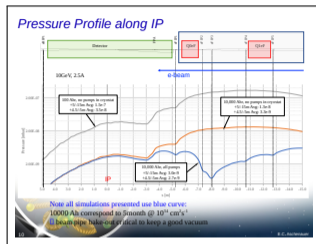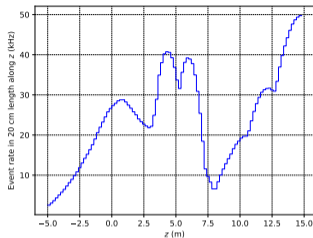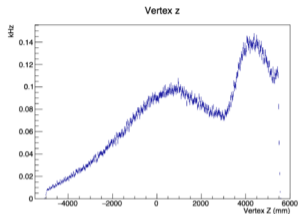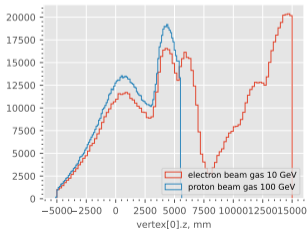# Beam gas background in EEEMCal and SiPM readout simulation

Dmitry Kalinkin

September 15, 2023
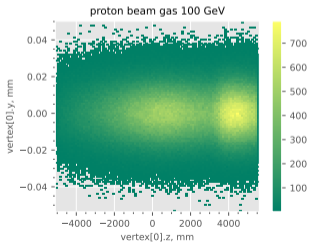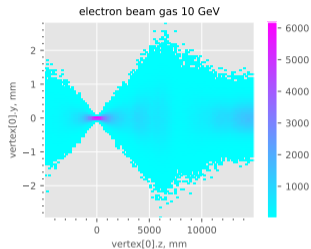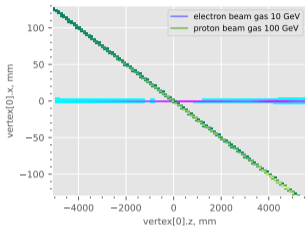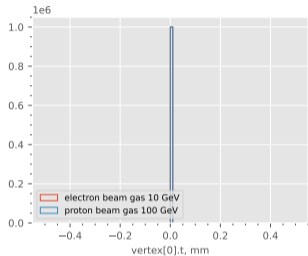
Beam gas background in EEEMCal

Input vertices

Hadron beam gas Electron beam gas Elke's presentation at TIC meeting

Input vertices

Simulated events

Arbitrary non-empty events

Hit rates

for E > 0 GeV

electron beam gas 10 GeV (EcalEndcapNHits)
DIS 10x100 (EcalEndcapNHits)
proton beam gas 100 GeV (EcalEndcapNHits)

for E > 0.1 GeV

electron beam gas 10 GeV (EcalEndcapNHits)
DIS 10x100 (EcalEndcapNHits)
proton beam gas 100 GeV (EcalEndcapNHits)

for E > 0.5 GeV

electron beam gas 10 GeV (EcalEndcapNHits)
DIS 10x100 (EcalEndcapNHits)
proton beam gas 100 GeV (EcalEndcapNHits)

for E > 1.0 GeV

electron beam gas 10 GeV (EcalEndcapNHits)
DIS 10x100 (EcalEndcapNHits)
proton beam gas 100 GeV (EcalEndcapNHits)

Background embedding

Input files:

```
S3/eictest/EPIC/EVGEN/DIS/NC/10x100/minQ2=1/pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc
S3/eictest/EPIC/EVGEN/BACKGROUNDS/BEAMGAS/electron/beam_gas_ep_10GeV_foam_emin10keV_10Mevt_vtx.hepmc
```

Using HEPMC merger (very likely, freq settings are not correct! this is WIP)

```
python3 HEPMC_Merger/signal_background_merger.py \
  --signalFile pythia8NCDIS_10x100_minQ2=1_beamEffects_xAngle=-0.025_hiDiv_1.hepmc \
  --signalFreq 0 \
  --bg1File "../beam_gas_ep_10GeV_foam_emin10keV_10Mevt_vtx.hepmc" --bg1Freq 1852 \
  --bg2File "" --bg2Freq 1852 --bg3File ""
```

$E_{\text{dep.}}/p$
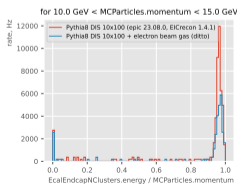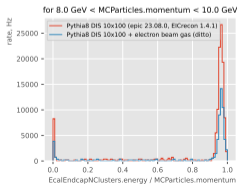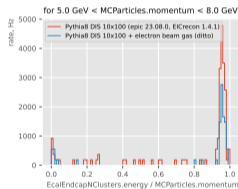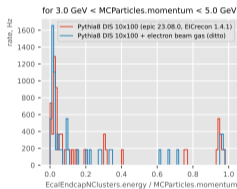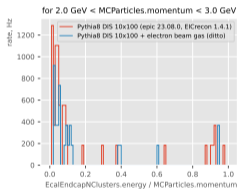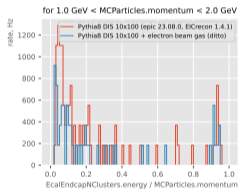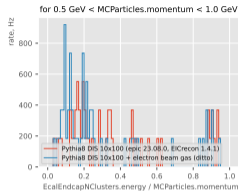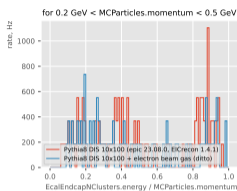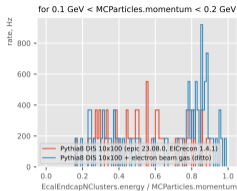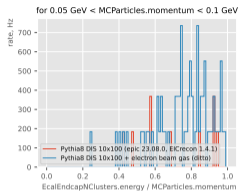
Summary

Electron beam background is dominant
Embedding studies are WIP

Some extra read:
https://wiki.bnl.gov/EPIC/index.php?title=Background
https://indico.bnl.gov/event/20355/contributions/80365/
attachments/49573/84742/Changes%20to%20the%20simulations%
20needed%20for%20background%20integration.pdf

SiPM readout simulation

Previous discussions

This was previously discussed in the context of SciGlass back in September 2022
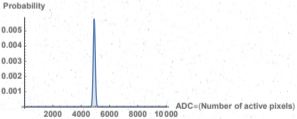https://indico.bnl.gov/event/17074/.

`kSiPM_photon_digitization'' in Fun4All

» Defines a probability for a single pixel to fire:

$$P_{\text{pixel}} = 1 - \exp\left(-\frac{E_{\text{tower}} \times N_{\text{photoelectrons/GeV}}}{N_{\text{pixels}}}\right)$$

$$N_{\text{photons}} \sim \text{Binomial}(N_{\text{pixels}}, P_{\text{pixel}})$$

» Produces a following distribution of N_{photons} for a 1 GeV tower:

» And is converted back to energy using a "gain" of $\frac{1}{N_{\text{photoelectrons/GeV}}}$.

University of Kentucky

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For barrel review this was implemented, but in EICrecon it was not.

Original code from ECCE/sPhenix (equivalent to the formula on the previous slide):

```
const double photon_count_mean = energy * m_PhotonElecYieldVisibleGeV;
const double poission_param_per_pixel = photon_count_mean / m_SiPMEffectivePixel;
const double prob_activated_per_pixel = gsl_cdf_poisson_Q(0, poission_param_per_pixel);
const double active_pixel = gsl_ran_binomial(m_RandomGenerator , prob_activated_per_pixel, m_SiPMEffectivePixel);
```

To my understanding, two effects are considered:

1. Pixel saturation (source of non-linearity)

   A formula (the Poissonian $1 - \exp(-\lambda)$ part) for the mean signal is given in a few references, e.g.
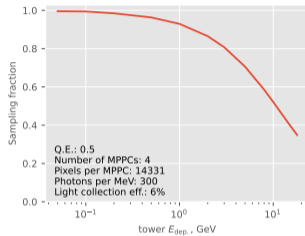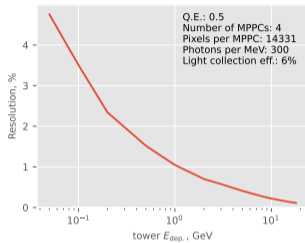
   https://arxiv.org/abs/1510.01102v4

2. Statistical fluctuations from light collection and QE

   It is not clear what reference the fluctuation (binomial distribution) part comes from. It does not make sense e.g. in the limit of no saturation (large N_{pixels}) – my suspicion is that this part was made up at sPhenix.

Numerical evaluation

50 μm pitch S14160-6050HS

10 μm pitch (S14160-6010PS pixel count scaled by $\times$25 from the S14160-6050HS)
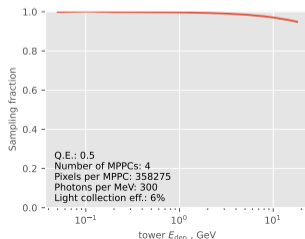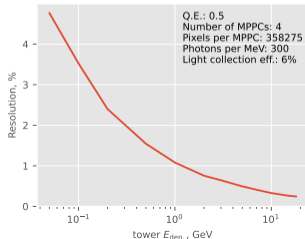
Summary

Fluctuations implementation is questionable
Implementation in EICrecon is WIP