Semi-inclusive hadron+jet measurement in Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV with the STAR experiment

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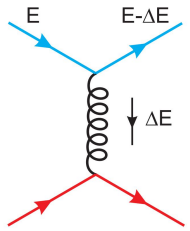
Jet quenching in QGP

Hard probe: Jets

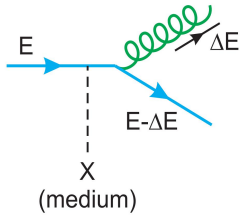
- Produced at early stage of the collisions
- Cross section in vacuum is calculable using pQCD

Parton energy loss in medium:

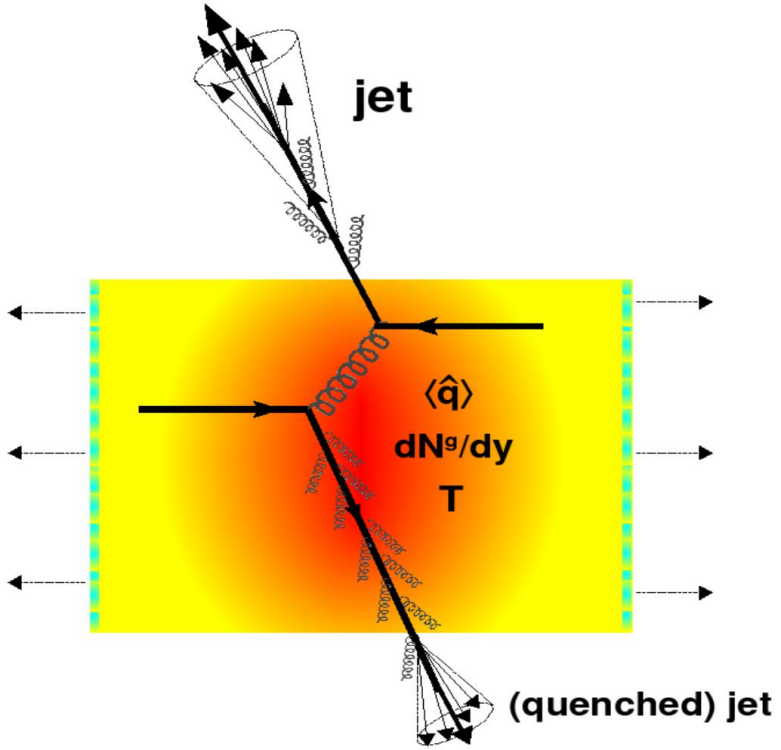
- Collisional and radiative energy loss



collisional energy loss



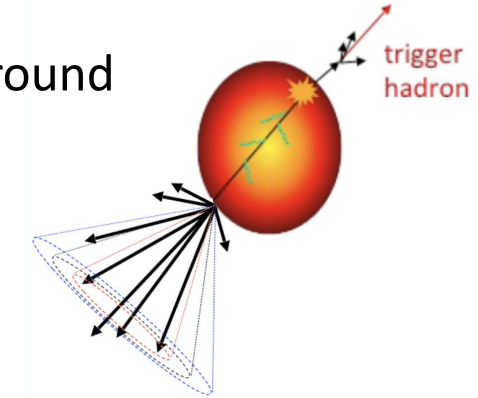
radiative energy loss



- Depends on both traversing parton's initial energy (also mass/virtuality) and medium properties, such as temperature of the medium, strong interaction coupling strength (α_s), and path length, etc.

Semi-inclusive hadron+jet to study jet quenching

- Semi-inclusive recoil jet measurement suppresses the combinational background

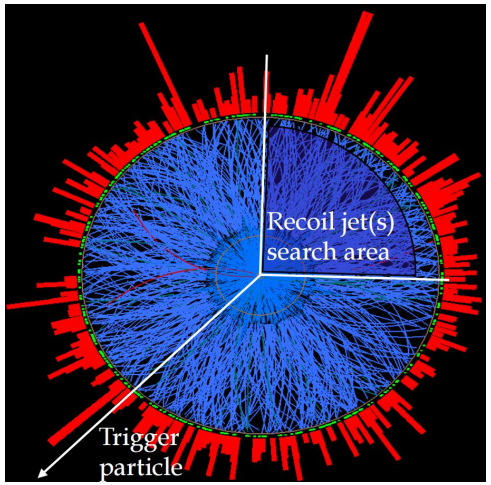


- Trigger-normalized yield of jets recoiling from a high p_T trigger hadron

$$\frac{1}{N_{\mathrm{trig}}^{\mathrm{AA}}} \cdot \frac{d^3 N_{\mathrm{jet}}^{\mathrm{AA}}}{dp_{\mathrm{T,jet}}^{\mathrm{ch}} d\Delta\phi d\eta_{\mathrm{jet}}}\bigg|_{p_{\mathrm{T,trig}}} = \left(\frac{1}{\sigma^{\mathrm{AA\to h+jet+X}}} \cdot \frac{d^3\sigma^{\mathrm{AA\to h+jet+X}}}{dp_{\mathrm{T,jet}}^{\mathrm{ch}} d\Delta\phi d\eta_{\mathrm{jet}}}\right)\bigg|_{p_{\mathrm{T,trig}}}$$

- We measure the projection of the jet yield integrated over a recoil region in azimuth relative to the trigger hadron direction

$$Y\left(p_{\mathrm{T,jet}}^{\mathrm{ch}}\right) = \int_{3\pi/4}^{5\pi/4} d\Delta\phi \left[\frac{1}{N_{\mathrm{trig}}^{\mathrm{AA}}} \cdot \frac{d^3 N_{\mathrm{jet}}^{\mathrm{AA}}}{dp_{\mathrm{T,jet}}^{\mathrm{ch}} d\Delta\phi d\eta_{\mathrm{jet}}}\bigg|_{p_{\mathrm{T,trig}} > p_{\mathrm{T,thresh}}}\right]$$



- Jet quenching observable:

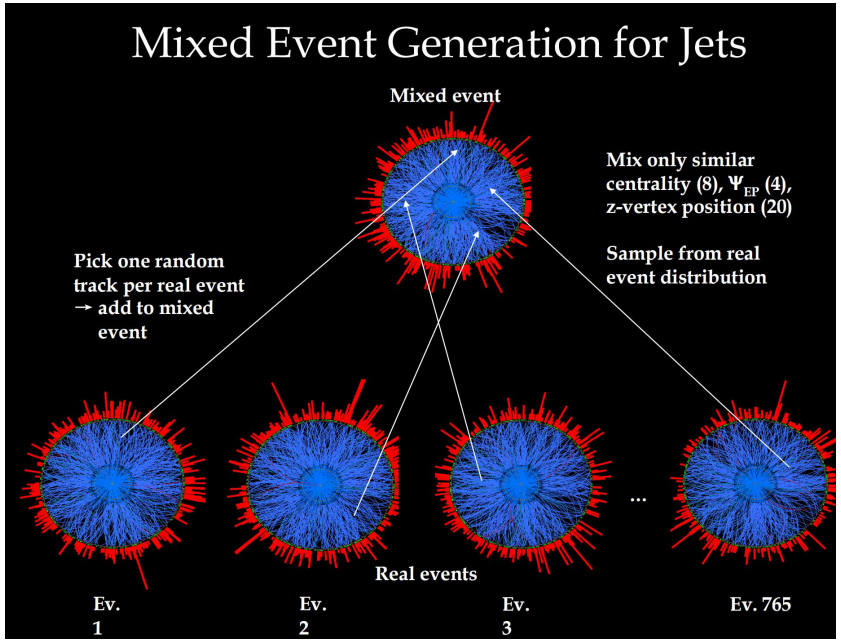
$$I_{\mathrm{CP}} = \frac{Y(p_{\mathrm{T,jet}}^{\mathrm{ch}})\big|_{0-10\%}}{Y(p_{\mathrm{T,jet}}^{\mathrm{ch}})\big|_{60-80\%}}$$

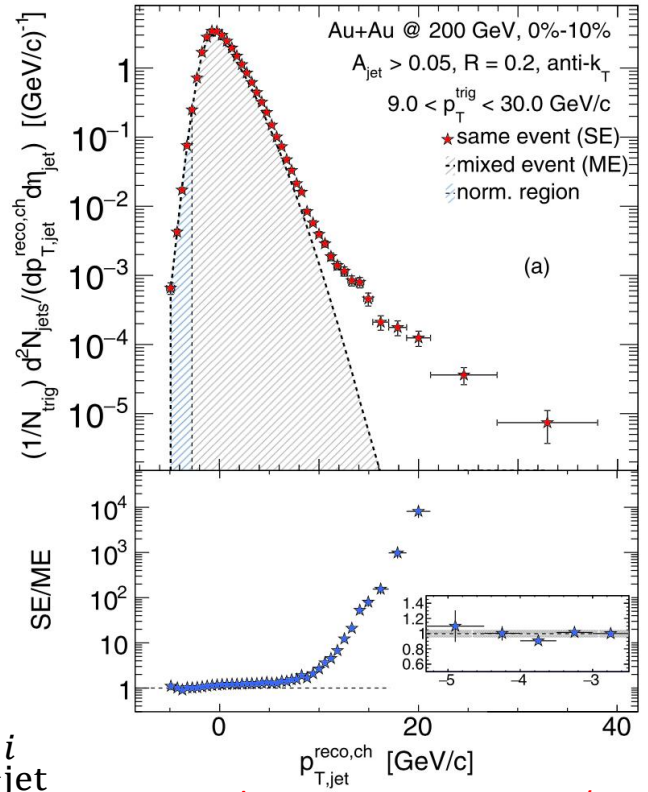
Semi-inclusive hadron+jet measurement in STAR

- Use anti-k_T algorithm to reconstruct jets and calculate recoil charged jet transverse momentum

  Corrected by the estimated background energy density
- Uncorrelated jet yield correction: Mixed-Event (ME) approach
- Correction for Jet Energy Scale (JES) and Jet Energy Resolution (JER) effects:

  Unfolding -> Factorize instrumentation and background fluctuation effects





$$p_{\mathrm{T,jet}}^{\mathrm{reco},i} = p_{\mathrm{T,jet}}^{\mathrm{raw},i} - \rho \cdot A_{\mathrm{jet}}^{i}$$

$$\rho = median\left\{\frac{p_{\mathrm{T,jet}}^{\mathrm{raw},i}}{A_{\mathrm{jet}}^{i}}\right\}; \quad A_{\mathrm{jet}}^{i} : Area\ of\ jet$$

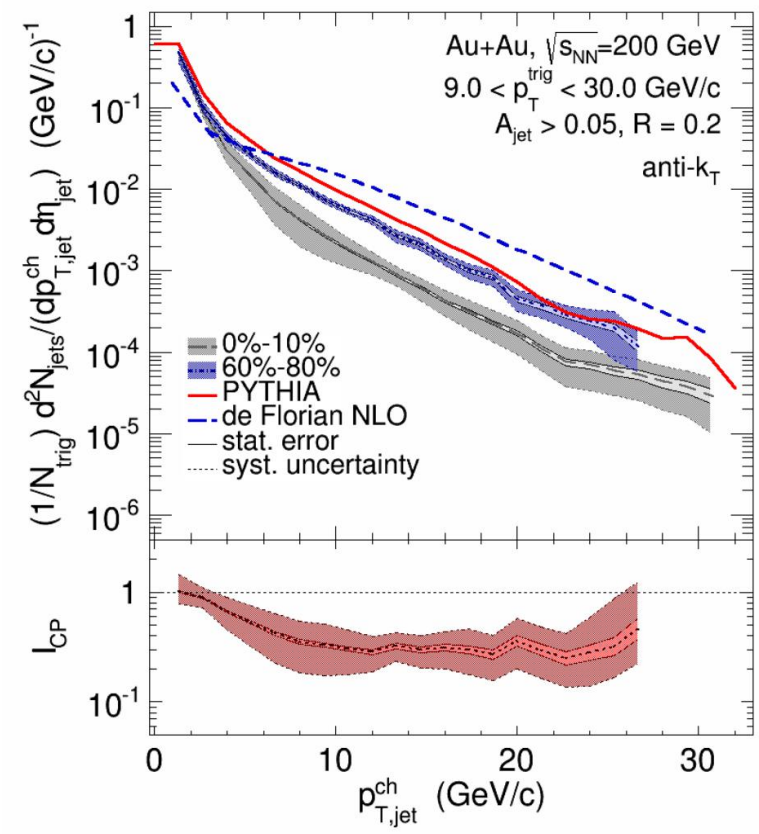
STAR: Phys. Rev. C 96, 024905 (2017)

Semi-inclusive hadron+jet measurement in STAR

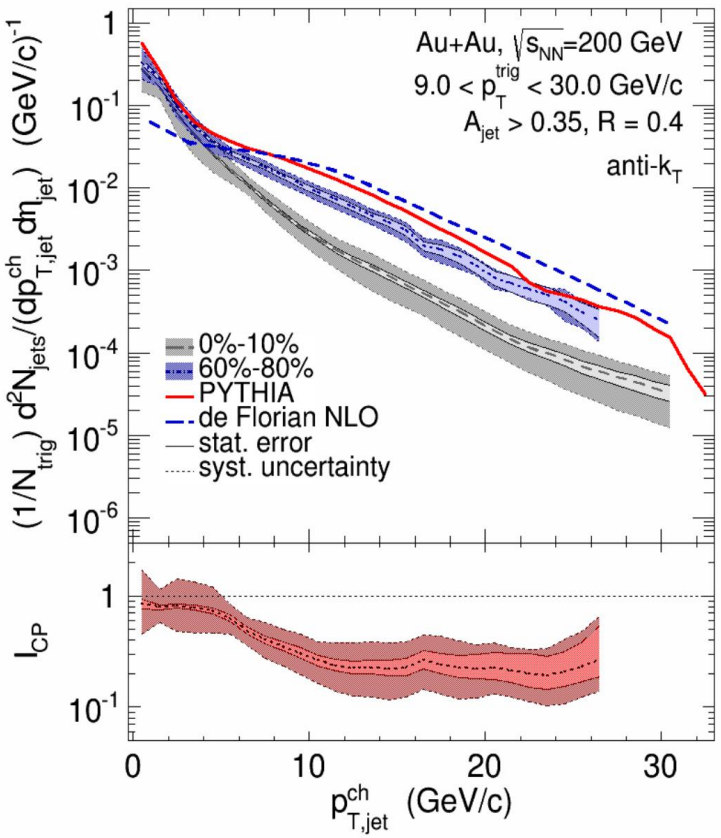
STAR: Phys. Rev. C 96, 024905 (2017)

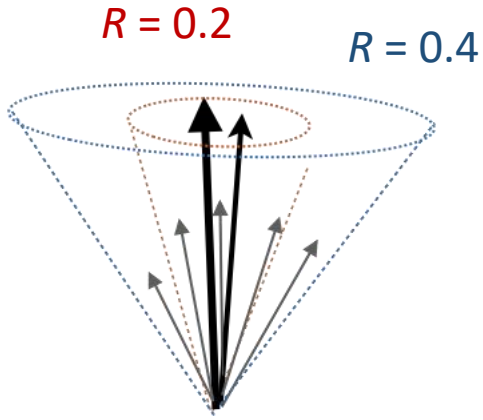
Results in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV

Jet R = 0.2



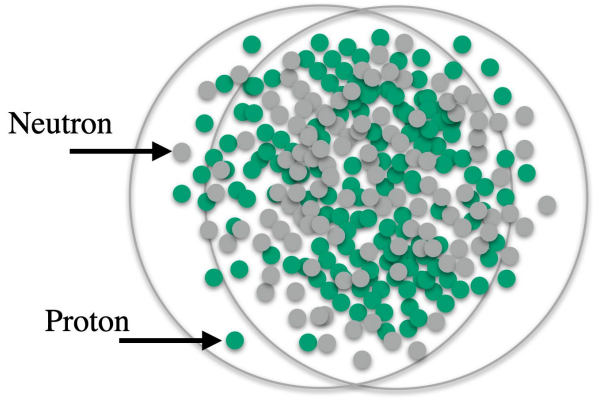
Jet R = 0.4



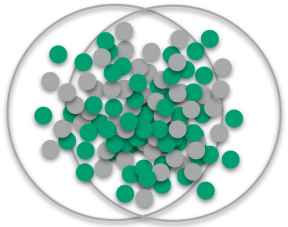


Strong suppression of recoil charged jet yields in central to peripheral Au+Au collisions for jets with R=0.2 and R=0.4

Semi-incl. h+jet in Ru+Ru and Zr+Zr



$^{197}_{79}Au + ^{197}_{79}Au$



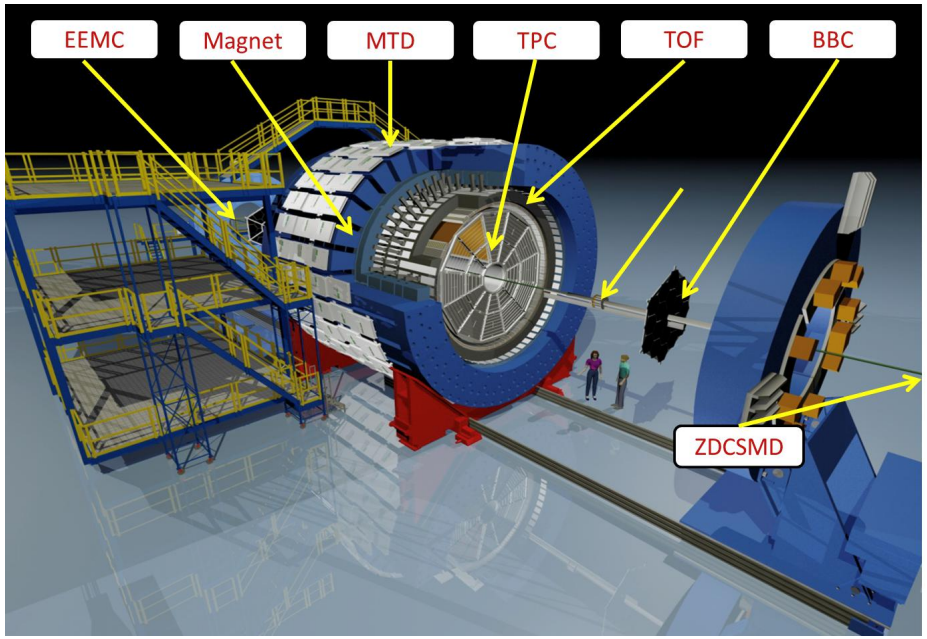
$^{96}_{40}Zr + ^{96}_{40}Zr$ / $^{96}_{44}Ru + ^{96}_{44}Ru$

Study jet-quenching in a relatively smaller collision system (Zr+Zr and Ru+Ru) than Au+Au collisions using semi-inclusive h+jet measurement

Provide information of parton energy loss for different initial energy density, temperature of the medium, and smaller path length compared to Au+Au collisions

STAR detector

Time Projection Chamber (TPC):
Provides tracking for charged particles within ± 1 unit of pseudo-rapidity and covers 2π in azimuth



Year 2018 data taking for Ru+Ru and Zr+Zr at $\sqrt{s_{NN}}$ = 200 GeV
full production(~4B good events) is ready and being actively worked on, but only 13% statistics are shown in this talk
Charged particles:

$|\eta| < 1, 0.2 < p_T < 30$ GeV/c

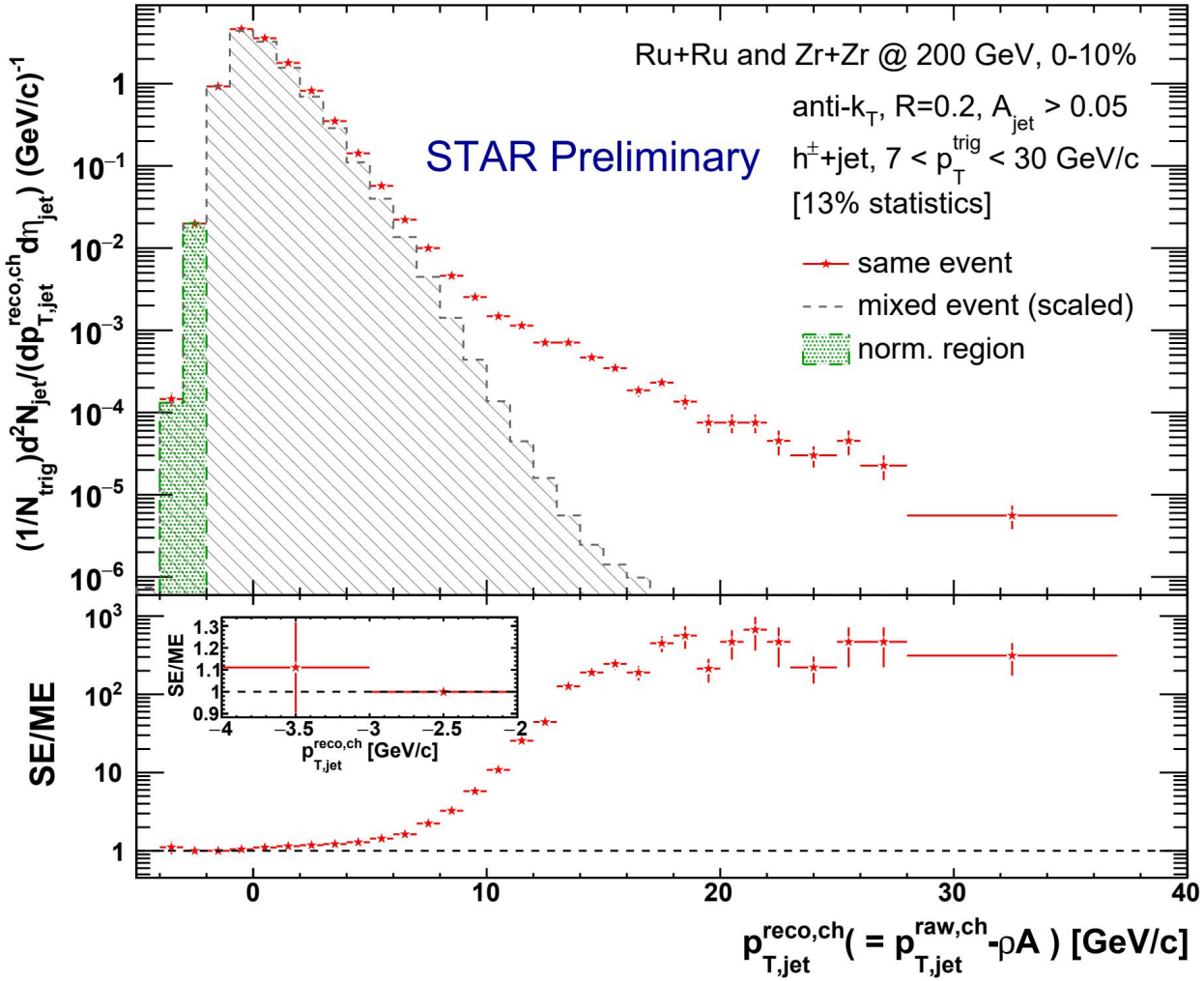
Jet reconstruction:

anti-k_T algorithm, Jet R = 0.2 and 0.4, $|\eta_{jet}| < 1$ - Jet R

	0-10% centrality	60-80% centrality
Current statistics for this presentation (~13%)	~124k (trigger events $7 < p_T^{trig} < 30$ GeV/c)	~14k (trigger events $7 < p_T^{trig} < 30$ GeV/c)
Full statistics (ongoing)	~0.95M	~0.11M

h+jet p_T spectrum for jets with R = 0.2

0-10% centrality in Ru+Ru and Zr+Zr collisions

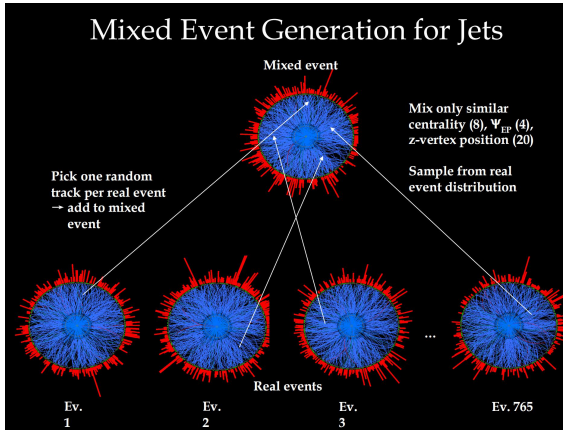


$$7 < p_{\mathrm{T}}^{\mathrm{trig}} < 30\ \mathrm{GeV}/c$$

$p_{\mathrm{T,jet}}^{\mathrm{reco}} < 0$: Almost identical between the same-event (SE) and mixed-event (ME) jet p_T spectra

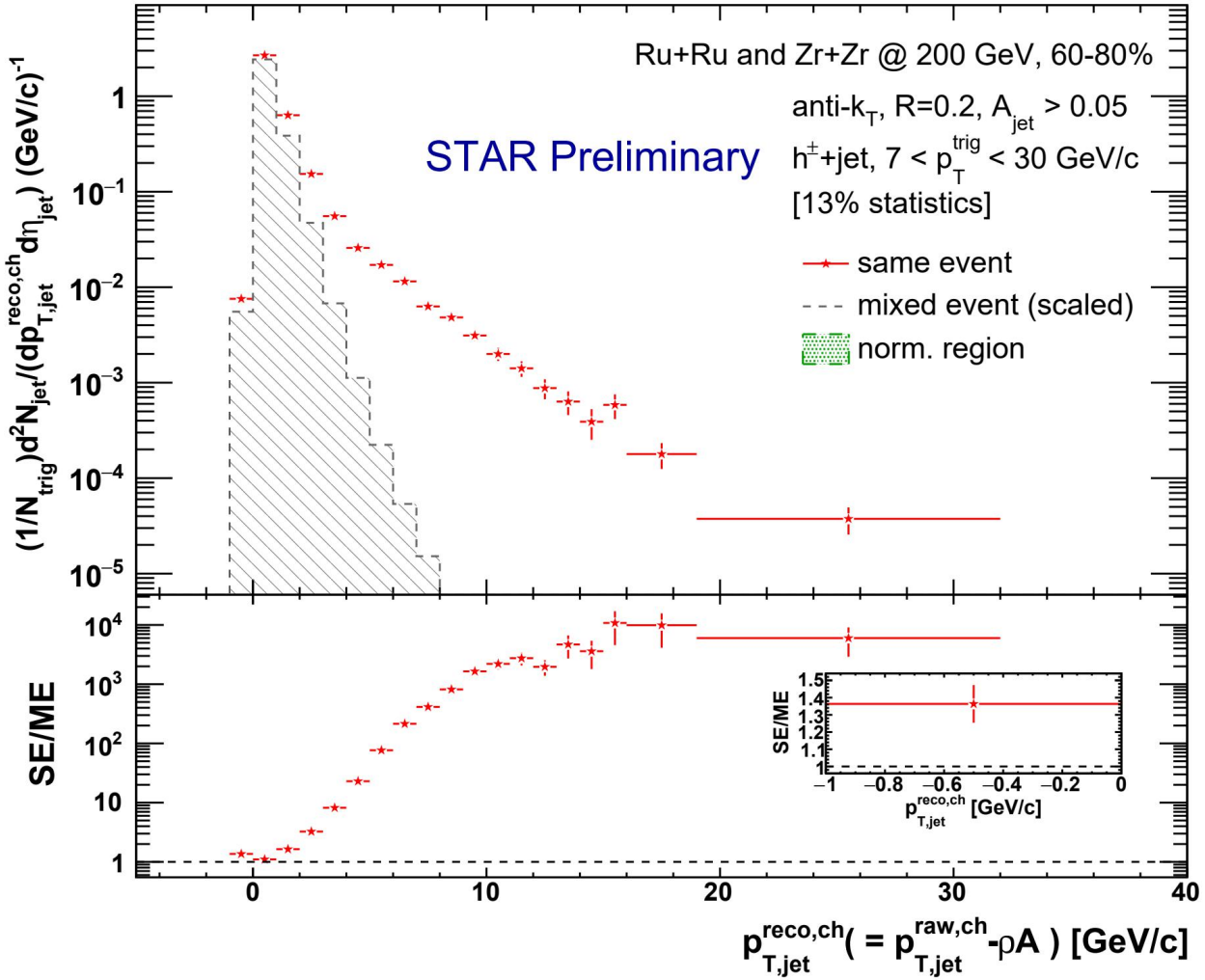
$p_{\mathrm{T,jet}}^{\mathrm{reco}} > 0$: Correlated (w.r.t. trigger particles) jet contribution dominates over uncorrelated jet contribution at high $p_{\mathrm{T,jet}}^{\mathrm{reco}}$

ME works very well for this analysis



h+jet p_T spectrum for jets with R = 0.2

60-80% centrality in Ru+Ru and Zr+Zr collisions



$$7 < p_{\mathrm{T}}^{\mathrm{trig}} < 30\ \mathrm{GeV}/c$$

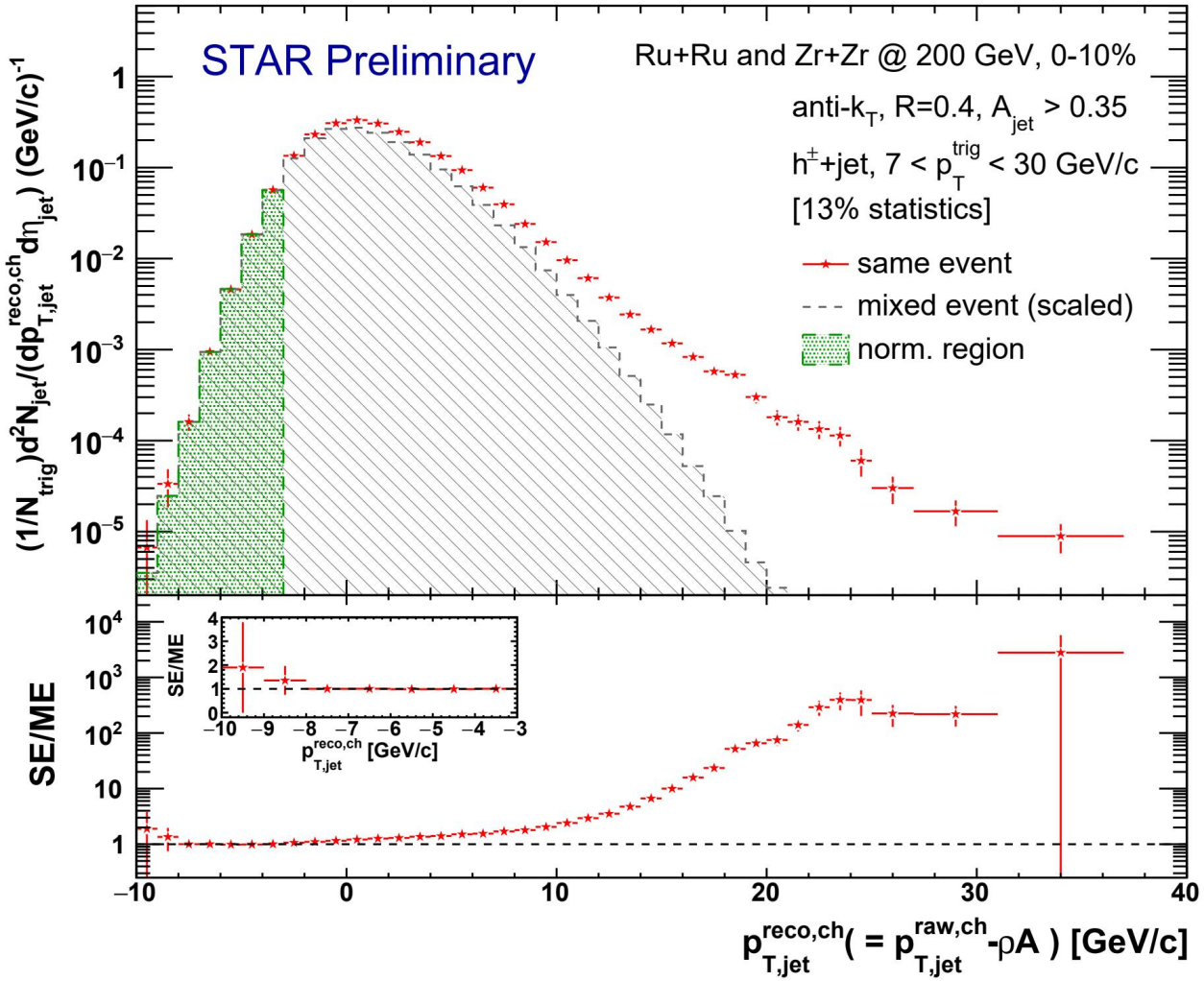
$p_{\mathrm{T,jet}}^{\mathrm{reco}} < 0$: Almost identical between the same-event (SE) and mixed-event (ME) jet p_T spectra

Uncorrelated jet contribution is less in 60-80% centrality compared to 0-10% centrality

$p_{\mathrm{T,jet}}^{\mathrm{reco}} > 0$: Correlated (w.r.t. trigger particles) jet contribution dominates over uncorrelated jet contribution at high $p_{\mathrm{T,jet}}^{\mathrm{reco}}$

h+jet p_T spectrum for jets with R = 0.4

0-10% centrality in Ru+Ru and Zr+Zr collisions



$$7 < p_{\mathrm{T}}^{\mathrm{trig}} < 30\ \mathrm{GeV}/c$$

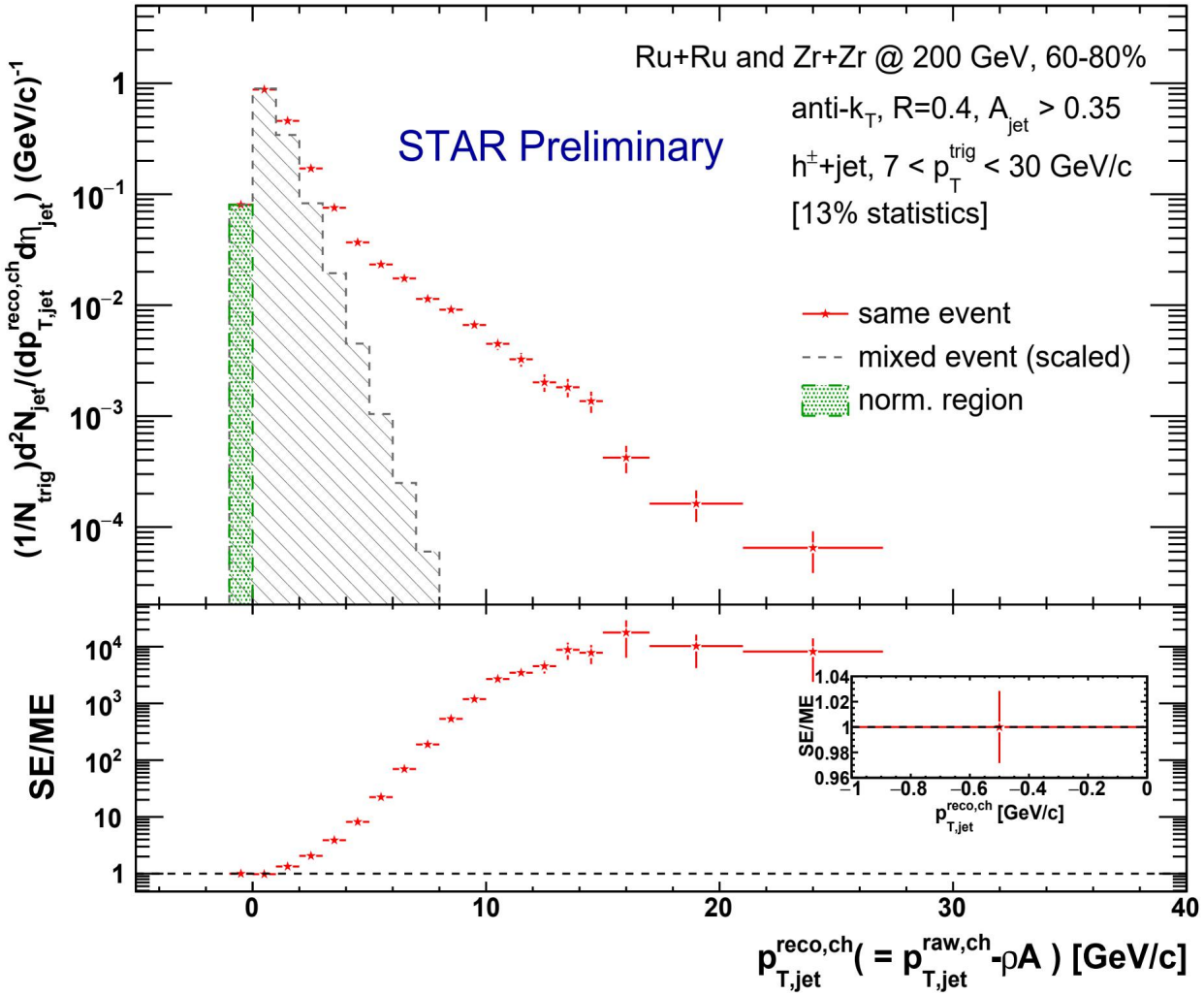
$p_{\mathrm{T,jet}}^{\mathrm{reco}} < 0$: Almost identical between the same-event (SE) and mixed-event (ME) jet p_T spectra

Relatively large uncorrelated contribution due to larger jet R = 0.4

$p_{\mathrm{T,jet}}^{\mathrm{reco}} > 0$: Correlated (w.r.t. trigger particles) jet contribution dominates over uncorrelated jet contribution at high $p_{\mathrm{T,jet}}^{\mathrm{reco}}$

h+jet p_T spectrum for jets with R = 0.4

60-80% centrality in Ru+Ru and Zr+Zr collisions



$$7 < p_{\mathrm{T}}^{\mathrm{trig}} < 30\ \mathrm{GeV}/c$$

$p_{\mathrm{T,jet}}^{\mathrm{reco}} < 0$: Almost identical between the same-event (SE) and mixed-event (ME) jet p_T spectra

Uncorrelated jet contribution is less in 60-80% centrality compared to 0-10% centrality

$p_{\mathrm{T,jet}}^{\mathrm{reco}} > 0$: Correlated (w.r.t. trigger particles) jet contribution dominates over uncorrelated jet contribution at high $p_{\mathrm{T,jet}}^{\mathrm{reco}}$

Summary

- STAR published semi-inclusive h+jet measurements in Au+Au collisions
  - Observed strong suppression in recoil jets in central relative to peripheral collisions
  - Similar level of suppression for jet radii *R* between 0.2 and 0.5 within uncertainties
- Ru+Ru and Zr+Zr collisions can help to study parton energy loss in a relatively small collision system compared to Au+Au collisions
  - In this talk, we presented preliminary results with 13% statistics
  - ME approach for precise background correction works well
  - Work on full statistics and different correction

Outlook

We are working on full statistics for Ru+Ru and Zr+Zr collisions

- 13% statistics for this presentation
- Full statistics have a large impact for this measurement
- We expect to have a high jet p_T reach
- Smaller systematic uncertainties in these data than Au+Au collisions for the 0-10% centrality

	0-10% centrality	60-80% centrality
Current statistics for this presentation (~13%)	~124k (trigger events $7 < p_T^{trig} < 30$ GeV/c)	~14k (trigger events $7 < p_T^{trig} < 30$ GeV/c)
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Ongoing work: fully corrected recoil charged jet p_T spectrum and calculation of nuclear modification factor (I_{CP})

Thank You!