Heavy Flavor Measurements and Projections at sPHENIX

Alex Patton (MIT)

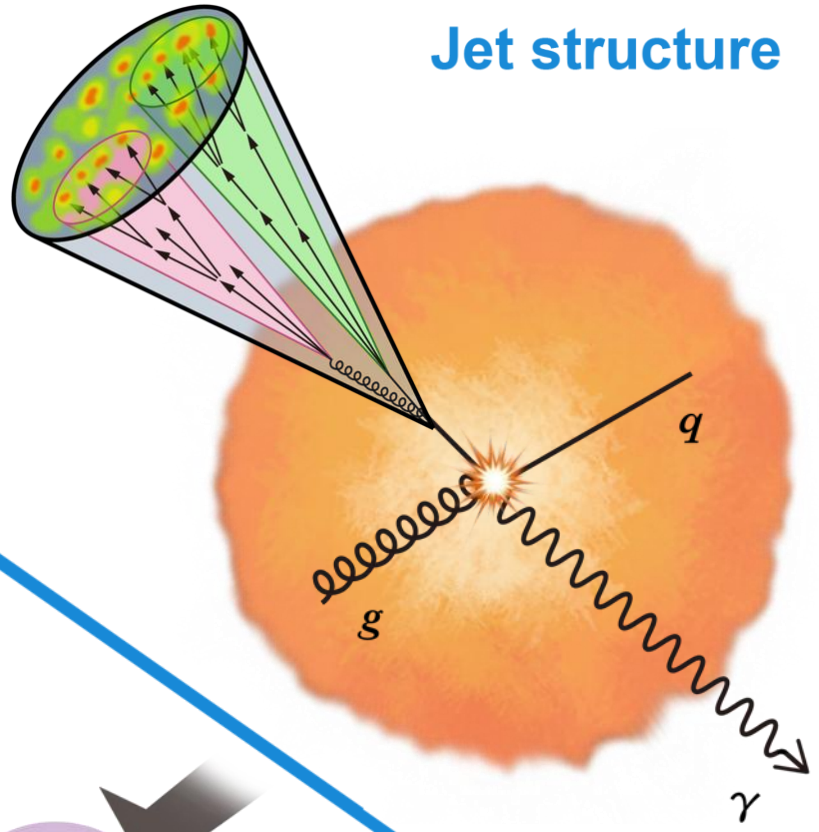
2025 AGS/RHIC Users' Meeting

Physics Program

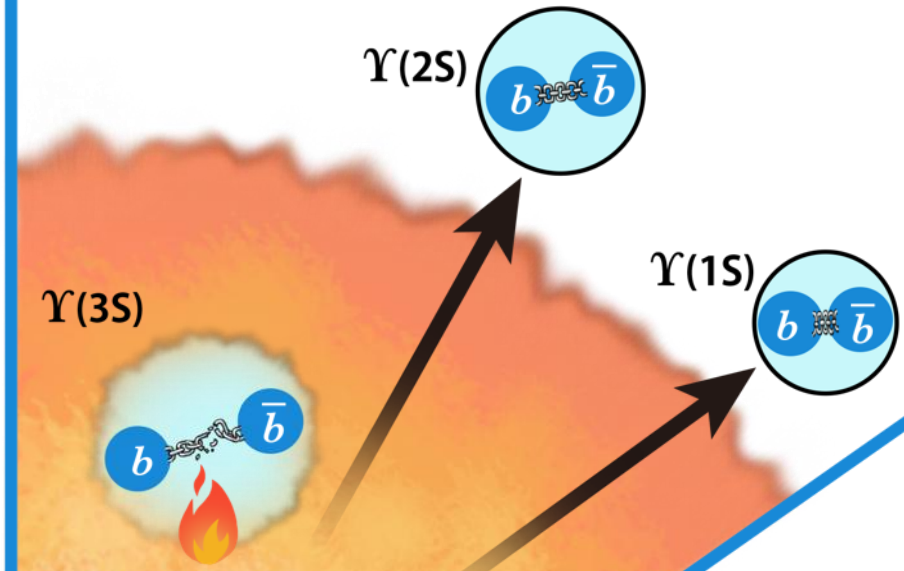
sPHENIX

Jet structure

9:00 Wednesday

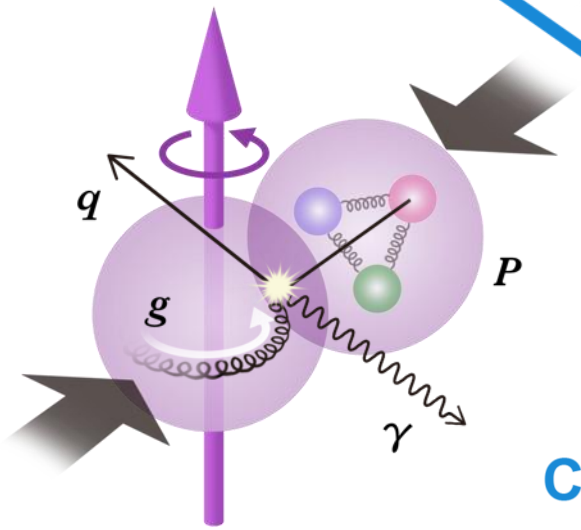


Quarkonium spectroscopy



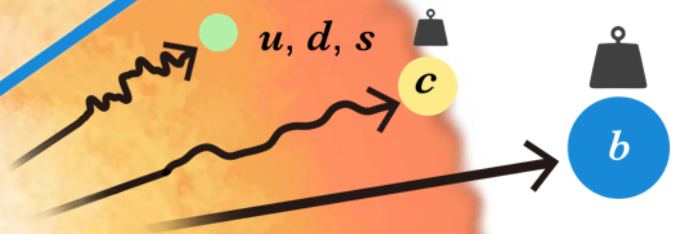
Cold QCD

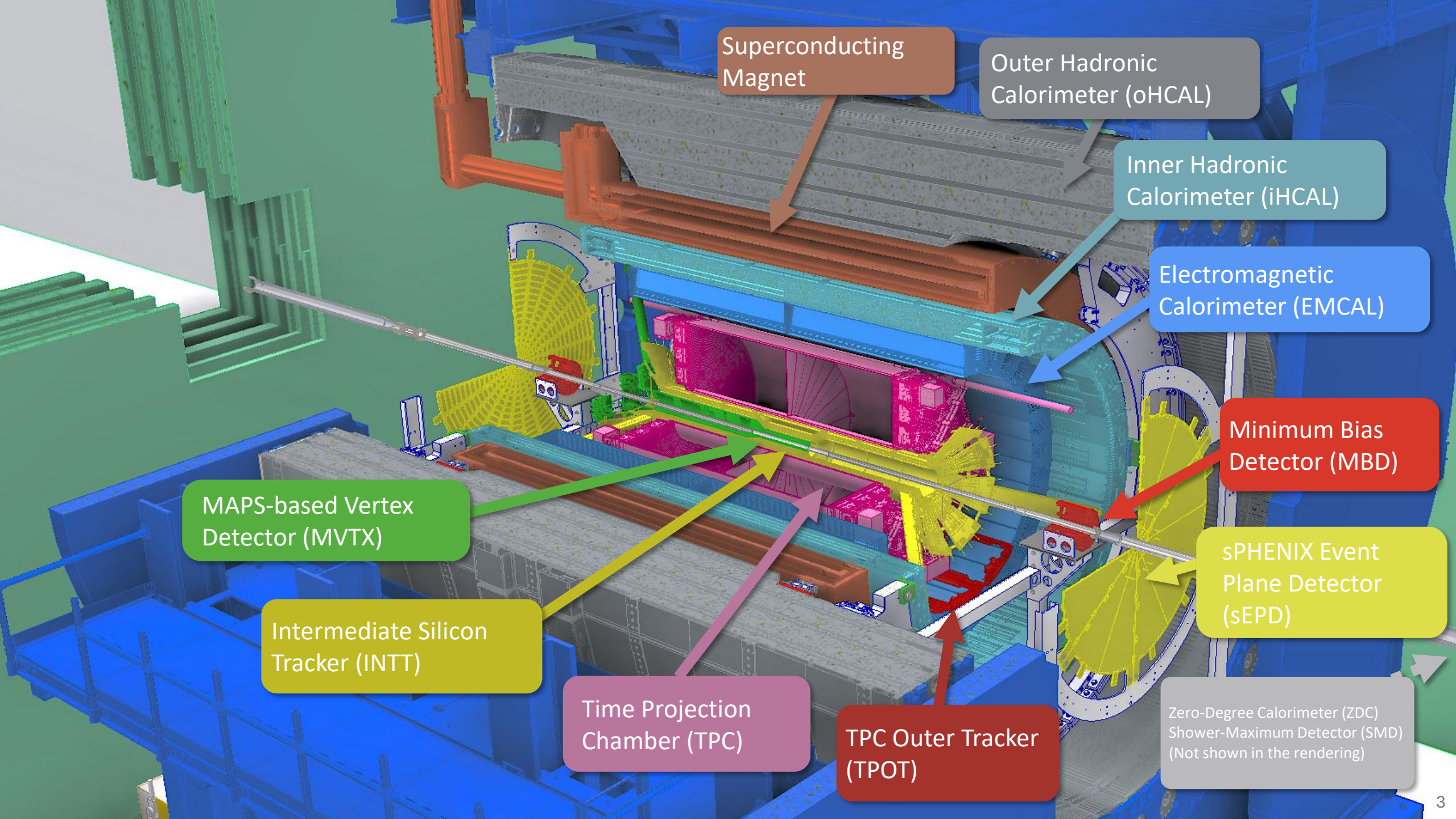
1:55 pm Tuesday



Plenary Talks
Thursday
Run Report 11:20
Highlights 2:30

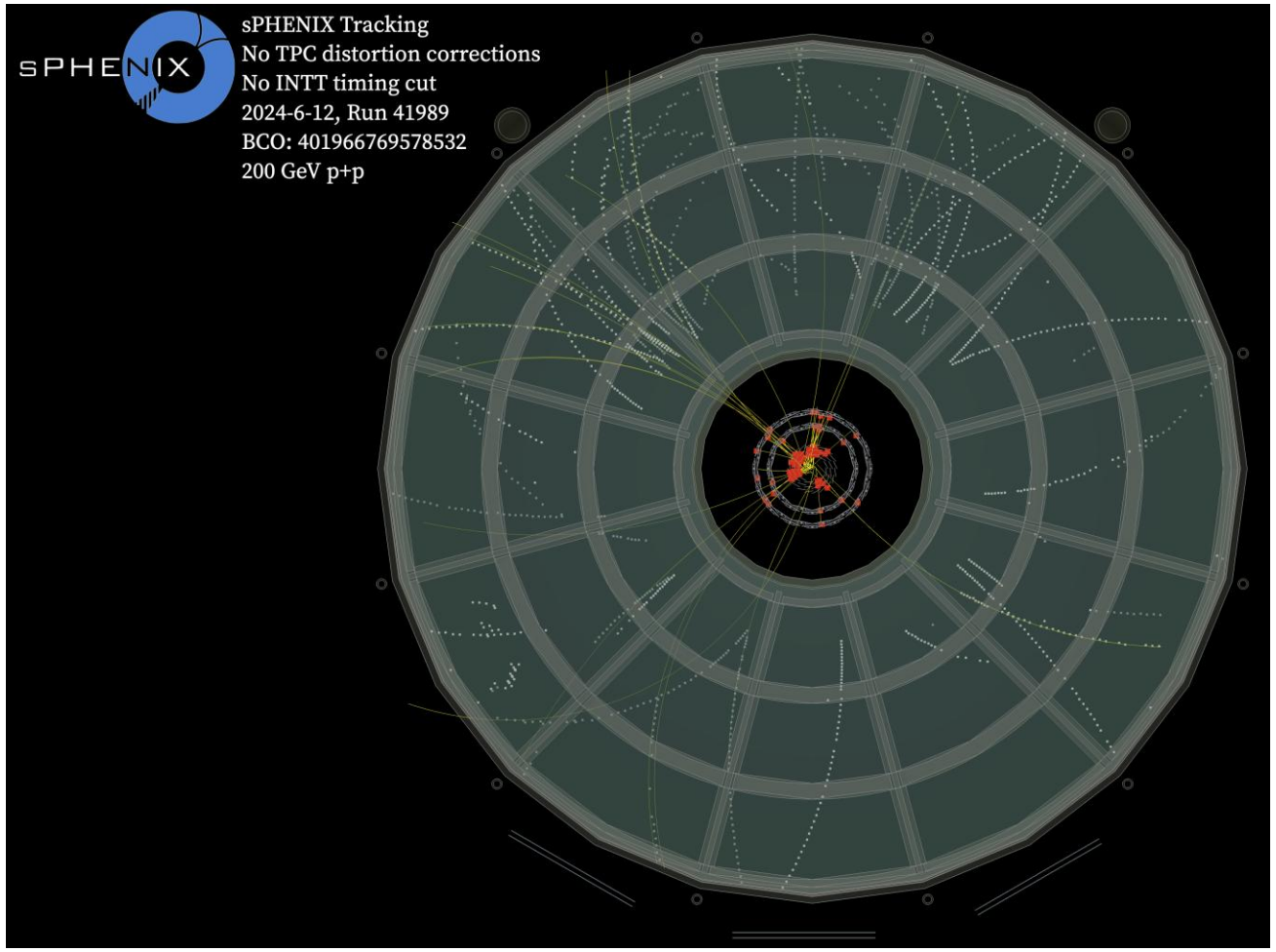
Parton energy loss




Superconducting Magnet
Outer Hadronic Calorimeter (oHCAL)
Inner Hadronic Calorimeter (iHCAL)
Electromagnetic Calorimeter (EMCAL)
Minimum Bias Detector (MBD)
sPHENIX Event Plane Detector (sEPD)
MAPS-based Vertex Detector (MVTX)
Intermediate Silicon Tracker (INTT)
Time Projection Chamber (TPC)
TPC Outer Tracker (TPOT)
Zero-Degree Calorimeter (ZDC)
Shower-Maximum Detector (SMD)
(Not shown in the rendering)

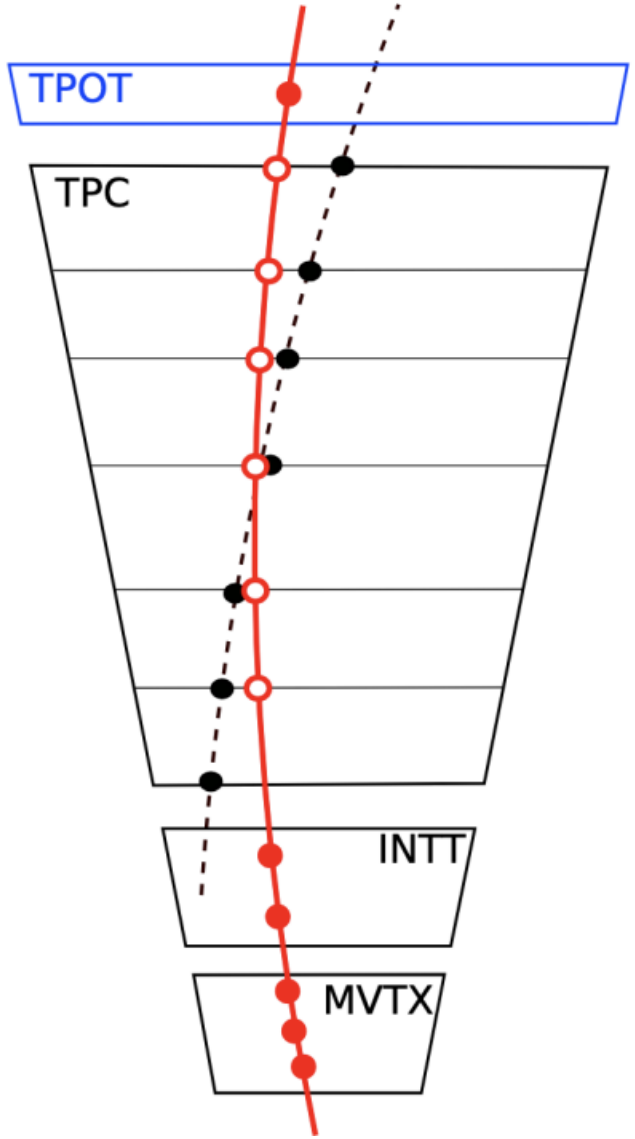
Tracking Detectors

- MAPS based Vertex Detector (MVTX)
  - 3 layers of MAPS staves
  - Vertex Resolution
  - O(1-10) micron precision
- Intermediate Tracker (INTT)
  - 4 layers of Silicon Strips
  - Bunch crossing separation
  - ~100 ns integration time
- Time Projection Chamber (TPC)
  - 48 Layers with GEM-based readout
  - Momentum Resolution and dE/dx
  - O(100) micron precision
- TPC Outer Tracker (TPOT)
  - Micromegas Detector
  - TPC space charge distortion calibration



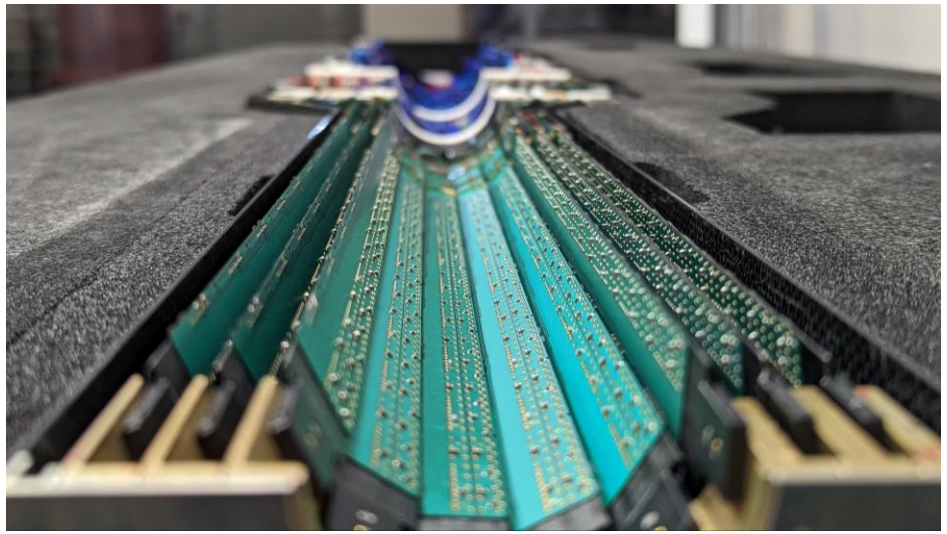
Distortion Corrections

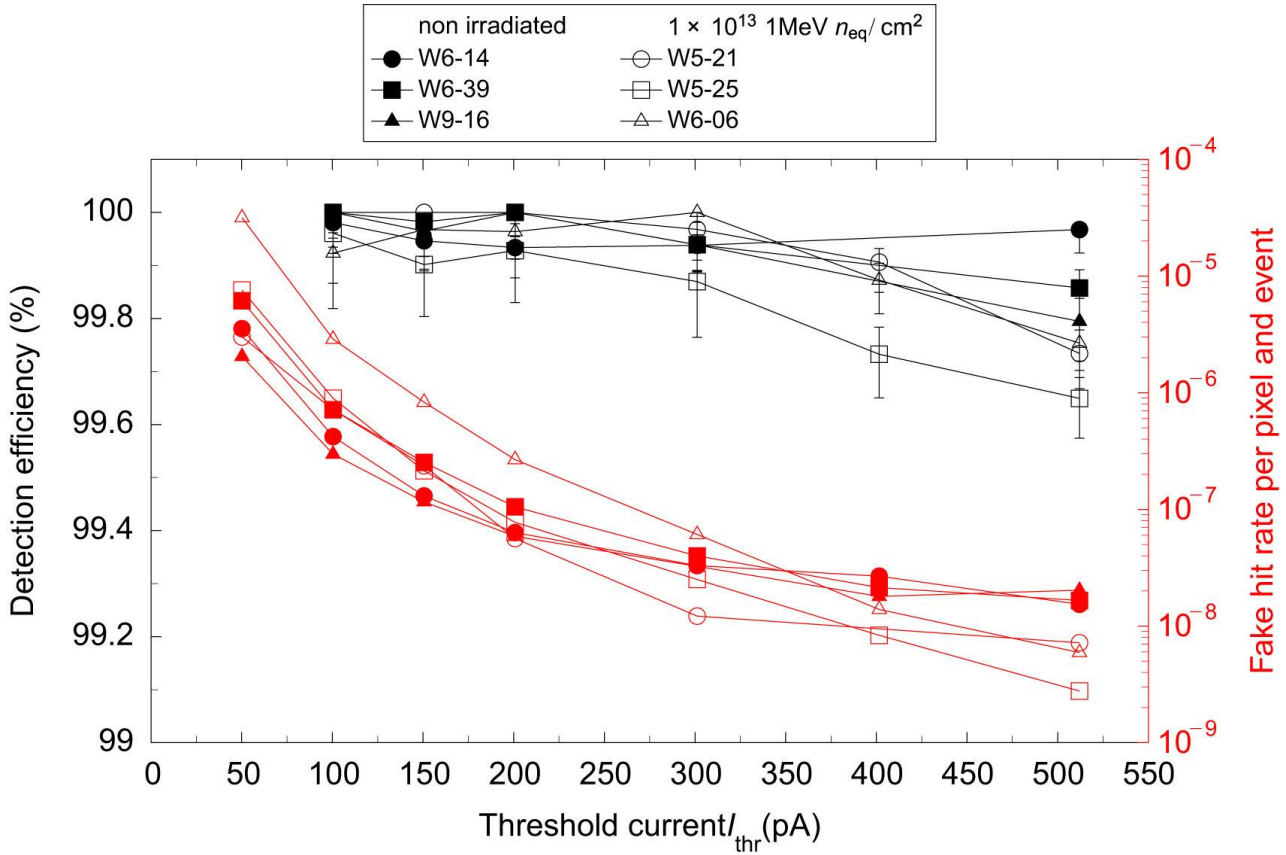
- O(*cm)* distortions reconstructed with pulsed laser system for static corrections
- O(*mm*) distortions reconstructed with tracks with TPOT for average corrections
- O(100 *μm*) distortions reconstructed with diffuse laser for fluctuation corrections
- Use MVTX, INTT, and TPOT to define precisely timed in trajectory, and calibrate with TPC residuals
- Currently only using average corrections in our reconstruction, and using a simpler method while fitting is developed



MVTX

Sensor thickness [μm]	50
Pixel size [μm] / matrix	29 x 27 / 1024 x 512
Technology	180nm CMOS
Power Consumption [mW/cm^2]	40
Stave Material Budget	0.3% X_0
Hit resolution [μm]	< 6
Channels	226M

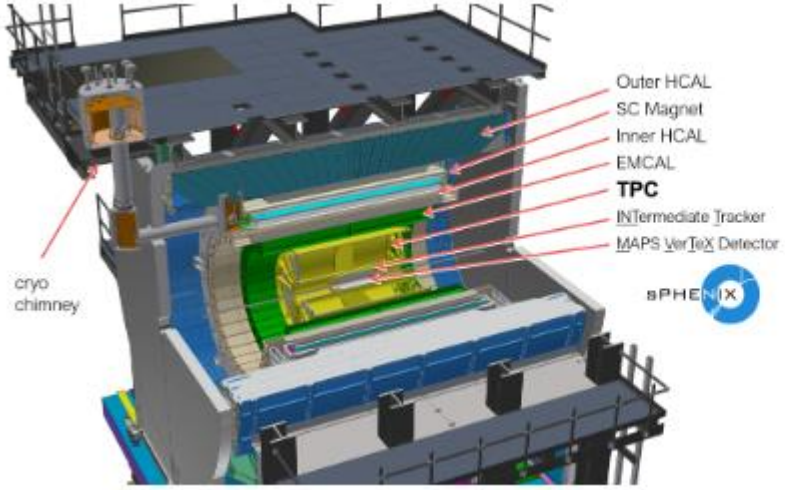


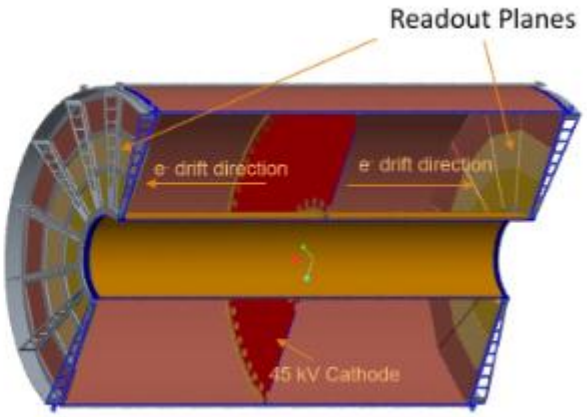


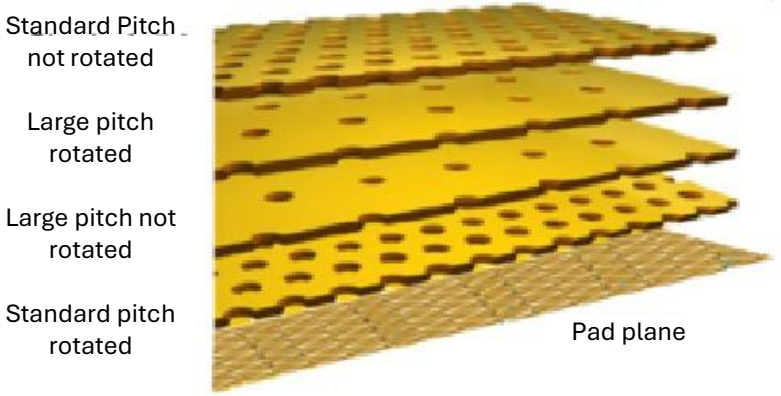
[NIM-A 2015.09.057]

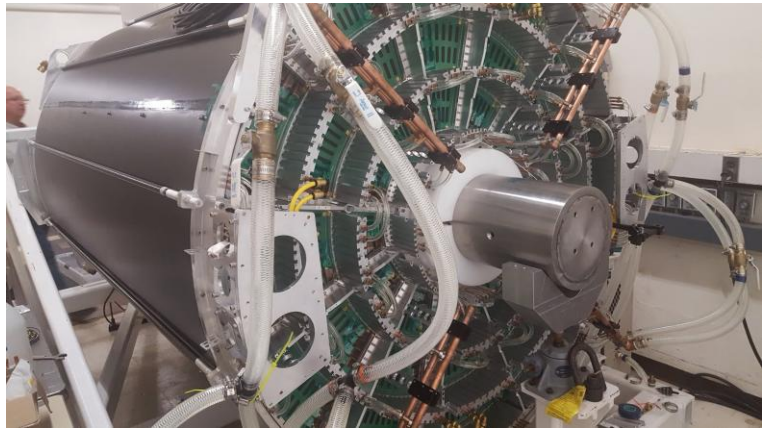
TPC

- Gaseous Drift Detector
  - Ar/CF4/Isobutane Gas
    - 14 μs drift time
  - GEM (Gaseous Electron Multiplier) amplification
- 72 GEM modules/2 sides
  - 36 modules/ full ϕ
  - 3 modules / full r
  - 20 < r < 78 cm, |η| < 1.1, full ϕ
- Measures Momentum
  - Target momentum resolution
    - Δp/p = 0.02 for p ~ 5 GeV
    - O(150 μm) spatial resolution



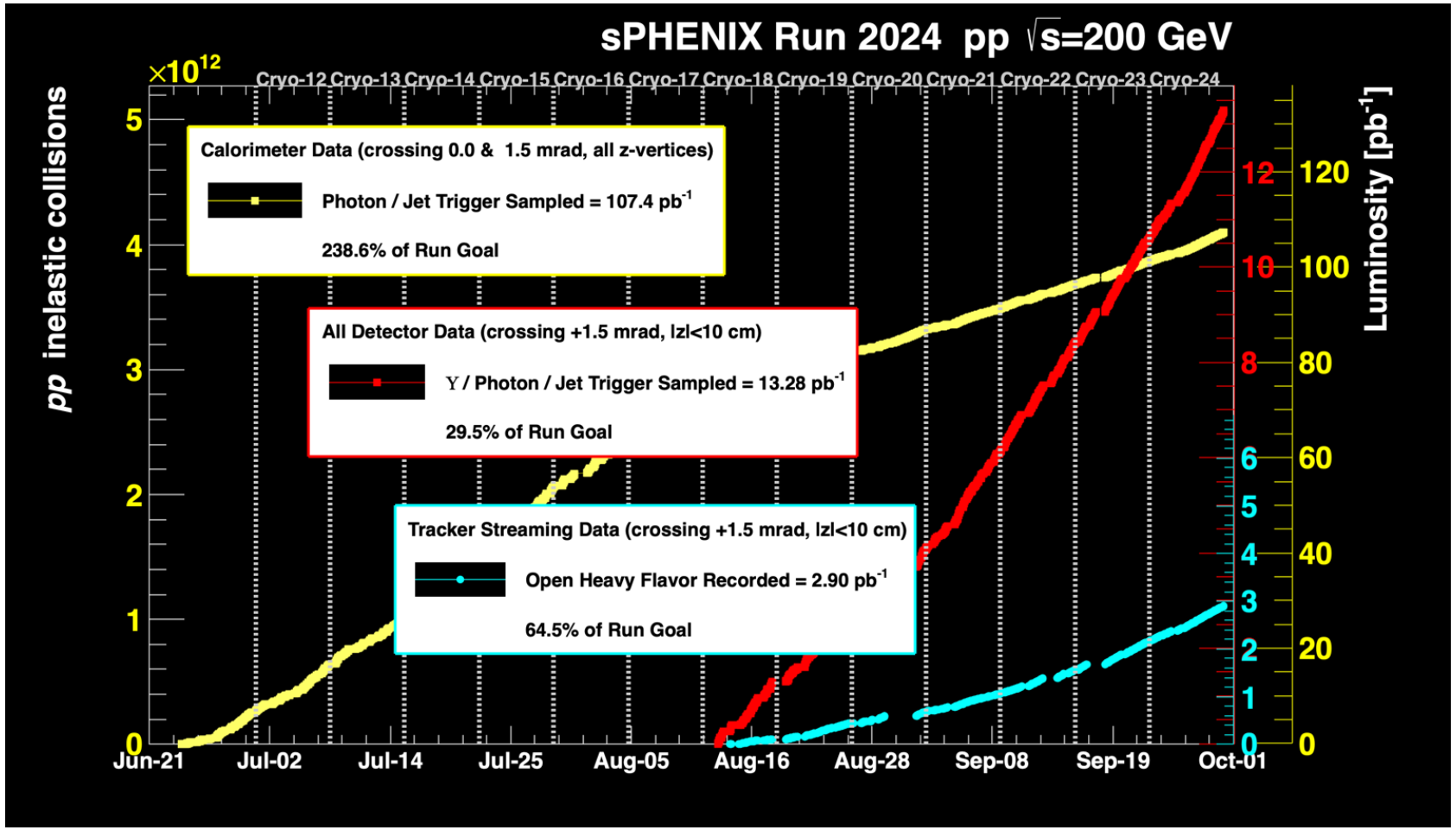






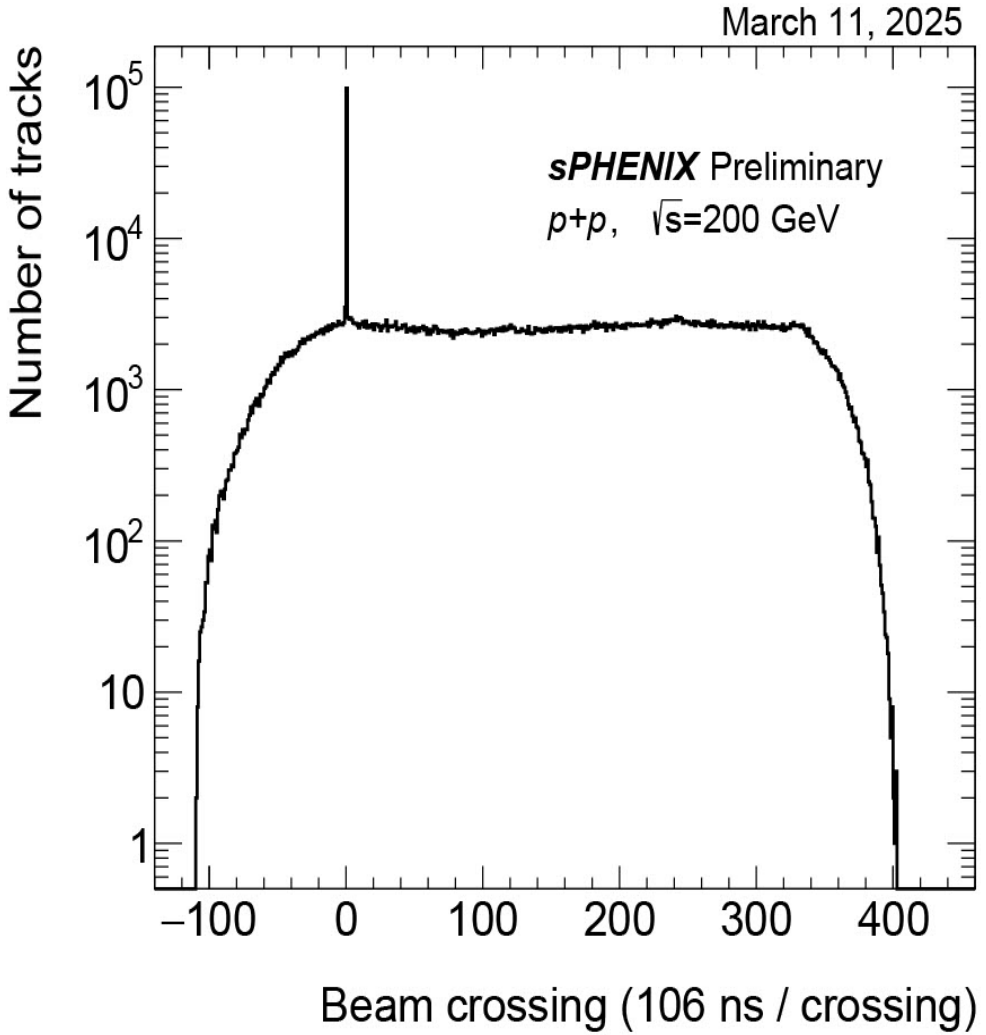
sPHENIX Data Acquisition

- Within the timeframe we ran all trackers, we took streaming data at a faster rate than original projected
- In 6 weeks, we got 13 pb^{-1} of All Detector Data and 2.9 pb^{-1} of Tracker Streaming Data
- Goal of 7 nb^{-1} all detector data in Au+Au for upcoming run

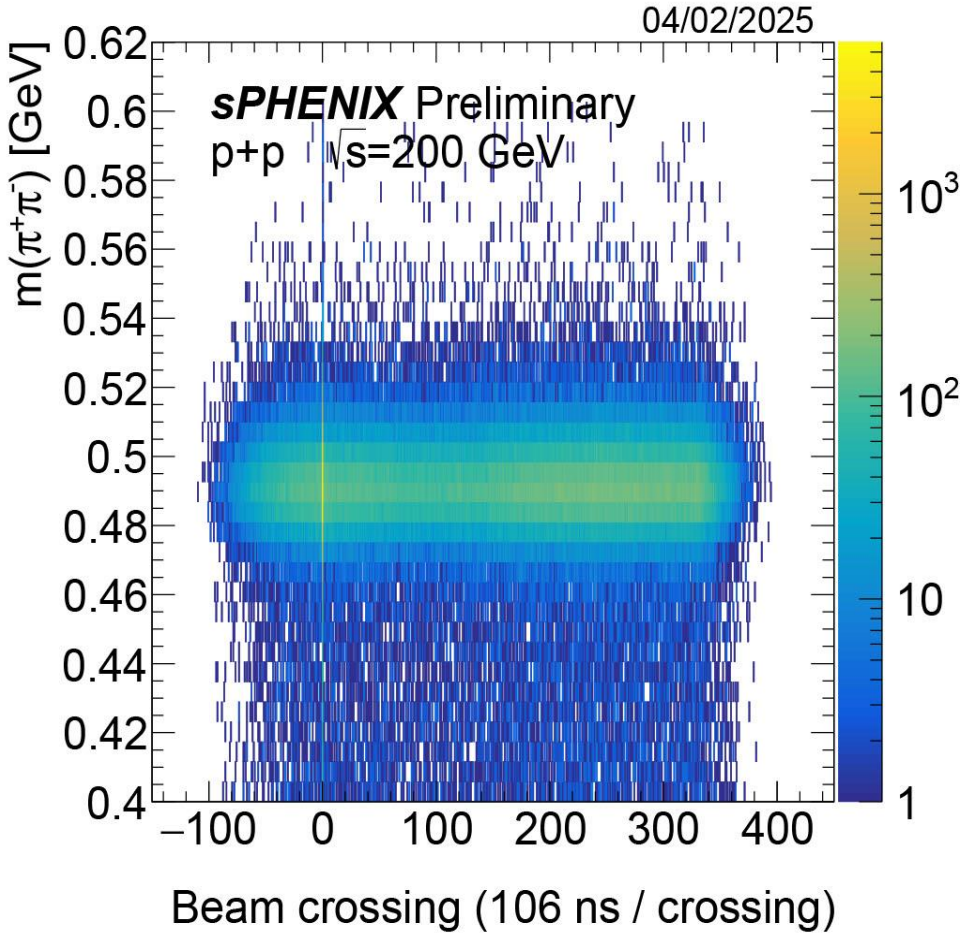


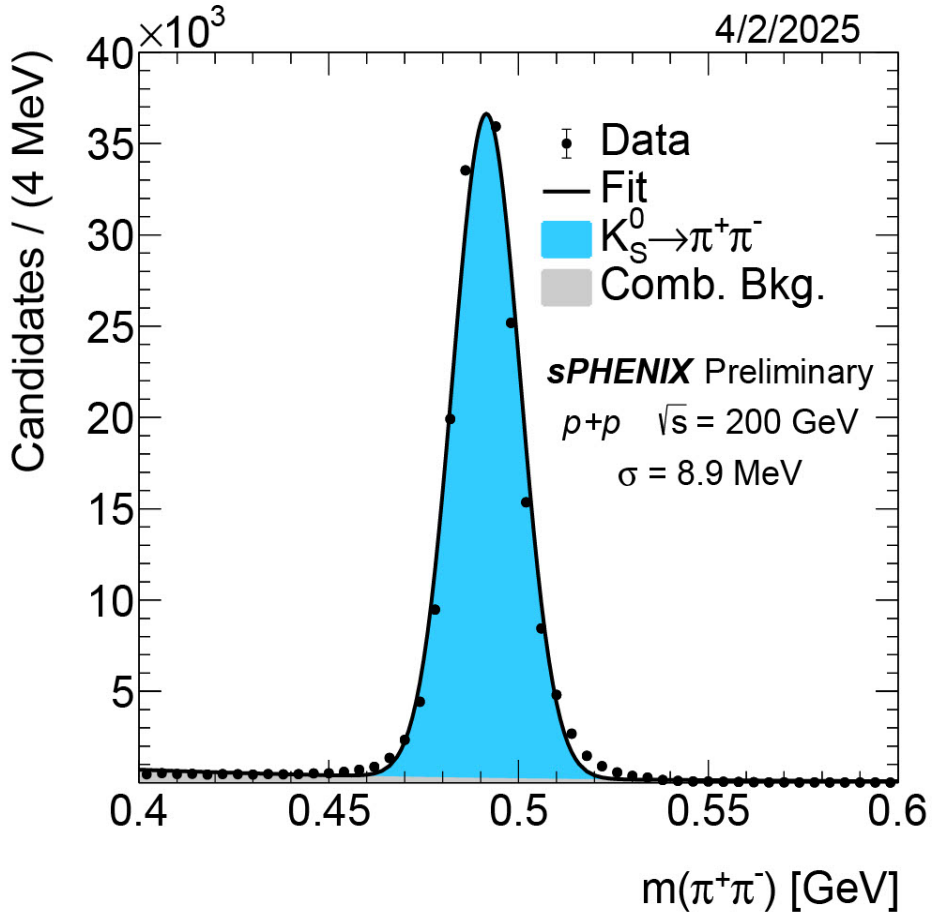
Streaming Readout

- Tracking detectors operate with extended streaming readout
- Enables collection of large unbiased *p+p* dataset for open heavy flavor studies
  - Candidates which are untriggerable require streaming readout
- The peak at beam crossing 0 is data from the trigger
- Tracks are reconstructed with approximately constant efficiency as function of crossing number



K Short and Streaming

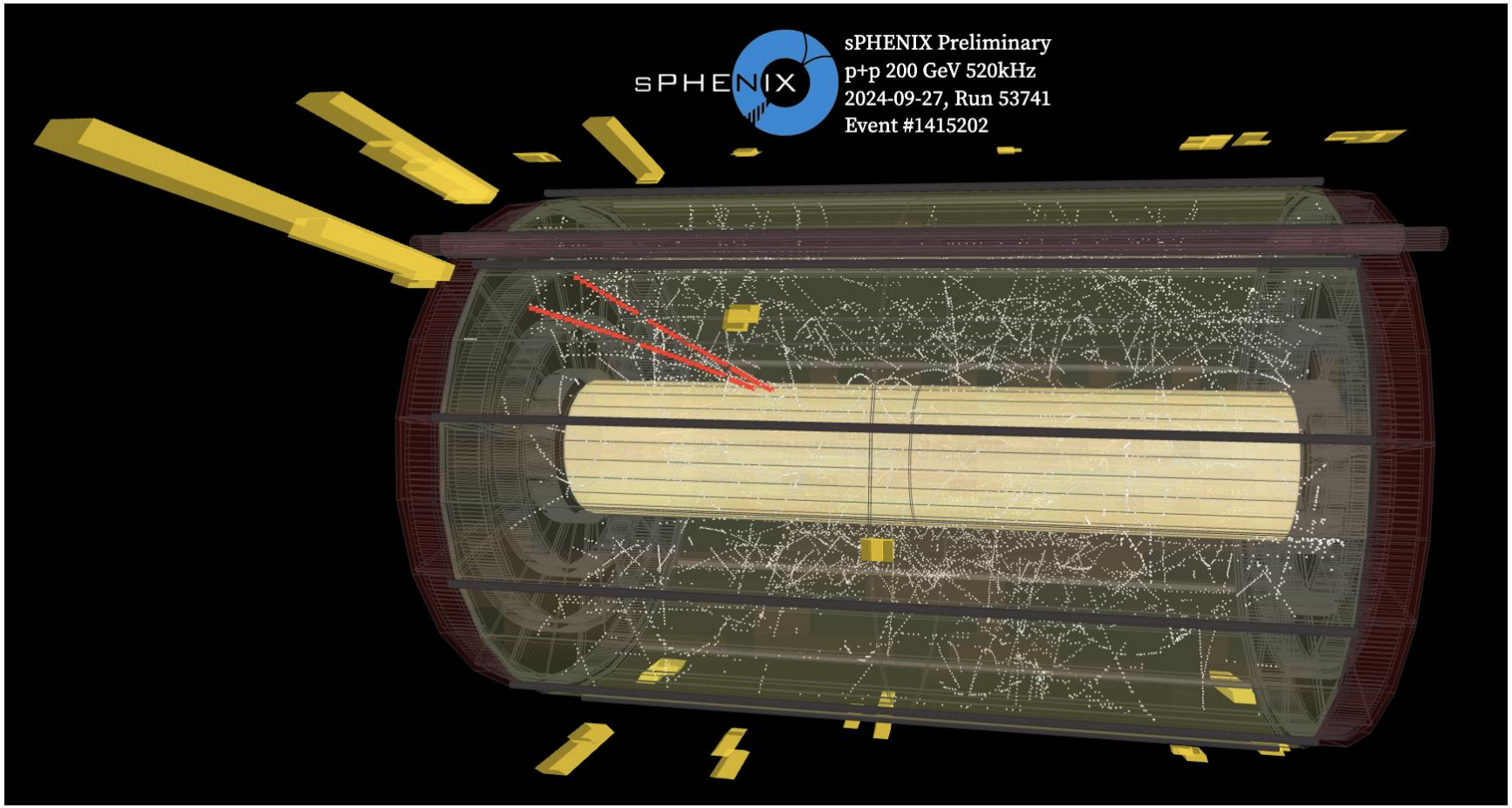




- Clear K_S^0 peak after optimizing cuts, reconstructible across all beam crossings
- Beam crossing 0 being the trigger, and this plot demonstrates the power of streaming readout

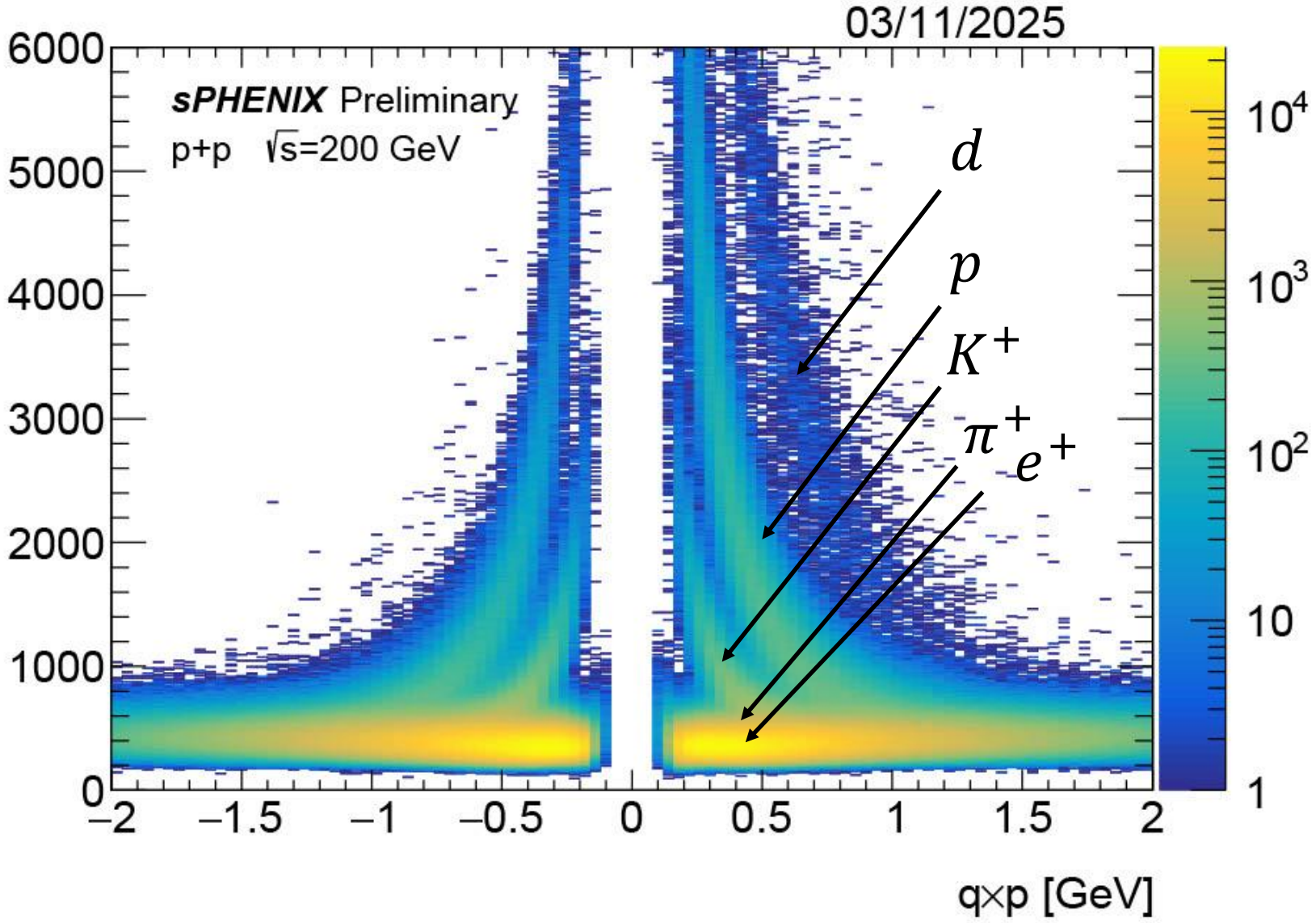
Track Calorimeter Matching

- Our first photon conversion event display
- e^+ e^- that have high energy deposits in the EMCal
- Bar is proportional to the energy deposit
- Unlocks Quarkonia programs

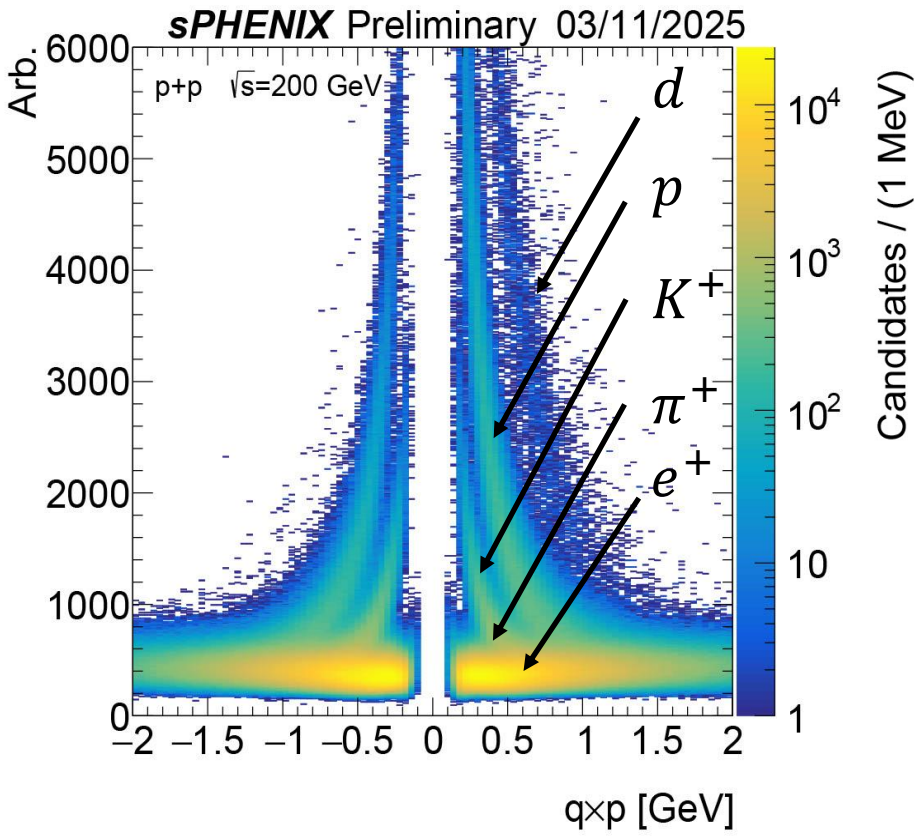


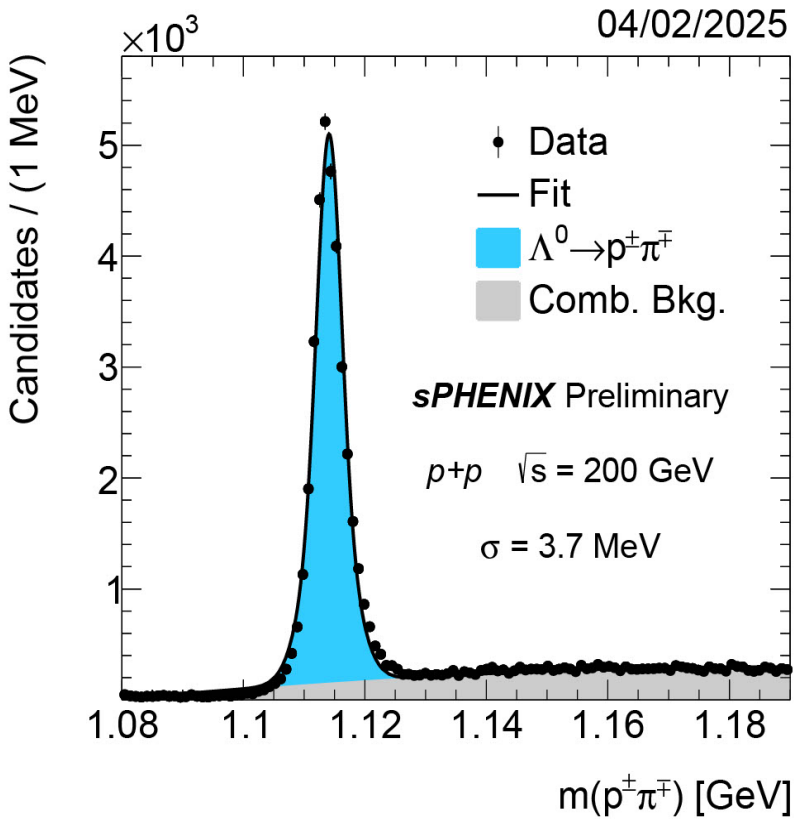
Particle ID with dE/dx

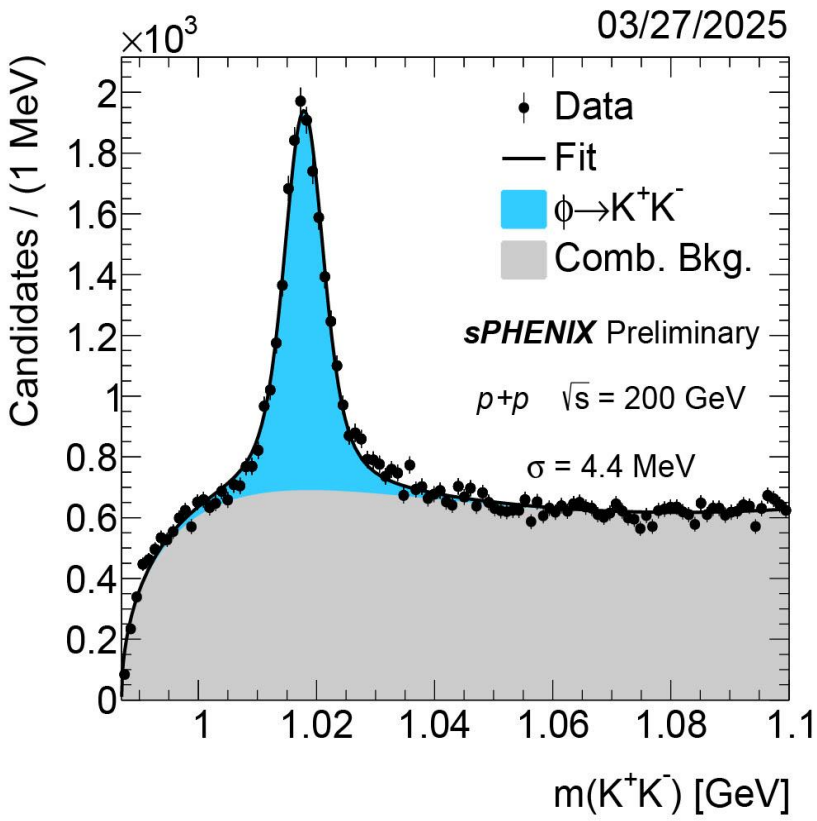
- TPC is able to show defined bands for different particles based off dE/dx
- This allows for background suppression
- TPC not originally designed for dE/dx PID



PID with dE/dx

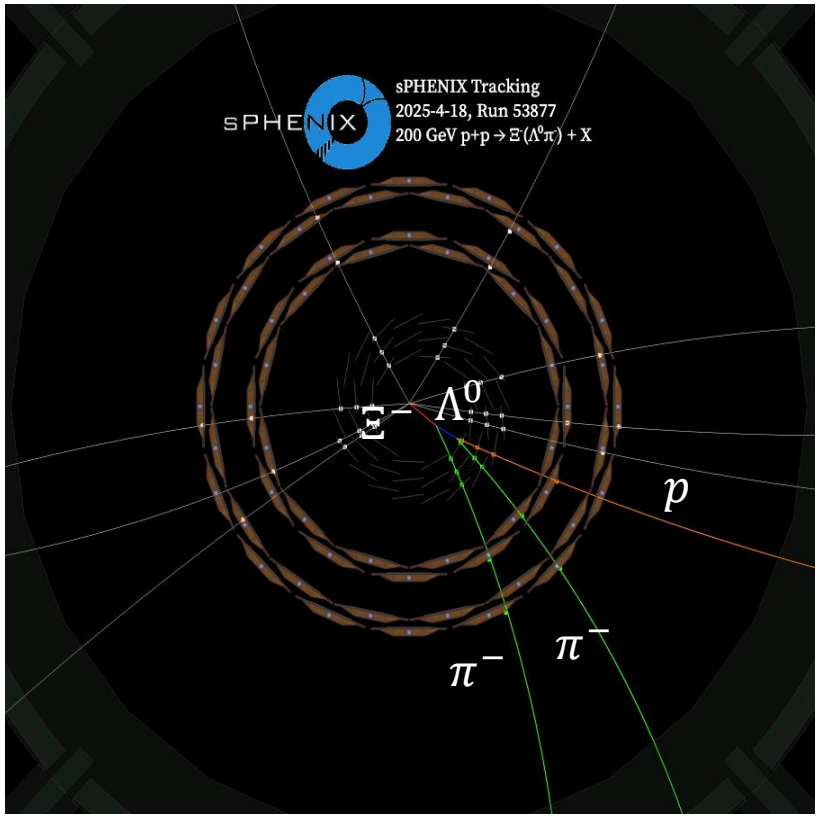


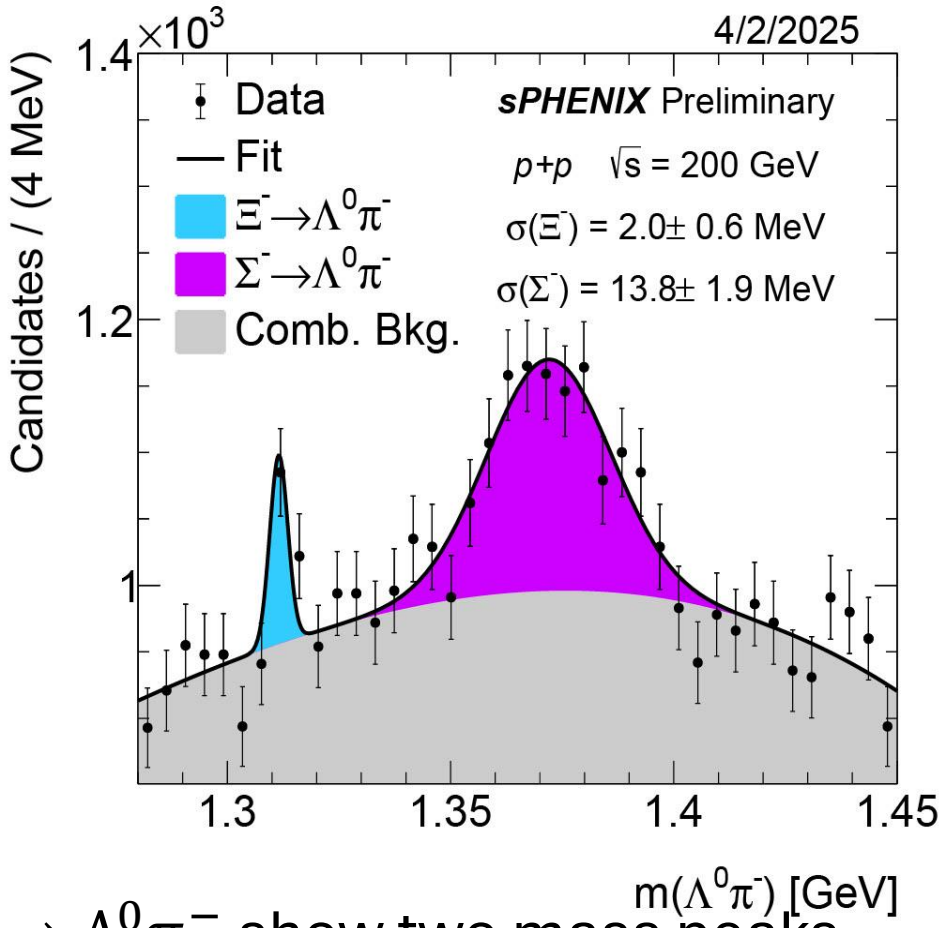




- Particle ID separation with early dE/dx calibrations (despite not being designed for this)
- Used for background suppression at low momentum
- Used for both proton selection in Λ decay and Kaon selection in Φ decay

Event Display and Three Track Decays

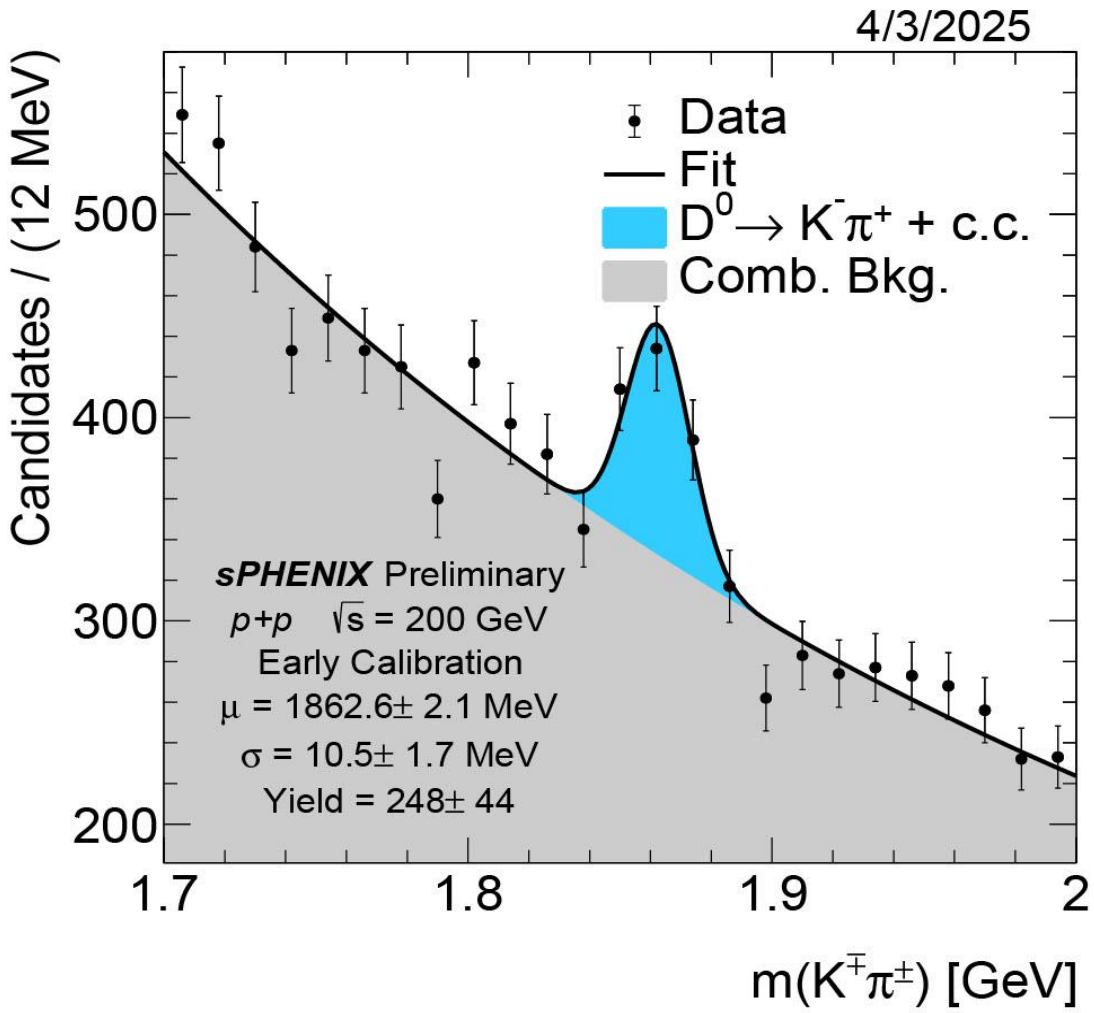




- Reconstruction of $\Xi^- \rightarrow \Lambda^0\pi^-$ and $\Sigma^- \rightarrow \Lambda^0\pi^-$ show two mass peaks
- Complex Decay Topology
- On the left is a single event display for Ξ^- decay

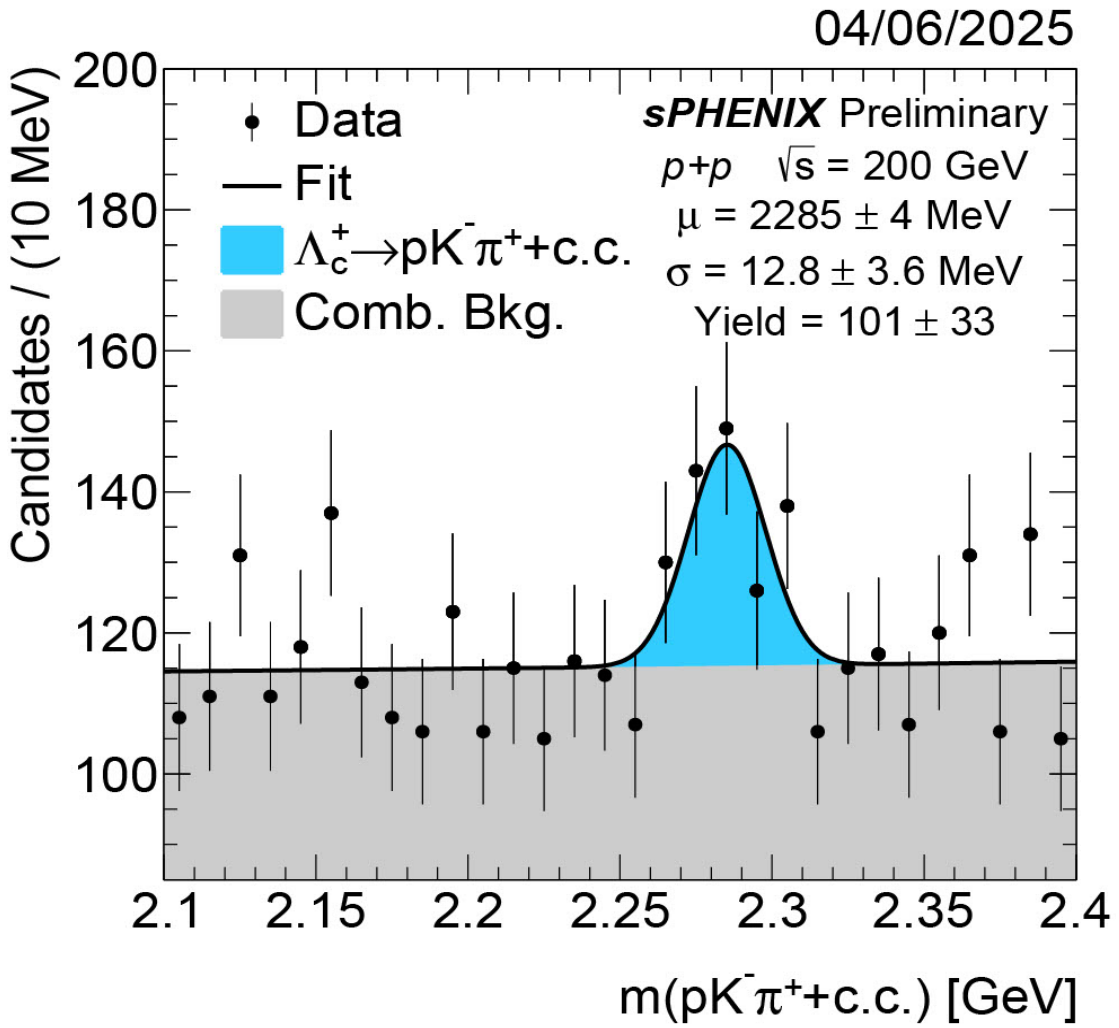
D^0 Reconstruction

- D^0 invariant mass peak measured at above 5σ significance
- This corresponds to only ~1 hour of data
- Still early calibrations and efforts to improve selection efficiencies are ongoing to improve yields
- We expect about a factor of 100 increase in yield from calibrations



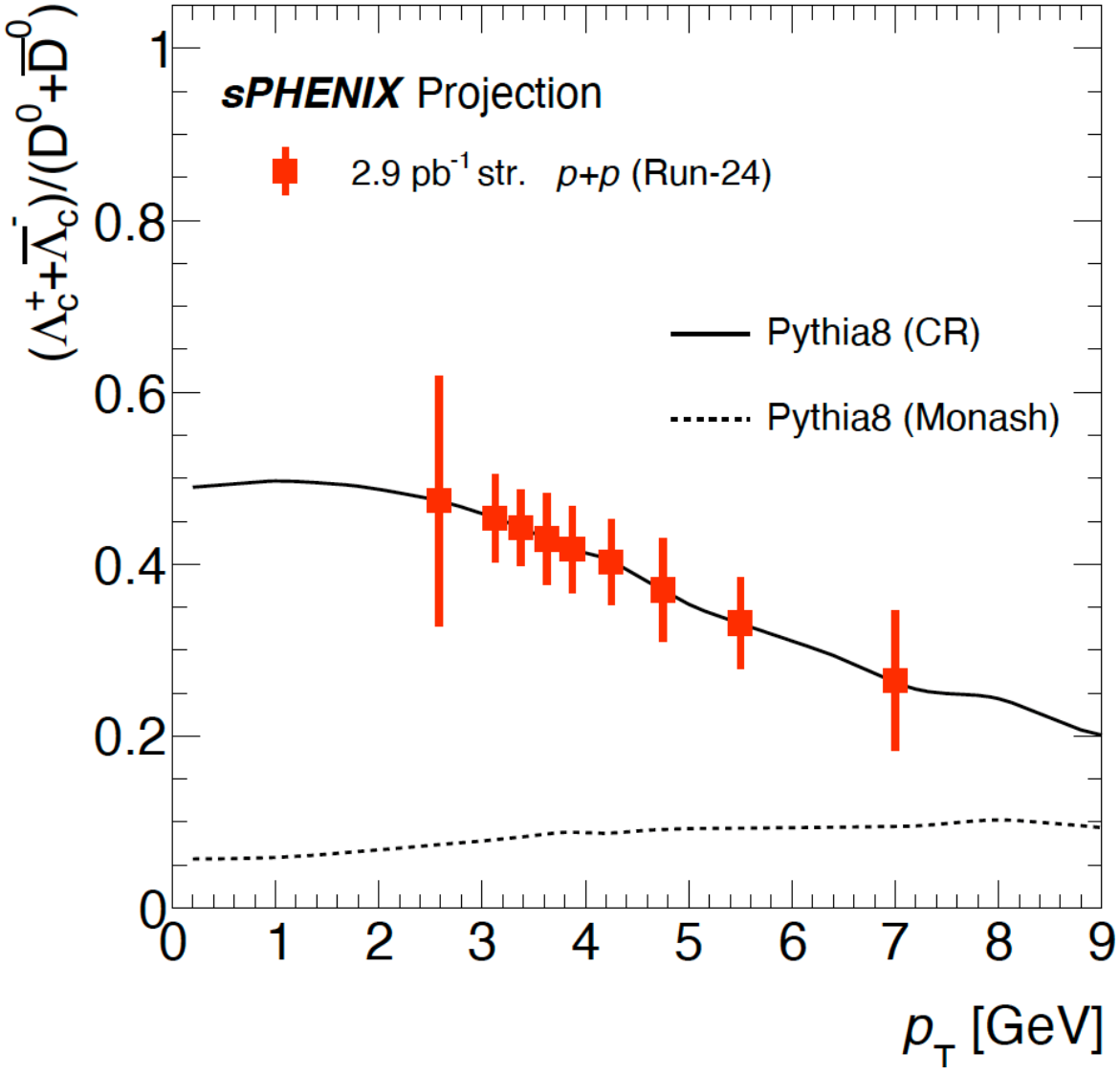
Λ_C^+ Reconstruction

- First Λ_C^+ invariant mass peak of ~3σ confidence in p+p at RHIC
- Once again, this only ~1 hour of data
- Still very early calibrations that we are still working to improve
- Three track decay, more complex than D^0 and will improve more as our tracking improves



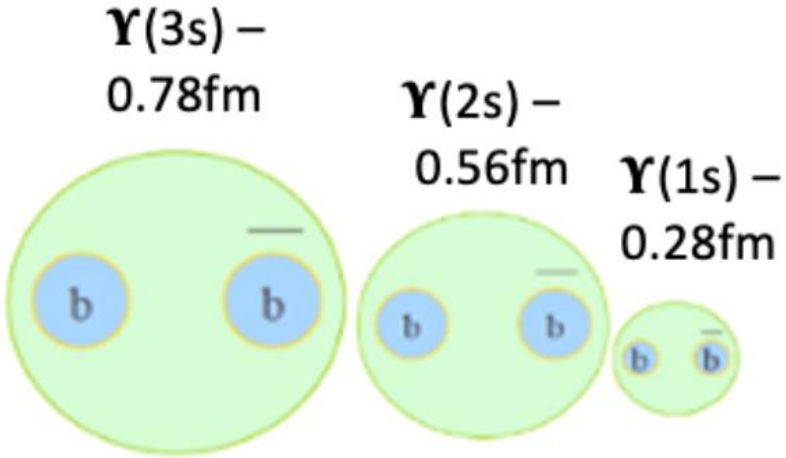
Lambda C to D0 Ratio

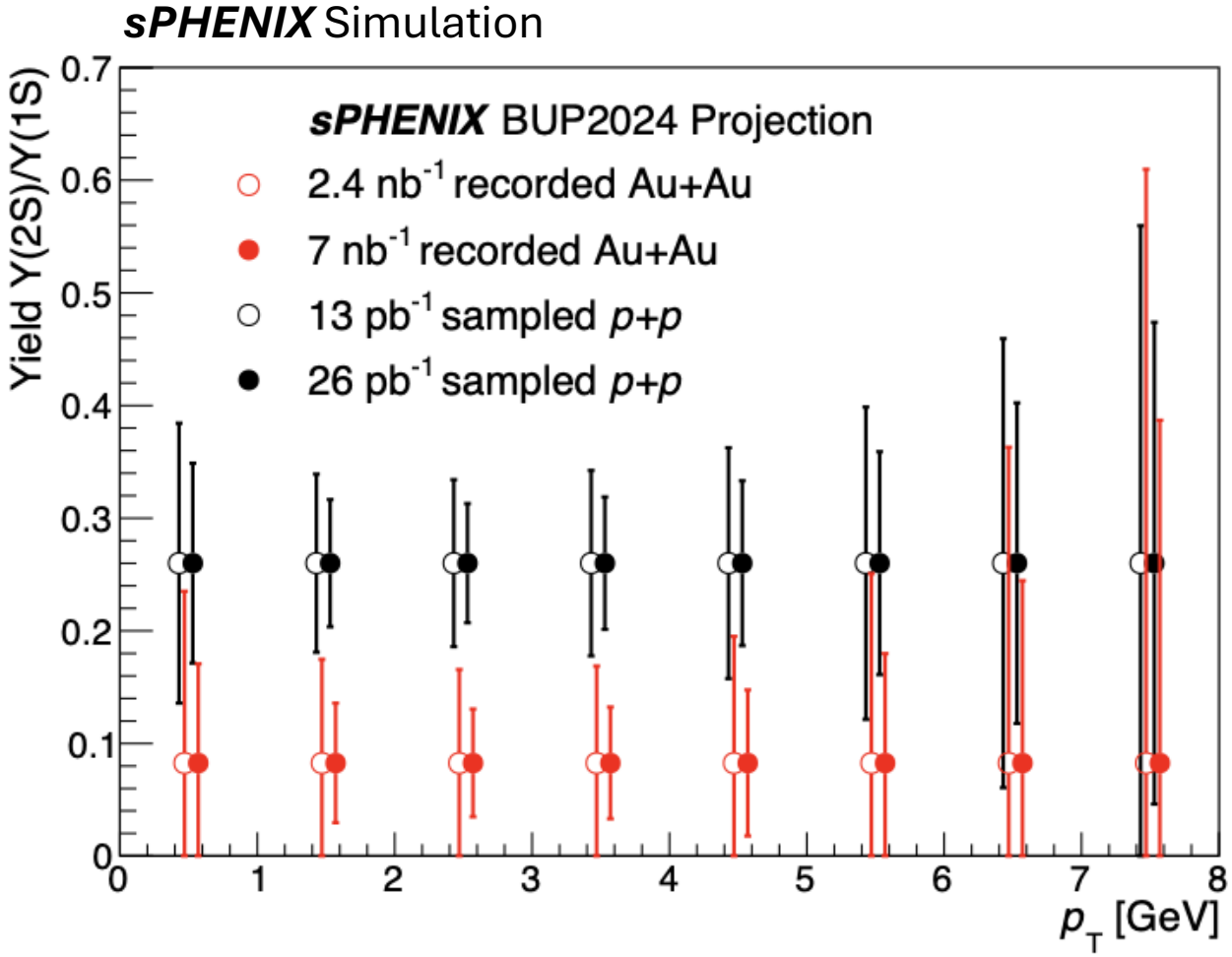
- First measurement of p+p Λ_C^+/D^0 at RHIC
- Huge benefit from streaming readout
- Need good understanding of tracking efficiency for this measurement



Upsilon Projections

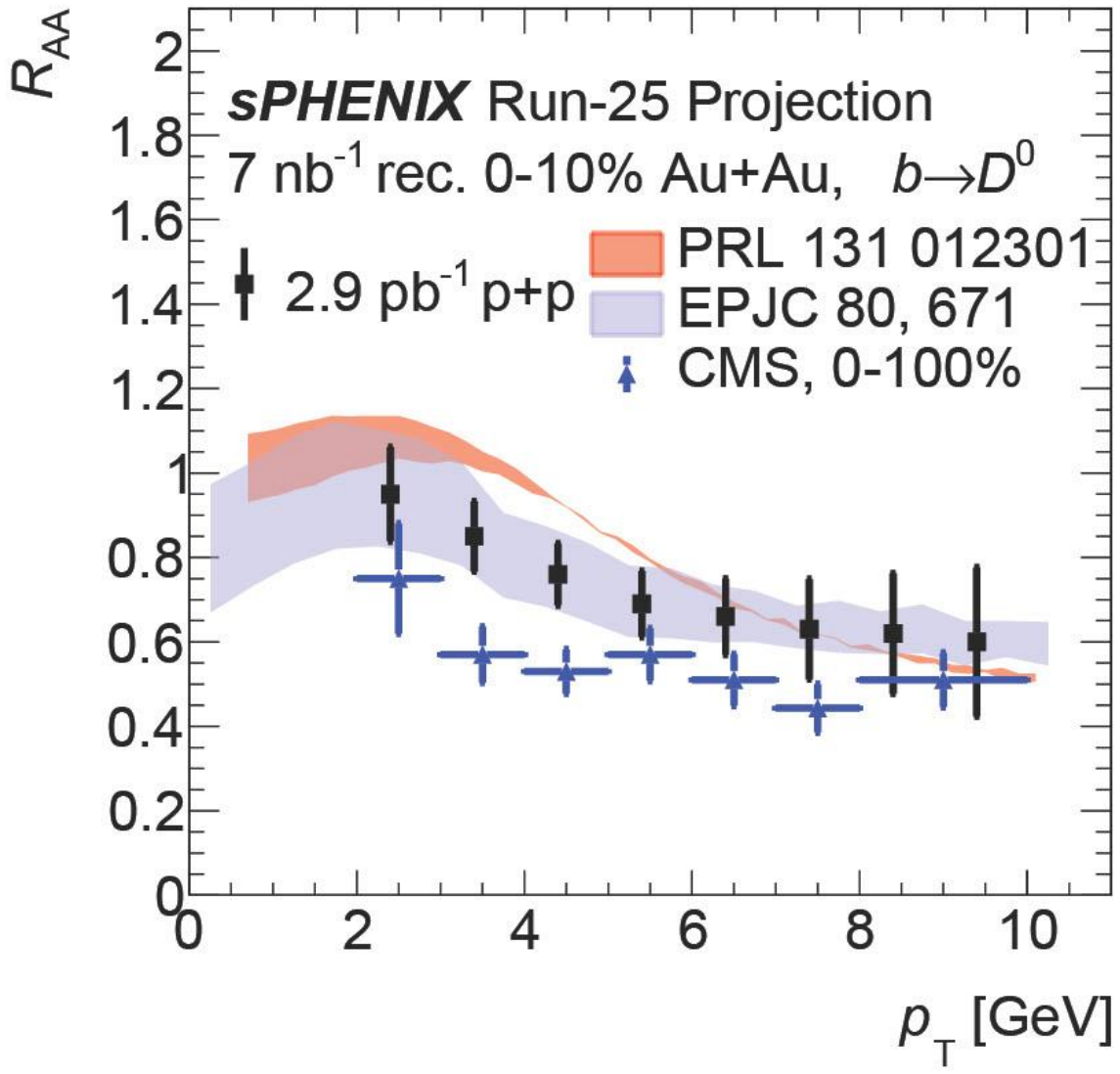
- Upsilons allow for probing of QGP at different length scales
- Projections of 2S/1S yields
- Minimal goal Au+Au luminosity in open circle
- Our hope is for 7 nb^{-1} Au+Au integrated luminosity and to double our pp dataset in this year's run





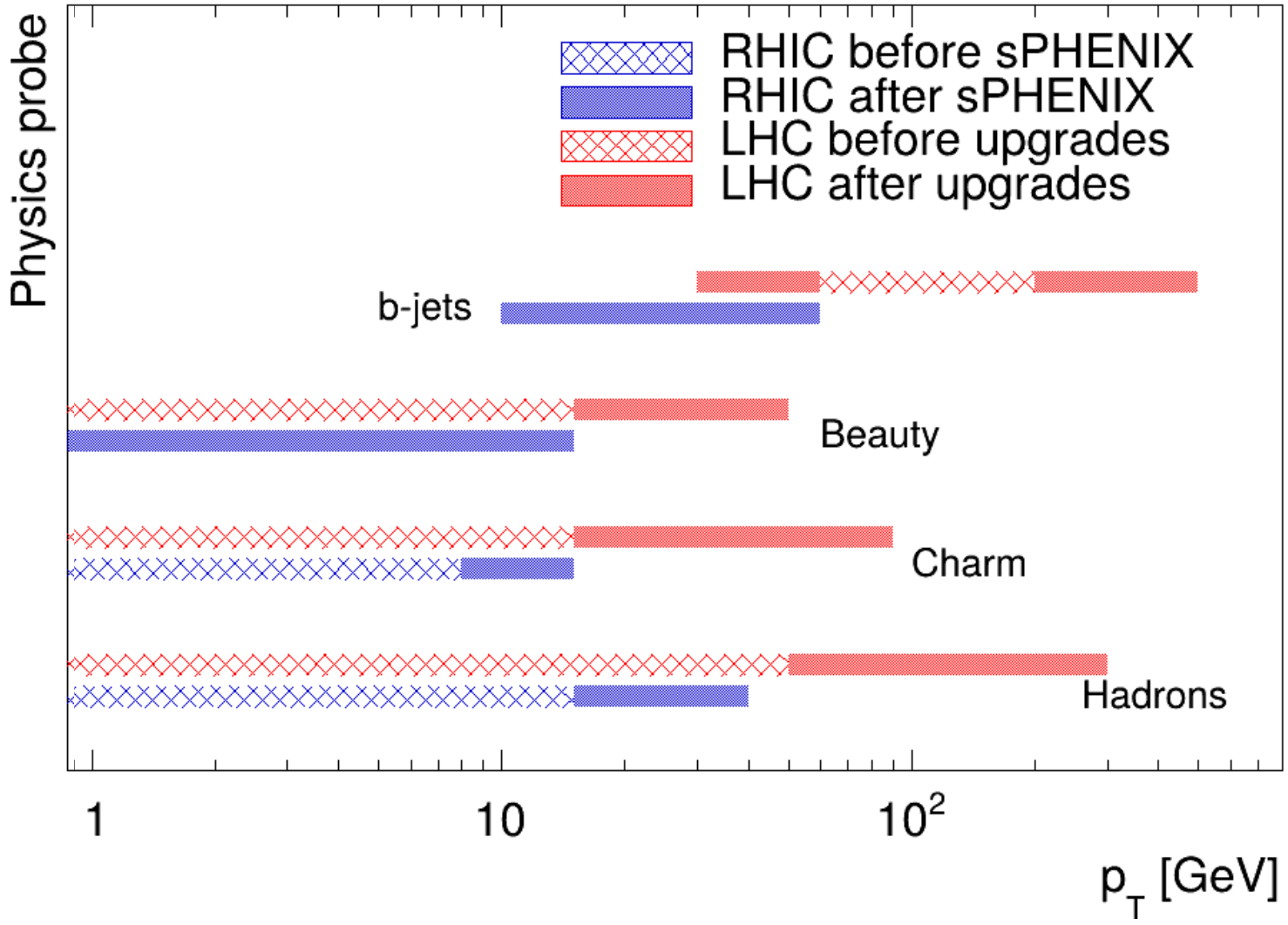
B Hadron Projections

- Projections of R_{AA} in b-> D^0 which is new to RHIC
- This projection uses 0-100% Centrality in CMS but only 0-10% Centrality in sPHENIX
- sPHENIX will lead to complementarity between RHIC and LHC
- Current *p*+*p* sample along with projected Au+Au sample



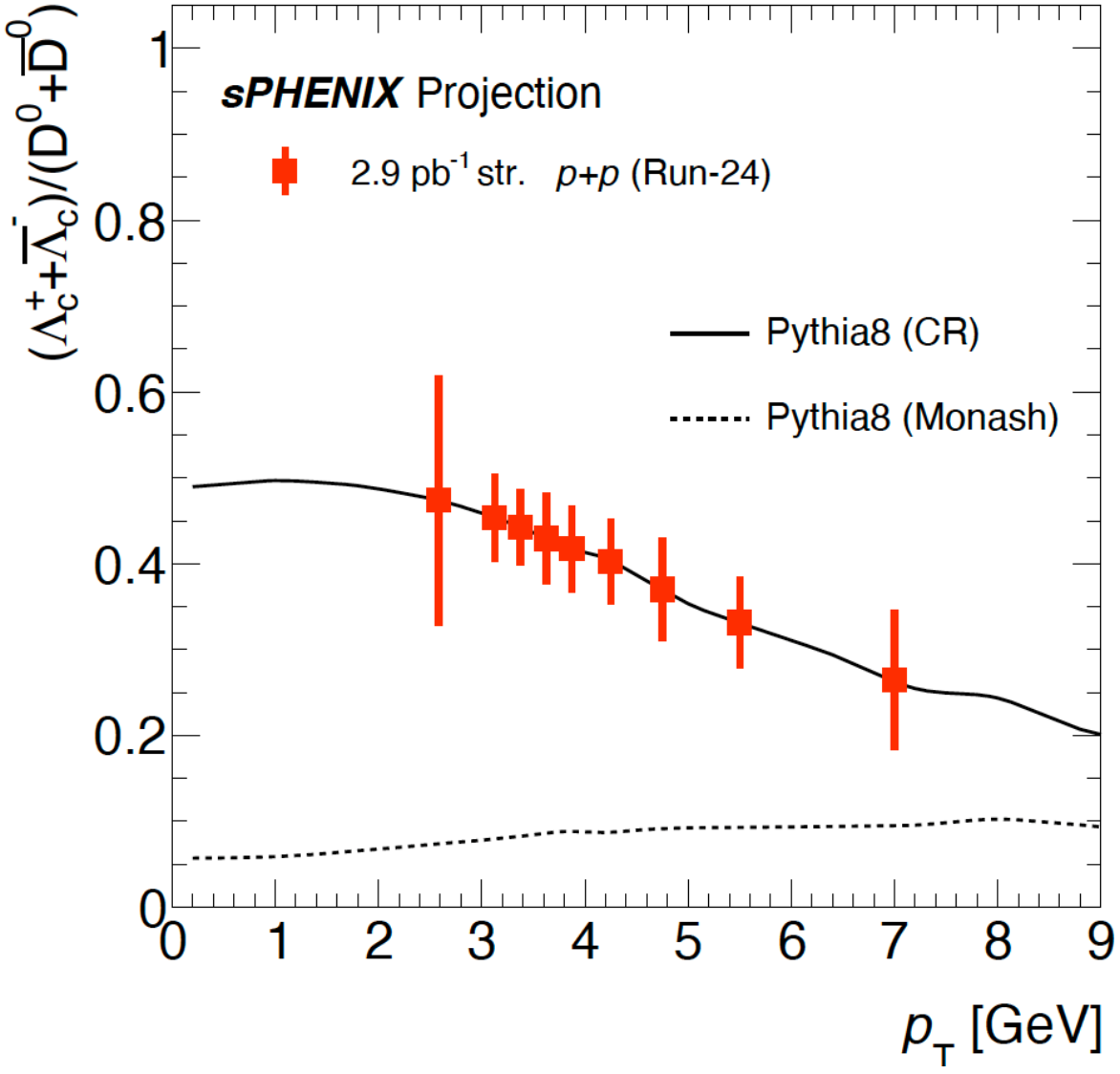
RHIC vs LHC

- Projections for heavy flavor measurements show RHIC before and after sPHENIX
- Measurements at RHIC that compliment LHC
- Hadronic Calorimeter new for RHIC to enable jets



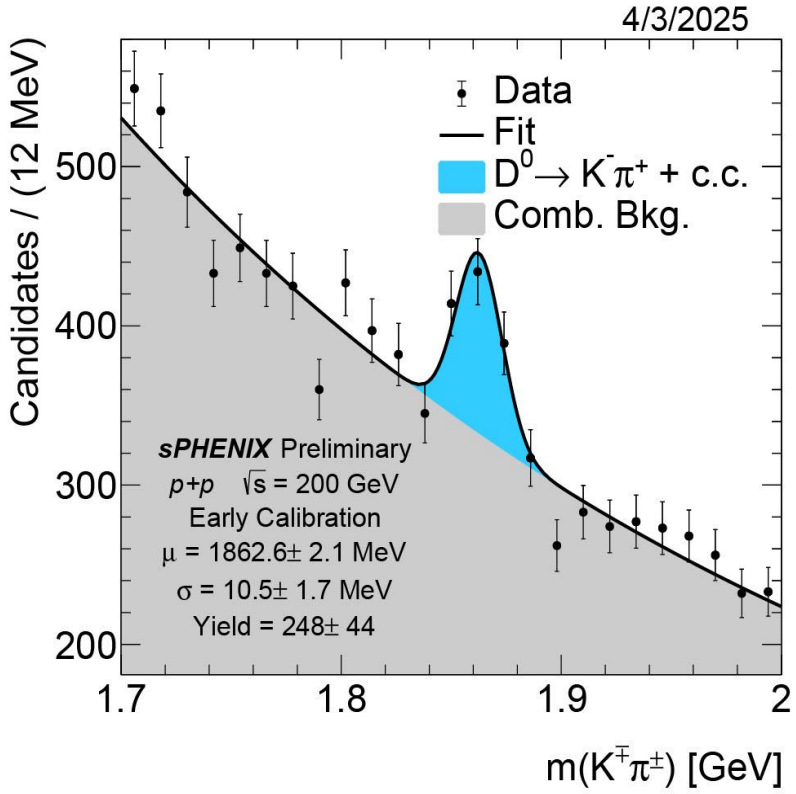
What's Next?

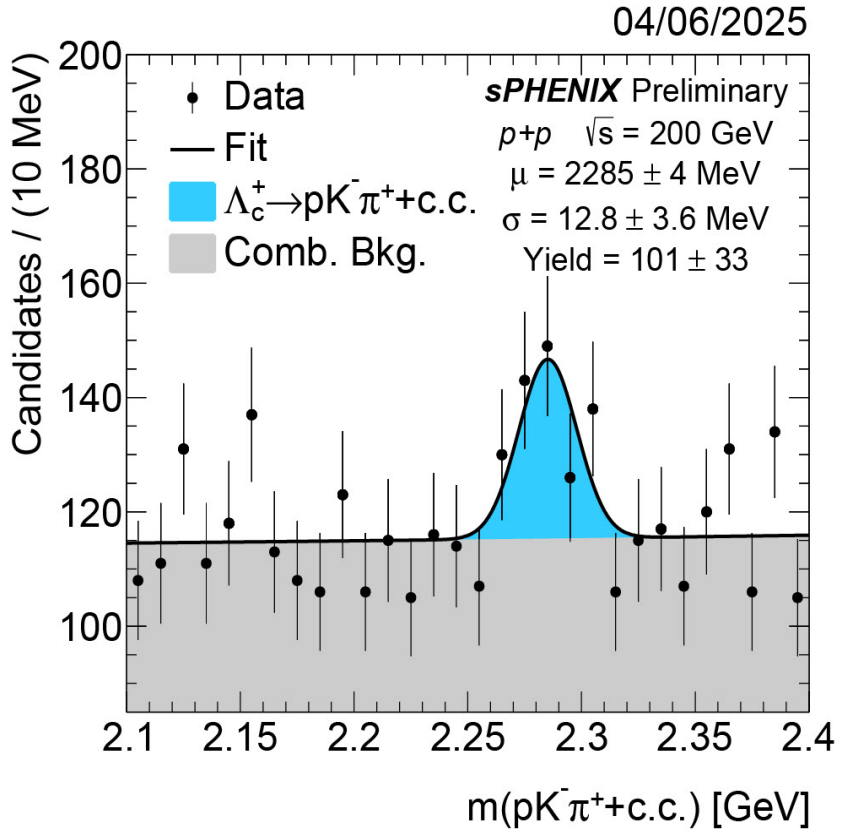
- We will improve our reconstructions
  - 100+ hours of data
  - Better efficiency
- Currently we are preparing for Au+Au
- Upcoming analyses with *p*+*p* data we have
  - Λ_C^+/D^0 ratio
  - D_S^+/D^+ ratio



Summary

- sPHENIX took a large p+p dataset thanks to streaming readout
- We have our first heavy flavor signatures, including Λ_C^+ which is new to RHIC in p+p
- Use Λ_C^+/D^0 ratio to probe hadronization models





BACKUP

TPC Isobutane Saga

- Originally, used Ar:CF4 mixture but there were sparks at operative voltage
- Isobutane to the rescue!
- Quenches the UV component of the electron avalanche
- Allows for higher gain at lower voltage by moving the electron attachment away from the GEM holes