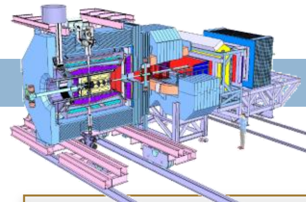
THE SIMULATION- AND ANALYSIS-FRAMEWORK FAIRROOT

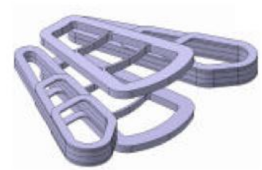
CHEP 2012, New York

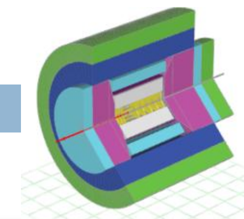
Outline

- History
- Features
- New and Recent Projects
- Time Based Simulation
- Example
- Summary and Outlook

FairRoot: timeline







Start testing the VMC concept for CBM

Panda decided to join-> FairRoot: same Base package for different experiments

R3B joined

EIC (Electron Ion Collider BNL) EICRoot

2004

2006

2010

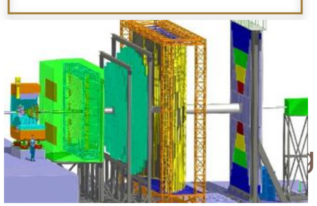
2011

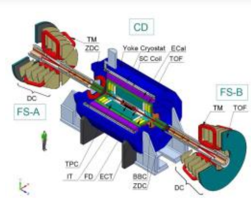
First Release of CbmRoot

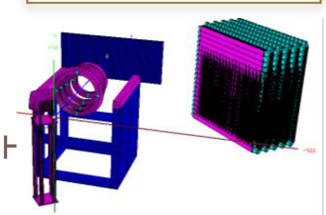
MPD (NICA) start also using FairRoot

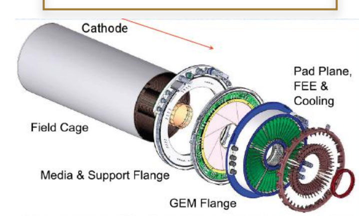
ASYEOS joined (ASYEOSRoot)

GEM-TPC separated from PANDA branch (FOPIRoot)









Developer Team

Core Team:

Mohammad Al-Turany	GSI-IT	2003
Denis Bertini	GSI-IT	2003
Florian Uhlig	CBM/IT	2006
Radek Karabowicz	PANDA/IT	2008
Dmytro Kresan	R3B/IT	2011
Tobias Stockmanns	PANDA	

long list of people who have contributed pieces of code to FairRoot since the project started end of 2003

People participated major features:

Ilse König	HADES
Volker Friese	CBM

FairRoot

- Framework for simulation, reconstruction and data analysis
- Very flexible
  - No executable
    - Use plug-in mechanism from Root to load libraries only when needed
    - Use Root macros to define the experimental setup or the tasks for reconstruction/analysis
    - Use Root macros to set the configuration (Geant3, Geant4, …)
  - No fixed simulation model
    - Use different simulation models (Geant3, Geant4, …) with the same user code (VMC)

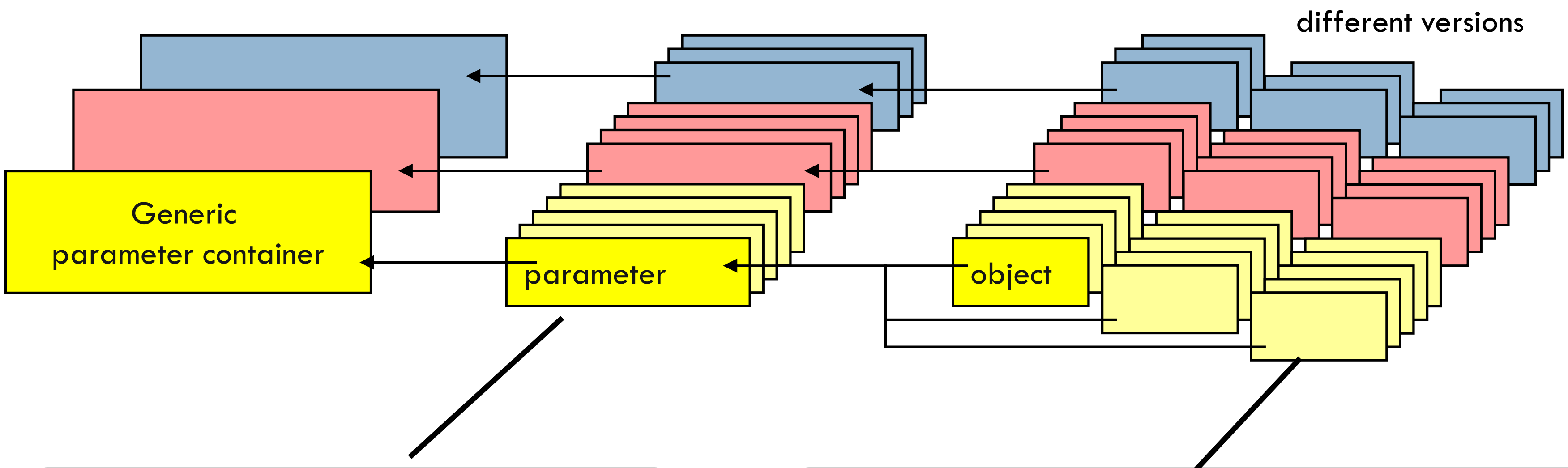
FairRoot cont.

- Very flexible
  - No fixed navigation engine / geometry management
    - Use Root TGeoManager for geometry management
      - Geometry can be defined using different input formats
        - ASCII files in format inherited from HADES
        - Root files
        - Defined directly in the source code
      - Use TEve as base for general event display
    - Geometry is described once. Then it can be converted (VGM) to choose between different MC's and different navigations
      - G4 native geometry and navigation
      - G4 native geometry and Root
      - …

FairRoot cont.

- Very flexible
  - No fixed output structure
    - Use a dynamic event structure based on Root TFolder and TTree which is created automatically
      - Depend on registered data classes
    - Data output possible after each step
    - Simulation and reconstruction can be done in one go or in several steps
  - Use runtime data base
    - Developed for the HADES experiment
    - Decouple parameter handling in FairRoot from parameter storage
    - runtime data base IO to/from
      - ASCII files
      - Root files
      - Database

Parameter IO

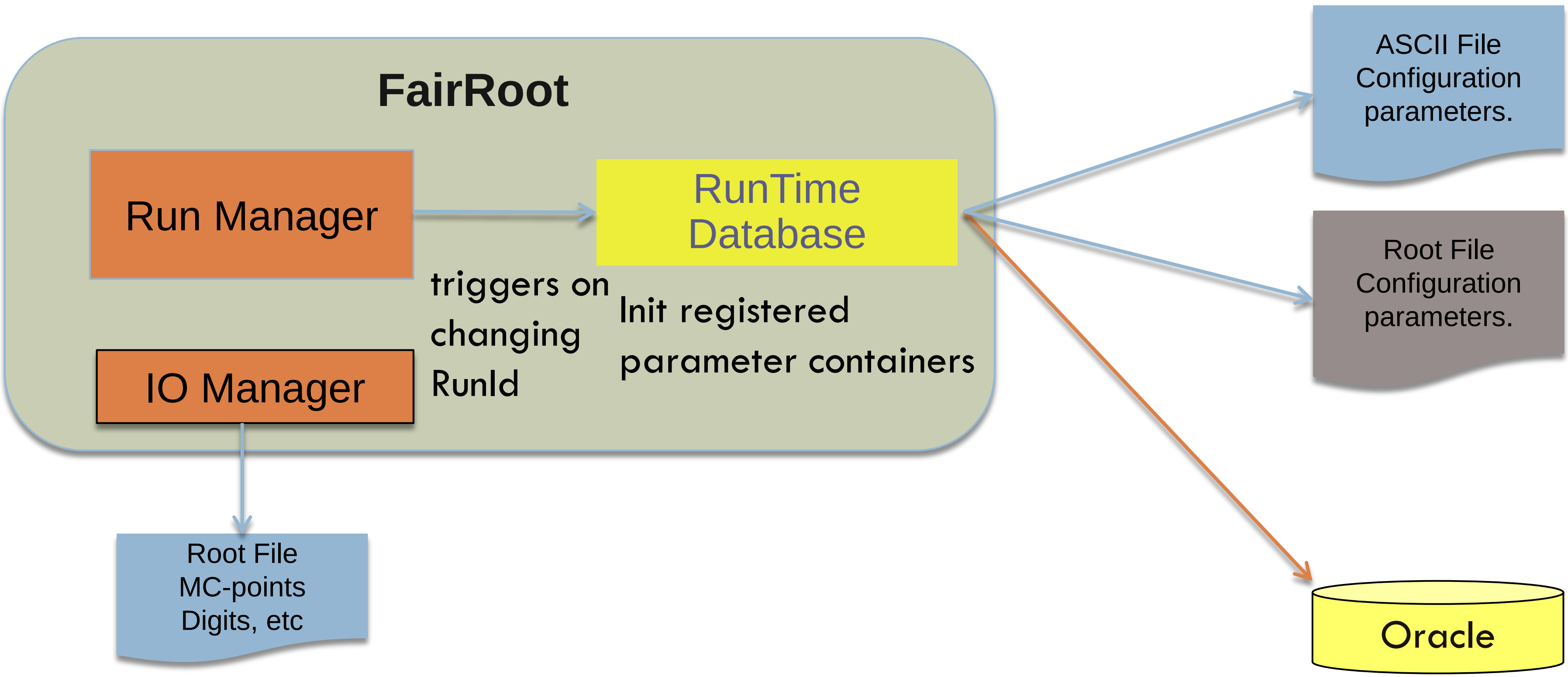


name
type: Int_t, Float_t, Double_t, Char_t, Text_t, UChar_t, class type
value(s)

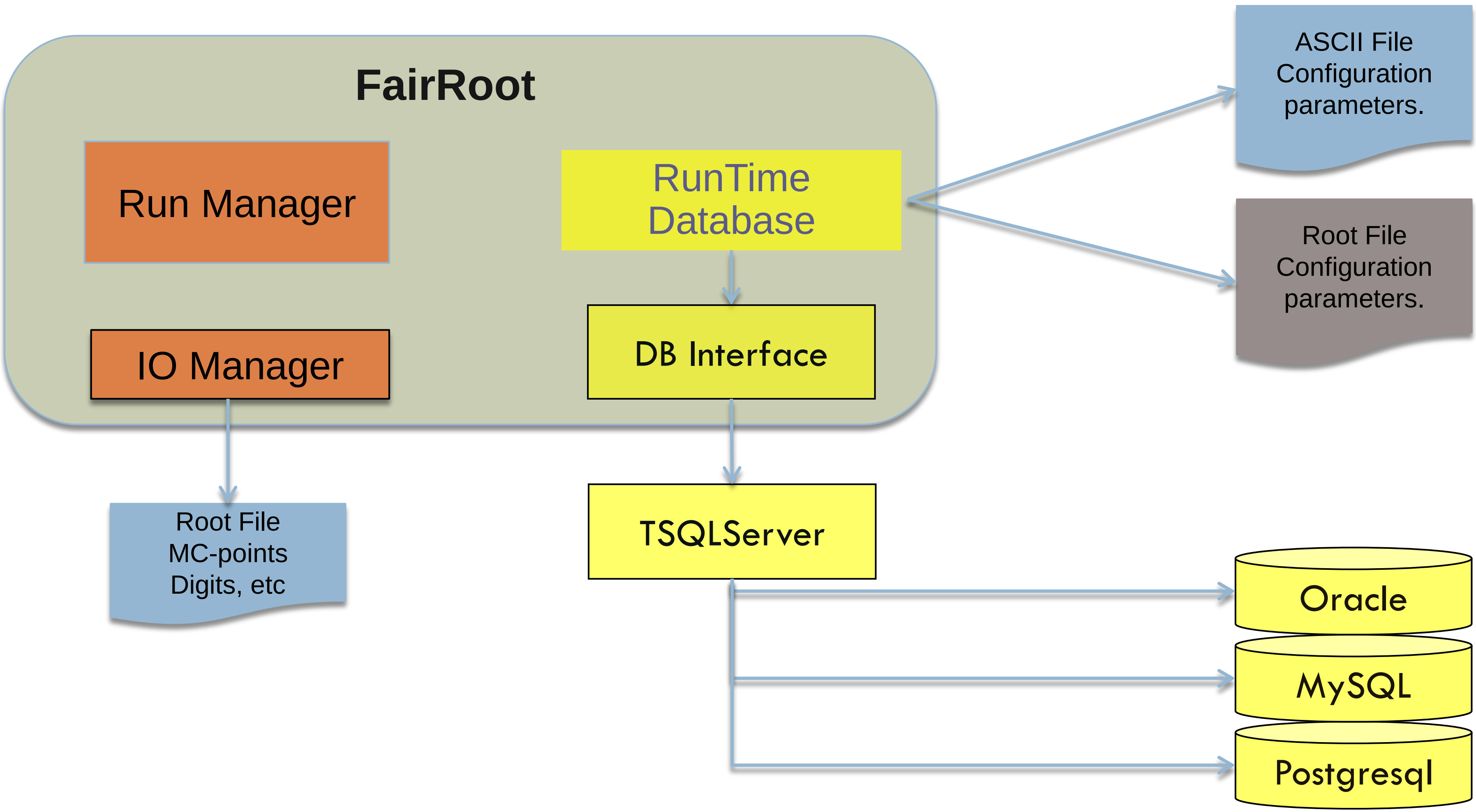
any class derived from TObject
decoded in the analysis interface by
ROOT streamer

stored as byte array (RAW or BLOB)
number of values (single value or array)
class version
streamer info, root version for ROOT classes
own version management

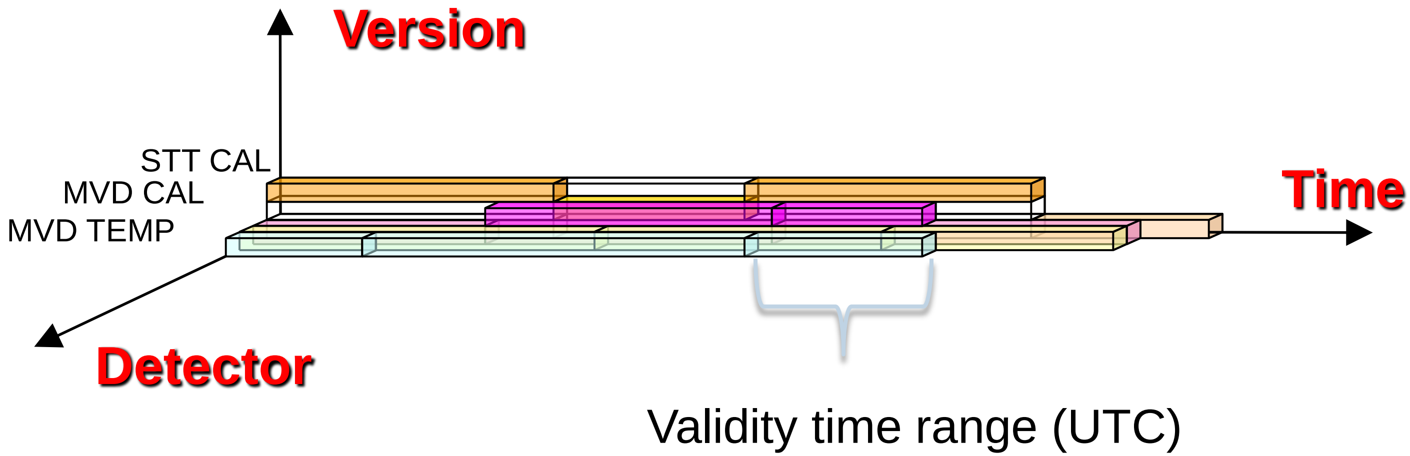
FairRoot DB


FairRoot
Run Manager
RunTime Database
IO Manager
triggers on changing RunId
Init registered parameter containers
ASCII File Configuration parameters.
Root File Configuration parameters.
Oracle
Root File MC-points Digits, etc

FairRoot DB extended



Version management



The Query process

1. Context (Timestamp,Detector,Version) is the primary key
2. Context converted to unique SeqNo
3. SeqNo used as keys to access all rows in main table
4. System gives user access of all such rows

Proof in FairRoot

- PROOF - Parallel ROOt Facility.
- It allows parallel processing of large amount of data. The output results can be directly visualized (e.g. the output histogram can be drawn at the end of the proof session).
- The data which you process with PROOF can reside on your computer, PROOF cluster disks or grid.
- The usage of PROOF is transparent: you use the same code you are running locally on your computer.
- No special installation of PROOF software is necessary to execute your code: PROOF is included in ROOT distribution.
- Proof runs on computing clusters as well as on your local many core computer

Trivial parallelism

Sequential processing

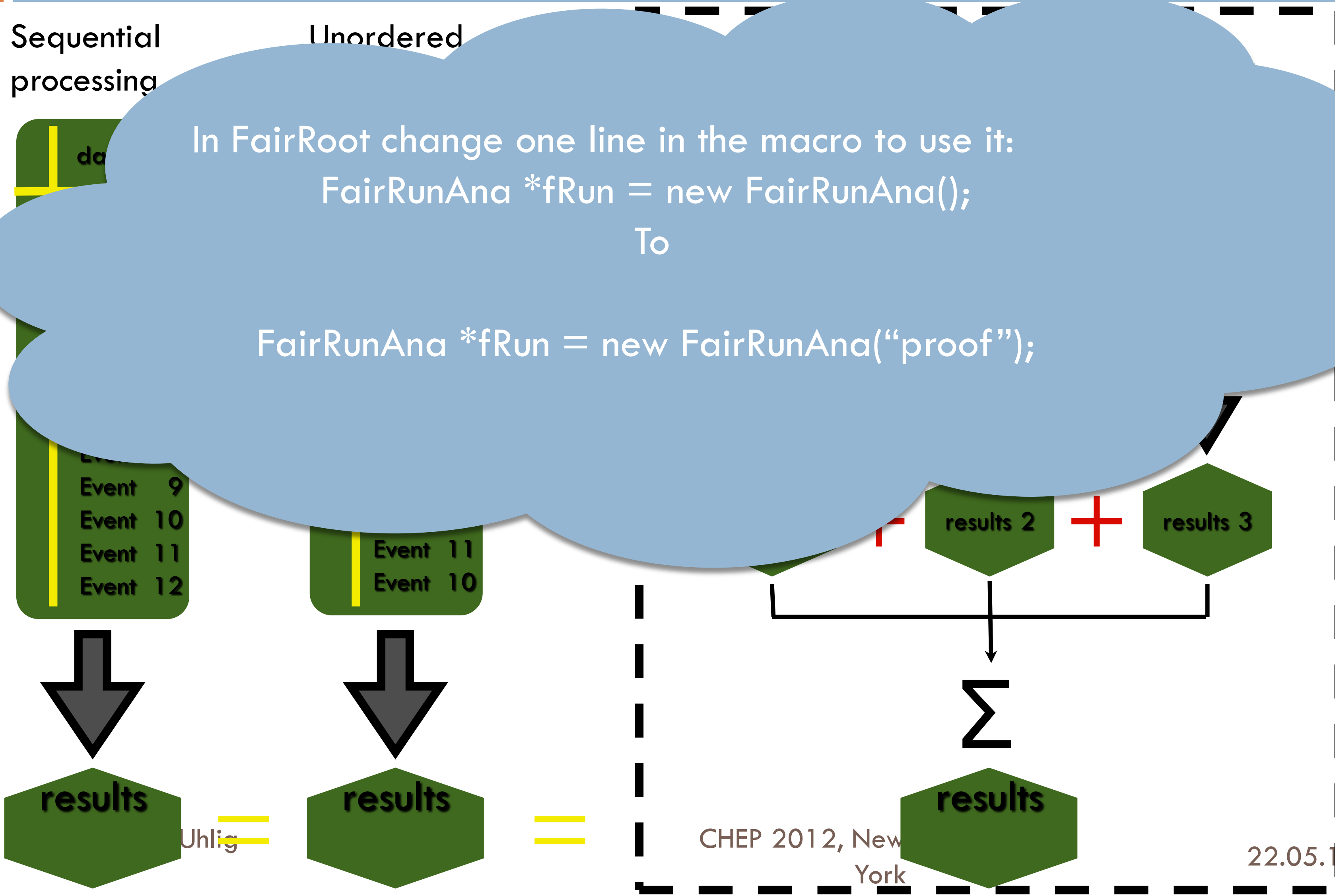
Unordered

In FairRoot change one line in the macro to use it:

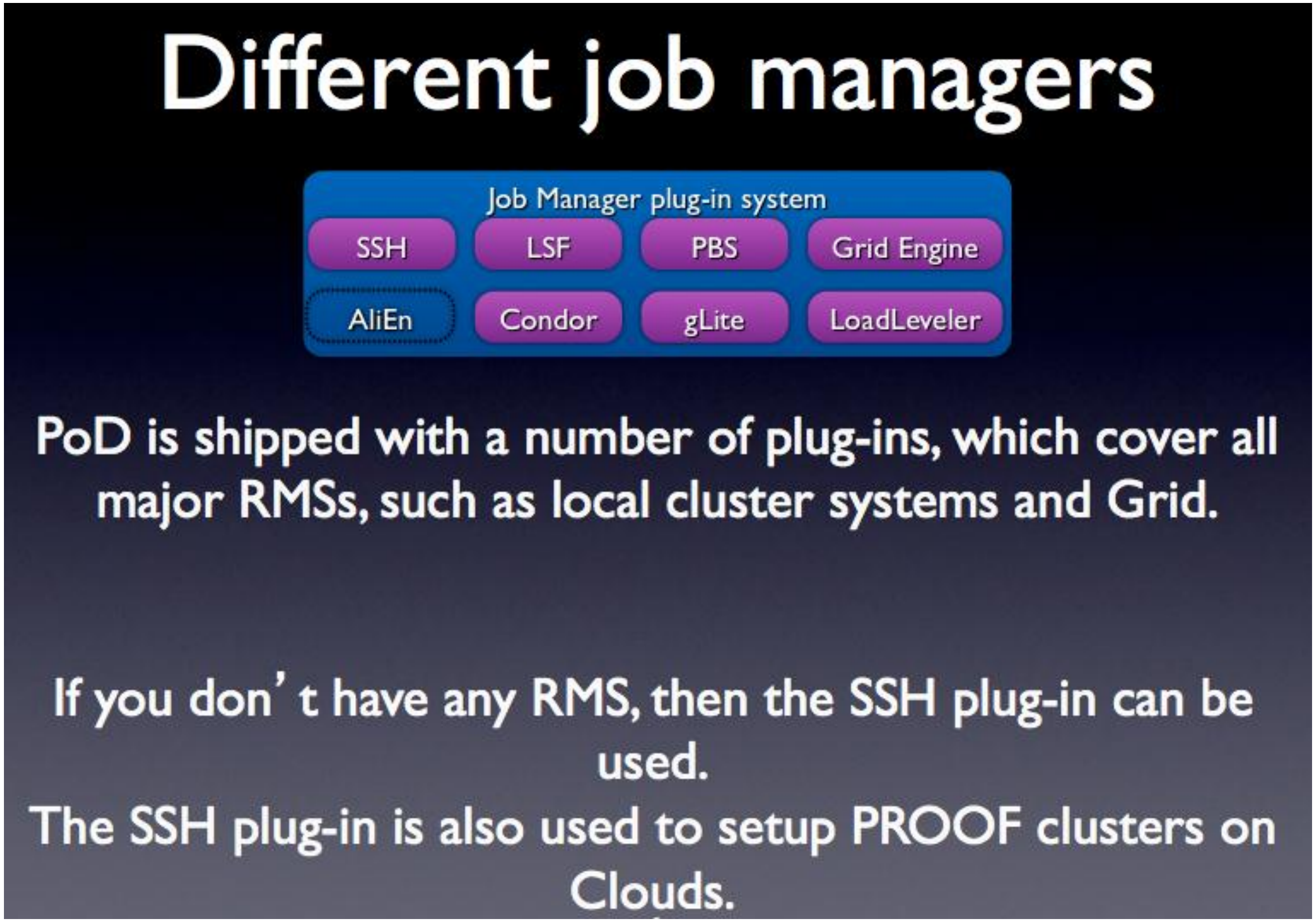
FairRunAna *fRun = new FairRunAna();

To

FairRunAna *fRun = new FairRunAna("proof");



Proof on Demand

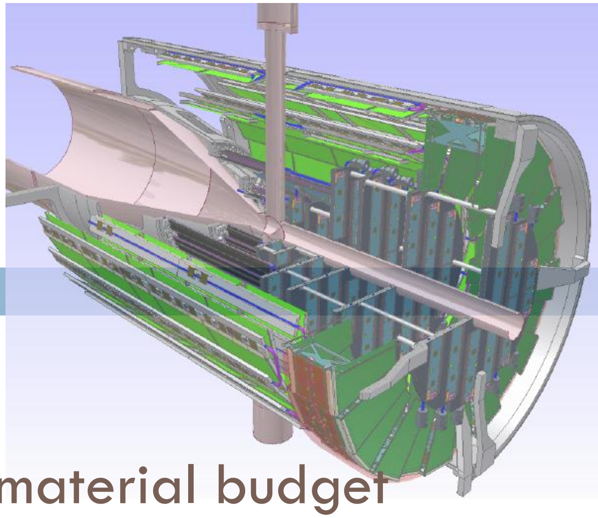


PoD: Anar Manafov, GSI ([22] 21/05; [21] Postersession 1)

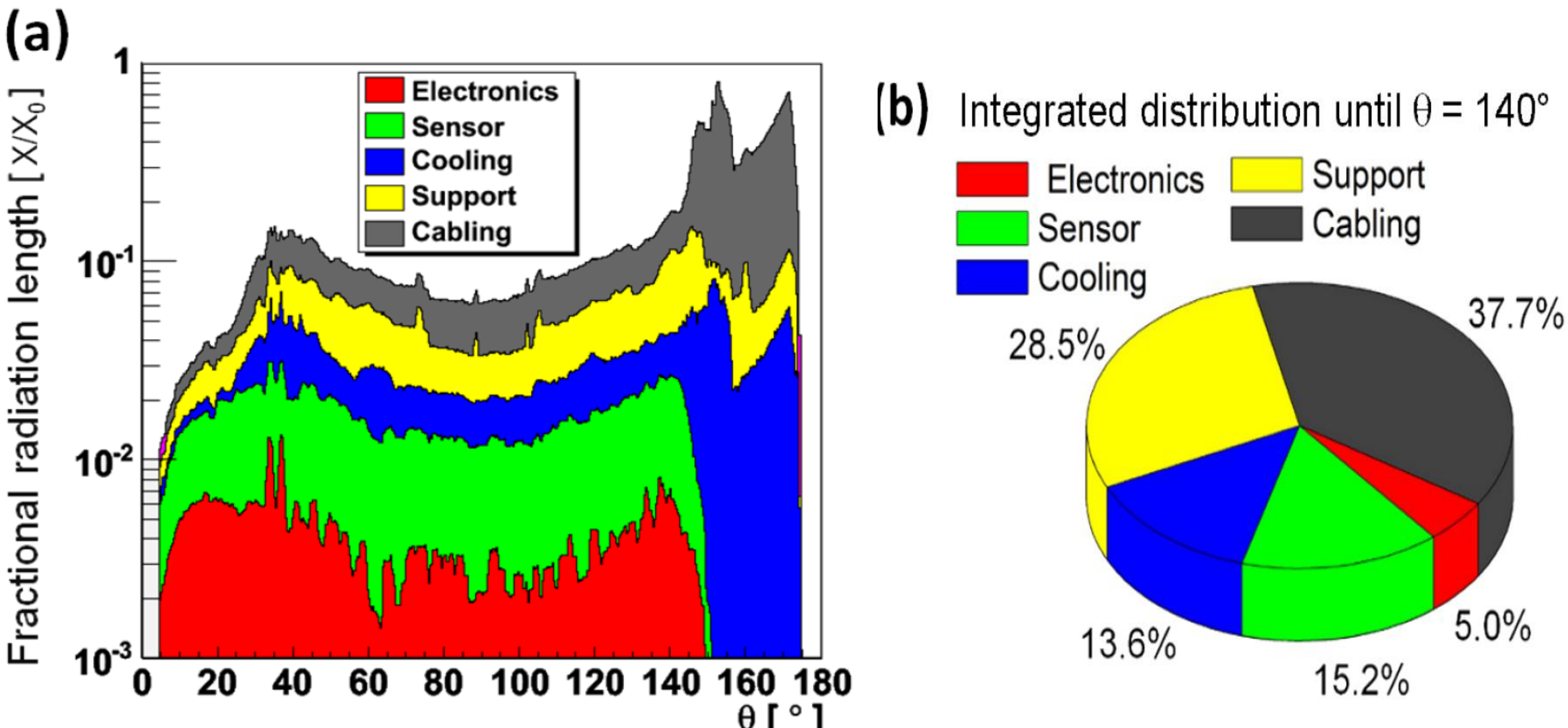
GPU support in FairRoot

- CUDA is fully integrated into the FairRoot build system
- CMake creates shared libraries for cuda part
- FairCuda is a class which wraps CUDA implemented functions so that they can be used directly from ROOT CINT or compiled code
- See talk of Mohammad Al-Turany
  - [353] 24/05, 5.25PM, Room 905/907

Radiation length info FairRadLenManager

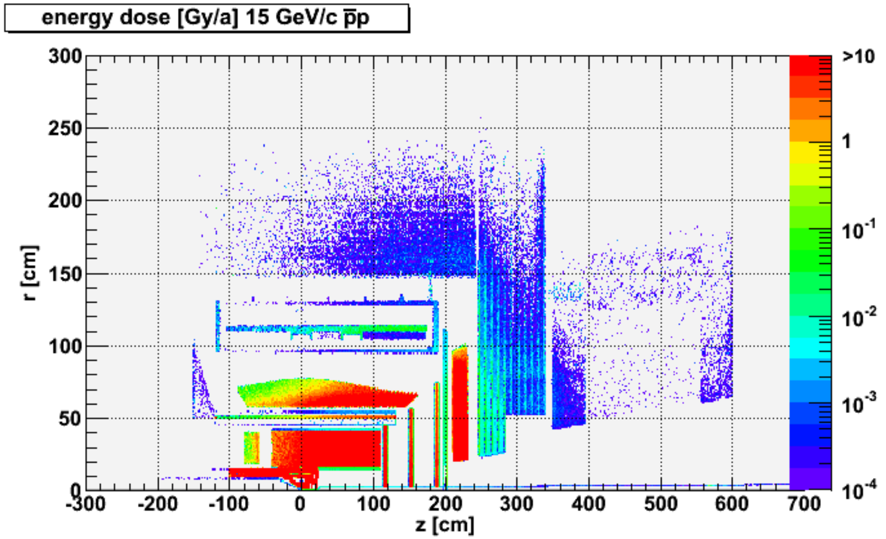


Example: Contributions of different
Functional parts of the PANDA MVD to the overall material budget



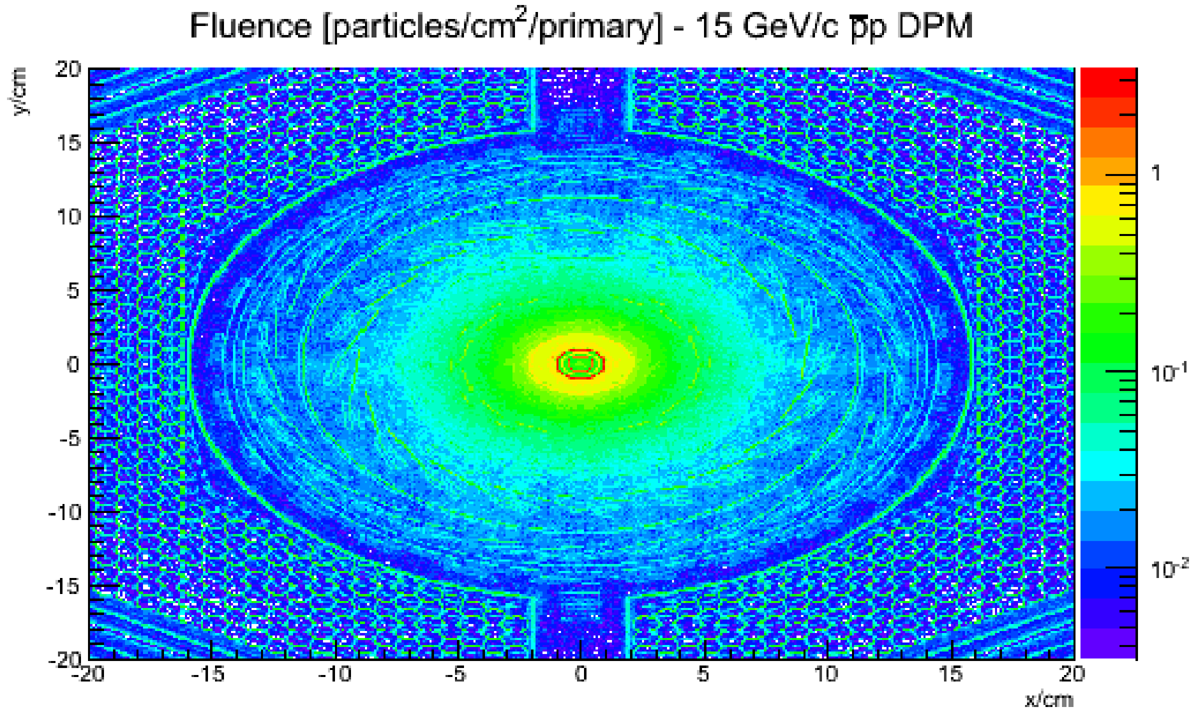
Dose studies FairRadMapManager

- What energy dose will be accumulated during a certain time of operation?
- Create all physical volumes with correct material assignment
- Run the simulation engine
- FairRadMapManager will sum up every deposited energy in each volume in the geometry



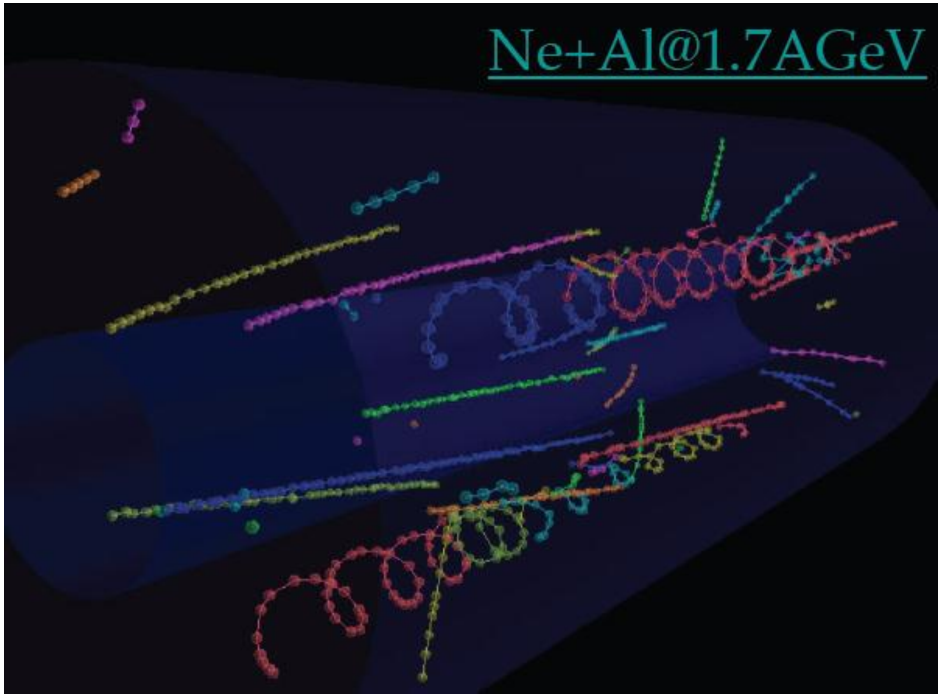
Dose studies FairRadGridManager

Determine the particle fluency through a certain boundary (surface) and deduce a map. Knowing the volume and density of the object of interest and the specific energy loss doses can be estimated



FairRoot for real data

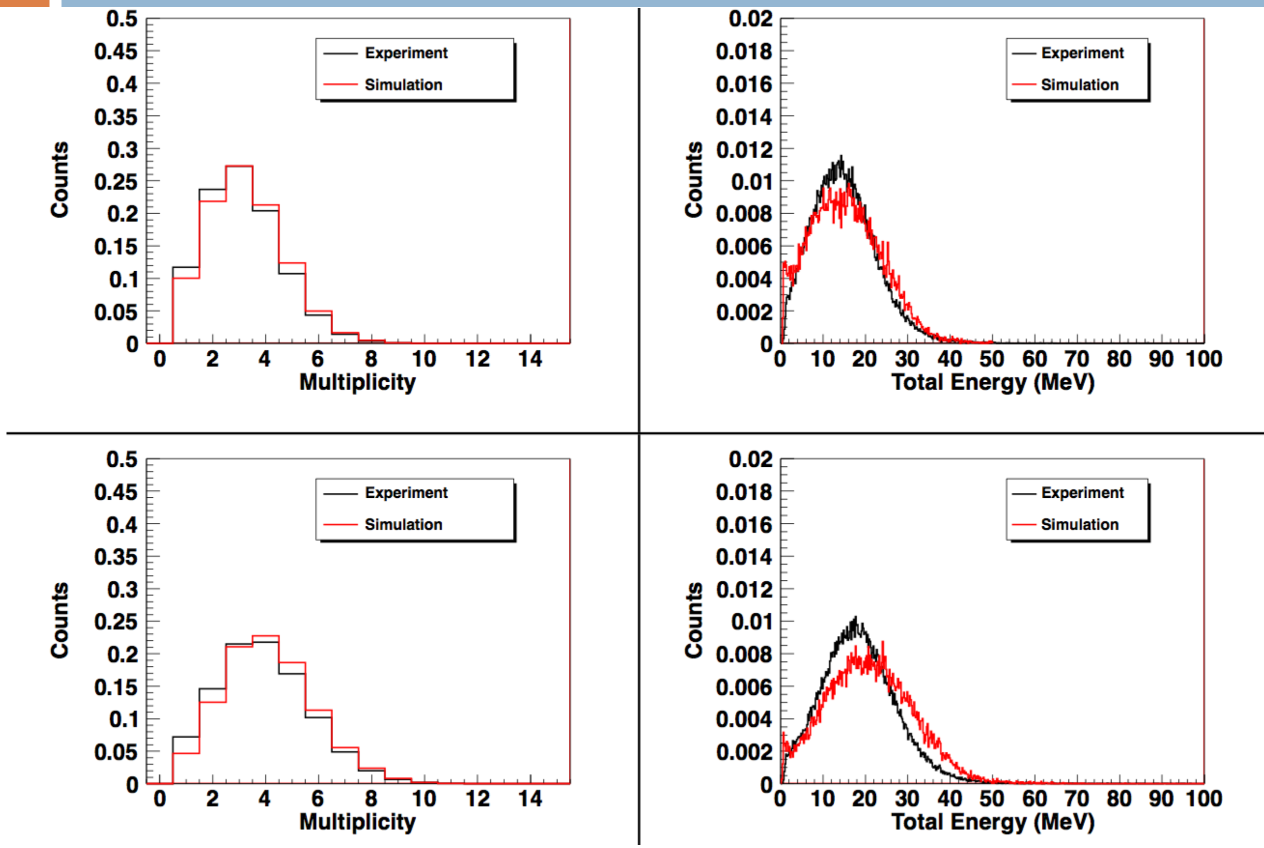
- FairRoot was designed from the beginning to combine simulation and analysis in one tool.
- Using the same internal structure the user can compare easily at any time/level the real data with the simulation

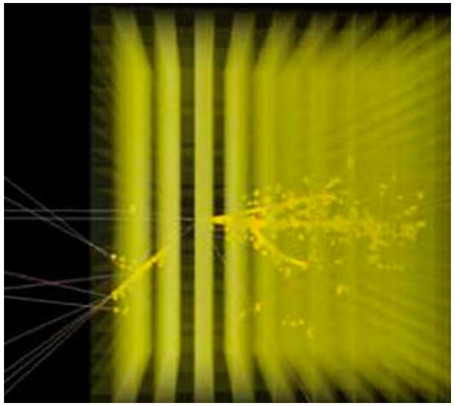


Reconstructed Beam EVENT

The large GEM-TPC Prototype
L. Fabbietti for the GEM-TPC Collaboration

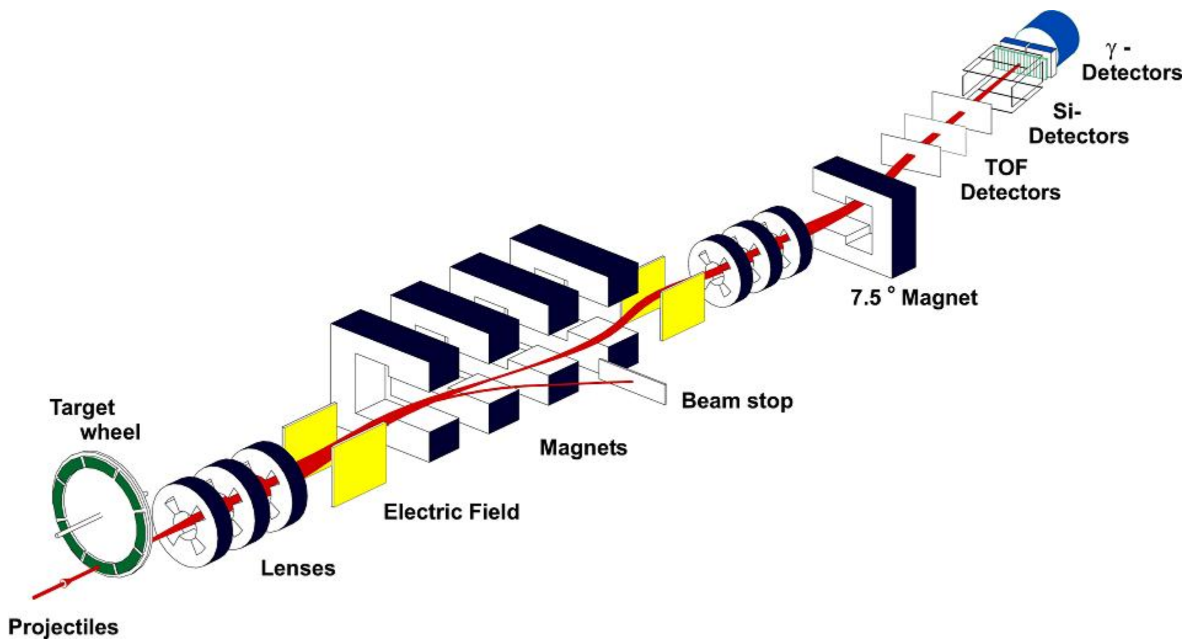
NeuLAND: The High Resolution Neutron Time-of-Flight Spectrometer for R3B





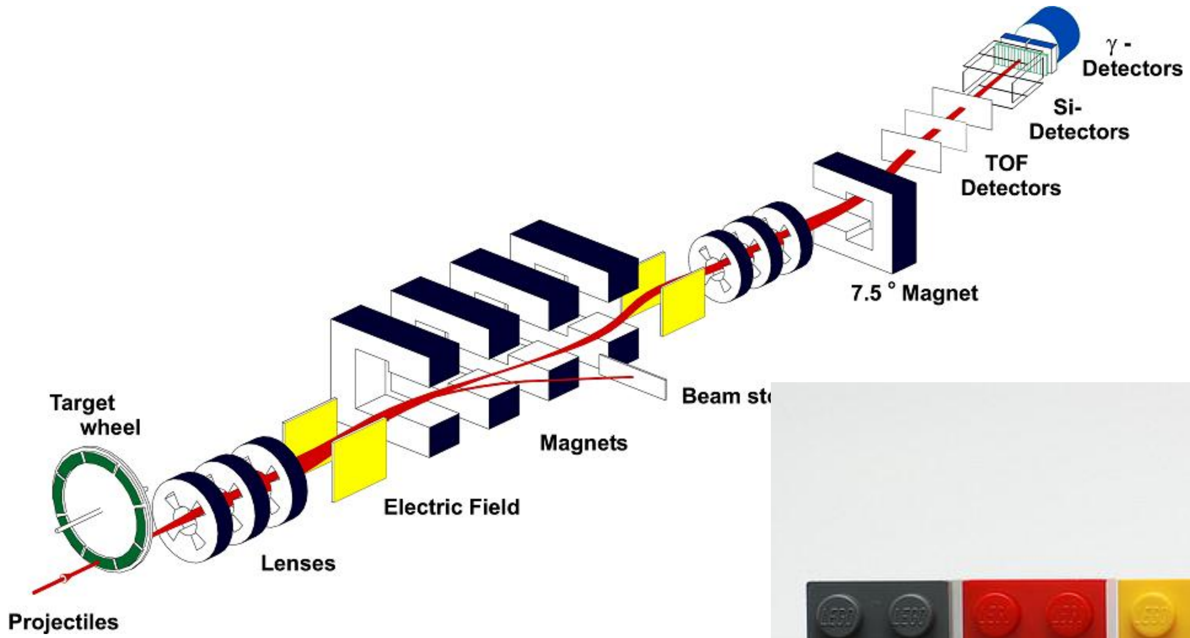
Comparison of LAND response to neutrons from 170 to 1050 MeV from experiment (black lines) and from R3BRoot simulations (red lines).

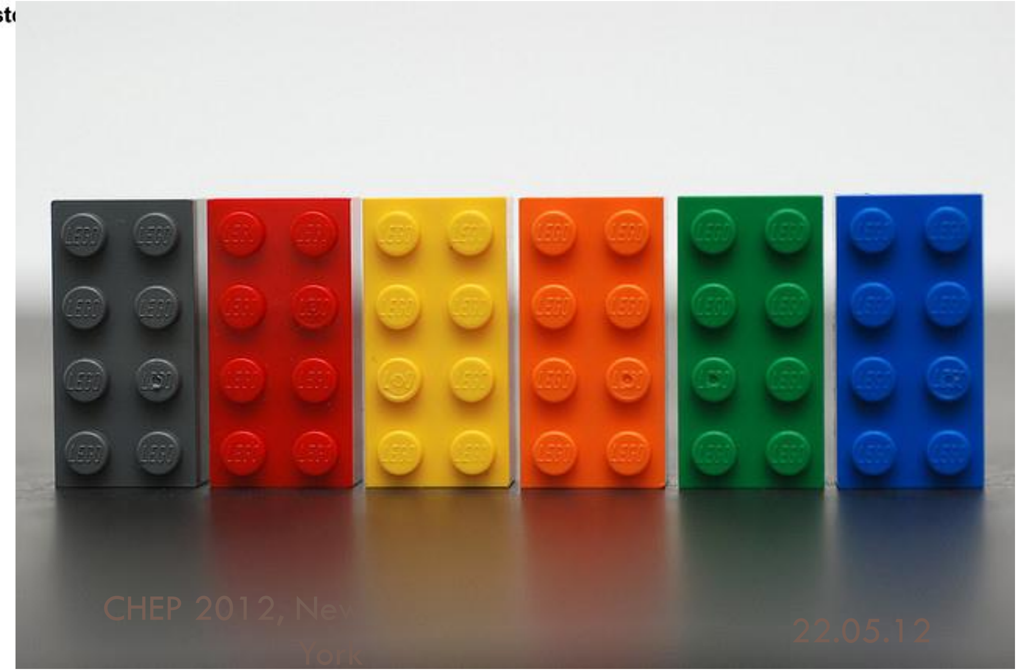
Triggered Experiment



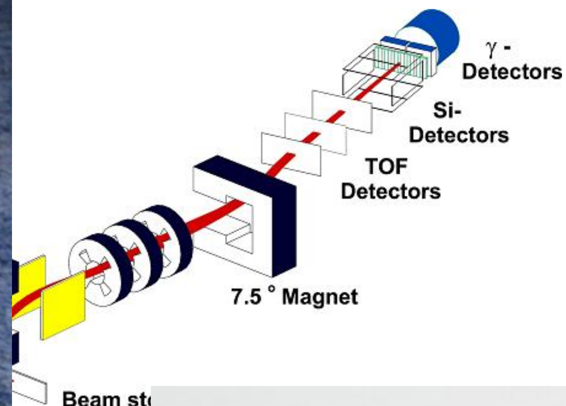
- Use SHIP (Separator for Heavy Ion reaction products) as example
- If particle enters detector region the data tacking is triggered
- When DAQ reads out the detectors everything belongs to this event

Triggered Experiment

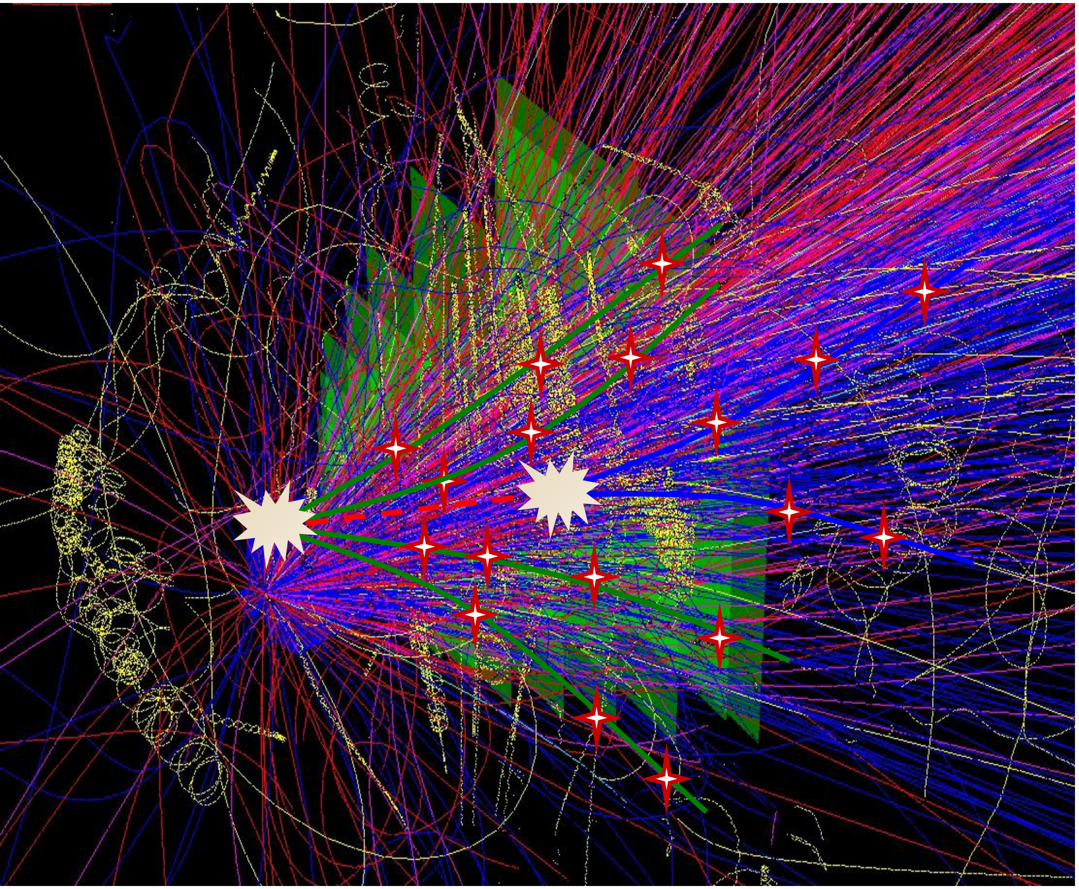




Triggered Experiment

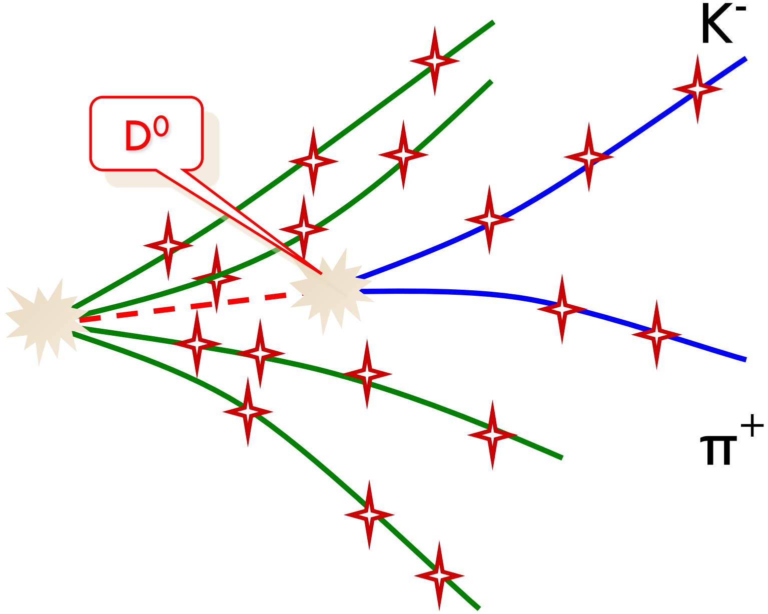


The Challenge



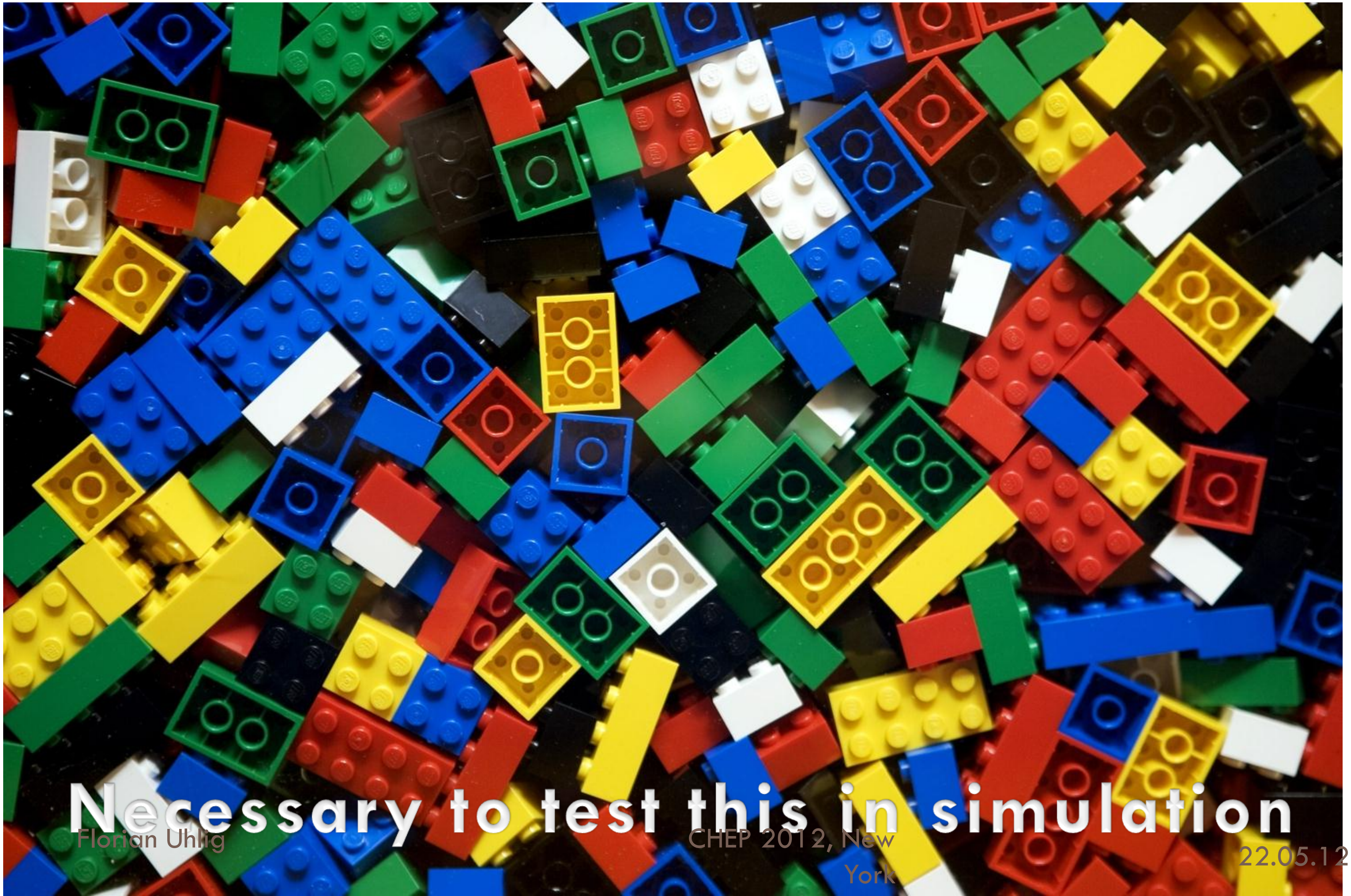
- Central events have up to 1000 charged particles inside acceptance
- Looking for rare probes require events rates up to 10^7 per second
- Complicated trigger signature
- Searching for secondary vertex requires reconstruction of a large part of the event

The Challenge

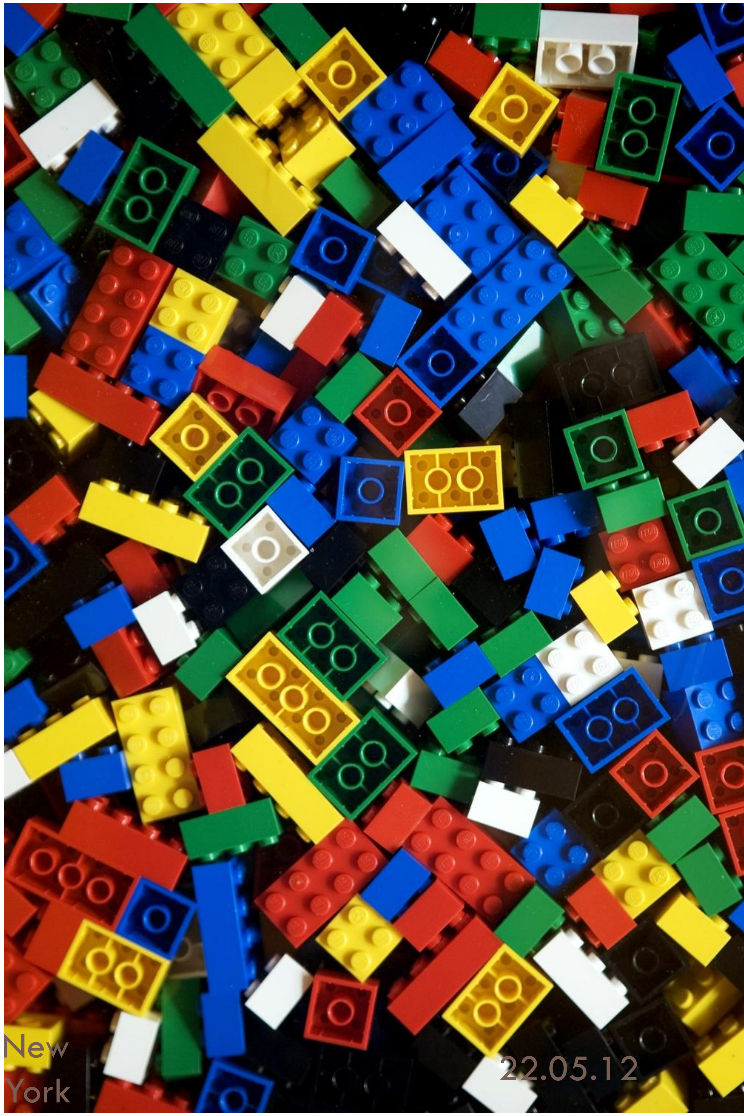


- Central events have up to 1000 charged particles inside acceptance
- Looking for rare probes require events rates up to 10^7 per second
- Complicated trigger signature
- Searching for secondary vertex requires reconstruction of a large part of the event
- Conventional hardware trigger not feasible: no dead time allowed
- Self-triggered autonomous front-ends pushing time-stamped data forwards to DAQ

The Challenge

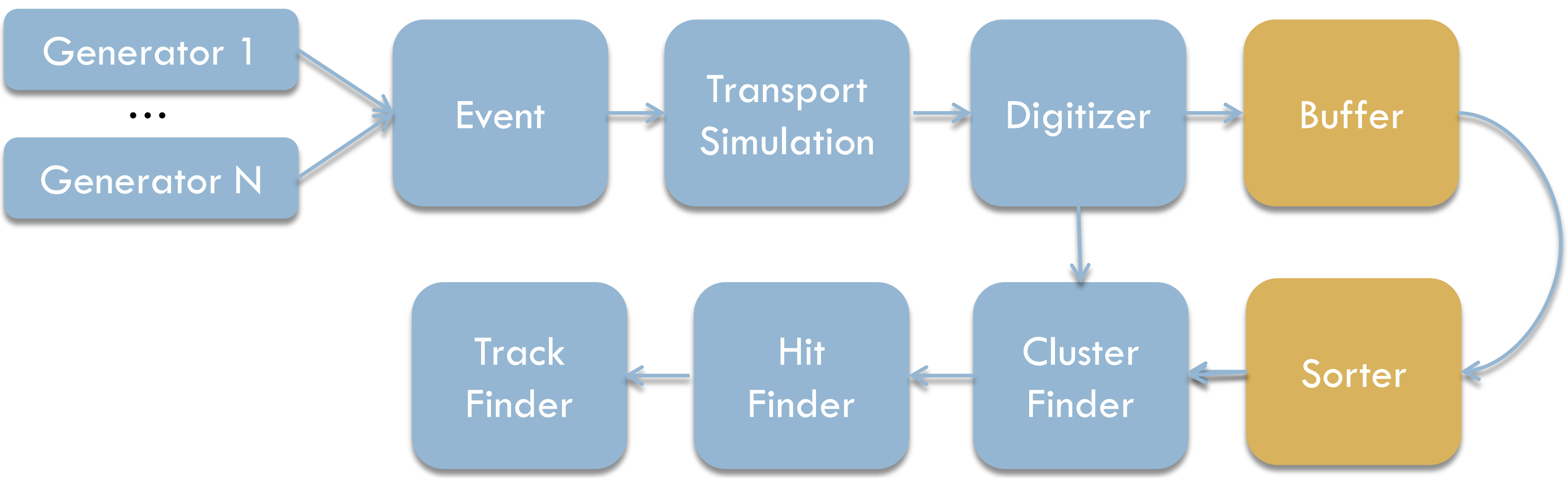


Task for FairRoot

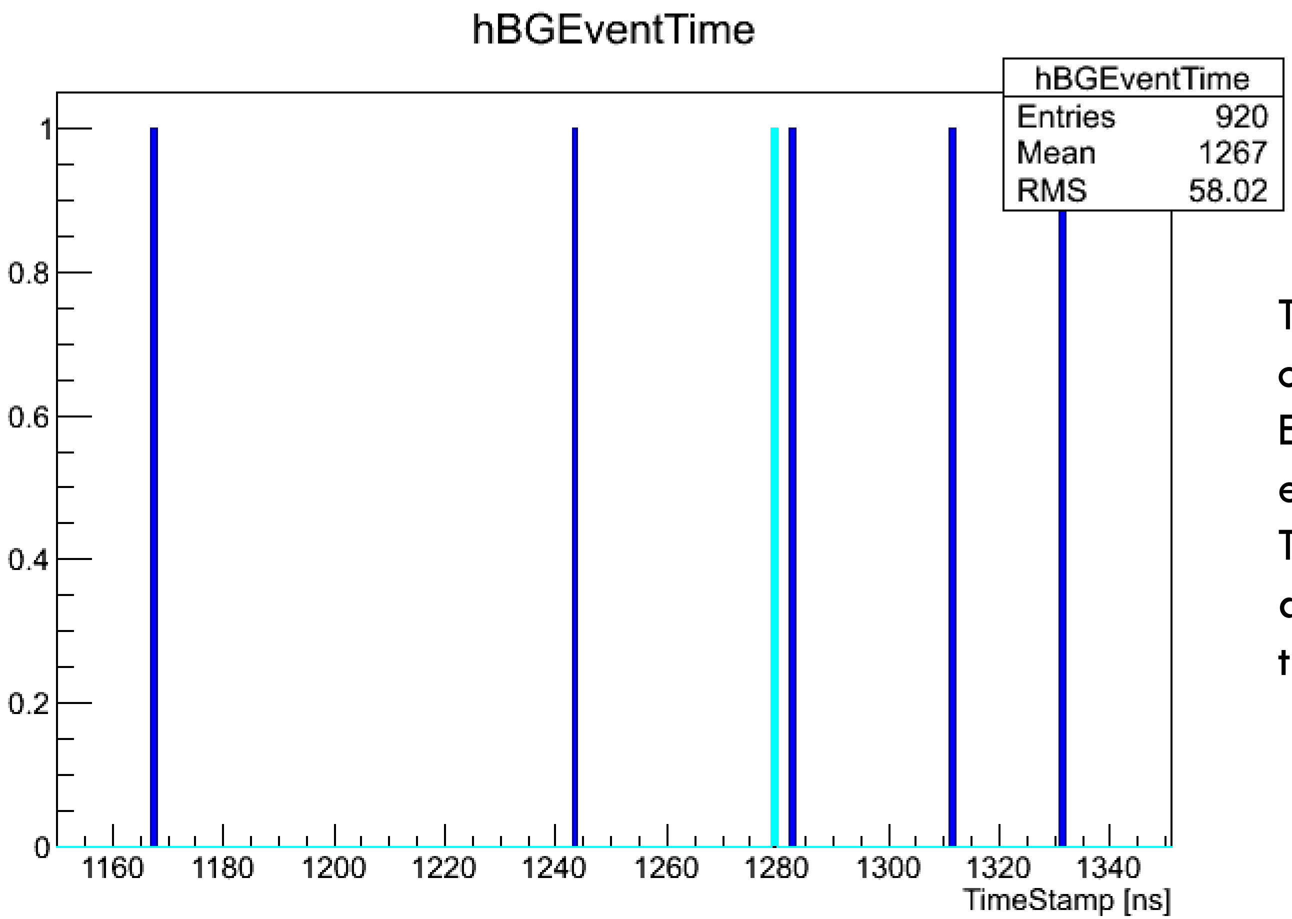


Time based simulation

- Provide functionality for the tasks "event mixing" in the digitization stage and "time sorting" in the reconstruction stage



Event Time



The absolute event time is calculated by the framework

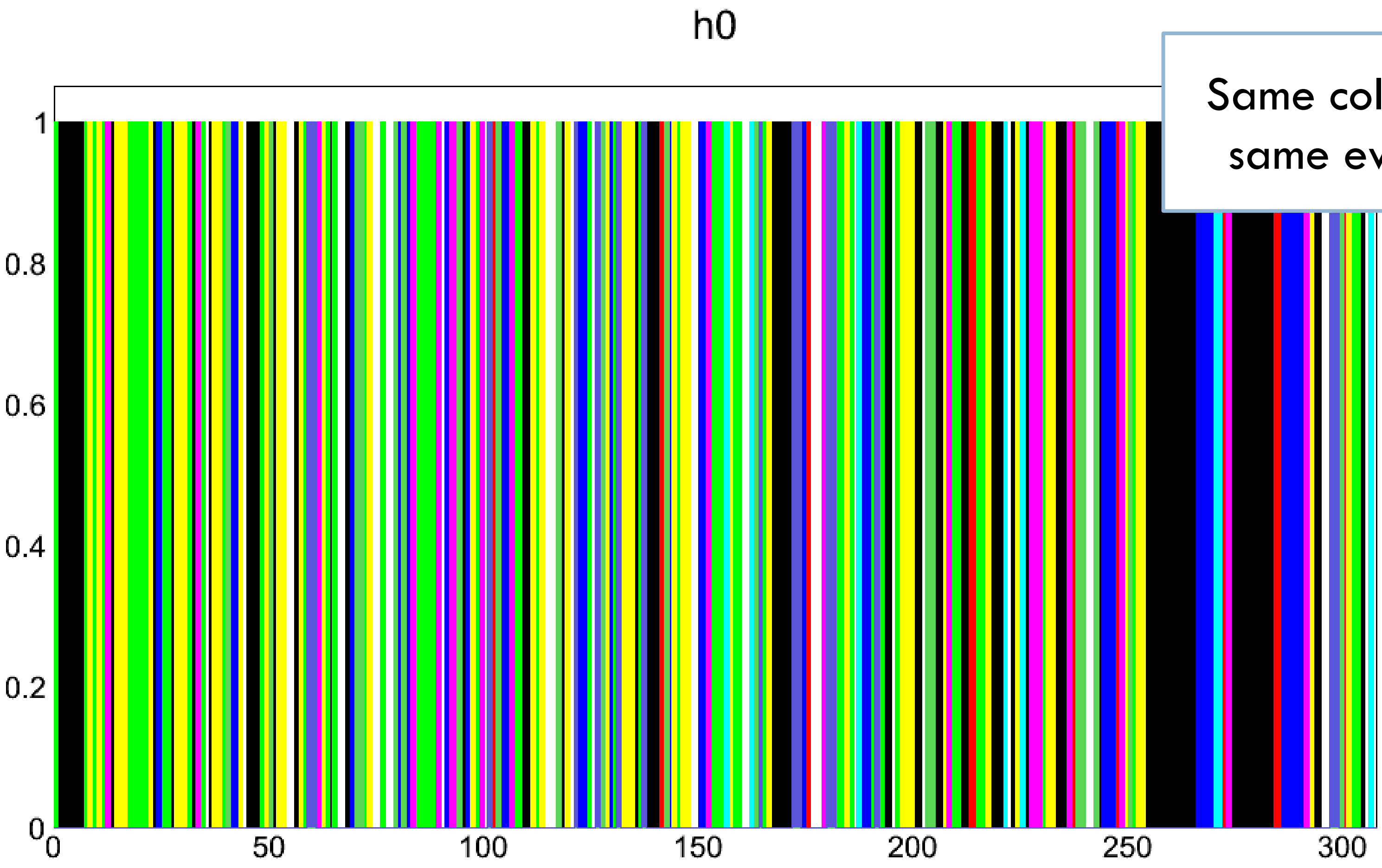
Experiments define functions for event time calculation

Time of detector digi is this absolute time + the time inside the MC event

FairWriteoutBuffer

- Base class to store detector data (digis) between events
- Buffer stores data together with absolute time until this data is active and can be influenced by later events
  - This time is detector dependent and is defined individually
- If the same detector element is hit at a later time the data can be/is modified
  - Modifications are detector and electronics dependent
- Result is a randomized data stream which is stored in a TClonesArray which would be the input to the DAQ

Randomized Digi Data

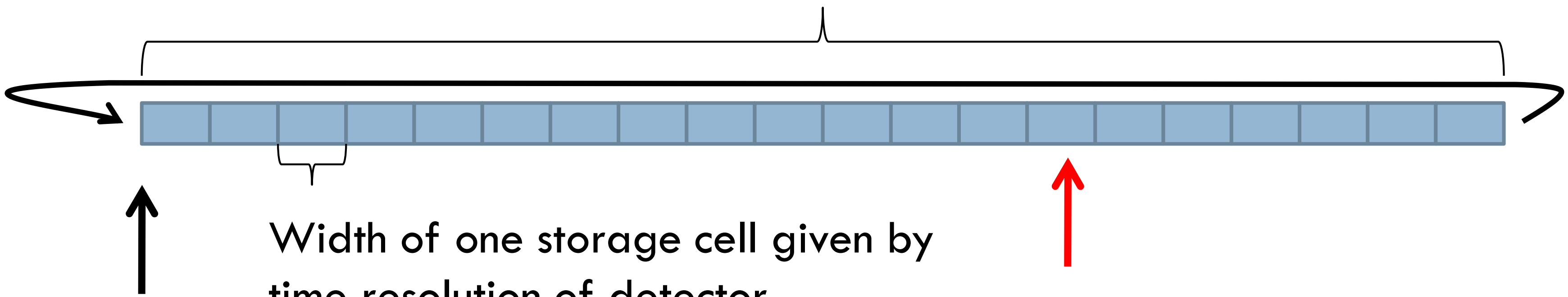


Same color = same event

Array index

Sorter – Technical Implementation

Number of storage cells given by the spread of the time stamps within the data stream



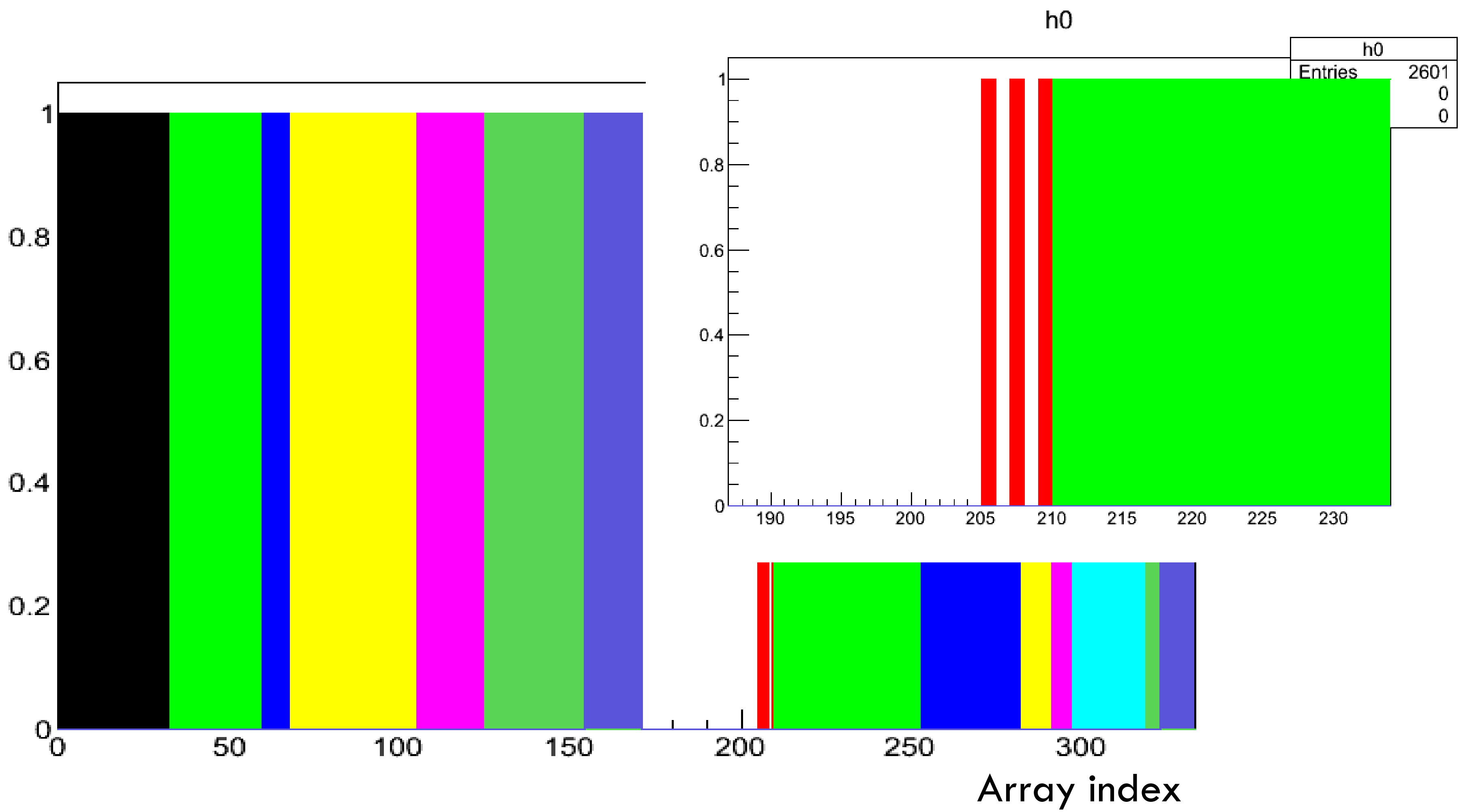
Width of one storage cell given by time resolution of detector

0-Element Pointer

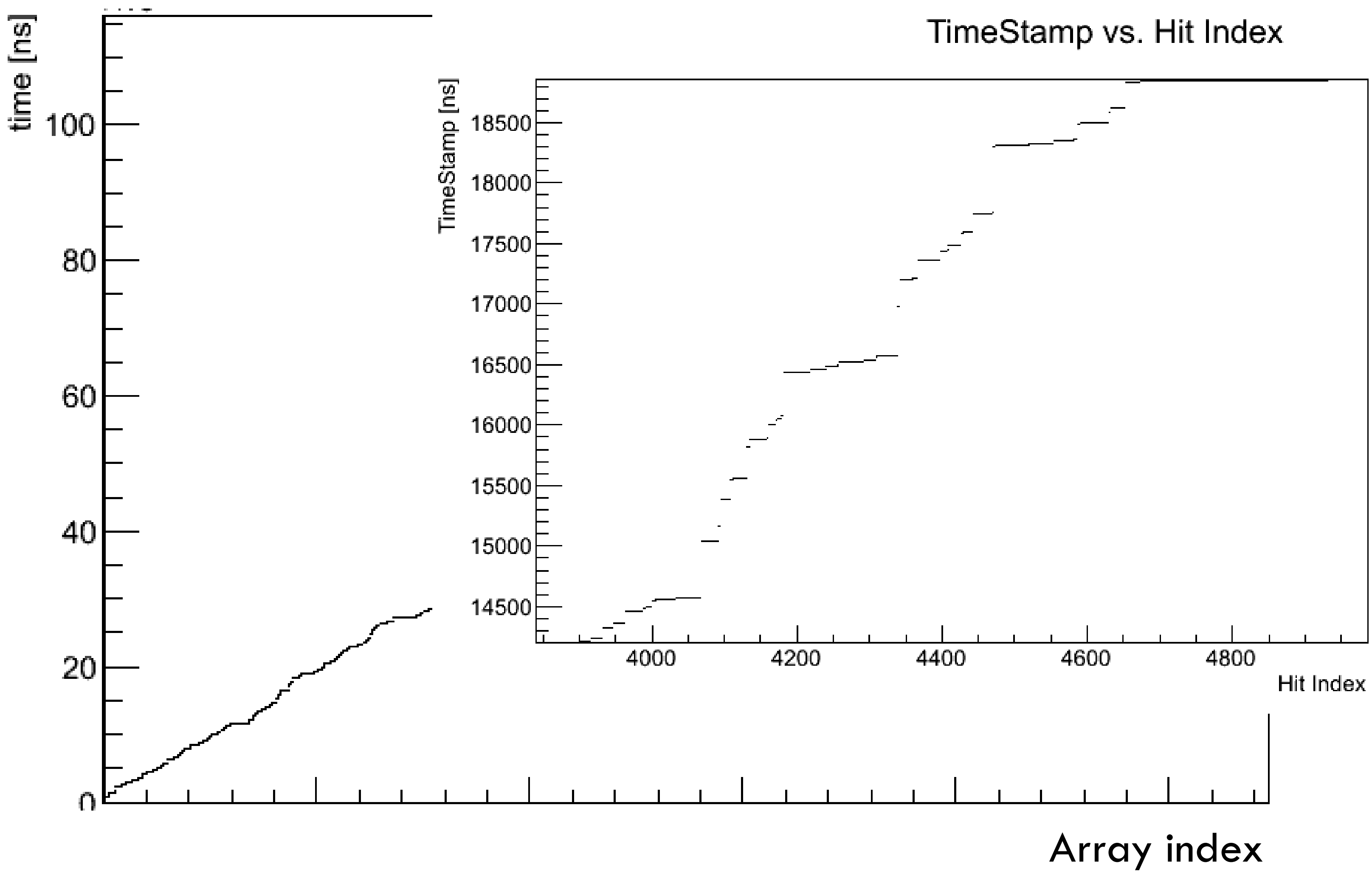
Storage Pointer position calculated numerically from time stamp

If a storage position is calculated which would override old data, the old data is saved to disk and the storage cell is freed

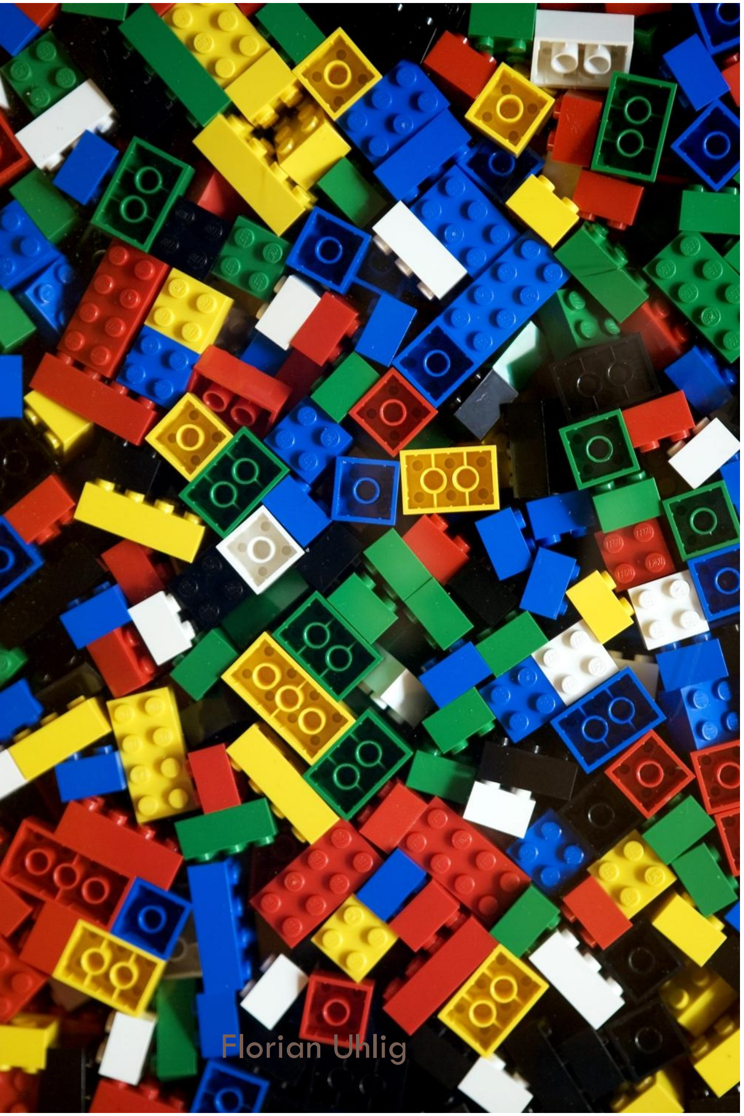
Sorted Digi Data



Sorted Digi Data



Task for Experiments
Event Builder



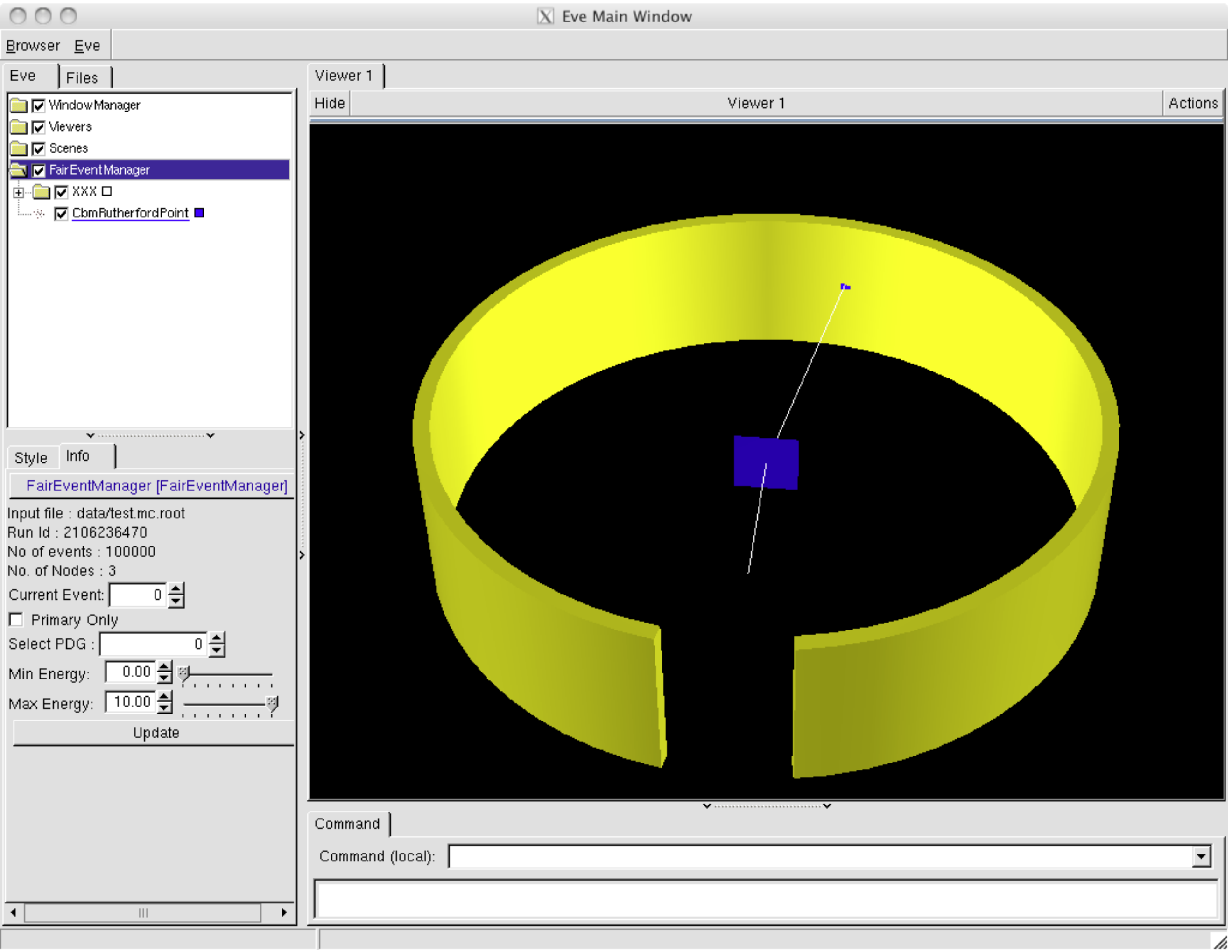
Read back the Data Eventbuilder

- Read data from IO Manager using different functions
- Different algorithms already available
  - Read data up to a given absolute time
  - Read data in a given time window
  - Read data until next time gap of certain size
- Other algorithms can be (easily) implemented if needed

Example: Rutherford Experiment

- Scattering of 5MeV alpha particles at a 2µm gold foil
- Unexpected large scattering angles observed
- Implementation using FairRoot needs
  - 600 lines of c++ source code created mostly automatically (copied from a template)
  - 60 lines of code for the build system
  - 200 lines of code for the steering macros
  - 70 lines of code for the geometry and media definition

Rutherford Experiment



- Change experimental setup
- Change material properties
- Change simulation engine
- Change physical processes

Summary and Outlook

- Hope I could show you that FairRoot
  - is flexible
  - is easy to use
  - is easy to extend
- Special tools to do dose studies
- Tools for time based simulation are implemented
  - Calculation of event time
  - Mixing of events by automatic buffering and write out when needed
  - Fast sorting of data
  - Several event builder functions

Summary and Outlook

- Many more topics only touched or not showed at all
  - Proof integration
  - Database connectivity
  - GPU usage inside of FairRoot
  - Build and test system
  - …
- Resources
  - Webpage: http://fairroot.gsi.de
  - Forum: http://forum.gsi.de
  - Test Dashboard: http://cdash.gsi.de/CDash

FairRoot related talks and poster

- [606] Future Experiments and Impact on Computing
- [394] Event reconstruction in the PandaRoot framework
- [353] Track finding and fitting on GPUs, first steps toward a software trigger
- [40] STEPtoRoot – from CAD to monte carlo simulations
- [399] Electron reconstruction and identification capabilities of the CBM Experiment at FAIR