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Measurements of jet and soft activity in $\sqrt{s_{\mathrm{NN}}} = 200$ GeV *p*+Au collisions at STAR

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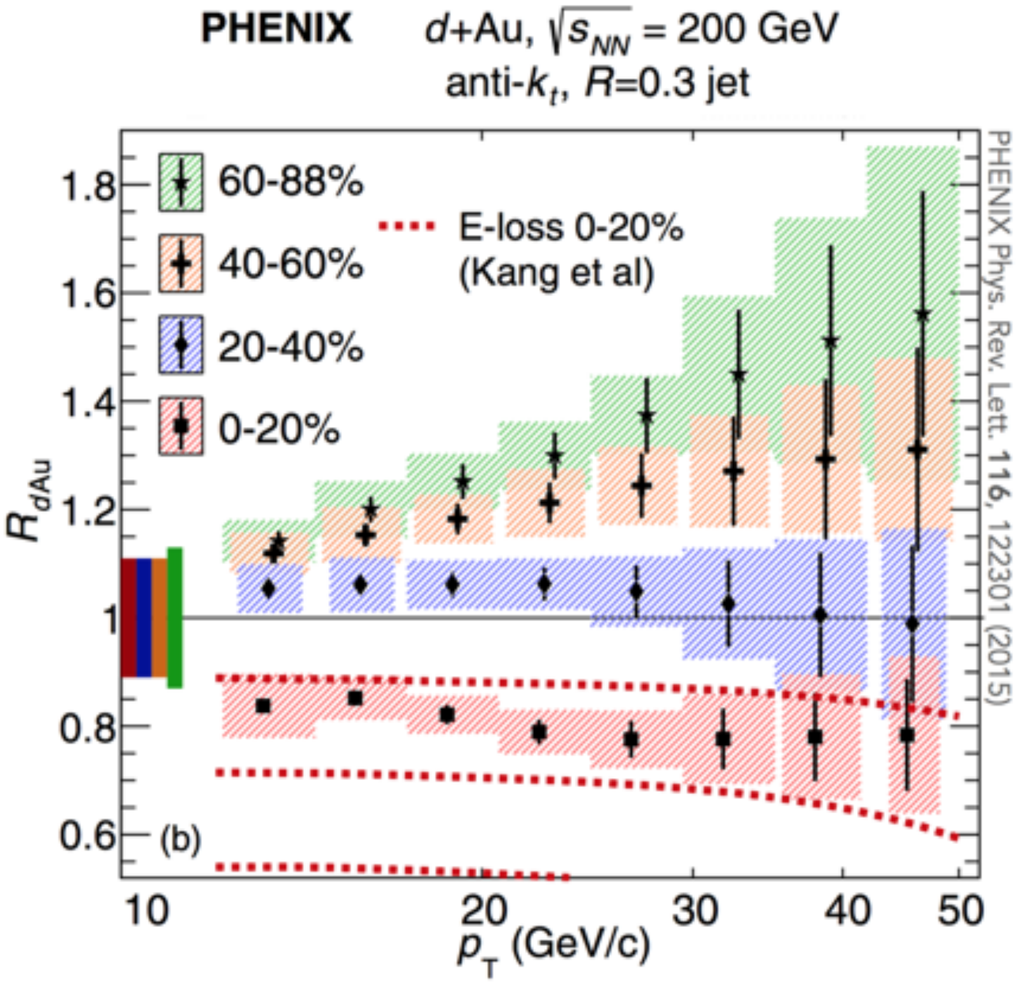
APS physics

Introduction



- Jets commonly used to probe for existence and properties of quark-gluon plasma (QGP)
- Unexpected observation by ATLAS and PHENIX of jet modification in small systems (such as *p*+A), thought *too small* of a system to form QGP
- Effect of hard scattering (jet) on soft particle production?
  - Specifically, event activity (EA) at backward rapidity and underlying event (UE) at mid-rapidity (used to define centrality)

Jet Suppression in ATLAS: *Phys. Let. B. 748* https://doi.org/10.1016/j.physletb.2015.07.023

Experiment

Barrel Electromagnetic Calorimeter (BEMC)

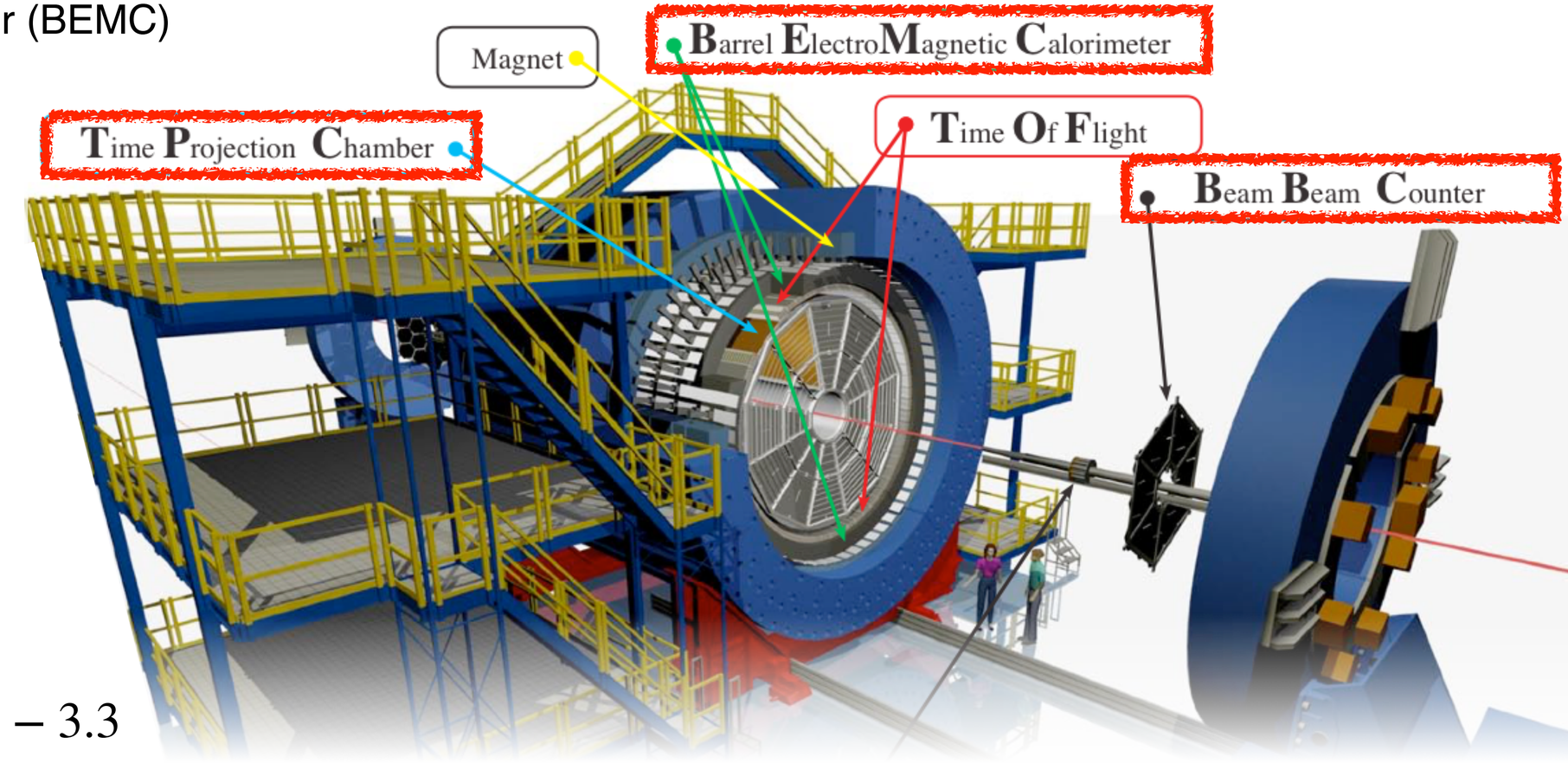
- $0.2 \leq E_{\mathrm{T}} \leq 30.0$ GeV
- γ, π^0, $e^{\pm}$, … $|\eta| < 1$,
- $0 < \phi < 2\pi$

Time Projection Chamber (TPC)

- Charged tracks, $|\eta| < 1$
- $0.2 \leq p_{\mathrm{T}} \leq 30.0$ GeV/c
- $0 < \phi < 2\pi$

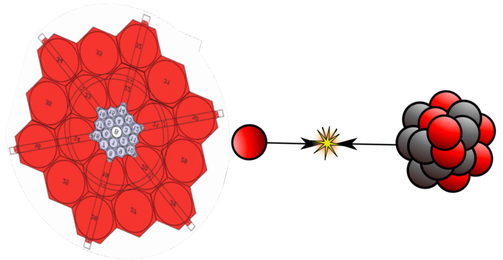
Beam Beam Counter (BBC)

- Scintillator detector
- East inner BBC: $-5.2 < \eta < -3.3$

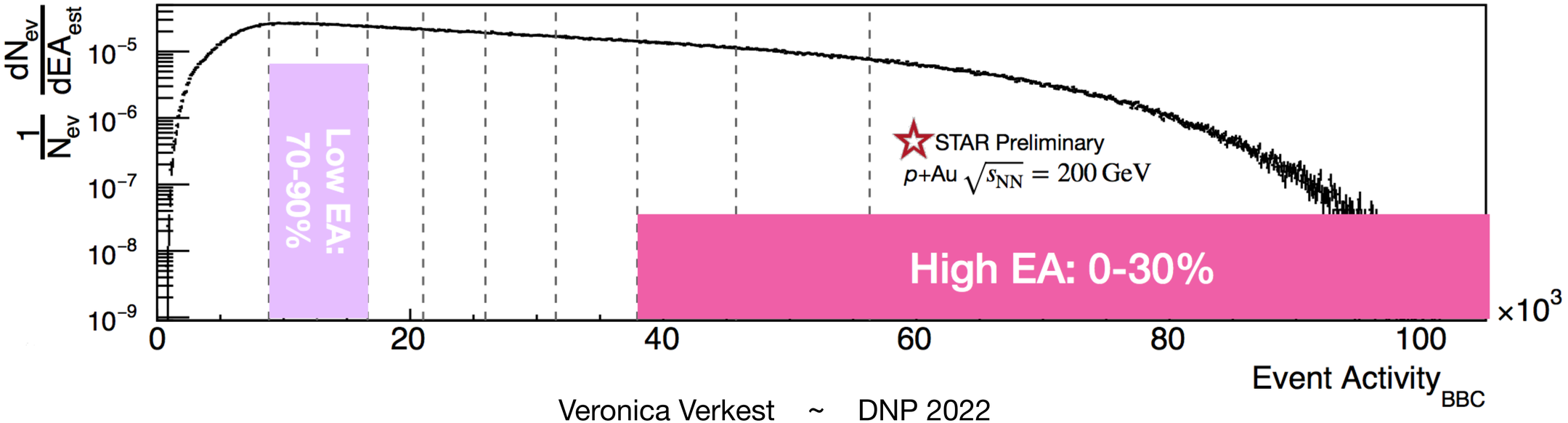


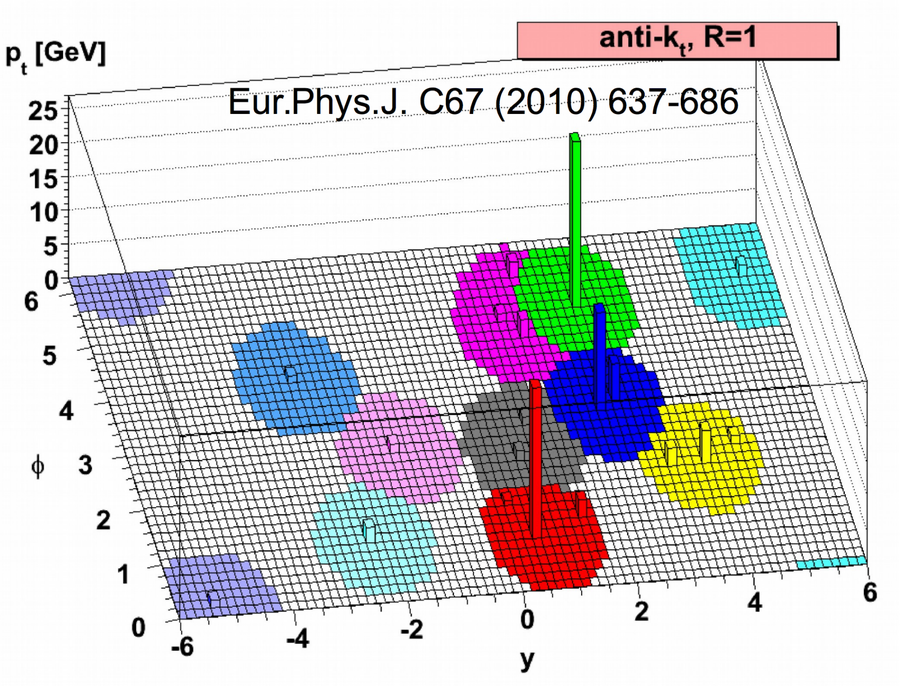
Solenoidal Tracker At RHIC : $-1 < \eta < 1, 0 < \phi < 2\pi$

Event activity



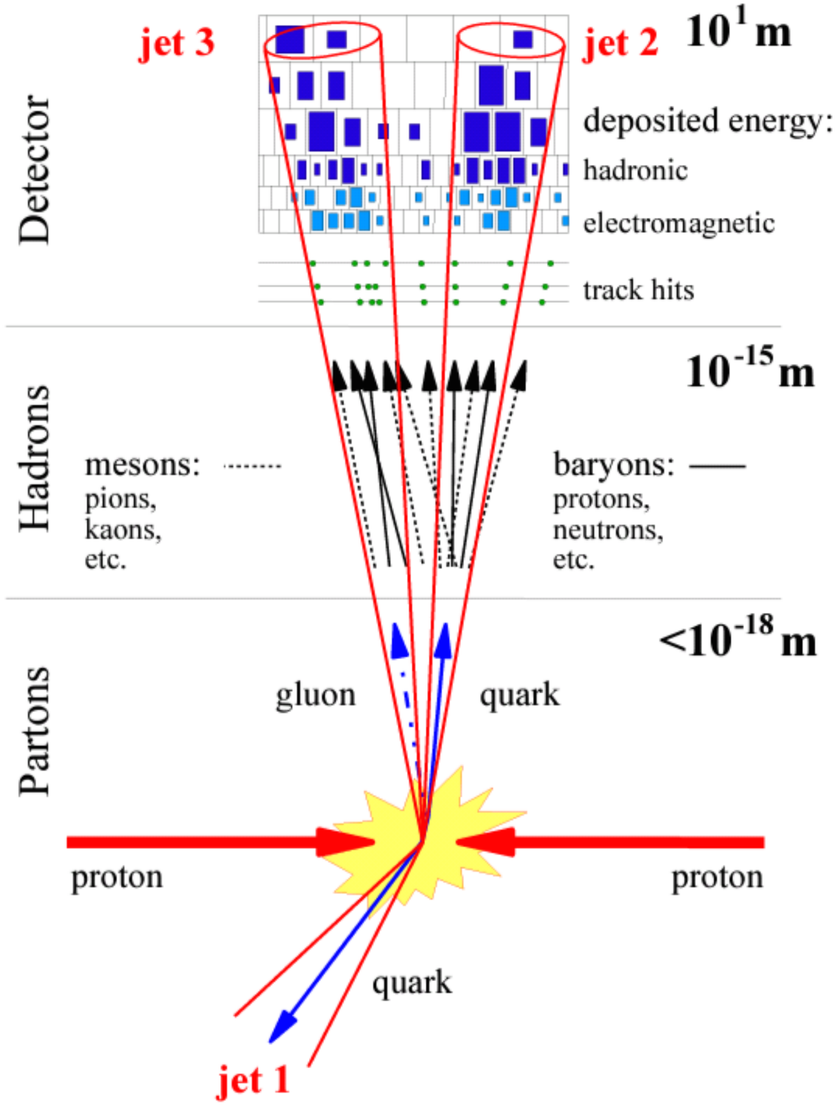
- Event activity (EA) defined by the signal sum (iBBCEsum) of the **inner tiles of the BBC** in the Au-going direction ($-5.2 < \eta < -3.3$)
- Centrality not easily defined in *p*+Au collisions; use backward event activity (EA) as a proxy for centrality (related to impact parameter)
- EA percentiles determined by iBBCEsum distribution of min-bias *p*+Au events





Jet finding

Jet: highly-energetic spray of collimated hadrons resulting from a **hard scattering** of partons; small cross section



Rabbertz, K.
https://doi.org/10.1007/978-3-319-42115-5

- Relate theory to experiment: reconstruct kinematics of hard scattered partons from final state particles in the detector
- Hard scattering: large momentum transfer (Q^2)
- Jets clustered using the anti-k_T algorithm with resolution parameter, R=0.4

Jets and UE measurement method

- Trigger: BEMC tower with transverse energy $E_{\mathrm{T}} > 5.4$ GeV
- Must be within the leading jet radius or the leading jet must be in the trigger recoil region: $|\phi_{\mathrm{lead}} - \phi_{\mathrm{trig}}| < R$ or $|\phi_{\mathrm{lead}} - \phi_{\mathrm{trig}}| > \pi - R$
- $R = 0.4$ anti-k_{T} jets
- Jet requirements: $|\eta_{\mathrm{lead}}| < 1 - R$ and $10 < p_{\mathrm{T,lead}}^{\mathrm{reco}} \leq 30$ GeV/c

Charged tracks:

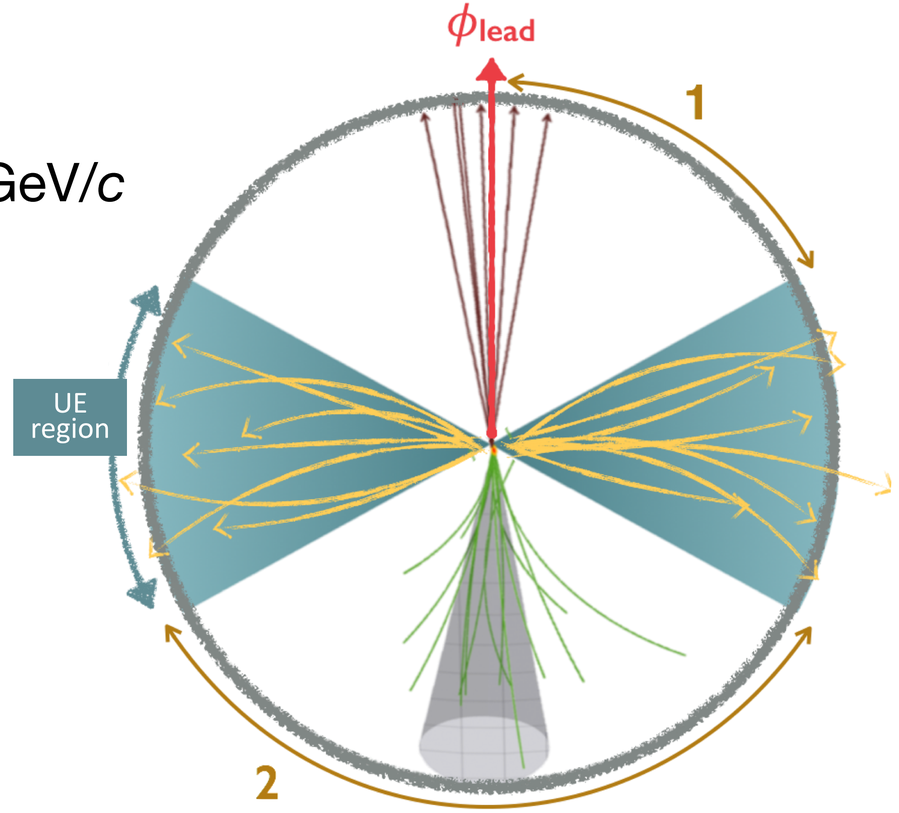
$0.2 \leq p_{\mathrm{T}} \leq 30.0$ GeV/c

Neutral towers:

$0.2 \leq E_{\mathrm{T}} \leq 30.0$ GeV

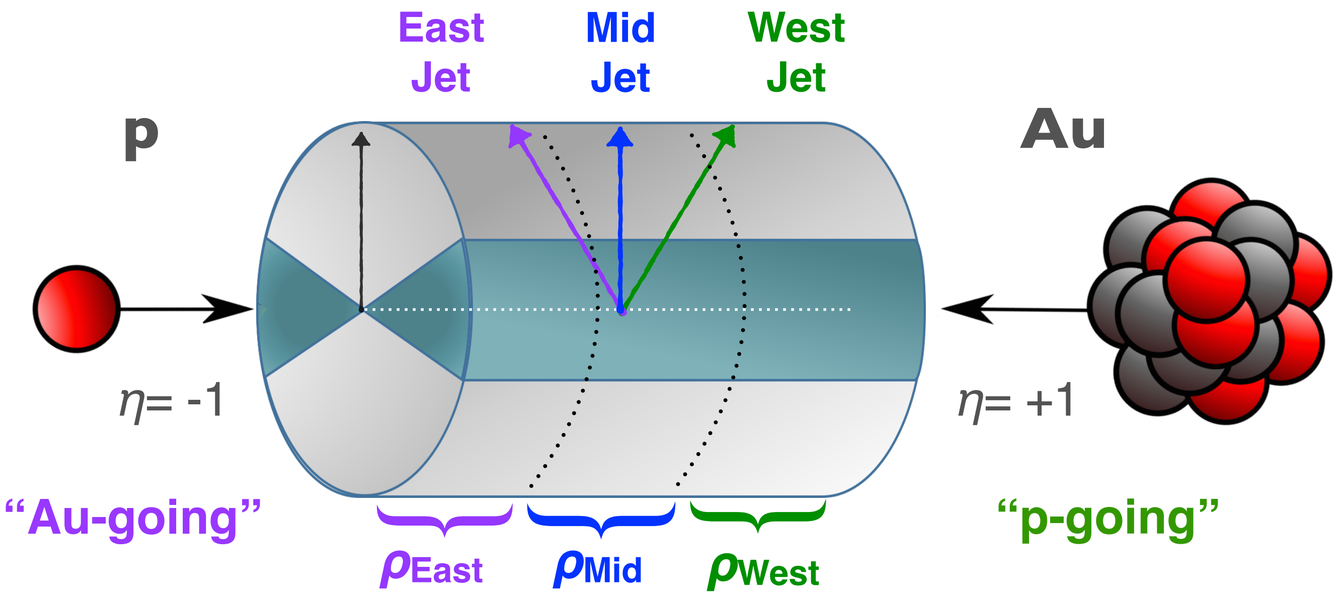
$$p_{\mathrm{T,jet}}^{\mathrm{reco}} = p_{\mathrm{T,jet}}^{\mathrm{raw}} - \langle \rho \rangle \cdot A_{\mathrm{jet}}$$

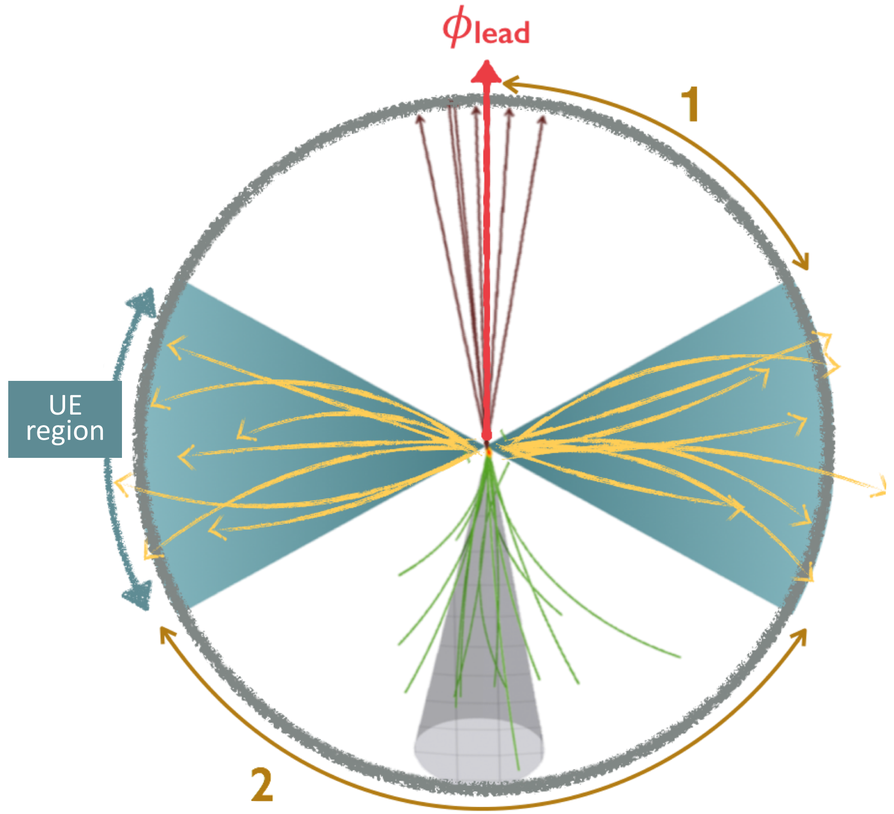
$$\langle \rho \rangle = \left\langle \rho \left(\eta_{\mathrm{jet}}, \mathrm{EA}_{\mathrm{BBC}} \right) \right\rangle$$



Jets and UE measurement method

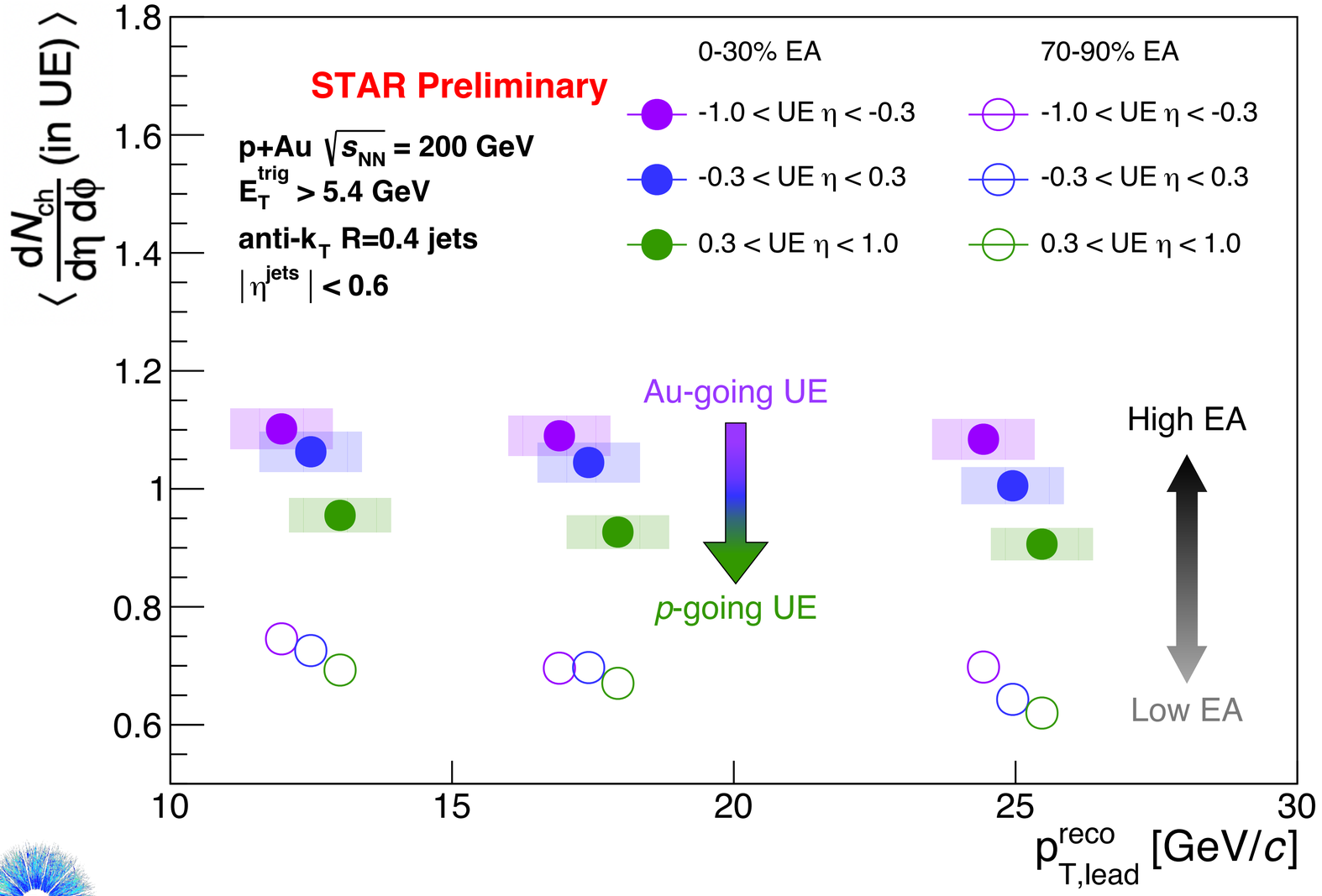
UE is defined by charged particle production in $1 < |\phi_{\text{lead}} - \phi_{\text{UE}}| < \pi - 1$





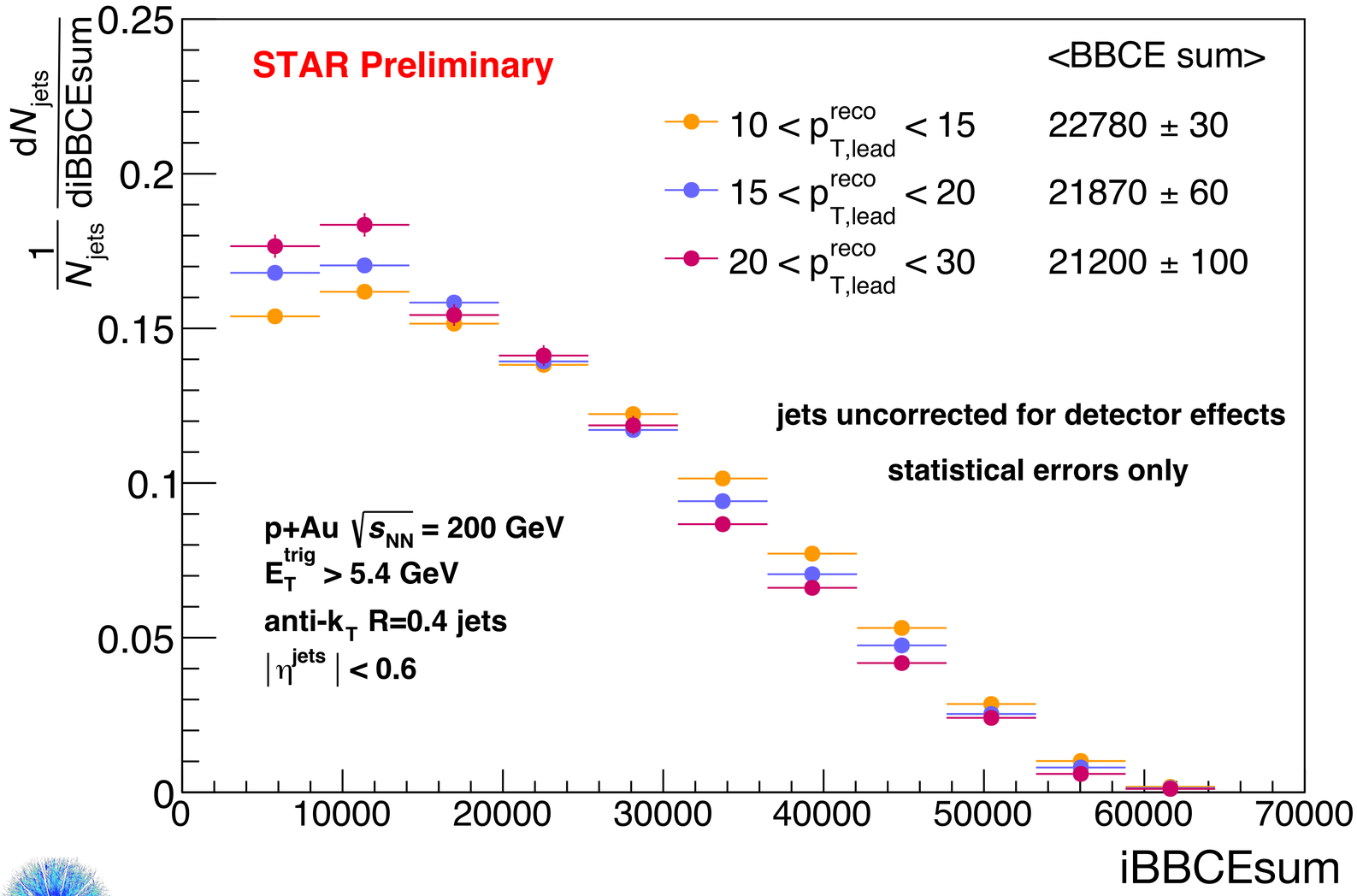
$$\rho = \frac{\mathrm{d}N^{\mathrm{ch}}}{\mathrm{d}\eta \mathrm{d}\phi}$$

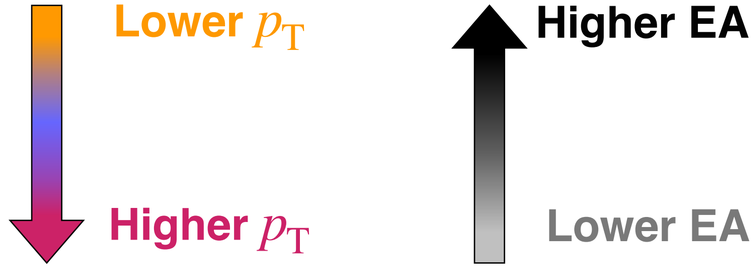
Jet and UE correlation



- UE charged particle multiplicity is higher in events with a larger EA as measured by the Au-going BBC ($-5.2 < \eta < -3.3$)
- UE is larger in the Au-going direction, and does not have a significant dependence on leading jet p_T

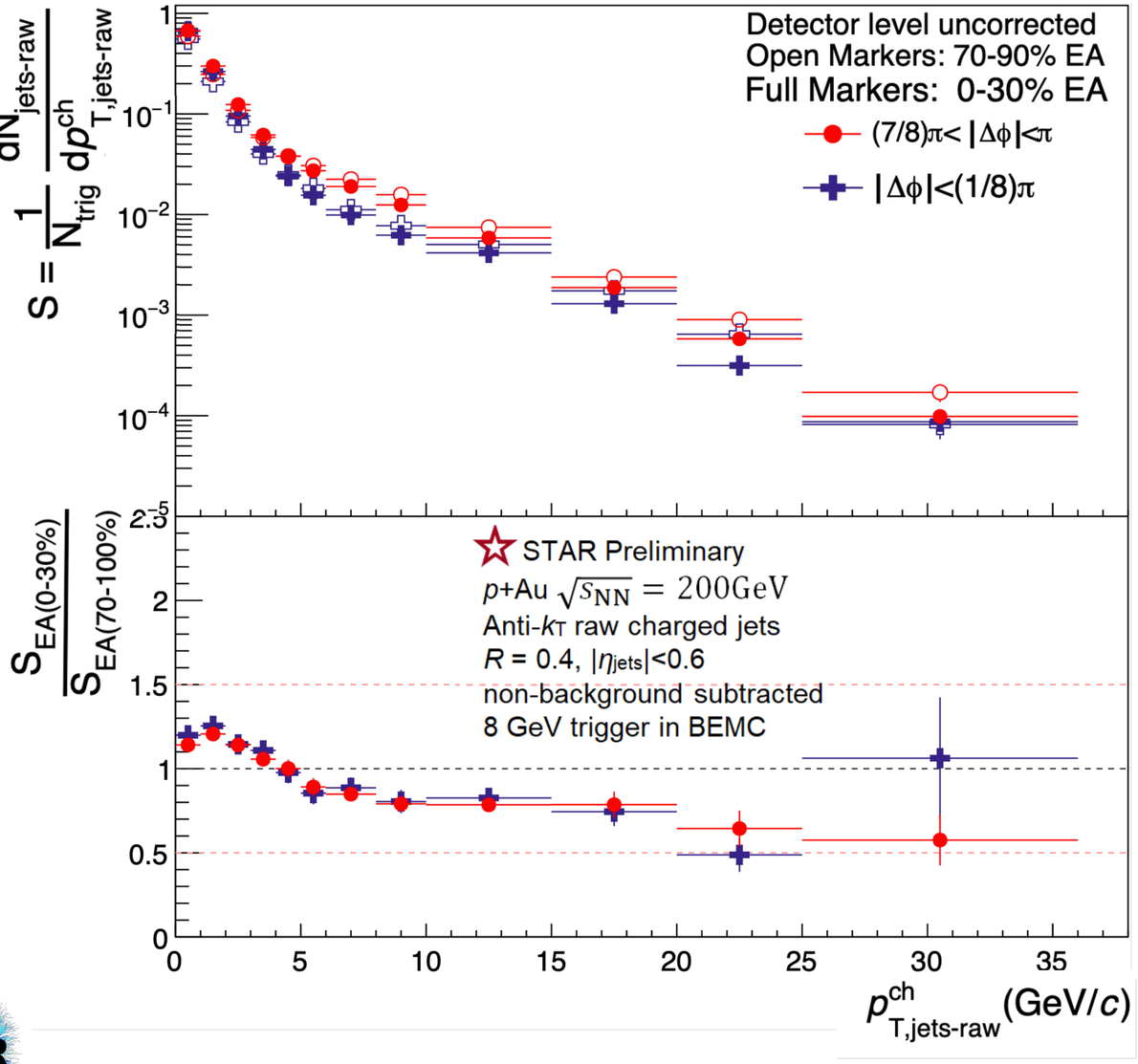
Activity-dependent jet yields



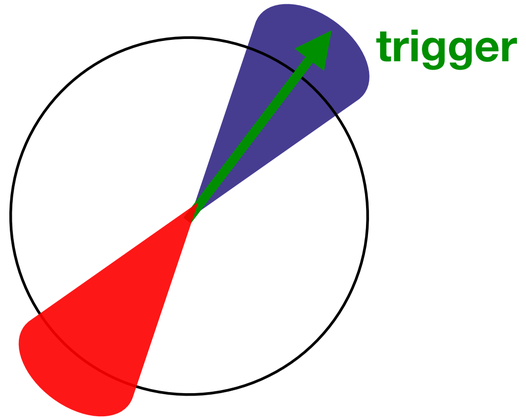


- Anti-correlation between EA_{BBC} (iBBCEsum) and leading jet p_T
  - ➡ Events binned by higher (lower) jet p_T have a lower (higher) average EA_{BBC}, naively classified as more peripheral (central)

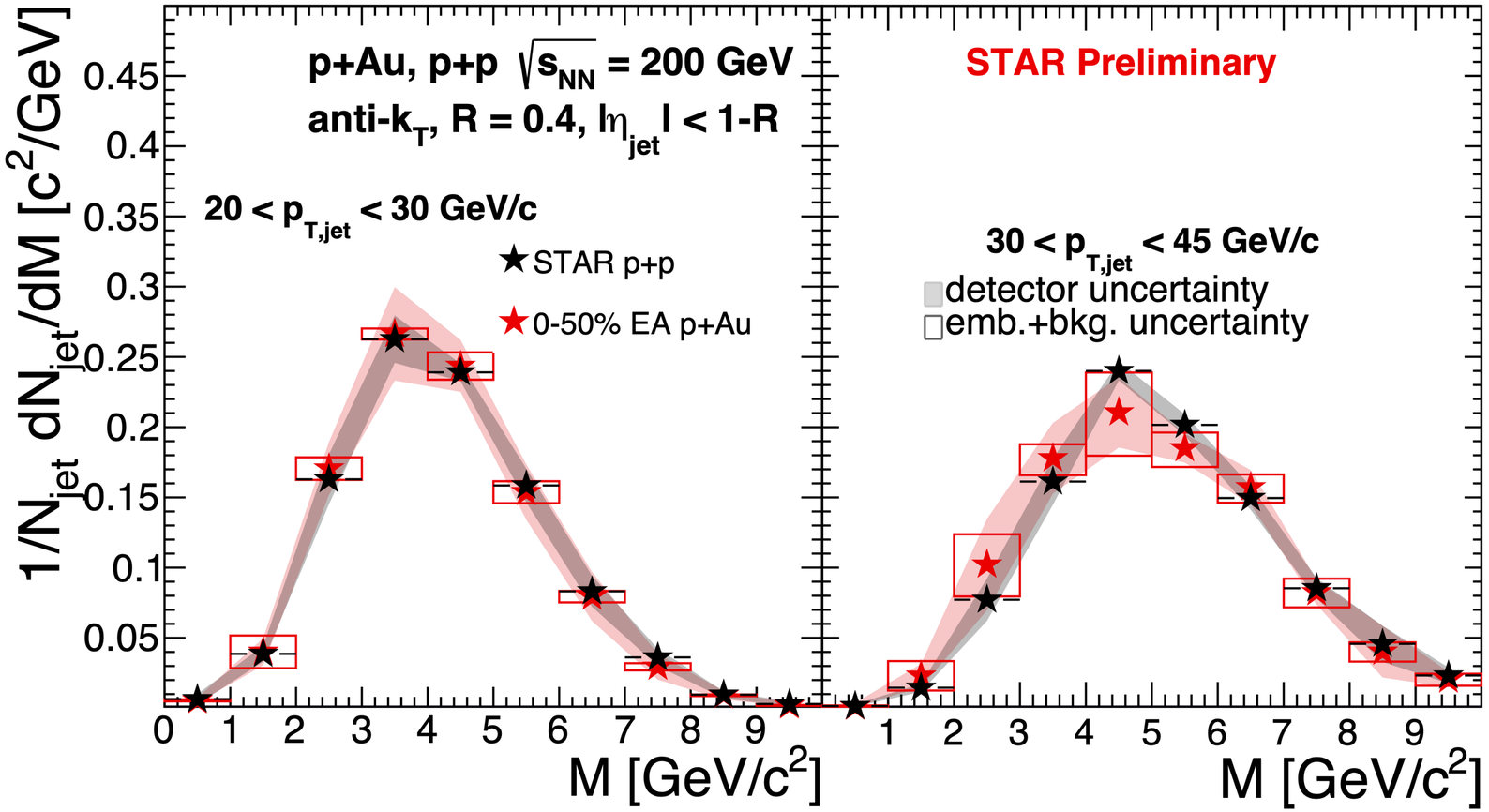
Activity-dependent jet yields



- Yield of semi-inclusive high-p_T jets per charged hadron trigger suppressed in high EA_{BBC} events relative to low EA_{BBC} events
  - Similarly for EA_{UE} (not shown), where EA_{UE} is the charged UE p_T density at mid-rapidity ($|\eta| < 1$)
- The suppression is comparable for jets on the trigger and recoil side



Jet mass: *p*+*p* vs. *p*+Au



$$M = \sqrt{E^2 - \mathbf{p}^2}$$

No significant change of the jet mass between ***p*+*p*** and **central *p*+Au** [*Phys. Rev. D 104, 052007*]

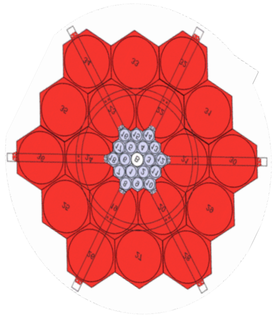
↳ No signs of medium-induced modification to jet mass in this data

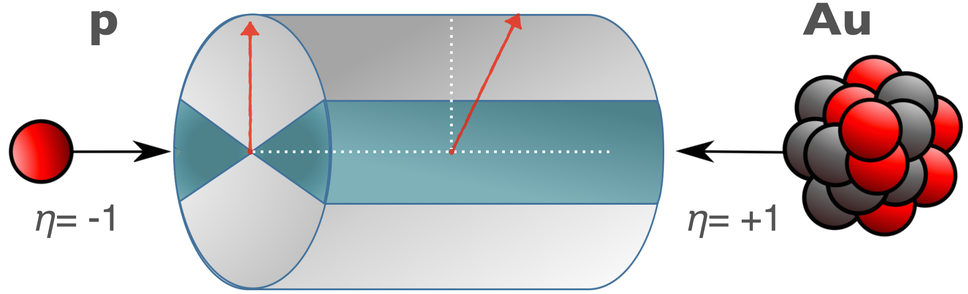
Conclusion

- EA correlated with UE multiplicity and anti-correlated with high-Q^2 jets
  - Dependence of soft particle production (EA) on the initial hard jet scattering
- Semi-inclusive jet spectra suppressed at high EA_{BBC} for both trigger and recoil jet
  - Inconsistent with naive jet quenching picture
- Jet mass in central *p*+Au consistent with *pp*
  - No signs of medium-induced jet mass modification in the measured kinematic range

Measurements indicate EA vs. Q^2 correlations from early time effects (over large rapidities)

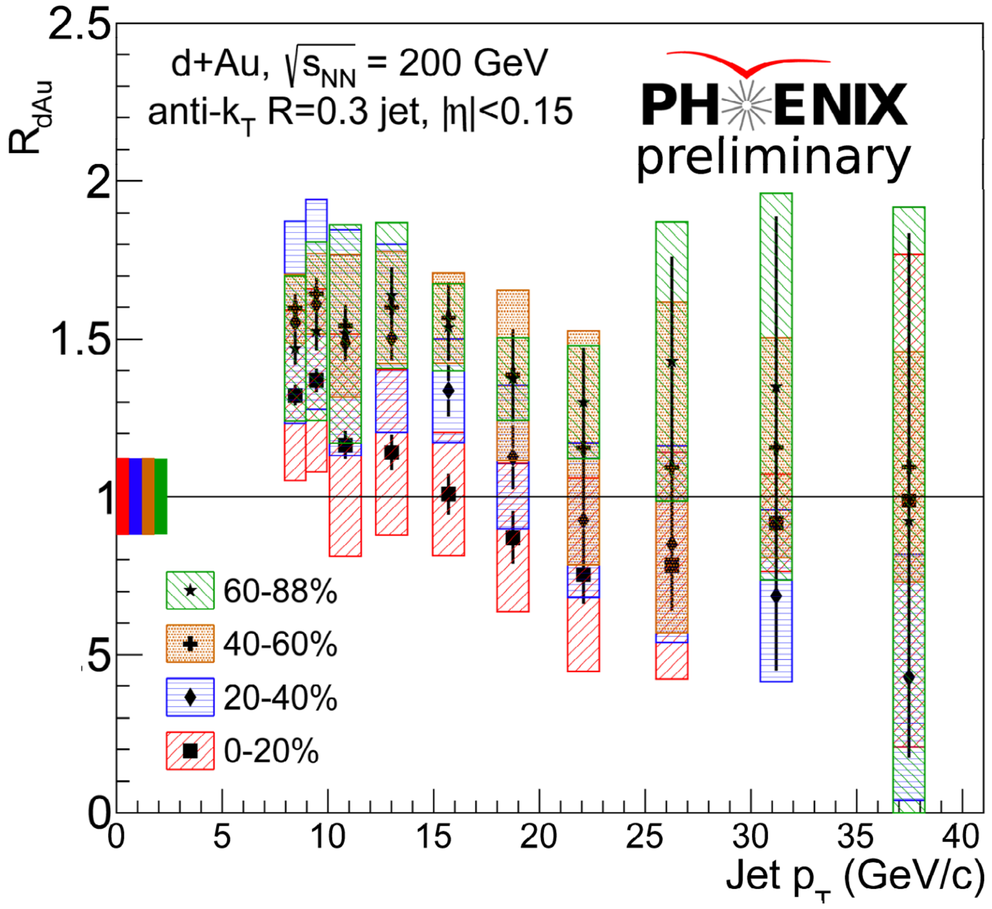
↳ Jet quenching disfavored by STAR jet measurements in *p*+Au collisions





Backup

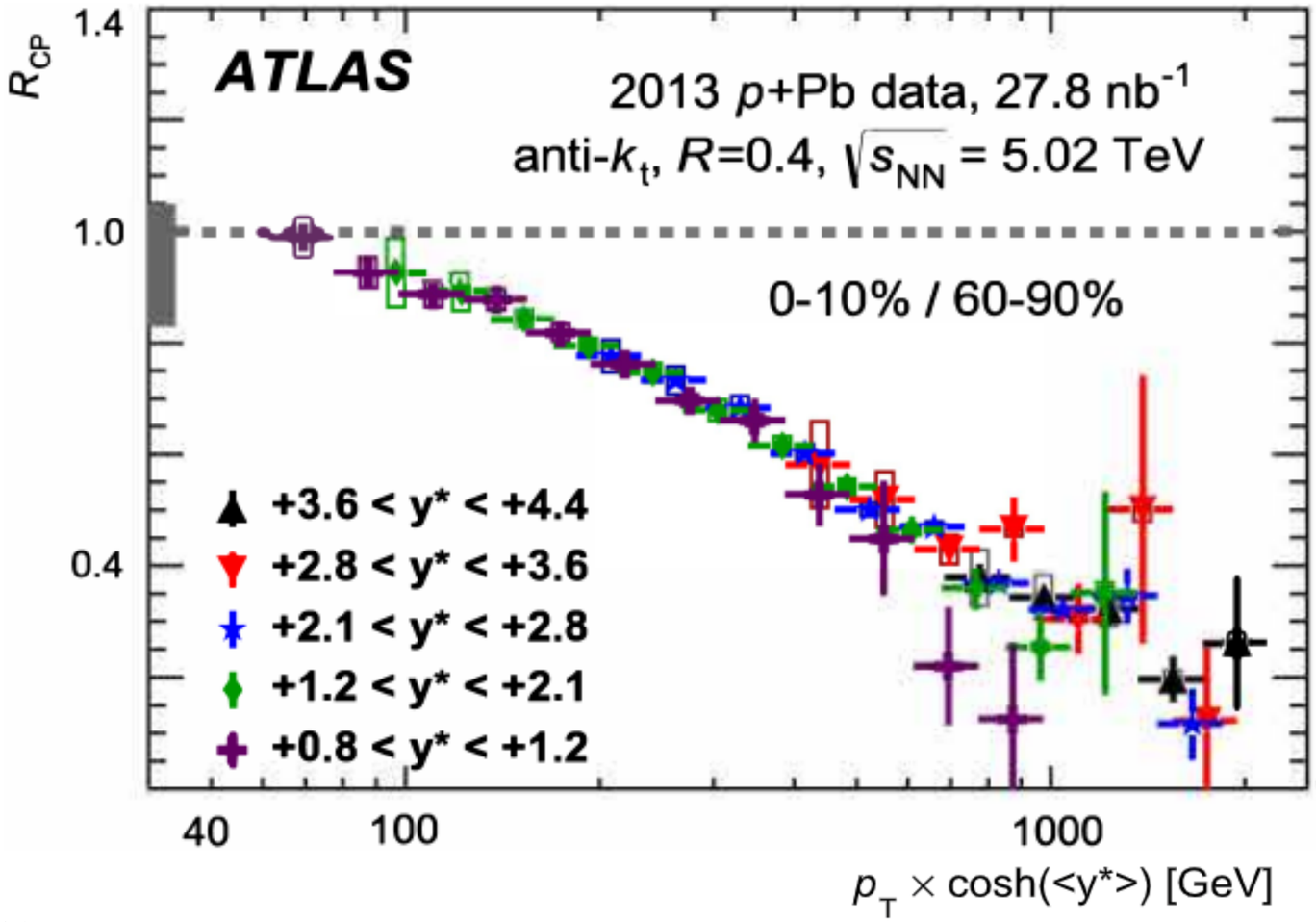
PHENIX R_{d+Au} erratum



- An erratum to the PHENIX R_{d+Au} is being prepared
- The analysis was re-done after removing noisy towers
- R_{d+Au} no longer shows jet suppression in central events, but still shows enhancement in peripheral events

Lajoie https://moriond.in2p3.fr/2021/QCD/

Jet suppression in ATLAS *p*+Pb

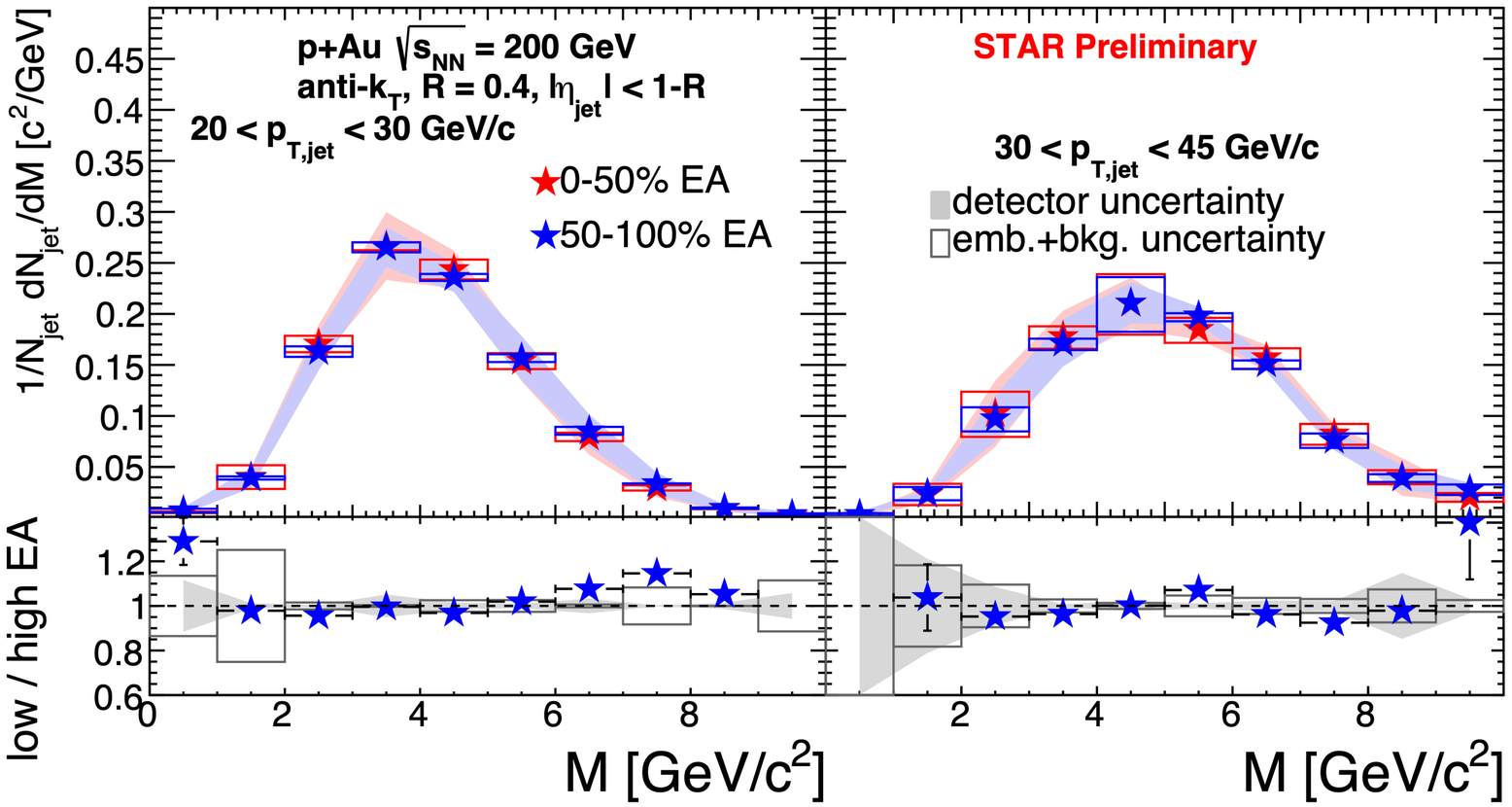


$$p_{\mathrm{T}} \times \cosh\left(< y^{*} > \right) \approx E$$

- Significant jet suppression of central events is seen in the forward and mid-rapidity regions
- This suppression indicates dependence of the jet production on initial kinematics, such as the longitudinal momentum fraction of the hard-scattered parton

Phys. Let. B. 748 https://doi.org/10.1016/j.physletb.2015.07.023

Jet mass as a function of EA

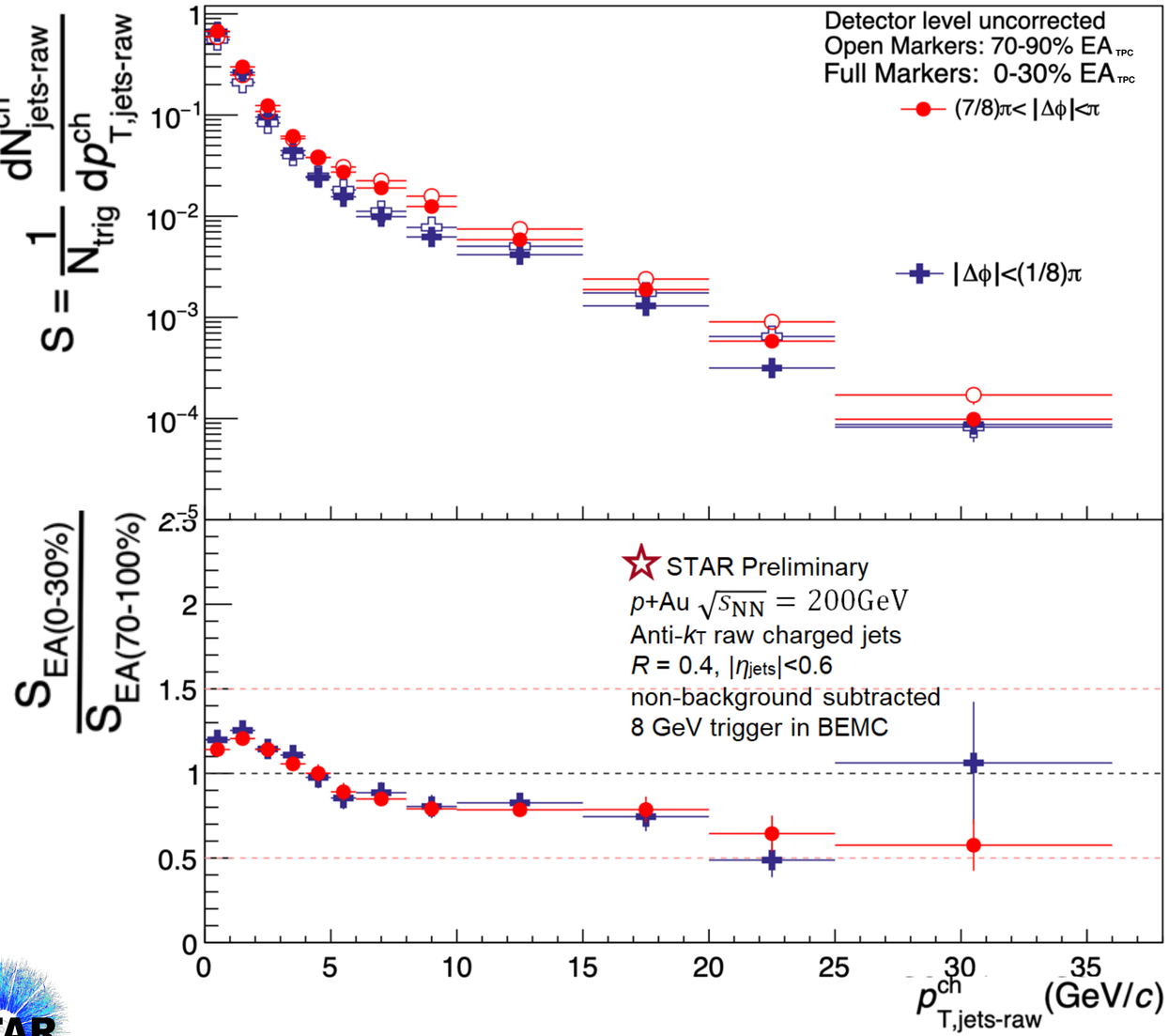


$$M = \sqrt{E^2 - \mathbf{p}^2}$$

- No significant change of the jet mass with EA
  - No signs of medium-induced modification to jet mass

Phys. Rev. D 104, 052007

Activity-dependent jet yields



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