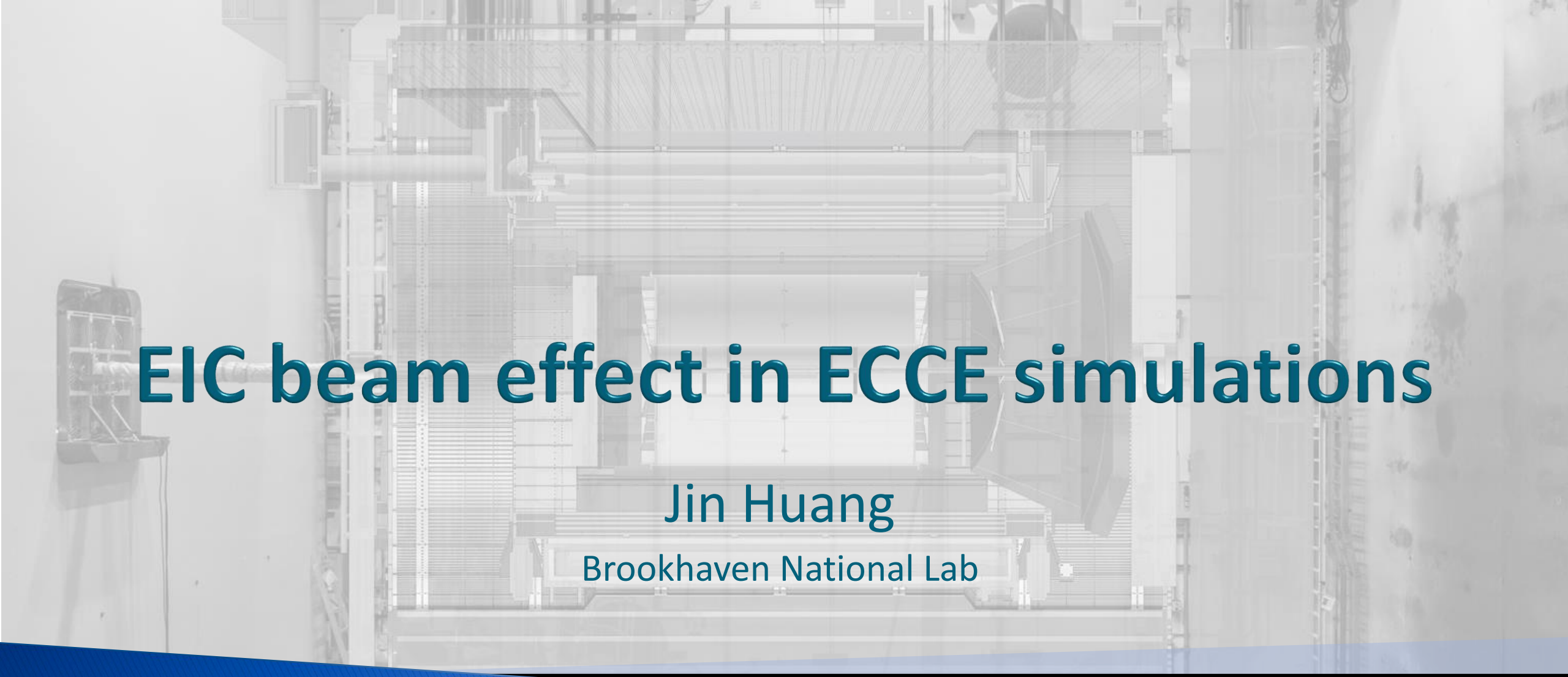


EIC beam effect in ECCE simulations

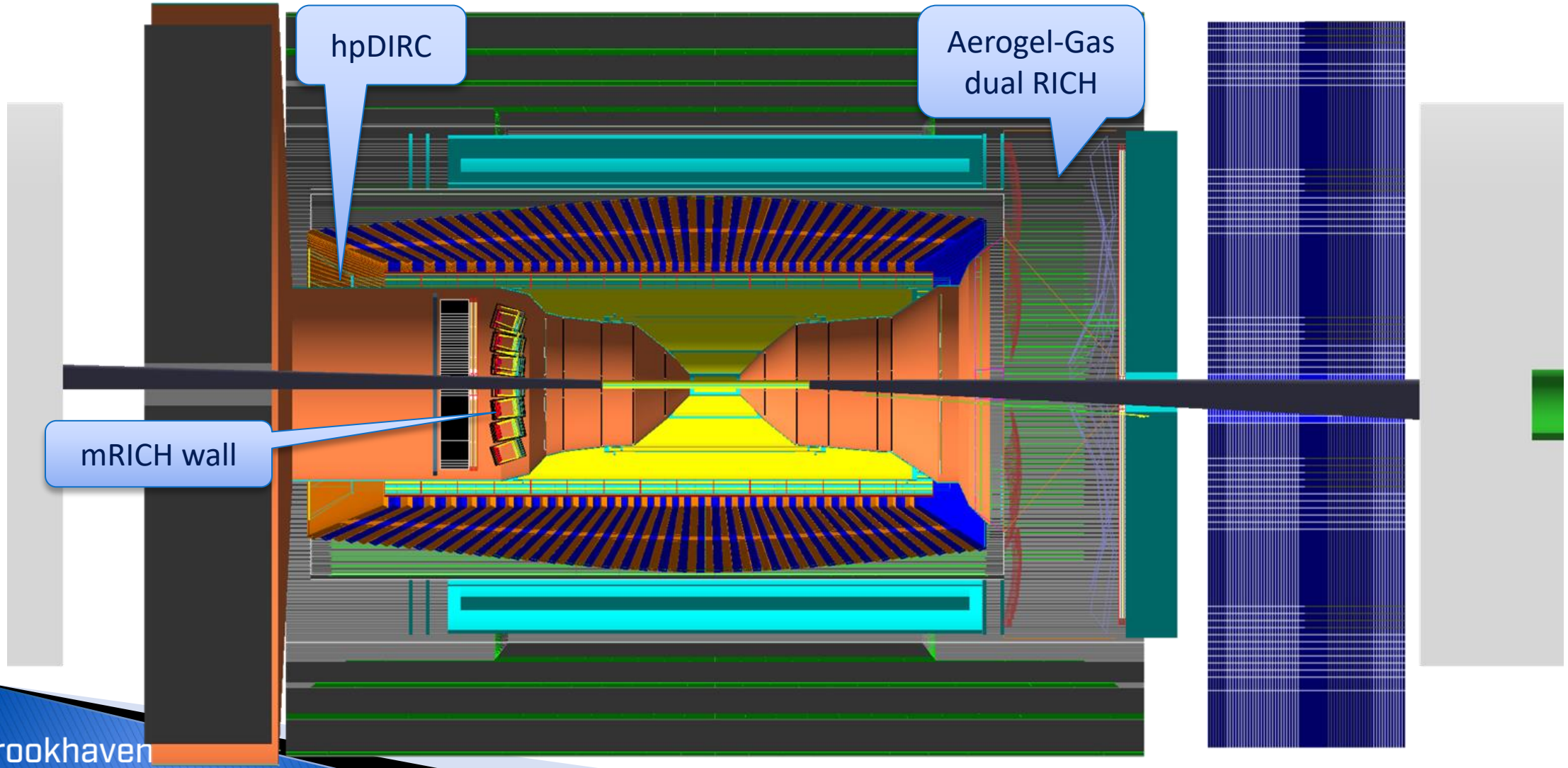
Jin Huang

Brookhaven National Lab

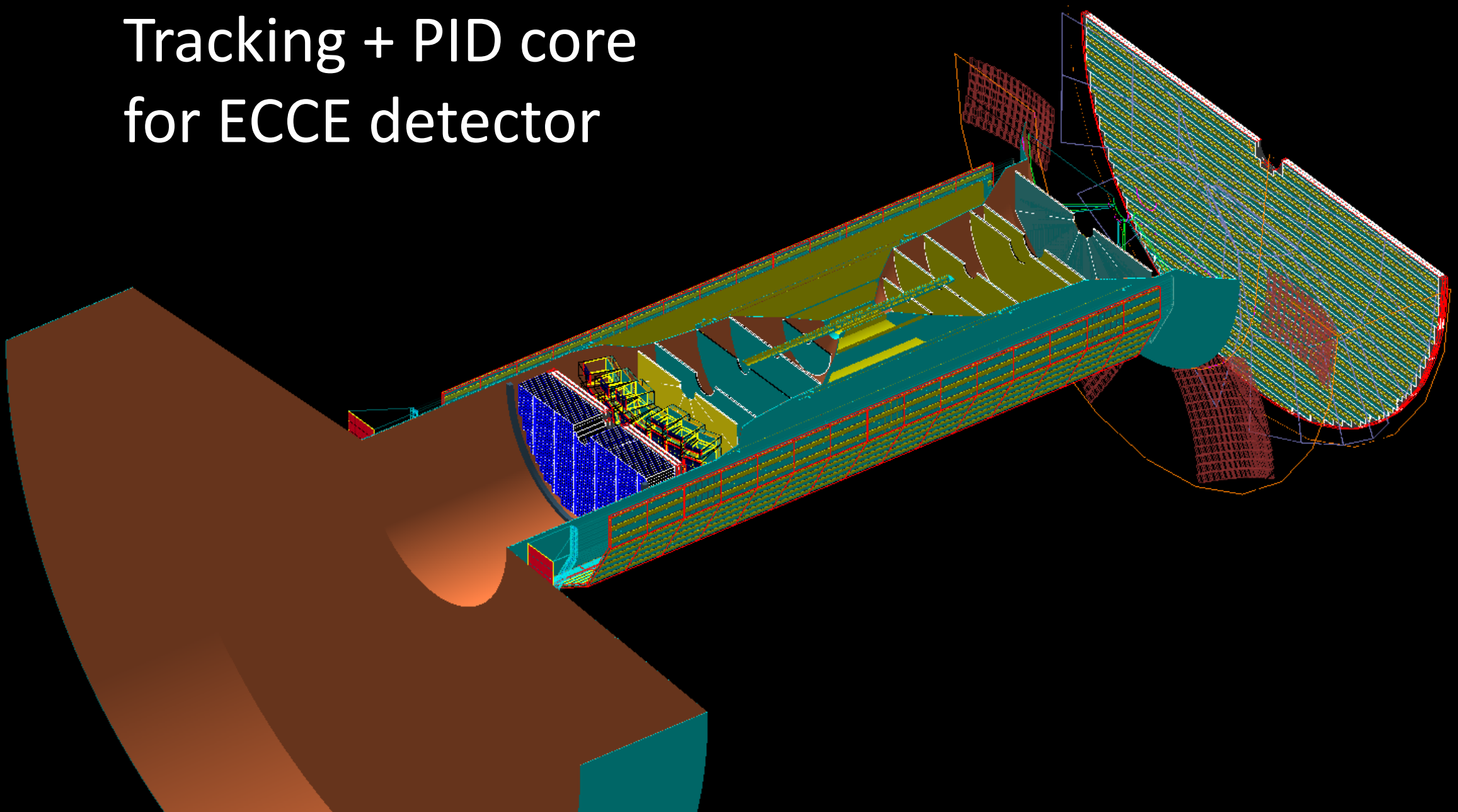
Brookhaven National Laboratory

Any green text is a clickable link

ECCE detector in current simulation production

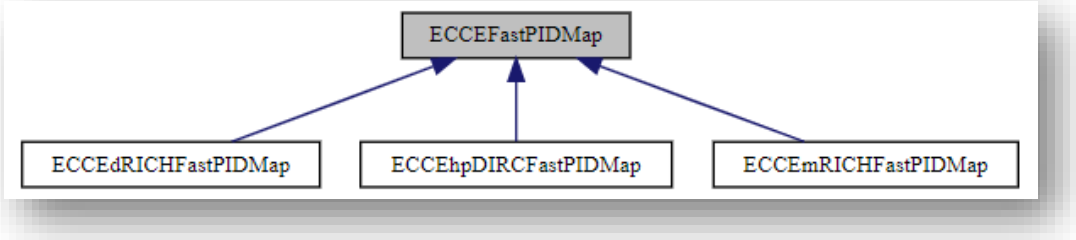


Tracking + PID core for ECCE detector

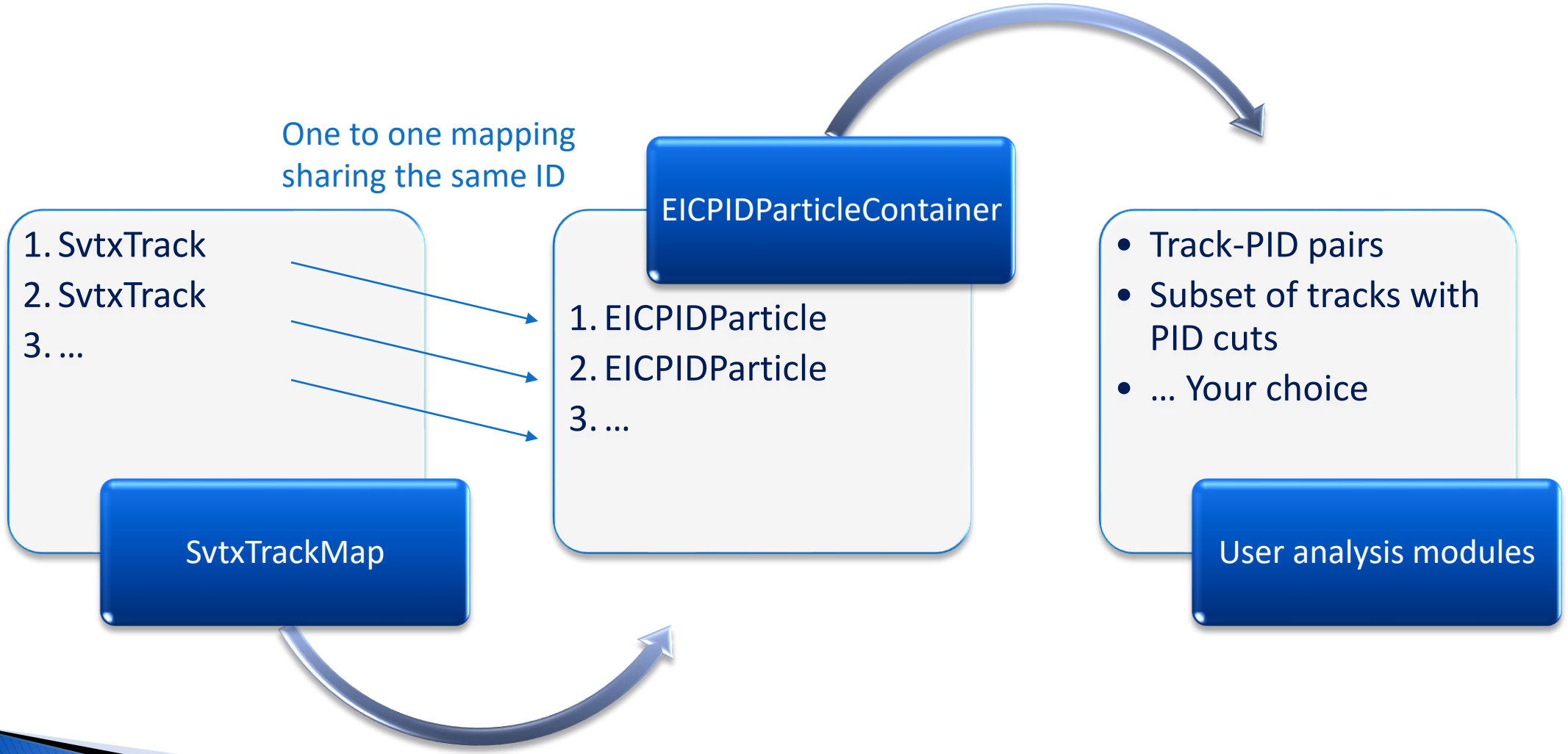


Concept

- PID group implemented detailed PID detectors in Geant4 simulation
- Digitization and reconstruction is still in the work
- Therefore, we will start the physics projection with fast parameterization of the *Cherenkov* PID detector performance, initially provided by PID group https://github.com/ECCE-EIC/ecce-detectors/tree/master/FastPID
- A set of infrastructure allow us to use these parameterization integrated in the simulation-reconstruction workflow.
- Switch to full RICH PID reconstruction will be transparent to analyzers
- Very recent addition, call for volunteer to help (1) validation (2) maintain parameterization

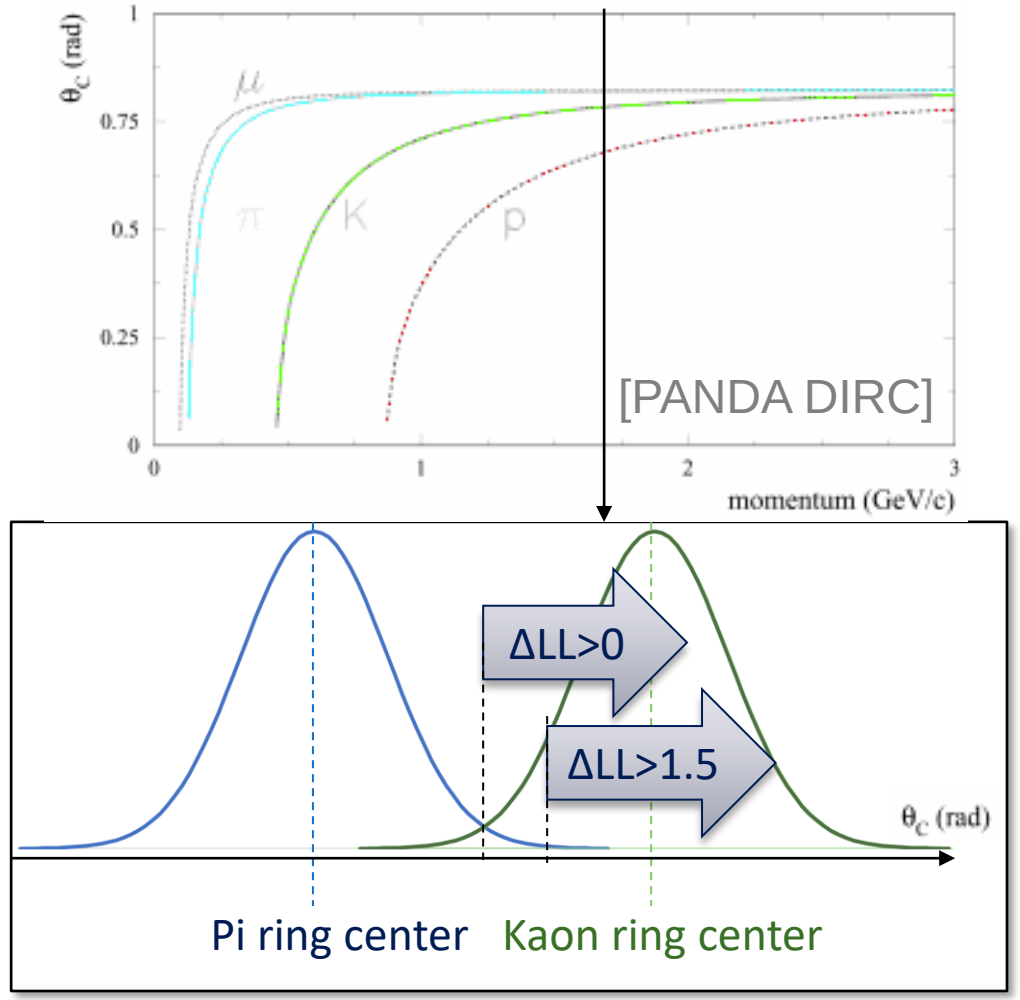


PID information representation on DST



PID information representation in EICPIDParticle

- As in many PID analysis, we use a log-likelihood (LL) to represent the *relative* likelihood of a track under a specific PID hypothesis : e/μ/π/K/proton
  - e/mu parameterization only provided by DIRC
- Hypothesis test based on ΔLL or Likelihood ratio
  - Analyzer choice to choose cut & working point
  - e.g. LL[K] - LL[π] >0 for particle flow jet sample and LL[K] - LL[π] >1.5 for purer kaon in Δs measurement
  - As fastPID is based on Gaussianess assumption of PID measurement, ΔLL~-0.5*ΔChi2
  - If two particle can not be differentiated, they are assigned the same LL.



PID information representation in EICPIDParticle

- Loglikelihood are stored as 2D matrix:
  [mRICH/DIRC/AeroGel/Gas detector] x
  [e/mu/pi/K/proton hypothesis]
  float **get_LogLikelyhood** (**EICPIDDefs::PIDCandidate pid**, **EICPIDDefs::PIDDetector** det)
- Convenience function to grab a simple sum:
  float **get_SumLogLikelyhood** (**EICPIDDefs::PIDCandidate pid**)
- Flexibility to store other convenient information, e.g. truth information
- ToF track beta can be further tagged in EICPIDParticle, but not reconstructed in production (yet)

Sample print of EICPIDParticle:: **identify()**

```
Class EICPIDParticlev1 id: 7, m_LogLikelyhoodMap.size() = 3, prop_map.size() = 3
        PID Candidate 211 from detector ID 4 dRICH_Gas :         LogLikelyhood = -1793.07
        PID Candidate 321 from detector ID 4 dRICH_Gas :         LogLikelyhood = -0.184642
        PID Candidate 2212 from detector ID 4 dRICH_Gas :        LogLikelyhood = -4362.05
        0:      Truth PID =     321
        1:      Truth Momentum =        14.2942
        2:      Truth eta =     2.68637
```

Example usage : user analysis module

- ECCE analysis module tutorial:
  https://github.com/ECCE-EIC/tutorials/tree/master/AnaTutorialECCE

[Link to this code block]

```
// match to PIDparticles
if (pidcontainer)
{
  // EICPIDParticle are index the same as the tracks
  const EICPIDParticle *pid_particle =
      pidcontainer->findEICPIDParticle(track->get_id());

  if (pid_particle)
  {
    // top level log likelihood sums.
    // More detailed per-detector information also available at  EICPIDParticle::get_LogLikelyhood(
    m_tr_pion_loglikelihood = pid_particle->get_SumLogLikelyhood(EICPIDDefs::PionCandiate);
    m_tr_kaon_loglikelihood = pid_particle->get_SumLogLikelyhood(EICPIDDefs::KaonCandiate);
    m_tr_proton_loglikelihood = pid_particle->get_SumLogLikelyhood(EICPIDDefs::ProtonCandiate);
  }
}
```

Example DIRC separation from one pion track (below 3-sigma separation but ID-ed)

```
root [4] tracktree->Show(10)
======> EVENT:10
...
 m_tr_p         = 14.2146
 m_tr_eta       = -0.562195
 m_tr_pion_loglikelihood = -0.232099
 m_tr_kaon_loglikelihood = -1.79295
 m_tr_proton_loglikelihood = -14.2288
 m_truthtrackpid = -211
```

Example usage : EventEvaluatorEIC output

- Associated with track output from event evaluator: eic/fun4all_eicdetectors@commits/8606cb
- Provide summed LL with `track_pion_LL:track_kaon_LL:track_proton_LL`, summed over all available RICH detectors

Example global RICH separation from five proton tracks as in event eval output

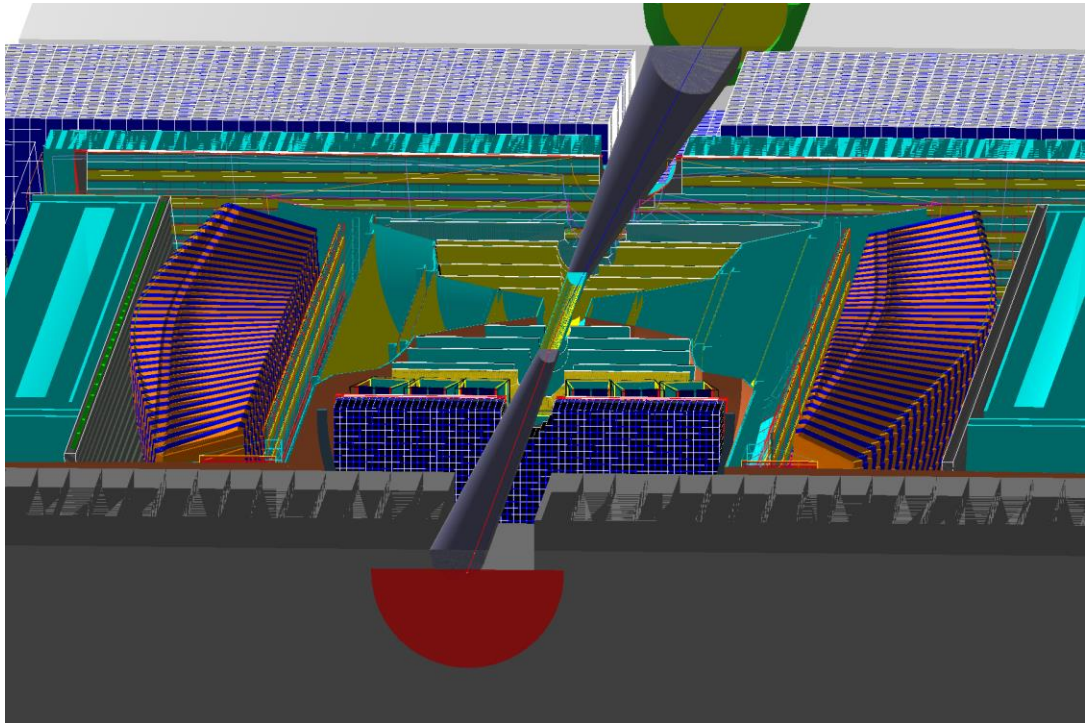
```
root [3] event_tree->Scan("tracks_px:tracks_py:tracks_pz:track_pion_LL:track_kaon_LL:track_proton_LL")
************************************************************************************
*    Row   * Instance * tracks_px * tracks_py * tracks_pz * track_pio * track_kao * track_p*
************************************************************************************
*        0 *        0 * 2.8094716 * 10.832331 * -8.918649 *         0 *         0 *         0 *
*        0 *        1 * -0.756398 * 0.6121297 * -8.025662 * -46.41987 * -27.67037 * -0.689787 *
*        0 *        2 * -0.798823 * -0.728434 * -9.631127 * -12.36966 * -6.310642 * -0.125061 *
*        0 *        3 * -9.714311 * 1.6666913 * -8.282917 * -3.562910 * -1.034013 * -2.115377 *
*        0 *        4 * -0.298632 * -9.196583 * -4.959475 * -8.636099 * -4.424894 * -0.071253 *
```

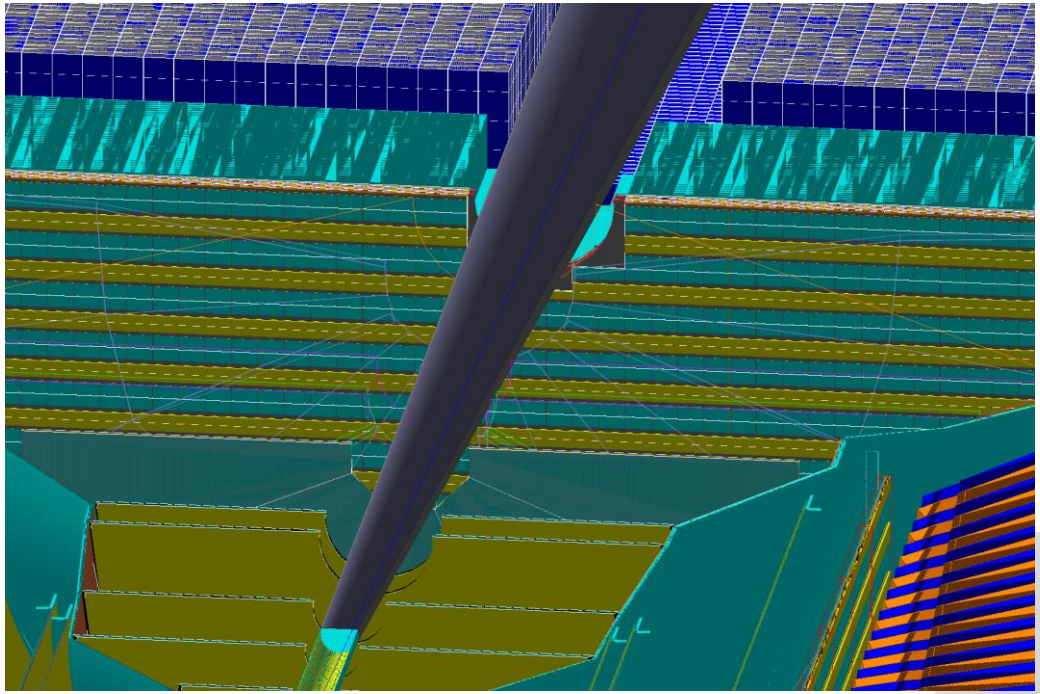
One track missed DIRC bar in G4

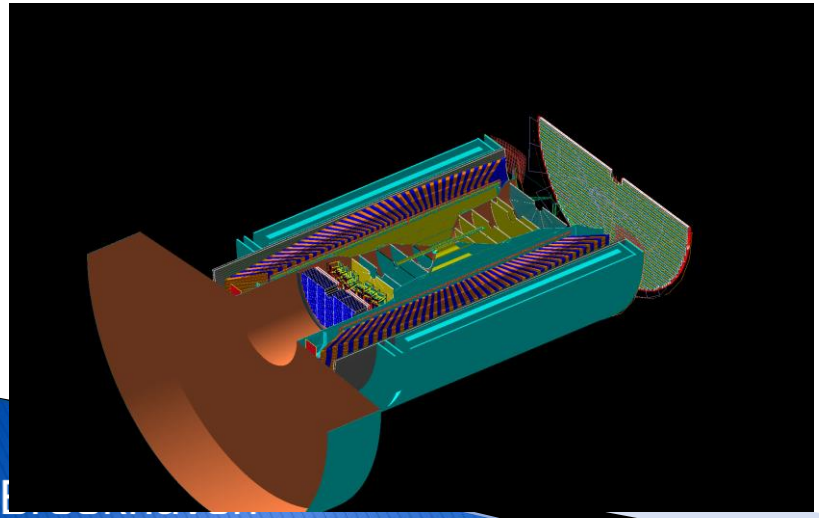
References

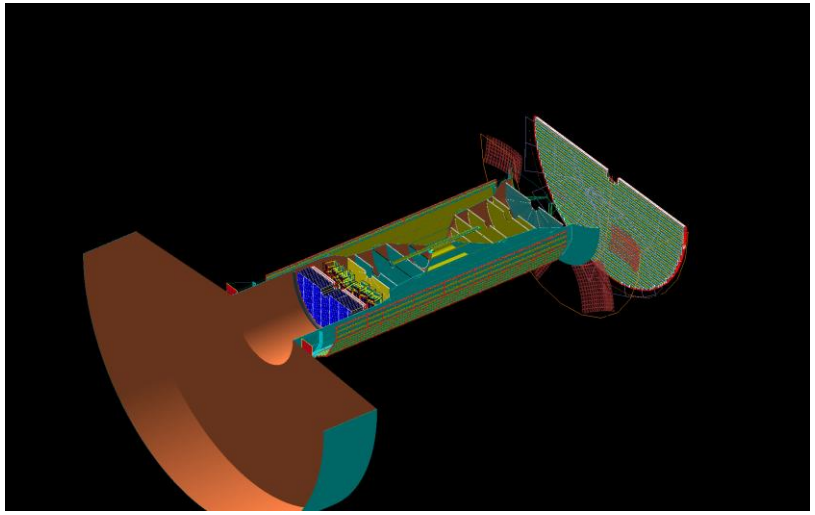
- PID infrastructure: **Introduce Fast PID in reconstruction** eic/fun4all_eicdetectors#61
  - EICPIDParticle , EICPIDParticleContainer , EventEvaluatorEIC
- Fast PID reconstruction module: **Introduce Fast PID in reconstruction** ecce-detectors#1
  - ECCEFastPIDReco , ECCEFastPIDMap
- Database entry: calibrations#11
- Tutorial on how to use the PID object: **Add PID particle examples** tutorials#4
  - AnaTutorialECCE
- Main macros updated: https://github.com/ECCE-EIC/macros/pull/69

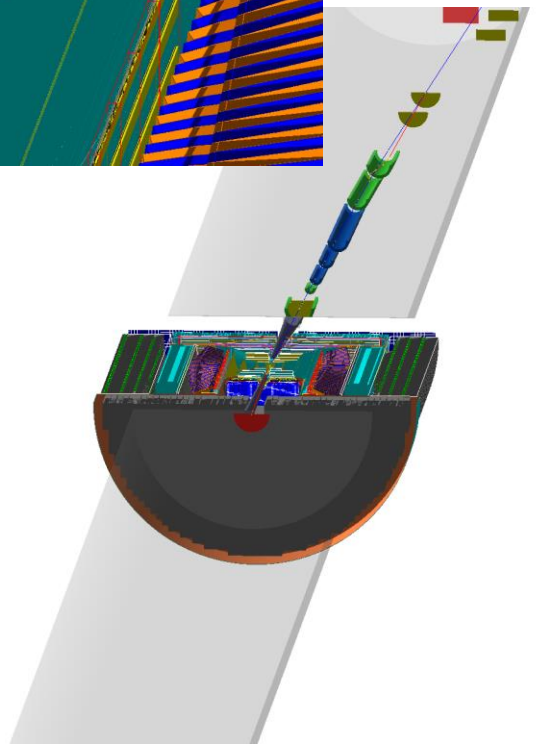
Extra information



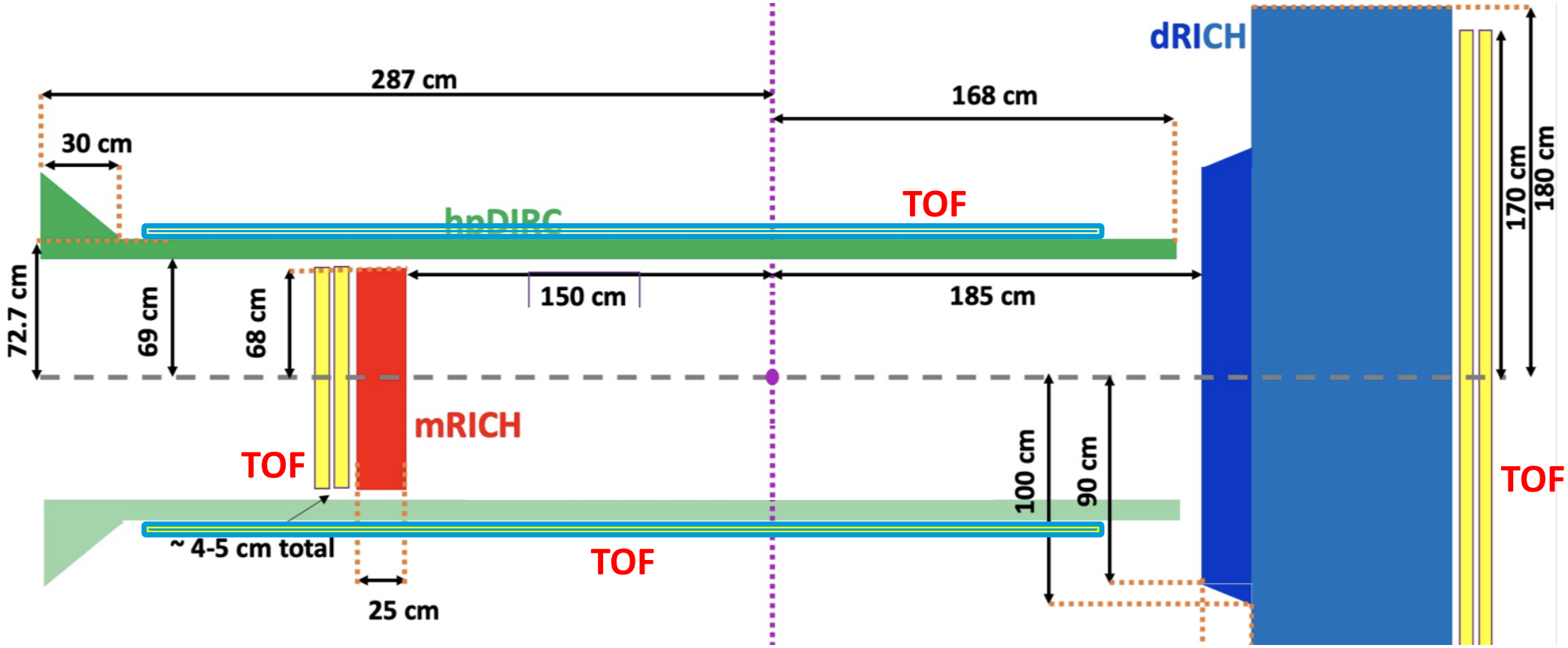








ECCE PID: Cherenkov + TOF



Cherenkov PID Coverage

- **h-endcap: dRICH**
  - **Ring imaging:**
    - **π/K < 50 GeV/c**
    - **e/π <15 GeV/c**
  - **"Veto" mode:**
    - **e/ π above few MeV/c** (up to ~15 GeV/c)
    - **π/K,p above 0.7 GeV/c** (or ~1 GeV/c at "full efficiency")
    - **K/p > 2.5 Gev/c** (or ~3 GeV/c at "full efficiency")
- **e-endcap: mRICH**
  - **Ring imaging:**
    - ***π/K: 2-8 GeV/c***
    - **e/π : 0.6-2./2.5 GeV/c**
  - **"Veto" mode:**
    - **k/π : 0.6-2 GeV/c**
    - **e/π : <0.6 GeV/c**
    - **k/P <3.8 GeV/c**
- **barrel: hpDIRC**
  - **Ring imaging:**
    - ***π/K <6-7 GeV/c***
    - **e/π <1.2 GeV/c**
  - **"Veto" mode:**
    - **e,k/π >0.2/0.3GeV/c**
    - **k/P >1 GeV/c**

TOF PID Coverage

e/π covered by dRICH

π/K < 1 (2) GeV/c need ~230 (65) ps resolution (3m path)

K/p < 3 (4) GeV/c need ~80 (45) ps resolution (3m path)

e/π covered by mRICH (@ low-p)

π/K < 0.6 (1) GeV/c need ~380 (150) ps resolution (1.75m path)

K/p < 3.8 GeV/c covered by mRICH

e/π < 0.3 (0.5) GeV/c need ~65 (25) ps resolution (0.8m path)

π/k < 0.3 (0.5) GeV/c need ~500 (230) ps resolution (0.8m path)

K/p < 1 (2) GeV/c need ~160 (45) ps resolution (0.8m path)

Threshold operation

SvtxTrack_FastSim Object truth_track_id:9id: 7 charge: 1 chisq: 11.7208 ndf:11
(px,py,pz) = (1.96418,0.304114,14.5252)
(x,y,z) = (0.000100966,-0.000681415,3.24726)
with particle: PHG4Particlev2 name: kaon+, track id: 9, vtxid: 1, parent id: 0, primary id: 9, pid: 321, px: 1.91587, py: 0.296479, pz: 14.1621, phi: 0.153531, eta: 2.68637, e: 14.3027
Result in momentum of 14.2942GeV/c at eta = 2.68637
double ECCEdRICHFastPIDMap::numSigma(double, double, ECCEdRICHFastPIDMap::type) const C2F6: processing tracks momentum = 14.2942 eta = 2.68637 thr1 = 3.48856 thr2 = 12.3395
double ECCEdRICHFastPIDMap::numSigma(double, double, ECCEdRICHFastPIDMap::type) const C2F6: processing tracks momentum = 14.2942 eta = 2.68637 cherenkovAngle(p, mass1) = 0.0387769 cherenkovAngle(p, mass2)) = 0.0201803 cherenkovAngleSigma(eta, p, mass1) = 0.000313725
double ECCEdRICHFastPIDMap::numSigma(double, double, ECCEdRICHFastPIDMap::type) const C2F6: processing tracks momentum = 14.2942 eta = 2.68637 thr1 = 12.3395 thr2 = 23.4521
virtual ECCEFastPIDMap::PIDCandidate_LogLikelihood_map ECCEdRICHFastPIDMap::getFastSmearLogLikelihood(int, double, double) const C2F6: processing tracks momentum = 14.2942 eta = 2.68637 Nsigma_piK = 59.2766 Nsigma_Kp = 94.0106
Class EICPIDParticlev1 id: 7, m_LogLikelyhoodMap.size() = 3, prop_map.size() = 3
    PID Candidate 211 from detector ID 4 dRICH_Gas : LogLikelyhood = -1793.07
    PID Candidate 321 from detector ID 4 dRICH_Gas : LogLikelyhood = -0.184642
    PID Candidate 2212 from detector ID 4 dRICH_Gas : LogLikelyhood = -4362.05
    0: Truth PID = 321
    1: Truth Momentum = 14.2942
    2: Truth eta = 2.68637