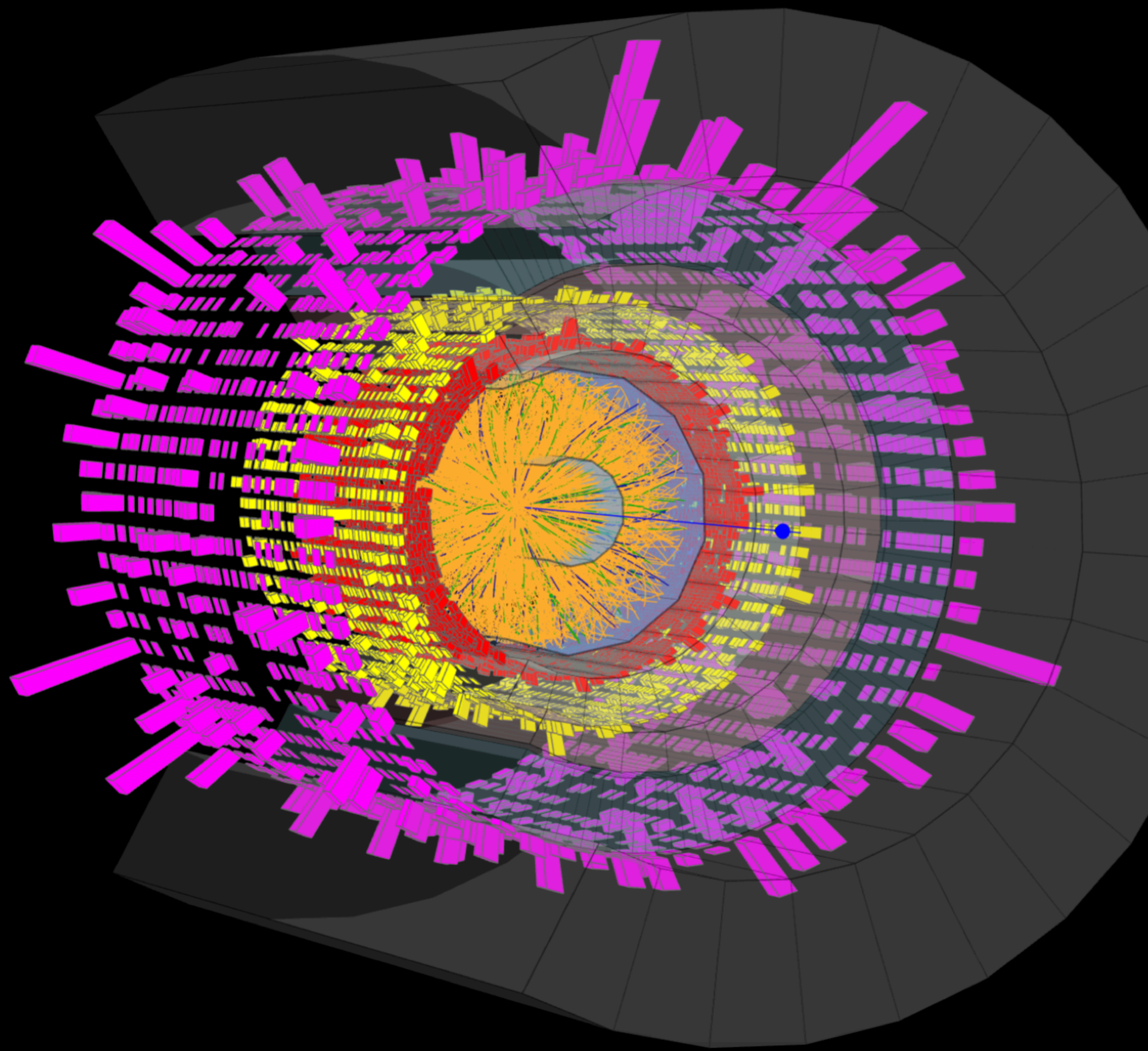
The sPHENIX experiment at RHIC

Sebastian Tapia Araya
Universidad Técnica Federico Santa Maria
for sPHENIX collaboration



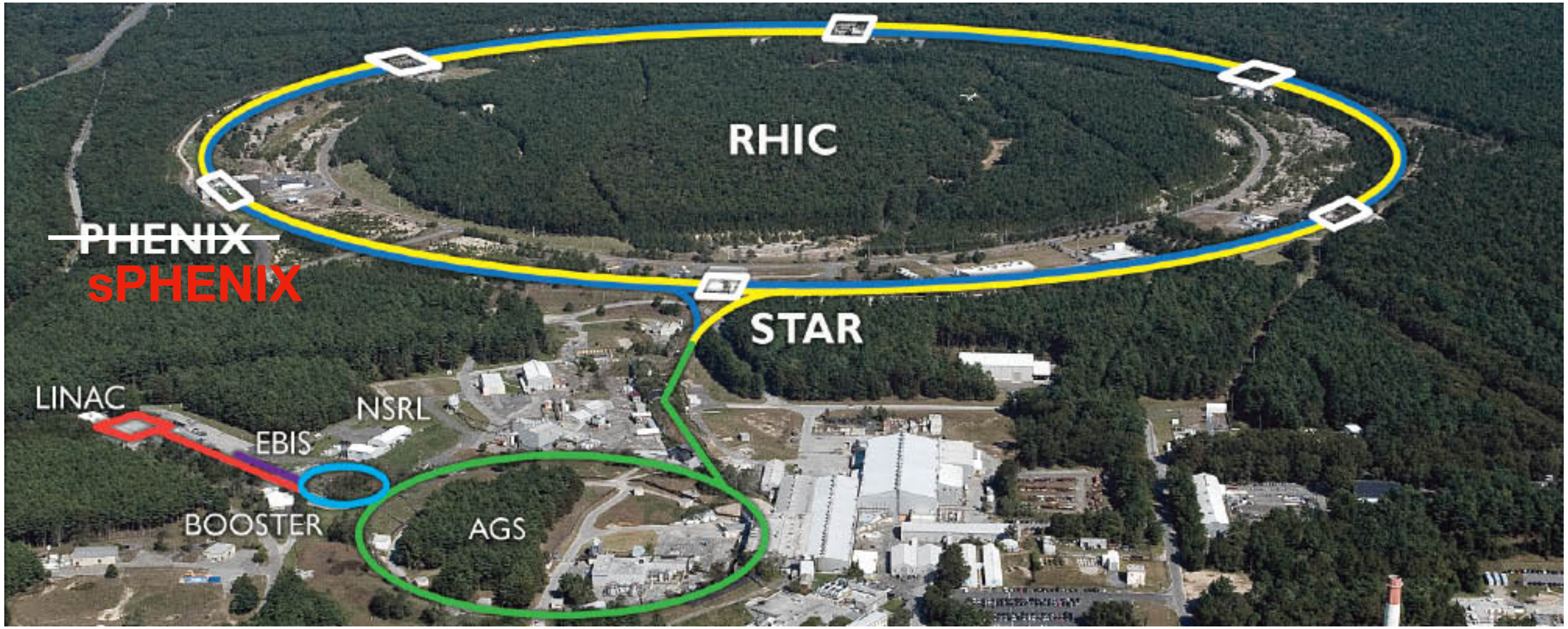
HEP2023

13 Jan 2023

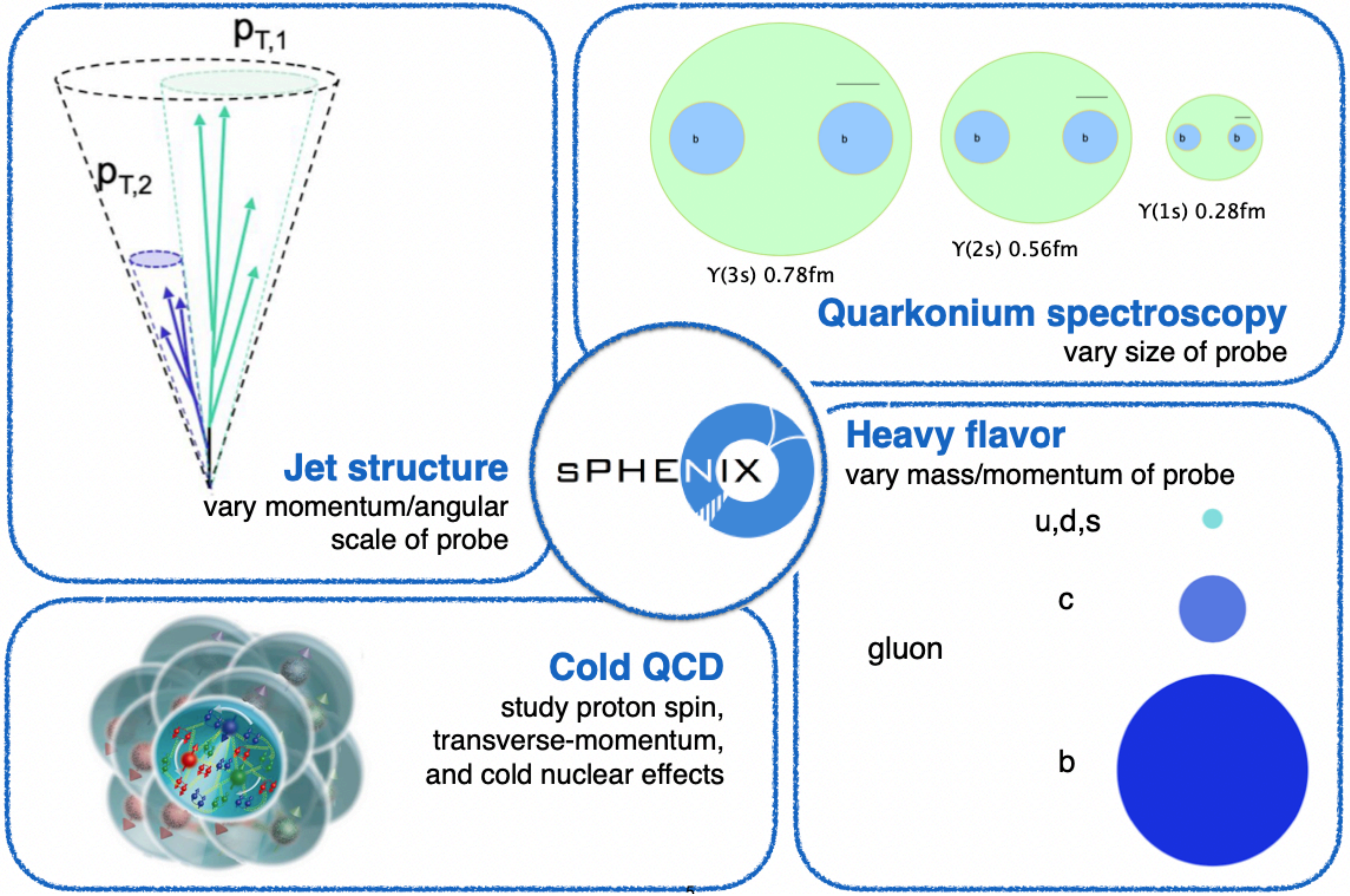
What is sPHENIX?

- sPHENIX **will complete** at BNL in the PHENIX experimental hall
- sPHENIX is the first new detector at any hadron collider in over a decade!
- sPHENIX has unique, purpose-built capabilities never before deployed at RHIC

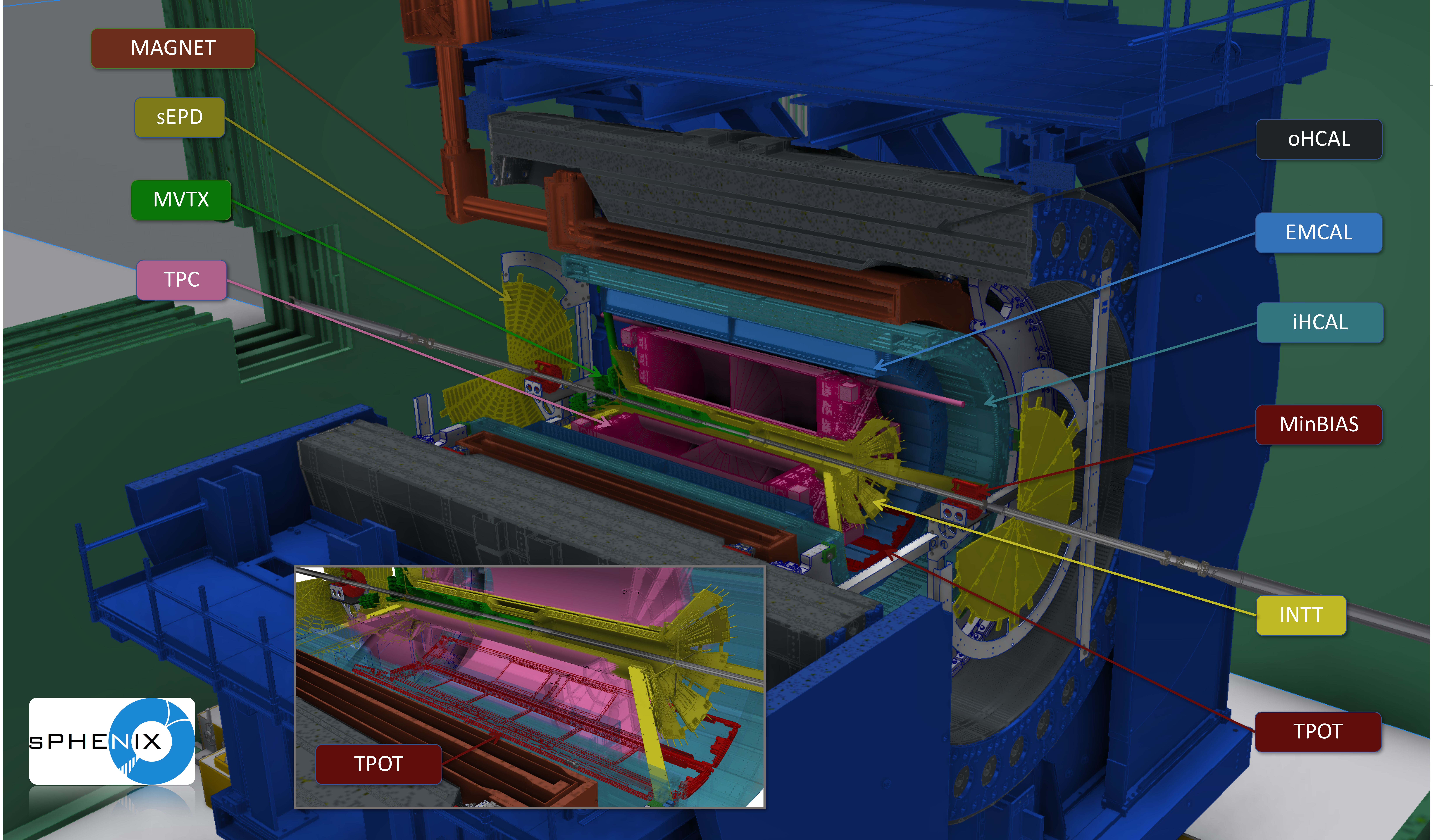
…to complete the scientific journey
started at RHIC over twenty years ago!



sPHENIX physics program



The Goal: Probe the inner workings of Quark-Gluon-Plasma


MAGNET
sEPD
MVTX
TPC
oHCAL
EMCAL
iHCAL
MinBIAS
INTT
TPOT
TPOT
sPHENIX

sPHENIX Tracking system

Vertexing:

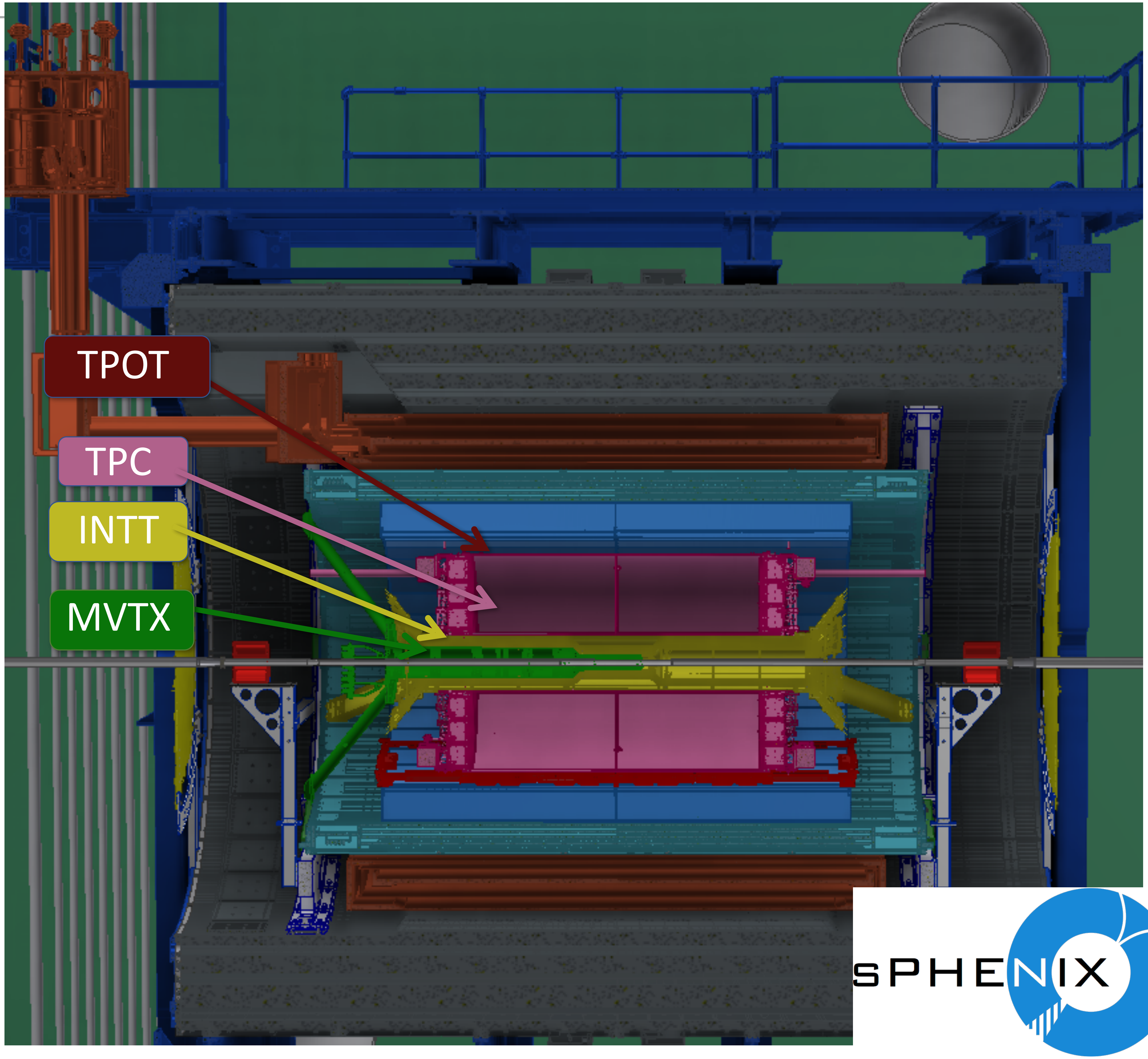
- MAPS-based micro-VerTeX detector (MVTX)
- 3-layers Monolithic Active Pixel Sensors (MAPS) covering 2.5-4 cm radius

Timing:

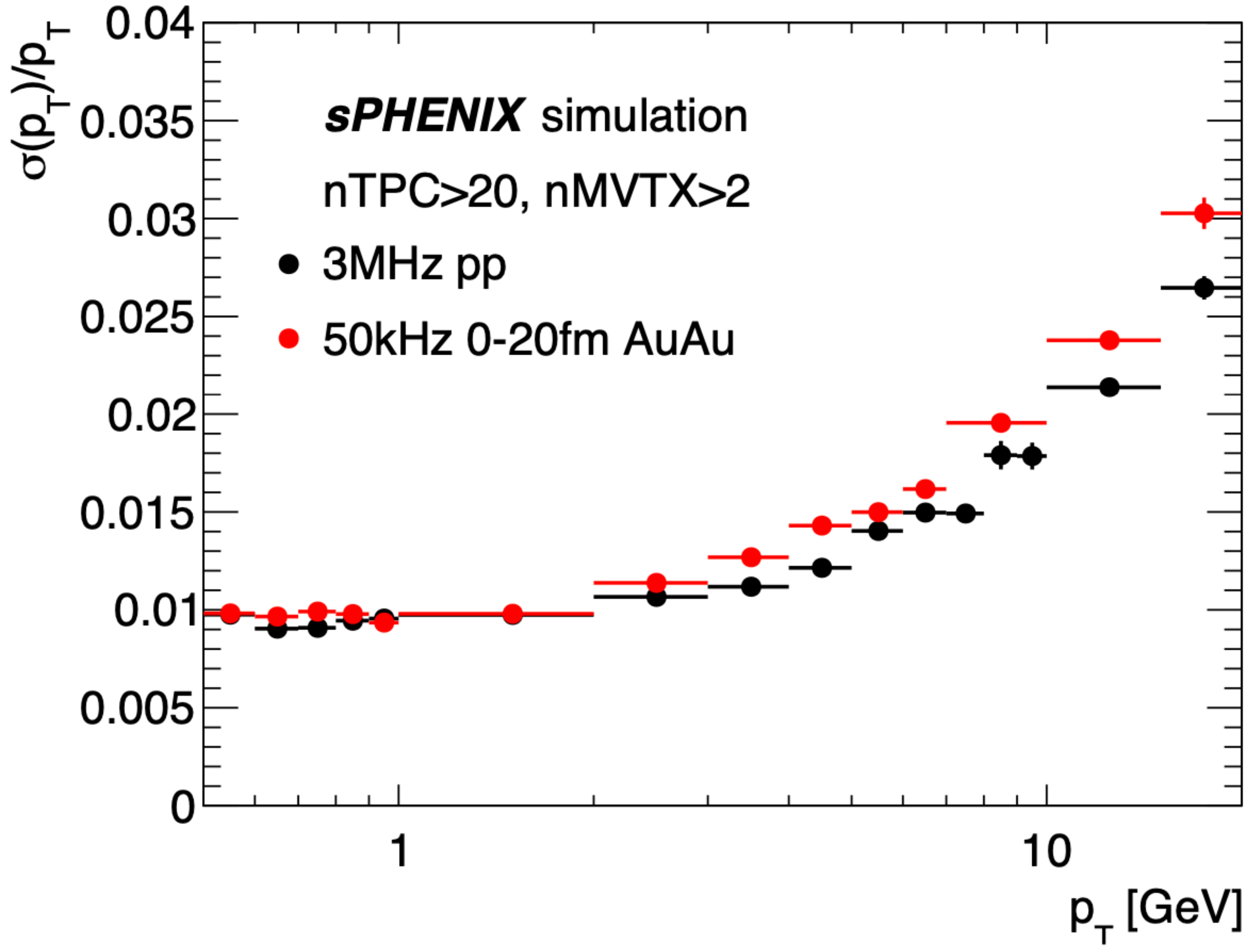
- Intermediate Silicon Tracker (INTT)
- 4-layers (7-10 cm radius)
- Fast O(100ns) integration time

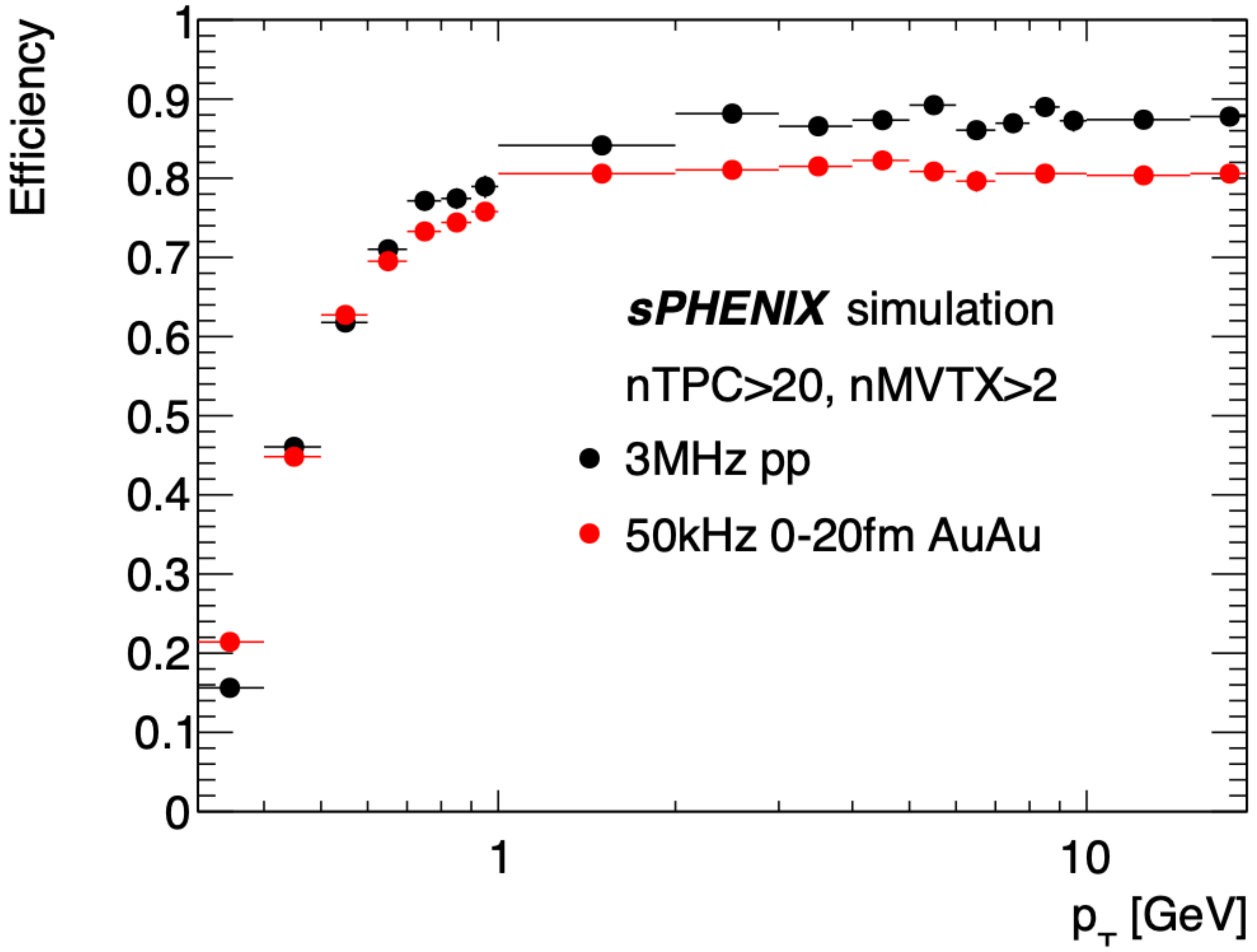
Momentum:

- Time Projection Chamber (TPC)
- 48-layers (30-78cm radius)
- $\Delta p/p \sim 1\%$ at 5 GeV/c
- R-ϕ resolution ~ 150 μm



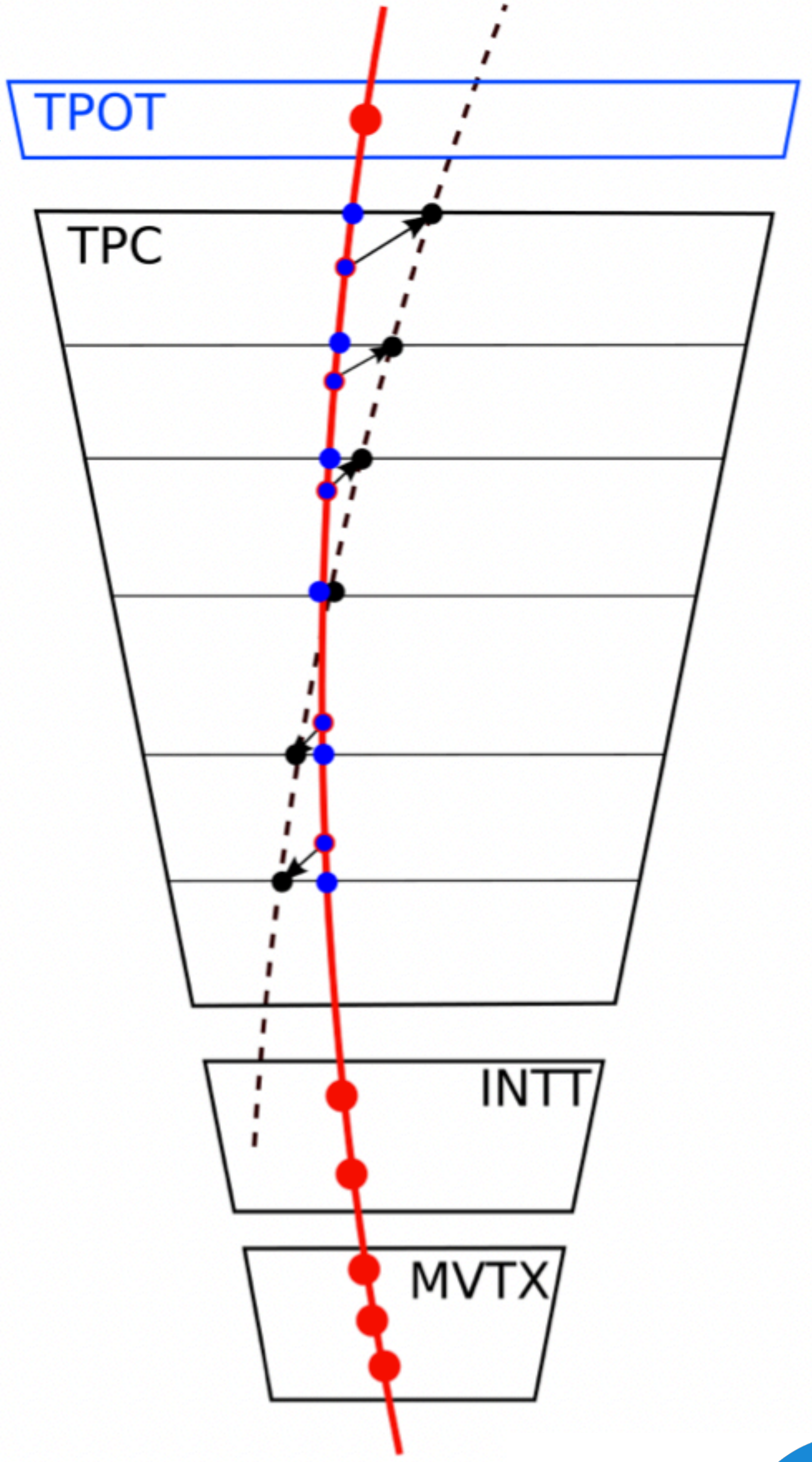
sPHENIX Tracking system





Calibration:

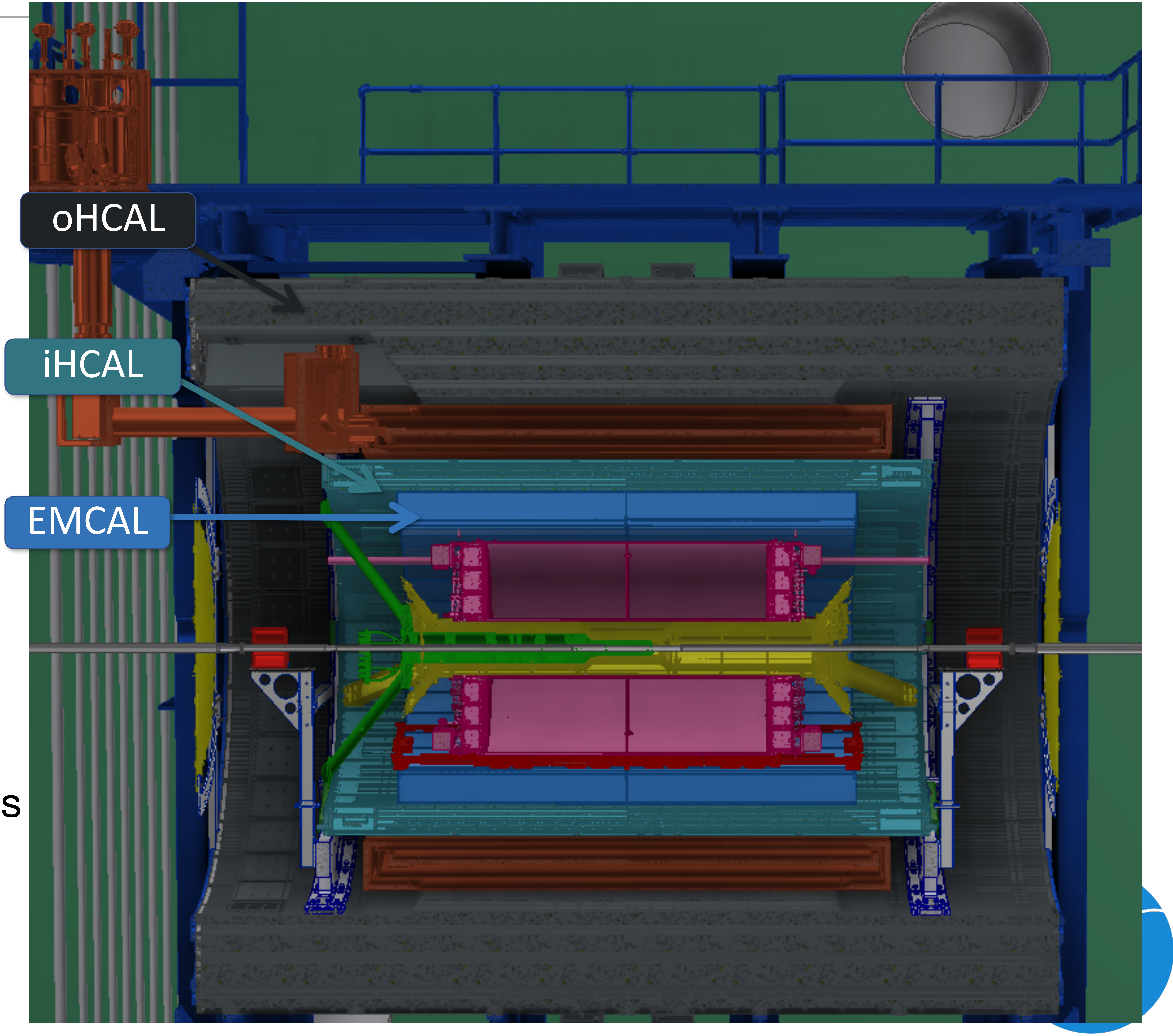
- TPC Outer Tracker (TPOT)
- 8 modules of Micromegas inserted between TPC and EMCAL



Good efficiency and momentum resolution by combining MVTX and TPC

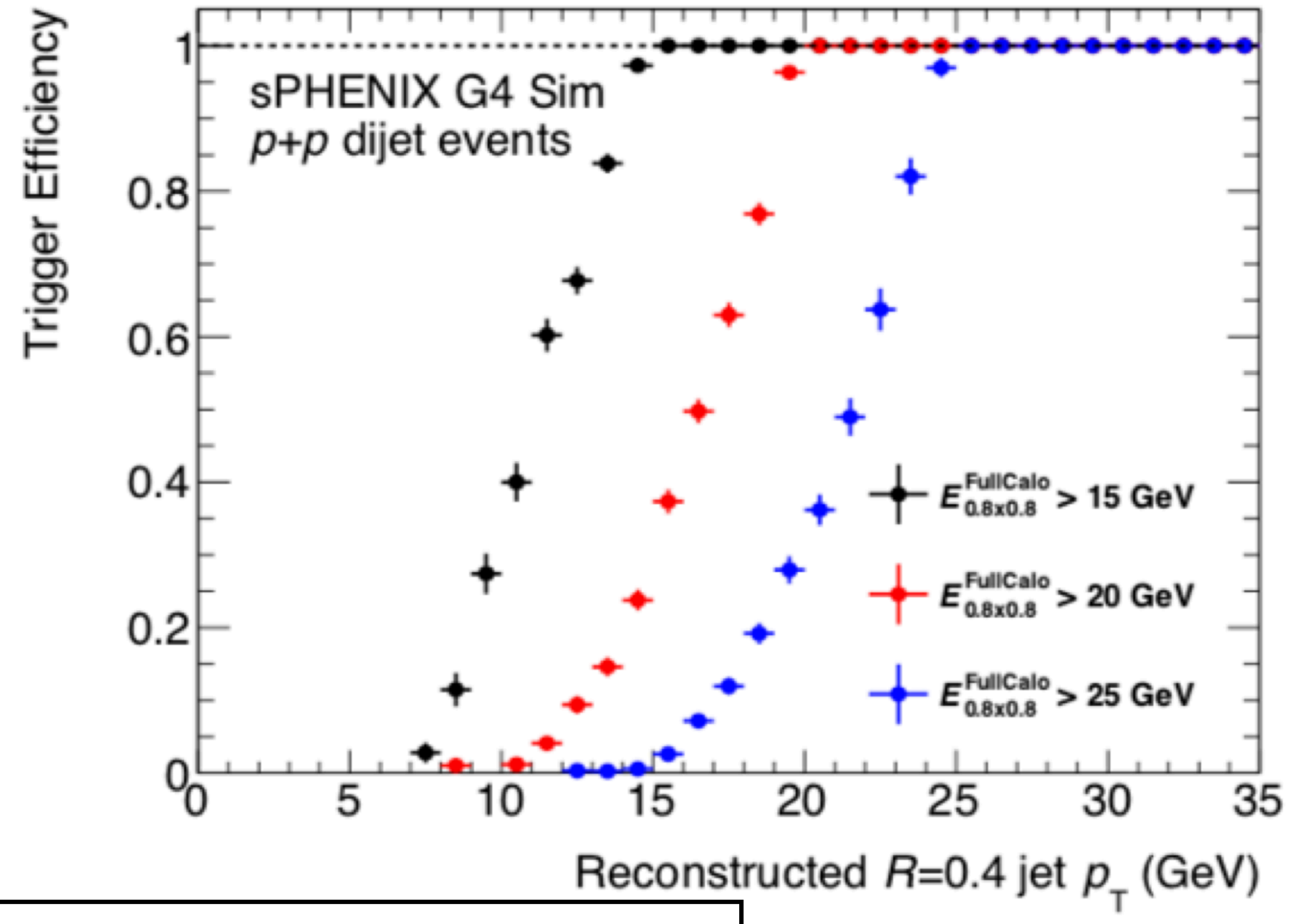
sPHENIX Calorimeter system

- HCAL and EMCAL sampling calorimeters, covering 2π in azimuth, $|\eta| < 1.1$, 15kHz read-out rate
- First mid-rapidity hadronic calorimeter at RHIC, 0.1x0.1 segmentation
- Allows to capture full jet energy
  - reduce fragmentation bias and improve resolution
- Allows systematic comparison of **particle flow** vs **calo** vs **track jets**
- 15%/√E or better for photons and electrons
- Allows unbiased jet trigger in p+p
  - Unbiased Au+Au by not using a trigger

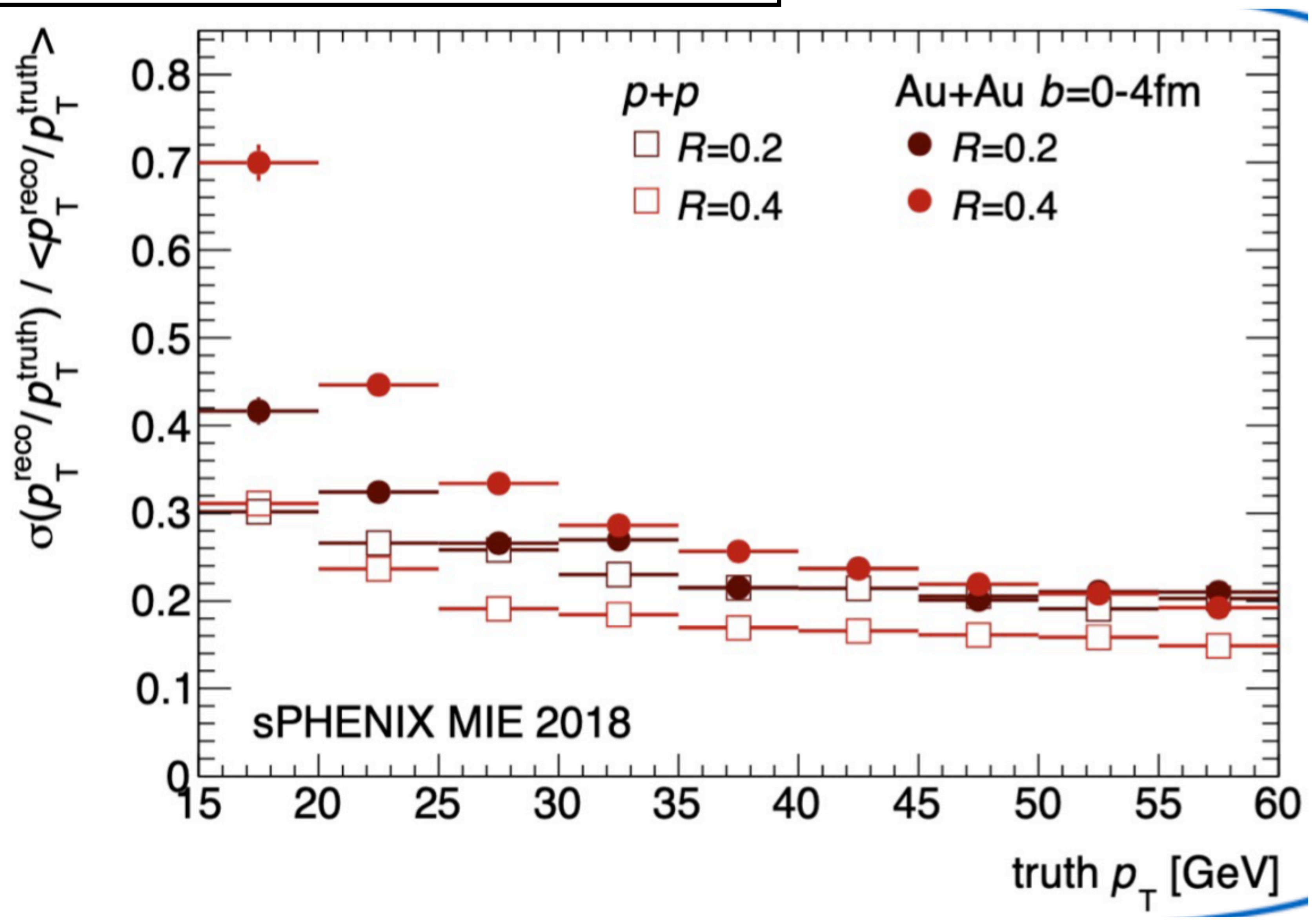


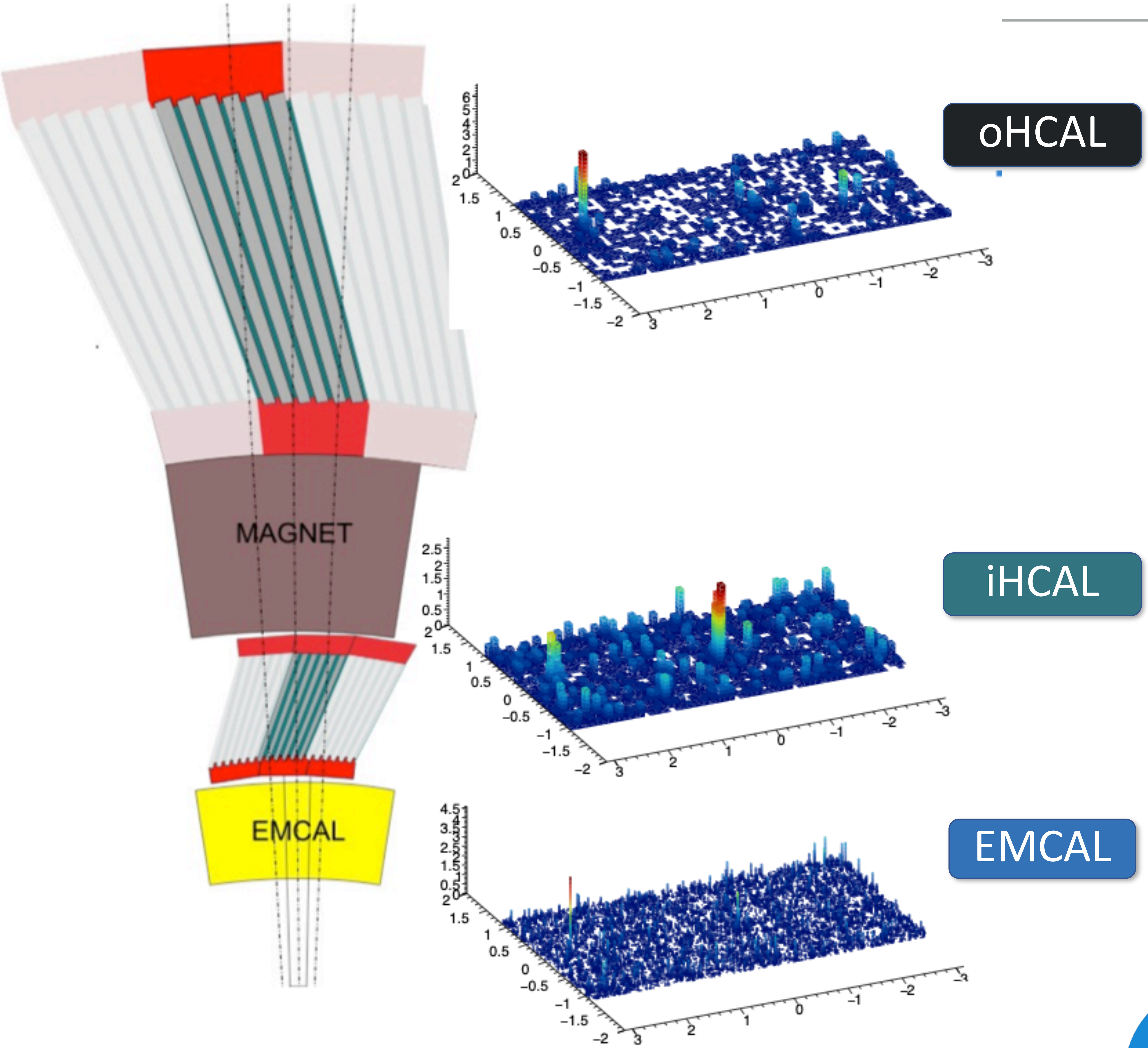
sPHENIX Calorimeter system == Unbiased jet trigger in p+p

Jet trigger turn-on curve (pp)



Jet energy resolution

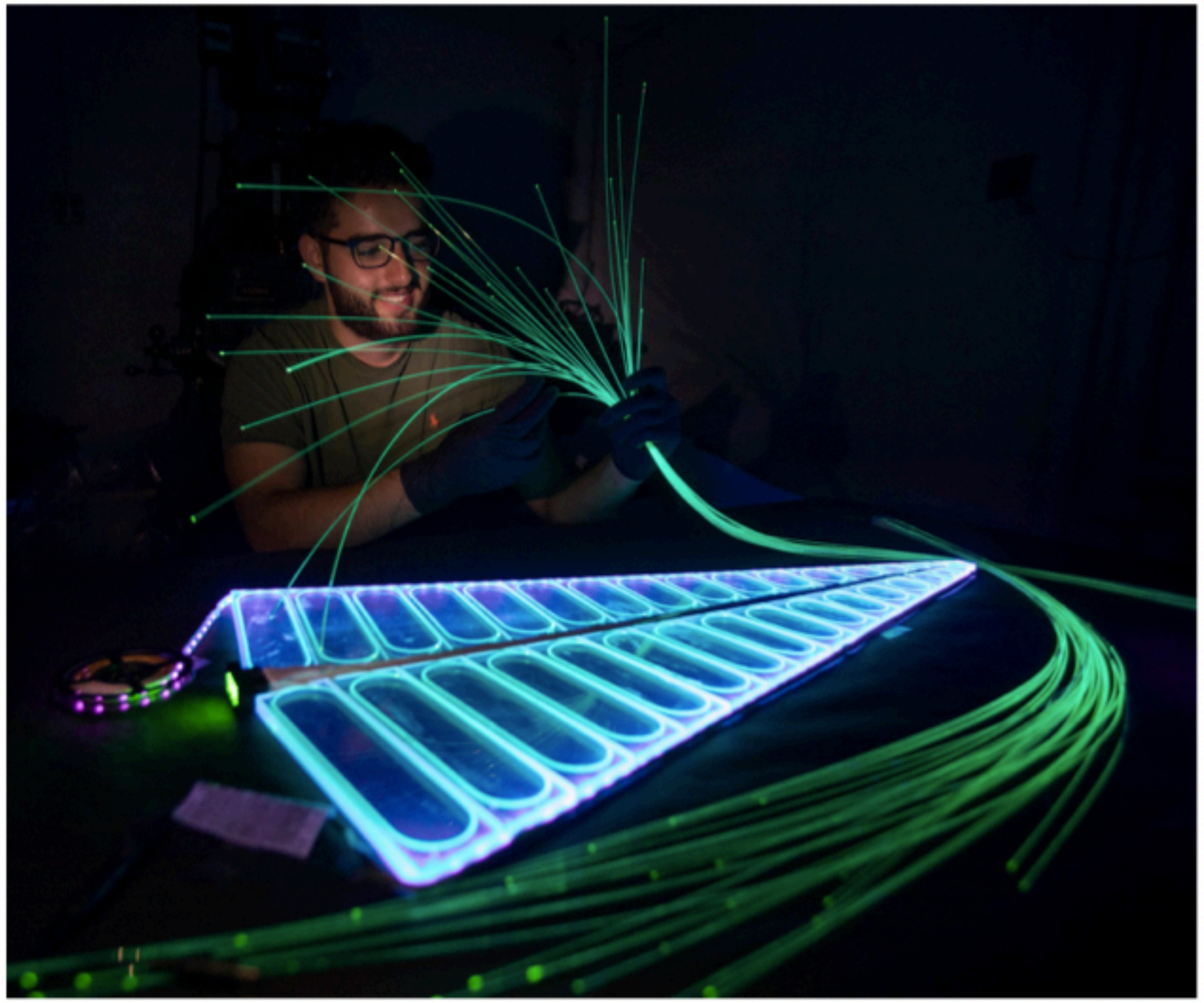




- Good energy resolution in p+p and Au+Au
- Au+Au is limited by UE fluctuations

Event Characterization

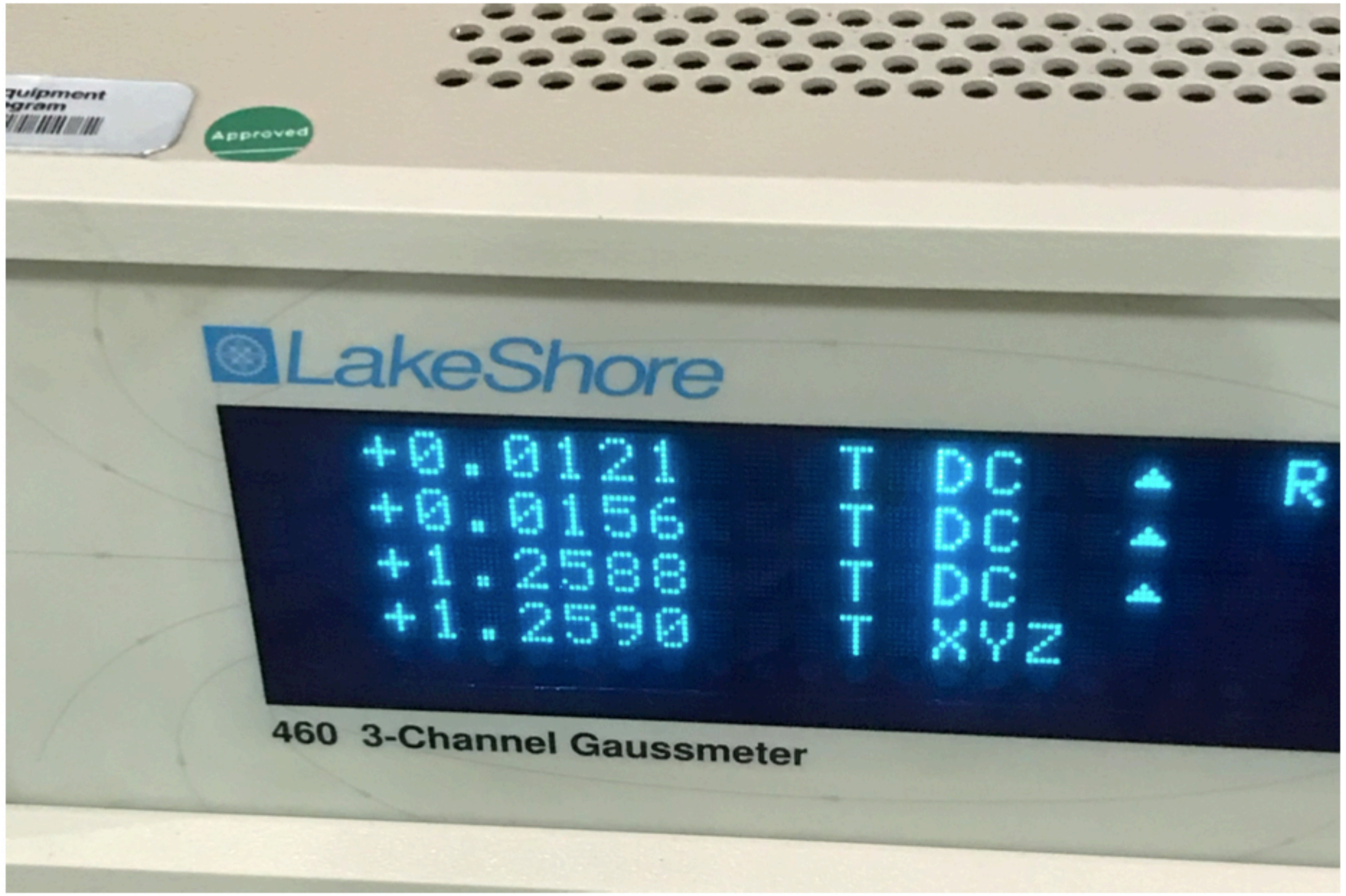
Min. Bias Detector (MBD)
- Covers 3.51 < | eta | < 4.61
- Reuse PHENIX Beam-Beam Counter
- 128 channels of 3 cm thick quartz radiator on mesh dynode PMT
- Timing resolution: 120 ps



sPHENIX Event Plane Detector (sEPD)
- 2 wheels; 2.0 < |η| < 4.9
- Scintillator plastic (1.2 cm thick), embedded WLS fibers

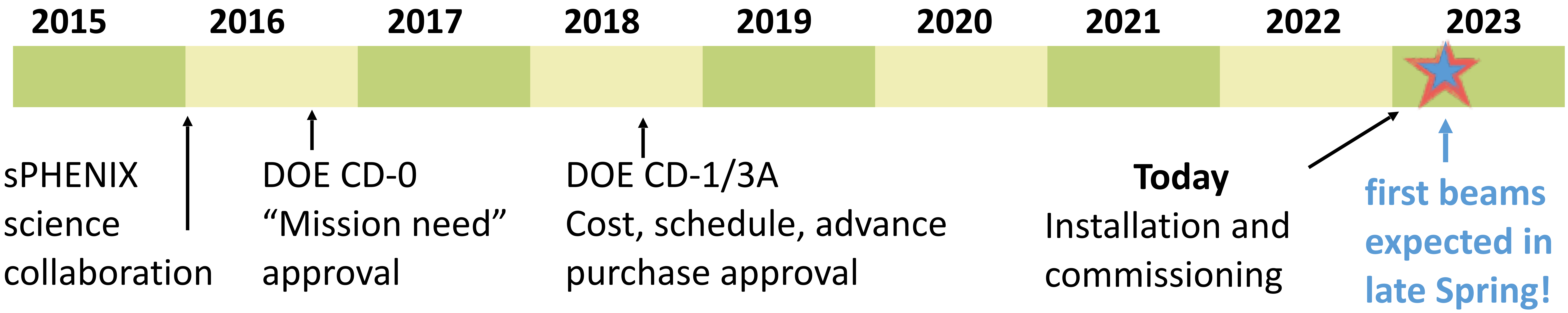
Event plane measurement for jet, heavy flavor, and small systems flow!

SuperConducting Magnet

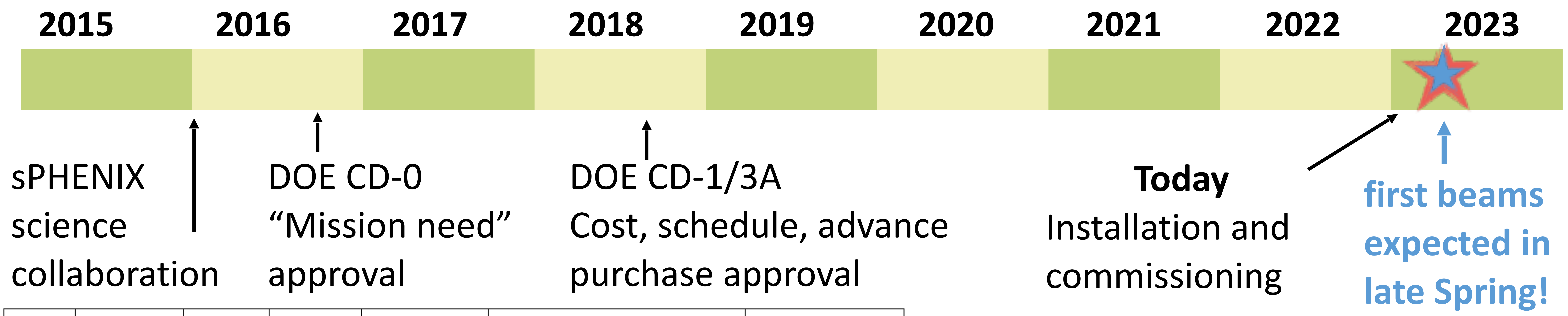


- BaBar solenoid installed is sPHENIX IR (October 2021)
- Successfully ramped to full current in position
- Field mapped by expert team from CERN

sPHENIX run plan



sPHENIX 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}

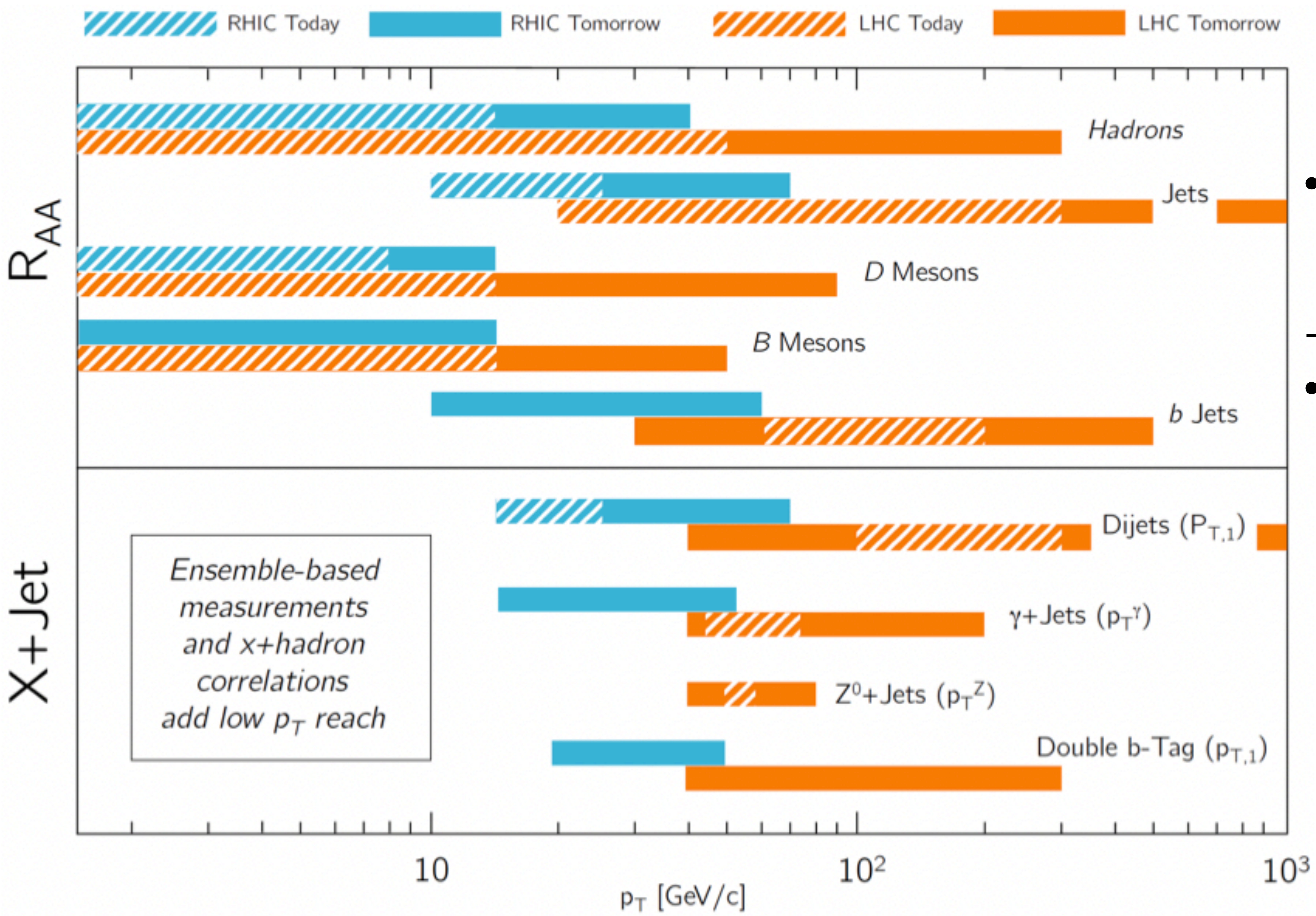
Extensive **3-year** data taking starting in a few months

Year-1: commissioning and first physics

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)

RHIC and LHC



- sPHENIX enables expanded kinematic ranges for many observable

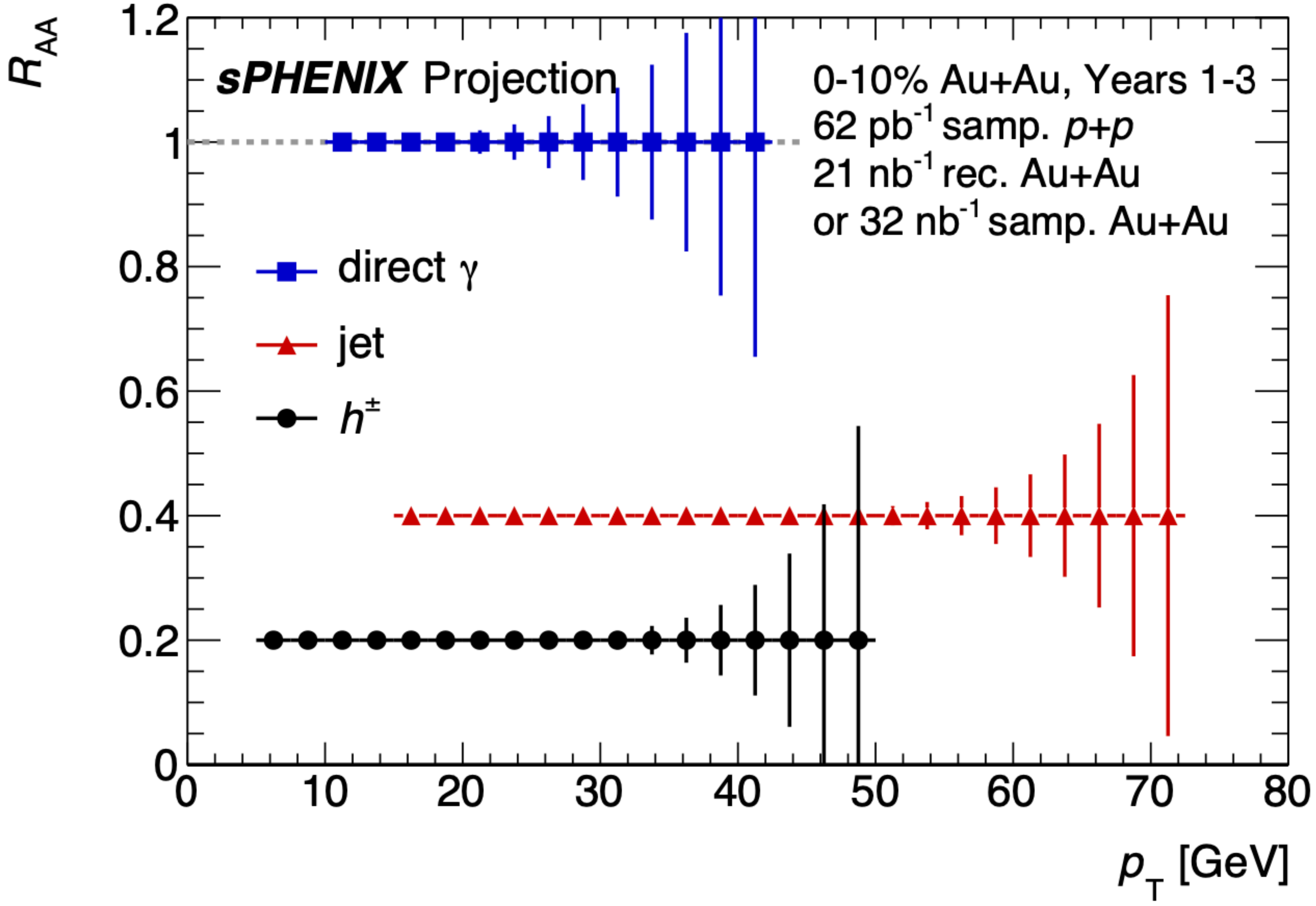
—> allows for overlap with LHC

- Some measurements for first time at RHIC!

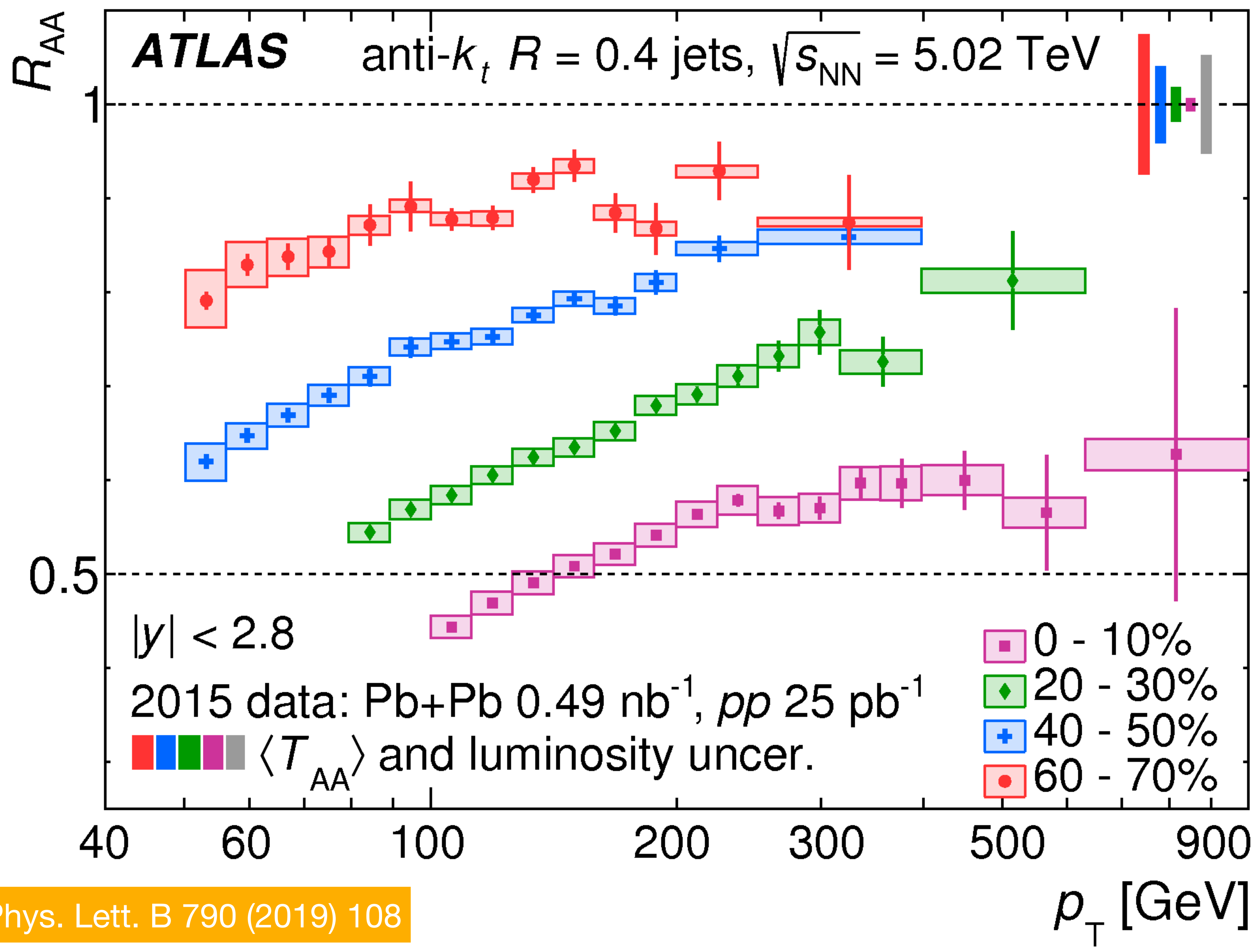
sPHENIX physics

Jet Quenching

Jets are known to lose energy when going through the Quark-Gluon-Plasma



Inclusive jets R_{AA}



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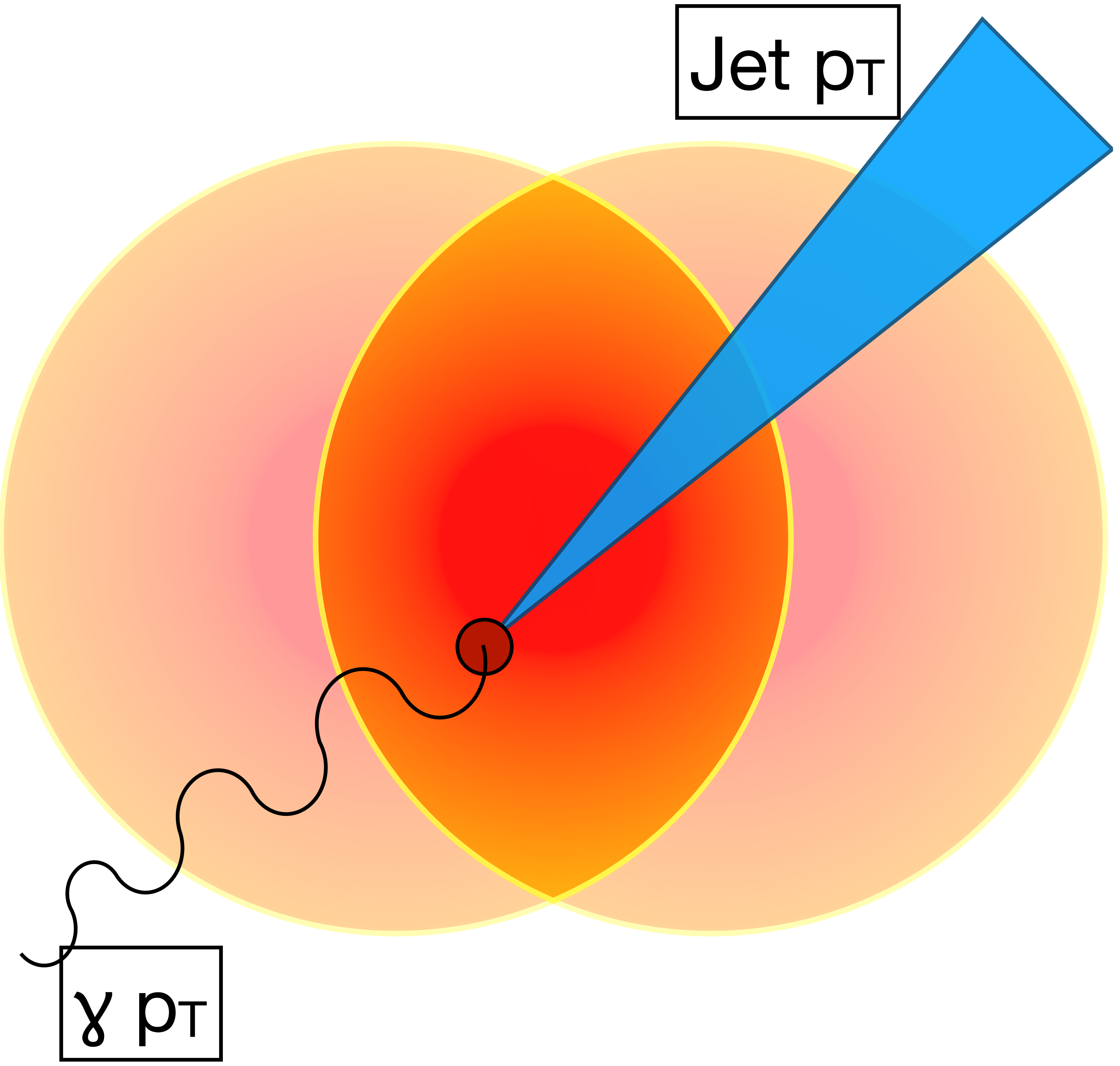
sPHENIX will meet up with the LHC kinematic range on the high end and push low in p_T

$$R_{AA} = \frac{N_{AA}}{T_{AA}\sigma_{pp}} = 1$$; No nuclear effect

$$R_{AA} = \frac{N_{AA}}{T_{AA}\sigma_{pp}} \neq 1$$; Nuclear modification

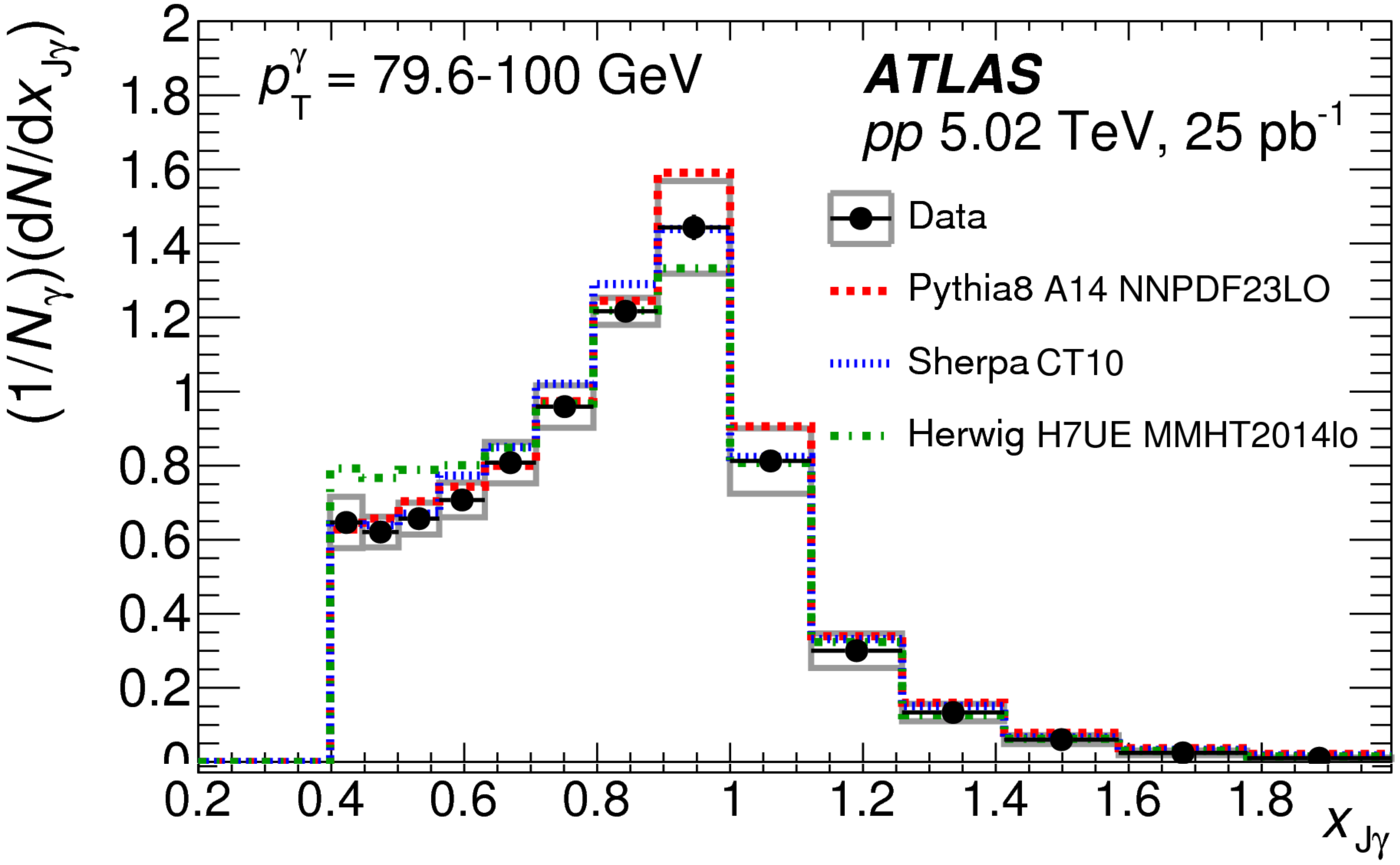
Photon-Jet correlations



Z/γ-tagged jets are useful for two reasons:

1) Constraining initial the jet momentum

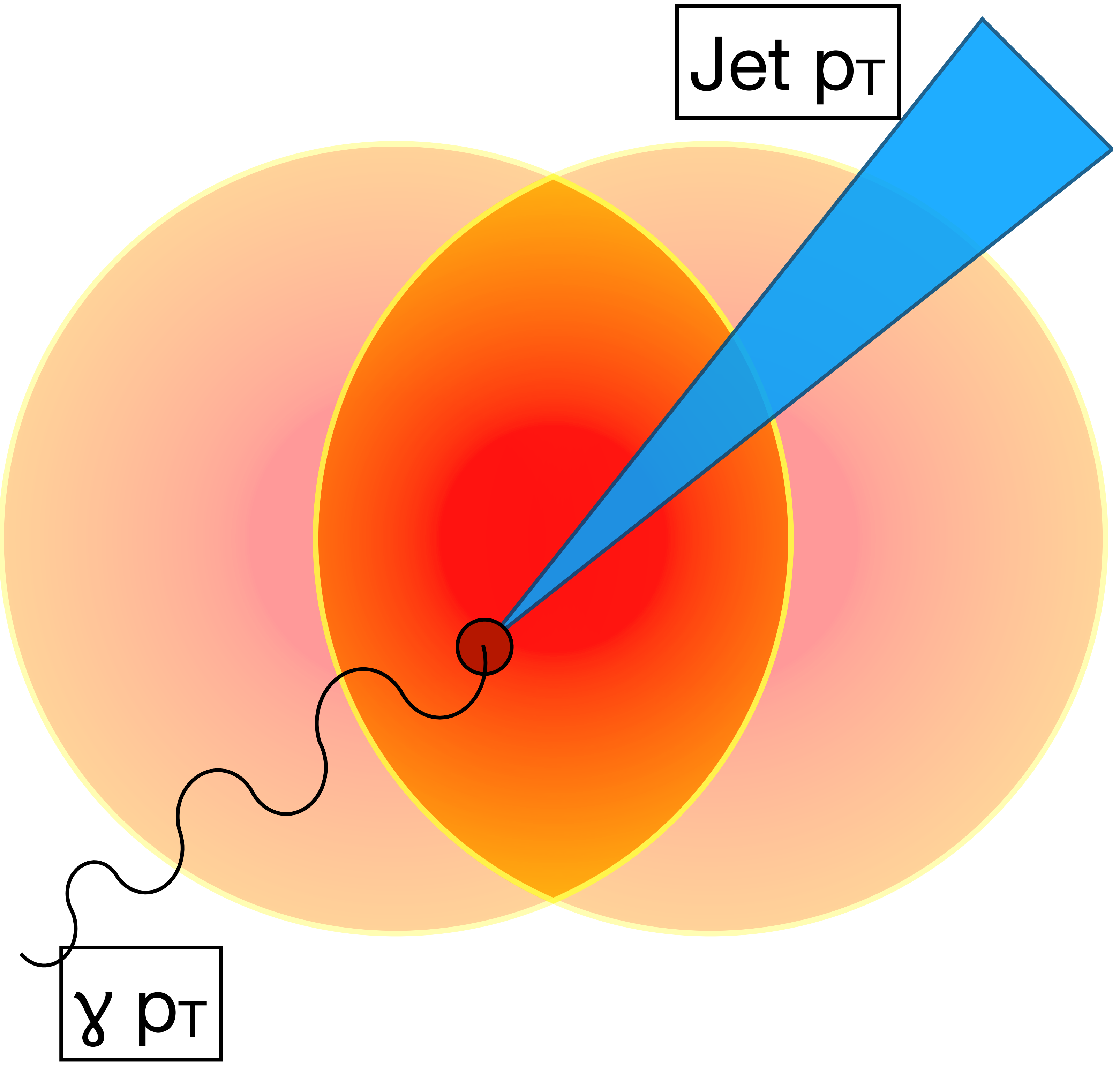
- E/W bosons do not interact strongly with QGP
- Different than di-jets where both jets are quenched



Momentum imbalance:

$$x_{j\gamma} = p_T^{jet}/p_T^{\gamma}$$

Photon-Jet correlations

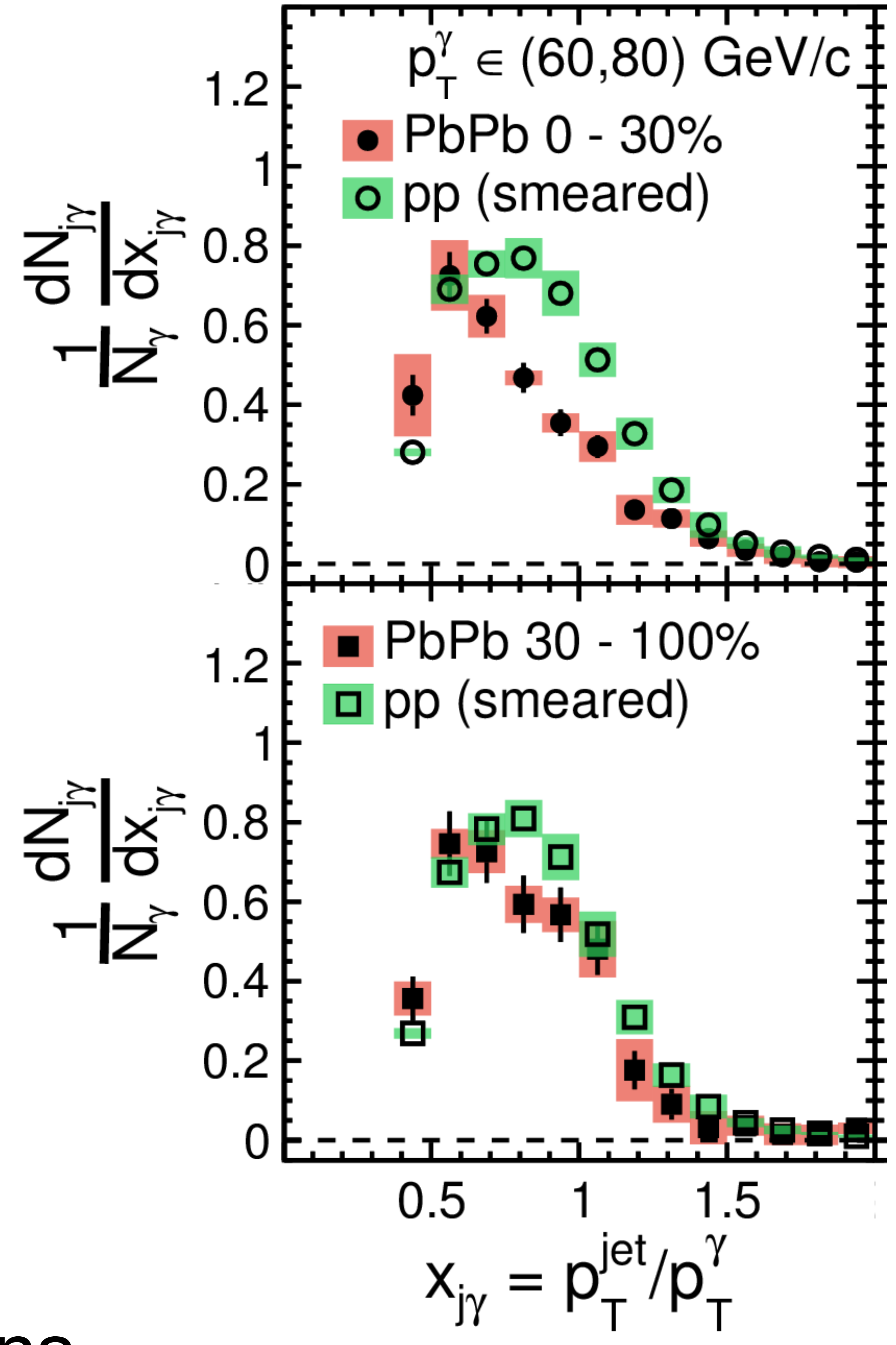


Momentum imbalance:

$$x_{j\gamma} = p_T^{jet}/p_T^{\gamma}$$

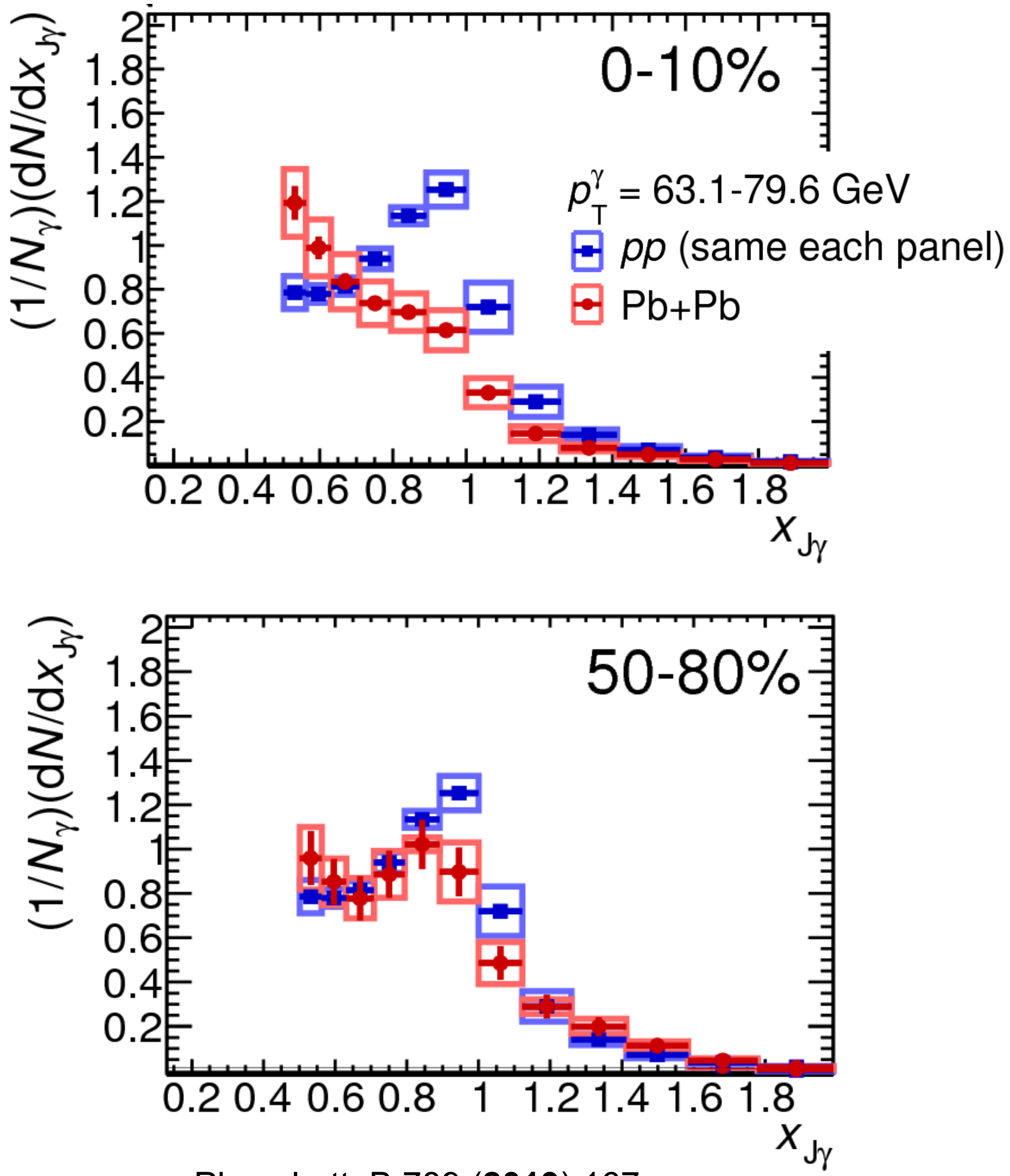
- Consistent results between detectors
- Jets loss more energy in central collisions
- pT > 60 GeV

CMS $\Delta\phi > 7\pi/8$ $p_T^{jet} > 30\ GeV$ $|\eta^{jet}| < 1.6$ $|\eta^{\gamma}| < 1.44$



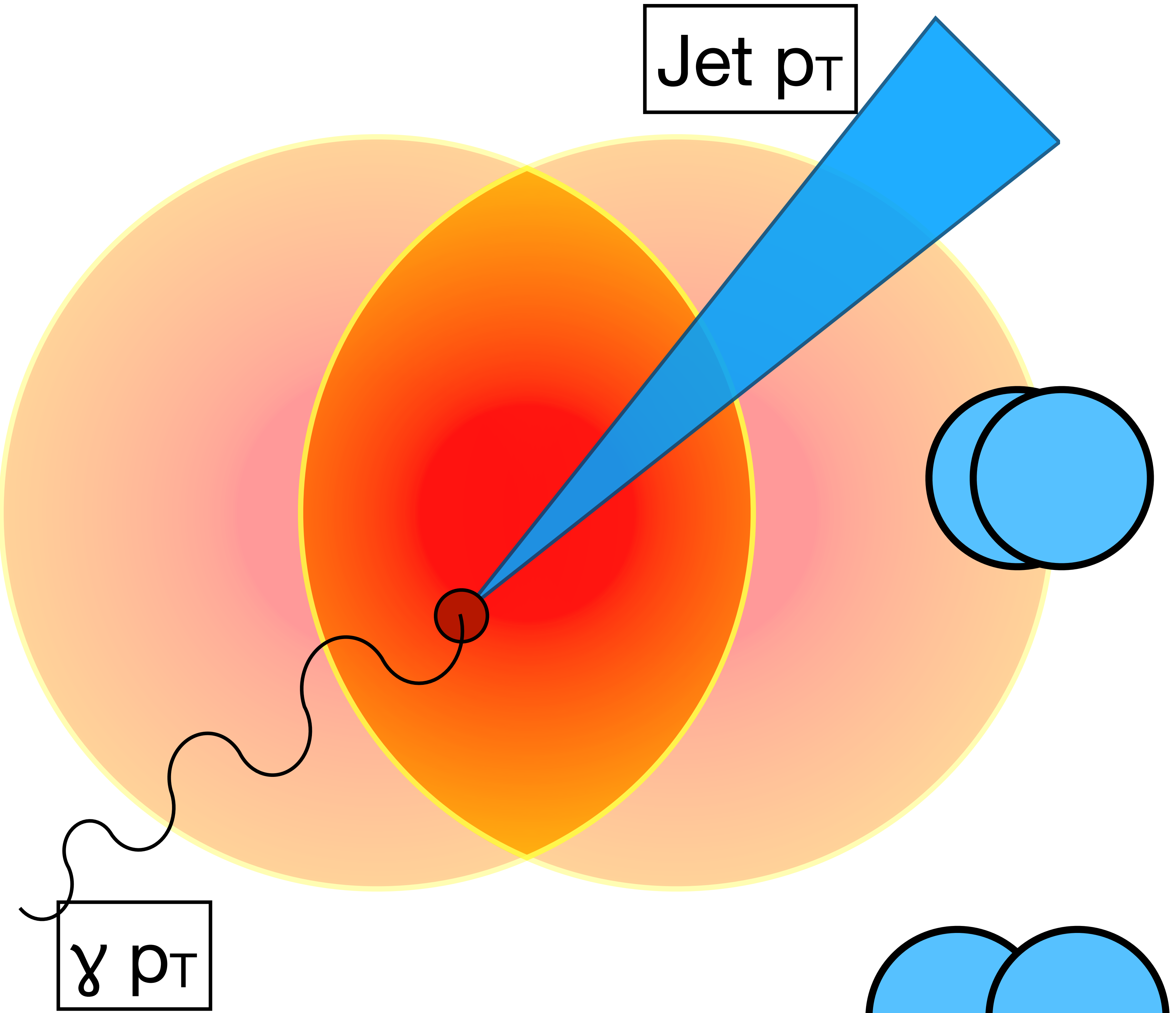
Phys. Lett. B 785 (**2018**) 14

ATLAS $\Delta\phi > 7\pi/8$ $p_T^{jet} > 31.6\ GeV$ $|\eta^{jet}| < 2.8$ $|\eta^{\gamma}| < 2.37$



Phys. Lett. B 789 (**2019**) 167

Photon-Jet correlations



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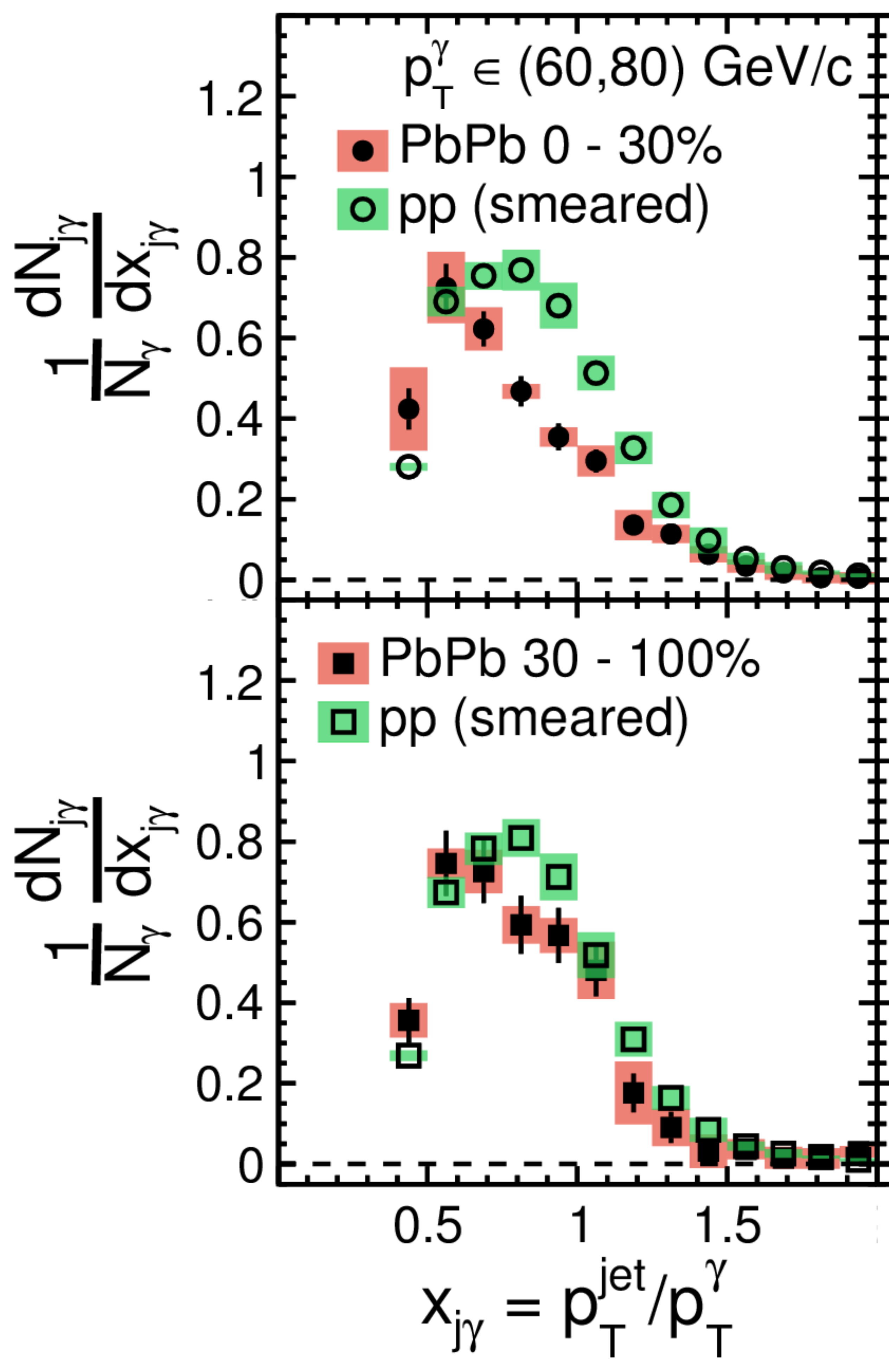

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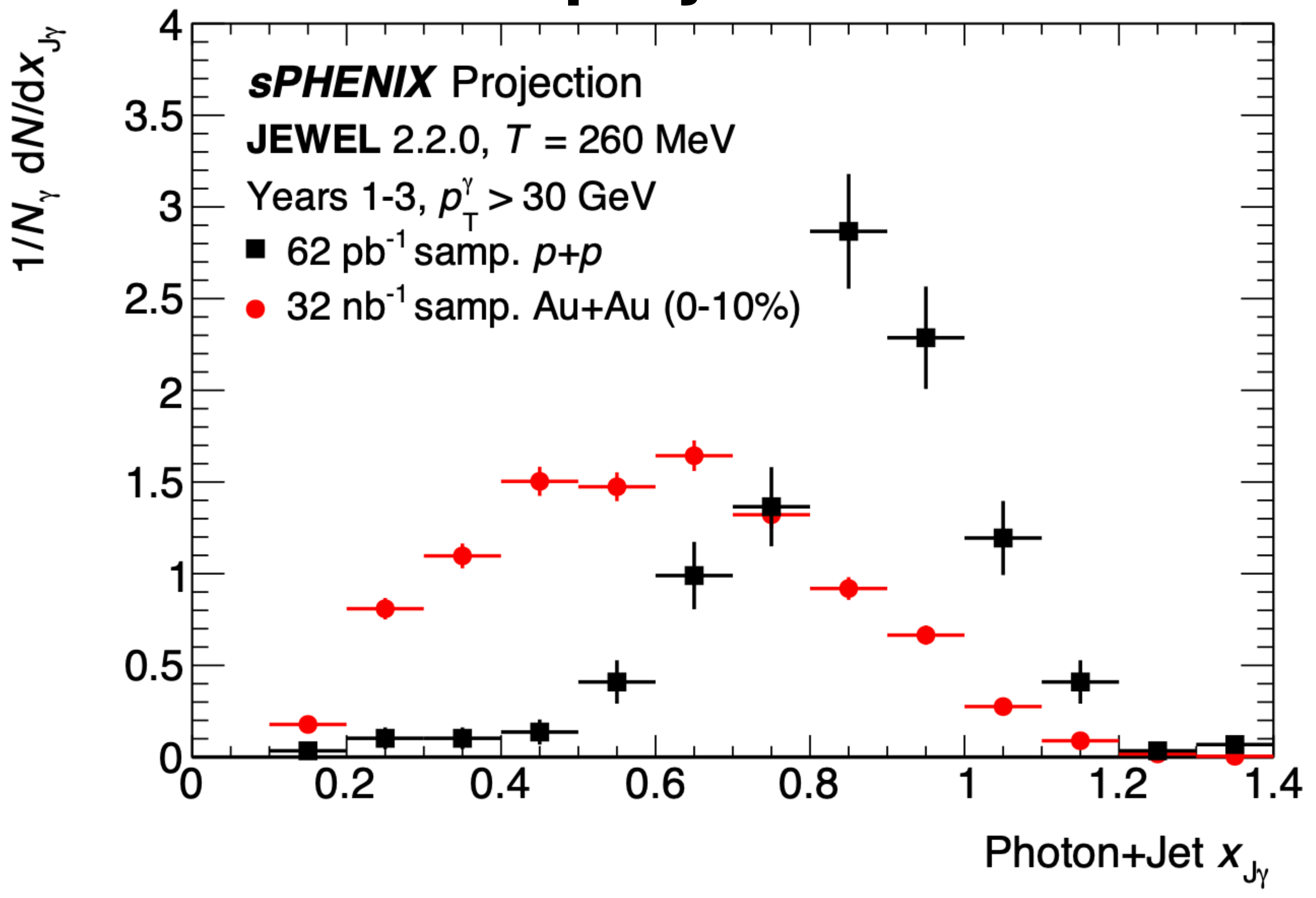
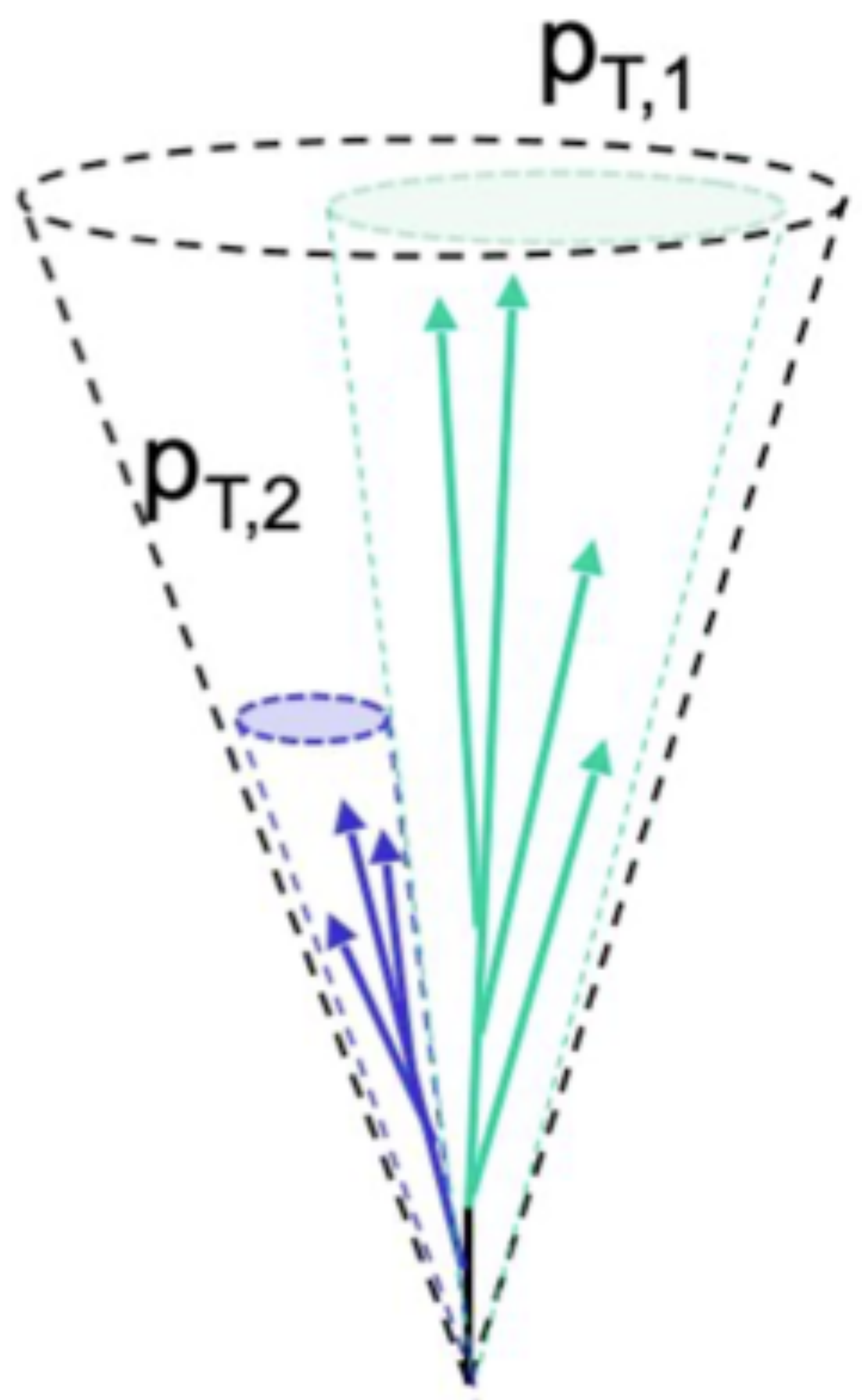
sPHENIX projection



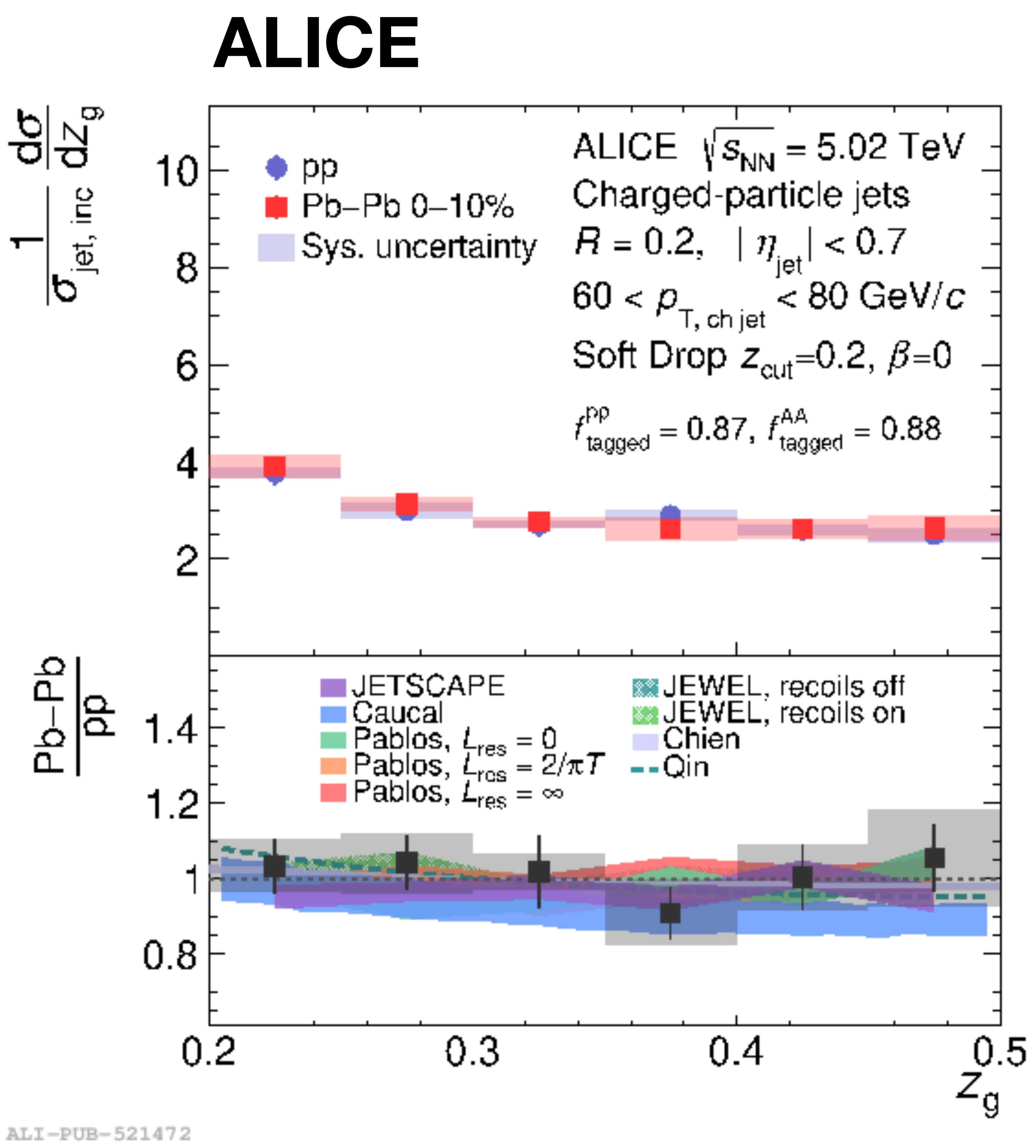
- Statistical projections for **p+p** and **0-10% Au+Au** (shape taken from **JEWEL**)
- Study **flavor dependence** of energy loss
  - **Lower p_T than LHC**

Jet substructure



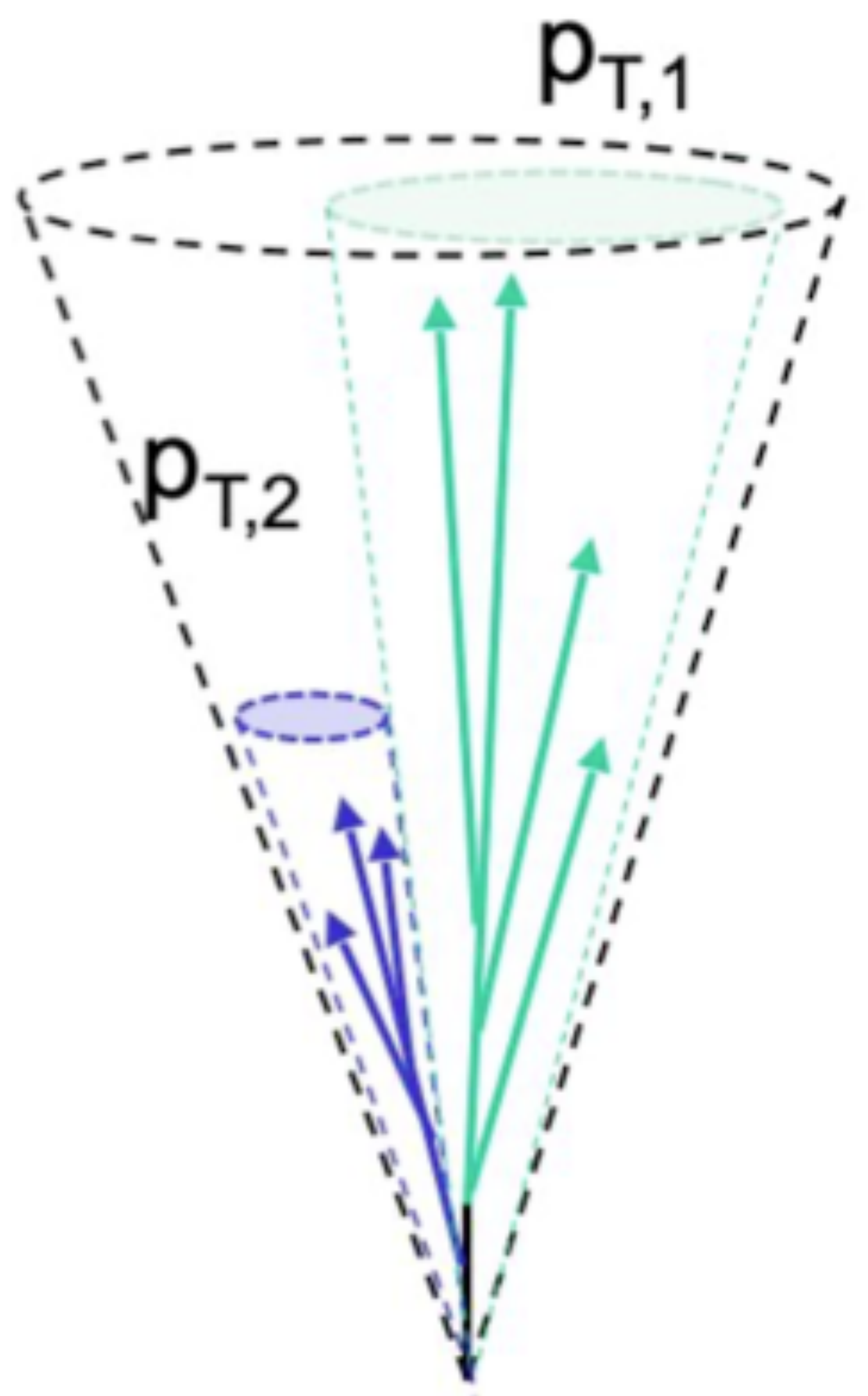
Groomed momentum fraction

$$z_g = \frac{min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$



- No significant modification
- Mostly consistent with models

Jet substructure



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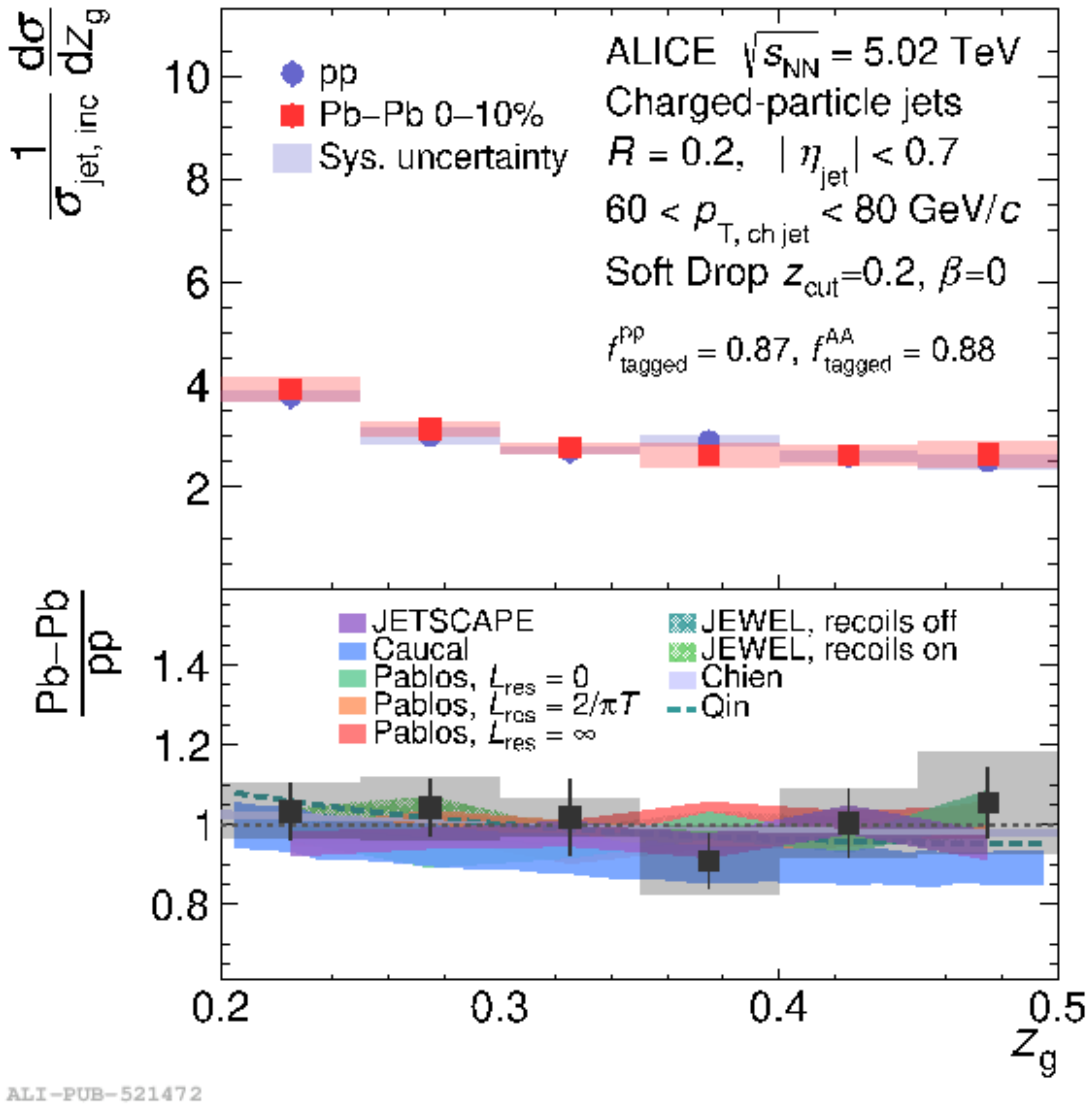
ALICE



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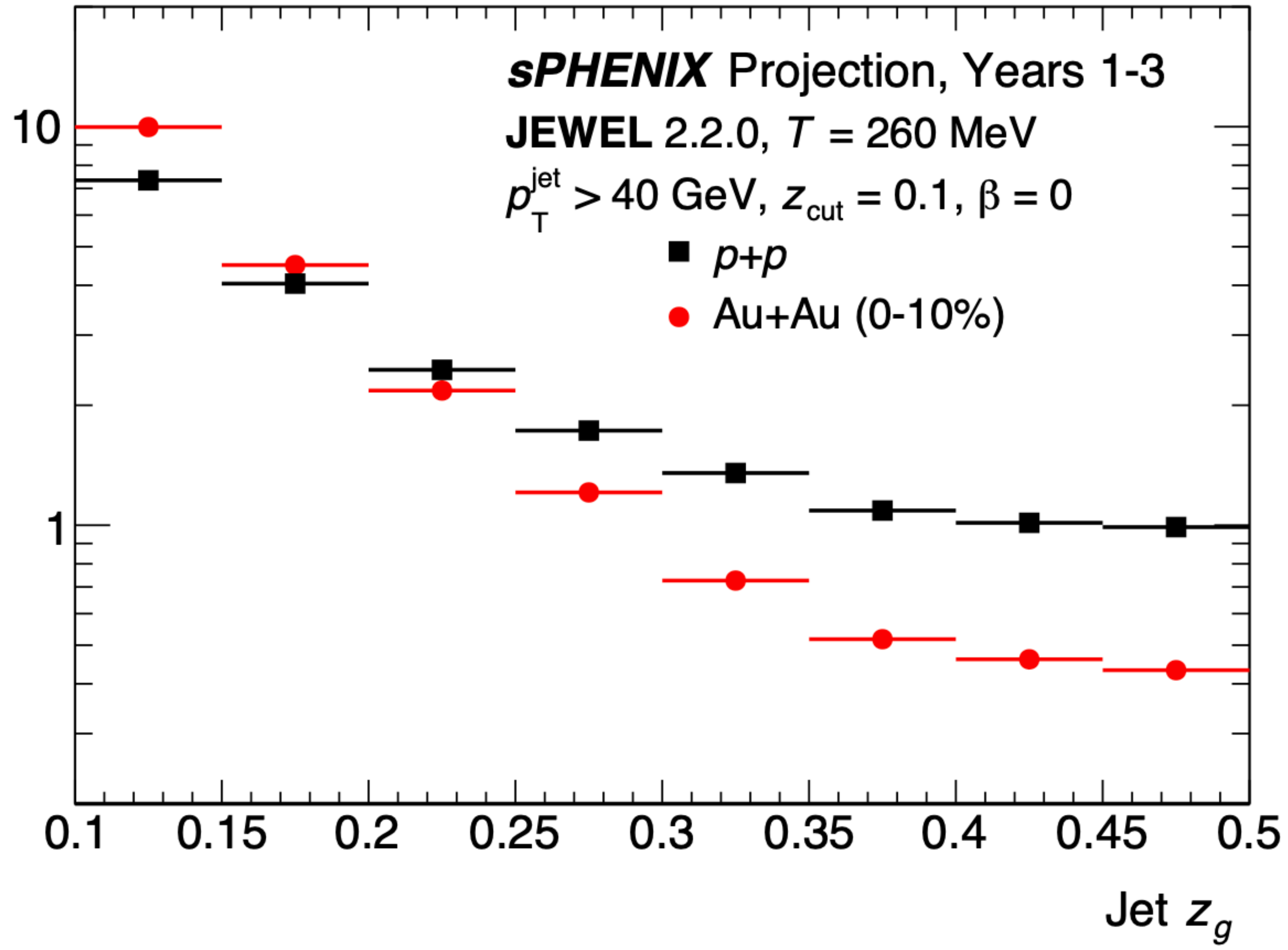
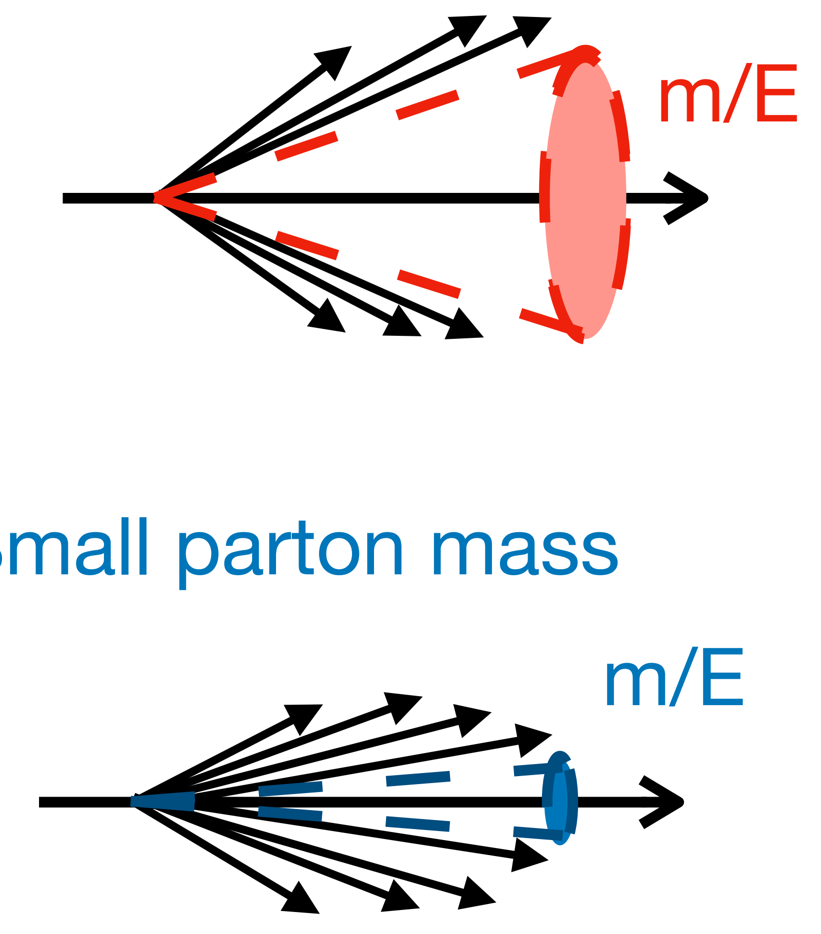


- Jet substructure measurements with fine segmentation of calorimeter+good tracking resolution
- Study evolution of parton shower
  - **Lower p_T than LHC**

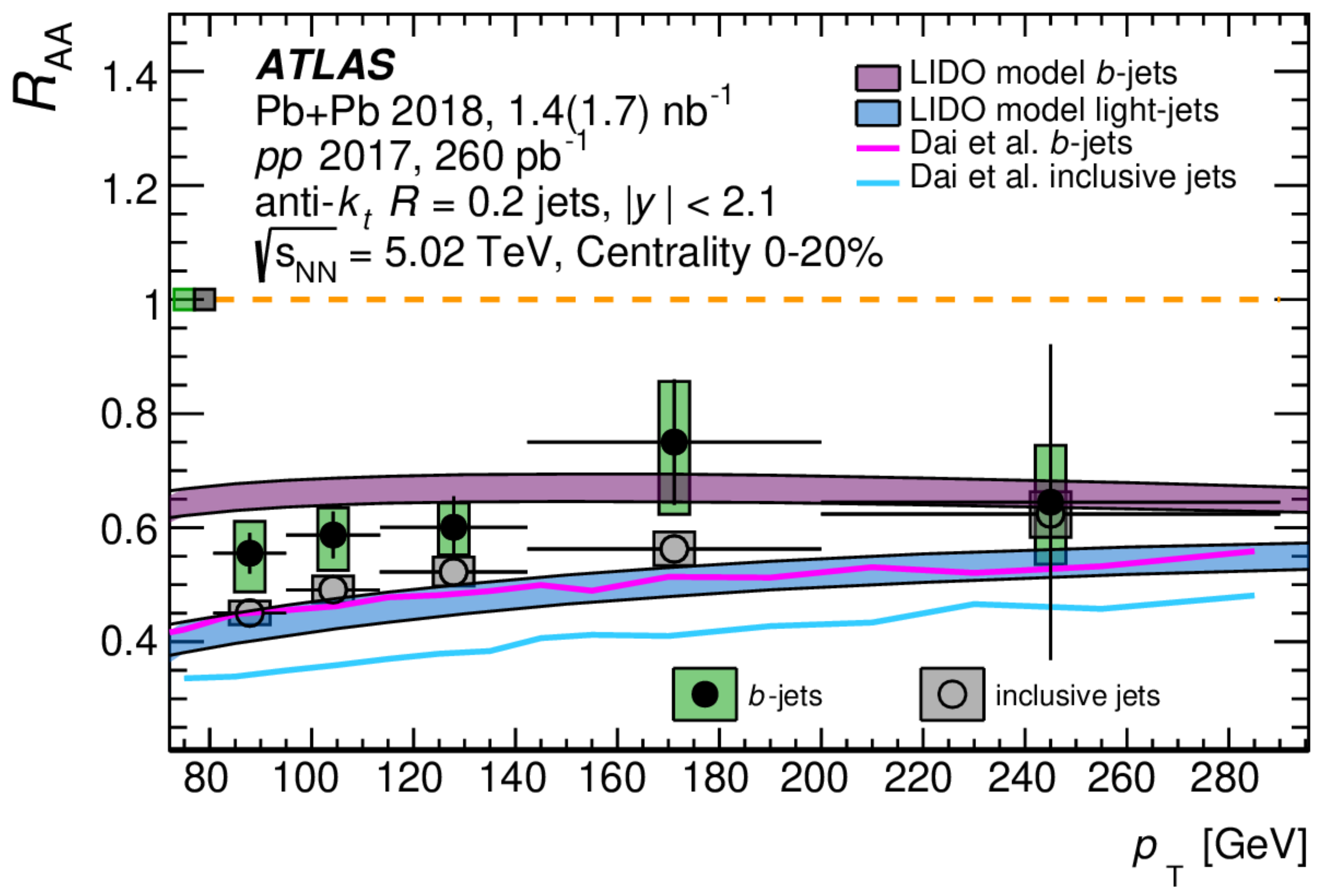
b-tagged Jets

Mass dependence expected due to “dead-cone effect”



Radiation is suppressed in θ < m/E

ATLAS



- *b*-jet found to be **less suppressed** than inclusive jets in central collisions
- But very high p_T for dead-cone effect to play a relevant role

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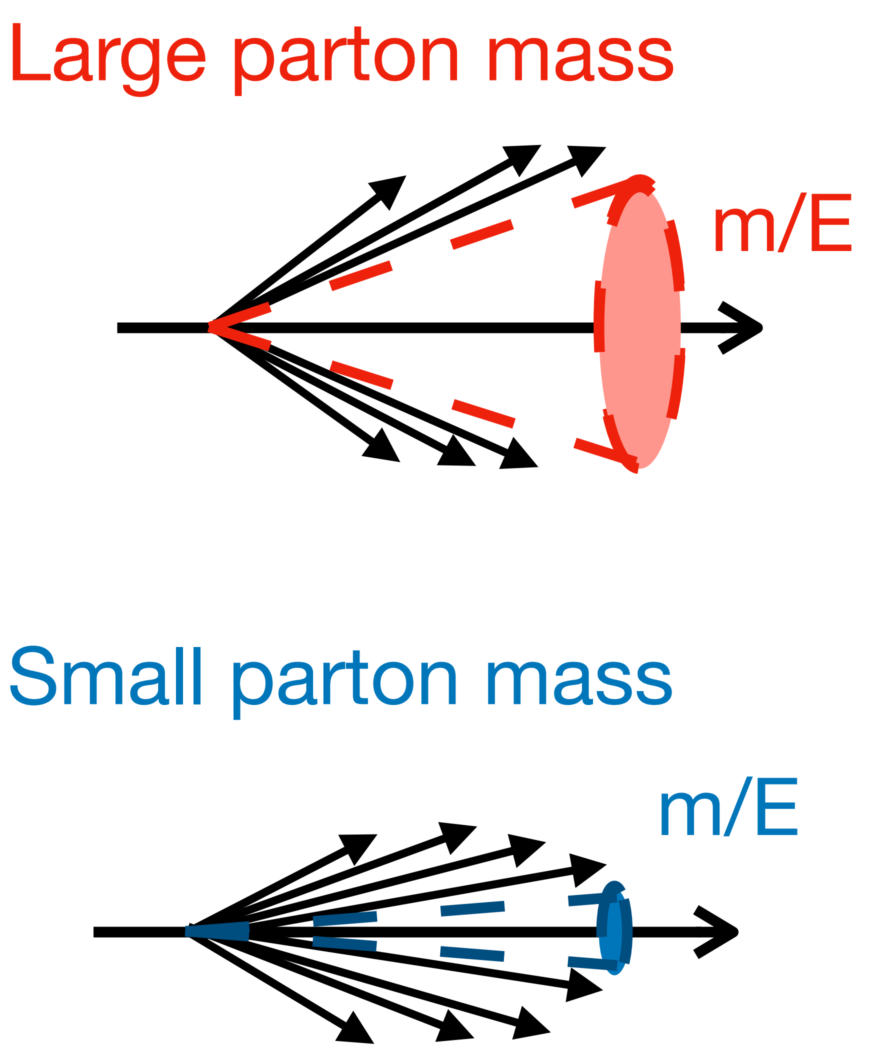

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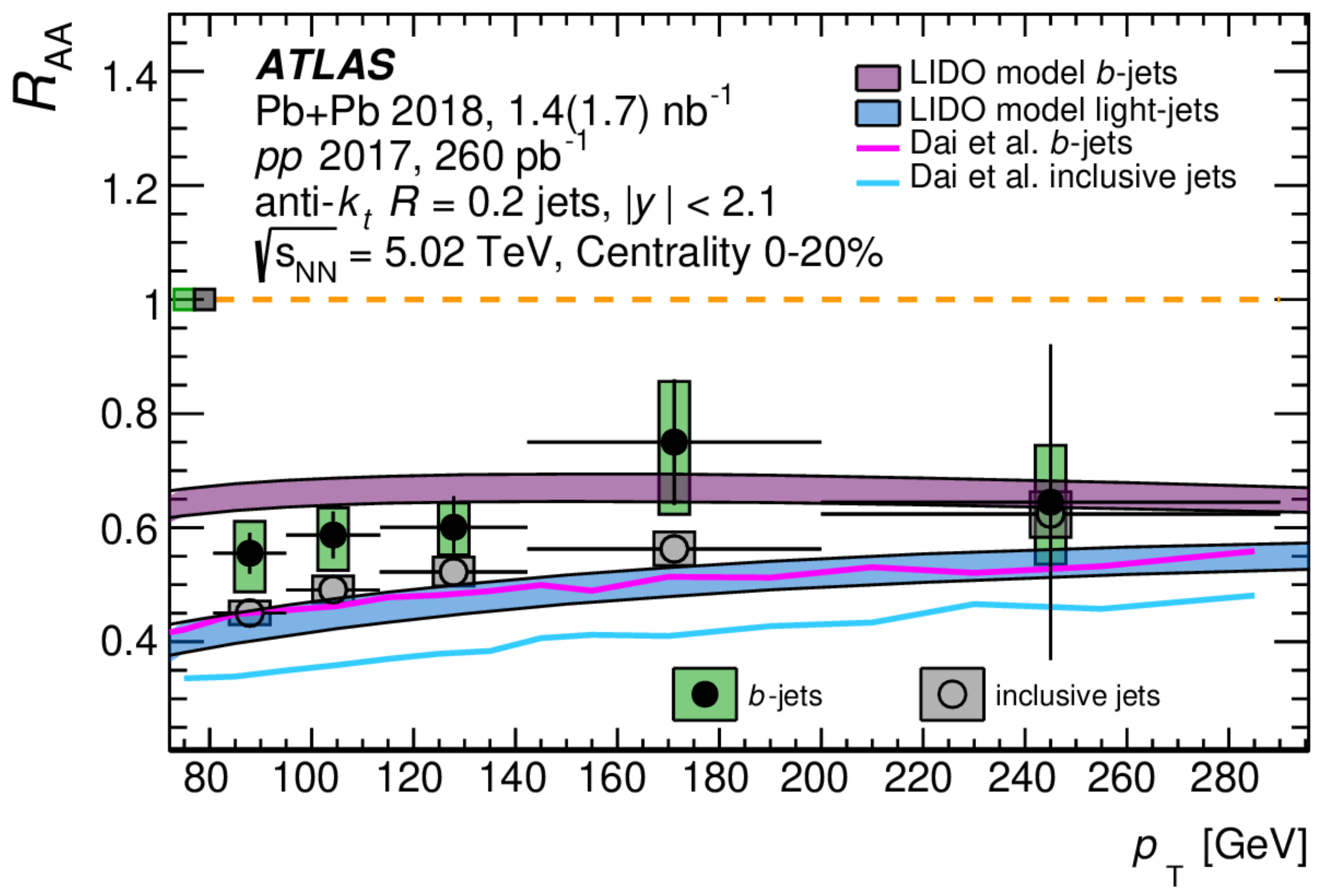

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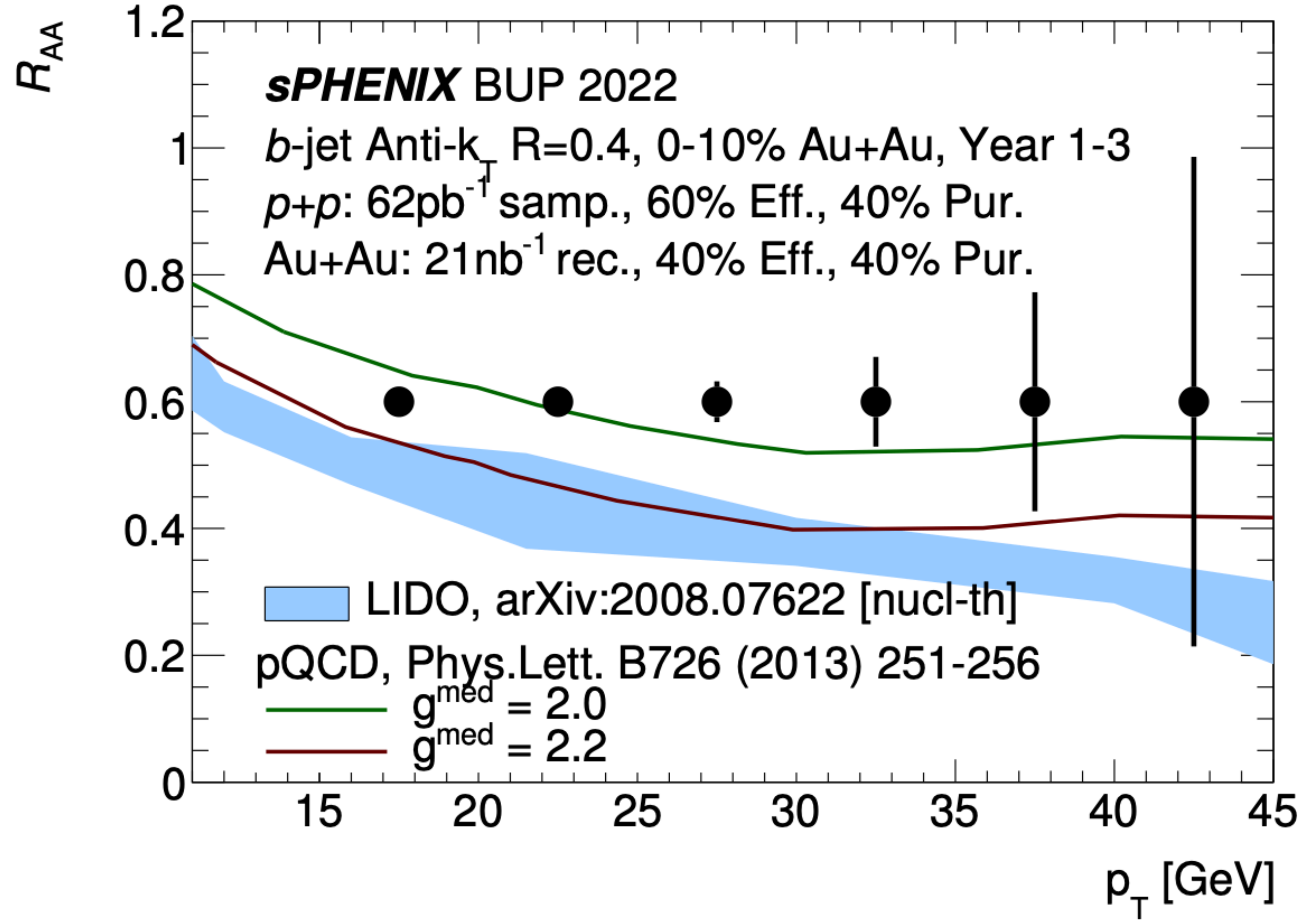
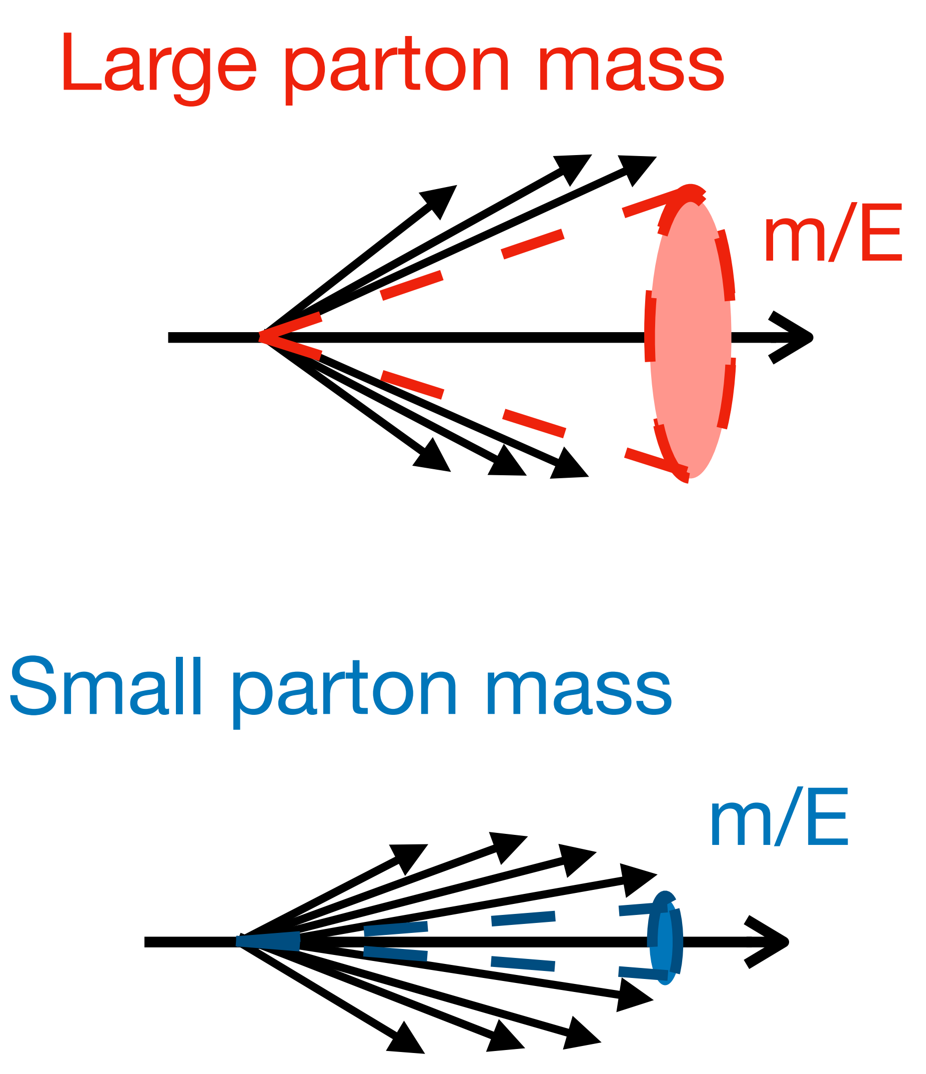


- Completely new channel at RHIC - unique sPHENIX capability
- **p_T > 15 GeV,** closer to b-mass, making the mass effect more relevant

b-tagged Jets

Mass dependence expected due to "dead-cone effect"



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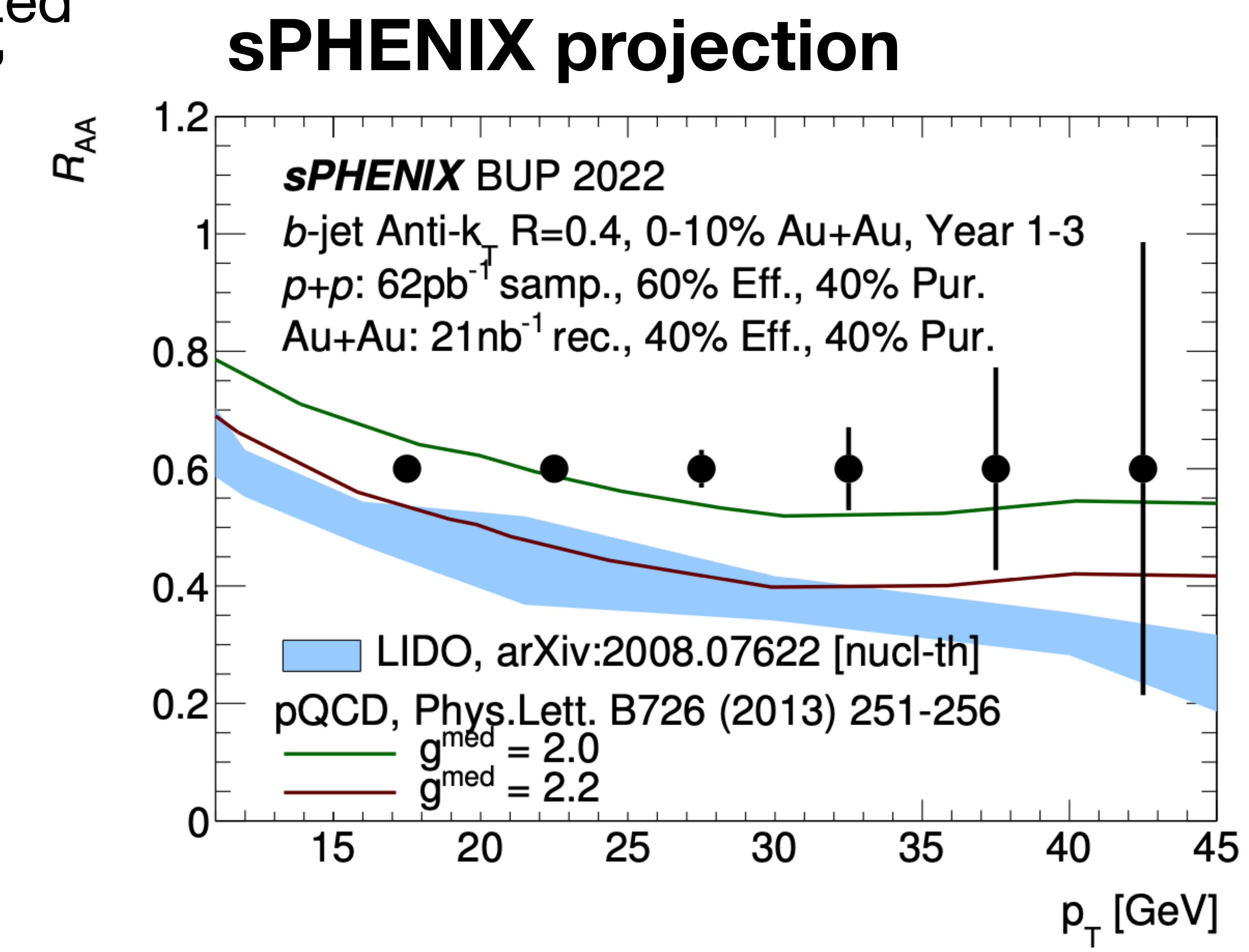
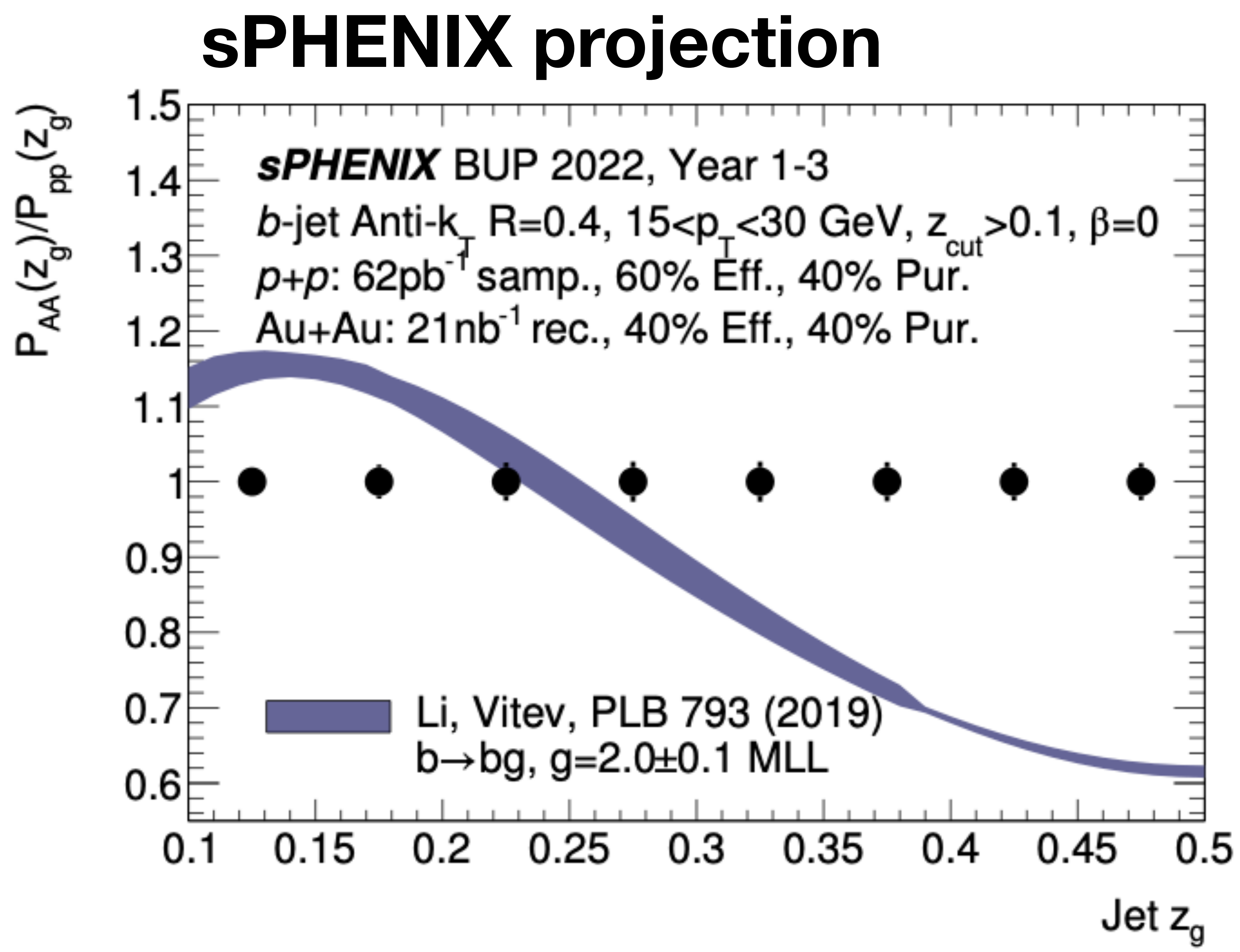


- Completely new channel at RHIC - unique sPHENIX capability
- **p_T > 15 GeV**

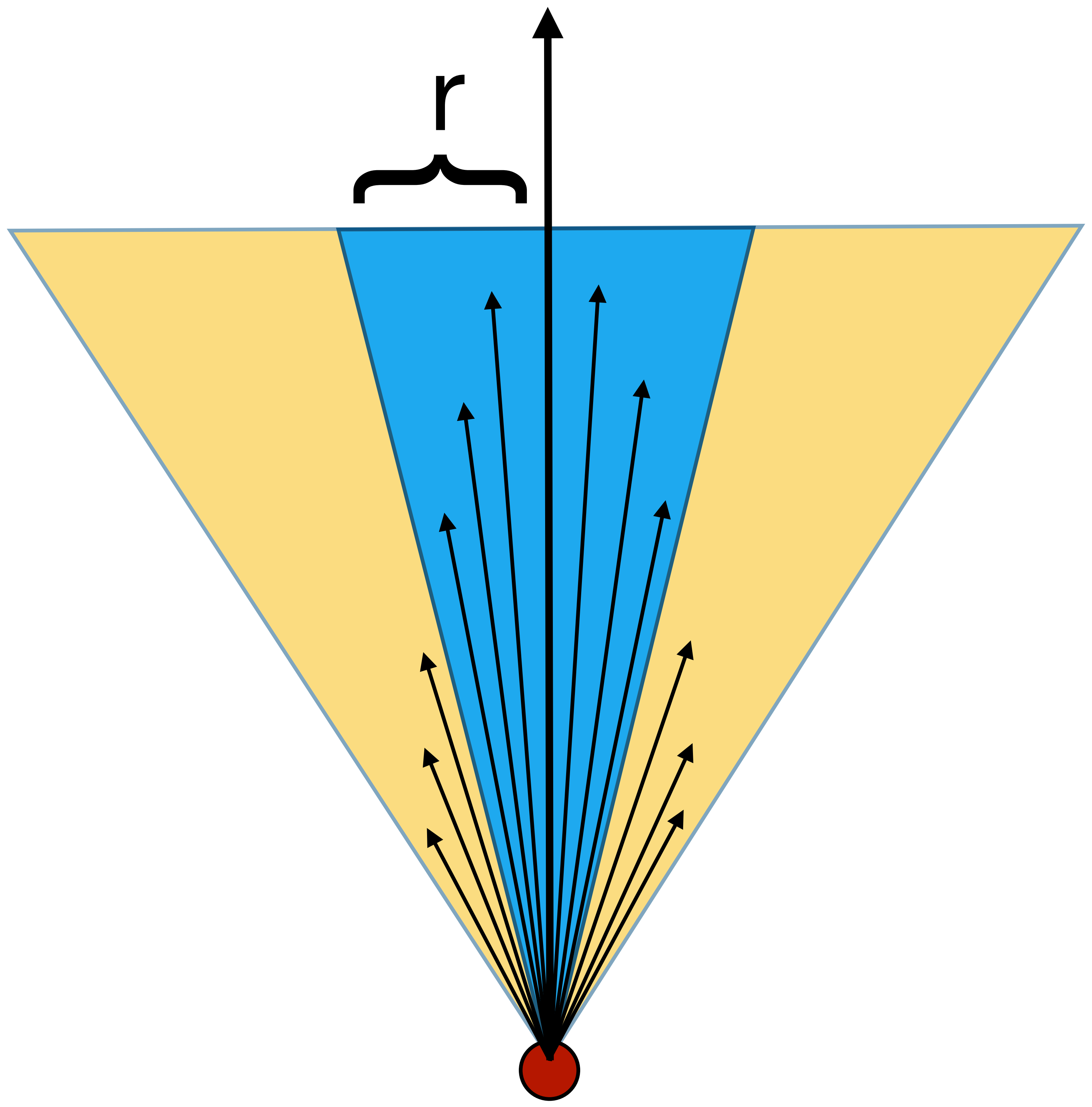


- Sufficiently large yield to look at b-jet structure, e.g. ratio of z in Au+Au/p+p

$$z_g = \frac{min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

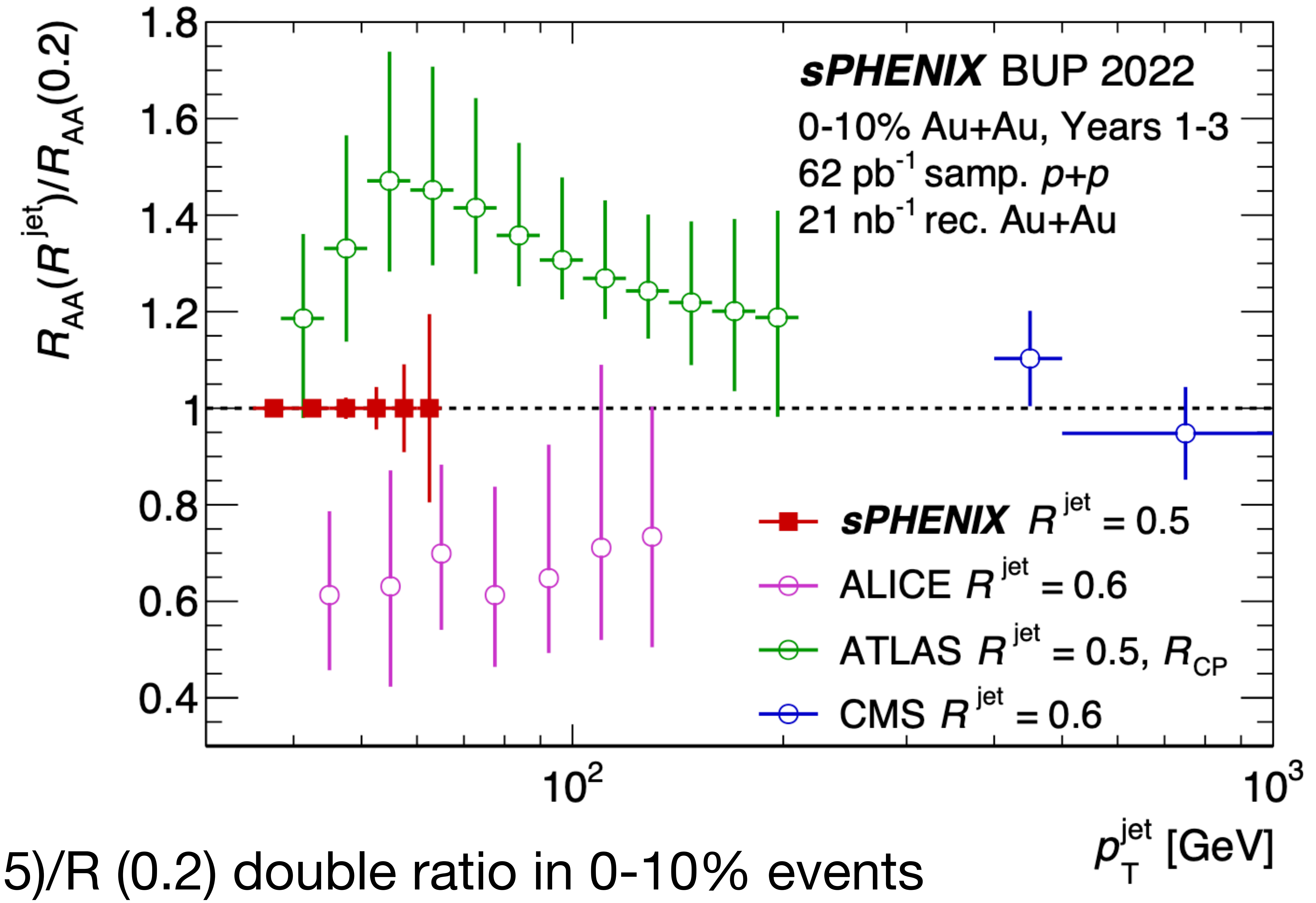
Jets: open questions from LHC

$$r = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$



Tension in Jet R-dependence

- key info on jet-shape modification
- **Difficult to measure at LHC in p_T < 50 GeV region where effects may be large**

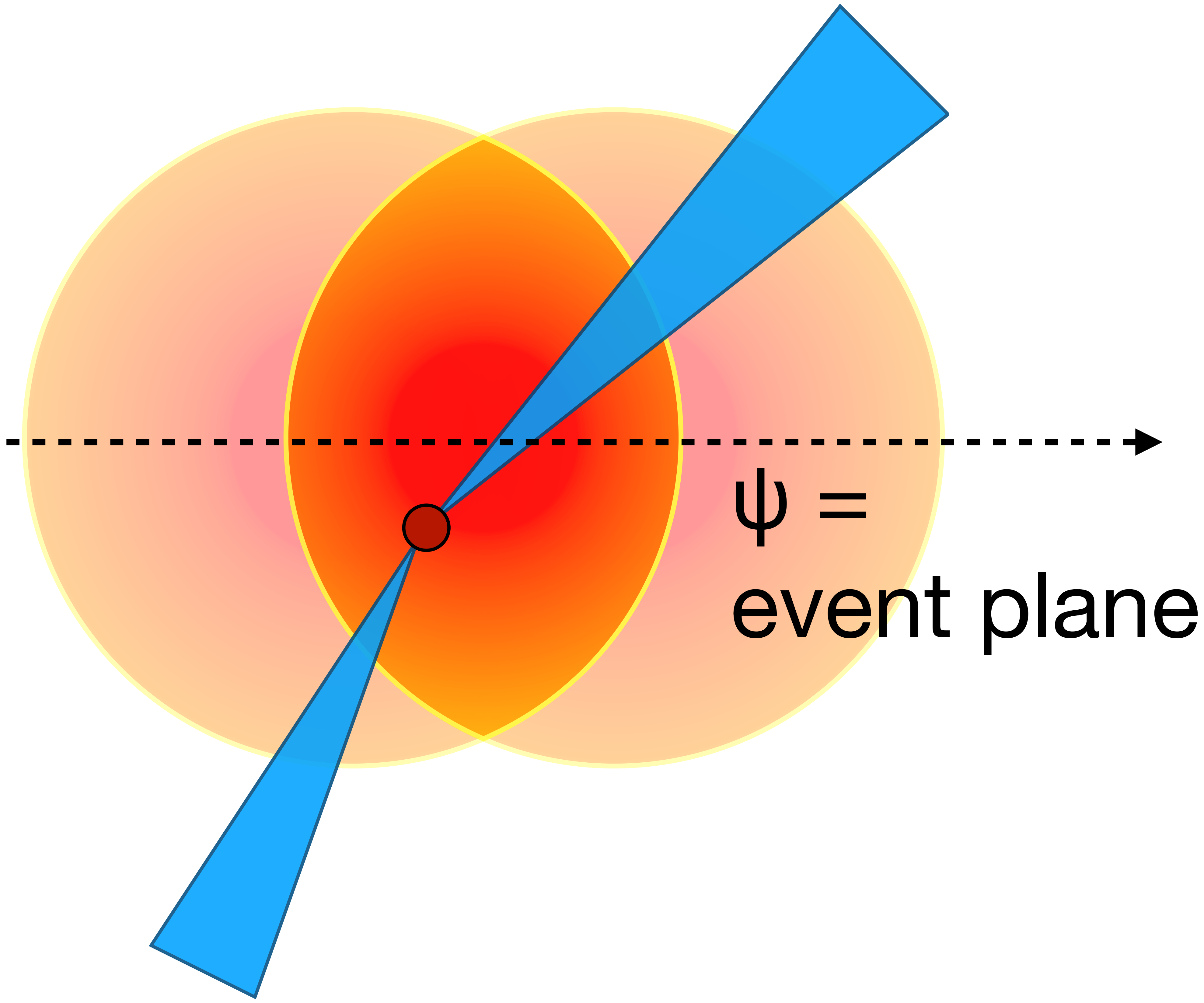


- Projected R(0.5)/R (0.2) double ratio in 0-10% events

Jets: open questions from LHC

Correlation of jets with the event planes, ψ

- Sensitive to path length energy loss



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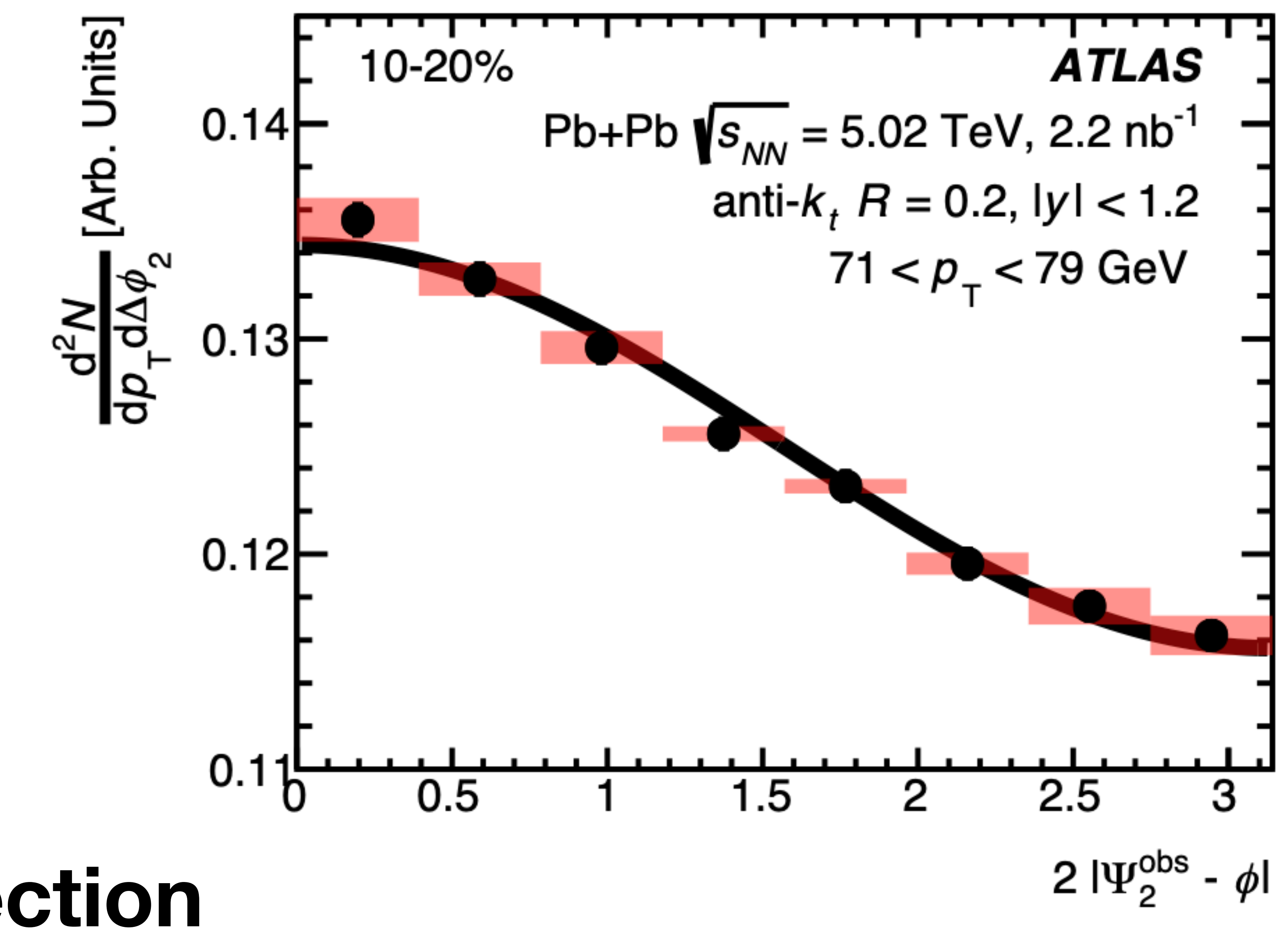
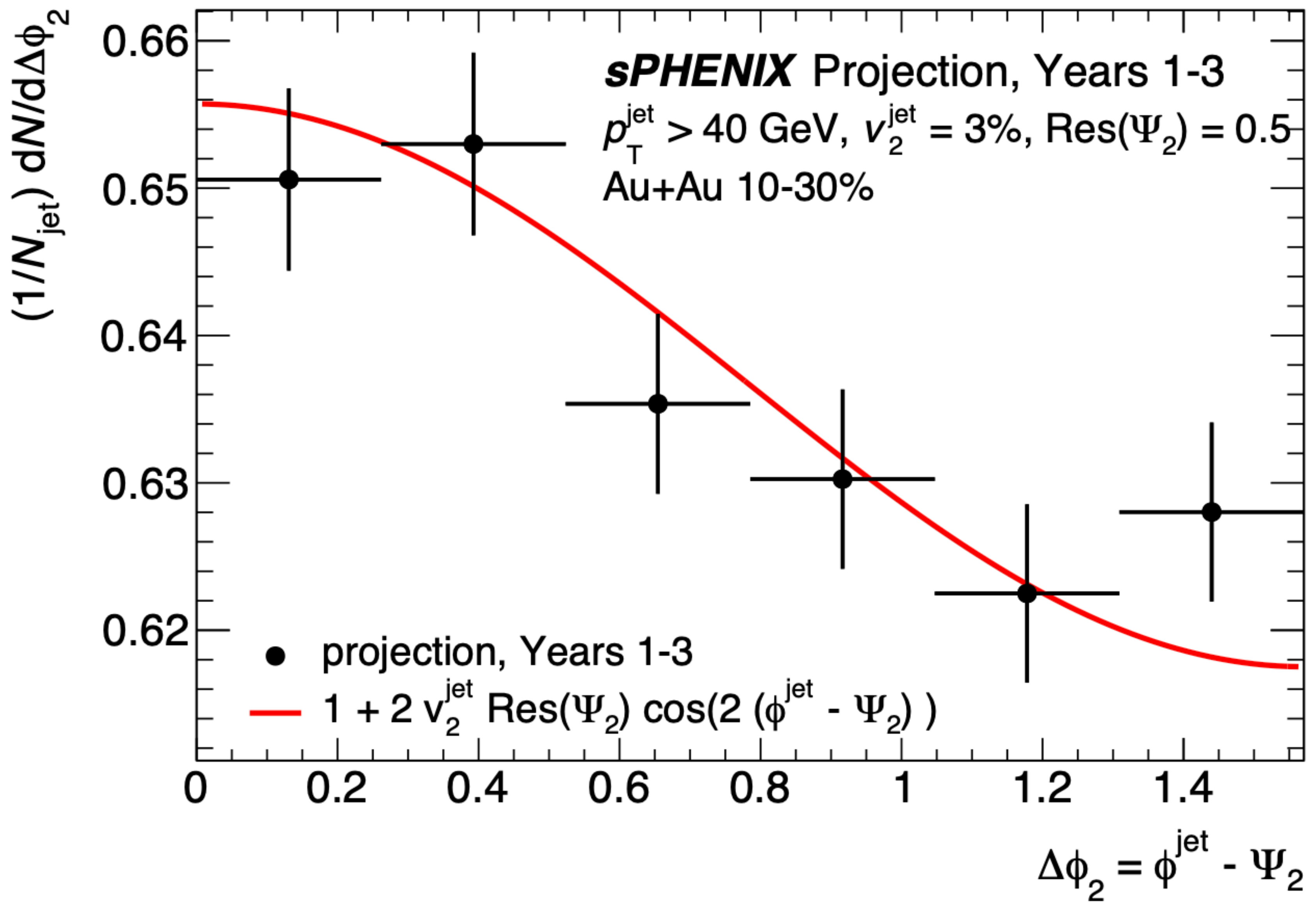


sPHENIX projection



Jets: open questions from LHC

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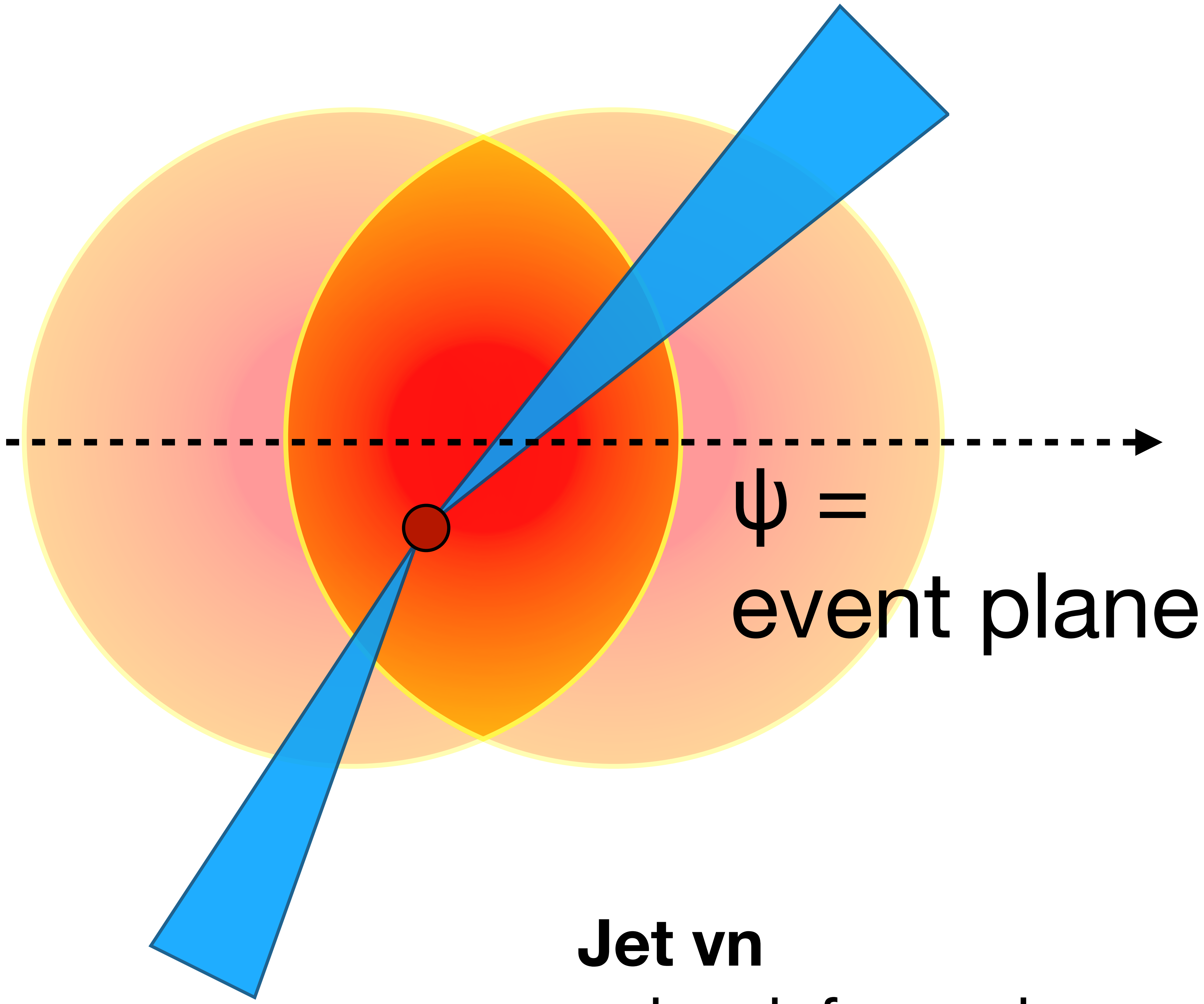
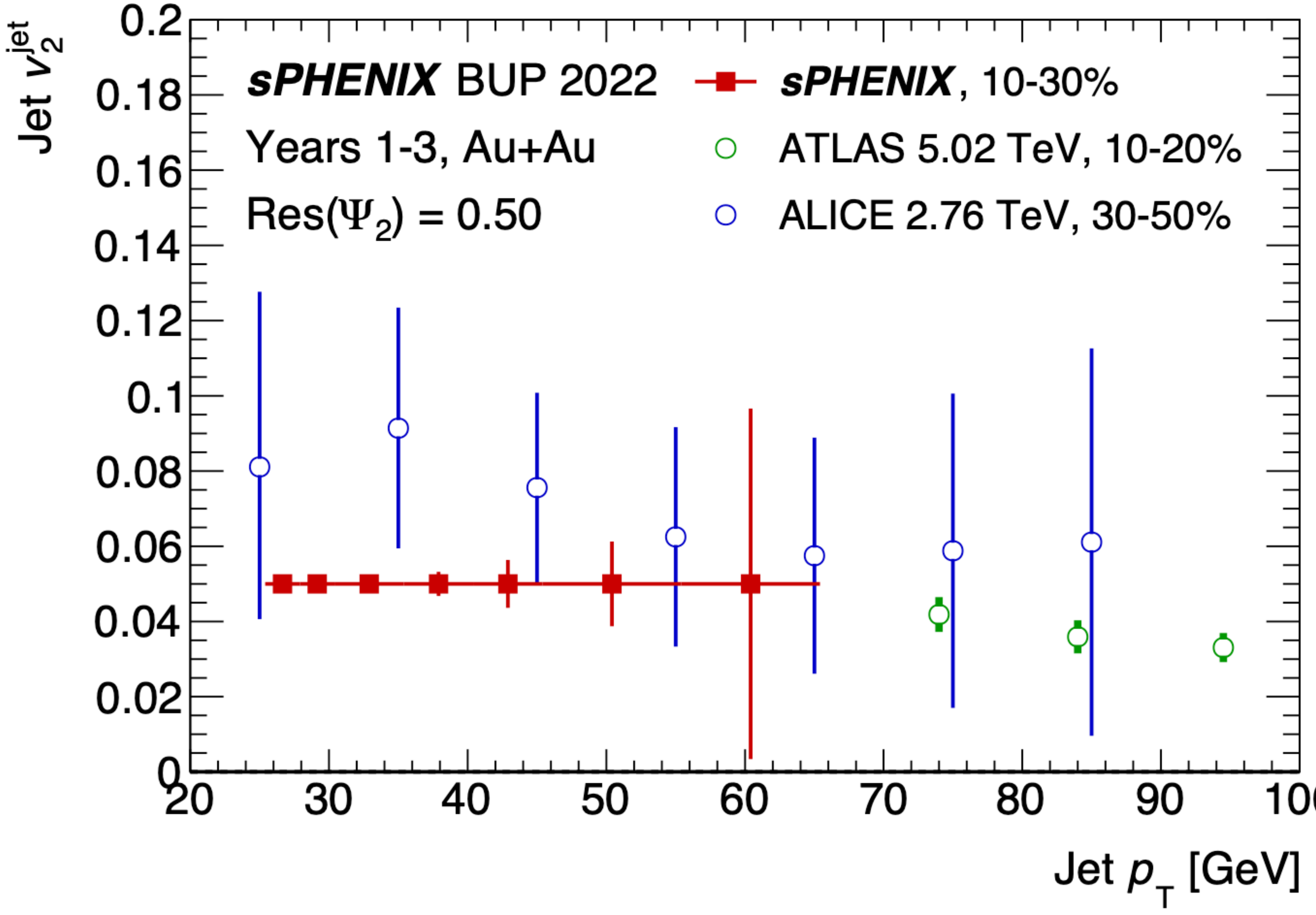


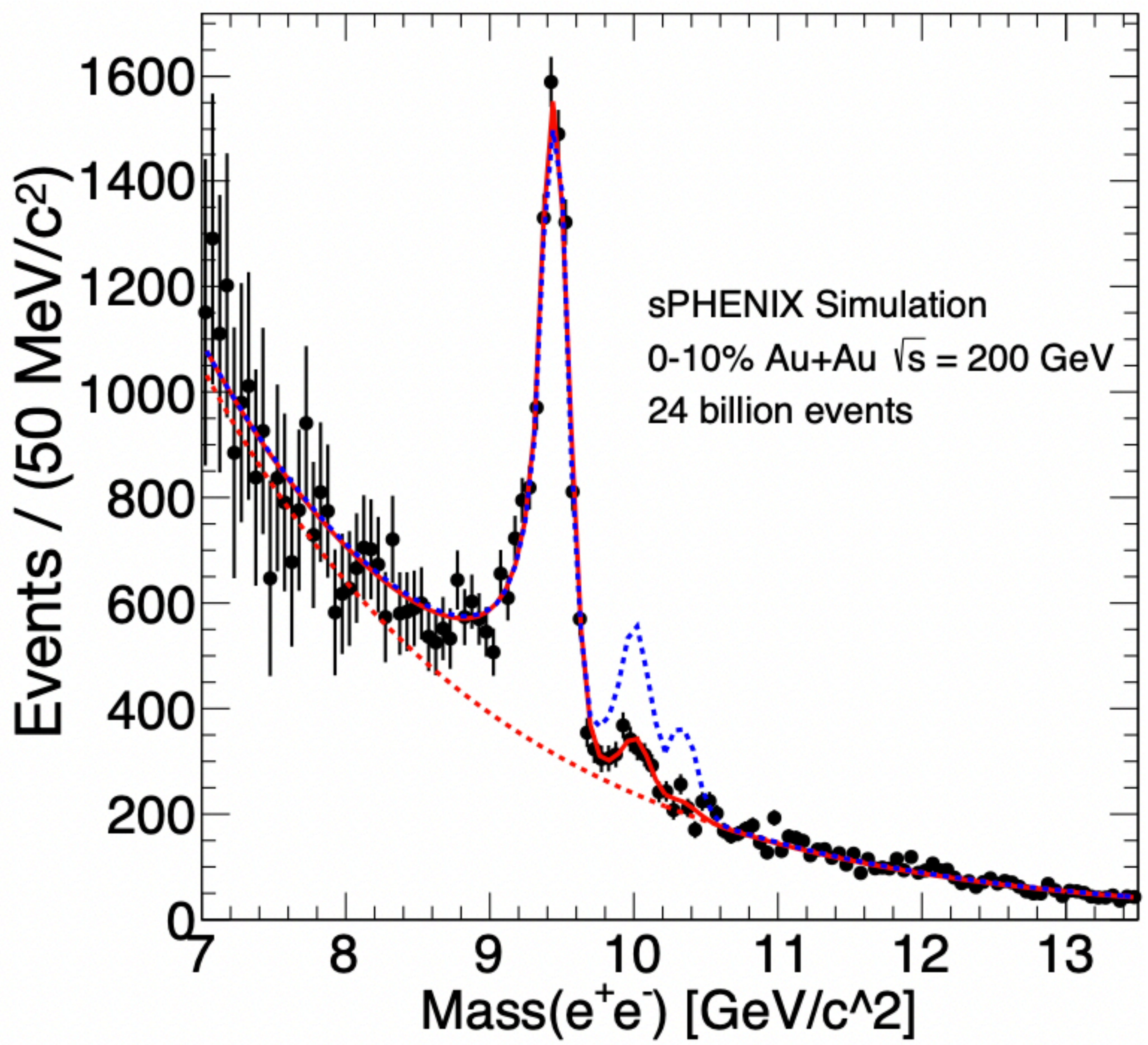
sPHENIX projection



Jet vn
- key info on shape modification and geometry dependence
- **Difficult to measure at LHC in pT < 50 GeV region where effects may be large**

Upsilon physics

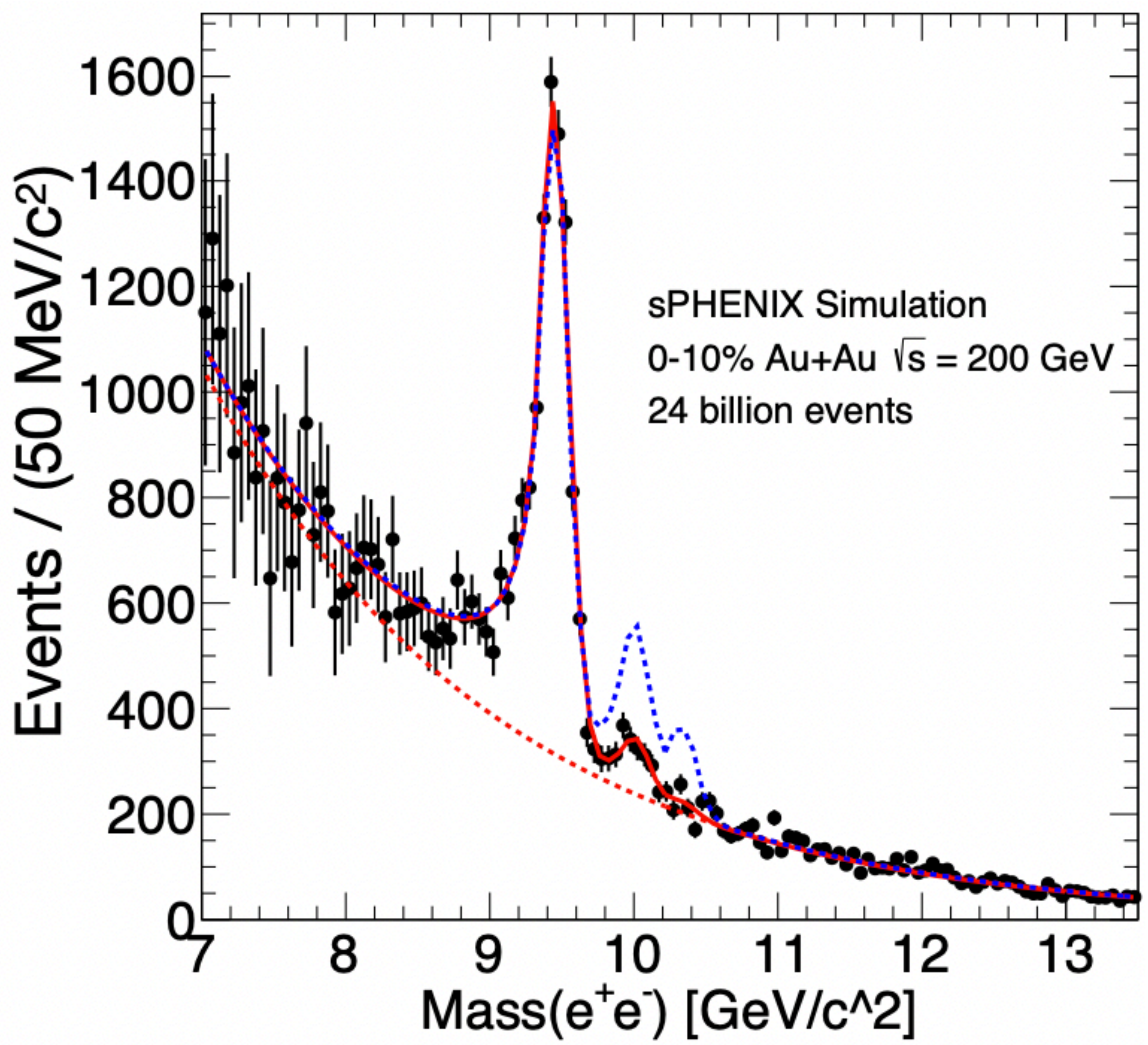
Mass Reconstruction



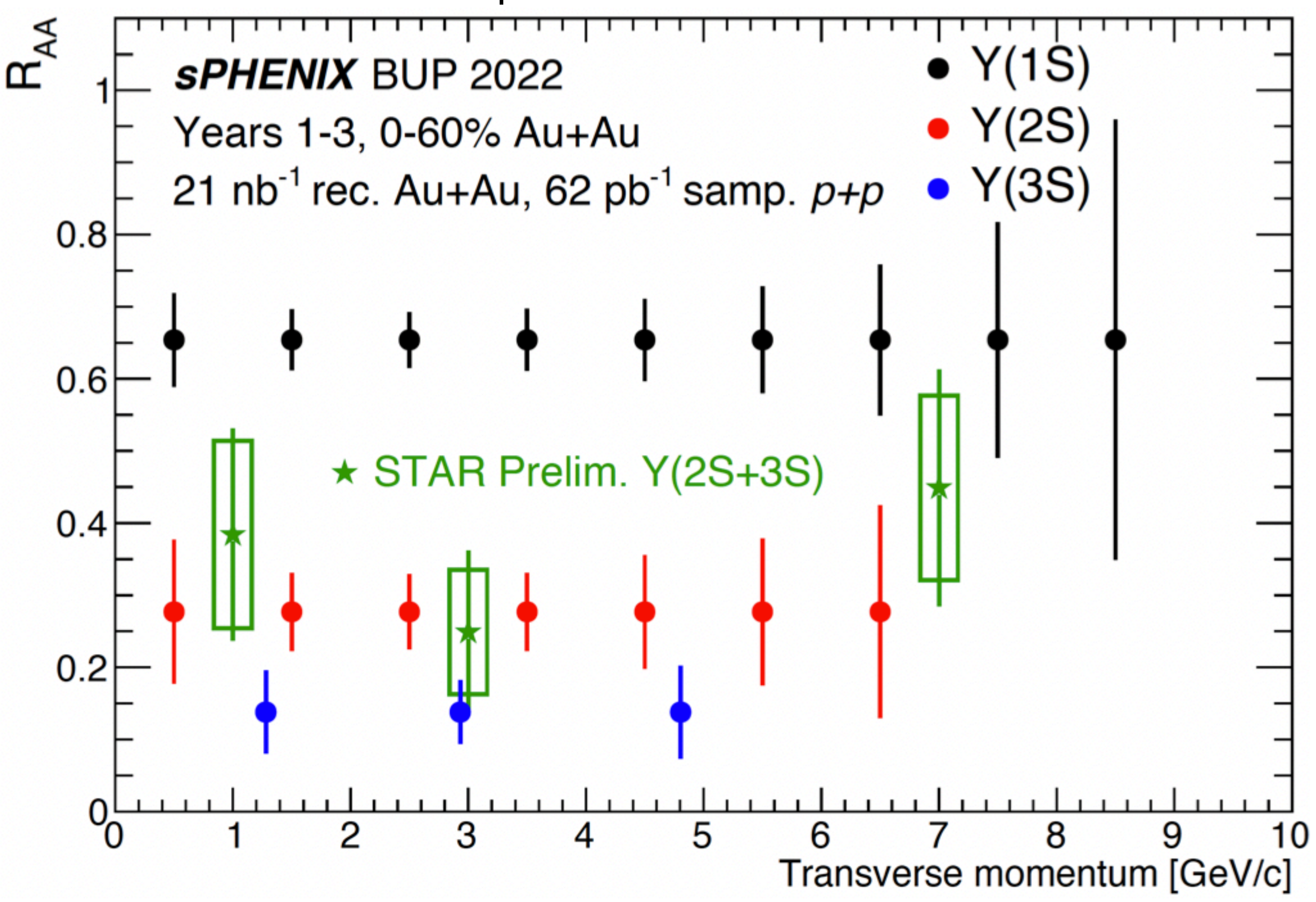
- Excellent mass resolution will allow three ϒ states separation

Upsilon physics

Mass Reconstruction



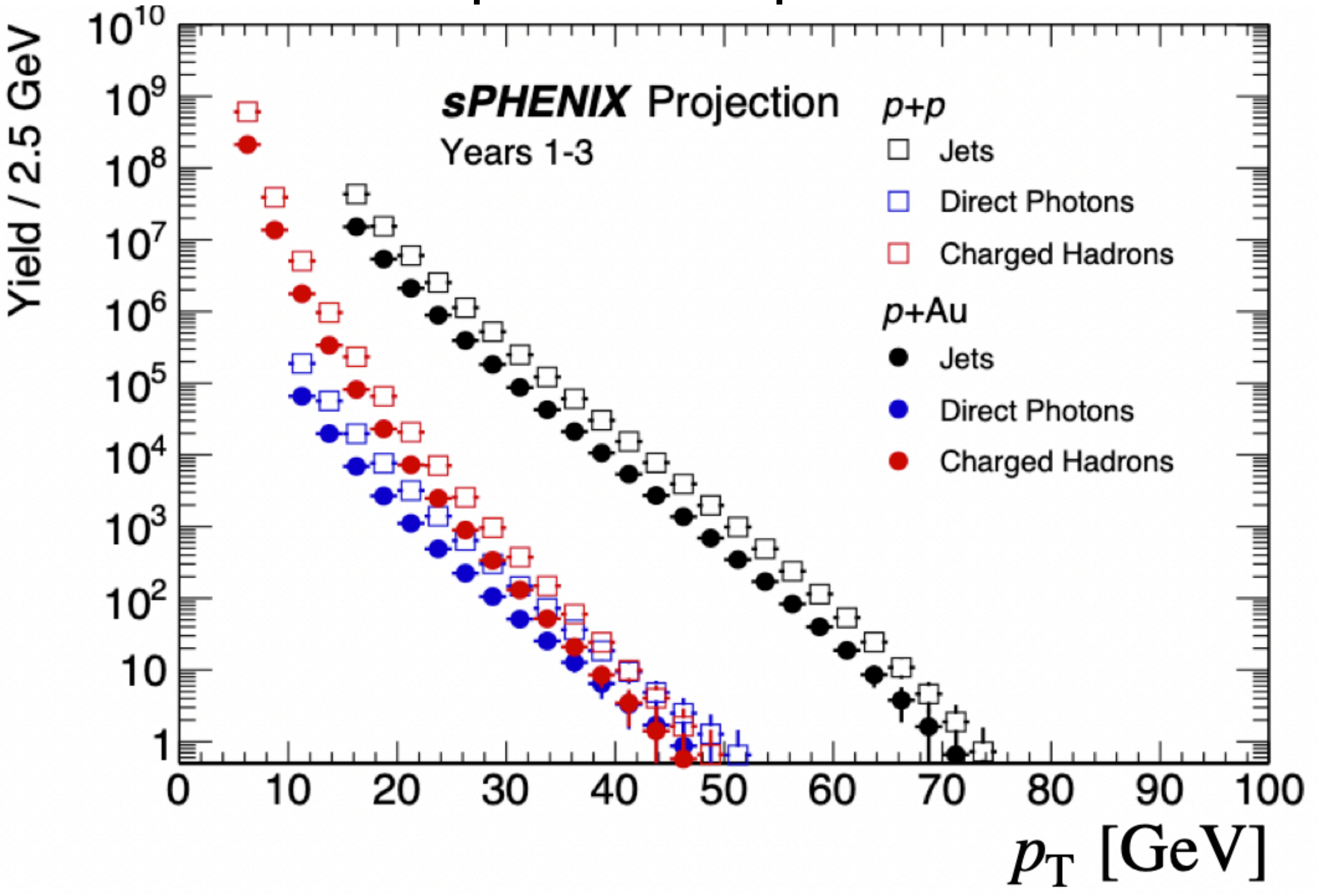
R_{AA} vs N_{part}



- Excellent mass resolution will allow three Υ states separation
- Chance for clean measurement of Υ(3S) suppression —> Test of models

Cold QCD Physics

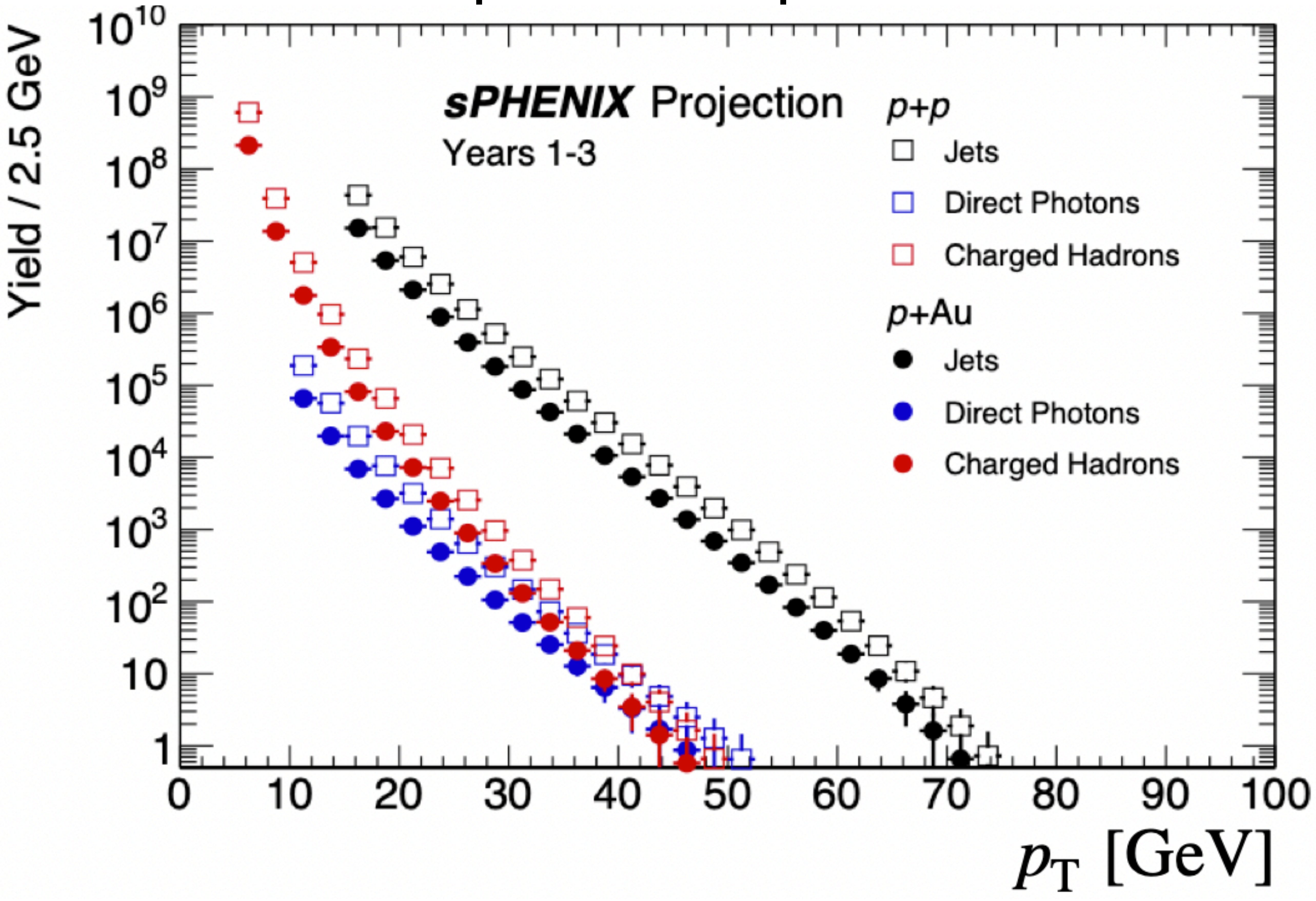
Hard probes in p+Au



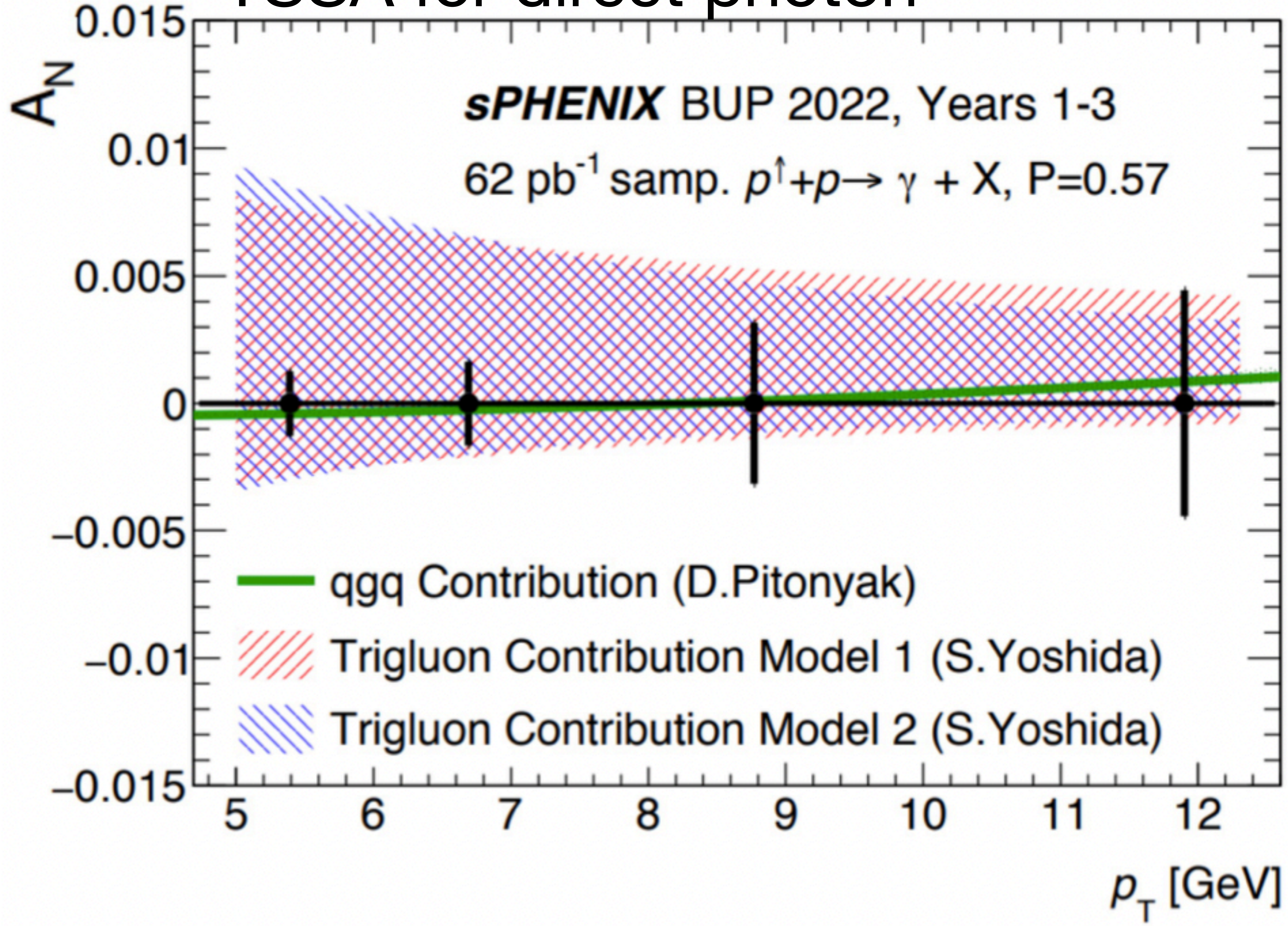
- Study of nuclear modifications using **unpolarized** p+Au measurements

Cold QCD Physics

Hard probes in p+Au



TSSA for direct photon



- Study of nuclear modifications using **unpolarized** p+Au measurements

Spin measurements such as transverse single spin asymmetry (**TSSA**) can be achieved using the **beam polarization**

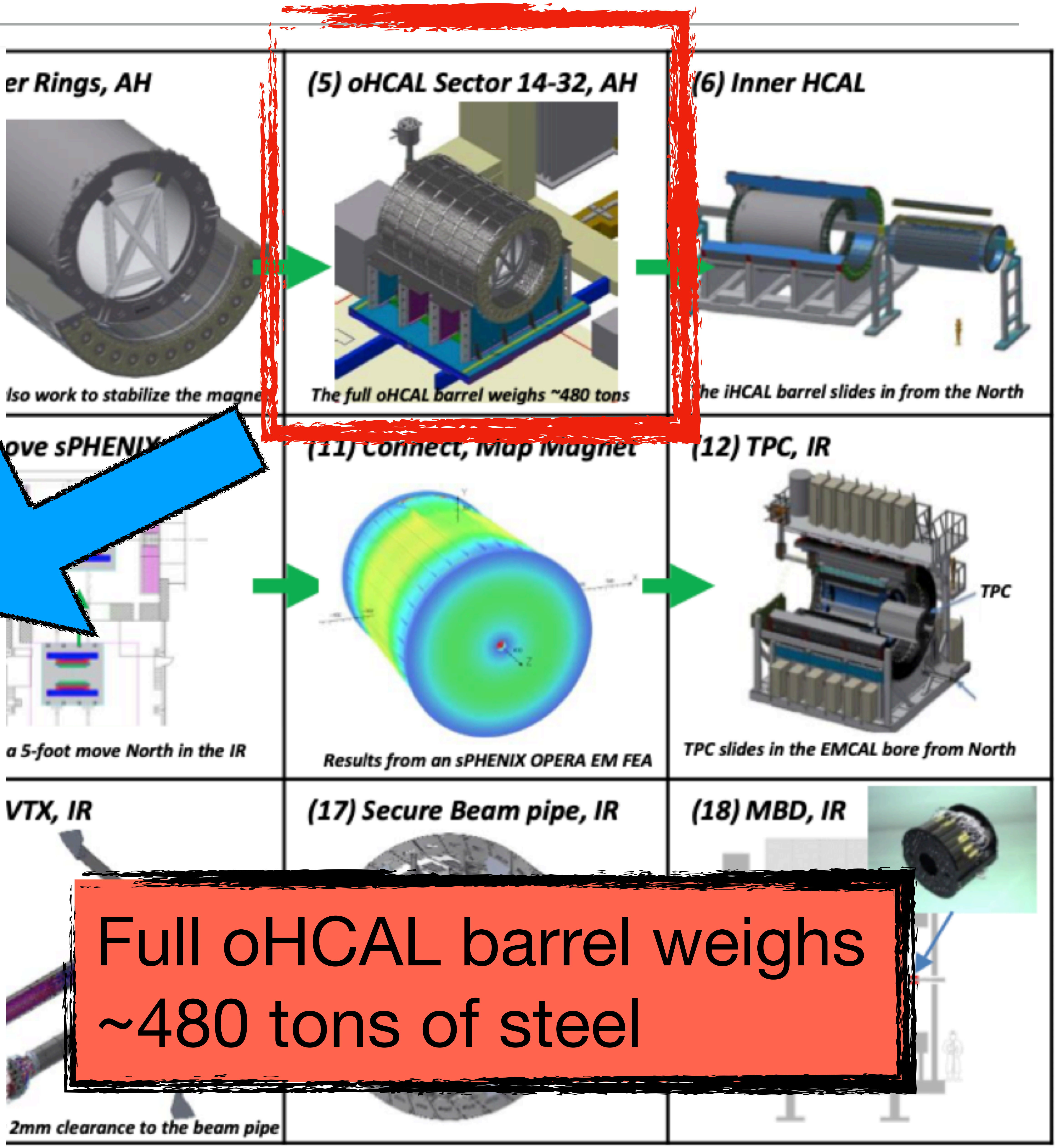
sPHENIX construction — where are we?

sPHENIX construction — where are we?

Carriage installation complete!
- Jun. 2021

sPHENIX construction — where are we?

sPHENIX construction — where are we?



sPHENIX construction — where are we?

sPHENIX construction — where are we?

sPHENIX construction — where are we?

- Calorimeters fully installed and cabled
- Detector has been moved into data-taking position
- Magnet mapping done by CERN team (center at 1.4 T)

sPHENIX construction — where are we?

Ready for beam late Spring

Thank you!!

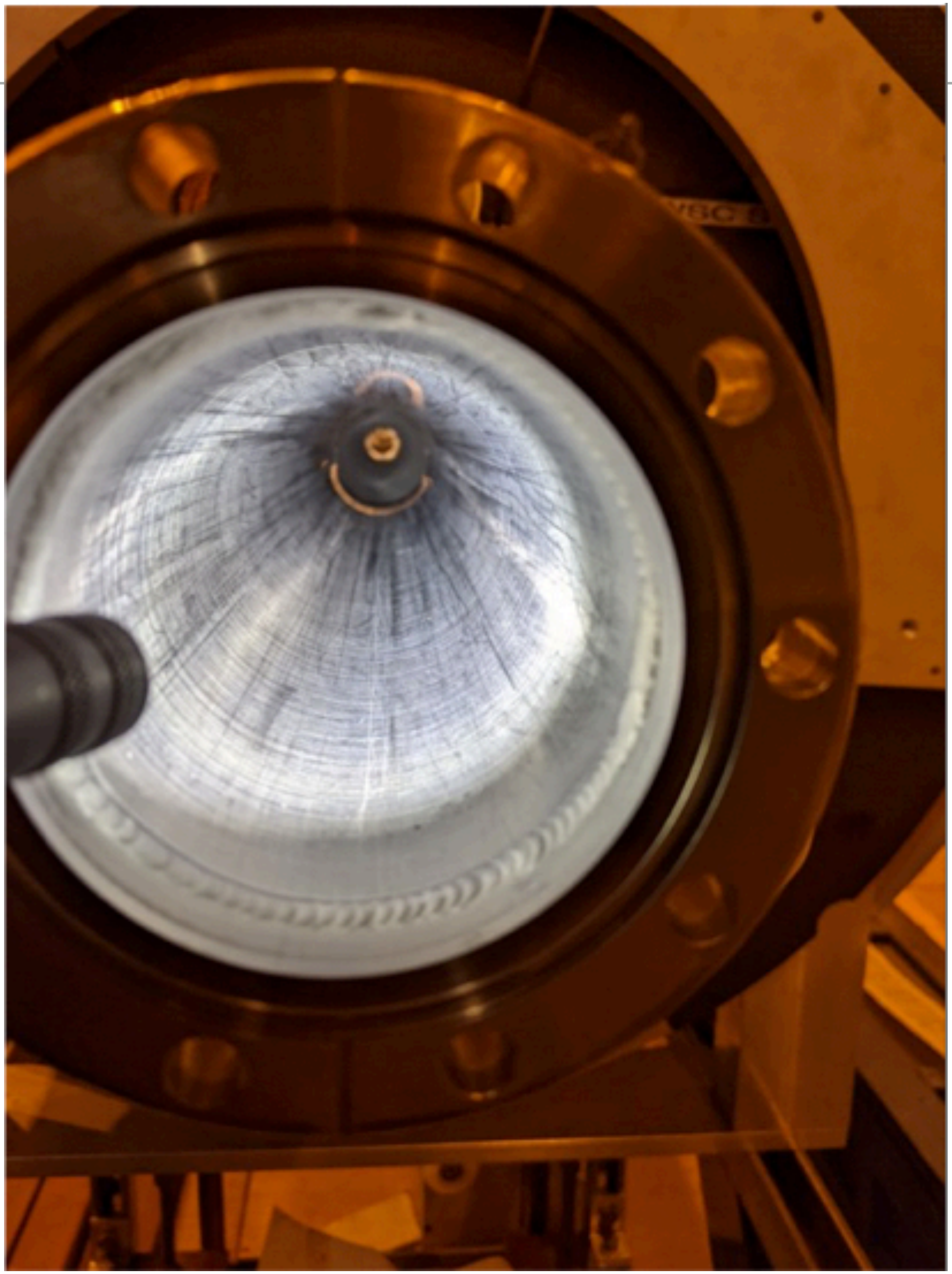
Beampipe

- sPHENIX beampipe shipped to California for work
- Lost in warehouse fire in 2022!
- STAR had a spare beampipe that is in good condition and is compatible with sPHENIX design.

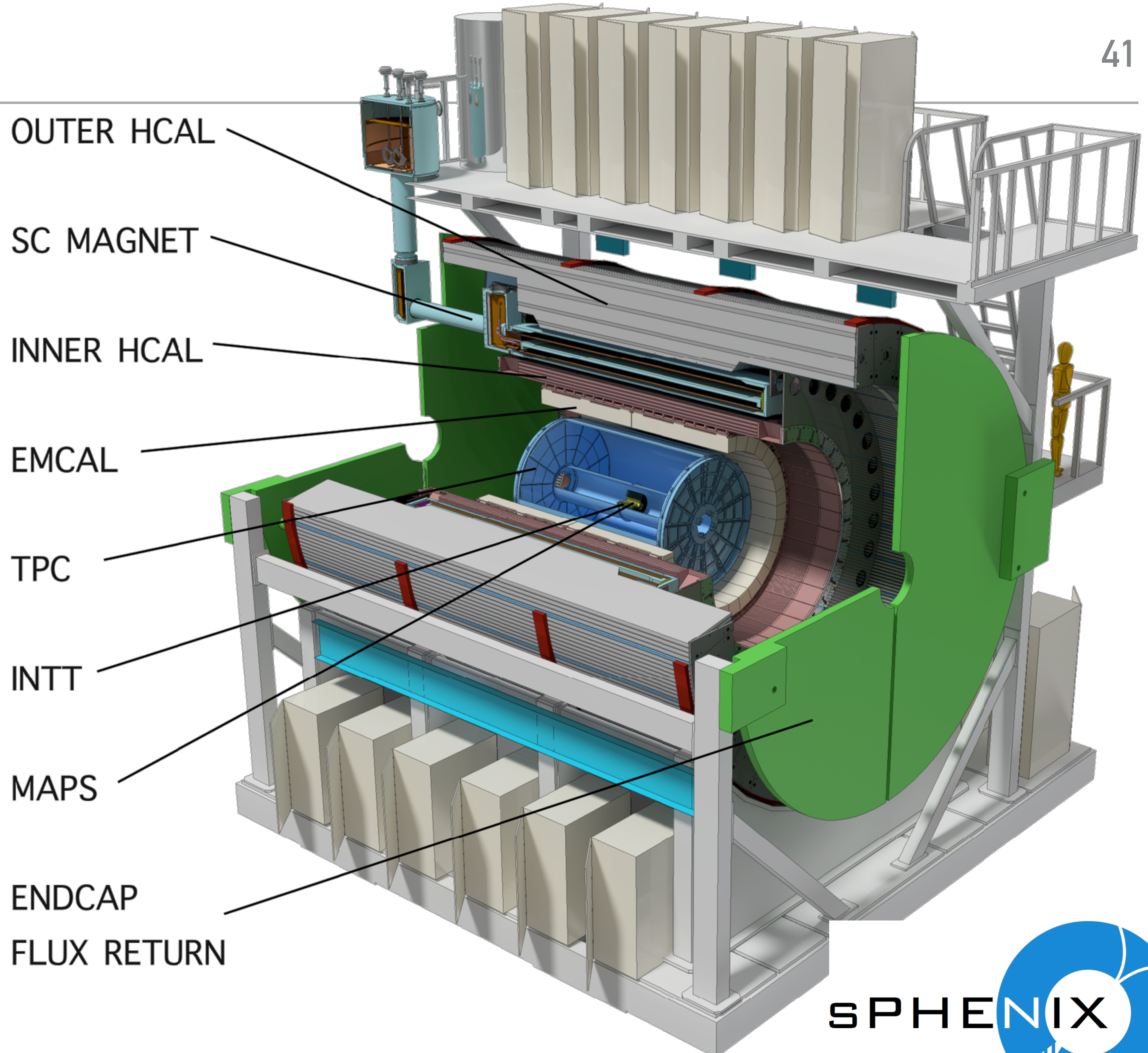
Multiple UPS trucks destroyed by flames when fire breaks out at Lancaster facility

One person was sent to the hospital with a minor burn injury, though it's unclear if he or she was a UPS worker.

By Eric Resendiz via
Tuesday, April 12, 2022



sPHENIX detector

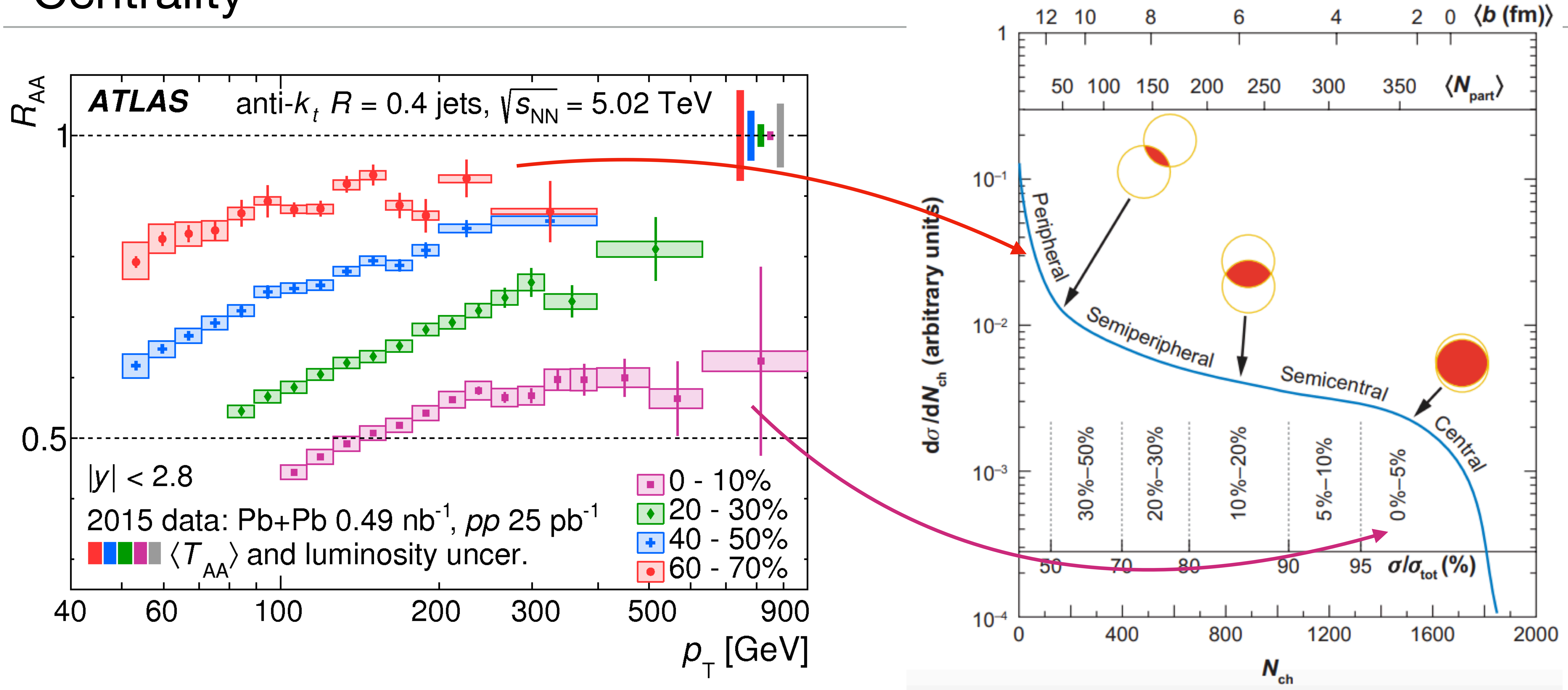


15 kHz calo trigger + 10% streaming DAQ
10 GB/s data logging

* **sEPD**(Event Plane Detector), **MBD**(Minimum-bias detector), and **TPOT**(TPC Outer Tracker) not shown in the figure

sPHENIX

Centrality



Centrality, a proxy for impact parameter

Central collisions ==> larger volume of QGP ==> more suppression