



# & Geant 4

**Pedro Arce (CERN/IFCA-Santander)**  
Vladimir Ivantchenko (CERN/Budker Institute)

GEANT4 Workshop

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# HARP will measure.....

Geant 4

Hadronic production cross sections ( $d\sigma/dP_t \cdot dP_l$ )  
at various energies and with various targets

Goal: 2% accuracy over **all** phase space  
 $O(10^6)$  events/setting, low systematic error

## *Current Run (2001):*

CERN PS, T9 beam: 2 GeV/c - 15 GeV/c protons,  $\pi^-$ ,  $\pi^+$ ,  $K^-$ ,  $K^+$

Targets: Be, C, Al, Cu, Fe, Pb, W (thin and thick)

- Measurements with solid and cryogenic targets, 2001

## *Future plans:*

- Measurements with incoming Deuterium and Helium, 2002
- ~100 GeV incoming beam, using NA49 set-up



## Deliverables

**Geant 4**

### Input data

for the design of the Neutrino factory/Muon collider

### Input data

for the Atmospheric neutrino flux calculations

### Precise predictions

of the neutrino fluxes for the K2K and MiniBooNE experiments

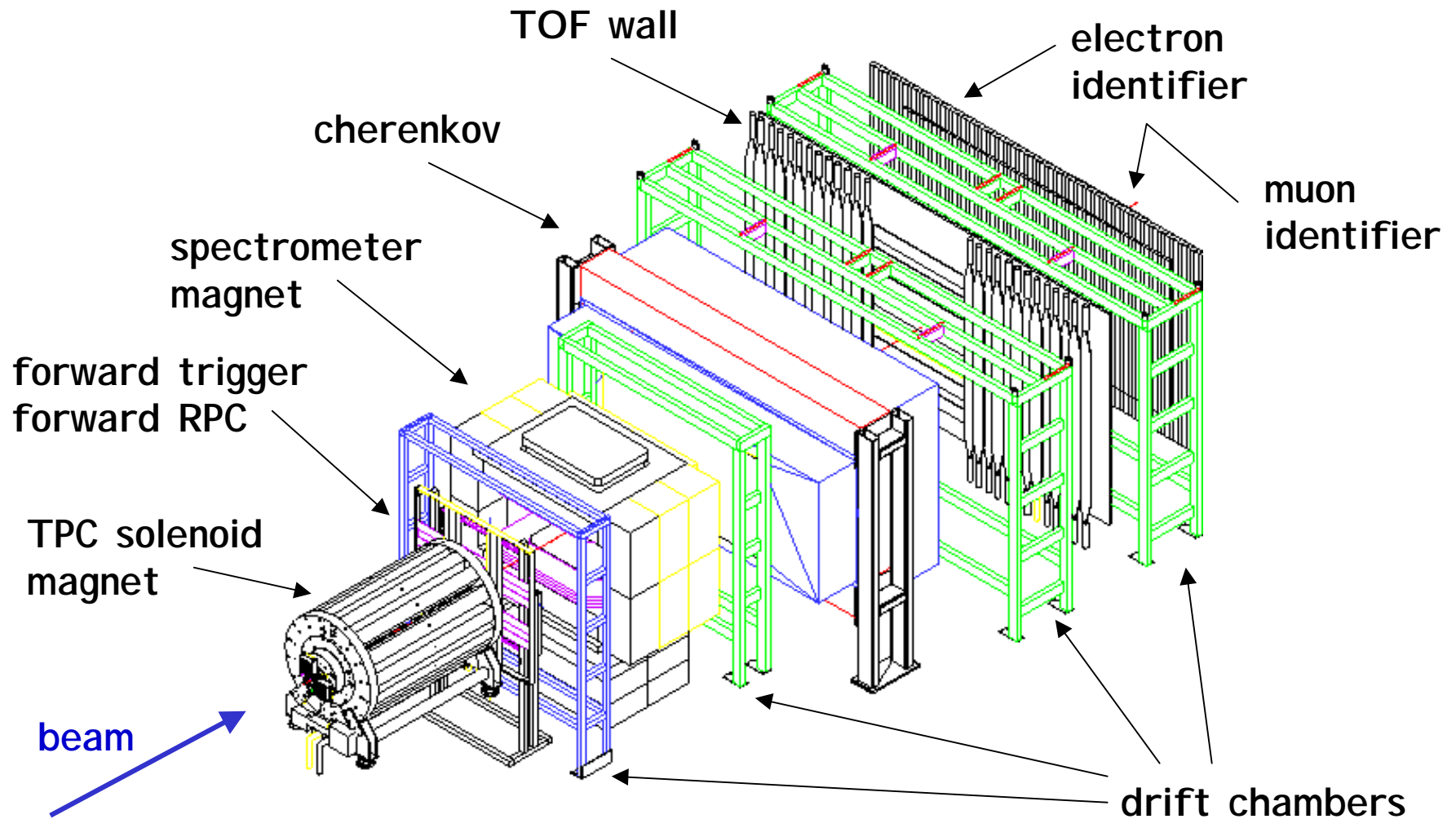
### Input data

for the hadron generators in Monte Carlo simulation packages



# Experimental setup

Geant 4







# Experimental setup

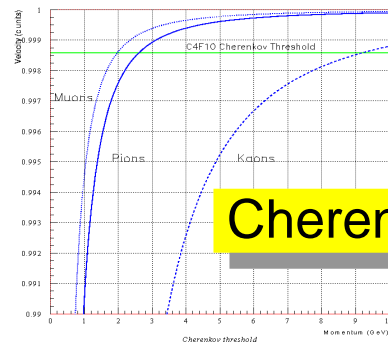
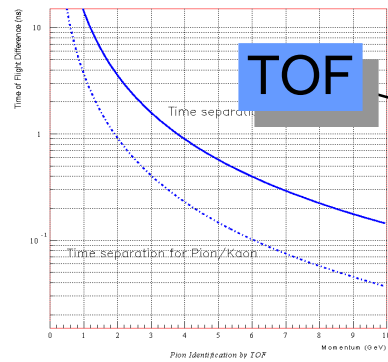
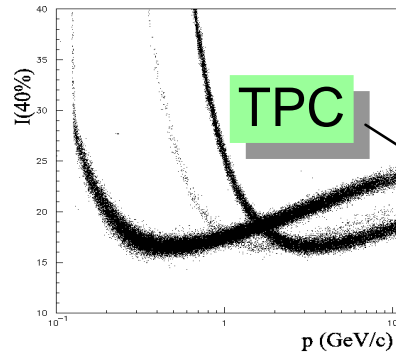
**Geant 4**



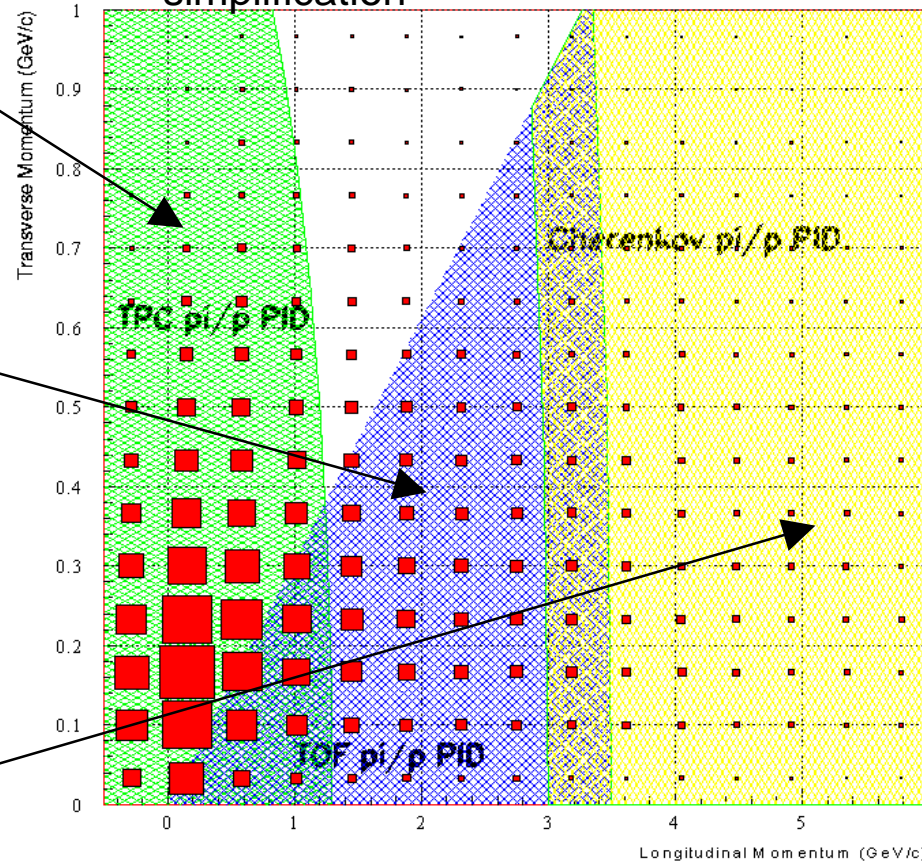


# $p/\pi$ separation

## Geant 4



$p/\pi$  separation at  $4\sigma$  level, “conservative” simplification



Pt-PI box plot of  $\pi$  distribution from 15 GeV p on Be thin target





# Software Process

Geant 4

- Stringent time schedule required adoption of **software engineering standards**.
- Software deliverables for the Technical Run:
  - Project and Configuration Management Plans
  - User and Software Requirements Documents
  - Architectural Design Document & Design Diagrams
  - Test Plan and Release Procedures
  - Traceability matrixes across software deliverables
- Domains identification & dependency structure lead to:
  - definition of releasable units (libraries and source code),
  - definition of working groups (and schedules),
  - definition of ordering for unit&system testing and for release.

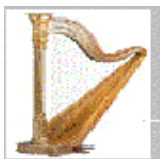


# Software Functionality

Geant 4

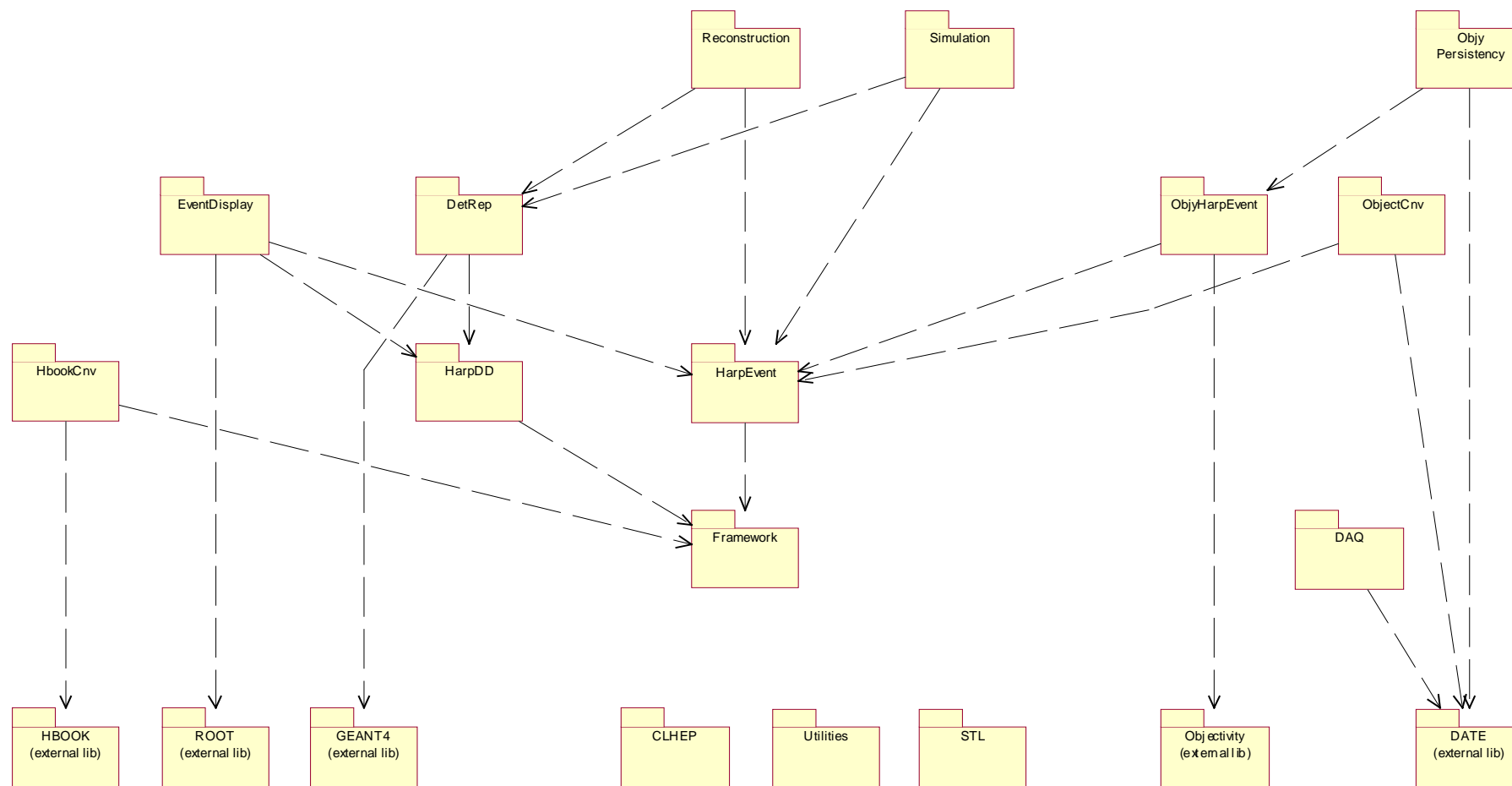
- **DAQ** and detectors readout (DATE).
- **Storage** and retrieval of physics data and settings (Objectivity DB, AMS-HPSS interface).
- **Framework** including application manager, interfaces & data exchange for the components, and event model (GAUDI).
- Physics **Simulation** & Detector Model (GEANT4).
- Physics **Reconstruction** for DC data.
- Online **Monitoring** & Offline **Calibration** of detectors.
- User Interface and **Event Display** (ROOT).
- Foundation libs & **Utilities** (STL, CLHEP).





# Software architecture

## Geant 4





# Geometry Description

## Geant 4

### ✓ From ASCII files based on a few tags

#### ◆ Define a single logical volume (solid and material): **VOLU**

```
:VOLU "TPC" "TUBE" "Air" 3 0.0 454.0 1100.0
```

#### ◆ Define a logical volume made up of a subtraction (addition, intersection) of two volumes: **VOLU\_SUBS(\_ADD/\_INTERS)**

```
:VOLU_SUBS "Tpc Gas" "Tpc Gas1" "Tpc Gas2" "RM0" 0. 0. -560.25
```

#### ◆ Single positioning: **POS**

```
:POS "Tpc Gas" 1 "TPC" "RM0" :ONLY 0.00 0.00 40.0
```

#### ◆ Replica: **DIV\_NUM / DIV\_STEP**

```
:DIV_NUM "PAD sector" "PAD support" "Epoxy" 6 "PHI"
```

#### ◆ Positioning with a parameterisation: **POS\_PARAM** (only a few available)

- Change position at each copy
- Change rotation at each copy

```
:POS_PARAM "PAD" 1 "PAD sector" "CIRCLE" $n11 0.08635 -0.43177 82.22
```

#### ◆ Set visibility of a logical volume: **VIS**

```
:VIS "PAD" OFF
```

#### ◆ Set the RGB colour of a logical volume: **COLOUR/:COLOR**

```
:COLOUR "PAD" 1. 0. 0.
```



# Geometry Description (II)

## Geant 4

### ◆ Define rotation matrices: **ROTM**

```
:ROTM "RM0" 90.00 0.00 90.00 90.00 0.00 0.00
```

### ◆ Materials

#### • Define an element: **ELEM**

```
:ELEM "Fluorine" "F" 9. 18.998
```

#### • Define a simple material (1 element): **MATE**

```
:MATE "Aluminium" 13. 26.98 2.7
```

#### • Define a mixture (made of elements or materials): **MIXT**

- by weight fractions
- by number of atoms
- by volume

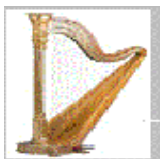
```
:MIXT "Air" 1.214e-3 4
      "Nitrogen" 0.7494
      "Oxygen" 0.2369
      "Argon" 0.0129
      "Hydrogen" 0.0008
```



# Geometry Representations

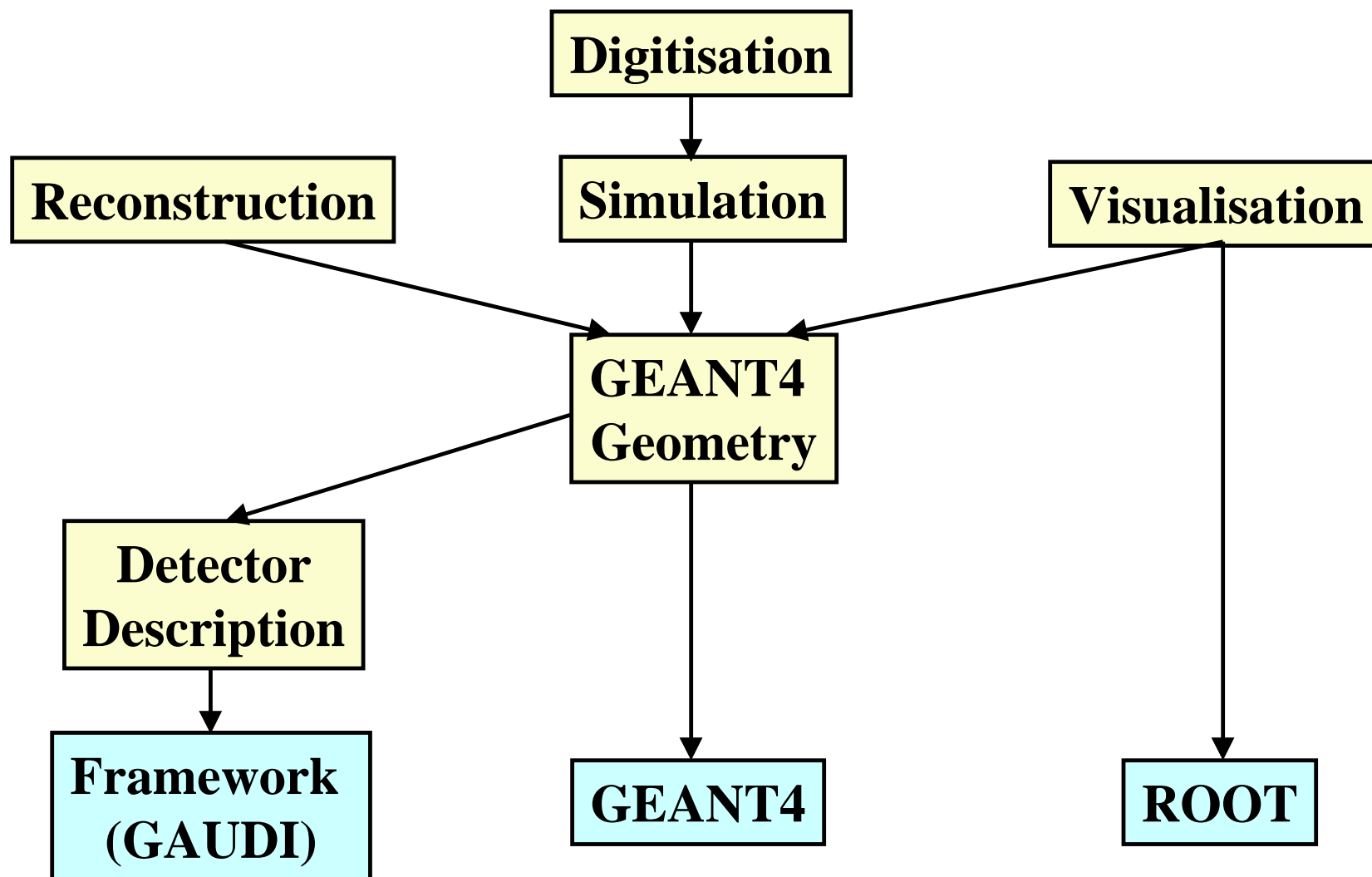
Geant 4

- ◆ Generic representation independent GEANT4
- ◆ GEANT4 representation
  - access all data from the generic representation
- ◆ Digitisation / Reconstruction
  - ask GEANT4 representation for the volumes they need (by name)  
`HdrGeometryMgr::getInstance()->getTouchables("TpcSector#2/TpcPad#12")`  
return GEANT4 independent representation: touchables and logical volumes
- ◆ Visualisation (ROOT)
  - ask generic representation, except replicated and parameterised positionings, where it asks GEANT4  
builds ROOT representation



# Software architecture

Geant 4







# GEANT4 simulation

Geant 4

- ◆ Takes care of:
  - Primary generator
  - Physics list
  - User actions
  
- ◆ GEANT4 geometry representation is in another package
  - Reconstruction/visualisation can use GEANT4 geometry without initialising G4RunManager
  
- ◆ Two magnetic field maps parameterised
  
- ◆ Three PrimaryGenerators available allowed
  - HarpGun, G4GeneralParticleSource, T9 beam generator
  
- ◆ Multiple run/event/stacking/tracking/stepping actions allowed
  - one action registered to GEANT4, that loops to the actions registered to it
  
- ◆ GEANT4 event loop managed by GAUDI event loop
  - each event is simulated then reconstructed



# GEANT4 error propagator

Geant 4

## ★ What it does:

Needed for track reconstruction:

- ◆ Start with an initial track state (energy, position and direction with their errors) in some subdetector
- ◆ **GEANT4e**: calculates the track state in another surface of the detector

## ★ How it does it:

- ◆ Propagates average trajectory
- ◆ Computes average energy loss (positive or negative)
- ◆ Propagates errors:
  - ◆ Propagates errors along the trajectory
  - ◆ Adds fluctuation in multiple scattering
  - ◆ Adds fluctuation in energy loss
  - ◆ Adds errors of magnetic field



# GEANT4 error propagator

Geant 4

## ★ Status:

- ◆ Uses G4Transportation to propagate from an initial track state to a user defined surface (infinite plane) in the
  - ◆ GEANT4 geometry
  - ◆ GEANT4 magnetic field
- ◆ Propagates errors in case of no magnetic field (linear trajectory)

## ★ Plans

- ◆ Propagate errors in magnetic field for different trajectory representations
  - ◆ Assume helix trajectory?
  - ◆ Calculate errors of RungeKutta?



## Status of GEANT4 simulation

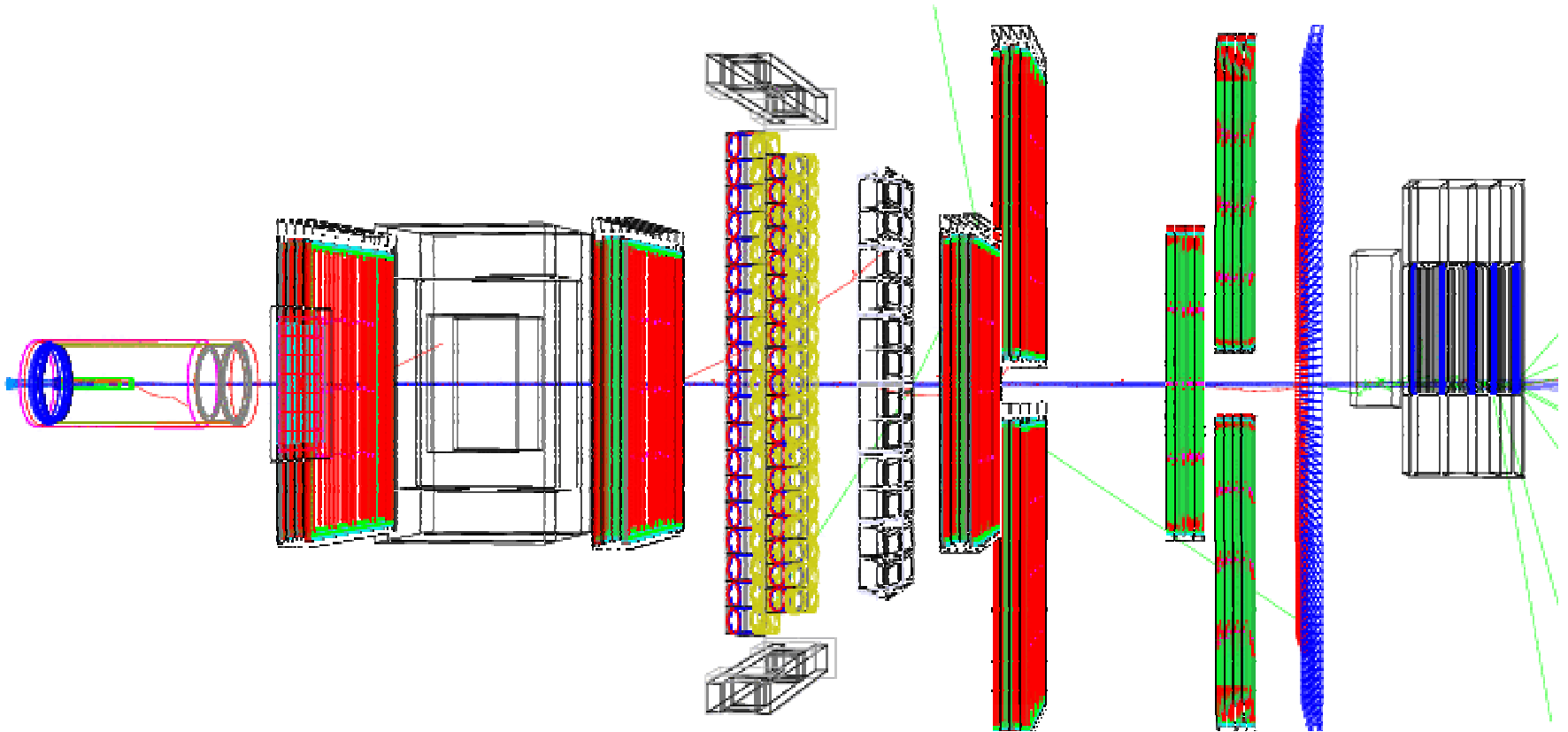
**Geant 4**

- ☺ All geometry described
- ☺ Magnetic field described (parameterised)
- ☺ Physics list electromagnetic and hadronic
- ☺ Digitisation implemented for two main subdetectors (Tracking Projection Chamber and Drift Chambers)
- ☹ Work on progress for digitisation of other subdetectors
  
- ☺ Reconstruction in DC and TPC using GEANT4:
  - error propagator (GEANT4e)
  - simulated events for debugging



# HARP with GEANT4

Geant 4







## Status of GEANT4 simulation (II) **Geant 4**

- ☹ No real data before july 2001
- ☹ Reconstruction and analysis software not ready before end of year

Several thousands of events produced

No need of mass production of simulated events before a few months

No results of cross sections for GEANT4 before six months