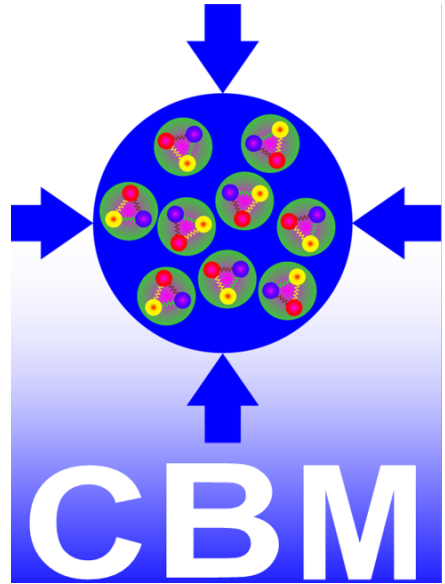




Strangeness and Hypernuclei Signal Extraction and Mixed-Event Background Studies using AnalysisTree with KFParticle

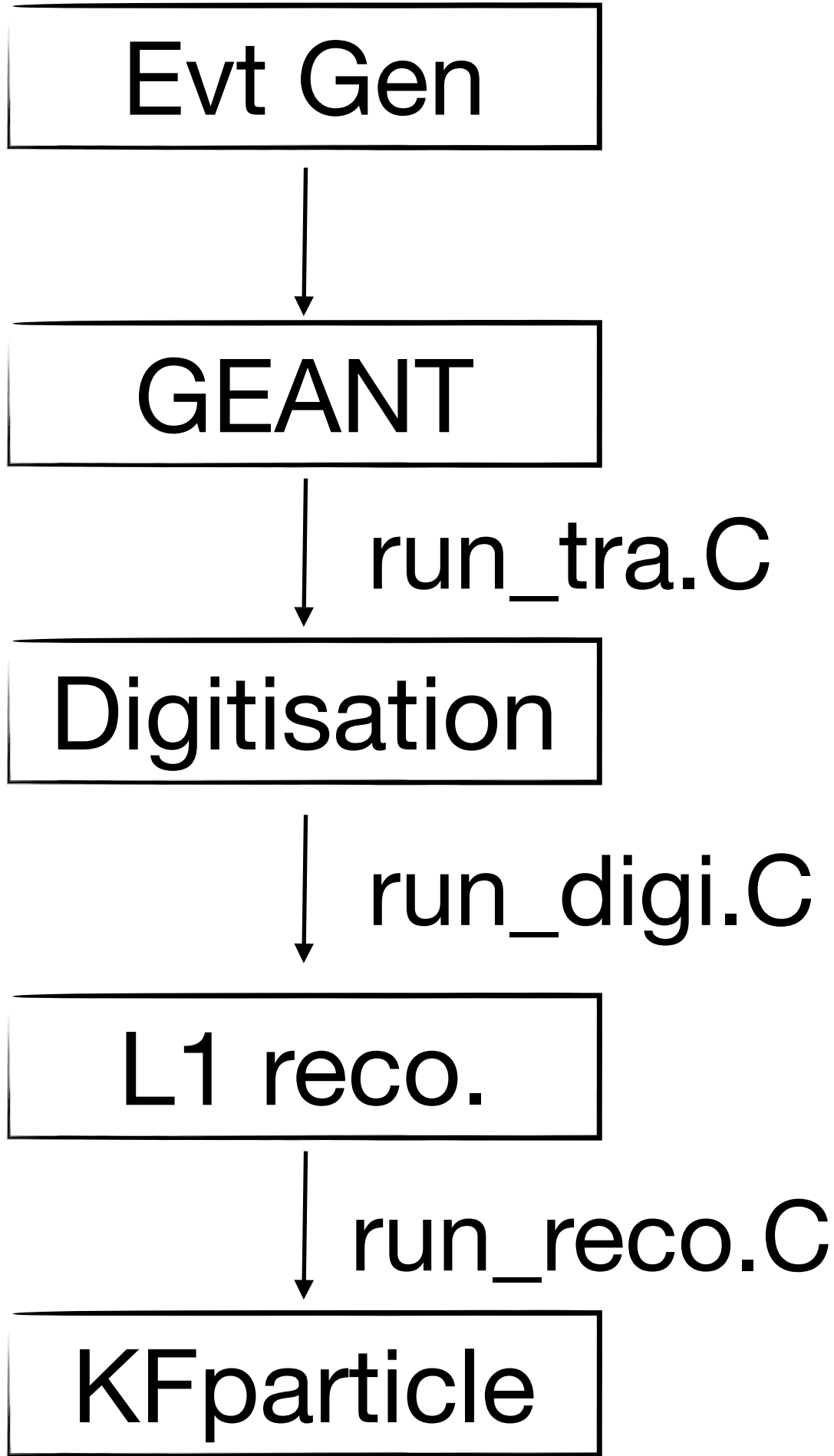
Iouri Vassiliev, Yingjie Zhou

Outline

1. Existing CBM KFParticle
2. Results of AnalysisTree + KFParticle
3. Event Mixing Background

2025/10/21

Existing CBM KFPparticle



Input files form simulation and reconstruction chain

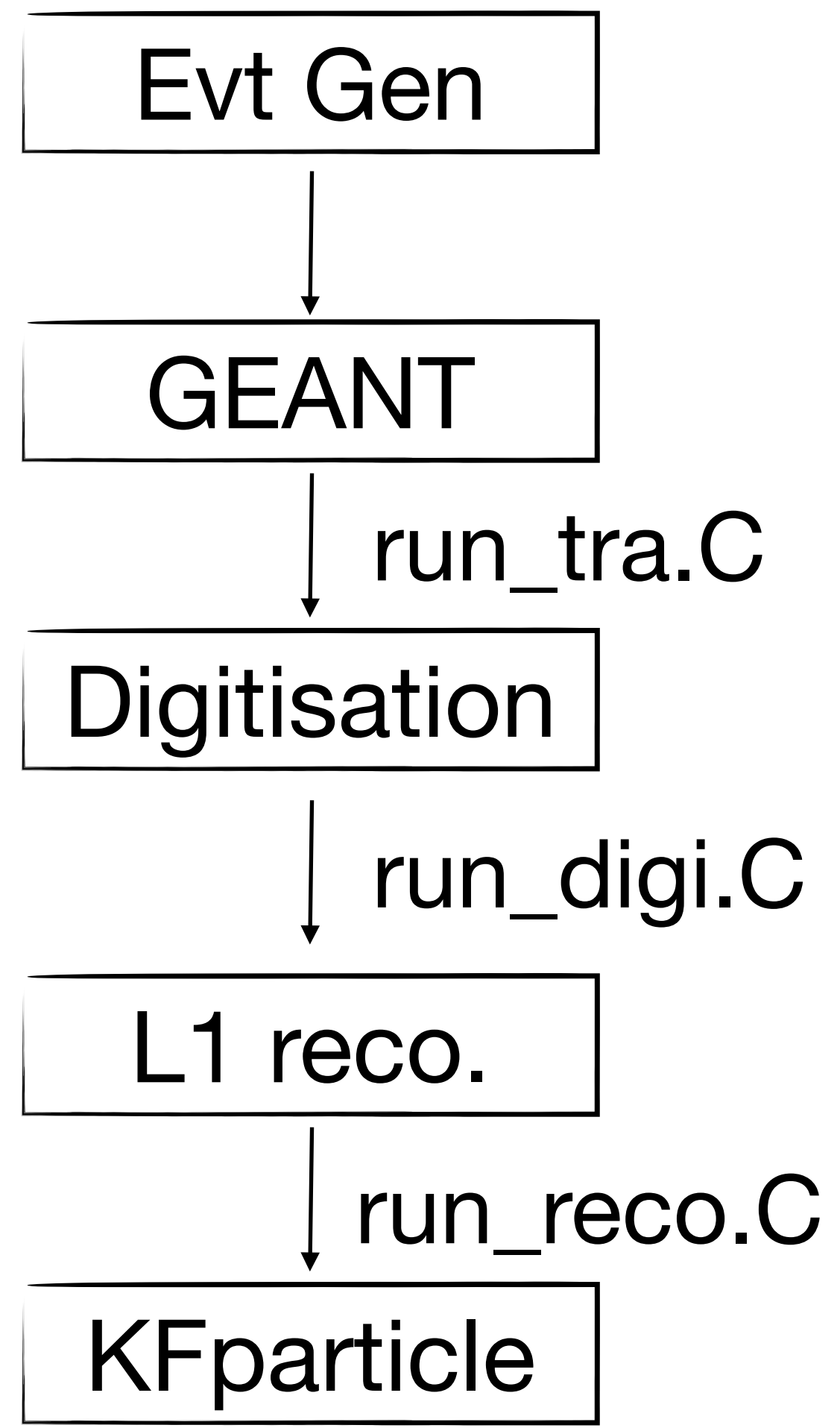
```
total 1.5G
-rw-r--r--. 1 zyingjie cbm 262K Oct 19 14:39 00001.geo.root
-rw-r--r--. 1 zyingjie cbm 761M Oct 19 14:39 00001.tra.root
-rw-r--r--. 1 zyingjie cbm 73M Oct 19 14:39 00001.par.root
-rw-r--r--. 1 zyingjie cbm 296M Oct 19 14:39 00001.raw.root
-rw-r--r--. 1 zyingjie cbm 483M Oct 19 14:43 00001.reco.root
```

Code location: cbmroot/reco/KF

CMakeLists.txt	CbmKFParticleFinder.h	CbmKFSecondaryVertexFinder.h	KF.cmake
CbmKF.cxx	CbmKFParticleFinderPID.cxx	CbmKFTrackInterface.cxx	KFLinkDef.h
CbmKF.h	CbmKFParticleFinderPID.h	CbmKFTrackInterface.h	KFParticleInterface.cmake
CbmKFFieldMath.cxx	CbmKFParticleFinderQa.cxx	CbmKFUMeasurement.cxx	KFParticleInterfaceLinkDef.h
CbmKFFieldMath.h	CbmKFParticleFinderQa.h	CbmKFUMeasurement.h	KFQA
CbmKFHit.cxx	CbmKFParticleInterface.cxx	CbmKFVertexInterface.cxx	KFQA.cmake
CbmKFHit.h	CbmKFParticleInterface.h	CbmKFVertexInterface.h	KFQALinkDef.h
CbmKFMaterial.cxx	CbmKFPixelMeasurement.cxx	CbmKfFitTracksTask.cxx	ParticleFitter
CbmKFMaterial.h	CbmKFPixelMeasurement.h	CbmKfFitTracksTask.h	obsolete
CbmKFMath.cxx	CbmKFPrimaryVertexFinder.cxx	CbmKfTrackFitter.cxx	
CbmKFMath.h	CbmKFPrimaryVertexFinder.h	CbmKfTrackFitter.h	
CbmKFParticleFinder.cxx	CbmKFSecondaryVertexFinder.cxx	Interface	

Existing CBM KFPparticle

cbmroot/macro/KF/kf_kfparticle.C



kf_kfparticle.C

```
kf_kfparticle.C
{0.00717827, -0.00257353, 0.00389851, -9.83097e-05, 1.33011e-06},
{0.001348, 0.00220126, 0.0023619, 7.35395e-05, -4.06706e-06},
{0.00142972, 0.00308919, 0.00326995, 6.91715e-05, -2.44194e-06},
{0.261491, -0.103121, 0.0247587, -0.00123286, 2.61731e-05}, //TODO tune for SIS300
{0.657274, -0.22355, 0.0430177, -0.0026822, 7.34146e-05},
{0.116525, -0.045522, 0.0151319, -0.000495545, 4.43144e-06}}

};

kfParticleFinderPID->SetCuts(cutsSIS100);
}
else {
kfParticleFinderPID->UseMCPID();
}

run->AddTask(kfParticleFinderPID);

// -----

// ----- KF Particle Finder -----
CbmKFParticleFinder* kfParticleFinder = new CbmKFParticleFinder();
kfParticleFinder->SetPIDInformation(kfParticleFinderPID);
if (iDecay > -1) kfParticleFinder->UseMCPV();
if (superEvent) kfParticleFinder->SetSuperEventAnalysis(); // SuperEvent
run->AddTask(kfParticleFinder);
// -----

// ----- KF Particle Finder QA -----
CbmKFParticleFinderQa* kfParticleFinderQA =
new CbmKFParticleFinderQa("CbmKFParticleFinderQa", 0, kfParticleFinder->GetTopoReconstructor(), histoFile.Data());
kfParticleFinderQA->SetPrintEffFrequency(nEvents);
if (superEvent) kfParticleFinderQA->SetSuperEventAnalysis(); // SuperEvent
kfParticleFinderQA->SetEffFileName(effFile.Data());
if (iDecay > -1) {
TString referenceResults = srcDir + "/input/qa/KF/reference/";
if (useDetectorPID) referenceResults += "realpid/";
else
referenceResults += "mcpid/";
kfParticleFinderQA->SetReferenceResults(referenceResults);
kfParticleFinderQA->SetDecayToAnalyse(iDecay);
kfParticleFinderQA->SetCheckDecayQA();
}
run->AddTask(kfParticleFinderQA);
// -----
```


Existing CBM KFPparticle

Evt Gen



GEANT



Digitisation



L1 reco.



KFPparticle

.....

kf_kfparticle.C

CBM Class used:
Event: CbmEvent, CbmVertex,
FairMCEventHeader
PID: CbmStsTrack, CbmTofHit, CbmTrdTrack

Environment:
CBMRoot installation required

PID

tracks

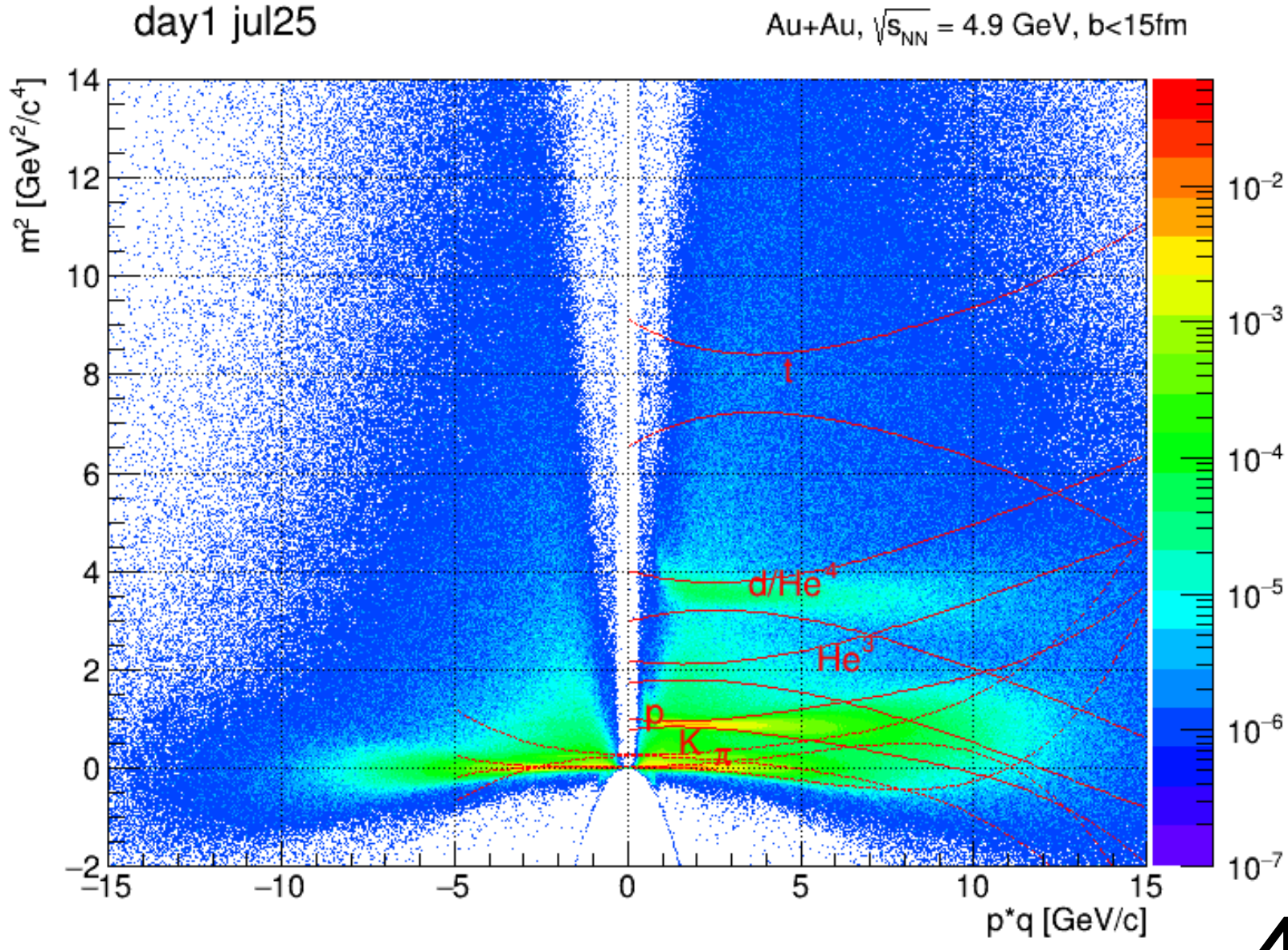
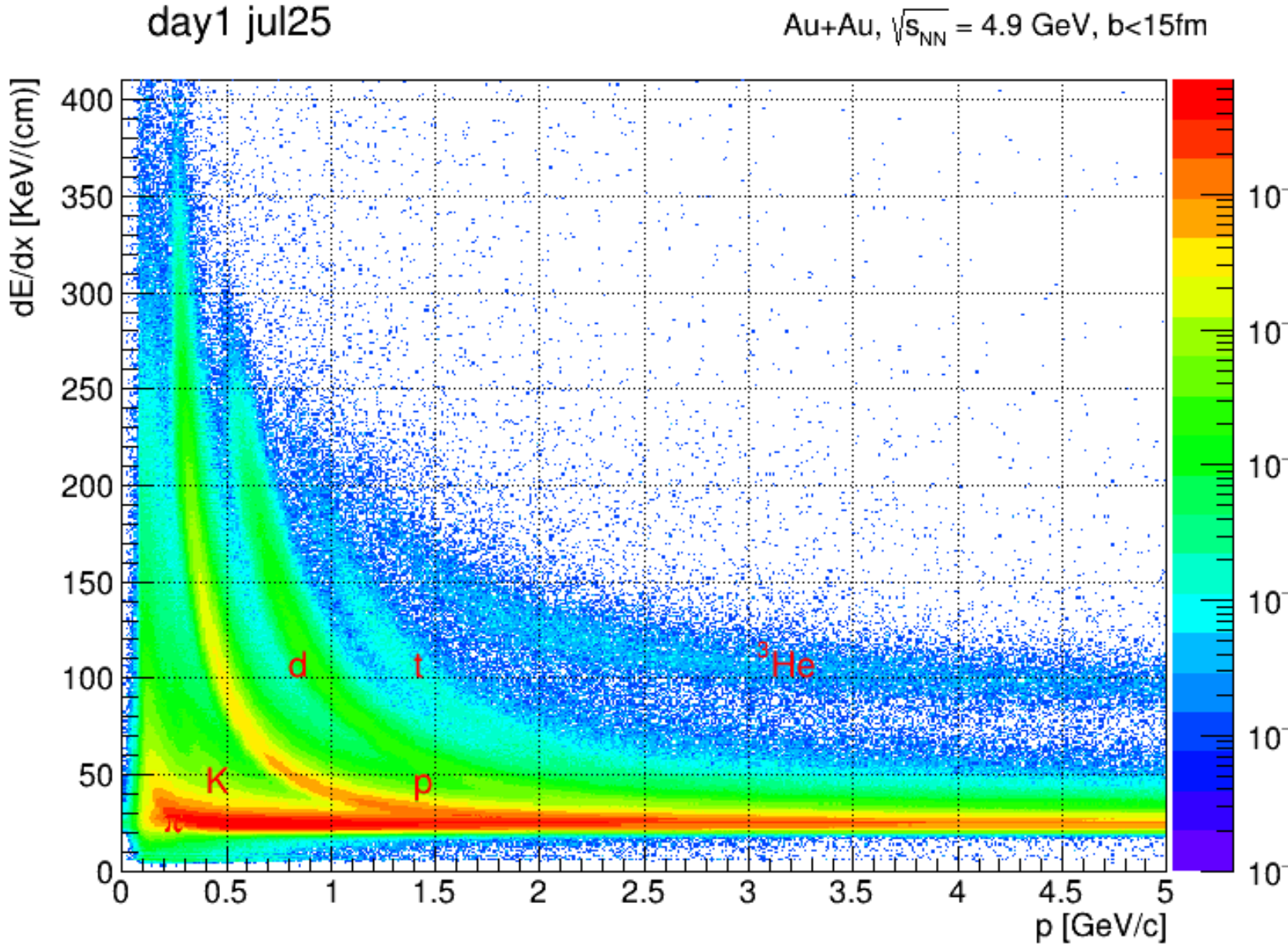
Particle Finder



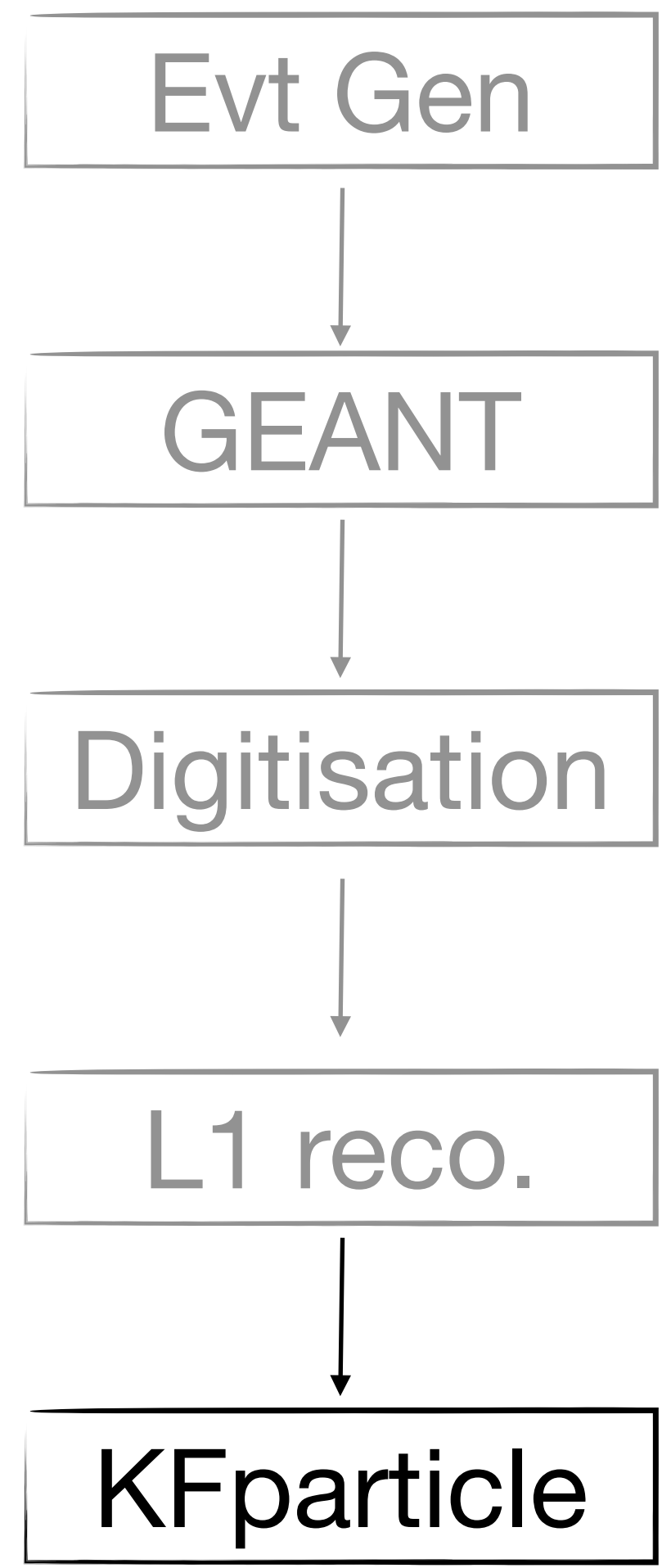
QA



CbmKFPparticleFinderPID.h
CbmKFPparticleFinderPID.cxx

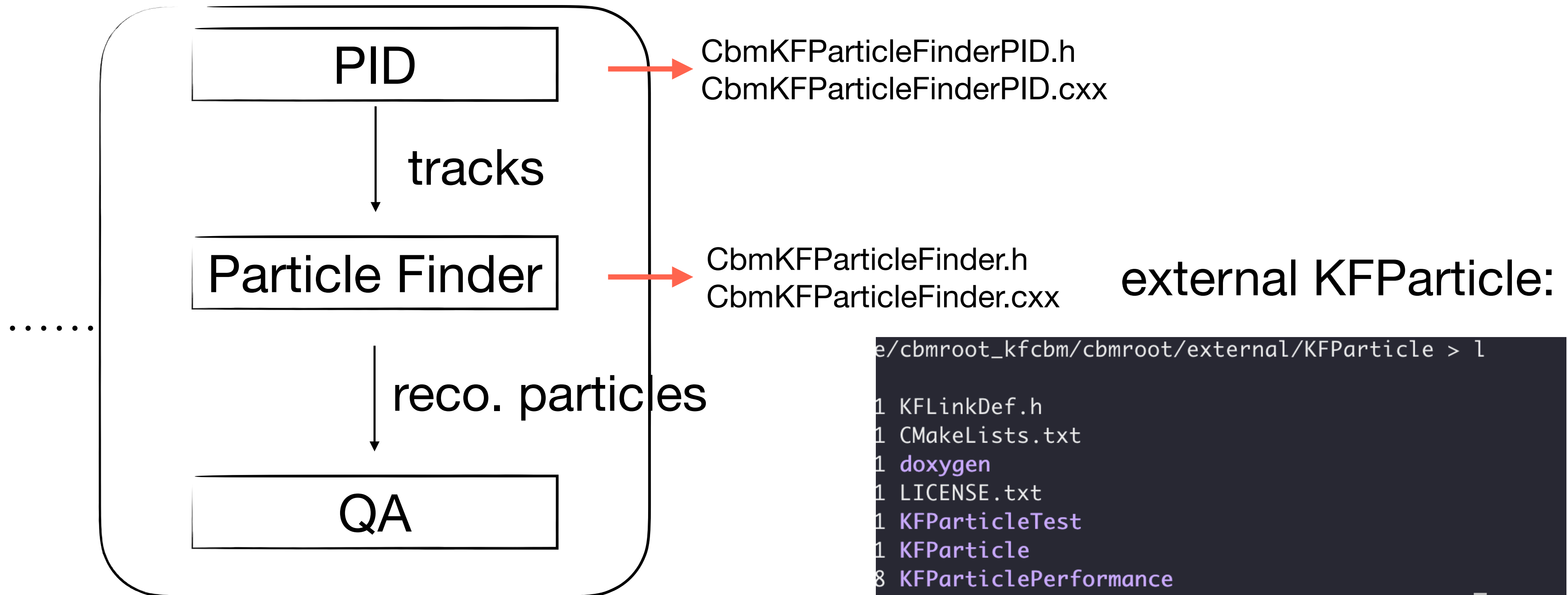


Existing CBM KFPparticle

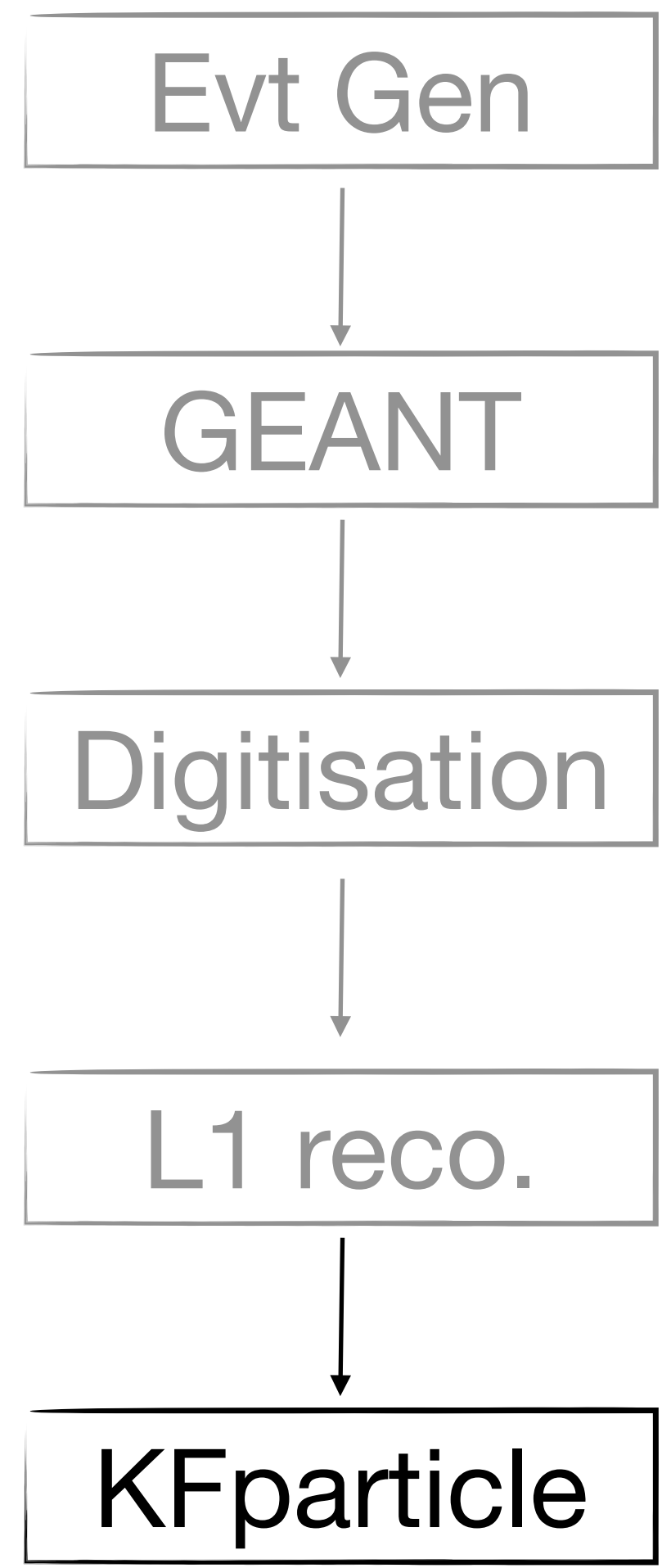


CBM Class used:
Event: CbmEvent, CbmVertex, FairMCEventHeader
PID: CbmStsTrack, CbmTofHit, CbmTrdTrack

Environment:
CBMRoot installation required

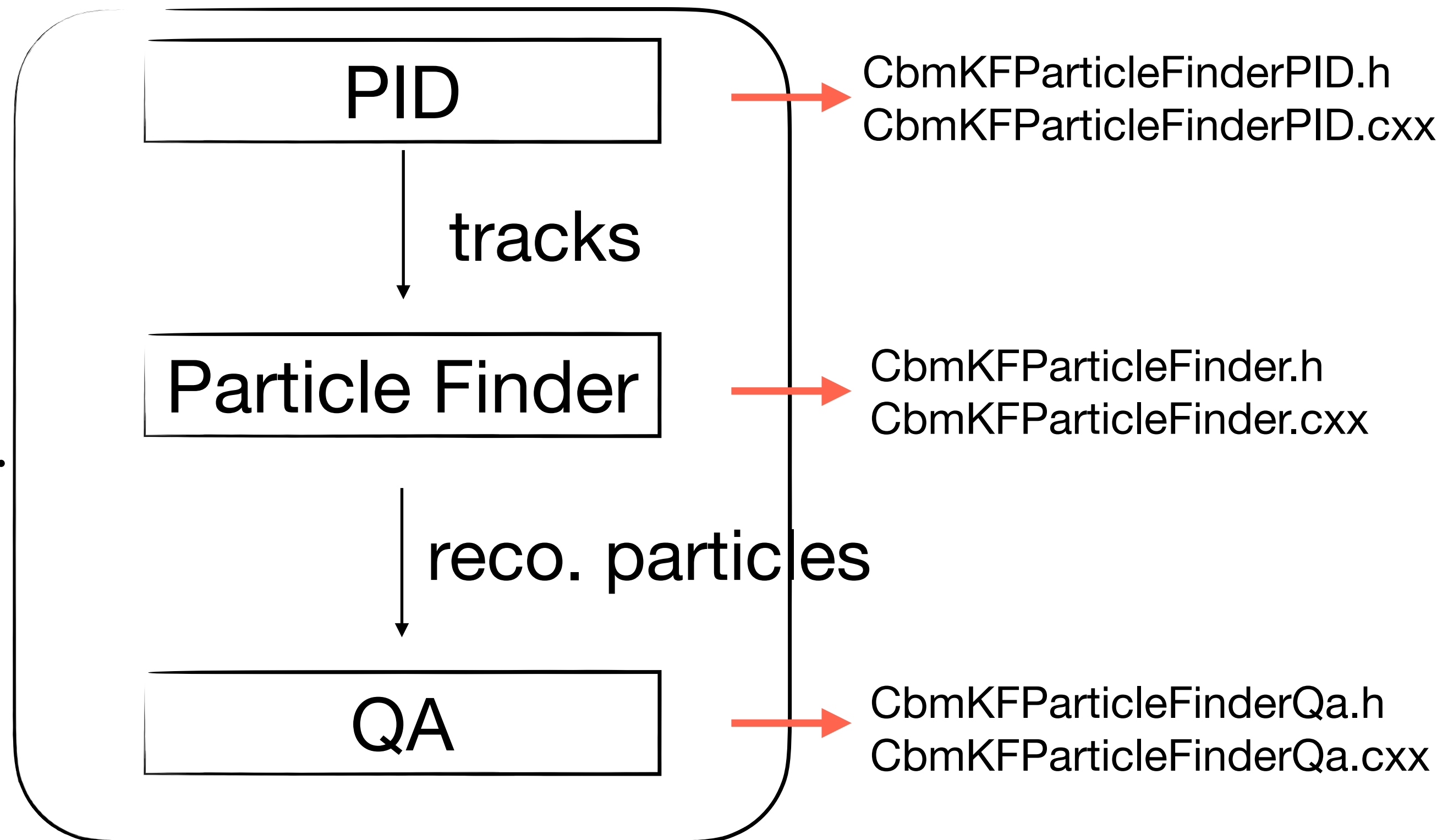


Existing CBM KFPparticle

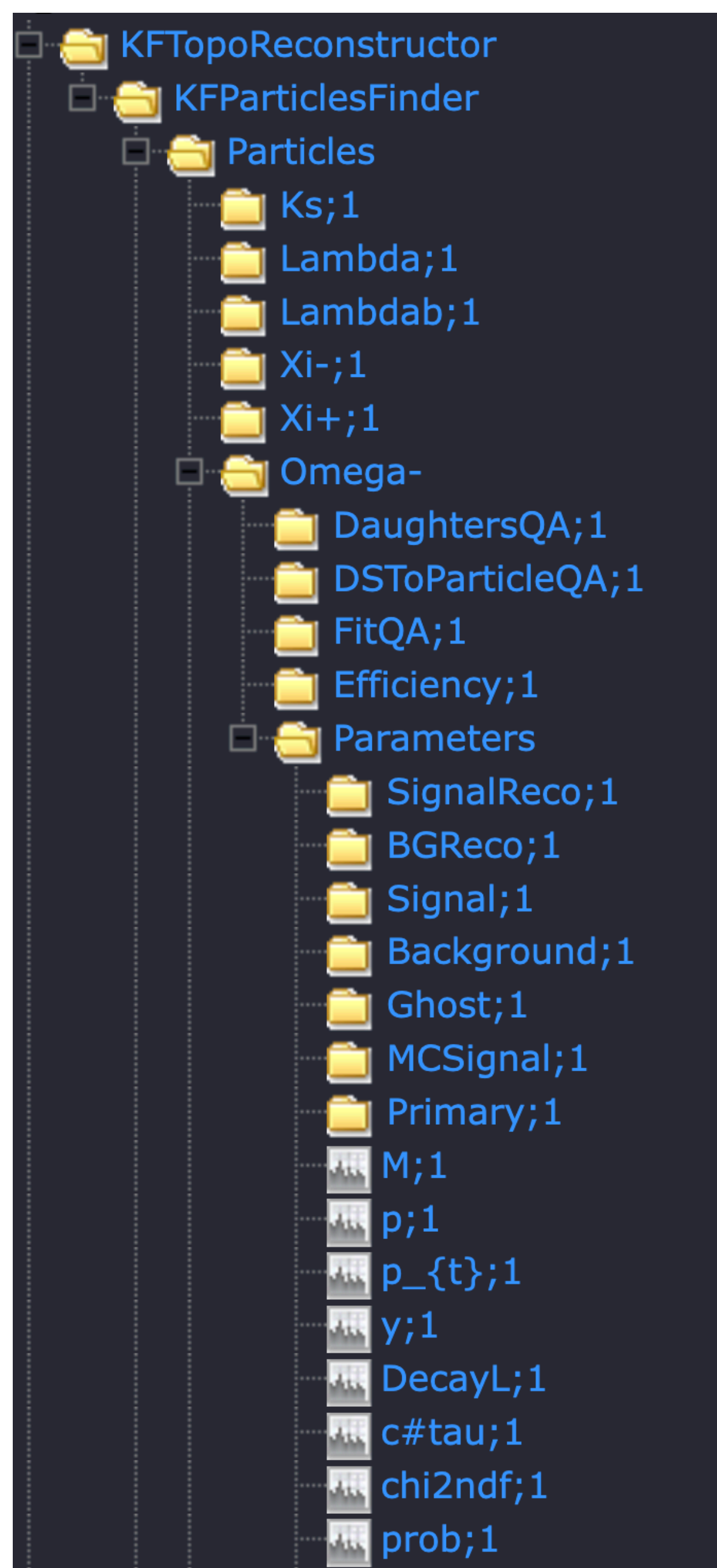


CBM Class used:
Event: CbmEvent, CbmVertex, FairMCEventHeader
PID: CbmStsTrack, CbmTofHit, CbmTrdTrack

Environment:
CBMRoot installation required



Output: Histograms



CBM AnalysisTree

- Reduce amount of used disk space - store only needed information for analysis

```
-rw-r--r--. 1 nobody cbm 105M Sep  6 21:41 00001.analysisistree.root
```

- Include analysis-level information not available at the reconstruction stage

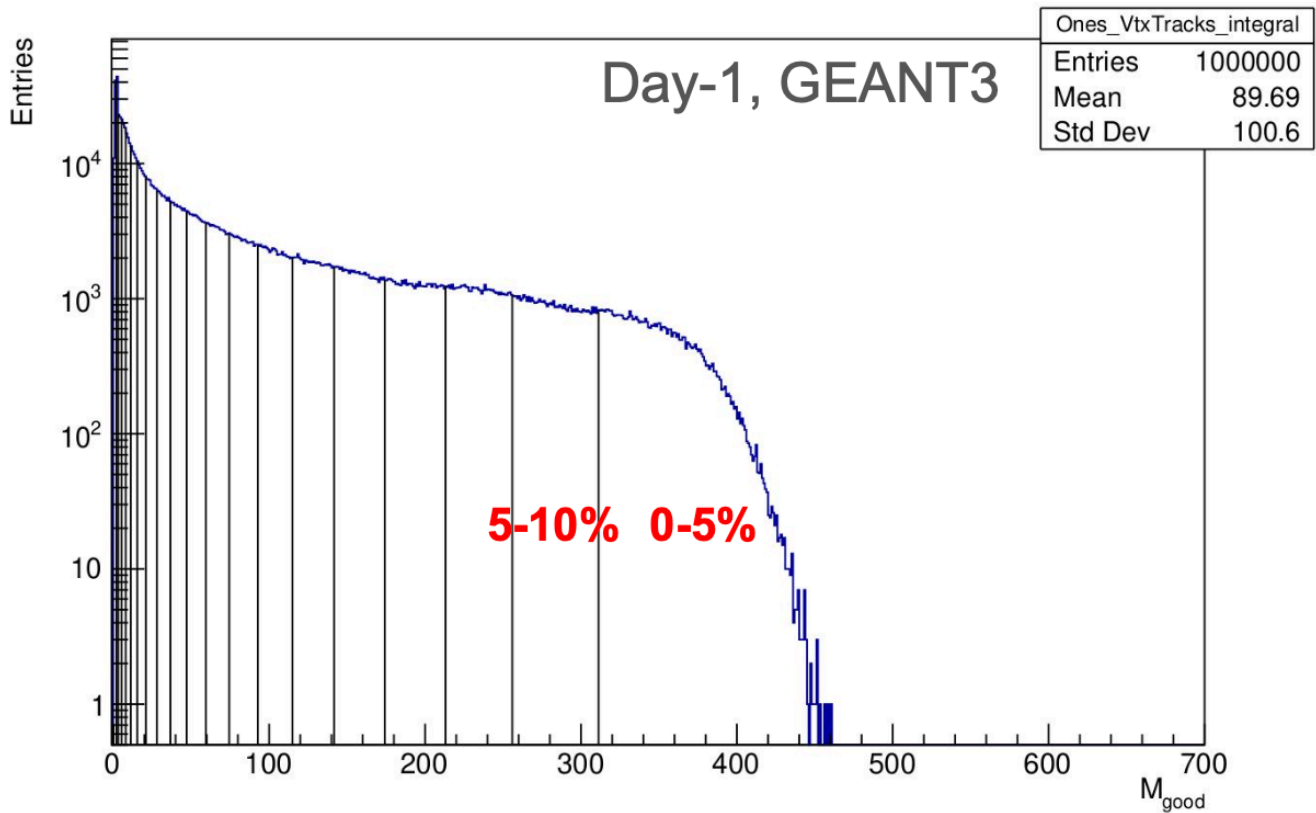
Detector PID
Centrality
Event plane

...

- Goal: develop code to read AnalysisTree for KFParticle reconstruction

Centrality integration to AnalysisTree

- Centrality estimator based on selected track multiplicity (simple 1D slicing)



- *Minimum track quality selection:
 - $\chi^2_{\text{Vertex}} < 3$
 - $N_{\text{MVD+STS}} > 4$
 - $\chi^2/\text{ndf} < 3$
 - $0.2 < \eta < 6$ *first iteration: to be improved!*

- *Renaming convention:
 - rTee, RecEventHeader → aTree, AnaEventHeader
 - additional field: AnaEventHeader.centrality_tracks (centrality %)

- AT files including centrality estimator can be found here:

/lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/day-1
/lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/cfv
/lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant4/auau/pbeam12agev/mbias/small_clusters/day-1

AnalysisTree + KFParticle

Environment:

AnalysisTree, KFParticle

e.g. Event: CbmEvent, CbmVertex,
FairMCEventHeader
PID: CbmStsTrack, CbmTofHit, CbmTrdTrack

↓ **Transferred to
AnalysisTree framework**

Event: RecEventHeader
PID: SimParticles, VtxTracks, TofHits

- Code adapted from Oleksii Lubynets:
cbmroot/analysis/common/at_kfpf_interface

- ✓ **Current version includes:**
- MC and Detector PID
 - KFParticle Reconstruction
 - MC–reconstructed matching
 - Output: Tree and histograms

AnalysisTree + KFParticle

Environment:

AnalysisTree, KFParticle

e.g. Event: CbmEvent, CbmVertex,
FairMCEventHeader
PID: CbmStsTrack, CbmTofHit, CbmTrdTrack

 **Transferred to
AnalysisTree framework**

Event: RecEventHeader
PID: SimParticles, VtxTracks, TofHits

Easily to run: root -l run_at_kfpf.C ✓

Input: analysistree.root

Output: Reconstructed particle topological +
daughter + MC information

```
void run_at_kf(int nEntries = -1, const std::string& dataset = "00001", const std::string&
ATTree = "aTree")
{
    ATKFParticleFinder man;
    std::string Dir = "/lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/
auau/pbeam12agev/mbias/small_clusters/day-1/AT/" + dataset;
    std::cout << Dir.c_str() << std::endl;
    const std::string ATFile = Dir + "/" + dataset + ".analysistree.root";
    man.SetOutputFileName(dataset);
    man.InitInput(ATFile.c_str(), ATTree.c_str());
    man.InitOutput(std::string(dataset + ".kfpf tree.root"));
    man.SetPIDMode(2); // 1 - mc PID, 2 - detector PID
    man.AddDecayToReconstructionList( 310 ); //Ks
    man.AddDecayToReconstructionList( 3122); //Lambda
    man.AddDecayToReconstructionList( -3122); //Lambdab
    man.AddDecayToReconstructionList( 3312); //Xi-
    man.AddDecayToReconstructionList( -3312); //Xi+
    man.AddDecayToReconstructionList( 3334); //Om-
    man.AddDecayToReconstructionList( -3334); //Om+

    man.AddDecayToReconstructionList( 3003); //LN
    man.AddDecayToReconstructionList( 3103); //LNN
    man.AddDecayToReconstructionList( 3004); //3HL
    man.AddDecayToReconstructionList( 3005); //4HL
    man.AddDecayToReconstructionList( 3006); //4HeL
    man.AddDecayToReconstructionList( 3007); //5HeL
    man.AddDecayToReconstructionList( 3008); //4HLL->He4Lpi-
    man.AddDecayToReconstructionList( 3009); //4HLL->H3Lppi-
    man.AddDecayToReconstructionList( 3012); //3HL_dpipi

    man.AddDecayToReconstructionList( 7003112); //Sigma-_{pi-n}
    man.AddDecayToReconstructionList( 7003222); //Sigma+_{pi-n}
    man.AddDecayToReconstructionList( 7003312); //Xi-_{pi-L}*

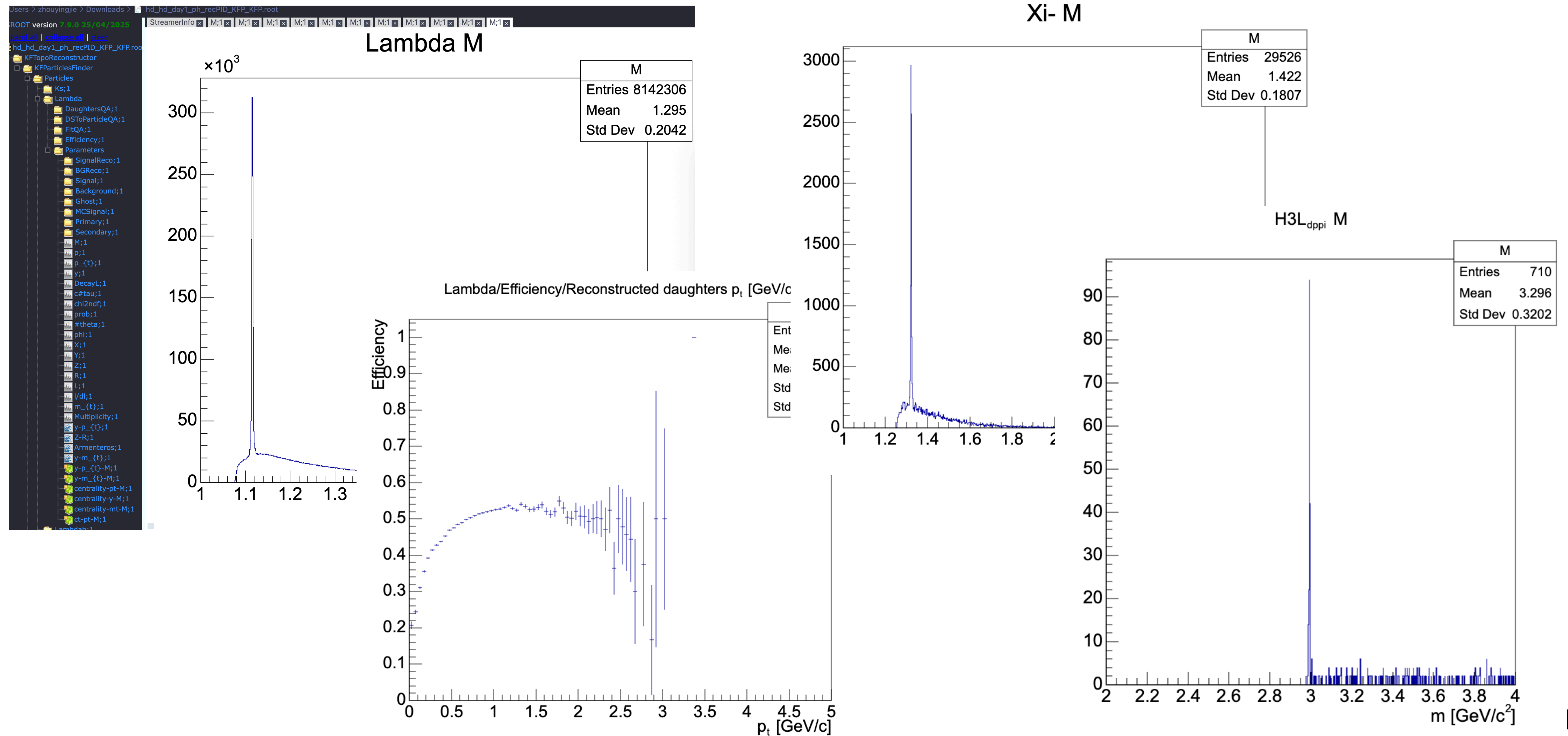
    man.AddDecayToReconstructionList( 113 ); //rho->pipi
    man.AddDecayToReconstructionList( 333 ); //phi_KK

    man.InitQa();

    // cuts
    man.SetChiPrimaryCut2D(0.); //16.
    man.SetChi2Cut2D(3.); //3.
    man.SetLdLCut2D(5.); //10.
    man.SetLdLCutCharmManybodyDecays(5.); //5.
    man.SetChi2TopoCutCharmManybodyDecays(5.); //5.
    man.SetChi2CutCharmManybodyDecays(6.); //6.
    man.SetPrimaryProbCut(0.0001);
    man.SetPrintEffFrequency(999);
    man.Run(nEntries);
    // man.Run(10);
}
```

Result from AnalysisTree + KFParticle

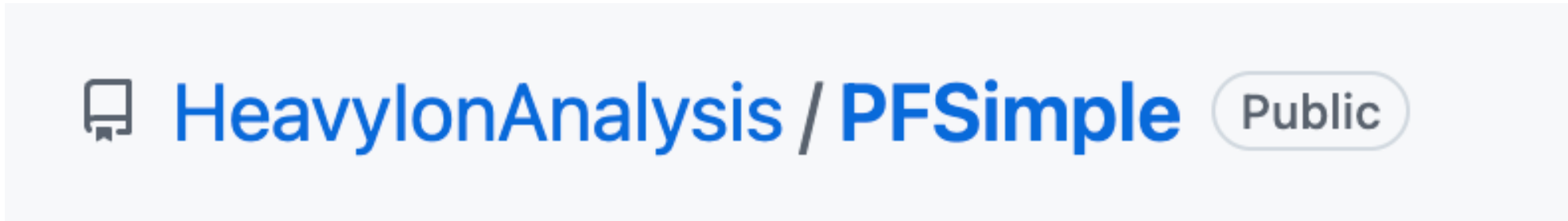
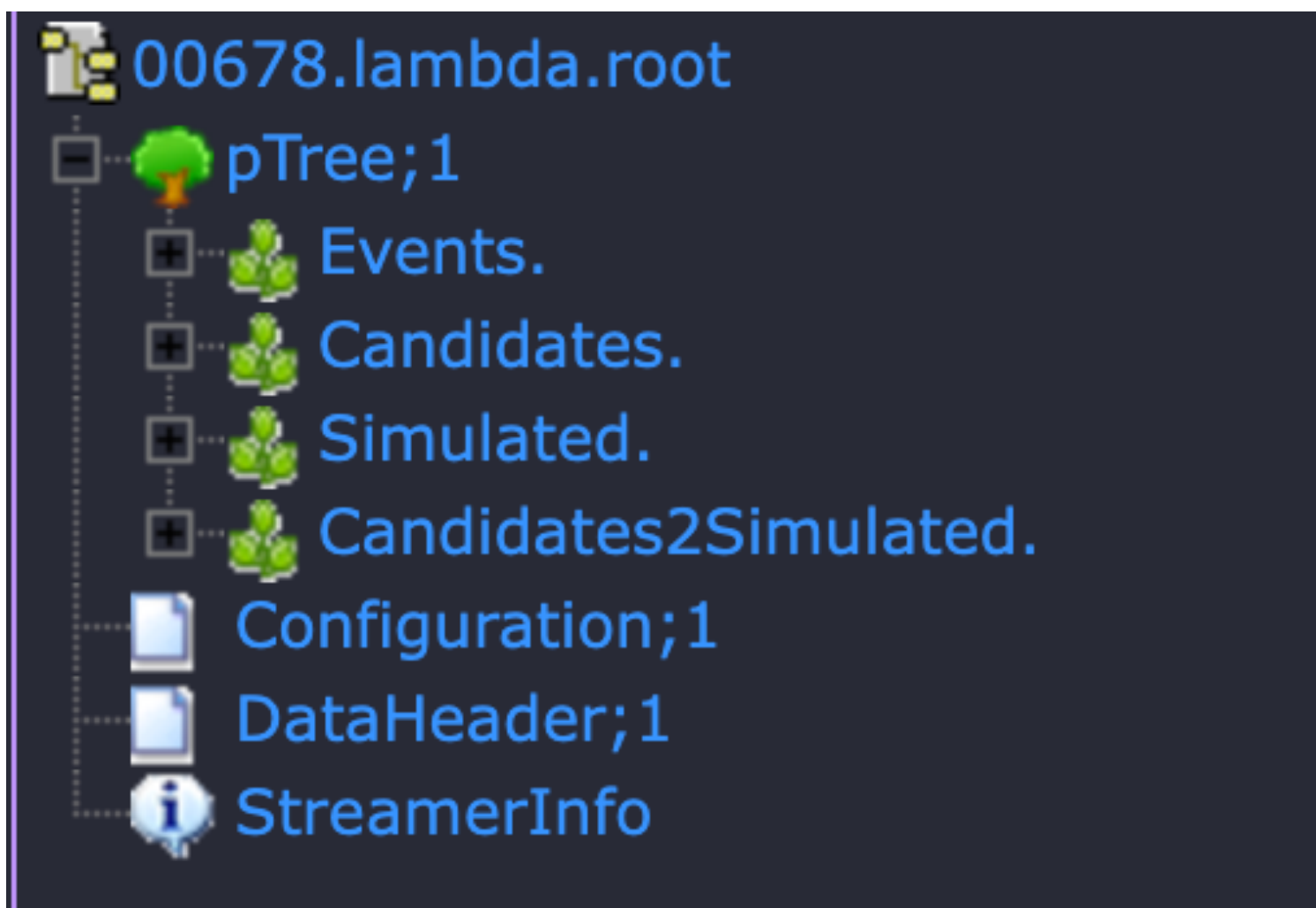
- Output histograms (same as CBMKFParticle)



Result from AnalysisTree + KFParticle

Tree:

- Option to save data in the same structure as the **PFSimple** tree (AT format)



Ongoing...

- Option to store an additional ROOT tree containing:
 - Mother MC information: Primary or secondary
 - Daughter MC information
 - Daughter track IDs

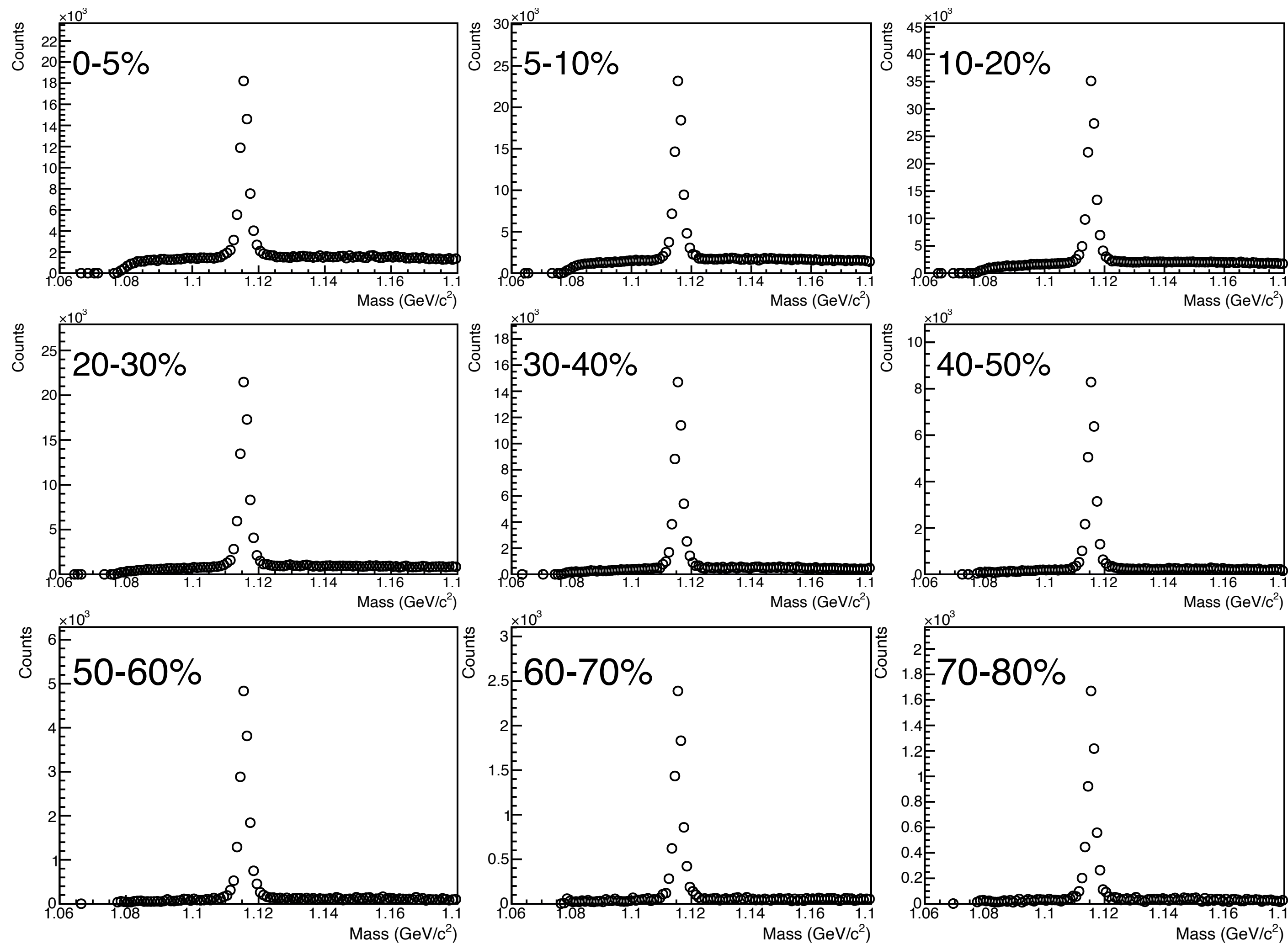
PF Simple	
chi2geo	
chi2_prim_first	
chi2_prim_seond	
chi2_topo	
cosine_first	
cosine_second	
cosine_topo	
distance	dca between daug
l	decay lenght
dl	uncert. of l
px	v0 momentum
py	
pz	
x	dca of V0
y	
z	
pid	mc pid (assumed
dau1id	id of first daughte
dau2id	id of second daug

*Table from Daniel

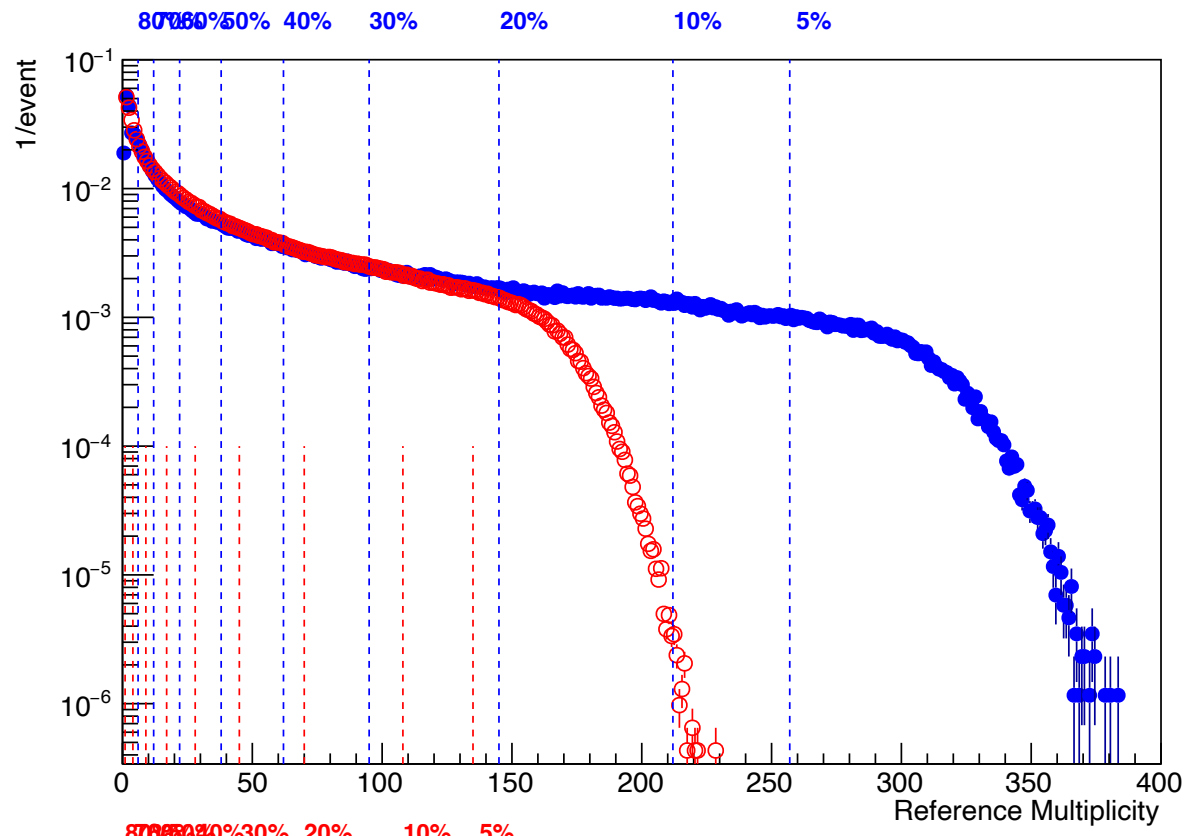
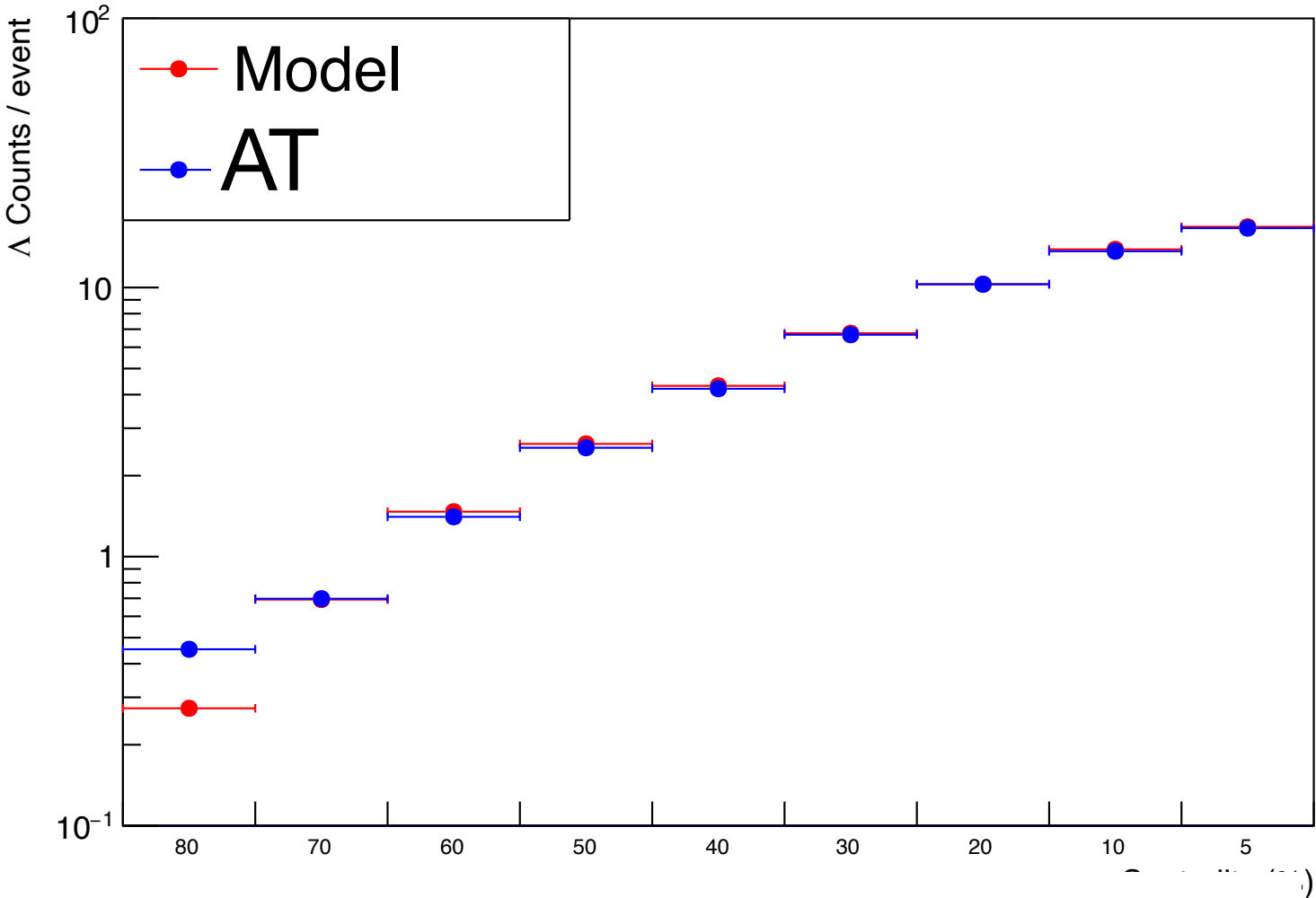
Results from AnalysisTree + KFParticle

- Lambda at different centrality

AT: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/day-1



- Yields are consistent with model predictions, except for peripheral collisions



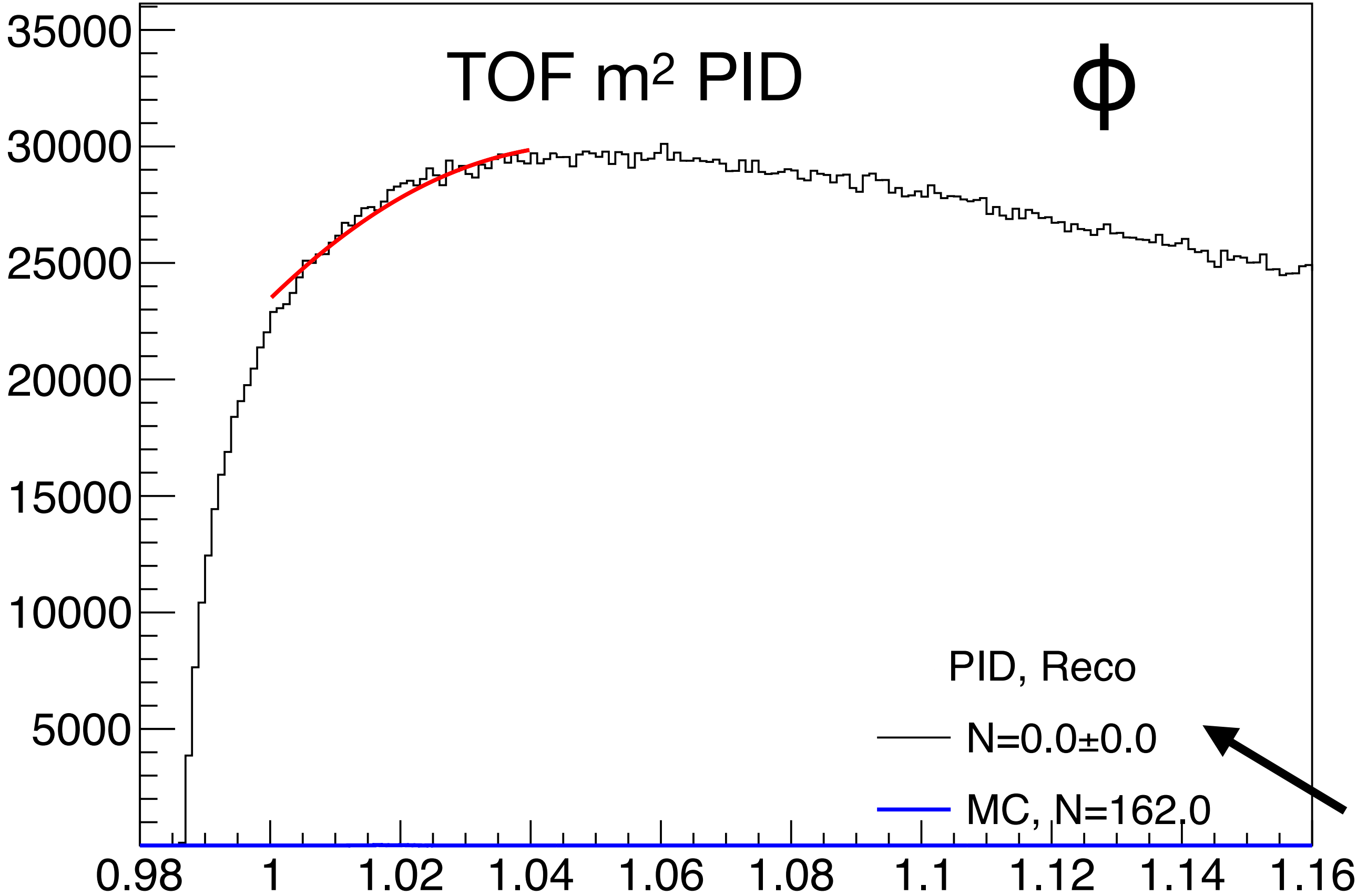
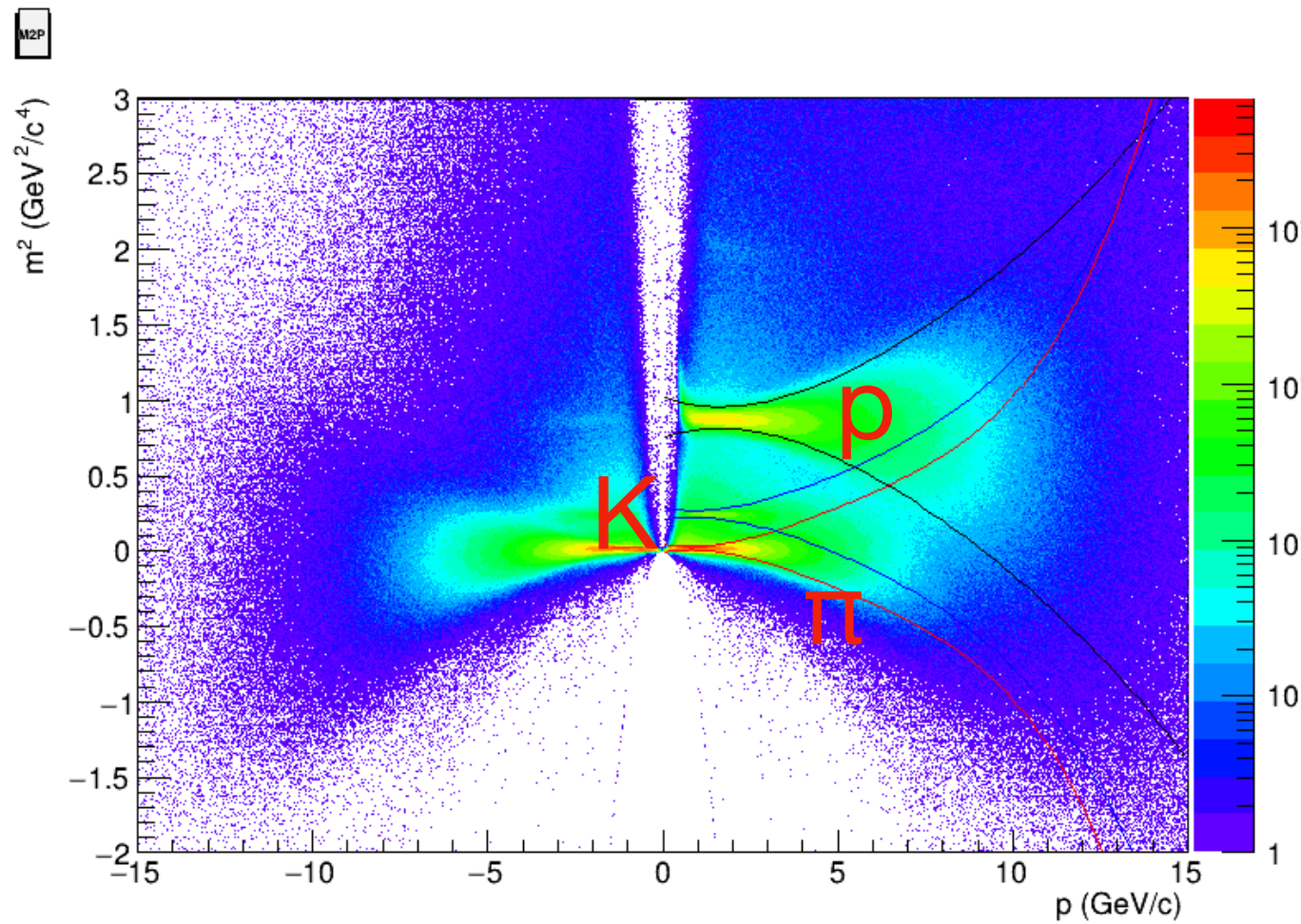
Results from AT + KFParticle

- Input from UrQMD AT testing file from Frederic

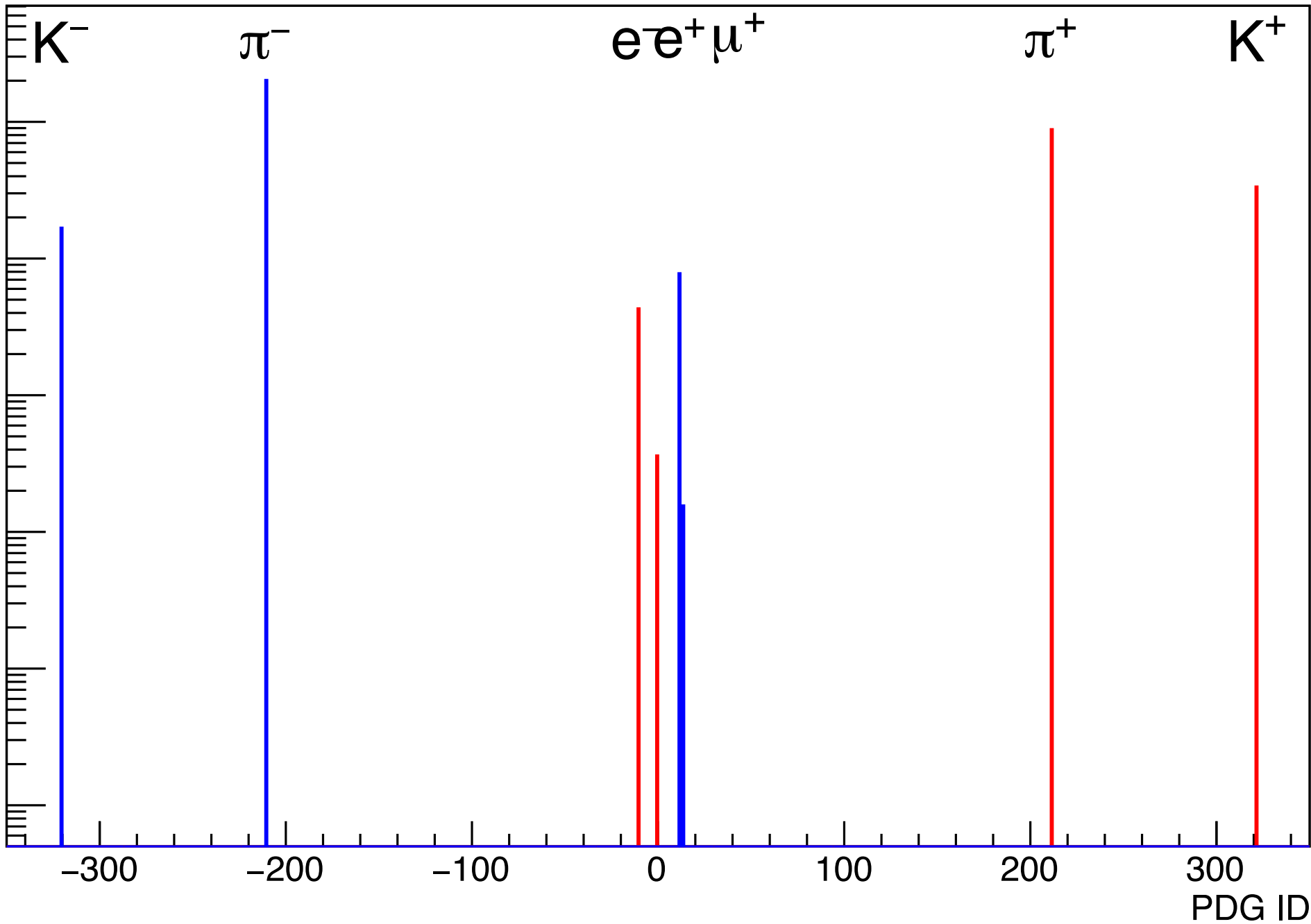
dataset: ~100*1000 events

unigen: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/urqmd/day-1/unigen

AT: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/urqmd/day-1/AT/



ϕ candidates daughters' MC PDG



Significant combinatorial background and mis-PID

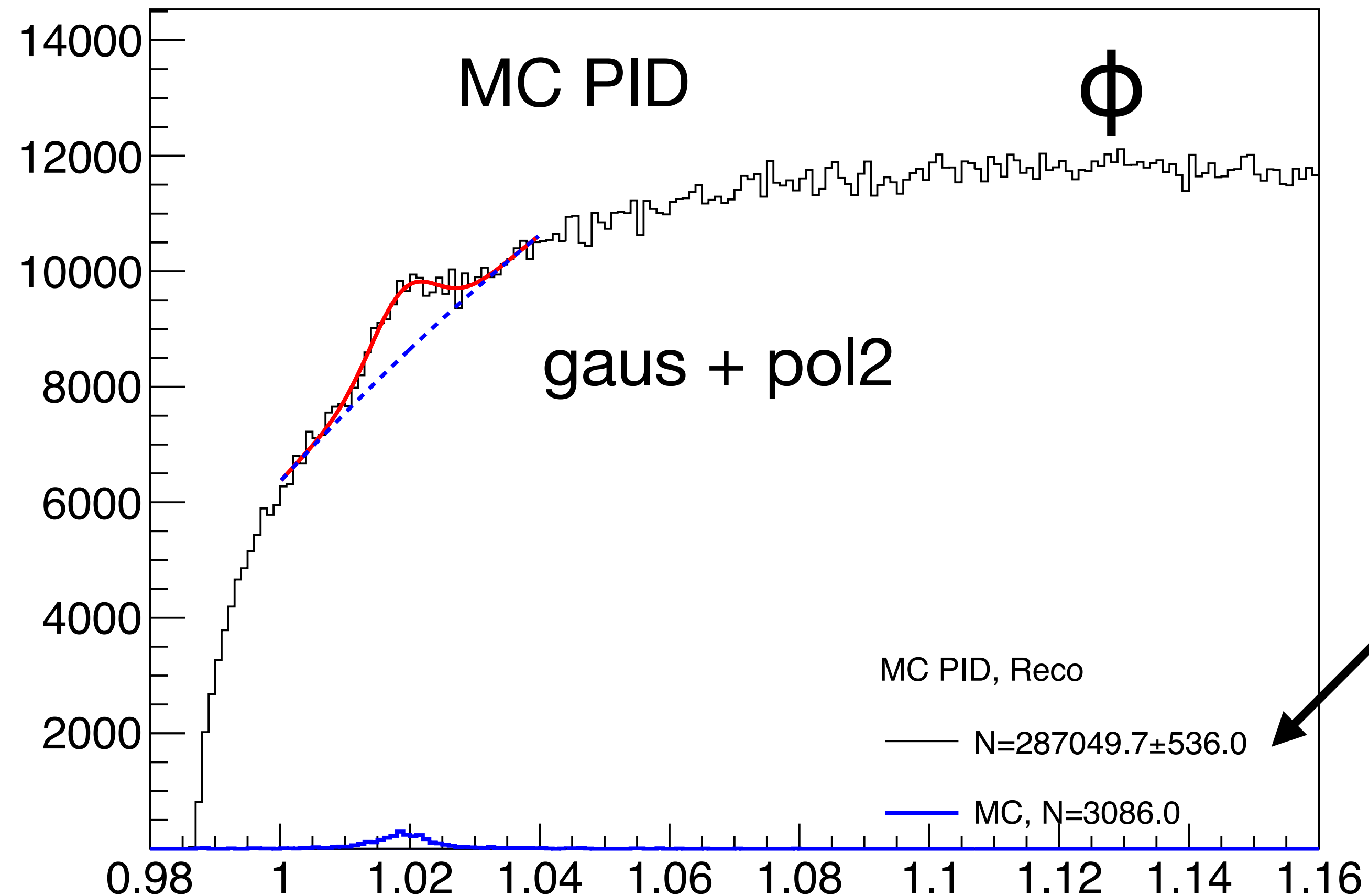
Results from AT + KFParticle

- Input from UrQMD AT testing file from Frederic

dataset: $\sim 100 \times 1000$ events

unigen: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/urqmd/day-1/unigen

AT: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/urqmd/day-1/AT/

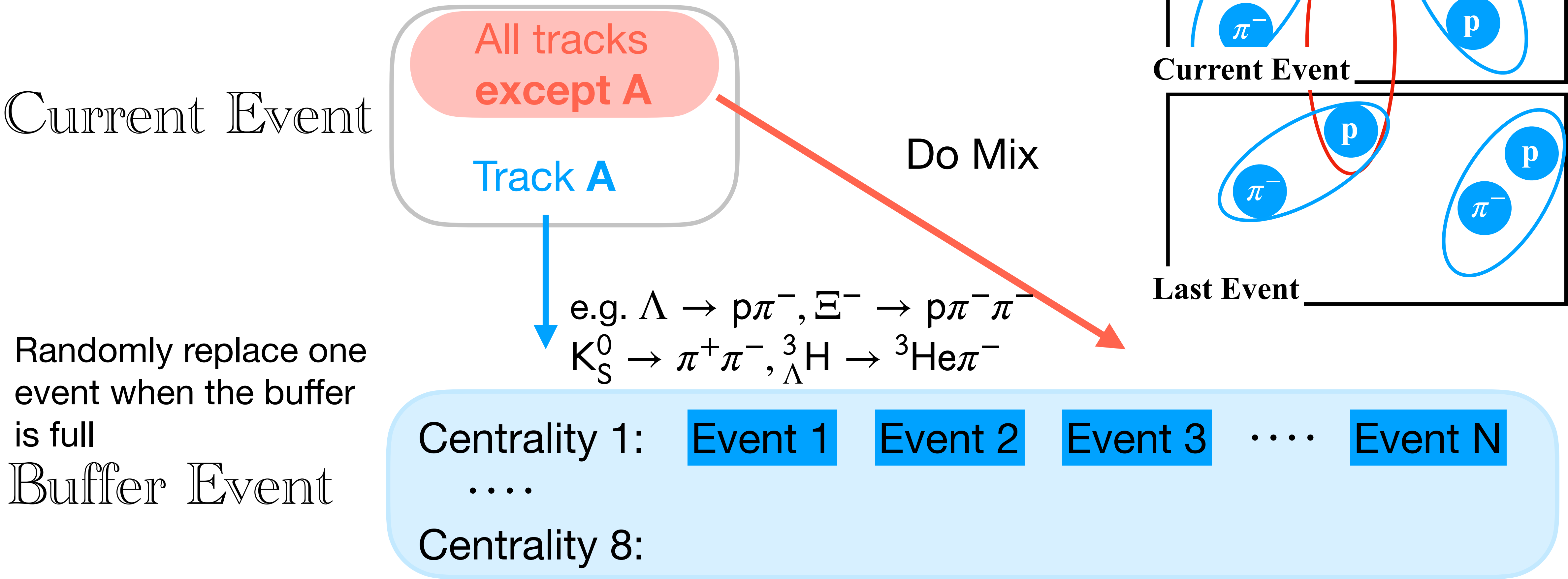


The fit overestimates the yield compared to MC input — results not reliable

A more robust background estimation is needed

Background from Event Mixing

- Create an event buffer outside the main event loop



- Mix tracks from events with similar characteristics (e.g., centrality, event-plane angle)

Background from Event Mixing

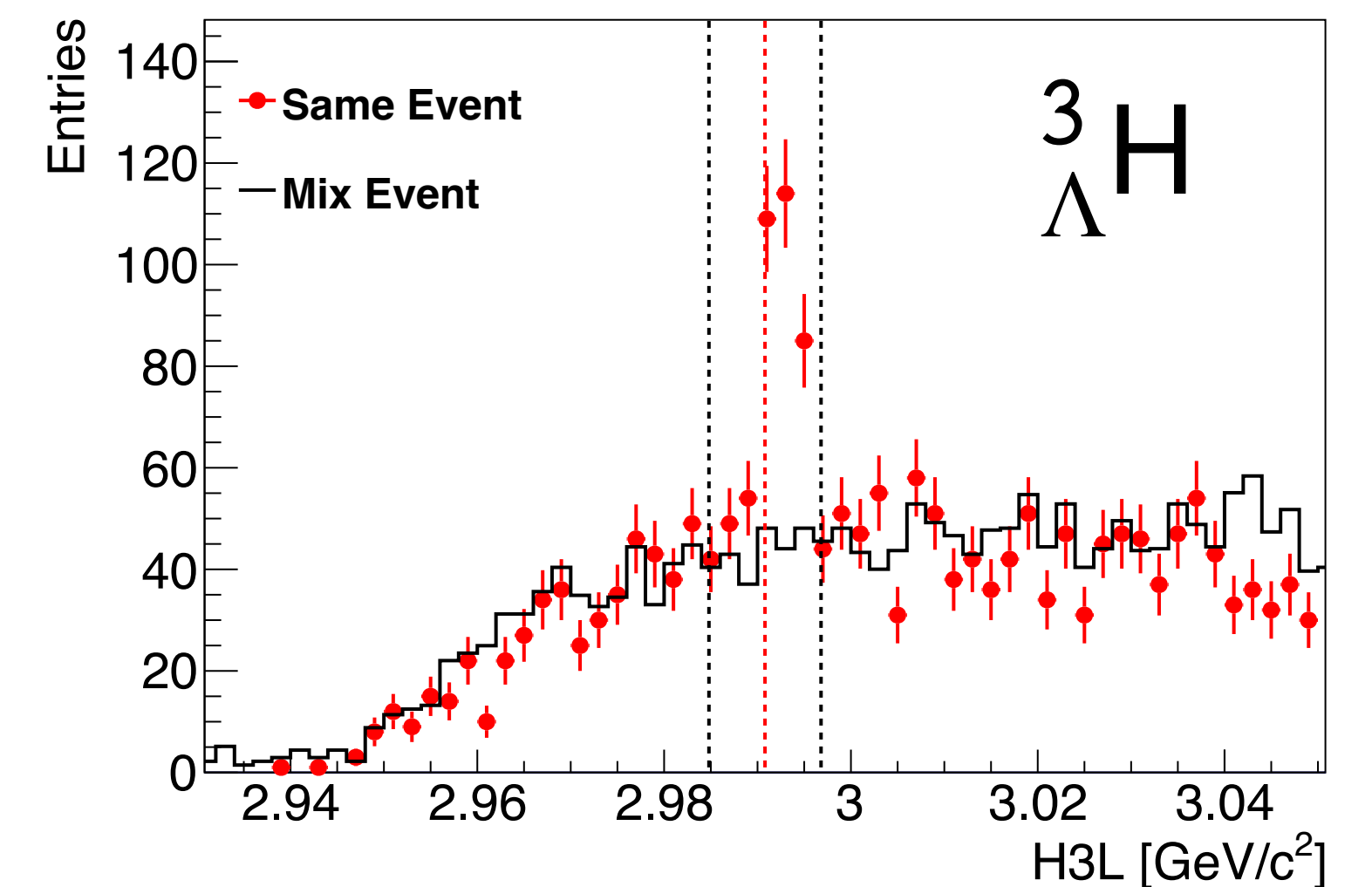
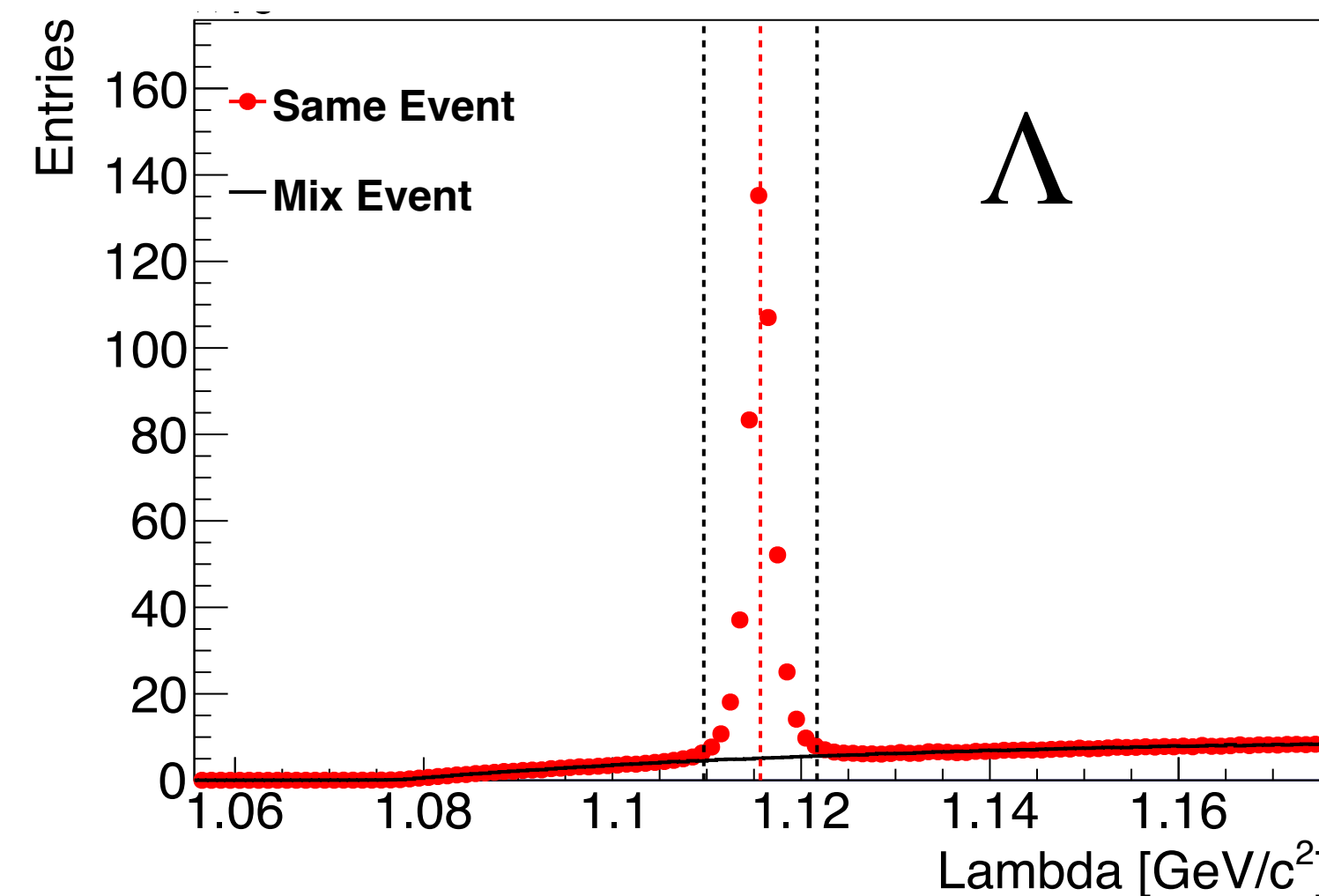
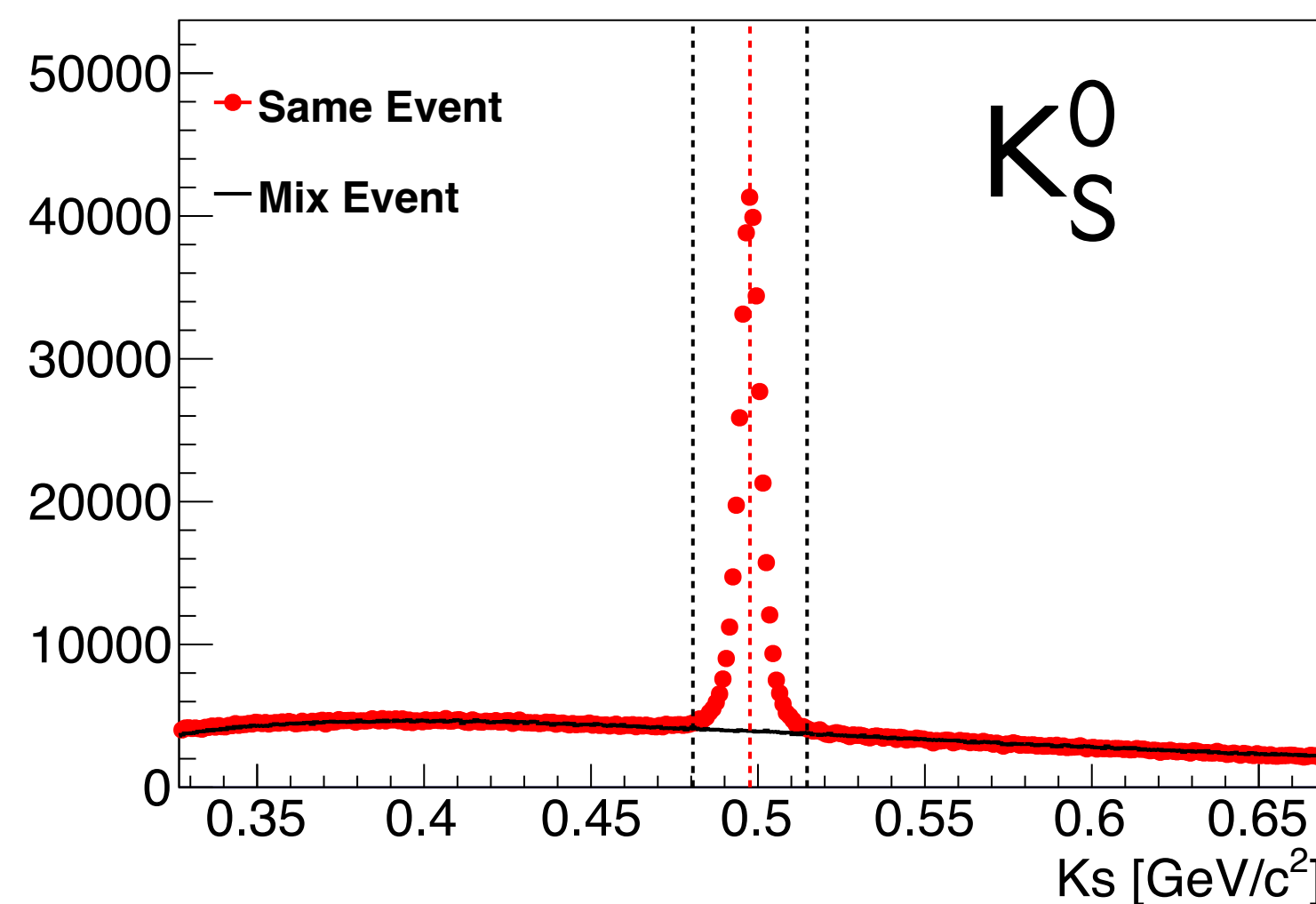
- Flexible Boolean flags to enable or disable mixed-event analysis
- Configurable event-pool parameters (e.g., how many events)



kfParticleFinder->SetMixEventAnalysis() // e.g. default is close

kfParticleFinder->SetMixEventTrkPID(**A**) // e.g. 321 for ϕ , K^* , -211 for Λ , Ξ etc.

kfParticleFinder->SetMixEventBuffer(N) // e.g. 5



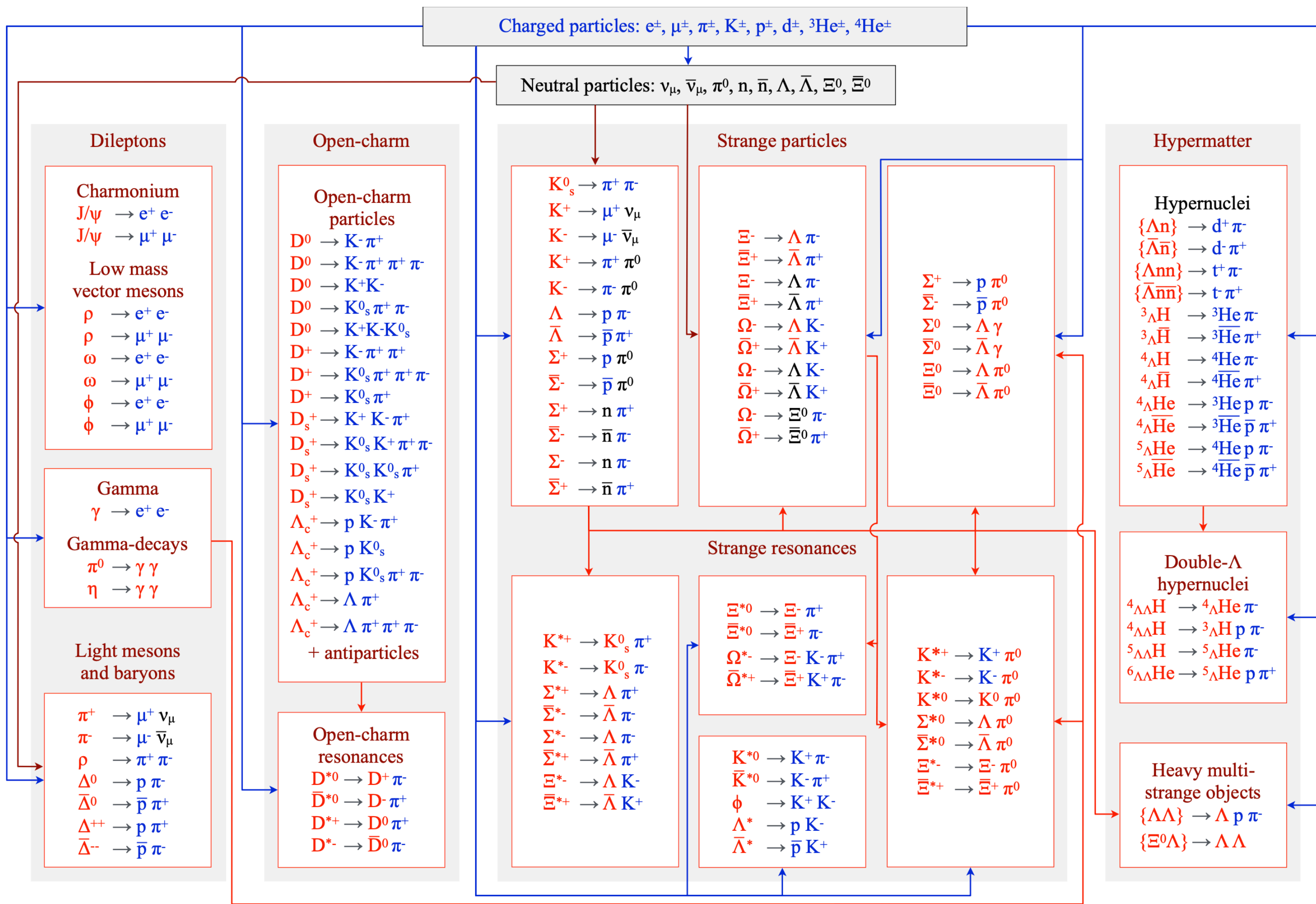
- The mixed-event background smoothly reproduces the shape of the true-event background
- Validated by Krzysztof

Summary and Outlook

✓ Common AnalysisTree + KFParticle

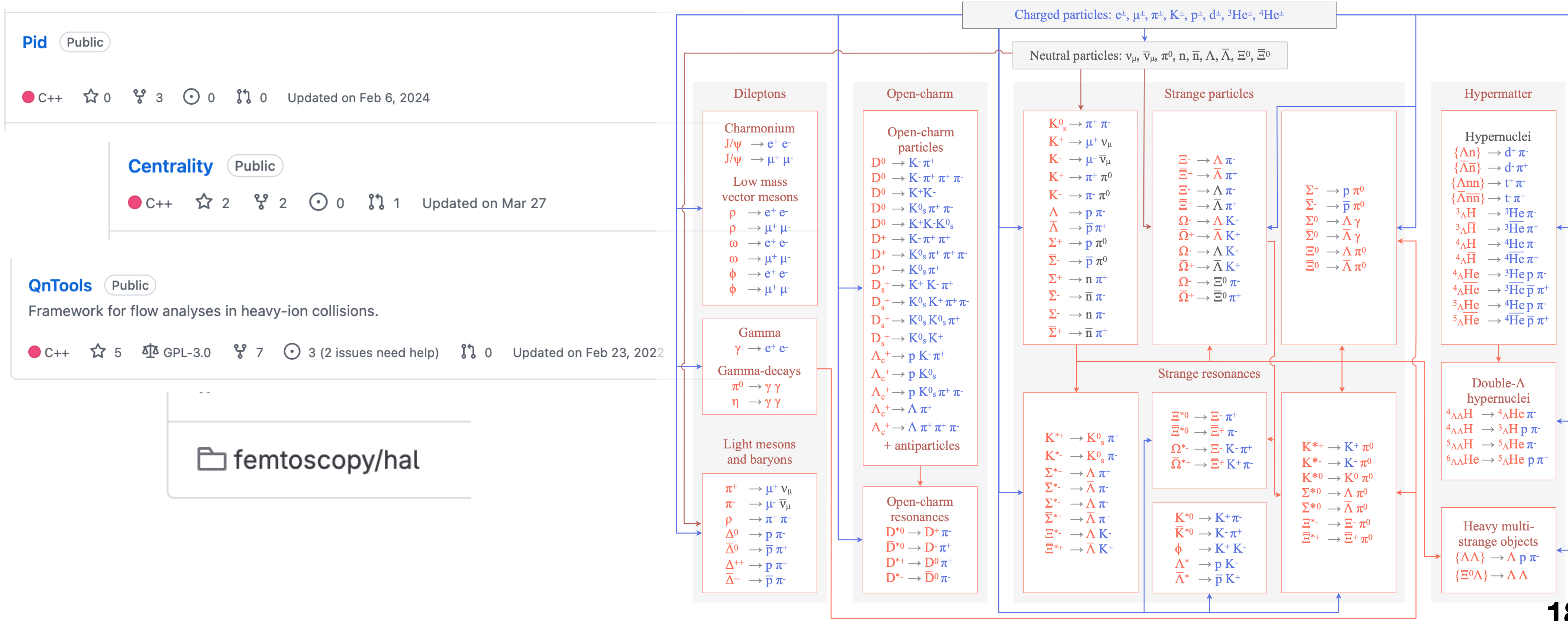
- More than 100 decays
- All reconstructed simultaneously in one go
- Implemented and validated within STAR, ALICE, and PANDA

e.g. STAR has advanced KFParticle version for hypernuclei analysis



Summary and Outlook

- ✓ Common AnalysisTree + KFParticle
 - Read Input include PID, Centrality ...
 - Provides Output for femtoscopy, flow ...



Summary and Outlook

✓ Common AnalysisTree + KFParticle

- Read Input include PID, Centrality ...
- Provides Output for femtoscopy, flow ...

Next steps:

Currently compiling AnalysisTree + KFParticle within the CBMRoot environment

- Need to prepare a standalone compilation script
- Check the output PFSimple structure together with Susanne

✓ Event Mixing Method for background estimation

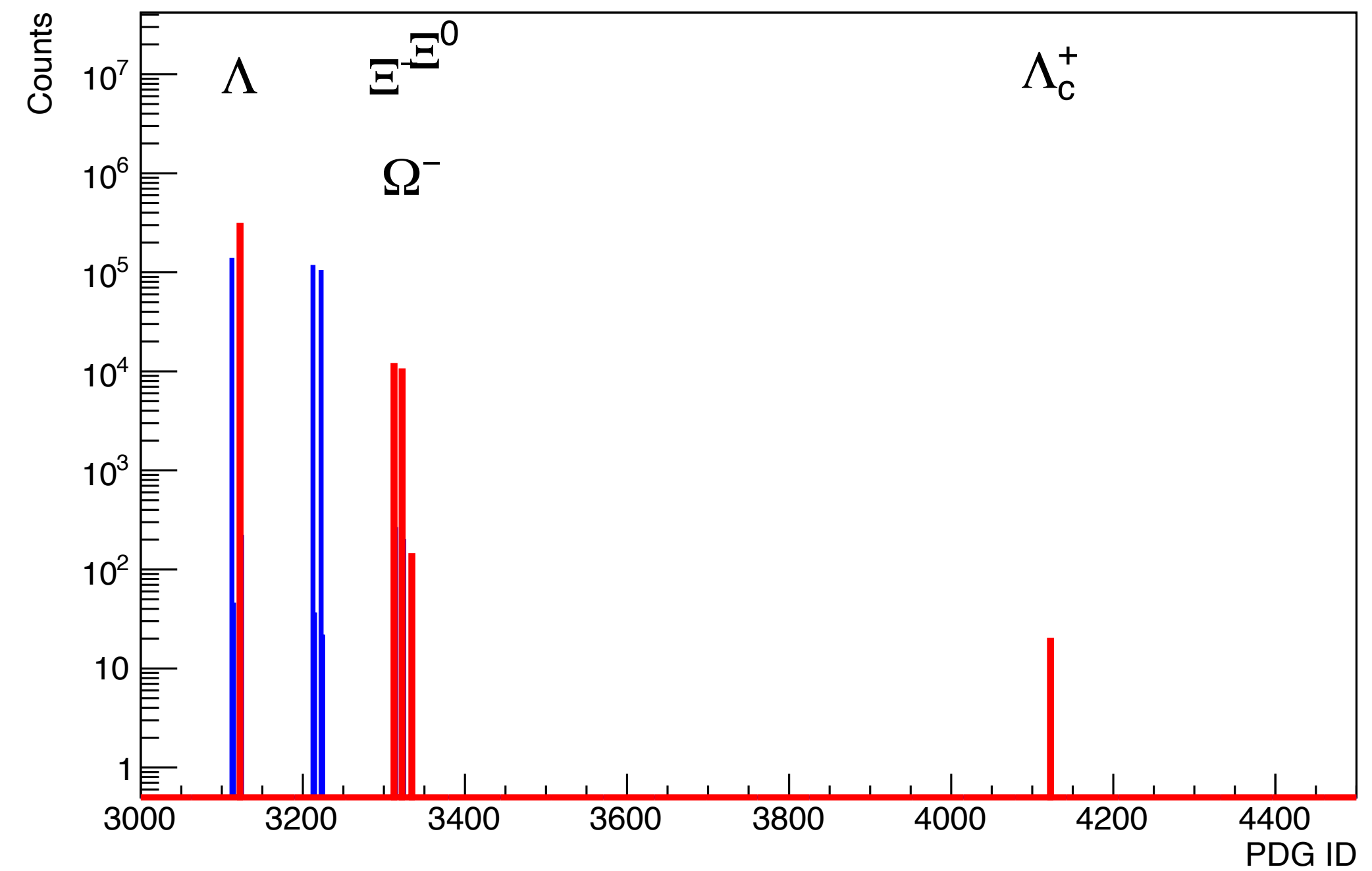
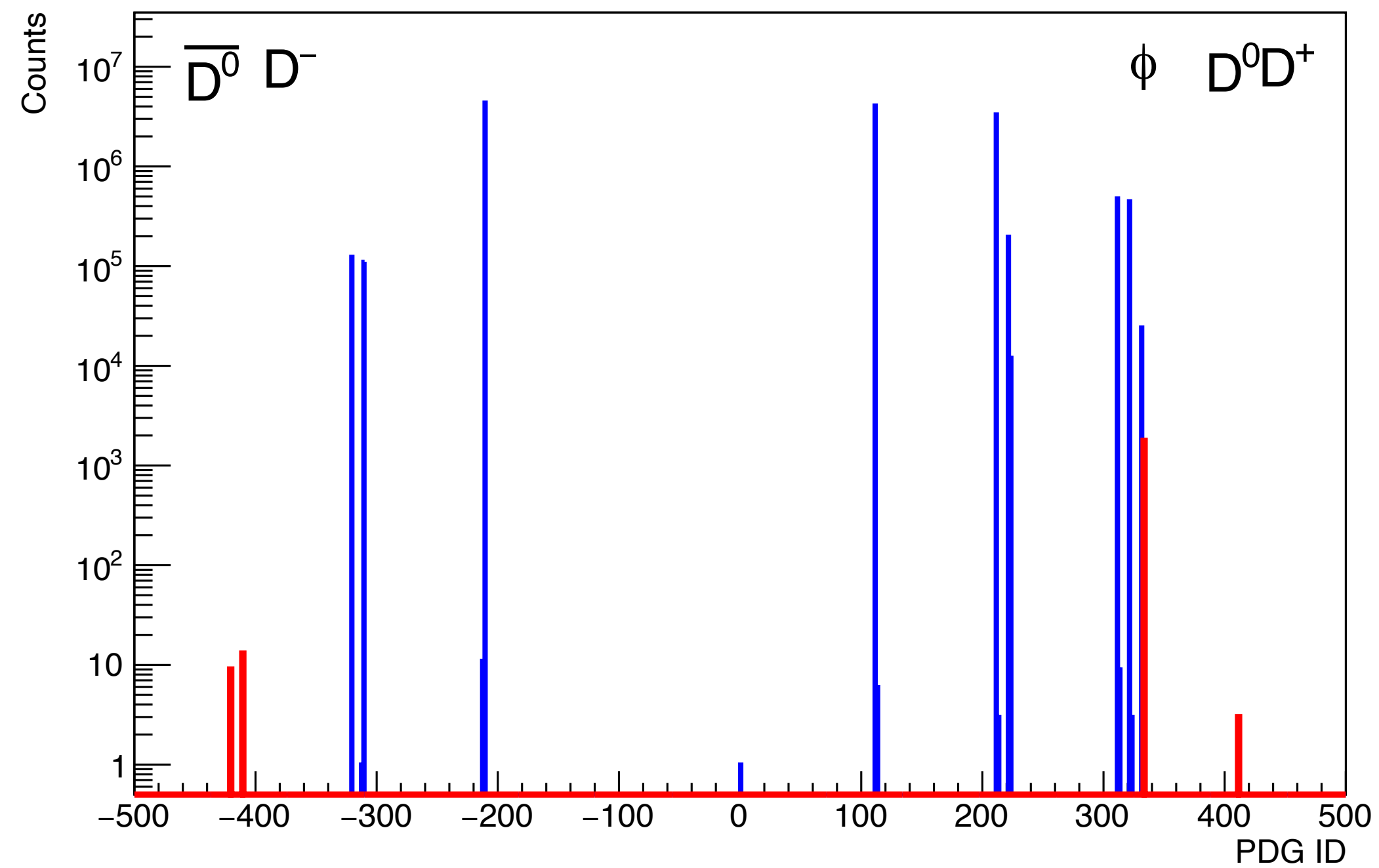
Next steps:

- Implement many-body background (e.g., two-step decays in double- Λ hypernuclei)
- Transfer newly added code from CBM KFParticle to the AT+KFParticle framework

Backup Slides

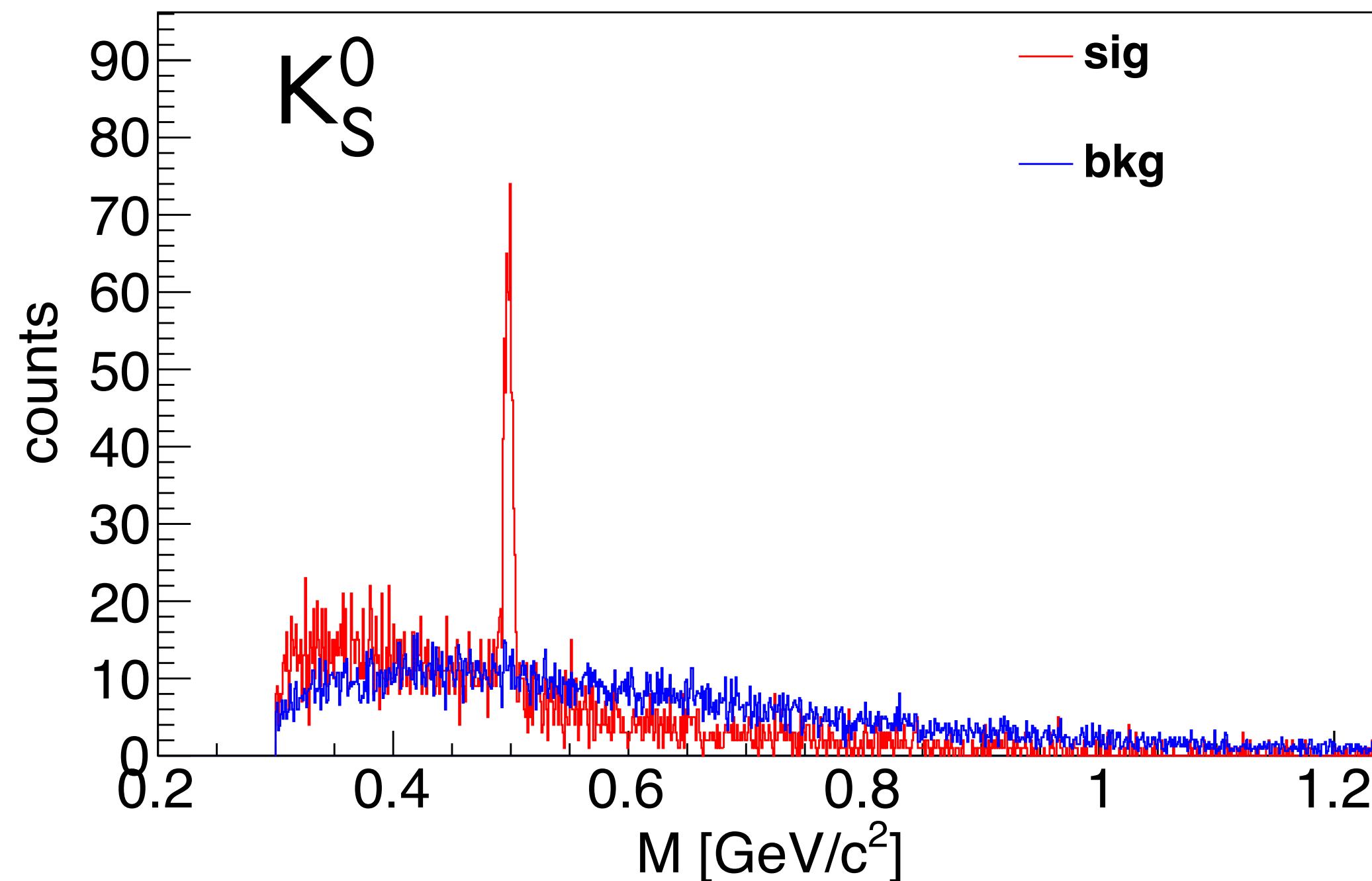
89K urqmd events

unigen: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/urqmd/day-1/unigen



Background from Rotation Track Method

rotate daughter π 180°



- Rotate tracks randomly Before reconstruction
- Non-uniform and not periodic phi distribution (e.g., not symmetric under 90° or 180° rotation) $\rightarrow$ this simple rotation background method not work

π^+ ϕ distribution

