# Radiation Heating from the ILC damping wigglers

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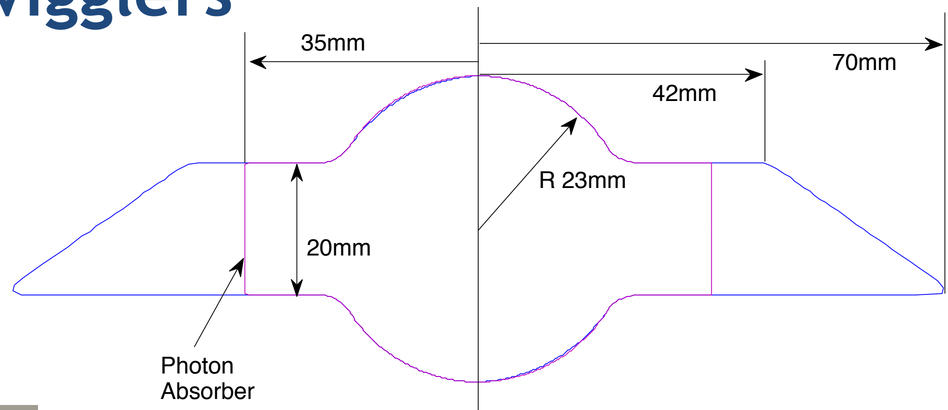
# Outline

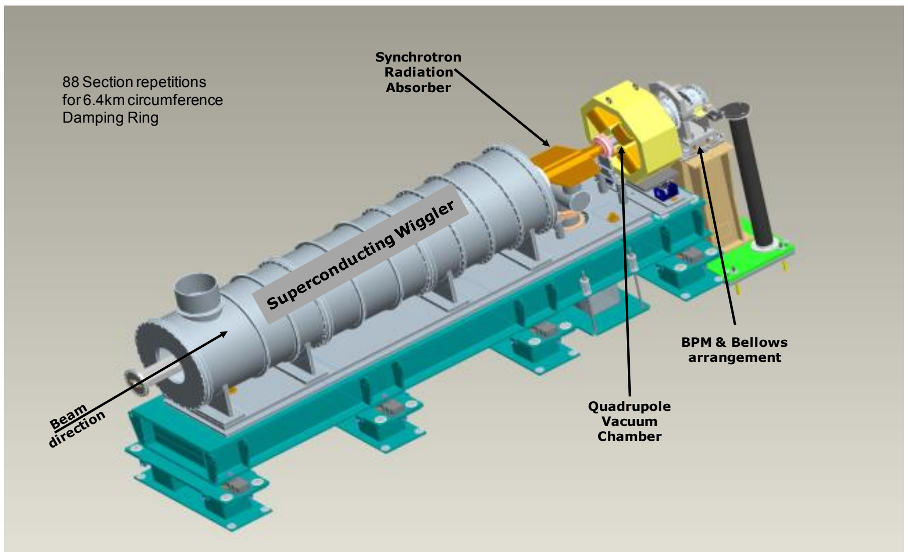
- Introduction
- Distribution of power from 1 wiggler cell
- Distribution of power from the full wiggler section
- Dependence on surface roughness
- Dependence on photon absorber aperture
- Compare ideal and realistic orbits
- Summary

# Layout of the damping wigglers

- For the 3.2km ILC DR wiggler section there are two wiggler magnets per cell




Wiggler vacuum chamber with antechamber




Layout of the 6.4km ILC DR wiggler module.
Courtesy: K. Zolotarev, IPAC10 WEPE094

| Parameter | Value |
|---|---|
| Lattice | 5-Hz, low power |
| Beam Energy | 5 GeV |
| Beam Current | 389.2 mA |
| Wiggler Length | 2.2 m (6 poles) |
| Wiggler Period | 30 cm |
| Max B field | 1.51 T |
| Num of Wigglers | 54 |

# Analytical calculation of the radiation Heat load

- Calculate the power over a given solid angle by integrating,

$$\frac{dP}{d\Omega} = \frac{d^2P}{d\theta d\psi} = P_T \frac{21\gamma^2}{16\pi K} G(K) f_K(\gamma\theta, \gamma\psi)$$

θ, horizontal; ψ, vertical

- Where K is the deflection parameter and

$$P_T[kW] = 0.663 E^2[GeV] B_0^2[T] L[m] I[A]$$

- For a wiggler K is assumed to be large so,

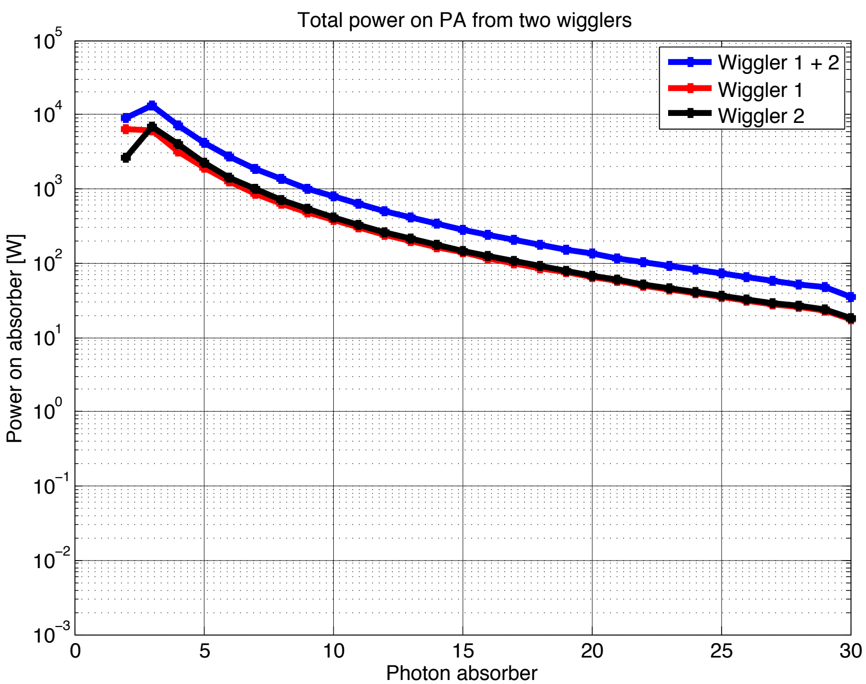
$$G(K \to \infty) = 1$$

$$K \to \infty : f_K(\gamma\theta, \gamma\psi) = \sqrt{1 - (\gamma\theta/K)^2} \left\{ \frac{1}{\left(1+(\gamma\psi)^2\right)^{5/2}} + \frac{5(\gamma\psi)^2}{7\left(1+(\gamma\psi)^2\right)^{7/2}} \right\}$$

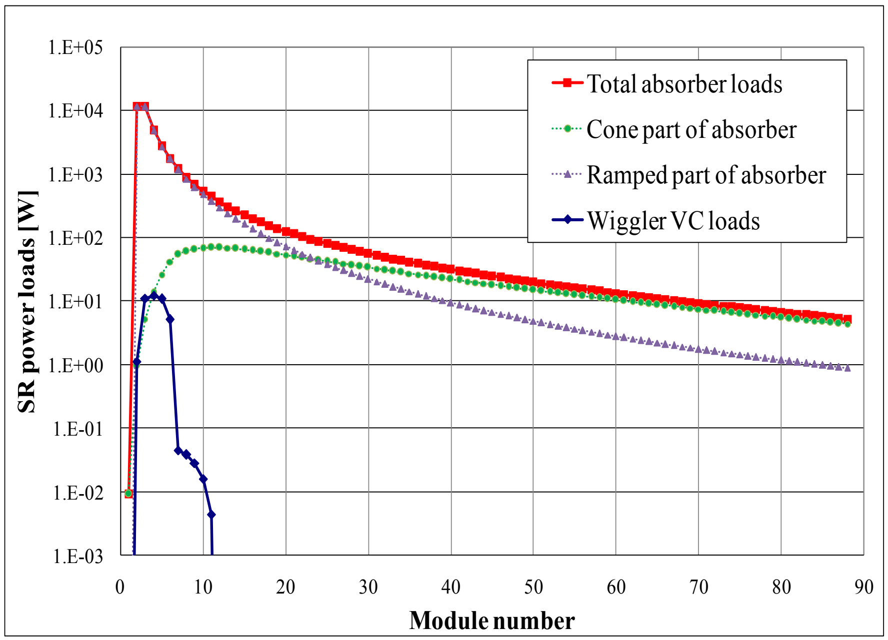
K-J. Kim, Nucl Instrum. And Meth in Phys Res A246 (1986)

# Analytical heat load: 3.2-km vs 6.4-km ring

- Calculations for 3.2km ring includes power on both inside and outside photon absorber.
- A different wiggler design was used for the 6.4km damping ring, however the results for the small ring have a similar dependence on S, as was calculated.




Power dissipation from the first wiggler cell in the 3.2-km damping ring.



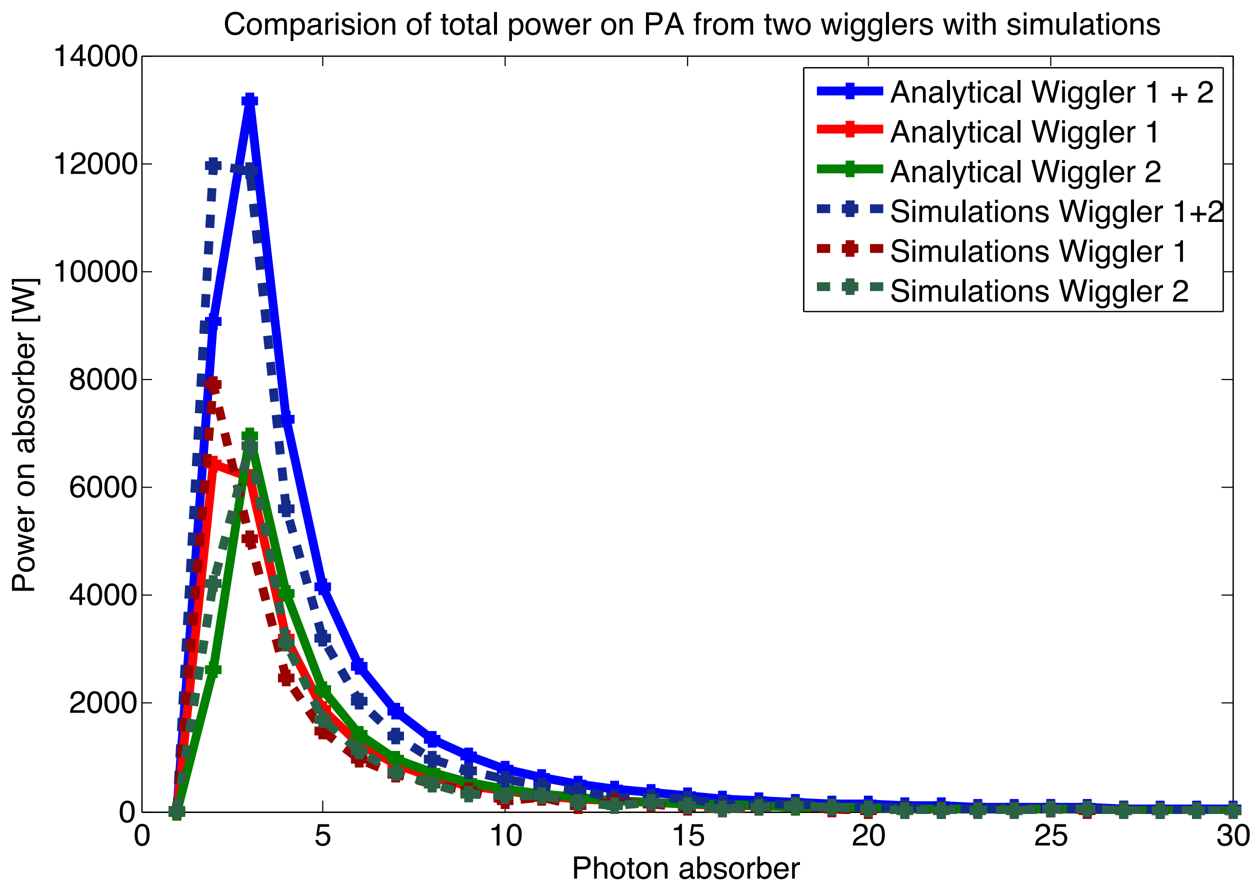

Power dissipation from first wiggler in the 6.4 km damping ring. Courtesy: K. Zolotarev, IPAC10 WEPE094

# Simulation vs. analytical heat load: 3.2-km ring

- Simulations and calculations include the power from both the inside and outside photon absorber.
- Synrad3d* code used for simulations. Assuming no photon reflections.
- Each simulation used 600K macro-photons.
- Simulation power calculated by:

$$P[W] = Int * Eng * I[A]$$

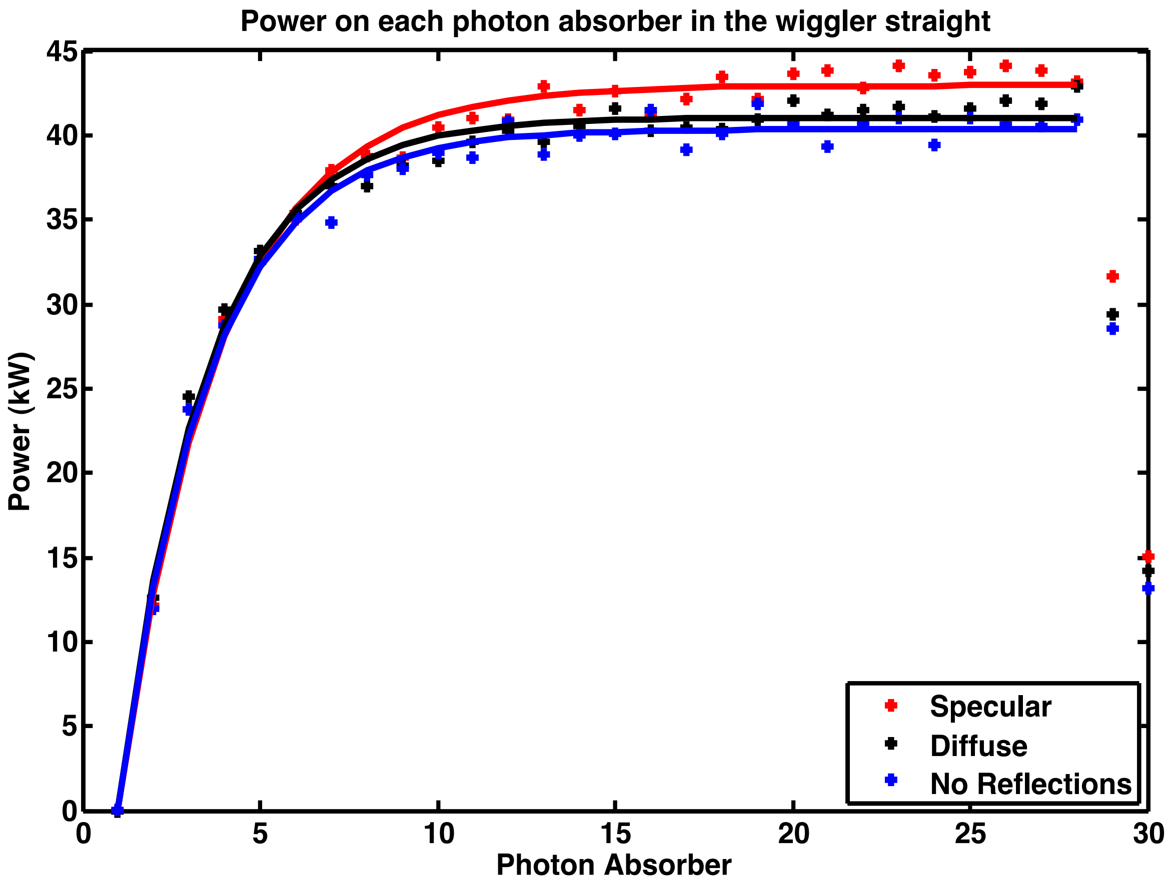
- Eng = total energy
- Int = intensity




*G. Dugan, Synrad3d photon propagation and scattering simulation, ECLOUD10

# Power distribution along the full wiggler section

- Power from all wigglers in the wiggler section of the damping rings
- Simulation results fit to exponential.
- Specular scattering reflectivity based on surface roughness of 4nm rms.
- Diffuse scattering has surface roughness of 100nm rms and 5 um correlation length.

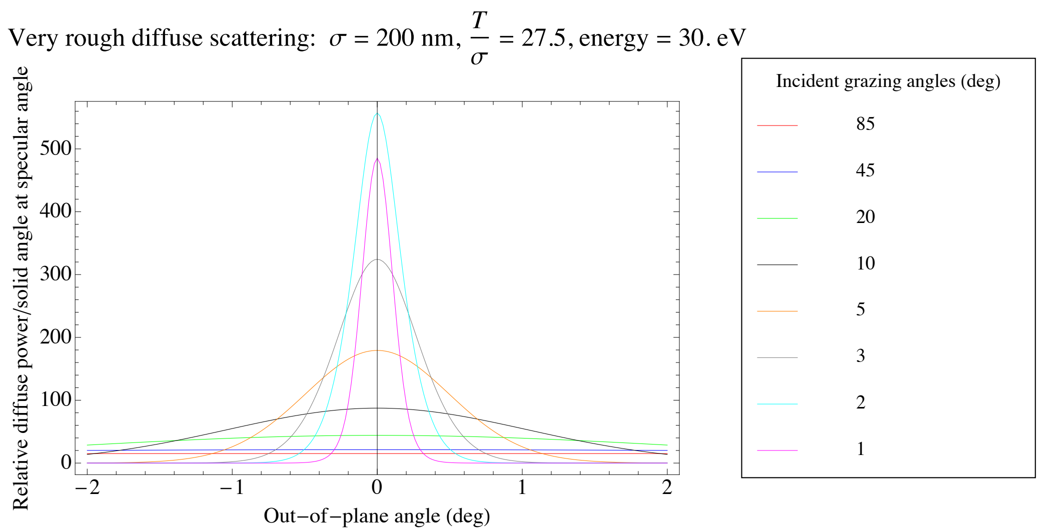


# Description of diffuse scattering

- Reflectivity is dependent on the photon energy, grazing angle, material and surface roughness.
- Surface roughness is described by the ratio of correlation length, T, over rms roughness, σ.

$$T/\sigma$$

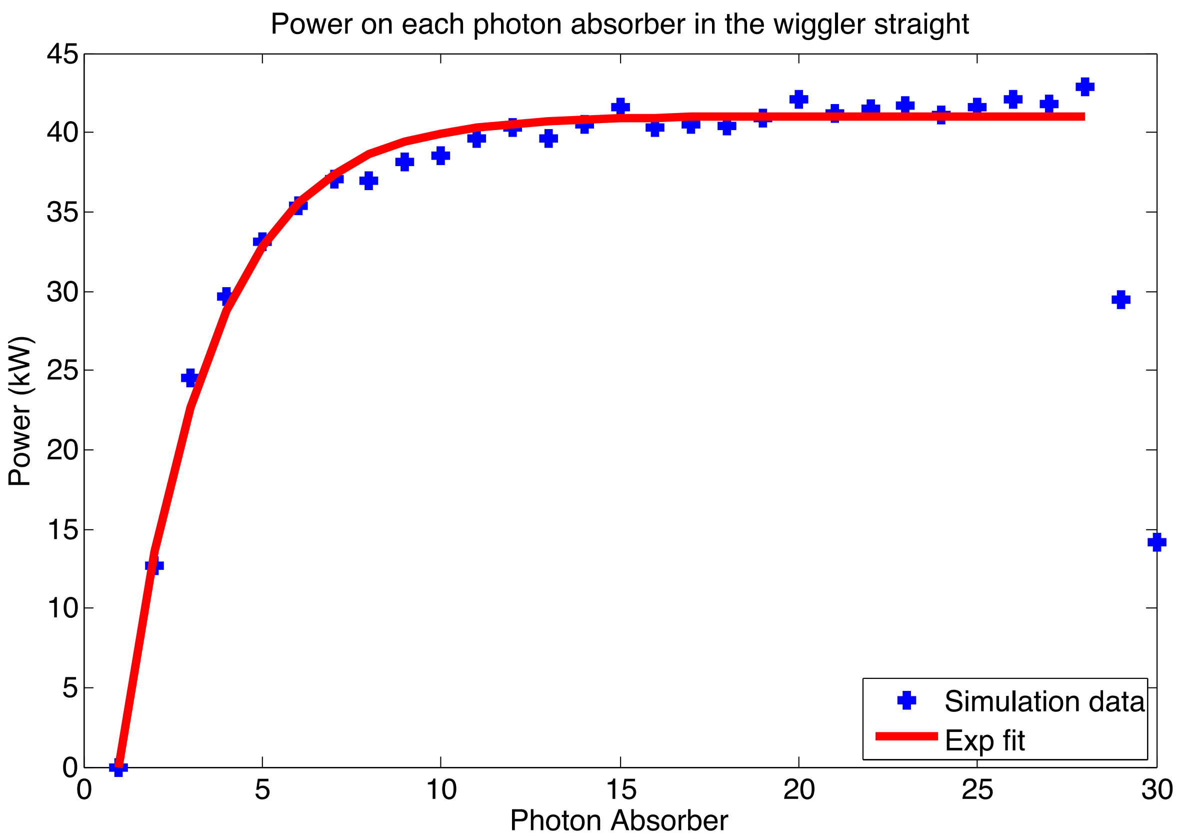
- Synrad3d assumes a 10nm carbon film on Al substrate.




Courtesy: G. Dugan, Synrad3d Manual

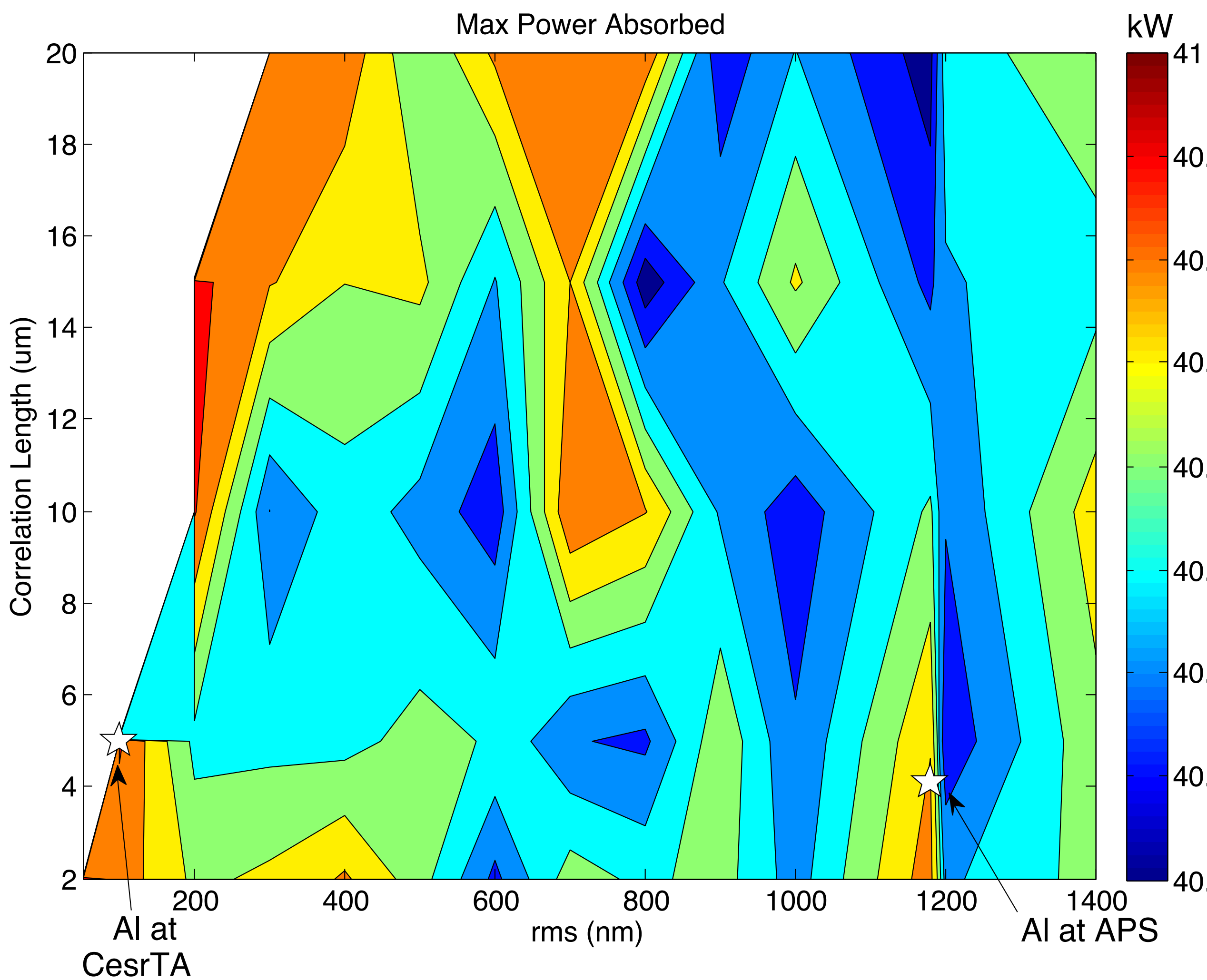
# Surface Roughness Dependence

- Using Synrad3d calculations were done to determine the heat load dependence on surface roughness
- The simulation results are fit with an exponential.
- Total photon absorber power = 41kW/photon absorber



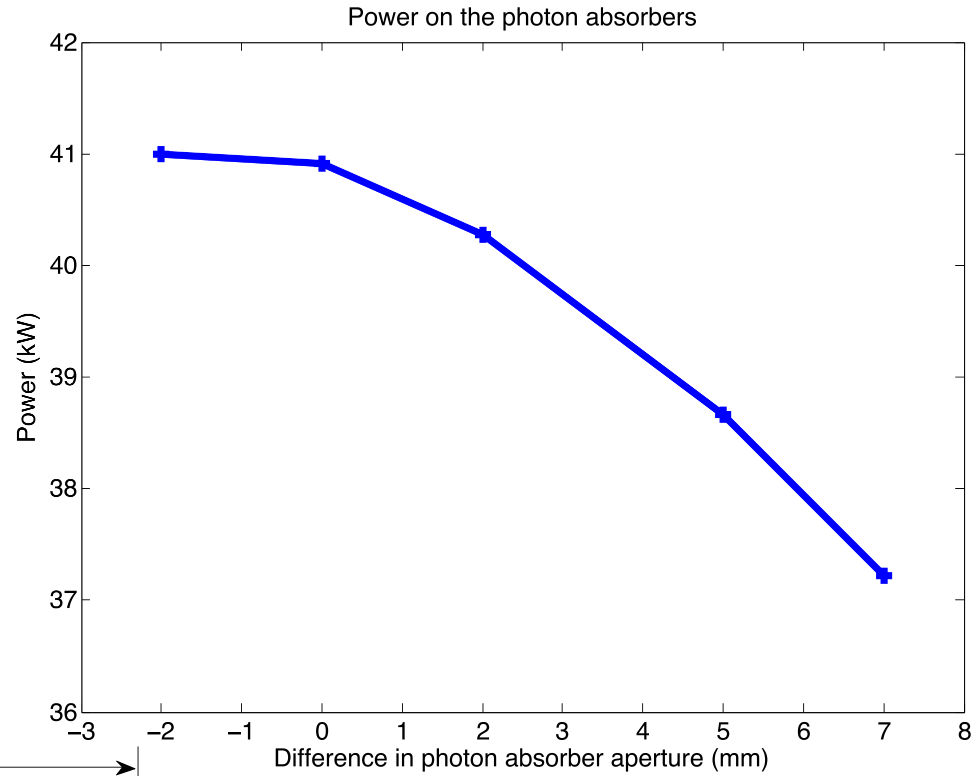
# Surface roughness dependence on the heat load

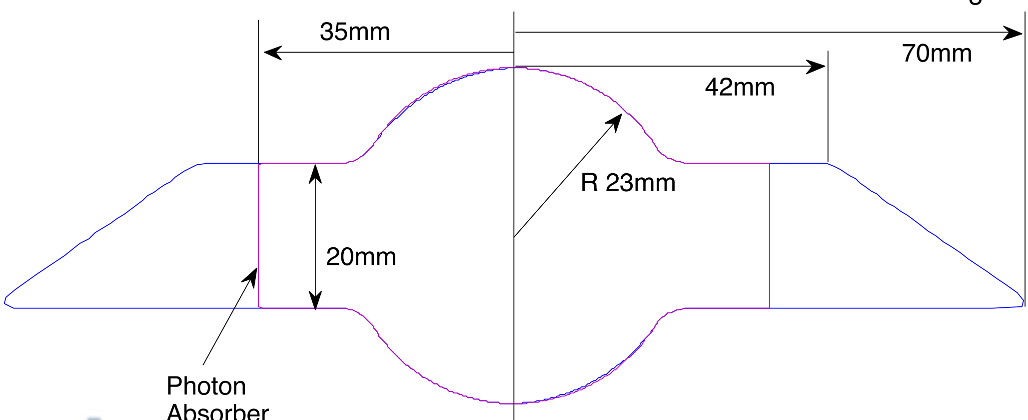
- Small dependence on the surface roughness
- The total power on each photon absorber ranges from 40.2kW to 41kW, difference of 0.8kW.
- ILC chamber surface will be unpolished extruded Al coated in TiN.  Which was not modeled



# Dependence on photon absorber aperture

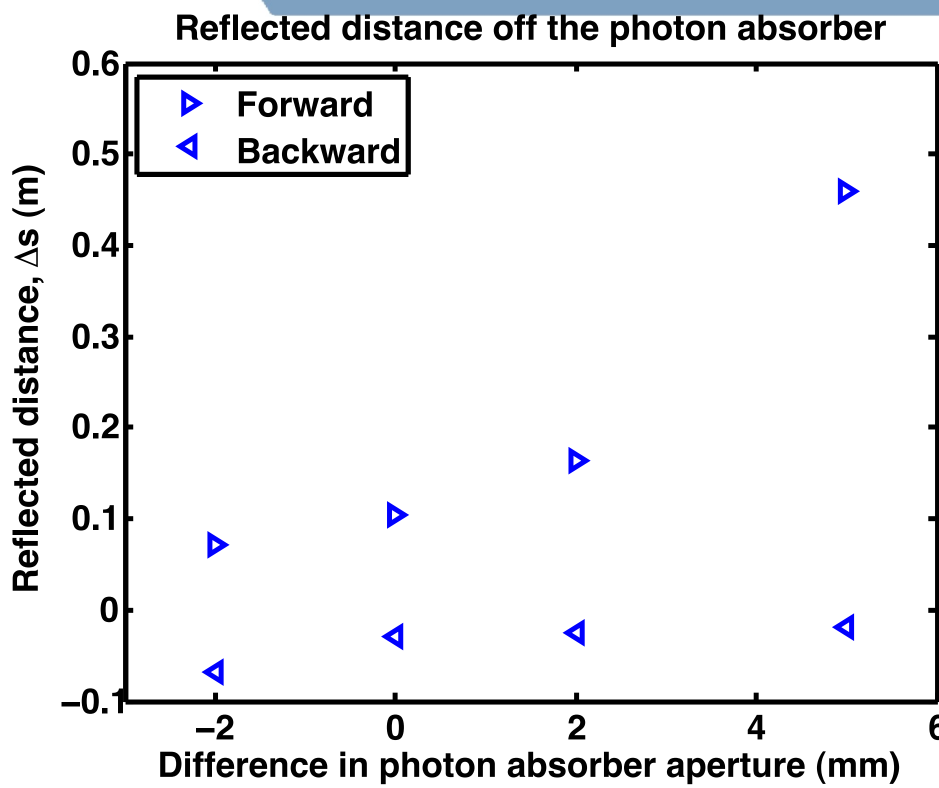
- By increasing the photon aperture the surface of the photon absorber decreases.
- It also decreases the angle of the photon absorber allowing more reflections off its surface.



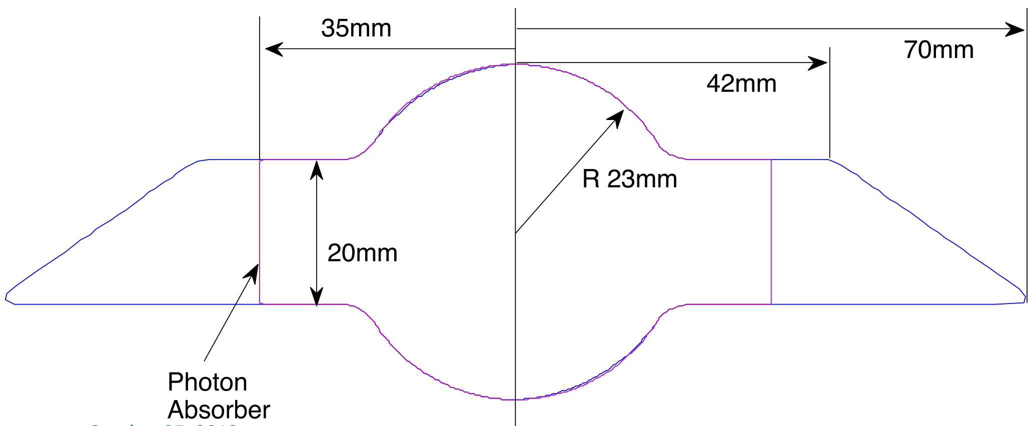



# Reflections off the photon absorber

- The increased photon absorber aperture decreases the photon absorber angle which increases the reflectivity.
- The reflected photons are able to travel upstream/downstream from the photon absorber.
- Based on a specular scatter calculation none of these would be absorbed in the wiggler cryostat.




Distance from the photon absorber to the wiggler:
Downstream: 1.06 m
Upstream: 1.47 m

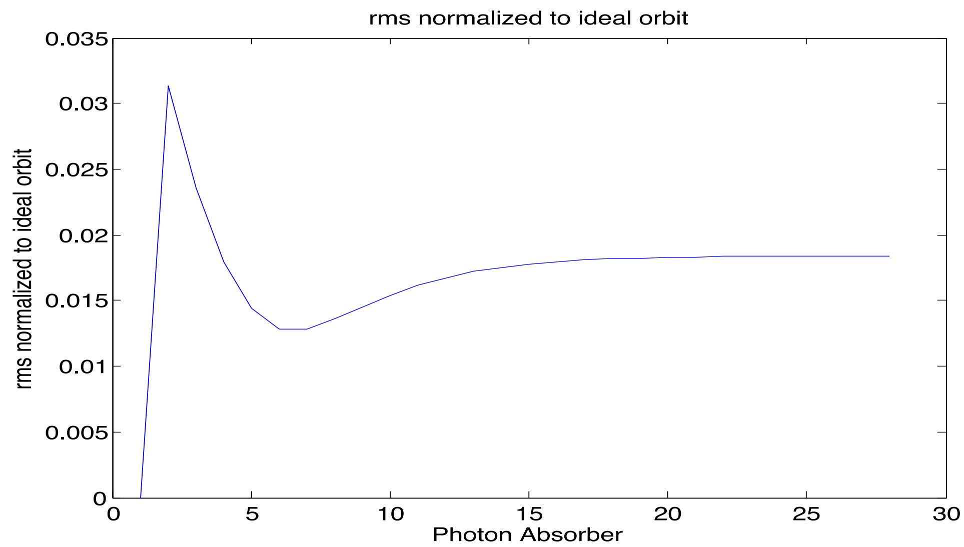


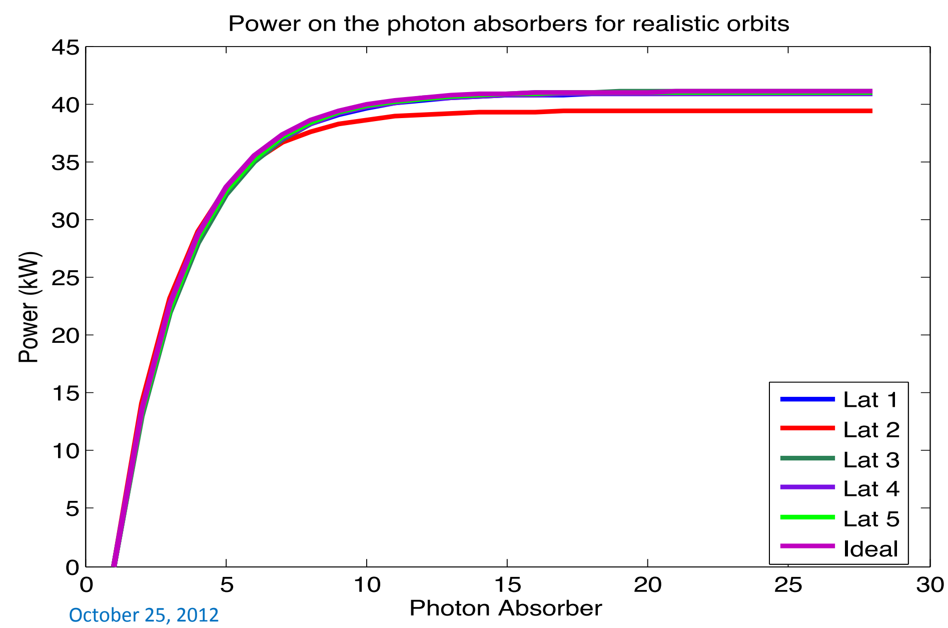
# Vertical photon absorber

- The current photon absorber design has a vertical photon absorber with a sawtooth.
- The vertical photon absorber reduces the reflections across the chamber, as shown on the last slide.
- With the addition of the saw tooth simulations will need to be done to determine the probability of back scatter off the steps.

# Comparison of ideal to realistic orbits

- The realistic orbits include magnet misalignments and corrector strengths.
- The normalized rms in photon absorber power remains small , < 3% difference in heat load.



# Summary

- The wiggler-induced power on the photon absorbers was analyzed for the 5-Hz low power damping ring.
- Synrad3d simulations compare well with current and previous analytical calculations.
- Power is not highly dependent on the surface roughness of the chamber.
- Simulations results shown here includes the power on both the inside and outside of the chamber so each photon absorber should be able to handle ~20kW+

- To be completed:
- Calculate the heat load for the 5-Hz high power and 10-Hz lattice
  - Heat load is linearly dependent on beam current, so the 5Hz high power damping ring, with a current of 779mA, will produce 80 kW on the photon absorbers.
- More detailed simulations of reflections off the photon absorbers.

Thanks to: Katherine Harkay (ANL), Jim Shanks (Cornell), Roger Dejus (ANL) and Kent Wootton (ASLS).