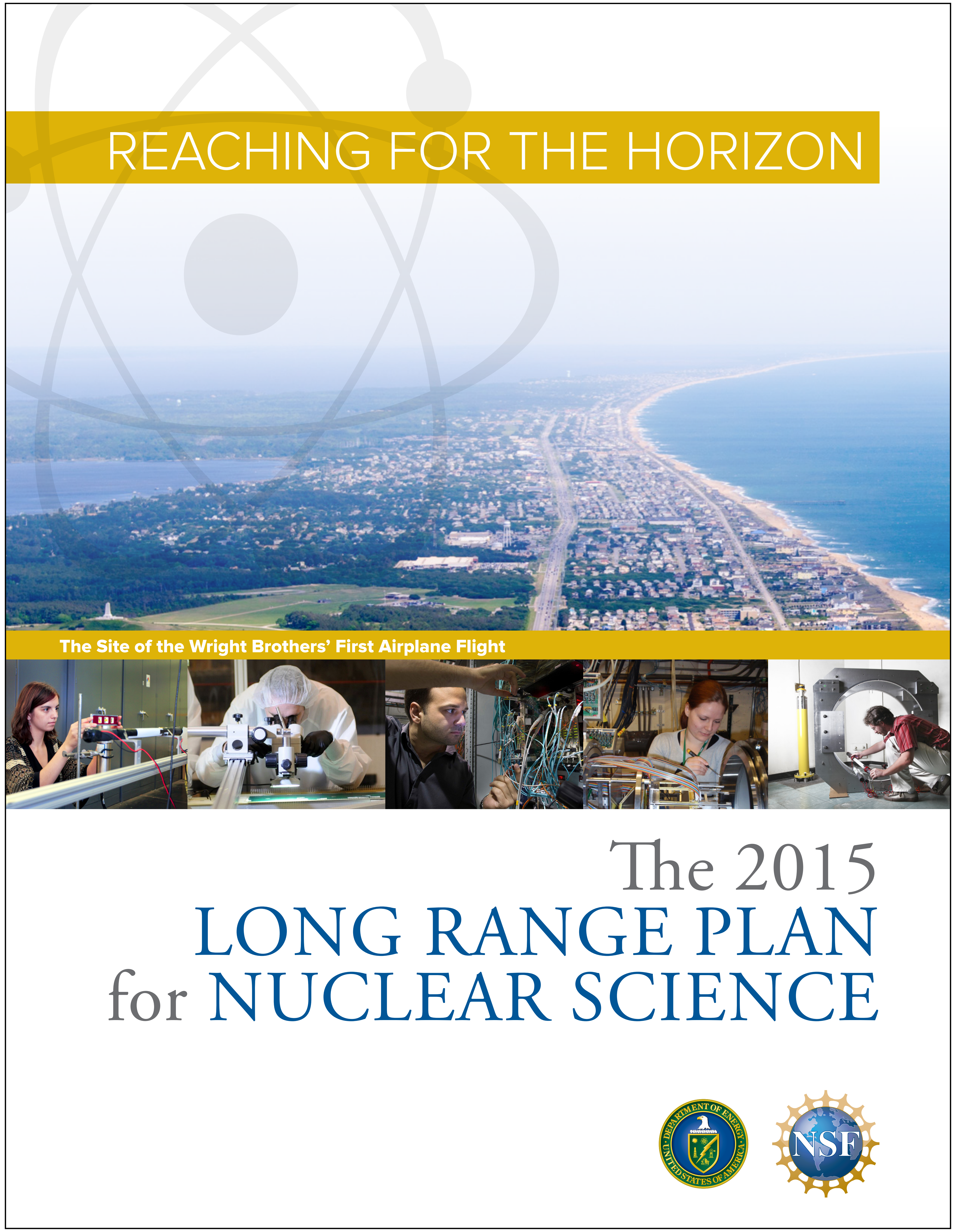
sPHENIX

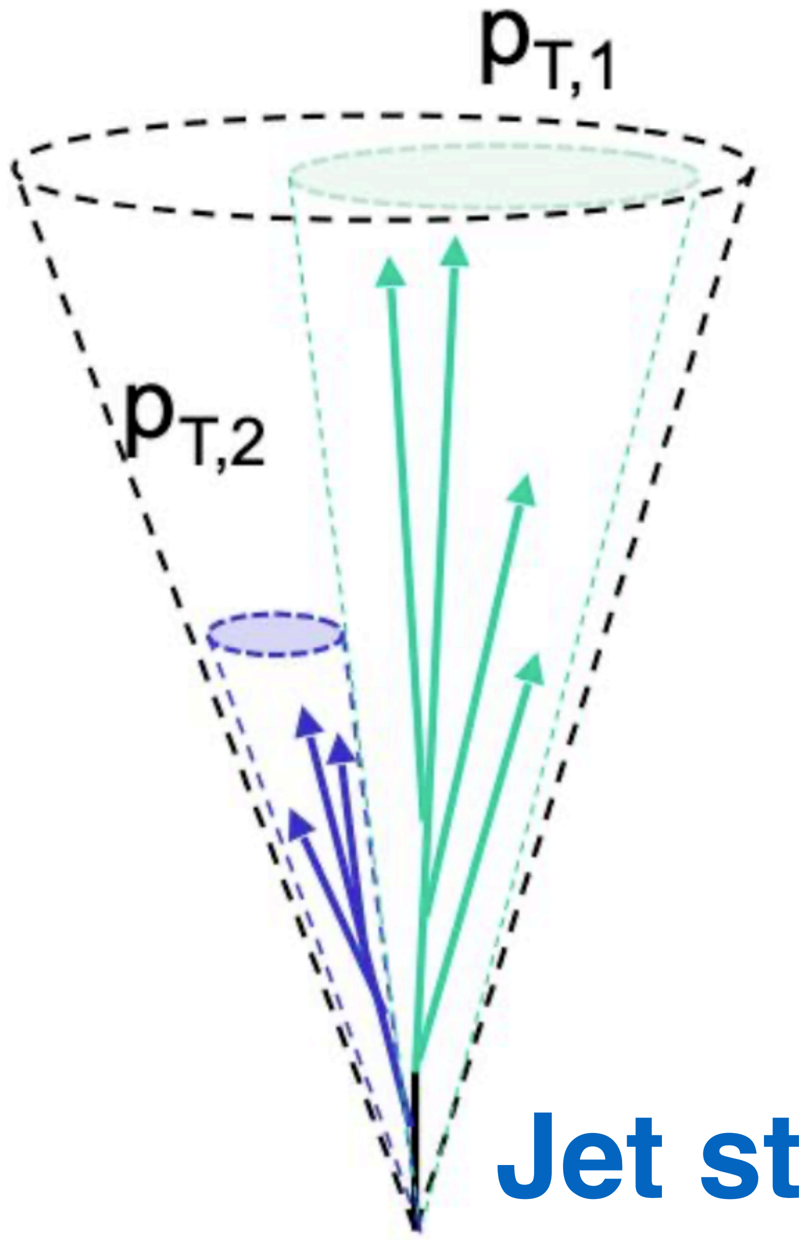
Anne Sickles for the sPHENIX Collaboration

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN



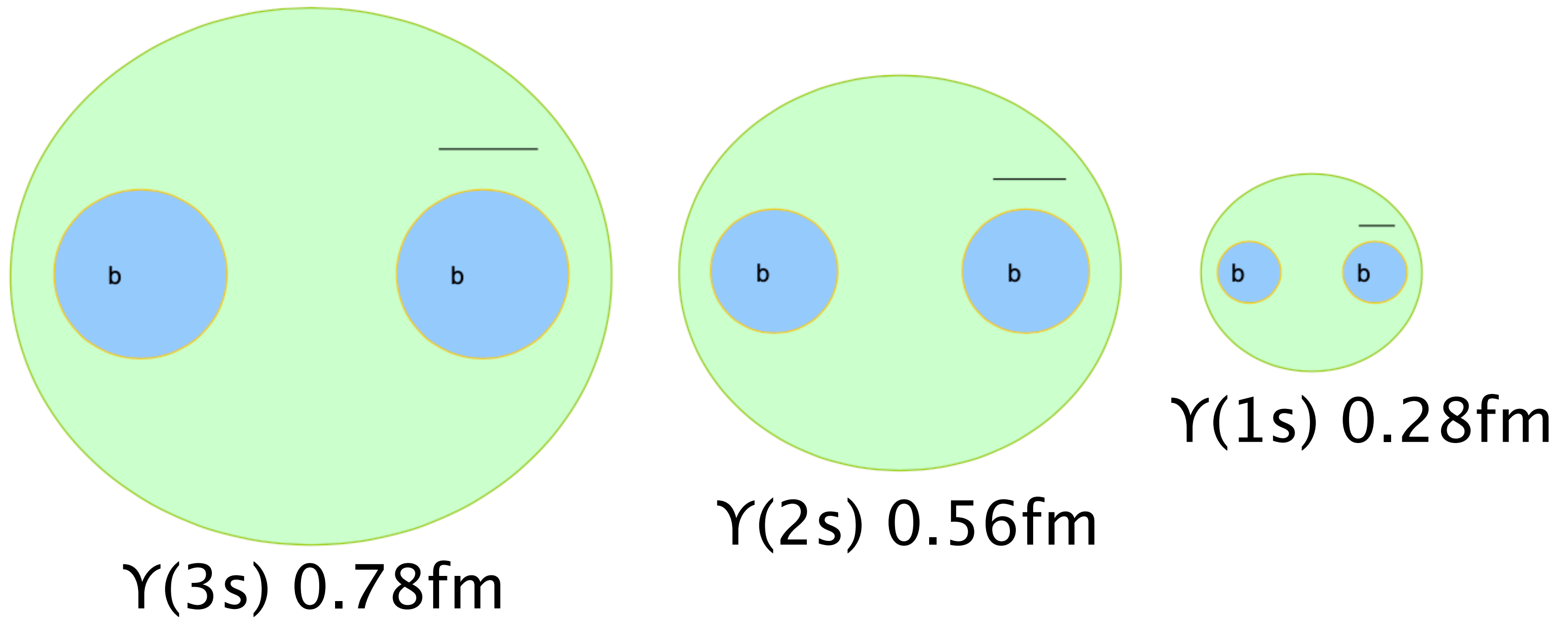
There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.**

sPHENIX Program



Jet structure

vary momentum/angular scale of probe

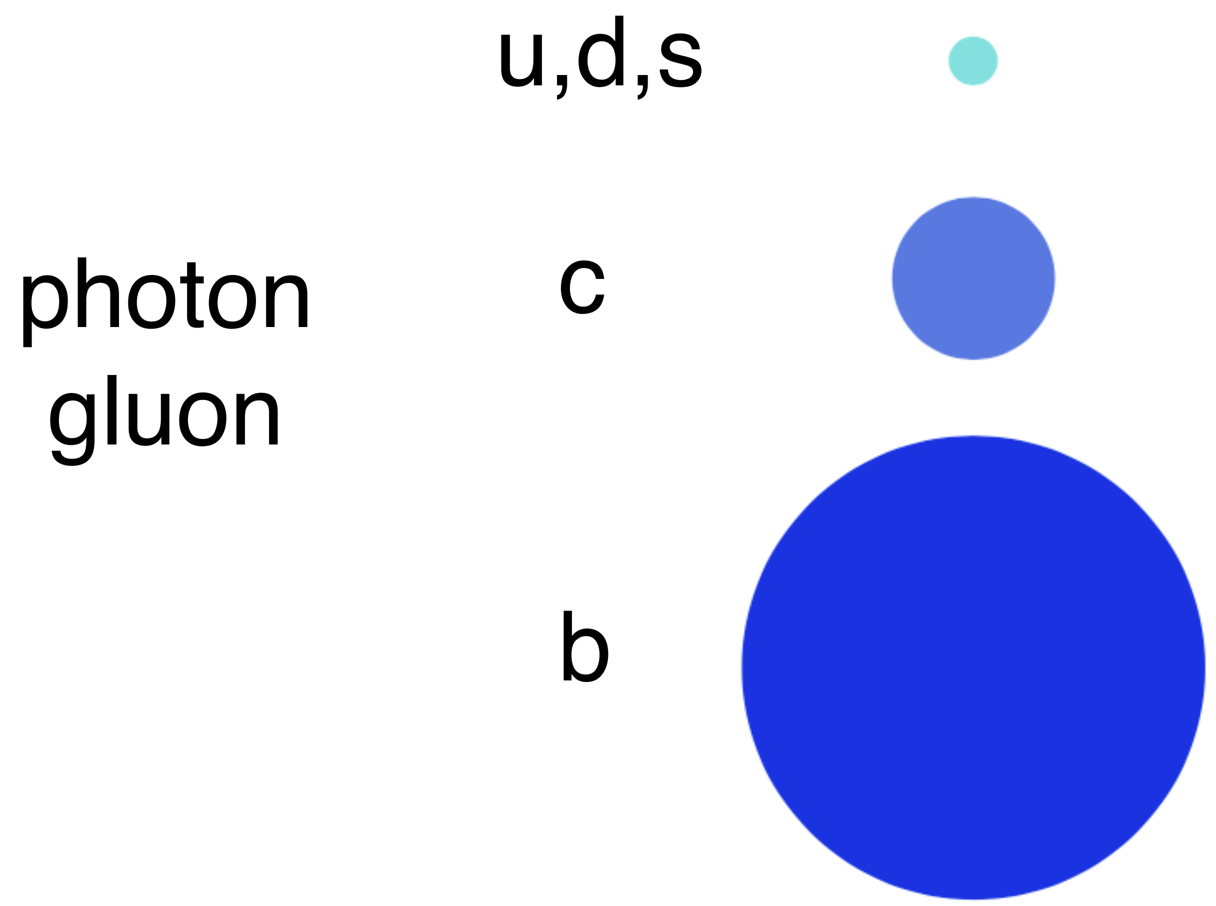


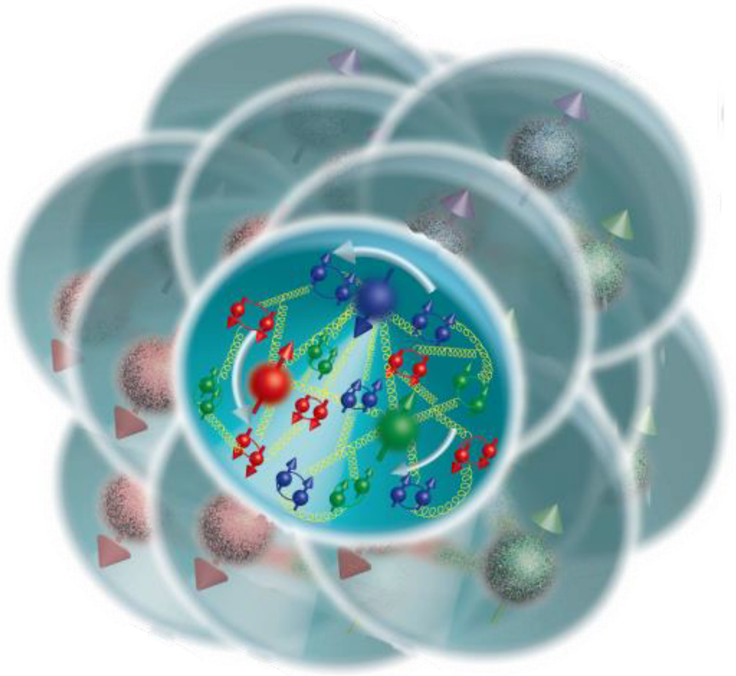
Quarkonium spectroscopy

vary size of probe

Parton energy loss

vary mass/momentum of probe

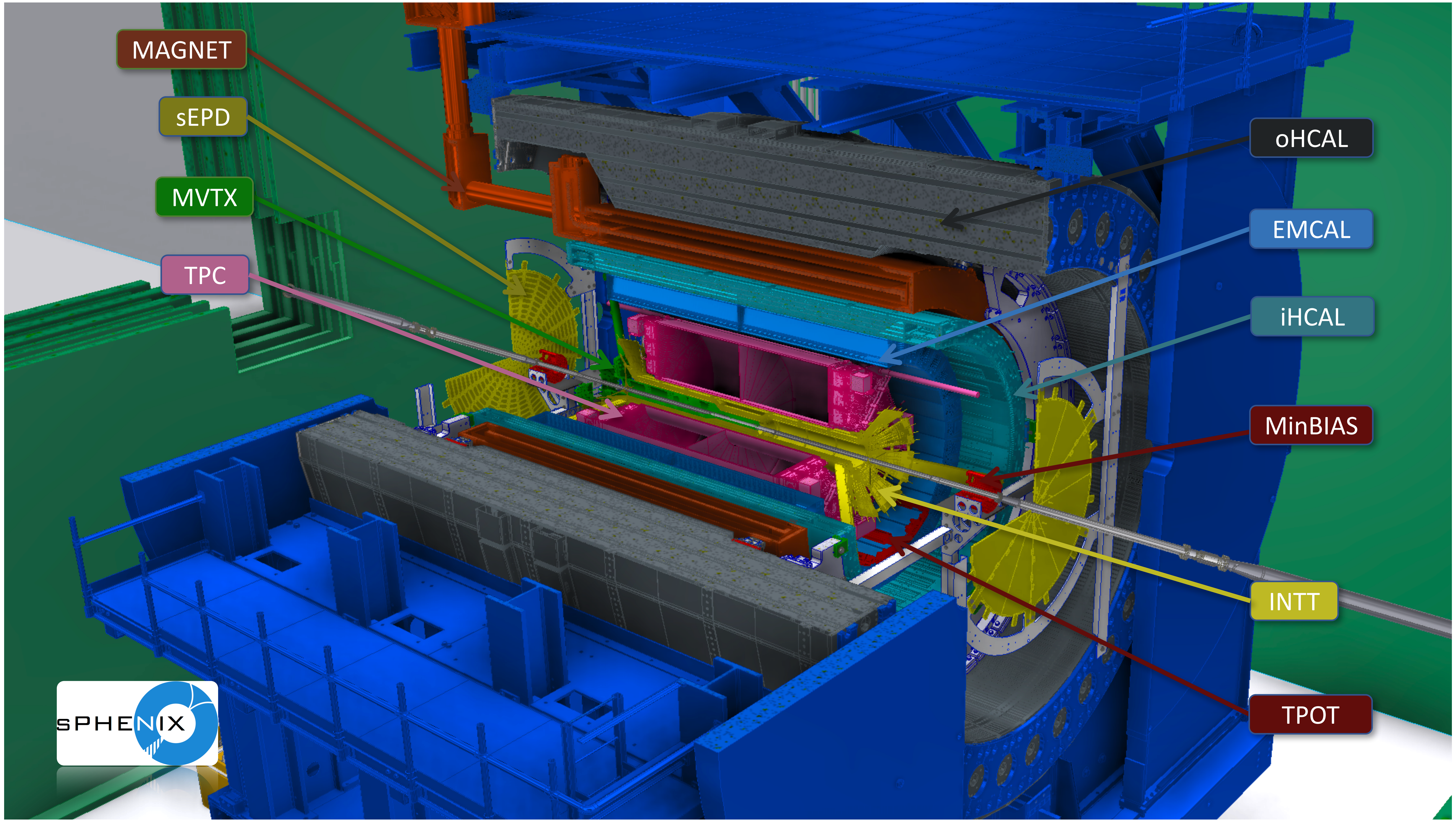




Cold QCD

study proton spin, transverse-momentum, and cold nuclear effects

sPHENIX Detector



- large, uniform acceptance
- full electromagnetic and hadronic calorimetry
- high precision tracking/ vertexing
- huge AuAu samples, without biased triggered

optimized for hard probes and unique among RHIC experiments!

sPHENIX relies on RHIC's ability to deliver high luminosity ion beams

Table 2: Demonstrated and projected luminosities for 100 GeV/nucleon Au+Au runs.

Parameter	Unit	FY2007	2010	2011	2014	2016	2023E	2025E
No of bunches k_b	…	103	111	111	111	111	111	111
Ions/bunch, initial N_b	10^9	1.1	1.1	1.3	1.6	2.0	2.4	2.90
Average beam current/ring I_{avg}	mA	112	121	147	176	224	265	319
Stored beam energy	MJ	0.36	0.39	0.47	0.56	0.71	0.84	1.0
Envelope function at IP β^*	m	0.85	0.75	0.75	0.70	0.70	0.70	0.65
Beam-beam parameter ξ/IP	10^{-3}	-1.7	-1.5	-2.1	-2.5	-3.9	-4.6	-5.6
Initial luminosity L_{init}	**10^{26} cm^{-2}s^{-1}**	**30**	**40**	**50**	**80**	**155**	**215**	**336**
Events per bunch-bunch crossing μ	…	0.08	0.10	0.13	0.21	0.40	0.55	0.86
Average/initial luminosity	%	40	50	60	62	56	58	60
Average store luminosity L_{avg}	**10^{26} cm^{-2}s^{-1}**	**12**	**20**	**30**	**50**	**87**	**125**	**200**
Time in store	%	48	53	59	68	65	60	60
Max. luminosity/week	μb^{-1}	380	650	1000	2200	3000	4530	7260
Min. luminosity/week	μb^{-1}						3000	3000
L within $\|z\|<10$ cm, $\theta = 0$ mrad, r_0/r_θ*	%						39/39	39/39
L within $\|z\|<10$ cm, $\theta = 2$ mrad, r_0/r_θ*	%						31/81	31/81

* Luminosity $L(z,\theta)$ within vertex cut $|z|$ for full crossing angle θ. The values r_0/r_θ are $r_0 = L(z,0)/L(10\text{ m},0)$ and $r_\theta = L(z,\theta)/L(10\text{ m},\theta)$.

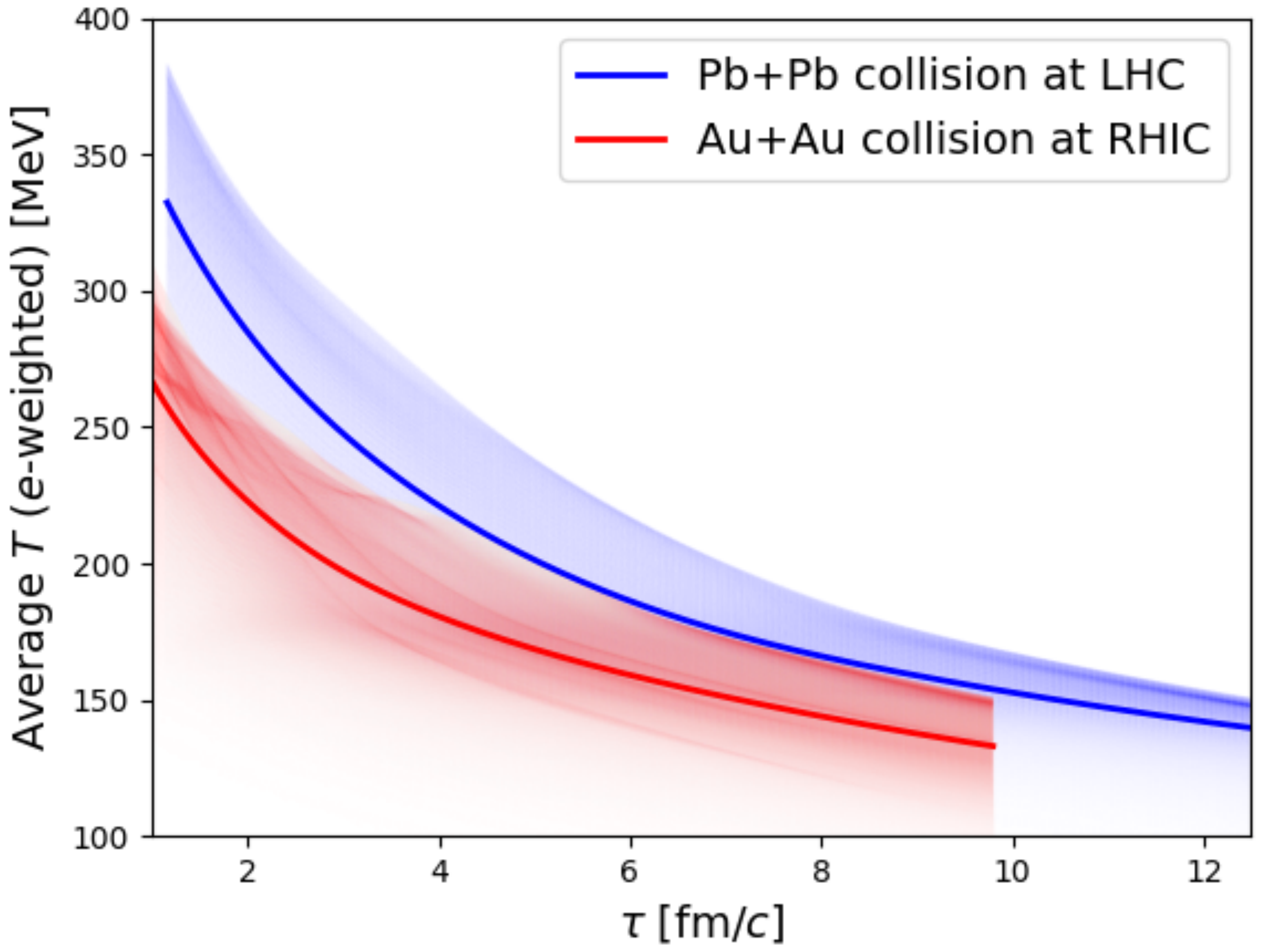
~2x increase in RHIC in sPHENIX era AuAu luminosity over 2016

https://www.rhichome.bnl.gov/RHIC/Runs/RhicProjections.pdf

why jets at RHIC?

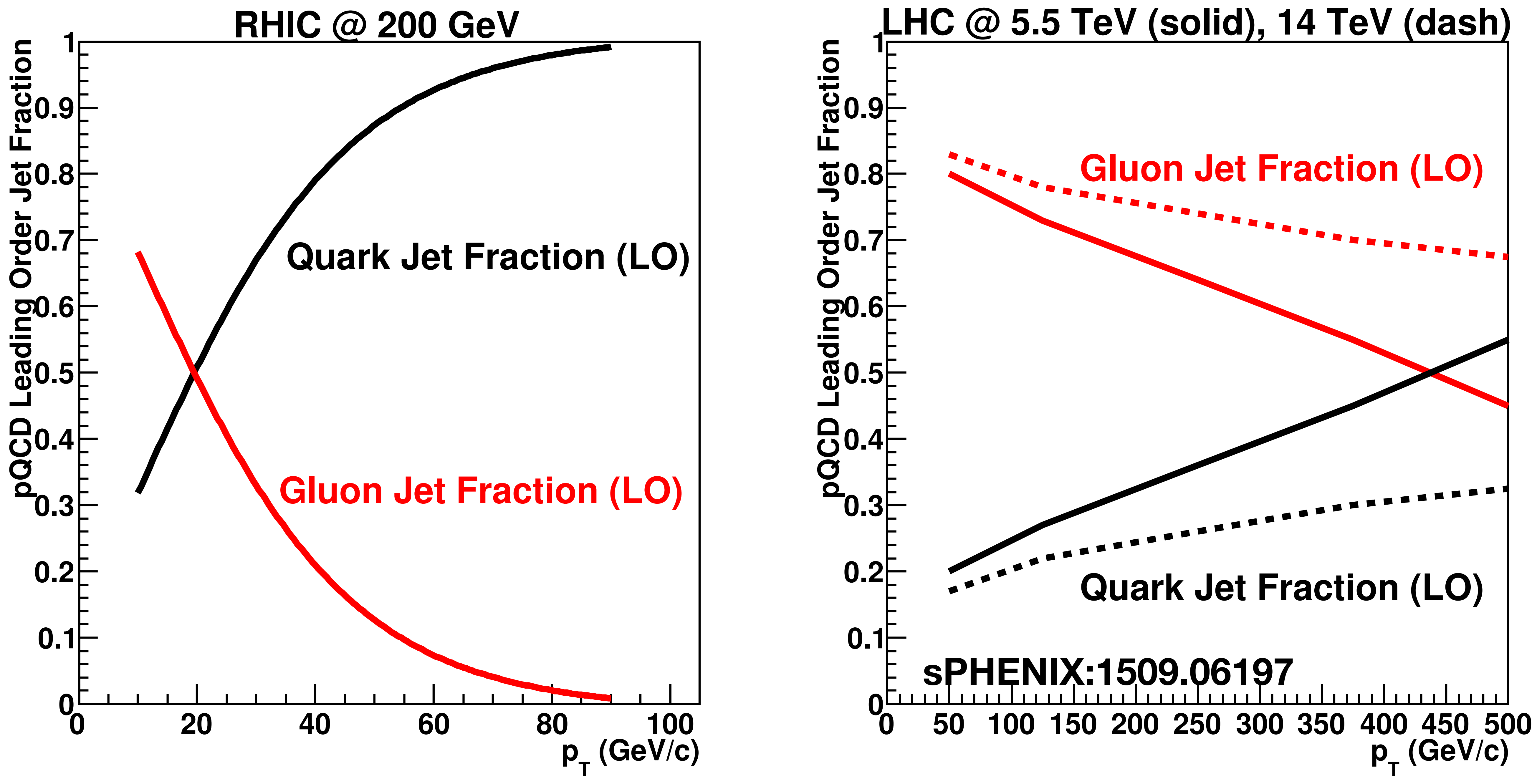
- Different QGP: lower temperatures, closer to the QGP transition

QGP temperature (plot: Christopher Plumberg)



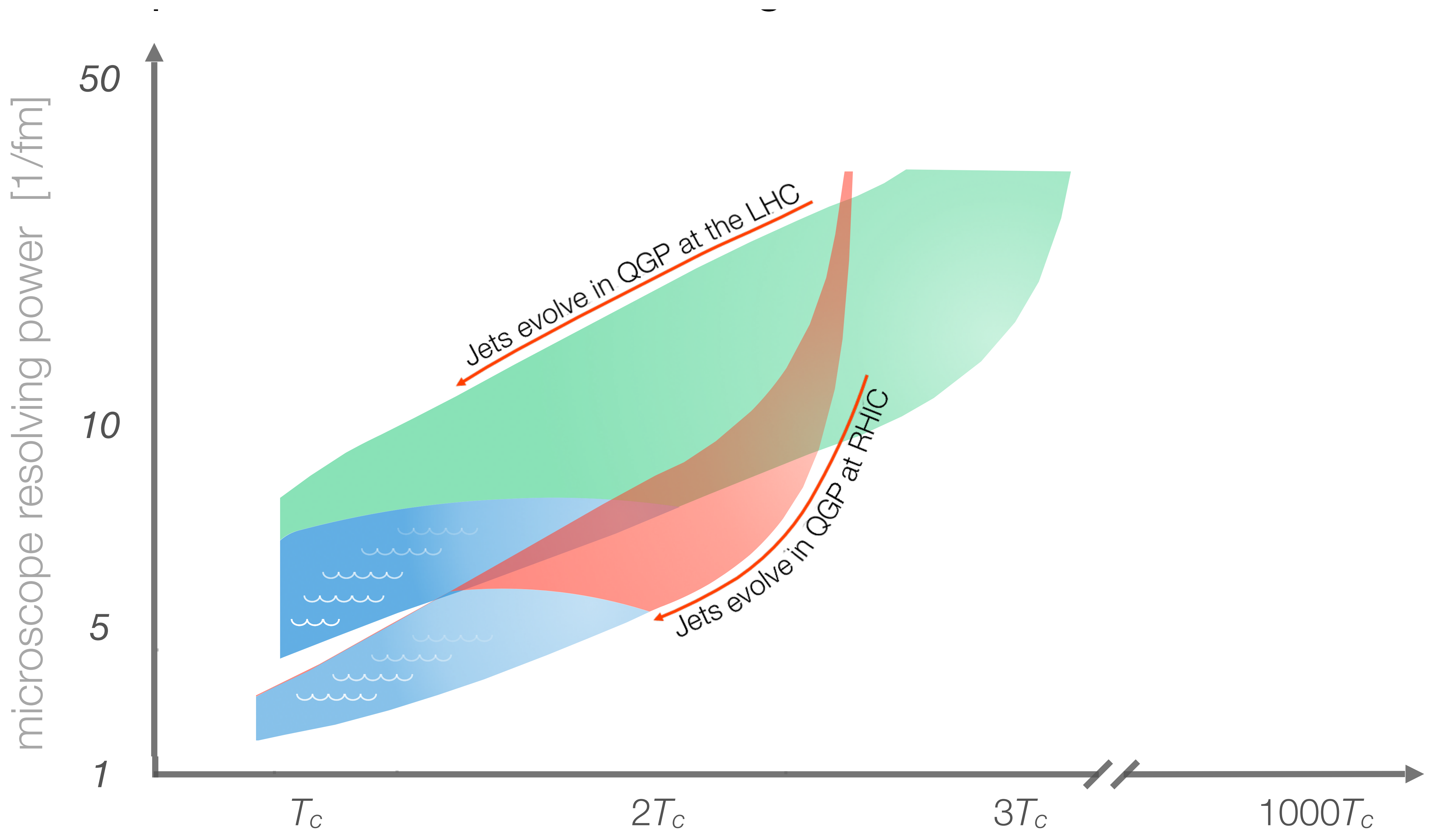
why jets at RHIC?

- Different QGP: lower temperatures, closer to the QGP transition
- Different jets: jet flavor composition at the lower collision energy



why jets at RHIC?

- Different QGP: lower temperatures, closer to the QGP transition
- Different jets: jet flavor composition at the lower collision energy
- Different QGP/jet interaction: lower energy jets are expected to spend more of their evolution interacting at QGP scales



jets evolve at **QGP scales** for a larger fraction of their evolution at **RHIC** than the **LHC**

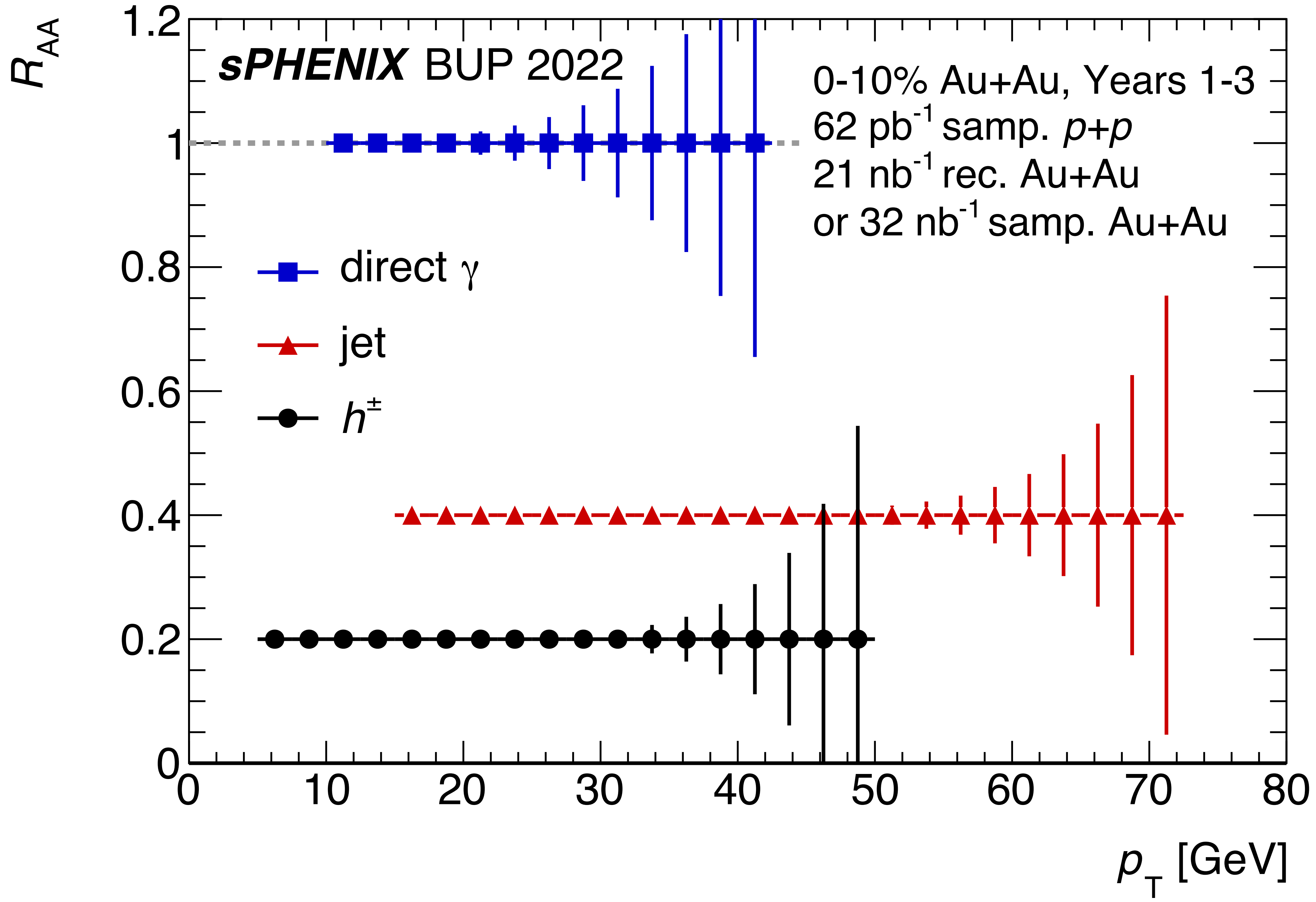
sPHENIX Run Plan

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\|z\| < 10$ cm	Samp. Lum. $\|z\| < 10$ 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}

- 2023: Commissioning & first AuAu physics
- 2024:
  - pp data for HI reference and transverse spin measurements
  - pA data: cold QCD & small systems measurements
- 2025: High luminosity AuAu running, >140B MB AuAu collisions recorded

https://indico.bnl.gov/event/15148/attachments/40846/68568/sPHENIX_Beam_Use_Proposal_2022.pdf

jets & photons



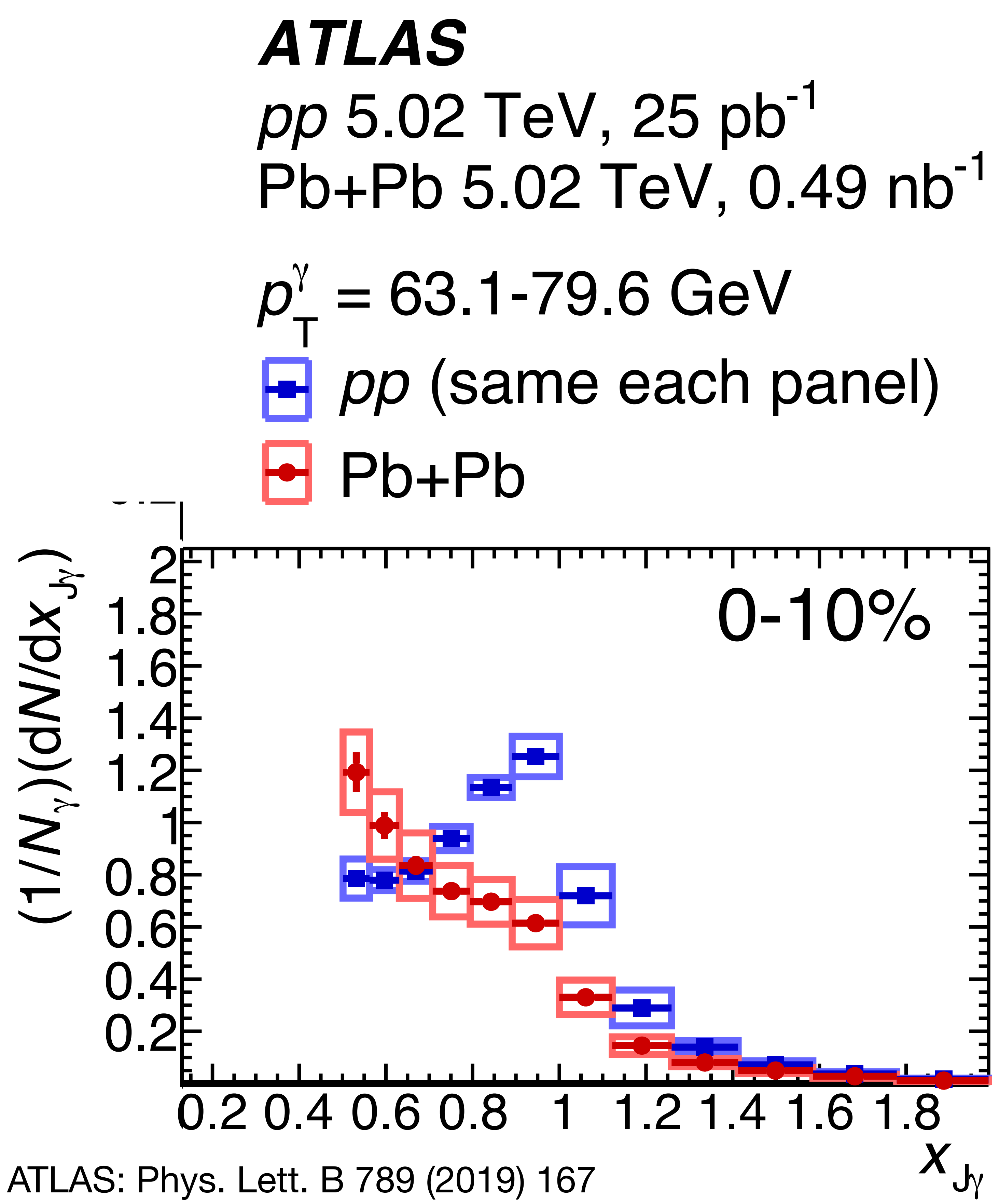
Signal	Au+Au 0–10% Counts	$p+p$ Counts
Jets $p_T > 20$ GeV	22 000 000	11 000 000
Jets $p_T > 40$ GeV	65 000	31 000
Direct Photons $p_T > 20$ GeV	47 000	5 800
Direct Photons $p_T > 30$ GeV	2 400	290
Charged Hadrons $p_T > 25$ GeV	4 300	4 100

three-year run plan provides jets in AuAu & pp collisions over nearly the whole kinematic range accessible at RHIC

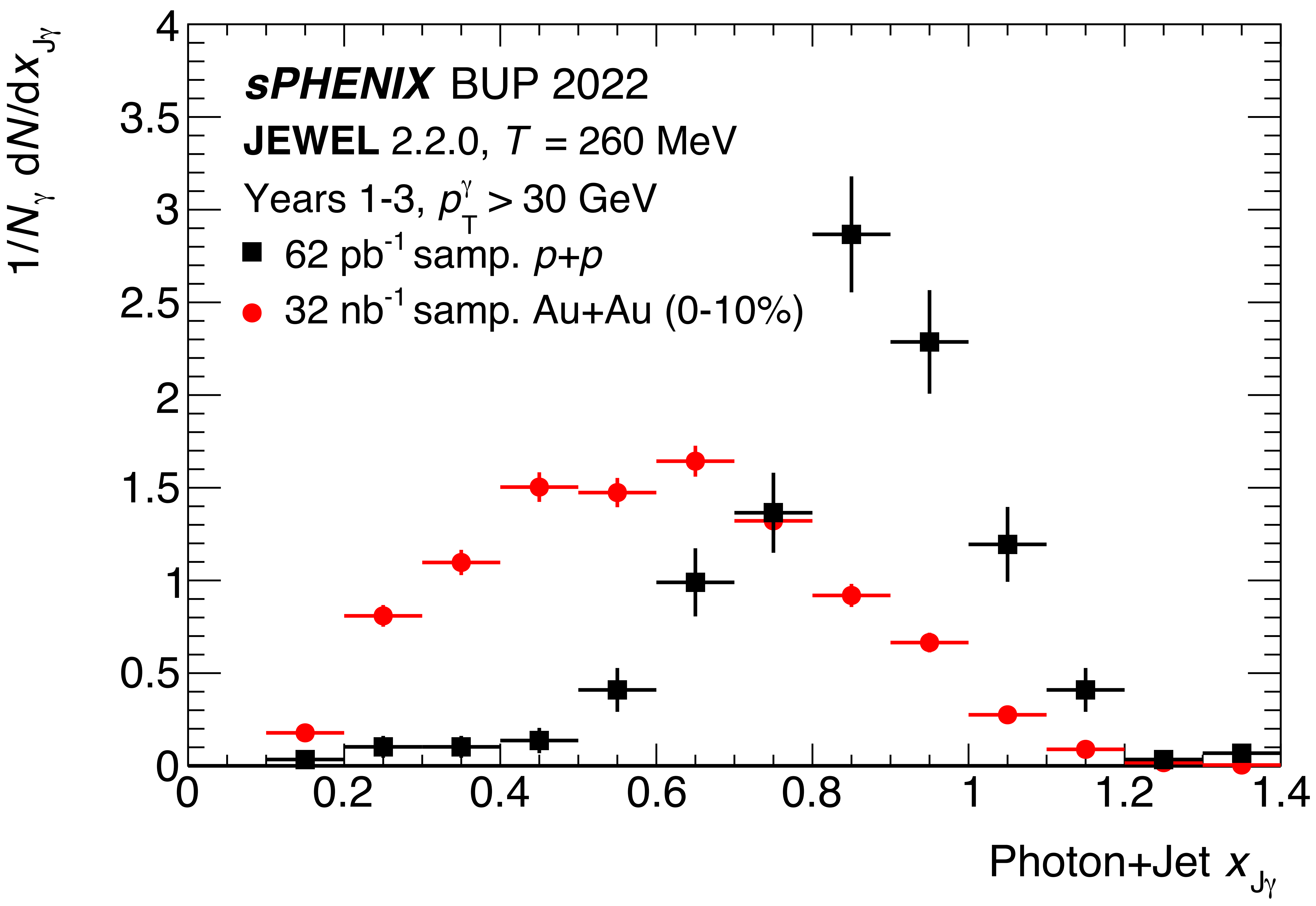
huge data samples allow for precision R_{AA} measurements + many other measurements

photon-jet measurements

photon-jet balance: key energy loss measurement

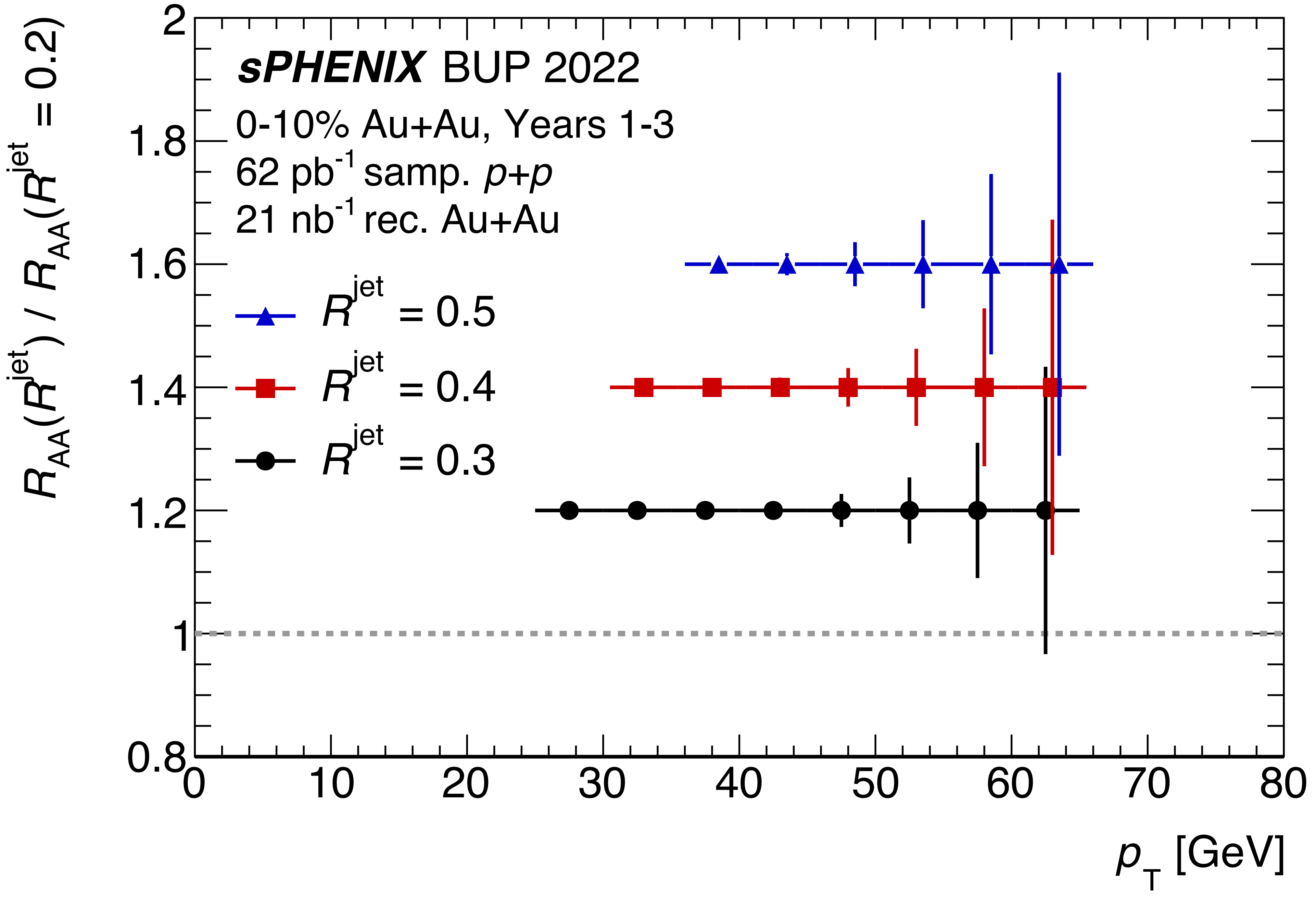


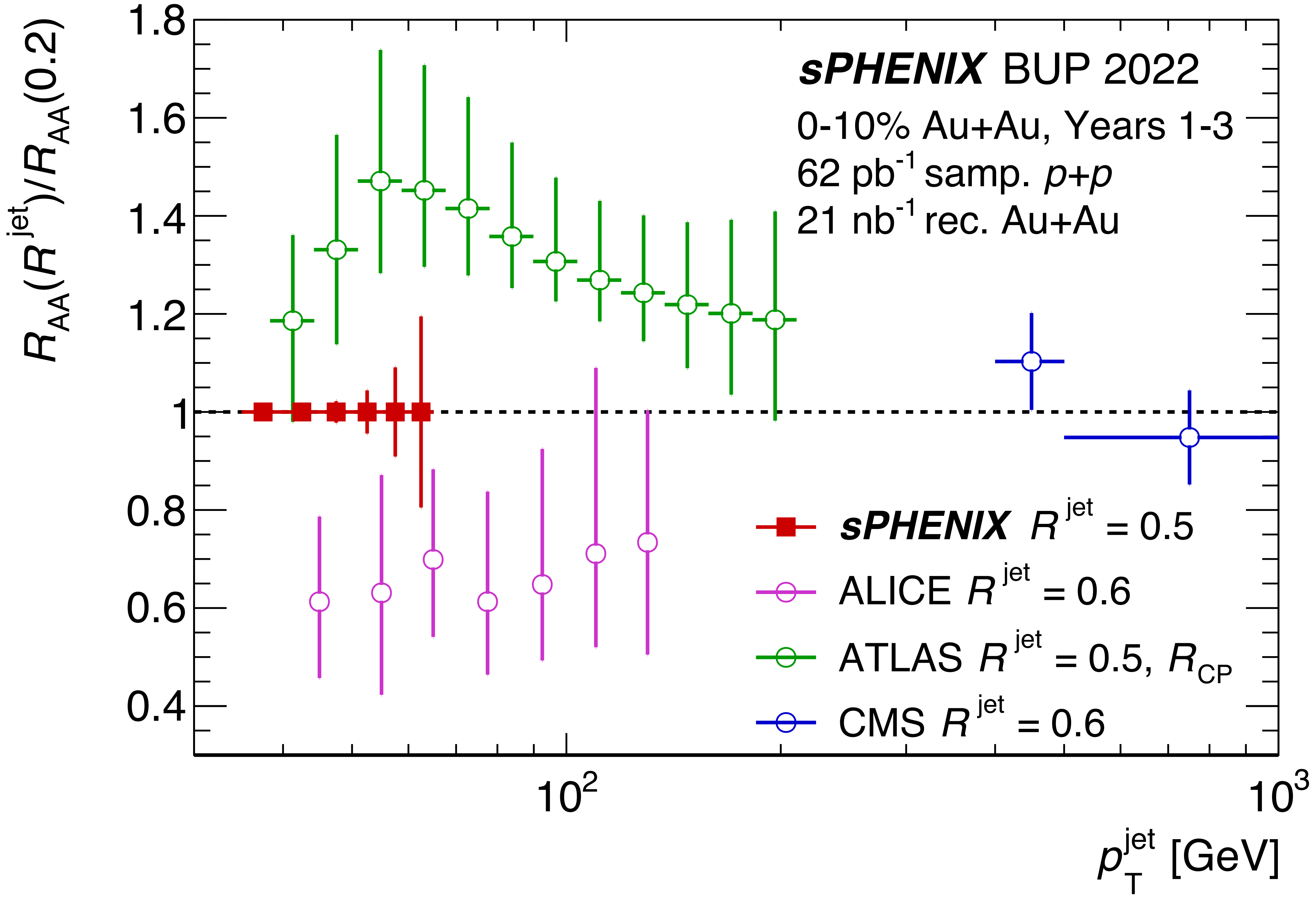
ATLAS: Phys. Lett. B 789 (2019) 167



sPHENIX will be able to make precise measurements in AuAu & pp collisions with lower momentum photons & jets than the LHC

jet radius dependent suppression



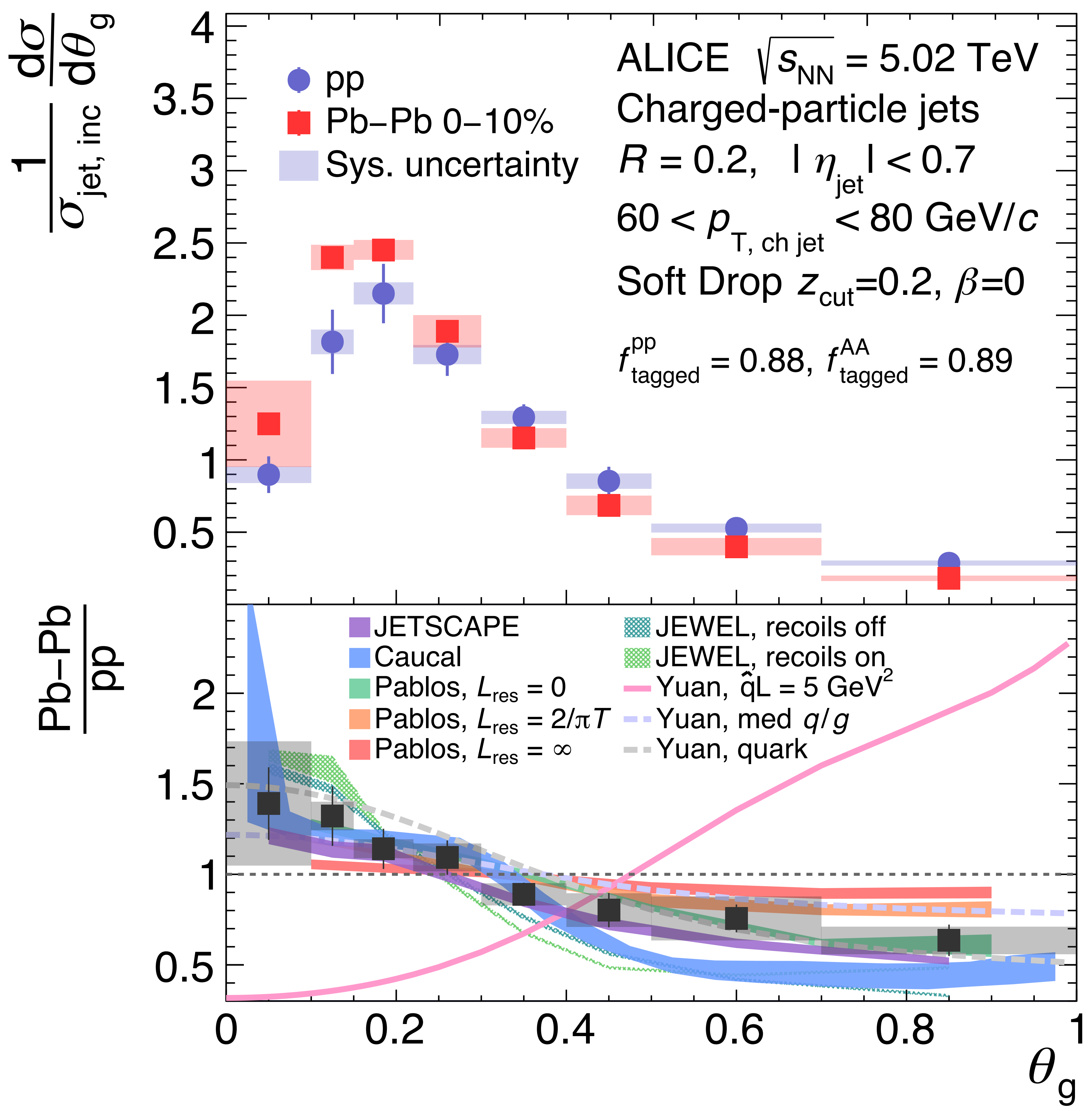


smaller UE event at RHIC helps the low p_T jet radius scan—an area where LHC measurements currently disagree

huge min-bias AuAu samples allow unbiased jet samples

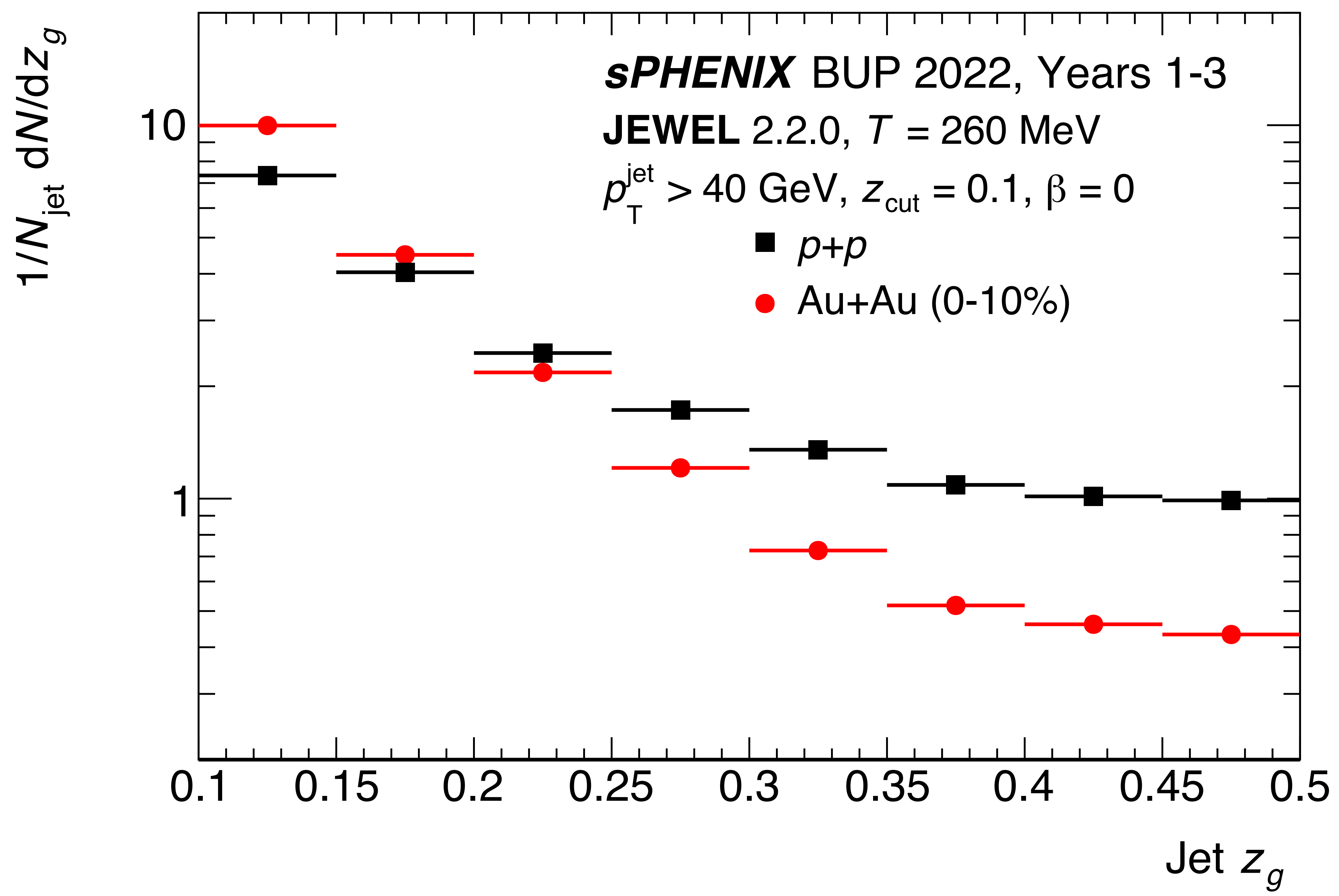
jet substructure

ALICE:2107.12984

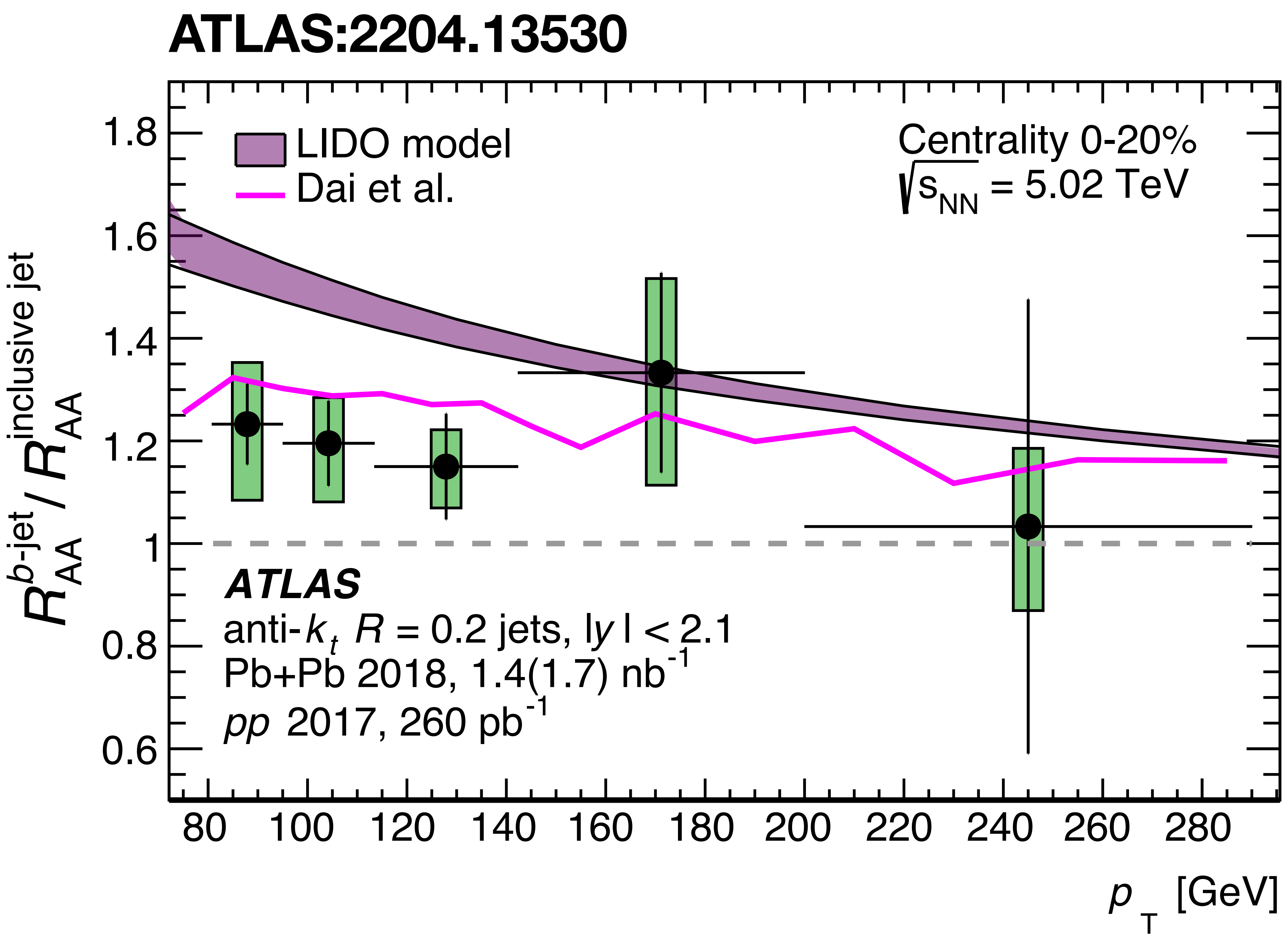


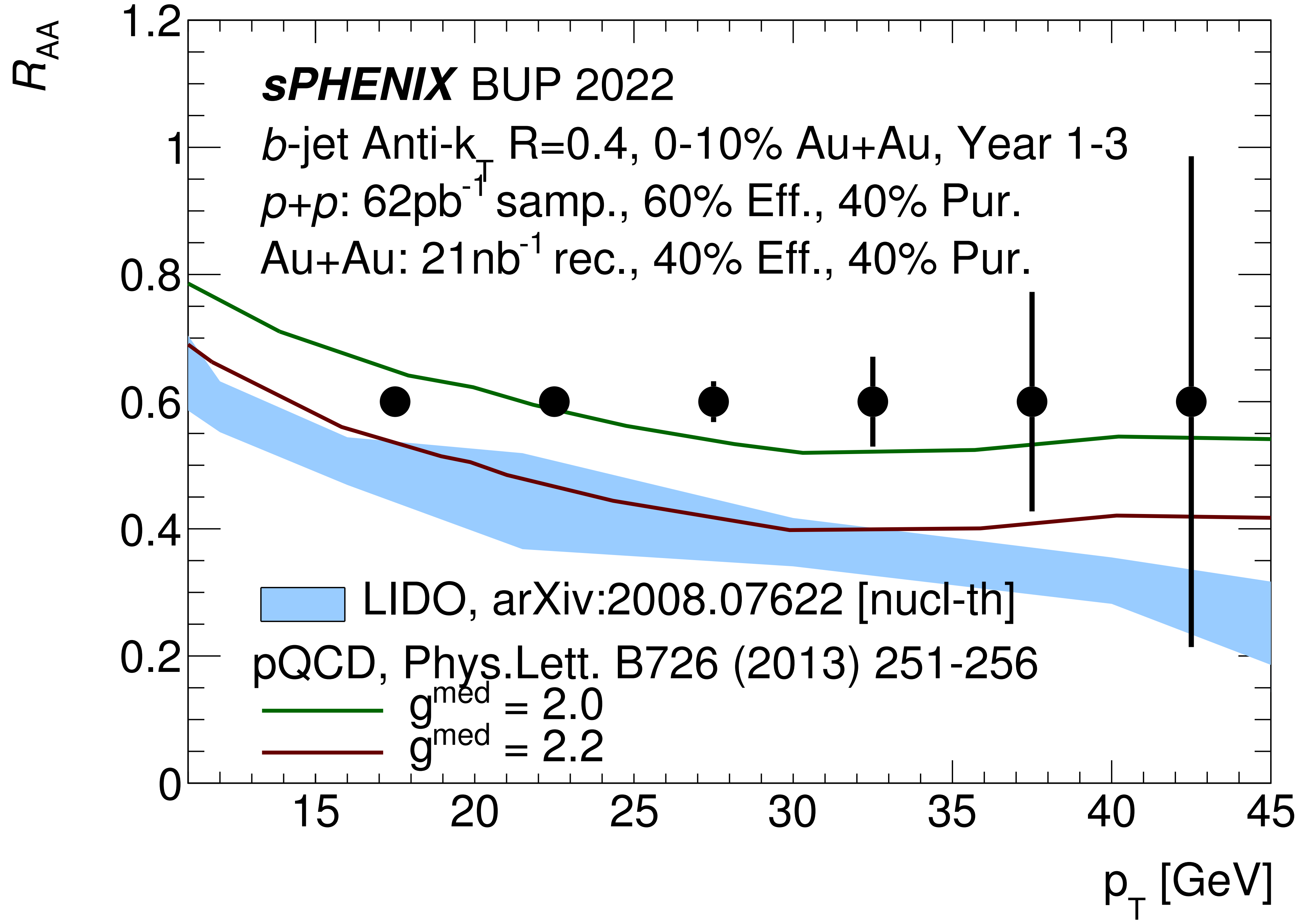
measurements of jet substructure provide information on how the QGP sees the developing parton shower

sPHENIX will be able to make a wide variety of substructure measurements with large data samples, excellent tracking & calorimetry



b-jet R_{AA}

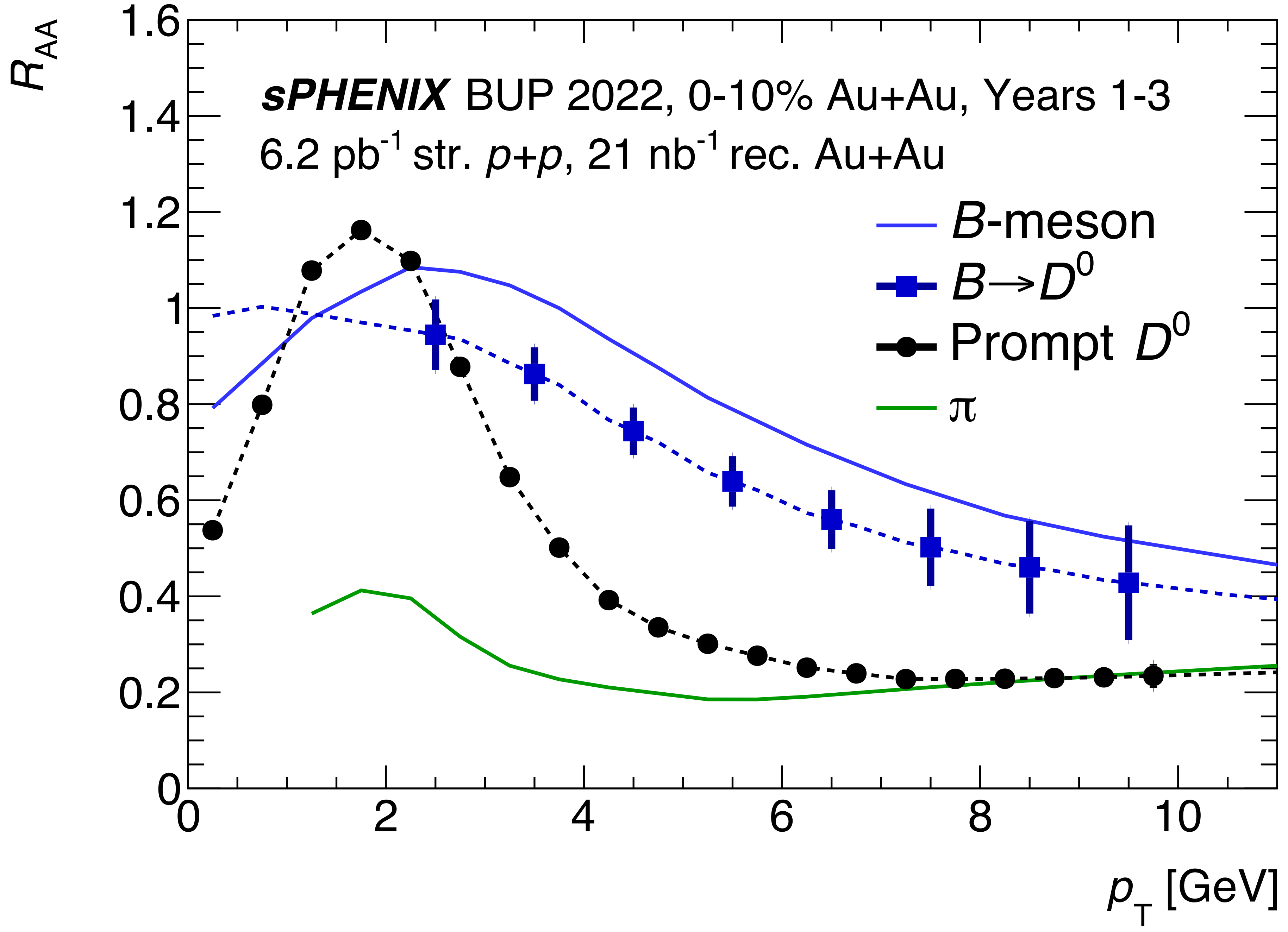


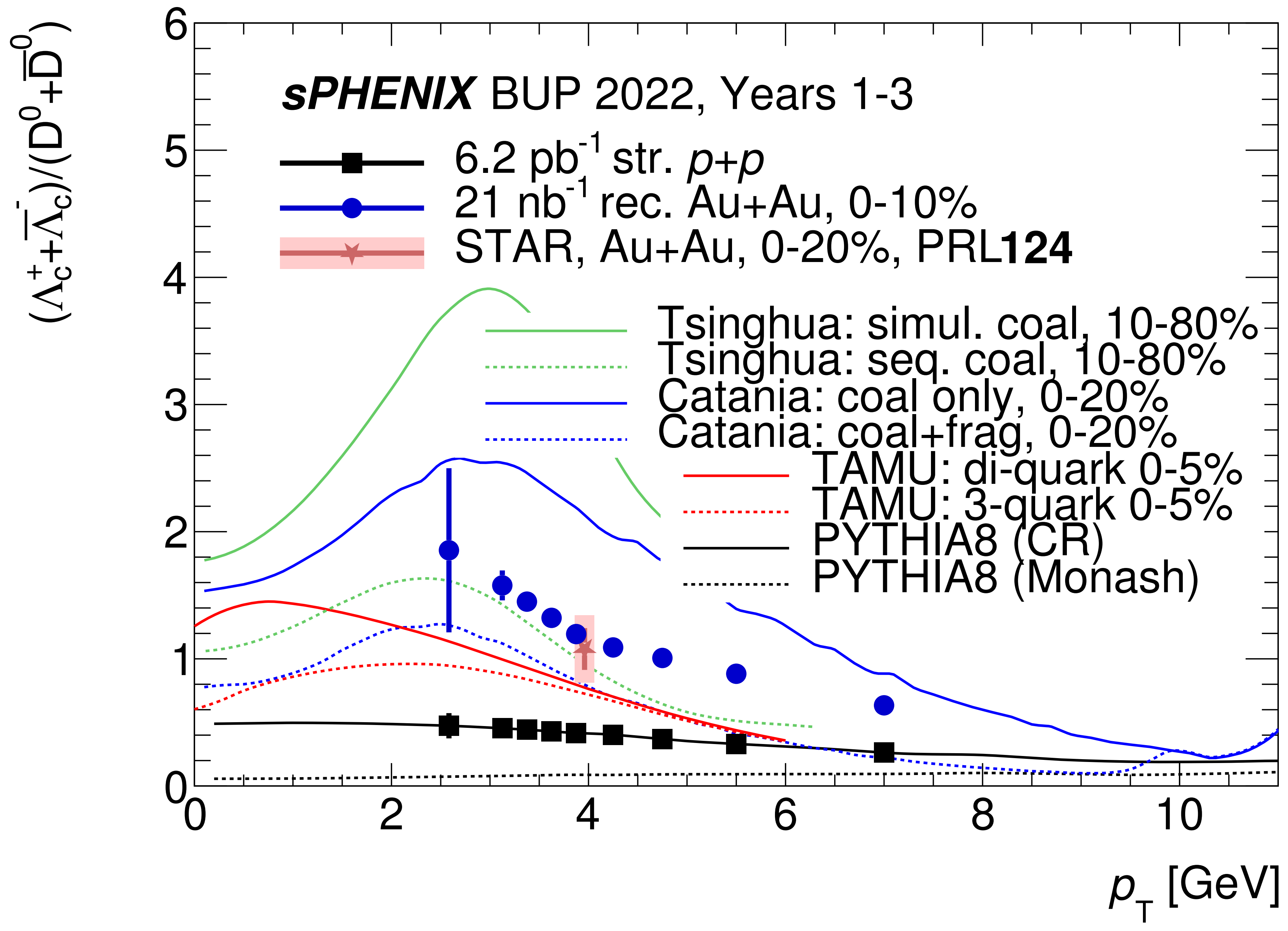


at the LHC, differences between inclusive and b-jet R_{AA} are expected from flavor effects (b-jets from gluon splitting) and mass effects (at the lower p_T end of the measurement)

sPHENIX data at much lower p_T will isolate the mass effects

HF hadrons

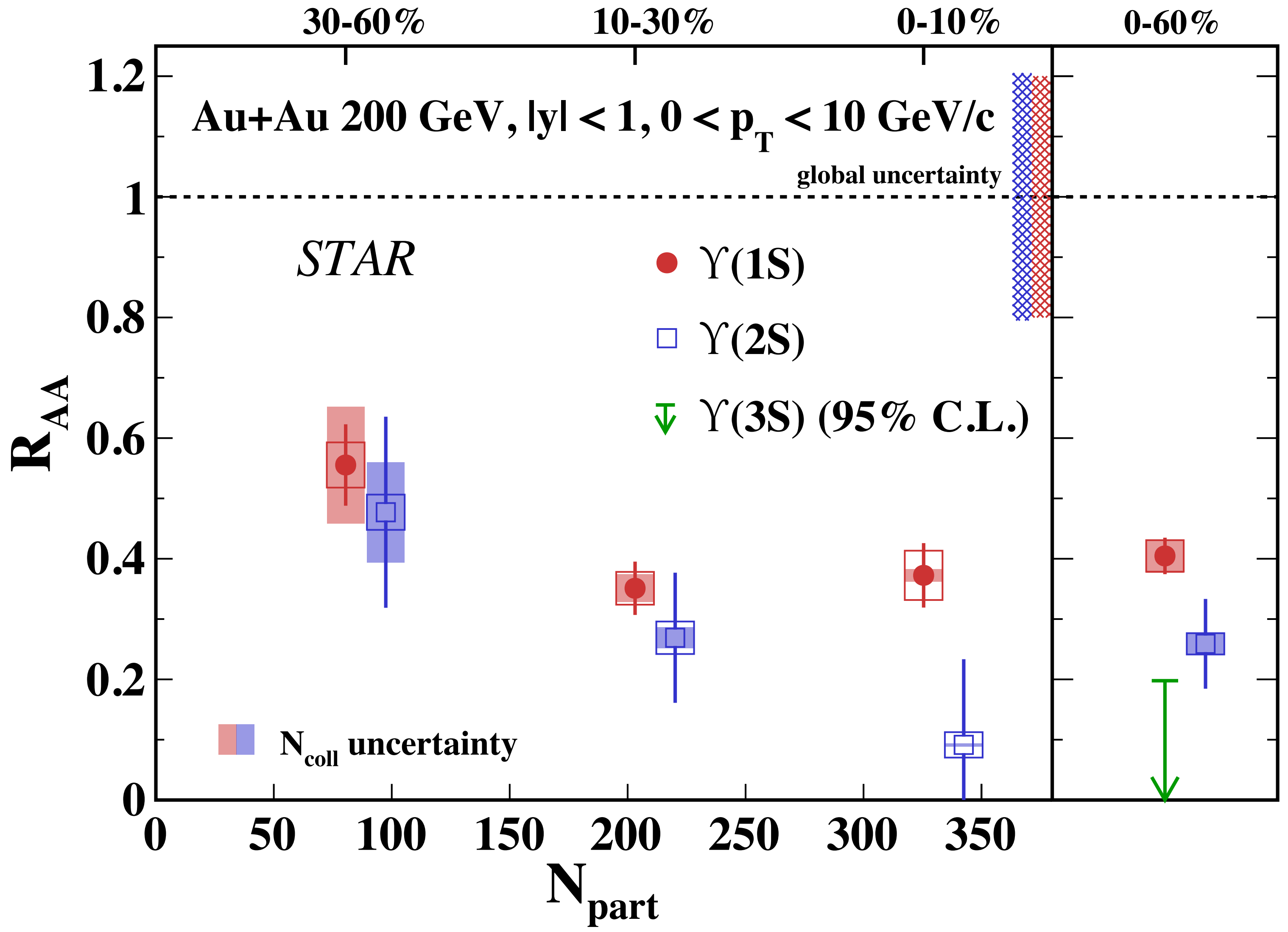


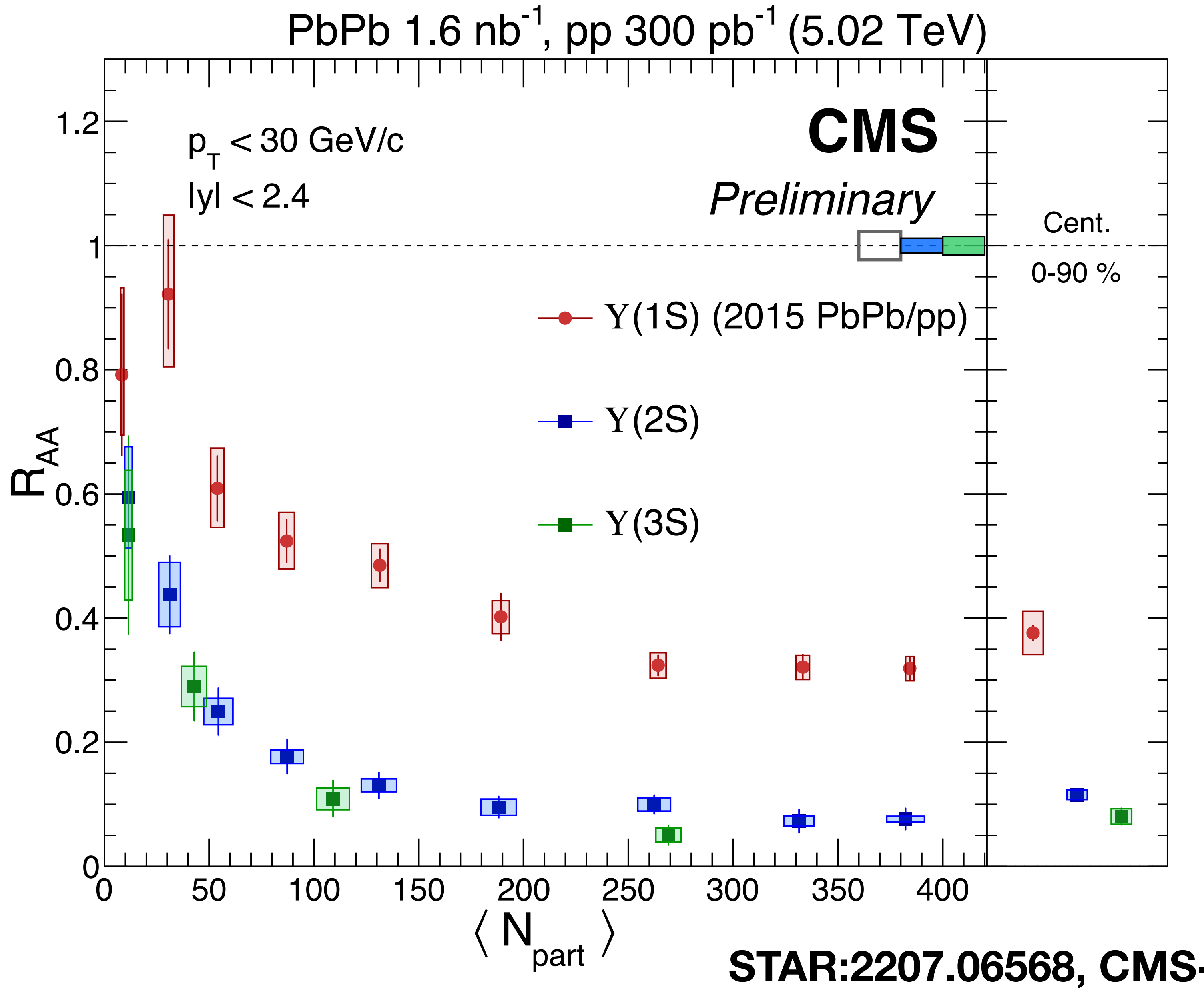


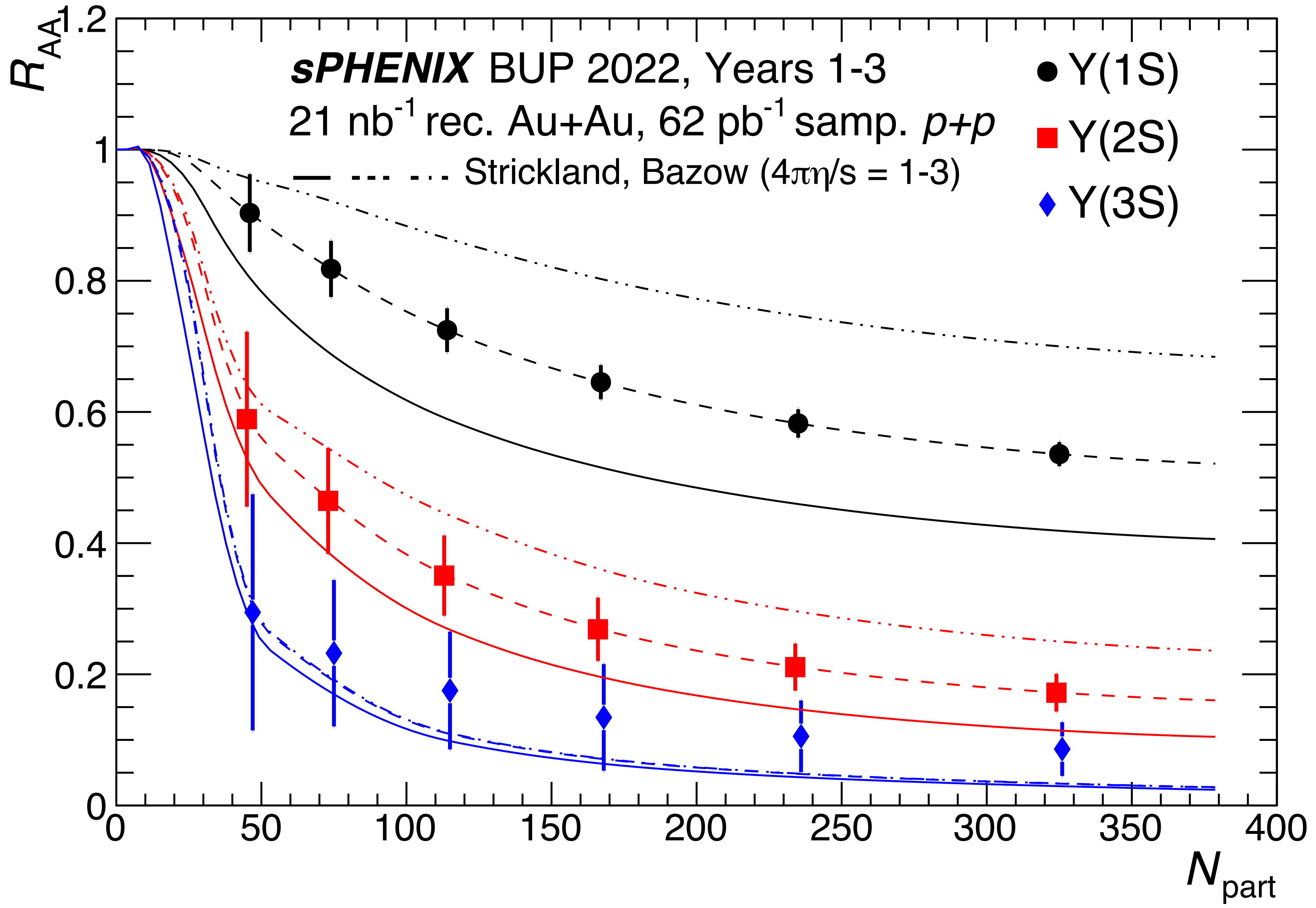
precision tracking allows for measurements of both charm and bottom hadrons

large min-bias AuAu samples & streaming readout in pp collisions will allow for R_{AA} (not R_{CP}) for these important probes

upsilons





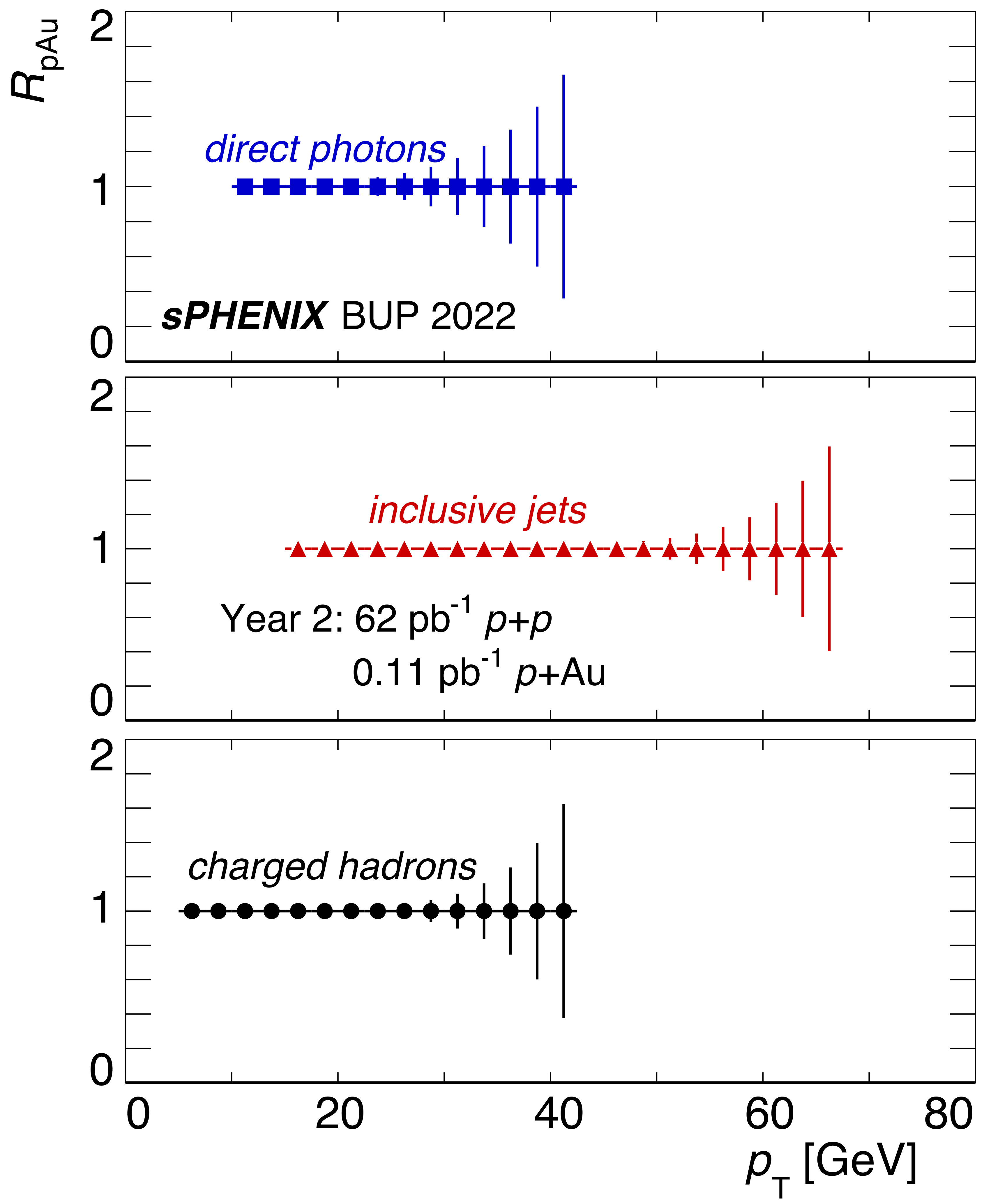


different upsilon suppression pattern observed at RHIC and LHC

precision sPHENIX measurement will be key to understanding the energy dependence of this effect

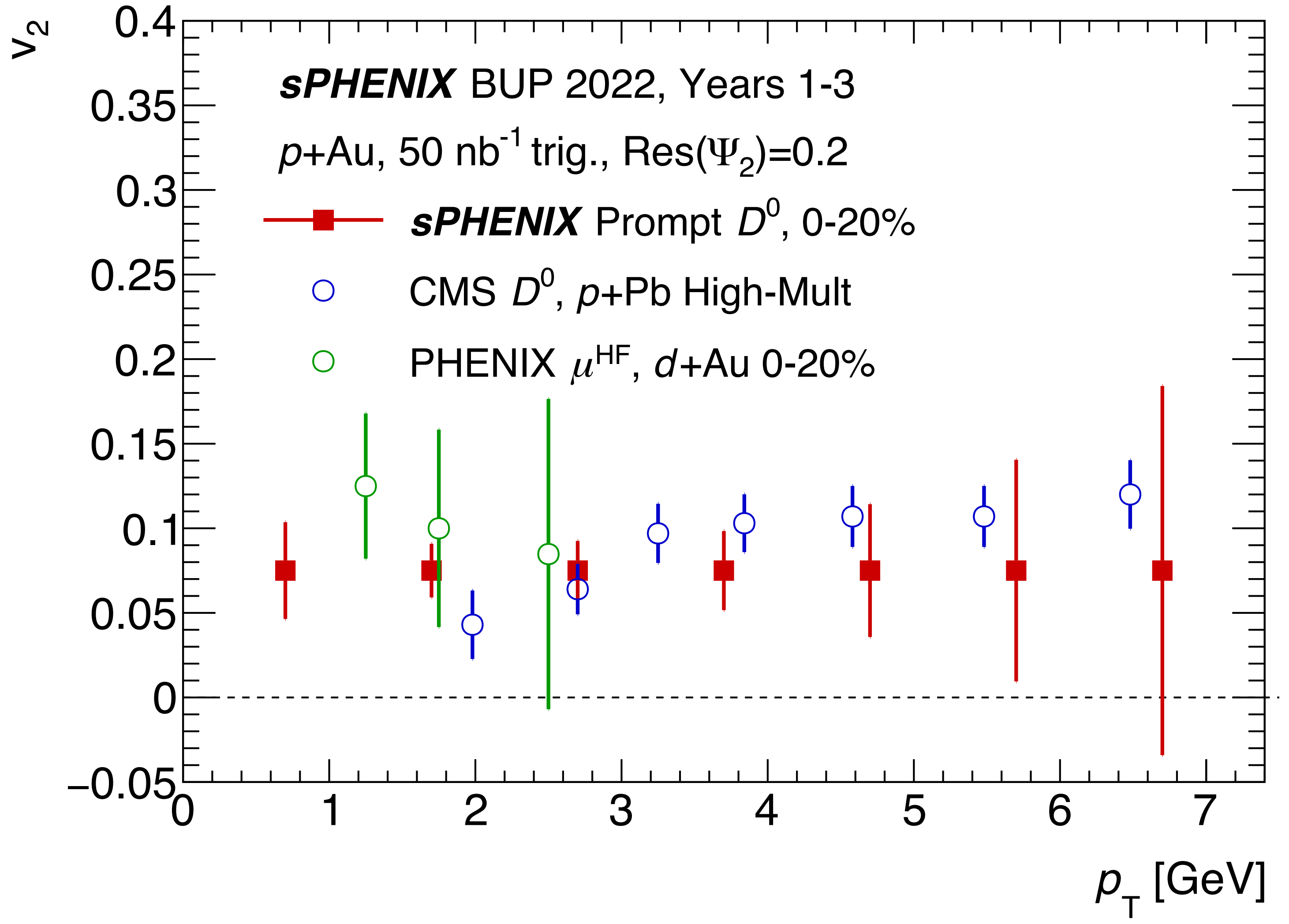
STAR:2207.06568, CMS-PAS-HIN-21-007

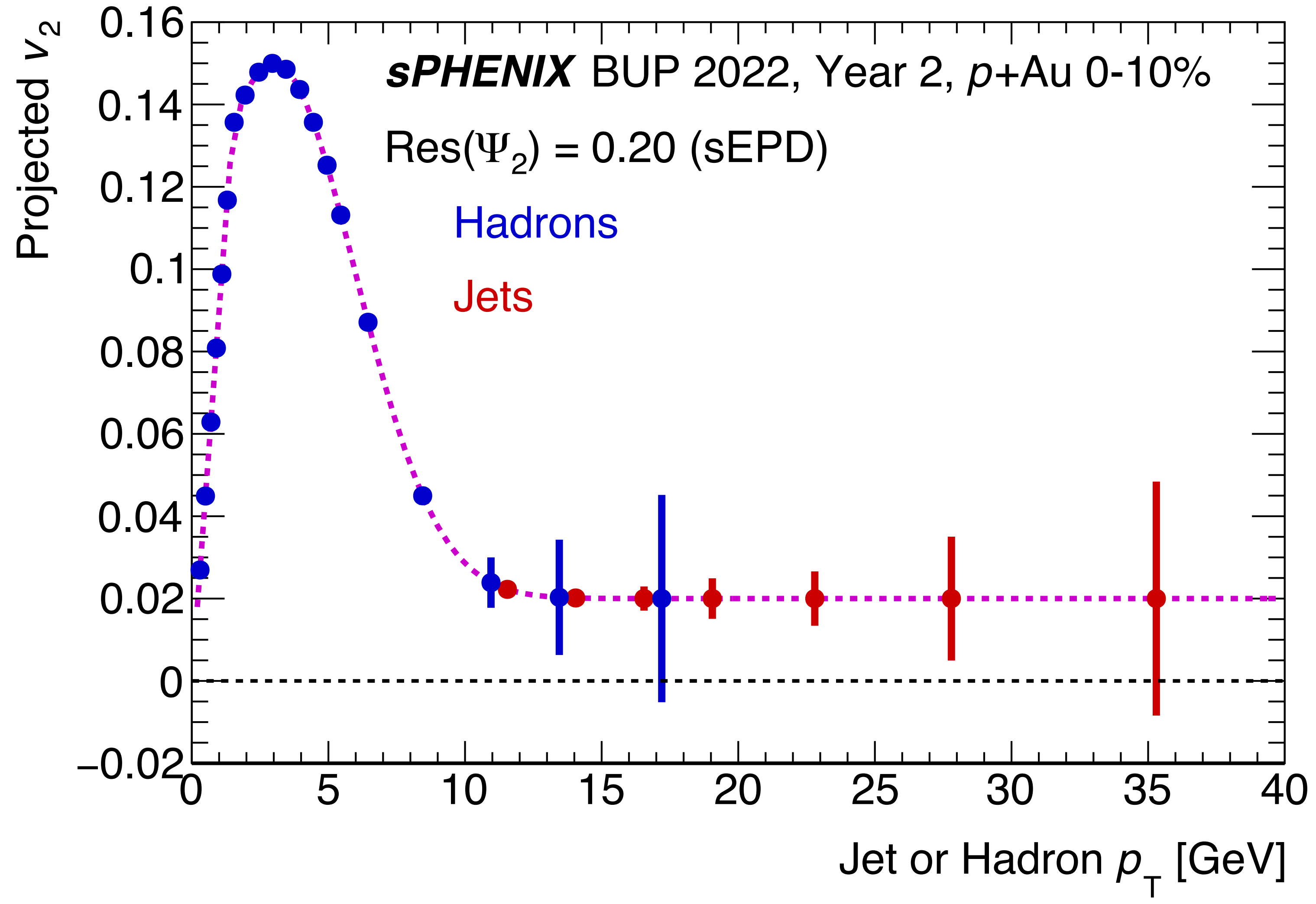
pA physics

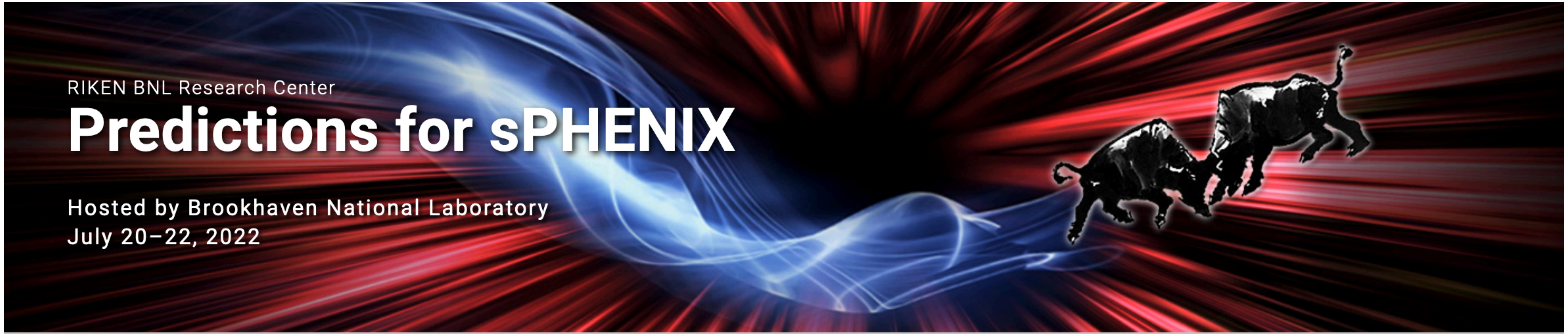


pA data has been very exciting over the last decade at both RHIC & the LHC

one highlight (out of many) for sPHENIX, high p_T v_2 for jets, hadrons & HF







https://www.bnl.gov/sphenix2022/

experimentalists & theorists discussing how to maximize the sPHENIX physics program

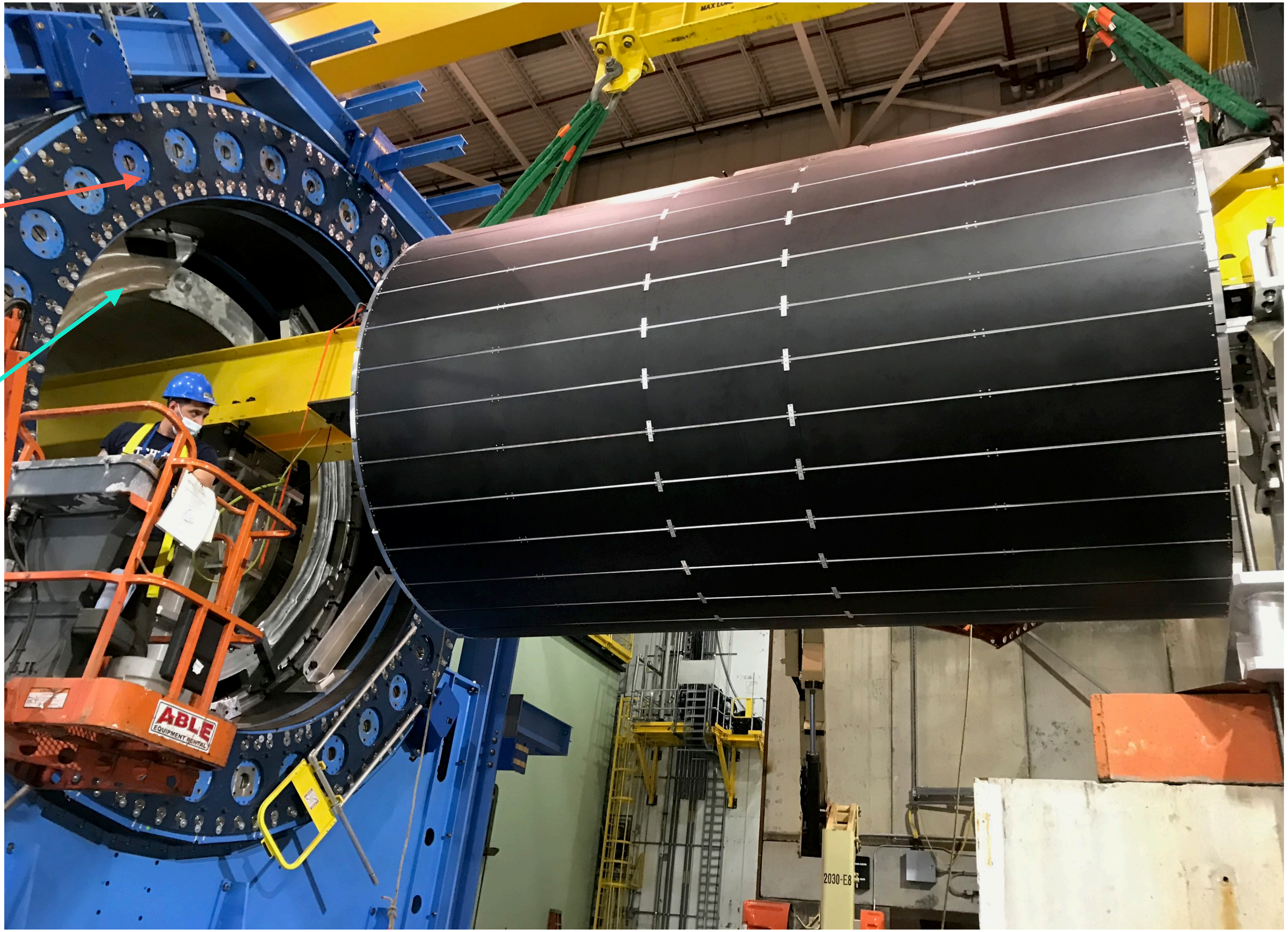
in addition to the theory contributions (and two excellent JETSCAPE talks from Amit & Raymond) there are sPHENIX talks overviewing the program and discussing the capabilities of the physics working groups in detail

with a tour of the detector to wrap up the meeting

Inner HCal installation

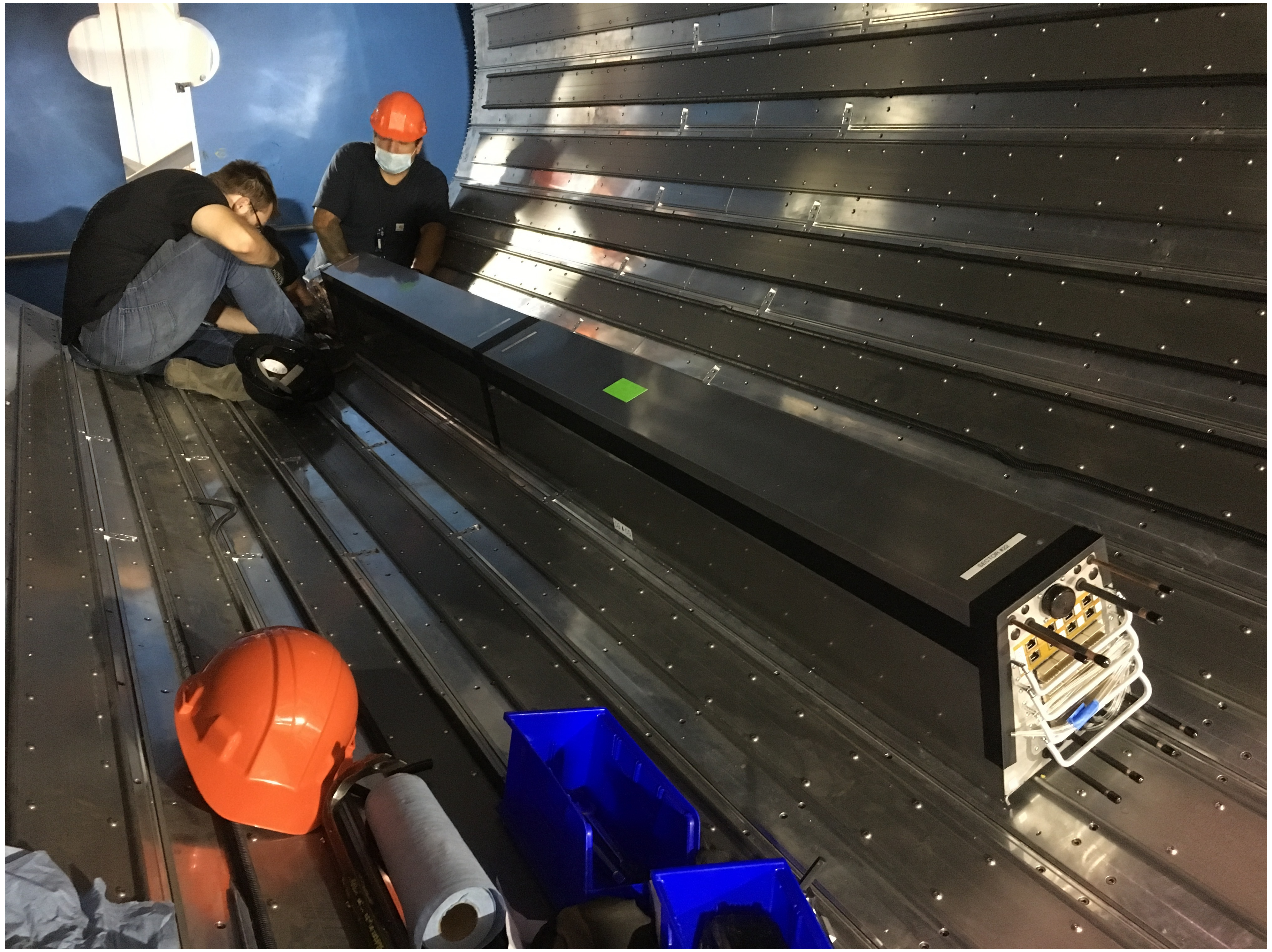
Outer HCal

Solenoid



June 2022

EMCal insallation



First 2 EMCal sectors installed into the Inner HCal earlier this week!

summary

- sPHENIX physics program essential to the completion of the RHIC science mission

- three year program takes advantage of new detector targeted to hard probes physics and excellent RHIC performance

    - BNL PAC 2022: "*The top overall priority in planning for the coming three years is to commission the sPHENIX detector and to achieve its scientific program.*"

- sPHENIX installation in full swing and the collaboration is on track for commissioning with beam and first physics in February 2023

collaboration is excited to work with the entire community to improve our understanding of QGP properties

backup

possible extra running

Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z \rvert < 10$ cm	Samp. Lum. $\lvert z \rvert < 10$ cm
2026	$p^{\uparrow}p^{\uparrow}$	200	28	15.5	1.0 pb^{-1} [10 kHz] 80 pb^{-1} [100%-str]	80 pb^{-1}
–	O+O	200	–	2	18 nb^{-1} 37 nb^{-1} [100%-str]	37 nb^{-1}
–	Ar+Ar	200	–	2	6 nb^{-1} 12 nb^{-1} [100%-str]	12 nb^{-1}
2027	Au+Au	200	28	24.5	30 nb^{-1} [100%-str/DeMux]	30 nb^{-1}

should the opportunity arise, sPHENIX could increase the pp luminosity, explore light ions and take a lot more AuAu data

jet anisotropy