Undulator Based Positron Source For CLIC

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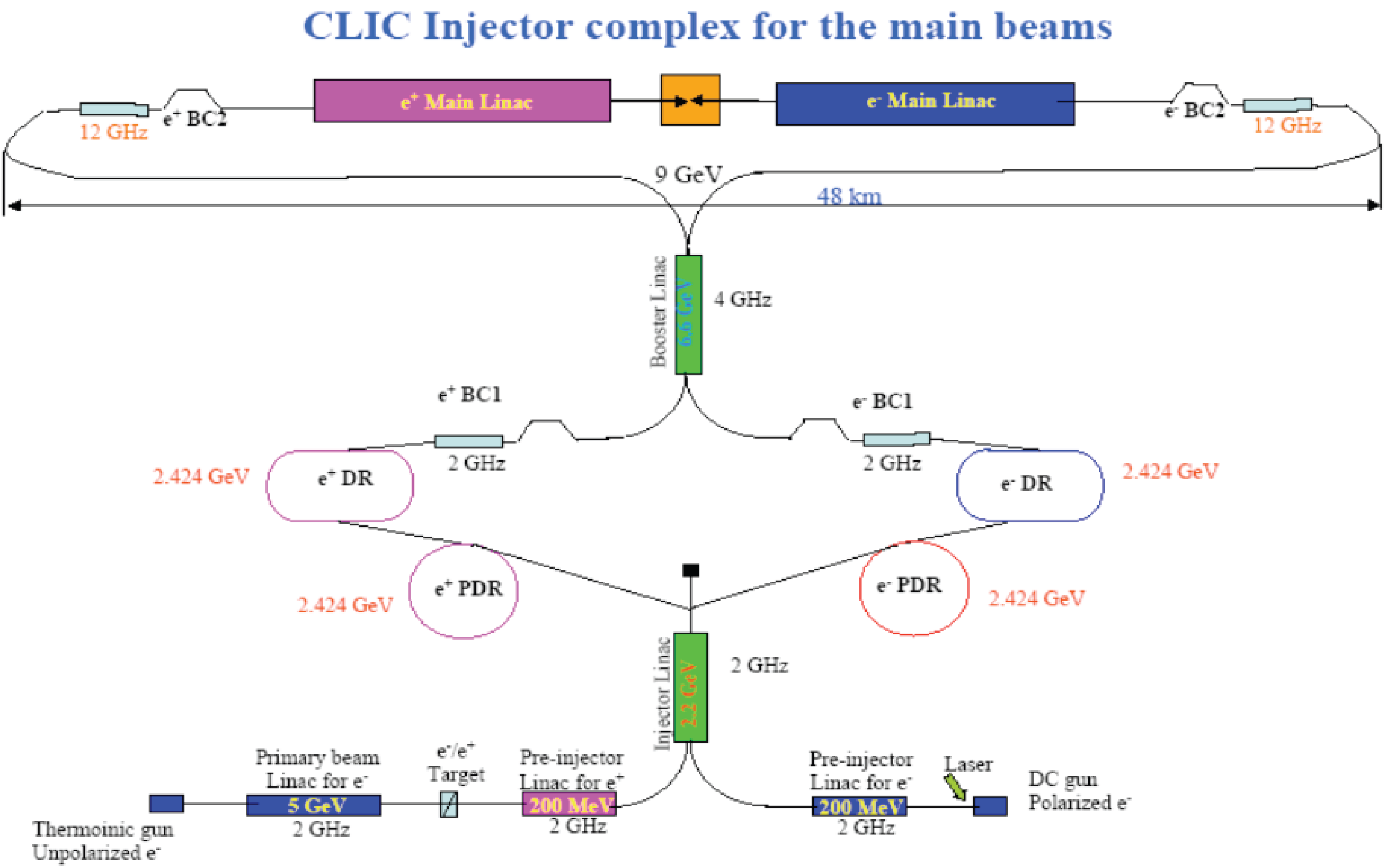
Outline

- **Introduction**
  - CLIC
  - Undulator based positron source

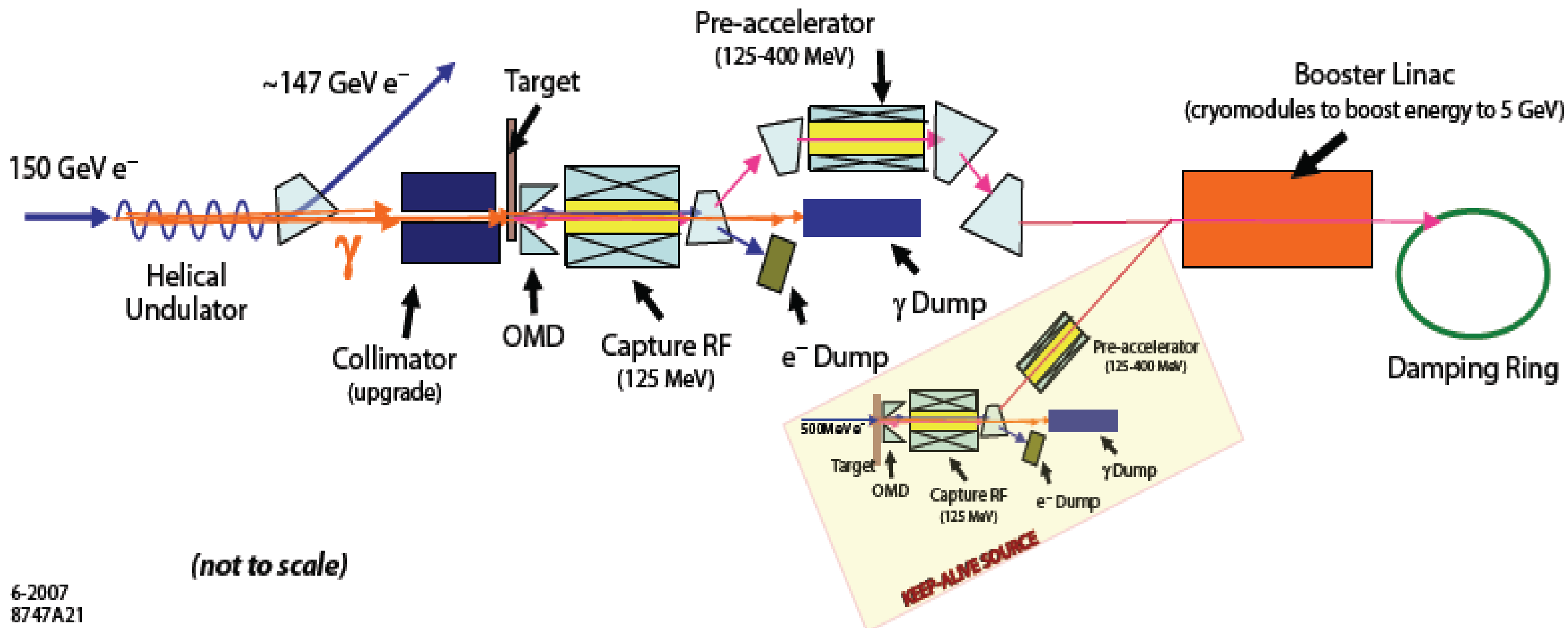
- **Impact of positron source design on production rate and polarisation:**
  - Undulator
  - Photon collimator
  - Target
  - Optical matching device

Compact Linear Collider (CLIC)

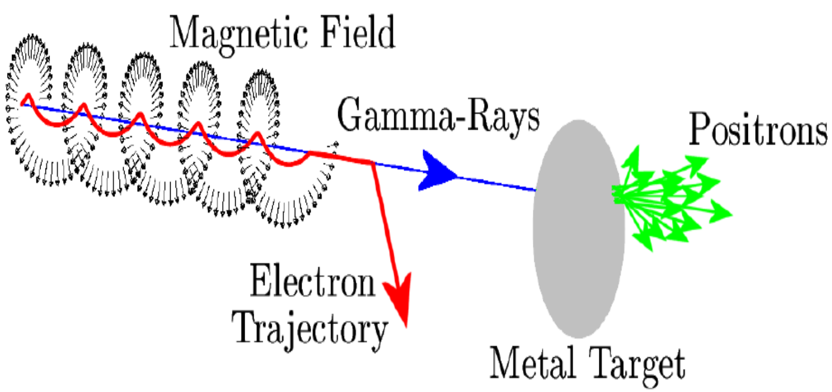


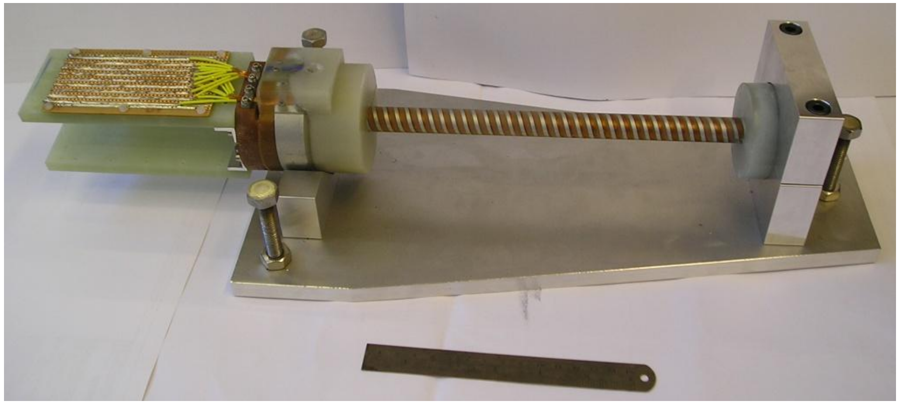
Potential Choices For CLIC Positron Source

- Conventional source
- Compton source
- Undulator Based Scheme

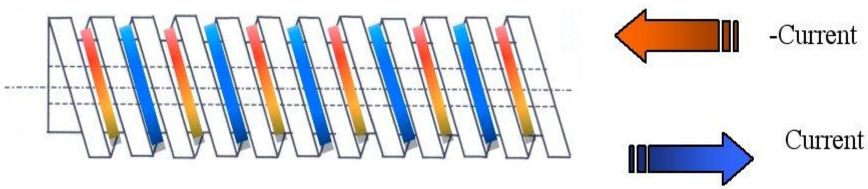


Helical Undulator

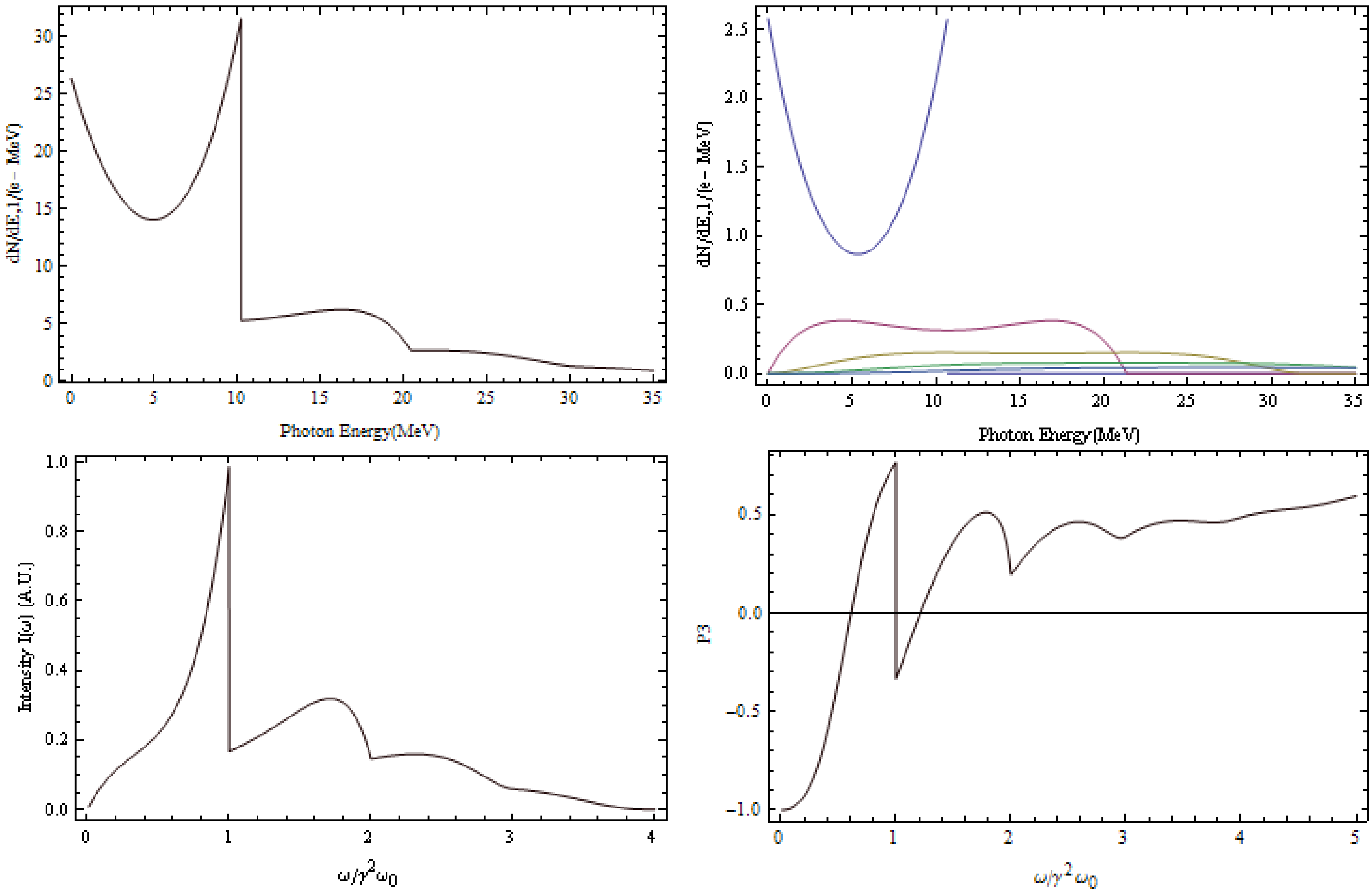




Undulator Parameters	Symbol	Value	Units
Undulator period	λ	1.15	cm
Undulator strength	K	0.92	
Undulator type		helical	
Active undulator length	L_u	147	m
Field on axis	B	0.86	T
Beam aperture		5.85	mm
Photon energy (1^{st} harmonic cutoff)	E_{c10}	10.06	MeV
Photon beam power	P_γ	131	kW



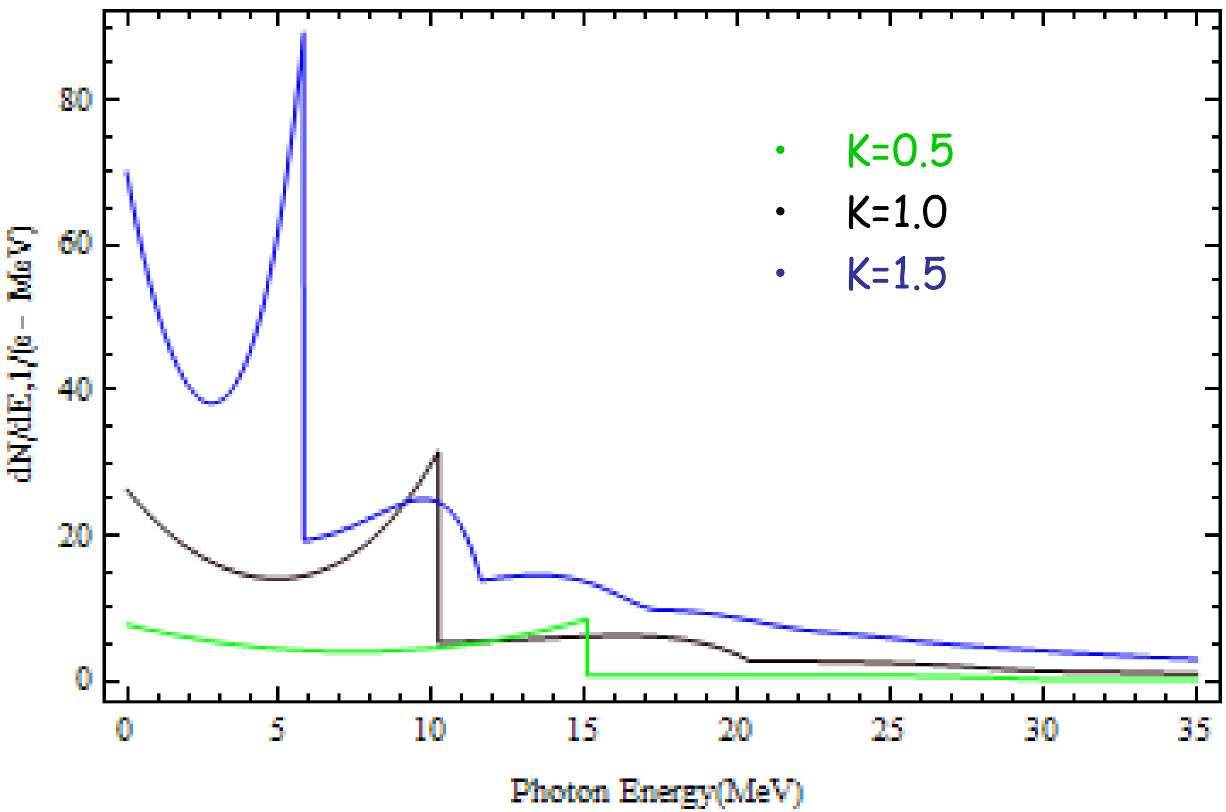
Helical Undulator



Undulator K Parameter

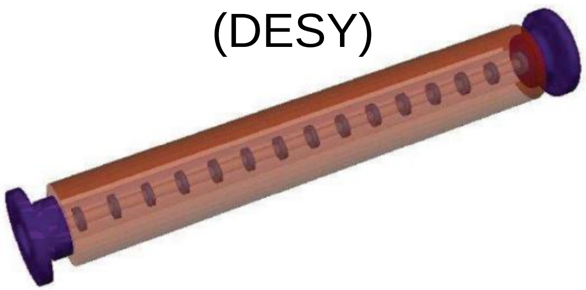
$$K = \frac{B_0 e}{m_0 c}\frac{\lambda_u}{2\pi} = 93.36 B_0[T]\lambda_u[m]$$

$\boldsymbol{B_0}$ is peak on-axis magnetic field,
$\boldsymbol{m_e}$ is electron mass,
$\boldsymbol{e}$ is electron charge,
$\boldsymbol{c}$ is speed of light.



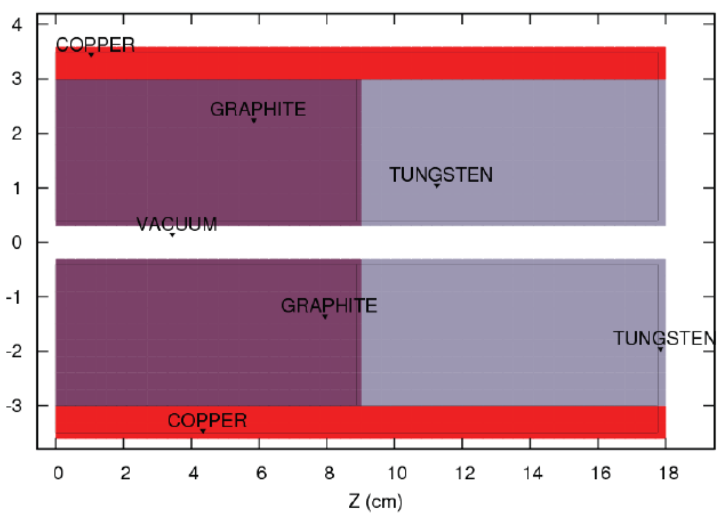
Photon Collimator

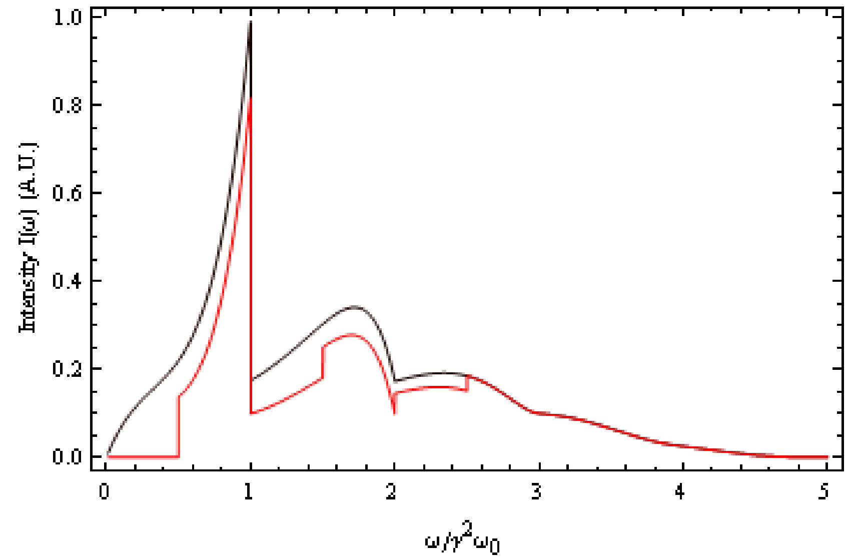
Model 1
(DESY)

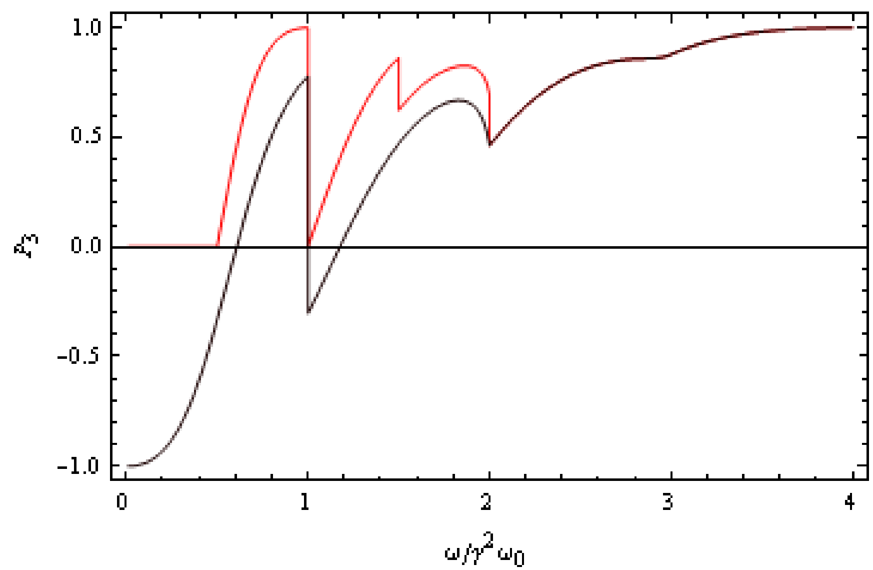


- Ti-spoilers, Cu-absorber
- Length is 90 cm, outer radius is 6 cm

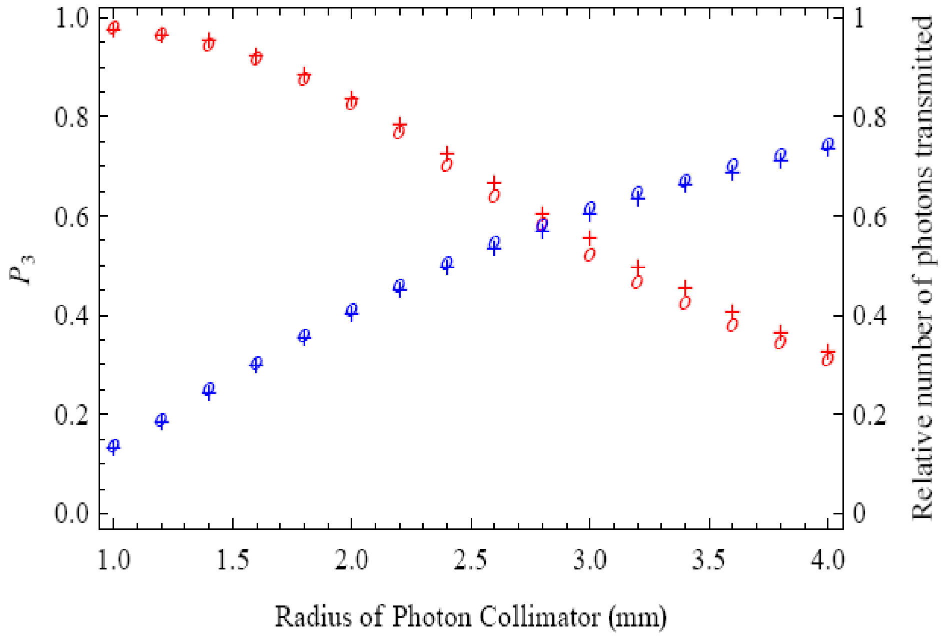
Model 2 (Cornell)







Collimation Effect



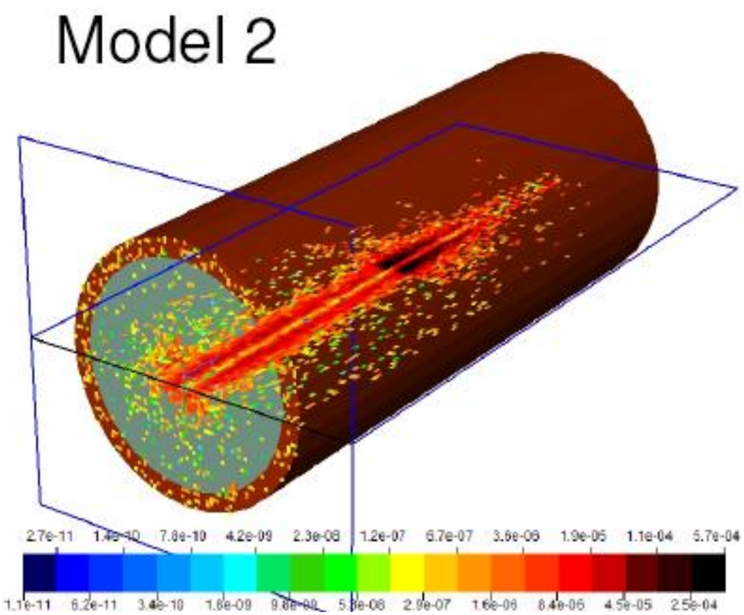
Polarisation (red) and number of **photons transmitted (blue)** as a function of collimator aperture (Model 1).

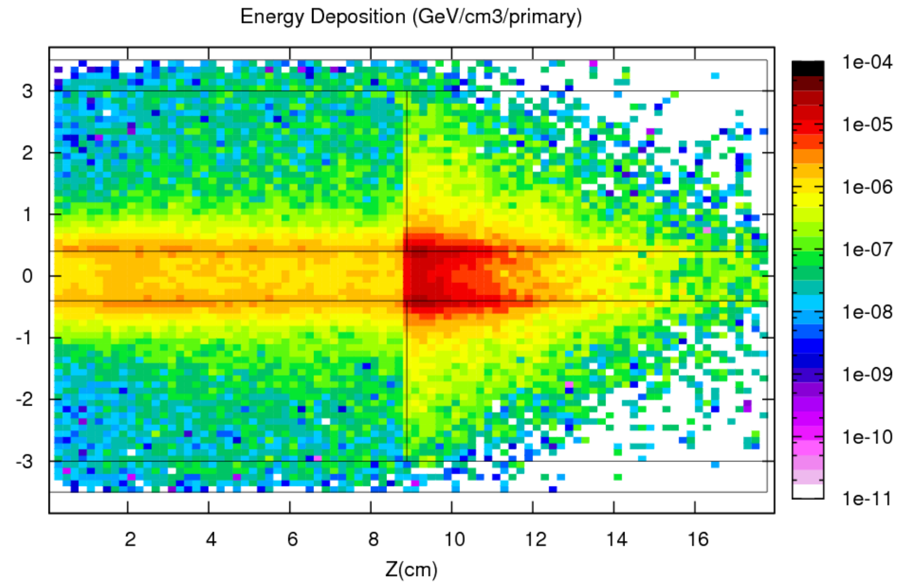
The number of photons transmitted is normalised to the uncollimated beam.

Analytical results (circles) are compared with **Fluka simulation** (crosses).

	Model 1		Model 2	
Inner Radius [mm]	Photons transmitted	Polarisation	Photons transmitted	Polarisation
2	41.50%	84.37%	41.20%	83.62%
3	60.80%	56.22%	61.10%	55.48%
4	74.10%	33.49%	74.10%	33.70%

Photon Collimator

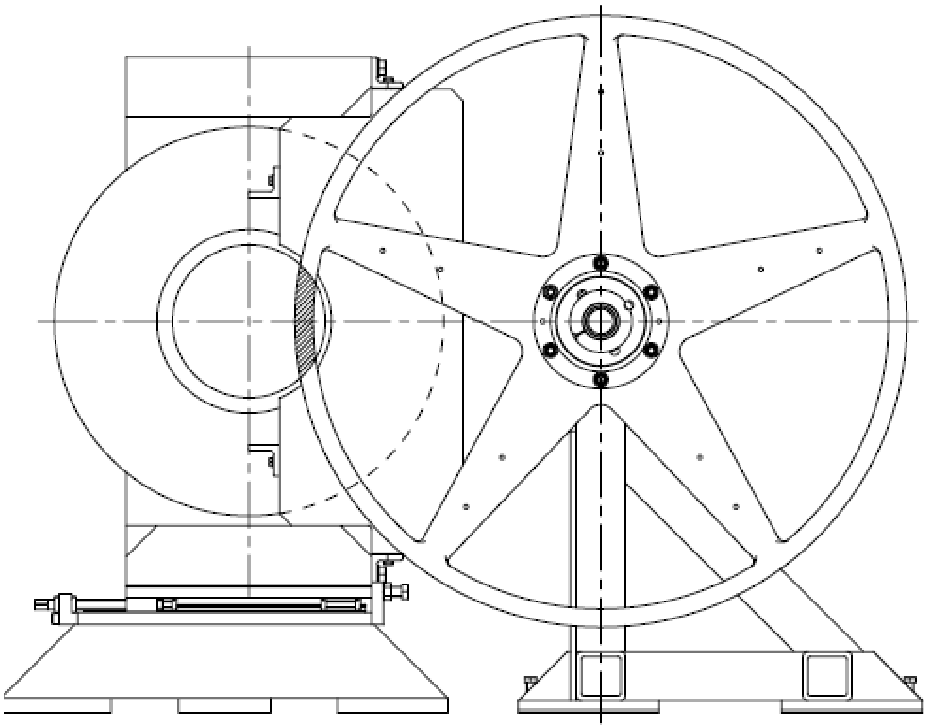


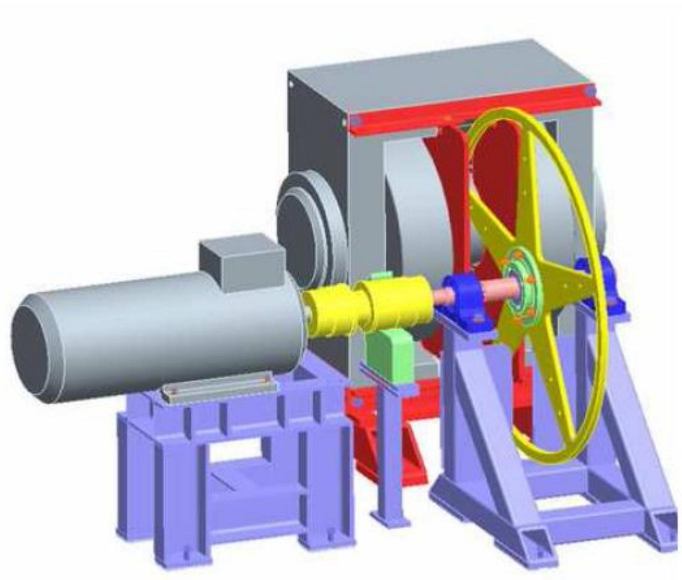


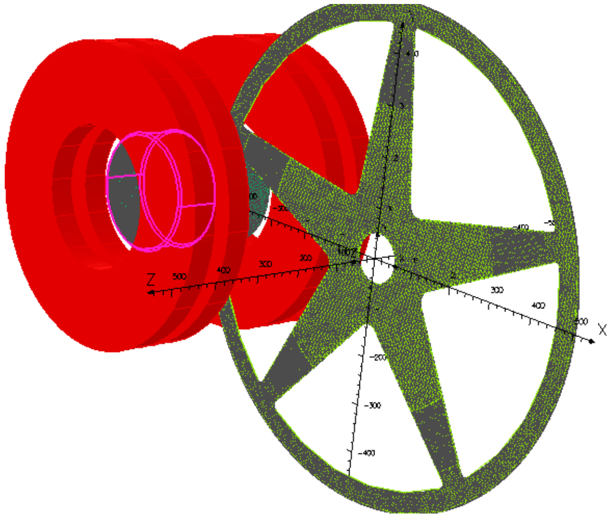
			Model 1		Model 2		
			Deposited Energy [MeV/pr]				
R_{col} [mm]	Trans. [%]	Pol. [%]	Ti	Cu	C	W	Cu
2	41	84	4.17 (34.7 %)		4.95 (41.1 %)		
			1.87	2.30	1.03	3.88	0.04
3	61	56	1.63 (13.6 %)		1.87 (15.6 %)		
			0.78	0.85	0.48	1.37	0.02
4	74	33	0.61 (5.1 %)		0.68 (5.7 %)		
			0.31	0.30	0.21	0.45	0.01

*There is less than 1% difference in the photon transport & polarisation between the two designs.

Target

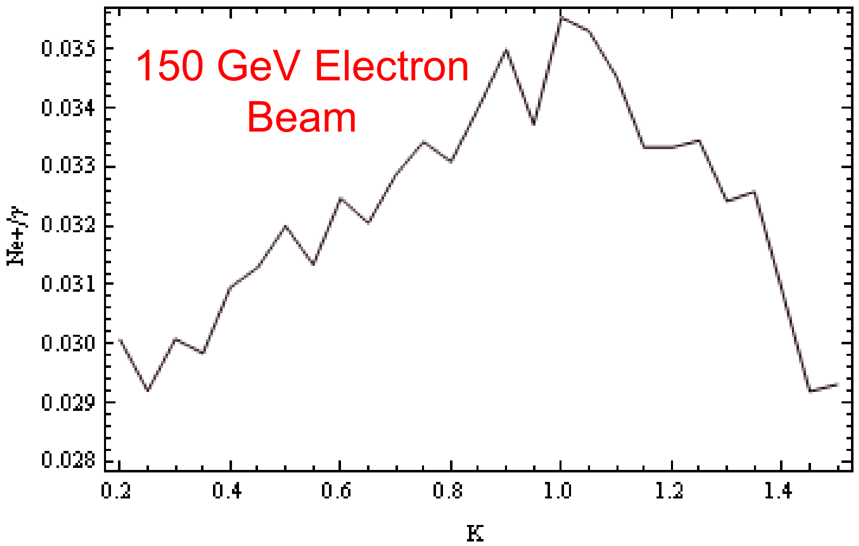


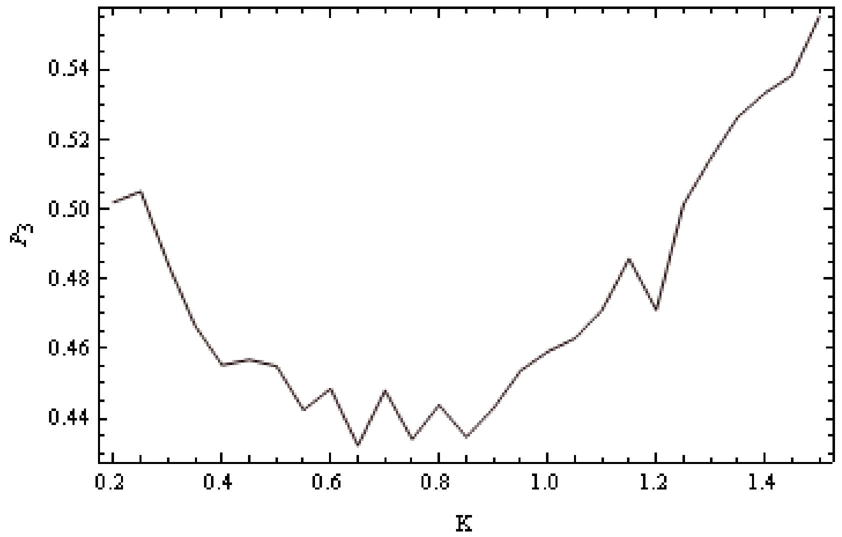


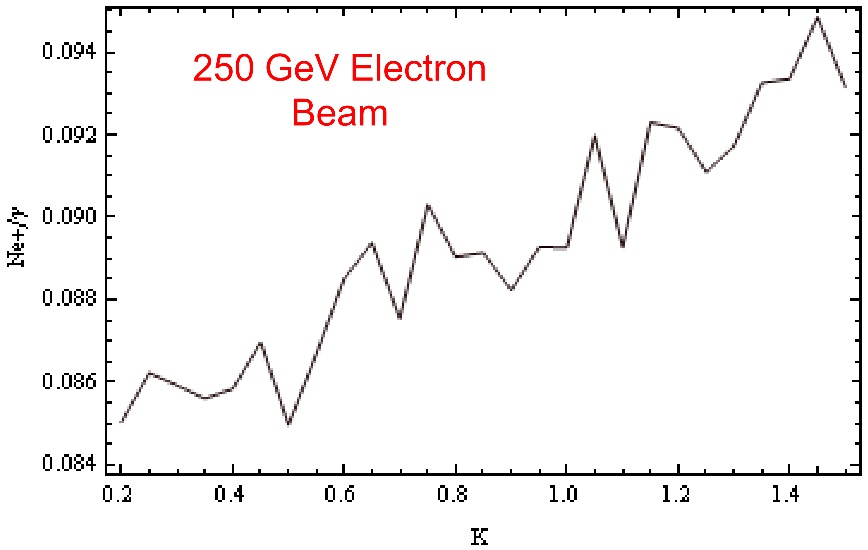


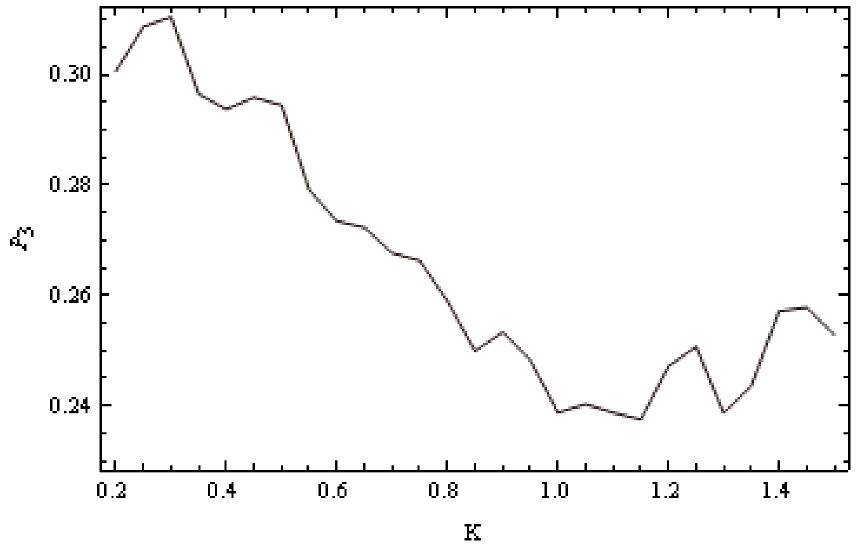
Target prototype operated by Liverpool and Lancaster staff at Daresbury Laboratory.

Positron Production Simulations



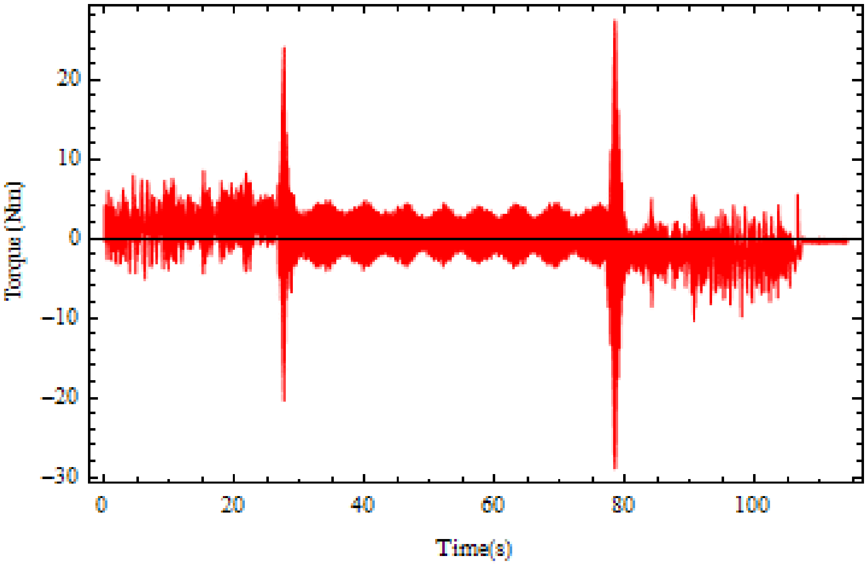


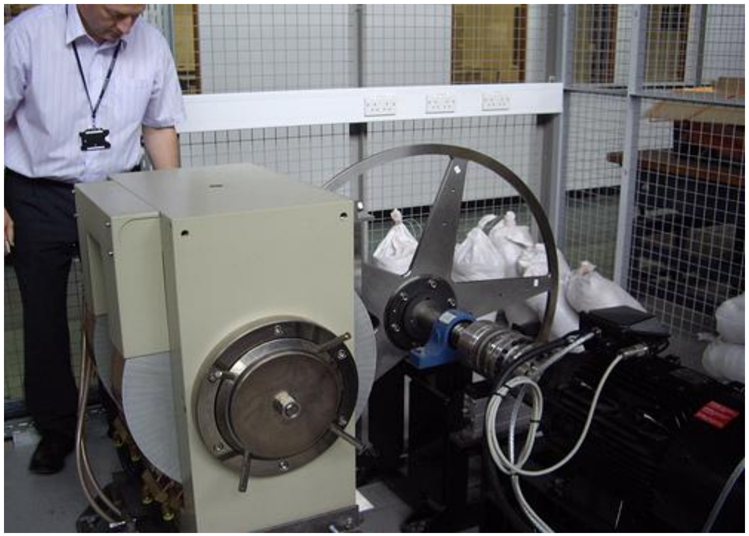




Target Prototype Experiment

The motivation for the prototype is to understand the mechanical and thermal issues with the target wheel.





- Wheel diameter ~1m.
- Material: titanium alloy (90% Ti, 6% Al, 4% V)
- Immersed in a magnetic field up to 1 Tesla
- Rotating speed up to 2000 rpm

Optical Matching Device

- OMD can improve capture efficiency, reducing the number of photons required
  - Shorter undulator
  - Lower heat load in target
  - Smaller dump
  - Less radiation

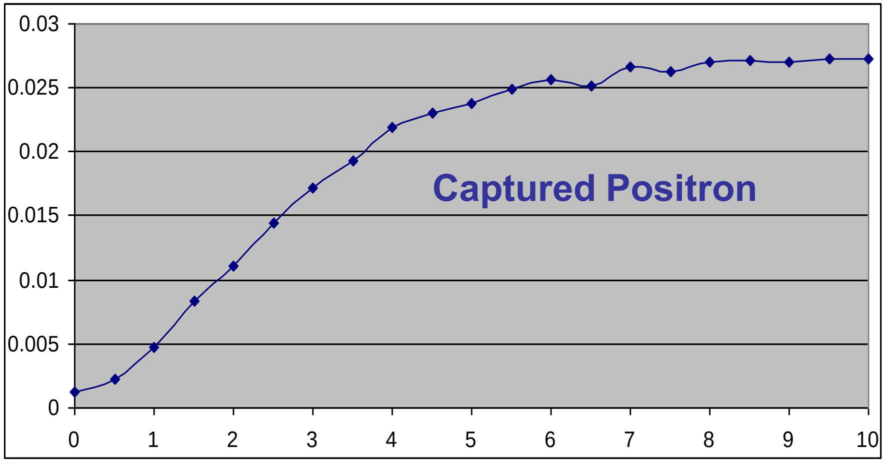
- B field in OMD

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

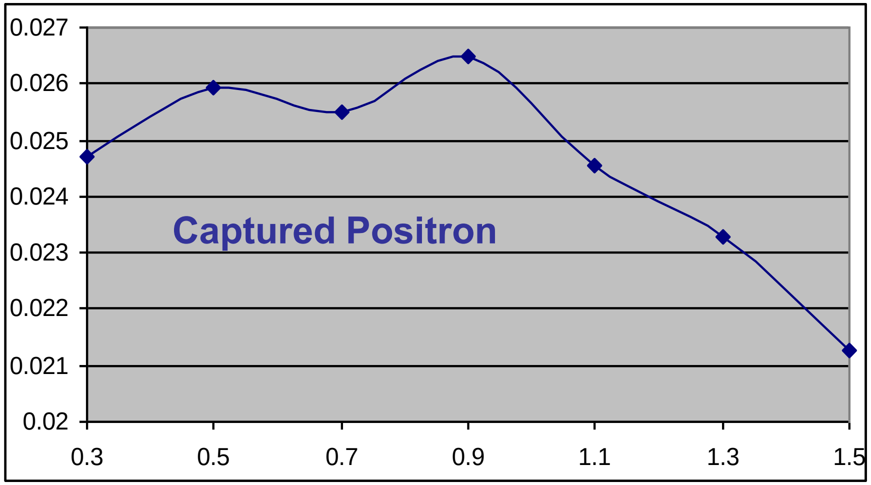
  - $\boldsymbol{B_0}$ is the initial field close to target
  - $\boldsymbol{g}$ is taper parameter (rate of reduction of magnetic field with distance from the target).
  - $\boldsymbol{z}$ is the longitudinal coordinate.

Optical Matching Device

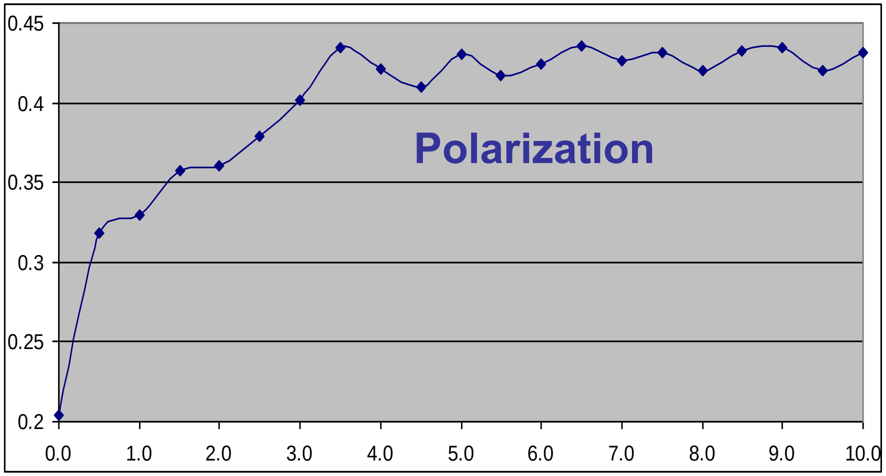
- 5-6T looks like a reasonable value for the initial field close to target.
- Here we calculate the positrons transmitted to the end of solenoid per photon on the target.
- Damping Ring acceptance needs to be considered.



OMD Field (Tesla)



K



OMD Field (Tesla)

Summary and outlook

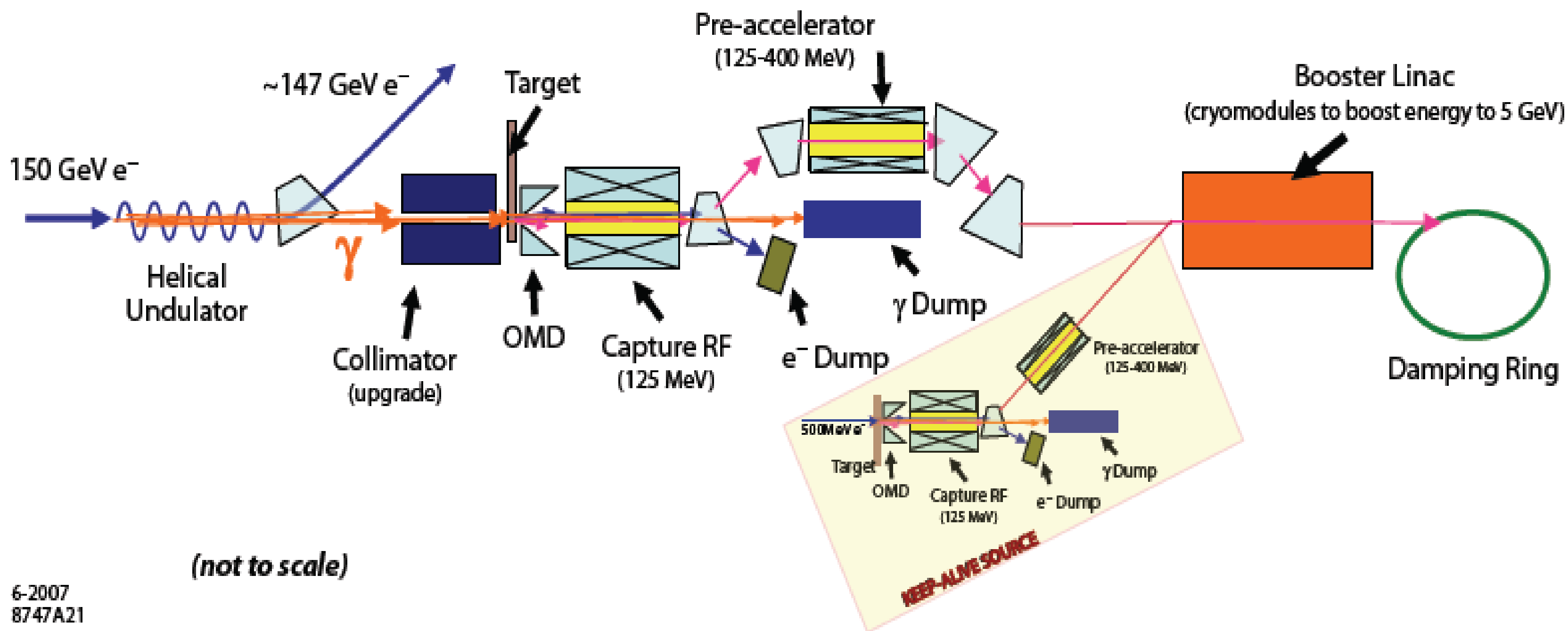
- Undulator:
  - Undulator photon spectrum and polarization have been understood, and successfully implemented in FLUKA, GEANT4 and Mathematica.

- Photon collimator:
  - Polarization and photon intensity can be adjusted by collimating the photon beam after the target.
  - Two designs for a photon collimator have been compared. Both designs have a similar effect, but the Cornell collimator design is more compact.
  - Studies of activation and heat deposition have been done. The Cornell collimator design may work well even without water cooling system.

Summary and outlook

- Target:
  - Simulations to optimise the design are in progress.
  - A prototype has been fully installed in Daresbury lab. Experiments are continuing, to study mechanical resonances, and thermal issues associated with eddy currents.

- Optical matching device:
  - 5-6T field strength is sufficient for positron capture.
  - Effect on polarization is small.
  - Effects of initial field, gradient, and matching distance need more detail studies.
  - Damping ring acceptance needs to be taken into account.



- All in all, the goal of studying undulator based positron source scheme is to understand how the parameters can be optimised for a range of operating scenarios in CLIC. Identify the strengths and weaknesses of the undulator scheme, then consider such a source as an alternative to the present baseline concept of CLIC.

The End

Thank you !