sPHENIX Physics Highlights

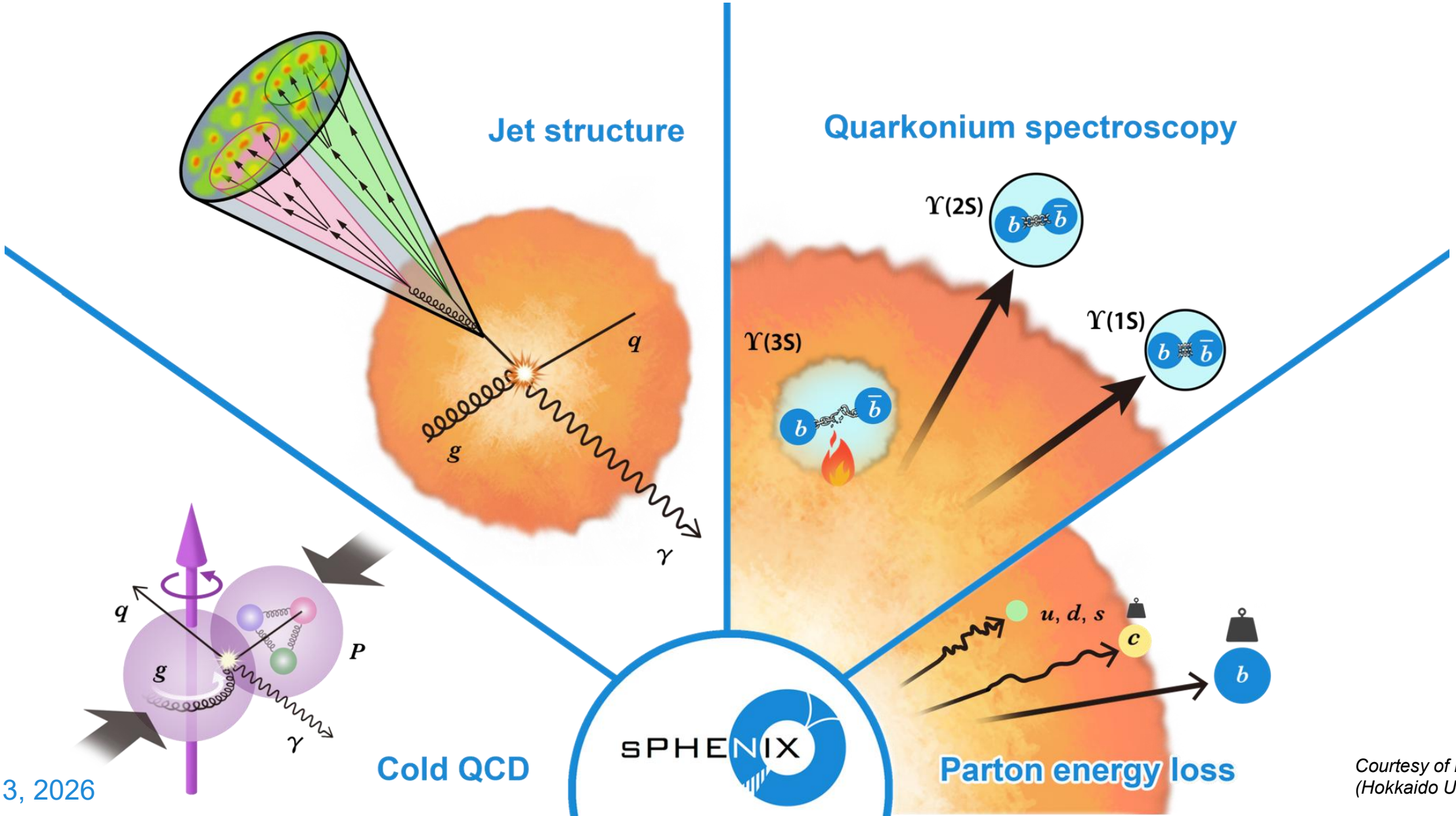
Tanner Mengel

University of Colorado, Boulder

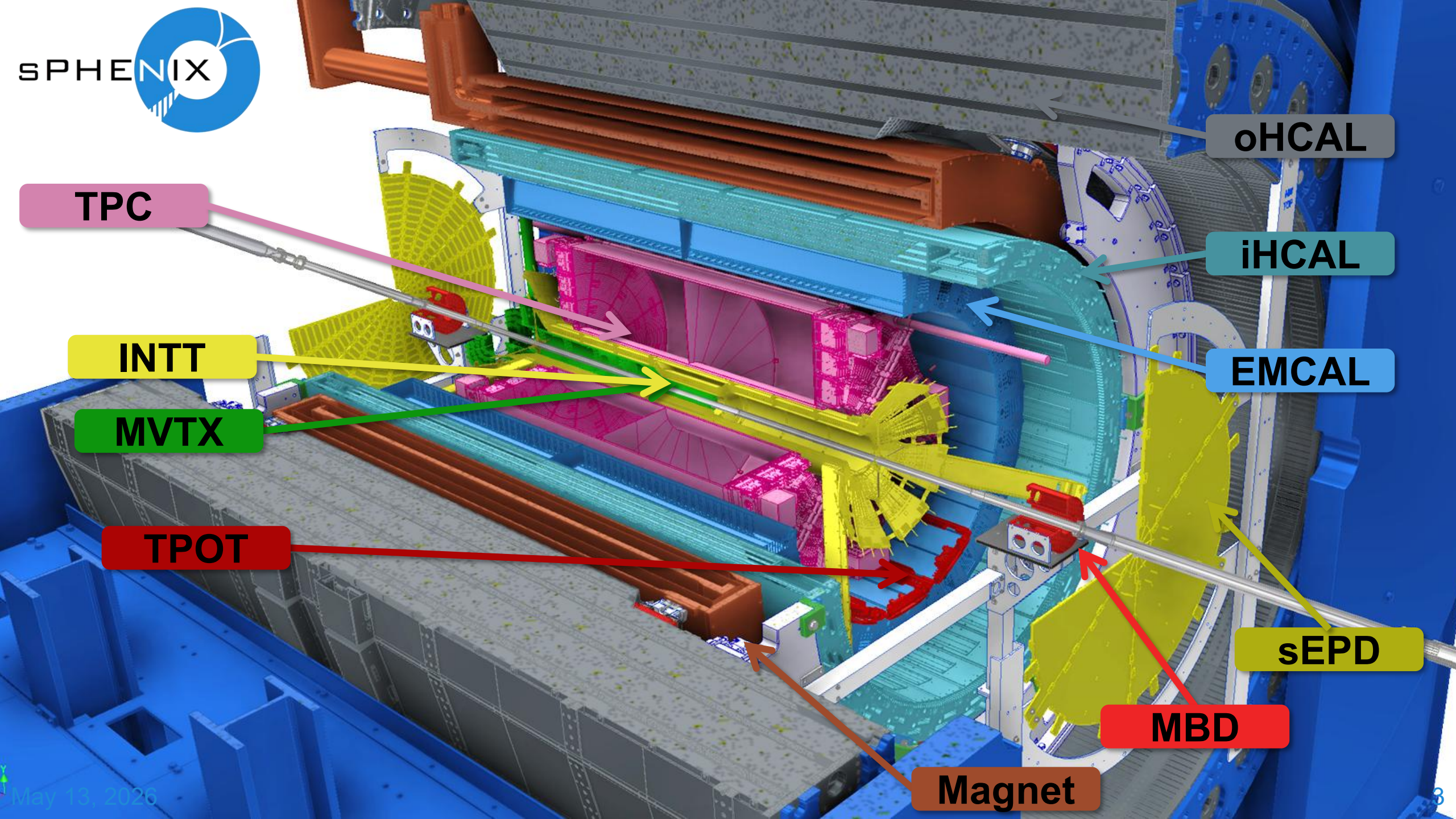
2026 RHIC/AGS Annual Users' Meeting

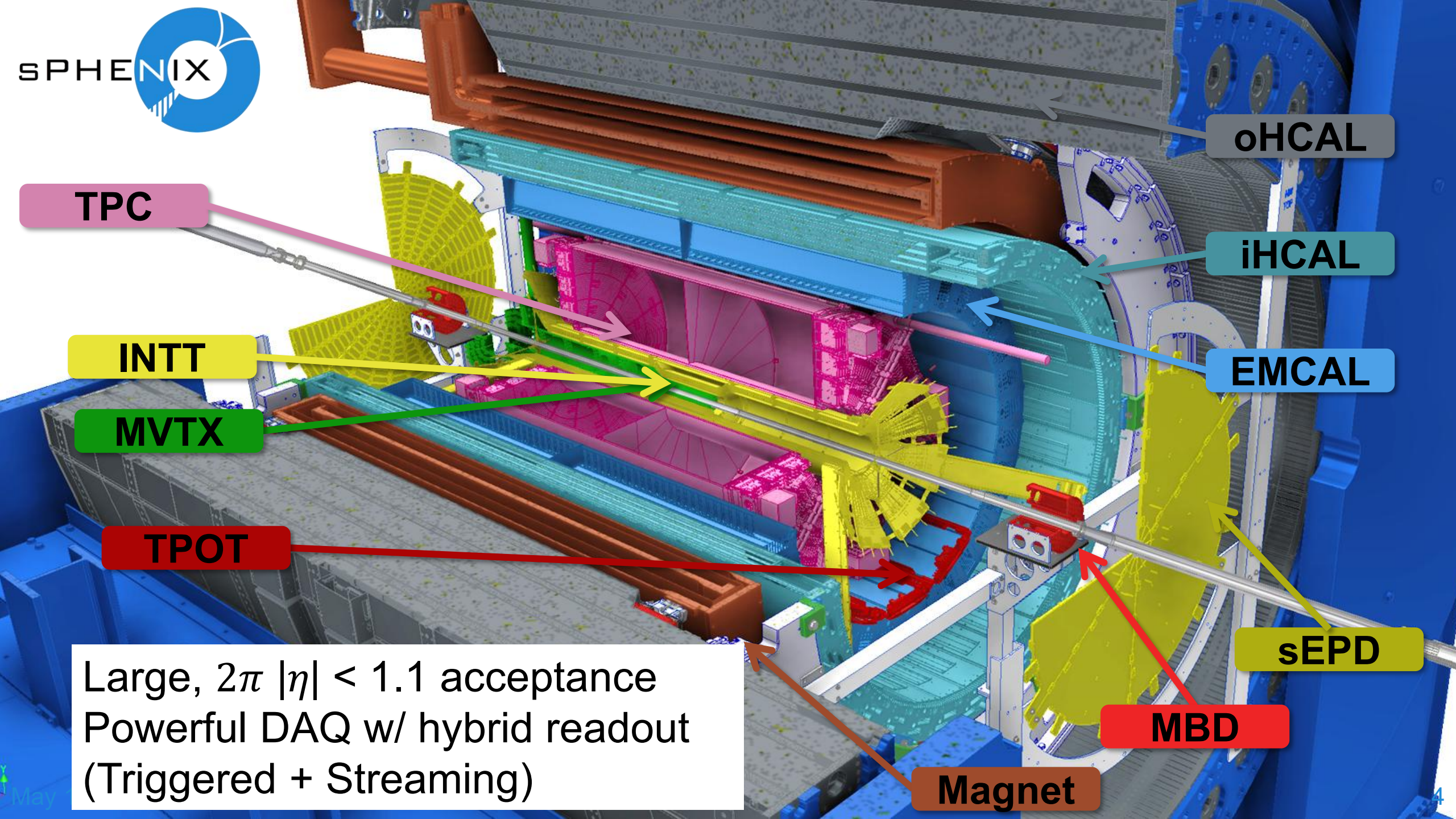
University of Colorado Boulder

sPHENIX physics program

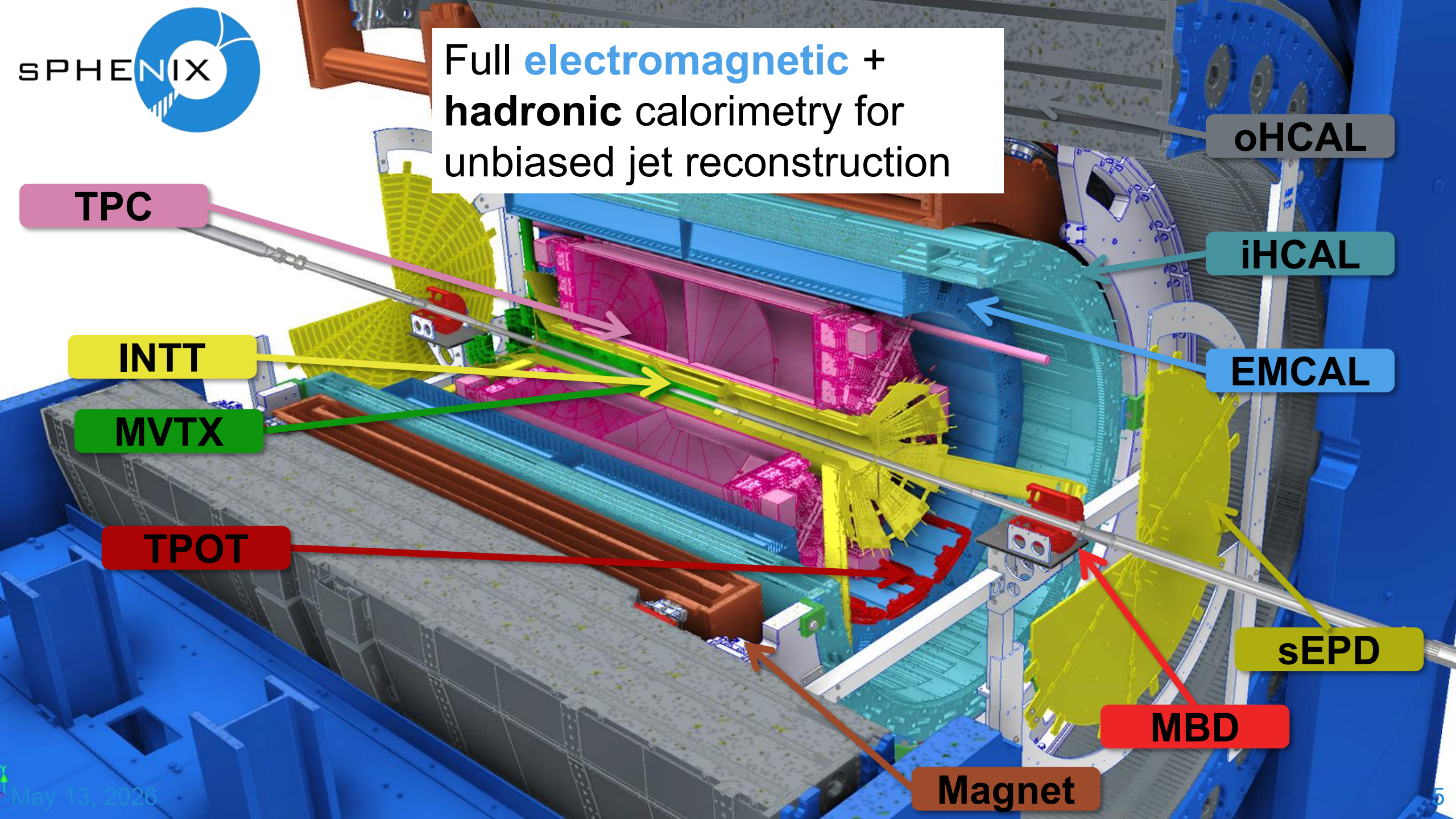


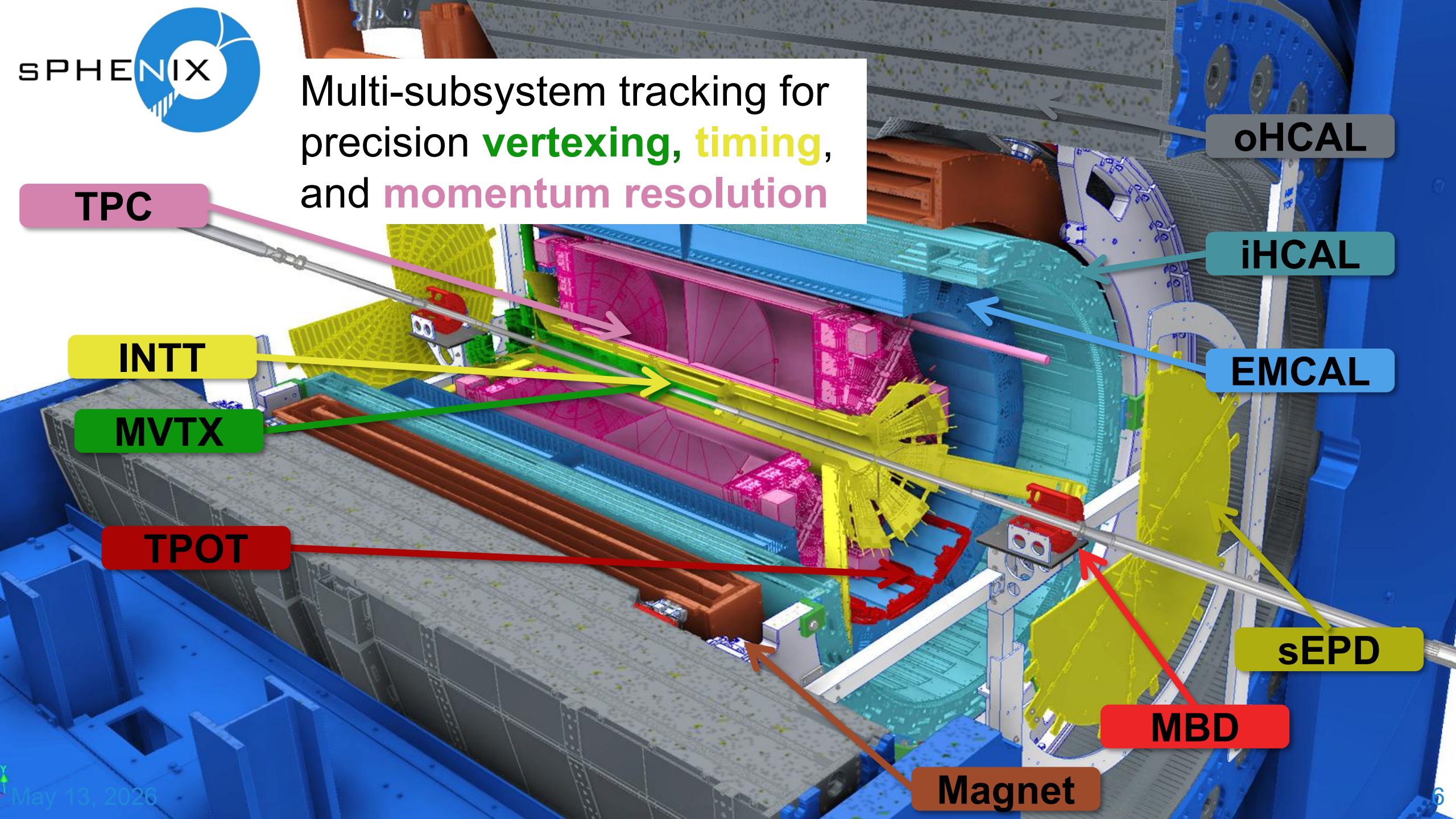
Courtesy of Misaki Ouchida (Hokkaido University)


sPHENIX
oHCAL
TPC
iHCAL
INTT
EMCAL
MVTX
TPOT
sEPD
MBD
Magnet

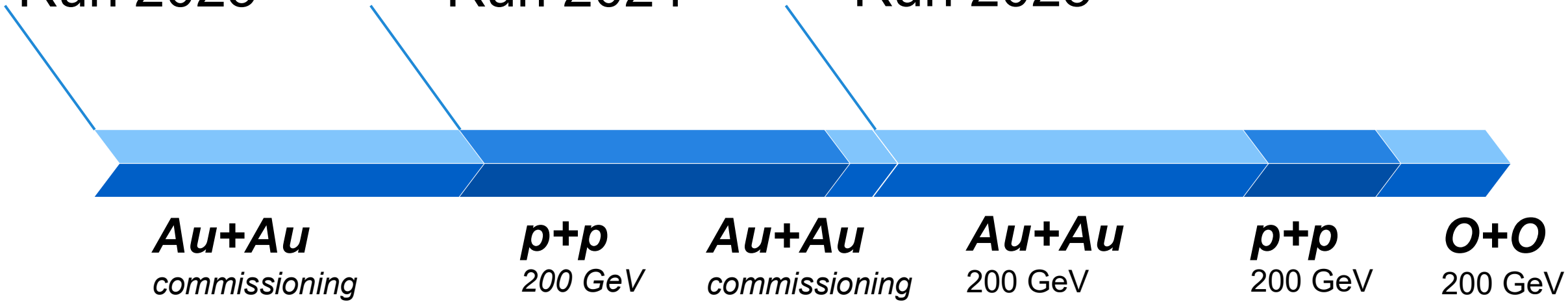


Large, 2π $|\eta| < 1.1$ acceptance
Powerful DAQ w/ hybrid readout
(Triggered + Streaming)


sPHENIX
Full electromagnetic + hadronic calorimetry for unbiased jet reconstruction
TPC
INTT
MVTX
TPOT
oHCAL
iHCAL
EMCAL
sEPD
MBD
Magnet


sPHENIX
Multi-subsystem tracking for precision vertexing, timing, and momentum resolution
TPC
INTT
MVTX
TPOT
oHCAL
iHCAL
EMCAL
sEPD
MBD
Magnet

sPHENIX running

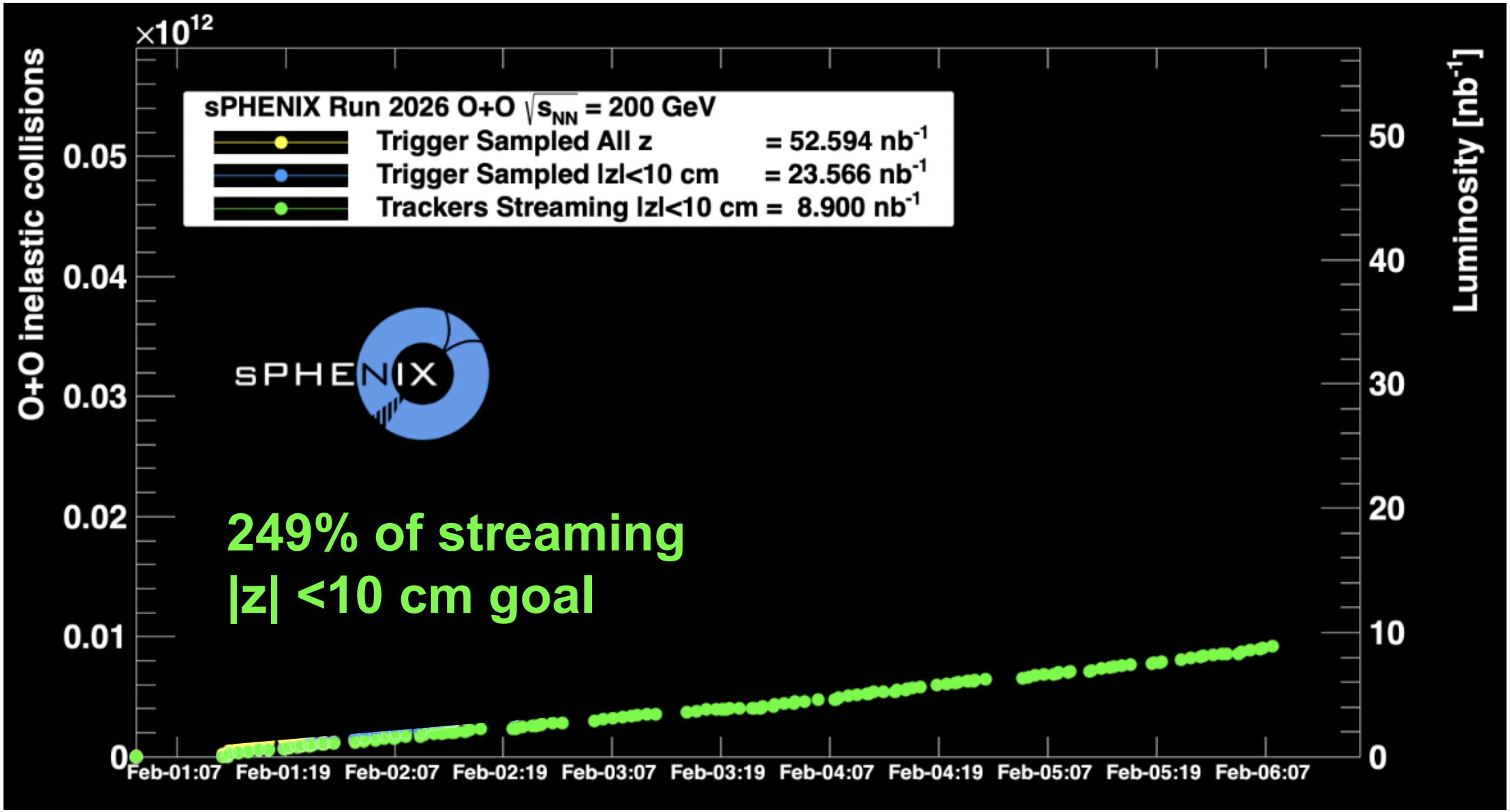


Data type	Use case
Triggered data (calo)	Calo only jet measurements, spin
Streaming data	Open heavy flavor, spin
Triggered data (full)	Jet structure, quarkonia, HF jets

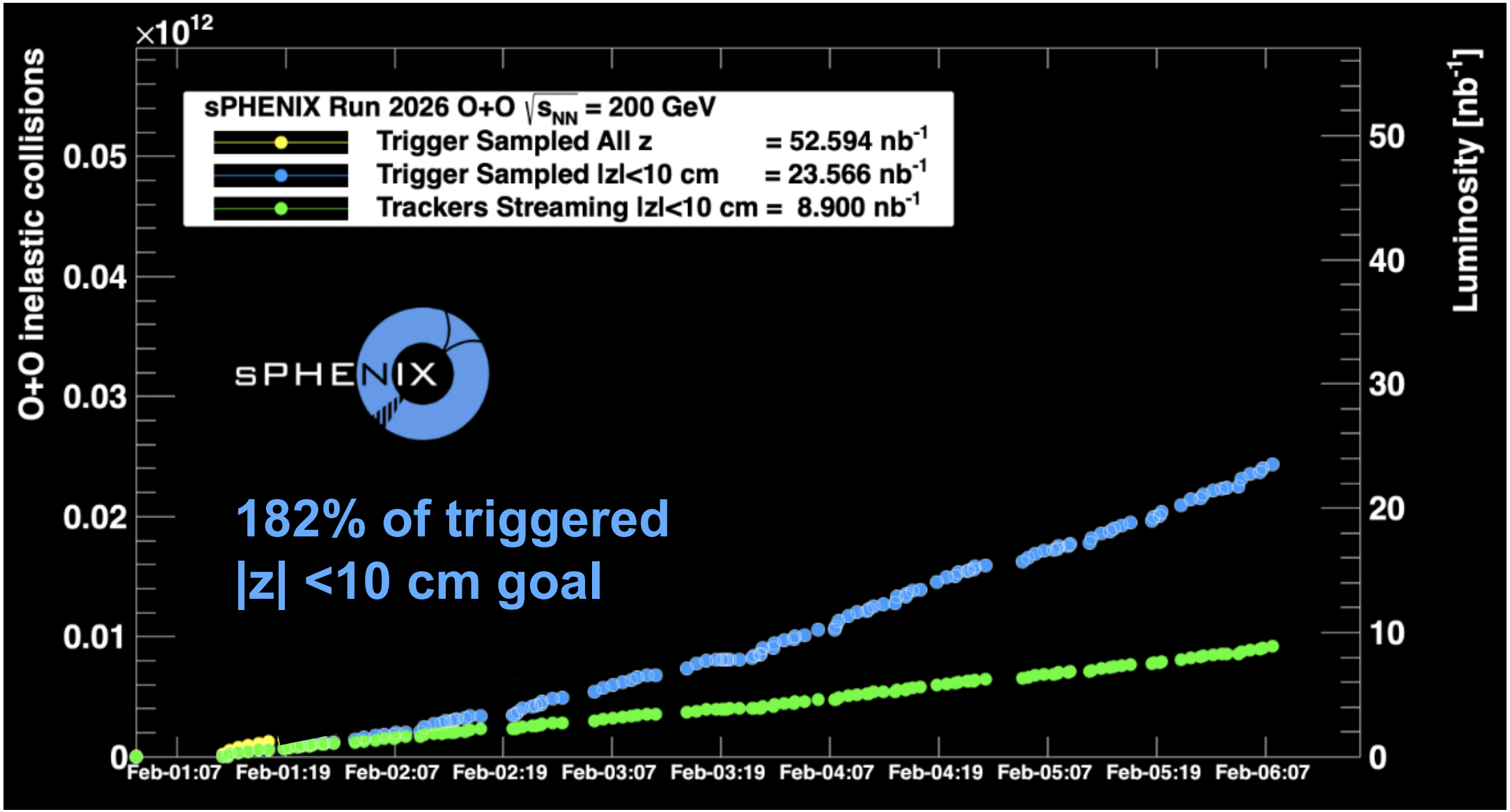
Species	Triggered data (calo)	Streaming data	Triggered data (full)
p+p	124 pb^{-1} sampled	12.6 pb^{-1} recorded	30.2 pb^{-1} sampled
Au+Au*	-	-	6.8 nb^{-1} recorded
O+O	52.6 nb^{-1} sampled	8.9 nb^{-1} recorded	23.6 nb^{-1} sampled

*Does not include 2024 Au+Au commissioning data

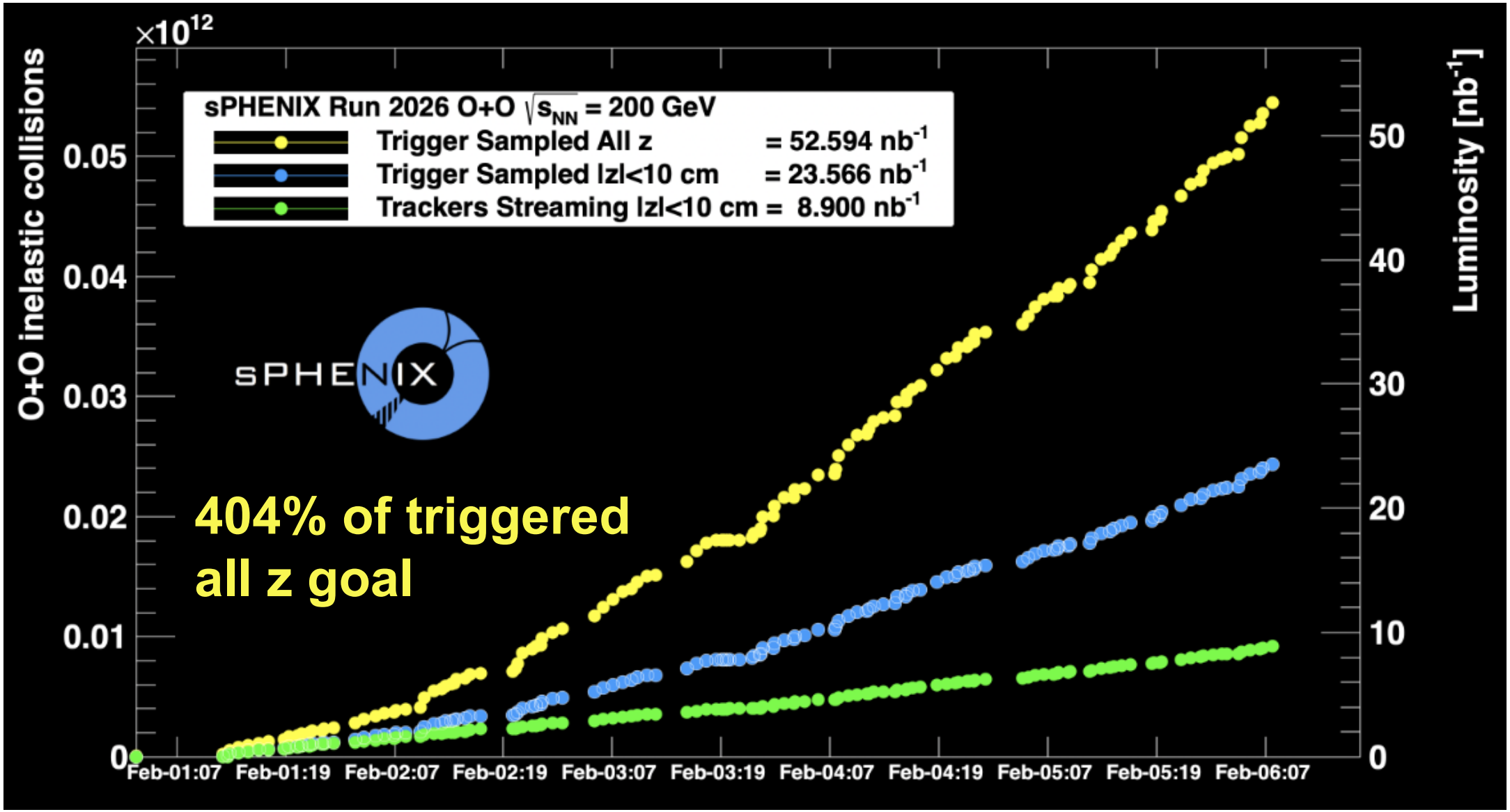
sPHENIX O+O luminosity



sPHENIX O+O luminosity

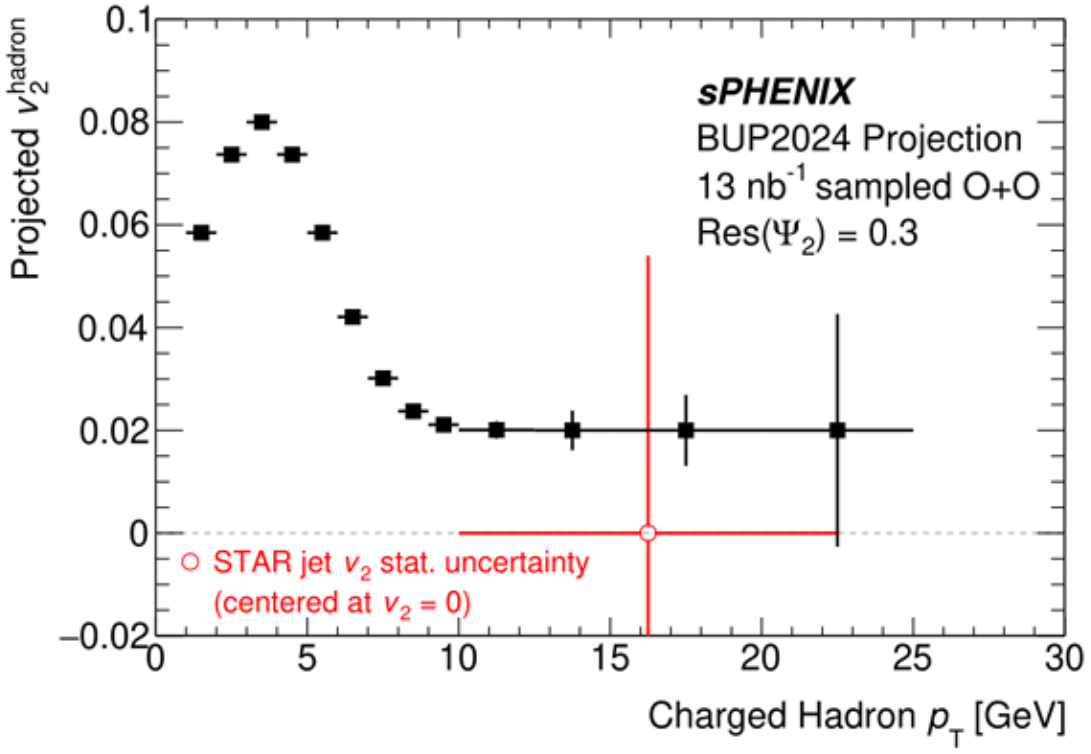


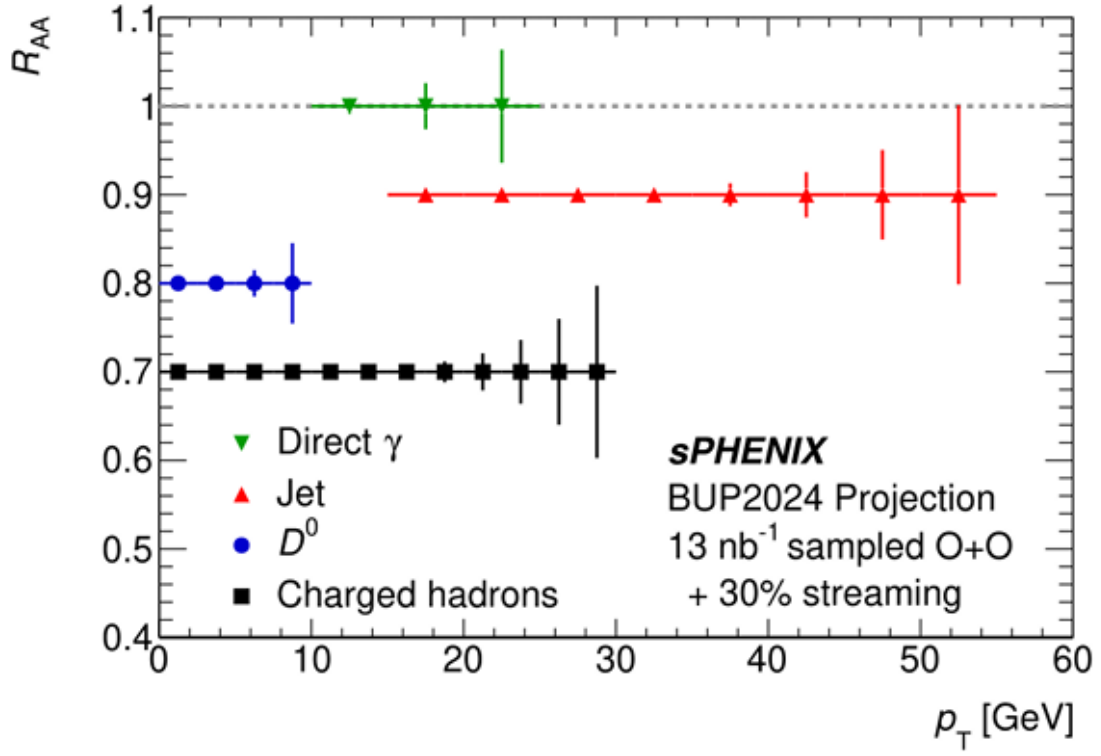
sPHENIX O+O luminosity



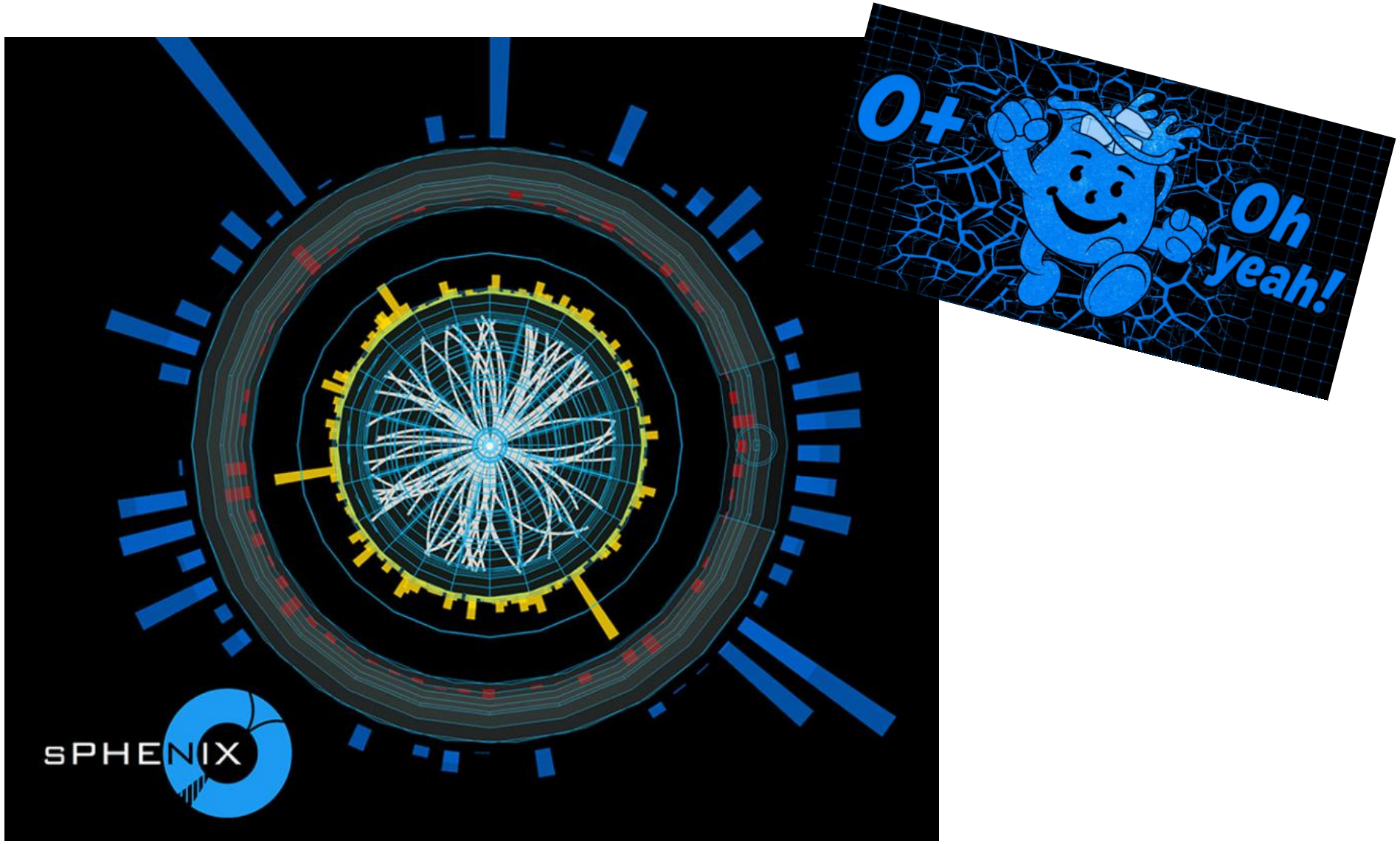
sPHENIX O+O projections

- Projections for charged hadron v_2 and R_{AA} have significant kinematic and overlap with LHC measurements assuming sampled 13 nb^{-1} of O+O





sPHENIX O+Oh yeah!

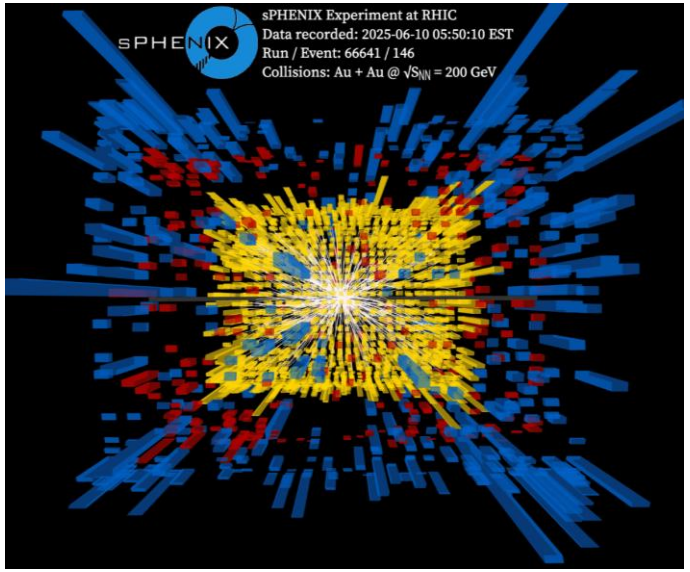


First physics publications

- Bulk measurements validate detector performance and provide direct comparison to other RHIC experiments
- First sPHENIX physics publications as of August 2025

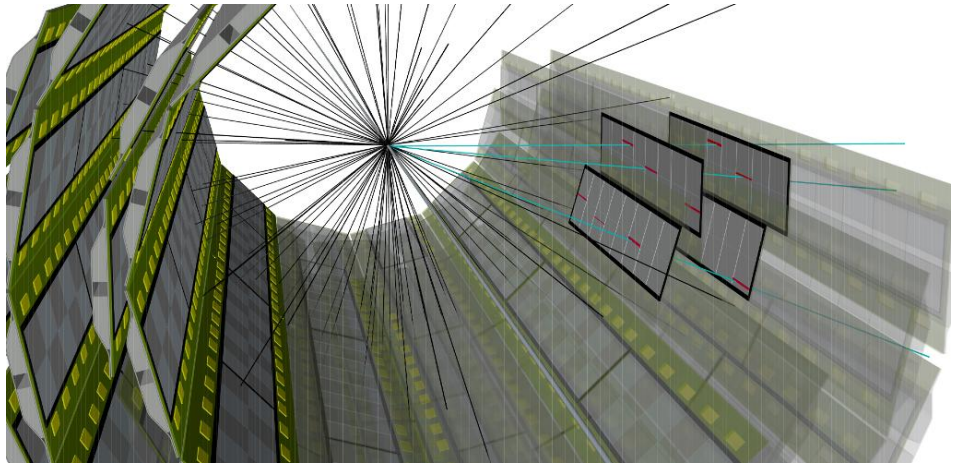
Calorimeter $dE_T/d\eta$ in Au+Au

Phys. Rev. C 112, 024908 (2025)



***Tracklet $dN_{ch}/d\eta$* in Au+Au**

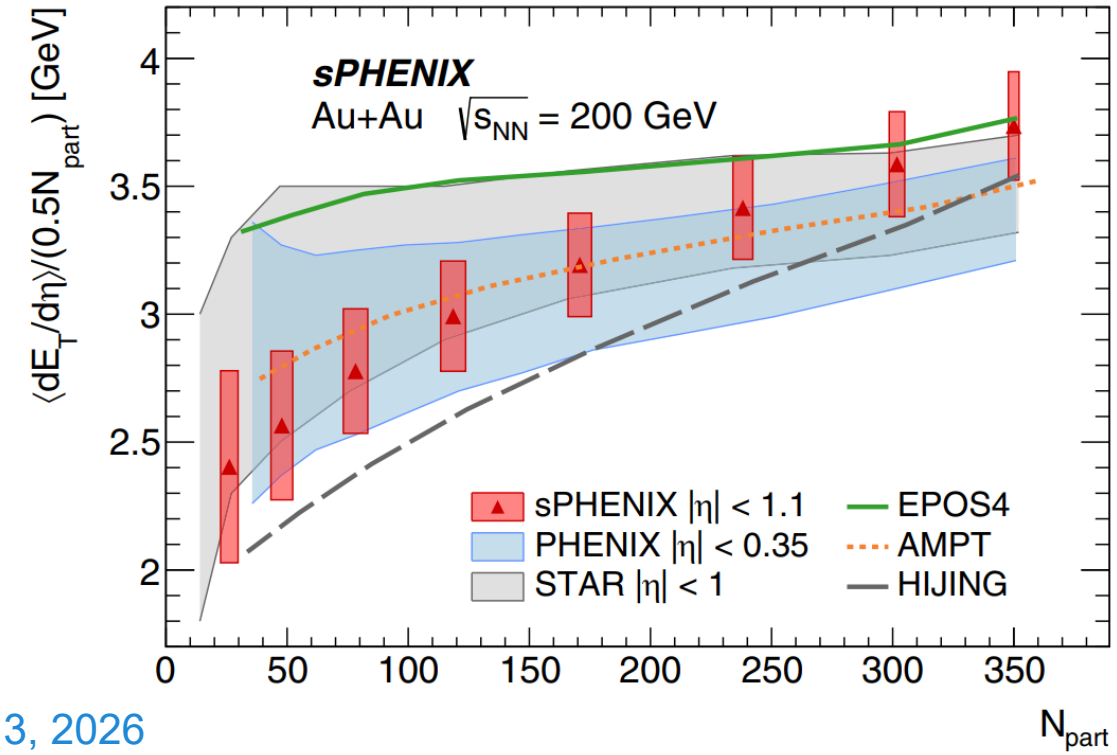
JHEP 08 (2025) 075



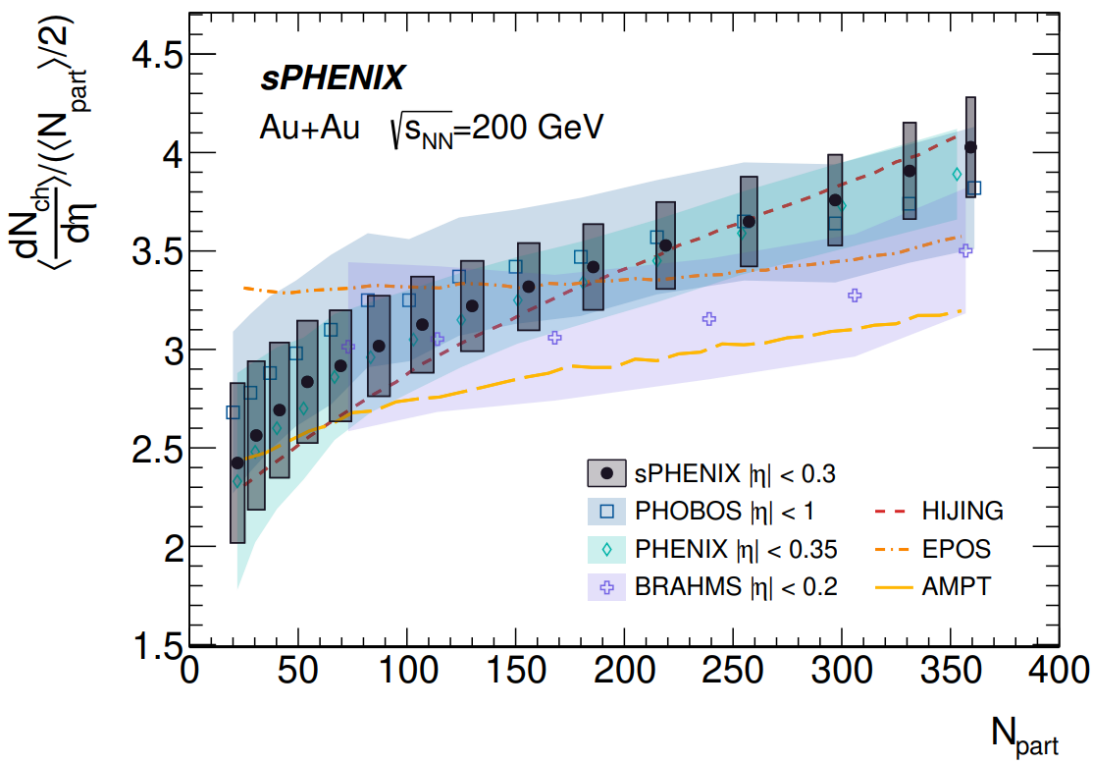
sPHENIX bulk measurements

- Bulk observables consistent with previous RHIC measurements
  - sPHENIX $dE_T/d\eta$ result best described by **AMPT** generator
  - sPHENIX $dN_{ch}/d\eta$ result best described by **HIJING** generator

$dE_T/d\eta$ in Au+Au: *Phys. Rev. C 112, 024908 (2025)*

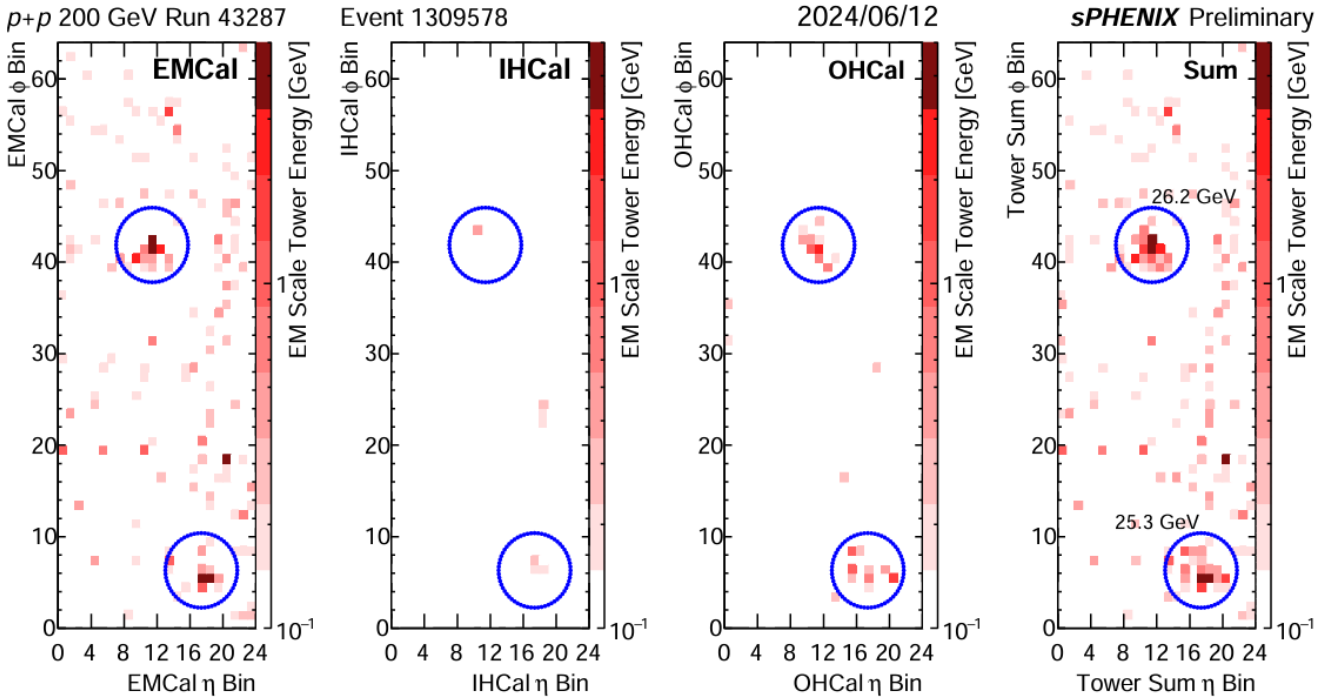


$dN_{ch}/d\eta$ in Au+Au: *JHEP 08 (2025) 075*



Calorimetric jet measurements

- Suite of jet results provide pQCD references and probe medium
- Calorimeter (*EMCal & HCal*) towers as input to anti-k_t algorithm
- **First jet results with neutral hadronic energy contribution at RHIC**

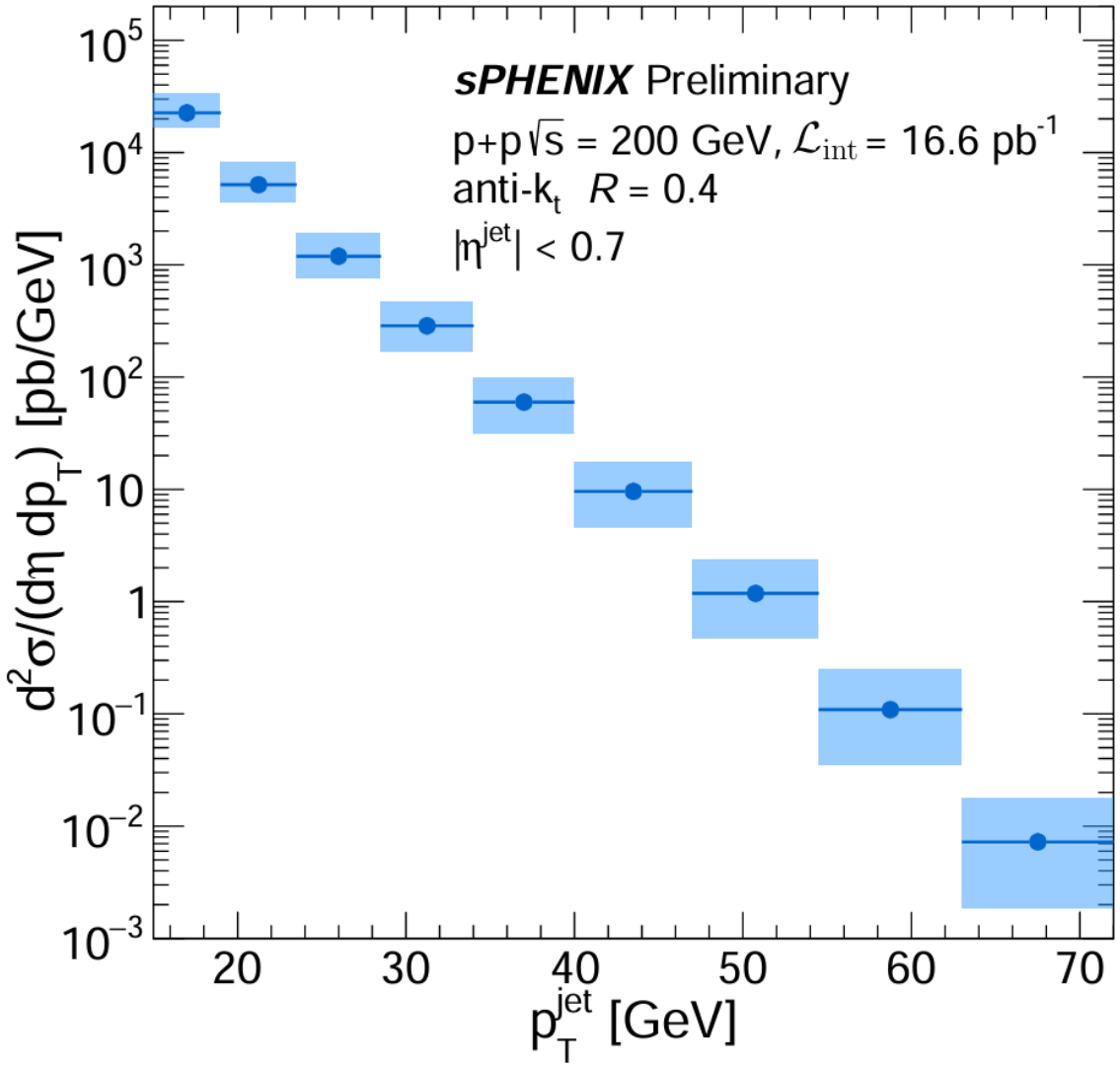


- *Inclusive jet cross section in p+p*
- *Dijet momentum imbalance (x_j) in p+p*
- *Dijet acoplanarity ($\Delta\phi$) in p+p*
- *Dijet momentum imbalance (x_j) in Au+Au*
- *Jet single spin asymmetries (A_N) in p+p*

Inclusive jet cross section in *p*+*p*

- Unfolded cross section of *R* = *0.4* anti-k_t calorimeter jets
- Kinematic reach up to 70 GeV
  - **Highest p_T jets observed at RHIC**
- Preliminary used 16.6 pb^{-1} of *p*+*p* dataset
  - **Final result with full dataset forth coming**

sPH-CONF-JET-2025-03



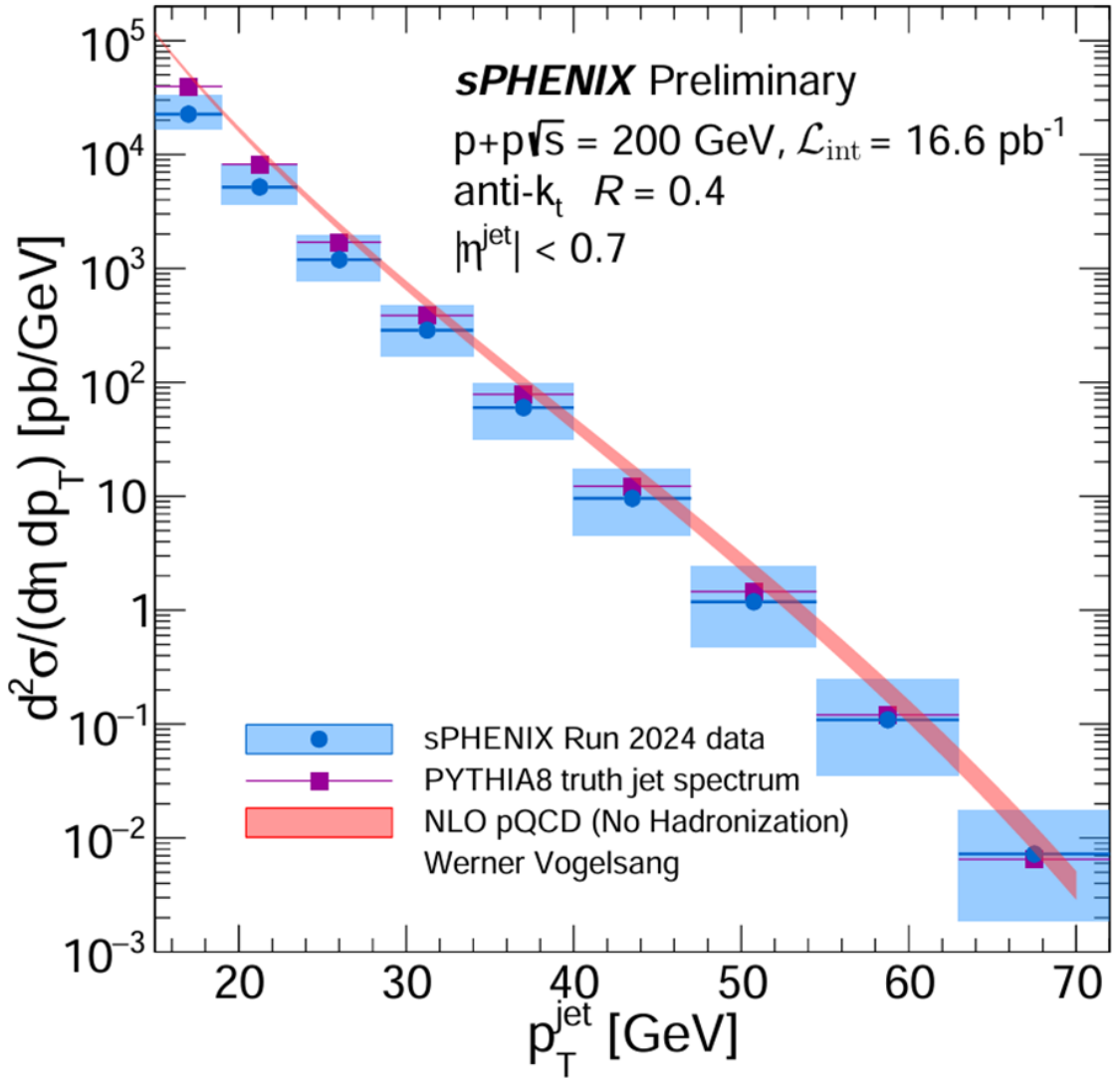
Inclusive jet cross section in *p*+*p*

sPH-CONF-JET-2025-03

- Systematic uncertainty dominated by jet energy scale on the hadronic response
  - **Expected to significantly improve with γ-jet + multi-jet in-situ calibration**

PYTHIA8: Detroit tune

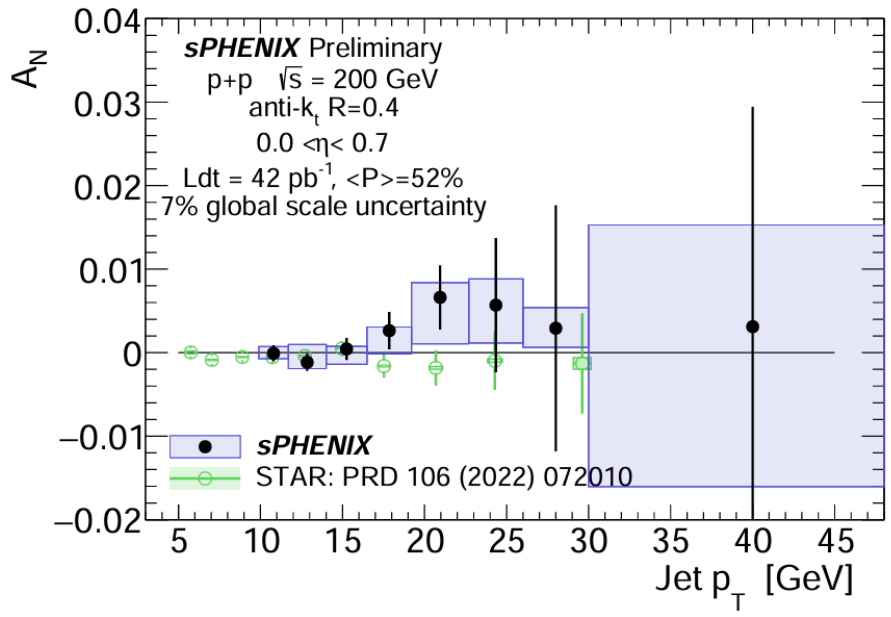
NLO pQCD W. Vogelsang: No hadronization in calculation

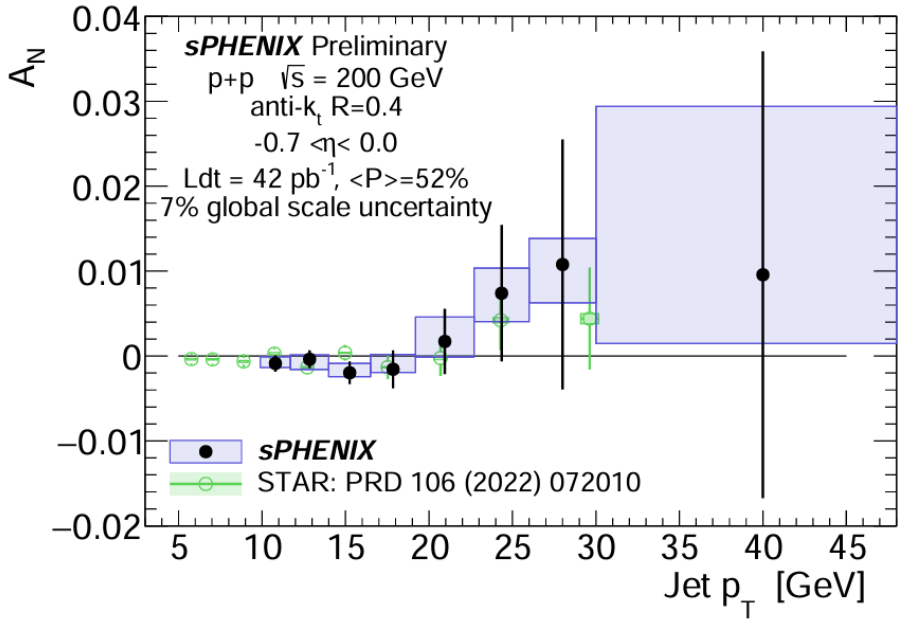


Jet A_N in *p*+*p*

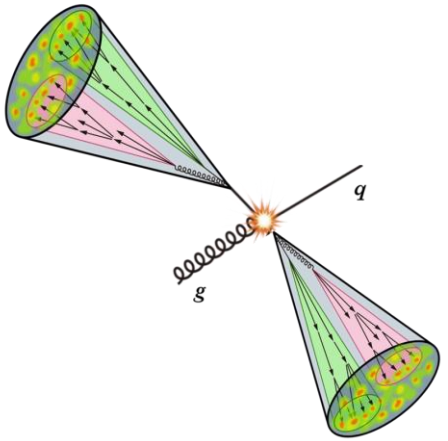
- Unfolded A_n for *R = 0.4* anti-k_t jets in polarized *p*+*p* collisions
- sPHENIX measurement consistent with **STAR results**
- Dominant systematic uncertainties from jet energy scale and jet energy resolution

sPH-CONF-COLDQCD-2025-02



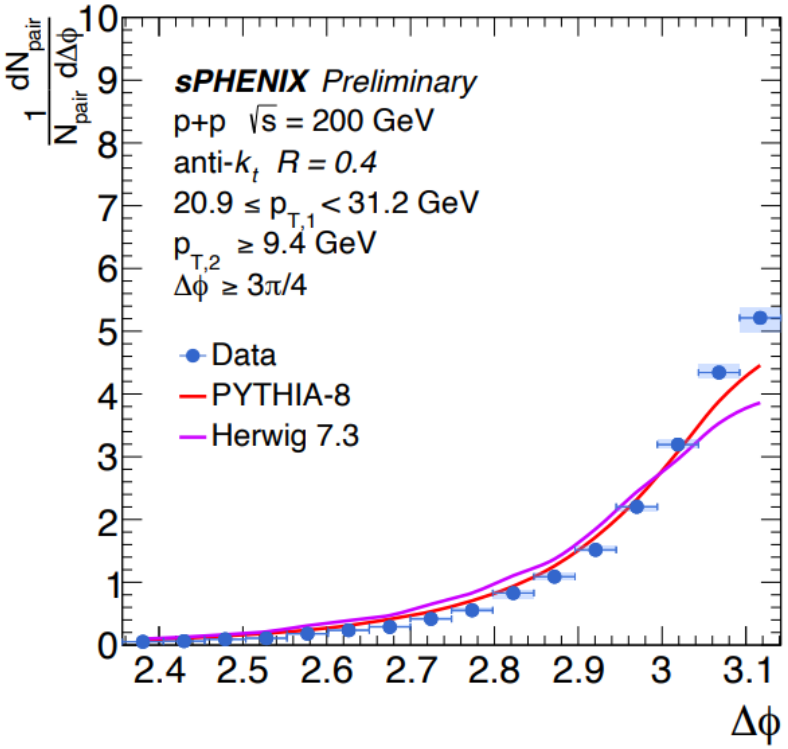


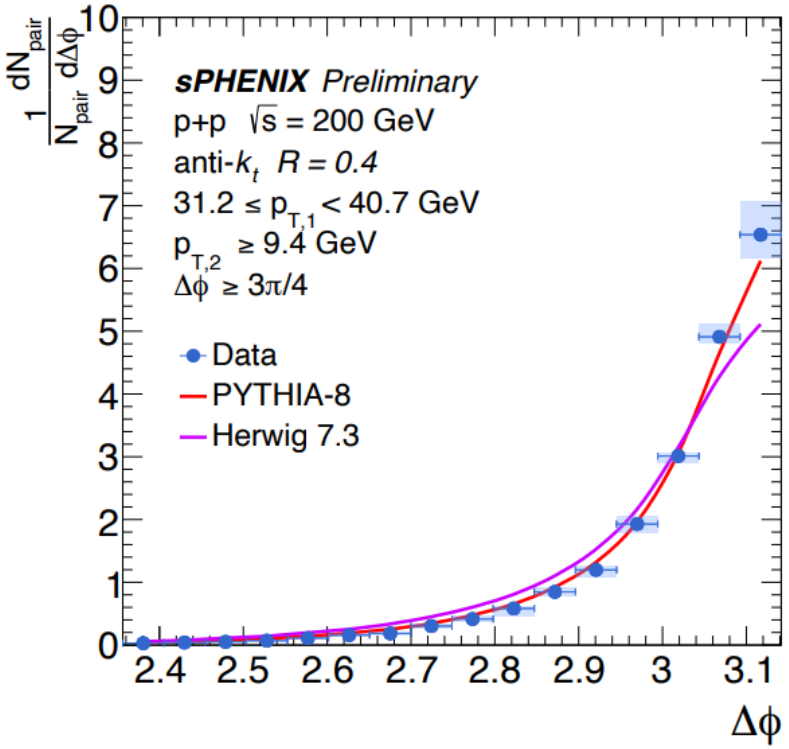
Dijet acoplanarity in *p+p*

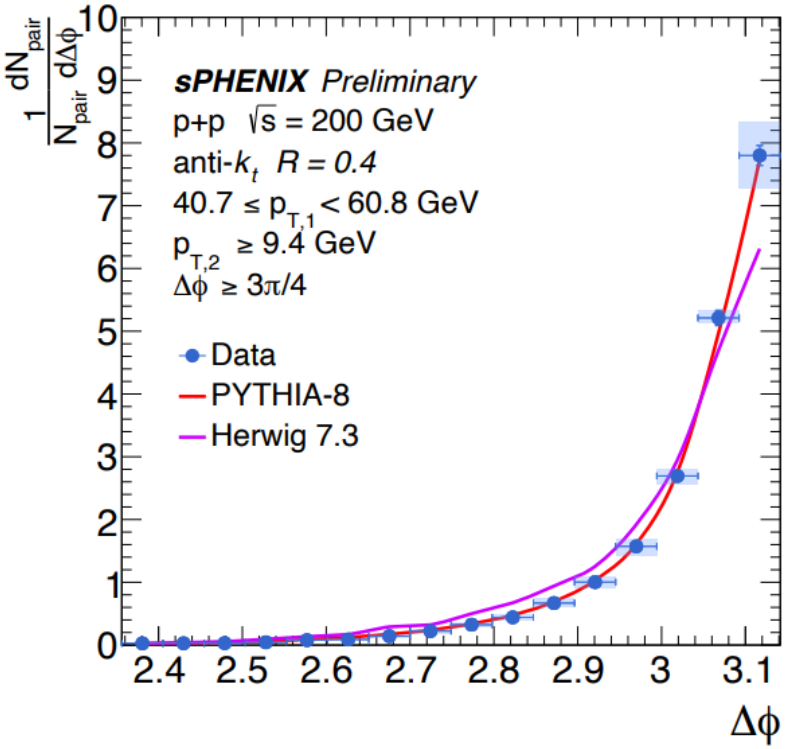


- *R = 0.4* anti-k_t calorimeter jets
- Higher $p_{T,1}$ → sharper away side peak
- Data favors **PYTHIA-8** over **HERWIG 7.3**

sPH-CONF-JET-2025-01





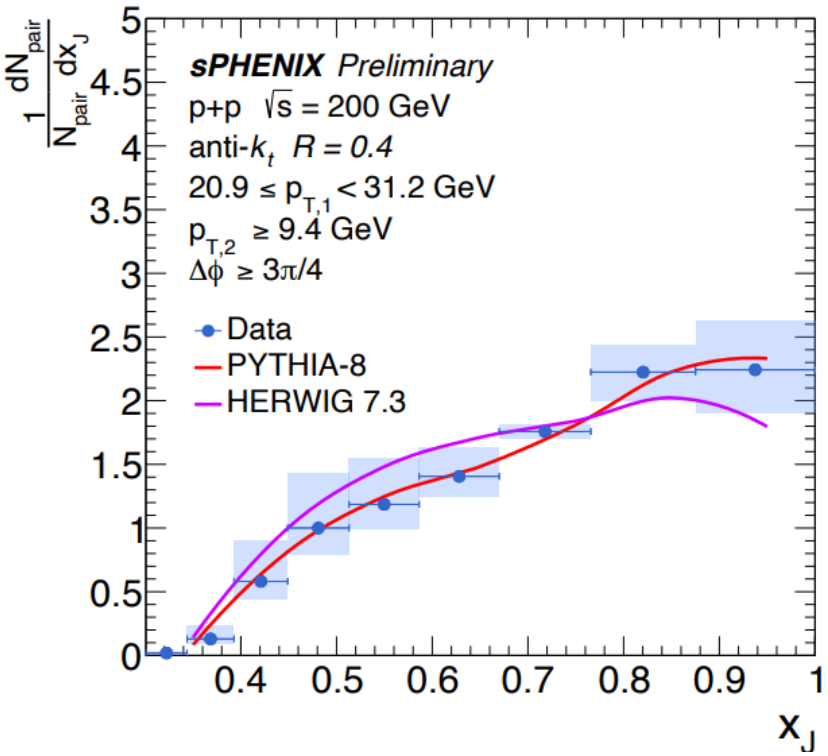


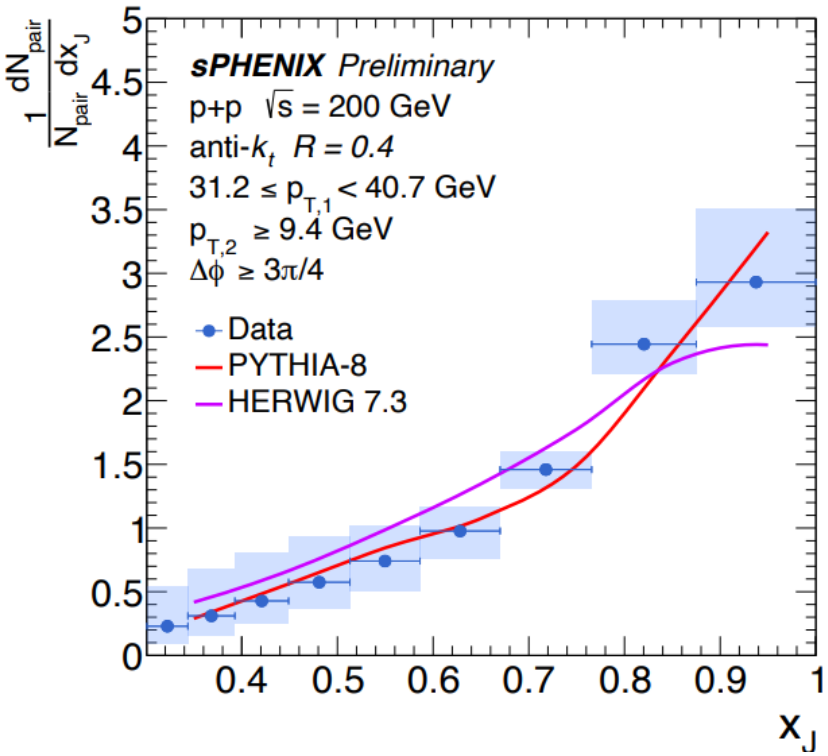
Dijet momentum imbalance in *p+p*

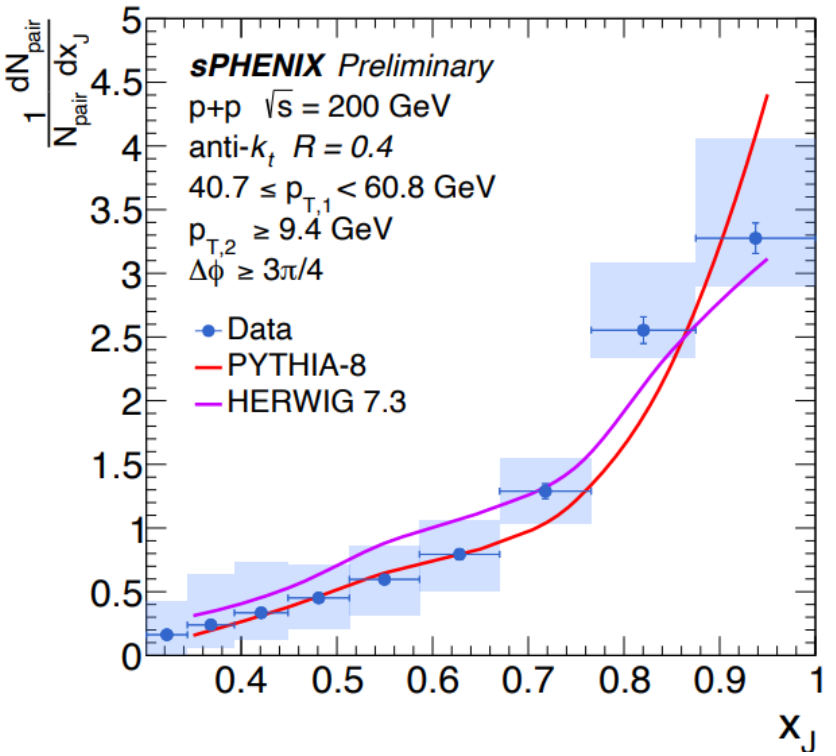
- Require dijet pair $\Delta\phi > 3\pi/4$, 2D unfolding in $p_{T,1}$, $p_{T,2}$
- Jet energy resolution is dominant systematic uncertainty
- Data favors **PYTHIA-8** over **HERWIG 7.3**

$$x_J = {p_{T,2}}/{p_{T,1}}$$

sPH-CONF-JET-2025-01

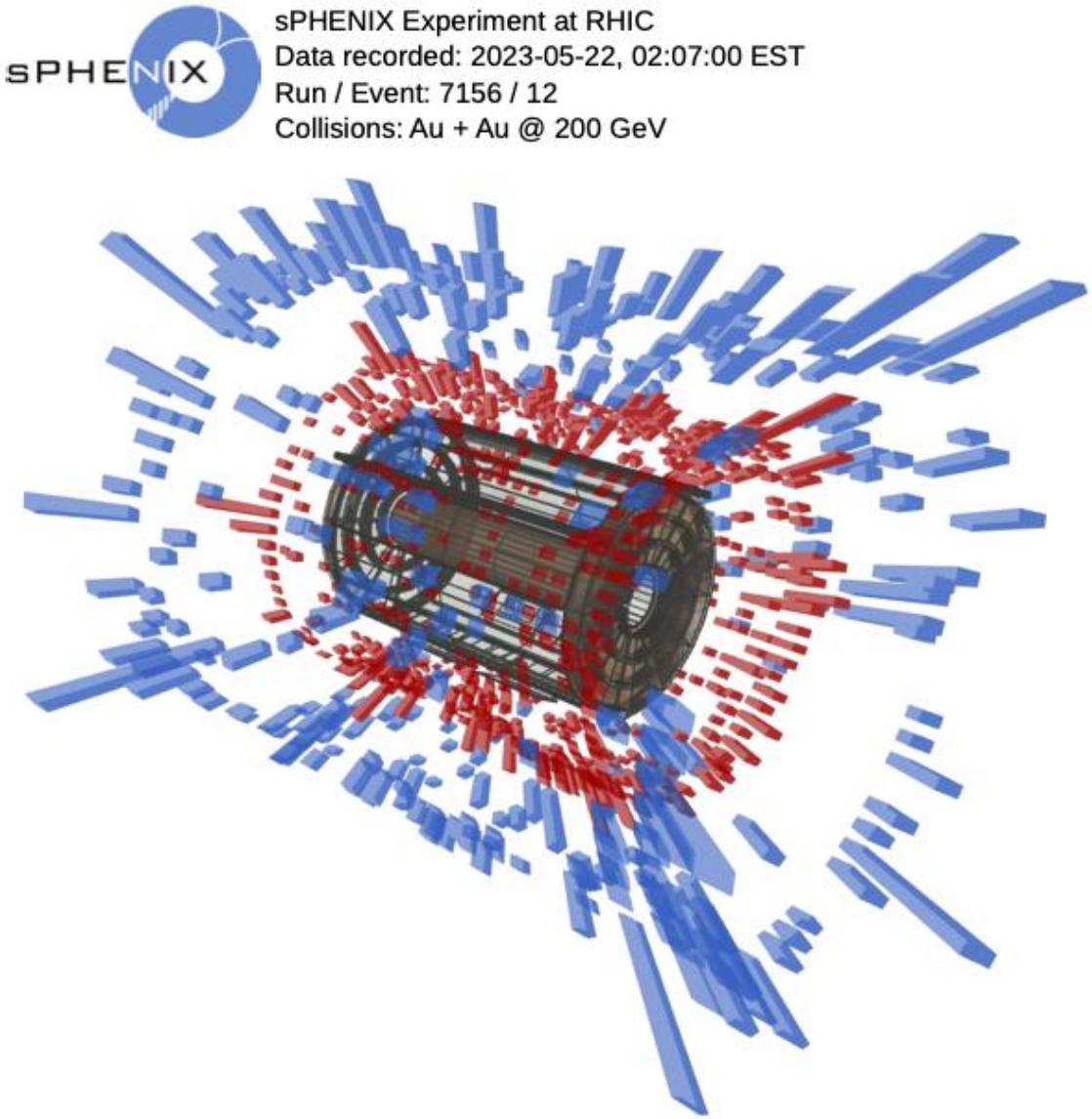






Jet measurements in Au+Au

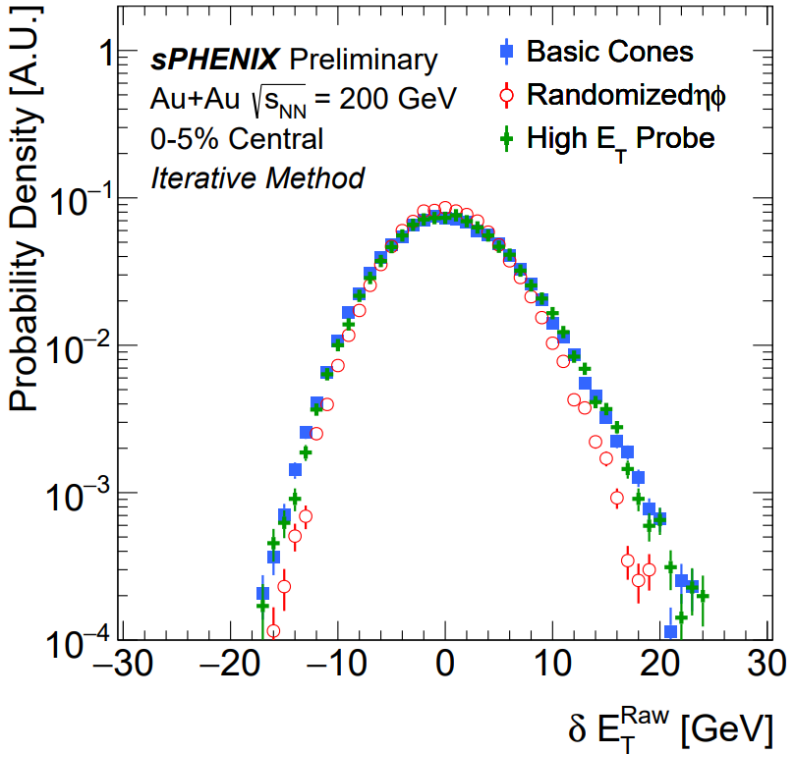
- In heavy ions, jets sit on top of a fluctuating azimuthally-modulated underlying event
- Local fluctuations in underlying event will affect jet energy resolution
- Flow-modulated combinatorial background contamination in $\Delta\phi$

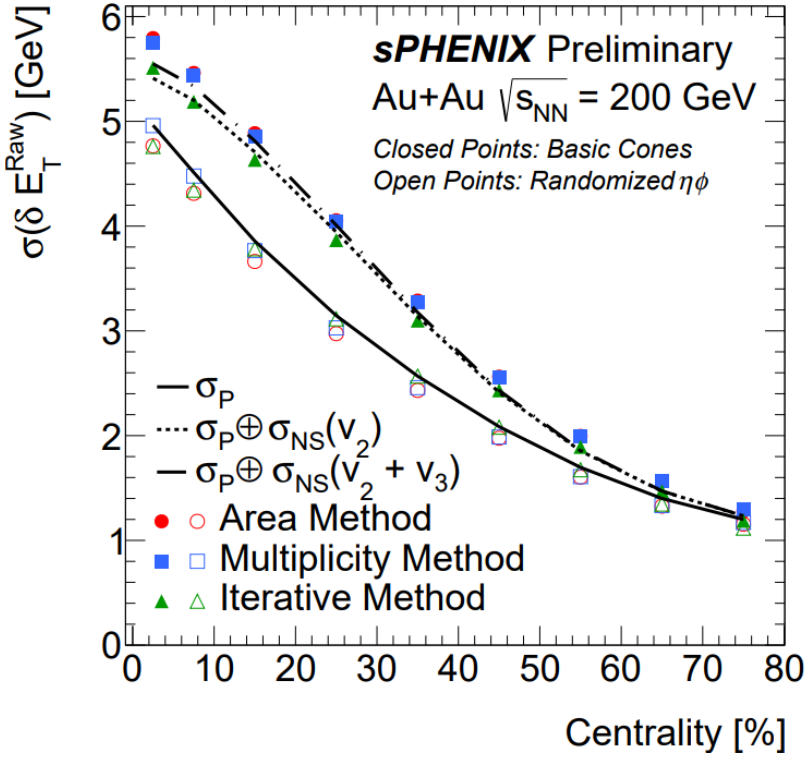


Underlying event in Au+Au

- Proper understanding of fluctuations needed for Au+Au jet reconstruction and UE subtraction
- Underlying event is subtracted using event-by-event iterative subtraction method

[sPH-CONF-JET-2025-04]

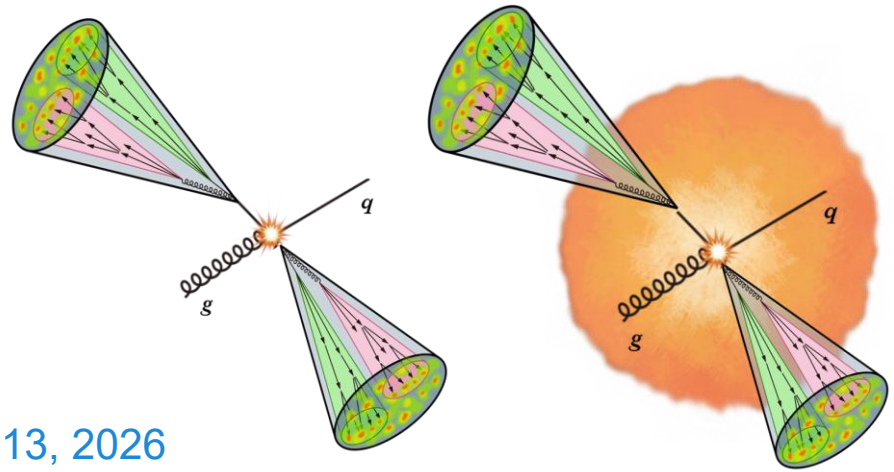


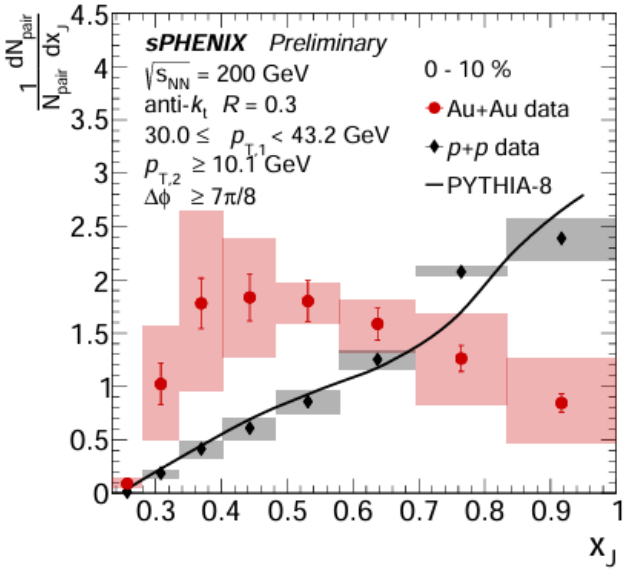


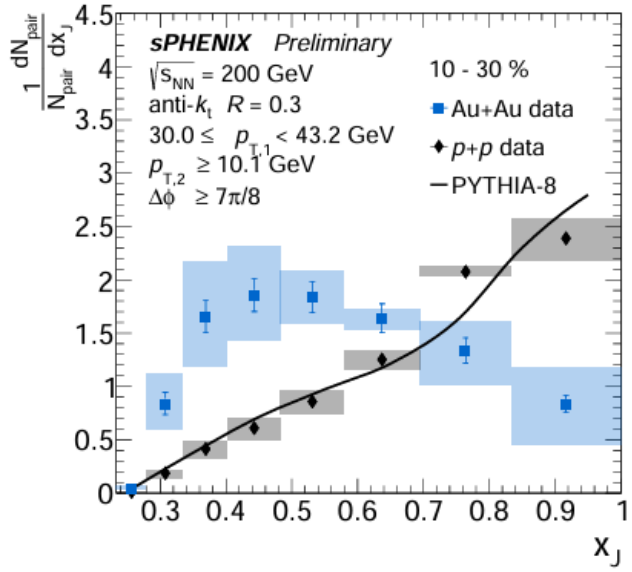
Dijets in Au+Au

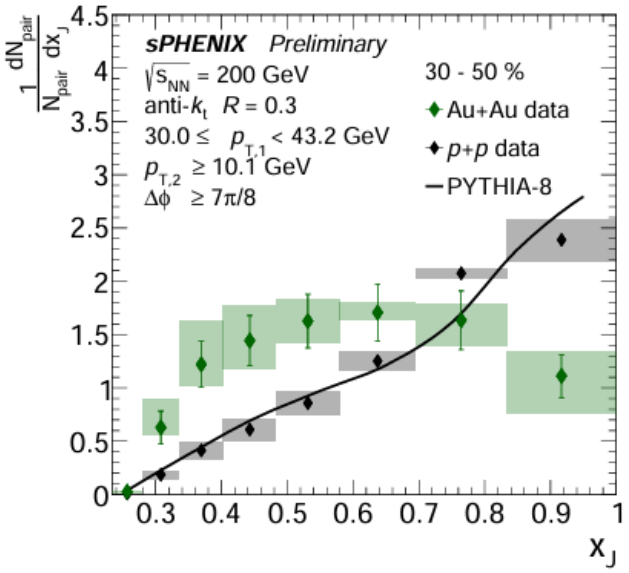
- Unfolded x_J for $R = 0.3$ anti-k_t calorimeter jets

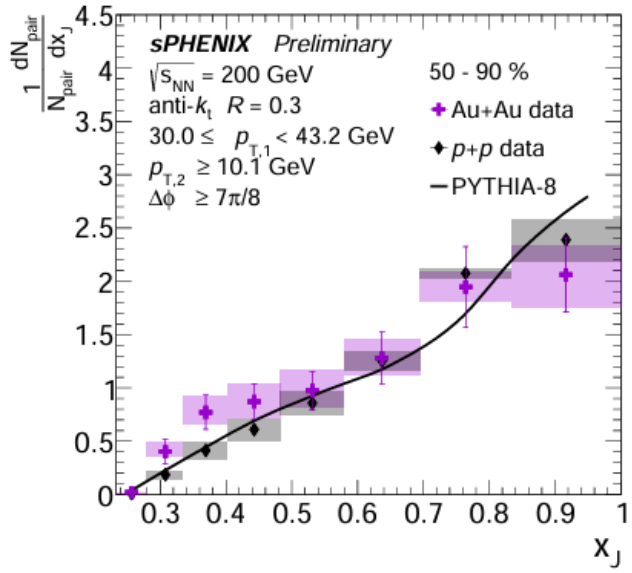
- Large observed suppression in 0-10% central events
  - x_J becomes more balanced in more peripheral events





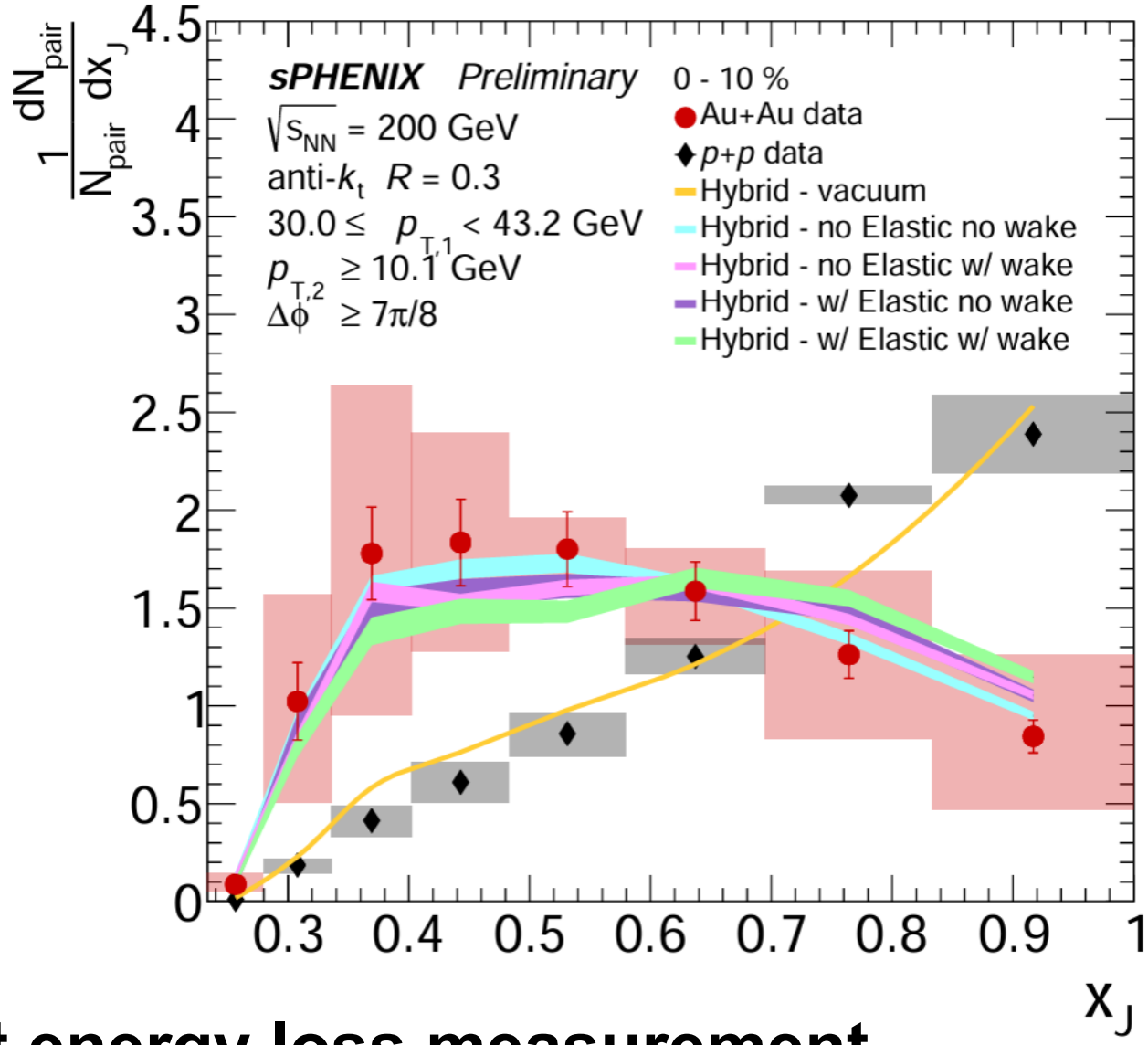






Dijet x_J in Au+Au

- sPHENIX measurement is consistent with all hybrid model predictions
  - *Hybrid Model: JHEP 2014, 19 (2014)*
- Dominant uncertainty is combinatorial background correction
  - ***Will be improved in final result***

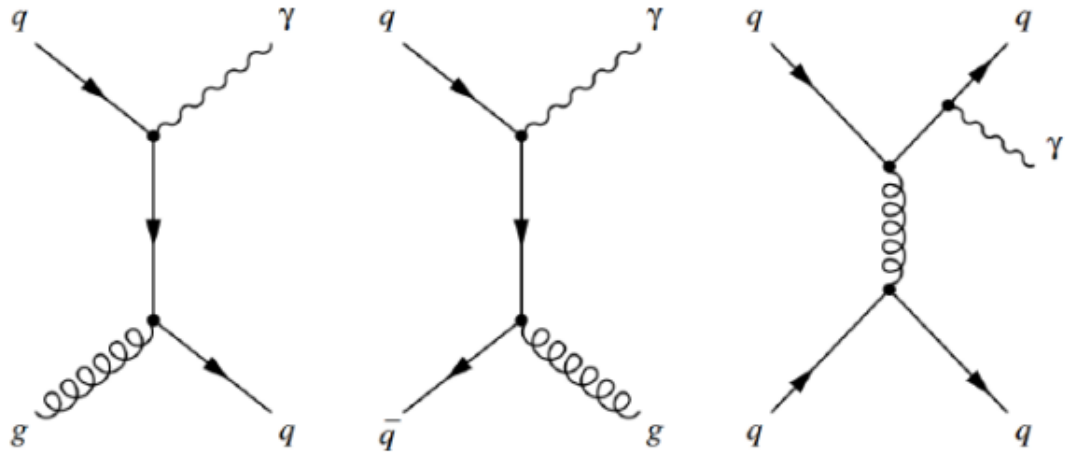


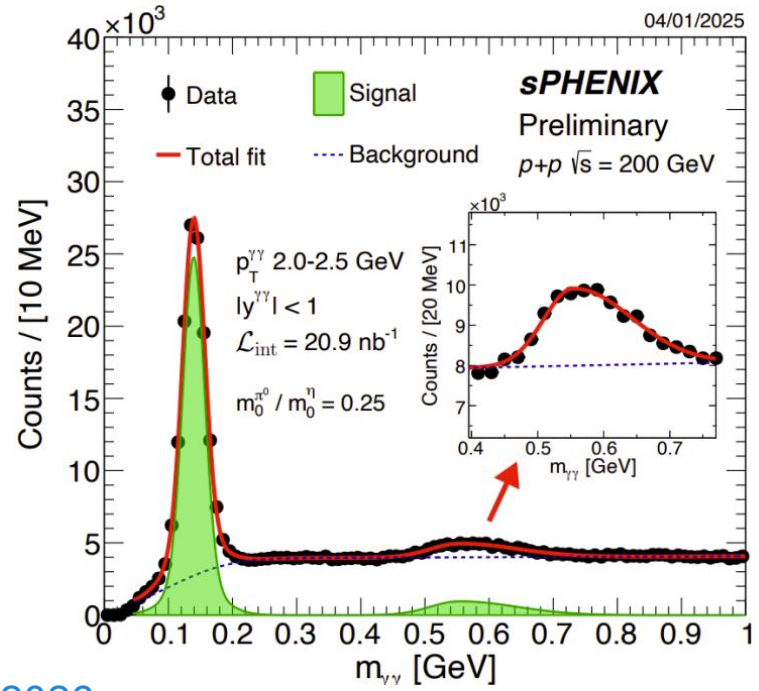
First sPHENIX jet energy loss measurement

Identified initial state probes

Prompt photons

- Primarily produced via hard scattering
- Direct access to initial state PDFs





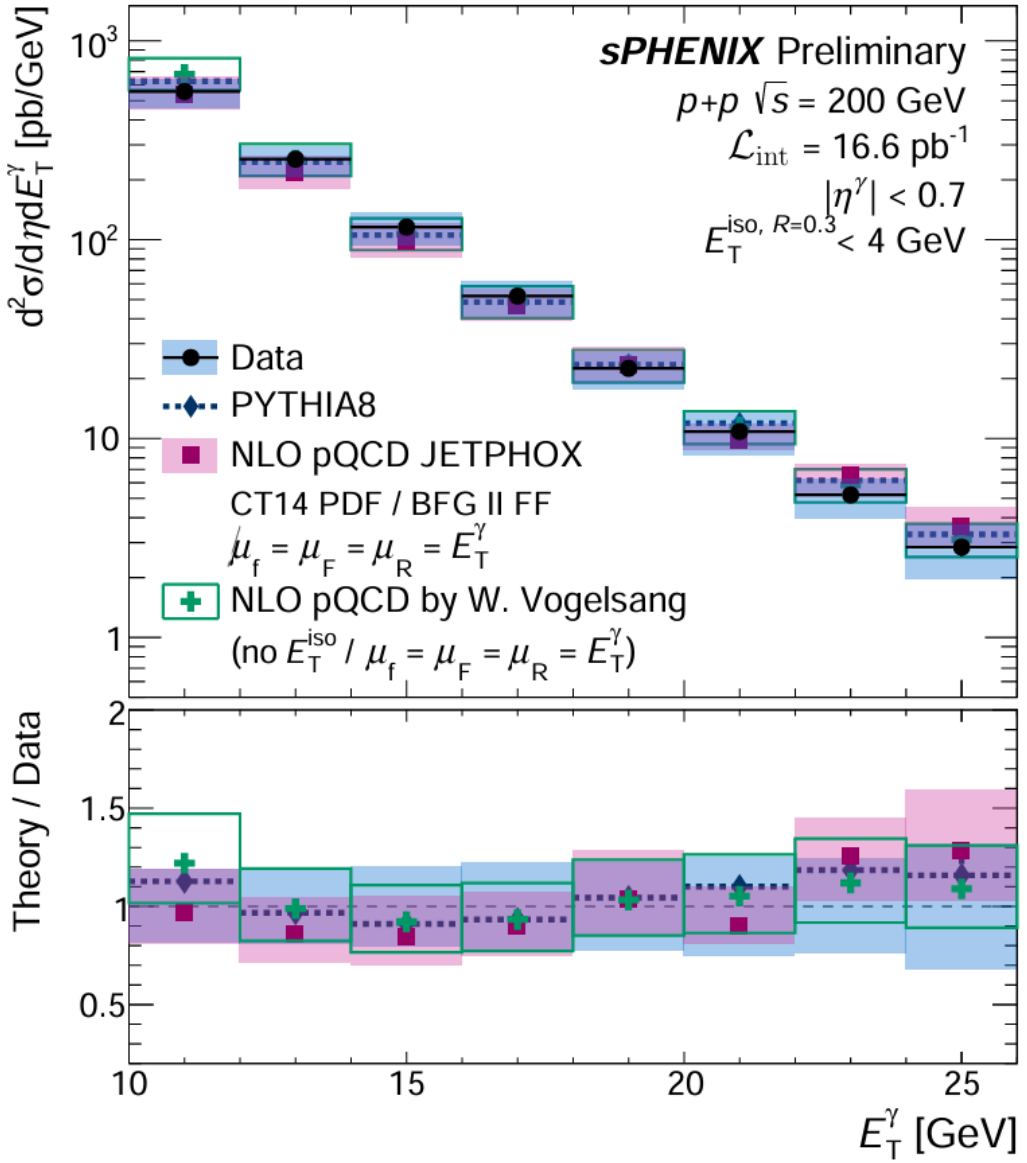
Neutral mesons

- Input for PDF/TMDs & tests of pQCD
- Used for calibration of the electromagnetic calorimeter

Isolated photon cross section in *p+p*

sPH-CONF-JET-2025-02

- Isolation requirement and identification via shower shape variables
- EM energy scale dominant source for systematic uncertainty
  - **Expected to be improved with full dataset**
- All predictions consistent with data within uncertainties



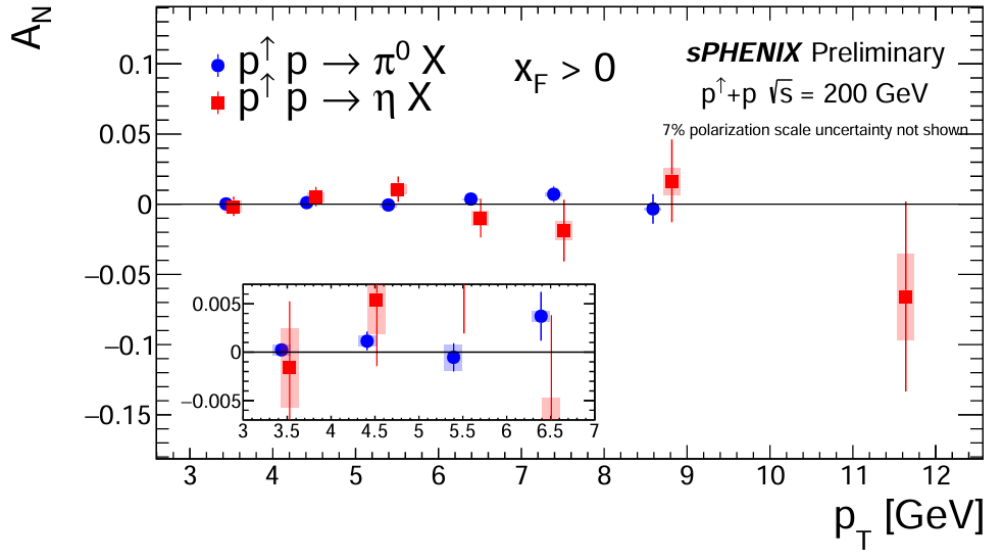
Neutral meson A_N in *p*+*p*

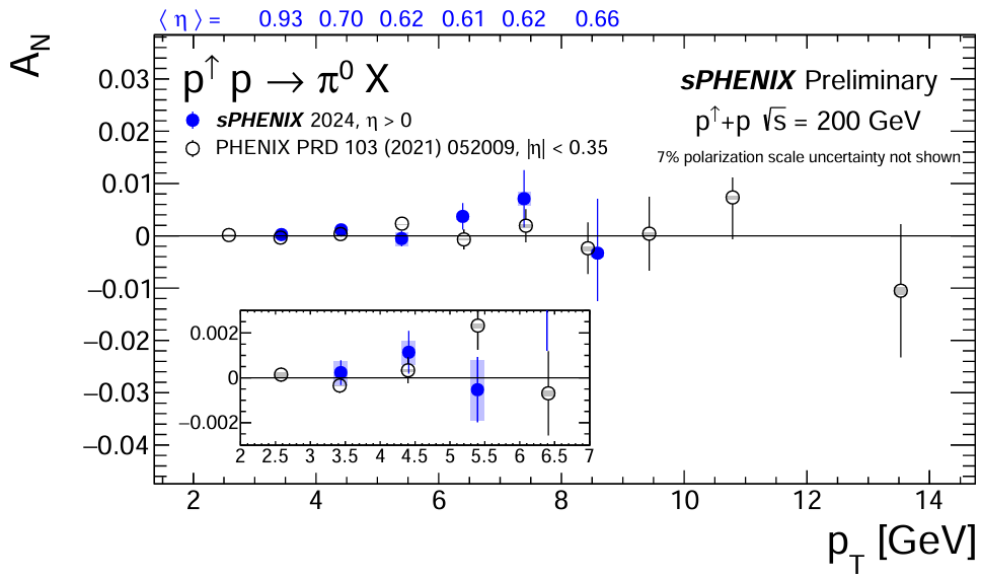
- Reconstruct π^0 and η with di-photon mass range, double side-band subtraction

- sPHENIX measurement is compatible with zero and PHENIX within the same rapidity ranges

$$A_N \propto \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

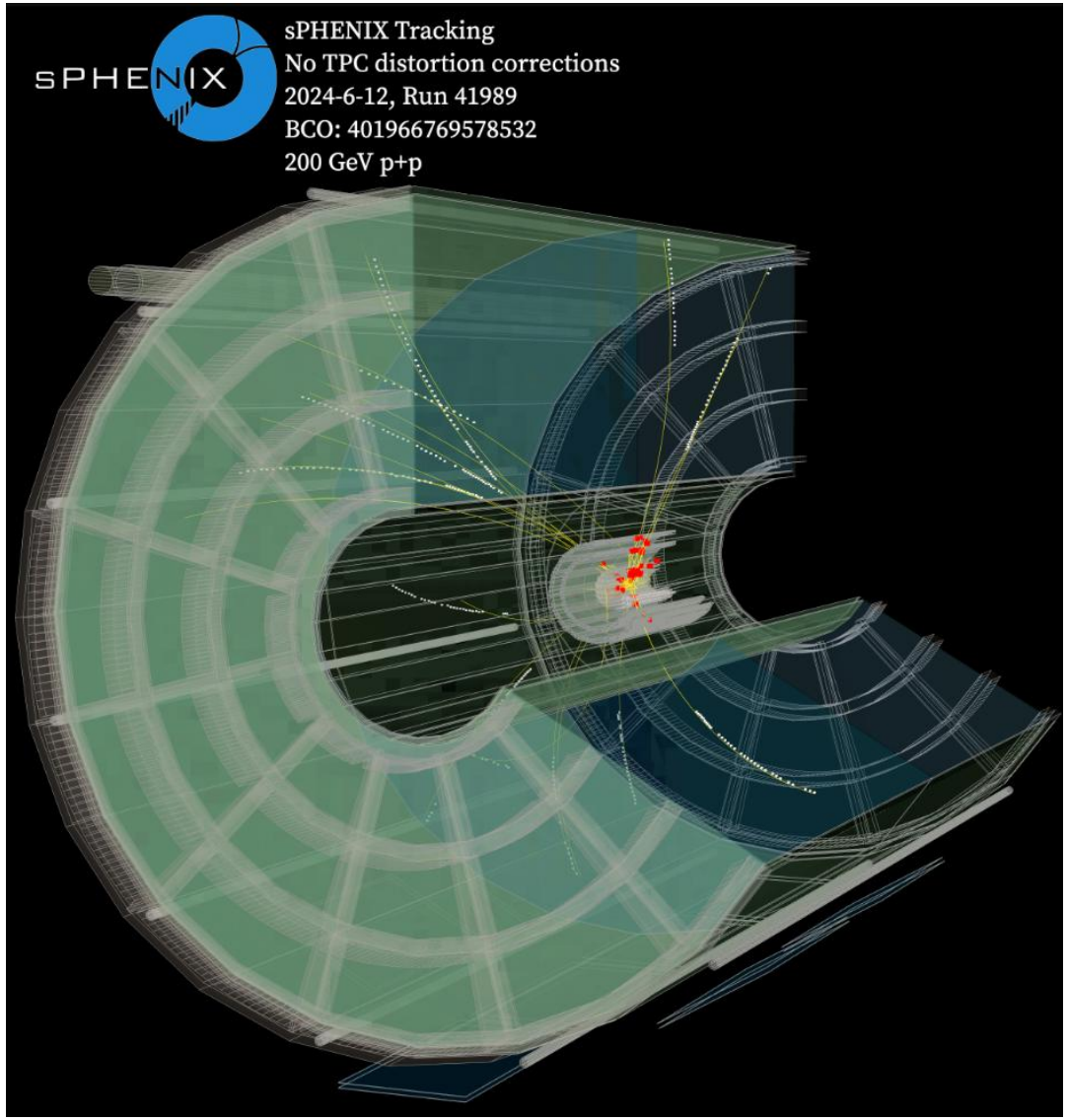
sPH-CONF-COLDQCD-2025-01





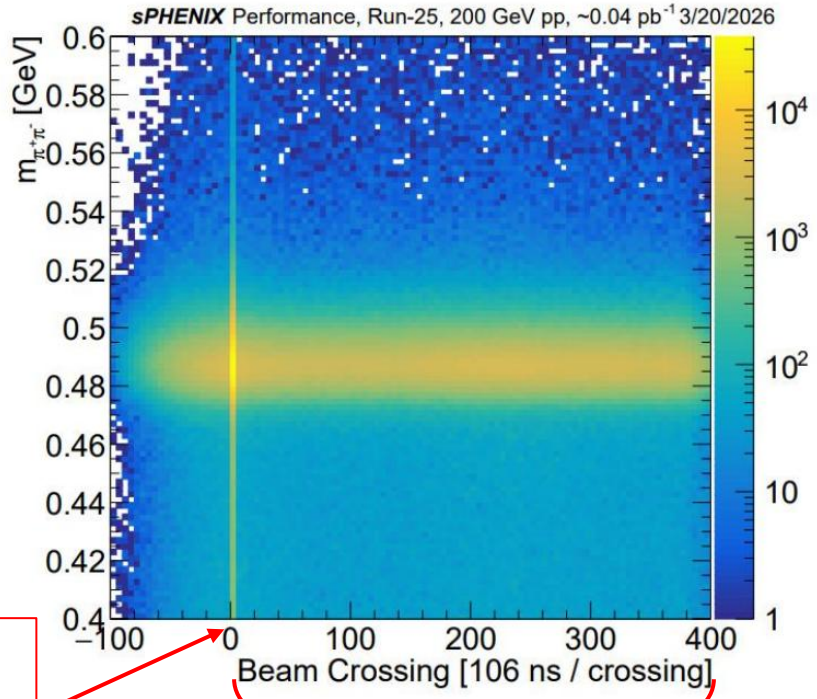
sPHENIX tracking subsystems

- MAPS vertex Detector (**MVTX**)
  - Three-layer Si pixel detector
  - High precision vertexing O(10 μm) at 2-3 GeV track p_T
- Intermediate Silicon Tracker (**INTT**)
  - Two-layer Si strip detector
  - Fast timing detector with O(100 ns) resolution of bunch crossings
- Time Projection Chamber (**TPC**)
  - GEM based gaseous drift chamber
  - Momentum resolution target of 2% at 5 GeV p_T
- TPC Outer Tracker (**TPOT**)
  - Micromega based gas detector
  - External to TPC, enables precision distortion calibration



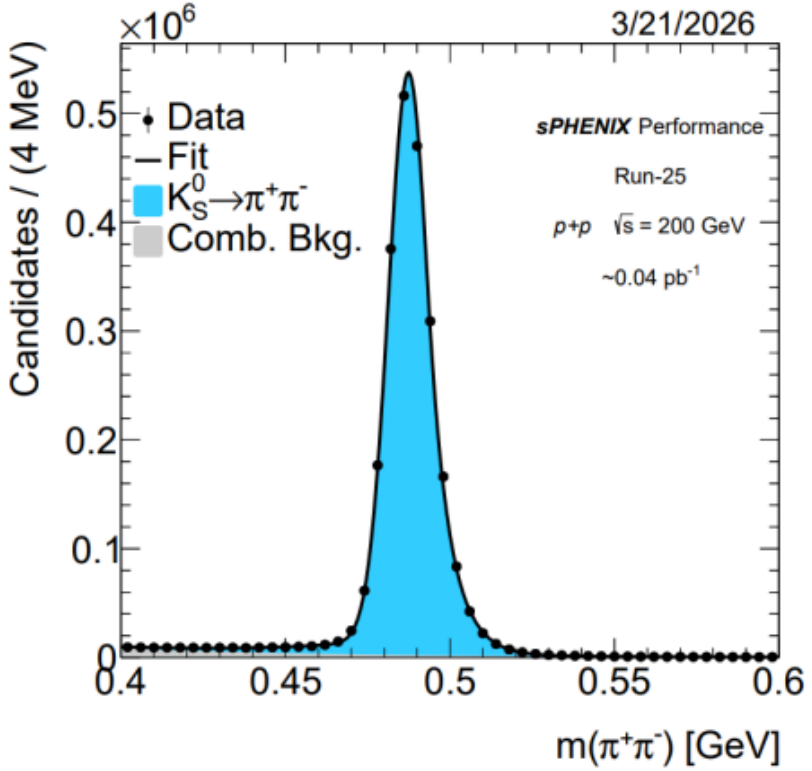
Extended readout

- sPHENIX tracking systems are a hybrid triggered + streaming readout
- Enables collection of unbiased samples in p+p and O+O collisions



Triggered bunch crossing

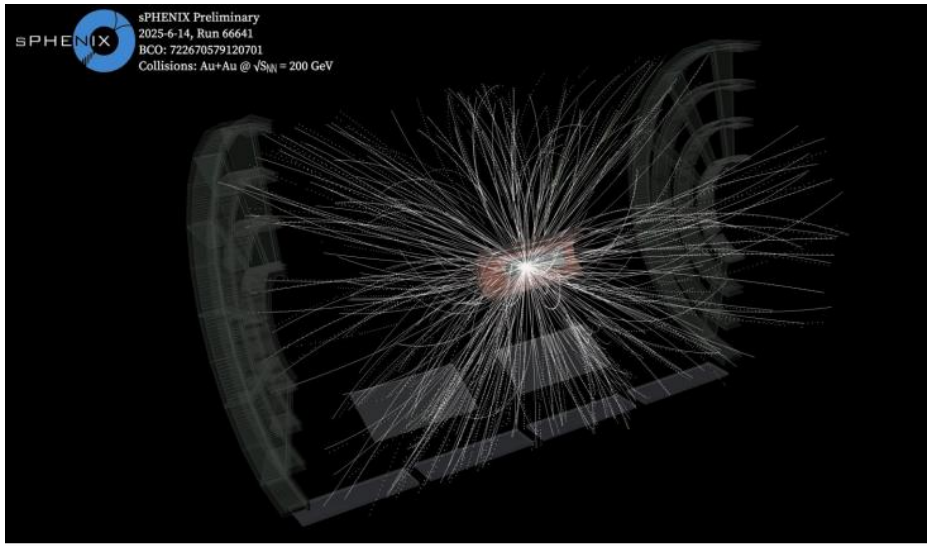
Recorded extended trigger frame (~40 μs)

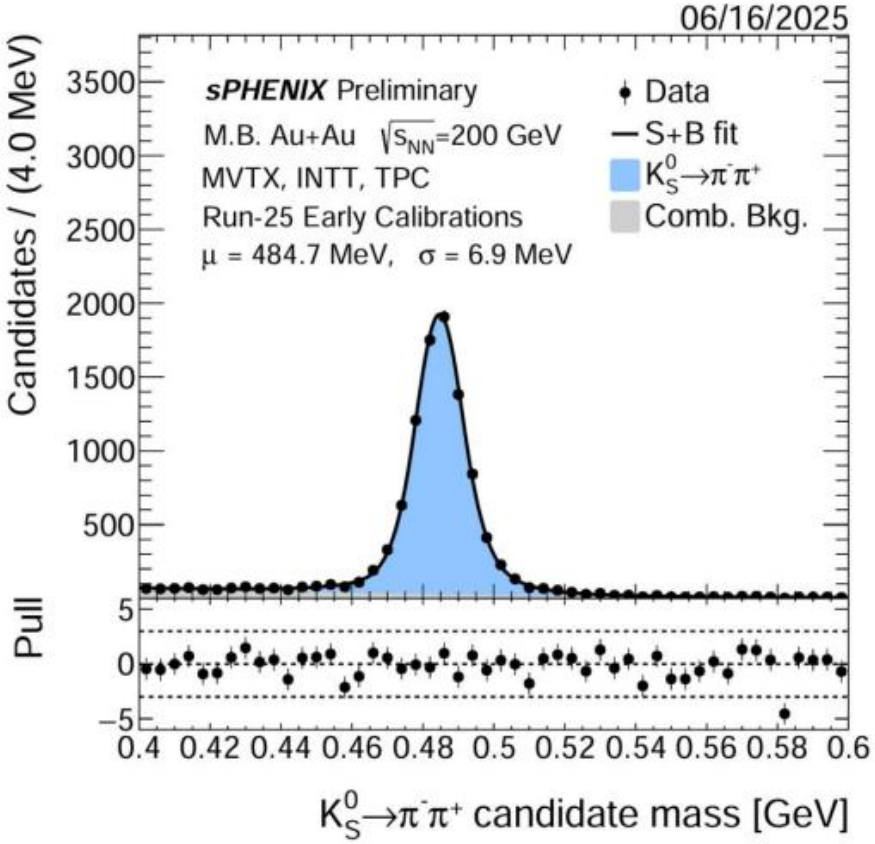


~4 hours of *p+p* data from Run 2025

sPHENIX track calibration efforts

- Existing preliminary tracking calibrations are adequate for strange resonance reconstruction
- Several analyses of strange hadron ratios are in progress



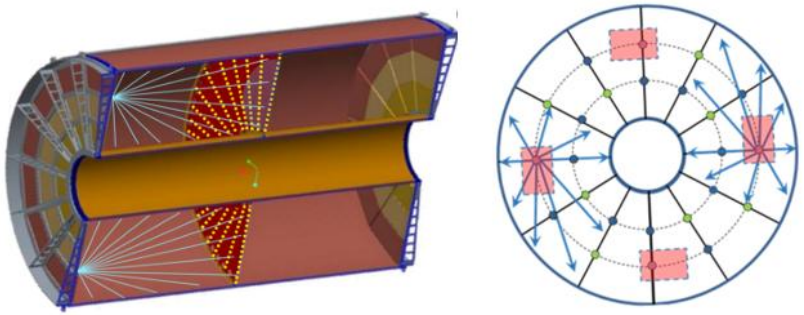


K_s^0 seen in ~1 minute of Au+Au collision data from run 2025

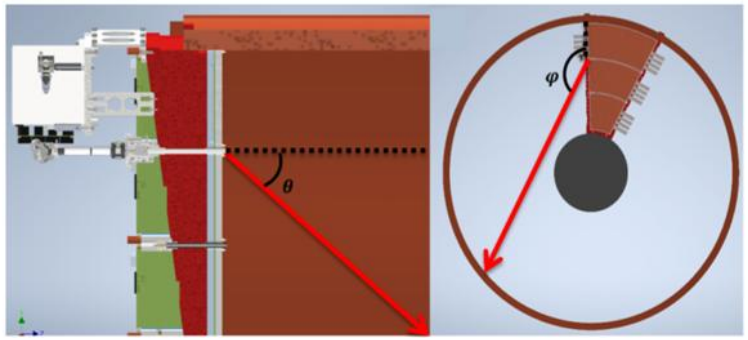
sPHENIX track calibration efforts

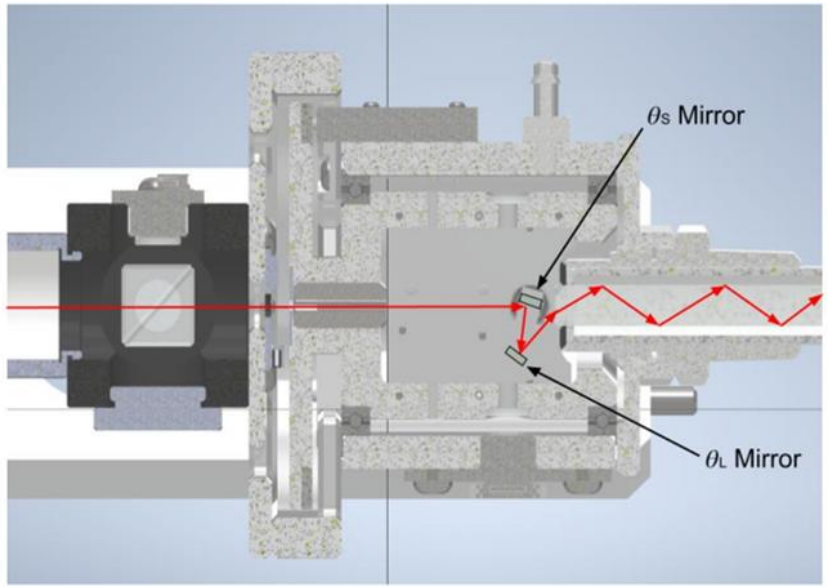
- For charm and bottom better control of the momentum scale is needed
- Work is ongoing to obtain more precise calibrations of:
  - $E \times B$ effects in the TPC
  - Beam related distortion effects in the TPC

Chenxi Ma: Study of Differential Nonlinearity in TPC Cluster Reconstruction



Chenliang Jin: Direct Laser Likelihood Fit Method for sPHENIX TPC Distortion Study

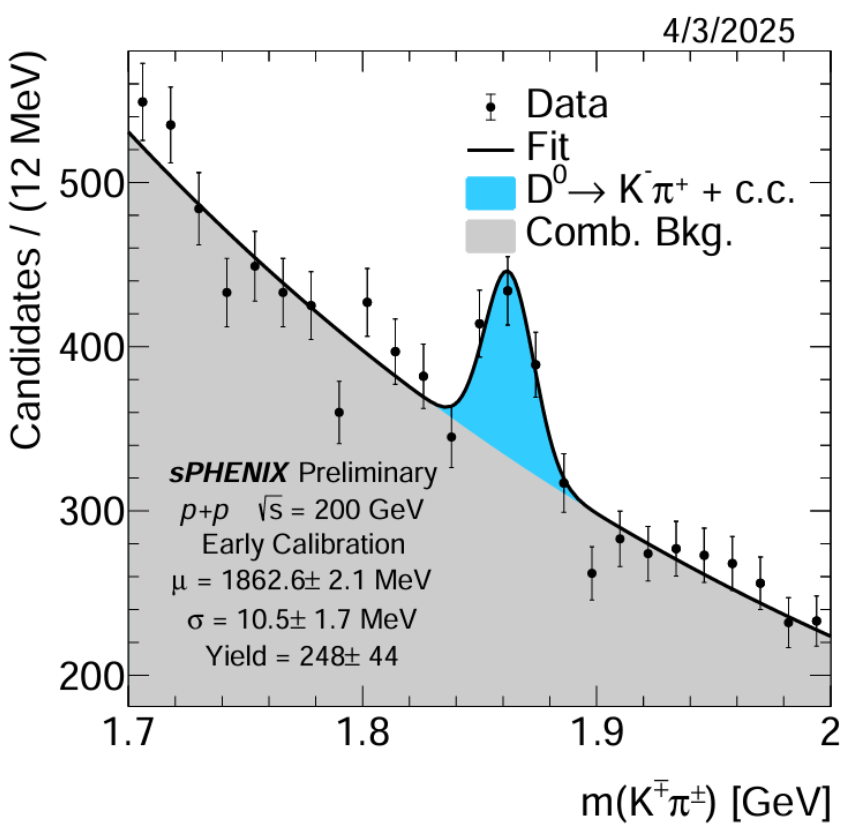


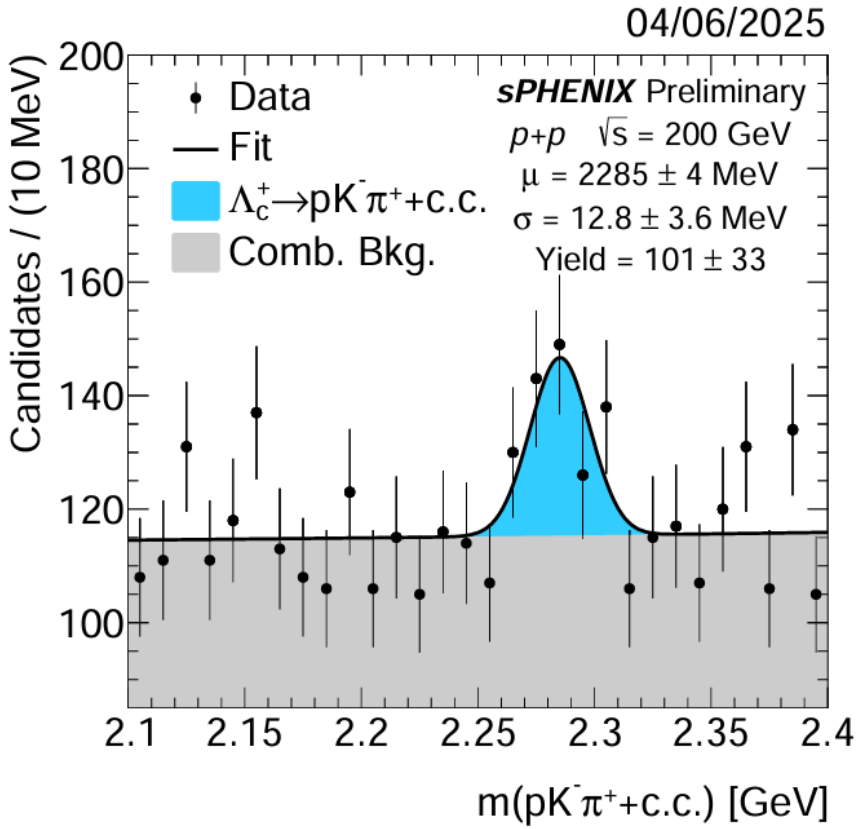


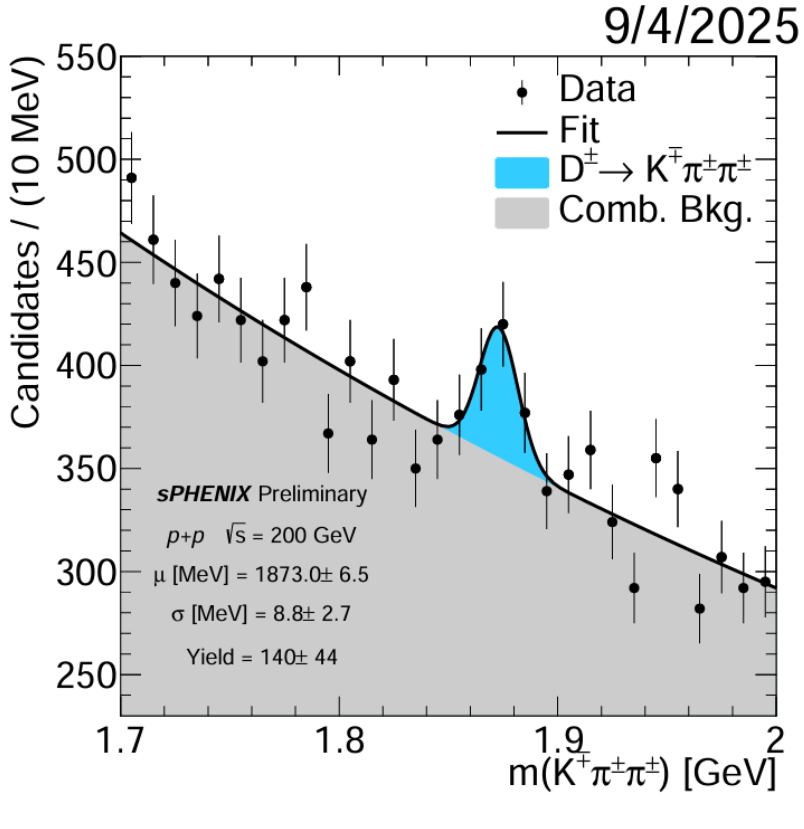
sPHENIX TPC direct laser

sPHENIX heavy flavor baseline

- Early calibration heavy flavor results for just 1 hour of *p*+*p* data
- Stay tuned for large RHIC datasets in *p*+*p*, Au+Au, and O+O



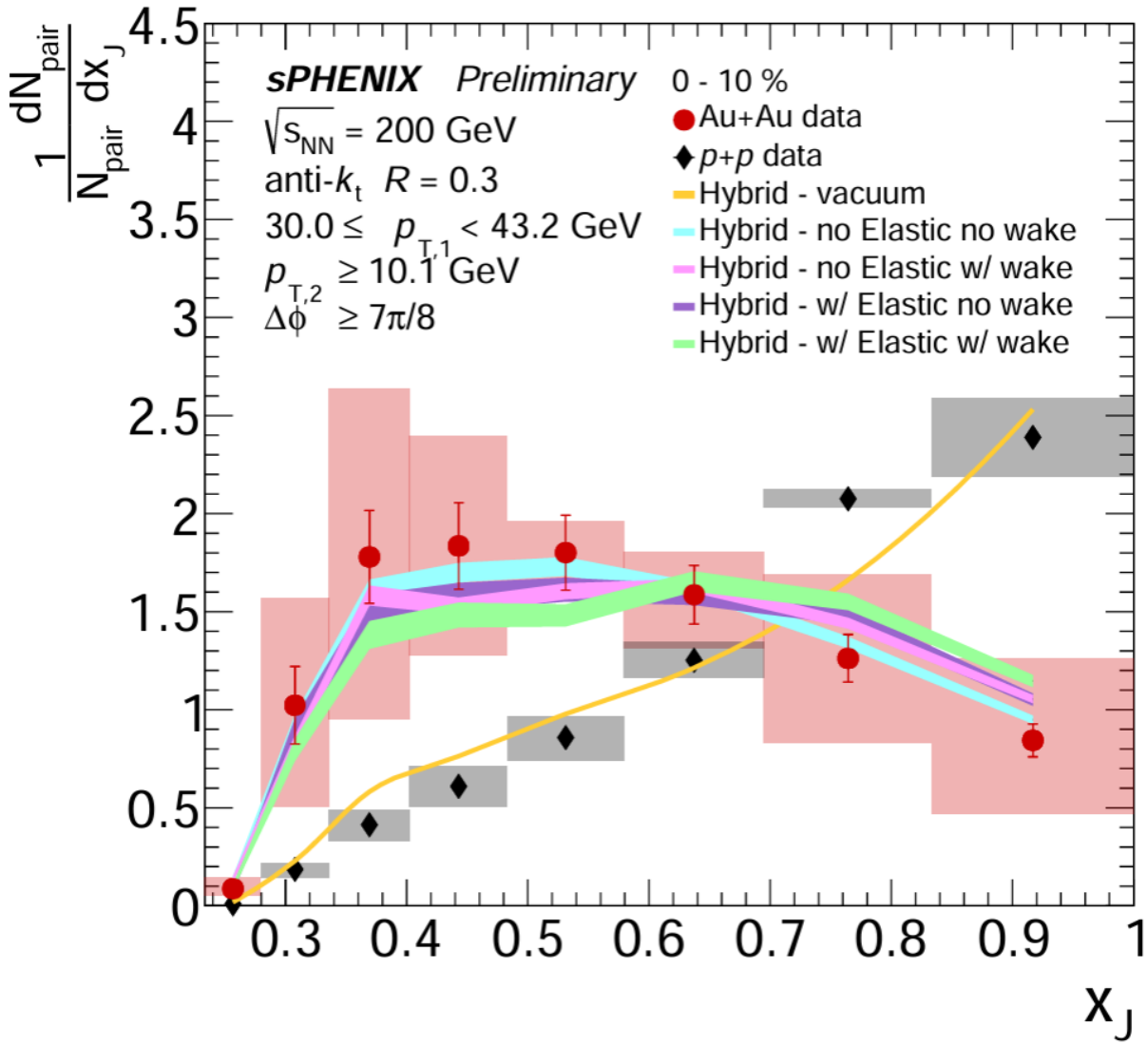




First Λ_c and D^+ results in *p*+*p* at RHIC

SUMMARY

- Large datasets have been collected in ***p+p***, **Au+Au**, and **O+O**
- Preliminary hard probe results in *p+p* have significant kinematic reach at RHIC energies
- First jet energy loss result from sPHENIX in Au+Au
- Massive calibration effort with rapid progress in both light and heavy flavor tracking



sPHENIX public results: https://www.sphenix.bnl.gov/PublicResults