Electron beam gas

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Update on electron beam - gas rates

- Lower limit on bremsstrahlung photons was decreased to 100 keV from previous 100 MeV
- Formalism for hard bremsstrahlung in event generator should still hold, literature shows the limit at $\mathcal{O}(10)$ keV
- Total cross section is 538 mb instead of 151 mb for 100 MeV
- Incident rate was taken for the location of inner vertex tracker, the total rate is 221 Hz
- Full DD4hep simulation was done with 10M events
- Events with bremsstrahlung photons at the lower limit of 100 keV still produce hits in detectors; depending on the actual thresholds it will have to be decreased

Geant for hit counts at inner vertex tracker

- Geant with realistic beampipe and counter for hits on its surface
- Event rate R_z per surface area at a given z is:

$$R_z = N_z \times \frac{R_{\text{prod}}}{N_{\text{sim}}} \Big/ S_z$$

- N_z is number of hits counted in interval δz at a given z
- R_{prod} is the total production rate
- N_{sim} is number of all simulated events
- S_z is area of cylindrical surface at a given z

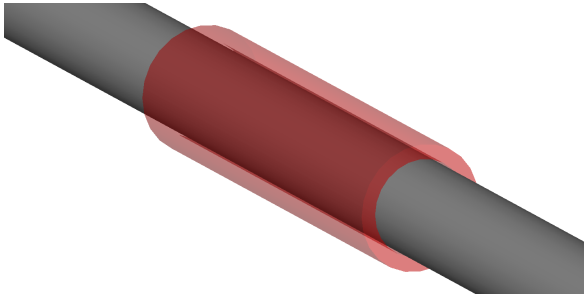
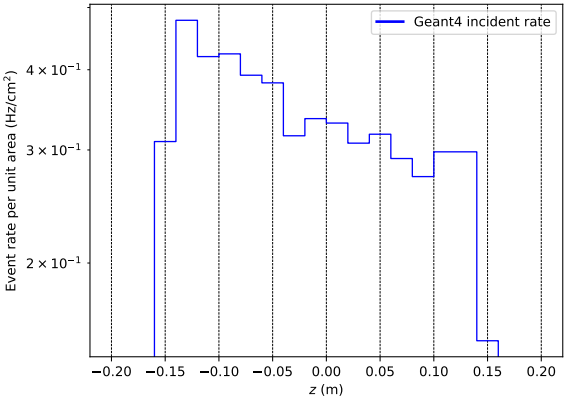


Figure: Counter at position of inner vertex tracker

Hit counts at inner vertex tracker

- Simulation of 100M beam-gas events with beampipe and counter from previous page
- Total incident rate at the location of inner vertex tracker is 221 Hz



Hit energy on vertex barrel tracker

- DD4hep simulation of 10M, beam-gas events, same hepmc sample as was used with the counter
- Energy of hits in vertex tracker
- Trying to understand the discontinuity at 1 keV

Figure: All energies (MeV)

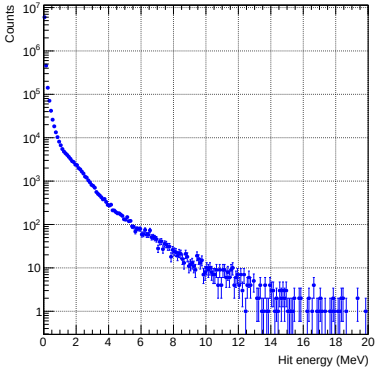
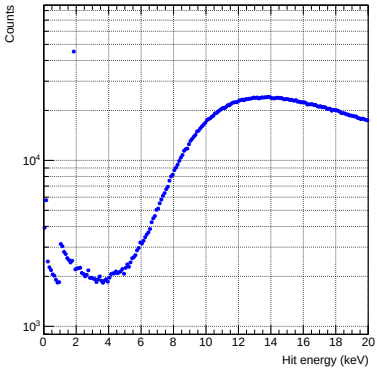


Figure: Zoom to low energies (keV)



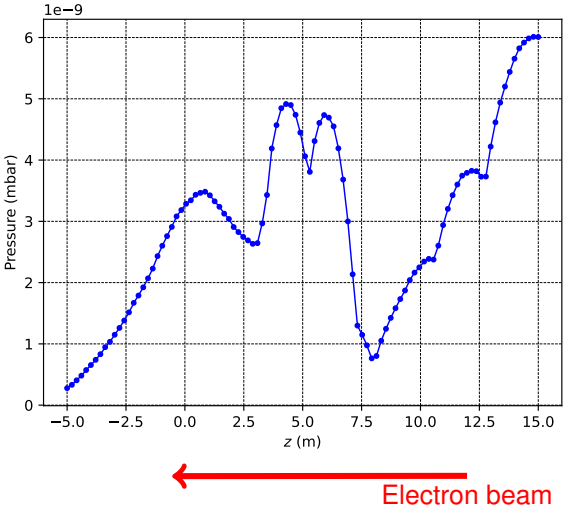
BACKUP

Electron beam - gas bremsstrahlung

- Beam electrons are incident on hydrogen and heavier gases
- Sample of 100M events for hydrogen was generated with bremsstrahlung photon and scattered electron in final state
- Beam angular divergence is applied to the photons and electrons
- Total cross section is σ_{BR} = 537.583 mb for photons above 100 keV
- Production rate is calculated for hydrogen based on chamber pressure and beam current
- Date on pressure and beam parameters are in indico.bnl.gov/event/10974/contributions/51260/
- Total production rate is 685.833 kHz for -5 < z < 15 m along electron beampipe (region with data on pressure)

Chamber pressure

- Pressure of H_2 gas from Detector.chamber.vacuum.Aug2021.xlsx
- Case of 10 000 Ahrs
- 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 event generator



Beam-gas interaction vertex

- Distribution of electron beam - gas interaction vertices
- Shape in x and y is given by beam size at a given location in z
- Shape in z follows the pressure
- Scale in z is in m, scale in x and y is mm

Figure: xz plane

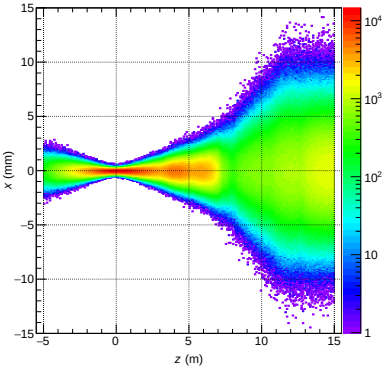
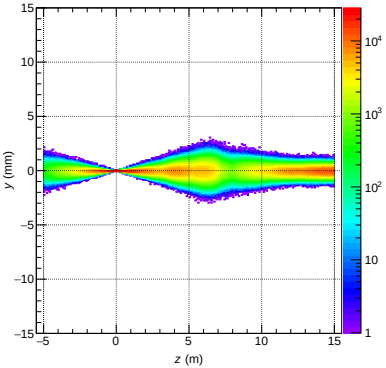


Figure: yz plane



Photon energy and angular spectrum

Figure: Photon energy

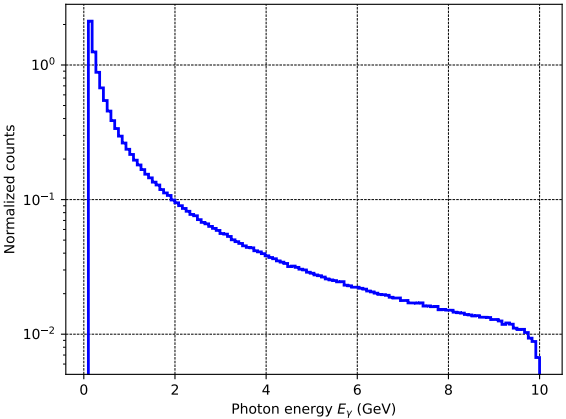
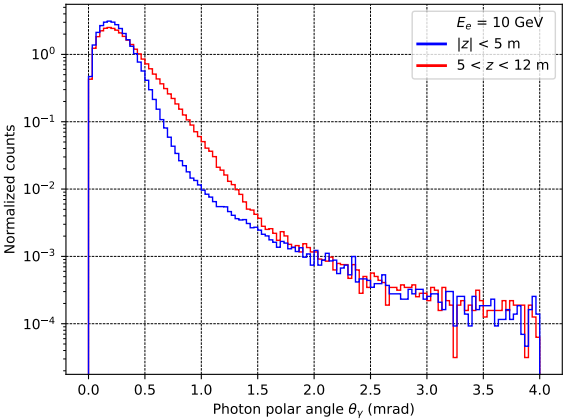


Figure: Photon polar angle



Electron energy and angular spectrum

Figure: Electron energy

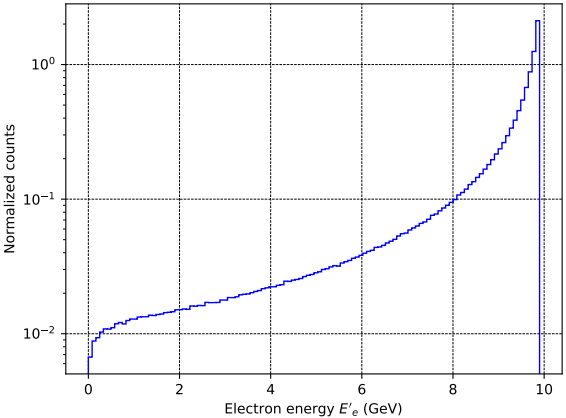
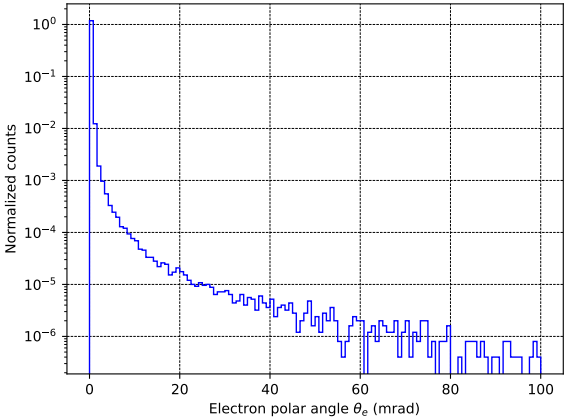
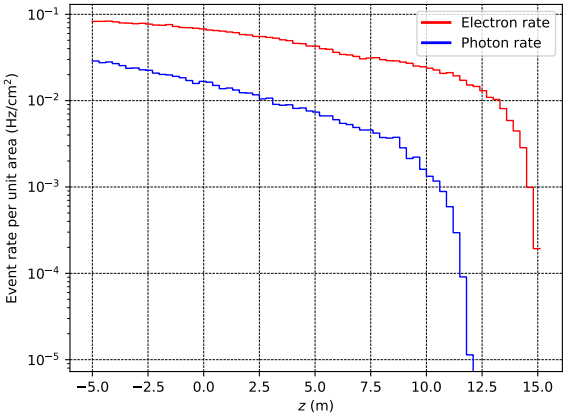


Figure: Electron polar angle



Event rate incident on inner surface of beam pipe

- Photons and electrons are projected on the inner surface of the beam pipe



- Total rate integrated over all z by photons and electrons together is 2.2 kHz

Calculation of production rate by bremsstrahlung on H_2 gas

- Rate R of bremsstrahlung events per second is

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

- Total cross section for $E_\gamma > 100$ keV is $\sigma_{\mathrm{BR}} = 537.583$ mb
- 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 by electron beam - gas due to bremsstrahlung

- Event rate R along z in δz = 20 cm
- Each interval δz contributes bremsstrahlung beam-gas rate shown in the plot
- Rate from a given range in z is a sum of individual δz contributions within that range