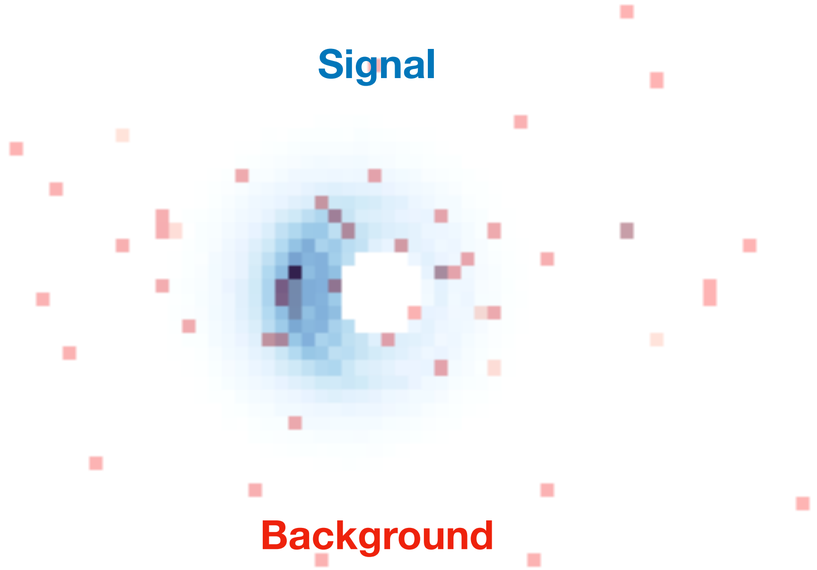
Background and track reconstruction studies



Reynier Cruz-Torres
Lawrence Berkeley National Laboratory

Presenting work done by lots of people: J. Adam, E. Aschenauer, W. Deconinck, J. Huang, A. Jentsch, K. Kauder, D. Lawrence, J. Nam, J. Osborn, B. Sterwerf, Z. Zhang, …

Electron Proton-Ion Collider Experiment Collaboration
January 10th, 2023

Outline

Backgrounds at the EIC

- Synchrotron radiation

- Primary collisions
  - Ionization radiation
  - Low Energy Neutron Radiation

- Beam-gas induced
  - Electron-gas interactions
  - Hadron-gas interactions

Wiki page to document background studies

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- Signal

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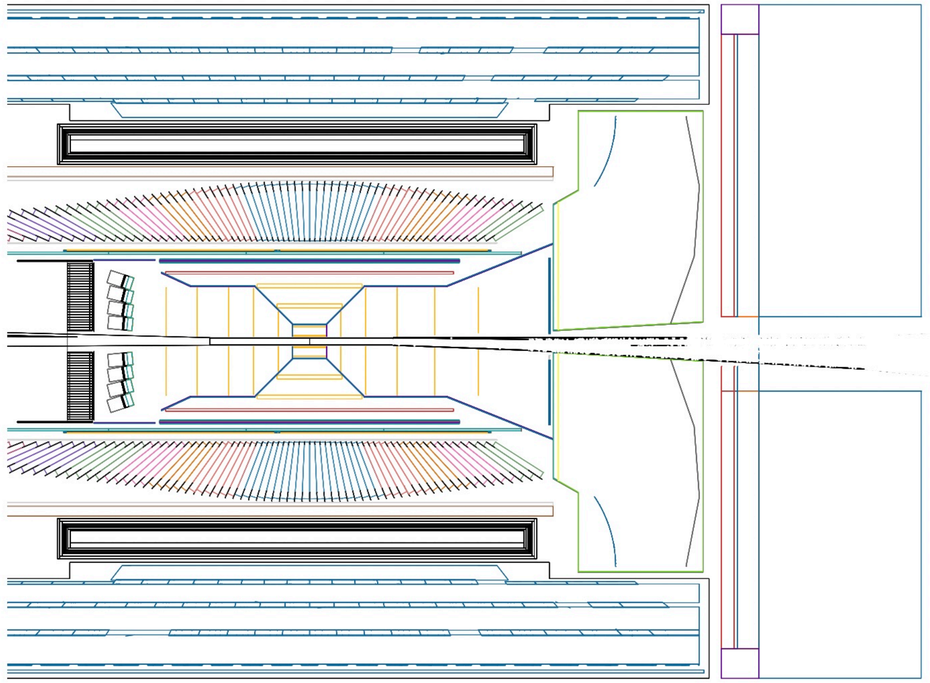


Wiki page to document background studies

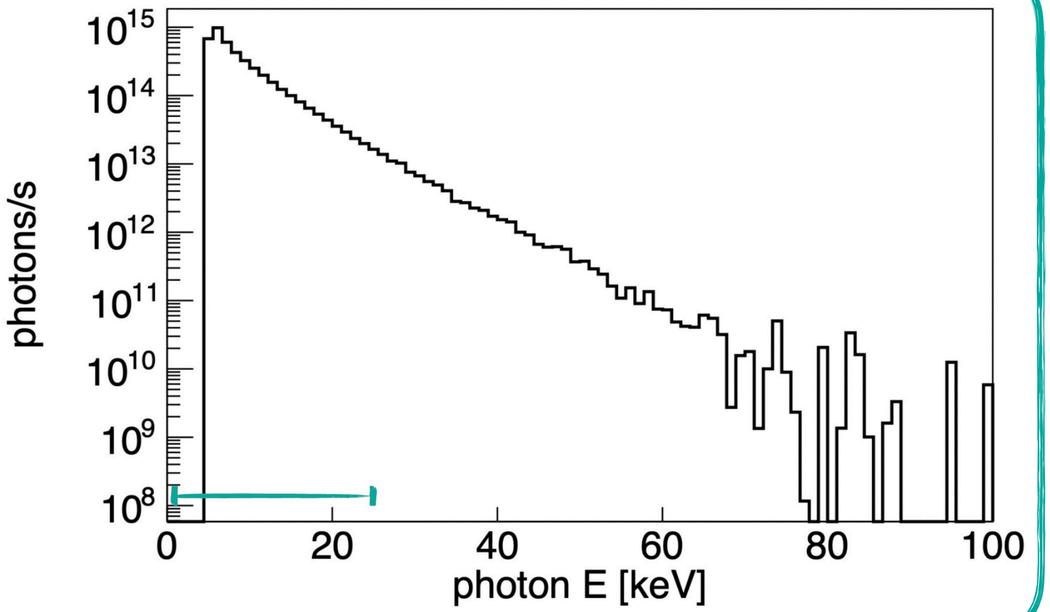
Synchrotron radiation

- Caused by quads and bending magnet upstream of IP

Simulations based on Synrad+ (by M. Stutzman)

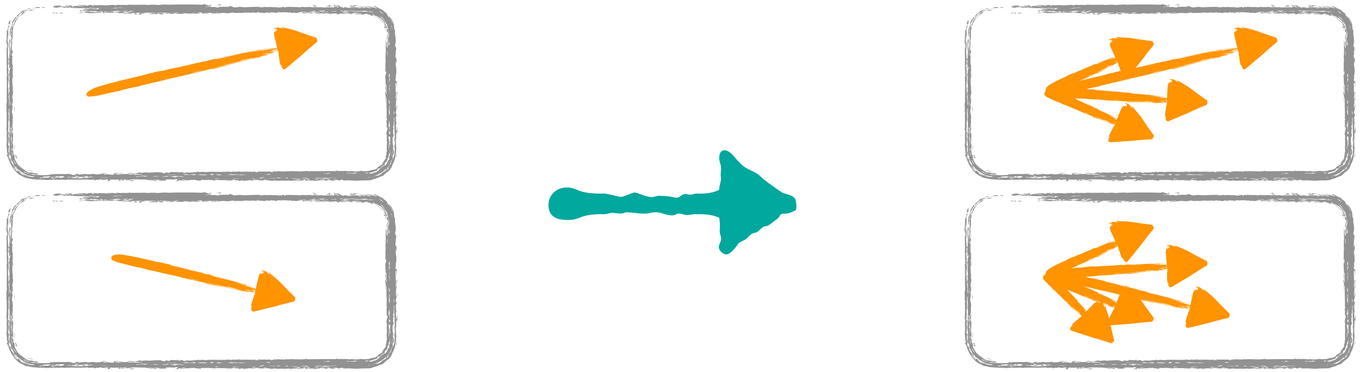
- virtual cylinder placed just inside the IR beampipe
- Electrons are propagated through B field
- resulting photons passing through cylinder are recorded

Output: hepmc file with single-photon “events” containing information related to photon vertex, momentum, and weight corresponding to equivalent photons / sec



Have

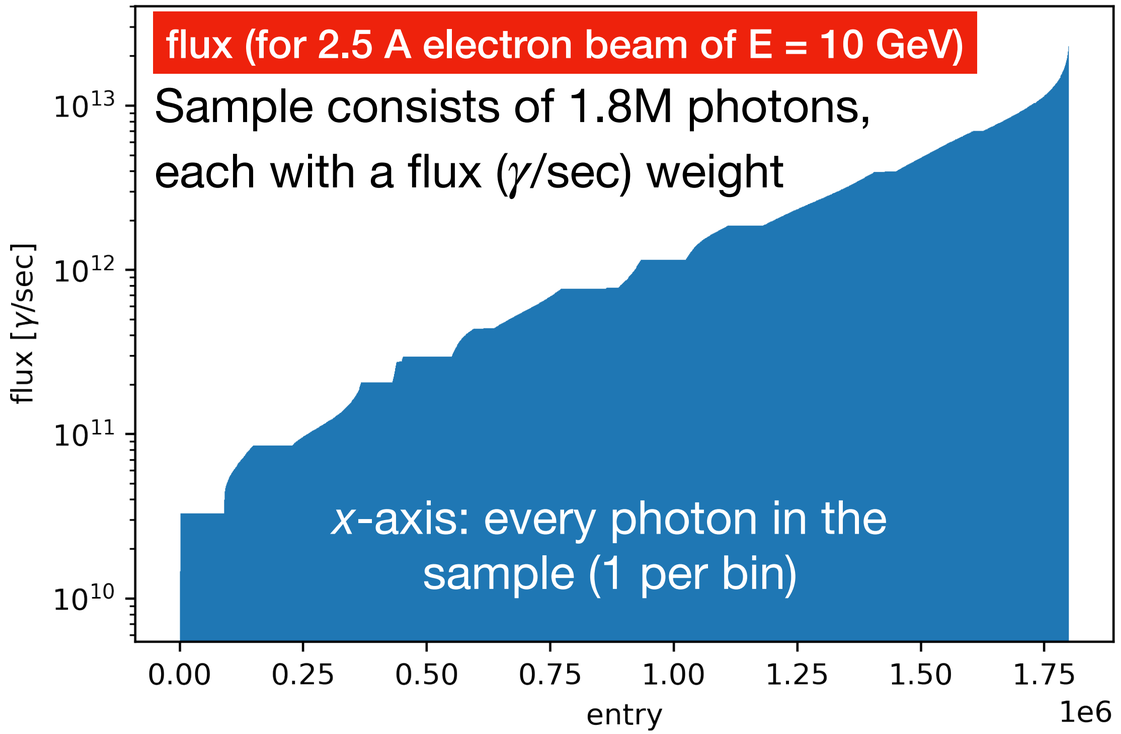
A series of single-photon events from a Synrad+ simulation.



Need

A series of events with many photons corresponding to a time integration window.

Synchrotron radiation event generator

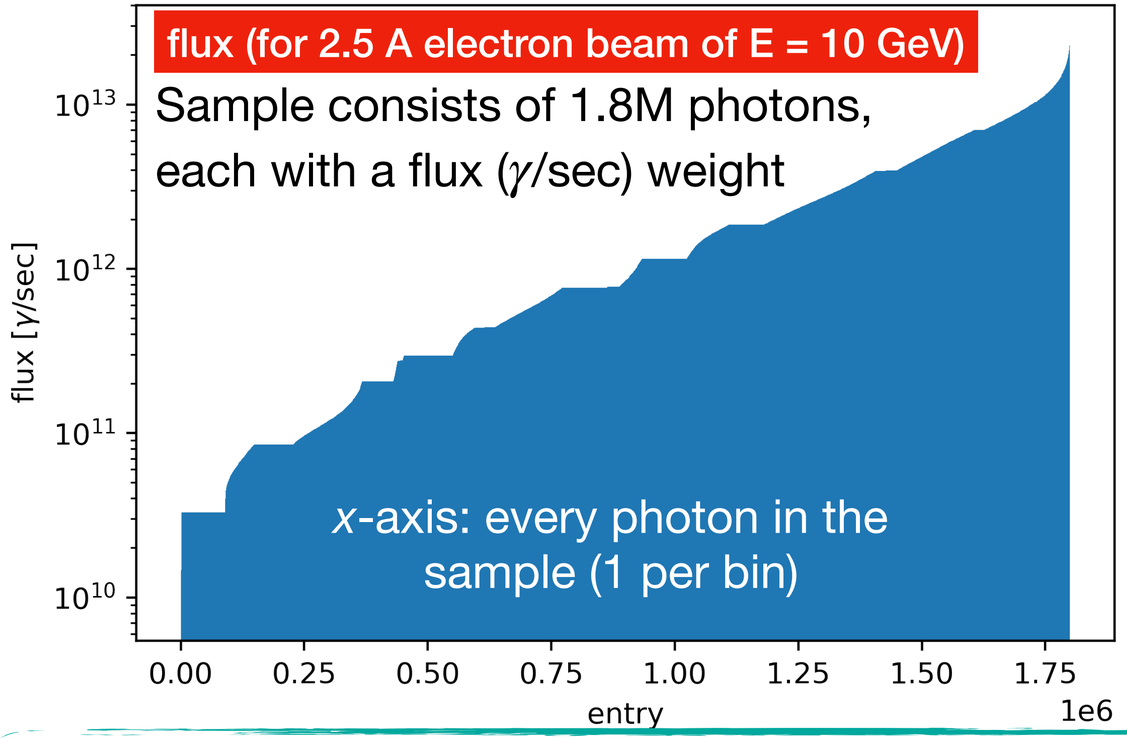


Define an integration window (IW)

```
integral = 0
while integral < IW:
    Randomly sample photon, add it to event
    integral += 1/flux
return event
```

Sample as many photons as fit in the defined time integration window

Synchrotron radiation event generator



Define an integration window (IW)

```
integral = 0
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    Randomly sample photon, add it to event
    integral += 1/flux
return event
```
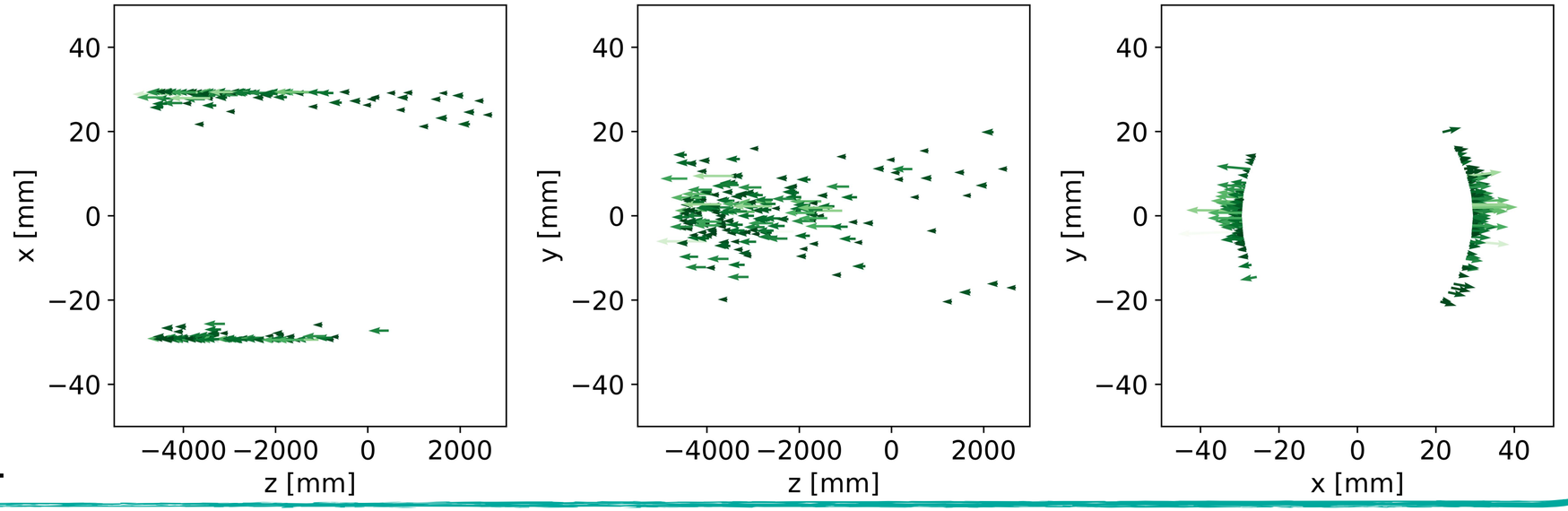

Sample as many photons as fit in the defined time integration window

Sample event for a 100 ns time integration window

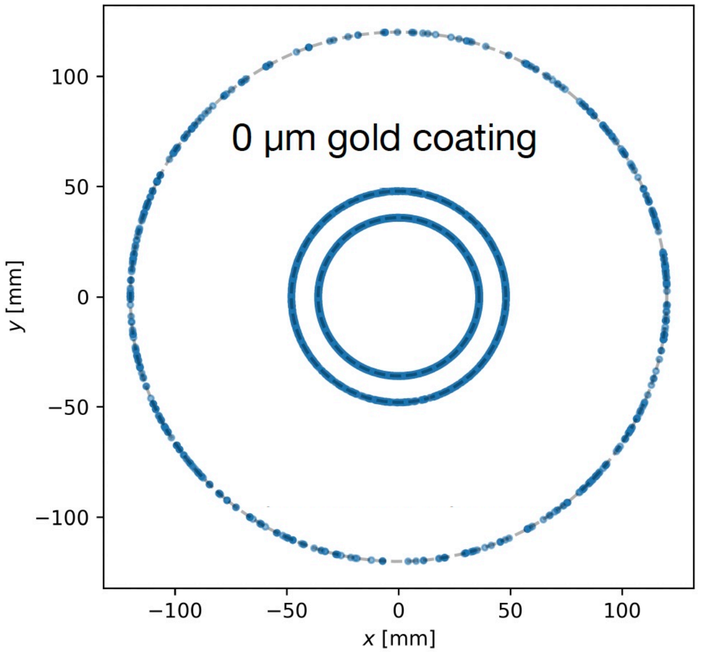


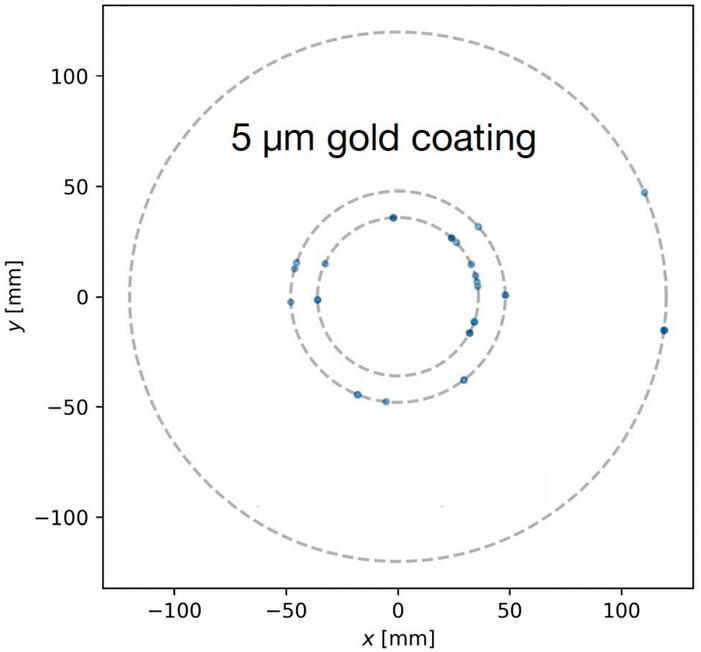
Study by Ben Sterwerf, **RCT**, et al.

Updated - EPIC

Synchrotron radiation results

Impact of gold coating in the beampipe





Study by Ben Sterwerf, **RCT**, et al.

See more details here

Updated - EPIC

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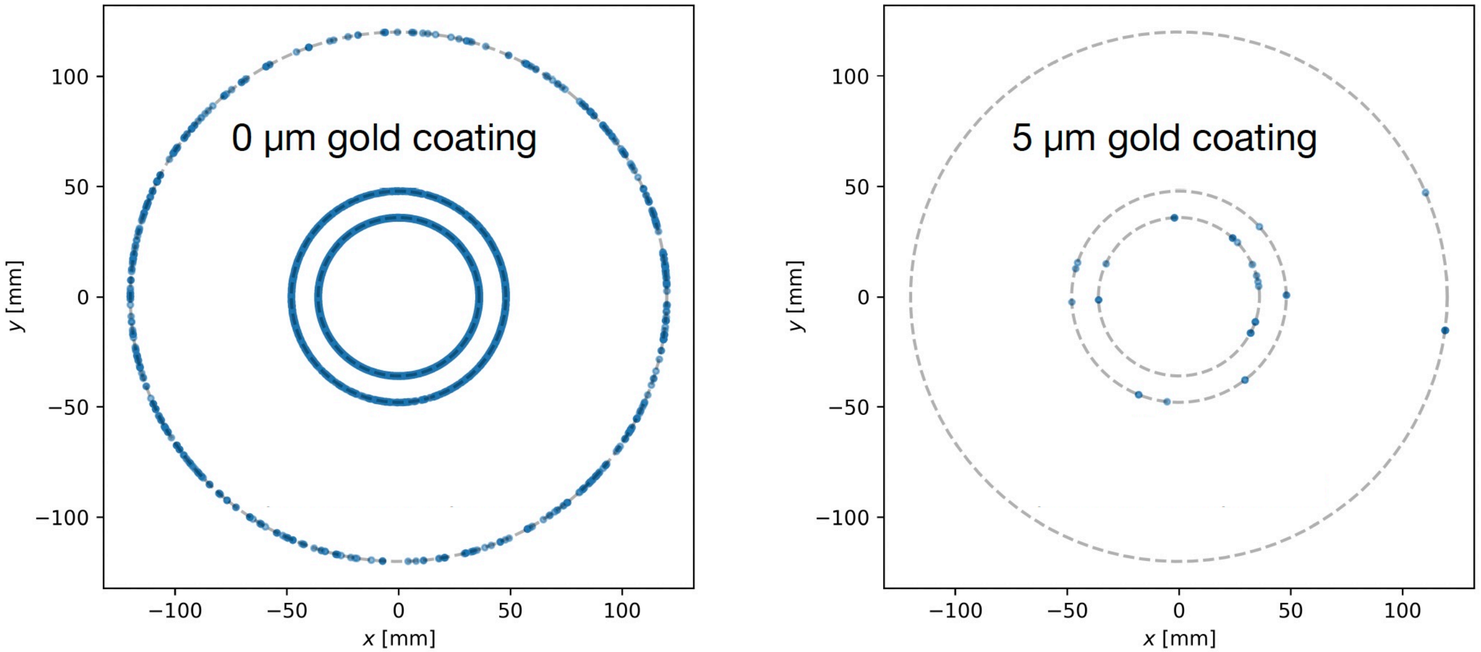

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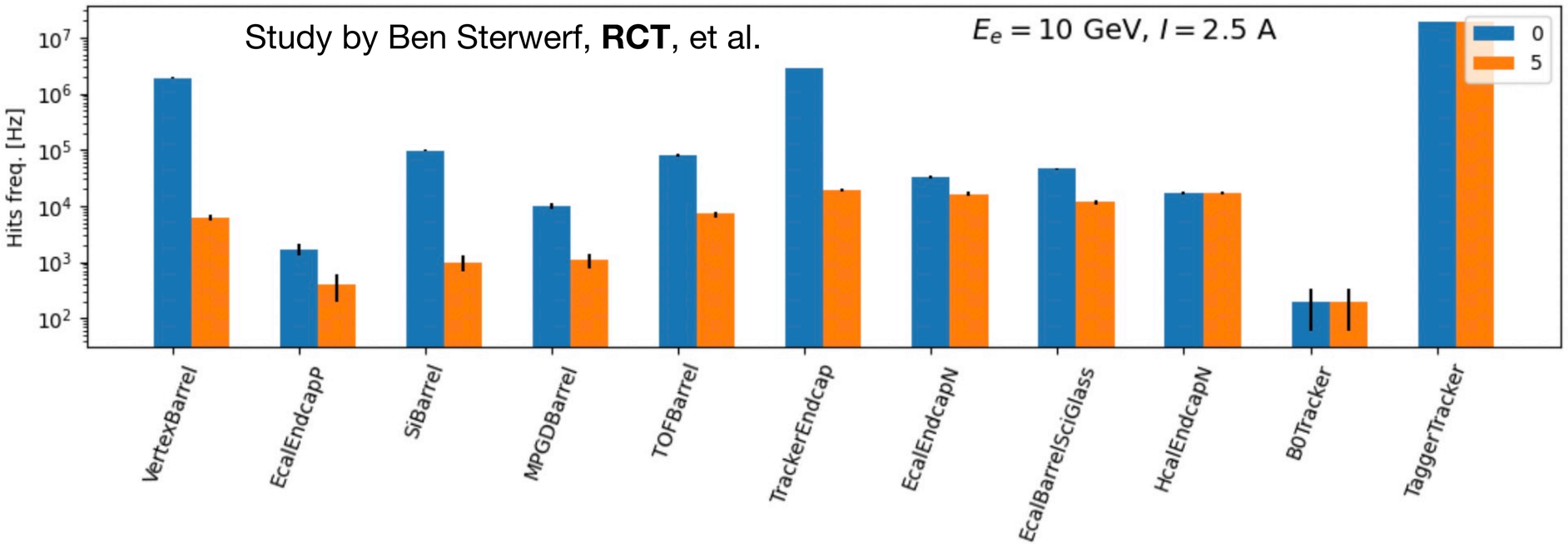
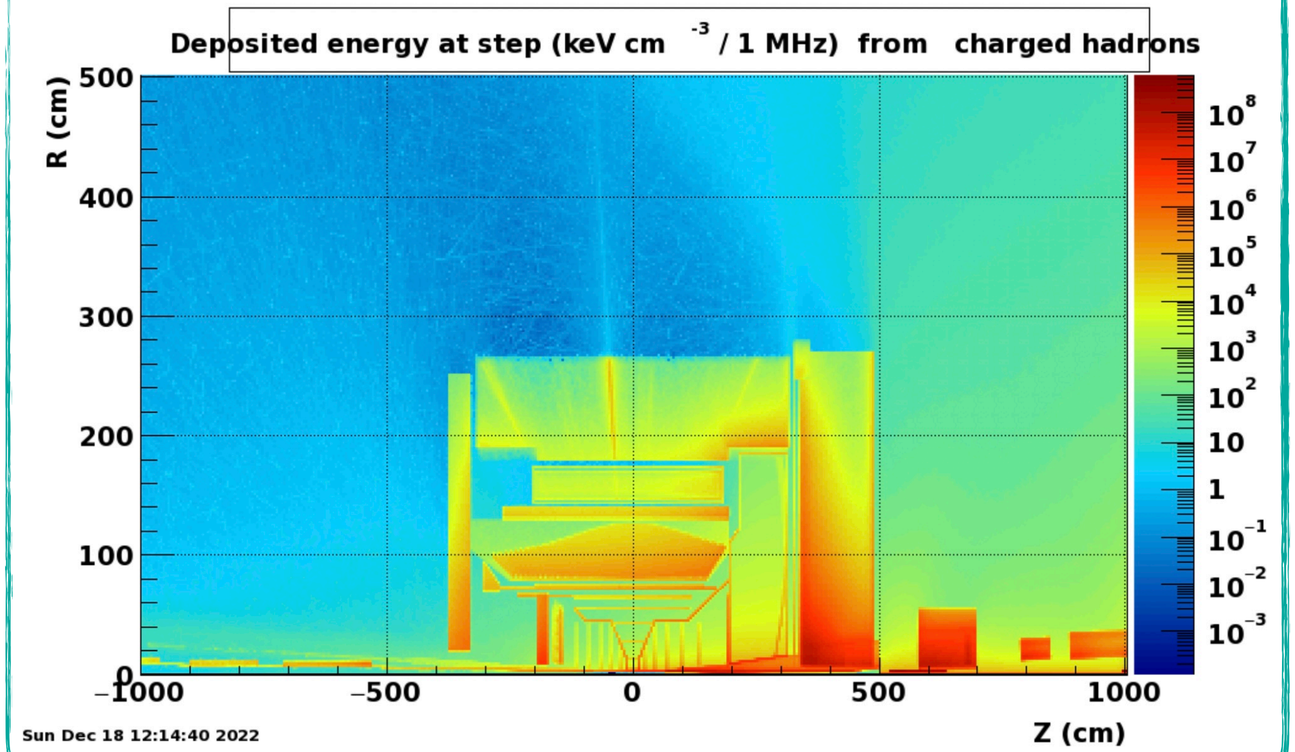


Updated - EPIC

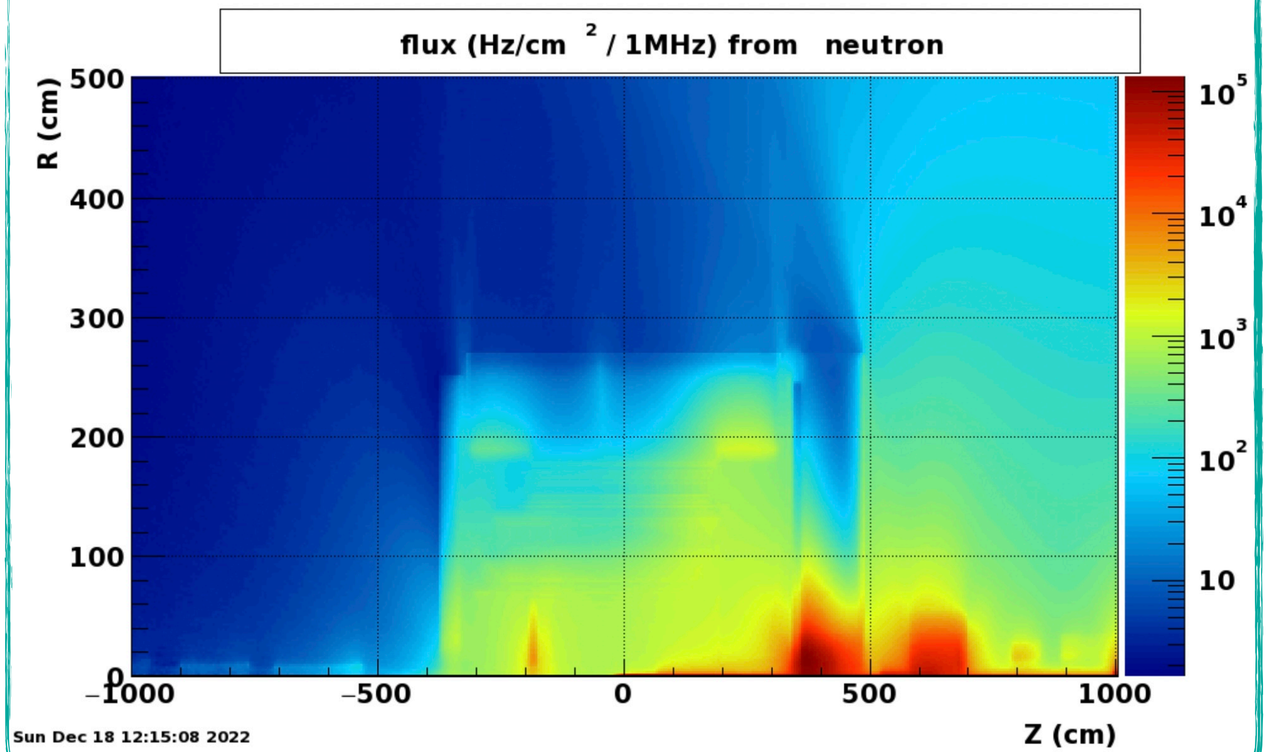
Primary Collisions

- Primary collisions → substantial fraction of ionizing radiation and low-energy neutron flux in the hall
- Simulations based on Pythia 6 tuned to HERMES, COMPASS and HERA with $Q^2 > 10^{-9}$ GeV^2

ionizing radiation



neutron flux



Study by Alex Jentsch, et al.

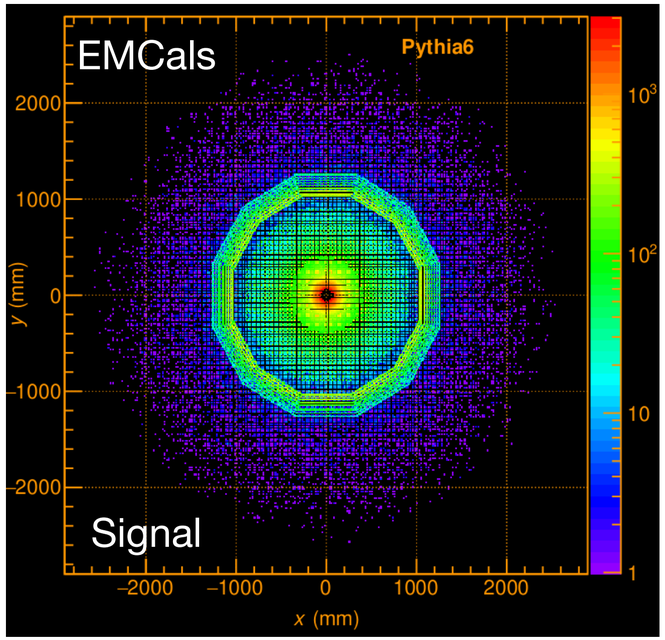
See more details here

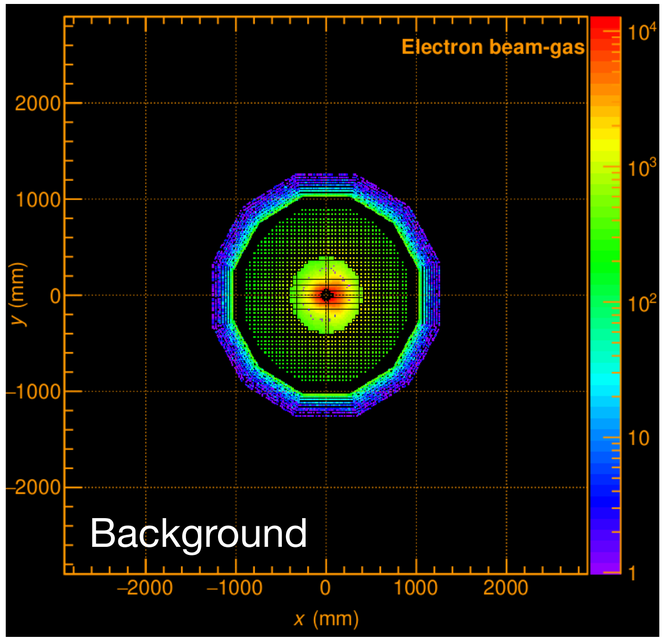
ATHENA detector - update in progress

Electron Beam-Gas interactions

vacuum after 10000 Ah (running of 5 month at 10^{34} cm^2s^{-1})

Interaction of beam particles with residual gas molecules in the beam pipe can impact detector performance and/or mimic physics signals

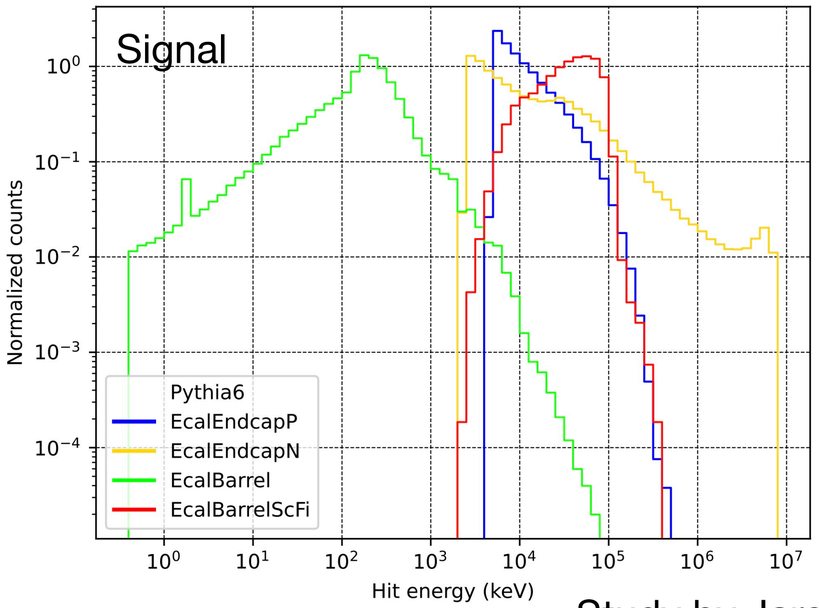


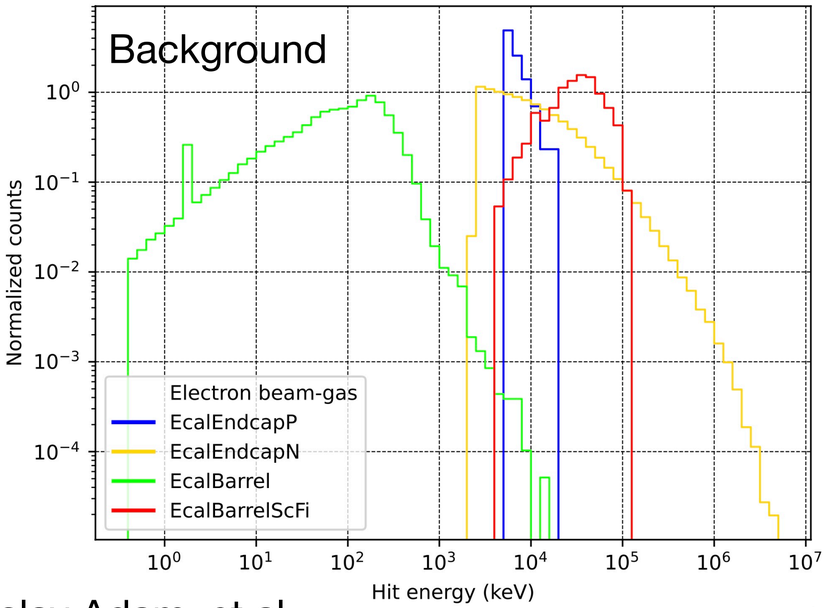


- main contribution to detector background are from Bethe-Heitler process:

$$e_{\text{beam}} + \mathrm{H}^2_{\text{rest gas}} \rightarrow e' + \gamma + \mathrm{H}^2_{\text{rest gas}}$$

off-momentum electrons will be shielded by collimators (detailed simulations of collimation system are underway)





See mode details here

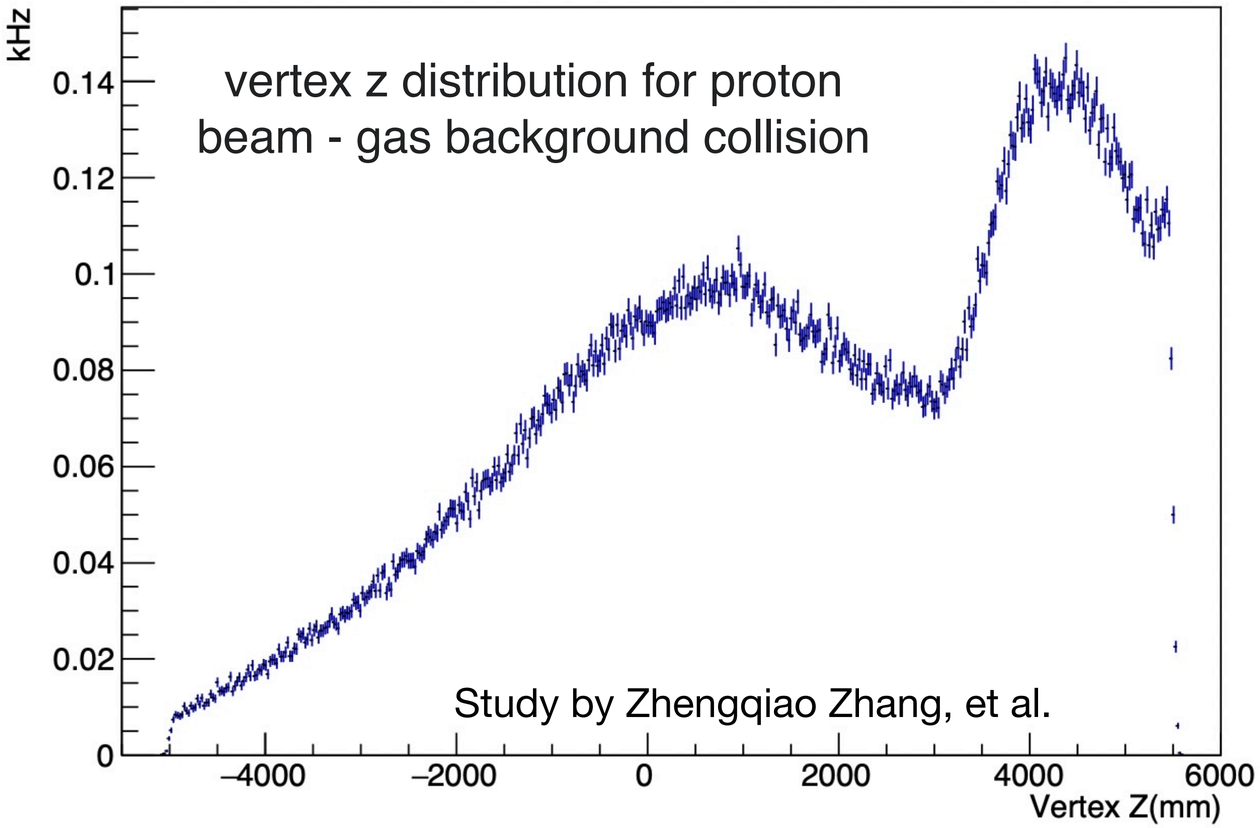
Study by Jaroslav Adam, et al.

Updated - EPIC

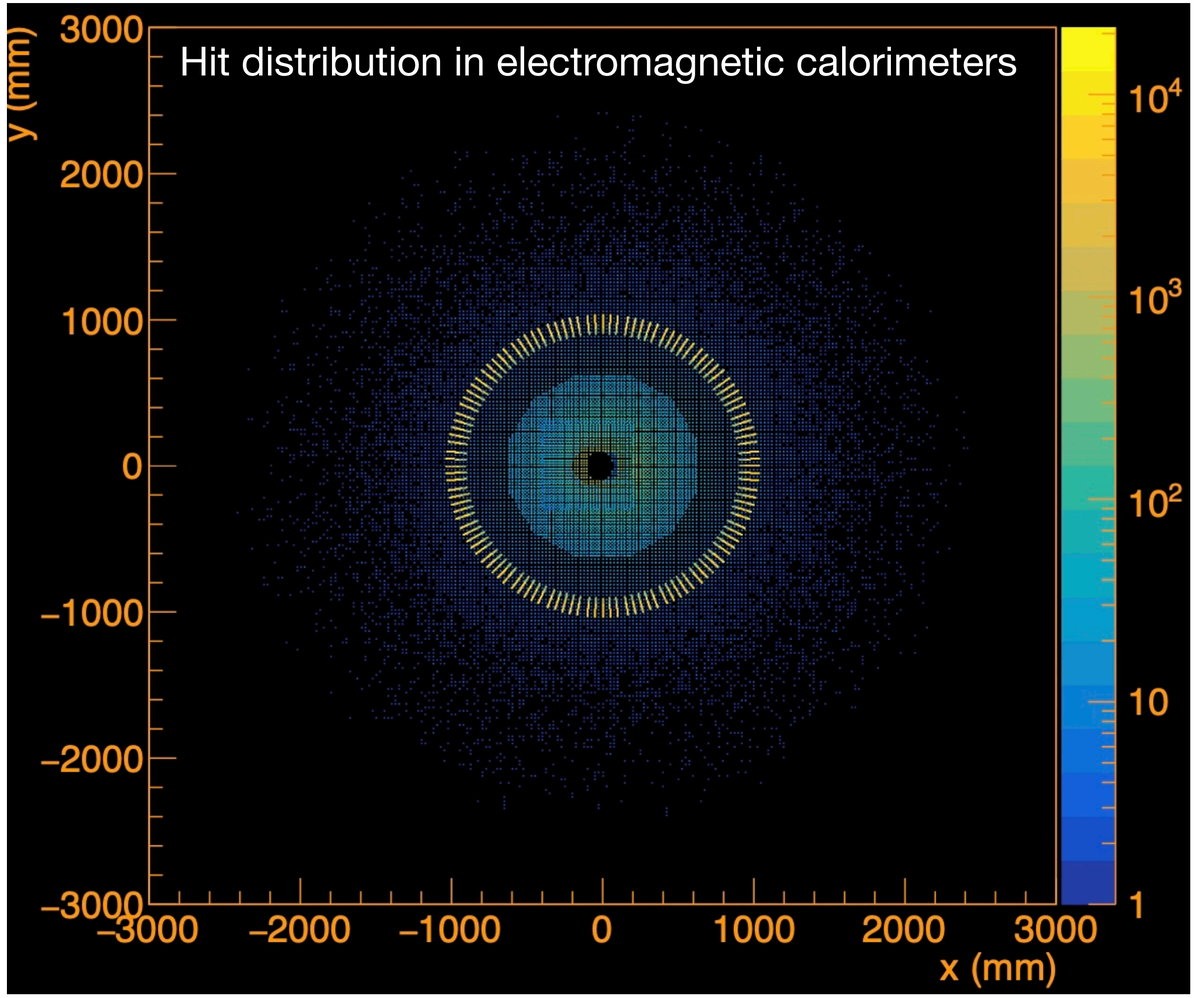
Hadron Beam-Gas interactions

vacuum after 10000 Ah (running of 5 month at 10^{34} cm^2s^{-1})

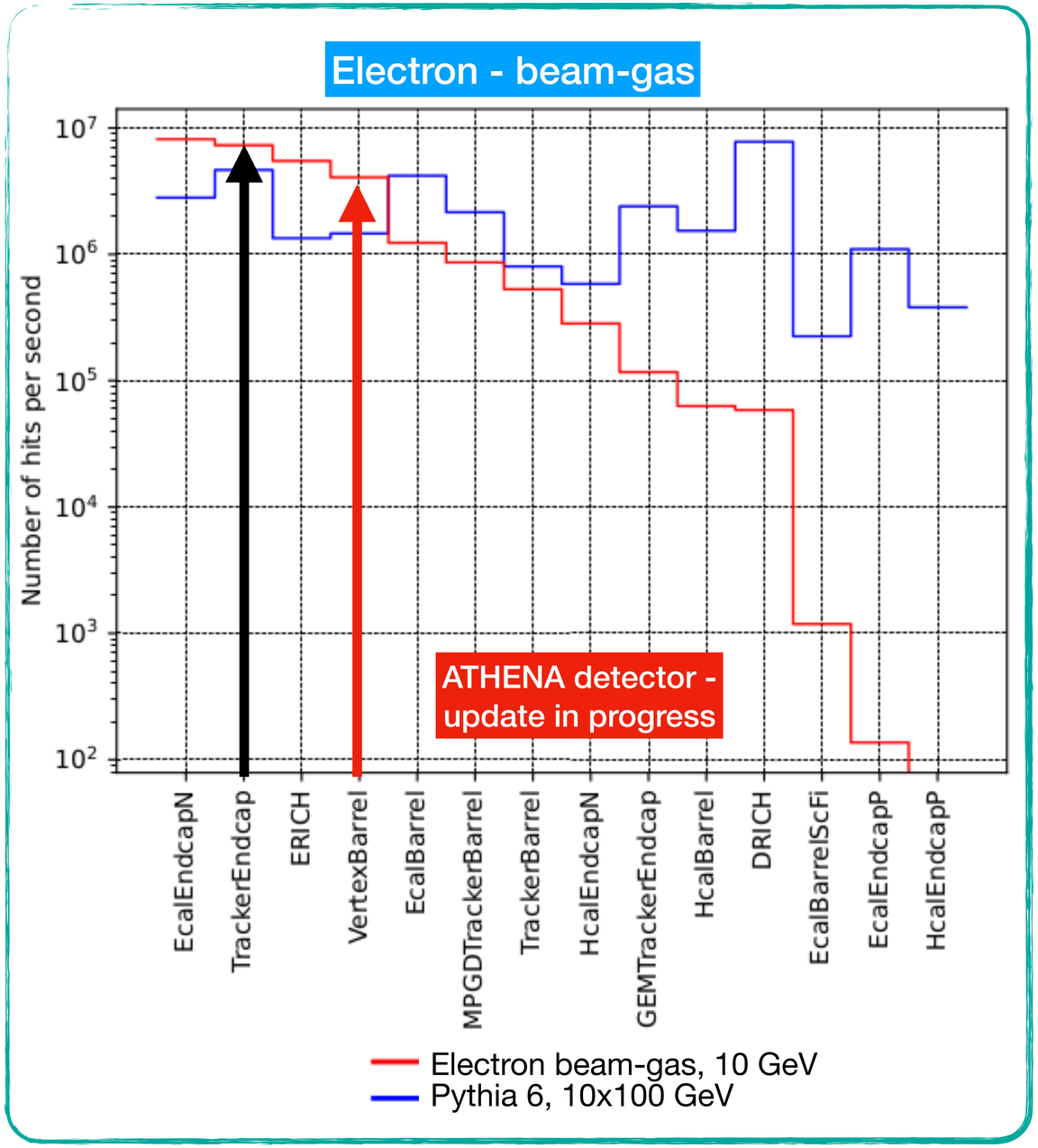
- concerning large hadronic cross section of the $p/A_{\mathrm{beam}} + \mathrm{H}^2_{\mathrm{rest\ gas}}$ interactions
- Secondary interactions of produced particles with detector components is one of the main sources of neutrons that thermalize within the detector hall

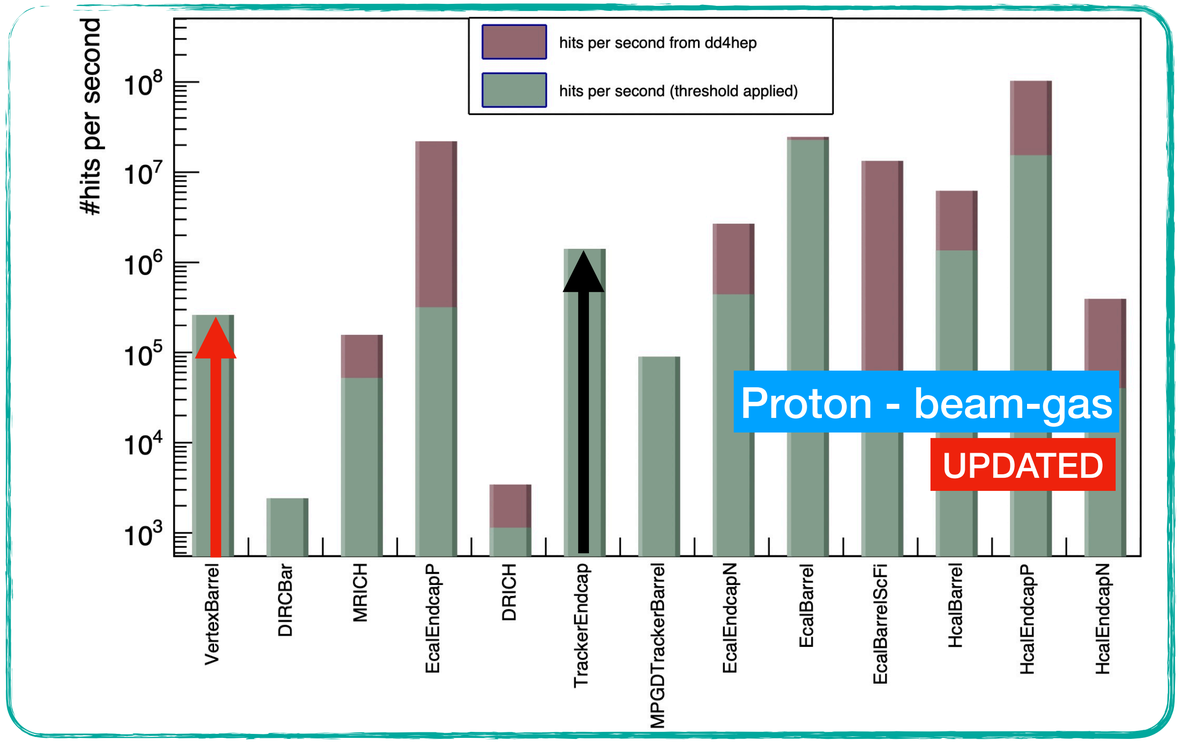


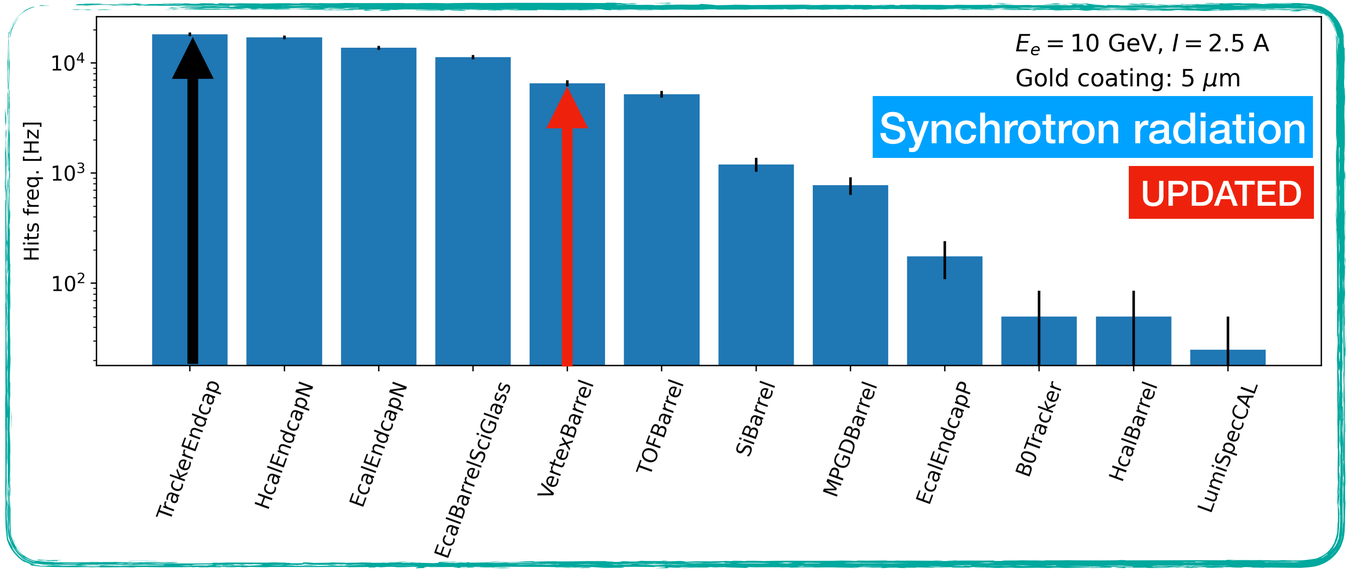
See more details here



Background comparisons







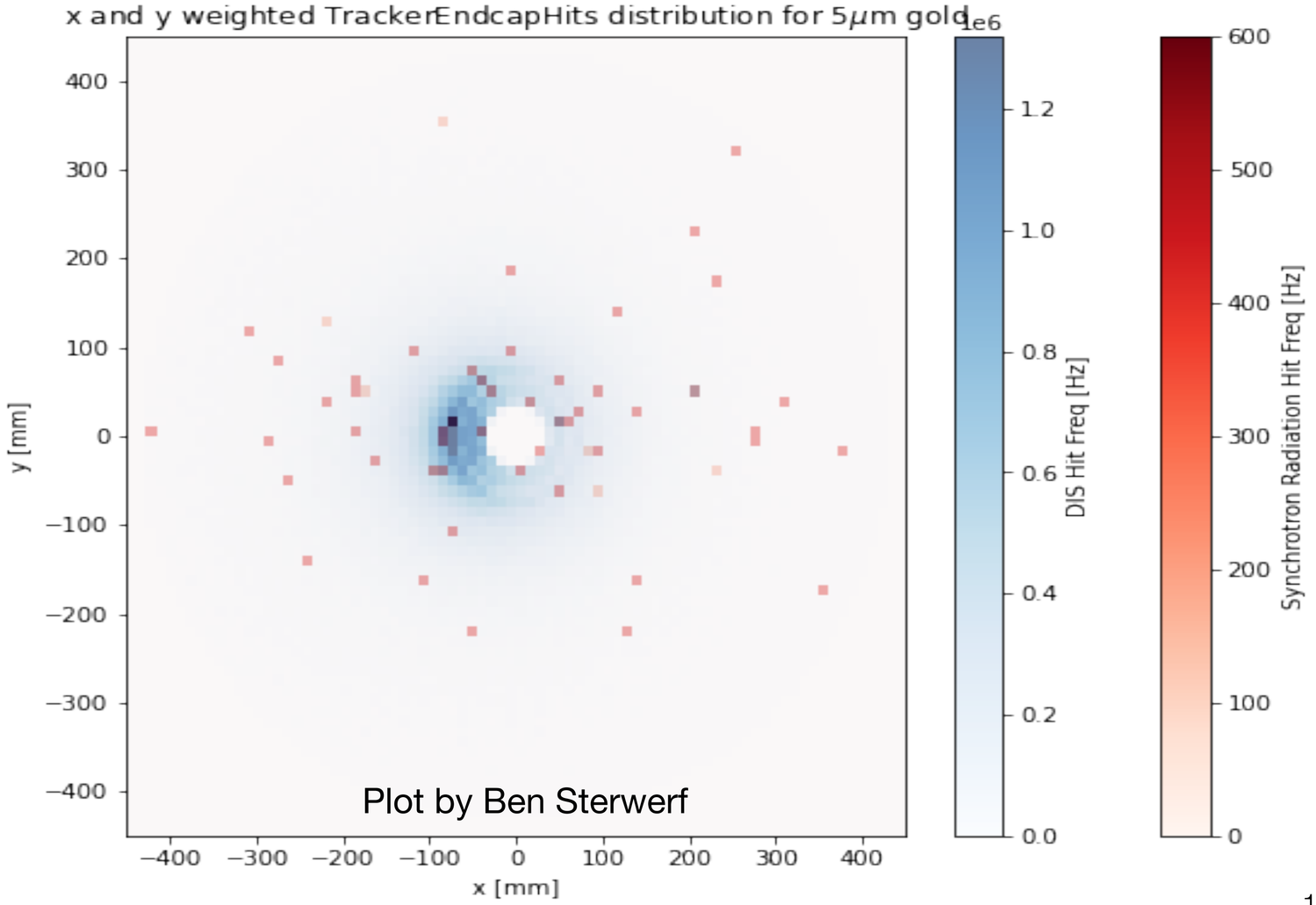
Testing background impact

Need to simulate dataset that emulates true EIC environment as precisely as possible
- mix signal and background sources
- propagate sample through GEANT simulation to assess impact on detector performances

Work by Kolja Kauder, David Lawrence, et al. to implement functionality to mix

$$\text{signal} + \sum_{i=1}^{N} \text{background}_i$$

After mixing, need realistic measurement conditions, e.g. track reconstruction not based on truth seeding



Progress on realistic track reconstruction

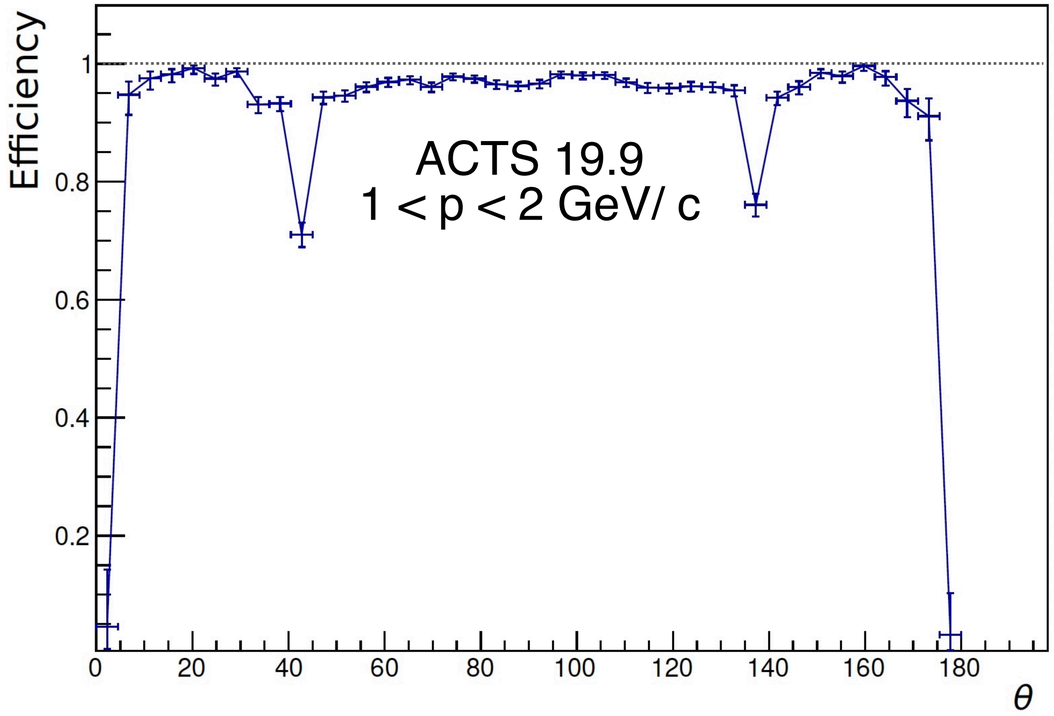
Seeding: retrieval of ≥ 3 space points that can form a track prototype.

- Most studies in EPIC with truth seeding*

*Truth seeding: the actual (experimentally unknown) group of hits associated with a track is given to the Kalman filter

- Realistic seeding is crucial to study background impact

- In ACTS: initial helical fit performed (inside the seeder) to initialize the combinatorial Kalman filter.



Study by Yue Shi Lai, et al.

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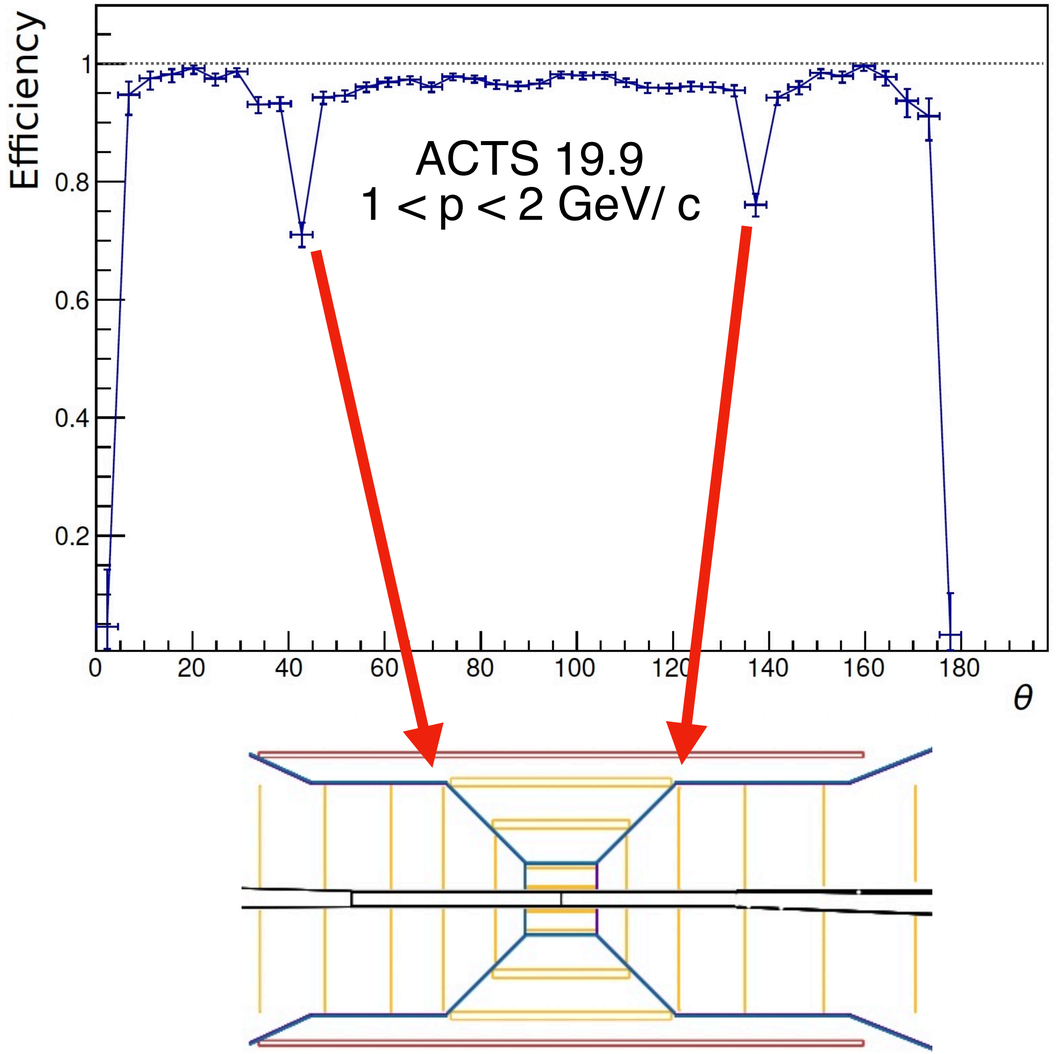
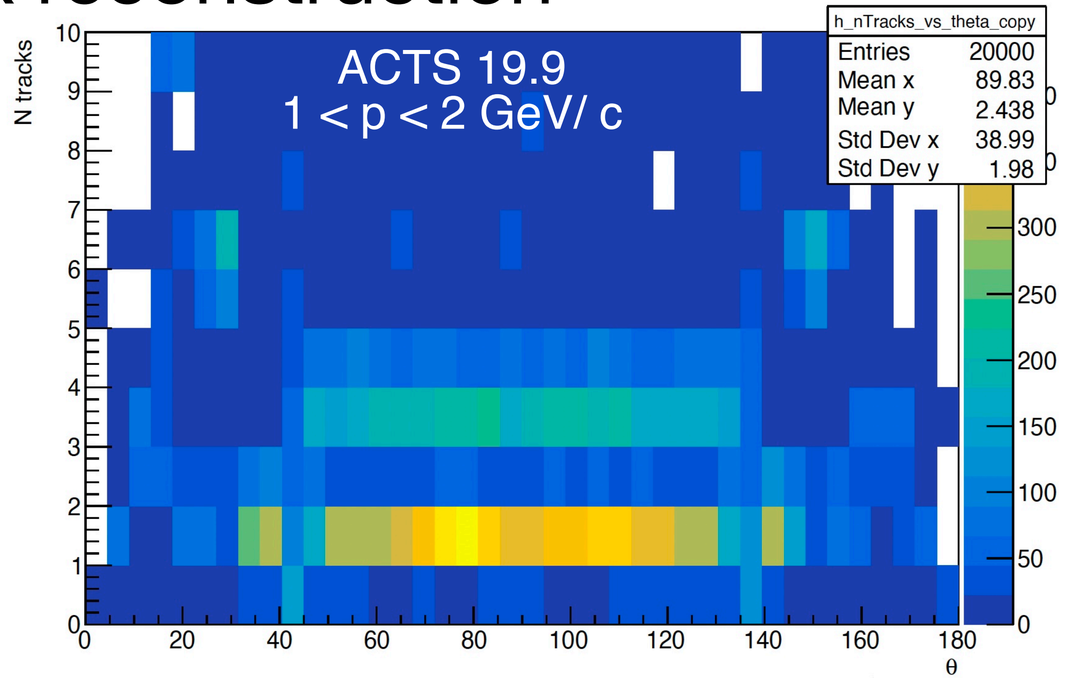


Study by Yue Shi Lai, et al.

Progress on realistic track reconstruction

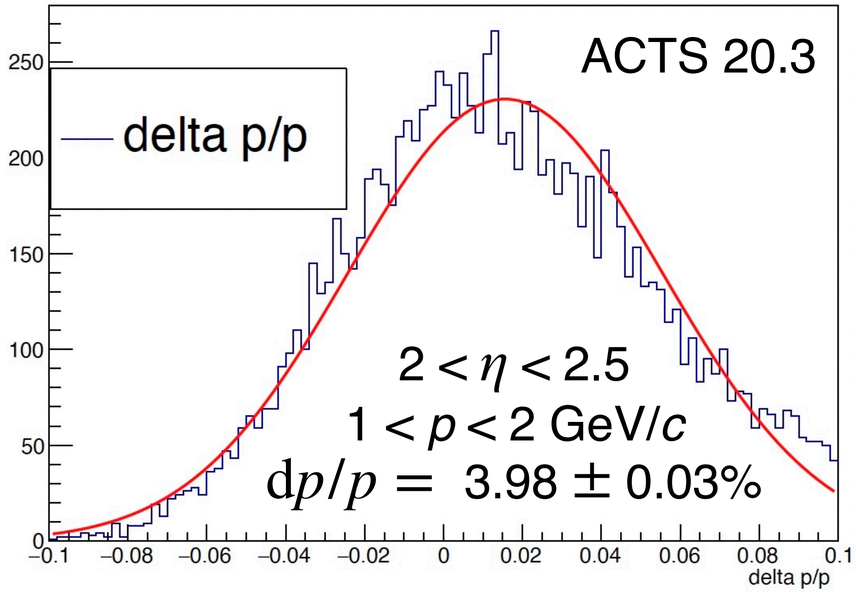
- A functioning binned seeder exists, with some caveats (resulting from the large η range and low p that is unusual for hadron collider ACTS was developed for)

- A unbinned "orthogonal" seeder is being developed, which may address the issue of the binned seeder



Study by Yue Shi Lai, et al.

- Binned seeder, Juggler & ACTS 19.9/20.3
- Mostly 1 seed/track, but some 3 or 4 seeds/track
- $\approx$ 2% of seeds fail due to issues with binned seeder
- Forward $\Delta p/p$ deteriorated vs. truth seeding (~1.5%)



Summary and Conclusions

- Several background sources have been identified and studied. Recently, a background task force was formed

- Most background studies have been updated with newest EPIC detector version. Updated studies on other backgrounds are underway

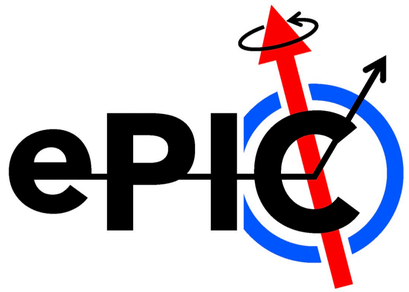
- Largest background source expected to be beam - gas interactions

- Currently working on functionality to combine backgrounds and signal

- Next step will be to study background impact on detector performance and physics, e.g. impact on track reconstruction

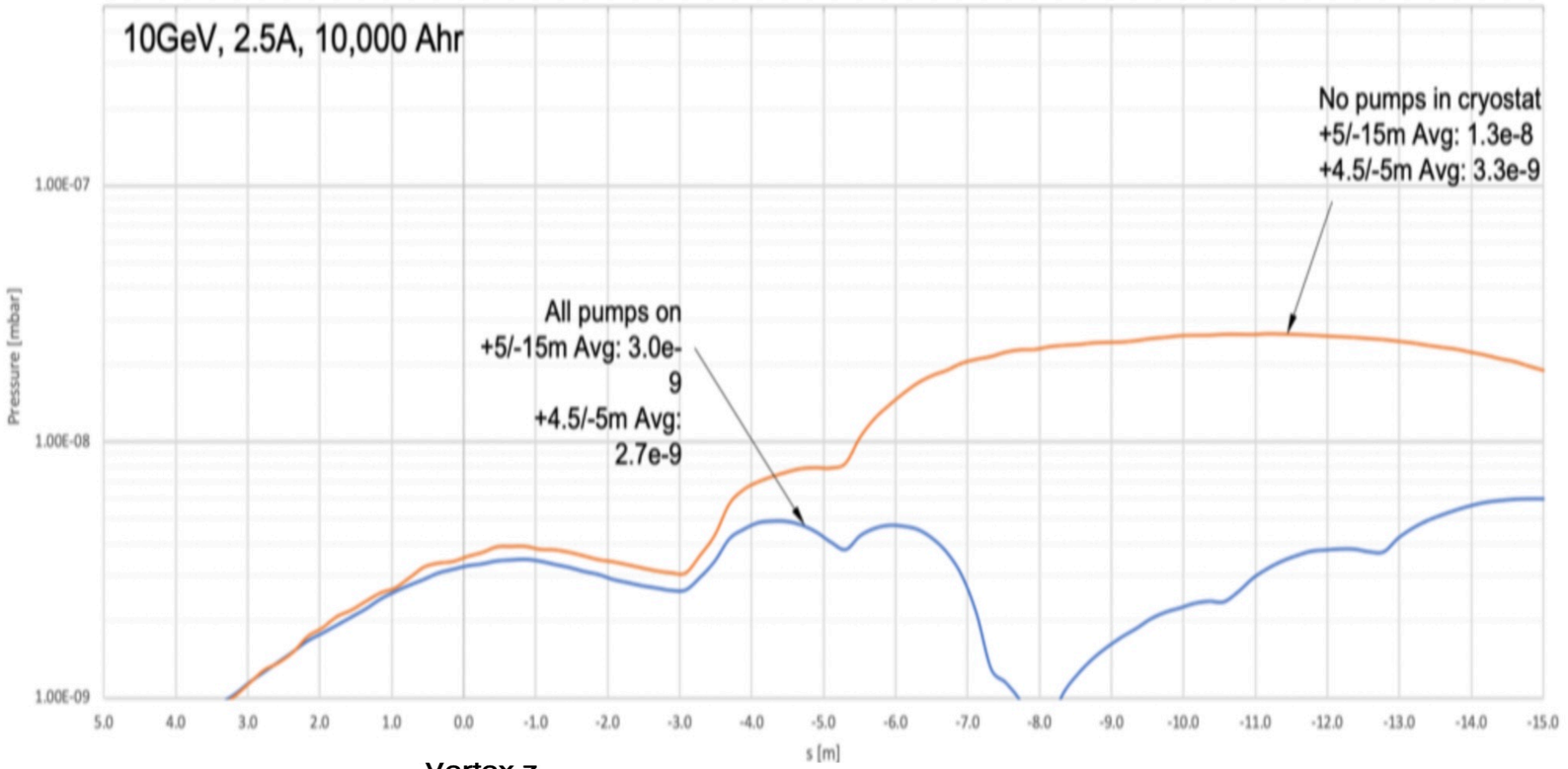
- Realistic track reconstruction is underway

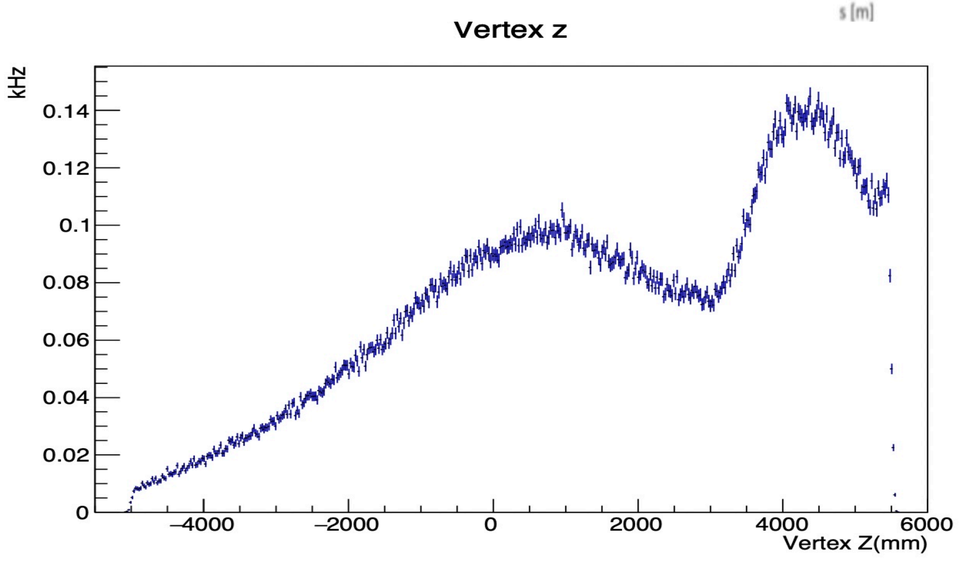
Thanks for your attention



Backup

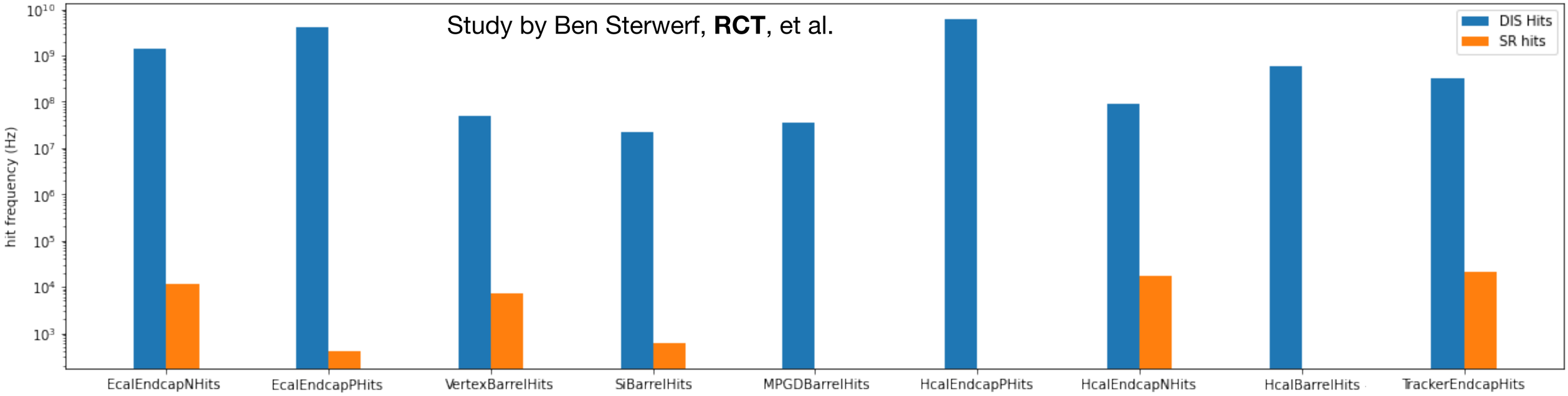
Vertex z distribution in hadron beam gas





Updated - EPIC

Synchrotron radiation results



Synchrotron event generator code

https://github.com/reynier0611/SR_event_generator

1. Download csv file stored here. You can get this file following one of the two methods below:

```
wget -O combined_data.csv 'https://drive.google.com/uc?export=download&id=1XX78_qeuoMK8xhuOB5QgbU
```

or

```
curl -L 'https://drive.google.com/uc?export=download&id=1XX78_qeuoMK8xhuOB5QgbUyye7Lv_xPg&confirm
```

2. Create a yaml configuration file (e.g. `config.yaml`) with the following information:
   - `input_single_photons`: path to csv file downloaded in step 1.
   - `n_events`: number of events to be generated.
   - `integration_window`: time window that will define one event.
   - `seed`: random seed for reproducibility. Set to 0 to leave the seed unconstrained.
3. Run the generator as:

```
python3 sr_generator.py --configFile config.yaml
```

Links to previous studies

Jin Huang - Beam gas, neutron flux, radiation does at EIC

Elke Aschenauer - EIC Physics and Detector

Wiki - ePIC Background

Wiki - ATHENA Background

Wiki - beam backgrounds