# *ALICE Offline Tutorial*

Alice Core Offline

21 March, 2013

# Part I
# AliRoot

# References

- AliRoot "OfflineBible"

see doc/OfflineBible.doc

- ALICE offline page
- Installation instruction
  - Compile the Alice offline framework... (D.Berzano)
  - How to set up a full ALICE software environment... (C.Holm)

# Outline

- The ALICE Offline Web Page
- Simulation
  - Generators
  - Configuration (Config.C)
- Reconstruction
- Classes for analysis
  - ESD classes
  - AOD classes
- Practical examples

# AliRoot: General Layout

- Root v5-34-02
- Geant3 v1-15
- AliRoot v5-03-Release

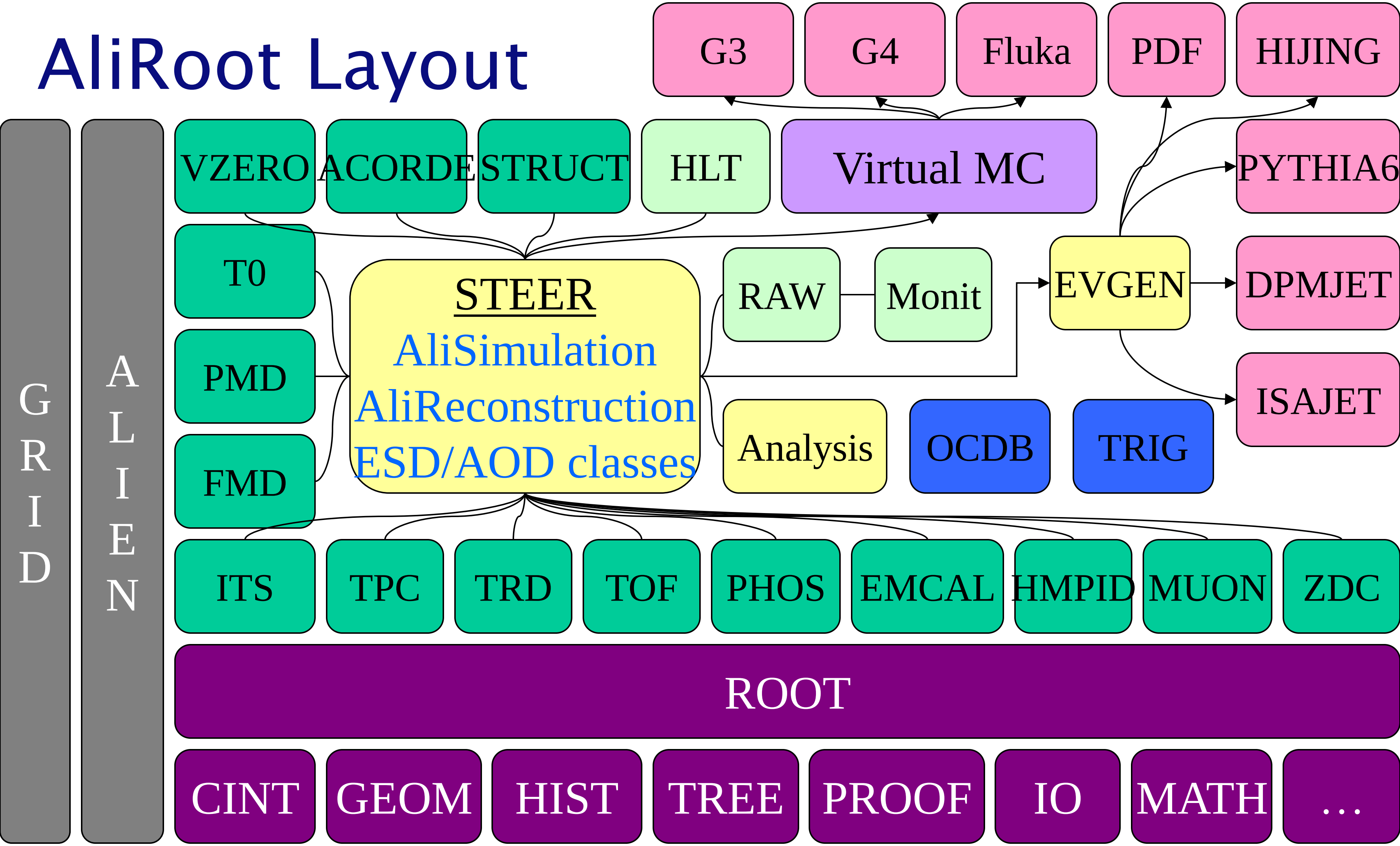
**AliRoot classes**

- General
  - Base classes
  - Steering
  - IO control
- Simulation
  - Interface classes
  - Event generators
  - Geometry & Materials
- Reconstruction
  - Clusterization
  - Tracking
  - PID
- Analysis
  - ESD/AOD classes
  - Analysis framework
  - PWG code

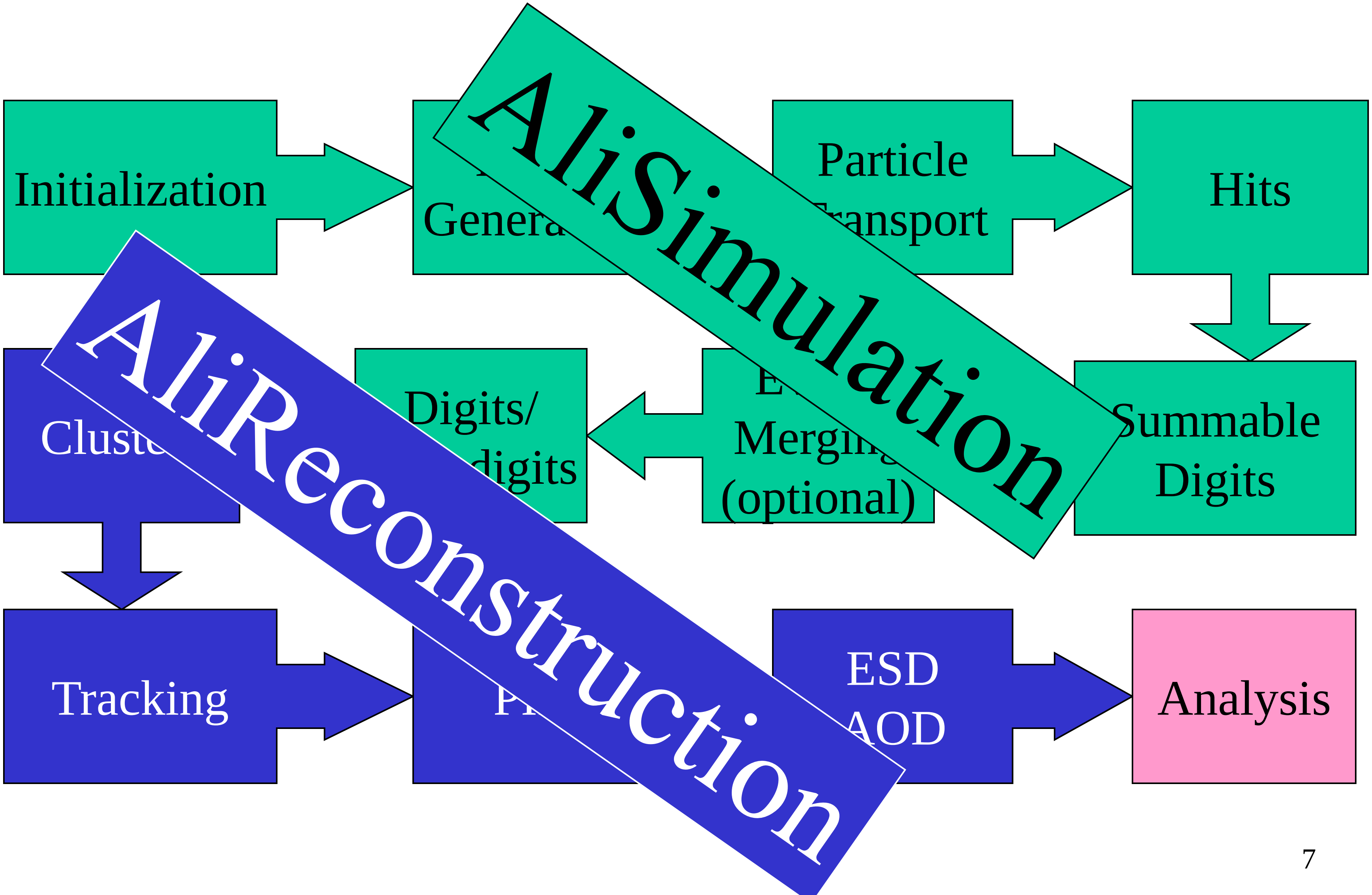
**AliRoot modules**

- General
  - STEER
  - EVGEN
  - ANALYSIS
- Detectors
  - ITS
  - TPC
  - TRD
- Generators
  - HIJING
  - PYTHIA6
  - HERWIG
- “On-line”
  - HLT
  - RAW
  - Monitor.

# AliRoot Layout



# AliRoot: Execution Flow



# Config.C: Steering the Simulation

- Sets random seed

```
Void Config(){
gRandom->SetSeed(123456789);
```

- Creates transporter

```
new TGeant3TGeo(“Transporter”);
```

- Creates RunLoader

```
AliRunLoader *rl =
    AliRunLoader::Open(“galice.root”,defaultFileNames,”recreate”);
gAlice->SetRunLoader(rl);
```

- Add MC particle decay model (Pythia6)

```
TVirtualMCDecayer *dec = AliDecayerPythia();
dec->Init();
```

- Set up transporter

```
gMC->SetExternalDecayer(dec);
…
gMC->SetCut(“CUTGAM”,1.e-3);
…
```

- Creates and sets up event simulator

```
AliGenHIJINGpara *gen = new AliGenHIJINGpara(100);
gen->Init(); // Registers its self to gAlice
```

- Defines ALICE Magnetic Field

```
gAlice->SetField(new AliMagFMaps(…);
```

- Defines All materials and geometries/detectors

```
AliBody *BODY = new AliBODY(“BODY”,”Alice envelope”);
// Registers itself to gAlice
```

# External Generators: HIJING

- HIJING
  - HIJING (Heavy Ion Jet INteraction Generator) combines
    - A QCD-inspired model of jet production with the Lund model for jet fragmentation
    - Hard or semi-hard parton scatterings with transverse momenta of a few GeV are expected to dominate high energy heavy ion collisions
    - The HIJING model has been developed with special emphasis on the role of mini jets in pp, pA and AA reactions at collider energies

# HIJING

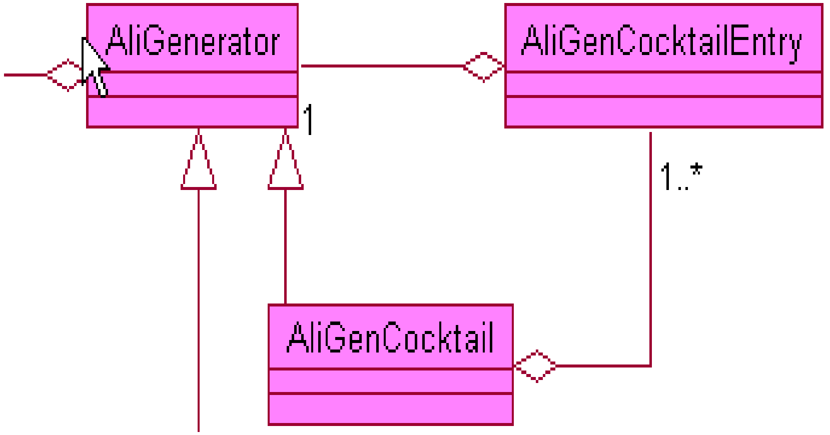
- Hijing used as
  - Underlying event in HI
    - Realistic fluctuations (N,E) from mini-jets
    - Pessimistic multiplicity (dN/dy ~ 6000)
  - Particle Correlation studies
    - Inclusive
    - And in reconstructed jets
  - Nuclear effects
    - Shadowing
    - Quenching (parton energy loss)

# pp

- Minimum Bias
  - Pythia, Herwig, Phojet
  - Pythia with ATLAS (or newer) Tuning
- Hard Probes
  - Pythia tuned to NLO (MNR)
    - NLO topology
  - Nuclear modification of structure functions via EKS in LHAPDF
- Pythia preconfigured processes
    - See $ALICE_ROOT/PYTHIA6/PythiaProcesses.h

# Event Generator Interfaces

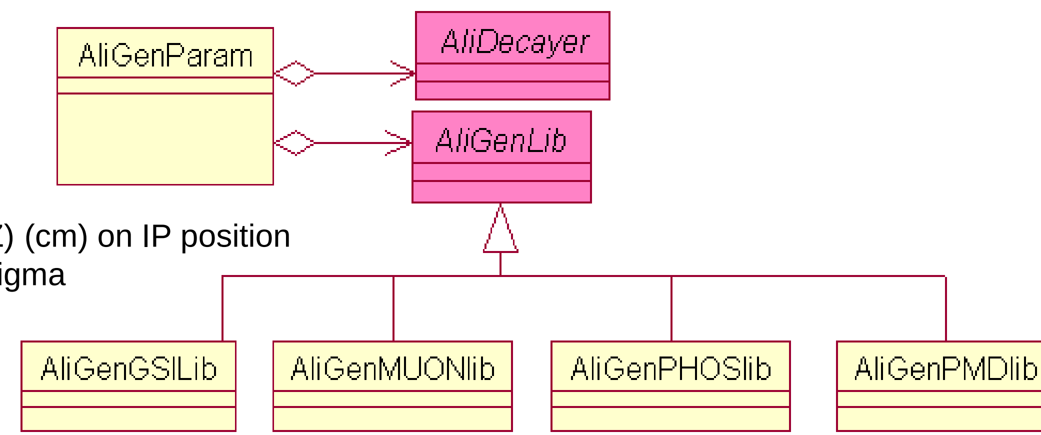
- Cocktail class to assemble events, for example:
  - Underlying event + hard process
  - Different muon sources
  - pA + slow nucleons



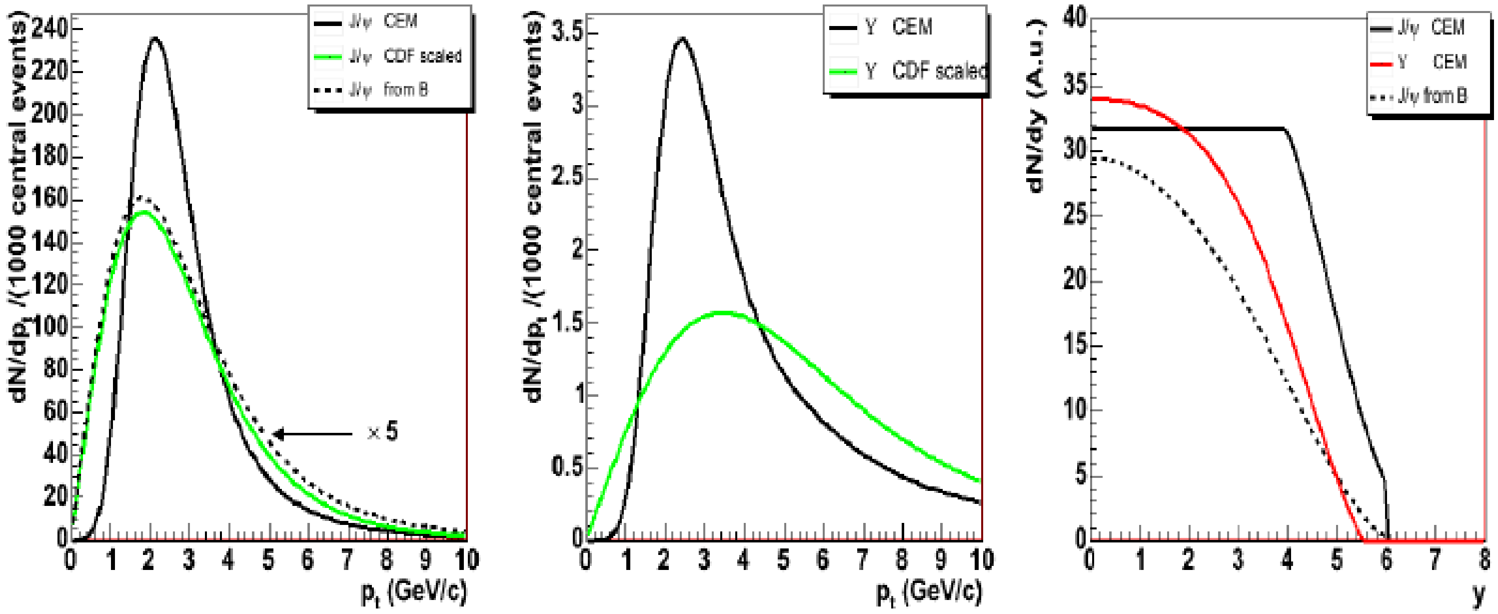
# Event Generator Interfaces: Parameterizations

**More examples in $ALICE_ROOT/macros/Config_PDC06_MUON.C**

```
// The cocktail generator
AliGenCocktail *gener = new AliGenCocktail();

// Phi meson (10 particles)
AliGenParam *phi = new AliGenParam(10,new AliGenMUONlib(),AliGenMUONlib::kPhi,"Vogt PbPb");
phi−>SetPtRange(0, 100);
phi->SetYRange(-1., +1.);
phi−>SetForceDecay(kDiElectron);

// Omega meson (10 particles)
AliGenParam *omega = new AliGenParam(10,new AliGenMUONlib(),AliGenMUONlib::kOmega,"Vogt PbPb");
omega−>SetPtRange(0, 100);
omega−>SetYRange(−1., +1.);
omega->SetForceDecay(kDiElectron);

// Adding all the components of the cocktail
gener −>AddGenerator(phi,"Phi",1);
gener −>AddGenerator(omega,"Omega",1);

// Settings, common for all components
gener −>SetOrigin(0, 0, 0);          // vertex position
gener −>SetSigma(0, 0, 5.3);         // Sigma in (X,Y,Z) (cm) on IP position
gener −>SetCutVertexZ(1.);           // Truncate at 1 sigma
gener −>SetVertexSmear(kPerEvent);
gener −>SetTrackingFlag(1);
gener >Init();
```



# Example: MUON Library




Parameterisations (pt and y of given particle):
kPhi, kOmega, kEta,
kJpsi, kJpsiFamily, kPsiP, kJpsiFromB,
kUpsilon, kUpsilonFamily, kUpsilonPP,
kCharm, kBeauty,
kPion, kKaon

# Generators: other examples

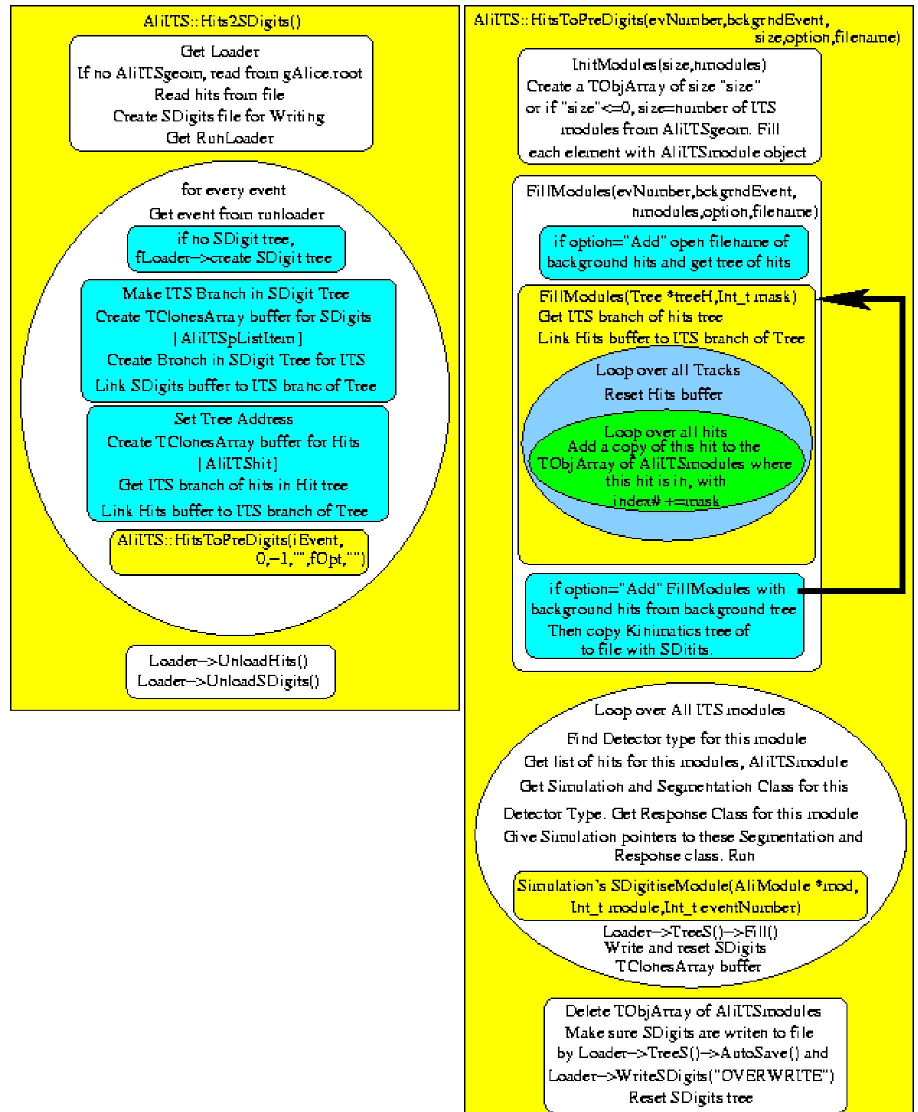
- In test/generators we have several new examples
  - TUHKMgen
  - EPOS
  - HERWIG
  - TTherminator
- It is enough to do ./runtest.sh in each subdirectory
  - The PbPb simulation is slow…

# Run MC: Particle Transport

- Particles are transported through geometry
- At each step, a call to StepManager of the class whose volume the particle is in
- Example: AliITSvPPRasymmFMD::StepManager
  - If not sensitive volume return
  - If not charged return
  - Record Hit, particle Position (start & end of this step), Momentum, Energy lost during last step, Sub-detector in, Time of Flight, Status, Charge, and Track Number
  - In the ITS, hits can also be “merged”
- Hits might be deleted after SDigitization

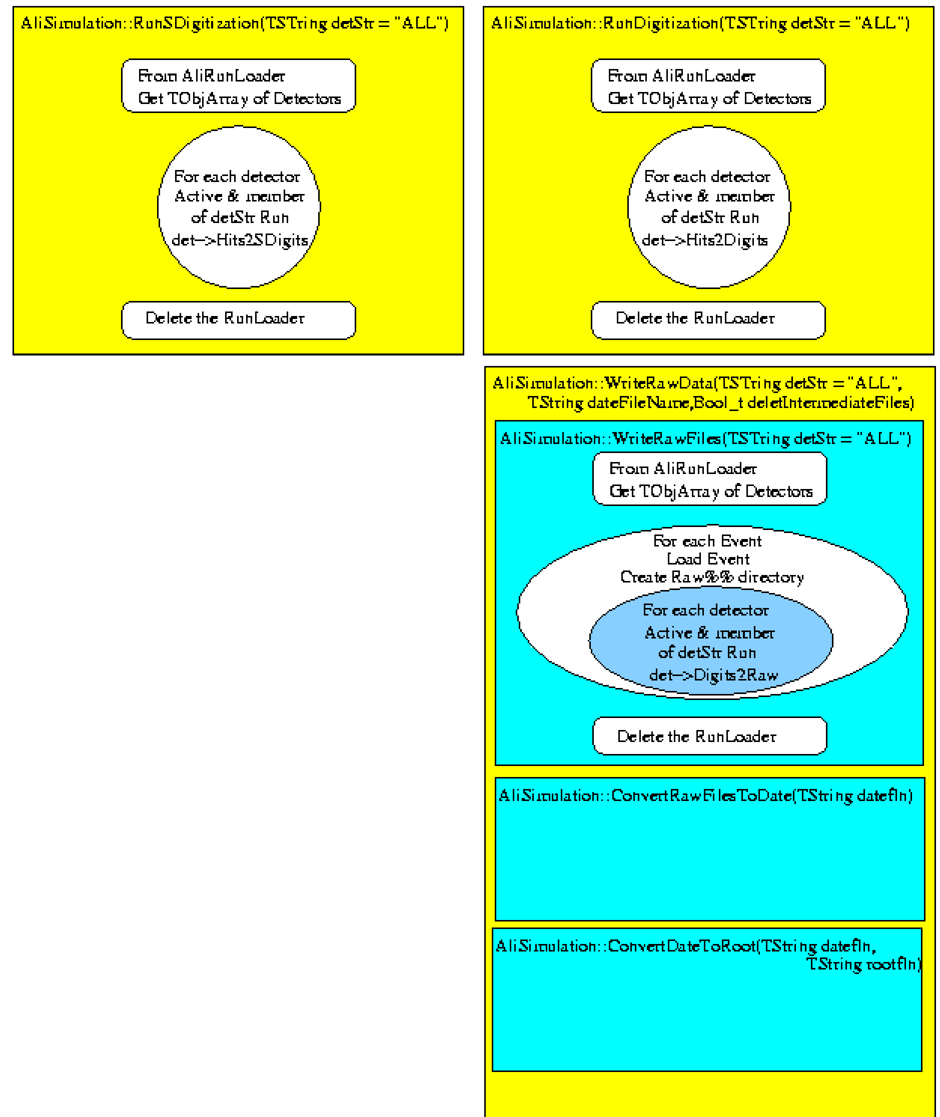
# Simulation: Summable Digits

- Apply all detector response simulation which allows results to be "merged"
  - Do not add noise
  - Do not convert AtD
  - Do not apply thresholds
- Some detectors use hits as SDigits
  - For PHOS, EMCAL the hits are already summed
  - HMPID saves rings/photons



# Digitization

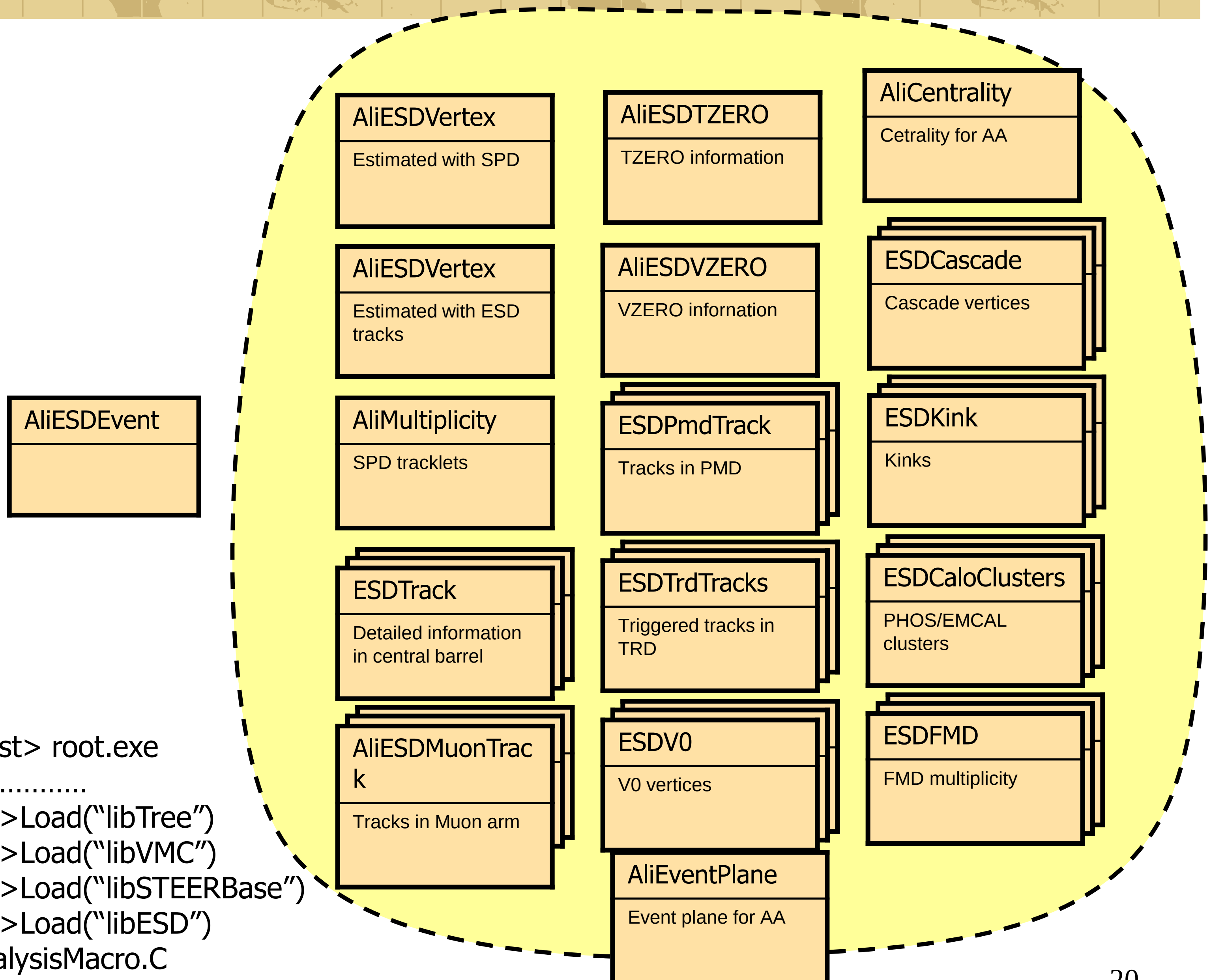
- Adds noise
  - Random for SPD, SSD
  - Correlated for SDD
- Applies threshold
  - Simple threshold for SPD,SSD
  - 2 level threshold for SDD
- Applies ADC-ing
  - 10 bit for SDD, SSD
  - 10⇒8 conversion for SDD
- Zero suppression
  - 2 integer coordinates, 1 integer signal
  - Simulation + info by detector type



# Reconstruction

- Possible inputs
  - DATE DDL files (only for test)
  - RAW DATE file (only for test)
  - RAW rootified file (standard format)
  - MC/Digit files (standard for simulated data)
- Local/Detector reconstruction (Files <DET>.RecPoints.root)
  - Calibration
  - Clusterisation
  - Cluster splitting…
- Vertex finder: Fills ESD
  - Primary vertex (Z coordinate) found in SPD, and/or T0.
- Tracking (HLT and/or Barrel), filling of ESD
  - Gives final vertex from tracks and secondary vertexes.
  - HLT uses Conformal mapping (or similar) or a fast Kalman filter
  - Final tracking is a full Kalman filter
    - In: {TPC→ITS}→ Out: {ITS→TPC →[TRD→TOF →(EMCAL|HMPID|PHOS)]}→ Refit: {TOF→TRD→TPC→ITS}
    - MUON.
- Combined (Bayesian) PID: Fills ESD

# The ESD




Ideally: user@host> root.exe

..........................

root[0] gSystem->Load("libTree")
root[1] gSystem->Load("libVMC")
root[2] gSystem->Load("libSTEERBase")
root[3] gSystem->Load("libESD")
root[4] .x AnyAnalysisMacro.C

# Common base classes for ESDs and AODs

**AliVEvent**

**AliESDEvent** **AliAODEvent**

**AliVHeader**

**AliESDHeader** **AliAODHeader**

**AliVParticle**

**AliExternalTrackParam** **AliAODTrack** **…**

**AliESDtrack**

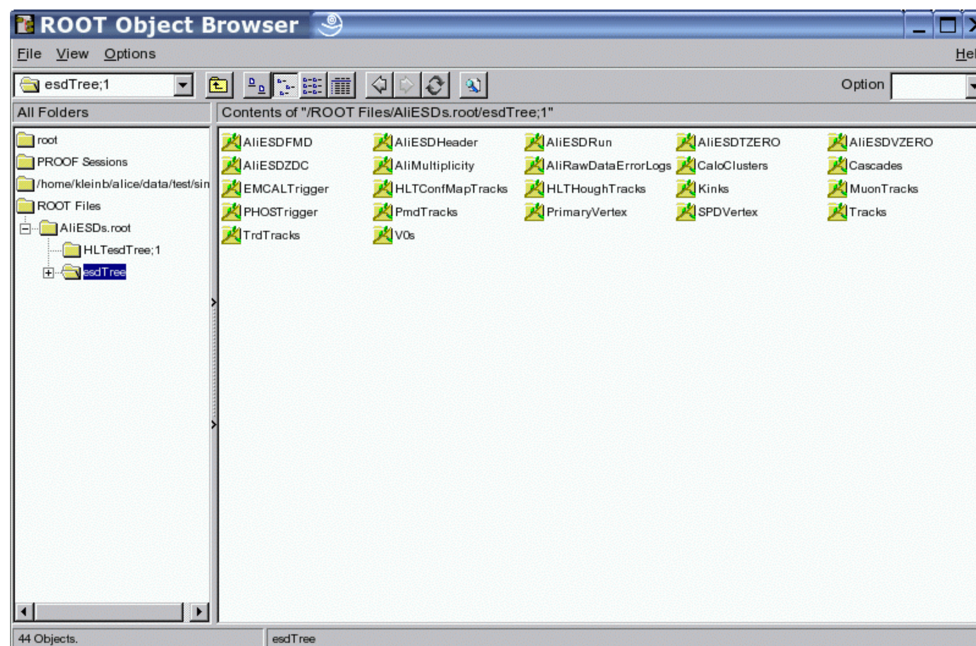
- standard access to containers
- common getters and setters
- some differences in the interface (to be "cured"!)

# Current content of the standard AOD

| | |
|---|---|
| **AliAODEvent** | contains an (extendable) TList |
| **AliAODHeader** | event information |
| **AliAODTrack** | TClonesArray of tracks |
| **AliAODVertex** | TClonesArray of vertices |
| **AliAODJet** | TClonesArray of jets |
| **AliAODTracklets** | Container for SPD tracklets |

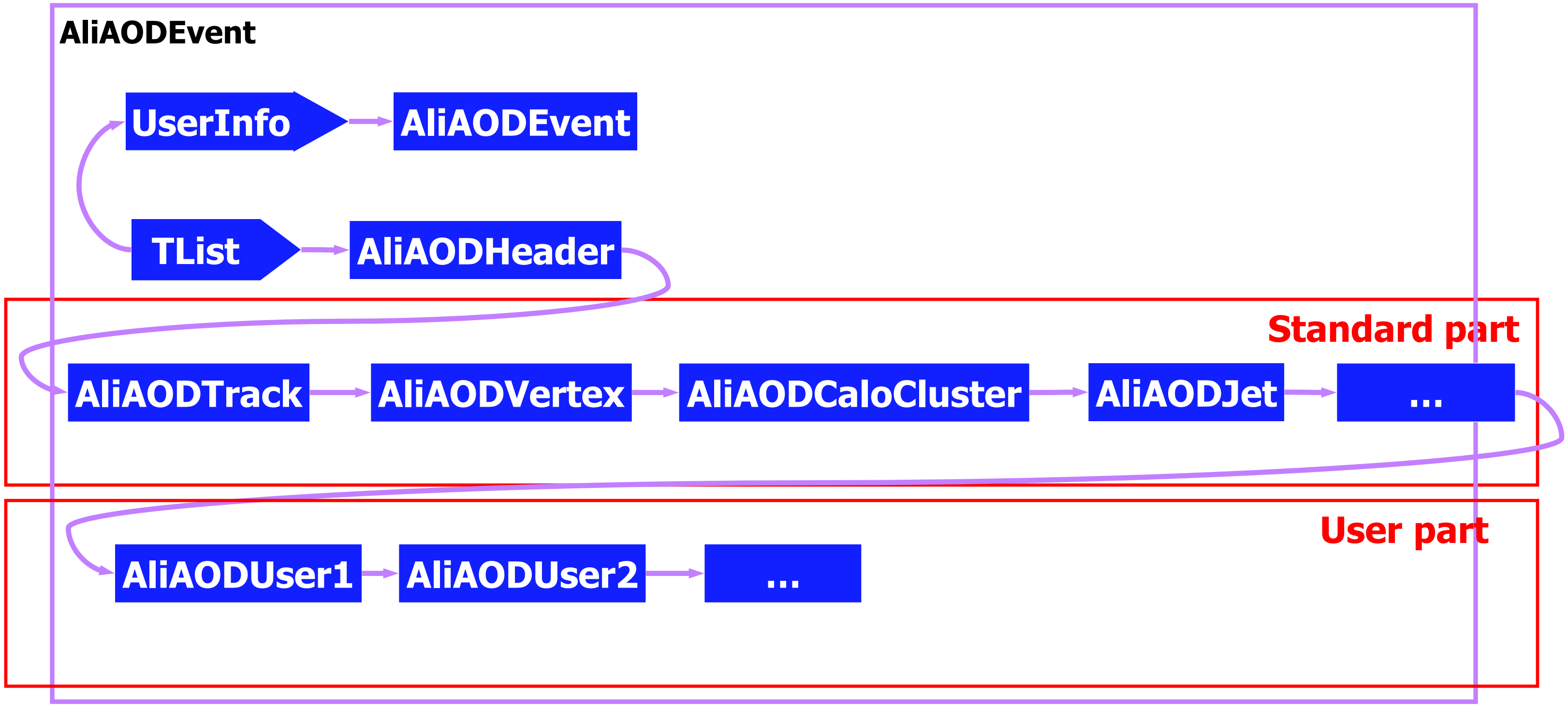
# The ESD Layout

- AliESDEvent()
  - Defines the interface to the ESD tree content
    - Mainly contains a TList of pointers
      - E.g. to TClonesArray of tracks
    - Access to standard contents
      - ...ReadFromTree(...)
      - ...GetEntry(Int_t)
      - AliESDEvent::GetTrack(Int_t)
  - Similar structure in the AODs

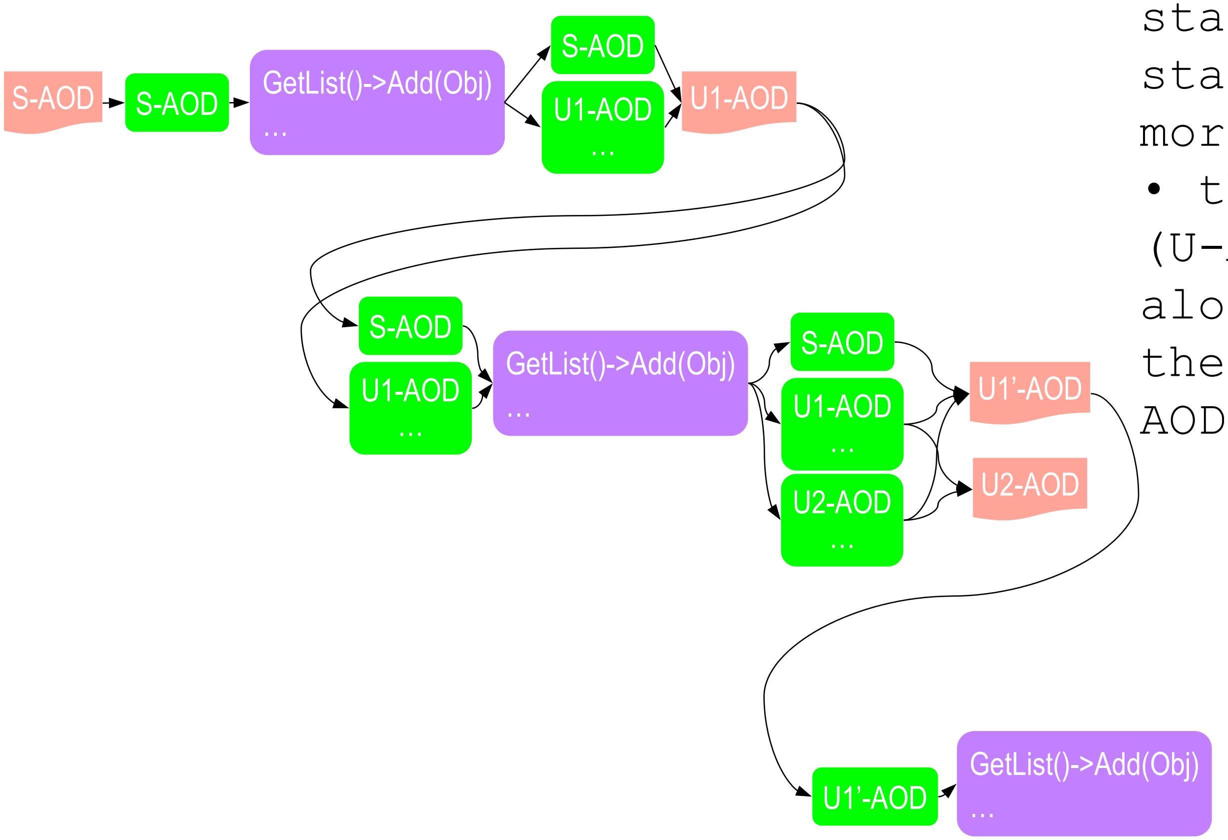


# General idea: ESD & AOD

- Very simple… use a list



# Extending the AOD




**<u>Flexible and Extendable</u>**

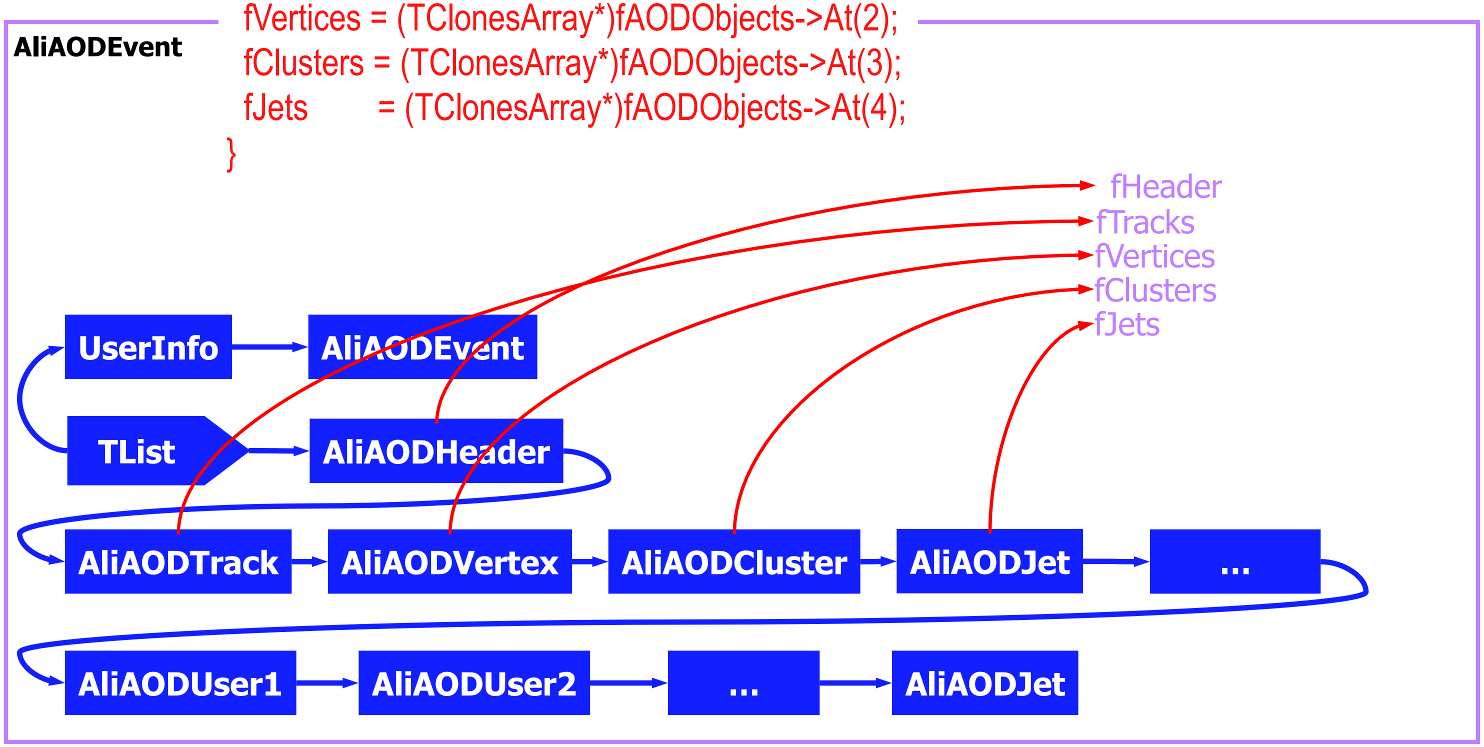
- users can just use the standard AOD (S-AOD) or start from it to obtain more detailed results
- this new information (U-AOD) can be stored alongside the S-AOD in the TList (= in the same AOD)

- The idea is that every user can extend the AODs with "non-standard" objects

# Reading back

```
void AliAODEvent::GetStdContent() const
{
  // set pointers for standard content

  fHeader   = (AliAODHeader*)fAODObjects->At(0);
  fTracks    = (TClonesArray*)fAODObjects->At(1);
  fVertices = (TClonesArray*)fAODObjects->At(2);
  fClusters = (TClonesArray*)fAODObjects->At(3);
  fJets        = (TClonesArray*)fAODObjects->At(4);
}
```

```
AliAODTrack* AliAODEvent::GetTrack(Int_t i) const
{ return (AliAODTrack*) fTracks->At(i); }
```




- …and the same user also can access the “non-standard” objects from the previous slide

# AliESDEvent and AliESDtrack classes

- Accumulation and exchange of tracking information among the barrel detectors
- Contained in the ESD and used for physics analysis

Class AliESDtrack : public AliExternalTrackParam

- final params
- reconstruction status flags
- length, time, combined PID
- vertex constrained params
- impact parameters & cov.matrix
- params at the outer TPC wall
- params at the inner TPC wall
- …
- detector specific info (chi2, num.of clusters, PID…)

# ESD Example: Loop on the tracks

```
void test1(const char * fname ="AliESDs.root") {
  TFile * file = TFile::Open(fname);
  TTree * tree = (TTree*)file->Get("esdTree");

  AliESDEvent * esd = new AliESDEvent();      // The signal ESD object is put here
  esd->ReadFromTree(tree);

  Int_t nev = tree->GetEntries();
  for (Int_t iev=0; iev<nev; iev++) {

    tree->GetEntry(iev); // Get ESD

    Int_t ntrk = esd->GetNumberOfTracks();
    for(Int_t irec=0; irec<ntrk; irec++) {
      AliESDtrack * track = esd->GetTrack(irec);
      cout << "Pt: " << track->Pt() << endl;
    }

  }

  file->Close();
}
```

# AOD Example: Loop on the tracks

```
AliAODEvent *event= new AliAODEvent();        //The reconstructed events are
TTree *aodTree = …;                            //stored in TTrees  (and so can be
“chained”)
event->ReadFromTree(aodTree);                  //Sets the branch adresses for
                                               //AliAODEvent content

Int_t i=0;
while (aodTree->GetEvent(i++)) {               //loop over the reconstructed events
    …                                          //select run, event number etc…
  if (event->GetEventType() != … )  continue;  //select the event type
  AliAODVertex *primary=event->GetPrimaryVertex();
  if (/* some cuts on the primary vertex */)  continue;

  Int_t ntracks=event->GetNumberOfTracks();
  for (i=0; i<ntracks; i++) {                  //loop over ESD tracks (or kinks, V0s…)
    AliAODTrack *track=event->GetTrack(i);
    if (/* select tracks according to proper selection (quality) criteria  */) {
       …                                       //do whatever with the selected tracks
    }
  }
```

# ESD Example: PID

```
AliESDEvent *event=new AliESDEvent();               //The reconstructed events are
TTree *esdTree = …;                                 //stored in TTrees  (and so can be “chained”)
event->ReadFromTree(esdTree);                       //Sets the branch adresses for AliESDEvent content
Int_t i=0;
while (esdTree->GetEvent(i++) {                     //loop over the reconstructed events
    …                                               //event selection…

    Double_t priors[AliPID::kSPECIES]={…}           //A set of a priori probabilities
    AliPID::SetPriors(priors);

    Int_t ntracks=event->GetNumberOfTracks();
    for (i=0; i<ntracks; i++) {                     //loop over ESD tracks (or kinks, V0s …)
        AliESDtrack *track=event->GetTrack(i);

        ULong _t status=AliESDtrack::kTPCpid | AliESDtrack::kTOFpid;
        if ((track->GetStatus()&status) != status)  continue;   //select tracks with the proper status
        if ( … )  continue;                         //some other selection (quality) criteria


        Double_t probDensity[AliPID::kSPECIES];  track->GetESDpid(probDensity);
        AliPID pid(probDensity);

        Double_t   pp=pid.GetProbablity(AliPID::kProton);      // probability to be a proton
        Double_t   pk=pid.GetProbability(AliPID::kKaon);       // probability to be a kaon
        …
        if (pp > 1./AliPID::kSPECIES) { /* this is a proton */}
    }
}
```

# Pieces needed for simulation/reconstruction

- sim.C macro that runs the simulation
  - AliSimulation sim;
  - sim.Run();
- rec.C macro that runs the reconstruction
  - AliReconstruction rec;
  - rec.Run();
- Config.C macro that configures the simulation

# Files produced in Sim/Rec

- Simulation
  - galice.root: Event header
  - Kinematics.root: MC particles
  - DET.Hits.root: Hits of MC particles in sensitive regions
  - DET.(S)Digits.root: Induced signal in the electronics
  - raw.root: Digits converted to the RAW data format (optional)
- Reconstruction
  - galice.root: Event header
  - DET.RecPoints.root: Clusters
  - AliESDs.root: "Event Summary Data" Reconstruction output
  - AliESDfriends.root: Reconstruction debugging information (optional)
  - AliAOD.root: "Analysis Object Data" Condensed reconstruction output (optional)

# Exercises from $ALICE_ROOT/test

- Particle gun (test/gun)
- Generation from a kinematics tree (test/genkine)
- Event merging (test/merge)
- Proton-proton benchmark (test/ppbench)
- Pb-Pb benchmark (test/PbPbbench)
- Proton-proton simulation and reconstruction loading the libraries in Root (test/pploadlibs)

# Particle gun: $ALICE_ROOT/test/gun

## Cocktail generator

```
AliGenCocktail *gener = new AliGenCocktail();
gener->SetPhiRange(0, 360);
 …
gener->SetThetaRange(thmin,thmax);
gener->SetOrigin(0, 0, 0);  //vertex position
gener->SetSigma(0, 0, 0);   //Sigma in (X,Y,Z) (cm) on IP position
```

## Components

```
AliGenFixed *pG1=new AliGenFixed(1);
pG1->SetPart(2212);
pG1->SetMomentum(2.5);
pG1->SetTheta(109.5-3);
pG1->SetPhi(10);
gener->AddGenerator(pG1,"g1",1);
```

## Simulation

```
AliSimulation sim;
sim.SetMakeSDigits("TRD TOF PHOS HMPID EMCAL MUON FMD ZDC PMD T0 VZERO");
sim.SetMakeDigitsFromHits("ITS TPC");
sim.SetWriteRawData("ALL","raw.root",kTRUE)
```

## Reconstruction from raw

```
AliMagFMaps* field = new AliMagFMaps("Maps","Maps", 2, 1., 10., AliMagFMaps::k5kG);
AliTracker::SetFieldMap(field,kTRUE);
AliReconstruction reco;
reco.SetUniformFieldTracking(kFALSE);
reco.SetWriteESDfriend();
reco.SetWriteAlignmentData();
AliTPCRecoParam * tpcRecoParam = AliTPCRecoParam::GetLowFluxParam();
AliTPCReconstructor::SetRecoParam(tpcRecoParam);
reco.SetInput("raw.root");
reco.SetWriteAOD();
reco.Run();
```

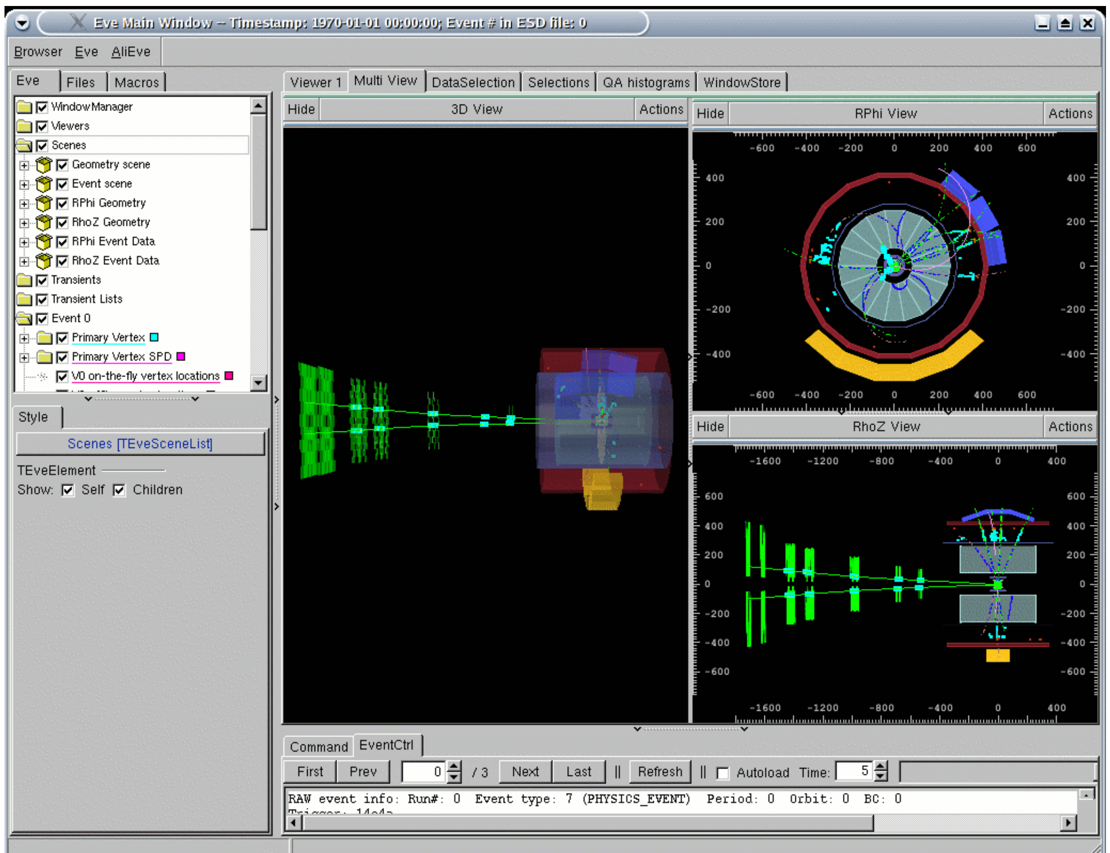
# Exercise

- Modify the example to test the identification of muons in the barrel detectors
- Modify test.C to print only the muon tracks

# Visualization

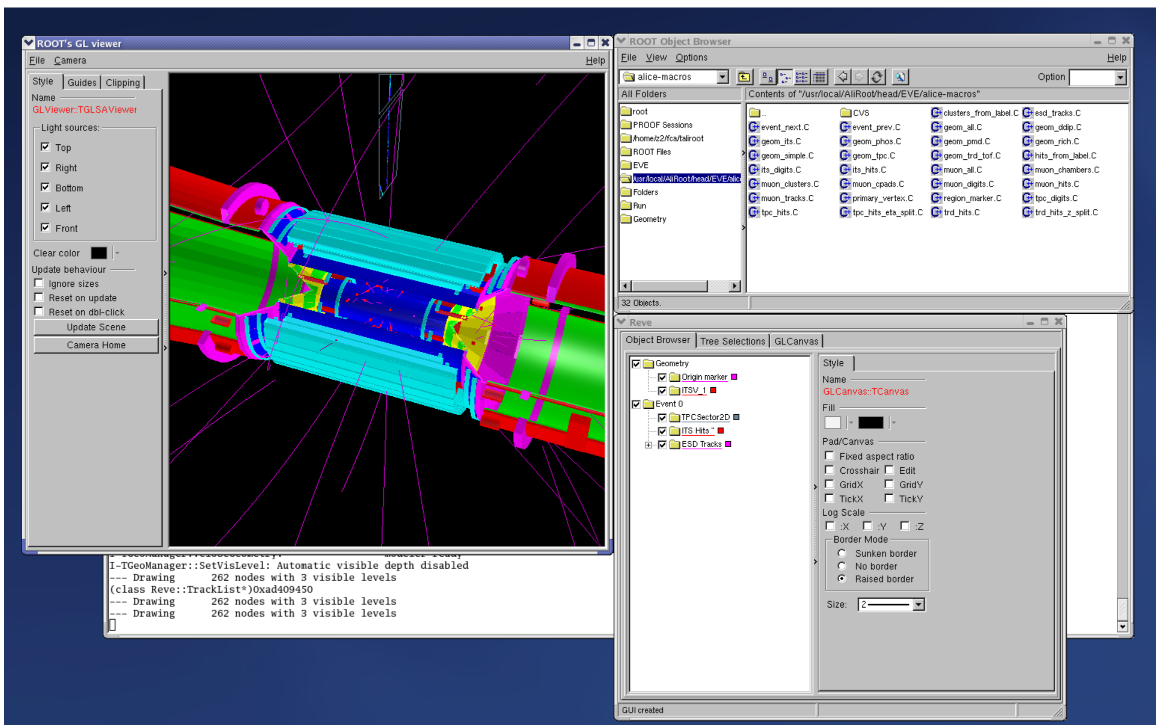
http://aliceinfo.cern.ch/Offline/Activities/Visualisation/

- Usage
  - alieve
  - .x visscan_local.C, visscan_raw.C, visscan_mcideal.C



# Visualization – II

- Usage
  - alieve
  - .x alieve_init.C
  - Use then the macros in the EVE folder in TBrowser



# Generation from a kinematics tree

- Creation of a kinematics tree: Pythia events containing D*→D0 π
  - See test/genkine/gen/fastSim.C
  - Selection of the specific decay modes via

```
AliPythia * py= AliPythia::Instance();
py->SetMDME(737,1,0); //forbid D*+->D+ + pi0
py->SetMDME(738,1,0); //forbid D*+->D+ + gamma
```

  - Selection of desired events in the event loop

- Simulation using the kinematic tree: see Config.C

```
AliGenExtFile *gener = new AliGenExtFile(-1);
AliGenReaderTreeK * reader = new AliGenReaderTreeK();

reader->SetFileName("galice.root");
reader->AddDir("../gen");
gener->SetReader(reader);
```

- Reconstruction

# Exercise

- Modify the example to select Pythia events containing the decay $\Lambda_c^+ \rightarrow pK\pi$
- Obtain the list of decays with

```
AliPythia * py = AliPythia::Instance()
py->Pylist(12); >> decays.txt
```

  - It is also in PYTHIA6/AliDecayerPythia.cxx
- Generate raw data
- Reconstruct from raw data

# Event merging: $ALICE_ROOT/test/merge

- Generate & reconstruct underlying events (./backgr)
  - Simulation (full chain up to Digits)
    - AliSimulation sim;
    - sim.Run(2);
  - Reconstruction
    - AliReconstruction rec;
    - rec.Run();
- Generate, merge & reconstruct signal events (./signal)
  - Simulation (with event merging)
    - AliSimulation sim;
    - sim.MergeWith("../backr/galice.root",3);
    - sim.Run(6);
  - Reconstruction
    - AliReconstruction rec;
    - rec.Run();

# Event merging: test.C

```
void test(const char * sdir ="signal",
          const char * bdir ="backgr") {

  TStopwatch timer;
  timer.Start();
  TString name;

  // Signal file, tree, and branch
  name = sdir;
  name += "/AliESDs.root";
  TFile * fSig = TFile::Open(name.Data());
  TTree * tSig = (TTree*)fSig->Get("esdTree");

  AliESDEvent * esdSig = new AliESDEvent; // The signal ESD
  esdSig->ReadFromTree(tSig);

  // Run loader (signal events)
  name = sdir;
  name += "/galice.root";
  AliRunLoader* rlSig = AliRunLoader::Open(name.Data());

  // Run loader (underlying events)
  name = bdir;
  name += "/galice.root";
  AliRunLoader* rlUnd = AliRunLoader::Open(name.Data(),"Underlying");

  // gAlice
  rlSig->LoadgAlice();
  rlUnd->LoadgAlice();
  gAlice = rlSig->GetAliRun();

  // Now load kinematics and event header
  rlSig->LoadKinematics();
  rlSig->LoadHeader();
  rlUnd->LoadKinematics();
  rlUnd->LoadHeader();

  // Loop on events: check that MC and data contain the same number of events
  Long64_t nevSig = rlSig->GetNumberOfEvents();
  Long64_t nevUnd = rlUnd->GetNumberOfEvents();
  Long64_t nSigPerUnd = nevSig/nevUnd;

  cout << nevSig << " signal events" << endl;
  cout << nevUnd << " underlying events" << endl;
  cout << nSigPerUnd << " signal events per one underlying" << endl;

  for (Int_t iev=0; iev<nevSig; iev++) {
    cout << "Signal event " << iev << endl;
    Int_t ievUnd = iev/nSigPerUnd;
    cout << "Underlying event " << ievUnd << endl;

    // Get signal ESD
    tSig->GetEntry(iev);
    // Get underlying kinematics
    rlUnd->GetEvent(ievUnd);

    // Particle stack
    AliStack * stackSig = rlSig->Stack();
    Int_t nPartSig = stackSig->GetNtrack();
    AliStack * stackUnd = rlUnd->Stack();
    Int_t nPartUnd = stackUnd->GetNtrack();

    Int_t nrec = esdSig->GetNumberOfTracks();
    cout << nrec << " reconstructed tracks" << endl;
    for(Int_t irec=0; irec<nrec; irec++) {
      AliESDtrack * track = esdSig->GetTrack(irec);
      UInt_t label = TMath::Abs(track->GetLabel());
      if (label>=10000000) {
            // Underlying event. 10000000 is the
            // value of fkMASKSTEP in AliRunDigitizer

            label %=10000000;
            if (label>=nPartUnd) continue;
            TParticle * part = stackUnd->Particle(label);

      }
      else {
            cout << " Track " << label << " from the signal event" << endl;
            if (label>=nPartSig) continue;
            TParticle * part = stackSig->Particle(label);
            if(part) part->Print();
      }

    }

  }
  fSig->Close();

  timer.Stop();
  timer.Print();
}
```

# PYTHIA preconfigured processes

- Heavy Flavors (open)
  - kPyCharm, kPyBeauty
  - kPyCharmUnforced, kPyBeautyUnforced
- kPyCharmPbPbMNR, kPyD0PbPbMNR, kPyDPlusPbPbMNR, kPyBeautyPbPbMNR, kPyCharmpPbMNR, kPyD0pPbMNR, kPyDPluspPbMNR, kPyBeautypPbMNR, kPyCharmppMNR, kPyD0ppMNR, kPyDPlusppMNR, kPyBeautyppMNR
- Heavy Flavor (resonances)
  - kPyJpsi, kPyJpsiChi
- Minimum Bias
  - kPyMb, kPyMbNonDiffr
- Jets and high-pT gammas
  - kPyJets, kPyDirectGamma,
- W
  - kPyW