Rates of electron beam gas

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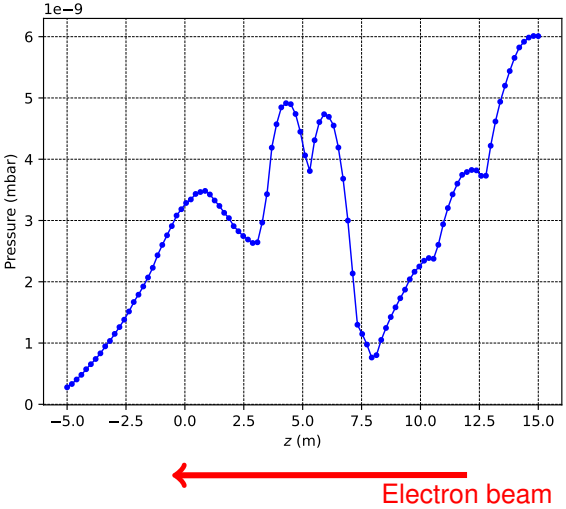
Introduction

- Beam electron are incident on hydrogen molecules, considered at rest
- Bremsstrahlung photon and scattered electron are produced in the interaction
- Origin of production rates given in the wiki in https://wiki.bnl.gov/EPIC/index.php?title=Background will be shown in the following
- Dedicated event generator for electron beam-gas was incorporated into existing generator in Comput.Phys.Commun. 272 (2022) 108251
- Interaction position follows hydrogen pressure in the vacuum chamber
- Data on pressure and beam parameters are in indico.bnl.gov/event/10974/contributions/51260/

Chamber pressure

- Pressure of H_2 gas from Detector.chamber.vacuum.Aug2021.xlsx (indico link on previous page)
- Case of $10\,000$ Ahrs (the best case)
- The pressure is given as a function of z along the beam
- Points are the data from xlsx, lines are a result of linear interpolation for use in the generator
- Full range from -5 to +15 meters is considered in the simulation

Beam-gas vertex distribution along z is given by the pressure



Bremsstrahlung beam-gas generator

- Implemented as an extension to the generator for luminosity studies in Comput.Phys.Commun. 272 (2022) 108251
- Double-differential bremsstrahlung cross section as a function of photon energy and polar angle is integrated with `TFoam` (gains precision also for photons at low energies)
- Outcome from the generator is the photon and scattered electron (HepMC3)
- Limit on minimal bremsstrahlung photon energy E_γ is set to 10 keV
- Total cross section for 10 GeV beam and $E_\gamma > 10$ keV is $\sigma_{\mathrm{BR}} = 699.392 \pm 0.041$ mb
- The limit on E_γ was determined by comparing two samples of 10M events with 10 keV and 100 keV limits; no appreciable increase in hit rates was observed, 10 keV is used for all results
- Vertex position is generated according to the beam gas interaction vertex
- Angular divergence is applied to the photon and electron according to its dependence on z of the vertex

Photon energy and angular spectrum

Figure: Photon energy

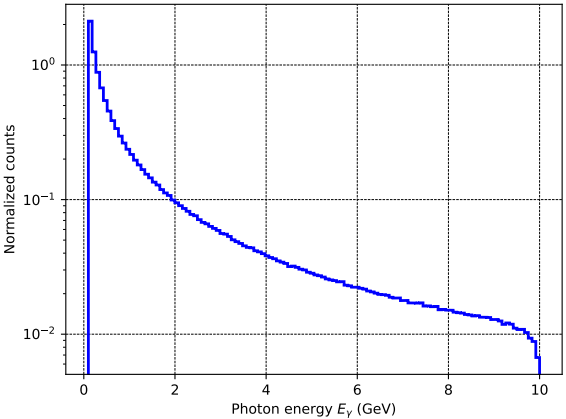
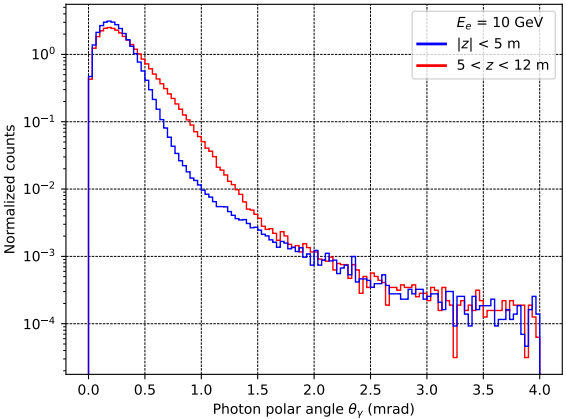


Figure: Photon polar angle



Electron energy and angular spectrum

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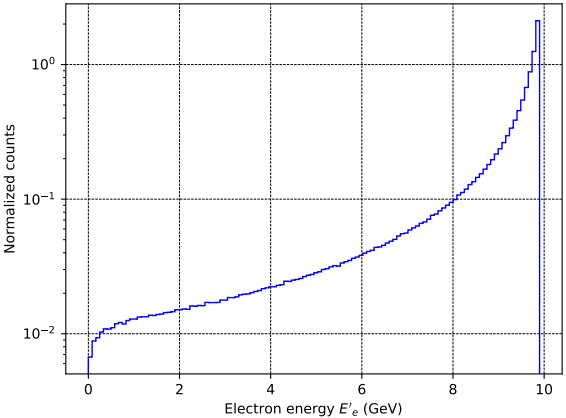
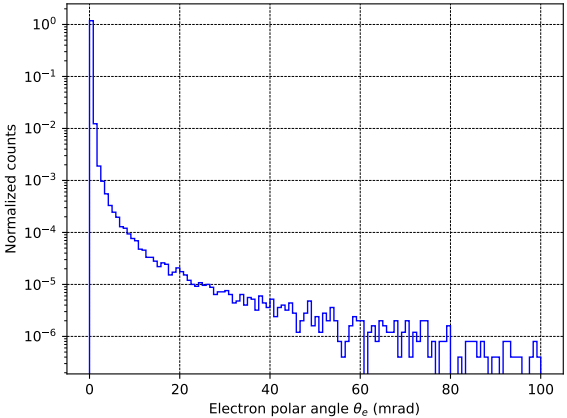


Figure: Electron polar angle



Calculation of production rate by bremsstrahlung on H_2 gas

- Rate R_{BR} of bremsstrahlung events per second is

$$R_{\mathrm{BR}} = \sigma_{\mathrm{BR}} \times I \times N$$

- Total cross section σ_{BR} is on page 4
- I is beam current in electrons per second, given by current in Amps from CDR Tab. 3.3 (2.5 A) divided by elemental charge in C
- N is surface density as number of protons per m^2 from pressure p, Boltzmann constant R_B and normal temperature T (293.15 K):

$$N = \delta z \times 2 \times p/(R_B \times T)$$

- Factor of 2 stands for two protons in H_2 which makes the pressure p
- δz is slice of length along z

Production rate for electron beam-gas due to bremsstrahlung

- Production rate R_{BR} along z is shown for δz = 20 cm
- Procedure from previous page 7 is followed
- Each interval δz contributes bremsstrahlung beam-gas rate shown in the plot
- Total production rate over all z for 10 GeV beam and $E_\gamma > 10$ keV is 3.177 MHz
- Same procedure is used for other beam energies for the rates on the wiki page