The sPHENIX Open and Close Heavy Flavor Program

Zhaozhong Shi
on behalf of the **sPHENIX** collaboration
Los Alamos National Laboratory
Email: zhaozhongshi@lanl.gov

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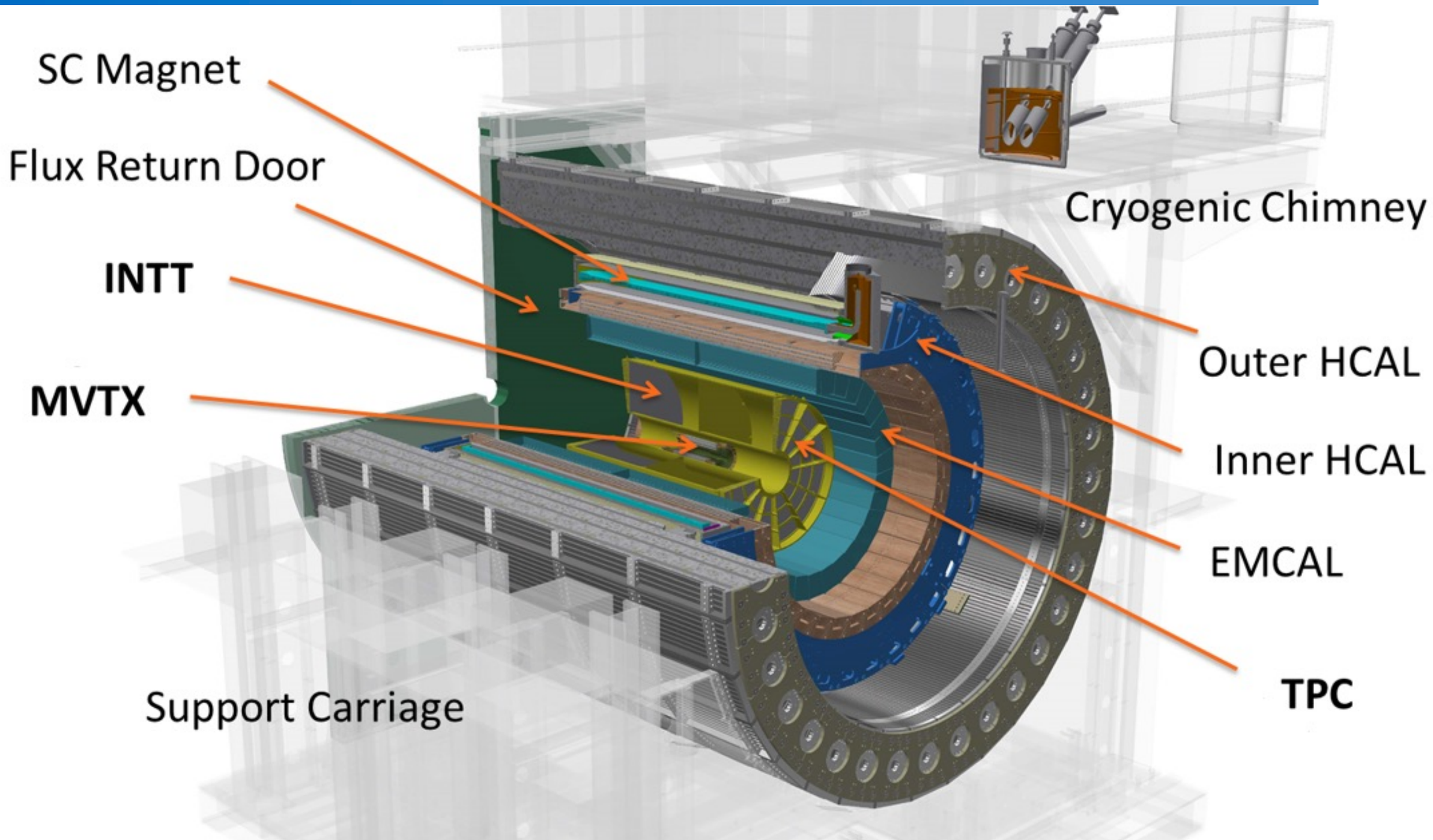
Los Alamos NATIONAL LABORATORY

sPHENIX

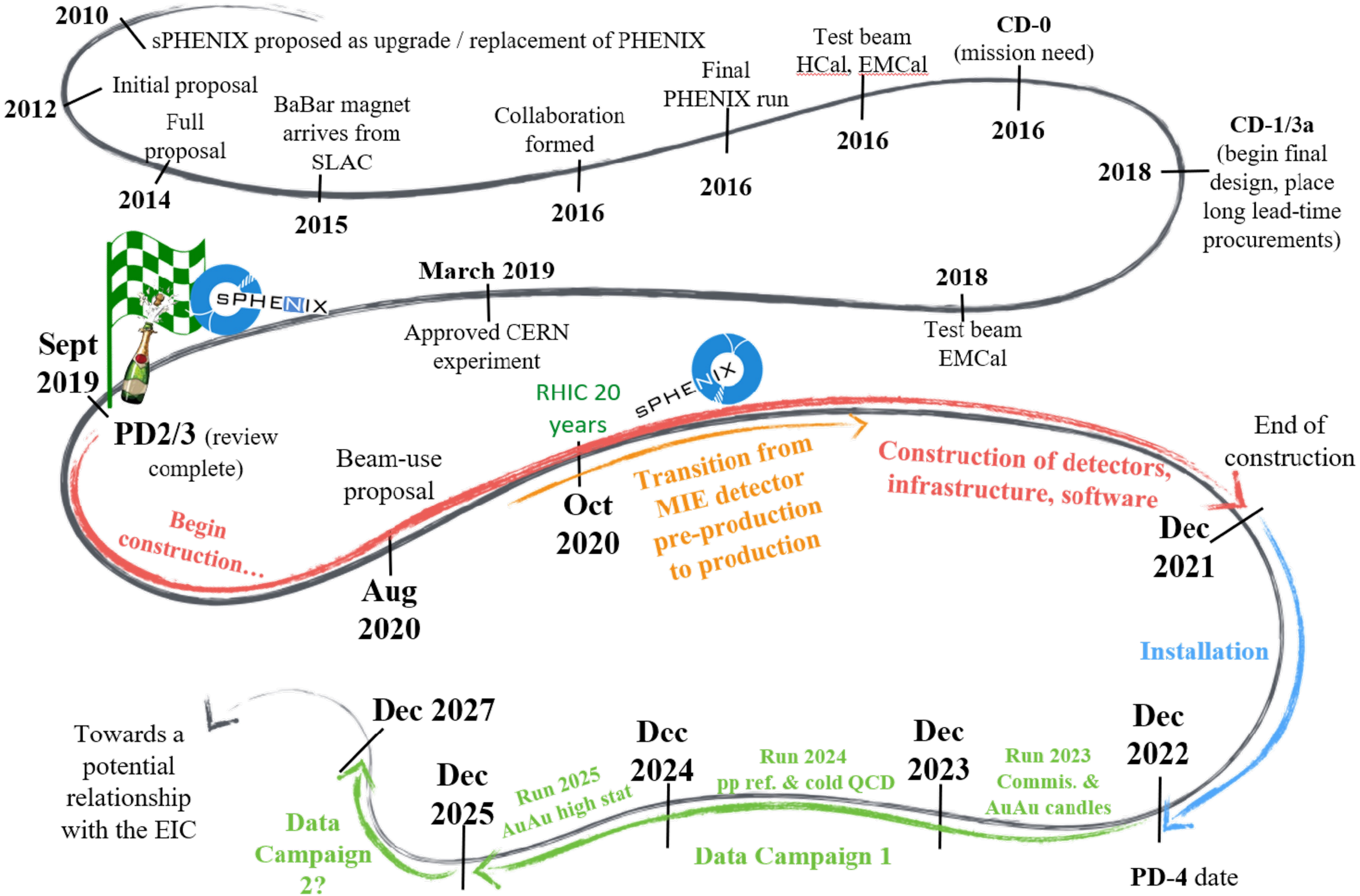
The sPHENIX Experiment at RHIC



2015 NSAC Long range Plan for Nuclear Science: sPHENIX experiment at RHIC

- Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales
- Complementary to LHC experiments

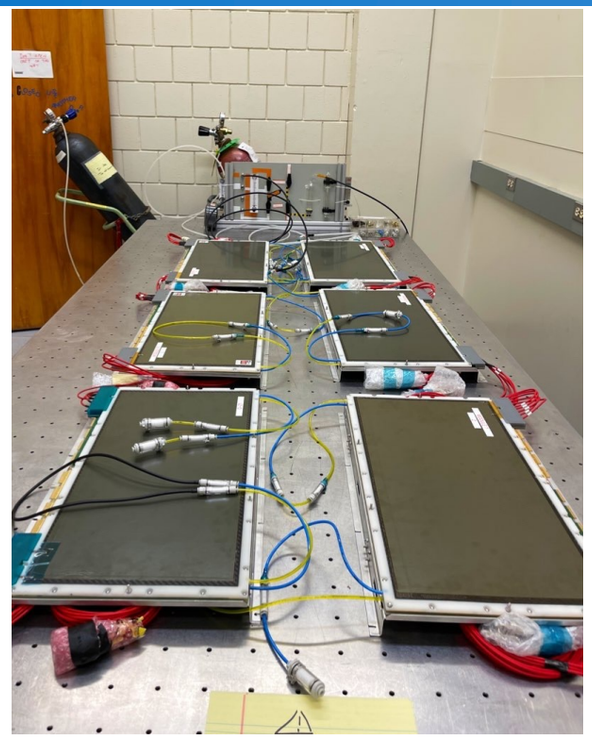
Overall sPHENIX Timeline



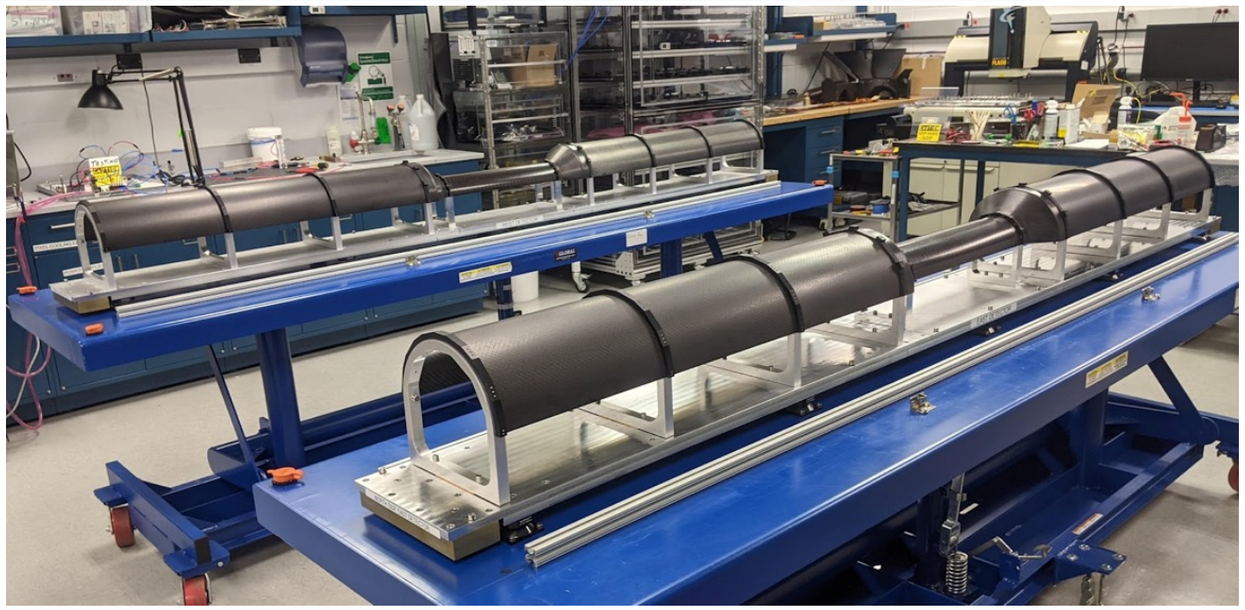
- Collective efforts of international collaboration from countries over two decades

sPHENIX Detector Commissioning

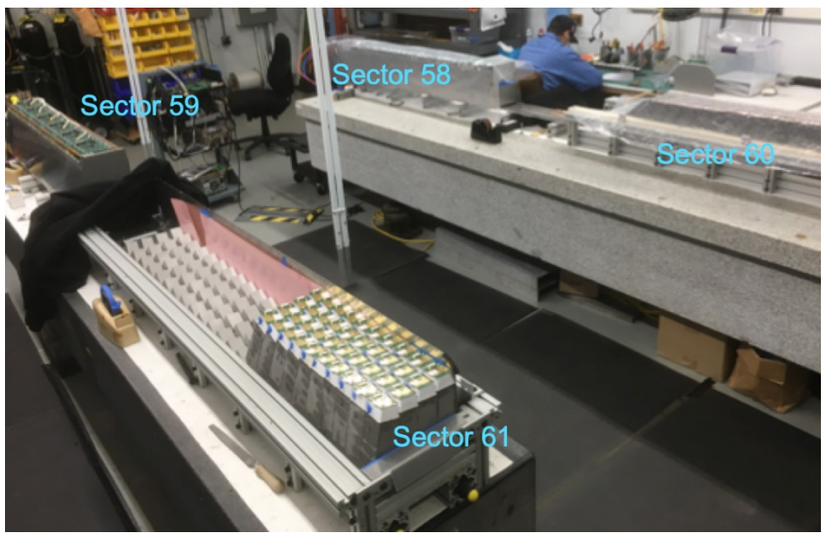
TPC commissioning at Stony Brook University



TPOT Effort By LANL/Stony Brook



INTT stave completed, carbon fiber parts at BNL



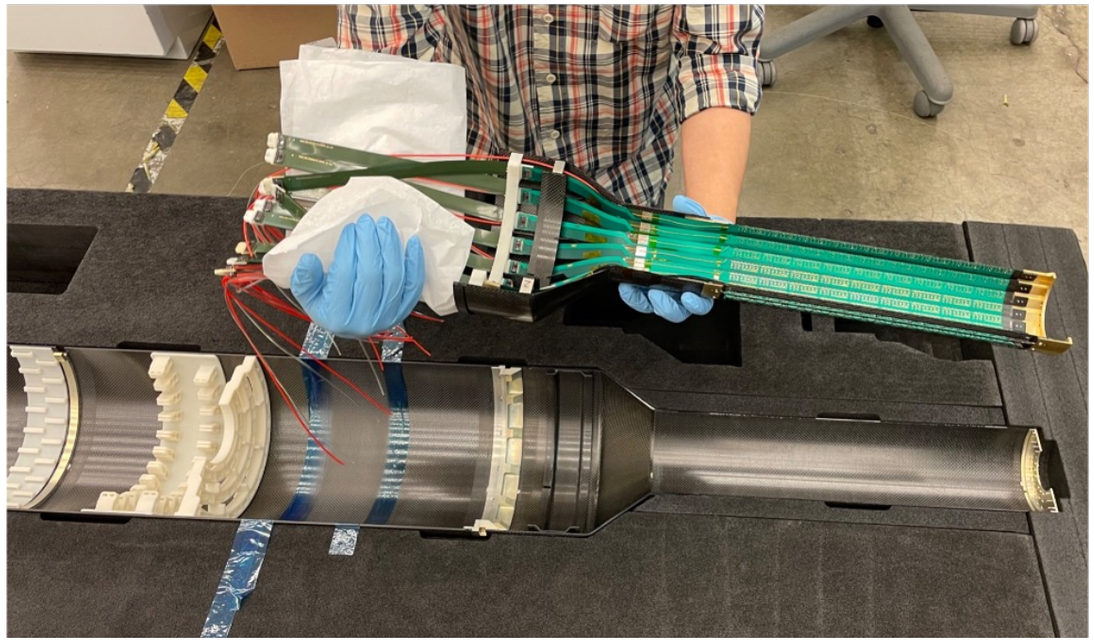
EMCAL assembly at BNL

Commissioning Task Force

sPHENIX detector with HCAL in the PHENIX hall

- Lots of commissioning activities of detectors ongoing in many places
- Collaborative and diverse workforce of students, postdocs, staff, and faculty
- Install the sPHENIX detector from outermost to innermost in the PHENIX hall at BNL

MVTX Commissioning Status

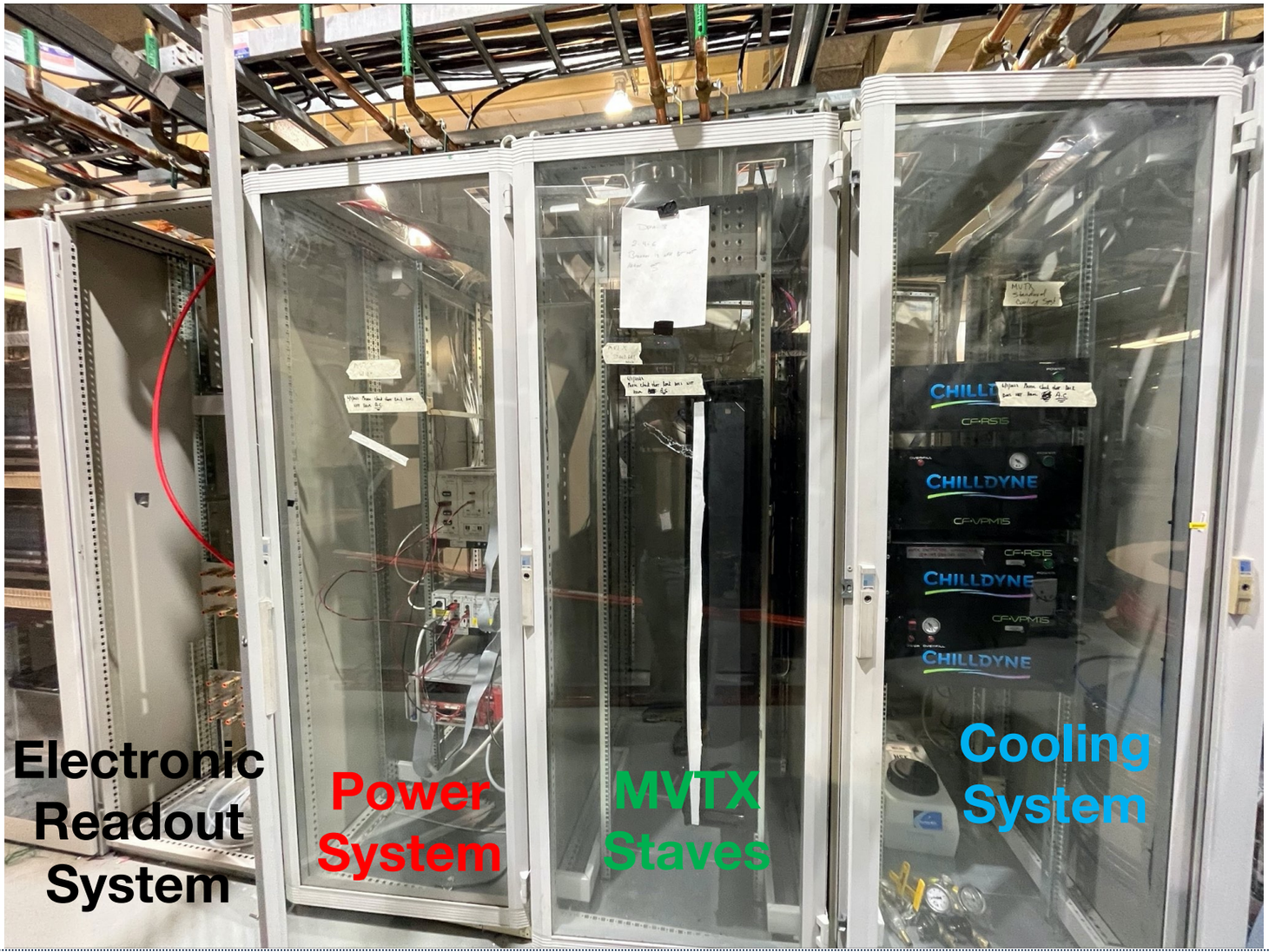


LBNL Assembly

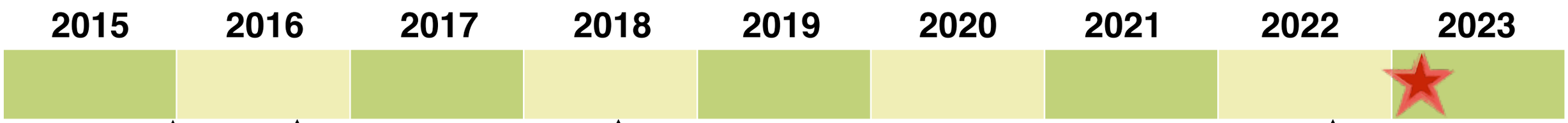
- Half detector assembly: stave gluing to carbon structure
- Precision alignment with machine CMM
- MVTX CAEN power system and cabling

BNL Commissioning

- Clean tent setup
  - MOSAIC system to test the functionality of the staves
- 8-stave MVTX telescope setup
  - Readout chain test
  - Detector alignment
  - Ensure high quality data taking



Proposed Run Plan

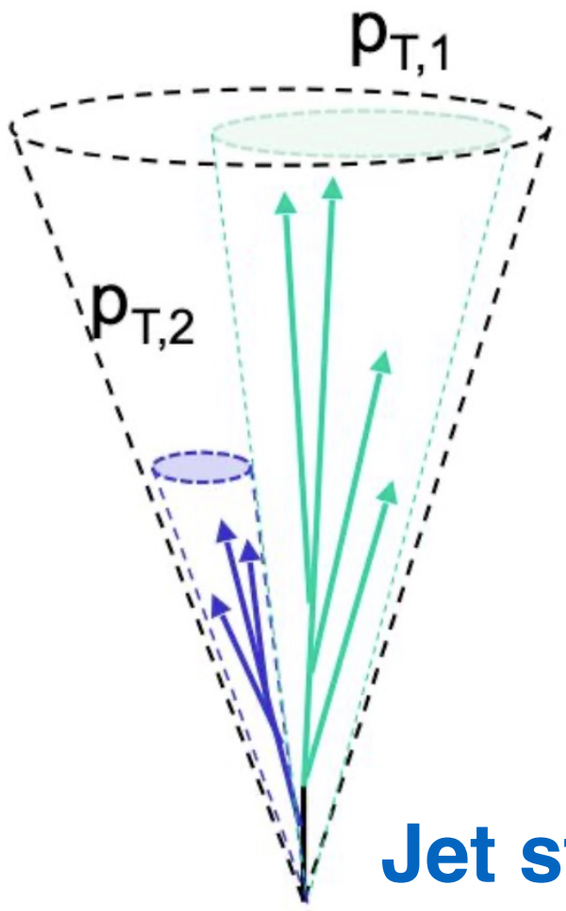


Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z\rvert$ <10 cm	Samp. Lum. $\lvert z\rvert$ <10 cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-*str*]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz] 0.01 pb^{-1} [10%-*str*]	0.11 pb^{-1}
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

sPHENIX Beam Use Proposal endorsed by the BNL NPP (Nuclear and Particle Physics) PAC (Physics Advisory Committee)

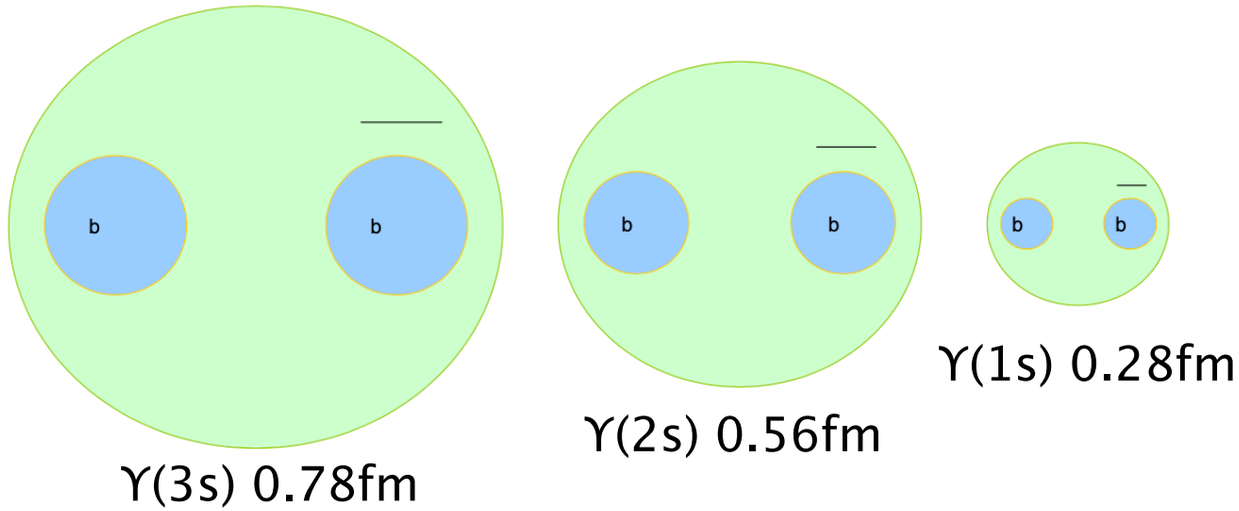
- Extensive **3-year** data taking starting in < 6 months
  - **Year-1**: commissioning and first physics in Au+Au
  - **Year-2**: p+p and p+Au runs for heavy-ion reference and cold QCD physics
  - **Year-3**: very large Au+Au dataset (145B events in total)

The sPHENIX Physics Program



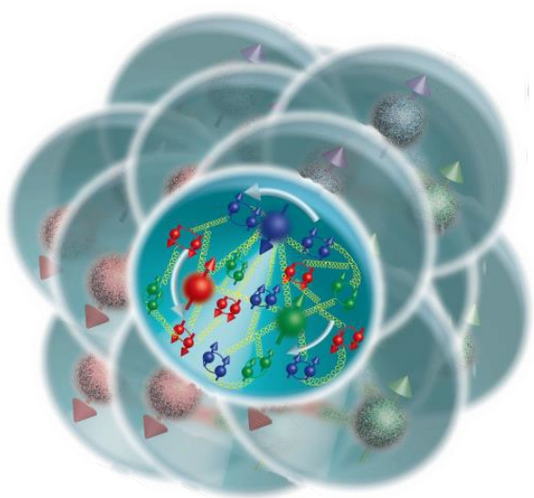
Jet structure

vary momentum/angular scale of probe



Quarkonium spectroscopy

vary size of probe

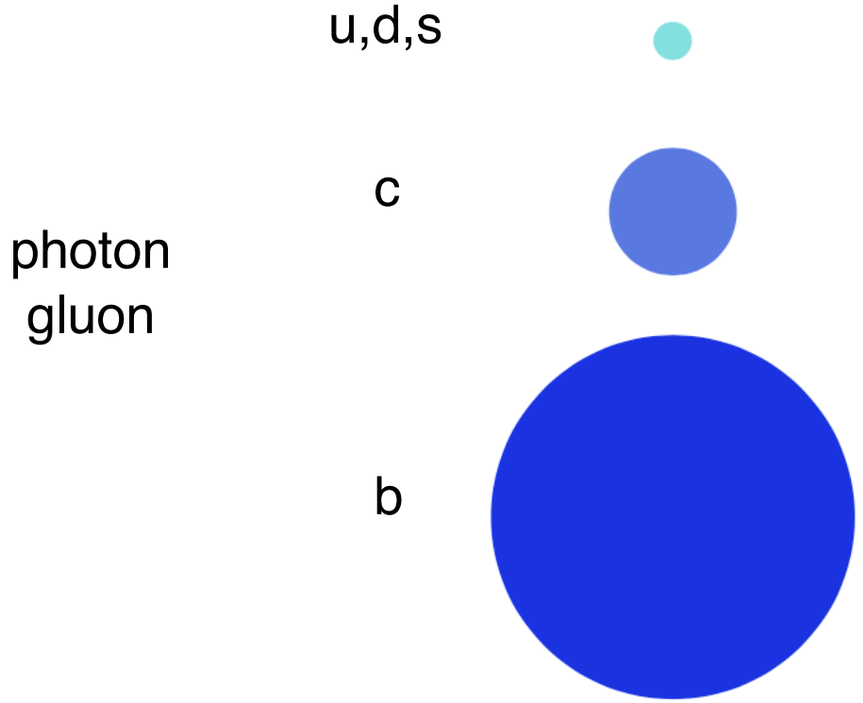


Cold QCD

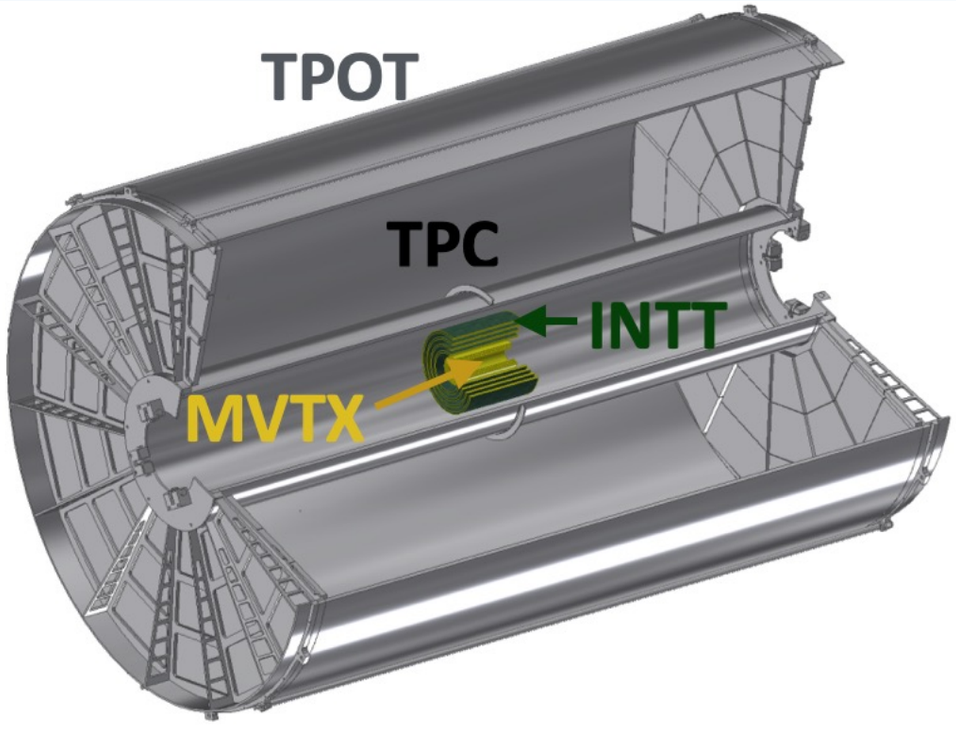
study proton spin, transverse-momentum, and cold nuclear effects

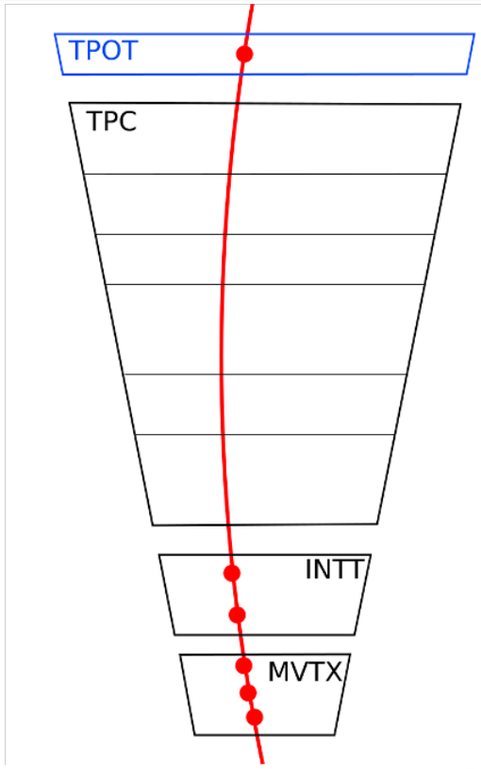
Parton energy loss

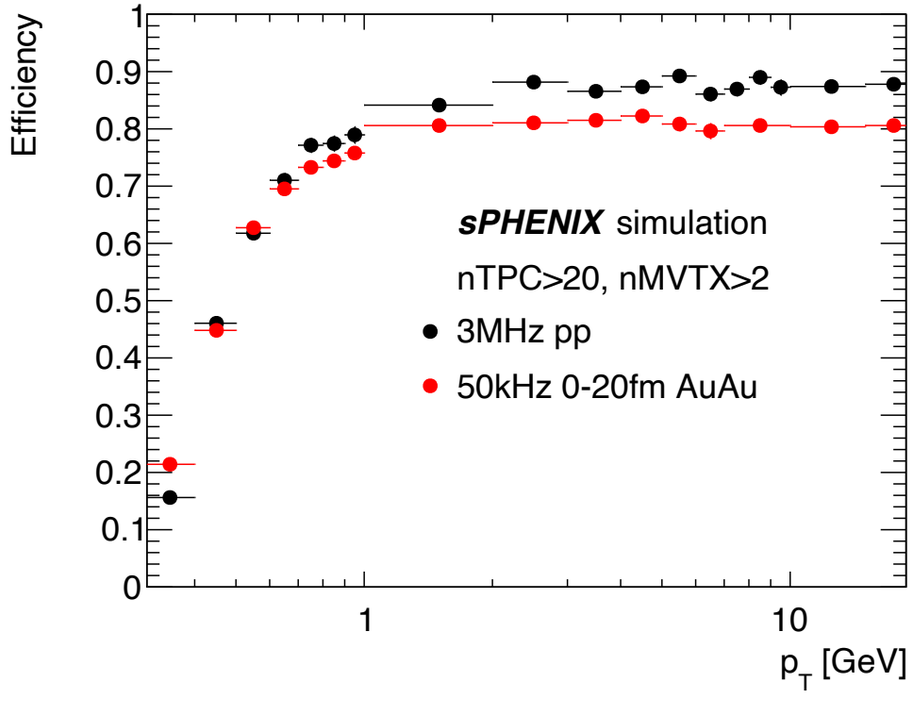
vary mass/momentum of probe

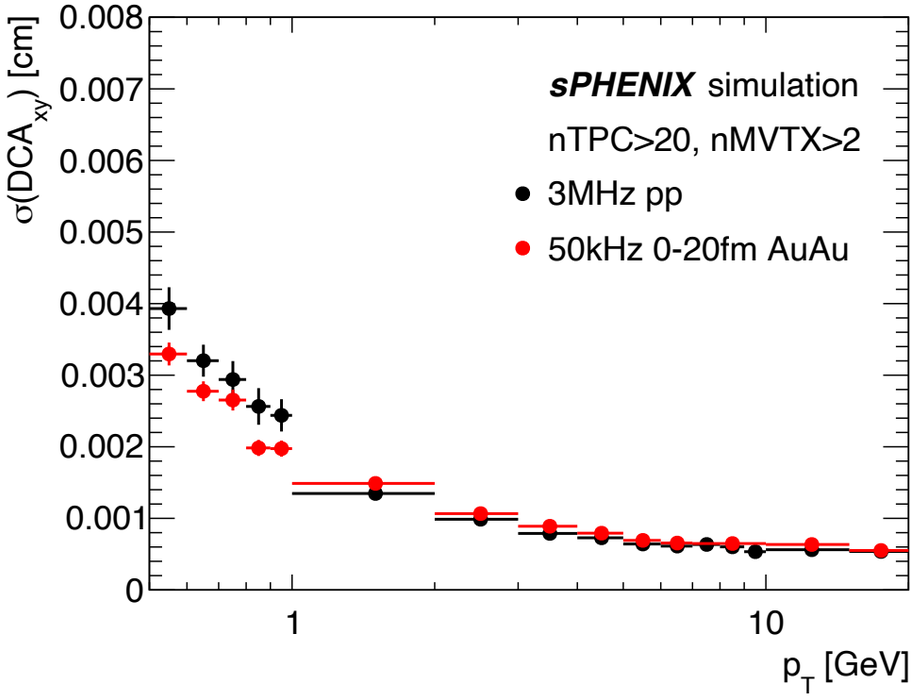


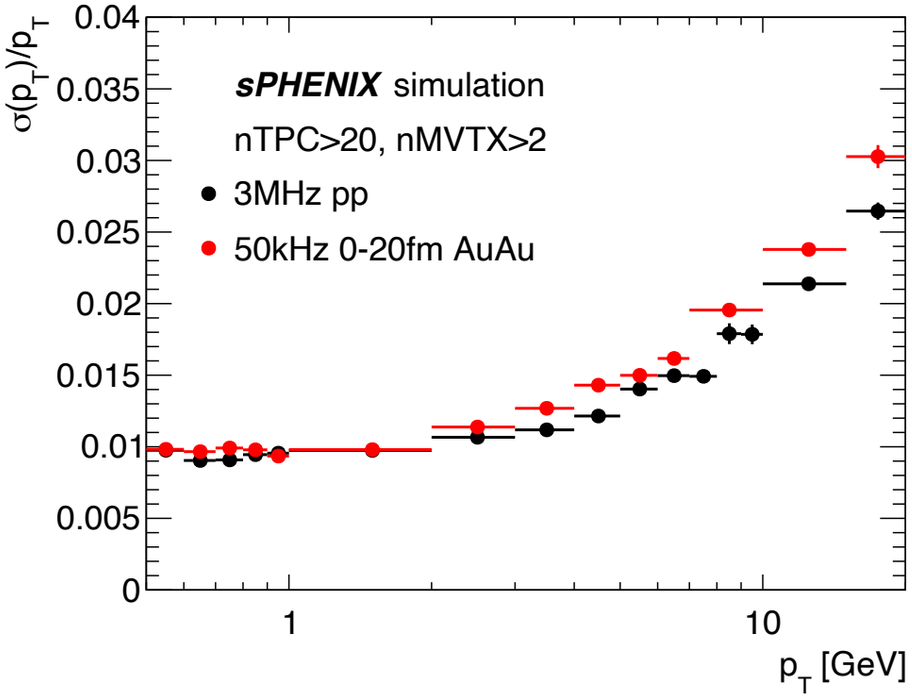
Tracking System and Performance





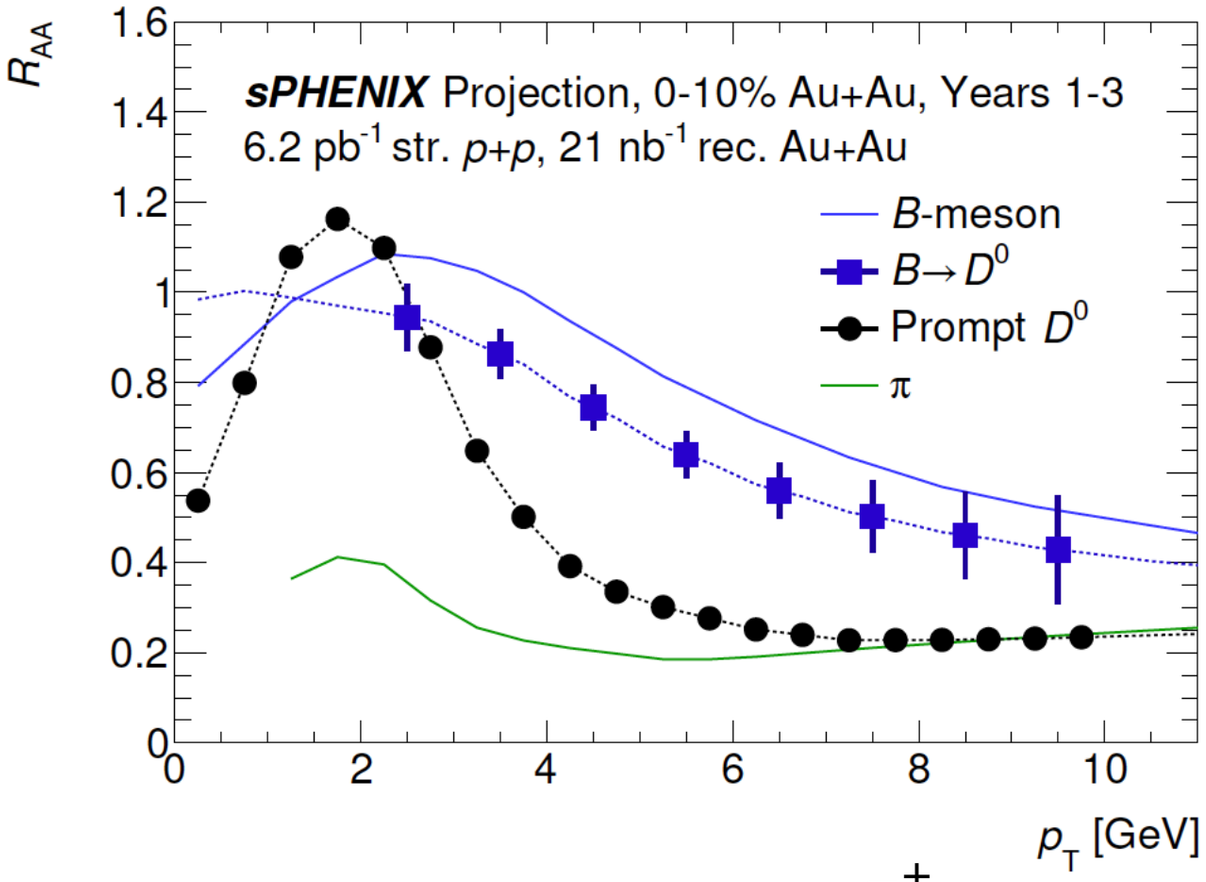


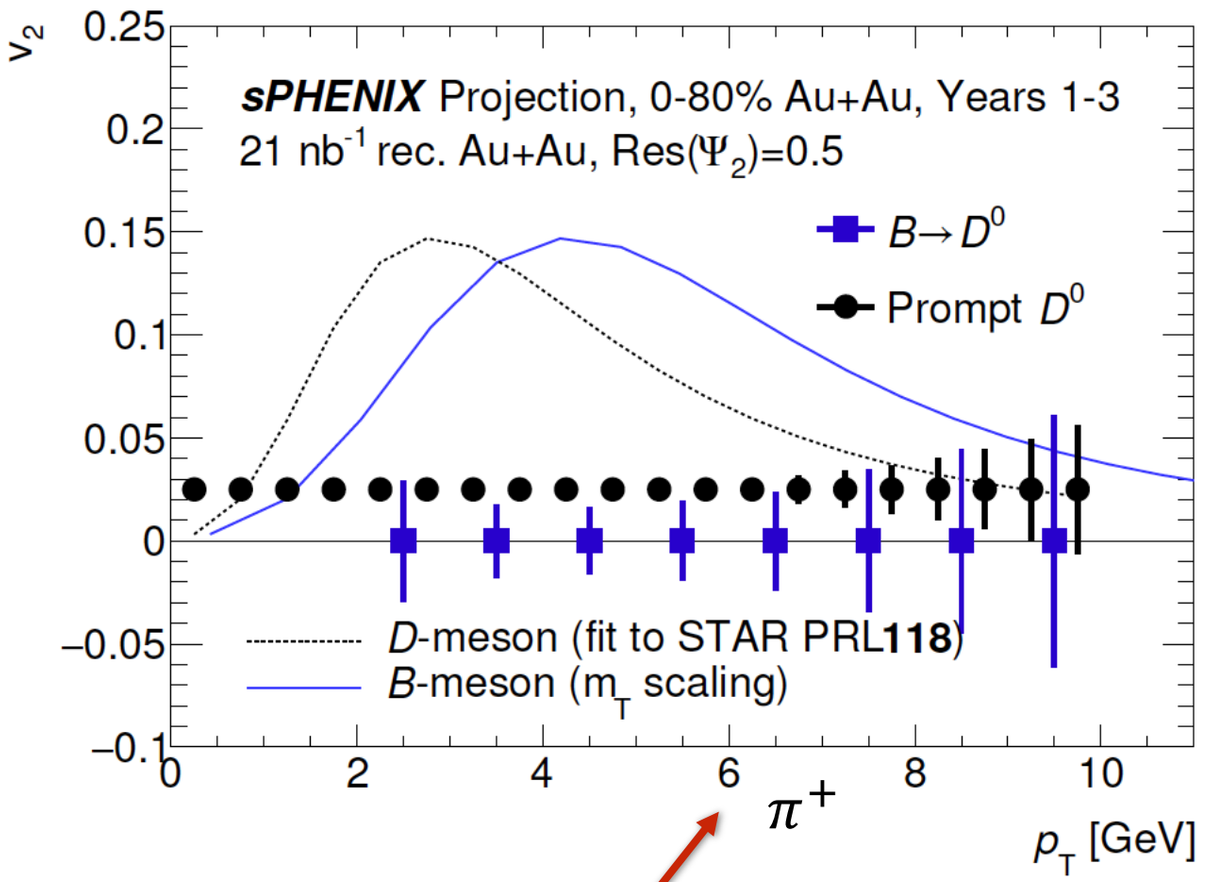




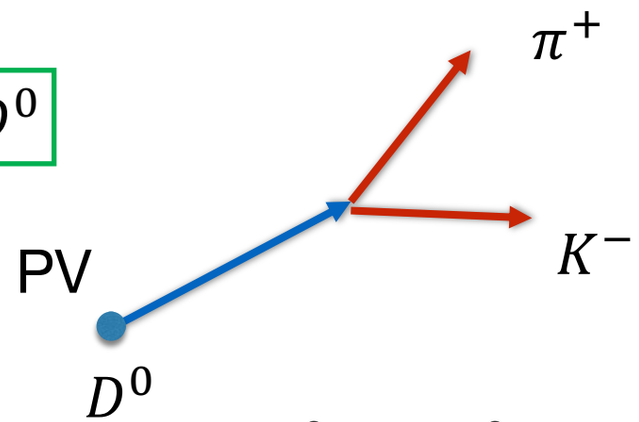
- MVTX and INTT operating in continuous streaming readout mode with fast electronics
- TPC + TPOT for main for outer tracking
- Excellent tracking reconstruction and vertexing performance for HF physics studies

Fully reconstructed D^0 mesons

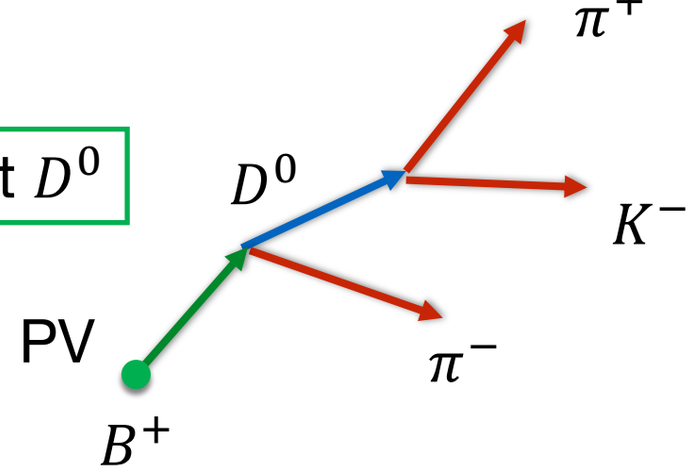




Prompt D^0

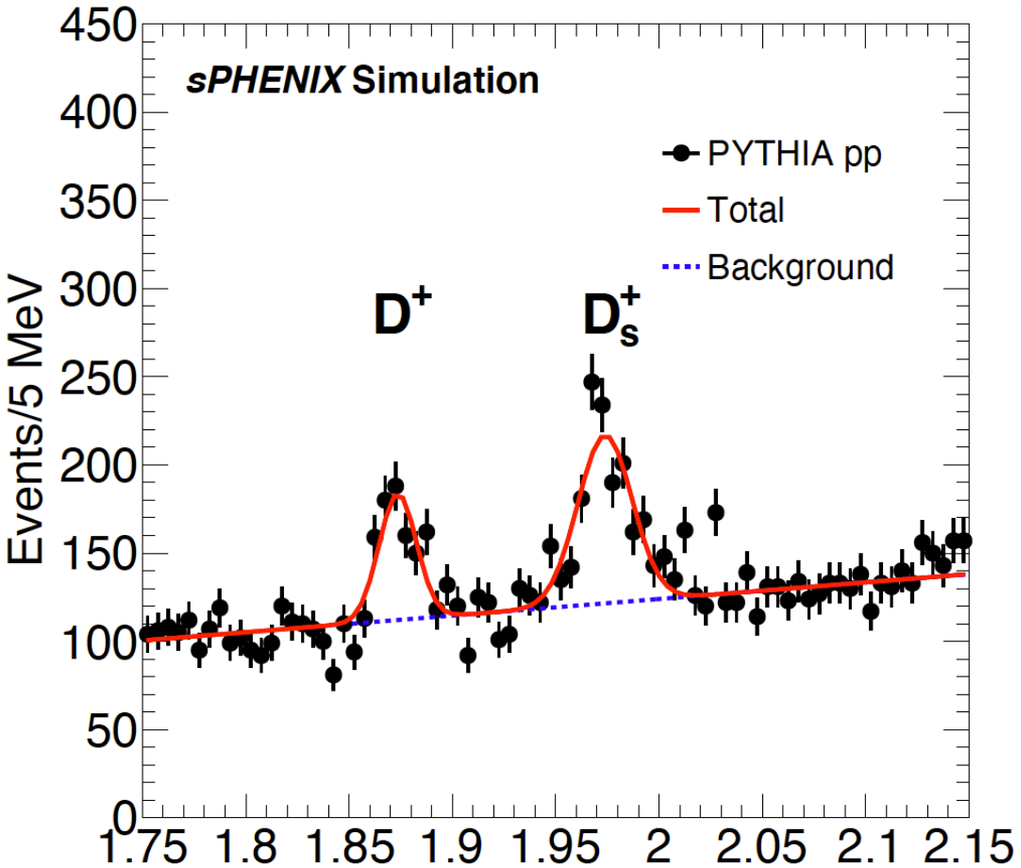


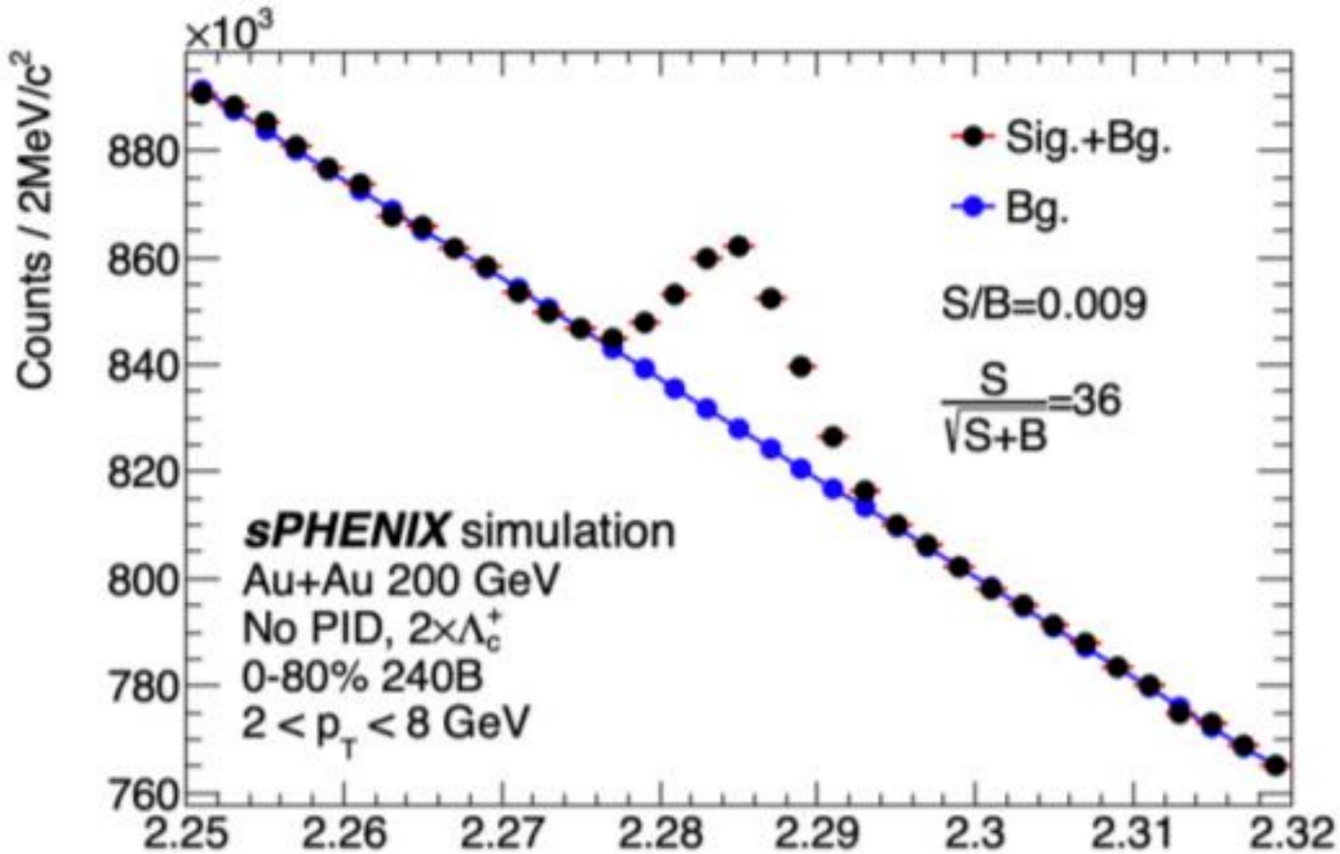
Non-Prompt D^0

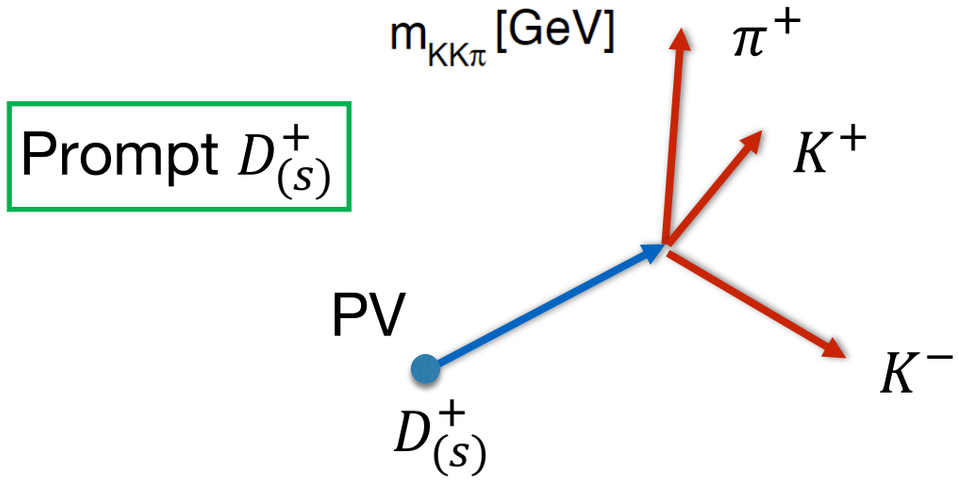


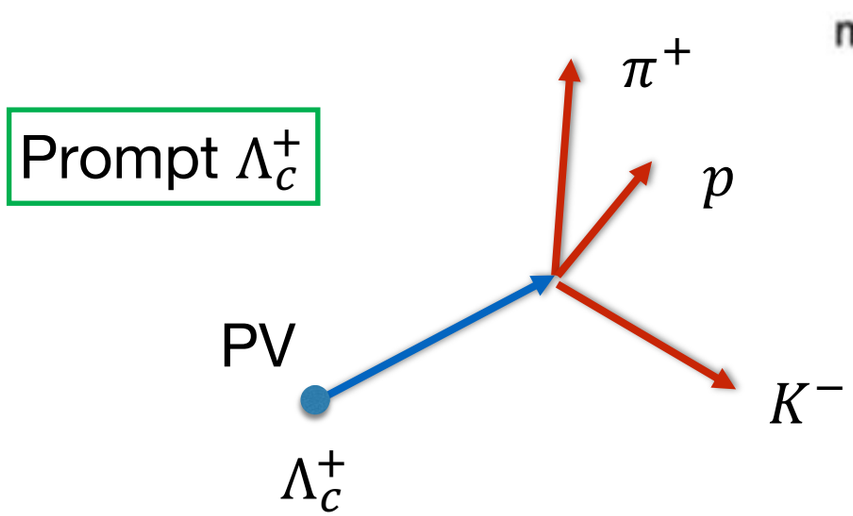
- Fully reconstructed D^0 via $D^0 \rightarrow K^-\pi^+$ without hadronic PID
- Charm quark energy loss mechanism to probe the internal structure of QGP
- Diffusion coefficient for charm quarks in QGP at RHIC energy
- Data-driven method to separate of prompt and non-prompt D^0 with DCA
- D^0 v_2: candidate measurement for Year 1 Heavy Flavor Physics

Charm Hadronization



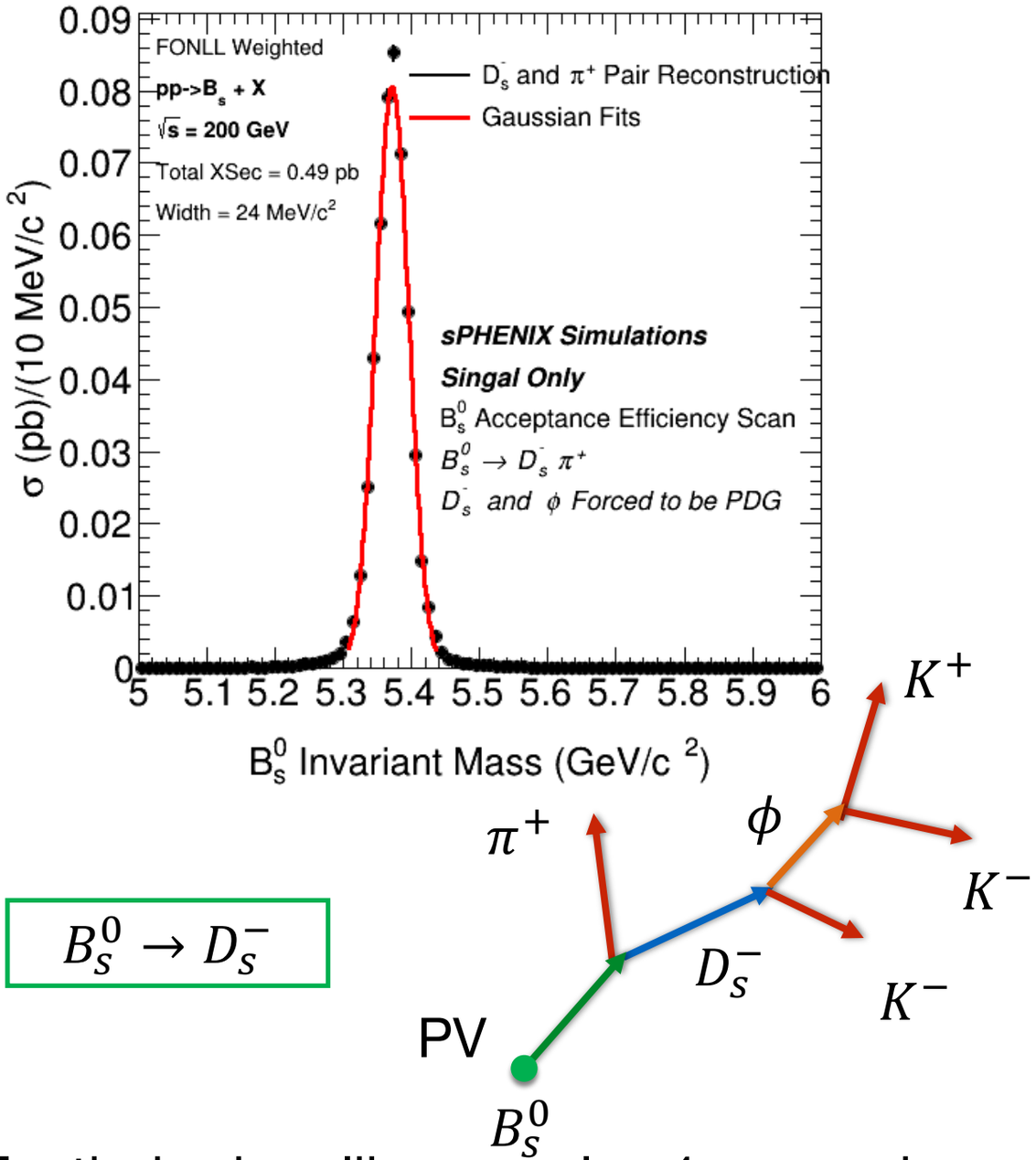


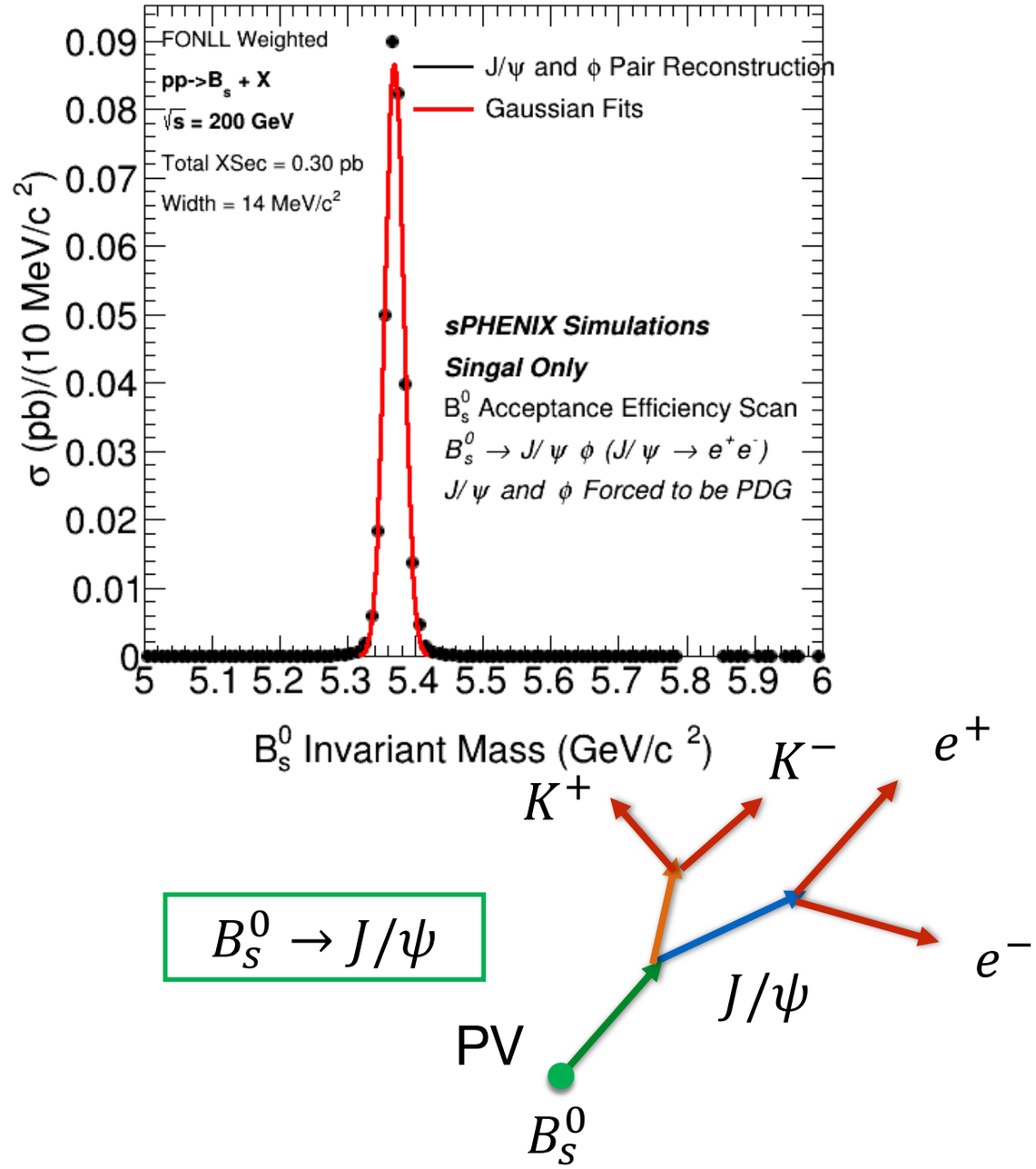




- More complex 3-prong decays
- High precision measurement thanks to streaming readout data taking and tracking
- Study charm hadronization from vacuum to QGP via the measurements of D_s^+/D^+ and Λ_c^+/D^0 as a function of event multiplicity

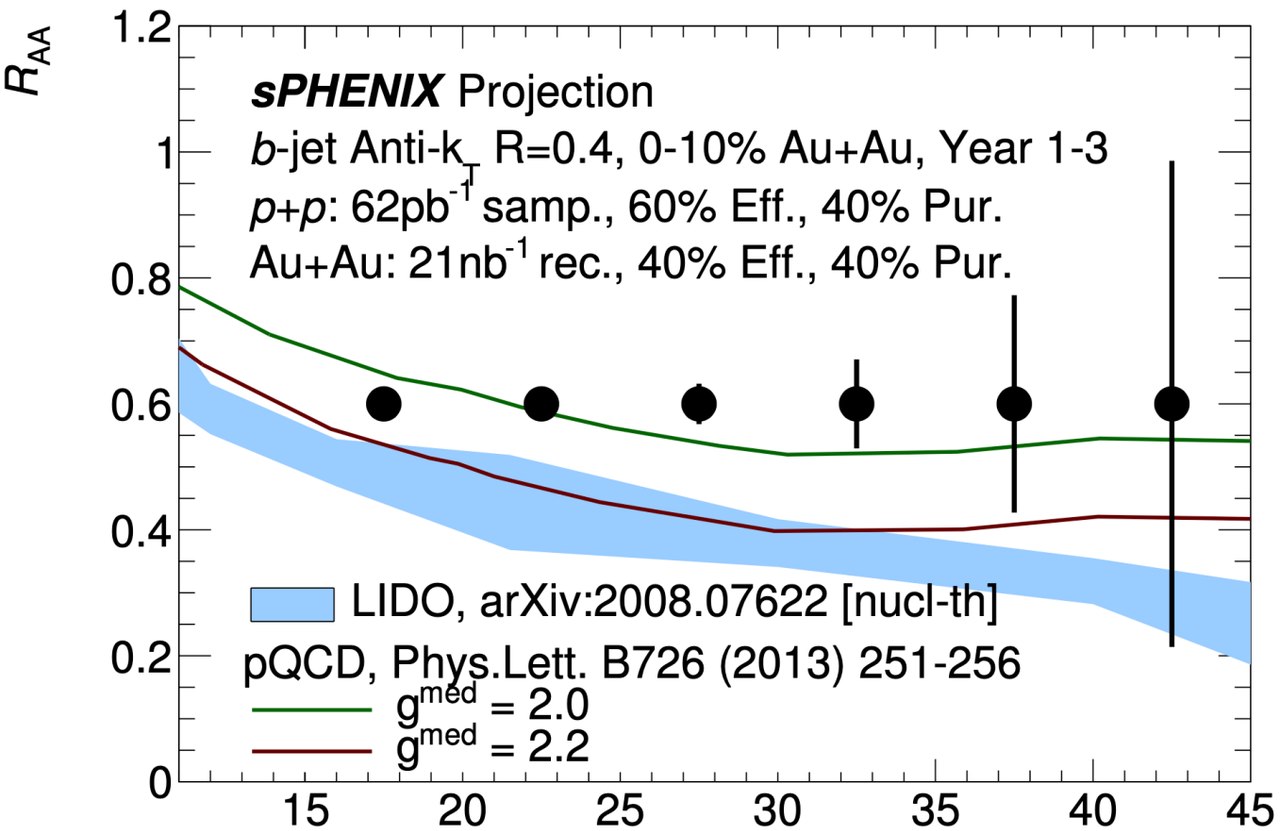
Fully Reconstructed B_s^0 Meson

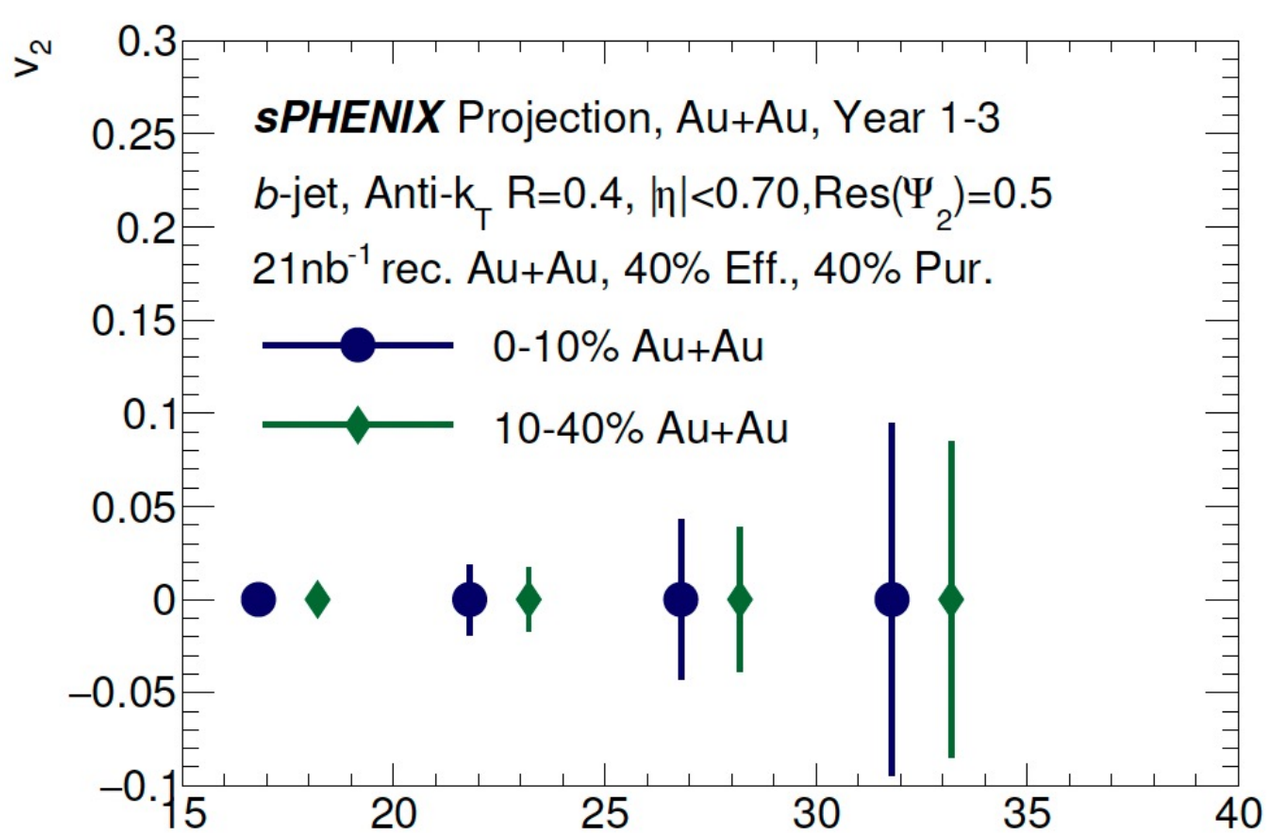




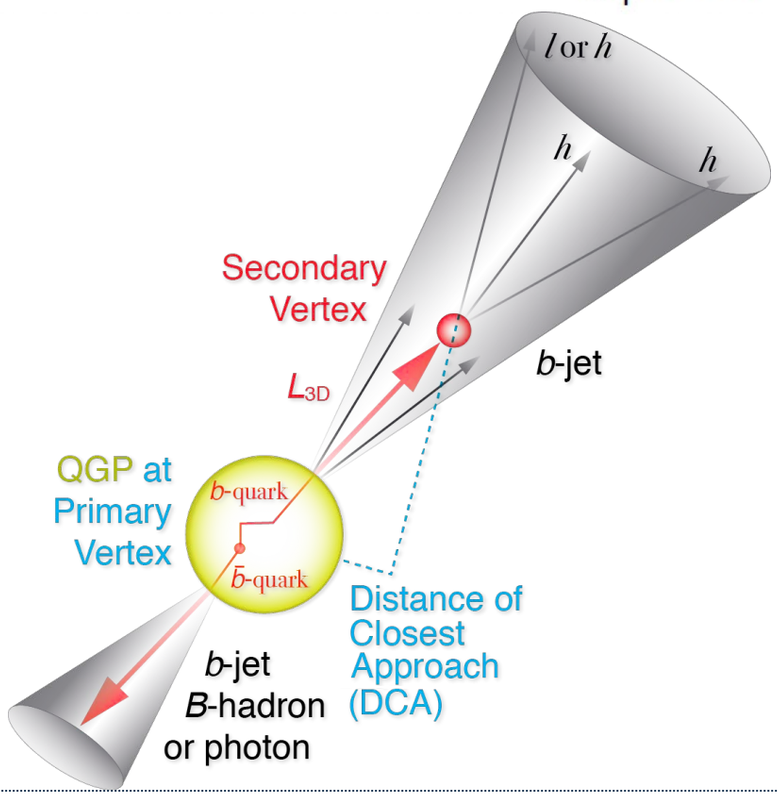
- Exotic-hadron like complex 4-prong decays
- FONLL weight B_s^0 in GEANT simulation for signal only prediction
- First observation of fully reconstructed B-meson in nuclear collisions at RHIC
- Study beauty quark hadronization mechanism with B_s^0/B^+ ratio
- Test QCD factorization theorem at RHIC energy in the beauty sector

b-jet R_{AA} and v_2 Measurement

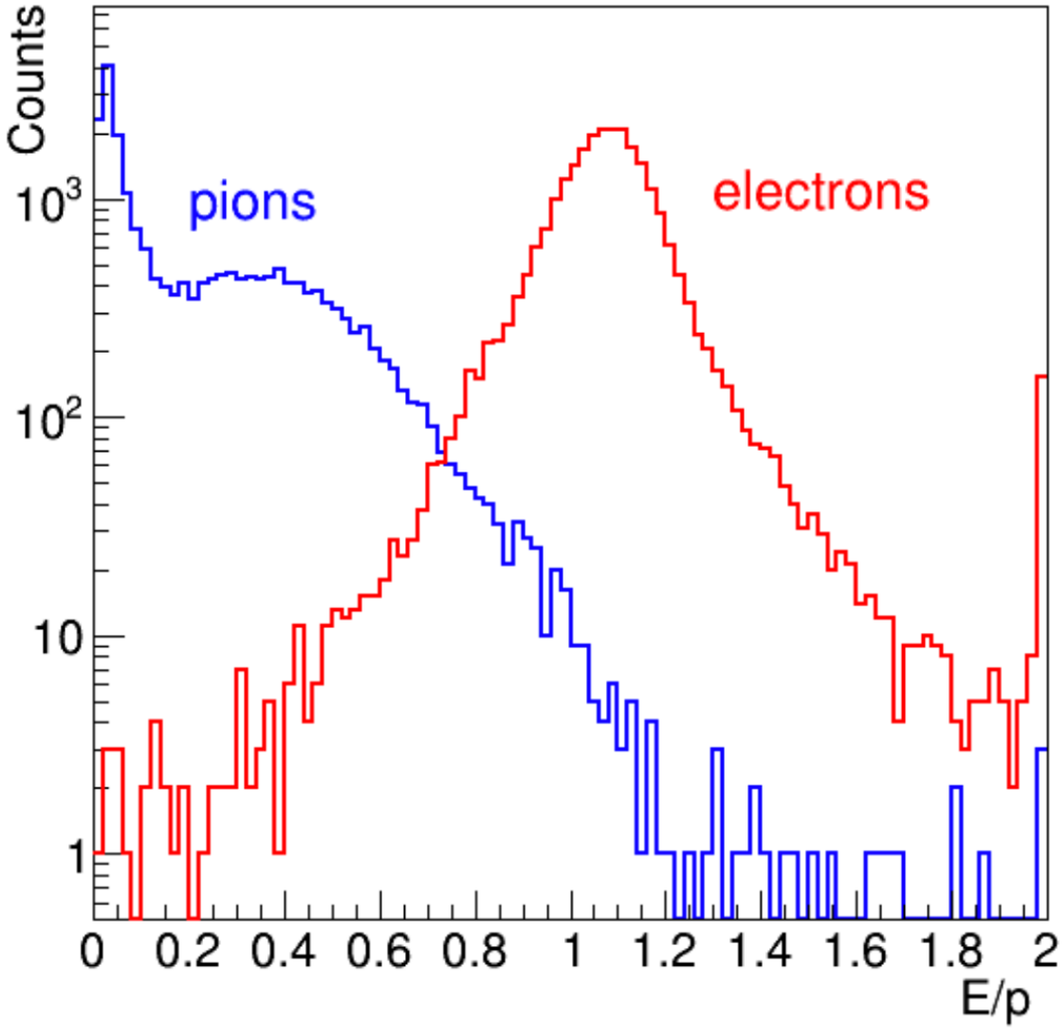


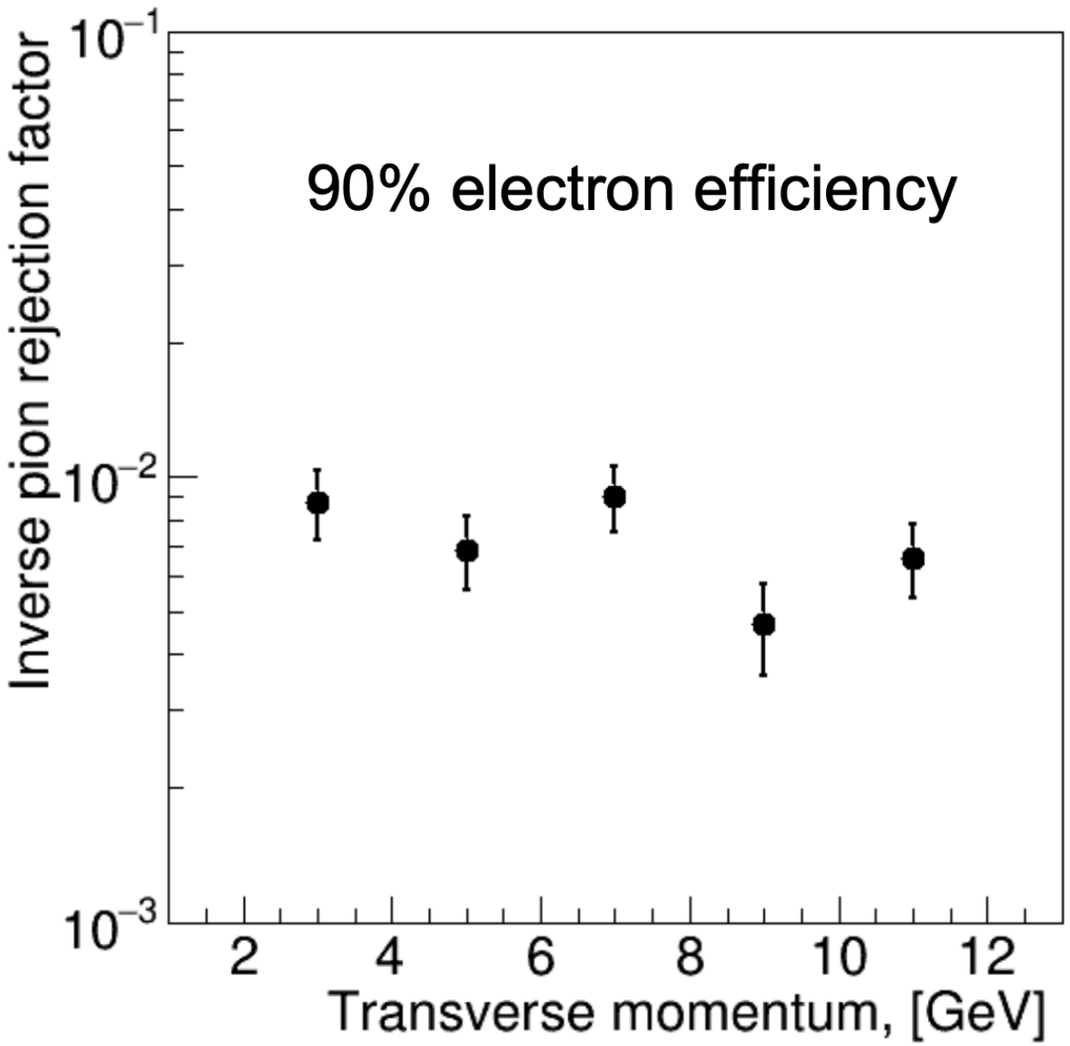


- Utilization of MVTX to reconstruct secondary vertex within the jet cone
  - Jets with displaced vertex to tag the b quarks
  - Inclusive measurement with better statistics
- First b-jet measurement at RHIC
- Sensitive to heavy-quark collisional and radiative in-medium energy loss
- Constrain beauty quark diffusion coefficient at RHIC energy
- Complementary to LHC with better measurements at lower p_T



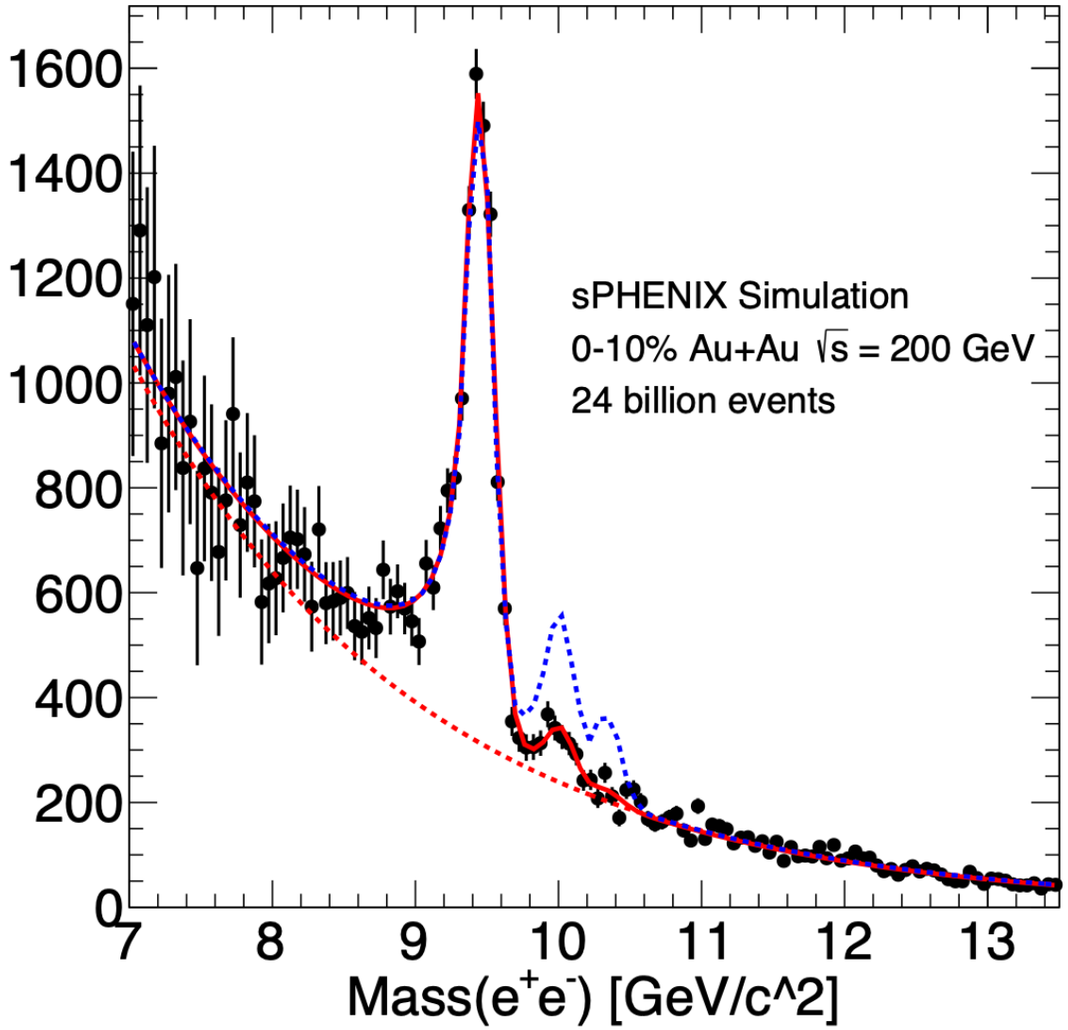
Electron Identification Capabilities

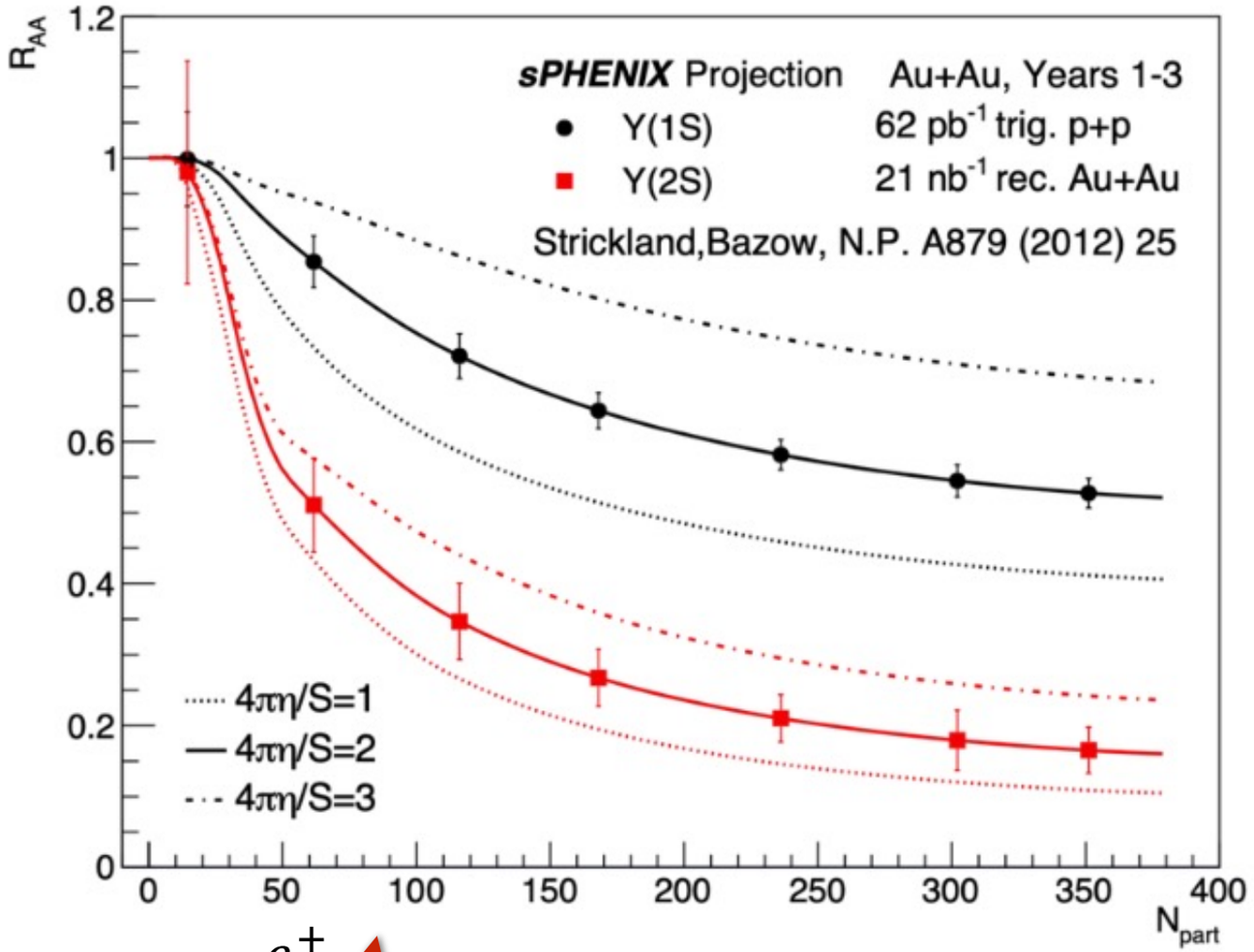




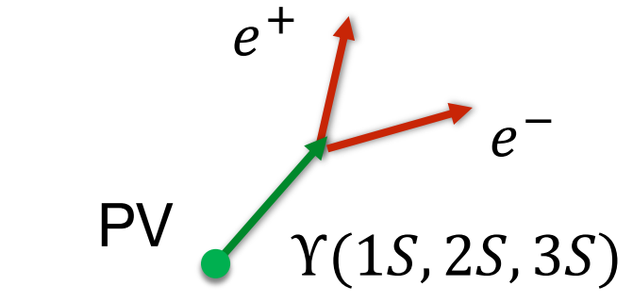
- Use shower core energy information from central EMCAL and HCAL for e/h separation
- Working point: EMCAL/p > 0.9 and iHCAL/EMCAL < 0.2 to maintain 90% electron efficiency
- Excellent electron identification capabilities for quarkonia background rejection
- Improvement with machine learning techniques in development
- Ongoing muons identification studies with machine learning techniques

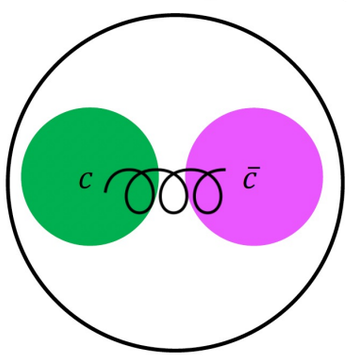
Upsilon Spectroscopy

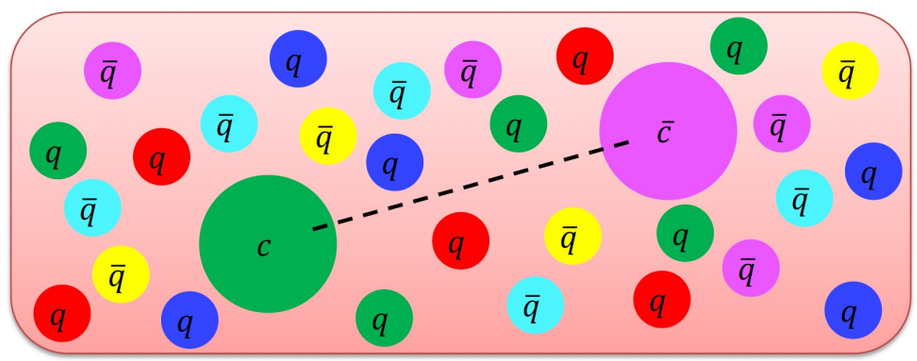




- Measuring QGP temperature via color screening effect
- Excellent mass resolution dielectronic decay channel
- R_{AA} measurement with high precision
- Potential observation of $\Upsilon(3S)$ at RHIC







Summary

The sPHENIX Experiment at RHIC

- Physics program: jet, **open heavy flavor**, **quarkonia**, cold QCD
- Detector commissioning: lots of activities are ongoing right now

Detector Performance

- Excellent tracking and vertexing capabilities for heavy flavor physics measurements
- Good electron identification performance for quarkonia background rejection

Open Heavy Flavor Physics Program

- Fully reconstructed charm and beauty hadron measurements
  - Heavy quark energy loss
  - Heavy quark diffusion
  - Heavy quark hadronization
- First inclusive b-jet measurements
  - Complementary to LHC experiments
  - Precision measurements at low p_T

Hidden heavy flavor Physics Program

- Upsilon Spectroscopy
  - measure the temperature of QGP
  - Potential observation of $\Upsilon(3S)$ at RHIC

First data taking starts in around 02/2023: STAY TUNE!

Thank You

- This work is supported by the United States Department of Energy Office of Science and Los Alamos National Laboratory Laboratory Directed Research & Development (LDRD)

- **Thank you very much for your attention!**

Back Up