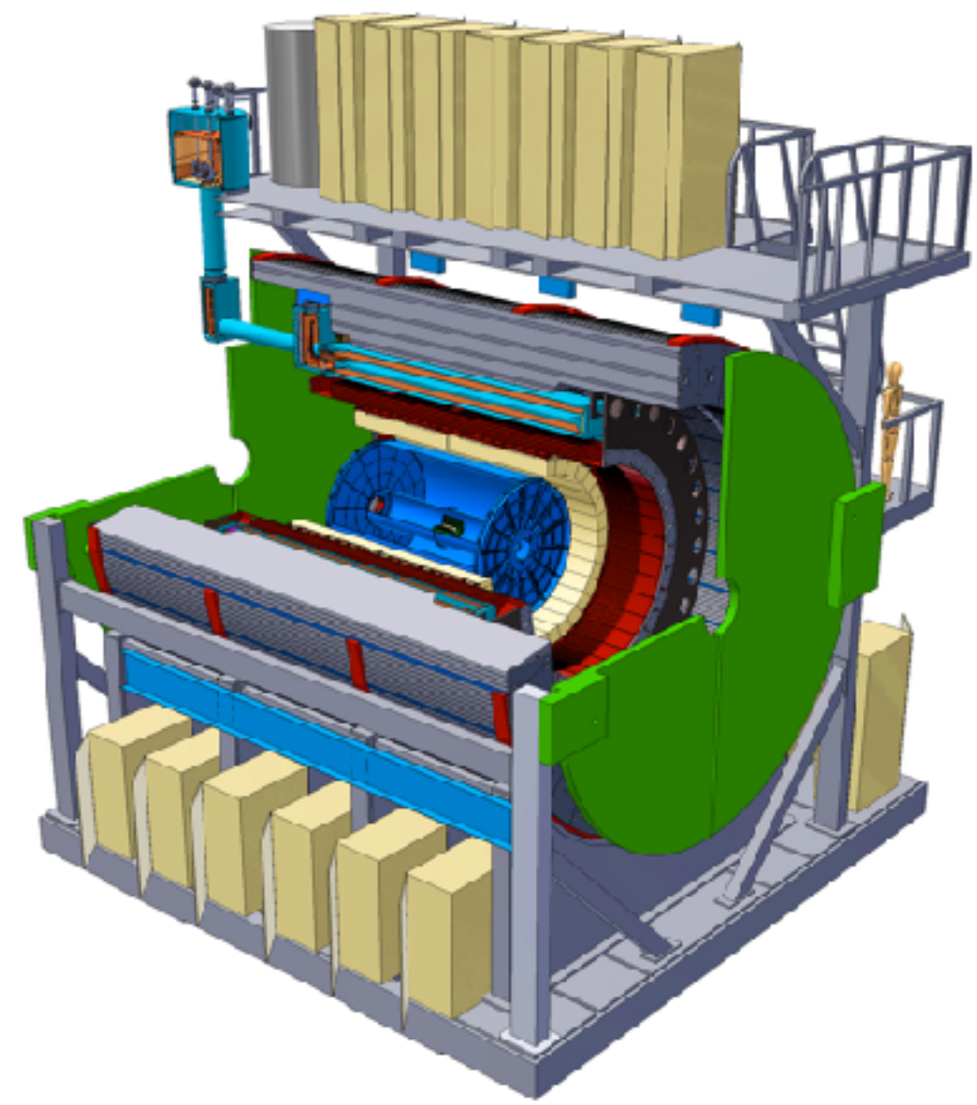
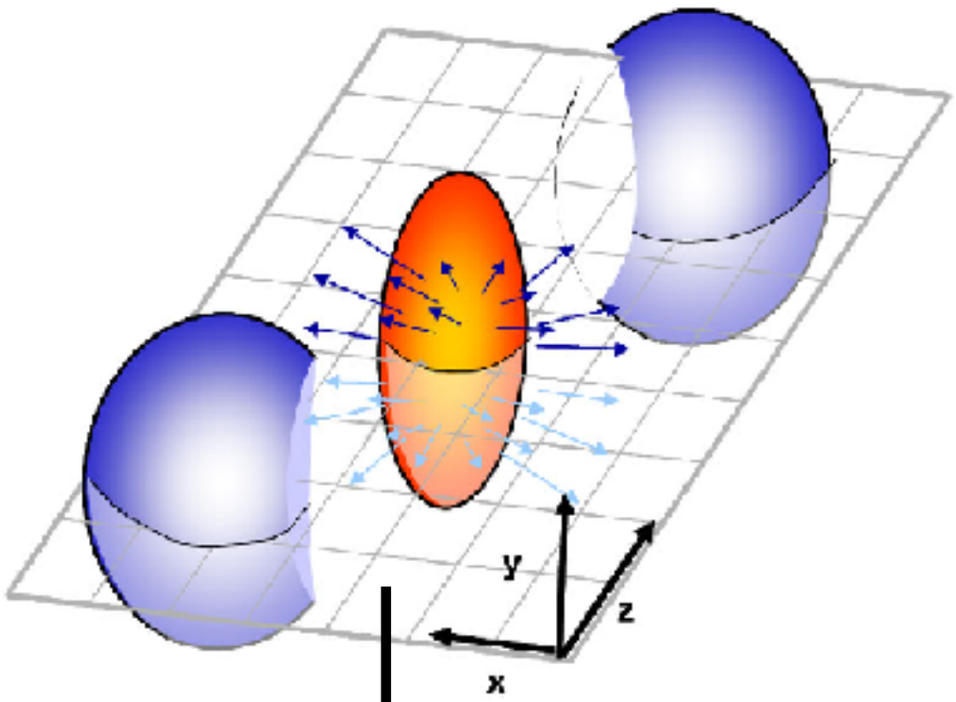
sPHENIX: Design, Status, Schedule

12 January 2018
UTFSM, Valparaiso, Chile

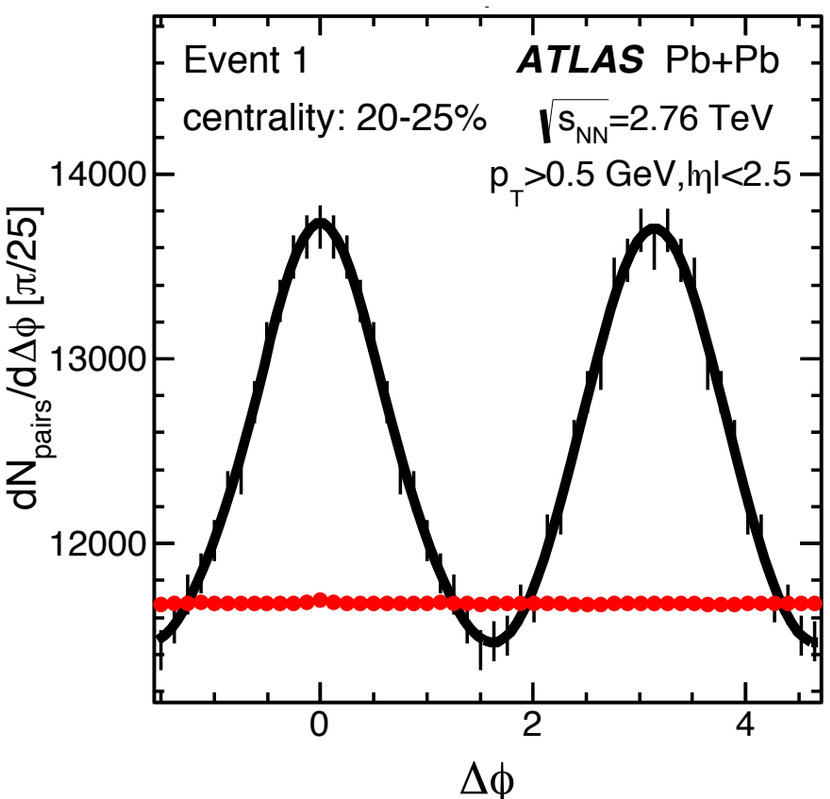
Dennis V. Perepelitsa
University of Colorado Boulder



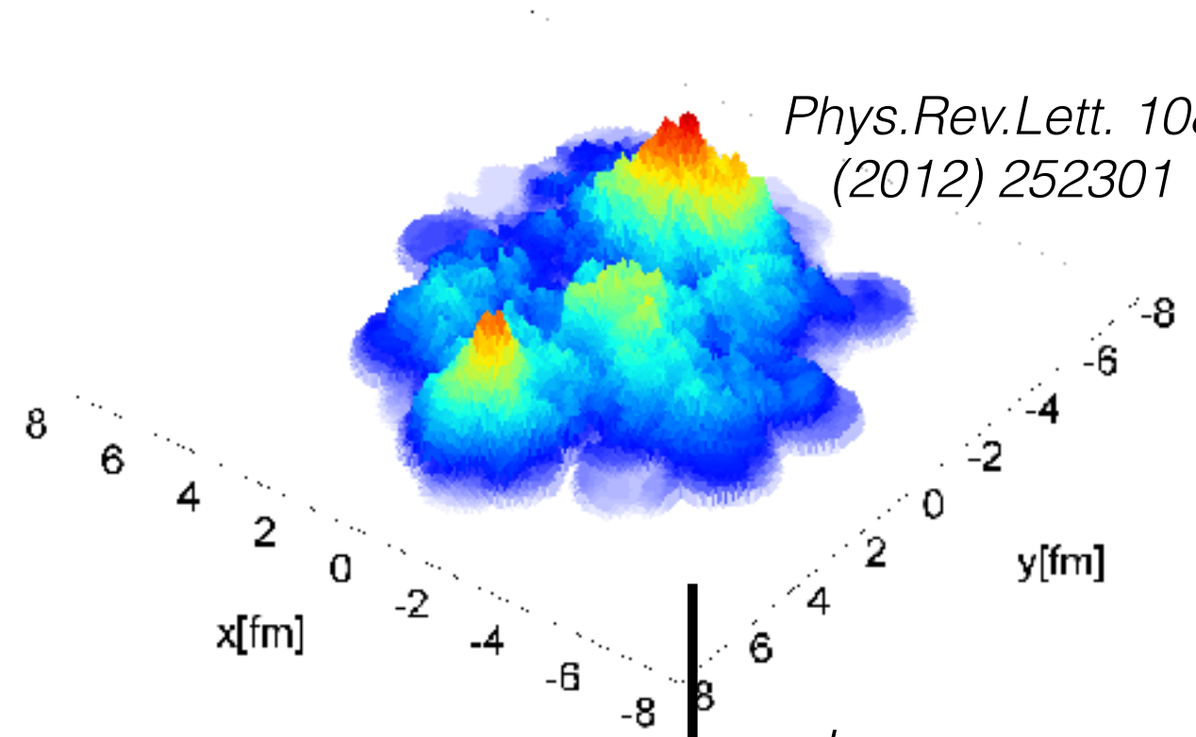
large-scale structure



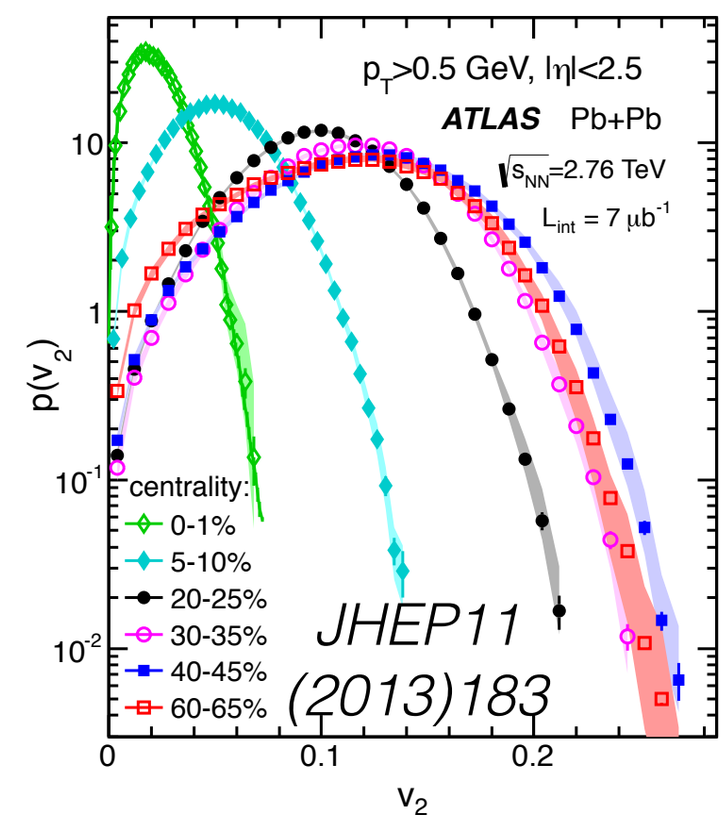
low viscosity



small-scale structure

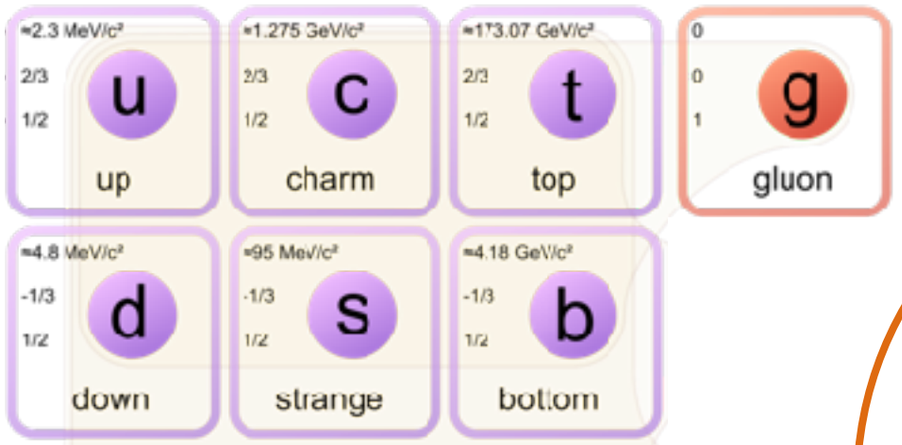


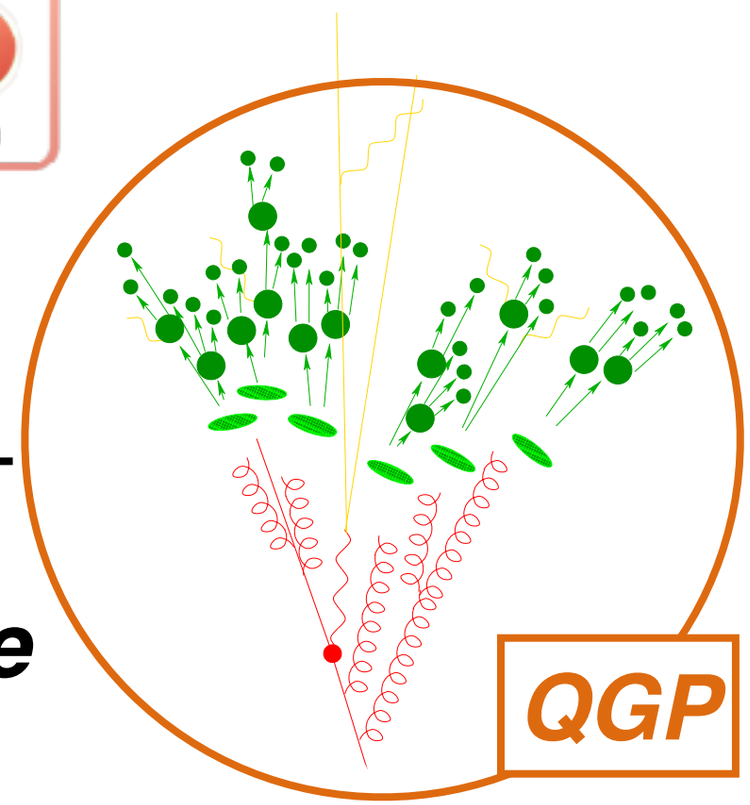
low viscosity

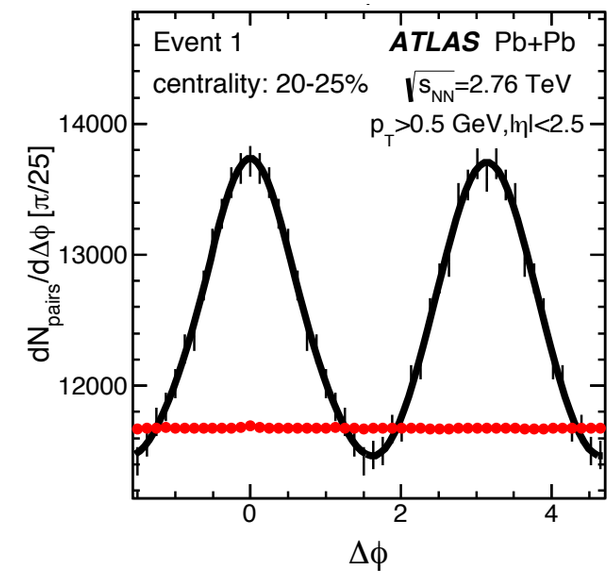


High-density, high-temperature regime of QCD matter: (near) perfect fluidity

QGP at different scales…





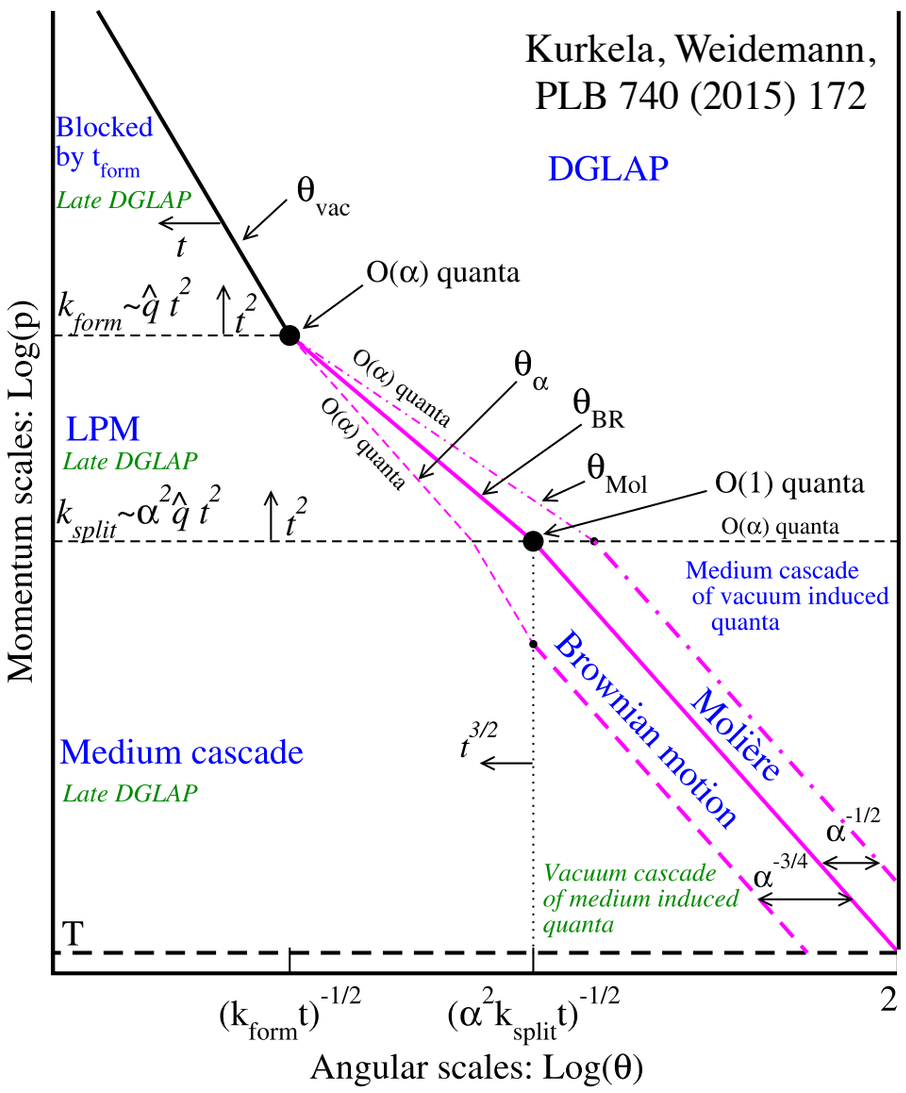


short-distance, ***asymptotically free*** *quarks and gluons*

collective, ***strongly-coupled****, long-distance behavior*

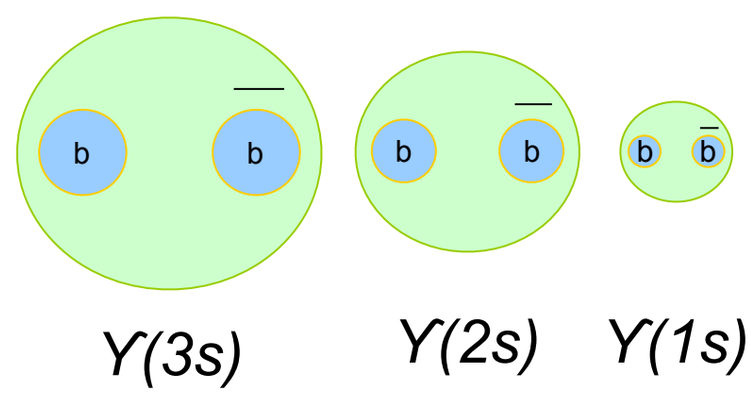
need multi-scale, internally generated probes of the ***QGP*** *medium…*

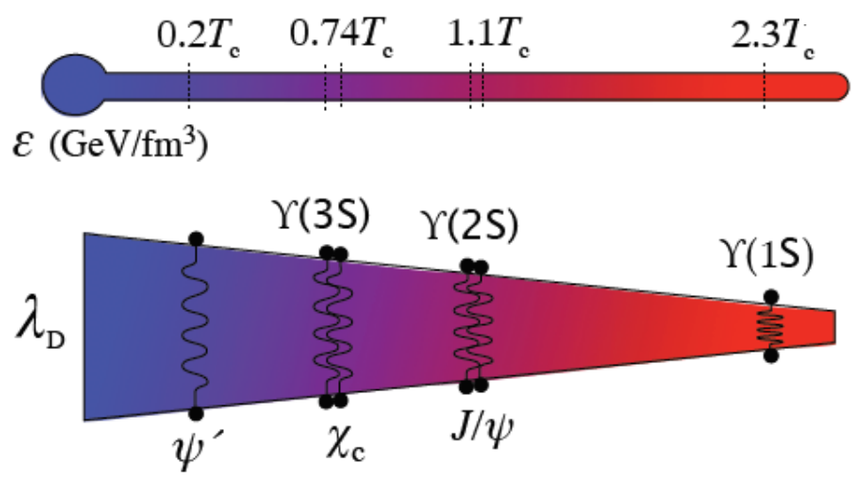
Multi-scale probes

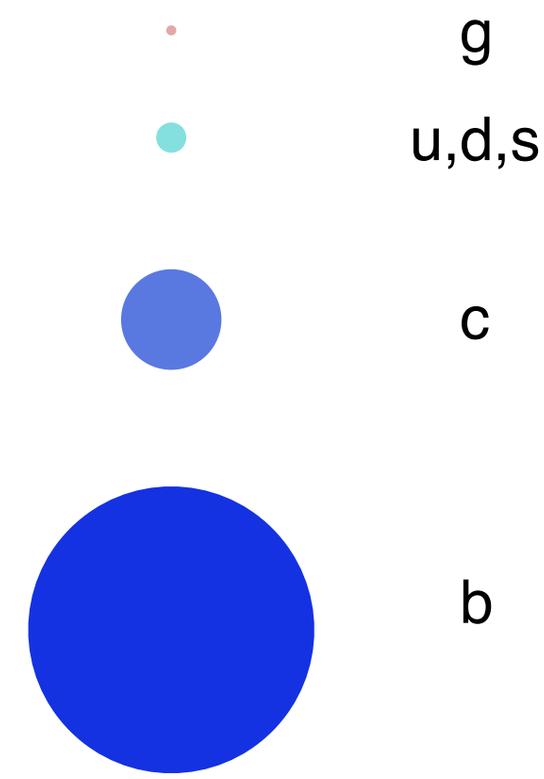


jets and jet structure

Upsilon spectroscopy







parton flavor/ mass

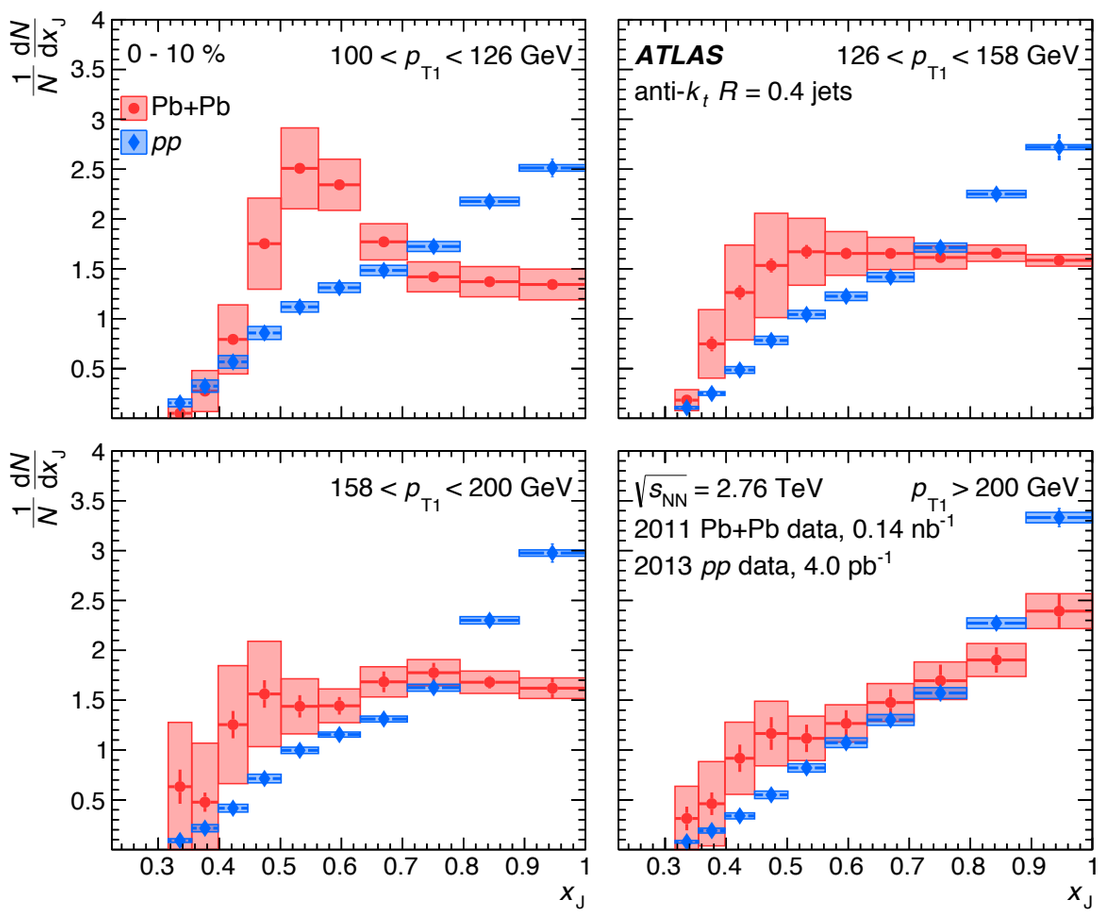
Context within U.S. nuclear physics

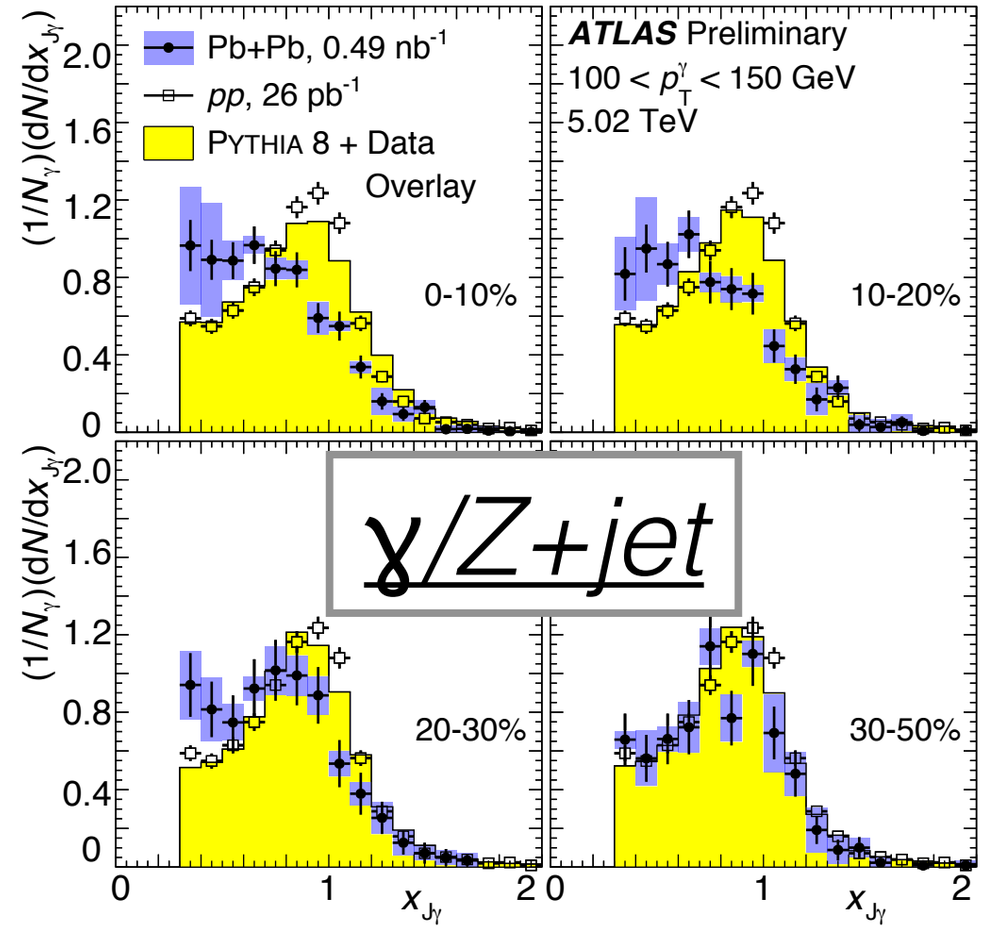
The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE

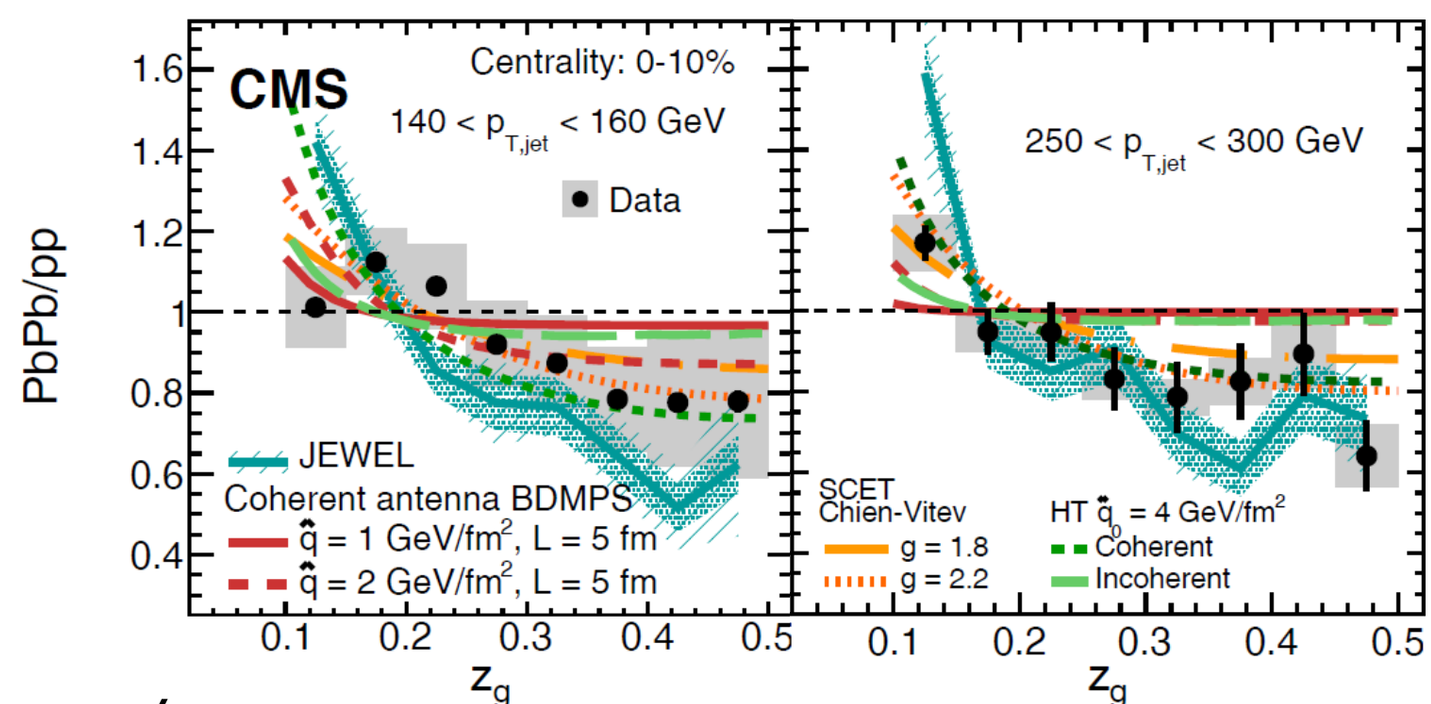
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

Jet probes of Pb+Pb @ LHC

(also high-statistics Upsilon measurements)



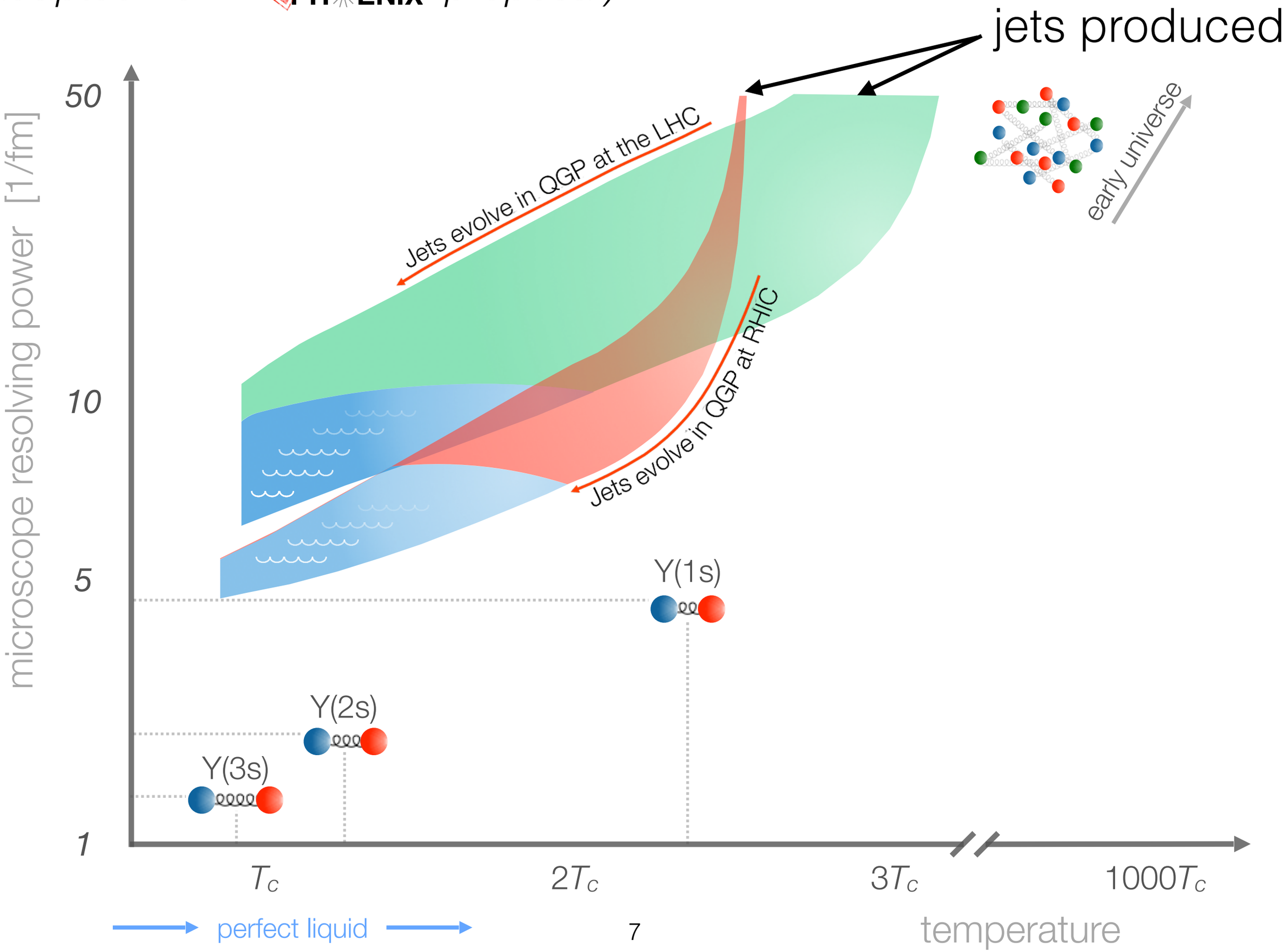




broad kinematic range w/ systematic control

jet structure/ sub-structure

(adapted from PHENIX *proposal)*



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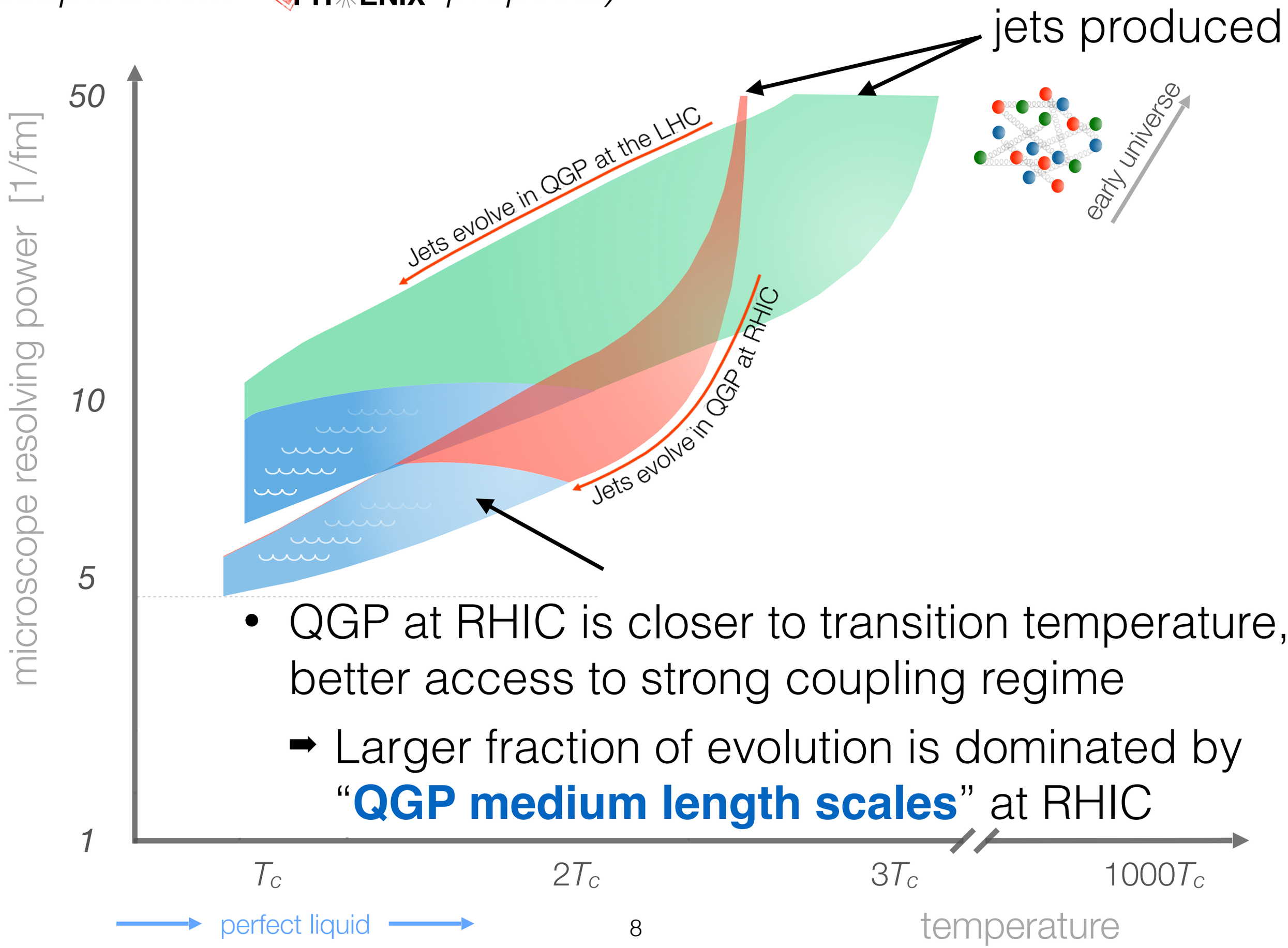
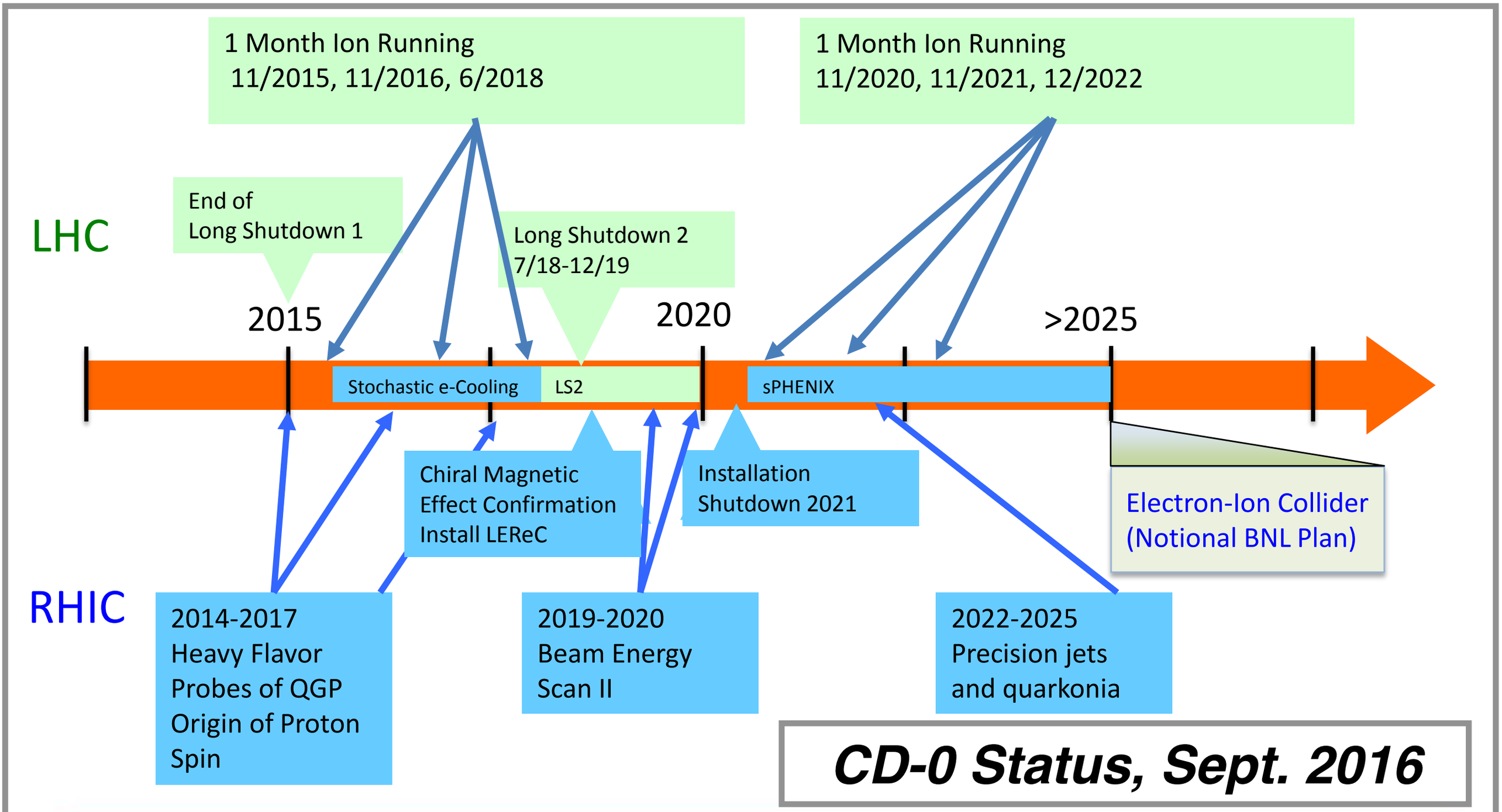


- QGP at RHIC is closer to transition temperature, better access to strong coupling regime
  - ➡ Larger fraction of evolution is dominated by "**QGP medium length scales**" at RHIC

sPHENIX Timeline

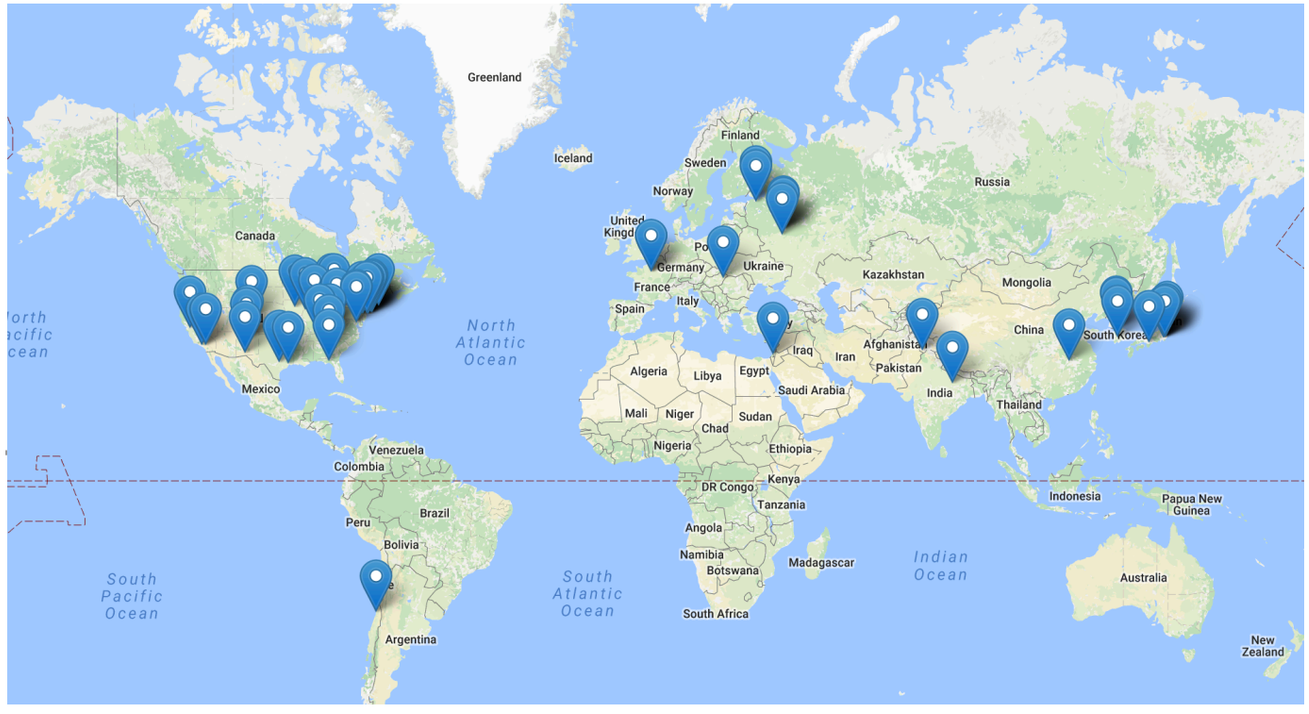
(slide from T. Hallman, DOE Nuclear Physics)



CD-0 Status, Sept. 2016

sPHENIX Scientific Collaboration formed Dec. 2015 >70 institutions

https://indico.bnl.gov/conferenceTimeTable.py?confId=3822



PHENIX Detector design

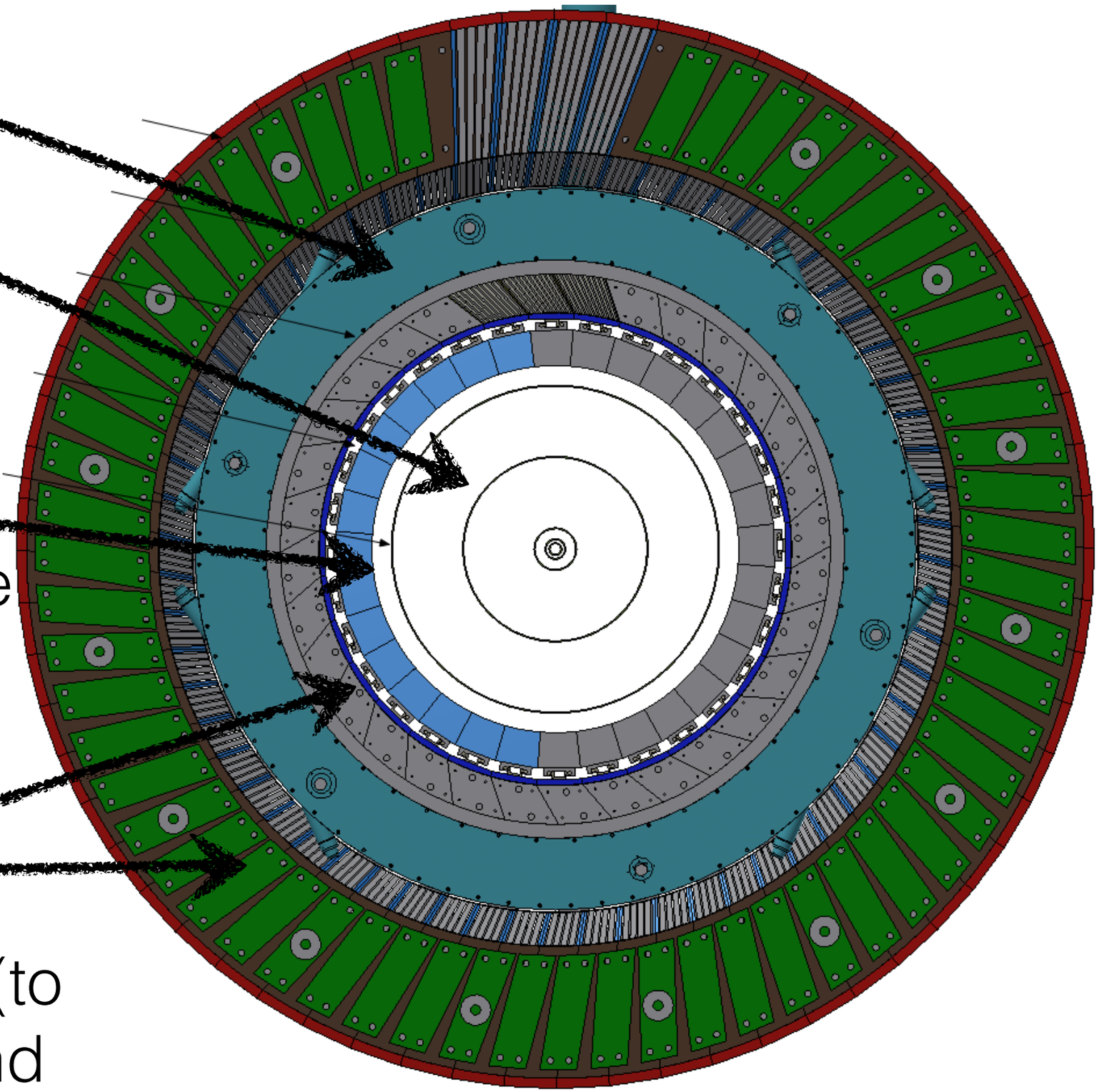
1.4 Tesla **magnet**, from BaBar expt.

tracking detectors (to measure *charged particles)*

electromagnetic calorimeter (to measure *photons* & *electrons)*

hadronic calorimeters (to measure *jets*)

DAQ / trigger system (to record large Au+Au and reference *pp* samples)



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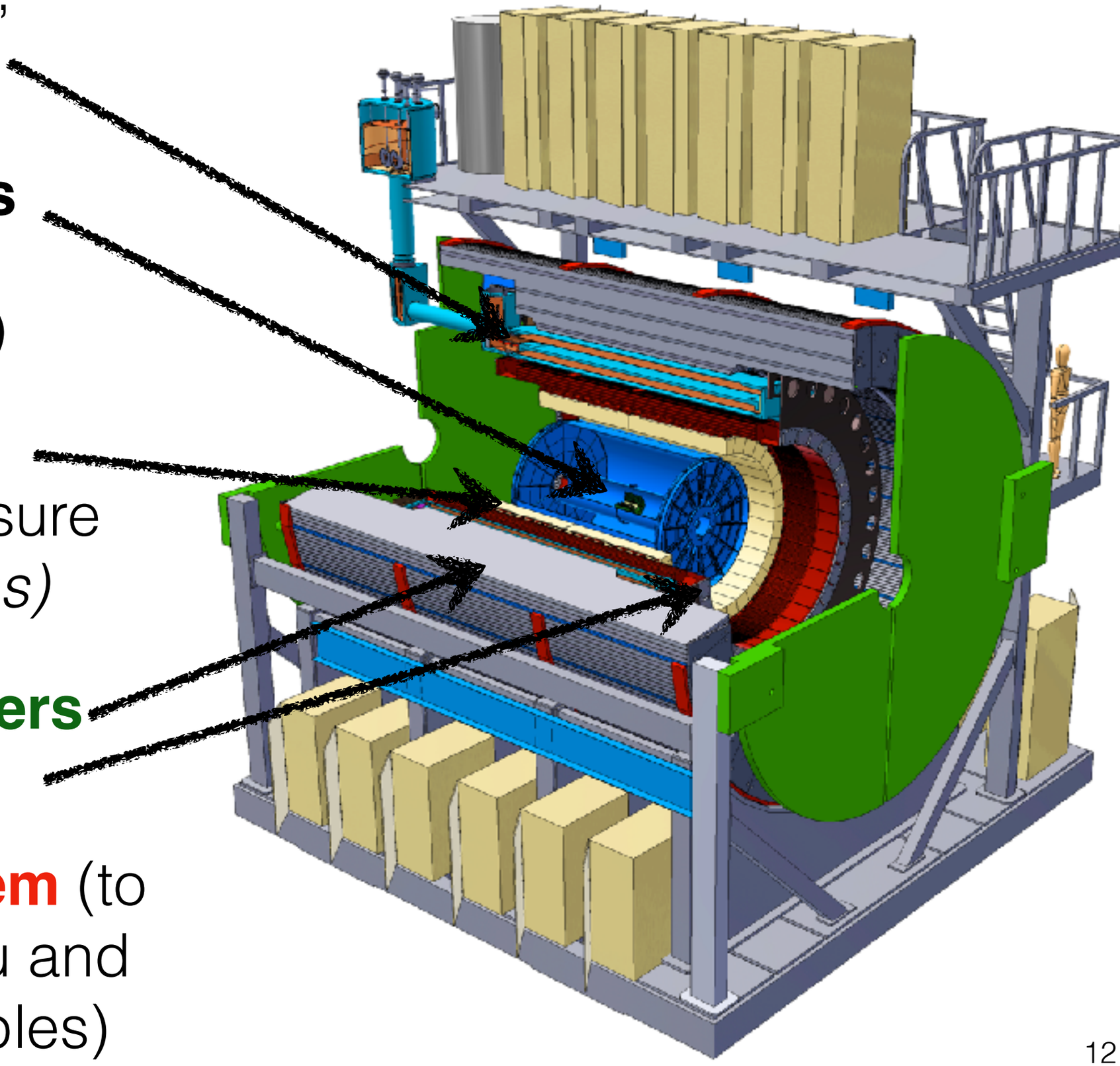


sPHENIX Tracking

MVTX (based on ALICE ITS upgrade):

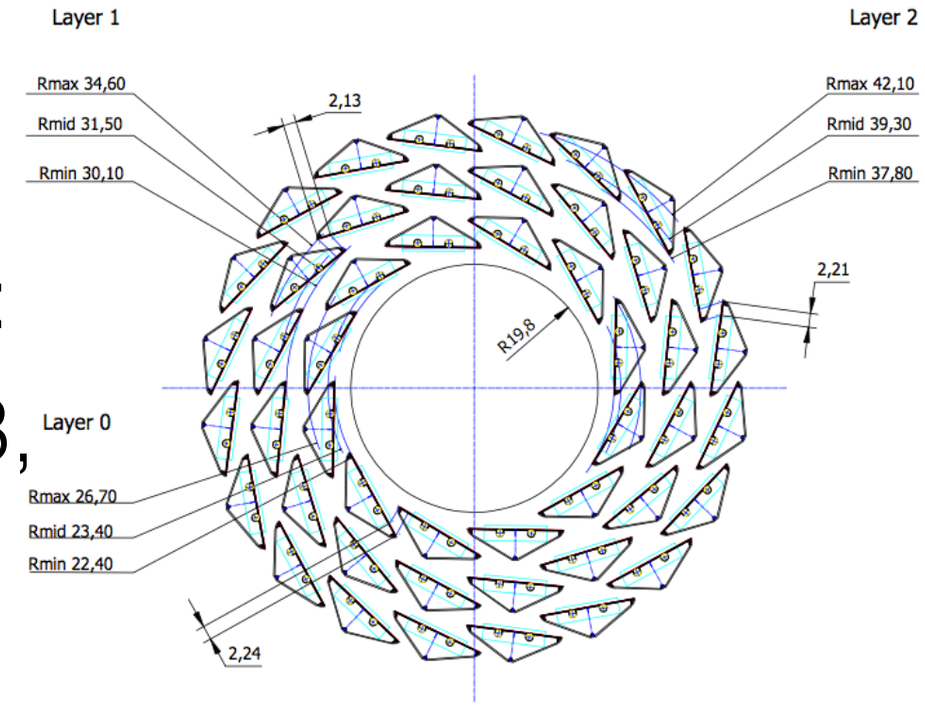
- ➡ 3-layer MAPS vertex tracker, R = 2.3, 3.1, 3.9 cm
- ➡ excellent 2-D DCA resolution, <25 μm for p_T > 1 GeV

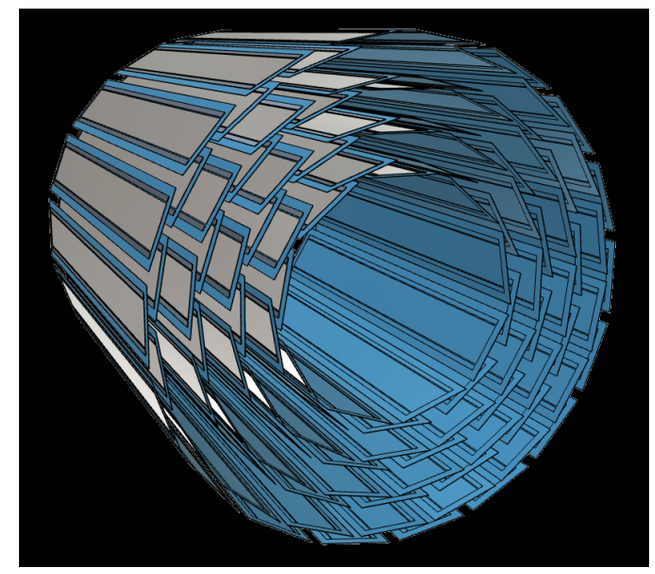
INTT:

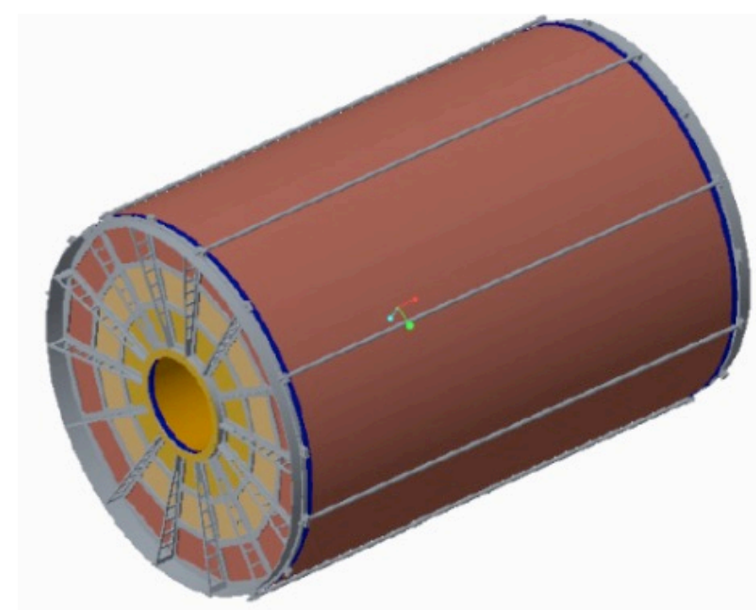
- ➡ 4-layer Si strip intermediate tracker
- ➡ pattern recognition, connects tracking systems, R = 6, 8, 10, 12 cm

TPC:

- ➡ continuous readout, R = 20-78 cm
- ➡ good momentum resolution p_T = 0.2-40 GeV

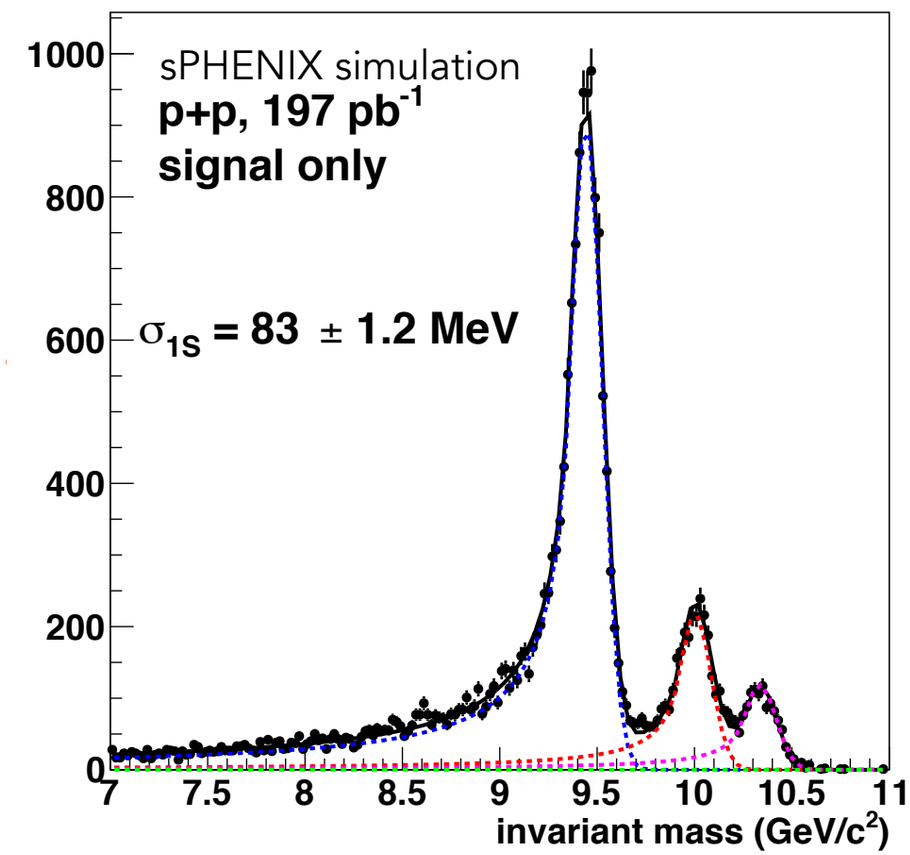




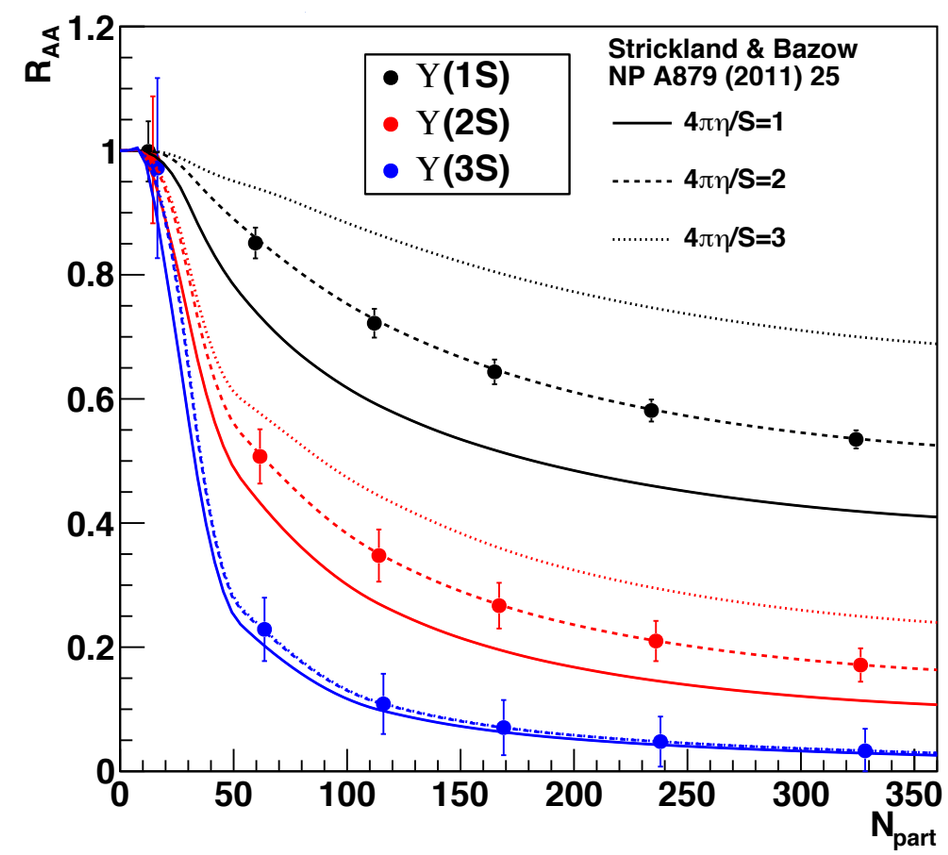


Upsilon spectroscopy

- Momentum resolution sufficient to separate 2S and 3S states, ($\sigma(M_{ee}) < 100$ MeV/c^2 at $p_T \sim 4.5$ GeV)
- Substantial work on TPC design & performance in high-luminosity *p*+*p* running: simulation of in-time pileup, etc.

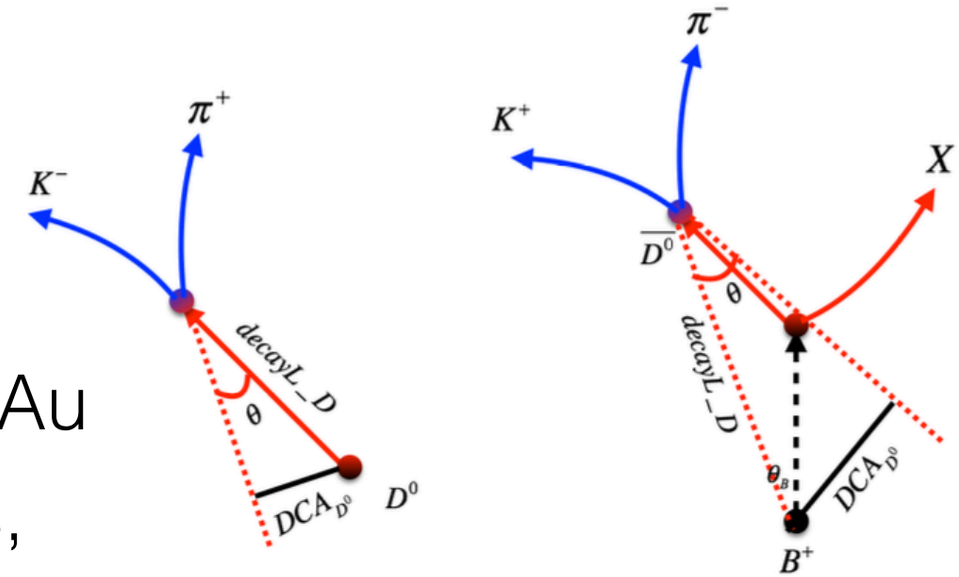


Upsilon state separation in p+p collisions



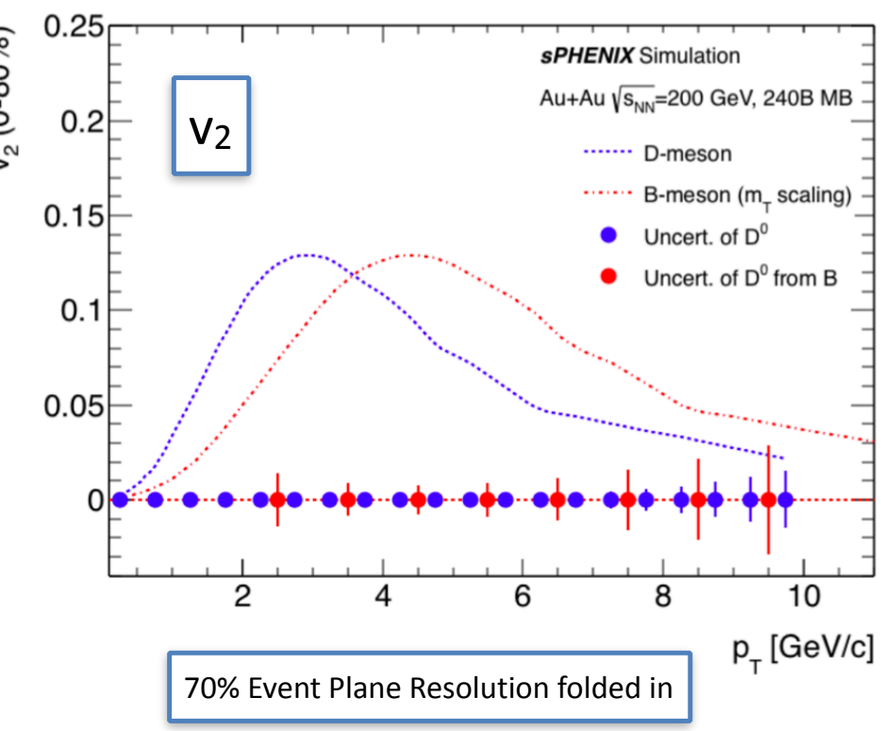
Statistical 1S/2S/3S projections

Heavy flavor reconstruction

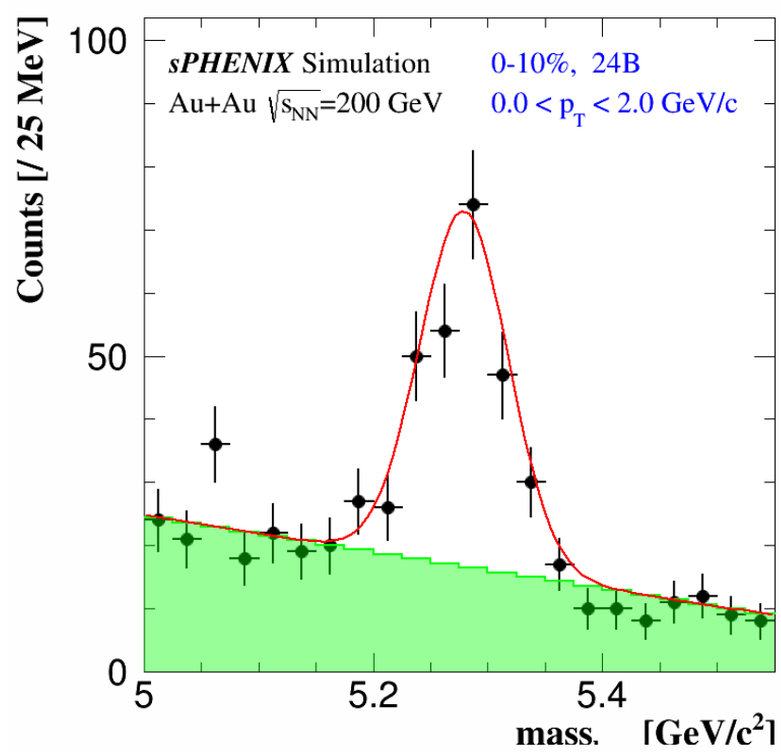


Measure identified *D* and *B* hadrons in Au+Au

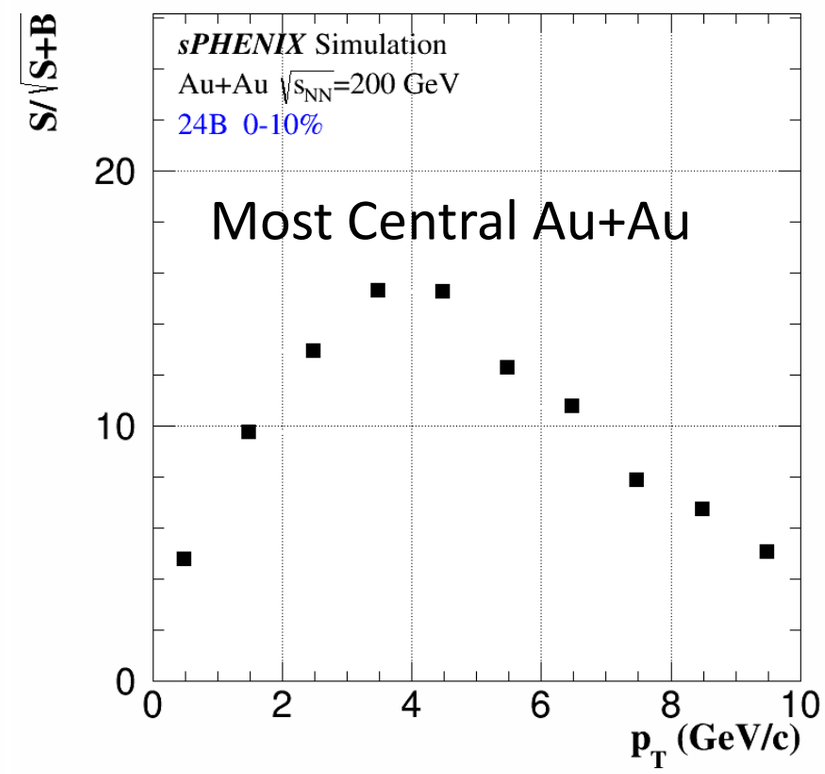
- ➡ use precision tracking & high statistics, without PID
- ➡ also, *b*- and c-jet tagging



Projected statistical uncertainties for Prompt & Non-Prompt D v_2



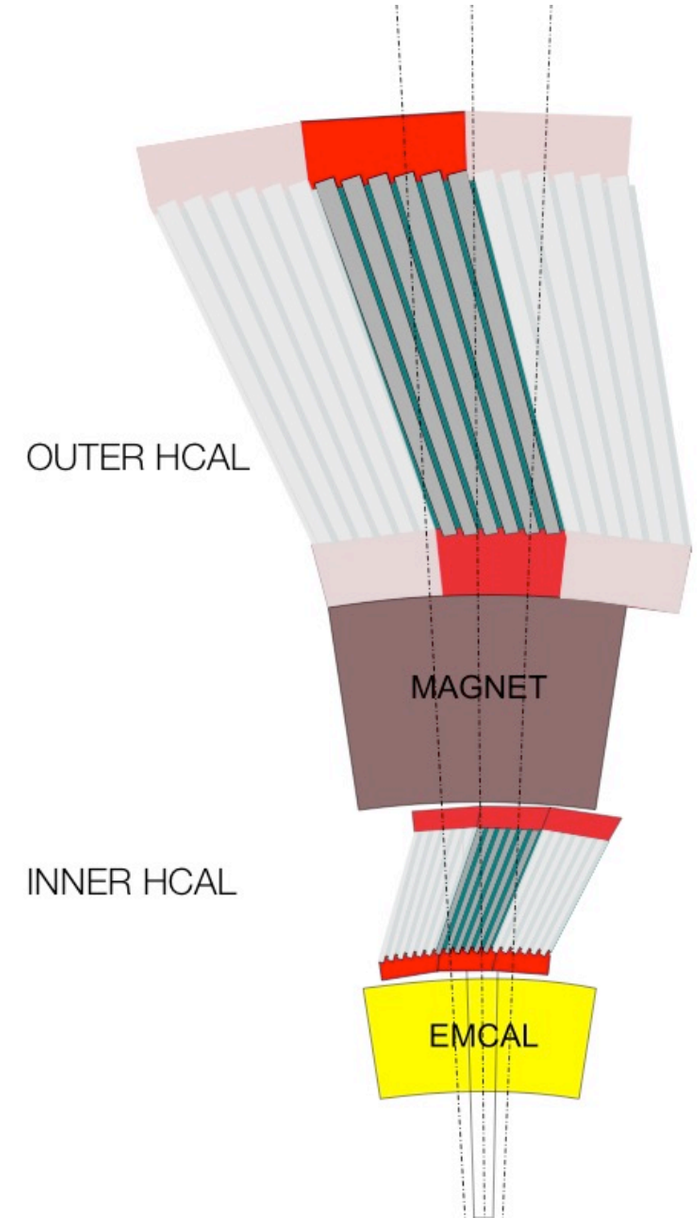
Fully reconstructed low-p_T B^+ mesons

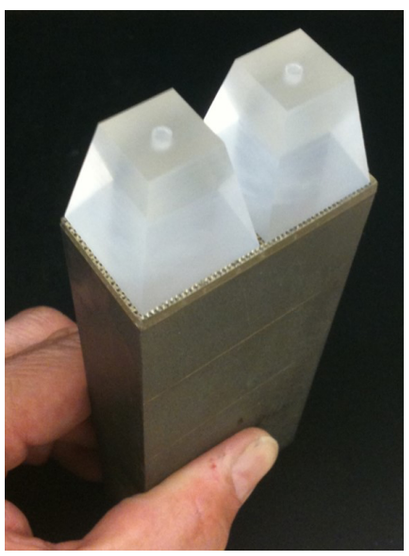


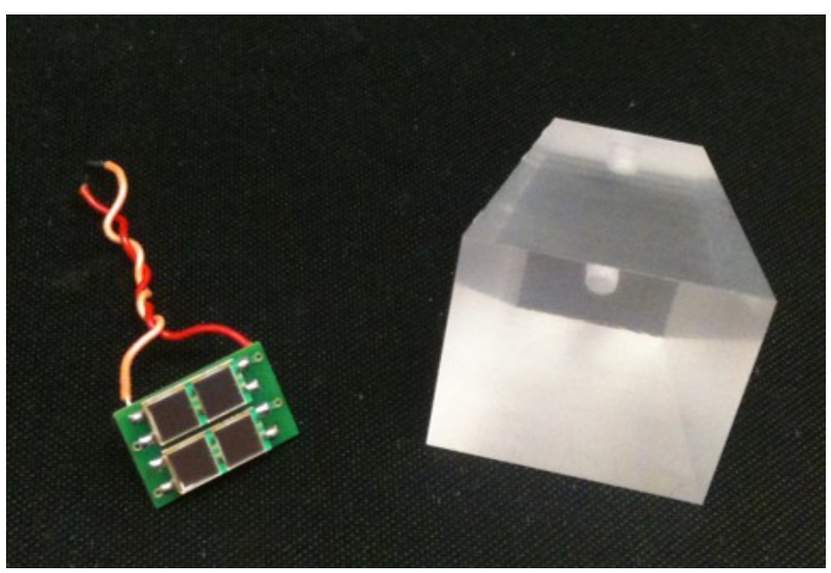
S/√(S+B) figure of merit in central Au+Au

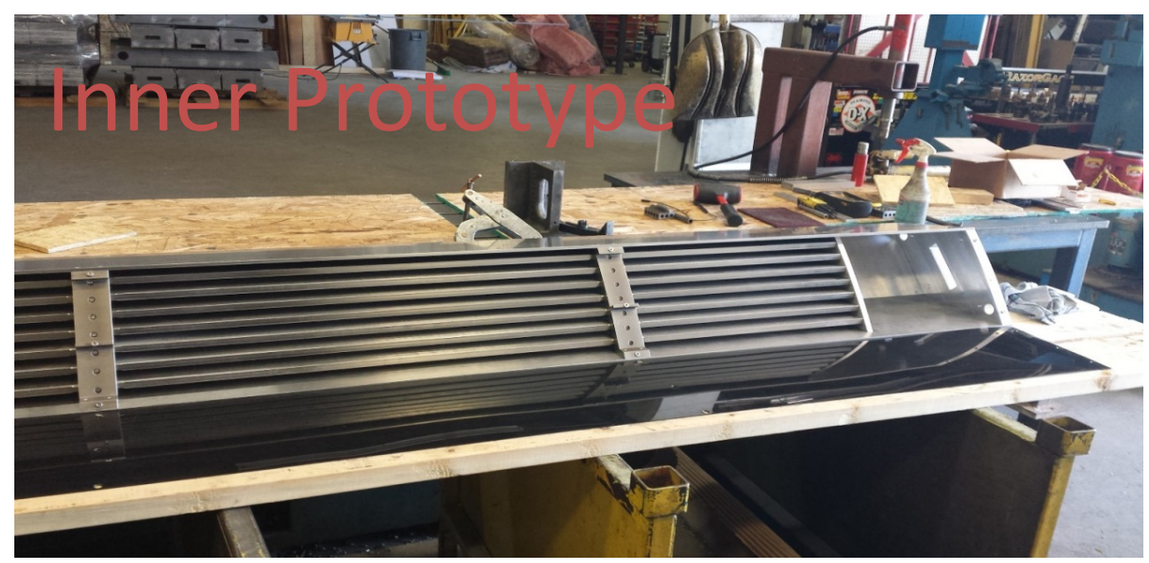
sPHENIX calorimetry

- EMCal: scintillating fibers embedded in W powder
  - ➡ $\Delta\eta\times\Delta\phi$ = 0.024x0.024, $\sigma_E/E = 15\%/\sqrt{E}$
- HCal: plastic scintillating tiles + tilted steel plates
  - ➡ Inner (1λ) and Outer (3.5λ) sections
  - ➡ $\Delta\eta\times\Delta\phi$ = 0.1x0.1, $\sigma_E/E = 100\%/\sqrt{E}$



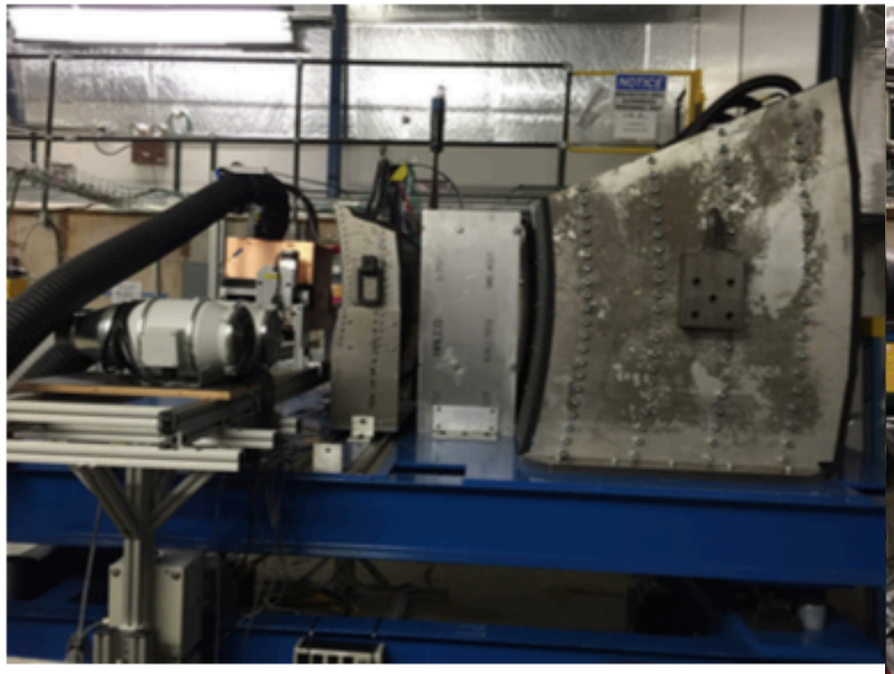






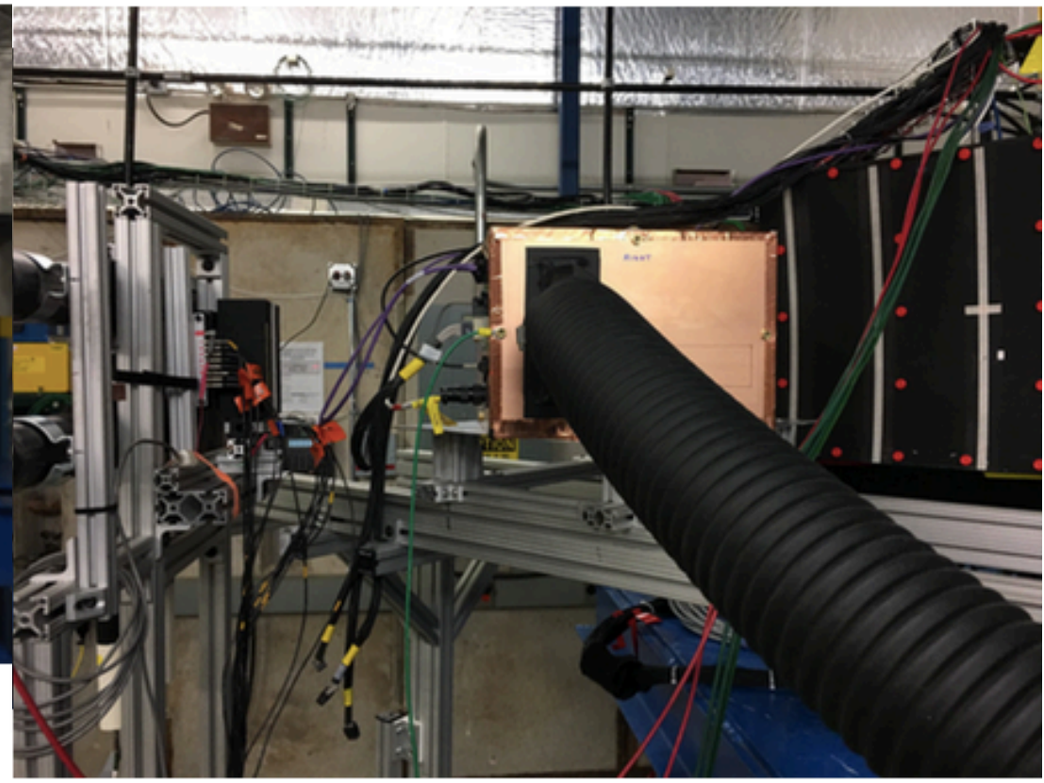
Calorimeter test beams

Proof of principle, Feb 2014



η~0 Geometry, Feb 2016

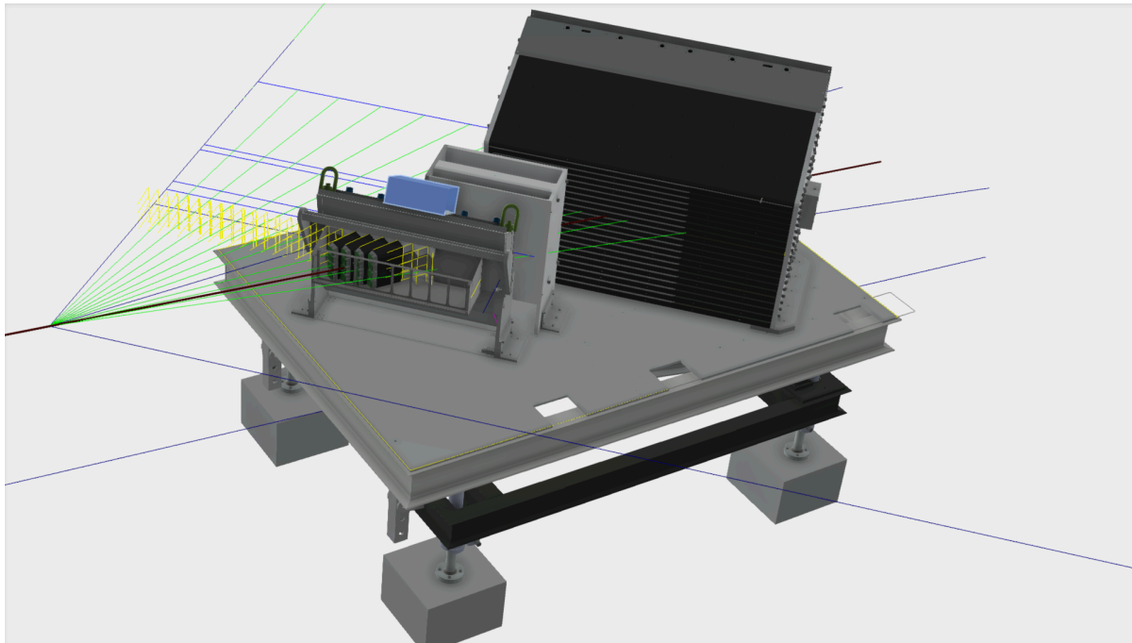
***physics.ins-det/1704.01461*, submitted to IEEE TNS**



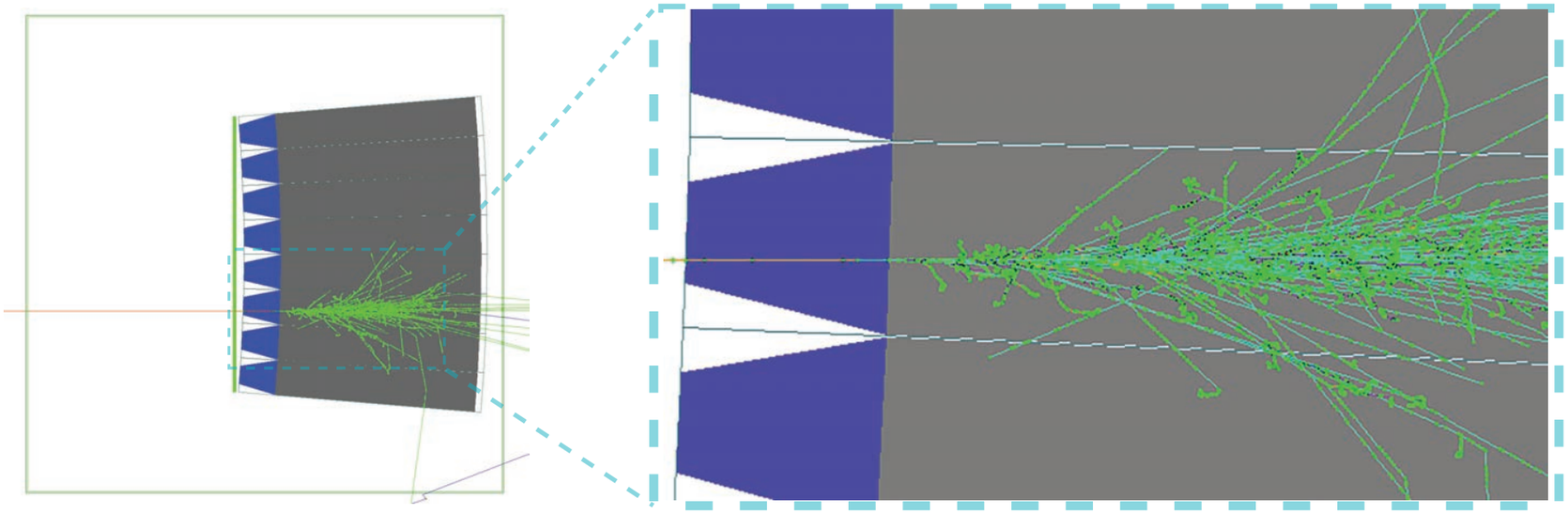
η~0.9 Geometry, Feb 2017

Combined test of improved large-η calorimetry design,

Feb-March '18 @ Fermilab →



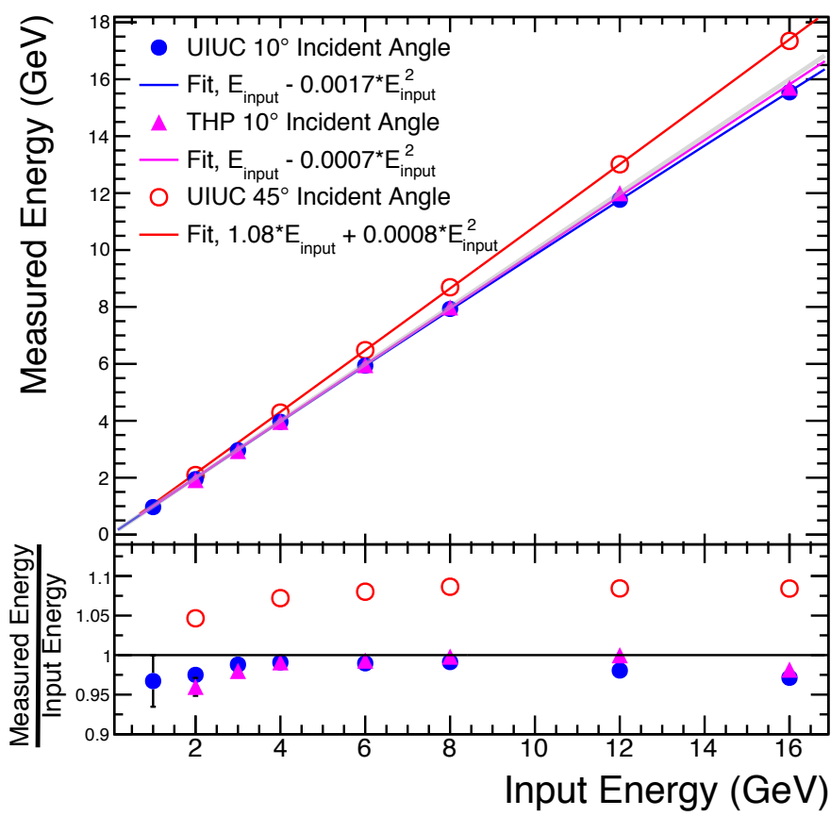
Test beam: EMCal

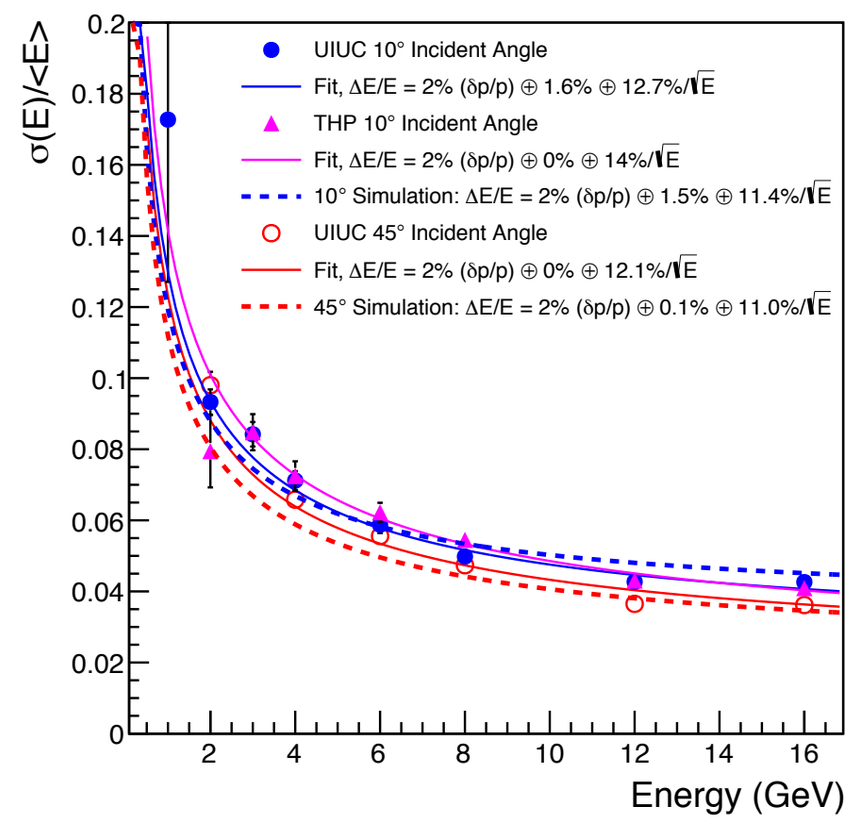


GEANT4 simulation of 8 GeV electron incident on EMCal (in test beam configuration)

Linearity and resolution vs. Electron Energy

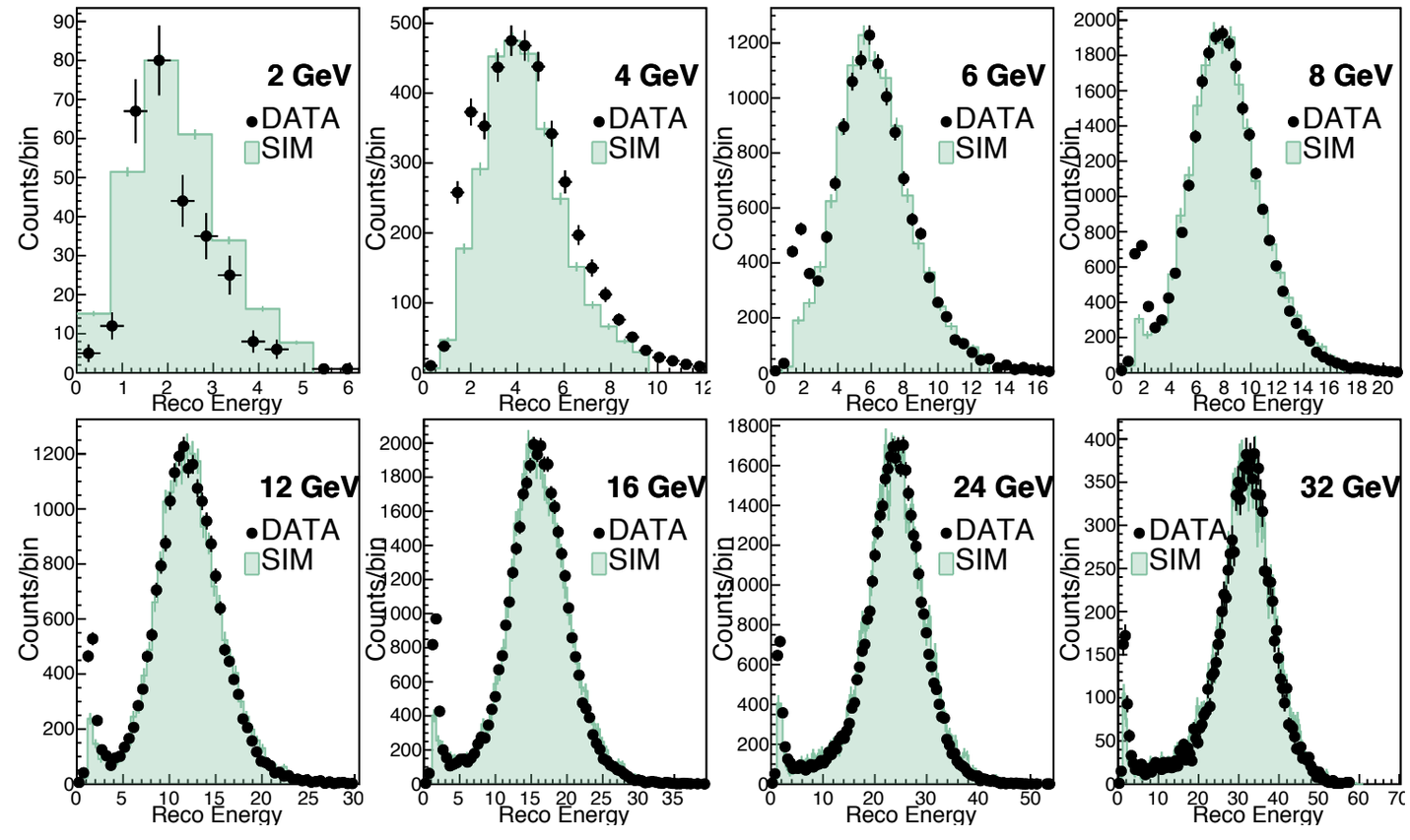
(different tower designs & incidence angles)

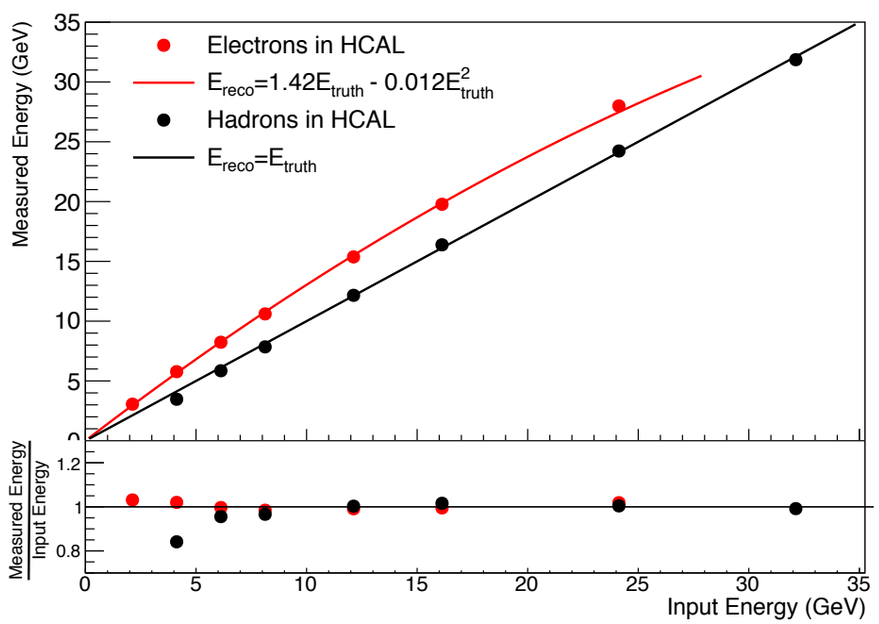




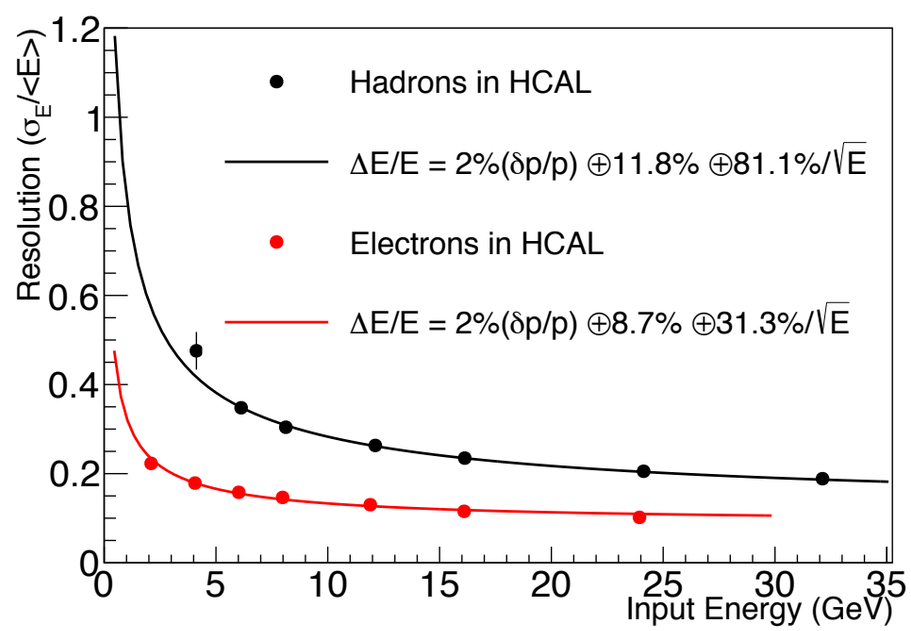
Test beam: HCal

Reconstructed hadron energy distribution, different incident energy (data/sim comparison)





(a)

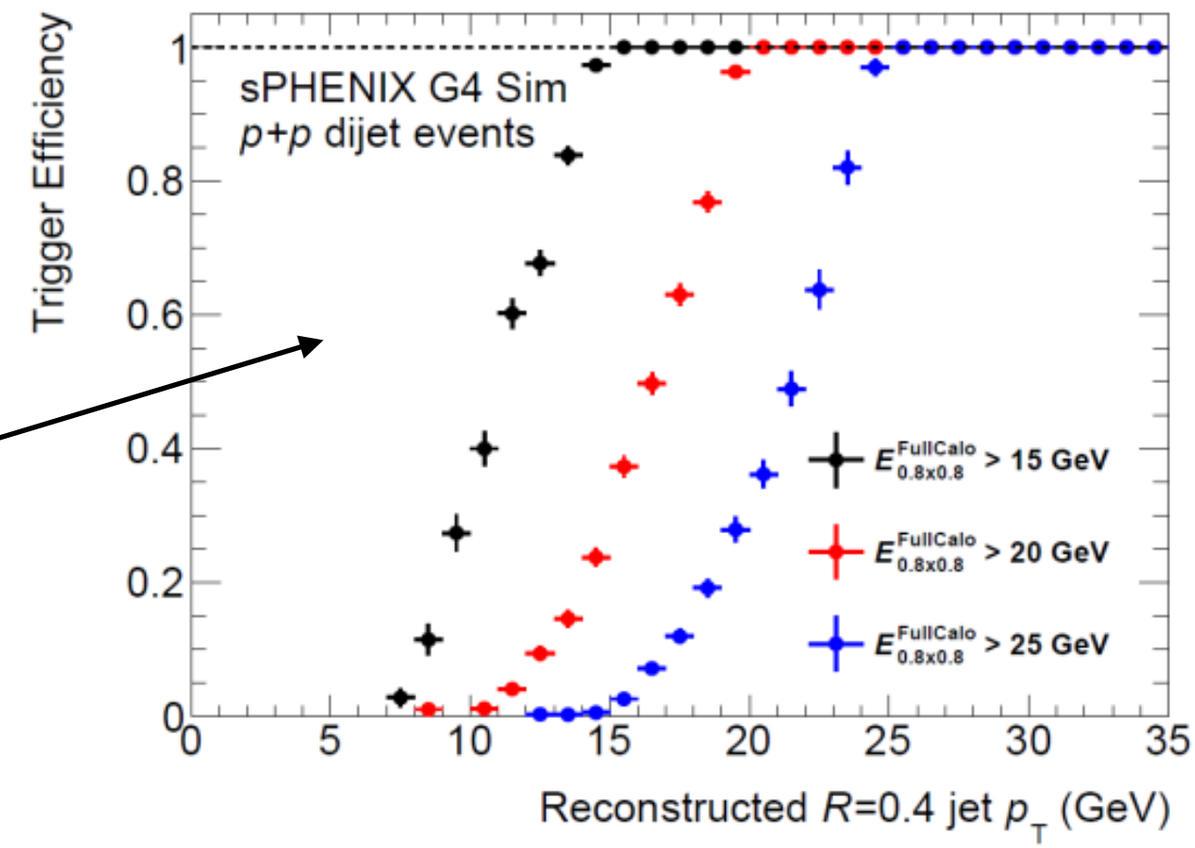


(b)

Linearity and resolution for electrons and hadrons in the HCal

DAQ & Trigger

- Large 15 kHz DAQ rate allows recording of Au+Au dataset minimum bias
- Efficient triggering for photons, jets, hadrons, Upsilons in *p*+*p* and *p*+Au
- Possible 5-year run plan with 200 GeV *p*+*p*, *p*+Au, Au+Au running



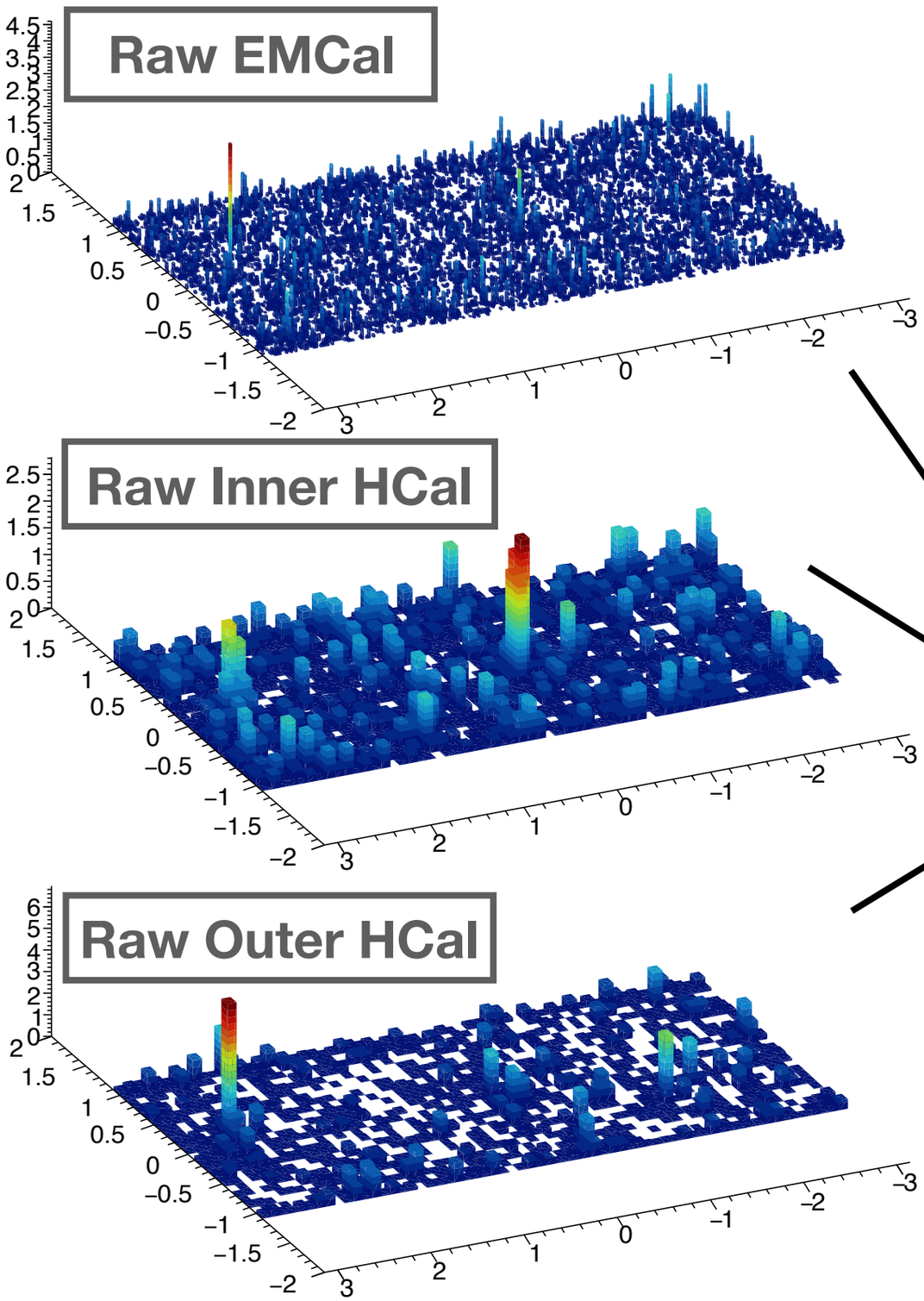
Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
Year-1	Au+Au	200	16.0	7 nb^{-1}	8.7 nb^{-1}	34 nb^{-1}
Year-2	p+p	200	11.5	—	48 pb^{-1}	267 pb^{-1}
Year-2	p+Au	200	11.5	—	0.33 pb^{-1}	1.46 pb^{-1}
Year-3	Au+Au	200	23.5	14 nb^{-1}	26 nb^{-1}	88 nb^{-1}
Year-4	p+p	200	23.5	—	149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

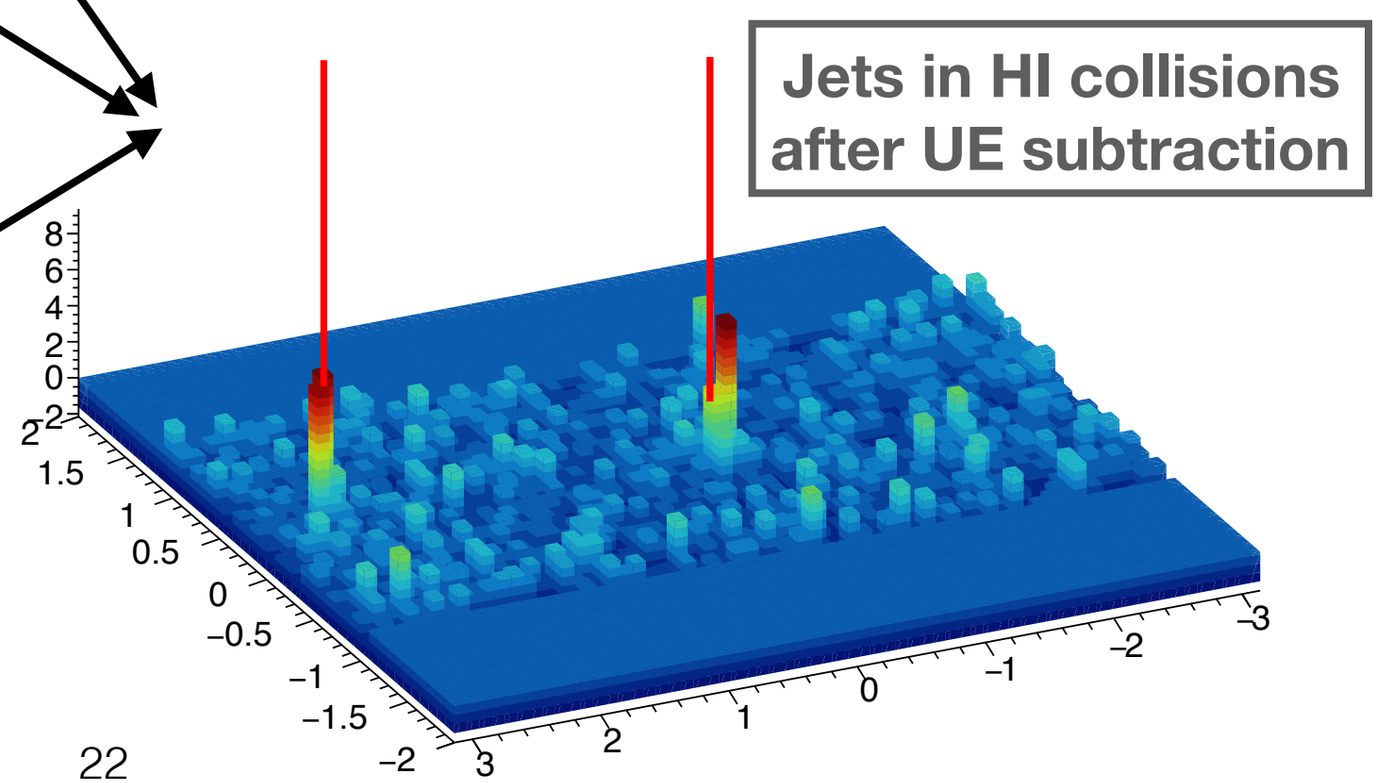
sPHENIX Magnet

- Formerly Babar magnet, 1.4 T solenoid
- Successful low-field test, full-field tests imminent

Simulations & Software

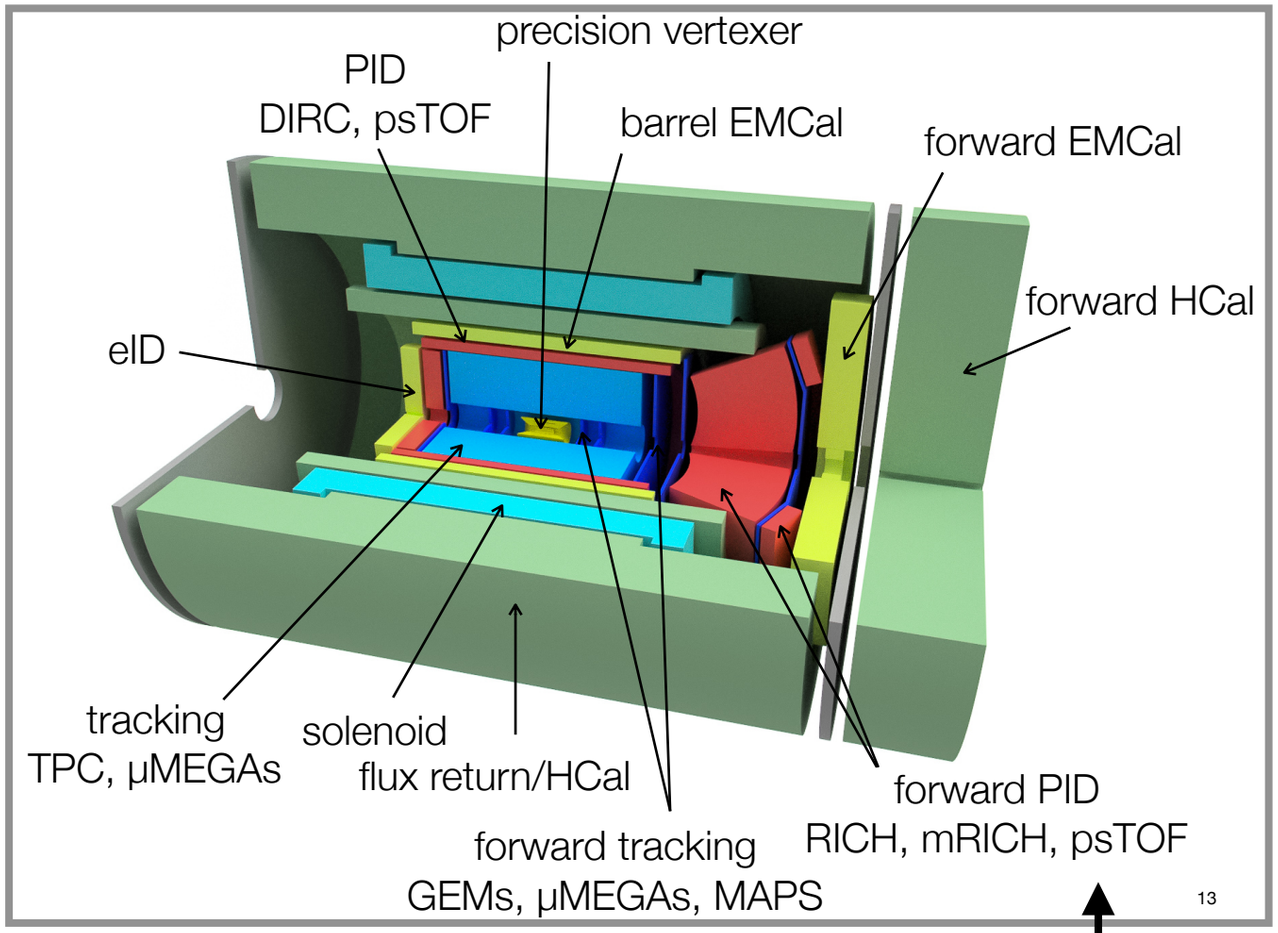
- Increasingly sophisticated GEANT-based description of detector & development of reconstruction software
  - ➡ track and vertex finding
  - ➡ electromagnetic and hadronic showering & clustering
  - ➡ jet finding in AA collisions





sPHENIX in “Cold QCD” context

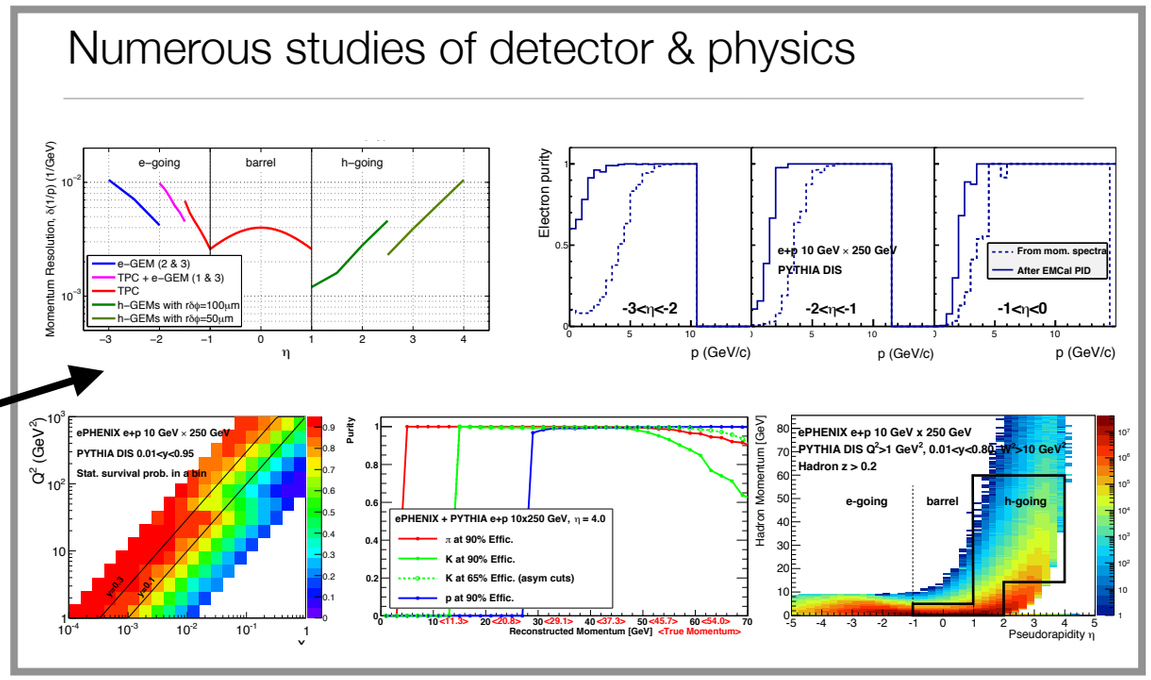
(slides from EIC UG Detector Discussion Mtg, Nov-Dec ’17)

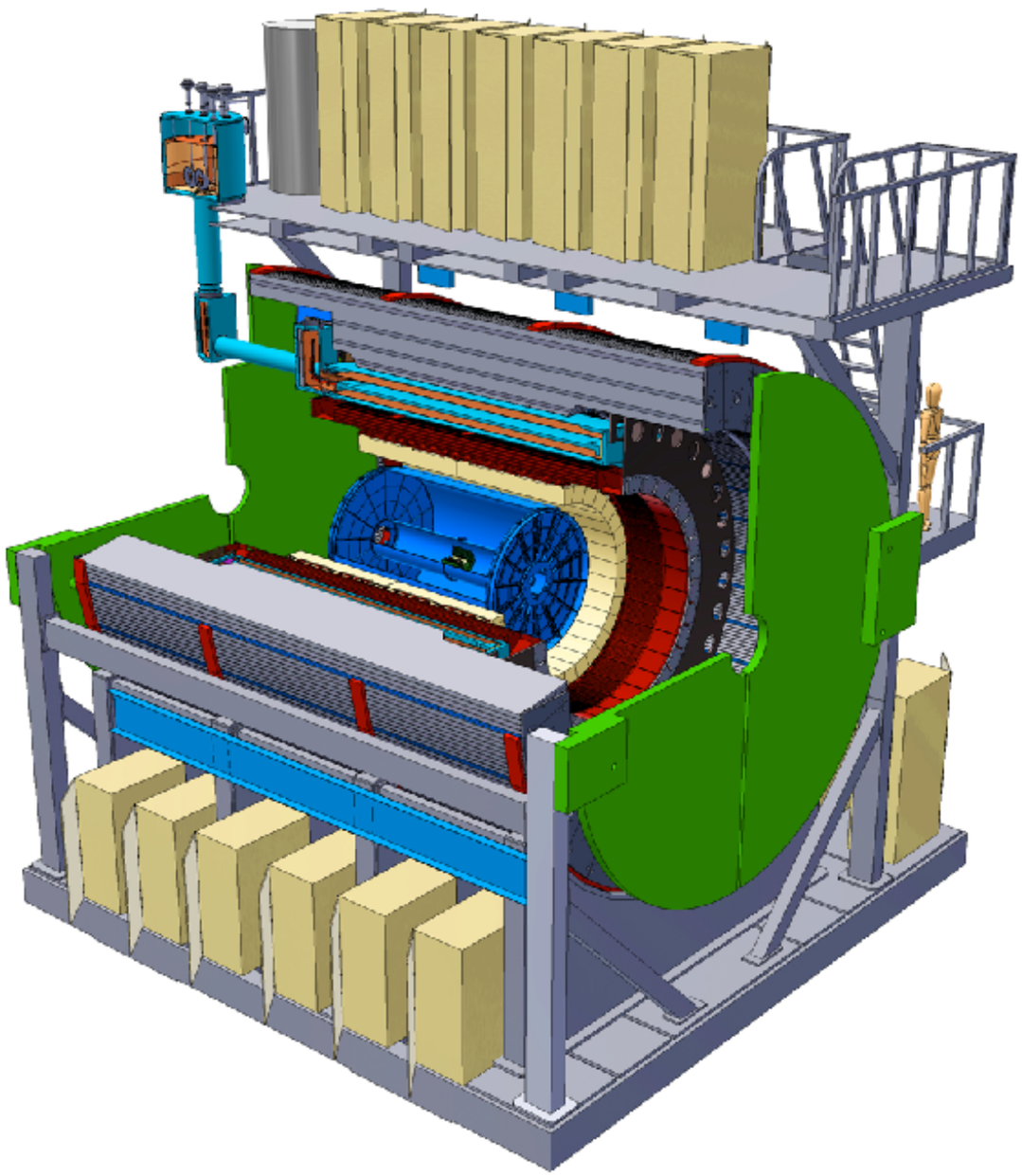


- Dedicated “Cold QCD” topical group for medium-energy physics
  - ➡ transition to Day-1 Electron Ion Collider (EIC) detector
  - ➡ physics with sPHENIX barrel in 2022-2025

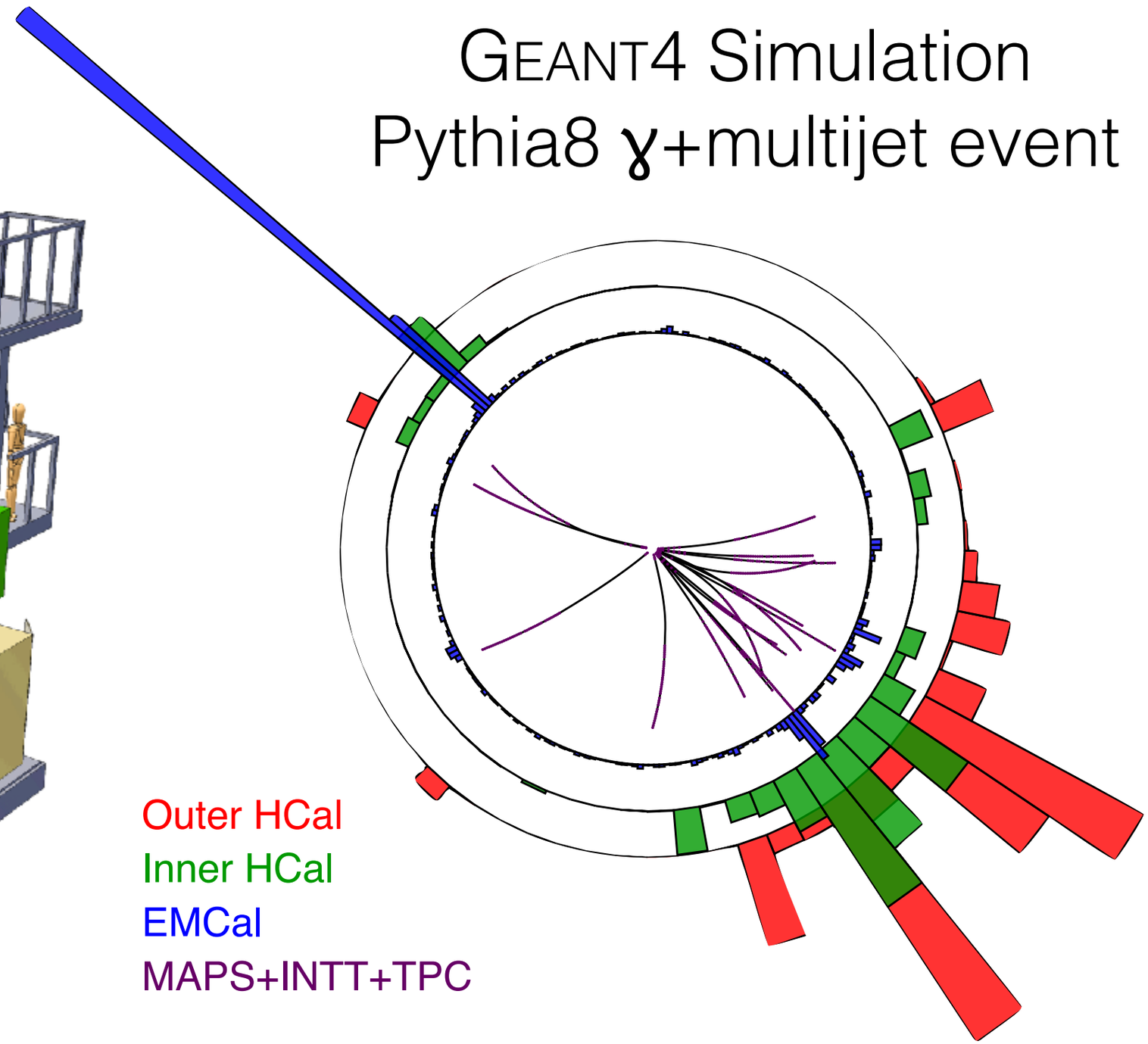
One (possible) evolution to a BNL-EIC detector

Studies of an “ePHENIX” for EIC physics





GEANT4 Simulation
Pythia8 γ+multijet event



thank you for your attention!