

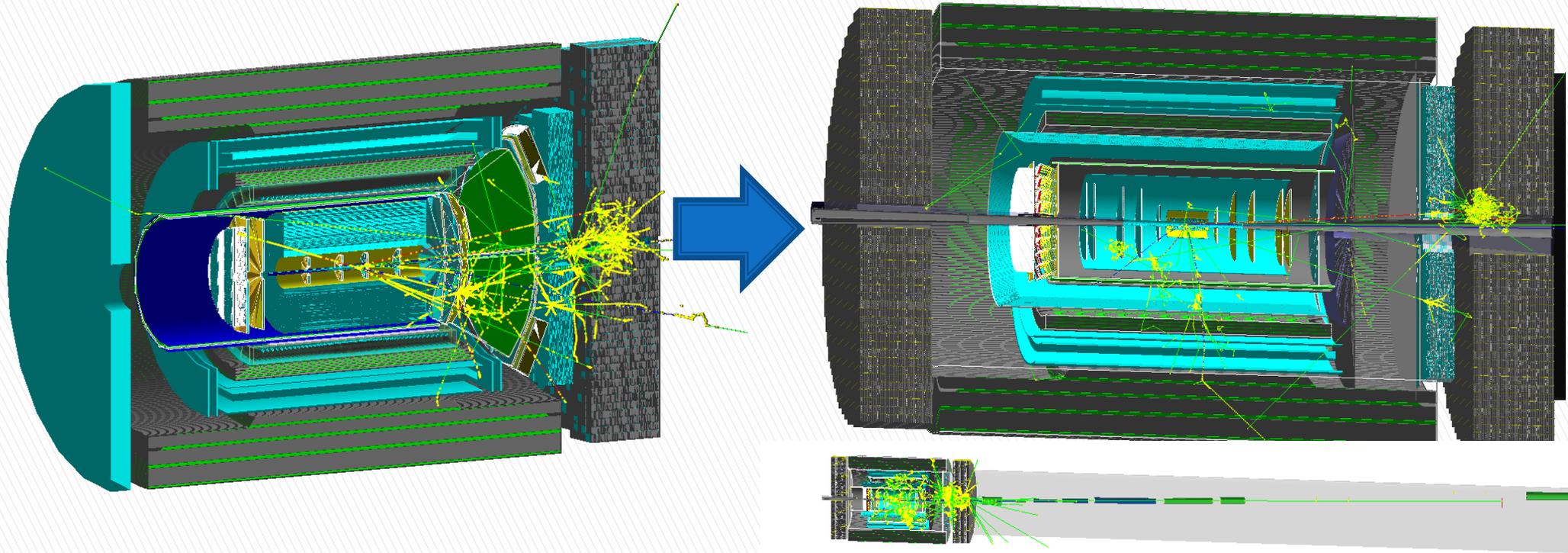


# Tracker background Studies

Jin Huang

Brookhaven National Lab

# ECCE concept as described in Fun4All simulation



ePHENIX concept, sPH-cQCD-2018-001

1<sup>st</sup> ECCE concept in draft setup

# EIC: unique collider

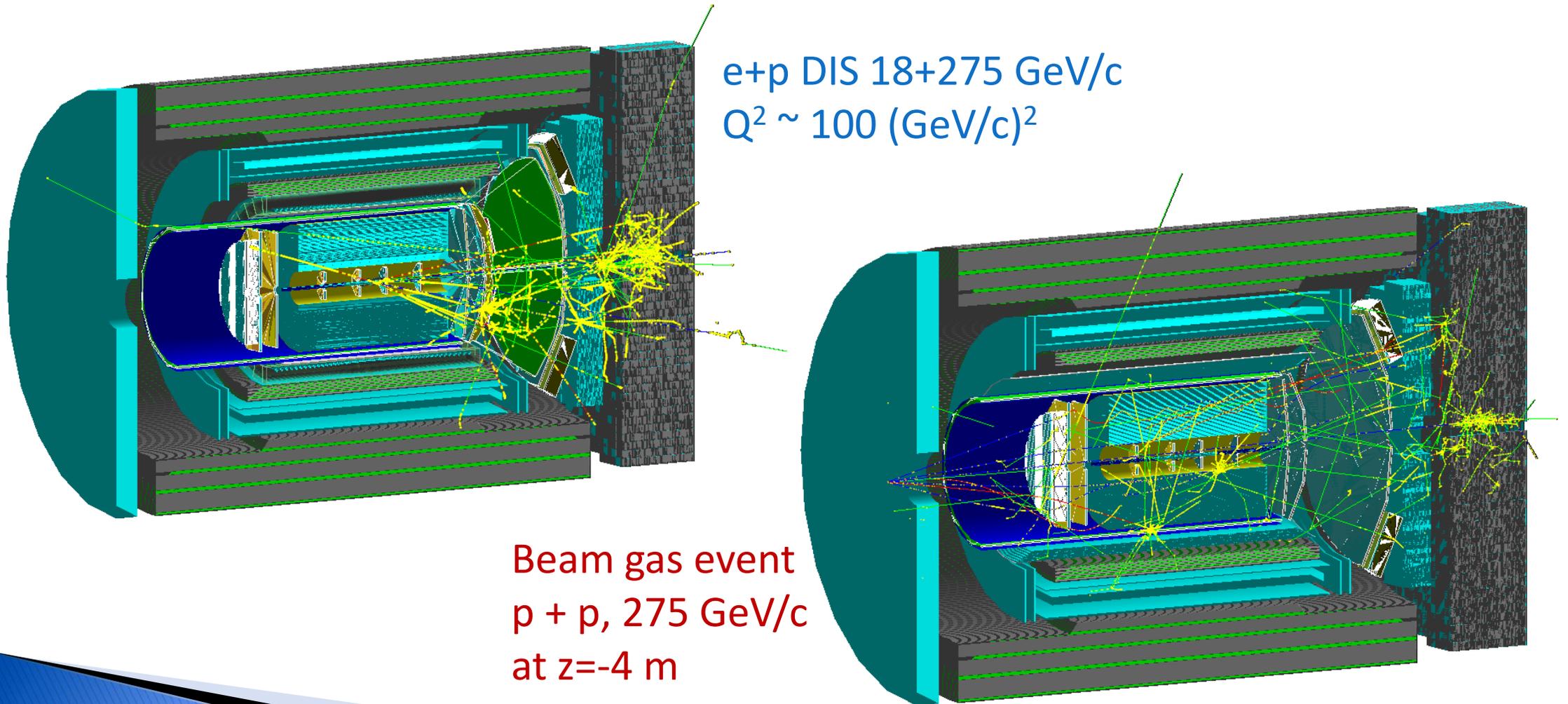
## → unique real-time system challenges

	EIC	RHIC	LHC → HL-LHC
Collision species	$\vec{e} + \vec{p}, \vec{e} + A$	$\vec{p} + \vec{p}/A, A + A$	$p + p/A, A + A$
Top x-N C.M. energy	140 GeV	510 GeV	13 TeV
Bunch spacing	10 ns	100 ns	25 ns
Peak x-N luminosity	$10^{34} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	$10^{34} \rightarrow 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
<b>x-N cross section</b>	<b>50 <math>\mu\text{b}</math></b>	<b>40 mb</b>	<b>80 mb</b>
Top collision rate	500 kHz	10 MHz	1-6 GHz
$dN_{\text{ch}}/d\eta$ in p+p/e+p	0.1-Few	~3	~6
<b>Charged particle rate</b>	<b>4M <math>N_{\text{ch}}/s</math></b>	<b>60M <math>N_{\text{ch}}/s</math></b>	<b>30G+ <math>N_{\text{ch}}/s</math></b>

- ▶ EIC luminosity is high, but collision cross section is small ( $\propto \alpha_{\text{EM}}^2$ ) → low collision rate
- ▶ But events are precious and have diverse topology → hard to trigger on all process
- ▶ Background and systematic control is crucial → avoiding a trigger bias

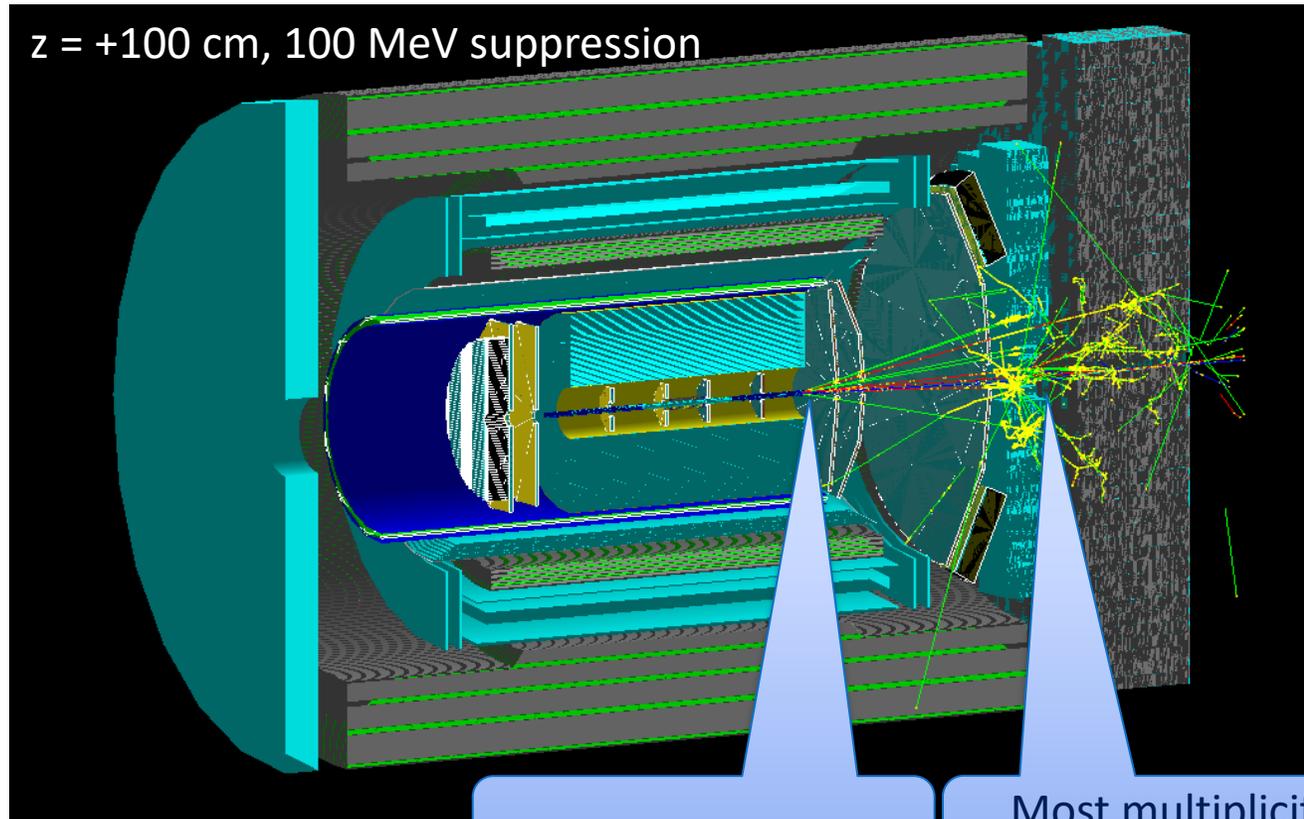
# EIC DAQ in Geant4 simulation

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



# Beam gas event in a detector

- ▶ 250 GeV proton beam on proton beam gas,  $\sqrt{s} \sim 22$  GeV
- ▶ For this illustration, use pythia-8 very-hard interaction event ( $\hat{q} > 5$  GeV/c)

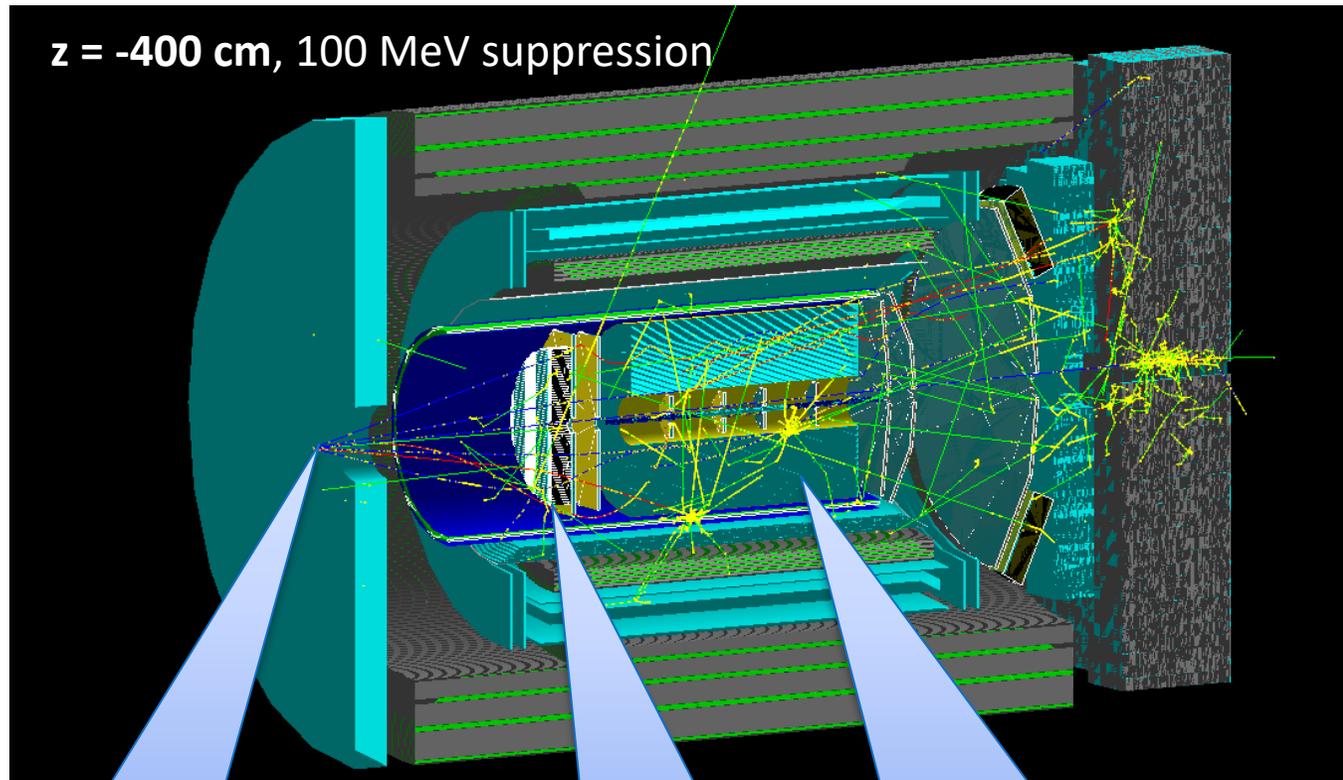


Gas event at  $z=1$  m

Most multiplicity goes to forward calo.

# Beam gas event in a detector

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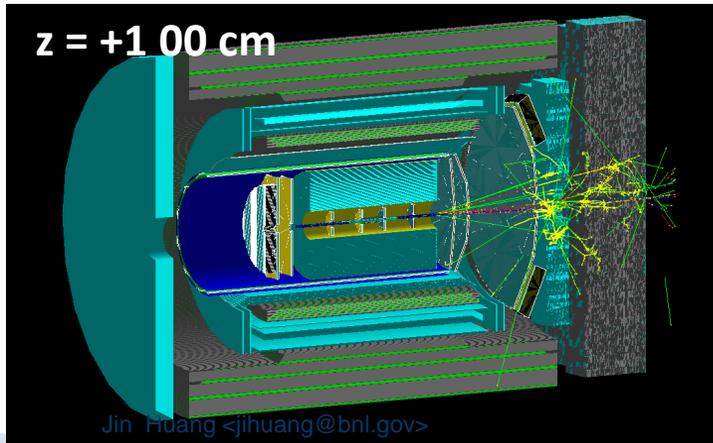
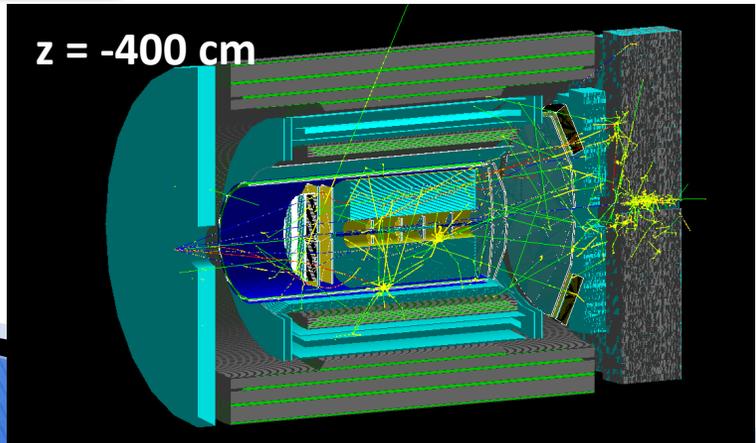
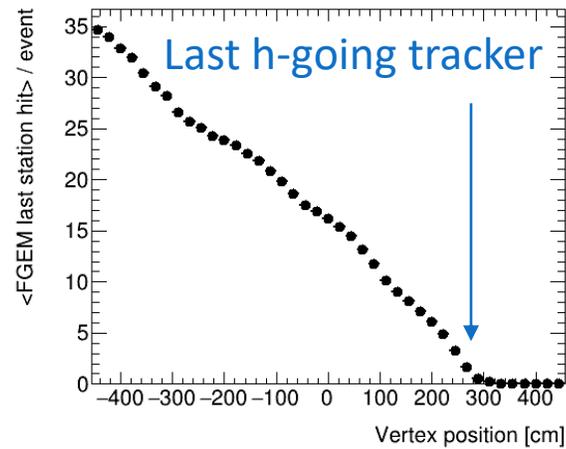
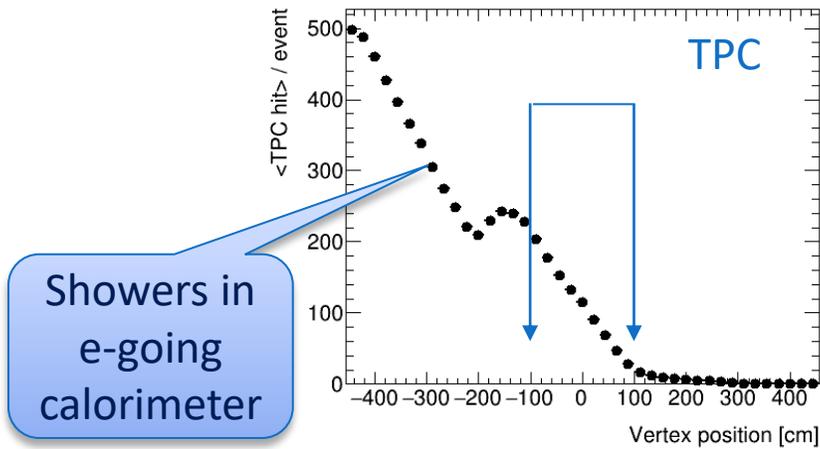
Gas event at  $z=-4$  m

Shower starts in e-going calorimeter

Induce multiplicity in trackers and forward calo

# Beam gas vertex sensitivity - tracker

- ▶ Average active hit for each beam gas vertex bin
- ▶ 250 GeV proton beam on proton beam gas, Pythia-8 M.B.



# Data Rate

## MAPS silicon tracker

## TPC

## Forward/backward GEM

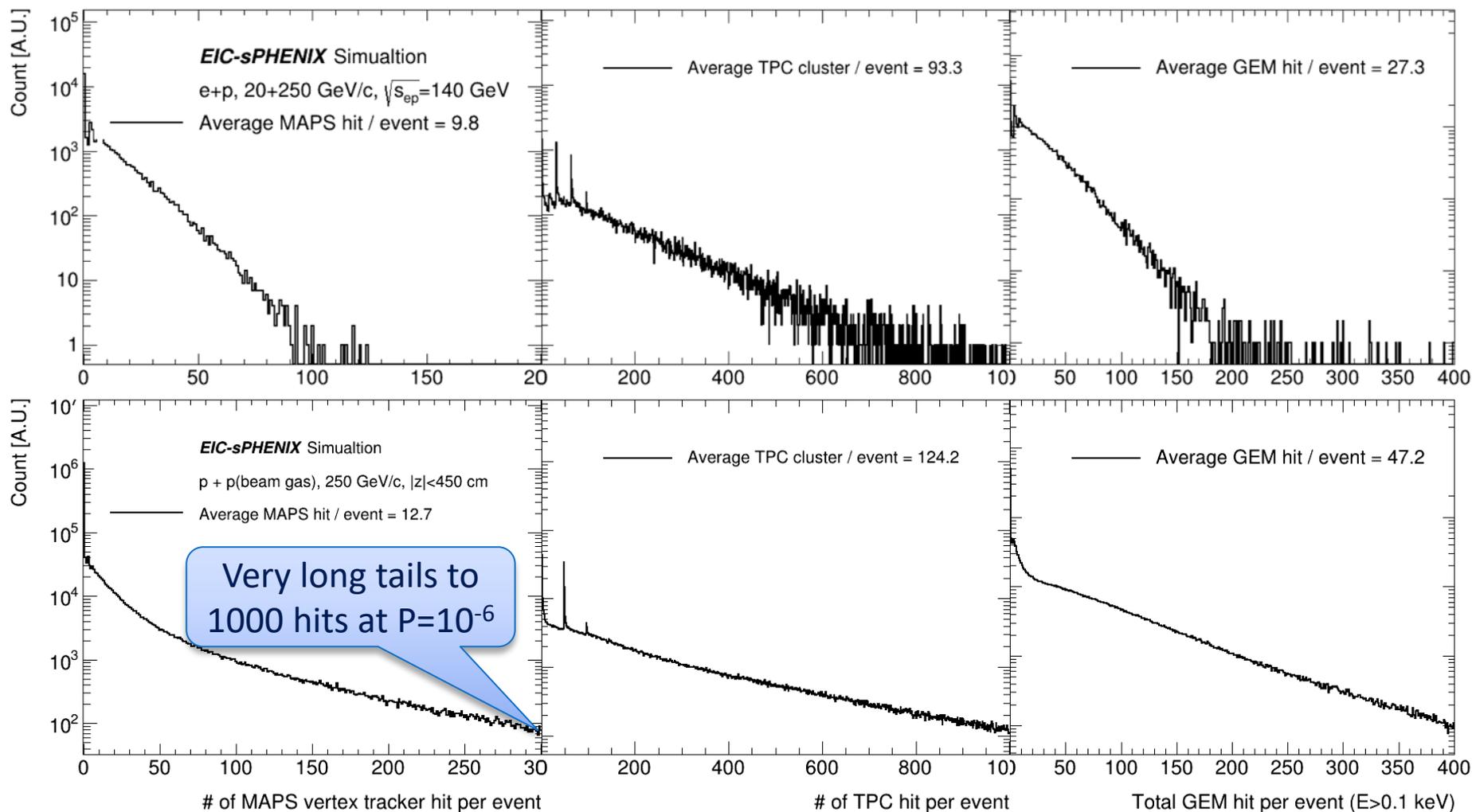
Raw data: 16-24 bit / MAPS hit  
(3-layer ALPIDE model)

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

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

e+p, Pythia6 Q2>0

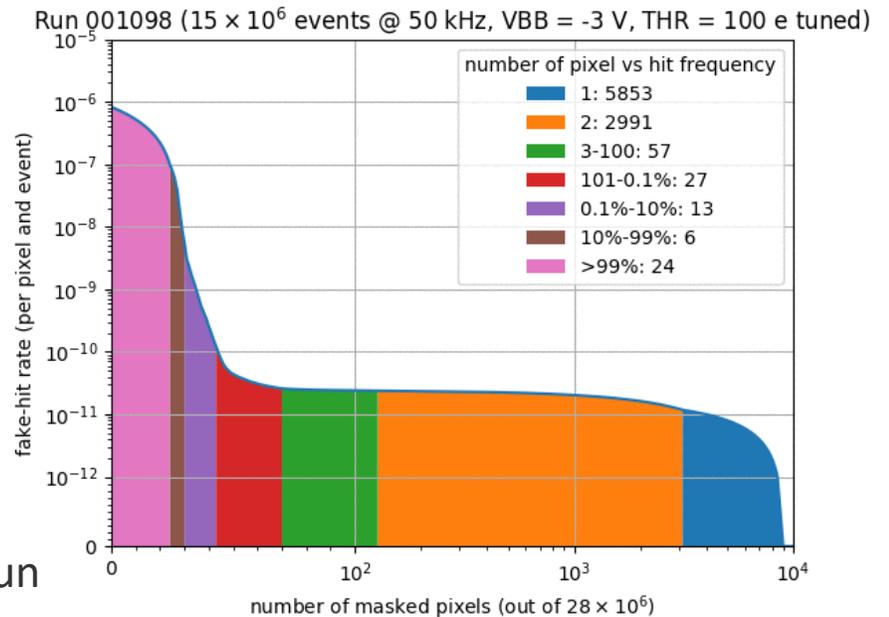
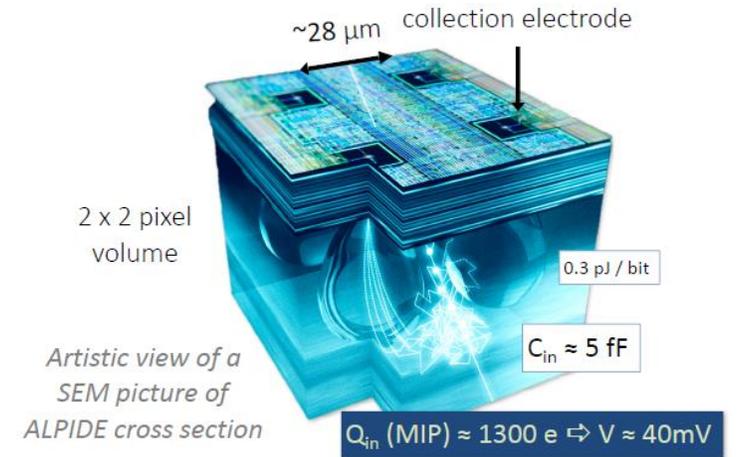
p+p(gas) Pythia8



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

# Considerations for SVT @ EIC : Intrinsic noise

- ▶ Largest-channel-count detector: silicon pixel vertex tracker
  - Most recent MAPS (ALPIDE) in large applications:
    - ALICE ITS: 12.5B channels
    - sPHENIX-EIC vertex tracker: 200M chan
- ▶ sPHENIX-EIC MAPS tracker
  - $10^{-5}$  noise rate x 100kHz frame → 5 Gbps, handleable
  - $10^{-10}$  noise rate x 100kHz frame → negligible
- ▶ EIC DMAPS
  - YR group quoting L. Gonella: expect noise of  $10^{-9}$
  - $10^{-9}$  noise rate x 100MHz frame → ~1 Gbps, handleable
- ▶ What about LGADs?



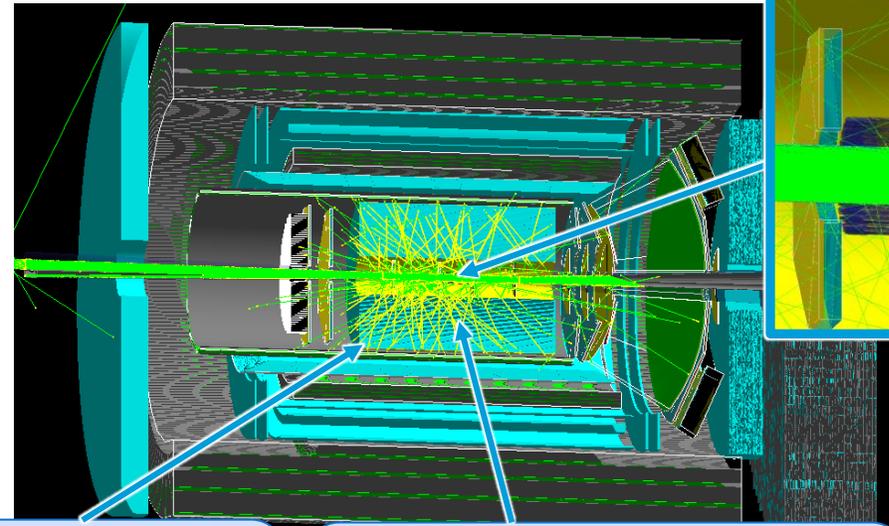
Ref: ALICE ITS commissioning run  
Felix Reidt, QM2019

# Considerations for SVT @ EIC : Synchrotron bgd.

- ▶ Synchrotron background is major challenge for high energy collider with electron beams
- ▶ Many detectors at EIC could be vulnerable to Synchrotron background
  - E.g. challenging for readout design, background filtering tracking, and fake large DCA for HF
- ▶ Strong emphasize on co-design of collider, IR and experiment that is low in Synchrotron background from the start:
  - eRD21 (talk C. Hyde)
  - bi-weekly IR background meeting joining accelerator and detector physicists

- 100k SynRad synchrotron photon by Marcy Stutzman (Jlab)
- Reproduce this Geant4 simulation from GitHub: [macros / SynRad->HepMC reader](#)

Top-down view, horizontal cut



Silicon tracker zoom-in

Photons can go far beyond the beam line

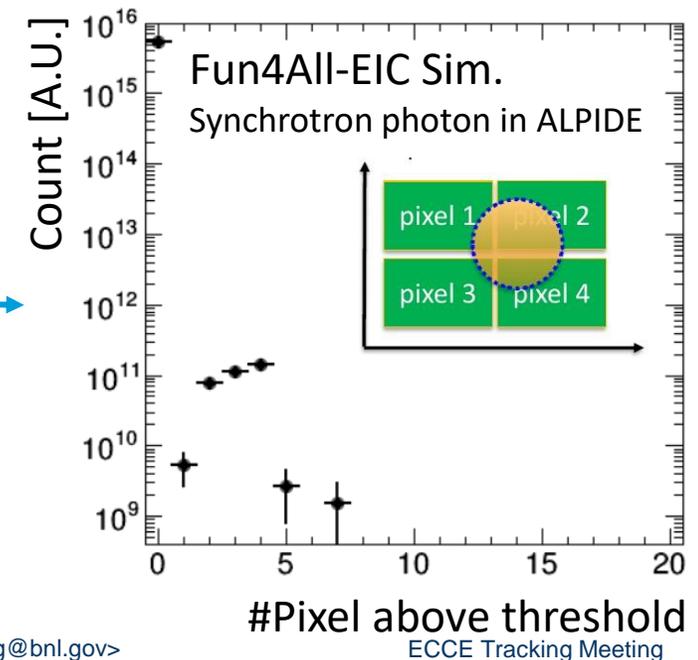
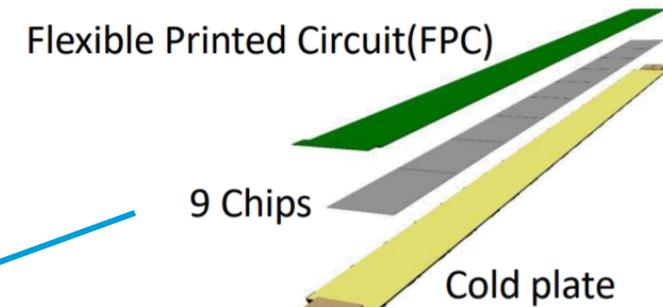
Synchrotron photon scatters through the low mass tracker PID region of central detector

# Synchrotron background: detector response

- ▶ Synchrotron photon interaction are digitized to detector data rate with sPHENIX ALPIDE model
- ▶ Calibrated with 2019 sPHENIX test-beam

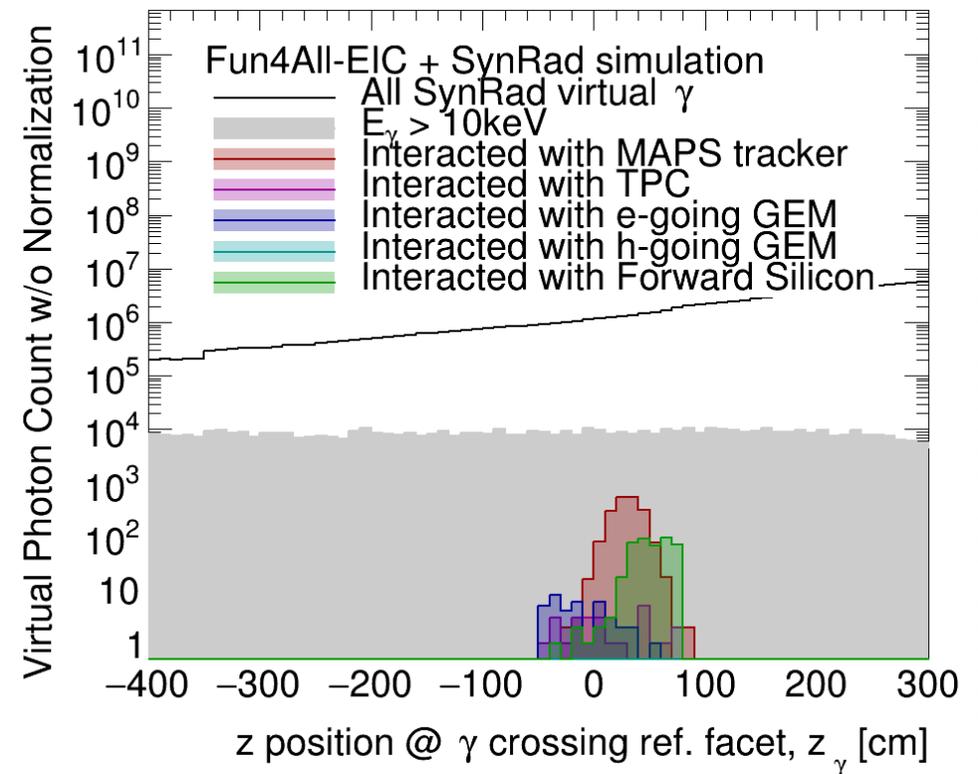
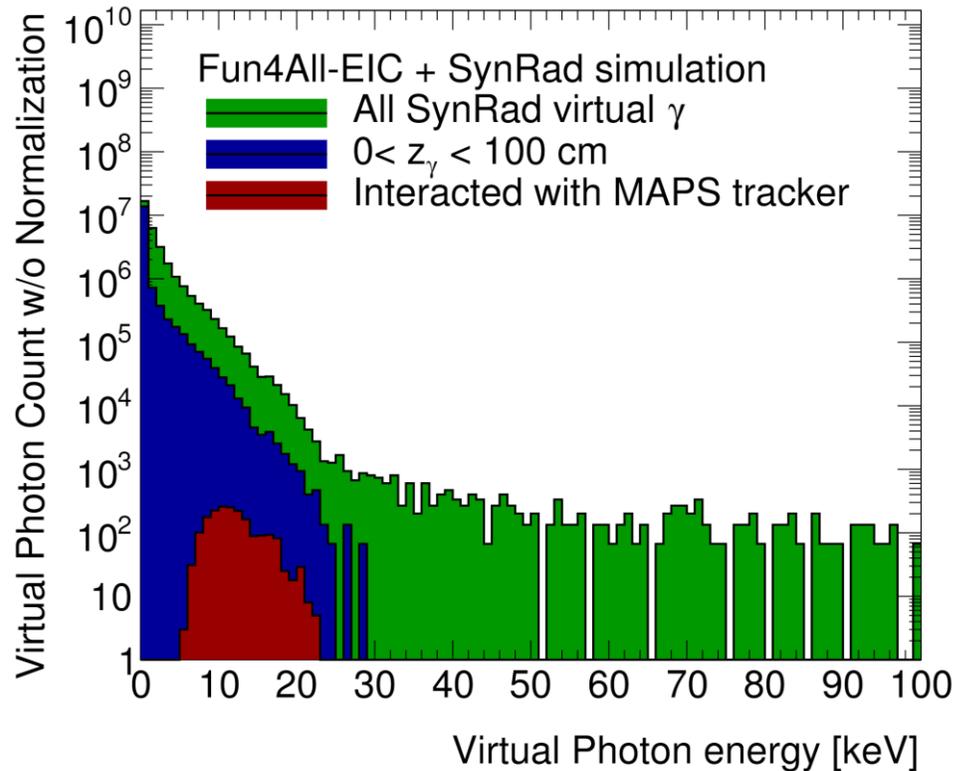
## sPHENIX/ALICE ALPIDE ASIC model:

- Geant4 transport
- (1.8 keV photon threshold for Be pipe)
- > Ionization energy loss in active silicon
- > produce ionization trail
- > ionization diffusion
- > map to readout pixels
- > electronics threshold (~1keV)
- > Pixel hit -> ALPIDE data format
- > Data rate



# Synchrotron background: detector response

- Iterating with accelerator design to avoid 10keV photon that exits -50 to +100cm from beam pipe



Energy dependence of MAPS vertex tracker to synchrotron

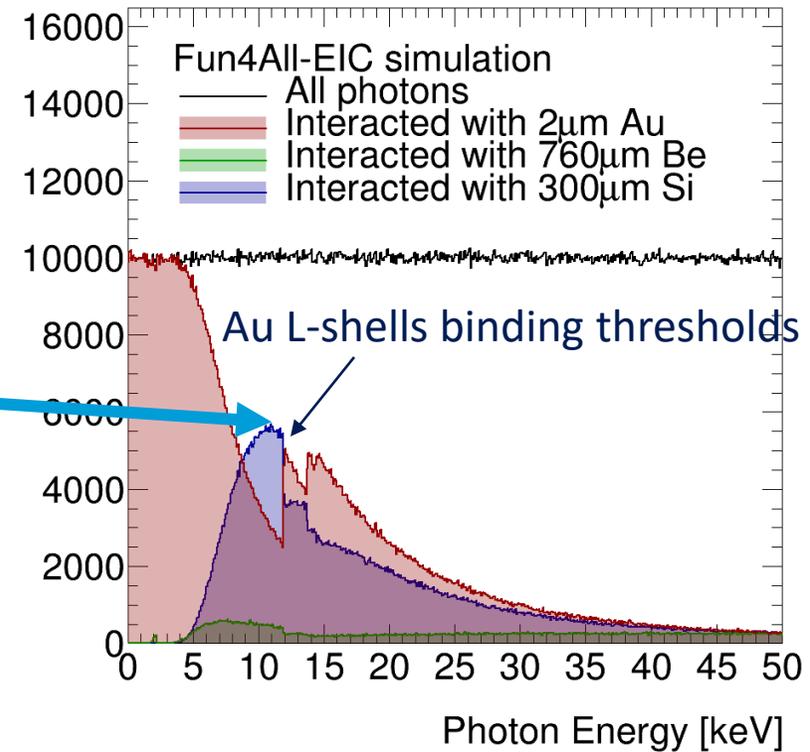
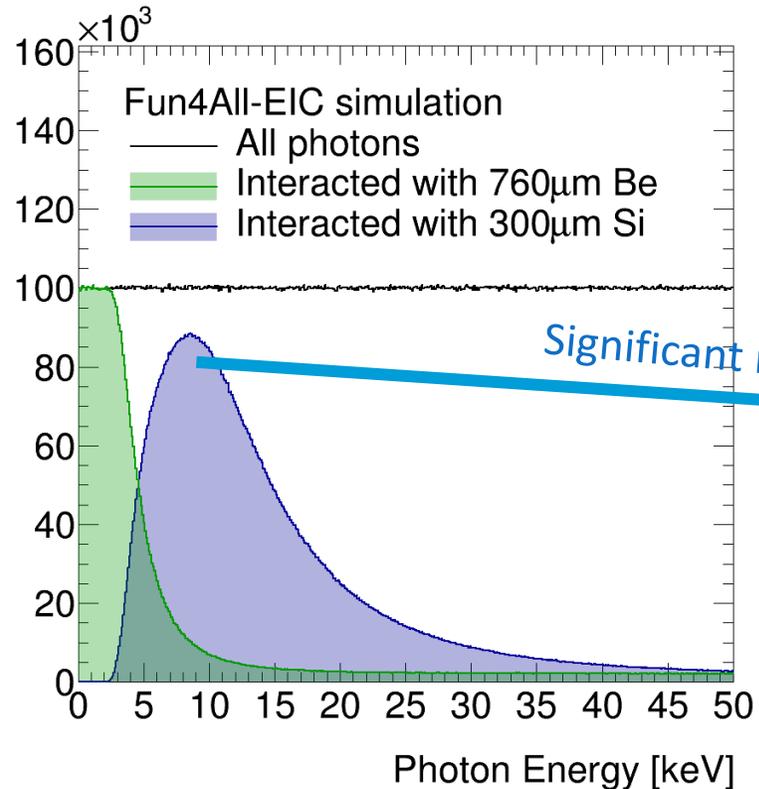
Beam-pipe exit-location

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

# Coating validation

Note: normal indenting.  
Further reduction if shallow indenting

- [https://nbviewer.jupyter.org/github/blackcathj/macros/blob/synrad\\_valid\\_flatphoton\\_AuCoating/macros/g4simulations/PhotonConversion.ipynb](https://nbviewer.jupyter.org/github/blackcathj/macros/blob/synrad_valid_flatphoton_AuCoating/macros/g4simulations/PhotonConversion.ipynb)

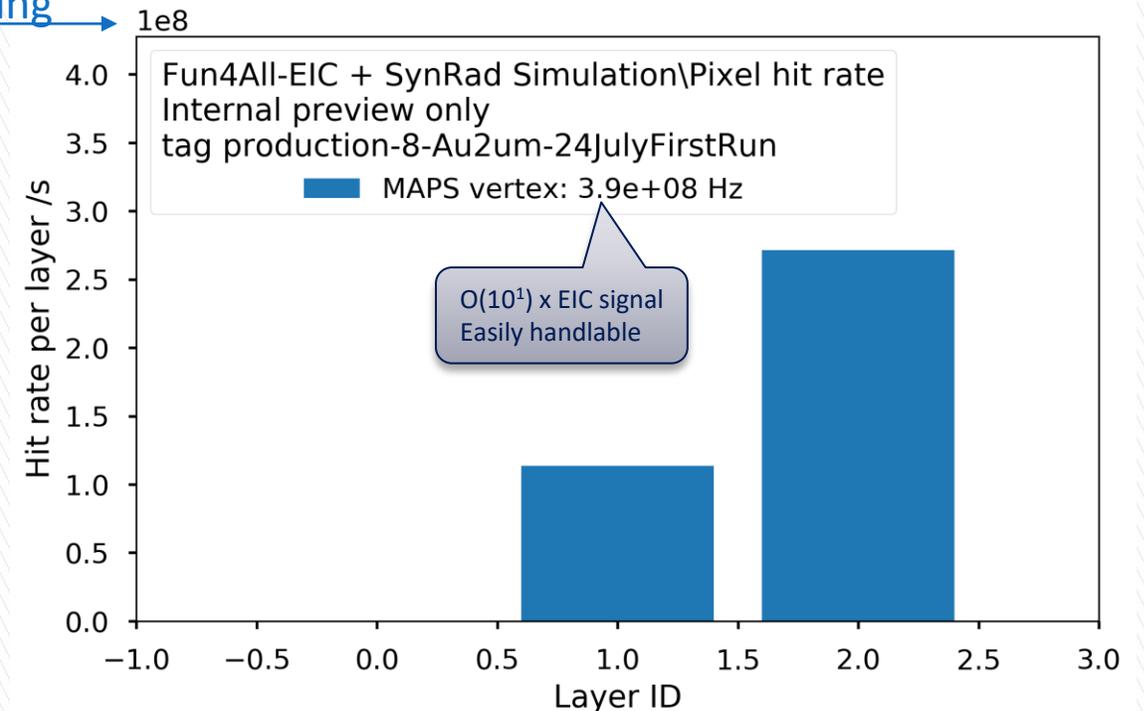
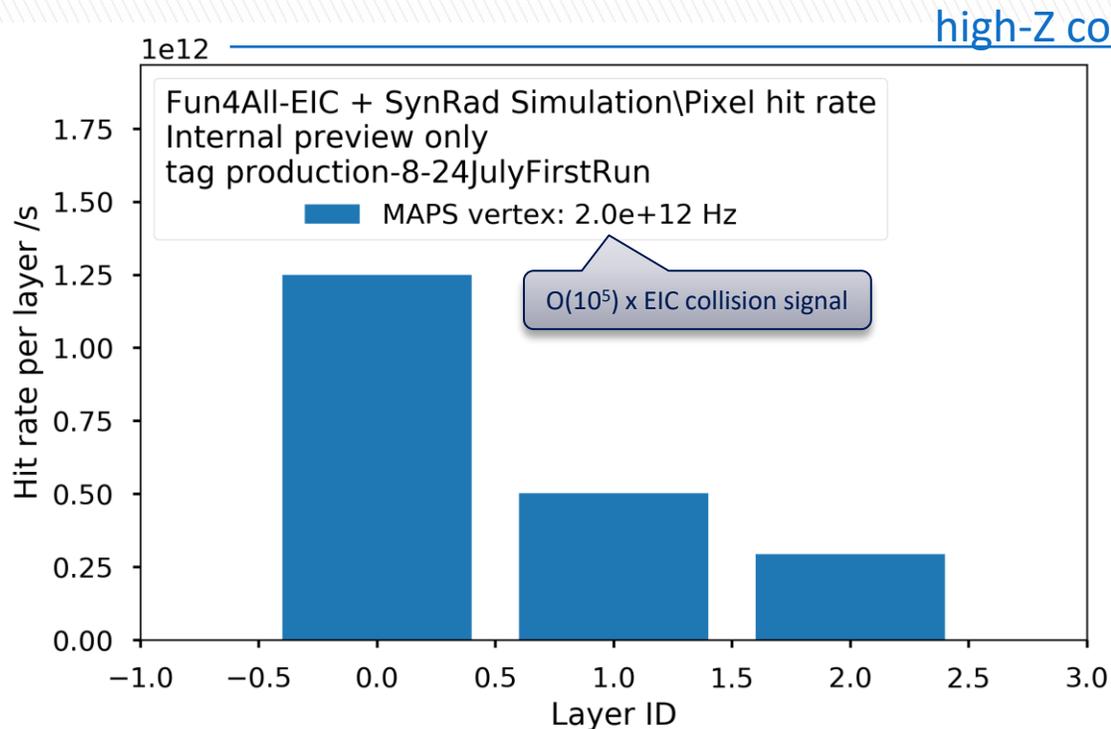


Photon on 30mil-Be and 300 $\mu\text{m}$  silicon

+2 $\mu\text{m}$  Au coating on be pipe  
0.06% X0 (30mil Be = 0.2% X0)

# 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 SVT prior to photon shield tuning, but high-Z coating on chamber, e.g. 2- $\mu\text{m}$  Au coating ( $0.06 X_0$ ) on Be pipe significantly reduces the synchrotron rate



Default 760 $\mu\text{m}$ -Be beam pipe

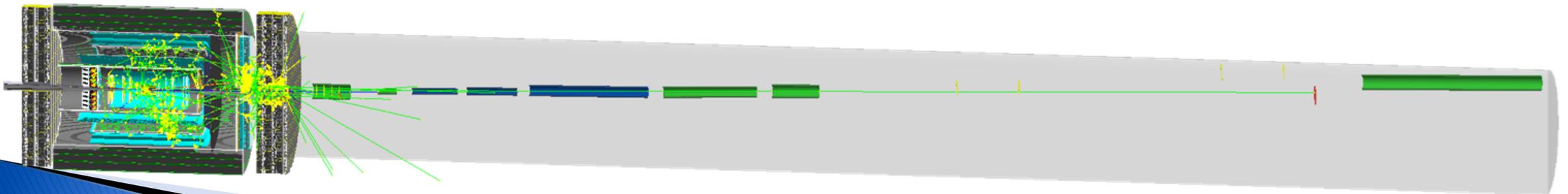
Dominated by dipole fan reflection. Expected to reduce with tuning

High-Z-coated beam pipe (+2 $\mu\text{m}$  Au)

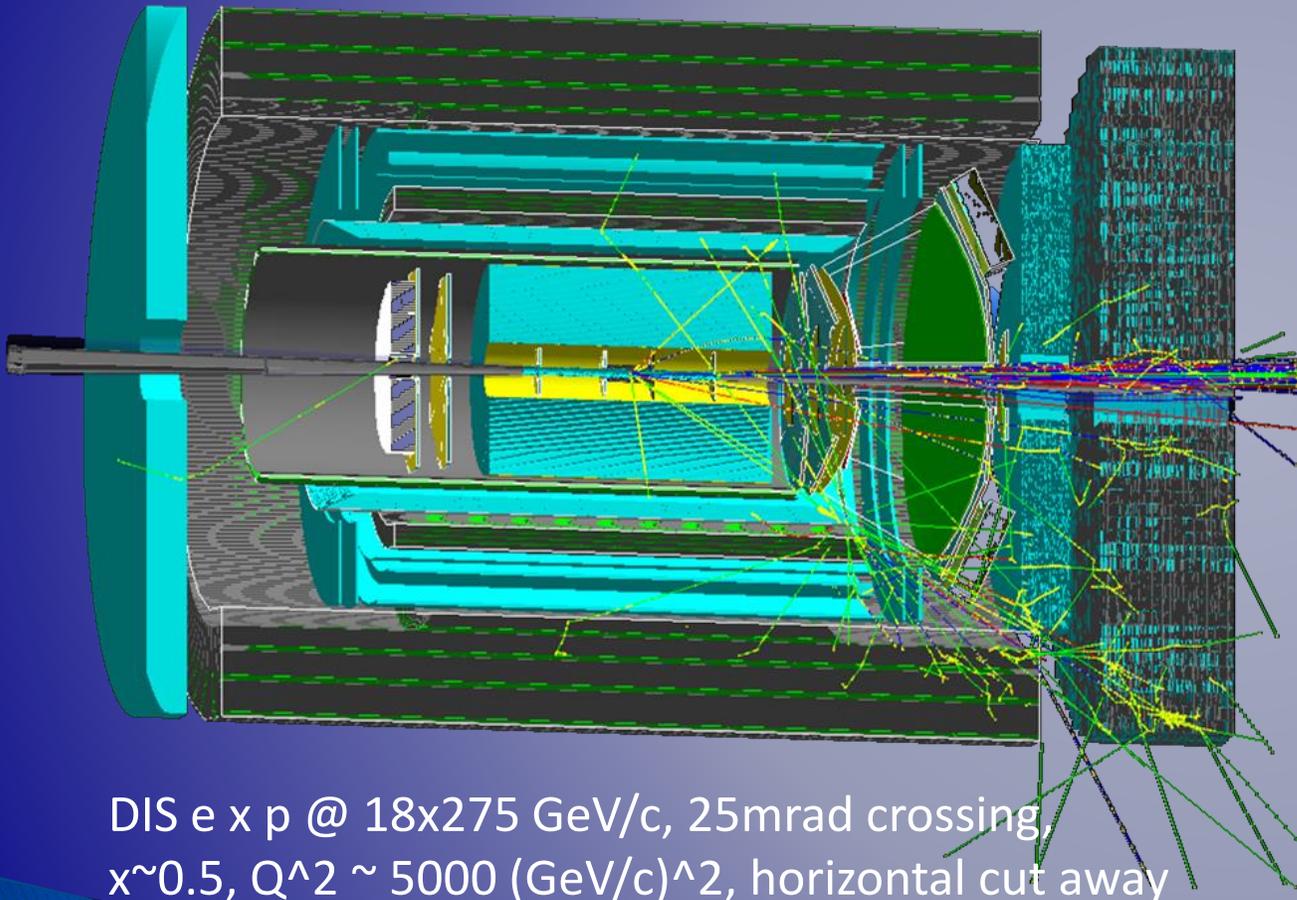
Dominated by dipole fan reflection. Expected to reduce with tuning

# Summary

- ▶ Precision low-cross section experiment desires low noise detector and low background
- ▶ Beam collision signal rate is very low comparing to RHIC and LHC
- ▶ Beam gas interaction in the exp. IR region is very low too
- ▶ Synchrotron rad radiation is quite concerning and uncertain, while EIC-project-sponsored design effort on-going to screen these photons upstream
  - Light coating of heavy element can significantly reduce Synchrotron hit in detector
  - Suggest simulate with 2-um Au coating on Be-pipe, which suppress background by four orders of magnitude and made the synrad background handle-able in May-2020 optics



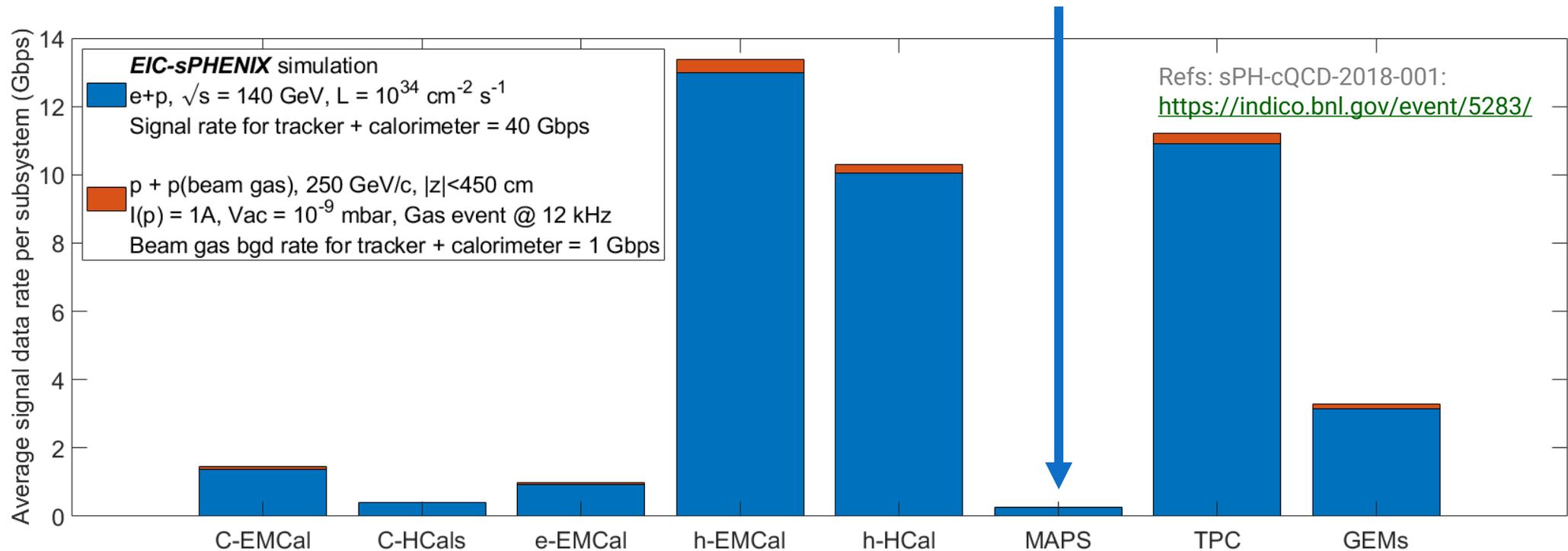
# Extra information



DIS e x p @ 18x275 GeV/c, 25mrad crossing,  
 $x \sim 0.5$ ,  $Q^2 \sim 5000 \text{ (GeV/c)}^2$ , horizontal cut away

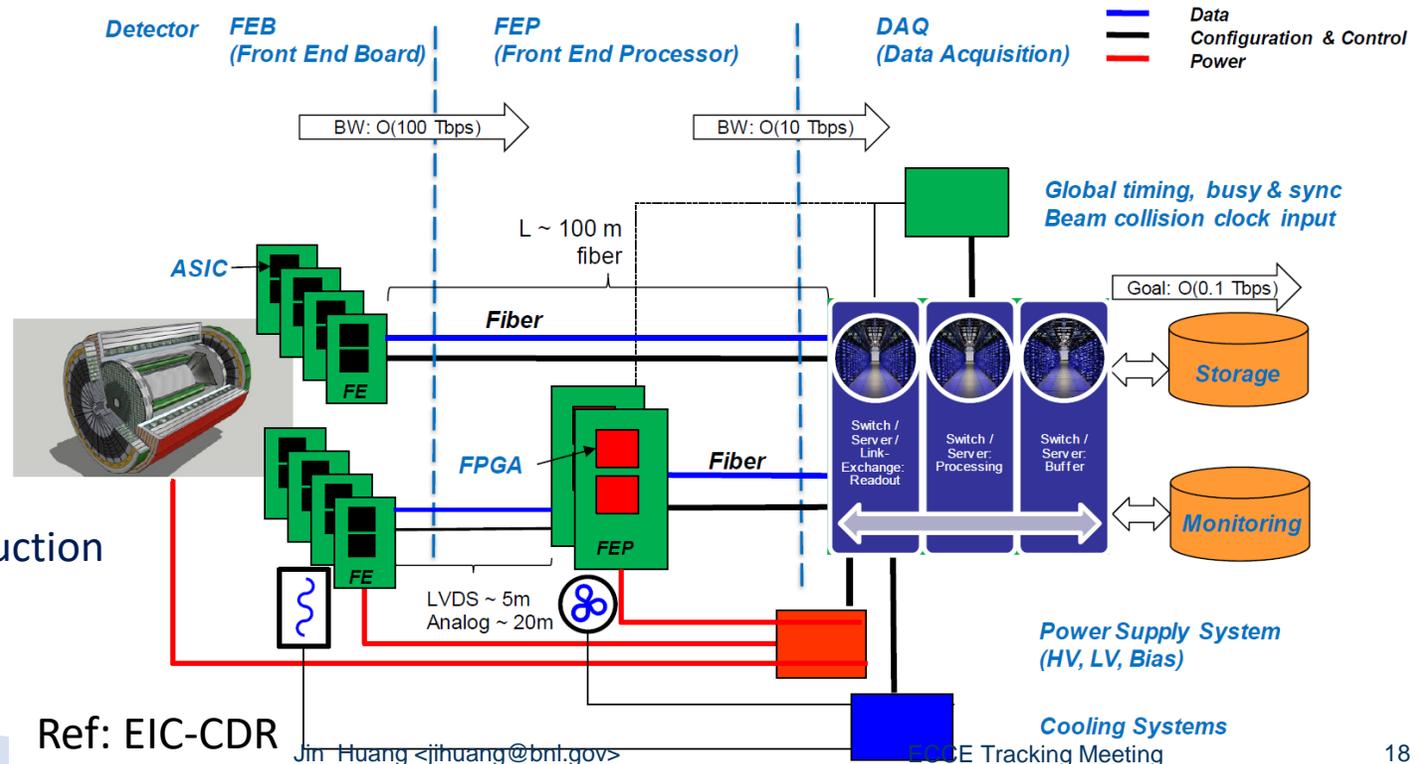
# Signal data rate -> DAQ strategy

- ▶ What we want to record: total collision signal  $\sim 100$  Gbps @  $10^{34}$  cm<sup>-2</sup> s<sup>-1</sup>
  - Assumption: sPHENIX data format, 100% noise, Less than sPHENIX peak disk rate.  $10^{-4}$  comparing to LHC collision
- ▶ Therefore, we could choose to stream out all EIC collisions data
  - In addition, DAQ may need to filter out excessive beam background and electronics noise, if they become dominant.
  - Very different from LHC, where it is necessary to filter out uninteresting p+p collisions (CMS/ATLAS/LHCb) or highly compress collision data (ALICE)
- ▶ Collision induced signal data from barrel silicon tracker is very moderate, but important considerations on additional rates from detector noise, synchrotron radiation and photon production rates (later slides)



# Strategy for an EIC real-time system

- ▶ For the signal data rate from EIC (100 Gbps, link), we can aim for filtering-out from background and streaming all collision without a hardware-based global triggering
  - Diversity of EIC event topology → streaming DAQ enables expected and **unexpected physics**
  - Streaming **minimizing systematics** by avoiding hardware trigger decision, keeping background and history
  - Aiming at 500kHz event rate, **multi- $\mu$ s-integration detectors** would require streaming, e.g. TPC, MAPS
- ▶ **EIC streaming DAQ**
  - Triggerless readout front-end (buffer length :  $\mu$ s)
  - DAQ interface to commodity computing (e.g. FELIX/CRU). Background filter if excessive bgd rate
  - Disk/tape storage of streaming time-framed zero-suppressed raw data (buffer length : s)
  - Online monitoring and calibration (latency : minutes)
  - Final Collision event tagging in offline production (latency : days+)

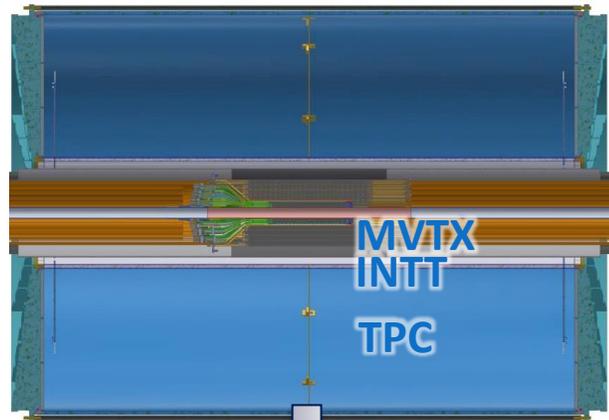


# Large-scale streaming readout towards EIC

- CRU/FELIX-based large-scale streaming DAQ application in ALICE, LHCb, sPHENIX and CBM [See also Last talk by Jo]
- Demonstrating streaming data mode with CLAS-12 and Hall-D calorimeters [[link to SRO VI](#)]



Precision timing digitizer DRS4GIO (SBIR/LDRD)

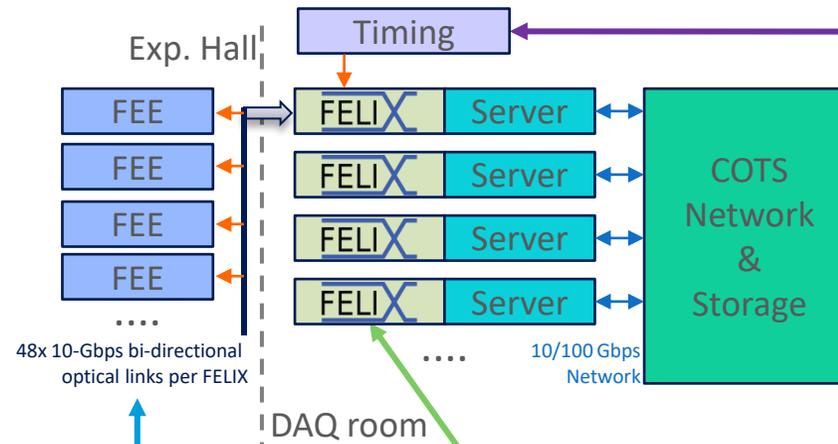


MVTX RU, 200M ch ALPIDE (ALICE/sPHENIX), FPHX (PHENIX)

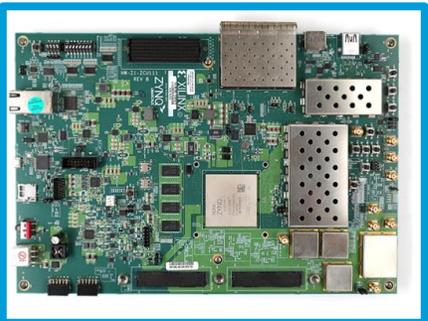


INTT ROC, 400k ch

## sPHENIX streaming DAQ for tracker



Global Timing Module (NSLS II/sPHENIX) To test with RHIC RF low glitter clock source



High density multiplexer+ ADC RFSoc Digitizer (LDRD)



TPC FEE, 160k ch



BNL-712 / FELIX v2 x48 (ATLAS/sPHENIX)

SAMPv5 (ALICE/sPHENIX)

# Streaming-DAQ enabled scientific connection:

## Gluon dynamics via heavy flavor $A_N$

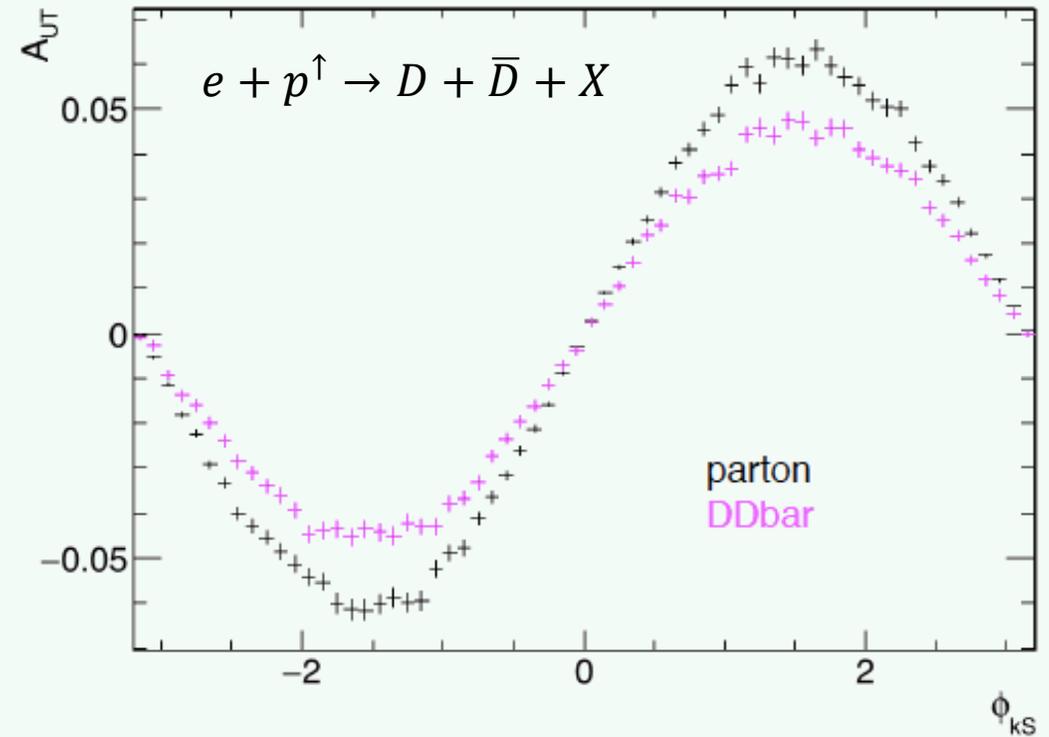
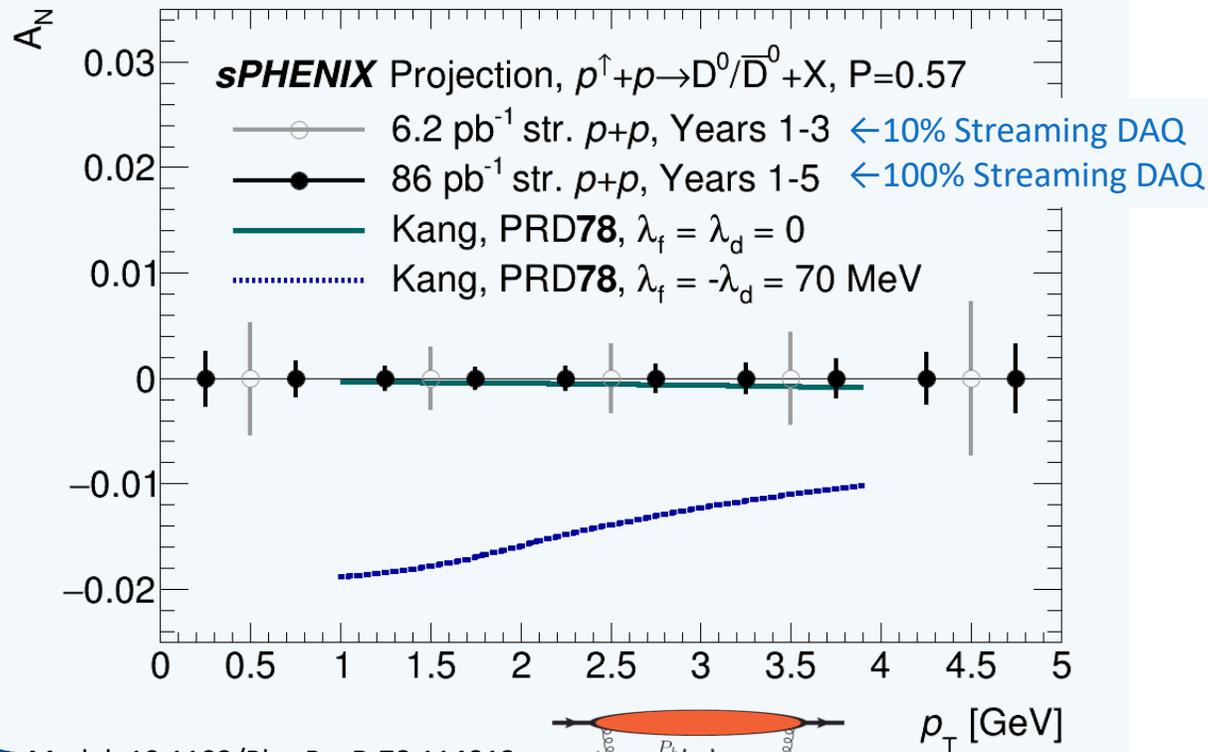
Join our CNFS HF@EIC workshop:

November 4-6, 2021, announcement to come

← Universality test on gluon Sievers →

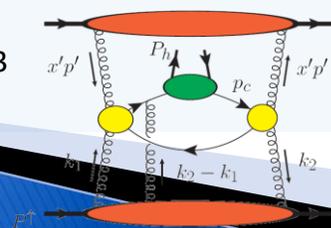
sPHENIX  $D^0$  trans. spin asymmetry,  $A_N \rightarrow$  Gluon Sievers via tri-g cor.

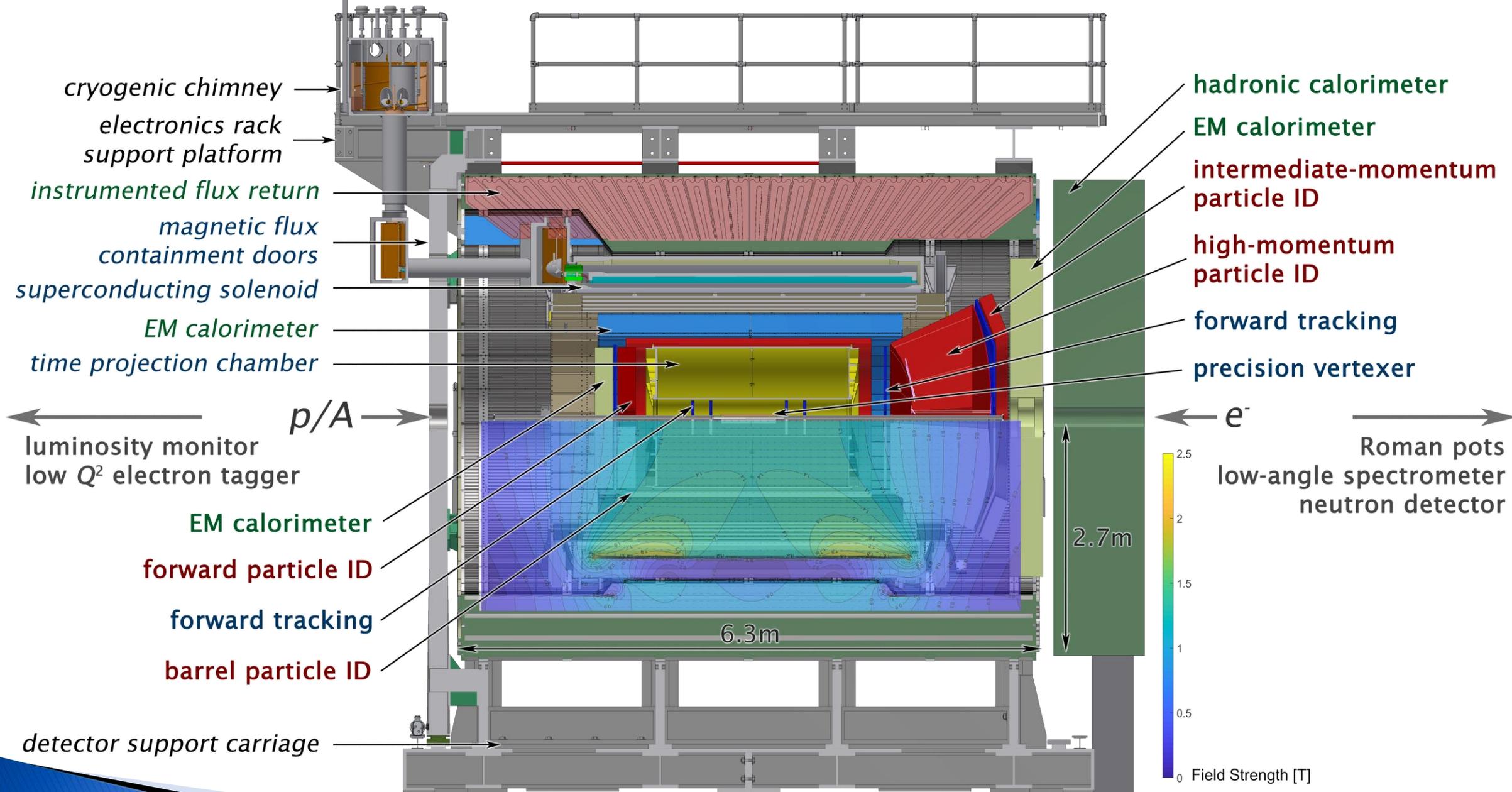
EIC SIDIS  $D^0$  transverse spin asymmetry  $\rightarrow$  Gluon Sievers



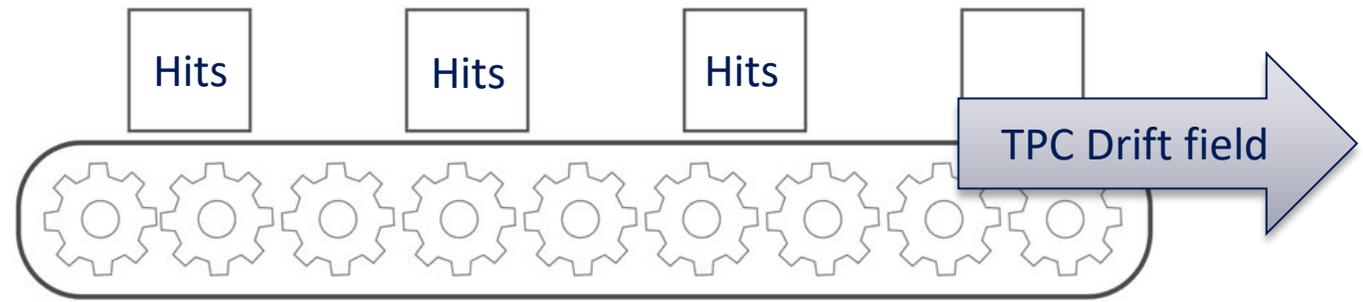
From Day-1 talk: X. Dong

Model: 10.1103/PhysRevD.78.114013

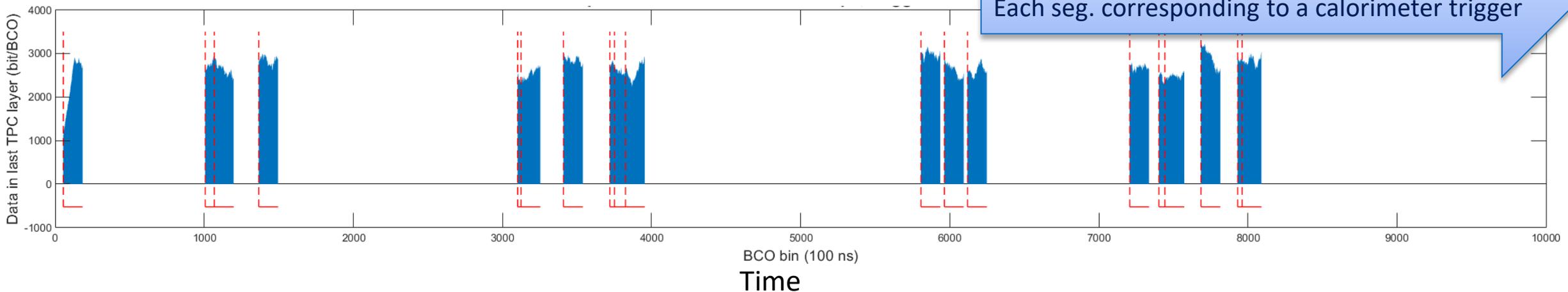
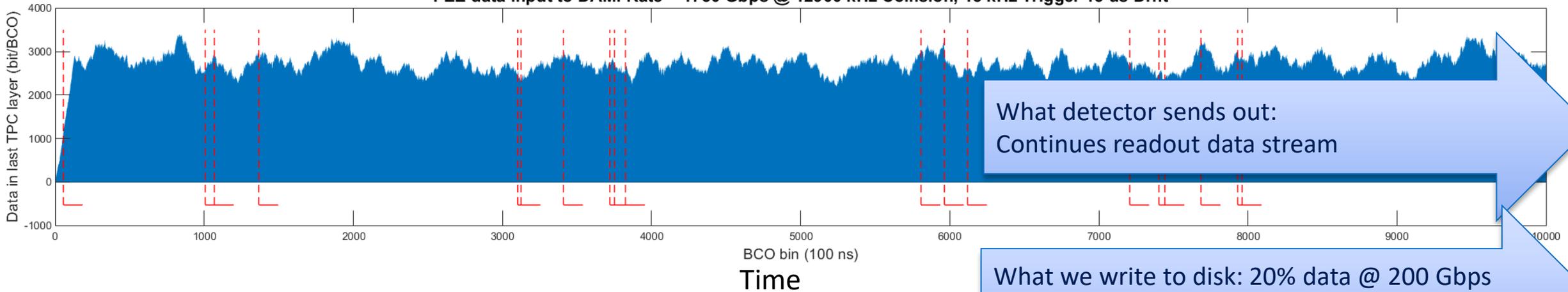




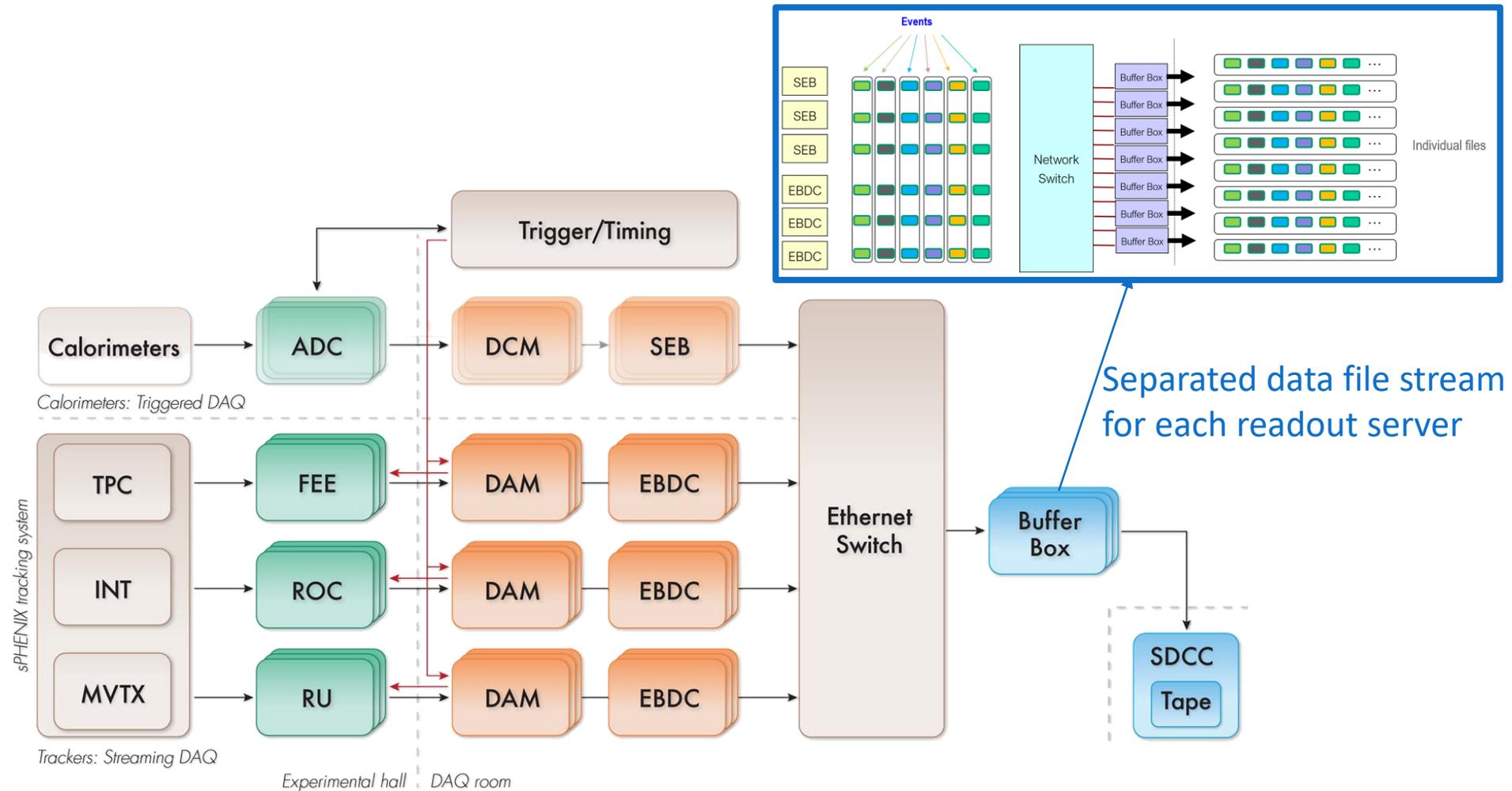
# TPC data stream in sPHENIX triggered DAQ



FEE data input to DAM. Rate = 1730 Gbps @ 12900 kHz Collision, 15 kHz Trigger 13 us Drift



# Readout hardware in current plan



See [Collaboration meeting DAQ talk by M. Purschke](#)