

BESIII Offline Software

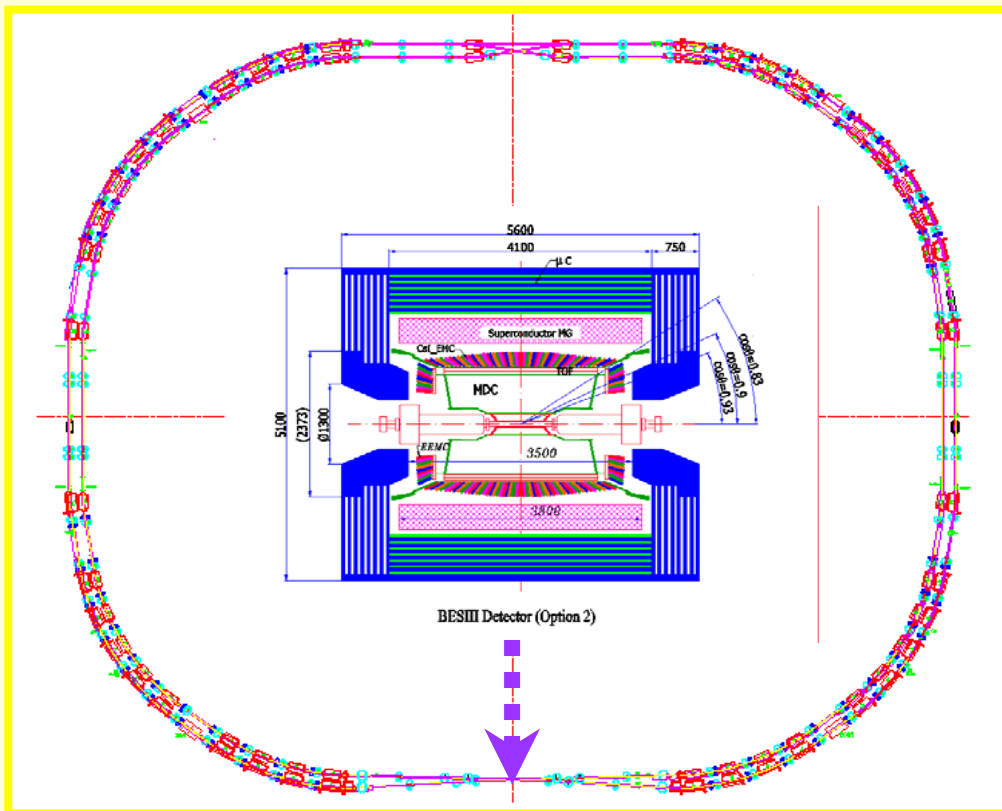
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CHEP06, Mumbai

14 February 2006

BEPCII Project



- ❖ Upgrade of BEPC
- ❖ e^+e^- multi-bunch collider
- ❖ Scheduled to provide collisions in summer, 2007.
- ❖ Designed peak luminosity: $10^{33} \text{cm}^{-2} \text{s}^{-1}$
- ❖ Physics: Charmonium Physics (J/ψ , $\Psi(2s)$), Light Hadron Spectroscopy, D/Ds Physics, QCD/R Value measurements etc.

BESIII Detector

Main Drift Chamber (MDC):

$$\sigma_{xy} = 130 \mu\text{m}$$

$$\Delta P/P = 0.5 \% @ 1 \text{ GeV}$$

$$\sigma_{dE/dx} = 6-7 \%$$

Super-conducting
Magnet: 1.0 Tesla

TOF System:

$$\sigma_T = 90 \text{ ps barrel}$$

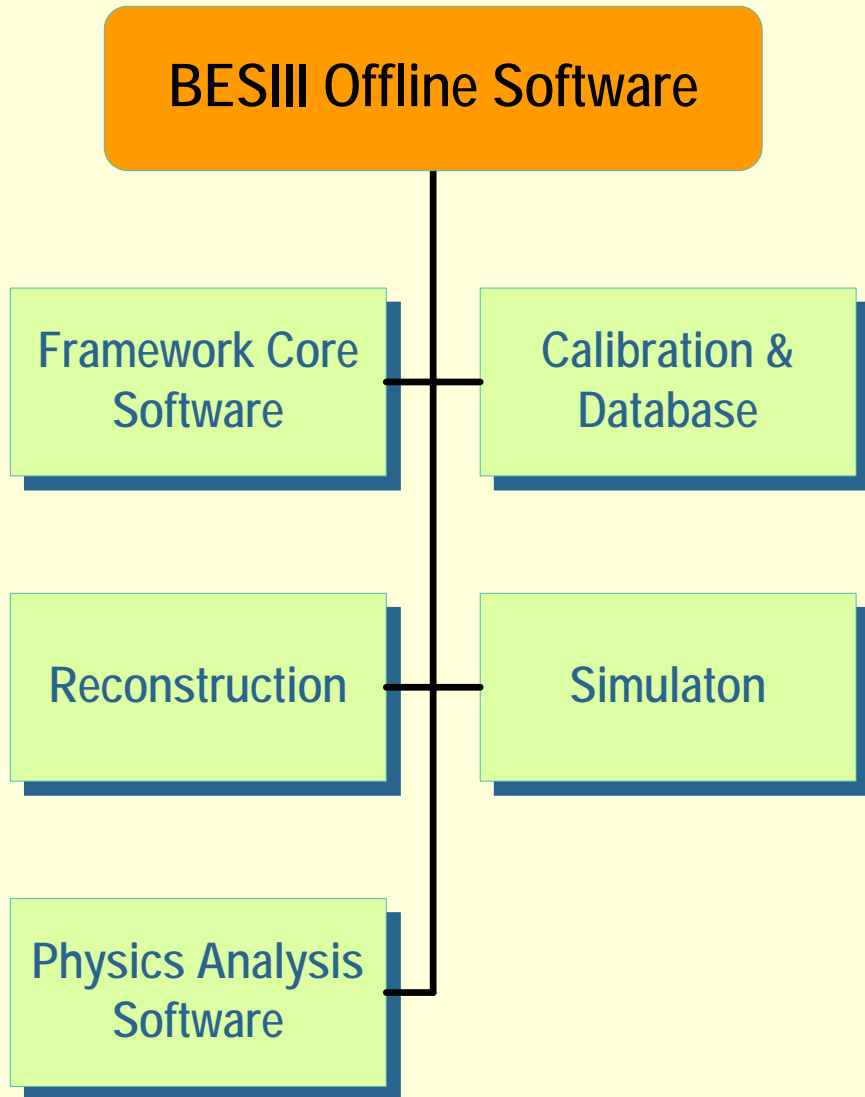
$$110 \text{ ps endcap}$$

Muon Chamber (MUC):
RPC based

EM Calorimeter (EMC): $\Delta E/E = 2.5 \% @ 1 \text{ GeV}$

$$\sigma_{z,\phi} = 0.6 \text{ cm} @ 1 \text{ GeV}$$

Organization

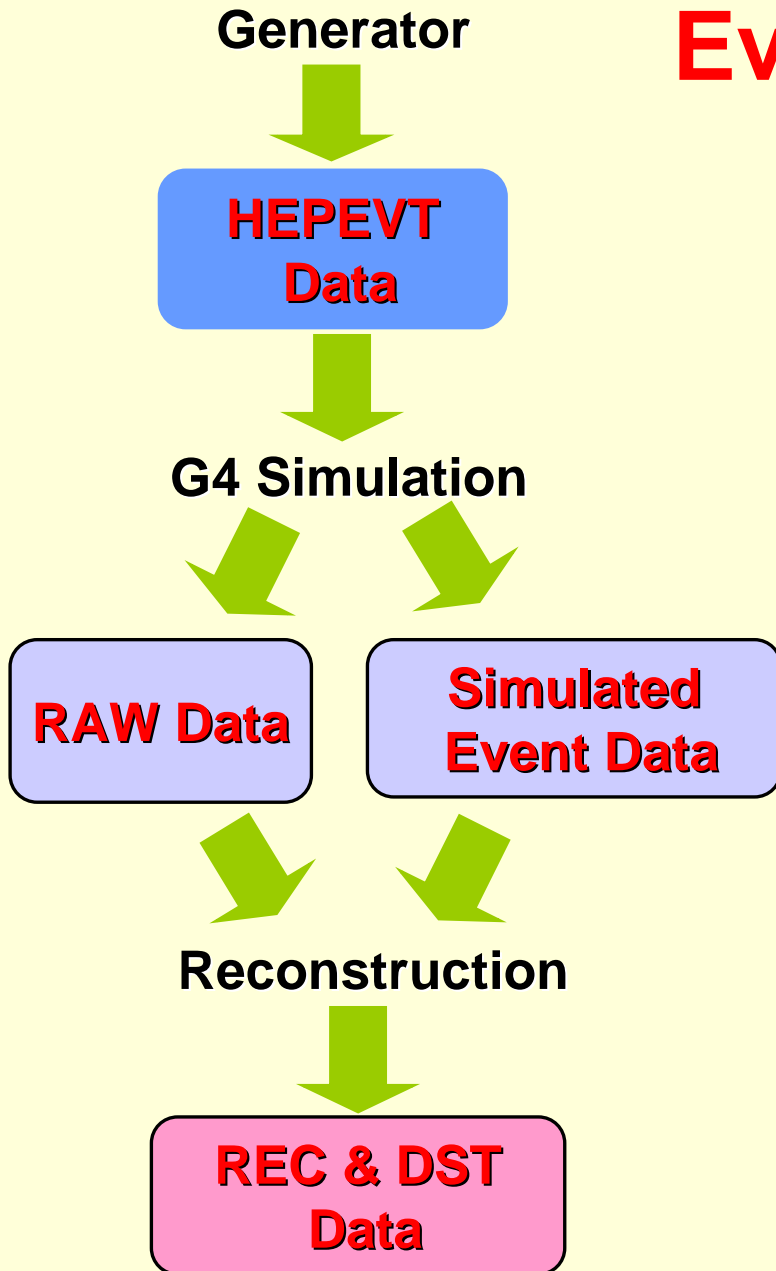


❖ Institutes participating

- Institute of High Energy Physics
- Peking University
- Shandong University
- University of Science and Technology of China
- Hunan University
- Zhejiang University
- Joint Institute for Nuclear Research, Russian

Software Environment

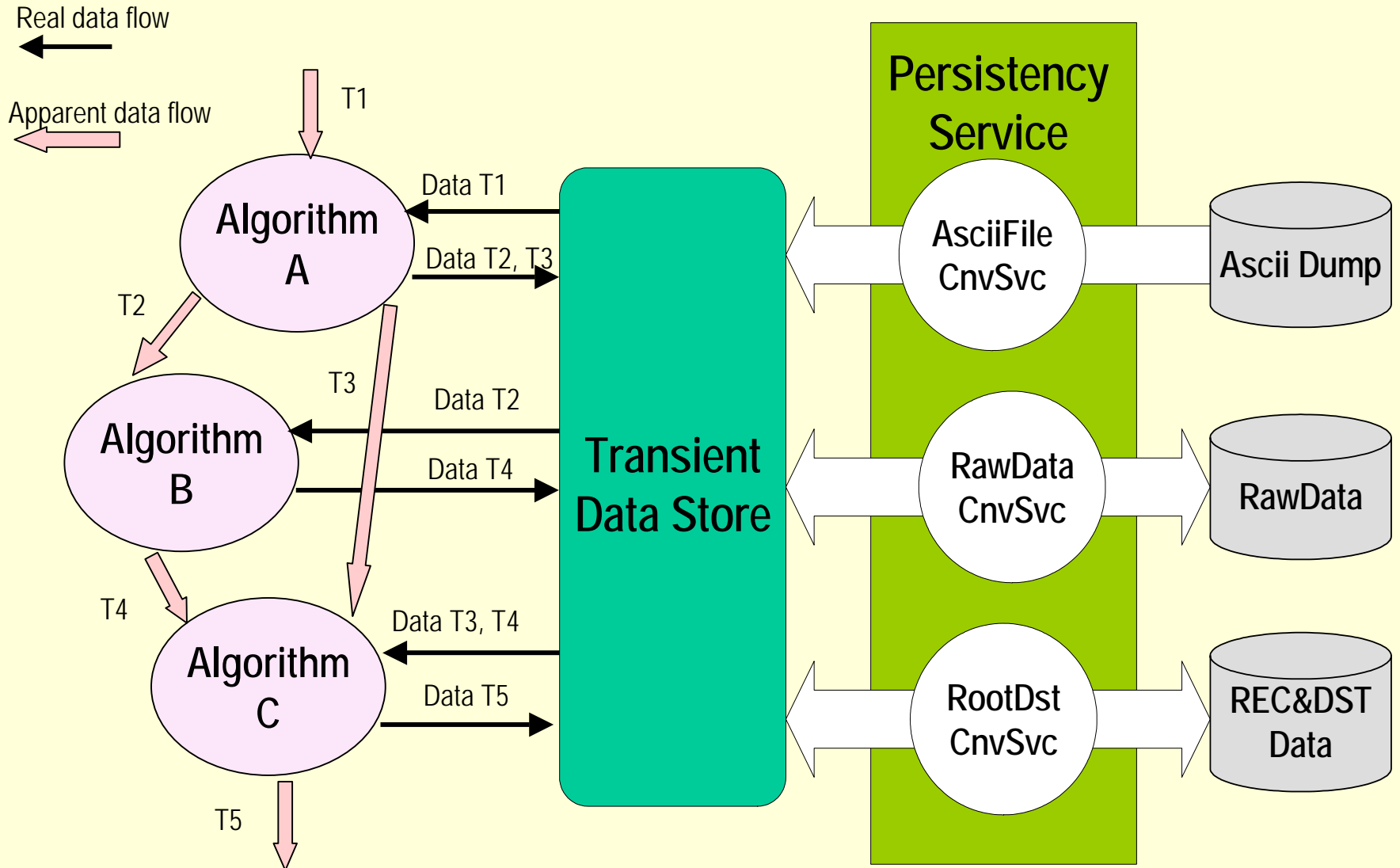
- ❖ Underlying framework
 - GAUDI (originally developed by LHCb)
- ❖ Simulation
 - GEANT4
- ❖ Other external LIBs:
 - CERNLIB, CLHEP, ROOT, AIDA, XercesC, GDML ...
- ❖ Database: PGSQL/MySQL
- ❖ Software configuration management
 - CMT and CVS
- ❖ Computer language: C++ (BESII legacy code written in Fortran)
- ❖ Operation system:
 - Redhat 7.3/gcc3.2 (now), SLC3/ gcc3.2.3 (in the future)
- ❖ Reused code from Belle, BaBar, ATLAS, GLAST ...



Event Data

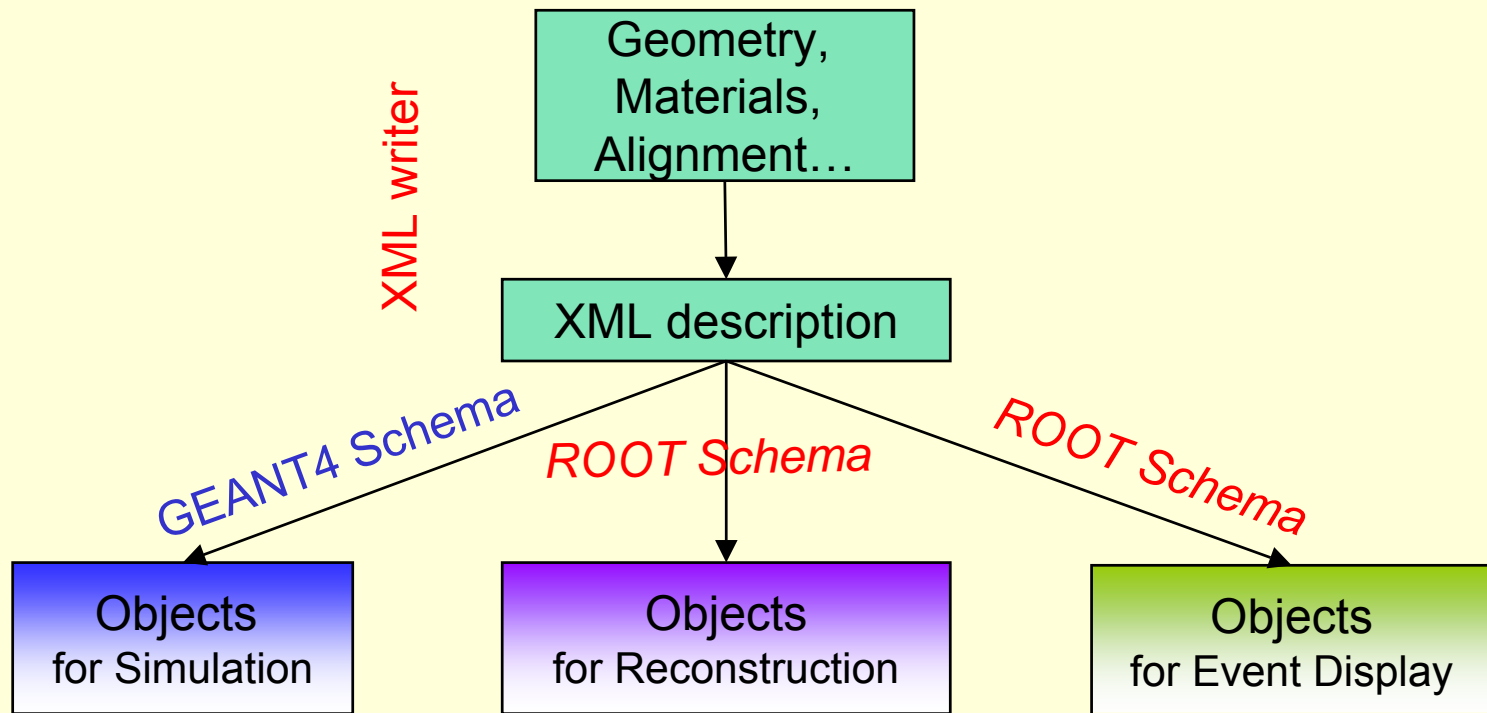
- ❖ HEPEVT Data
 - Kinematics information only
- ❖ RAW Data
 - Delivered by DAQ for reconstruction
 - Byte stream format
- ❖ Simulated Event Data
 - Contain digits, hits and other MC truth information
 - Ascii file format
- ❖ REC & DST Data
 - Reconstructed Data is event data written as output of reconstruction procedure
 - DST Data is a reduced event representation suitable for analysis
 - Both in ROOT format

Event Data Conversion Services

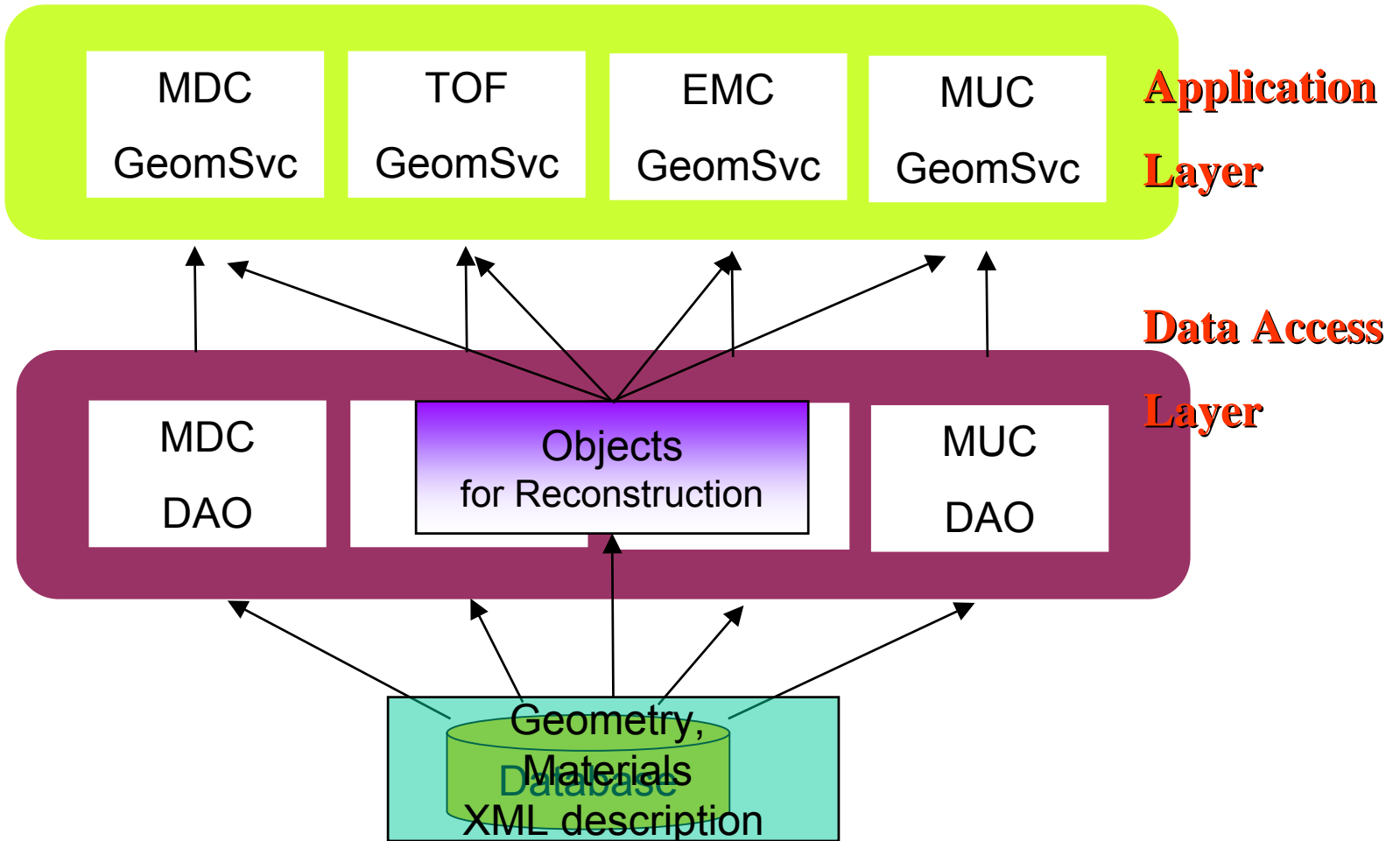


Detector Description

- ❖ Based GDML (Geometry Description Markup Language)
- ❖ Expanded the GEANT4 Schema and developed a new ROOT Schema for BESIII applications.
- ❖ GDML Detector Description has been used for simulation, event display and reconstruction.

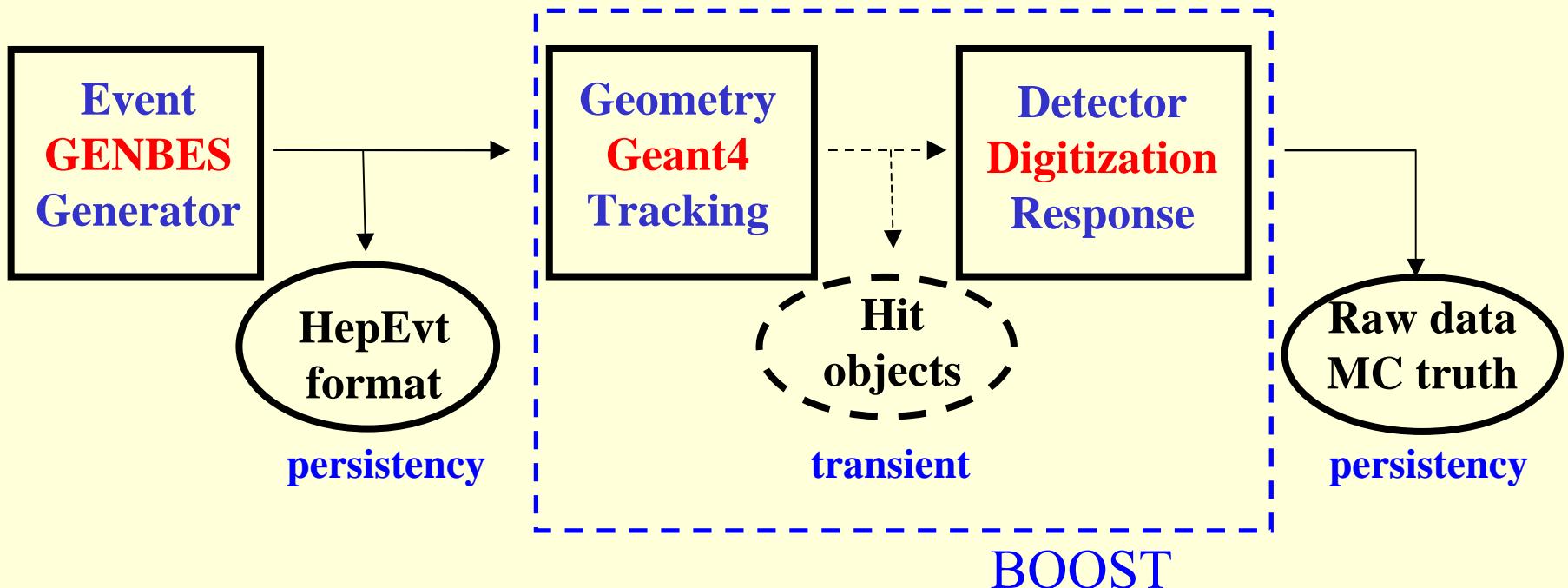


Access to Geometry Data



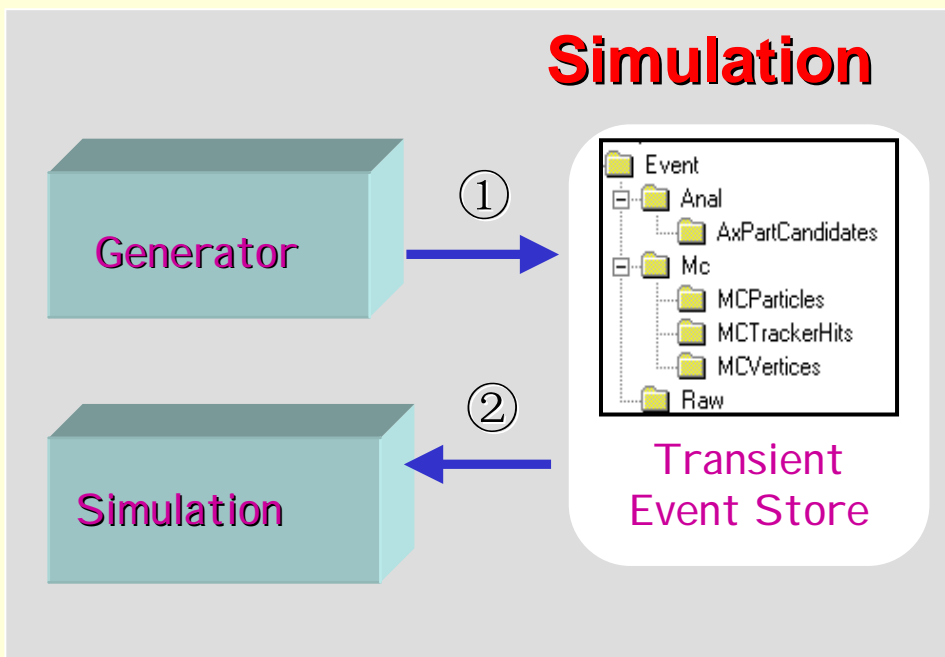
BESIII Simulation Tool

- ❖ BOOST (BESIII Objected Oriented Simulation Tool) is based on Geant4.
- ❖ Originally developed in a independent framework.
- ❖ Material and geometry data are read from GDML files.
- ❖ GENBES: BESII event generators.



Simulation Integration

- ❖ BESII has ~30 event generators written in Fortran
- ❖ Use C++ Hepevt_Wrapper to access the kinematics information generated by the generators



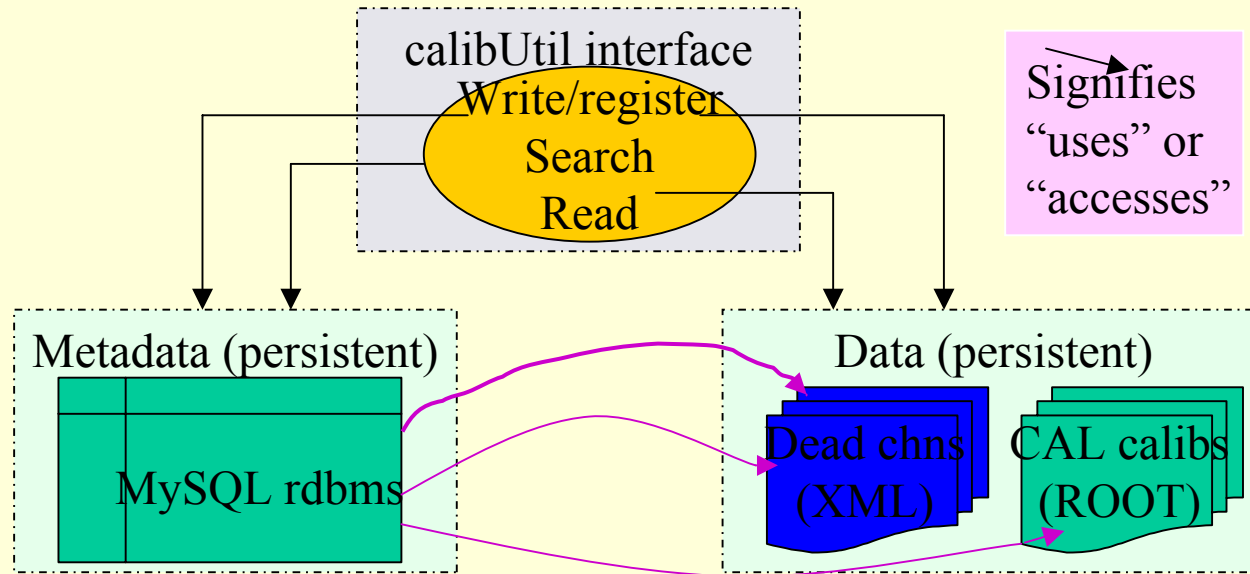
- ❖ Integration with BOOST simulation is based on ATLAS/Athena software.
- ❖ Currently both BES generators and BOOST have been integrated with the offline framework.

Reconstruction Algorithms

Sub-detector	Reconstruction Algorithms
MDC	<p>MdcPatRec : tracking algorithm based on BaBar software</p> <p>TrkReco: tracking algorithm based on Belle software</p> <p>MdcDedxAlg: calculating dE/dx information for MDC tracks.</p> <p>KalFit: track fitting algorithm using the Kalman Filter method.</p>
TOF	<p>TofRec: calculates the flight time of charged particles.</p>
Calorimeter	<p>EmcRec: a clustering algorithm for EM Calorimeter.</p>
Muon Chamber	<p>MucRec: tracking algorithm for Muon Chamber</p>
Other Algorithms	<p>T0 Calculation: determining the event start time T0.</p> <p>Tack Extrapolation: considering particles' deflection in the magnetic field and the ionization energy loss of particles in the material.</p>

Calibration

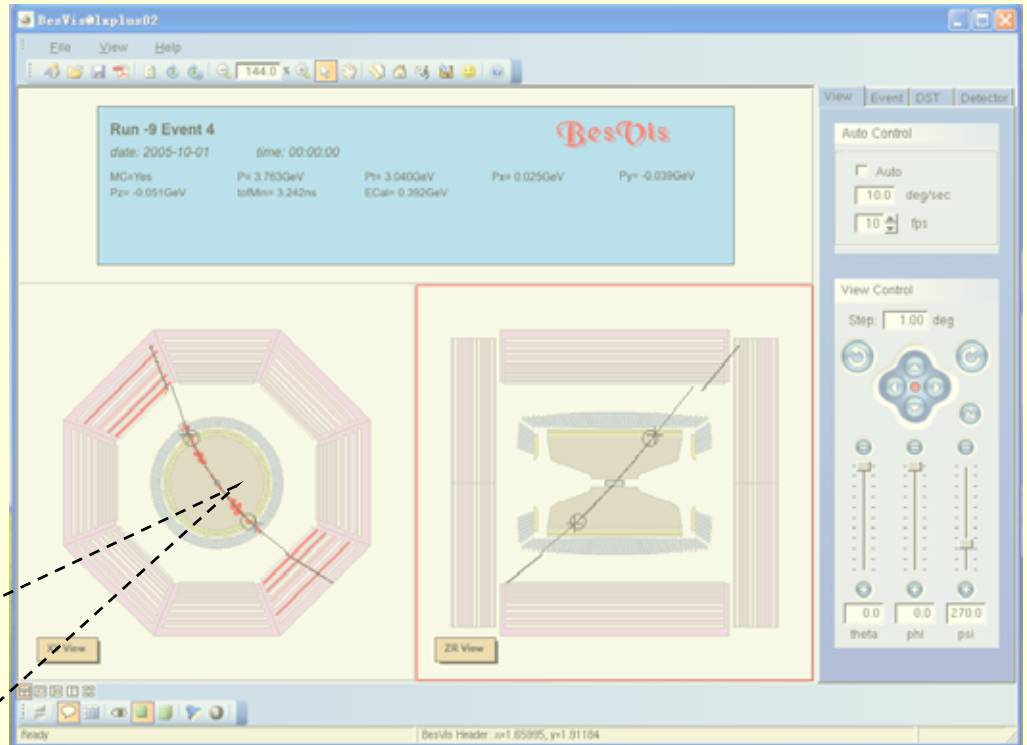
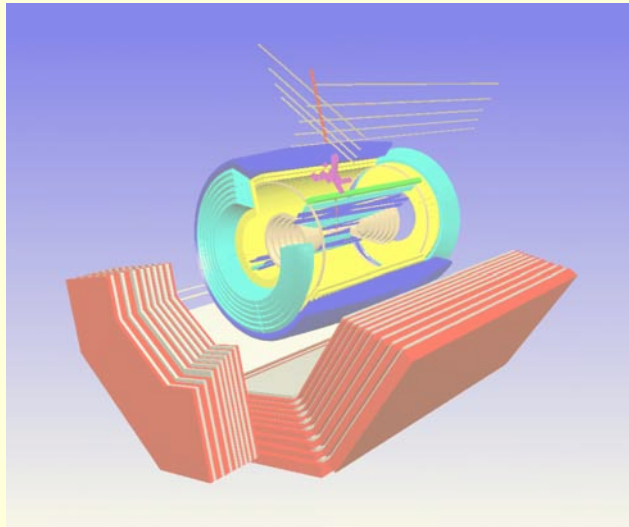
- ❖ Framework is based on GLAST calibration infrastructure



- ❖ Status

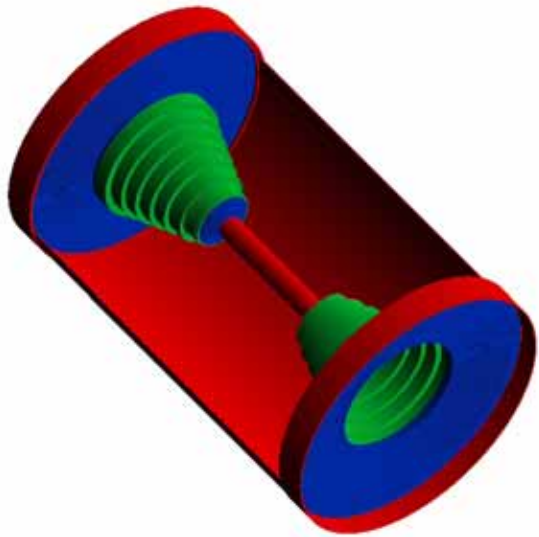
- Developed MDC, TOF and EMC calibration prototype algorithms
- Defined calibration data for each sub-detector
- Reconstruction algorithms are able to retrieve calibration constants through the framework.

Event Display Tool: BesVis

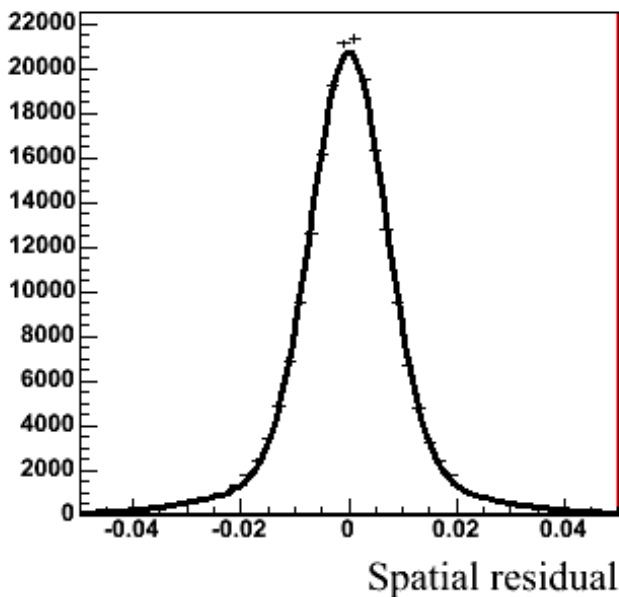


- ❖ Based on ROOT, OpenGL, X3D and XML
- ❖ Support both 2D and 3D view
- ❖ Operations and controls available through menu and toolbar items
- ❖ First version was released in December 2005.

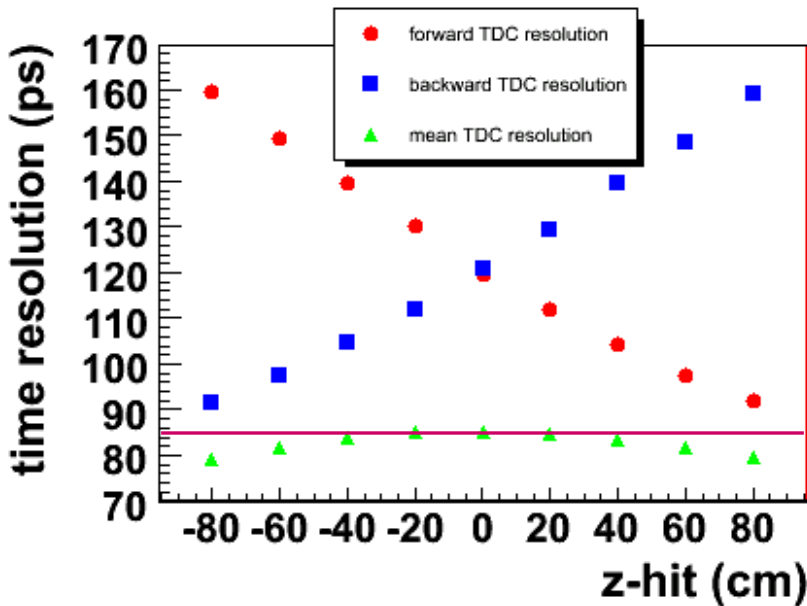
Main Drift Chamber Software



- ❖ Simulation
 - Stereo cells are described by G4TwistTube.
 - Digitization is based on parameters from test beam data.
- ❖ The calibration algorithm contains correction to
 - X-T relation, spatial resolution, T0, wire position, time walk.
- ❖ Reconstruction algorithms are: **TrkReco** and **MdcPatRec**. For single 1 GeV muons, both of them obtain:
 - Efficiency: **~99%**
 - Spatial resolution: **~110 μm**
- ❖ dE/dx resolution: **~6%** consistent with detector design report.



TOF Software

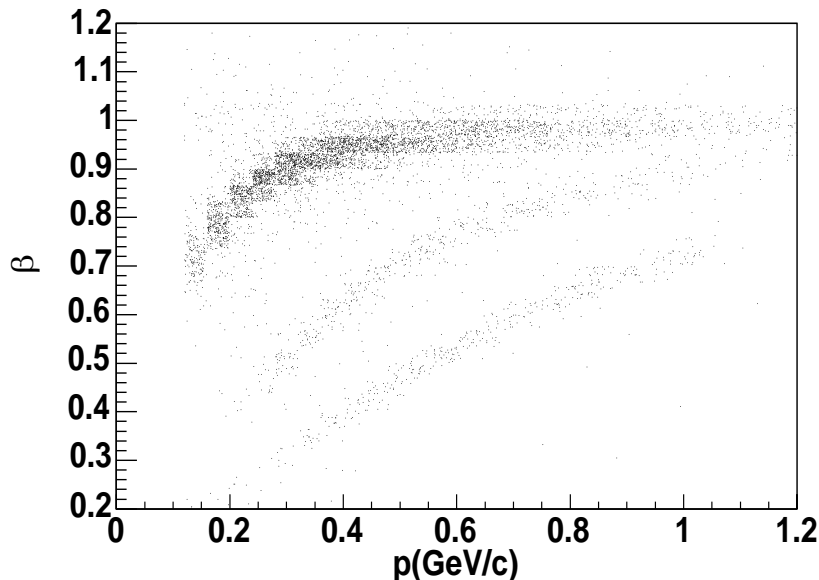


❖ Simulation

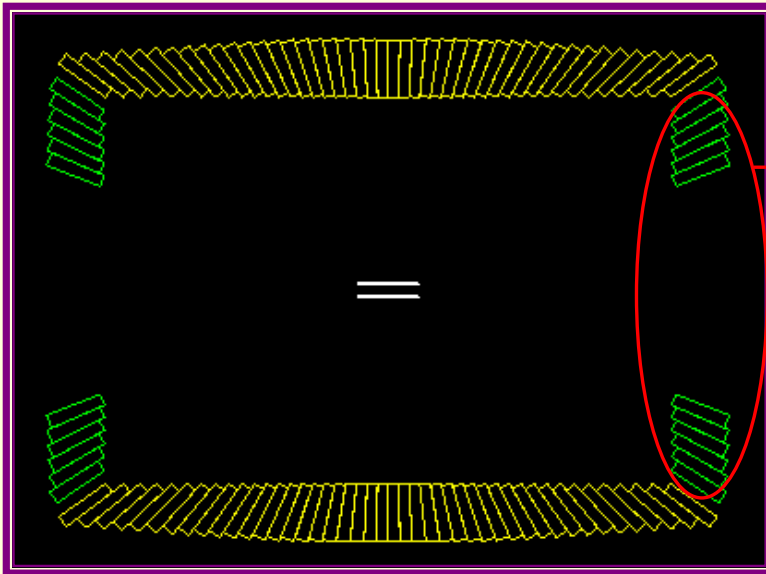
- Two-layered structure for Barrel
- Digitization takes into account: light production, light propagation and PMT response etc.
- Intrinsic time resolution: 85 ps

Calibration & reconstruction

- Calibration algorithm contains time correction, effective velocity and attenuation calibration.
- Reconstruction results have been used in particle identification



EM Calorimeter Software



❖ Simulation

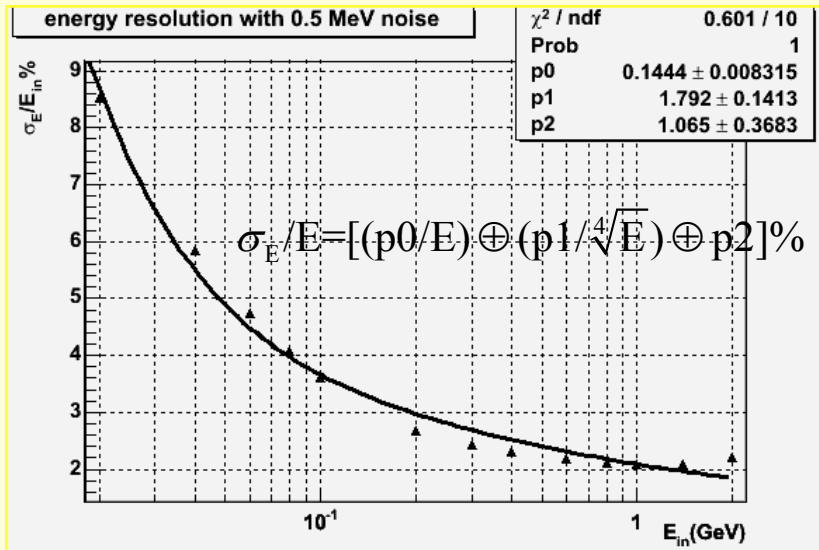
- End-cap is described by G4IrregBox.
- Full simulation of readout electronics is included in digitization.

❖ Energy calibration

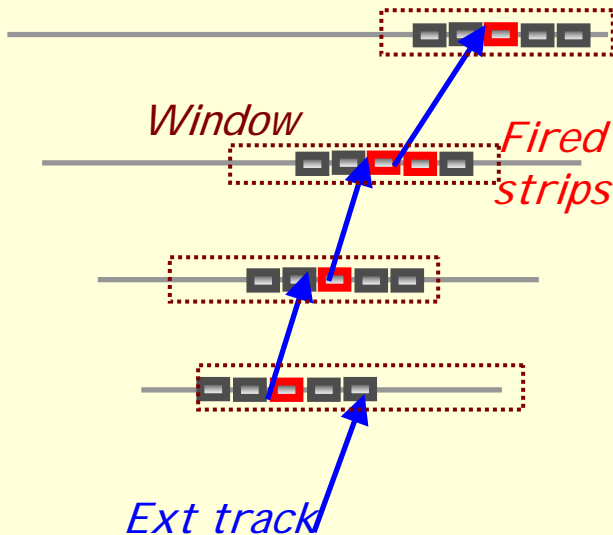
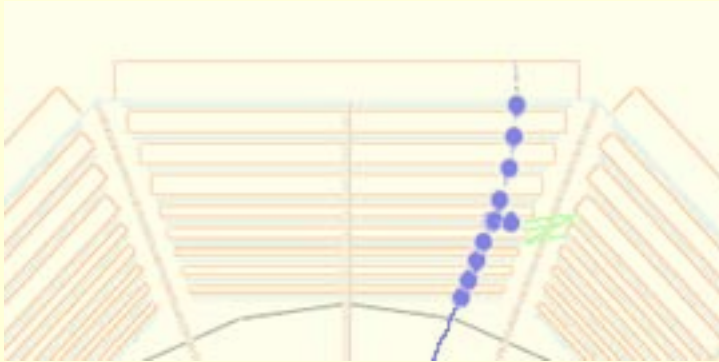
- Digit calibration: converting ADC channels into energy.
- Cluster calibration: correcting non-linearity of readout signals.

❖ Reconstruction

- $\Delta E/E = \sim 2\%$ @ 1GeV
- $\sigma_z = 0.6 \text{ cm}$ @ 1GeV



Muon Chamber Software



❖ Simulation

- RPC as sensitive detector
- Detailed to each read-out strip

❖ Reconstruction

- Tracking algorithm is seeded by the tracks extrapolated from MDC.
- Searching for hits gap by gap within predefined windows.

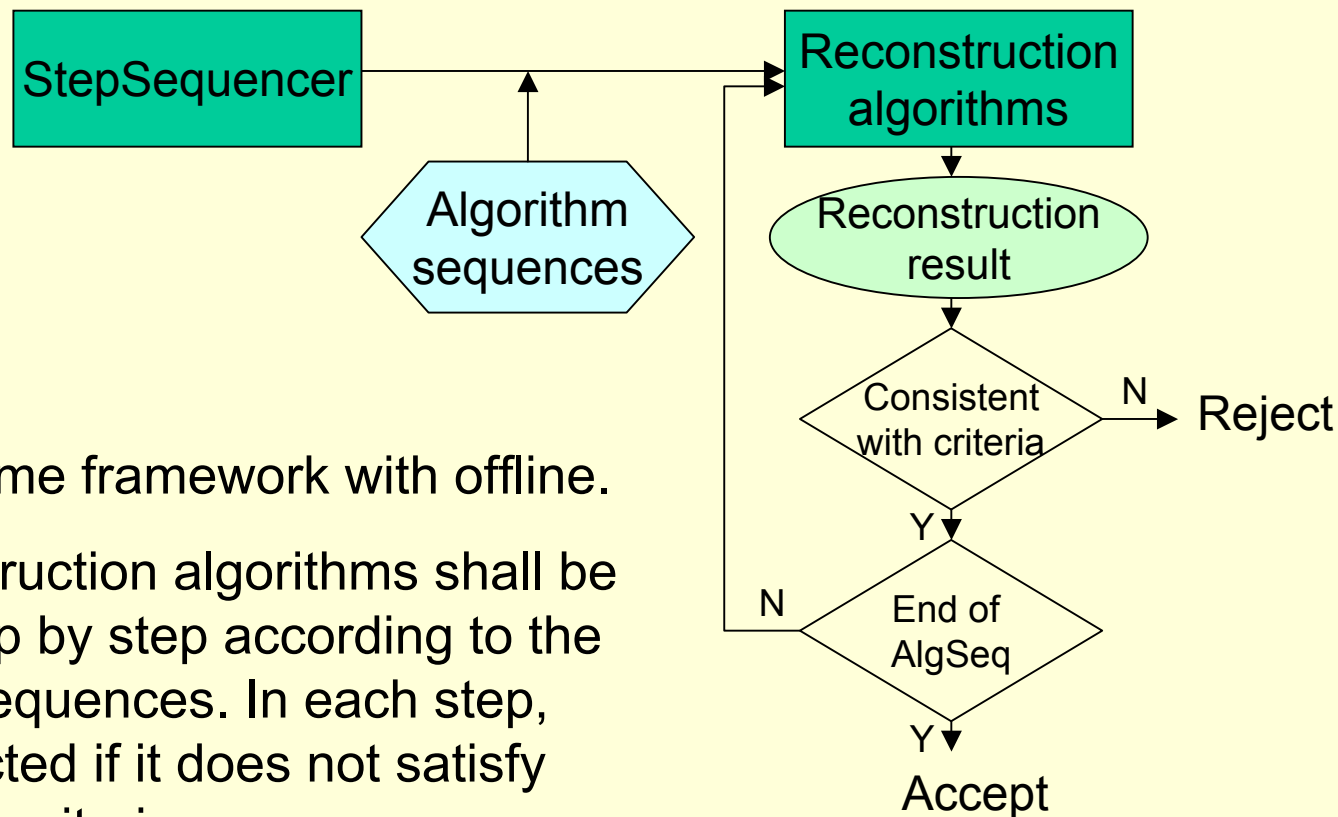
❖ Reconstruction efficiency: ~ 99% @ 1GeV

Physics Analysis Software

- ❖ Prototype software for physics analysis
 - Analysis event data model
 - Analysis event builder
 - Kinematics fitting
 - Secondary vertex finding
 - Particle identification

- ❖ Physicists already start physics studies.

Online Event Selection Software



- ❖ Share the same framework with offline.
- ❖ Fast reconstruction algorithms shall be executed step by step according to the predefined sequences. In each step, event is rejected if it does not satisfy any selection criteria.
- ❖ Fast reconstruction algorithms and steering prototypes that control event selection have been developed and tested in the online environment.

Major Releases

❖ BESIII alpha release

- integration with BOOST simulation
- Running the reconstruction chain for MDC, TOF, EMC and MUC can be achieved in the BESIII Gaudi framework.
- EDM for both Raw Data and reconstructed data developed. Completion of fully functional Event Data I/O.

Status: **published** in May, 2005

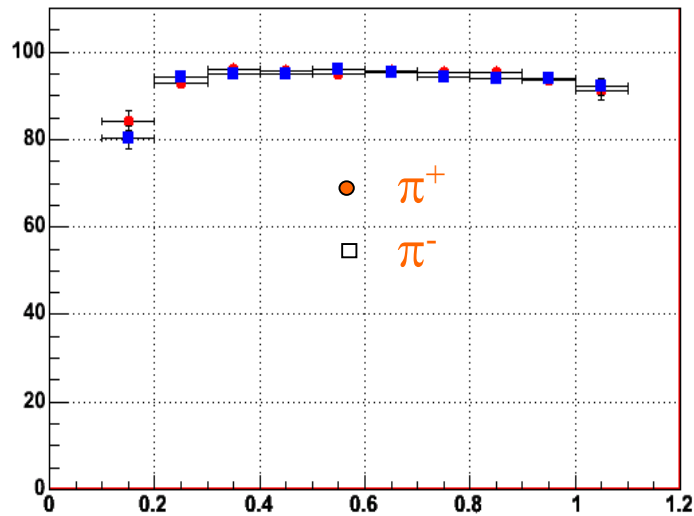
❖ BESIII beta release

- Simulation and reconstruction chain functions reasonably well and can successfully process thousands of events.
- Common physics analysis tools and utilities available.
- Physics study can start.

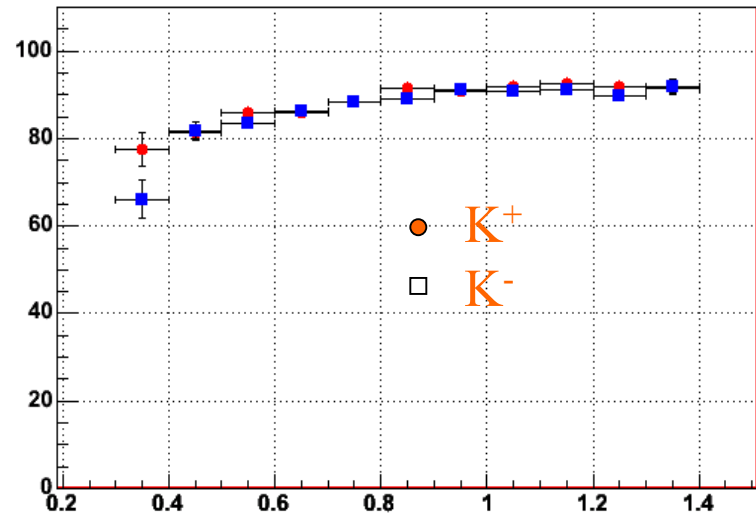
Status: **published** in November, 2005

Performance (1)

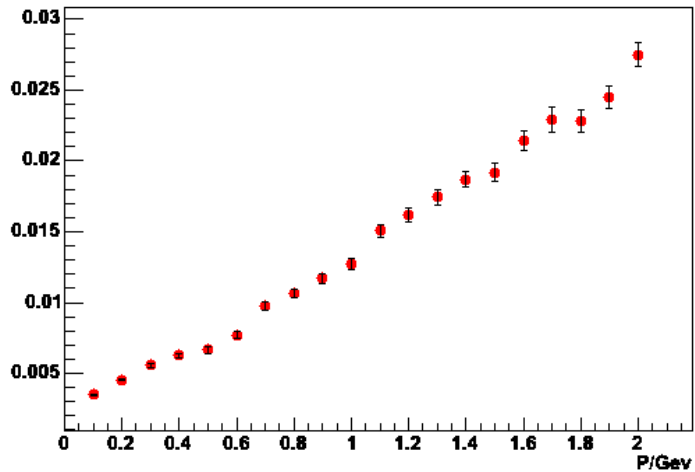
Tracking Efficiency of Pion



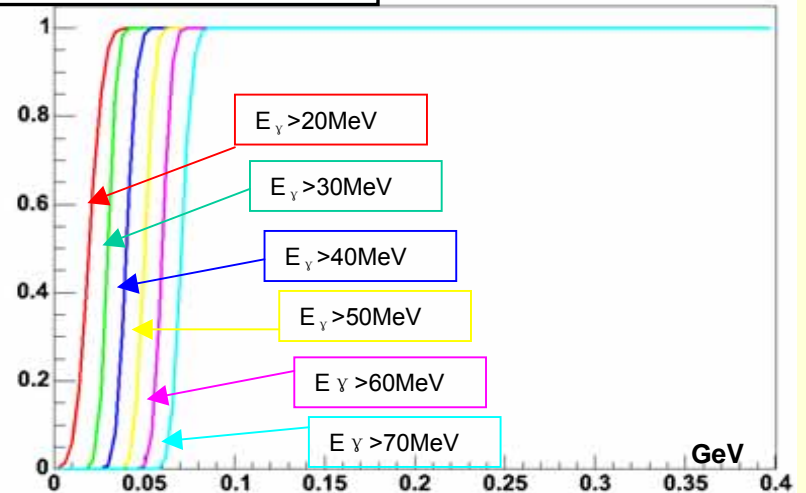
Tracking Efficiency of Kaon



Energy Resolution of Photons

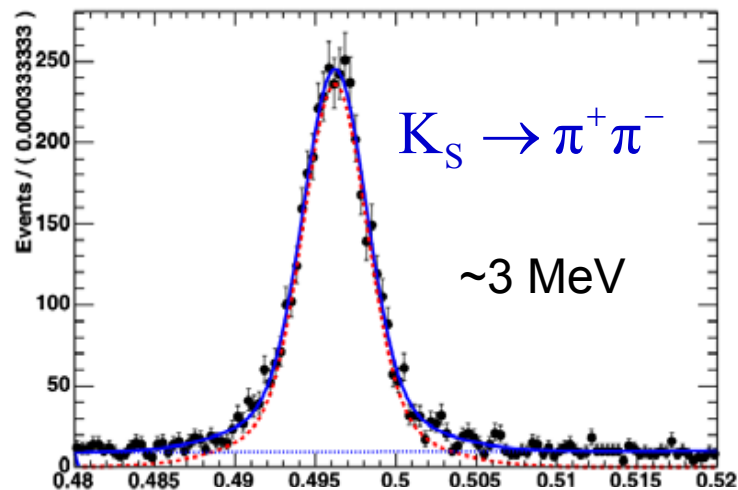


Detection Efficiency of Photons



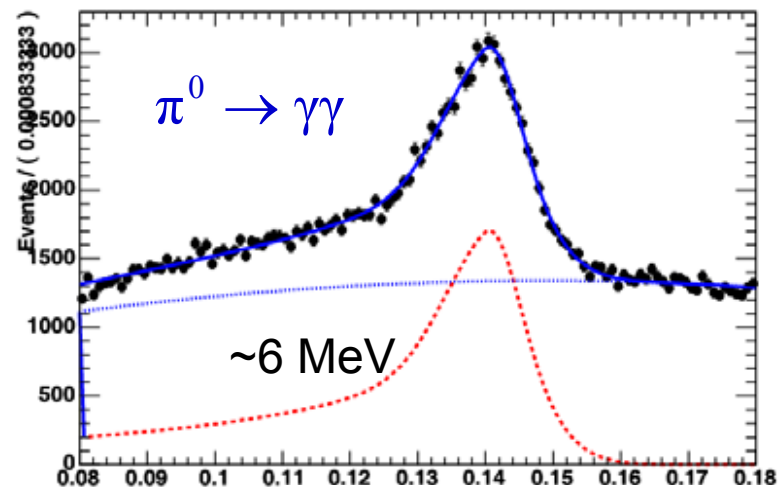
Performance (2)

A RooPlot of "Mass from psi(3770) data sample from Hek1"



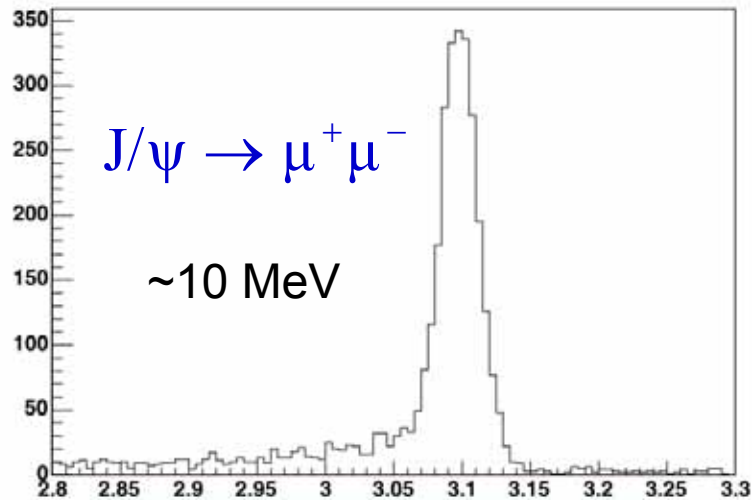
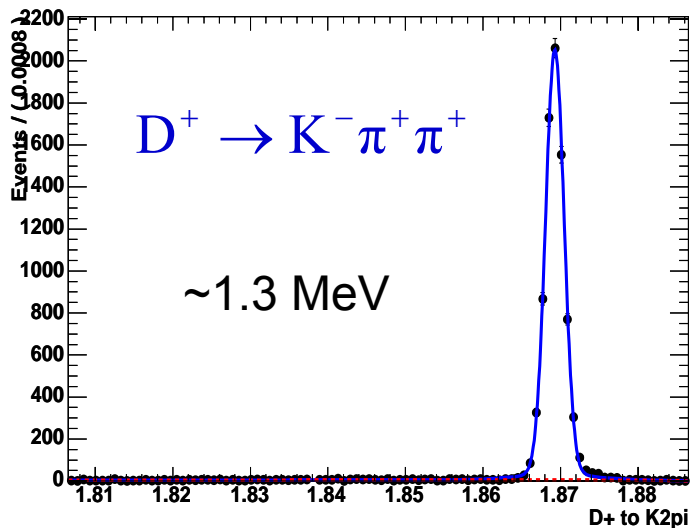
Data sample $\Psi' \rightarrow$ anything

A RooPlot of "Mass from psi(3770) data sample from Hek1"



Data sample $\Psi' \rightarrow$ anything

A RooPlot of "D+ to K2pi"

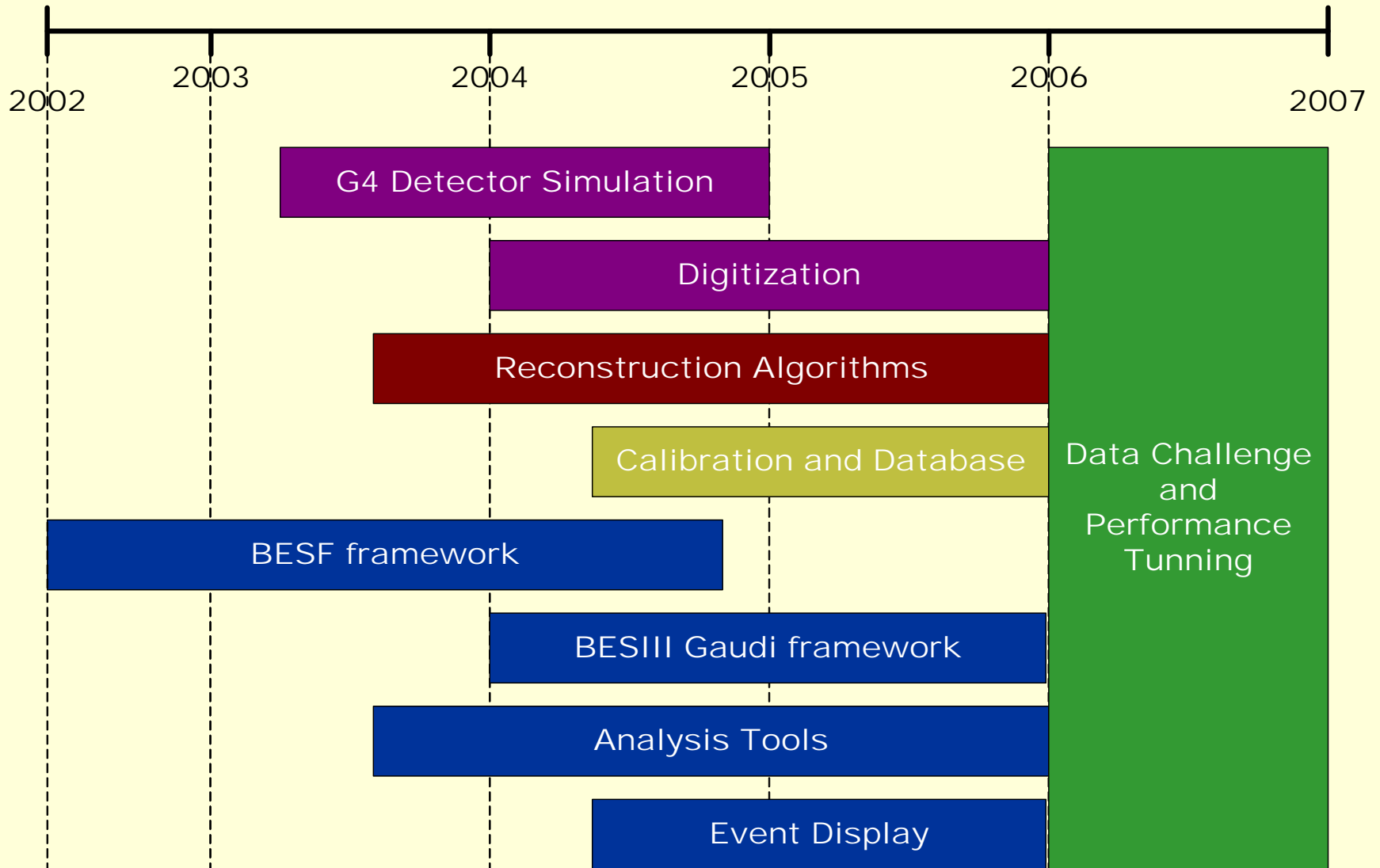


Data sample $\Psi' \rightarrow$ anything

Ongoing Activities

- ❖ Detector alignment, dead/hot channel services
- ❖ Cavern backgrounds and more realistic detector simulation
- ❖ Mixing of background events
- ❖ Migration to Gaudi v16r4/LCGCMT_35
- ❖ Analysis software will still evolve based on experience obtained from the current prototype.
- ❖ Performance studies
 - Physics: efficiency and resolution
 - System: algorithms' benchmarking and profiling, memory leakage etc.
- ❖ Performance optimization and Data Challenges

BESIII Software Timeline



Summary

- ❖ BESIII has successfully adopted GAUDI application framework.
- ❖ Based on Gaudi, the BESIII offline software was developed
 - Simulation
 - Calibration and reconstruction
 - Physics analysis
- ❖ Data challenge and software performance optimization are the major task for 2006.

Thank you !