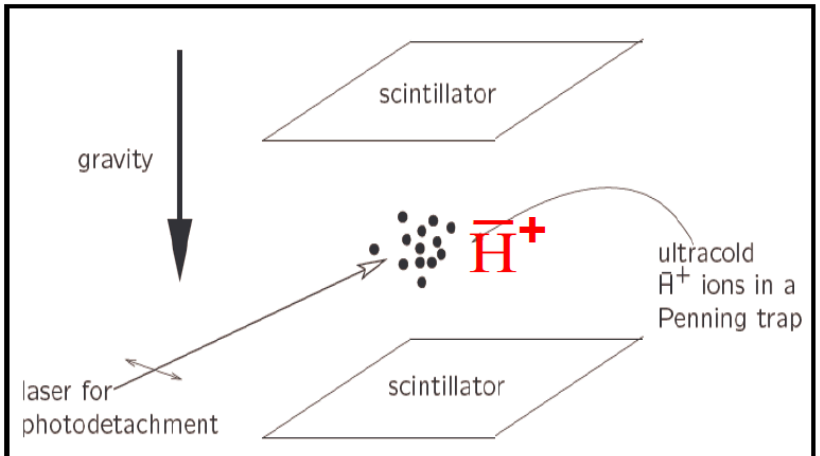
ortho-Ps (s=1) ~ 142,000 ps

Energy Levels



Gravitational Force on Anti-Hydrogen

Measure "free-fall" of $\bar{H}^+$ cooled to a few μK



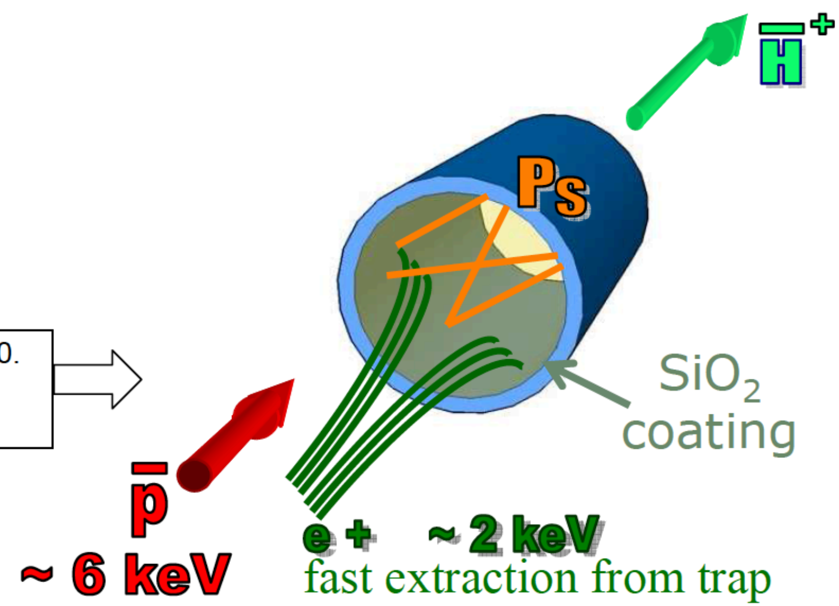
J.Walz & T. Hänsch,
General Relativity and Gravitation, **36** (2004) 561.

P.Pérez and A. Rosowsky, Nucl. Inst. Meth. A 545 (2005) 20-30.
P. Pérez et al., CERN-SPSC-2007-038, December 2007.
P. Perez, SLOPOS-11 communication

Needs high intensity slow positron beam!

$\bar{H}^+$ formation

$$\bar{p} + Ps \rightarrow \bar{H} + e^-$$
$$\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$$



Nuclear Physics (0.1 – 10 GeV)

Jefferson Lab's CEBAF Accelerator
CW electron beam to 3 halls
Electron Polarization ~90%
Max Energy: 11 GeV(ABC) / 12GeV(D)
Max Current: 200 uA

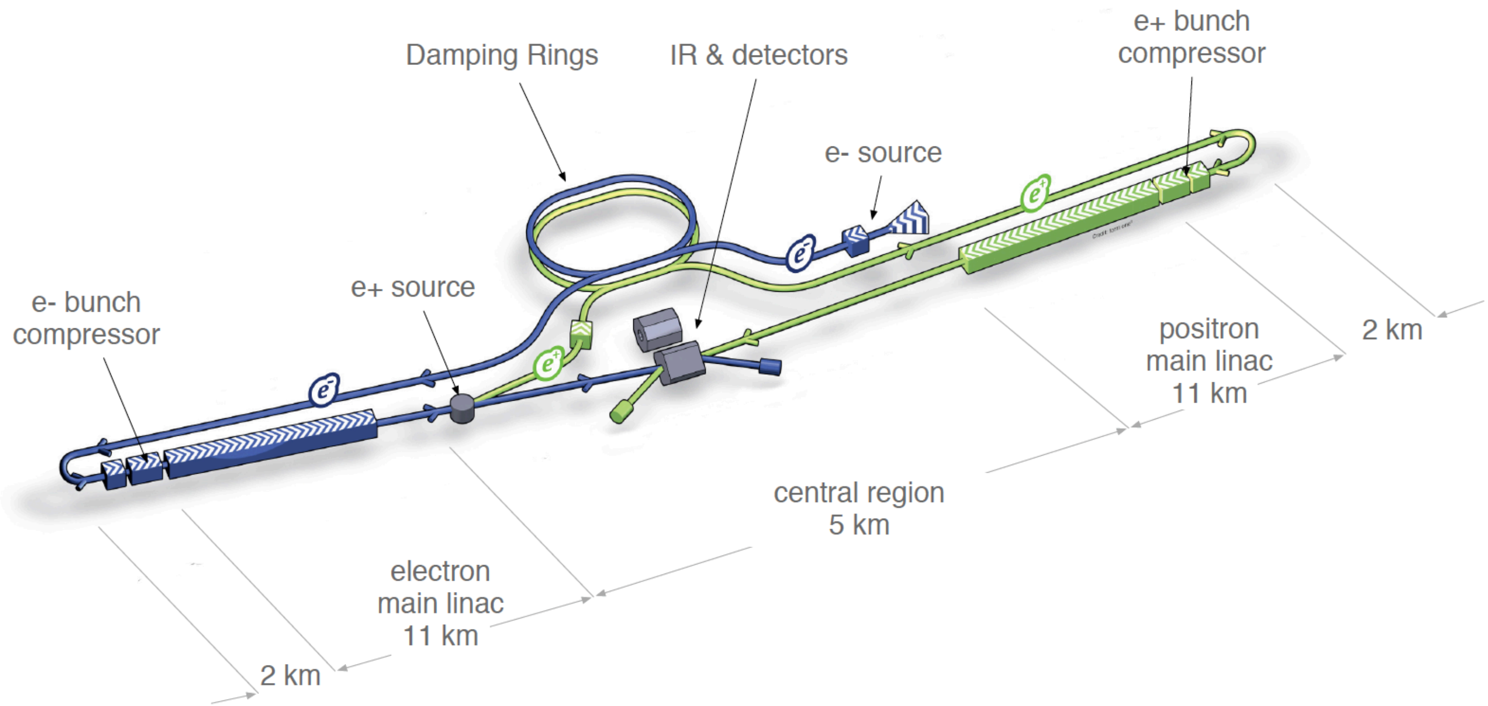
The charge and polarization of the probe beam provide degrees of freedom. An addition of a positron beam constrain the physical observables.

- Electromagnetic form factors (U,P)
- Generalized parton distributions (U,P)
- Inclusive structure functions (U,P)

- Search for the U-boson of dark matter (U)

Energy Frontier Tests of the Standard Model (1 TeV)

International Linear Collider design relies on the collision of *polarized electrons* and *polarized positrons* resulting in center-of-mass-energies from 200 GeV to 1 TeV



- Thrust is to provide precision tests of Standard Model that benefit from model independent reactions that do not depend on the additional “stuff” which results from colliding massive particles, e.g. like that at the LHC.

- The polarization of the e+ and e- further enhances the effective luminosity

Positron Sources

What are considerations to forming a positron beam ?

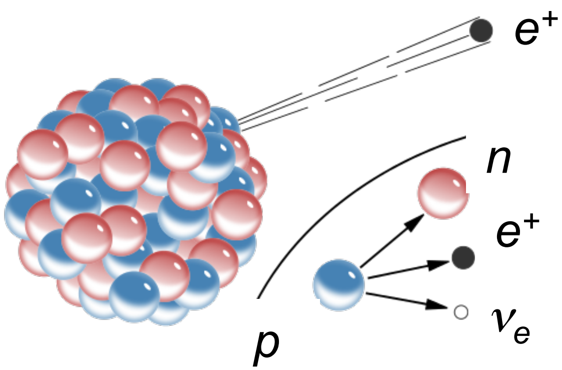
- Final energy
- Generation
- Collection
- Time Structure
- Power
- Radiation
- Polarization

Positron Generation by β Decay

Beta-plus (β^+) decay occurs when a proton inside a nucleus becomes a neutron via emitting W^+ (or absorbing W^-) via the weak interaction.

$$^{23}_{12}\text{Mg} \rightarrow {}^{23}_{11}\text{Na} + e^+ + \nu_e$$

The daughter nuclide retains the mass number (A) but the atomic number (Z) decreases by 1 unit.

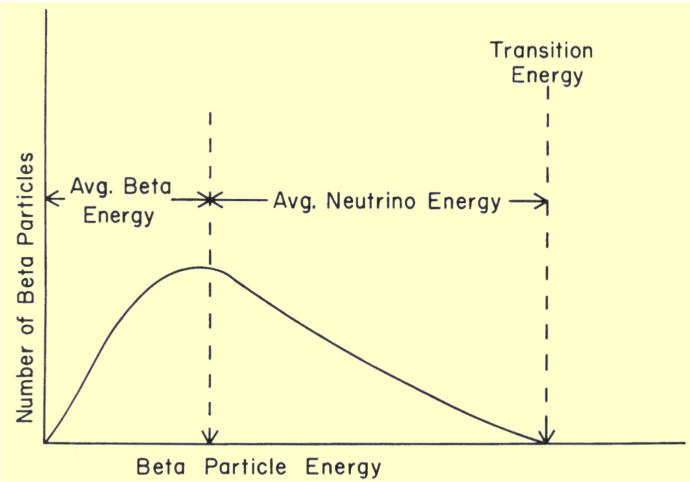


$$Q = \left[m_N\left({}^A_Z\text{X}\right) - m_N\left({}^{A}_{Z-1}\text{X}'\right) - m_e - m_{\nu_e}\right]c^2$$

$$Q = \left[m\left({}^A_Z\text{X}\right) - m\left({}^{A}_{Z-1}\text{X}'\right) - 2m_e\right]c^2$$

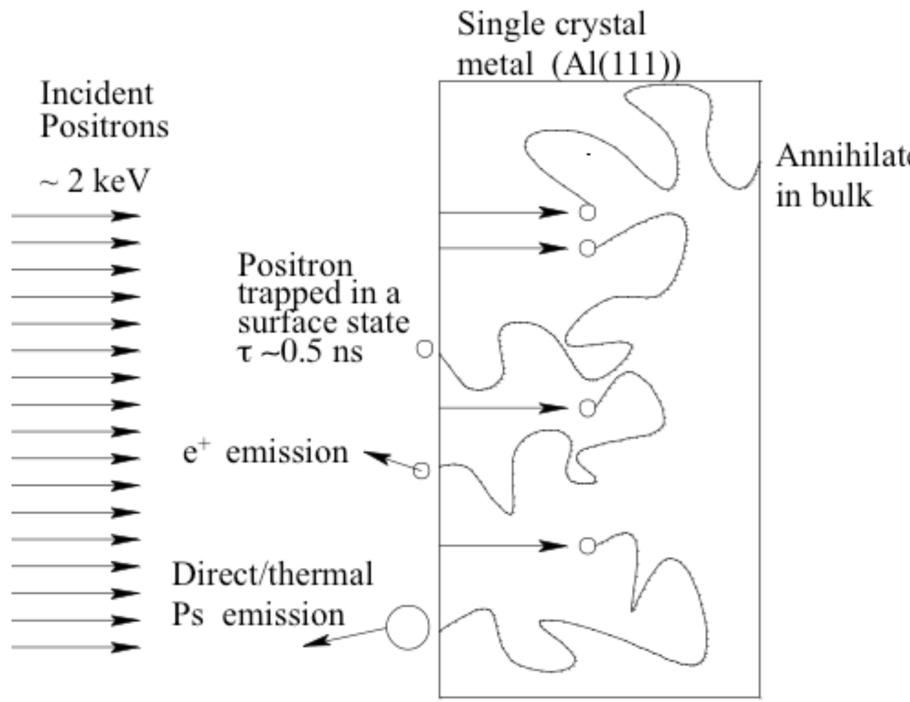
- Q > 0 which implies a lighter free proton cannot decay into a heavier neutron
- Q ~ few keV up to ~10 MeV which the kinetic energy partitioned to e+ and ν_e
- KE beta+ is typically ~1 MeV

Radioactive β^+ Sources



Typical source:

Na^{22}, mean 178keV, endpoint 545keV



Use of moderators

Many simply reflect (high Z backing)

Rapidly thermalize (~1 ps)

- core and conduction electrons
- plasmons ~ 10 V
- phonons ~ 1 V

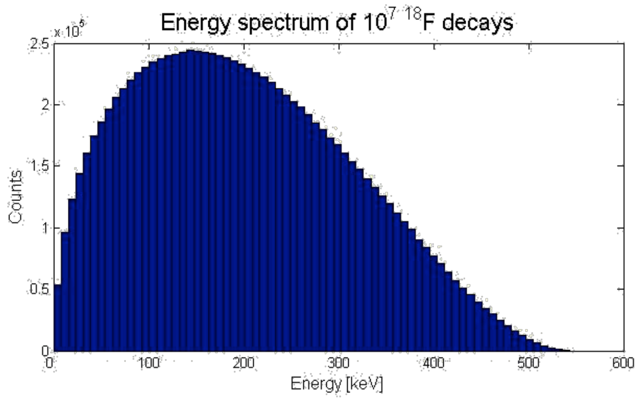
Their fate is varied

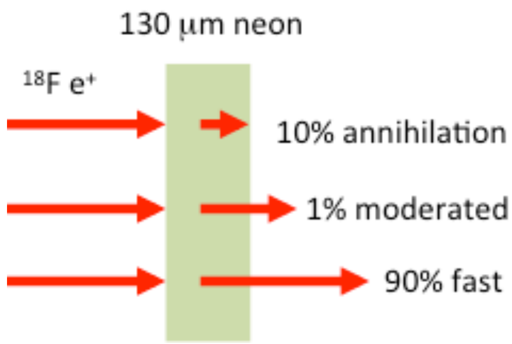
- Annihilate in bulk
- Captured at surface and annihilate
- Pick up e- and leave as Ps
- KE per work function

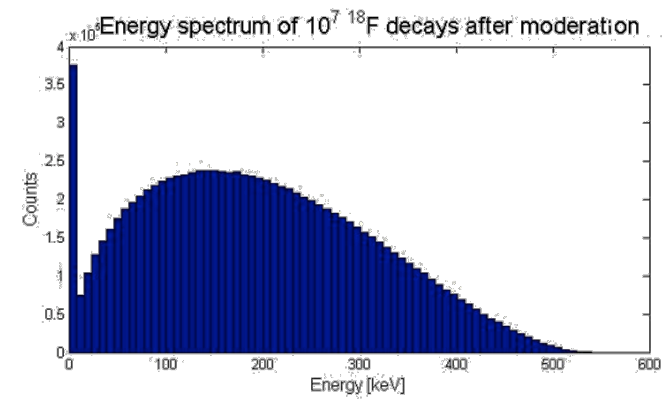
$\varepsilon = L/R * S$

ε: efficiency for e+ emission
L: diffusion length ~100 nm
R: range ~15,000 nm
S: surface prob ~ 35%

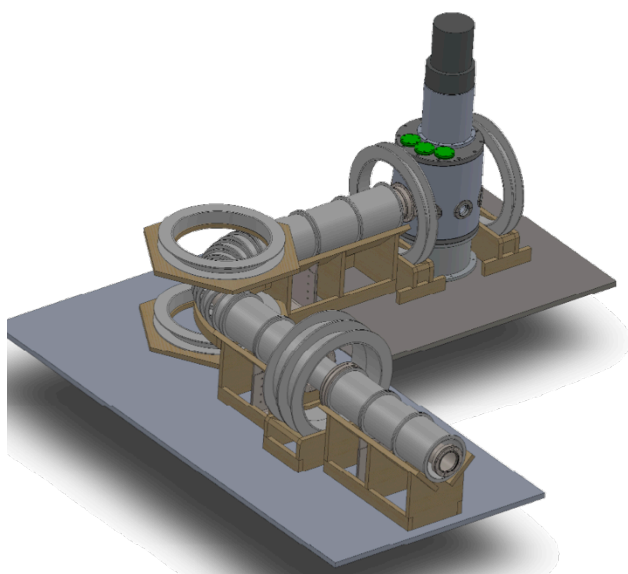
β^+ beam based on ^{18}F (30eV - 30 keV)







- A radioactive source (^{18}F) is moderated with frozen neon
- Moderation efficiency of 1% achieved for positrons of 2 eV +/- 1 eV
- 2 eV particles DC accelerated to 30eV - 30keV
- Magnetic energy selection of intense (10^6 e^+/s) mono-energetic beam
- Safe with concealed HV system and radiation shielding



β^+ beam based on ^{22}Na (0.5 - 6.5 MeV)

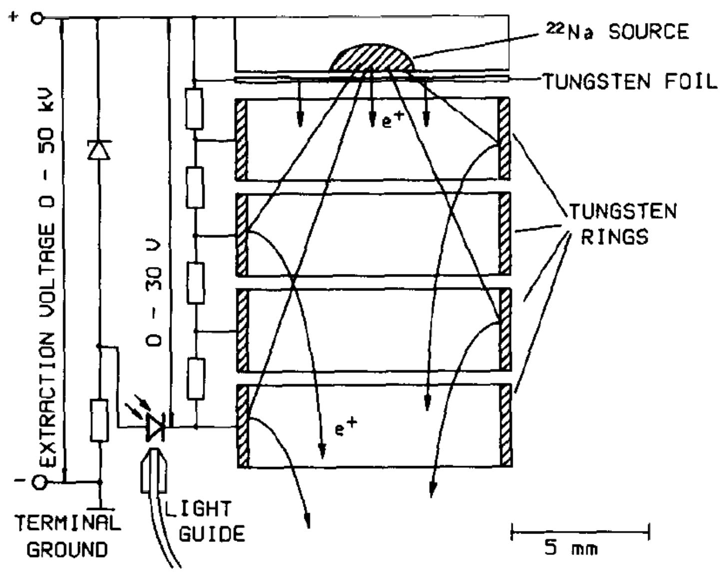


Fig. 1. Schematic of the slow-positron source with tungsten moderators.

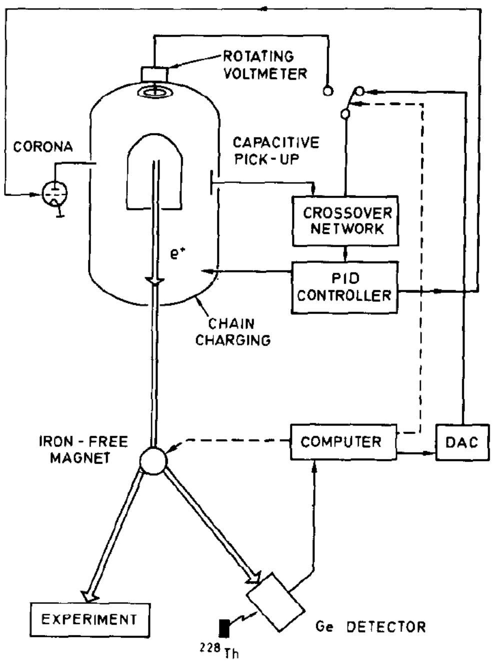


Fig. 3. Block diagram of the circuit used for the stabilization and calibration of the positron energy. The positron beam is periodically switched onto a windowless Ge detector for absolute energy measurement.

Nuclear Instruments and Methods in Physics Research B50 (1990) 300–306

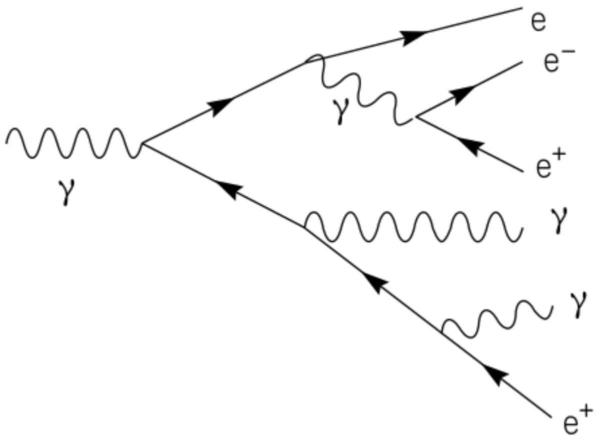
^{22}Na source (6 x l0^8 Bq) are moderated by a tungsten foil (thickness 3-6 micron) and tungsten rings (height X diameter = 3.3 mm X 10 mm) in a combined transmission-reflection geometry

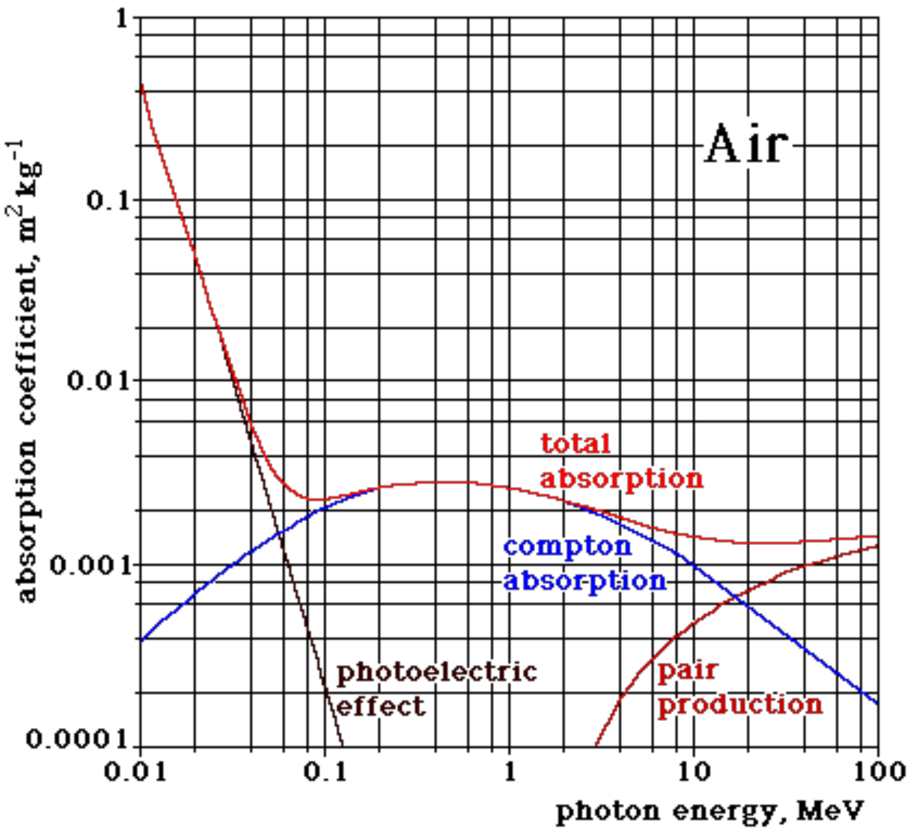
Intensity 6 x l0^4 e+/s at target
Pelletron DC acceleration 0.5 - 6.5 MeV
Energy stability $\Delta E/E < 10^{-4}$

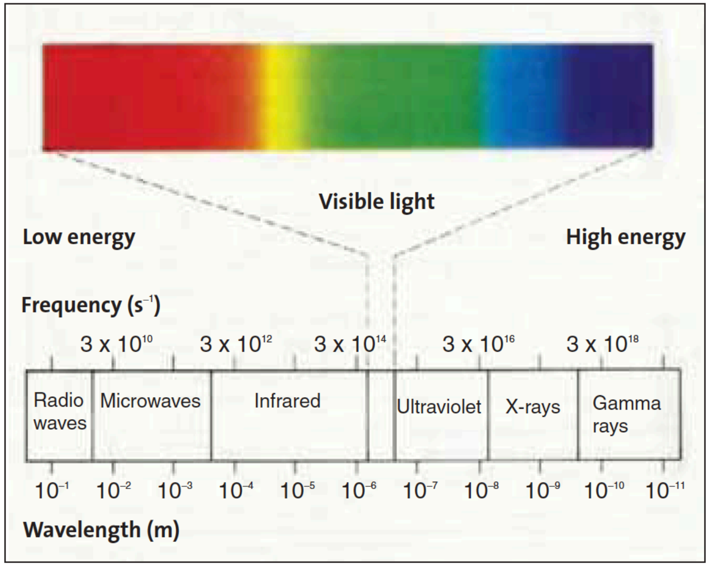
Positron Production by Electromagnetic Showers

An electromagnetic shower is generated by high energy electrons, positrons or photons in matter

- e+ and e- primarily emit photons (bremsstrahlung)
- Photons > ~few MeV dominate pair production

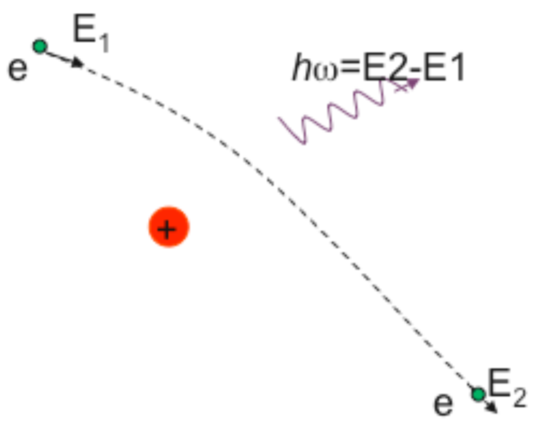




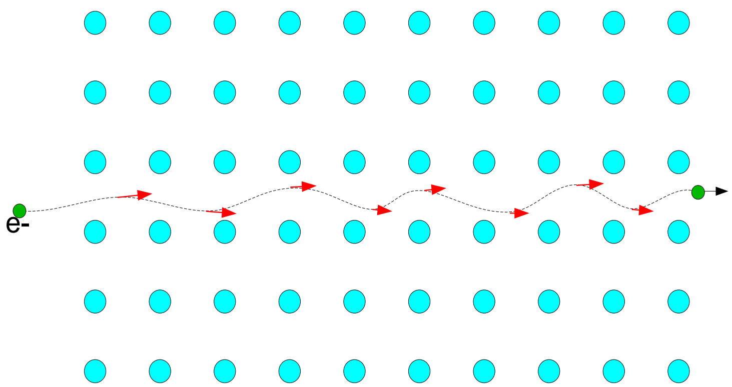


Generating Intense Gamma Rays

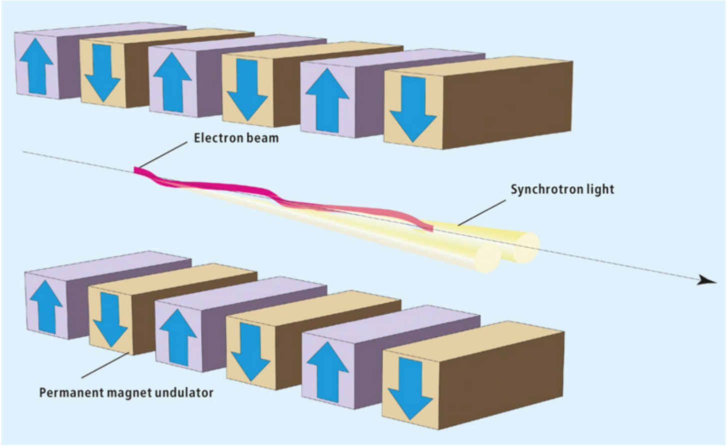
Bremsstrahlung



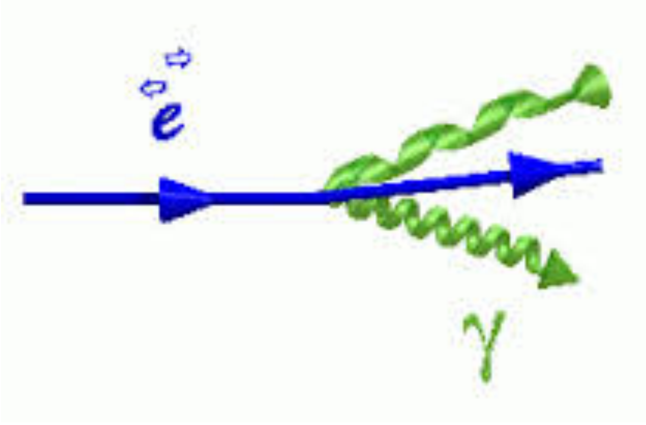
Coherent Bremsstrahlung



Undulator



Inverse Compton Scattering



Accelerator Positron Sources

Previous

- SLAC – Stanford Linear Accelerator Center (US)
- HERA – Hadron Electron Ring Accelerator (Germany)
- CESR – Cornell Electron Storage Ring (US)

Present

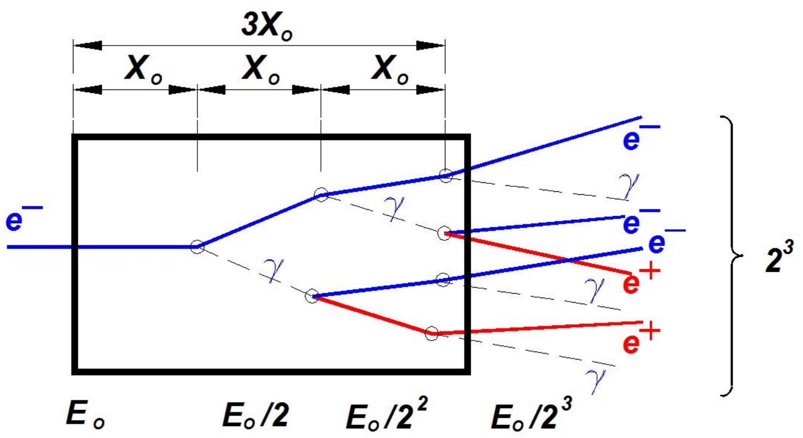
- BELLE/KEK – National Laboratory for High Energy Physics (Japan)
- VEPP – Budker Institute of Nuclear Physics (Russia)
- BEPCII – Beijing Electron Positron Collider (China)

Proposed

- ILC - International Linear Collider

Facilities	Driving e^- Beam				e^+ Source		Yield	$\varepsilon(e^+)$
	E (GeV)	$N(e^-)$	ω (Hz)	Size(mm)	Target (mm)	Matching	$N(e^+)$	(mm·mrad)
SLAC	33	$4\text{x}10^{10}$	120	2.5	W-Ta (24)	AMD	2×10^{12}	25 (at 200 MeV)
BEPCII	0.24	4.5×10^{18}	50	1-3	W (8 mm)	AMD	10^{16}	1.6 (1.89 GeV)
CESR	0.2	2×10^{11}	50	2.5	W-Re	QWT	10^{10}	-
KEK [50]	0.25	6×10^{19}	-	-	Ta	QWT	6×10^{17}	2 (at 1 GeV)
VEPP4	0.27	1.6×10^{11}	1	-	W	AMD	5×10^{8}	-
ILC	130	2.8×10^{13}	5	0.75	W76Re24	AMD	10^{14}	-

Yield from an Electromagnetic Shower



Positron yield depends on…

- Incident energy
- Target material
- Incident Intensity

Radiation length

- Mean electron energy loss (1/e)
- 7/9 mean path for pair production

$$X_0^{-1} \cong 4r_0^2 \alpha \frac{N_A}{A} Z(Z+1) \ln\left(\frac{183}{Z^{1/3}}\right) [cm^2/g]$$

Element	**C**	**Al**	**Ti**	**Fe**	**Cu**	**W**
Z	6	13	22	26	29	74
A	12	27	47.9	55.8	63.5	183.8
$E_c\ (MeV)$	84.2	42.8	26.2	22.4	20.2	8.1
$X_0\ (g/cm^2)$	43.3	24.3	16.1	13.84	13	6.8
$L\ (cm)$	19.2	9	3.58	1.75	1.45	0.35

Managing Beam Power

Large amount of power is deposited in the conversion target.

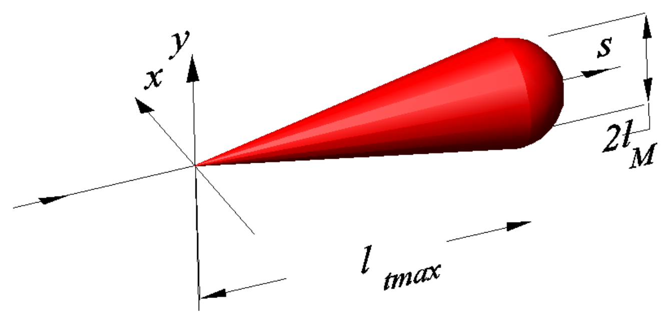
Beam power management depends upon…

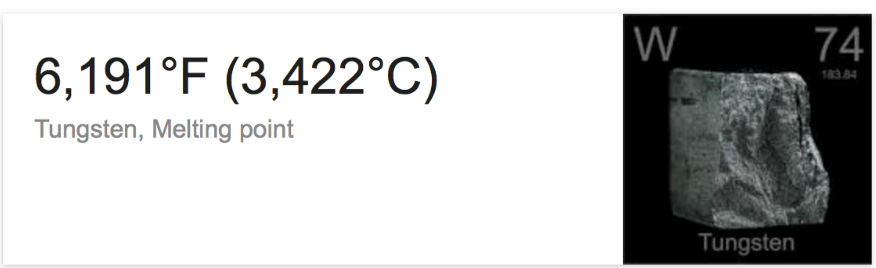
- Conversion efficiency to useful positrons (0.001 to 1)
- Required positron intensity
- Target material
- Time structure

It's not uncommon to require 10's of kW of beam power.

Consider 20 kW deposited in $1X_0$ of tungsten (W) :

$$\Delta T \cong \frac{E_{tot}}{mC_p} \cong \frac{E_{tot}}{\rho \frac{\pi}{3} l_{t_{\max}} l_M^2 C_p} \cong 3000\,\deg C$$

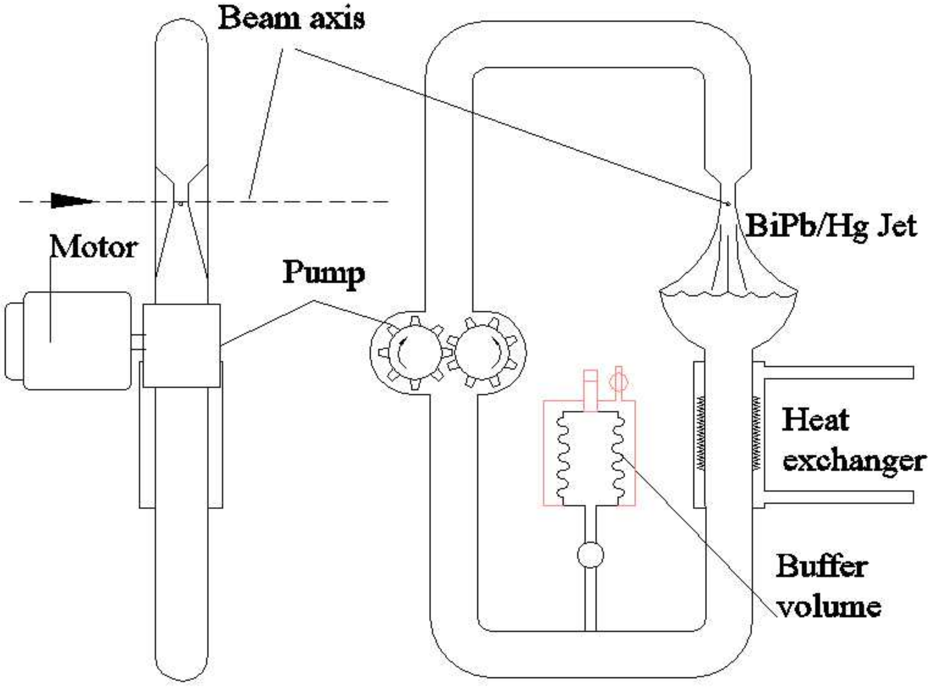


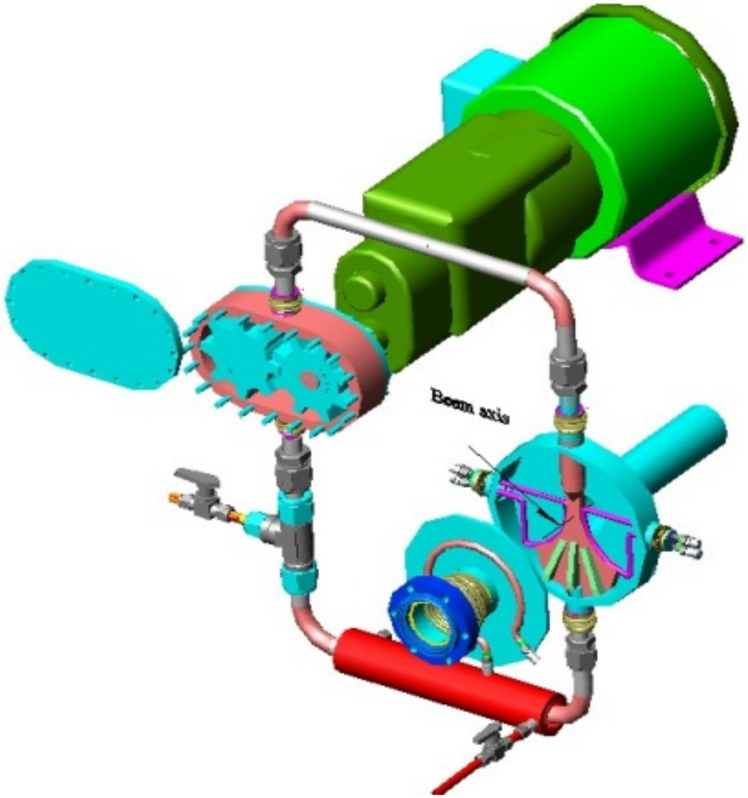


High-Z Liquid Jet Target

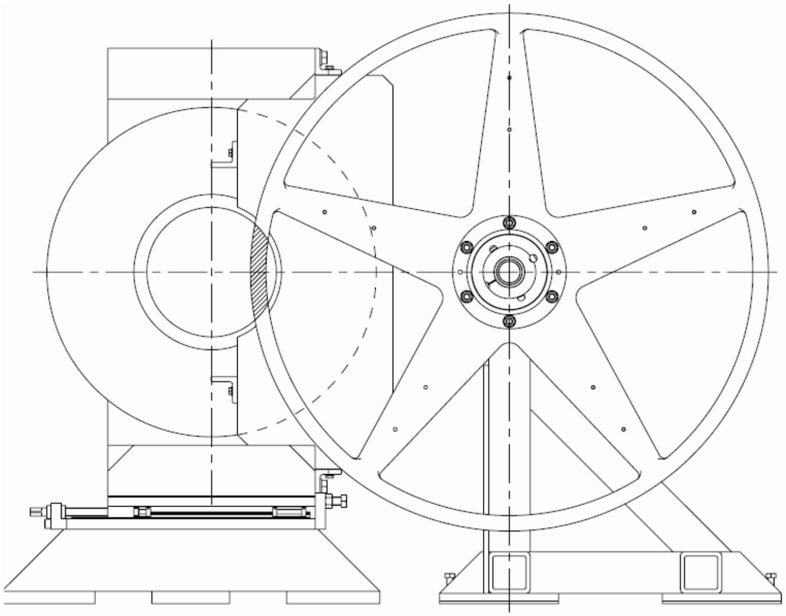
Jet or stream for rapid mass transfer
Heat exchangers
High boiling point metals

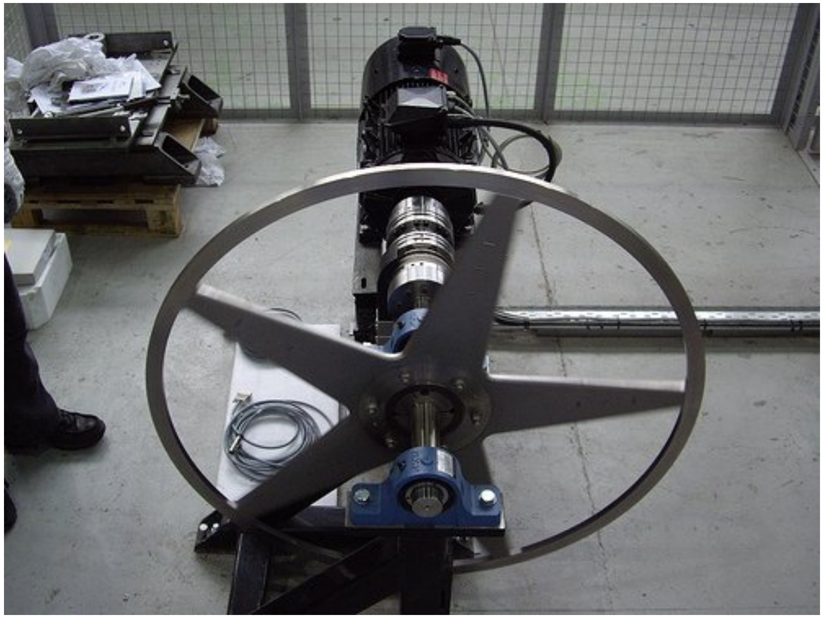
- Bismuth-Lead (BiPb) ~ 1670 ^{o}C
- Mercury (Hg) ~ 356 ^{o}C





Rapidly Rotating Cooled Solid Target





- ILC target design schematic and prototype
- 1 m diameter (2m projected)
- 2000 rpm
- Titanium alloy
- Water-cooled
- 10 kW power deposition @ 130 kW photons

Managing Neutrons

R.Montalbetti, L.Katz, J. Goldemberg, "*Photoneutron Cross Sections*", Phys.Rev. **91**, 659 (1953).

Elements →	C	W	Cu	Al	Fe	Pb	U
$E_{\gamma th}(\gamma,n)$ *MeV*	18.72[1]	6.19	9.91	13.03	11.21	6.73	6.04

[1]Natural Graphite contains 1.1% of C^{18} which has a threshold of 4.9 *MeV*

Neutron dose for electron beam carrying power $P[kW]$ at distance $R[m]$

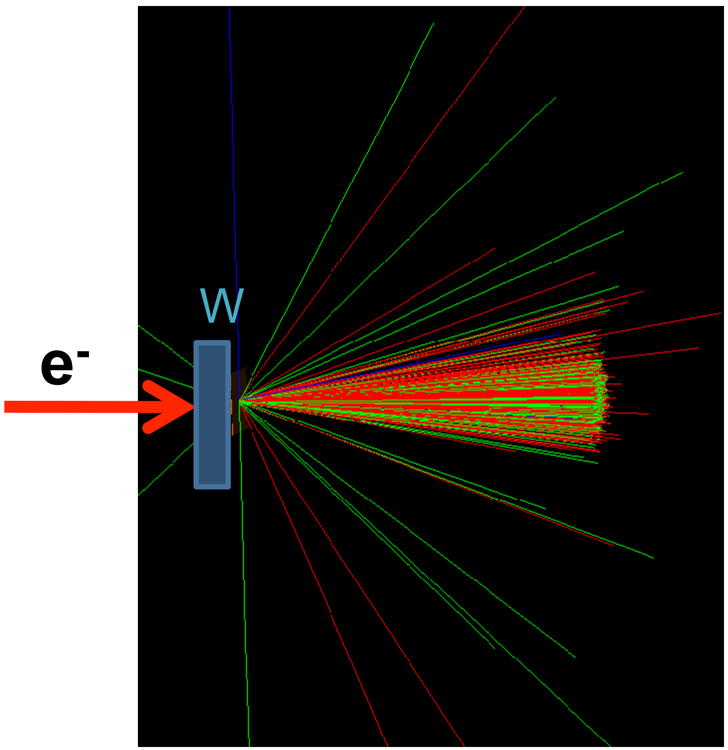
$$\dot{D}(rem/hour) \cong 93 \cdot Z^{0.73} \frac{P[kW]}{R[m]^2}$$

W.P.Swanson, "*Calculation of Neutron Yields Released by Electrons Incident on Selected Materials*", Health Physics, Vol.35, pp.353-367, 1978.

For any positron source operating above threshold (generally ALL) neutron shielding and radiological design is integral to overall design

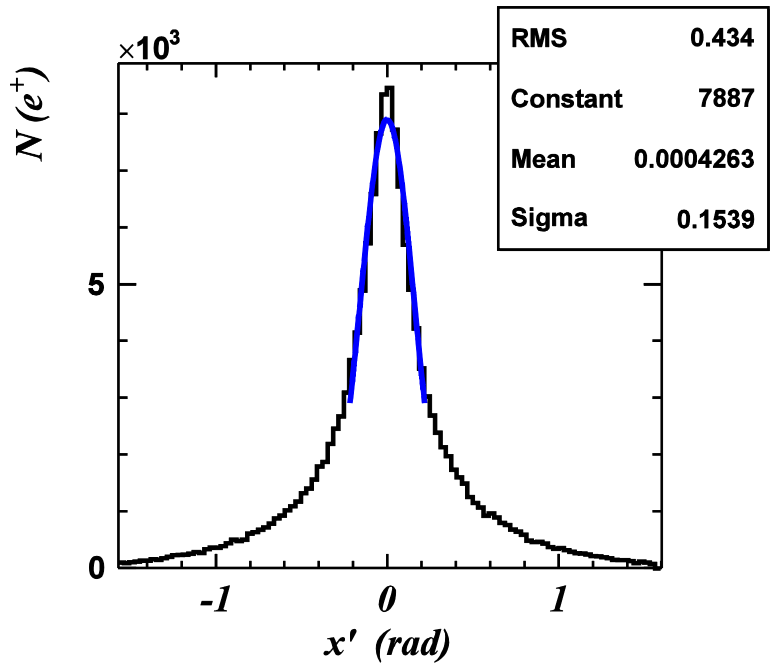
Angular Distribution

126 MeV e⁻ on 2 mm W



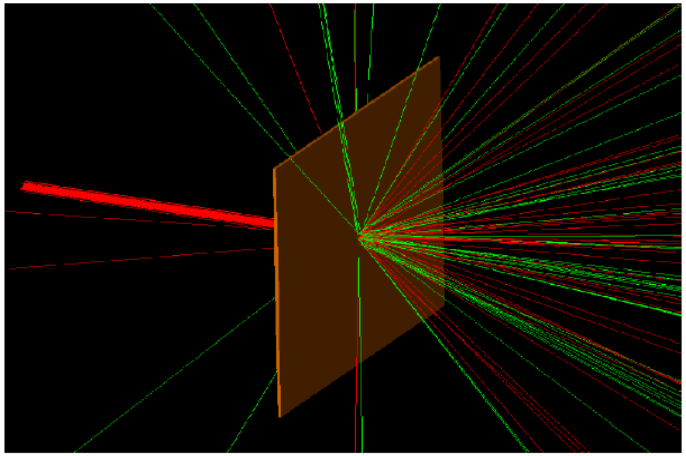
$$\theta \approx \frac{13.6MeV}{pc}\sqrt{\frac{x}{X_0}}$$

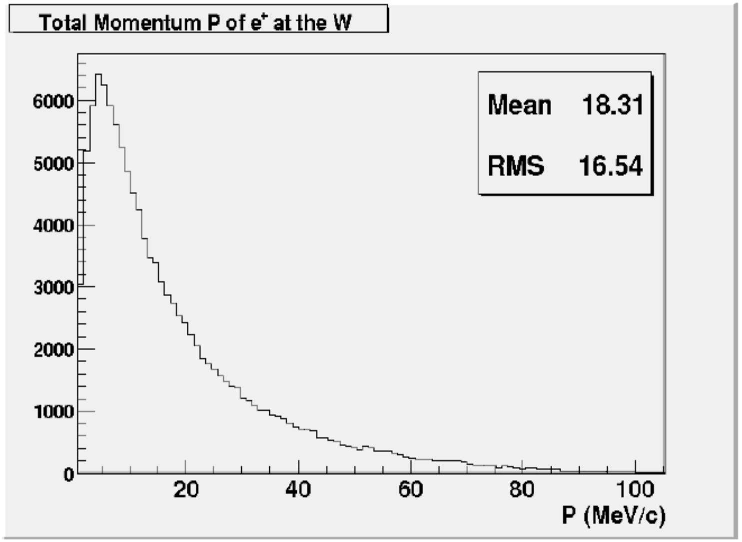
x/X_o : thickness in radiation length

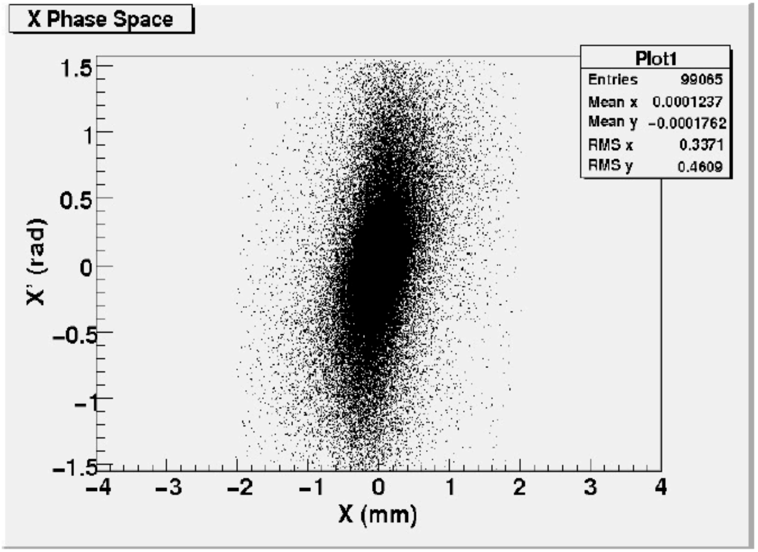


θ ~ 400 mrad ~ 23°

Momentum Distribution







Incident e- Beam Properties on a 3mm W:

Power = 120MeV×10mA = 1.2 MW

$\varepsilon = 10^{-8}$ m•rad

Emerging e+ Properties:

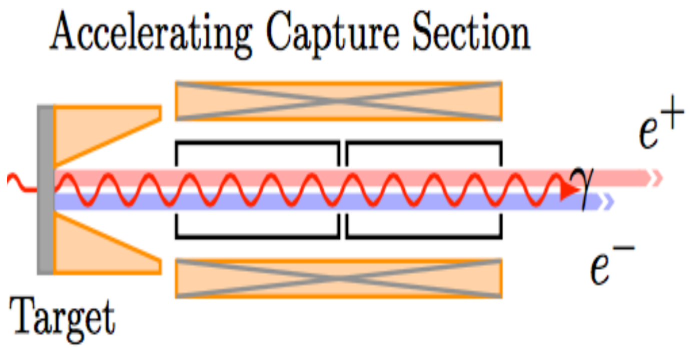
ε = 0.3 mm x 460 mrad ~ 14000x10^{-8} m•rad

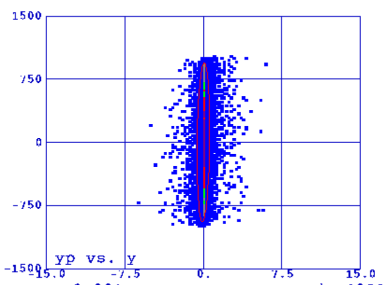
Yield : 0.12 e^+ per e^-

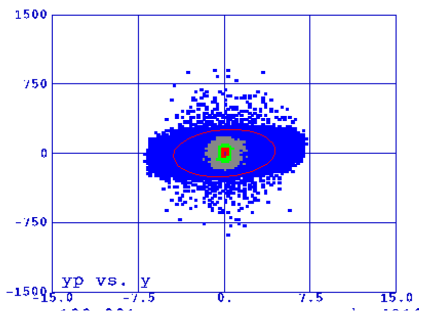
Taming the Positrons

High field solenoid transforms the large divergence small radius emittance at the radiator into a more nearly parallel beam at somewhat larger radius.

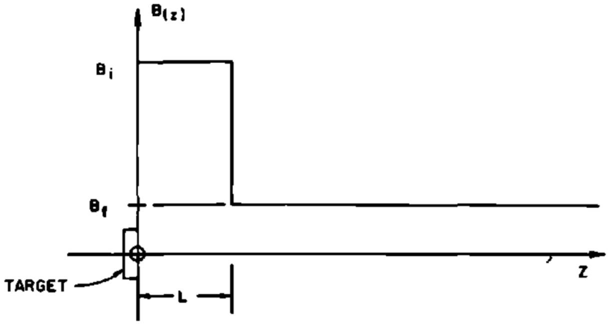
Low uniform-field solenoid holds the beam together through several accelerator sections until beam is focused by quadrupole lenses



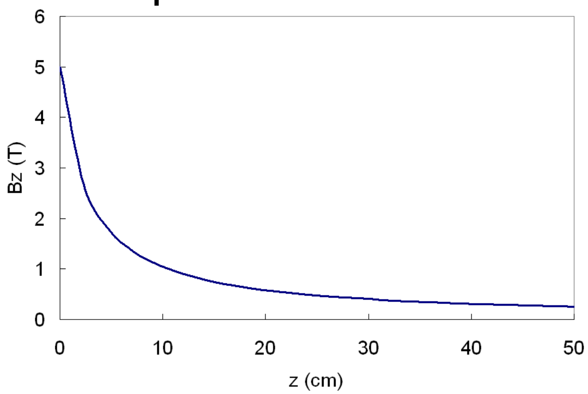




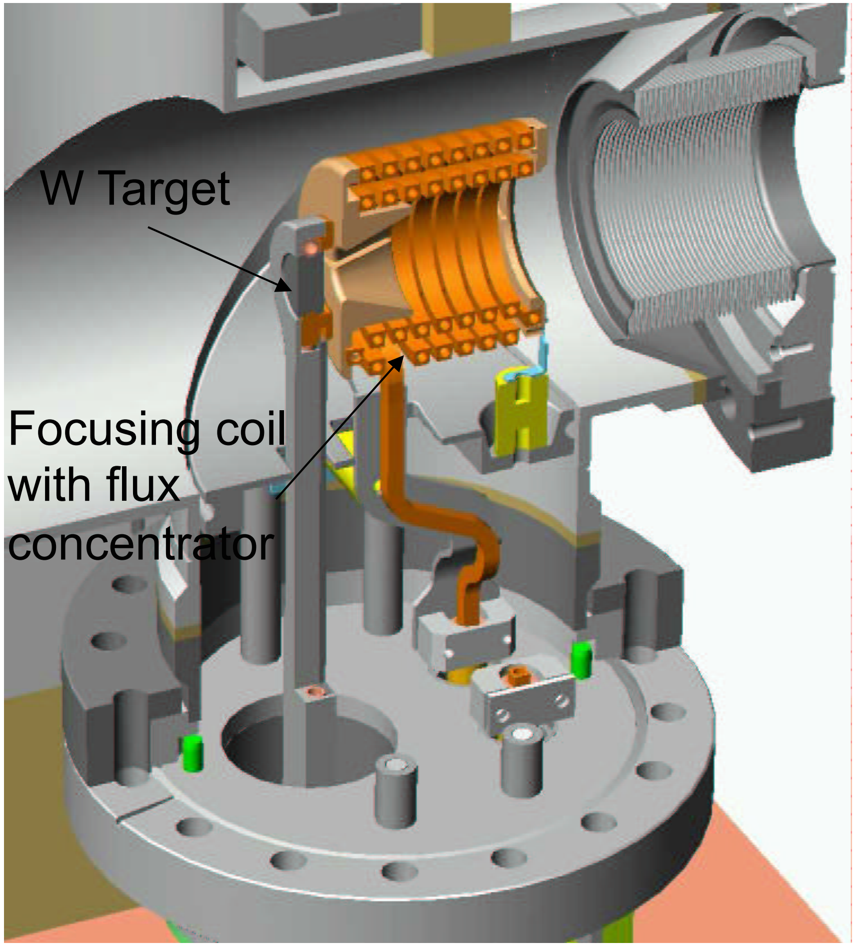
Quarter Wave Transformer

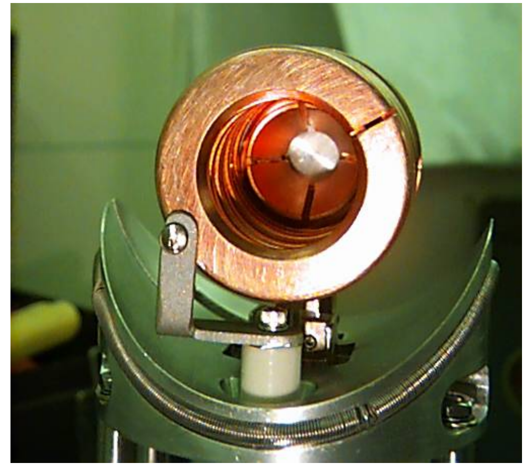


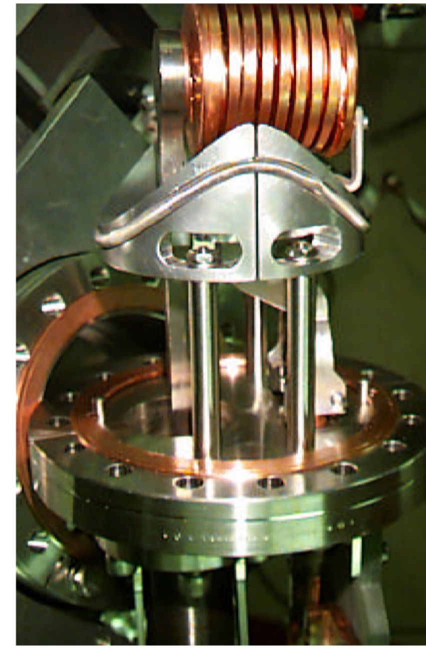
Tapered Transformer



Cornell Positron Source







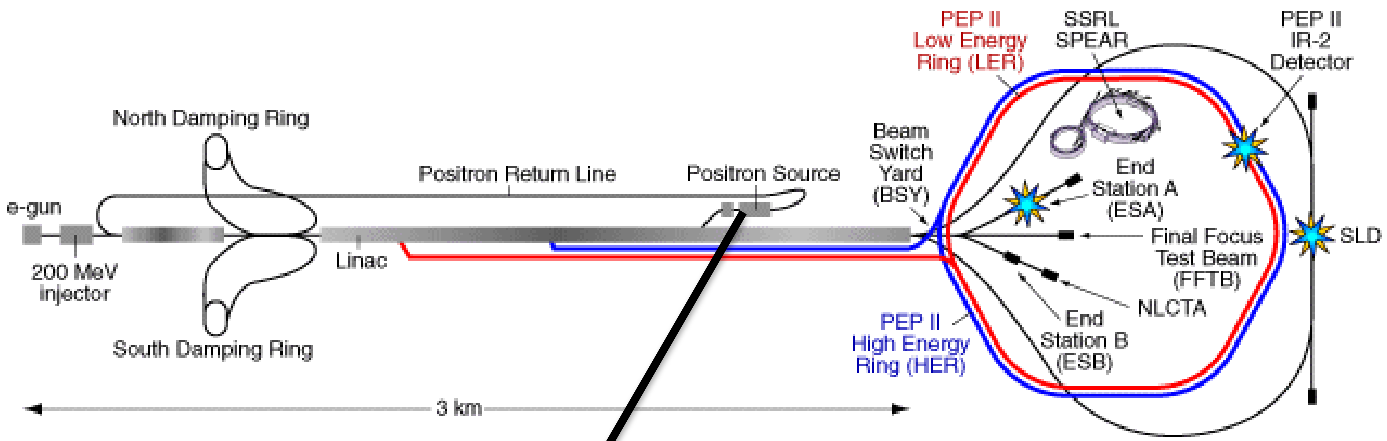
This short-focusing lens followed by RF structure immersed in solenoid

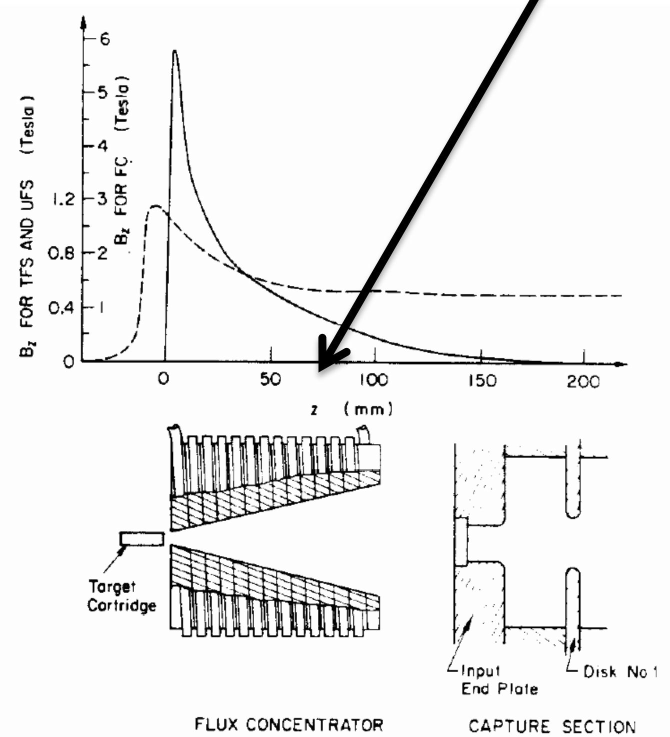
Positron rate ~10^{11} /sec at 50 Hz operation at ~200 MeV

Conversion efficiency~2.5%, DC power consumption ~2.5 kW

J. Barley, V. Medjidzade, A. Mikhailichenko, "New Positron Source for CESR", CBN-01-19, Oct 2001. 16pp.

Stanford Linear Accelerator Center (SLAC)





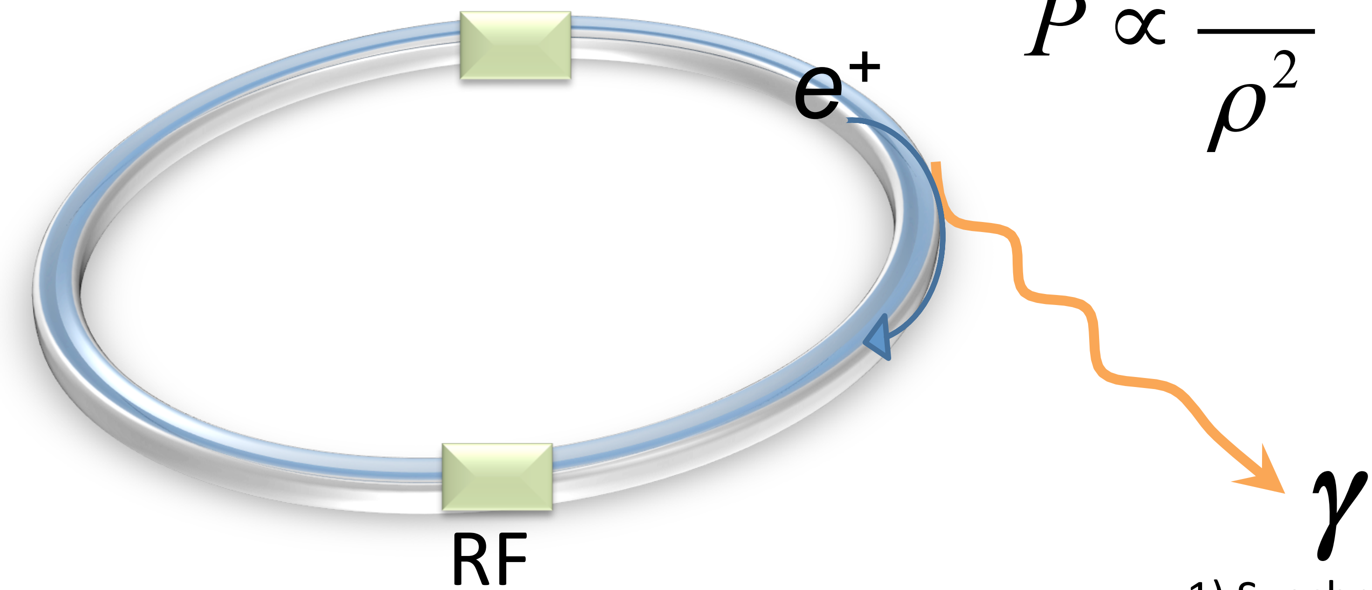
Driving electron beam	
Energy (GeV)	33.0
Spot Size 1σ (mm)	0.6
Intensity	5×10^{10} / pulse
Pulse Energy (Joule/pulse)	264.0
Pulse Rate (Hz)	120-180
Beam Power (kW)	47.0
Target	
Material	90% Ta - 10% W and WRe
Length (mm)	20 (or 6 rad. length)
Deposited Energy (Joule/pulse)	53.0
Deposited Power (kW)	9.0
Positron beam	
Capture Energy (MeV)	5 - 20
Spot Size (mm) 1σ	2.0
Normalized Emittance (m·rad)	10^{-2} at 200 MeV
Yield (e^+/e^-)	2.5

Damping Ring to Reduce Emittance

$$\varepsilon(t) = \varepsilon_{\text{inj}} e^{-2t/\tau} + \varepsilon_{\text{equ}} \left(1\text{-}e^{-2t/\tau}\right)$$

$$P \propto \frac{E^4}{\rho^2}$$

P :Radiated power
E: Energy of the particle
ρ : Bending radius



2) RF cavities restore energy to off-momentum particles undergoing synchrotron oscillations

1) Synchrotron radiation “steals” momentum from all components

SLAC e^+ (1.2 GeV, ρ=5.6m) damping time ~ 12 ms

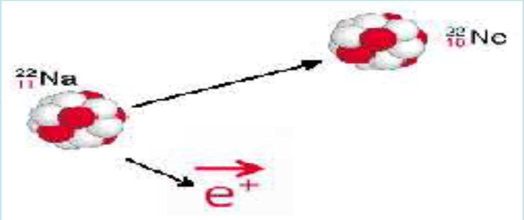
Lower energy increases damping time to seconds!

Therefore “long” damping times are not suited for CW operation

What about Polarization ?

Polarized β^+ Decay

L.A. Page & M. Heinberg. Phys. Rev. 106(6):1220-1224 (1957)

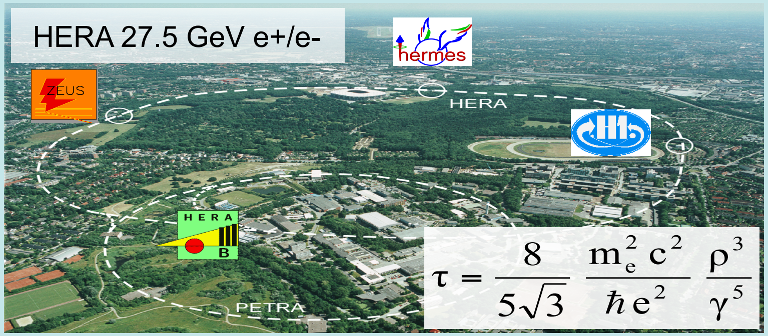


Polarized due to parity non-conservation in the weak interaction

$P(e^+) \sim 40$ %

Sokolov-Ternov Effect

D. Barber , AIP Conf. Proc. 588, 338 (2001)

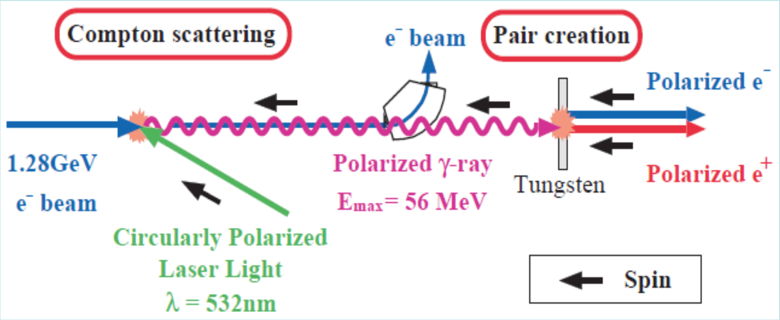


$$\tau = \frac{8}{5\sqrt{3}} \frac{m_e^2 c^2}{\hbar e^2} \frac{\rho^3}{\gamma^5}$$

$P(e^+) \sim 70$ %

Inverse Compton Backscattering (KEK)

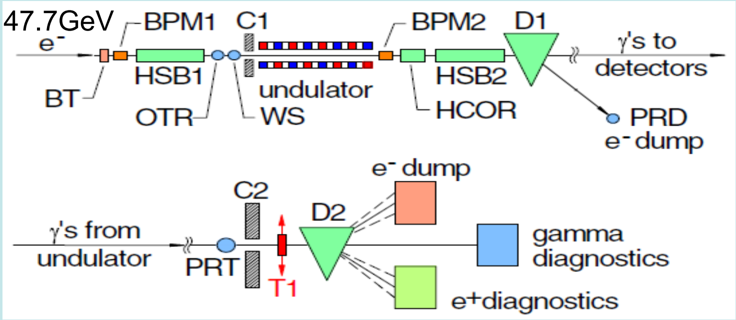
T. Omori et al, PRL 96 (2006) 114801



$P(e^+) = 73 \pm 15_{(stat)} \pm 19_{(syst)}$ %

Helical Undulator (SLAC E166)

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



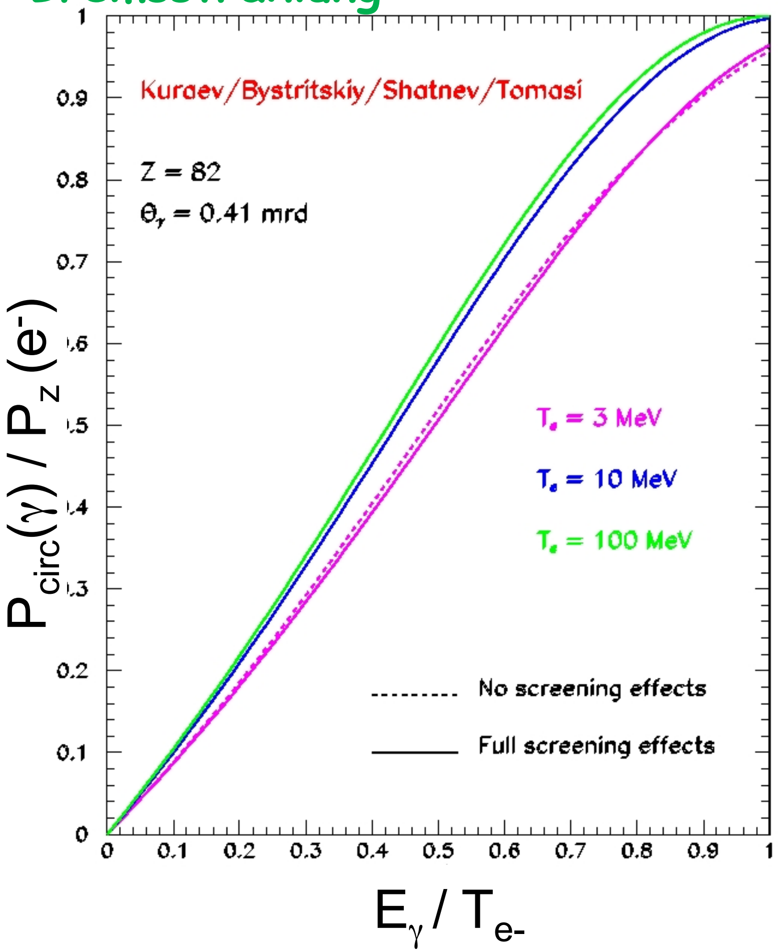
$P(e^+) = 80 \pm 7_{(stat)} \pm 9_{(syst)}$ %

New method using spin polarized electron beam

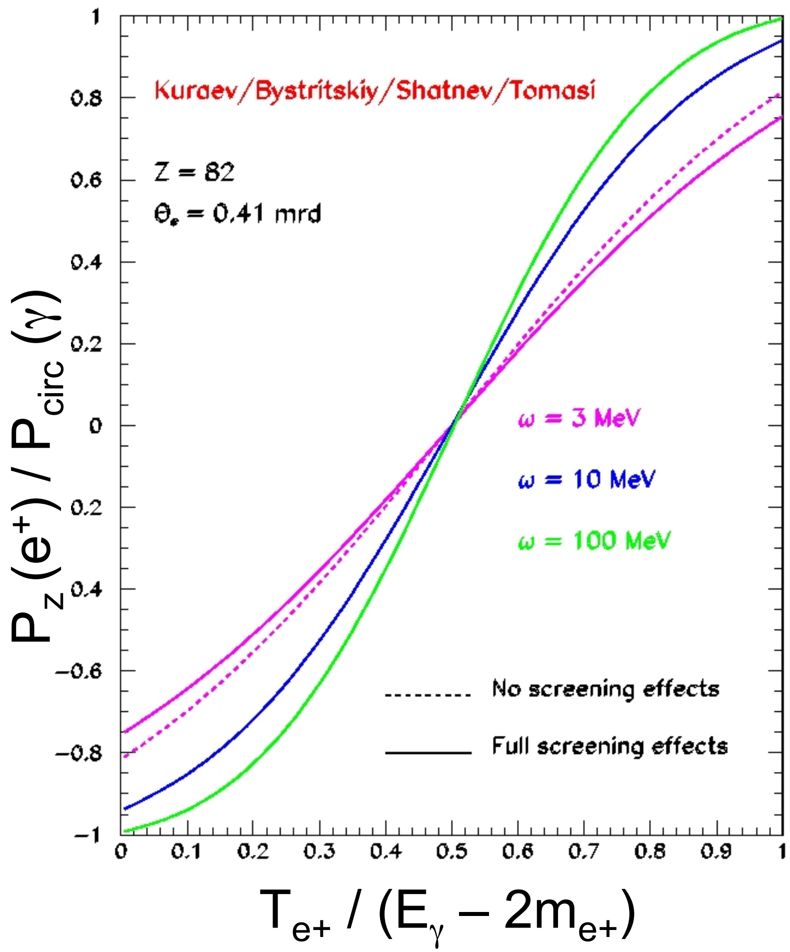
E.G. Bessonov, A.A. Mikhailichenko, EPAC (1996) A.P. Potylitsin, NIM A398 (1997) 395

$$\vec{e}^- \rightarrow \overset{\circlearrowright}{\gamma} \rightarrow \vec{e}^+ \; (+\, \vec{e}^-)$$

Bremsstrahlung



Pair Creation



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

Polarized Electrons for Polarized Positrons

A Proof-of-Principle Experiment

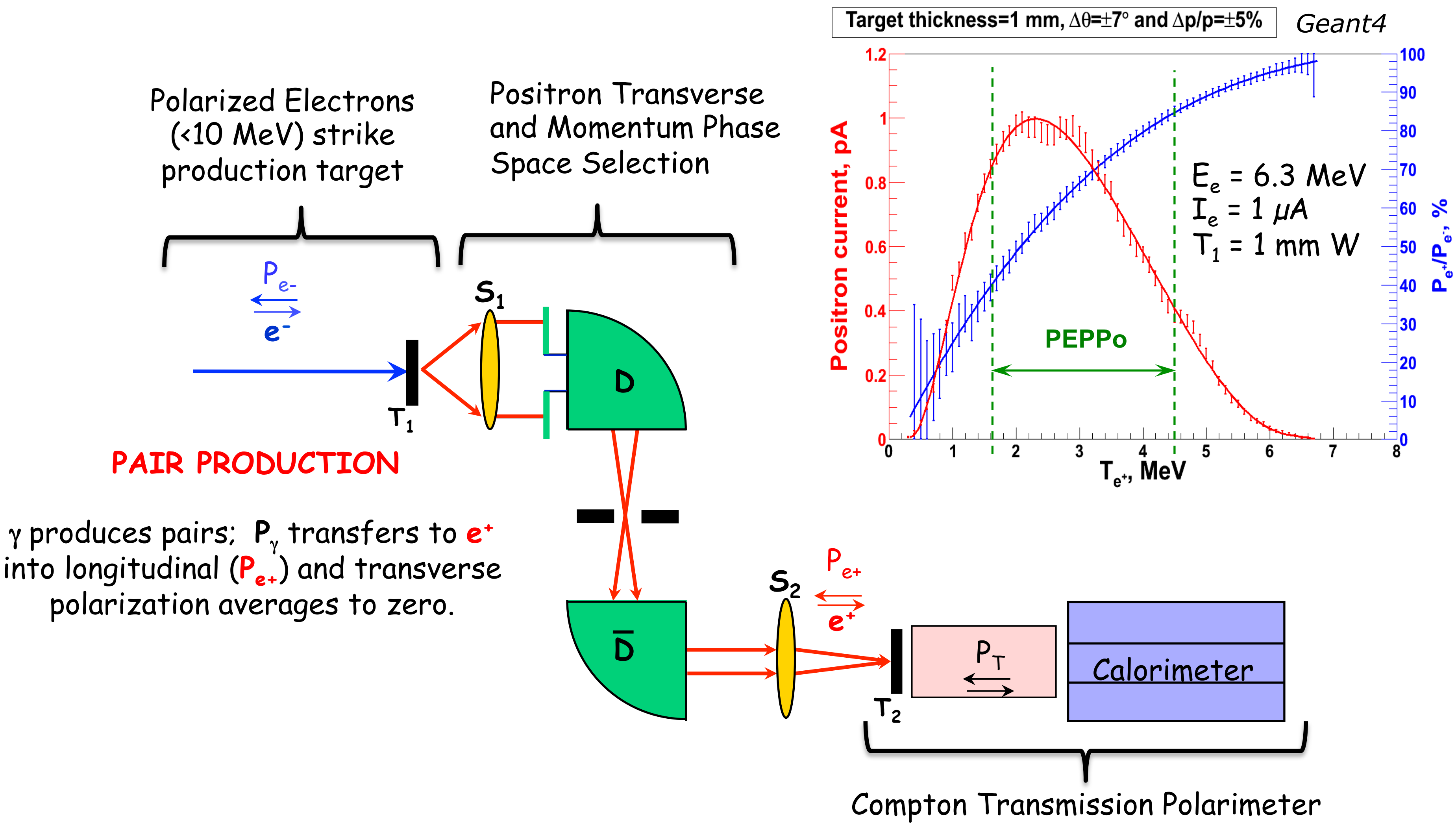
P. Aderley[1], A. Adeyemi[4], P. Aguilera[1], M. Ali, H. Areti[1], M. Baylac[2], J. Benesch[1], G. Bosson[2], B. Cade[1], A. Camsonne[1], L. Cardman[1], J. Clark[1], P. Cole[5], S. Covert[1], C. Cuevas[1], O. Dadoun[3], D. Dale[5], J. Dumas[1,2], E. Fanchini[2], T. Forest[5], E. Forman[1], A. Freyberger[1], E. Froidefond[2], S. Golge[6], J. Grames[1], P. Guèye[4], J. Hansknecht[1], P. Harrell[1], J. Hoskins[8], C. Hyde[7], R. Kazimi[1], Y. Kim[1,5], D. Machie[1], K. Mahoney[1], R. Mammei[1], M. Marton[2], J. McCarter[9], M. McCaughan[1], M. McHugh[10], D. McNulty[5], T. Michaelides[1], R. Michaels[1], C. Muñoz Camacho[11], J.-F. Muraz[2], K. Myers[12], A. Opper[10], M. Poelker[1], J.-S. Réal[2], L. Richardson[1], S. Setiniyazi[5], M. Stutzman[1], R. Suleiman[1], C. Tennant[1], C.-Y. Tsai[13], D. Turner[1], A. Variola[3], E. Voutier[2], Y. Wang[1], Y. Zhang[12]

[1] Jefferson Lab, Newport News, VA, US [2] LPSC, Grenoble, France [3] LAL, Orsay, France
[4] Hampton University, Hampton, VA, USA [5] Idaho State University & IAC, Pocatello, ID, USA
[6] North Carolina University, Durham, NC, USA [7] Old Dominion University, Norfolk, VA, US
[8] The College of William & Mary, Williamsburg, VA, USA [9] University of Virginia, Charlottesville, VA, USA
[10] George Washington University, Washington, DC, USA [11] IPN, Orsay, France
[12] Rutgers University, Piscataway, NJ, USA [13] Virginia Tech, Blacksburg, VA, USA

SLAC E-166 Collaboration
International Linear Collider Project
Jefferson Science Association Initiatives Award

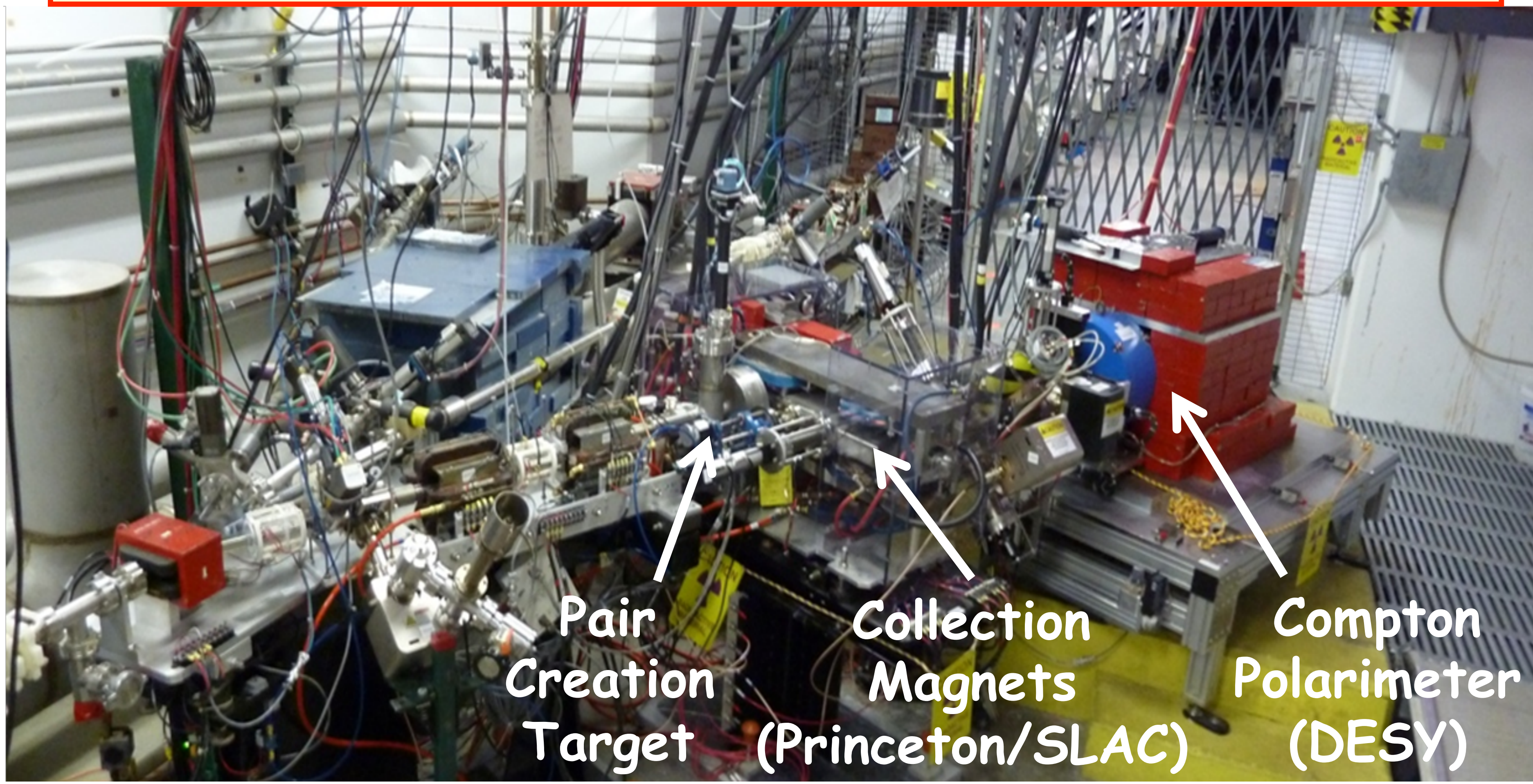
PEPPo Concept

J. Dumas, Ph.D. Dissertation, Joseph Fourier University, 2010

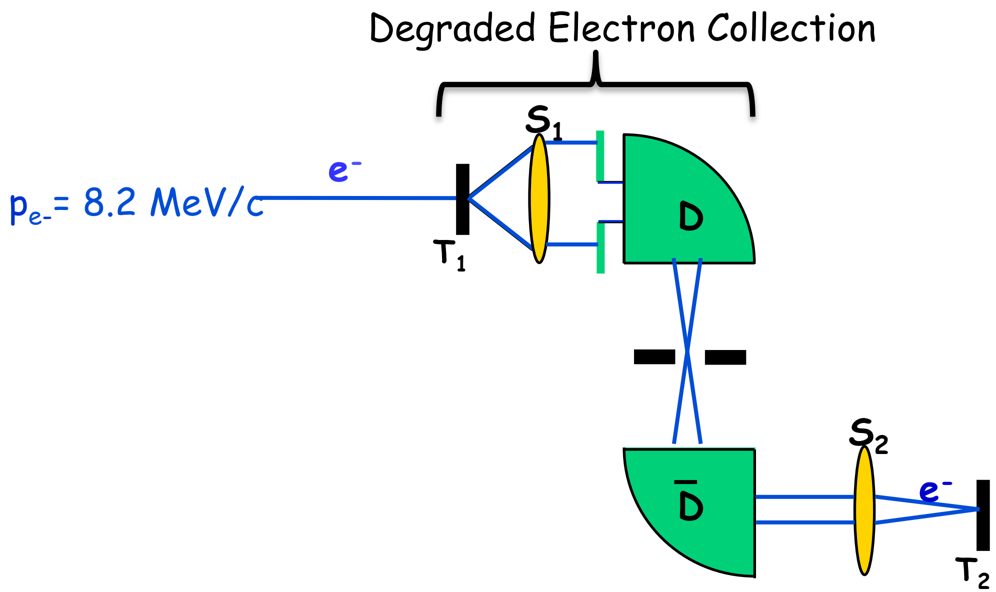


Staging PEPPo at Jefferson Lab CEBAF Injector

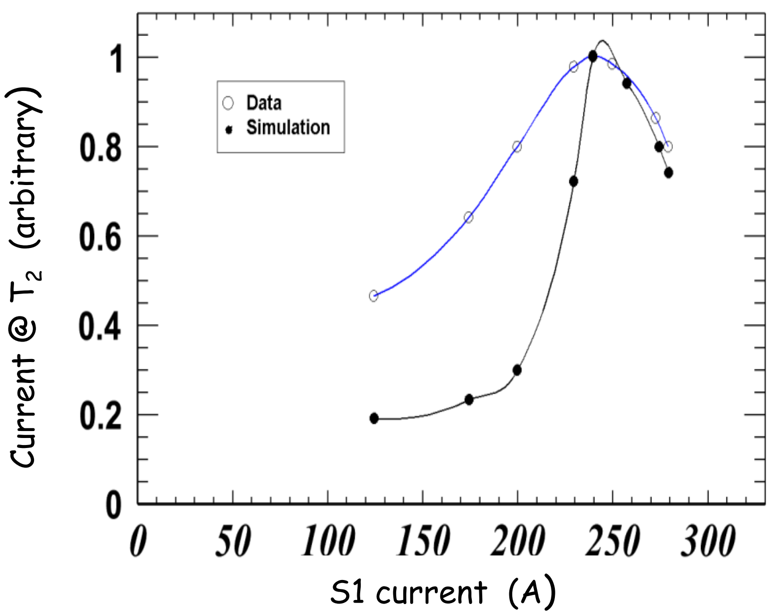
PEPPo measured the polarization transfer from 8.2 MeV/c longitudinal electrons to longitudinal positrons in the 3.1-6.2 MeV/c momentum range.

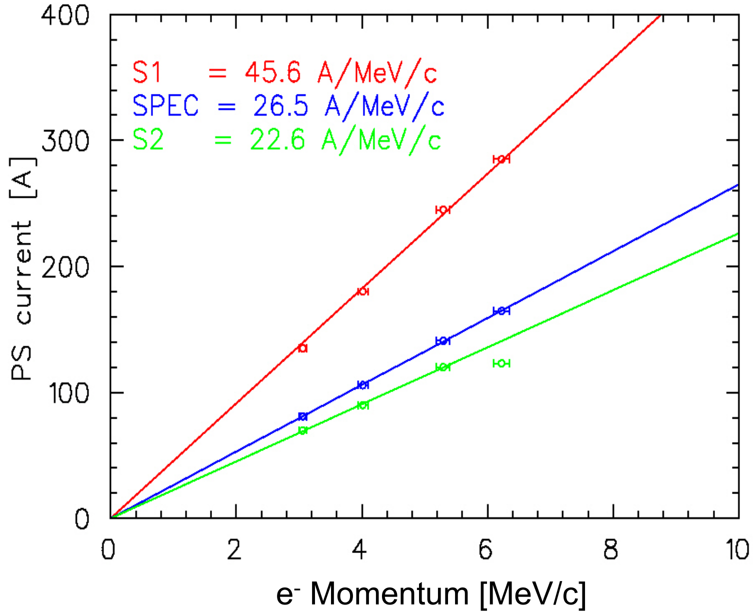


Optimizing Optics with Energy Degraded Electrons

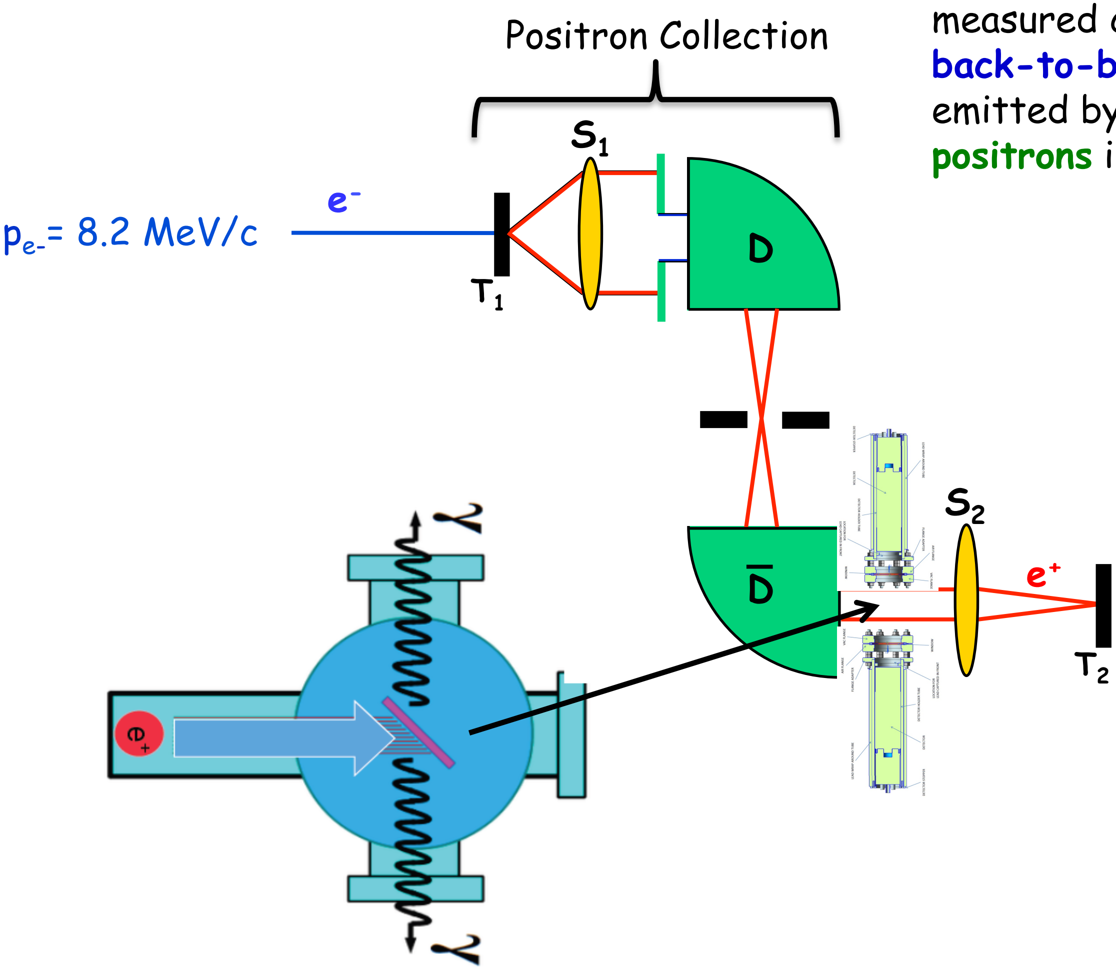


S_1 current optimization at 5.5 MeV/c

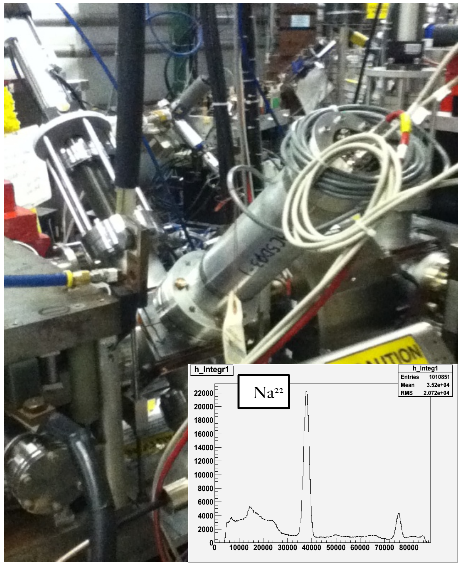




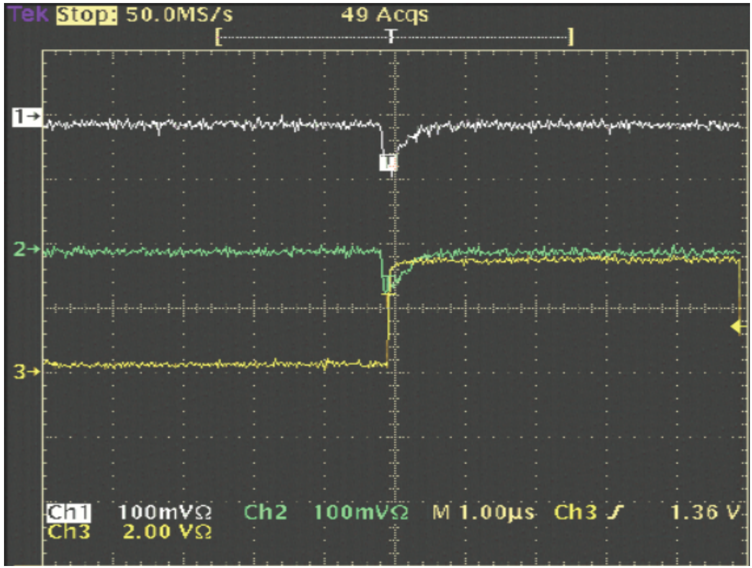
Detecting Positrons



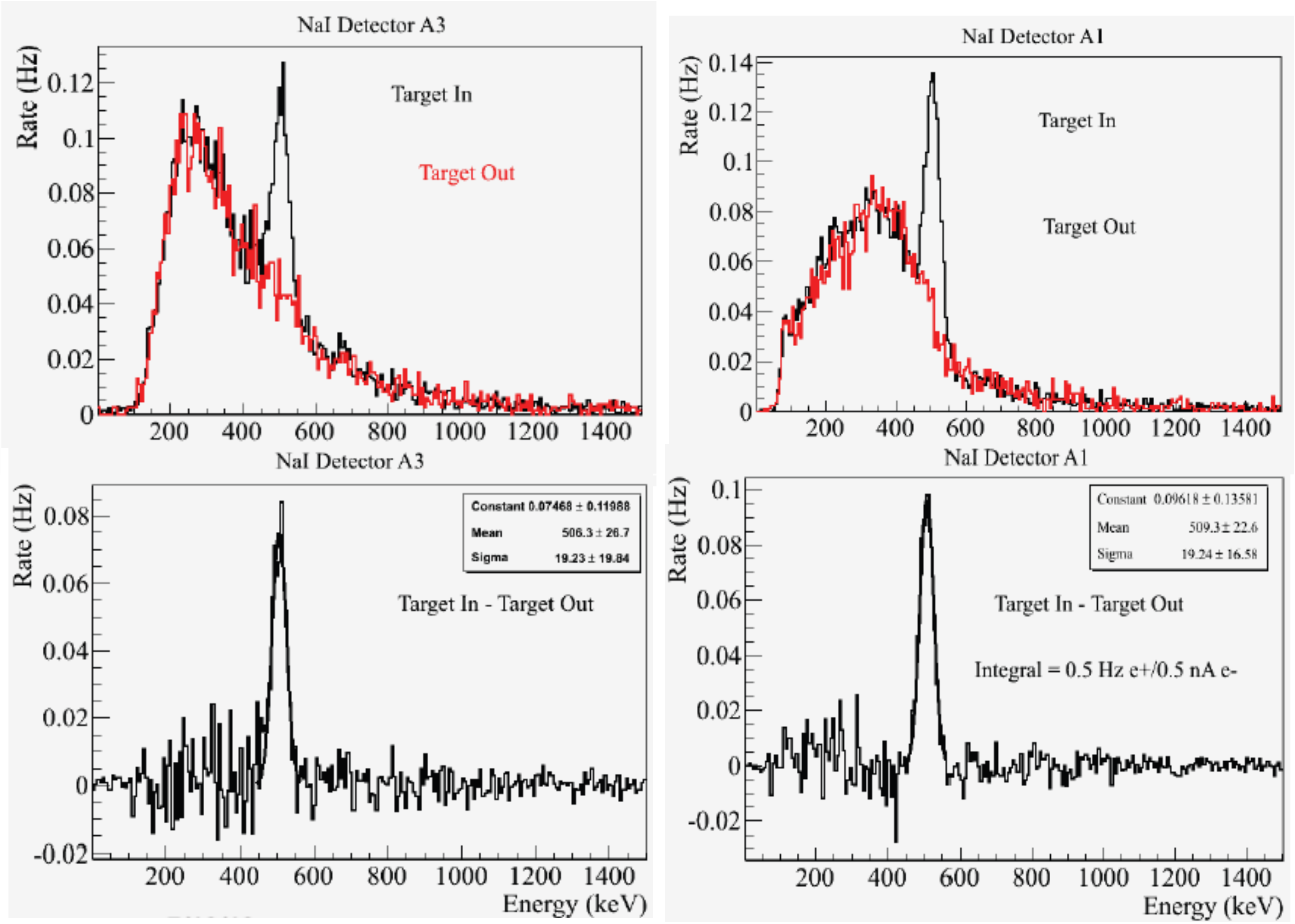
Two **NaI** detectors measured coincidence of **back-to-back photons** emitted by **annihilation** of **positrons** in a <u>viewscreen</u>.



Viewscreen
- 0.011 thick @ 45 deg to beam line
- 99.5% aluminum oxide Al_2O_3
- 0.5% chromium doped $Al_2O_3/Al_2O_3Cr_2O_3$



Measuring Positron Yield



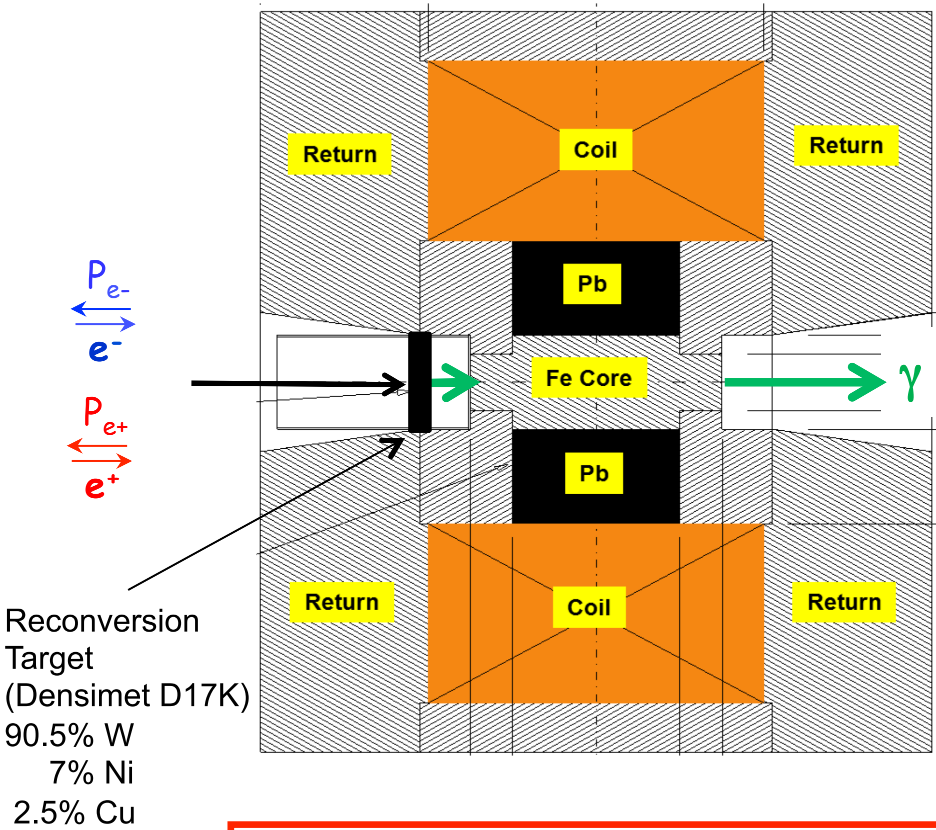
Detected e+ rate (1 e^+ per 10^{10} e^-)
Solid Angle (0.1 sr)
GEANT annihilation probability (1/400)
Coincidence detector efficiency (0.49 @ 511keV)

1 e^+ per 10^6 e^-
(consistent with proposal)

Compton Transmission Polarimeter

Electrons or **Positrons** radiate **polarized photons** by Bremmstrahlung in reconversion target

Energy dependent Compton scattering of **photons transmitted** through **polarized target** correspond to polarization of incoming **Electrons** or **Positrons** (aligned or anti-aligned).



$$A_T = \frac{N^+ - N^-}{N^+ + N^-} = \tanh(-P_3 P_T \mu_1 L)$$

μ1 - Compton absorption coefficient
L - target length
P_3 - photon polarization (long.)

$$A_T = P_e P_T A_e$$

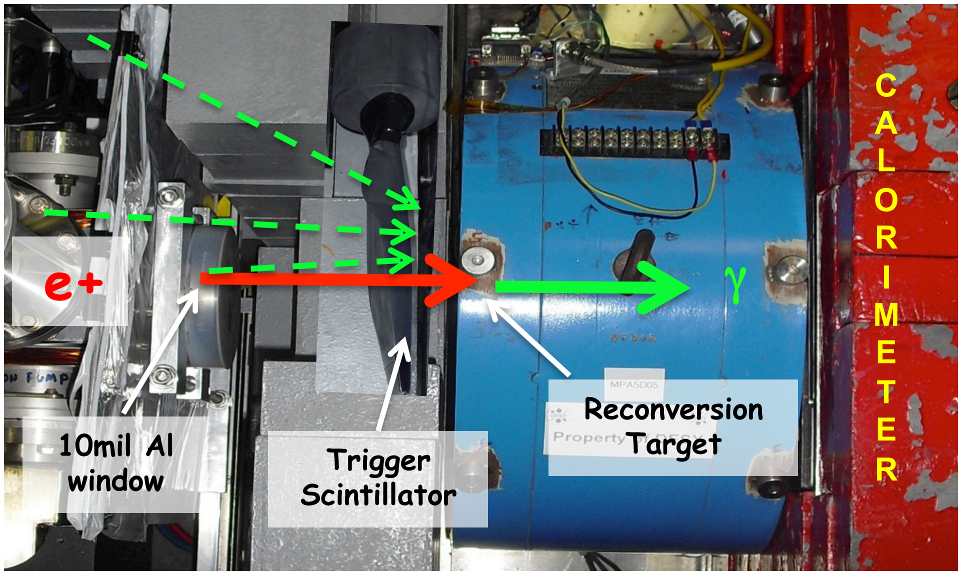
P_e - electron/positron polarization
P_T - target polarization
A_e - analyzing power

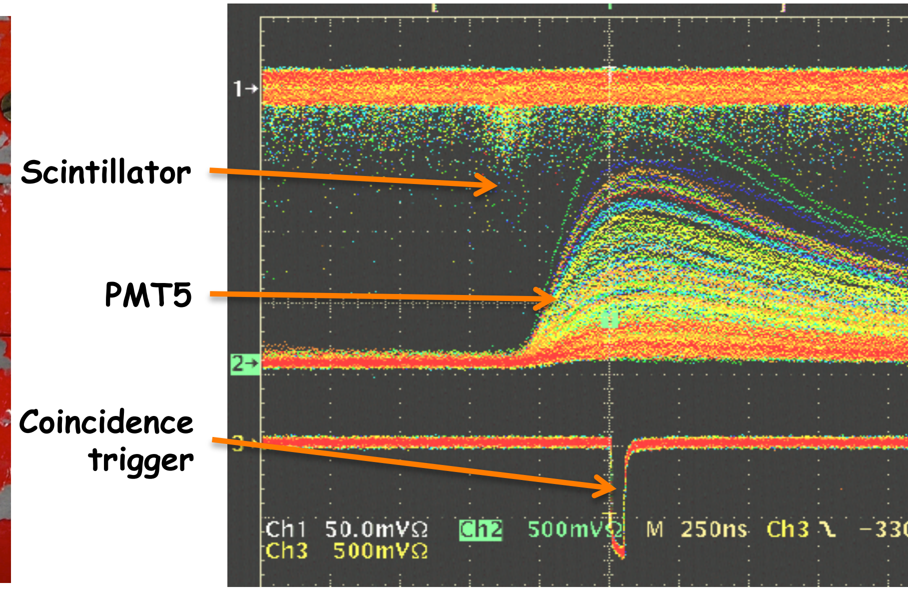
Bremmstrahlung photon spectrum requires energy-dependent analyses

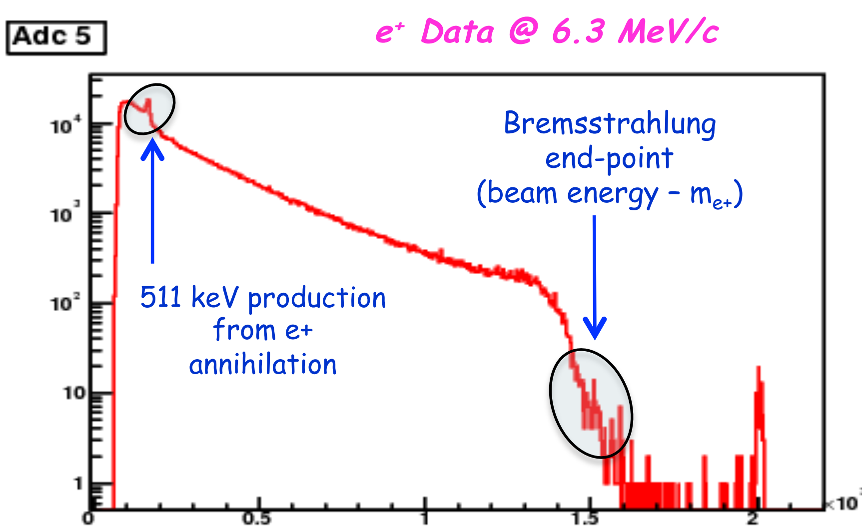
- Energy binning
- Energy integration

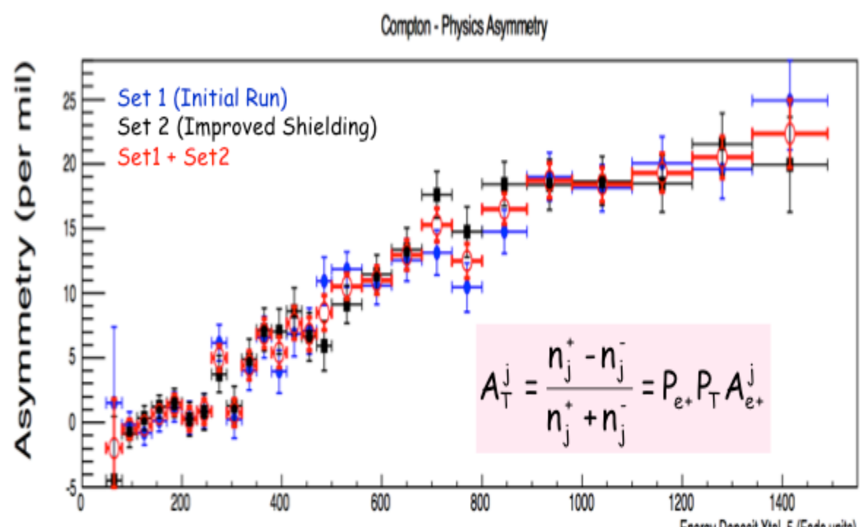
Positron Polarimetry

Positrons are detected in coincidence between a thin trigger scintillator placed prior to the reconversion target and the central crystal (PMT5) and tagged by e- helicity.



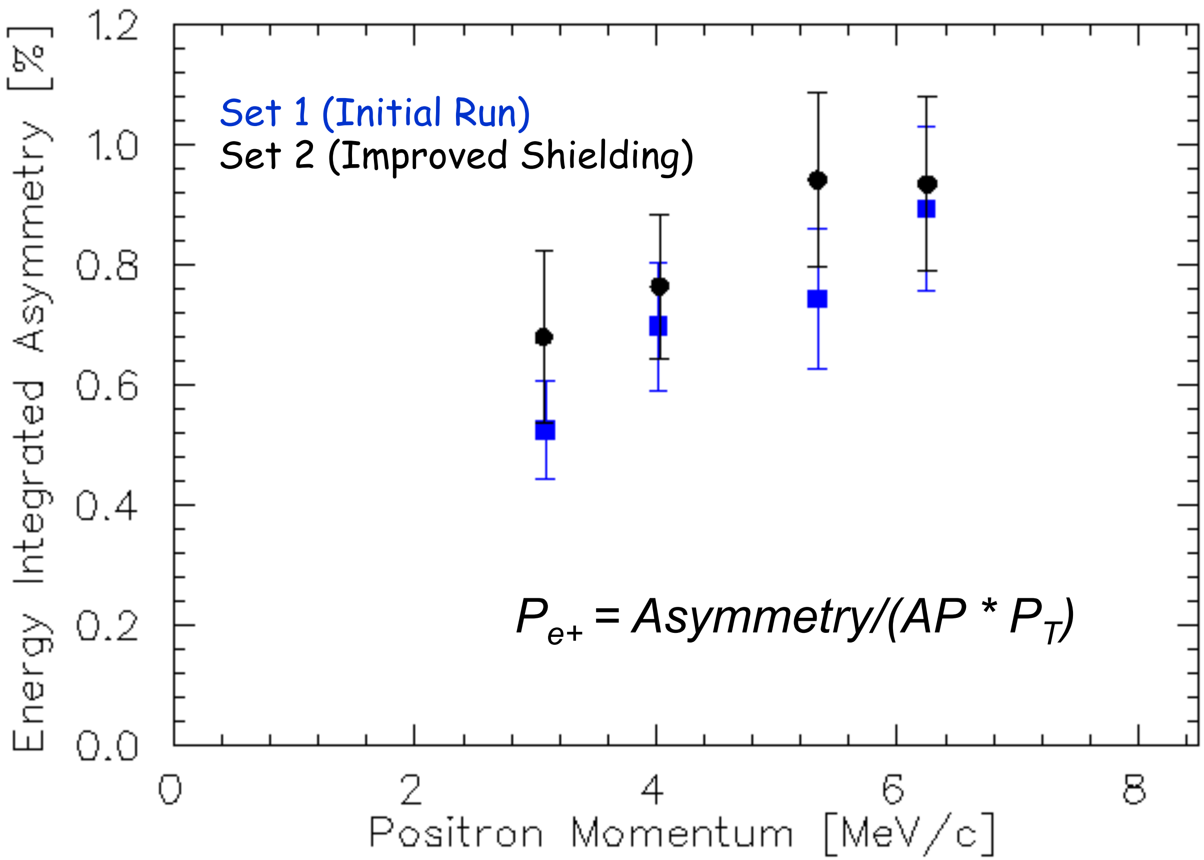






Preliminary Positron Results

Positron asymmetry **significantly non-zero**, **increases with momentum** and **reduction of background** (which may have analyzing power itself).

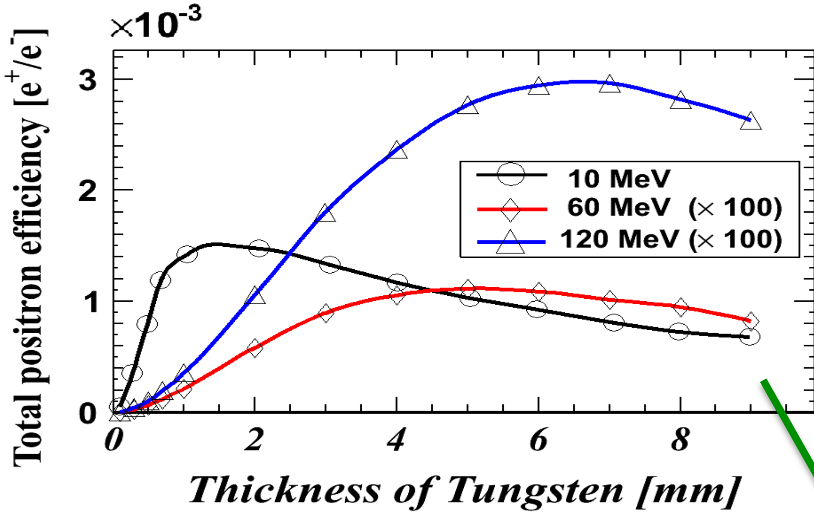


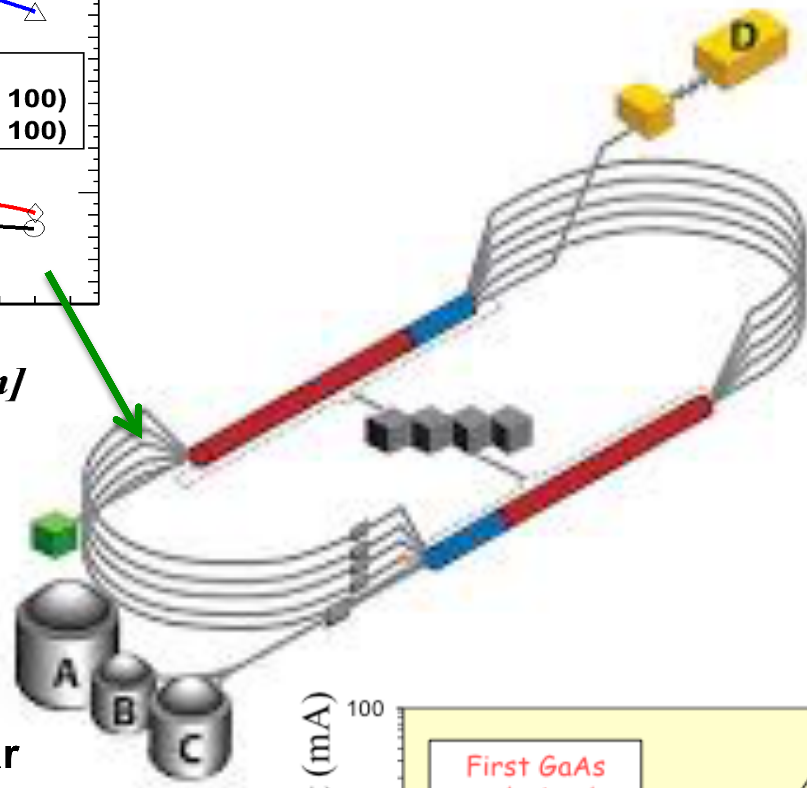
We are in final stages of analysis and should unveil results this Spring. Initial estimates indicate positron polarization may be as high as 70-80%

What about positrons at Jefferson Lab ?

Nuclear Physics
100 nA – 10 μA (CW)
Polarized

What about injecting positrons into CEBAF ?



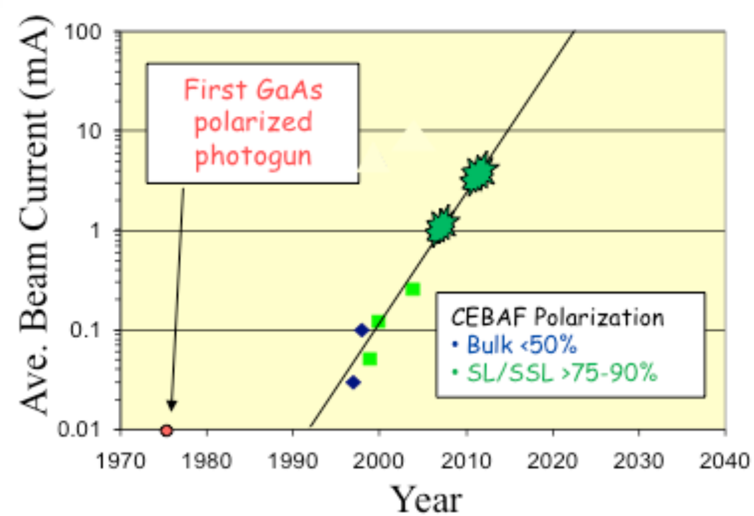


Arc dipole power supplies are **unipolar**

Low beam intensity challenging for diagnostics and pathlength control

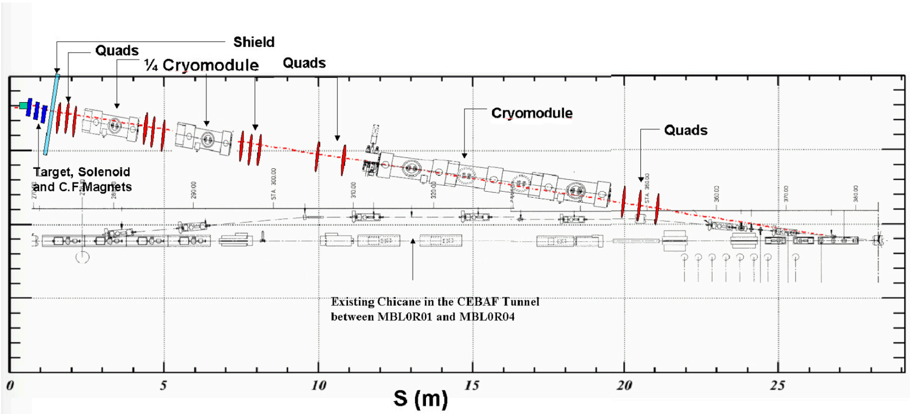
Injector driver ~requires **milliAmps**

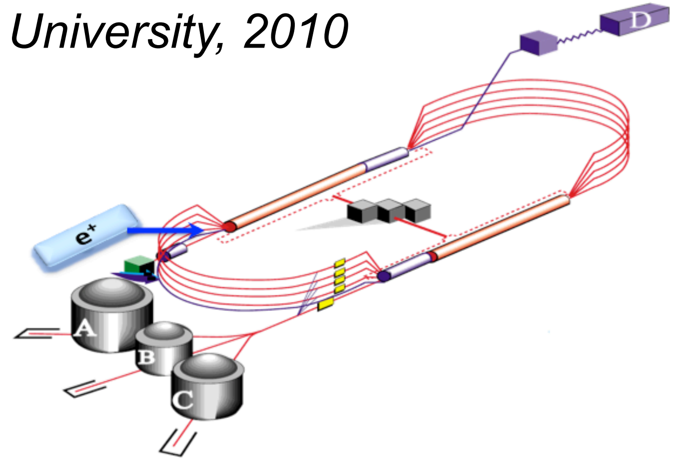
Manage **high power** 10's-100's kW

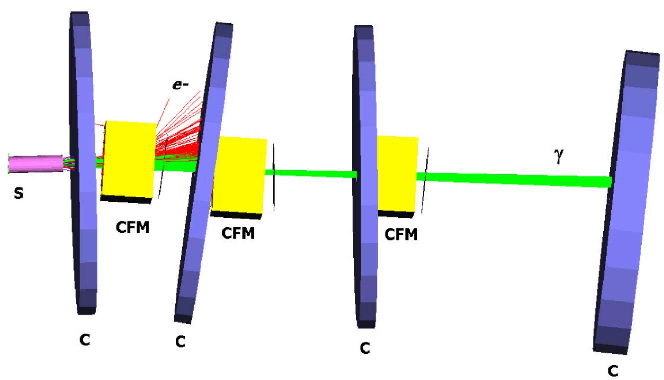


CW Positron Source at CEBAF

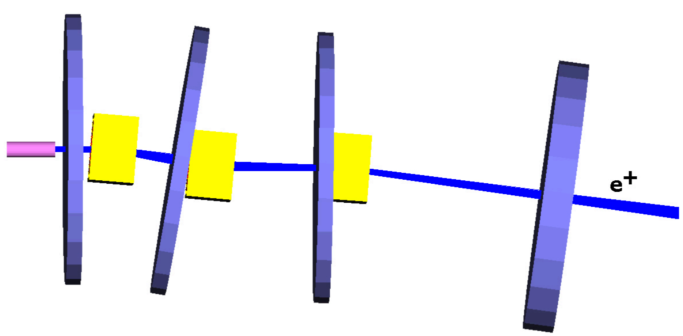
S. Golge, Ph.D. Dissertation, Old Dominion University, 2010







(a)



Combined Function Magnet Solution

- p (e-) = 126 MeV/c
- p (e^+) = 126 ±1.0 MeV/c
- σ_t = 1.8 ps (to maintain dp/p < 10^{-3})
- $\varepsilon_{x}/\varepsilon_{y}$ = 1.6/1.7 mm.mrad

Efficiency is ~ 2.9×10^{-4}

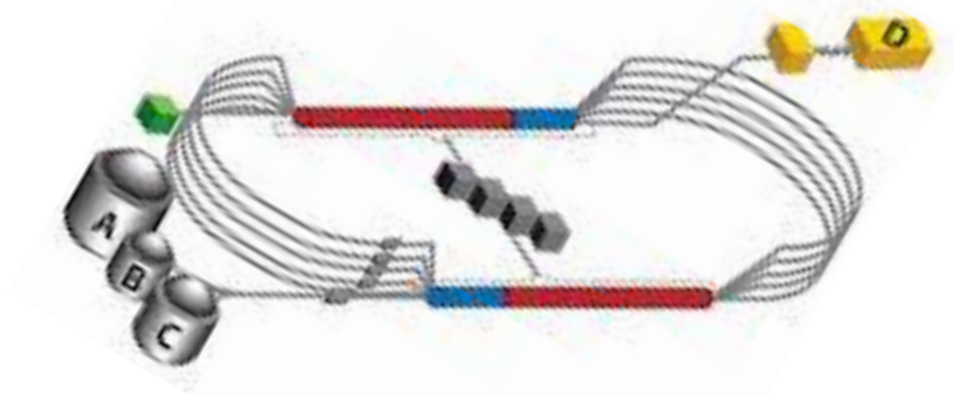
- 0.1 – 10 uA => 0.35 – 35 mA
- Very high power !

126 MeV/10 mA	Power Source (e^- and γ)	e^+	Deposited Power (%)	(kW)
Target	✓	✓	4.5	55
Solenoid	✓	✓	21.0	250
Collimators	✓	✓	10.0	120
Capture Area Magnets	✓	✓	17.0	200
1/4 Cryomodule-1		✓	2.0×10^{-3}	0.025
1/4 Cryomodule-2		✓	9.0×10^{-4}	0.01
Full Cryomodule		✓	1.2×10^{-3}	0.015

Electron Accelerators at Jefferson Lab

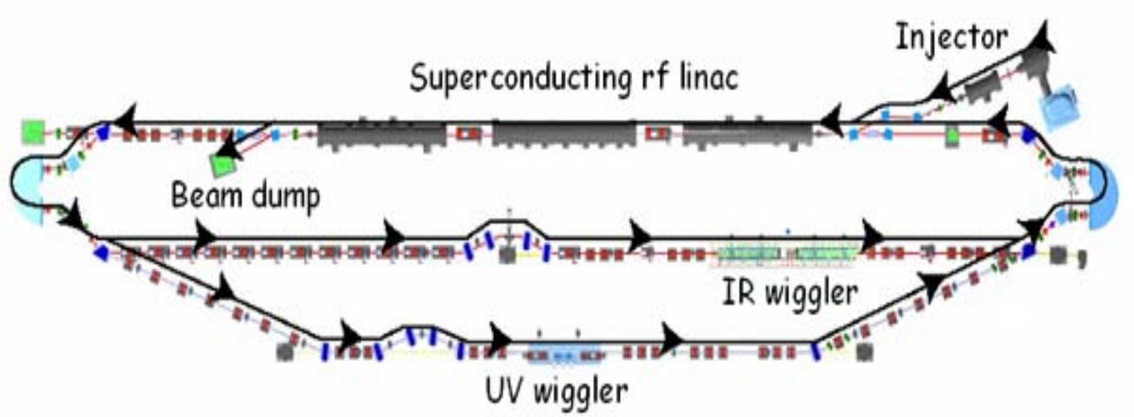
CEBAF
Improve conversion efficiency
- 1 GeV linac
- 12 GeV Hall D

Manage high power
- Shielded Radiator
- Accessible conversion target

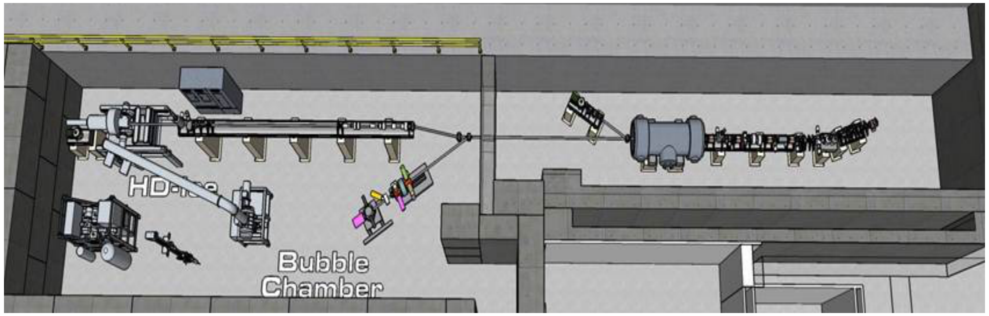


LERF
High current : 10 mA @ 200 MeV
- Test bed for CW concept

ERL dump : 10 mA @ 10 MeV
- Low intensity source



UITF
10 MeV/1 nA facility to test HDIce
Compatible with <1 nA e+ source
- Keep energy / photo-neutron yield small
- Add local shielding



Outlook

Expressed interest for positrons beams at Jefferson Lab

- International Workshop on Positrons at Jefferson Lab (2009)
- High Energy Nuclear Physics at CEBAF
- Dark matter searches
- Low Energy Materials Science

Demonstrated Accelerator R&D Interest

- J. Dumas, PhD, Polarized Positrons (2010)
- S. Golge, PhD, CW Positron Source (2010)
- PEPPo, PAC A Rating E11-105 (2012)
  - ✓ ILC and strong collaborative support
- L. Adeyemi, PhD, PEPPo Proof-of-Principle (expected 2015)

Possive Future Directions

- P. Degtiarenko, J. Grames, E. Voutier, Integrated Conceptual Design (Unfunded 2013 LDRD)
- Consideration being given for low energy positron progran at LERF
- Exploit accelerator expertise and facilities to develop integrated design and start addressing R&D challenges

Primary impetus will remain a compelling Physics motivation