Beam Dynamics Studies of ILC Positron Source at ANL

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LCWS 05, March 19, 2005

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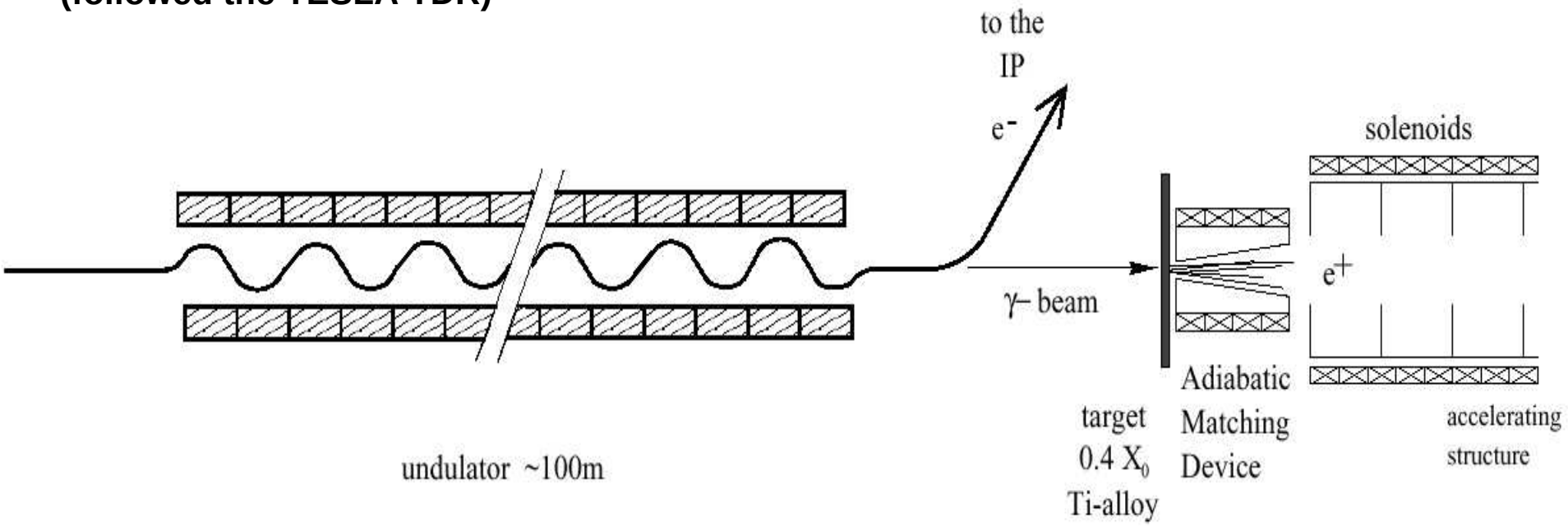
Positron Source Under the consideration at ANL

(followed the TESLA TDR)



TESLA TDR DESY 2002

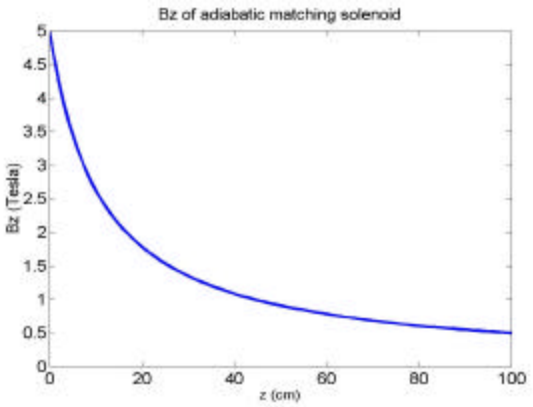
- **Use Gamma rays from the electron beam passing through an helical undulator (polarized) or planar wiggler (unpolarized).**
- **1.4 cm Ti Target in all cases.**
- **Both e+ and e- are produced and included in the calculations.**

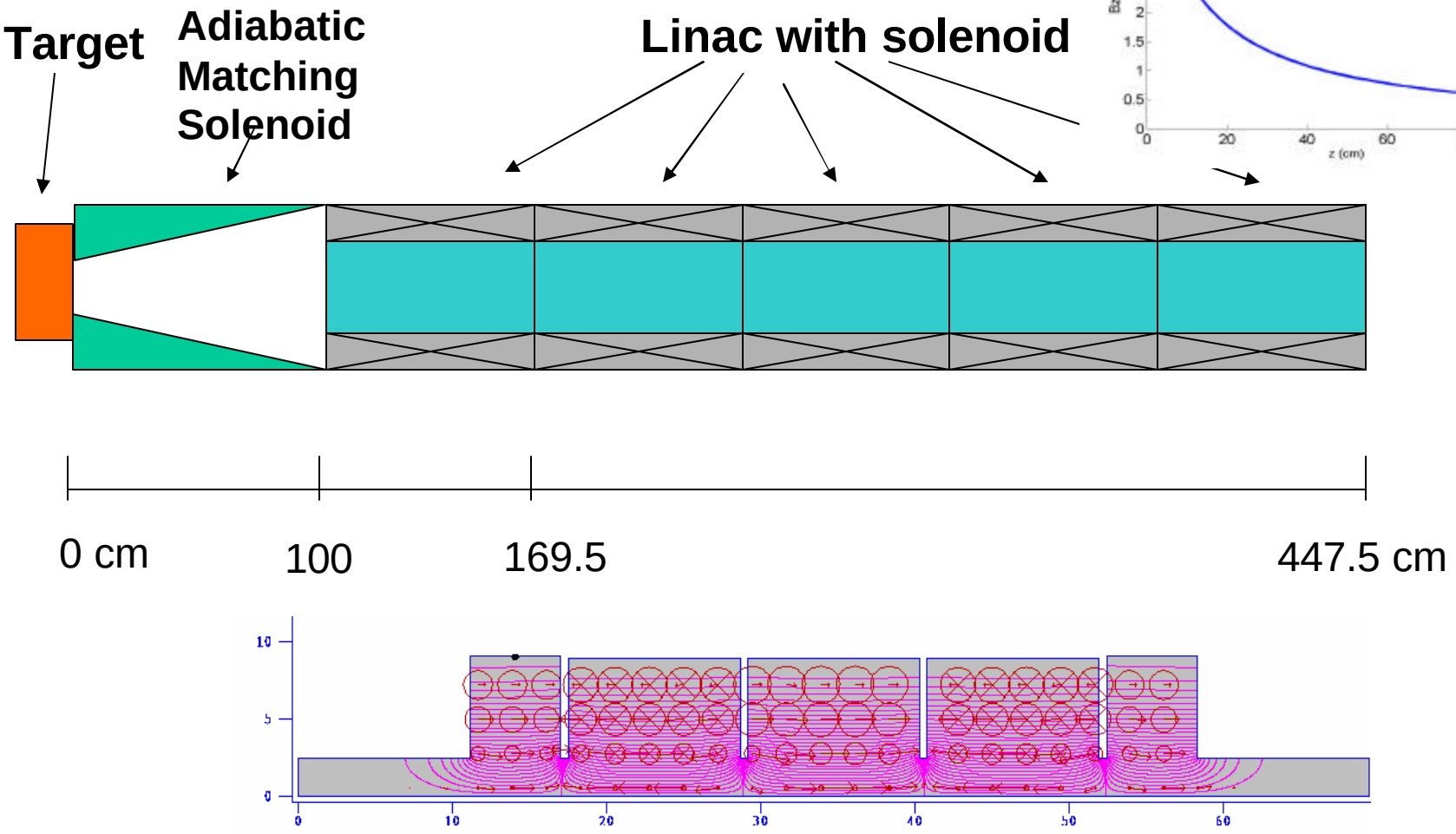
Approaches:

- **Damping ring requirements:**
  - Charge: 3 – 6 nC
  - Normalized emittance: $\varepsilon x+\varepsilon y < 0.048$ m-rad (measures beam divergence).
  - Energy spread < ± 1% (peak to peak): 15º of 1.3 GHz acceleration phase.
- **Followed the TESLA TDR design but with lower photon energy (10 MeV generated by 150 GeV e beam).**
- **PARMELA for beam dynamic simulation. (Including positron capture optics and accelerations).**
- **Normal pre-accelerator to accelerate the beam to 120 MeV; SC to 5 GeV with ~ 200 SC Tesla modules.**

Schematic of Positron Source and Pre Accelerator Layout

- **Target (1.4 cm Ti), Adiabatic Matching Solenoid (5 – 0.25 Tesla). 15 Linac Sections (~ 8 MeV each).**

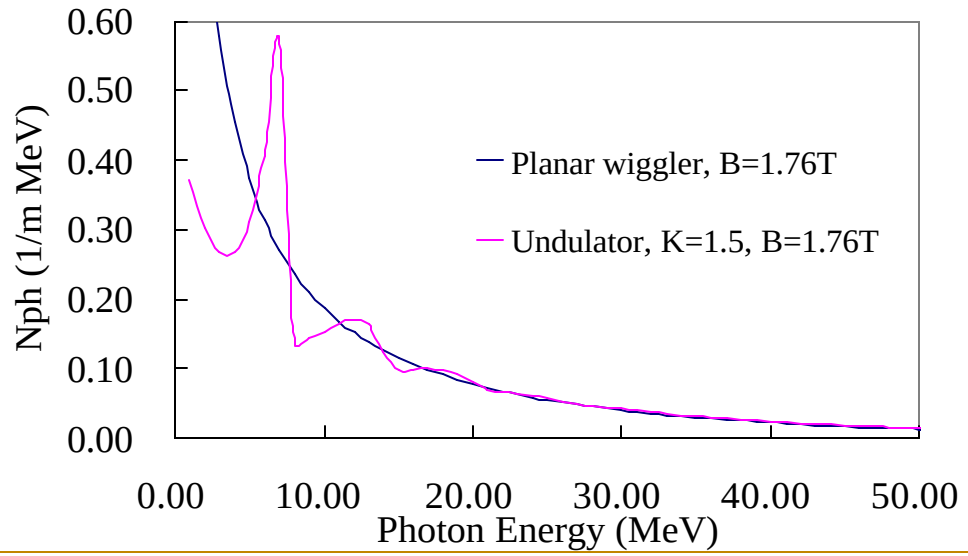




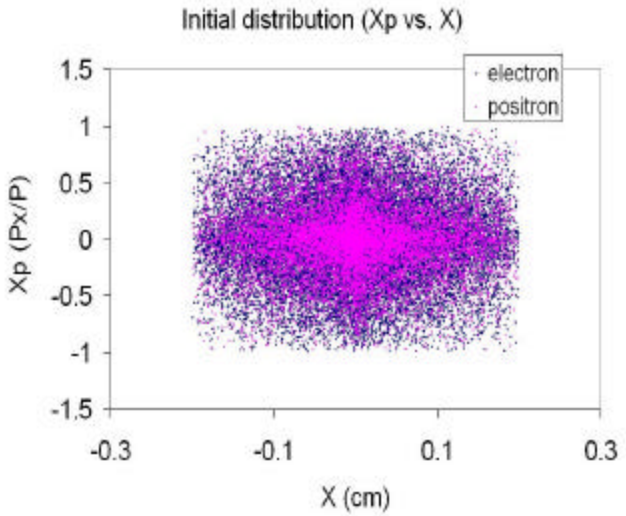
5 cell p mode iris loaded L band linac, the aperture D=5cm, T is about 0.74, E_0T=12MV/m, P=4.4MW. Total energy gain=8.4 MeV, Q=25000, r/Q=613 Ohm

Undulator requirement. (for 3nc captured e+ and 3nC drive electron beam at 150 GeV)

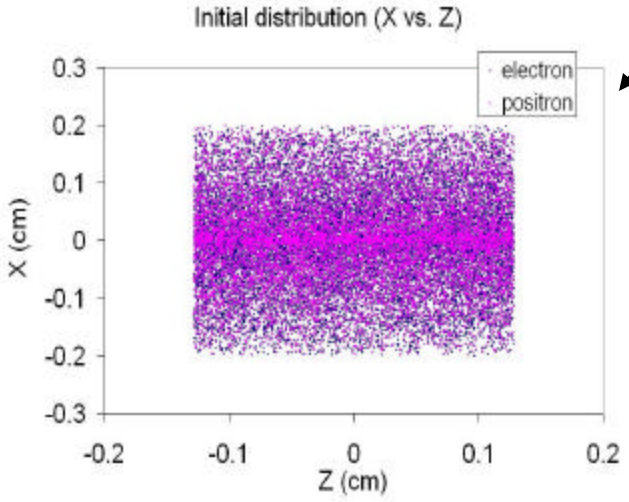
- **L is 22.4m for ex+ey <0.024 m-r. L = 18.7m for <0.048 m-r.**
- **Gamma Ray Power**
  - *for $e_x+e_y<0.048$, 67.KW, and $e_x+e_y<0.024$, 80.KW*
  - *Deposited energy on the target – 7% of gamma beam. 80% of Gamma ray will propagate through the target and cause radiation problems down stream.*
- **Initial positron and electron beam distributions are produced by EGS4. Number of electron = 25575, Number of positron = 14646, R_spot = 2mm.**
- **Positron energy spectrum:**

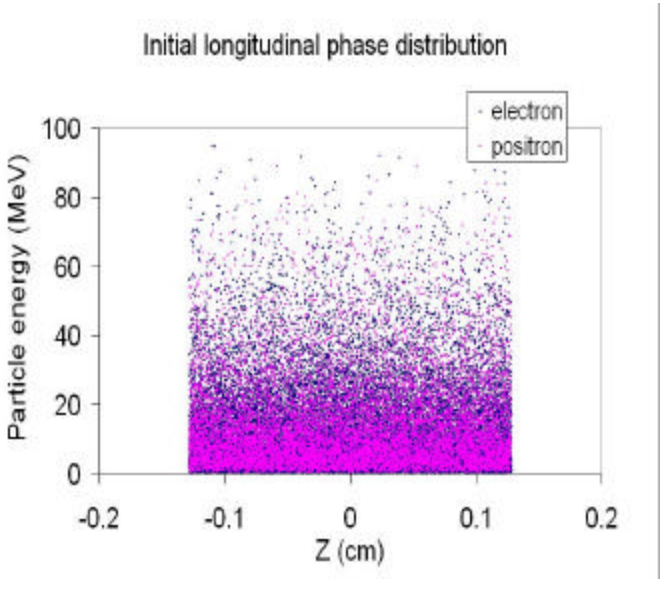


Initial particle distribution in phase space (at the target exit)



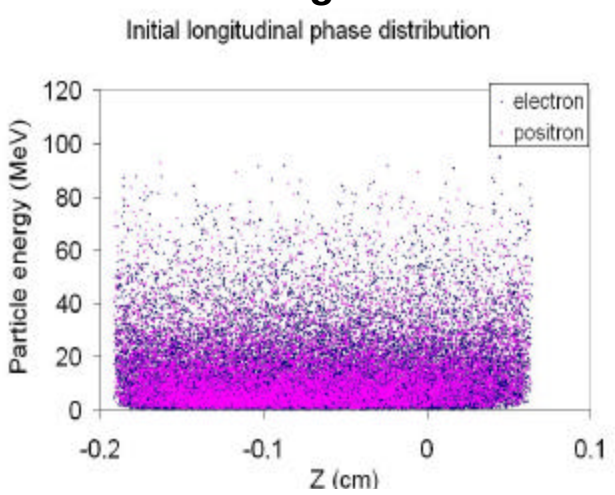
X and Y are symmetric.

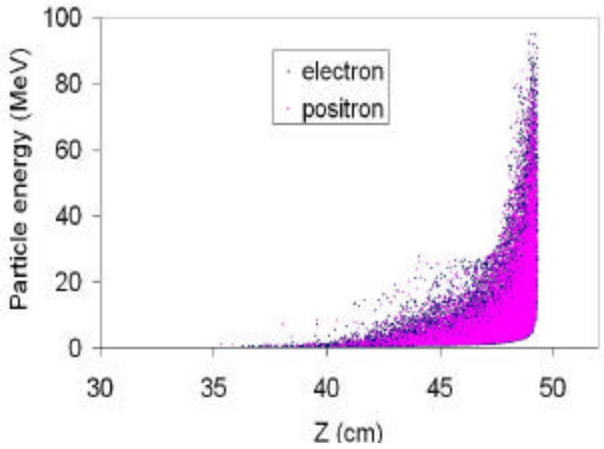


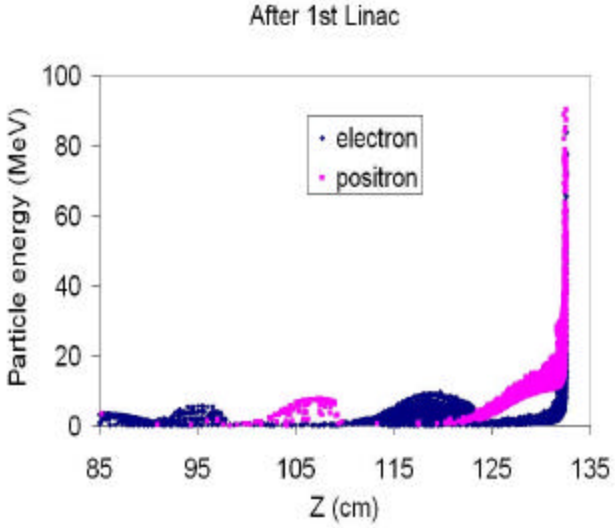


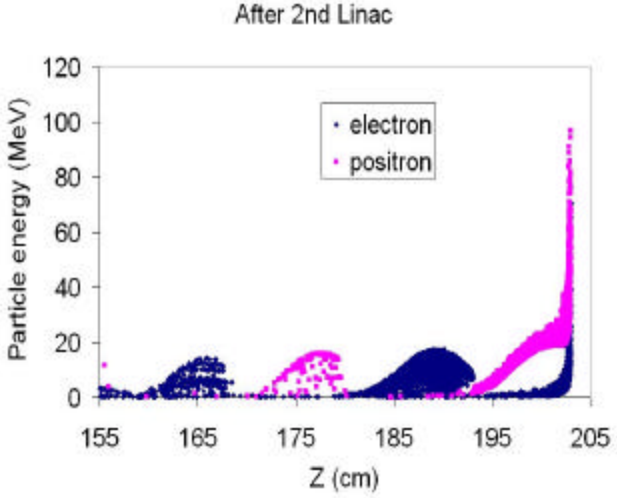
Longitudinal phase distribution evolution along beam line (1)

Target

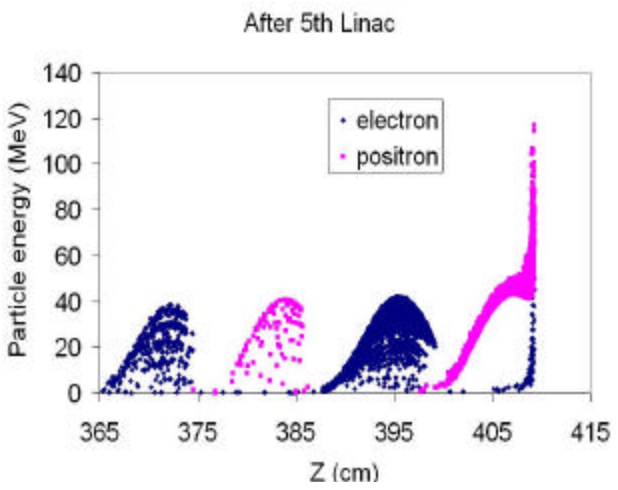


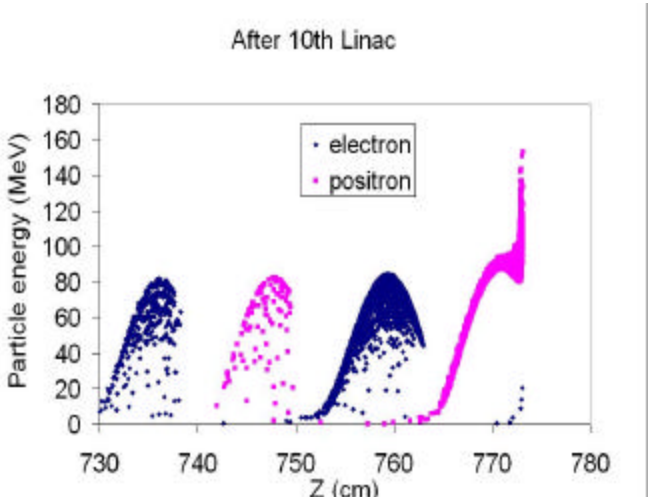


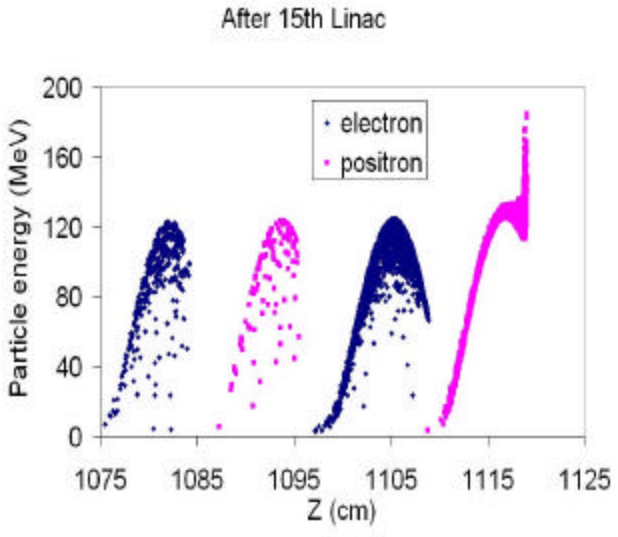


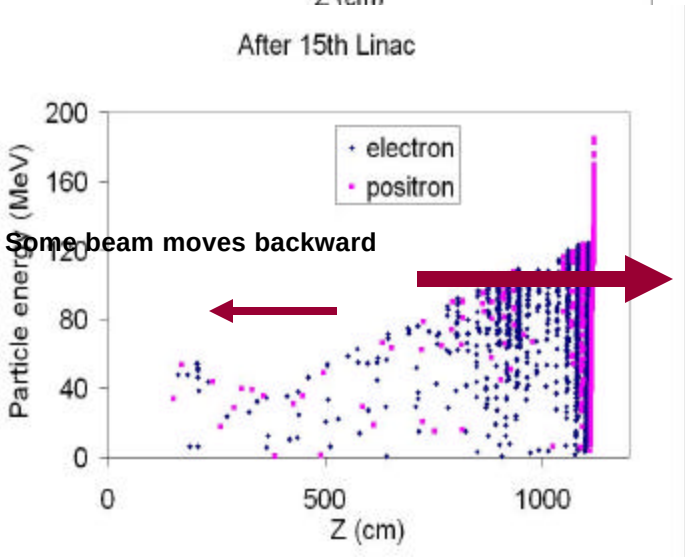


Longitudinal phase distribution evolution along beam line (2)

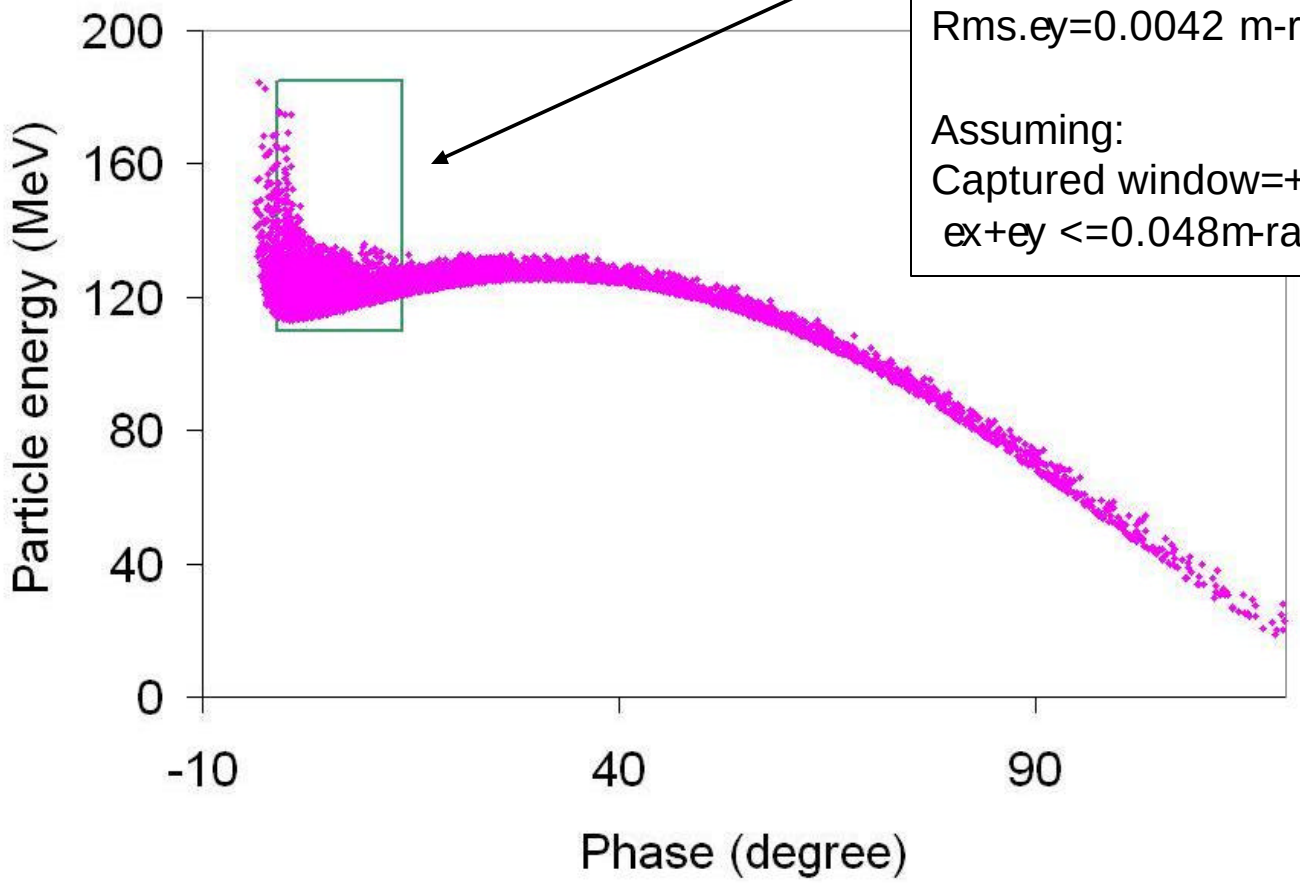








Capturing efficiency after 15th Linac (end of pre-acc)

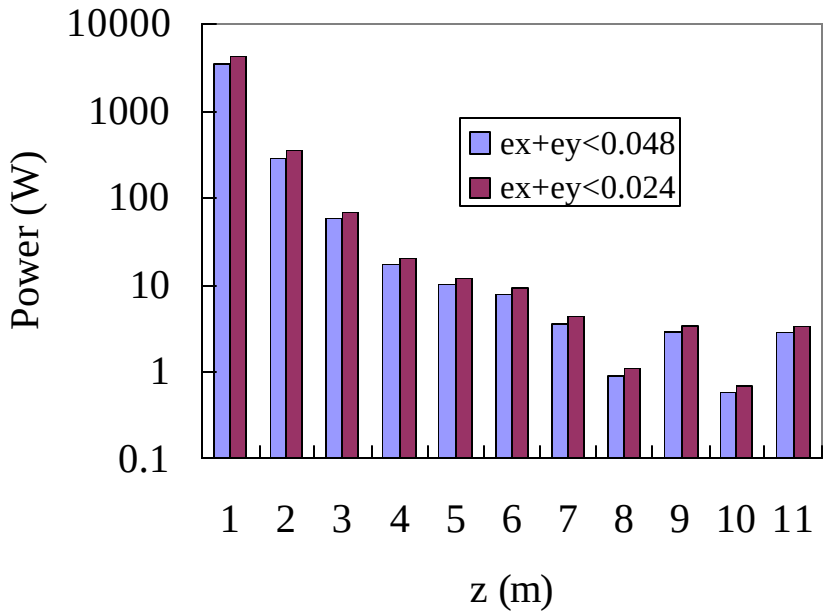


Captured efficiency = 27 %,
Rms.ex=0.0042 m-rad,
Rms.ey=0.0042 m-rad.

Assuming:
Captured window=+/- 7.5º,
ex+ey <=0.048m-rad,

Power lost along beam line, the captured positron beam is assumed to be 3nC

- **For helical undulator:**
  - $\varepsilon_x+\varepsilon_y<0.048$: 16KW
  - $\varepsilon_x+\varepsilon_y<0.024$: 20.19KW



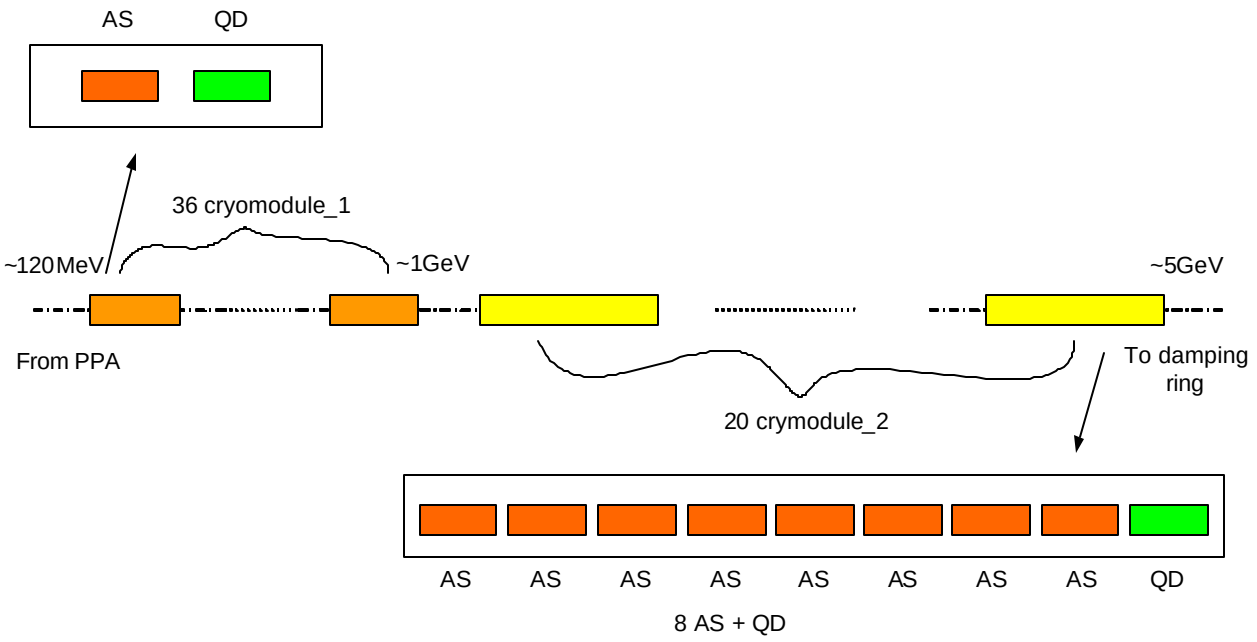
Power deposited in source target by backfired particles:

- **For helical undulator:**
  - ex+ey<0.048: 435.3W
  - ex+ey<0.024: 520.5W

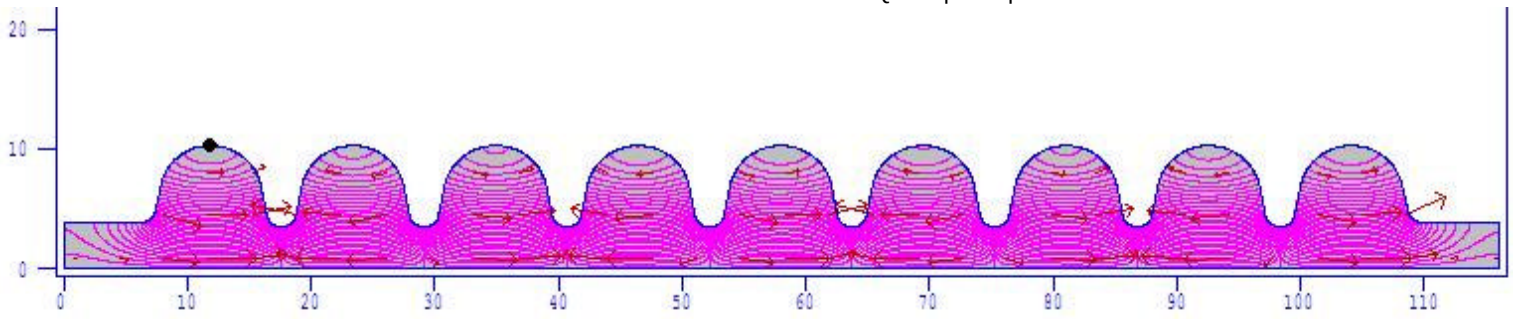
Beam Acceleration to 5 GeV (to Damping Ring)

- **The captured positrons with energy ~120MeV are separated from background particles (method is under study), and then accelerated up to ~5 GeV using Tesla-type 9-cell L-band p -mode superconducting cavities. Quadrupole doublets are used to focus positron beam.**
- **During the acceleration process, no more positron losses.**

Boosting Energy to 5 GeV to Damping Ring Input

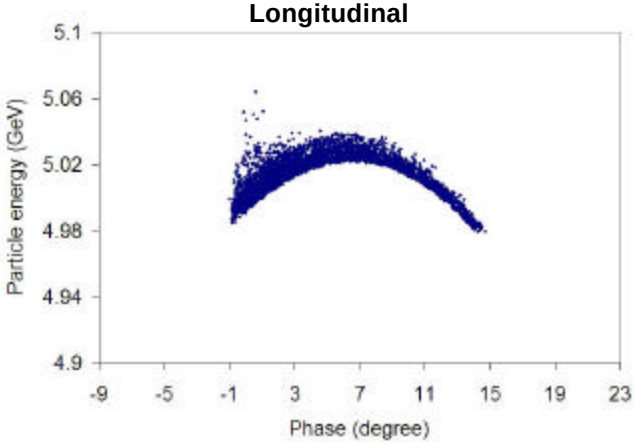


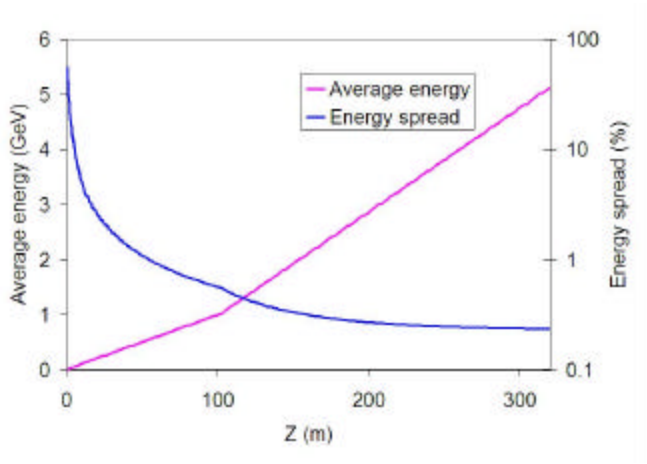
AS = accelerating structure
QD = quadrupole doublet



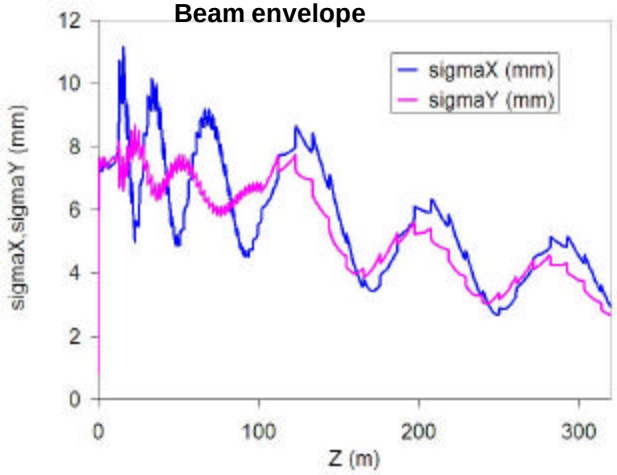
6-D phase distribution @ 5 GeV (before the damping ring)

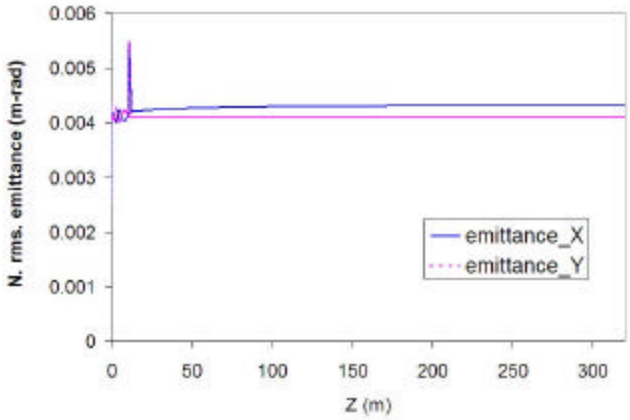
Longitudinal





Beam envelope

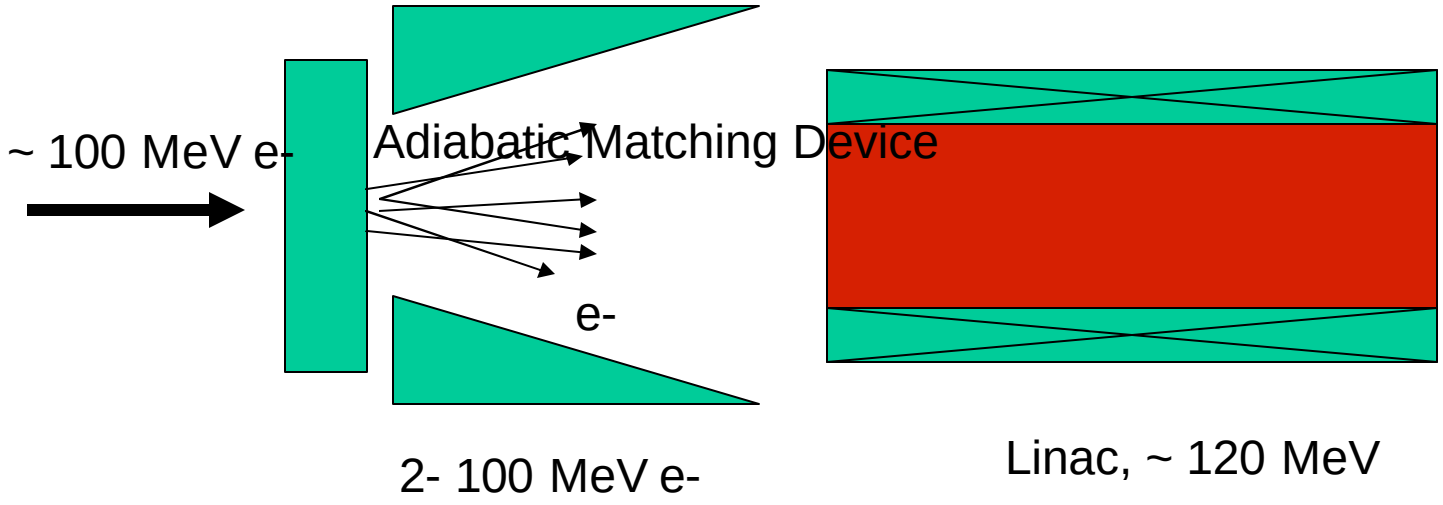




Positron source emulator

Motivation: ***to condition the positron linac and positron damping ring without gamma ray produced positron source or auxiliary positron source.***

Method: ***Use electron beam from an L-band RF gun to generate a "simulated" e+ beam.*** *Speed up the commission process.*



Looking for a few good targets (Using EGS 4):

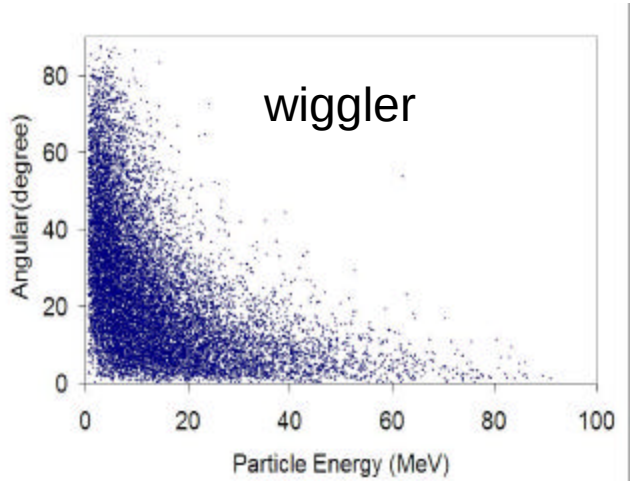
- Energy, energy spread
- Angular distribution
- Factors under the consideration: **beam energy, target materials, and target thickness**.

So far, we settle on Be:

We found: Target material: Be,

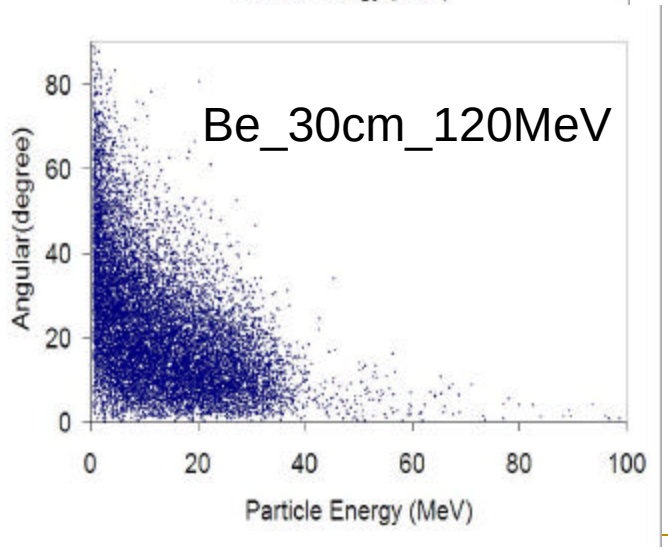
Target thickness: 30cm,

Electron energy target: 120MeV,

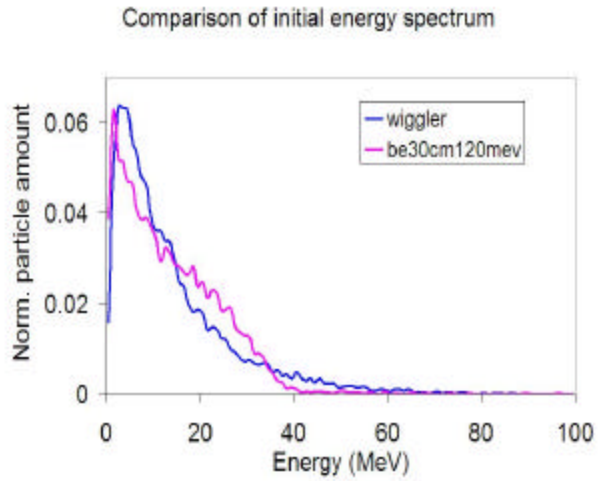


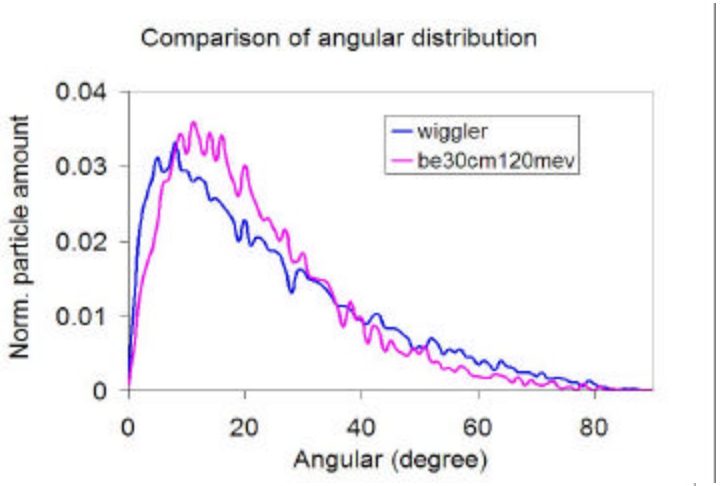
Number of particles yielded from target:13396,

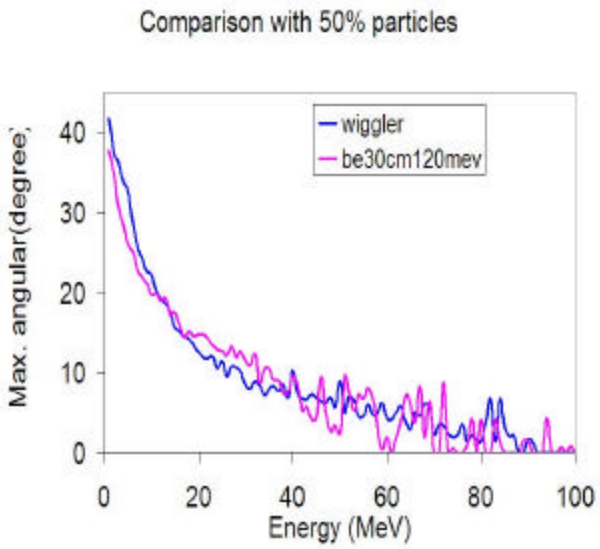
Number of particles bombarding target: 30000.

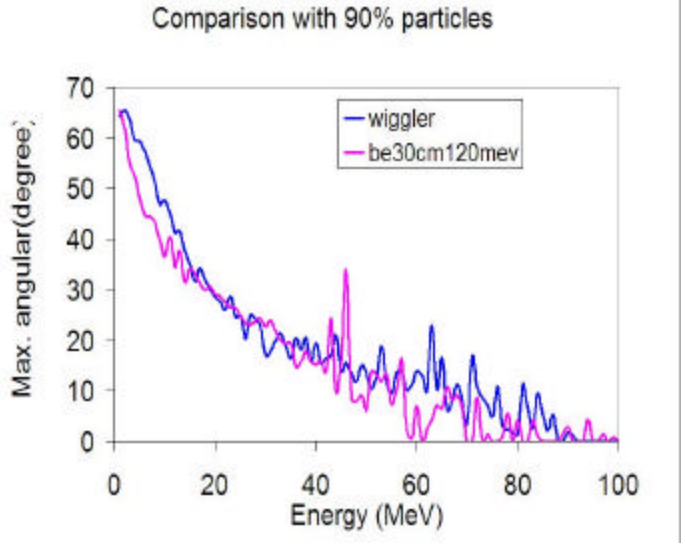


Comparisons with planer wiggler positron (it is almost the same for polarized)

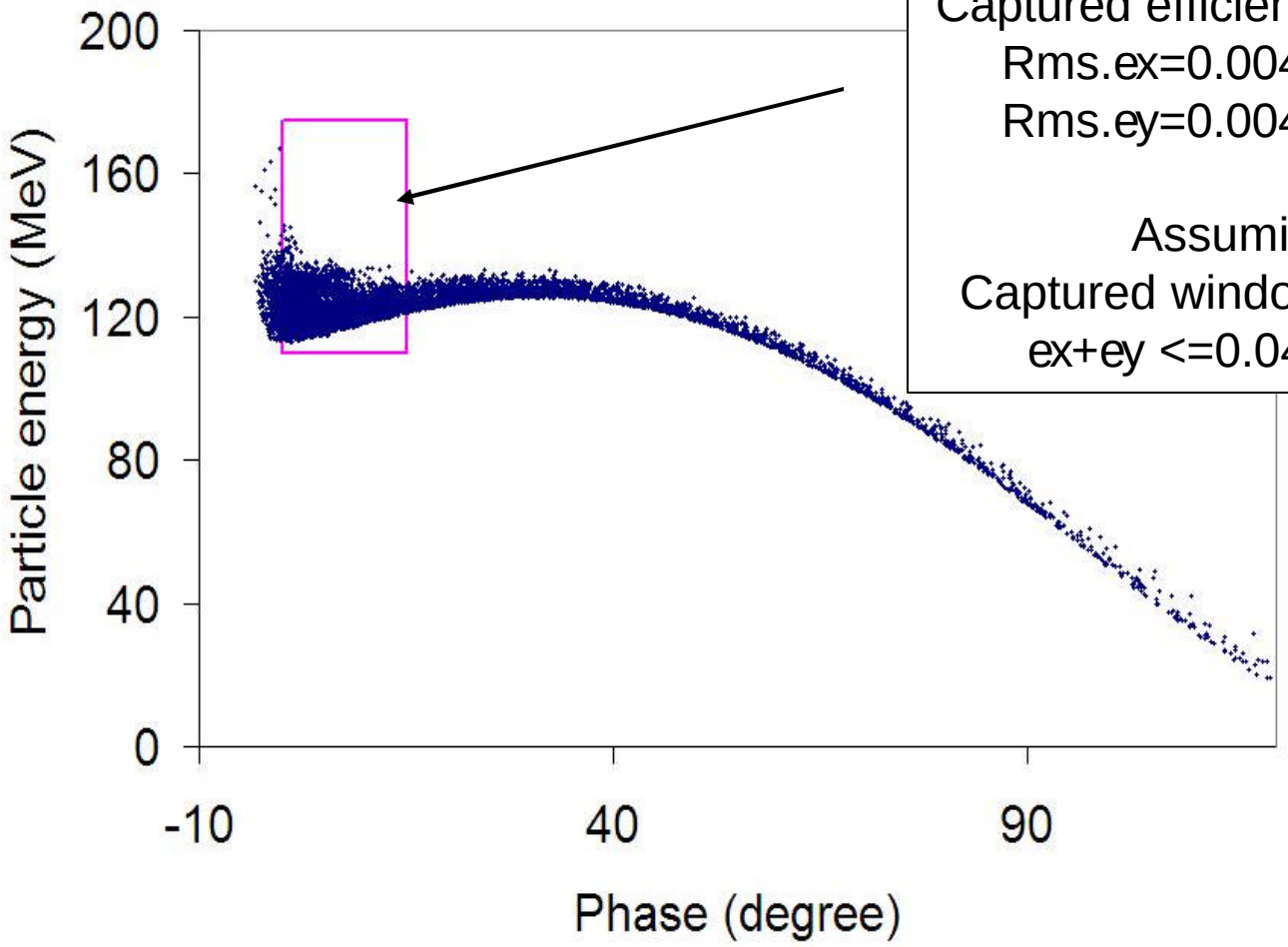








Captured efficiency after 15th Linac



Captured efficiency = 26.4%,
Rms.ex=0.0046 m-rad,
Rms.ey=0.0046 m-rad.

Assuming:
Captured window=+/- 7.5º,
ex+ey <=0.048m-rad.

Summary

- **We have simulated electron and positron beam dynamics from target to damping ring input. Major parts of electron and positron beams are lost in the pre-accelerators. This may provide a base for radiation shielding calculations.**
- **The capture efficiency can be 27% for e+ with constrain of emittance ex+ey<0.048 m-rad (rms <0.005 m-rad in both planes) and longitudinal phase space (+-7.5 degree which is 1% energy spread). This result will be used as realistic input for Damping Ring.**
- **A "positron" capturing hardware can be built and then tested using scattered electron beam from an RF photocathode. It can be used to study all the followings before the real gamma ray based e+ source is ready:**
  - Conditioning the positron pre-accelerator linac, SC accelerator and damping ring. This will greatly reduce the commissioning period for the ILC positron linac and damping ring.