BROOKHAVEN
NATIONAL LABORATORY

EIC software

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NPPS Group Meeting August,23 2019

Contents of this talk

- Fast simulation tool: eic-smear
- Software frameworks
  - GEMC
  - fun4all
  - EicRoot
  - Argonne EIC software initiative
- PID consortium GEANT4 software (one slide)
- Near-term future trend(s)

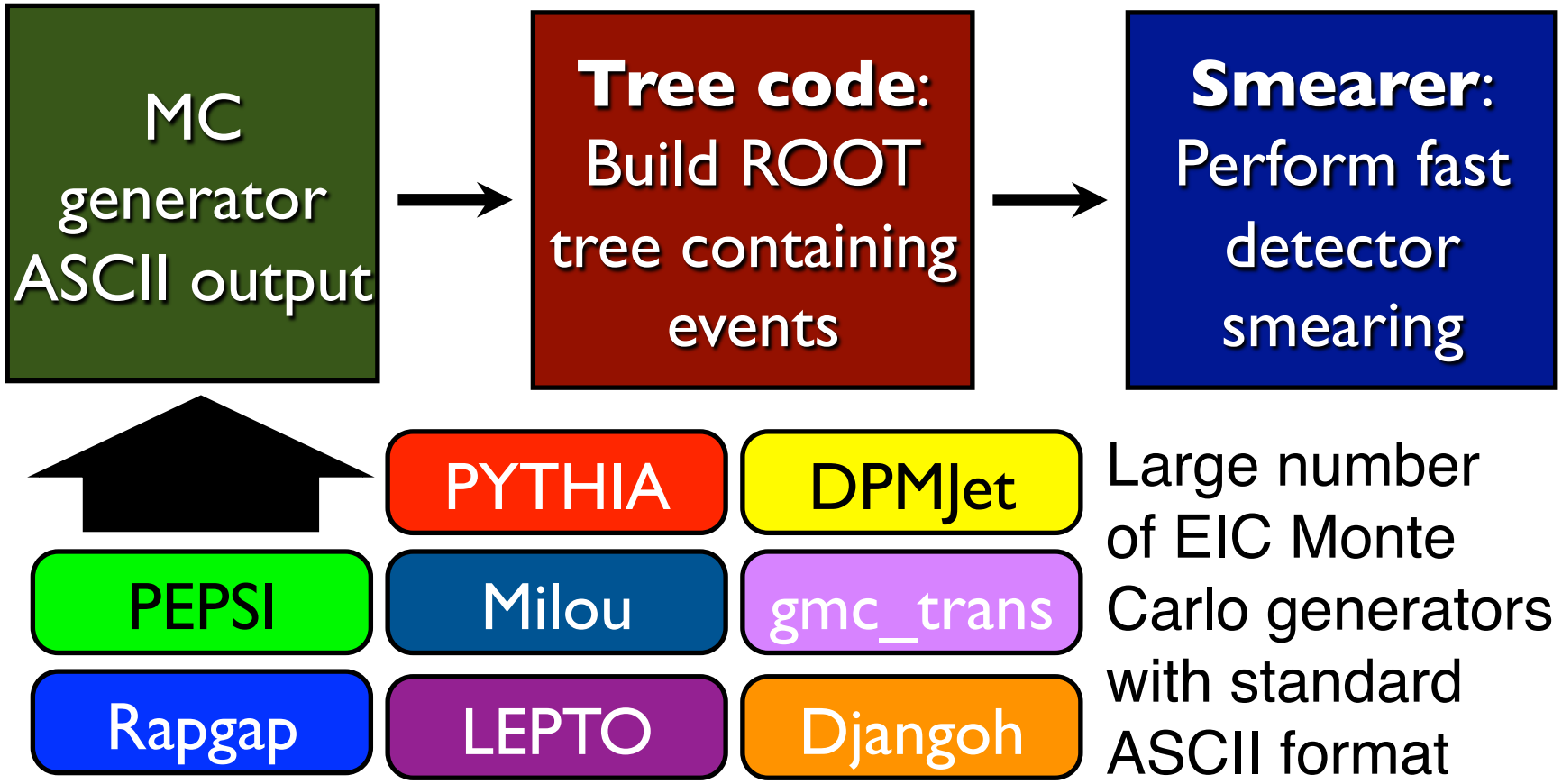
Materials taken from presentations of T.Burton, M.Ungaro, E.Sichtermann, J.Repond, D.Lawrence, D.Romanov, Y.Furletova & others

eic-smear

by Tom Burton (BNL TF group)

Overview

- **C++** code, runs in **ROOT**
- Build with **configure/Make** or **CMake**
- **`libeicsmear.so`** to load in ROOT

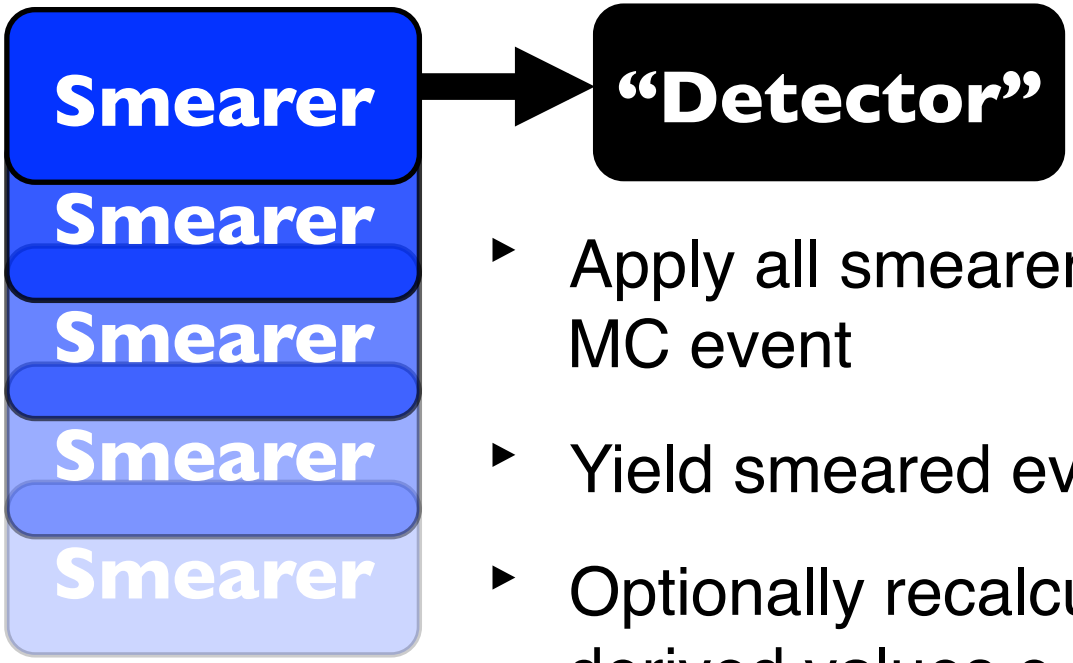


Smearing

"**Smearer**" defines some element of performance + acceptance

- Built-in standard smearers provided with eic-smear
- Users can define own smearers using inheritance

NOT a "physical detector": represents the **overall performance** in measuring a quantity.



- Apply all smearers to an MC event
- Yield smeared event
- Optionally recalculate derived values e.g x, Q^2

How to use it

- Write a ROOT script:

```
Smear::Detector createDetector() {
// Resolution in momentum, sigma(P).
// sigma(P) = 0.4%P + 0.3%P^2.
Smear::Device tracking("P", "0.004 * P + 0.003 * pow(P, 2)");
  // Add devices to a Detector.
  Smear::Detector detector;
  detector.AddDevice(tracking);
  return detector;
}
```

Simple "Device" smearers define σ(X) via text string

- Smear your ROOT tree:

```
root[0] SmearTree(createDetector(), "mc.root", "smeared.root");
```

Handles event loop, file I/O

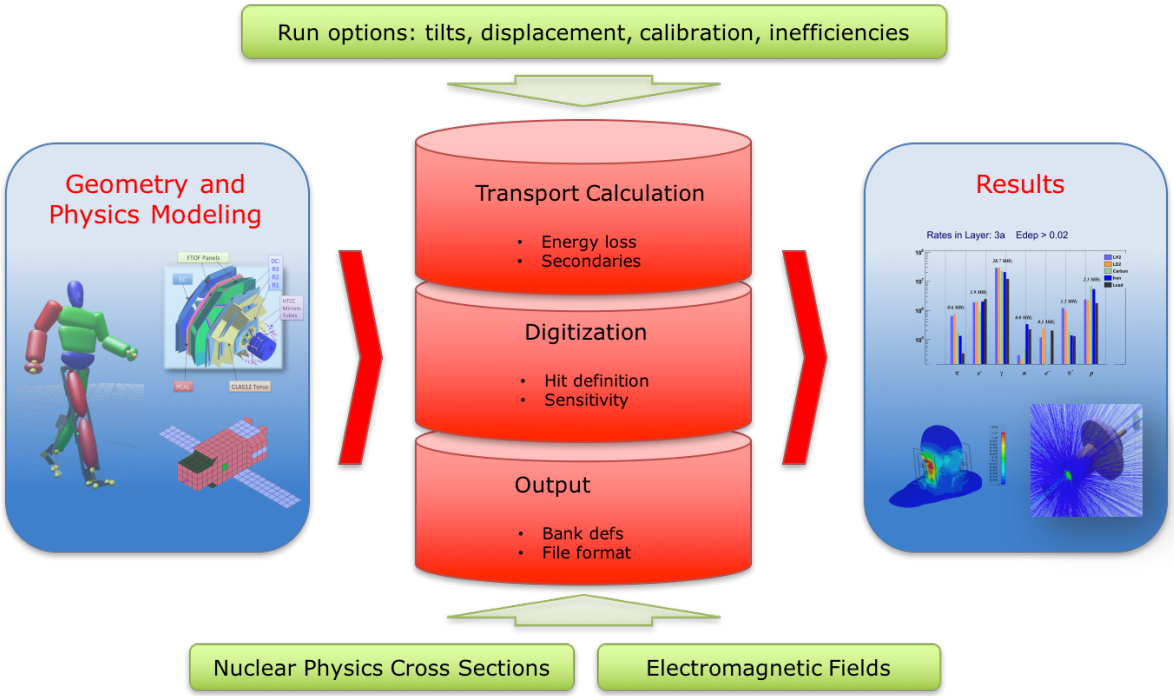
- "Standard" detector descriptions (like STAR or BeAST) exist

See K.Kauder: talk at the EIC software meeting 07/10/2019

GEMC

by Maurizio Ungaro (JLab)

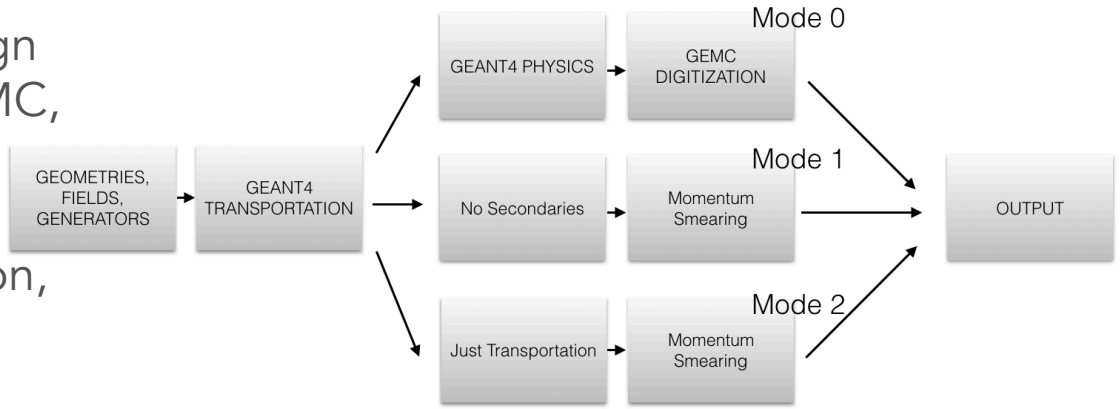
GEant4 MonteCarlo Architecture



- Application independent geometry/digitization/fields: definitions stored in databases
- Realistic hits treatment: electronic time window, voltage versus time signals.
- Sensitive attributes assigned at run time: real calibration, survey tilts and displacements.
- Plugins for generator formats (LUND, BEAGLE, easy expansion)
- Plugins for output formats (TXT, CODA, JSon, easy expansion)
- Realistic signal treatment allows for background rate studies, including pile-up effects

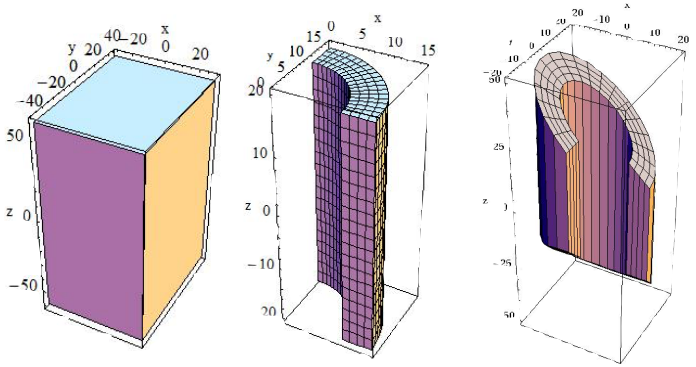
- Application for detector simulations based on Geant4
- Macro language for detector design
- Various geometry definitions: GEMC, gdml, CAD

- Data card (XML) to steer application, all Geant4 macro commands supported by design

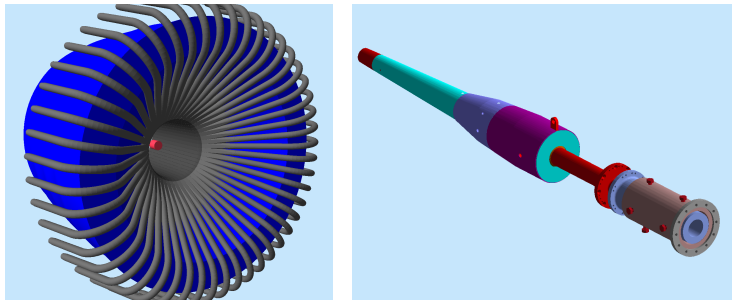


Geometry

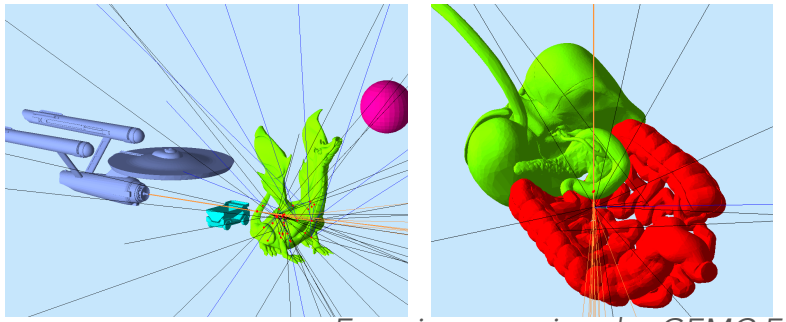
Native



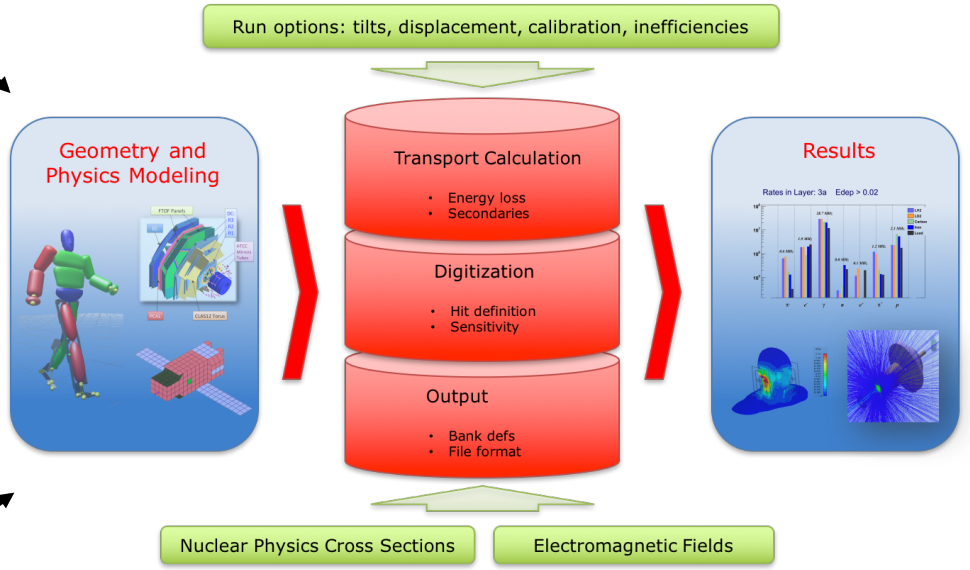
CAD

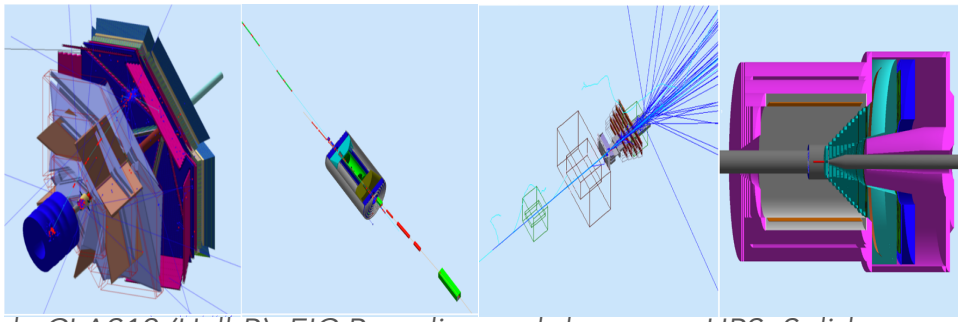


GDML



Input: Native, CAD, GDML. Arbitrary hierarchy, can be mixed and matched. Materials, sensitivity assigned at run-time.

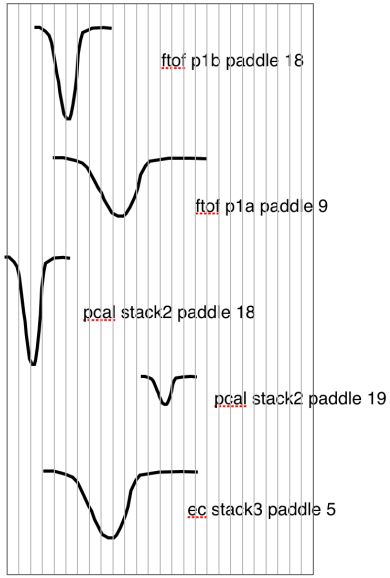


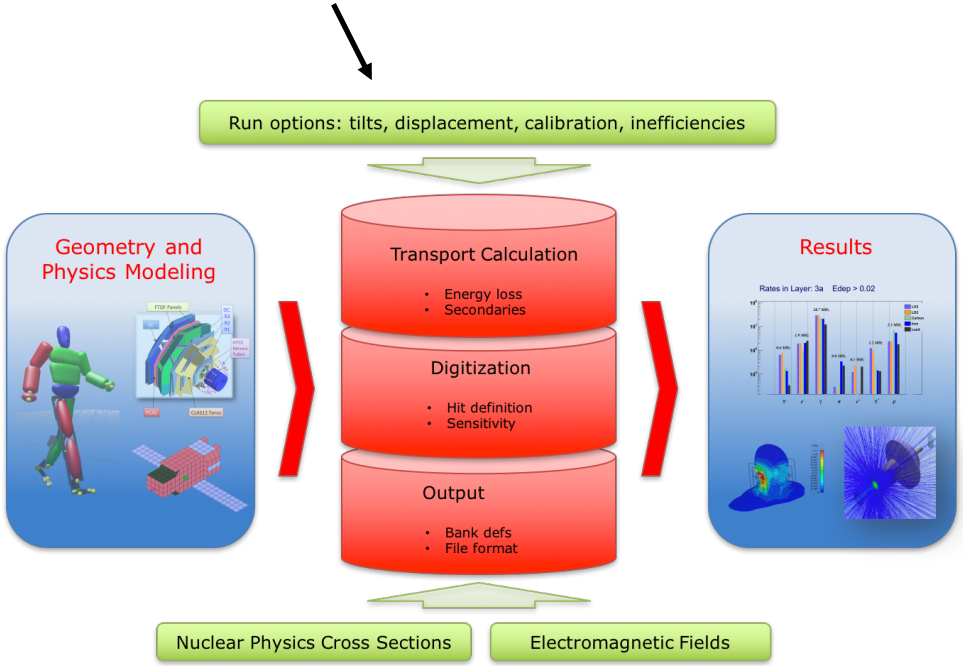


Experiments using the GEMC Framework: CLAS12 (Hall-B), EIC Beamline and detectors, HPS, Solid

Digitization, Output

- Single ADC/TDC over electronic time window.
- Voltage vs time signal.
- FADC output (4ns intervals or integratal mode)
- Automatic true information
- All g4 steps in the output

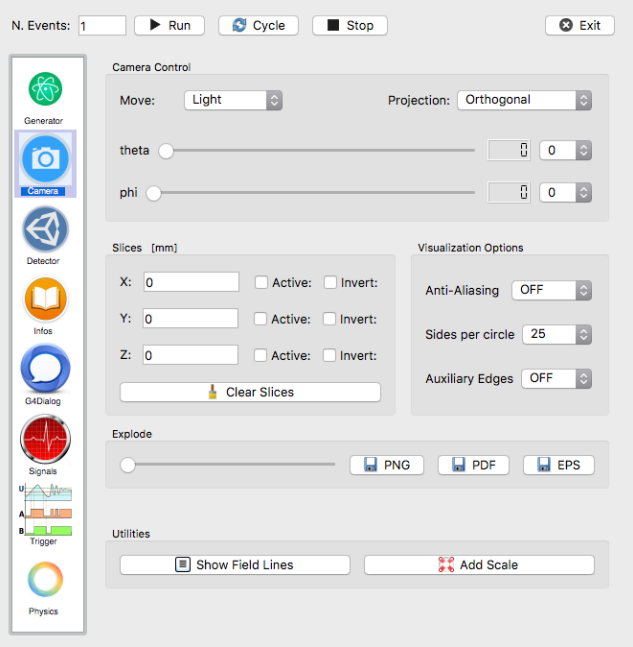


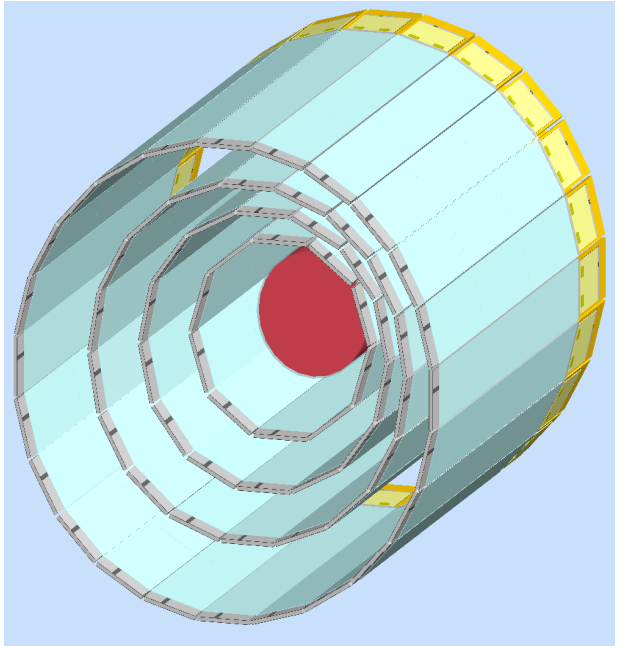



```
> BST
  > True Step by Step infos   (101, 0)
    - Edep                    (101, 1)
    - Pid                     (101, 2)
    - positions               (101, 3)

  > Dgtz Step by Step infos   (102, 0)
    - ADCL                    (102, 1)
    - ADCR                    (102, 2)

  > True Integrated infos     (103, 0)
    - Edep                    (103, 1)
    - Pid                     (103, 2)
    - positions               (103, 3)

  > Dgtz Integrated infos     (104, 0)
    - ADCL                    (104, 1)
    - ADCR                    (104, 2)

  > Voltage as a function of time (105, 0)
    - Identifier                  (105, 1)
    - Time                        (105, 2)
    - Voltage                     (105, 3)

 > Trigger Bank               (106, 0)
    - Identifier              (106, 1)
    - Time                    (106, 2)
    - Voltage                 (106, 3)
```

Graphical Interface

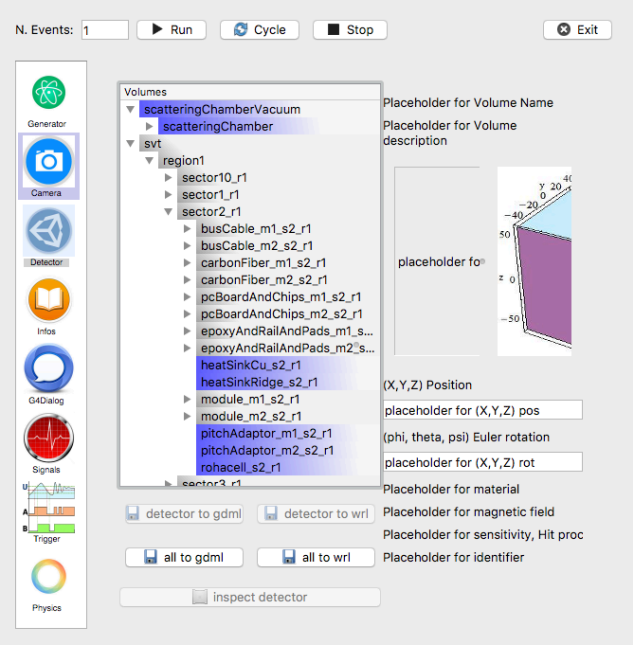
- Generator
- Event time window
- Background beams
- Camera views slices.
- Axis, Scale, Show field.

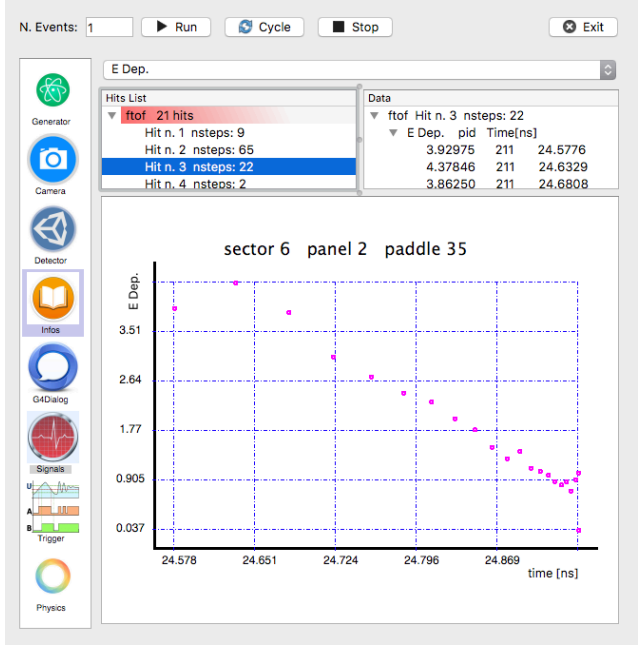




- Geant4 OpenGL View for the whole detector.
- Can inspect and open a view on single volumes.

- Volumes hierarchies and properties
- Output to GDML





- Graphical analysis of steps in a hit.
- Can choose variable to display.

fun4all

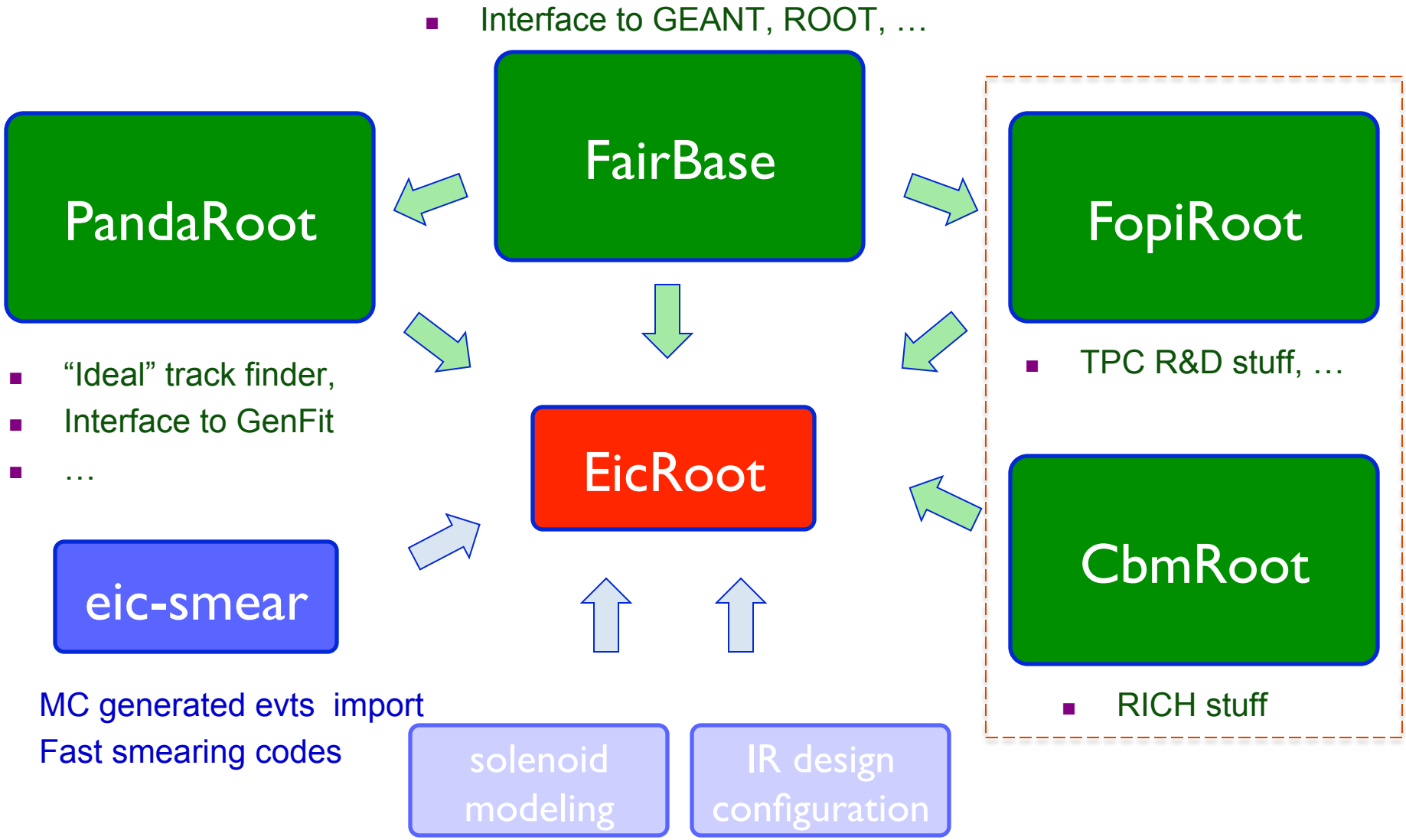
by Chris Pinkenburg (BNL)

See talk at the EIC software meeting 07/10/2019

EicRoot

by AK (BNL)

EicRoot framework building blocks



-> basically a yet another FairRoot software clone

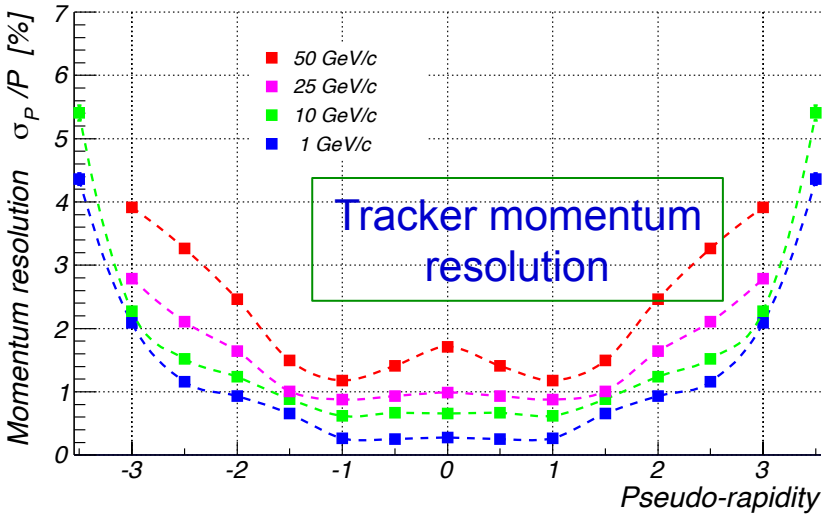
End user view

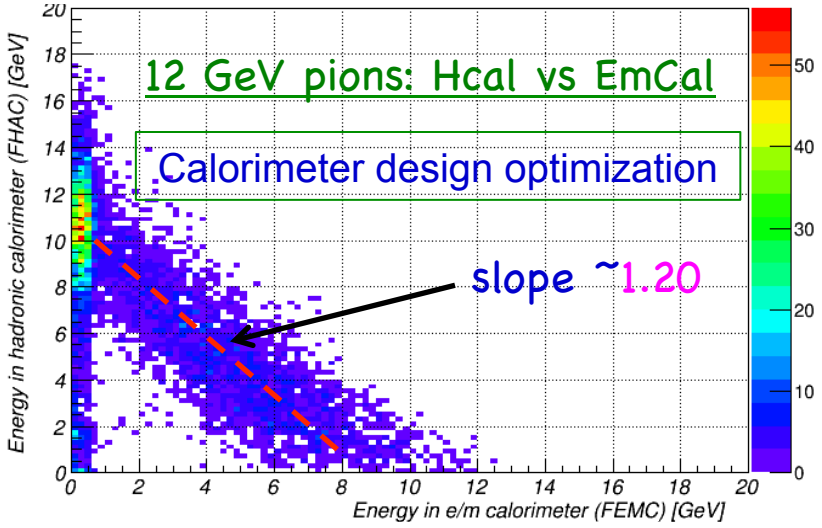
- No executable (steering through ROOT macro scripts)

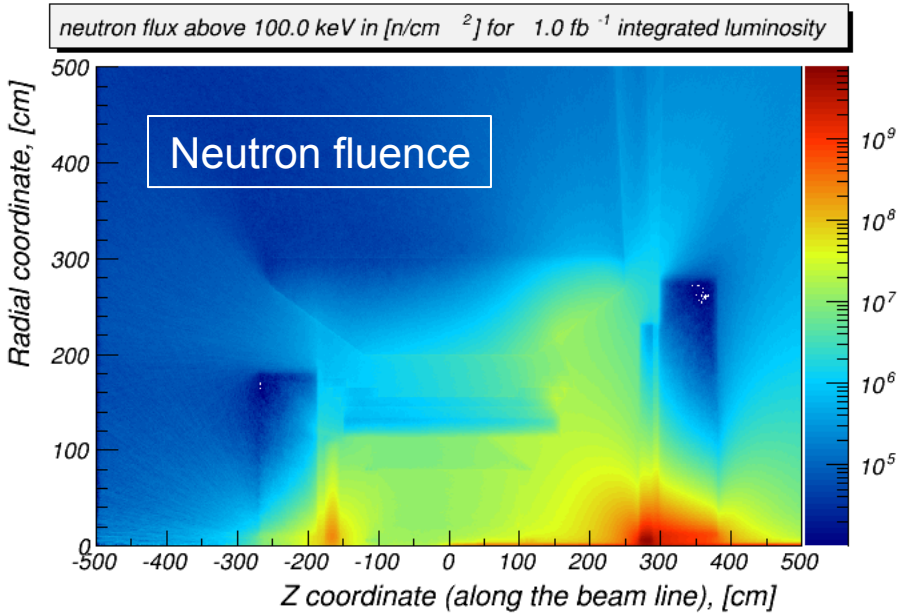
- ROOT files for analysis available after each step
- C++ class structure is well defined at each I/O stage

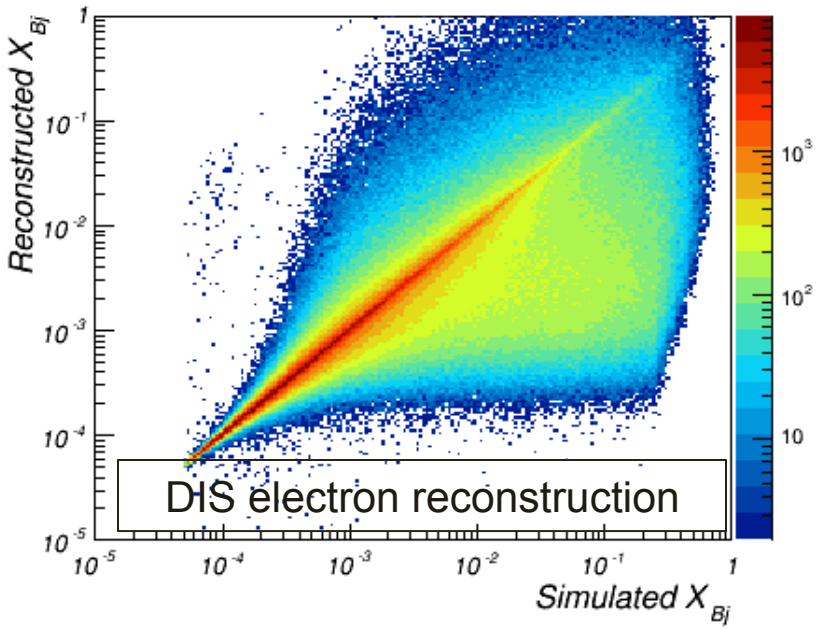
See AK: talk at the EIC software meeting 07/10/2019

Example case studies



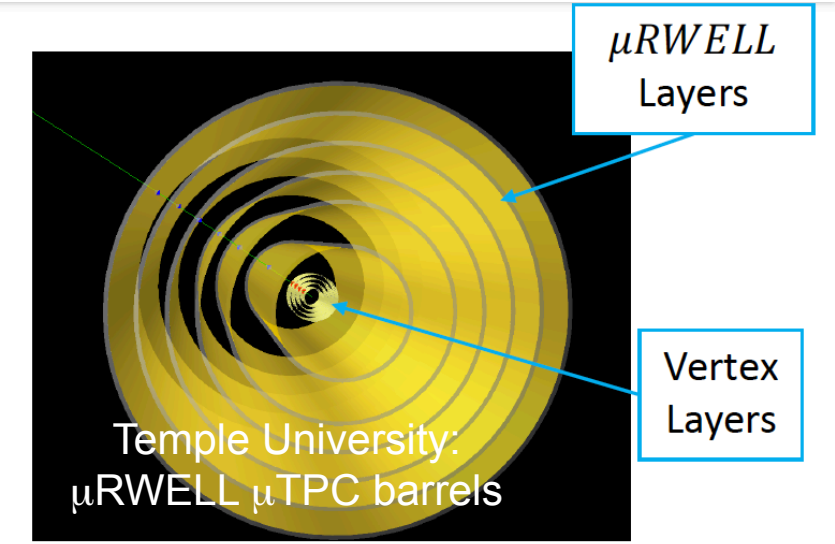


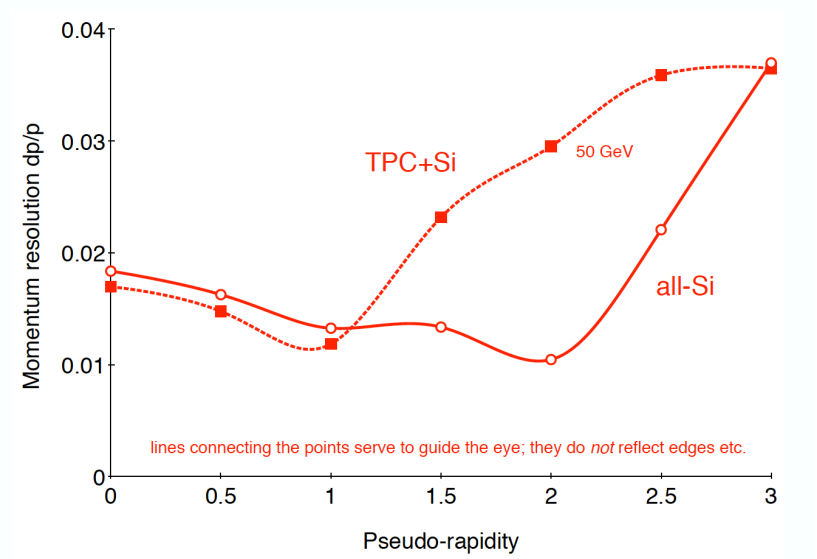


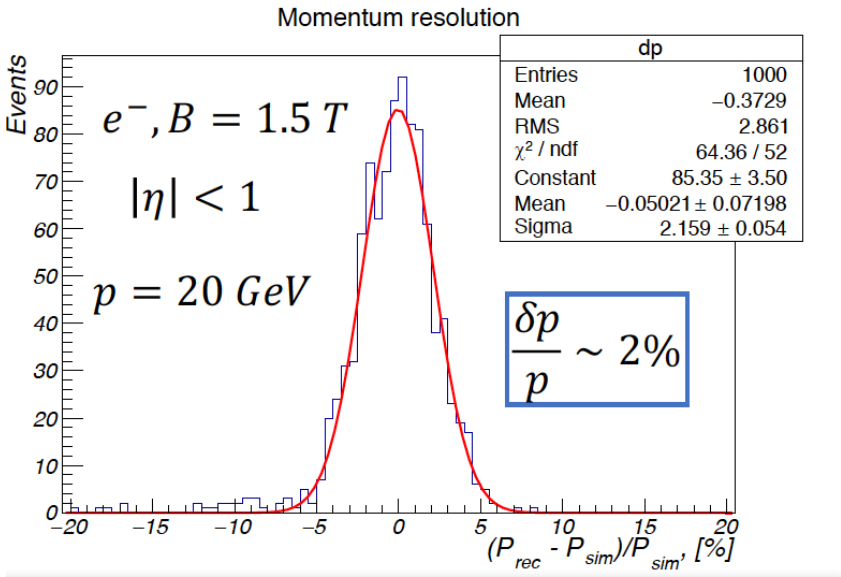


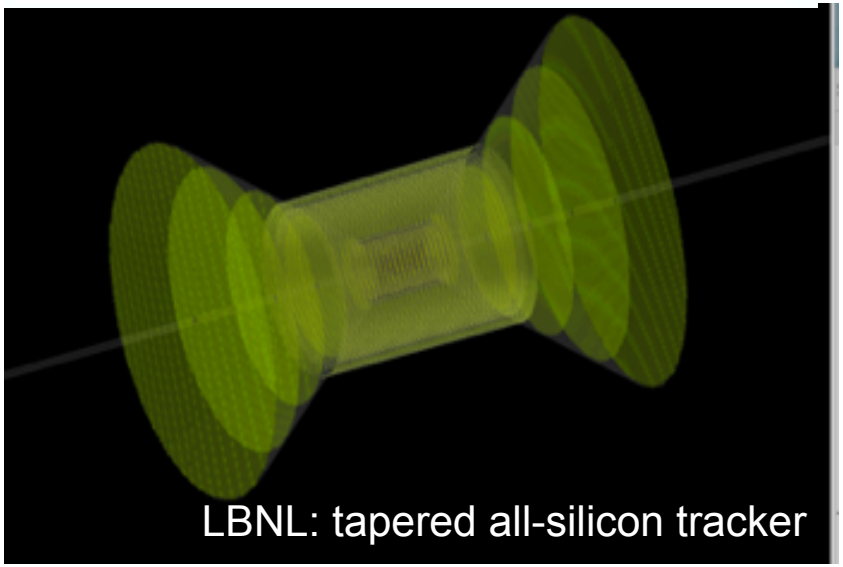
Current modeling work

- Possible central tracker configurations (alternatives to a TPC)

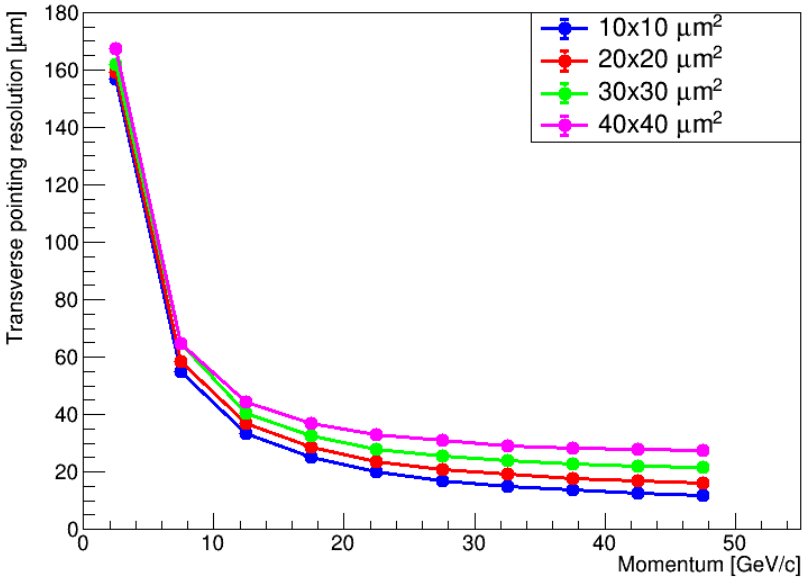


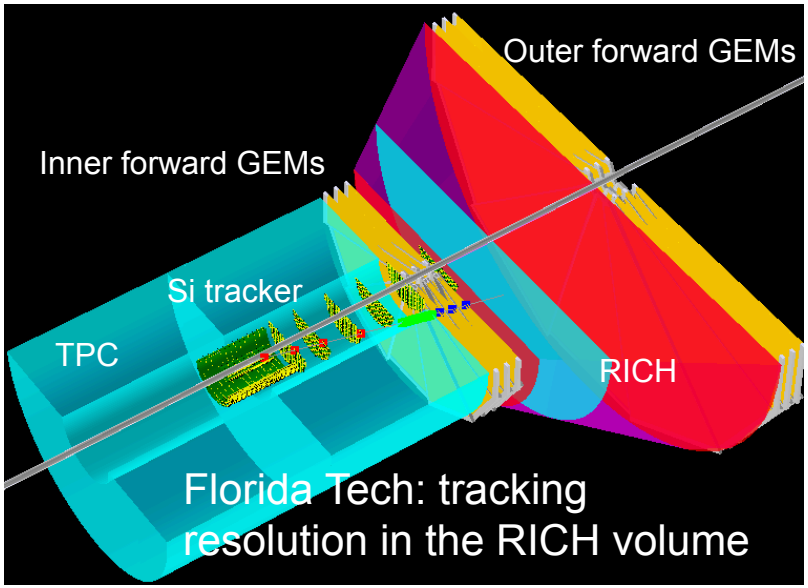


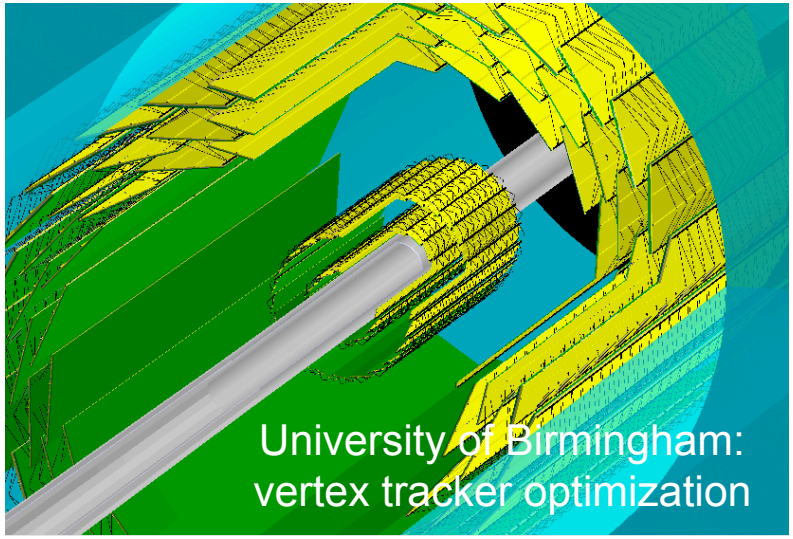




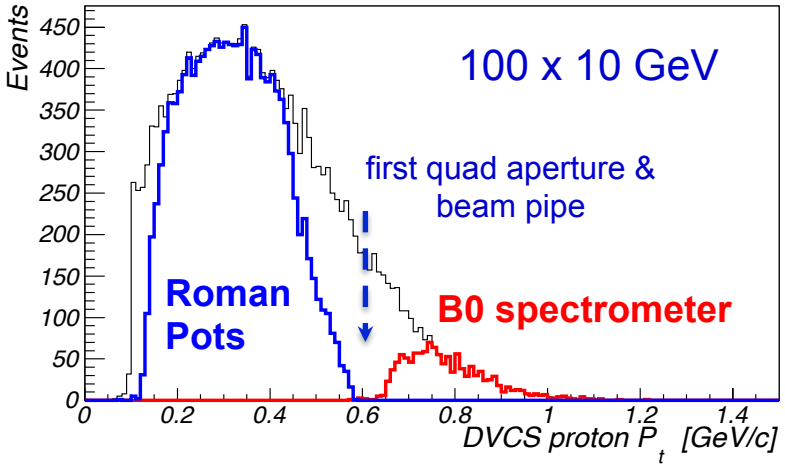
Current modeling work





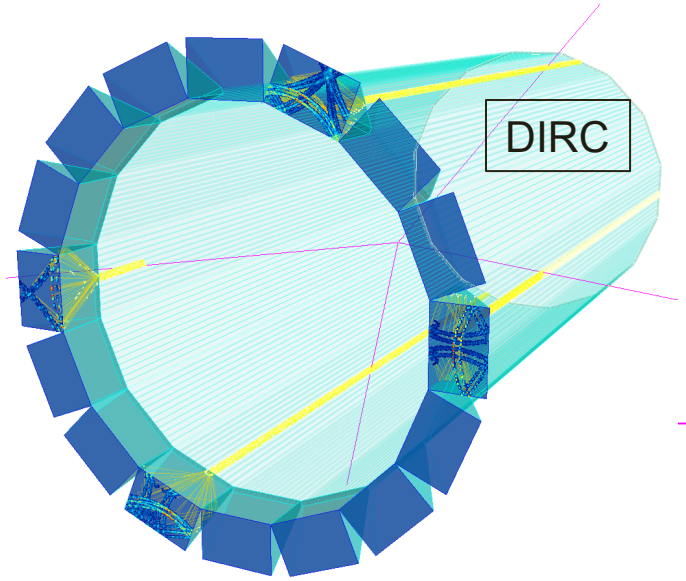


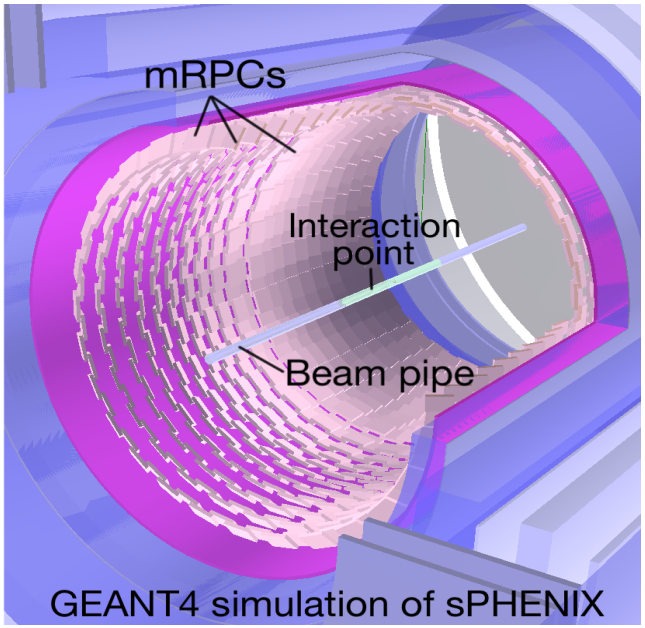
BNL: far forward acceptance

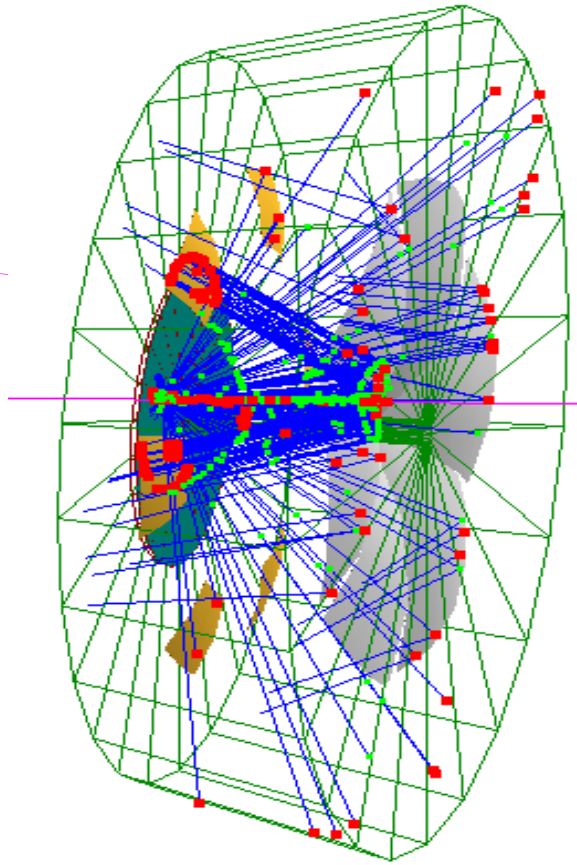


PID Consortium software

Mostly RICH & ToF applications

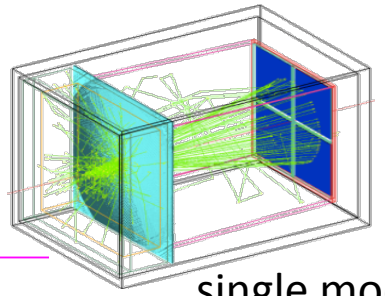




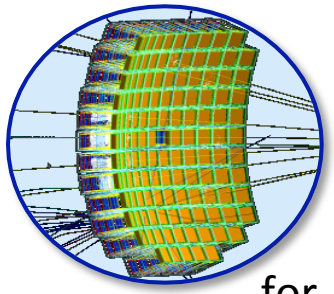


Dual radiator RICH

GEMC



single module



for JLEIC

Modular RICH

- All are custom GEANT4 codes

Argonne EIC software

Full simulation and reconstruction chain

Data Model

Event generation

Produce the simulation input events

Detector simulation

Particle transport through detectors

Digitization

Turn energy deposits in active media into detector hits

Reconstruction of

Event vertex, charged tracks, Particle Flow Objects (PFO)

Perform analysis

Collection of benchmark analyses

Argonne Software: Overview

Legacy chain

Adaptation of the SiD (ILC) simulation and reconstruction software chain

Major parts

- SLIC (wrapper around GEANT4)
- LCSIM (digitization and event reconstruction)
- slicPandora (PFA reconstruction)

Visualization with JAS4pp

Limitations

- Only SiD subdetectors (e.g. no RICH)
- Geometry description not centralized
- Geometry constrained to be symmetric
- Some parts difficult to maintain

Full chain

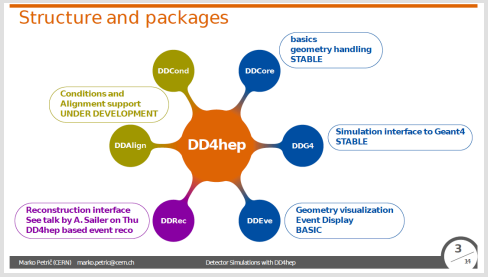
- Available
- Studies of F_2 reconstruction, timing…

Evolution chain

Evolved from the legacy chain

Geometry interface

DD4HEP



Features

- Fully maintainable
- Geometry obtained from single source
- Geometry can be parametrized
- Geometry not constrained to be symmetric
- New subsystems can be easily implemented

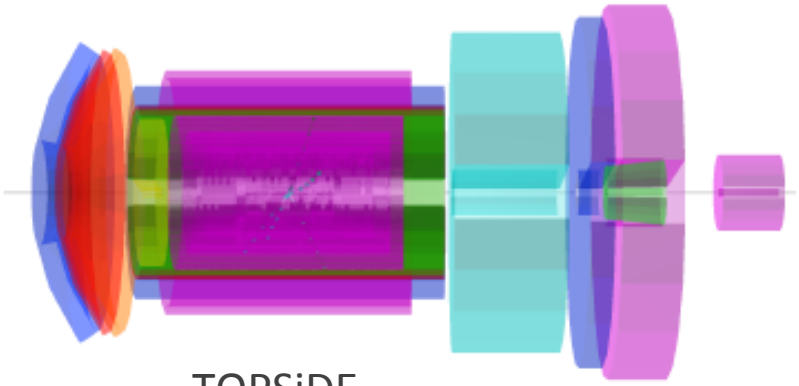
Still working on

- Realistic digitization
- Generic tracking
- PFA reconstruction
- Visualization

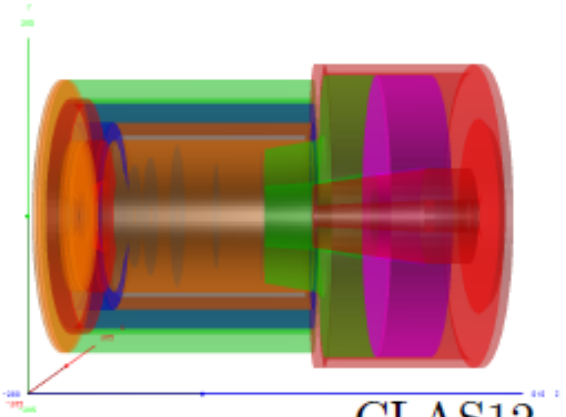
Nuclear Physics Detector Library (NPDet)

Collection of **parametrized** detectors which can be developed into full concepts

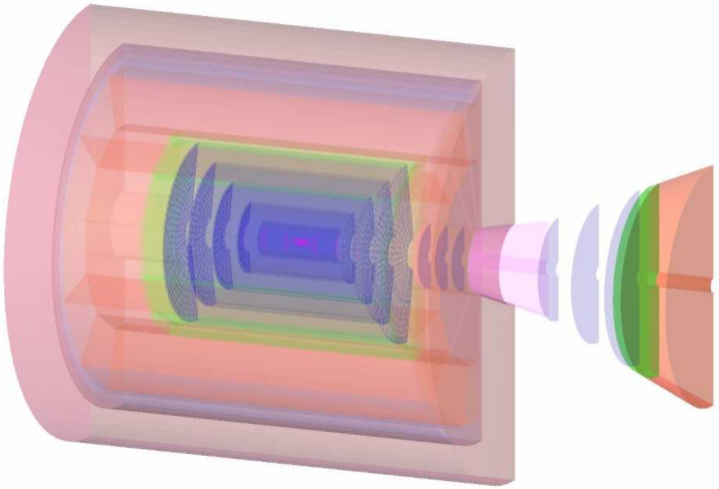
JLEIC (S. Johnston)



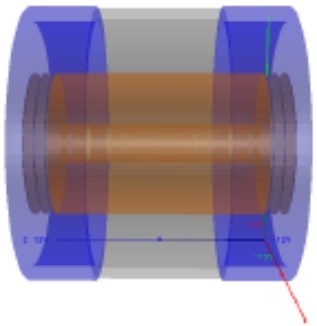
SOLID



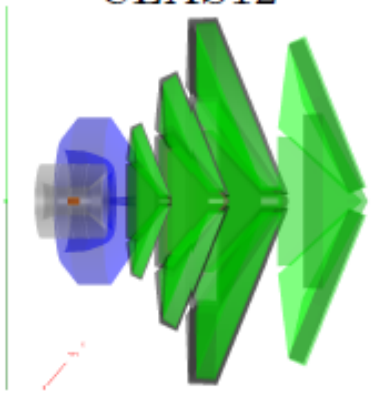
TOPSiDE



eRHIC



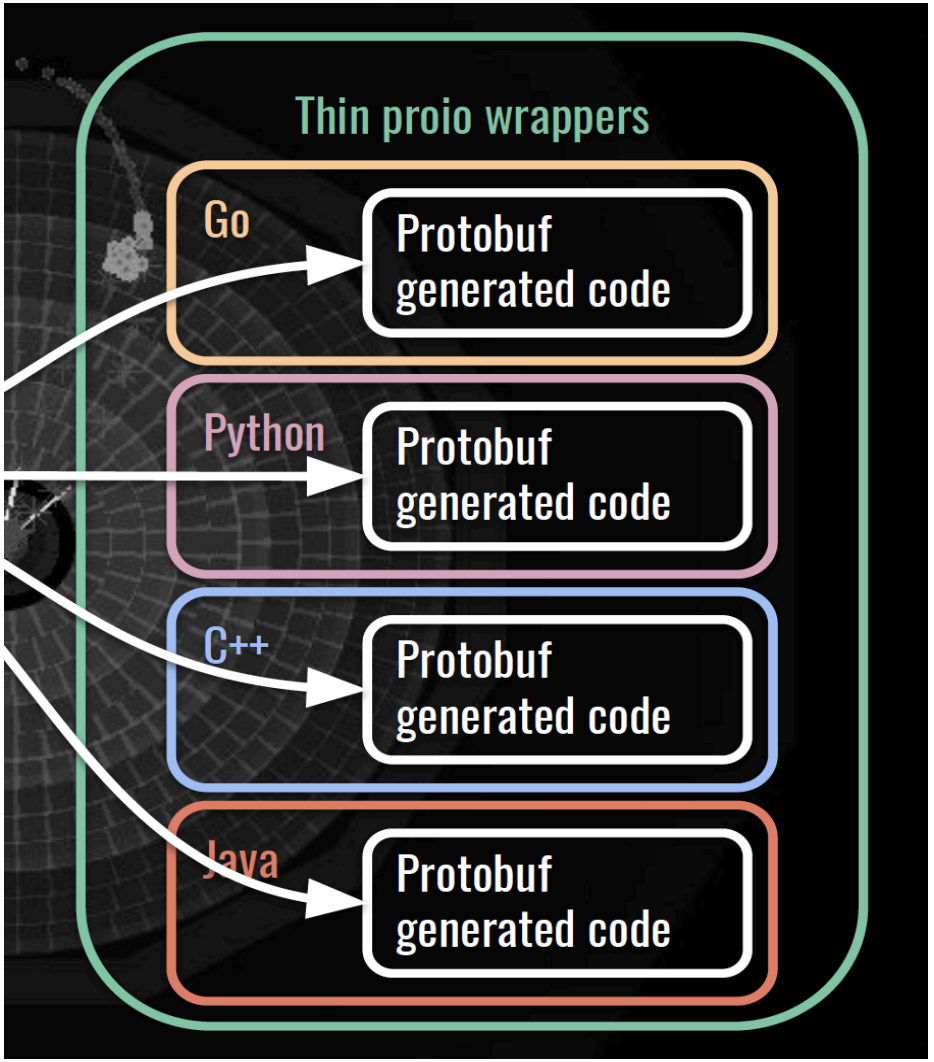
CLAS12



ProIO

ProIO Key Concepts

- Language-neutral I/O for streaming events
- Thin, native containers for protobuf messages, simply adding the concept of an event
- protobuf + event structure = ProIO
- Serialized output can be accessed effectively in archival file, or in a stream



Grand unification, yet another try

by Dmitry Romanov, David Lawrence,
Yulia Furletova & others (JLAB)

Key ingredients

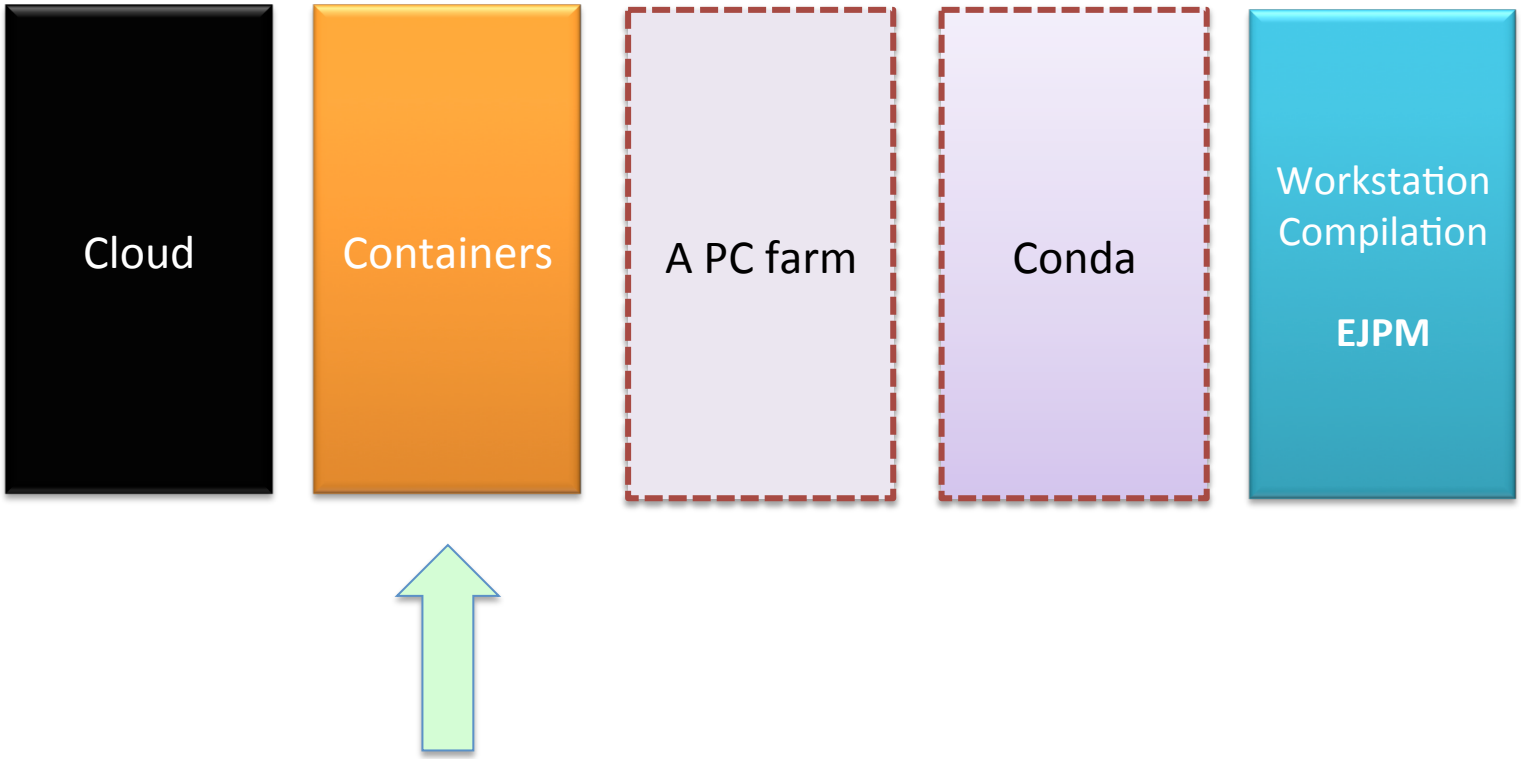
- (Docker) containers
- Jupyter notebooks
- JANA2 software framework
- g4e GEANT-based EIC detector sandbox

Software distribution model(s)

NO EFFORT AT ALL
Novice

Some effort
Experts

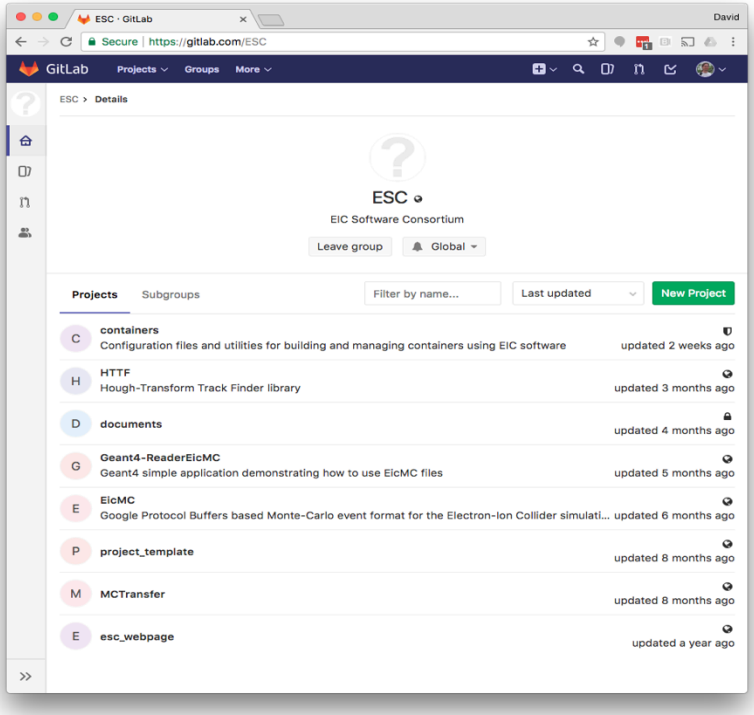
Efforts required axis

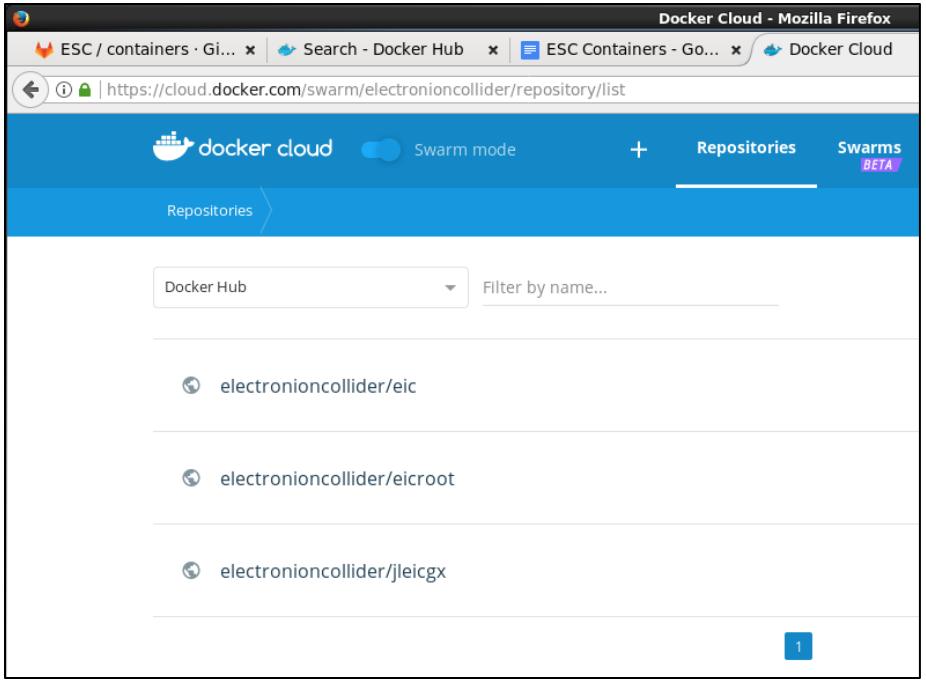


Main focus at present

A side note: EIC Docker containers

-> introduced in Aug,2017; went public by EICUG meeting in Nov,2017



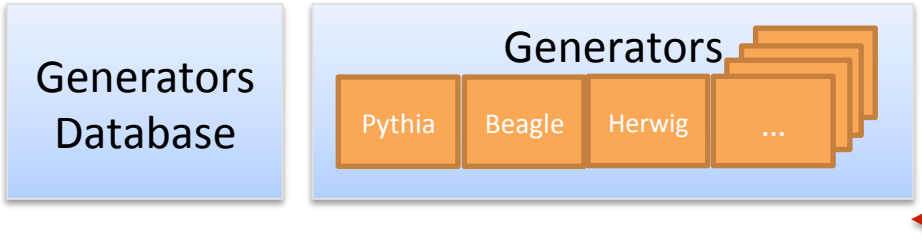


Clear benefits for EIC user community

- Allow EIC users to run the same software under standardized environment on any Linux, Mac OS or Windows machine, eventually including GRID sites, commercial cloud systems, and HPC resources
- Provide consistency between software generated at different facilities
- Make it easier for new users to start working on the physics program and detector design for the EIC, by minimizing the pain of “installation overhead”

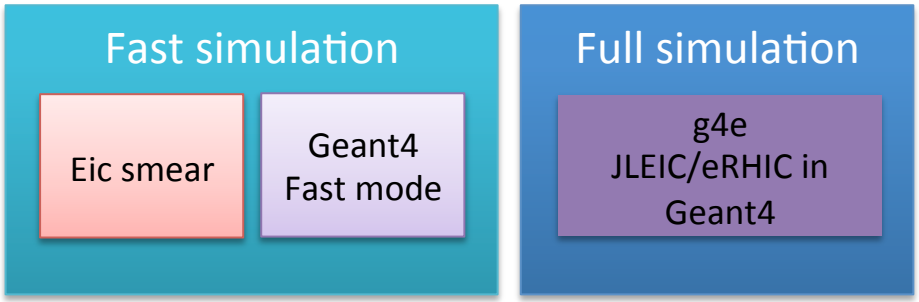
Core functionality overview

Database with various MC samples



(1)

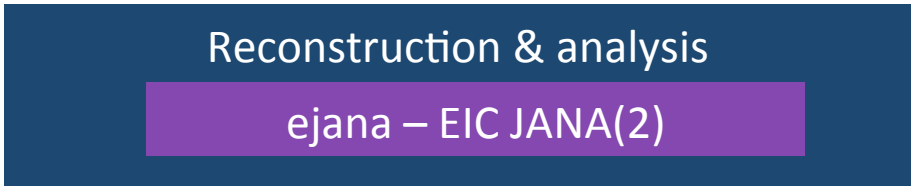
BNL & Jlab effort on Fast detector prototyping



g4e = Geant 4 EIC
Native C++ GEANT4 code with an EIC detector in it

(2)

ejana = EIC Jana
Community reference reconstruction



(3)

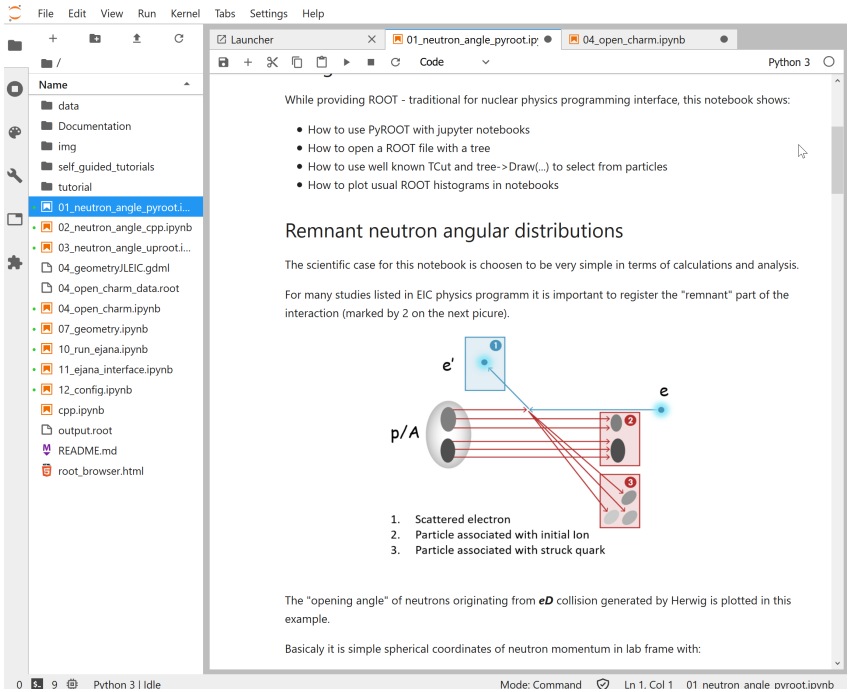
(1) MC events
(2) Digitized hits + magnetic field + material distribution
(3) Reconstructed events

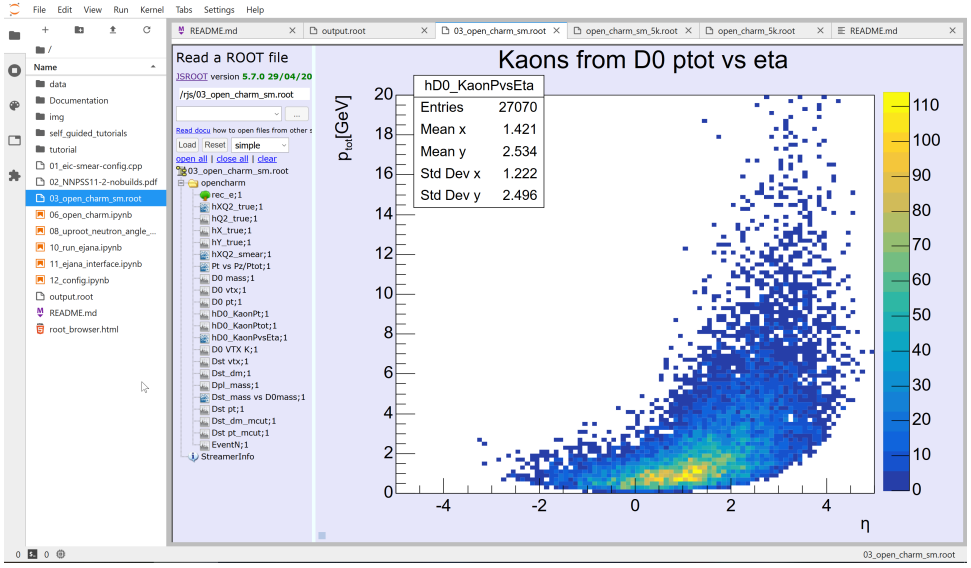
-> user access (with graphics) either directly or through SSH or Web interface

See D.Romanov: talk at the EIC software meeting 07/10/2019

JupyterLab Web interface

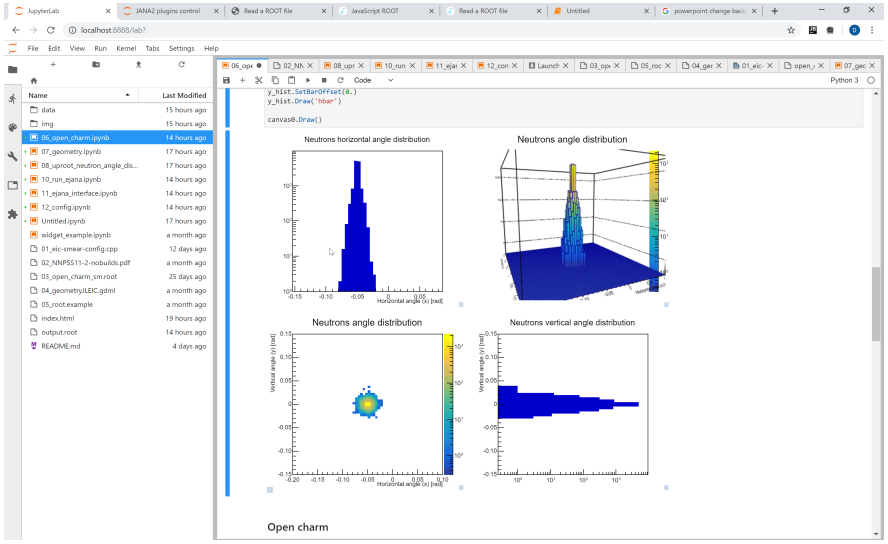
Wiki: *Jupyter Notebook is a web-based interactive computational environment for creating Jupyter notebook documents. The "notebook" term can colloquially make reference to many different entities, mainly the Jupyter web application, Jupyter Python web server, or Jupyter document format.*

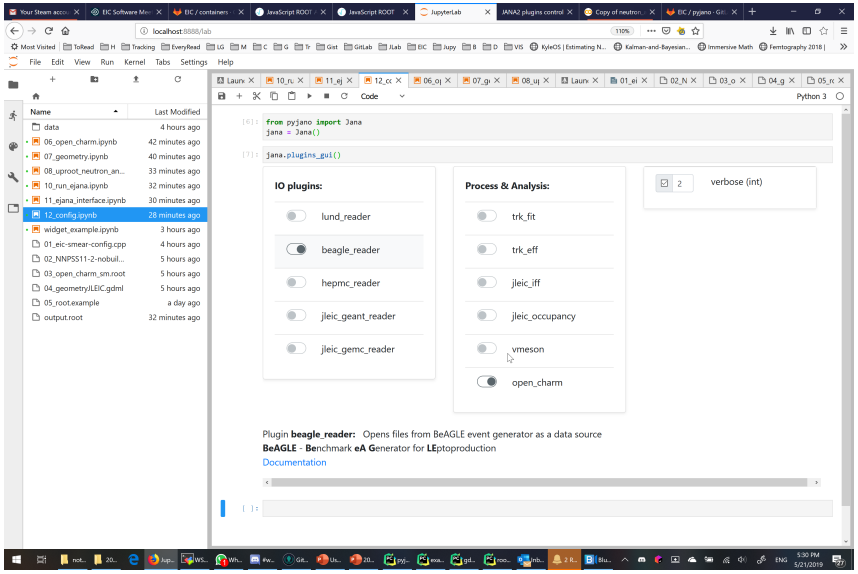


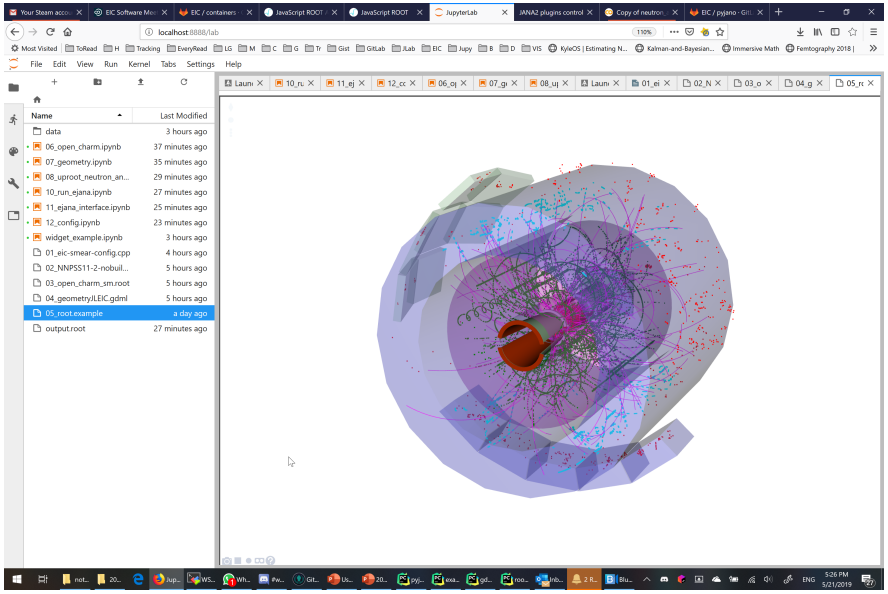


- Cloud based collaborative workspace
- The medium for studies, reports, analysis
- The bridge between modern Data Science and traditional Nuclear Physics methods

JupyterLab Web interface







- Self-documenting
- Appealing & modern ...
- ... yet not really mandatory to get access to the core (container) functionality

Community reference reconstruction

e^{JANA} - stands for EIC JANA

- Basic reconstruction
- Physics analysis
- **Users detector codebase integration**

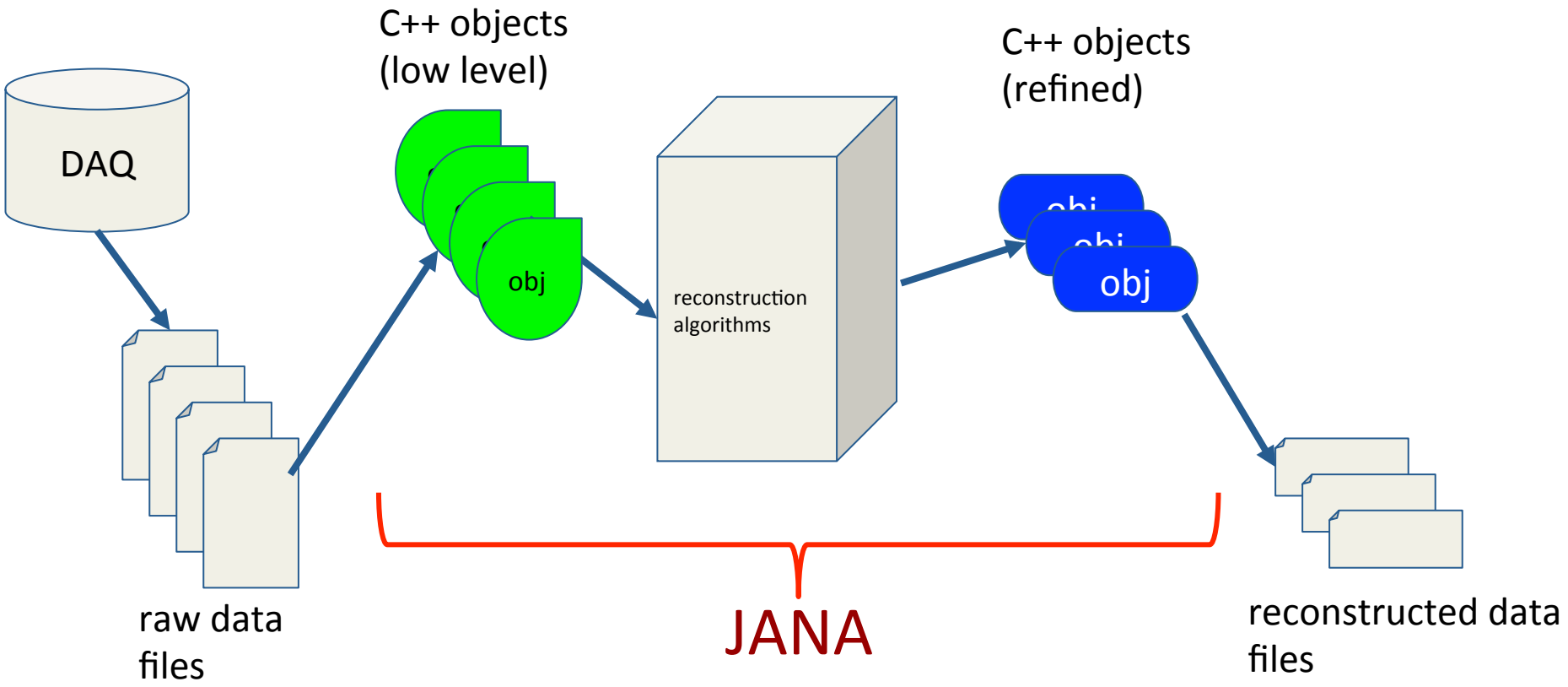
Reconstruction

- **Tracking** - Genfit
- **Vertex finding** – Rave
- **Physical analysis**:
  - ROOT C++ or
  - Python data science tools (Jupyter, Seaborn, Pandas, etc)

Any existing C++ (or even others) code can be:

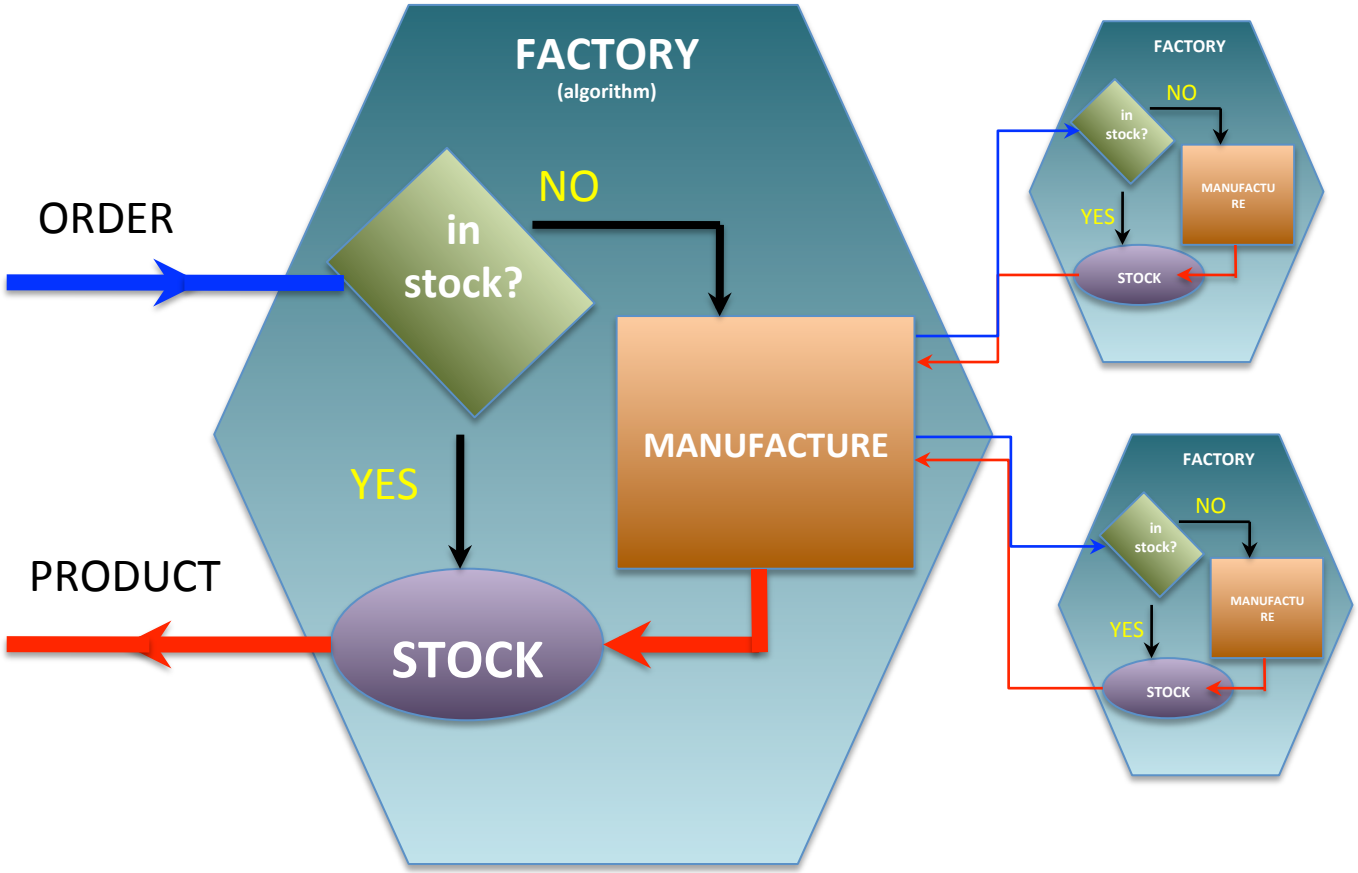
- compiled as JANA plugin
- run parallelized in eJANA
- accessed by other plugins

Jana(2) software framework



- Provide mechanism for many physicists to contribute reconstruction codes to the “shared pool”
- Implement multi-threading efficiently & external to the contributed codes
- Provide common mechanisms for accessing job configuration, calibrations, etc

Jana(2): factory model



Data on demand = Don't do it unless you need it

Stock = Don't do it twice

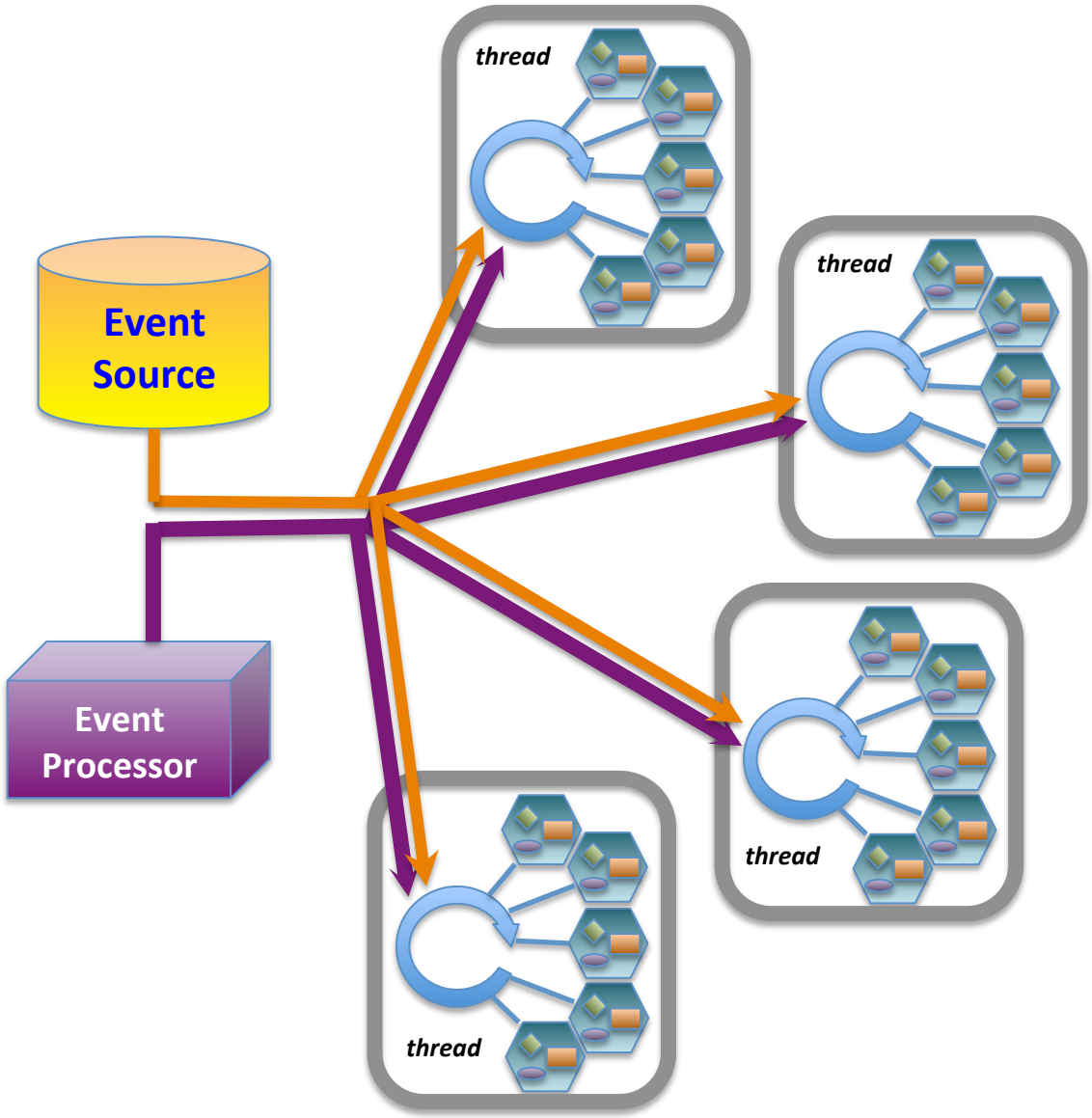
Conservation of CPU cycles!

Jana(2): multi-threading

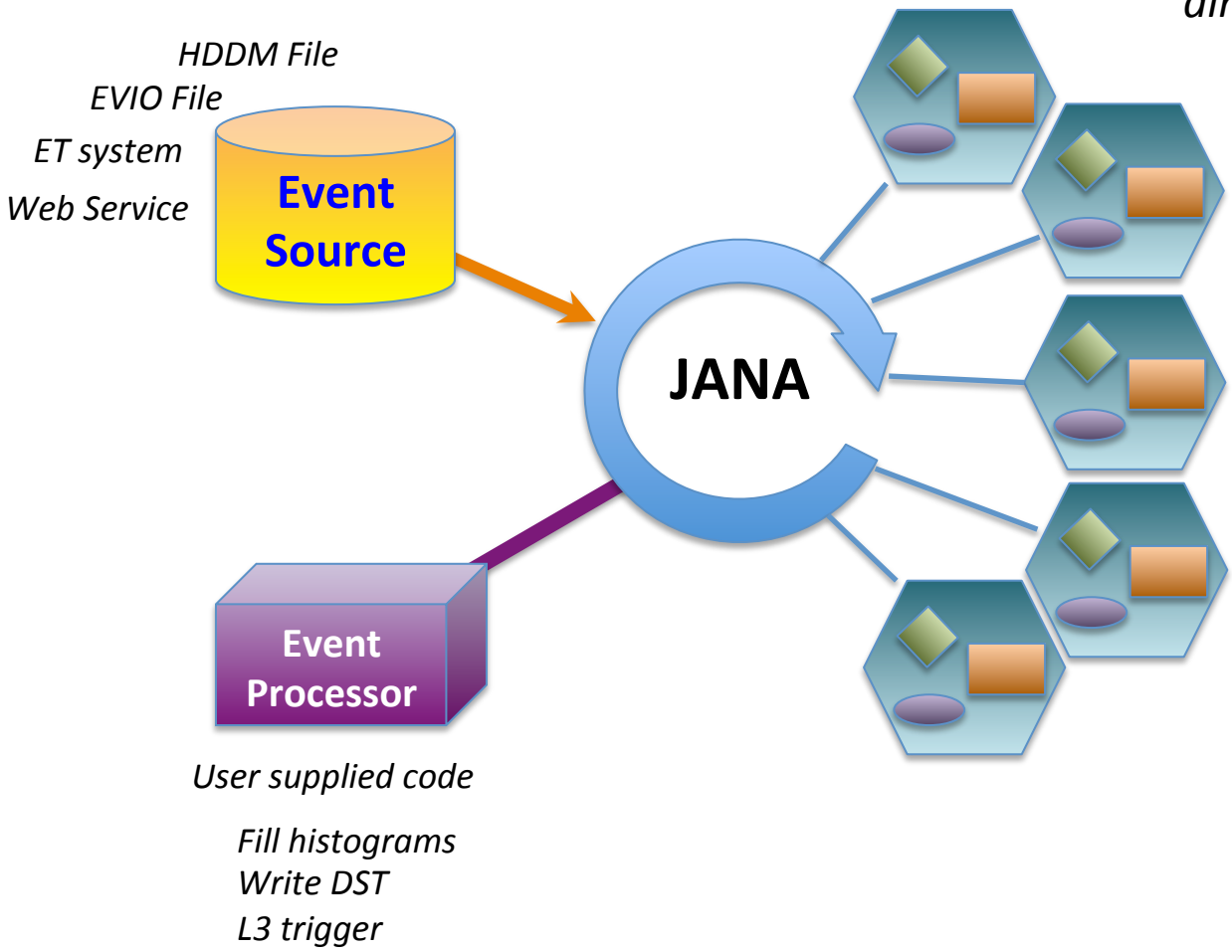
- *Each thread has a complete set of factories making it capable of completely reconstructing a single event*

- *Factories only work with other factories in the same thread eliminating the need for expensive mutex locking within the factories*

- *All events are seen by all Event Processors (multiple processors can exist in a program)*



Jana(2): event reconstruction scheme



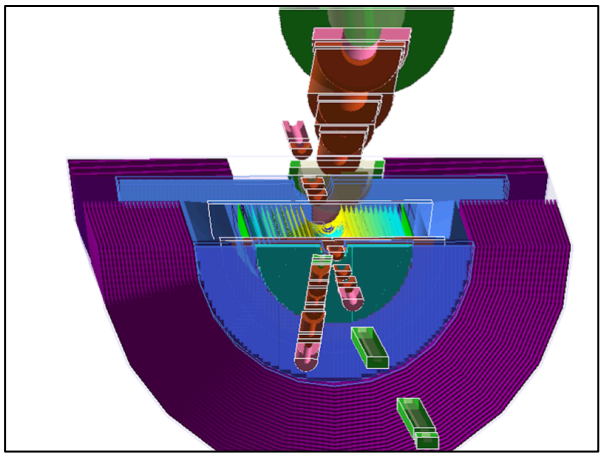
Framework has a layer that directs object requests to the factory that completes it

Multiple algorithms (factories) may exist in the same program that produce the same type of data objects

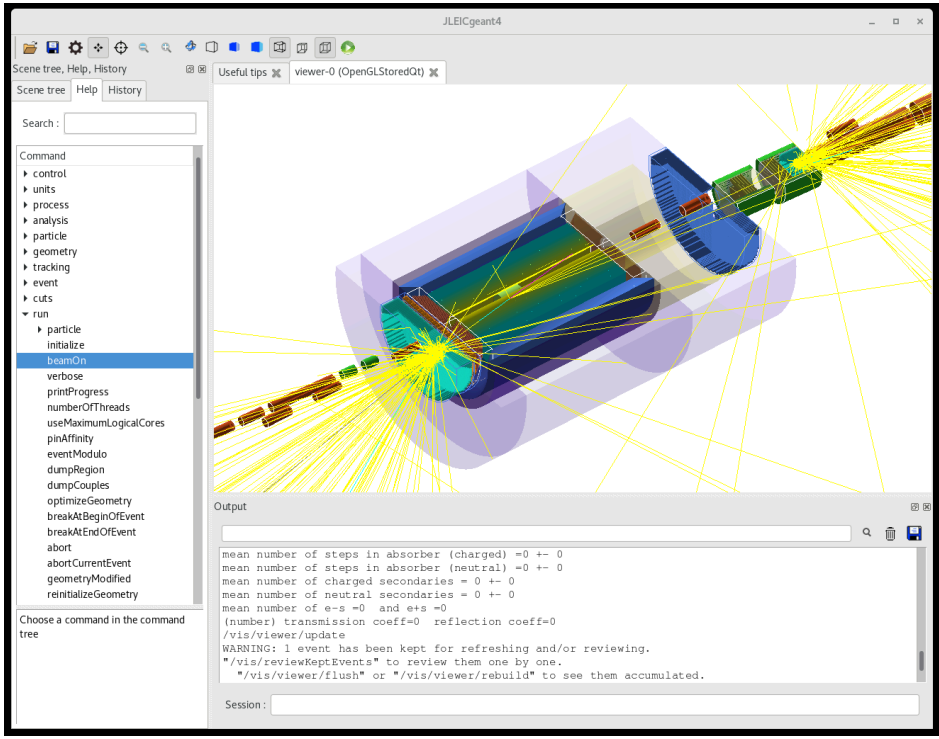
This allows the framework to easily redirect requests to alternate algorithms specified by the user at run time

[See D. Lawrence: talk at the EIC software meeting 05/21/2019]

GEANT 4 EIC



- The codename **g4e**: **Geant 4 EIC**
- **Beta** stage
- √s 100 GeV JLEIC design is implemented
- Imports CAD, accelerator group data
- Exports final Geometry in various formats
- Plain flattened analysis ready ROOT files
- Particle gun, Pythia6, Pythia8, Herwig, BeAGLE
- Work in progress: sensitive volumes, digitization, configuration



-> a candidate for a shared EIC detector sandbox software

[See Y.Furletova: talk at the EIC software meeting 07/10/2019]