# Physics Analysis Tools

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# Current Style of Analysis

- **The analysis preparation: the user runs the RecExec_joboptions.txt on the raw data in ATHENA. This produces a combined Ntuple (or ROOT) of the prepared data**
- **The analysis domain:**
  - **The user writes his own FORTRAN code of analysis and produces final results as HBOOK histograms**
  - **The user writes her own C++ analysis code and produces final results in ROOT histograms**
- **In the above process, the user writes his own analysis tools**

**This style of analysis is very restrictive →**

# Current Style of Analysis

- Interactive part not flexible: the analysis preparation (RecExec_joboptions) and the user analysis code run essentially in "batch" mode
- Not easy to play with a piece of the reconstruction algorithms
- Difficult to compare results since the user is writing her own tools
- Difficult to share pieces of codes
  - The use defines his own interface
  - Incomprehensible, thus black box, user codes

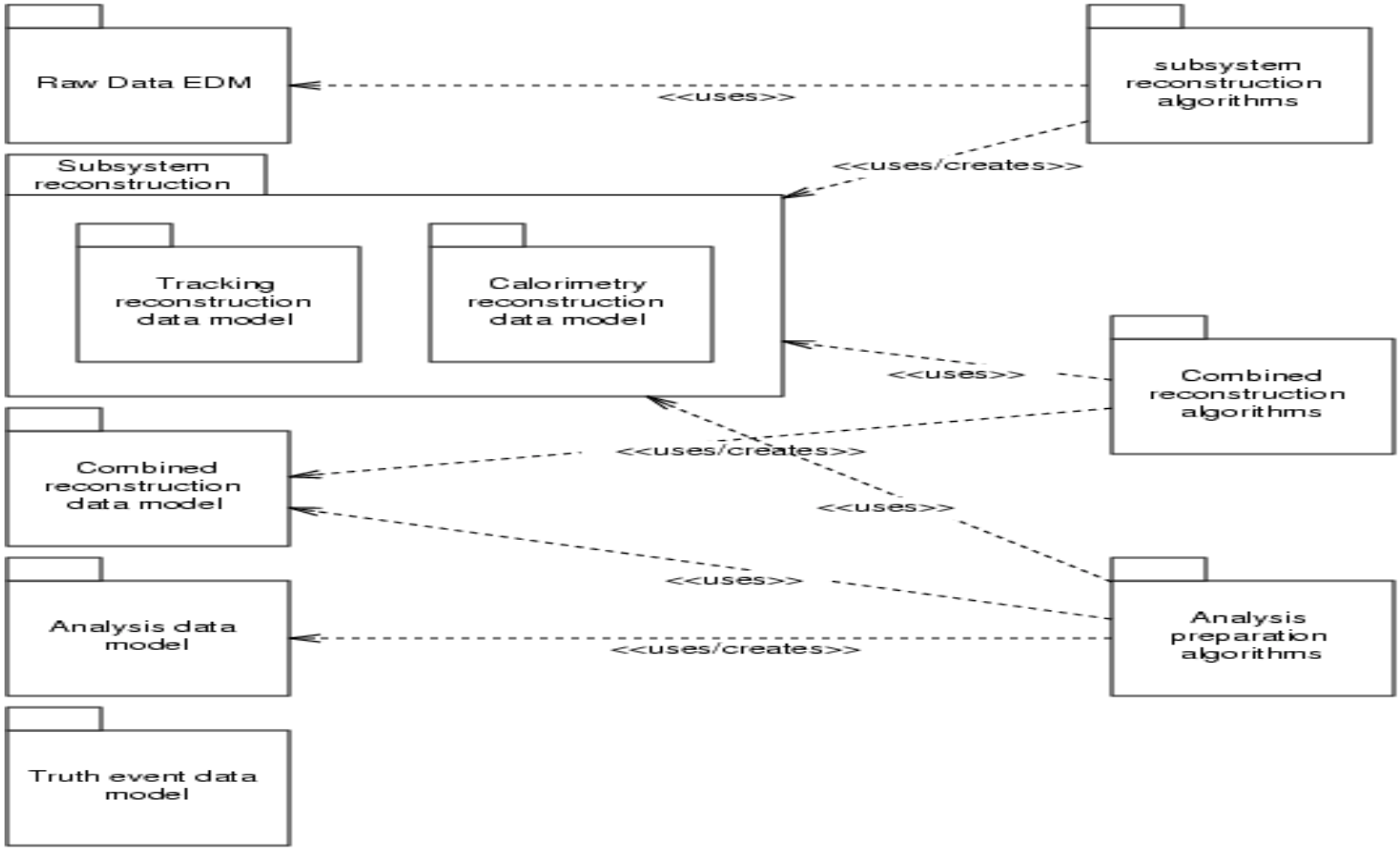
# RTF Recommendations

- **RTF = Reconstruction Task Force. Very brief overview… please read the final report:**

  **http://atlas-proj-rtf.web.cern.ch/atlas-proj-rtf/**

- **Modularity, granularity, baseline reconstruction**
- **Reconstruction top down design (dataflow)**
  - ✓ **Domains: sub-systems, combined reconstruction and analysis preparation**
  - ✓ **Analysis of algorithmic components, identified common tools**
  - ✓ **Integration of fast simulation**
  - ✓ **Steering**
- **EDM**
  - ✓ **Common interfaces between algorithms**
    - o **e.g. common classes for tracking subsystems**
  - ✓ **Design patterns to give uniformity to data classes in combined reconstruction domain**
  - ✓ **Approach to units and transformations**
  - ✓ **Separation of event and non-event data**
  - ✓ **Navigation**

# RTF Recommendations




**The User physics analysis domains and the analysis tools are not explicitly addressed by the RTF: I will concentrate on that**

# Analysis Preparation Domain

- Event Summary Data (ESD)
- Analysis Object Data (AOD)
- Event Tag
- Particle Definition algorithms

# Event Summary Data

- Read the interim report of the ESD/AOD task force:
  http://atlas.web.cern.ch/Atlas/GROUPS/SOFTWARE/OO/domains/Reconstruction/AODESD/AODESDtaskforce.htm
- ESD contains detailed output of the reconstruction --- target size 100kb per event
- ESD will be available at Tier 1 centers
- The reconstruction writes ESD --- need ESD data classes
- For Release 8.0.0, ESD classes are just the current EDM reconstruction classes with the requirements of persistency

# Analysis Object Data (AOD)

- AOD (10 kb per event) content could depend on the physics analysis, evolve with time. Different AOD streams to have different contents. But for 8.0.0, single stream content to satisfy all analyses
- AOD builders derive AOD from ESD and dispatch AOD to different streams
- AOD contain all the necessary data to do analyses
- The data in the AOD is in the ESD. AOD data class contains a pointer to the ESD
- AOD more widely distributed
- Streams defined from trigger-like signatures: few high pt muons or electrons, etc
- quantities that cannot be recalculated without going back to the ESD should be identified

# Event Tags

- Event Tags (1kb per event) allow a fast pre-selection of the events
- From each AOD stream Event Collection tags are made
- Other Event Collections, specific to particular physics analyses can be made, spanning several AOD streams

# ESD/AOD/TAG Examples

- Muon Tracks with track parameters at the spectrometer entrance (AOD)
- Lists of associated digits (ESD), also lists of nearby digits (ESD)
- Combined muon track (AOD), pointer to original muon track (AOD), pointer to original tracker track (AOD)
- Event Tag: somebody might want to unpack all the events which pass a specific trigger (e.g., multi-lepton trigger)

# Analysis Domain

- Analysis Helpers built on common analysis tools
- Prototype AOD classes of BNL for tools development
- Particle classes

# Analysis Tools Group

**Mailing list:** Atlas-phys-analysis-tools@cern.ch

**Coordinator:** Kétévi

**Web page:** www.usatlas.bnl.gov/PAT/ **dedicated to the activities of this group**

- Accessible from ATLAS main page "Analysis Tools"
- Accessible from ATLAS/Computing/Software Domains

**First Meeting held on Feb 11, 2004**

- **Agenda:** http://www.usatlas.bnl.gov/PAT/meetings/feb11-2004.htm
- **Short Term Plan:** http://www.usatlas.bnl.gov/PAT/pat_proposals.txt (summary of UCL workshop)

**Next Meeting:** Tuesday April 20, 04 (phone meeting)

**Future meetings:** to alternate with EDM or Validation meetings. Joint meetings with EDM foreseen

# Scope

- Span the gap from reconstruction to n-tuple analysis
- RTF mandate stopped at the “Analysis Preparation” Domain with the production of Analysis Data Model
- Goal is to provide an environment where reconstruction tools are available (e.g. refit tracks, vertices), but where advantage can be taken of “n-tuple” analysis tools (ROOT/PAW/JAS)
  - Operate in context of Athena framework
- Support both batch and interactive operations
- This session isn’t about ROOT/PAW/JAS as stand-alone tools
- Neither isn’t about distributed physics analysis (DIAL,AliEn...)

# Short Term Plan

**Time Scale: Software Week of May 04**
**http://www.usatlas.bnl.gov/PAT/pat_proposals.txt (summary of UCL workshop)**

- **ATHENA Analyses starting from AOD/ESD. Comparisons with same analyses from zebra or RDO**
- **In parallel, do the above in Python-scripting environment: GaudiPython, PyROOT, PyLCGDict – with documentation, adv./disadvantages (vs ATHENA)**
- **Common Analysis Helper – library of tools for analyses. Start from what is already done: Artemis Tools, I4Momentum+INavigable**

# Short Term Plan

**Working Prototypes for AOD classes:**

- Use the BNL AOD class implementations + whatever is missing, esp. the “slimming” e/gamma AOD – Endorsed by the AOD/ESD Task Force
- The above is a temporary solution: should not be released to ATLAS for analyses

# Short Term Plan

**Use Cases**

- SUSY analysis using persistified AOD – **F. Paige**
- AOD, particle Def. Algs, with Artemis – **K. Cranmer**
- Python scripting: PyLCGDict – **A. Stradling, M. Marino**
- H → 4l using persistified AOD – **A. Khodinov (+Kétévi)**
- Composite particles & relational trees **(V. Shelkov)**

**Particle Classes:**

- Scope: particle entity, not necessarily a single C++ class, to store (and use in analyses) the results of combined reconstruction. Class design to be discussed at the UCL workshop.

# I4Momentum Interface

- Read the section 3.2 of the RTF recommentadtions for details and look in the CVS repository under Event/FourMom for the implementation
- An interface to provide 4-momentum accessors, enforcing a uniform access to kinematic variables
- Uniform naming, common « look and feel »
  - ✓ Less code to write, less documentation to read
  - ✓ Avoid bugs:
    - o $P_x$=cos(phiVert)/PtInvVert
    - o ➔ wrong !
    - o $E_T$=E*sin(2*atan(exp(-eta)))
    - o ➔correct but three times slower than E/cosh(eta);

# I4Momentum Interface

- I4Momentum already implements some tools: pt(), eta(), phi(), e(), m(), etc
  - **The computation of the Z 4 momentum is now (done by Rousseau):**

```
m_hlvZ=m_egamma[0]->hlv()+m_egamma[1]->hlv();
```

  - **whereas it used to be:**

```
HepLorentzVector hlv[2];
const LArCluster* clus=0;
double eta,theta,px,py,pz,en;      // ..... 2 electrons
      for ( int i=0 ; i<2 ; ++i )
      {
       clus = m_egamma[i]->get_Cluster();
       eta = (clus)->eta();
       theta = 2. * atan(exp(-eta));
       px = (clus)->et() * sin((clus)->phi());
       py = (clus)->et() * cos((clus)->phi());
       pz = (clus)->et() / tan(theta);
       en = (clus)->et() / sin(theta);
                hlv[i].setPx(px);
                hlv[i].setPy(py);
                hlv[i].setPz(pz);
                hlv[i].setE(en);
      }
m_hlvZ=hlv[0]+hlv[1];
```

**Concise & cleaner code with I4Momentum**

- Other tools such as: dr=DR(I4Momentum,I4Momentum)
- Already being used by many packages in the reconstruction domain

# Navigation & Association

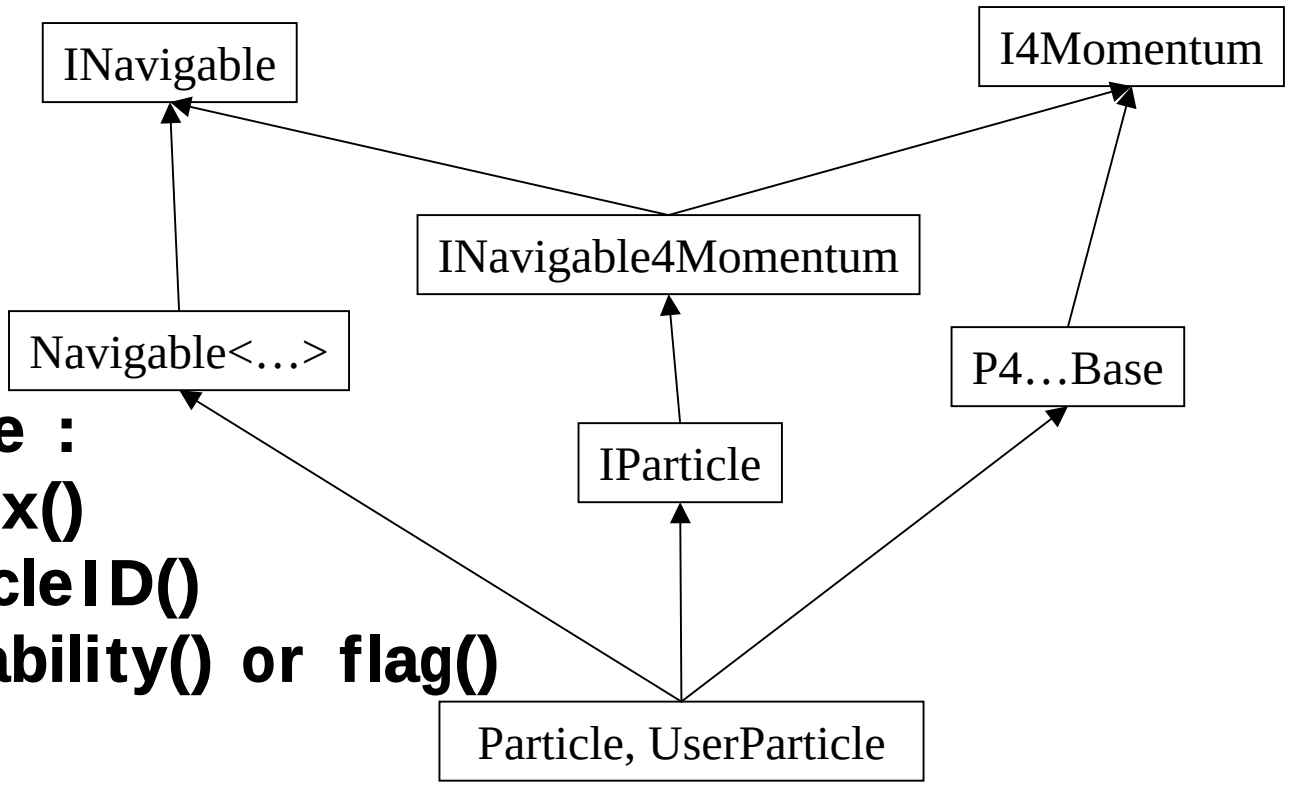
- **Navigation:** move around a relational tree, e.g., you reconstruct a H→ 4μ, you want to examine in details the MOORE or Inner Detector tracks
  - ✓ You ask the Higgs object for the combined μ tracks
  - ✓ You ask the combined track for the MOORE track
  - ✓ You ask the MOORE track for the hits_on_track
  - ✓ You ask the hit_on_track for the CSC digits or clusters
- **Associations:** not the same as navigation (an electron can be associated to a jet without belonging to the jet)
  - Internal, e.g., the Higgs object holds the lists of its combined μ candidates, H → 4 m.
  - External such as maps (tables): map (object1*, object2*), etc
- **Navigation & association are needed in Reconstruction ←→ Analysis domains for detailed and useful analyses**
- **A Navigation Interface, INavigable is already implemented for the calorimeter: EnergyCluster (CaloCluster, CaloTower, etc) are examples of navigable 4-vectors: I4Momentum&INavigable**

# Some Outcome of the UCL Workshop

- **Merge I4Momentum and INavigable into a single interface: INavigable4Momentum**
- **Analysis tools will be built on this common interface:**
  - ✓ Double dr = DR(const INav4Mom*, const INav4Mom*);
  - ✓ INav4Mom foo = doSomething(const INav4Mom*,const INav4Mom*);
  - ✓ StatusCode (bool) foo = doSomething(INav4Mom&);
  - ✓ More complicated tools

# Some Outcome of the UCL Workshop

- The particle class




**IParticle :**
- **vertex()**
- **particleID()**
- **Probability() or flag()**

**The particle class to be implemented for the BNL workshop**

# Artemis

- Self-contained analysis package. Follow the link in www.usatlas.bnl.gov/PAT/ for documentation on Artemis
- User has to write adaptors to reconstruction objects --- scalability issues
- Designed in a hierarchical way so can associate anything to anything in the user analysis domain
- Tools built on Artemis' IMomentum interface
- Can be modified to the INavigable4Momentum interface
- However, fully integration into the proposed RTF architectural framework for analysis bogged down on issues of associations. Further discussions in the analysis tools meetings: perhaps convergence by the BNL software week.

# Conclusions

- Analysis tools group formed recently: very few people so far
- Objective: analysis helpers for batch and interactive analyses
  - ✓ Analysis tools
  - ✓ Particle definition algorithms
  - ✓ Particle classes
  - ✓ ESD/AOD/TAGS
- Regular bi-weekly meetings: next on Tuesday April 20, 2004 at 17:00 CERN time
- Slow progress now but we are converging on the architectural model for the analysis domain
- Several use cases being exercised