Undulator Based Positron Sources for Future Colliders

Simulations with 'Realistic' Photon Spectra

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Presentation Overview

- 'Realistic' undulator spectra
- Simulation results
  - Yield and Polarization for Ideal Undulator
  - Yield and Polarization for 'Realistic' Undulator
- A different undulator

Realistic Undulator Spectra

- Analytical expression used by most simulations
- E.g. PPS-Sim uses Kincaid76
- Codes to generate 'Realistic' Spectrum developed at Cockcroft Institute by
  - David Newton
  - Duncan Scott

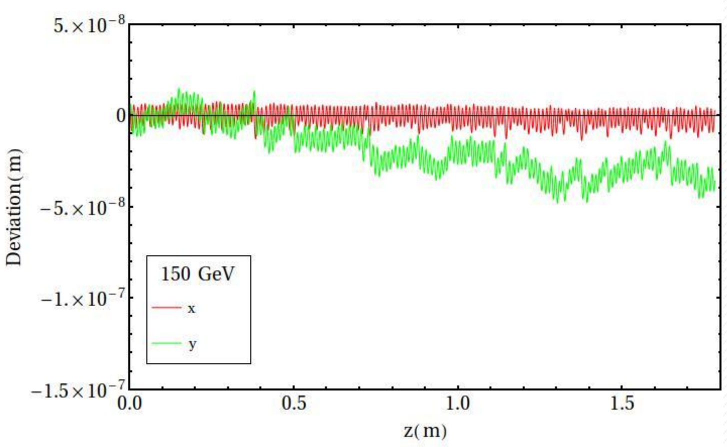
Realistic Undulator Spectra Simulations

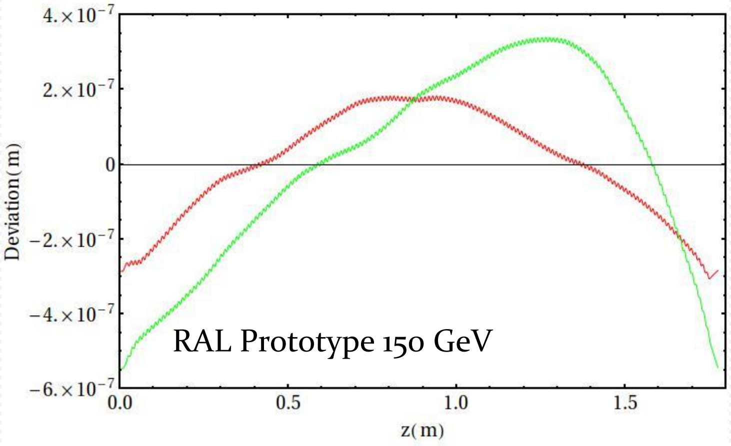
- David Newton's code generates a photon spectra for a given magnetic field map:
  - The code tracks particles through field map
  - Photon flux calculated by integrating along track
- To produce 'realistic' undulator photon spectra use:
  - Non-ideal field maps
  - Field map errors similar to field errors in the RAL prototypes

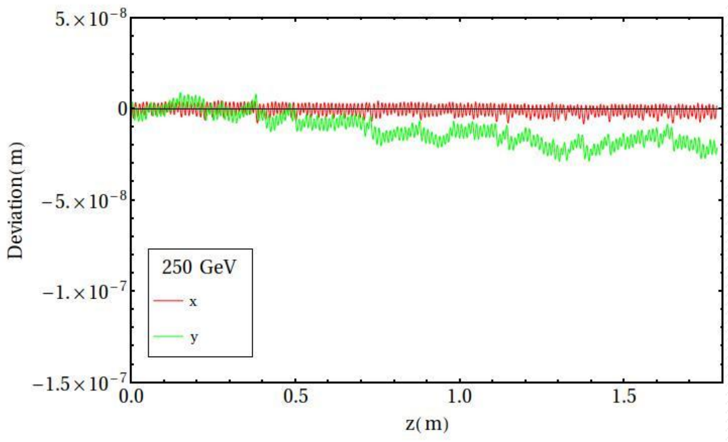
Tracking Particle Through 'Realistic' Field Maps

Largest deviation seen in RAL prototype max deviation is 10^{-6} m due to construction methods

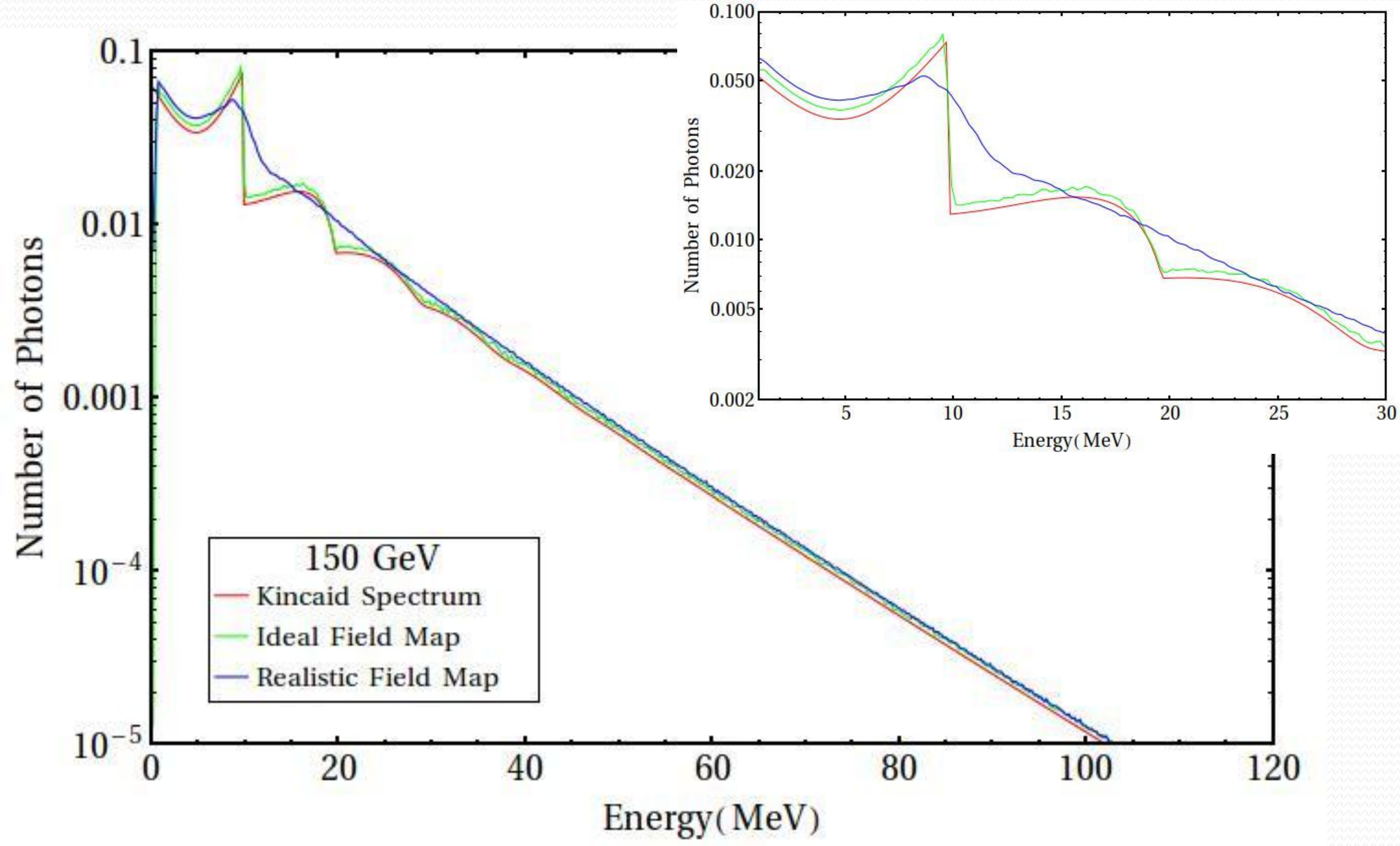
Deviation from field maps used is ~$5x10^{-8}$ m







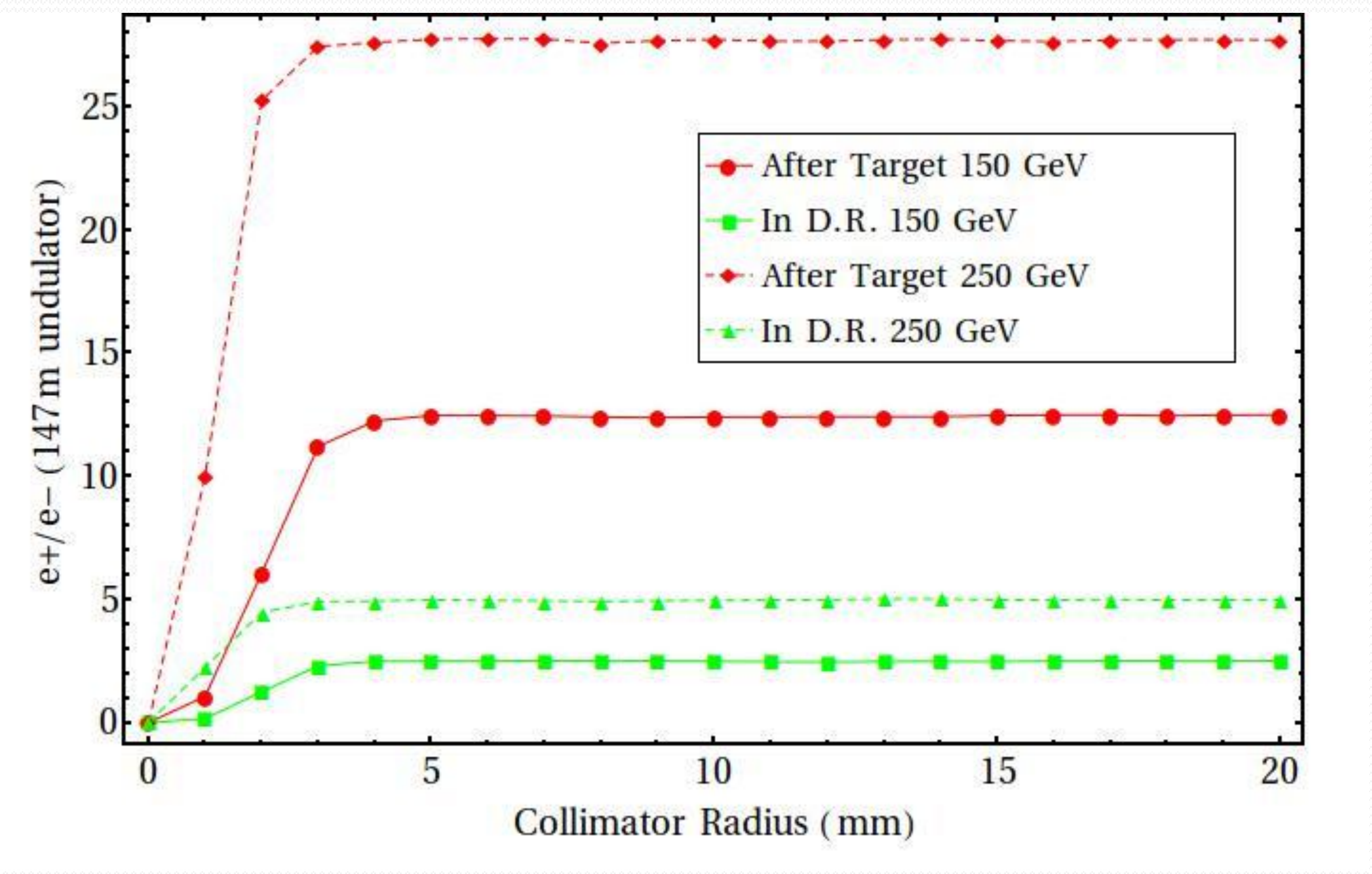
‘Realistic’ Undulator Spectra 150 GeV



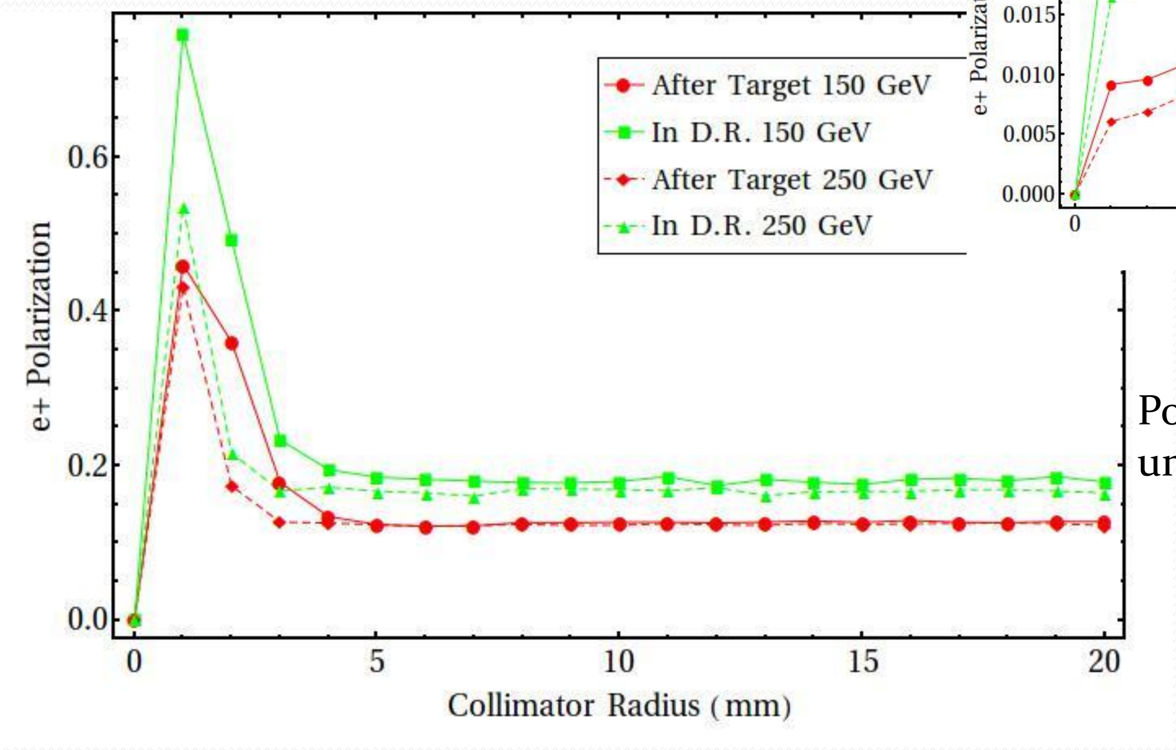
PPS-SIM

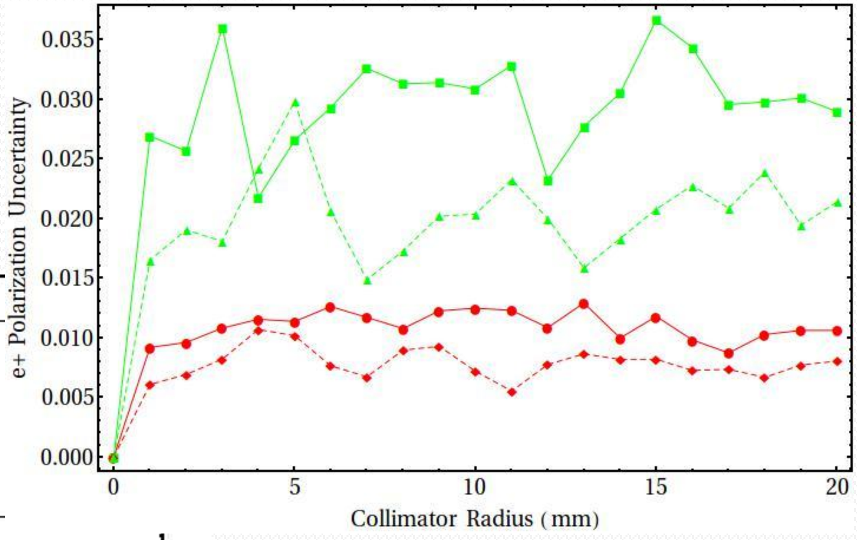
- PPS-SIM is a code originally developed at DESY that utilizes Geant4 to simulate the ILC positron source
  http://pps-sim.desy.de
- PPS-SIM currently simulates from the undulator to the first Capture RF cavity
- Simulations carried out using:
  - 147m long undulator 425m from the target
  - Flux Concentrator B_{ini} = 3.2 T, length = 12.0 cm, distance from target = 2.0 cm

Positron Yield Ideal Undulator



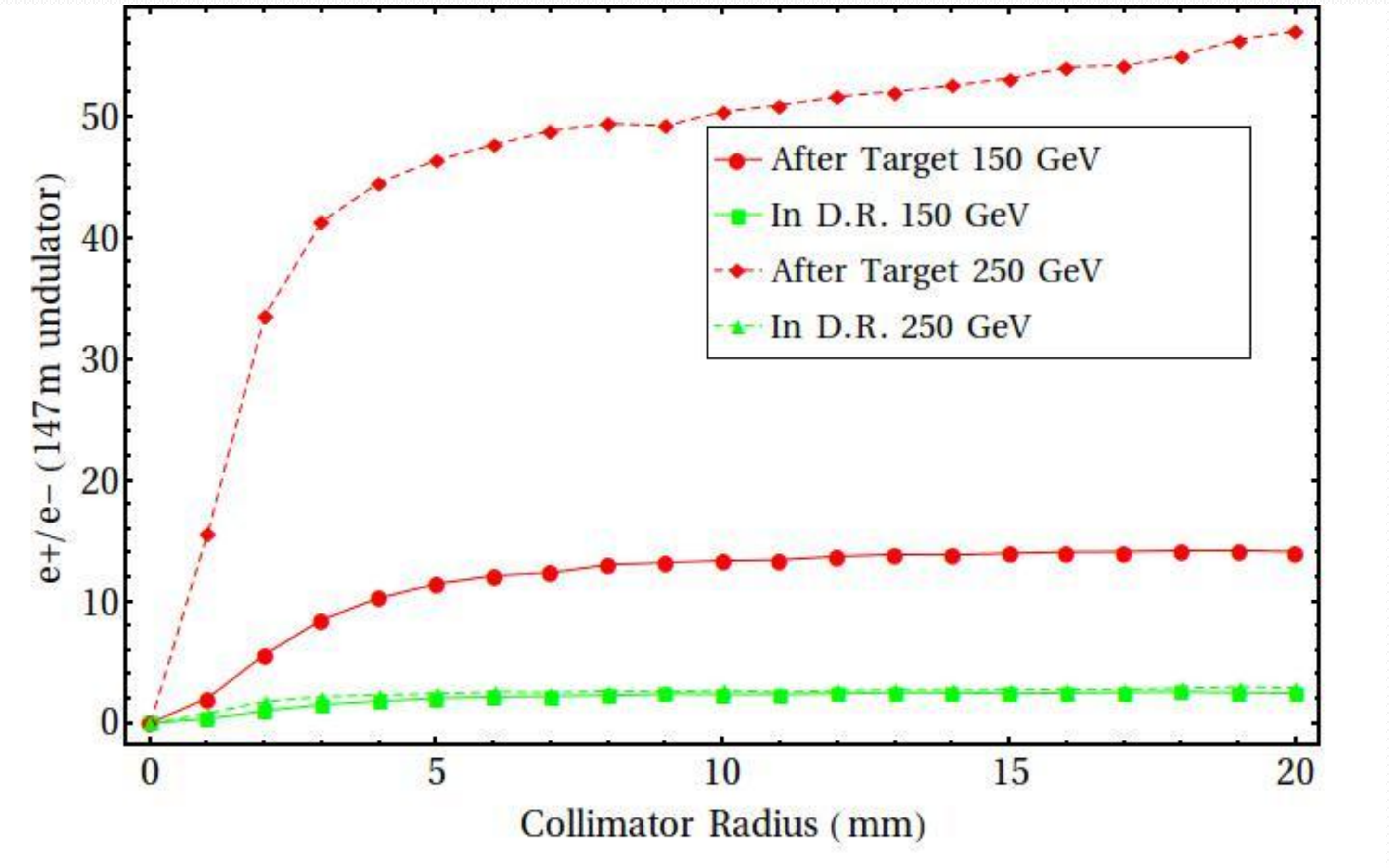
Positron Polarization Ideal Undulator





Polarization uncertainty is numerical uncertainty from PPS-Sim

Positron Yield Real Undulator



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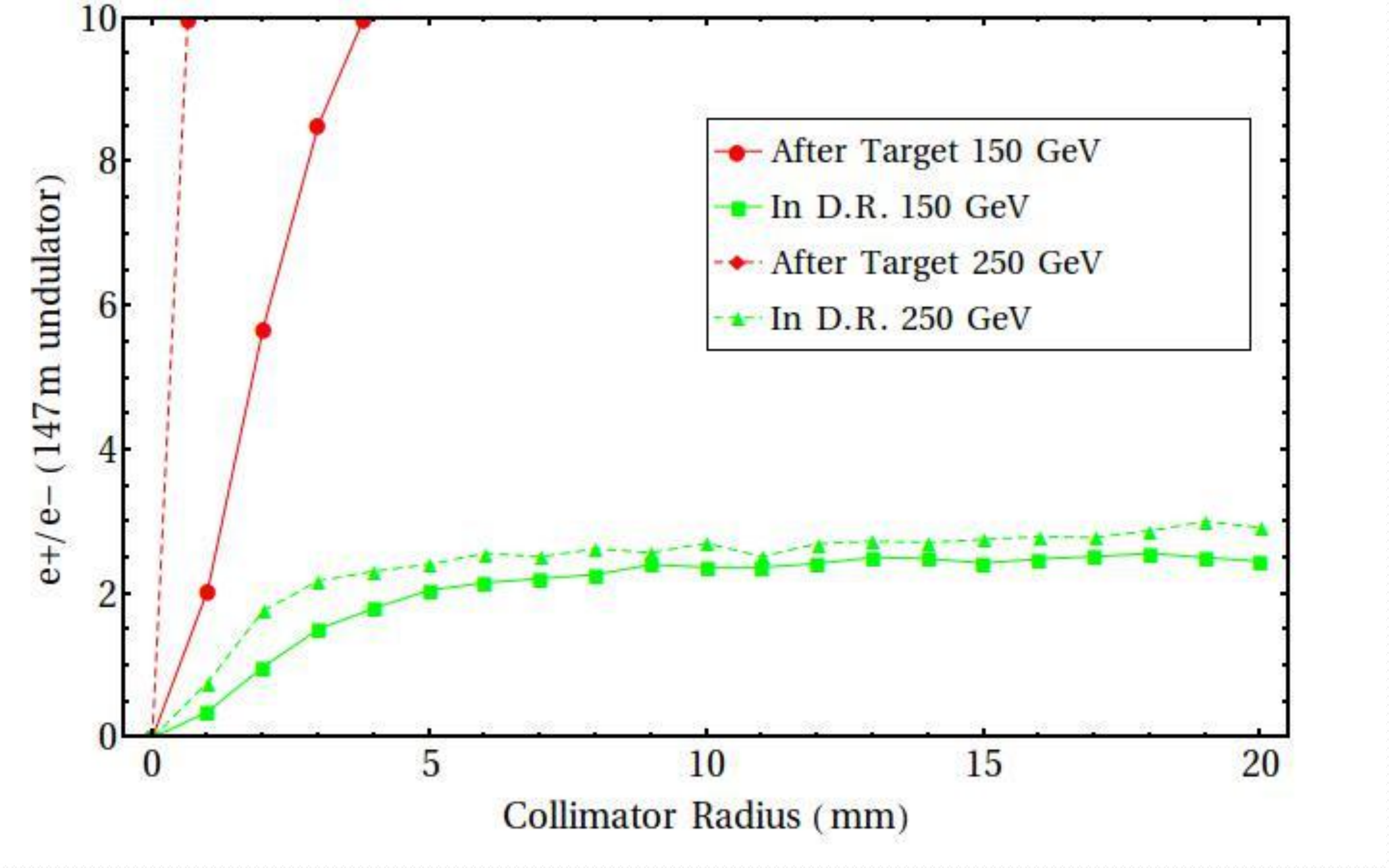

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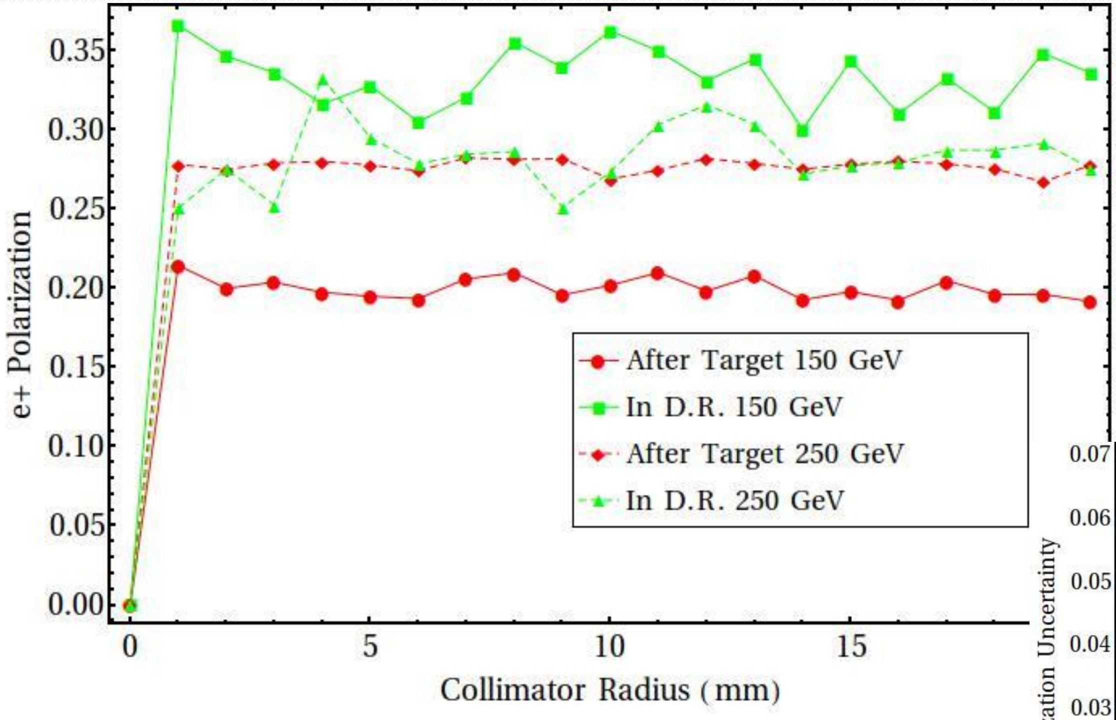

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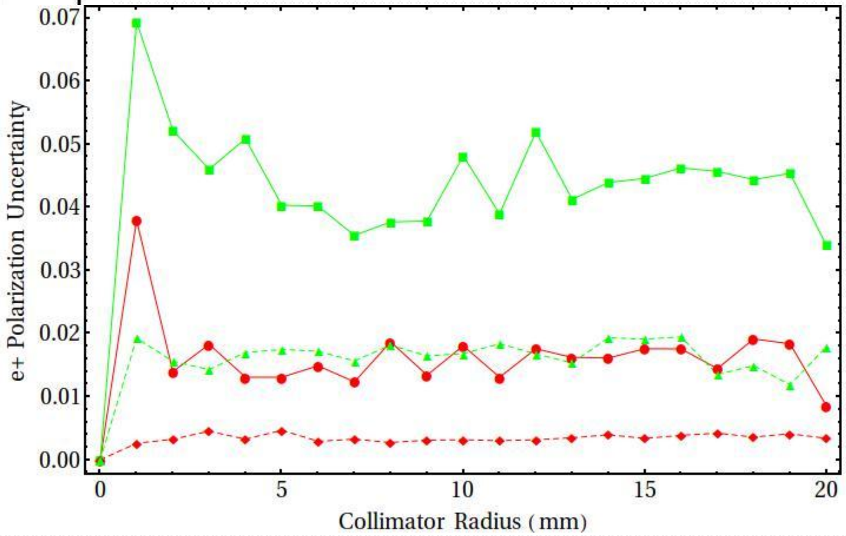
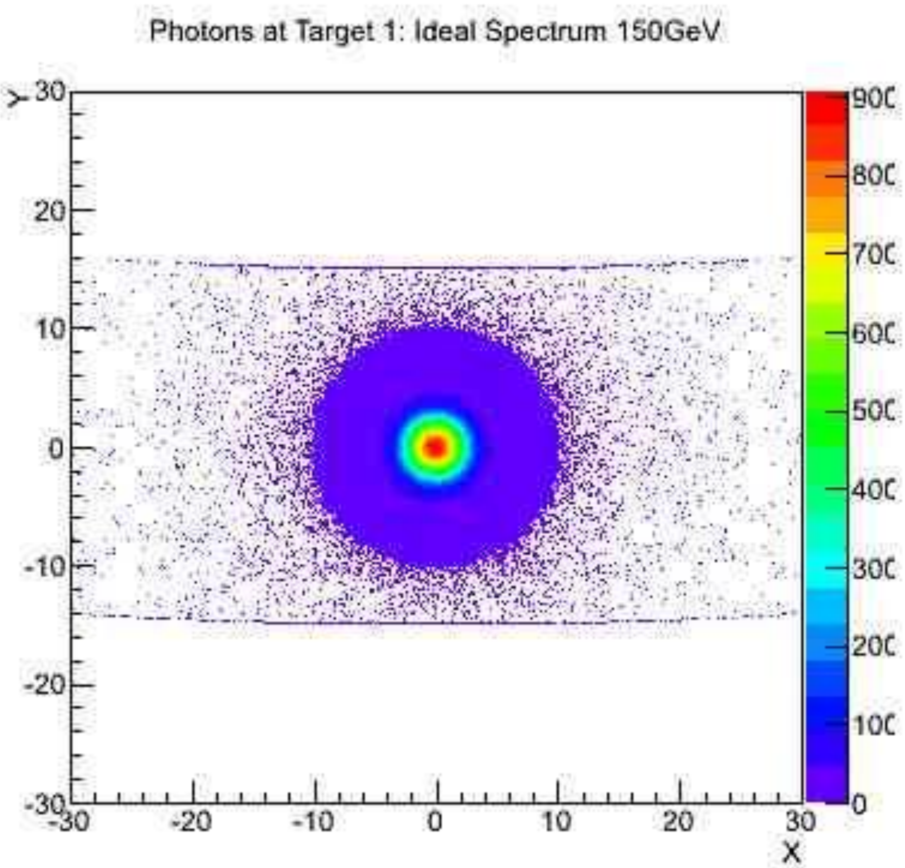
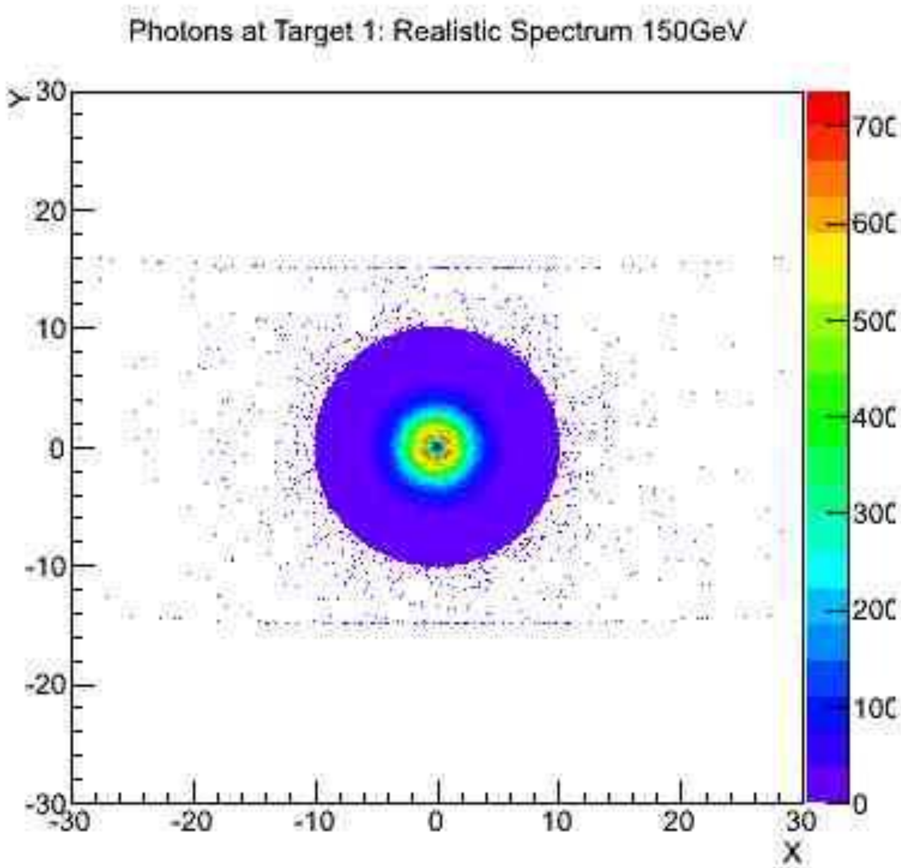


Conclusions of Simulations

- Ideal undulator gives broad agreement with results in TDR – polarization with high collimator radius still lower
- Collimation of 'realistic' spectra increases polarization
- Tight collimation of 'realistic' spectra is not optimal as yield drops rapidly
  - For 150GeV to get 1.5 e+/e- with r=1 mm need undulator length ~ 1000m

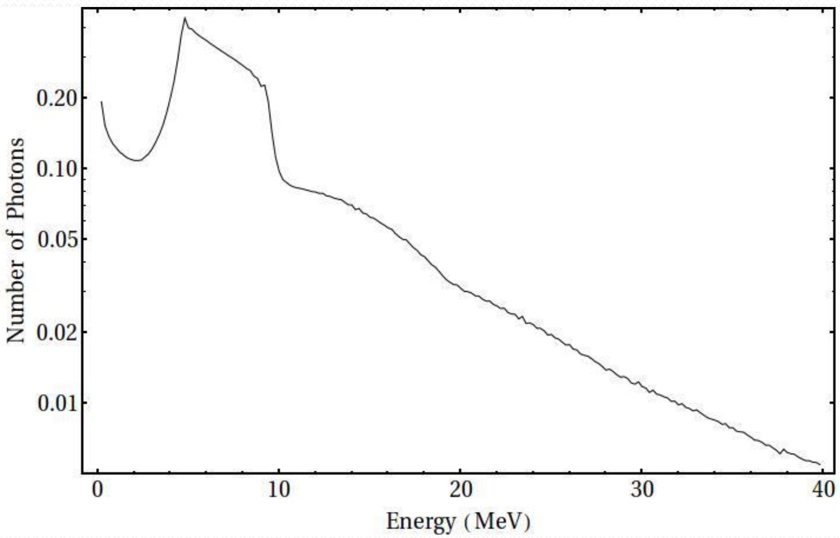
Distribution of Photons Realistic Spectra





Undulator Spectrum to Increase Polarization

- **Preliminary** work into the effects of different field maps on the photon spectra
- Making systematic changes to the undulator produces this photon spectrum
- It produces higher positron polarization whilst maintaining yield
- PPS-Sim results imply positron polarization of about 50% without collimation



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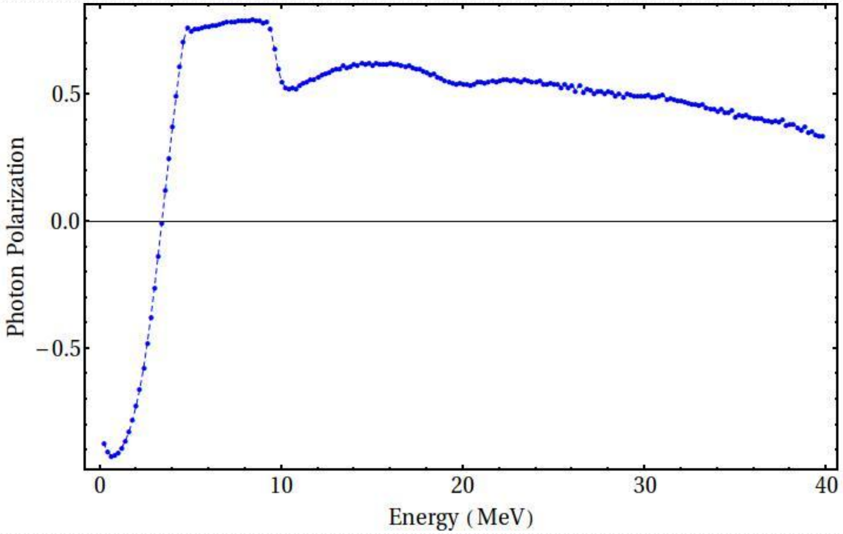

Conclusions

- 'Realistic' spectra simulations suggest higher polarization without collimation
- Tight collimation of a 'realistic' spectra impacts yield significantly
- Possibility to increase polarization with a different undulator configuration
- TDR recommendation:

"Simulations show that small errors in the undulator field will not reduce positron yield in the case of a large collimator aperture. The polarization strategy presented in the TDR assumes field errors in the undulator have a negligible impact on the angular distribution of the photon beam. In practice, the quality of the undulator field will determine the maximum possible polarization achievable for yields above 1.5 e^+/e^-."

Thank you for listening, are there any questions

Back Up Slides

Implementation of Tracking Code

Taken from talk by D. Newton, Synchrotron Radiation Output from the ILC Undulator, ILC Positron Source Workshop 2010

Analytic Tracking Code

- Characterise an arbrtrary magnetic field in terms of it's multipole expansion and generalised gradients to produce an analytical description of field as a fuction of the longitudinal coordinate [a]
- Use the analytical expression in differential algebra or Lie algebra code to generate a Taylor or Lie (symplectic) map for the dynamics in the magnet.
- Evaluate the analytical expressions to perform a numerical integration giving a fast particle tracking code to describe the evolution of the canonical coordinates within the magnet.
- The C++ code that has been has been written has a modular structure which facilitates extending the code
- A Synchrotron Radiation Module is being implemented which calculates the synchrotron emission from a particle into an arbitrary observation point
- eg ILC Helical undulator

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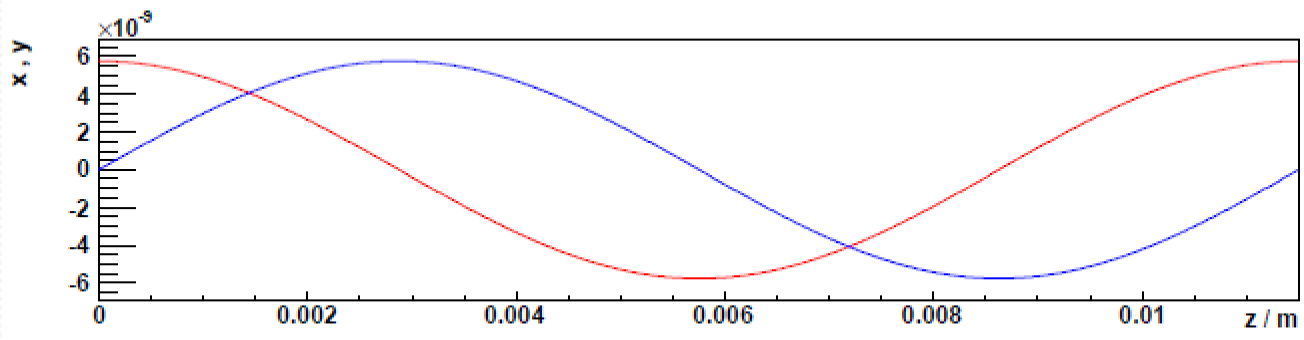
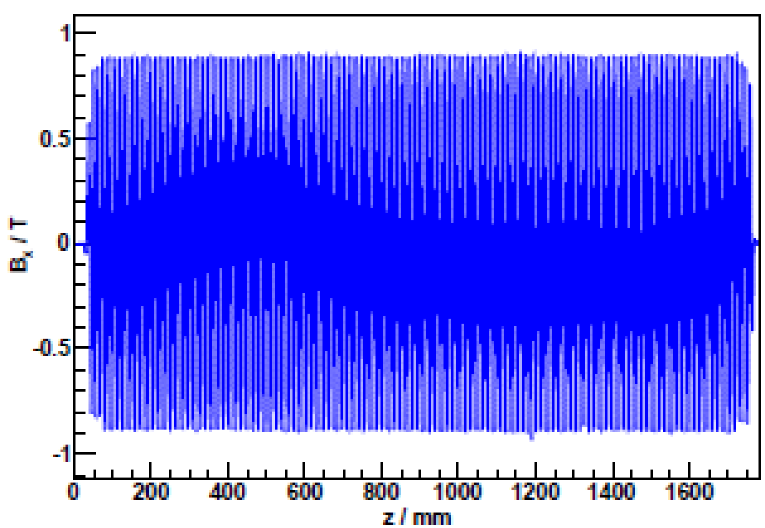
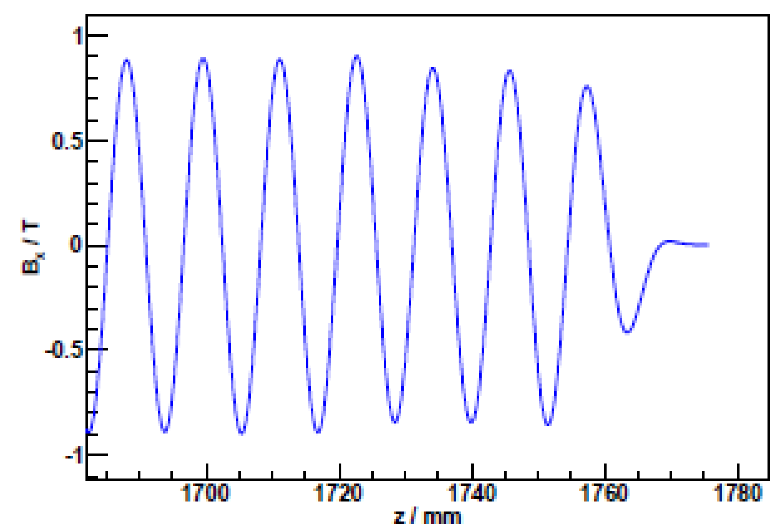
[a] Venturini and Dragt

Tracking through Field Maps

Taken from Synchrotron Radiation Output from the ILC undulator talk by D. Newton at ILC Positron Source Workshop 2010







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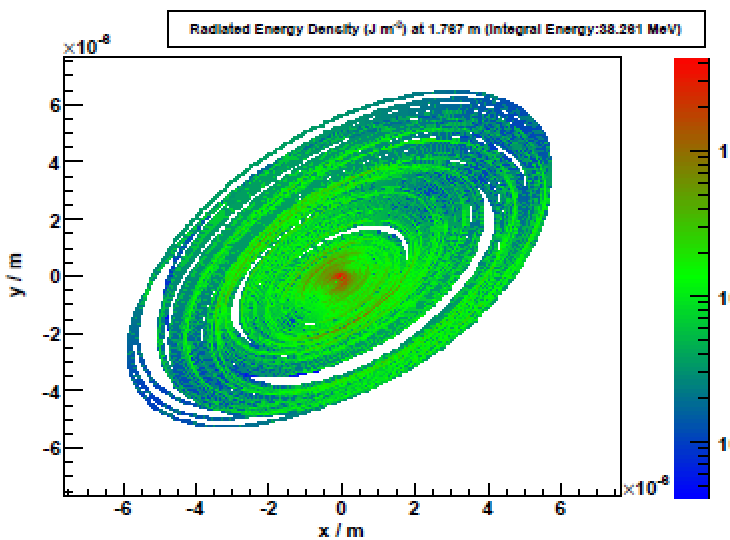

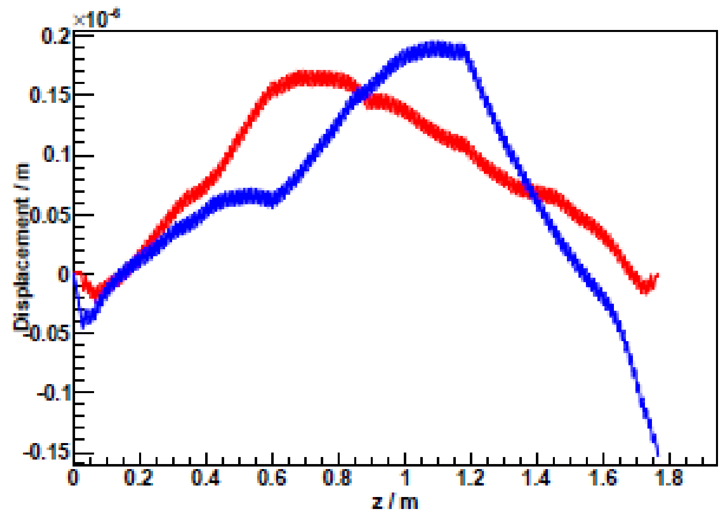

- These plots are for one of the 2m undulator prototypes constructed at RAL
- One shows the power radiated at the end and the other shows the trajectory through the undulator in x and y for a beam that enters at a correction angle
- The angular deviations off axis are of the order 1 μrad which when compared with k/γ (3.13 μrad for a drive beam energy of 150 GeV) are significant