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Analysis of Synchrotron Radiation using SYNRAD3D and plans to create a photoemission model

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ECLOUD10

October 11, 2010

U.S. Department of Energy

UChicago Argonne LLC

Office of Science
U.S. DEPARTMENT OF ENERGY

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Thanks to:

- My advisors
  - K. Harkay and A. Garfinkel
- The writers of SYNRAD3D
  - D. Sagan and G. Dugan
- K. Sonnad for converting the ILC lattice files to a BMAD readable file
- The rest of the ECLOUD ILC Group
  - J. Calvey
  - J. Crittendon

Outline

- Motivation for the simulations
- Introduction to SYNRAD3D
- ILC Damping Ring Analysis with reflections
- Retarding Field Analyzer analysis
- Future work

Motivation for this work

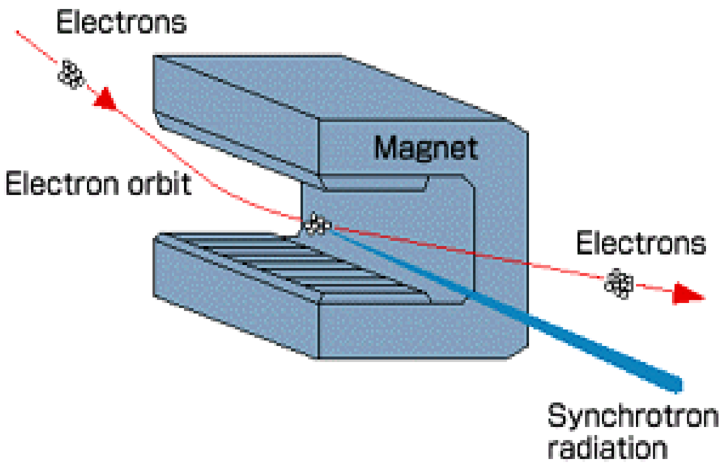
- SYNRAD3D provides a 3-dimensional model of synchrotron radiation, allowing a study of radiation reflection around the perimeter of the chamber as a function of s.
  - This will allow us to study various antechamber designs and other photon absorbers
- Final goal is to have a photoelectron model which includes photoemission energy
  - Will be able to compare the photoemission in various lattice elements such as dipoles and wigglers to RFA data.

SYNRAD3D

- Extension of SYNRAD (2D)
- Uses the Bmad Accelerator library
  - Better methodical accelerator design

- Written by David Sagan and Gerry Dugan

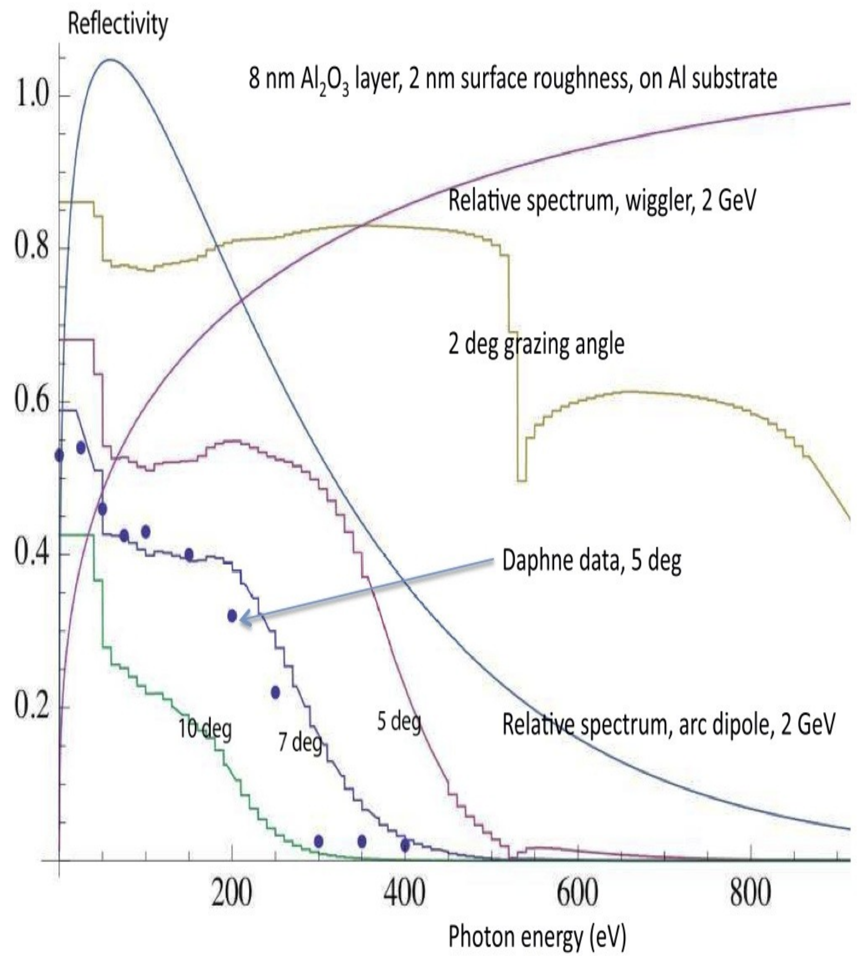
- Photon production and propagation code



Courtesy: http://www.jaea.go.jp

SYNRAD3D cont'

- Synrad3d is a photon tracking program
  - Uses radiation integrals to to generate photons
  - Follows the photons as they move in the chamber
- Uses photon reflectivity to determine if the photon is reflected or absorbed
- Currently all scatters are specular and elastic
  - This can be expanded later to diffuse scattering



Data from http://henke.lbl.gov/optical_constants/mirror2.html
Graph Courtesy G. Dugan

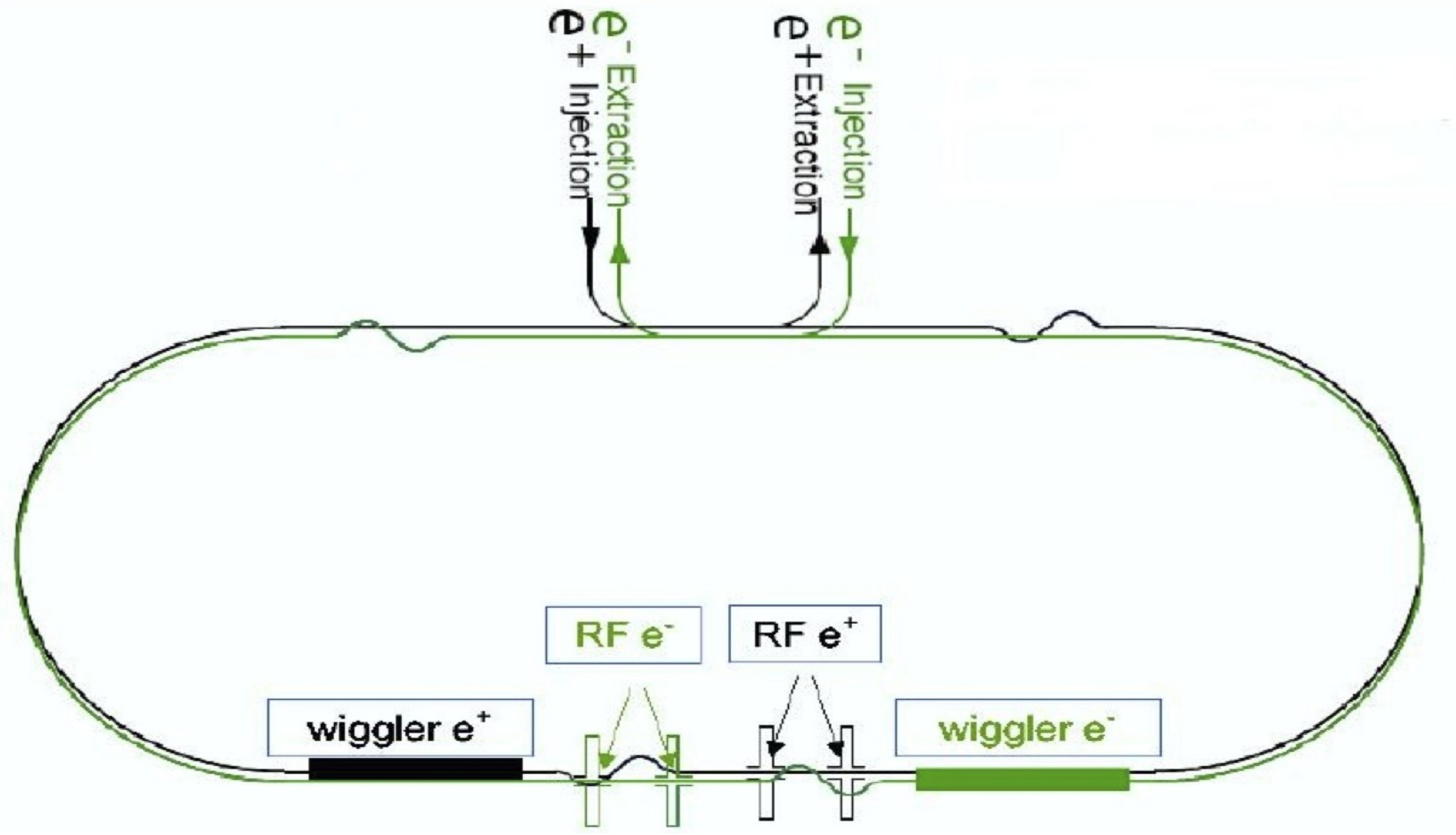
International Linear Collider (ILC)

- Using a smaller ring would have fewer elements and cost less.
  - Concerns for an increase in EC problems

- SYNRAD3D can test varying models for antechamber design, to optimize their effectiveness in reducing photon scattering.

- Since ILC is still under design it is important to understand and reduce potential problems before the accelerator is built. Simulations are a good way to test these new accelerators.

ILC Damping Rings

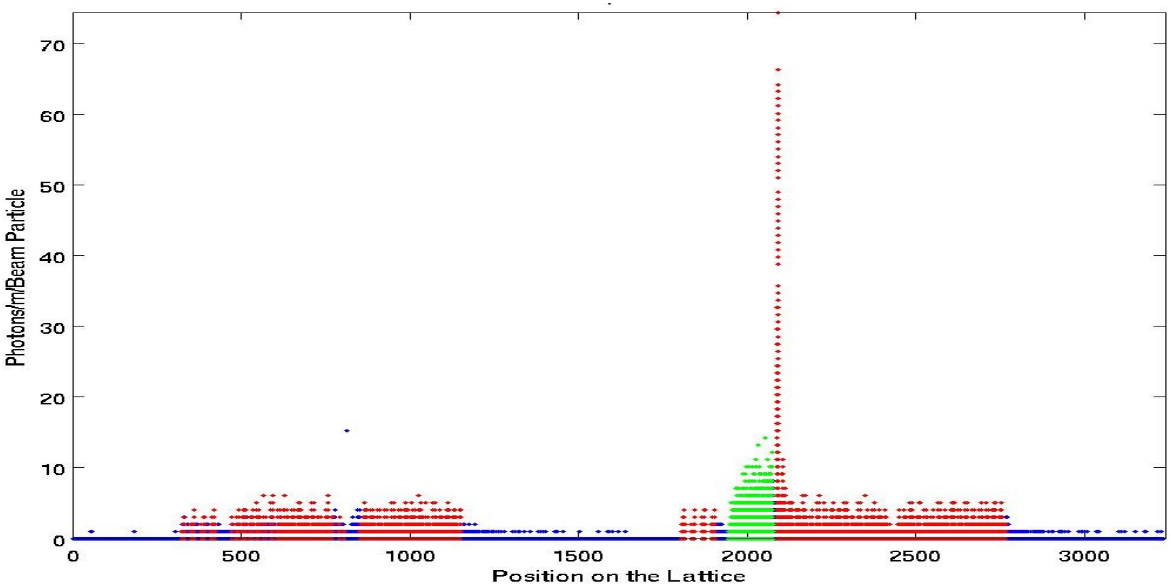


ILC Damping Rings Simulation for DSB3

- Normalization
  - photons/m/beam particle = N_L*I/L
  - For these graphs L= .01m
- Wigglers are modeled as alternating dipoles and drifts.

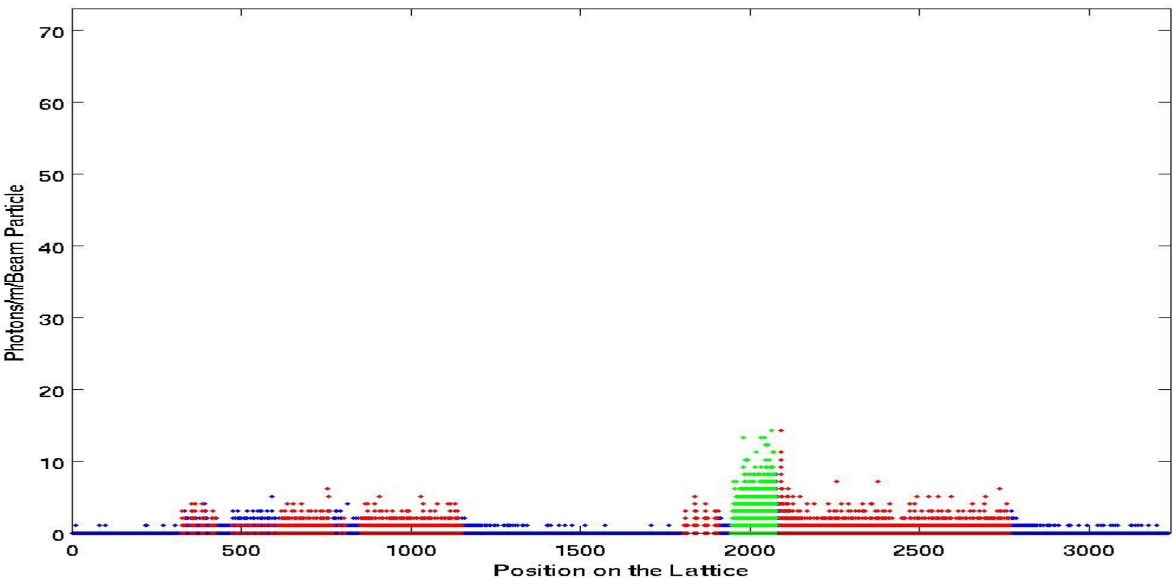
- For the 3.2 km ring
- There were 101,147 photons generated.
- Require energy > 4 eV
- Reflectivity turned on

DSB3/ 3.2 km Damping Ring

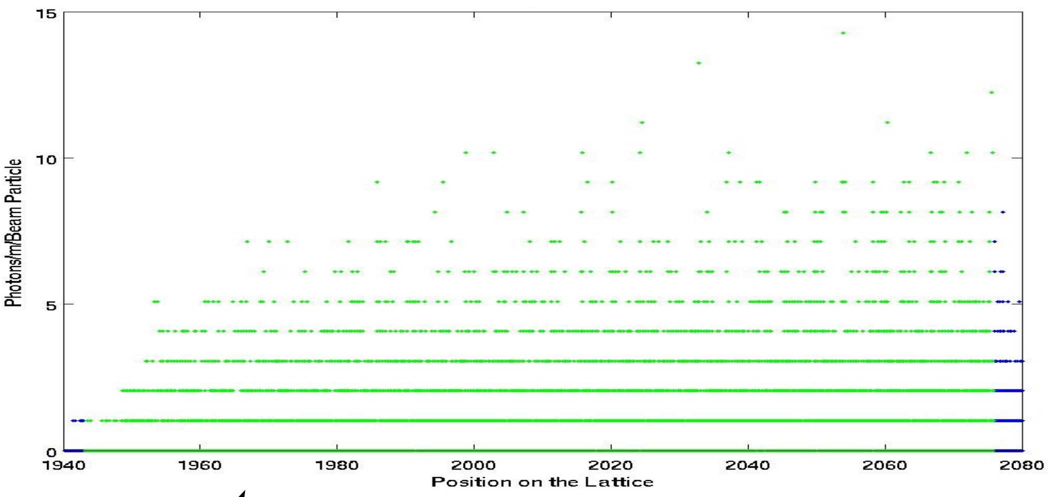


Outside of the chamber wall

Inside of the chamber wall



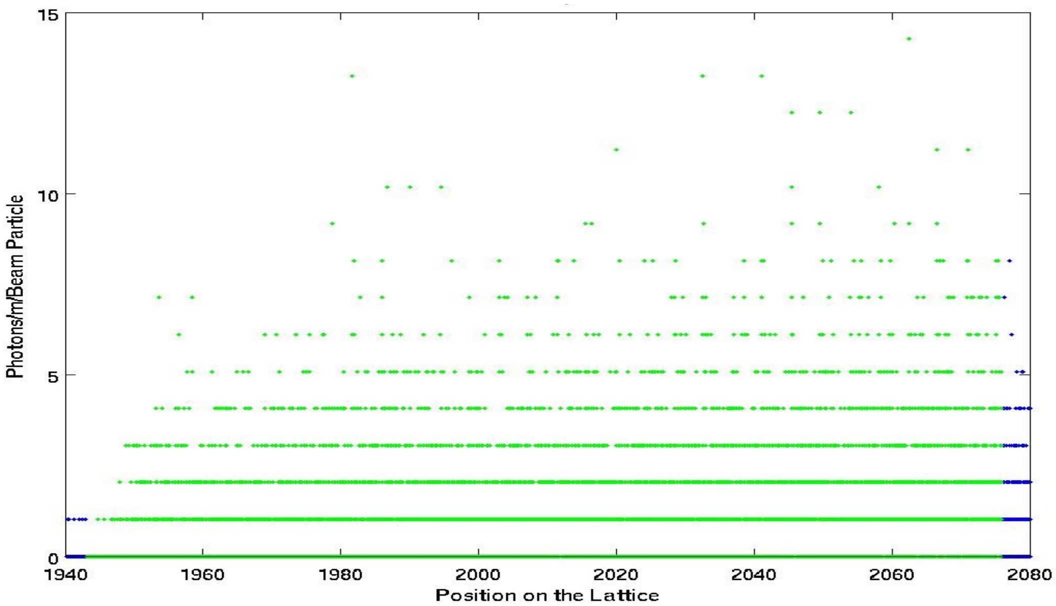
Wiggler section of the DSB3/3.2 km Ring



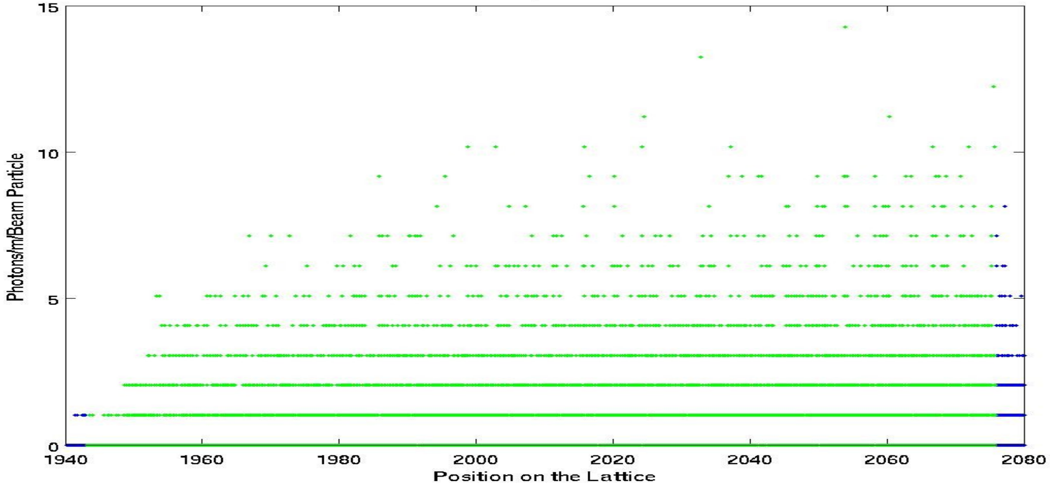
Throughout the wigglers there are high energy photons absorbed on both the inner and outer chamber walls

The outer wall of the chamber

The inner wall of the chamber

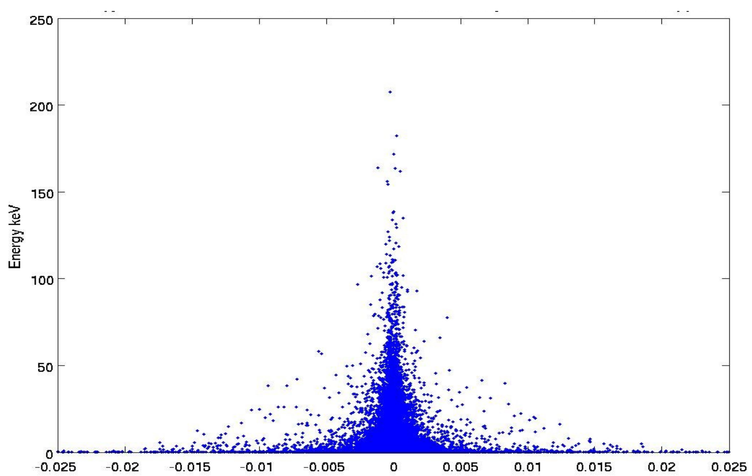


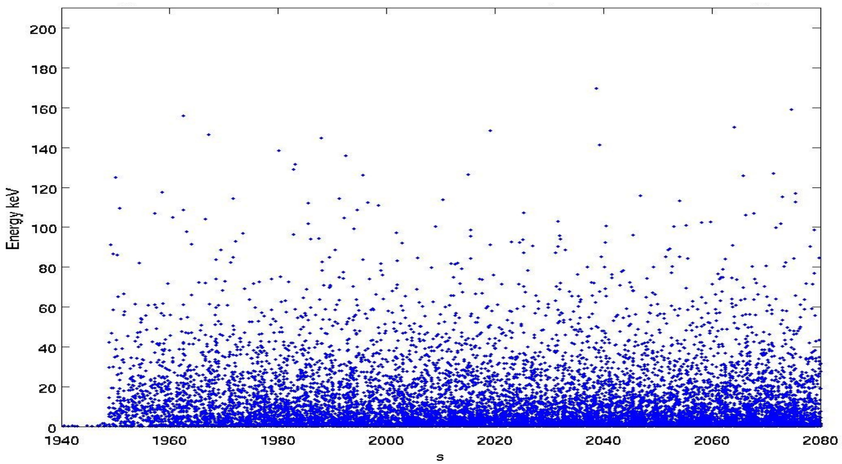
3.2 km Ring Wiggler section



Throughout the wigglers there are high energy photons on both the inner and outer chamber walls

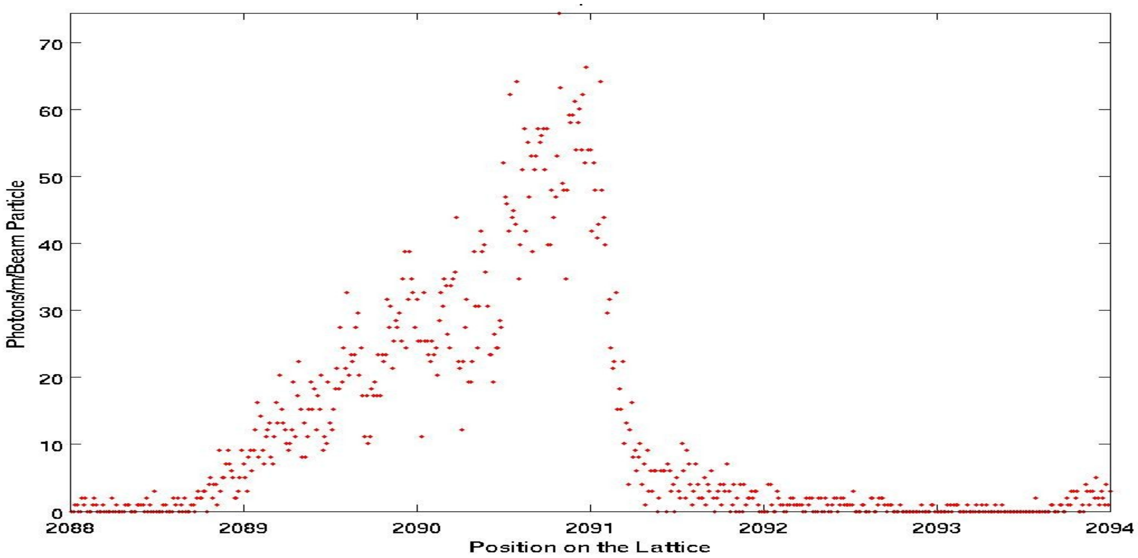
Energy distributed around the perimeter.





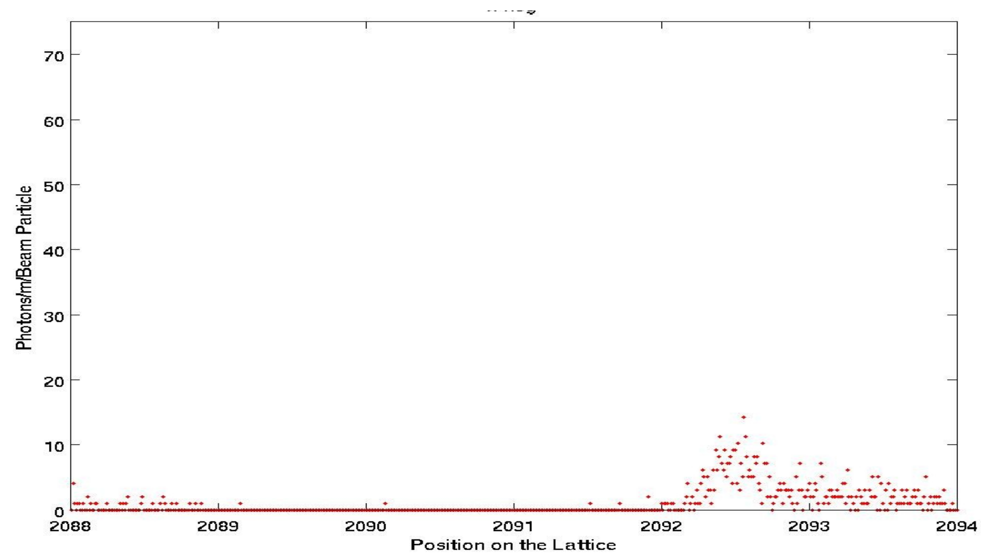
Energy distribution as a function of s.

Photon spike in the DSB3/3.2km ring

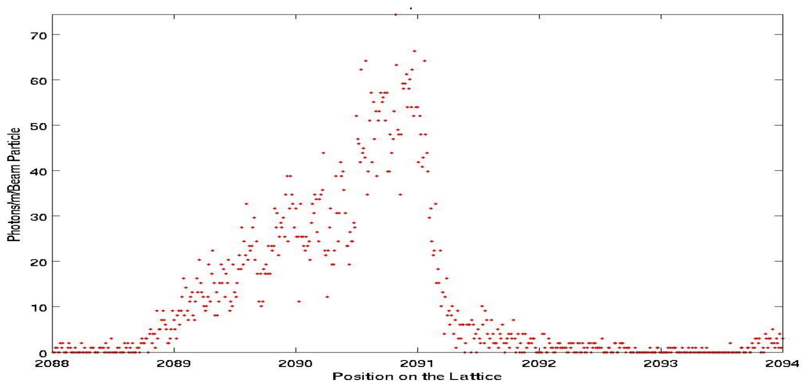


Outside of the chamber wall.

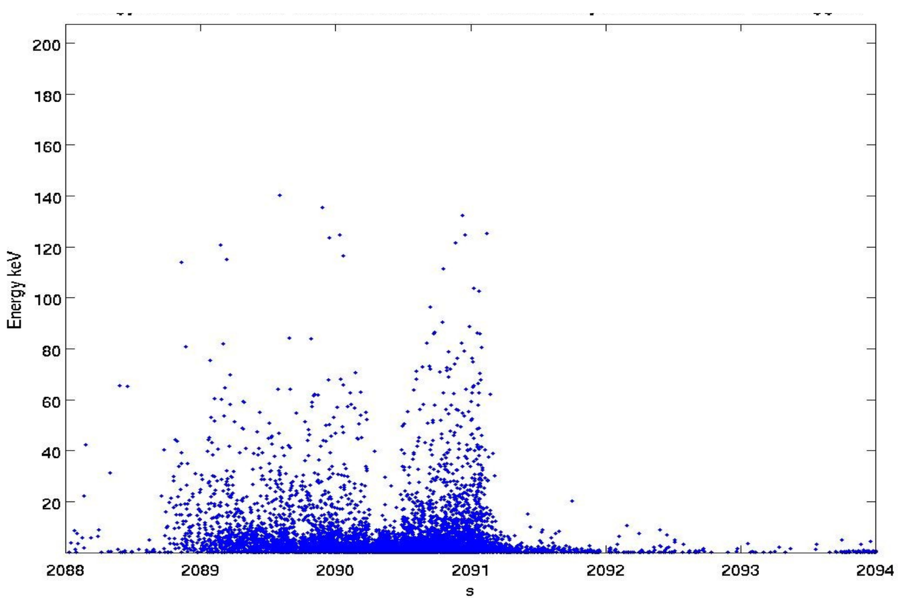
Inside of the chamber wall



Energy Distributed

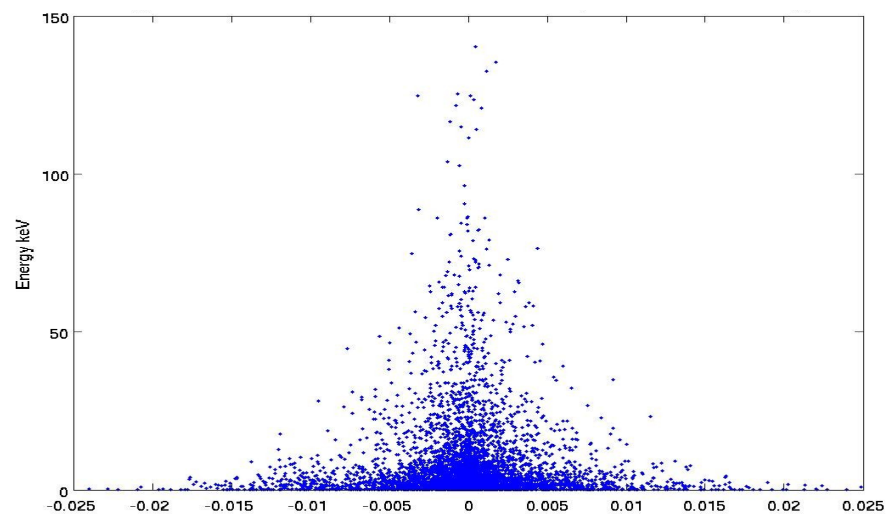


The highest energy photons are absorbed by the outer chamber wall

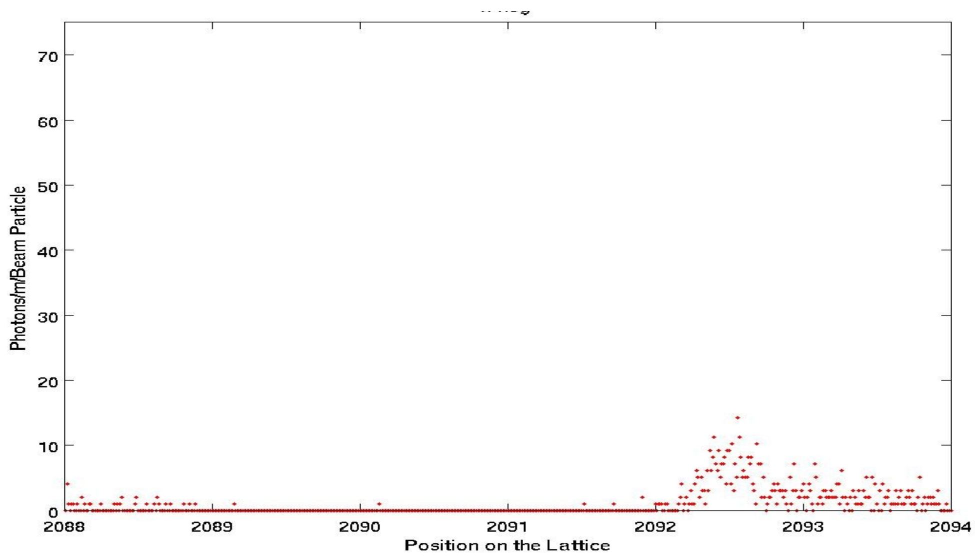


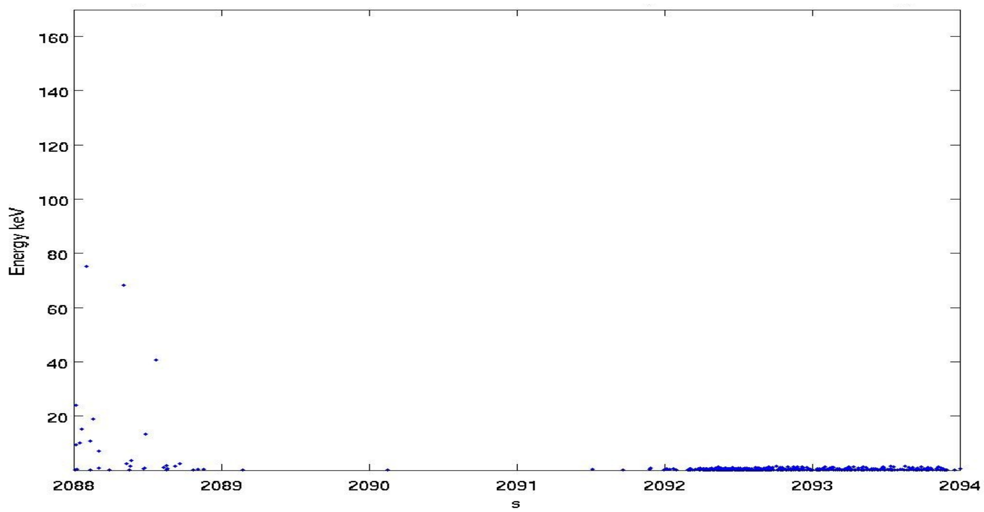
Energy distributed on the outer chamber wall by the radiation created in the wigglers

The higher energy photons move along the x-axis and would enter the antechamber



Energy Distribution on the inside of the chamber





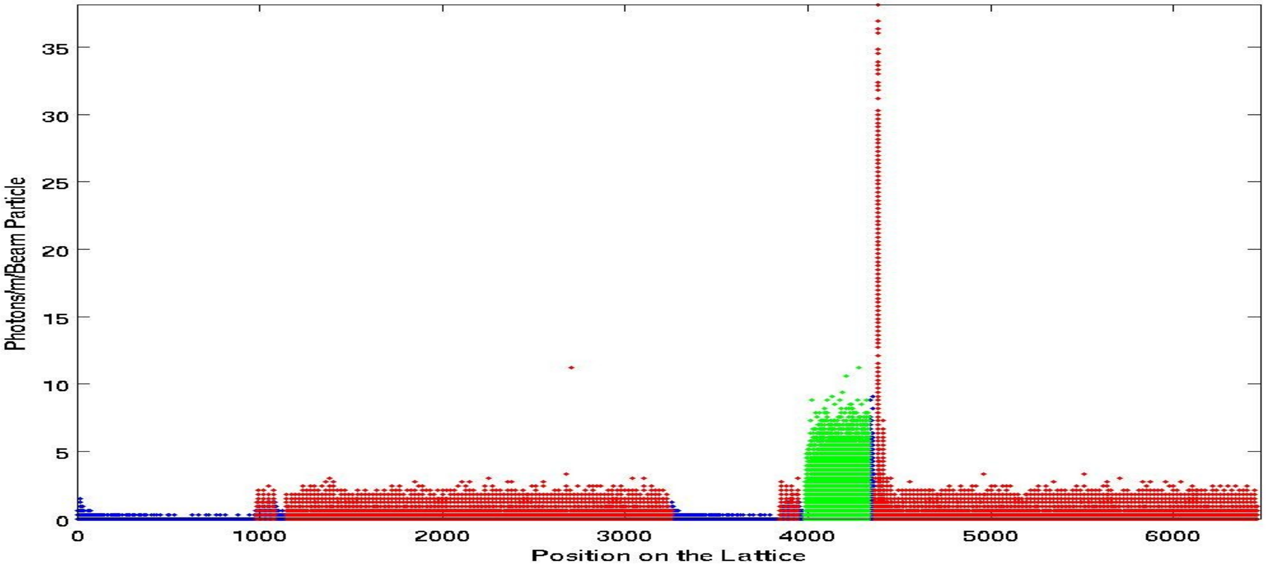
The low energy photons reflected off the chamber wall and were absorbed on the inside of the chamber

ILC Damping Ring Simulation for DCO4

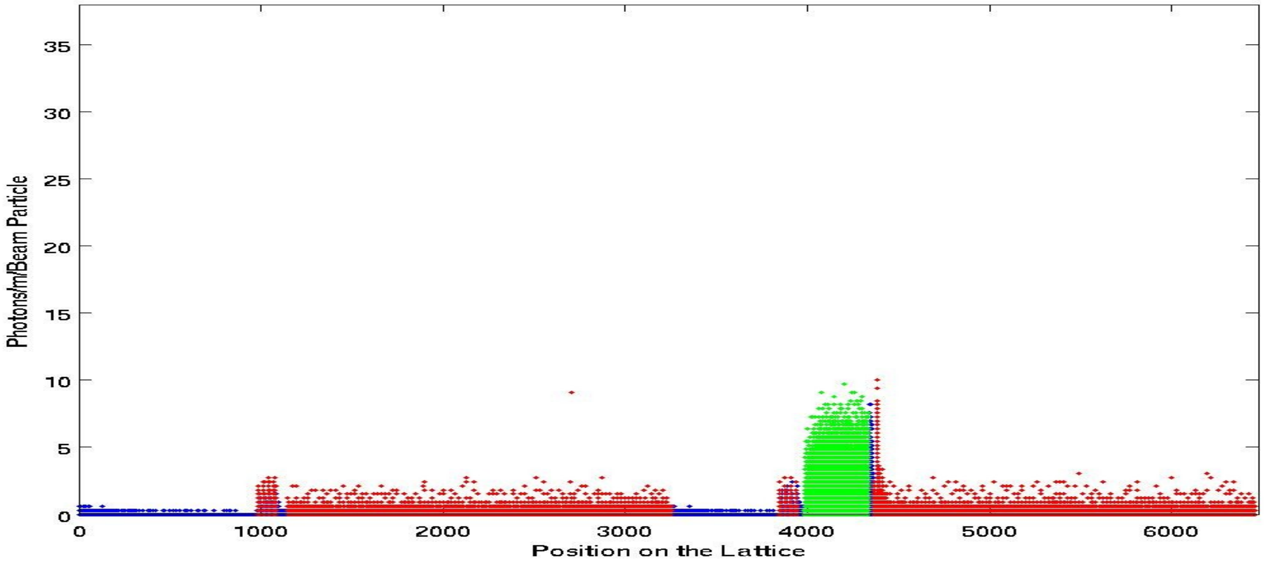
- Using the same normalization
  - photons/m/beam particle = N_L*I/L
  - For these graphs L= .01m
- Wigglers are modeled as alternating dipoles and drifts

- For the 6.4km ring
- Choose 559,417 photons to be generated to directly compare with the 3.2 km ring.
- Require energy > 4 eV
- Reflectivity turned on

DCO4/ 6.4km Damping Ring

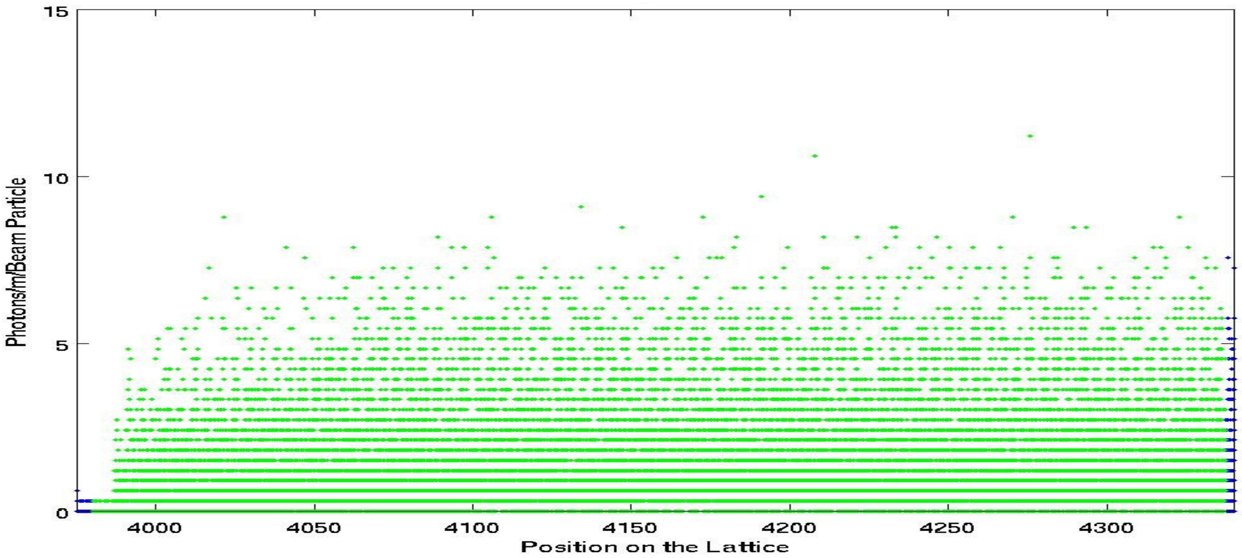


Outside of the chamber wall



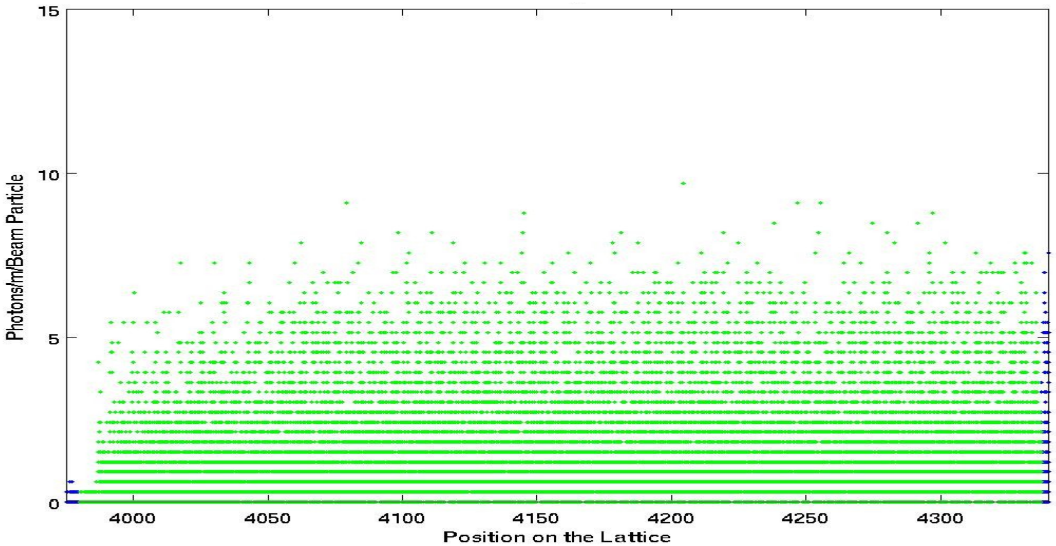
Inside of the chamber wall

Wigglers



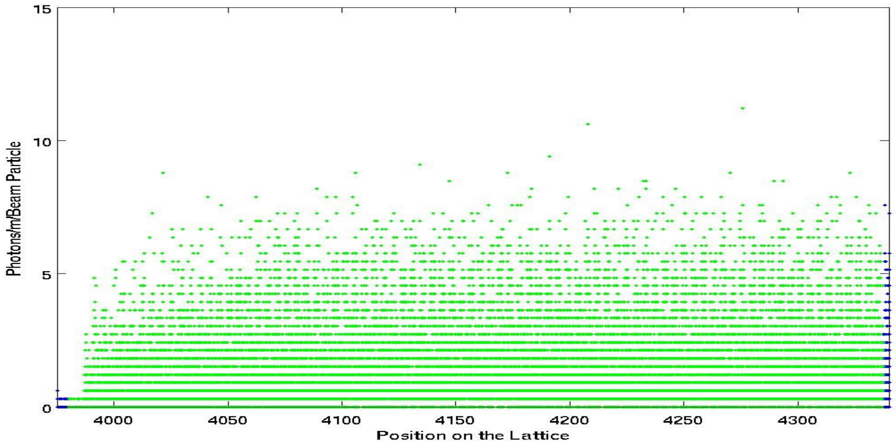
The photon flux on the outside of the chamber in the wiggler section

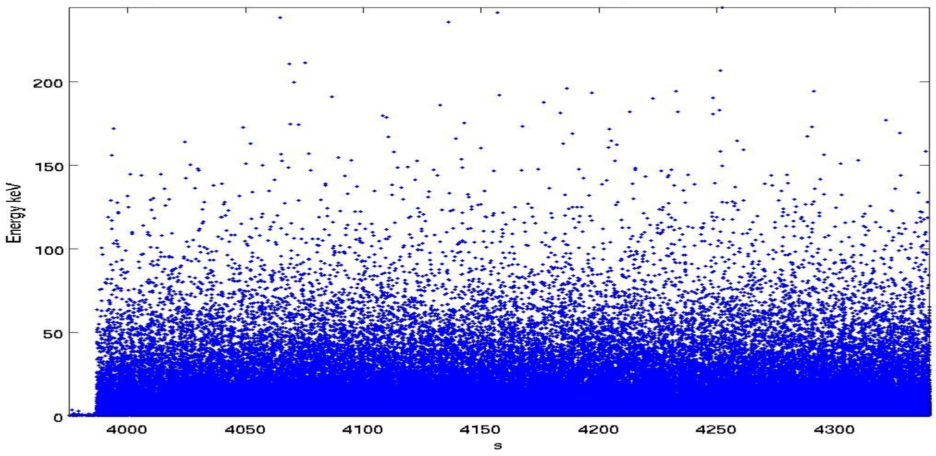
The inside chamber wall flux



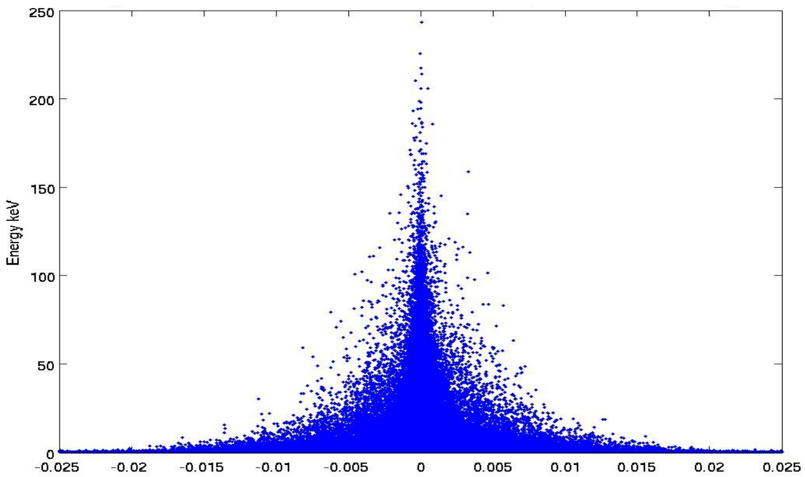
The outside chamber wall flux

Energy Distribution in the wigglers

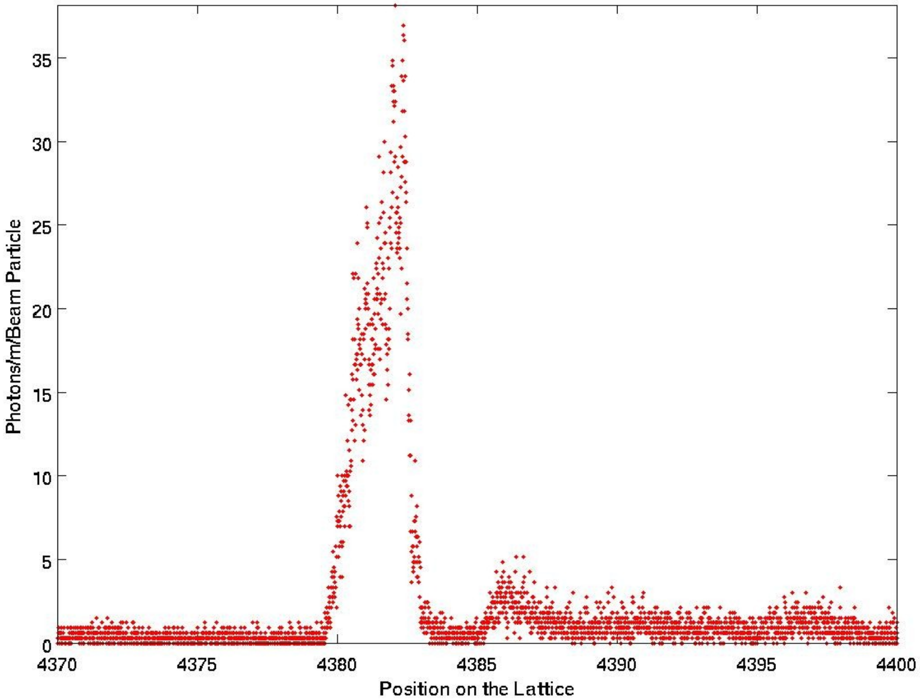




The high energy photons have a small scattering angle and are absorbed where the antechamber would be.

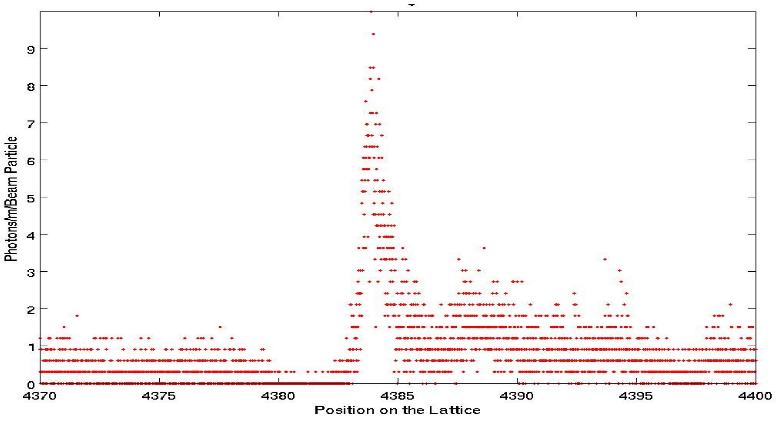


Flux spike after the wiggler

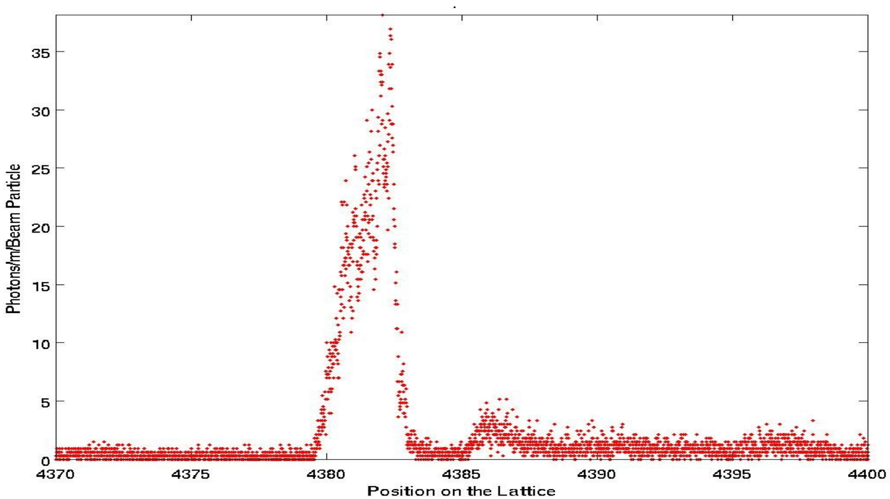


The photon flux for the larger 6.4km ring is half what is was for the 3.2 km ring at the spike.

The photons that weren't absorbed on the outside of the chamber create a flux on the inside of the chamber on same order as the wigglers.

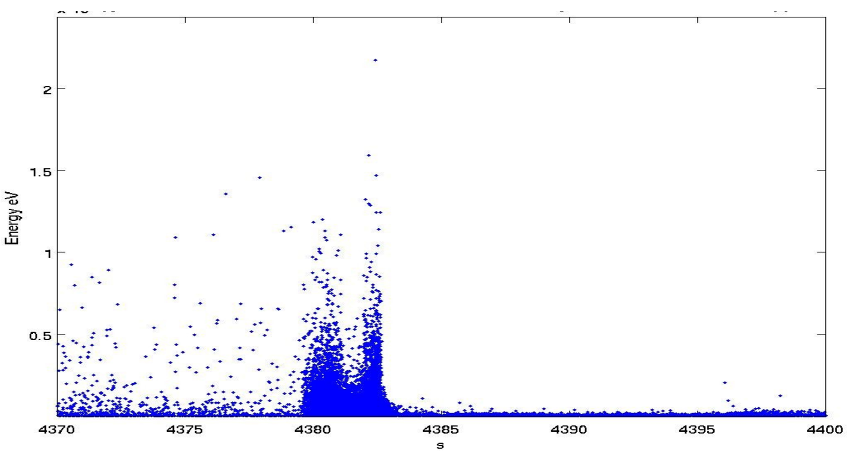


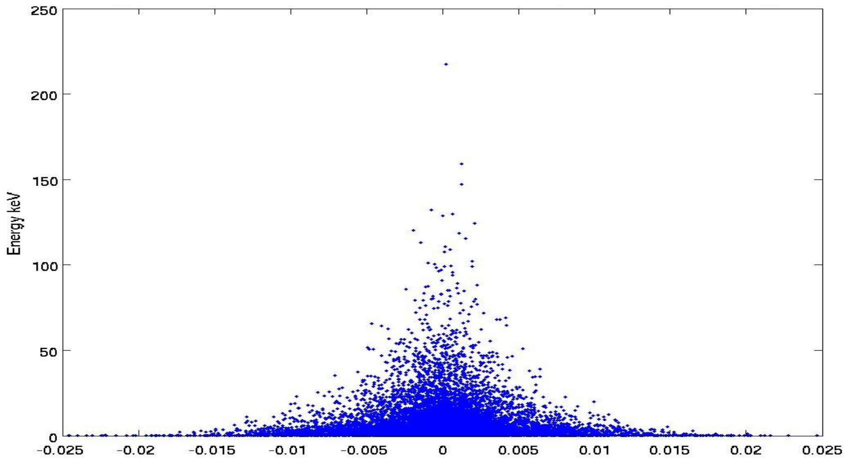
Energy distribution



Energy distributed on the outer chamber wall by the radiation created in the wigglers

The highest energy photons are absorbed by the outer chamber wall

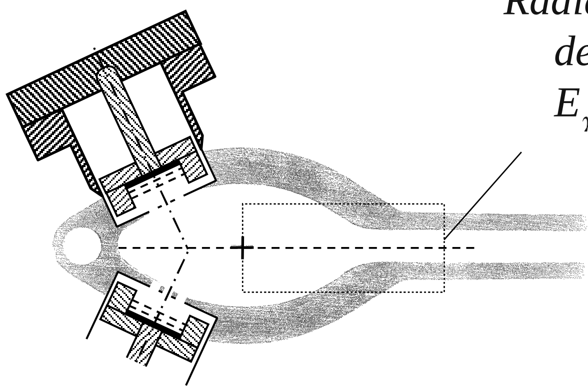




The higher energy photons move along the x-axis and would enter the antechamber

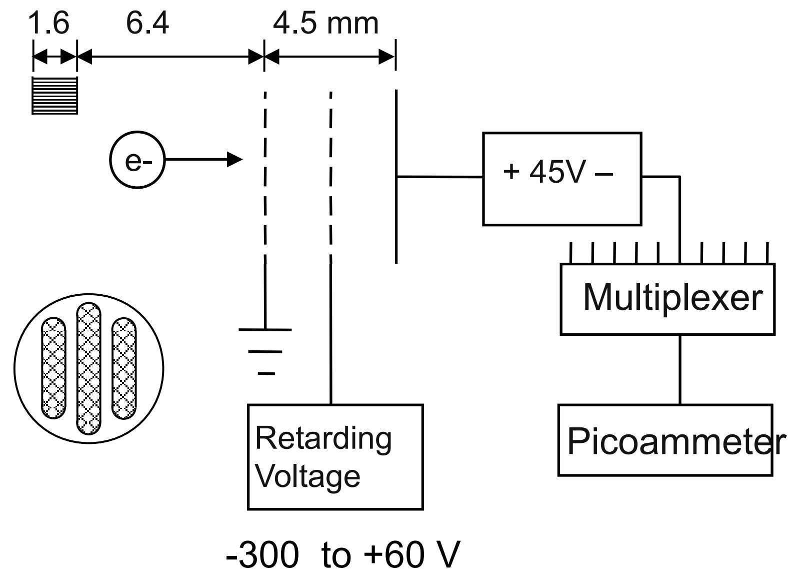
Retarding field analyzer (RFA) (R.Rosenberg)

RFA measures distribution of EC colliding with walls, trans. eff. 50%

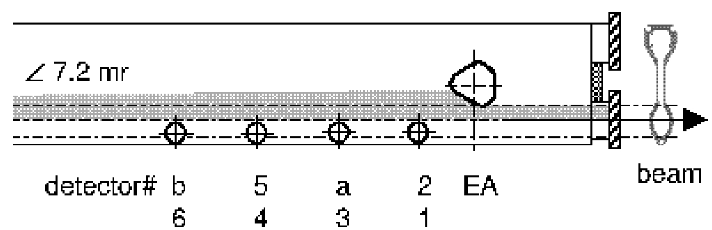


Radiation fan at det. #6 for $E_\gamma \geq 4$ eV

mounting on APS Al chamber ***behind vacuum penetration*** *(42* x *21 mm half-dim.)*



mounting on 5-m-long APS chamber, top view, showing radiation fan from downstream bending magnet. Pressure measured locally (3.5 m upstream of EA).

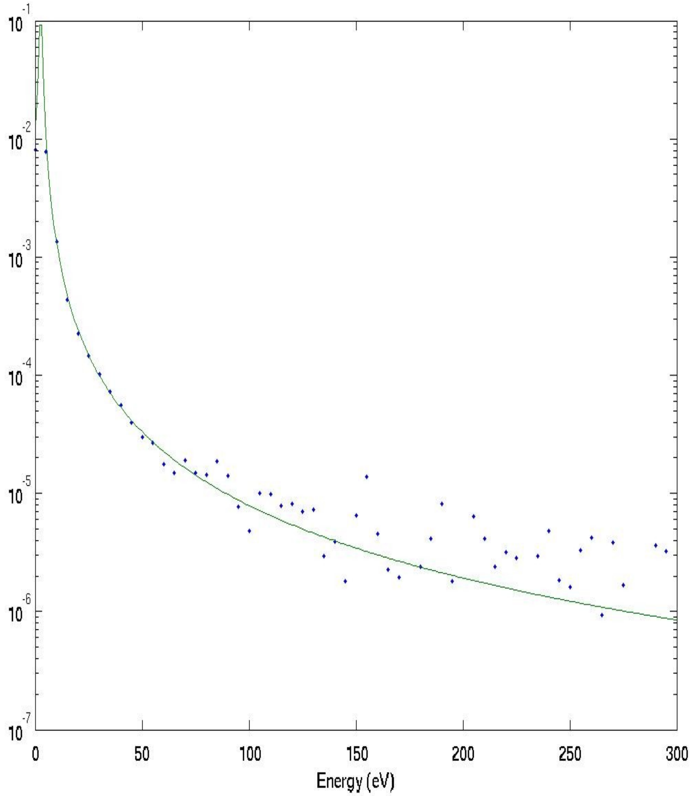


Fit for Detector 6

10 bunches 2 mA per bunch, 360nsec spacing

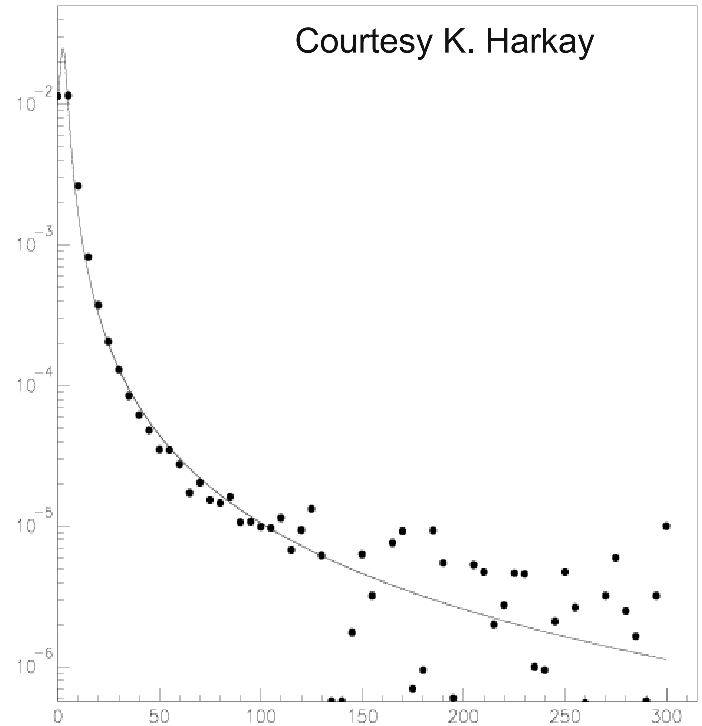
Detector 6 is 0.75m from the end absorber (EA) and has a wide bunch spacing so there should be few secondary electrons.

Electron Beam



C_1=0.1, Γ=1.5eV, <E>= 2.5eV

Positron Beam



C_1=0.05, Γ=4eV, <E>= 2.5eV

With no secondary electrons the data fits a lorentzian

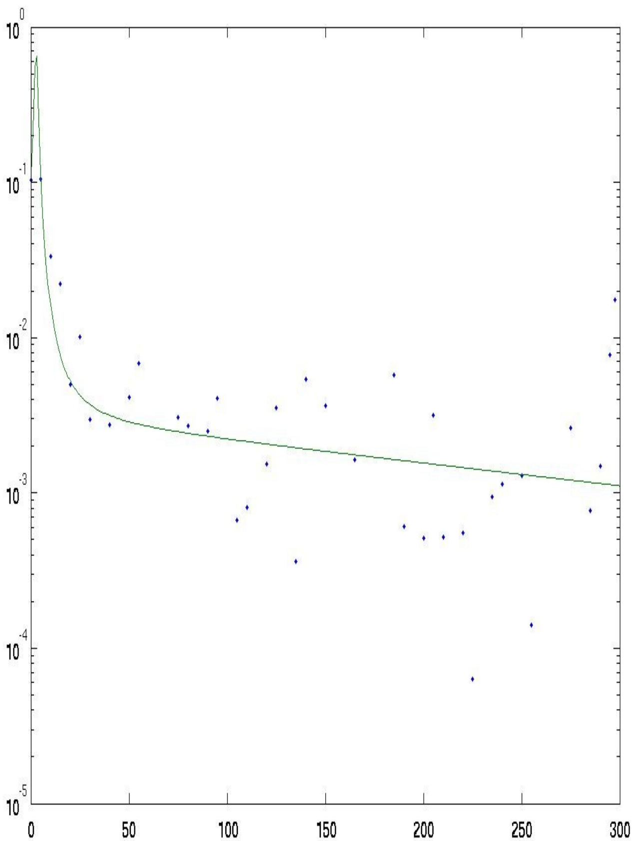
$$L = \frac{\frac{C_1\Gamma}{2}}{(\frac{\Gamma}{2})^2 + (E - \langle E \rangle)^2}$$

Fit for detector 1

10 bunches 2 mA per bunch, 360nsec spacing

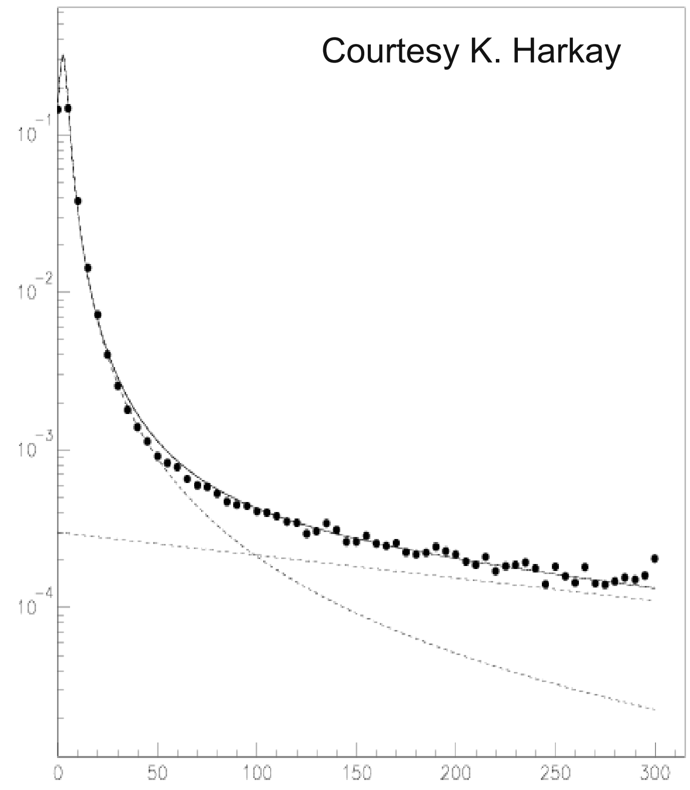
Detector 1 is 0.1m from the EA. This produces high energy photoelectrons that are collected.

Electron Beam



C_1=0.75, Γ=2eV, <E>= 2.6eV, C_2=0.003, C_3=300eV

Positron Beam



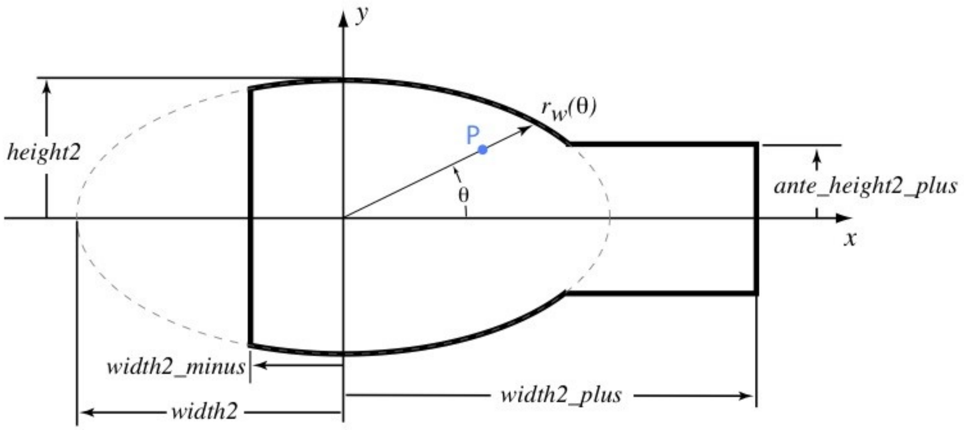
C_1=0.8, Γ=5eV, <E>= 2.5eV, C_2=0.003, C_3=300eV

The tail of the data no longer fits a lorentzian, and so the fit is now added to an exponential function

$$L = \frac{\frac{C_1 \Gamma}{2}}{\left(\frac{\Gamma}{2}\right)^2 + (E - \langle E \rangle)^2} + C_2 e^{-\frac{E}{C_3}}$$

Addition of the Antechamber

- The antechamber still needs to be validated
- The validation process is under discussion with David Sagan
  - Using data from APS for this, since I have access to the accelerator
- SYNRAD3D defines the antechamber as a rectangular addition to the basic chamber wall.



Courtesy: SYNRAD3D Manual

Photoelectron model

- Using simulated synchrotron radiation and RFA data from APS a photoemission model will be created.
- In addition to data and simulations, literature on X-ray photoemission spectroscopy (XPS) will be used.
- The photoemission model will be added into SYNRAD3D

Conclusion / Summary

- Now have a working 3D model of synchrotron radiation production and propagation in the accelerator chamber.
- Simulations are are consistent with what we expect
  - High energy photons are produced in the wigglers and have a small opening angle
- Once antechambers are validated various, locations and dimensions can be tested
- In progress: photoemission model