POSITRON COLLECTION IN LINEAR COLLIDER

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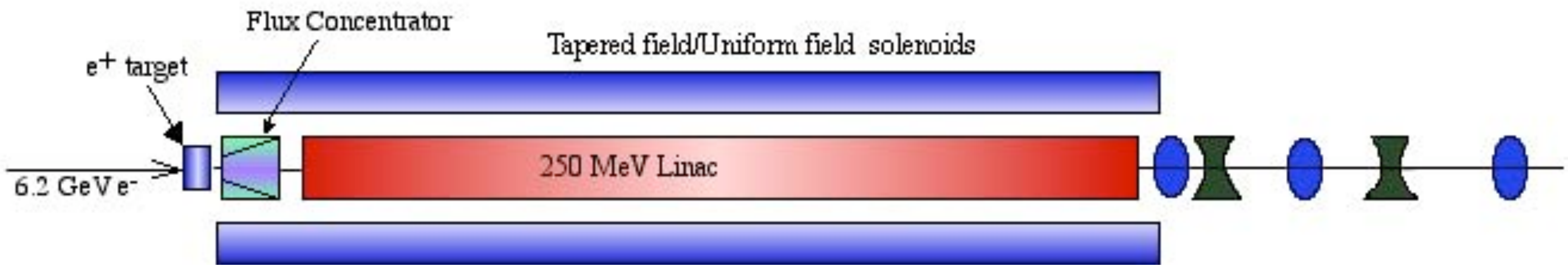
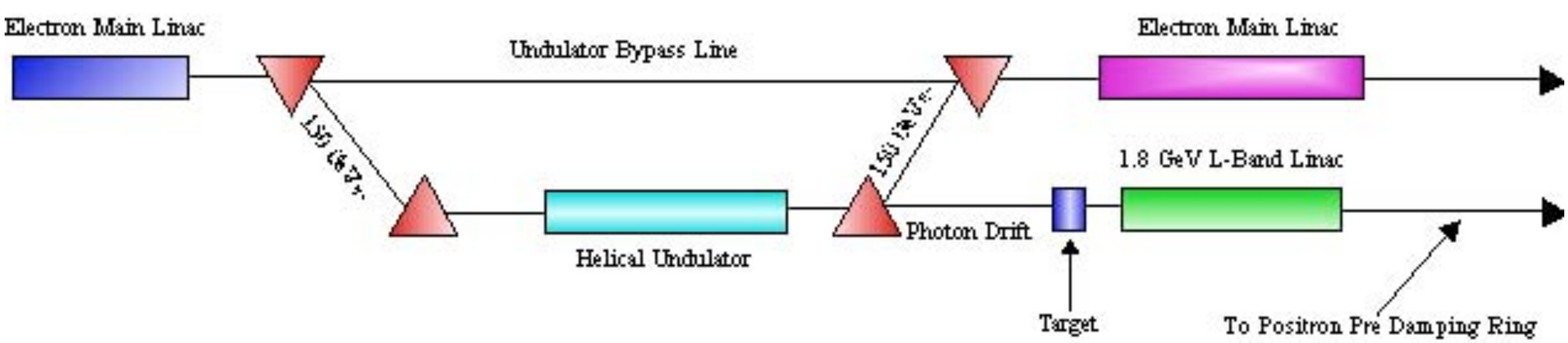
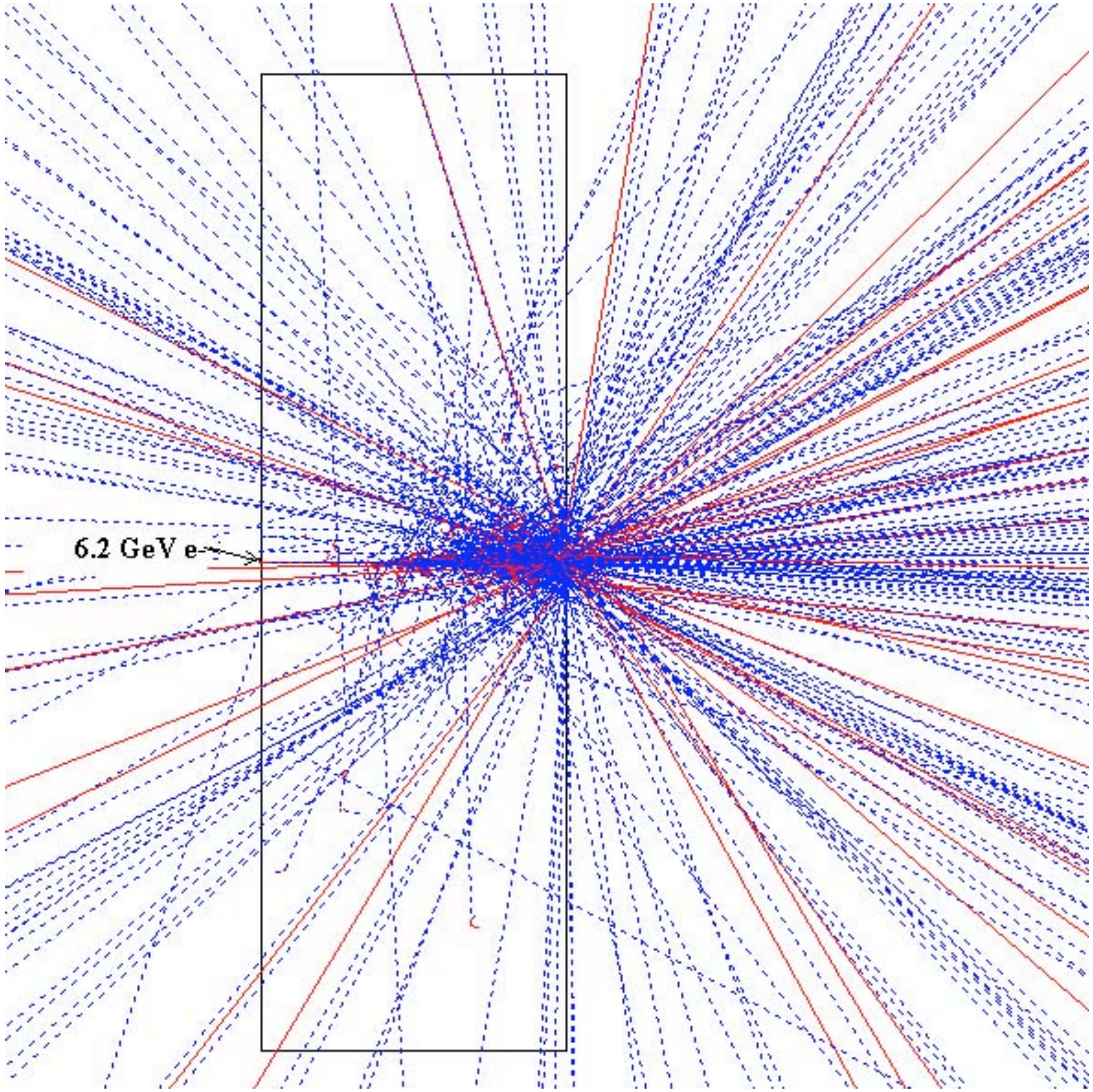


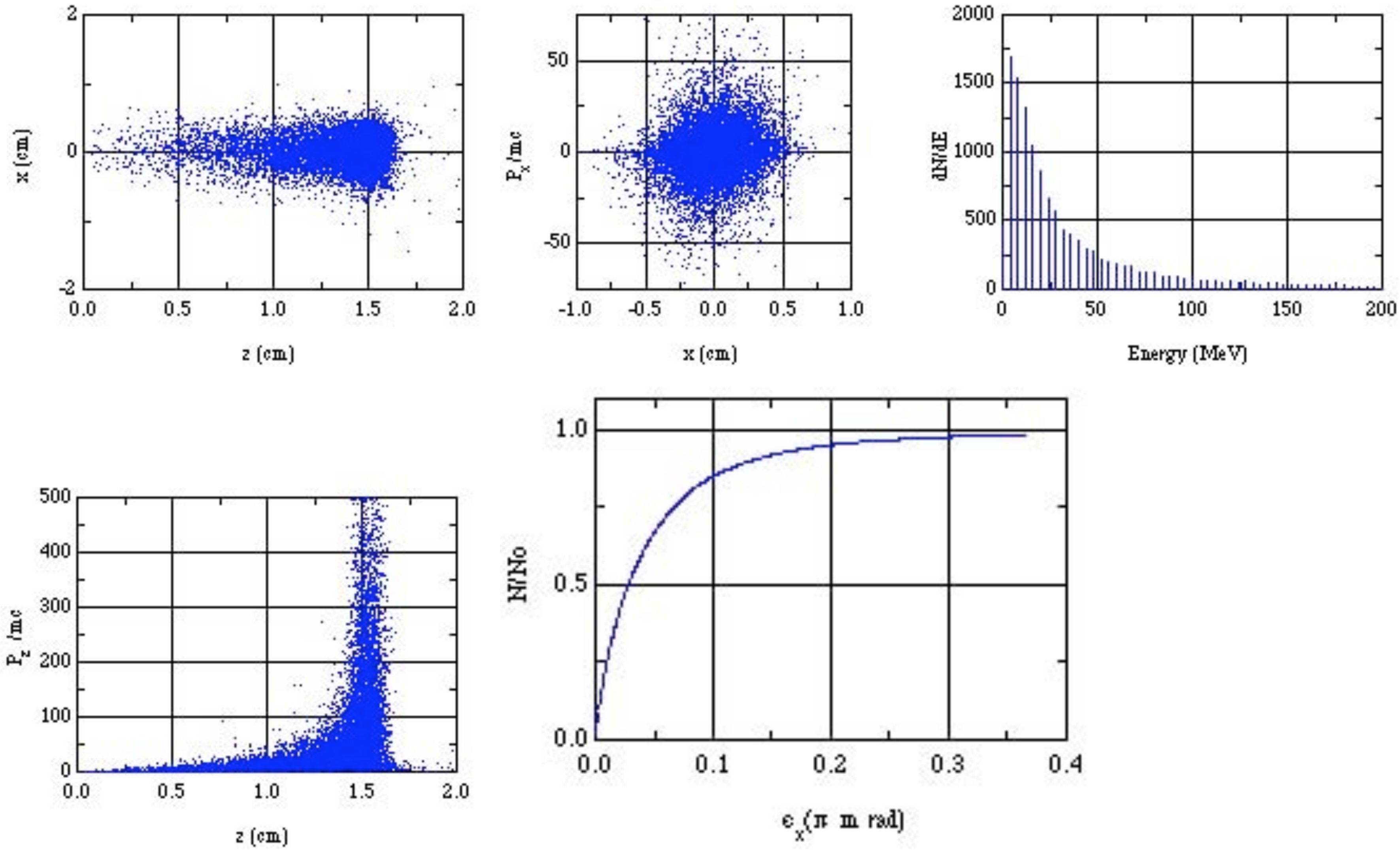
Conventional positron source layout.



Polarized positron injector layout.

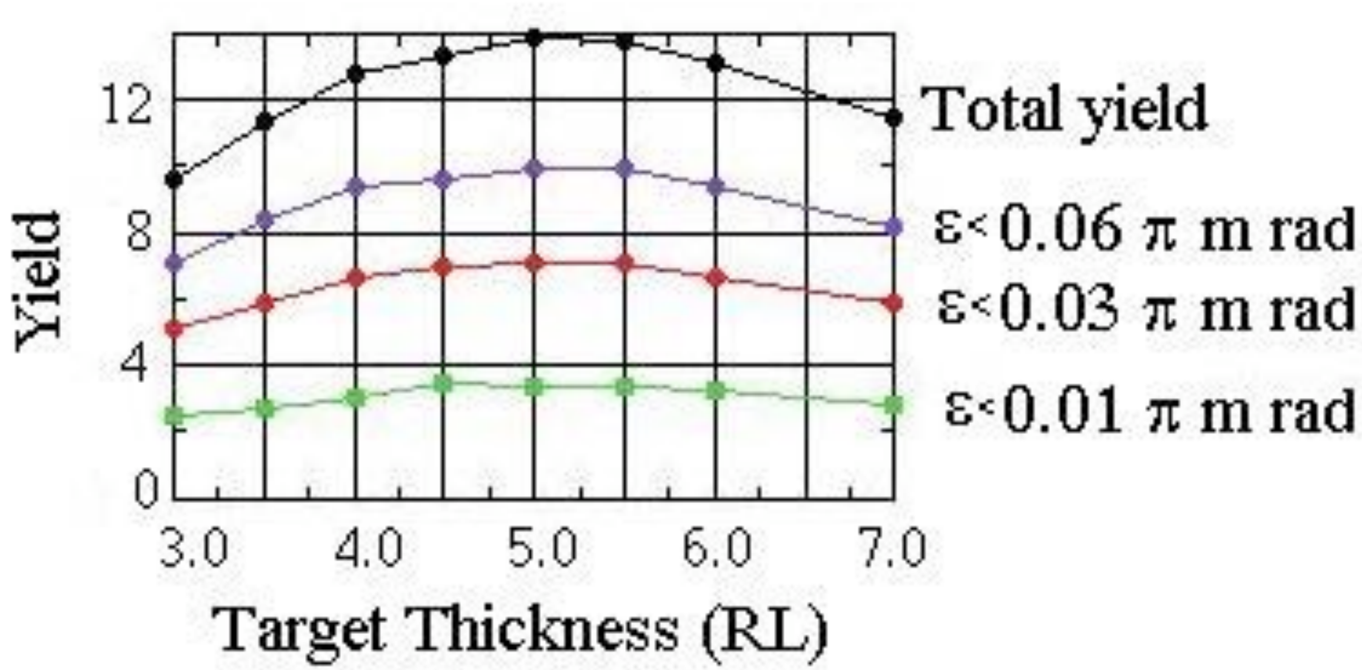


GEANT3 simulation of shower development generated by 6 GeV electron in 4.5RL 77W-Re target: (blue) photons, (red) electrons and positrons.



EGS generated positron distribution from 6 GeV electron beam with $\sigma_x = \sigma_y = 2$mm, $\sigma_t = 1.5$ ps hitting W-23Re 4.5RL target (by John Sheppard).

Positron yield from 6 GeV e- beam hitting 77W-23Re target

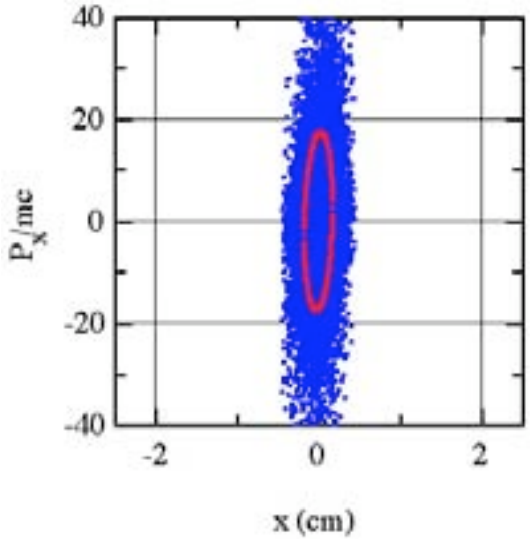


Positron yield: $Y = \frac{N_{e^+}}{N_{e^-}}$

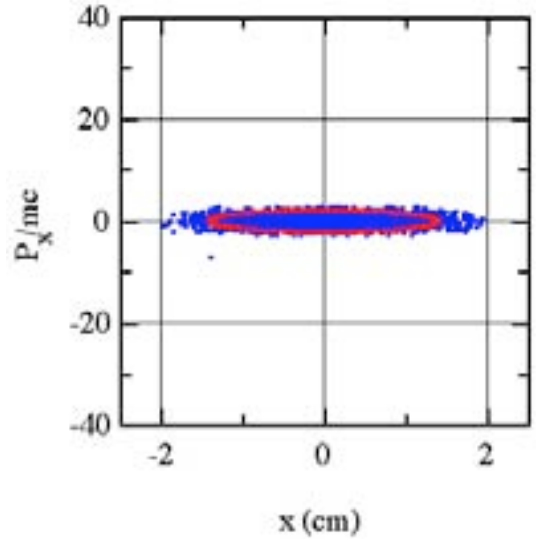
Positron capture: $C = \frac{N_{e^+}}{N_{e^+,\ \mathrm{target}}}$

Yield(5 GeV) = Capture x Yield(target)

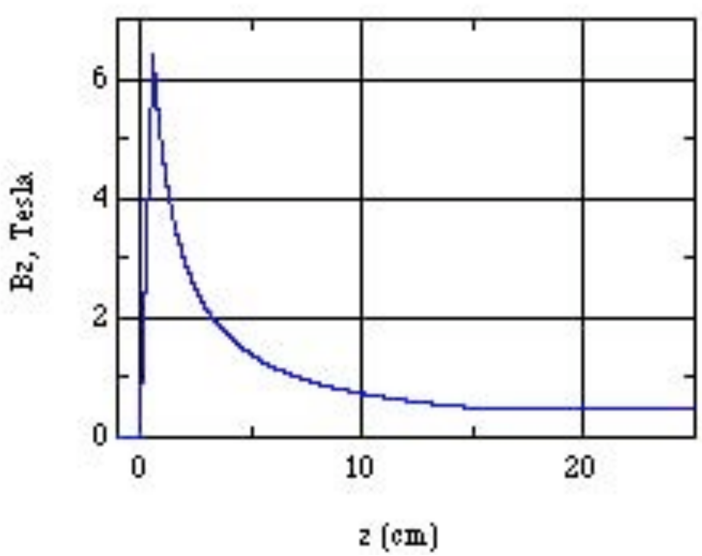
ADIABATIC TRANSFORMATION OF BEAM PHASE SPACE



(Blue) transverse beam emittance at the target.
(Red) emittance area of 0.03 π m rad.



(Blue) transverse beam emittance at 250 MeV.
(Red) emittance area of 0.03 π m rad.



Magnetic field profile in Adiabatic Matching Device: $B_z = B_{max}/(1 + gz)$.

Acceptance of solenoid

Equation of motion:

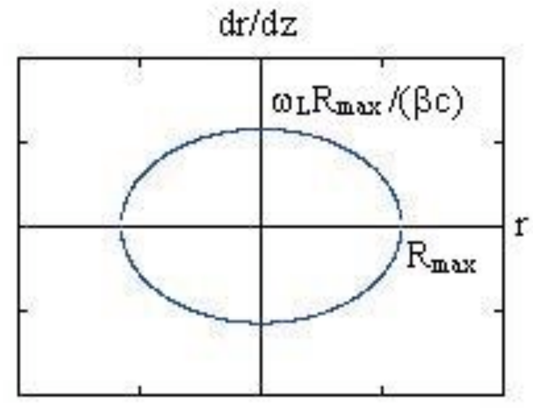
$$\frac{d^2r}{dt^2} + \omega_L^2 r = 0$$

where Larmor frequency:

$$\omega_L = eB/(2m\gamma)$$

First integral:

$$\left(\frac{dr}{dz}\right)^2 + \left(\frac{\omega_L}{\beta c}\right)^2 r^2 = \left(\frac{\omega_L}{\beta c}\right)^2 R_{max}^2$$

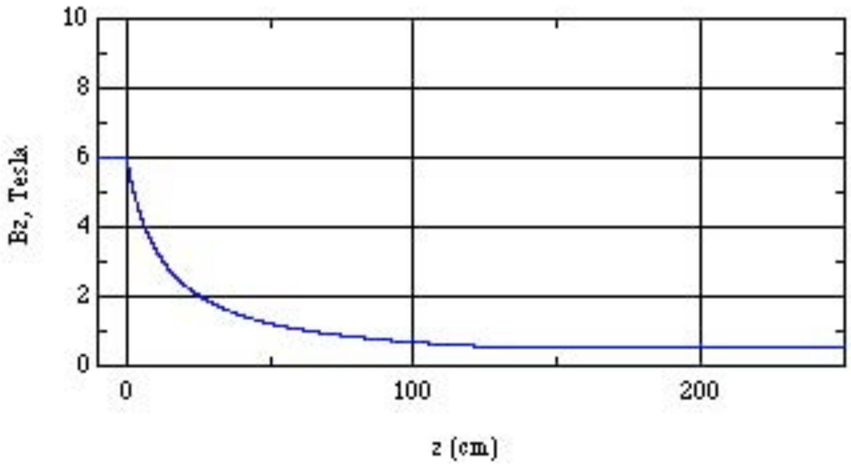


Acceptance:

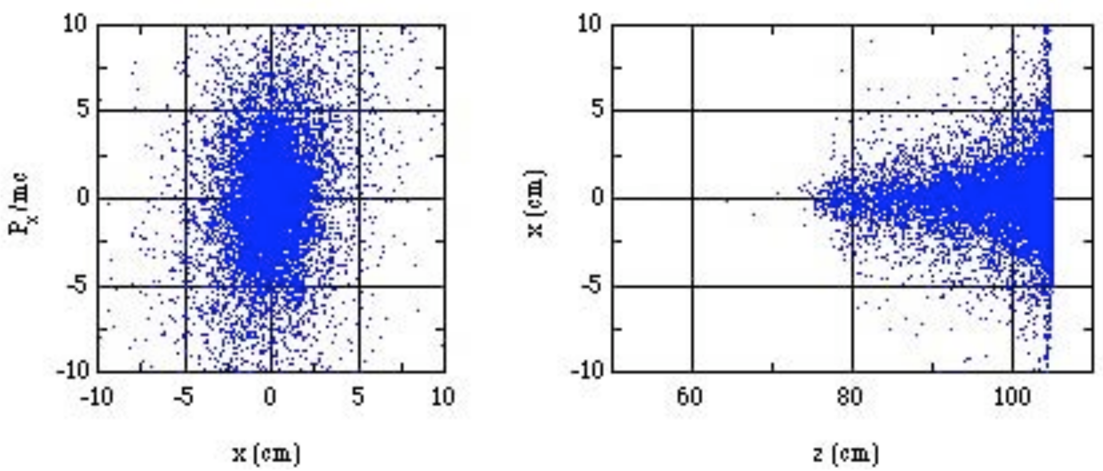
$$\ni = \frac{R_{max}^2\ \omega_L}{\beta c}$$

Normalized acceptance:

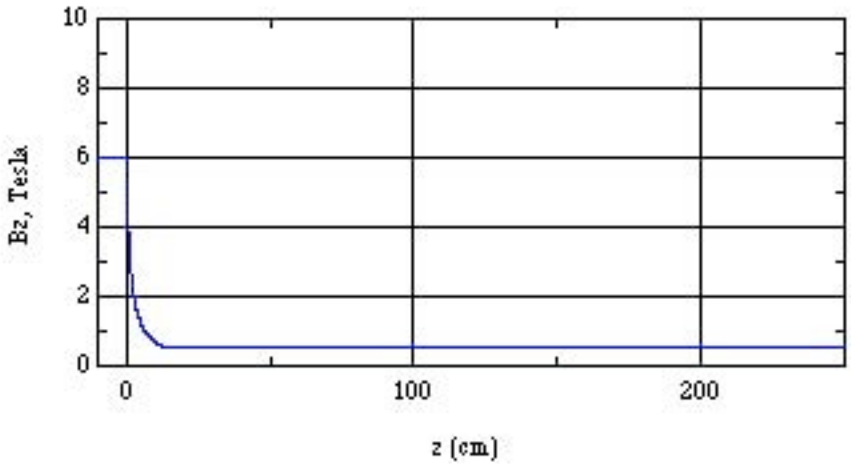
$$\varepsilon = \beta\gamma\ni = \frac{eB}{2mc} R_{max}^2$$



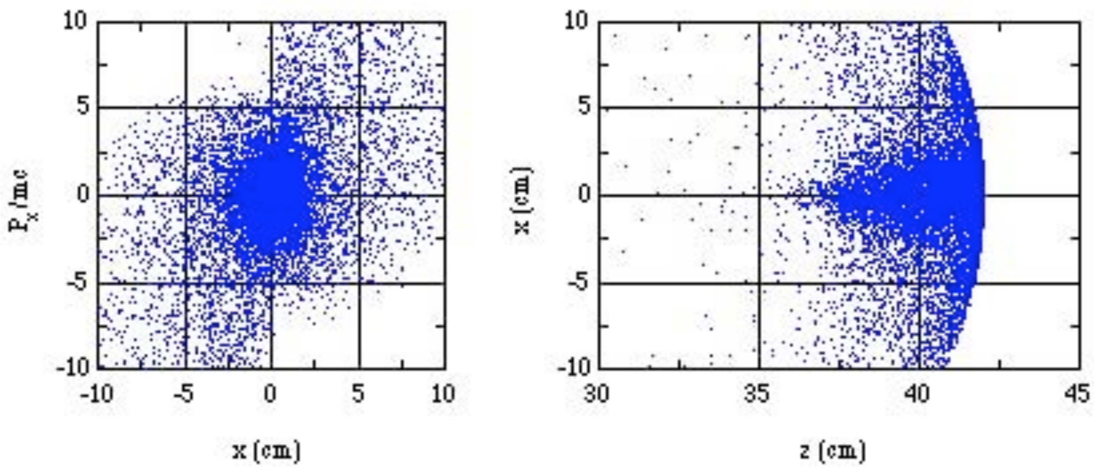
Field distribution B_{max}= 6 Tesla, B_{fin}= 0.5 Tesla, g = 0.078 cm^{-1}.



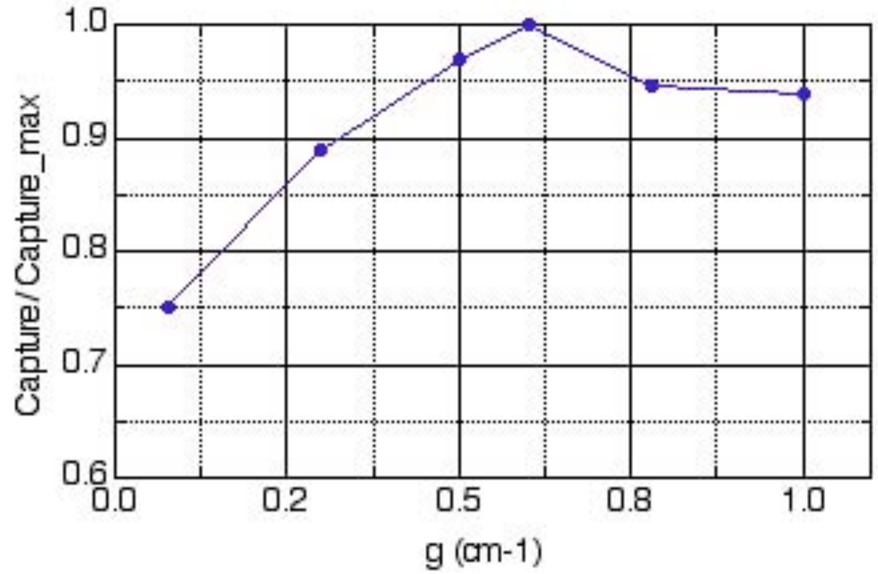
Particle distribution after adiabatic matching device with g = 0.078cm^{-1}.



Field distribution $B_{max} = 6$Tesla, $B_{fin} = 0.5$ Tesla, $g = 0.78\text{cm}^{-1}$.



Beam distribution after adiabatic matching device with $g = 0.78\text{cm}^{-1}$.

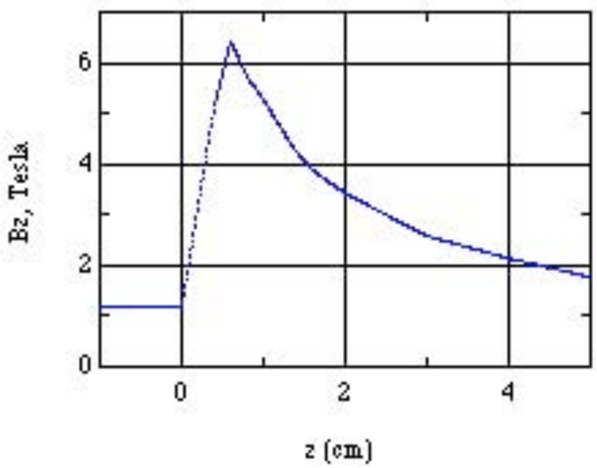


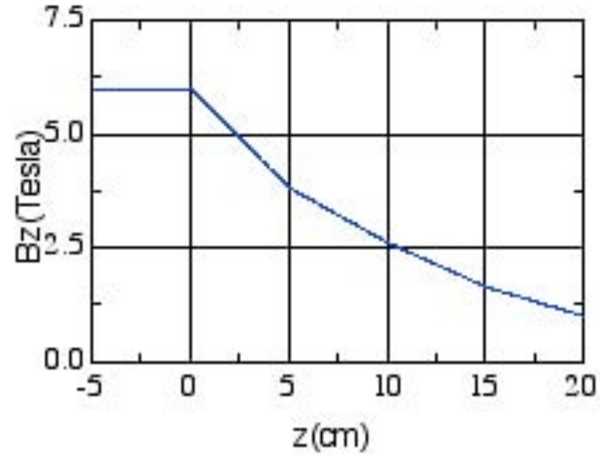
Positron capture as a function of adiabatic parameter g.

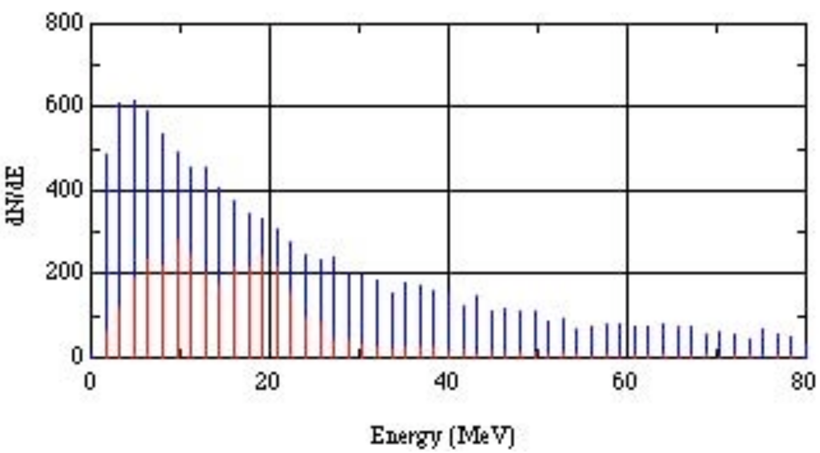
Immersed Target vs Shielded Target

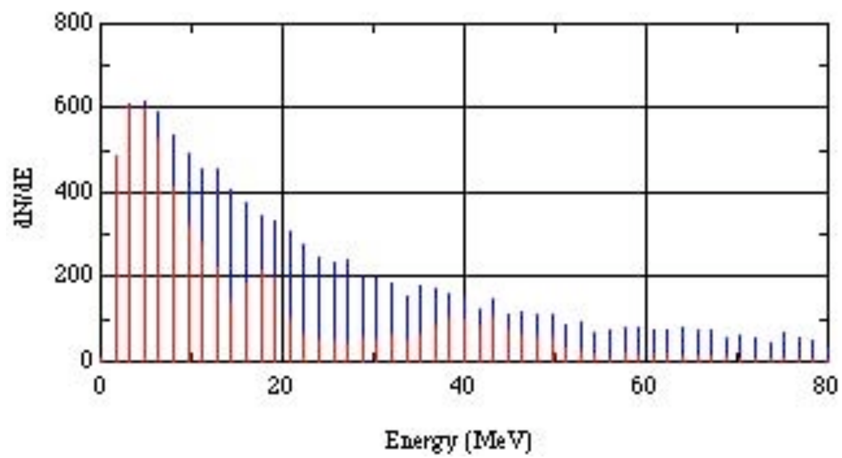
Shielded Target

Immersed Target









Field profile and acceptance of AMD, (blue): positrons generated at the target, (red) target positrons transmitted through AMD.

Effective emittance of the beam immersed in magnetic field

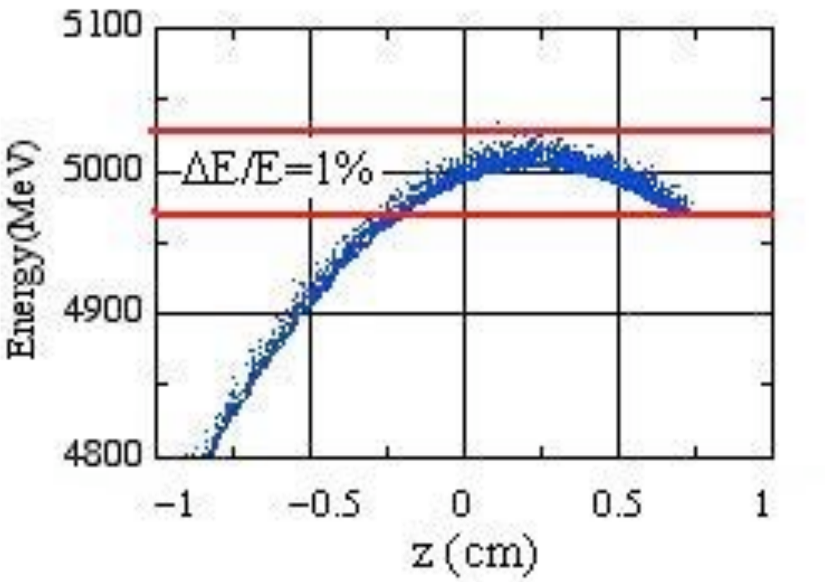
$$\boxed{\varepsilon = \sqrt{\varepsilon_o^2 + \left(\frac{e\,B_t\,R_t^2}{2\,m\,c}\right)^2}}$$

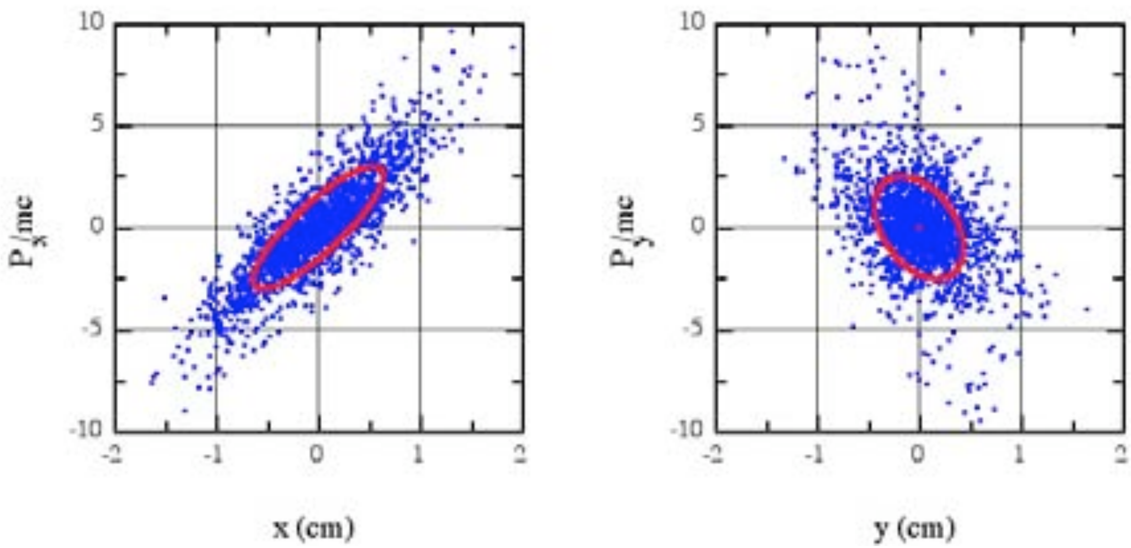
ε_o - beam emittance
B_t- field at the target
R_t- beam radius at the target

For $\varepsilon_0 = 0.1\ \pi$ m rad, B_t =6 Tesla, R_t = 5 mm

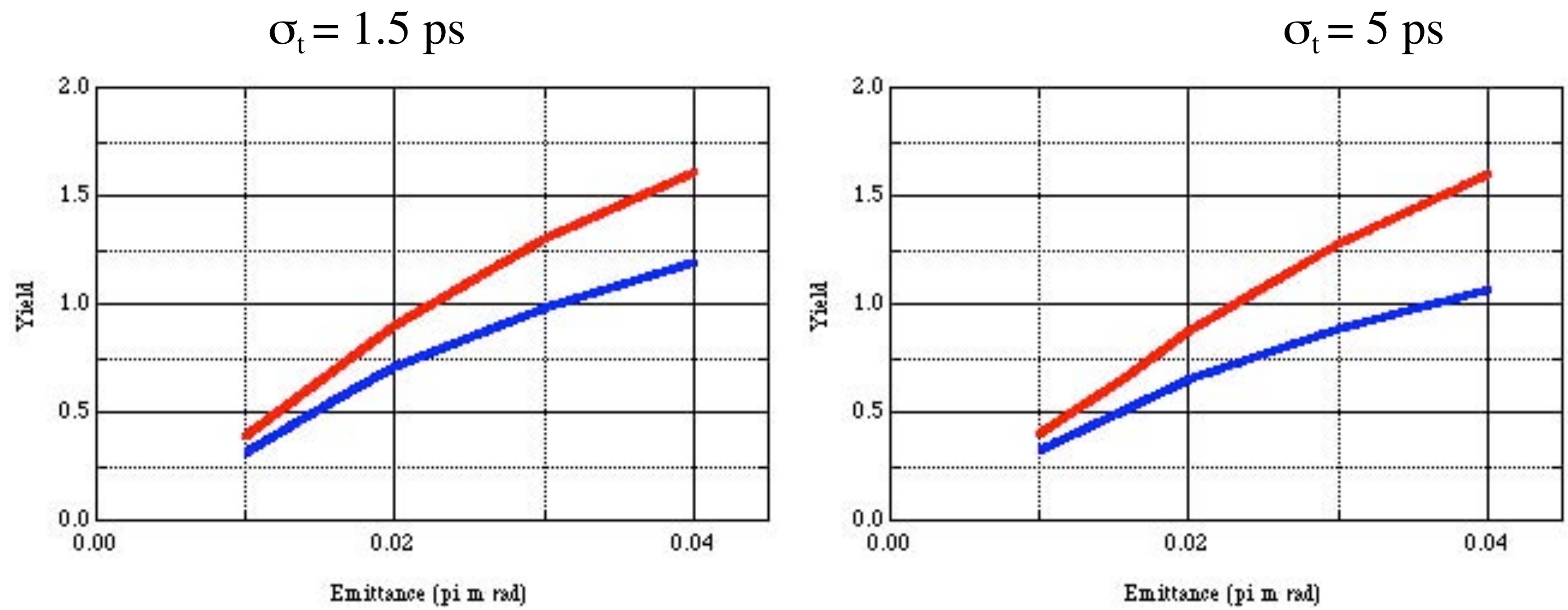
$$\boxed{\varepsilon = 1.1\ \varepsilon_o}$$

Acceleration of positrons



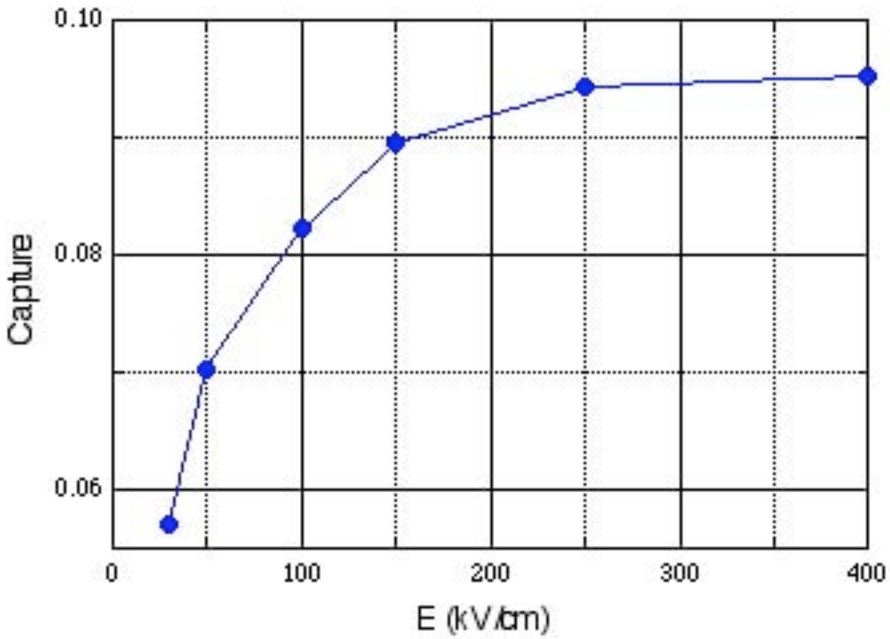


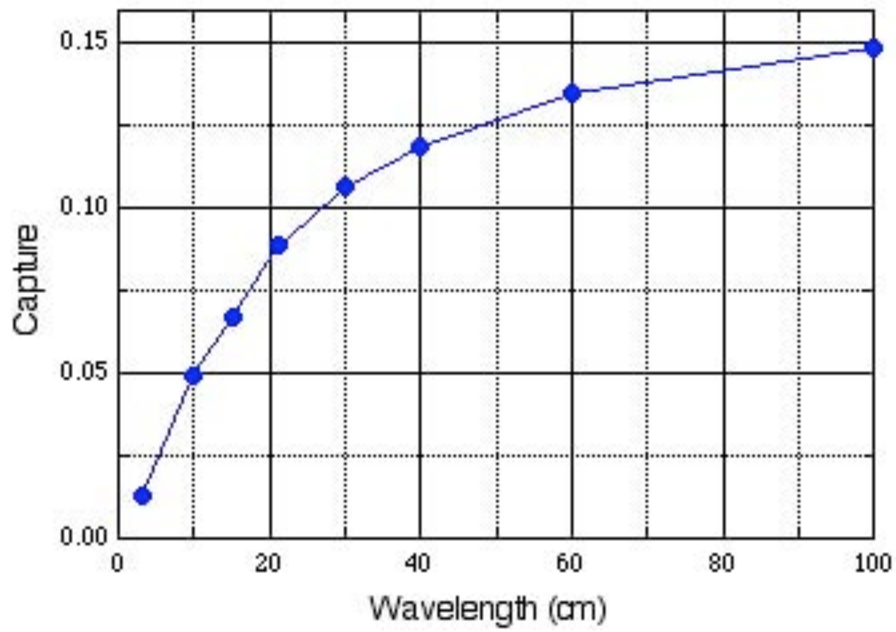
Distribution of accelerated positrons in phase space (red): area of 0.01 π m rad.



Positron yield at 5 GeV as a function of transverse beam emittance for accelerating gradient E = 12 MeV/m, (blue) $\Delta E/E \leq 1\%$, (red) $\Delta E/E \leq 2\%$.

Positron capture as a function of accelerating gradient and RF wavelength.

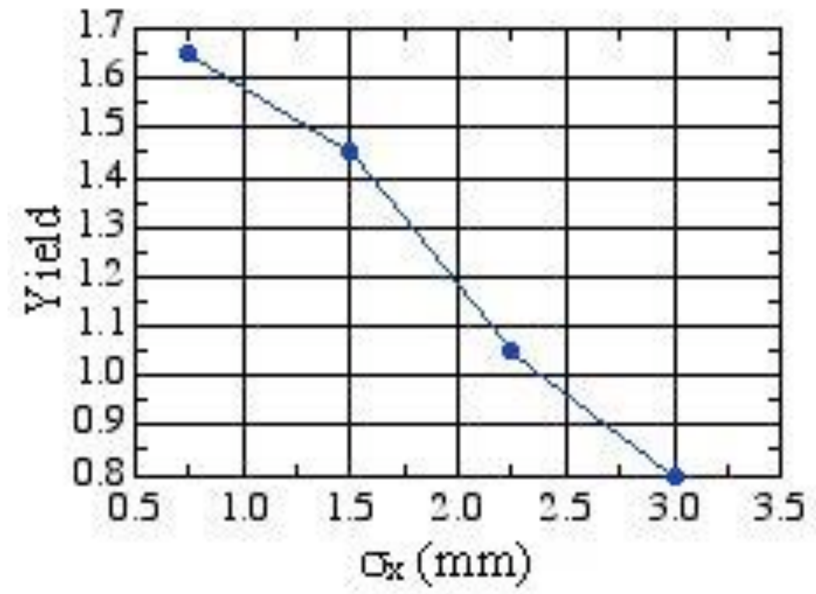


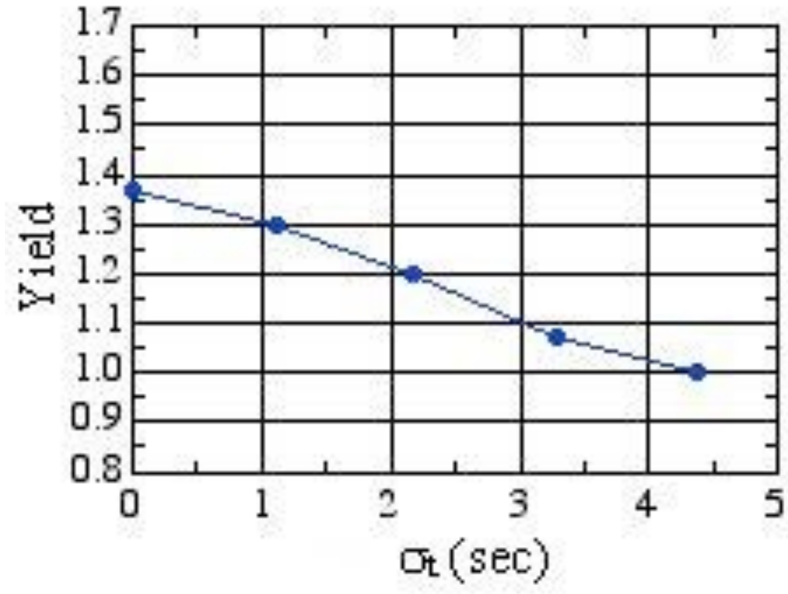


Longitudinal mapping:

$$\boxed{\sin \varphi = \sin \varphi_o - \frac{2\pi\, mc^2}{e\, E\, \lambda}\left(\frac{\gamma_o}{\beta_w} - \sqrt{\gamma_o^2 - 1 - p_t^2}\right)}$$

$$\boxed{\gamma = \gamma_o + \frac{eE}{mc^2} L \cos\varphi}$$





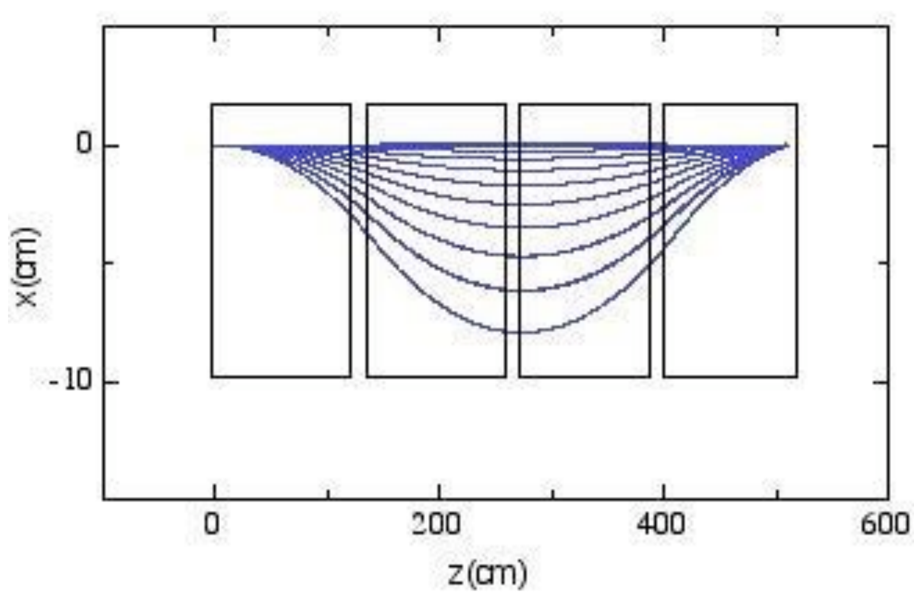
Positron yield as a function of transverse electron bunch size (bunch length $\sigma_t = 1$ ps, target Hg, 4RL, E = 25 MV/m).

Positron yield as a function of electron bunch length (σ_x=1.6 mm, target W-Re 4.5RL, E = 25 MV/m).

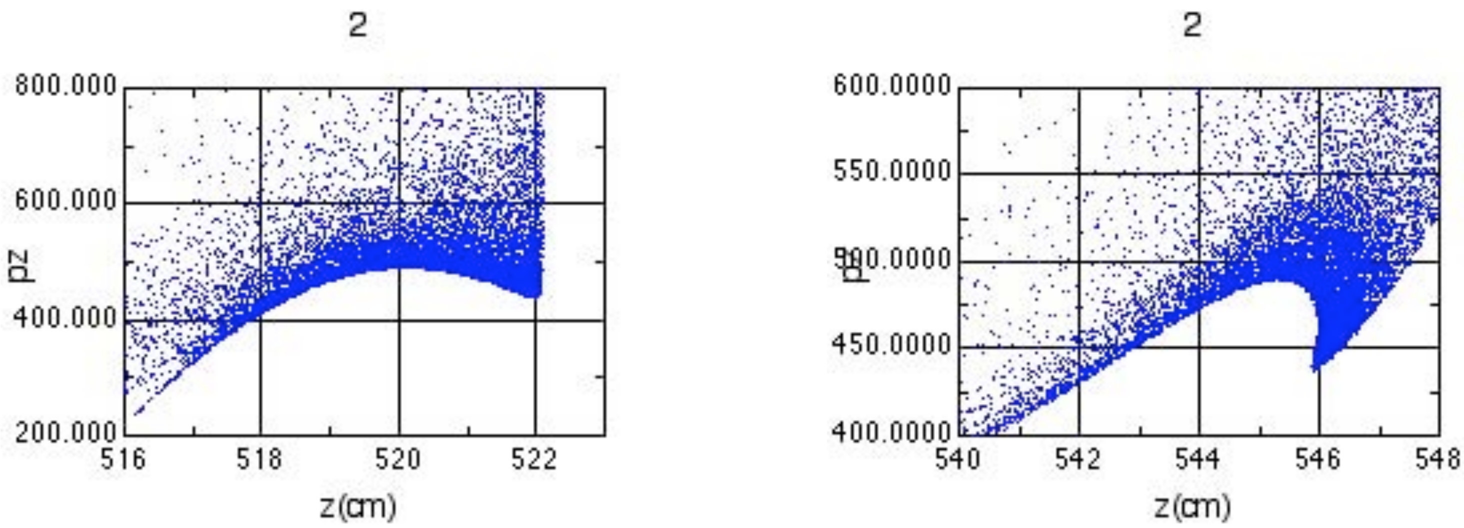
Magnetic compression for positron collector

Chicane parameters:

Beam energy	250MeV
Beam energy spread	20%
Bending radius	600cm
Bending angle	13°
Bending field	0.14 Tesla

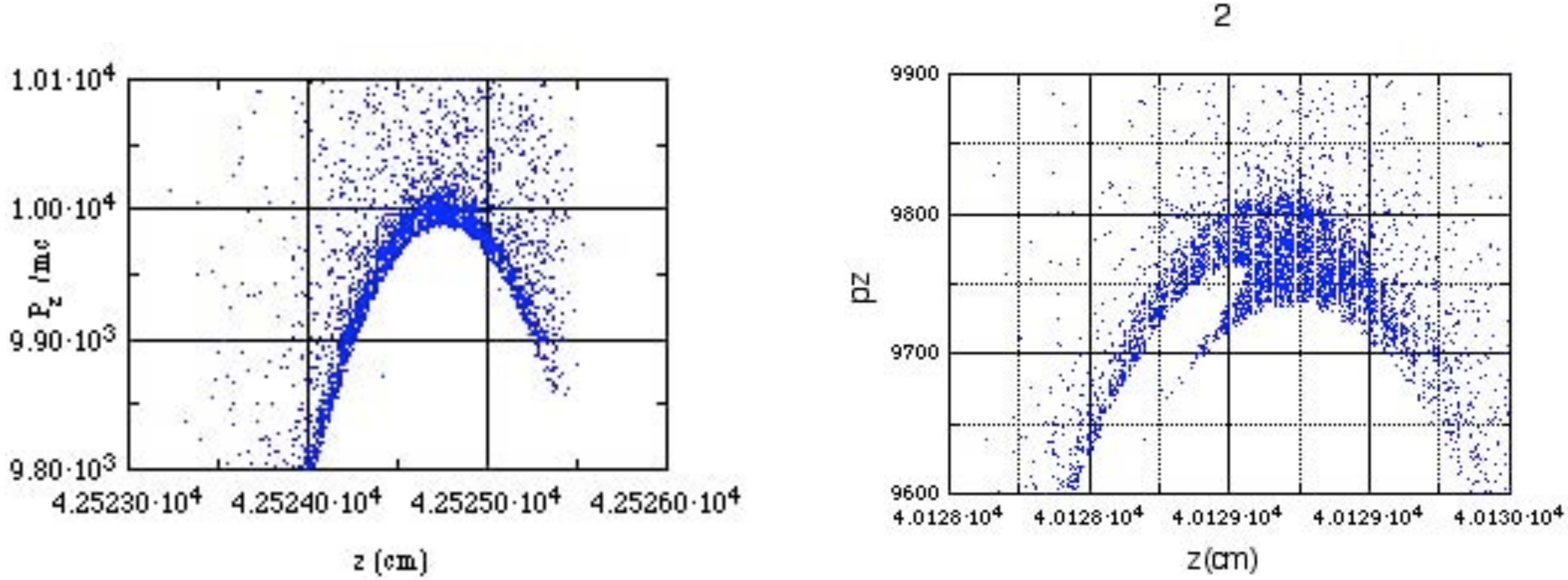


Transverse particle trajectories in chicane.



Longitudinal positron distribution before and after compression.

No Compression **With Compression**



Particle distribution at 5 GeV.

Positron yield with and without compression.

	No compression	With compression, E=12 MV/m	With compression, E=50 MV/m
Positron yield within $\varepsilon_x = \varepsilon_y \leq 0.03\ \pi$ m rad, $\Delta E/E \leq 1\%$	0.982	1.312	1.505

Parameters for conventional positron source collector

Target

Material	W23Re
Length	4.5 RL

Eletron Beam

Energy	6 GeV
Transverse size, $\sigma_x = \sigma_y$	1.5….2 mm
Longitudinal size, σ_t	1.5….5 ps

Adiabatic Matching Device

Field profile	$B_z = B_{max}/(1 + gz)$
Field at the target, B_{max}	6 Tesla
Field coefficient, g	0.6 cm^{-1}
Length of AMD	18 cm

Pre-accelerator

Wavelength	23 cm
Energy	0…...250 MeV
Focusing field	0.5 Tesla
Accelerating gradient	12 MeV/m

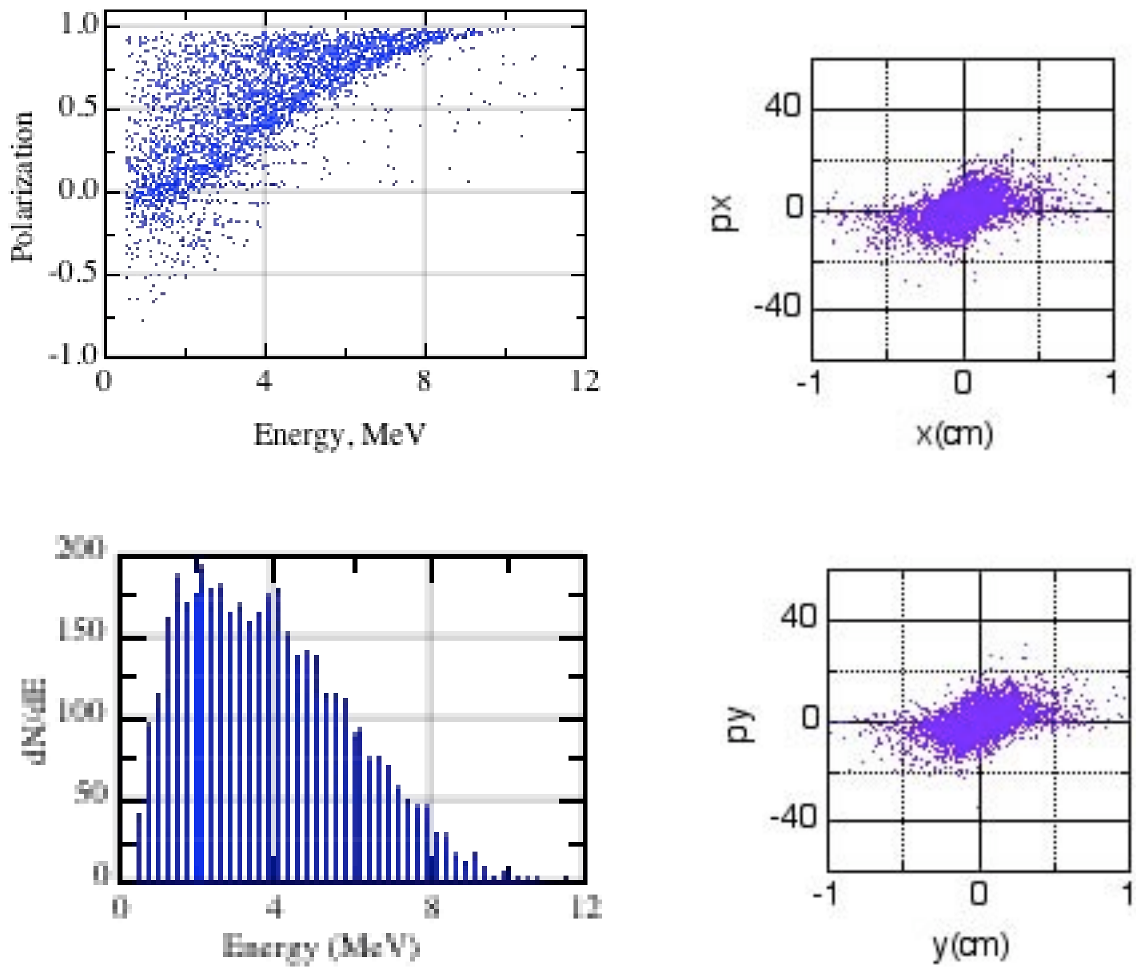
Chicane

Beam energy	250MeV
Beam energy spread	20%
Bending radius	600 cm
Bending angle	13^o
Bending field	0.14 Tesla

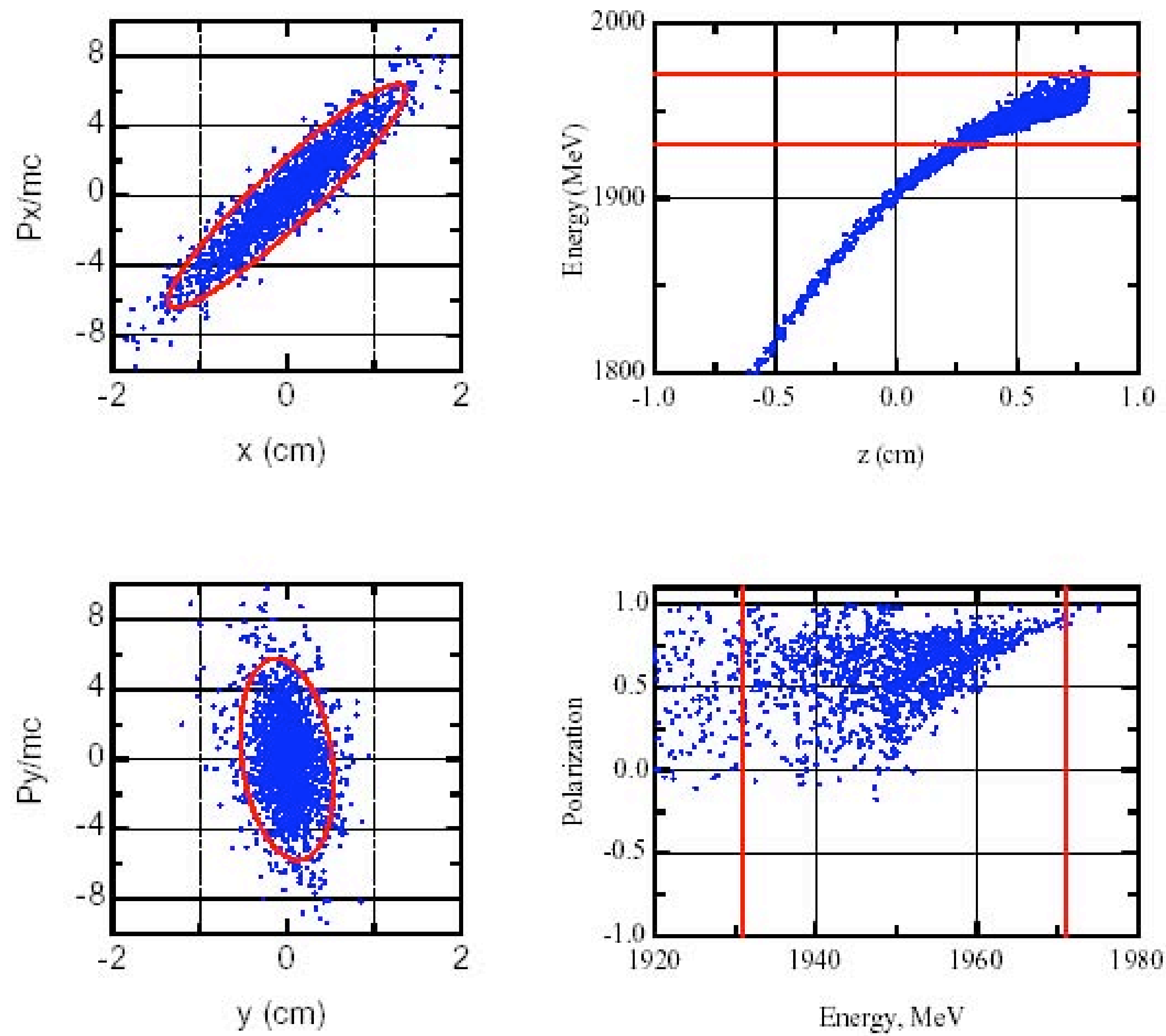
Accelerator

Wavelength	23 cm
Energy	5 GeV
Accelerating gradient	12 MeV/m

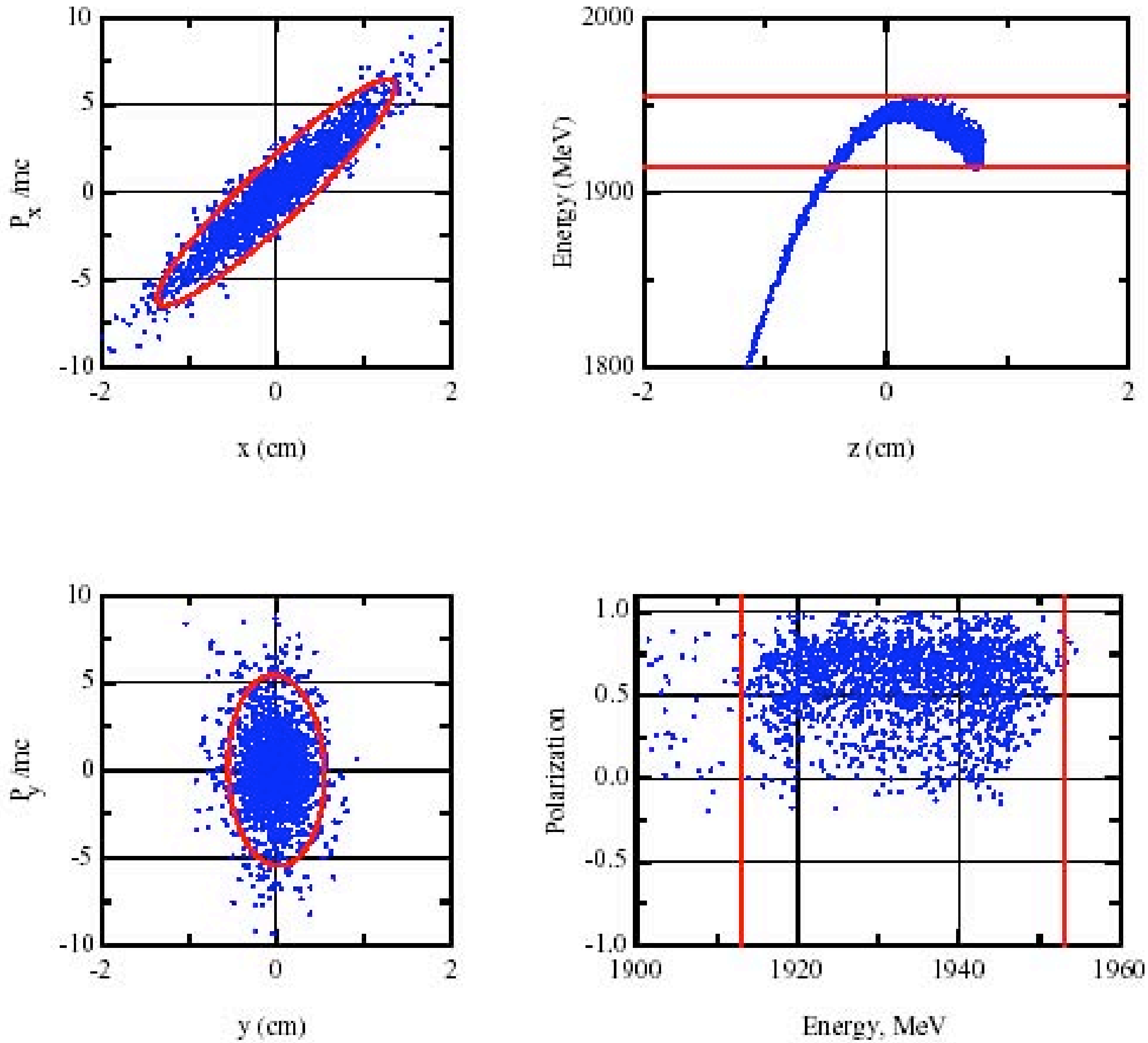
POLARIZED POSITRON CAPTURE



Initial distribution of positrons generated by 11.7 MeV γ – flux.

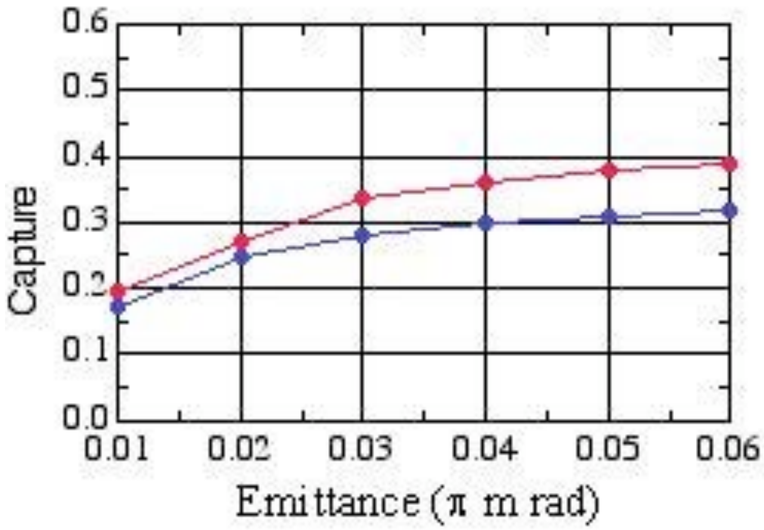


(Blue) distribution of positrons at 1.9 GeV obtained from 10.7 MeV γ-flux, (red) emittance area of 0.03 π m rad and ΔE/E=2%.

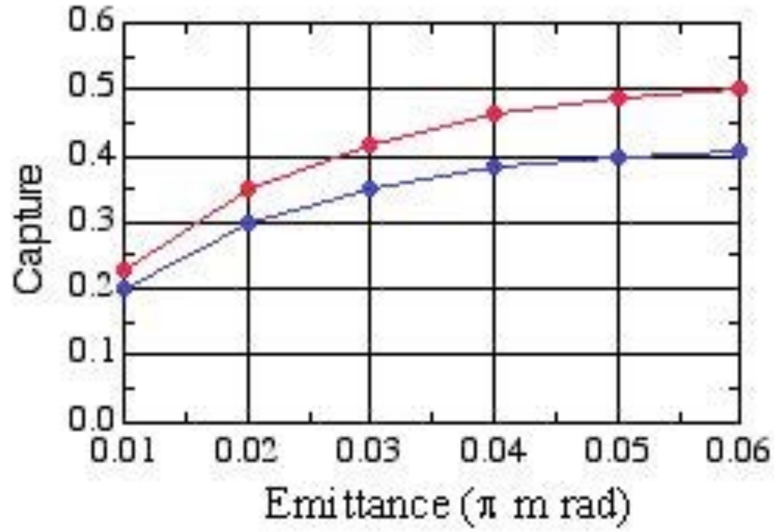


(Blue) distribution of positrons at 1.9 GeV obtained from 10.7 MeV γ-flux at RF phase φ =-11.5°, (red) emittance area of 0.03 π m rad and ΔE/E=2%.

(a)



(b)



Positron capture at 5 GeV as a function of beam emittance: (blue) $\Delta E/E < 1\%$, (red) $\Delta E/E < 2\%$,

(a) particles are on crest, beam polarization $\langle P_z \rangle = 0.51 \ldots 0.56$

(b) particles are off-crest, beam polarization $\langle P_z \rangle = 0.49 \ldots 0.53$

SUMMARY

1. Two schemes for positron production were considered:
   - conventional scheme, utilizing 6 GeV electron beam interacting with high-Z positron production target,
   - polarized positron production scheme based on polarized photons generated in helical undulator.
2. In electron-based source positron phase space density at the target has a maximum for target length of 4.5….5.5 RL.
3. Target immersed in magnetic field provides 40% more transmitted positrons than shielded target.
4. Positron transmission through adiabatic matching device has a maximum for the value of adiabatic parameter $g = 0.6\ cm^{-1}$.
5. The value of positron capture saturates for accelerating gradients $E > 25$ MV/m.
6. Positron yield for conventional source can reach the values of $Y = 1.0….1.3$ for $\varepsilon_x = \varepsilon_y \leq 0.03\ \pi$ m rad, $\Delta E/E \leq 1…2\%$.

7. Application of magnetic bunch compression results in 30% - 40% increase in positron capture.
8. The value of positron capture for undulator-based source is 3-4 larger than that of electron-based source because of better positron beam emittance after target.
9. Additional optimization of collector scheme might be done with respect to:
   - target material and thickness
   - incoming electron/photon beam sizes
   - photon beam energy
   - adiabatic matching magnetic field profile
   - accelerating gradient
   - deceleration of positrons
   - magnetic bunch compression.