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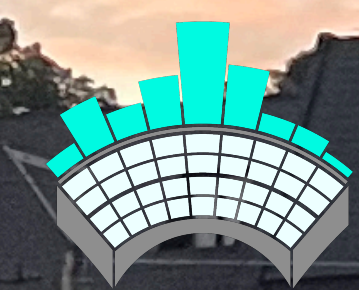
Brookhaven National Laboratory



Wright Laboratory

Yale

STAR Collaboration Overview



HP2024
NAGASAKI

Hard Probes 2024
長崎, 日本国

Isaac Mooney (Yale University, BNL) for the STAR Collaboration isaac.mooney@yale.edu

Solenoidal Tracker at RHIC (STAR)

Main subdetectors

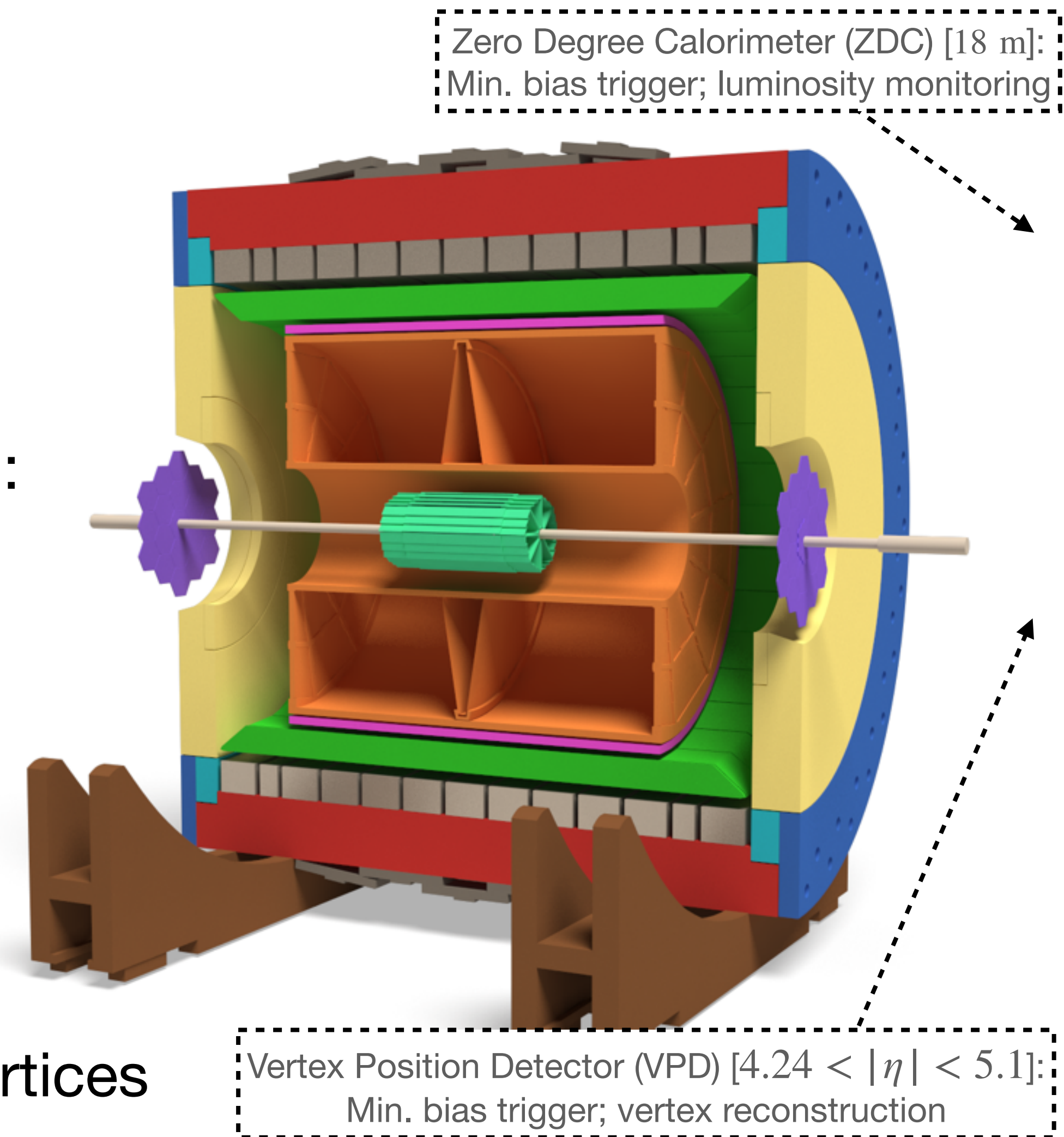
Relativistic Heavy Ion Collider (RHIC)
 collides $p+p$, isobars ($Zr+Zr$, $Ru+Ru$), $Au+Au$, etc.
 beams from $\sqrt{s_{NN}} = 3$ to 510 GeV

Time Projection Chamber (**TPC**) [$|\eta| < 1 \rightarrow 1.5$ w/ iTPC]:
 momenta of charged tracks + centrality

Barrel Electromagnetic Calorimeter (**BEMC**) [$|\eta| < 1$]:
 neutral energy deposits + online trigger

Time of Flight (**TOF**) [$|\eta| < 0.9$]: PID + pileup mitigation

Heavy flavor tracker (**HFT**) [$|\eta| < 1$]: displaced decay vertices



STAR contributions to HP'24

10 talks, 5 posters!

Scientific Program

1. Jet modification and medium response

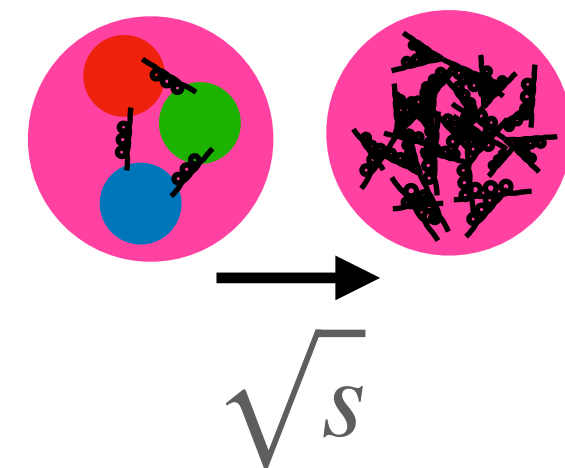
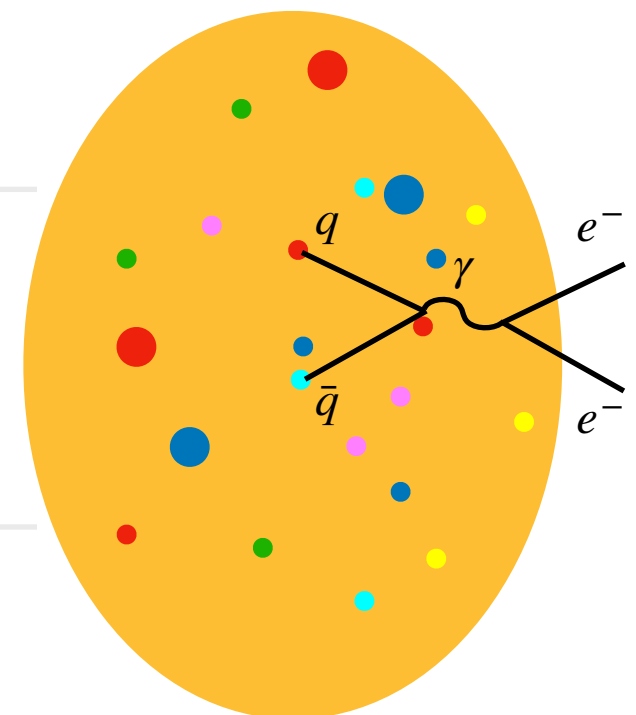
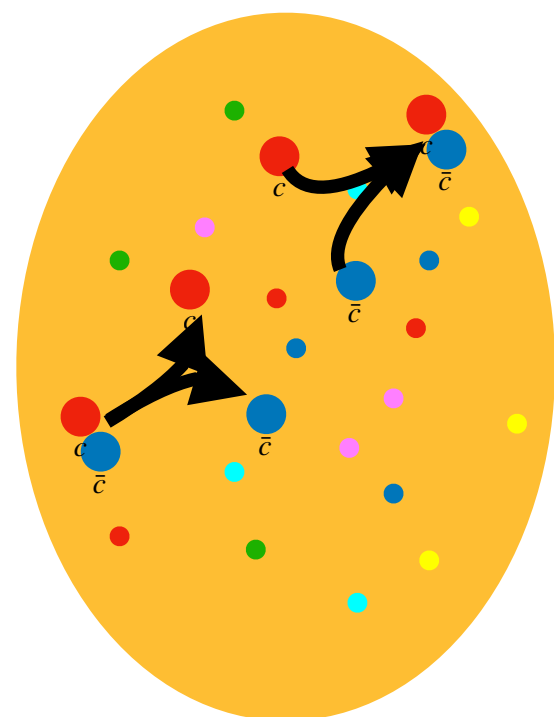
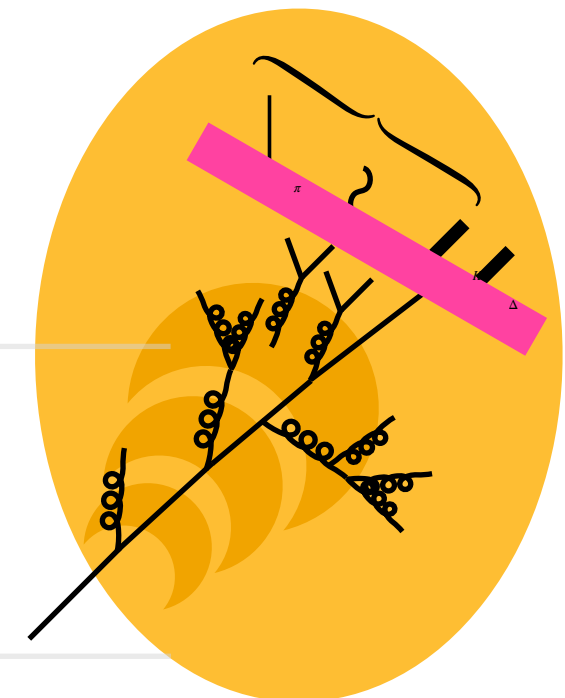
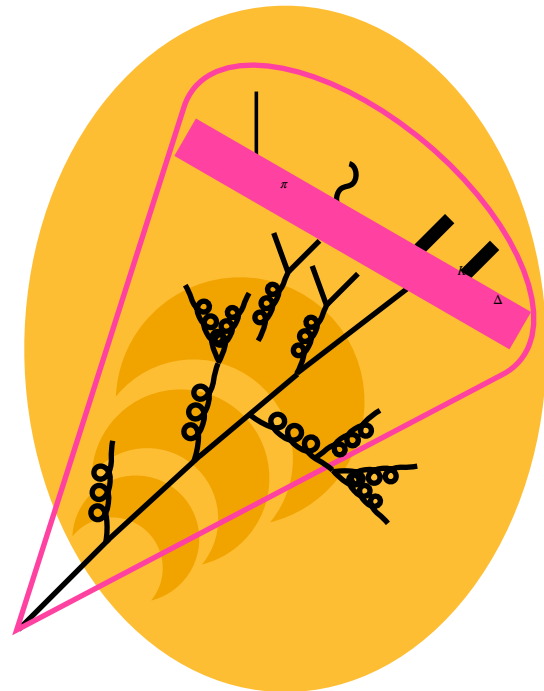
2. High momentum hadrons and correlations

3. Heavy quarks and quarkonia

4. Electromagnetic and electroweak probes

5. Nuclear PDFs, saturation, and early time dynamics

6. Future experimental facilities and new techniques



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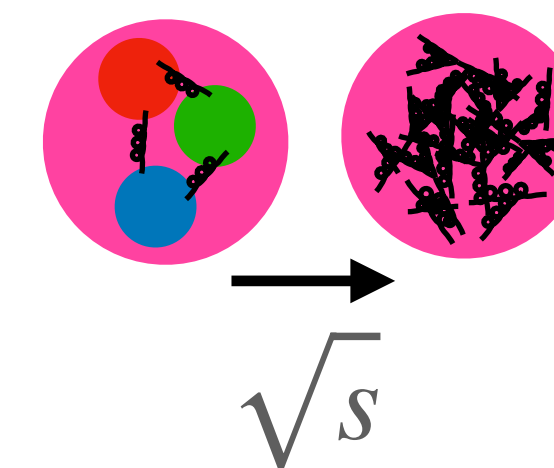
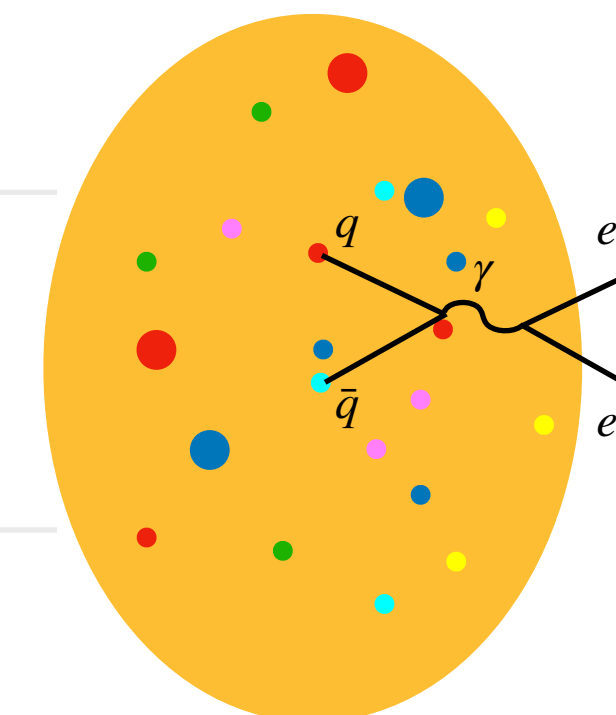
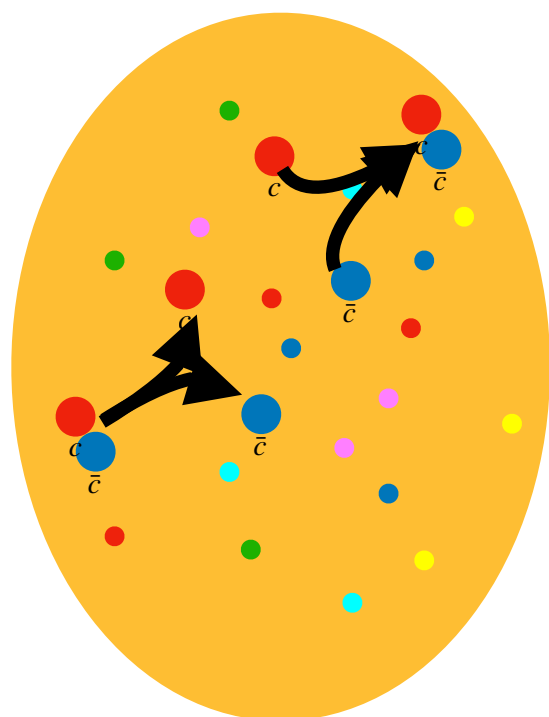
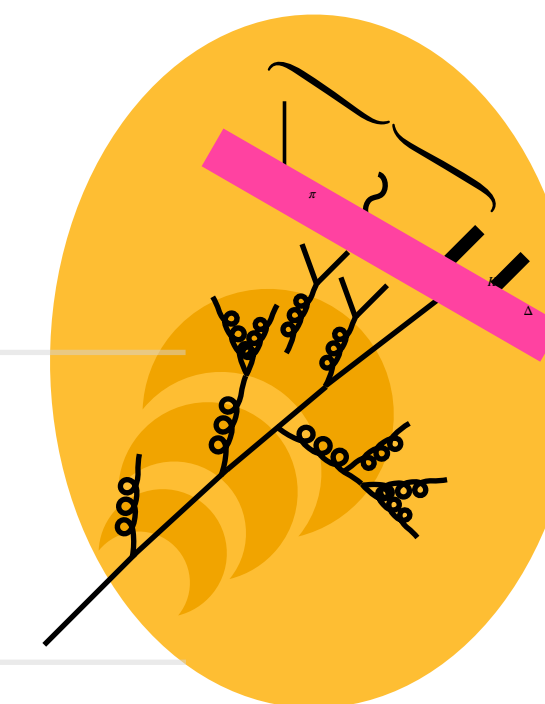
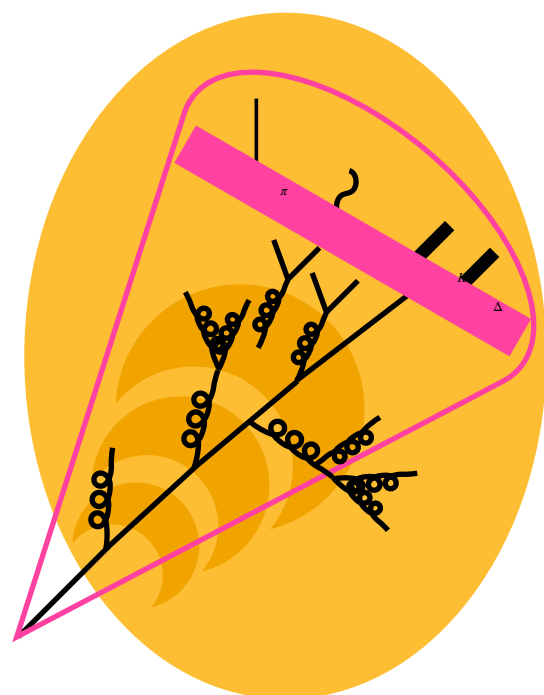
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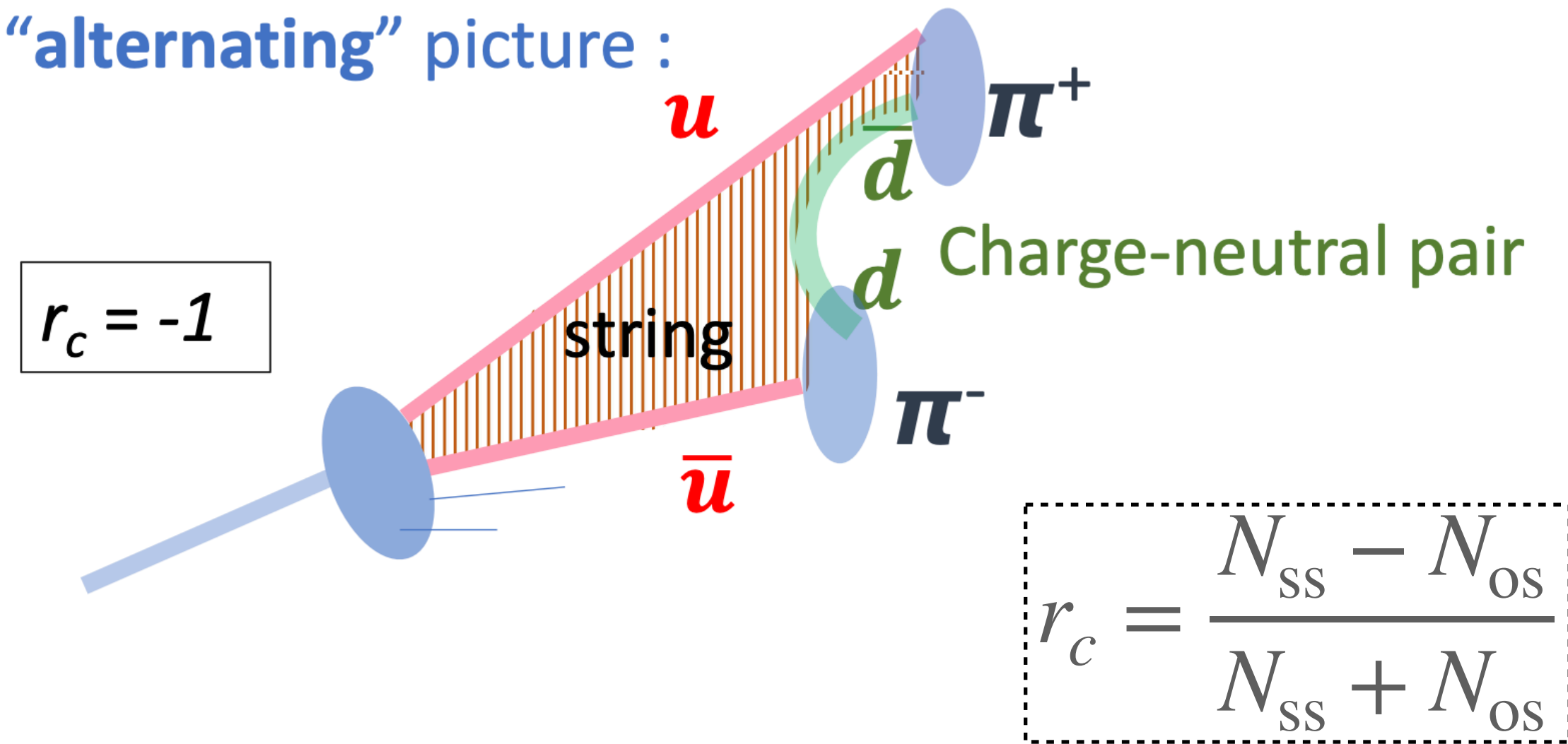
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Assessing fragmentation mechanism in jets

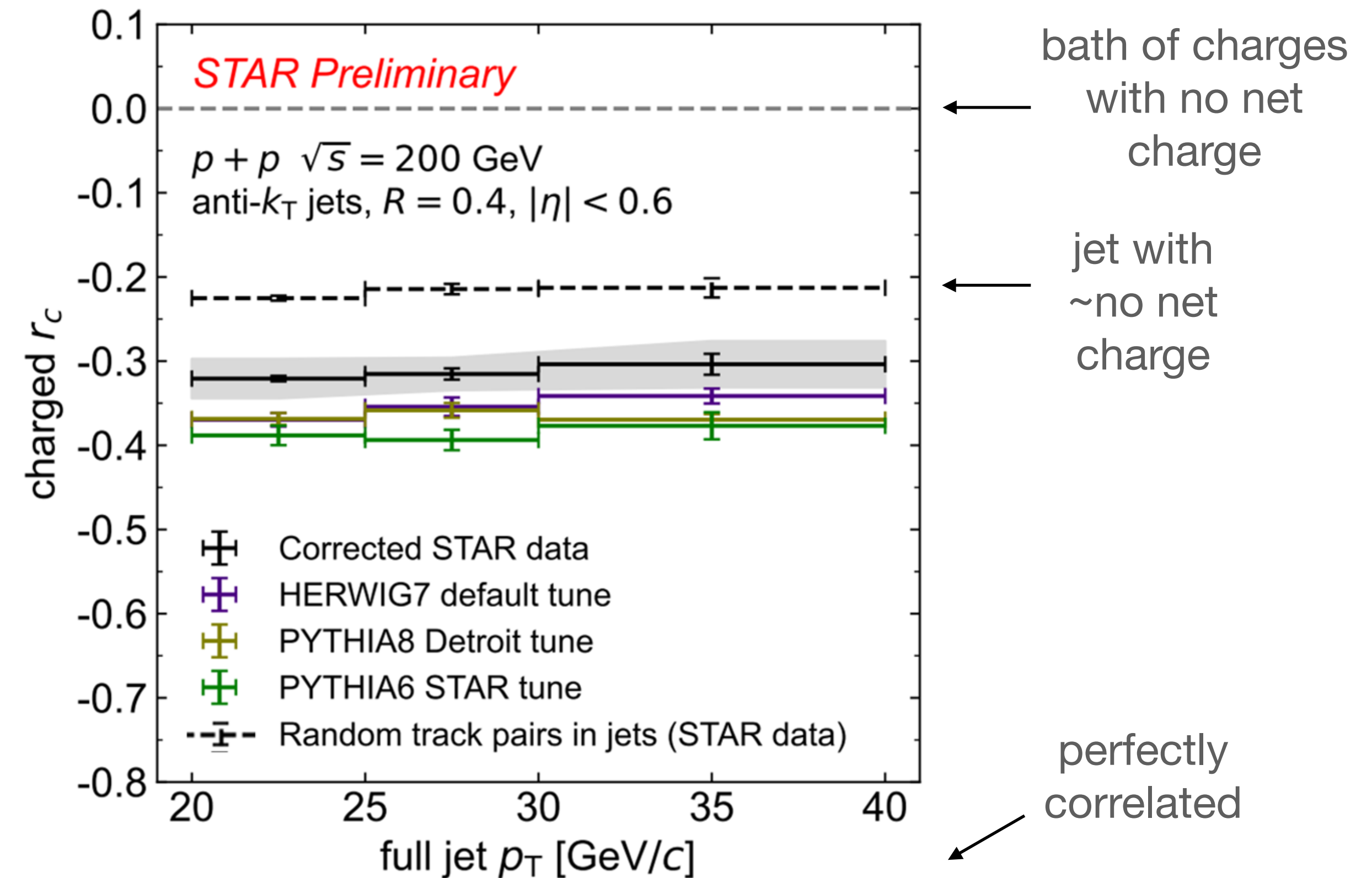
“alternating” picture :



Leading charge correlator, r_c , can probe contribution of string-like fragmentation

First pp measurement: MCs predict more charge correlation than supported by data

Outlook: extension to heavy-ion collisions ongoing



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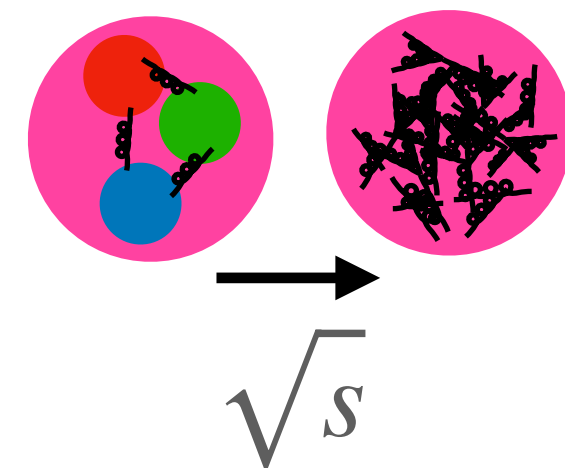
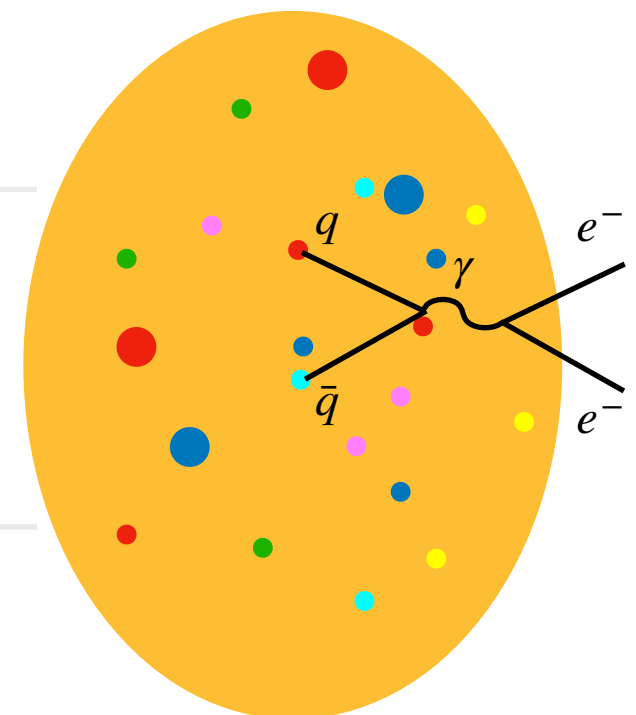
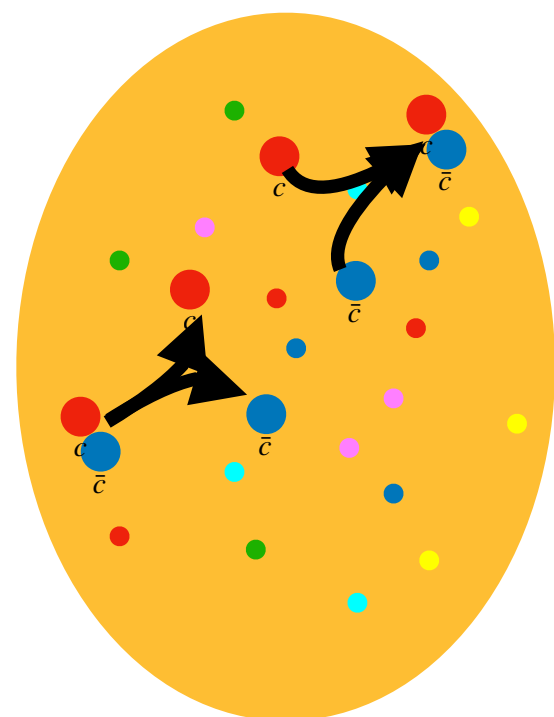
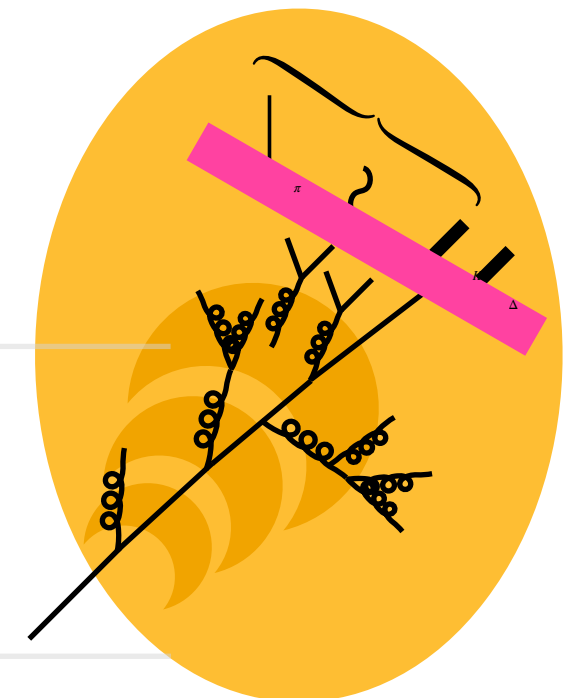
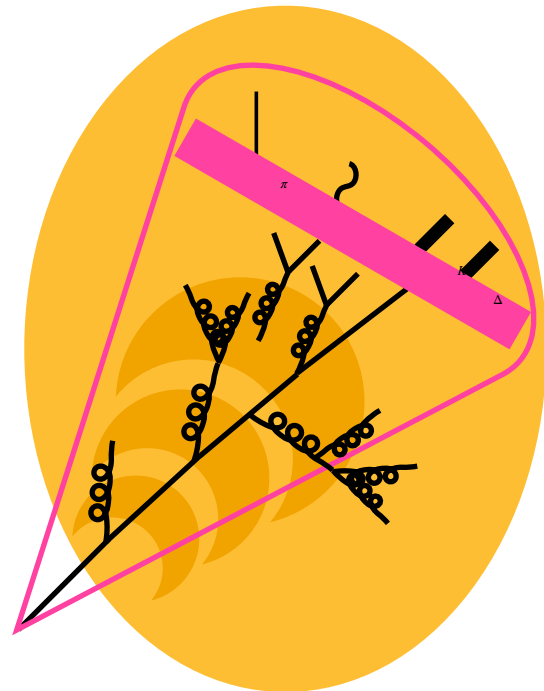
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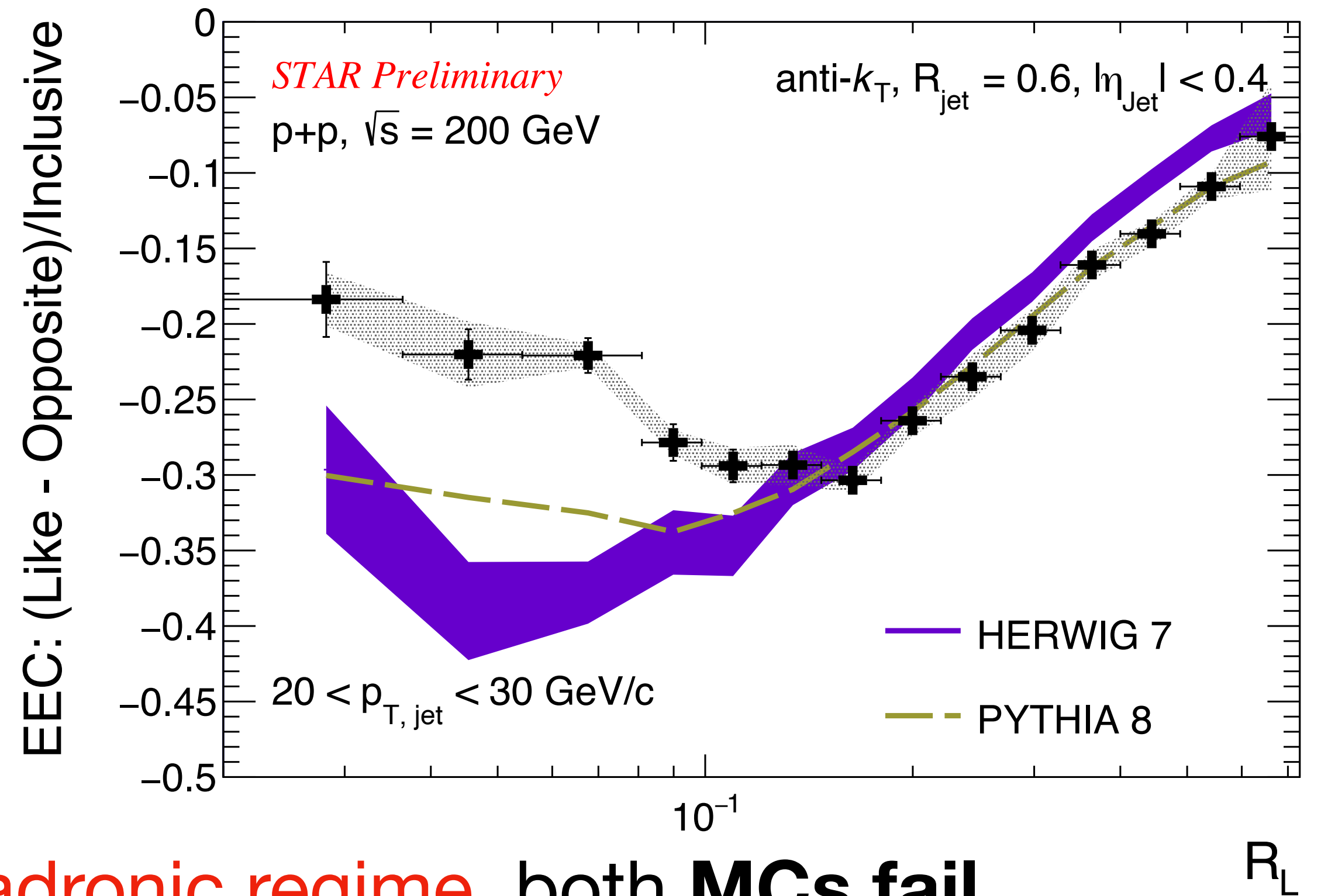
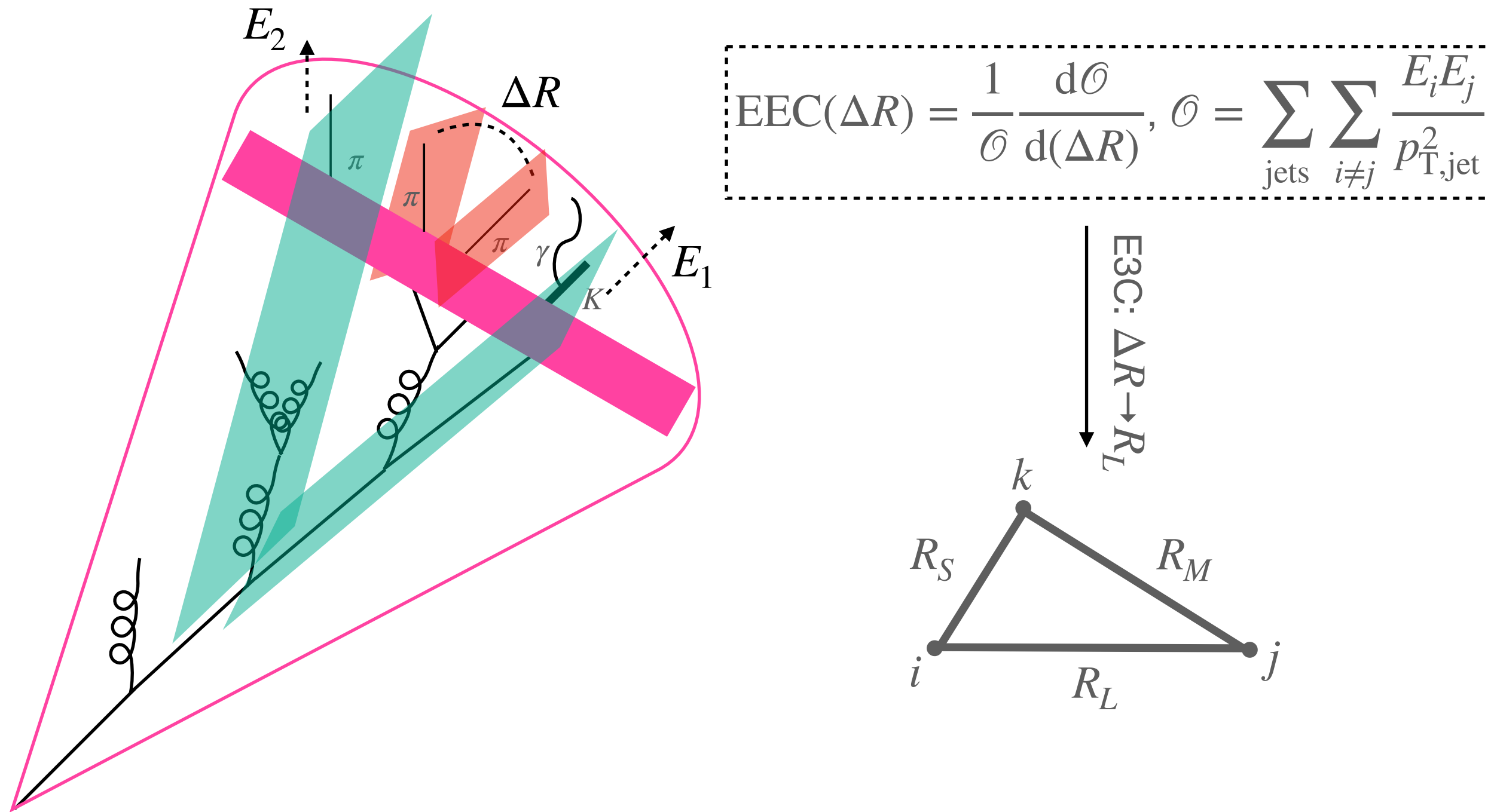
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Assessing fragmentation mechanism in jets



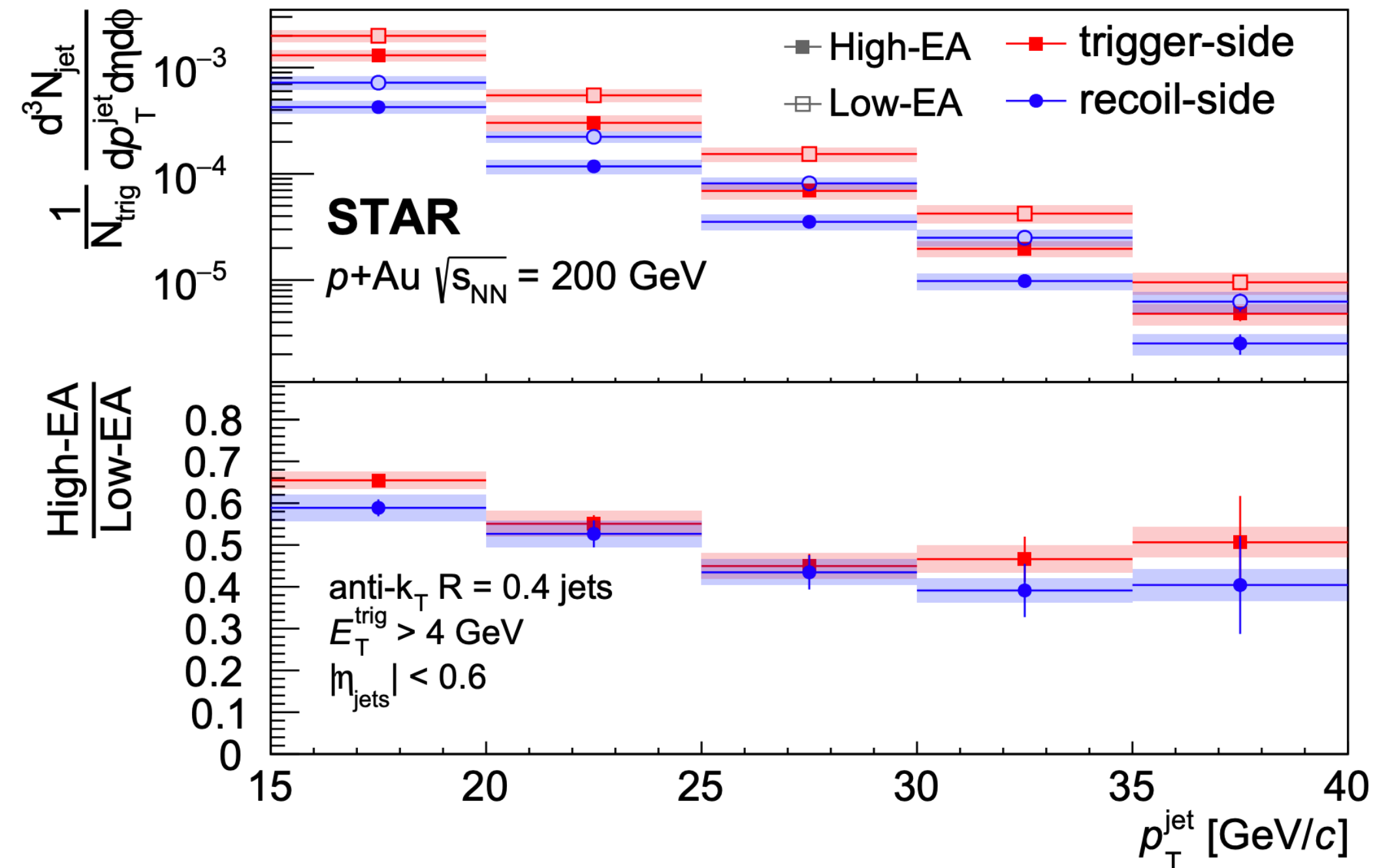
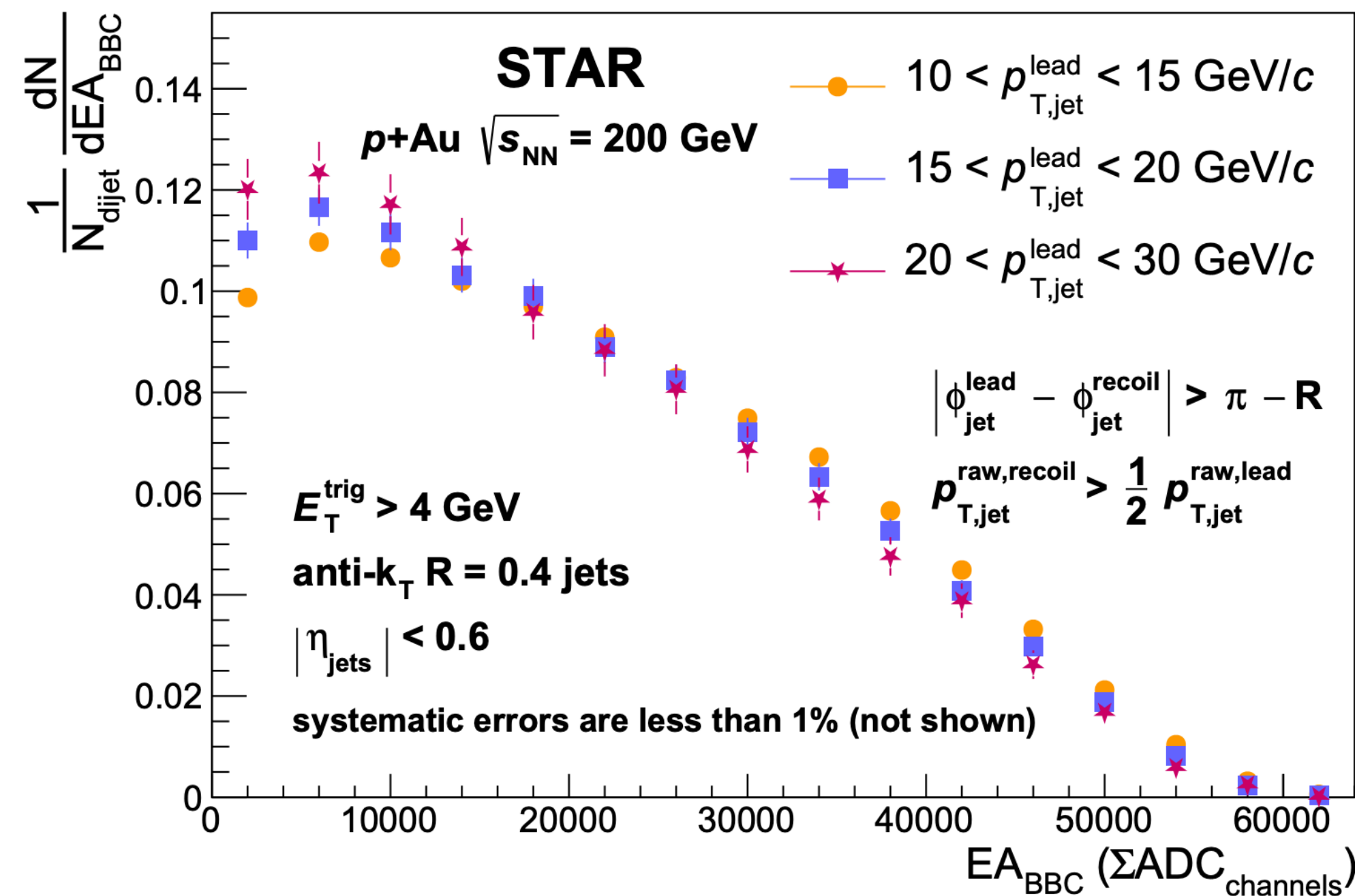
New charge-dependent EEC & E3C — in **hadronic regime**, both **MCs fail to capture data**; qualitatively consistent with behavior seen in r_c

Outlook: Extension to heavy-ion collisions ongoing

Interlude: quenching in small systems?

Recently accepted by PRC! — [arXiv:2404.08784](https://arxiv.org/abs/2404.08784)

Short answer: disfavored at RHIC by this set of measurements from STAR



Rather, modifications likely due to **early-time dynamics** and/or **initial state configuration**

Path-length-dependent quenching

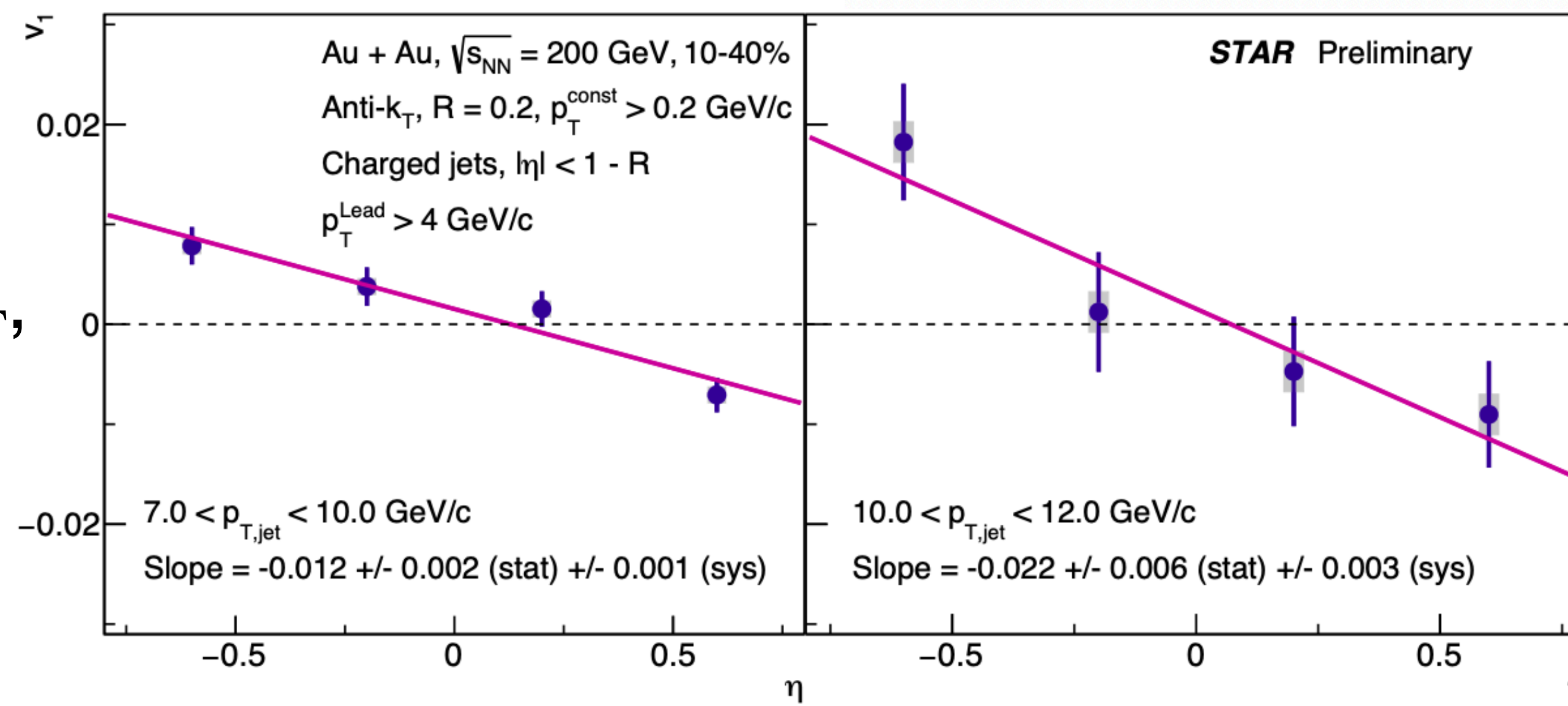
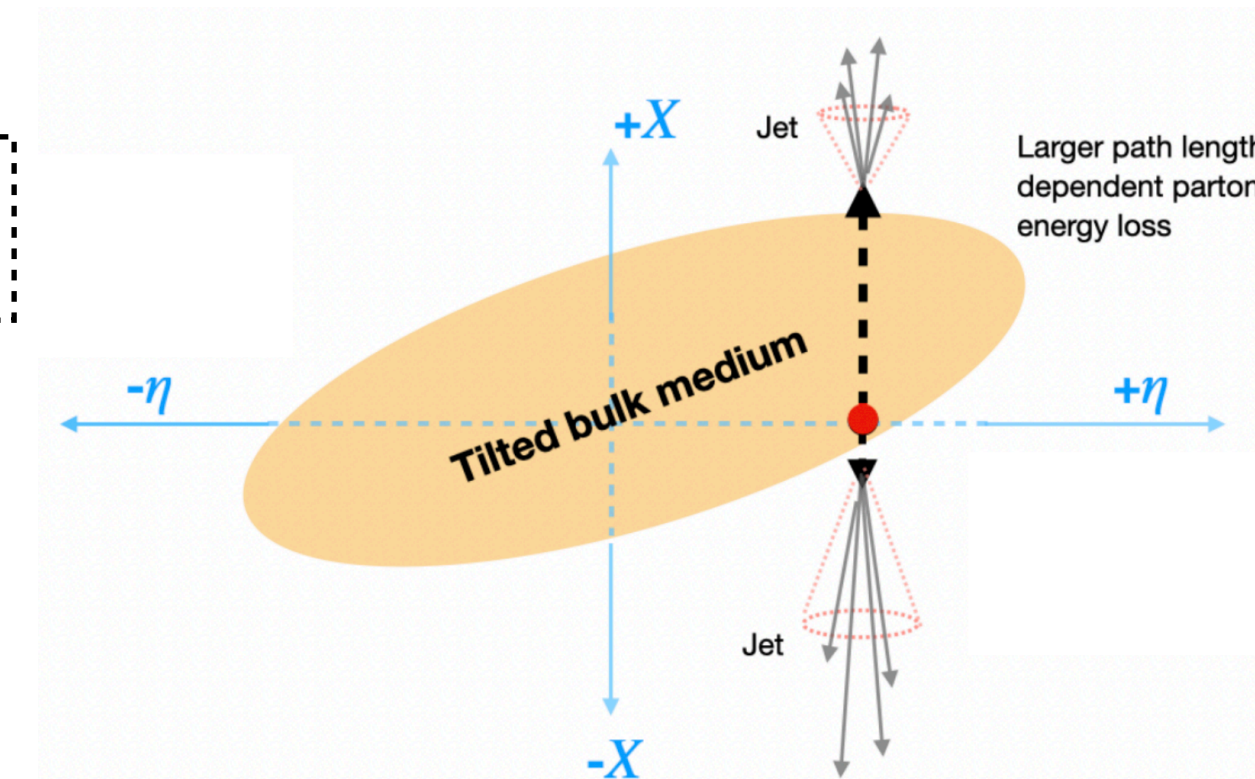
Bulk is tilted in heavy-ion collisions causing asymmetric paths for isotropically produced hard probes

Jet v_1 : a new observable to probe *pathlength-dependent energy loss* in QGP

Clear v_1 signal for all studied jet R , p_T , in **AuAu** data, similar for **isobar** systems as well

Outlook: event-shape engineering with multiplicity fluctuations

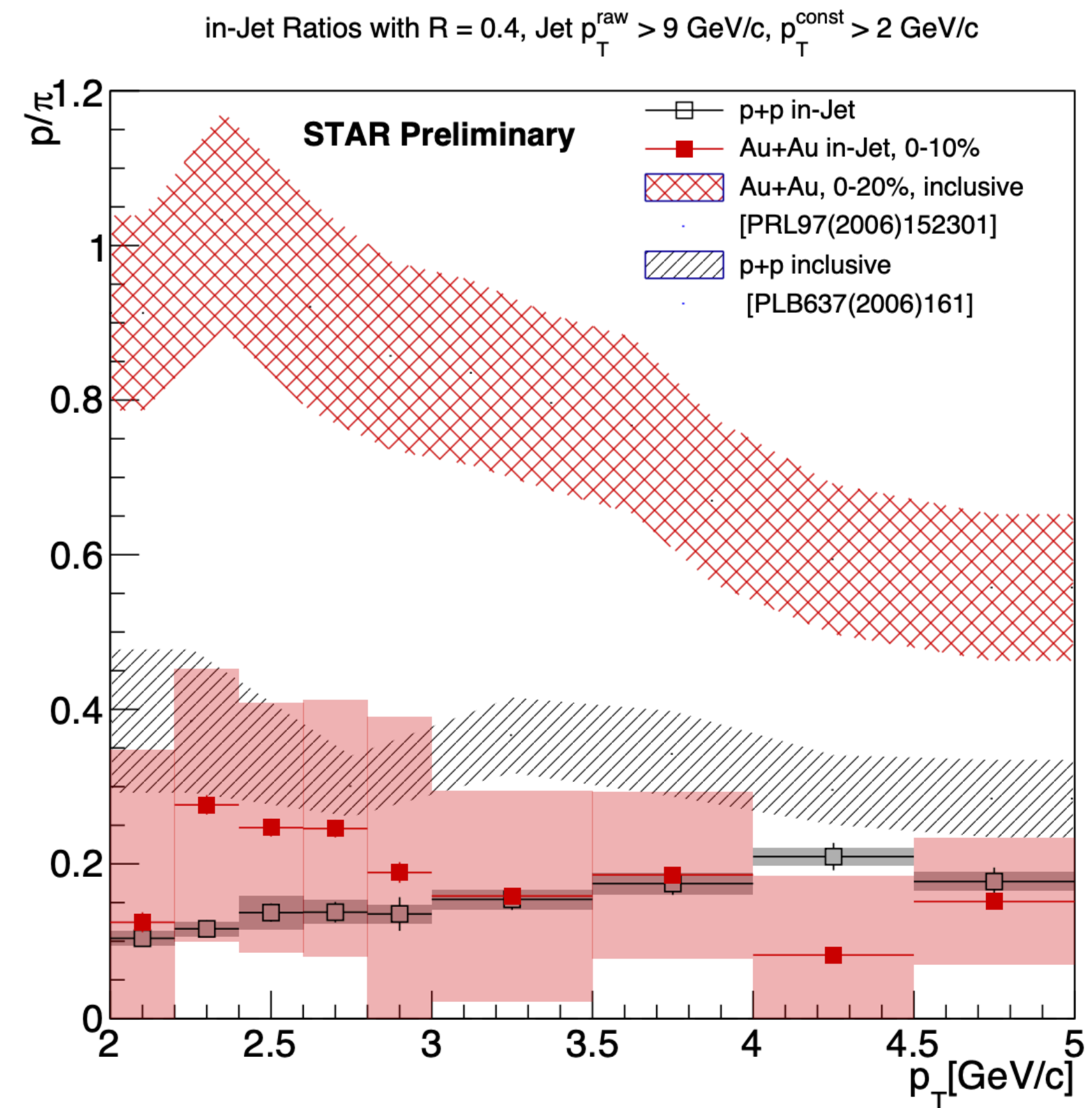
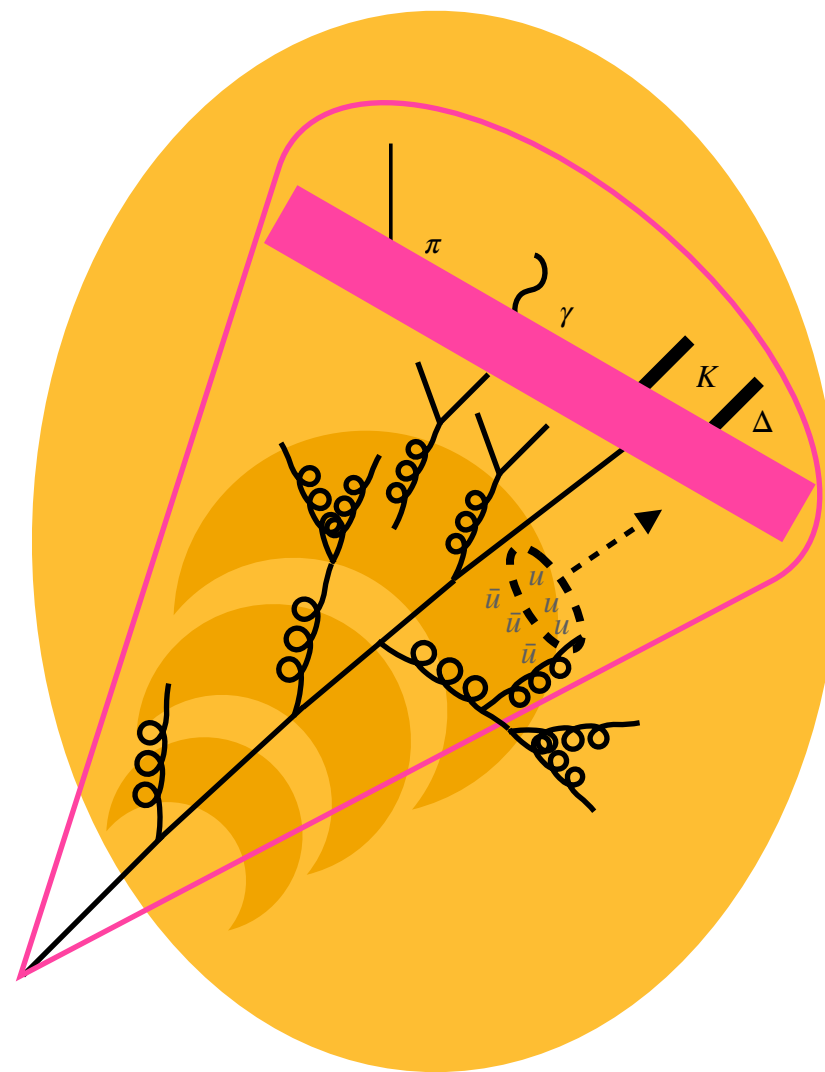
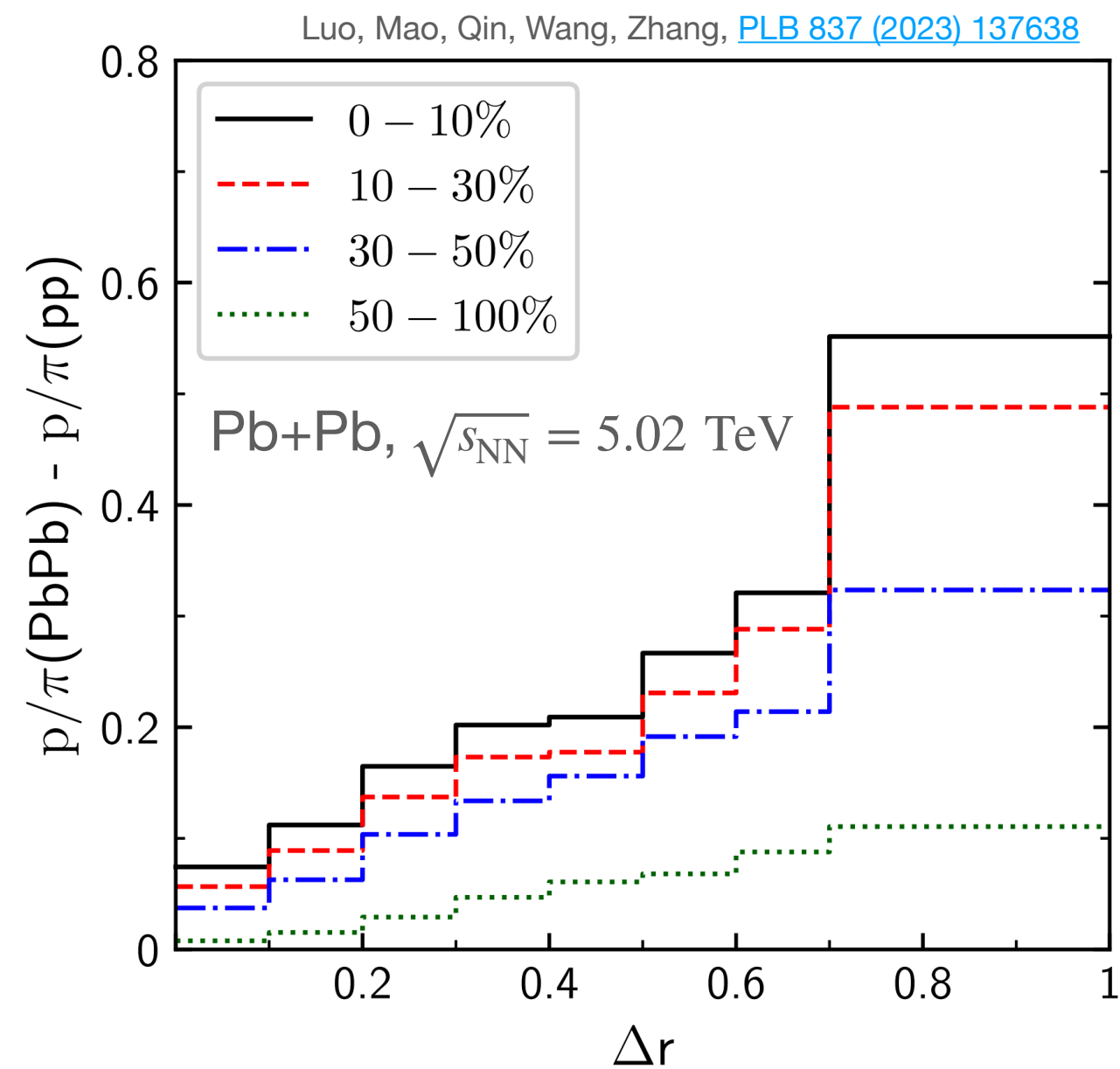
$$v_1(p_T, y) = \langle \cos(\phi - \Psi_{RP}) \rangle$$



Sooraj Radhakrishnan, Sep. 24, 14:00

Poster: Isaac Mooney, #98

Searching for medium response

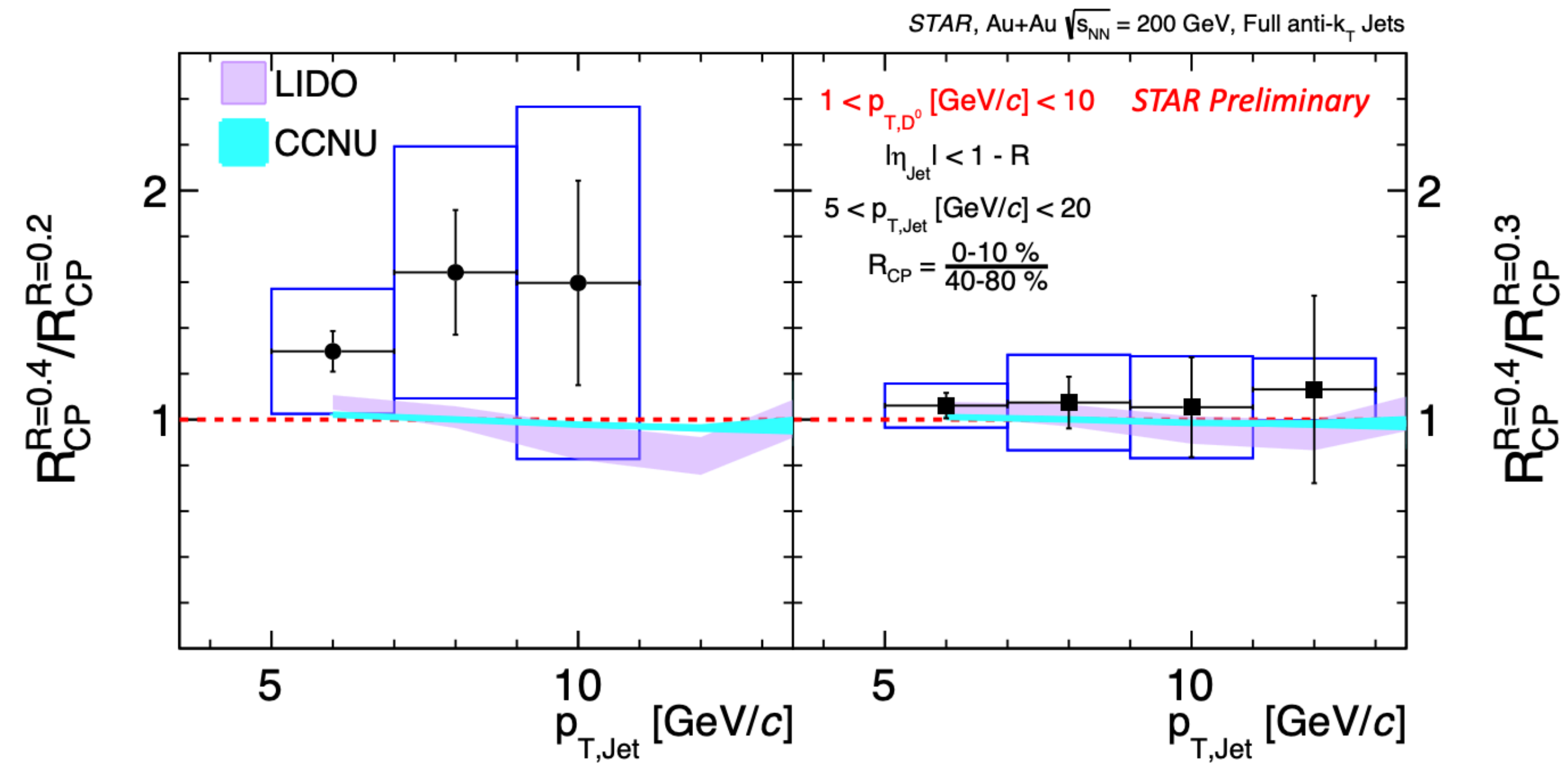
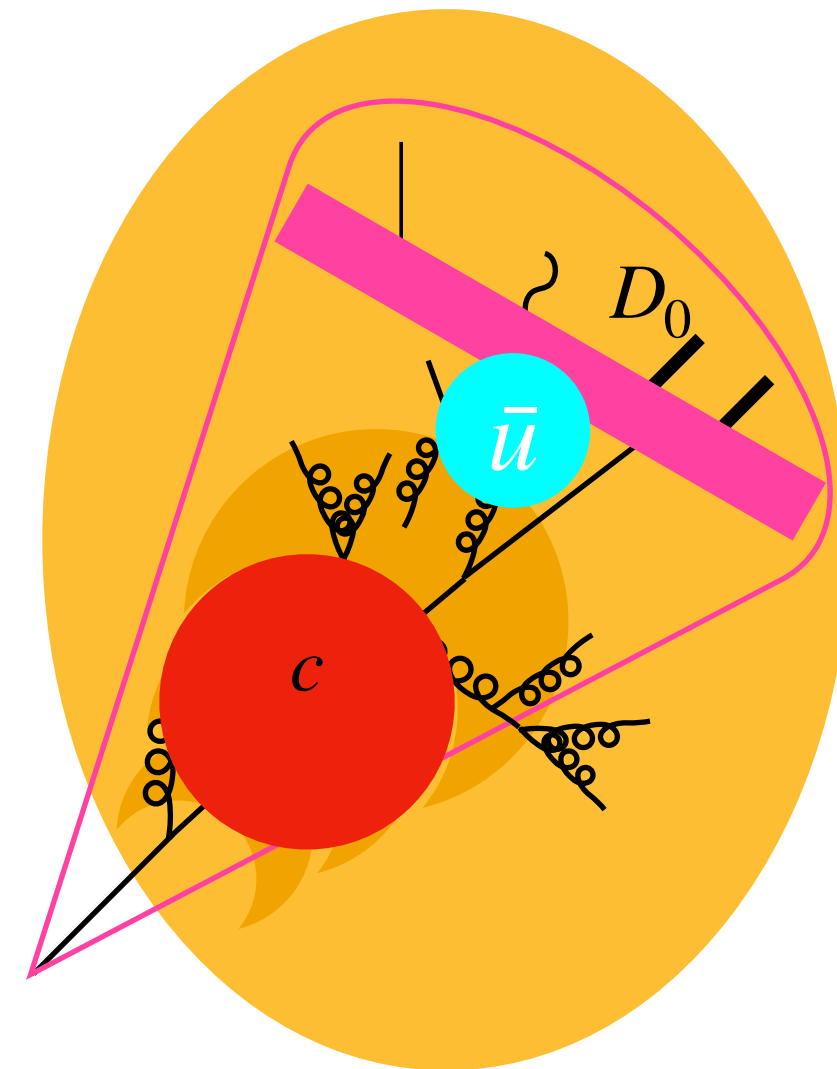
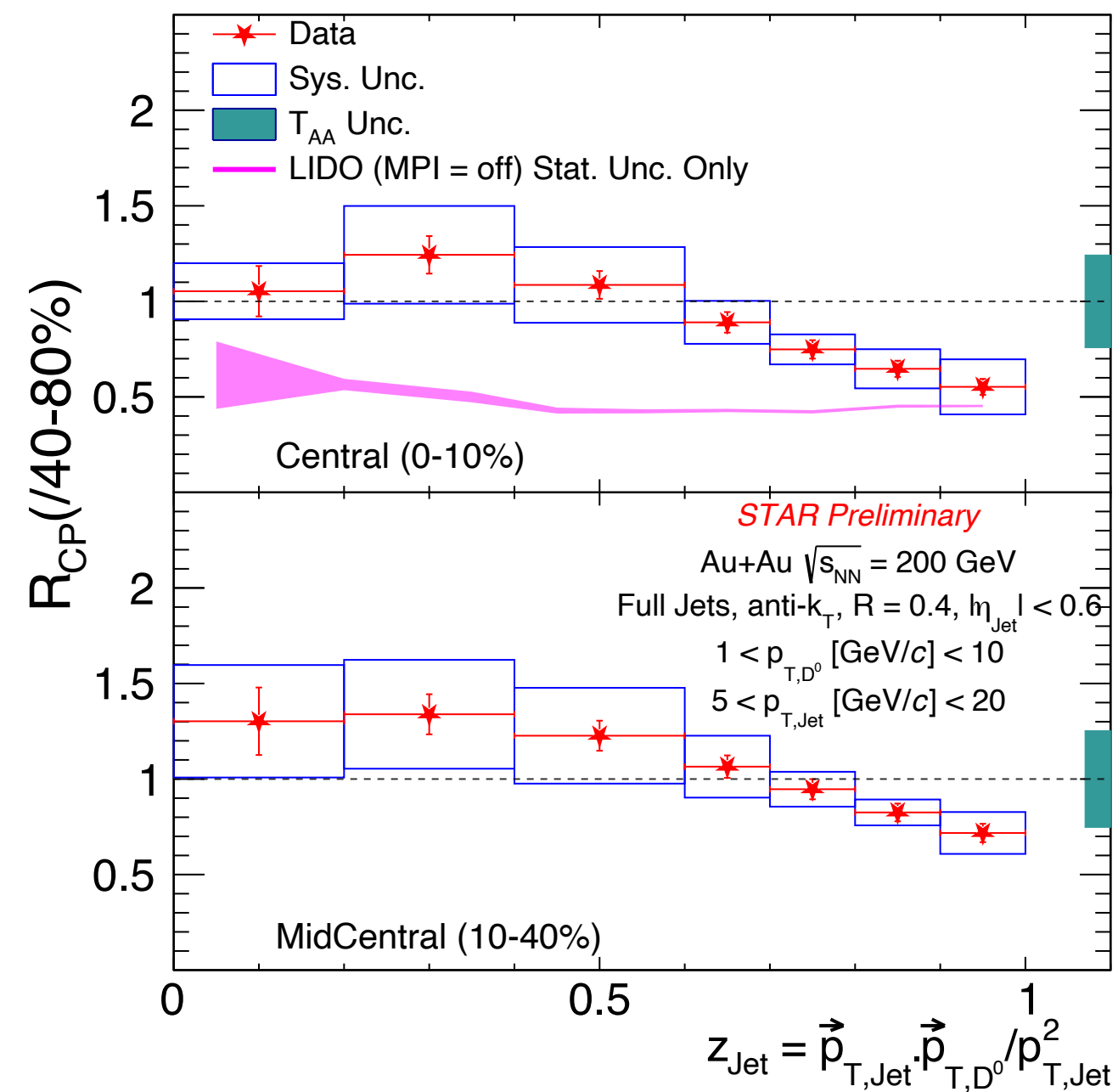


Possible expectation of *parton coalescence in jet*: enhanced baryon-to-meson ratio in A+A (left)

No observed modification of *in-jet* p/π ratio for $R = 0.2 - 0.4$ jets, after extension to lower constituent threshold (right)

Outlook: finalizing for publication in near future

Recovering charm-associated radiation



Wider jets \rightarrow more medium interaction/ E -loss \implies *ratio* < 1 ,
 but recover more energy + more potential for medium response \implies *ratio* > 1
 Observe: **No radius dependence of R_{CP}** within uncertainties.
 Agrees with models predicting minimal R -dependence of suppression.

Outlook: measuring generalized angularities

Diptanil Roy, Sep. 25, 11:50

Poster: Tanmay Pani, #97

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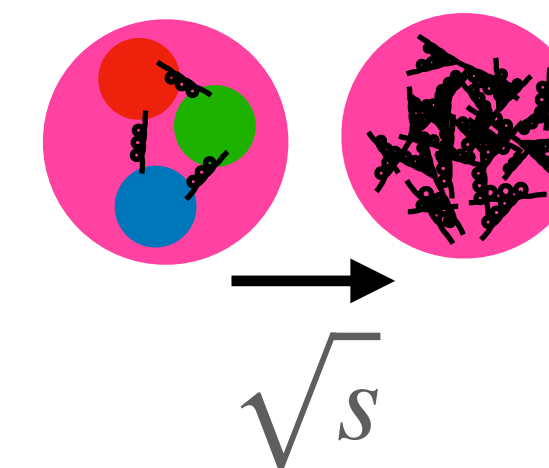
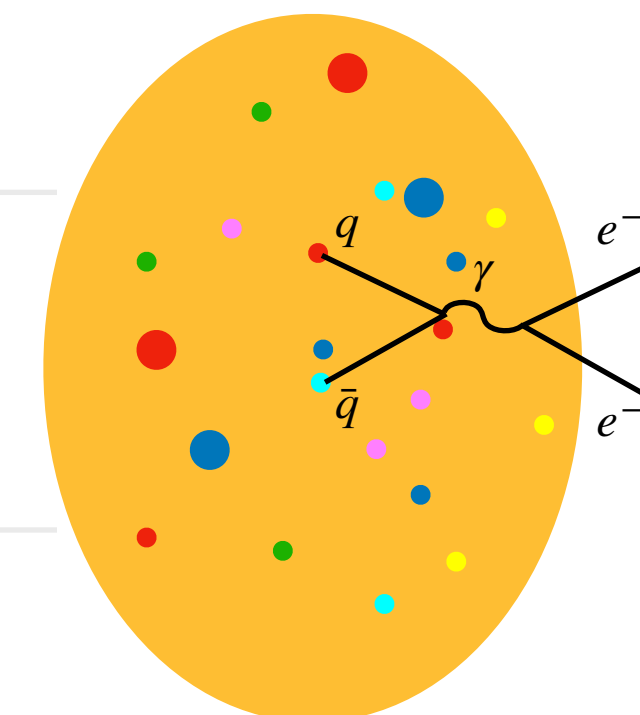
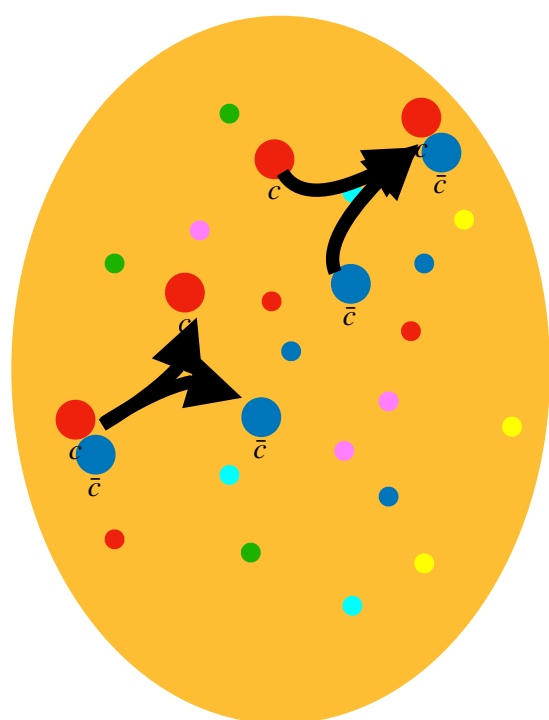
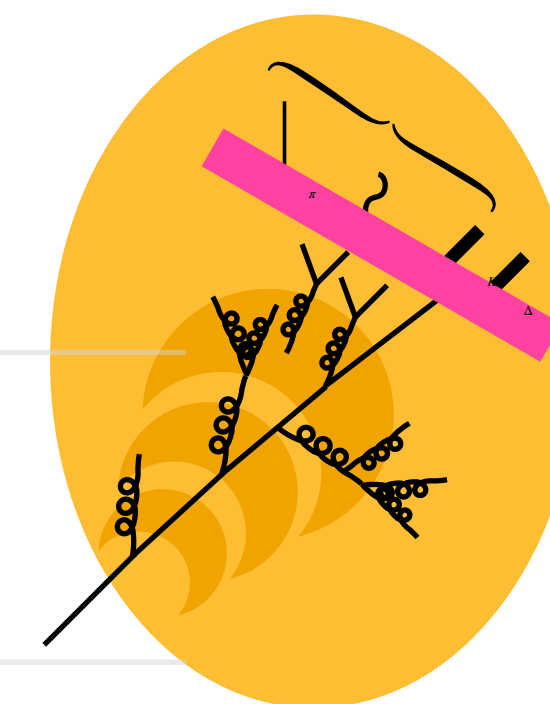
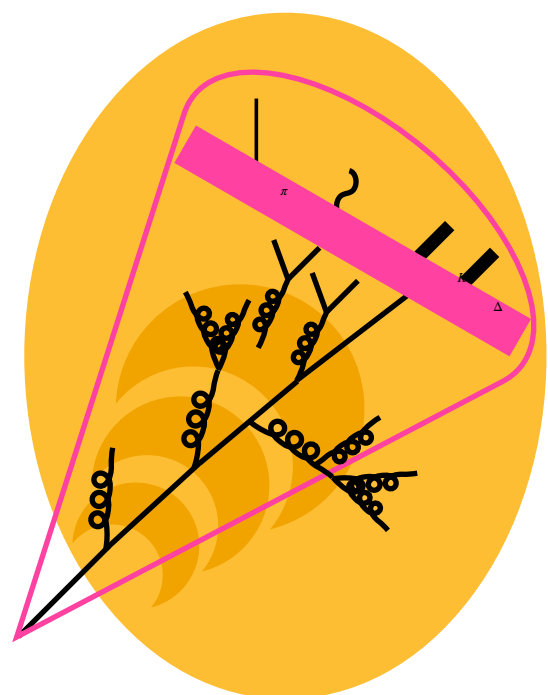
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Dissociation of charmonium states

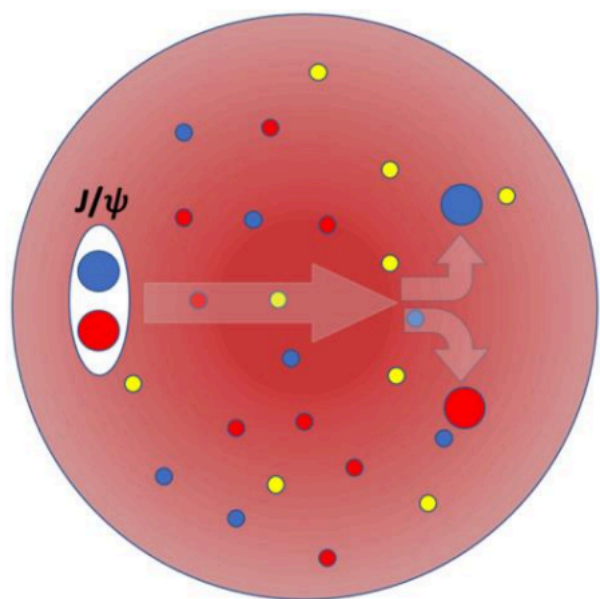
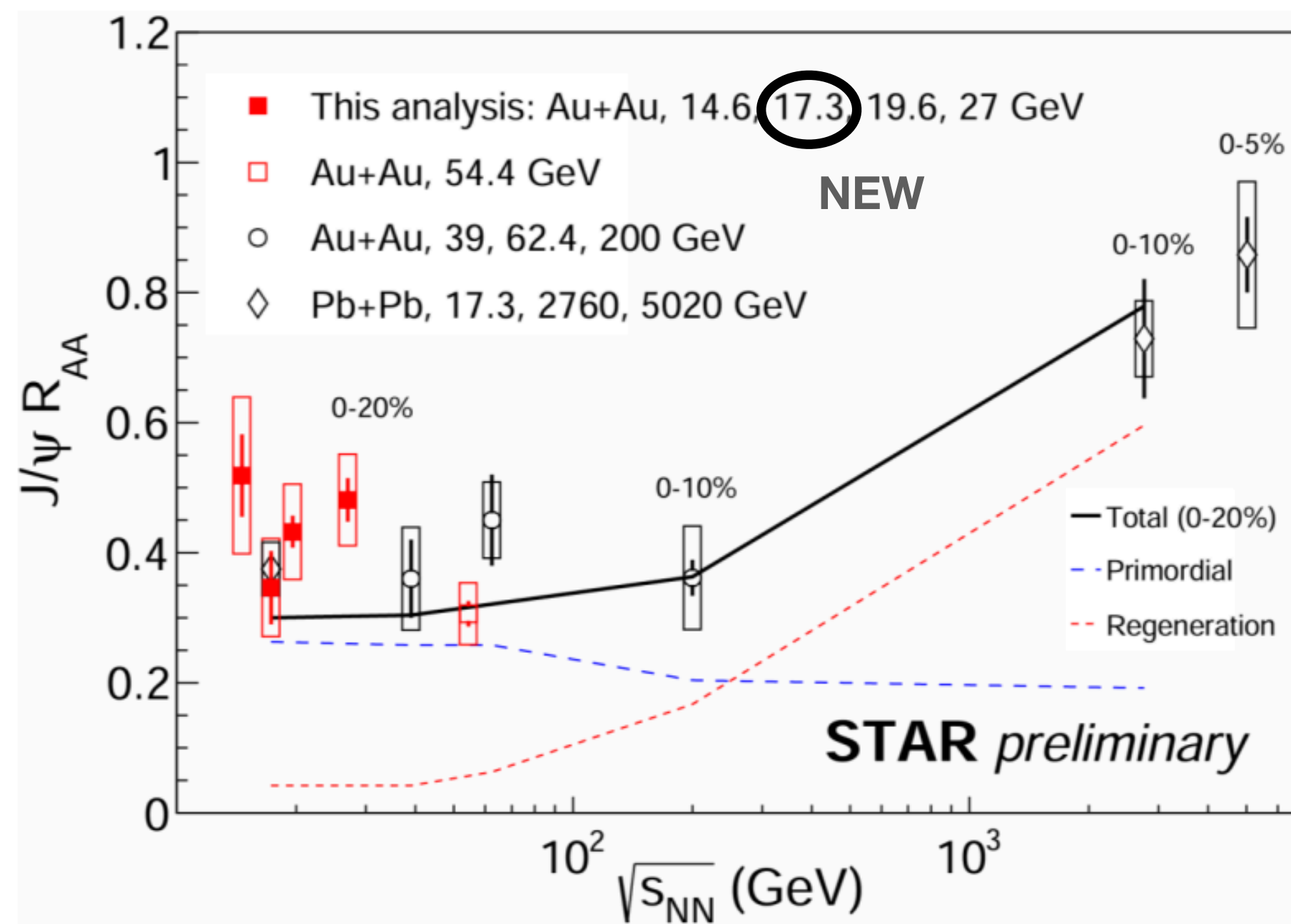
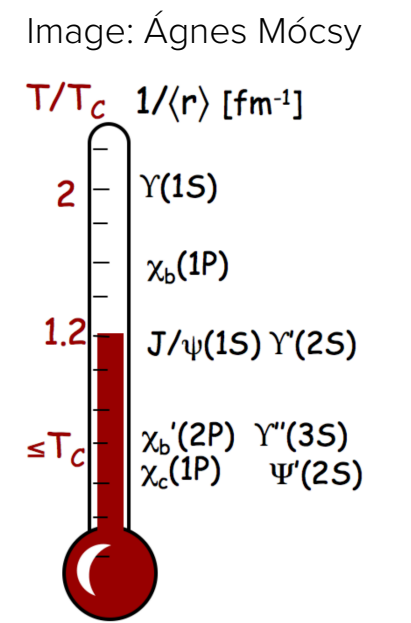
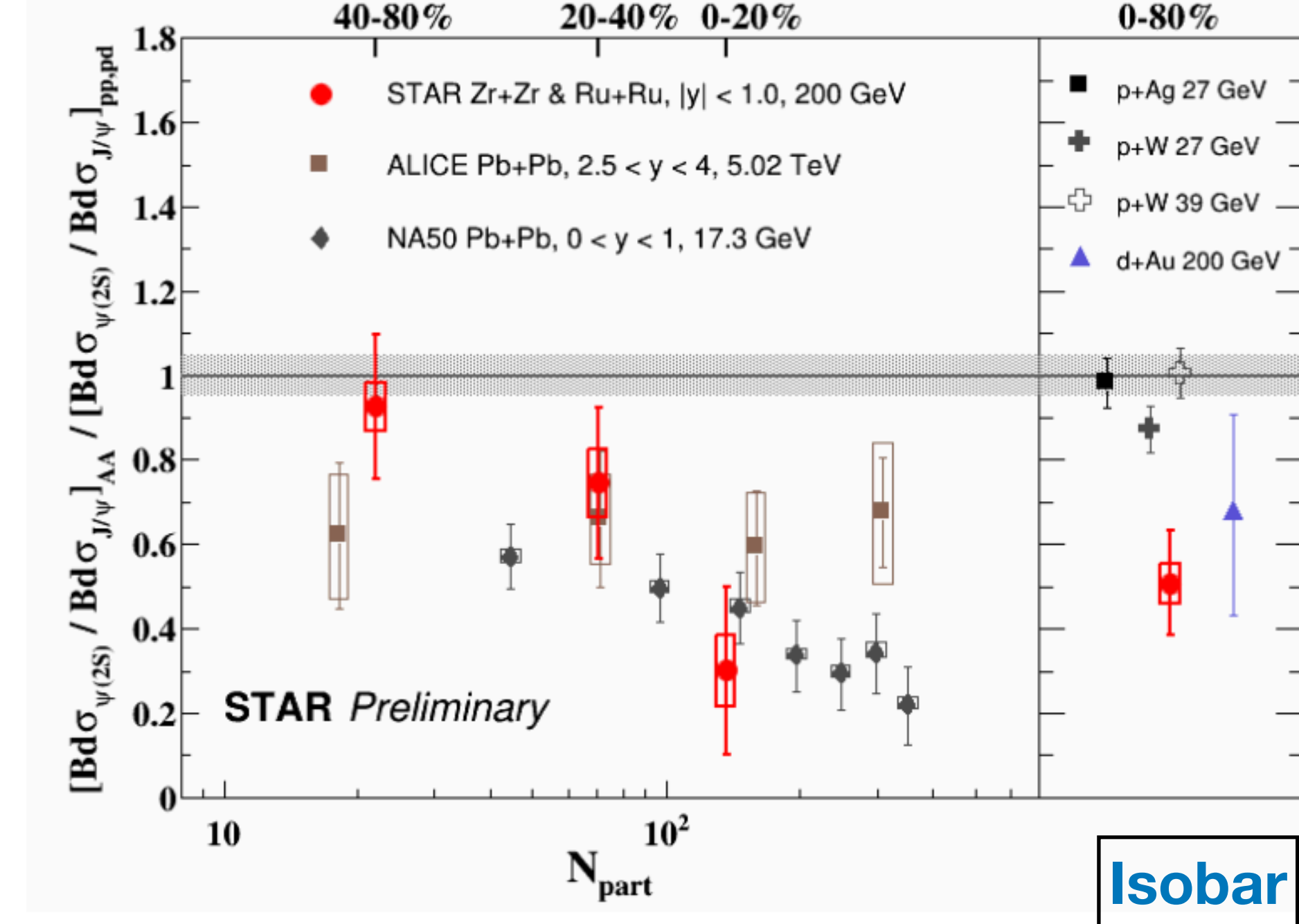
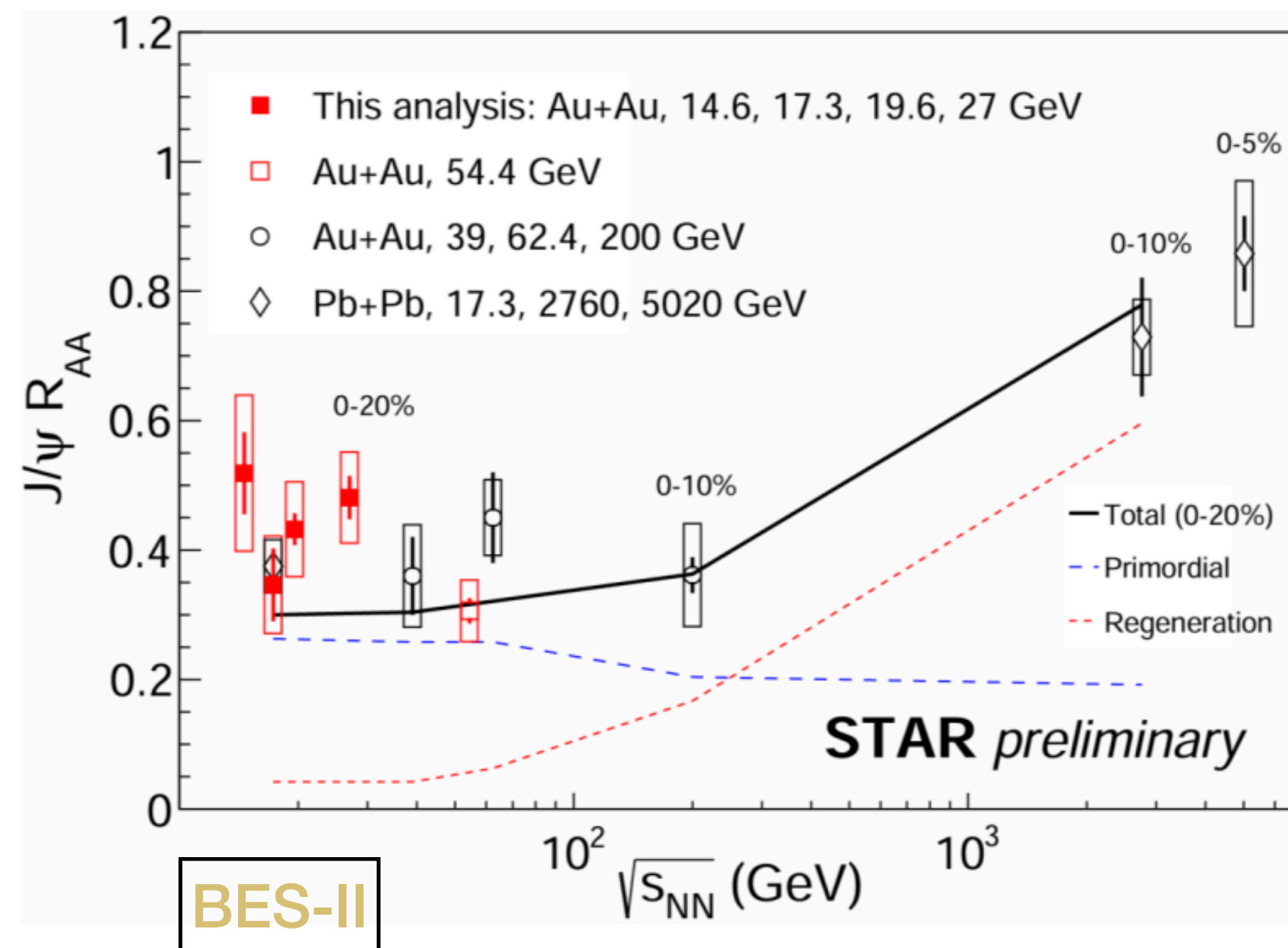
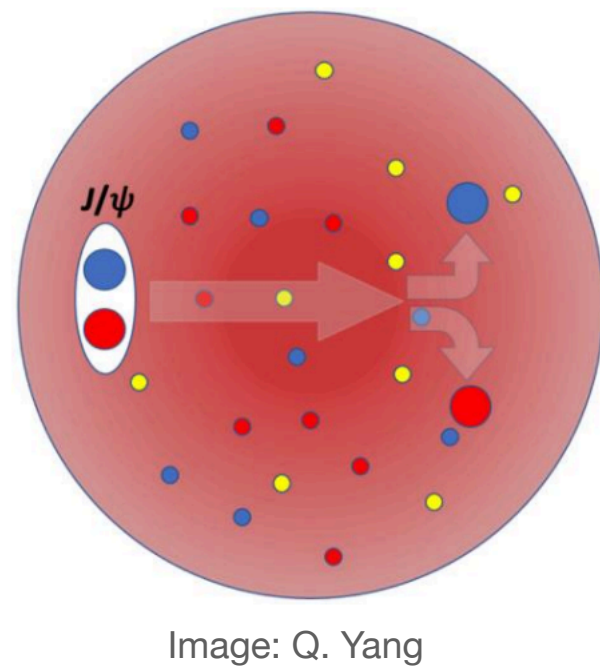


Image: Q. Yang



Filling in low-energy regime where primordial generation expected to be dominant. Consistent with SPS at 17.3 GeV; data & model exhibit **minimal energy dependence**.

Dissociation of charmonium states



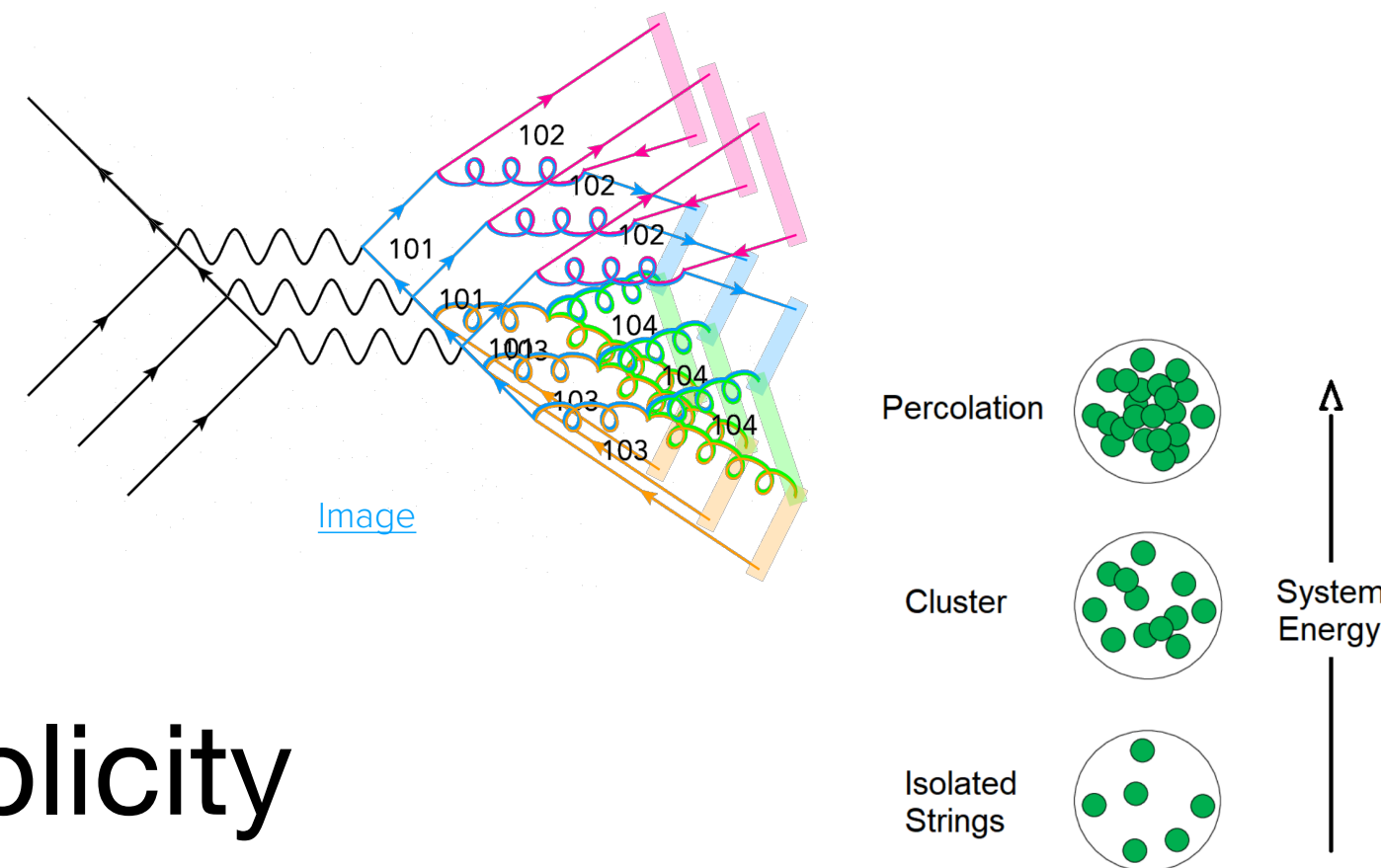
Filling in low-energy regime where primordial generation expected to be dominant. Consistent with SPS at 17.3 GeV; data & model exhibit **minimal energy dependence**.

$\psi(2S)/J/\psi / \psi(2S)/J/\psi < 1$: 1st RHIC observation of **charmonium sequential suppression**

Outlook: finalizing both analyses for publication in near future

Study of charmonium production mechanism

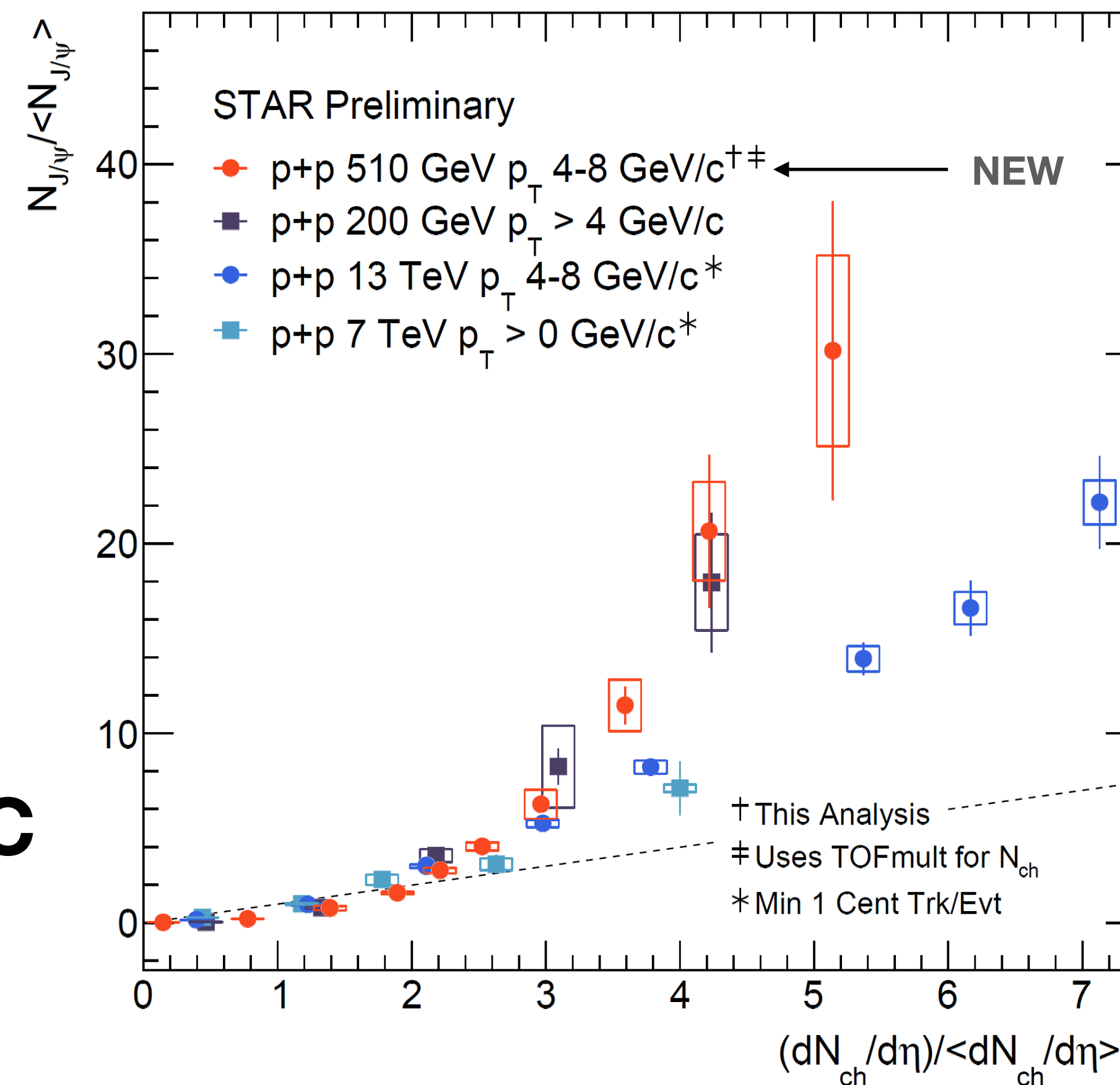
MPI, string percolation expected to play a role in J/ψ production, especially at high multiplicity



Consistency between 510 and 200 GeV at STAR + finer binning & extension to higher multiplicity

Large uncertainty in highest multiplicities, but **seems to be a steeper trend at RHIC than LHC**

Outlook: correcting multiplicity via unfolding



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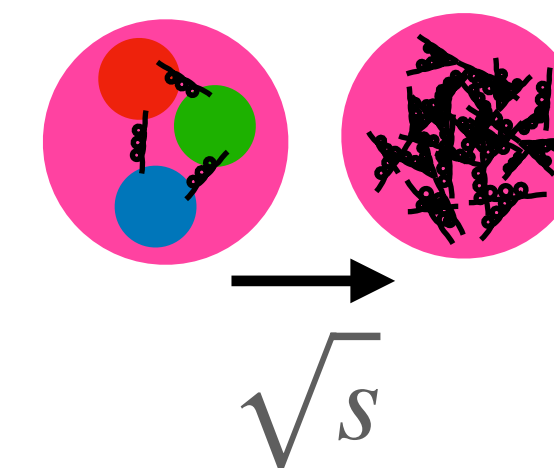
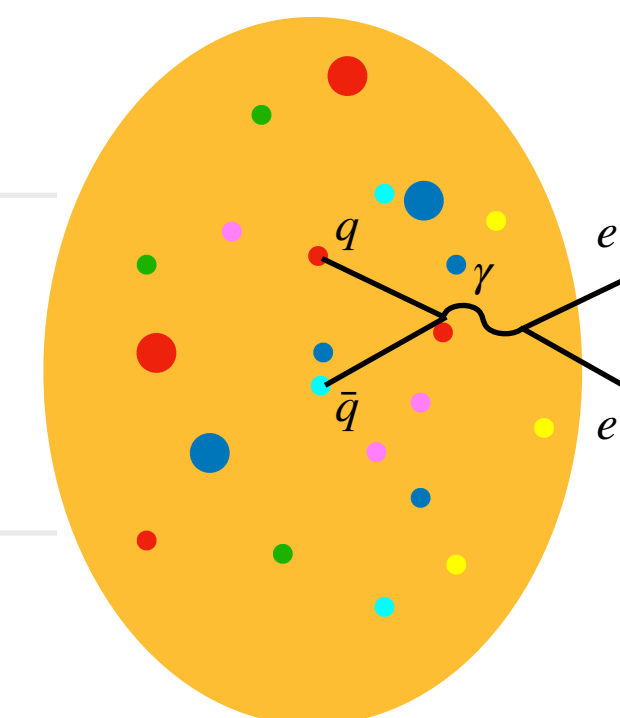
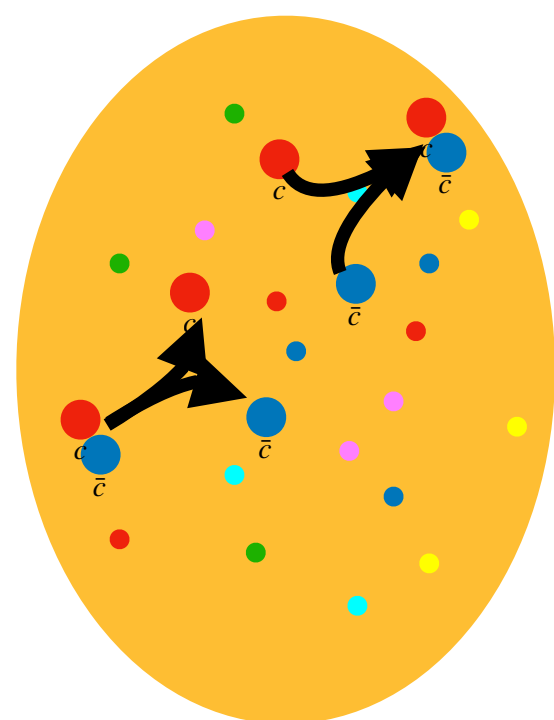
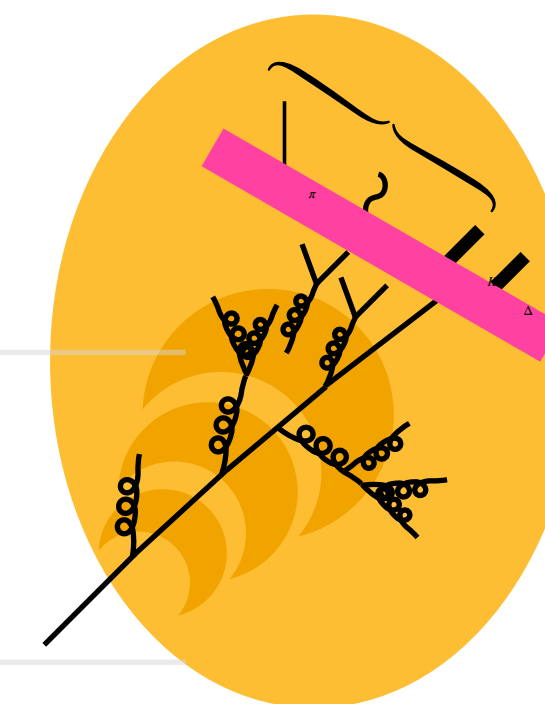
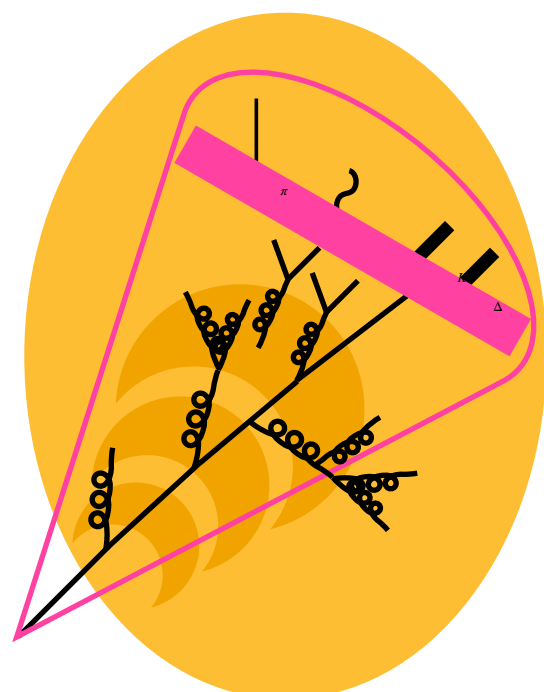
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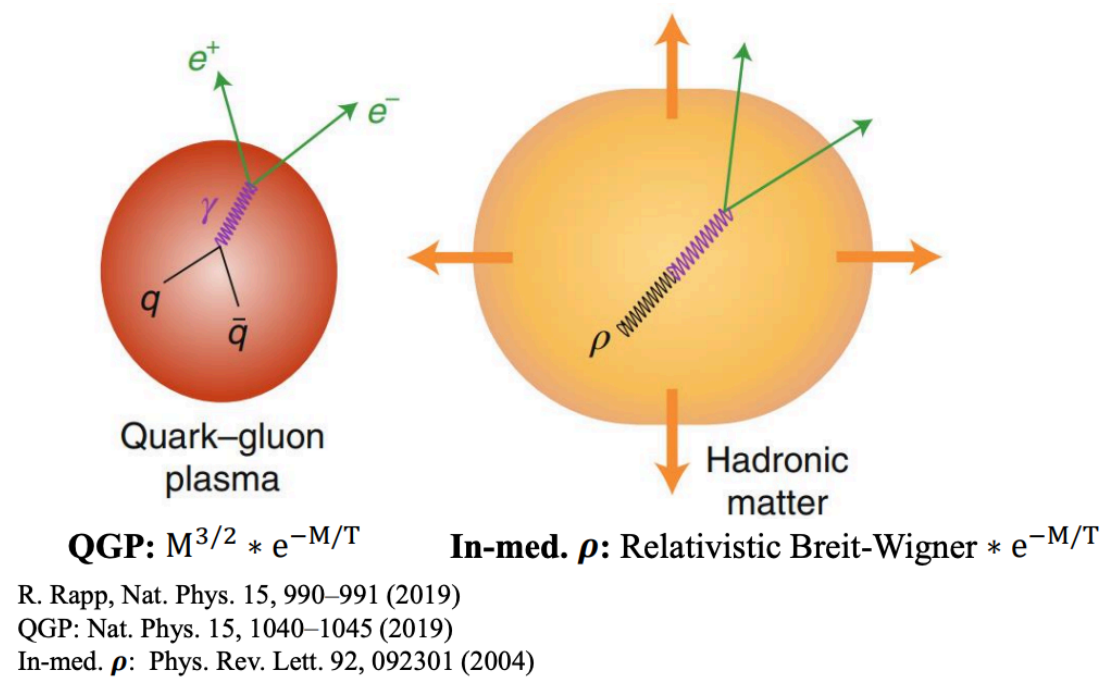
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6. Future experimental facilities and new techniques

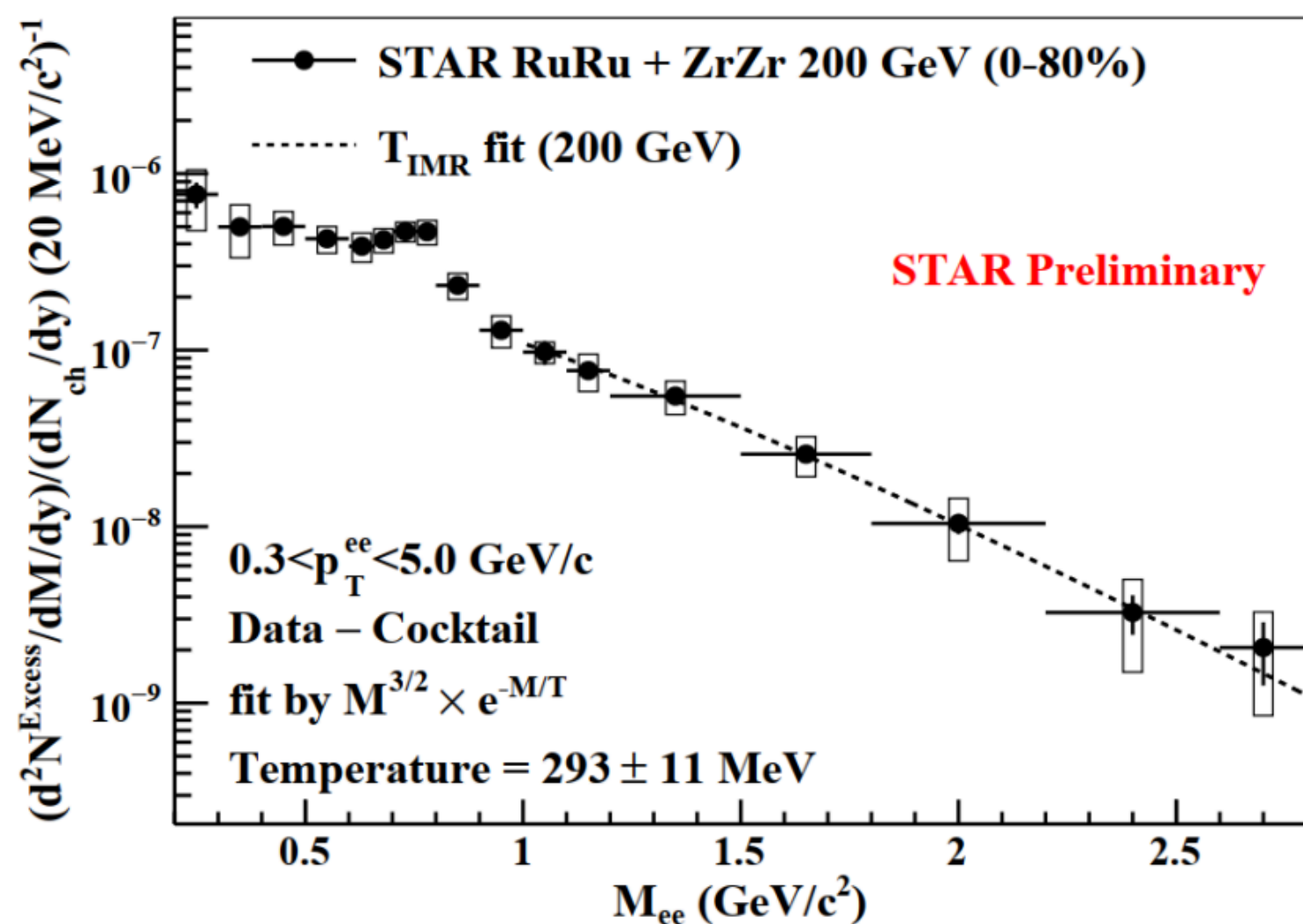
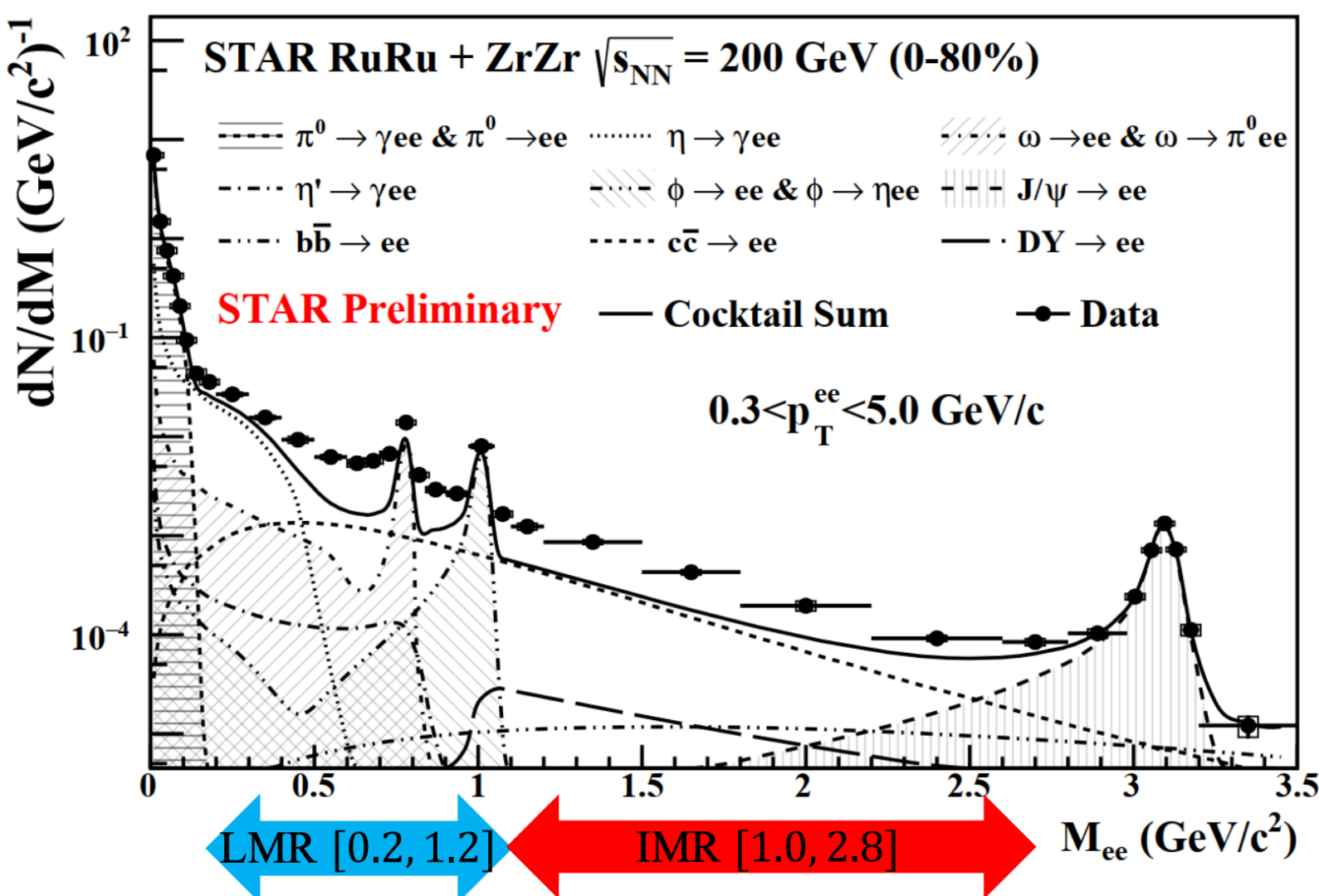


Accessing the QGP temperature

Isobar, 200 GeV

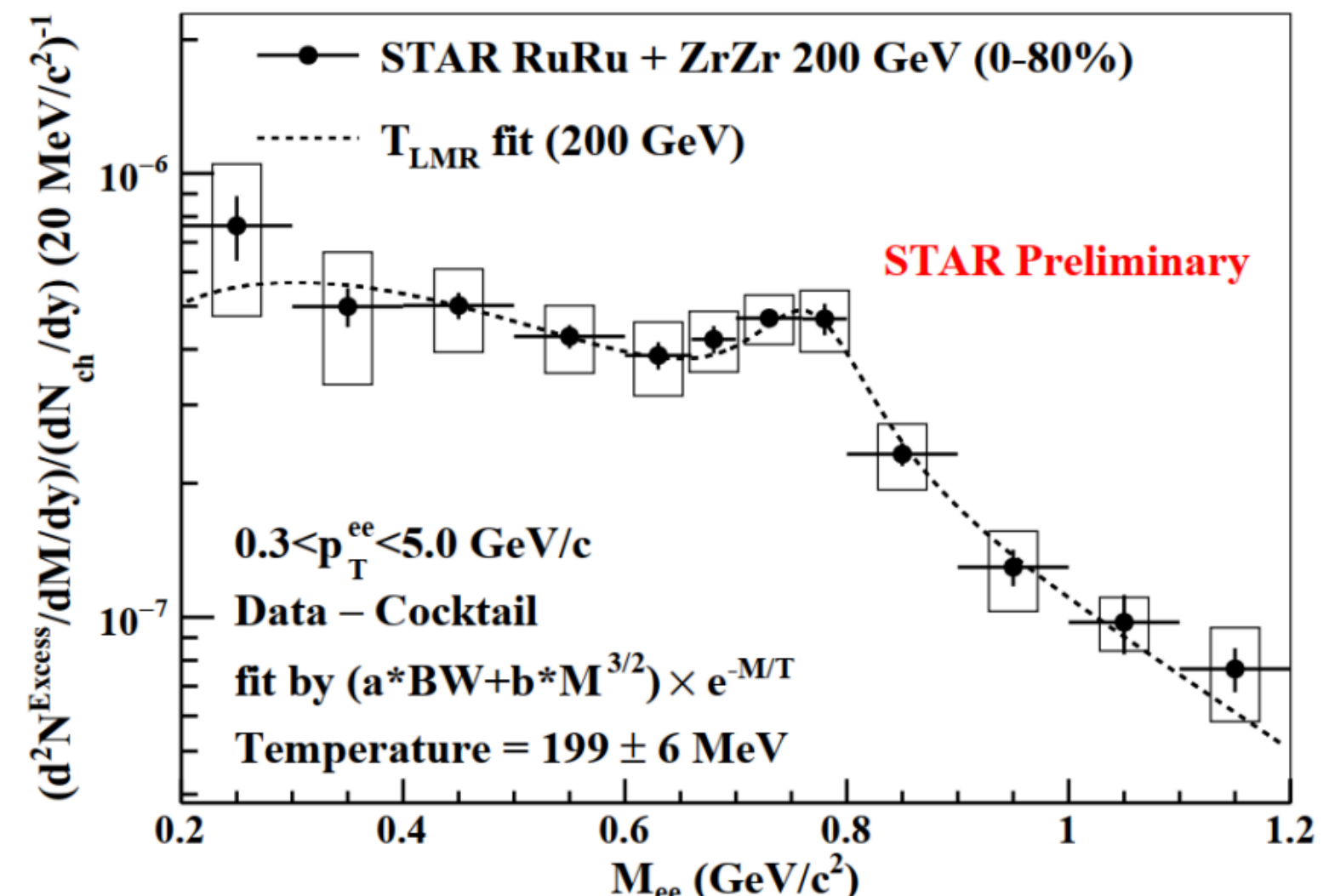


Excess (thermal, ρ) = data - cocktail



$T_{IMR}^{200 \text{ GeV}} = 293 \pm 11(\text{stat.}) \pm 27(\text{sys.}) \text{ MeV}$

Extract T early in partonic regime from IMR: well above T_{pc}



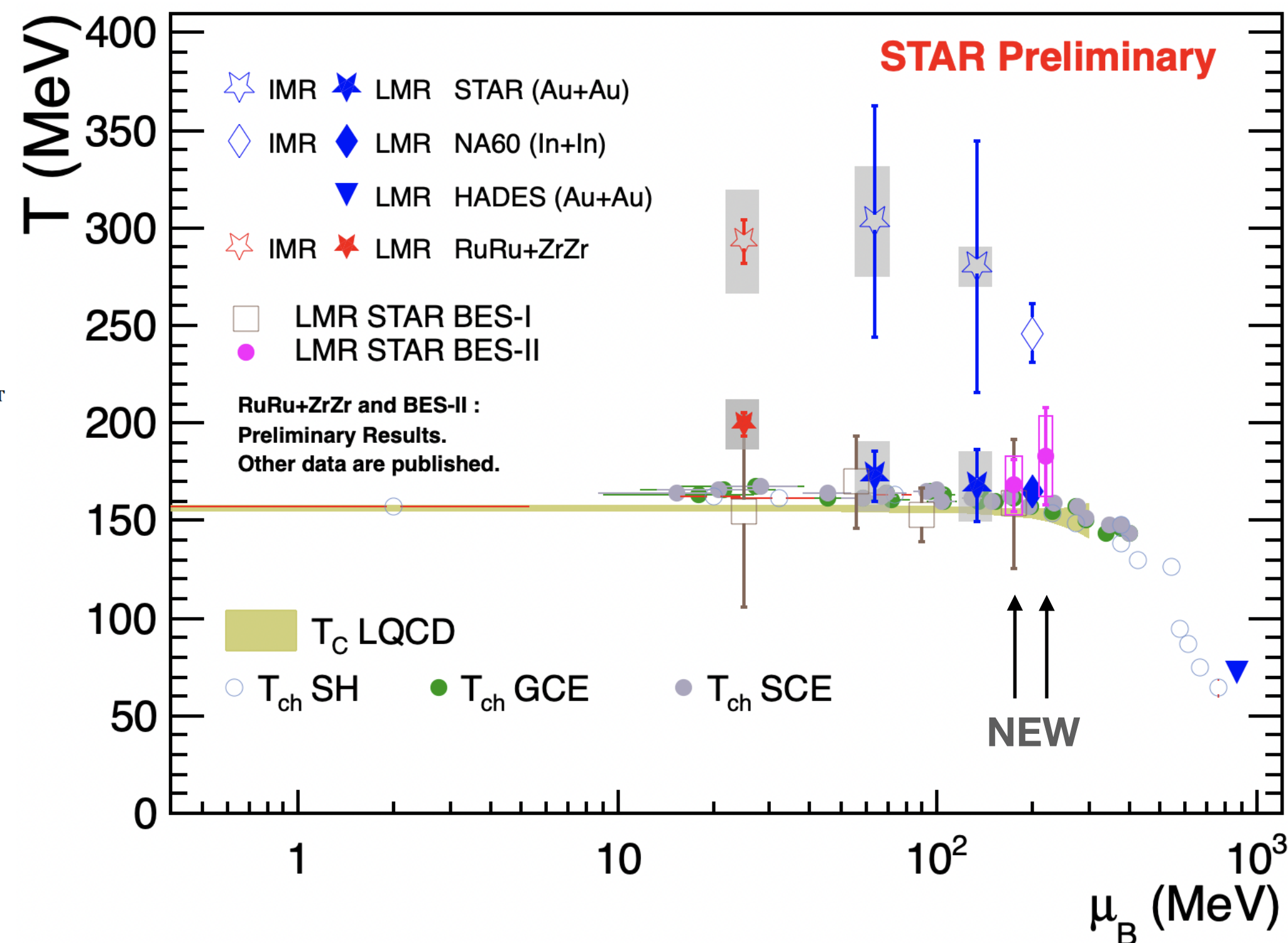
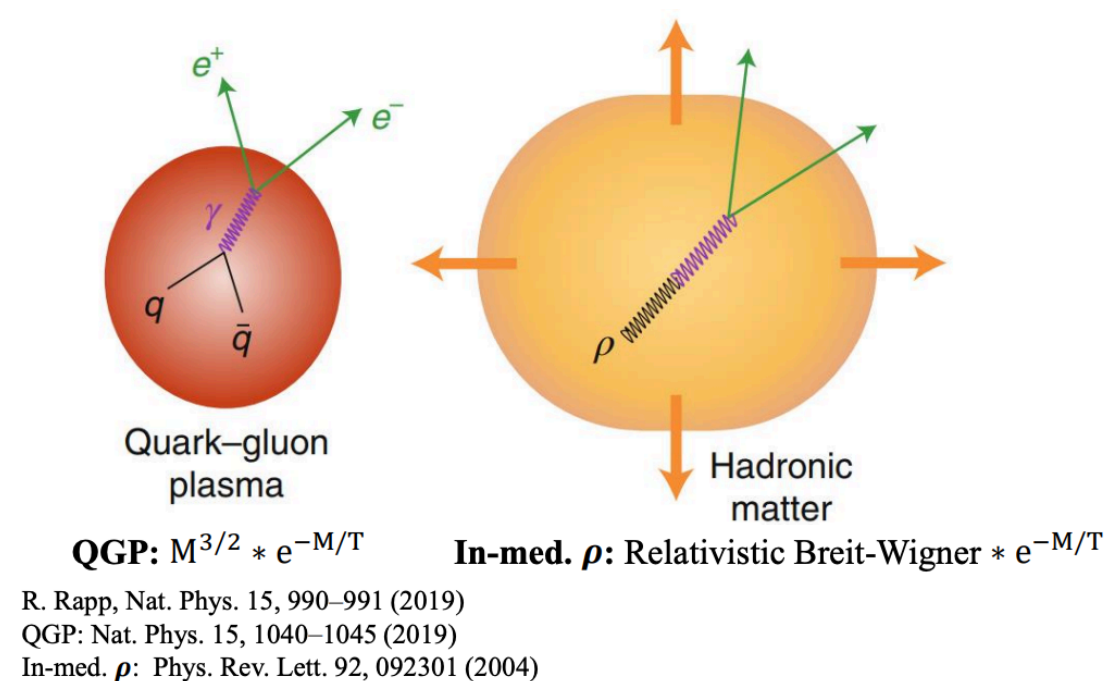
$T_{LMR}^{200 \text{ GeV}} = 199 \pm 6(\text{stat.}) \pm 13(\text{sys.}) \text{ MeV}$

Time-averaged T over the evolution, from LMR: hint of QGP contribution

Outlook: finalizing for publication in near future

Accessing the QGP temperature

BES-II



$$T_{LMR}^{14.6 \text{ GeV}} = 183 \pm 25(\text{stat.}) \pm 21(\text{sys.}) \text{ MeV}$$

$$T_{LMR}^{19.6 \text{ GeV}} = 168 \pm 13(\text{stat.}) \pm 15(\text{sys.}) \text{ MeV}$$

Also measure LMR in BES-II data for 1st time:
emission predominantly at phase transition

Outlook: reducing photonic conversion background to improve statistics

Chenliang Jin, Sep. 24, 11:30

Poster: Xianwen Bao, #101

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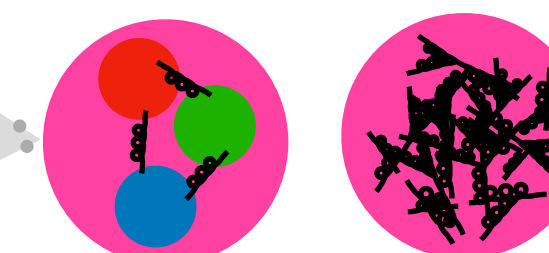
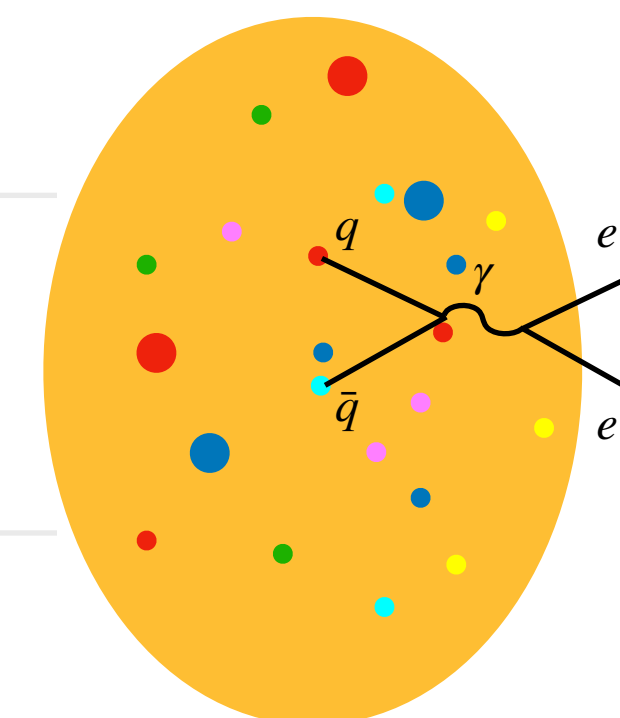
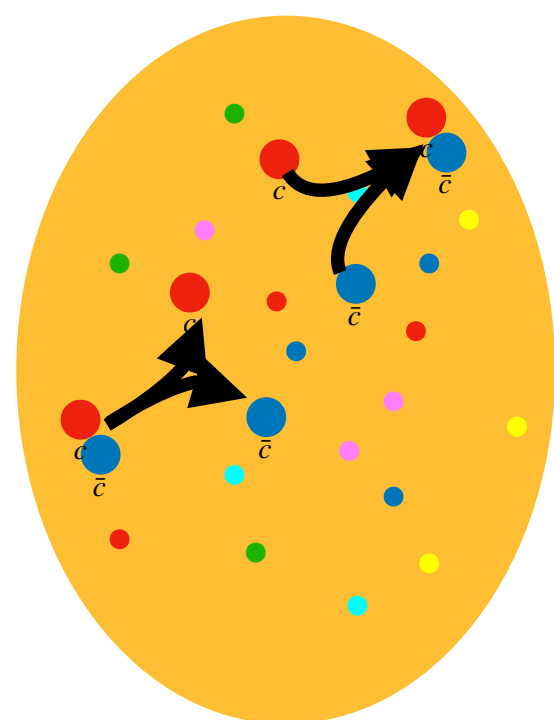
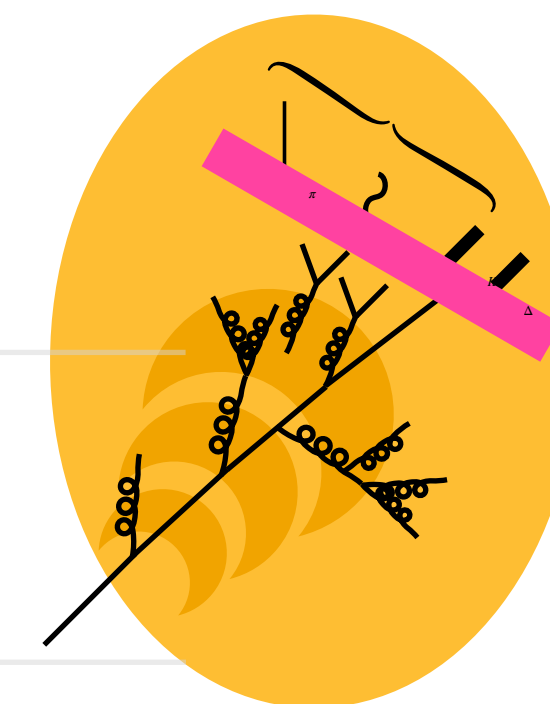
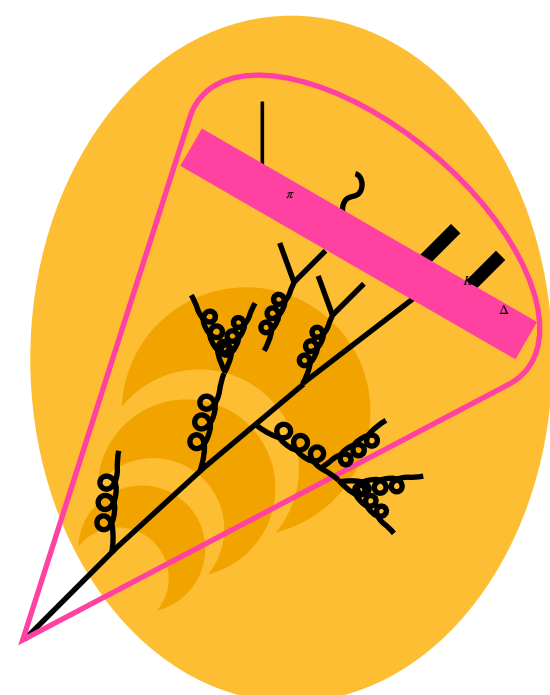
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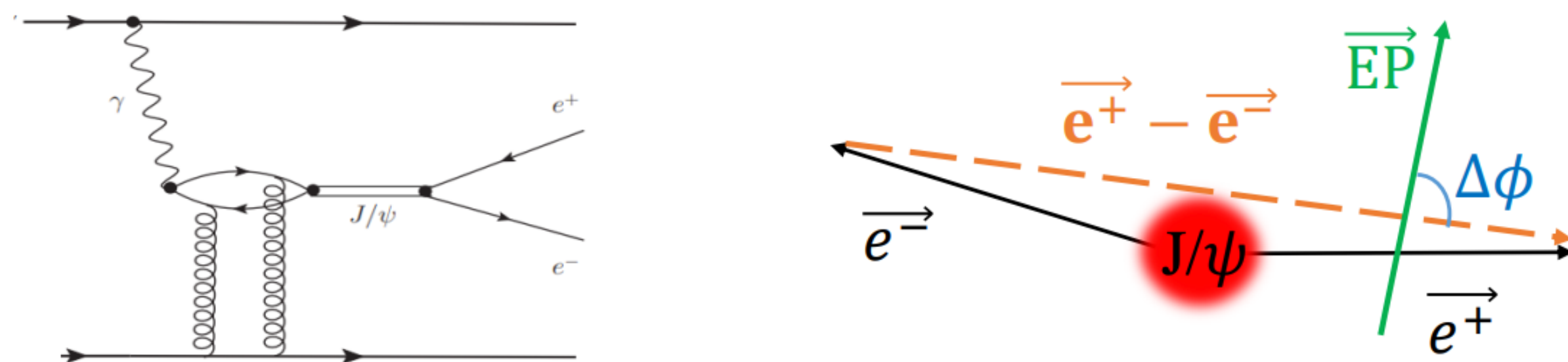
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\sqrt{s}

Accessing collision geometry

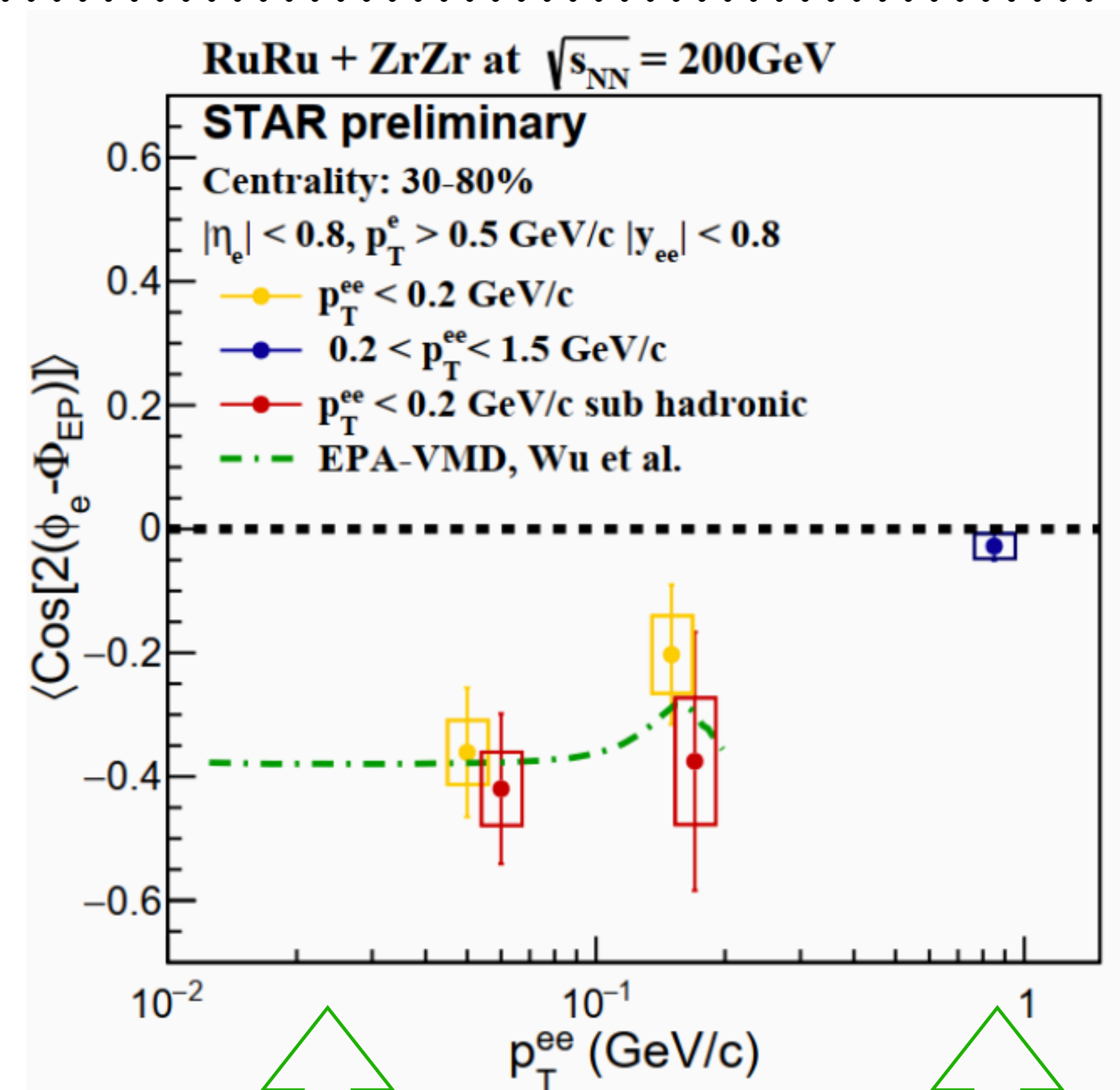


γ -induced- J/ψ inherits linear polarization from Weizsäcker-Williams photons

Observed e^+e^- decay azimuthal anisotropy, with direction related to event plane

Could be used as reliable estimator of reaction plane¹

Outlook: finalizing for publication in near future



γ -induced

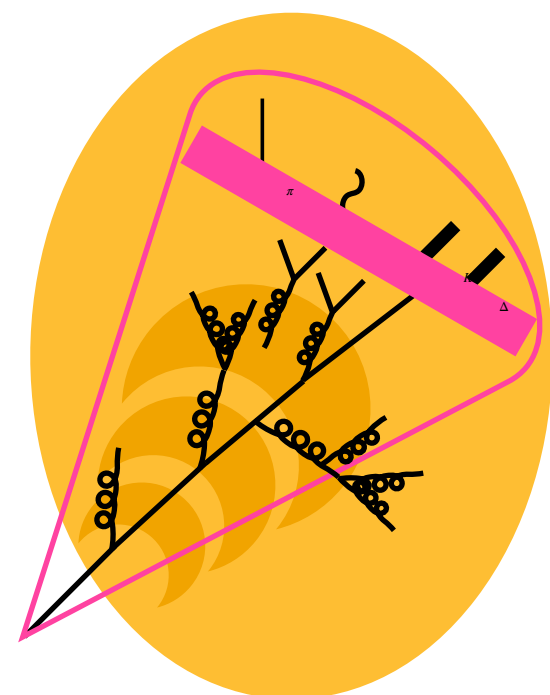
Hadronic processes

Kaiyang Wang, Sep. 25, 9:00

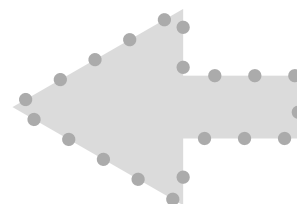
Poster: Xinbai Li, #129

Physics from STAR at Hard Probes

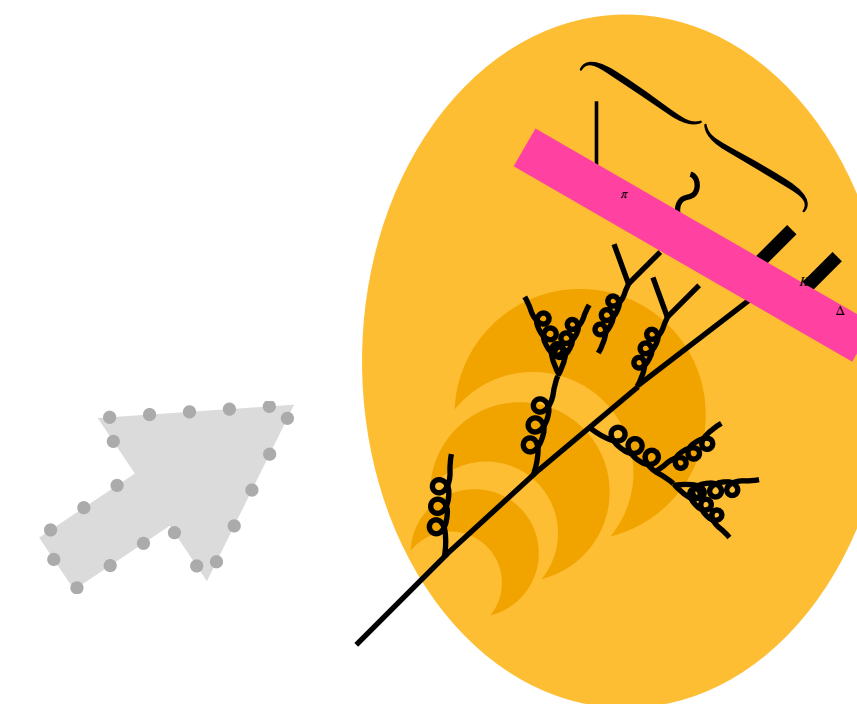
Pathlength dependence of energy loss



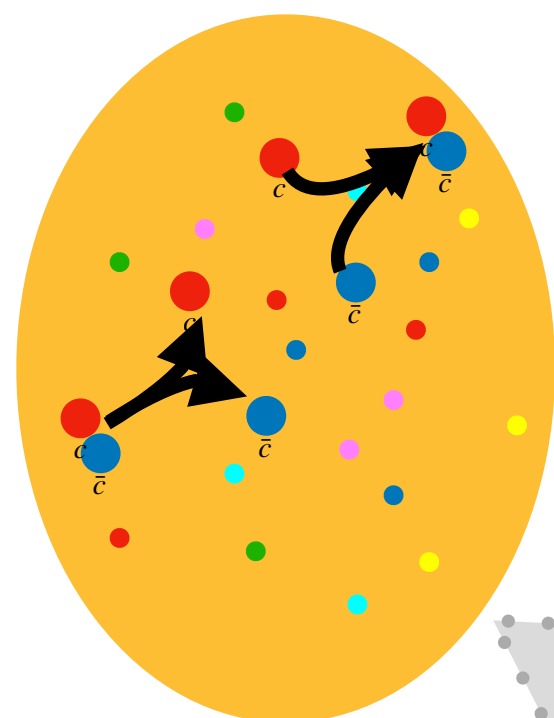
Medium-induced hadrochemistry effect not observed in jets



Testing limits of models' description of charge flow of hadronization



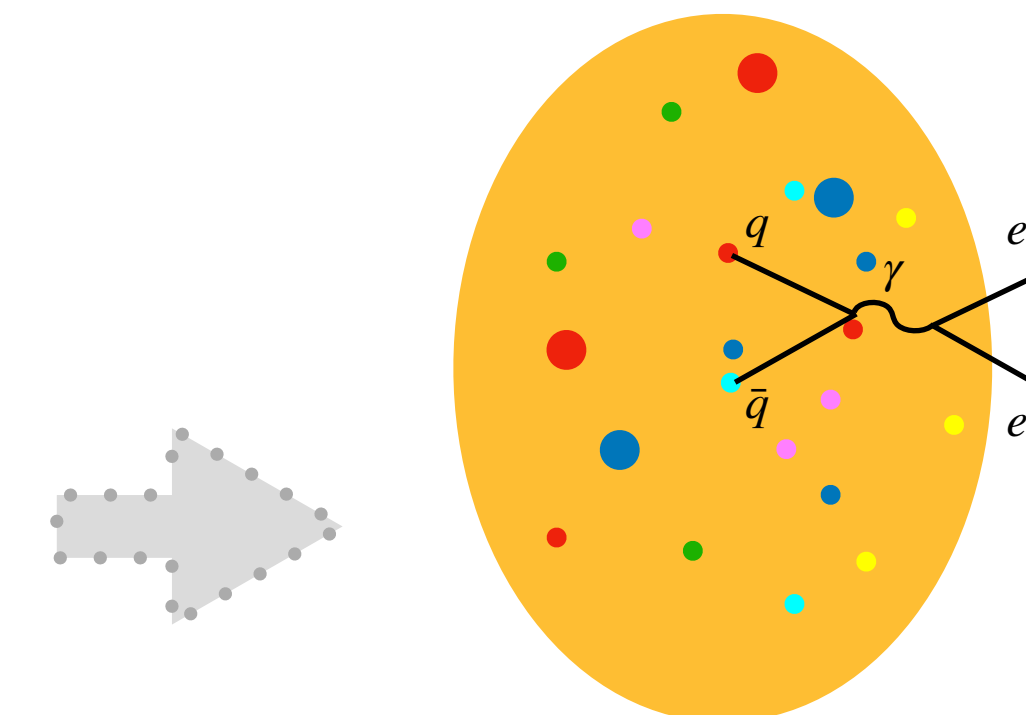
Suppression of jets with hard-fragmenting charm hadrons



Charmonium sequential suppression

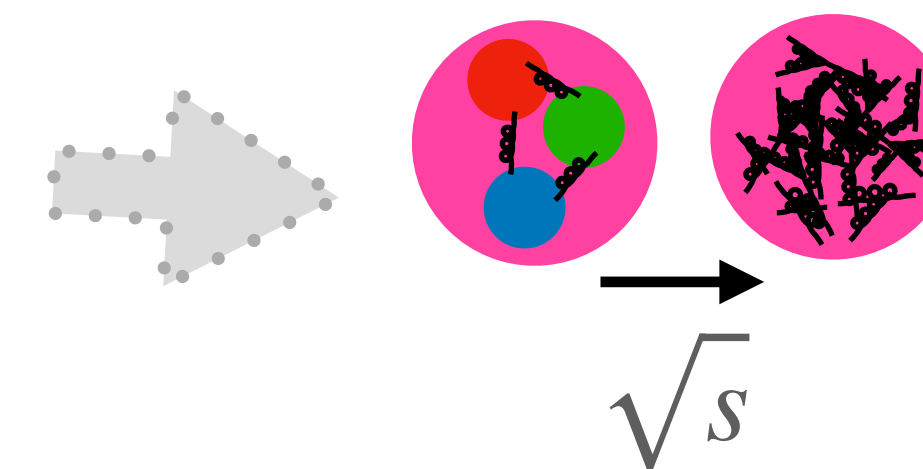


Reliable temperature extraction of QGP



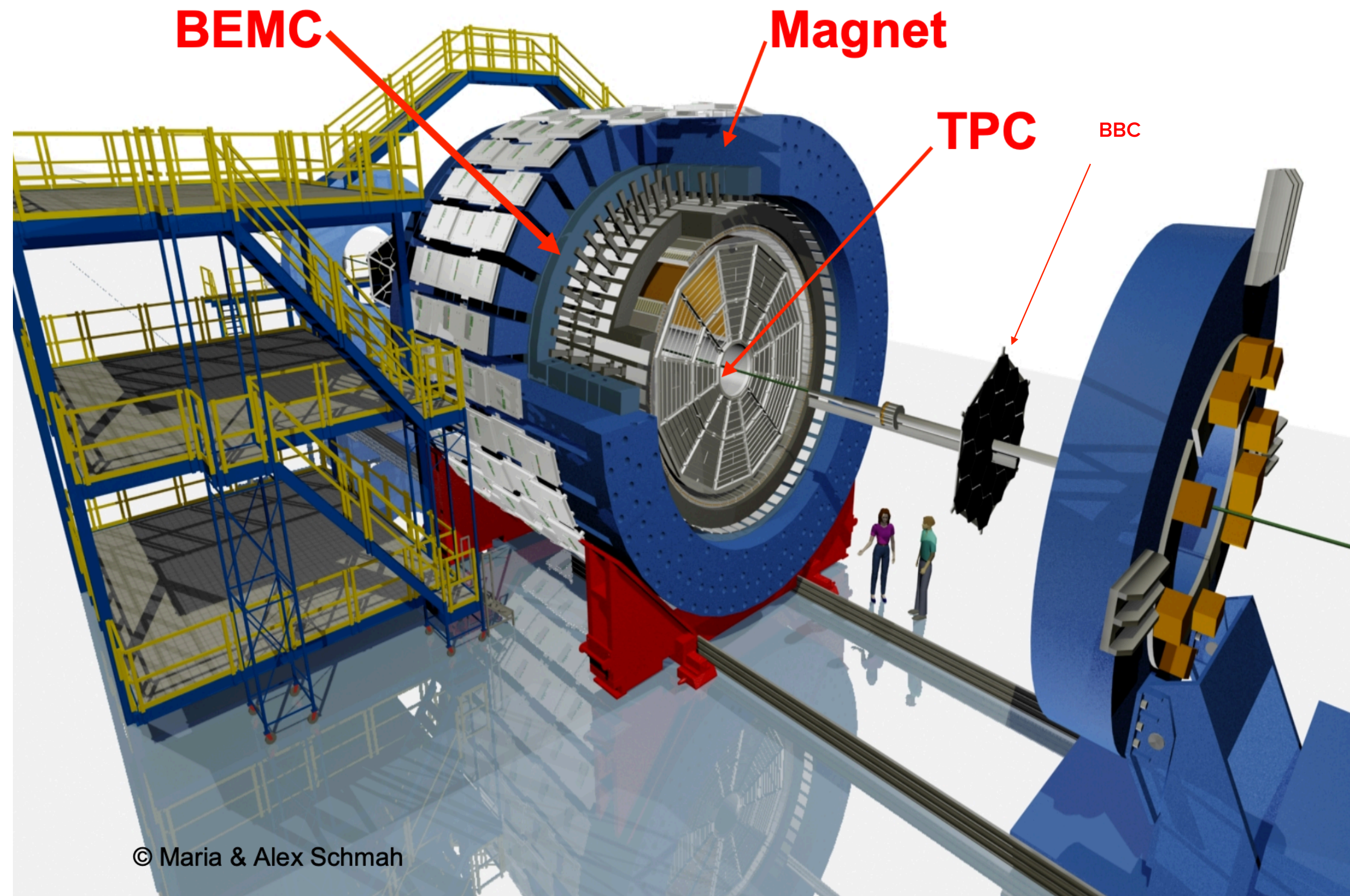
Possibly sizable MPI, string percolation contribution to J/ψ production

Influence of photon polarization and spin interference



Hard probes at STAR

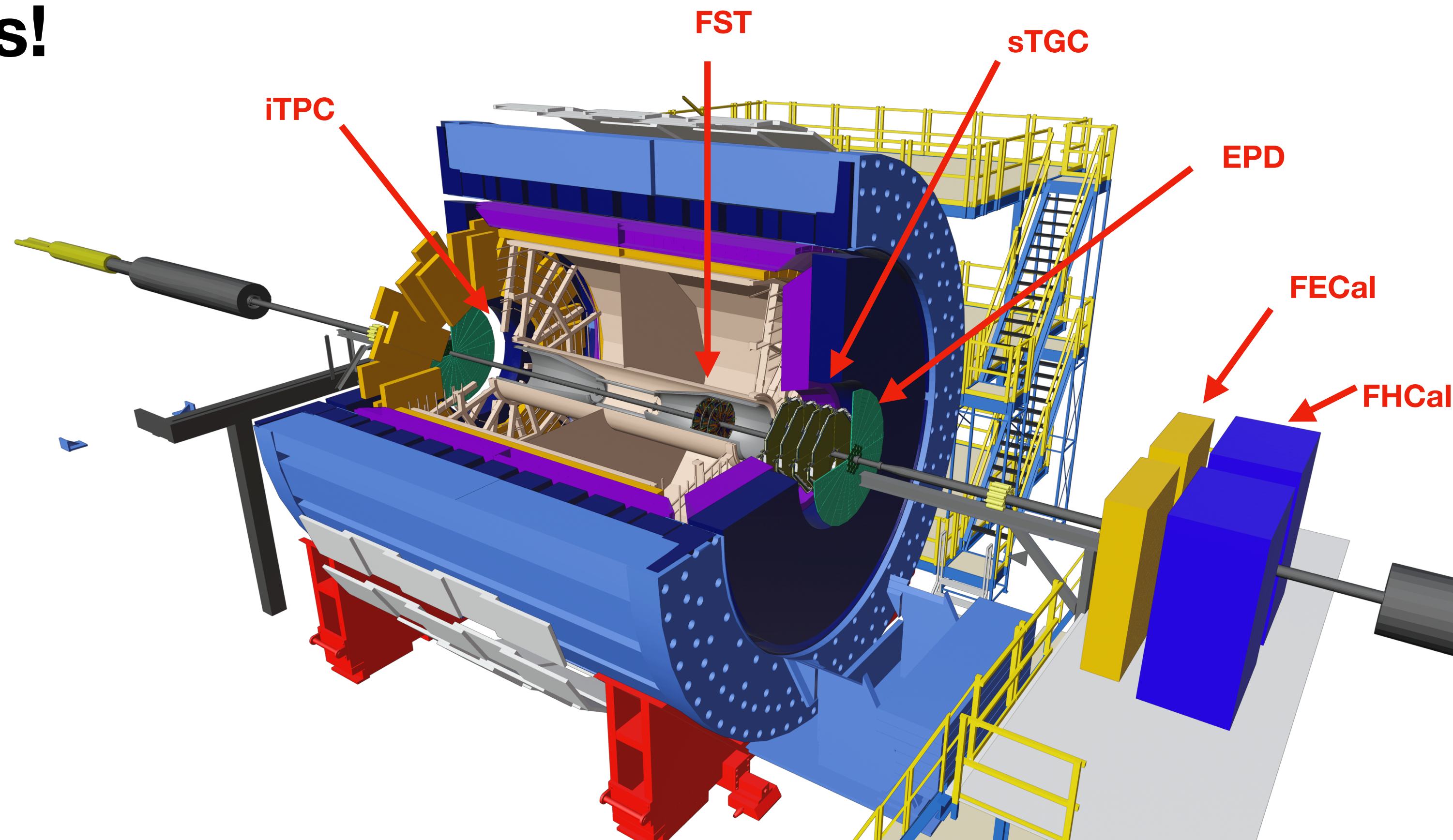
In the 2010s



© Maria & Alex Schmah

Hard probes at STAR

In the 2020s!



Precision tracking

*Forward jets →
different x ; q v. g*

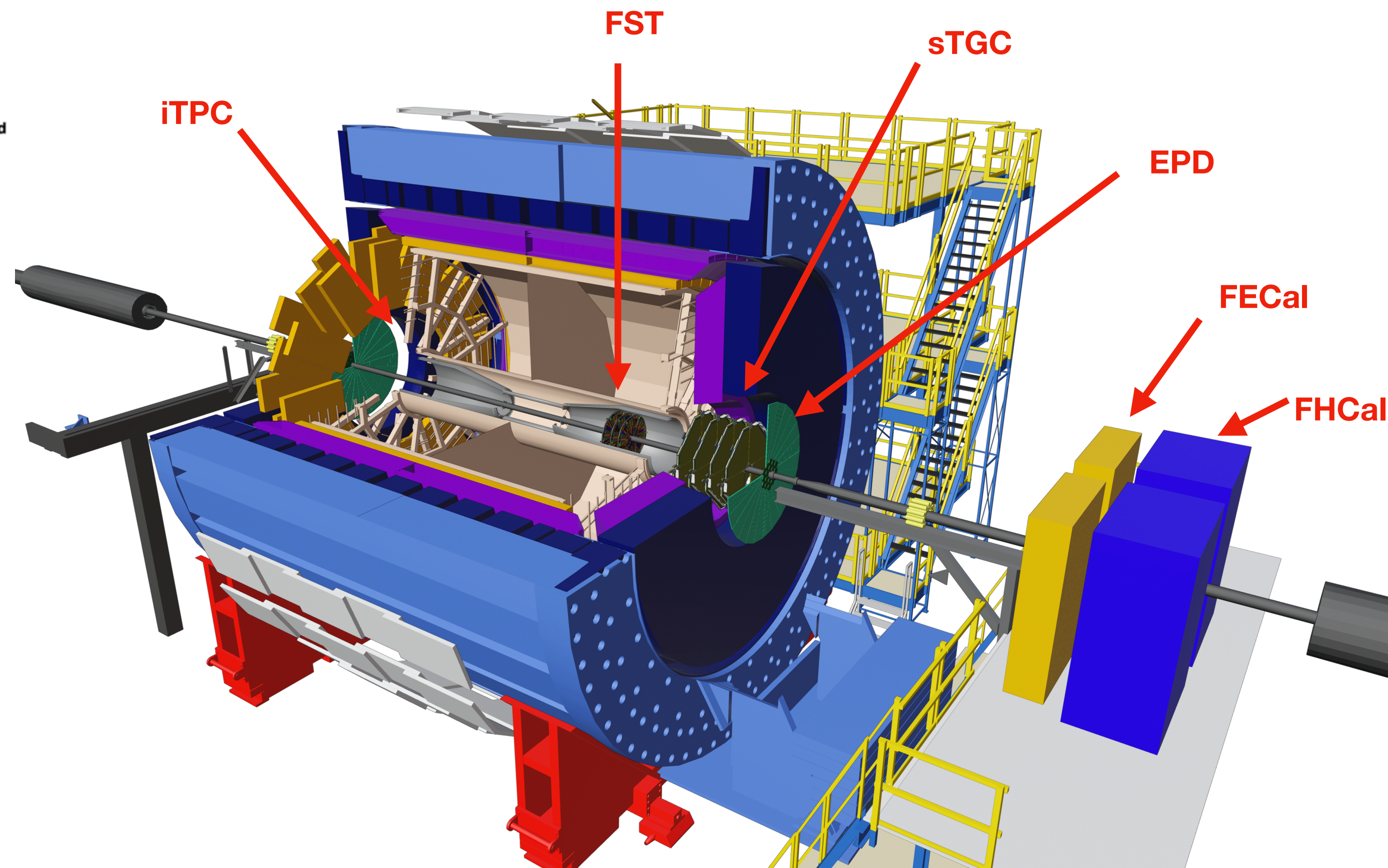
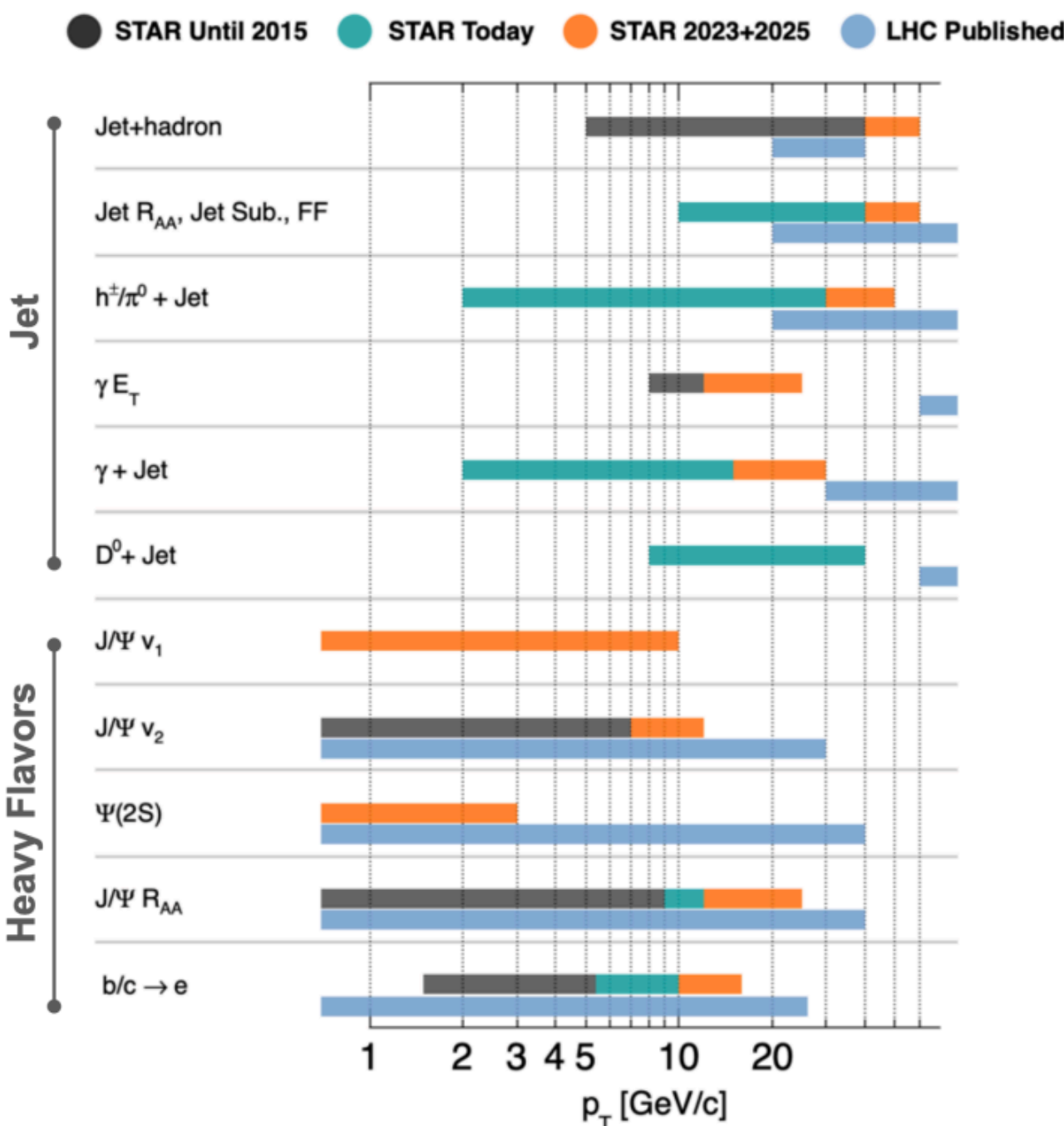
*Unbiased
centrality/EP
determination*

DAQ rate: 5 kHz

Etc!

Hard probes at STAR

In the 2020s!



Precision tracking

*Forward jets \rightarrow
different x ; q v. g*

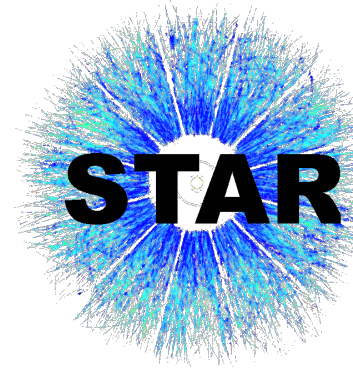
*Unbiased
centrality/EP
determination*

DAQ rate: 5 kHz

Etc!

Runs 23+25^{1,2}: expected $\sim 3 \times$ increase in statistics for hard probes measurements relative to current Au+Au analyses w/ Run 14 \rightarrow improved uncertainties & **kinematic reach / overlap w/ LHC**

Talks



Posters

Wei Zhang - Measurements of charmonium production in heavy-ion collisions at STAR - [Sep. 24, 9:40](#)

Gabe Dale-Gau - Measurements of Baryon-to-Meson Ratios Inside Jets in Au+Au and $p+p$ Collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR - [Sep 24, 10:50](#)

Andrew Tamis - Exploiting Two- and Three-point Charge-Energy Correlators at STAR as Probes of Jet Evolution - [Sep 24, 10:50](#)

Chenliang Jin - Thermal dielectron measurements in Au+Au collisions at BES-II energies with the STAR experiment - [Sep. 24, 11:30](#)

Jiaxuan Luo - Measurements of thermal dielectron and QGP temperature in isobar collisions at $\sqrt{s_{NN}} = 200$ GeV - [Sep. 24, 11:50](#)

Sooraj Radhakrishnan - Measurement of jet v_1 to study path length dependent jet energy loss in heavy-ion collisions at $\sqrt{s_{NN}} = 200$ GeV by STAR - [Sep 24, 14:00](#)

Brennan Schaefer - Measurement of J/ψ multiplicity dependent production in $p+p$ $\sqrt{s_{NN}} = 510$ GeV with STAR at RHIC - [Sep 24, 14:20](#)

Kaiyang Wang - Measurements of photon-induced J/ψ azimuthal anisotropy in isobar collisions at STAR - [Sep. 25, 9:00](#)

Youqi Song - Probing hadronization with the charge correlator ratio in pp and Ru+Ru/Zr+Zr collisions at $\sqrt{s_{NN}} = 200$ GeV at STAR - [Sep 25, 11:10](#)

Diptanil Roy - Charm Meson Tagged Jets in Au+Au Collisions at $\sqrt{s_{NN}} = 200$ GeV - [Sep 25, 11:50](#)

Diptanil Roy (for **Tanmay Pani**) - Observing jet quenching using generalized jet angularities in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV from STAR - [#97](#)

Isaac Mooney - Event-shape engineering of high-momentum probes in Au+Au collisions - [#98](#)

Xianwen Bao - Direct virtual photon production in Au+Au collisions with STAR BES-II data - [#101](#)

Jeongmyung Kang - Method of semi-inclusive jet mass measurement in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV with STAR - [#105](#)

Xinbai Li - The measurement of Drell-Söding process through exclusive $\pi^+\pi^-$ pair photoproduction in ultraperipheral Au+Au collisions at 200 GeV - [#129](#)

Thank you!