# Simulation towards ECCE proposal

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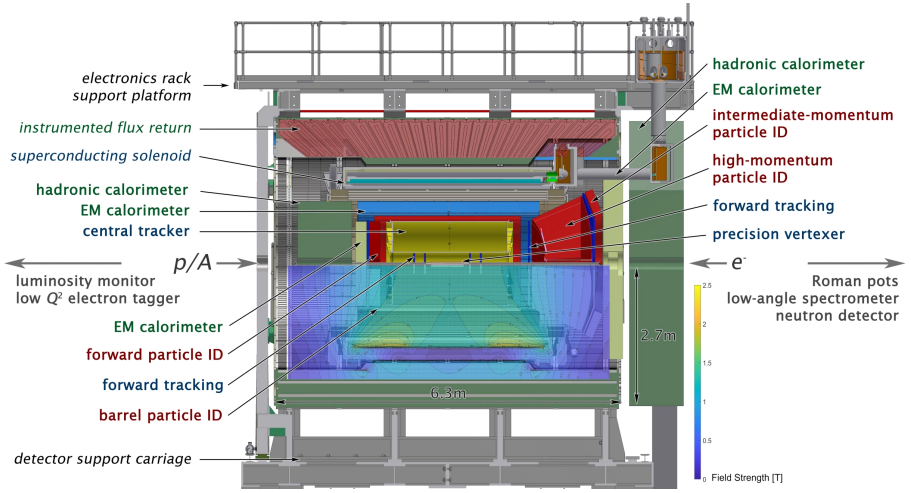
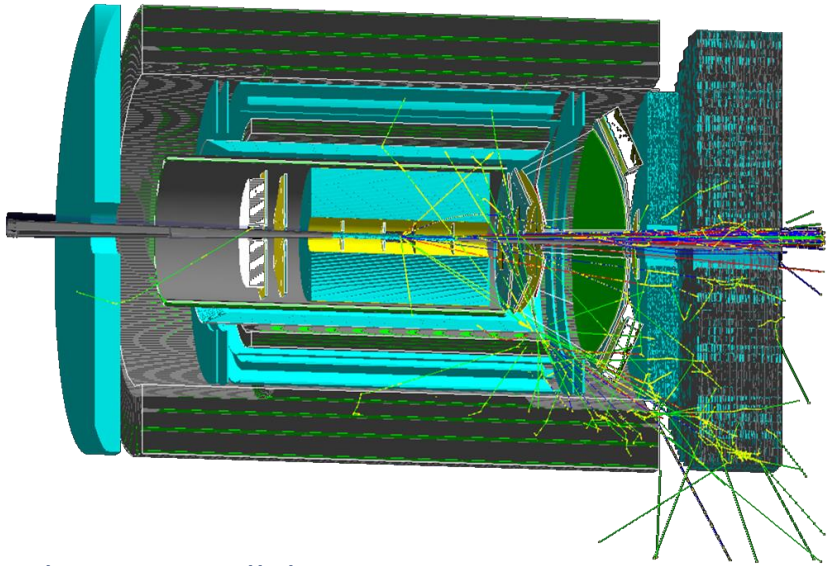
# ECCE simulation

## Concept from detector team
(an example with 1.5T magnet shown here)



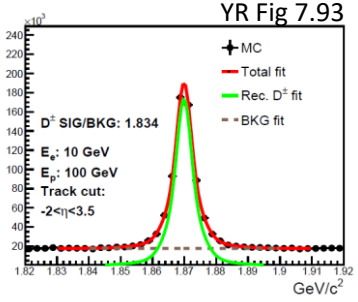

## Fun4All sim. and reconstruction

Yellow Report (YR) Fig 11.65

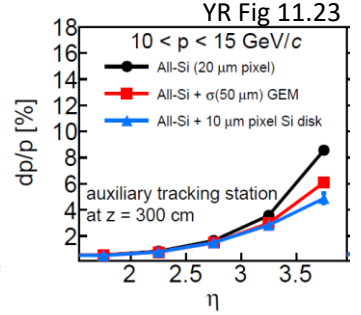


## Validating performance

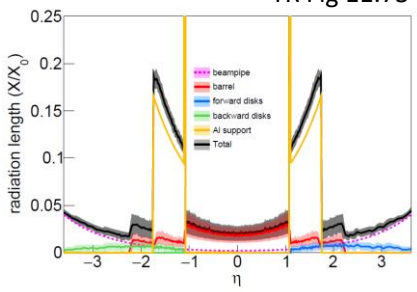
YR Fig 7.93



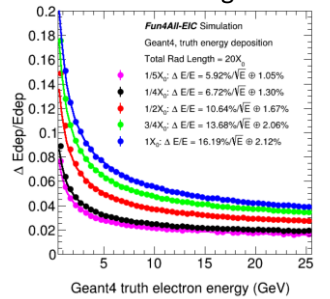

YR Fig 11.23



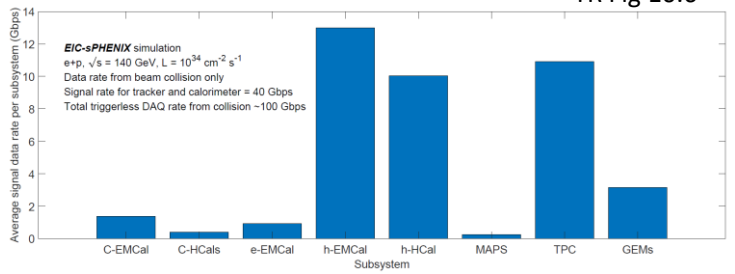

YR Fig 11.73




YR Fig 11.55




YR Fig 10.6




- Actual ECCE concept and study to be defined by the proto-collaboration. Figures in this slide are used for illustration purpose
- Fun4All-ECCE framework will be used as the simulation work in proposal stage
- ECCE simulation will be open to new software development/adoption/improvement for use in after the proposal stage

# Simulation coordination towards proposal

- Time is short
- Full G4 simulation can be time-consuming. Simulation team plan to help WGs plot most direct path for delivering plots in the proposal
- Simulation campaign will be planned around major plot deliverables for the proposal
- Parallelize detector definition and exercise of reco. tools using existing configurations
- For large sample, we will organize coordinated simulation production, making result DST files available to analyzers

- Dec 1st : proposal submission
- Nov 1st: final proposal for editing
- Sept 1st : all major simulation plot done. After this date, we just do polishing, composing narratives around the figures in the performance chapter of the proposal.
- Aug 1st : Final simulation production done
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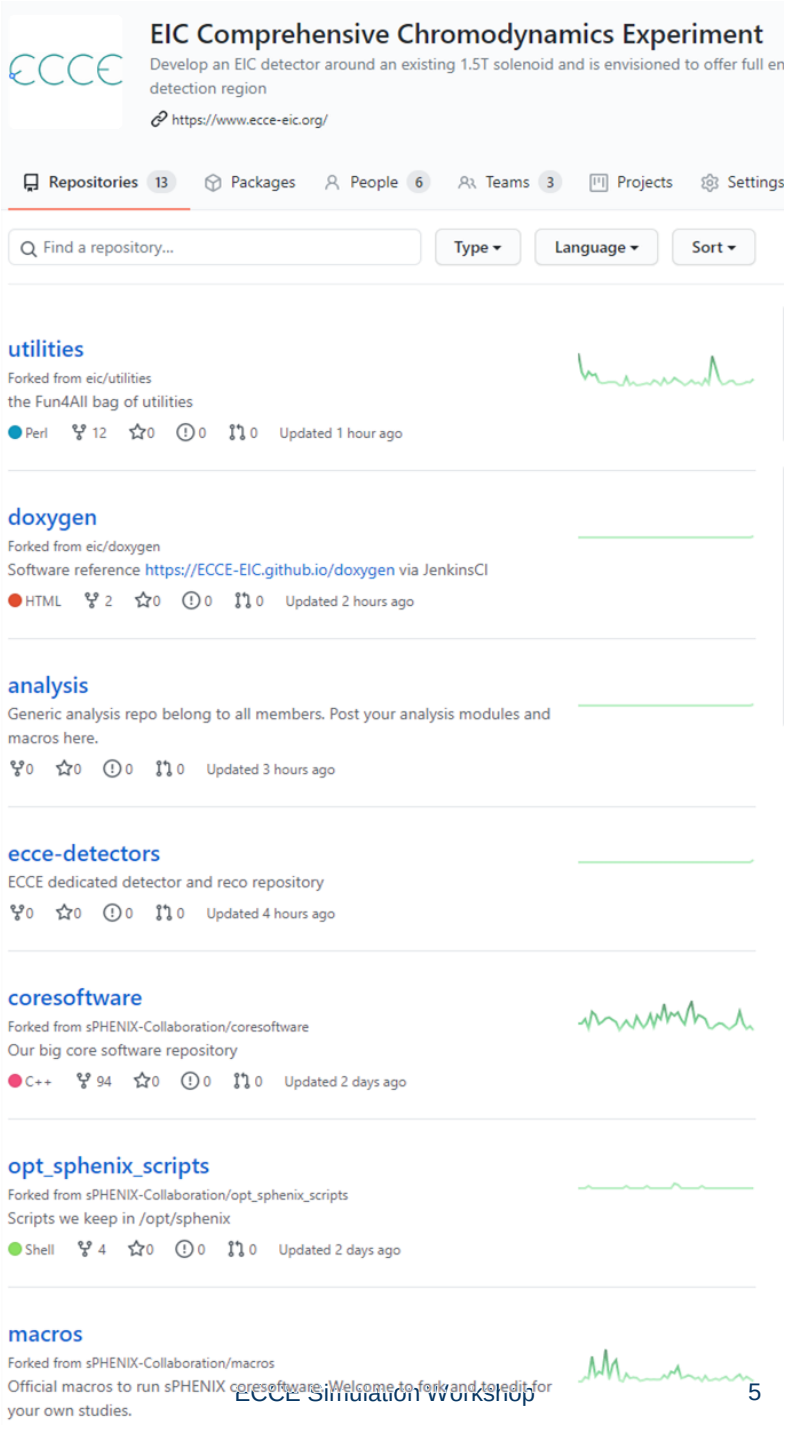
- May 1st: First simulation campaign, followed by first round of analysis. From May – July, many studies probably need another iteration of simulation-analysis to advance detector design.
- Entire Apr: develop simulation setup to run.
- Today: 1st simulation workshop

# Simulation Software Infrastructure

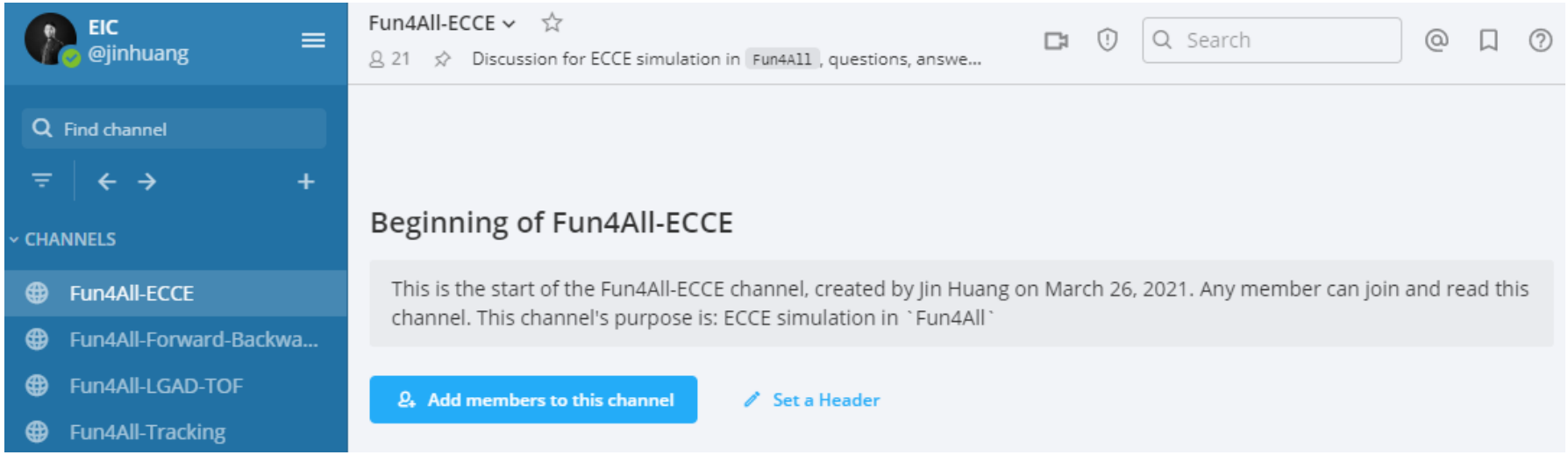
# Simulation Software Infrastructure

- https://github.com/ECCE-EIC/ is born this week!
  - Open-source software repository
  - Independent fork from EICUG and sPHENIX
- Please email your github username to jhuang@bnl.gov
- At the ECCE proposal stage we will avoid detach from sPHENIX core-software
  - Sync fork of Fun4All **core-software to sPHENIX**
  - Will implement CI gateway check before each syncing
- We will build our own detector and analysis on top of the Fun4All core:
  - **ecce-detectors [daily build, require pull request]**:
    G4 detector description, reco. Module
  - **macros [daily build, require pull request]**:
    ECCE detector description and common macros
  - **Analysis [collaboration-wide writable]**:
    Analysis module, macro, notebook



# Simulation Software Infrastructure: chat

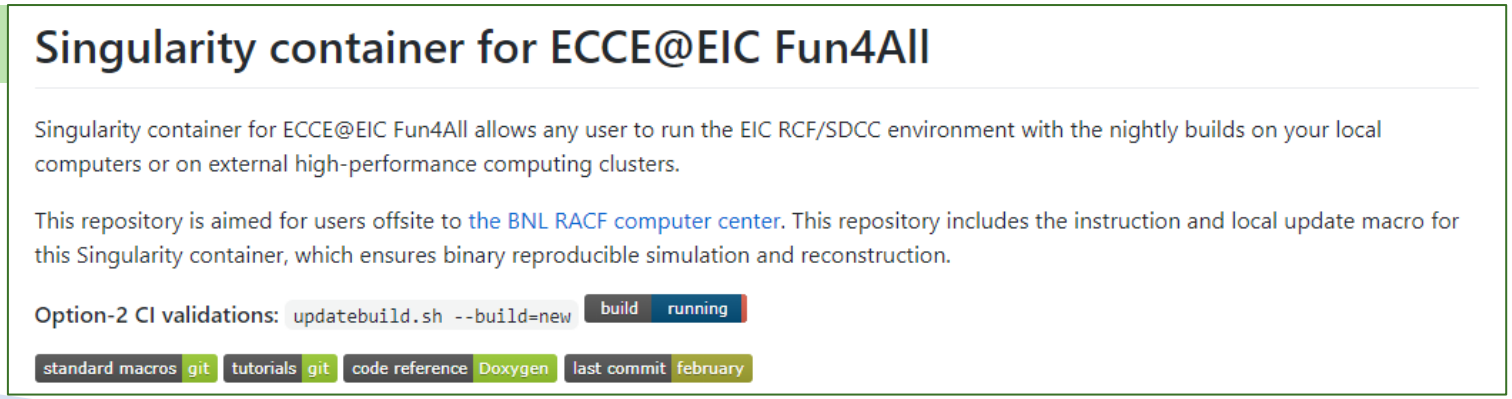
- As we are putting together software stack for ECCE, things will be broken and fixed.
- Don’t hesitate to ask questions!
- Instant chat for help/discussions on ECCE simulations https://chat.sdcc.bnl.gov/eic/channels/fun4all-ecce
- Don’t have BNL SDCC account? No problem: email jhuang@bnl.gov to get an invitation



# Simulation Software Infrastructure

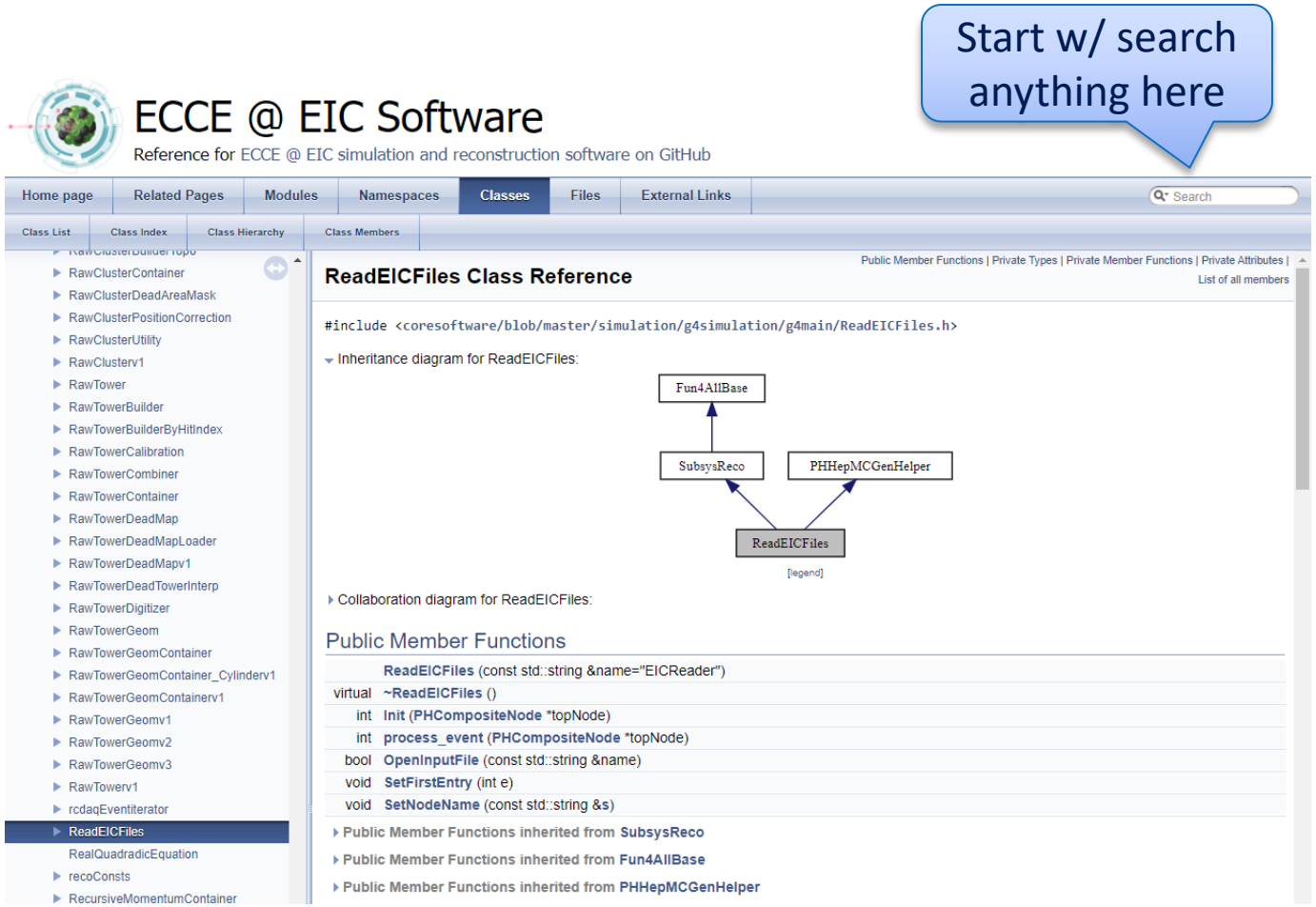
- Daily build of ECCE software and distribute via OpenScienceGrid CVMFS
- In place where sourced eic_setup.sh or sphenix_setup.sh:
  `source /cvmfs/eic.opensciencegrid.org/ecce/gcc-8.3/opt/fun4all/core/bin/ecce_setup.sh -n`
- See talk: Chris Pinkenburg
- Use out of box in major NP/HEP scientific computing centers
- Install in your institution Linux sever or laptop via Linux VM:
  https://github.com/ECCE-EIC/Singularity
- Same container can be used for EIC-Smear fast simulation [talk: Kolja ]

https://github.com/ECCE-EIC/Singularity

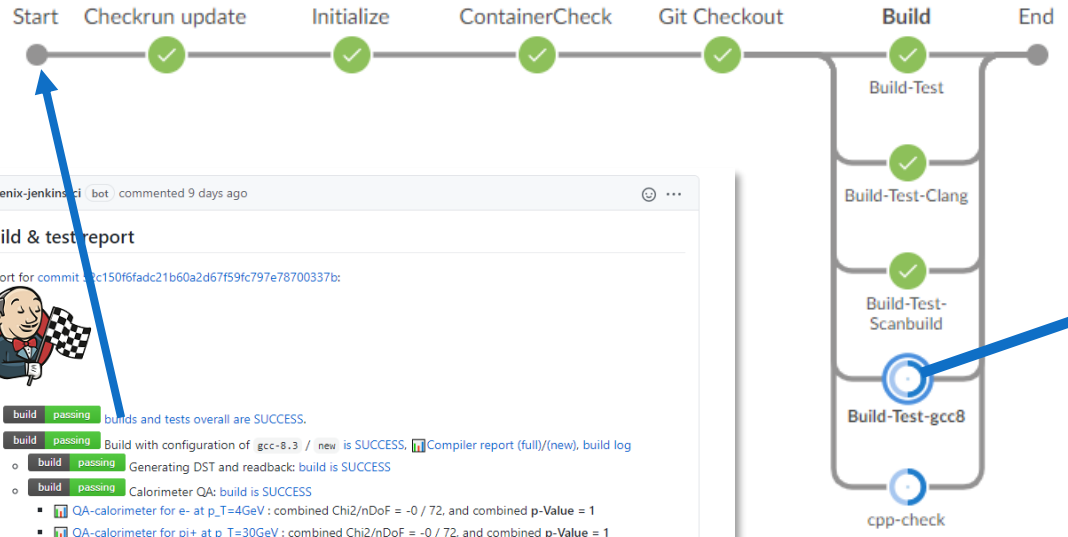


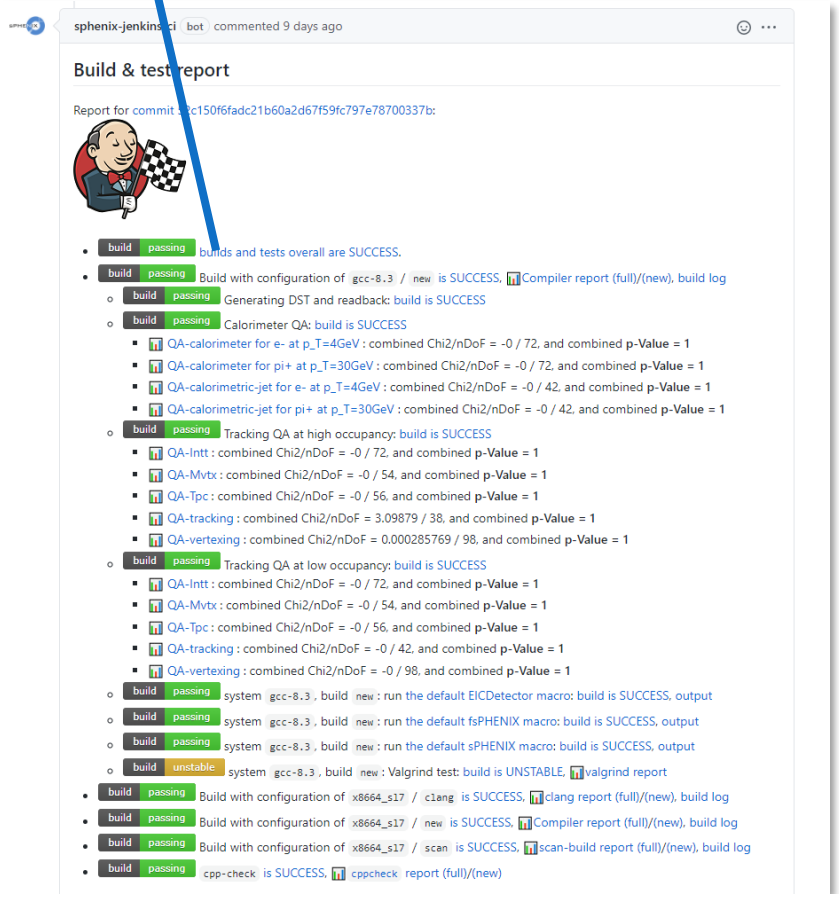
# How do I navigate around all this mountain of code?

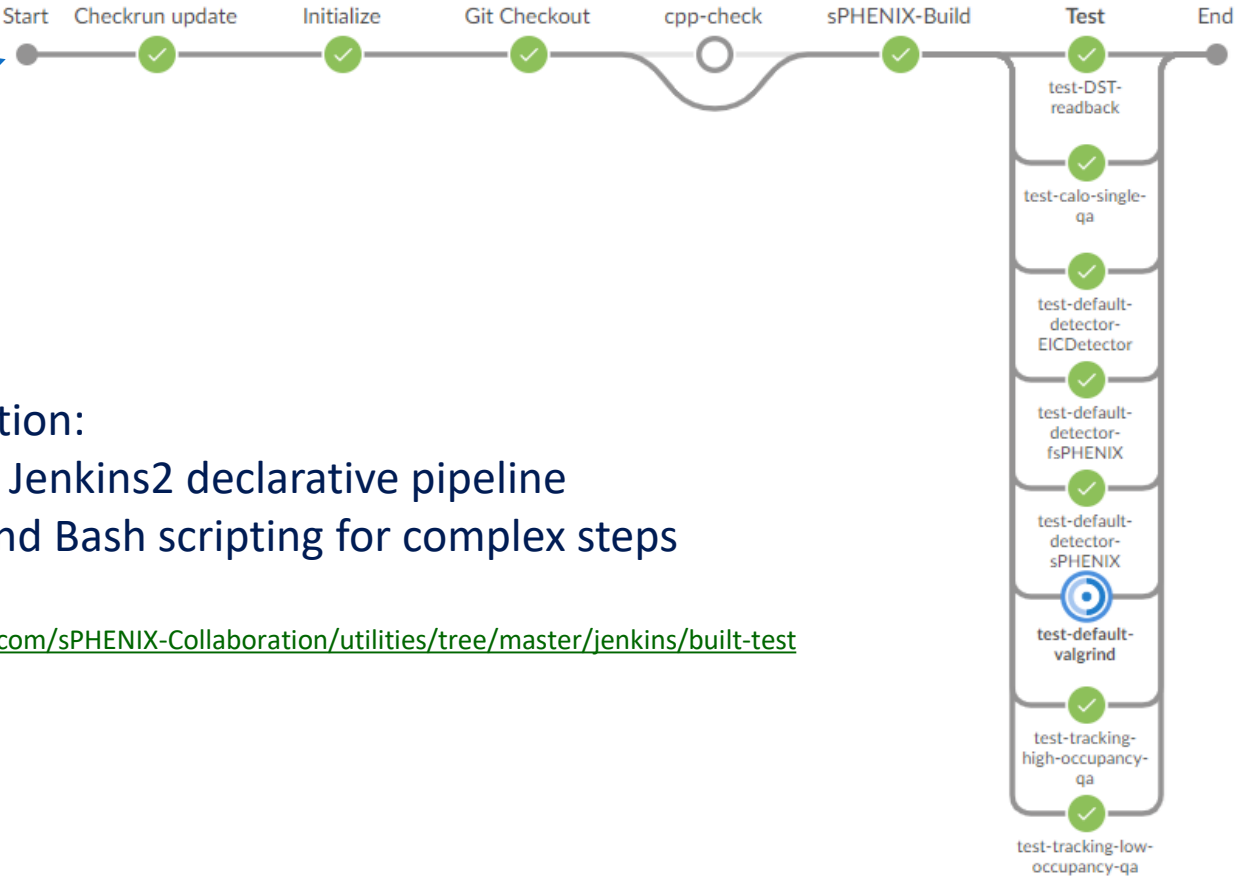
- ecce-eic.github.io/doxygen/
- All software on GitHub now digested in Doxygen via JenkinsCI
- Auto built at change of any repository
- Search anything in Doxygen site for ECCE GitHub software



# Fun4All Jenkins-CI Pipeline Workflow




- CI check in upstream sPHENIX-Fun4All repo
- Help needed to implement a CI QA pipeline in ECCE too

Implementation:

- Based on Jenkins2 declarative pipeline
- Python and Bash scripting for complex steps
- Git SCM:
  https://github.com/sPHENIX-Collaboration/utilities/tree/master/jenkins/built-test

e.g. https://github.com/sPHENIX-Collaboration/coresoftware/pull/1117#issuecomment-805131915

# Software modules

# Event generators

- Running example given in sample EIC sim macro: https://github.com/ECCE-EIC/macros/blob/master/detectors/EICDetector/Fun4All_G4_EICDetector.C
- Arbitrary set-of-particle generators for testing
- Main event generator input format: HepMC files
- Built-in generators : PYTHIA8.3, PYTHIA6, SARTRE
- Reads events generated in EIC-Smear package [talk: Kolja]
  - Share the same Singularity image and CVMFS vol. Source different setup macros.
  - Allow comparison of same event sample processed by EIC-Smear and by the Fun4All simulation-reco.
- Support multiple background pile ups

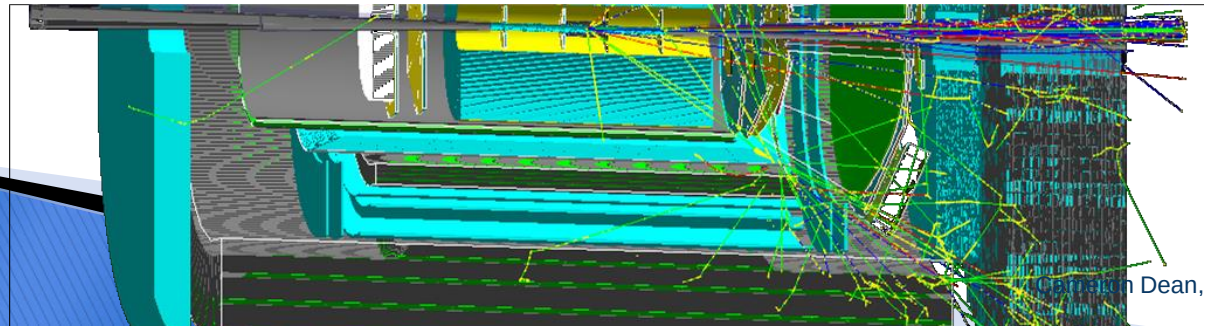
Note: All EIC full event generator has EIC beam parameters applied by default: collision crossing angle, beam divergence, vertex smear, crab cavity kick [ref]. Also can switch off in the main macro

https://eic.github.io/software/mcgen.html

# Status of detector descriptions

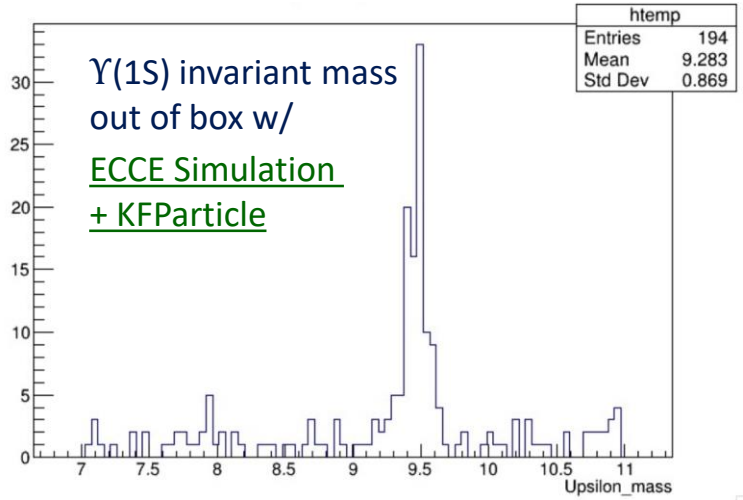
- Full detector model provides digitization and various level of reconstruction chain
- For fast prototyping, fast detector model can be built with simple shapes on macro level
- Adding detectors: see talk Friedericke Bock & Nicolas Schmidt

| Detector | Status / link to code | Help needed |
|---|---|---|
| Silicon trackers | Full model for ALPIDE, fast model for ITS3, FST | Update ECCE setup |
| TPC | Full model, fast model | EIC setup, dE/dx |
| MPGD tracker | Fast model | Update ECCE setup |
| Barrel Calorimeter | Full model for SPACAL, sPHENIX HCals, fast model for Shashlyke | Update ECCE setup |
| Forward calorimeter | Full model for Shashlyke, PbScifi, fast model for crystal calorimeter | Light collection uniformity |
| PID / TOF | Full model for MRPC and Fast model for LGAD | Update ECCE setup |
| PID / RICH | Full model for mRICH, Gas RICH; missing DIRC and dual RICH (material placeholder) | dRICH, RICH reco |
| Far forward | Fast model [Talk: Ciprian] | Beamline material |



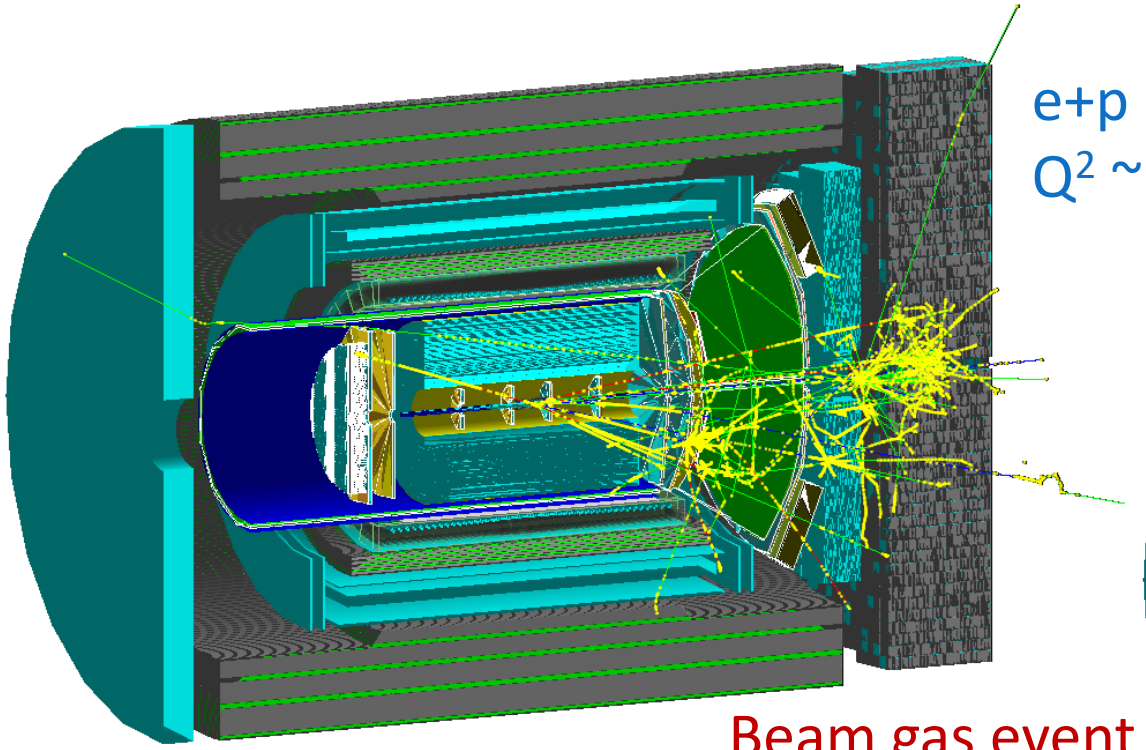
# Reconstruction

- Tracking:
  - Use GenFit2 for fast prototyping (PHG4TrackFastSim), widely used in YR tracking studies
  - sPHENIX switched to ACTS: fast to fit but long development time for adopting new tracker set ***Not*** suited for ECCE at this stage [help needed: pattern reco. with ACTS]
- Calo reco:
  - Clusterizers, FastJet, Particle flow jet (prototype, need volunteer)
- PID reco:
  - GenFit2 for TOF, e.g. track length and timing smearing
  - RICH has to rely on fast smearing (help needed: full reco of RICH need major development)
- Resonance search/HF reconstruction:
  - KFParticle
- Detailed truth tracing evaluation chain
  - e.g. what portion of reco jet is from a truth jet

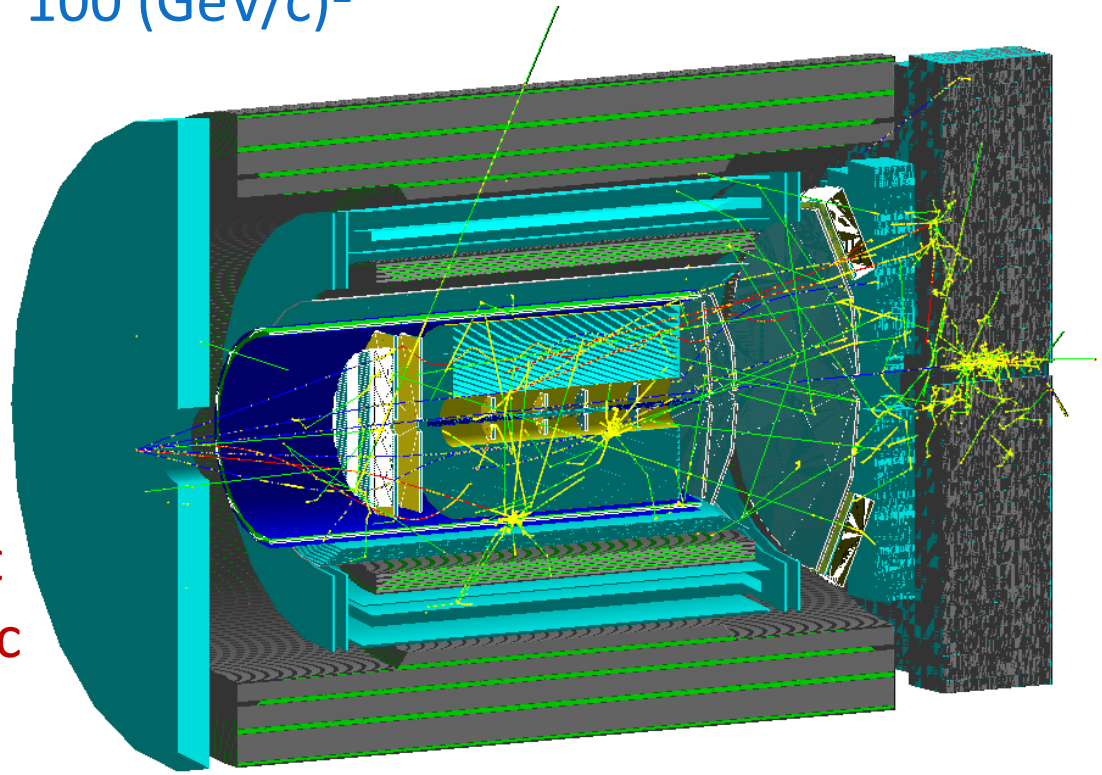


# Background embedding: beam gas interaction

- Built-in Pythia8 for beam gas interaction background generation



e+p DIS 18+275 GeV/c
$Q^2 \sim 100\ (GeV/c)^2$

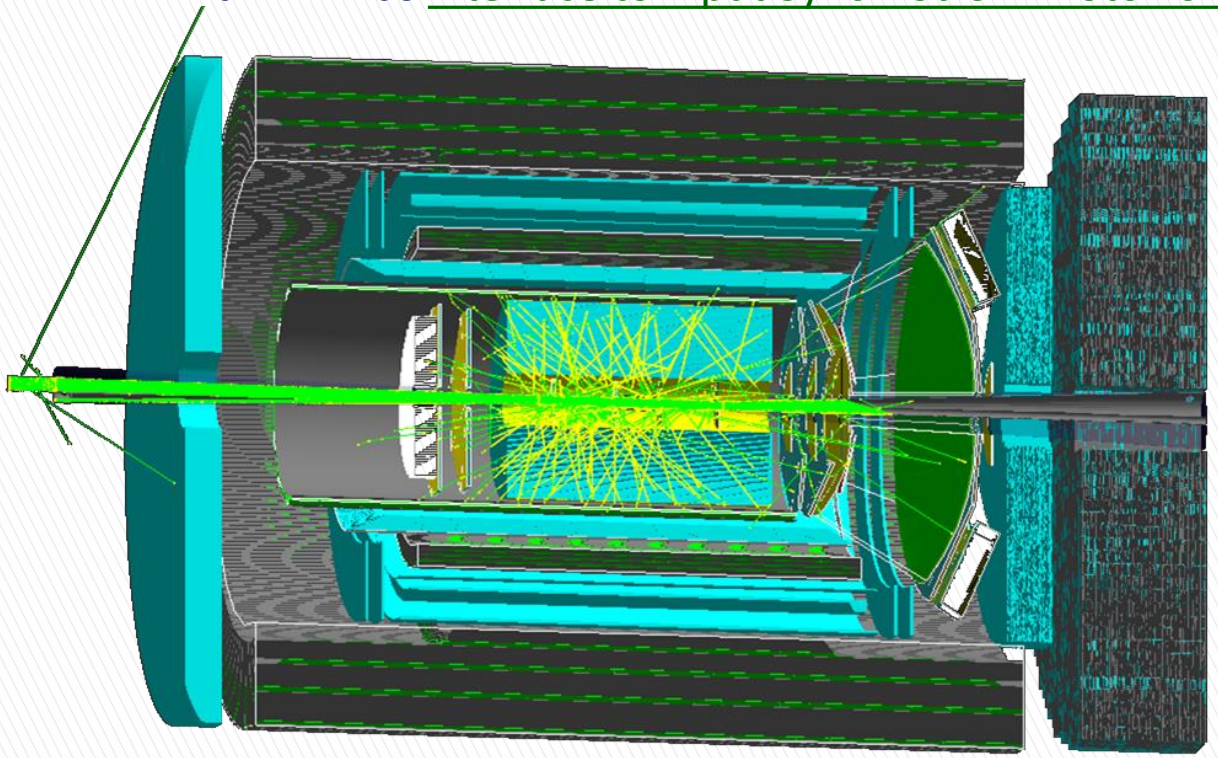


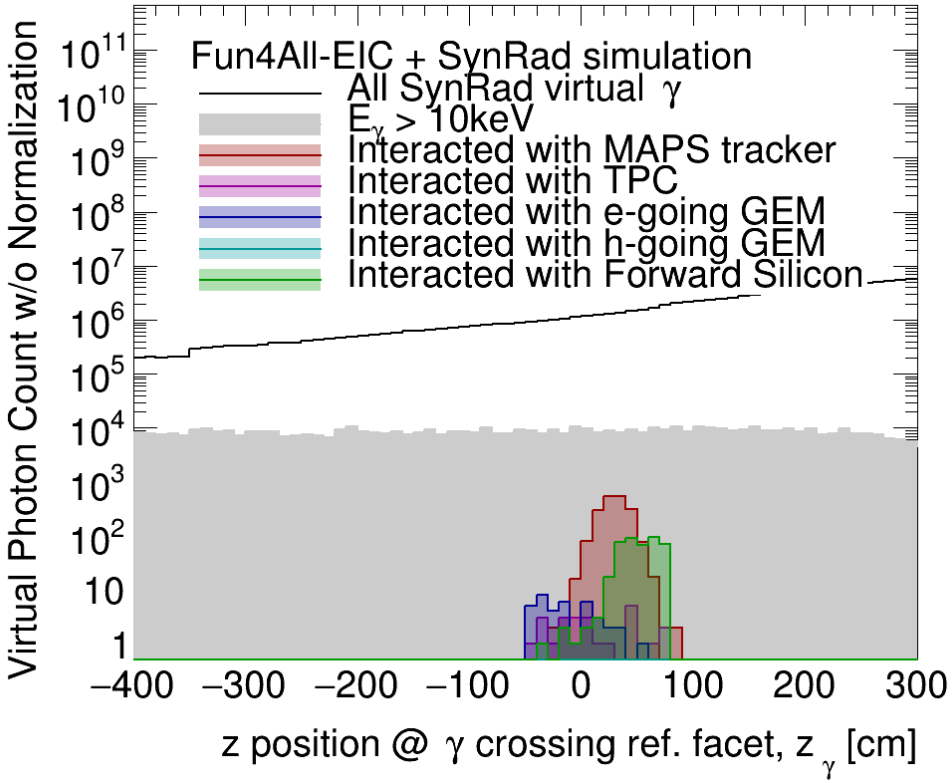
Beam gas event
p + p, 275 GeV/c
at z=-4 m

Refs: sPH-cQCD-2018-001: https://indico.bnl.gov/event/5283/

# Background embedding : Synchrotron radiation

- Fun4All has interface to input Synchrotron Photon simulation, used in Synchrotron study leading to CD-1 review






100k Synchrotron photon in full detector simulation [YR Fig 10.12]

Detector background as function of beam-pipe exit-location

Note: all photons simulated for detector interaction, without cuts on z or energy. EIC/July-2020 lattice & chamber

# Summary

- Time is short
- Good foundation for ECCE simulation based on Fun4All
- Will help WGs design simulation path for each specific study
- Help needed in many area
- Don't hesitate to ask questions
- Send jhuang@bnl.gov
  - Your GitHub username to join http://github.com/ECCE-EIC
  - If no BNL account, email to enter MatterMost chat

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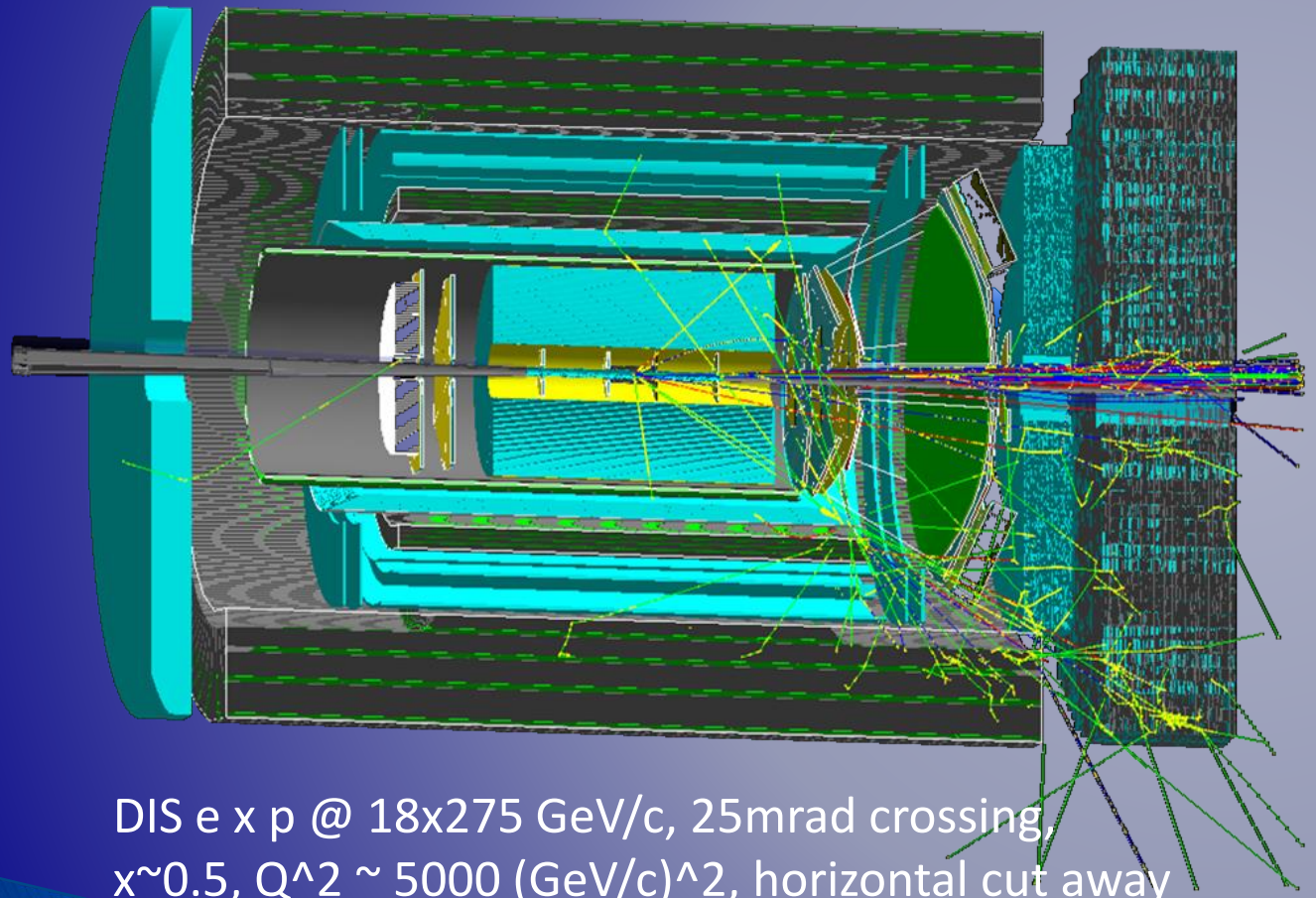
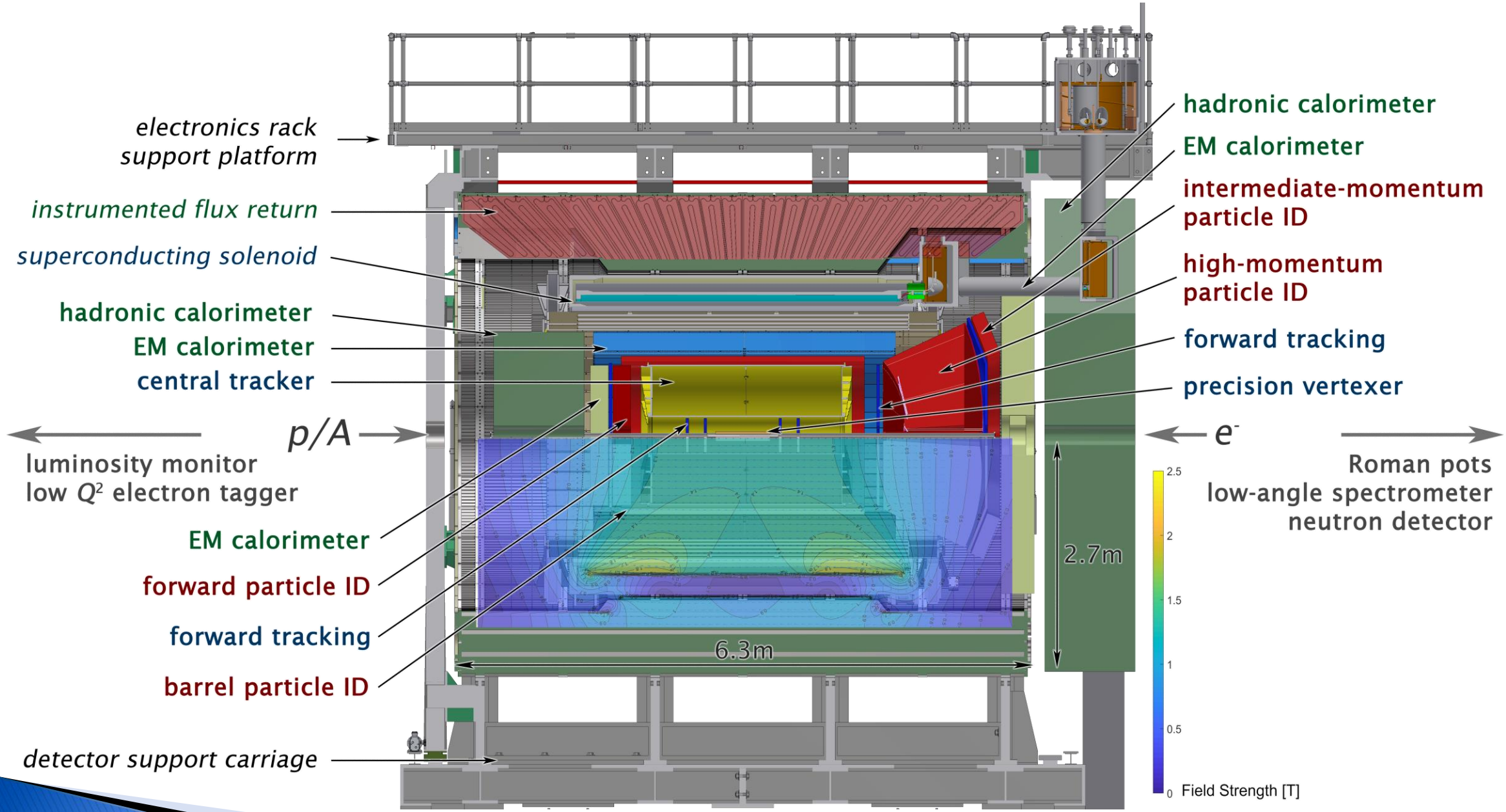
# Extra information



DIS e x p @ 18x275 GeV/c, 25mrad crossing,
x~0.5, Q^2 ~ 5000 (GeV/c)^2, horizontal cut away


electronics rack support platform
instrumented flux return
superconducting solenoid
hadronic calorimeter
EM calorimeter
central tracker
p/A
luminosity monitor
low Q² electron tagger
EM calorimeter
forward particle ID
forward tracking
barrel particle ID
detector support carriage
hadronic calorimeter
EM calorimeter
intermediate-momentum particle ID
high-momentum particle ID
forward tracking
precision vertexer
e⁻
Roman pots
low-angle spectrometer
neutron detector
6.3m
2.7m
2.5
2
1.5
1
0.5
0
Field Strength [T]

# EIC x-sec : further quantification [Courtesy E. Aschenauer]

- Inelastic e+p scattering x-sec:
  - For a luminosity of $10^{34}$ $cm^{-2}s^{-1}$ 50ub corresponds to **500 kHz**
- Elastic e+p cross-section:
  - For EIC central barrel, elastic cross section is **small** comparing to the inclusive QCD processes
- Beam gas interaction:
  - Beam proton – beam gas fix target inelastic interactions. The pp elastic cross section is smaller (~7 mb)
  - For a vacuum of $10^{-9}$ mbar in the detector volume (10m) this gives a rate of **14 kHz**

| Beam [GeV] | HERA | 5 x 50 | 10 x 100 | 18 x 275 |
|---|---|---|---|---|
| $Q^2>10^{-9}$ GeV | 65.6 | **29.9** | **41.4** | **54.3 ub** |
| $Q^2>1$ GeV | 1.29 | 0.45 | 0.65 | 0.94 ub |

| Beam [GeV] | HERA | 5 x 50 | 10 x 100 | 18 x 275 |
|---|---|---|---|---|
| $\sigma$ [$y_{Exp}$ >-4] | 5 pb | **5 ub** | **0.7 ub** | **0.06 ub** |
| $\sigma$ [$y_{Exp}$ >-6] | 11 ub | 420 ub | 100 ub | 29 ub |

| $E_p$: | 50 GeV | 100 GeV | 275 GeV | 920 GeV |
|---|---|---|---|---|
| | **38.4 mb** | **38.4 mb** | **39.4 mb** | 41.8 mb |

# Data Rate

**MAPS silicon tracker**

Raw data: 16-24 bit / MAPS hit (3-layer ALPIDE model)

**TPC**

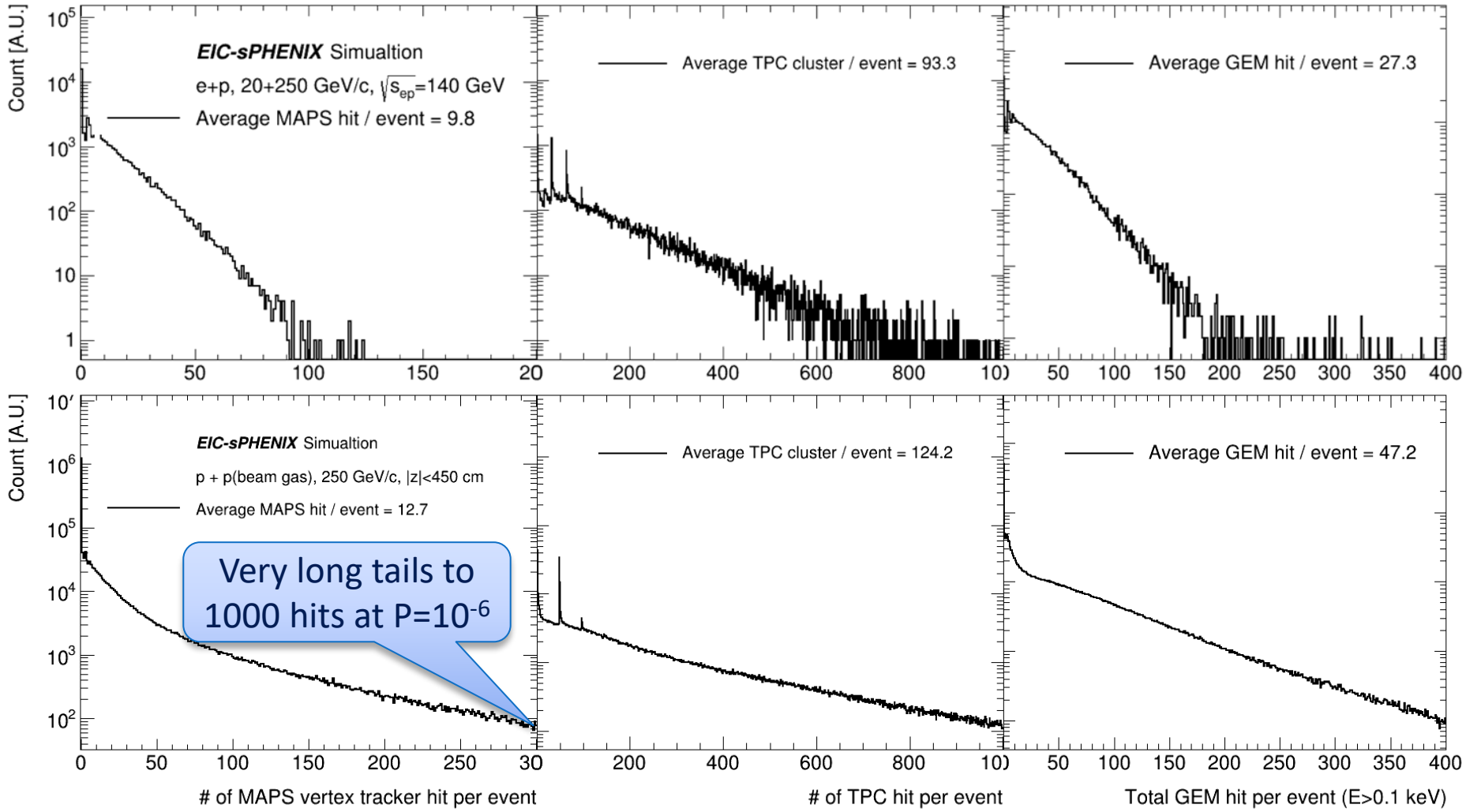
Raw data: 3x5 10 bit / TPC hit + headers (60 bits)

**Forward/backward GEM**

Raw data: 3x5 10 bit / GEM hit + headers (60 bits)

e+p, Pythia6 Q2>0

p+p(gas) Pythia8

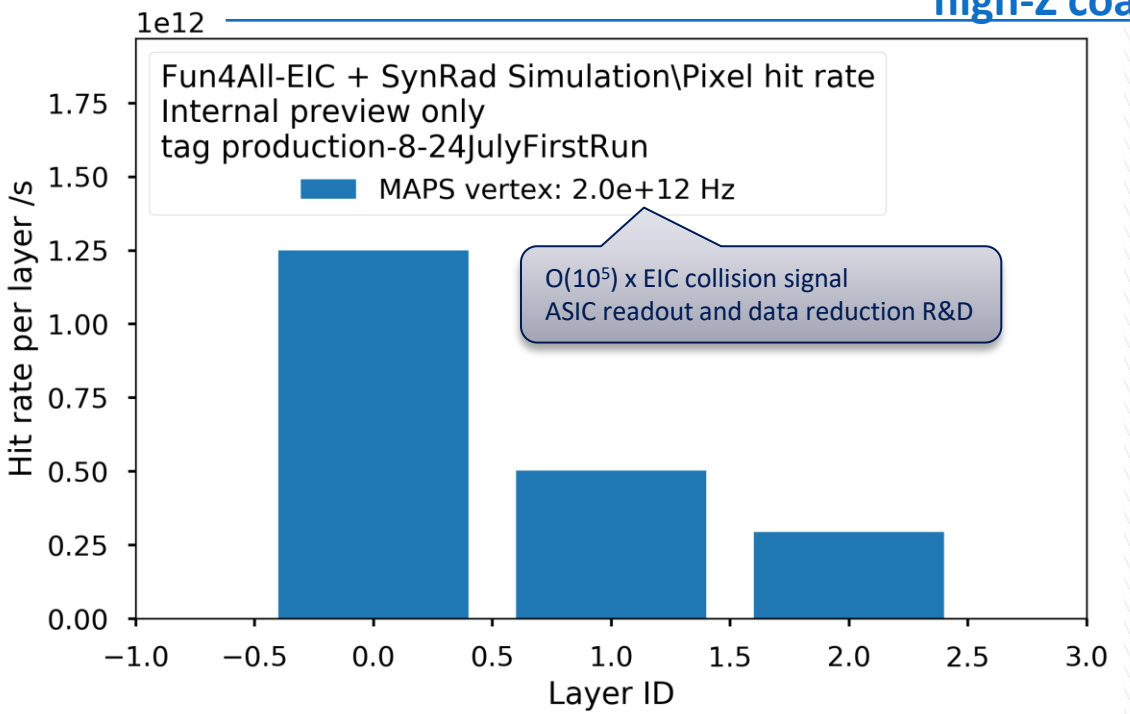


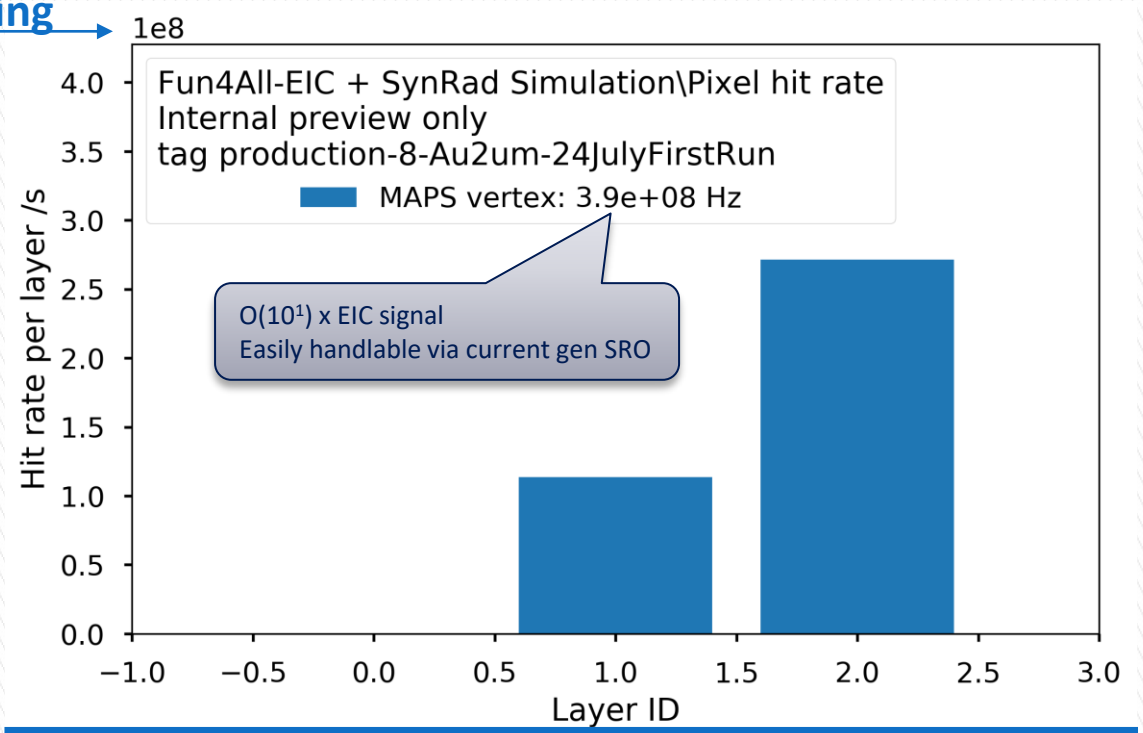

Refs: sPH-cQCD-2018-001: https://indico.bnl.gov/event/5283/

# Synchrotron background: detector response

- In the most recent lattice + beam chamber geometry, there is a known issue with main dipole fan reflect over far upstream beam chamber to Be-beam pipe section.
- Beam chamber tuning on-going, expect to reduce by orders of magnitude [DO NOT QUOTE THIS RATE]
- The reflected dipole fan induce high hit rate in barrel detectors prior to photon shield tuning, but high-Z coating on chamber, e.g. 2-μm Au coating (0.06 $X_0$) on Be pipe significantly reduces the synchrotron rate

high-Z coating →




**Default 760μm-Be beam pipe**

Dominated by dipole fan reflection. Expected to reduce with tuning

**High-Z-coated beam pipe (+2μm Au)**

Dominated by dipole fan reflection. Expected to reduce with tuning