Design of the Photon Collimators for the ILC Positron Helical Undulator

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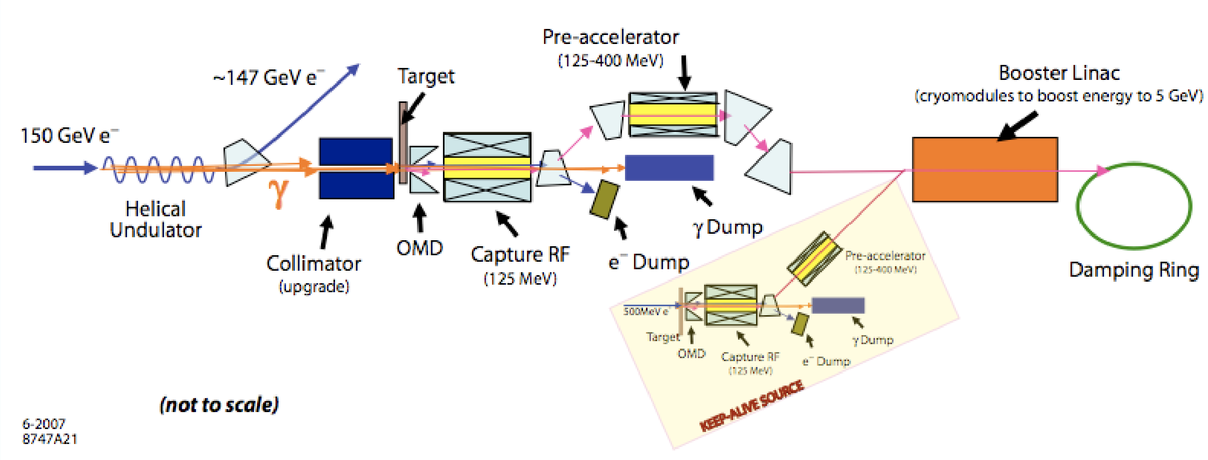
Introduction

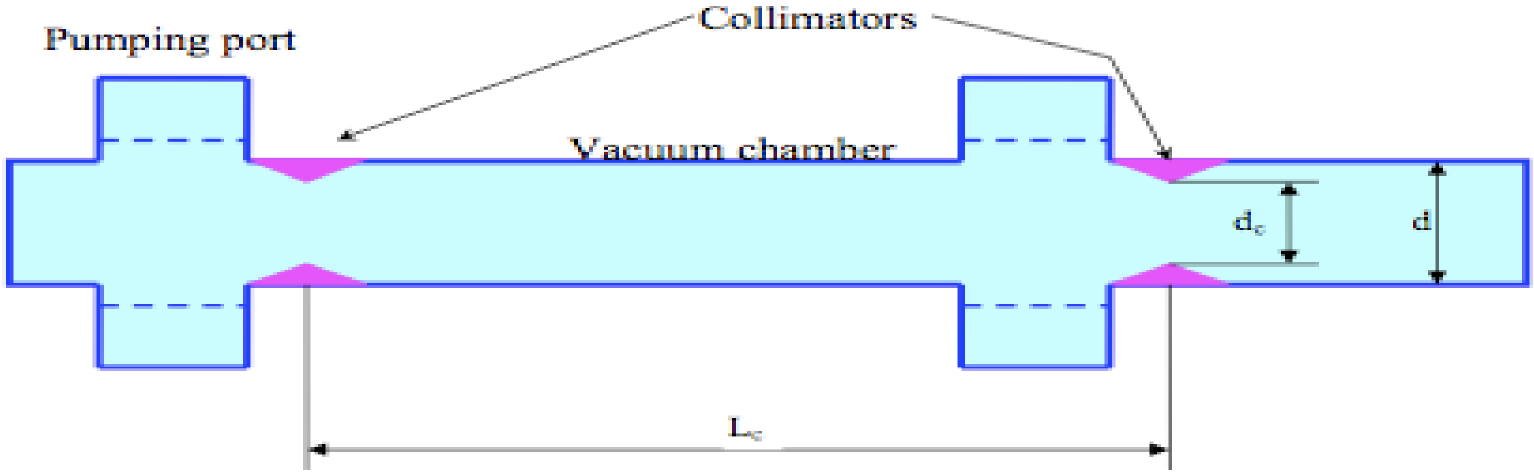


- 150 GeV electron beam ->circularly polarized photons
- photon collimators -> used to protect the vacuum vessel
- the vacuum specifications of ~100 nTorr ->

a highly demanding task

Previous work

- Collimators should have axially symmetric apertures
- Diameter should be smaller than the beam pipe
- Provide screening of the downstream elements



Goal

- A complete design of the collimator hasn't been done so far
- A collimator model is proposed:

  - photon absorption

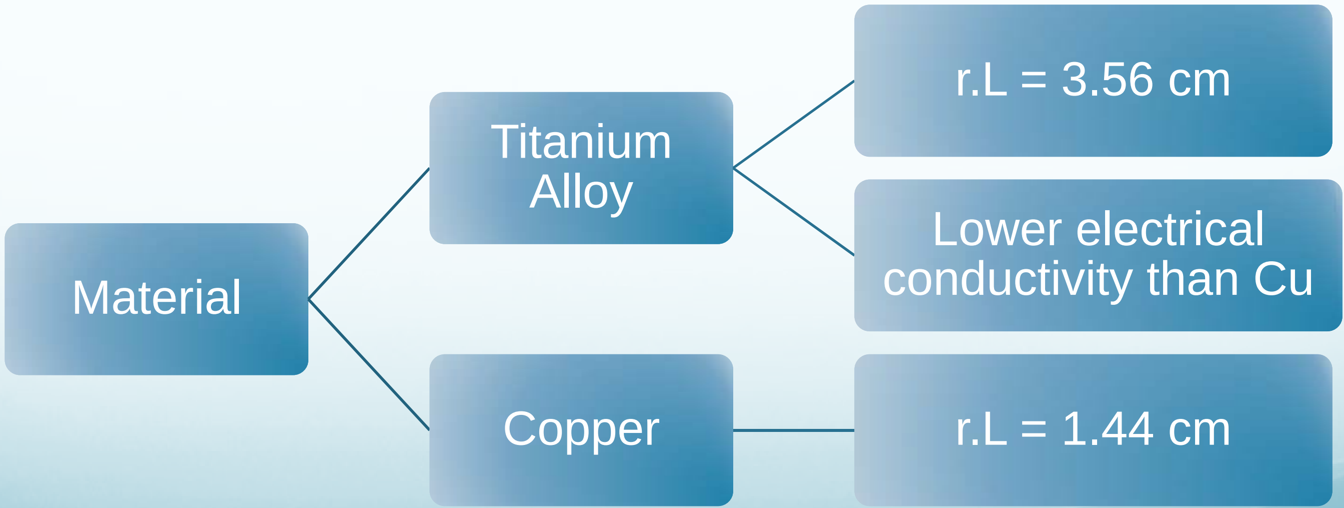
  - secondary particle production

  - vacuum pressure

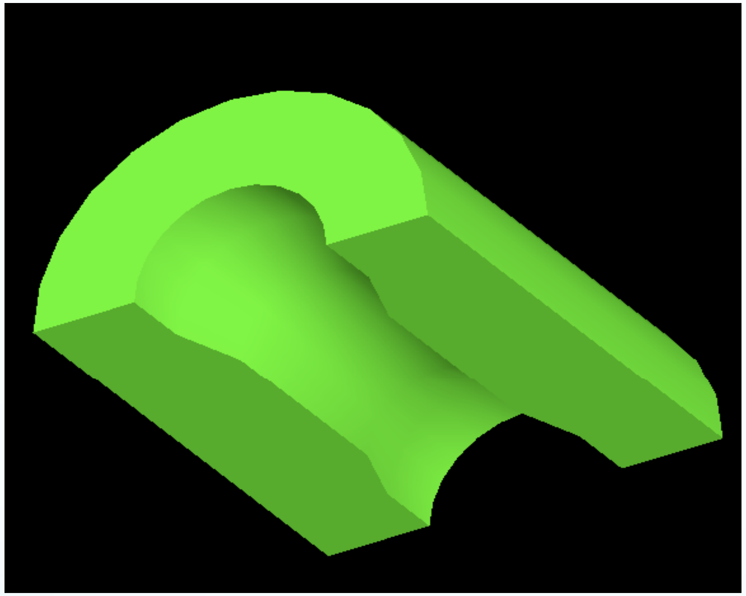
  - energy deposition

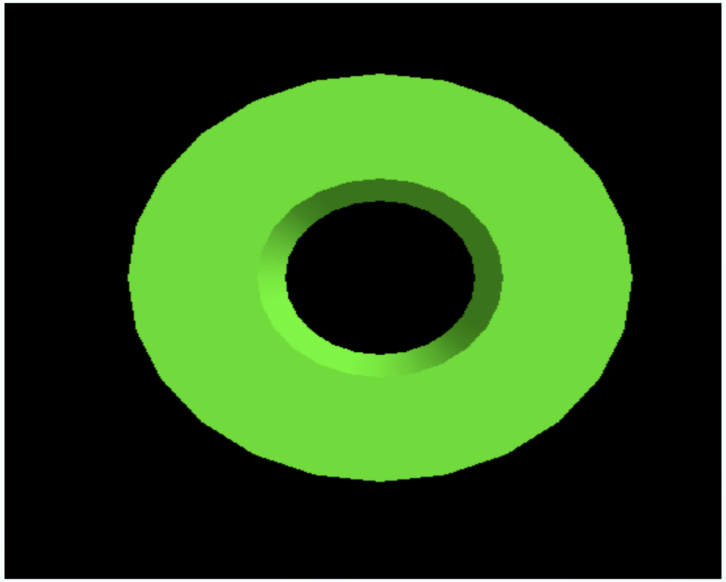
Photon Collimator Design

- Investigation of the possible collimator design
- Primary scope: stop the incident photons on the collimator (>95%)
- Materials:



Photon Collimator Design





Parameter	Value
Beam pipe radius	2.85 mm
Upper flat section	14 cm
Lower flat section	20 cm
Collimator gap	2.2 mm

Photon Spectrum

- Synchrotron radiation spectrum calculated with SPECTRA
- SPECTRA is time consuming for low energy photons (<100KeV) or distances larger than ~30 m
- For this initial study: collimators placed at 30 m from the undulator module
- A new code is developed to deal with unusual cases - SPUR
- Photon spectrum in the range 1-100 MeV and between the angles 67.9 and 97.35 urad

Beam Parameters

Parameter	Unit	Value
Energy	GeV	150
Current	uA	45
Undulator period	mm	11.5
Undulator K parameter		0.92, 0.92
Undulator aperture	mm	5.85
Undulator length	m	150
e^- beam size	um	66.75, 4.45
e^- beam divergence	urad	0.3, 4.45

Undulator and electron beam parameters used to calculate the photon spectrum incident on the collimator.

Photon absorption

Goal : the collimators should stop at least 95% of the incident photons

- Performed Geant4 simulations (10^5 photons in the bunch)

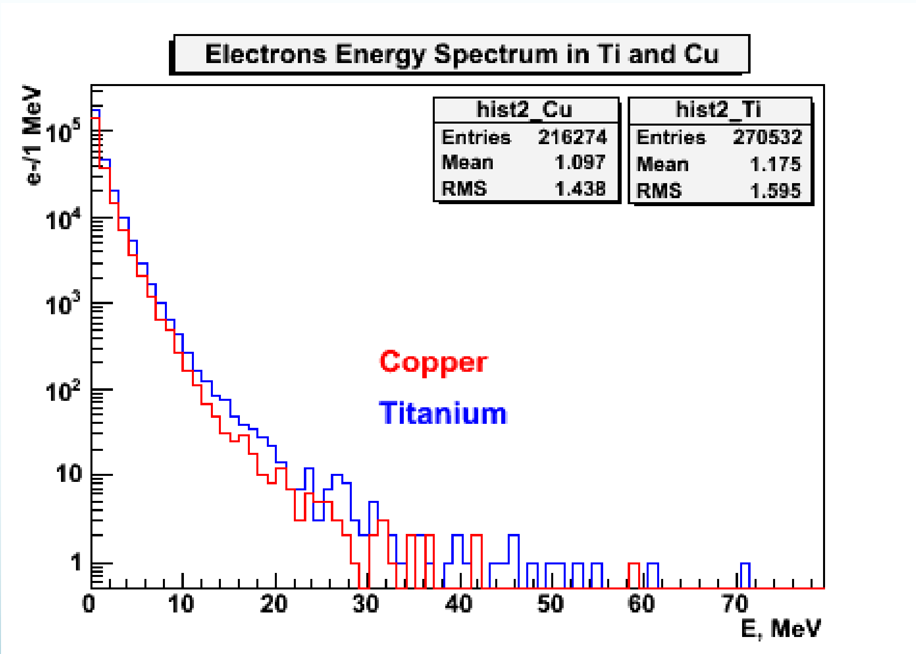
- Six combinations of collimator-undulator modules were modelled

-For Ti Alloy: 96% photons stopped

-For Copper: 99% photons stopped

Production of Secondary Particles

Electron Production



- Secondary particles generated when photons pass through
- Electromagnetic shower modelled in both Cu and Ti
- Similar energy range for both materials
- Low energy range (0-30 MeV)
- More secondary electrons produced in Ti than in Cu

Secondary Particle Production

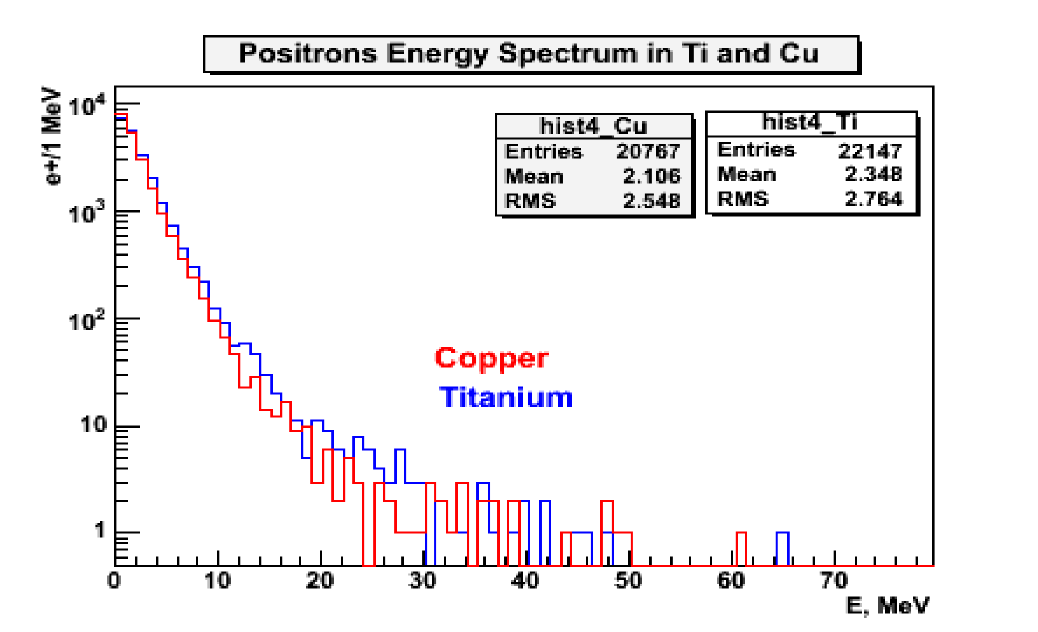
• higher transmission in Ti than in Cu

• differences between two spectra due to the fact that moresecondariesare stoppedinside Cu

- 20 cm ≅ 14 r.l in Cu

- 20 cm ≅ 6 r.l in Ti

•low energy range ->good for vaccum pressure

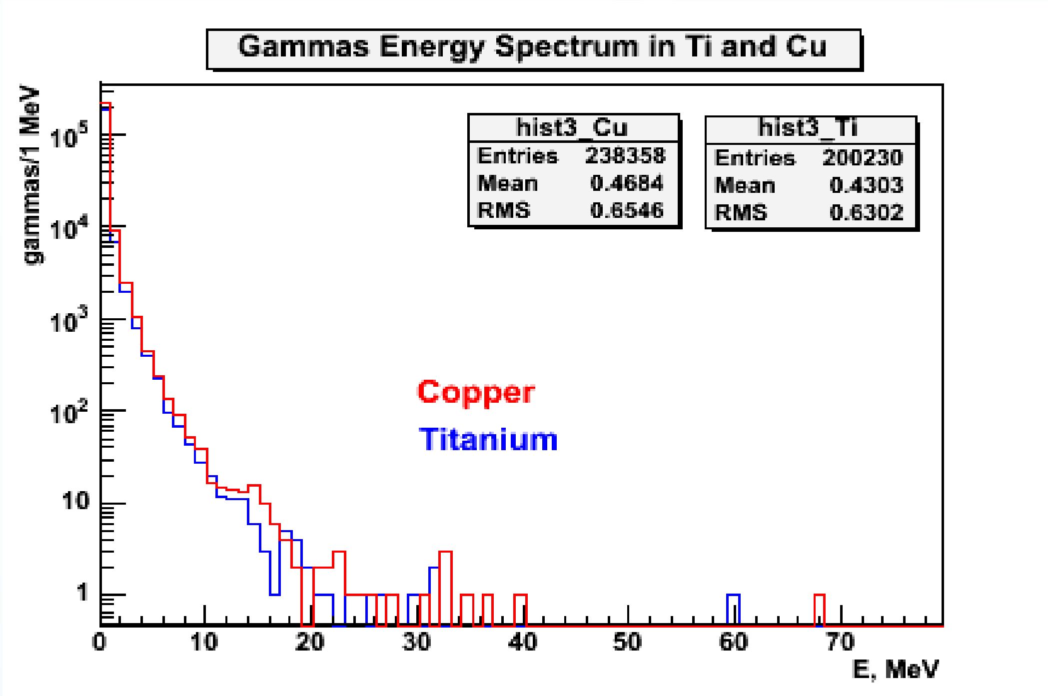


Positron Production

Secondary Particles Production

- Similar energy range for photon production in both Ti and Cu

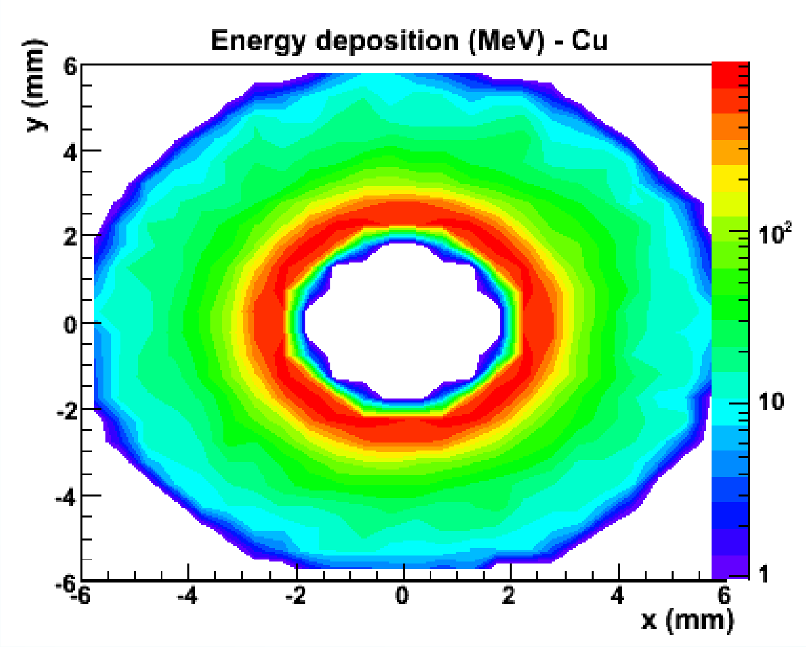
- low energy range (0-30 MeV)



Gamma production

Energy Deposition

- Due to the electromagnetic shower
- Energy peak is at the collimator location
- Energy also deposited in the beam pipe following the collimator
  - 100 MeV/20 cm in Ti
  - 10 MeV/20 cm in Cu
- In a transverse section the max energy deposition is at collimator location (radius 2.2 mm)
- energy deposition in the beam pipe is due to showering

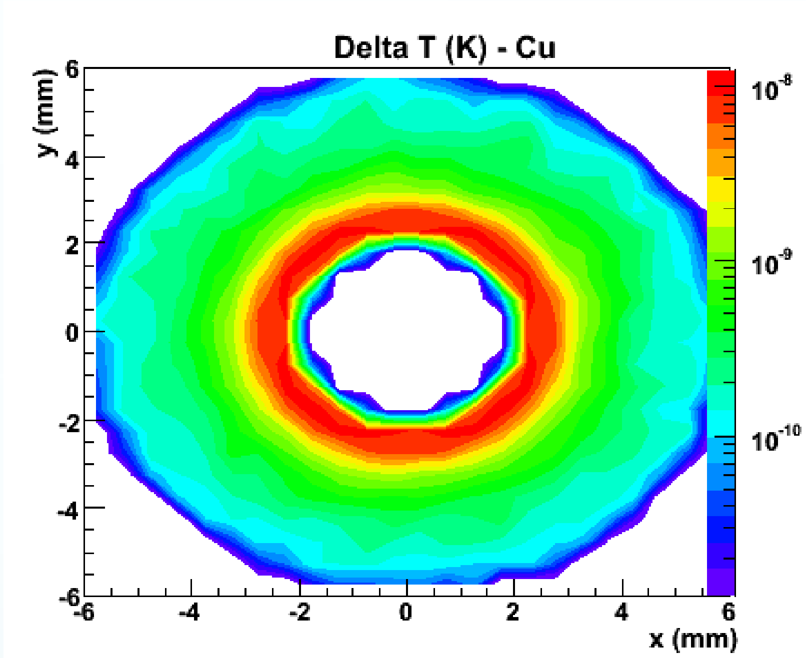


Energy deposition profile in a collimator slice

Temperature Rise

- calculated using the material properties (density, specific heat)
- Ti: 6×10^{-9} K
- Cu: $2 \; 10^{-8}$ K
- temperature increase is small, the fracture temperature is not exceeded

Conclusion: the collimators can not be damaged



Instantaneous temperature rise in Cu

Conclusion

- A possible geometry with high photon absorption efficiency has been modelled for Cu and Ti
- Copper is a better candidate
- Secondaries have a low energy spectrum -> determine the change in the vacuum pressure
- Energy deposition and temperature rise showed that the collimators are safe
- Wakefield effects can be minimised by using as bulk material Cu
- Cu collimator can be make shorter (less room in the final engineering design?)