sPHENIX Prospects for Heavy Flavor Physics & Tracking Detectors Status Update

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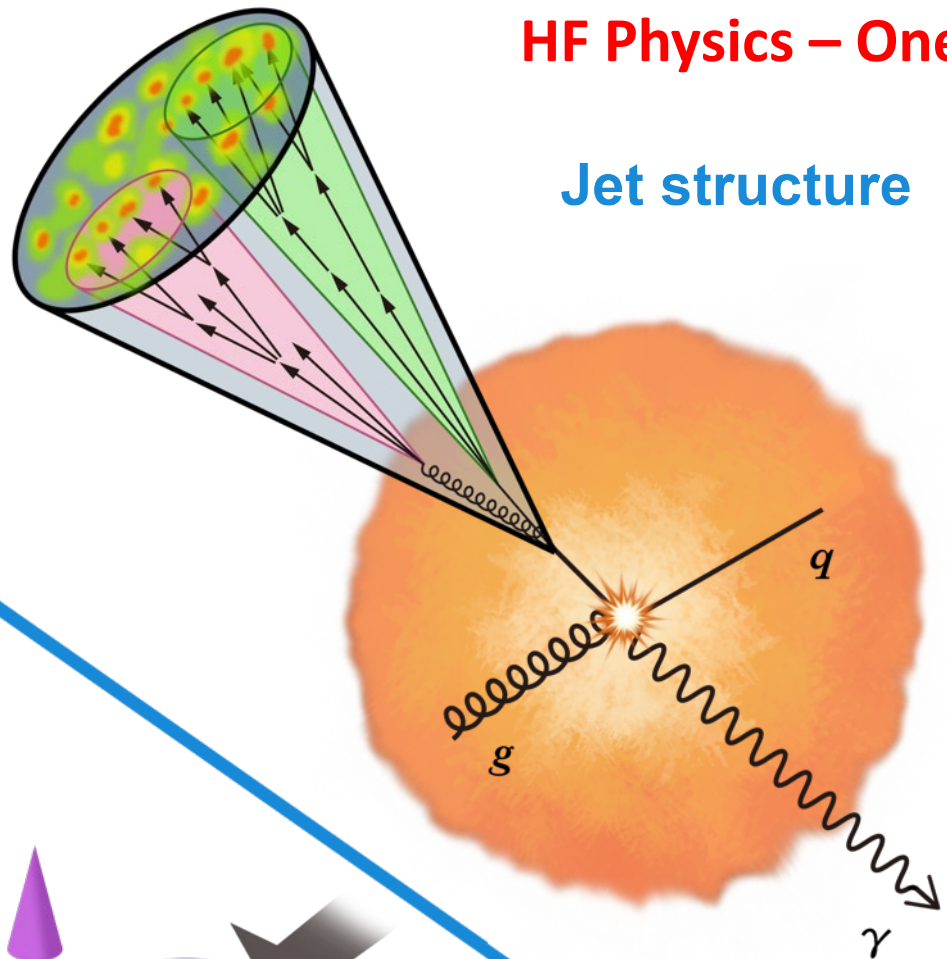
For the sPHENIX Collaboration
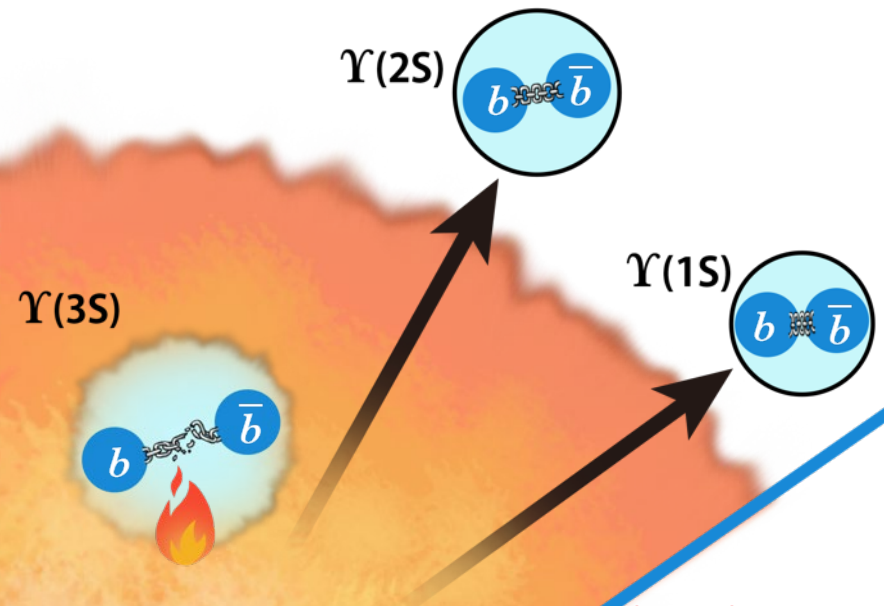
SQM2024, June 3-7, 2024 Strasbourg, France

HF Physics – One Cornerstone of sPHENIX Scientific Program
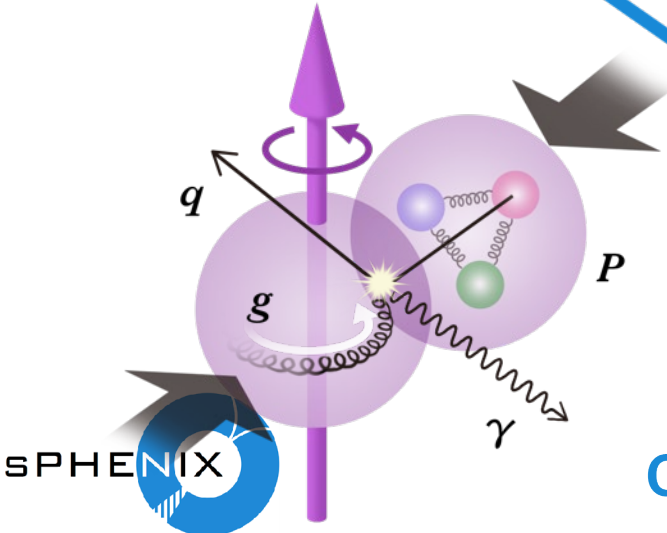
Jet structure

Quarkonium spectroscopy

$\Upsilon(2S)$

b — $\bar{b}$

$\Upsilon(1S)$

b — $\bar{b}$

$\Upsilon(3S)$

b — $\bar{b}$

q

g

γ

Physical Dynamics are inter-correlated !
-- HF tagged jets
-- HF probes of gluon structure
-- HF probes of QGP bulk properties

u, d, s

c

b

Cold QCD

q

g

P

γ

sPHENIX

Parton energy loss

sPHENIX Detectors All Critical for HF Physics

Unique sPHENIX Detector Capabilities – Enable

    -- Direct Reconstruction from Hadronic Decays for D^0, $D^{\pm}$, D_S and Λ_C

    -- Tagged charm and bottom decays:

                           semi-leptonic decays C $\rightarrow$ e+X and B $\rightarrow$ e+X

                           B $\rightarrow$ D+X

    -- C/B tagged jets

All sPHENIX Detectors Critical:

    -- TPC, TPOT, INTT and MVTX + Stream Readout

    -- EMCal, IHCal, OHCal

    -- Min Bias Detector (MBD), sPHENIX Event-Plane Detector (sEPD), ZDC

Hard Probes -- High p_T region means p_T > 6 GeV/c

STAR (Au+Au; $\sqrt{s_{NN}}$ = 200 GeV; Mid-rapidity)

K_S^0 $\frac{K^+ + K^-}{2}$ $\Lambda + \overline{\Lambda}$ $\frac{h^+ + h^-}{2}$

R_{CP}

$[dn/(N_{binary} dp_T)]^{peripheral}$

$\frac{0-5\%}{40-60\%}$

Scaling
—— binary
—·— participant

$[dn/(N_{binary} dp_T)]^{central}$

$\frac{0-5\%}{60-80\%}$

Transverse Momentum p_T (GeV/c)
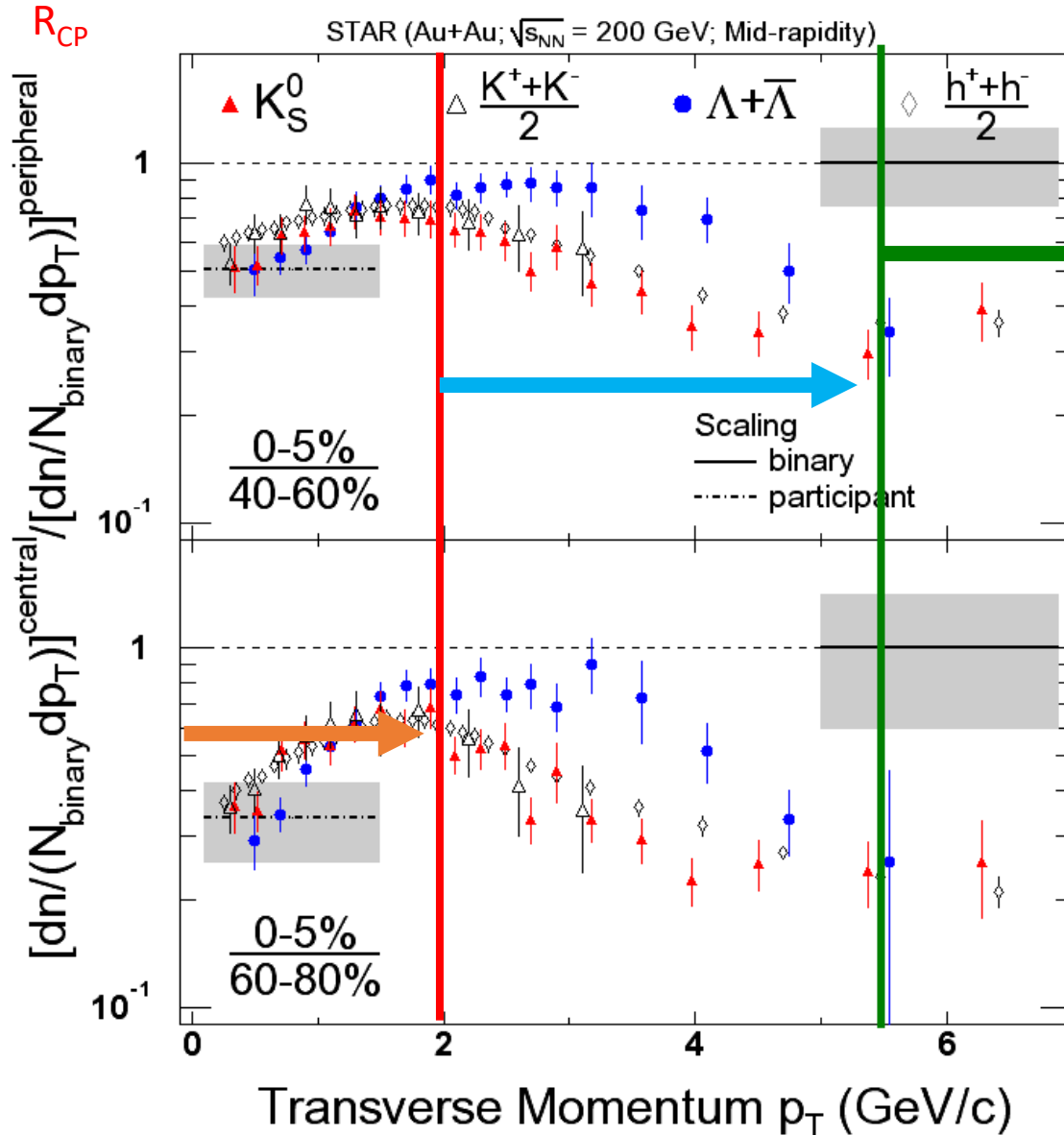
Three Distinct P_T Regions:

-- **Fragmentation**

-- **Multi-parton dynamics (recombination or coalescence or …)**

-- **Hydrodynamics (constituent quarks ? parton dynamics from gluons to constituent quarks?)**

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sPHENIX Heavy Flavor Physics – Broad Perspectives

$P_T < 6$ GeV/c Region

Hydrodynamics   -- **Diffusion in QGP**
                 -- **Particle mass effect**

Coalescence/Recombination
                 -- **baryon versus meson**
                 -- **Origin of collective flow**

sPHENIX – greater statistics
                 -- **rare heavy particles**
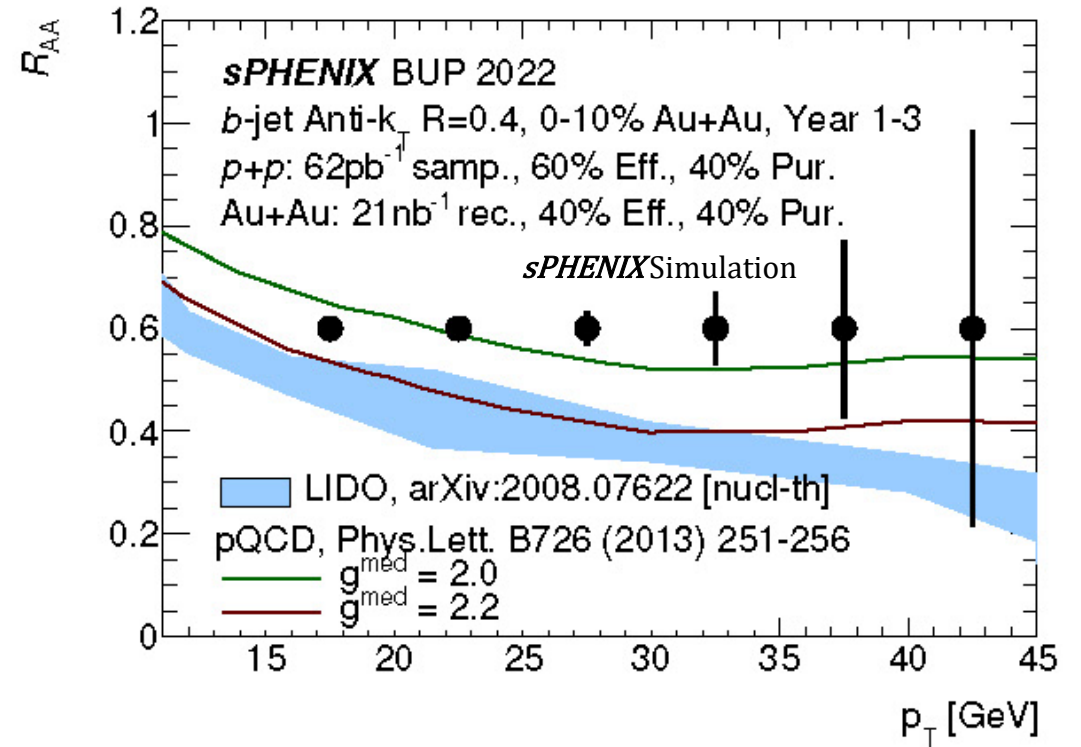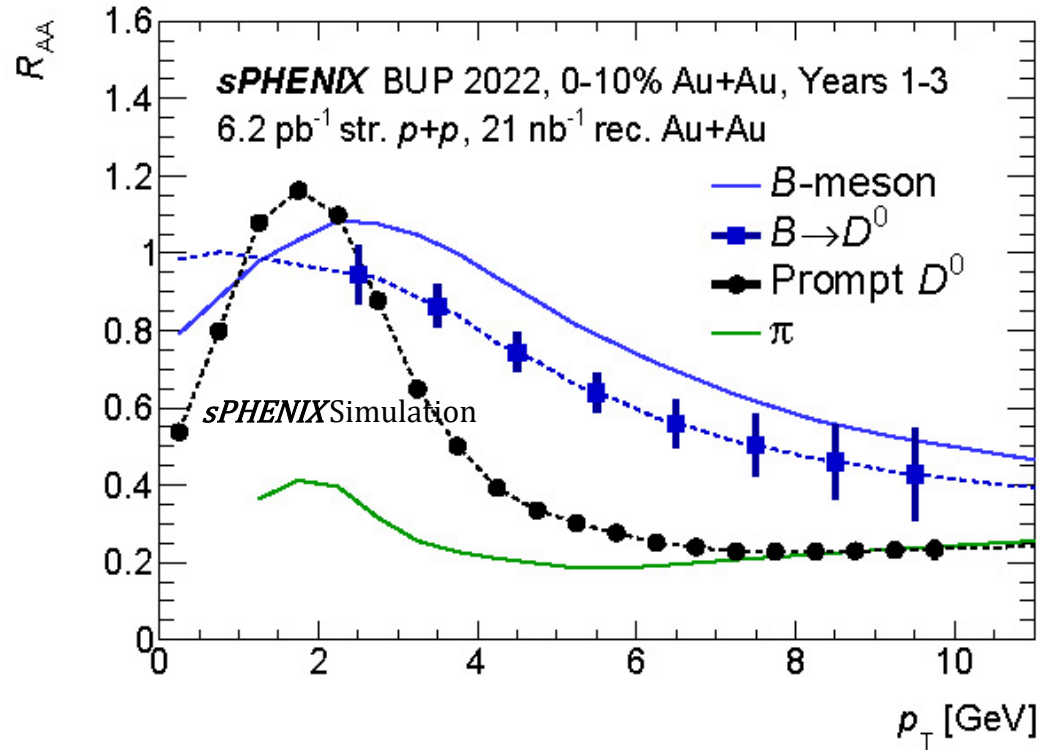
$P_T > 6$ GeV/c Region

Jet energy loss mechanism:
                 -- **quark mass dependence**
                 -- **radiative versus collisional**

Origin of jet collectivity
                 -- **path length dependence of**
                       parton energy loss
                 -- **Non-flow correlations**

Medium responses to jet energy loss

sPHENIX Unique @RHIC

Expectations from sPHENIX Beam Use Request

**High pT region for single particle (pT > 6 GeV/c) and for jets
– Key ingredients for sPHENIX science**

Expectations from sPHENIX Beam Use Request
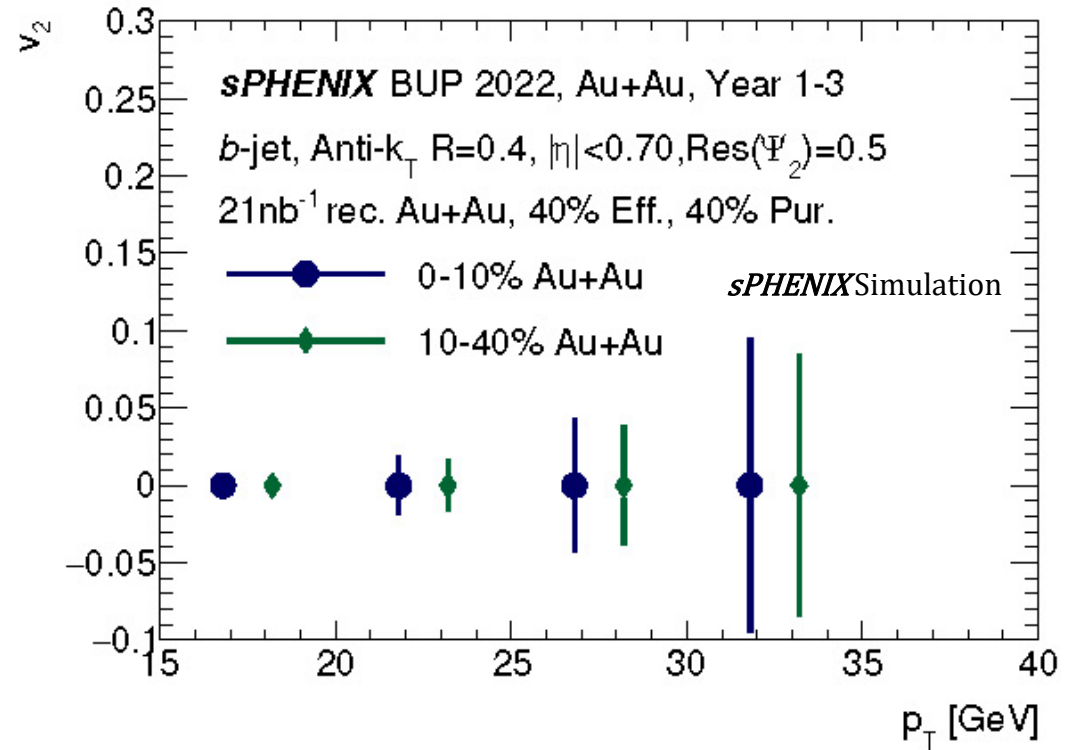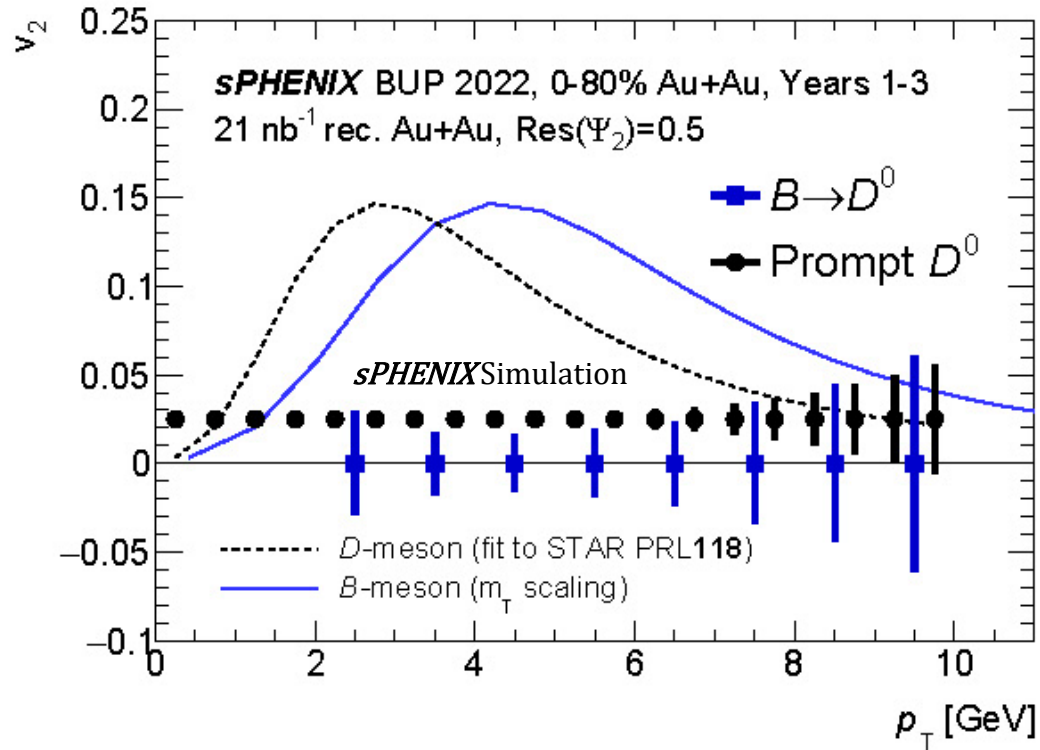
The B meson/jet measurements will always be statistics limited; ML applications to improve efficiency and purity !
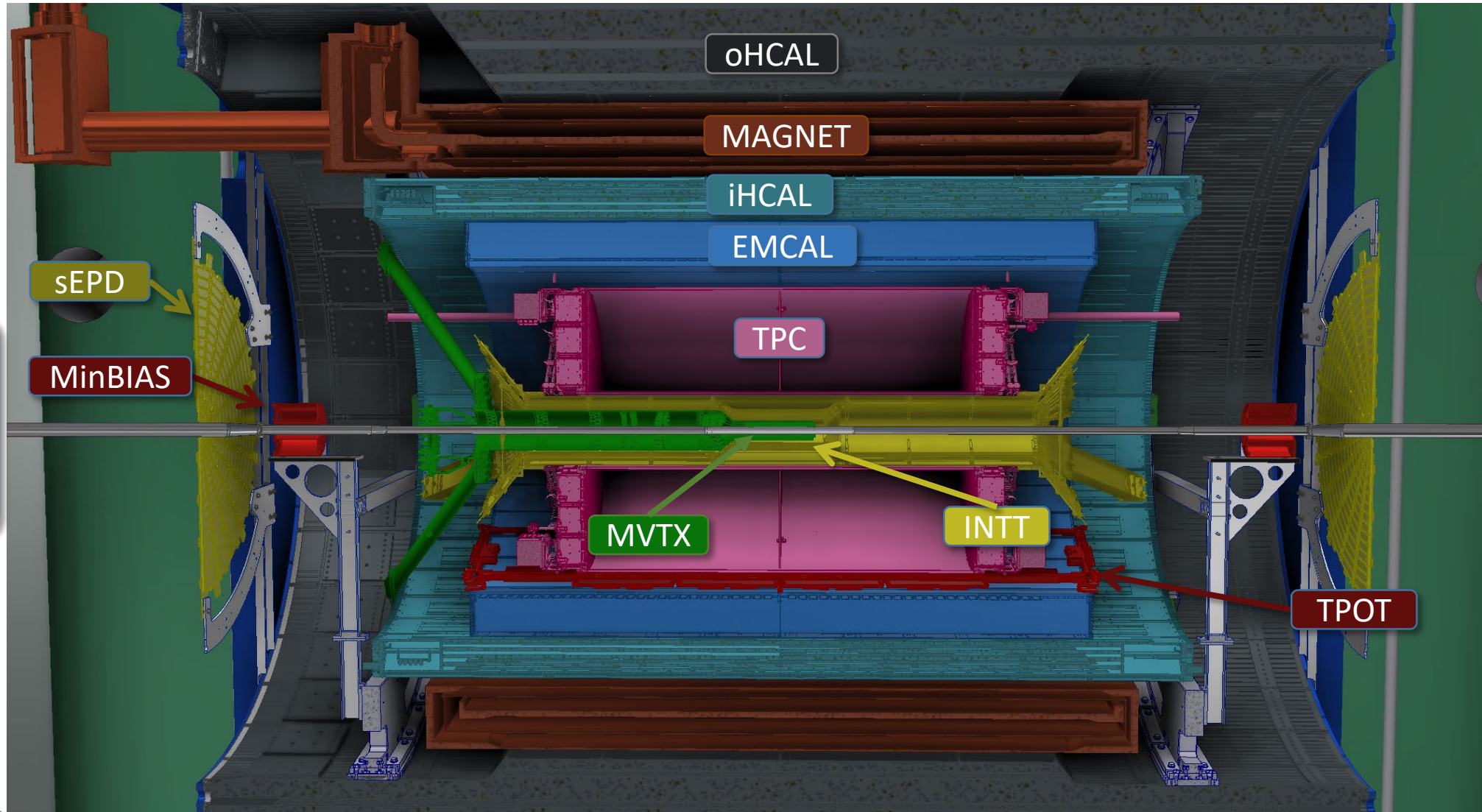
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Charm Baryons – Key probe for hadronization dynamics and charm flow
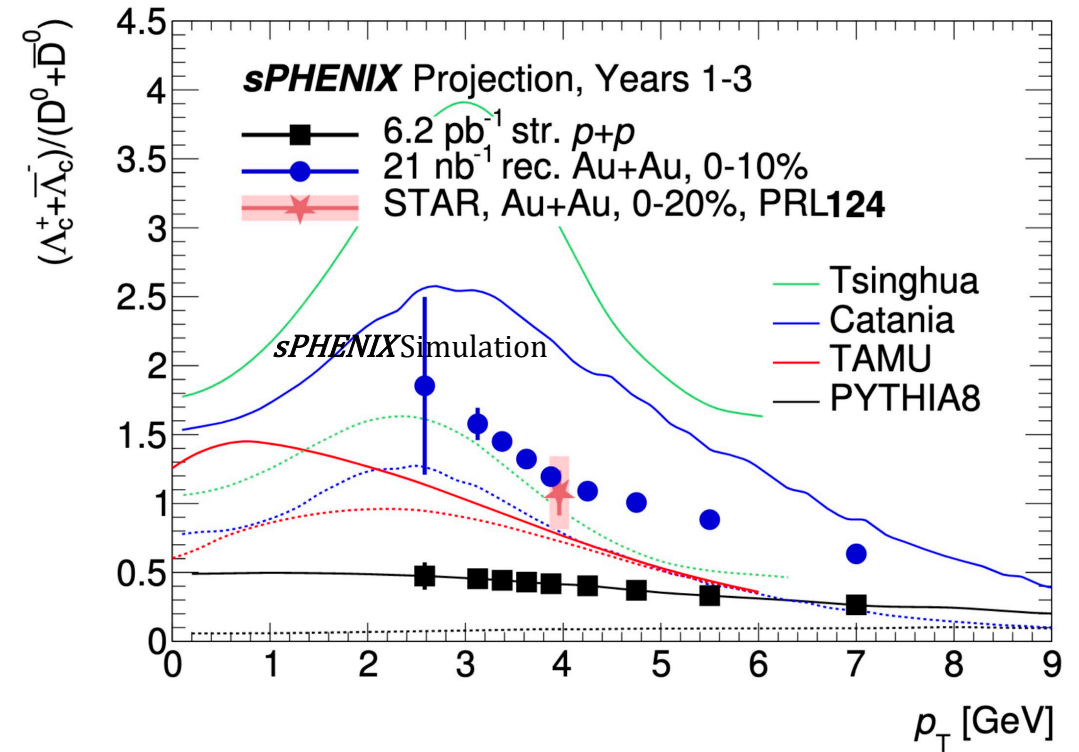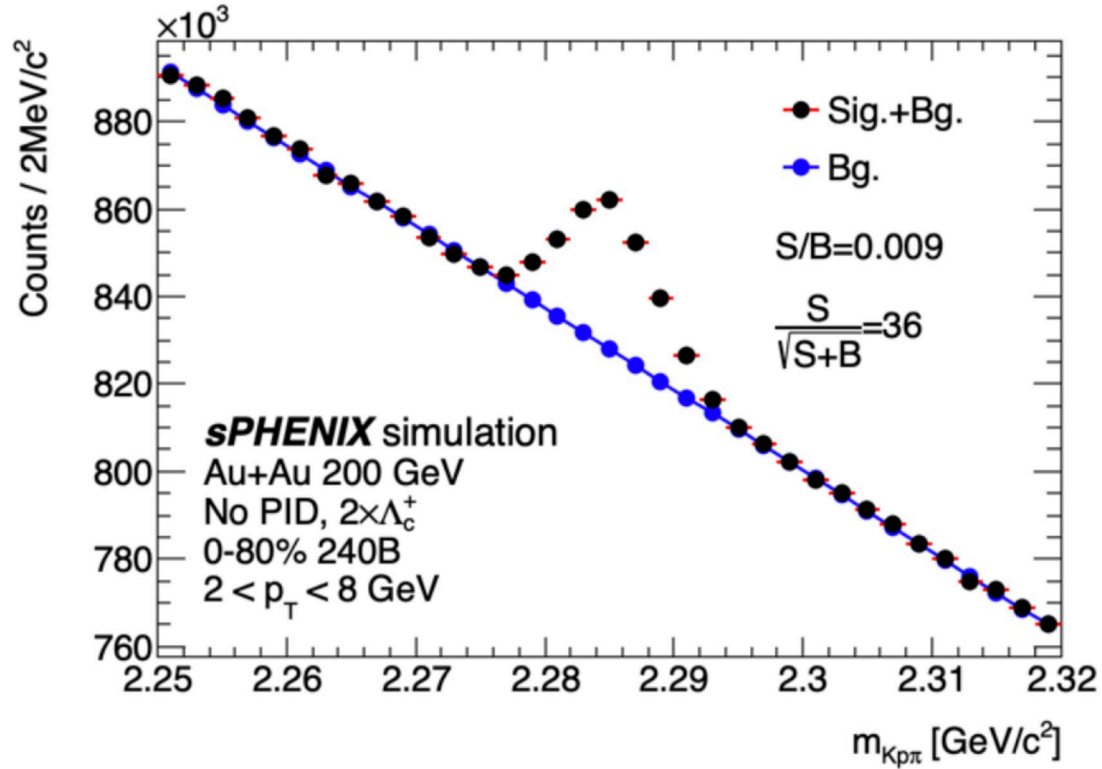
**Tracking detectors Stream Readout for p+p collisions – major advantage for sPHENIX
-- allow for p+p reference data from the same experiment**

Other charm baryons Ξ_c Ω_c ?
$\Lambda_b \rightarrow \Lambda_c$ X ??

The sPHENIX detector

The Time-Projection Chamber

1.6 m

2.11 m

EP w/ modules

CM

O-FC

I-FC

72 modules
2(z), 12(φ), 3(r)

Quad-GEM Gain Stage
Operated @ low IBF

"Cathode Wedge"

Inside of TPC field cage

Run 2024 p+p Data

05/28/2024

sPHENIX Preliminary
p+p, ~210k events
Uncalibrated TPC-only
r(SV) ≥ 3 cm

Data
K_S^0 PDG Mass
Fit
$K_S^0 \rightarrow \pi^+ \pi^-$
Comb. Bkg.

05/28/2024

sPHENIX Preliminary
p+p, ~210k events
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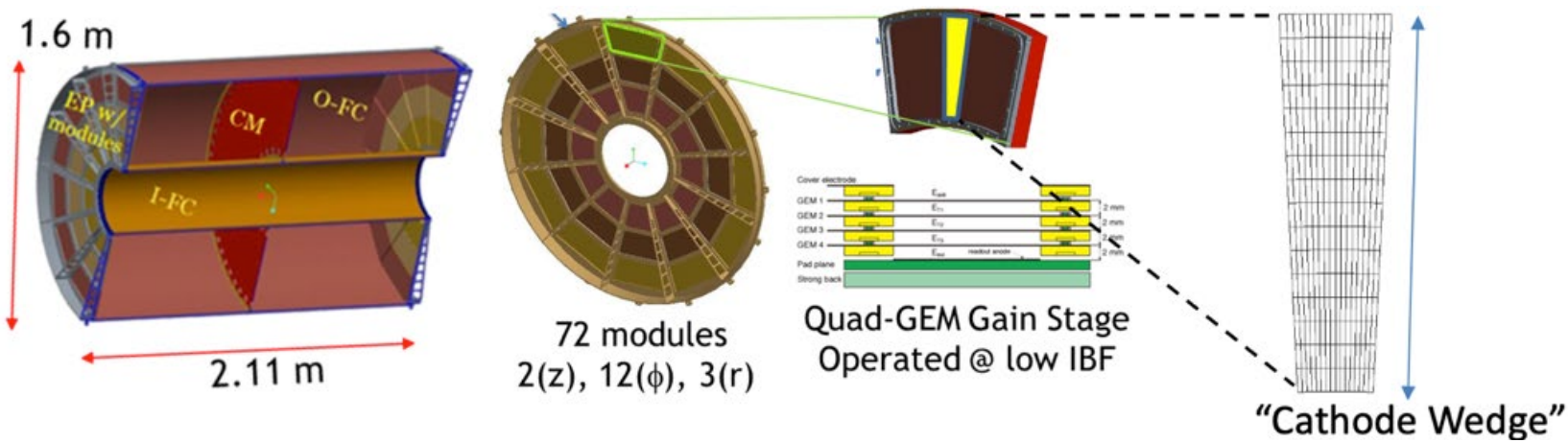
Data
Λ^0 PDG Mass
Fit
$\Lambda^0 \rightarrow p^\pm \pi^\mp$
Comb. Bkg.
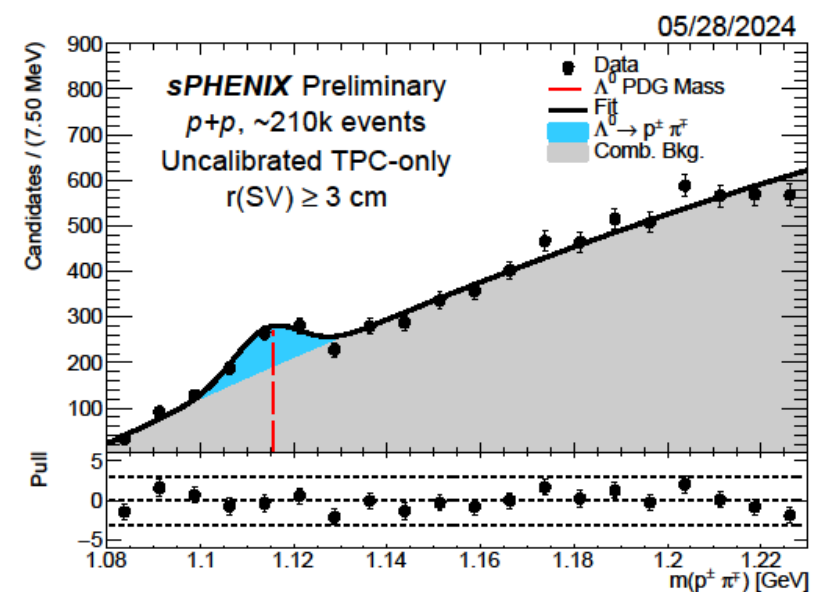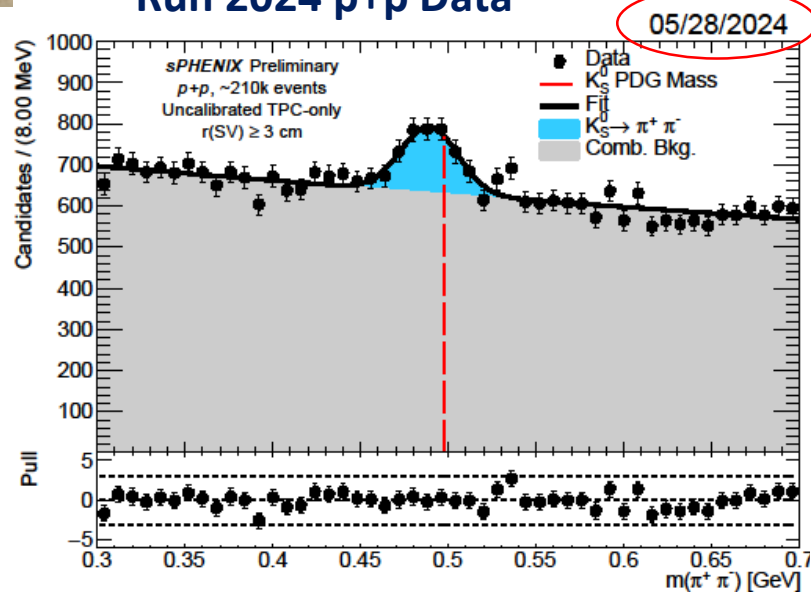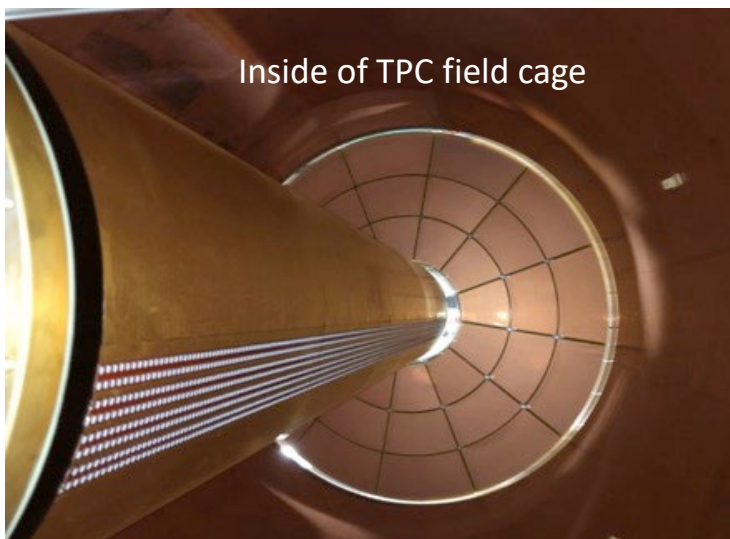
The Time Projection Outer Tracker (TPOT)

- **The TPOT consists of eight identical modules, two Micromegas chambers/module. Each module is 56x32 cm^2.**

- **TPOT has approximately 8% coverage of the TPC acceptance.**

- **Gas is 95/5 Ar/iC4H10.**

- **TPOT provides additional spatial reference points outside of the TPC to calibrate for beam induced space charge distortions.**
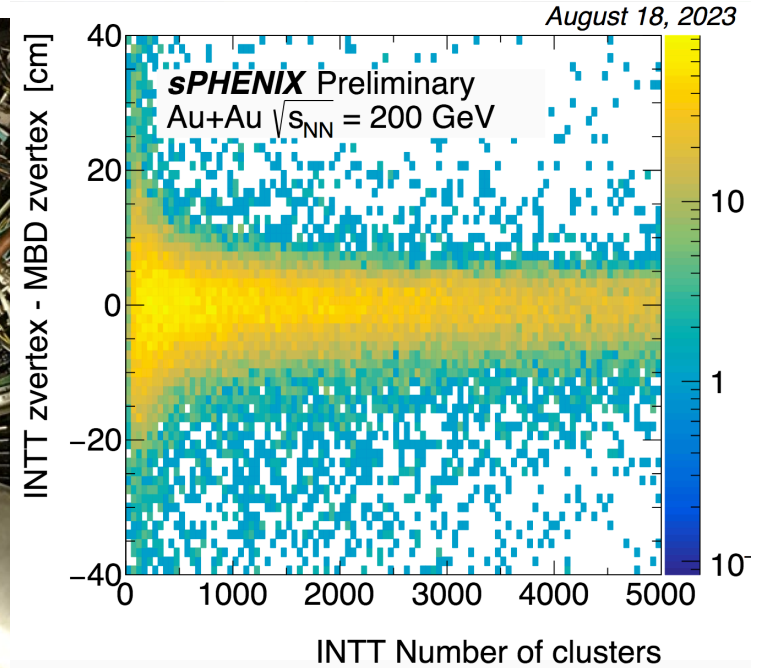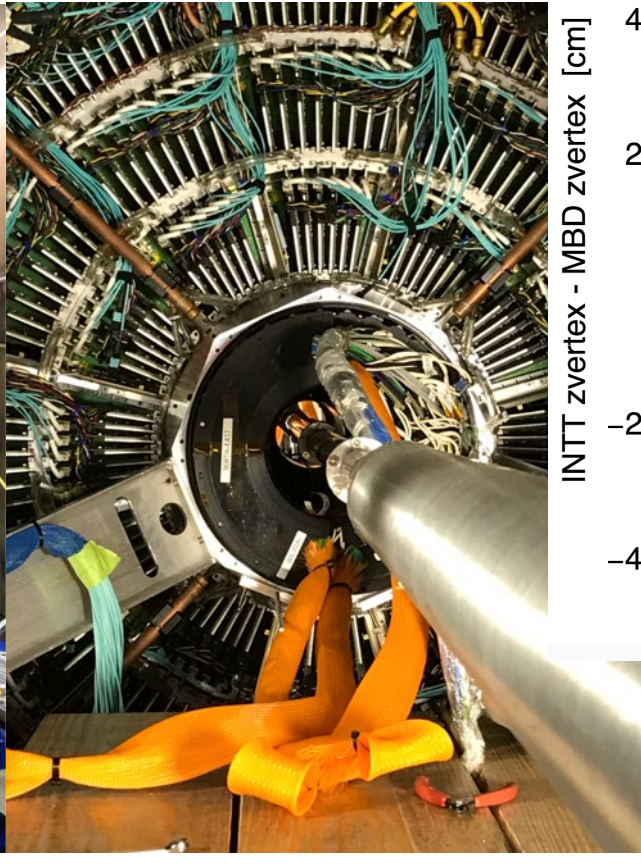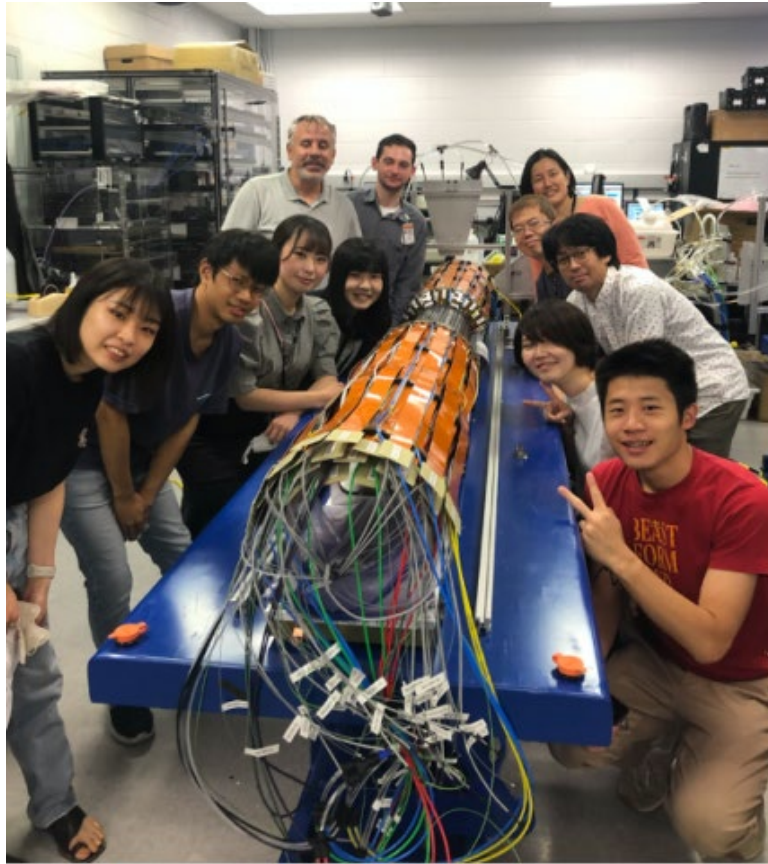
arXiv: 2403.13789, submitted to NIMA

07/11/2023

sPHENIX Preliminary
Au+Au $\sqrt{s_{NN}}$ = 200 GeV

sPHENIX

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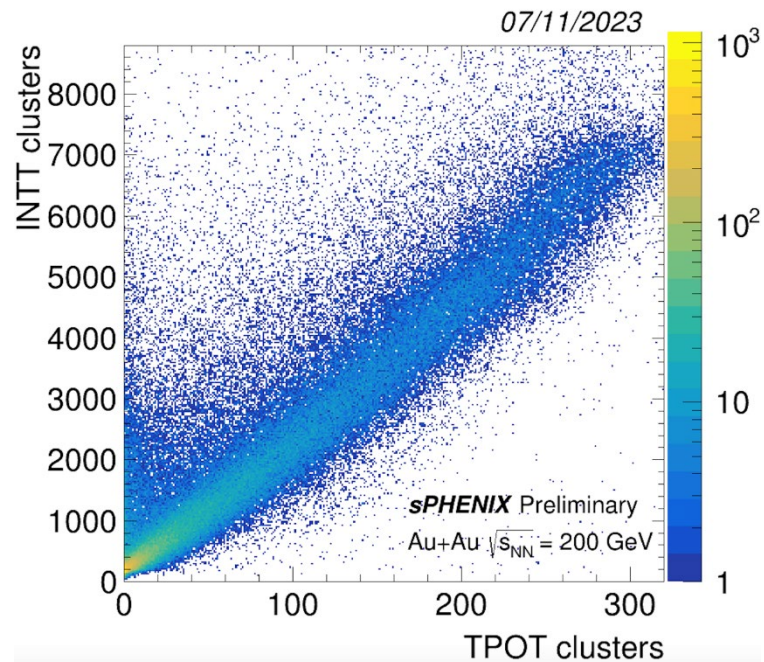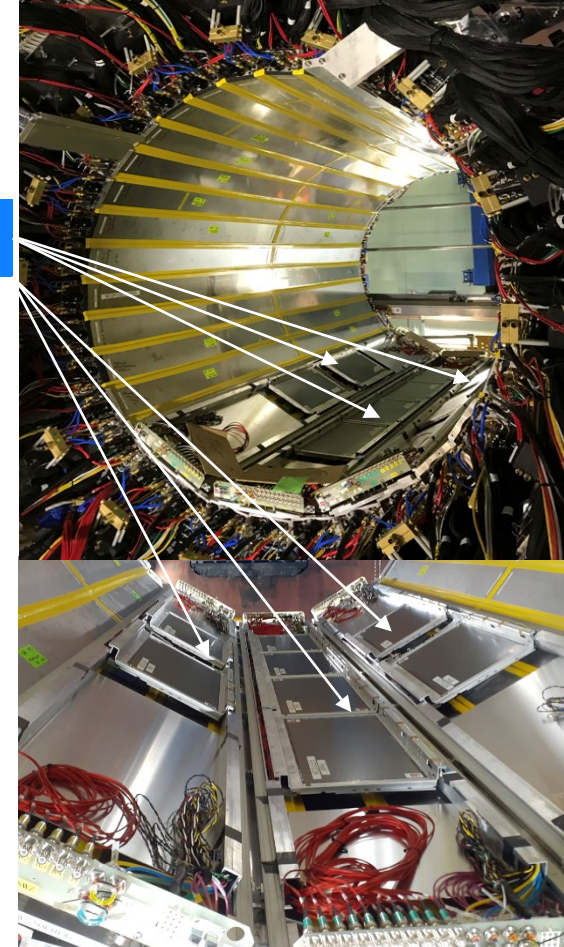
sPHENIX Intermediate Tracker (INTT)

Two-layer silicon-strip detector.

Fast response time of 60 ns allows for time stamp of collisions in stream readout for pile up rejections

Monolithic Active Pixel Vertex Detector (MVTX)

- **The MVTX is a 226M channel, 3-layer MAPS-based pixel detector.**
- **The MVTX is a copy of inner 3 layers of the ALICE ITS w/ a custom design of service supports**
- **Staves and ROCs produced at CERN w/ participation from sPHENIX collaborators**
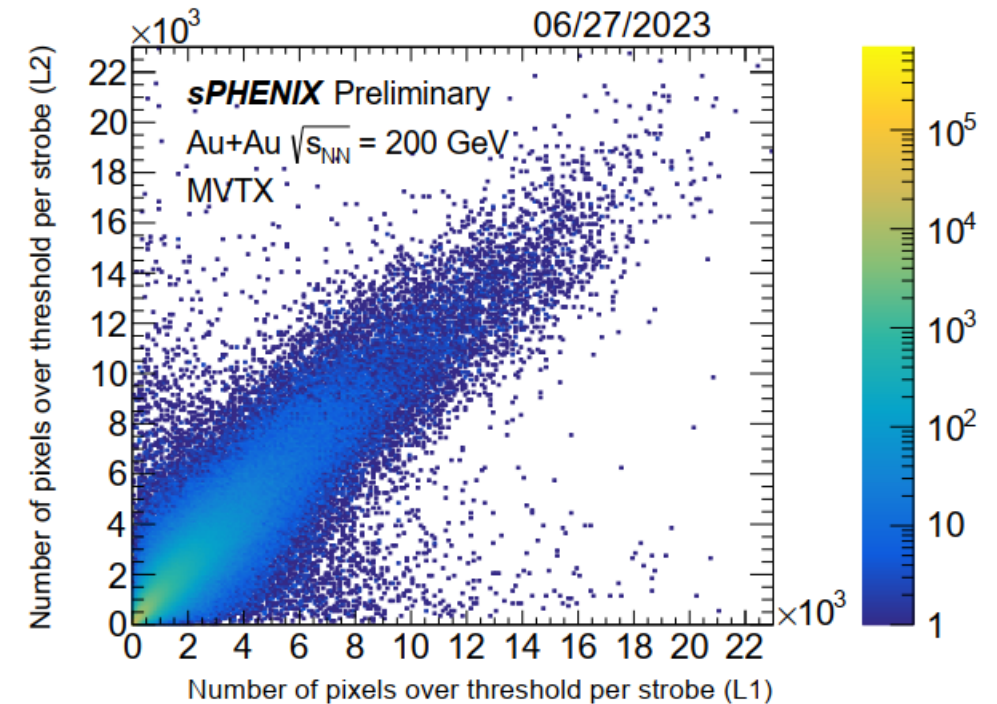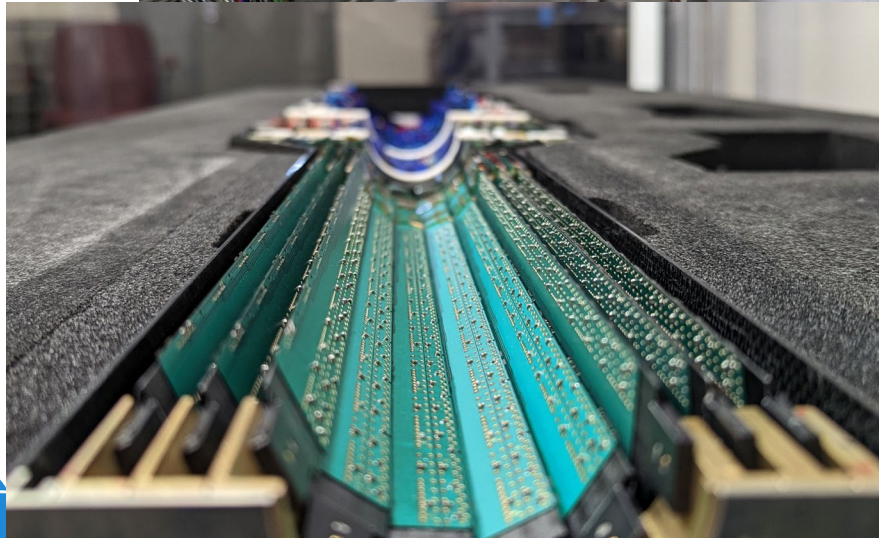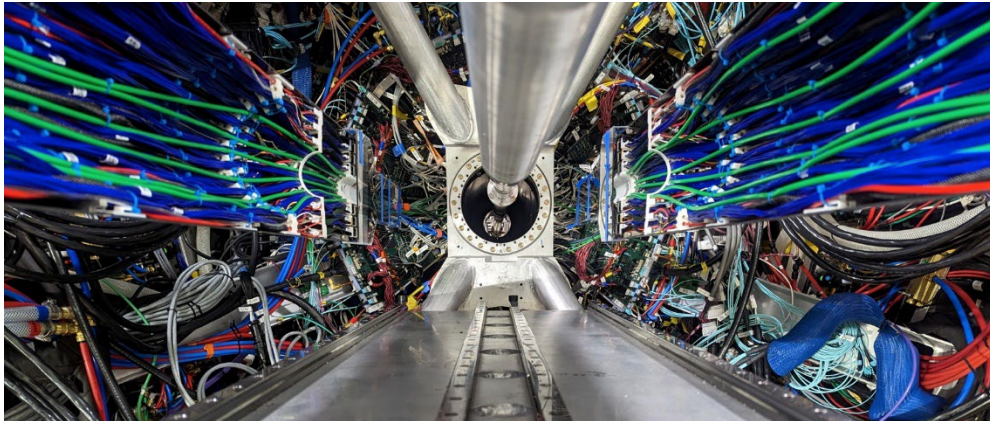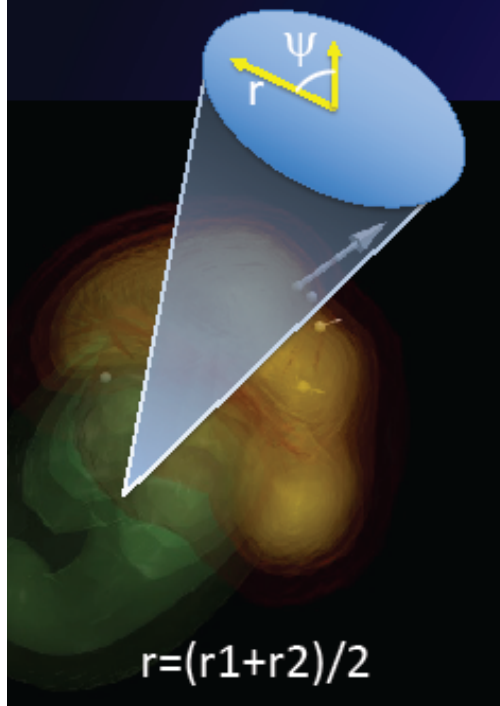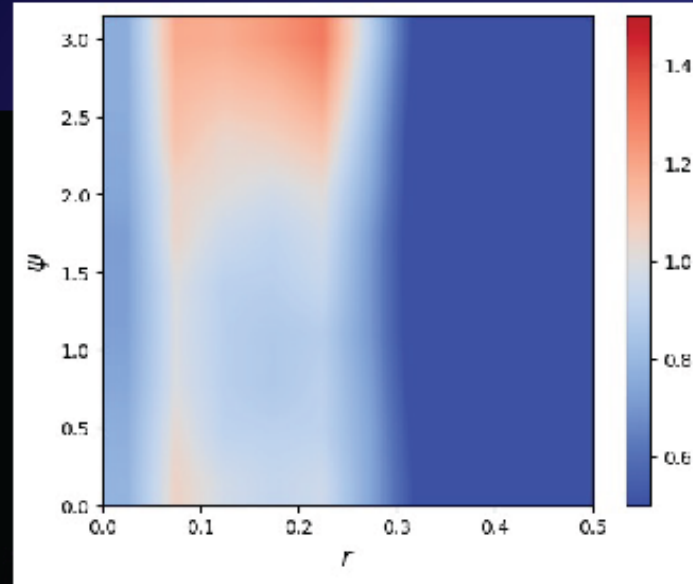

Stream readout

Exciting New Physics Opportunities to Explore at RHIC

XinNian Wang Recent Proposal for Mach-cone Search with γ-jet
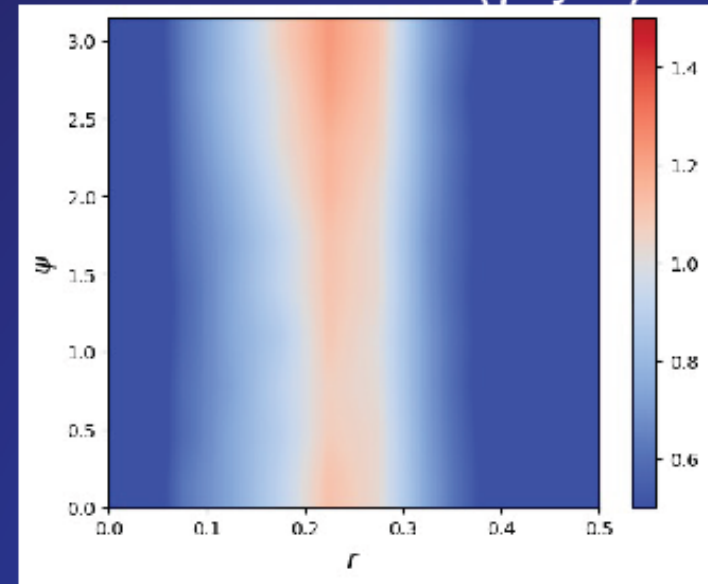
We hope to extend the method for heavy flavor jets

Summary and Outlook

The sPHENIX tracking detectors are taking p+p data with stream readout TOGETHER at a rate ~ 15 kHz

The HF physics requires 10's micron vertex resolution –
   the collaboration is working intensively on alignment/calibration to achieve this goal !

It is an exciting period from now to the SQM2026!

Stay tuned for future sPHENIX results:
https://www.sphenix.bnl.gov/PublicResults