Analysis Framework of Resonance for Run 3

Basics of LFResonanceInitializer

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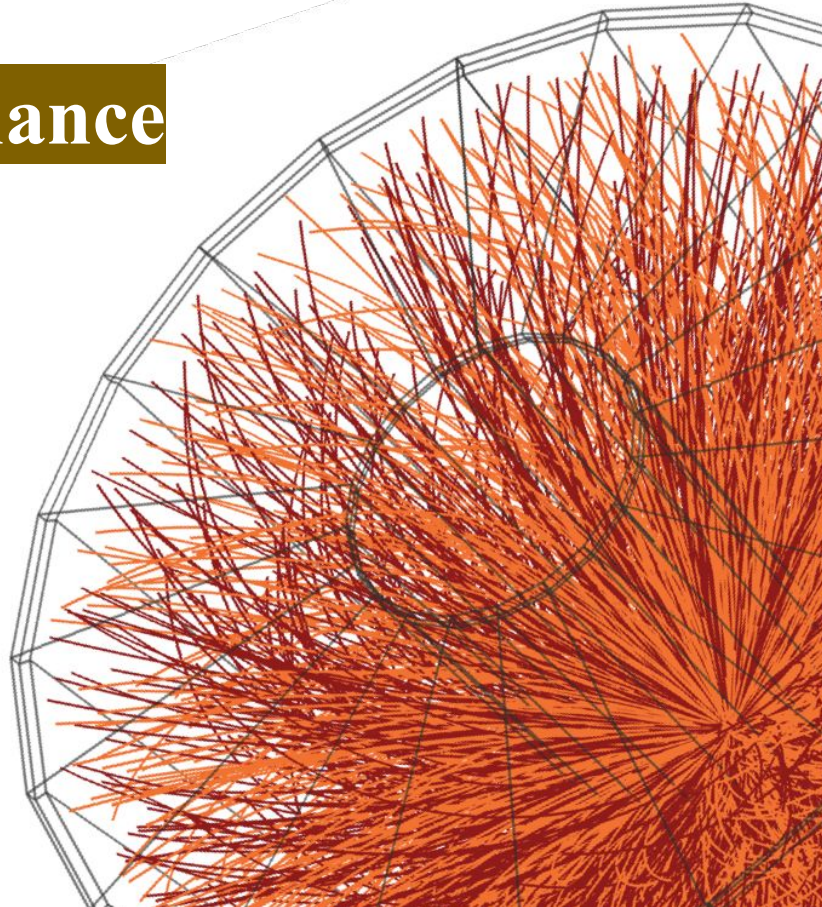
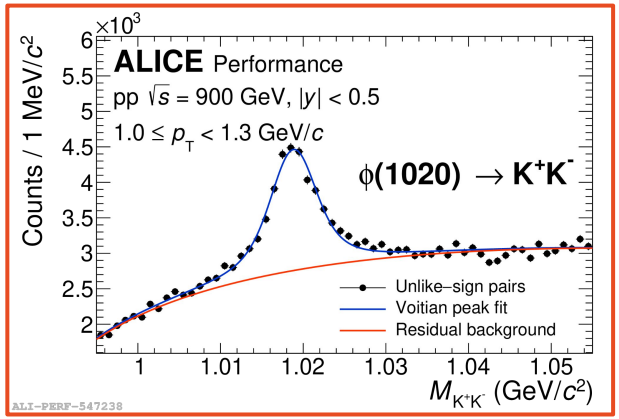
O2 Analysis Tutorial 4.0
https://indico.cern.ch/event/1425820/
16th October 2024



Goal of this session

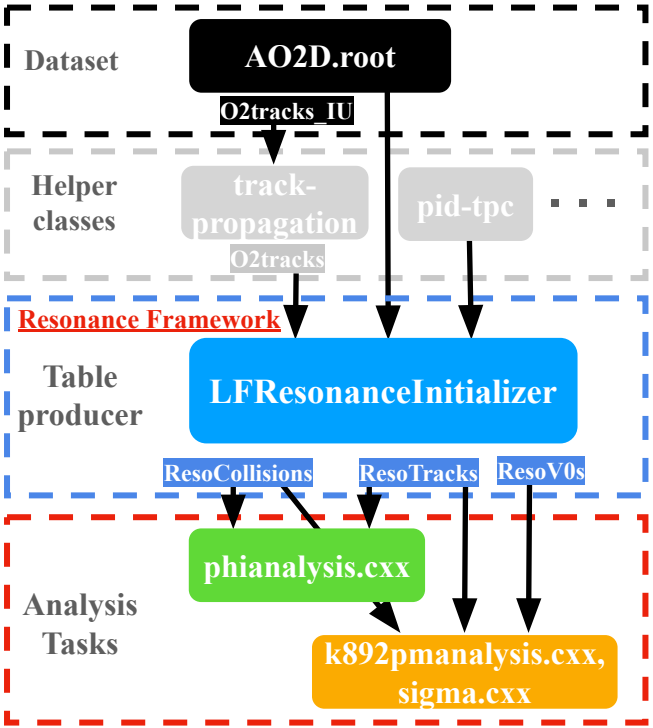
Get you **acquainted with**:

- Resonance analysis framework workflow
- Basics of **ResoInitializer**
- Produce **derived table**
- Produce invariant mass distributions for ϕ using derived data and MC
- Get help if things don't work as expected



Analysis framework workflow

Concept: General table producer for whole resonance analyses



- Unlike RUN2 analysis, most of the analysis data have to be processed **on the fly**
  - This process is done by **Helper class**
  - ✓ E.g. **track propagation** for ITS track, **Λ**/K_s^0/Cascade reconstruction
- **Resonance Framework** refines all information needed for resonance analysis
  - Event (collision) information: **ResoCollisions**
  - Daughter (Track/V0/Cascade) information: **ResoTracks/ResoV0s/ResoCascades**
  - MC information: **ResoMCParents/ResoMCTracks/ResoMCV0s/ResoMCCascades**
- **Analysis tasks** takes only input from the output of the framework
  - Having **similar shape / common selections** with the other resonance analysis
  - Possibility to process with **derived dataset** produced by the framework

Resonance Initializer

Analysis framework

- Resonance Initializer (lf-reso2initializer, O2Physics/PWGLF/TableProducer/Resonances/LFResonanceInitializer)
  - Main table producer, producing 8 tables:
    - **ResoCollisions**, **ResoTracks/ResoV0s/ResoCascades/ ResoMCParents/ResoMCTracks/ResoMCV0s/ResoMCCascades**
      MC related tables
    - Table definition: O2Physics/PWGLF/DataModel/LFResonanceTables.h
  - Applying common basic selections: **event cuts, track cuts, V0 selection**
  - 6 individual processes: *Track/V0/Cascade w/wo MC*

Run only 1 process

- **processTrackData:** ResoCollisions, ResoTracks
- **processTrackV0Data:** ResoCollisions, ResoTracks, ResoV0s
- **processTrackMC:** ResoCollisions, ResoTracks, ResoMCTracks, ResoMCParents
  MC related processes
- **processTrackV0MC:** ResoCollisions, ResoTracks, ResoV0s, ResoMCTracks, ResoMCParents, ResoMCV0s
  MC related processes

- Resonance analyses based on decay mode:
  - Track + Track decay: **$K(892)^0$, $\Phi(1020)$, $\Lambda(1520)$**
  - Track + V0 decay: **$K(892)^{\pm}$, $\Sigma(1385)^{\pm}$, $\Xi(1820)$**
  - Track + Cascade decay: **$\Xi(1530)^0$, $\Omega(2012)$**
  - V0 + V0 decay: **$\Xi(1820)$**
  - V0 + Cascade decay: **$\Omega(2012)$**

Resonance Initializer

Analysis framework

- Resonance Initializer (lf-reso2initializer, O2Physics/PWGLF/TableProducer/Resonances/LFResonanceInitializer)
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    - **ResoCollisions**, **ResoTracks/ResoV0s/ResoCascades/ResoMCParents/ResoMCTracks/ResoMCV0s/ResoMCCascades**
      MC related tables
    - Table definition: O2Physics/PWGLF/DataModel/LFResonanceTables.h
  - Applying common basic selections: **event cuts, track cuts, v0 selection**
  - 6 individual processes: *Track/V0/Cascade w/wo MC*

Run only 1 process

- **processTrackData:** ResoCollisions, ResoTracks
- **processTrackV0Data:** ResoCollisions, ResoTracks, ResoV0s
- **processTrackMC:** ResoCollisions, ResoTracks, ResoMCTracks, ResoMCParents
  MC related processes
- **processTrackV0MC:** ResoCollisions, ResoTracks, ResoV0s, ResoMCTracks, ResoMCParents, ResoMCV0s
  MC related processes

Data processing

MC processing

- Resonance analyses based on decay mode:
  - Track + Track decay: **$K(892)^0$, $\Phi(1020)$, $\Lambda(1520)$**
  - Track + V0 decay: **$K(892)^{\pm}$, $\Sigma(1385)^{\pm}$, $\Xi(1820)$**
  - Track + Cascade decay: **$\Xi(1530)^0$, $\Omega(2012)$**
  - V0 + V0 decay: **$\Xi(1820)$**
  - V0 + Cascade decay: **$\Omega(2012)$**

Resonance Initializer

Analysis framework

- Resonance Initializer (lf-reso2initializer, O2Physics/PWGLF/TableProducer/Resonances/LFResonanceInitializer)
  - Main table producer, producing 8 tables:
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      MC related tables
    - Table definition: O2Physics/PWGLF/DataModel/LFResonanceTables.h
  - Applying common basic selections: **event cuts, track cuts, v0 selection**
  - 6 individual processes: *Track/V0/Cascade w/wo MC*

Run only 1 process

- **processTrackData:** ResoCollisions, ResoTracks
- **processTrackV0Data:** ResoCollisions, ResoTracks, ResoV0s
- **processTrackMC:** ResoCollisions, ResoTracks, ResoMCTracks, ResoMCParents
  MC related processes
- **processTrackV0MC:** ResoCollisions, ResoTracks, ResoV0s, ResoMCTracks, ResoMCParents, ResoMCV0s
  MC related processes

Data processing

MC processing

- Resonance analyses based on decay mode:
  - Track + Track decay: **$K(892)^0$, $\Phi(1020)$, $\Lambda(1520)$**
  - Track + V0 decay: **$K(892)^{\pm}$, $\Sigma(1385)^{\pm}$, $\Xi(1820)$**
  - Track + Cascade decay: **$\Xi(1530)^0$, $\Omega(2012)$**
  - V0 + V0 decay: **$\Xi(1820)$**
  - V0 + Cascade decay: **$\Omega(2012)$**

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

ResoTracks

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Sign,
resodaughter::TPCNClsCrossedRows,
resodaughter::TPCNClsFound,
resodaughter::ITSNCls,
o2::aod::track::DcaXY,
o2::aod::track::DcaZ,
o2::aod::track::X,
o2::aod::track::Alpha,
resodaughter::HasITS,
resodaughter::HasTPC,
resodaughter::HasTOF,
o2::aod::pidtpc::TPCNSigmaPi,
o2::aod::pidtpc::TPCNSigmaKa,
o2::aod::pidtpc::TPCNSigmaPr,
o2::aod::pidtpc::TPCNSigmaEl,
o2::aod::pidtof::TOFNSigmaPi,
```

```
o2::aod::pidtof::TOFNSigmaKa,
o2::aod::pidtof::TOFNSigmaPr,
o2::aod::pidtof::TOFNSigmaEl,
o2::aod::track::TPCSignal,
o2::aod::track::PassedITSRefit,
o2::aod::track::PassedTPCRefit,
resodaughter::IsGlobalTrackWoDCA,
resodaughter::IsGlobalTrack,
resodaughter::IsPrimaryTrack,
resodaughter::IsPVContributor,
resodaughter::TPCCrossedRowsOverFindableCls
, o2::aod::track::ITSChi2NCl,
o2::aod::track::TPCChi2NCl
```

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

ResoTracks

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Sign,
resodaughter::TPCNClsCrossedRows,
resodaughter::TPCNClsFound,
resodaughter::ITSNCls,
o2::aod::track::DcaXY,
o2::aod::track::DcaZ,
o2::aod::track::X,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::SiblingIds,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCTracks

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

ResoTracks

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Sign,
resodaughter::TPCNClsCrossedRows,
resodaughter::TPCNClsFound,
resodaughter::ITSNCls,
o2::aod::track::DcaXY,
o2::aod::track::DcaZ,
o2::aod::track::X,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::SiblingIds,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCTracks

ResoV0s

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Indices,
resodaughter::V0CosPA,
resodaughter::DaughDCA,
v0data::DCAPosToPV,
v0data::DCANegToPV,
v0data::DCAV0ToPV,
resodaughter::MLambda,
resodaughter::MAntiLambda,
resodaughter::MK0Short,
resodaughter::TransRadius,
resodaughter::DecayVtxX,
resodaughter::DecayVtxY,
resodaughter::DecayVtxZ
```

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

ResoTracks

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Sign,
resodaughter::TPCNClsCrossedRows,
resodaughter::TPCNClsFound,
resodaughter::ITSNCls,
o2::aod::track::DcaXY,
o2::aod::track::DcaZ,
o2::aod::track::X,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::SiblingIds,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCTracks

ResoV0s

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Indices,
resodaughter::V0CosPA,
resodaughter::DaughDCA,
v0data::DCAPosToPV,
v0data::DCANegToPV,
v0data::DCAV0ToPV,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::DaughterID1,
resodaughter::DaughterID2,
resodaughter::DaughterPDG1,
resodaughter::DaughterPDG2,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCV0s

Resonance Initializer

Data tables

ResoCollisions

```
o2::aod::mult::MultNTracksPV,
collision::PosX,
collision::PosY,
collision::PosZ,
resocollision::Cent,
resocollision::Spherocity,
resocollision::EvtPl,
resocollision::EvtPlResAB,
resocollision::EvtPlResAC,
resocollision::EvtPlResBC,
resocollision::BMagField,
timestamp::Timestamp
```

- **Basic event information**
  - Vertex positions
  - Multiplicity Percentile
  - Multiplicity
  - Sphericity
  - Magnet information
    Disabled by default
  - Timestamp of the current event

ResoTracks

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Sign,
resodaughter::TPCNClsCrossedRows,
resodaughter::TPCNClsFound,
resodaughter::ITSNCls,
o2::aod::track::DcaXY,
o2::aod::track::DcaZ,
o2::aod::track::X,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::SiblingIds,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCTracks

ResoV0s

```
resodaughter::ResoCollisionId,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
resodaughter::Indices,
resodaughter::V0CosPA,
resodaughter::DaughDCA,
v0data::DCAPosToPV,
v0data::DCANegToPV,
v0data::DCAV0ToPV,
...
```

```
mcparticle::PdgCode,
resodaughter::MothersId,
resodaughter::MotherPDG,
resodaughter::DaughterID1,
resodaughter::DaughterID2,
resodaughter::DaughterPDG1,
resodaughter::DaughterPDG2,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator
```

ResoMCV0s

ResoMCParents

```
resodaughter::ResoCollisionId,
resodaughter::McParticleId,
mcparticle::PdgCode,
resodaughter::DaughterPDG1,
resodaughter::DaughterPDG2,
resodaughter::IsPhysicalPrimary,
resodaughter::ProducedByGenerator,
resodaughter::Pt,
resodaughter::Px,
resodaughter::Py,
resodaughter::Pz,
resodaughter::Eta,
resodaughter::Phi,
mcparticle::Y
```

- MC true particles without selection.
- Can be used for counting total number of resonances **to get the reconstruction efficiency**

Hands-on 1: Execute resonance initializer

Run the script

1. **Download these files**

   - **AO2D file**: https://cernbox.cern.ch/s/s2tD3JCoMZhtiCQ

or

```
alien_cp
/alice/data/2022/LHC22o/528531/apass7/0620/o2_ctf_run00528531_orbit0445929728_tf0000648764_epn115/001/AO2D.root
file://AO2D_LHC22o_528531_apass7_0620_o2_ctf_run00528531_orbit0445929728_tf0000648764_epn115_001.root
```

   - **Configuration file**: https://cernbox.cern.ch/s/xczhvC7uaVKIE8h

2. **Prepare the input data list**

   - Make an inputdata.txt file and add the input file

or

```
echo AO2D_LHC22o_528531_apass7_0620_o2_ctf_run00528531_orbit0445929728_tf0000648764_epn115_001.root >
inputdata.txt
```

   - **Bash shell script:**
     https://cernbox.cern.ch/s/yv8BfQ3jMrOj6cj

Hands-on 1: Execute resonance initializer

Run the script

3. **Run the task with all helper tasks**
   - **o2-analysis-lf-reso2initializer**
   - o2-analysis-pid-tpc
   - o2-analysis-pid-tof
   - o2-analysis-pid-tof-base
   - o2-analysis-pid-tpc-base
   - o2-analysis-centrality-table
   - o2-analysis-multiplicity-table
   - o2-analysis-event-selection
   - o2-analysis-ft0-corrected-table
   - o2-analysis-trackselection
   - o2-analysis-track-propagation
   - o2-analysis-timestamp

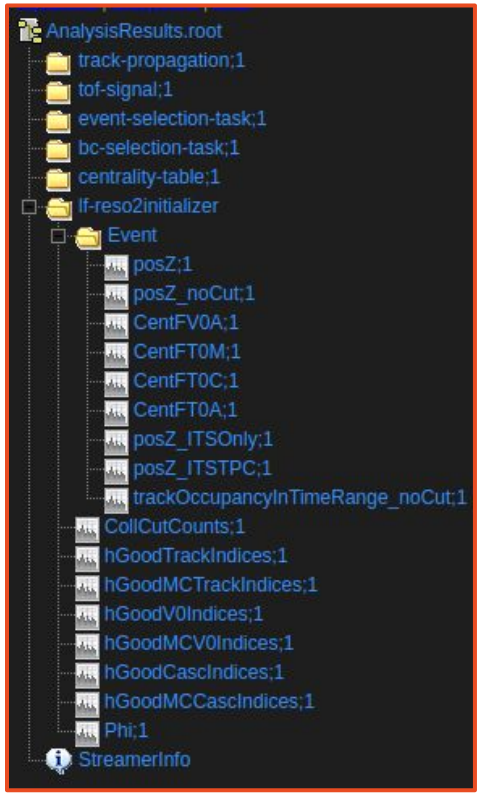
PID

Centrality

```
o2-analysis-lf-reso2initializer -b  --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tpc -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tof -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tof-base -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tpc-base -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-centrality-table -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-multiplicity-table -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-event-selection -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-ft0-corrected-table -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-trackselection -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-track-propagation -b --configuration
json://configuration_resoinitializer_pp.json |
o2-analysis-timestamp -b --configuration
json://configuration_resoinitializer_pp.json --aod-file
@inputdata.txt
```

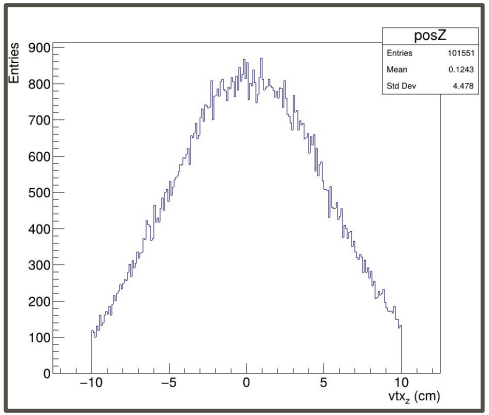
Hands-on 1: Execute resonance initializer

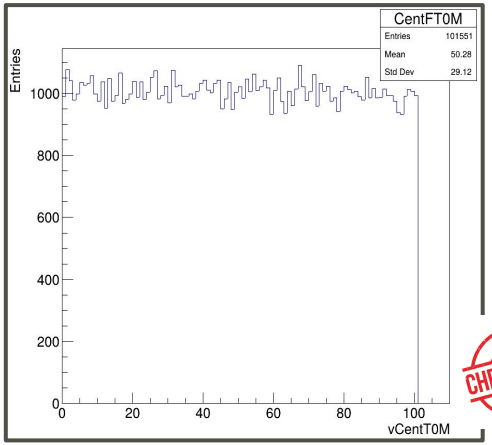
Output



Inside the `AnalysisResults.root` file...

- `bc-selection-task` outputs
- `event-selection-task` outputs
- **`lf-reso2initializer` outputs**
  - Event
    - Vertex-z position histogram
    - Centrality from various estimators
    - Multiplicity (signal intensity) from T0A/C/M
  - QA outputs
    only if we select `ConfFillQA` option





Hands-on 2: Produce derived resonance table

- **Same as before, but adding this option to the** `o2-analysis-lf-reso2initializer --aod-writer-json OutputDirector.json`
  - Bash shell script: **https://cernbox.cern.ch/s/1QUxPZnFqoalbUZ**
  - Detailed Tutorial: **https://indico.cern.ch/event/1425820/timetable/#8-derived-data-in-o2o2physics**

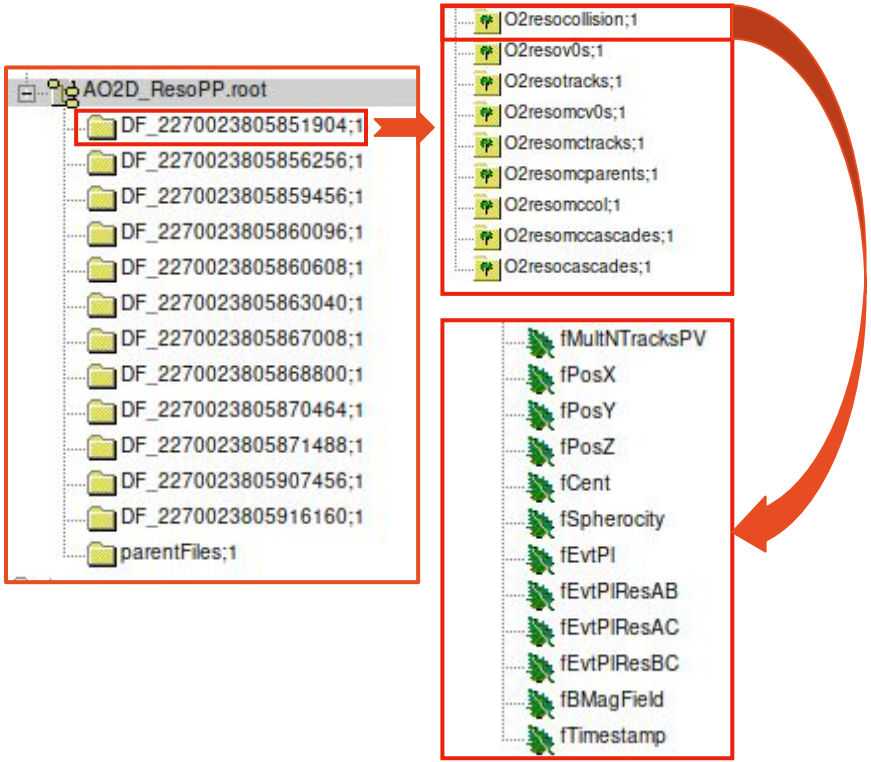
```
o2-analysis-lf-reso2initializer -b --configuration json://configuration_resoinitializer_pp.json
--aod-writer-json OutputDirector.json |
o2-analysis-pid-tpc -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tof -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tof-base -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-pid-tpc-base -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-centrality-table -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-multiplicity-table -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-event-selection -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-ft0-corrected-table -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-trackselection -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-track-propagation -b --configuration json://configuration_resoinitializer_pp.json |
o2-analysis-timestamp -b --configuration json://configuration_resoinitializer_pp.json --aod-file
@inputdata.txt
```

```
{
  "OutputDirector": {
    "debug_mode": true,
    "resfile": "AO2D_ResoPP",
    "OutputDescriptors": [
      {
        "table": "AOD/RESOMCTRACKS/0"
      },
      {
        "table": "AOD/RESOTRACKS/0"
      },
      {
        "table": "AOD/RESOV0S/0"
      },
      {
        "table": "AOD/RESOMCV0S/0"
      },
      {
        "table": "AOD/RESOCASCADES/0"
      },
      {
        "table": "AOD/RESOMCCASCADES/0"
      },
      {
        "table": "AOD/RESOCOLLISION/0"
      },
      {
        "table": "AOD/RESOMCCOL/0"
      },
      {
        "table": "AOD/RESOMCPARENTS/0"
      }
    ],
    "ntfmerge": 1
  }
}
```

Hands-on 2: Produce derived resonance table

Output:

```
664M Oct 12 15:29 AO2D_LHC22o_528531_apass7_0620_o2_ctf_run00528531_orbit0445929728_tf0000648764_epn115_001.root
 37M Oct 12 16:49 AO2D_ResoPP.root
```



- **Size comparison**
  - For given pp 13.6 TeV dataset
    - **664 MB → 37 MB** (~ **5.6 %** of original)
  - Case of Pb-Pb 5.36 TeV
    - **2.8 GB → 146.5 MB** (~ **5.1 %** of original)

✓ Compression rate can be affected based on the selection cut applied.

- **Inside the derived dataset:**
  - One can find the **produced tables!**

Hands-on 3: Using the derived data

- **Start from the previous output**
  - or download from here: **https://cernbox.cern.ch/s/fpbFod0UkA3oK6P**
- **First task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step0.cxx`
  - bash script & configuration: **https://cernbox.cern.ch/s/WPZOuo2SL1mFEWB**
  - Command:
    - `o2-analysistutorial-lf-resonances-step0 -b --aod-file AO2D_ResoPP.root` **Default**
    - `o2-analysistutorial-lf-resonances-step0 -b --aod-file AO2D_ResoPP.root --nBins 10` **Input from cli**
    - `o2-analysistutorial-lf-resonances-step0 -b --aod-file AO2D_ResoPP.root --configuration json://configuration_resotutorial_0.json` **Using configuration.json**

Detail: Resonances_step0 #1

```cpp
struct resonances_tutorial {
  HistogramRegistry histos{"histos", {}, OutputObjHandlingPolicy::AnalysisObject};

  // Configurable for number of bins
  Configurable<int> nBins{"nBins", 100, "N bins in all histos"};
  // Configurable for min pT cut
  Configurable<double> cMinPtcut{"cMinPtcut", 0.15, "Track minium pt cut"};

  // Initialize the ananlysis task
  void init(o2::framework::InitContext&)
  {
    // register histograms
    histos.add("hVertexZ", "hVertexZ", HistType::kTH1F, {{nBins, -15., 15.}});
    histos.add("hEta", "Eta distribution", kTH1F, {{200, -1.0f, 1.0f}});
  }
```

Histogram output

Configurable

Initializing variables

Detail: Resonances_step0 #2

```cpp
// Track selection
template <typename TrackType>
bool trackCut(const TrackType track)
{
  // basic track cuts
  if (std::abs(track.pt()) < cMinPtcut)
    return false;

  return true;
}
```

Track selection

```cpp
// Fill histograms (main function)
template <bool IsMC, bool IsMix, typename CollisionType, typename TracksType>
void fillHistograms(const CollisionType& collision, const TracksType& dTracks1, const TracksType& dTracks2)
{
  for (auto track1 : dTracks1) { // loop over all dTracks1
    if (!trackCut(track1))
      continue; // track selection and PID selection
    histos.fill(HIST("hEta"), track1.eta());
  }
}
```

Template function for all kinds of process

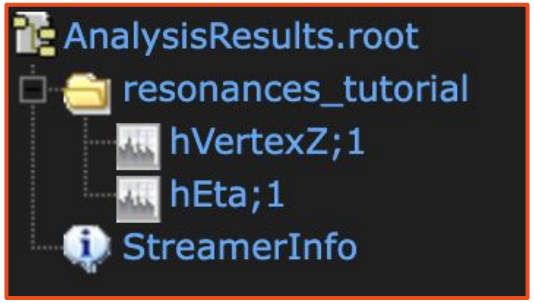
```cpp
// Process the data
void process(aod::ResoCollision& collision, aod::ResoTracks const& resotracks)
{
  // Fill the event counter
  histos.fill(HIST("hVertexZ"), collision.posZ());
  fillHistograms<false, false>(collision, resotracks, resotracks); // Fill histograms, no MC, no mixing
}
```

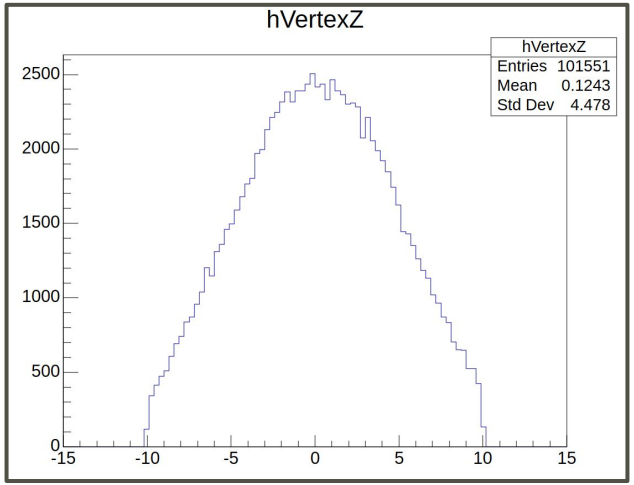
Resonance table!

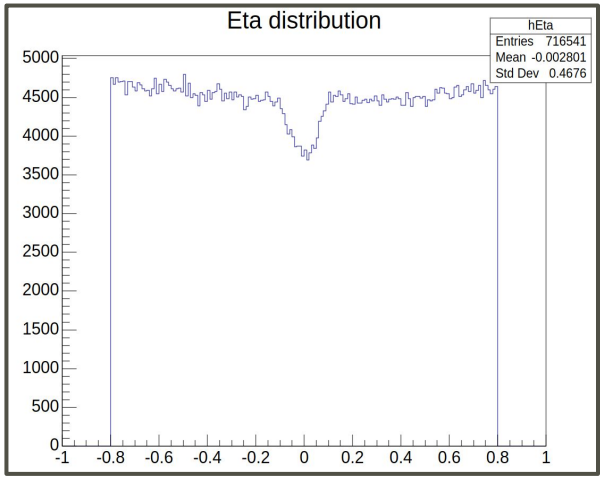
Main process loop

Hands-on 3: Using the derived data

Output







- **There will be two histograms.**
  - You can adjust the number of bins by using the configurable **`nBins`**

Hands-on 4: Draw ϕ invariant mass histogram

- **Using the resonance derived output**
  - Download from here: **https://cernbox.cern.ch/s/fpbFod0UkA3oK6P**
- **Modify the first task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step0.cxx`
  - **Example:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step1.cxx`
    - bash script & configuration: **https://cernbox.cern.ch/s/KYdxHUtI0SCnQOu**
- **Strategy**
  - Add Track Selection
  - Add the PID Selection
  - Add the second track loop
  - Reconstruct the resonance

Detail: Resonances_step1 #1

Add track selection

```
// Track selection
// primary track condition
Configurable<bool> cfgPrimaryTrack{"cfgPrimaryTrack", true, "Primary track selection"};
Configurable<bool> cfgGlobalWoDCATrack{"cfgGlobalWoDCATrack", true, "Global track selection without DCA"};
Configurable<bool> cfgPVContributor{"cfgPVContributor", true, "PV contributor track selection"};
// DCA Selections
// DCAr to PV
Configurable<double> cMaxDCArToPVcut{"cMaxDCArToPVcut", 0.5, "Track DCAr cut to PV Maximum"};
// DCAz to PV
Configurable<double> cMaxDCAzToPVcut{"cMaxDCAzToPVcut", 2.0, "Track DCAz cut to PV Maximum"};
Configurable<double> cMinDCAzToPVcut{"cMinDCAzToPVcut", 0.0, "Track DCAz cut to PV Minimum"};
```

Track-selection helper

DCA Selections

Track-selection filter reference: O2Physics/Common/DataModel/TrackSelectionTables.h

Detail: Resonances_step1 #2

Add track selection

```
// Track selection
template <typename TrackType>
bool trackCut(const TrackType track)
{
  // basic track cuts
  if (std::abs(track.pt()) < cMinPtcut)
    return false;
  if (std::abs(track.dcaXY()) > cMaxDCArToPVcut)
    return false;
  if (std::abs(track.dcaZ()) > cMaxDCAzToPVcut)
    return false;
  if (cfgPrimaryTrack && !track.isPrimaryTrack())
    return false;
  if (cfgGlobalWoDCATrack && !track.isGlobalTrackWoDCA())
    return false;
  if (cfgPVContributor && !track.isPVContributor())
    return false;
  return true;
}
```

Additional track-selections

Detail: Resonances_step1 #3

Add PID selection

```
// PID selection
Configurable<float> nsigmaCutTPC{"nsigmacutTPC", 3.0, "Value of the TPC Nsigma cut"};
Configurable<float> nsigmaCutCombined{"nsigmaCutCombined", 3.0, "Value of the TOF Nsigma cut"};
```

```
// PID selection TPC +TOF Veto
template <typename T>
bool selectionPID(const T& candidate)
{
  if (candidate.hasTOF() && (candidate.tofNSigmaKa() * candidate.tofNSigmaKa() + candidate.tpcNSigmaKa()
  * candidate.tpcNSigmaKa()) < (2.0 * nsigmaCutCombined * nsigmaCutCombined)) {
    return true;
  } else if (std::abs(candidate.tpcNSigmaKa()) < nsigmaCutTPC) {
    return true;
  }
  return false;
}
```

Dedicated function for PID selection

Detail: Resonances_step1 #4

Add second track loop

```
template <bool IsMC, bool IsMix, typename CollisionType, typename TracksType>
void fillHistograms(const CollisionType& collision, const TracksType& dTracks1, const TracksType& dTracks2)
{
  auto multiplicity = collision.multV0M();
  for (auto track1 : dTracks1) { // loop over all dTracks1
    if (!trackCut(track1) || !selectionPID(track1)) {
      continue; // track selection and PID selection
    }
    // QA plots
    histos.fill(HIST("hEta"), track1.eta());
    histos.fill(HIST("hDcaxy"), track1.dcaXY());
    histos.fill(HIST("hDcaz"), track1.dcaZ());
    histos.fill(HIST("hNsigmaKaonTPC"), track1.tpcNSigmaKa());
    if (track1.hasTOF()) {
      histos.fill(HIST("hNsigmaKaonTOF"), track1.tofNSigmaKa());
    }
    for (auto track2 : dTracks2) { // loop over all dTracks2
      if (!trackCut(track2) || !selectionPID(track2)) {
        continue; // track selection and PID selection
      }
      if (track2.index() <= track1.index()) {
        continue; // condition to avoid double counting of pair
      }
```

Track selection

Second track loop

Prevent double counting

Detail: Resonances_step1 #5

Reconstruct the resonance

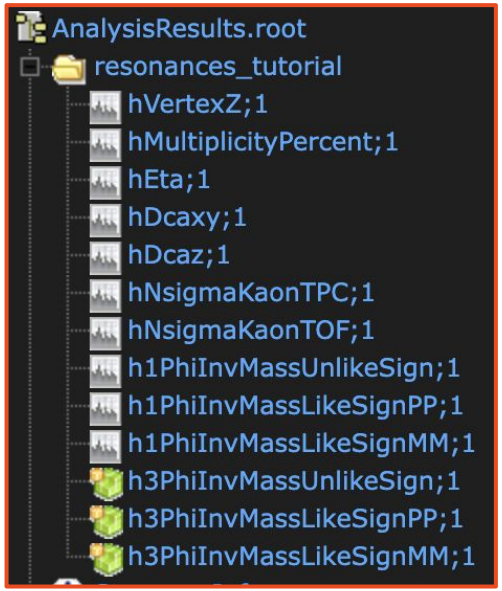
```
// Fill histograms (main function)
double rapidity, mass, pT, paircharge;
TLorentzVector daughter1, daughter2, mother;
```

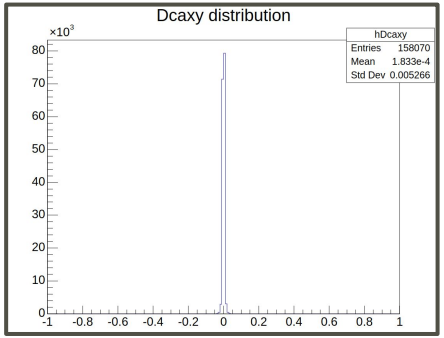
Common variables (TLorentzVector)

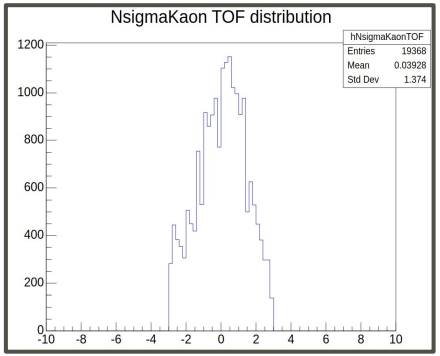
```
daughter1.SetXYZM(track1.px(), track1.py(), track1.pz(), massKa); // set the daughter1 4-momentum
daughter2.SetXYZM(track2.px(), track2.py(), track2.pz(), massKa); // set the daughter2 4-momentum
mother = daughter1 + daughter2;                                   // calculate the mother 4-momentum
mass = mother.M();
pT = mother.Pt();
rapidity = mother.Rapidity();
paircharge = track1.sign() * track2.sign();

if (std::abs(rapidity) > 0.5)
  continue; // rapidity cut

if (paircharge < 0) { // unlike sign
  histos.fill(HIST("h3PhiInvMassUnlikeSign"), multiplicity, pT, mass);
  histos.fill(HIST("h1PhiInvMassUnlikeSign"), mass);
```

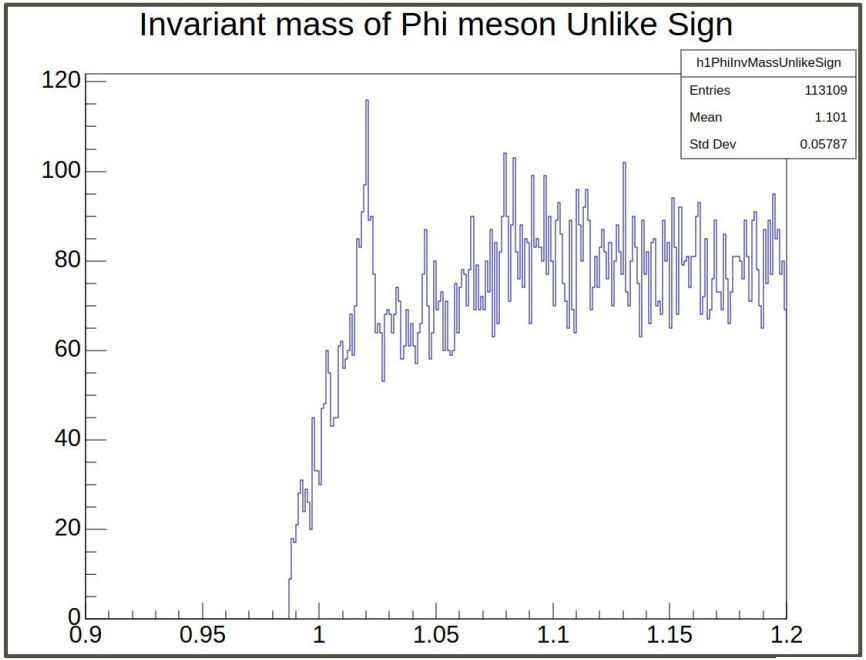
Hands-on 4: Draw ϕ invariant mass histogram

Output









Hands-on 5: Event Mixing

- **Using the resonance derived output**
  - Download from here: **https://cernbox.cern.ch/s/fpbFod0UkA3oK6P**
- **Modify the previous task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step1.cxx`
  - **Example:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step2.cxx`
    - bash script & configuration: **https://cernbox.cern.ch/s/W0dhB3L8ycAGExZ**
  - Add new process for Event mixing
  - Define a new binning type and pairs
  - Fill the histogram

Detail: Resonances_step2

Simplest event-mixing

```
// Event Mixing
Configurable<int> nEvtMixing{"nEvtMixing", 5, "Number of events to mix"};
ConfigurableAxis CfgVtxBins{"CfgVtxBins", {VARIABLE_WIDTH, -10.0f, -8.f, -6.f, -4.f,
-2.f, 0.f, 2.f, 4.f, 6.f, 8.f, 10.f}, "Mixing bins - z-vertex"};
ConfigurableAxis CfgMultBins{"CfgMultBins", {VARIABLE_WIDTH, 0., 1., 5., 10., 30.,
50., 70., 100., 110.}, "Mixing bins - multiplicity"};
```

Configurable for Event-Mixing (2D pool)

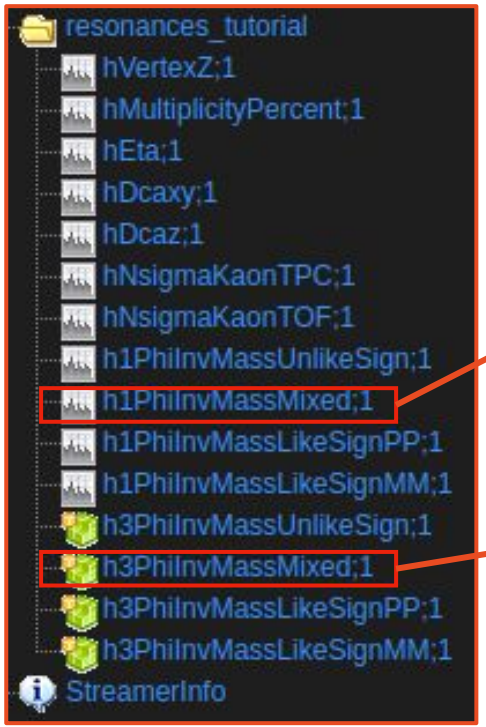
```
// Processing Event Mixing
using BinningTypeVtxZT0M = ColumnBinningPolicy<aod::collision::PosZ, aod::resocollision::MultV0M>;
void processME(o2::aod::ResoCollisions& collisions, aod::ResoTracks const& resotracks)
{
  auto tracksTuple = std::make_tuple(resotracks);
  BinningTypeVtxZT0M colBinning{{CfgVtxBins, CfgMultBins}, true};
  SameKindPair<aod::ResoCollisions, aod::ResoTracks, BinningTypeVtxZT0M> pairs{colBinning, nEvtMixing, -1, collisions,
  tracksTuple, &cache}; // -1 is the number of the bin to skip

  for (auto& [collision1, tracks1, collision2, tracks2] : pairs) { // loop over all pairs
    fillHistograms<false, true>(collision1, tracks1, tracks2);     // Fill histograms, no MC, mixing
  }
};
PROCESS_SWITCH(resonances_tutorial, processME, "Process EventMixing for combinatorial background", false); // Event Mixing
```

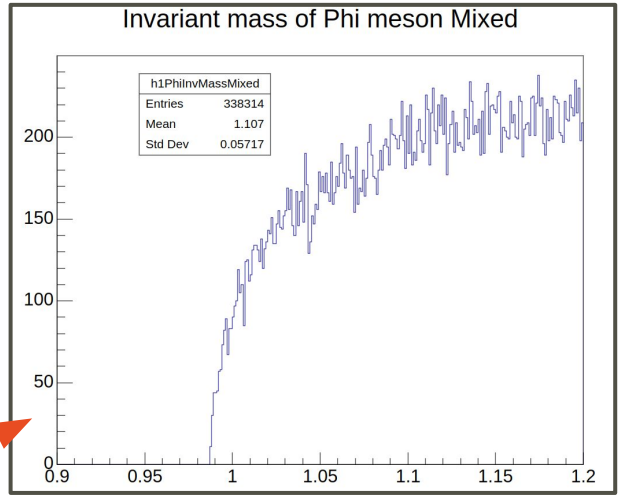
Make a new process

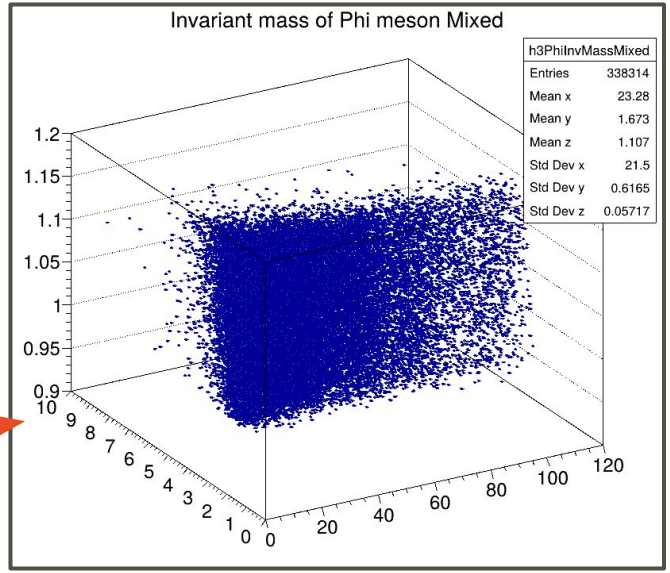
Let the function know

Hands-on 5: ϕ invariant mass for Mixed Event

Output







Step towards determining efficiency

Hands-on 6: Downloading and preparing the MC

Run the script

1. **Download these files**

   - **AO2D file**: https://cernbox.cern.ch/s/5sZh1DZMsITR7Q9

     or

     ```
     alien_cp /alice/sim/2024/LHC24f3b/0/529691/AOD/001/AO2D.root
     file://AO2D_MC_LHC24f3b_529691_apass7_2024_001.root
     ```

   - **Configuration file**: https://cernbox.cern.ch/s/aAvo9y2W1BbhxOK
     https://cernbox.cern.ch/s/IvUGQjFBYiUgWeD

2. **Prepare the input data list**

   - Make an inputdata.txt file and add the input file

     or

     ```
     echo AO2D_MC_LHC24f3b_529691_apass7_2024_001.root > inputMC.txt
     ```

Hands-on 6: Produce resonance table for MC

- **Same as before, but adding this option to the** `o2-analysis-lf-reso2initializer --aod-writer-json OutputDirectorMC.json`
  - Bash shell script: **https://cernbox.cern.ch/s/ZK1SiGqdHUrZM1a**
  - Detailed Tutorial: **https://indico.cern.ch/event/1425820/timetable/#8-derived-data-in-o2o2physics**

```
o2-analysis-lf-reso2initializer -b --configuration json://configuration_resoinitializer_pp_MC.json
--aod-writer-json OutputDirectorMC.json |
o2-analysis-pid-tpc -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-pid-tof -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-pid-tof-base -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-pid-tpc-base -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-centrality-table -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-multiplicity-table -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-event-selection -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-ft0-corrected-table -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-trackselection -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-track-propagation -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-mccollision-converter -b --configuration json://configuration_resoinitializer_pp_MC.json |
o2-analysis-timestamp -b --configuration json://configuration_resoinitializer_pp_MC.json --aod-file @inputMC.txt
```

```
{
  "OutputDirector": {
    "debug_mode": true,
    "resfile": "AO2D_ResoPP_MC",
    "OutputDescriptors": [
      {
        "table": "AOD/RESOMCTRACKS/0"
      },
      {
        "table": "AOD/RESOTRACKS/0"
      },
      {
        "table": "AOD/RESOV0S/0"
      },
      {
        "table": "AOD/RESOMCV0S/0"
      },
      {
        "table": "AOD/RESOCASCADES/0"
      },
      {
        "table": "AOD/RESOMCCASCADES/0"
      },
      {
        "table": "AOD/RESOCOLLISION/0"
      },
      {
        "table": "AOD/RESOMCCOL/0"
      },
      {
        "table": "AOD/RESOMCPARENTS/0"
      }
    ],
    "ntfmerge": 1
  }
}
```

CHECKPOINT

Hands-on 7: Execute basic task on MC

- **Start from the previous output**

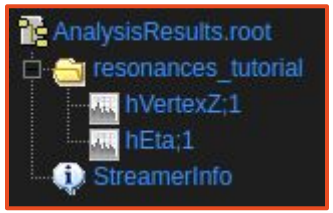
  or download from here: **https://cernbox.cern.ch/s/mfS89OMWuYRU15f**

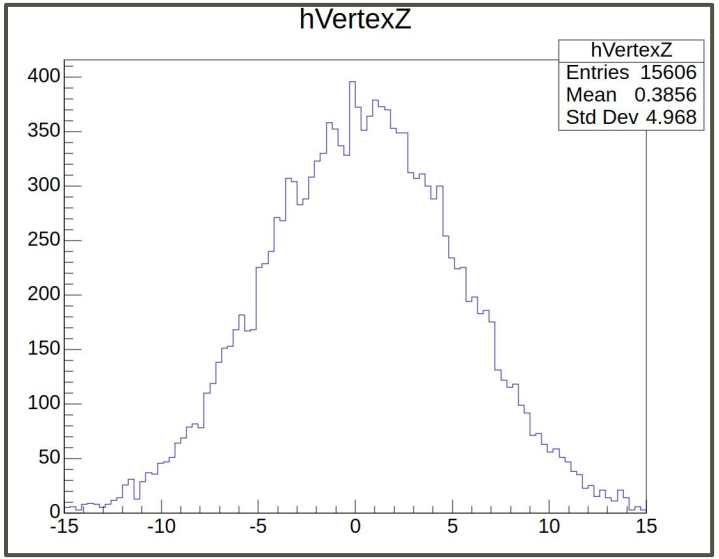
- **First task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step3.cxx`
  - bash script & configuration: **https://cernbox.cern.ch/s/D5U7rM1bL4XuzgZ**
  - Command:

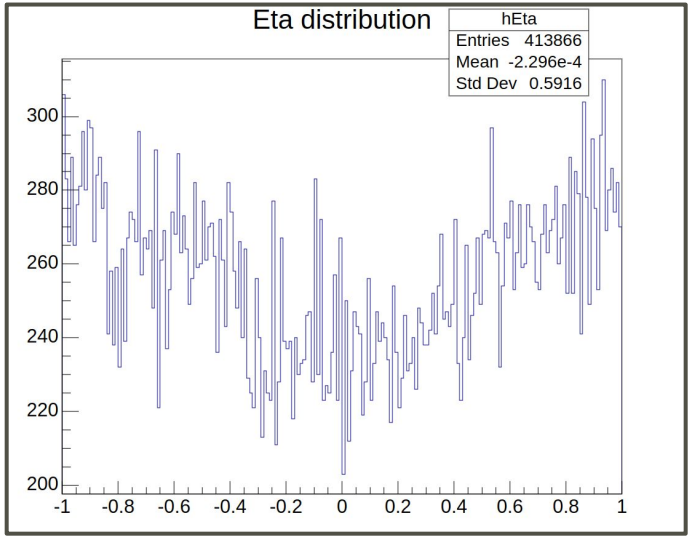
```
o2-analysistutorial-lf-resonances-step3 -b --aod-file AO2D_ResoPP_MC.root --configuration
json://configuration_resotutorial_MC.json
```

Hands-on 7: Execute basic task on MC

Output







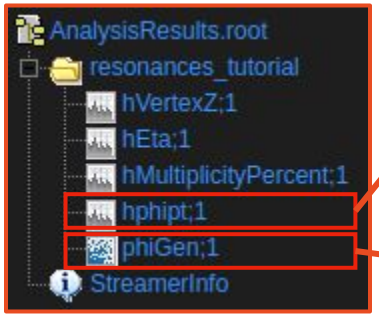
- **There will be two histograms.**
  - You can adjust the number of bins by using the configurable **`nBins`**

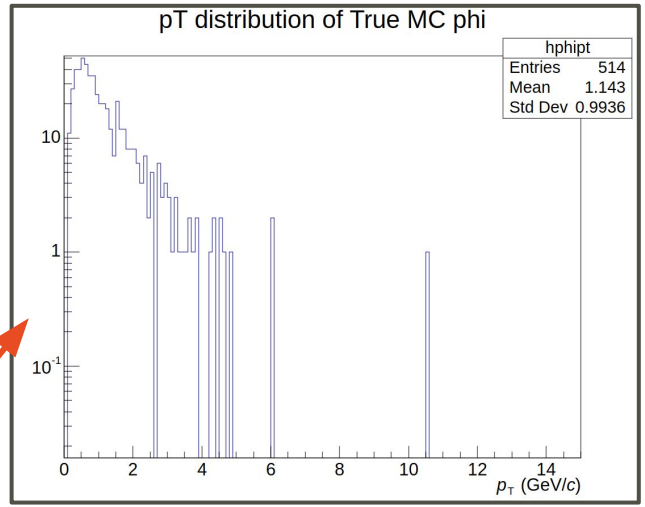
Hands-on 8: Draw pt Distribution for generated ϕ

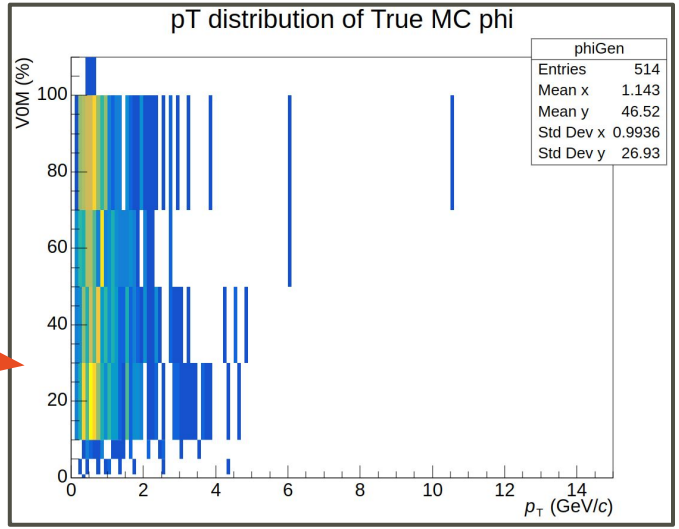
- **Using the resonance derived output**
  - Download from here: **https://cernbox.cern.ch/s/mfS89OMWuYRU15f**
- **Modify the first task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step3.cxx`
  - **Example:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step4.cxx`
    - bash script & configuration: **https://cernbox.cern.ch/s/rZ5ikHT35hXWeQE**
- **Strategy**
  - Add Rapidity Selection
  - Add PDG Selection for ϕ and its daughters
  - Draw pt distribution of ϕ

Hands-on 8: p_T Distribution for generated ϕ

Output







Hands-on 9: Reconstructed MC tracks from ResoMCTracks Table

- **Start from the previous output**

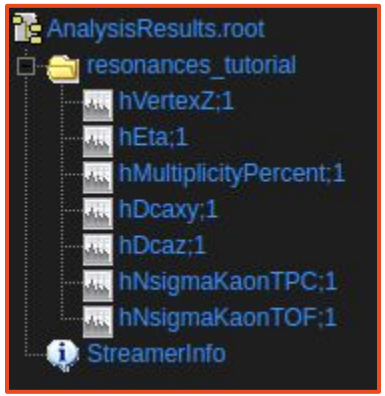
  or download from here: **https://cernbox.cern.ch/s/mfS89OMWuYRU15f**

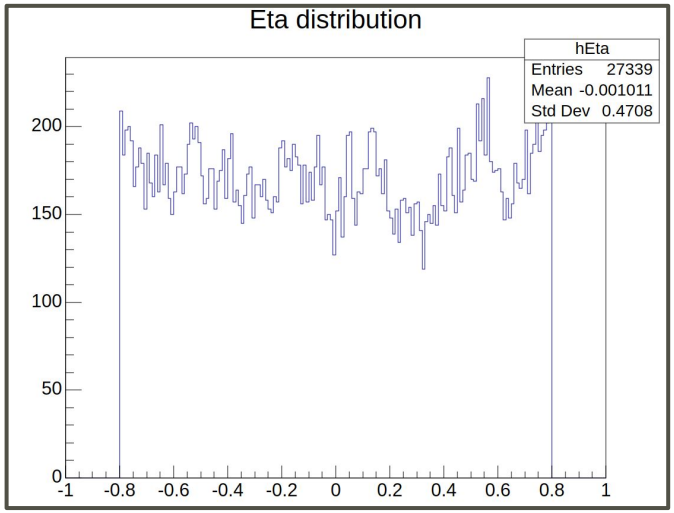
- **First task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step5.cxx`
  - **bash script & configuration:** **https://cernbox.cern.ch/s/eY6zD9htnYmChmx**
  - **Command:**

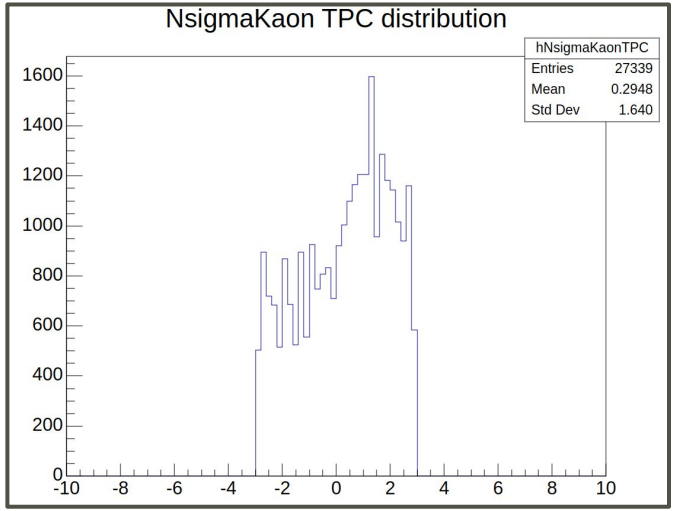
```
o2-analysistutorial-lf-resonances-step5 -b --aod-file AO2D_ResoPP_MC.root
--configuration json://configuration_resotutorial_MC.json
```

Hands-on 9: Reconstructed MC tracks from ResoMCTracks Table

Output







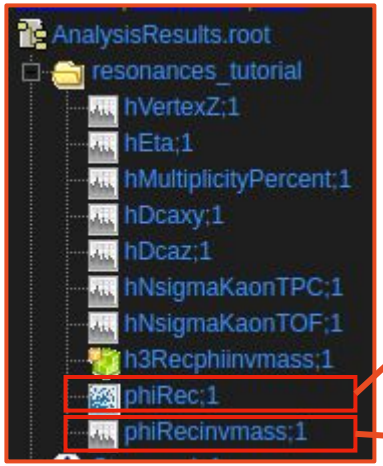
- **There will be two histograms.**
  - You can adjust the number of bins by using the configurable **`nBins`**

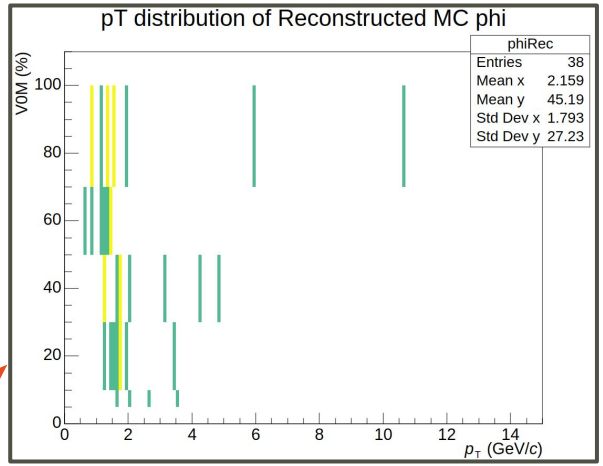
Hands-on 10: p_T Distribution for Reconstructed ϕ

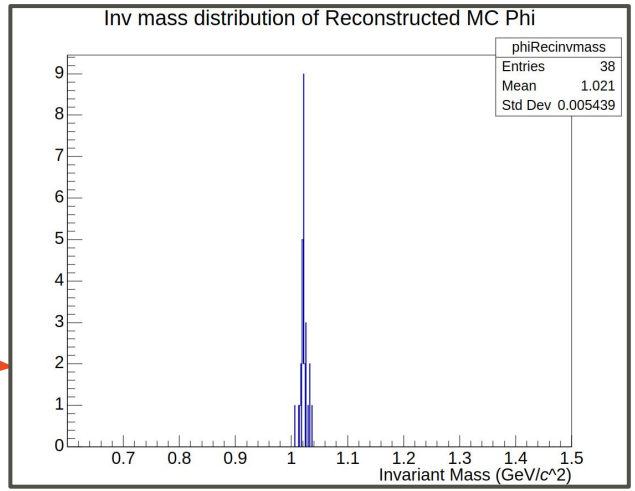
- **Using the resonance derived output**
  - Download from here: **https://cernbox.cern.ch/s/mfS89OMWuYRU15f**
- **Modify the first task:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step5.cxx`
  - **Example:** `O2Physics/Tutorials/PWGLF/Resonance/resonances_step6.cxx`
    - bash script & configuration: **https://cernbox.cern.ch/s/jcy4voug0dQUANH**
- **Strategy**
  - Add Rapidity Selection
  - Add PDG Selection for ϕ and its daughters
  - Draw QA plots and p_T distribution for ϕ

Hands-on 10: p_T Distribution for Reconstructed ϕ

Output







Summary

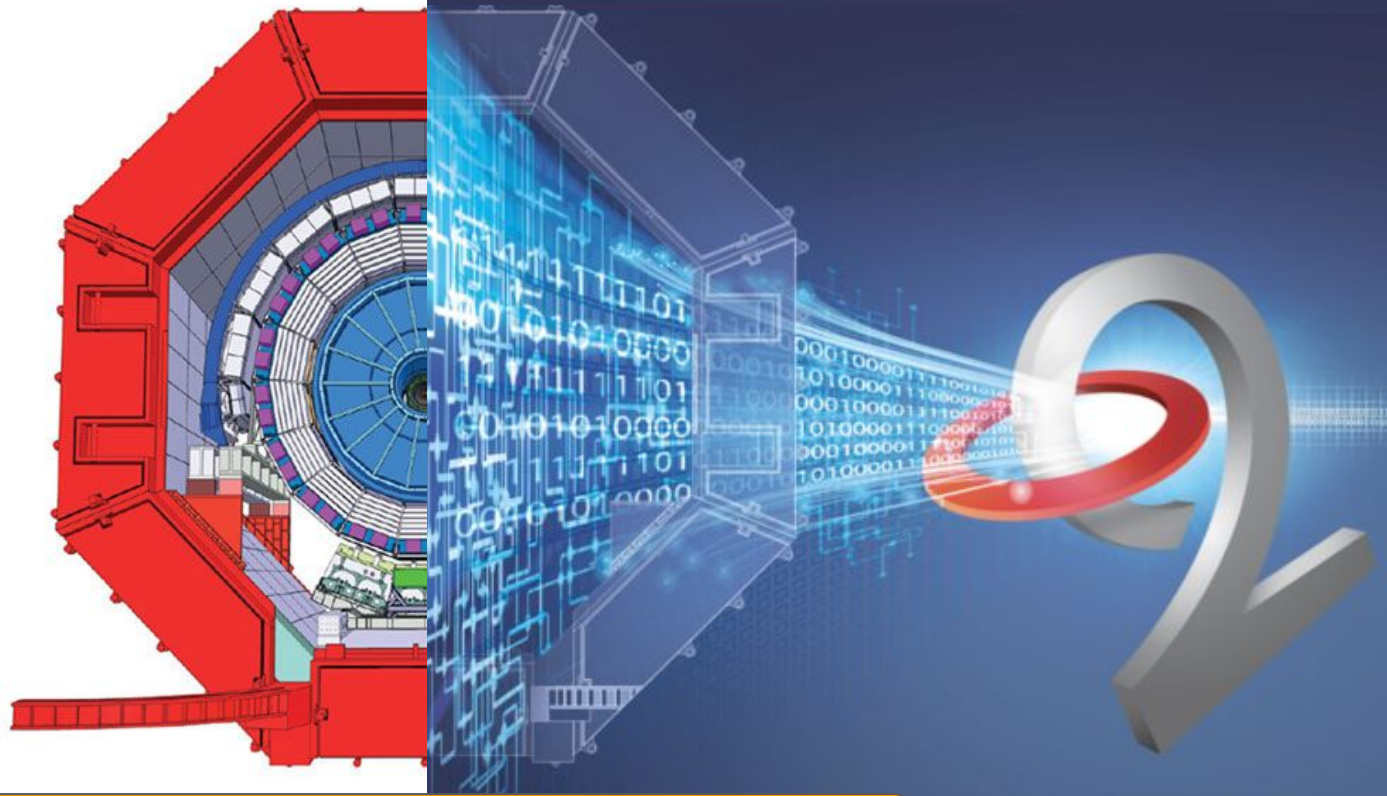
In this talk, you learned:

- Resonance Framework in O^2Physics
- Derived resonance tables and how to subscribe to them in your analysis
- Apply simple kinematic selections
- Apply PID selections
- Perform analysis on MC

Now you are ready for your resonance analysis :-) !!

Mattermost

https://mattermost.web.cern.ch/alice/channels/resonance-o2framework



Thank you for your attention