2025 RHIC/AGS ANNUAL USERS' MEETING

RHIC 25:

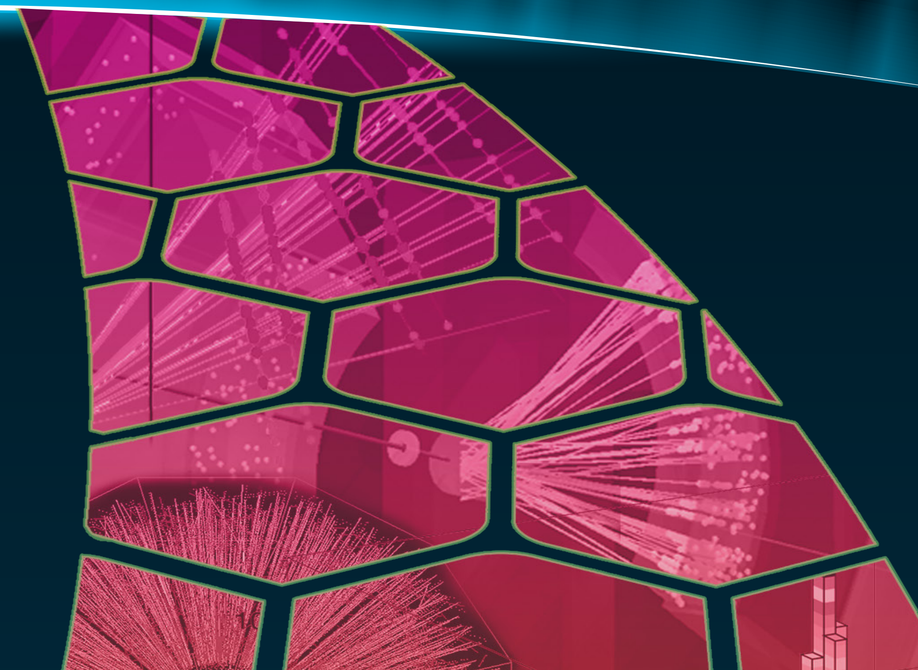
A quarter century of discovery

May 20-23, 2025

From RHIC to the LHC and Back Again

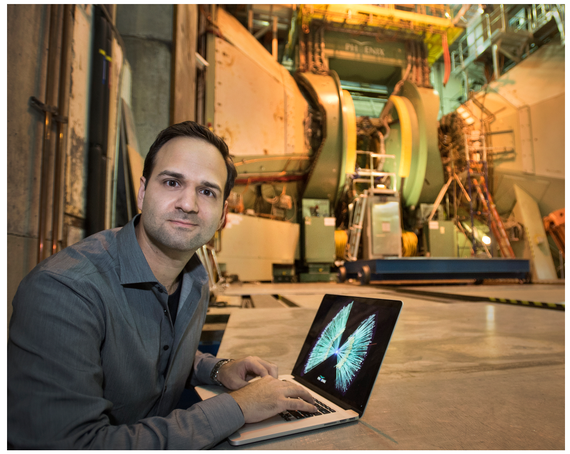
Dennis V. Perepelitsa

University of Colorado **Boulder**



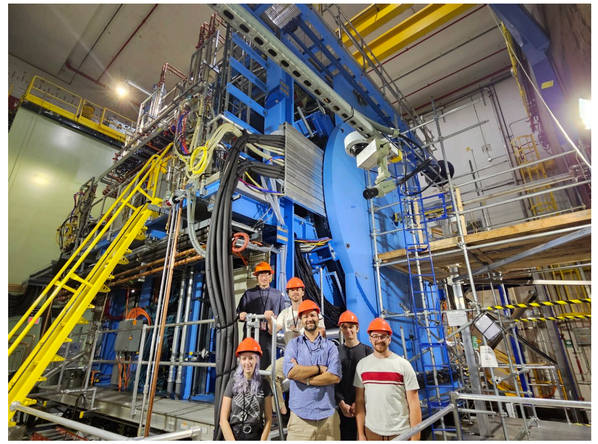
A (partially personal) reflection on what we learned from heavy ions at the LHC, how we brought that knowledge back to RHIC, and what QGP physics we can do **better**

This symposium talk is focused on **sPHENIX**



RHIC-PHENIX
(decommissioned 2016)

LHC-ATLAS
(heavy ions starting in 2010)



RHIC-sPHENIX
(start commissioning 2023)

PHENIX

ATLAS EXPERIMENT

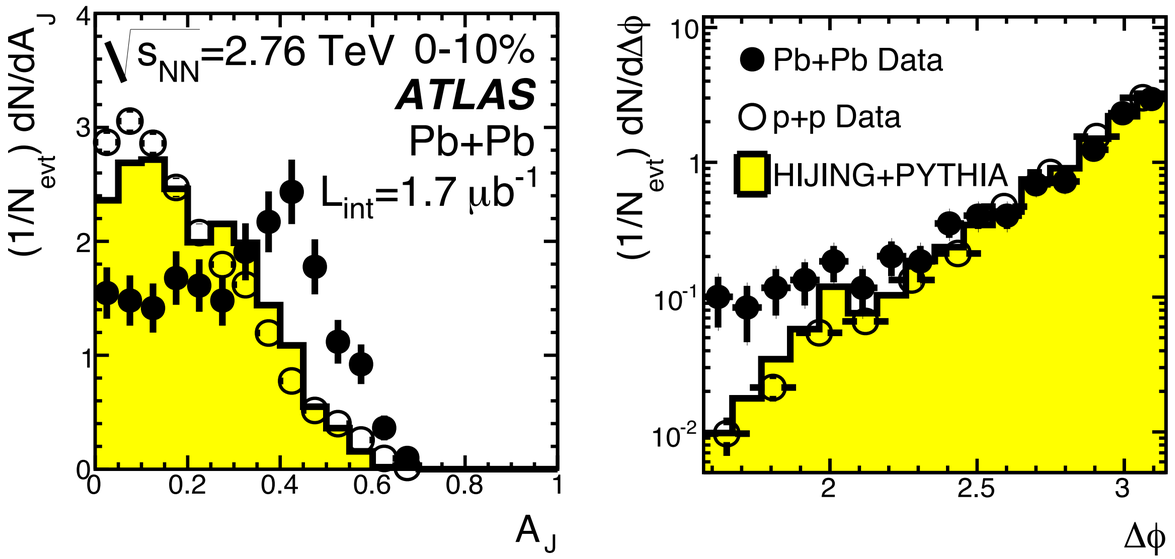
sPHENIX

In sPHENIX, **many exceptional and hard-working young scientists** are dedicating the start of their careers to a totally new collider detector

sPHENIX “Heroes” Page

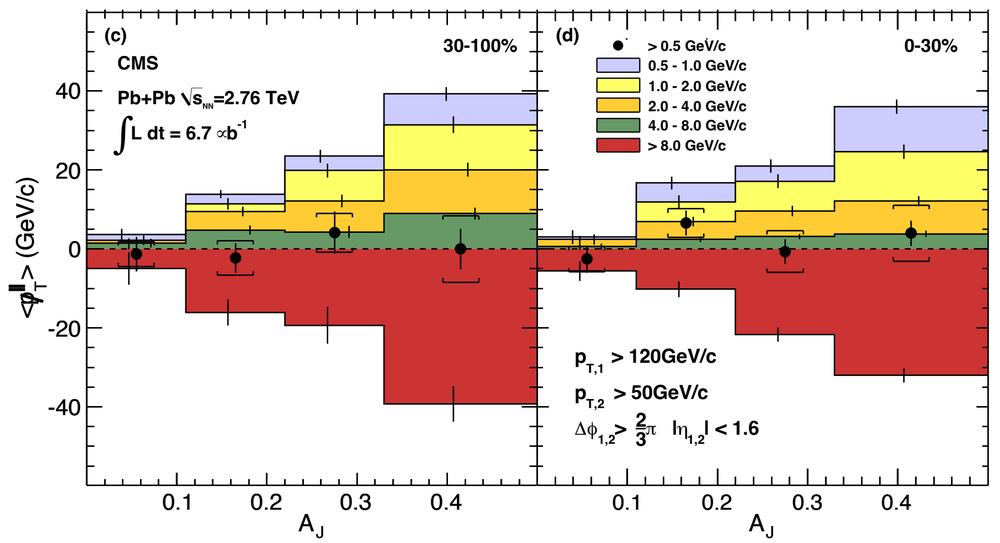
Shock and awe from first LHC results

ATLAS PRL 105 (2010) 252303



Event-by-event jet quenching!

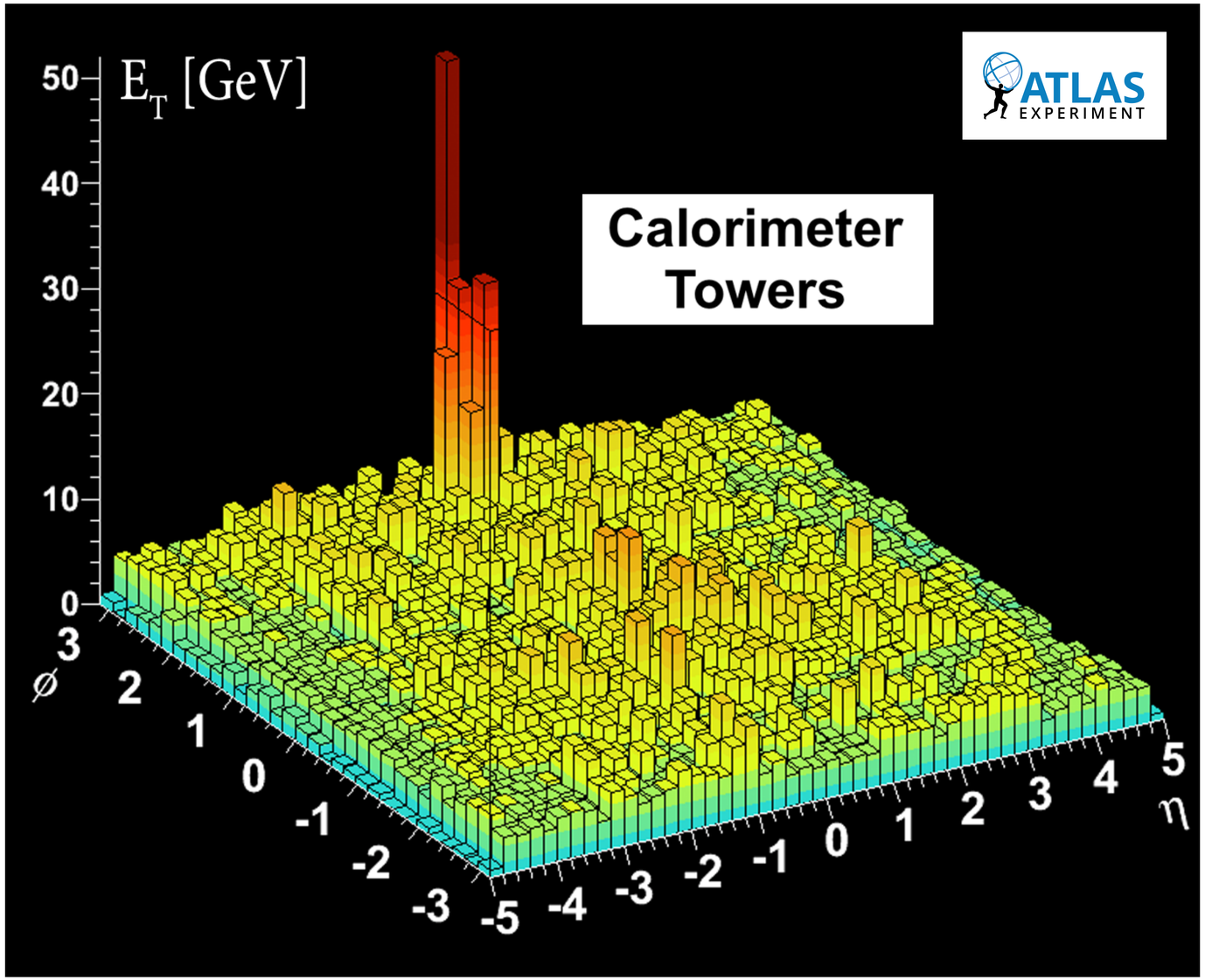
CMS PRC 84 (2011) 024906



Dissection of quenched energy flow!

Dramatic demonstration of the promise of **fully reconstructed jets** in heavy ion collisions

What's needed for event-by-event jet quenching?



1. Full (EM+Hadronic) calorimeter system

To confirm the dijets are indeed asymmetric

2. Large acceptance

To confirm the balancing jet didn't escape the detector

3. High rate

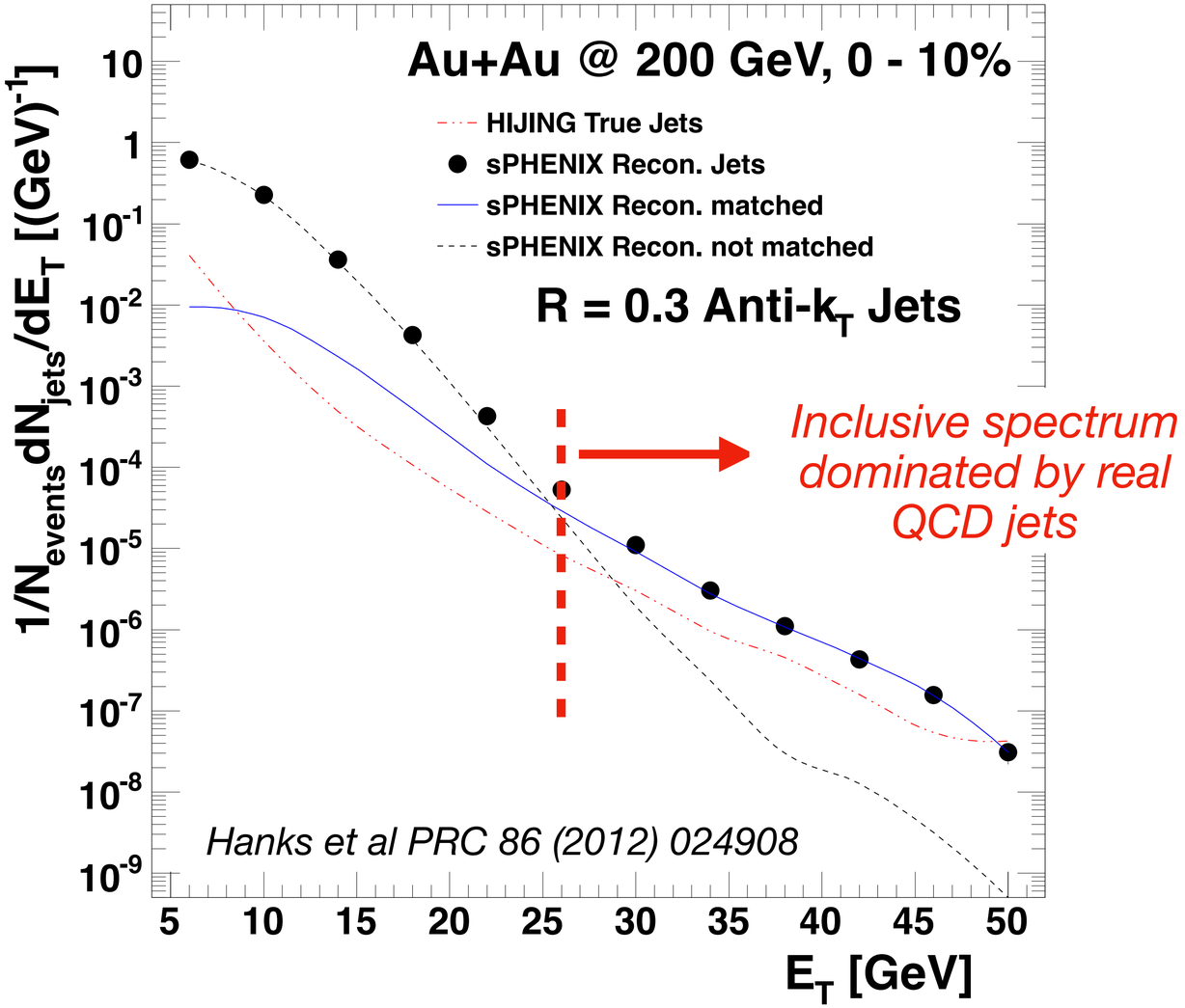
To see rare jet events far above the UE background

Go/no-go for calorimeter jets in AA at RHIC

ATLAS/CMS-style “event by event” estimate & subtraction of underlying event in **full calorimeter system**

Key proof of principle in 2012 that one can identify fake-free p_T thresholds

This algorithm is now the main one in sPHENIX (with small modifications)



Making a concrete proposal

Plans,

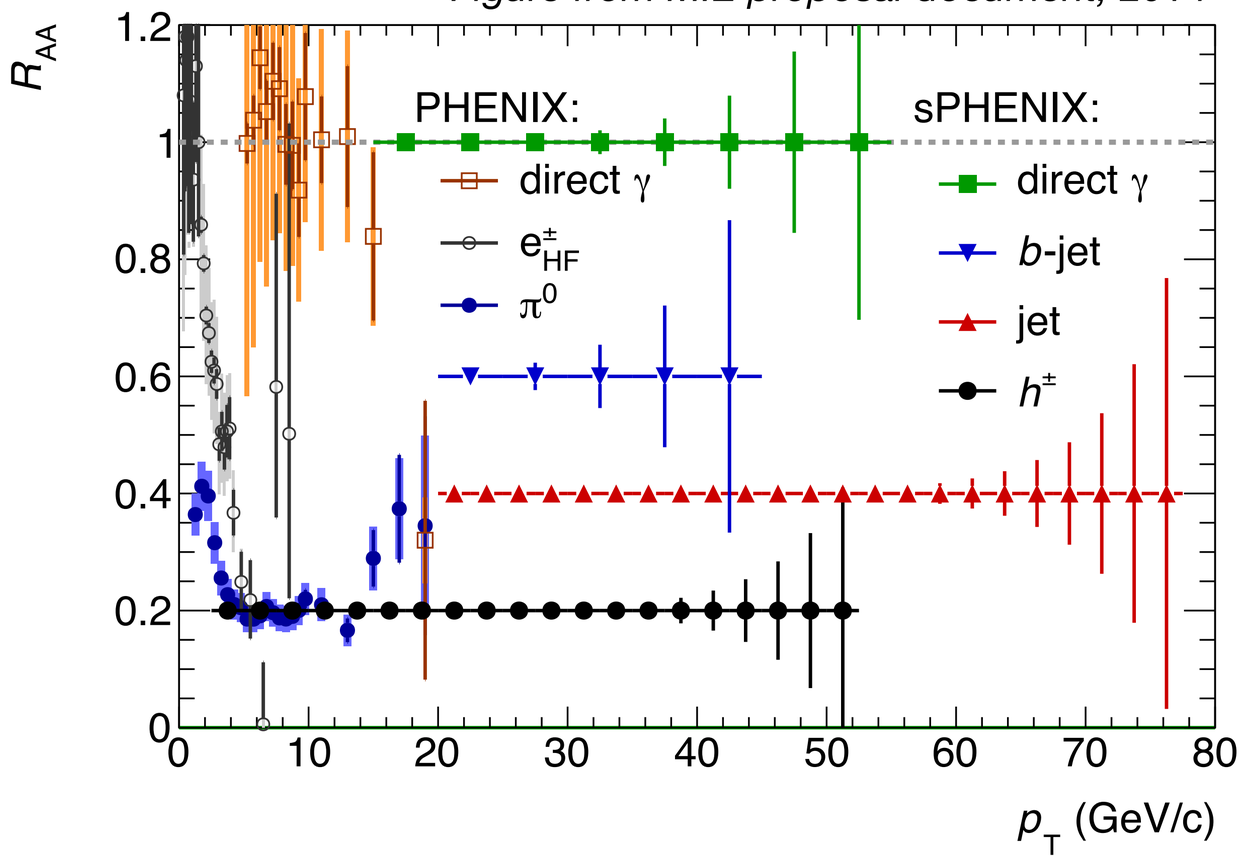
Proposals,

Reports,

Reviews,

…

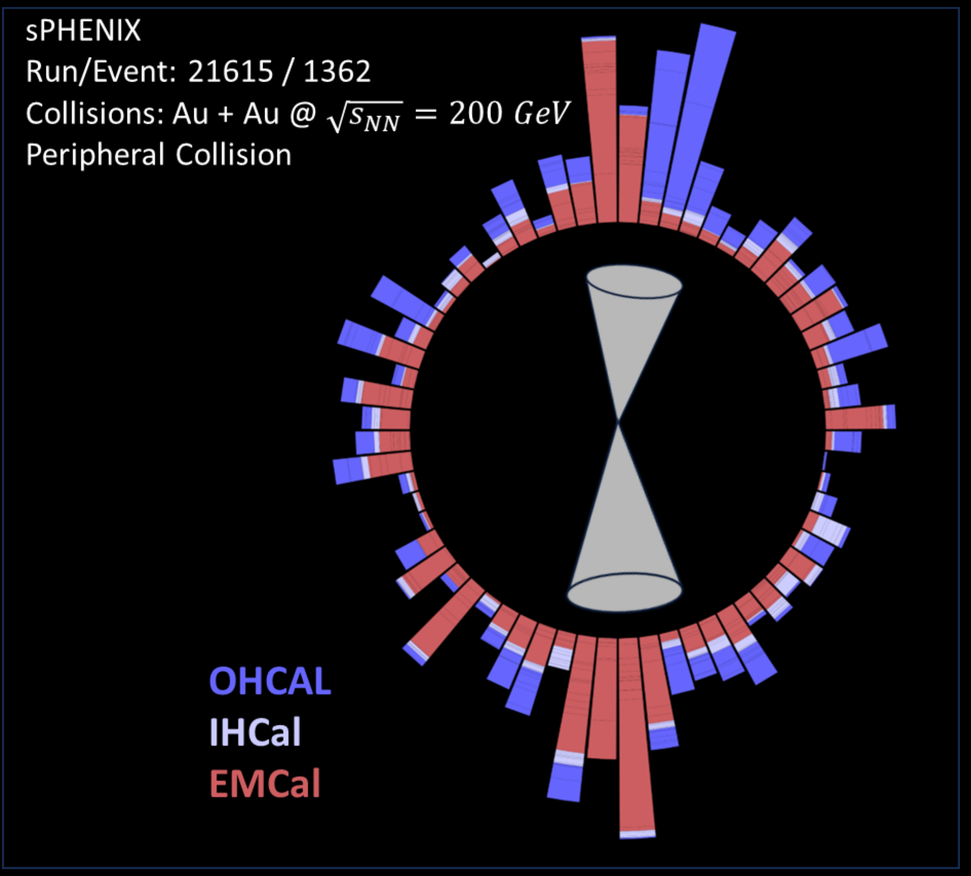
Figure from MIE proposal document, 2014

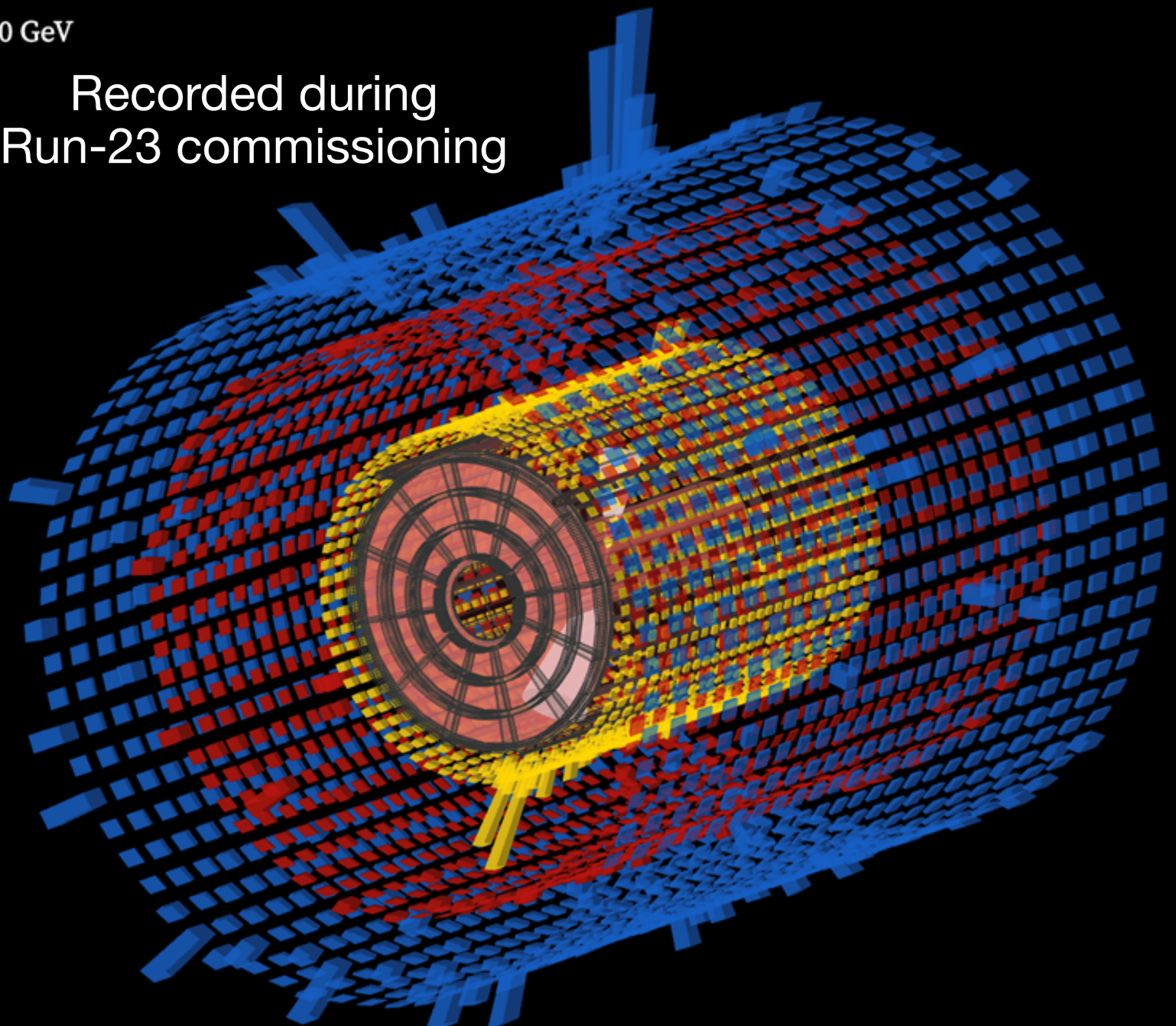


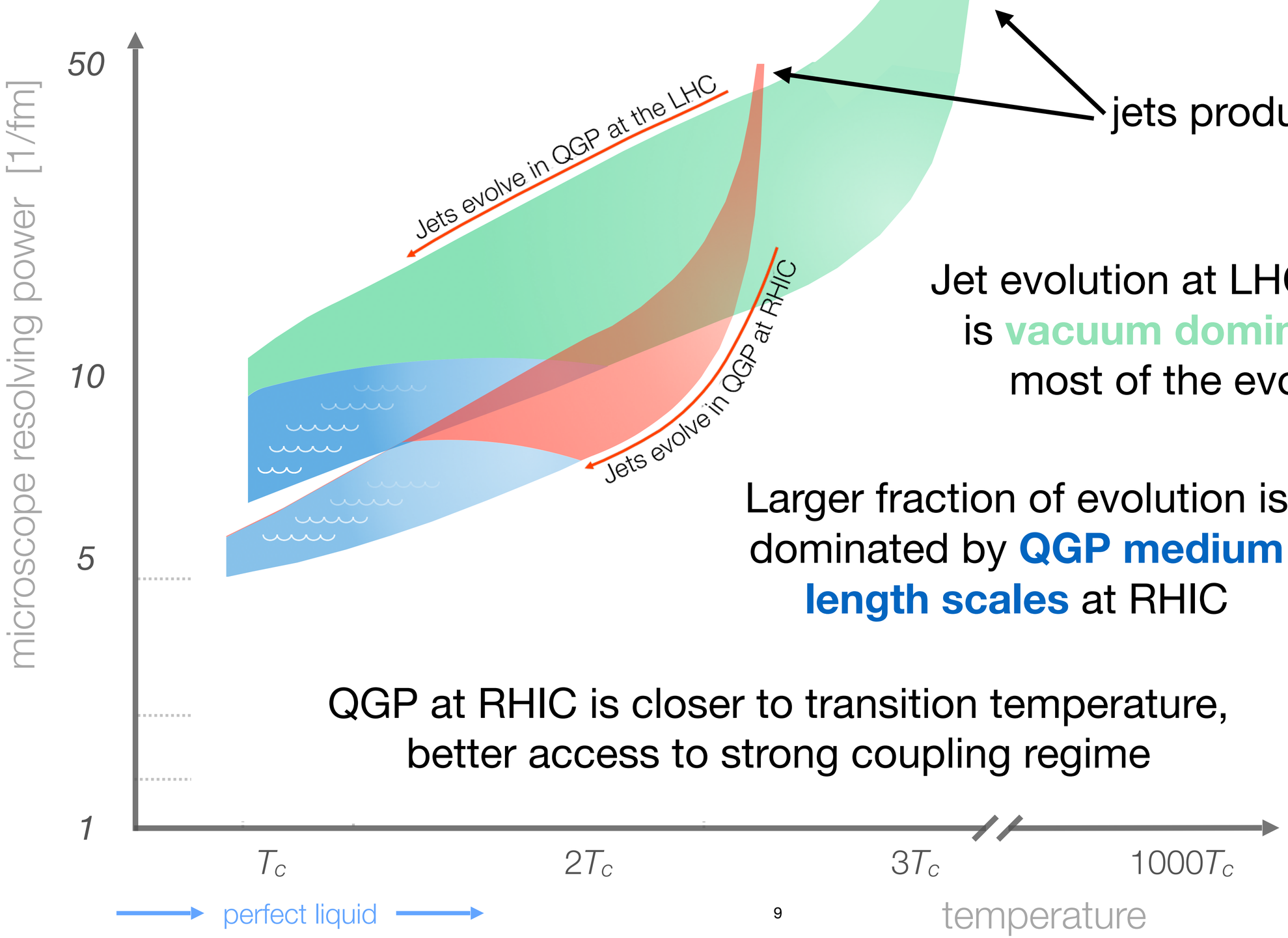
Early quantitative projections of physics reach, given AA luminosity assumptions + sPHENIX acceptance / rate

sPHENIX Experiment at RHIC
Run / Event: 21615 / 1362
Collisions: Au + Au @ $\sqrt{S_{NN}}$ = 200 GeV

Recorded during
Run-23 commissioning







Jet evolution at LHC energies is **vacuum dominated** for most of the evolution

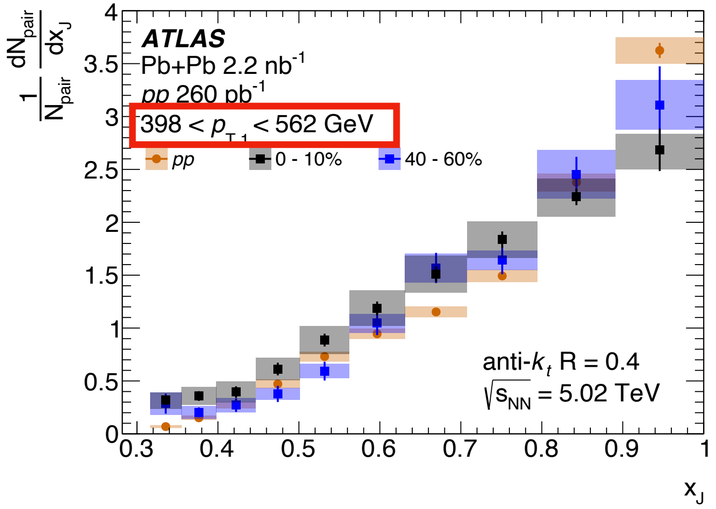
Larger fraction of evolution is dominated by **QGP medium length scales** at RHIC

QGP at RHIC is closer to transition temperature, better access to strong coupling regime

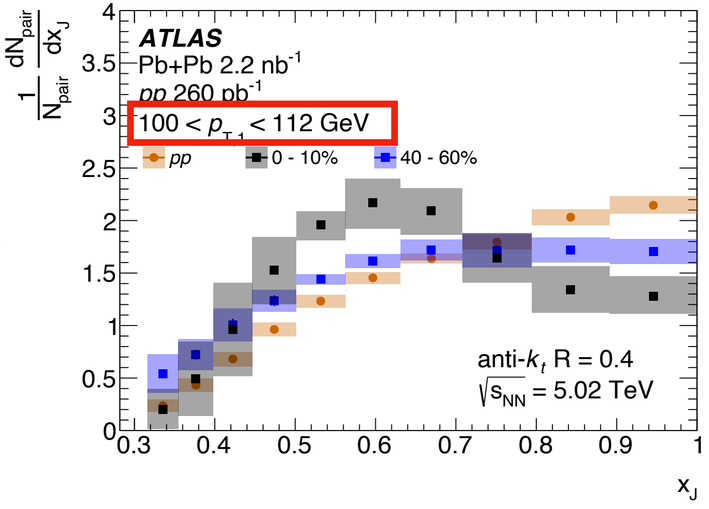
(adapted from nucl-ex/1501.06197)

LHC jets with $p_{\mathrm{T}} >> p_{\mathrm{T}}^{QGP}$

ATLAS PRC 107 (2023) 054908



lower p_T

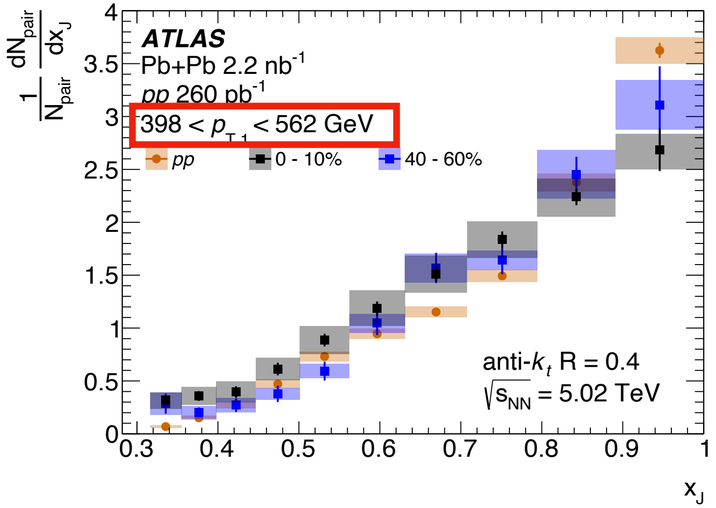


lower p_T → ?

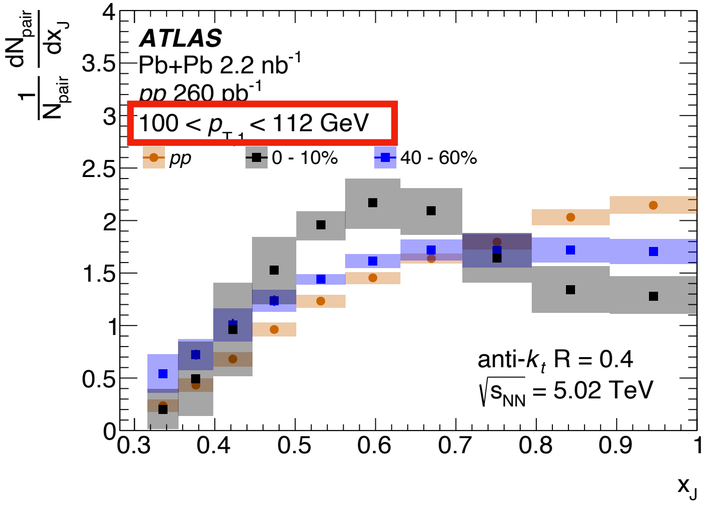
Dijets become more strongly asymmetric at lower p_T ...

LHC jets with $p_{\mathrm{T}} >> p_{\mathrm{T}}^{QGP}$

ATLAS PRC 107 (2023) 054908



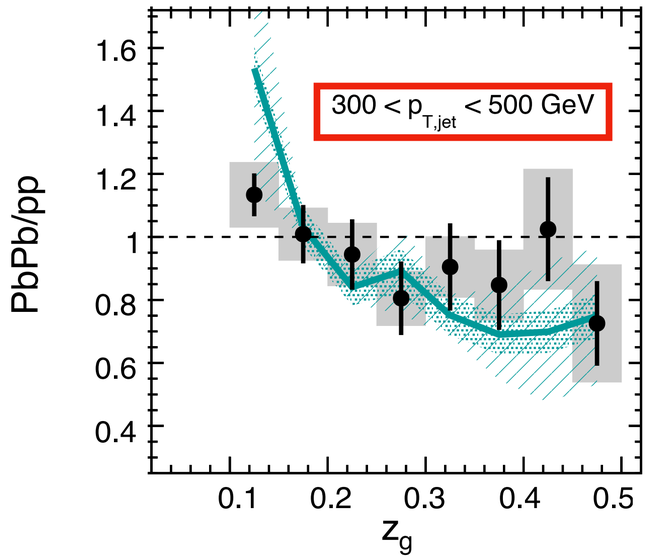
lower p_T



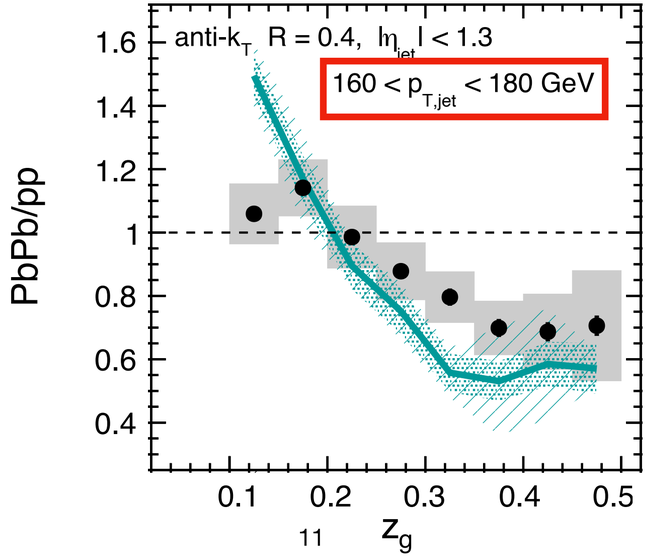
lower p_T ?

Dijets become more strongly asymmetric at lower p_T ...

CMS PRL 120 (2018) 142302



lower p_T

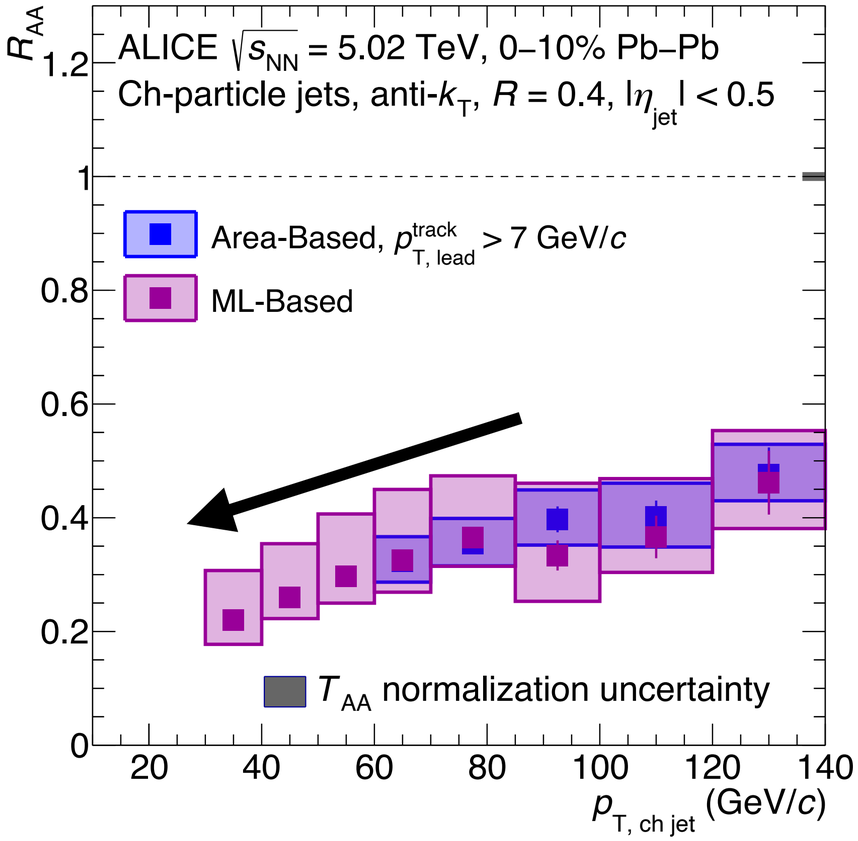


lower p_T ?

Jet sub-structure become more modified at lower p_T…

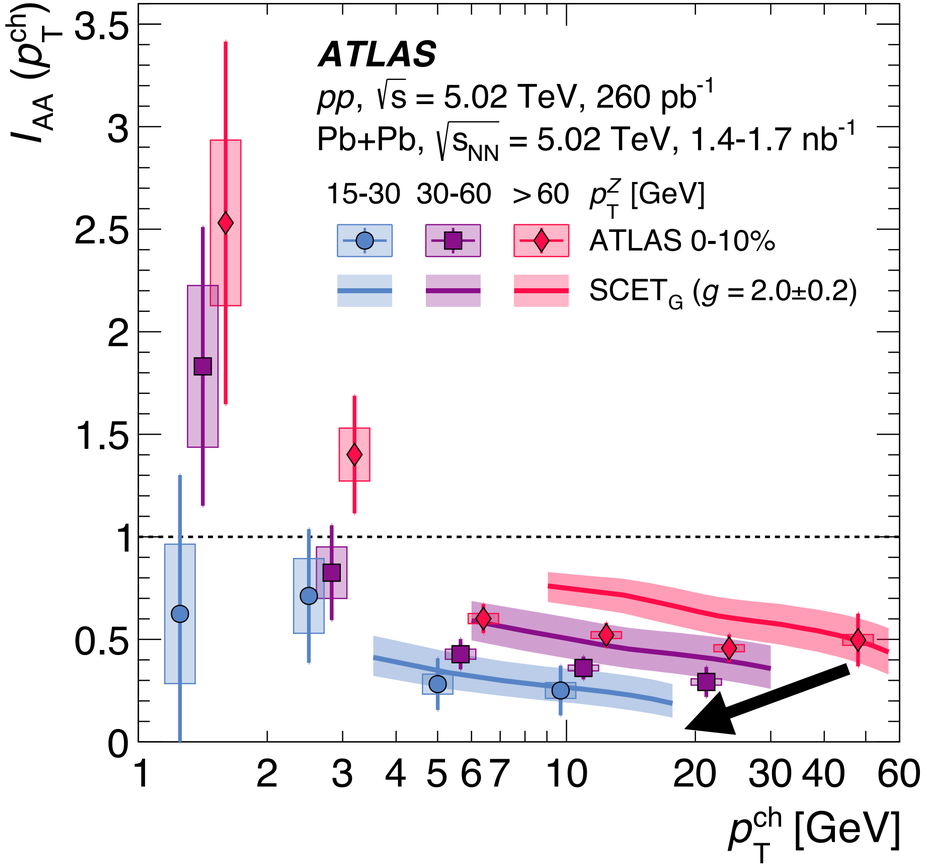
The strongest jet modification is all at low-p_T!

ALICE PLB 849 (2024) 138412

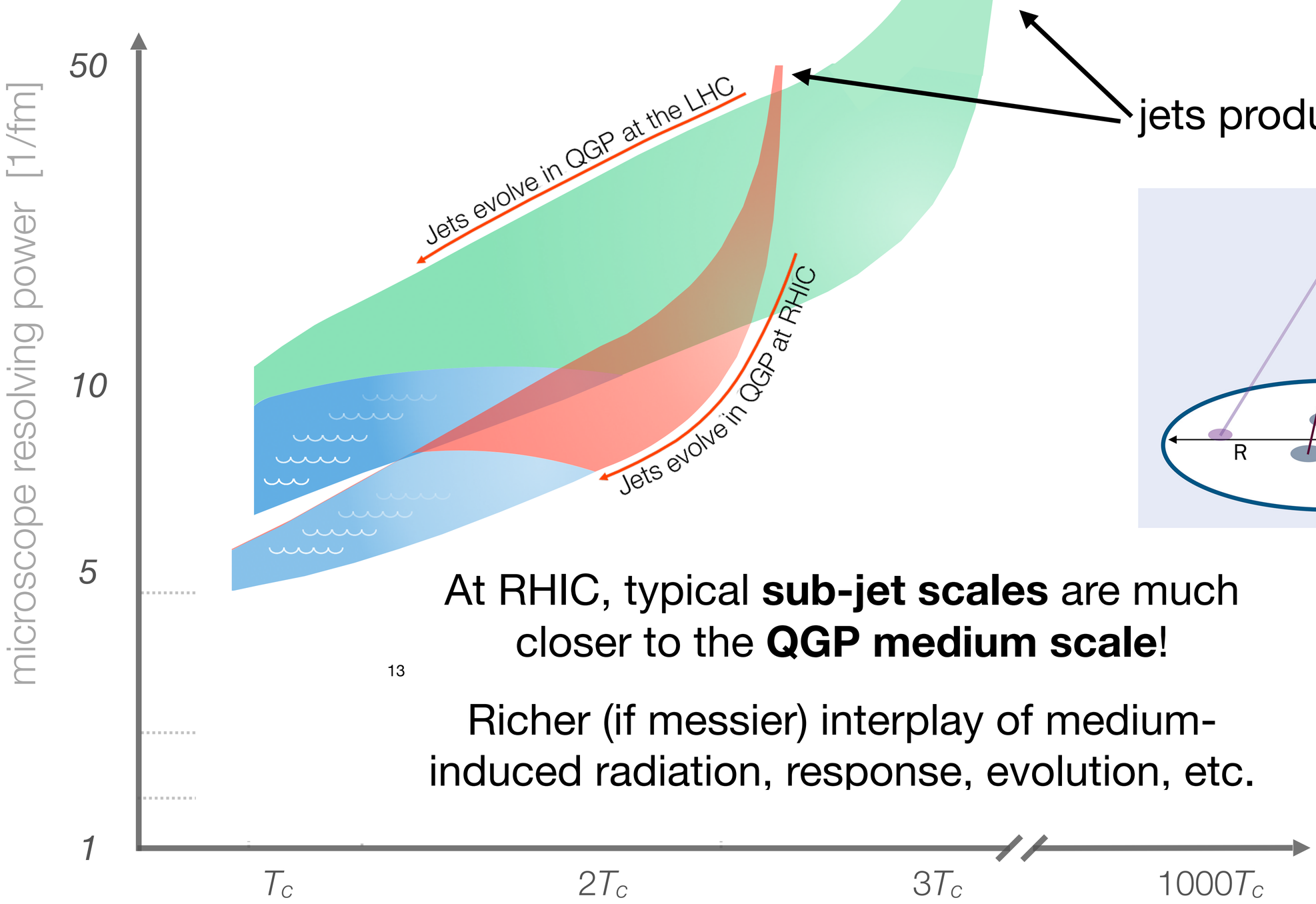


Factor of 2 reduction in R_{AA} in going from ~100 GeV to ~30 GeV jets!

ATLAS PRL 126 (2021) 072301



Factor of 2 reduction in I_{AA} in going from ~60 GeV to ~15 GeV Z+hadron events!



At RHIC, typical **sub-jet scales** are much closer to the **QGP medium scale**!

Richer (if messier) interplay of medium-induced radiation, response, evolution, etc.

(adapted from nucl-ex/1501.06197)

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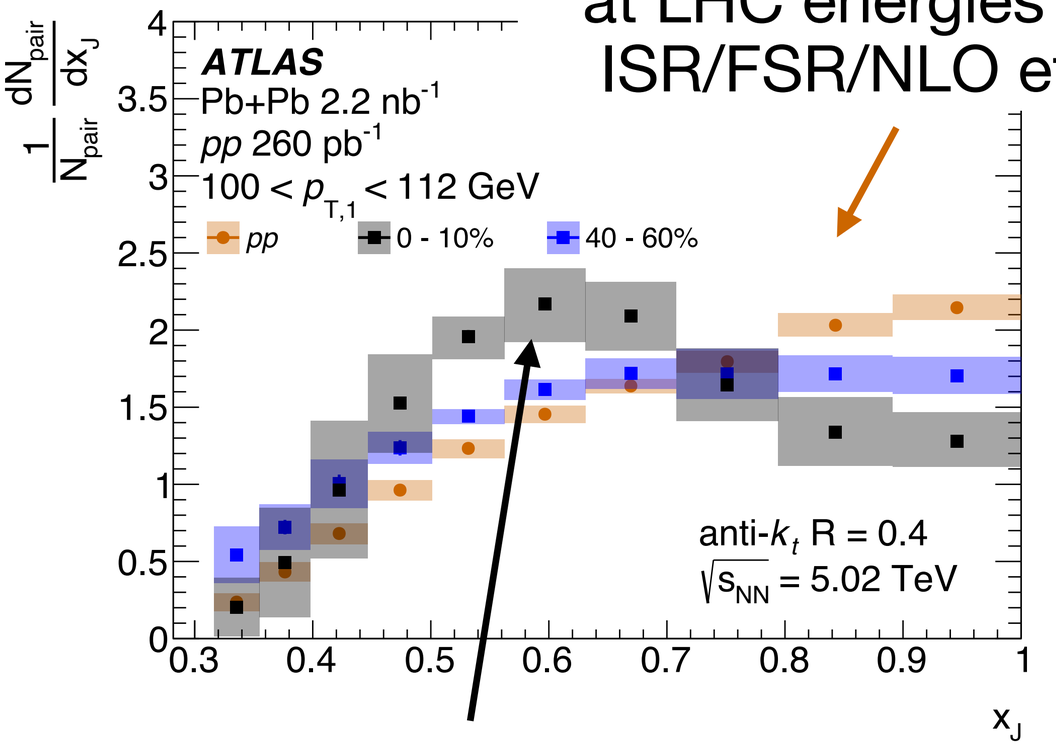
Kinematic correlations at RHIC vs LHC

ATLAS PRC 107 (2023) 054908

Very broad x_J distribution at LHC energies - large ISR/FSR/NLO effects!



Complicated interpretation in AA — jet-by-jet *E*-loss, role of 3rd jet, etc.

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ATLAS PRC 107 (2023) 054908

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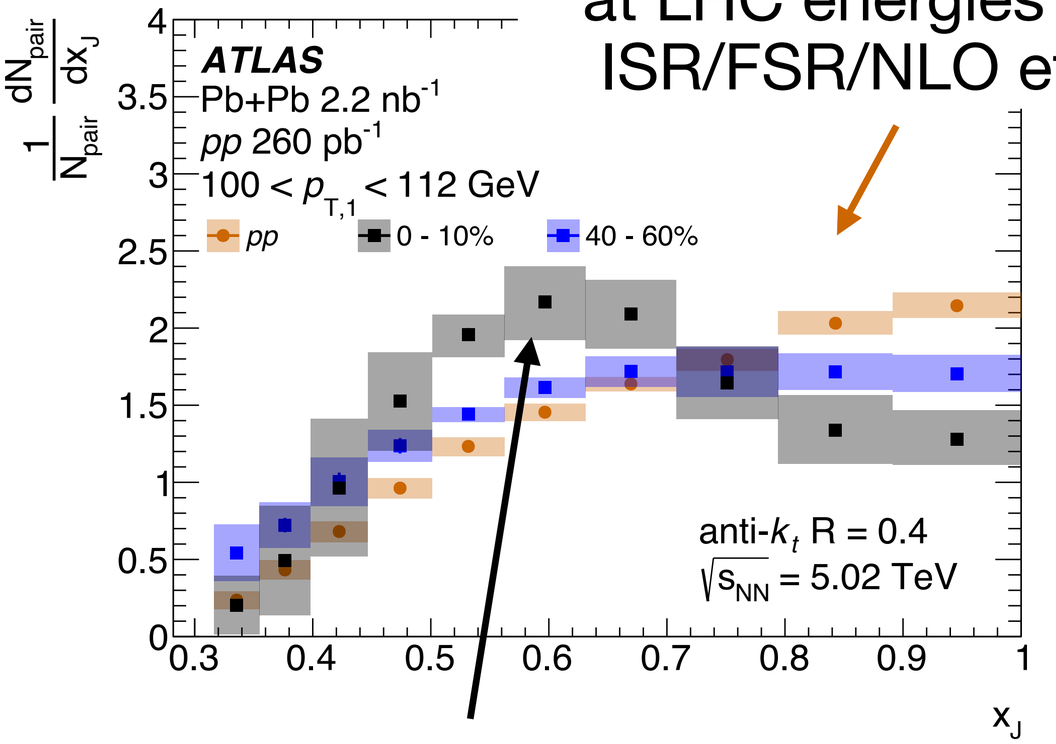

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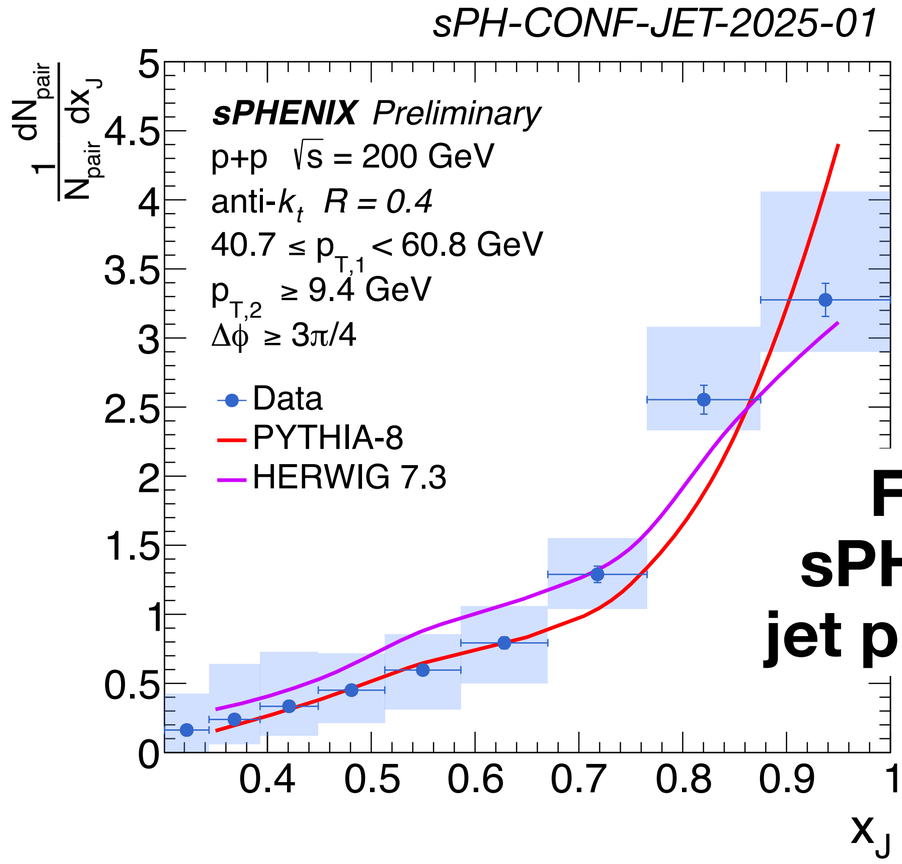
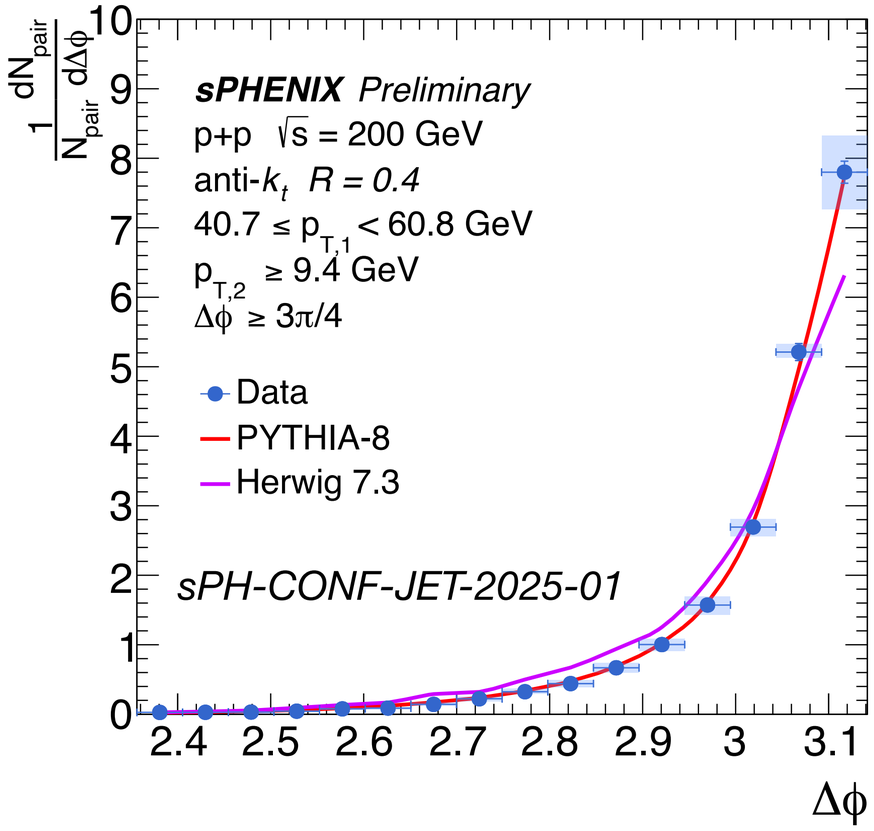
sPH-CONF-JET-2025-01



First sPHENIX jet physics!

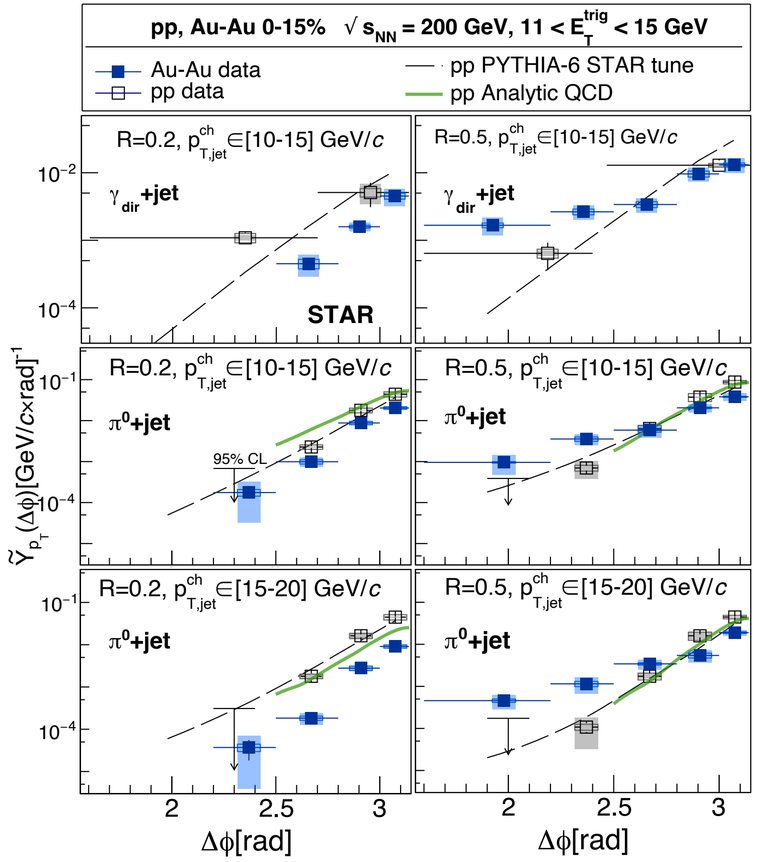
Exceptionally sharp correlation in RHIC *p+p* — large sensitivity to QGP effects!

Kinematic correlations at RHIC vs LHC



Sharp “back-to-back” azimuthal correlations as well — enables sensitive studies of medium response, searches for quasiparticle scattering, etc.

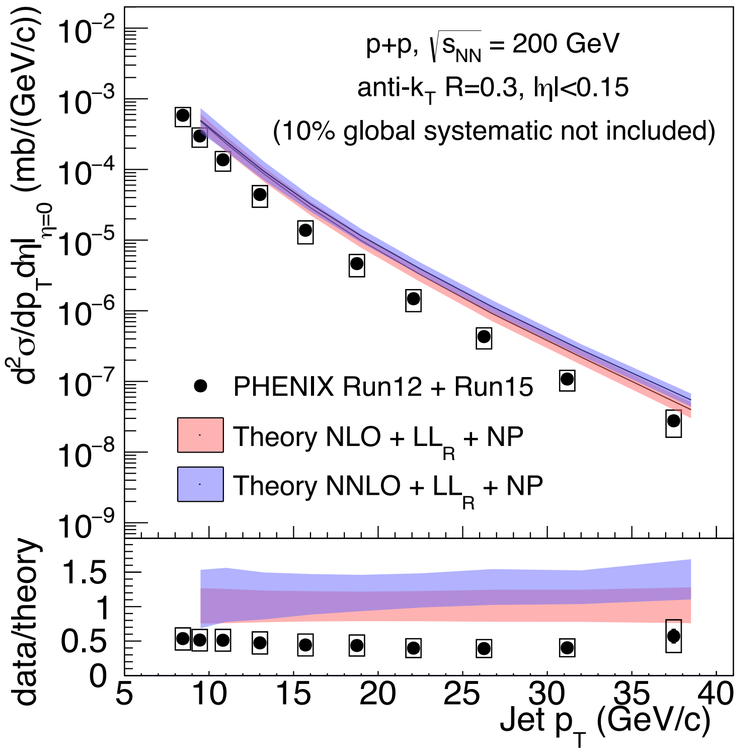
STAR, nucl-ex/2505.05789

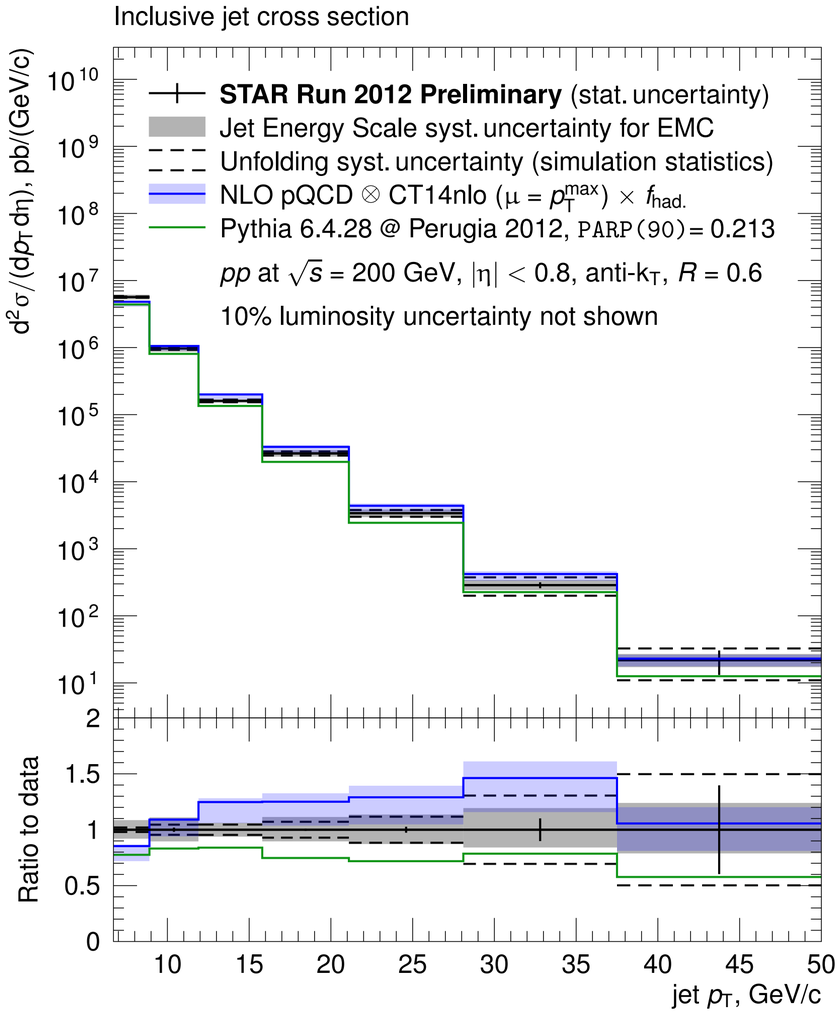


Good example of exploiting this feature in, e.g., STAR

Prior jet spectra at RHIC

PHENIX, hep-ex/2408.11144





Very hard work within existing PHENIX and STAR experiments on jet measurements — major motivation for a **purpose-built jet detector at RHIC which builds off this knowledge base**

Kinematic reach

Uncertainties smaller than marker size even at 70 GeV!

Only 1/6th of available Run-24 *p+p* luminosity

The promised sPHENIX experimental capability has arrived, 15 years after the PHENIX decadal plan

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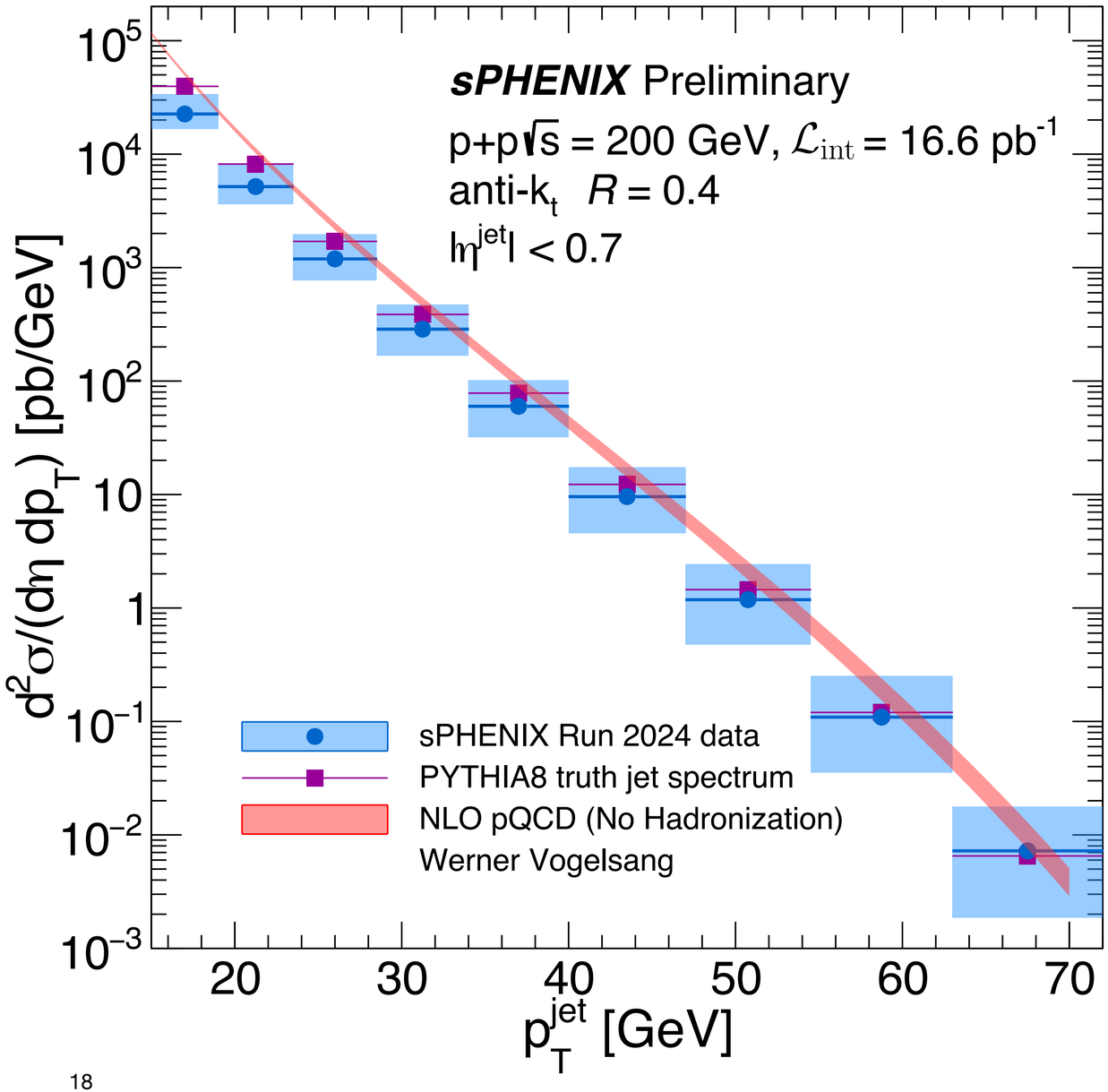
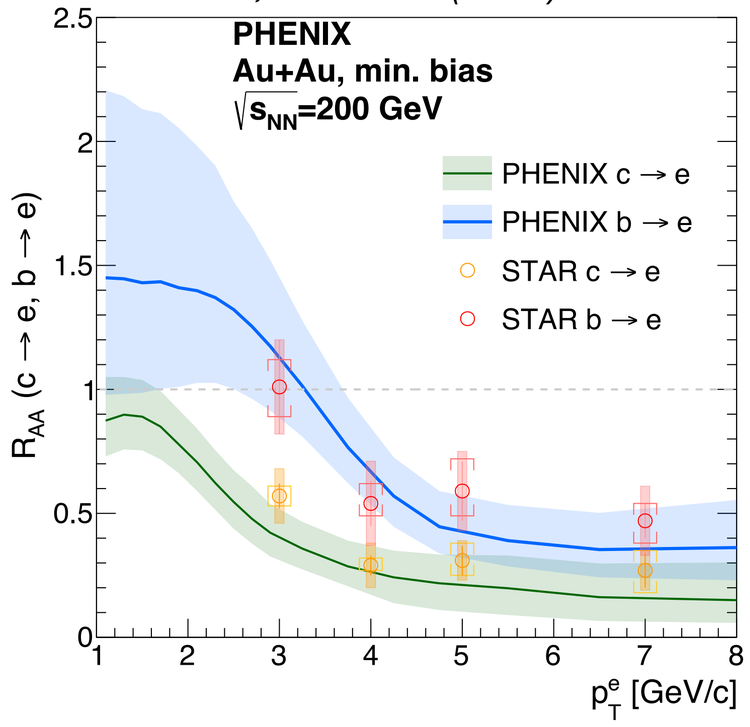
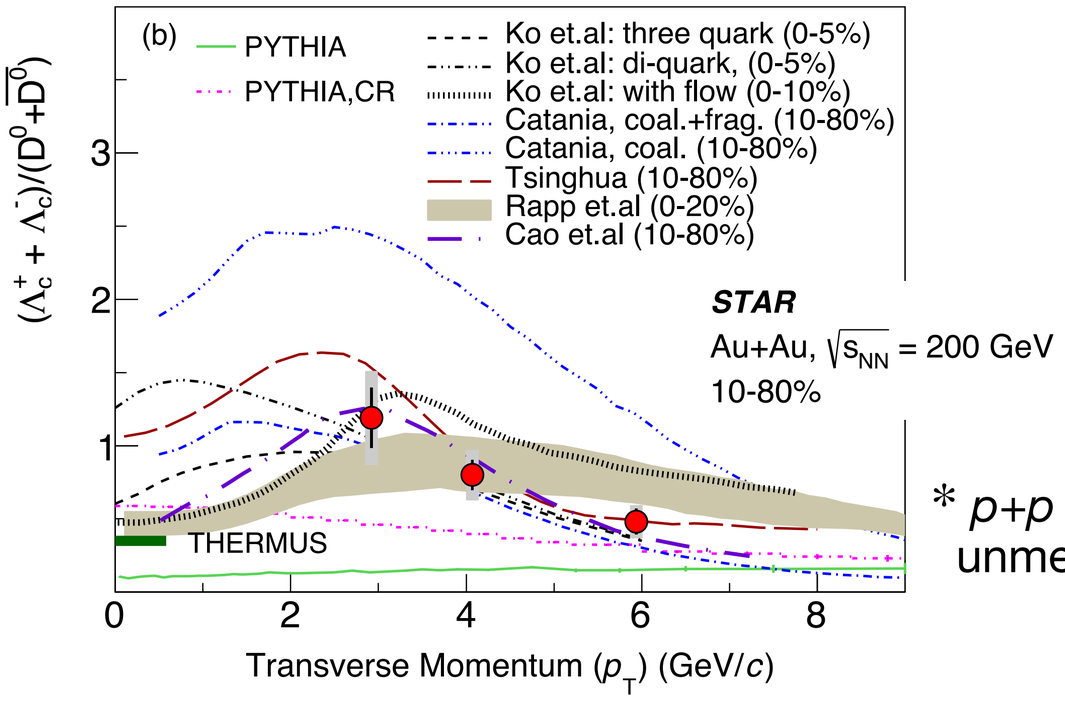


Open heavy flavor at RHIC

PHENIX, PRC 109 (2024) 044907



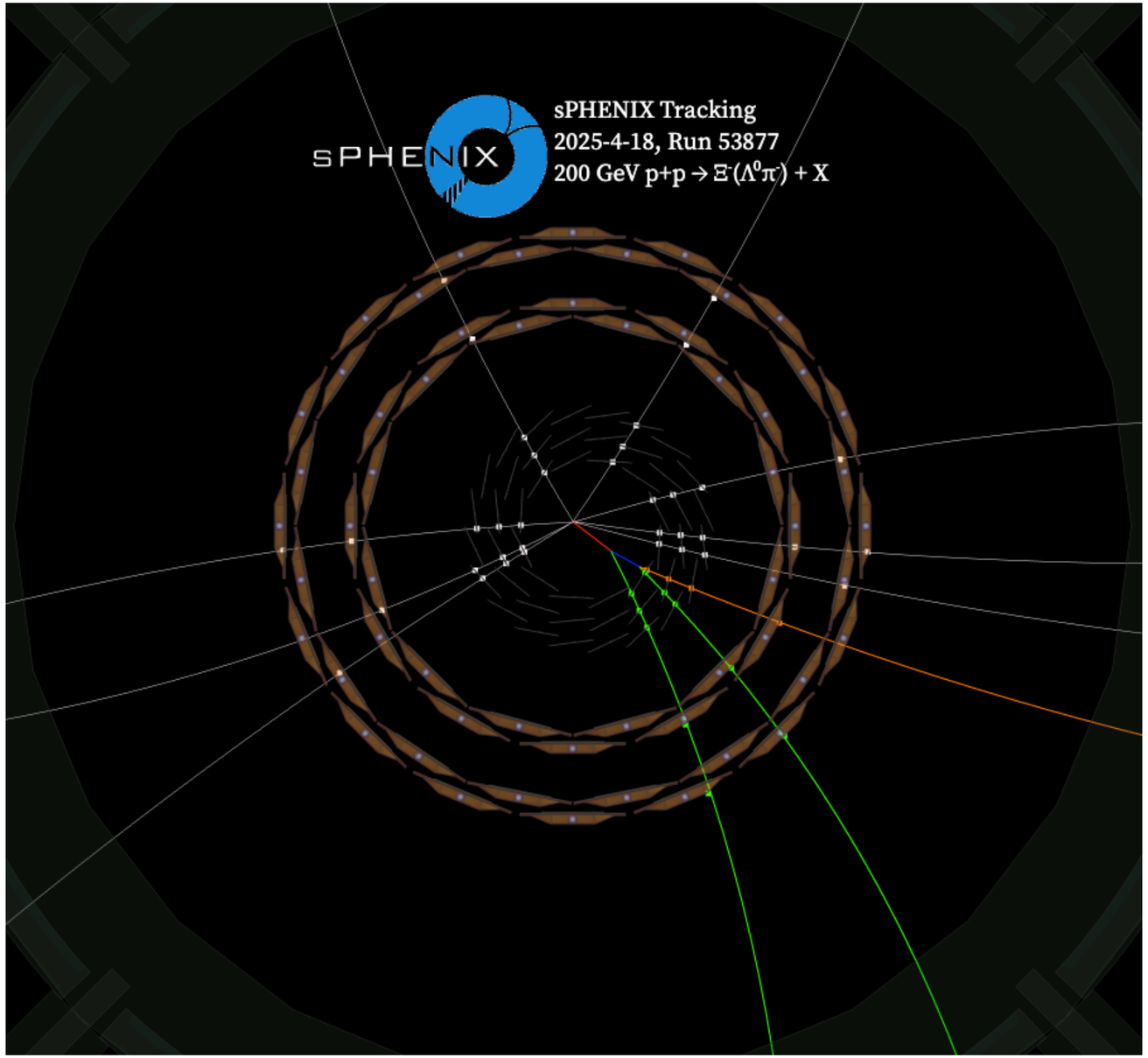
STAR, PRL 124 (2020) 172301



* *p+p* baseline unmeasured

Strong opening of the heavy flavor sector by existing RHIC experiments

Lessons from the LHC for the next leap forward: **large datasets (including *p+p*) + precision vertexing** is sufficient for HF physics, even without explicit PID



Example event

$$\Xi^- \rightarrow \Lambda^0(\rightarrow p^+\pi^-)\pi^-$$

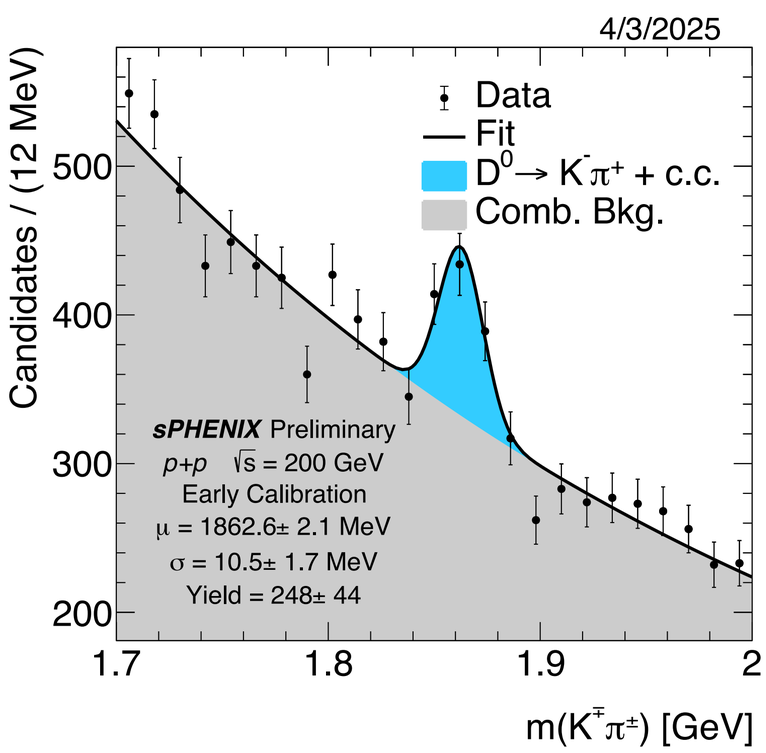
Streaming readout is a **cutting edge capability** — sPHENIX is on the forefront of technology that will be used for **all future NP detectors**, with major connection to ALICE/LHCb

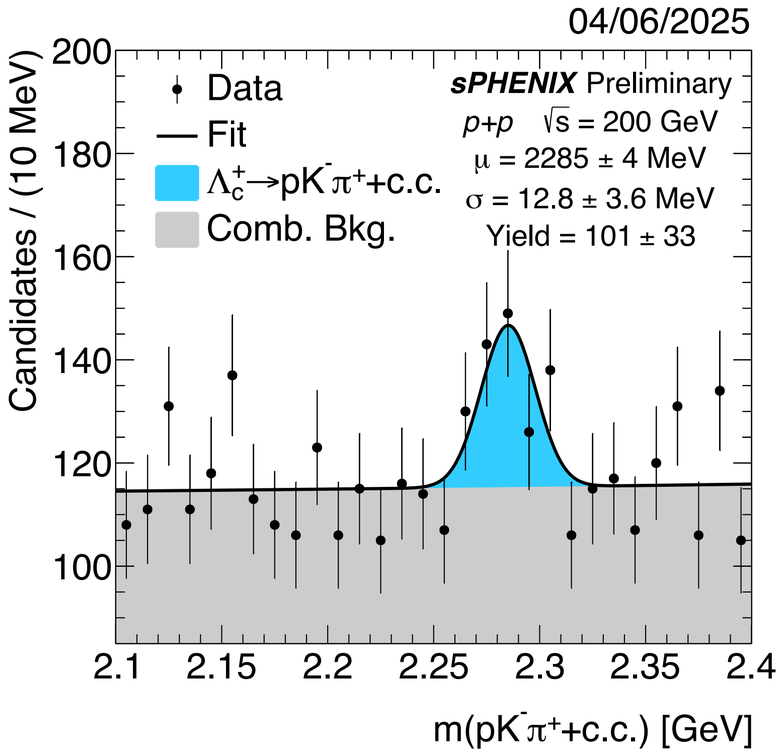
In Run-24, collected unbiased *p+p* events at ~200 kHz: a ≈10^3 increase over best D^0 cross-section at RHIC (*)

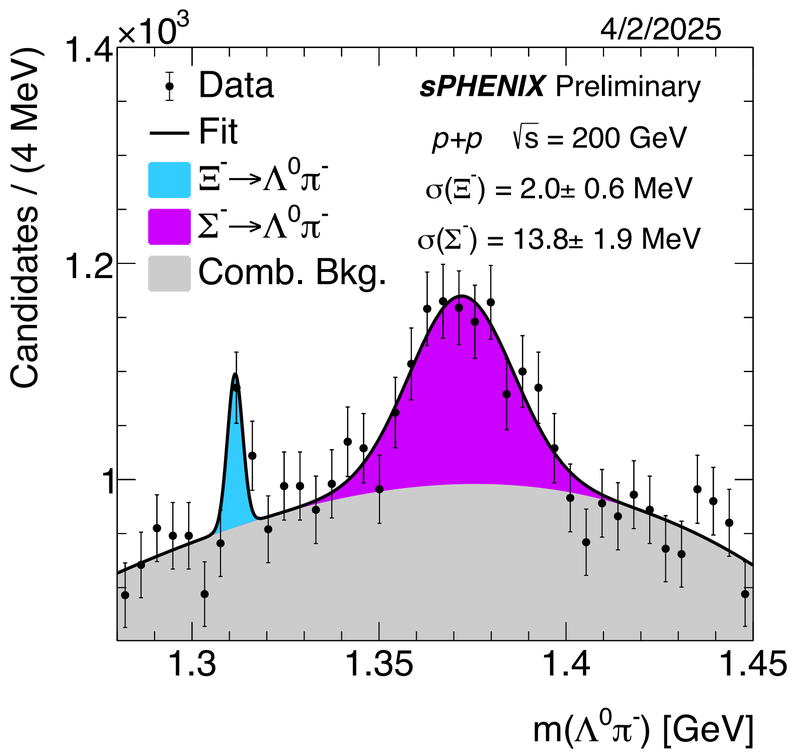
(*) STAR, PRD 86 (2012) 072013

Swift progress on open charm

Only one hour of data analyzed!



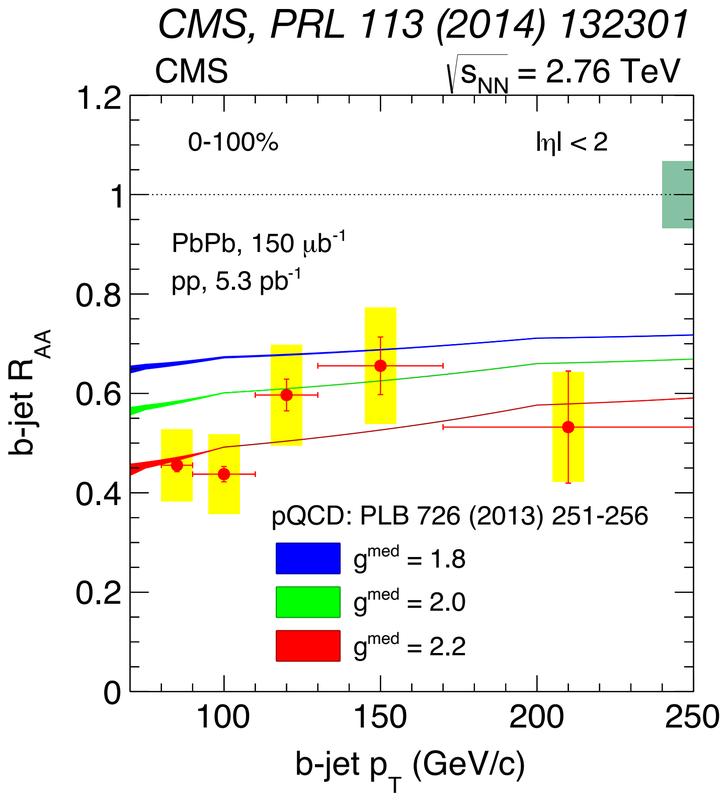




Calibration of a complicated four-component tracking system **while** producing preliminary physics measurements **while also** preparing for this year's Run

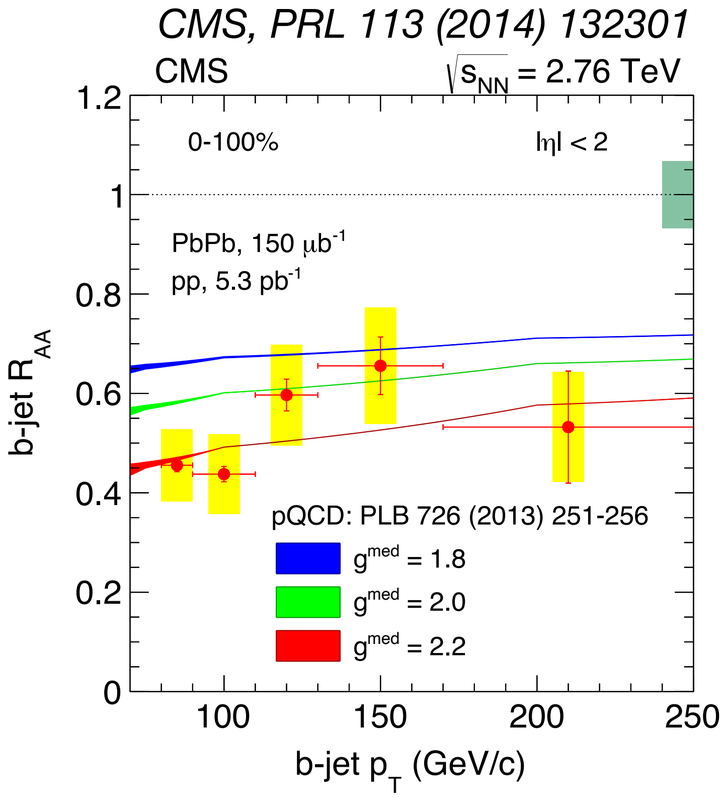
Walking while chewing gum while juggling while humming while etc.…

b-jet physics is best at RHIC



Full *b*-jet tagging at LHC, but at these p_T ranges, they behave like light quark jets …

b-jet physics is best at RHIC



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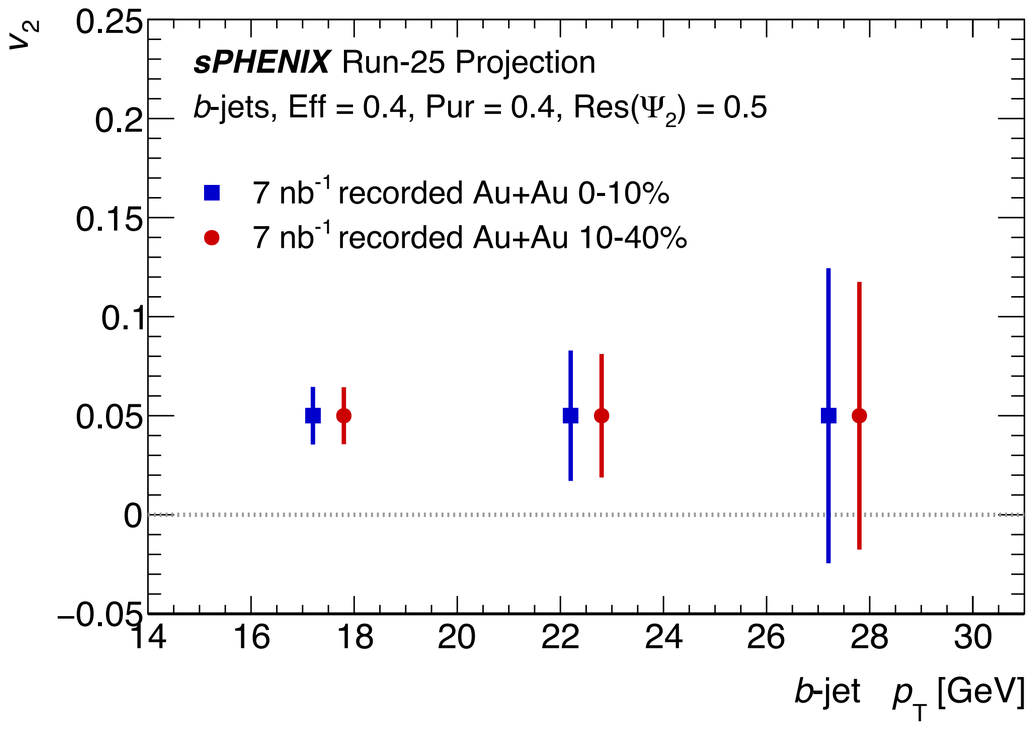
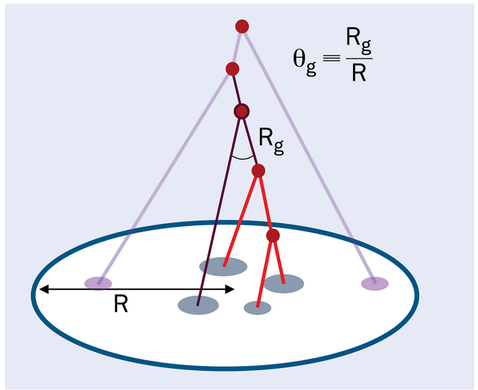
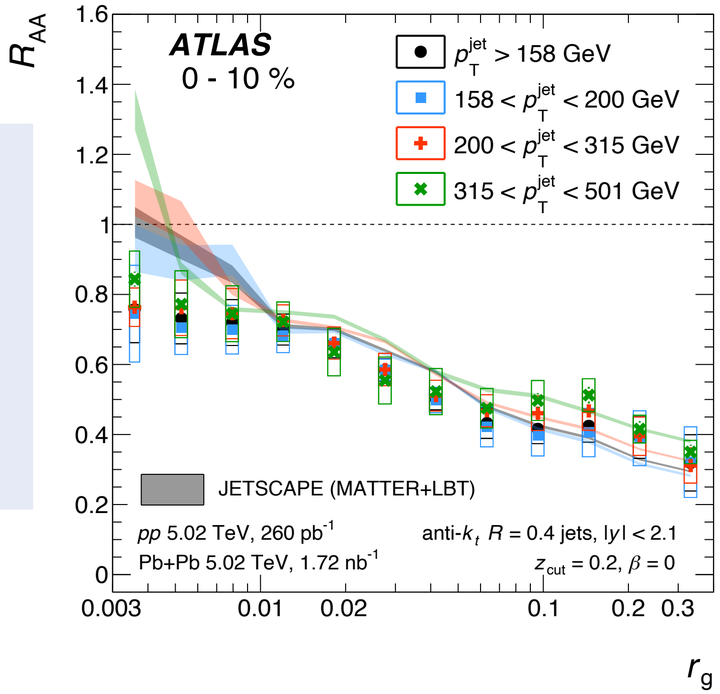


sPHENIX designed to do *b*-tagging, applied in a kinematic range much more **sensitive to the mass effect**

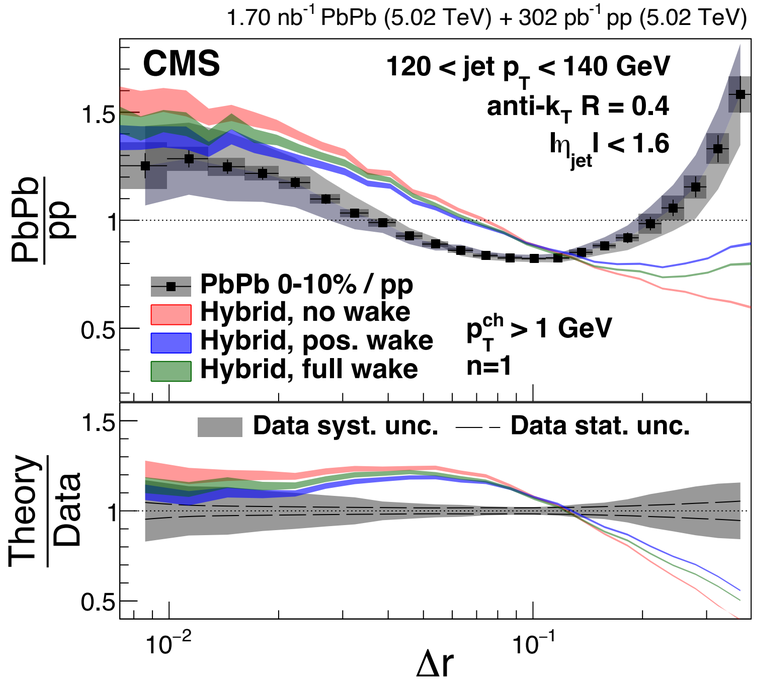
A broadly-capable detector can follow the science

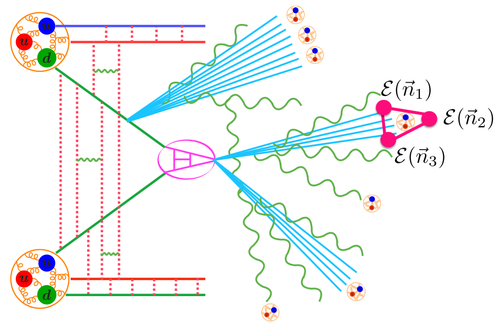


ATLAS, PRC 107 (2023) 054909



CMS, nucl-ex/2503.19993

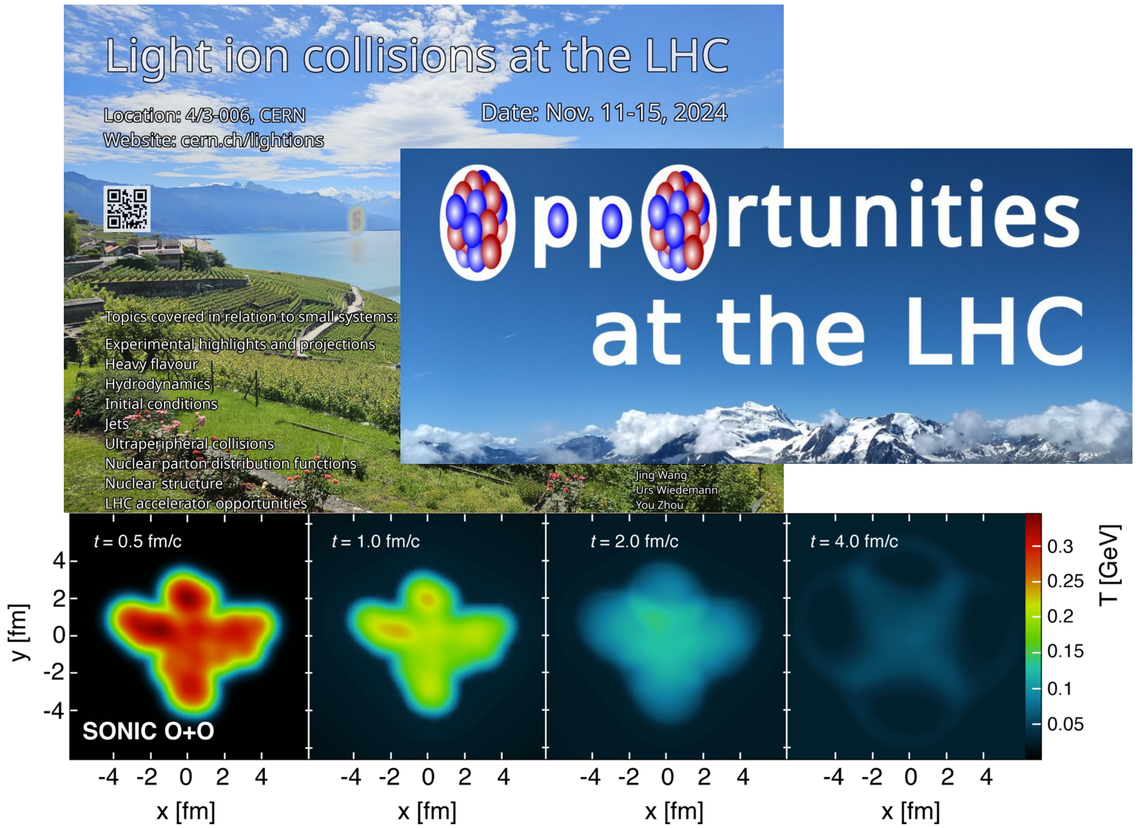




Many developments in jet physics since original sPHENIX design

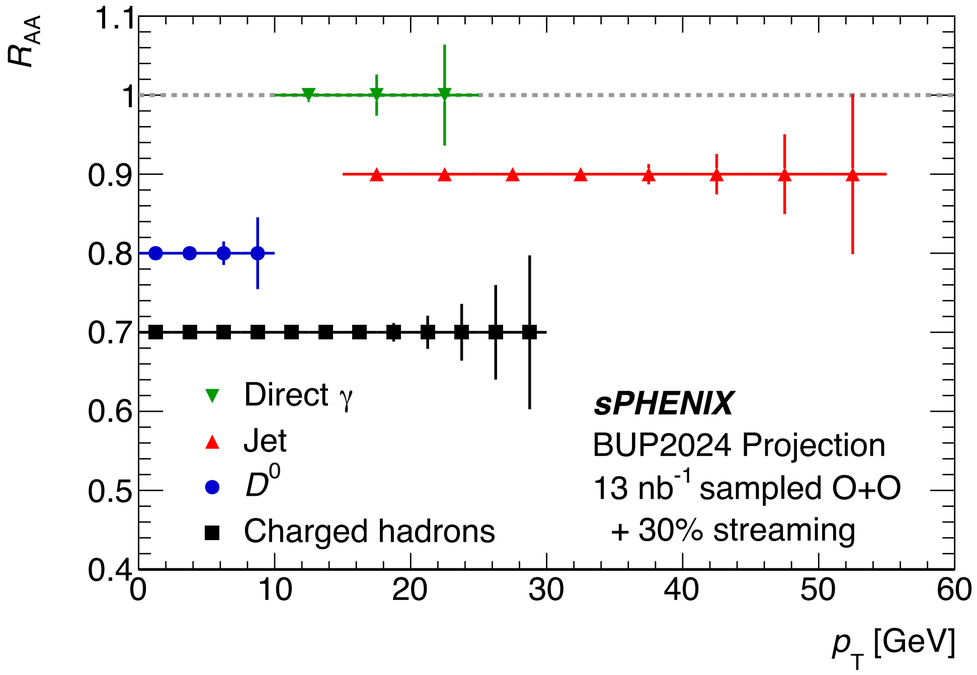
Large acceptance, high rate, hermetic calorimetry, high-precision tracking ⇒ perfect configuration for **complementarity with LHC Run-3**

Oxygen



Huge amount of excitement in the heavy-ion physics community about O+O running later this summer at the LHC

Impact of a two-week run, based on the short RHIC Run-21 experience

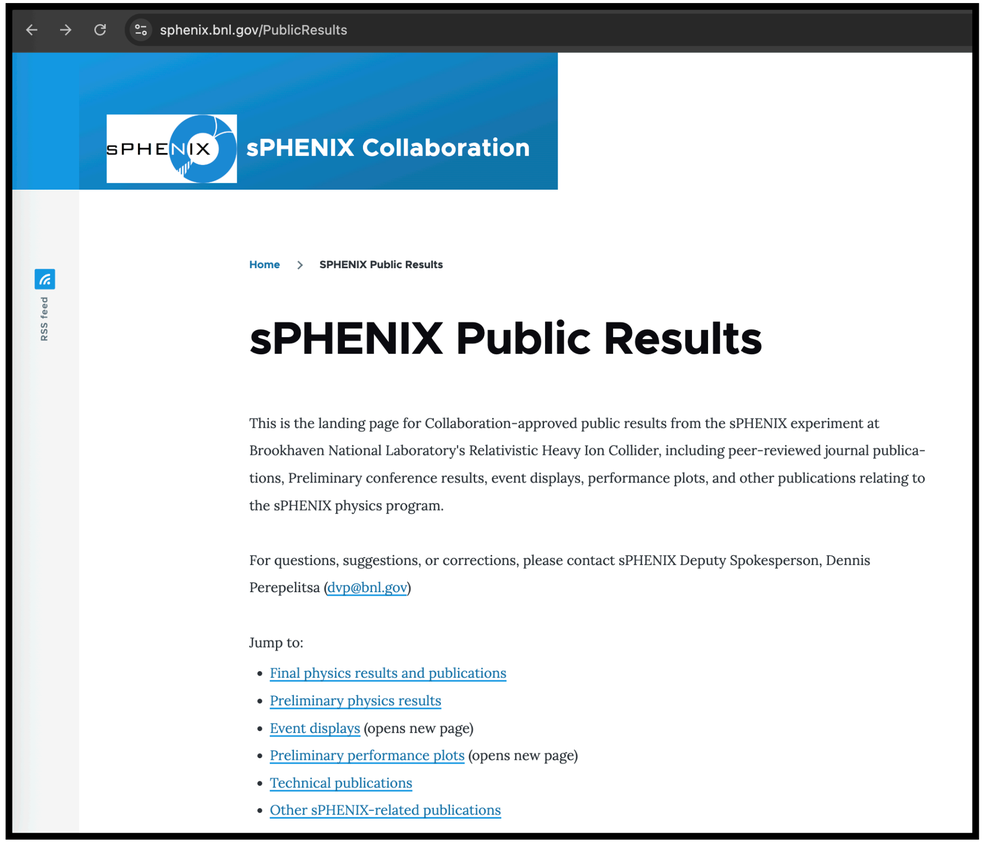


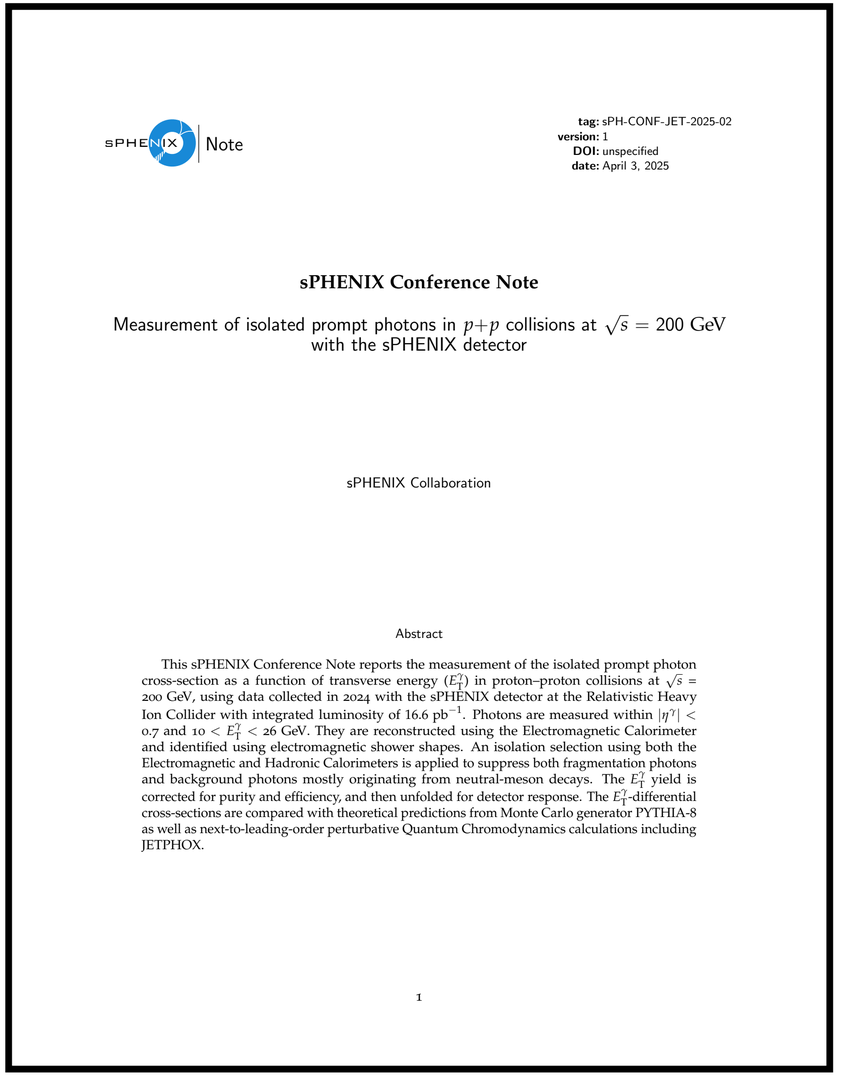
sPHENIX's RHIC-unique capabilities mean we can co-lead on this physics

Years-long investment in sPHENIX + RHIC's unique flexibility = major return on investment!

Other LHC influences

sPHENIX Public Results page




sPHENIX Note

tag: sPH-CONF-JET-2025-02
version: 1
DOI: unspecified
date: April 3, 2025

sPHENIX Conference Note

Measurement of isolated prompt photons in p+p collisions at $\sqrt{s} = 200$ GeV with the sPHENIX detector

sPHENIX Collaboration

Abstract

This sPHENIX Conference Note reports the measurement of the isolated prompt photon cross-section as a function of transverse energy (E_{T}^{γ}) in proton–proton collisions at $\sqrt{s}$ = 200 GeV, using data collected in 2024 with the sPHENIX detector at the Relativistic Heavy Ion Collider with integrated luminosity of 16.6 pb^{-1}. Photons are measured within $|\eta^{\gamma}| < 0.7$ and $10 < E_{\mathrm{T}}^{\gamma} < 26$ GeV. They are reconstructed using the Electromagnetic Calorimeter and identified using electromagnetic shower shapes. An isolation selection using both the Electromagnetic and Hadronic Calorimeters is applied to suppress both fragmentation photons and background photons mostly originating from neutral-meson decays. The E_{T}^{γ} yield is corrected for purity and efficiency, and then unfolded for detector response. The E_{T}^{γ}-differential cross-sections are compared with theoretical predictions from Monte Carlo generator PYTHIA-8 as well as next-to-leading-order perturbative Quantum Chromodynamics calculations including JETPHOX.

1

Every event display, performance plot, Preliminary result, paper, has easy-to-find, high-resolution figures

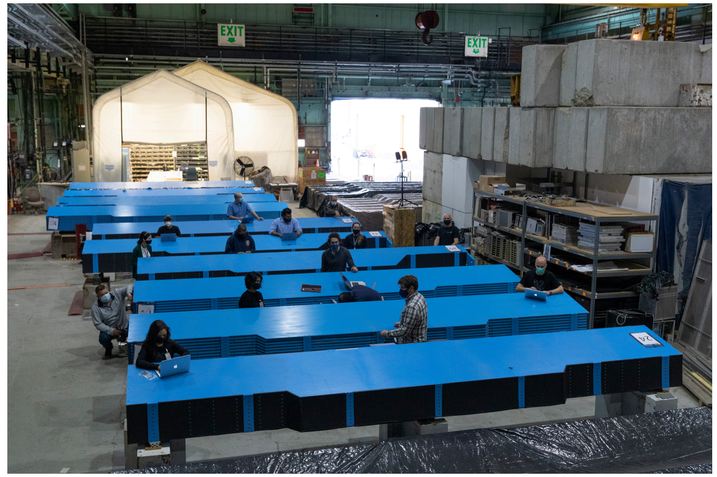
Every Preliminary result has a public “conference note” document with a description of key details

Beam time, beam time, beam time

- Flagship sPHENIX QGP measurements (γ+jets, b-jets, Upsilons)
- Expansive kinematic reach
- Critical *p*+*p* baselines
- Small collision systems with RHIC- and world-unique capabilities

➡ They all rely on **large integrated luminosities**

The sPHENIX science program will not be limited by any lack of courage, ingenuity, or dedication from its people … only by **beam time**



Bringing the scientific and technical advancements of the LHC back to the USA and finishing the physics mission of RHIC!