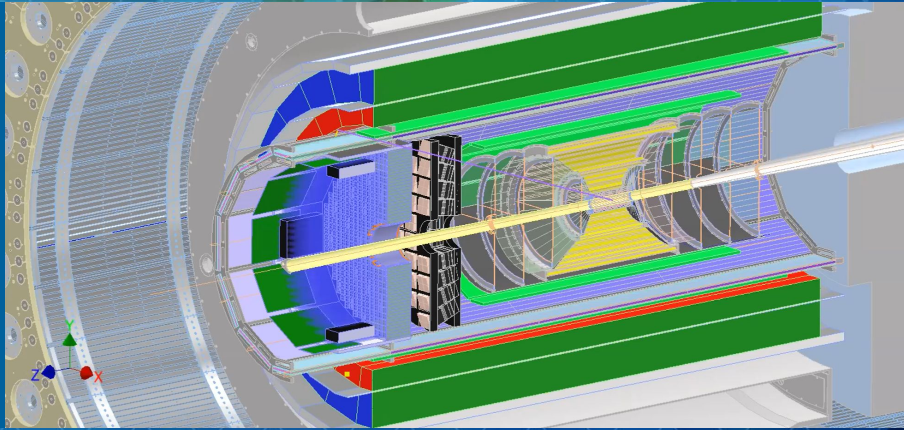
BIC Simulation Meeting

AstroPix Occupancy



Tommy Tsang, Maria Żurek

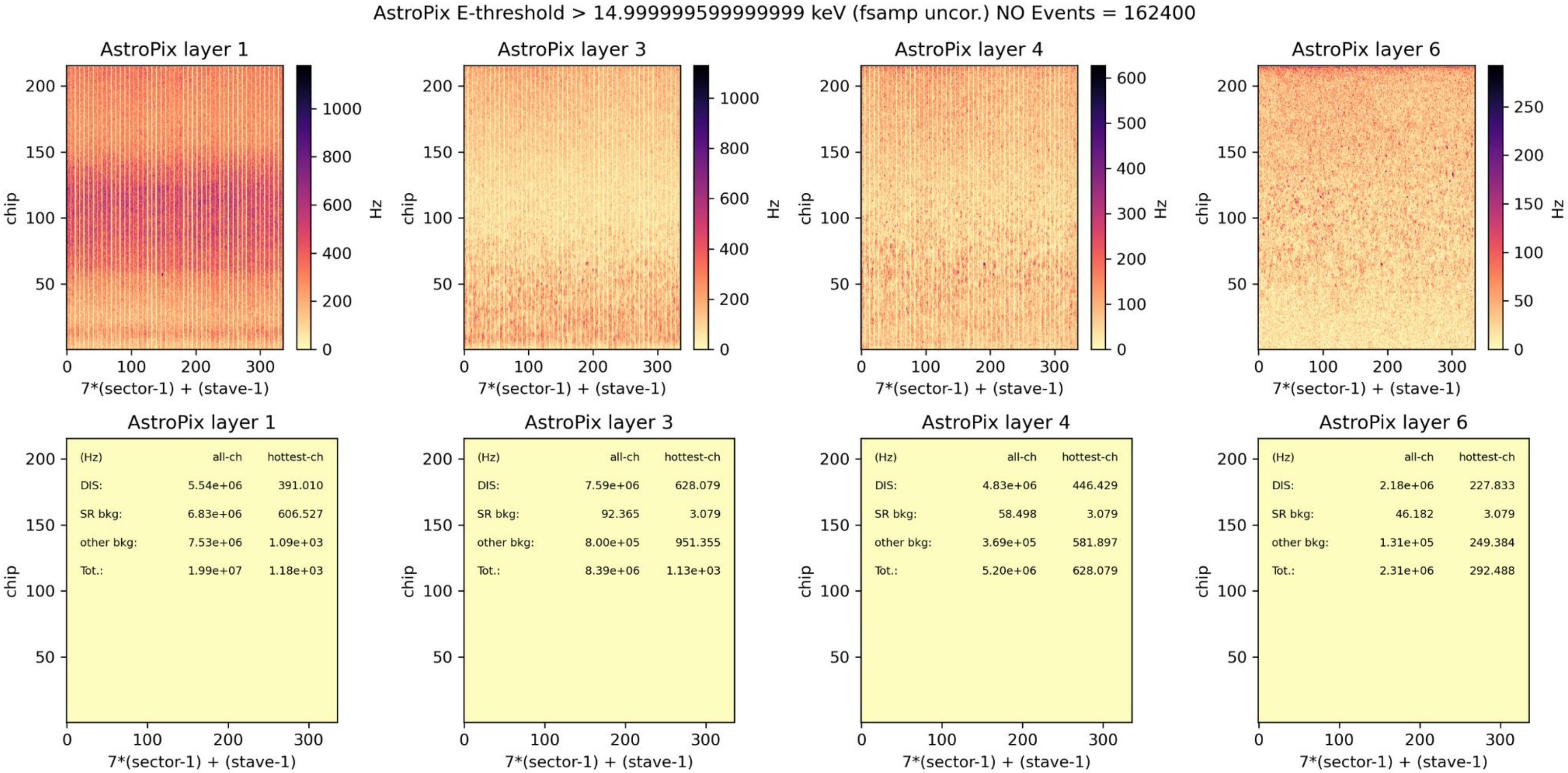
Samples used

1. To study the expected occupancies on the AstroPix layers we used the samples recommended by TIC in the charge related to the background studies: https://indico.bnl.gov/event/31599/contributions/120324/attachments/68421/117639/TIC_20260223.pdf

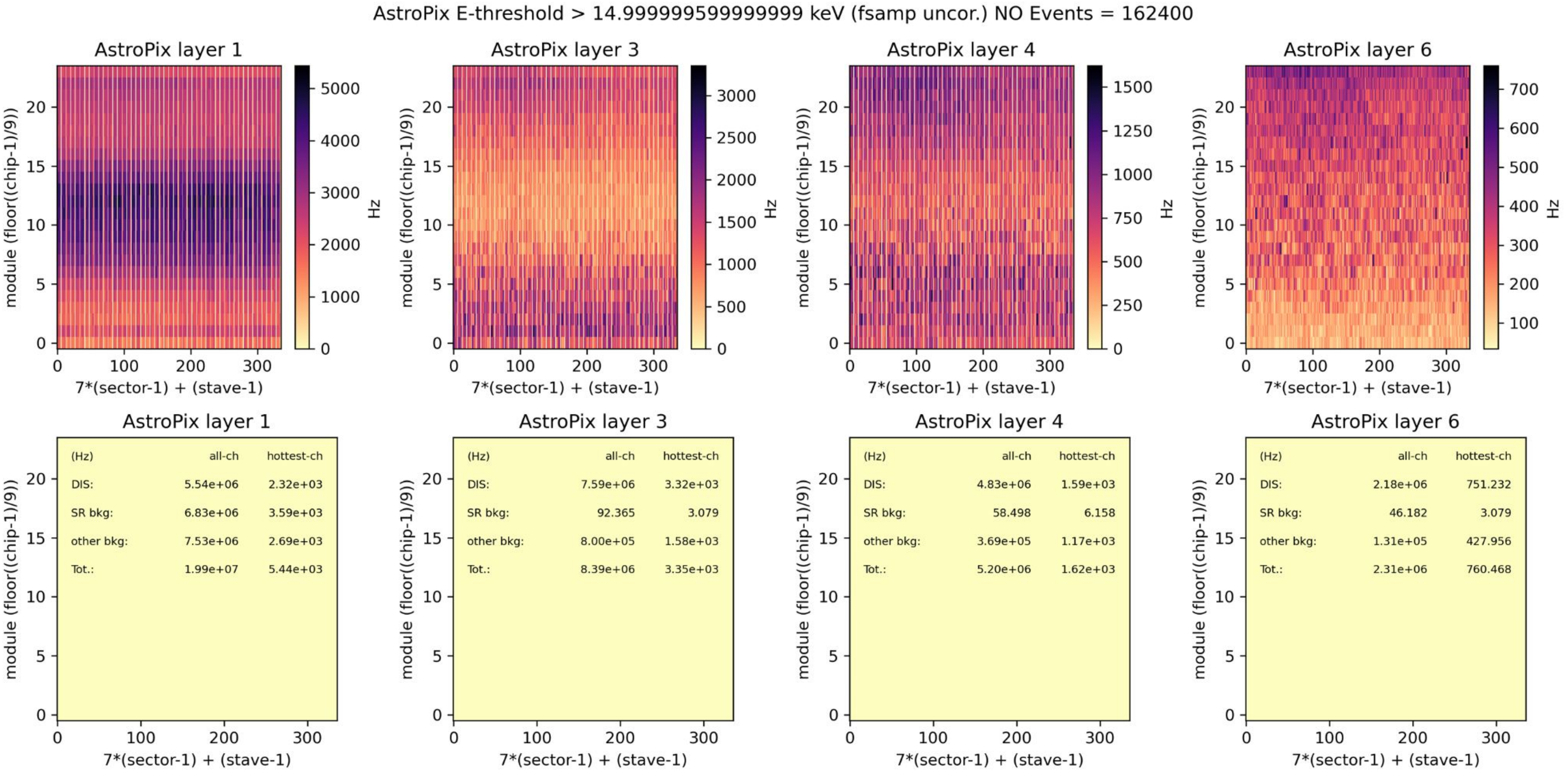
2. Files used: root://dtneic.jlab.org//volatile/eic/EPIC/FULL/26.02.0/epic_craterlake/Bkg_Exact1S_2us/GoldCt/10um/DIS/NC/10x100/minQ2=1/
   a. Each even has a DIS event with 2us beam background merged
   b. Note that the used files are with the min Q^2=1 GeV^2, these are not min-bias data, so the rates for signals and background have quite some uncertainty on it
   c. It is not clear when the min-bias samples with merged background will be provided

3. The detailed presentation for AstroPix (and SciFi) rates by Tommy Tsang is available here: https://indico.bnl.gov/event/33107/contributions/125260/attachments/71457/122476/summary_calorimeter_occupancy.pdf

Rates per chip



Rates per module



Max rates per chip/module/stave

We assume < 1 Hz/chip

Readout Element	Max Hit Rate / Readout Element (Physics) (Hz)	Max Hit Rate / Readout Element (SR) (Hz)	Max Hit Rate / Readout Element (Other Backgrounds) (Hz)	Expected Noise Hit Rate / Readout Element (Hz)	Max Hit Rate (All Sources) (Hz / Readout Element)	Avg Hit Rate / Readout Element (Hz)
Chip	628	606	1090		1180	138.117284
Module	3320	3590	2690		5440	1243.055556
Stave	31700	28800	28900		39600	14916.66667

- **We need to take those numbers with a grain of salt (see slide 2)**
- **What factor margin can we reasonably take (question/discussion)**
- **Our old (extreme case estimate) was ~ 900 kHz (factor ~20)**

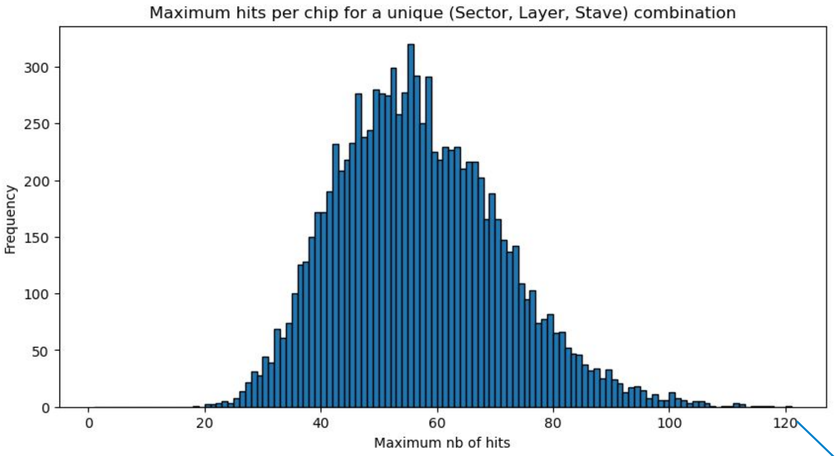
Backup

Max nb of hits per chip form a single shower

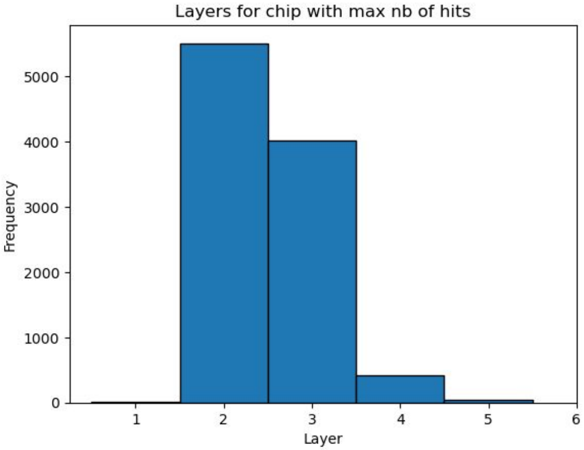
Those hits will be seen in a chip at the same moment
Case studies: photon at η = 0 (18 GeV), e at η = -1.4 (18 GeV)

e at η = -1.4 (18 GeV)

Max nb of pixels fired per chip



Layer where it happens



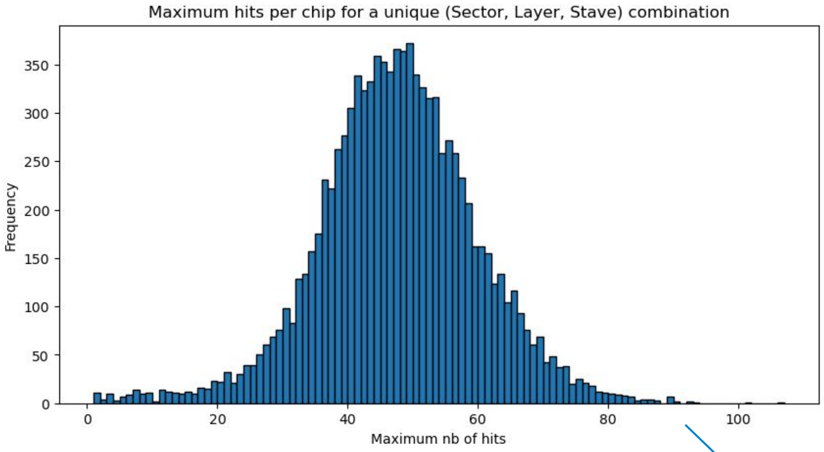
up to 120 hits

Max nb of hits per chip form a single shower

Those hits will be seen in a chip at the same moment
Case studies: photon at η = 0 (18 GeV), e at η = -1.4 (18 GeV), e at η = 1.25 (18 GeV)

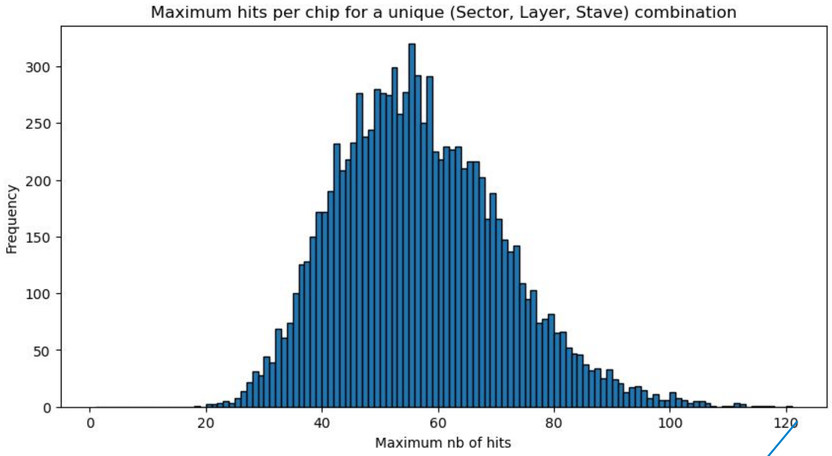
photon at η = 0 (18 GeV)

Max nb of pixels fired per chip



e at η = -1.4 (18 GeV)

Max nb of pixels fired per chip



up to ~90 hits

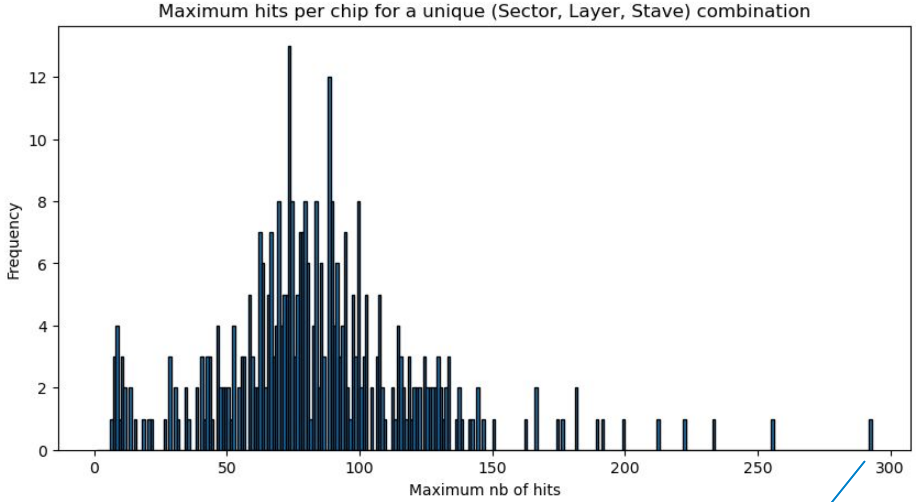
up to 120 hits

Max nb of hits per chip form a single shower (4 layers)

Those hits will be seen in a chip at the same moment
Case studies: photon at η = 0 (18 GeV), e at η = -1.4 (18 GeV), e at η = 1.25 (18 GeV)

Pythia, DIS NC, 18x275, Q2 > 1000

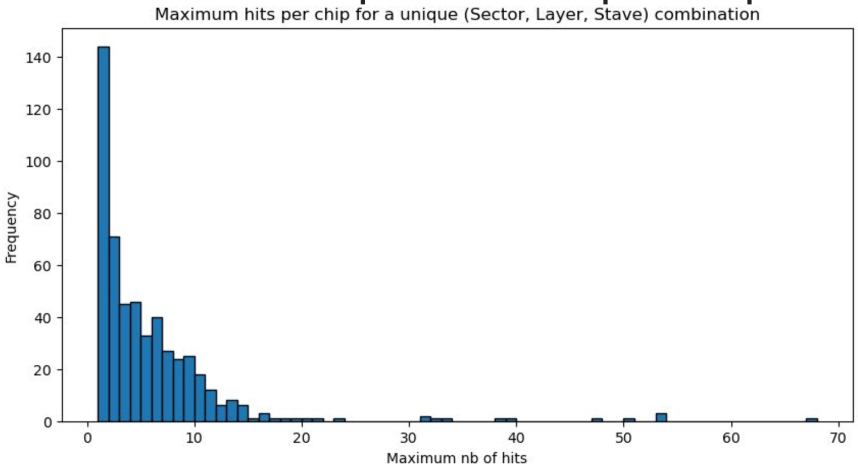
Max nb of pixels fired per chip



up to ~300 hits (extreme)

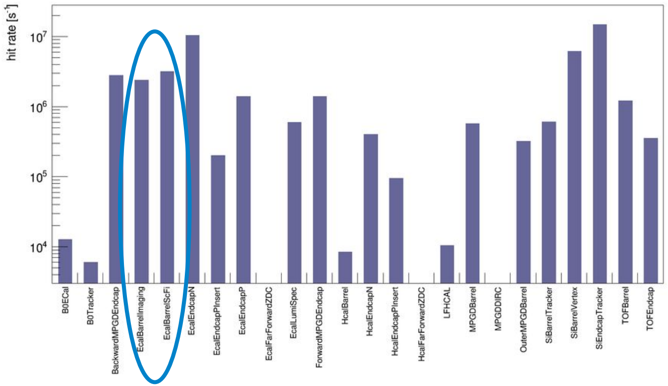
Pythia, DIS NC, 18x275, Q2 > 1

Max nb of pixels fired per chip

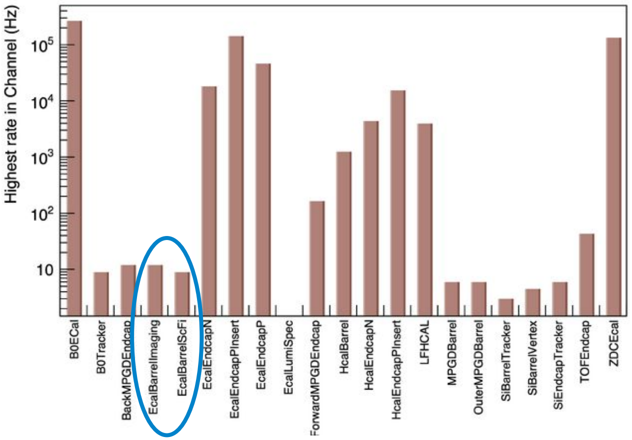


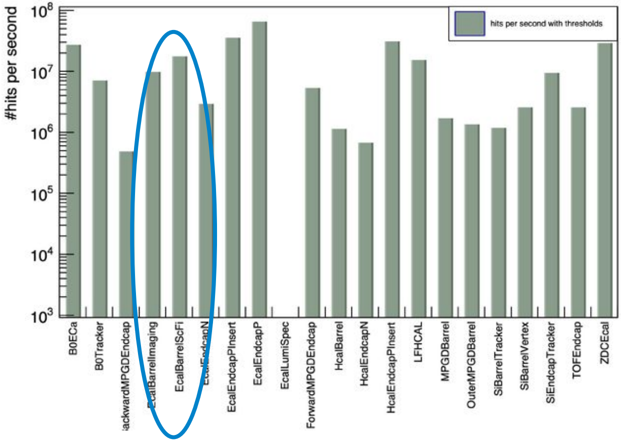
Expected Rates - Backgrounds

https://wiki.bnl.gov/EPIC/index.php?title=Hadron_Beam_Gas



Electron beam background
10 x 100 GeV

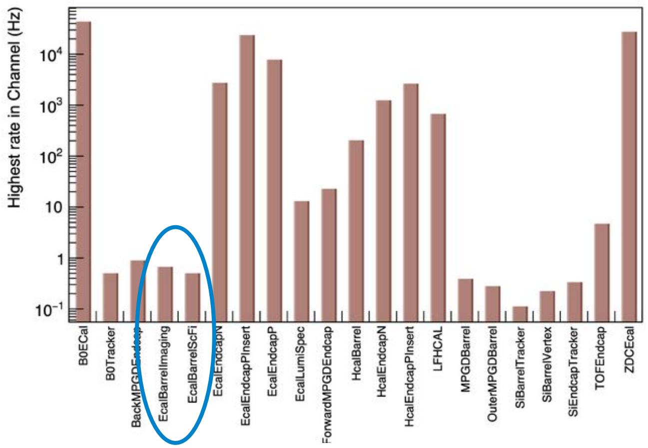


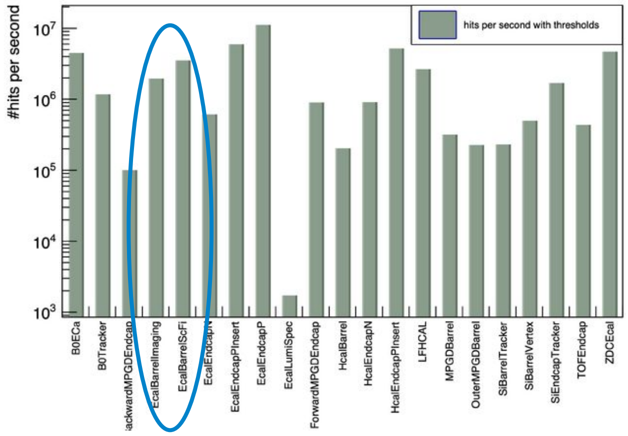


Hadron beam background
10 x 100 GeV

Expected Rates - Pythia

https://wiki.bnl.gov/EPIC/index.php?title=Hadron_Beam_Gas





- Dataset for electron-proton (ep) DIS with 18X275GeV, where $0<Q^2<1$
- The luminosity of the data set is 1.54×10^{33} cm^2s^{-1}
- The collision rate for this ep DIS 18x275GeV is 83 kHz

Total: Max pixel rate < 21 Hz
We could assume 21 Hz with 300 hits (per chip)? (very upper limit)

Old estimate

with 36 kHz per stave with 25 hits/stave

Daisy-chain throughput does not lead to dropped hits: method

Specs:

- One silicon stave is 108 Astropix sensors daisy-chained together, which measures 2 cm x 216 cm (one chip x half calorimeter length).
- Each Astropix sensor has 1360 pixels. The on-chip buffer has the same size as the number of pixels.
- It takes ~ 1 μs to push a hit from the Astropix chip to the periphery. The hit will go onto the hit buffer of the adjacent chip, taking 1 μs hops until it reaches the data aggregator at the end of the chain

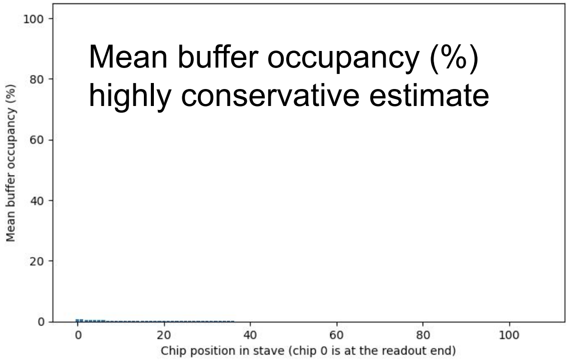
Question: *Is there any risk for dropped hits due to traffic jams in the daisy chain?*

Method:

- Simulate the daisy chain for an *absurdly* high upper limit to show there are no issues (we do not have holistic full background+physics simulations available right now). If it works in this upper limit it will not be an issue for realistic operation.
  - Overestimate 1: The expected hit rate for all imaging layers together is well below < 3×10^7 Hz based on physics + background simulations done with an energy threshold of 0.4keV (correct threshold is 20keV so likely 1 or more orders of magnitude too large).
  - Overestimate 2: This corresponds to a raw hit rate of <36kHz per stave (high occupancy staves), let's assume this is not the *hit* rate but rather the *event* rate.
  - Overestimate 3: Let's assume every one of these events is a highest occupancy event (max occupancy/stave is <25hits/stave, which we found in the Pythia8 NC Q^2 > 1000 GeV^2 samples).
  - **Hence: highly conservative (unrealistically high) upper limit would be an event rate of 36kHz per stave with a multiplicity of 25 hits/stave.** This is what we simulated.*

* Note that the numbers we are simulating corresponds to a hit rate of 900kHz per stave, which is a dramatic overestimate.

Daisy-chain throughput does not lead to dropped hits: Results



Highly conservative (unrealistically high) upper limit would be an event rate of 36kHz per stave with a multiplicity of 25 hits/stave. This corresponds to assuming every hit is really an outlier high-multiplicity event. This is what we simulated.

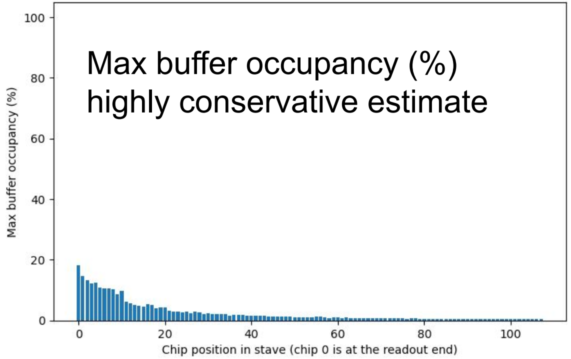
We ran the simulation until the results stabilized.

The mean buffer occupancy is very low.

The maximum buffer occupancy (highest-seen buffer usage for each of the chips) increases as we go towards the readout end of the daisy chain.

In this upper limit scenario, we never exceeded 20% buffer occupancy and **never dropped a hit**.

Realistic estimates will be orders of magnitude lower.



eRD115 - Barrel EM Calorimeter

- First year of R&D which combines Pb/Scifi technology with a high-precision position detector(Astropix).
- Despite many problems (funding, test beam) FY24 R&D progressing very well.
- Successful integration of Astropix and BabyCal has been achieved on the readout side adding one Astropix board to the DAQ stream in the first phase, and two boards in parallel in the second phase.
- Not all tasks completed - integration of BabyCal and Astropix with the short Pb/Scifi sections (SFils): fundamental to clarify needs for final detector configuration (#position sectors, π/e, π^0/γ disc.)

- First results from latest test beam at FTBF but not enough details on π/e, π^0/γ separation.
- Did not see results on BabyCal energy resolution and response from ANL 2023 test beam.
- No assessment of the efficiencies of the AstroPix ASICs shown.
- In general the AstroPix development may need further scrutiny.

- We commend the team for the work done since summer 2023, and we provide our full support for an extension of the R&D period to FY 2025. (Not clear if this should be supported by R&D or PED?)
- Extend the R&D to horizontal arrangements of AstroPix to mimic better the situation in the experiment. Check reproducibility of layer production.
- Carry out tests on the efficiency of the AstroPix ASIC with the multilayer setup.
- Confront early AstroPix performance with specs.
- Data-simulation comparison should still be completed. Similarly, linearity tests should be carried out to decide an eventual selection of other SiPM models.
- Keep working on detector mechanical integration and cooling., and robust procedures for detector construction.