Tracking software tools for EIC PID community & related topics

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EIC PID Workshop Stony Brook

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Contents

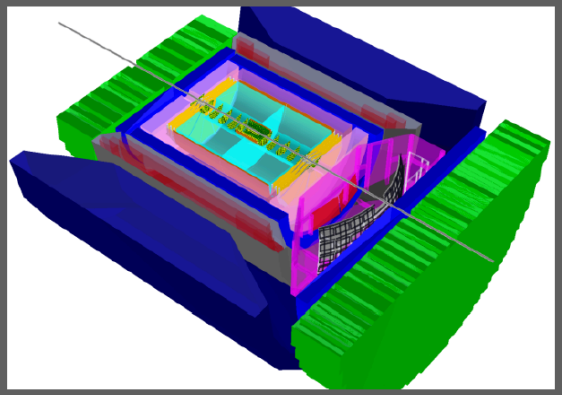
- Requirements
- Existing solutions
- Future plans
- Discussion?

What does PID need from tracking?

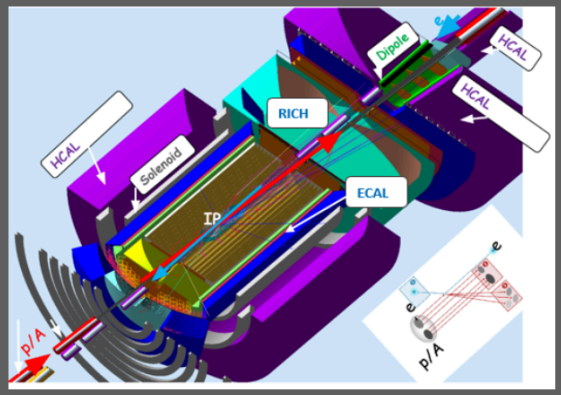
- Track fits and parameterization at various locations
  - Forward RICH
  - Backward RICH
  - DIRC
  - ...
- Vertexing (charm)
- Path length estimates (ToF)
- Estimates of magnetic field distortions (forward RICH)
- ...

General purpose detector concepts

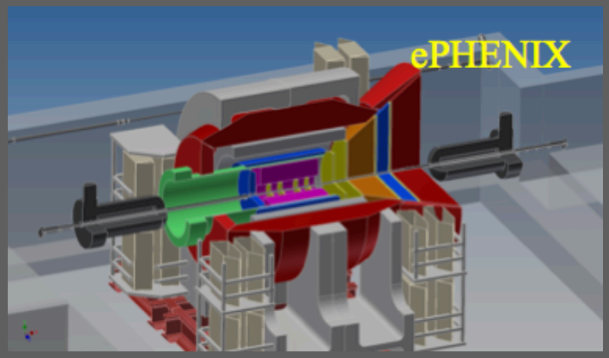
Brookhaven concept: BEAST



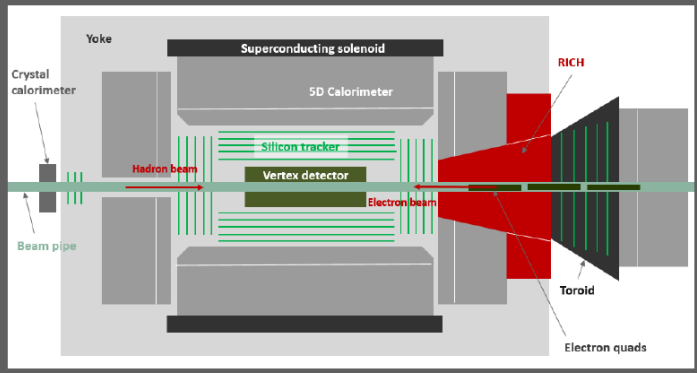
Jefferson lab concept: JLEIC



sPhenix → ePhenix



Argonne concept: TOPSiDE

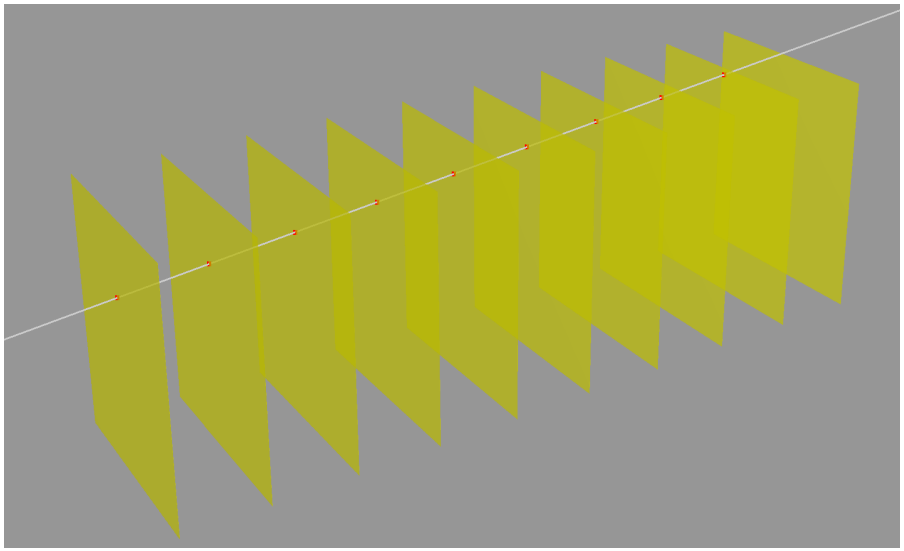


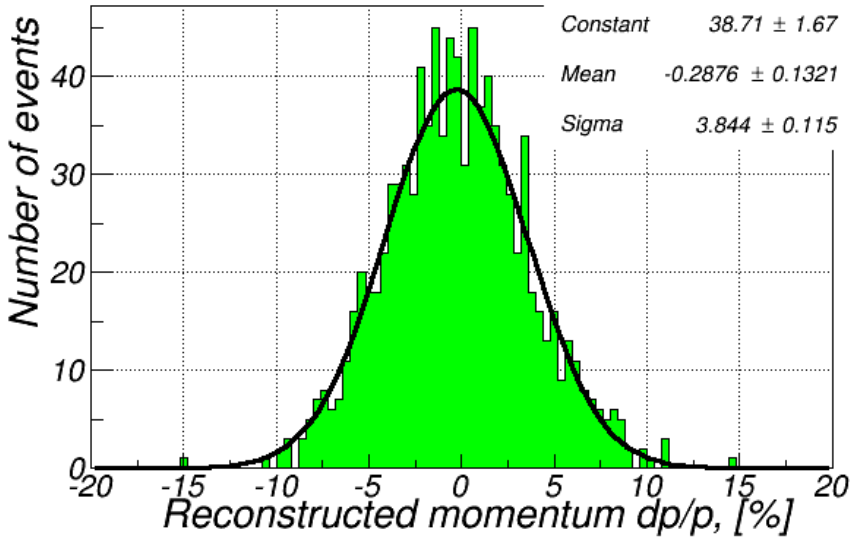
-> software frameworks are strictly bound to the detector concepts

Existing software

EicRoot example #1: basic forward tracker

Which momentum resolution for 10 GeV/c pions will I get in ~3T field with 10 MAPS layers at η=3?



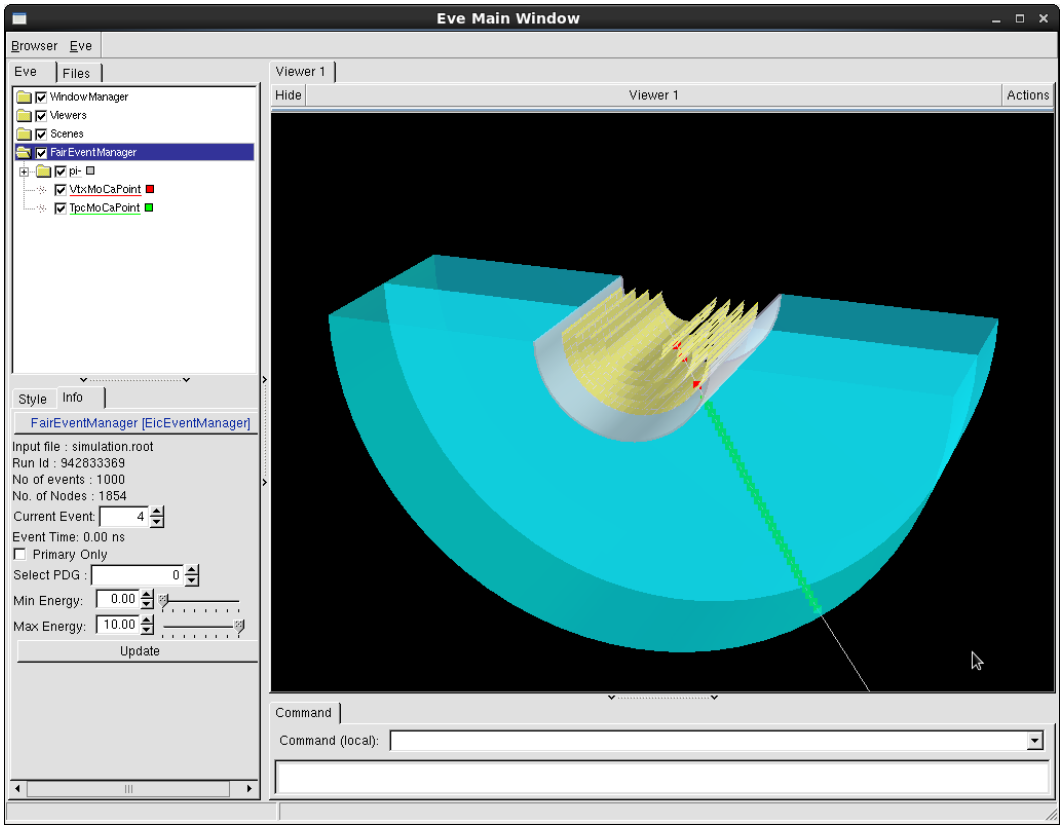


- Configurable geometry, material budget & resolutions
- Complete Kalman filter track fit

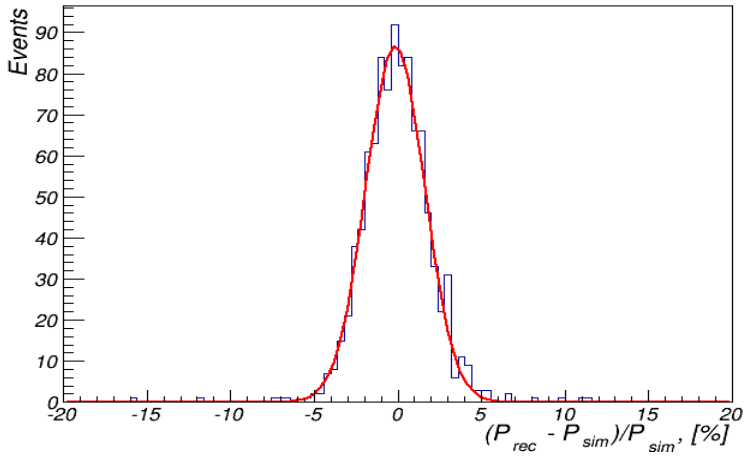
-> see examples/tracking/config.1 directory for details

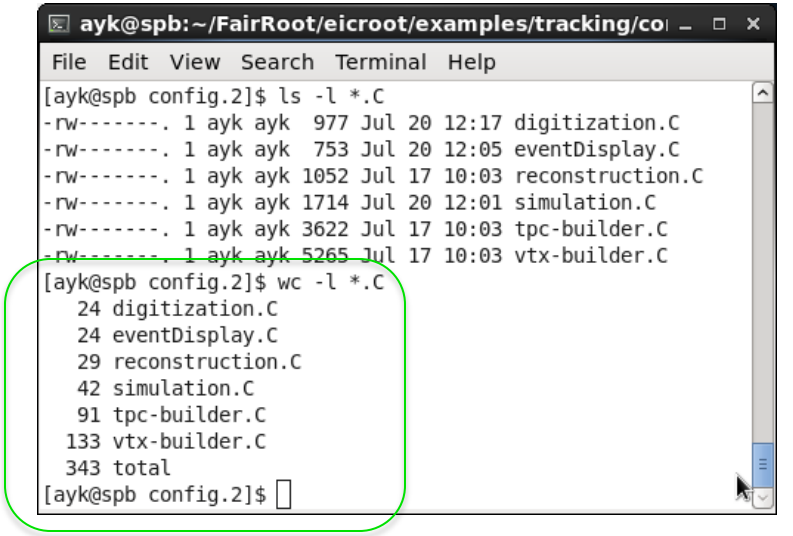
EicRoot example #2: vertex+barrel tracker

Consider now vertex tracker + TPC in 3T field; shoot 10 GeV/c pions at θ=75^{o}



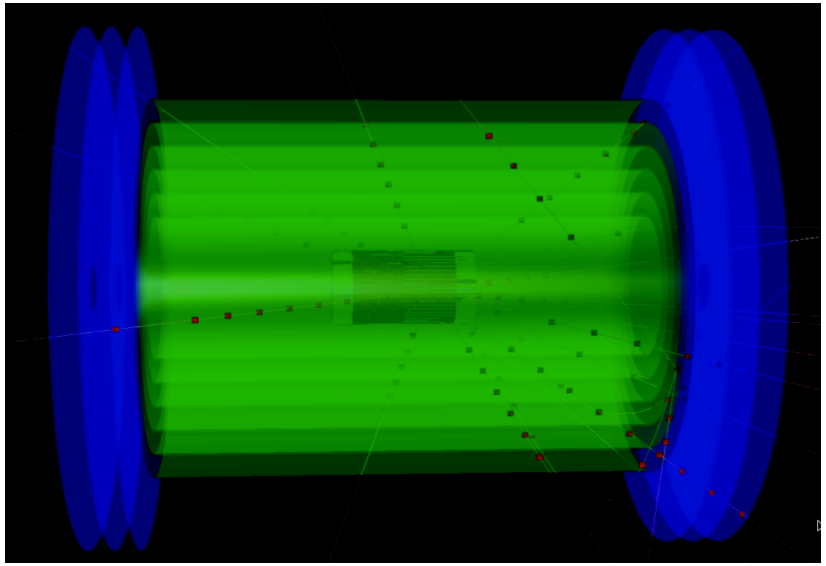
Momentum resolution



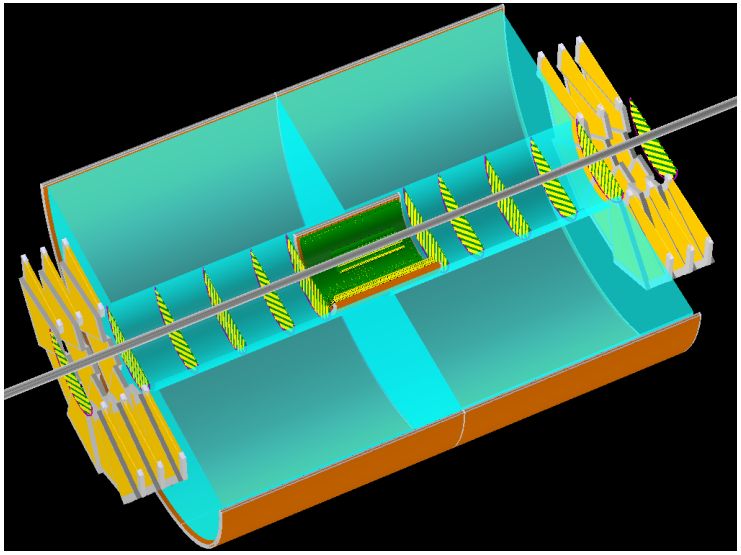


-> see examples/tracking/config.2 directory for details

EicRoot: modular geometry



- TPC completely replaced by 6 layers of cylindrical micromegas
- No-structure GEM disks in the endcap

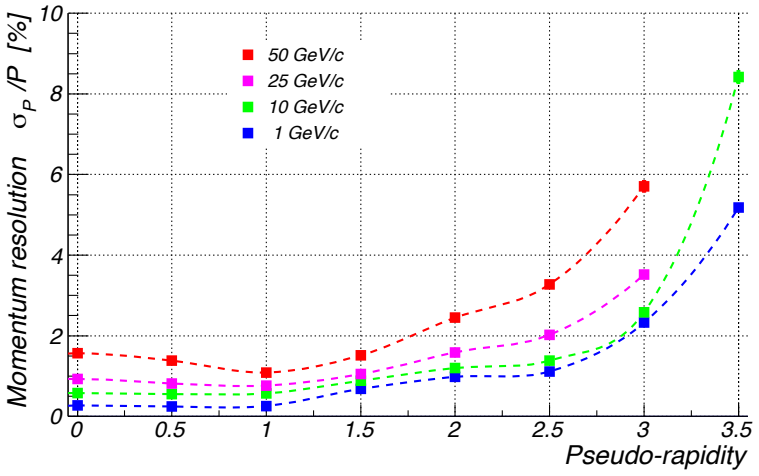


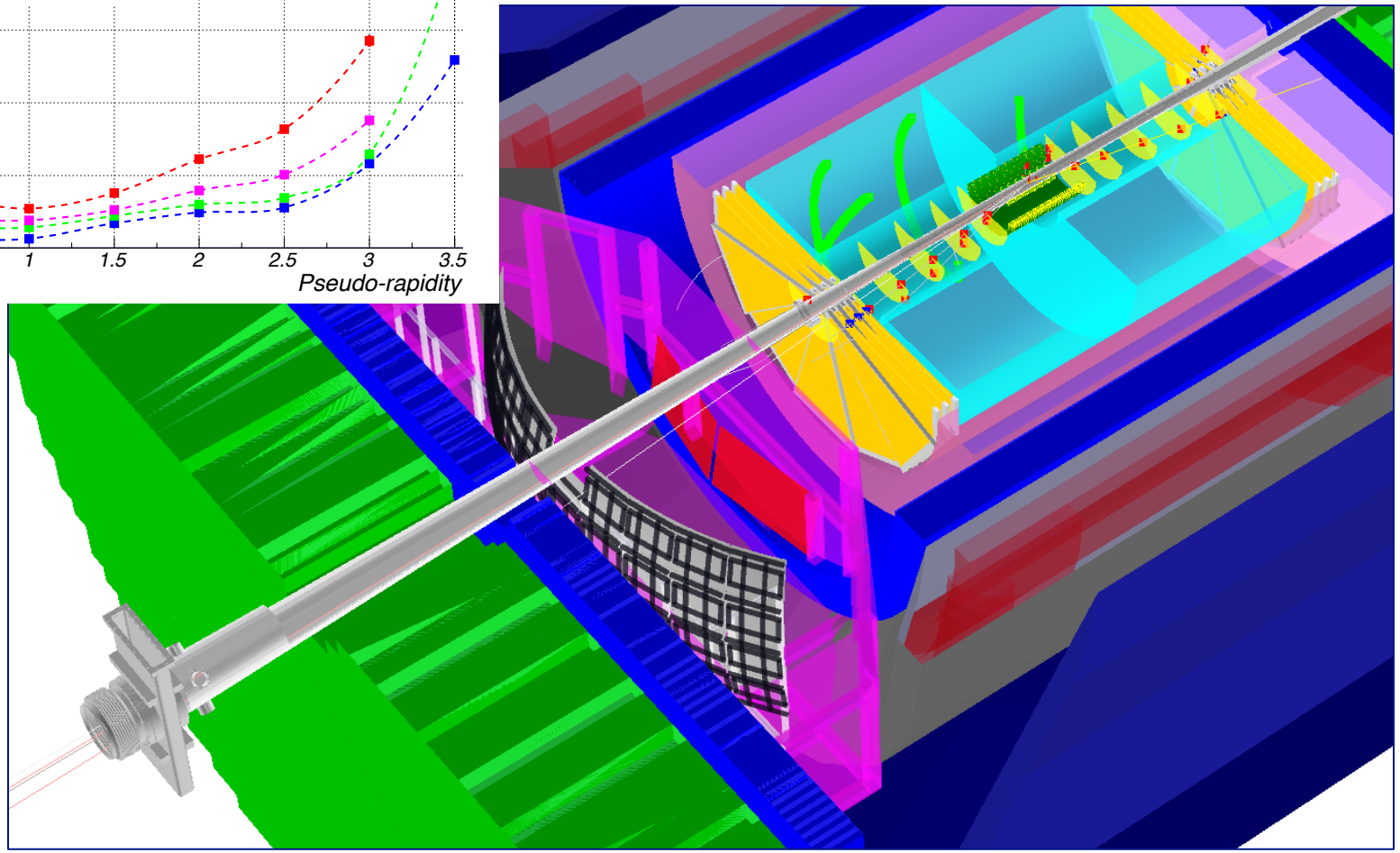
- TPC with reduced outer radius is just appended by few micromegas layers

-> reconstruction codes will work the same way as before once respective ROOT steering scripts modified accordingly

EicRoot: BeAST momentum resolution

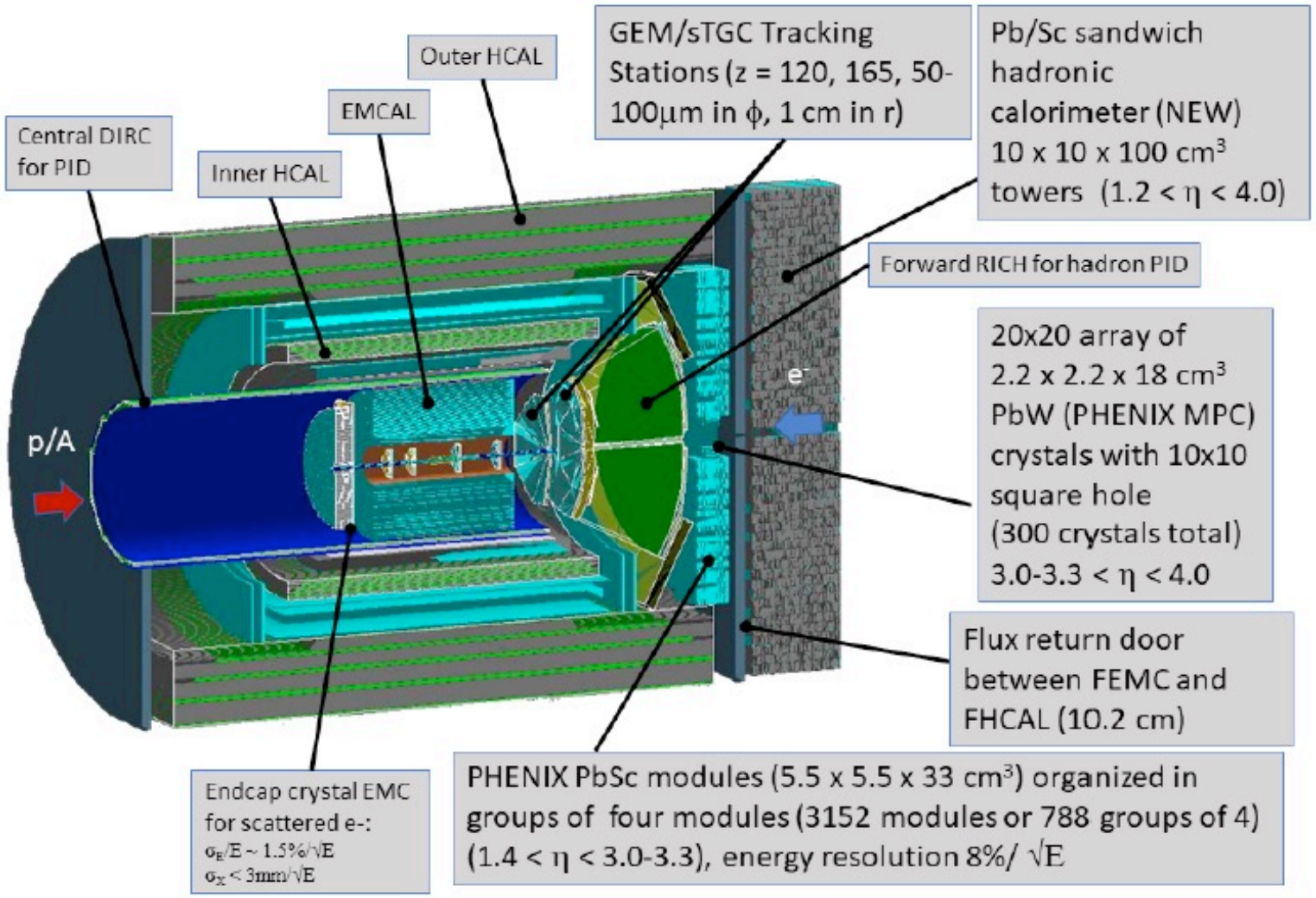
-> be aware: IR geometry is a fast moving target!





hadronic calorimeters | e/m calorimeters | RICH detectors | silicon trackers | GEM trackers | TPC

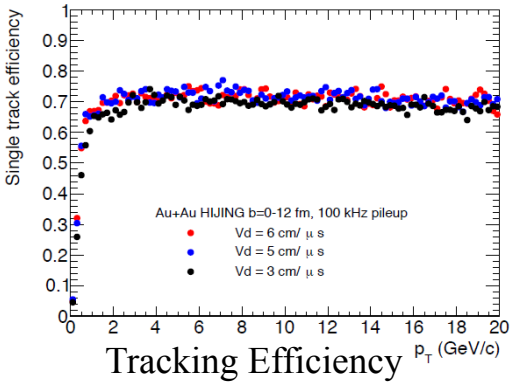
fun4all: a complete software suite



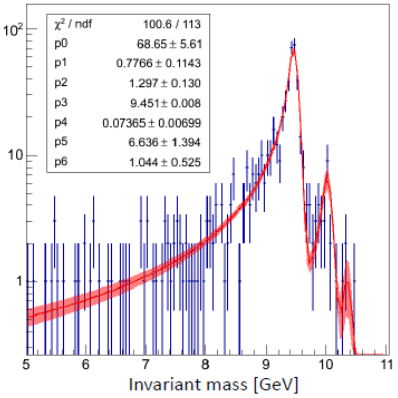
Fully developed G4 model, including digitization and reconstruction

by Chris Pinkenburg

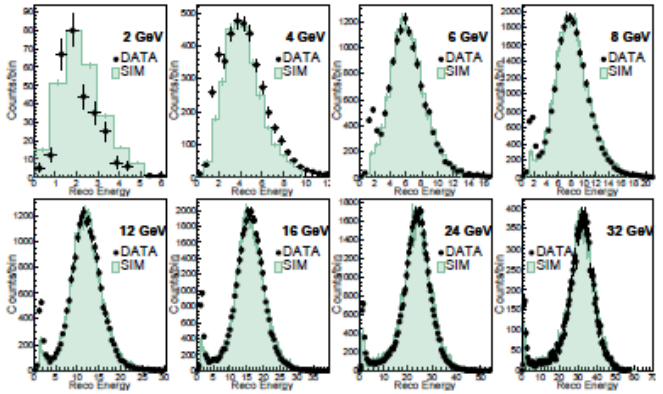
fun4all: case study examples



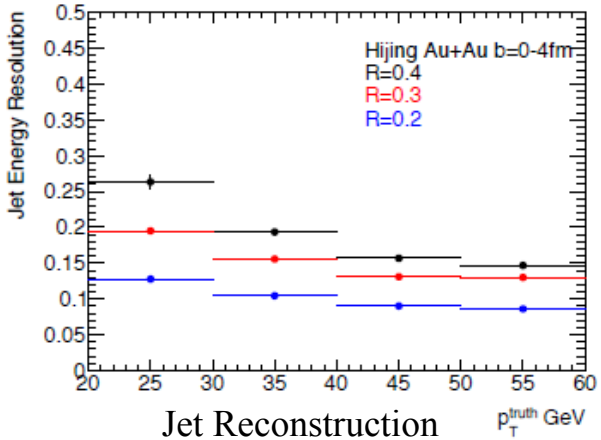
Tracking Efficiency



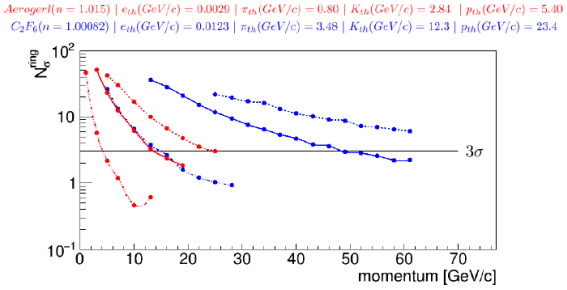
Upsilon Reconstruction



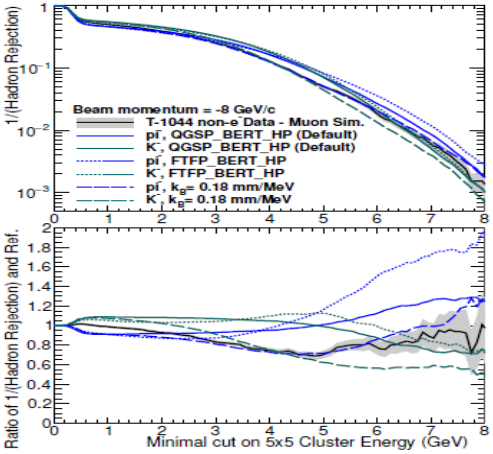
Hadronic Calorimeter Test Beam



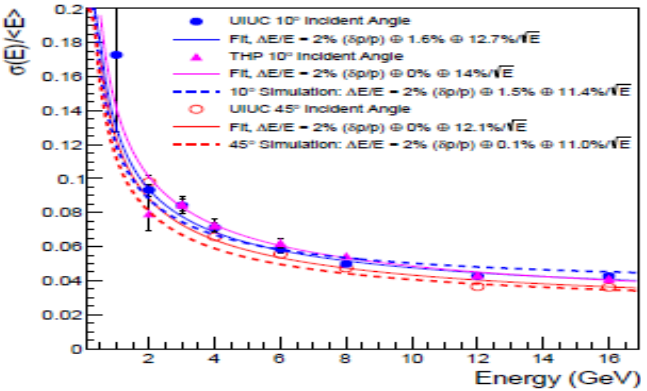
Jet Reconstruction



Rich PID



EmCal Hadron Rejection



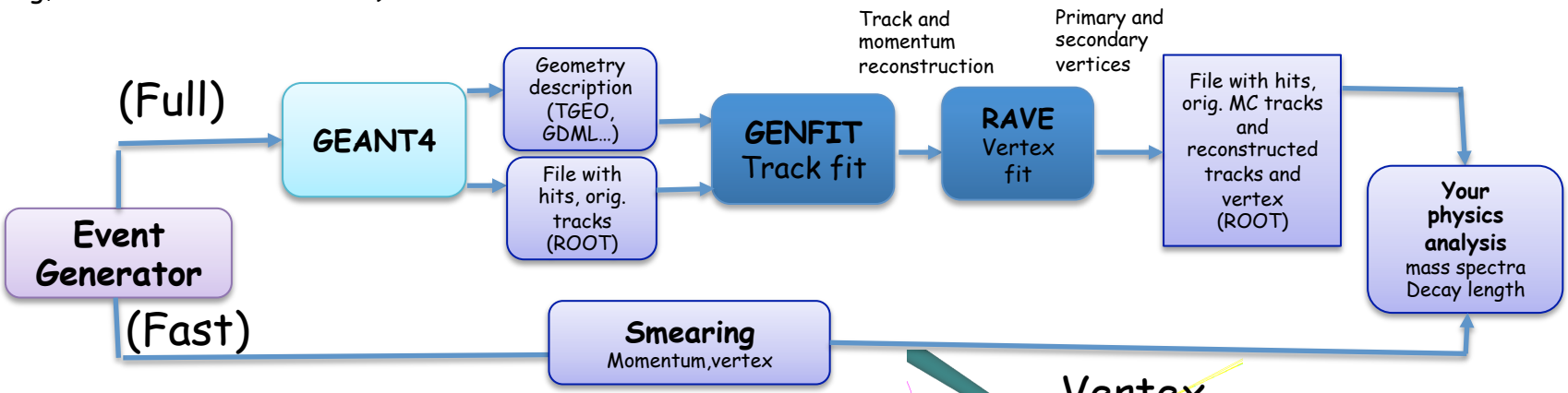
EmCal Test Beam

Contains all you need to simulate and analyze data NOW

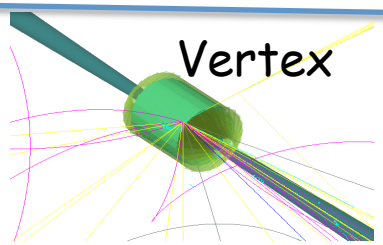
by Chris Pinkenburg

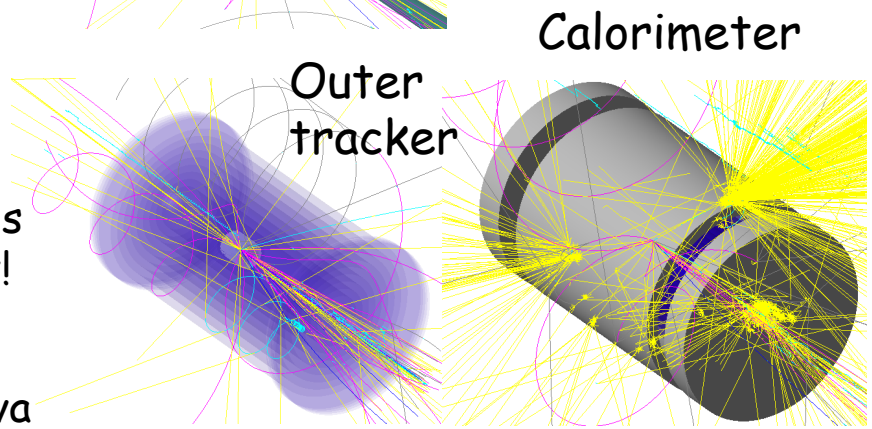
RECONSTRUCTION CHAIN (FOR LDRD)

This chain has been developed to validate tracking and vertex parameters and was used for JLAB LDRD- 1601/1701 project ("Nuclear gluons with charm at EIC") to estimate a detector effect on a charm reconstruction. (Many thanks to "software consortium", especially to Whitney Armstrong, for ideas and discussions)



- Geometry created/described **inside GEANT4**, and then distributed via **Root TGEO**
- All parts are connected via intermediate **Root files** (ntuples)
- Event generators (Pythia6, Herwig 6 and 7) HEPMC, Lund format.
- Original (MC) tracks are traced down to analysis
- No pattern recognition ! Only track fit and vtx!



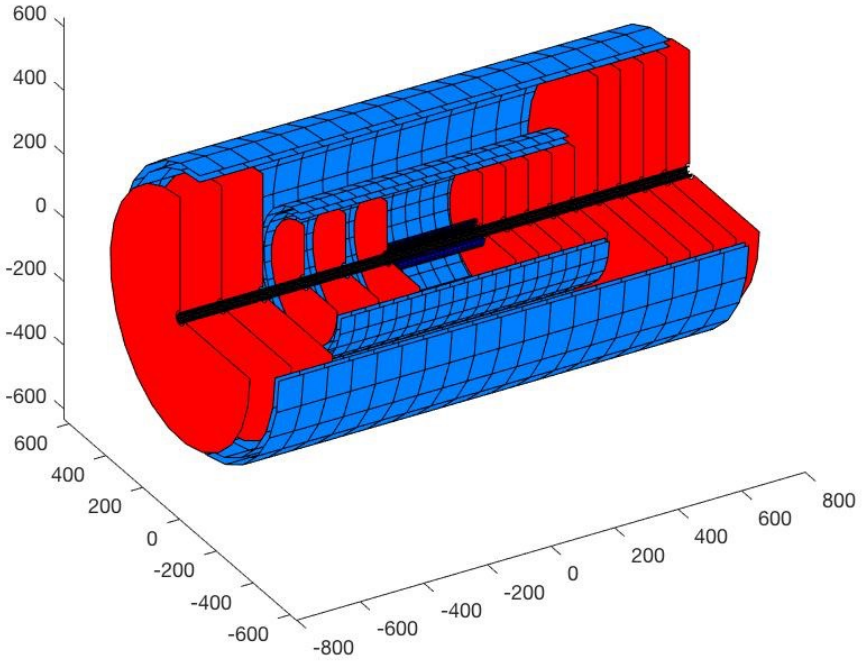


Yulia Furletova

https://wiki.jlab.org/nuclear_gluons/

Silicon tracker Simulation Tools

LiC Detector Toy enables fast, initial optimizations of tracking detector configuration concepts



- Originally developed for ILC studies (Regler et al, 2008),
- Helix track model,
- Multiple scattering,
- Full track reconstruction from digitized hits using a Kalman filter.

Successfully used by eRD16 for their thin silicon (MAPS) efforts, (being) extended to vertexing and timing studies.

slide provided by Ernst Sichtermann

Path forward: Docker containers

eRD20 container project

Container technology

- **Container** := very lightweight Virtual Machine
- **Main players**
  - **Docker** industry standard, requires admin privilege on host
  - **Singularity** standard on OSG, can run entirely in unprivileged mode
  - **Shifter** (NERSC only)

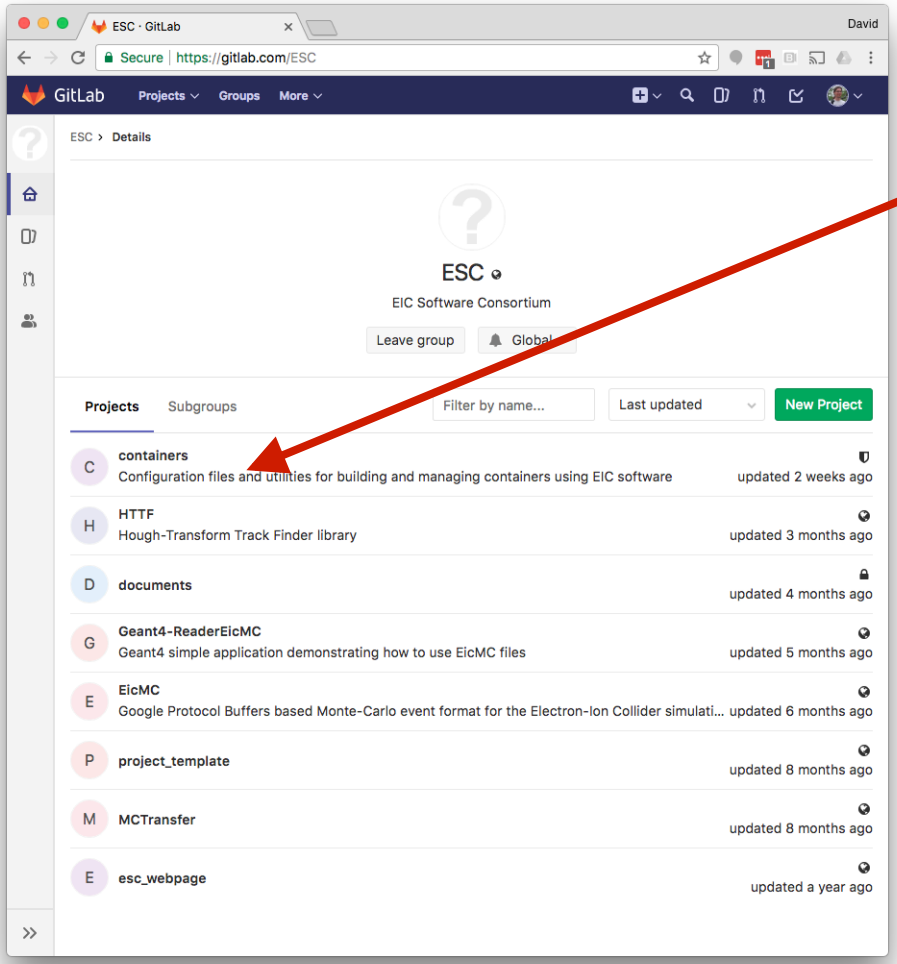
Benefits for EIC user community

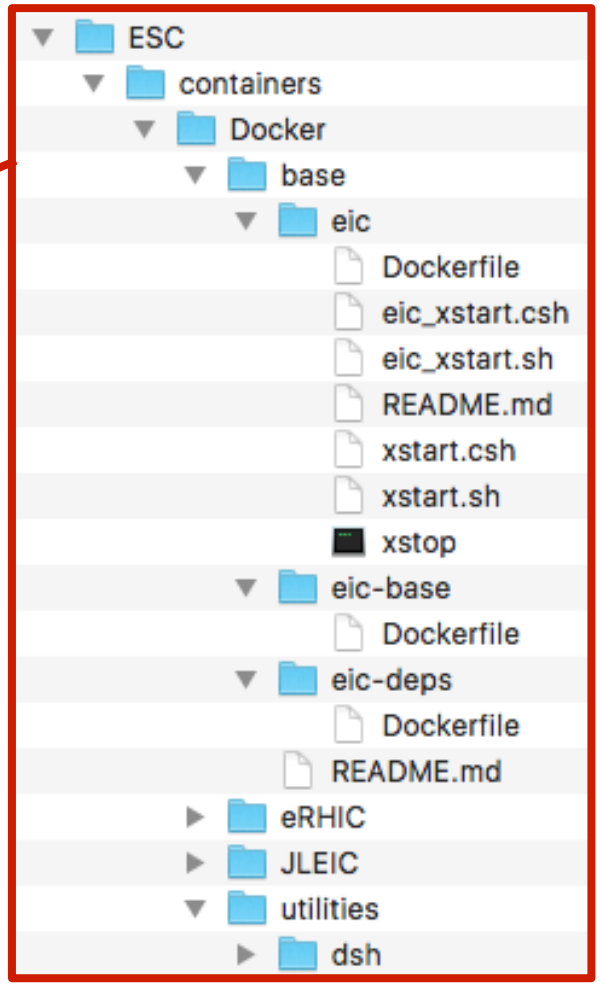
- Allow EIC users to run the same software under standardized environment on any Linux, Mac OS or Windows machine, eventually including GRID sites, commercial cloud systems, and HPC resources
- Provide consistency between software generated at different facilities
- Make it easier for new users to start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

Community document draft released few weeks ago *by D. Blyth (ANL), W. Deconinck (William & Mary), MD (Jlab), A. Dotti (SLAC), AK (BNL), and* ***D. Lawrence (JLab)***

eRD20 container repository on GitLab

Source files for generating EIC containers are available: *https://gitlab.com/ESC*





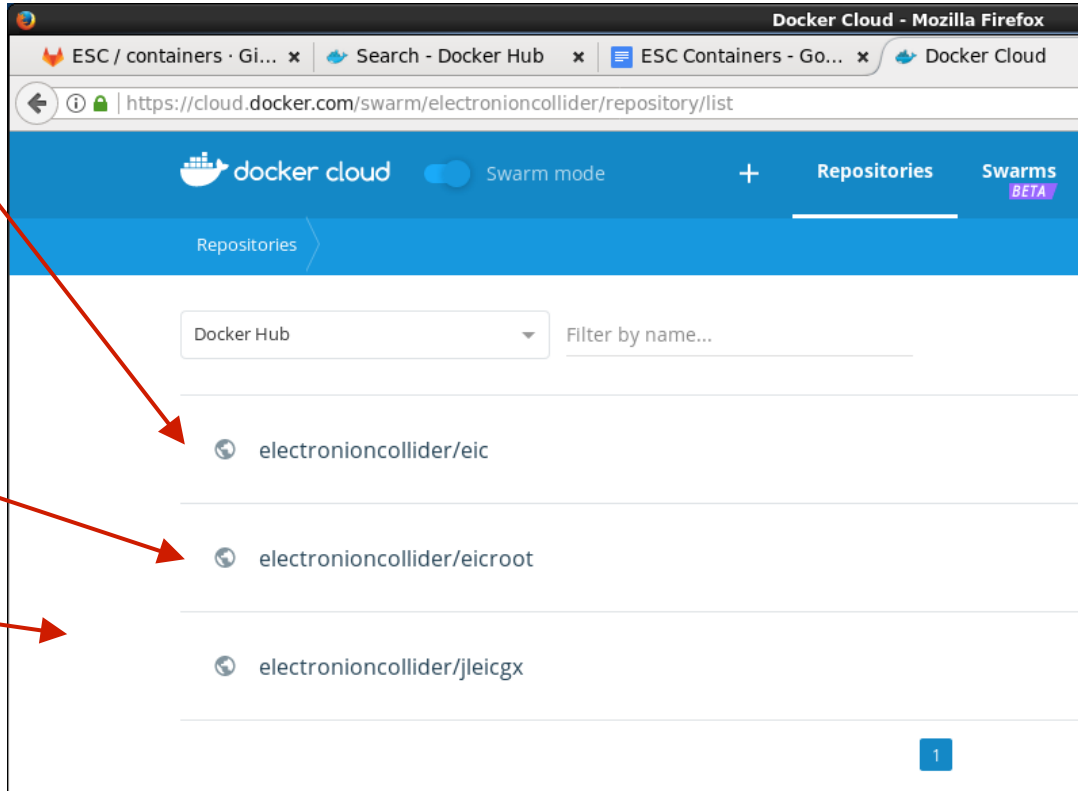
eRD20 container images on Docker cloud

https://cloud.docker.com/swarm/electronioncollider/repository/list

Generic base image
- based on CentOS 7
- includes:
  - ROOT 6
  - Geant4 10.3.3
  - CLHEP 2.3.4.5
  - support for OpenGL graphics

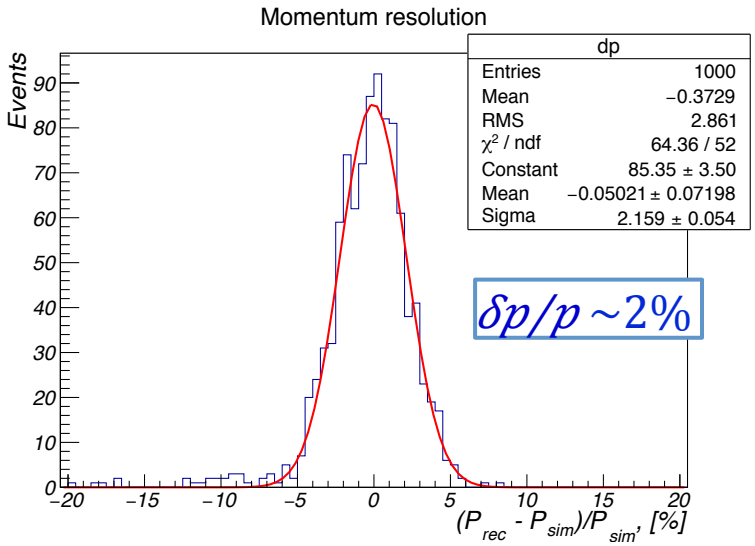
eRHIC software
- EicRoot

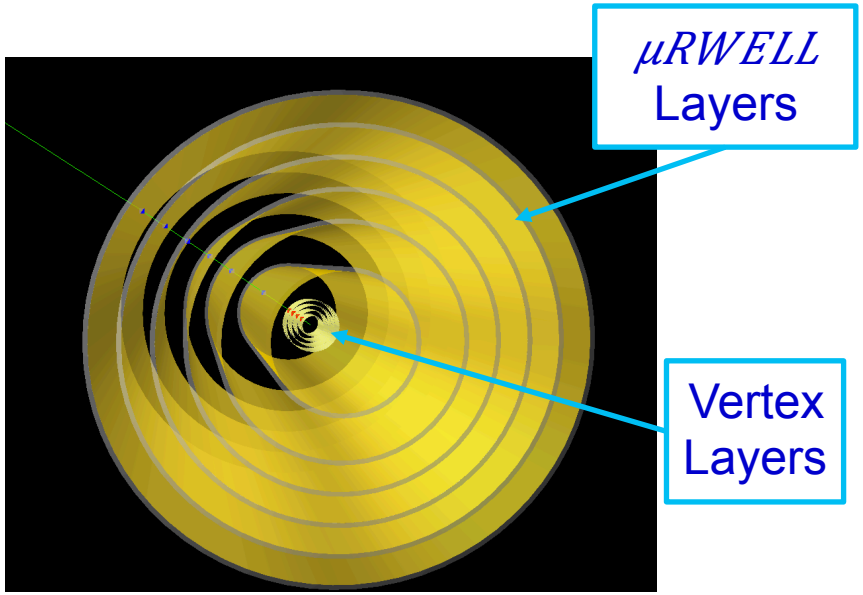
JLEIC software
- GEMC



Does it work in general? YES!

- Initial simulation Investigates central tracking system consisting of silicon vertex detector and cylindrical μRWELL operating in μTPC mode within EicRoot.
  - μTPC mode will allow reconstruction of Z track and could reduce material budget from more traditional central tracking solutions.
- Silicon vertex detector
  - **Four** silicon layers each with **X-Y** pixel resolution of **20 μm – 20 μm**
- Cylindrical μRWELL Barrel Tracker

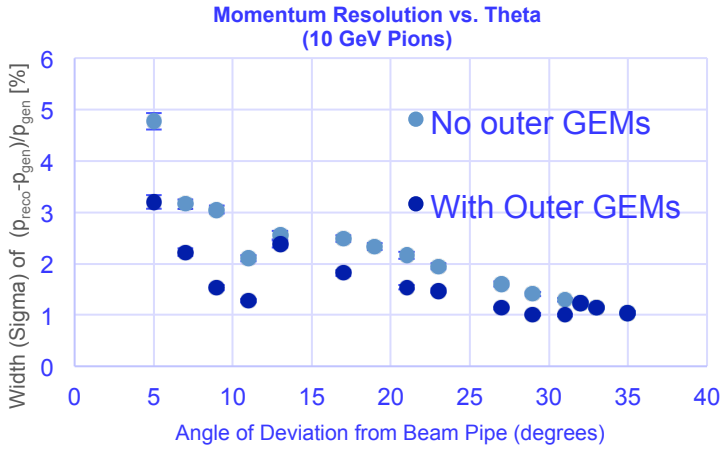


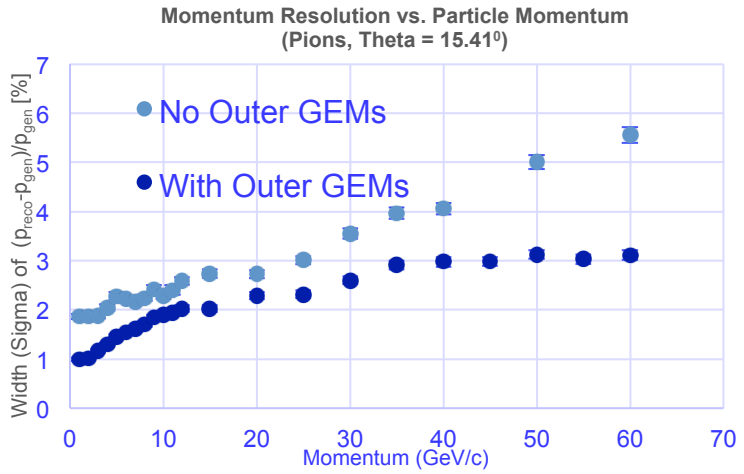


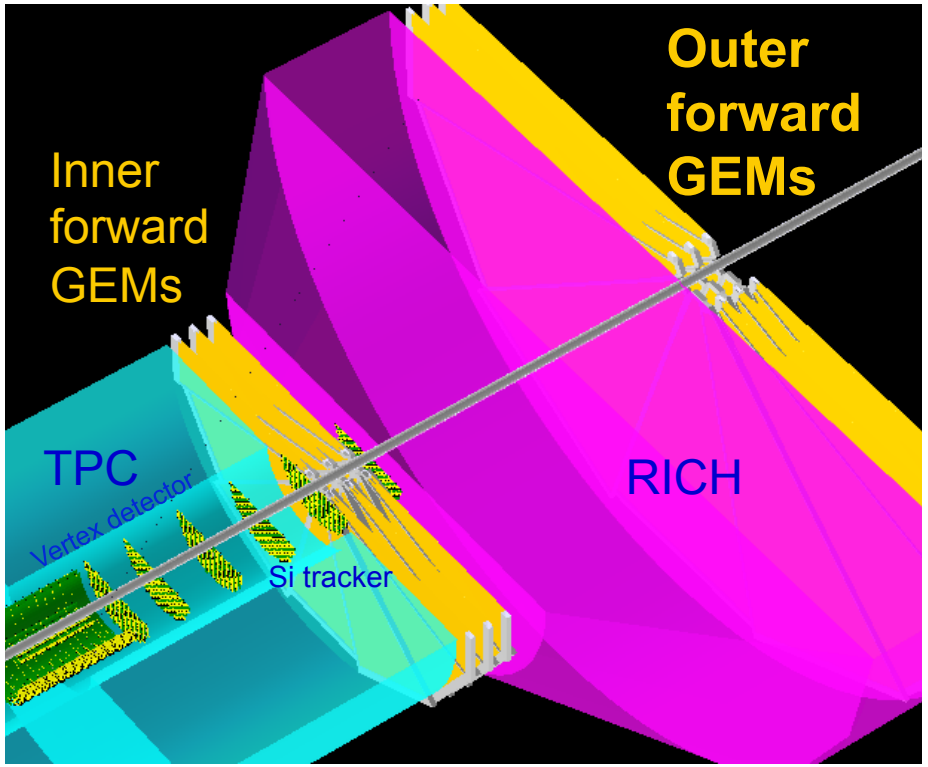
by Matt Posik

Does it work in general? YES!

- Impact of the outer forward GEM detectors on seeding the RICH ring reconstruction in BeAST geometry







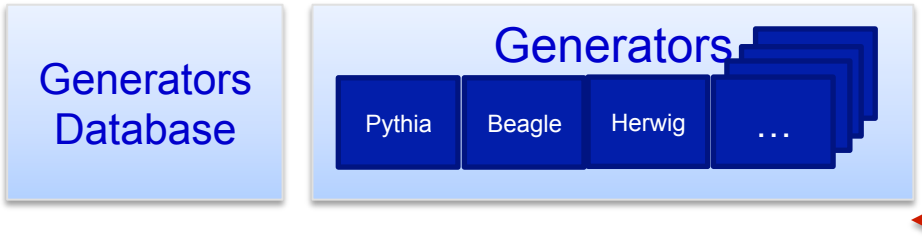
by Matt Bomberger

Grand unification, yet another try

by Dmitry Romanov, David Lawrence & others (JLAB)

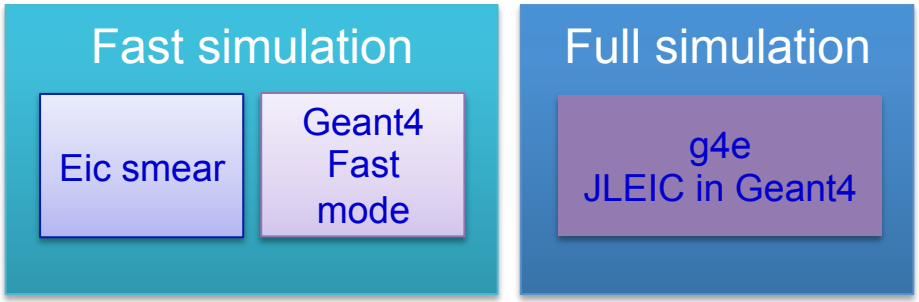
Overview

Database with various MC samples



(1)

BNL & Jlab effort on Fast detector prototyping



g4e = Geant 4 EIC
C++ genue GEANT4 with JLEIC detector in it

(2)

ejana = EIC Jana
Community reference reconstruction

(3)

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

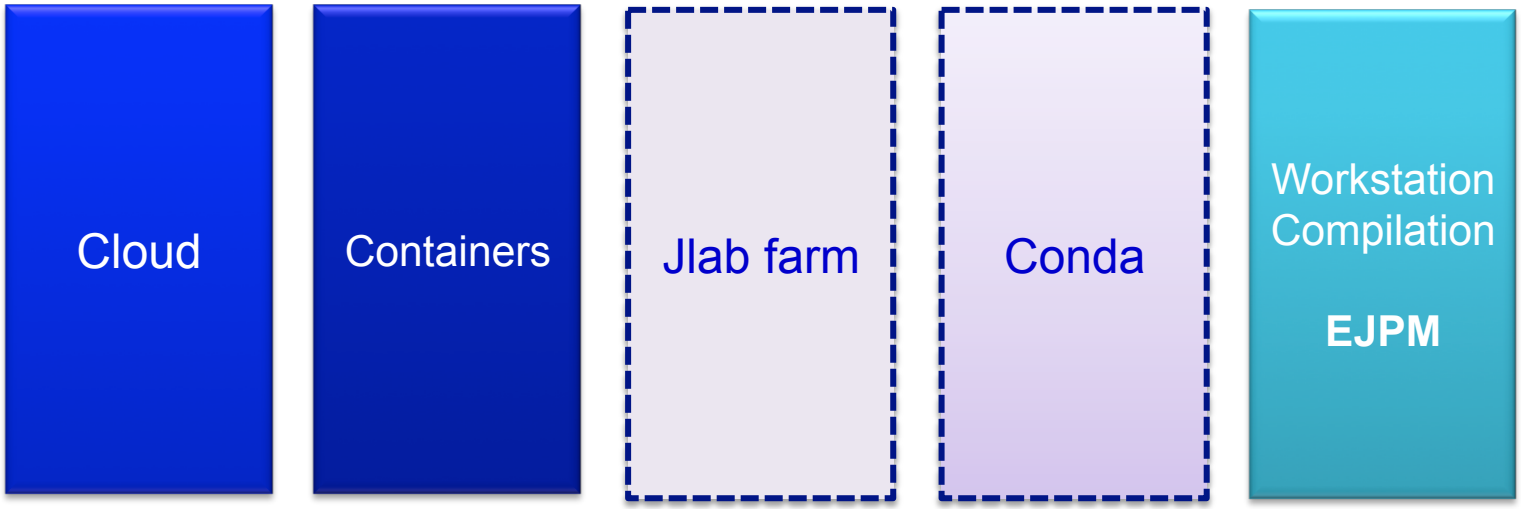
by Dmitry Romanov

Software distribution

NO EFFORT AT ALL
Novice

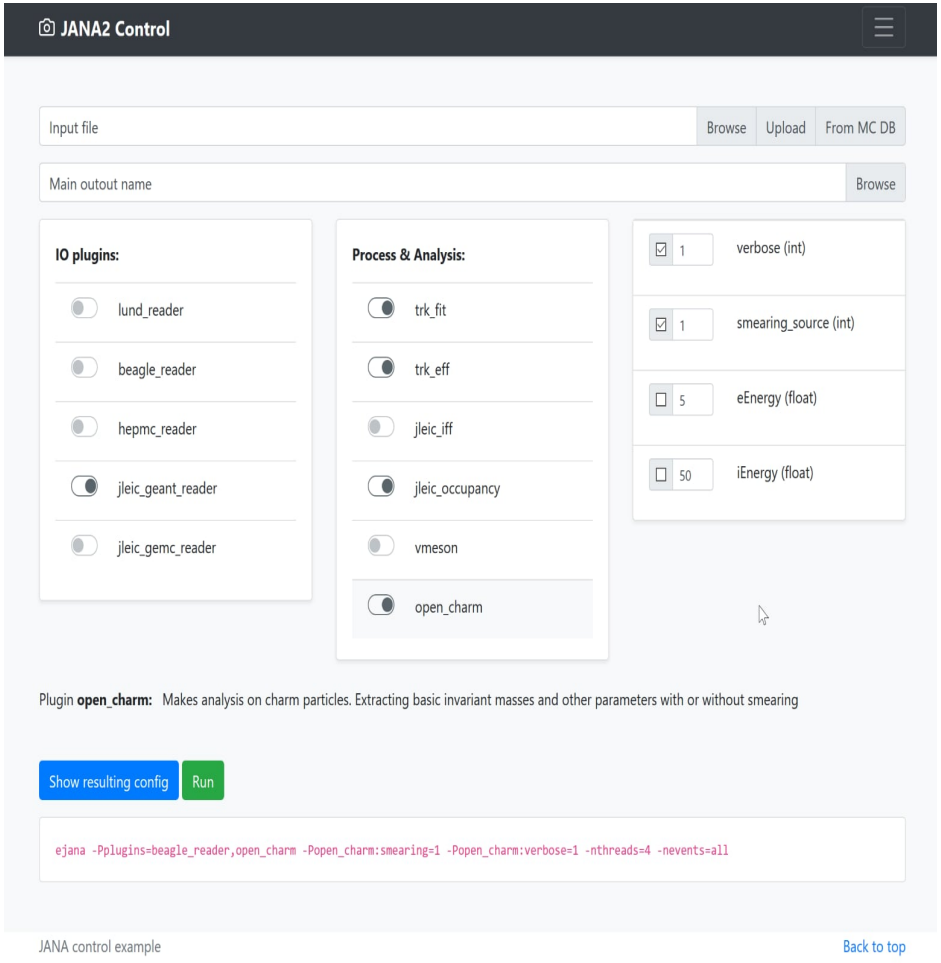
Some effort
Experts

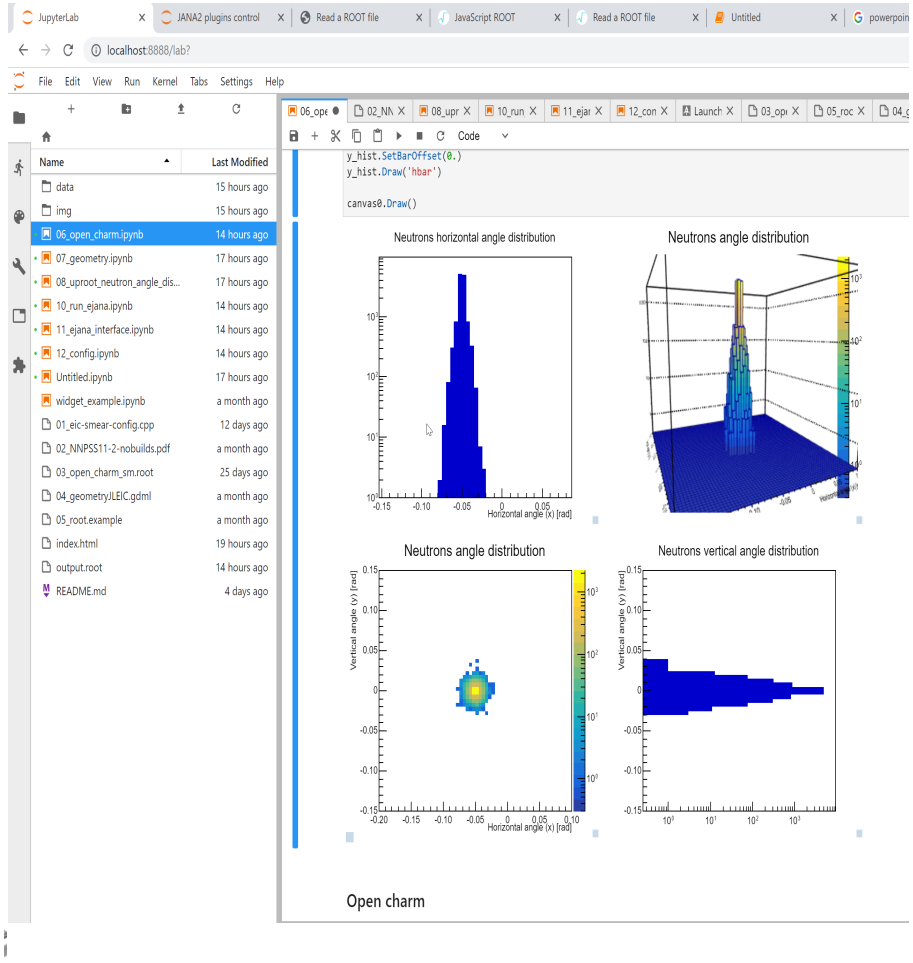
Efforts required axis



by Dmitry Romanov

User interface





Workflow oriented interactive environment based on Jupyter

by Dmitry Romanov

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)

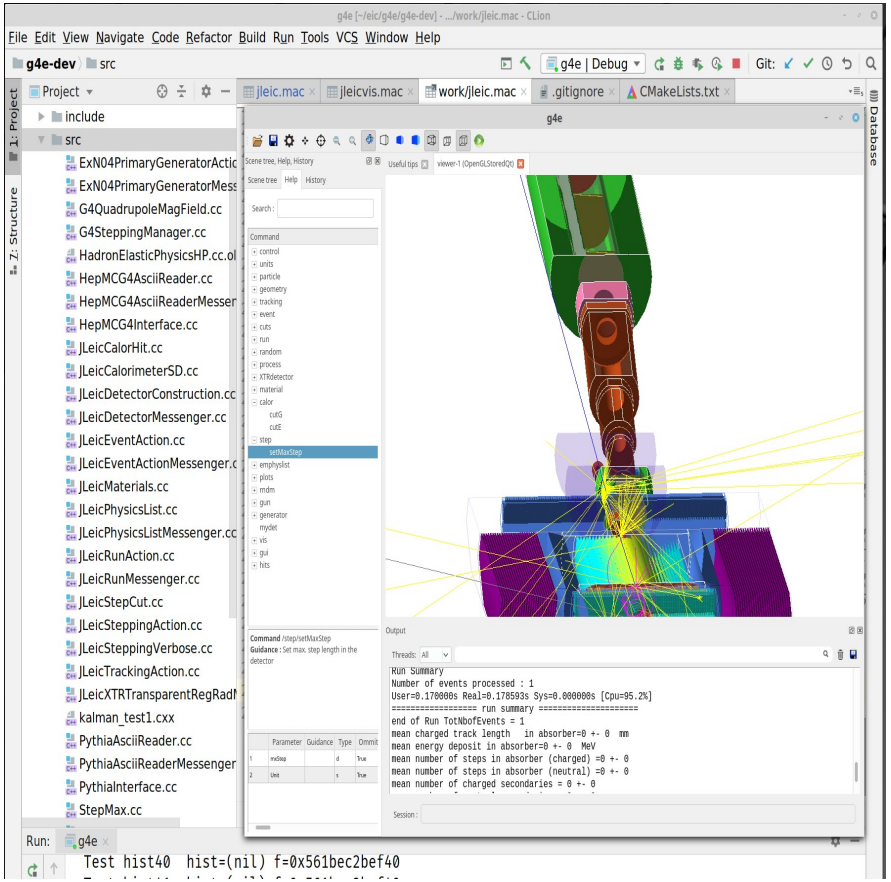
Any existing C++ (or even others) code can be:

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

by Dmitry Romanov

Geant 4 EIC

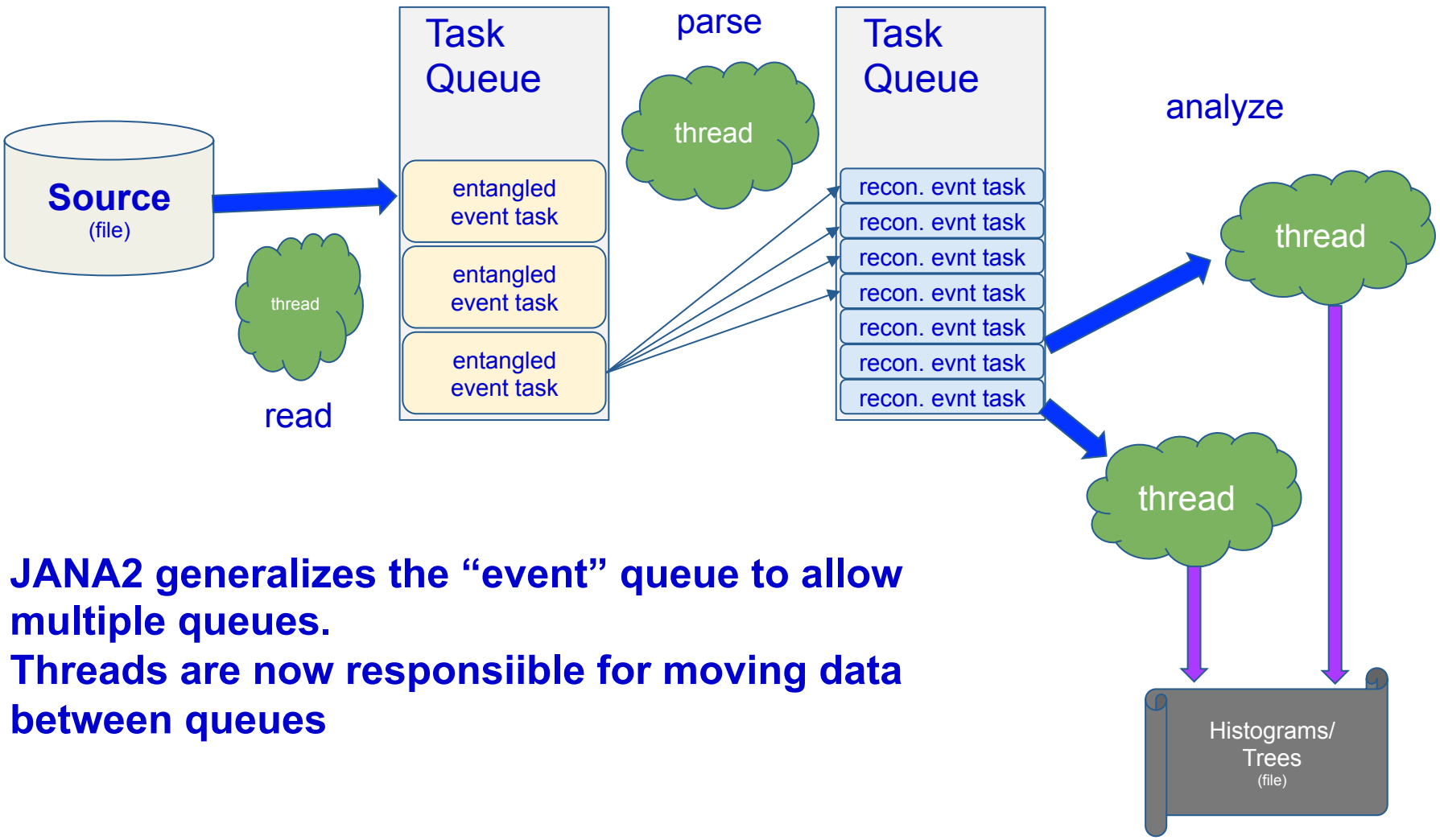
- The codename **g4e** – stands for **Geant 4 EIC**
- **Beta** stage
- √s 100 GeV design is implemented
- Imports CAD, accelerator group data
- Exports final Geometry in various formats
- Plain flattened analysis ready ROOT files



For those who prefer scripting over compilation
***Geant 4 python** can be used*

by Dmitry Romanov

JANA(2)



JANA2 generalizes the "event" queue to allow multiple queues.
Threads are now responsiible for moving data between queues

by David Lawrence

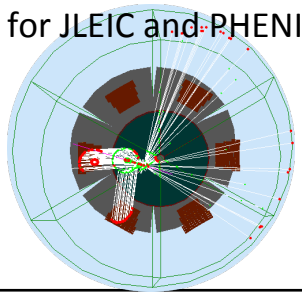
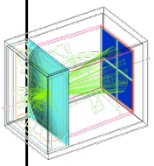
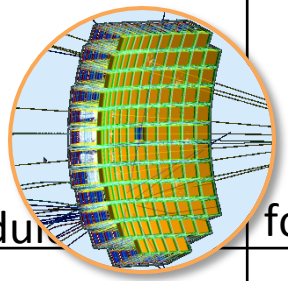
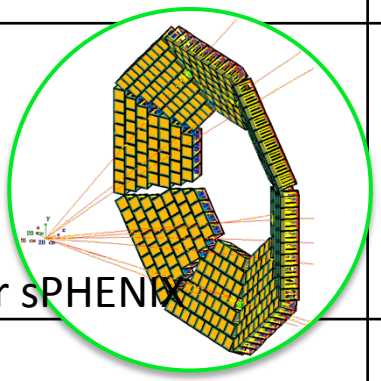
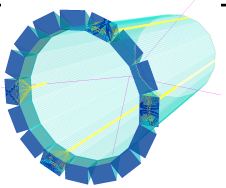
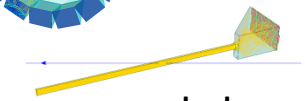
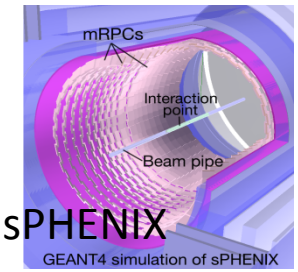
JANA(2)

- Provide mechanism for many physicists to contribute code to the full reconstruction program
- Implement multi-threading efficiently and external to contributed code
- Provide common mechanisms for accessing job configuration parameters, calibration constants, etc...

by David Lawrence

	Analysis / Event Reconstruction
dRICH	**general:** **standalone c++ and ROOT** **Input:** **GEMC root file and Fun4All root file**, others can be supported **Algorithm:** **Inverse Ray Tracing algorithm** in c++ class **Future:** easy integration for any c++ based framework
mRICH	**general:** **standalone c++ and ROOT** **Input:** **GEMC root file,** others can be supported **Algorithm:** **Hough Transform Algorithm** in c++ for simple study **Likelihood Analysis** in c++ for real experiments **Future:** easy integration for any c++ based framework
DIRC	**general:** **standalone c++ and ROOT** **Input:** **customized root file,** others can be supported **Algorithm:** **geometrical reconstruction, time-based imaging** **Future:** easy integration for any c++ based framework
psTOF	**general:** **standalone c++ and ROOT** **Input:** **Fun4All root file,** others can be supported **Algorithm:** **Time reconstruction parametrized from data, path-length using Runge-Kutta in a Kalman-Filter track fit** in c++ **Future:** easy integration for any C++ based framework

Simulation

	Generic Geant4	GEMC	Fun4all	eicROOT
dRICH		for JLEIC and PHENIX 	planned	
mRICH		for JLEIC  single modul 	for sPHENIX 	in progress
DIRC	 Full setup  prototype	planned	planned	straightforward (from FairROOT)
psTOF			for sPHENIX 	

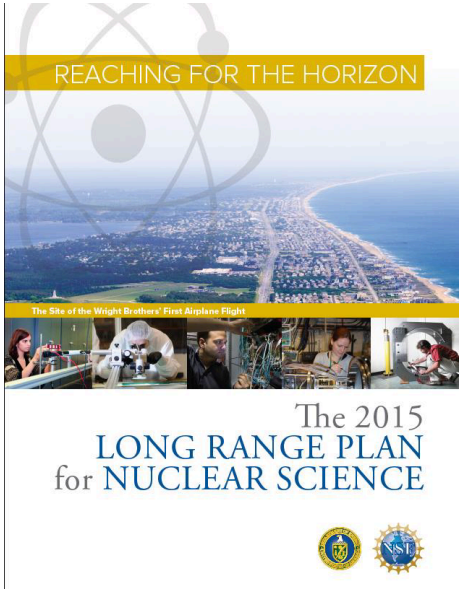
Conclusions

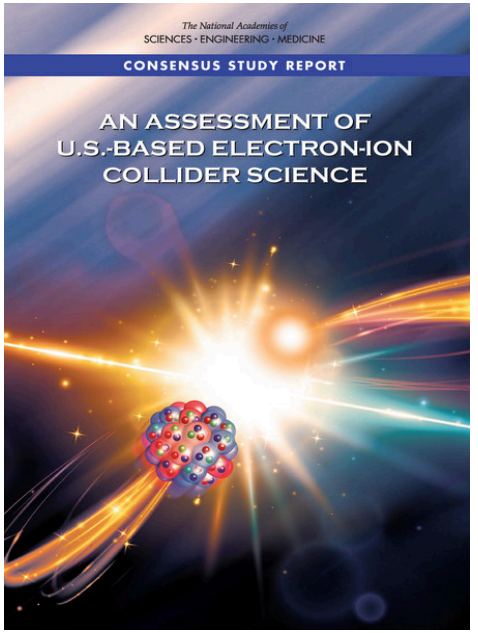
- Some “tracking for PID” tools do exist: help yourself & use them (or ask experts to provide the tracking estimates)
- Write & contribute your own detector component codes ...
- ... but be aware that EIC software paradigm may change in the near future

Backup

EIC timelines

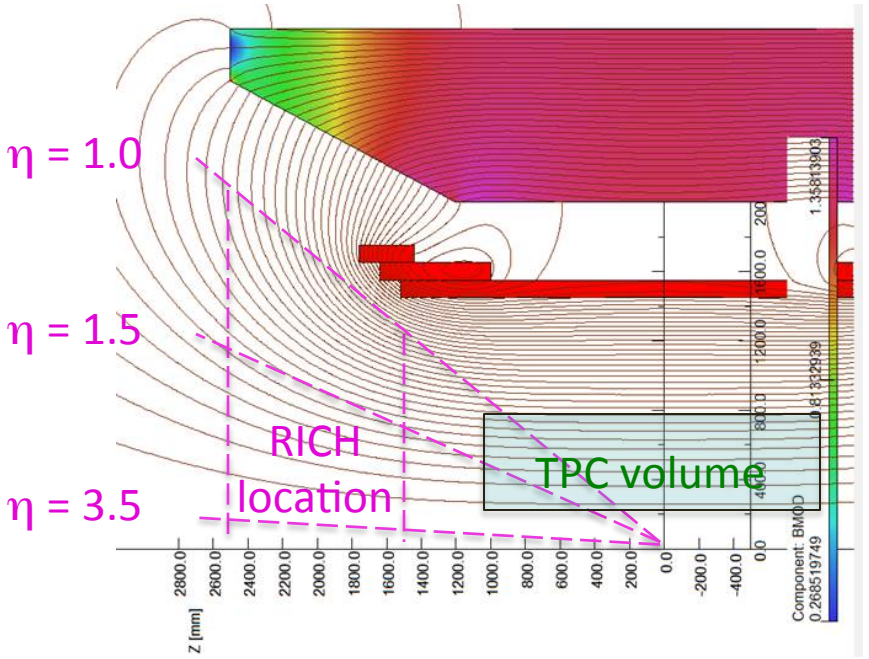
- 2015 NSAC (NP) Long-Range Plan:
  - "We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction."
- 2018 NAS review:
  - "The committee finds that the science that can be addressed by an EIC is compelling, fundamental and timely."
- President's budget request for FY2020:
  - Critical Decision-0, Approve Mission Need, is planned for FY2019





Main detector magnet

- Prefer open solenoid with a large (3T) field:
  - ideal for a TPC
  - sufficient B*dl integral at $|\eta|$ ~ 3.0..3.5
  - almost azimuthally-symmetric acceptance
  - minimal adverse effect on the electron beam
  - no passive material in the acceptance



- However:
  - too high low-momentum particle cutoff
  - large inhomogeneous fringe field ...
  - ... causing severe problems for the gaseous RICH ...
  - ... which one can try to mitigate by shaping up the field
  - large stray fields, which may require clamping ...
  - ... therefore causing field degradation in the RICH ...
  - ... and large asymmetric forces on the support system
  - photo-sensors do not like magnetic field in general ...
  - ... and there is a huge difference between say LAPPD performance in 1.5T and 3.0T magnetic field ...
  - ... but modern MCPs with <10μm pores may work well?