sPHENIX simulation

(from three view points: simulation team, HF topical group, and DAQ)

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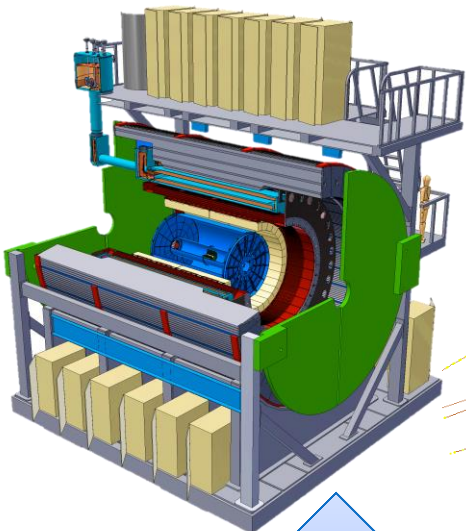
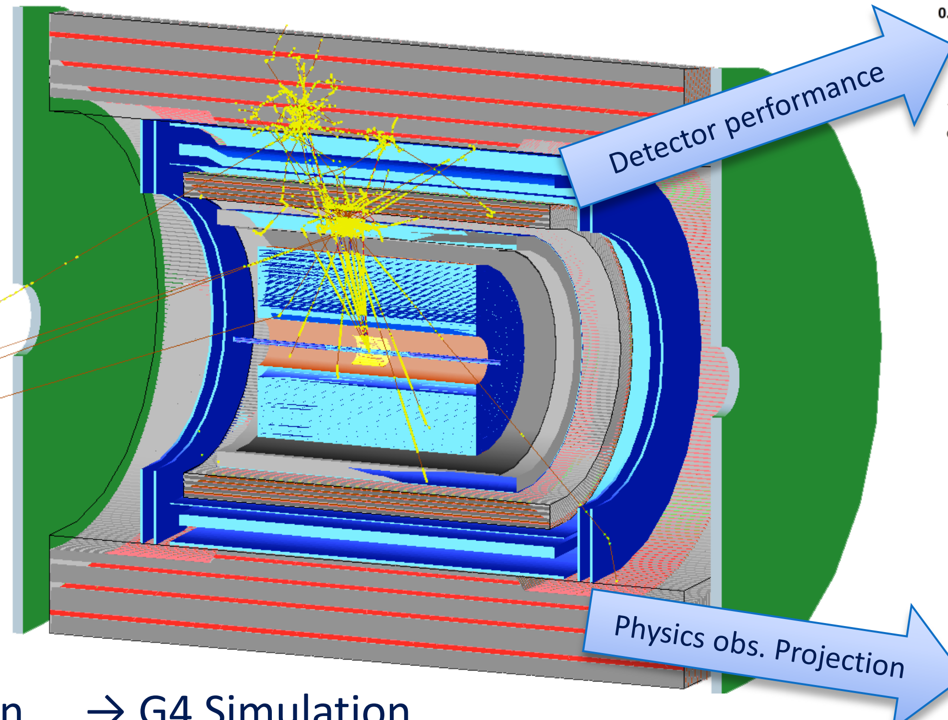
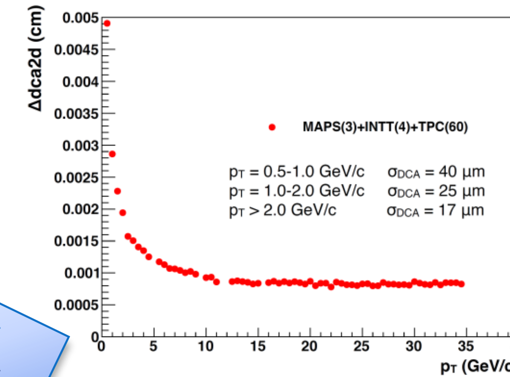
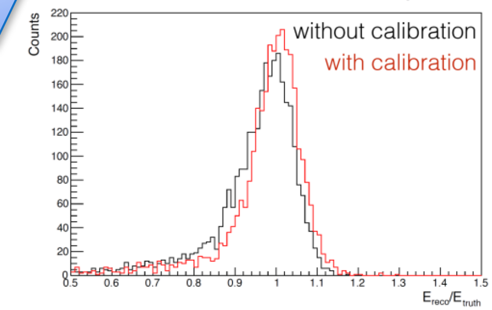
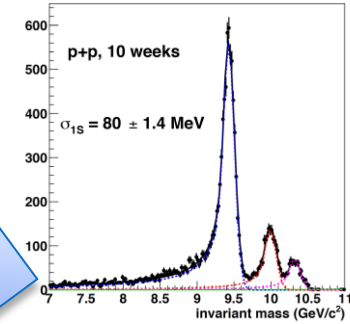
sPHENIX Software

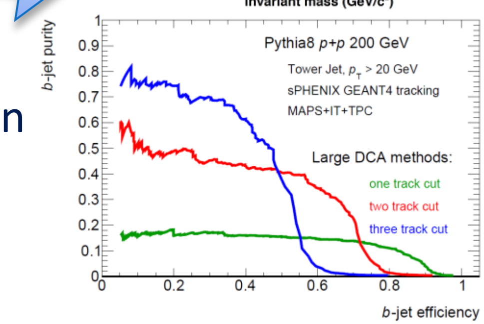












Detector Design → G4 Simulation

→ Digitization

Reconstruction

Real Data

Open source @ GitHub

https://github.com/sPHENIX-Collaboration/

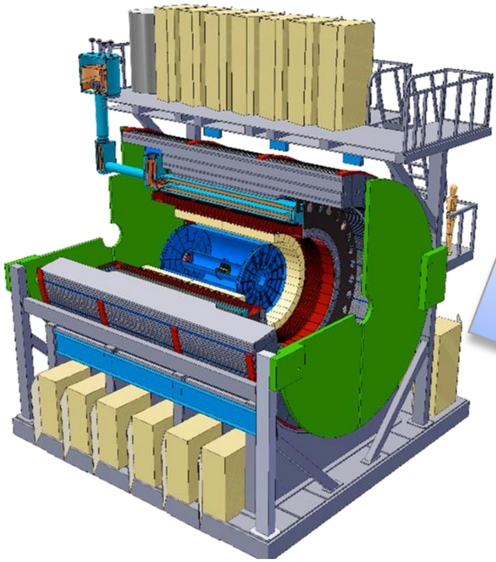
Core software: 200k line of code

Analysis: 59k line of code

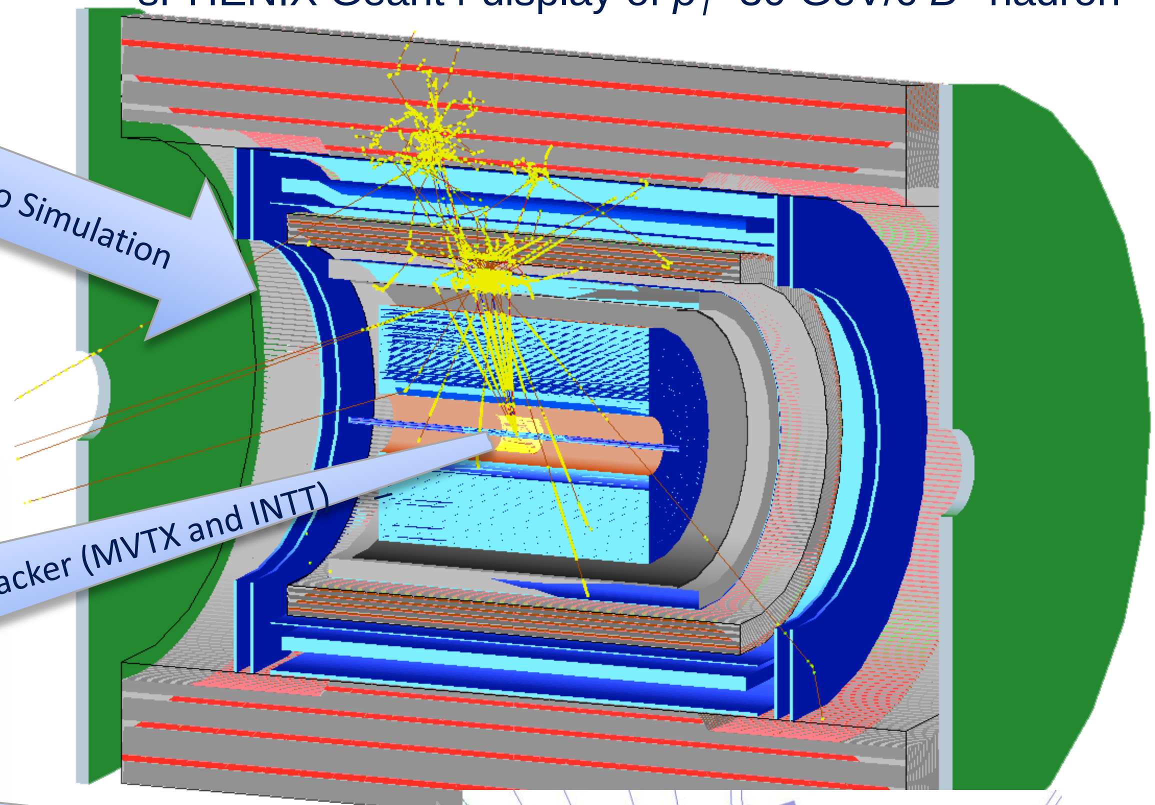
Subsystem simulation and reconstruction

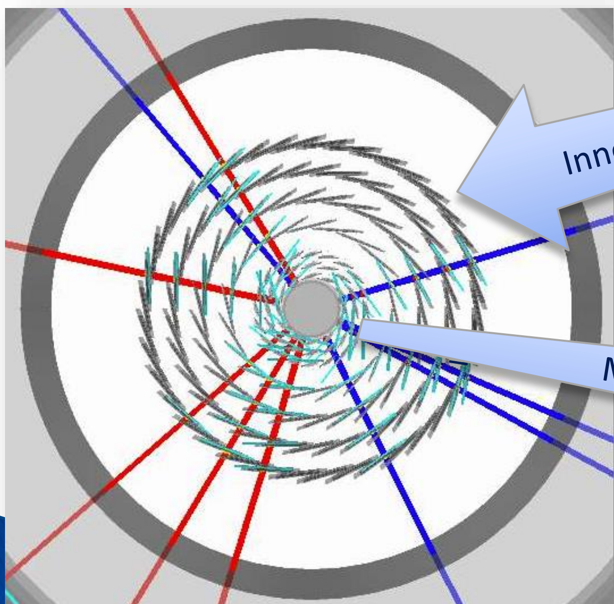
Full detector simulation + reconstruction

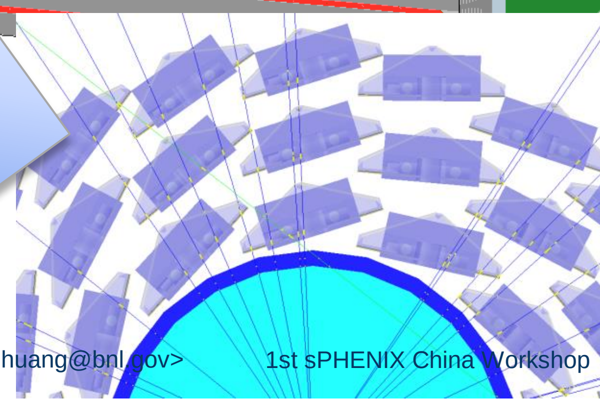
Open source @ GitHub : https://github.com/sPHENIX-Collaboration/



sPHENIX Geant4 display of p_T=30 GeV/c B^+-hadron



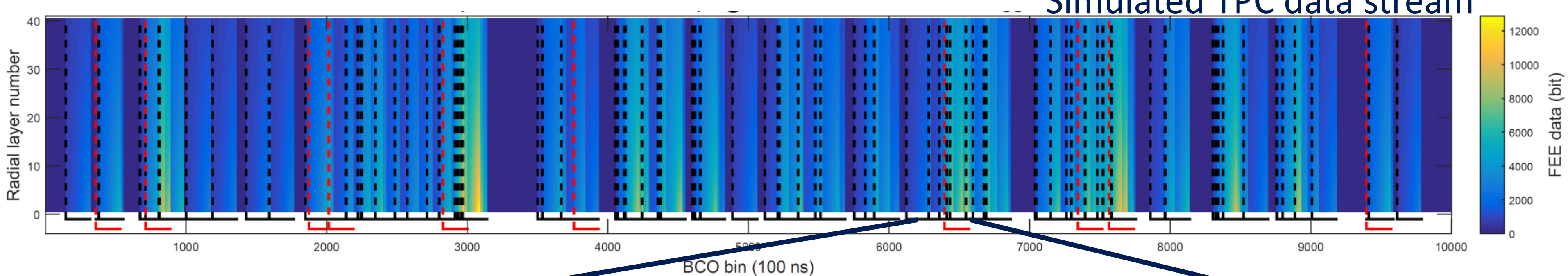




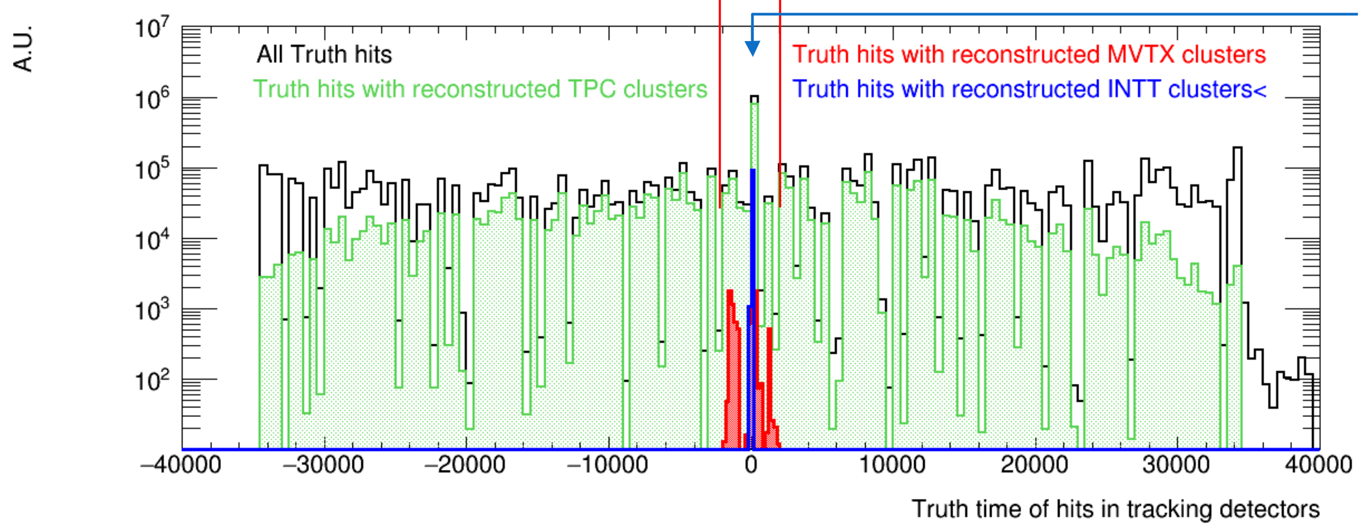
Event generator: event pile up

- High rate → Pile up → studied in our software suit

Simulated TPC data stream



Collisions: +/- 35 μs TPC: +/- 35 μs MVTX: +/- 2 μs INTT: [-20 ns, +80 ns]



Tracking simulation + reconstruction

Event generation
- Multi event generators
- Pile up

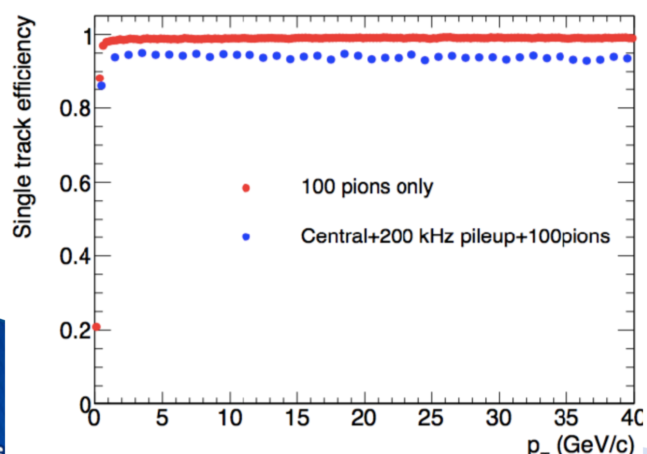
Tracker simulation
- Detailed ladder models
- Improving TPC ionization simualtion

Pattern recognition, ghost rejection
- Hough transform seeding
- Kalman filter propagation
- 2 iterations

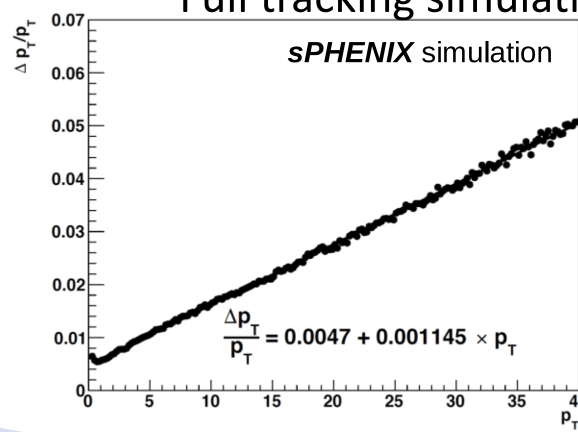
Track fit
- GenFit2-based Kalman filter

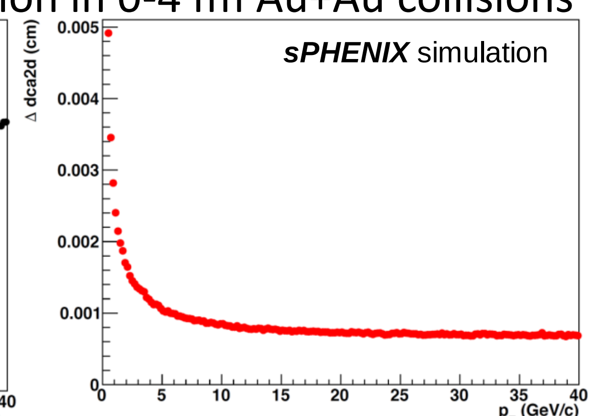
Final Vertex finding
- RAVE-based multivertex finding and fitting

- Tracking software improved significantly over the past year from a team of hardworking developers
- Full simulation + reco chain
- Improving details of detector description and improving tracking speed



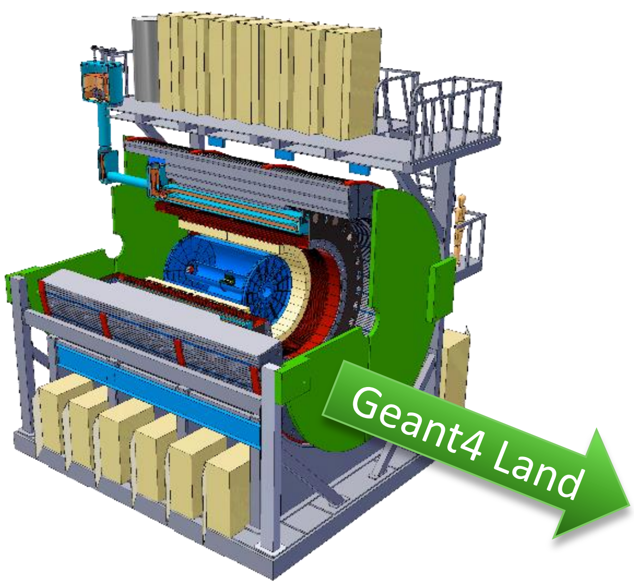
Full tracking simulation in 0-4 fm Au+Au collisions



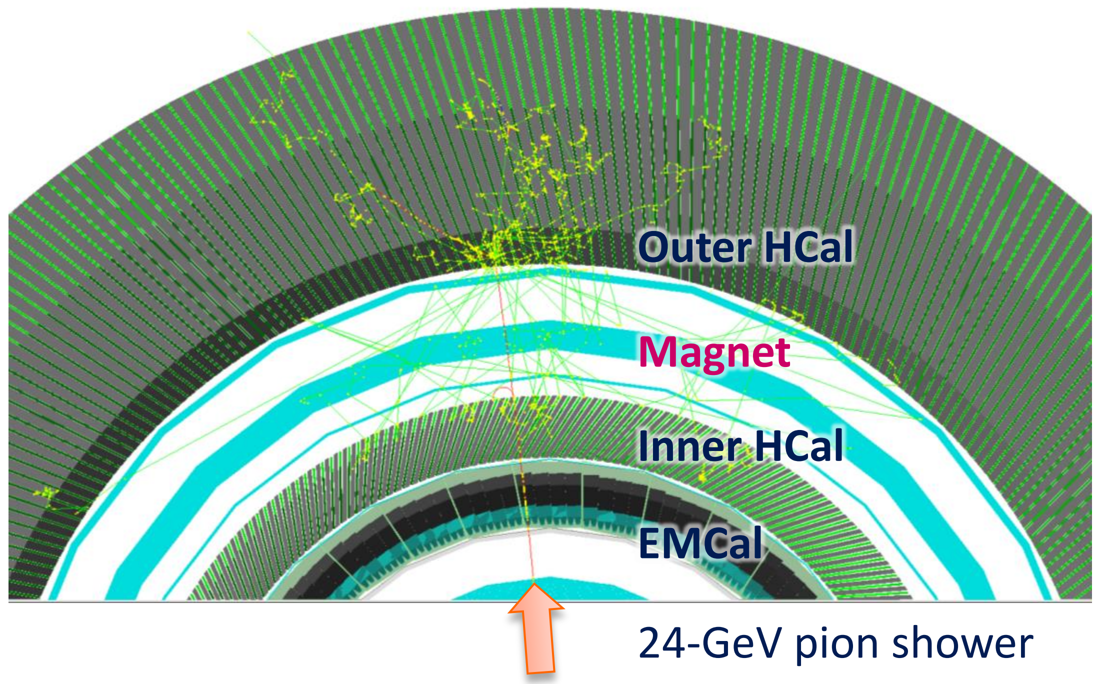


Calorimeters: in Simulation

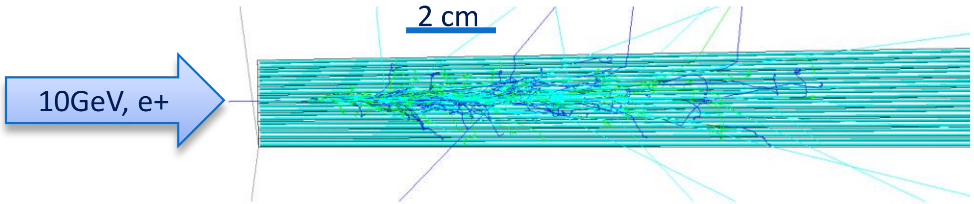
- EM calorimeter (EMCal) : 18 X_0 W-SPACAL
- Inner hadron calorimeter (Inner HCal) : .25 λ_0 Al (Scint. Sampling)
- sPHENIX coil and cryostat. (Magnet): 1.4 X_0 Coil & Cryostat
- Outer hadron calorimeter (Outer HCal) : 4 λ_0 SS-Scint. sampling



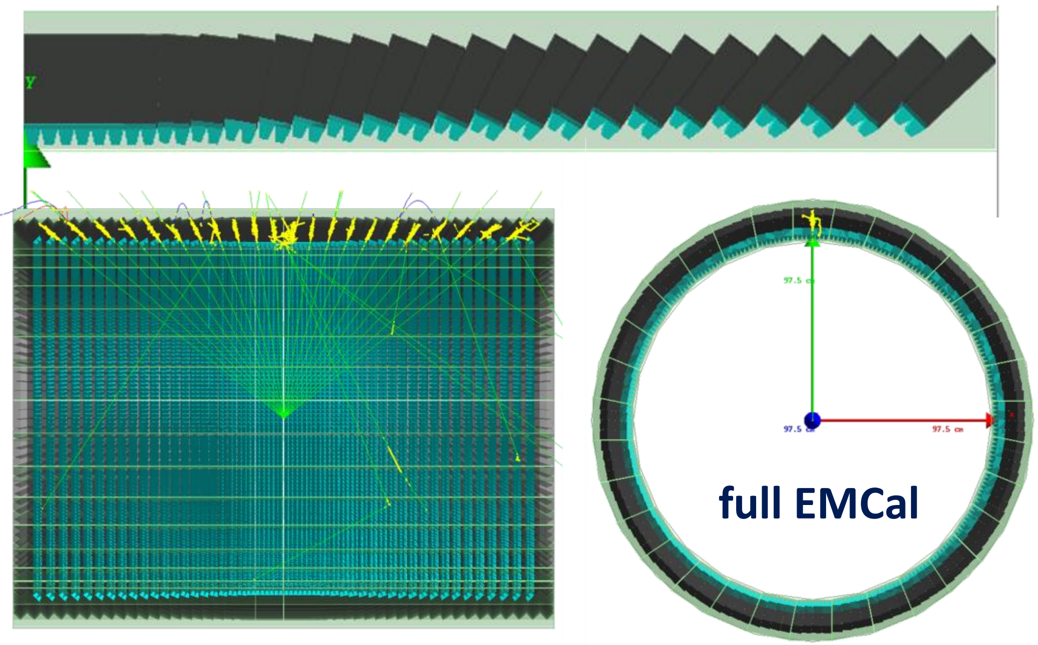
Beam view of **full calorimeters**



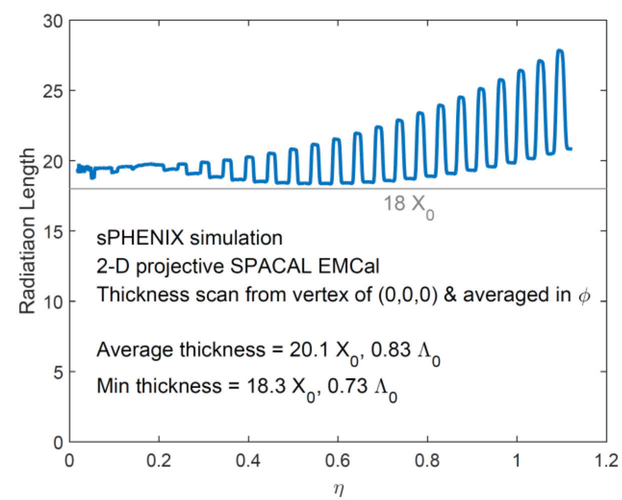
Simulation Setup: EMCal



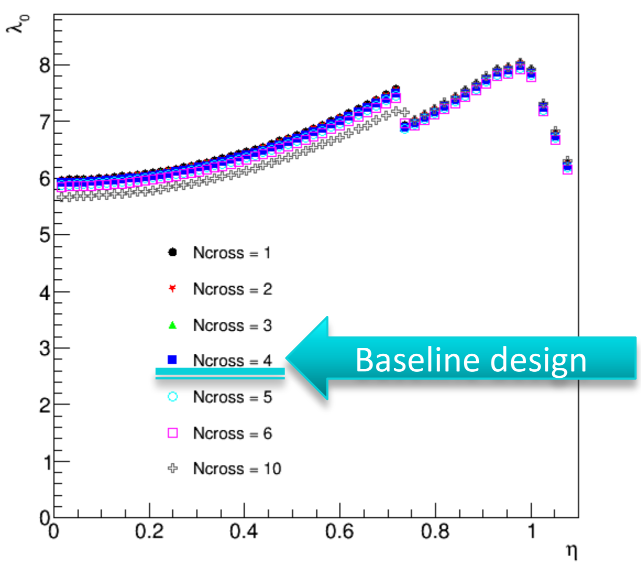
SPACAL Tower
w/ fibers displayed



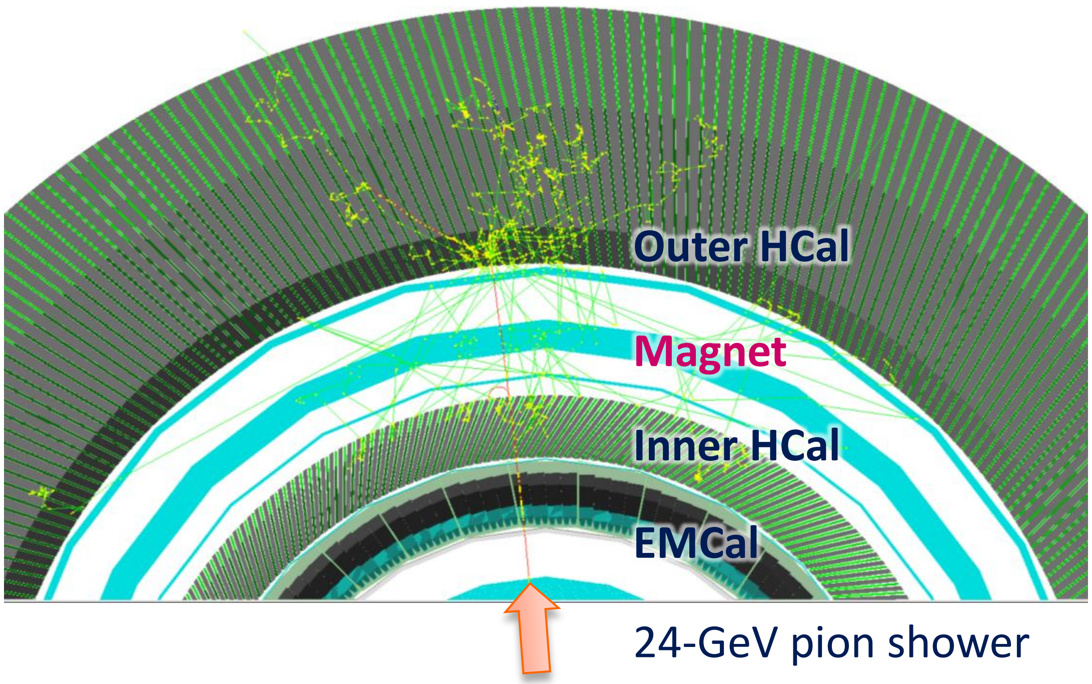
EMCal Half Sector
(fibers simulated but hidden from display)



Simulation Setup: HCal



Beam view of **full calorimeters**

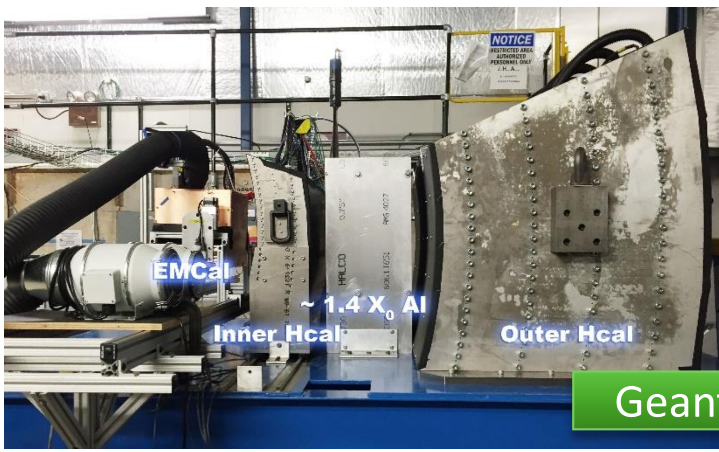


24-GeV pion shower

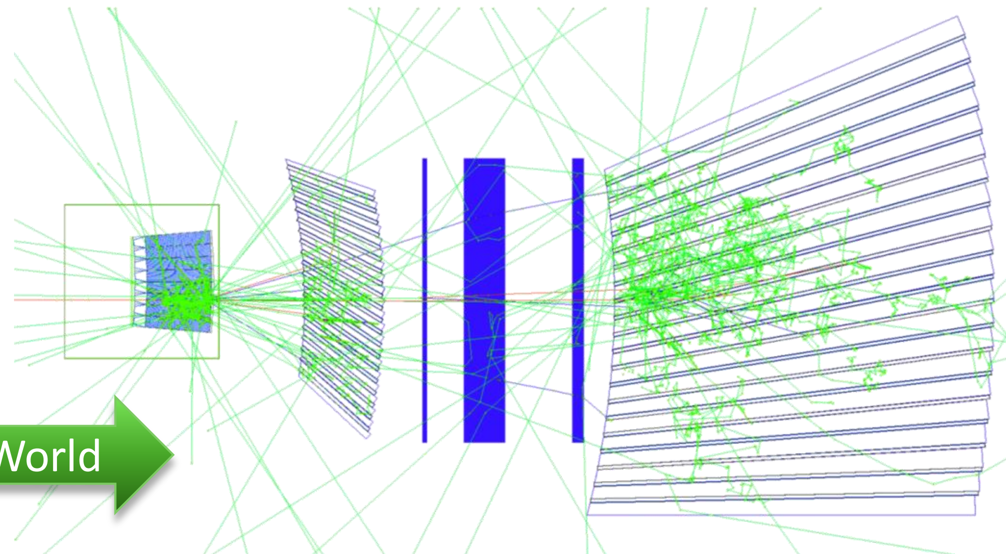
Calorimeter simulation & analysis chain:

GEANT4 hit → Scintillation light model → Light collection model → Tower readout → Digitization → Calibrated tower energy → Clustering/Track matching/Jet finding

Test Beam Verification [arXiv:1704.01461]

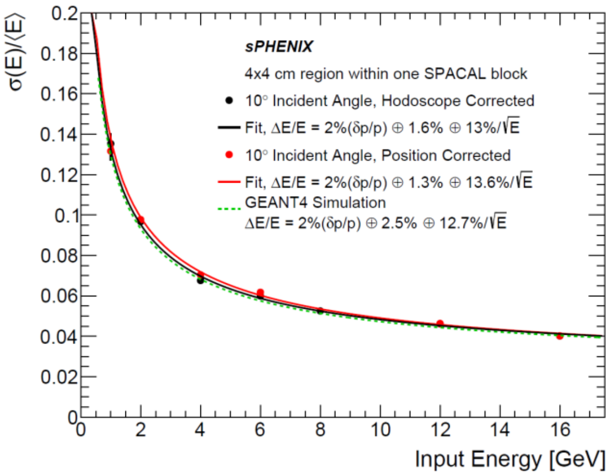


Geant4 World



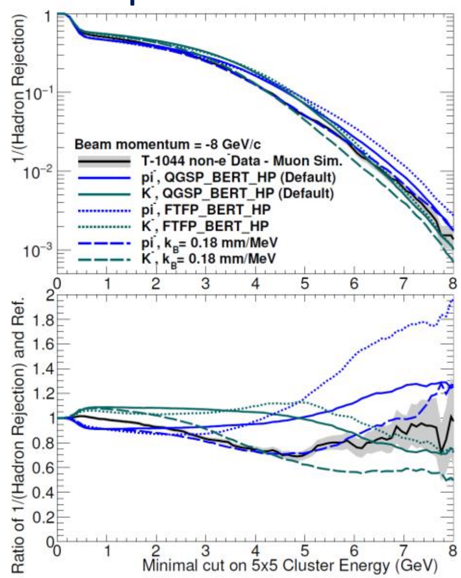
Test Beam Verification [arXiv:1704.01461]

EMCal energy resolution for EM shower in tower center

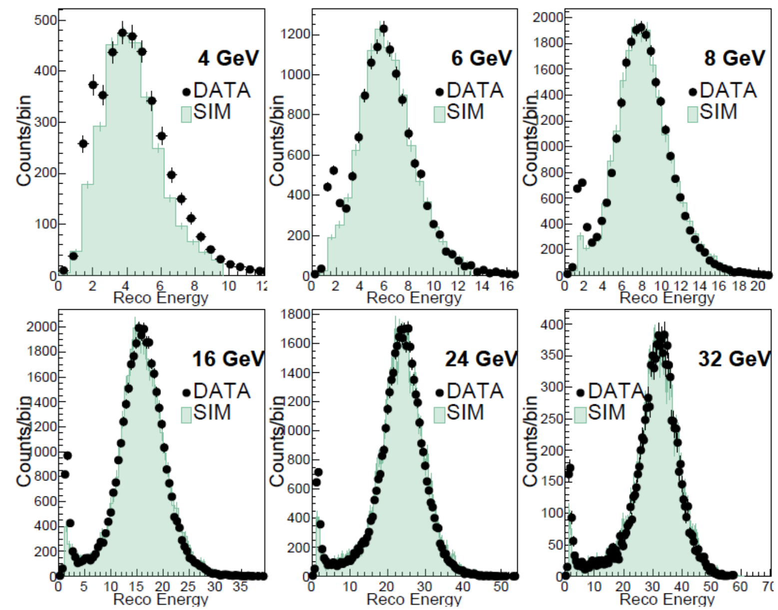


New 2017 data

EMCal rejection for pion-

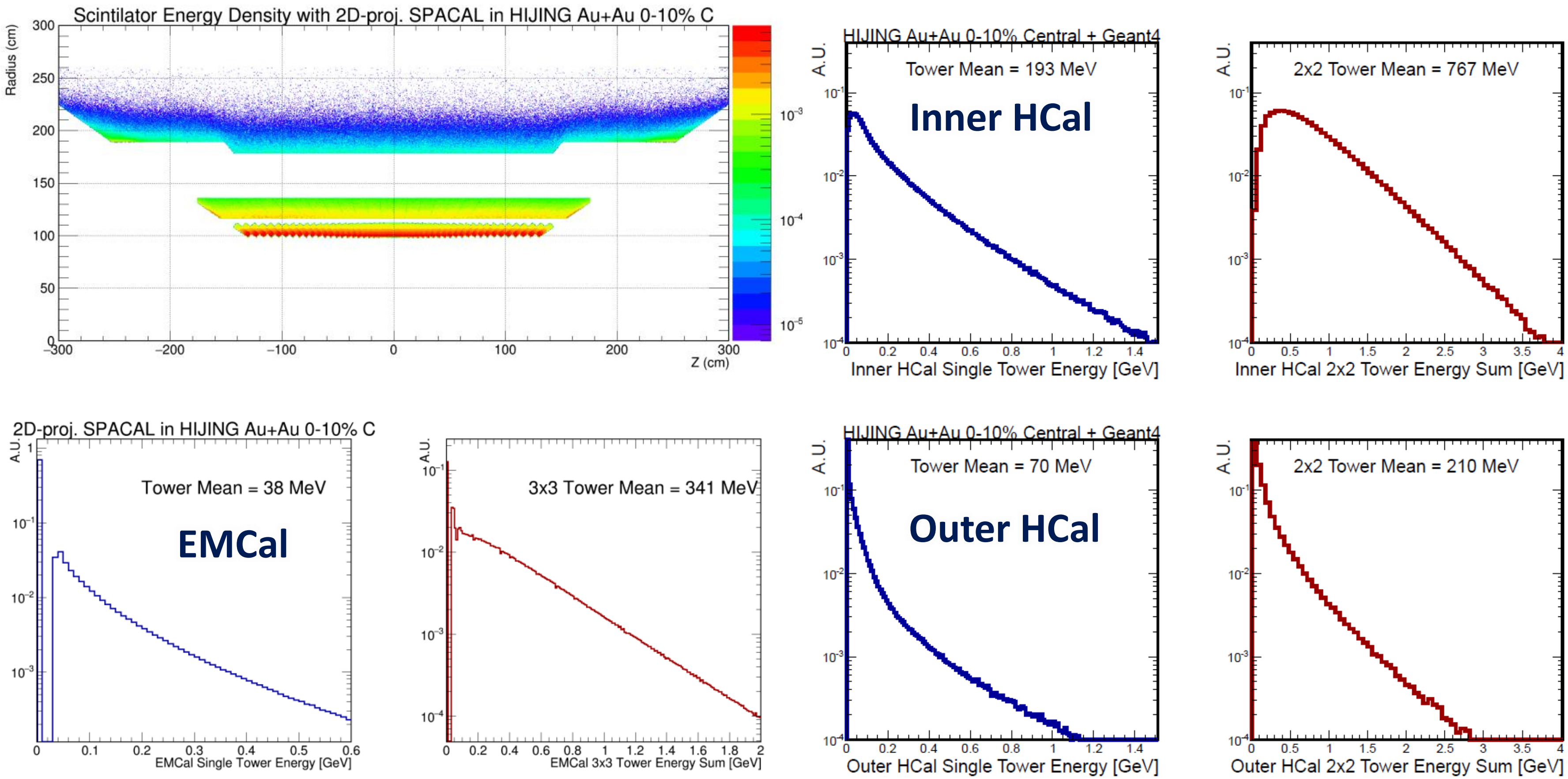


HCal energy response for pion-

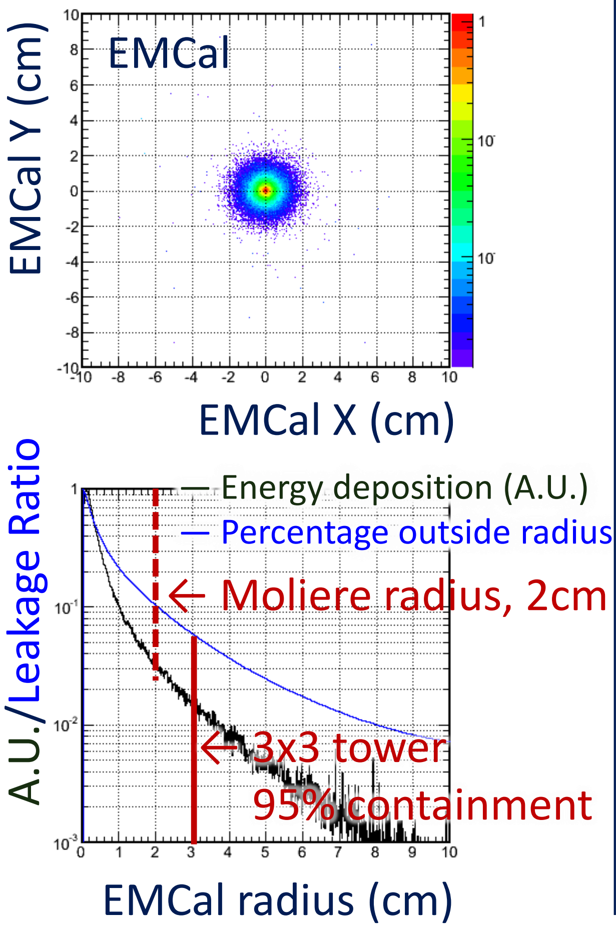


2016 data and submitted to IEEE TNS

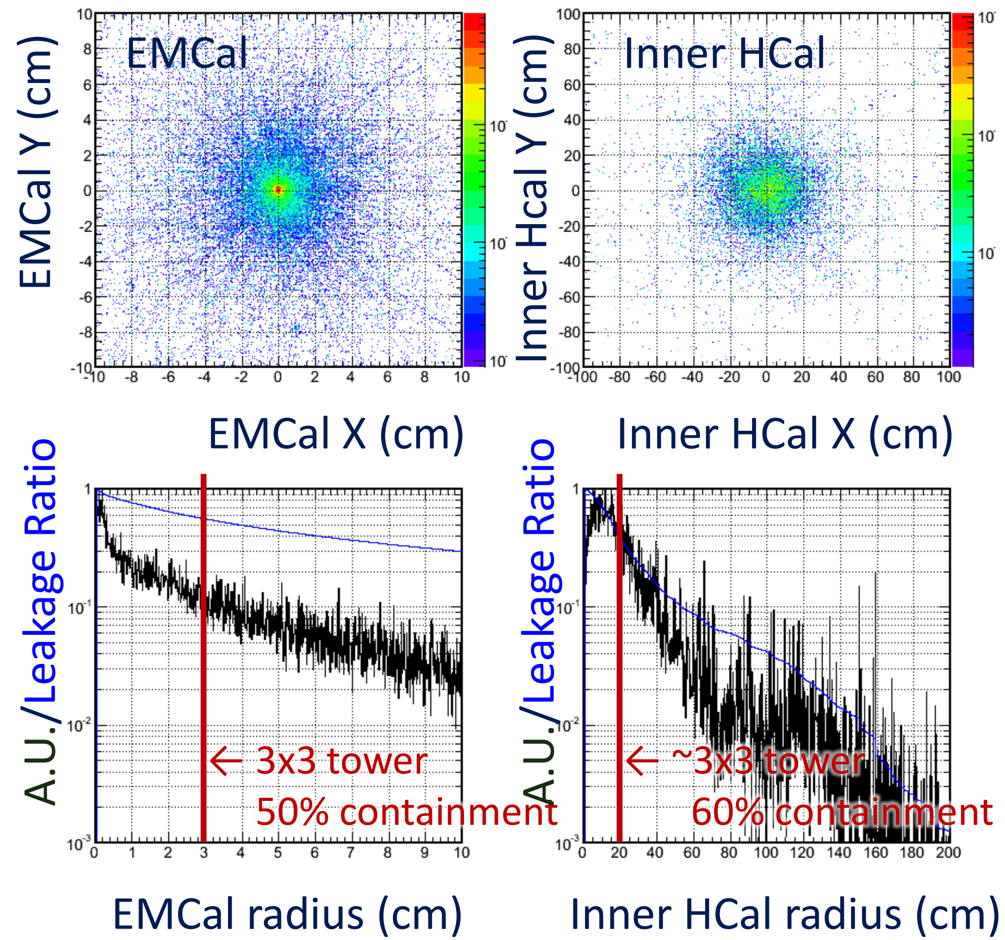
Au+Au background → Compact shower



4 GeV Electrons in EMCal



4 GeV Pions in EMCal, that **passed E/p electron-ID cut**

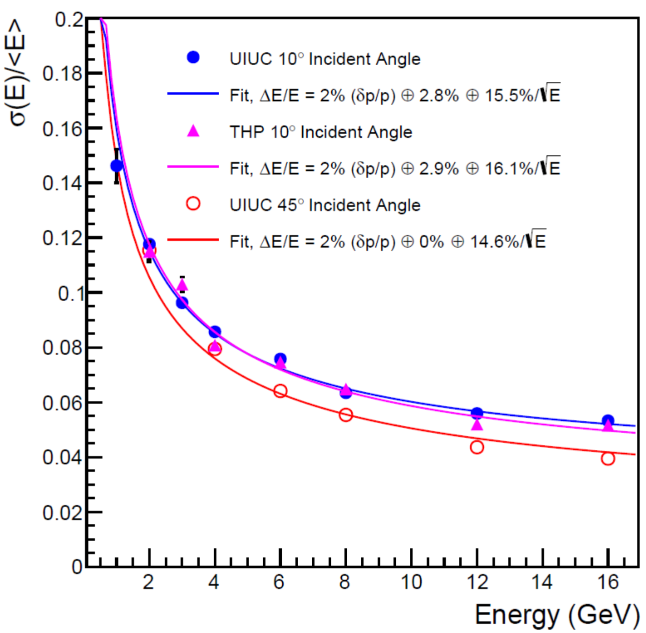


Performance simulations

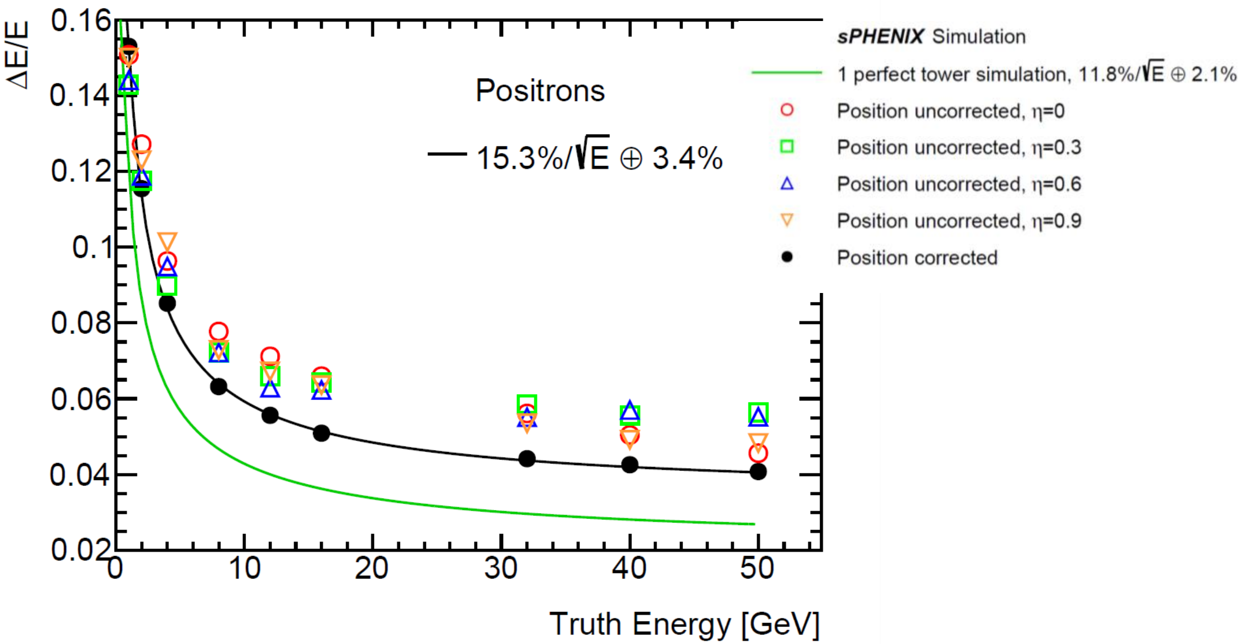
Performance : Single EM Showers

- Applied cluster-position-based non-uniformity correction as used in test beam analysis
- **dE/E ~ 15%/ √(E) + 4% (meets sPHENIX goal)**

Beam test [arXiv:1704.01461]

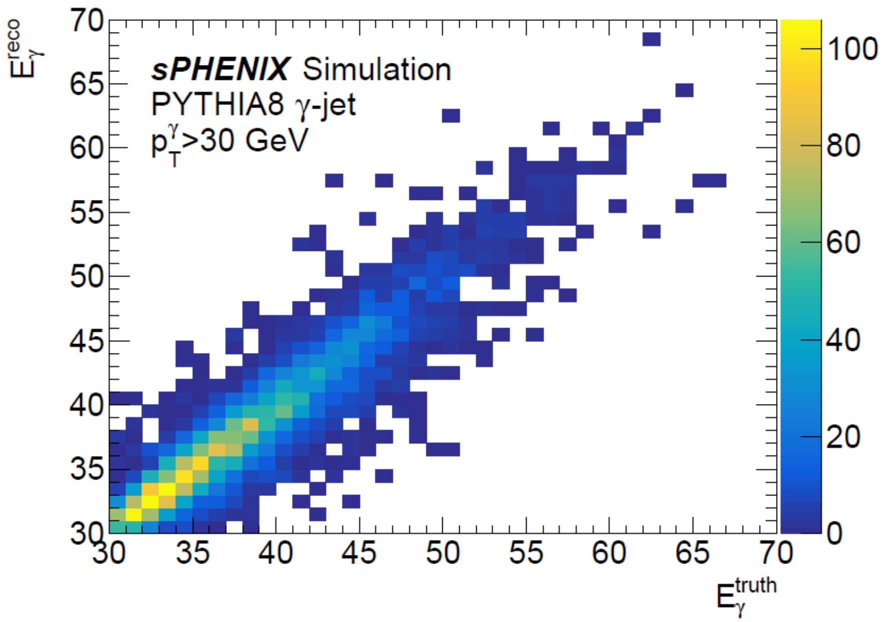


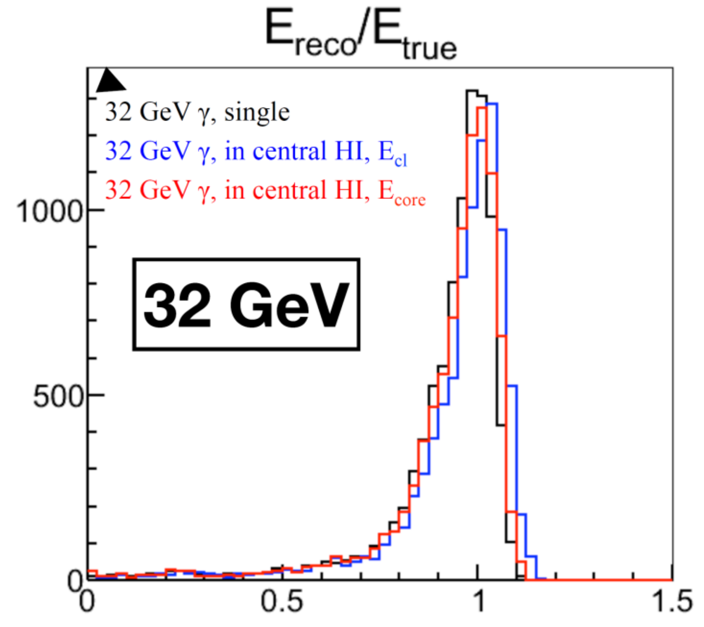
Full sPHENIX detector **simulation**



Performance : Photon in Full Event

- Good linearity up to photon kinematic limit of sPHENIX
- Good photon response shown in full event simulations



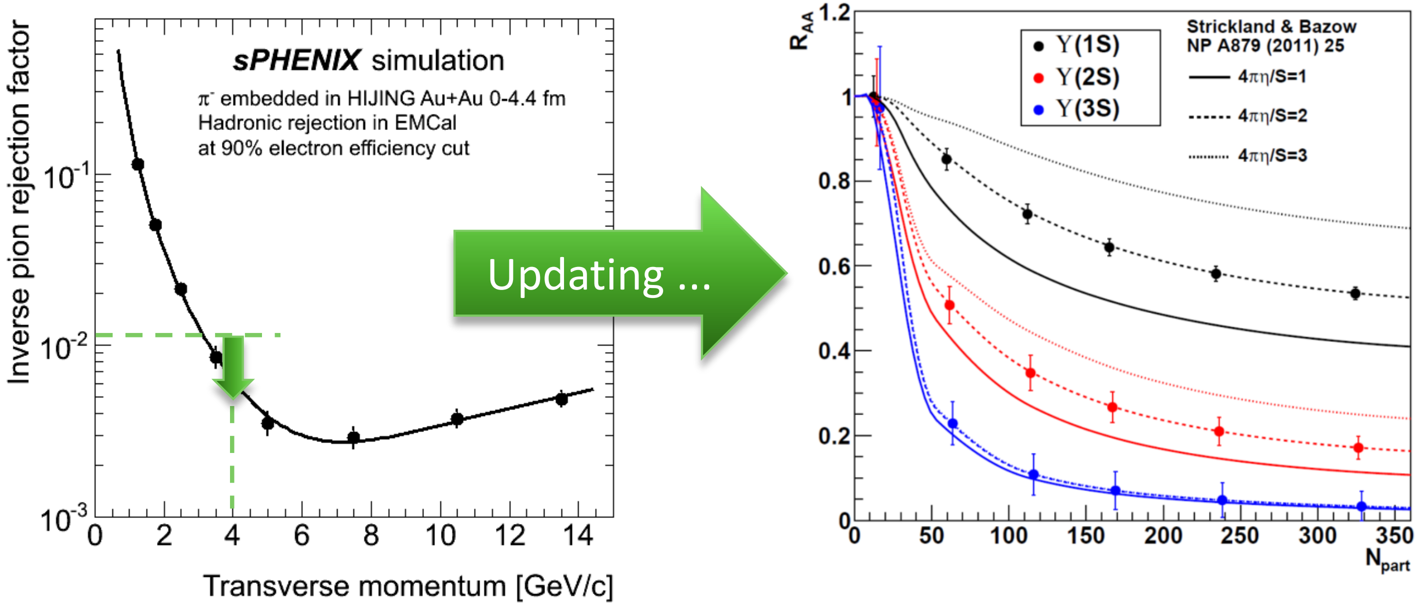


Physics Performance : Electron-ID

- Critical driving factor for EMCal design: Upsilon electron ID
- Satisfied detector requirement
  (>90:1-pion rejection @ p_T=4 GeV/c in central Au+Au collisions at 70% efficiency)
- Updating Upsilon background and R_{AA} projections

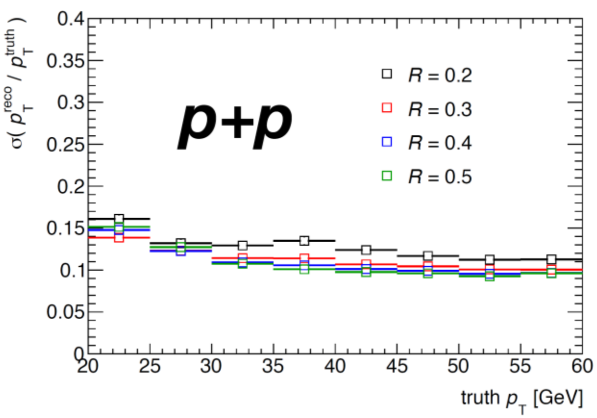
Pion rejection
@ 90% efficiency
(higher than spec.)

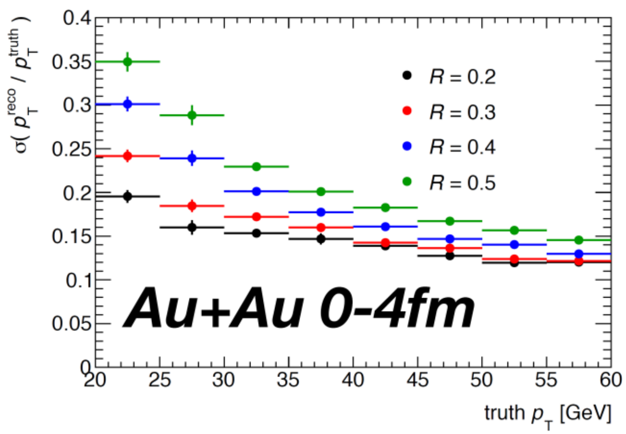
Upsilon R_{AA} projections in **sPHENIX proposal**

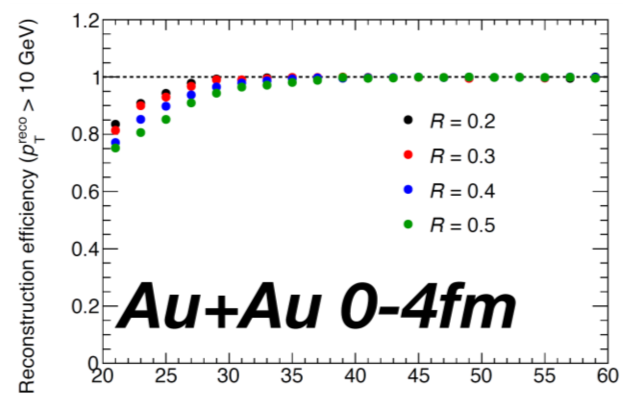


Performance : Jet Finding

- Jets in p+p and central Au+Au collisions are also studied in full detector simulations
- Jet finding followed by ATLAS style iterative background subtraction [10.1103/PhysRevC.86.024908]
- Performance meeting sPHENIX spec.
- Further improving underlying event subtraction and fake-jet rejection algorithm based on RHIC and LHC experiences

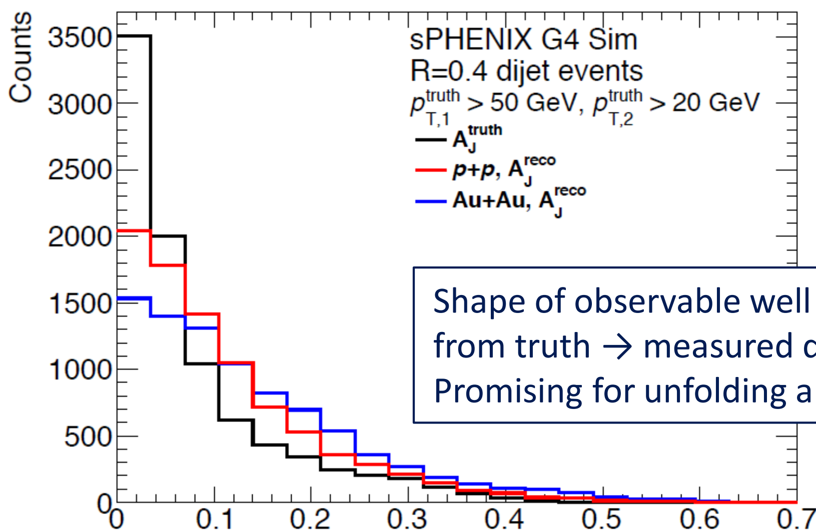






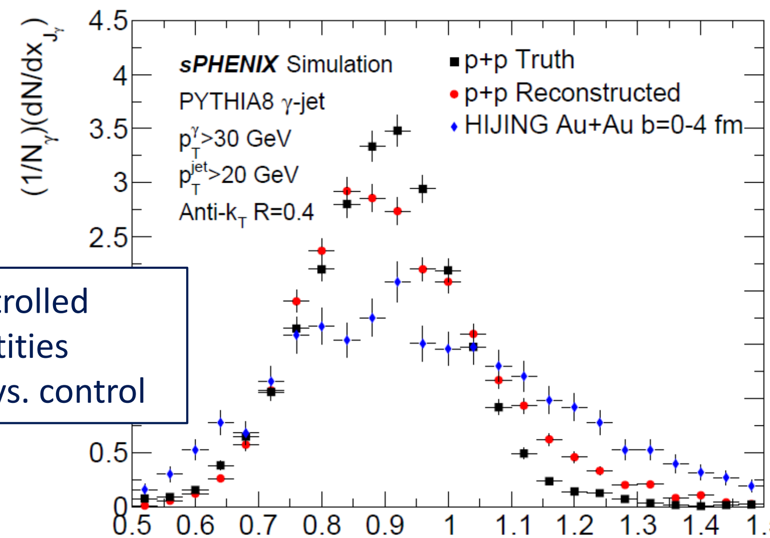
Physics Performance : Jet Observables

- Jet-balance/imbalance observables simulated in full detector events:
  day-1 measurement, resolution under control
- On-going effort in understanding the details of the jet simulations and unfolding studies.
- Expanding jet observables studied with the updated design and simulations



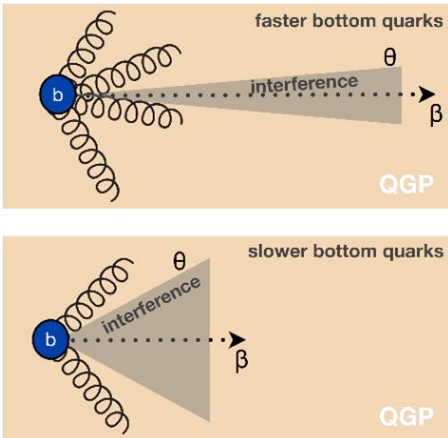
Di-jet transverse momentum asymmetry

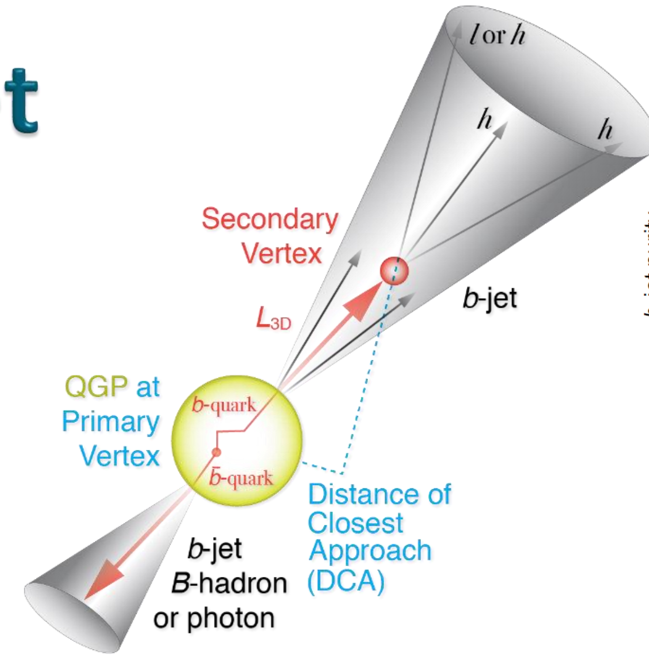
Shape of observable well controlled
from truth → measured quantities
Promising for unfolding and sys. control

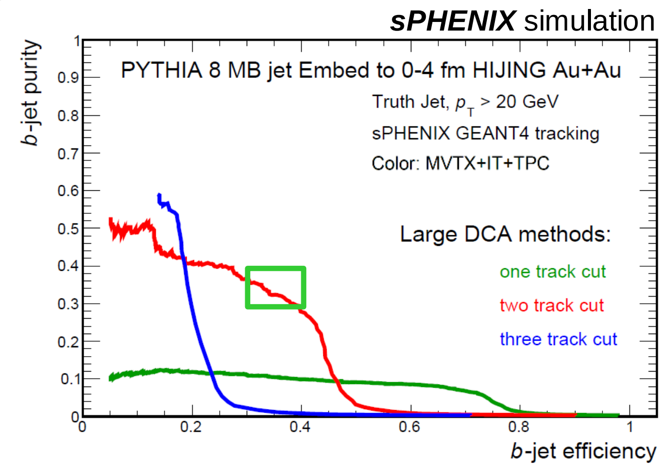


γ-jet transverse momentum balance

b-quark jet

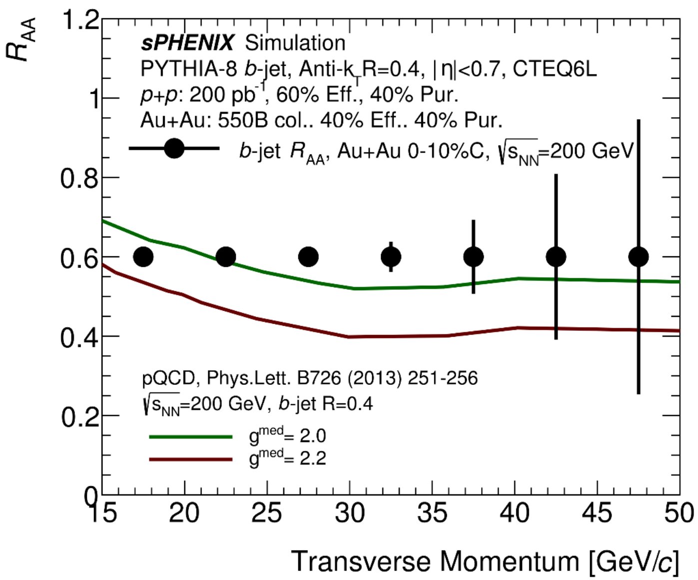


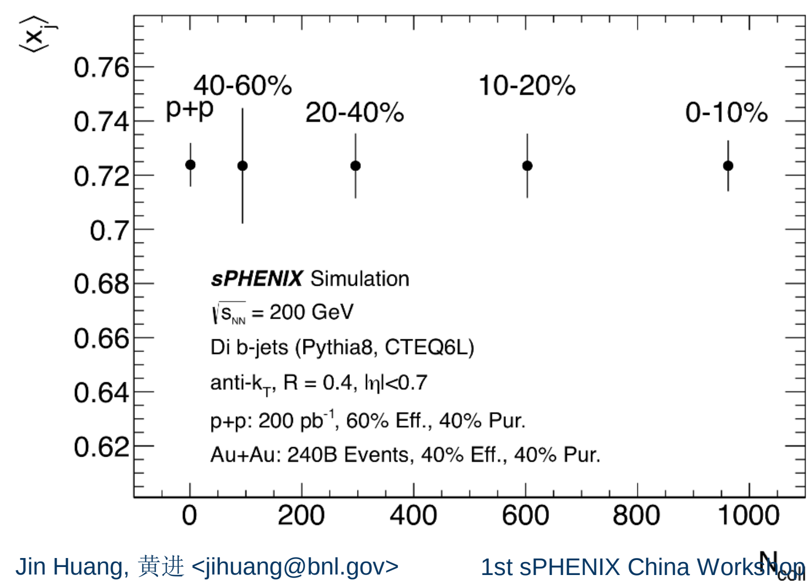




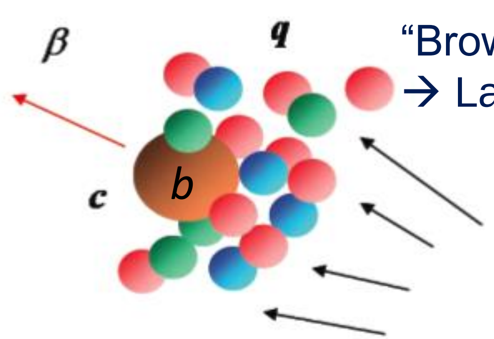
CMS work-point, Phys. Rev. Lett. 113, 132301 (2014)

b-jet + light jet: differential sensitivity to radiative VS collisional energy loss.





Precision open bottom meson



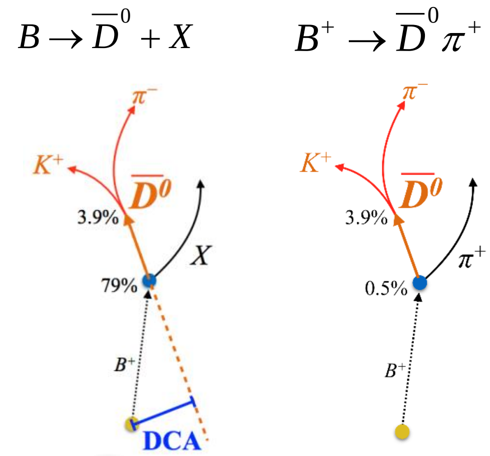
"Brownian" motion → Langevin simu.

$$\frac{dp^i}{dt} = -\eta_D p^i + \xi^i(t)$$

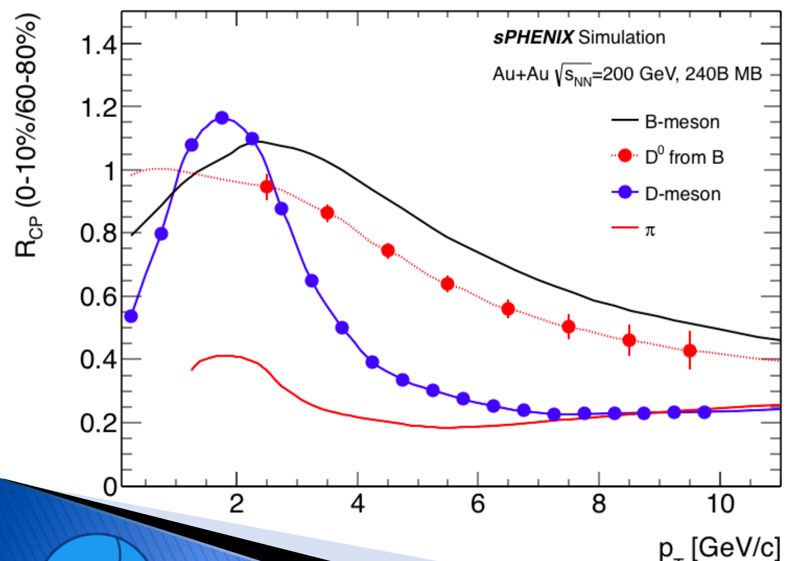
drag

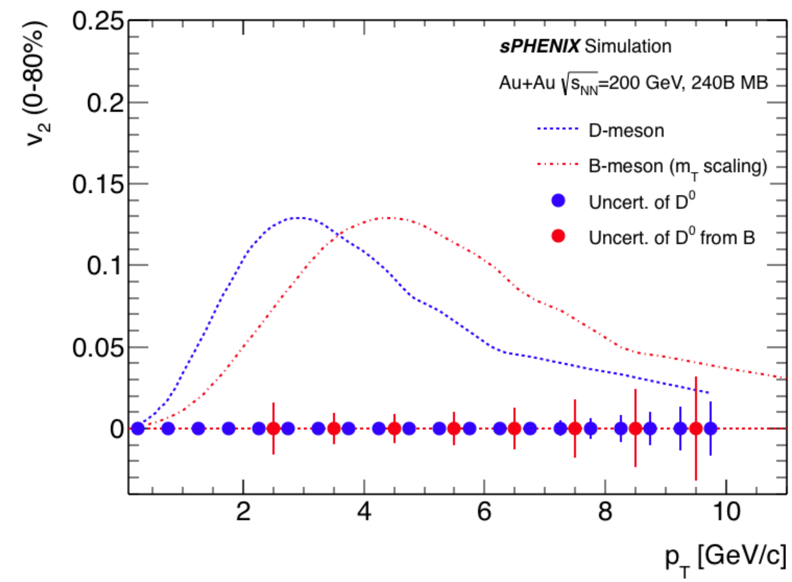
fluctuations

Diffusion coefficient D_{HQ}



B-meson program: p_T 2-10 GeV/*c*, precisely determine the bottom quark collectivity → clean access to D_{HQ}



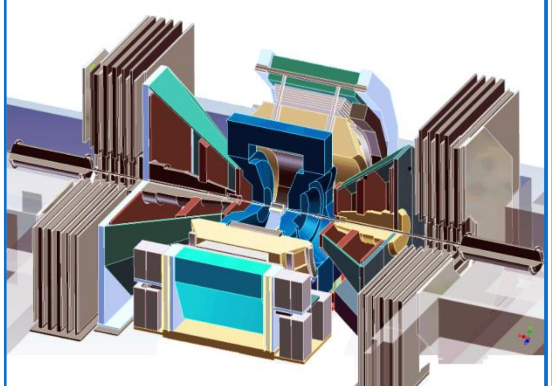


Beyond sPHENIX

Evolution of the PHENIX Interaction region

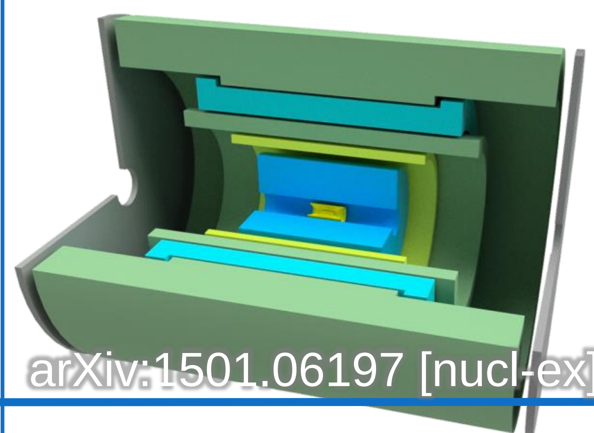
PHENIX experiment

- 16y+ operation
- Broad spectrum of physics (QGP, Hadron Physics, DM)
- 170+ physics papers with 24k citations
- Last run in this form 2016



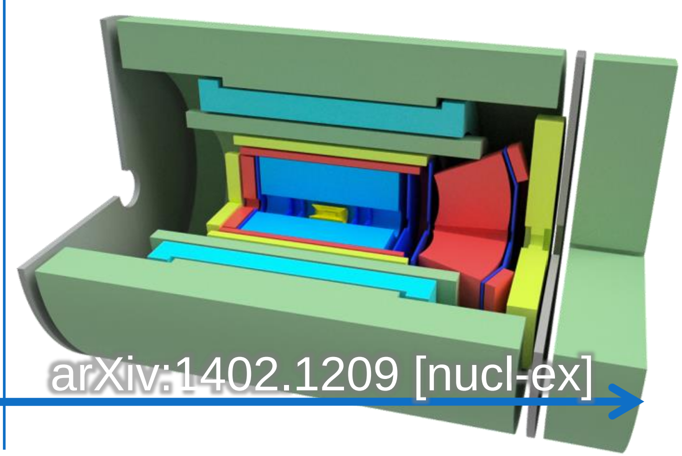
sPHENIX

- Comprehensive central upgrade base on BaBar magnet
- Rich jet and HF physics program
  → nature of QGP
- Possible forward tracking, and calorimeter → Spin, CNM



An EIC detector

- Path of PHENIX upgrade leads to a capable EIC detector
- Large coverage of tracking, calorimetry and PID
- Open for new collaboration/new ideas

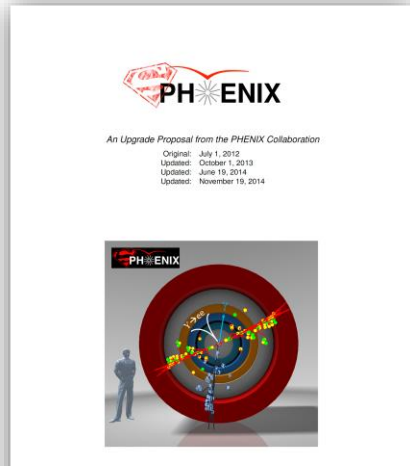


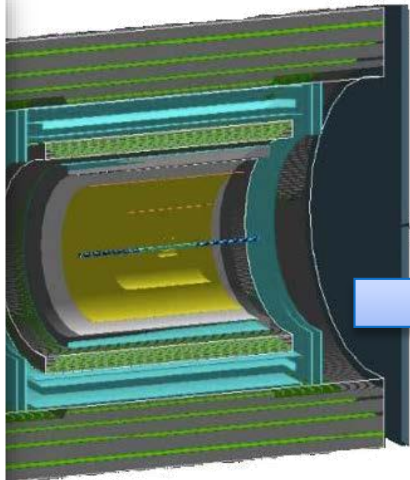
~2000 | 2017→2022, CD-0 @ 2016 | ≥2025 | Time

RHIC: A+A, spin-polarized p+p, spin-polarized p+A

EIC: e+p, e+A

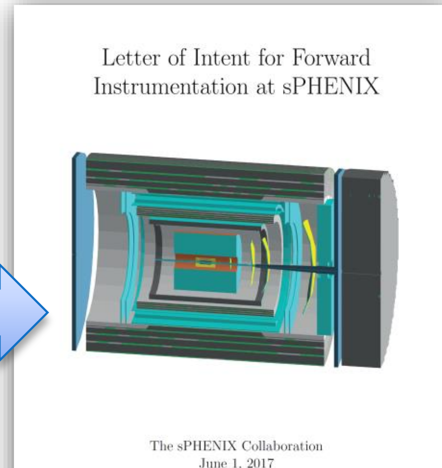
Evolving upgrade concepts

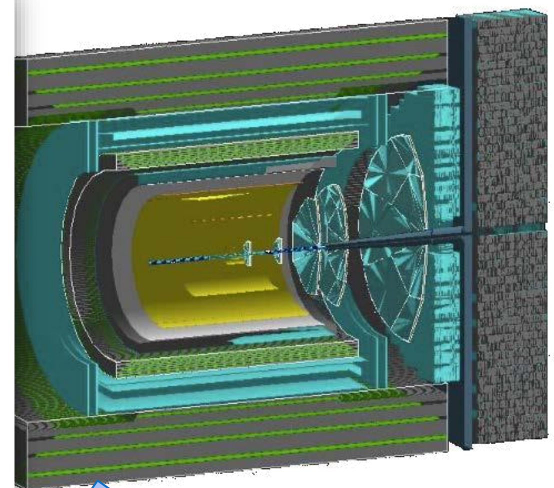




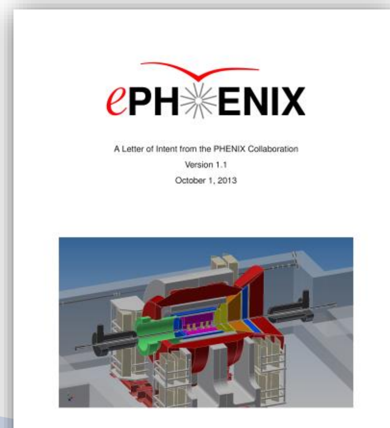
arXiv:1501.06197

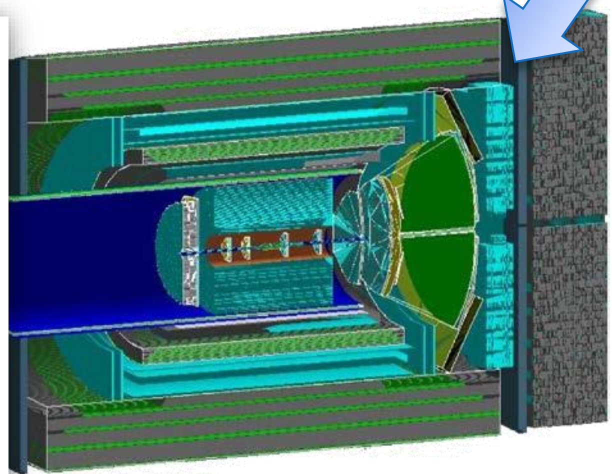
CDR in preparation





To RHIC PAC 2017

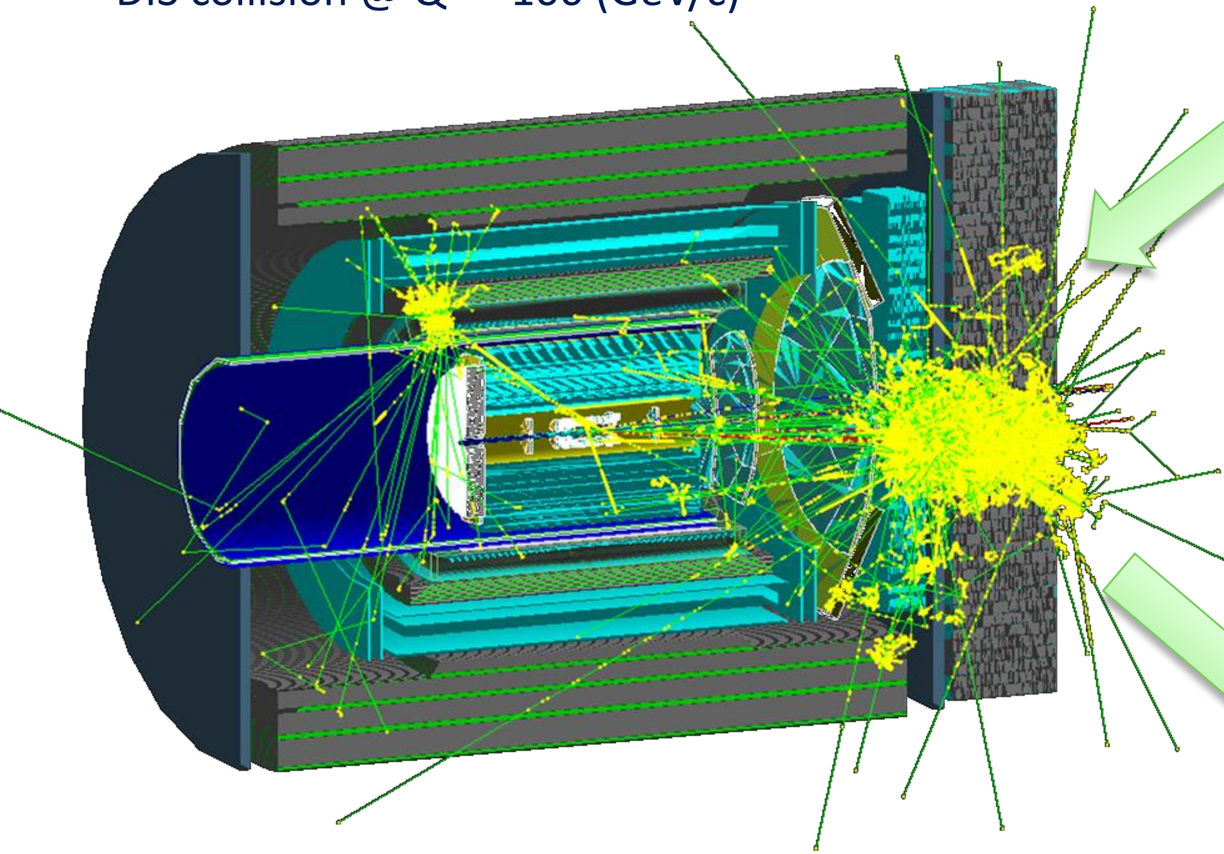


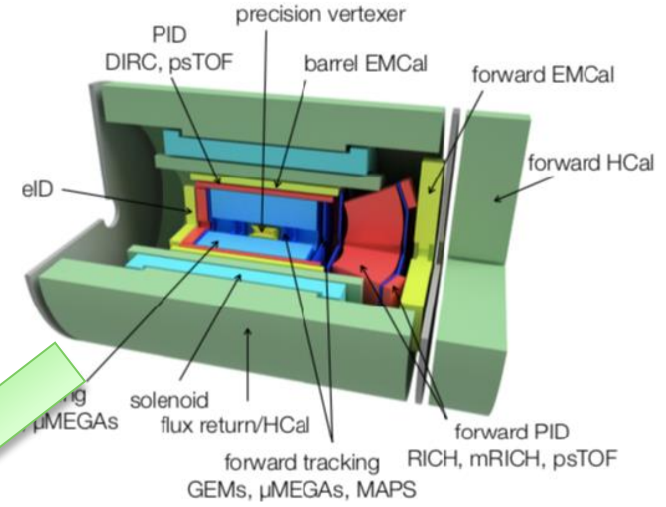


arXiv:1402.1209

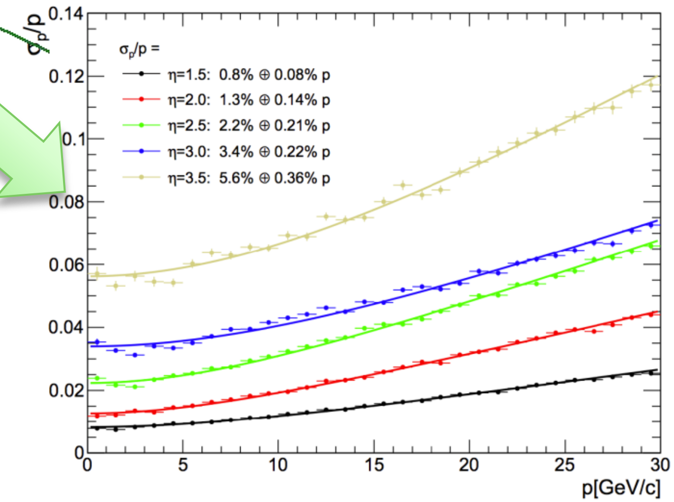
EIC detector studies

DIS collision @ $Q^2 \approx 100\ (\mathrm{GeV}/c)^2$





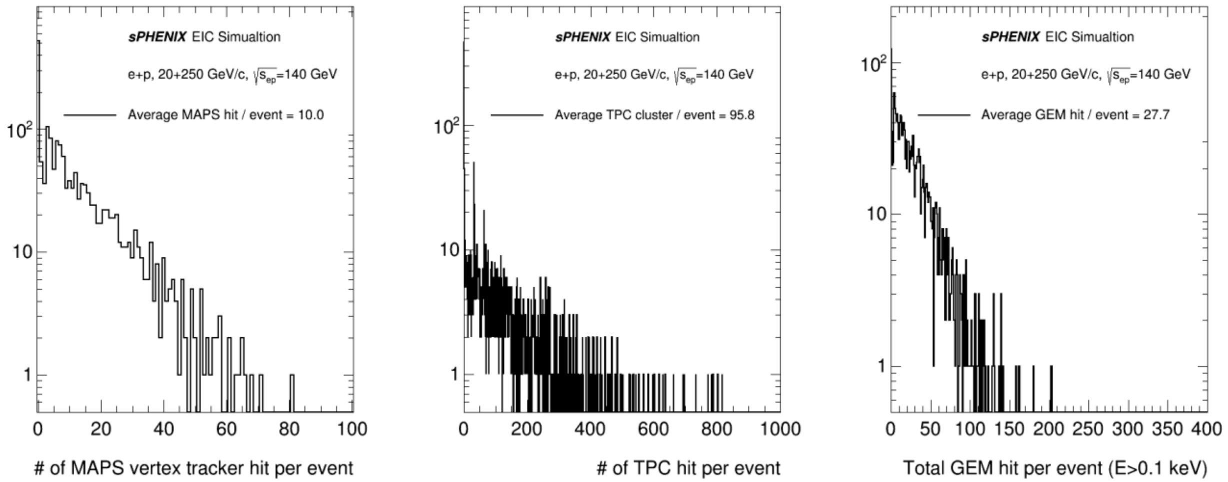
Forward tracking resolution (Haiwang Yu)

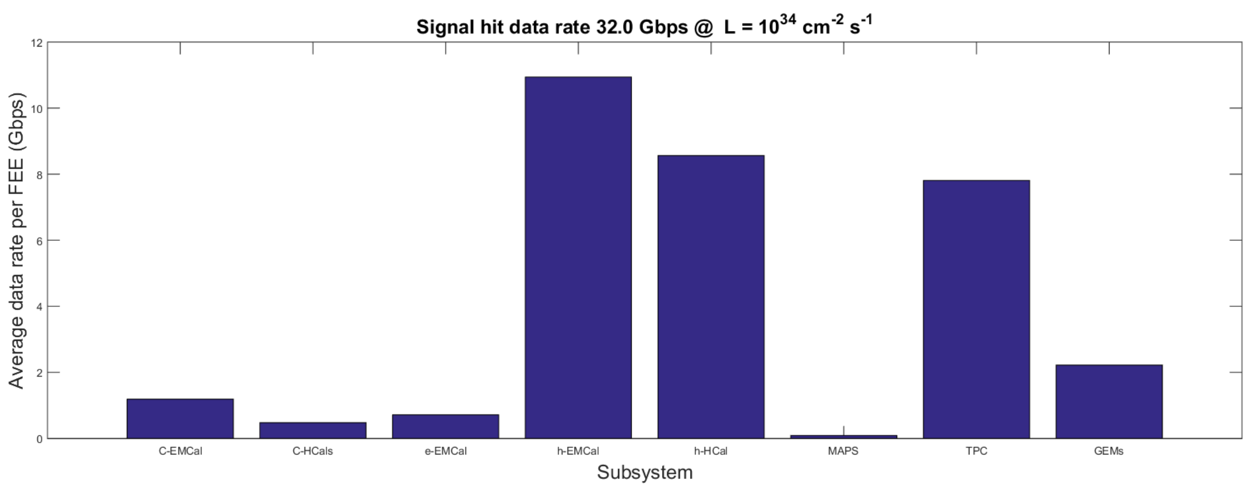


EIC LOI being updated this year. Many opportunity to contribute and design future of sPHENIX

Full detector EIC simulation in sPHENIX framework:
Promise to stream readout EIC detector with sPHENIX DAQ

See my slide @ EIC stream readout meeting and sPHENIX cold-QCD TG meeting
https://indico.bnl.gov/event/4464/contributions/20809/attachments/17998/22285/2018.04.02_EIC_Stream_Readout2.pdf





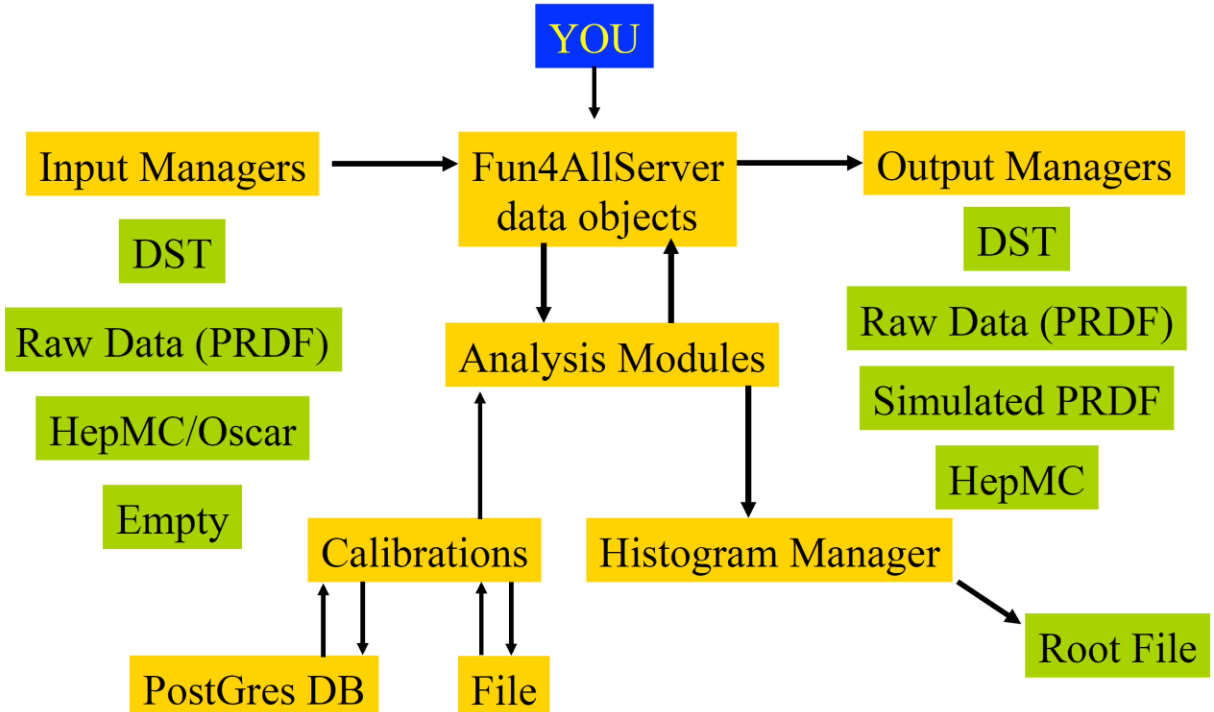
50 ub cross section
@ L = 10^{34} cm^{-2} s^{-1}
→
~100 Gbps (30 Gbps+ PID + headers) stream readout EIC without triggering
≈ sPHENIX DAQ disk rate

How to get involved

How to get involved

- Always good to start with day-1 checklist
- Discussion group:
  - sPHENIX simulation meeting: https://indico.bnl.gov/categoryDisplay.py?categId=88
  - Software and repository email list:
    - https://lists.bnl.gov/mailman/listinfo/sphenix-software-l
    - https://lists.bnl.gov/mailman/listinfo/sphenix-github-l
- Documentation
  - Software wiki: https://wiki.bnl.gov/sPHENIX/index.php/Software
  - Doxygen software reference: https://www.phenix.bnl.gov/WWW/sPHENIX/doxygen/html/
- Resource
  - RCAF
    - Works with both PHENIX and STAR(in testing) existing RCF account
    - 10 TB per user base disk associated with sPHENIX group tag: Register with this form .
  - sPHENIX code repository: https://github.com/sPHENIX-Collaboration

Framework: Fun4All



- Based on PHENIX software framework, a.k.a. Fun4All
  - Modular design, C++ based, 1 PB data / week PHENIX data analysis
- Built-in Geant4 support Common macro run the simulation and standard analysis chain
- Easy access for user modules in analysis : https://wiki.bnl.gov/sPHENIX/index.php/Example_of_using_DST_nodes

Framework: Logistic

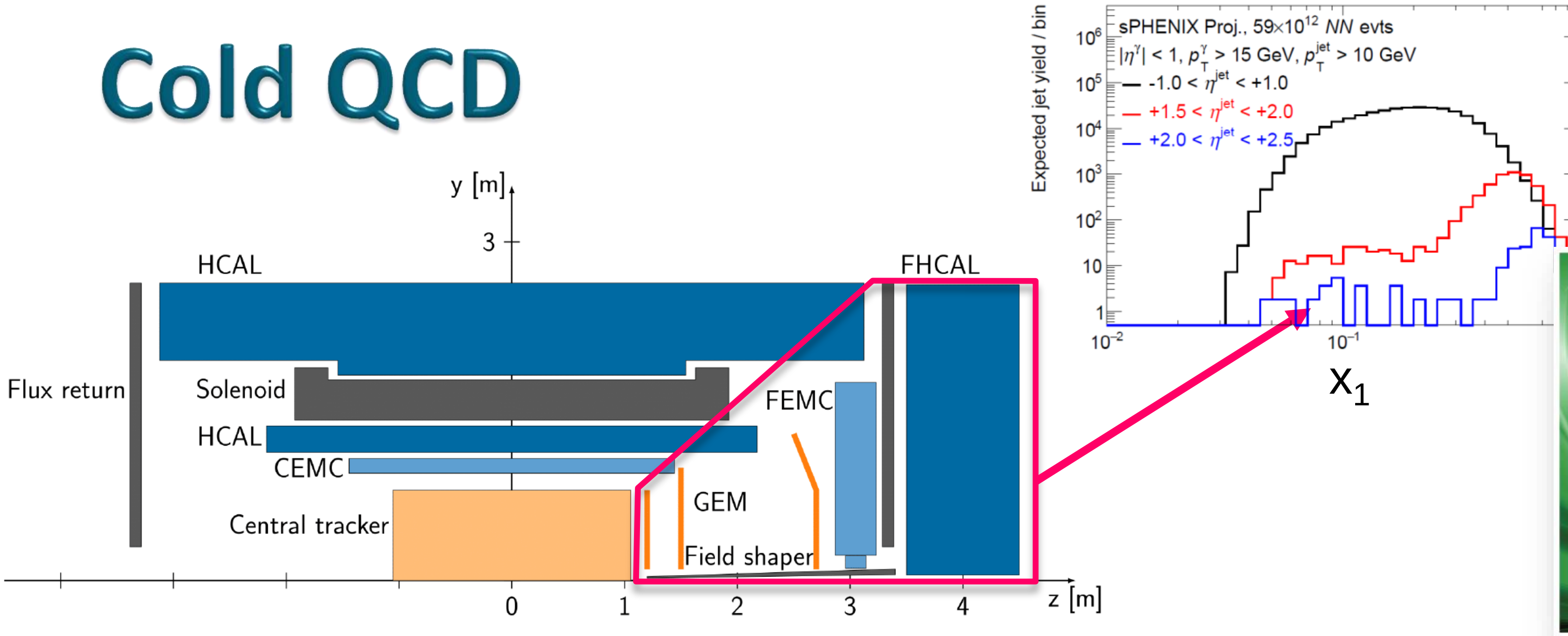
- Repositories: https://github.com/sPHENIX-Collaboration
  - ***analysis***: which contains the analysis modules. Everyone who is a collaborator (request to join here) can update this repository directly.
  - ***coresoftware***: which contains the framework, the G4 simulation and the Event library to read raw data.
    - Pull request & review required for updates
  - ***macros***: which contains macros to run the show.
    - Pull request & review required for updates
- Nightly build:
  - Most recent software build for use on RCF daily (new builds)
  - Weekly snapshot of software environment (ana builds)
- Further information :
  - https://wiki.bnl.gov/sPHENIX/index.php/Software

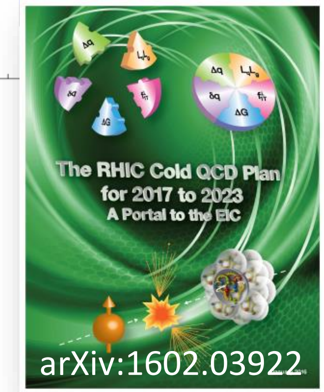
Summary

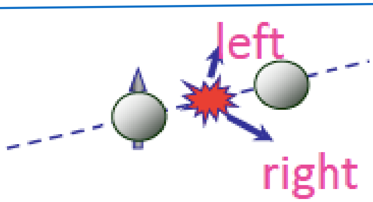
- sPHENIX has a robust simulation + reconstruction software
  - Checked with test beam with detailed detector description
  - Used in large studies in multiple campaigns
  - Improving fidelity of simulation, optimizing speed of reconstruction
- Current simulation show designed detector fit sPHENIX scientific goals
- Many opportunity for Chinese collaborator to contribute
  - Detector refinement
  - Studies of physics opportunities : four topical groups
- Join me this afternoon for a tutorial
- Always start from here: day-1 checklist

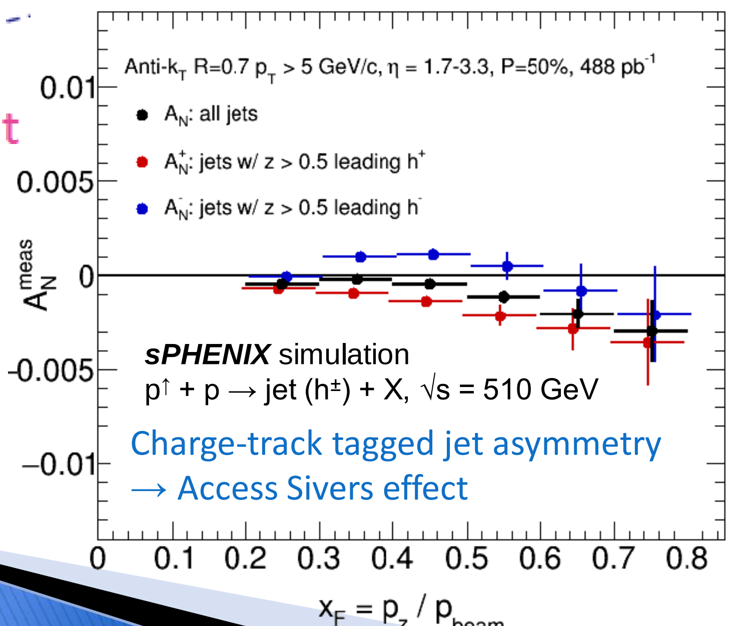
Extra Information

Cold QCD

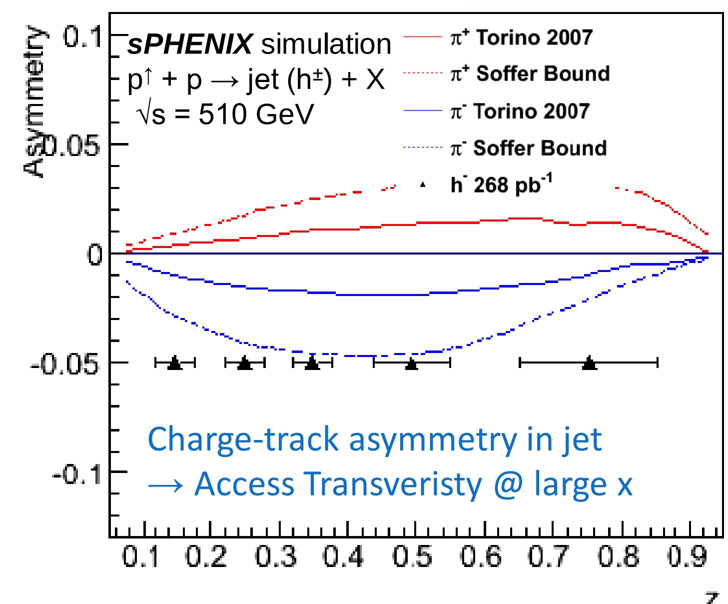








Charge-track tagged jet asymmetry
→ Access Sivers effect

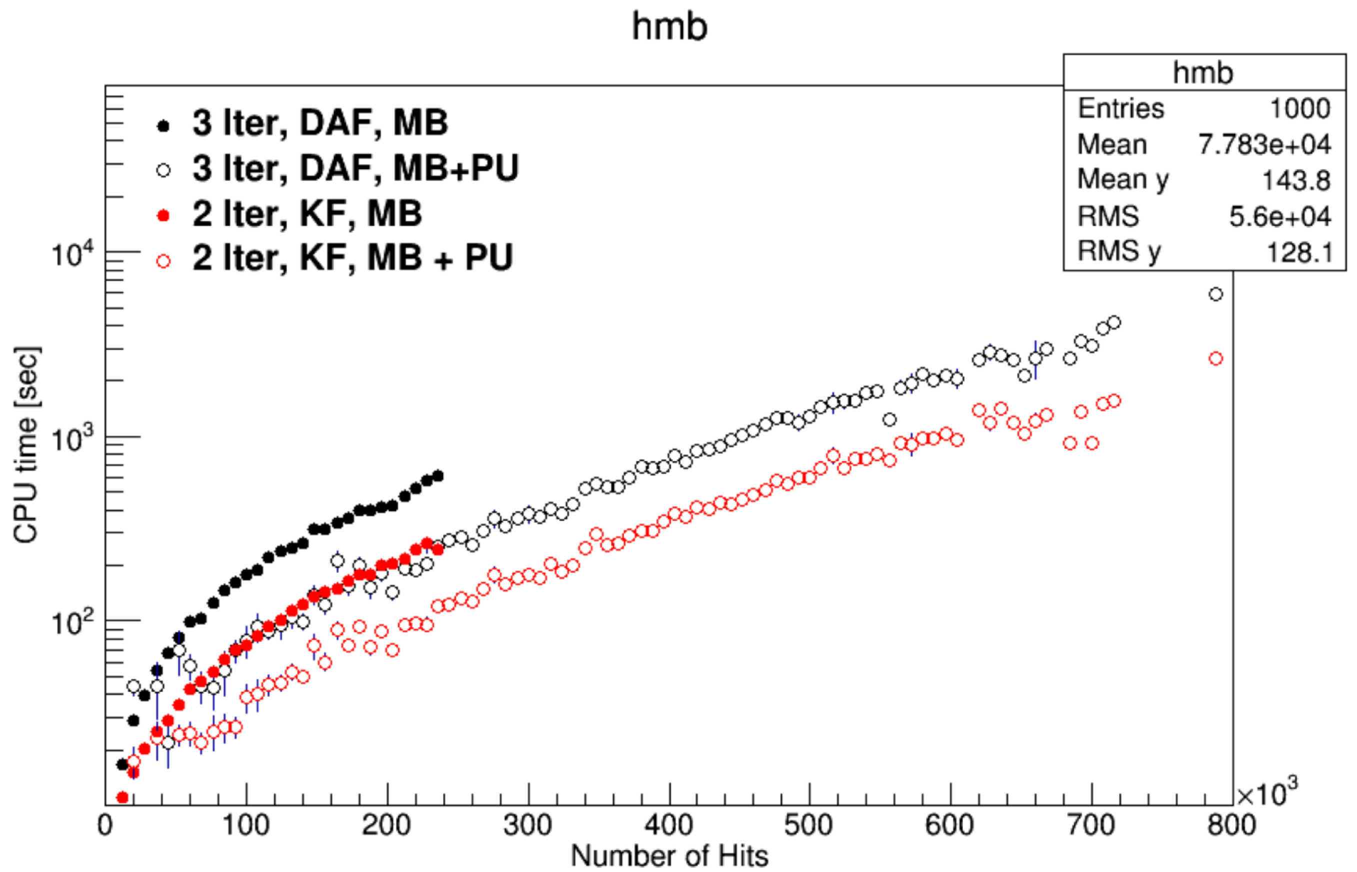


Charge-track asymmetry in jet
→ Access Transverisity @ large x

Event generator

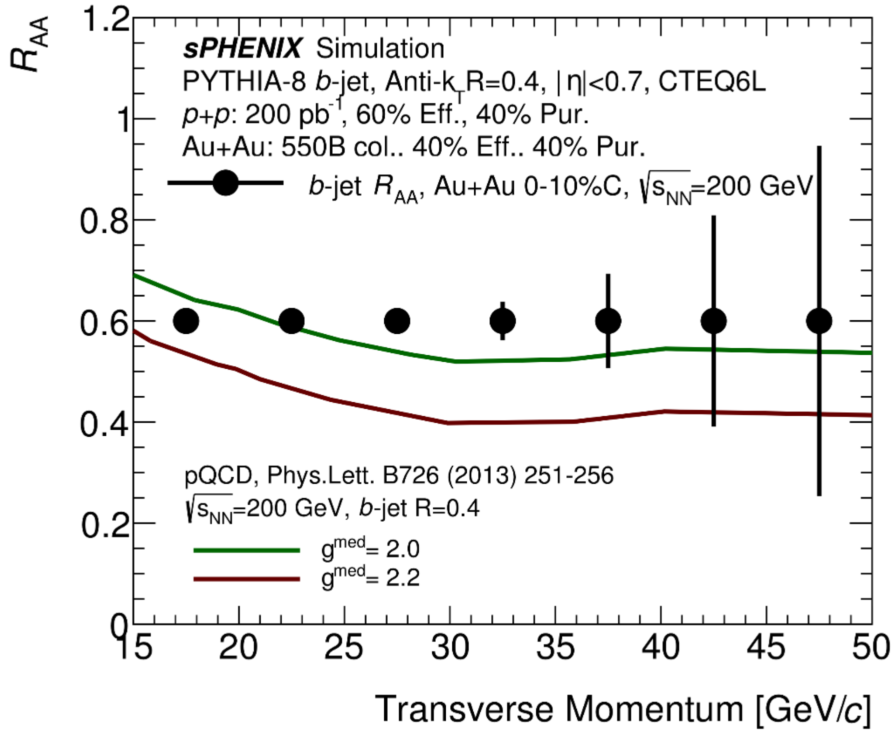
- Standard inputs: HEPMC format
  - Fun4AllHepMCInputManager -> HepMCNodeReader
- Generators in
  - Pythia8 for p+p: PHPythia8
  - Pythia6 for p+p/e+p: PHPythia6
  - Hijing for p+A, A+A
- Additional event generator
  - JEWEL/PHSartre/sHepGEN
  - Suits of EIC event generators via EIC-Smear package
  - Of-course single particle generator for testing
- For your study, welcome to contribute your favorite generator or HepMC data sets:
  - https://github.com/sPHENIX-Collaboration/coresoftware/tree/master/generators

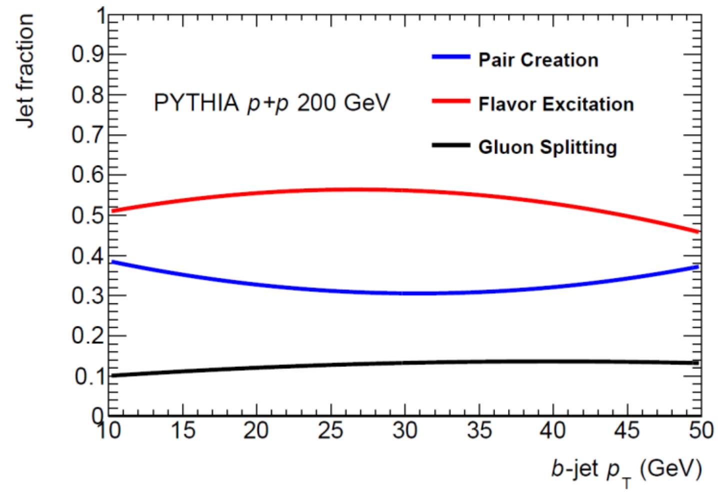
CPU performance vs number of hits

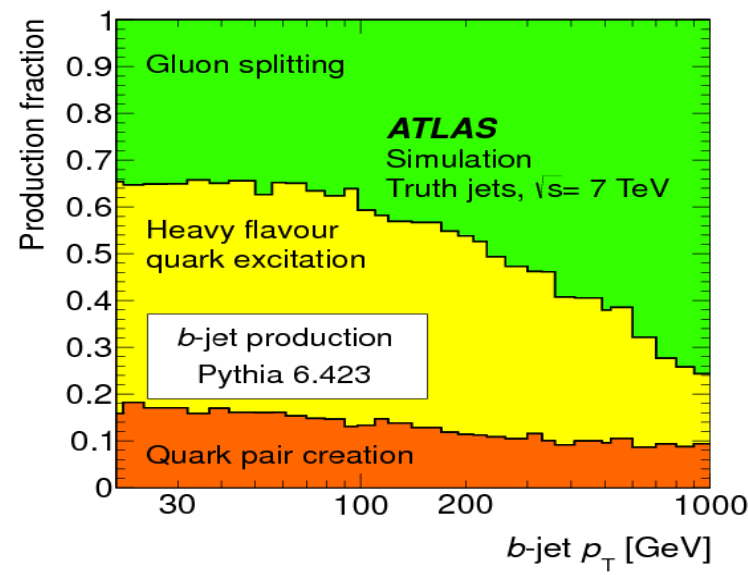


- In case I haven't mentioned it yet: Yes, pile-up really really hurts…

Inclusive b-jet R_{AA} Performance







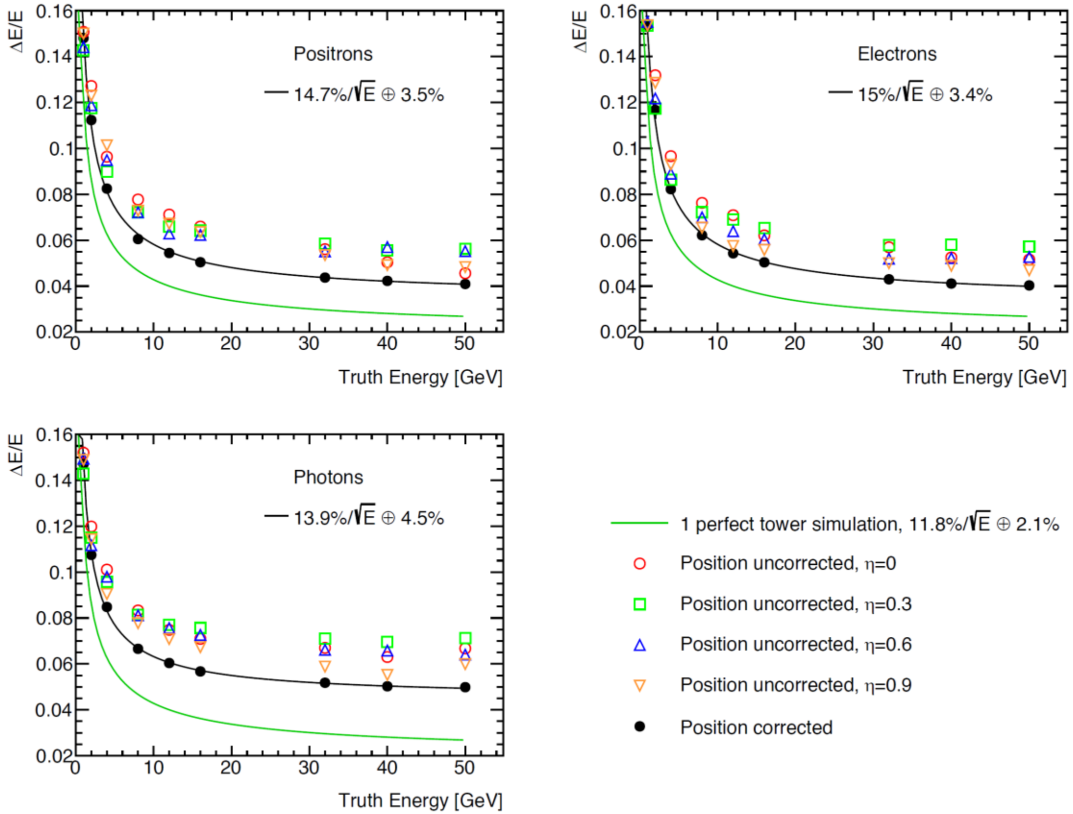
MVTX aiming first b-jet nuclear modification factor @ RHIC, covering ~15-40 GeV/c

- Mass dependence of parton energy loss
- Cleaner access to partonic kinematics

Uniqueness at RHIC (vs. LHC)

- Gluon splitting contribution is much less (~10%)

EMCal: EM-shower energy resolution



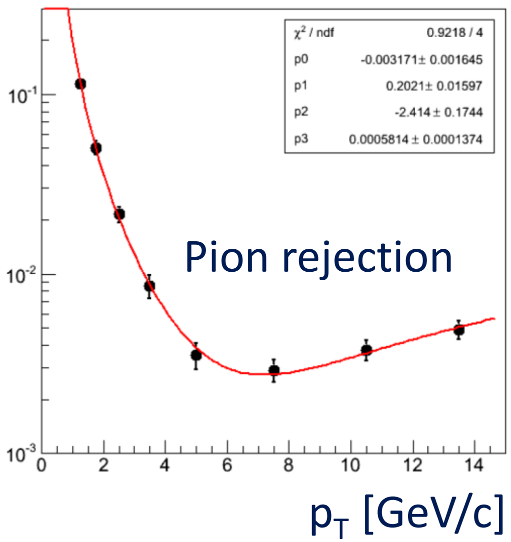
Joe Osborn (UMich), June 13 Sim meeting

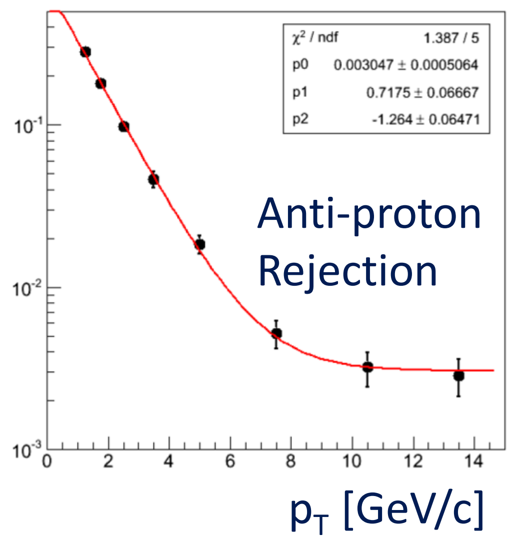
Request:

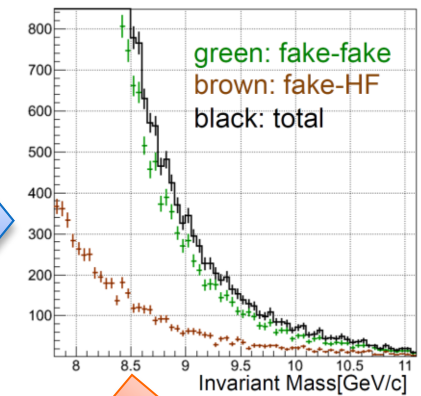
- Update with EMCal tower-by-tower calibration
- Apply sPHENIX style

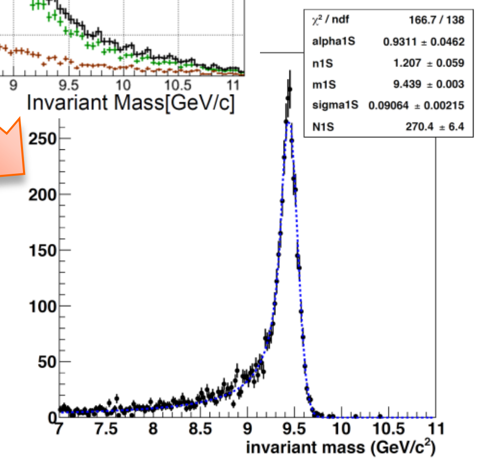
EMCal: Hadron rejection

Hadron rejection @ 90% electron eff. for embedded particle in 0-4.4 fm Au+Au collision
Work by Sasha Lebedev (ISU), quoted from Quarkonium-TG wiki, June-2017 Col. meeting









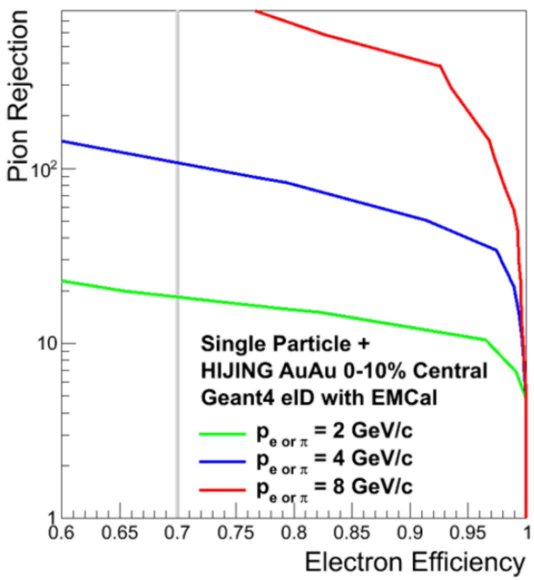
Requests in priorities:

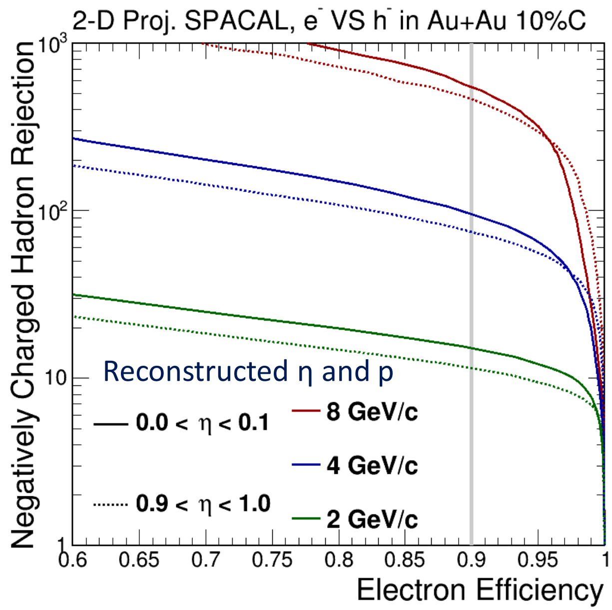
1. Update to sPHENIX plotting style
2. Produce Upsilon spectrum update with updated background
3. Use 2017 EMCal design and tracking simulations. Help on running?
4. Finalizing Upsilon R_AA projection?

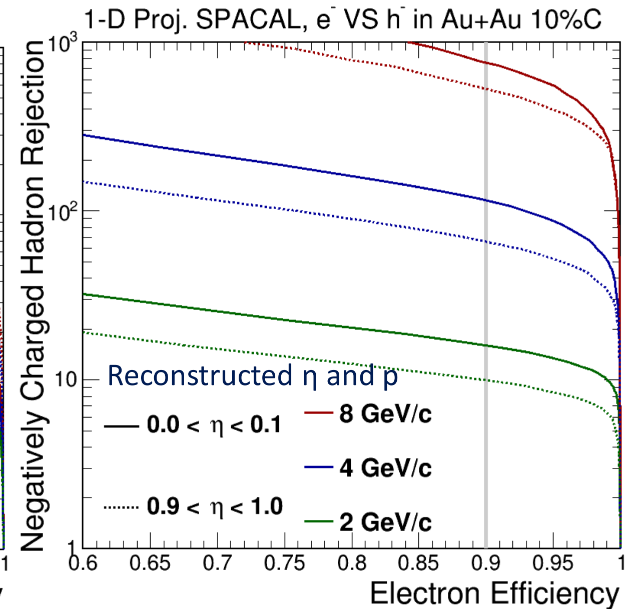
More in Sasha's talk today.

Performance : electron-ID in Au+Au

Updated and more detailed simulation show good safety margin on electron-ID performance on top of the baseline design (as required to reach Upsilon program physics goal)







Baseline performance, design goals

- Sum all scintillator energy
- 1D SPACAL material with hits grouped into 2D SPACAL towers

2D projective SPACAL

- Updated studies (Preliminary)
- Sum all hadron taking account of hadron ratio
- Full digitization (w/ Birk corrections)
- Full tracking with silicon opt.
- Fully implemented 2D SPACAL (tower/support structure)

1D projective SPACAL

- Updated studies (Preliminary)
- Sum all hadron taking account of hadron ratio
- Full digitization (w/ Birk corrections)
- Full tracking with silicon opt.
- Ideally towering (no-tower boarder, no enclosure structure)