Bremsstrahlung background in electron polarimeter at ESR

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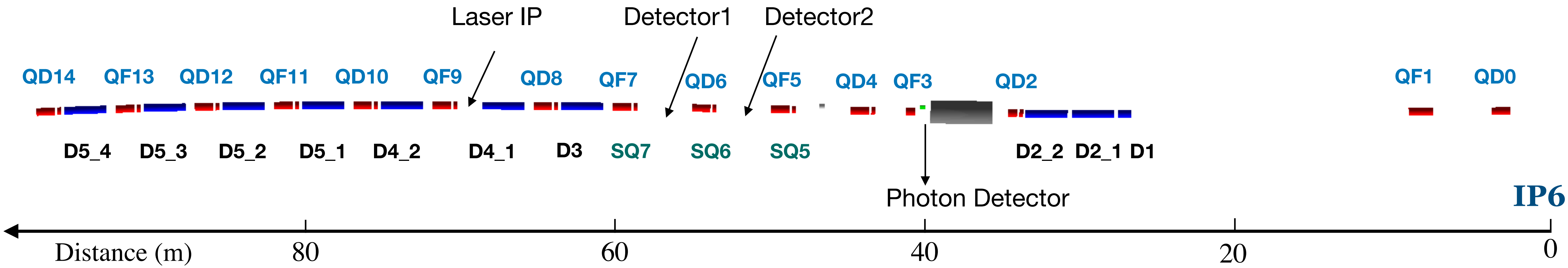
Motivation

- Dave was considering about the technique of performing the energy-weighted integral without a threshold for the photon detector.
- This technique requires a controllable background from synchrotron radiation and Bremsstrahlung.
- The synchrotron radiation study was conducted on the previous lattice and required a 1mm tungsten shield to block all the synchrotron radiation photons. I conducted a similar study for the latest lattice; it seems a 0.2mm shield might be enough, but this may not be correct. I need more time to verify this.
- In this talk, I will present the study on Bremsstrahlung.

Lattice Version 6.2

Latest version



Laser IP:

Beam Energy	P_L	P_T
5GeV	99.1%	13.2%
10GeV	96.5%	26.2%
18GeV	89.0%	45.6%

	bending angle	length
D5	12.2 mrad	2.726 meters
D4	1.5 mrad	2.726 meters
D3	13.0 mrad	2.726 meters
D2	-12.3 mrad	2.726 meters
D1	-1.5 mrad	0.89 meters

To contrast with the previous version, the bending angles for D5 and D2 have seen an increase of 0.3 mrad and 0.5 mrad, respectively.

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BetaX = 28.3 meters
BetaY = 28.1 meters
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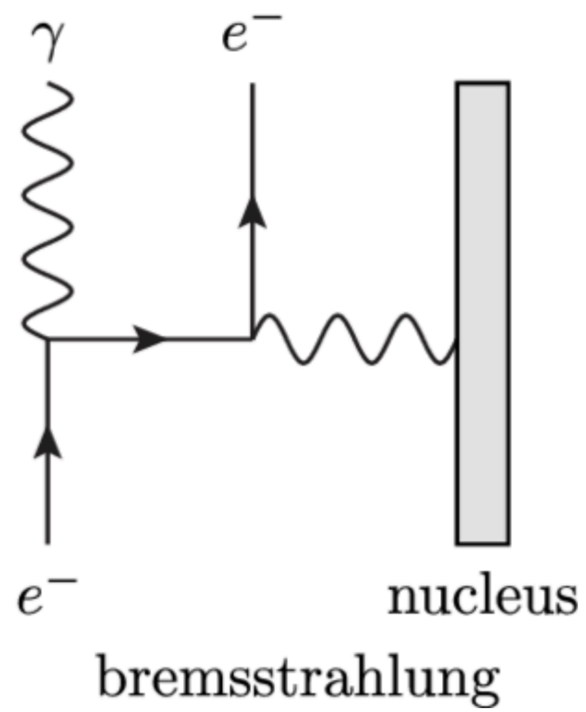
Cross section of Bremsstrahlung on H_2 gas

Feynman diagram of Bremsstrahlung



Here, we consider the electron beam colliding with the residual H_2 gas in the beam pipe. In principle, we need to know the gas pressure along the beamline; however, I don't think we have that information yet. Therefore, I assume a uniform distribution of the gas pressure, which is 1.0e-08 mbar, a typical value around IP6.

Follow the Eq. 93.16 in Lifshitz QED textbook (section 93)

$$\frac{d^2\sigma}{d\omega d\delta} = 8Z^2\alpha r_e^2 \frac{1}{\omega}\frac{\varepsilon'}{\varepsilon}\frac{\delta}{(1+\delta^2)^2}\left(\left[\frac{\varepsilon}{\varepsilon'} + \frac{\varepsilon'}{\varepsilon} - \frac{4\delta^2}{(1+\delta^2)^2}\right]\ln\frac{2\varepsilon\varepsilon'}{m_e\omega} - \frac{1}{2}\left[\frac{\varepsilon}{\varepsilon'} + \frac{\varepsilon'}{\varepsilon} + 2 - \frac{16\delta^2}{(1+\delta^2)^2}\right]\right)$$

Here **ω** is the photon energy, **ε** is the electron beam energy, **ε'** is the energy of scattered electron, **$\delta = \theta^*\varepsilon/m_e$**

Total cross section for $E_\gamma > 0.1$ GeV is 185.723 mb;

Beam parameters and beam gas rate

Species	proton	electron
Energy [GeV]	275	18
CM energy [GeV]	140.7	
Bunch intensity [10^{10}]	18.9	6.2
No. of bunches	290	
Beam current [A]	0.69	0.227
RMS norm. emit., h/v [μm]	5.2/0.46	845/70
RMS emittance, h/v [nm]	17.6/1.6	24.0/2.0
β^*, h/v [cm]]	417/38	306/30
IP RMS beam size, h/v [μm]	271/24	

Electron beam gas collision rate = $L_{bg}*\sigma_{eH}{}^2$;
Luminosity of background = (beam current) * (average gas density) * (length);
Current = (0.227C/s)*(electrons/1.6e-19C) = 1.4187500e+18 electrons/s;
Length = 40.0m;
$\boldsymbol{\sigma_{eH2}}$ = 185.723mb *2;

PM = dRT;
R =0.0821 atm/mol;
P =1.0e-08 mbar = 1.0e-08*0.000986923 atm = 9.8692300e-12 atm
T = 293k;
M = 1.00794g/mol (molar mass)
Density = 1.0587422e-13g/L = 2.47072e+08 H2/cm3

Electron beam gas collision rate =
1.4187500e+18(s-1)* 2.47072e+08(cm-3)*4000(cm)*185.723*(1.0e-27cm2) *2 = 521**kHz**; //18GeV

Transverse beam size

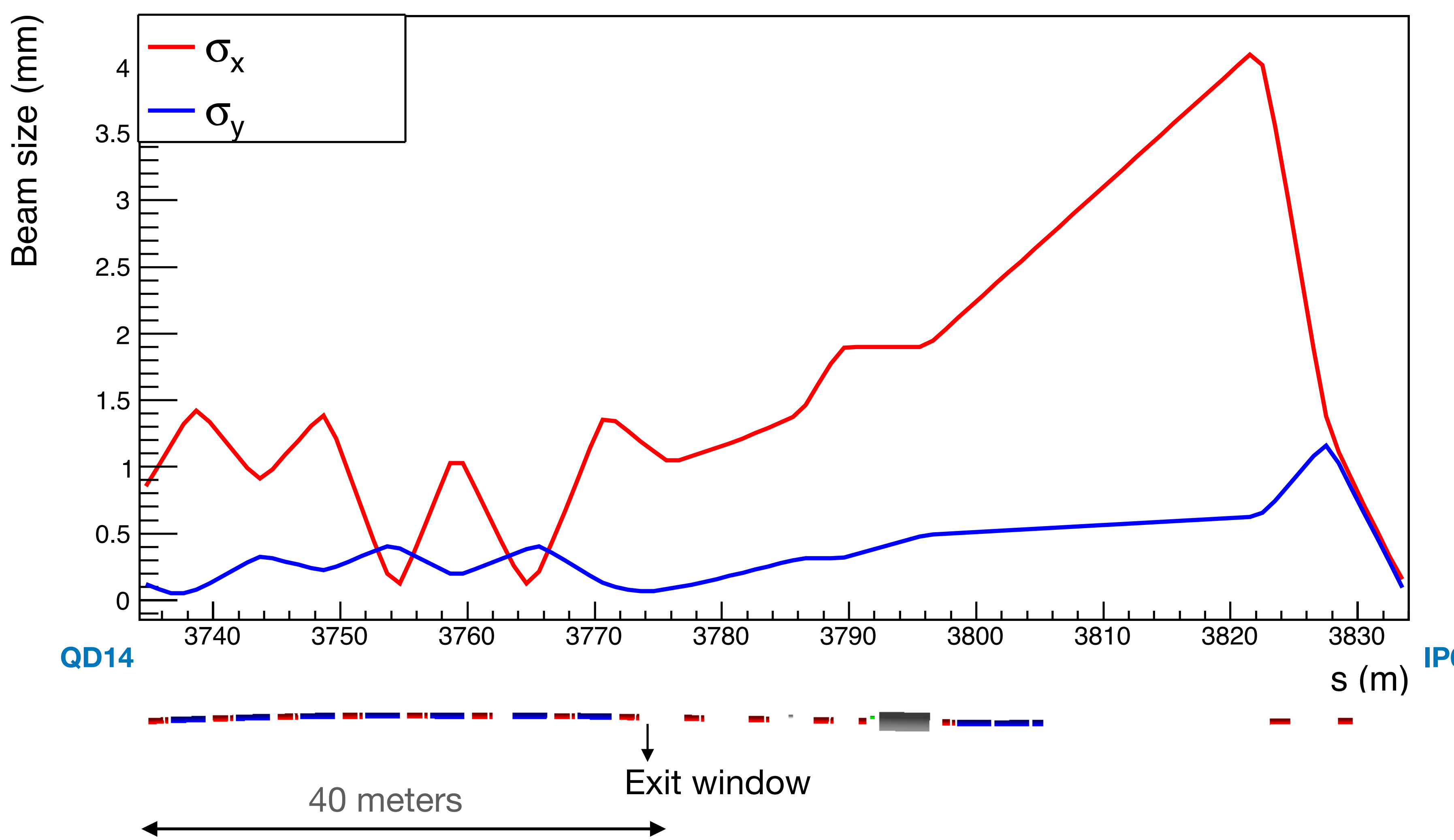
The emittance between two points is conserved, regardless of the change in beam shape and orientation, so the twins parameters transform as:

$$\begin{pmatrix} \beta \\ \alpha \\ \gamma \end{pmatrix} = \begin{pmatrix} C^2 & -2SC & S^2 \\ -CC' & (S'C + SC') & -SS' \\ C'^2 & -2S'C' & S'^2 \end{pmatrix} \begin{pmatrix} \beta_o \\ \alpha_o \\ \gamma_o \end{pmatrix}$$

- The collision vertex depends on the beam size;
- Beam size can be given by the emittance and beta function as

$$\sigma_{x,y} = \sqrt{\epsilon_{x,y}\beta_{x,y}}$$

- The beta functions can be calculated using the transform matrix along the beamline;

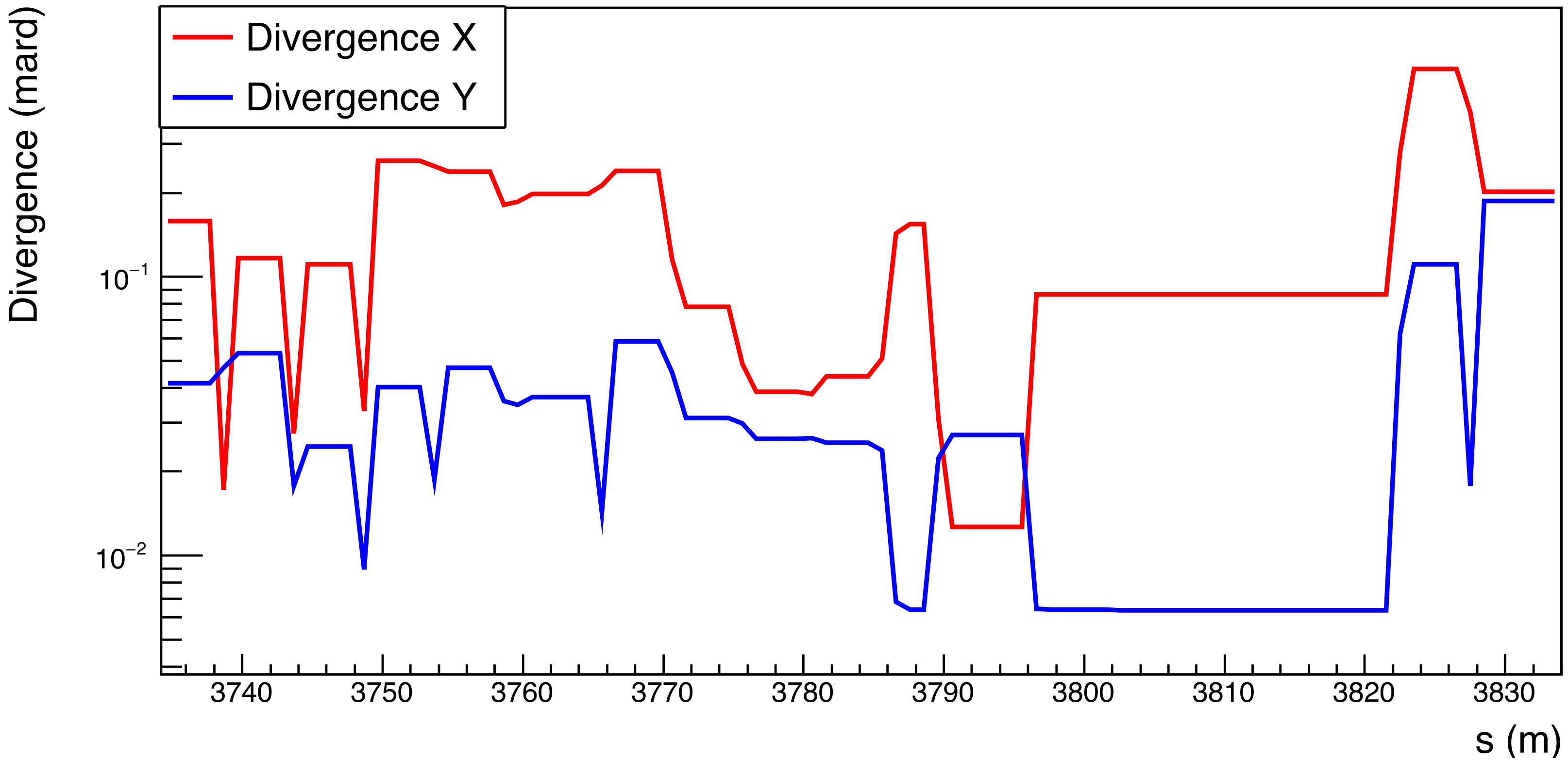


Beam angular divergence

- Angular divergence gives spread in the angles of beam particles;
- With α and β from the beam lattice, the divergence can be given by

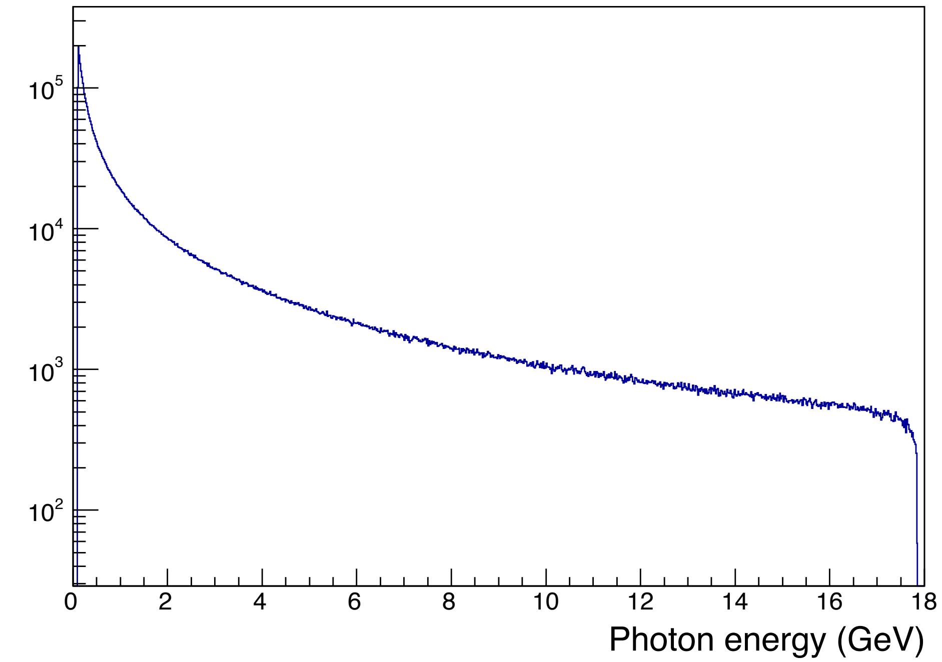
$$\sigma_\theta = \sqrt{\epsilon \frac{1+\alpha^2}{\beta}}$$

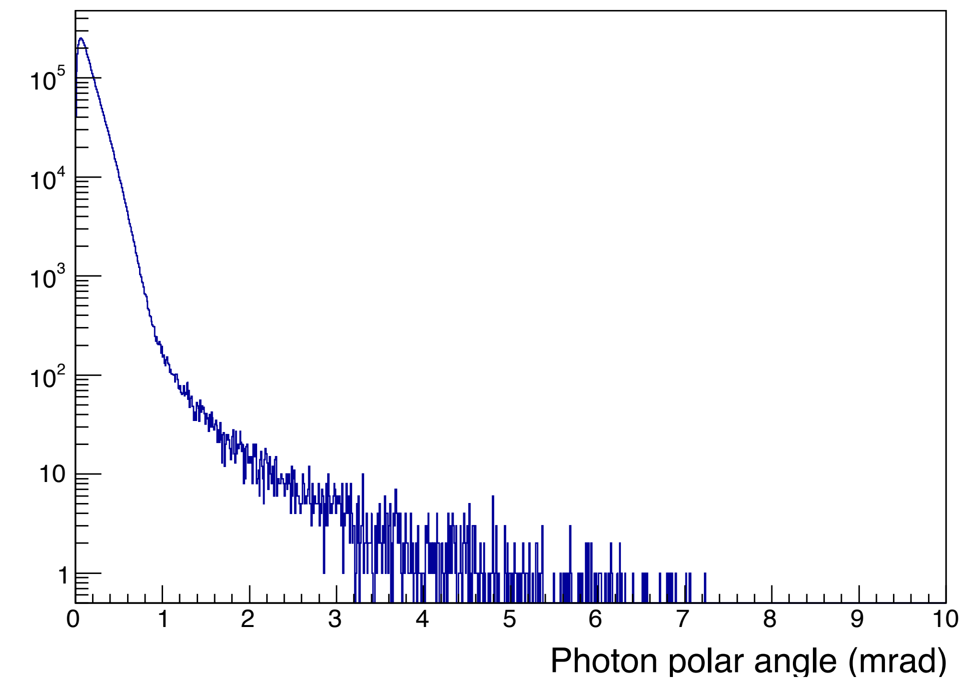
- The divergence is applied to generated photon and electron as random Gaussian rotations imposed on particles 3-momenta with the width of σ_θ;



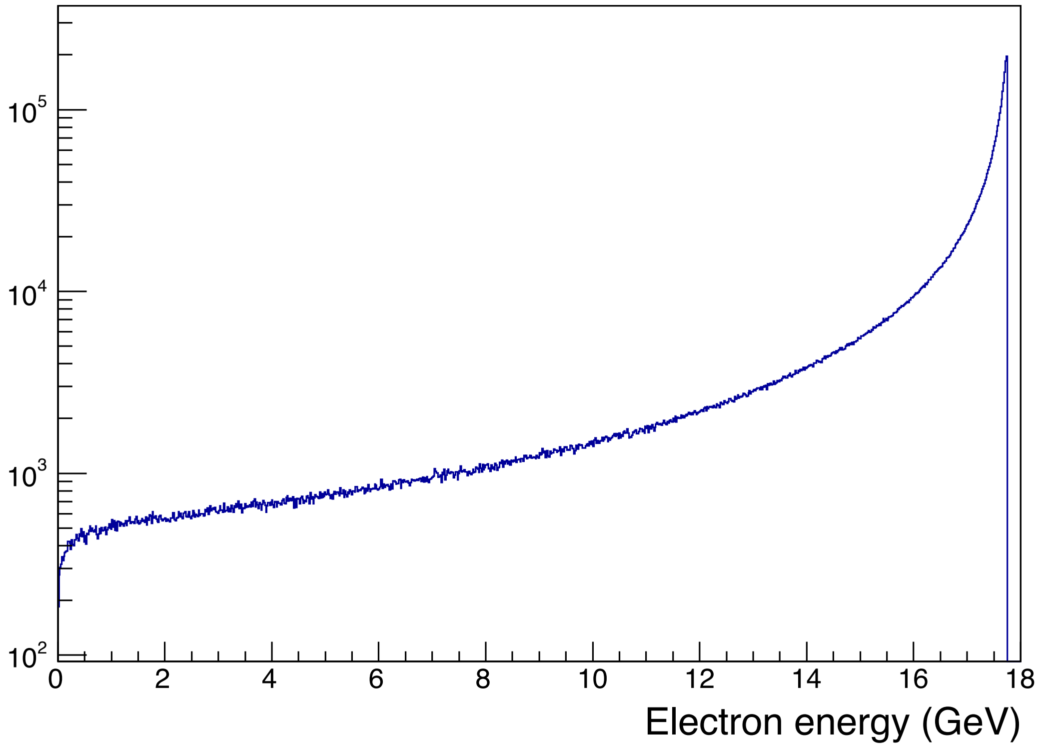
Photon energy and polar angle

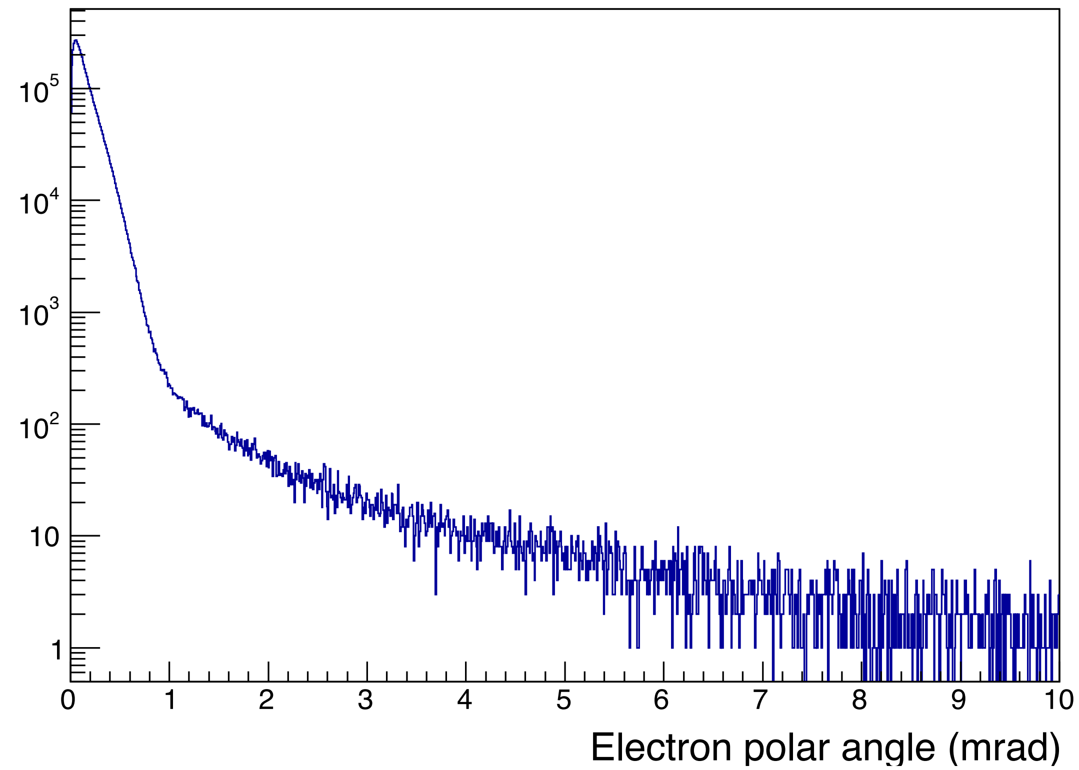
- By integrating the double differential cross section of the Bremsstrahlung process with the beam effect, I generated 5 M events distributed along the 40-meter length of the beamline, particularly focused around the exit window.
- The energy of the photons ranges from a minimum threshold of 0.1 GeV up to the energy level of the beam.
- The Bremsstrahlung photons are in the quite forward direction;
- These events were then put into the simulation framework of the electron polarimeter.





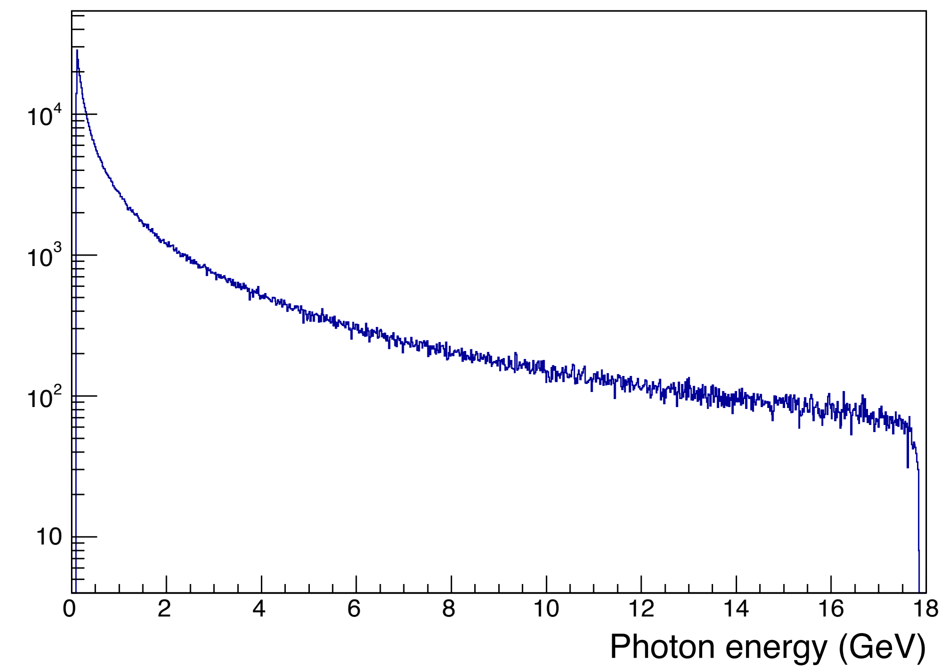
Scattered electron energy and polar angle

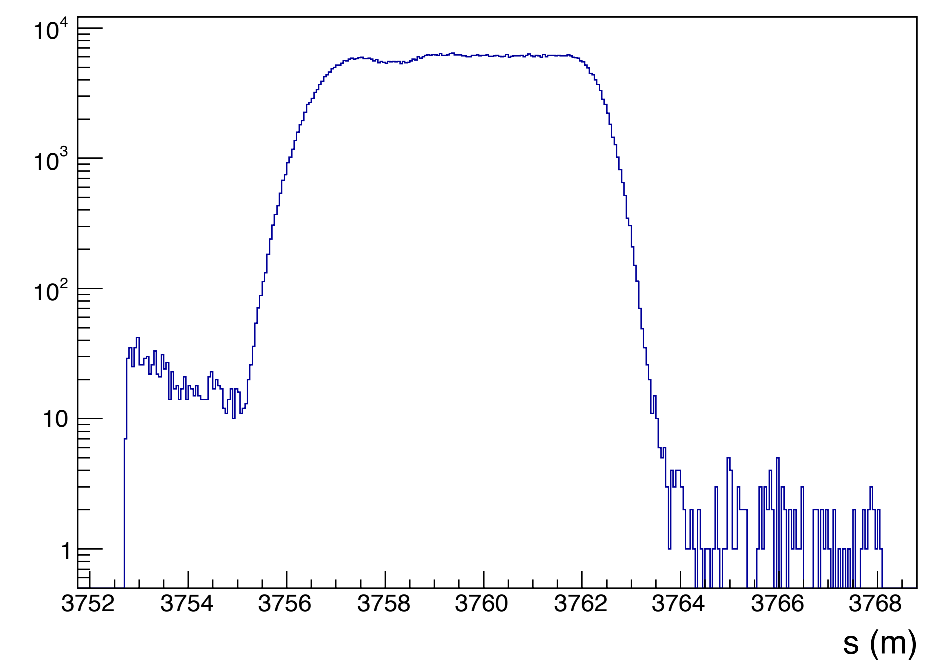


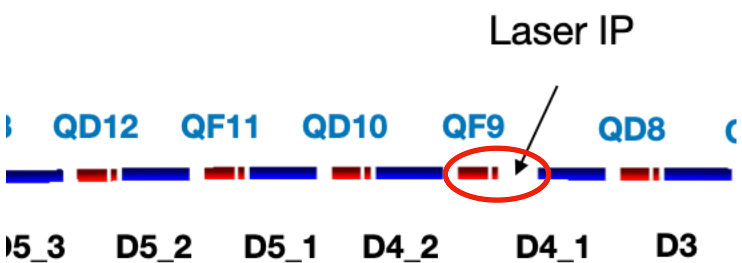


Detection of Bremsstrahlung Photons in the Photon Detector

- Electrons scattered from Bremsstrahlung are deflected in the opposite direction by the magnet, resulting in the detection of only Bremsstrahlung photons in the photon detector.
- The primary source of photons is the beamline spanning approximately 3752 to 3764 meters, concentrated around the laser IP.
- The photon detector registers a total deposited energy of about 1.76e5 GeV per second.
- As we have 2.29e7 bunches per second, the energy deposited from Bremsstrahlung per individual bunch time amounts to around 0.0077 GeV.
- Assuming roughly one Compton event per bunch, the energy deposition is estimated at 3.4 GeV per bunch, making the 0.0077 GeV seemingly negligible in comparison.







Summary

- The amount of background radiation from Bremsstrahlung affecting the photon detector is very low, just 0.0077GeV per bunch.
- The residual gas pressure around the laser Interaction Point (IP) is crucial.
- Need to double-check the background from synchrotron radiation.
- Next, study the background for the electron detectors.