Yield Of Undulator-Based Positron Source At High Electron Beam Energies

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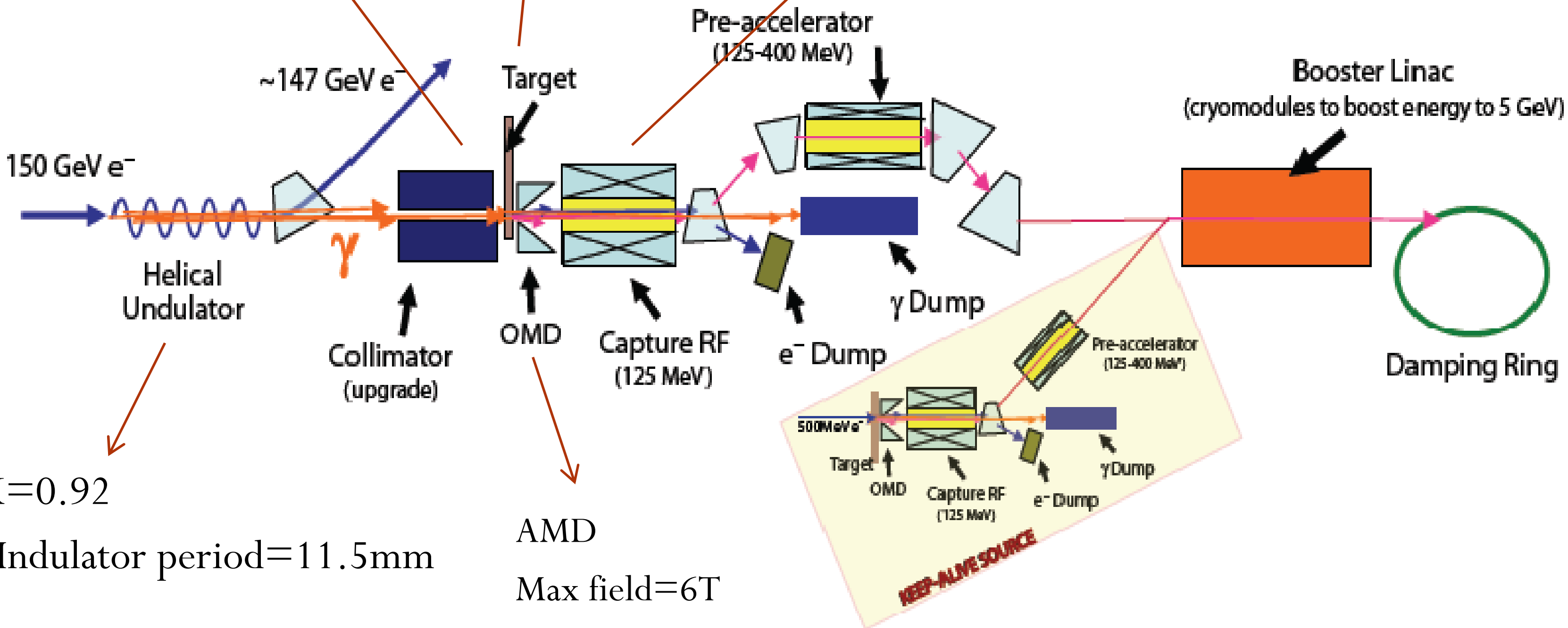
Undulator-Based Positron Source

No photon collimator

14.8mm titanium alloy target

Solenoid field=0.5T



K=0.92

Undulator period=11.5mm

AMD

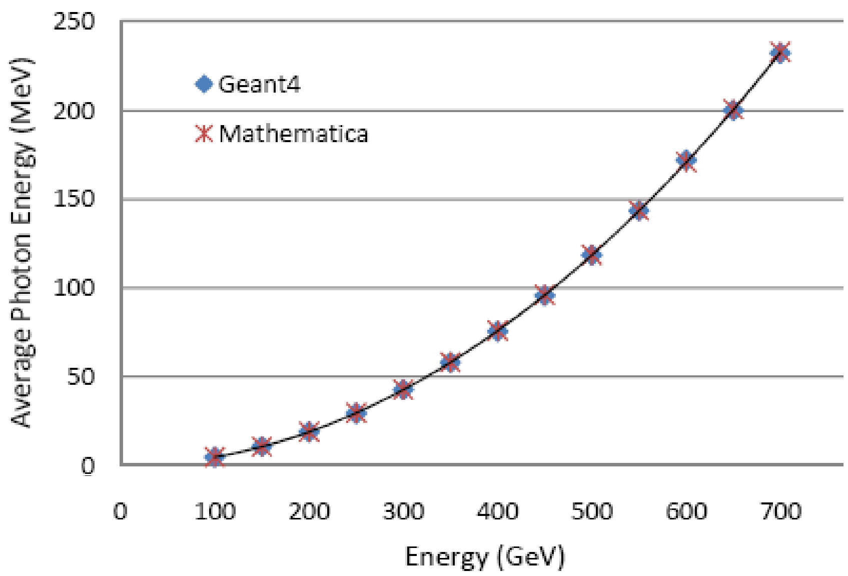
Max field=6T

Taper parameter=0.03/mm

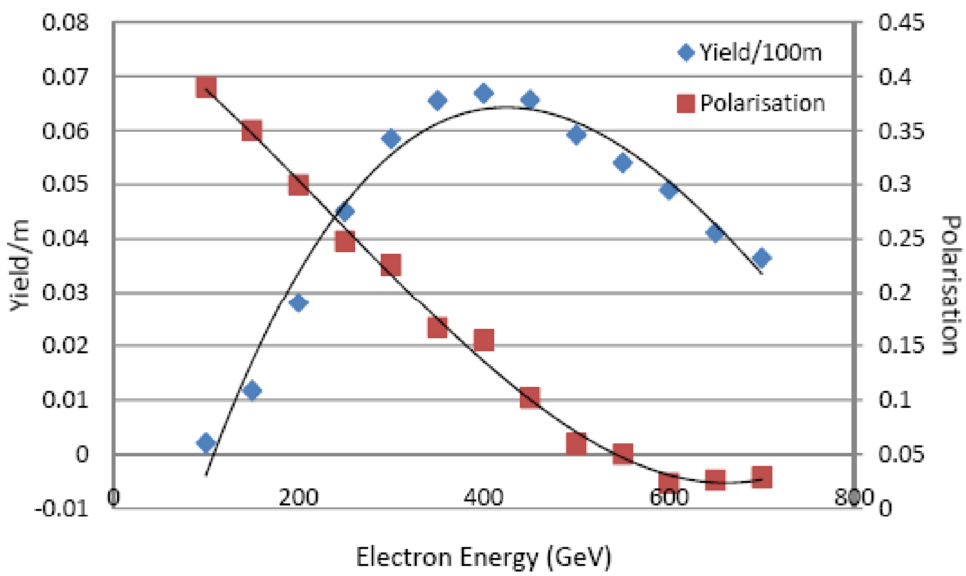
Energy Scan Up To 700 GeV

- ILC will operate in the range of 250 GeV. Here the energy scan is up to 700 GeV because of CLIC consideration.
- The average photon energy increases rapidly with electron energy.
- The positron yield peaks with an electron beam energy of around 400 GeV. Beyond this energy, the yield appears to decrease, because of damping ring acceptance limitations.

Average Photon Energy

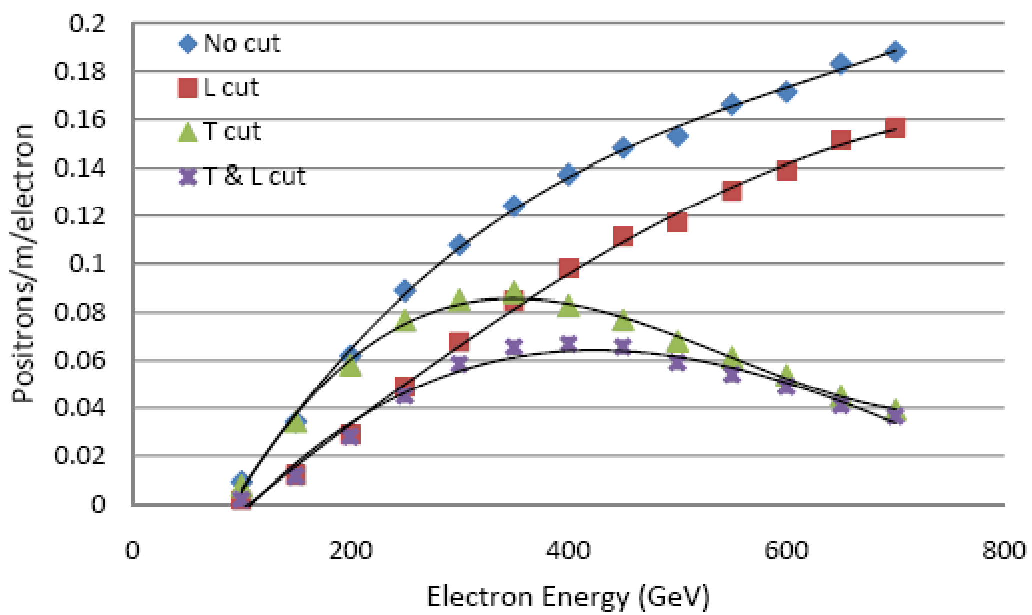


Positron Yield and Polarisation



Effect Of Acceptance On Positron Yield

- L refers to damping ring longitudinal acceptance (longitudinal cut) which equals 10 mm (corresponding to 1% energy spread after 5 GeV 1.3 GHz booster linac).
- T refers to damping ring transverse acceptance (transverse cut) which equals 90 mm rad.



Up to 350 GeV driving electron beam, the Longitudinal cut is the limitation of getting high yield.

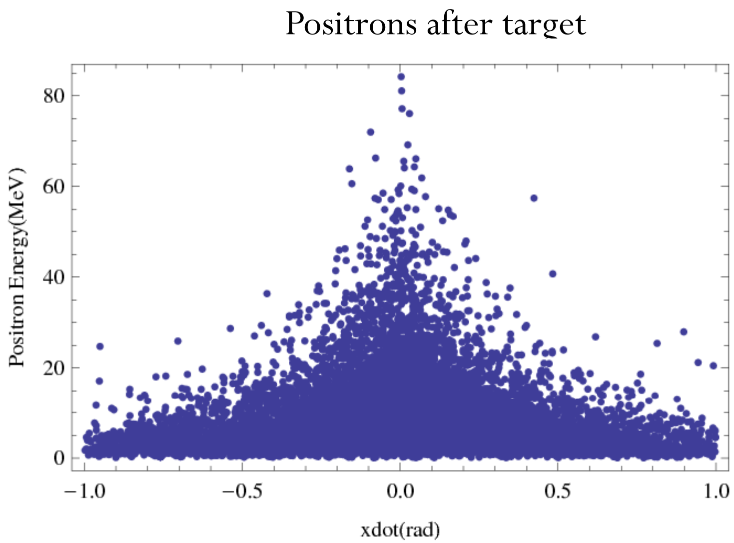
When the electron energy is higher than 350 GeV, transverse cut will be the limitation. And the number of positrons in the transverse acceptance will be less as energy increasing.

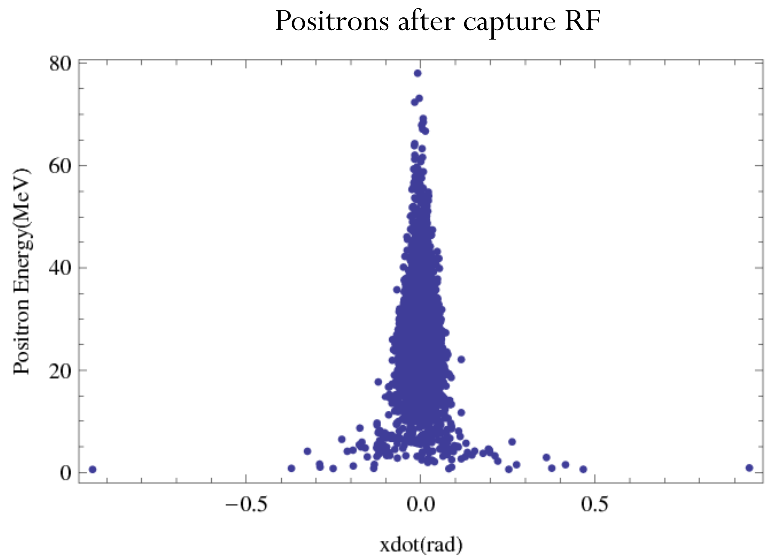
Effect Of Capture On Positron Energy

150GeV

Electron

Energy

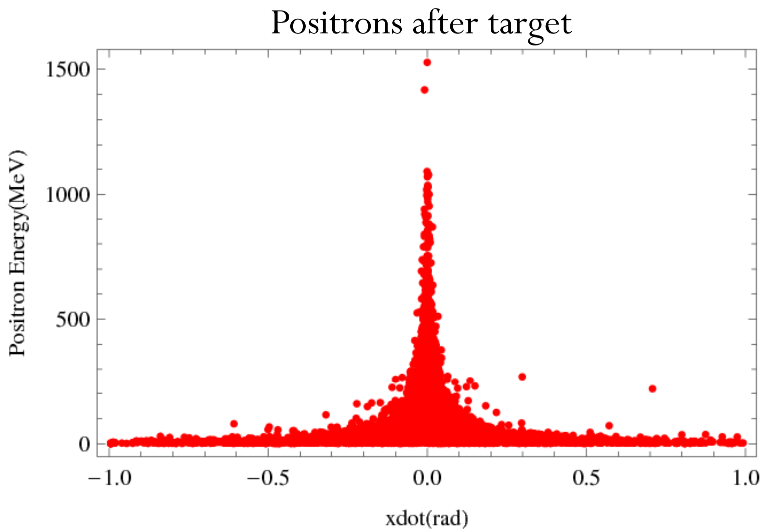


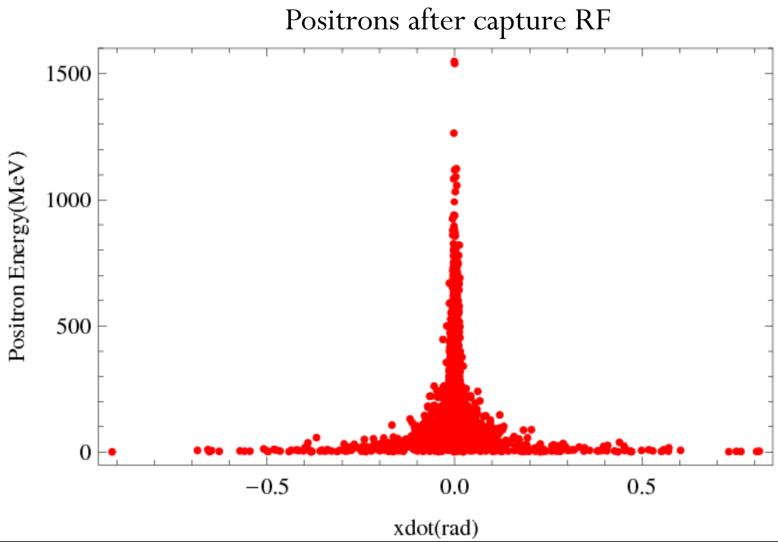


600GeV

Electron

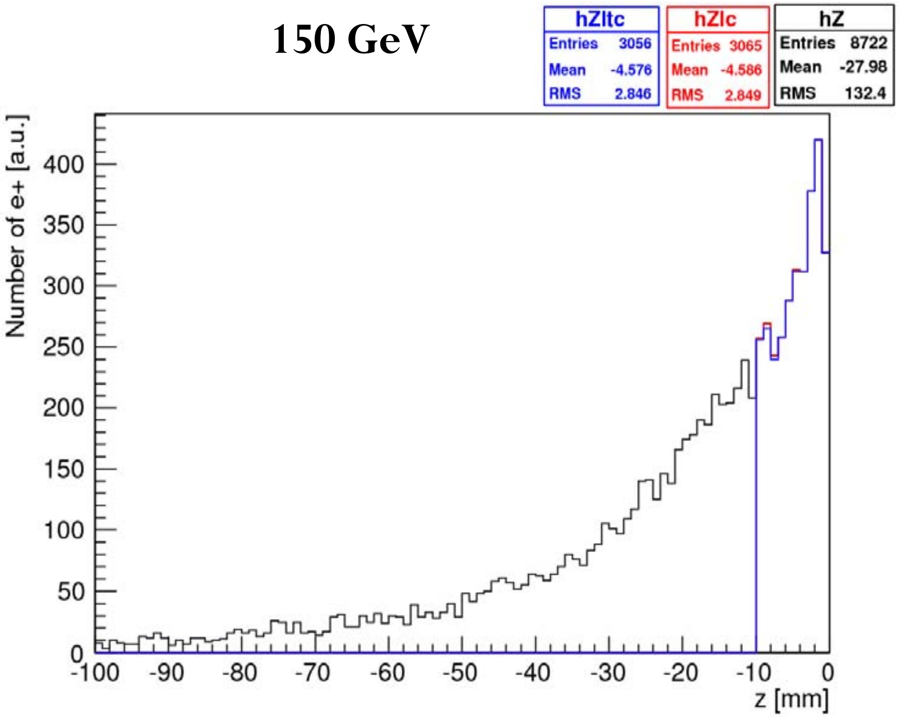
Energy



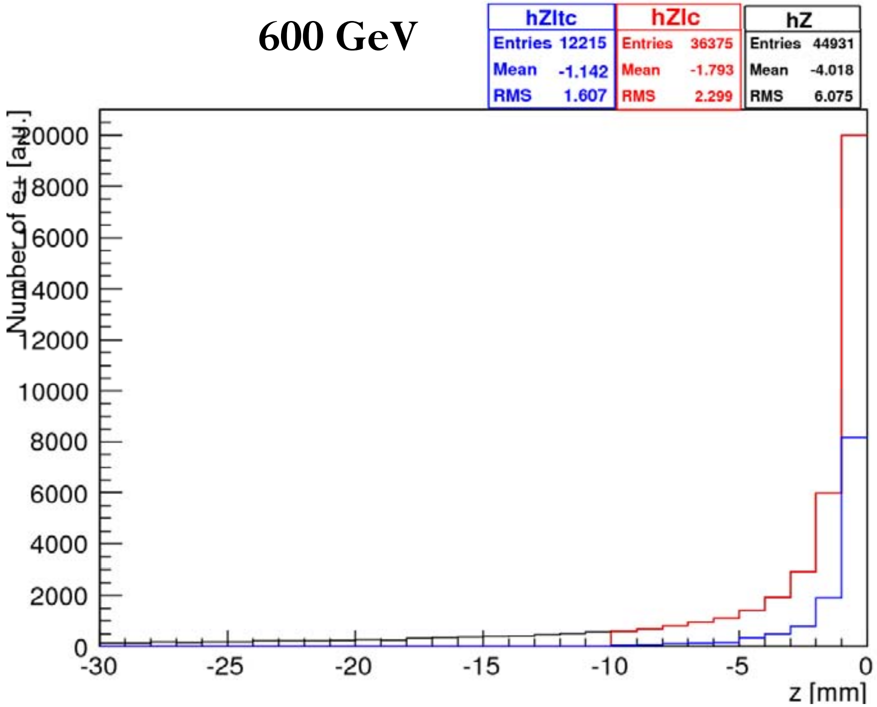


Longitudinal Distribution

150 GeV



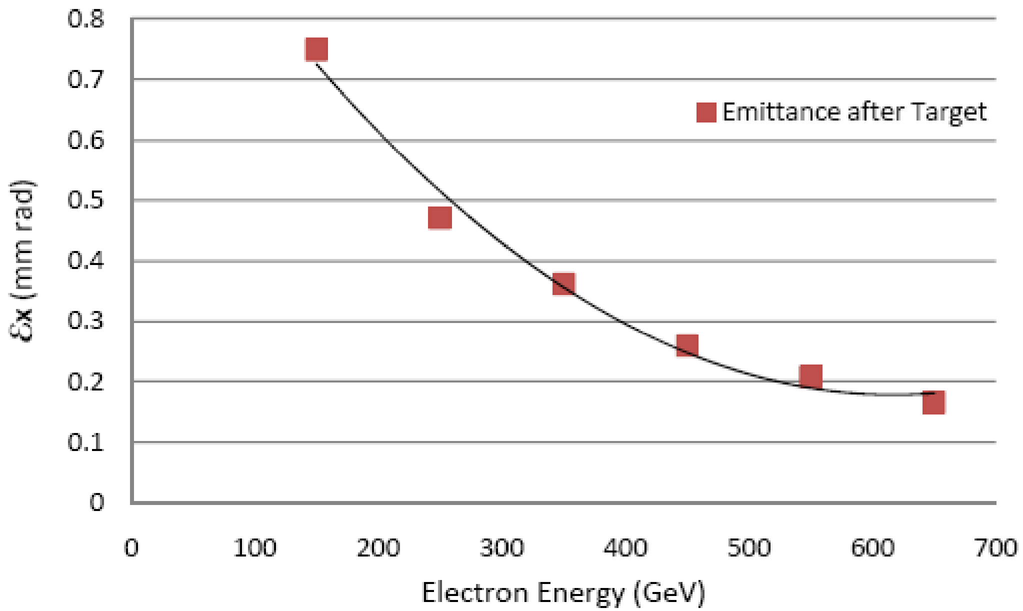
600 GeV



The positron bunch length from 150 GeV electron beam energy will be about 3-4 times longer than from 600 GeV electron beam energy. That is why the L cut is the limitation for the lower energy driving beam.

Emittance & Acceptance

- Positron after target: large angle and small lateral dimensions ---"small beta function"
- Capture RF acceptance: small angle and large lateral dimensions ---"large beta function"
- AMD is used as the matching device (other candidate like flux concentrator, QWT and Lithium lens are also available)
- Peak field of AMD is 6 T. Taper parameter is 0.03/mm. The magnetic field decreases to 0.5 T in 366.6mm linking to 0.5 T solenoid.



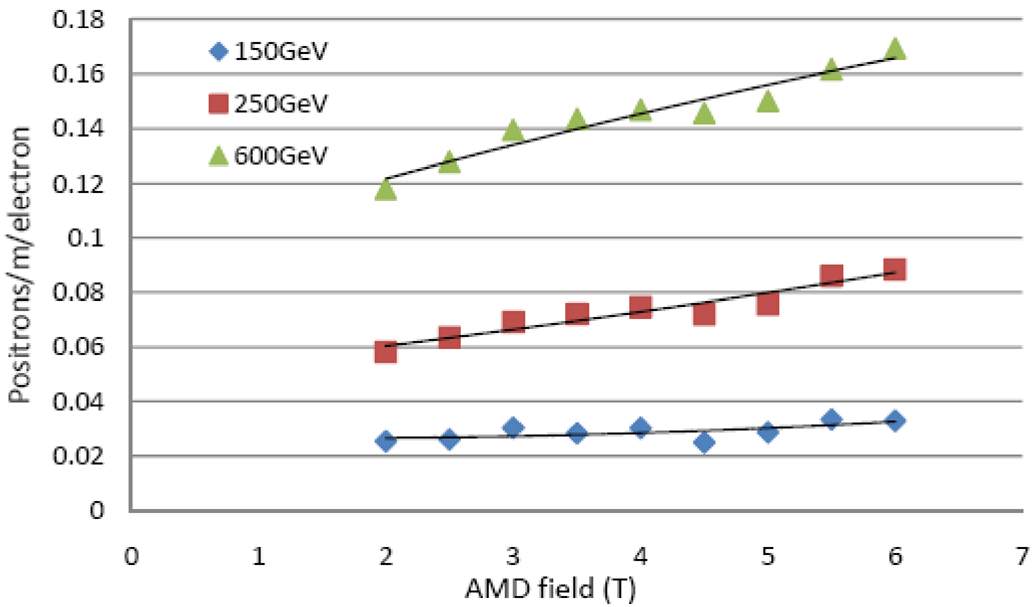
- B field in AMD varies with z as:

$$B_{AMD} = \frac{B_0}{1+gz}$$

  - B_0 is the initial field close to target
  - g is taper parameter (rate of reduction of magnetic field with distance from the target).
  - z is the longitudinal coordinate.

Captured Positrons

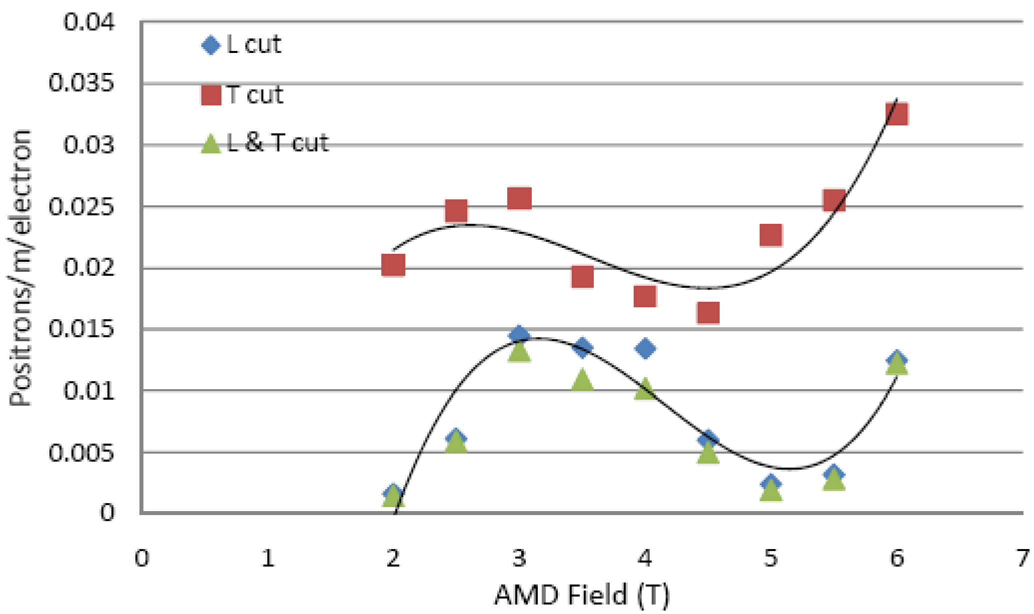
- The number of captured positrons without considering the damping ring acceptance will increase as a function of AMD peak field.
- The question is how many of captured positrons can be accepted by the damping ring and, ultimately, used for collisions at the IP.



Captured positrons per meter of undulator per electron as a function of AMD peak field for the electron beam energy of 150 GeV (green), 250 GeV (red) and 600 GeV (blue). The matching distance will vary as the peak field changes in order to link to the 0.5 T solenoid. The taper parameter is constant.

L and T cut for 150 GeV

- The figure shows the number of positrons per meter of undulator per electron in the L (blue) and T (red) damping ring acceptance as a function of peak AMD field.
- The green marker is the number of positrons in both L and T damping ring acceptance (i.e. positrons that can be accepted by the damping ring).
- For 150 GeV, the L cut is the limitation of the yield.

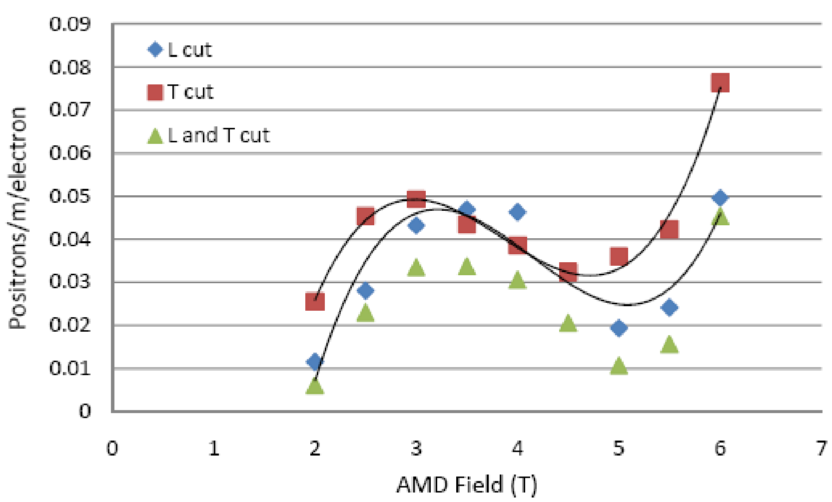


The oscillations occur because the optics are not being correctly re-matched as the peak field is varied.

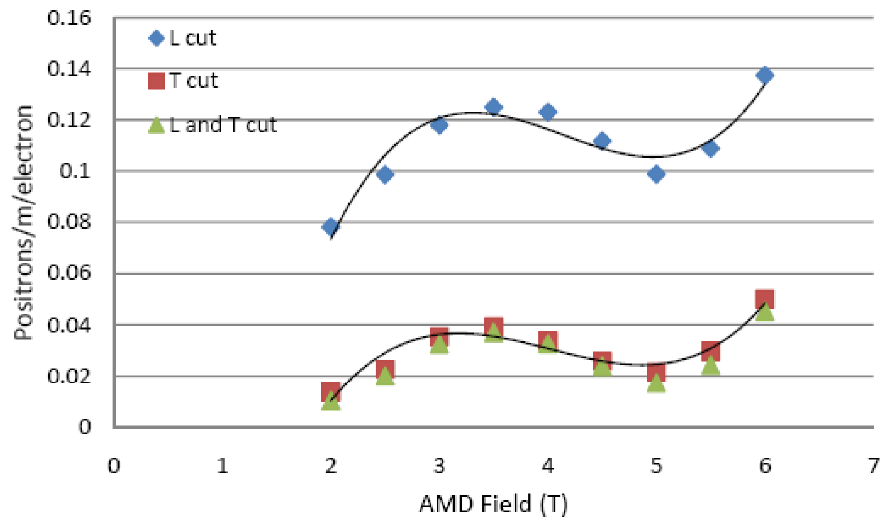
L and T cut for 250 GeV & 600 GeV

- For 250 GeV driving electron beam, the curve of L cut and T cut get close to each other. Most of the time, L cut is still the limitation of the yield but the boundary is not that clear as 150GeV.
- For 600 GeV driving electron beam, the curve shows the opposite behaviour compared with 150 GeV. The L cut is no longer the limitation of yield, instead, the T cut curve is much lower than the L cut curve, in which case, the positron yield is limited by the T cut.

250GeV



600GeV



Number of positrons per meter of undulator per electron as a function of AMD peak field. Red are the number of positrons left after applying the T cut, blue is after applying L cut and green is after applying L and T cut (we can consider it as positron yield). The matching distance varies as a function of peak field following the equation show in previous slide.

Summary and Future Work

- For ILC, 150 GeV and 250 GeV are two of the best choices of the driving electron beam. 250 GeV will produce higher positron yield but the high average photon energy will be one of the worries.

- Higher energy electron beam should give lower emittance positron beam. The damping ring acceptance is likely to limit overall yield, and is more important at 150 GeV electron energy than 350 GeV and 600 GeV.

- To understand the yield as a function of system parameters (e.g. AMD peak field), the optics must be carefully matched. Work is on-going to characterise the yield and optimise the various parameters.