

STAR Experimental Highlights

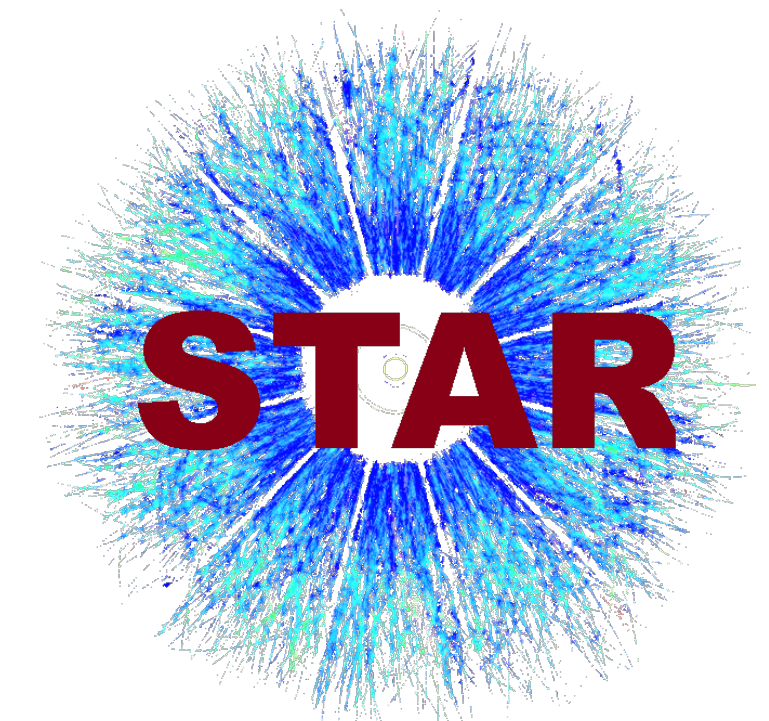
Nihar Ranjan Sahoo (SDU) and Joern Putschke (WSU)
(for the STAR collaboration)



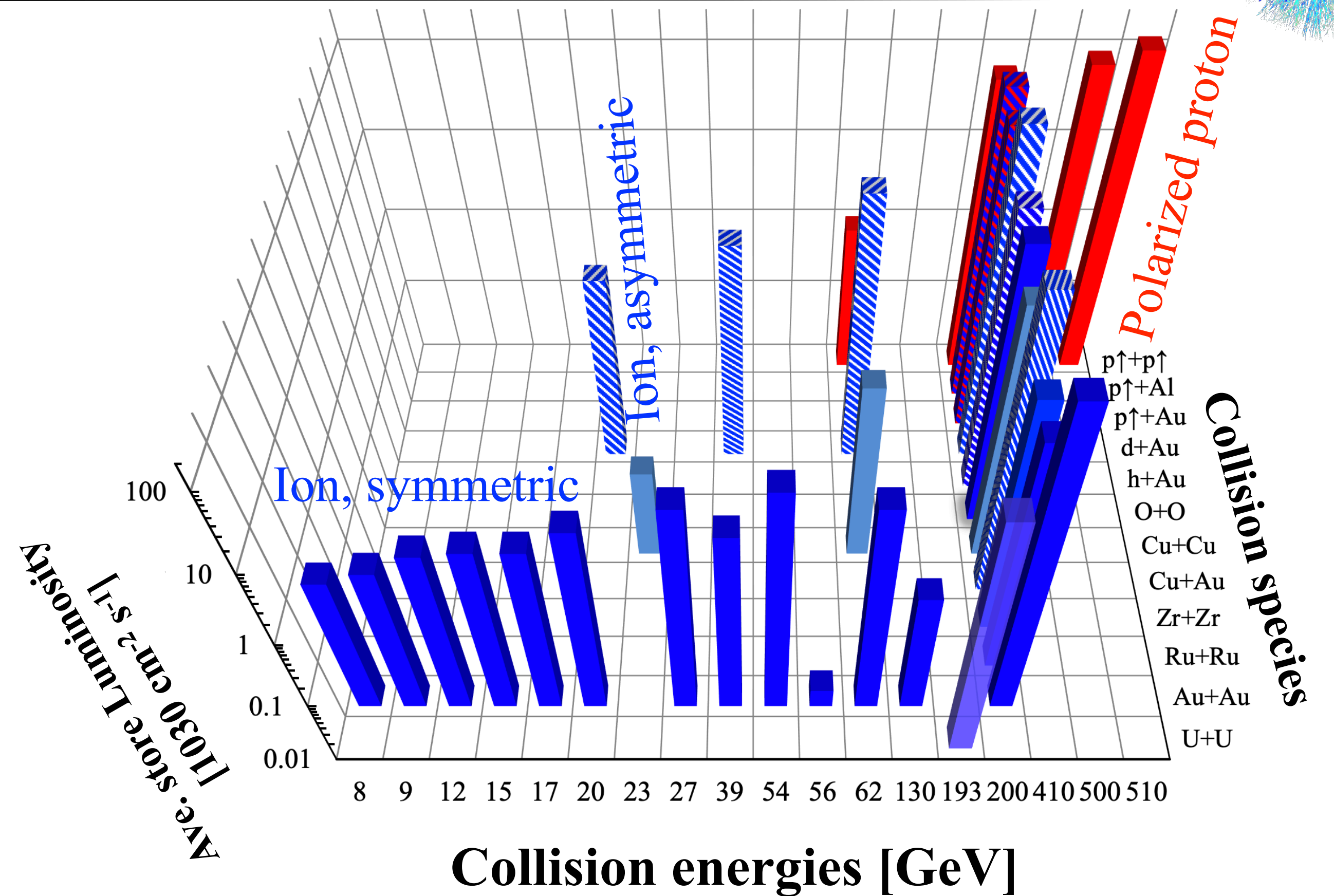
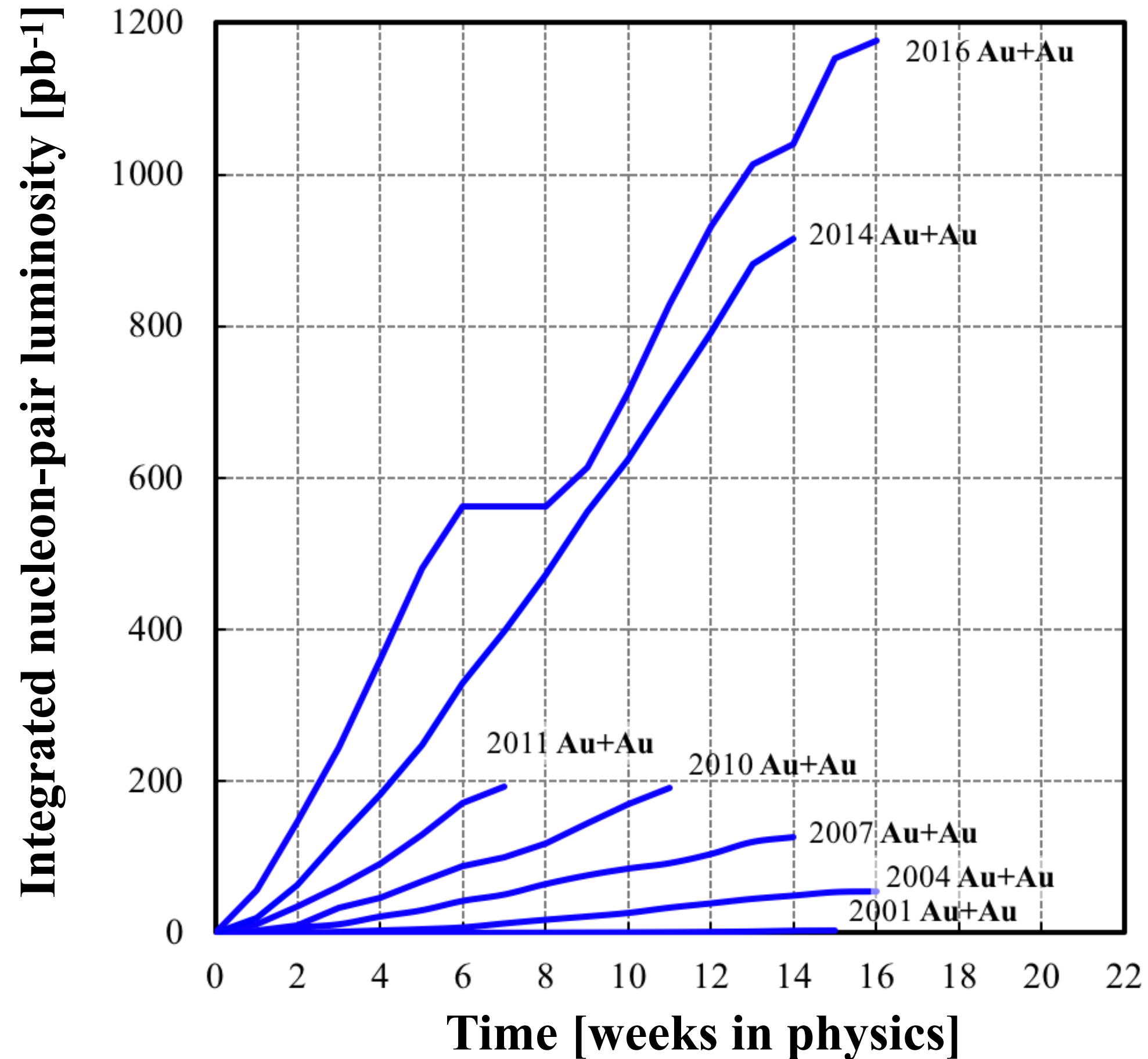
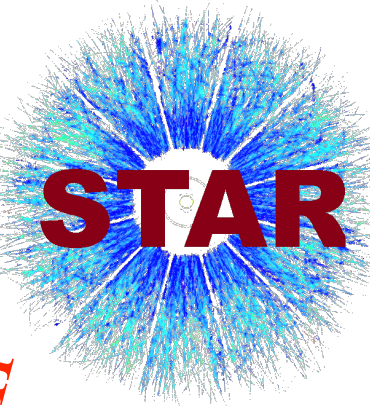
Germany
26 - 31 March 2023



Supported in part by
U.S. DEPARTMENT OF
ENERGY



RHIC energies, collision species and luminosity



p+p, Ru+Ru, Zr+Zr and Au+Au data are presented at this conference

- Increased luminosity improves the precision of our measurements
- Different collision species allow to study the hot QCD medium at different conditions

STAR detector

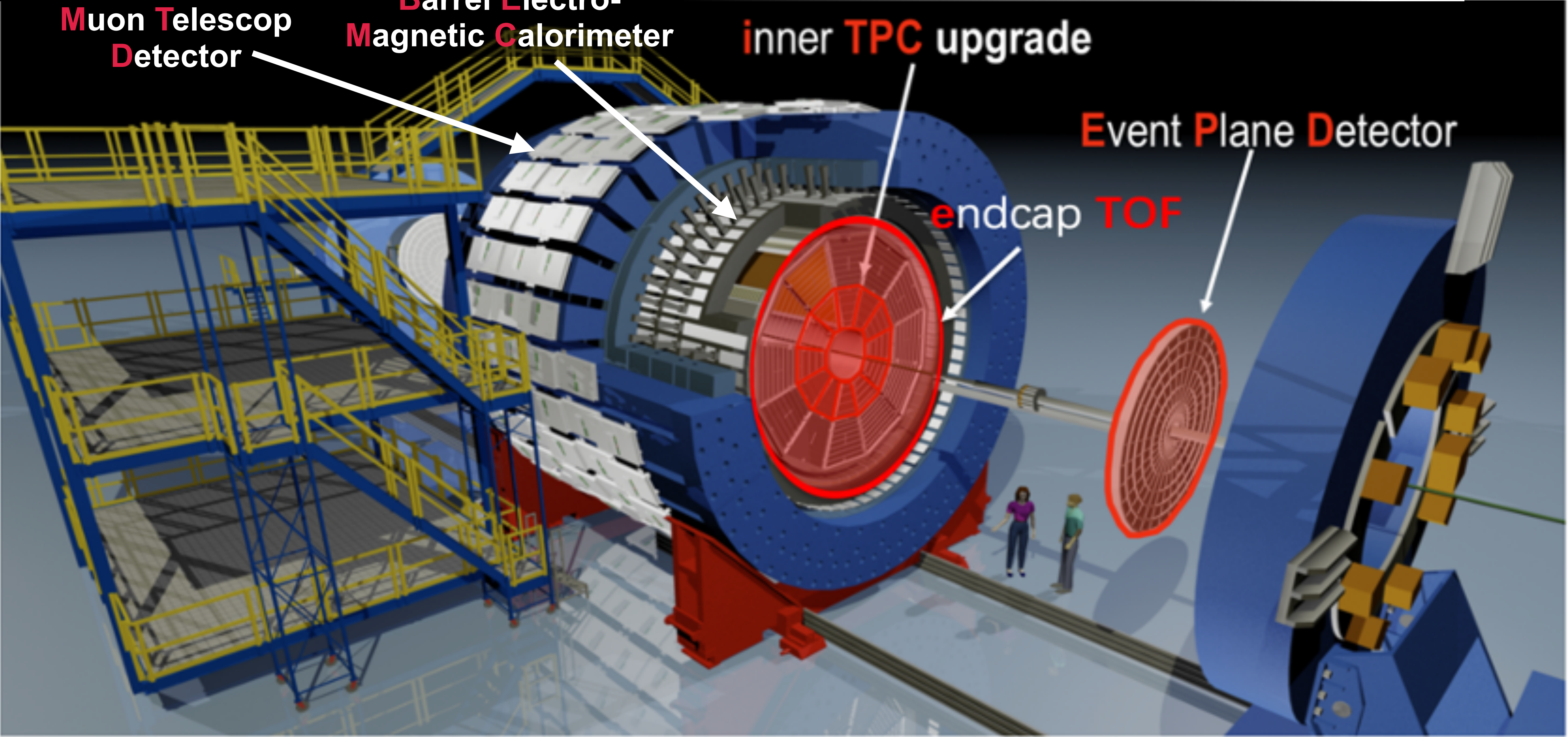
Muon Telescope
Detector

Barrel Electro-
Magnetic Calorimeter

inner TPC upgrade

Event Plane Detector

endcap TOF





1. Probing fundamental QCD: theory vs. reality

Energy-energy correlations and jet substructure

2. What do hard probes tell us about QGP?

System size dependence of jet and heavy-flavor production and flow

Different manifestations of jet-medium interaction and their consequences

7 parallel talks + 3 posters presentations



1. Probing fundamental QCD: theory vs reality

Energy-energy correlations and jet substructure

2. What do hard probes tell us about QGP?

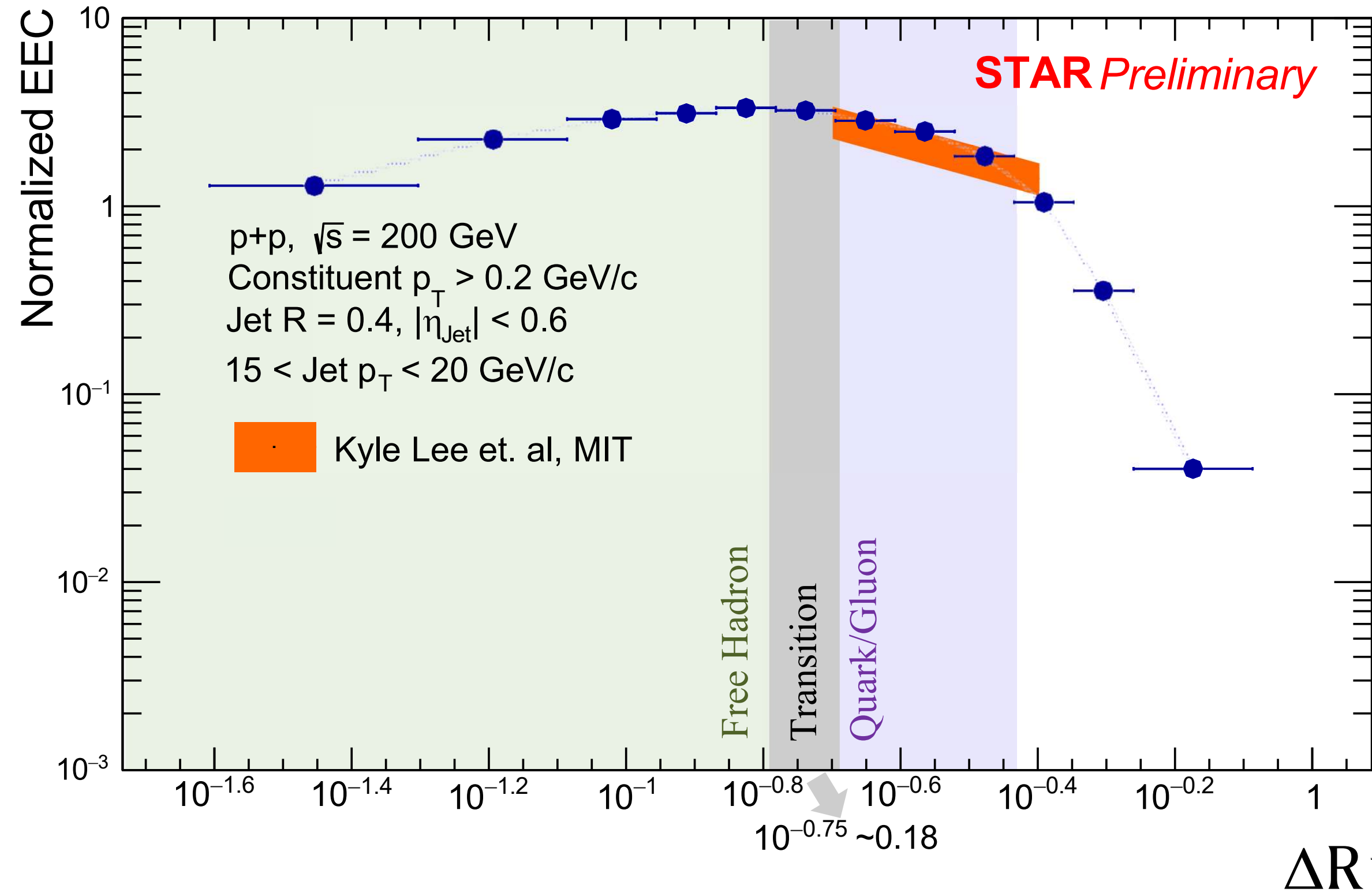
System size dependence of jet and heavy-flavor production and flow

Different manifestations of jet-medium interaction and their consequences

Energy-energy correlation

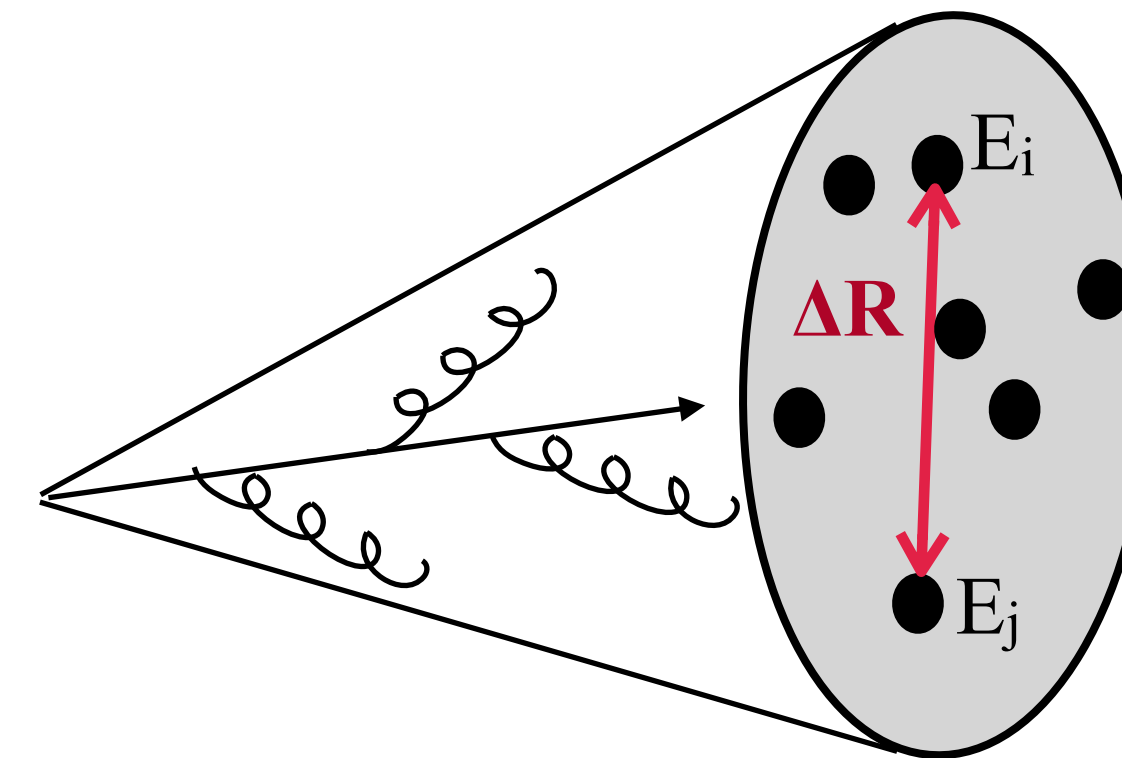


Andrew Tamis
29 Mar, 11.30



“field theory faces reality”

[arXiv:2205.03414](https://arxiv.org/abs/2205.03414) , [2209.11236](https://arxiv.org/abs/2209.11236)



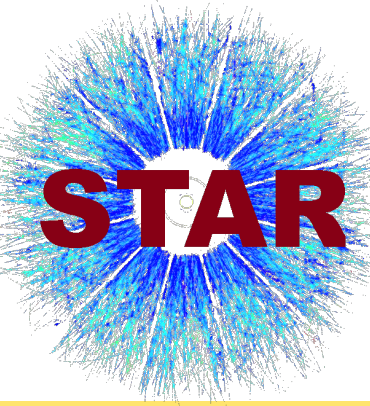
Correlation functions of energy flow operators

$$\text{Normalized EEC} = \frac{1}{\sum_{\text{jets}} \sum_{i \neq j} \frac{E_i E_j}{p_{T,\text{jet}}^2}} \frac{d(\sum_{\text{jets}} \sum_{i \neq j} \frac{E_i E_j}{p_{T,\text{jet}}^2})}{d(\Delta R)}$$

Transition region at $\Delta R \times p_T^{\text{jet}} \sim 2 - 3 \text{ GeV}$ independent on jet energy

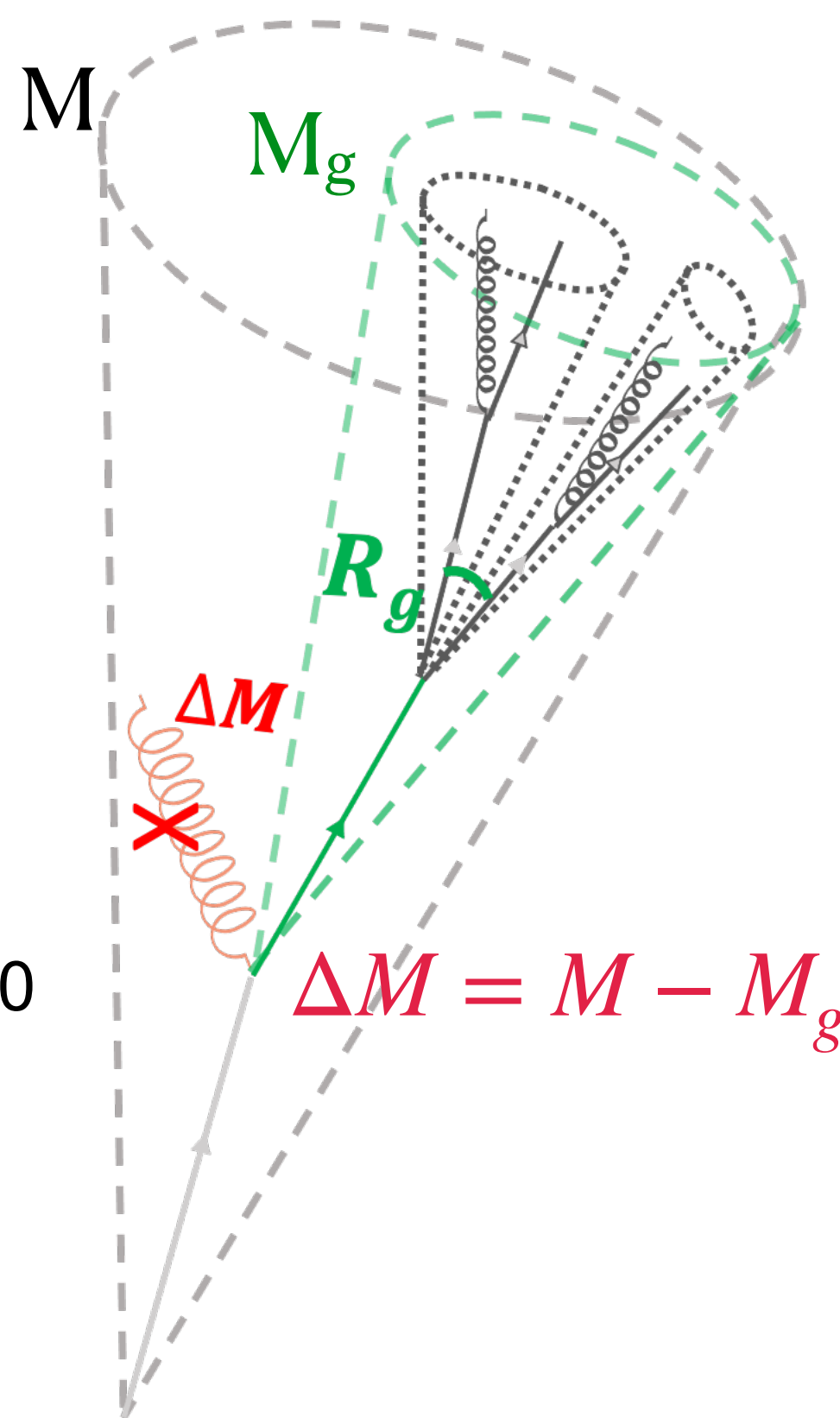
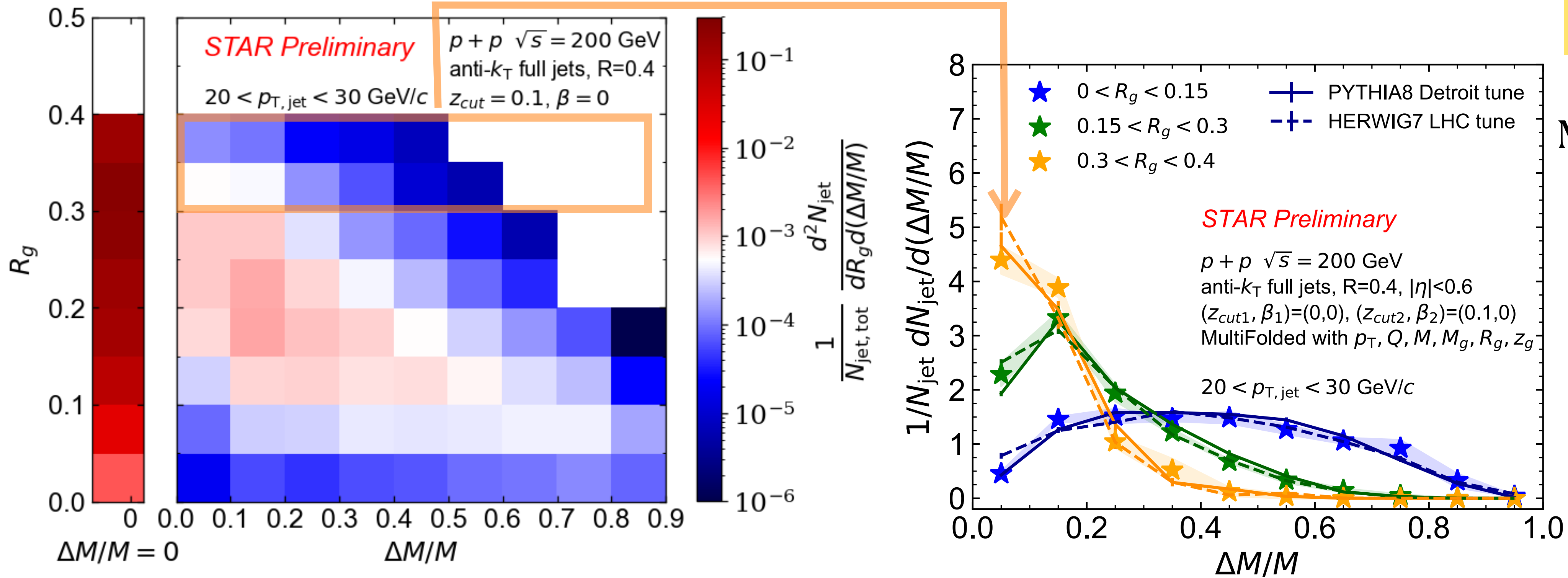
→ Confinement of quark/gluon degrees of freedom into hadrons occurs at universal momentum scale

Isolating non-perturbative contribution in vacuum shower



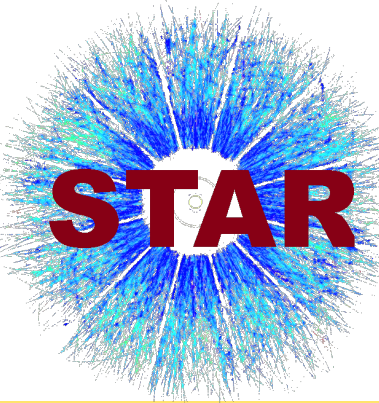
Reconstruct jet; then groom to isolate non-perturbative part of shower

Monika Robotková
30 Mar, 9.00

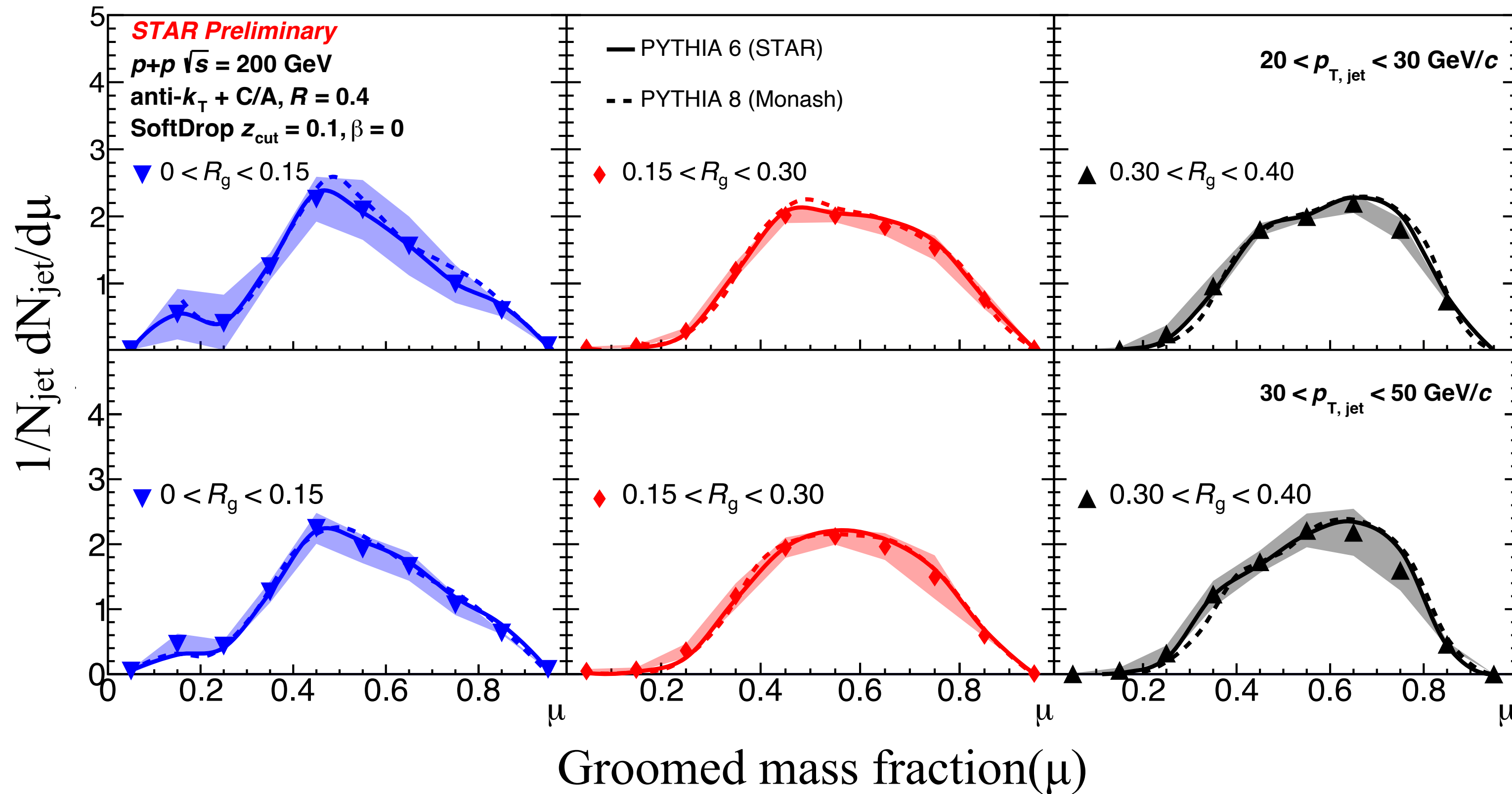


Anti-correlation between collinear dropped jet mass $\Delta M/M$ and R_g
 → consistent with angular ordering of the parton shower

How groomed mass fraction varies with splitting angles?



Monika Robotková
30 Mar, 9.00



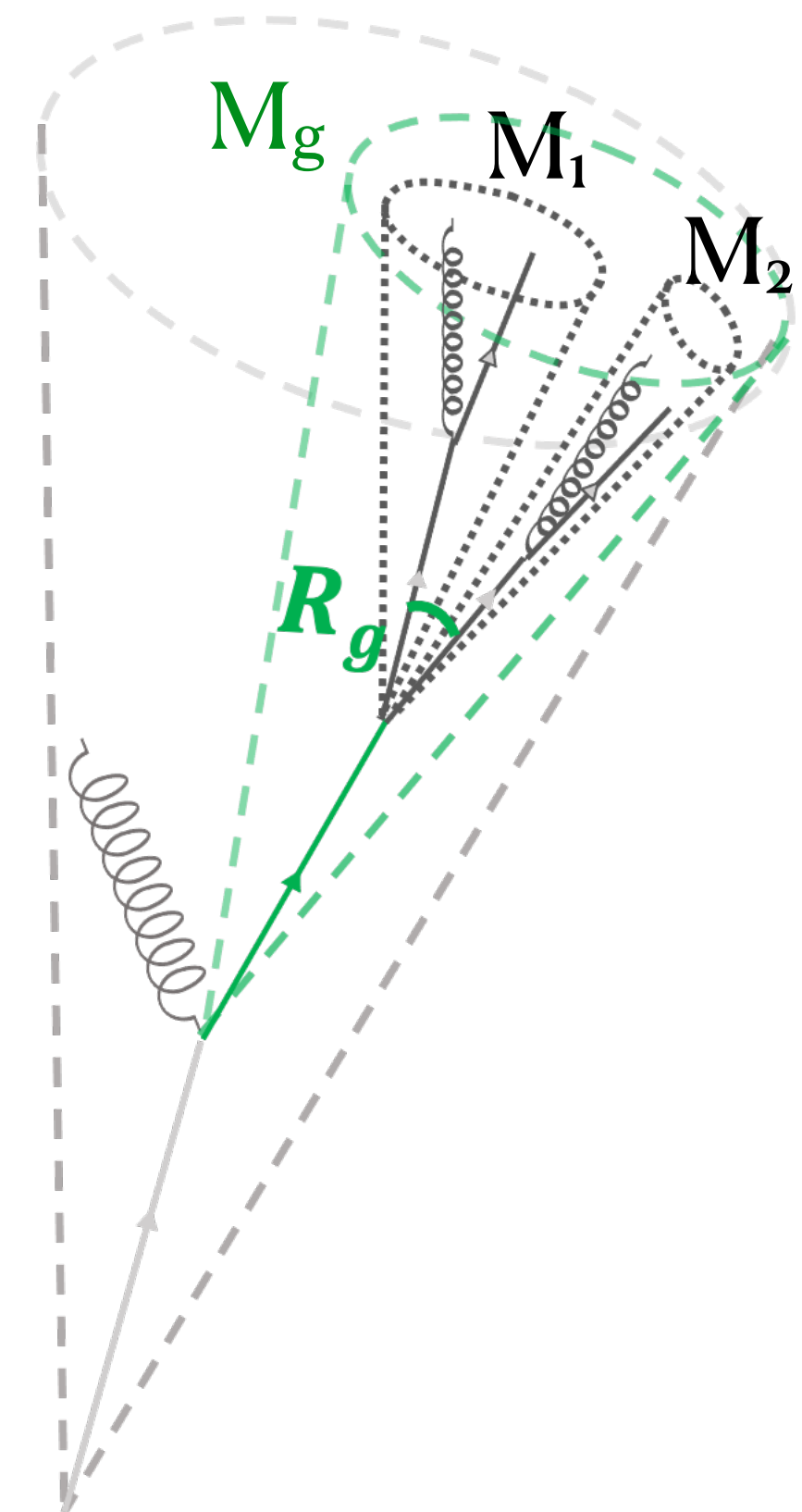
Groomed mass fraction

$$\mu \equiv \frac{\max(M_1, M_2)}{M_g}$$

$$\mu \in [0, 1]$$

With SoftDrop
condition

$$z_{\text{cut}} = 0.1 \text{ and } \beta = 0$$



Shift of μ to smaller values at smaller angles indicates a faster reduction of virtuality in the jet shower

Model vs. data : jet shapes and hadronization



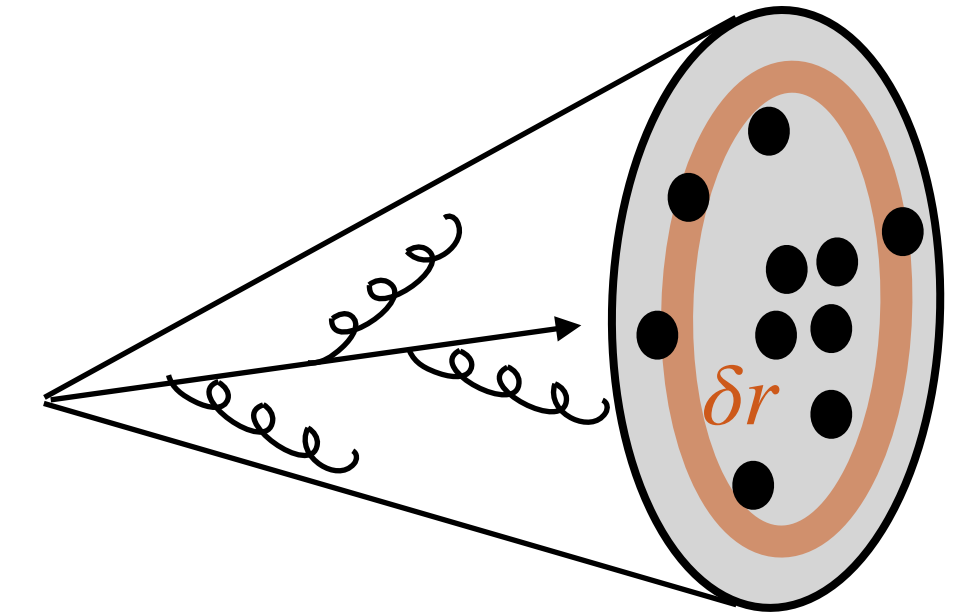
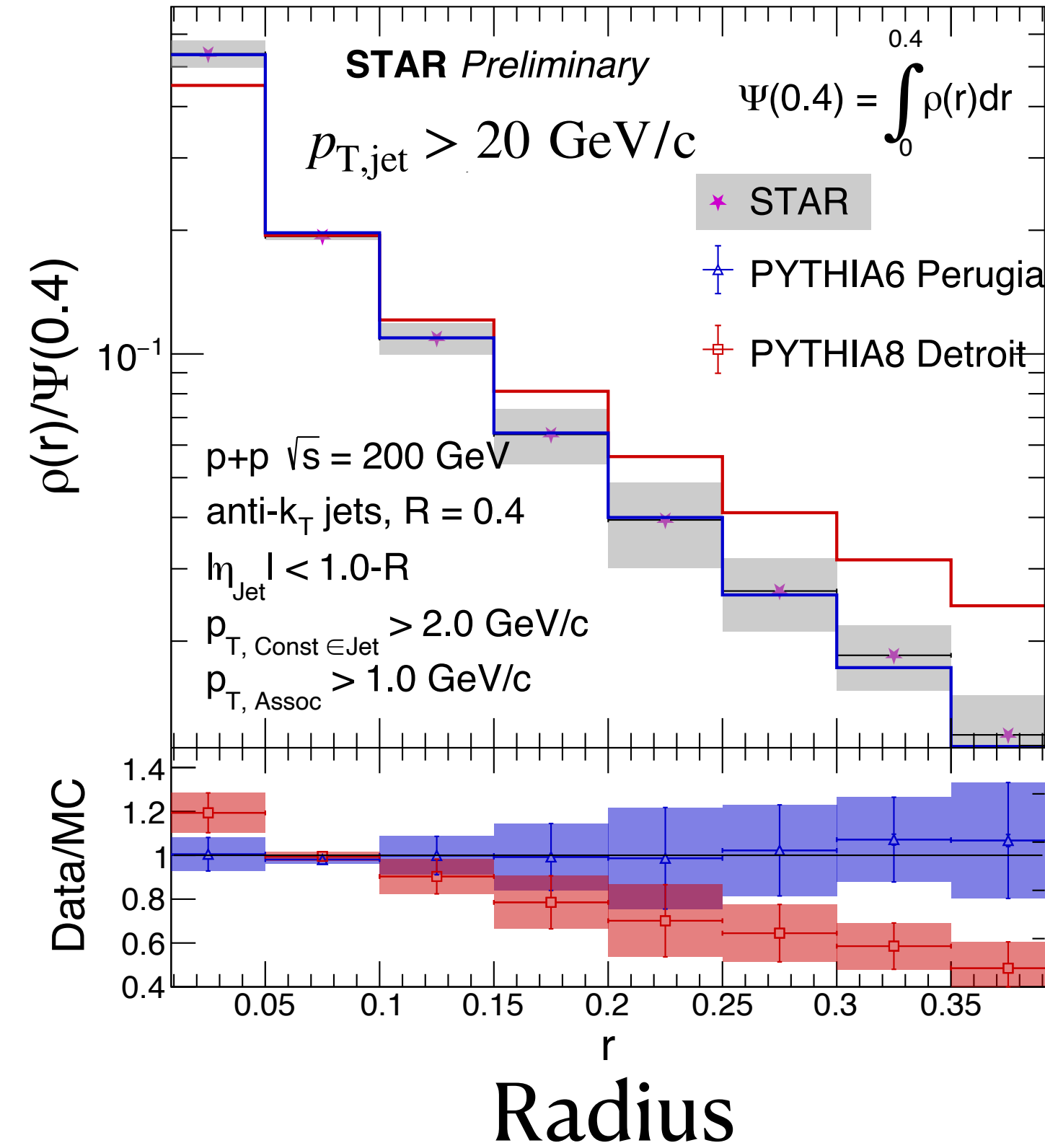
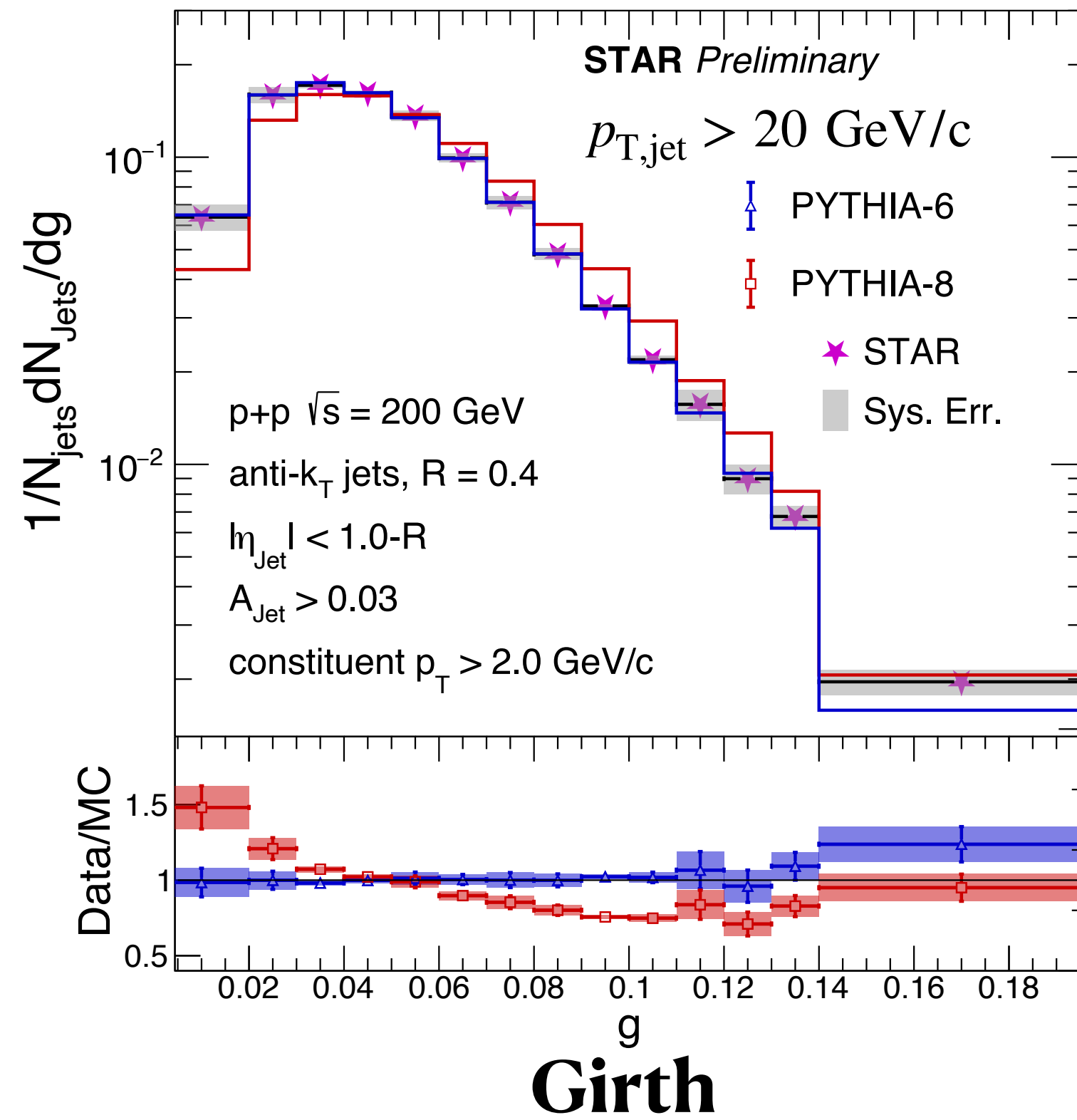
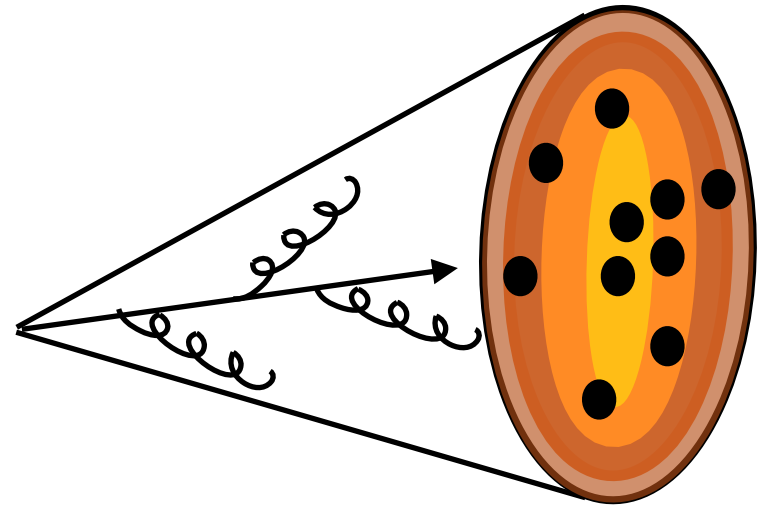
Tanmay Pani
28 Mar, 11.10

Girth

$$g = \frac{\sum_{\text{trks}} p_{T,\text{trk}}(\Delta R)}{p_{T,\text{jet}}}$$

Differential Jet Shapes

$$\rho(r) = \frac{1}{\delta r} \frac{1}{N_{\text{jets}}} \sum_{\text{jets}} \frac{\sum_{r^{\text{trk}} \in (r-\delta r/2, r+\delta r/2)} p_{T,\text{trk}}}{p_{T,\text{jet}}}$$



Data agree with PYTHIA6 Perugia tune; PYTHIA-8 Detroit needs further tuning



1. Probing fundamental QCD: theory vs reality

Energy-energy correlations and jet substructure

2. **What do hard probes tell us about QGP?**

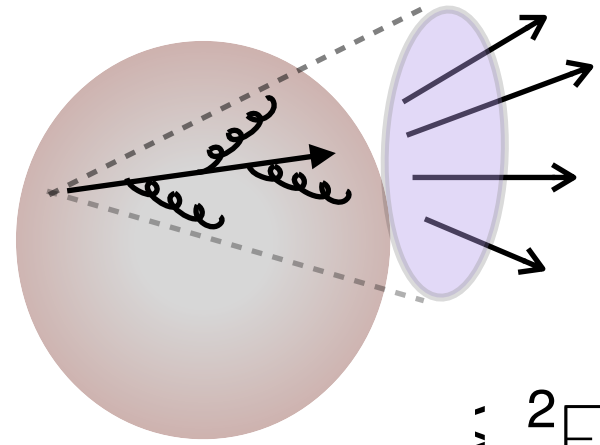
System size dependence of jet and heavy-flavor production and flow

Different manifestations of jet-medium interaction and their consequences

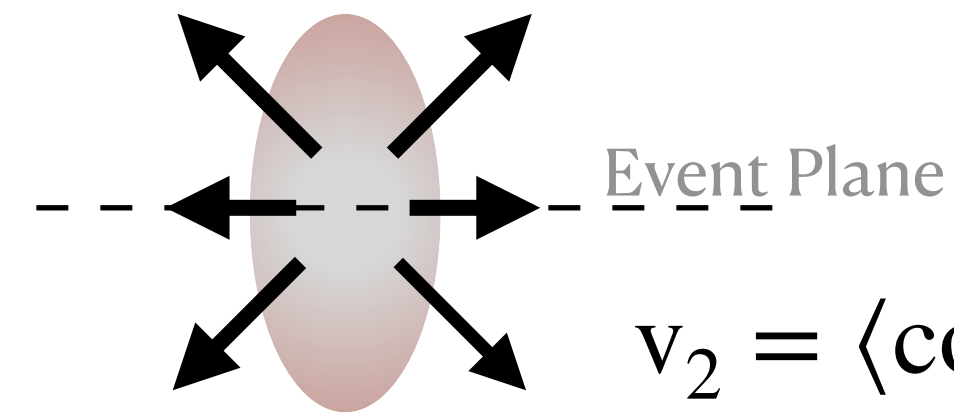


Isobar data: hadron R_{AA} and jet v_2

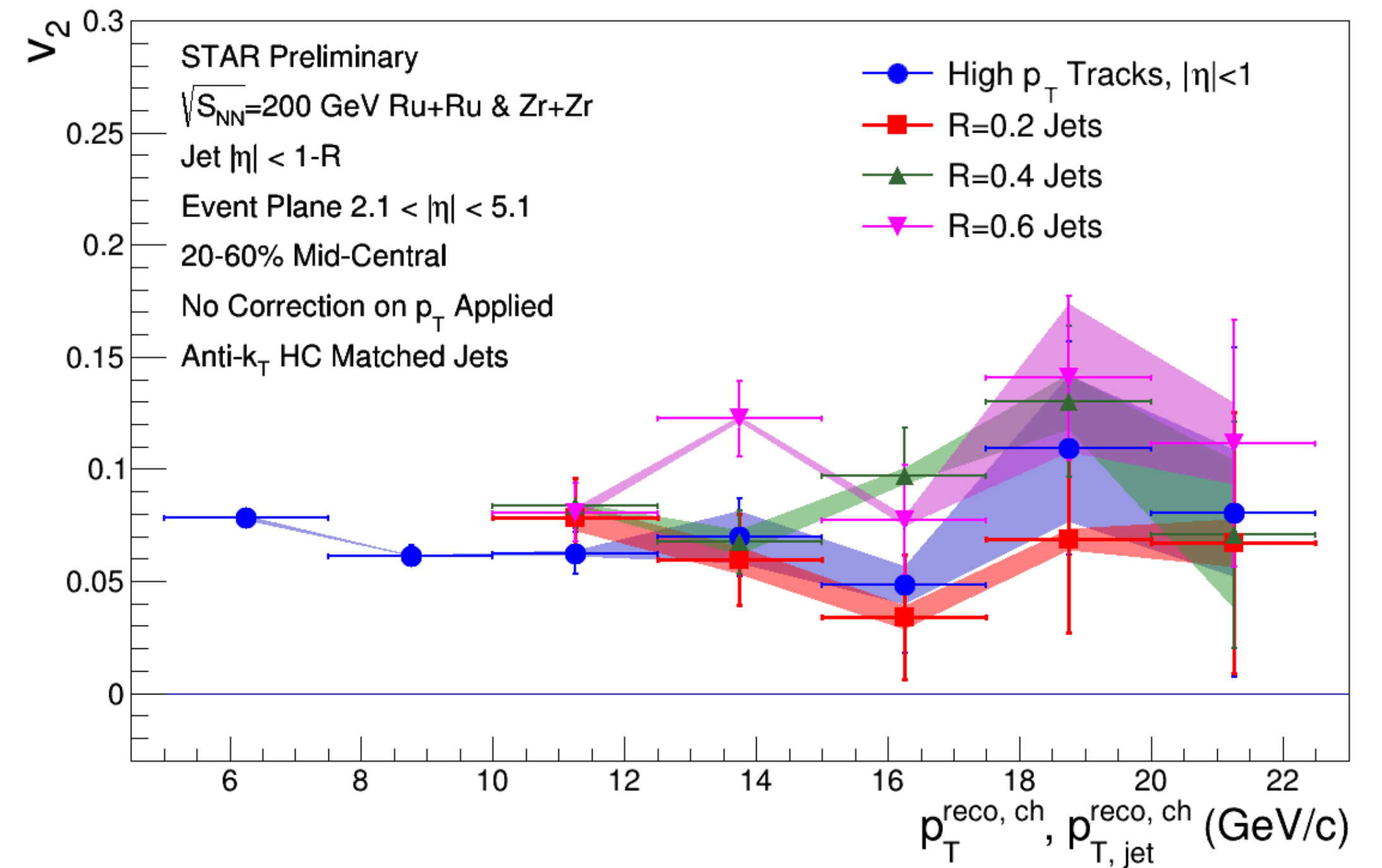
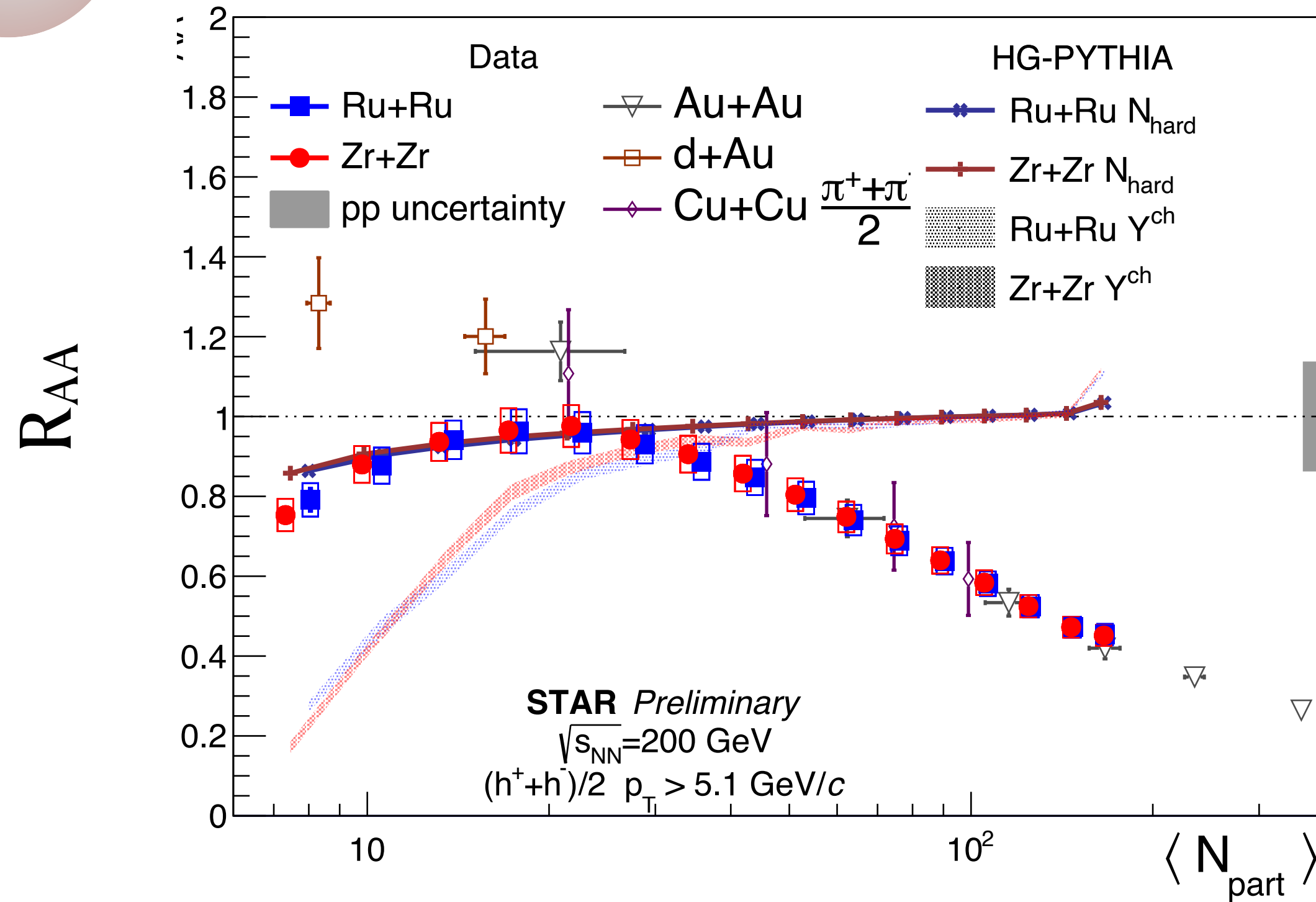
Talk: Tristan Protzman
29 Mar, 15.00
Poster: Isaac Mooney



Inclusive hadron suppression



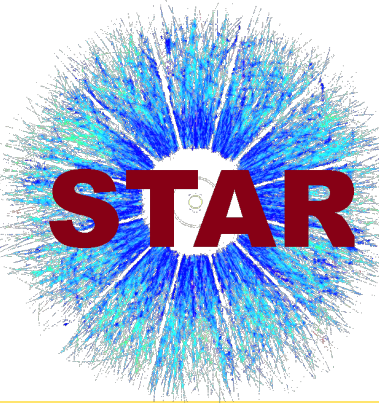
$$v_2 = \langle \cos(2(\phi - \psi_2)) \rangle$$



Similar R_{AA} suppression at comparable $\langle N_{part} \rangle$
→ Energy density rather than initial geometry dominates average jet energy loss

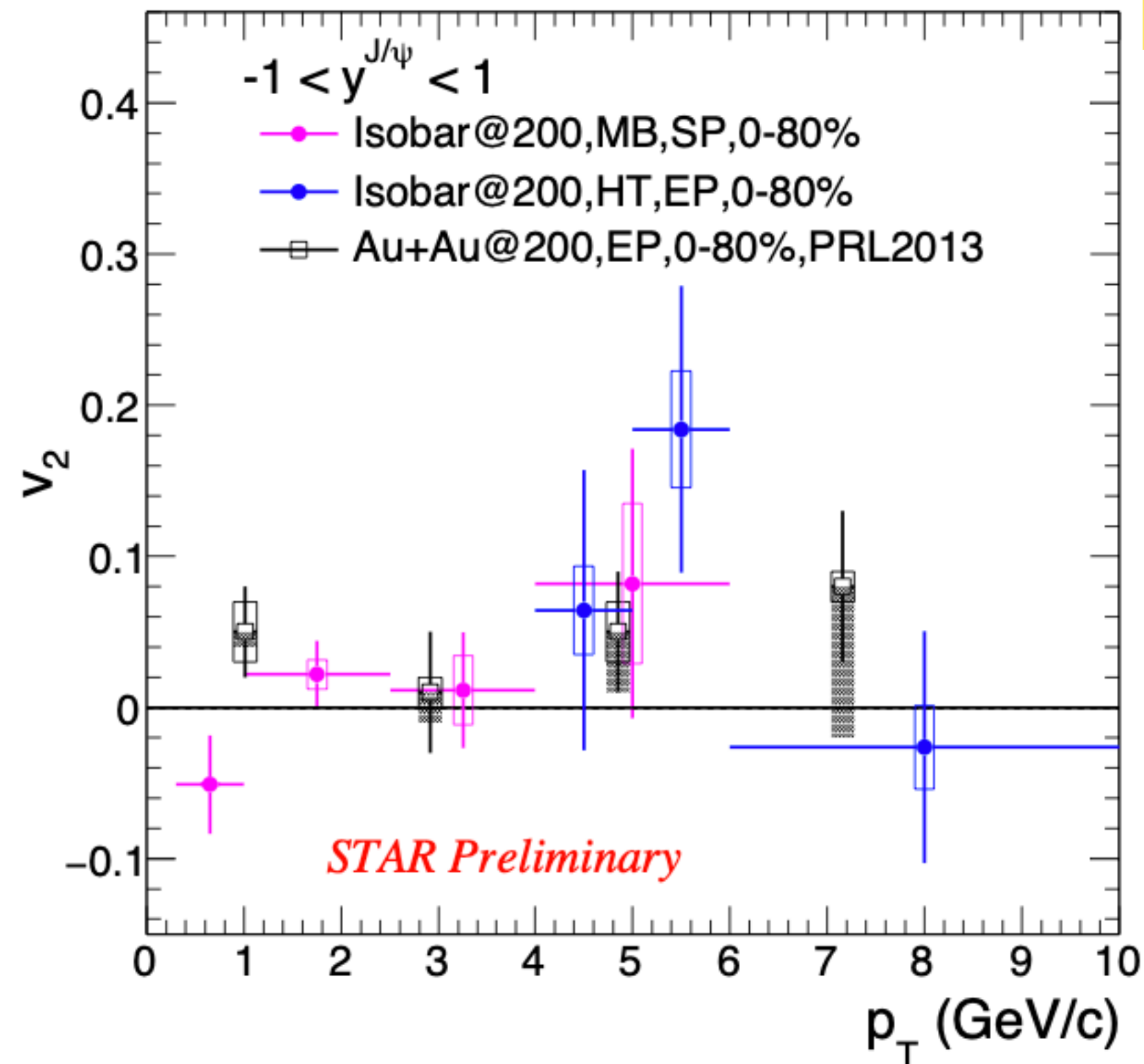
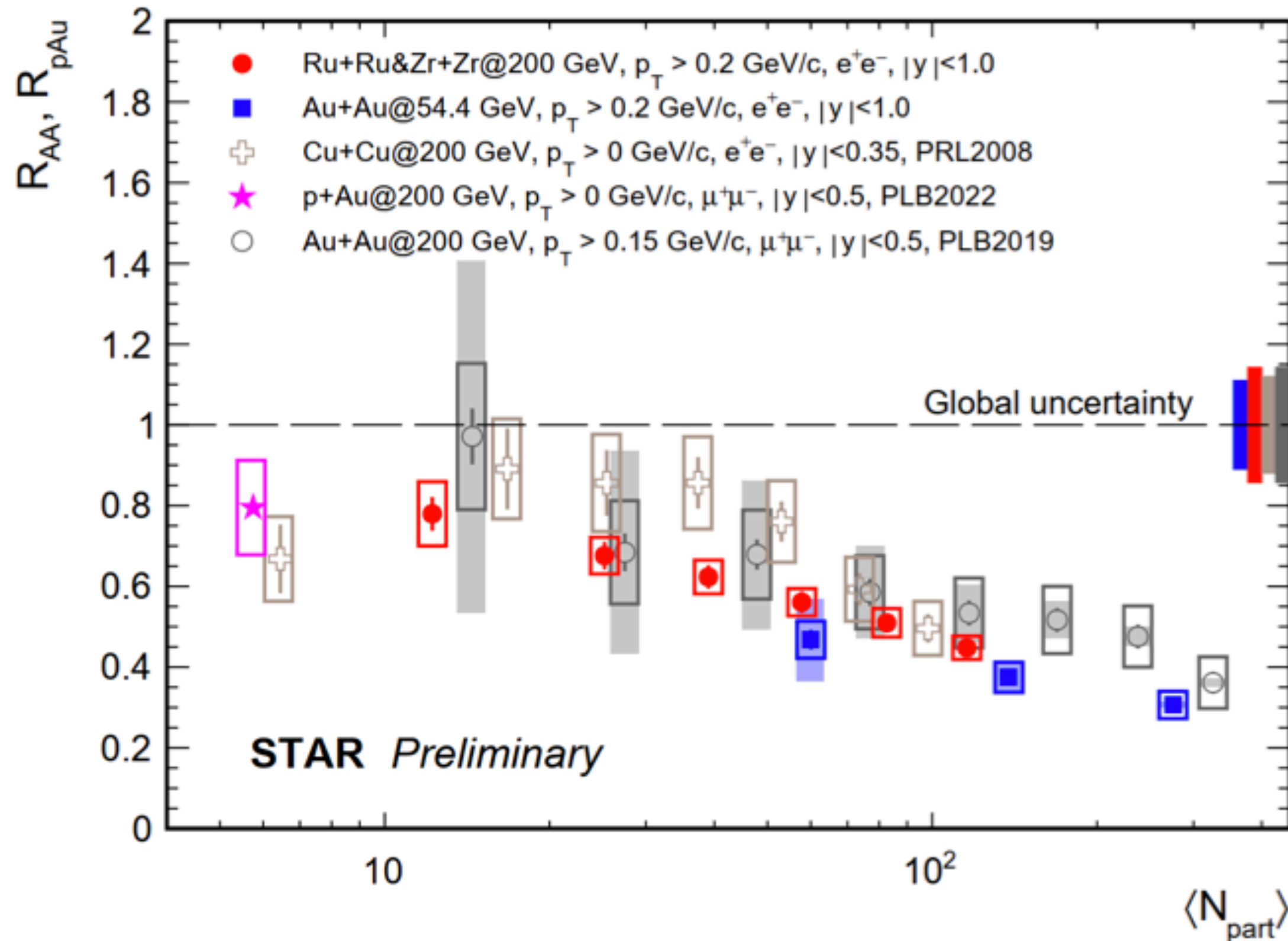
High- p_T jet shows non-zero v_2 ;
no jet R dependence

Isobar data: J/ψ R_{AA} and v_2



Yan Wang
30 Mar, 10.00

Highest precision J/ψ measurement at RHIC energies to date



No significant collision system and energy dependence at similar $\langle N_{part} \rangle$;
But strong suppression as in Au+Au

No significant J/ψ v_2 is observed

Indication of small regeneration effect and/or small charm quark flow in Isobar?

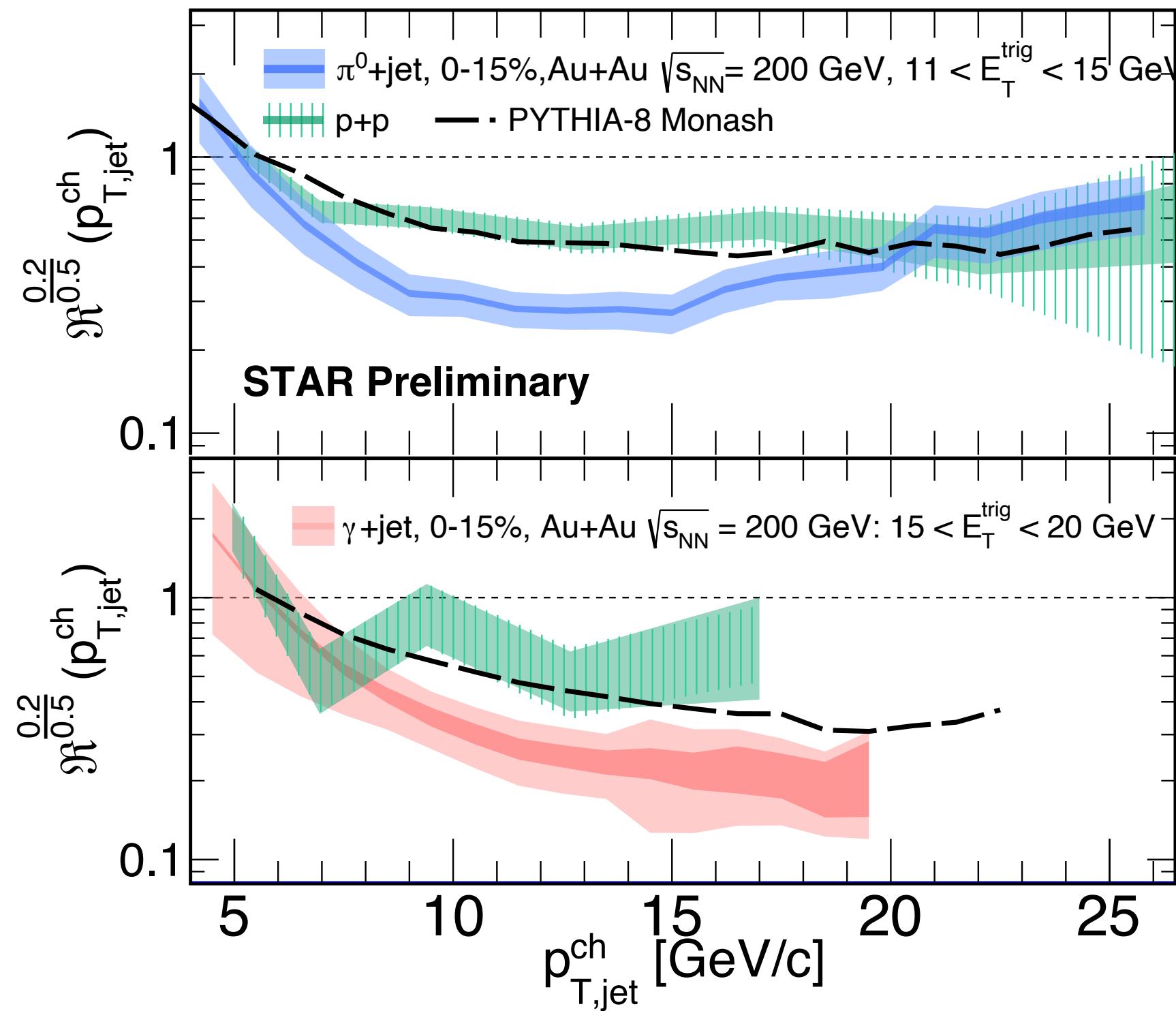
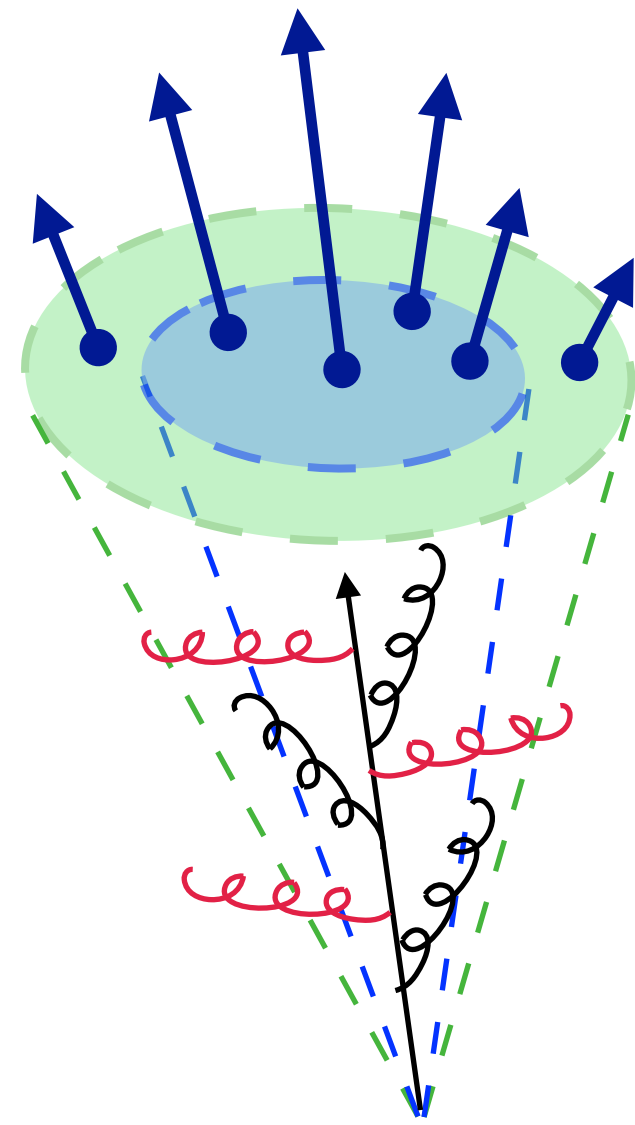
Au+Au data: probing the jet-medium interaction



$$\mathcal{R}_{\text{large-R}}^{\text{small-R}} = \frac{Y(p_{T,\text{jet}}^{\text{ch}})^{\text{small-R}}}{Y(p_{T,\text{jet}}^{\text{ch}})^{\text{large-R}}}$$

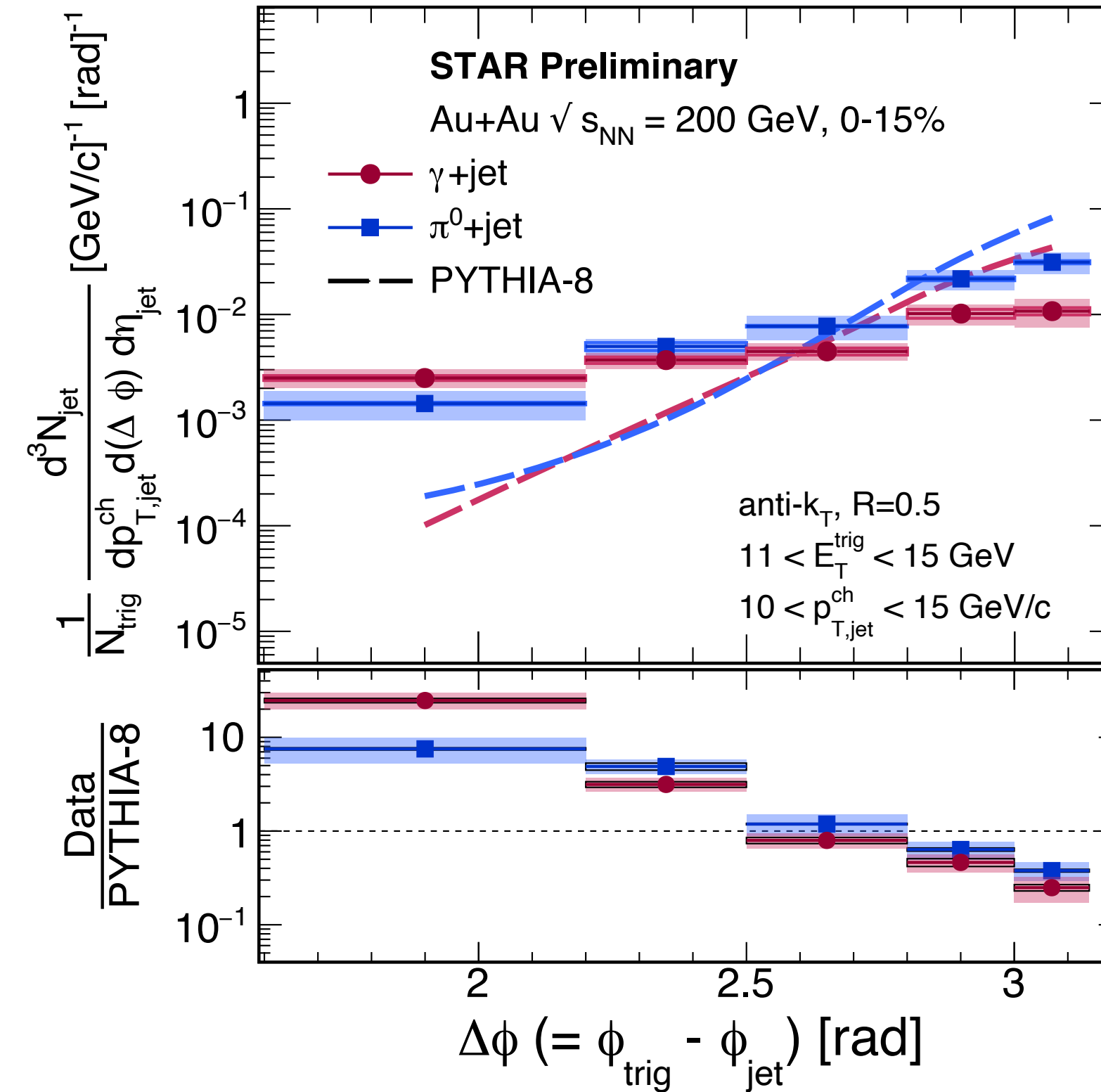
Semi-inclusive γ +jet and π^0 +jet measurement

Yang He
30 Mar, 9:40



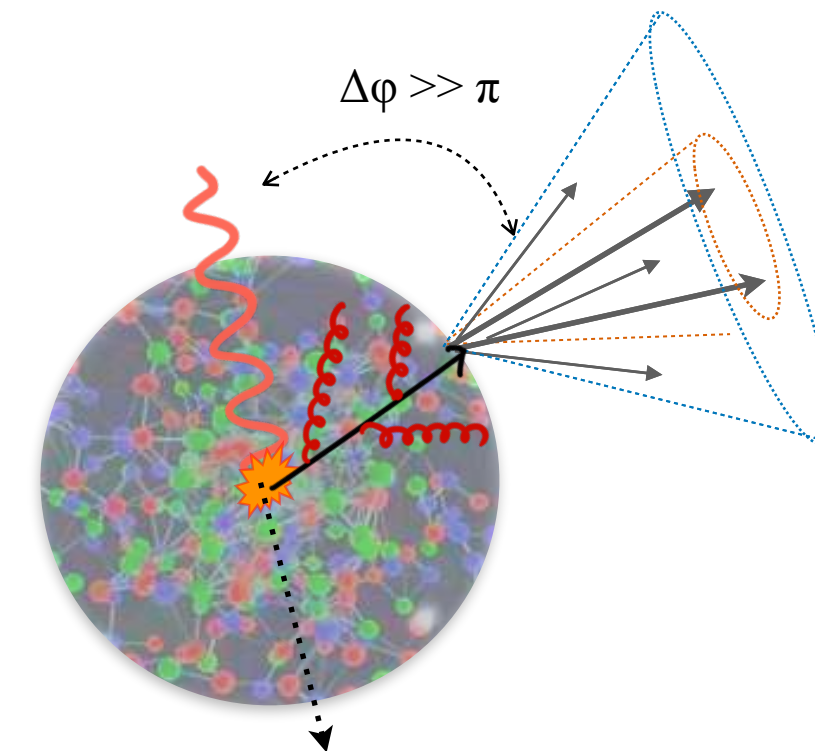
In-medium intra-jet broadening

→ Disentangle vacuum shower
and in-medium radiation

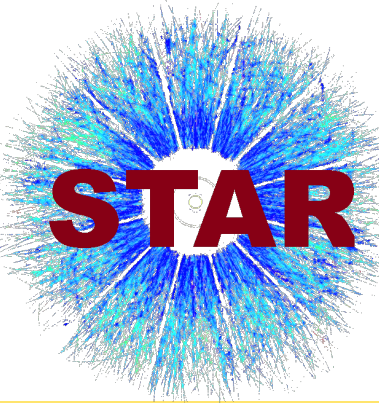


Large off-axis jet yield (acoplanarity) in Au+Au

→ In-medium jet scattering?
→ Medium response?

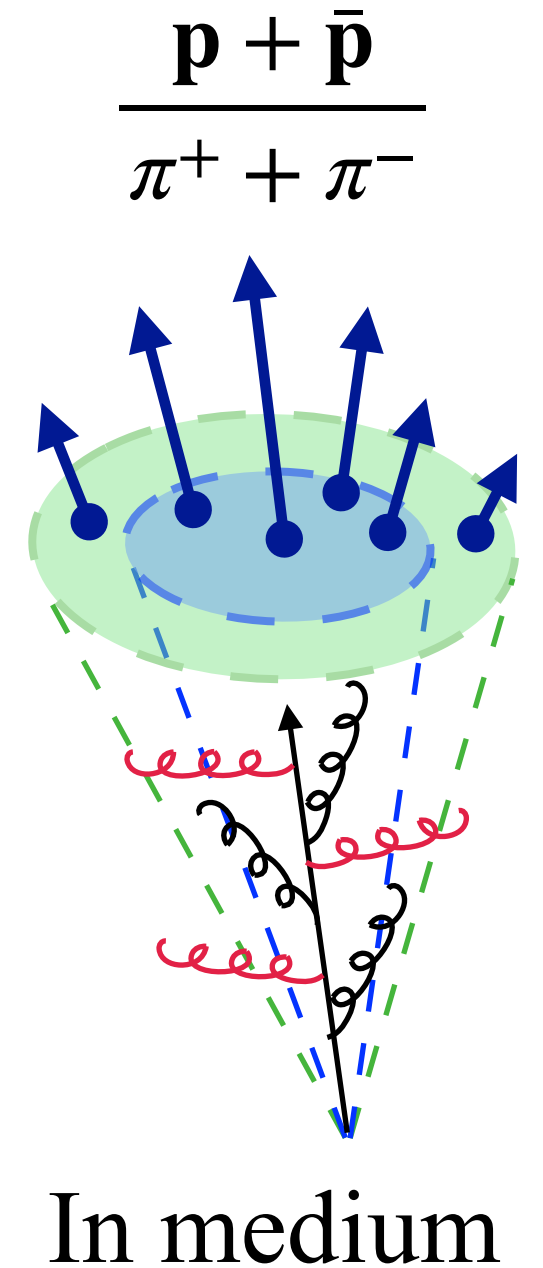
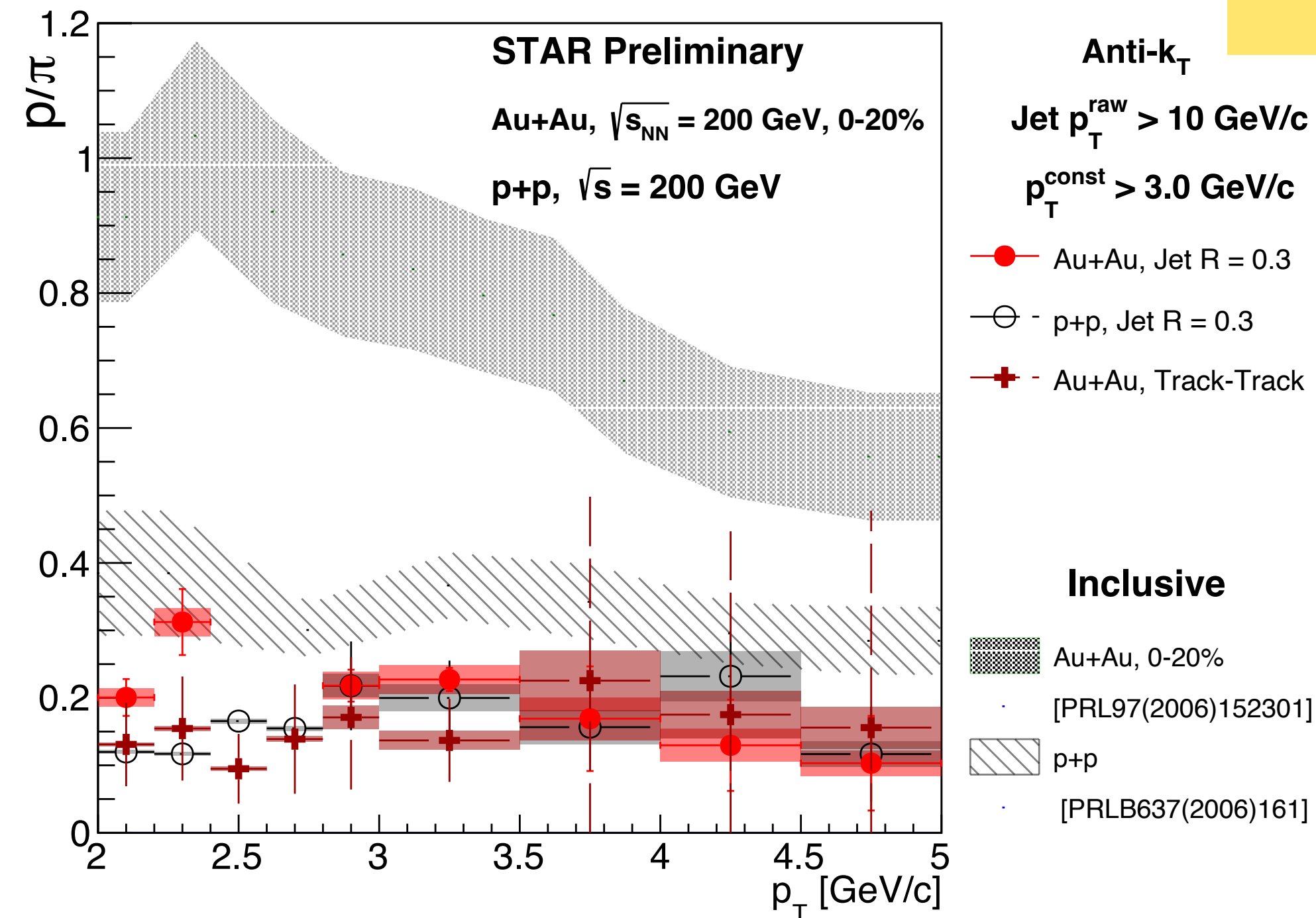
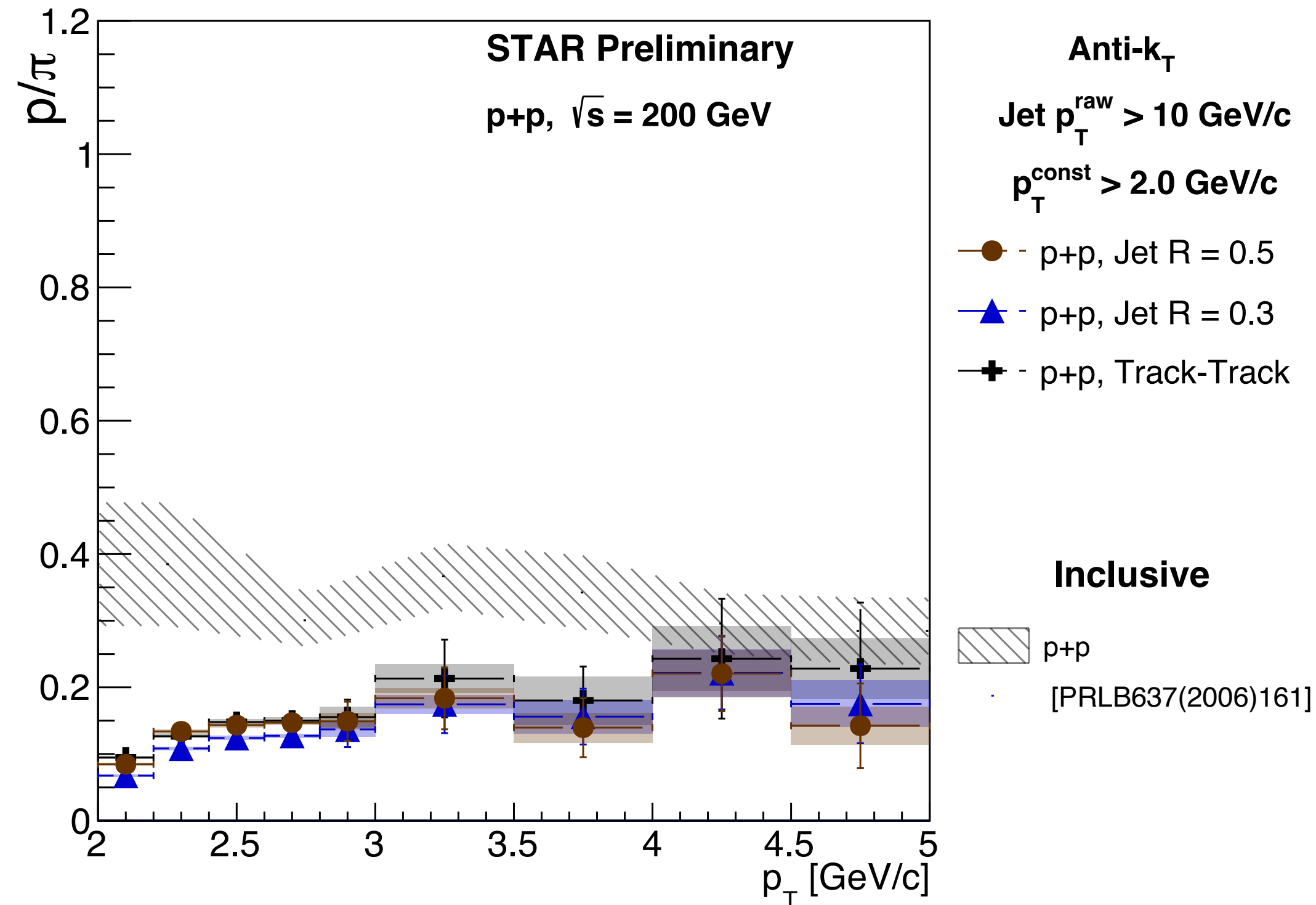


Au+Au data: Jet chemistry in the QGP



First baryon-to-meson ratio measurement inside a jet at RHIC

Gabriel Dale-Gau
28 Mar, 15.40



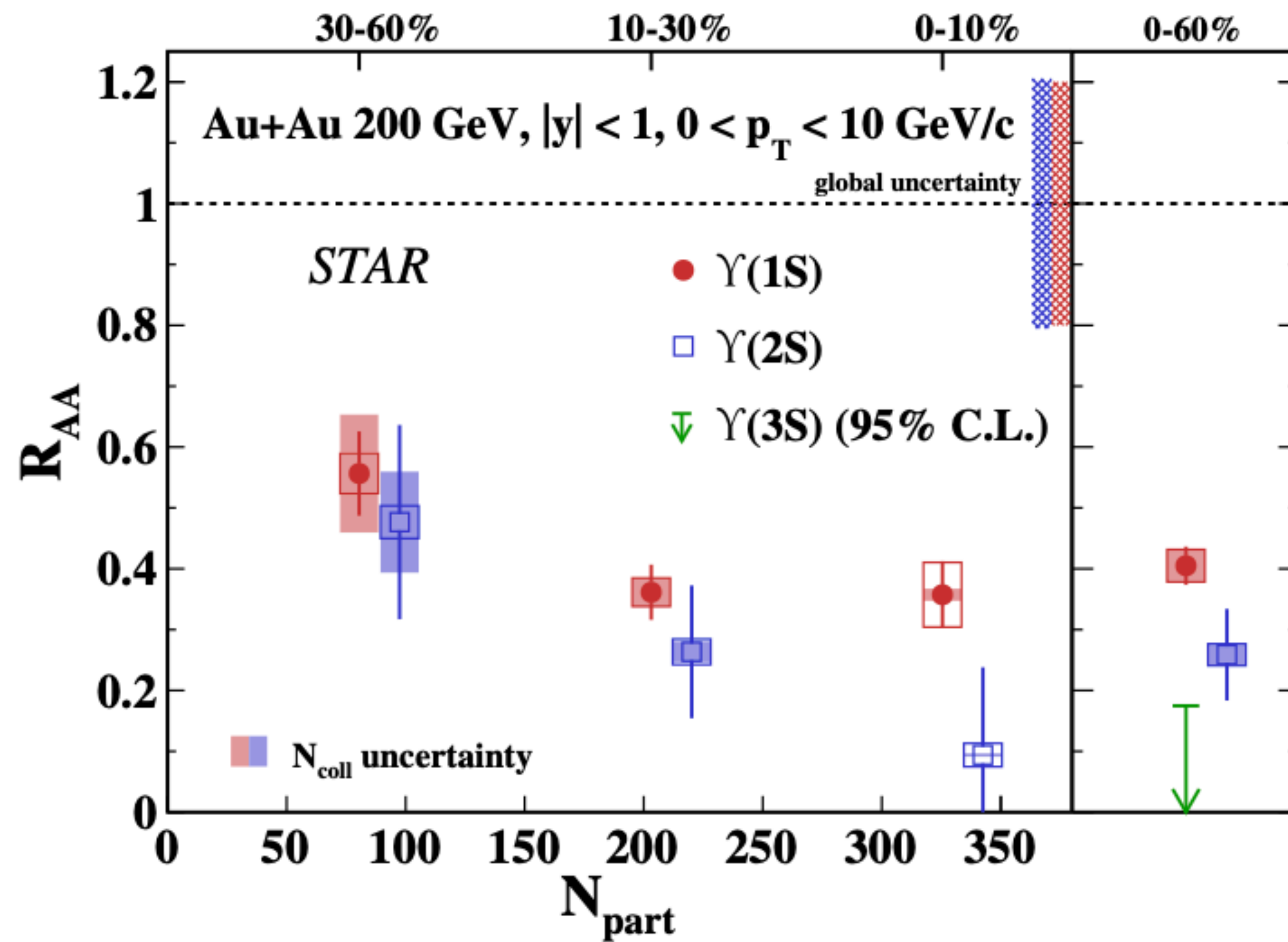
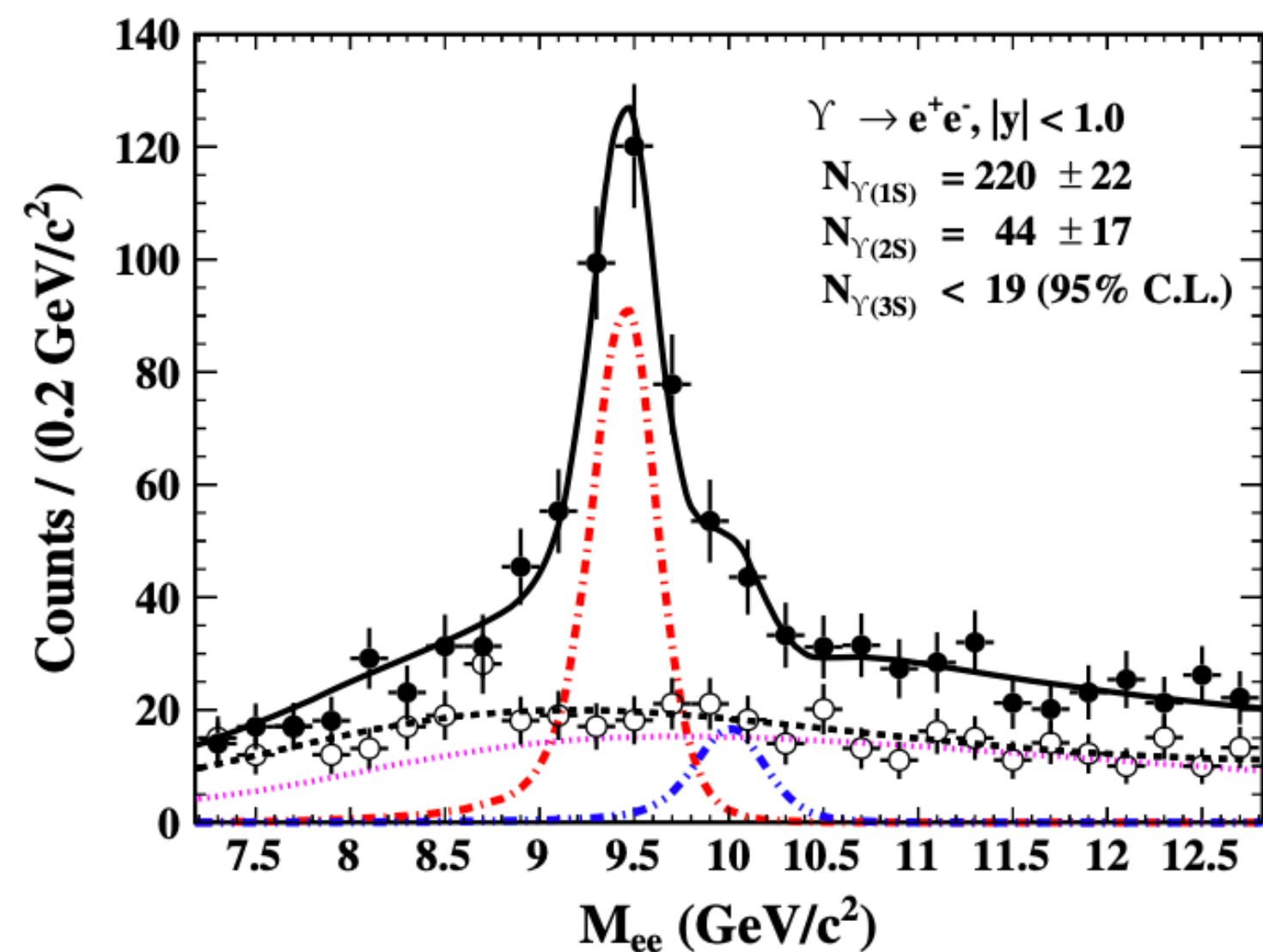
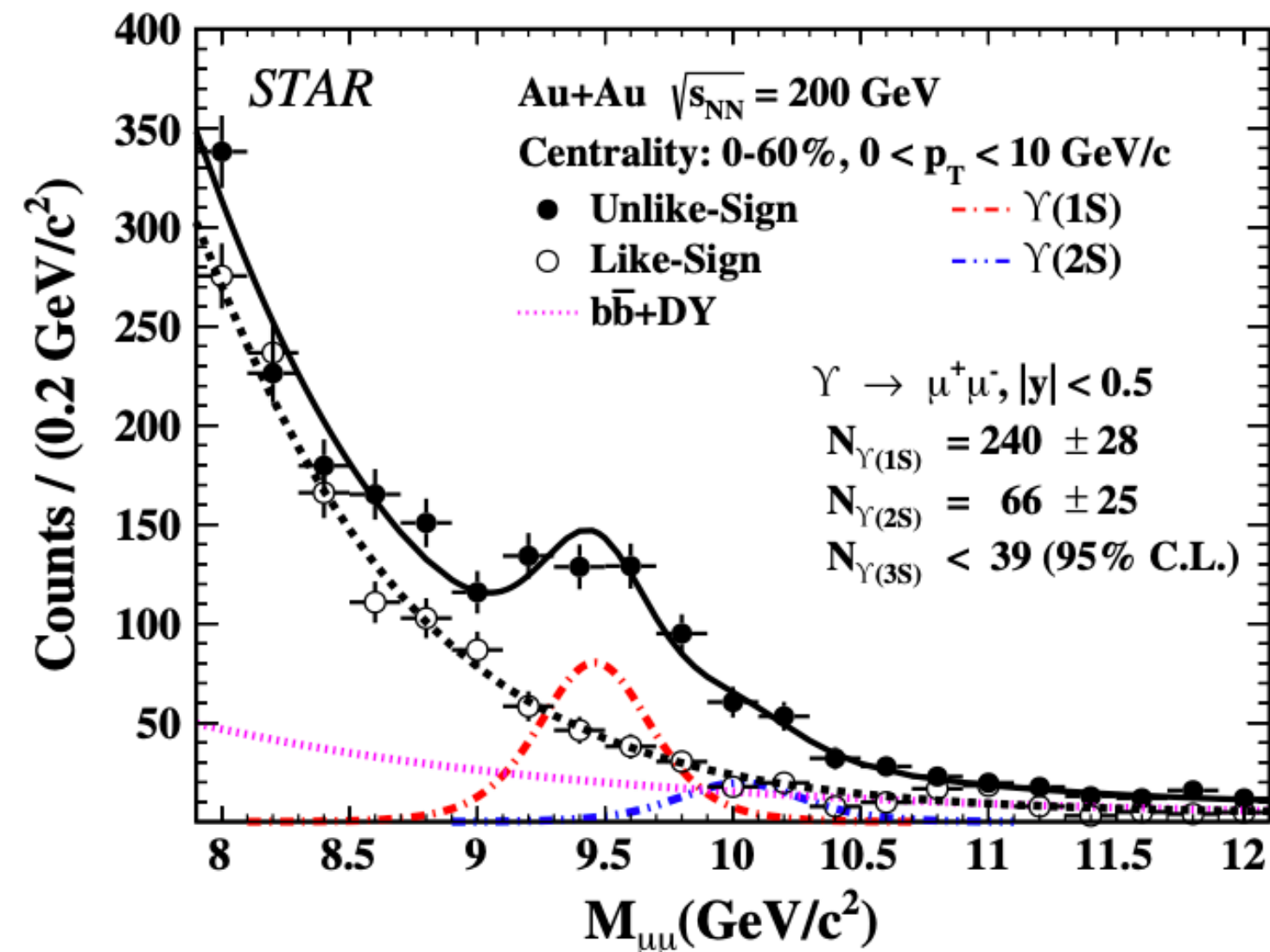
- Strong preference of π over proton production in jets
- Similar p/π ratio in Au+Au and p+p with hard core jet selection with constituent $p_T > 3.0$ GeV/c

Can jet-medium interaction modify jet chemistry?

→ look at p/π ratio at lower p_T (stay tuned)

QGP temperature: sequential Υ suppression

STAR: PRL 130, 112301 (2023)



$\Upsilon(2S)$ and $\Upsilon(3S)$ significantly more suppressed than $\Upsilon(1S)$

Sufficient QGP temperature to melt excited Υ states
at top RHIC energies

What have we learned?

From QCD in vacuum to hot-dense QCD medium

In vacuum (p+p collisions)

Vacuum parton shower sensitive to initial soft-wide angle radiation and a universal scale for parton-hadron transition

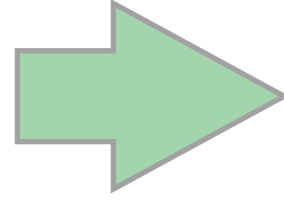
In smaller collision system (isobar collisions)

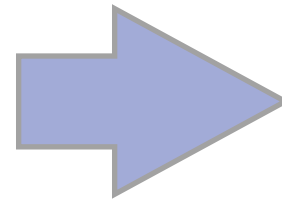
Same level of jet and J/ψ suppression as seen in Au+Au collisions at similar $\langle N_{part} \rangle$; Non-zero jet anisotropy (v_2); but zero J/ψ v_2 in isobar collisions

In larger collision system (Au+Au collisions)

Probe different manifestation of jet-medium interaction (intra-jet broadening, jet suppression, and acoplanarity)

Big picture

 Interplay between perturbative and non-perturbative QCD

 Are parton energy loss and flow sensitive to initial energy density or collision geometry?

 Probing the microstructure and dynamics of QGP

STAR continues to explore on these questions in Run23+25...



STAR's next data taking plan and its physics program

STAR detector with recent upgrades



iTPC

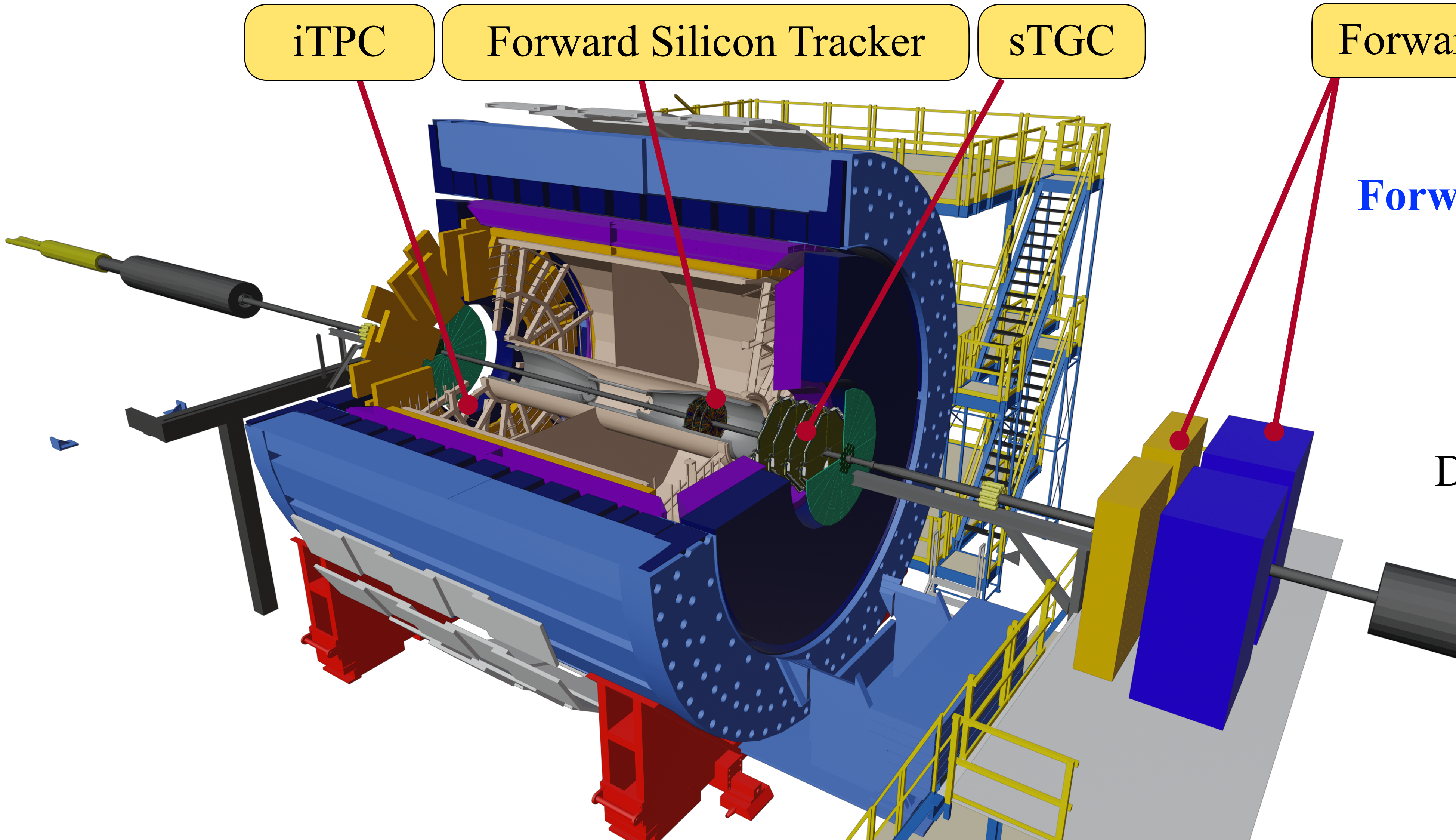
Forward Silicon Tracker

sTGC

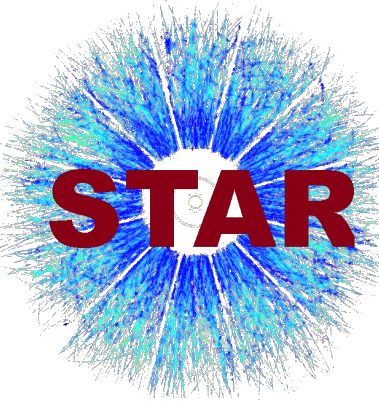
Forward EMCal and HCal

Forward detector upgrade

DAQ rate: 5000 Hz

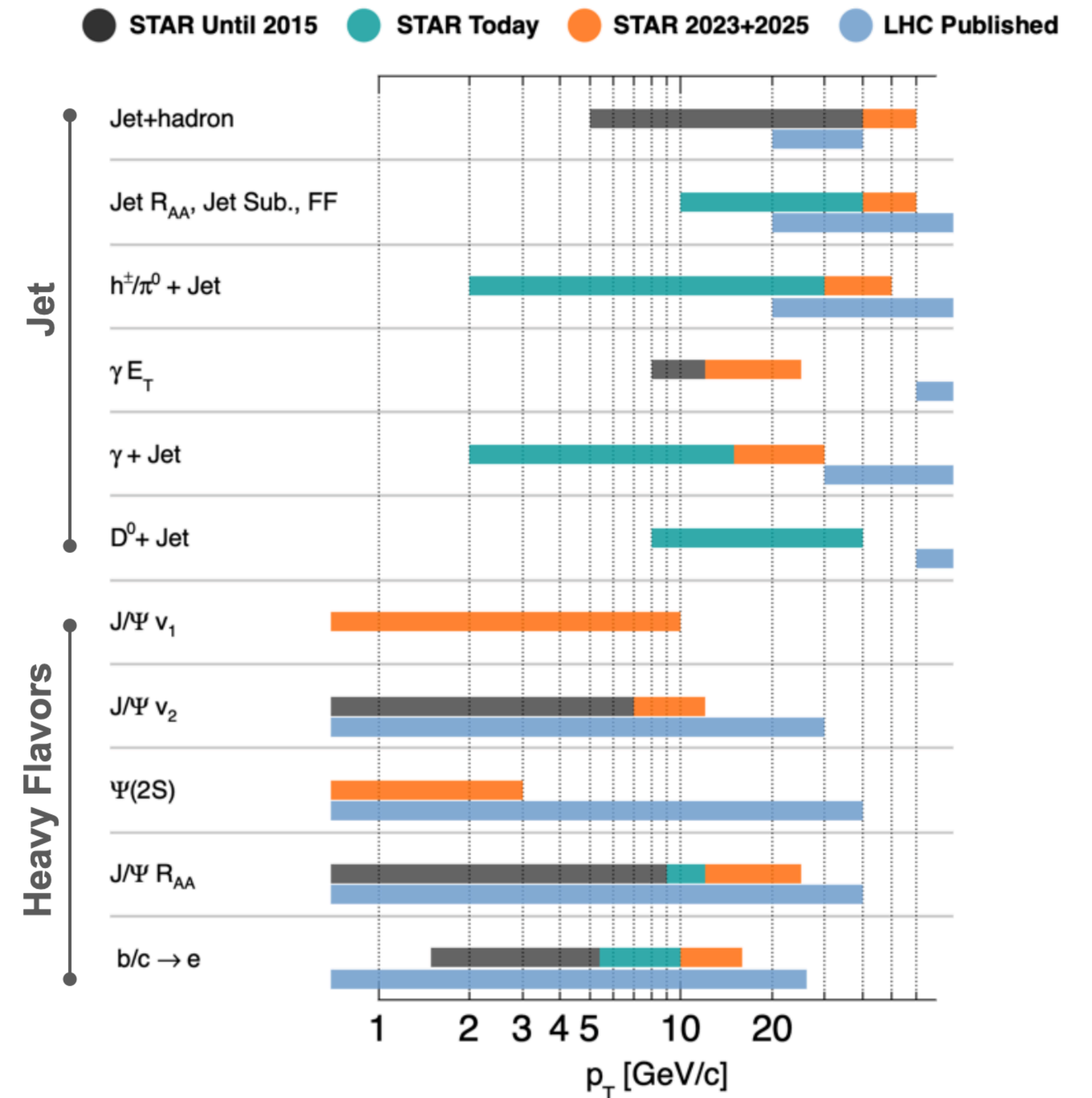


STAR hard probes physics program



$\sqrt{s_{NN}}$ (GeV)	Species	Number Events/ Sampled Luminosity	Year
200	Au+Au	20B / 40 nb ⁻¹	2023+2025
200	<i>p+p</i>	235 pb ⁻¹	2024
200	<i>p+Au</i>	1.3 pb ⁻¹	2024

Study the microstructure of the QGP
Precision jet and heavy-flavor measurements



STAR BUR-2022:

[https://indico.bnl.gov/event/15148/attachments/40846/68609/STAR_BUR_Runs23_25___2022\(1\).pdf](https://indico.bnl.gov/event/15148/attachments/40846/68609/STAR_BUR_Runs23_25___2022(1).pdf)



Oral presentations:

1. **Tanmay Pani:** *Jet shape observables in p+p and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR [28 Mar, 11.10]*
2. **Monika Robotkova:** *Systematic exploration of multi-scale jet substructure in p+p collisions at $\sqrt{s_{NN}} = 200$ GeV by the STAR experiment [30 Mar, 9.00]*
3. **Gabriel Dale-Gau:** *Measurements of Baryon-to-Meson Ratios in Jets in Au+Au and p+p Collisions at $\sqrt{s_{NN}} = 200$ GeV by STAR [28 Mar, 15.40]*
4. **Yang He:** *Measurements of semi-inclusive γ +jet and hadron+jet distributions in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV with STAR [30 Mar, 9:40]*
5. **Tristan Protzman:** *Medium effects on Hadrons and Jets in $\sqrt{s_{NN}} = 200$ GeV Isobar collisions at STAR [29 Mar, 15.00]*
6. **Yan Wang:** *J/ ψ production in Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}} = 200$ GeV with the STAR experiment [30 Mar, 10.00]*
7. **Andrew Tamis:** *Measurement of two-point energy Correlators within jets in p+p collisions at $\sqrt{s} = 200$ GeV [29 Mar, 15.00]*

Poster presentations:

1. **Priyanka Roy Chowdhury:** *Femtoscopic correlations of D^0 mesons with identified hadrons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR*
2. **Brennan Schaefer:** *Measurement of the event multiplicity dependence of J/ ψ production in p+p collisions at $\sqrt{s} = 500$ GeV with STAR at RHIC*
3. **Isaac Mooney:** *Nuclear modification of charged hadrons and jets in isobar collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR*

Thank you!