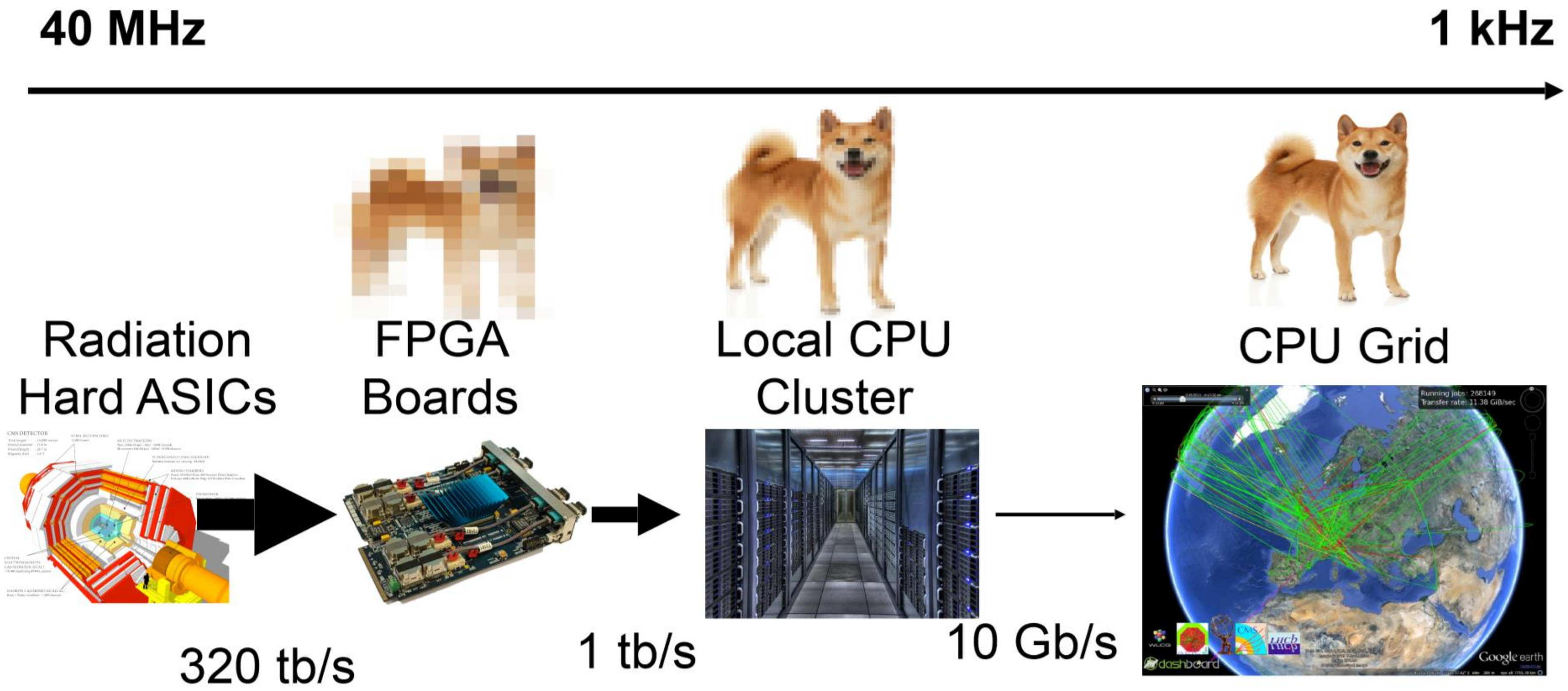
Introduction to Readout Session

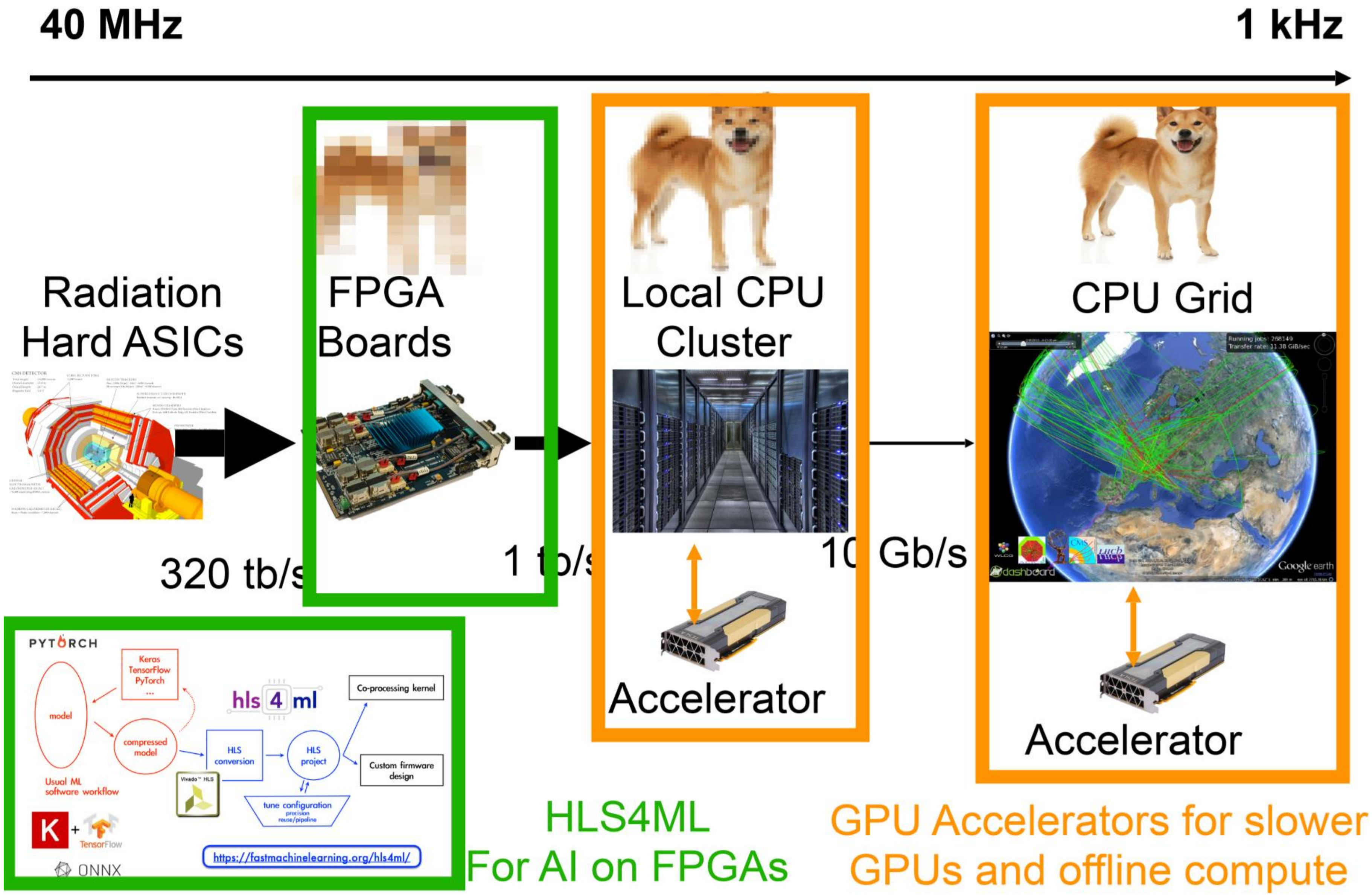
Philip Harris
Massachusetts Institute of Technology

Jin Huang
Brookhaven National Lab

AI and Data readout at LHC



AI and Data readout at LHC



EIC: unique collider
→ unique readout 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} cm^{-2} s^{-1}	10^{32} cm^{-2} s^{-1}	10^{34} → 10^{35} cm^{-2} s^{-1}
x-N cross section	**50 μb**	**40 mb**	**80 mb**
Top collision rate	500 kHz	10 MHz	1-6 GHz
$dN_{ch}/d\eta$ in p+p/e+p	0.1-Few	~3	~6
Charged particle rate	**4M N_{ch}/s**	**60M N_{ch}/s**	**30G+ N_{ch}/s**

- EIC luminosity is high, but collision cross section is small ($\propto \alpha_{EM}^2$) → low collision signal rate
- EIC events are precious and have diverse topology → stream recording all collision data
- Background and systematic control is crucial → AI data reduction, understand AI biases

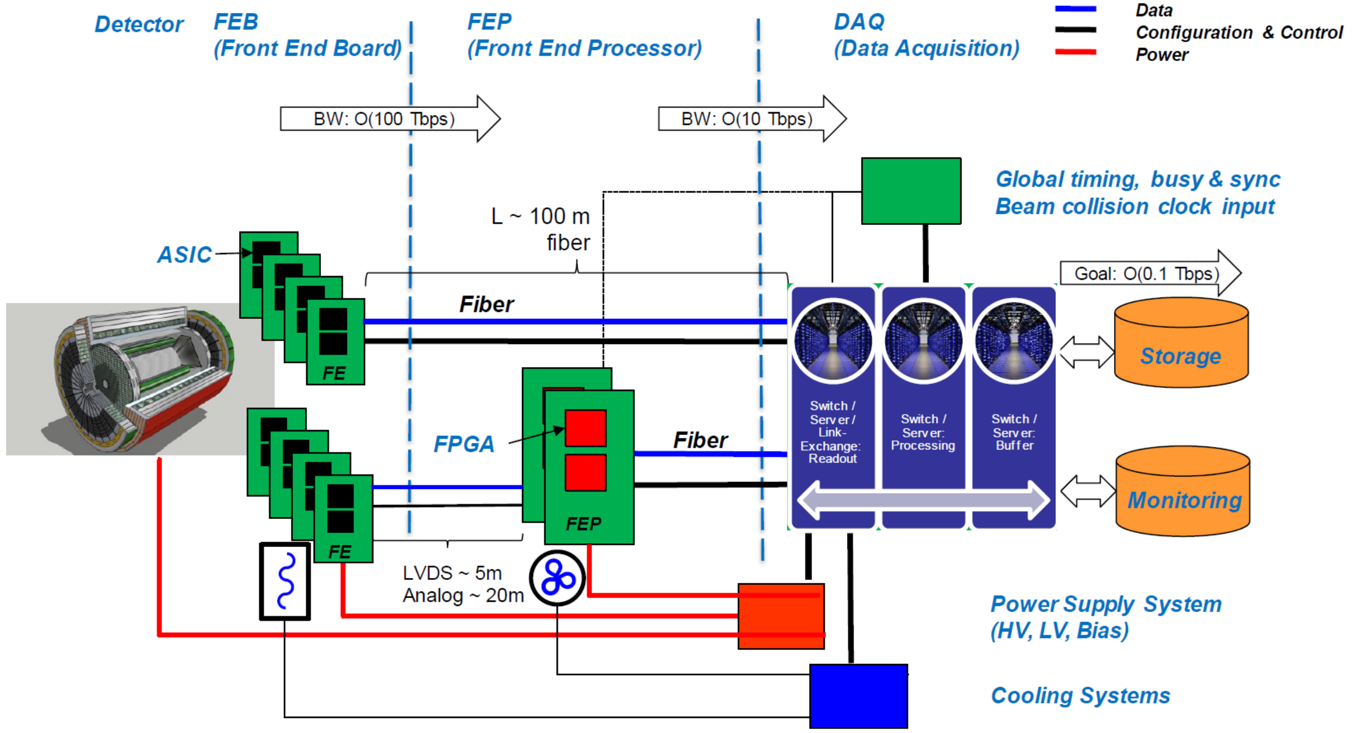
Real-time computing for streaming data pipeline

- Despite low signal rate, the raw data rate can be filled with noises and background
- Bright opportunities for

1. Streaming data reduction to fit permanent storage
2. Monitoring, feedback to detector/machine control
3. Online event reconstruction

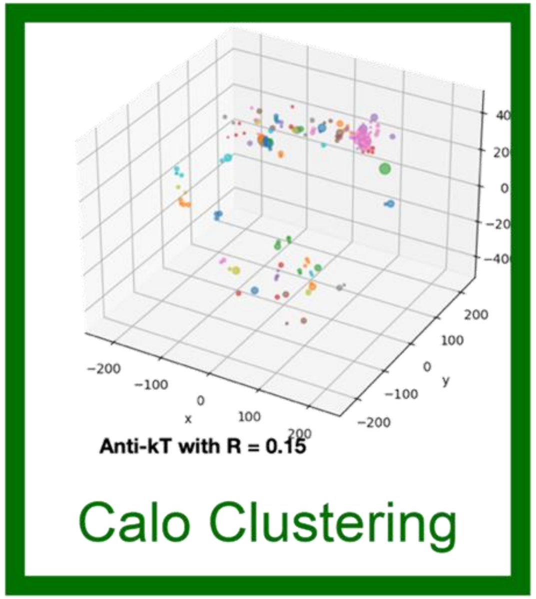
ASIC, FPGA | FPGA, TPU, GPU, CPU

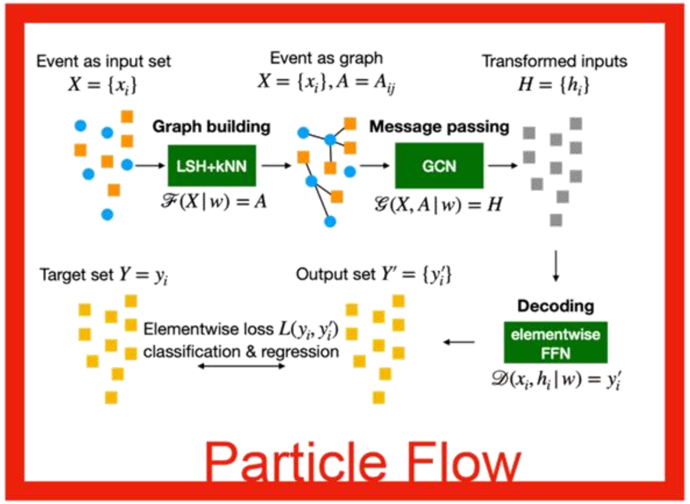
Digitizer BW: 10^2 Tbps → Readout BW: 10^2 Tbps → Storage: 10^{-1} Tbps



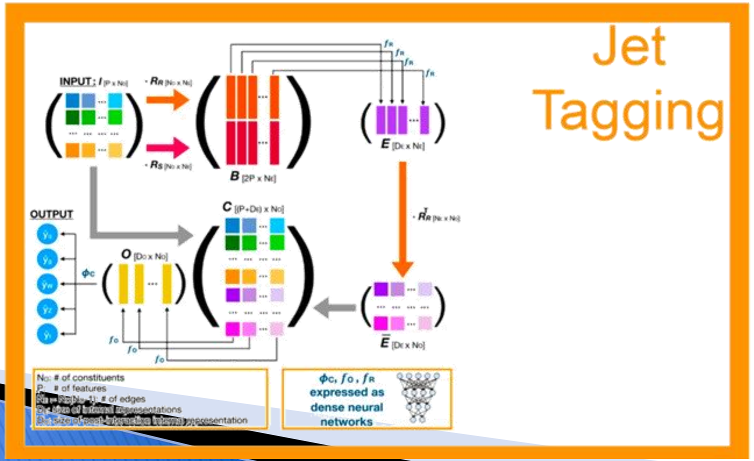
[EIC CDR]

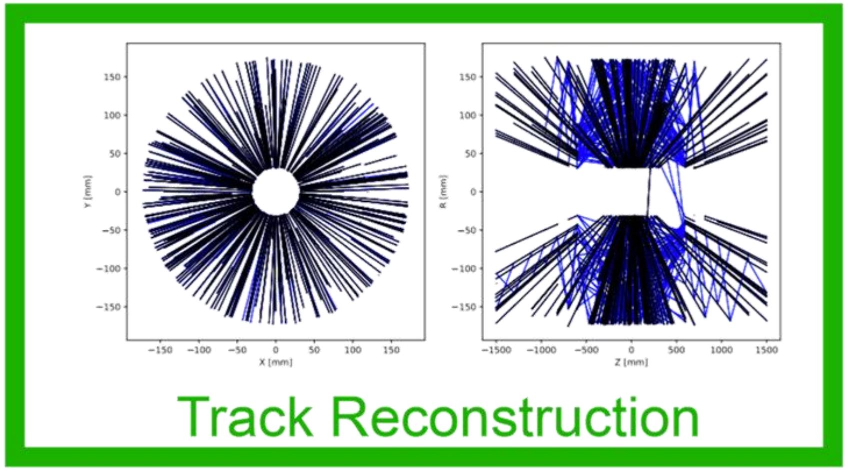
Variety of AI Algorithms





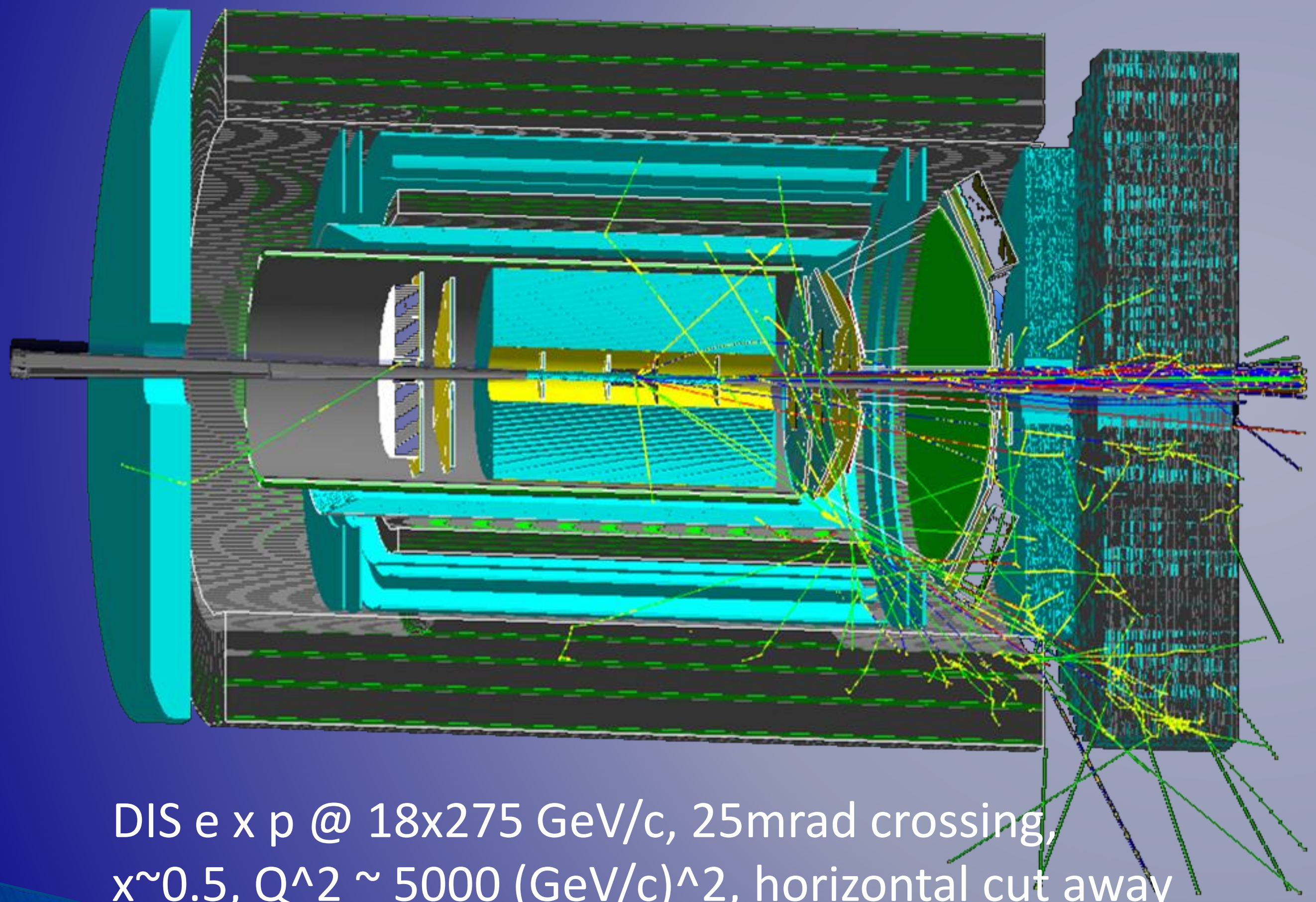
Many AI Algorithms are in the pipeline





This session: AI application to EIC Readout

- Global overviews:
  - AI in readout at HEP: Dylan Rankin (MIT)
  - EIC Readout Overview: Fernando Barbosa (JLab)
- AI Applications
  - Real-time AI tracking and tagging:
    Dantong Yu (NJIT)
  - Real-time data compression with Bicephalous Convolutional Auto-Encoder:
    Yi Huang (BNL)
  - Event tagging and triggering on FPGA:
    Sergey Furletov (JLab)



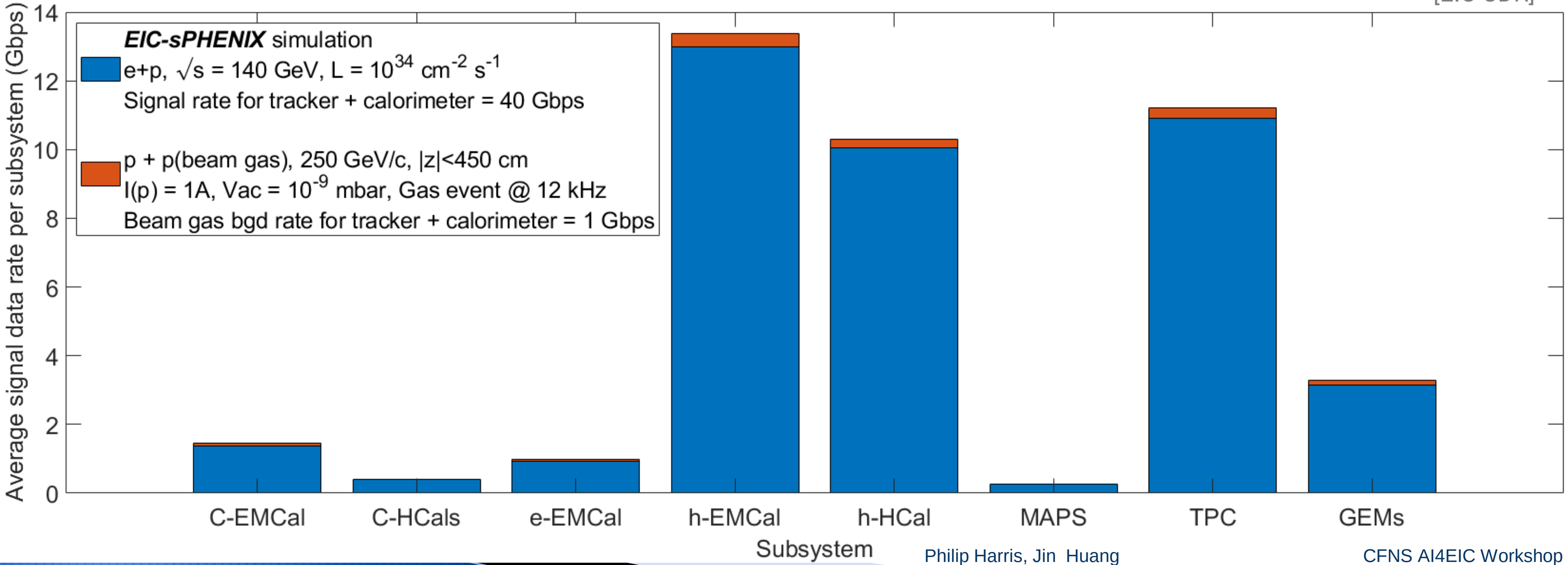
Extra information

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

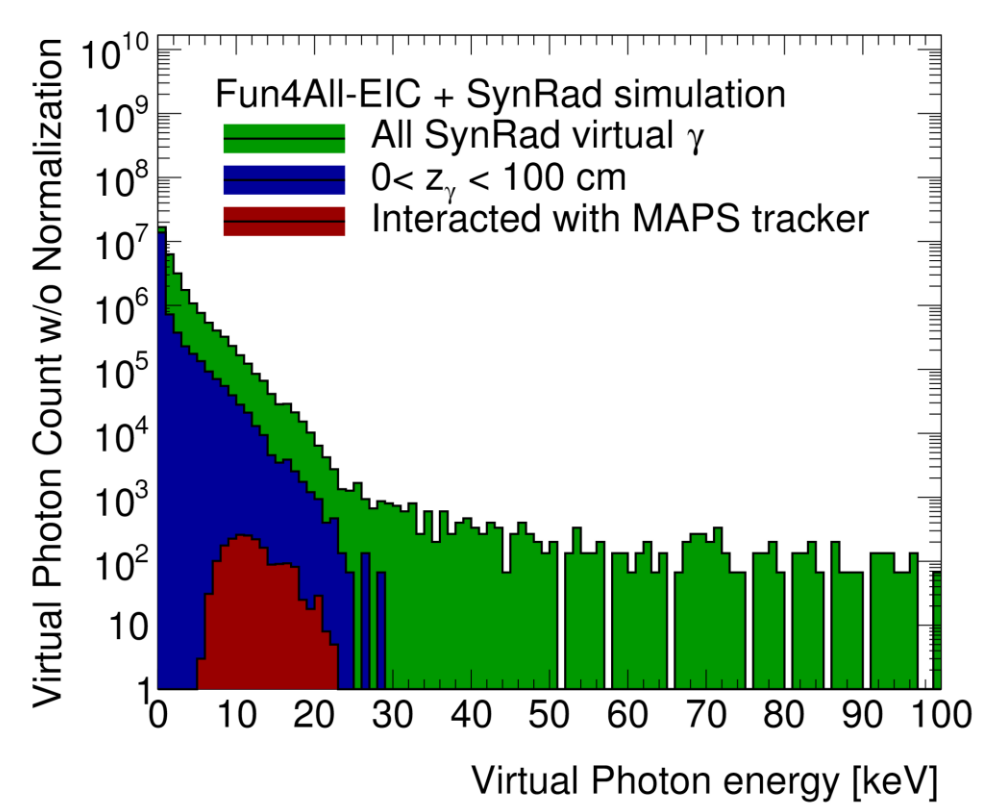
Signal data rate -> DAQ strategy

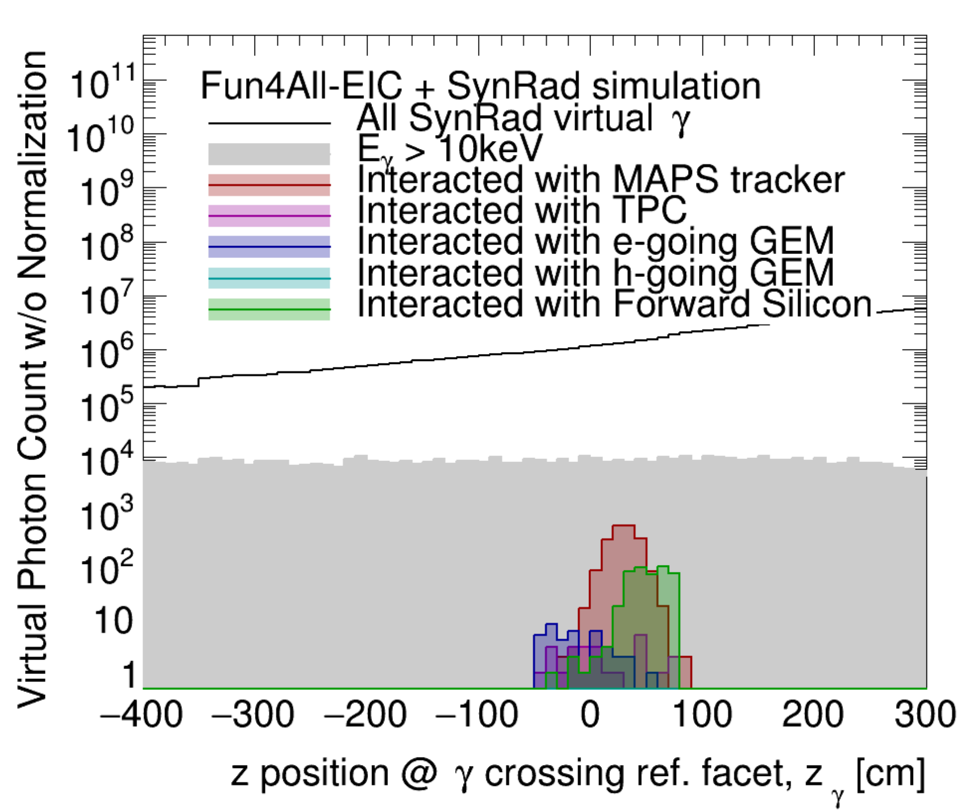
- What we want to record at the end: total collision signal ~ 100 Gbps @ 10^{34} cm^{-2} s^{-1}
- Therefore, we could choose to stream out all EIC collisions data
- Orders of magnitude different from LHC, where it is necessary to filter out uninteresting p+p collisions (CMS/ATLAS/LHCb) or highly compress collision data (ALICE)

[EIC CDR]



But, that is not the whole story: e.g. synchrotron background is still uncertain!





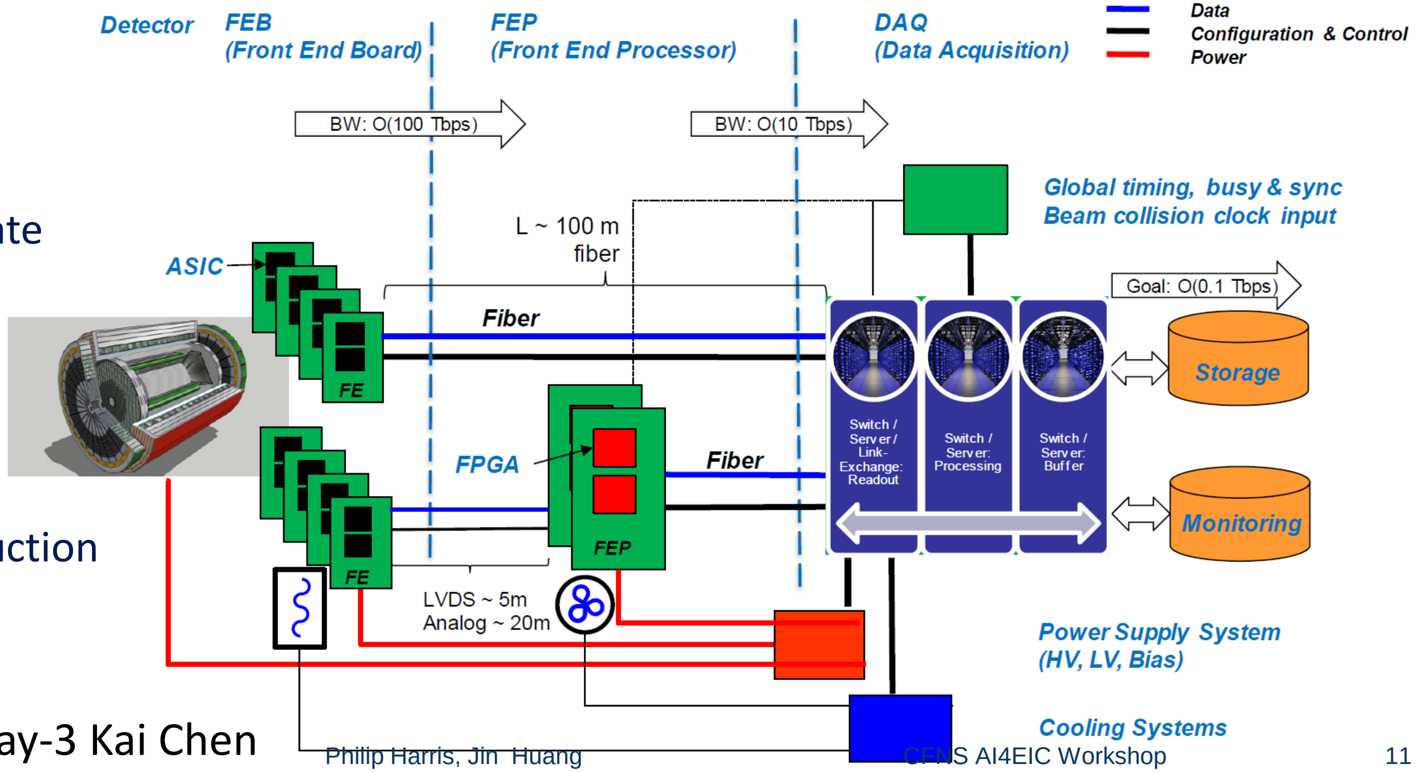
Energy dependence of MAPS vertex tracker to synchrotron

Beam-pipe exit-location

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

Strategy for an EIC real-time system

- For the signal data rate from EIC (100 Gbps, see also 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-μs-integration detectors would require streaming, e.g. TPC, MAPS
- **EIC streaming DAQ**
  - → Triggerless readout front-end (buffer length : μs)
  - → DAQ interface to commodity computing (e.g. FELIX/CRU). Background filter if excessive background 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+)

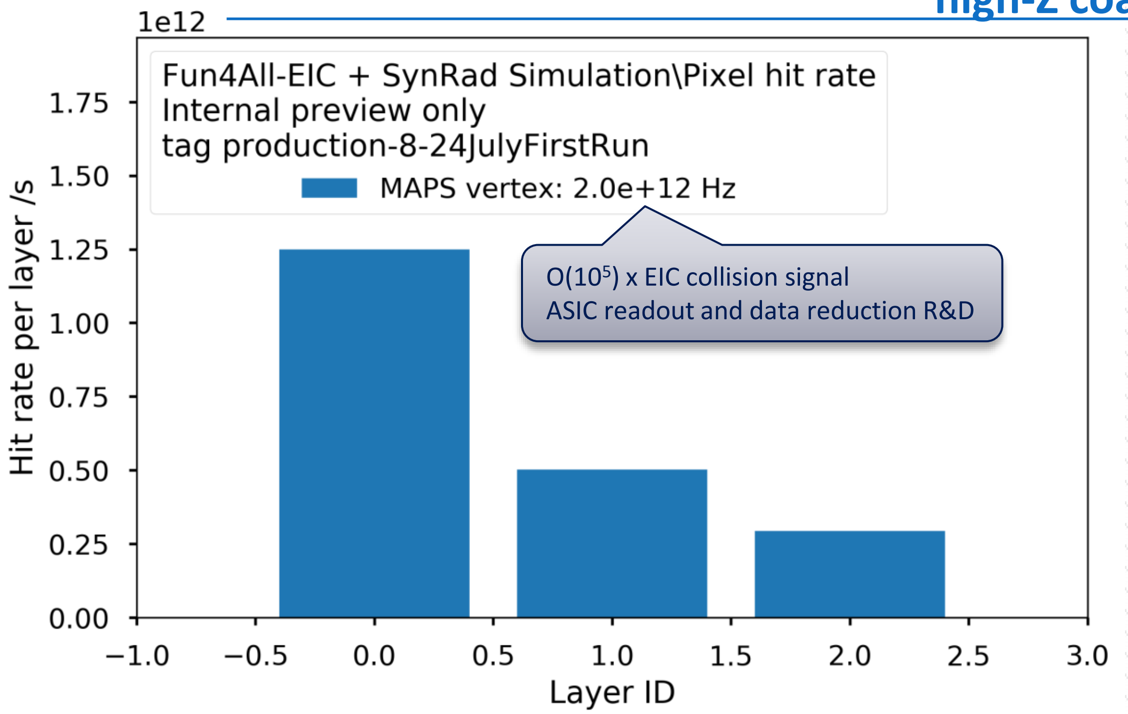


Ref: EIC-CDR, See also Day-3 Kai Chen

Synchrotron background: detector response

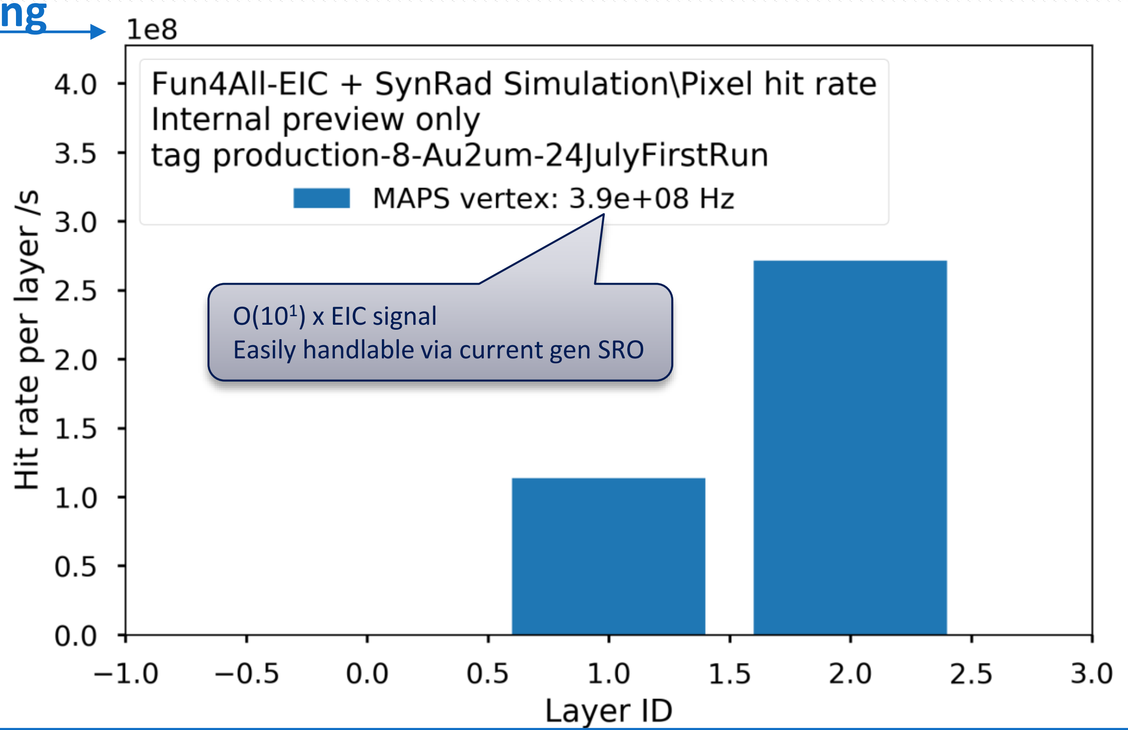
- In the most recent lattice + beam chamber geometry, there is a known issue with main dipole fan reflect over far upstream beam chamber to Be-beam pipe section.
- Beam chamber tuning on-going, expect to reduce by orders of magnitude [DO NOT QUOTE THIS RATE]
- The reflected dipole fan induce high hit 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