EUROTeV Photon Conversion Target Project

Ian Bailey

University of Liverpool /

Cockcroft Institute UK

EUROTeV: WP4 (polarised positron source) PTCD task

I. Bailey, J. Dainton (Cockcroft Institute / University of Liverpool)

D. Scott (CCLRC Daresbury Laboratory / Cockcroft Institute / University of Liverpool)

P. Cooke, P. Sutcliffe (University of Liverpool)

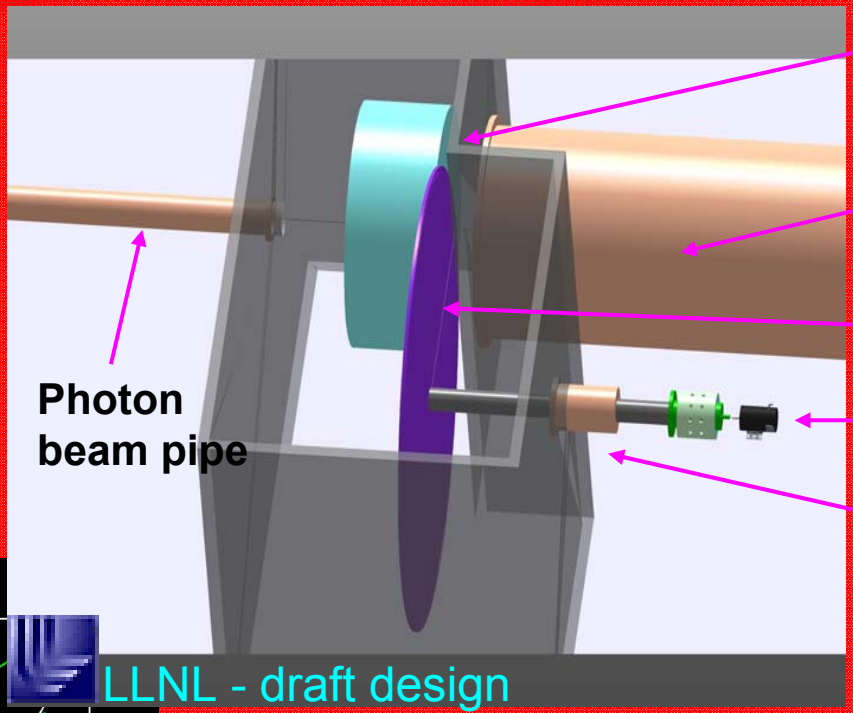
In collaboration with

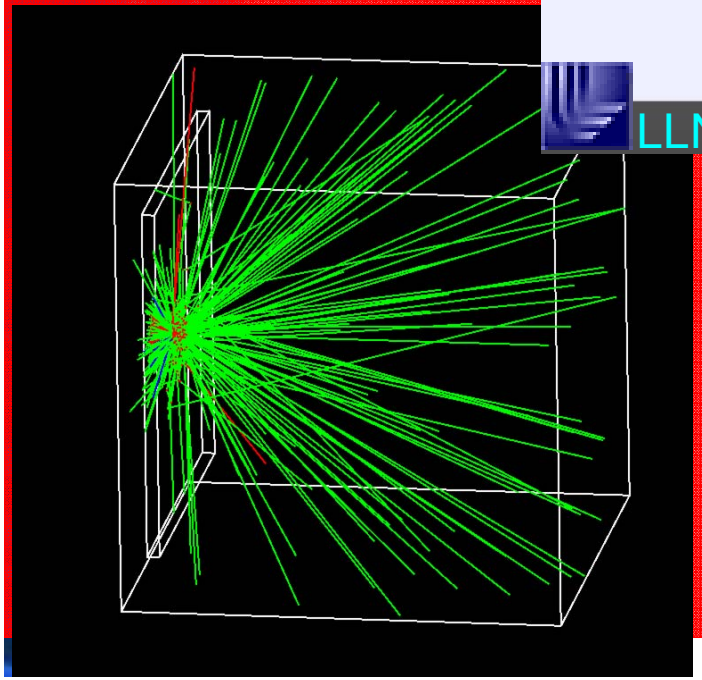
Jeff Gronberg, Werner Stein (LLNL)

Vinod Bharadwaj, John Sheppard (SLAC)

Project Overview

The University of Liverpool heads a EUROTeV-funded task to carry out design studies of the conversion target and photon collimator for the polarised positron source.





- Working in collaboration with SLAC and LLNL.
- Developing water-cooled rotating wheel design.
- 0.4 radiation length titanium alloy rim.
- Radius approximately 1 m.
- Rotates at approximately 1000 rpm.

Relevance to Compton Source?

- EUROTeV PTCD R&D primarily intended to develop target for undulator-based source.
- Requirements for Compton source target are generally less demanding(?) Difference in photon energies(?)
- We should avoid needless duplication of target R&D work between undulator and Compton 'communities'.

- Outline of talk
  - Specify operating conditions for which target design has been developed.
  - Give overview of current design.
  - Summarise future plans.

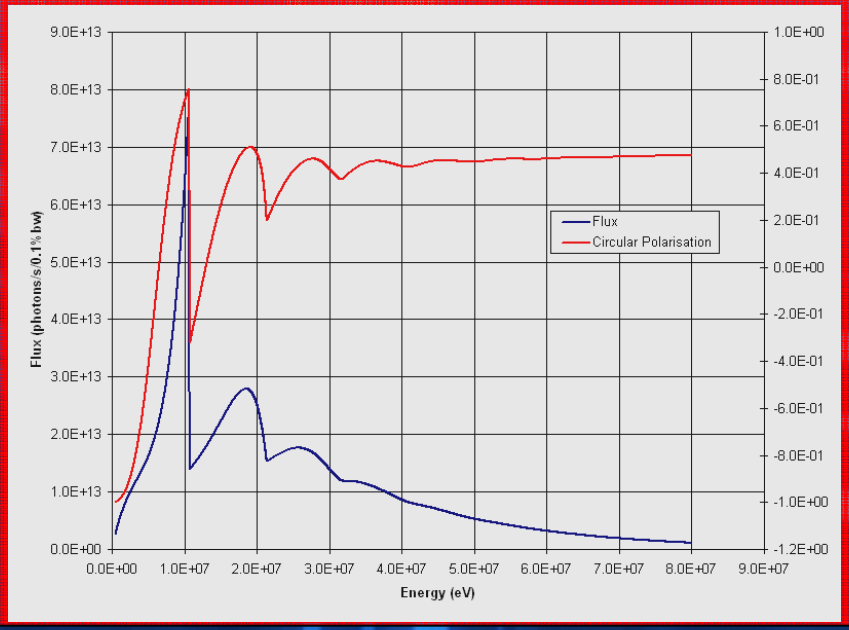
Undulator Photon Beam (BCD)

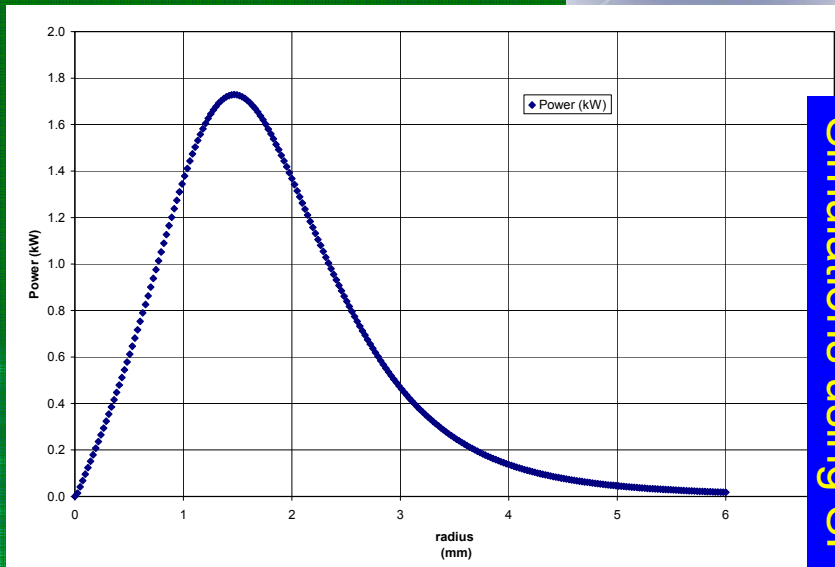
- Assume K=1, 1cm period, 100m long undulator.
- Assume nominal ILC e^- bunch structure.
- Neglect collimation.
- Target 450m downstream of undulator.

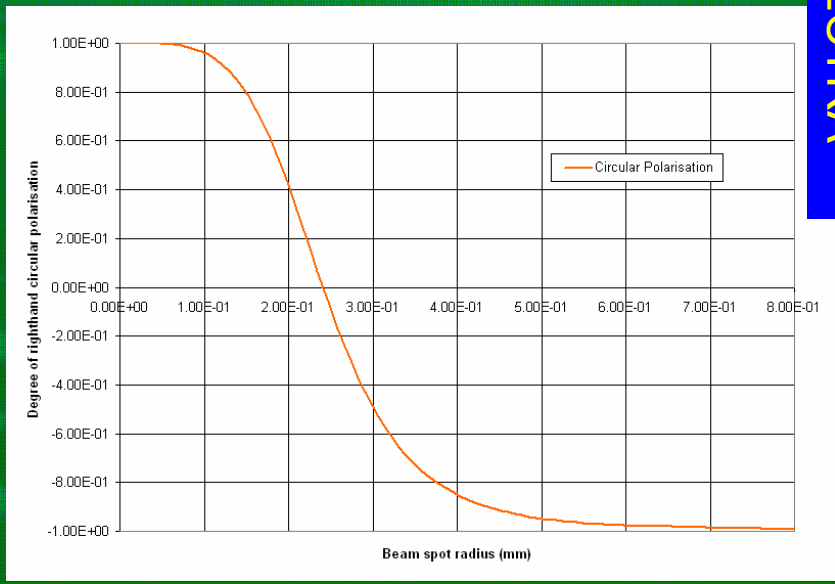
Total photon beam power: 145 kW

Average photon energy: 13MeV

Beam spot rms ≈1.5 mm (0.75mm in BCD)







Simulations using SPECTRA

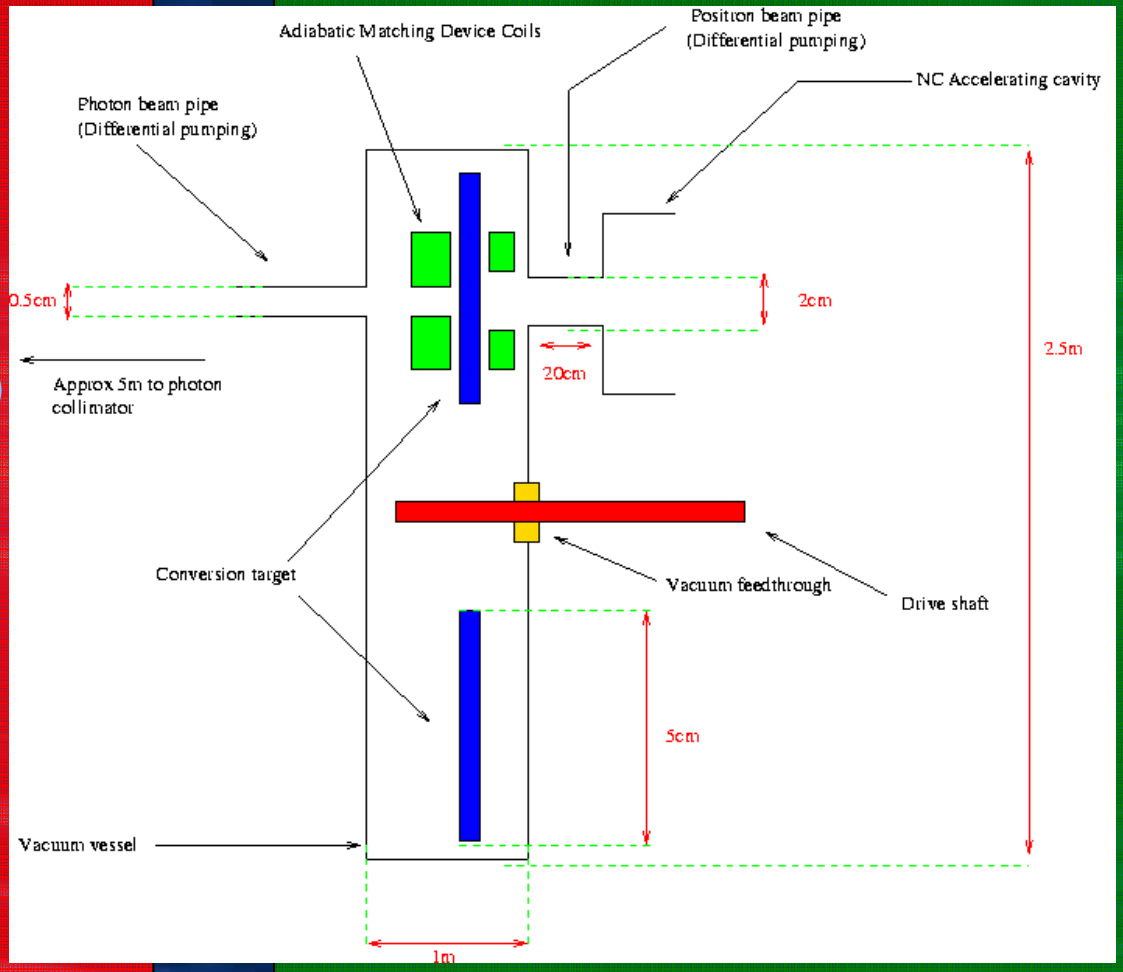
Undulator Photon Beam (2)

	Minimum ILC parameters	Nominal	Maximum ILC parameters	
Pulse frequency	5	5	5	Hz
Pulse train length	0.2	1	2.6	ms
Bunch length	0.5	1	1.7	ps
Bunches / pulse	1330	2820	5640	
Bunch spacing	154	308	461	ns
Energy (*)	10.6	21.2	21.2	J/bunch
Number of photons (*)	6.6	13.4	13.4	10^{12} photons/bunch
First harmonic photon energy	10	10	10	MeV
Number of polarised positrons required from source (no losses)	0.7	2.8	5.6	10^{14} positrons/s
Photon Beam power w/o coll. (*)	70	300	600	kW
Length of undulator (*)	200	200	200	m

* $\Rightarrow$ "Proportional to undulator length"

Target Systems

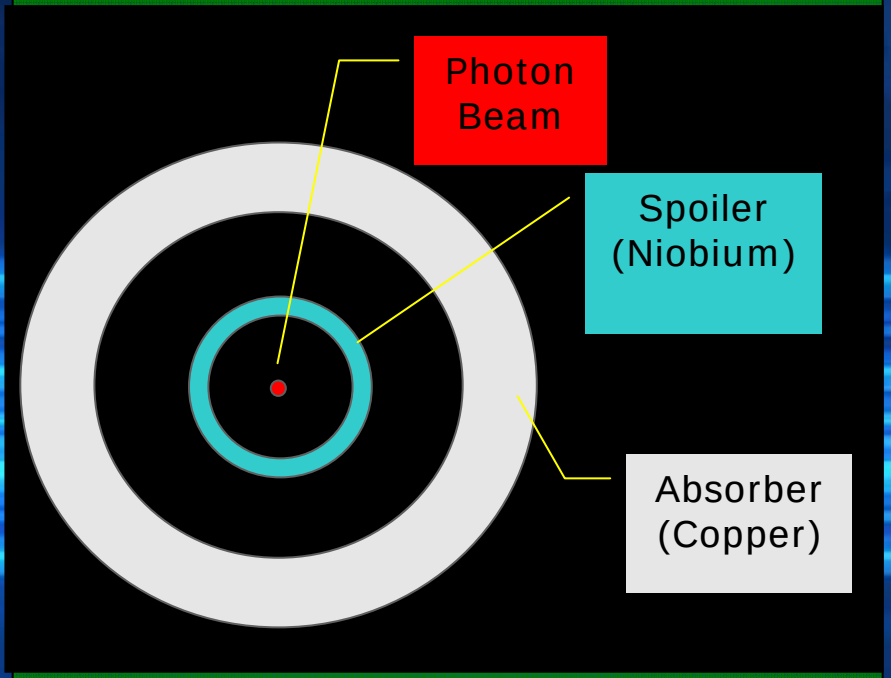
- Approx 400 m downstream of undulator
- Key sub systems
  - Target wheel
  - Drive system
  - Cooling system
  - Vacuum system (10^{-8}Torr)
  - Remote-handling system
  - Diagnostic and control systems
- Target support systems
  - Photon collimator
  - Photon beam dump
  - Capture optics
  - NC rf cavity



Not to scale! For illustration only.

Photon Collimator

- Scrape photon beam
- At high photon energies
  - Scattering angles in spoiler become large
    - No need for B field
  - Need to cool absorber
  - Need to cool spoiler?
- Cylindrical geometry
- Aperture not adjustable
  - Interchangeable collimators needed
- A. Mikhailichenko (Cornell) has alternative pyrolytic graphite and tungsten design.

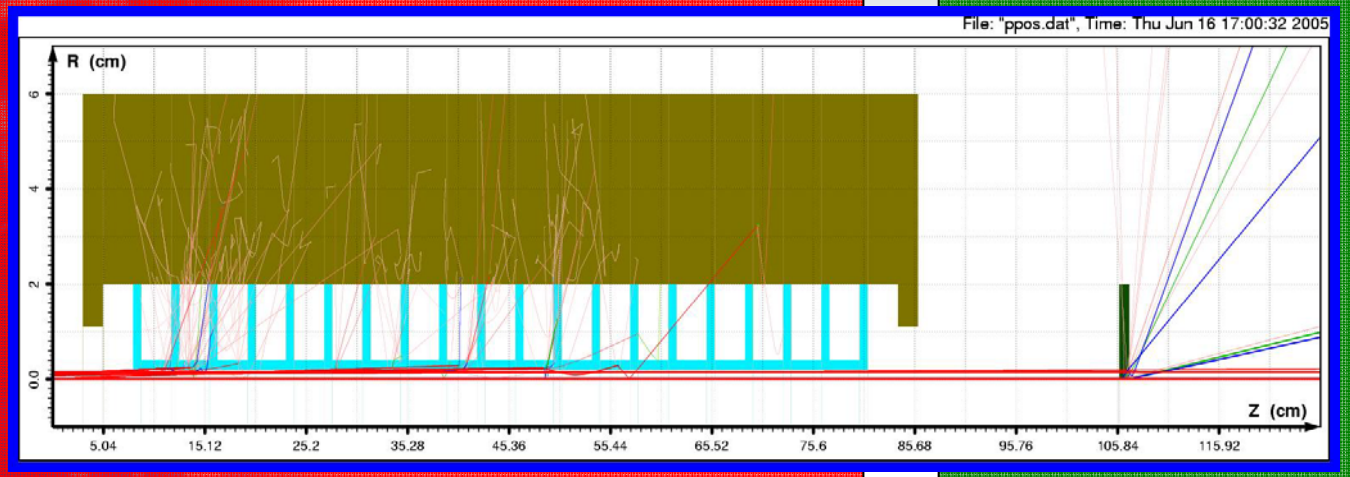


(N. Golubeva, V. Balandin - DESY)

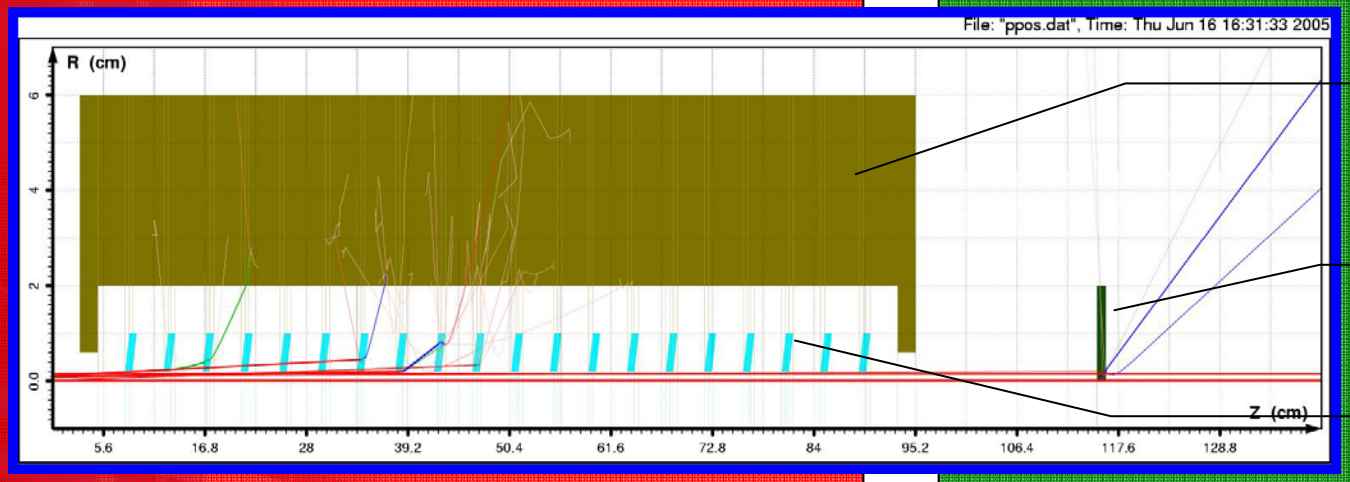
Photon Collimator Simulations

EGS4 Simulations

(sideview of collimator)



- Photons
- Electrons
- Positrons



Absorber

Target

Spoiler

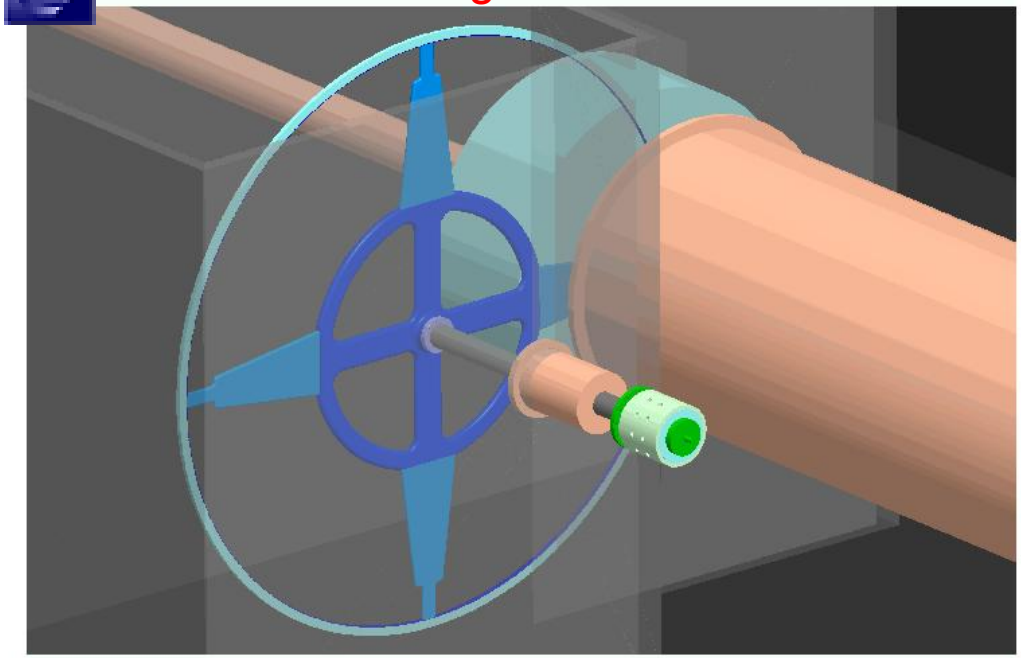
N. Golubeva, V. Balandin - DESY

Target Wheel Design

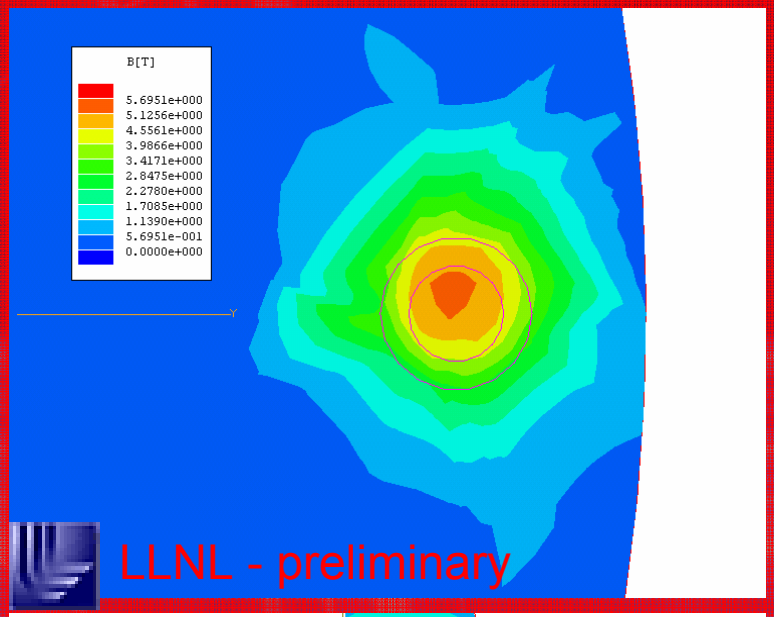
Target wheel diameter	2	m
Target thickness	1.4	cm
Wheel RPM	1000	rpm
Wheel perimeter velocity	100	m/s
Stress in wheel due to rotation	$3x10^7$ (4)	Pa (ksi)
Maximum Ti temperature increase	411	K
Peak stress due to beam energy deposition	$4x10^8$ (58)	Pa (ksi)
Expected lifetime of target wheel at ILC	2	years

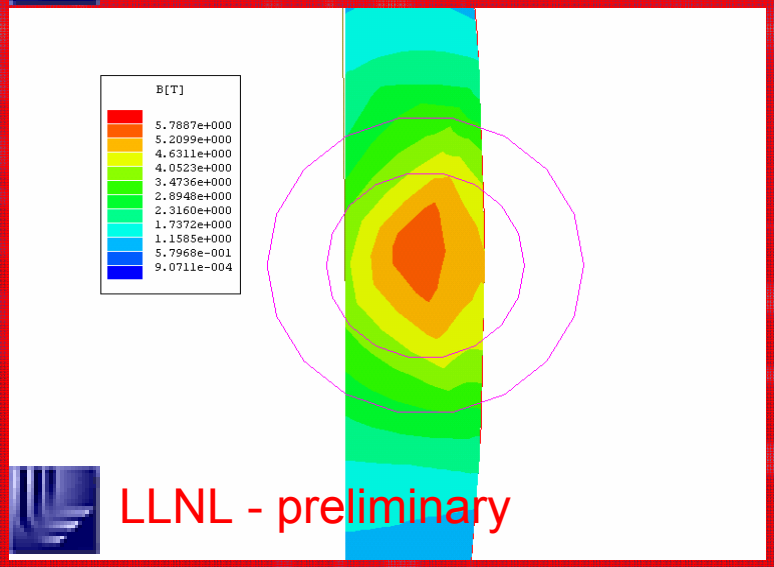
Numbers refer to LLNL study of earlier solid-disc design.

LLNL - draft design



Eddy Current Simulations





Initial “Maxwell 3D” simulations by W. Stein and D. Mayhall at LLNL indicate:

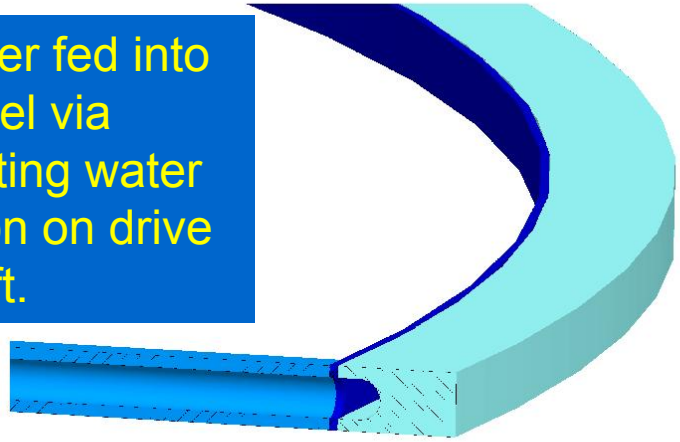
- ~2MW eddy current power loss for 1m radius solid Ti disc in 6T field of AMD.
- <20kW power loss for current 1m radius Ti rim design.
- Simulations yet to be calibrated to SLAC rotating disc experiment.

Power Deposition & Cooling

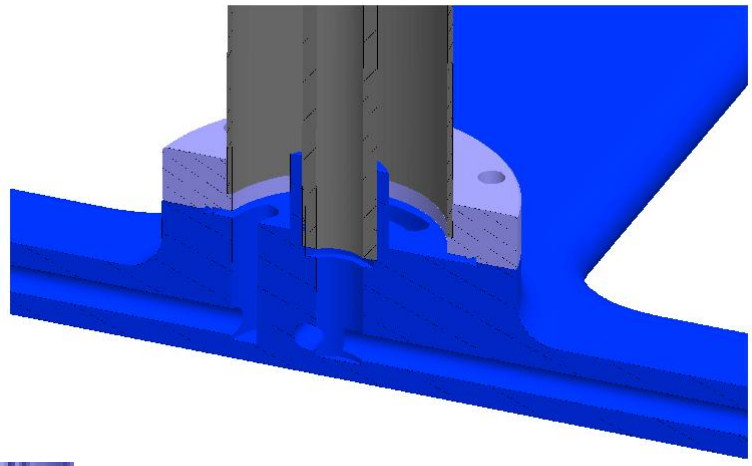
Approximately 10% of photon beam power is deposited in target wheel (≈30kW)

Degrees target rotates between bunches	1.85E-03
Degrees target rotates over pulse duration	5.21E+00
Degrees target rotates between pulses	1.19E+03
Phase advance between start of consecutive pulses (degrees)	1.20E+02
Number of overlapping consecutive bunches (95% energy containment)	9.59E+01
Total energy deposition of overlapping bunches (J)	1.02E+02
Total duration of overlapping bunches (s)	2.95E-05
Total volume of target struck by beam over bunch duration (m^3)	9.90E-08
Bunch energy deposition (J/g)	2.39E+00
Total volume of target struck by beam over pulse duration (m^3)	3.80E-06
Pulse energy deposition (J/g)	1.75E+02
Bunch (peak) deposited power density (W/l)	1.08E+16

Water fed into wheel via rotating water union on drive shaft.



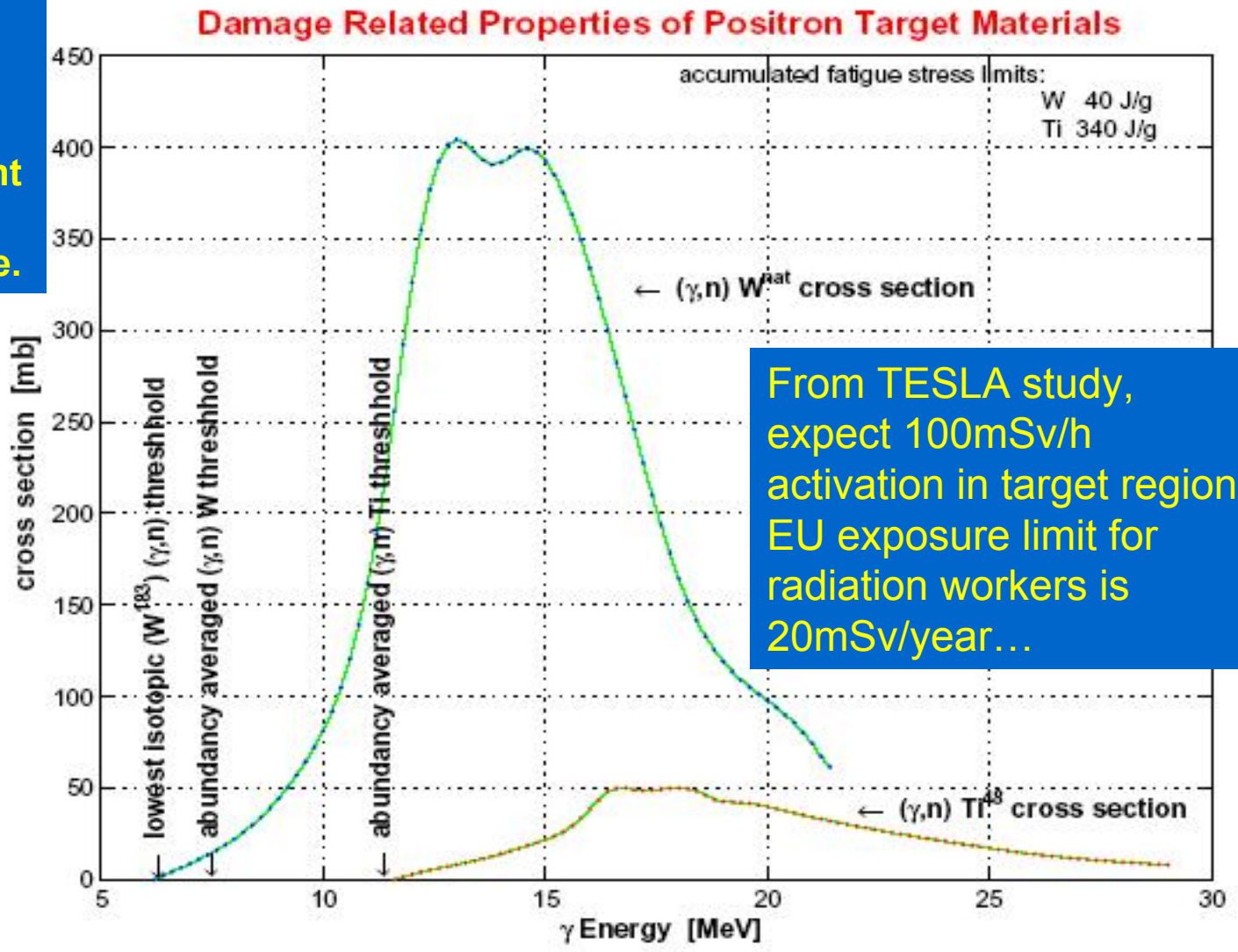
LLNL - draft design



LLNL - draft design

Neutron Production

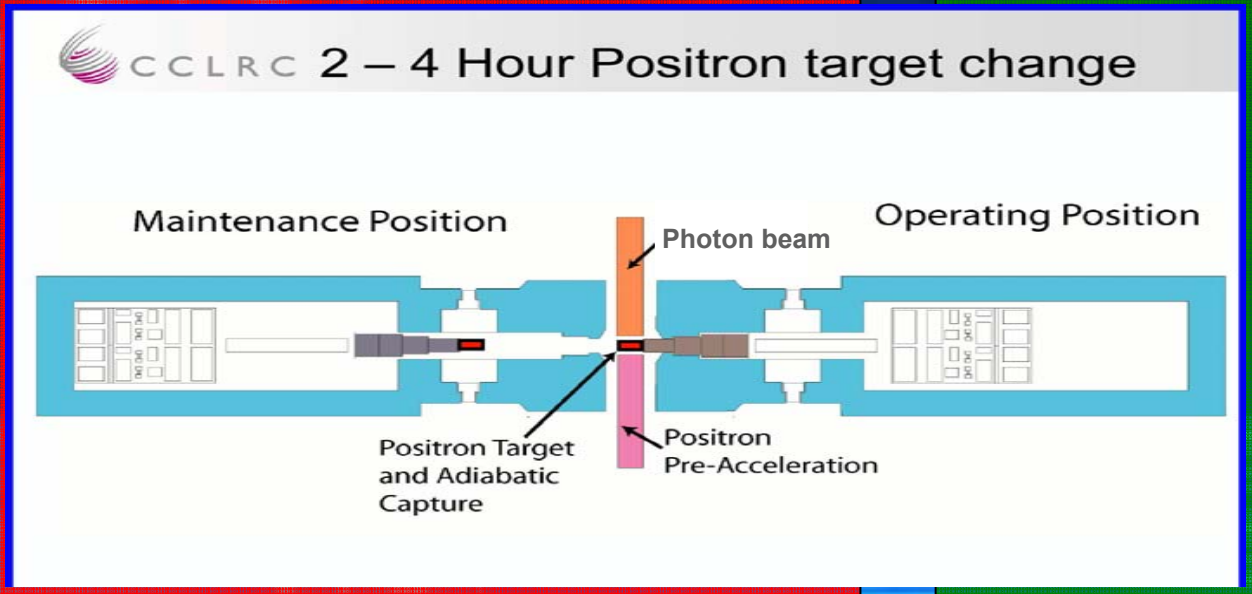
Undulator photon energy of 10 MeV chosen to avoid giant neutron resonance.



From TESLA study, expect 100mSv/h activation in target region. EU exposure limit for radiation workers is 20mSv/year…

V. Bharadwaj - Positron Source Workshop, Daresbury 2005

Remote-Handling

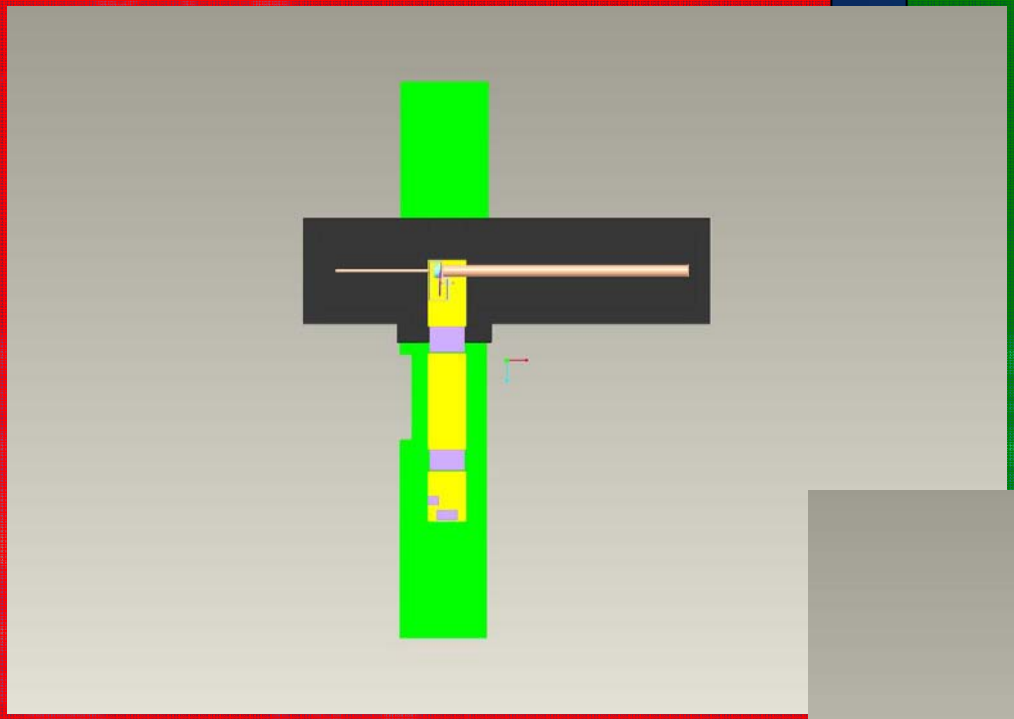


- Full maintenance remote-handling concept suggested by Tim Broome (RAL) at Daresbury Positron Source Workshop 2005.
- Two hot cells.
- Based on ISIS second target station.

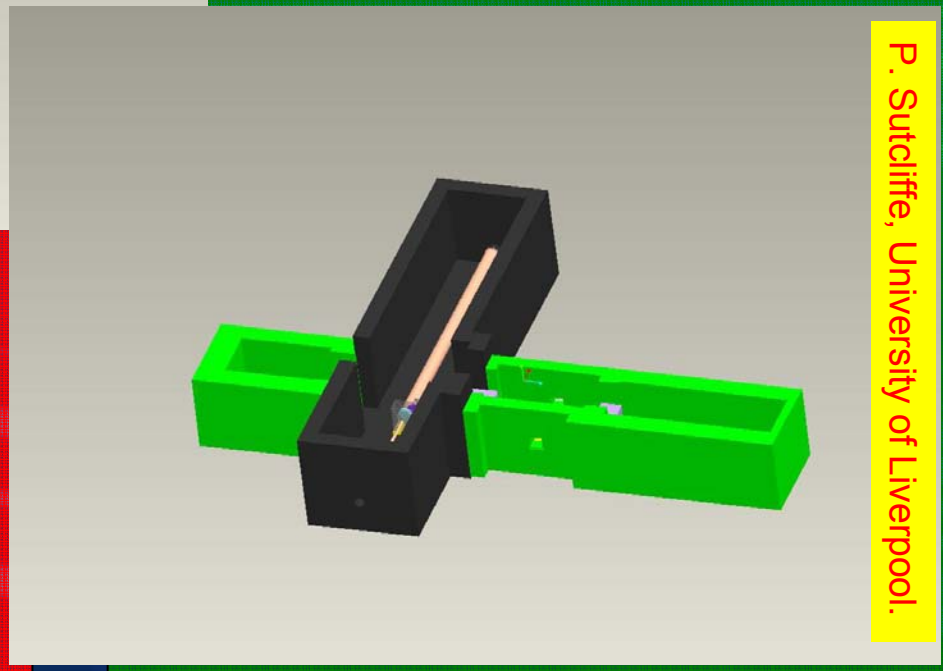
Each hot cell consists of:

- Super-structure and shielding
- 2 lead glass windows (1m x 1m viewing area, 1m thick)
- 2 pairs of master-slave manipulators
- In-cell crane
- Ventilation system
- Camera and sound system (8 videos cameras)
- Posting port
- Miscellaneous tools…

Remote Handling (2)



Cheapest option may be to move any faulty target to a holding cell until ‘cool’ enough to be handled manually. Will depend on component reliability.



P. Sutcliffe, University of Liverpool.

Alternative single hot cell design.

Suited to two targets in series.

UK Plans

The University of Liverpool and other interested UK institutes (DL, RAL, …) propose to further develop the LLNL design and build prototypes of the target systems to determine the reliability.

The UK ILC accelerator community is in the process of drafting a funding bid to PPARC (2007-2010) in which the target and undulator R&D will be an important component.

International positron target meeting at BINP May 10th-12th to coordinate ILC target system R&D.

EU funding? Coordination needed through ELAN, EUROTeV, etc.

Prototyping to demonstrate:

- Stability of rotating target
- Reliability of drive mechanism and vacuum seals.
- Rotation of target in B field of capture optics.
- Reliability of water-cooling system for required thermal load (average / peak?)
- Engineering techniques for manufacture of water-cooling channels.
- Radiation hardness of the target systems.

Further Studies

Liverpool and collaborators propose to seek funding for:

- **Remote-handling design effort.**
- **Photon-collimator design effort.**
- **(Photon-dump design effort?)**

LLNL intend to carry out further mechanical, thermal and vibrational studies that underpin the target design.

SLAC will continue with activation simulations, spinning disc experiment, etc.

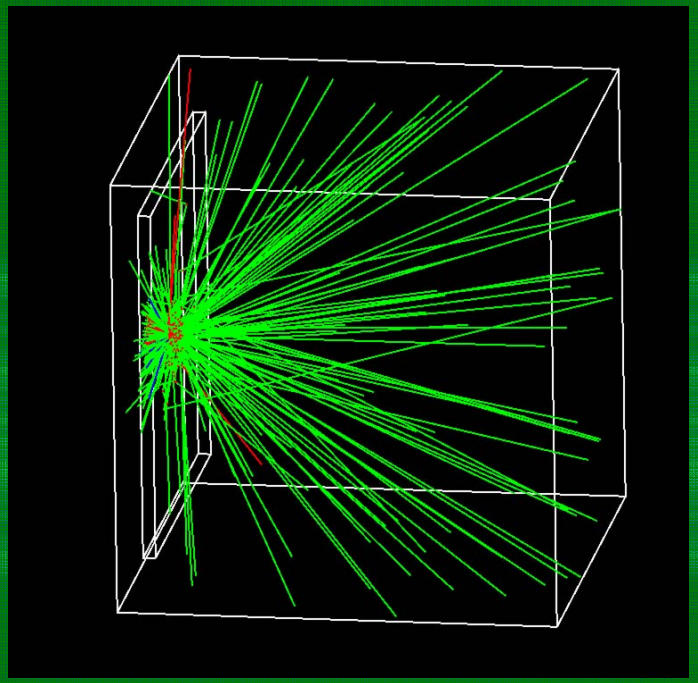
Also radiation studies at DESY within EUROTeV?

No guarantees of UK funding success…

but a core UK target R&D programme will continue in all eventualities.

Summary

- There exists substantial R&D on baseline positron source target design at LLNL, SLAC and Liverpool.
- The UK hopes to expand its contribution beyond current EUROTeV programme.
- Potential overlaps between undulator and Compton target systems (eg remote-handling).



- Scope for further collaboration / cooperation?