Simulating Cerenkov photons on GPU

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Detector simulations at EIC

- Why are detector (Monte Carlo) simulations useful?
  - Detector performance
    - Accurate modeling of detector response
    - Optimization of detector design
  - Data analysis and interpretation
    - Event reconstruction
  - Calibration and alignment
  - Fundamental research:
    - Testing theoretical models

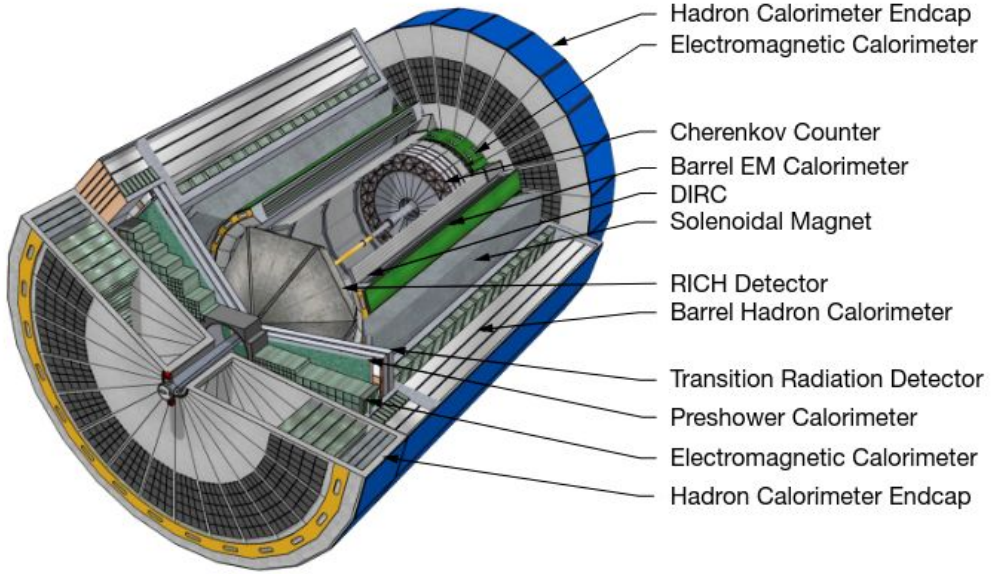
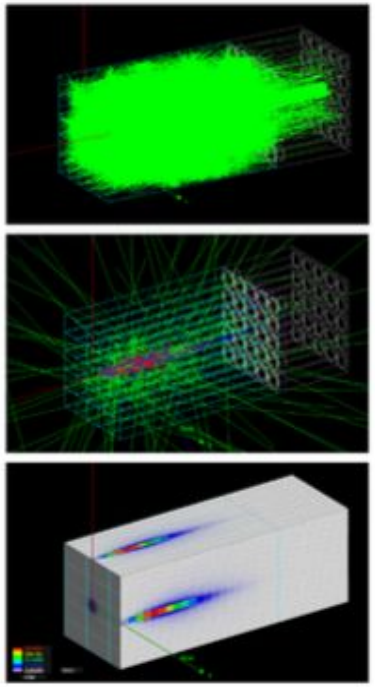


Figure 9.2: A cutaway illustration of a generic EIC concept detector.

https://arxiv.org/pdf/2103.05419

Detector simulations at EIC

- The problem with detector simulations:
  - Can be very slow for complex geometry and interaction
- For Cerenkov detectors and calorimeters ~99% of time is spent on simulating optical photons



- Full simulation with optical photon transport to photo-multipliers
  - 18.41 sec/event

x 154

- Full simulation without optical photon transport
  - 0.119 sec/event

x 137

- Shower parameterization with GFlash
  - 0.00087 sec/event

5 GeV electron in an Electromagnetic calorimeter, with Geant4 tools using eAST

How to make MC simulations faster?

- Let’s use GPUs!
- Many projects building generic MC sim. on GPUs for years
  - Very hard
- Low hanging fruit:
  - GPU for optical photon simulation only
  - What makes it faster?
  - Gaming!

This is a calculation on GPU!

MARBLES! Watch Nvidia's entire breathtaking Ampere GPU visual demo

ASUS TUF Gaming NVIDIA GeForce RTX 3080

How to make MC simulations faster?

- Let's use GPUs!
- Many projects building generic MC sim. on GPUs for years
  - Very hard
- Low hanging fruit:
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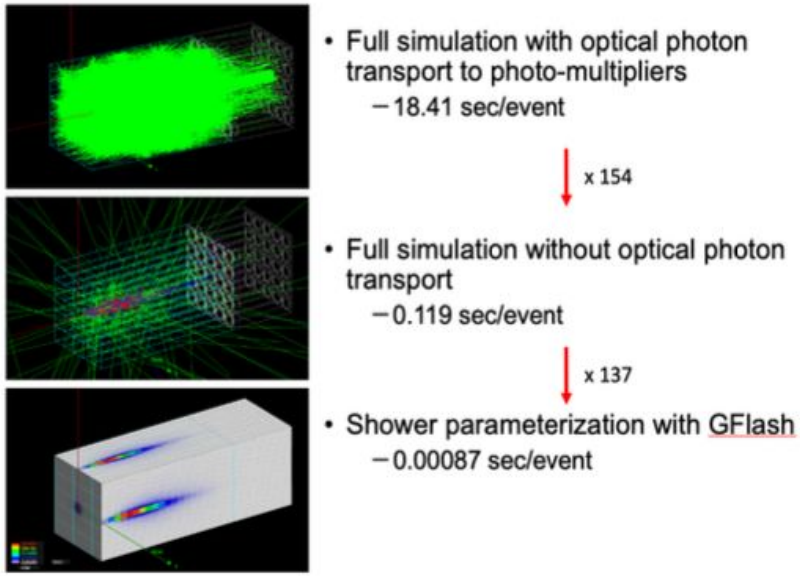
- Main tasks:
  - Convert detector geometry into GPU compatible one
  - Implement all the optical physics on GPU
    - Rayleigh scattering, Fresnel reflection, polarization…
  - Transfer optical photon data to GPU
  - Perform ray-tracing
  - Return results from GPU and integrate with other SW

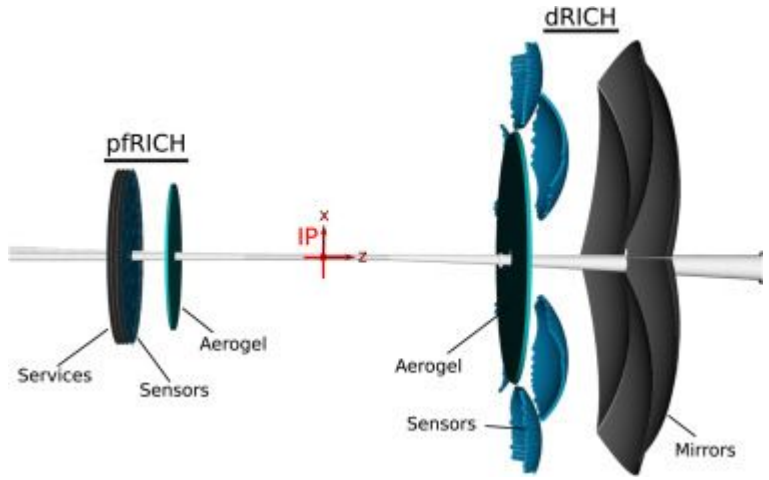


5 GeV electron in an Electromagnetic calorimeter, with Geant4 tools using eAST

Where to use at EIC?

- We will use proximity-focusing Ring Imaging CHerenkov (pfRICH) detector to test our GPU optical photon propagation
- Then the next target is dual-radiator Ring Imaging Cherenkov (dRICH)
- Simulating Cerenkov photons on GPU will yield 10-100x faster detector simulations
    - We can simulate a lot of detector geometries

      -> better detector optimization



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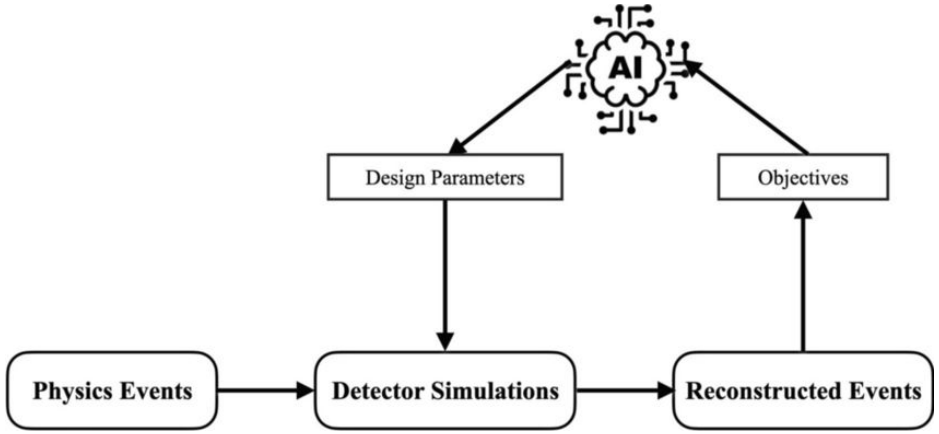
  - Provide more data to ML -> better detector optimization with ML
  - Artificial Intelligence for the Electron Ion Collider (AI4EIC)



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