The energy deposition over the length of the ILC undulator

(250GeV)

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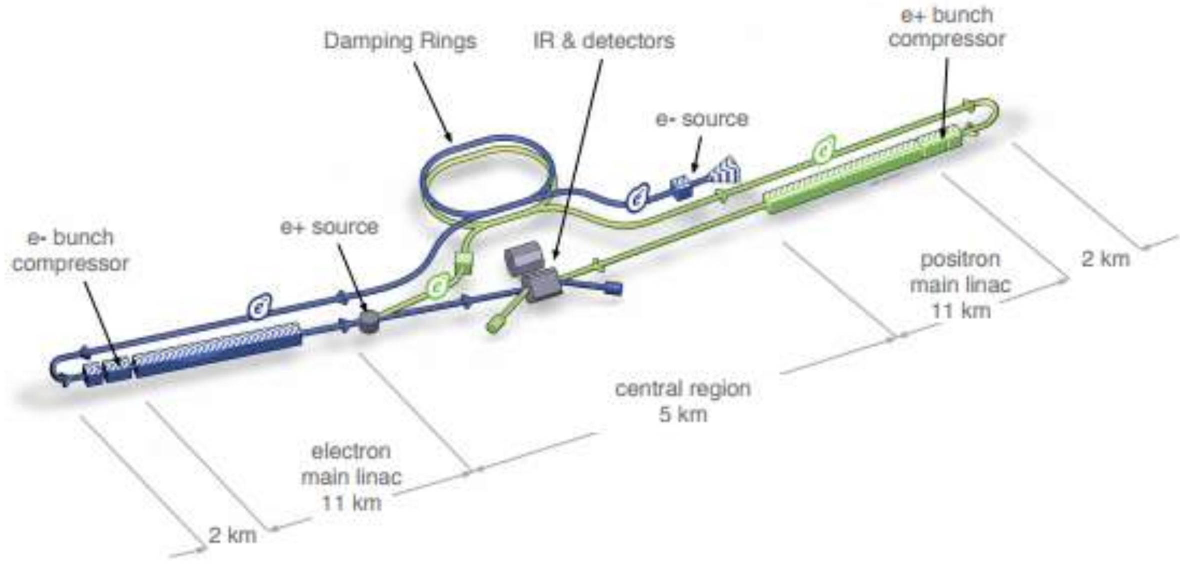
Outline

- The International Linear Collider (ILC).
- Helical Undulator based Positron Source.
- HUSR software
- Comparison between ideal and realistic undulator modules
  - in terms of Flux,
  - average photon energy and power.
- Focus: E_{cm} = 250GeV ⇔ E_{e-} = 125GeV
- The whole Helical Undulator (Ideal and Realistic) was simulated for ideal and realistic B fields.
  - Energy Deposition inside the Undulator was considered.
- The effect of adding masks inside the undulator on the Photon Numbers and Polarization was studied.
- Conclusion

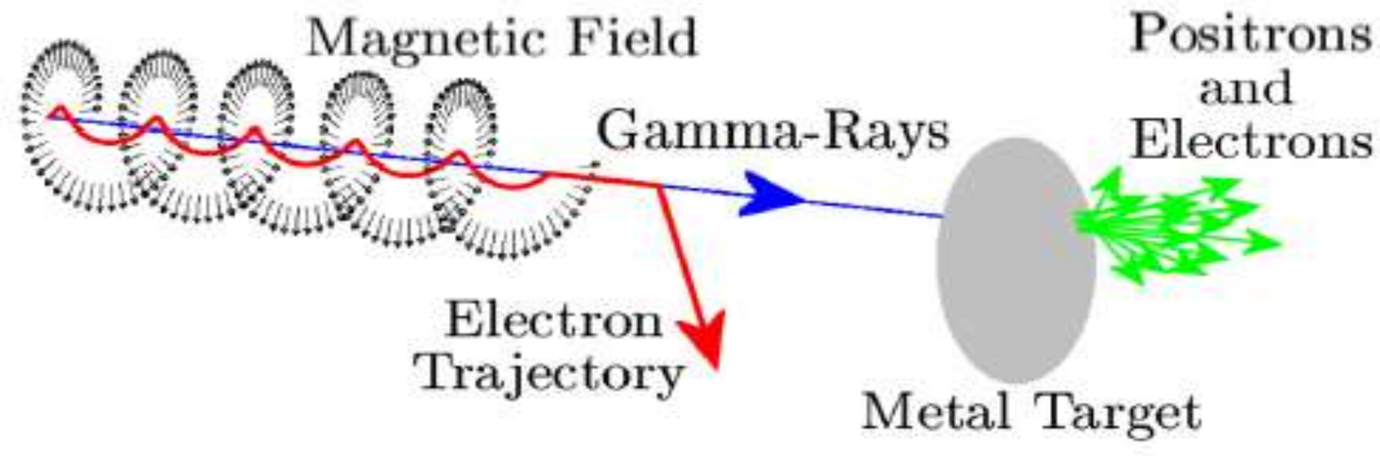
International Linear Collider

- •Two sources: polarized electron source and undulator based positron source.
- •Two Damping rings : for electrons and positrons with energy 5 GeV.
- •Two main LINACs, total length 30km.
- •Beam Delivery System.
- •Interaction Point (IP).
- •Two Detectors: the International Large Detector (ILD) and the Silicon Detector (SiD).



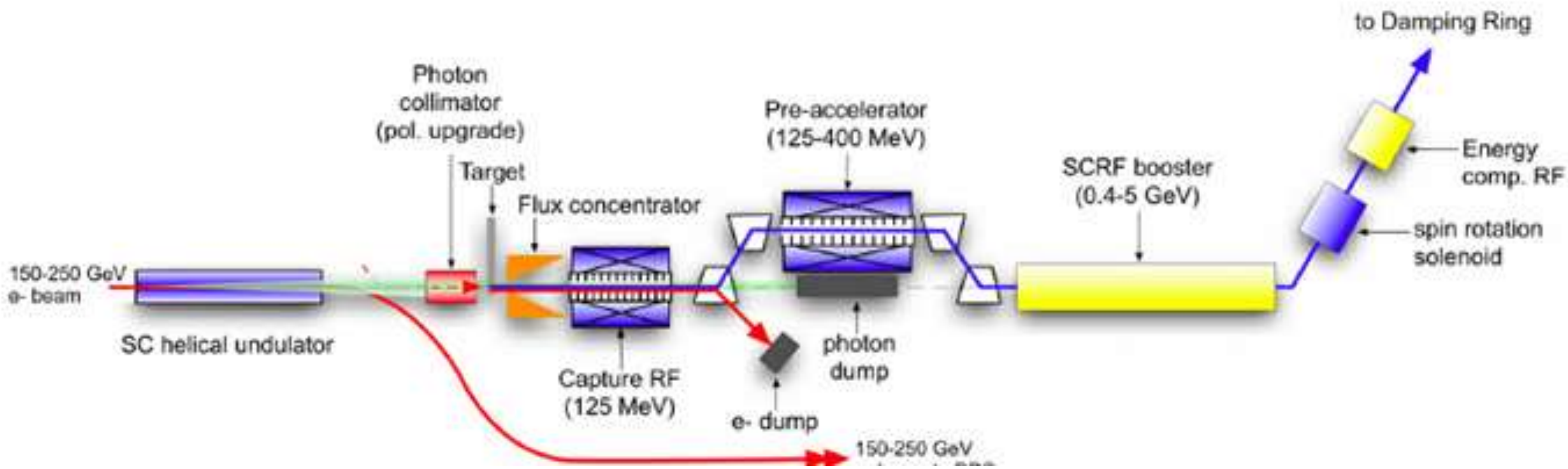
Helical Undulator based Positron Source.

• after end of main linac, electrons loss energy when they pass superconducting Helical Undulator.
• create circularly polarized photons in the helical B field.
• Electrons enter the Beam Delivery System (BDS) which transport e+ and e- to the IP.
• photons hit spinning Ti6Al4V target and produce electrons-positron pairs (Felix talk).



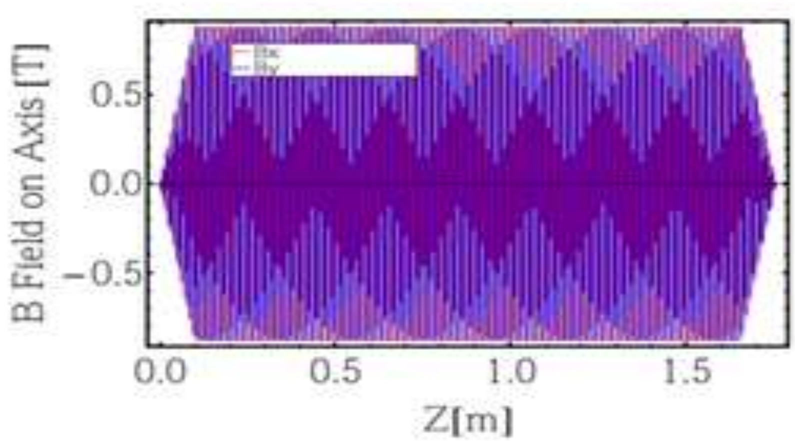
Helical Undulator based on Positron Source.

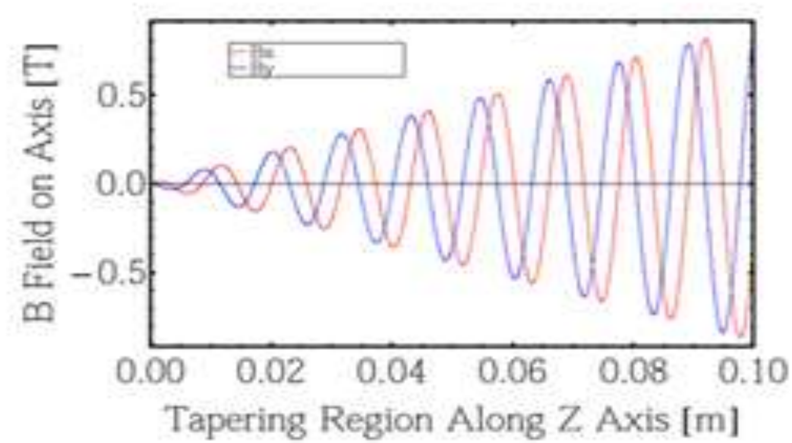
- e+ will be captured and accelerated up to 5GeV and then sent to positron damping ring



HUSR Software Spectra

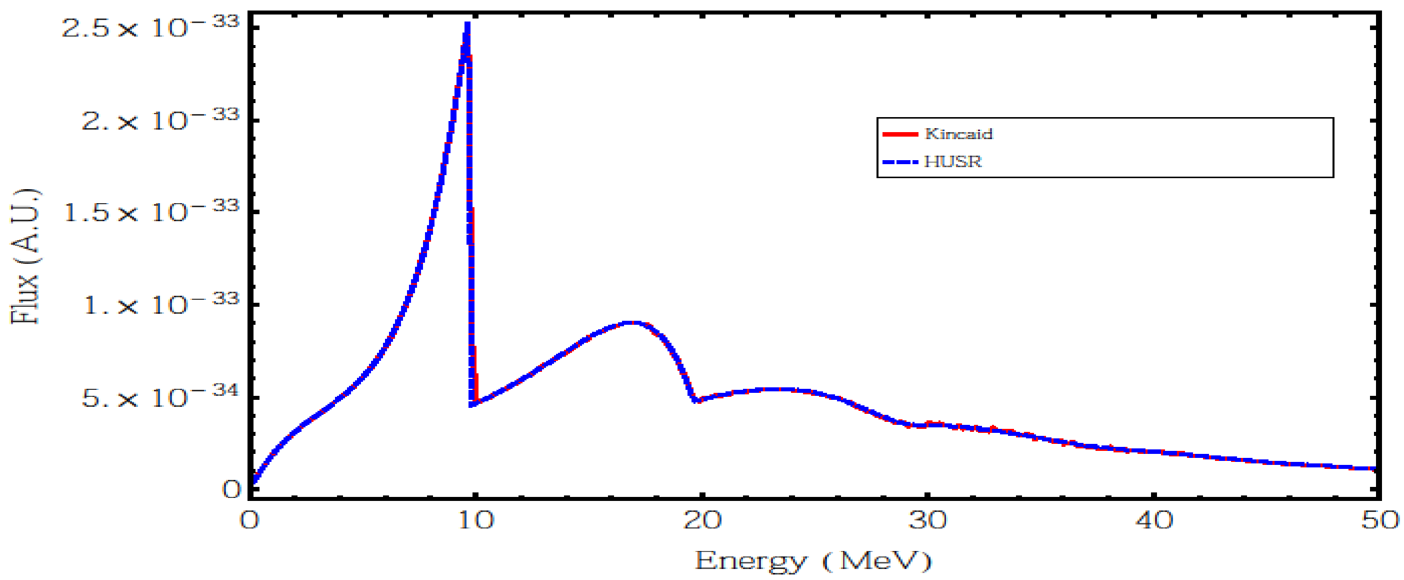
- **HUSR: H**elical **U**ndulator **S**ynchrotron **R**adiation
- Can simulate photon spectra produced by a Helical Undulator
- **Developed at Cockcroft Institute by David Newton.**
- HUSR simulates a photon spectrum from an arbitrary magnetic field map.
- **Using different arbitrary maps is possible in HUSR e.g. include errors in the magnet, tapering, etc.**
- Some HUSR advantages: Speed of the calculation and can be extended to more functionality as it is a C++ code





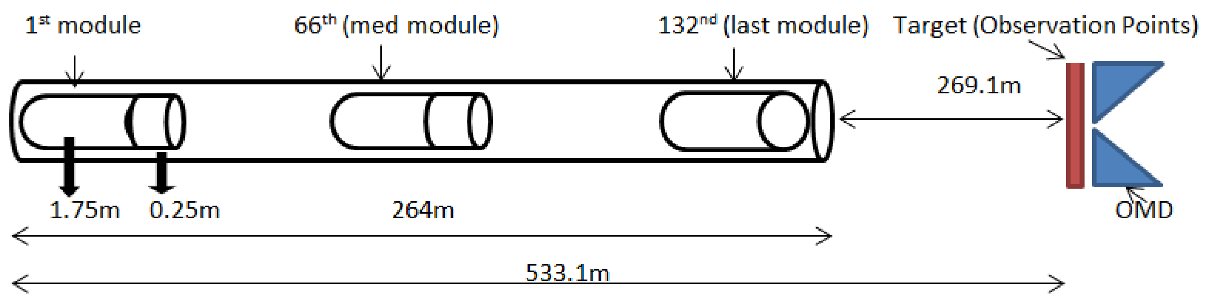
Bench marking HUSR energy spectra with Kincaid energy spectra

- Kincaid Equation: calculates the radiation spectrum that is produced when high-energy electrons travel through a perfect helical magnetic field.[1]
- The photon energy spectrum generated by 125 GeV electron by Kincaid Equation is shown in red, and HUSR in blue.
- They **agreed** as we see



Simulated Helical Undulator

- Schematic of an Undulator-based Positron Source showing the main components including the helical undulator, conversion target (observation points), Optical Matching Device (OMD)
- Undulator length: 132 modules * 1.75 = 231 m , Total length = 264 m
- The first, the 66th and the last module were chosen to compare Ideal and realistic modules
- The realistic undulator means: two types of error were introduced into the simulated field map.
  1. errors in in the magnetic field strength
  2. Errors in the period size.



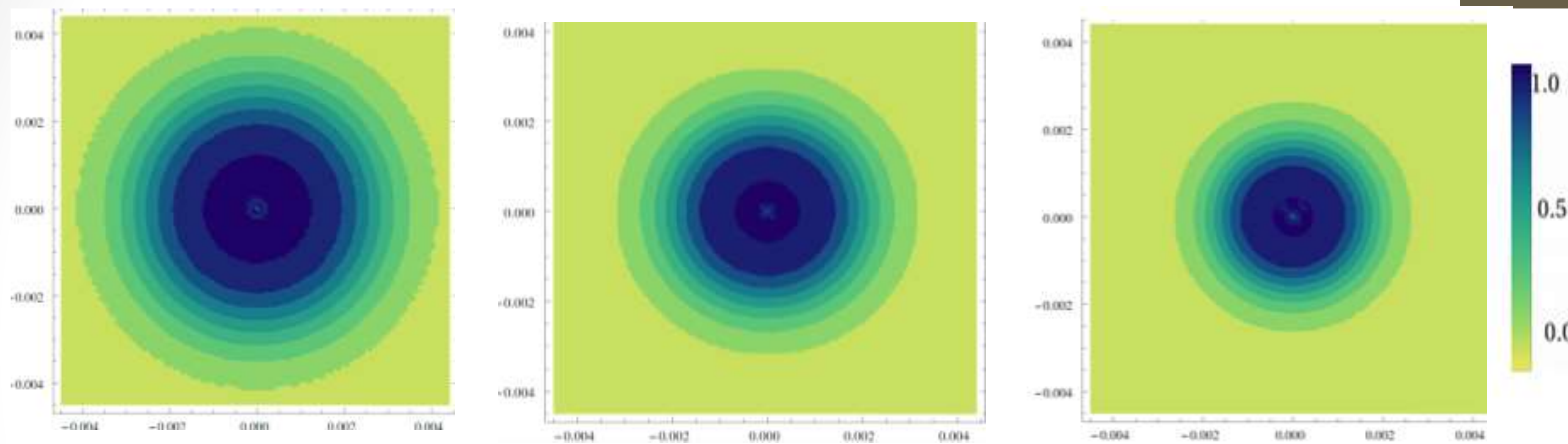
Parameters Used

Parameters	
Electron Energy (GeV)	125
Bunch population	2.00E+10
Number of bunches	1312
Repetition rate (Hz)	5
Unit Length (m)	1.75
Number of undulator units	132
Net length of undulator (m)	231
Total length of undulator section (m)	264
Distance between undulator section to the target (m)	269.1
Undulator period (m)	0.0115
K value	0.85
Magnetic field [T]	0.79
Inner radius (mm)	2.9

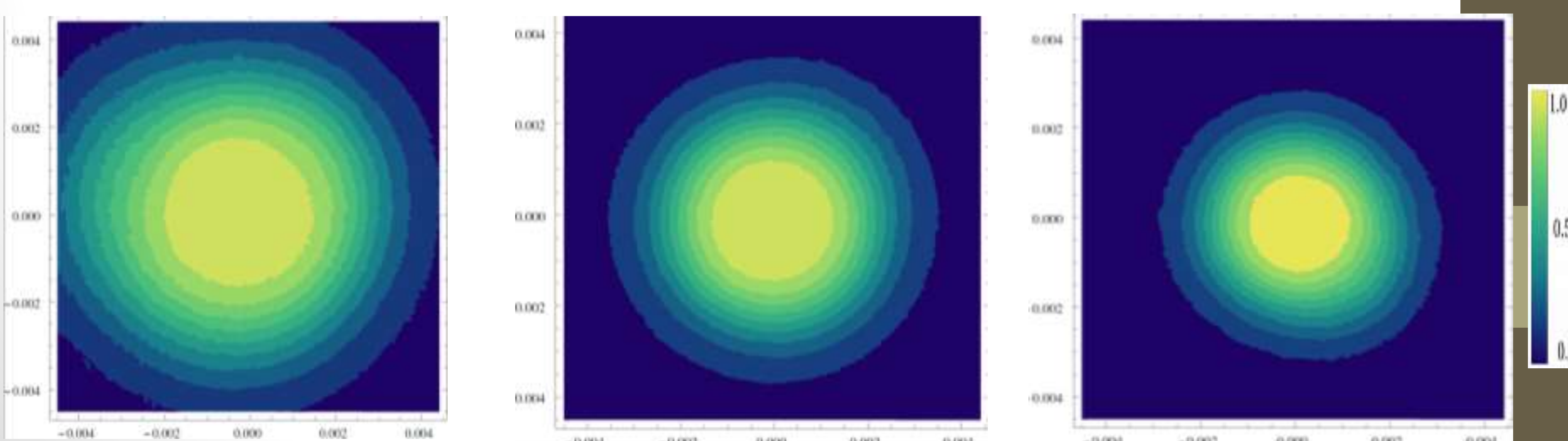
Flux distribution at the target layer, created in the n^{th} module

Flux in each undulator module normalized to 1

Ideal: 1st modul (531m to target) 66th modul (401.1m away) last modul(269.1m away)



Realistic: 1st modul (531m to target) 66th modul (med) (401.1m) last modul(269.1 m)

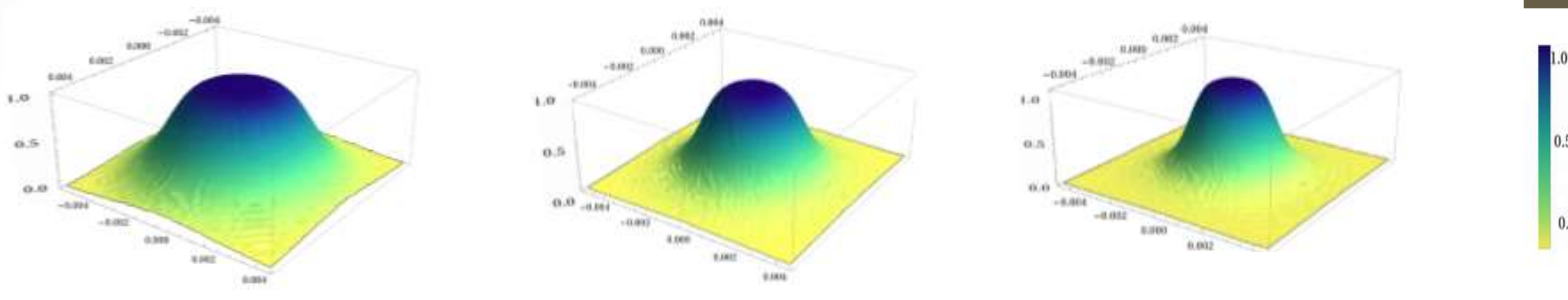


The flux distribution on the target

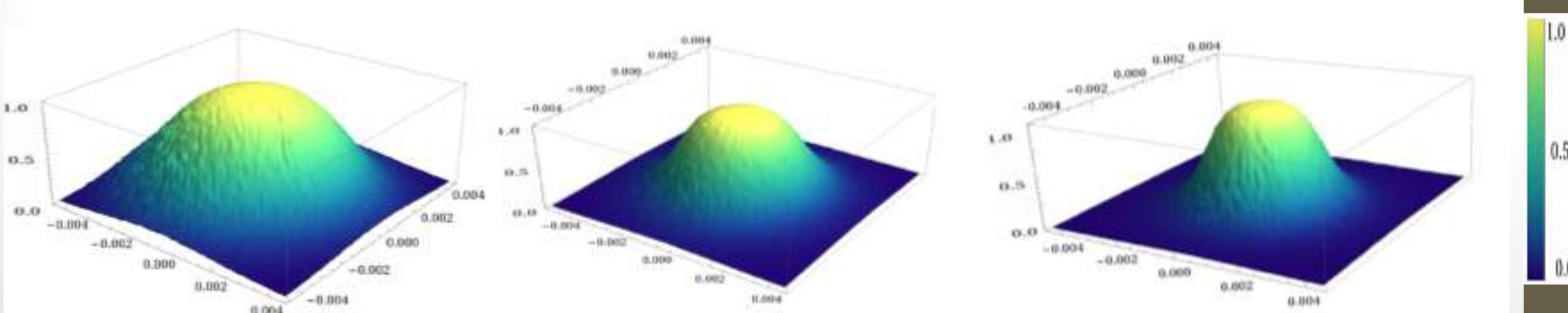
We can see the differences on Flux Distribution on the target depending on the distance between module and target.

Flux in each undulator module normalized to 1.

Ideal: 1st modul (531m away) 66th modul (401.1m away last modul(269.1 m away)



Realistic: 1st modul (531m away) 66th modul (401.1m away) last modul(269.1 m away)



Average Photon Energy and Flux Distribution from Ideal and Realistic Modules

	Ideal undulator B field		
	Photons/Sec/module	Average photon Energy (MeV)	Power (W)
1st module	2.70E+14	7.4 MeV	454
66th module	2.78E+14		467
last module	2.85E+14		479
	Realistic undulator B field		
	Photons/Sec/module	Average photon Energy (MeV)	Power W
1st module	2.62E+14	7.2 MeV	440
66th module	2.74E+14		461
last module	2.79E+14		469

Power on the target (ideal & realistic undulator B field)

The whole helical undulator was simulated for both Ideal and Realistic B field.

132 ideal undulator modules were simulated.

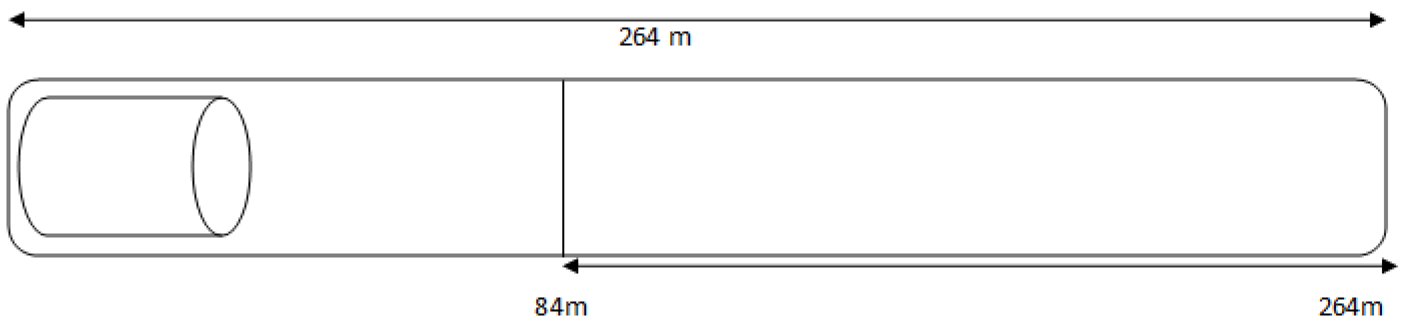
132 realistic undulator modules were simulated as well.

As shown 5% is between the ideal & realistic

	Average Photon energy (MeV)	Power (KW)
Ideal	7.4 MeV	63.2
Realistic	7.2 MeV	60.1

Energy Deposition on the undulator wall

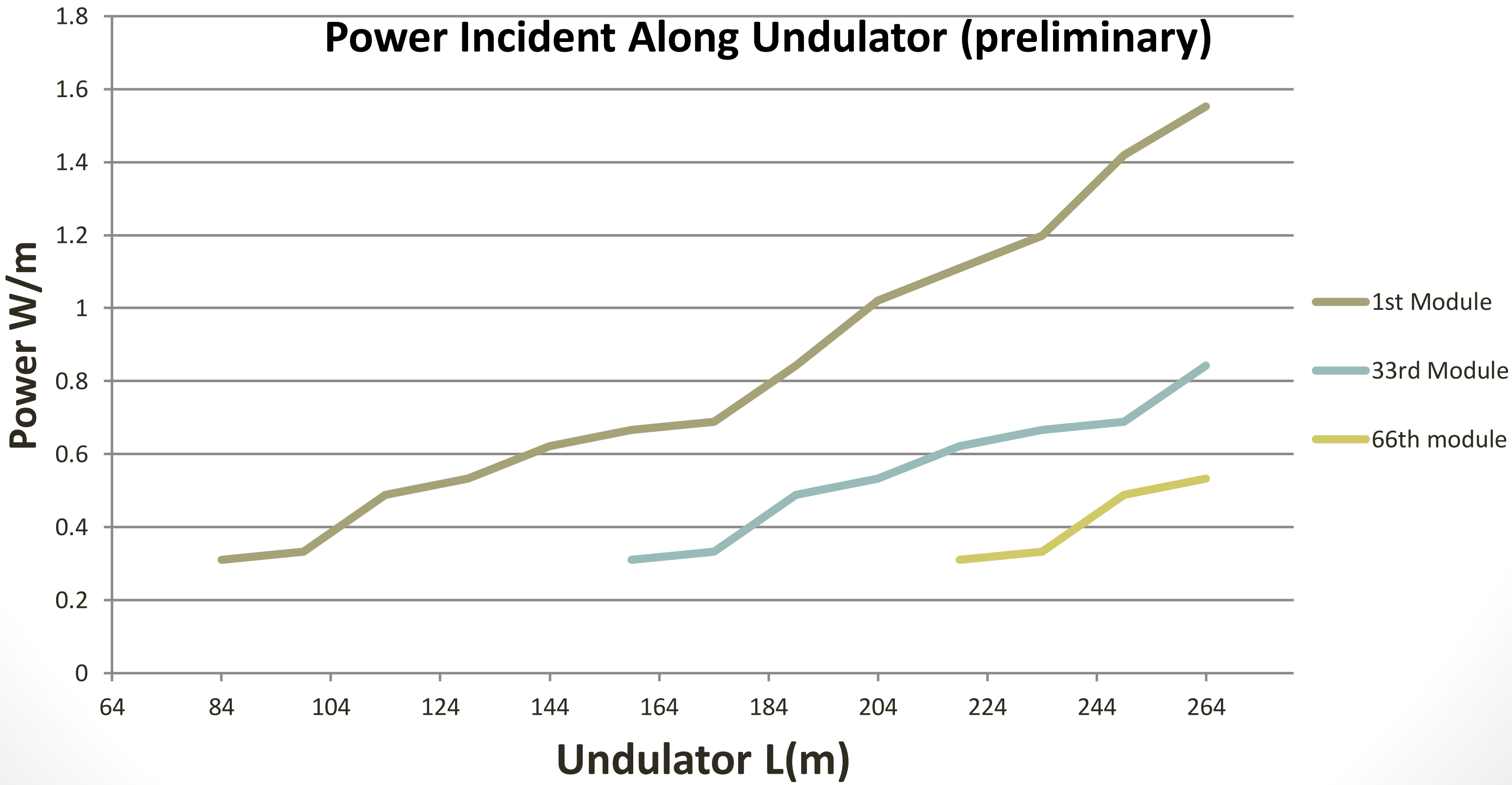
- To save time, I simulated the energy deposited by photons which are created in the 1st , 33rd and 66th module along the undulator by steps (Step width 16 m)
- For distances below 84 m between module and observation point the photon spectra is unreliable.
- Thus, the energy deposition in the undulator area was studied from 84 m to the end of the undulator (264 m).



Energy Deposition on the undulator

Since the energy deposition along the undulator, cannot be calculated with HUSR, the photon spectra were taken to calculate the incident power.

This plot shows the energy deposition of photons from 1st , 33rd and the 66th module in the undulator.

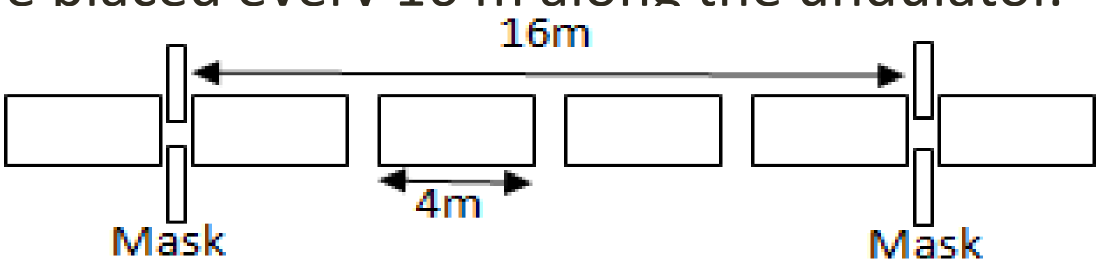


Energy Deposition on the undulator

- It is clear that the Incident Power from all modules is too high.
- It means heat load for cryogenic system is too large.
- The maximum allowable heat load in the superconducting undulator is 1 W/m .[3]

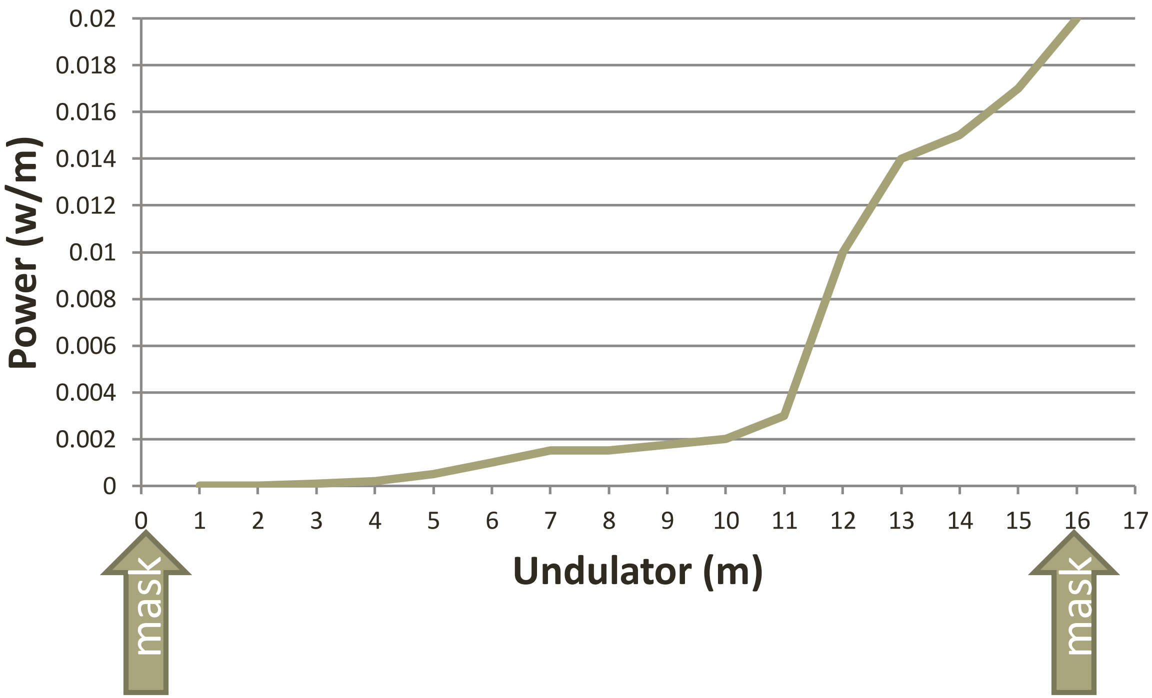
Masks

- To protect our undulator wall we need to add some masks to absorb the power.
- Masks should be designed to achieve the required vacuum.
- Based on an earlier study [2,3] for a shorter undulator and an electron beam energy of 150GeV we assume masks with 4.4 mm Diameter inside the undulator (6 mm).
- Masks are placed every 16 m along the undulator.



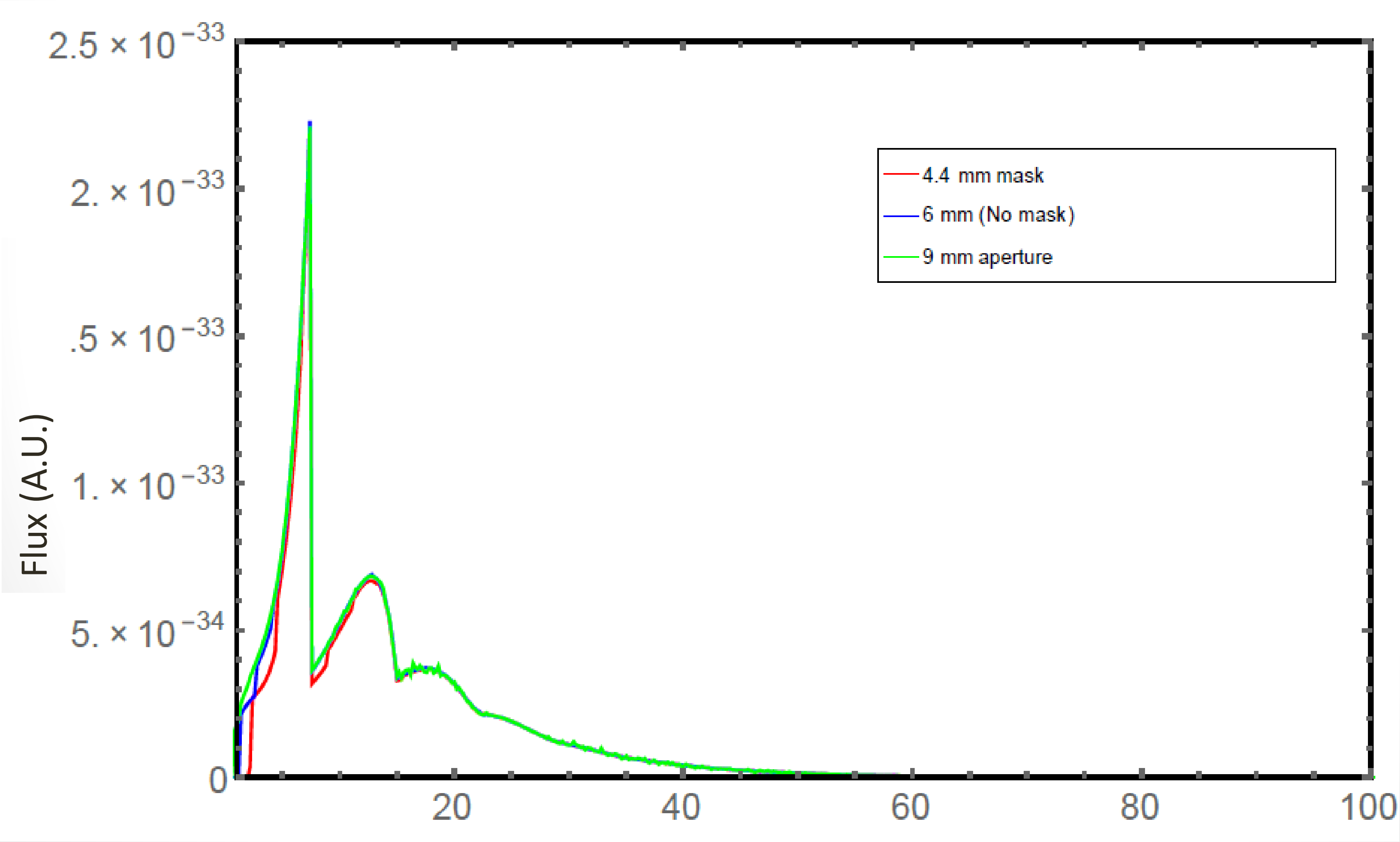
Energy deposition after a Mask (4.4mm)

This plot shows the energy deposition of photons from one module in the undulator between **two** masks.
Fluctuations may be due to low statistics; study will be repeated with larger statistics.



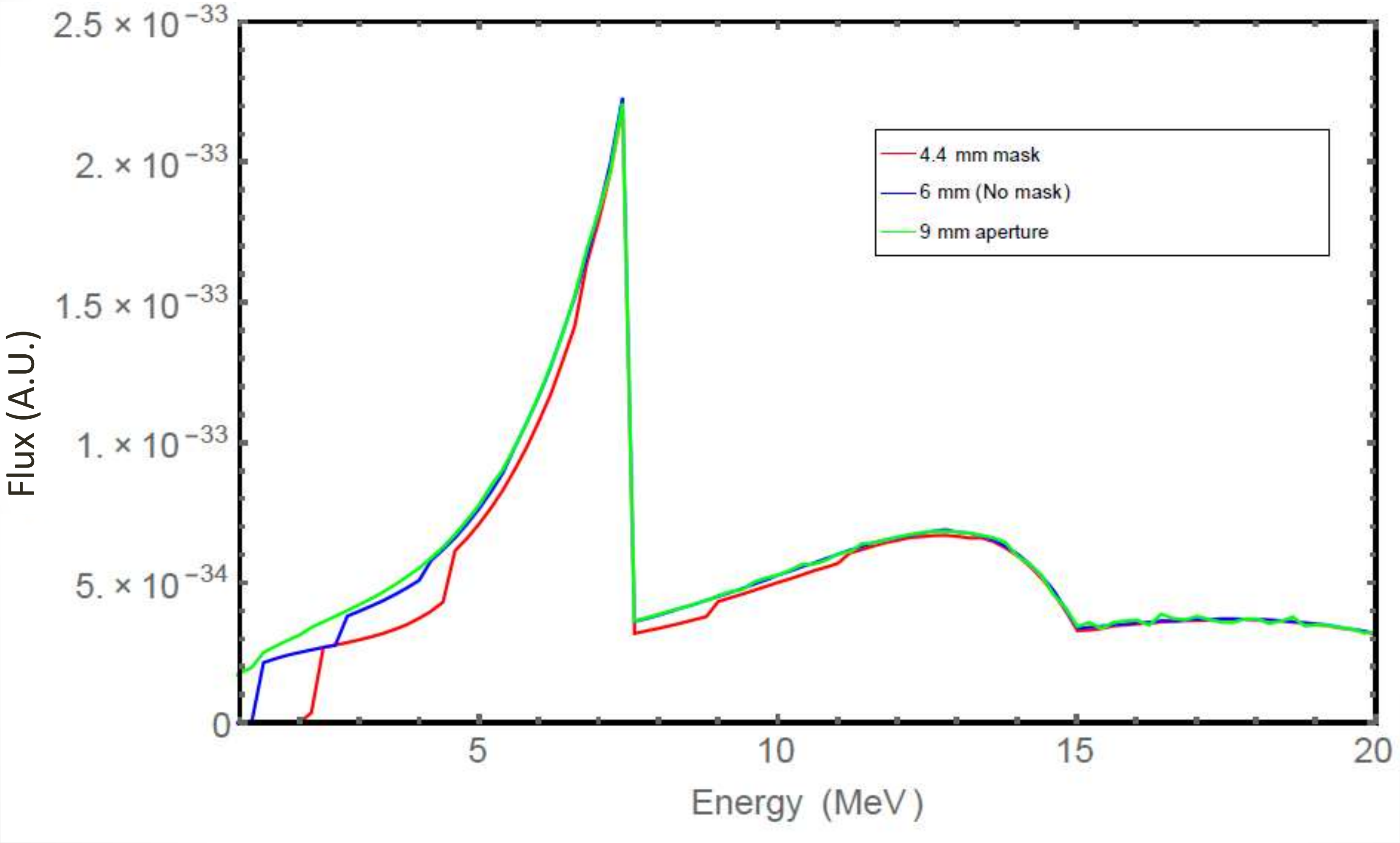
Masks

This plot shows the photon spectrum with and without masks for ideal B-field



Masks

This plot is a zoomed-in version of the previous plot showing the first three harmonics.
Photons with energy less then 2MeV will be absorbed with mask(RED).

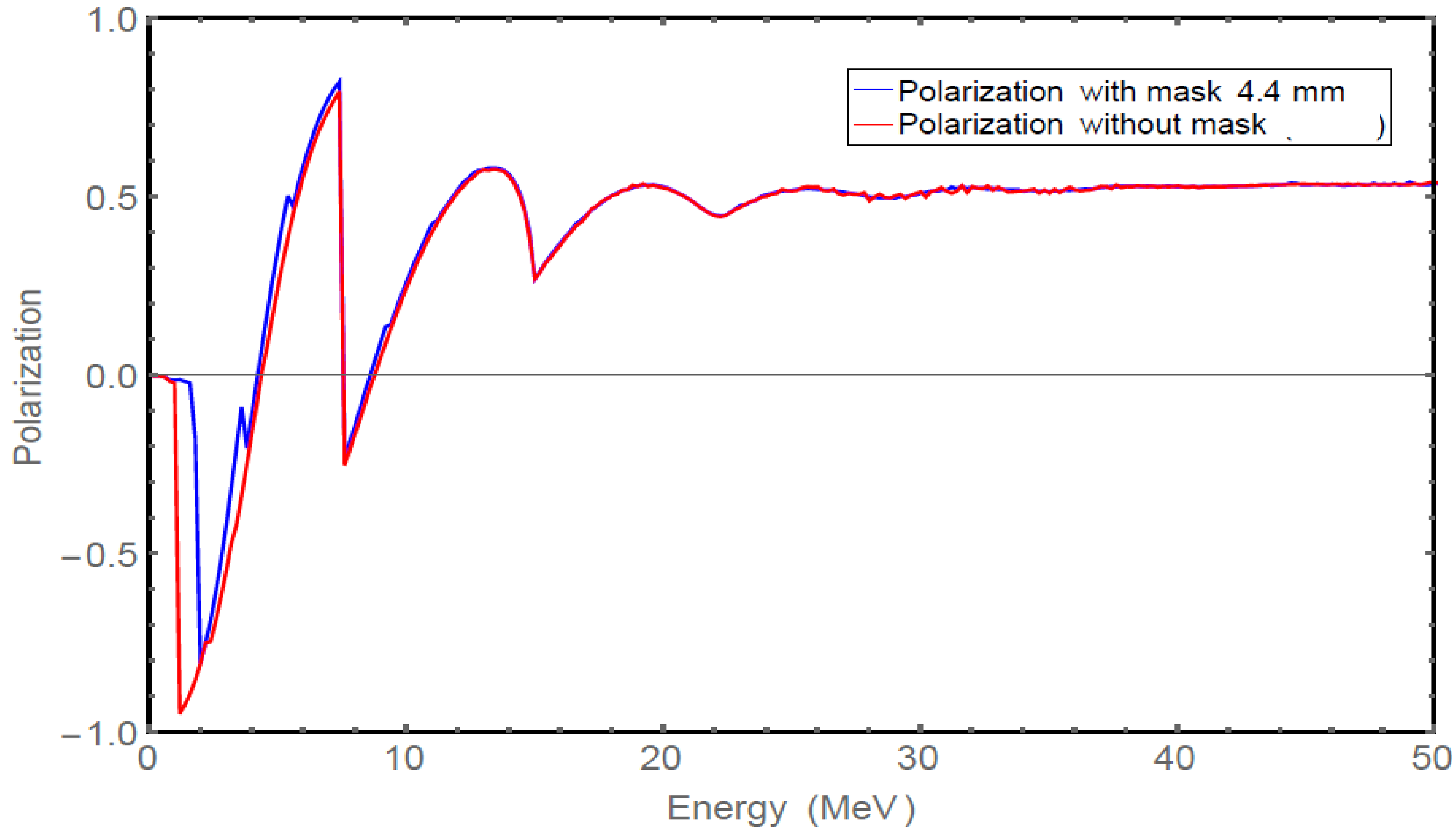


Photon Polarization with Masks

With masks photon numbers will decrease and the polarization of Photons, $P\gamma$, **increases.**

$$P\gamma = \frac{P_L - P_R}{P_L + P_R}$$

P_L and P_R are left and right Photon number , respectively.



Conclusion

- Photon flux distribution at the target was considered for ideal and realistic B fields for 125 GeV electron energy. The position of the modules was taken into account (beginning, middle, end of undulator).
- The energy deposited along the undulator wall was studied for the ideal undulator B field.
- Masks were added to protect the Undulator wall.
- Masks should be designed.
- The Photon spectrum and polarization were considered when mask with 4.4 mm diameter were added inside the Undulator.
- In case using masks, power deposition on Undulator wall will **decrease**, whereas Photon Polarization will **increase**.

Future Plans

- Studies on energy deposition along undulator will be finalized for Realistic B field.
- Influence of realistic undulator B field, masks and a Photon Collimator between Undulator and target on the positron yield and polarization will be studied.

References

1) B.M. Kincaid. A short-period helical wiggler as an improved source of synchrotron radiation, volume 48 of Journal of Applied Physics. 1977.
2) A. Bungau et al. “Design of the Photon Collimators for the ILC Positron Helical Undulator.” EUROTeV-Report-2008-047.
3) Duncan J. Scott, “An Investigation into the Design of the Helical Undulator for the International Linear Collider Positron Source”, PhD Thesis, University of Liverpool, 2008

Thank you
for your attention