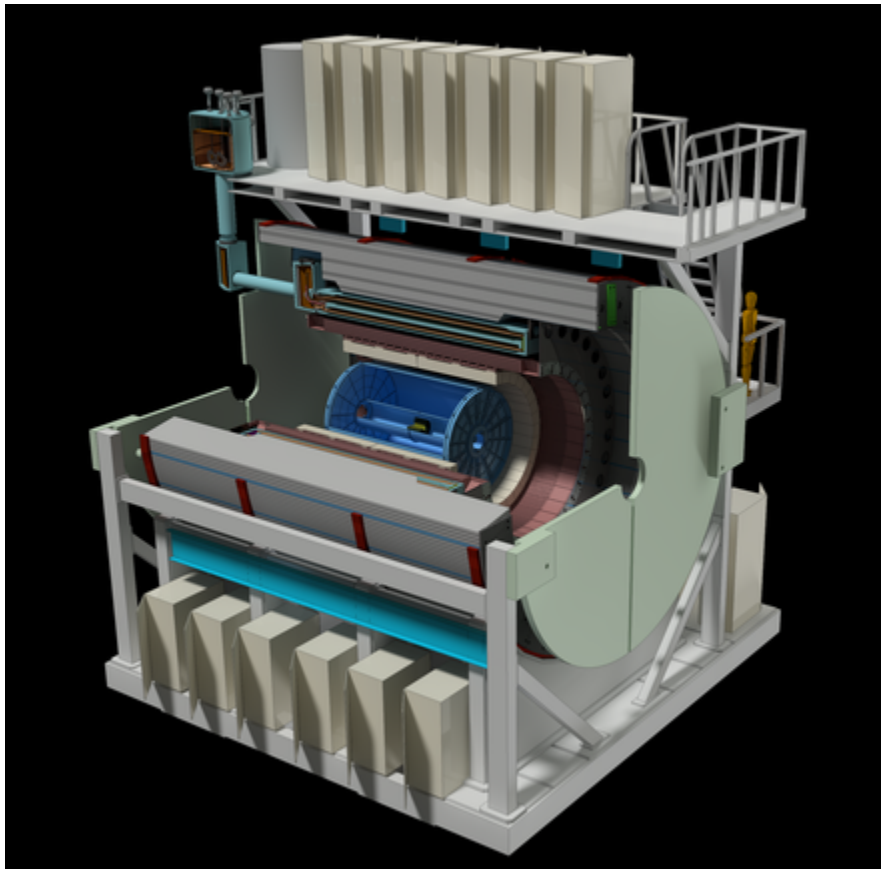
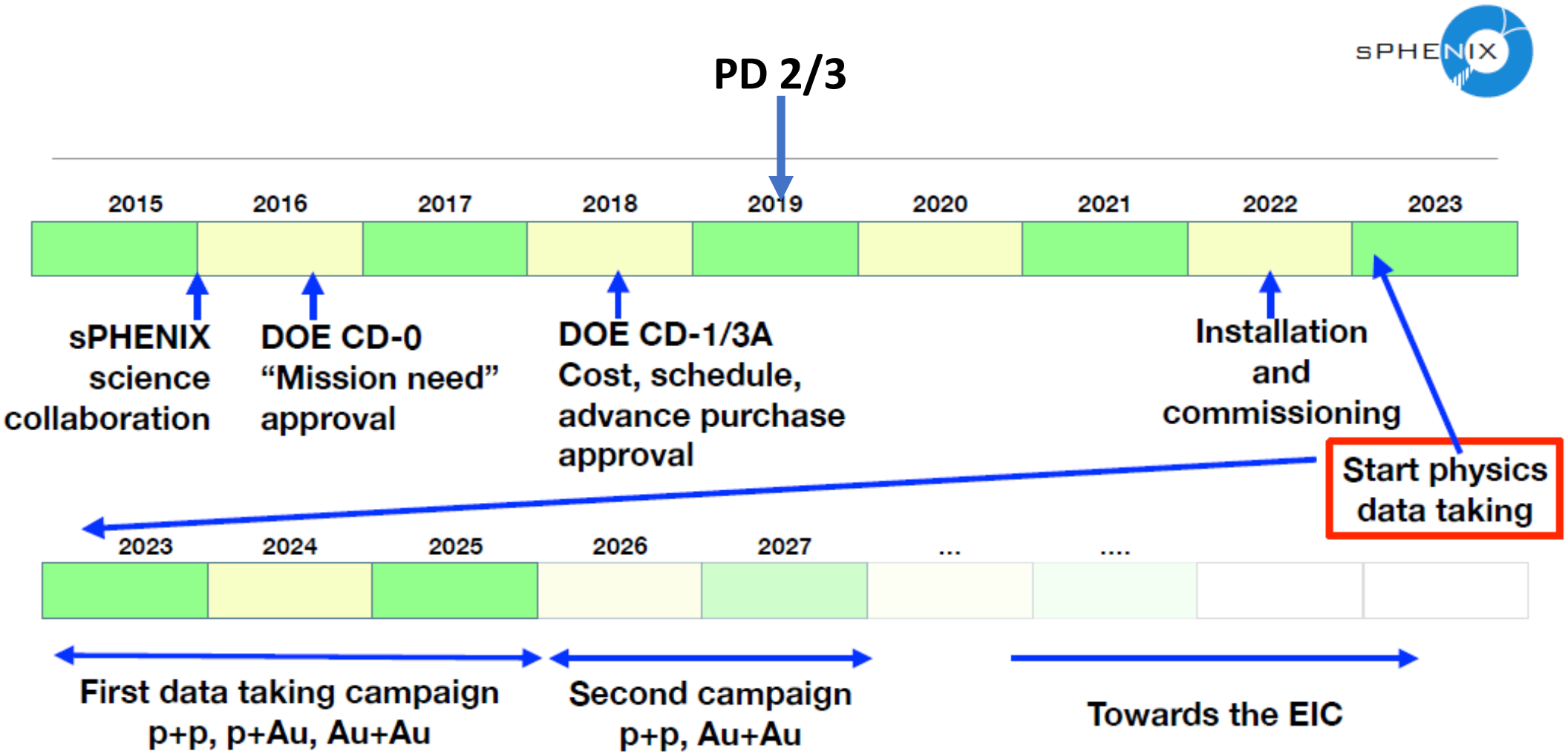
sPHENIX computing



sPHENIX timeline



record 240B minimum bias Au+Au events
record 35/nb, sample 83/nb

https://indico.bnl.gov/event/4788/attachments/19066/24594/sph-trg-000_06142018.pdf

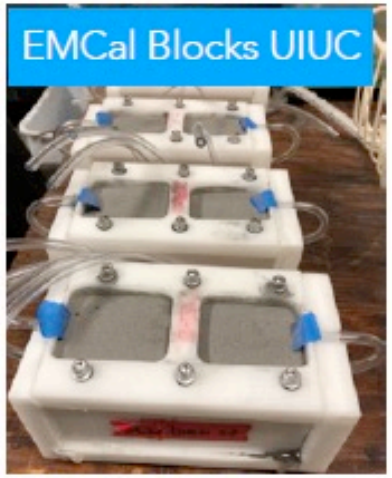

1st sPHENIX workfest, 2011 in Boulder
Computing corner:
Adding G4 to PHENIX software

A week later

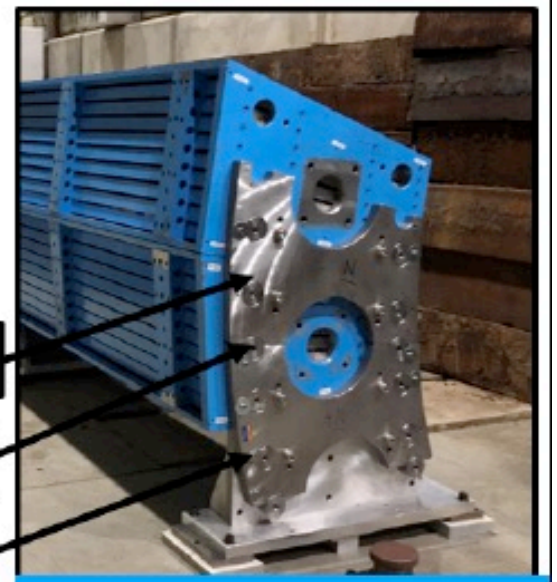
The first sPHENIX event display
(of a pythia event)

Fast forward to 2019, it is really happening


EMCal Sector-0 BNL

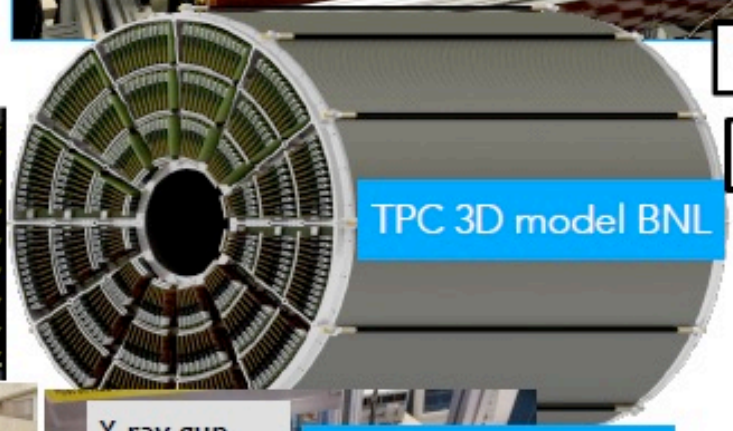

EMCal Blocks UIUC


TPC Outer Field Cage- SBU

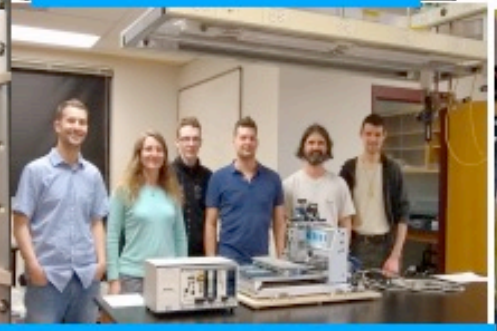


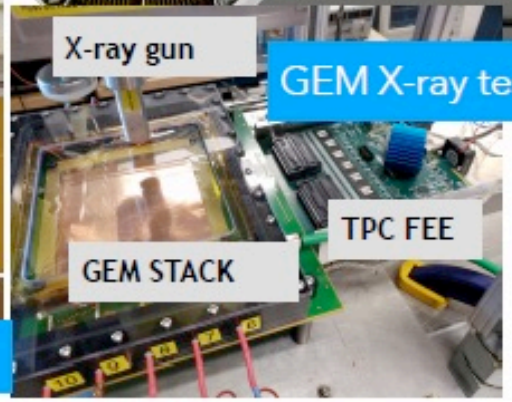
HCal Sectors, flux return BNL


SAMPA v5 Sao Paulo


TPC 3D model BNL


Digitizer Crate Columbia


SiPM Testing U Mich/Debrecen

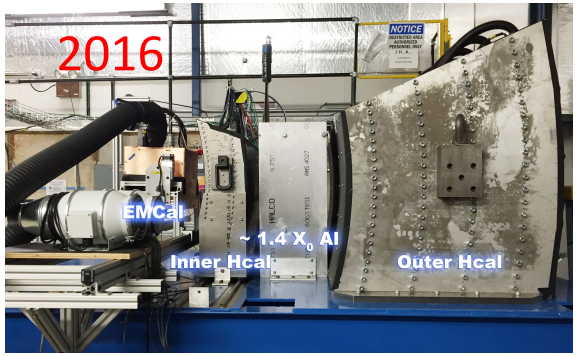


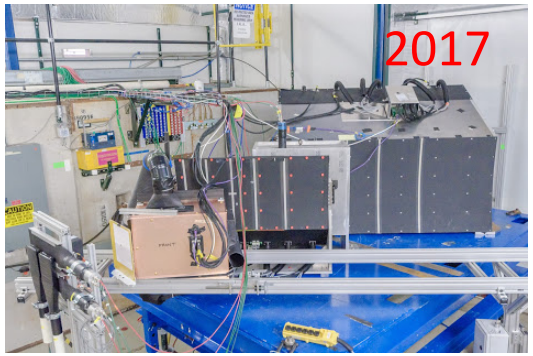
GEM X-ray test BNL


MBD - RIKEN


HCal Tiles- Uniplast, GSU

Test Beam, Test Beam and more Test Beam





Not only simulations, We also get exposed to real data written in our envisioned daq format

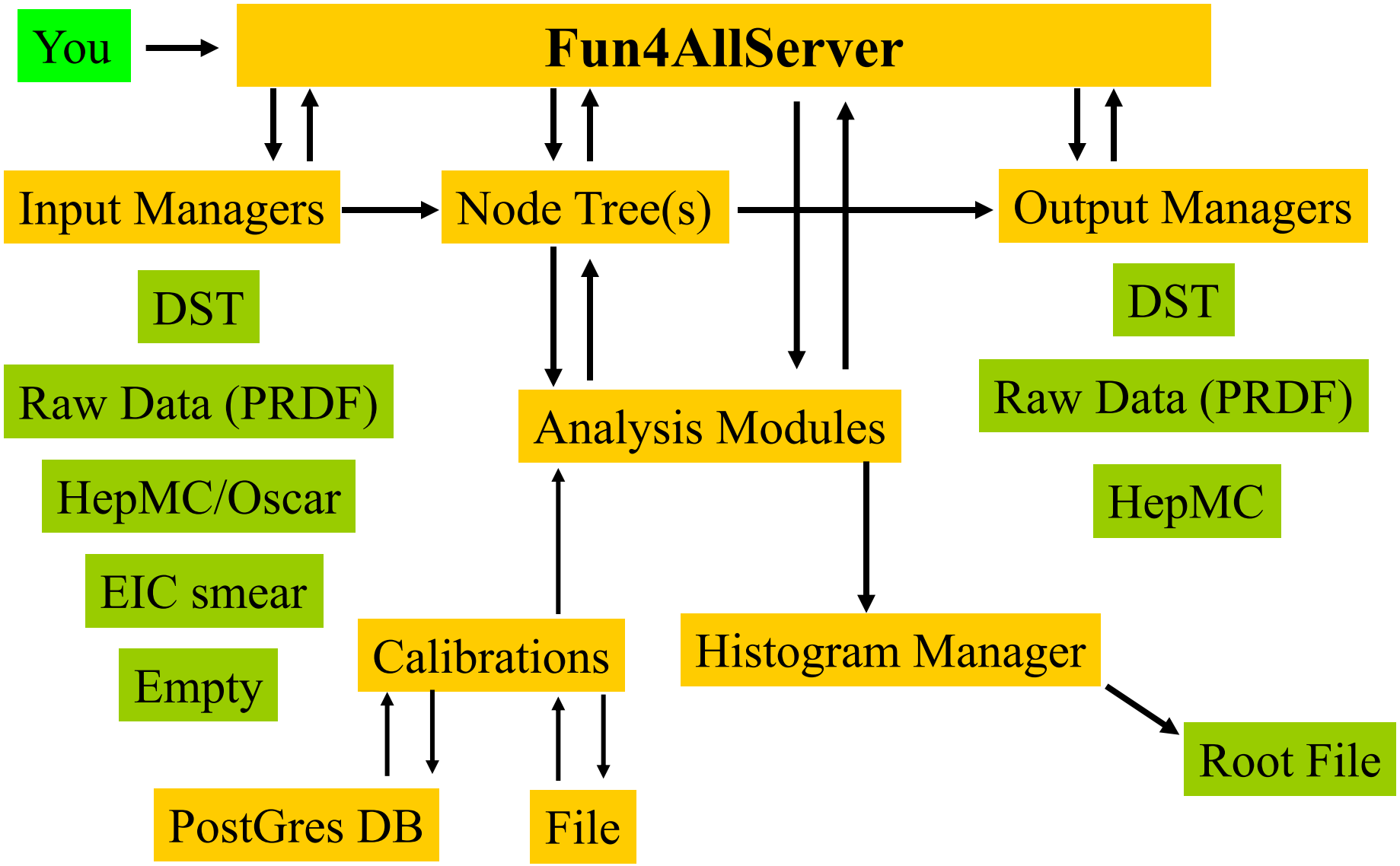
Executive Summary Framework

Fun4All was developed for data reconstruction by people who used it to analyze data
- Data was coming it already
- Had to combine a zoo of subsystems each with their own ideas how to do things
- No computing group, manpower came from the collaboration
- It has been in production since 2003 (constantly updated for new needs)
- Used for raw data reconstruction, analysis, simulations (G3 runs separately), embedding
- Processed PB of data with many B of events

sPHENIX branched off in April 2015
- Major revamping – made large effort to fix all those lessons learned things
- Code checkers: cppcheck, scan, clang, coverity, valgrind, insure, 100% reproducible running
- Good – PHENIX subsystem zoo reduced to basically 2 types:
  - Calorimeters (means need for clustering, use PHENIX clusterizer)
  - Inner Tracking silicon+tpc (means need for tracking, based on genfit)

Fermilab E1039 (Seaquest) branched off in 2017

Structure of our framework Fun4All



That's all there is to it, no backdoor communications – steered by ROOT macros

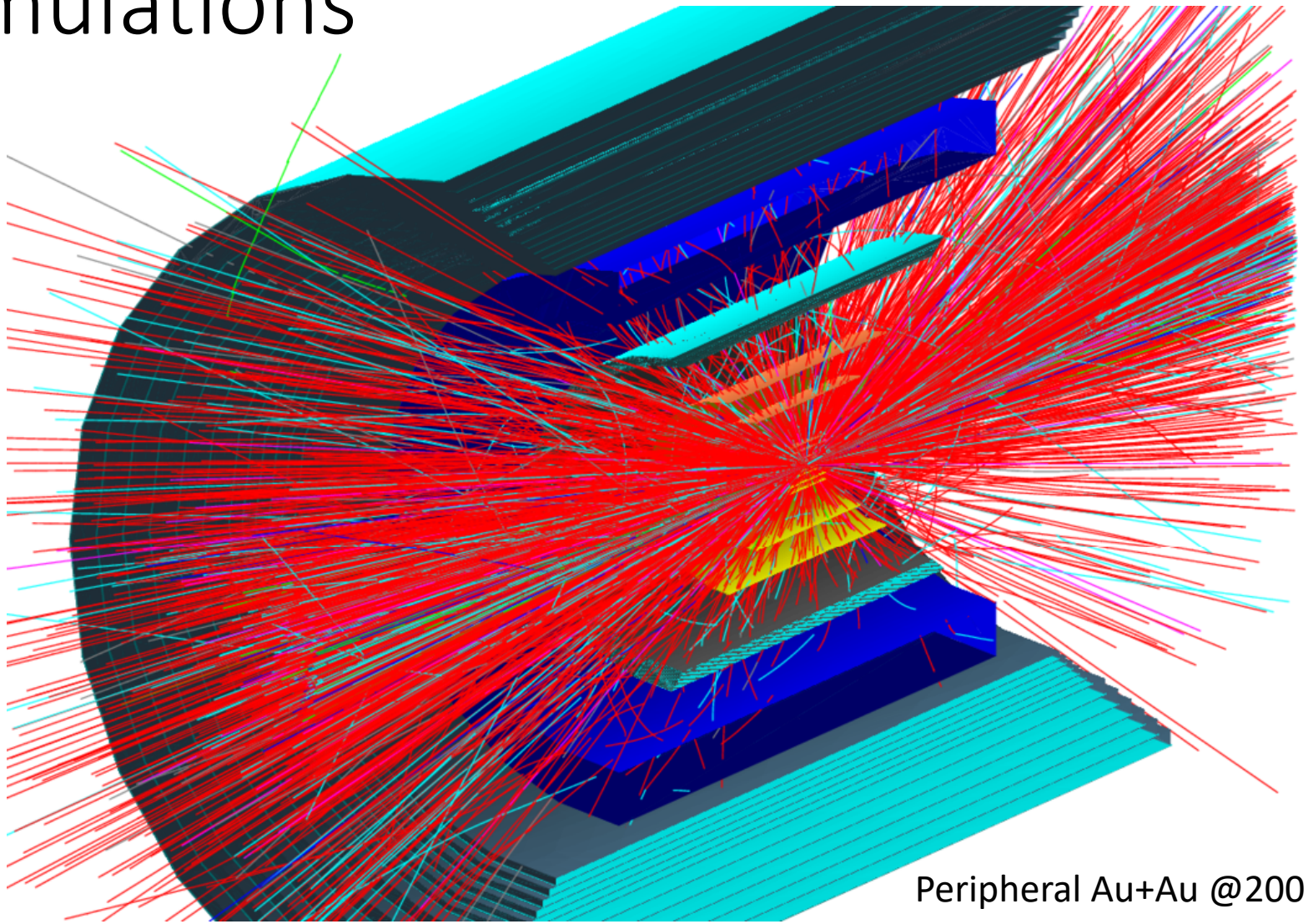
Keep it simple – Analysis Module Baseclass

You need to inherit from the SubsysReco Baseclass (offline/framework/fun4all/SubsysReco.h) which gives the methods which are called by Fun4All. If you don't implement all of them it's perfectly fine (the beauty of base classes)

- Init(PHCompositeNode *topNode): called once when you register the module with the Fun4AllServer
- InitRun(PHCompositeNode *topNode): called before the first event is analyzed and whenever data from a new run is encountered
- process_event (PHCompositeNode *topNode): called for every event
- ResetEvent(PHCompositeNode *topNode): called after each event is processed so you can clean up leftovers of this event in your code
- EndRun(const int runnumber): called before the InitRun is called (caveat the Node tree already contains the data from the first event of the new run)
- End(PHCompositeNode *topNode): Last call before we quit

If you create another node tree you can tell Fun4All to call your module with the respective topNode when you register your modue

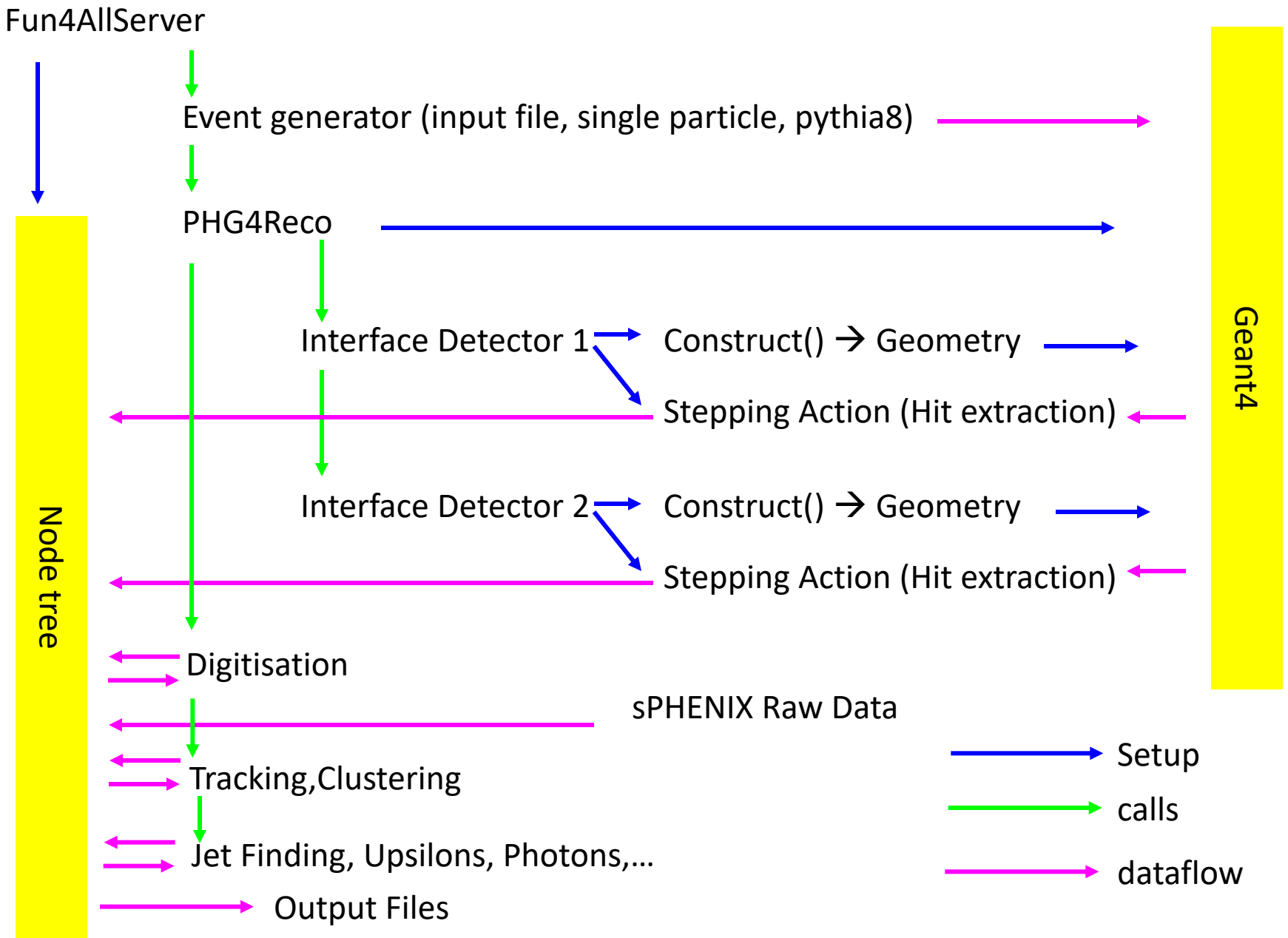
Simulations



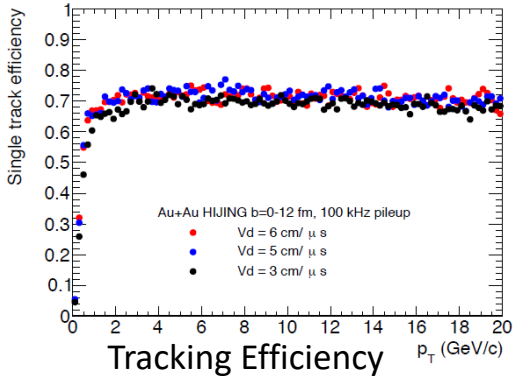
Peripheral Au+Au @200 GeV Hijing event

Event displays are the easy part, how do we actually analyze this mess?

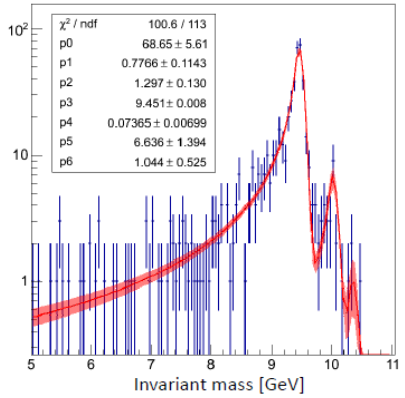
G4 program flow within Fun4All



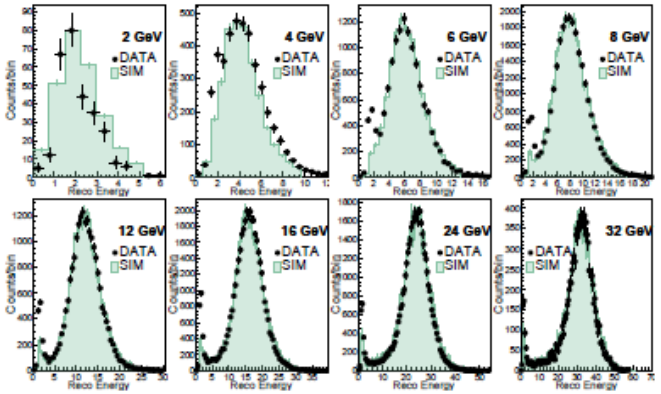
More than just pretty event displays



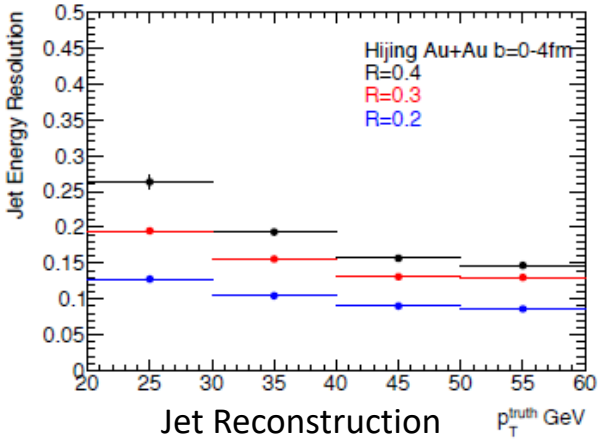
Tracking Efficiency



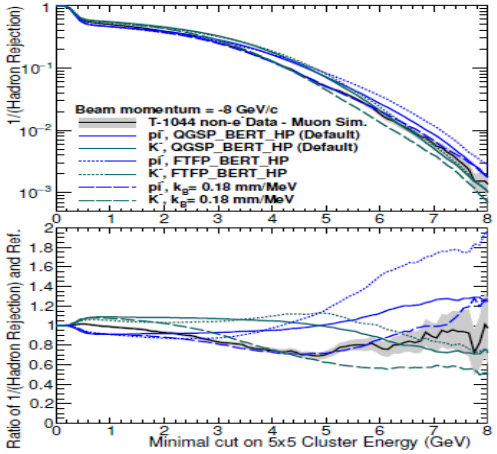
Upsilon Reconstruction



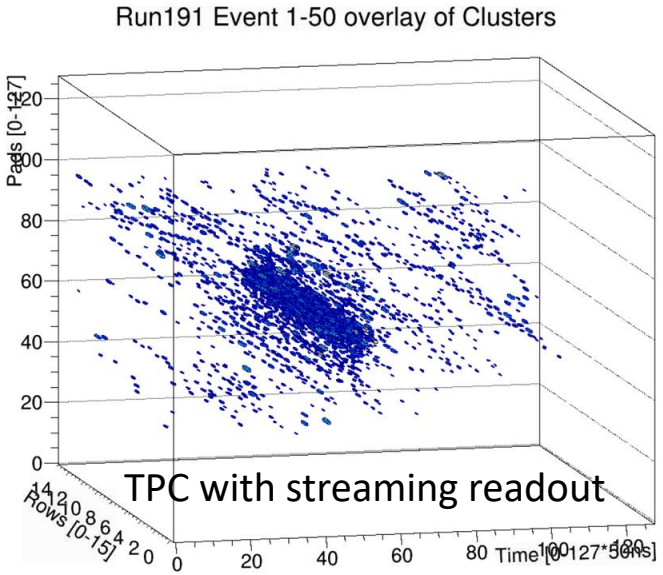
Hadronic Calorimeter Test Beam



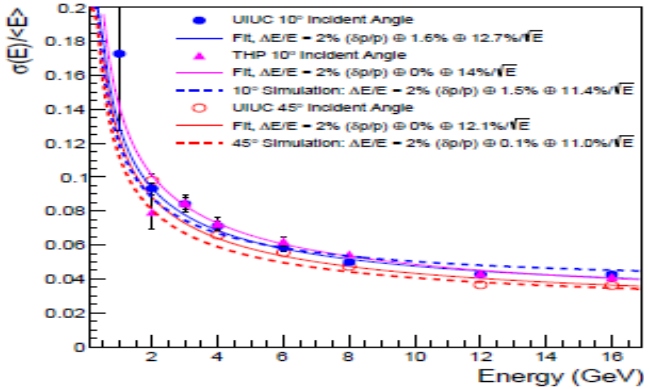
Jet Reconstruction



EmCal Hadron Rejection



TPC with streaming readout



EmCal Test Beam

sPHENIX Run Plan

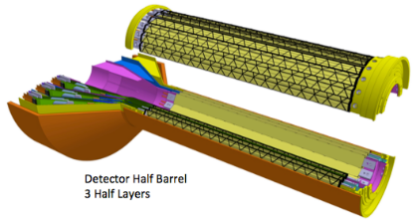
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149 pb^{-1}	783 pb^{-1}
Year-5	Au+Au	200	23.5	14 nb^{-1}	48 nb^{-1}	92 nb^{-1}

Only events in a +- 10cm vertex range have the full tracking information

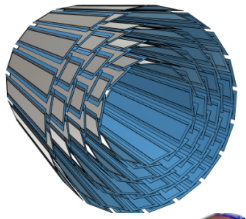
Event vertex range is +- 30cm (right column)

Species	Energy [GeV]	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Au+Au	200	35 nb^{-1} (239 billion)	80 nb^{-1} (550 billion)	214 nb^{-1} (1.5 trillion)
p+p	200	—	197 pb^{-1} (8.3 trillion)	1.0 fb^{-1} (44 trillion)
p+Au	200	—	0.33 pb^{-1} (0.6 trillion)	1.46 pb^{-1} (2.6 trillion)

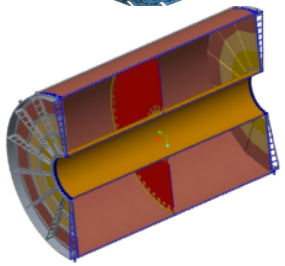
The large data producers in 200 GeV Au+Au (worst case)



Monolithic Active Pixel Sensors (MAPS) ~ 35GBit/s

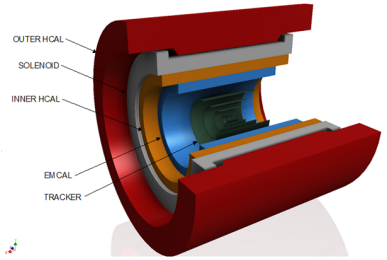


Intermediate Silicon Strip Tracker (INTT) ~ 7GBit/s



Compact Time Projection Chamber (TPC) ~ 80Gbit/s

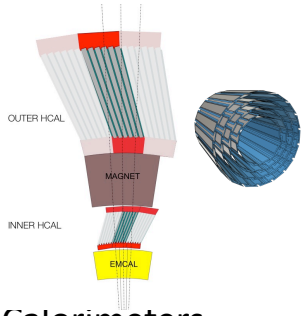
Calorimeters (primarily Emcal, hadronic cal.) ~ 8GBit/s



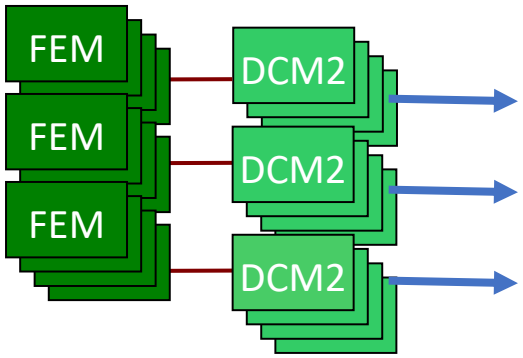
~ 130GBit/s

After applying RHIC x sPHENIX duty factor ~ 100GBit/s

Two Classes of Front-end Hardware

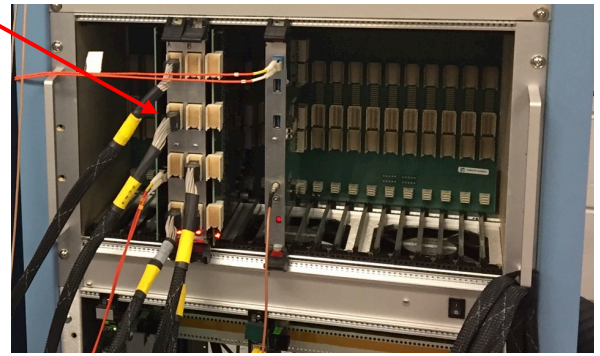


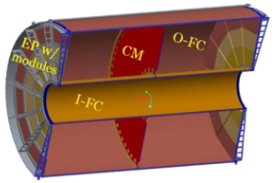
Calorimeters, INTT, MBD



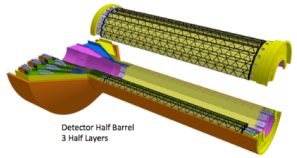
The calorimeters, the INTT, and the MBD re-use the PHENIX "Data Collection Modules" (v2)

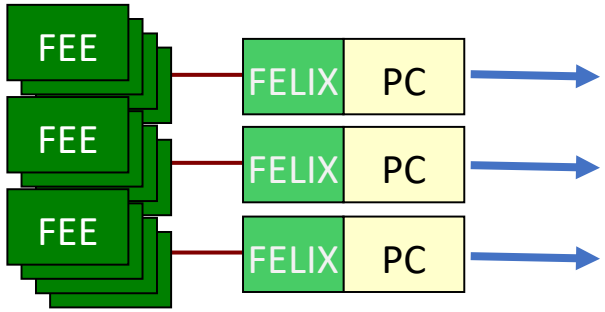
Triggered readout





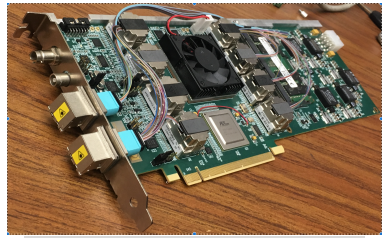
TPC, MVTX



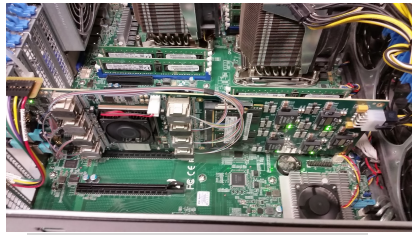


The TPC and the MVTX are read out through the ATLAS "FELIX" card directly into a standard PC

Streaming readout



ATLAS FELIX Card



Installed in a PC

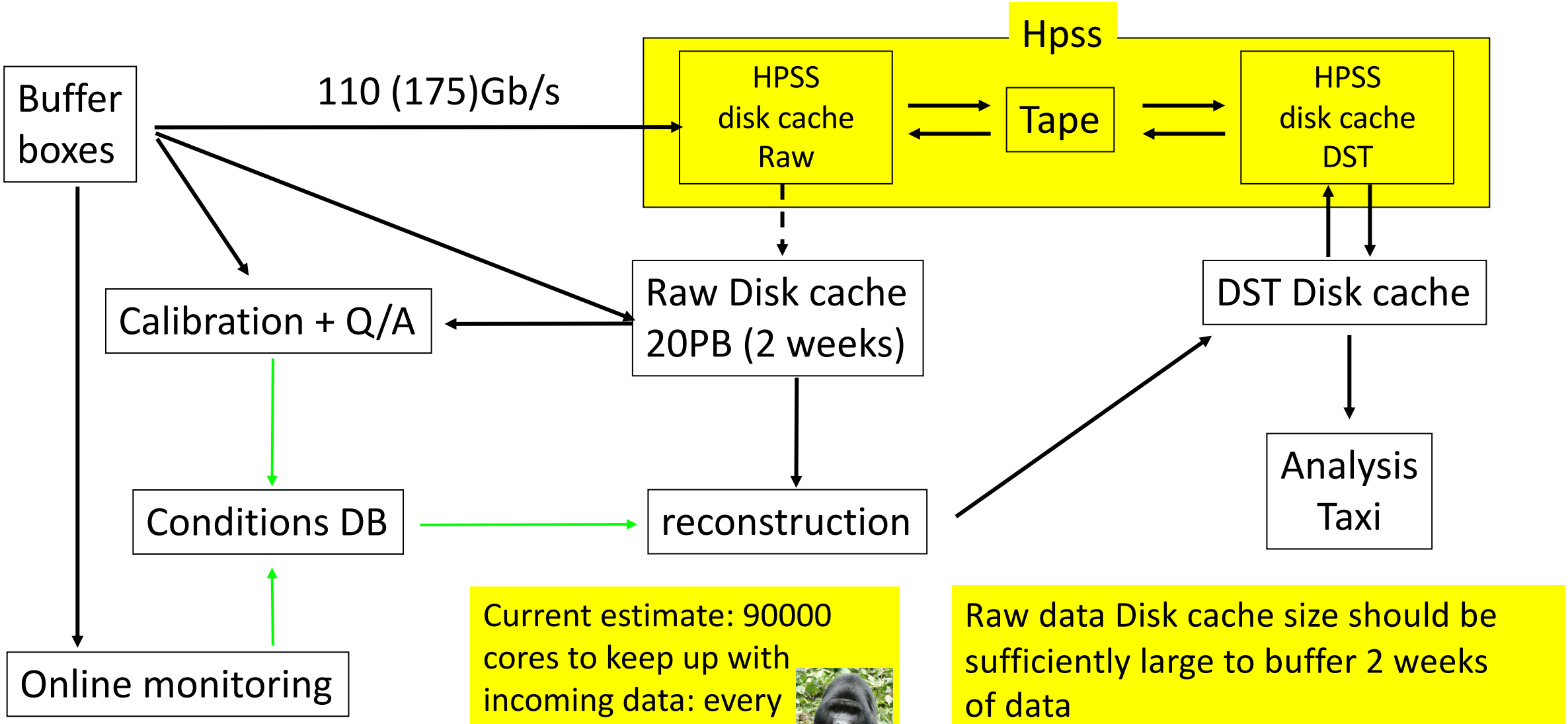
Event rates

- The run plan is to acquire 15 kHz of collisions (subtract 1.5 weeks for rampup):
  - Run 1: Au+Au: 14.5 weeks · 60% RHIC uptime · 60% sPHENIX uptime ⟶ 47 billion events, 1.7 Mbyte/event → 75PB (110Gb/s)
  - Run 2 and 4: p+p, p+A: 22 weeks · 60% RHIC uptime · 80% sPHENIX uptime ⟶ 96 billion events, 1.6 Mbyte/event → 143PB
  - Run 3 and 5: Au+Au: 22 weeks · 60% RHIC uptime · 80% sPHENIX uptime ⟶ 96 billion events, 1.6 Mbyte/event → 143PB
- The DAQ system is designed for a sustained event rate of 15kHz
- We cannot “trade” smaller event sizes for higher rates.
- The new detectors (TPC, MVTX) will not have the ultimate data reduction factors until at least Year-4 (based on ALICE and others’ experience), with lzo compression in daq only minor change in data volume

Event building

- Nothing in online requires the assembling of **all** events (we do not employ level2 triggers, all events selected by our level1 triggers are recorded)
- Moving the event builder to the offline world makes it a lot simpler
  - The offline event builder does not have to keep up with peak rates
  - In offline we have many more cpus at our disposal
  - Crashes can be easily debugged
  - No loss of data due to event builder issues
  - Subevents are ordered in raw data files
- Disadvantage: Need to deal with ~60 input files in data reconstruction
- Still need to build a fraction of the events for monitoring purposes
- Combining triggered with streamed readout is going to be fun

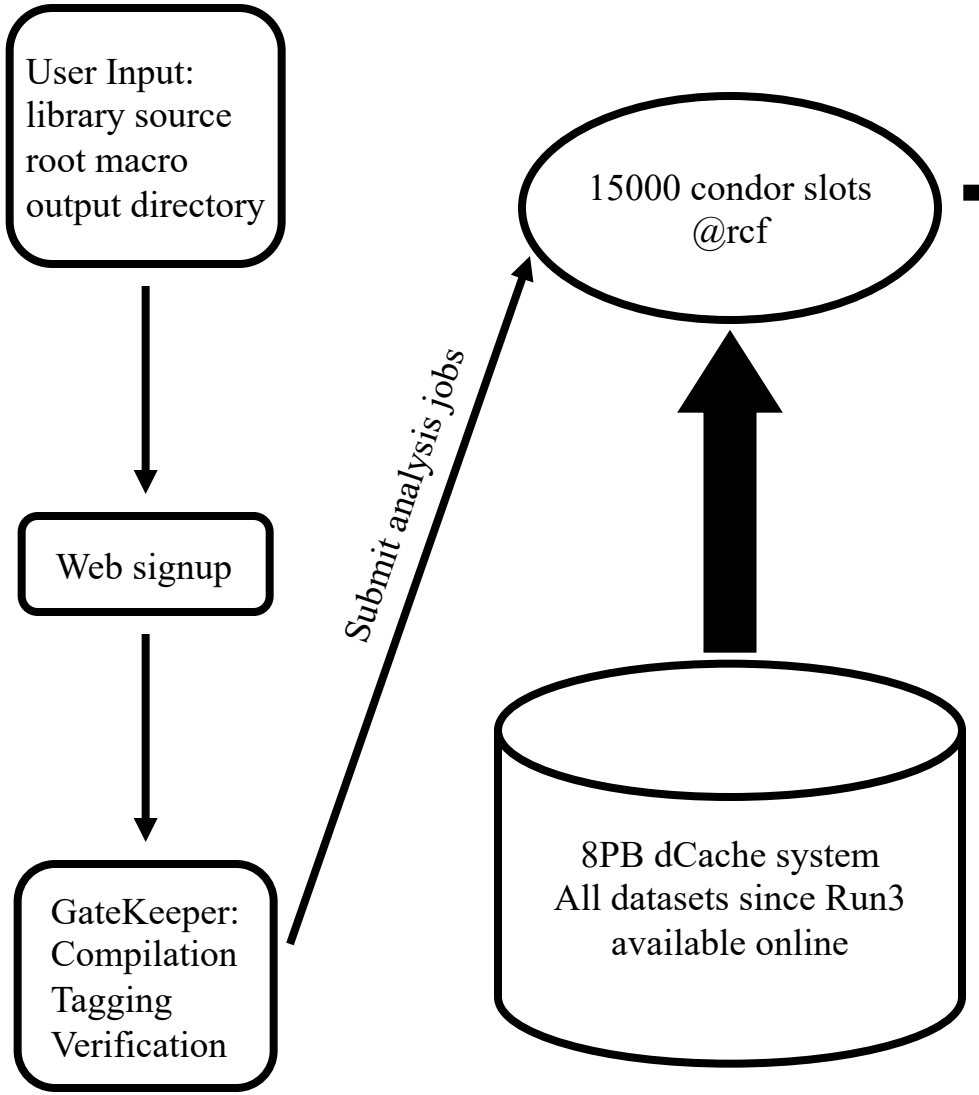
Reconstruction + analysis flow



Current estimate: 90000 cores to keep up with incoming data: every second is 6000 cores

Raw data Disk cache size should be sufficiently large to buffer 2 weeks of data
Reconstructed data disk cache should ideally keep all reconstructed output

The Analysis Taxi, mother of all trains



- Fully automatized
- Modules running over same dataset are combined to save resources
- Provides immediate access to all PHENIX datasets since Run3
- Turnaround time typically hours
- Vastly improves PHENIX analysis productivity
- Relieves users from managing thousands of condor jobs
- Keeps records for analysis “paper trail”

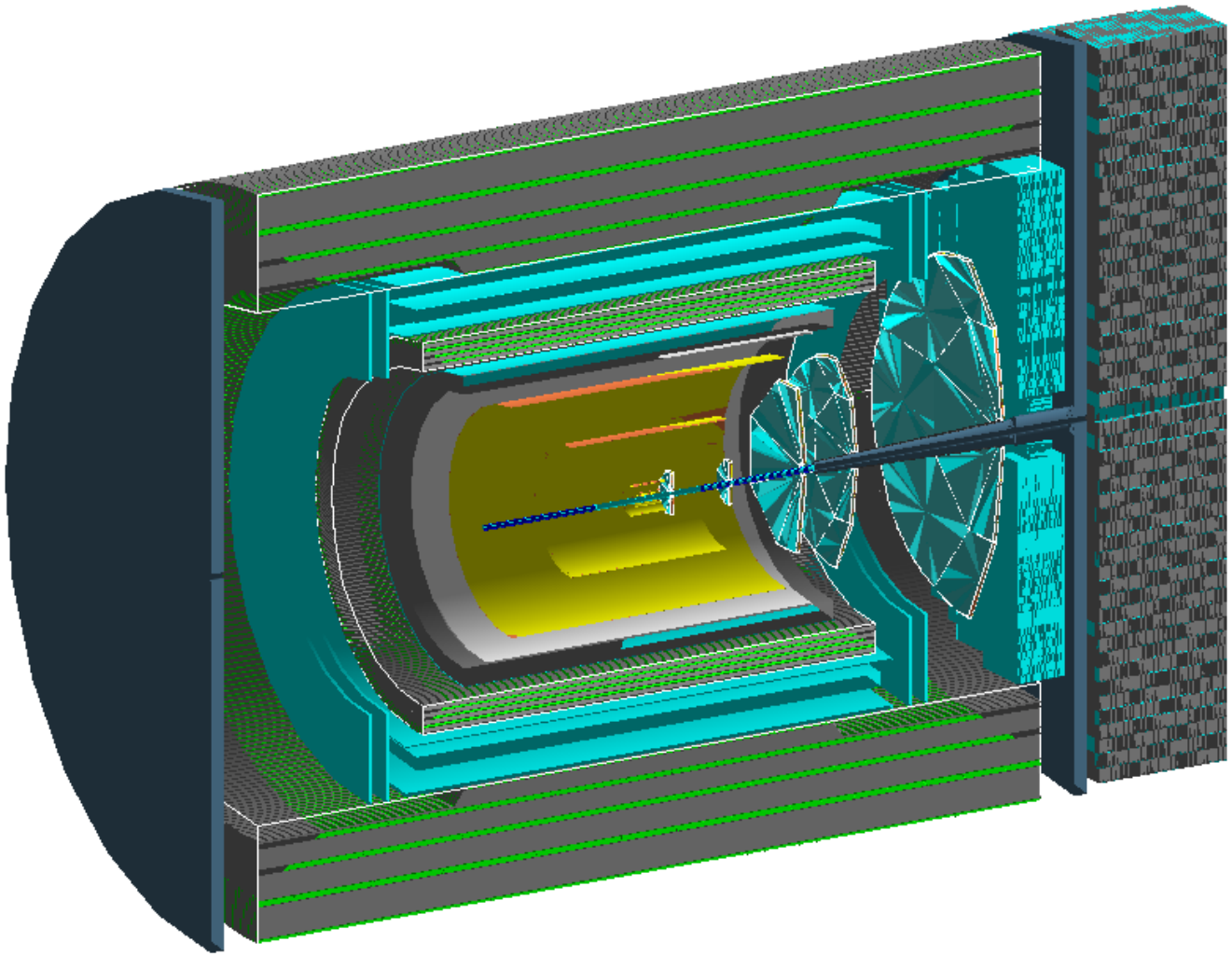
Towards EIC

The challenges of heavy ion event reconstruction dwarfs whatever the EIC will throw at us
sPHENIX might (will) evolve into the day 1 EIC detector by adding forward instrumentation
In any case - the central parts of the proposed EIC detectors are very similar to sPHENIX
→ Any improvement made to sPHENIX software will benefit the EIC program

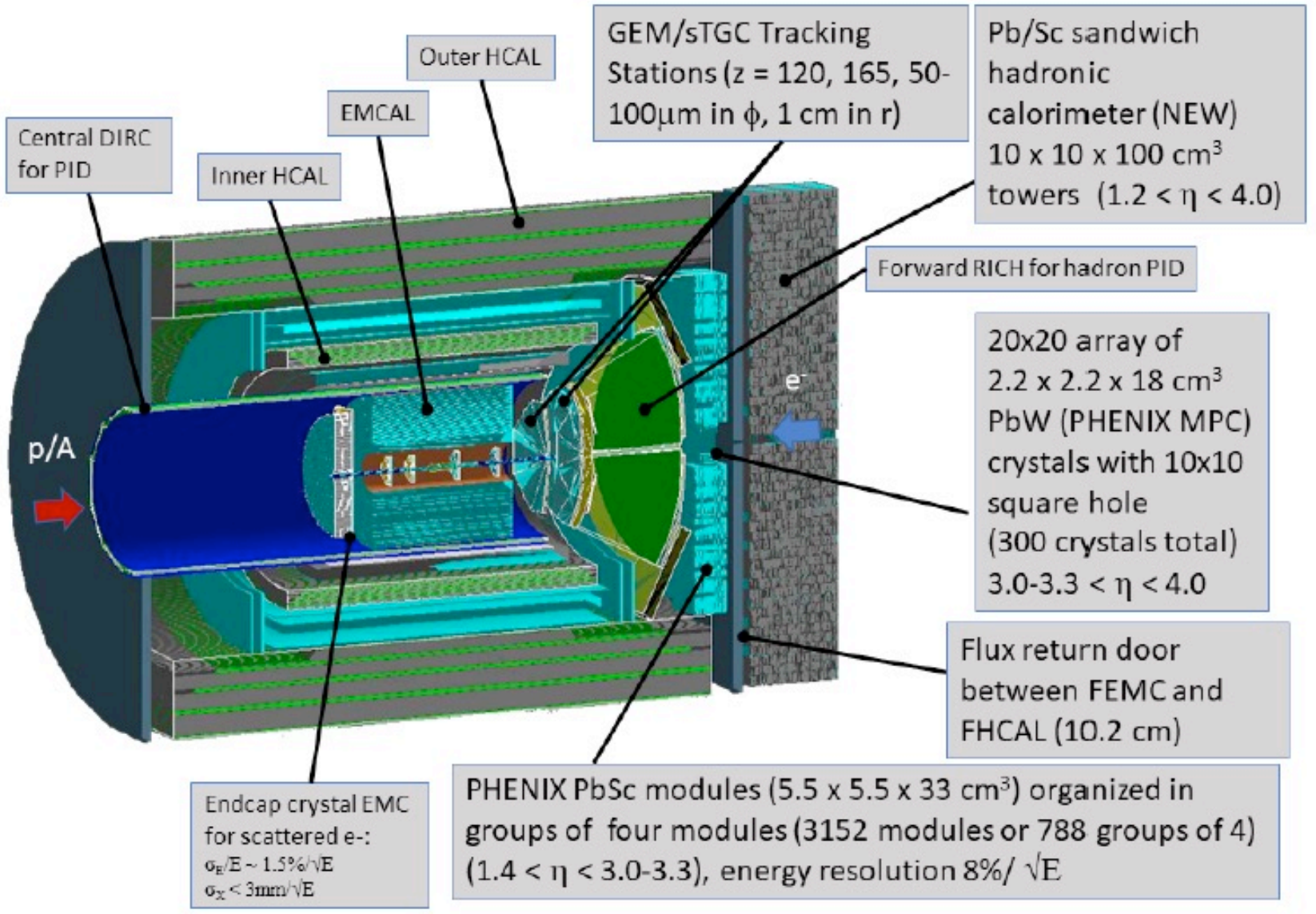
Our software is containerized (singularity), the code in github, our libraries are in cvmfs
https://github.com/sPHENIX-Collaboration/Singularity
→ The OSG can provide the computing resources needed by non sPHENIX EIC users

We have some tutorials how to put together simple detectors from basic shapes:
https://github.com/sPHENIX-Collaboration/tutorials

fsPHENIX – forward instrumentation for cold QCD

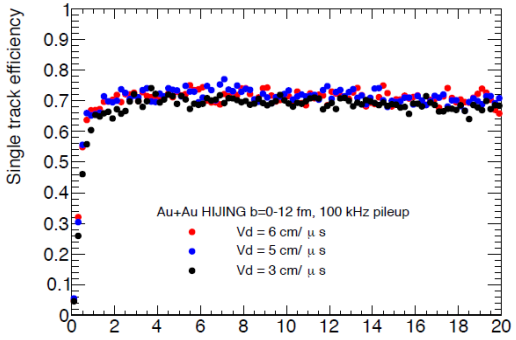


ePHENIX out of the box

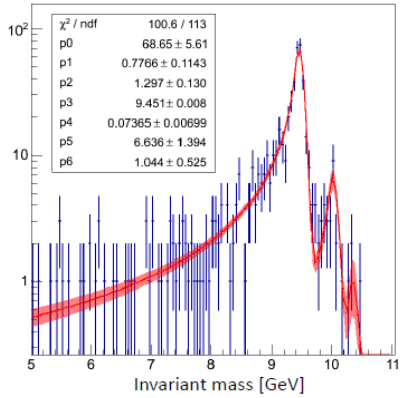


Fully developed G4 model, including digitization and reconstruction

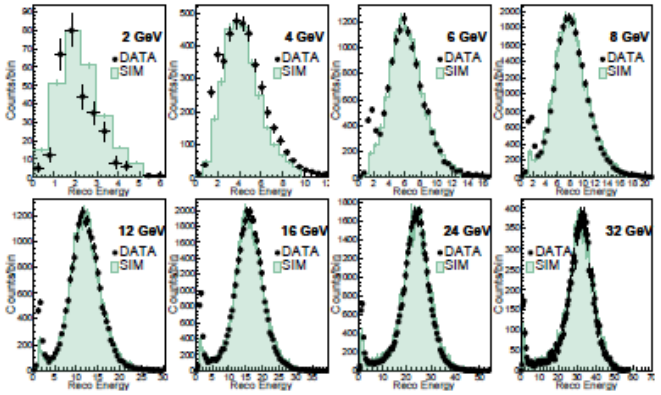
More than just pretty event displays



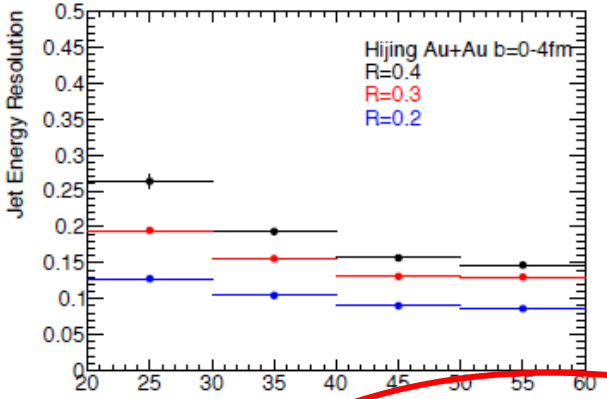
Tracking Efficiency



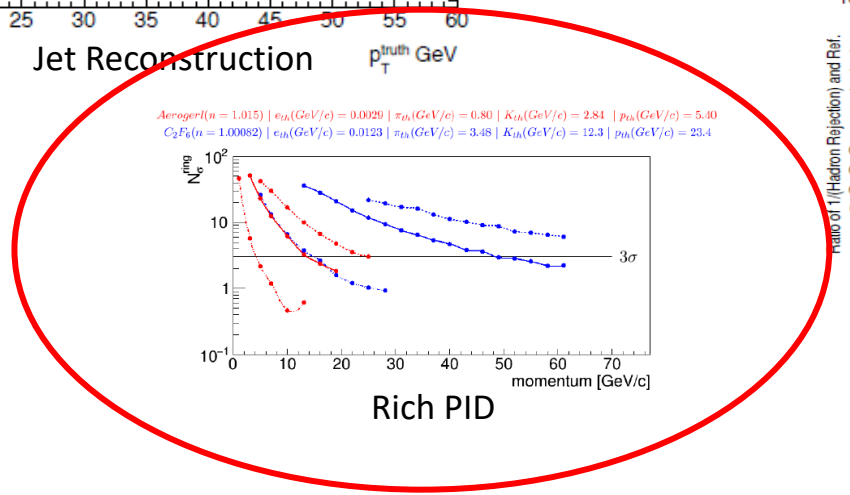
Upsilon Reconstruction



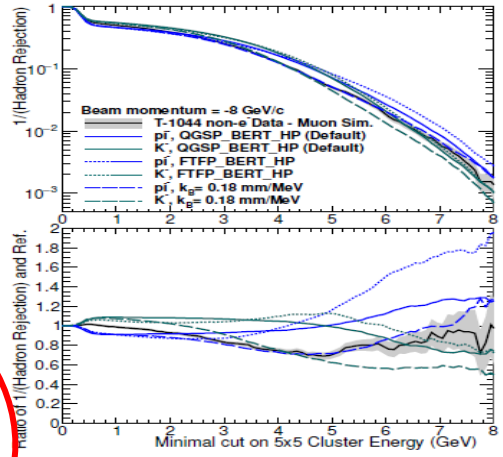
Hadronic Calorimeter Test Beam



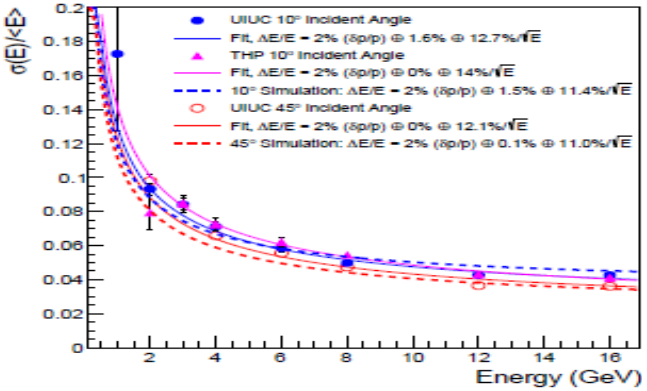
Jet Reconstruction



Rich PID



EmCal Hadron Rejection



EmCal Test Beam

Contains all you need to simulate and analyze data NOW
Stonybrook is looking into the detection of leptoquarks, hopefully first results in time for the EIC users meeting July 22-26