

Simulating Internal Bremsstrahlung in the OLYMPUS Radiative Generator

Axel Schmidt

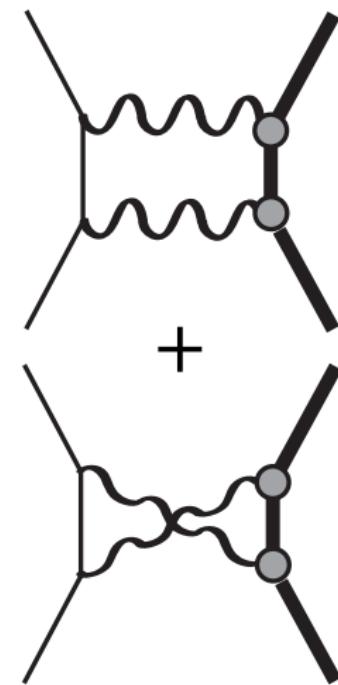
Massachusetts Institute of Technology

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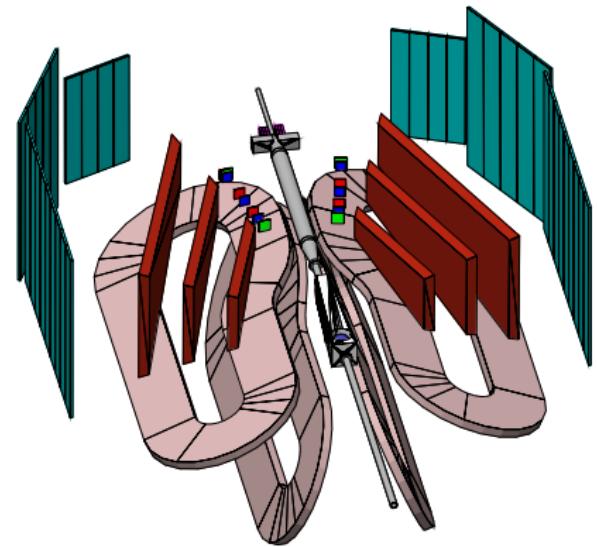
The OLYMPUS Experiment

- $\sigma_{e^+p}/\sigma_{e^-p} \rightarrow$ hard 2γ exchange



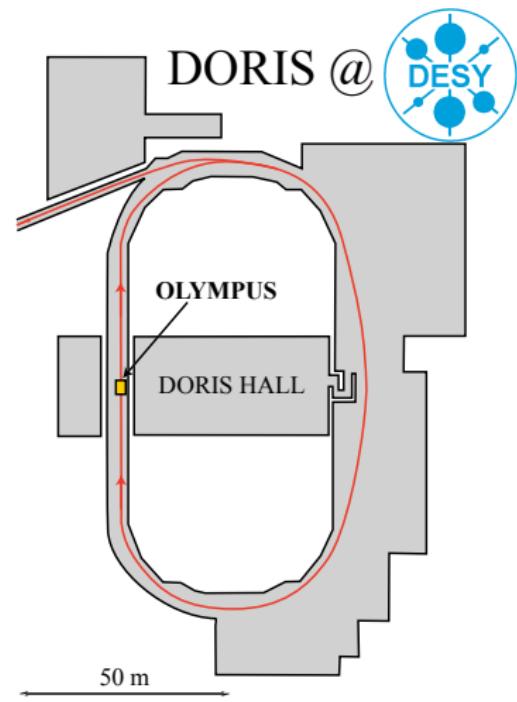
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- $\sigma_{e^+p}/\sigma_{e^-p} \rightarrow$ hard 2γ exchange
- Magnetic spectrometer



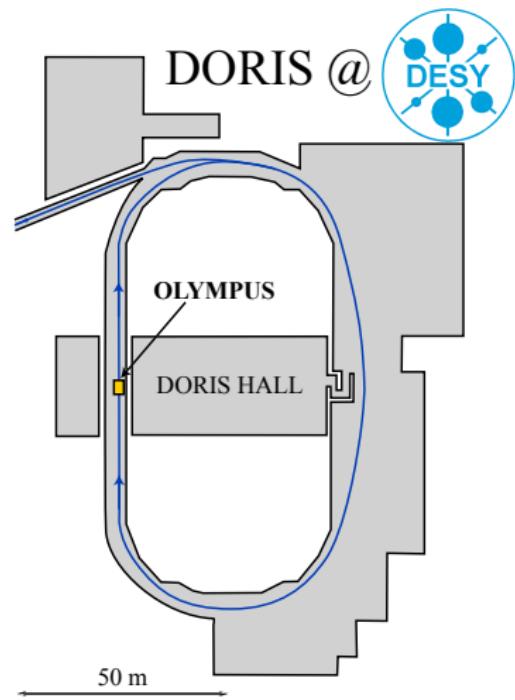
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- DORIS storage ring @ DESY



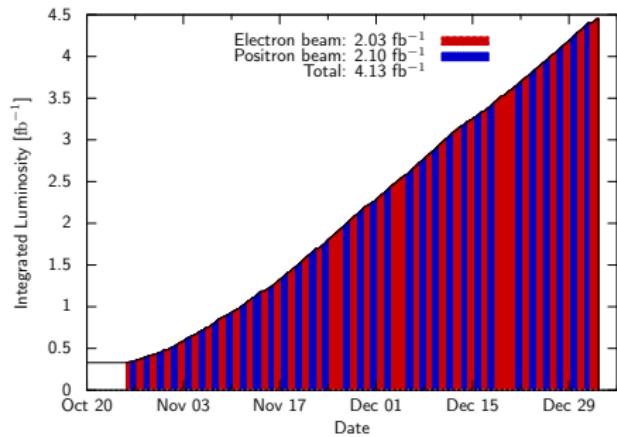
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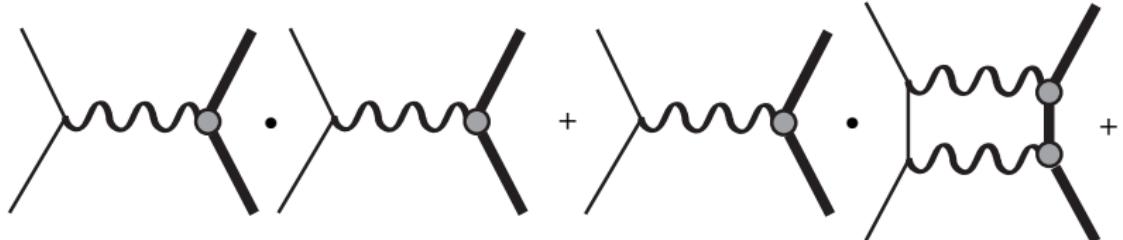
- $\sigma_{e+p}/\sigma_{e-p} \rightarrow$ hard 2γ exchange
- Magnetic spectrometer
- DORIS storage ring @ DESY
- Alternating beam species
- Collected $\approx 4 \text{ fb}^{-1}$ in 2012



Outline

- Generator Requirements
- Bremsstrahlung Calculation
- Implementing Bremsstrahlung

Isolating Hard 2γ Exchange

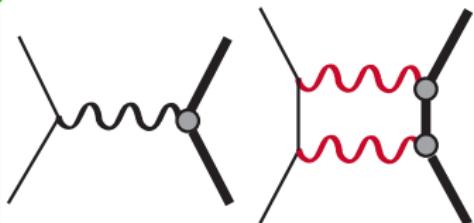
$$|M|^2 = \langle \text{---} \cdot \text{---} \rangle + \langle \text{---} \cdot \text{---} \rangle + \dots$$


Isolating Hard 2γ Exchange

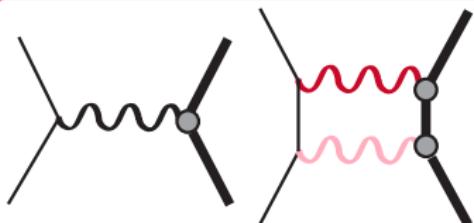
$$|M|^2 = \langle \text{wavy line} \cdot \text{wavy line} \rangle + \dots$$

The equation illustrates the calculation of the squared magnitude of the amplitude ($|M|^2$) for a process involving two photons. It shows a sum of terms, each represented by a wavy line (photon) interacting with a solid line (radiative generator). The terms are separated by plus signs, indicating different contributions to the total cross-section.

Lepton-Sign-Odd Contributions



Hard 2γ

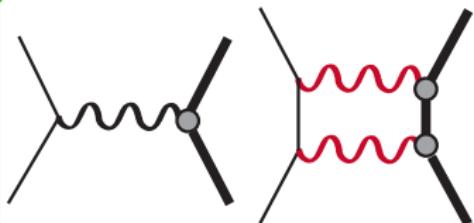


Soft 2γ

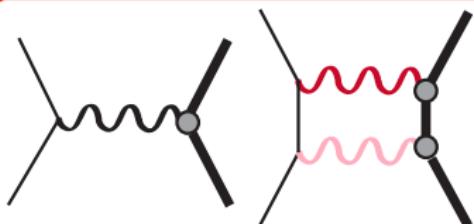


Bremsstrahlung:
 e - p -Interference

Lepton-Sign-Odd Contributions



Hard 2γ



Soft 2γ



Bremsstrahlung:
ep-Interference

- Hard vs. Soft → Standard definitions
- Bremsstrahlung must be accurate!

OLYMPUS Radiative Generator

MIT is developing a Radiative Generator.

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Same approach as Mainz A1 Generator¹

¹Described in J.C. Bernauer thesis

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Caveats

- Not release-ready
- Components still being tested

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Bremsstrahlung is key component.

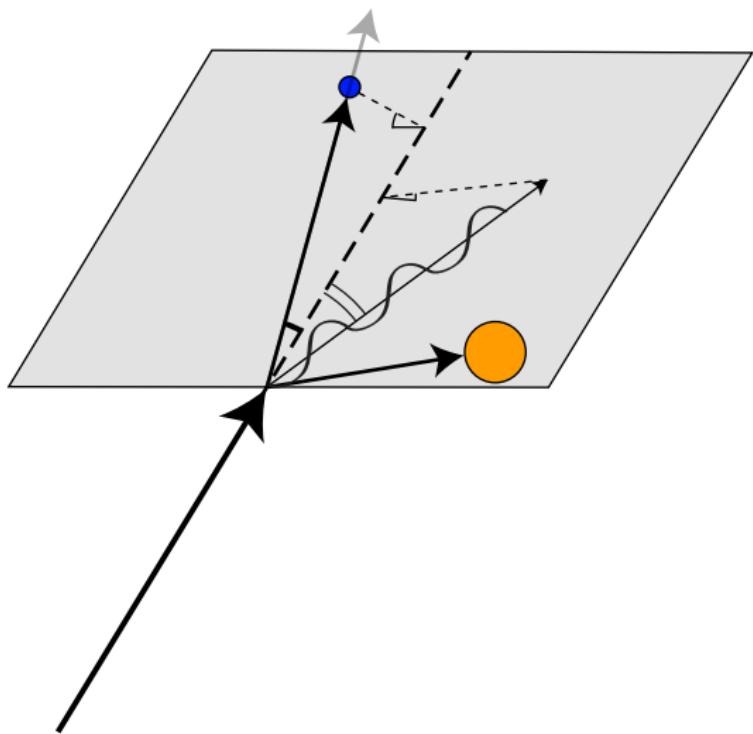
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Cross Section Calculation

Design Goals

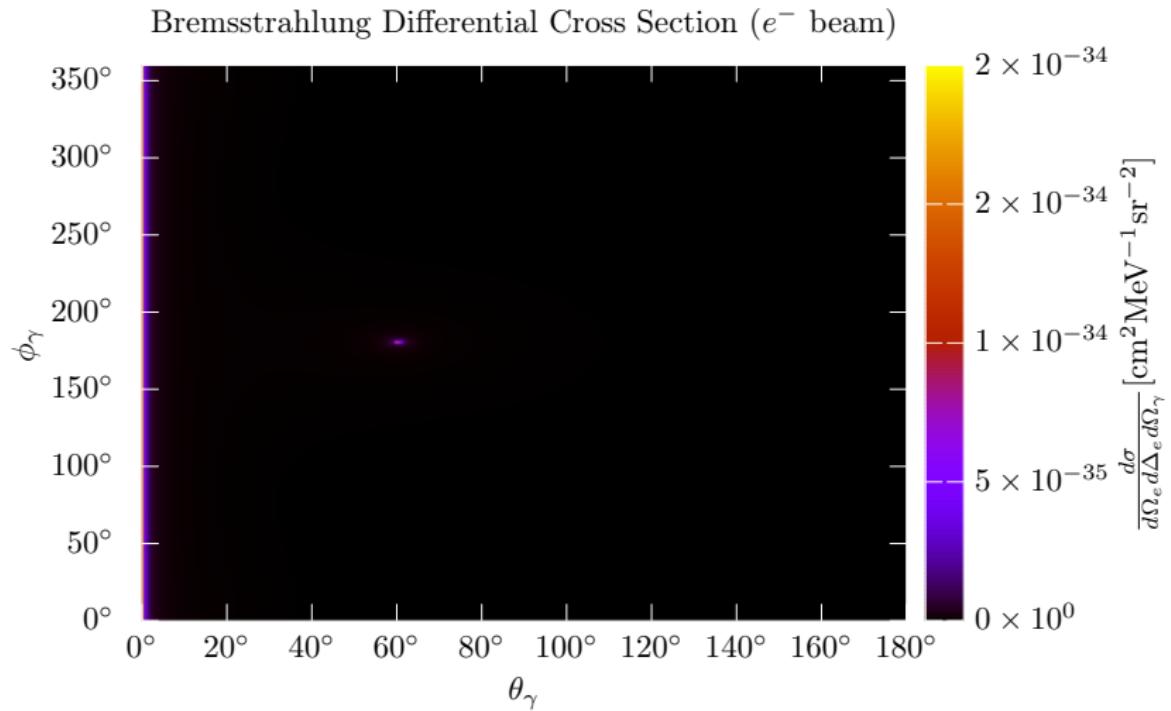
- e^- and p diagrams
- Avoid approximations (where possible)
 - No soft-photon approximation
 - No peaking approximation
- Evolution of the form factors at each proton vertex
 - Proton current taken as on-shell

Cross Section Calculations: Kinematics



- Detector-plane coordinates
- Fixed
 - $E_{\text{beam}} = 2.01 \text{ GeV}$
 - $\theta_e = 60^\circ$
 - $\phi_e = 180^\circ$
 - $\Delta E' = 20 \text{ MeV}$
- Vary the photon direction

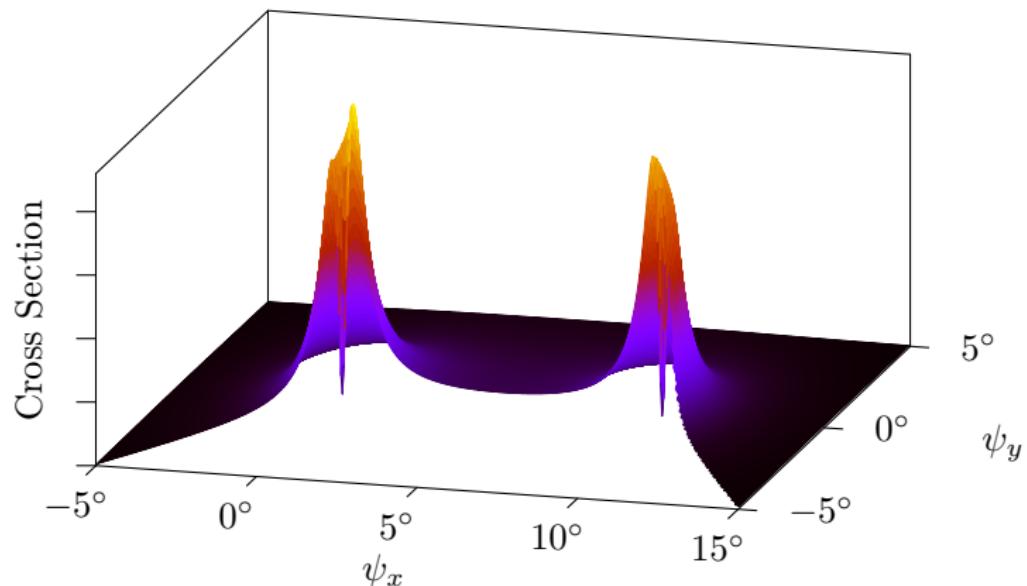
Cross Section Calculations



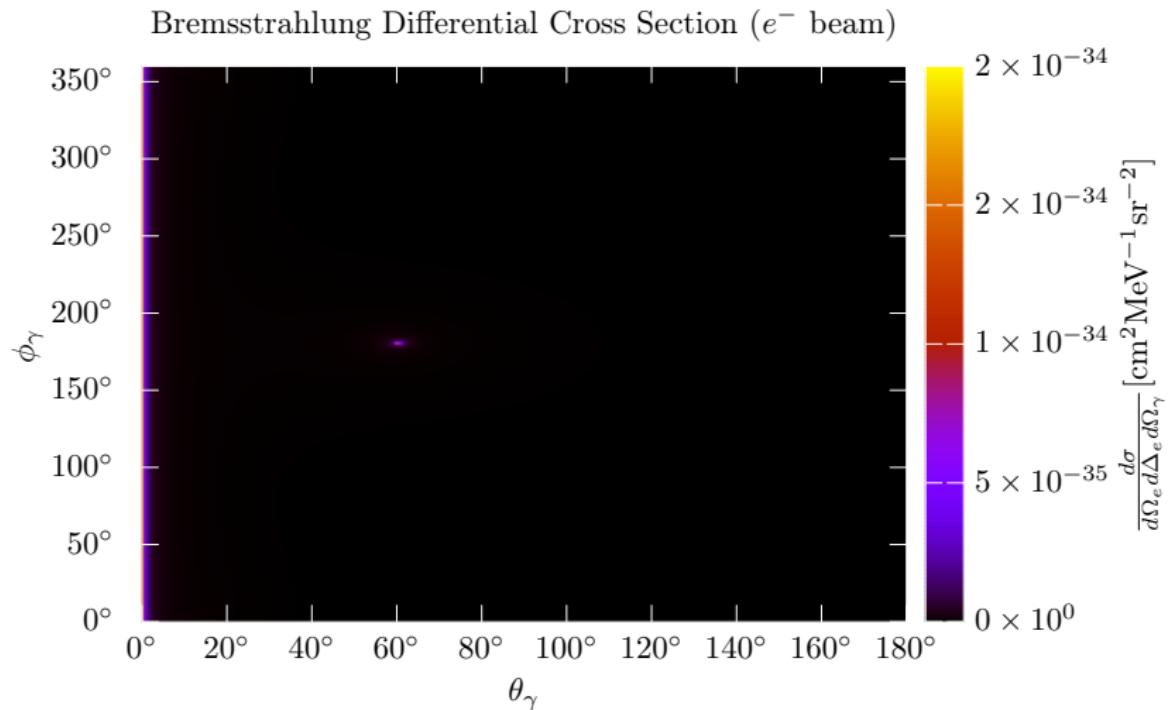
Bremsstrahlung Peaks

Bremsstrahlung Cross Section

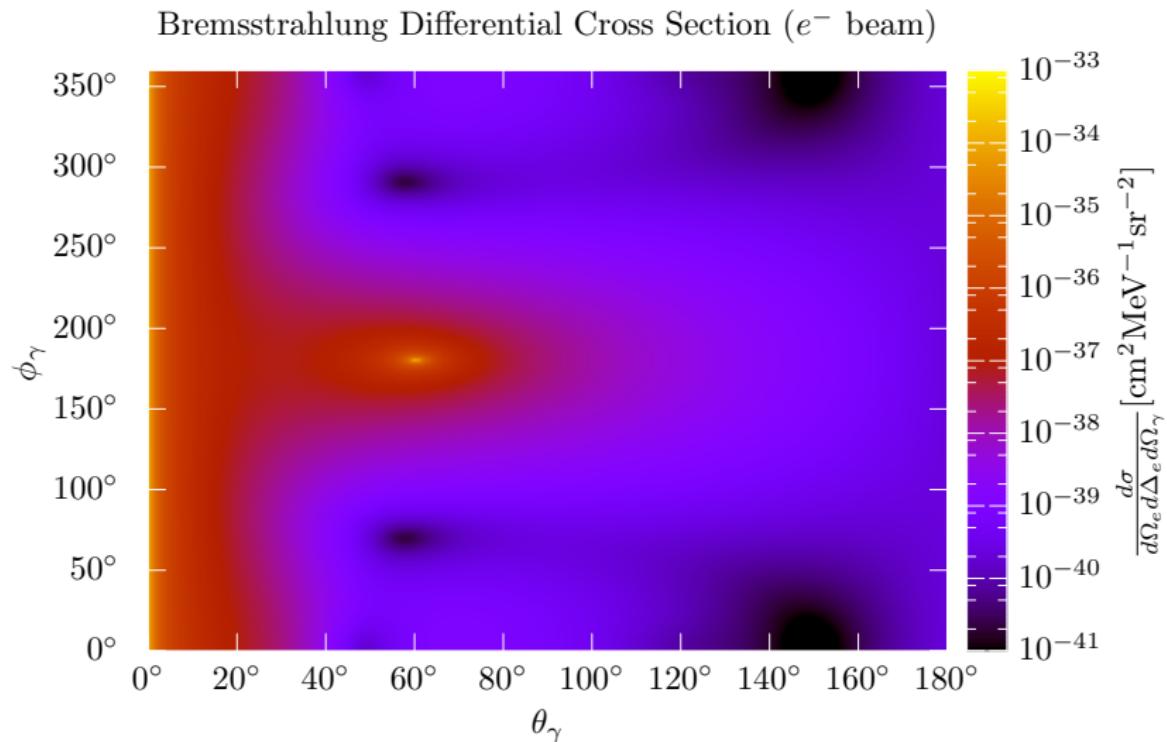
$E_{beam} = 100\text{MeV}$, $\Delta E = 1\text{MeV}$, $\theta_e = 10^\circ$



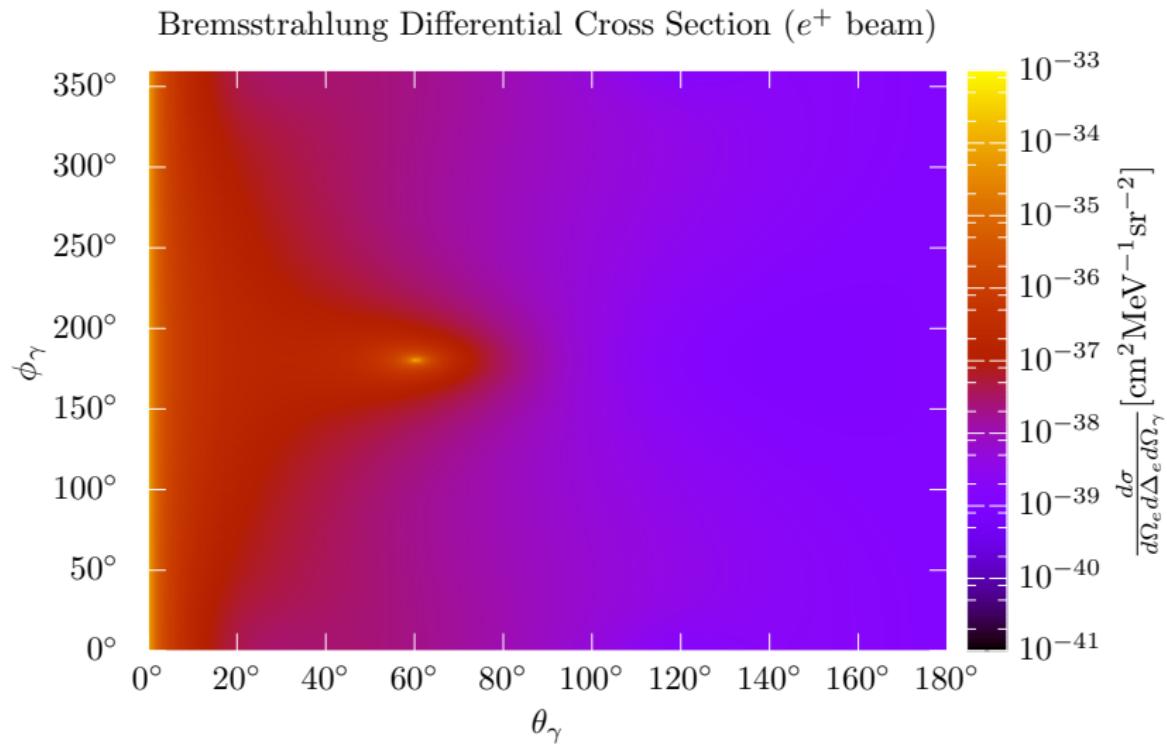
Cross Section Calculation (e^- Beam)



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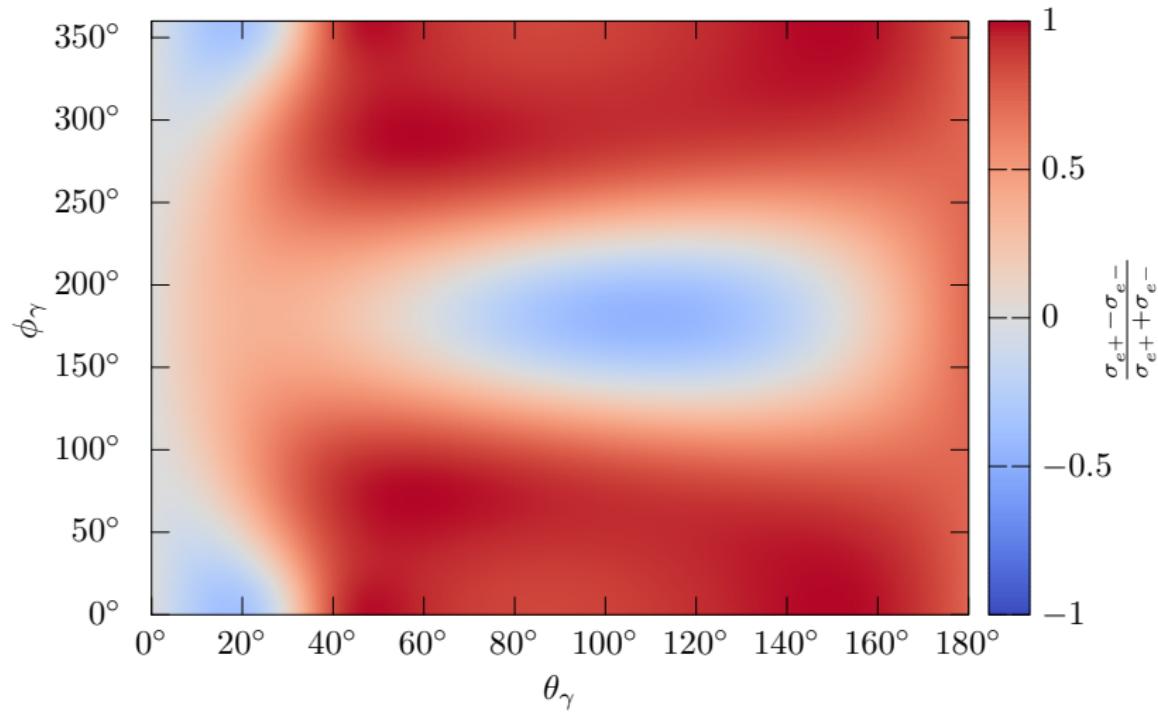


Cross Section Calculation (e^+ Beam)

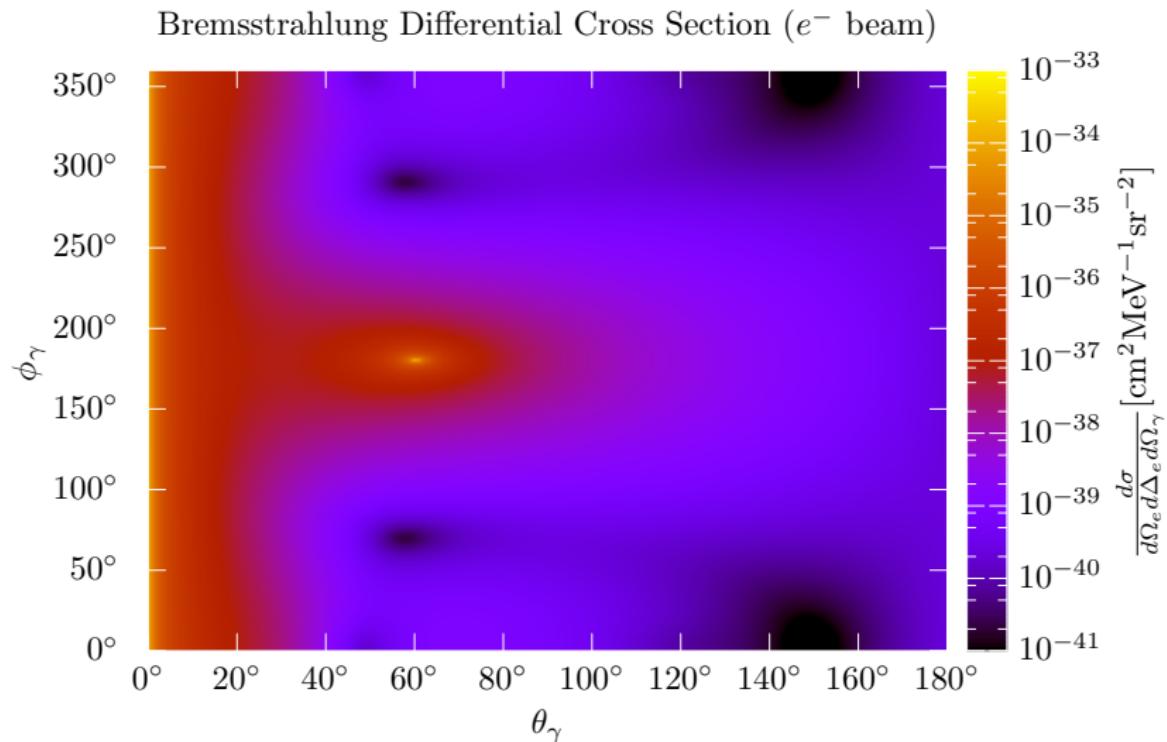


Cross Section Asymmetry

Bremsstrahlung Cross Section Lepton Sign Asymmetry



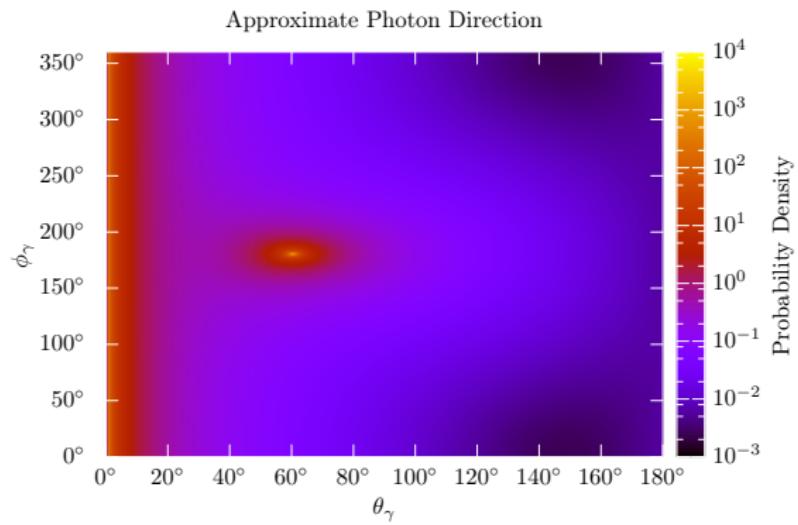
Cross Section Calculation (e^- Beam)



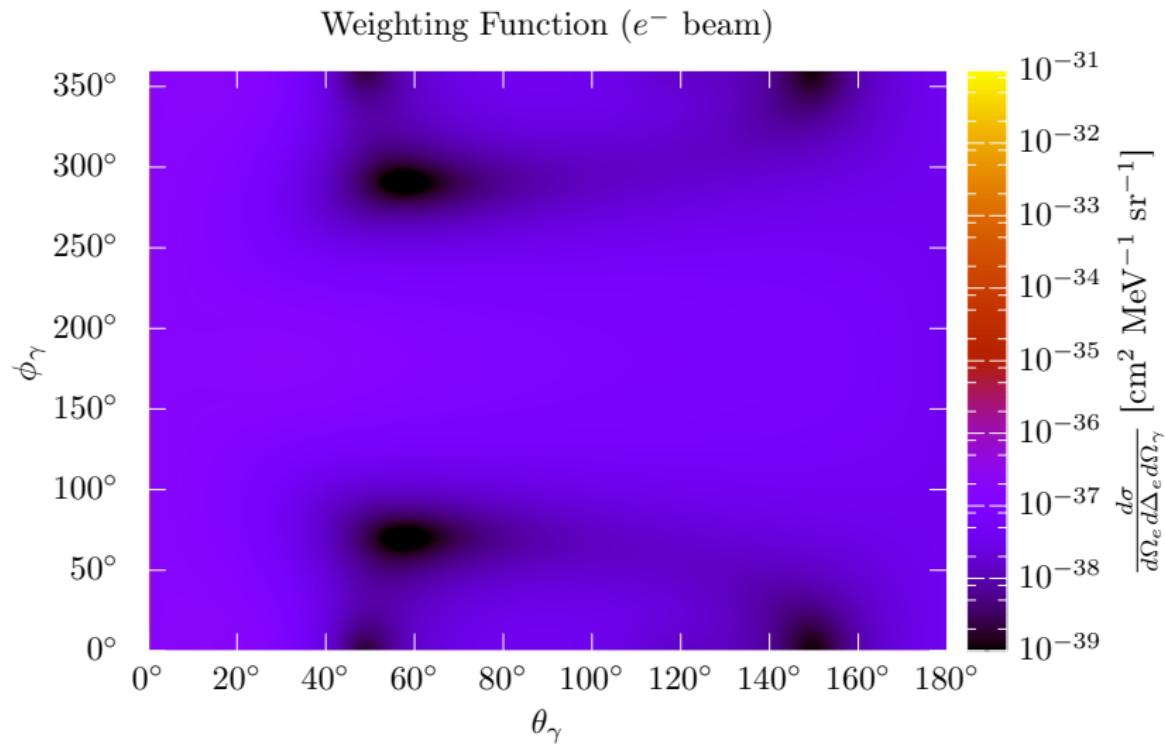
Approximate Probability Distribution

$$P(\cos \theta) \propto \frac{1 - \cos^2 \theta}{\left(\frac{1}{\beta} - \cos \theta\right)^2}$$

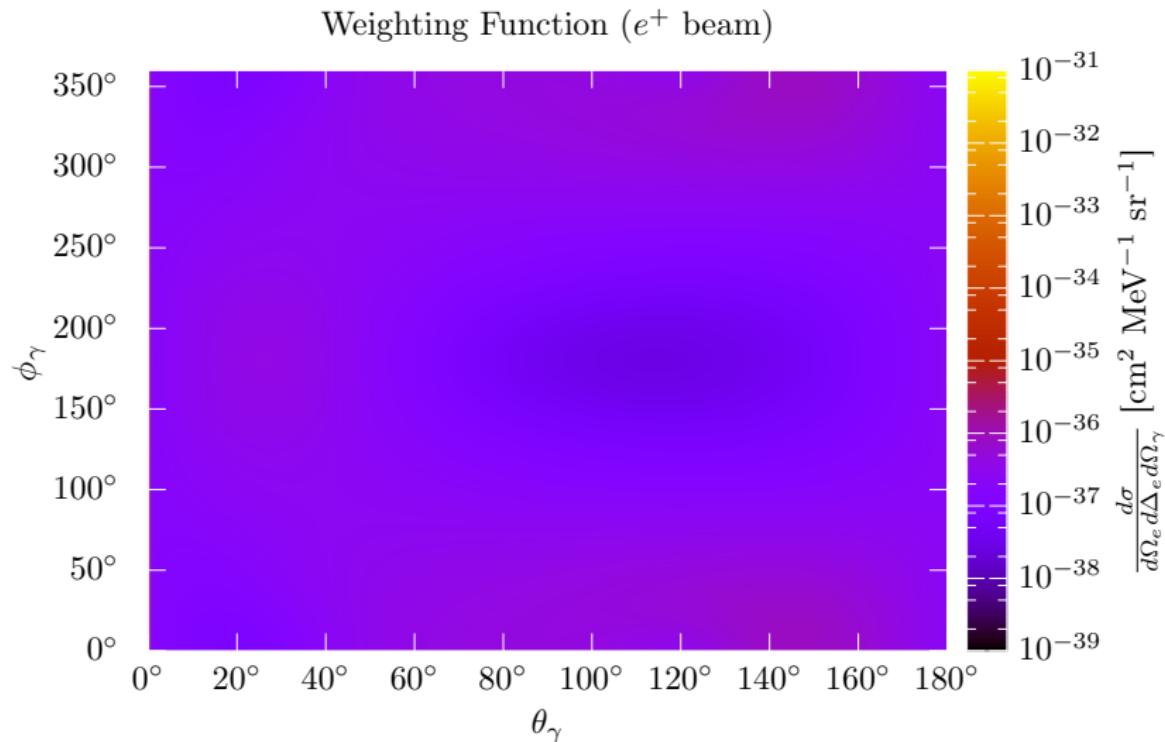
Efficient to sample!
Technique from Mainz A1



Weighting Function (e^- Beam)



Weighting Function (e^+ Beam)



Building the Generator

- Same approach as the Mainz A1 Generator

Features

- Weighted generator
 - Quick sampling
 - Simple event by event adjustments
- Accommodates any standard correction
 - Mo + Tsai
 - Grammer + Yennie
 - Maximon + Tjon

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Improvements

- More sophisticated bremsstrahlung kinematics
- Includes interference (crucial for OLYMPUS!)

Procedure

Following Mainz A1:

$$\text{Cross Section} = e^\delta \times \frac{d^5\sigma}{d\Omega_e d\Delta E' d\Omega_\gamma}$$

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$$\text{Sample from } P(\Delta E') \propto \frac{t}{\Delta E'} \left(\frac{\Delta E'}{E'_{\text{elastic}}} \right)^t$$

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$$\text{Weight becomes: } e^{\delta_{\text{elastic}}} \times |\mathcal{M}'|^2 \times \frac{\Delta E'}{tk}$$

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- Bremsstrahlung Calculation
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- Implementation
 - Improved Mainz A1 method