Report from Background Task Force

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Presenting work done by J. Adam, E. Aschenauer, W. Deconinck, J. Huang, A. Jentsch, K. Kauder, J. Nam, J. Osborn, D. Romanov, B. Sterwerf, Z. Zhang, ...

Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY Jefferson Lab U.S. DEPARTMENT OF ENERGY | Office of Science

Indico for background taskforce meeting:
https://indico.bnl.gov/category/461/

Email-list:
eic-projdet-background-l@lists.bnl.gov

Wiki page for ePIC background:
https://wiki.bnl.gov/EPIC/index.php?title=Background

Background/Radiation

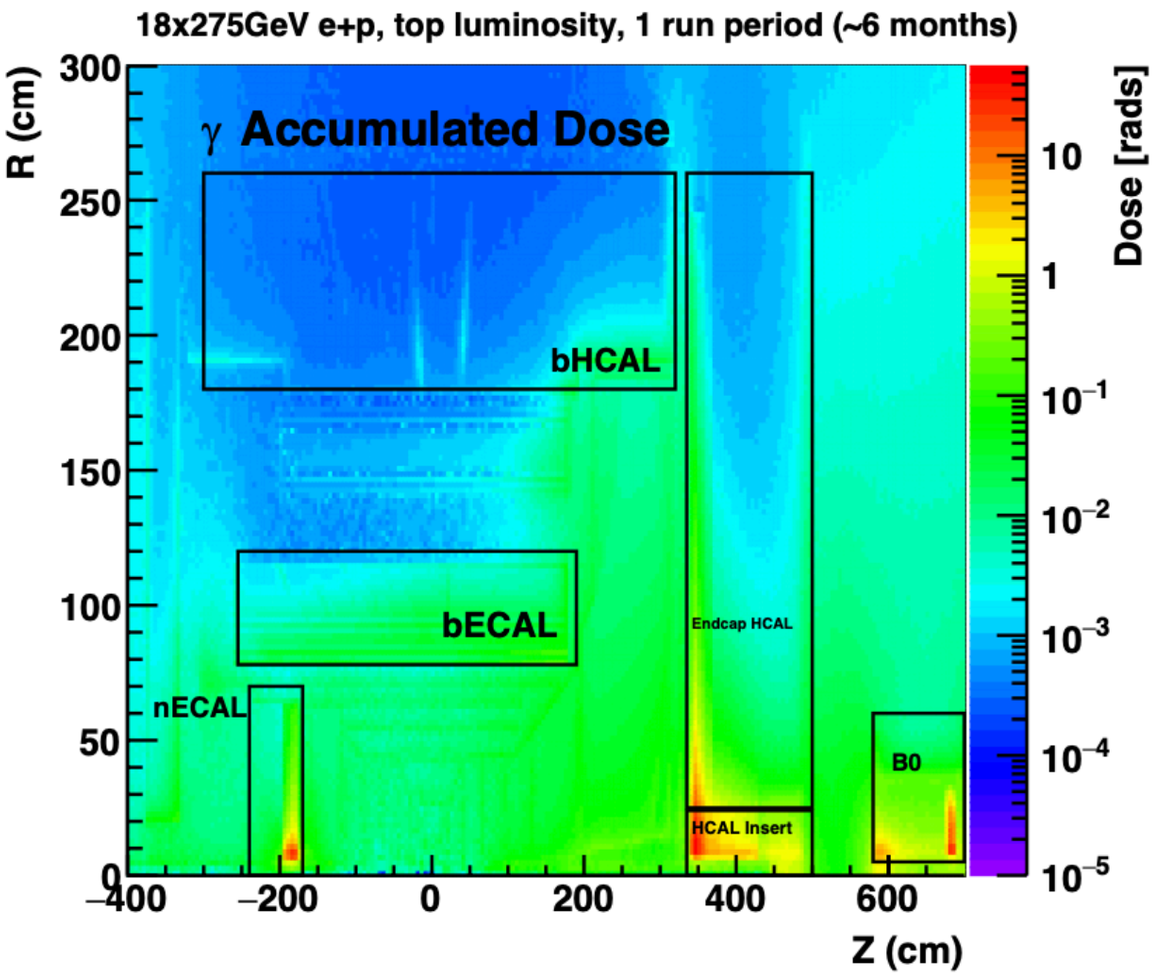
- The HERA and KEK experience shows that having backgrounds under control is crucial for the EIC detector performance;
- There are several background/radiation sources :
  - Primary collisions
    - Ionization radiation
    - Low energy neutron radiation
  - Beam-gas induced
    - Hadron-gas interaction
    - Electron-gas interaction
  - Synchrotron radiation
    - Origin: quads and bending magnet upstream of IP
    - Tails in electron bunches: can produce hard radiation

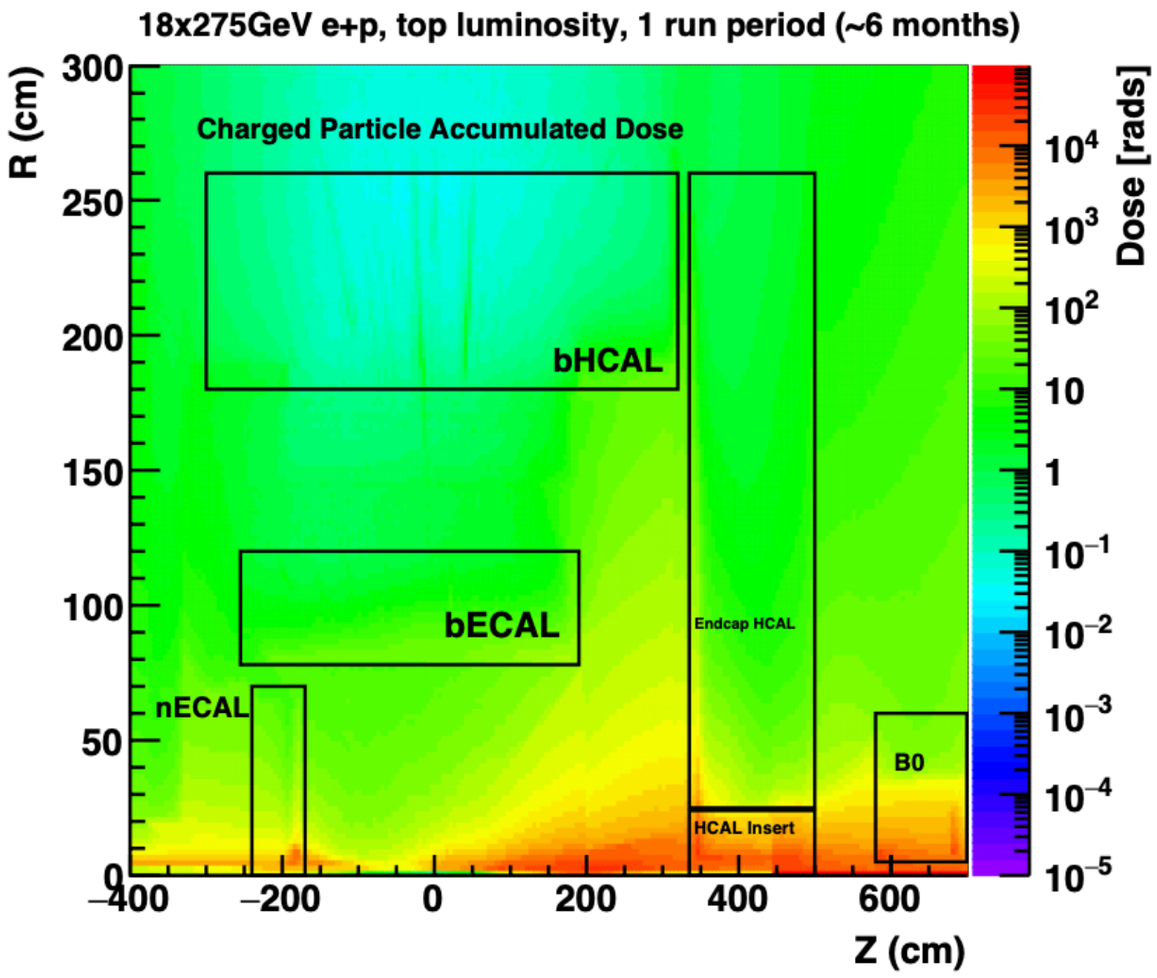
Important to note:

- No pileup from collisions 500 kHz @10^{34} $cm^{-2}s^{-1}$ → coll. every 200 bunches

Radiation Doses (min-bias, no beam gas)

Study by Alex Jentsch

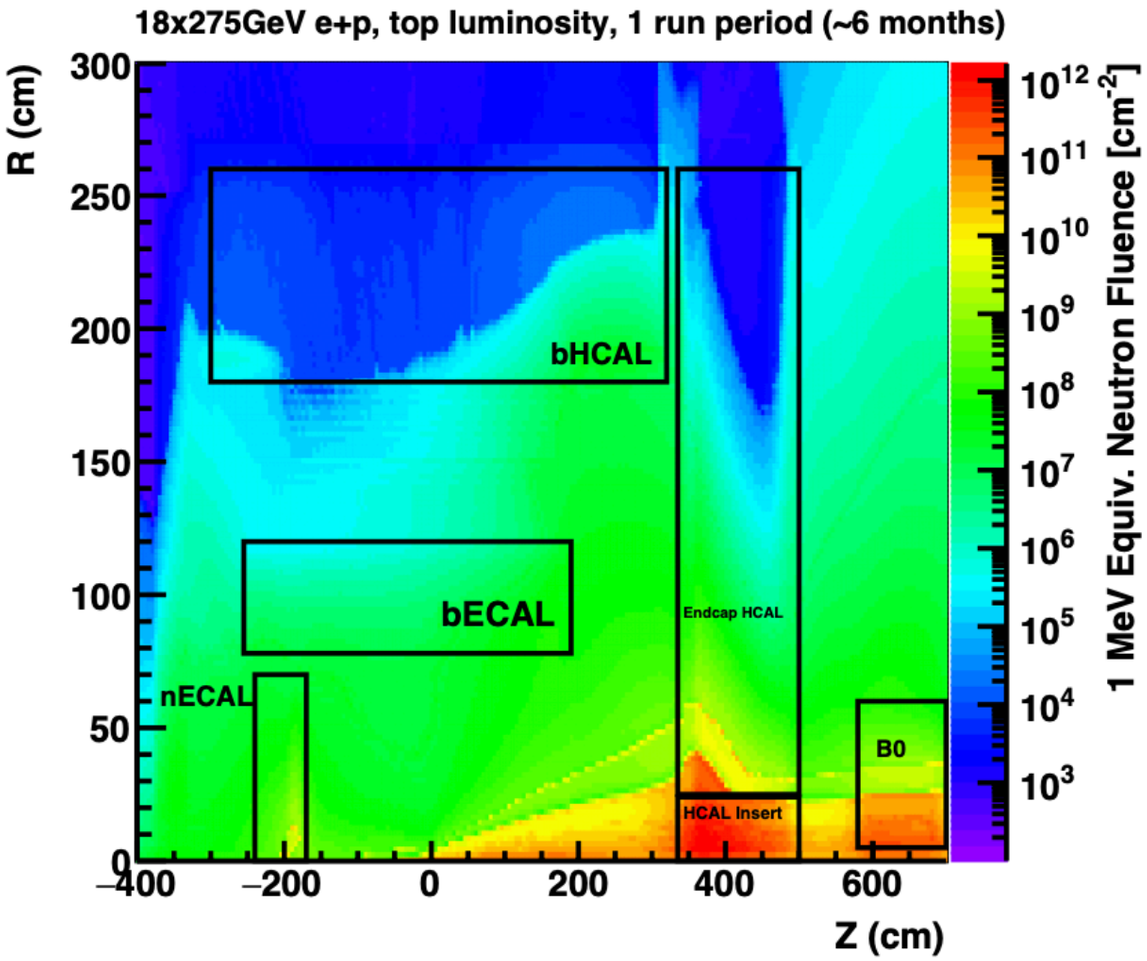


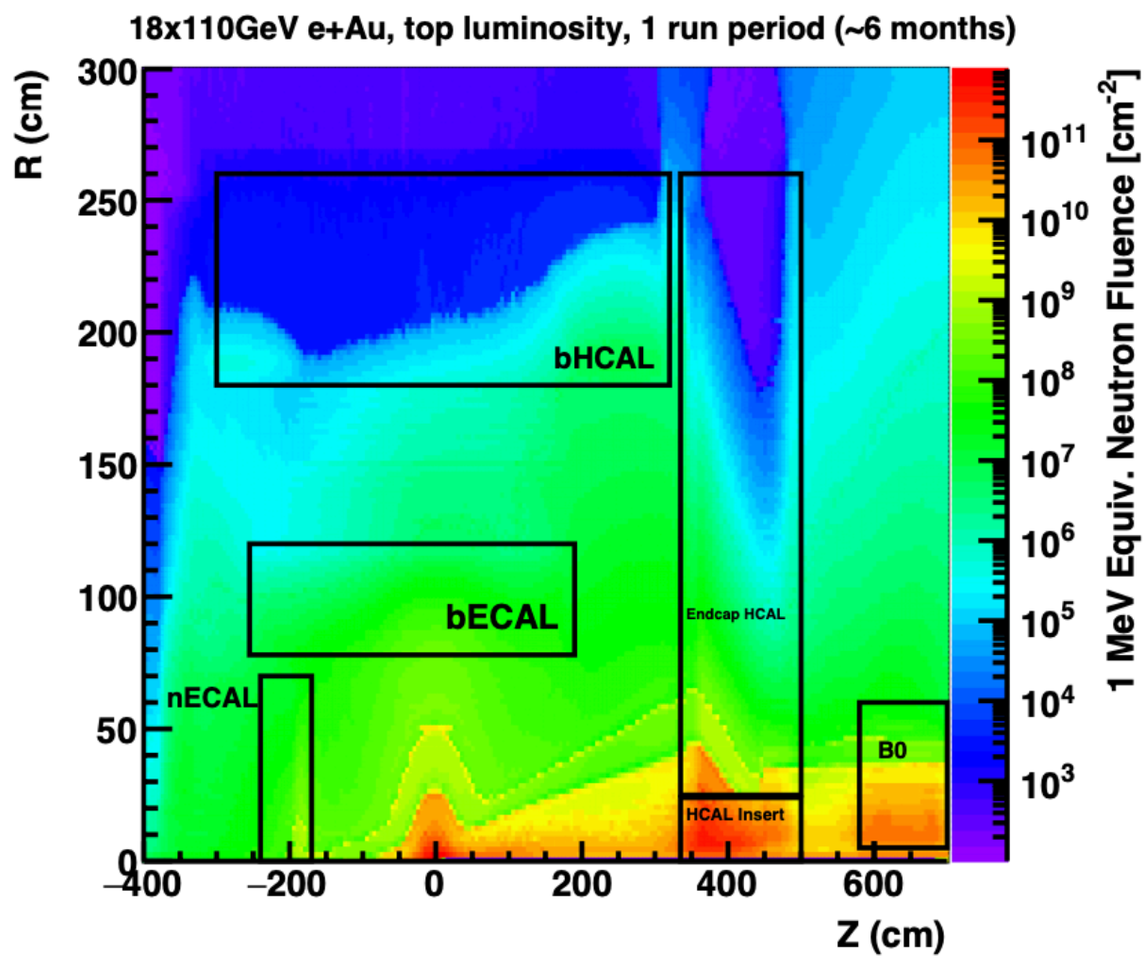


- Simulations done using GEANT3 + GCALOR, validated with measured particle fluxes from STAR.
  - Y. Fisyak et al., NIM A 756, pg. 68-72 (2014)
- Radiation doses from gamma and charged particles fairly low across most of ePIC.
- Regions of highest dose near the beam line - can reach ~ 100 kRad.

See more details here

Neutron Fluence (min-bias, no beam gas)





- 1 MeV equivalent neutron fluence highest near the beamline -> implications for SiPMs.
- Far-Forward and Far-Backward still under study.
- (left) e+p PYTHIA, (right) e+Au BeAGLE.
  - Main difference due to kinematics – medium c.o.m. E produces more mid-rapidity particles.
- These are for min-bias collisions only – beam gas not included here.
  - **Note:** hadron beam+gas rates ~5x lower than min-bias rate (can vary with vacuum quality).

Threshold and timing

Information on the threshold and timing for sub detectors can be found in:
https://docs.google.com/spreadsheets/d/1s8oXj36SqIh7TJeHFH89gQ_ayU1_SVEpWQNkx6sETKs/edit#gid=238482234

EPIC Detector Digitization Model

File Edit View Insert Format Data Tools Extensions Help

Share

A1

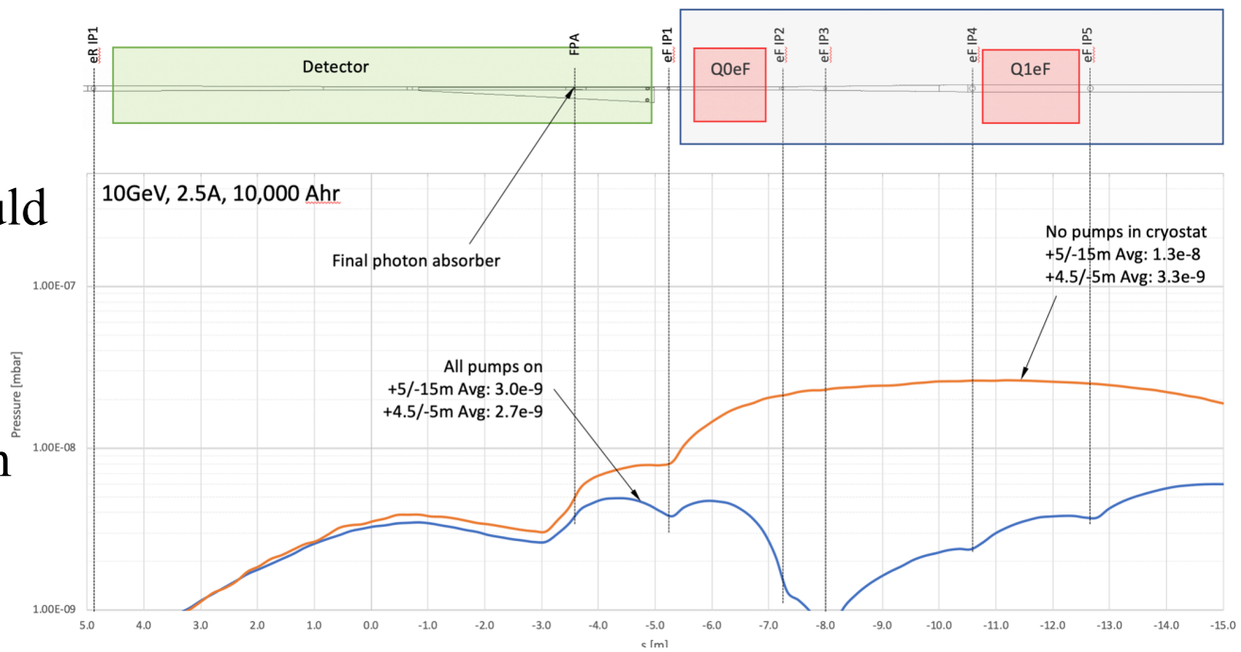
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			**DWG input for the digitization model (More description below line 40; updated on top of the last discussion at https://indico.bnl.gov/event/18156/)** **Please enter column C to R, In particular update to column F-P**											
2						**Analog Features**				**Type (A) Digitizers Gated (eg. ITS 3)**		**Type (B) Digitizers TOA/TOT: (eg. EICROC, ALCOR, HGCROC64)**		
3	**Subsystem**	**Region**	**Channel Count**	**Threshold [keV, MeV or p.e.]**	**Intrinsic/dark noise rate at this threshold [Hz, noise hit per chan per second]**	**Shaping time (FWHM)**	**2 us (target value)**	**Total hit time resolution**	**Charge sharing**	**Gate on time (integration time)**	**Gate off time (deadtime)**	**Time resolution**	**Time bits**	**ADC/TOT bits**
4	**MAPS**	**Barrel**	**17G**	0.65 keV	10^-3 per pixel per second (limit)				1.2 at 90deg	2 us (target value)				
5	**MAPS**	**Disks**	**19G**	0.65 keV	10^-3 per pixel per second (limit)				1.2 at 90deg	2 us (target value)				
6	**MPGD**	**Barrel**	**30k--60k**	~0.25keV	~1	~500 ns	~20 ns	~20 ns	3-5					
7	**LGAD**	**Barrel**	**2.4M**	0.5 keV	30 Hz / channel	5 ns		30 ps	2			10 ps	10	8
8	**LGAD**	**Forward**	**8.9M**	0.5 keV	30 Hz / channel	5 ns		25 ps	2*2 in x*y			10 ps	10	8
9	**pfRICH**	**Backward**	**~70k**	<0.5 p.e.	~100Hz/channel									
10	**mRICH**	**Backward**	**69632**	0.5 p.e.	TBD depending on sensor choices (as dRICH)									
11	**DIRC**	**Barrel**	**74k**	0.2 p.e.	100 Hz/channel									
12	**dRICH**	**Forward**	**320 k**	0.5 p.e.	1-100 kHz / channel									
13	**EEMC**	**Backward**	**3000**	5000 keV	probably 0	100 ns	few ns	few ns	yes			100ps	TOA = 25ps TOT = 50ps	TOA = 10 TOT =12
14	**SciGlass**	**Barrel**												
15	**AstroPix**	**Barrel**	**510M pixels (3.54E+05 chips)**	15 keV	0	1 us			1 (maybe consider 1-2)	< 6 us		<50 ns		12 bit

[latest] Digitization model | [old] leading-order approximation for Digitization | Explore

- The spreadsheet shows the details about the threshold, analog features, digitizer type, and more for all sub detectors;
- The hit rates for sub detectors from all background sources must apply the specific threshold and timing in the speardsheet;

Hadron Beam-Gas interactions

- We use Charles Hetzel's vacuum simulation after 10000Ahr (All pumps on, a few years running at $10^{34}cm^2s^{-1}$);
- The option for vacuum we used is optimistic, we would study the background using conservative option;
- -5.5m < s <5m beam gas is considered;
- Hadron beam gas events (p + $H^2_{rest\ gas}$ interactions) produced by Pythia8 including beam effects, stored in HepMc3 files, Au gas events will be investigated;
- We used dd4hep simulation in ePIC to get the hits information in all sub-detectors;

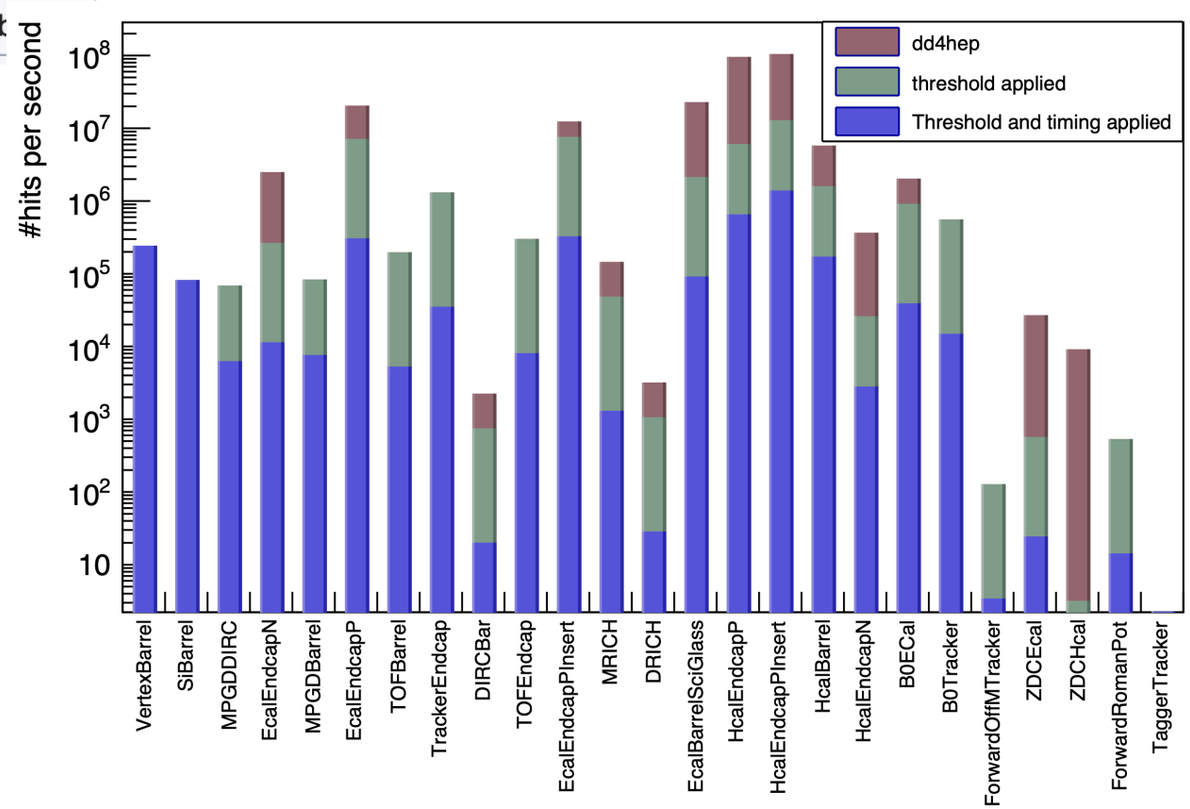


cross-section in nb	5x41 GeV	5x100 GeV	10x100 GeV	10x275 GeV	18x275 GeV
DIS ep	28.5ub	35ub	41ub	50ub	54ub
hadron beam (p) gas	77.3mb	76.8mb	76.8mb	78.5mb	78.5mb

rates in kHz	5x41 GeV	5x100 GeV	10x100 GeV	10x275 GeV	18x275 GeV
DIS ep	12.5 kHz	129 kHz	184 kHz	500 kHz	83 kHz
hadron beam gas	12.2kHz	22.0kHz	31.9kHz	32.6kHz	22.5kHz

- HepMC3 fiels for background events can be found in the directories on S3: **S3/eictest/EPIC/EVGEN/BACKGROUNDS/**
- The hit rates for all sub detectors - including data directly from dd4hep and cases with threshold and timing applied - presented in a figure on the right;

See more details here

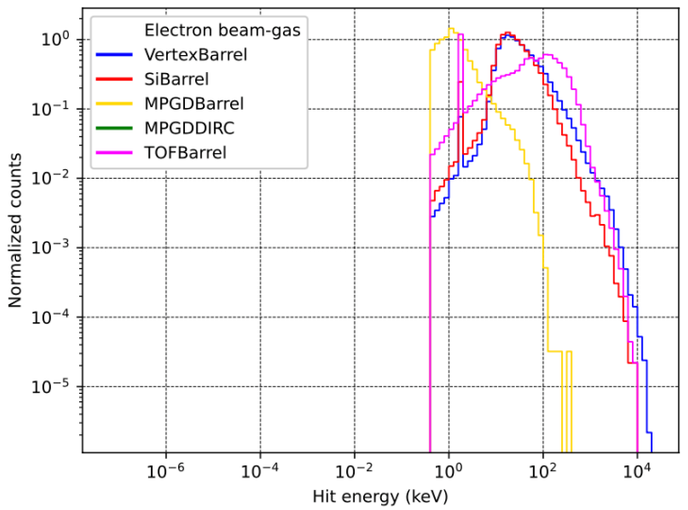


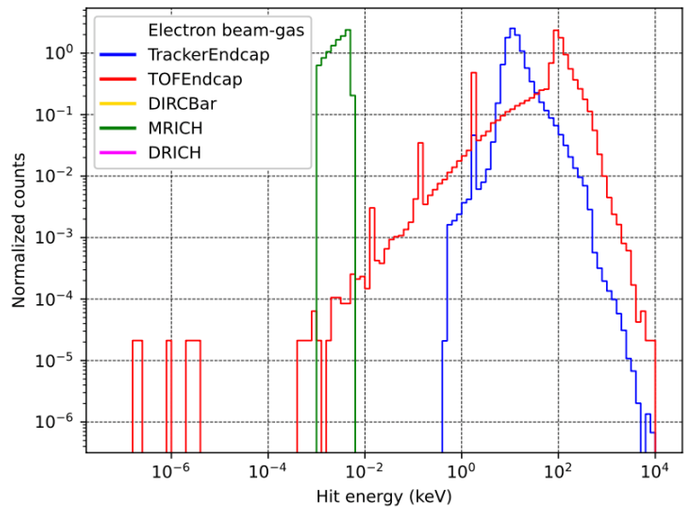
Study by Zhengqiao Zhang

Electron Beam-Gas interactions

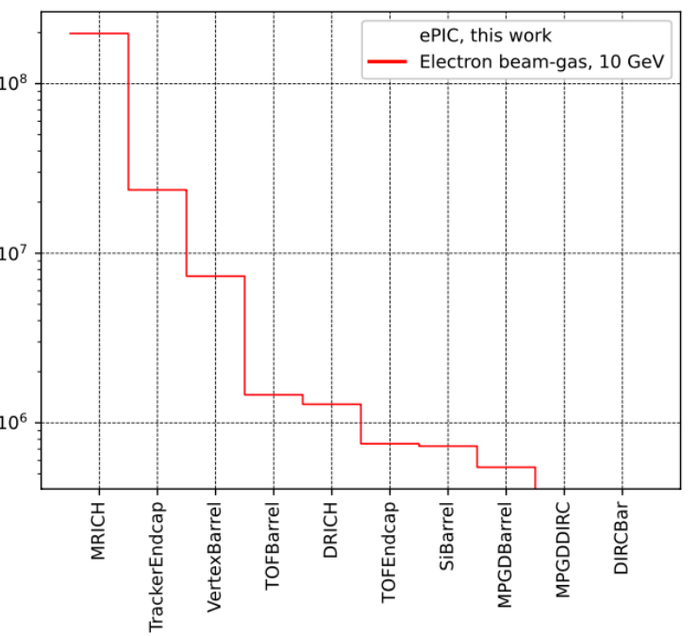
Study by Jaroslav Adam and Jakub Češka

rates in kHz	5x41 GeV	5x100 GeV	10x100 GeV	10x275 GeV	18x275 GeV
DIS ep	12.5 kHz	129 kHz	184 kHz	500 kHz	83 kHz
hadron beam gas	12.2kHz	22.0kHz	31.9kHz	32.6kHz	22.5kHz
electron beam gas	kHz	kHz	3177.25 kHz	3177.25 kHz	kHz

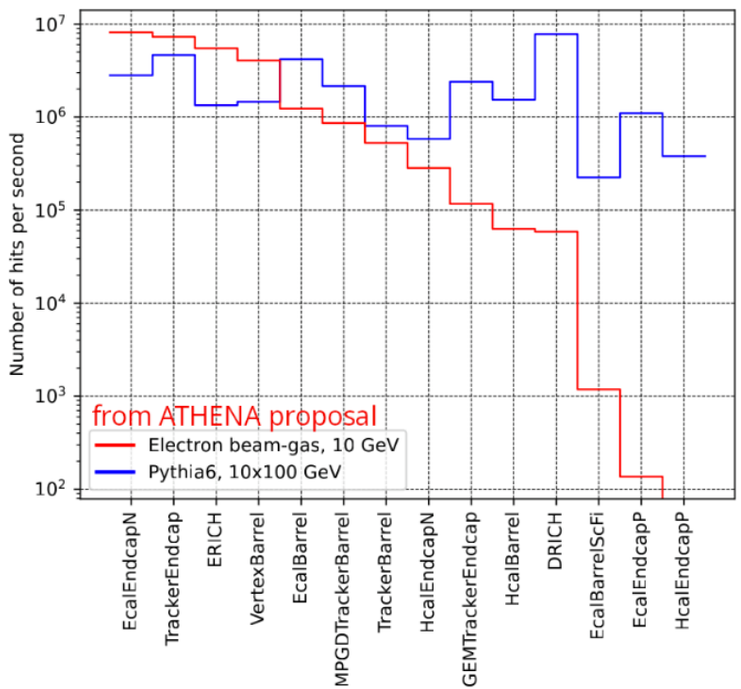




ePIC, this work



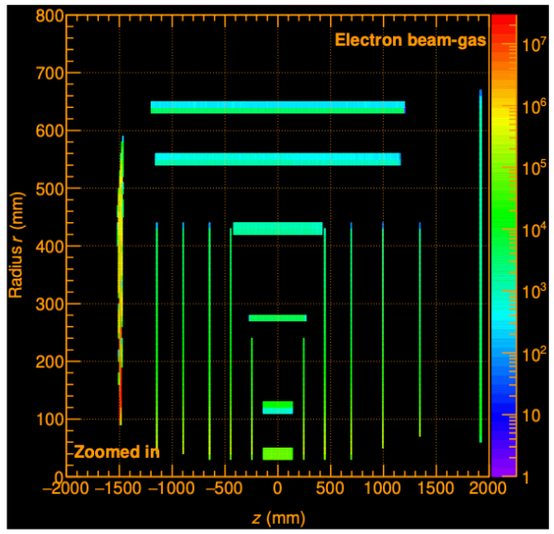
from ATHENA proposal

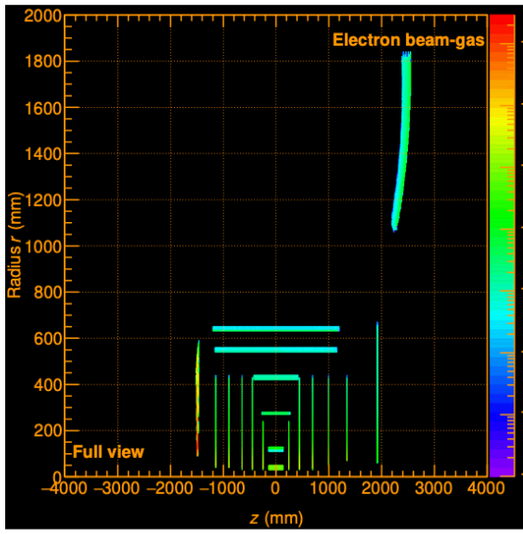


- Main contribution to detector background are from Bethe-Heitler process:

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

- Vacuum after 10000Ahr (All pumps on);
- The rate of electron beam gas is much higher;
- Off-momentum electrons will be shielded by collimators (detailed simulations of collimation system are underway);
- Threshold based on Athena, we are updating the results using ePIC threshold and timing;





See more details here

Synchrotron Radiation

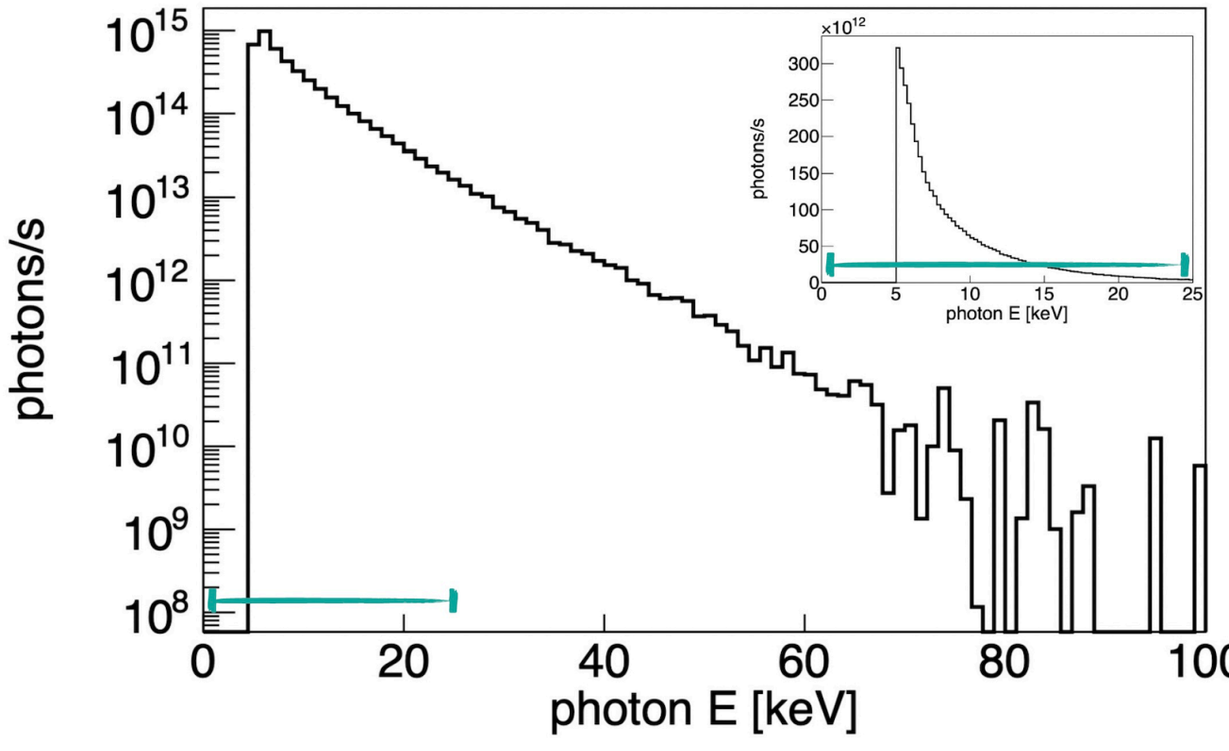
Study by Reynier Cruz-Torres
and Daniel Sterwerf

Caused by quads and bending magnet upstream of IP;

Simulations based on Synrad+ (by M. Stutzman)

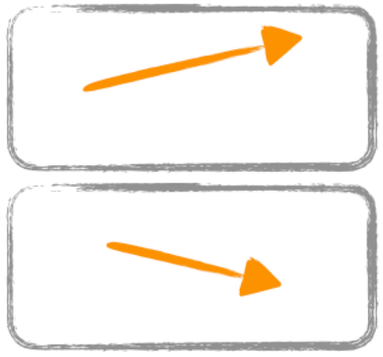
- virtual cylinder placed just inside the IR beampipe
- Electrons are propagated through B field
- resulting photons passing through cylinder are recorde

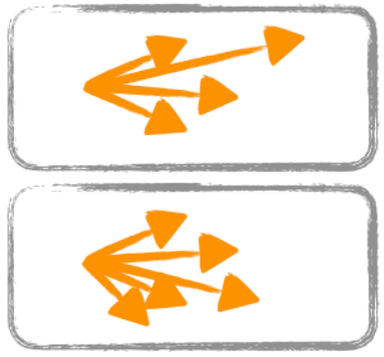
Output: hepmc file with single-photon “events” containin information related to photon vertex, momentum, and weight corresponding to equivalent photons / sec;



Have

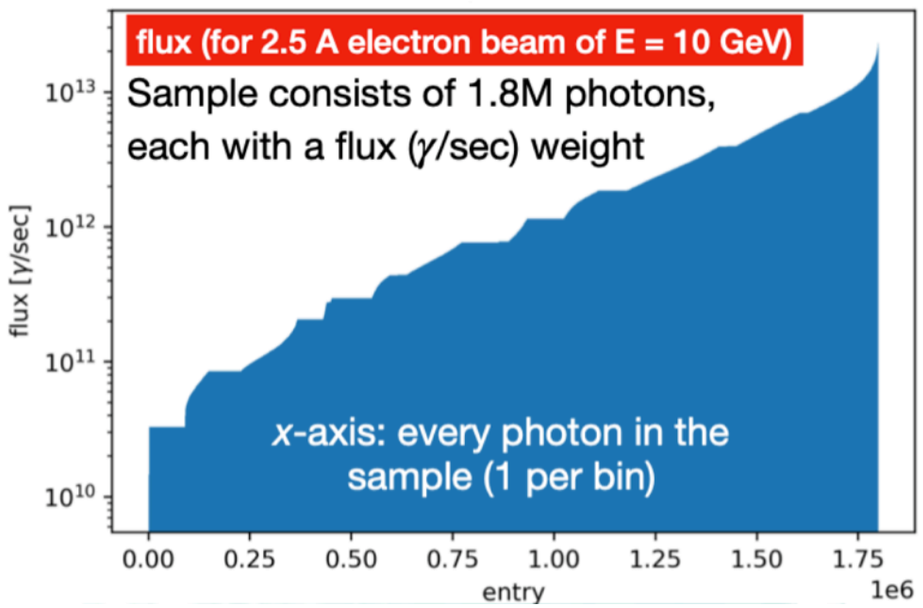
A series of single-photon events from a Synrad+ simulation.





Need

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



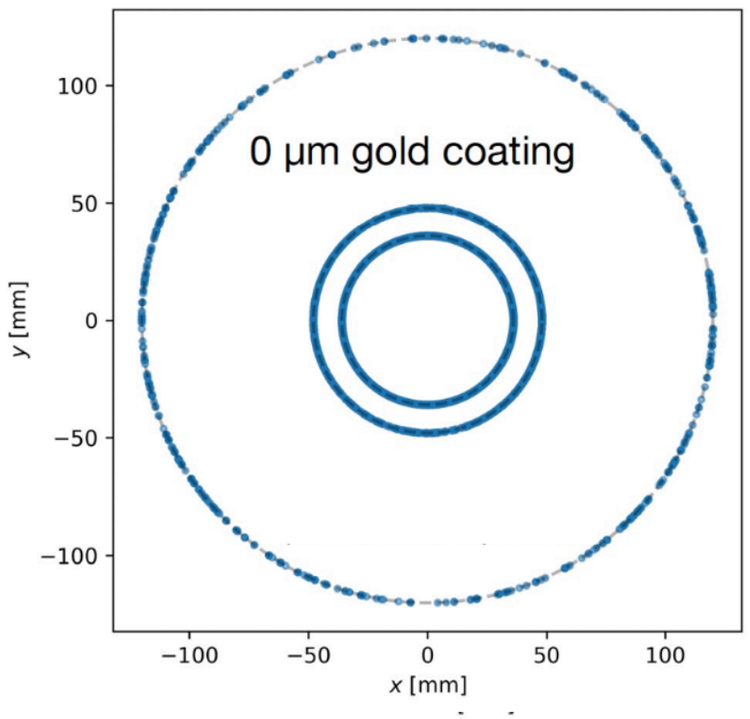
Define an integration window (IW)

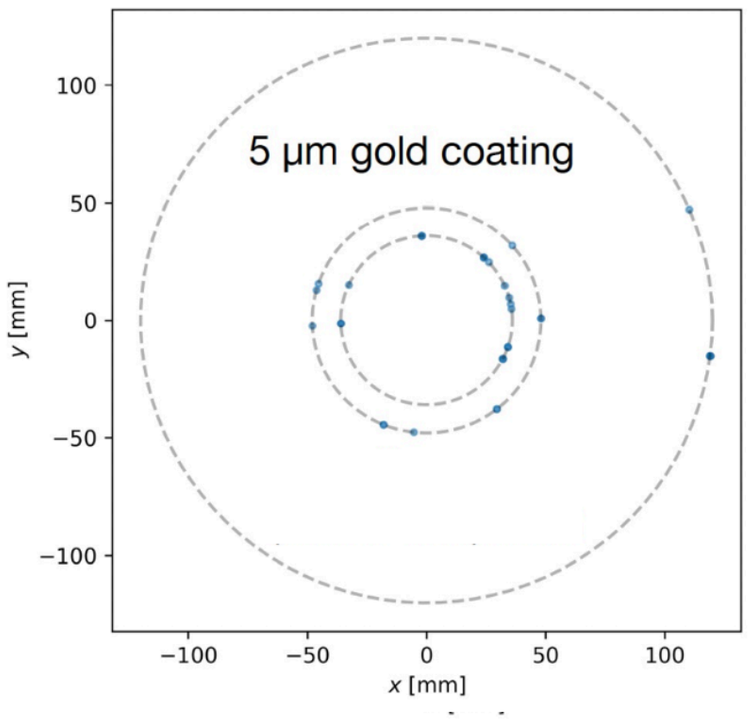
```
integral = 0
while integral < IW:
    Randomly sample photon, add it to event
    integral += 1/flux
return event
```

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

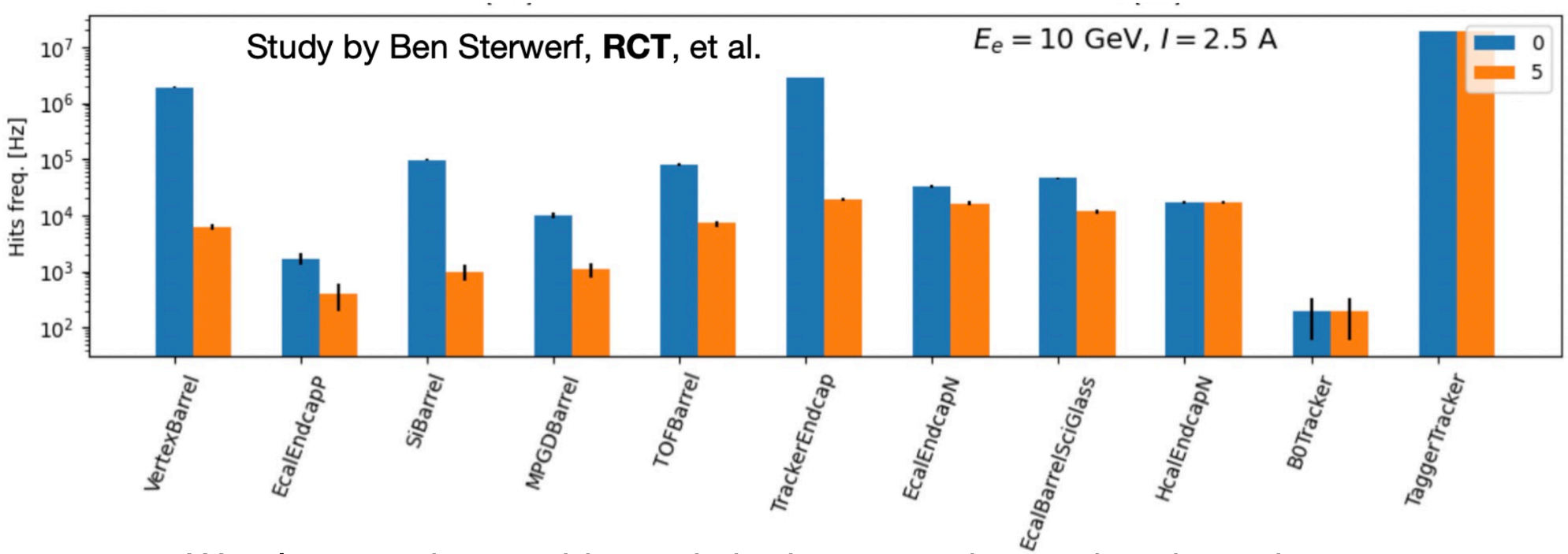
Synchrotron Radiation Results

- The gold coating reduces the expected hits in these layers by two orders of magnitude;





See more details here



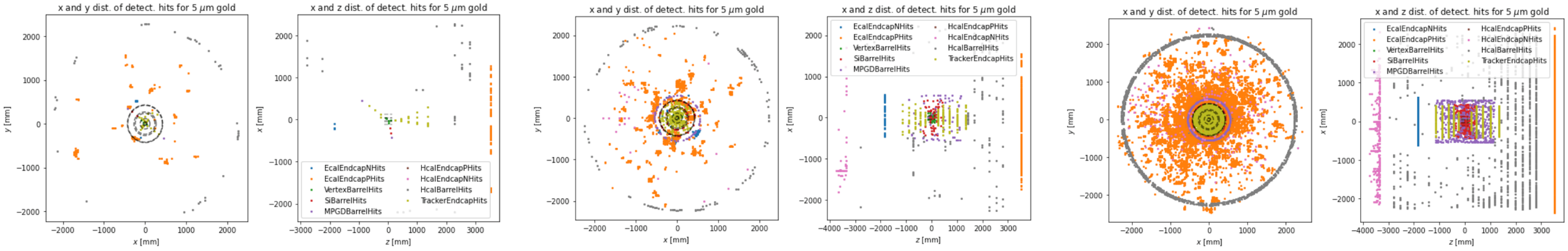
- We plan to enhance this study by incorporating updated synchrotron radiation input from the machine group this summer.

Software status

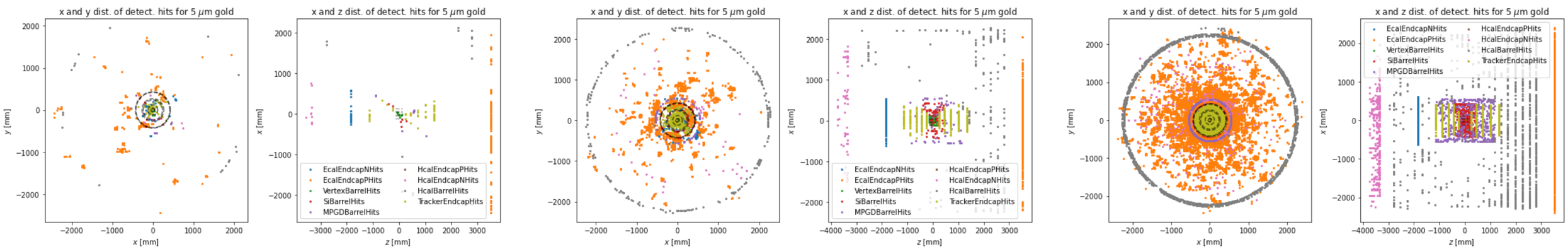
- Benjamen Sterwerf is analyzing Kolja Kauder's merged file, with some preliminary results below;
- Kolja is refining the file for better memory usage;
- Delay software threshold application until June due to its complexity, and won't integrate timing info into EicRecon until the current pull request is incorporated.
- Currently, Kolja is testing the 'worst case' file through dd4hep, aiding tracking algorithm and troubleshooting;

1 Event | 10 Events | 100 Events

Pure signal



Signal & Background



- Average Run Time Per combination Event: 11.06 seconds/event
- Files include the following background sources: Beam gas and synchrotron radiation

Summary

- Several background sources have been identified and studied, background task force has been formed;
- Most background studies have been updated with newest ePIC detector version;
- Largest background source expected to be electron beam-gas interactions;
- Functionality to combine HepMC events of backgrounds and signal has been done;
- Our current focus is on analyzing the detector occupancy;
- We plan to incorporate a new vacuum input for our study;
- We will examine the background's impact on detector performance and physics, particularly its effect on track reconstruction;
- Realistic track reconstruction is underway;

Wiki page for ePIC background:
https://wiki.bnl.gov/EPIC/index.php?title=Background

Indico for background taskforce meeting: **https://indico.bnl.gov/category/461/**
Email-list: **eic-projdet-background-l@lists.bnl.gov**