Background and track reconstruction studies

Signal **Background**
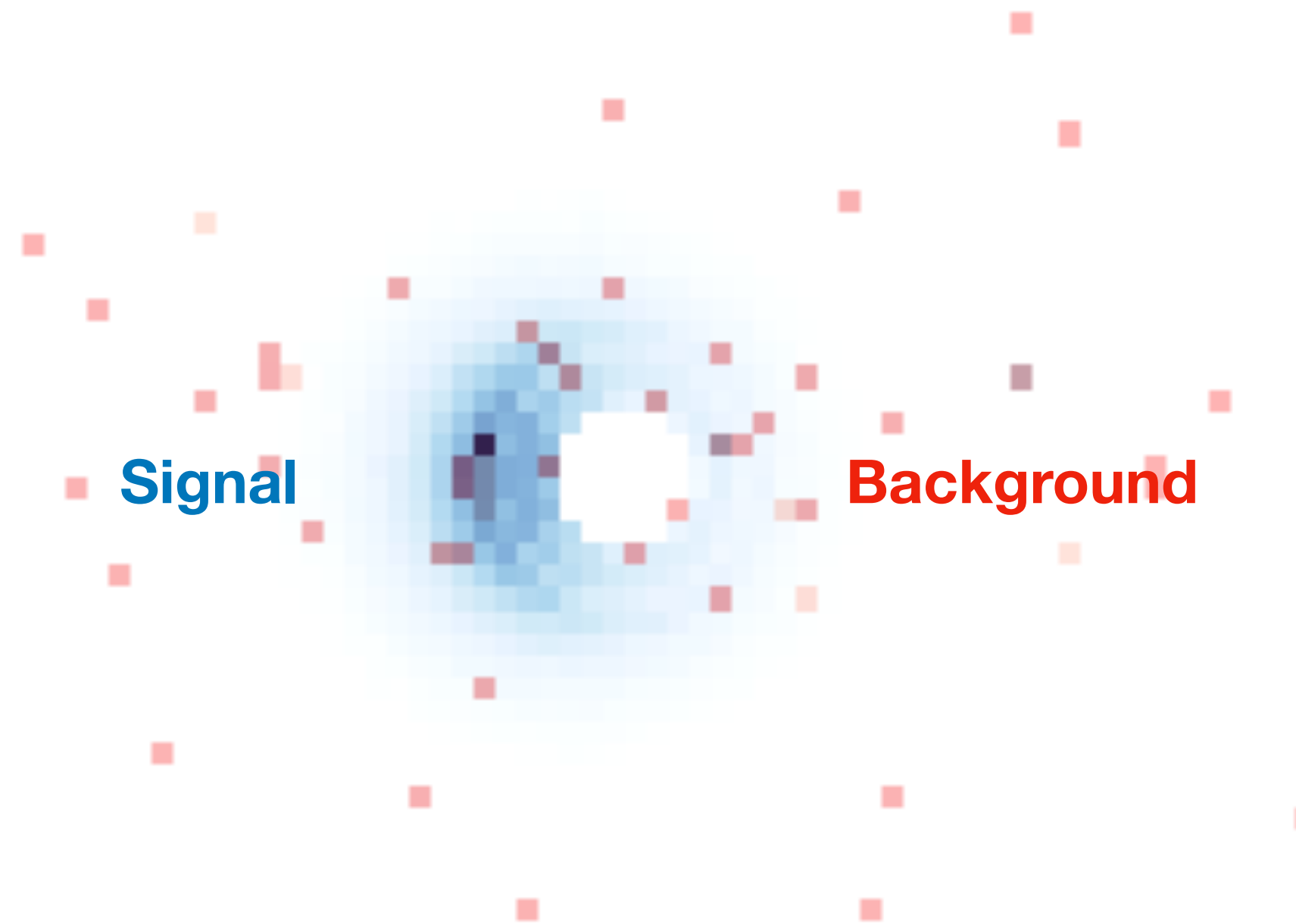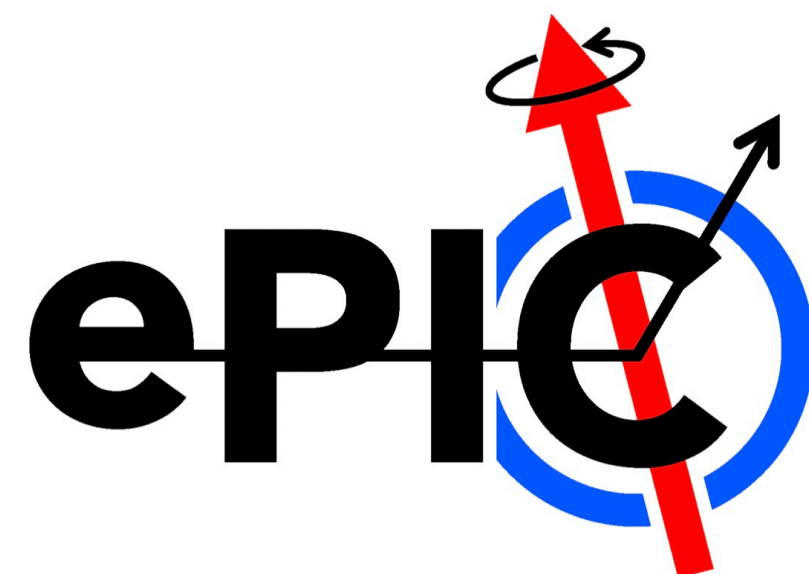
Reynier Cruz-Torres
Lawrence Berkeley National Laboratory

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

UC EIC Consortium Meeting
January 27th, 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

Some of these are work in progress

Wiki page to document background studies

Outline

Backgrounds at the EIC

- Synchrotron radiation ⟶ M. Stutzman, B. Sterwerf, **RCT**, et al.

- Primary collisions ⟶ Alex Jentsch, et al.
  - Ionization radiation
  - Low Energy Neutron Radiation

- Beam-gas induced
  - Electron-gas interactions ⟶ Jaroslav Adam, et al.
  - Hadron-gas interactions ⟶ Zhengqiao Zhang, et al.

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Next steps

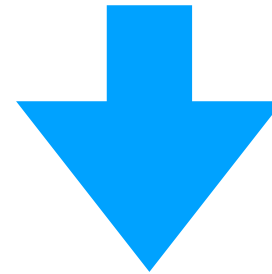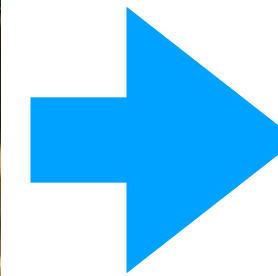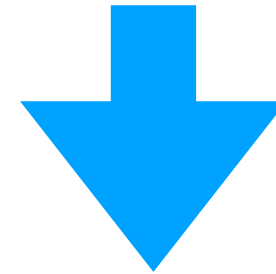Wiki page to document background studies

Outline
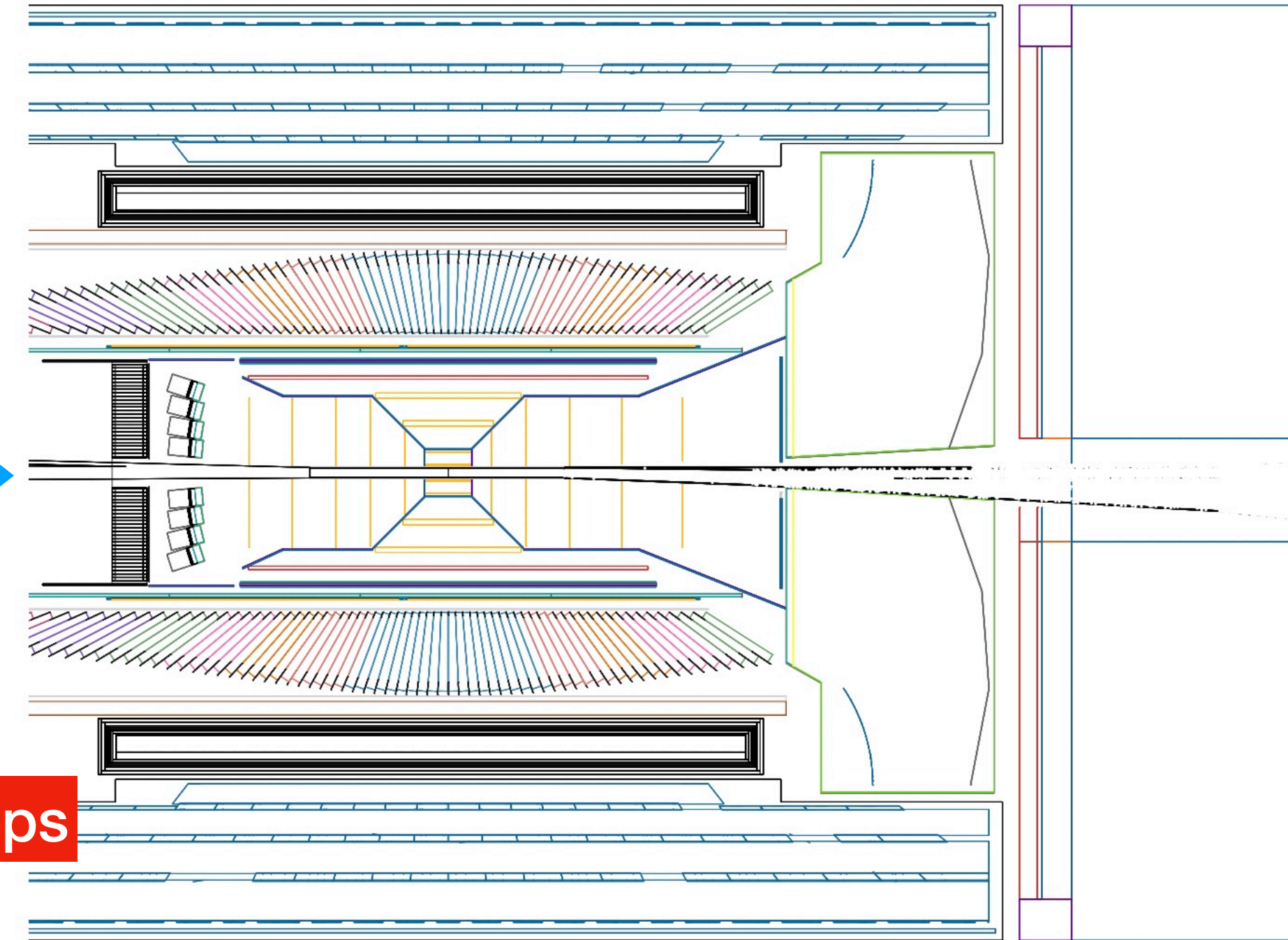
Backgrounds at the EIC

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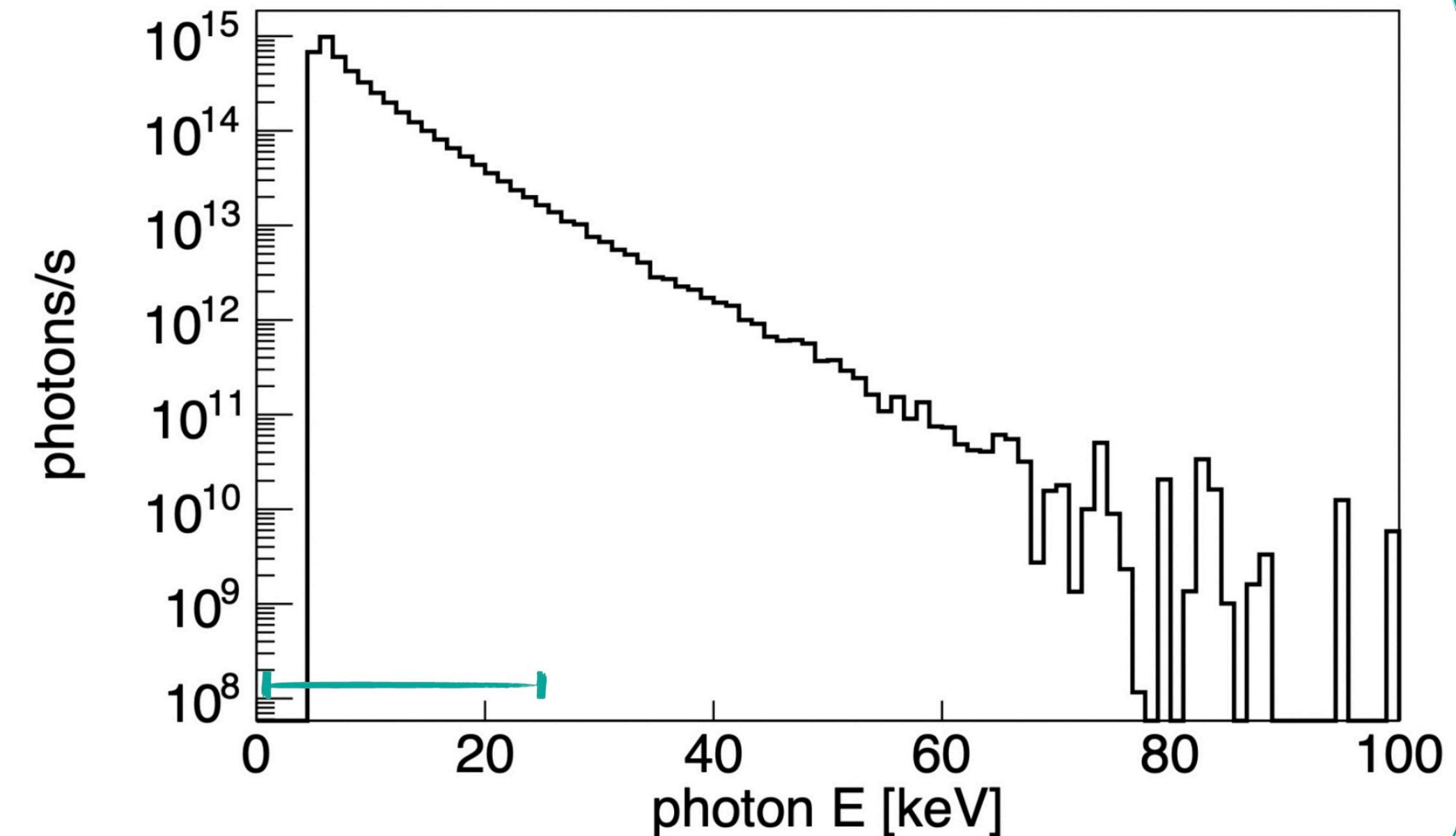
Synchrotron radiation

- 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
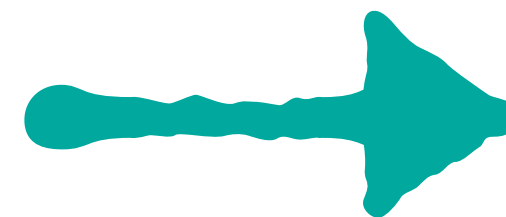   weight corresponding to equivalent photons / sec

Have

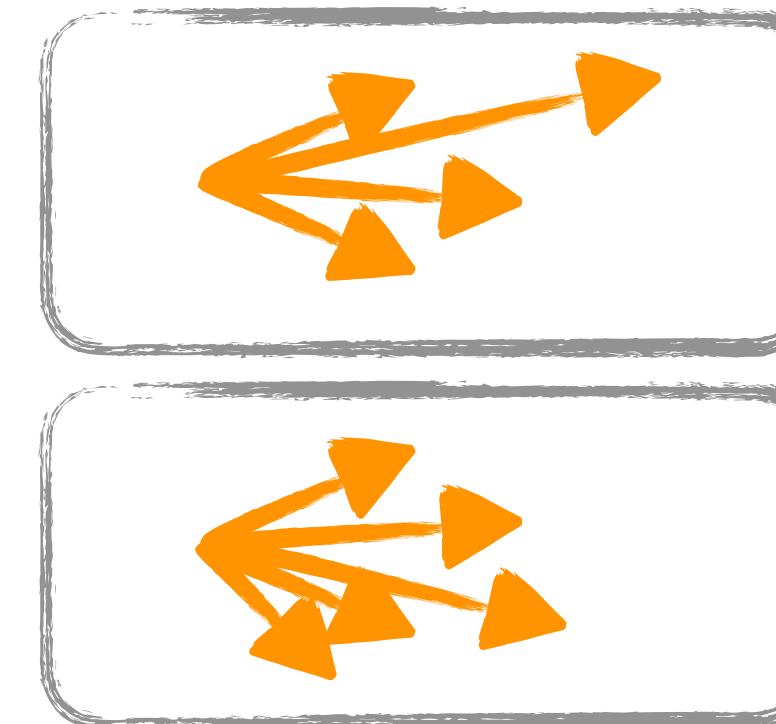A series of single-photon events from a Synrad+ simulation.
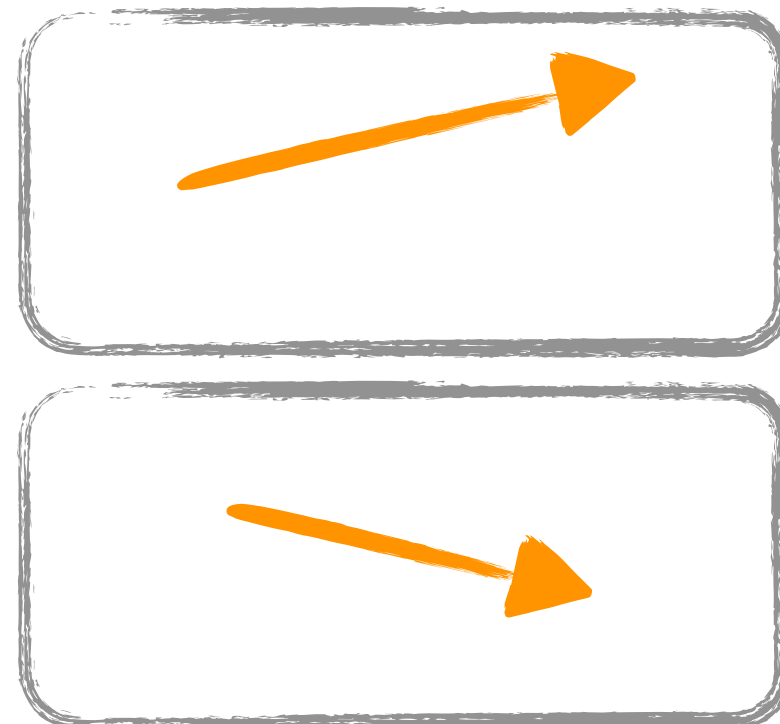
Our work

Need

A series of events with many photons corresponding to a time integration window.
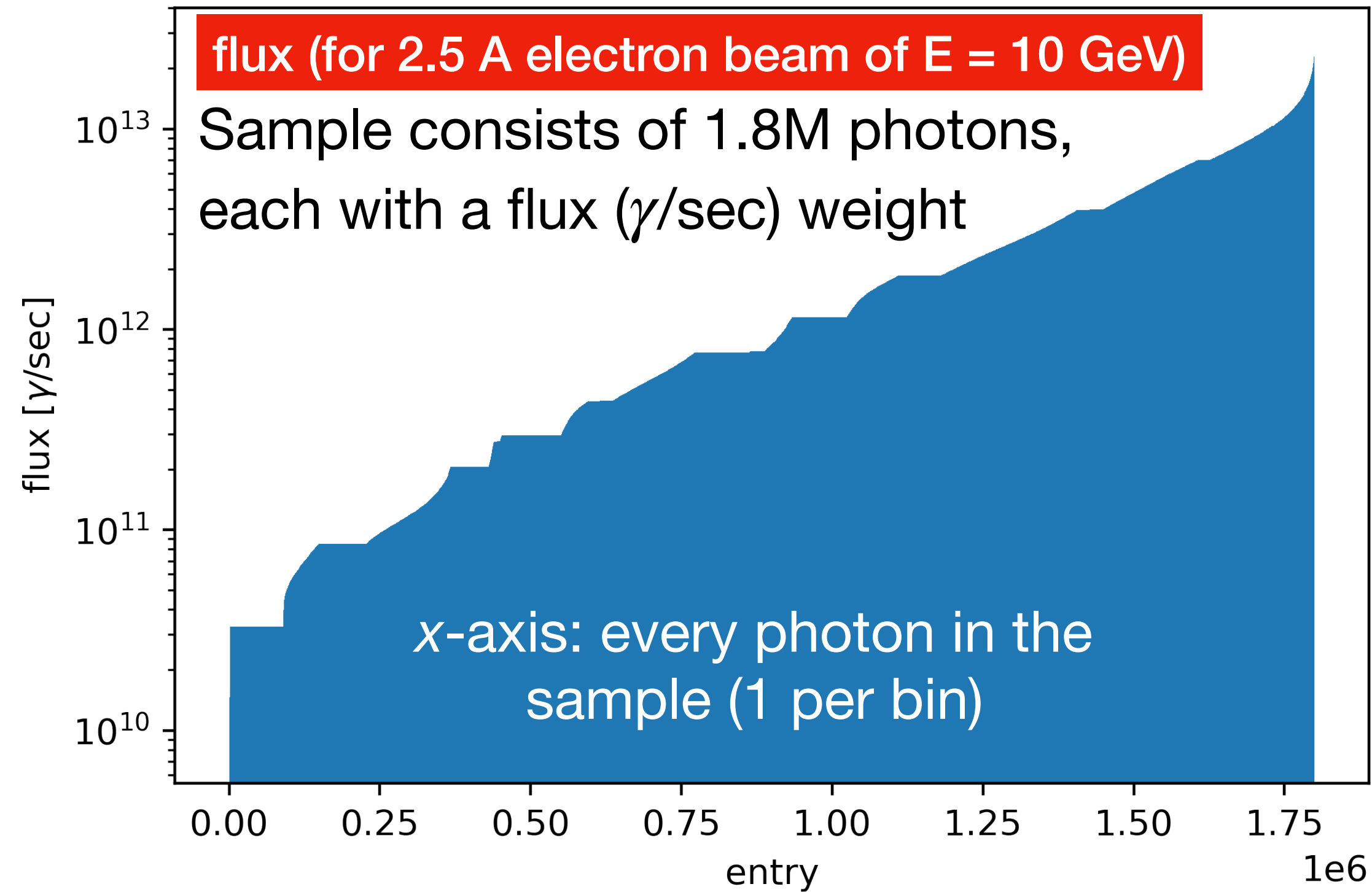
Synchrotron radiation event generator

flux (for 2.5 A electron beam of E = 10 GeV)

Sample consists of 1.8M photons, each with a flux (γ/sec) weight

x-axis: every photon in the sample (1 per bin)

flux [γ/sec]

entry

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

flux (for 2.5 A electron beam of E = 10 GeV)

Sample consists of 1.8M photons, each with a flux (γ/sec) weight
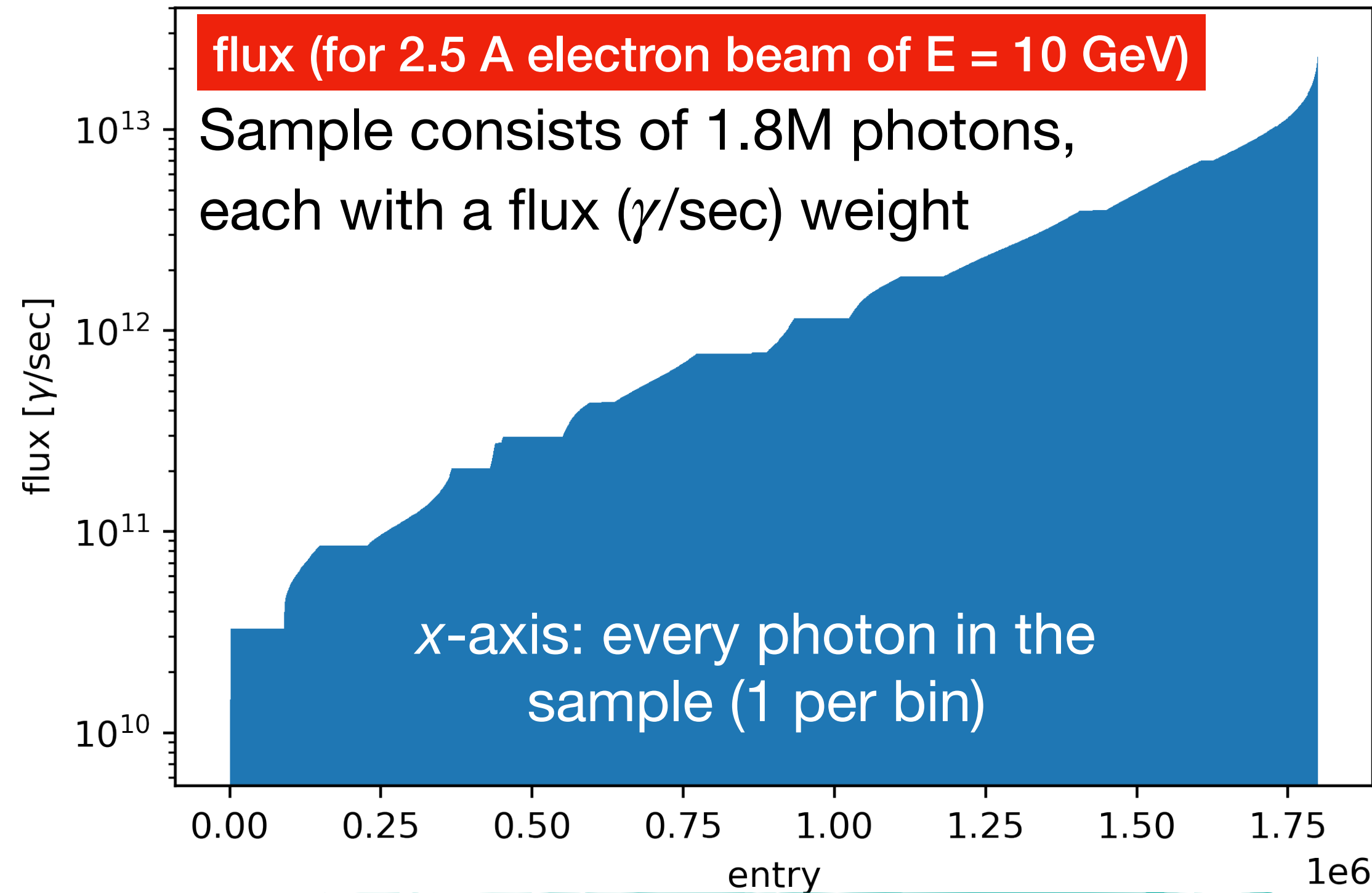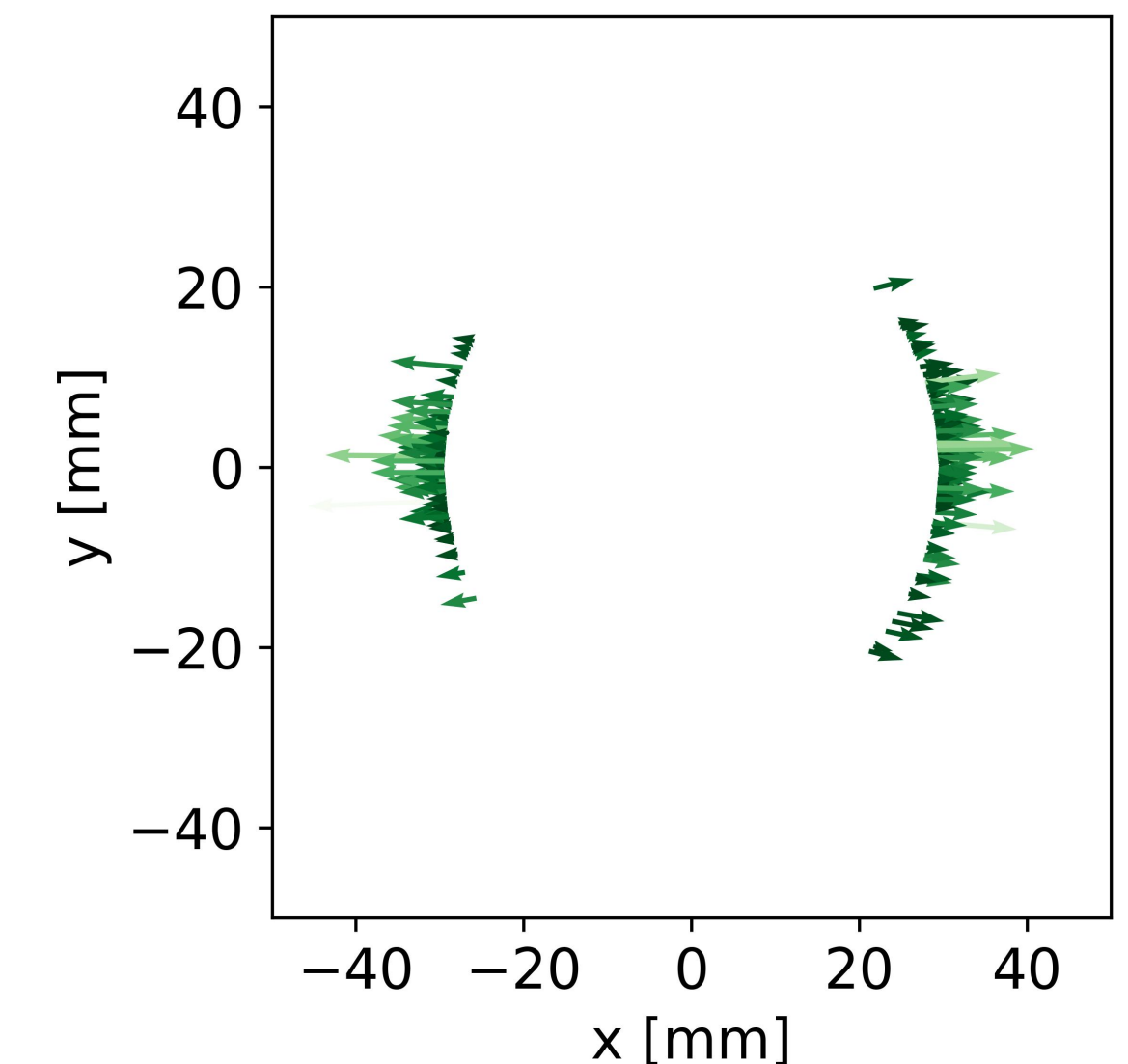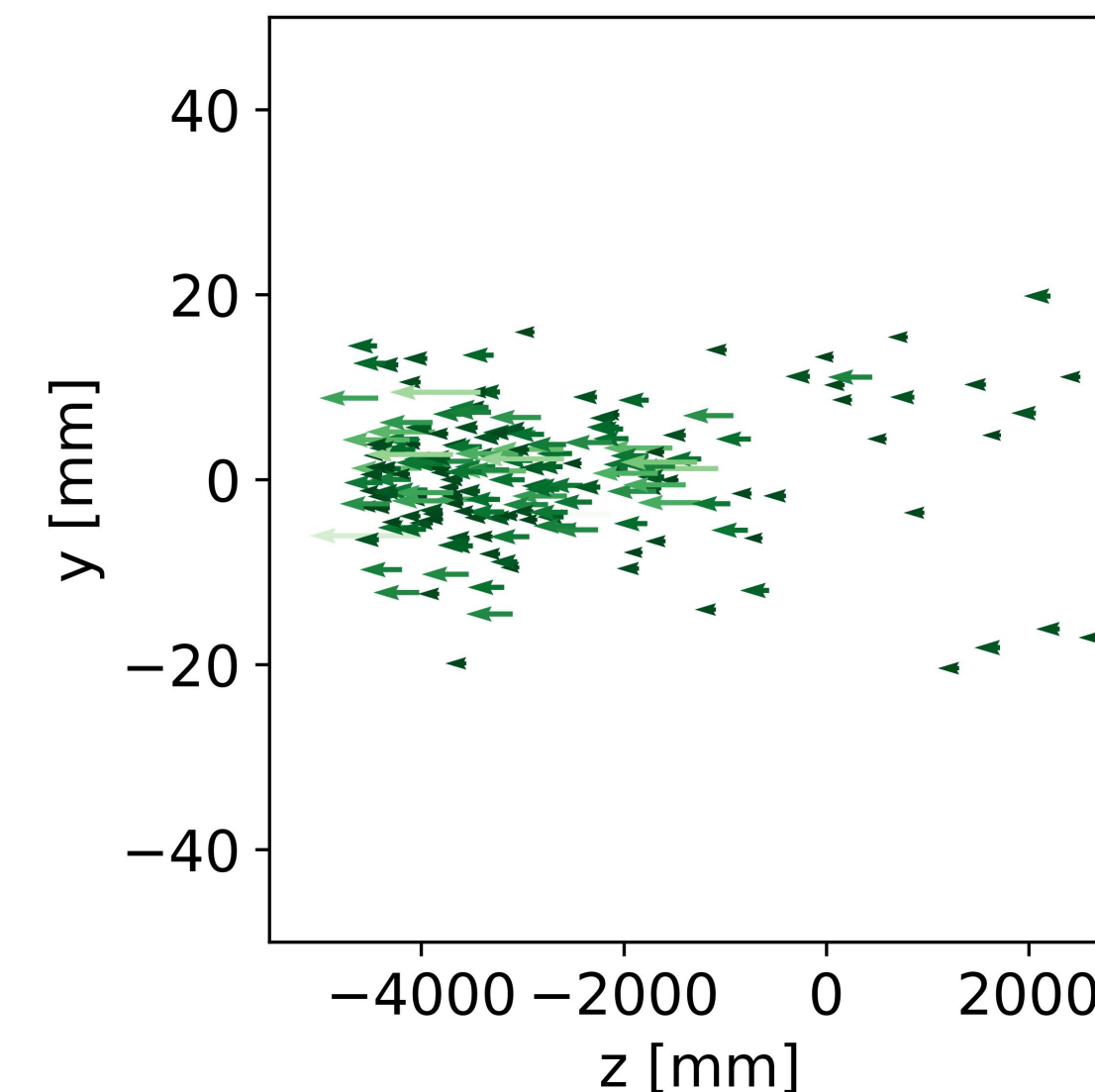
x-axis: every photon in the sample (1 per bin)

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

Sample event for a 100 ns time integration window
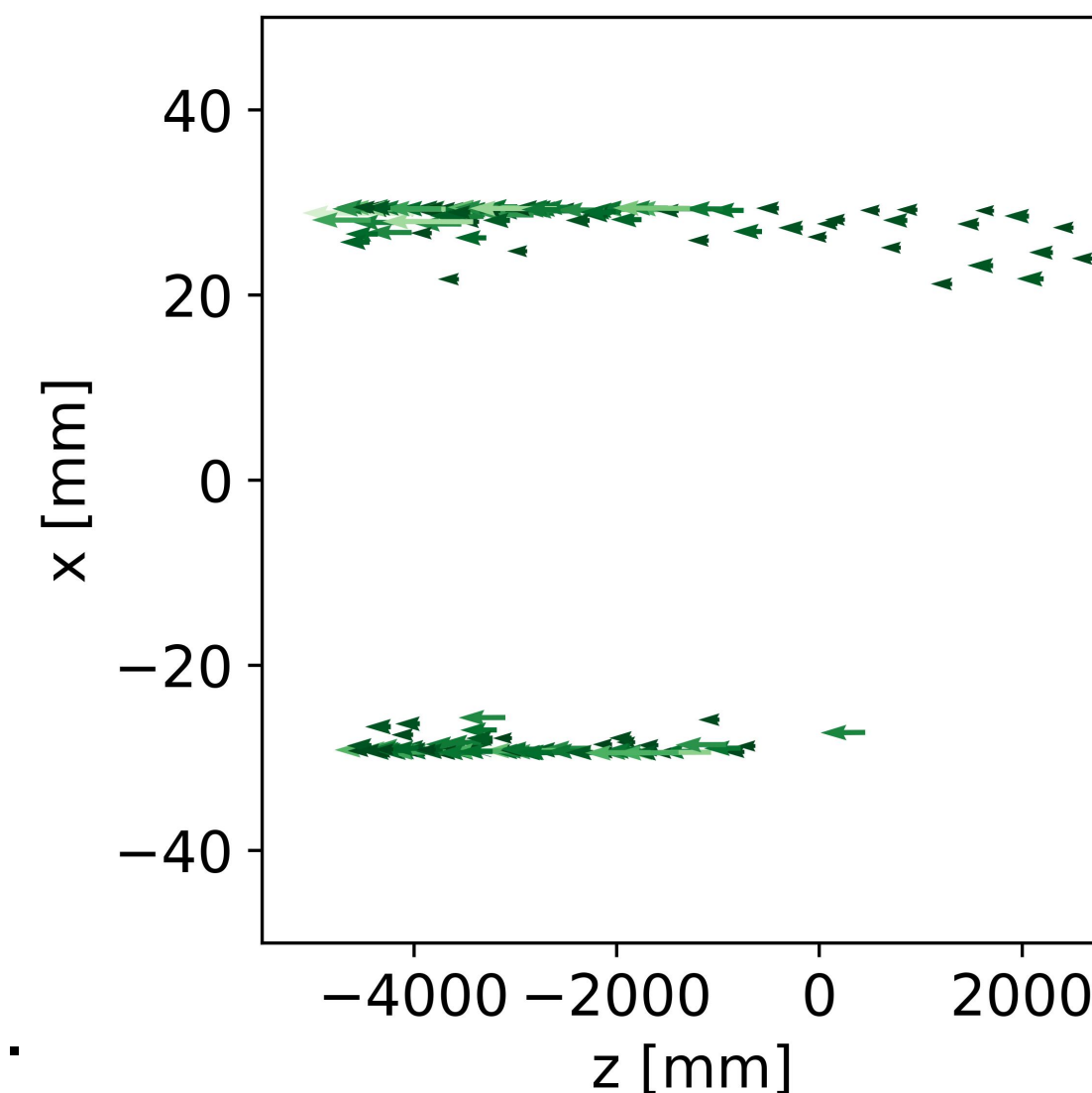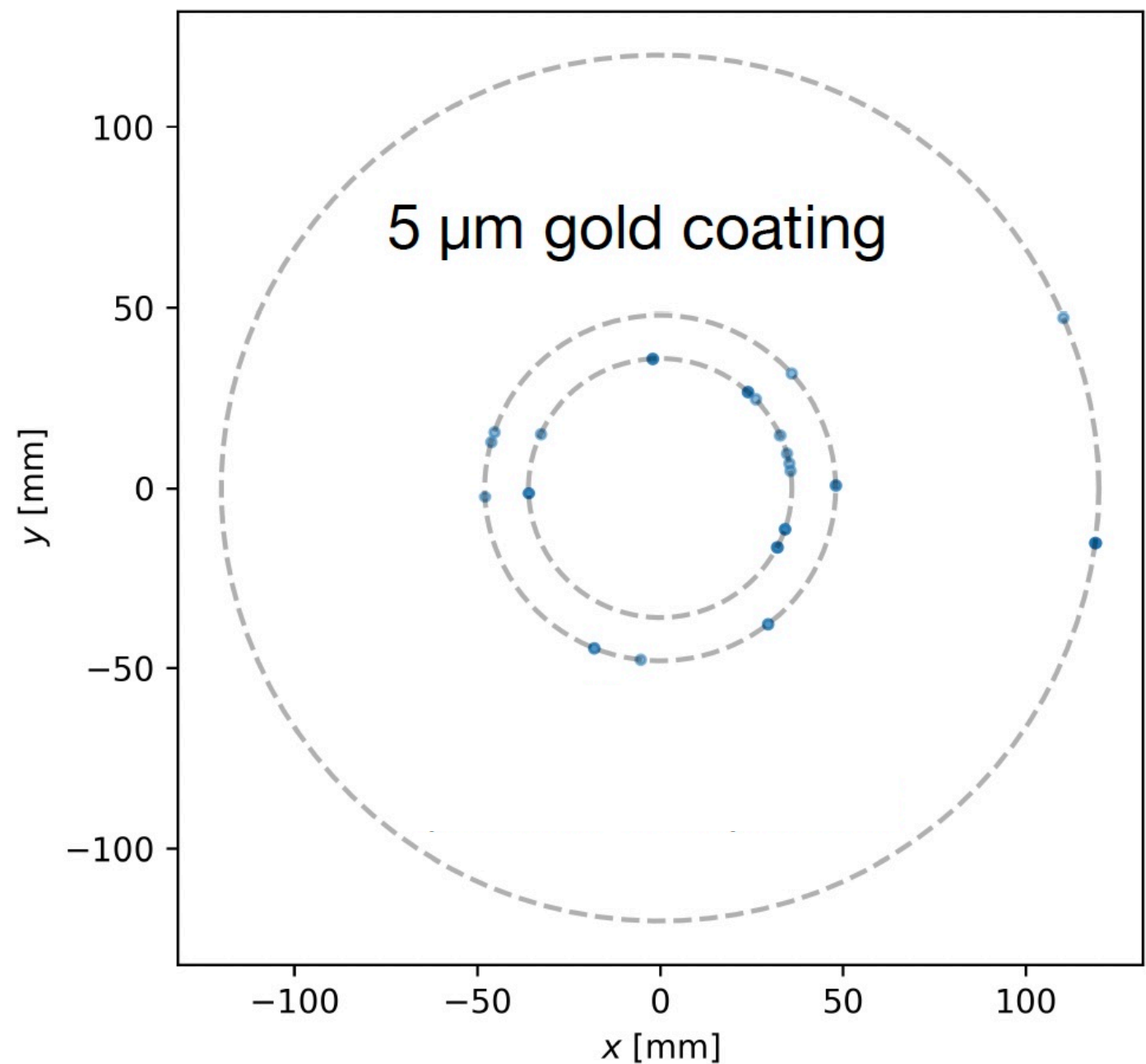

Study by Ben Sterwerf, **RCT**, et al.

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Synchrotron radiation results

Impact of gold coating in the beampipe
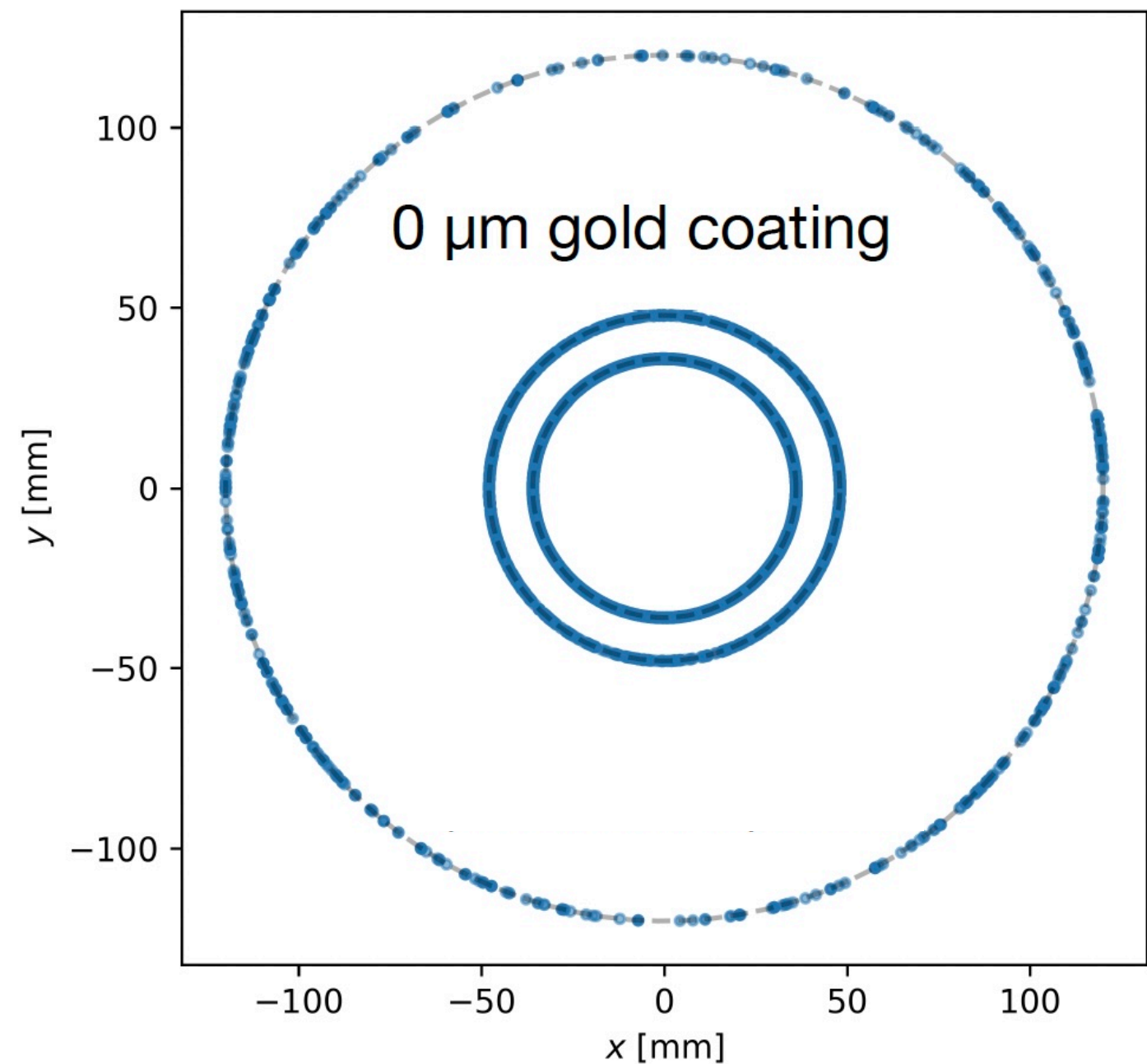
See more details in next talk by Ben Sterwerf

See more details [here](#)

Synchrotron radiation results

Impact of gold coating in the beampipe

0 μm gold coating

5 μm gold coating

See more details here

See more details in next talk by Ben Sterwerf

$E_e = 10$ GeV, $I = 2.5$ A

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Synchrotron event generator code

1. Download csv file stored here. You can get this file following one of the two methods below:
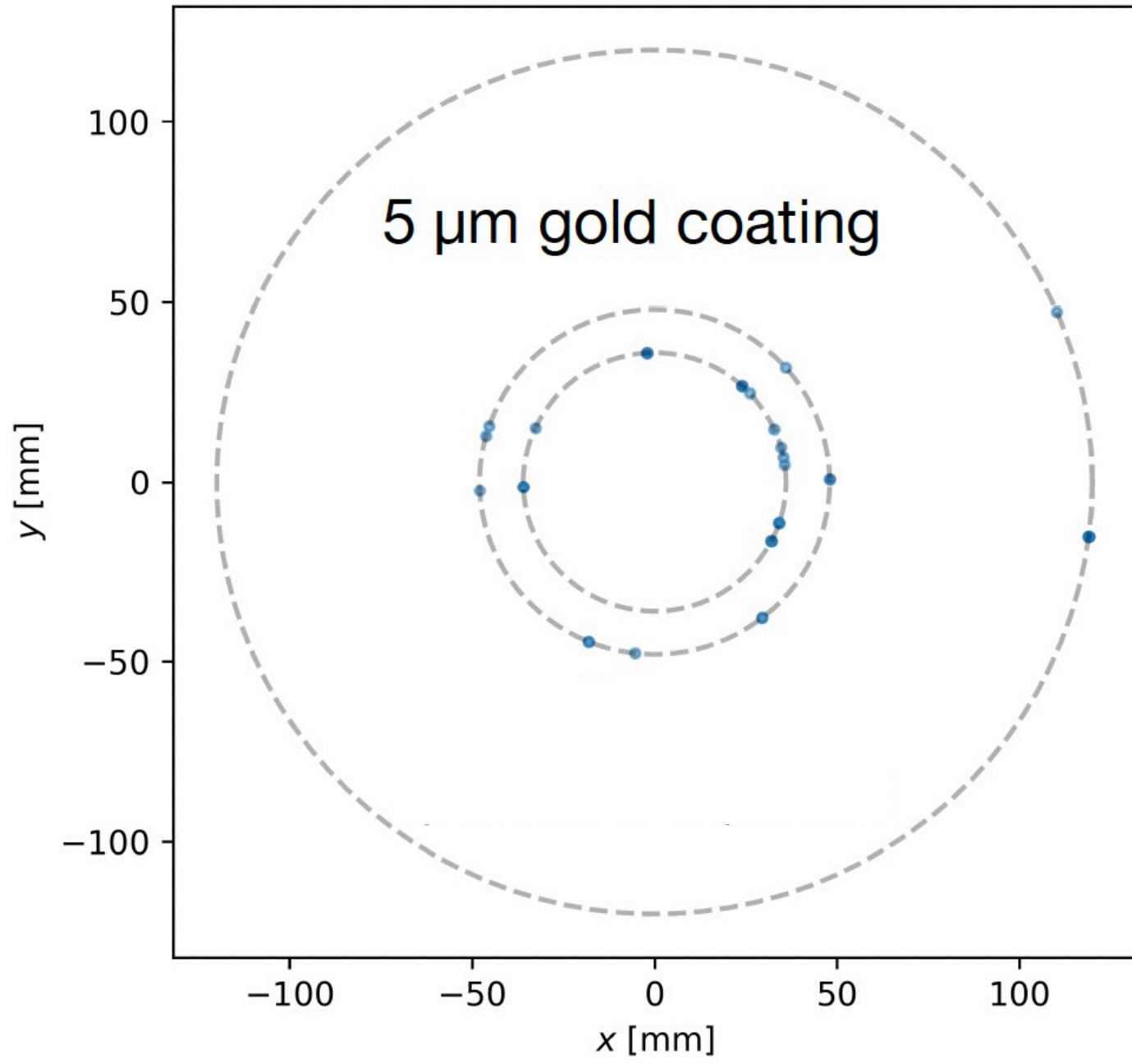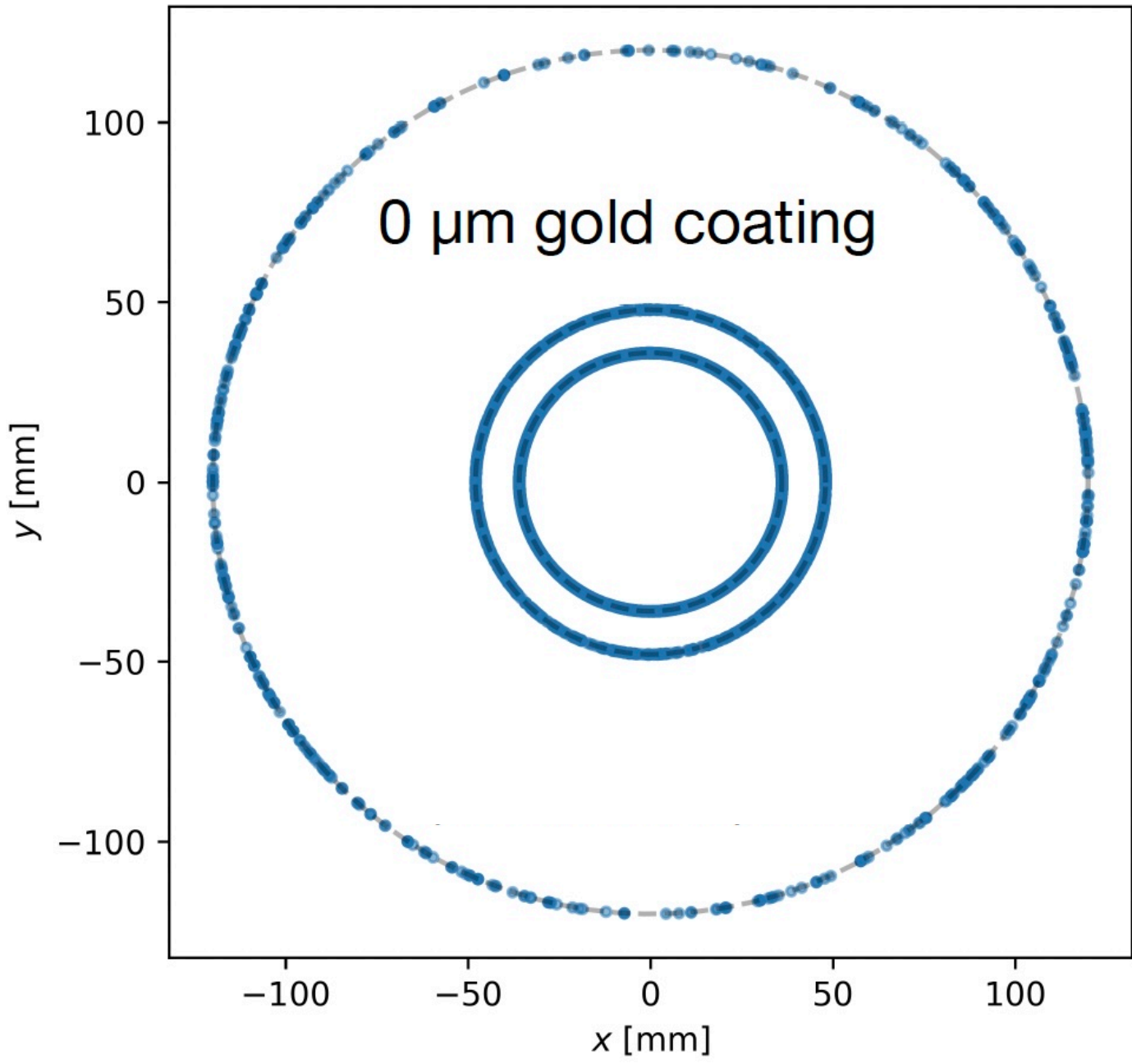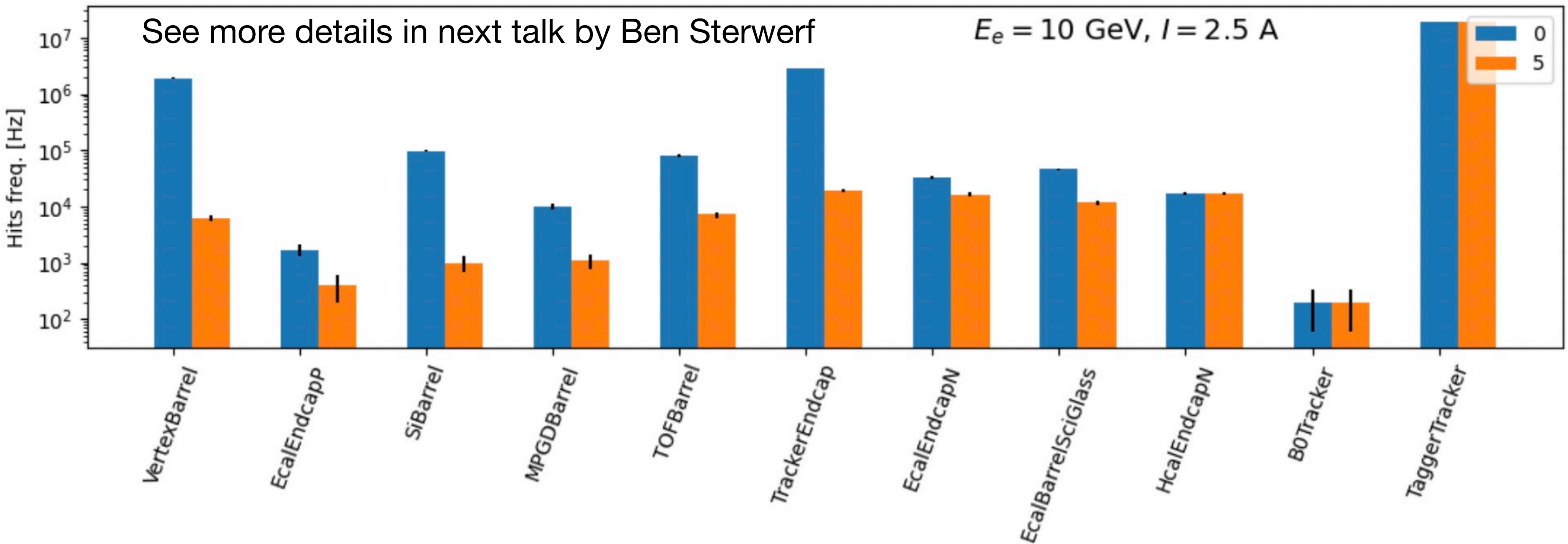
```
wget -O combined_data.csv 'https://drive.google.com/uc?export=download&id=1XX78_qeuoMK8xhuOB5QgbU
```

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.
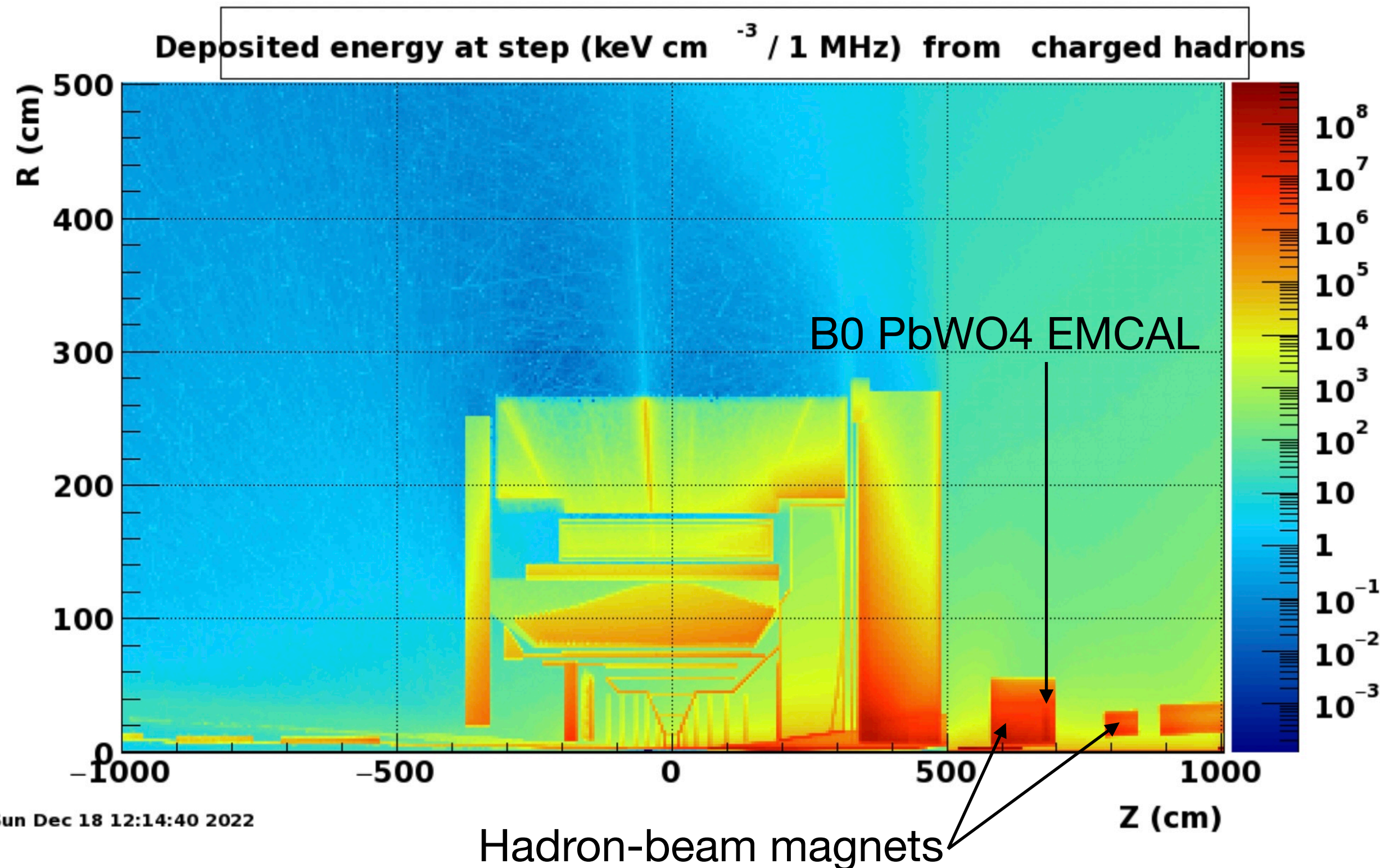
3. Run the generator as:
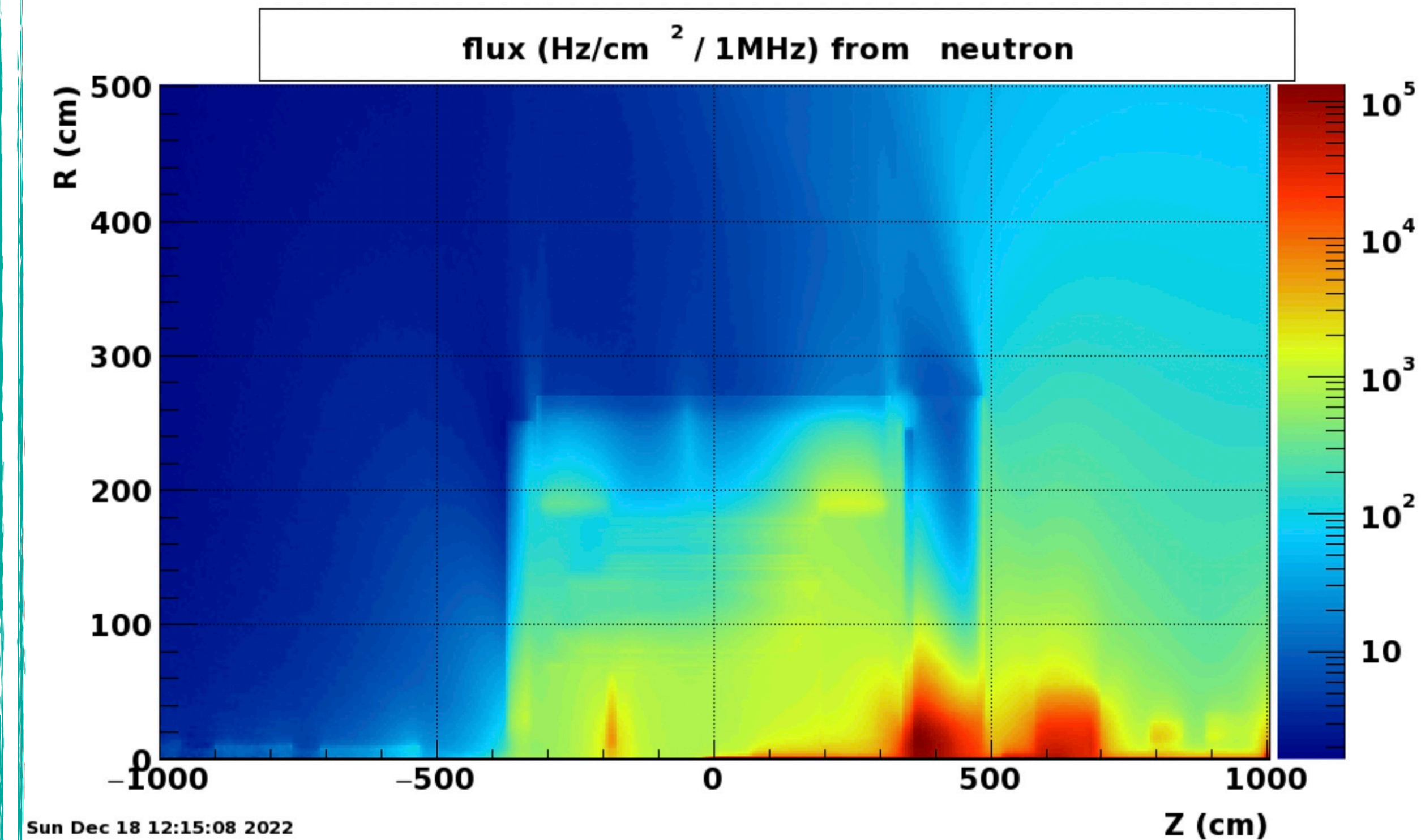
```
python3 sr_generator.py --configFile config.yaml
```

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

Study by Alex Jentsch, et al.

See more details here

Electron Beam-Gas interactions

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:

$$e_{\text{beam}} + \text{H}^2_{\text{rest gas}} \rightarrow e' + \gamma + \text{H}^2_{\text{rest gas}}$$
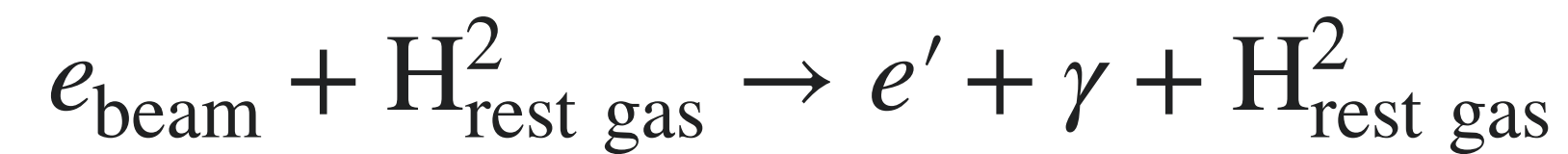
off-momentum electrons will be shielded by collimators (detailed simulations of collimation system are underway)

Electron Beam-Gas interactions

See mode details here

Study by Jaroslav Adam, et al. 14

Hadron Beam-Gas interactions
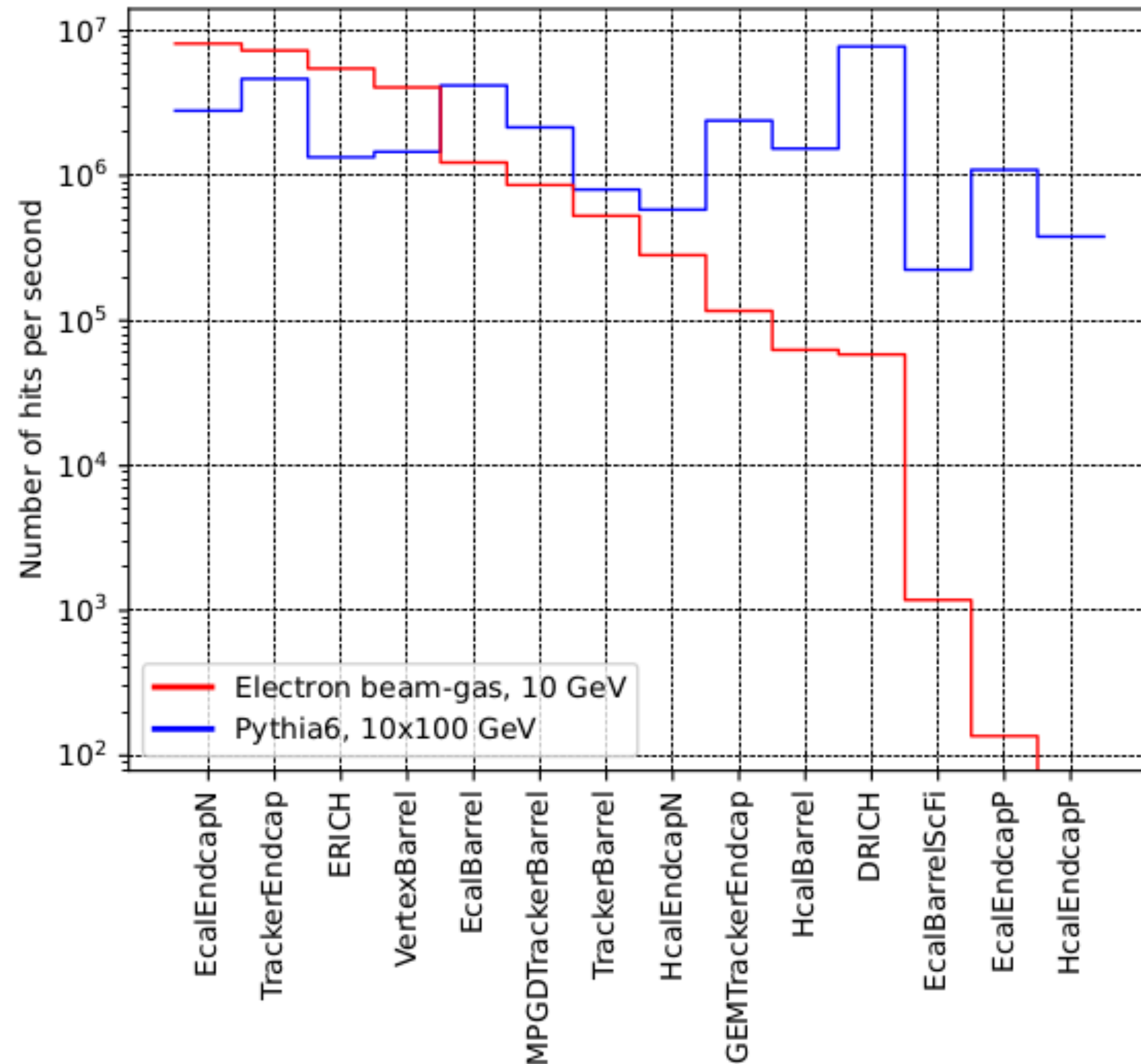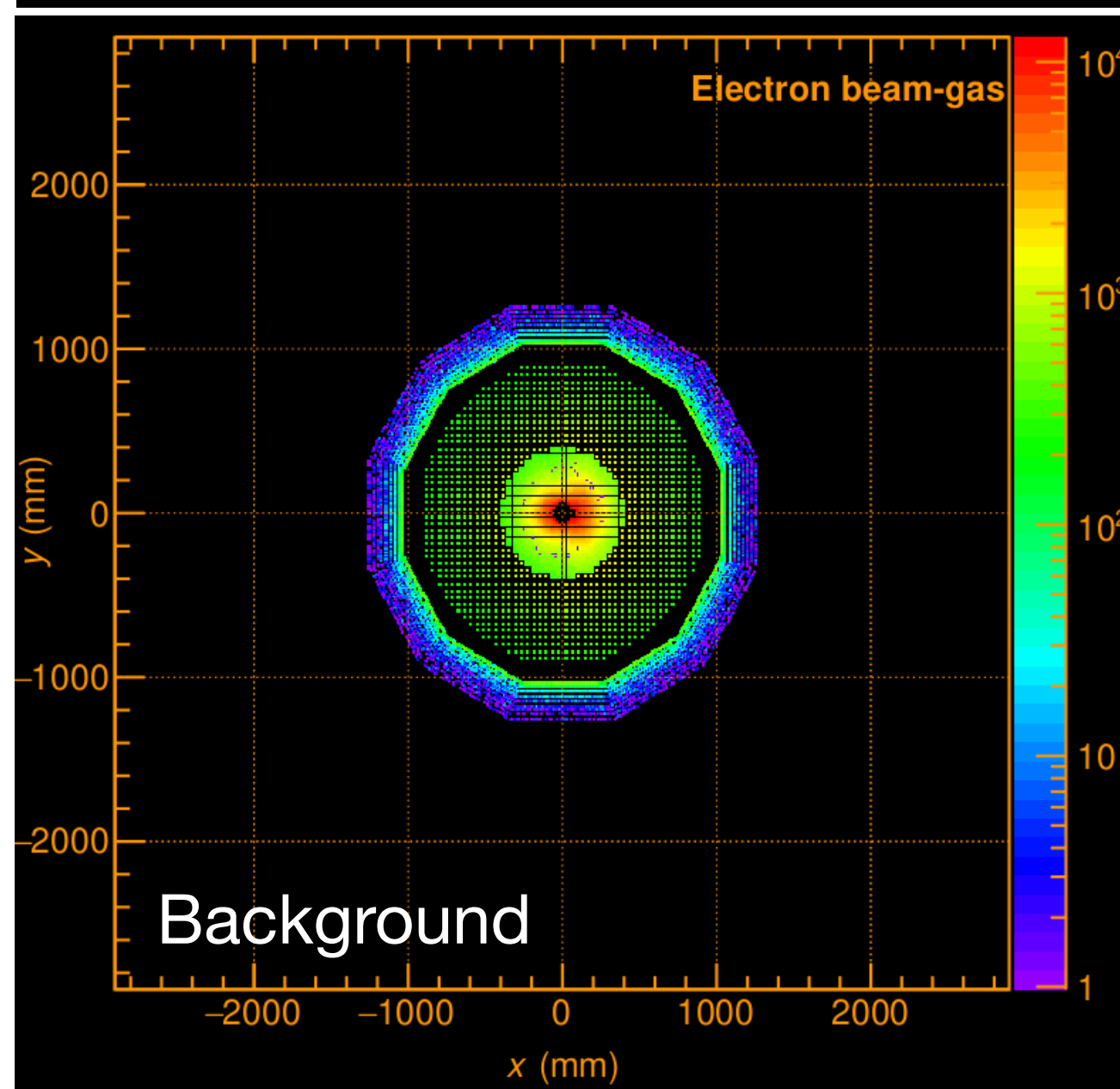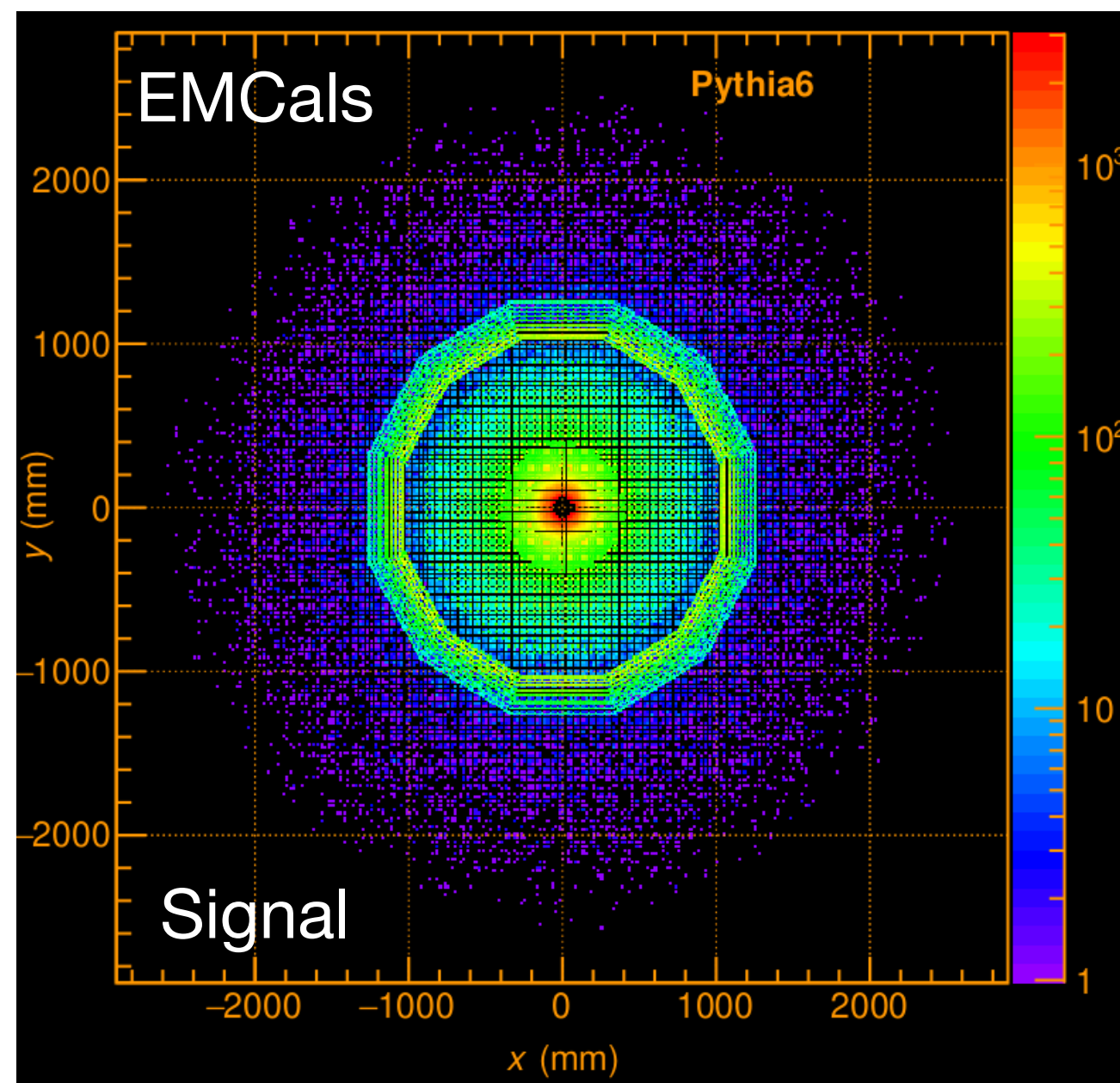
- concerning large hadronic cross section of the $p/A_\text{beam} + \text{H}^2_\text{rest gas}$ interactions

- Secondary interactions of produced particles with detector components is one of the main sources of neutrons that thermalize within the detector hall

Hit distribution in electromagnetic calorimeters

Study by Zhengqiao Zhang, et al.

See more details here
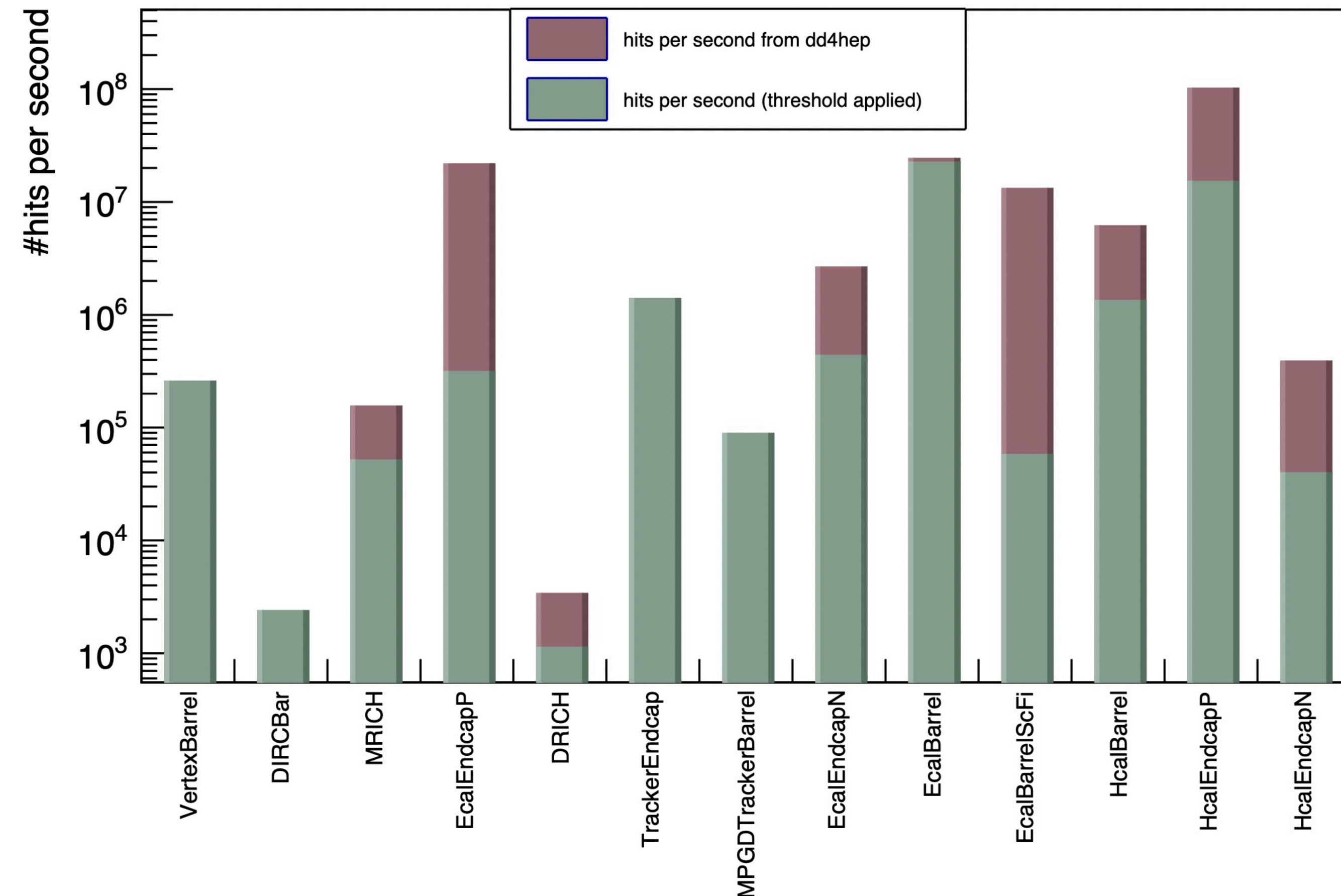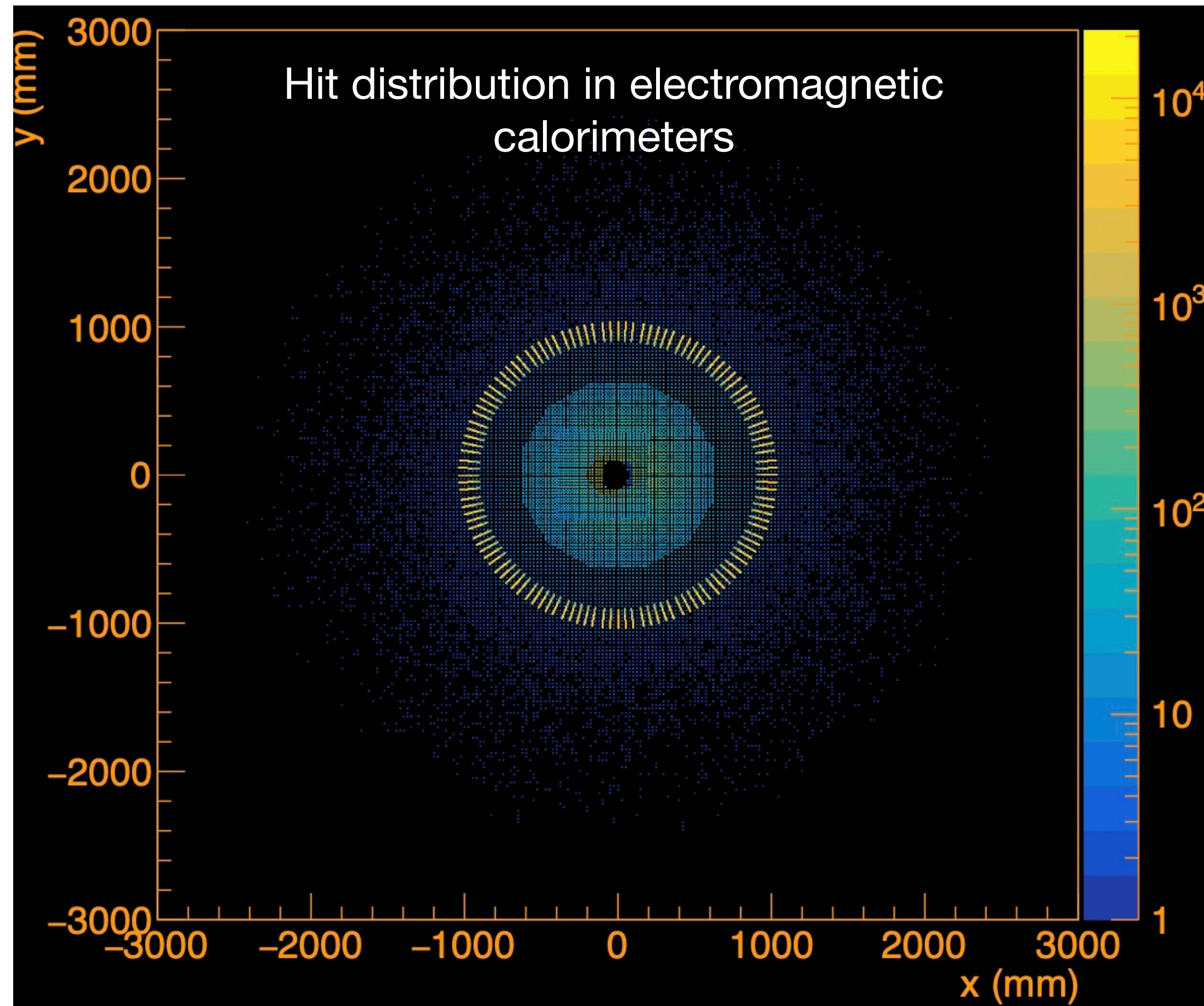
Energy thresholds (ATHENA era)

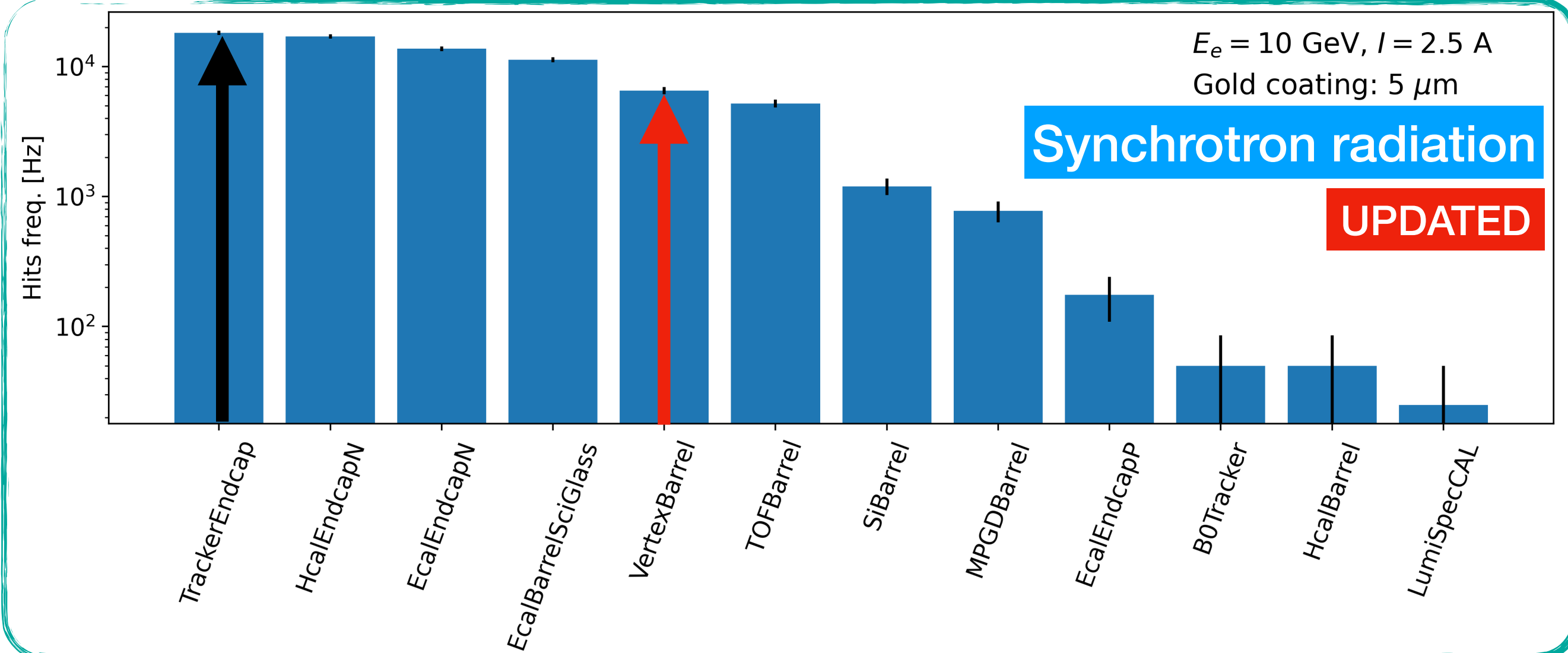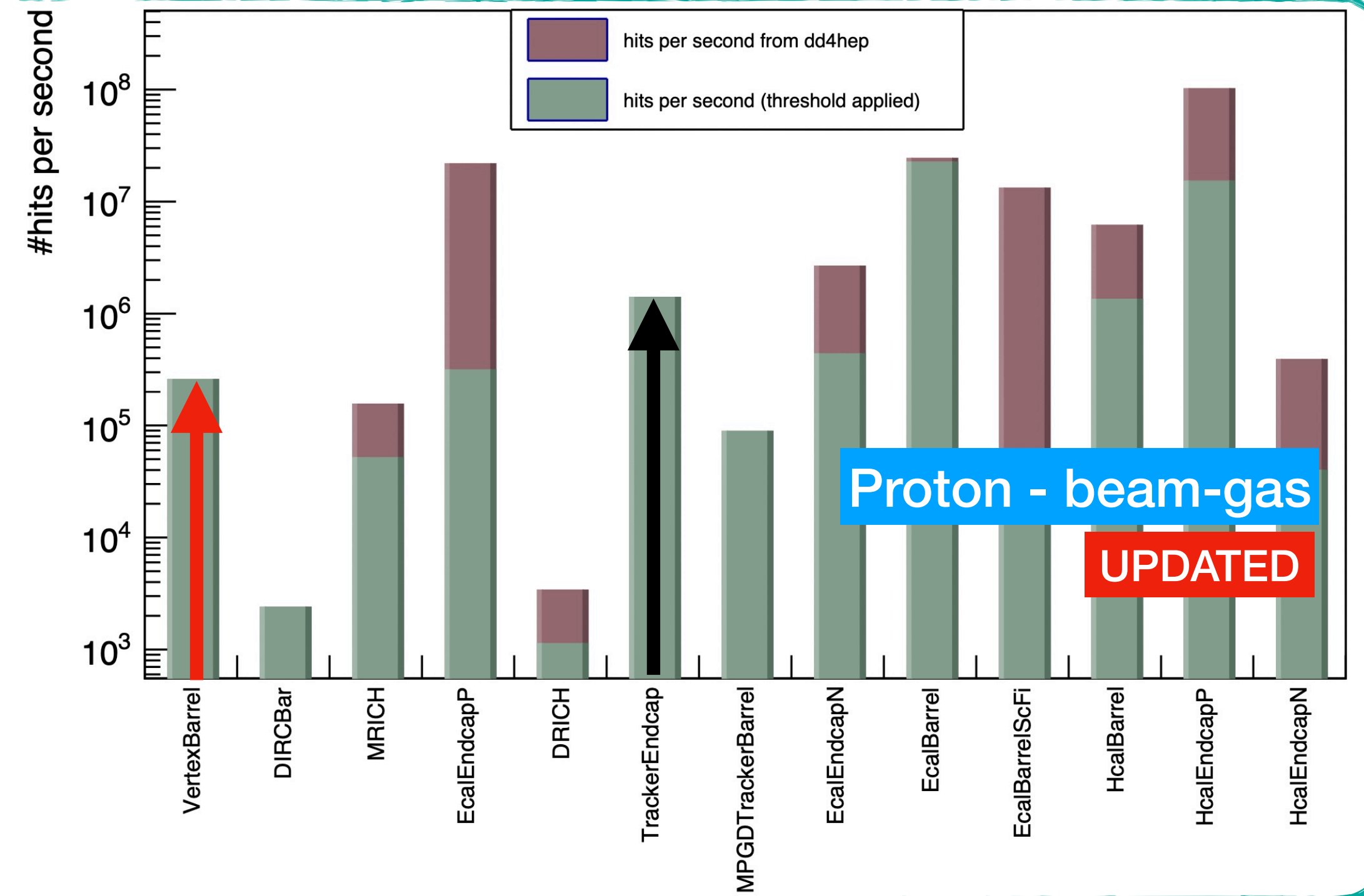|	readout	Threshold
VertexBarrel	0.010mm*0.010mm	0.4keV
DIRCBar	3.0mm*3.0mm	
ERICH	3.2mm*3.2mm	divided by 3
EcalEndcapP	1 fiber (20.5mm*20.5mm)	5 MeV
DRICH	3.2mm*3.2mm	divided by 3
TrackerBarrel	0.010mm*0.010mm	0.4 keV
TrackerEndcap	0.010mm*0.010mm	0.4 keV
MPGDTrackerBarrel	0.52mm*0.52mm	0.2 keV
GEMTrackerEndcap	0.17mm*0.87mm	0.2 keV
EcalEndcapN	1 fiber (20.5mm*20.5mm)	2.5 MeV
EcalBarrel	0.5mm*0.5mm	0.4 keV
B0Preshower		
EcalBarrelScFi	1 fiber	2.5 MeV
HcalBarrel	100.0mm*100.0mm	0.1 MeV
HcalEndcapP	100.0mm*100.0mm	300 MeV
HcalEndcapN	100.0mm*100.0mm	0.1 MeV

Table copied from slide 10 here

Background comparisons

Electron - beam-gas
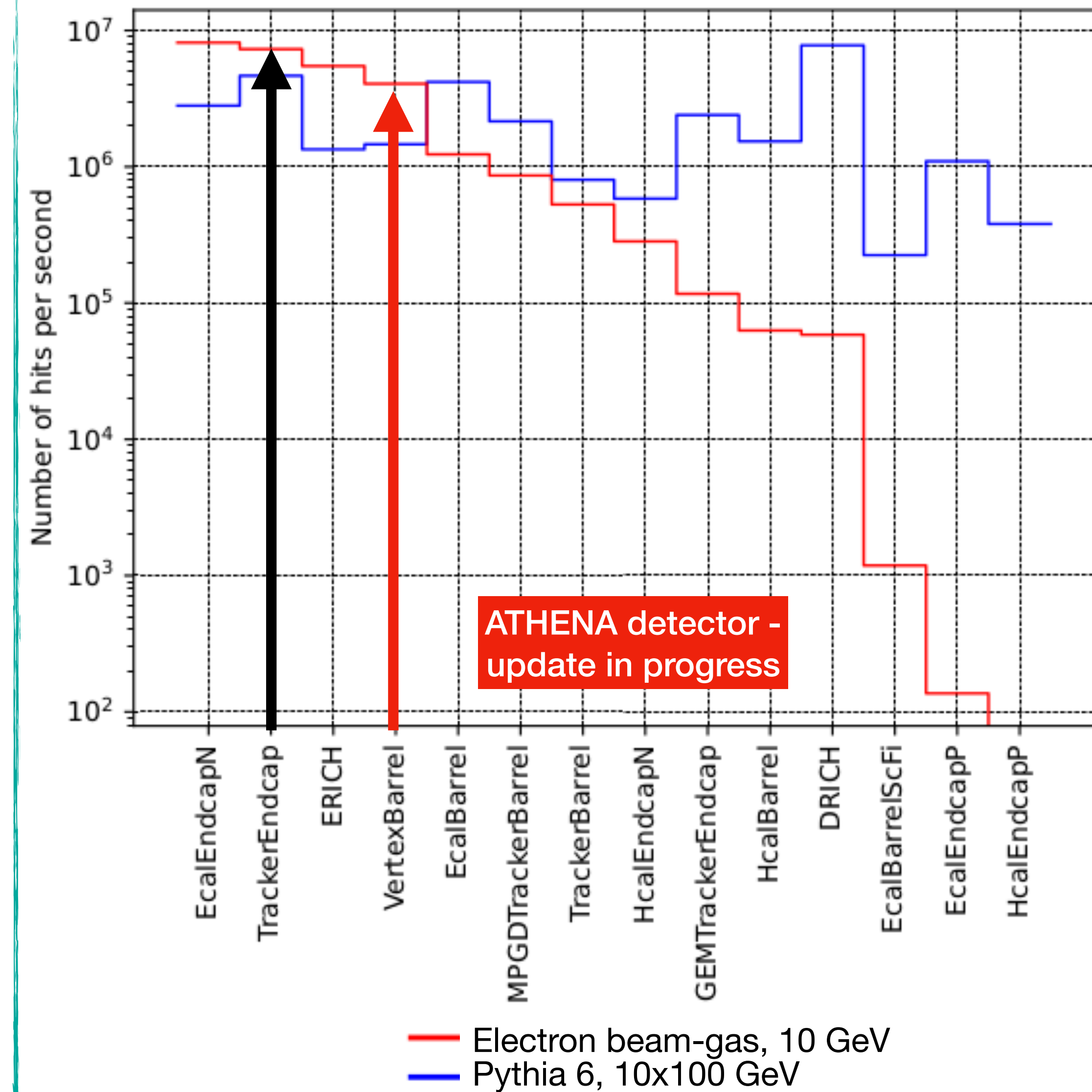
ATHENA detector - update in progress

Electron beam-gas, 10 GeV
Pythia 6, 10x100 GeV

hits per second from dd4hep
hits per second (threshold applied)

Proton - beam-gas

UPDATED

E_e = 10 GeV, I = 2.5 A
Gold coating: 5 μm

Synchrotron radiation

UPDATED

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

Testing background impact

Need to simulate dataset that emulates true EIC environment as precisely as possible
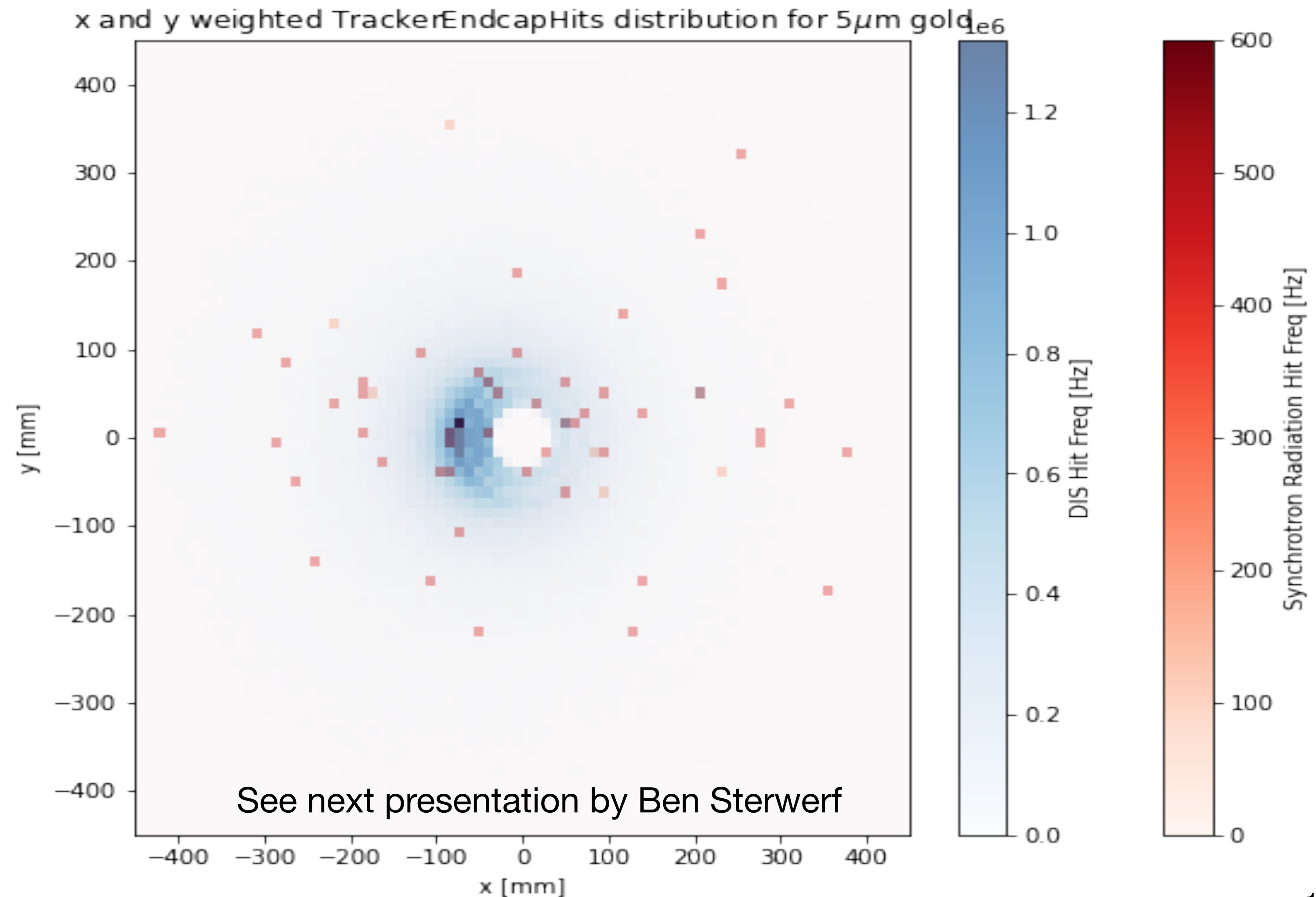- mix signal and background sources
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$$\text{signal} + \sum_{i=1}^{N} \text{background}_i$$

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

x and y weighted TrackerEndcapHits distribution for 5μm gold

See next presentation by Ben Sterwerf

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
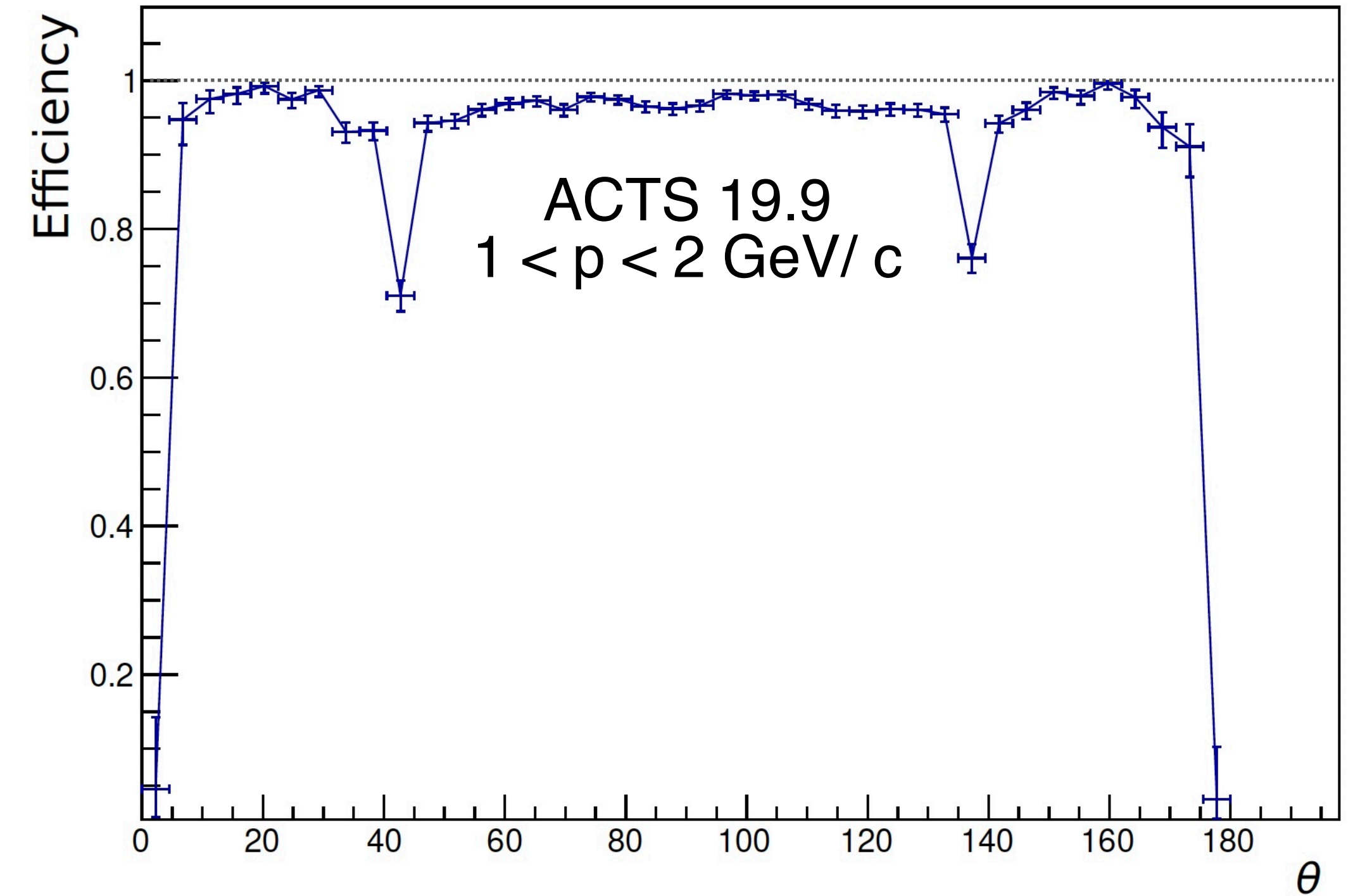
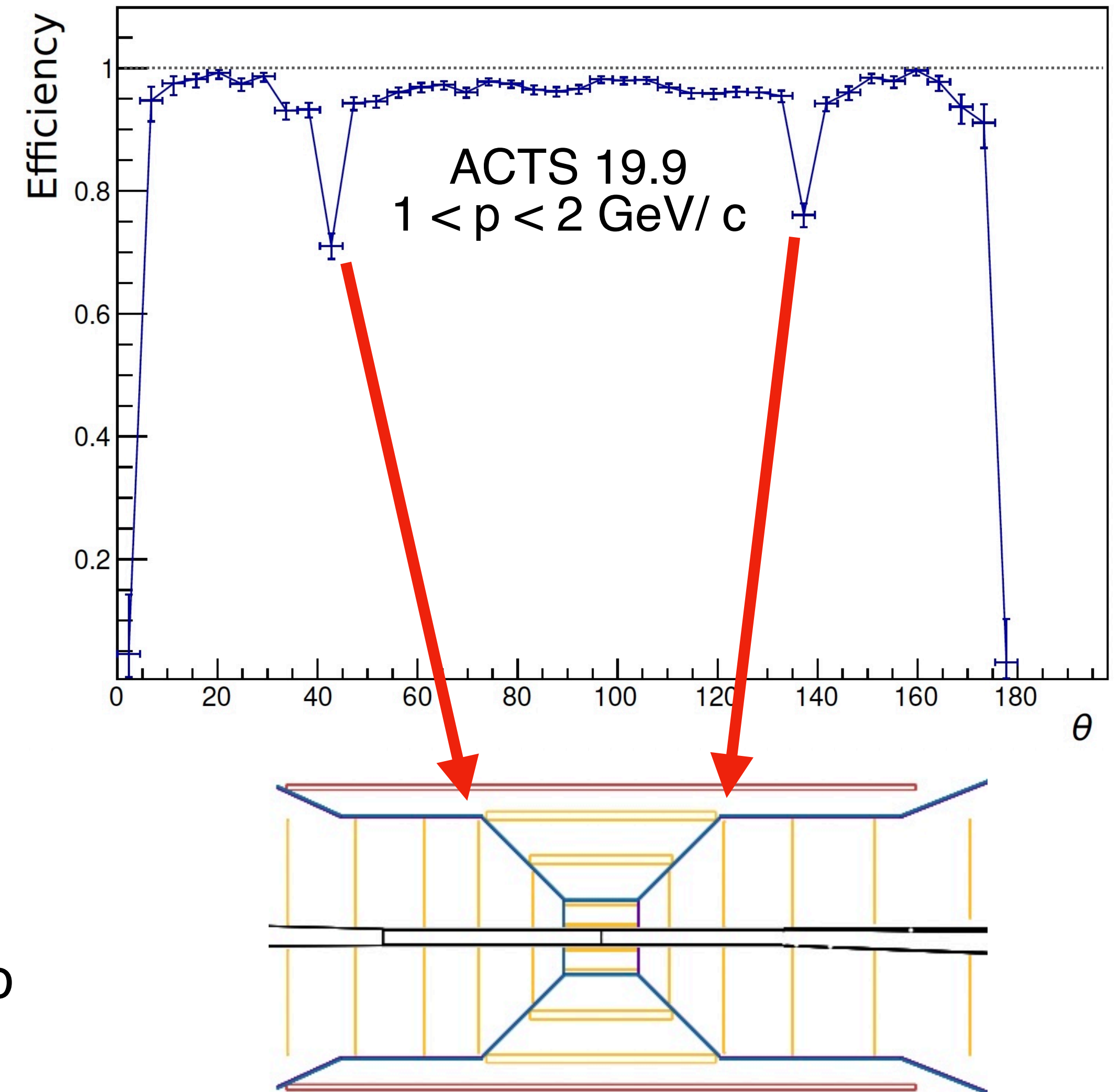# Thanks for your attention
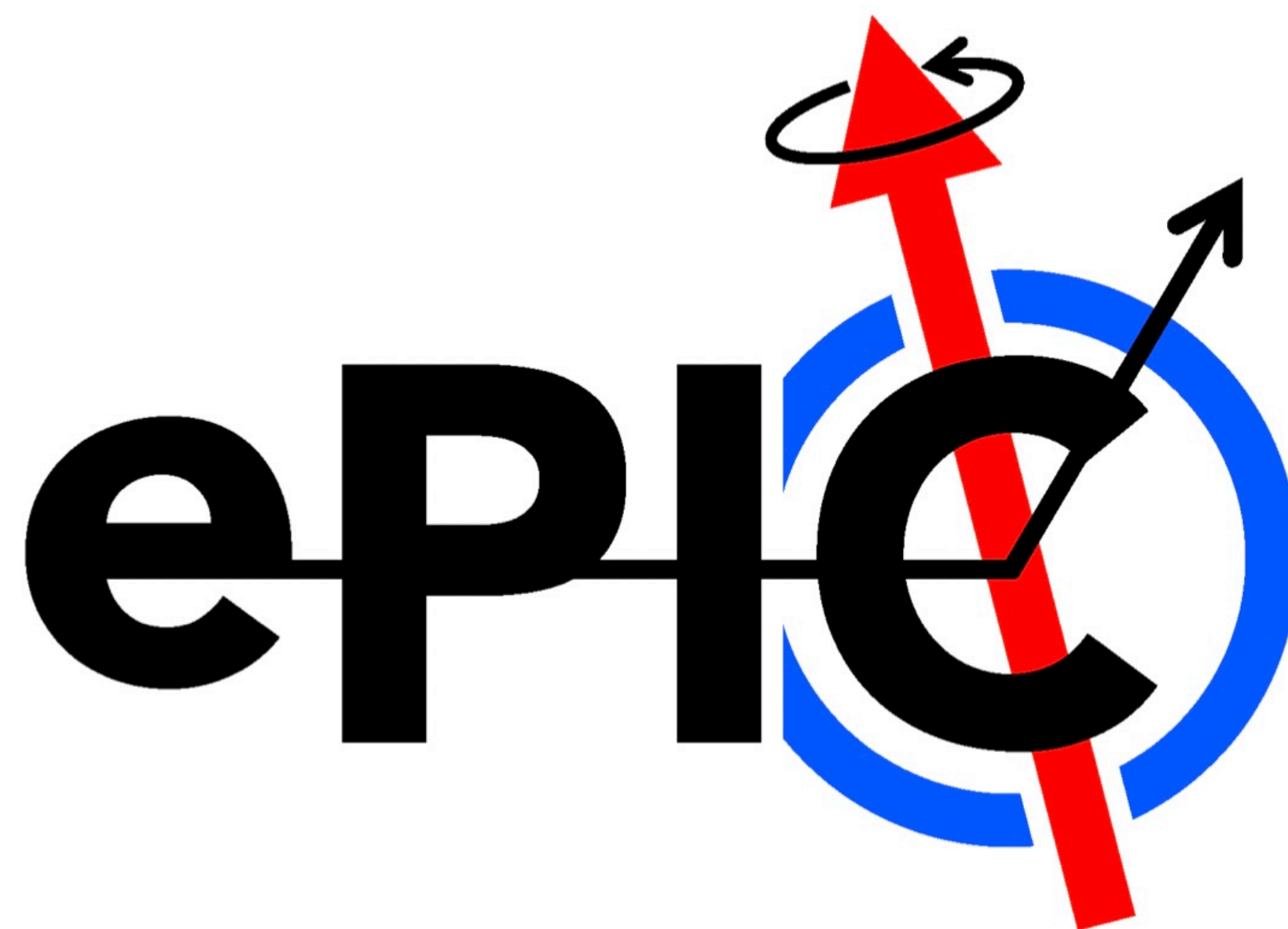
Backup

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.

ACTS 19.9
$1 < p < 2$ GeV/ c

Efficiency

θ

Study by Yue Shi Lai, et al.

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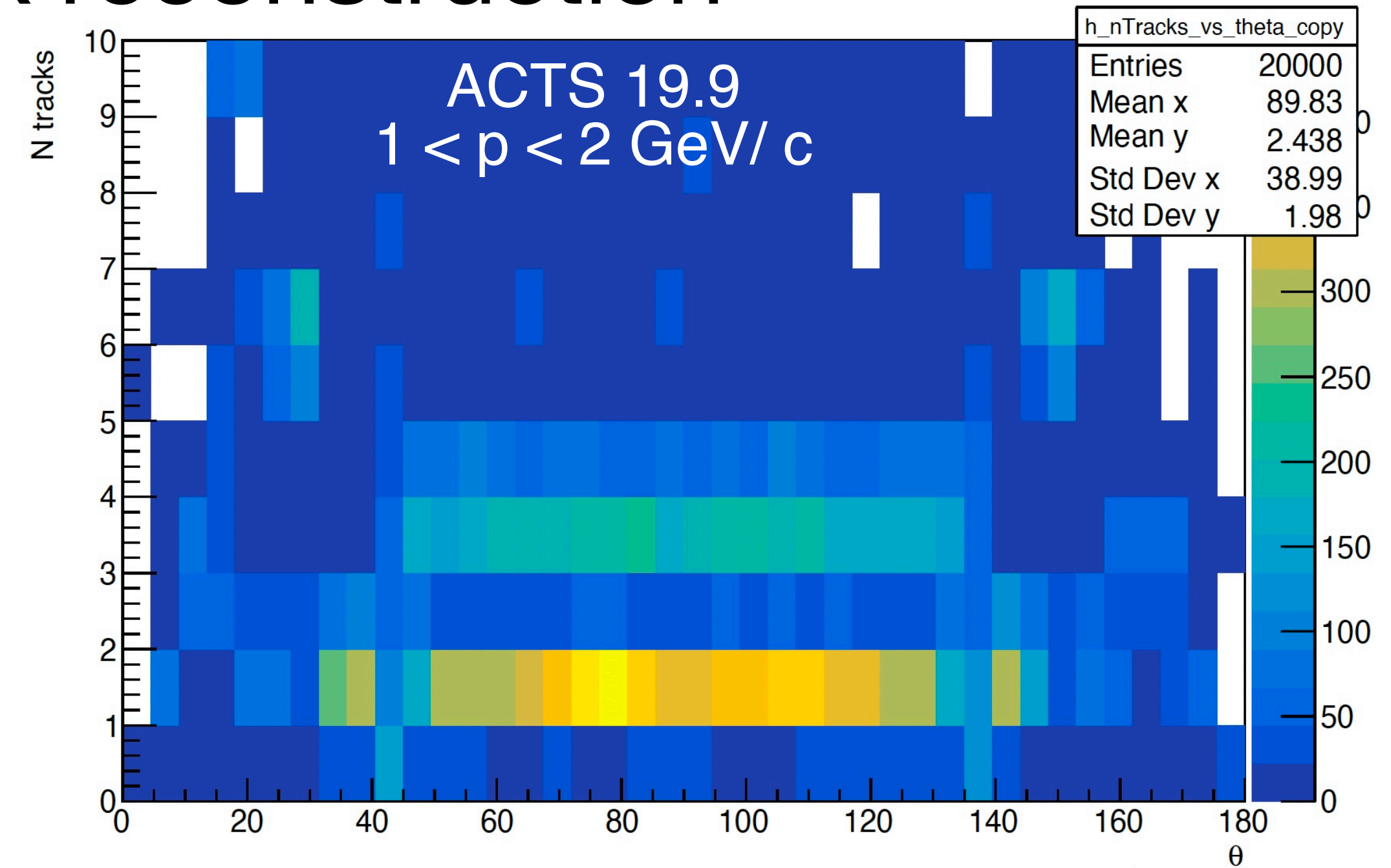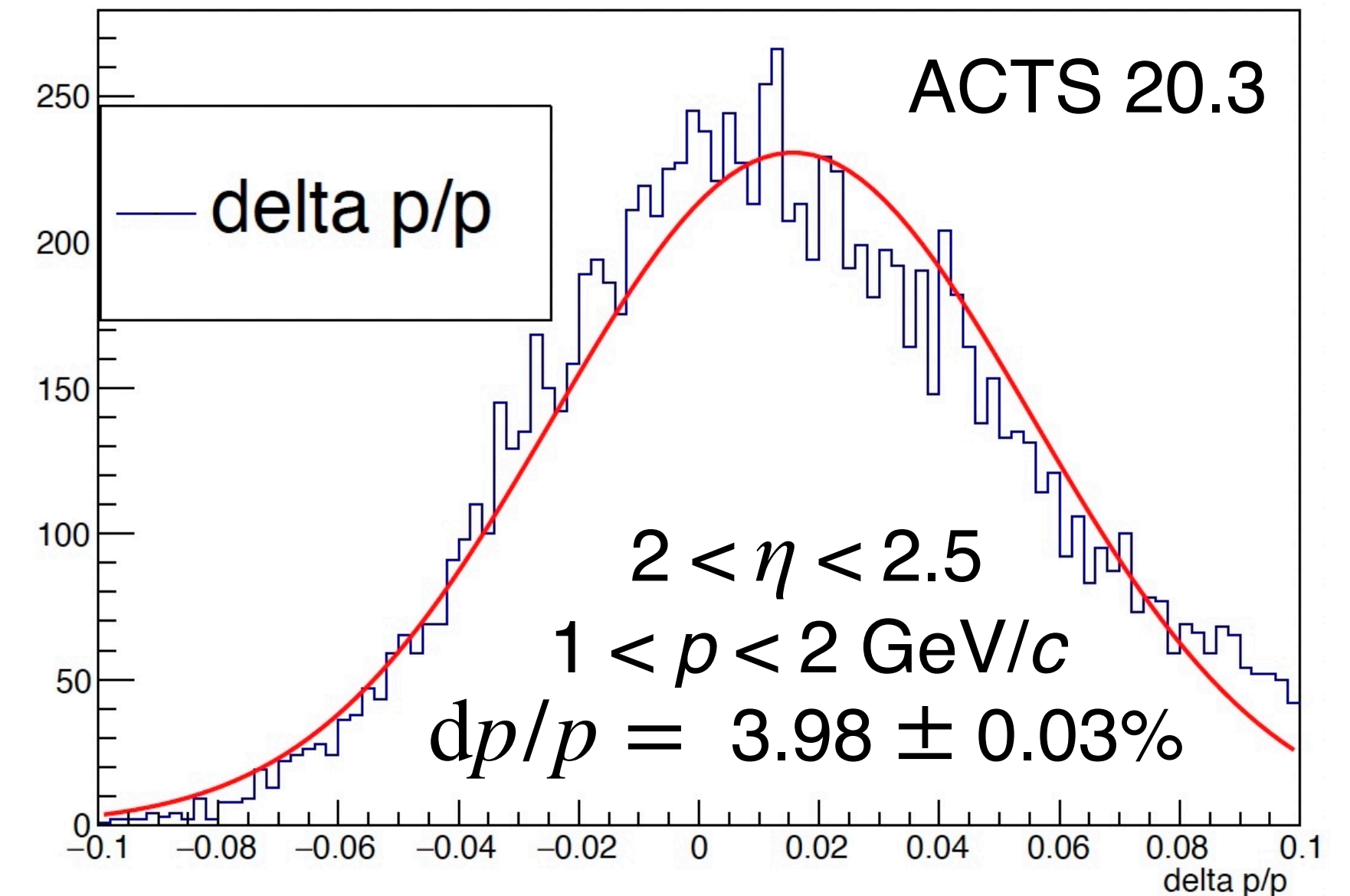

ACTS 19.9
$1 < p < 2$ GeV/ c

Study by Yue Shi Lai, et al.

Progress on realistic track reconstruction

ACTS 19.9
1 < p < 2 GeV/ c

h_nTracks_vs_theta_copy	
Entries	20000
Mean x	89.83
Mean y	2.438
Std Dev x	38.99
Std Dev y	1.98

- 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)

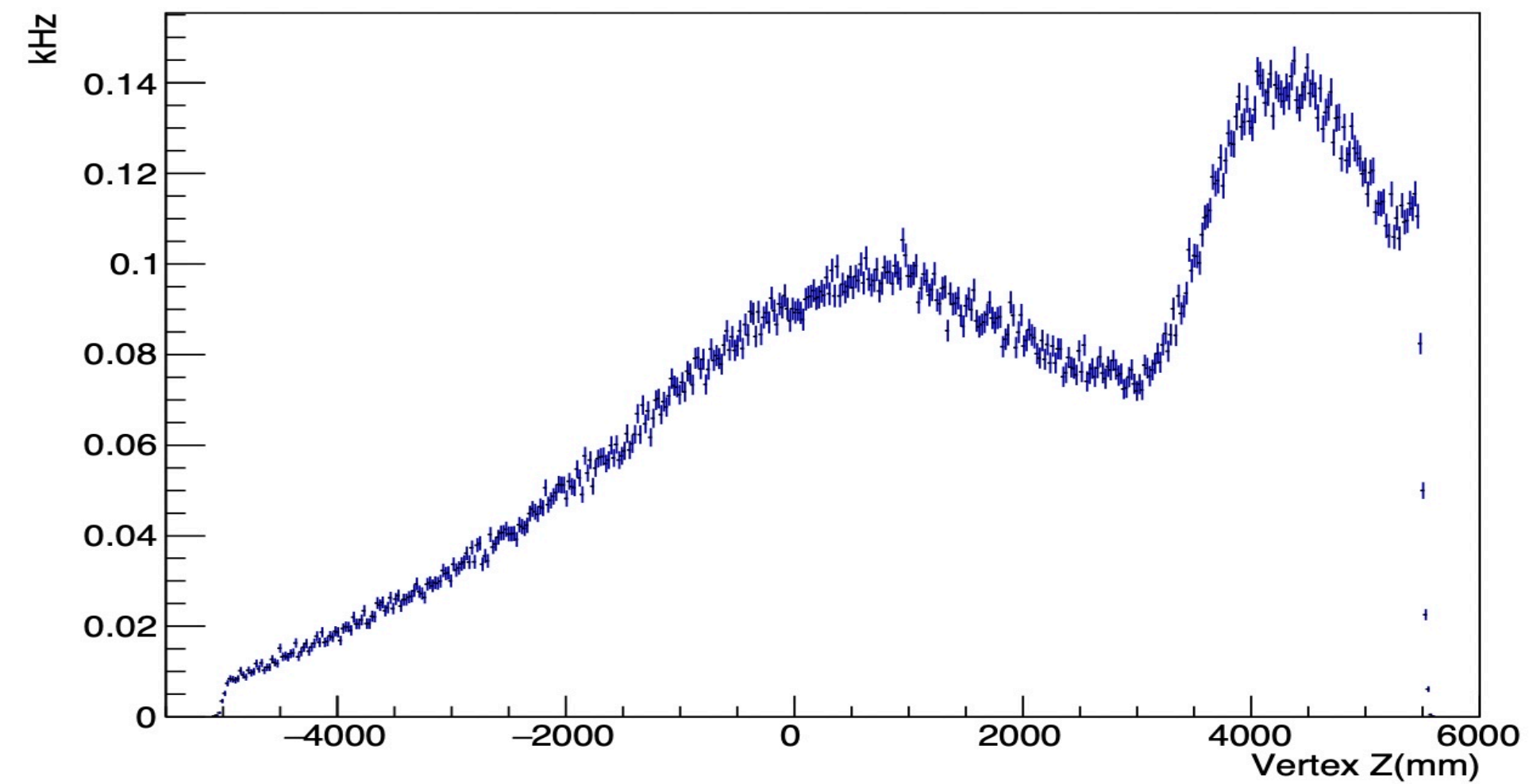- A unbinned "orthogonal" seeder is being developed, which may address the issue of the binned seeder
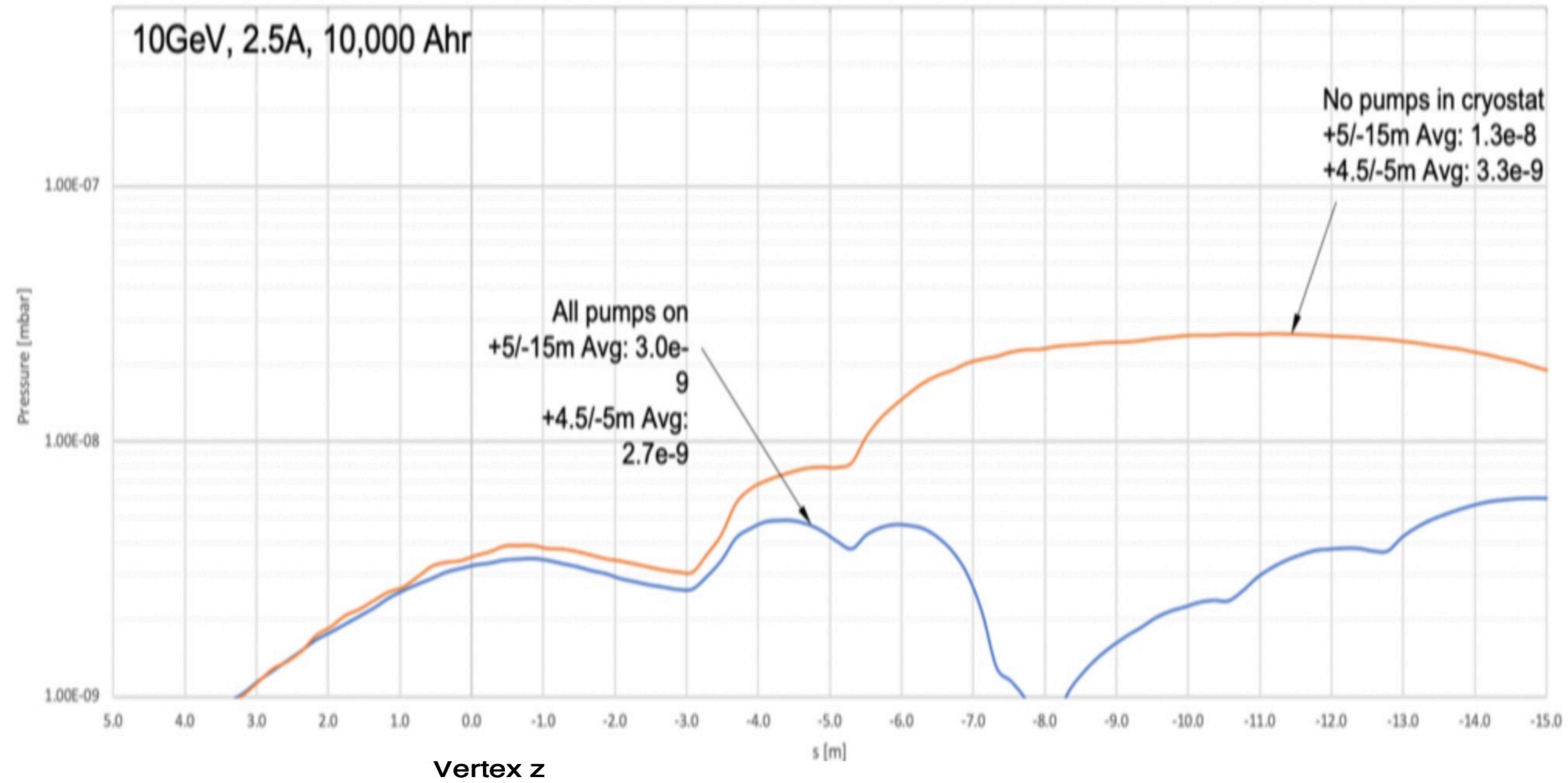
Study by Yue Shi Lai, et al.

- ■ 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

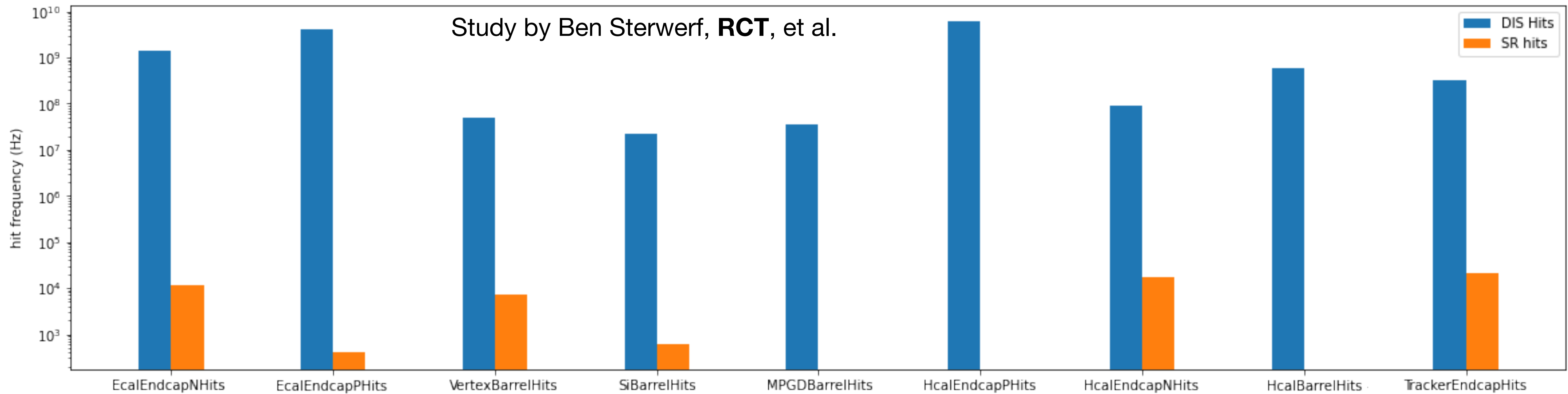- ■ Forward $\Delta p/p$ deteriorated vs. truth seeding (~1.5%)

ACTS 20.3

delta p/p

$2 < \eta < 2.5$
$1 < p < 2$ GeV/c
$\mathrm{d}p/p = 3.98 \pm 0.03\%$

25

Vertex z distribution in hadron beam gas

10GeV, 2.5A, 10,000 Ahr

No pumps in cryostat
+5/-15m Avg: 1.3e-8
+4.5/-5m Avg: 3.3e-9

All pumps on
+5/-15m Avg: 3.0e-9
+4.5/-5m Avg: 2.7e-9

Vertex z

Synchrotron radiation results

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

Links to previous studies

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

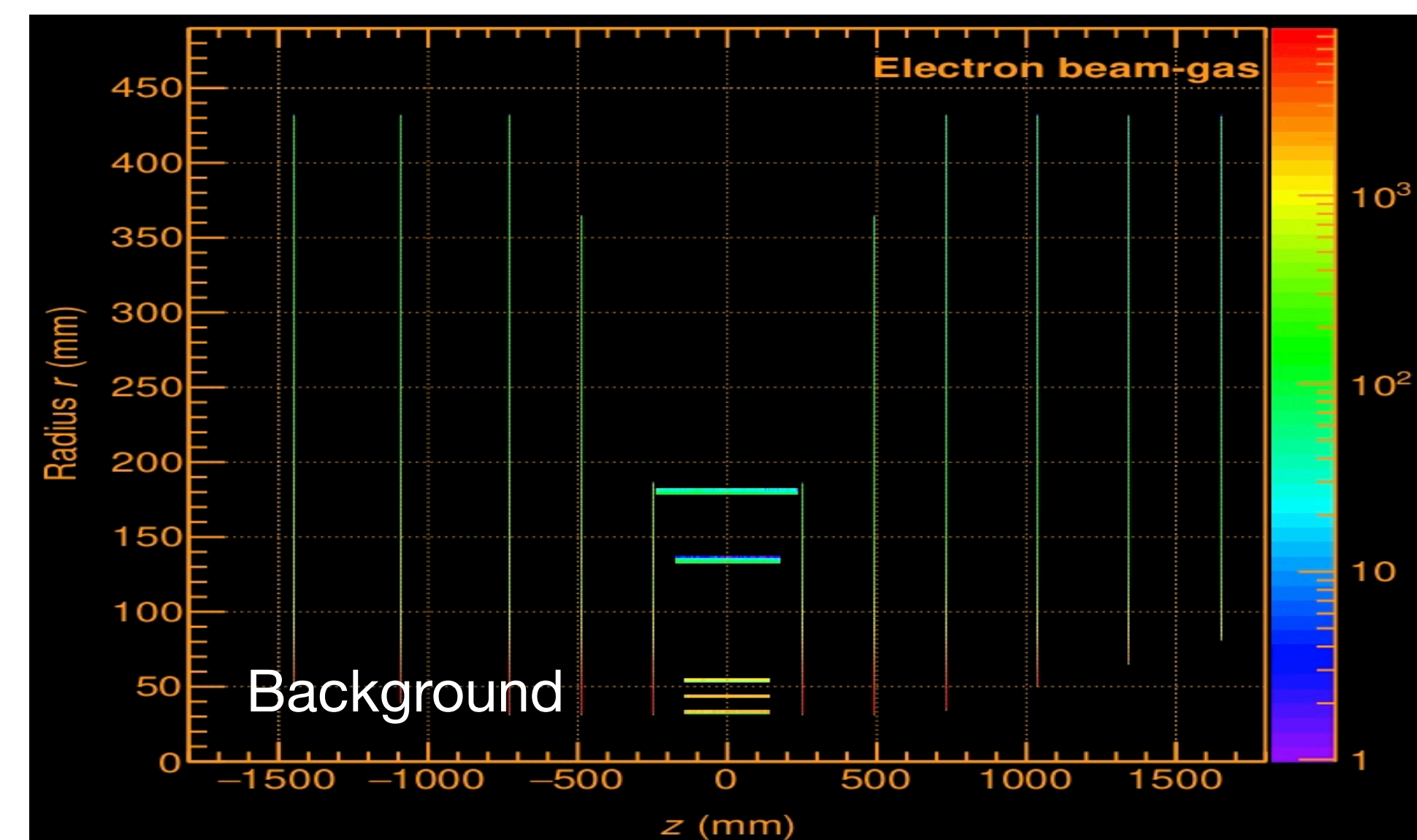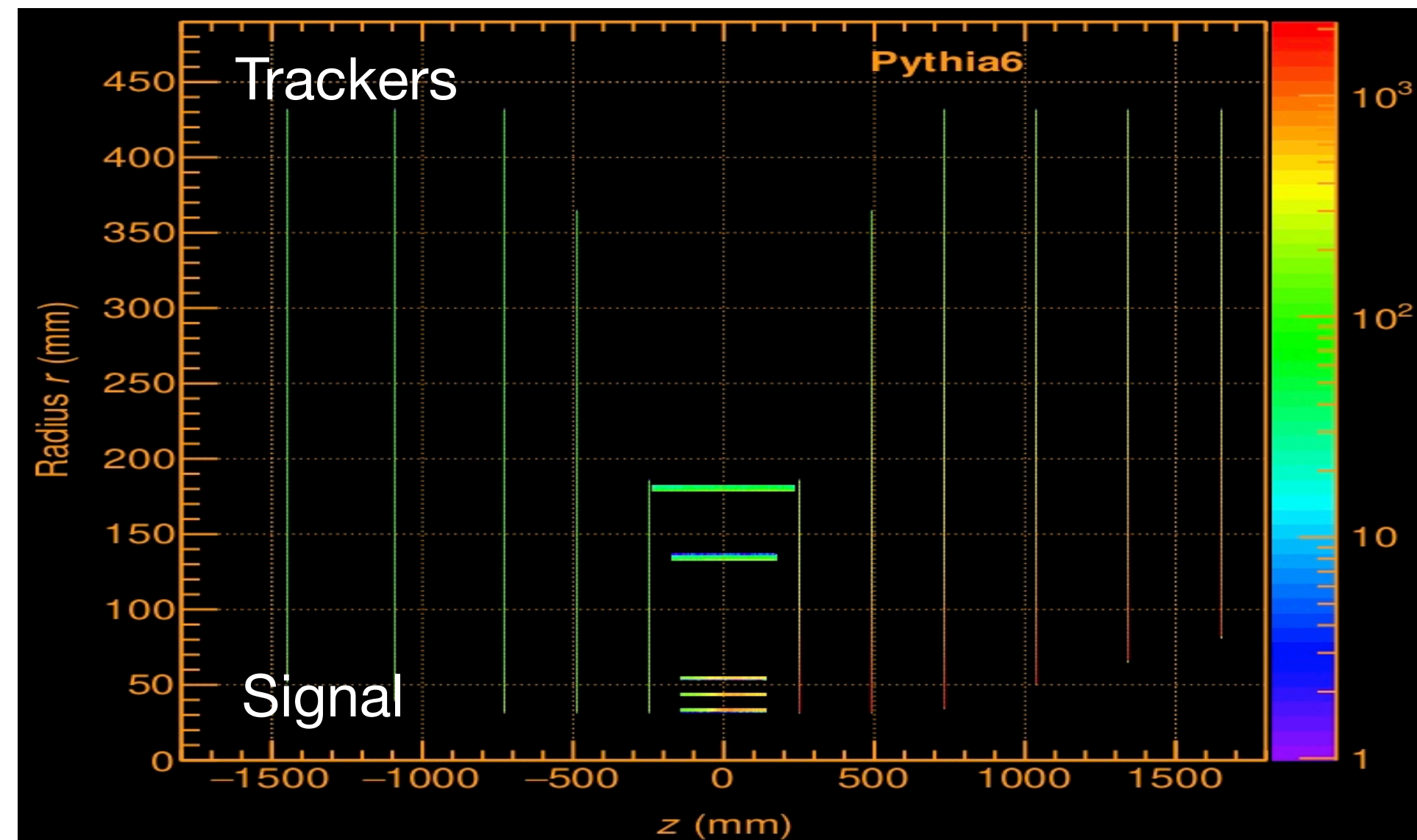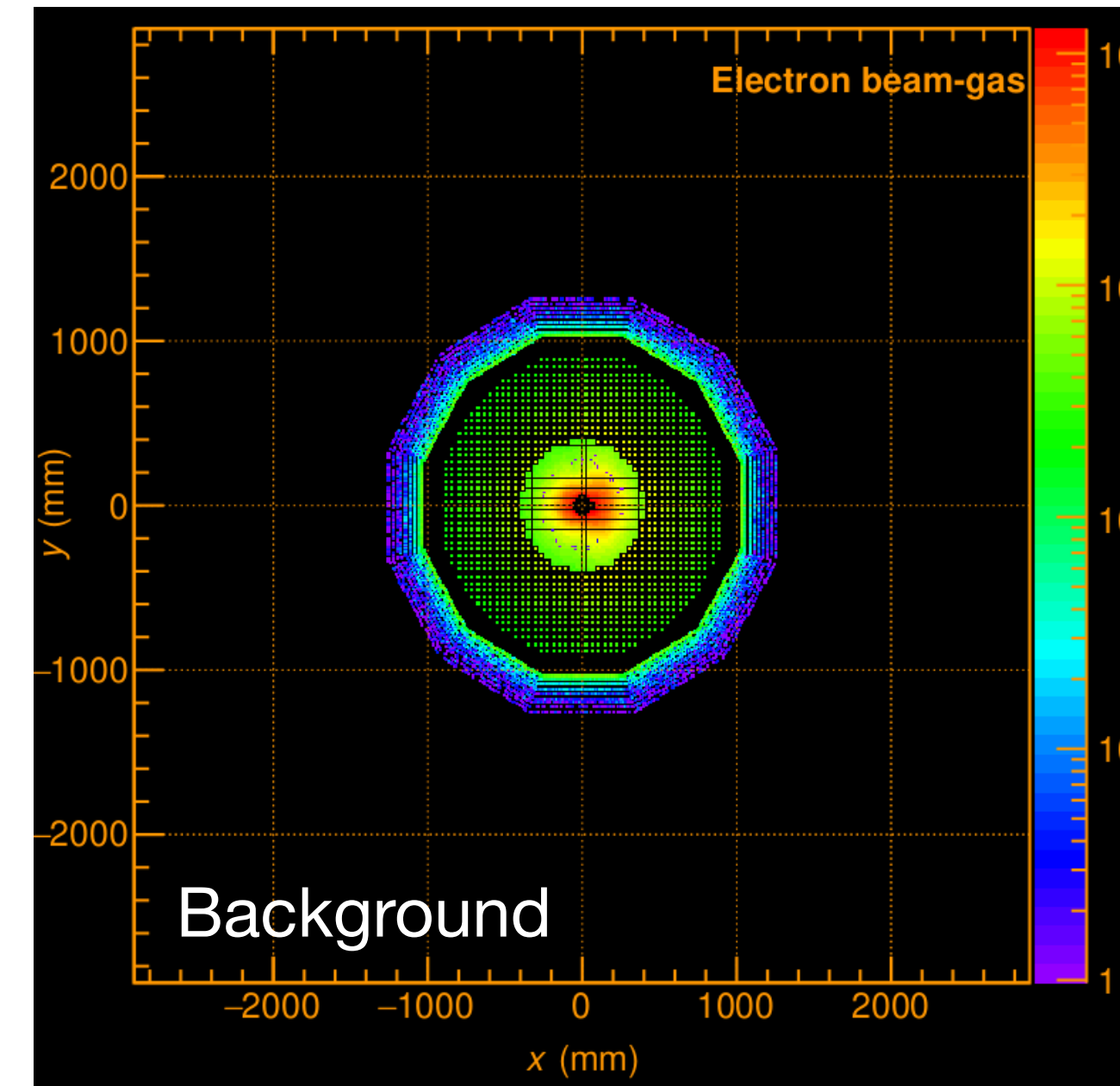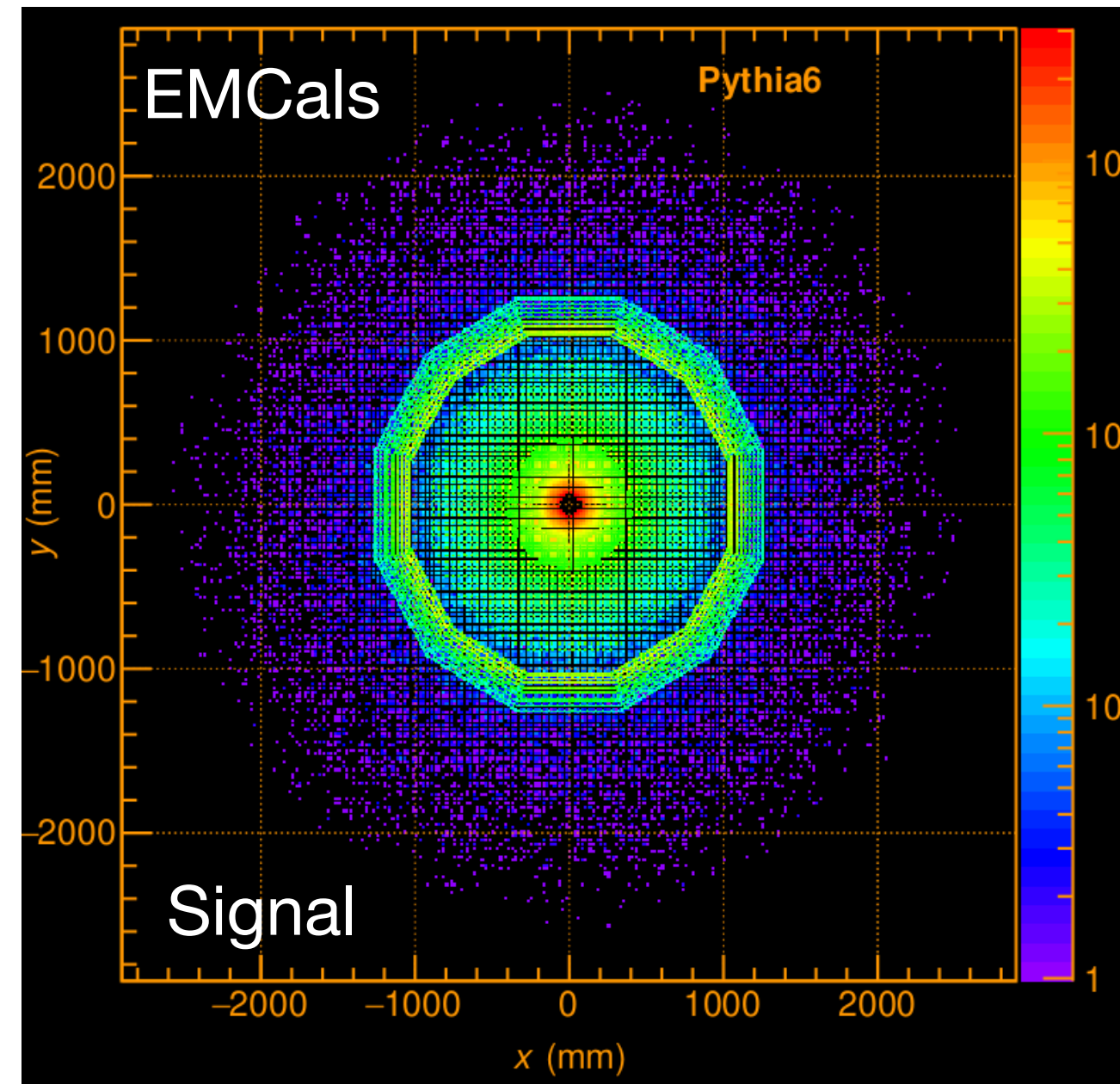**Elke Aschenauer - EIC Physics and Detector**

Wiki - ePIC Background

Wiki - ATHENA Background

Wiki - beam backgrounds

Electron Beam-Gas interactions

See mode details here

Study by Jaroslav Adam, et al.

Electron Beam-Gas interactions

EMCals
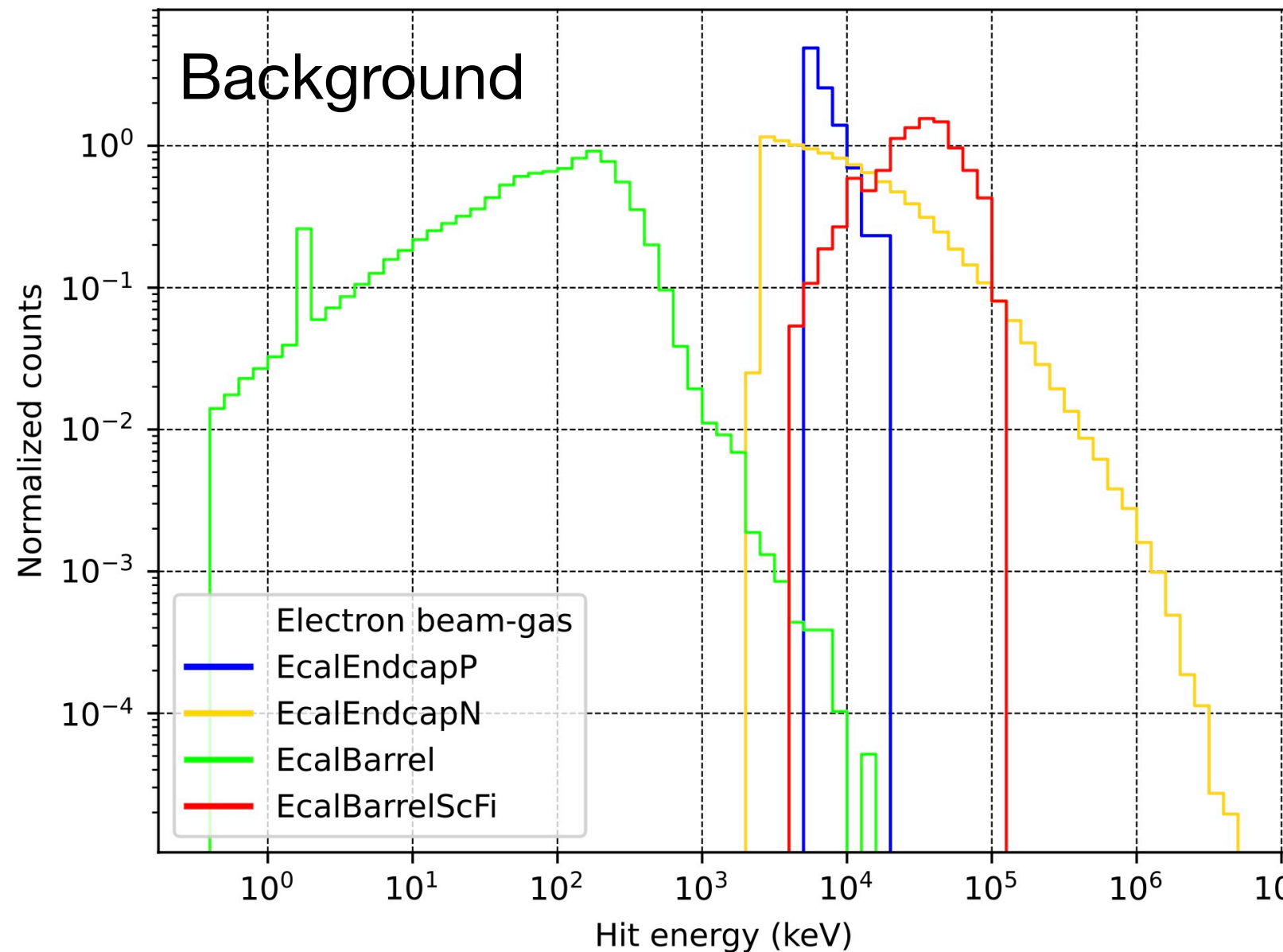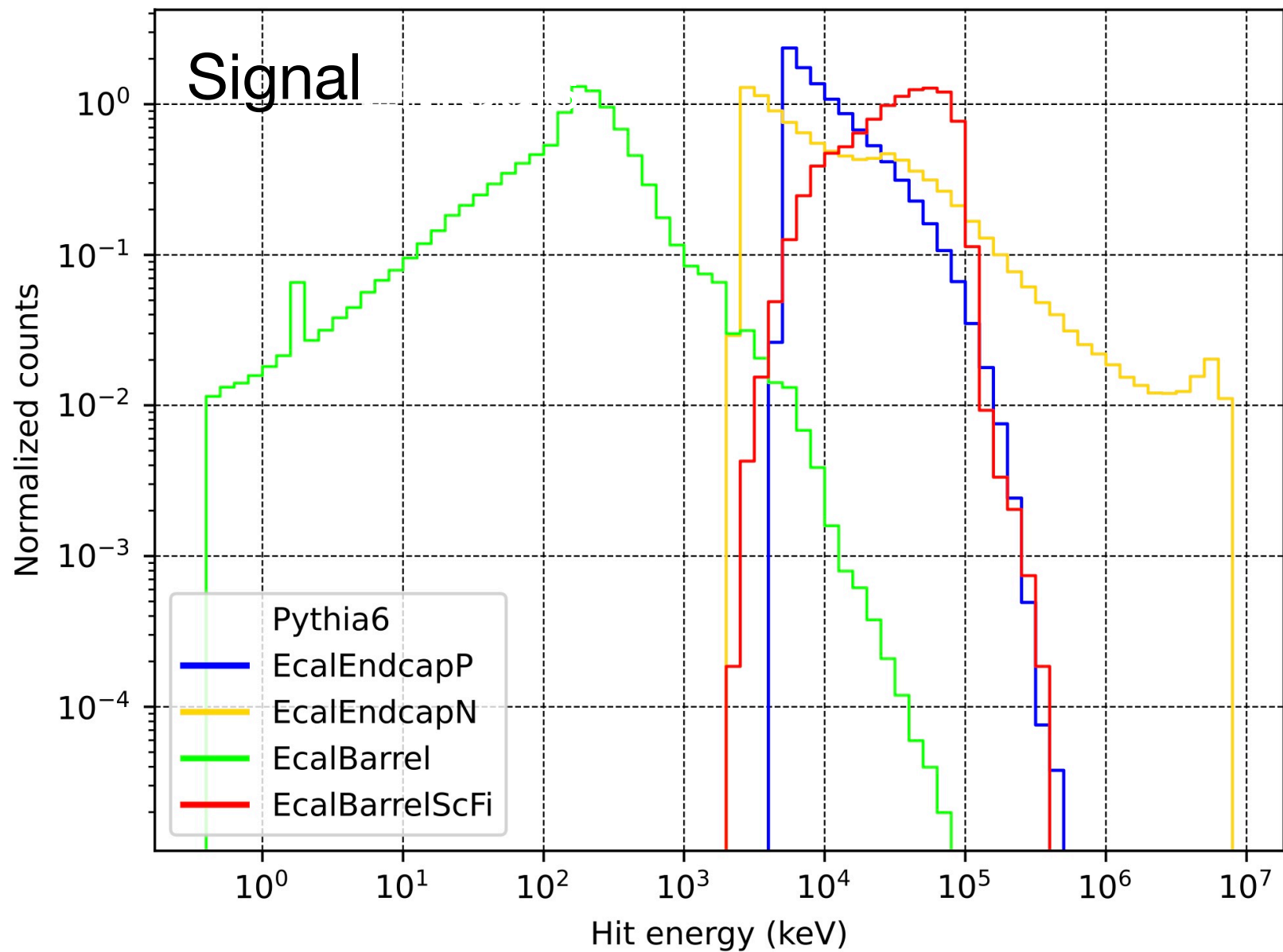
Trackers

See mode details here

Study by Jaroslav Adam, et al.