Supported in part by:
U.S. DEPARTMENT OF ENERGY | Office of Science
&
Yale Postdoctoral Scholars Travel Fund
&
CEU Mentorship Program

Wright Laboratory

Jets in STAR

The Fall Meeting of the Division of Nuclear Physics of the American Physical Society and Physical Society of Japan

Waikoloa, Hawaii
December 1, 2023

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

STAR

Yale

How to understand jet evolution in vacuum

Two ways: the How and the What

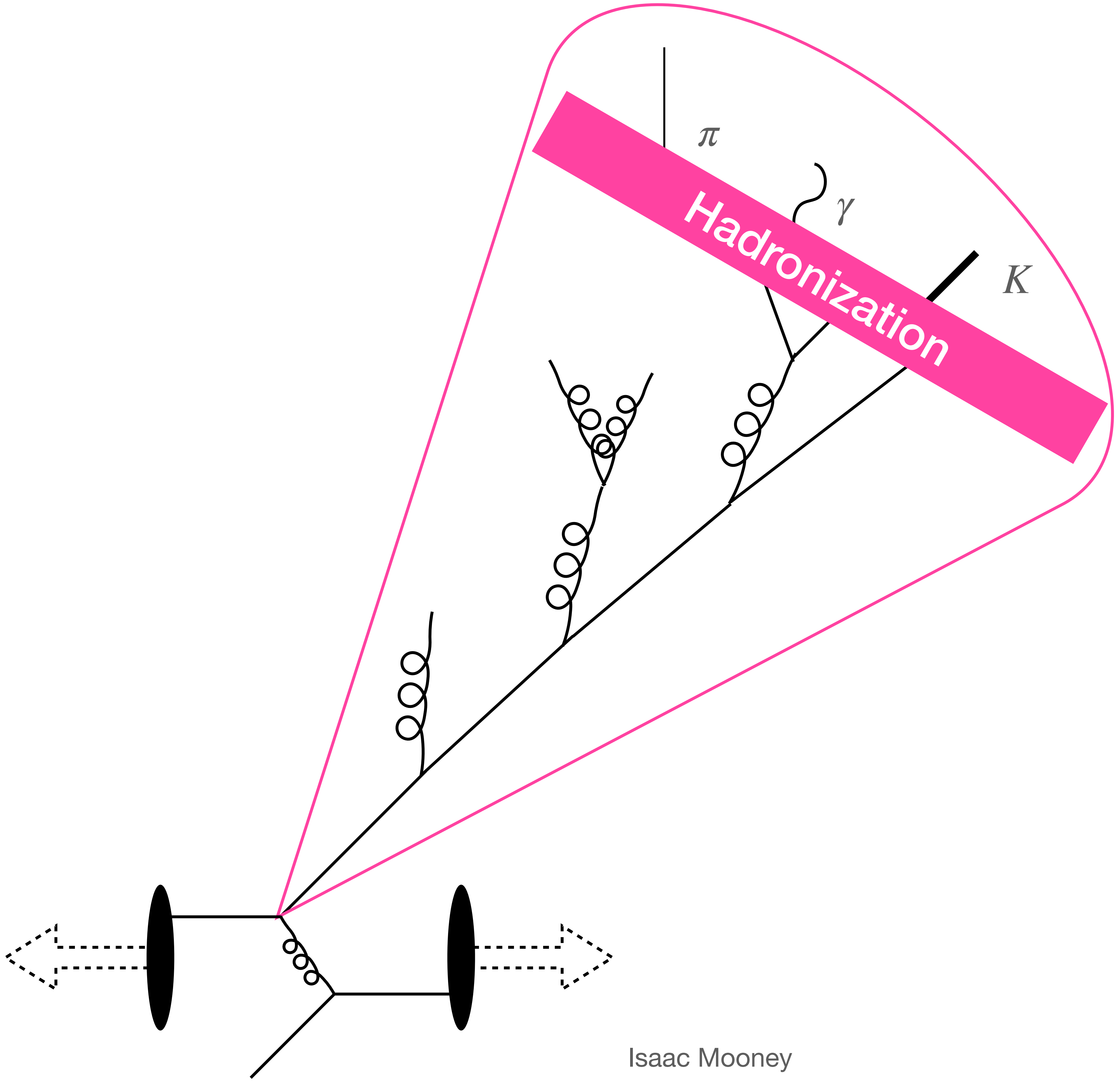
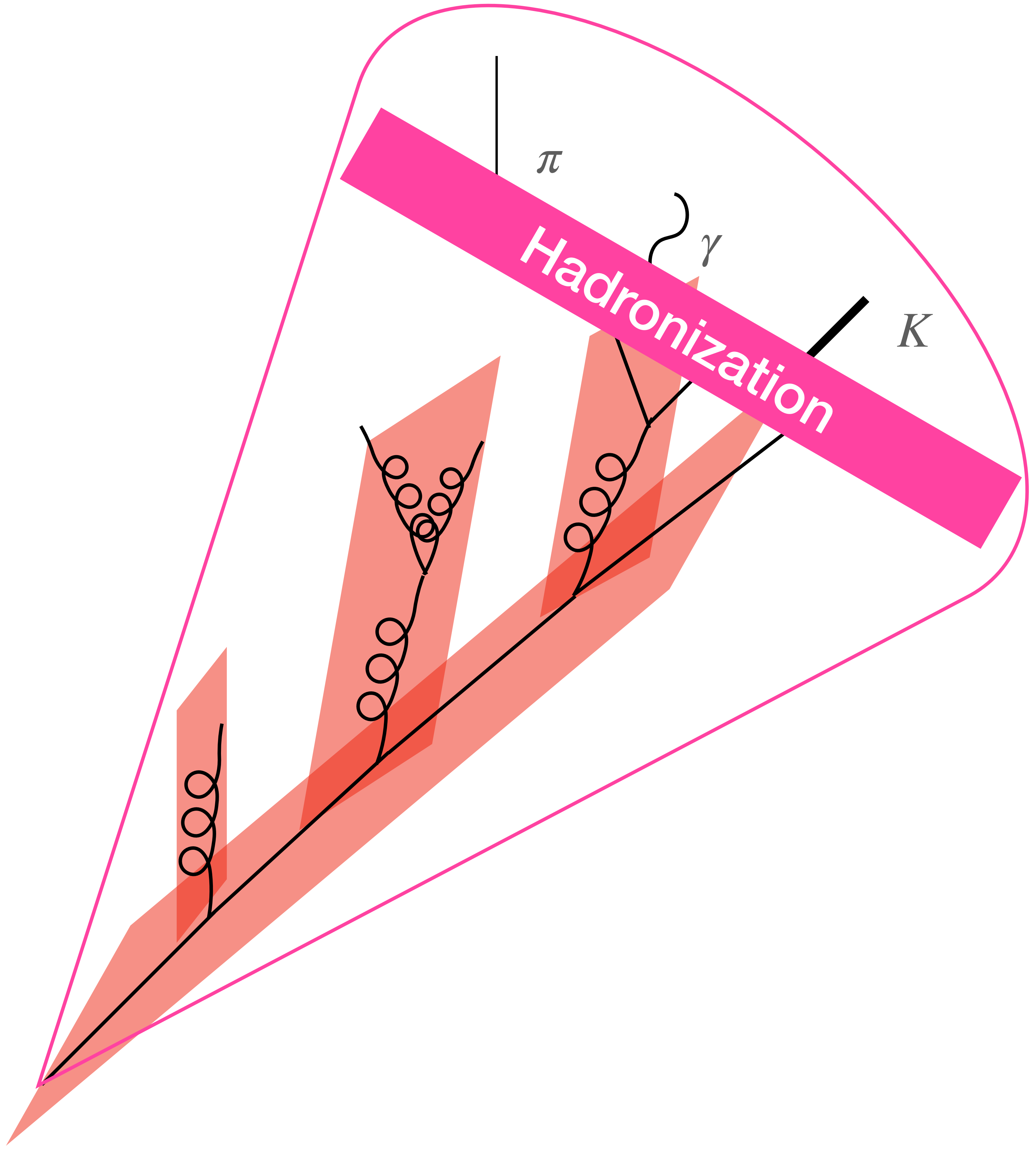


Image inspired by Kamel Khelifa Kerfa

How to understand jet evolution in vacuum

Two ways: the How and the What

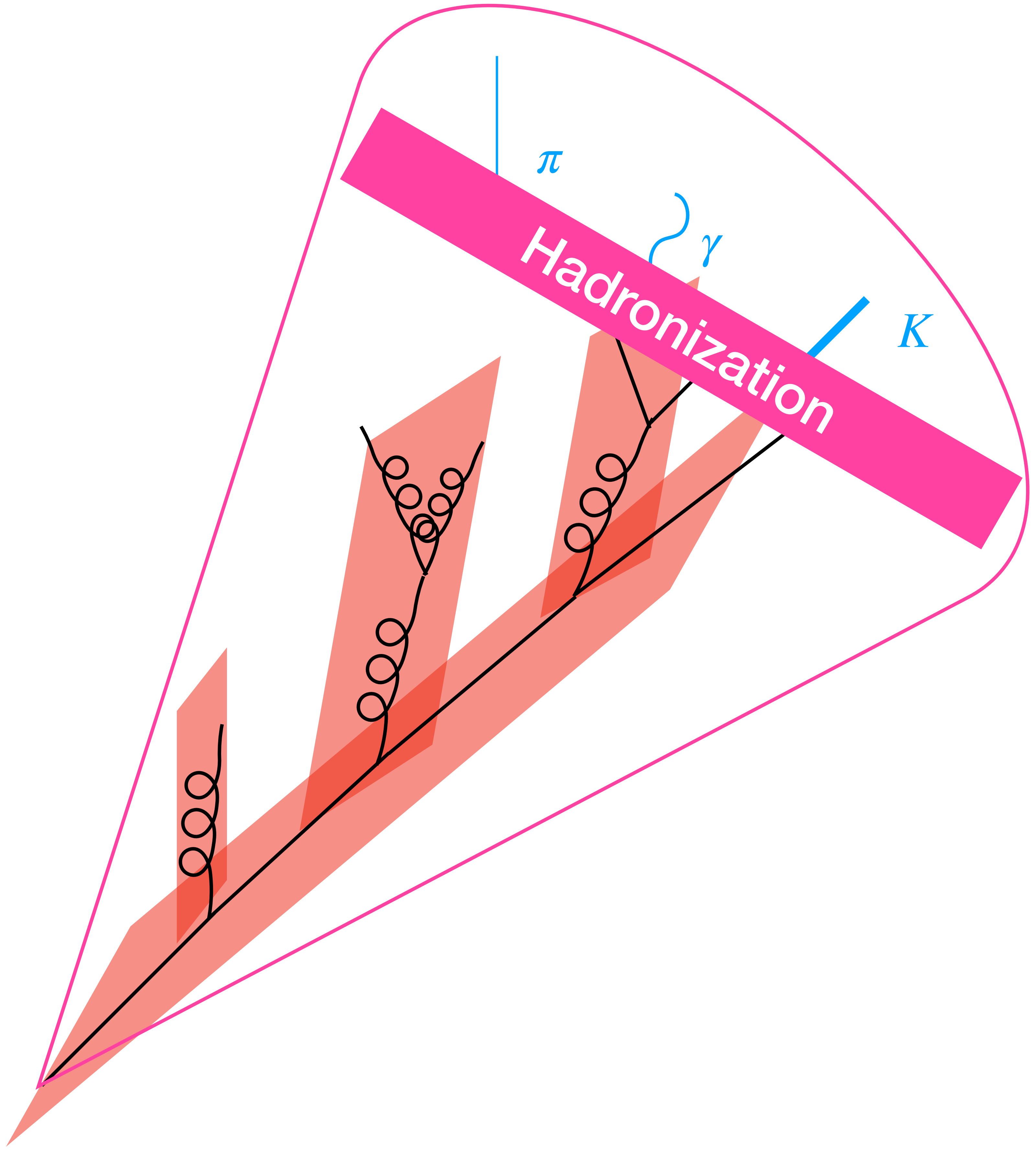
Energy flows



How to understand jet evolution in vacuum

Two ways: the How and the What

Energy flows

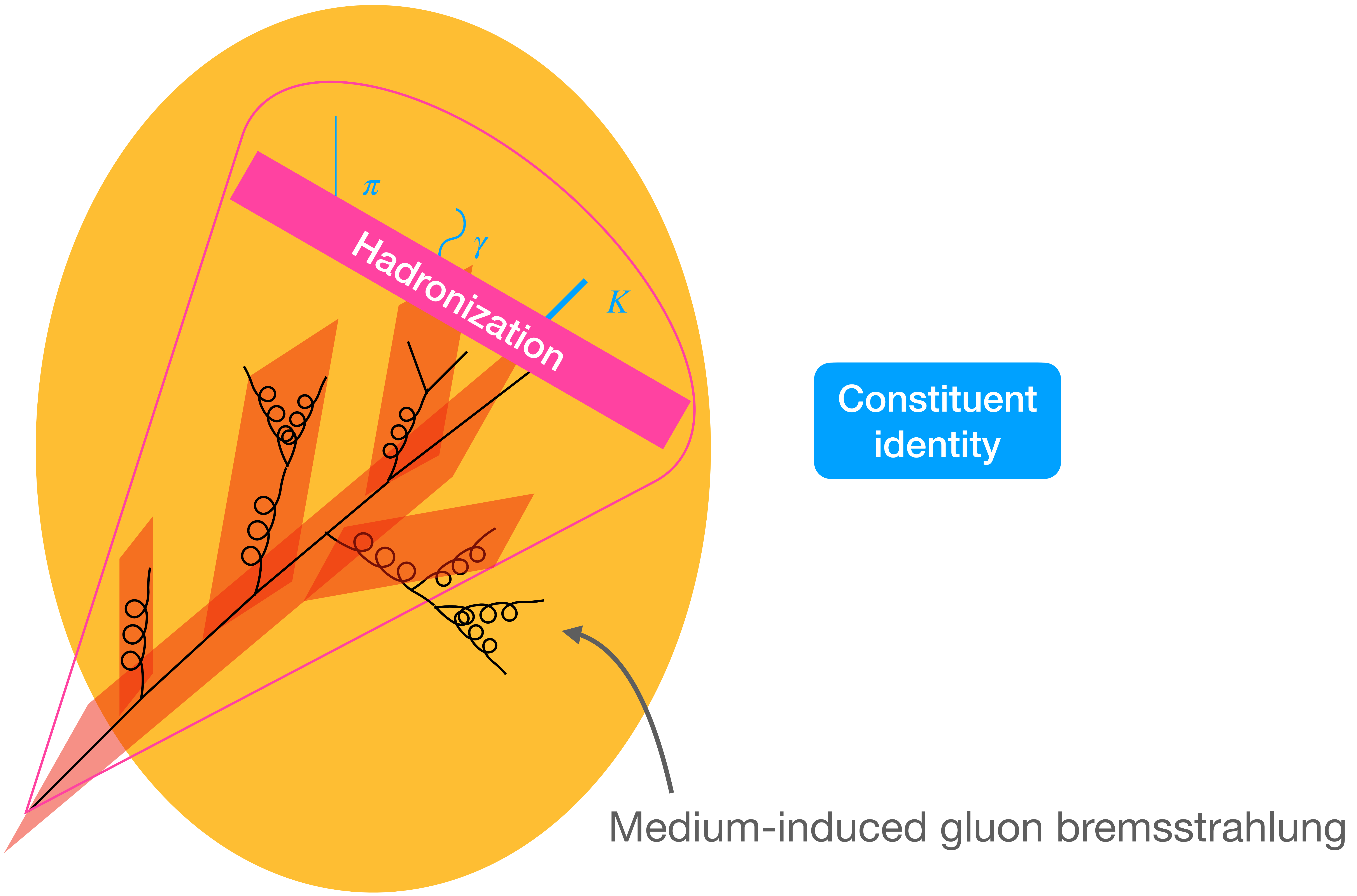


Constituent identity

How to understand jet evolution in media

Two ways: the How and the What

Energy flows



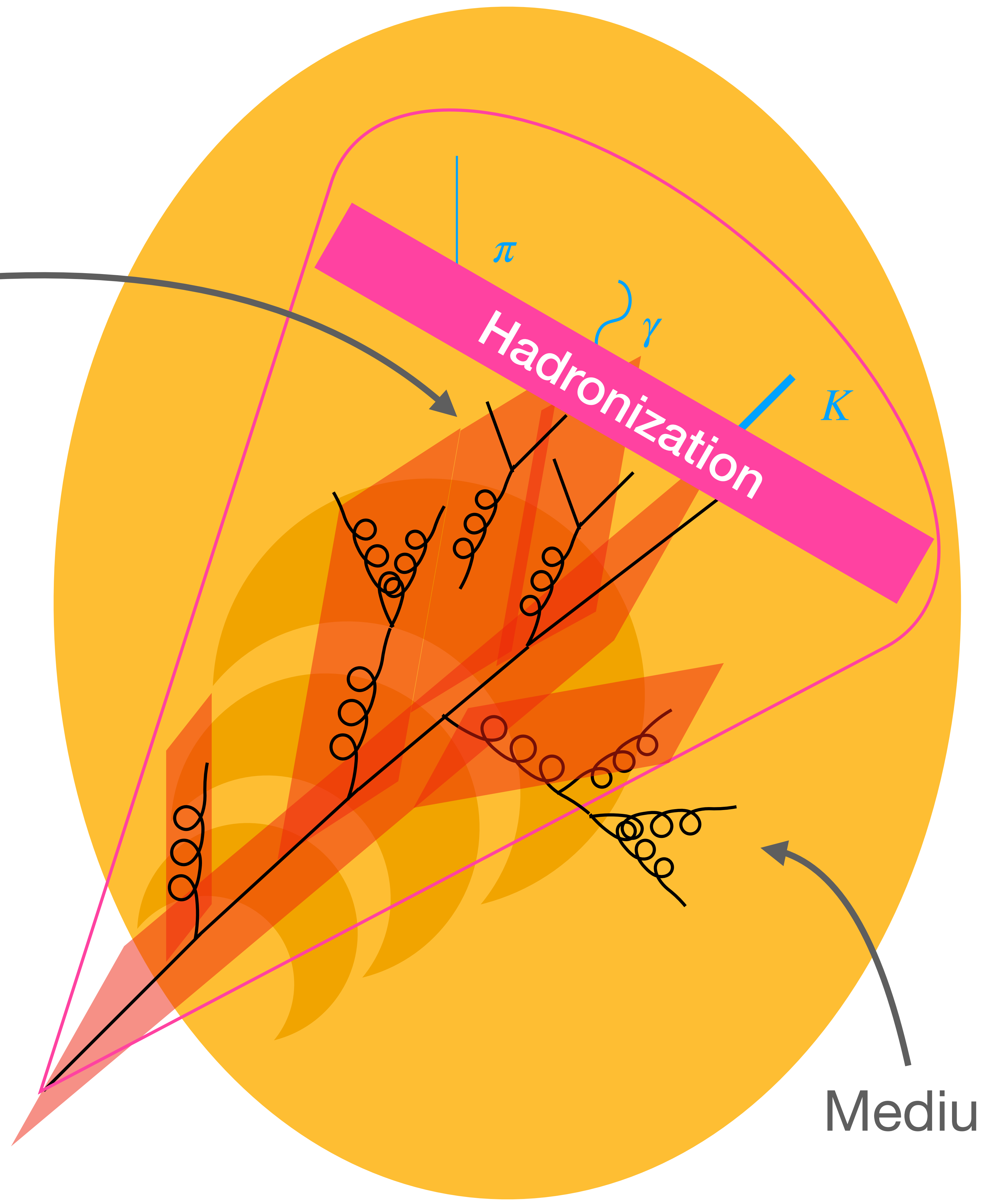
Constituent identity

How to understand jet evolution in media

Two ways: the How and the What

Jet-induced medium response

Energy flows



Constituent identity

Medium-induced gluon bremsstrahlung

How to understand jet evolution in media

Two ways: the How and the What

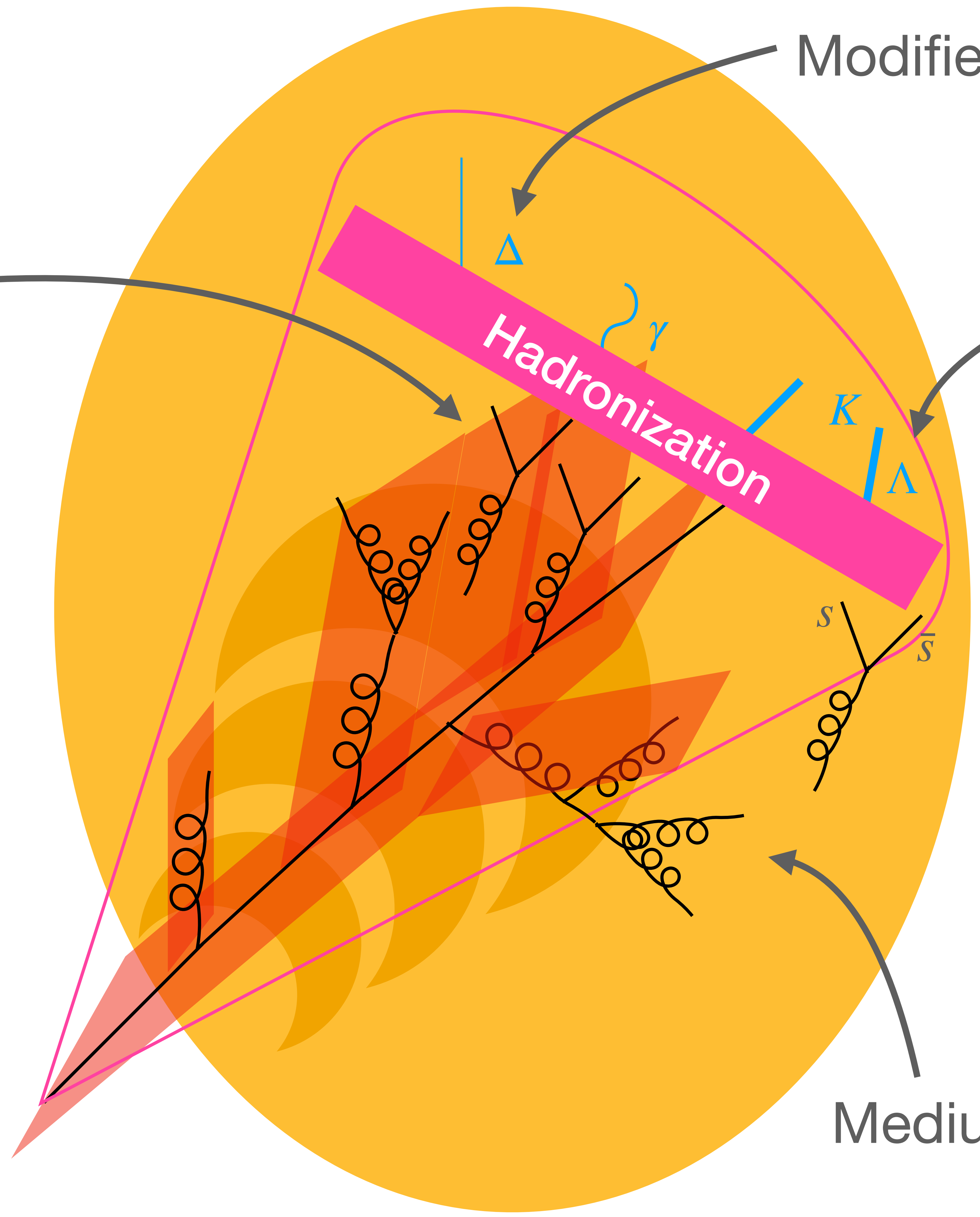
Jet-induced medium response

Modified fragmentation

Coalescence

Energy flows

Constituent identity



Medium-induced gluon bremsstrahlung

Solenoidal Tracker at RHIC (STAR)

Main subdetectors, as of mid-2010s

Relativistic Heavy Ion Collider (RHIC)
collides p+p, p+Au, O+O, Zr+Zr, Ru+Ru, Au+Au, etc.
beams at $\sqrt{s_{NN}}$ = 200 GeV, etc.

Time Projection Chamber (TPC) [$|\eta| < 1$]:
momenta of charged tracks + centrality

Barrel Electromagnetic Calorimeter (BEMC) [$|\eta| < 1$]:
neutral energy deposits + provides online trigger
(Jet Patch: $E_T^{patch} > 7.4$ GeV, High Tower: $E_T > 4.2$ GeV)

Inner Beam-Beam Counter (iBBC) [$3.4 < |\eta| < 5.0$]:
forward detector,
east/Au-going side activity used as centrality proxy in p+Au

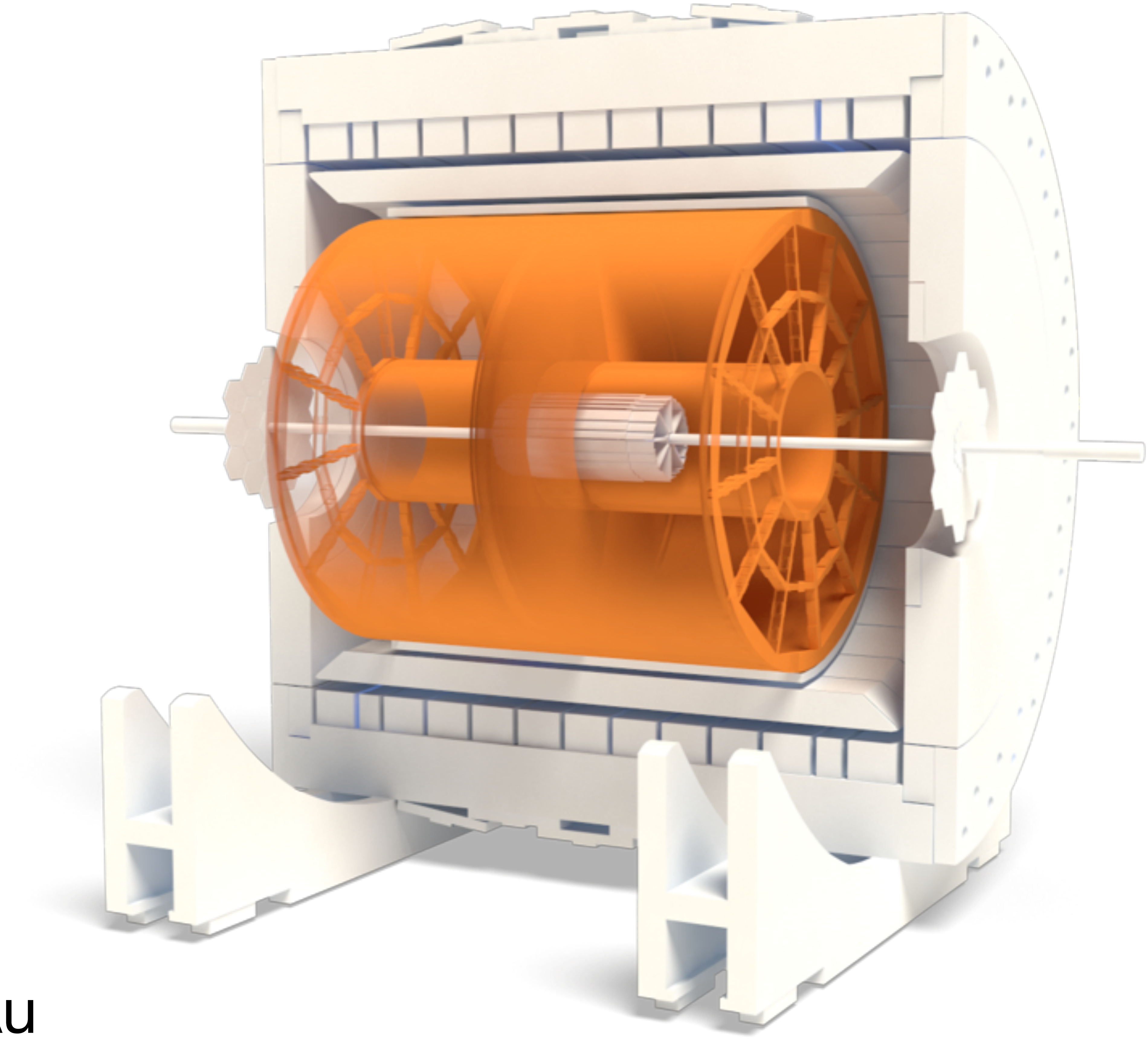


Image: NSWW

Solenoidal Tracker at RHIC (STAR)

Main subdetectors, as of mid-2010s

Relativistic Heavy Ion Collider (RHIC)
collides *p*+*p*, *p*+Au, O+O, Zr+Zr, Ru+Ru, Au+Au, etc.
beams at $\sqrt{s_{NN}}$ = 200 GeV, etc.

Time Projection Chamber (TPC) [$|\eta| < 1$]:
momenta of charged tracks + centrality

Barrel Electromagnetic Calorimeter (BEMC) [$|\eta| < 1$]:
neutral energy deposits + provides online trigger
(Jet Patch: $E_T^{patch} > 7.4$ GeV, High Tower: $E_T > 4.2$ GeV)

Inner Beam-Beam Counter (iBBC) [$3.4 < |\eta| < 5.0$]:
forward detector,
east/Au-going side activity used as centrality proxy in *p*+Au

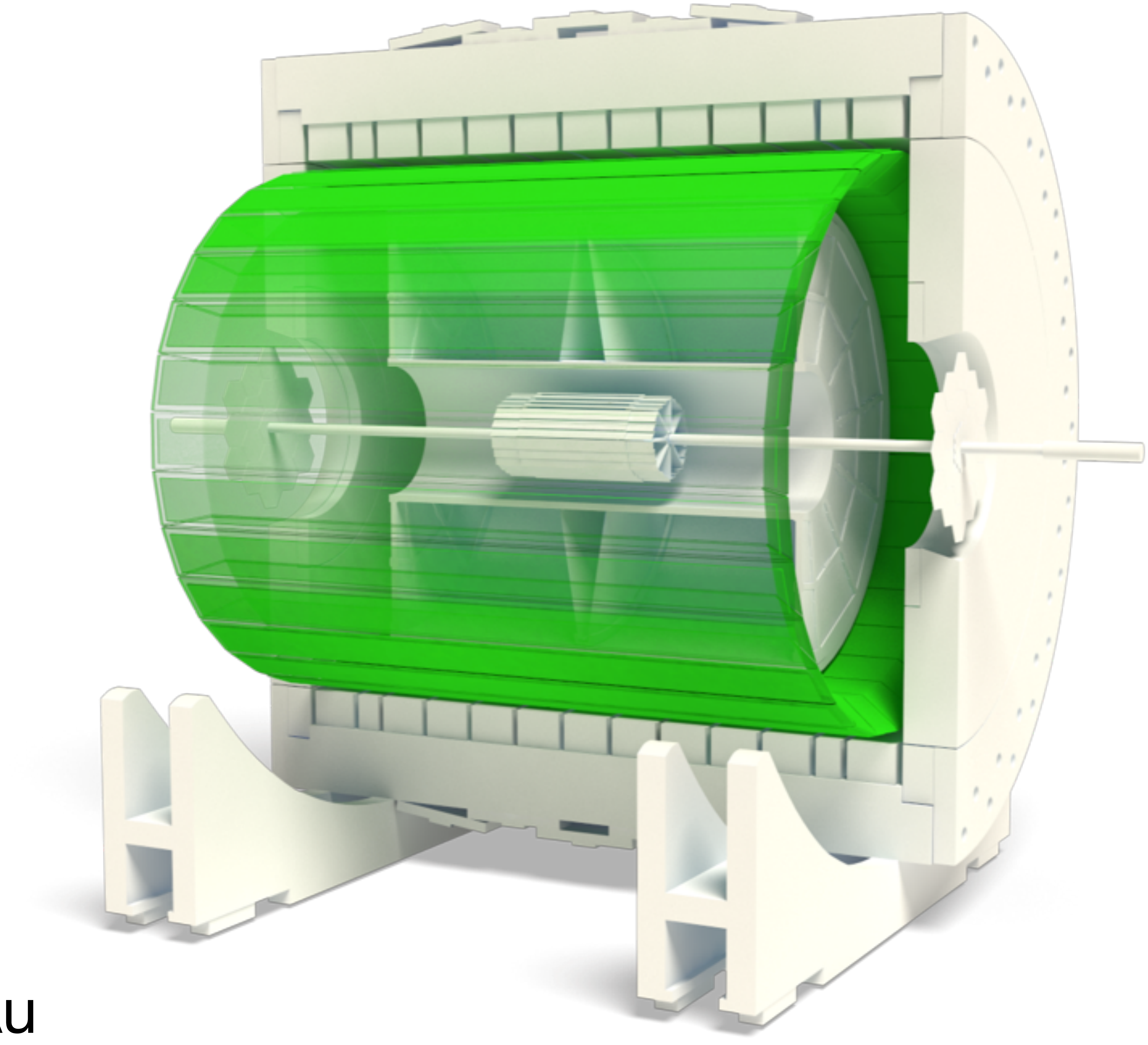


Image: NSWW

Solenoidal Tracker at RHIC (STAR)

Main subdetectors, as of mid-2010s

Relativistic Heavy Ion Collider (RHIC)
collides p+p, p+Au, O+O, Zr+Zr, Ru+Ru, Au+Au, etc.
beams at $\sqrt{s_{NN}}$ = 200 GeV, etc.

Time Projection Chamber (TPC) [$|\eta| < 1$]:
momenta of charged tracks + centrality

Barrel Electromagnetic Calorimeter (BEMC) [$|\eta| < 1$]:
neutral energy deposits + provides online trigger
(Jet Patch: $E_T^{patch} > 7.4$ GeV, High Tower: $E_T > 4.2$ GeV)

Inner Beam-Beam Counter (iBBC) [$3.4 < |\eta| < 5.0$]:
forward detector,
east/Au-going side activity used as centrality proxy in p+Au

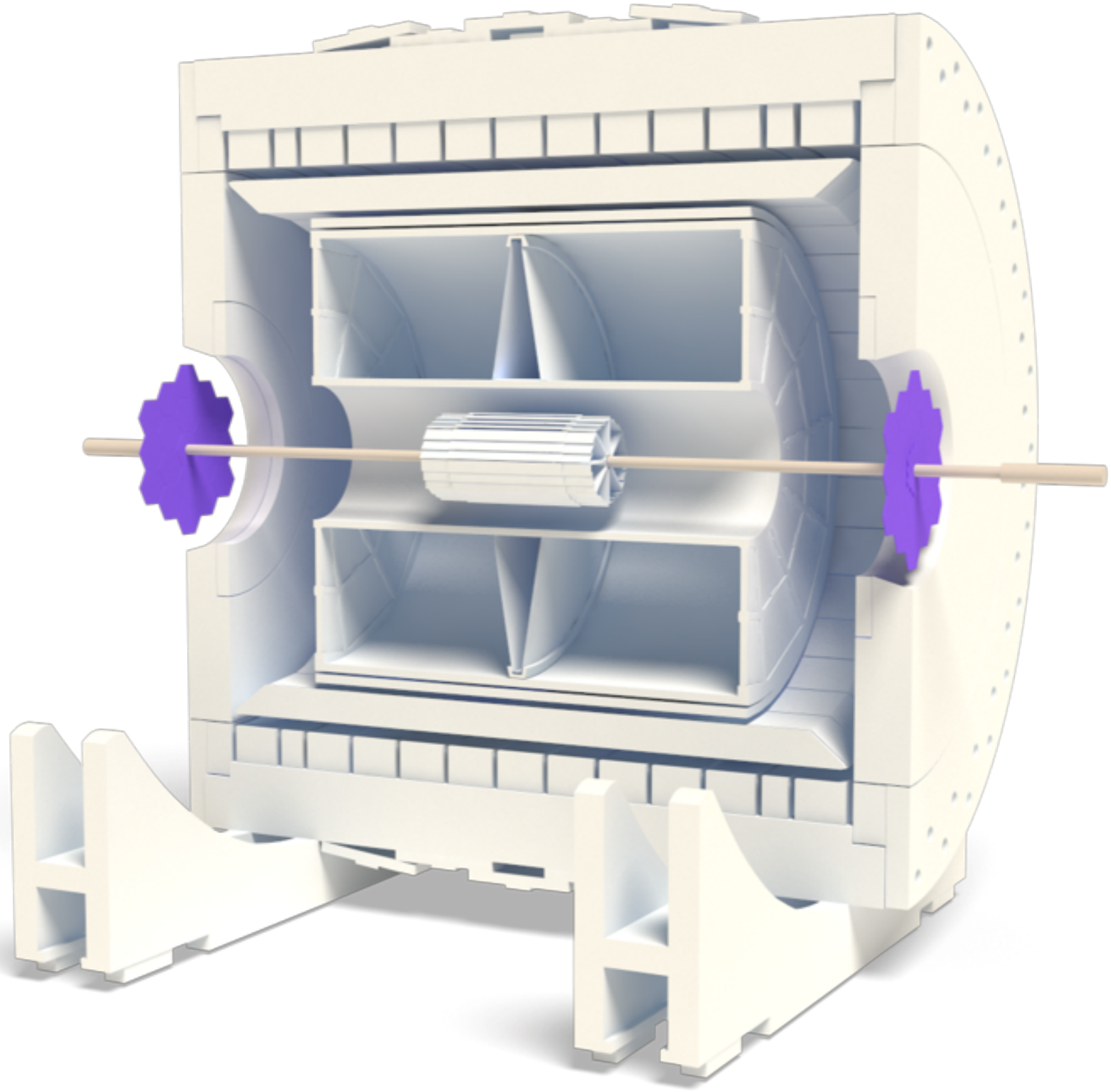


Image: NSWW

Solenoidal Tracker at RHIC (STAR)

Main subdetectors, as of mid-2010s

Relativistic Heavy Ion Collider (RHIC) collides *p*+*p*, *p*+Au, O+O, Zr+Zr, Ru+Ru, Au+Au, etc. beams at $\sqrt{s_{NN}}$ = 200 GeV, etc.

Time Projection Chamber (TPC) [$|\eta| < 1$]: momenta of charged tracks + centrality

Barrel Electromagnetic Calorimeter (BEMC) [$|\eta| < 1$]: neutral energy deposits + provides online trigger (Jet Patch: $E_T^{patch} > 7.4$ GeV, High Tower: $E_T > 4.2$ GeV)

Inner Beam-Beam Counter (iBBC) [$3.4 < |\eta| < 5.0$]: forward detector, east/Au-going side activity used as centrality proxy in *p*+Au

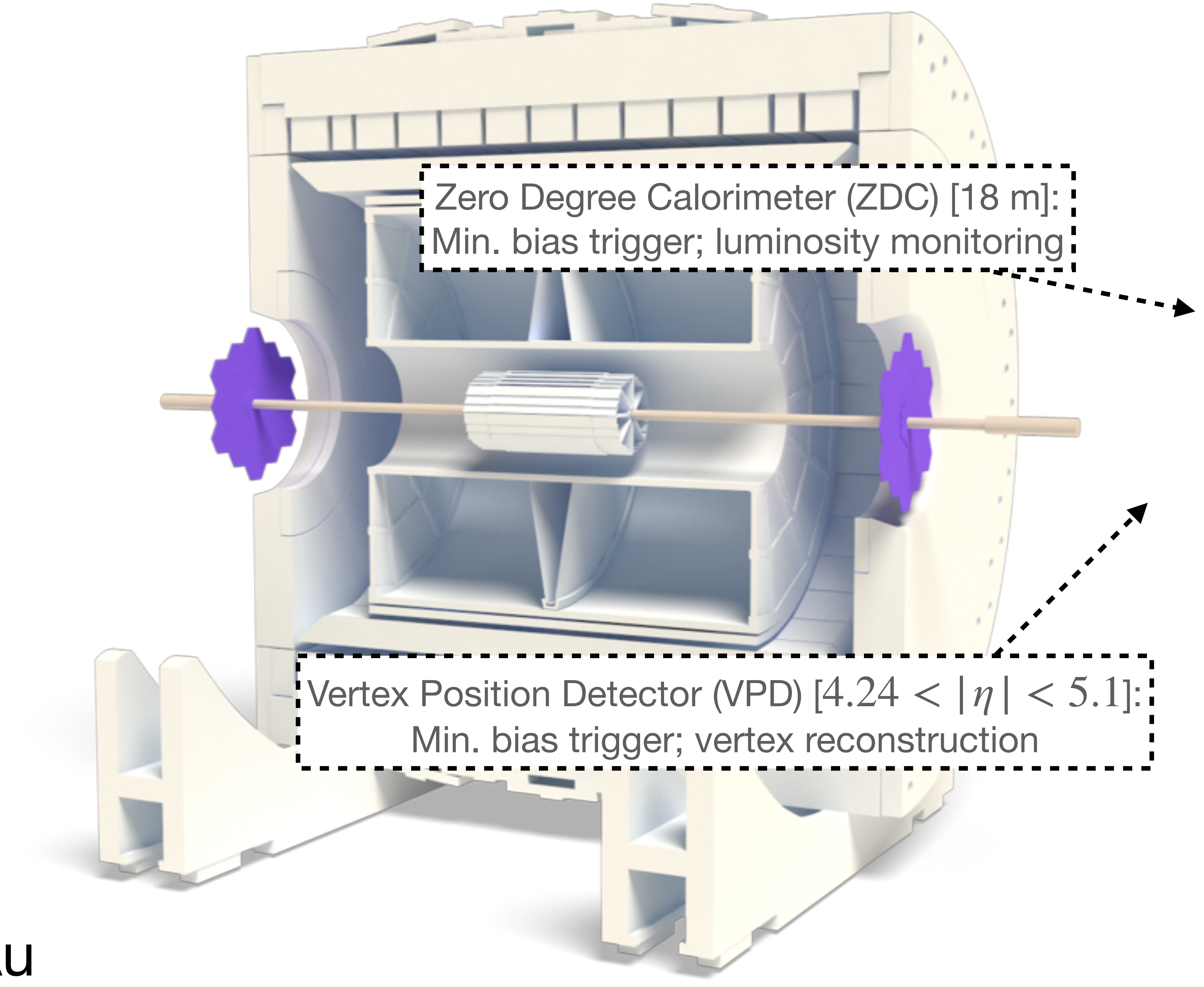


Image: NSWW

Energy flows

Precision QCD; exploring the Lund plane
w/ multi-dimensional jet substructure

Separating p- and np-QCD
w/ energy correlators

Path-length dependence of jet energy loss in medium
w/ jet anisotropies (w/r/t event plane)

Energy-density dependence of jet energy loss in medium;
angular distribution of radiation in quenched jets
w/ inclusive/semi-inclusive jet & high-p_T hadron yields

Precision QCD; exploring the Lund plane
w/ multi-dimensional jet substructure

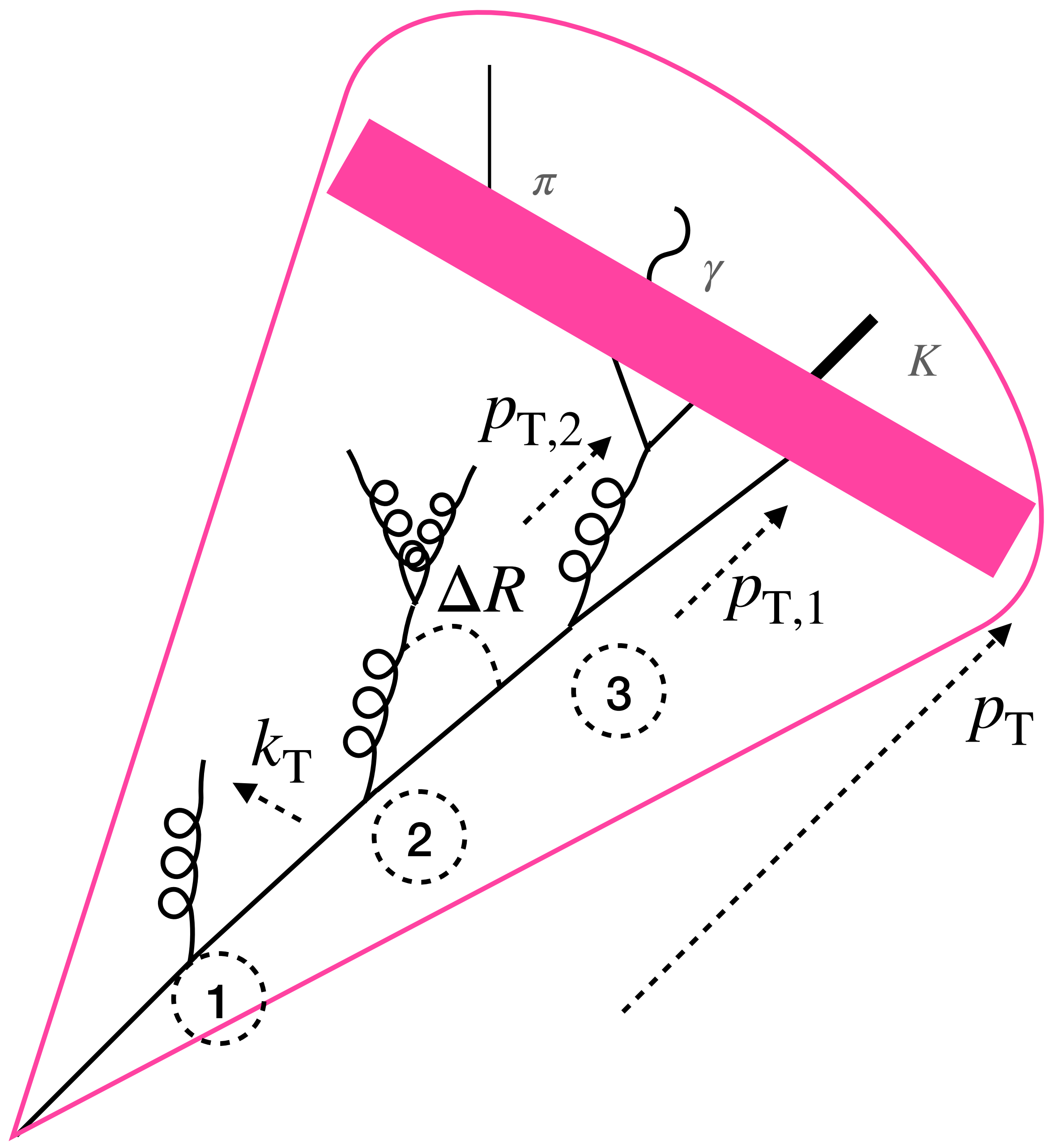
Separating p- and np-QCD
w/ energy correlators

Energy flows

Path-length dependence of jet energy loss in medium
w/ jet anisotropies (w/r/t event plane)

Energy-density dependence of jet energy loss in medium;
angular distribution of radiation in quenched jets
w/ inclusive/semi-inclusive jet & high-p_T hadron yields

Jet substructure



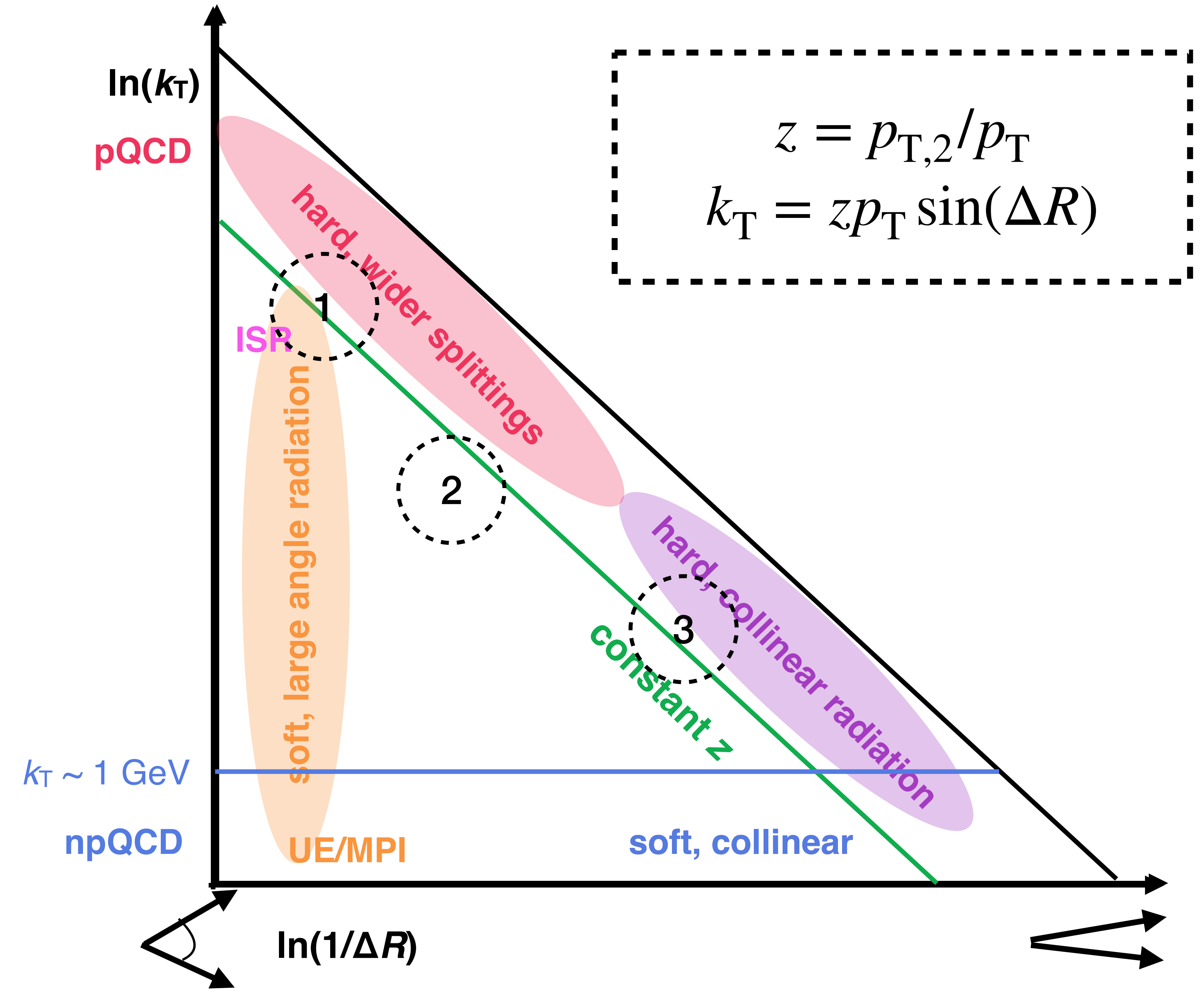
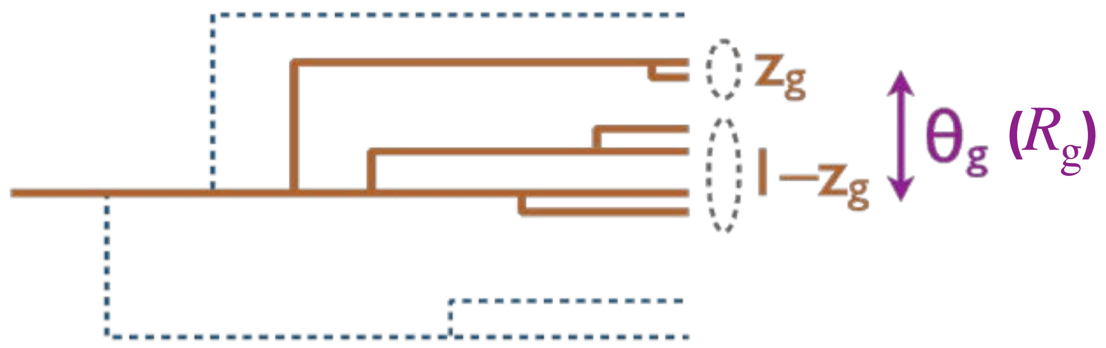


Image: Laura Havener, modified from Andrews et al., J.Phys.G 47 (2020) 6, 065102

$$\frac{\min\left(p_{T,i}, p_{T,j}\right)}{p_{T,i} + p_{T,j}} > z_{cut} \left(\frac{\Delta R_{ij}}{R}\right)^{\beta}$$

$$z_g = \frac{\min\left(p_{T,1}, p_{T,2}\right)}{p_{T,1} + p_{T,2}}$$



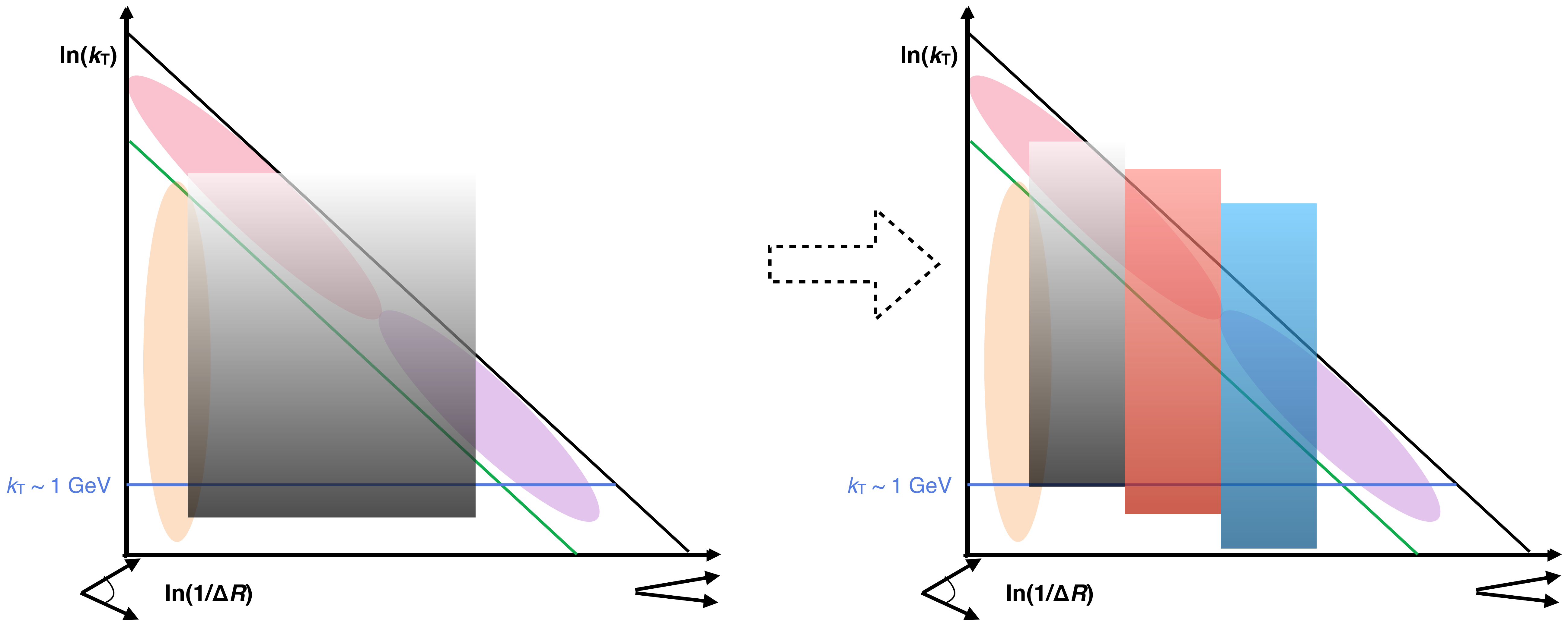
$$M_g = \left|\sum_{i \in J_g} p_i\right|$$

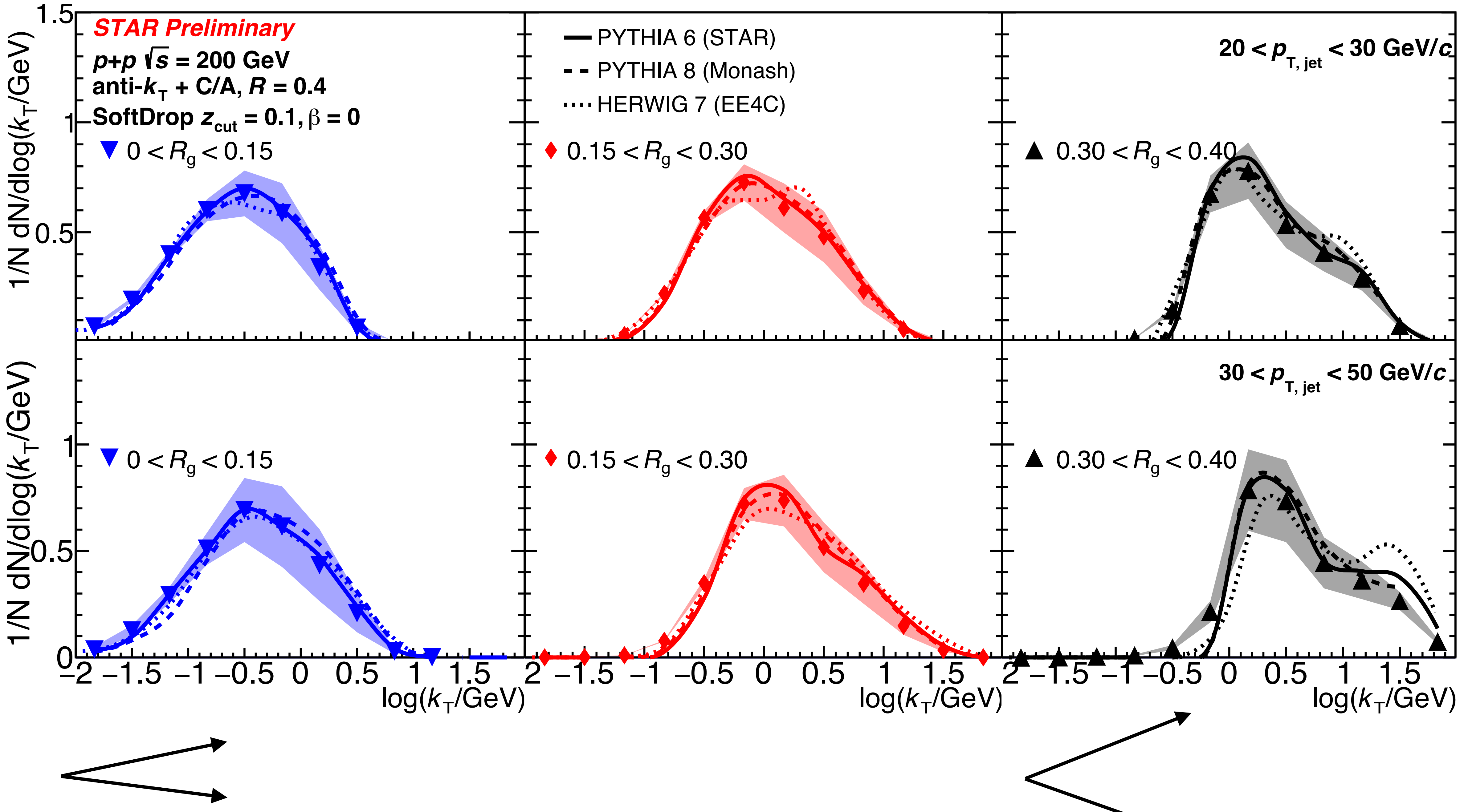
Image: Larkoski, Marzani, Thaler, Xue, PRL 119 (2017) 13, 132003

SoftDrop[1] grooming: reduce soft non-perturbative contribution
→ better theoretical control

[1]Larkoski, Marzani, Soyez, Thaler, JHEP 05 (2014), 146

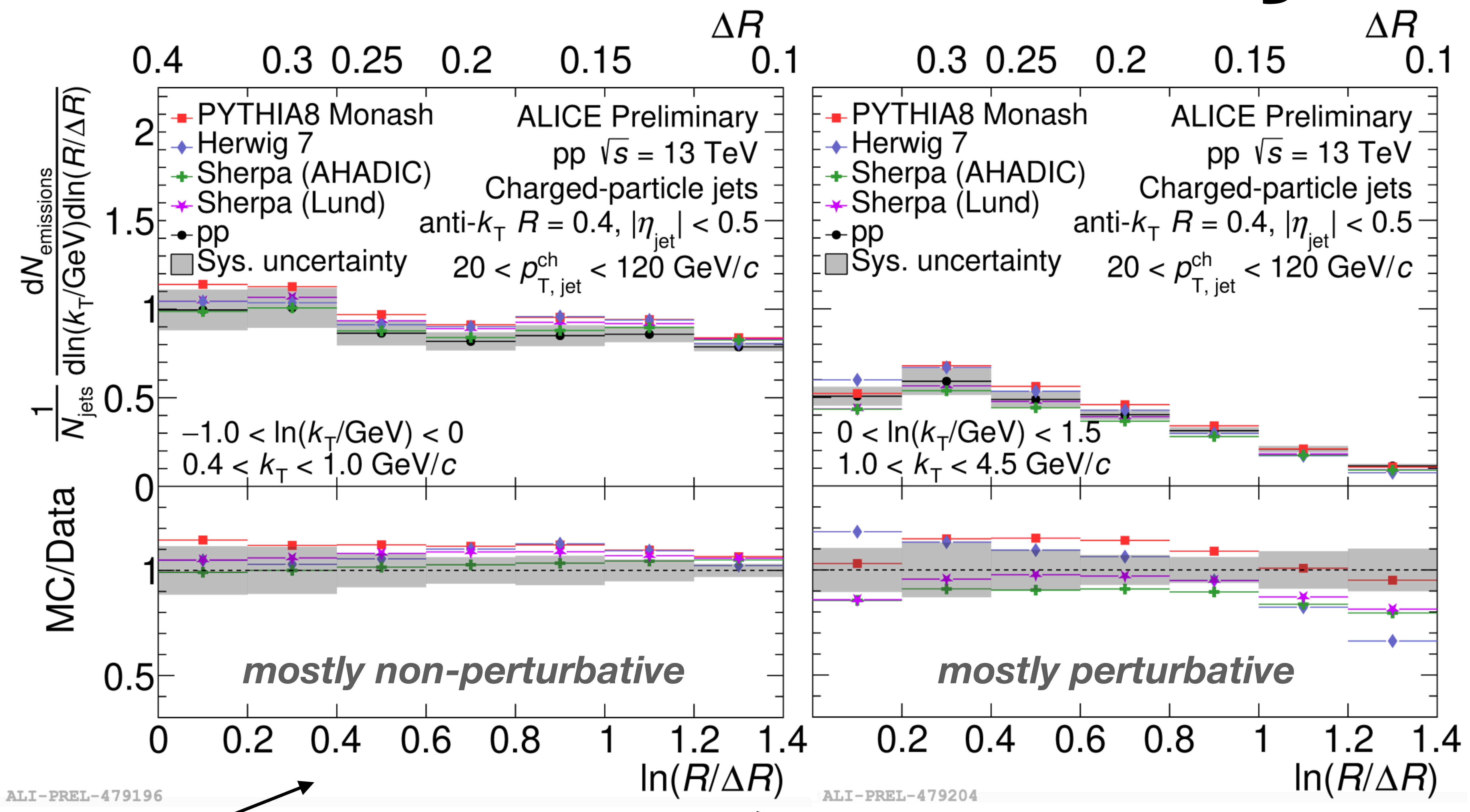
Multi-dimensional jet substructure



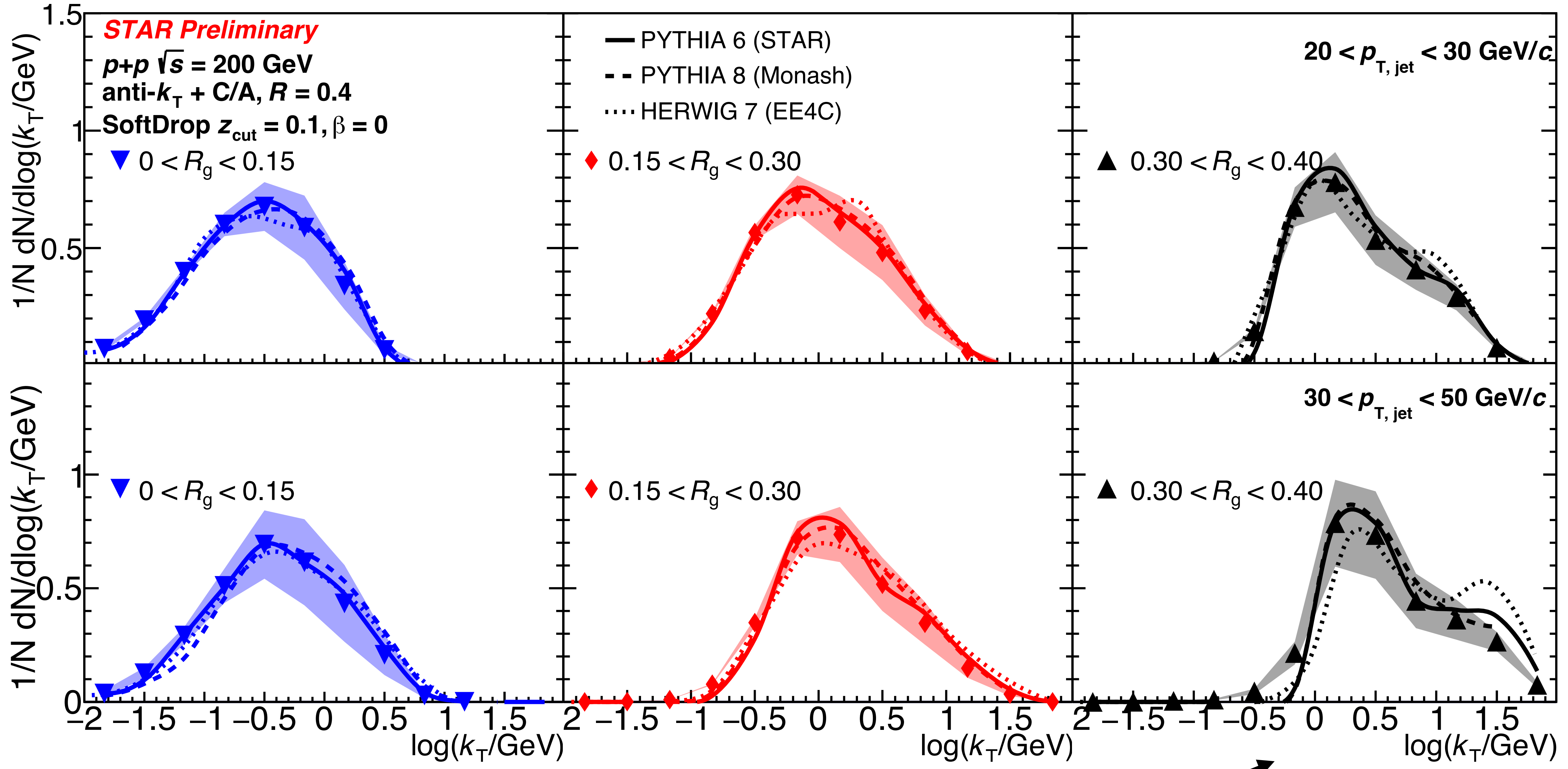


- Now able to make slices in the Lund Plane → more stringent tests of Monte Carlo (MC) models
- Observe: wider splits are harder. MCs in good agreement.

Multi-dimensional jet substructure



Havener, PoS EPS-HEP2021 (2022), 364

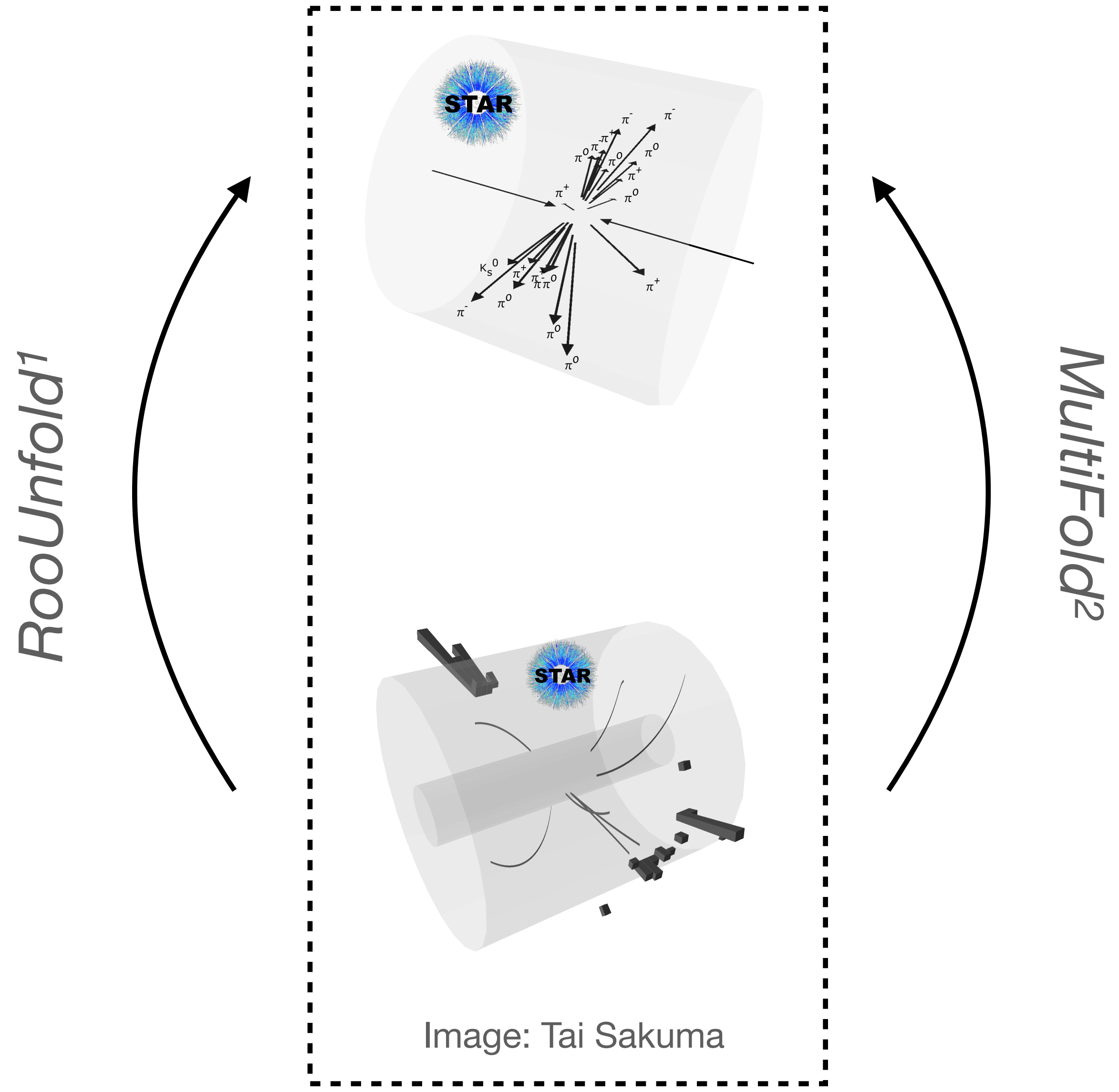


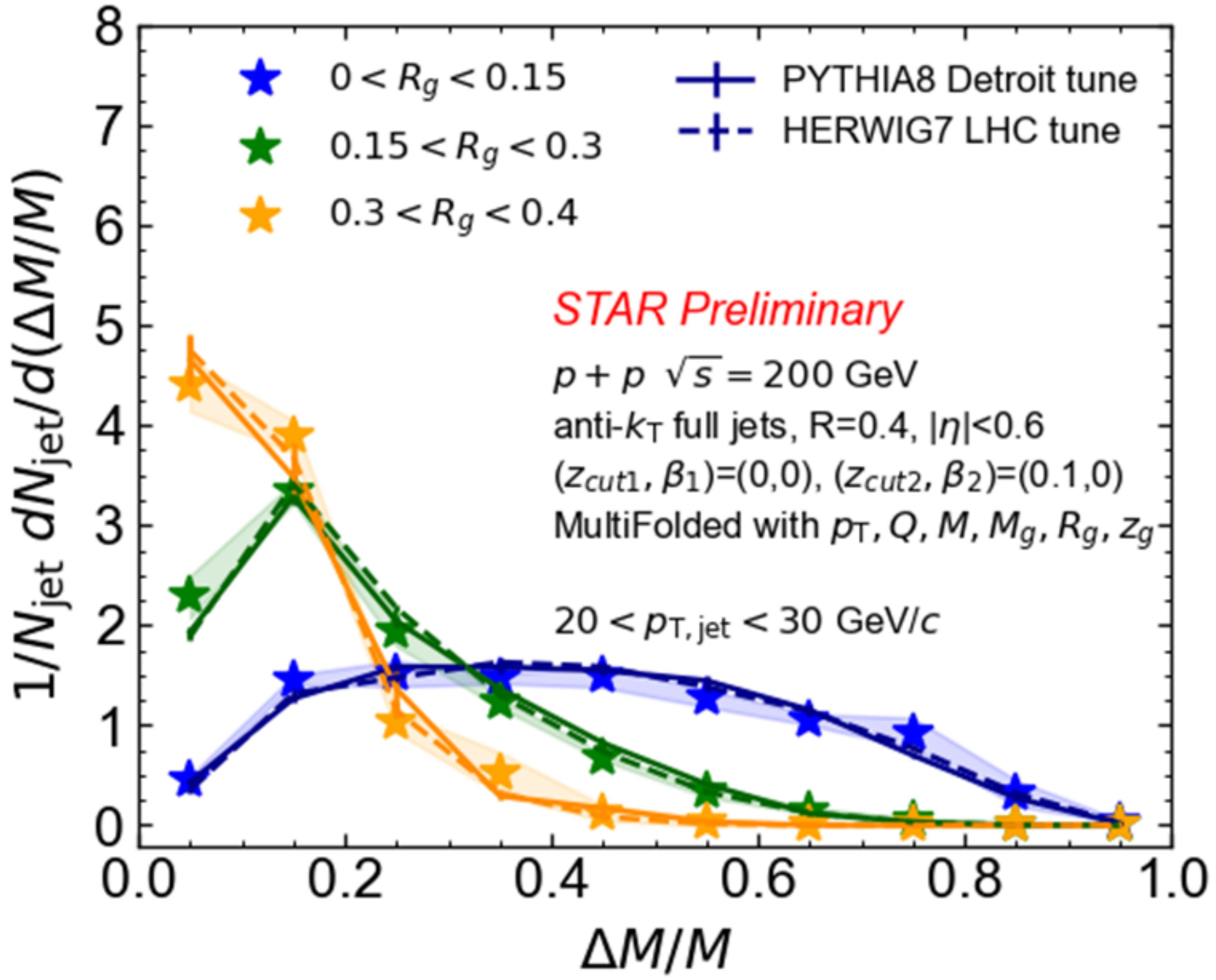
- Now able to make slices in the Lund Plane → more stringent tests of Monte Carlo (MC) models
- Observe similarly in ALICE: high-k_T splits are wider. But tension with models for narrow splits with high k_T

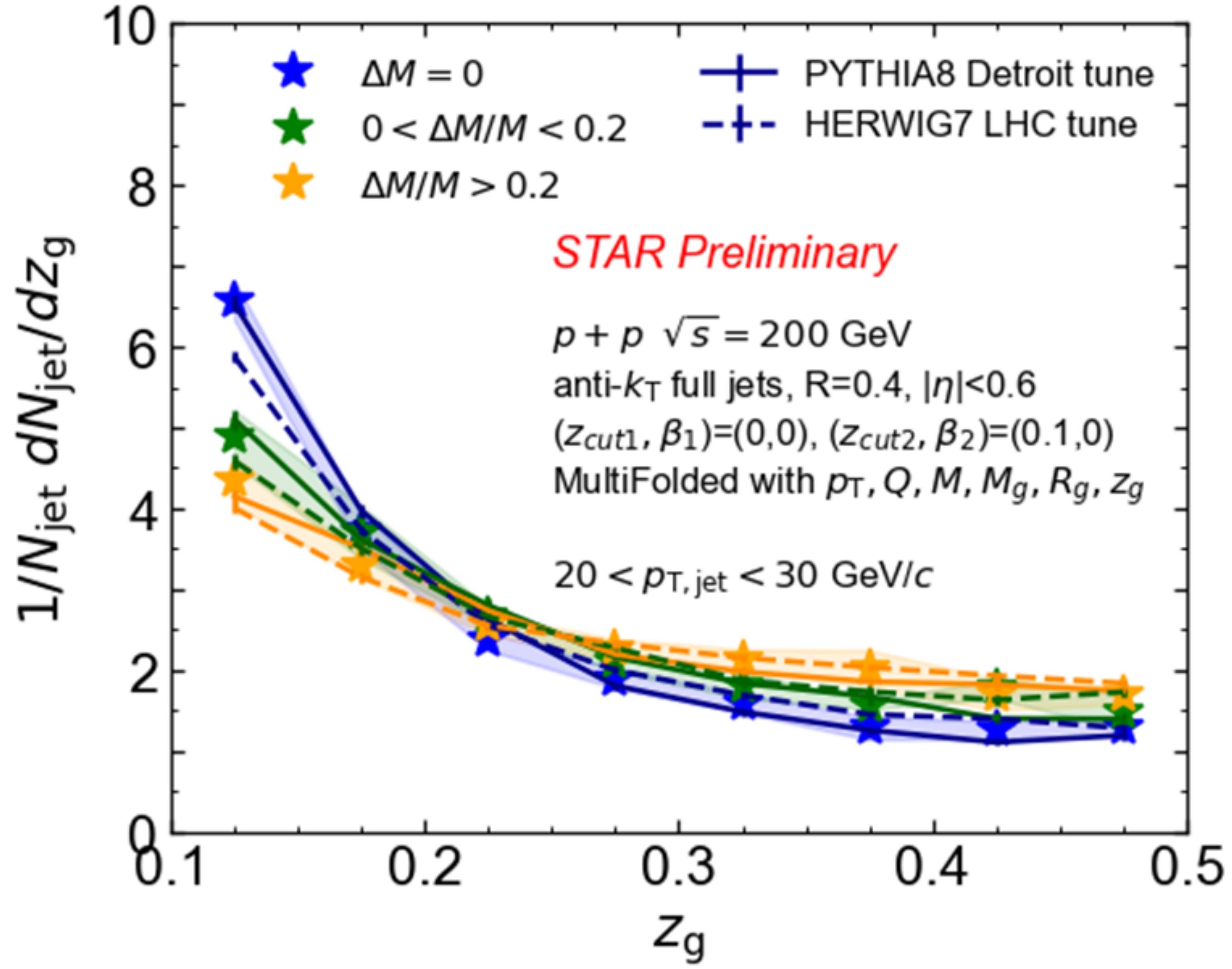
N-dimensional observables

With MultiFold

$\Delta M = M - M_g$





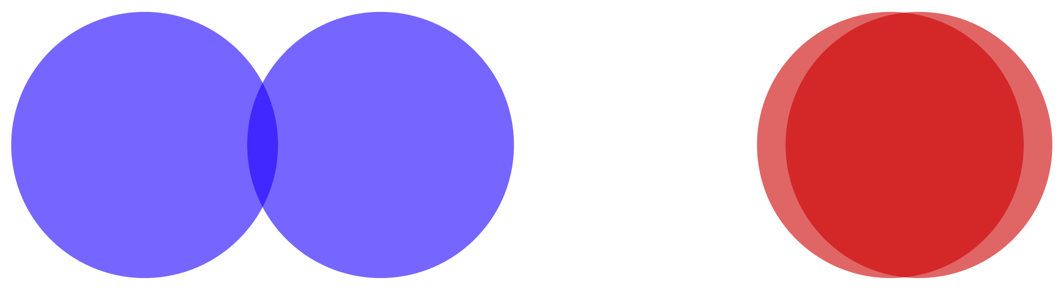


- First application of MultiFold at RHIC
- Consistent with angular ordering + kinematic constraint between early and late time splittings

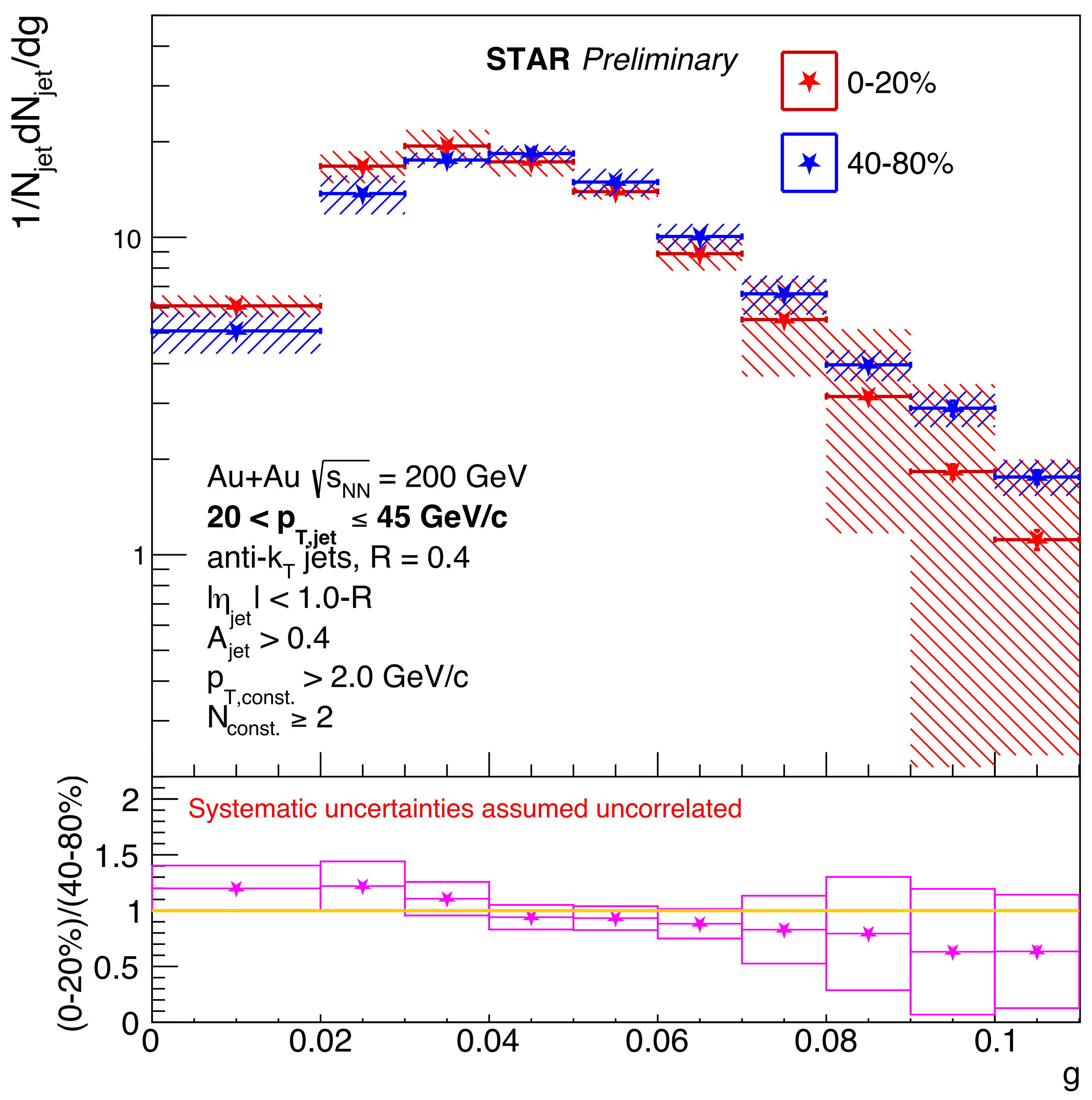
[1]D'Agostini, arXiv:1010.0632
[2]Andreassen, Komiske, Metodiev, Nachman, Thaler, PRL 124 (2020) 18, 182001

Generalized angularities in AA

With MultiFold

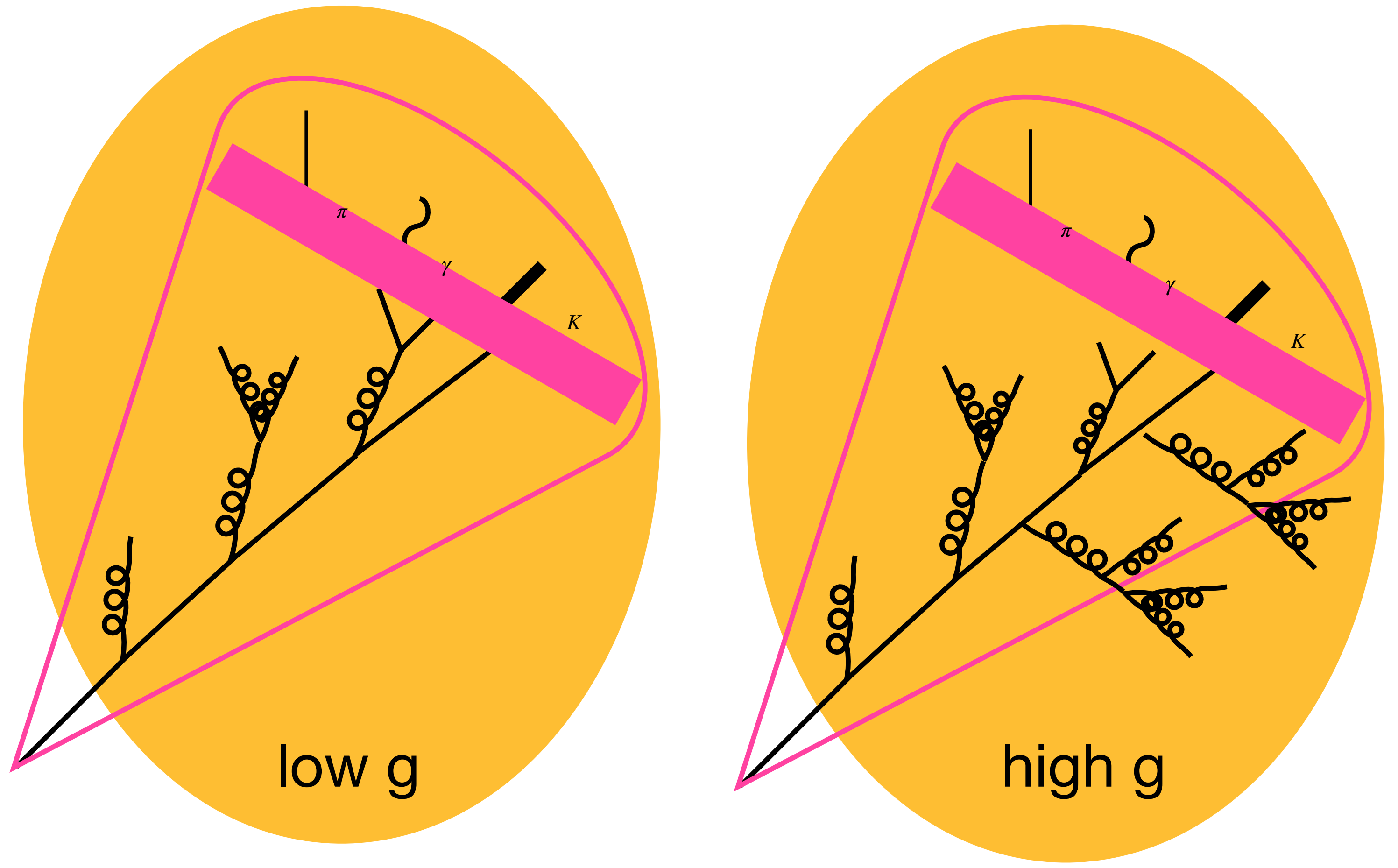


Data corrected using MultiFold in 7D



$$\lambda_\beta^\kappa = \sum_{\text{cons}\in\text{jet}} \left(\frac{p_{T,\text{cons}}}{p_{T,\text{jet}}}\right)^\kappa \Delta R\,(\text{cons},\text{jet})^\beta$$

$$g = \lambda_1^1 = \frac{\sum_{\text{trk}\in\text{jet}} p_{T,\text{trk}} \Delta R}{p_{T,\text{jet}}}$$



- Generalized angularities allow tunable contribution of momentum, angular scales in IRC safe way
- With conservative systematic uncertainties *in biased pop.*, girth in peripheral and central collisions are consistent

Precision QCD; exploring the Lund plane
w/ multi-dimensional jet substructure

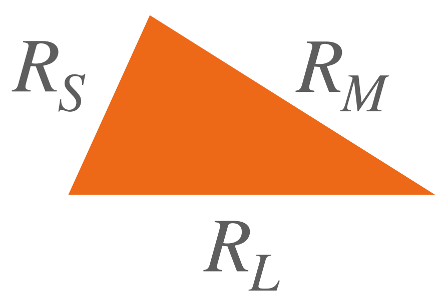
Separating p- and np-QCD
w/ *energy correlators*

Energy flows

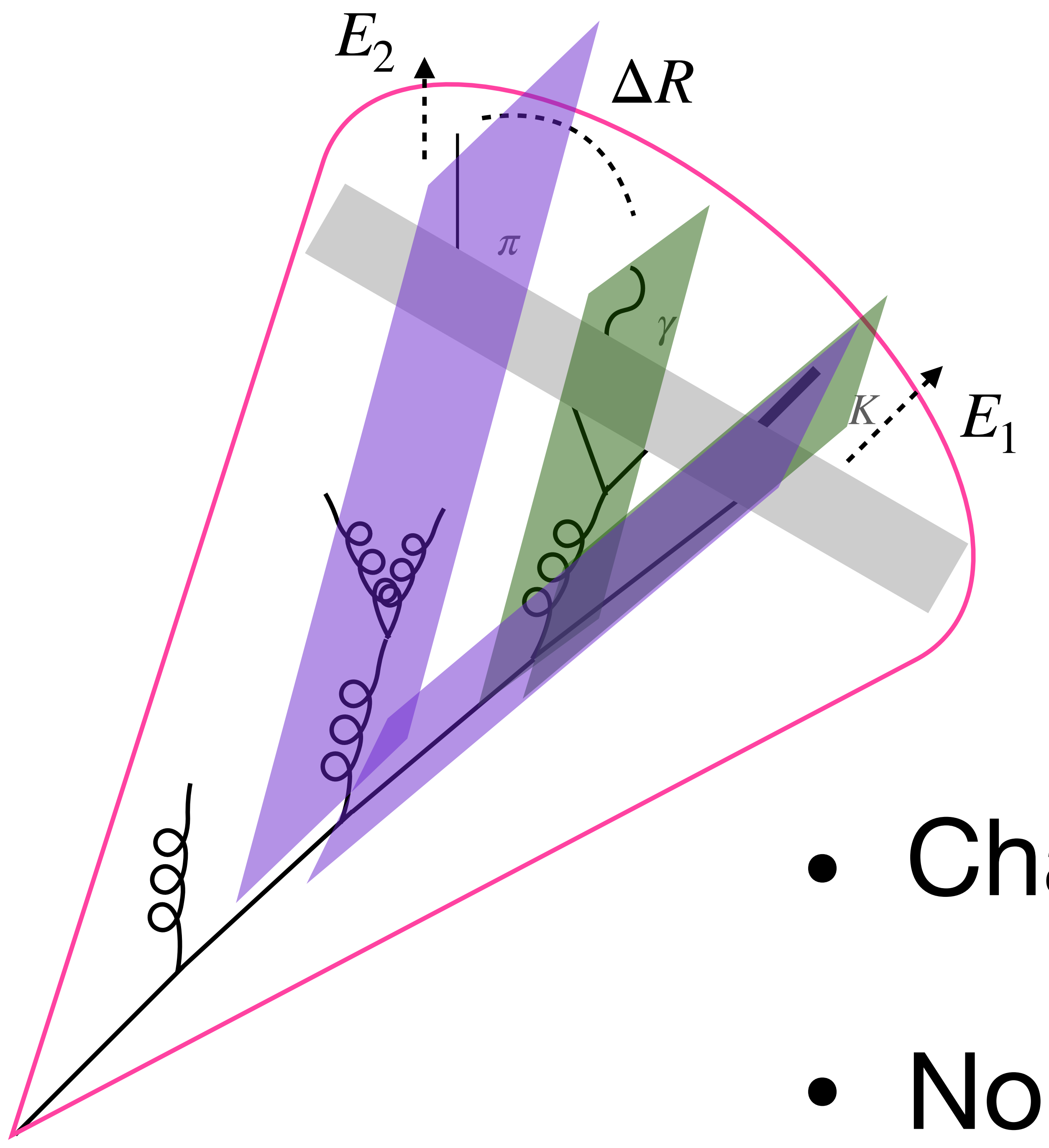
Path-length dependence of jet energy loss in medium
w/ jet anisotropies (w/r/t event plane)

Energy-density dependence of jet energy loss in medium;
angular distribution of radiation in quenched jets
w/ inclusive/semi-inclusive jet & high-p_T hadron yields

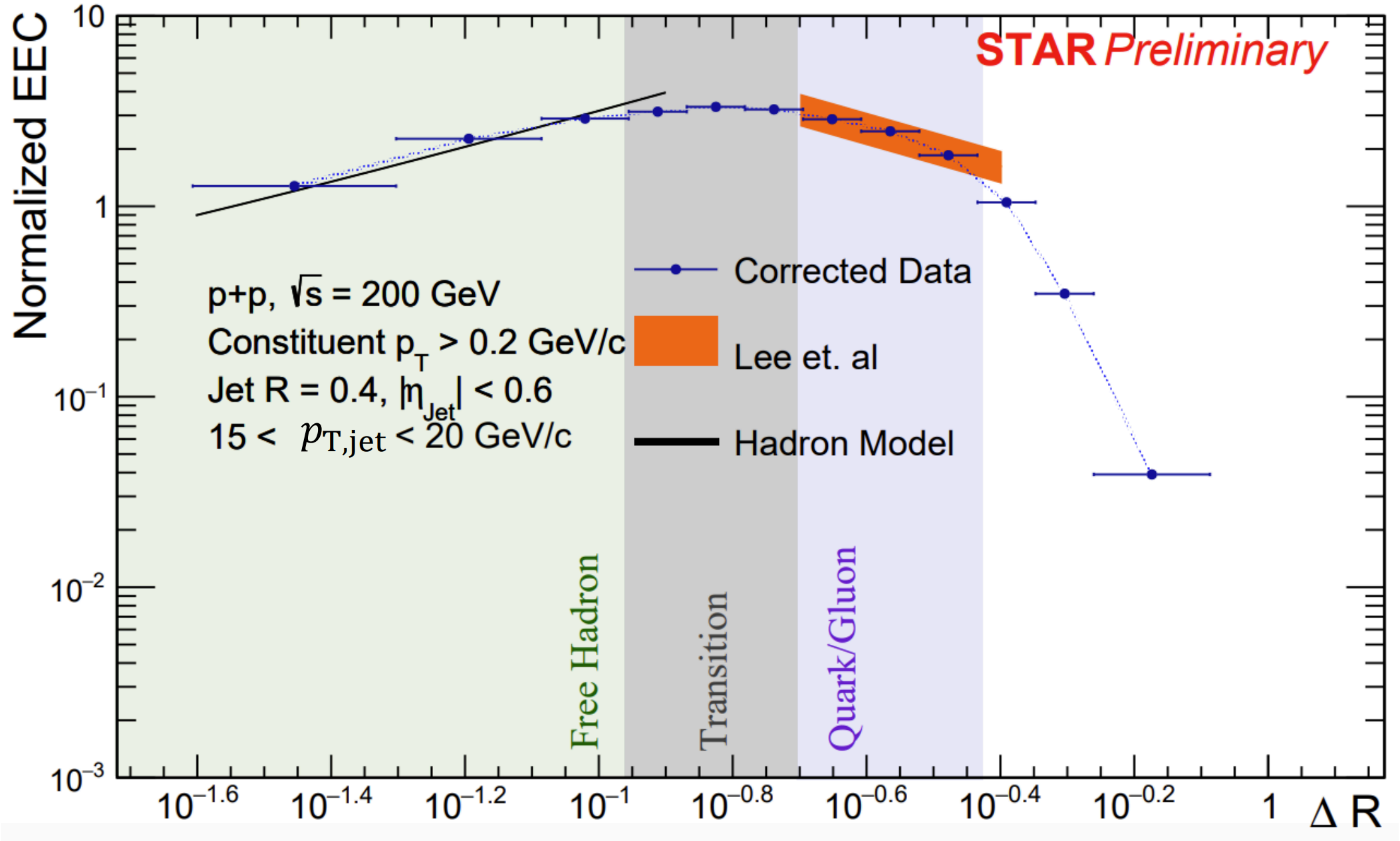
Energy correlators



$$\text{ENC}\left(R_L\right) = \left(\prod_{k=1}^{N}\int d\Omega_{\vec{n}_k}\right)\delta\left(R_L - \Delta\hat{R}_L\right)\frac{1}{\left(E_{\text{jet}}\right)^N}\left\langle \mathcal{E}\left(\vec{n}_1\right)\mathcal{E}\left(\vec{n}_2\right)\dots\mathcal{E}\left(\vec{n}_N\right)\right\rangle$$ [1,2,3]



$$\text{EEC}(\Delta R) = \frac{1}{\mathcal{O}}\frac{d\mathcal{O}}{d(\Delta R)},\ \mathcal{O} = \sum_{\text{jets}}\sum_{i\neq j}\frac{E_iE_j}{p^2_{\text{T,jet}}}$$

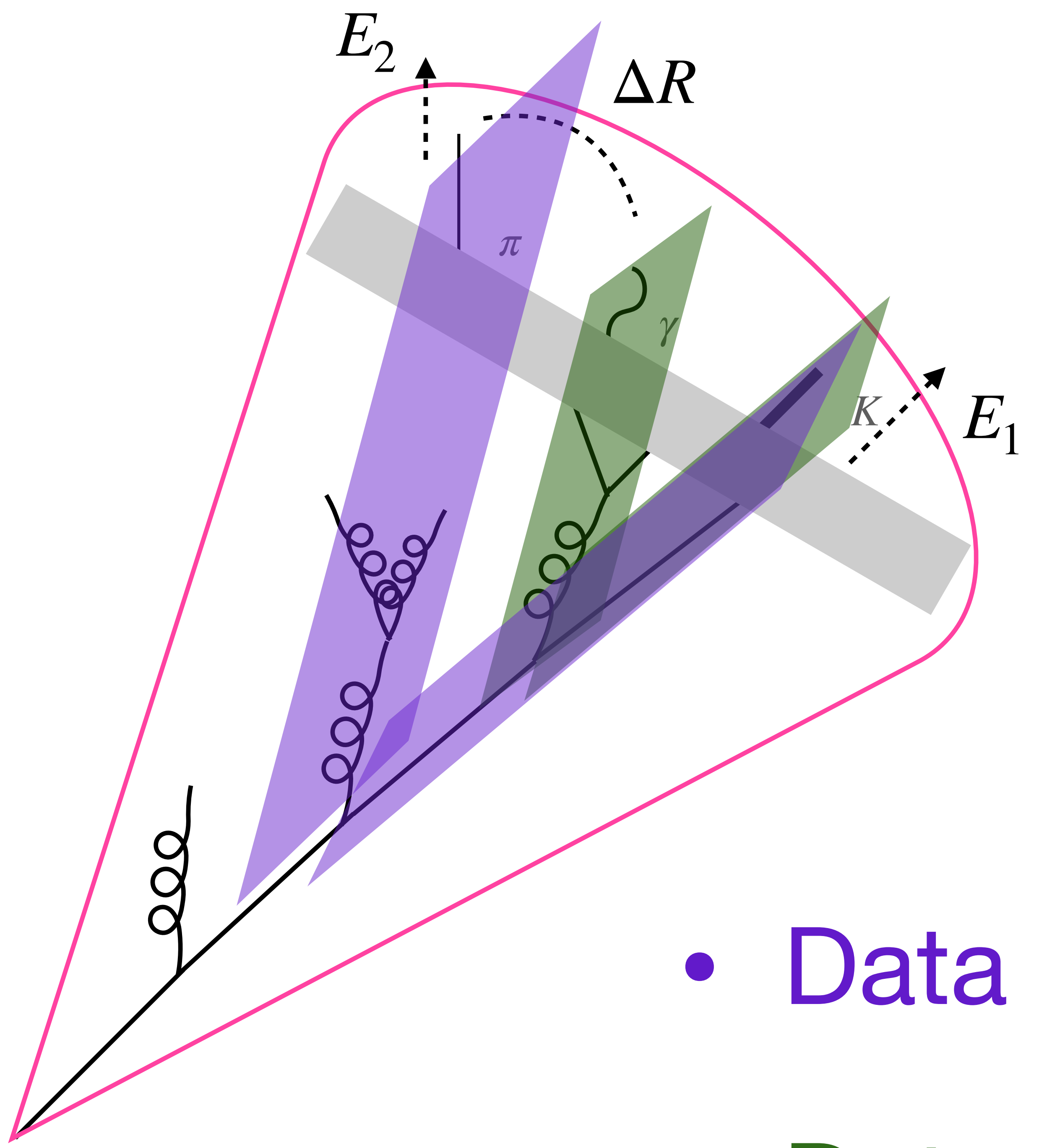


- Change in scaling when virtuality $\sim p_T R_L \sim \Lambda_{QCD}$ so $R_L^{\text{transition}} \propto 1/p_T$
- No need to recluster or remove npQCD contributions
- Simple scaling in the hadronic and partonic regimes

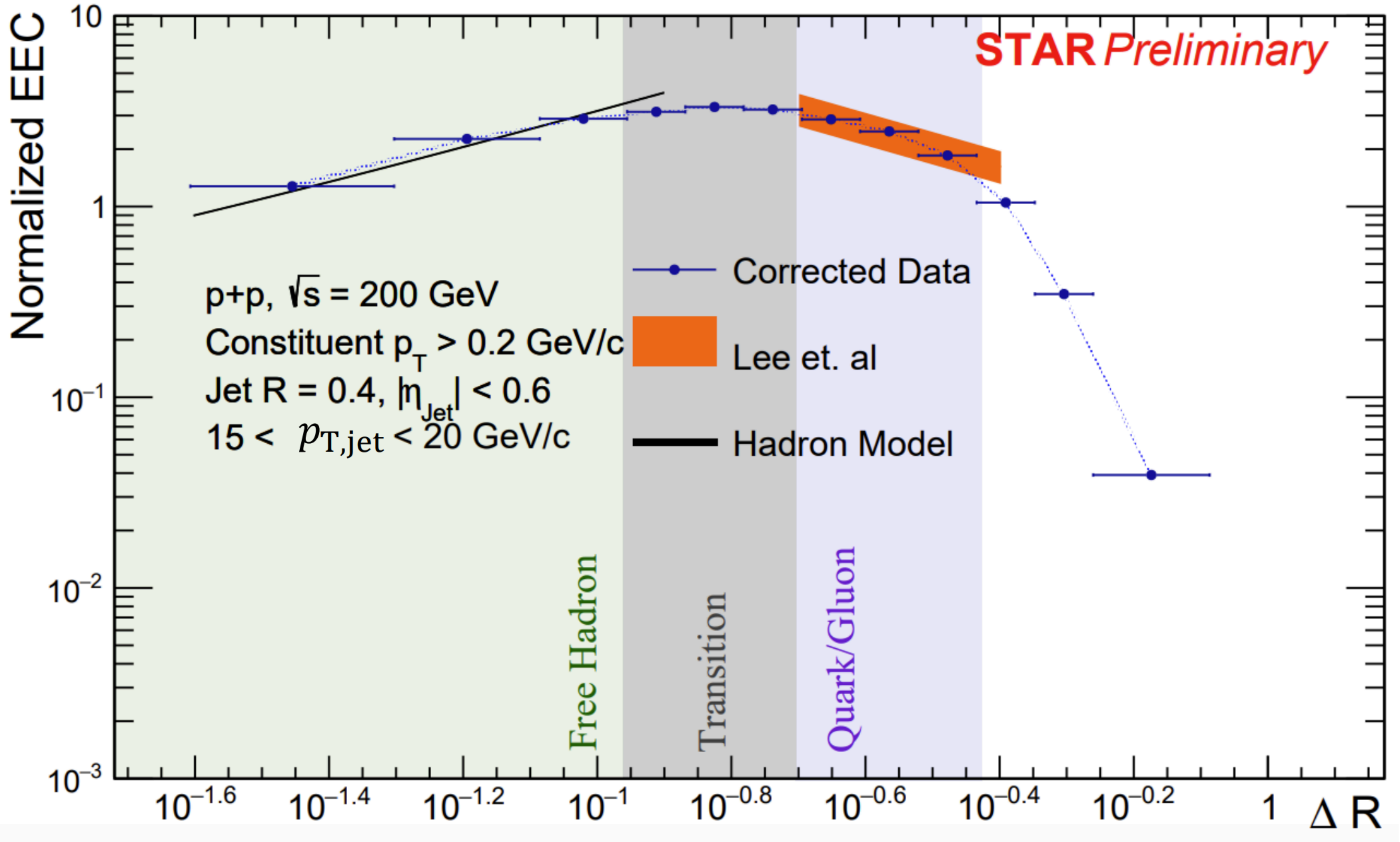
[1] Basham, Brown, Ellis, Love, PRL 41 (1978), 1585
[2] Chen, Moult, Zhang, Zhu, PRD 102 (2020) 5, 054012
[3] Komiske, Moult, Thaler, Zhu, PRL 130 (2023) 5, 051901

Energy correlators

$$\text{ENC}\left(R_L\right) = \left(\prod_{k=1}^{N}\int d\Omega_{\vec{n}_k}\right)\delta\left(R_L - \Delta\hat{R}_L\right)\frac{1}{\left(E_{\text{jet}}\right)^N}\left\langle \mathscr{E}\left(\vec{n}_1\right)\mathscr{E}\left(\vec{n}_2\right)\ldots\mathscr{E}\left(\vec{n}_N\right)\right\rangle^{1,2,3}$$



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

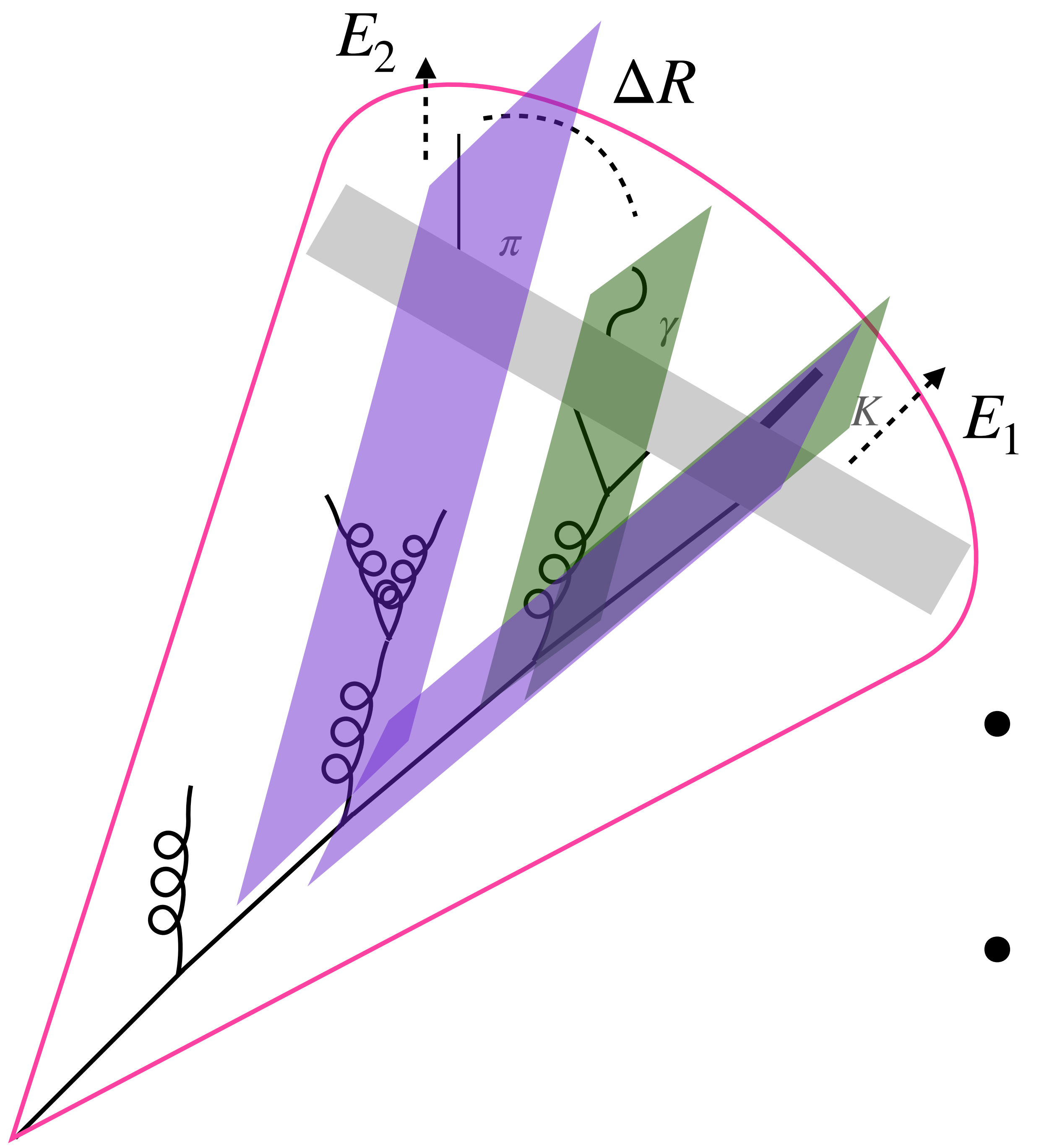


- Data agree well with NLL pQCD calculation (& MC model, not shown)
- Data agree well with model assuming non-interacting hadrons

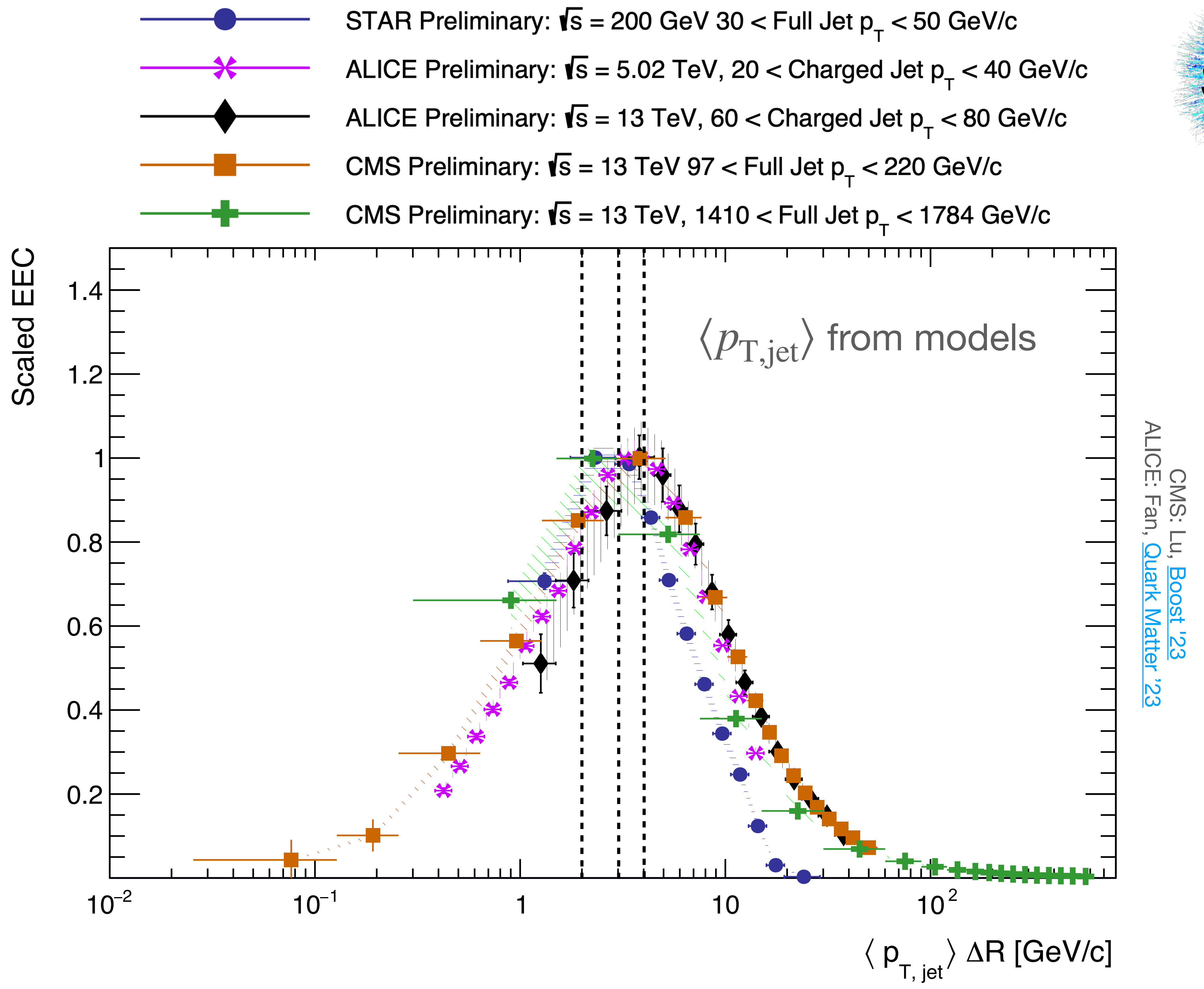
[1]Basham, Brown, Ellis, Love, PRL 41 (1978), 1585
[2]Chen, Moult, Zhang, Zhu, PRD 102 (2020) 5, 054012
[3]Komiske, Moult, Thaler, Zhu, PRL 130 (2023) 5, 051901

Energy correlators

$$\text{ENC}(R_L) = \left(\prod_{k=1}^{N} \int d\Omega_{\vec{n}_k}\right) \delta\left(R_L - \Delta\hat{R}_L\right) \frac{1}{\left(E_{\text{jet}}\right)^N} \left\langle \mathcal{E}(\vec{n}_1)\, \mathcal{E}(\vec{n}_2) \ldots \mathcal{E}(\vec{n}_N) \right\rangle^{1,2,3}$$



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



- Testing universality of transition region by comparing to LHC data:
- ~ 2 orders of magnitude in $\sqrt{s}$ and $p_{\text{T,jet}}$ from STAR → ALICE → CMS, transition ~ 2 – 4 GeV/c
- STAR more similar to CMS high-p_T (high-x) jets than ALICE or CMS low-p_T jets — **q vs. g** differences

[1]Basham, Brown, Ellis, Love, PRL 41 (1978), 1585
[2]Chen, Moult, Zhang, Zhu, PRD 102 (2020) 5, 054012
[3]Komiske, Moult, Thaler, Zhu, PRL 130 (2023) 5, 051901

STAR

Precision QCD; exploring the Lund plane
w/ *multi-dimensional jet substructure*

Separating p- and np-QCD
w/ *energy correlators*

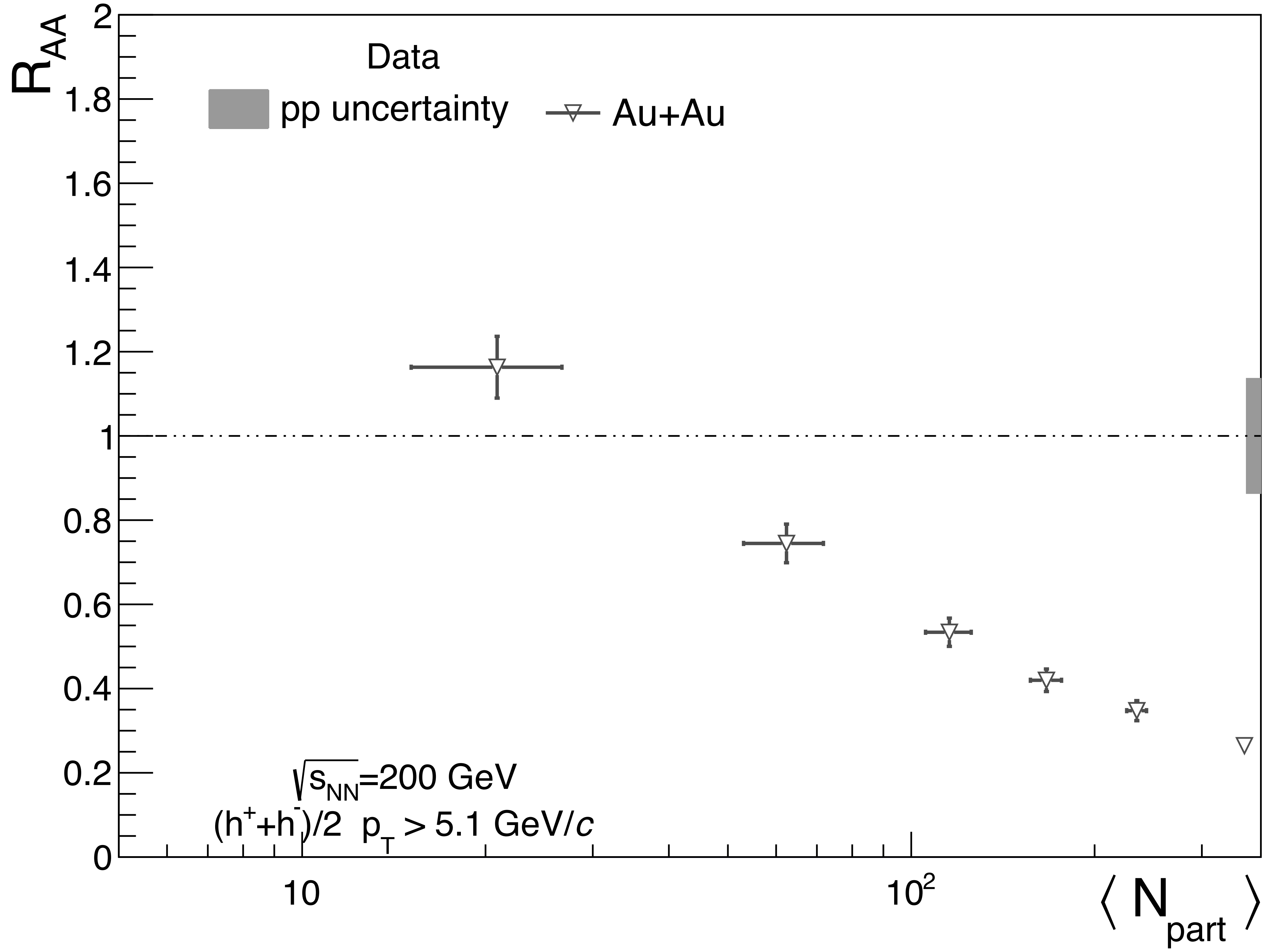
Energy flows

Path-length dependence of jet energy loss in medium
w/ *jet anisotropies (w/r/t event plane)*

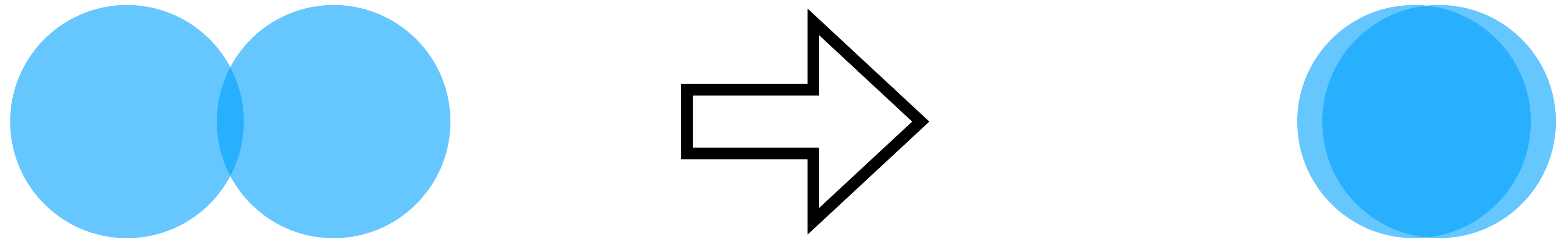
Energy-density dependence of jet energy loss in medium;
angular distribution of radiation in quenched jets
w/ *inclusive/semi-inclusive jet & high-p_T hadron yields*

Inclusive yield modification

$$R_{AA} = \frac{1}{N_{ev}^{AA}} \frac{d^2N^{AA}/d\eta dp_T}{\langle T_{AA} \rangle \, d^2\sigma^{NN}/d\eta dp_T}, \; \langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$$



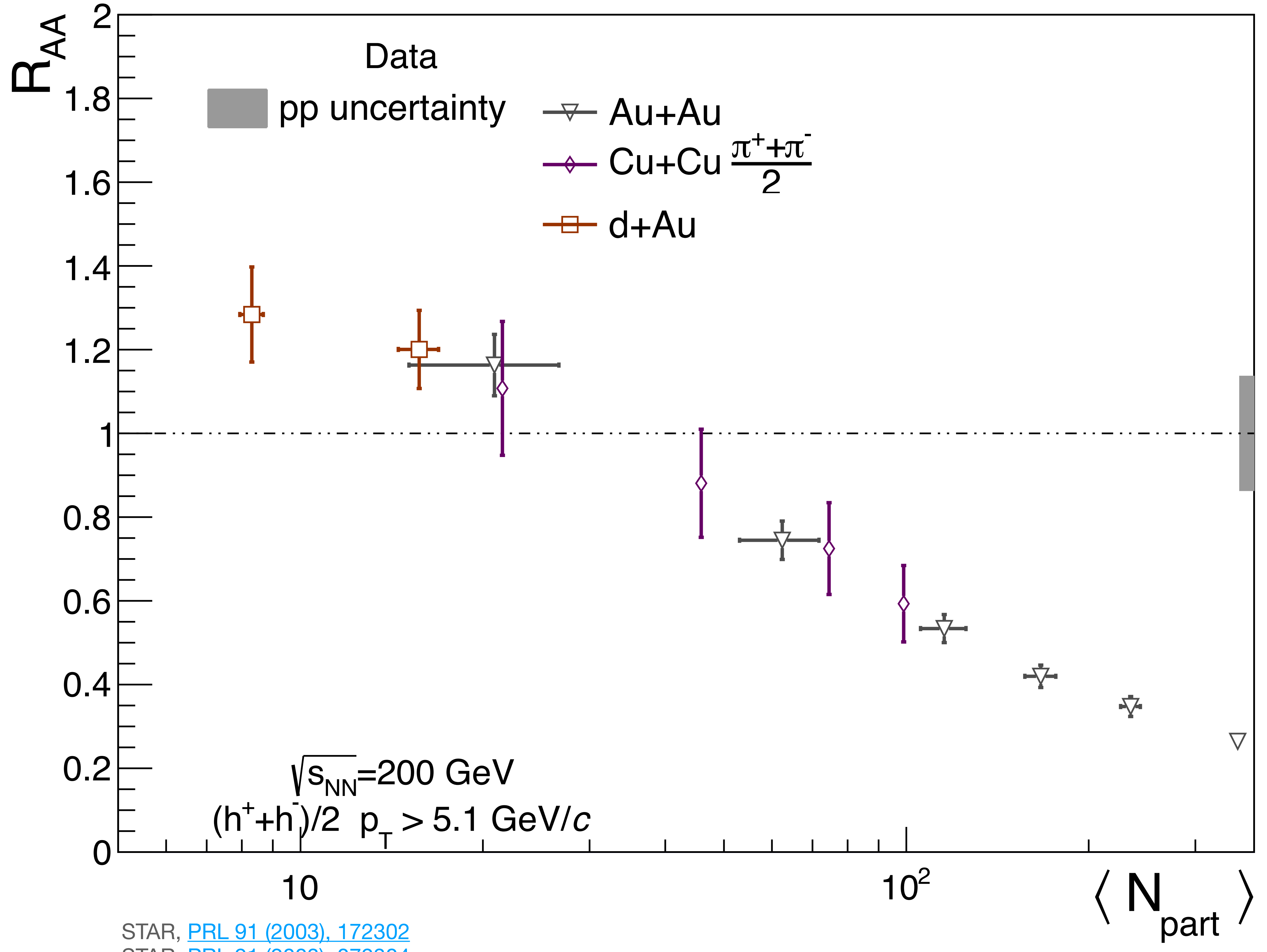
STAR, PRL 91 (2003), 172302



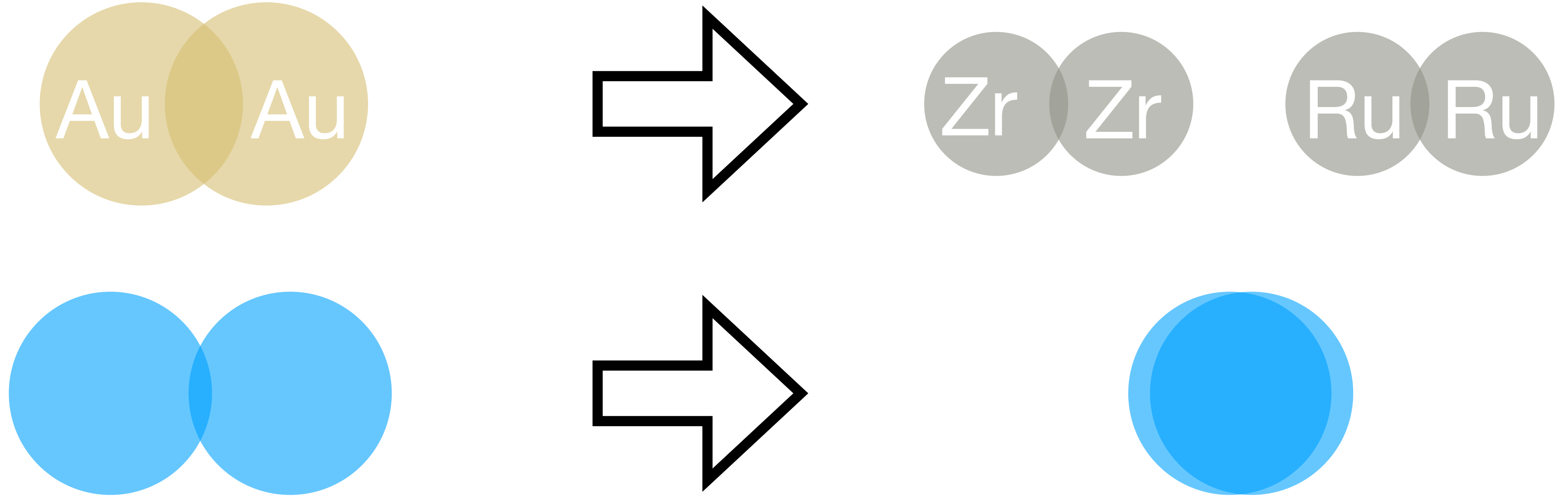
- Suppression strongly increases with $\langle N_{part} \rangle$

Inclusive yield modification

$$R_{AA} = \frac{1}{N_{ev}^{AA}} \frac{d^2N^{AA}/d\eta dp_T}{\langle T_{AA}\rangle\, d^2\sigma^{NN}/d\eta dp_T},\ \langle T_{AA}\rangle = \langle N_{coll}\rangle / \sigma_{inel}^{NN}$$



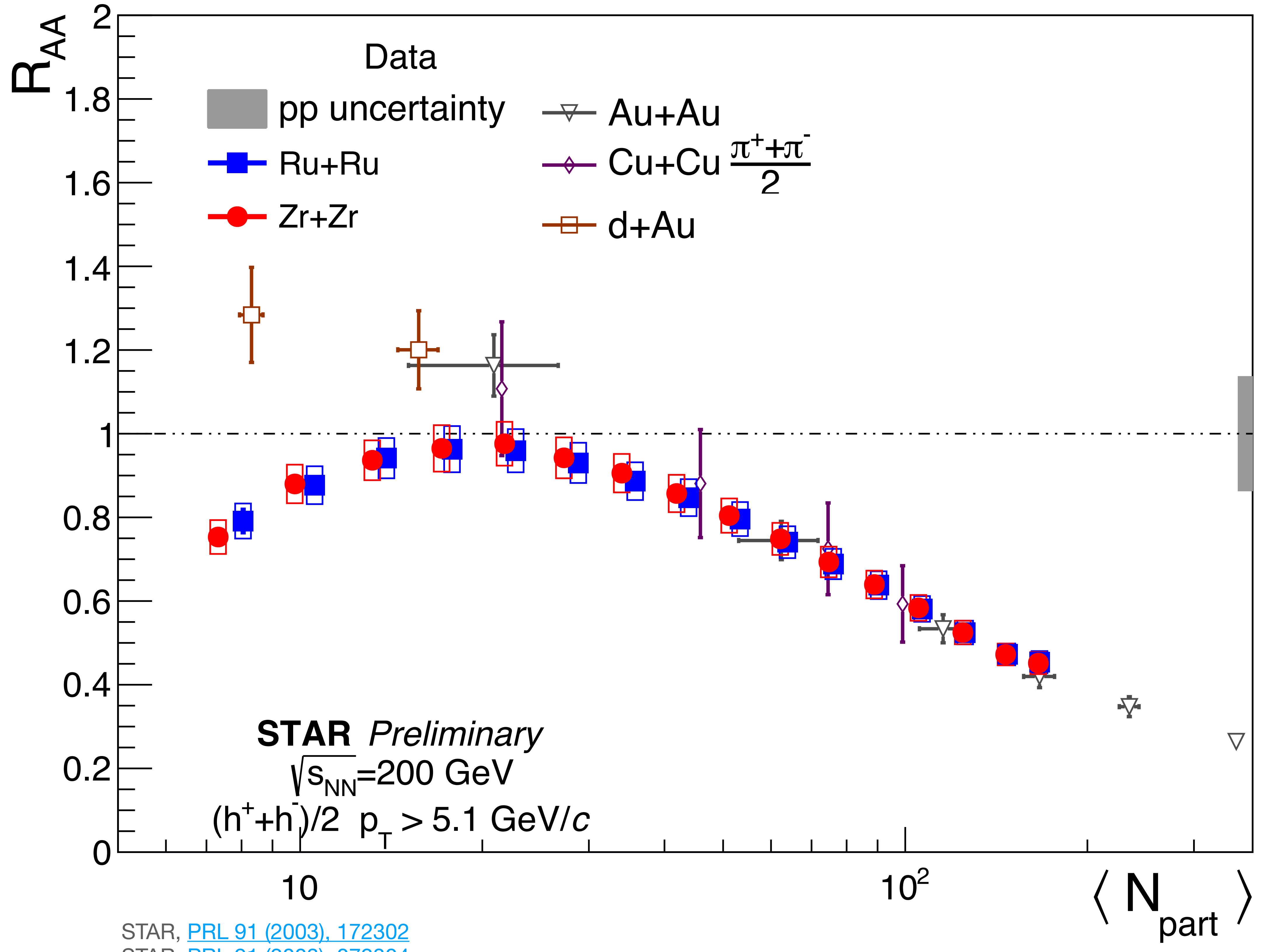
STAR, PRL 91 (2003), 172302
STAR, PRL 91 (2003), 072304
STAR, PRC 81 (2010), 054907



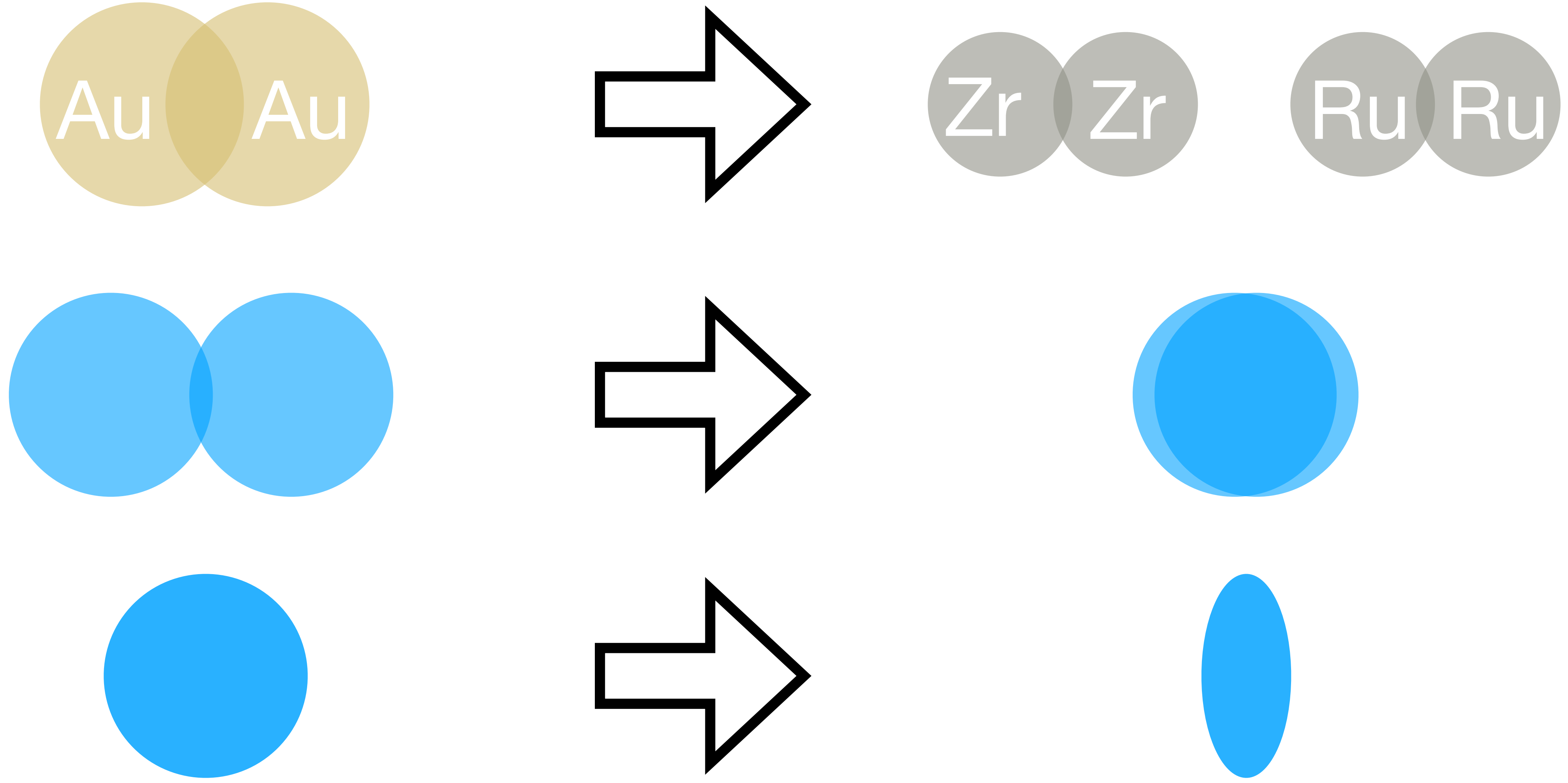
- R_{AA} scales with $\langle N_{part}\rangle$ independent of collision species (system size)

Inclusive yield modification

$$R_{AA} = \frac{1}{N_{ev}^{AA}} \frac{d^2N^{AA}/d\eta dp_T}{\langle T_{AA} \rangle \, d^2\sigma^{NN}/d\eta dp_T}, \; \langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$$



STAR, PRL 91 (2003), 172302
STAR, PRL 91 (2003), 072304
STAR, PRC 81 (2010), 054907

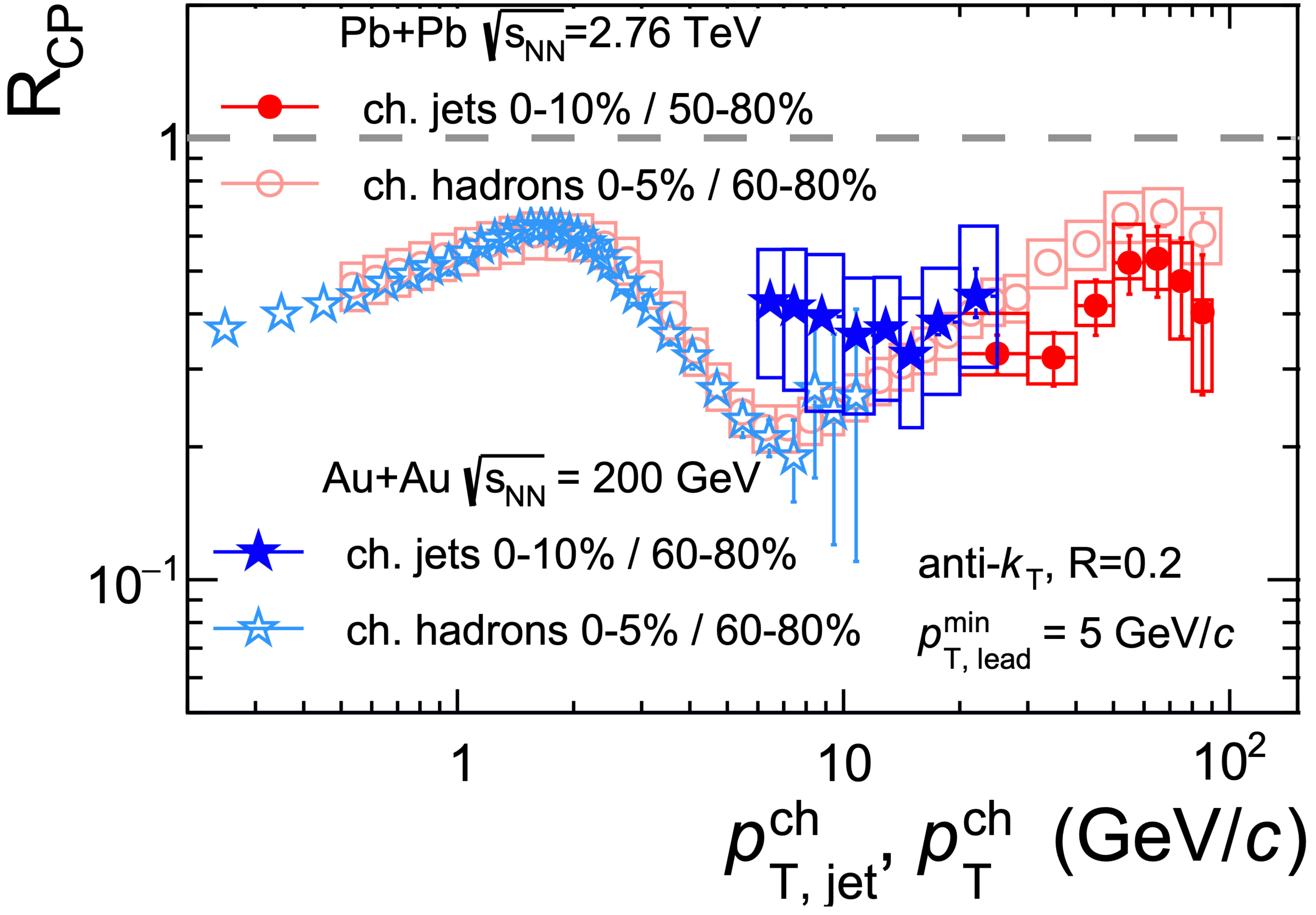


- R_{AA} scales with $\langle N_{part} \rangle$ independent of collision species (system size), above ~ 20
- Later: for given $\langle N_{part} \rangle$, how does geometry influence E-loss?

Inclusive yield modification

$$R_{CP} = \frac{N_{ev}^{P}}{N_{ev}^{C}} \frac{\langle T_{AA,P} \rangle}{\langle T_{AA,C} \rangle} \frac{d^2N^C/d\eta dp_T}{d^2N^P/d\eta dp_T}, \ \langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$$

STAR, PRC 102 (2020) 5, 054913, STAR, PRL 91 (2003) 172302, ALICE, JHEP 03 (2014) 013, ALICE, JHEP 09 (2015) 050

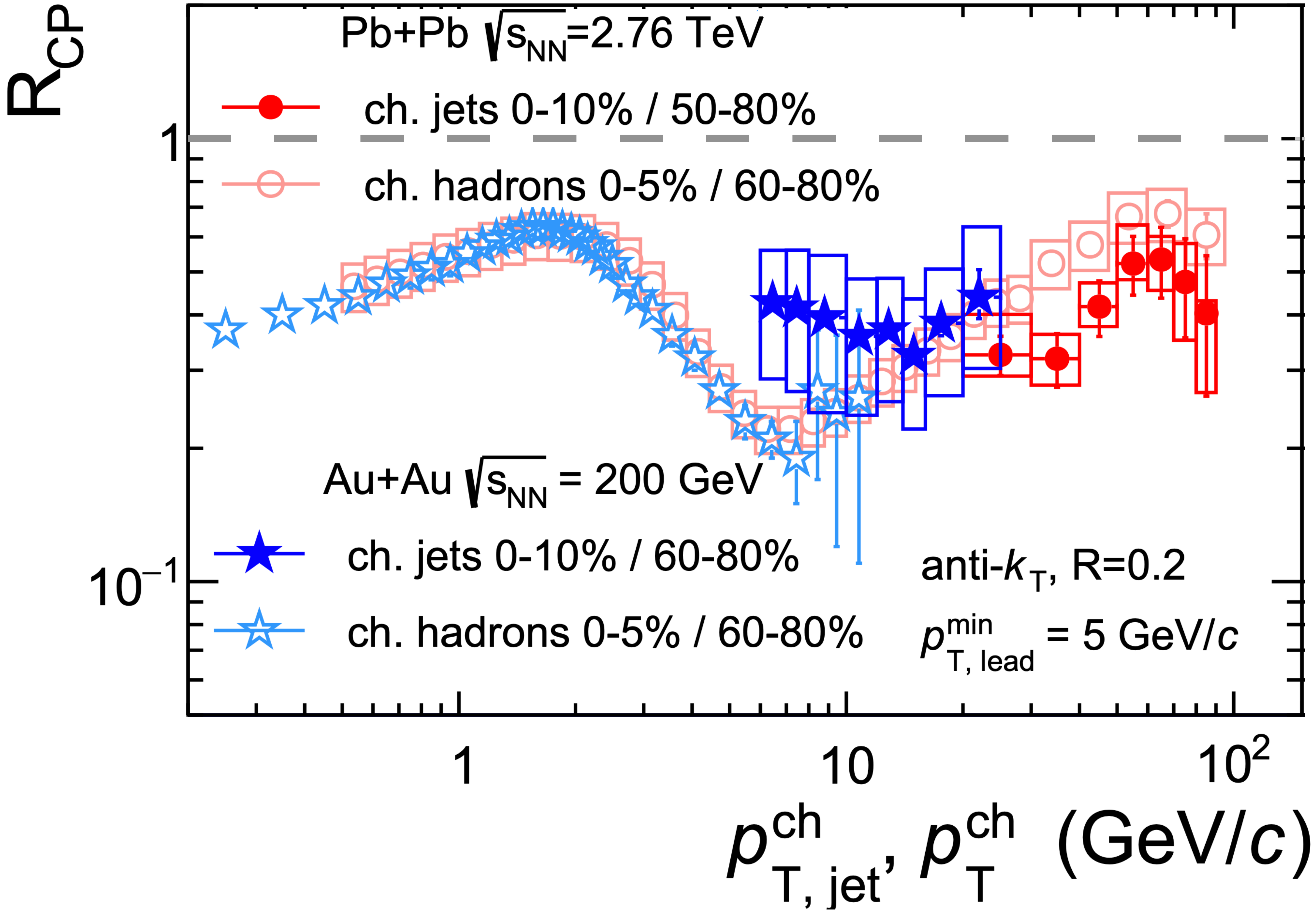


- Jet R_{AA} consistent with hadron R_{AA}
- Strong suppression across p_T
- RHIC and LHC jets already have kinematic overlap
    - Similar quenching?

Inclusive yield modification

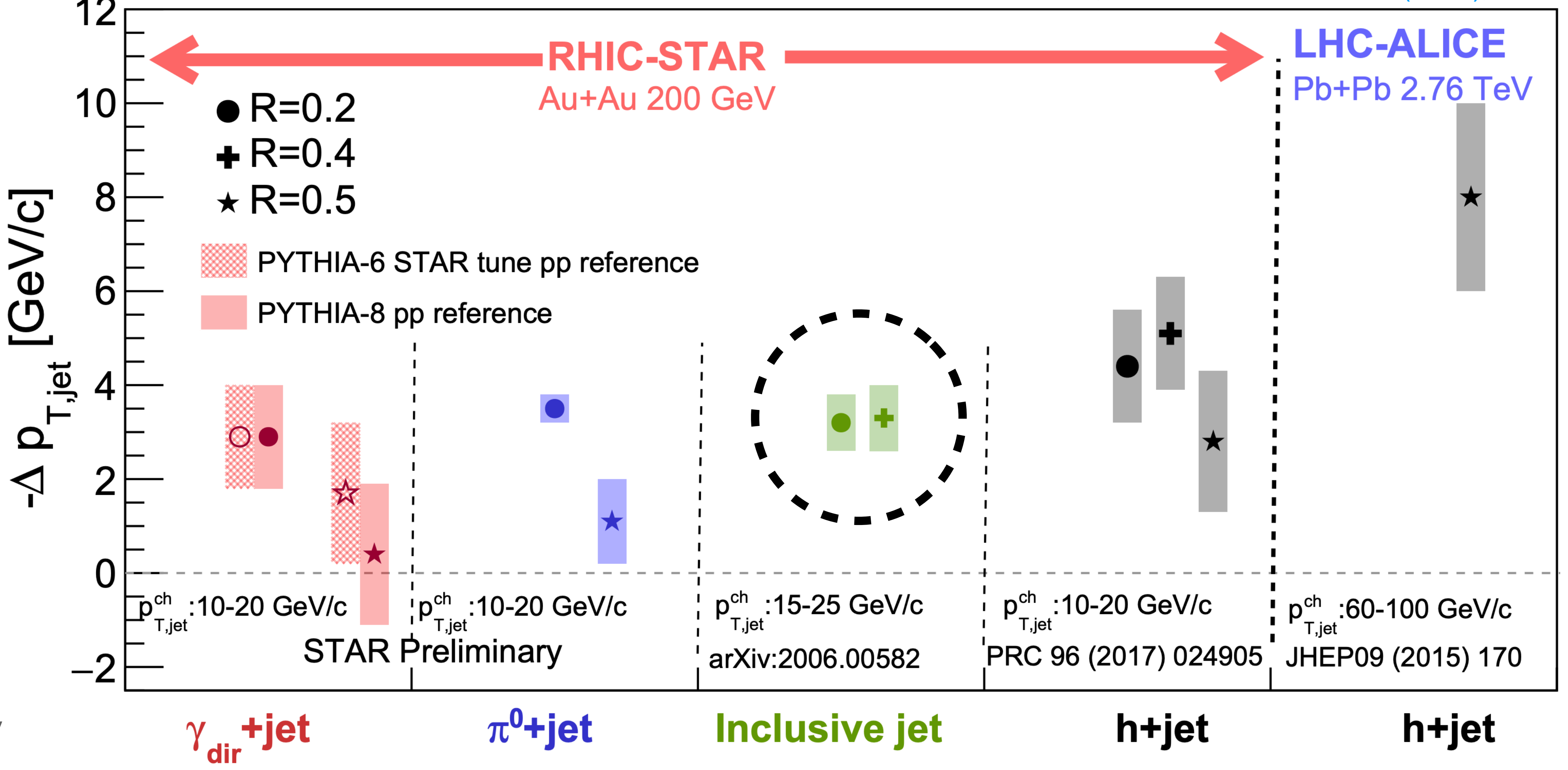
$$R_{CP} = \frac{N_{ev}^{P}}{N_{ev}^{C}} \frac{\langle T_{AA,P} \rangle}{\langle T_{AA,C} \rangle} \frac{d^2N^C/d\eta dp_T}{d^2N^P/d\eta dp_T}, \langle T_{AA} \rangle = \langle N_{coll} \rangle / \sigma_{inel}^{NN}$$

STAR, PRC 102 (2020) 5, 054913, STAR, PRL 91 (2003) 172302, ALICE, JHEP 03 (2014) 013, ALICE, JHEP 09 (2015) 050



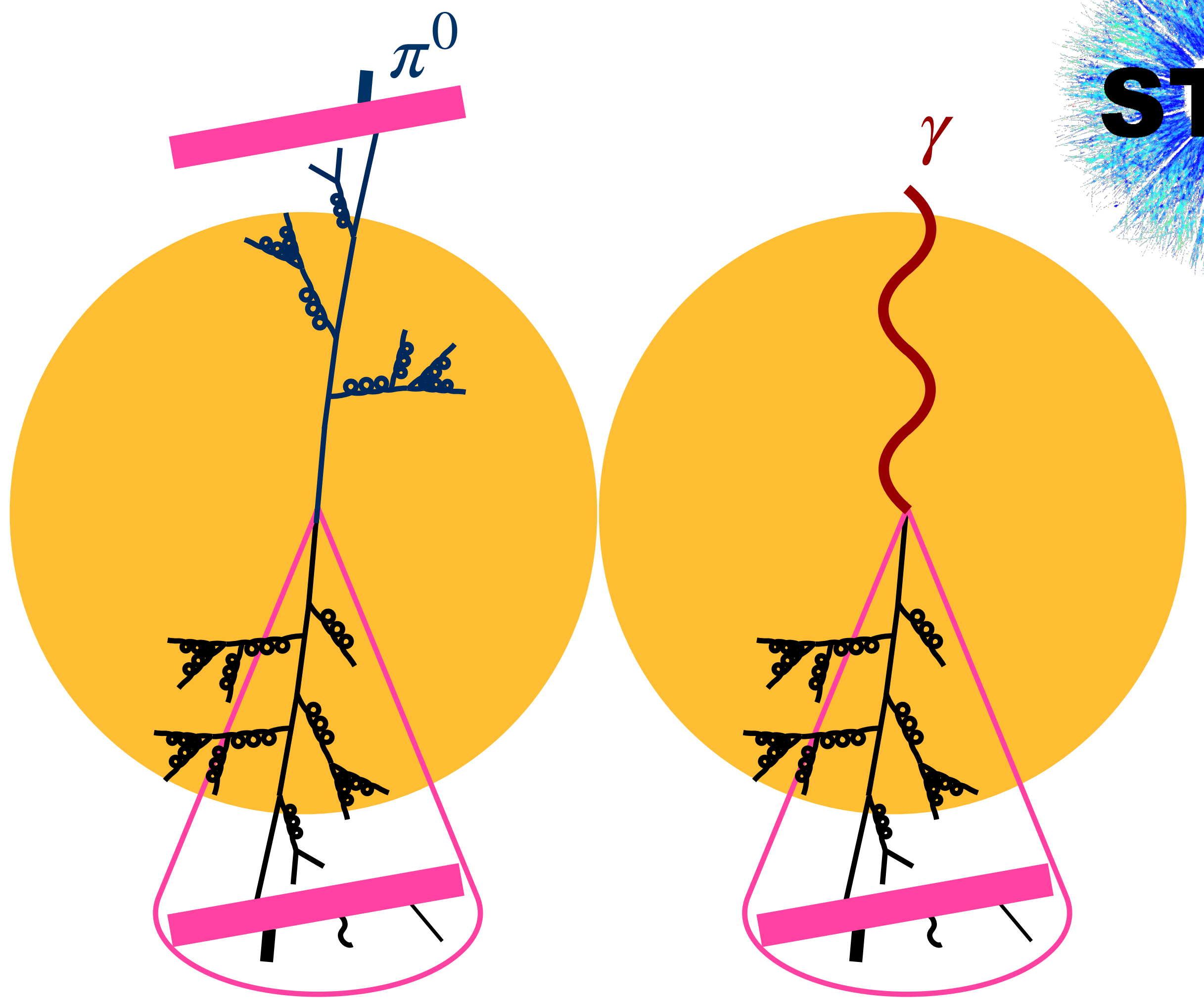
- Jet R_{AA} consistent with hadron R_{AA}
- Strong suppression across p_T
- RHIC and LHC jets already have kinematic overlap
  - Similar quenching?
    Absolute, smaller. Relative, *larger!*

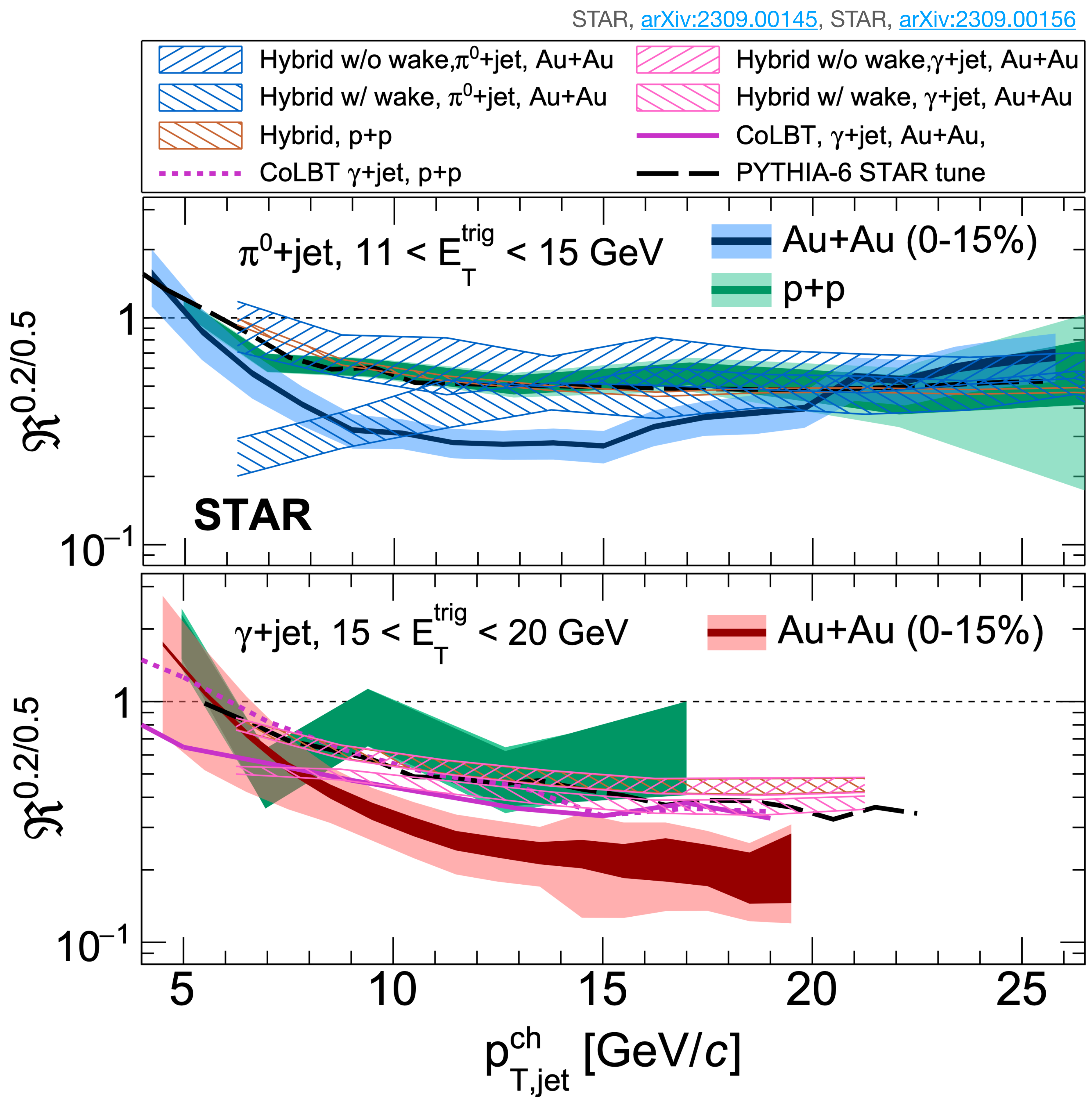
Sahoo, PoS HardProbes2020 (2021), 132



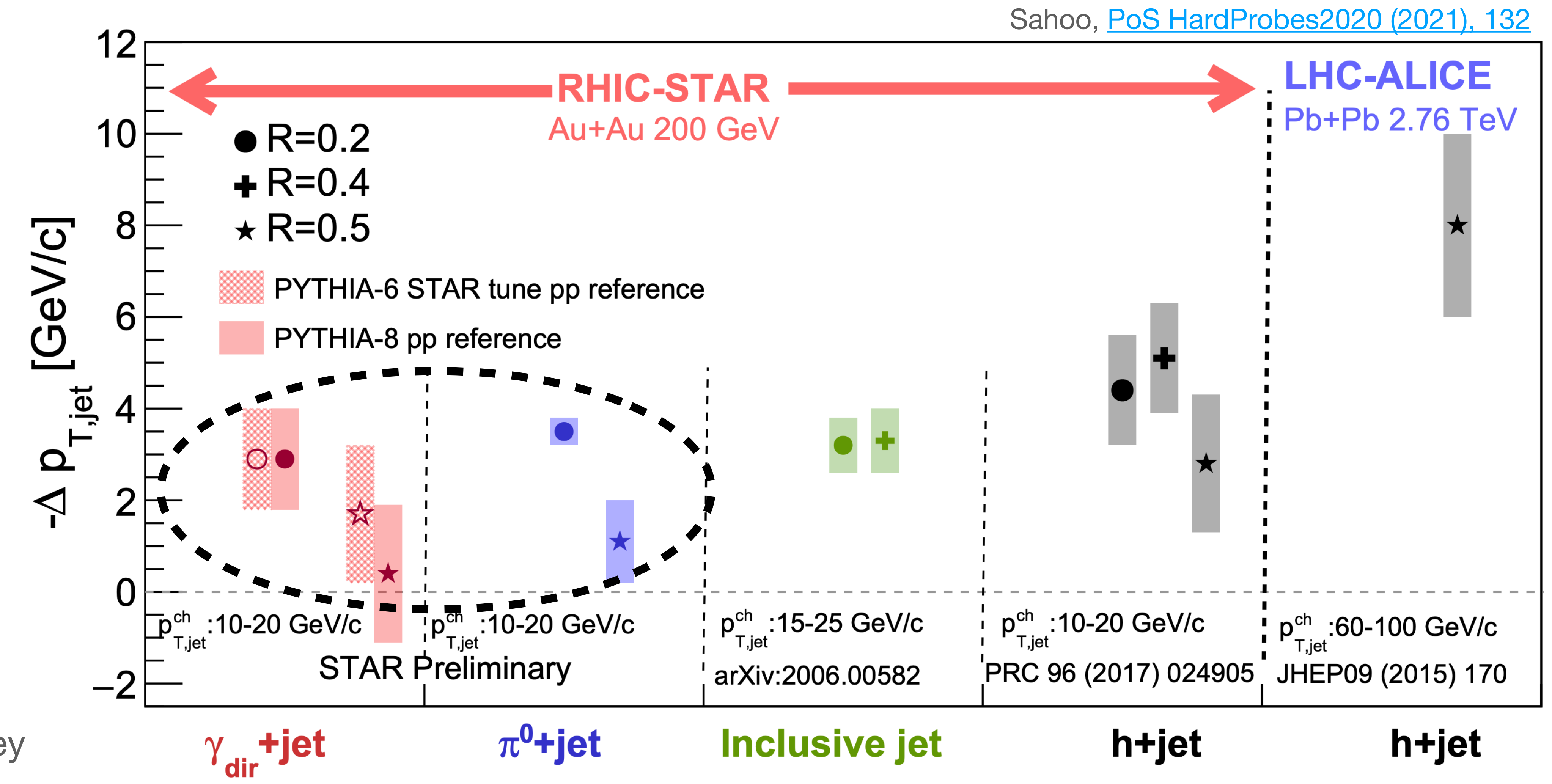
Semi-inclusive yield modification

$$I_{AA} = Y^{AA}(p^{ch}_{T,jet}, R)/Y^{pp}(p^{ch}_{T,jet}, R),\ Y(p^{ch}_{T,jet}, R) = \frac{1}{N_{trig}} \int_{3\pi/4}^{5\pi/4} d\Delta\phi \left[\frac{d^2 N_{jet}(R)}{dp^{ch}_{T,jet} d\Delta\phi} \right]_{E_T^{trig} \in [E_T^{min}, E_T^{max}]}$$



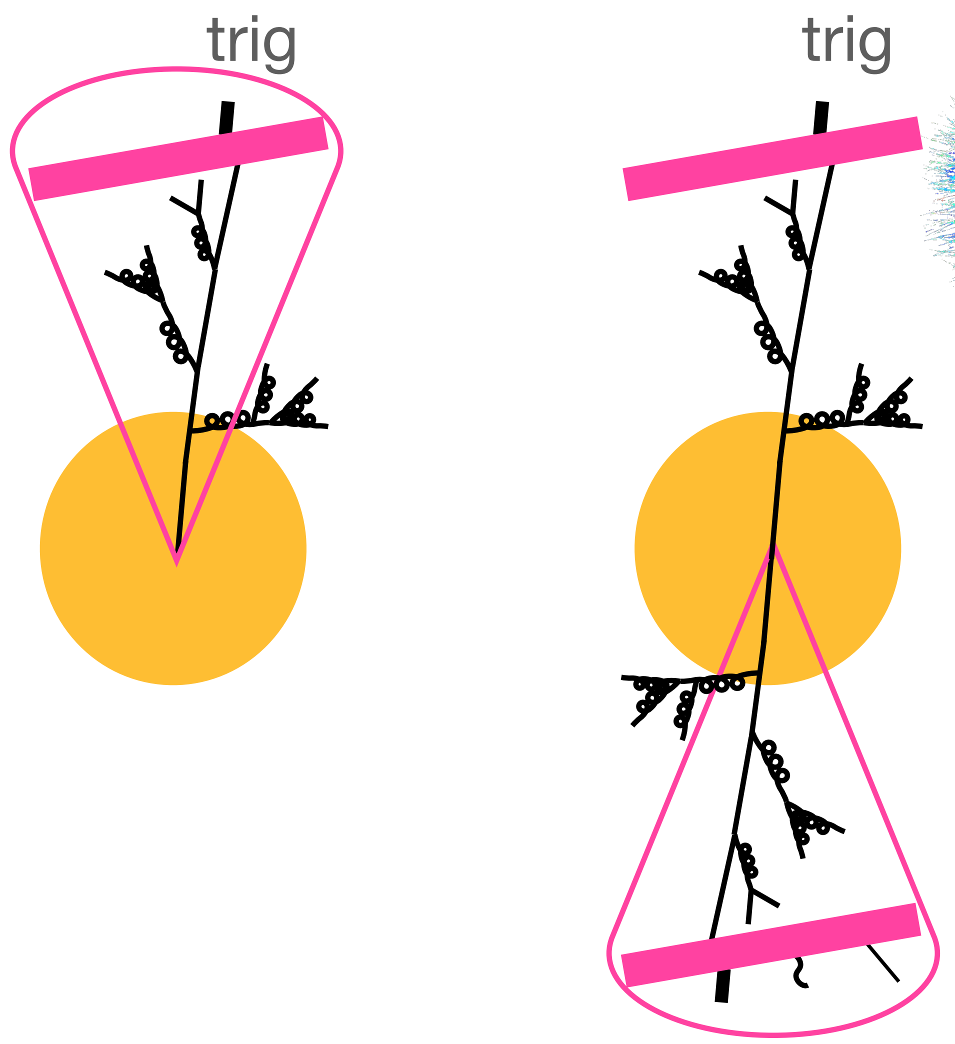


- Recoil jet yield suppression in AuAu, stronger in small R jets
- Clear observation of *intra-jet broadening*
- Models unable to quantitatively describe the effect

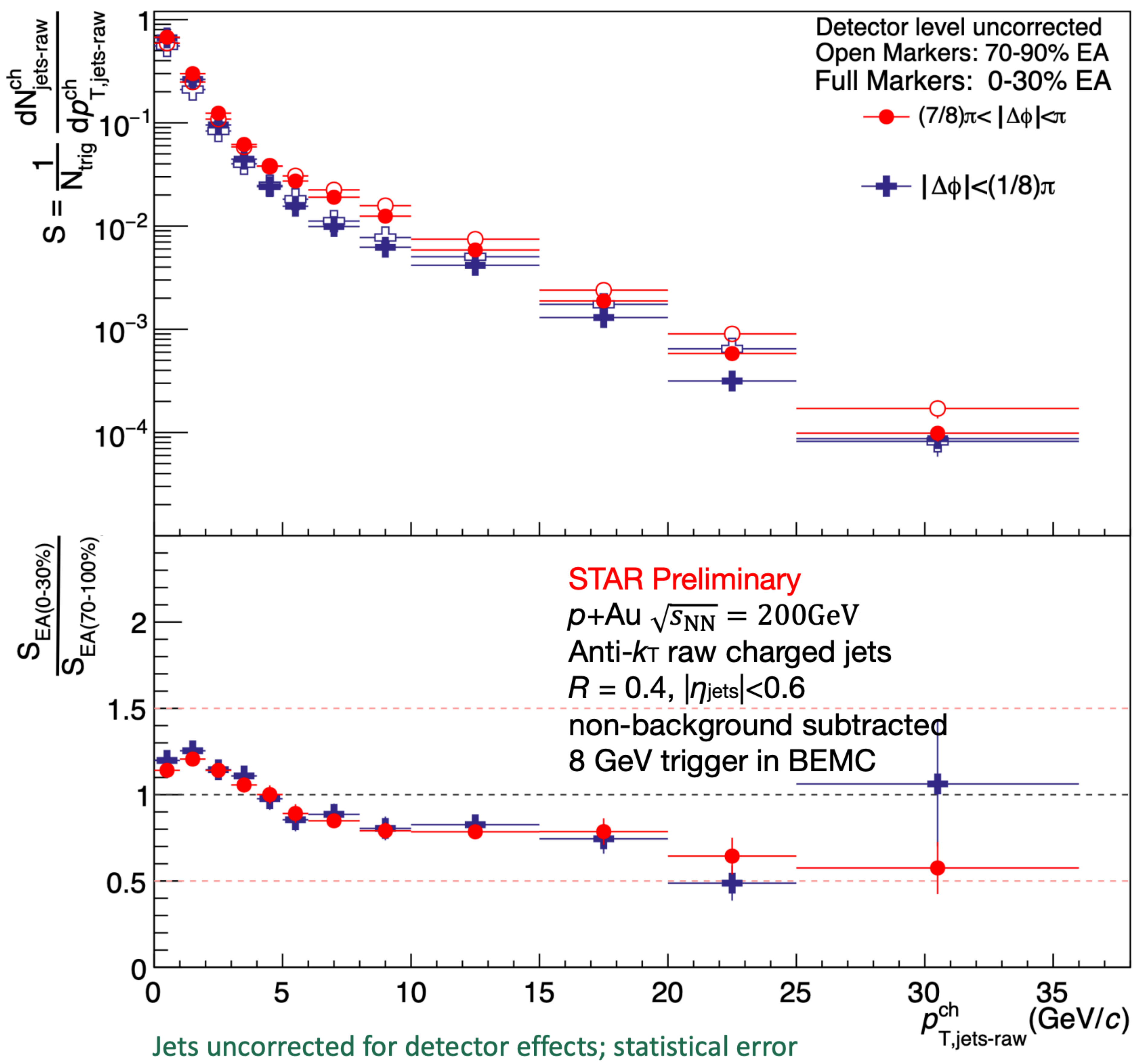


Semi-inclusive yield modification

in pAu collisions



[1]CMS, JHEP 09 (2010), 091
[2]CMS, PLB 718 (2013), 795
[3]ALICE, PLB 719 (2013), 29
[4]ATLAS, PLB 748 (2015), 392
[5]PHENIX, PRL 116 (2016), 122301
[6]ALICE, Nat. Phys. 13 (2017), 535



Jets uncorrected for detector effects; statistical error bars only; however, detector effects cancel in the ratio

- Hot nuclear matter effects in pAu collisions?[1,2,3,4,5,6,...]
- Jet yield suppression, but on both *near* and *away* side → not surface bias as typical in AA with high p_T trigger…
- Jet substructure*, dijet p_T balance A_J* also unmodified
- Anti-correlation of event activity at large rapidity with jet p_T at mid-rapidity* suggests $t \sim 0$ kinematics[7,8]

*not shown

[7]Alvioli, Cole, Frankfurt, Perepelitsa, Strikman, PRC 93 (2016), 011902(R)
[8]Armesto, Gülhan, Milhano, PLB 747 (2015), 441

Precision QCD; exploring the Lund plane
w/ multi-dimensional jet substructure

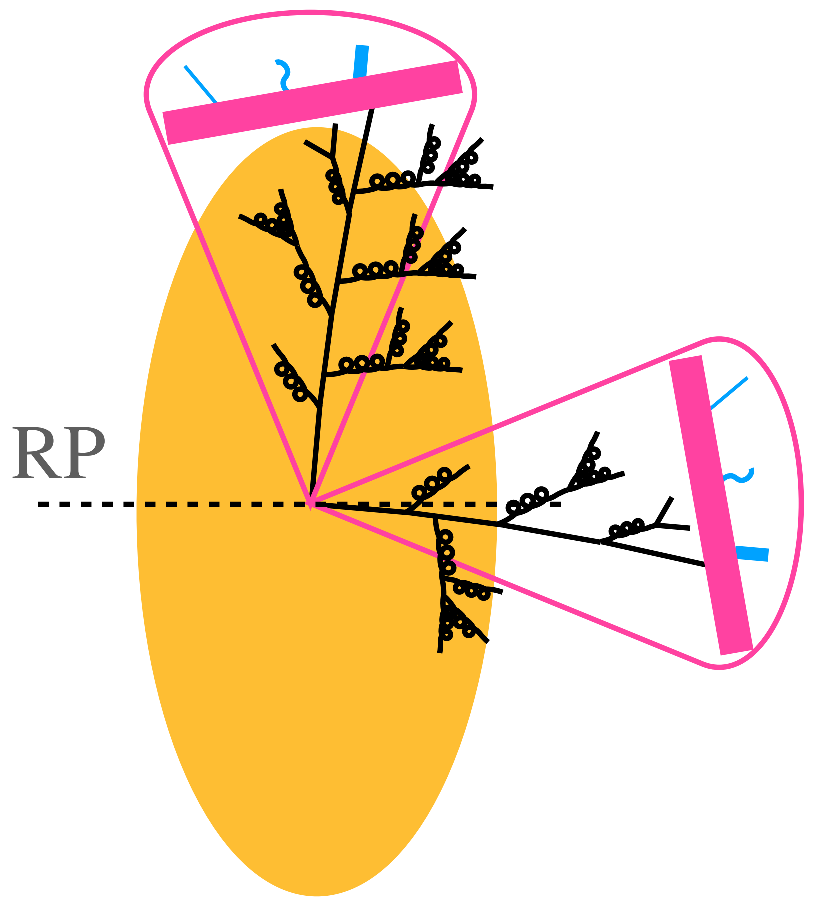
Separating p- and np-QCD
w/ energy correlators

Energy flows

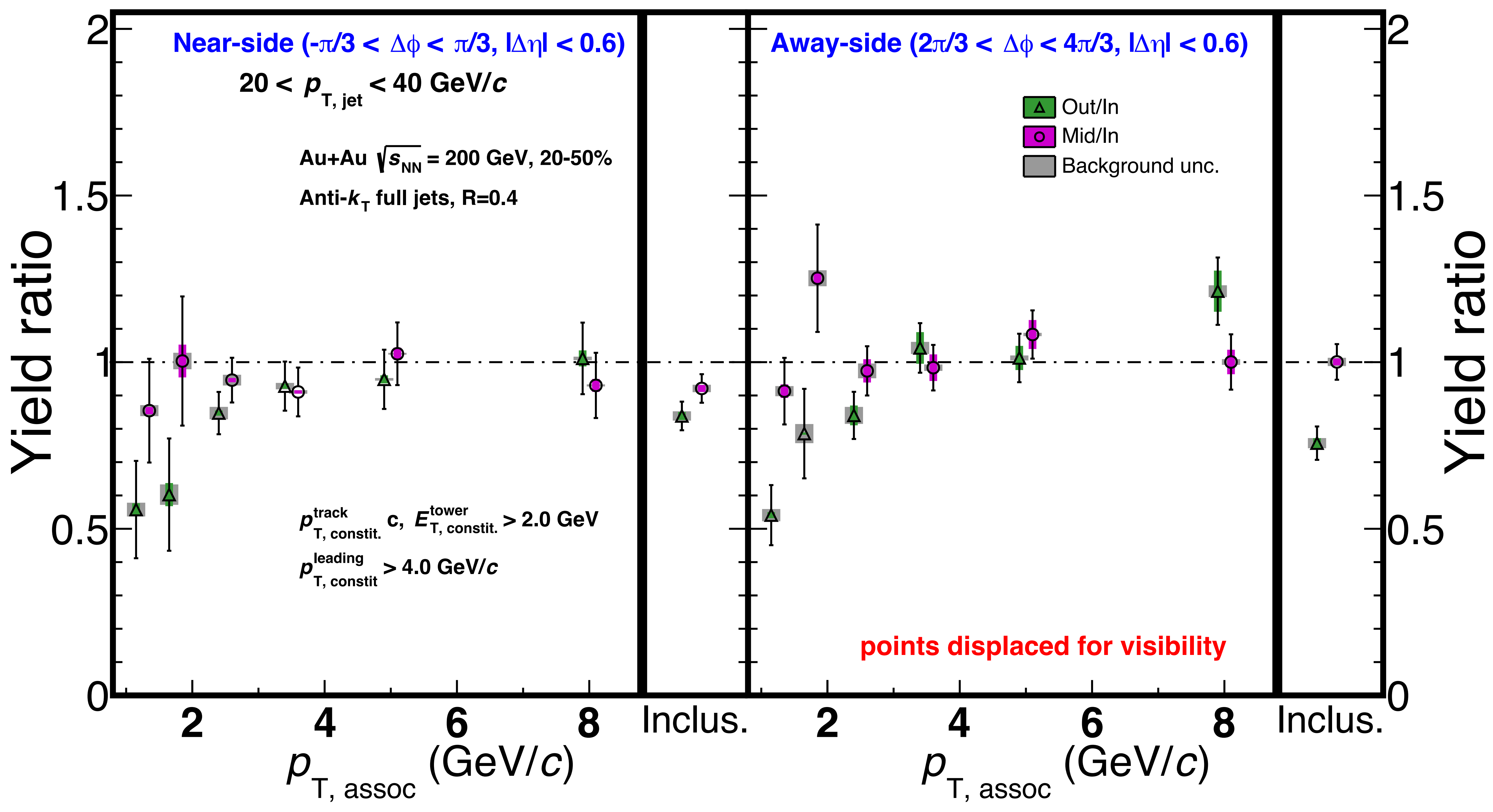
Path-length dependence of jet energy loss in medium
w/ jet anisotropies (w/r/t event plane)

Energy-density dependence of jet energy loss in medium;
angular distribution of radiation in quenched jets
w/ inclusive/semi-inclusive jet & high-p_T hadron yields

Event plane (EP) dep. of associated hadron yields



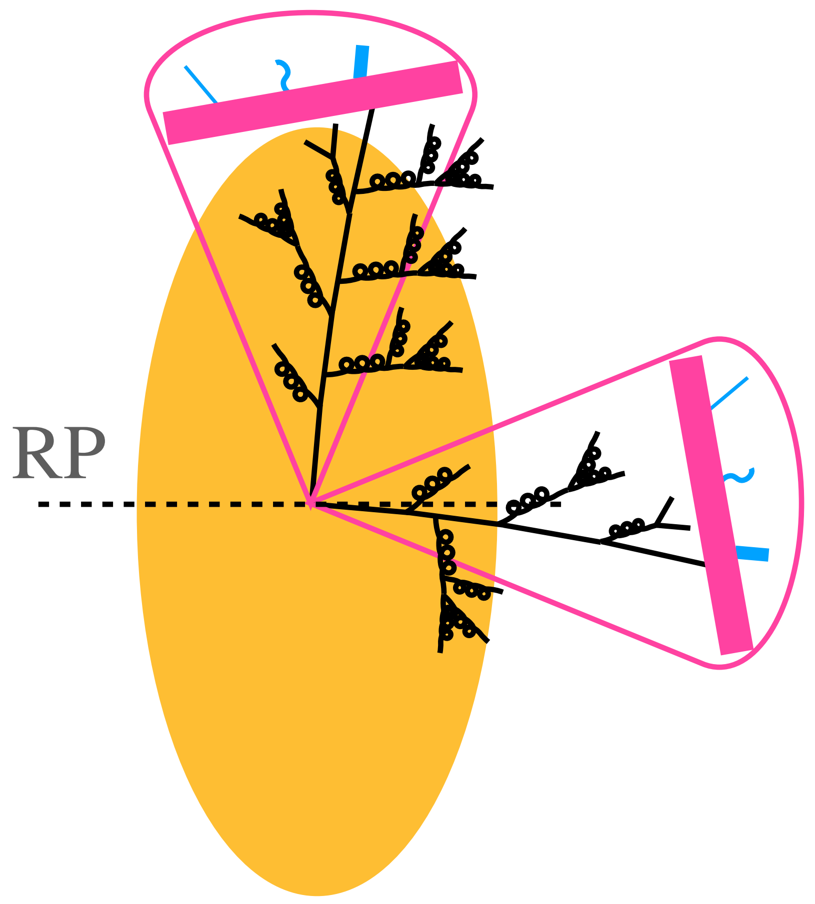
STAR, arXiv:2307.13891



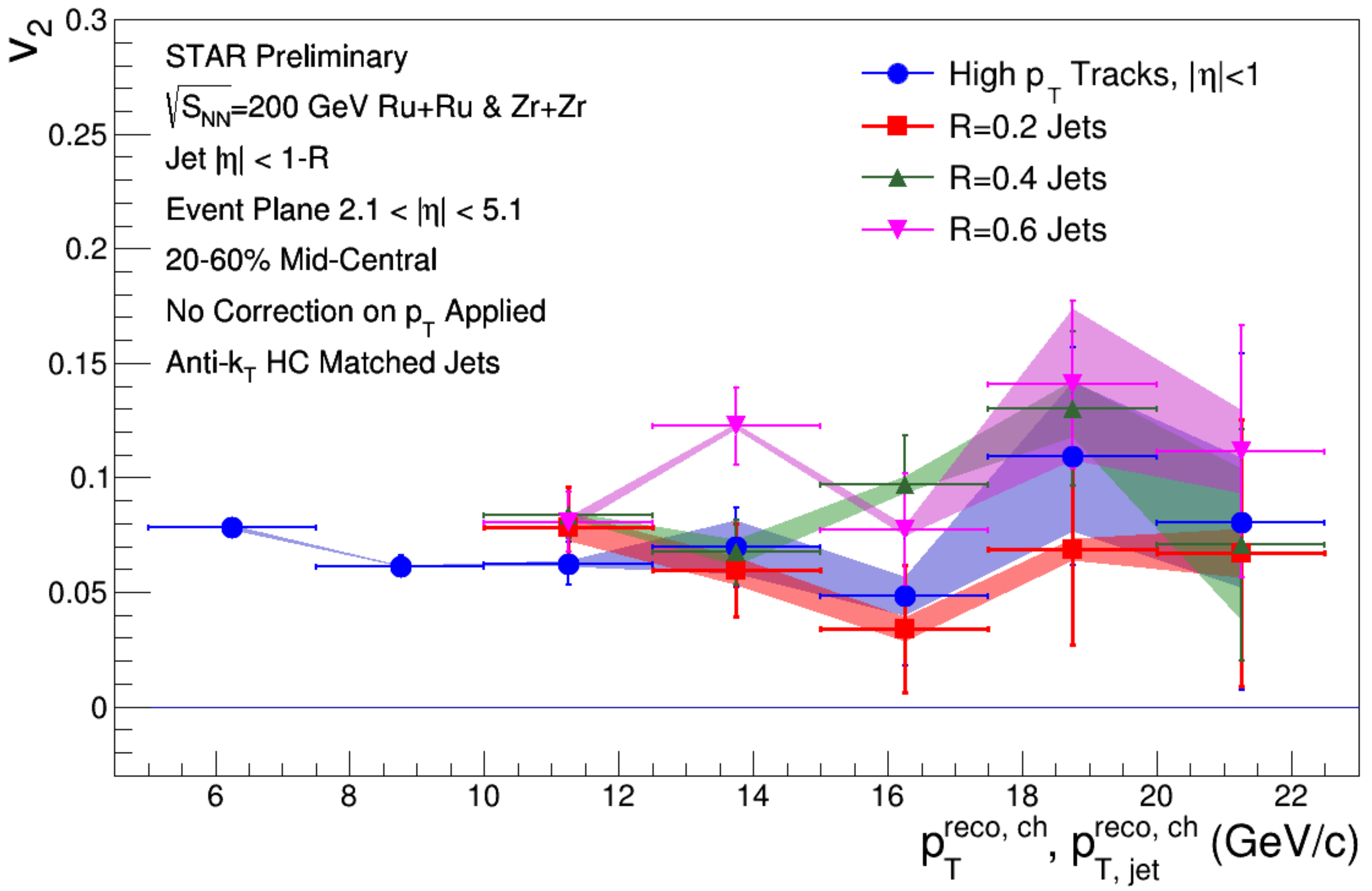
- *Expectation*: high (low)-p_T suppression (enhancement) for out-of-plane (OOP) vs. in-plane (IP) jets: path-length dependent quenching
- No significant deviation from unity within uncertainties
- Jet energy loss / medium density fluctuations spoiling effect?

Jet v_2

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



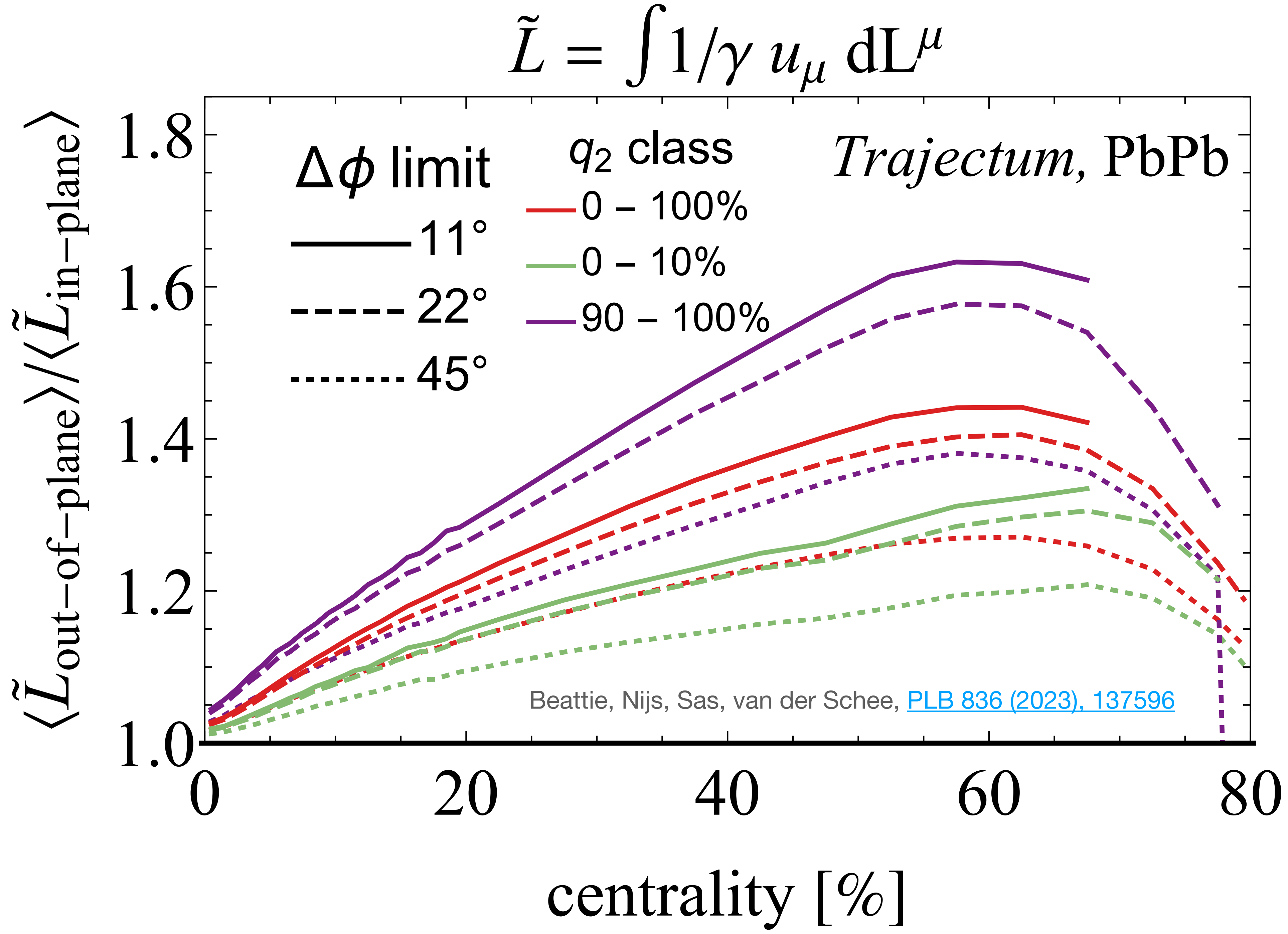
- New forward detector at STAR, *EPD*, gives improved reaction plane (RP) resolution, no autocorrelation with mid-rapidity measurement
- v_2 in this context linked to **path-length dependent quenching**, not flow
- Clear v_2 signal, independent of jet R, p_T, in high-statistics isobar data

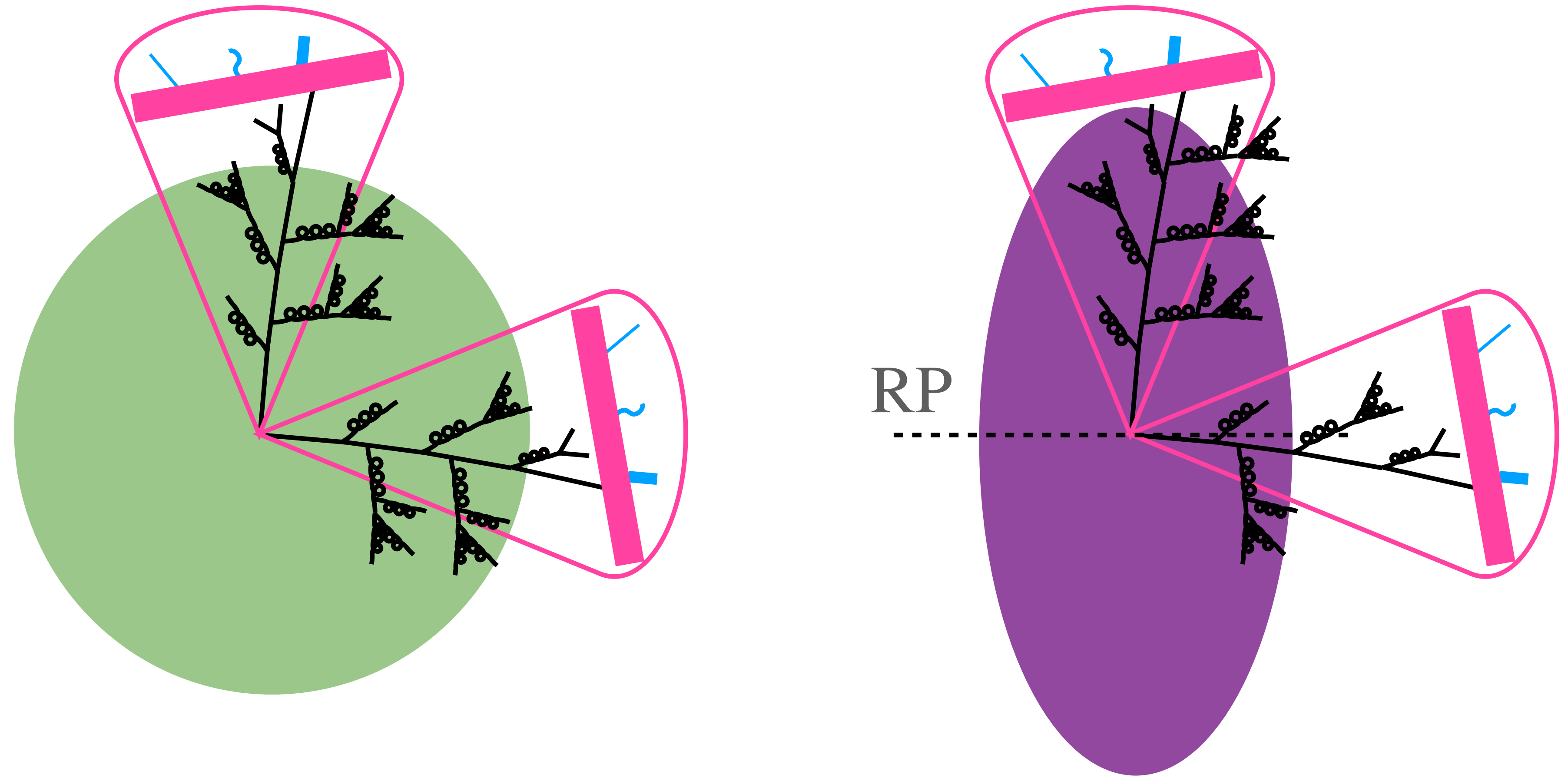


Event-shape engineering[1]

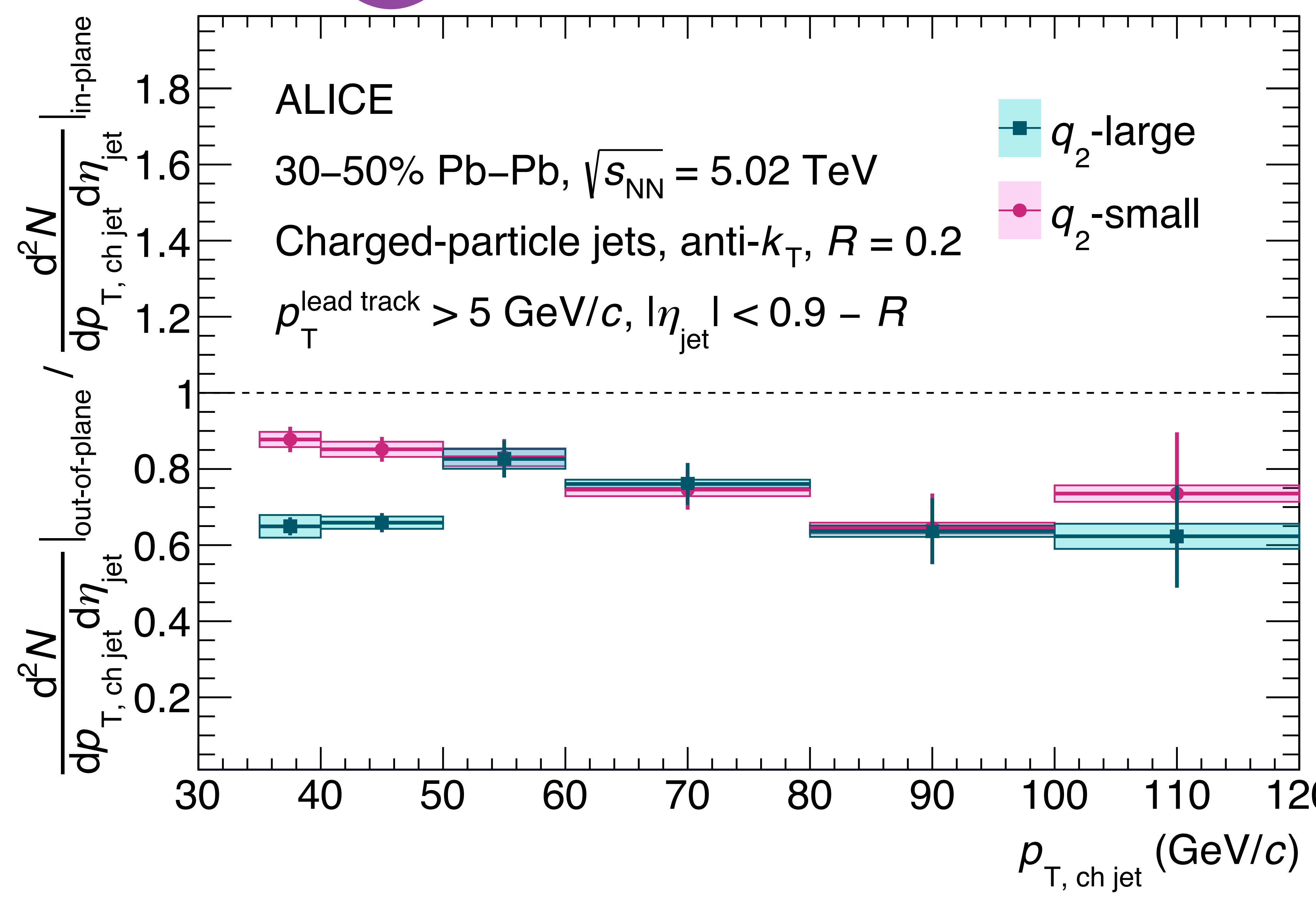
$Q_2 = (\sum_{i=1}^{M} w_i \cos(2\phi_i), \sum_{i=1}^{M} w_i \sin(2\phi_i))$, $q_2 = |Q_2|/\sqrt{M}$,
w_i: nMIP weight, M: multiplicity

$v_2 = \langle \cos(2(\phi - \Psi_2)) \rangle$





ALICE, 2307.14097



- Select on the shape using reduced flow vector q_2 → average path length difference in Trajectum model
- ALICE: low-p$_T$ difference in IP, OOP yields for highly elliptical events

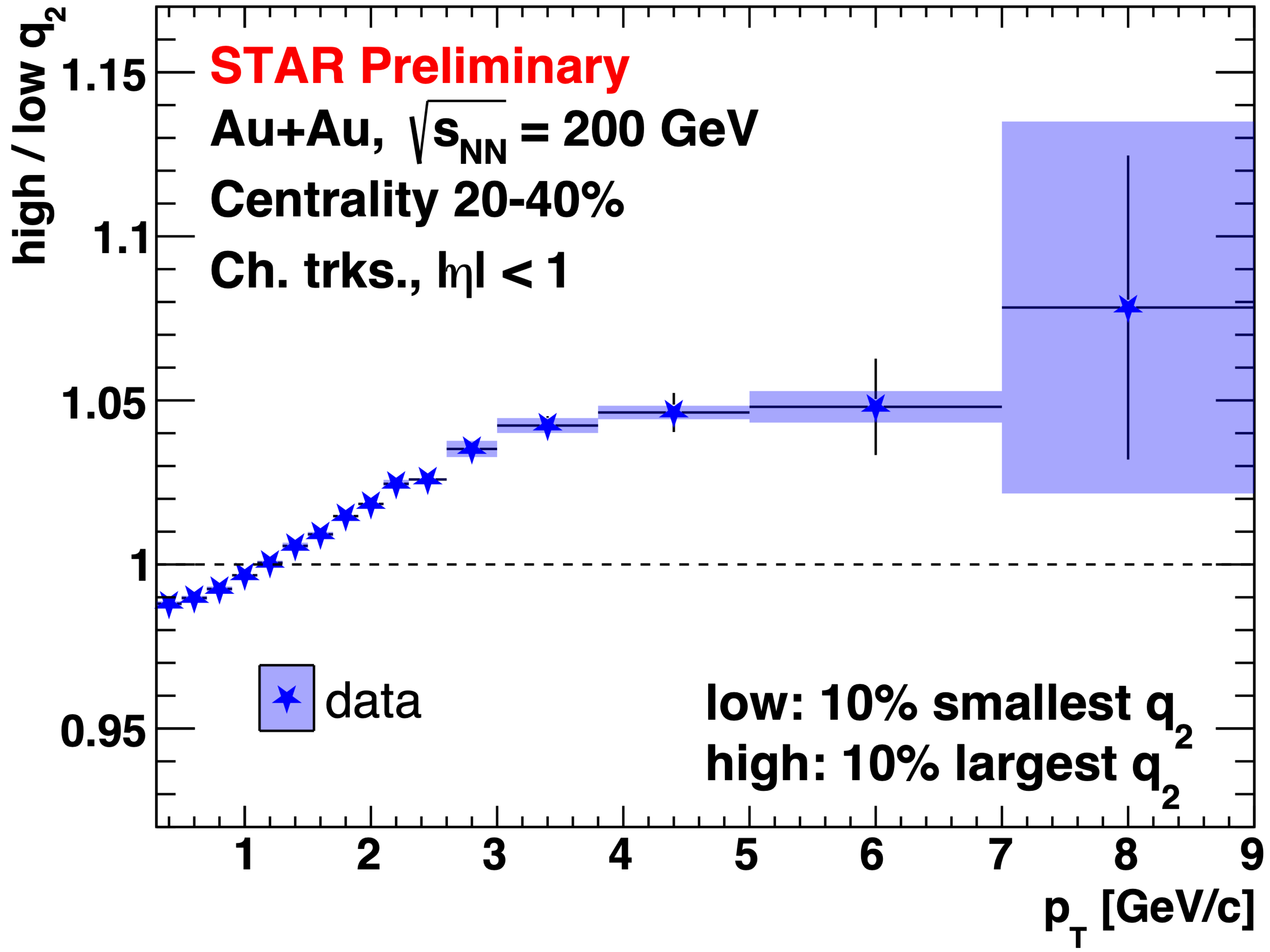
[1] Schukraft, Timmins, Voloshin, PLB 719 (2013), 394-398

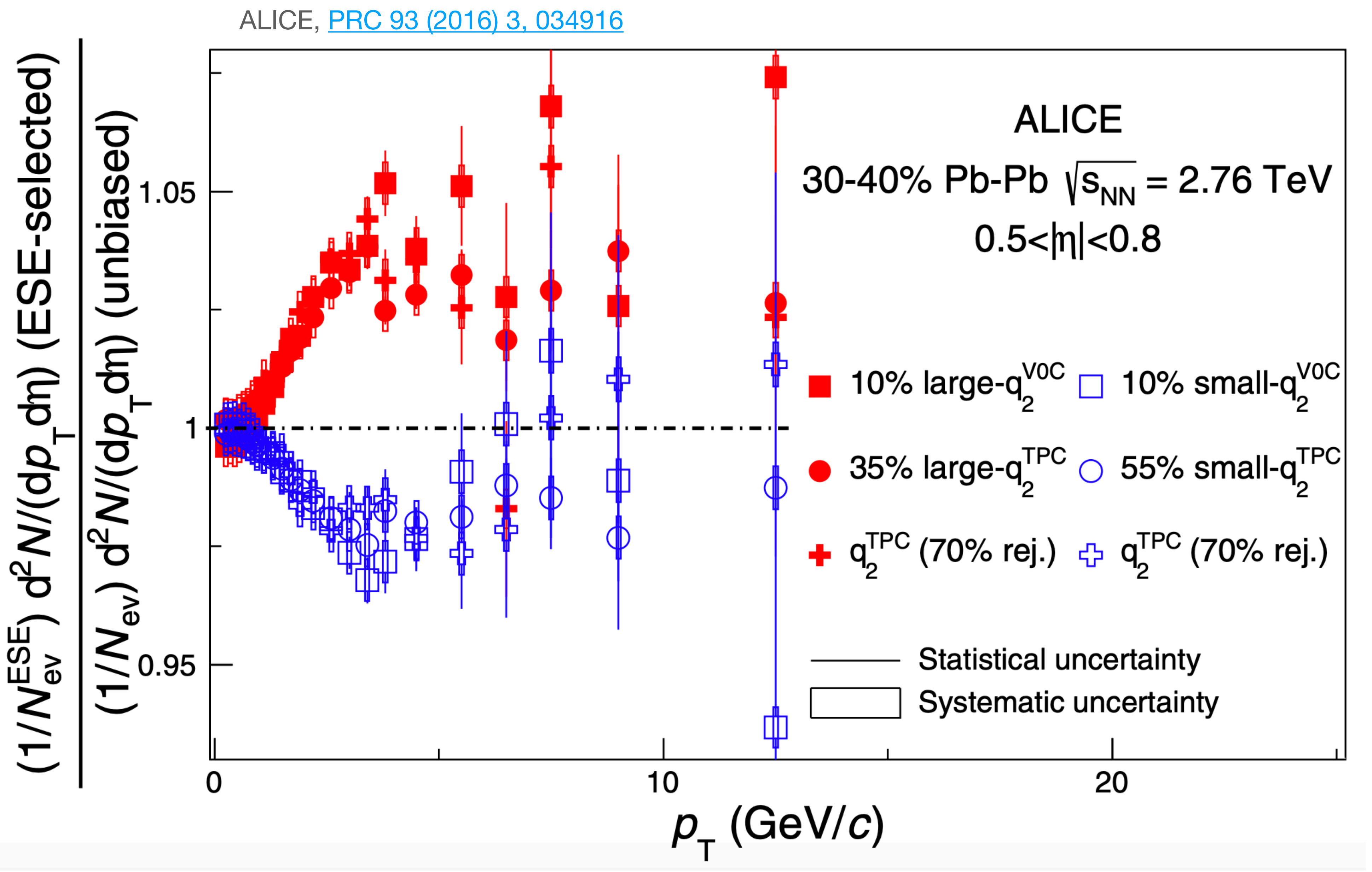
Event-shape engineering

$$Q_2 = \left(\sum_{i=1}^{M} w_i \cos(2\phi_i), \sum_{i=1}^{M} w_i \sin(2\phi_i)\right),\ q_2 = |Q_2|/\sqrt{M},$$

w_i: nMIP weight, M: multiplicity

$$v_2 = \langle \cos(2(\phi - \Psi_2)) \rangle$$



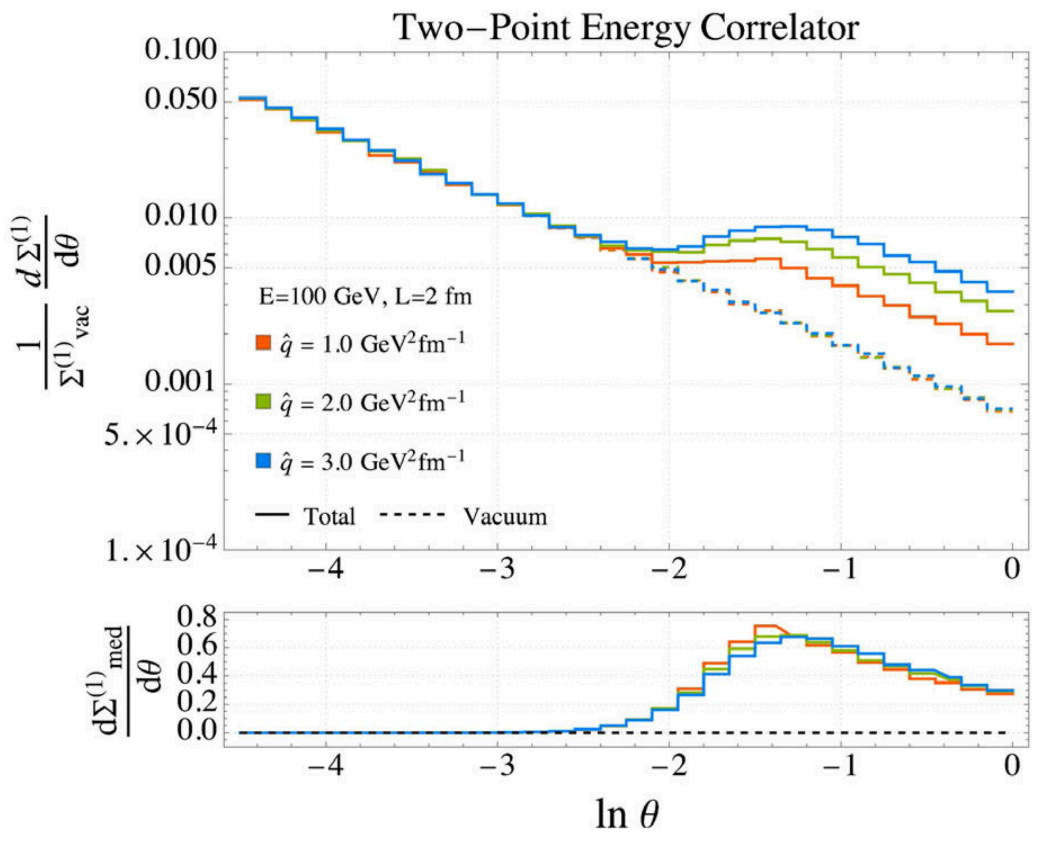


- STAR analysis ongoing — without selecting on EP angle, see enhancement at mid-p_T of charged track yields, for high vs. low q_2 events
- Interplay between eccentricity/density, elliptic/radial flow. Also observed by ALICE

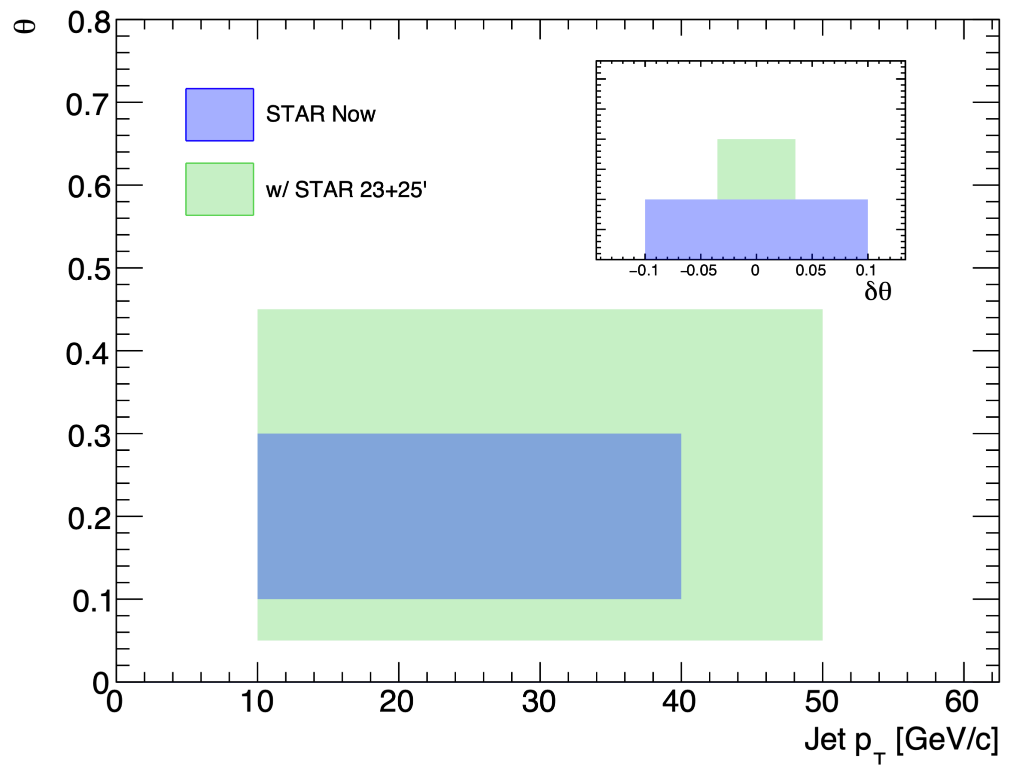
Future prospects

Energy flows

Andres, Dominguez, Kunnawalkam Elayavalli, Holguin, Marquet, Moult, PRL 130 (2023) 26, 262301



- *Generalized angularities*: less conservative systematic uncertainties, extension to jet momentum profile $\rho(r)$
- *EECs*: higher orders; charge-dependent; in heavy-ion collisions
- R_{AA}: analyzing R_{pAu}
- *Jet* v_2: extended to OO collisions, studying non-flow contribution
- *Event shape engineering*: event-plane angle dependence study in progress
- *Runs 23+25*[1,2]: expected ~3x increase in statistics relative to current AA analyses w/ Run 14 → improved uncertainties e.g. for γ_{dir}+jet I_{AA}, and **kinematic reach / overlap with LHC**



[1] SN0793
[2] SN0819

Hadronization mechanism
w/ *flavor correlators*

Hadrochemistry modification via medium response
w/ *baryon-to-meson ratios*

Constituent identity

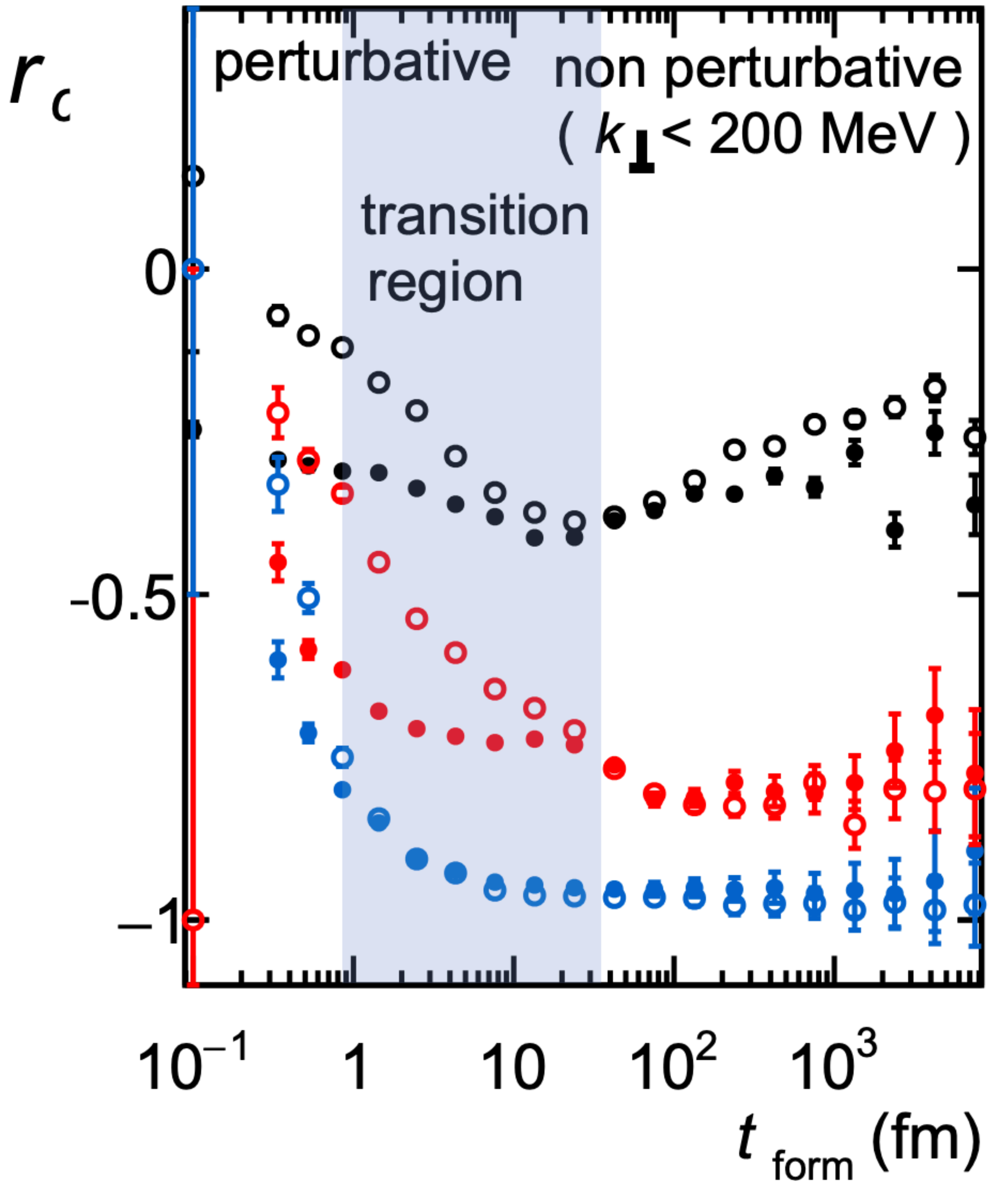
Charm quark energy loss, diffusion, fragmentation modification in medium
w/ *charmed-jet yields*

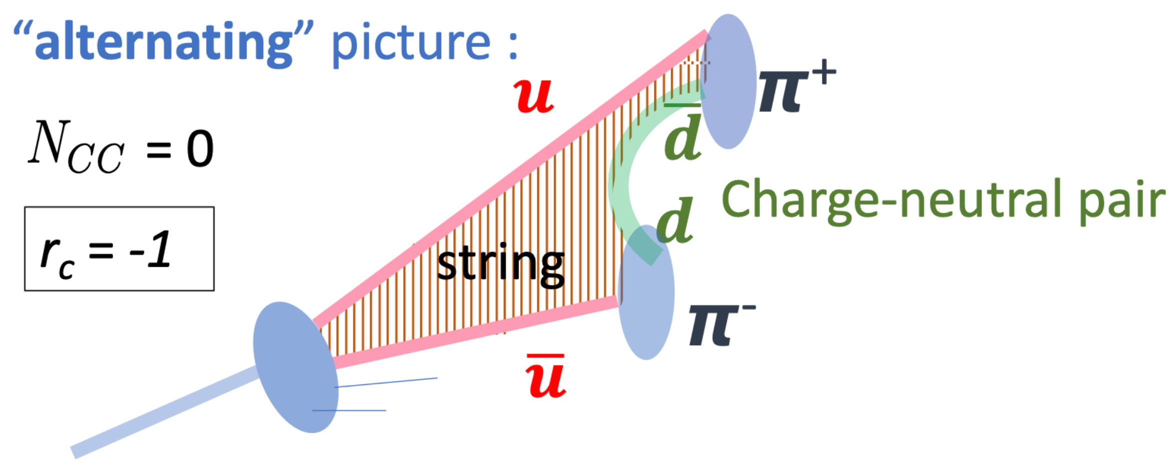
Flavor correlators in jets

$$r_c(X) = \frac{d\sigma_{h_1h_2}/dX - d\sigma_{h_1\bar{h}_2}/dX}{d\sigma_{h_1h_2}/dX + d\sigma_{h_1\bar{h}_2}/dX}$$

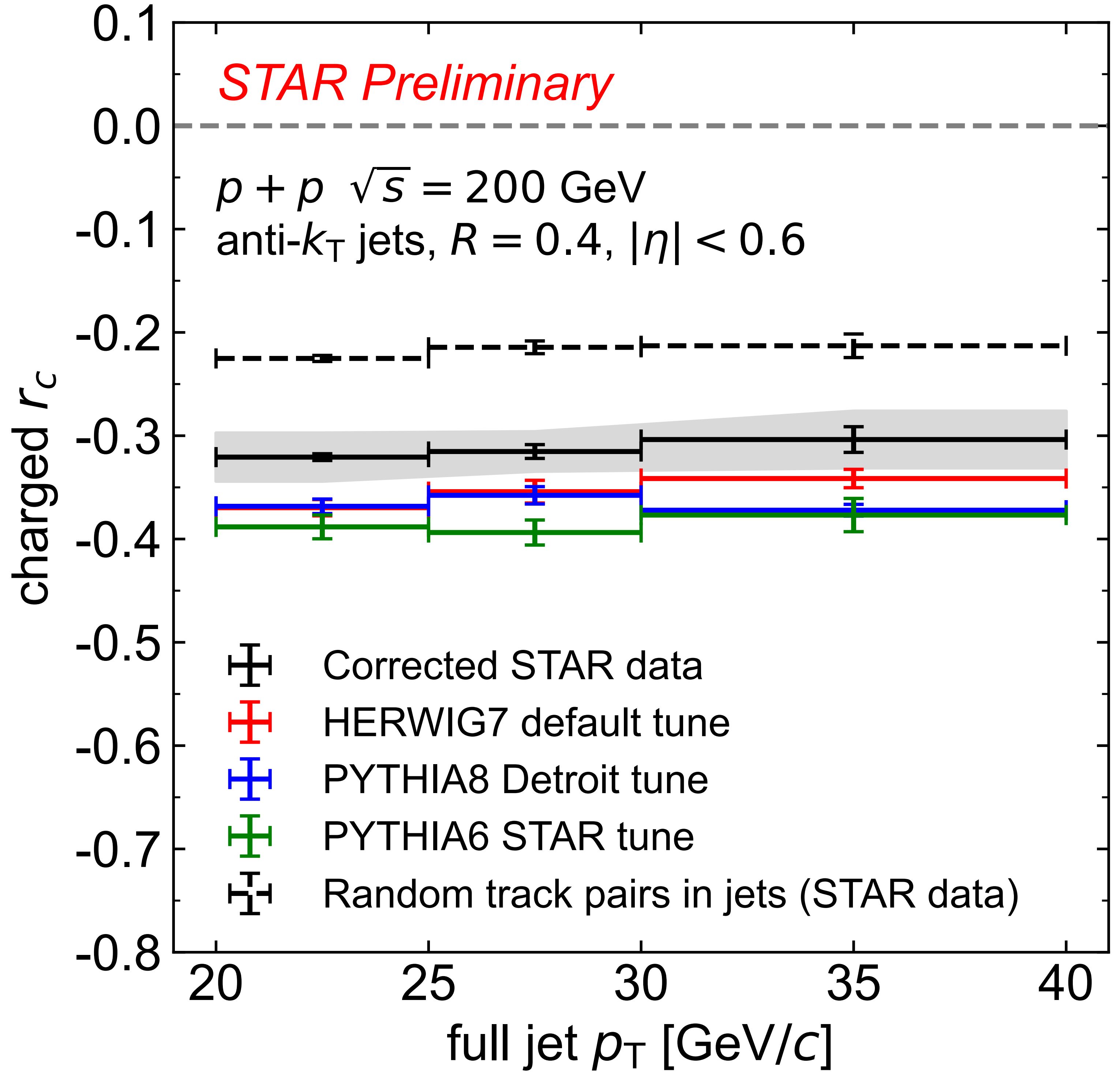
$$r_c = \frac{N_{ss} - N_{os}}{N_{ss} + N_{os}}$$

Chien, Deshpande, Mondal, Sterman, PRD 105 (2022) 5, L051502





$$t_{\text{form}} = z(1-z)p/k_\perp^2$$
with $p = p^{h_1} + p^{h_2}$
and $z = p^{h_2}/p$



bath of charges with no net charge

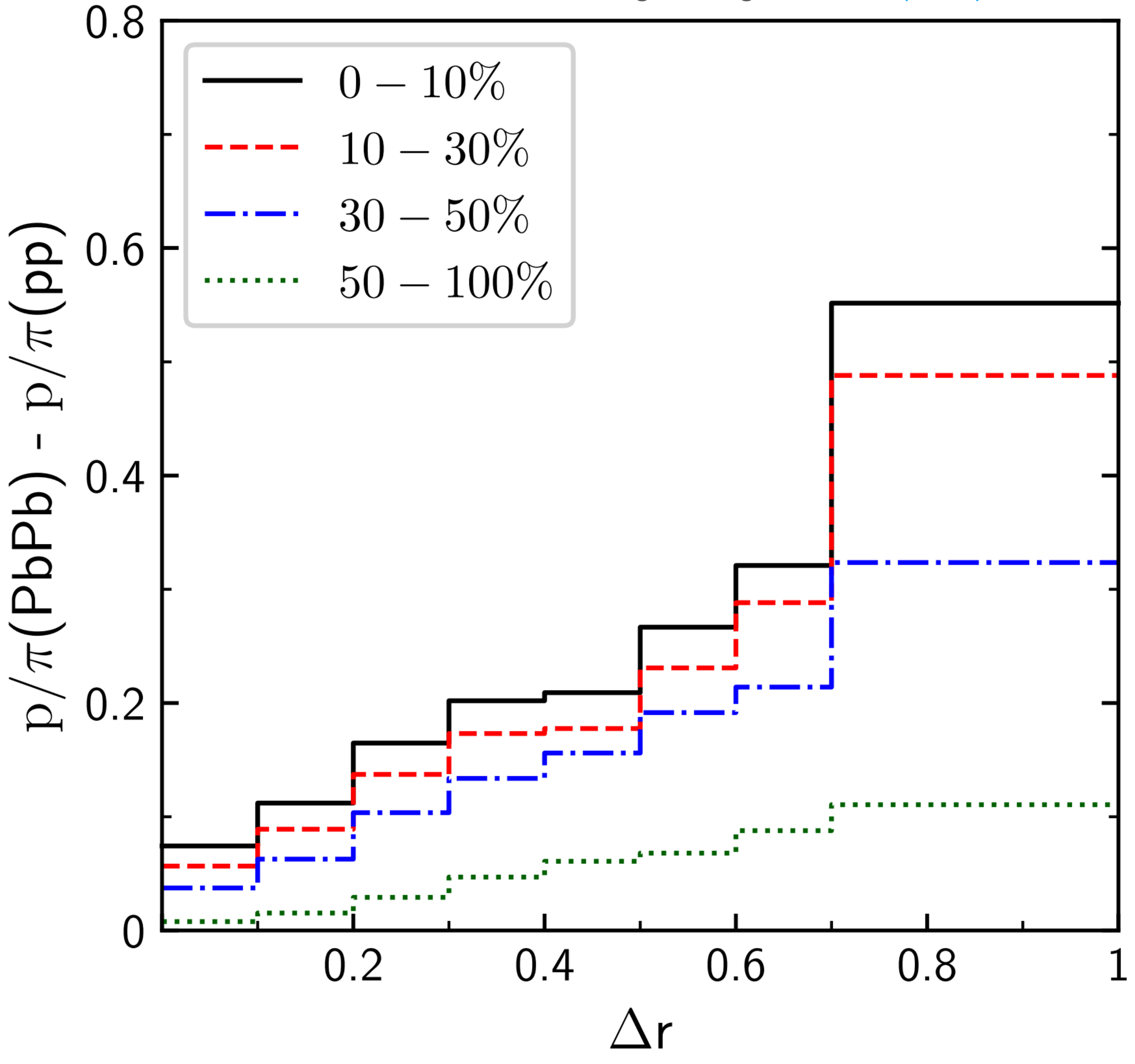
jet with ~no net charge

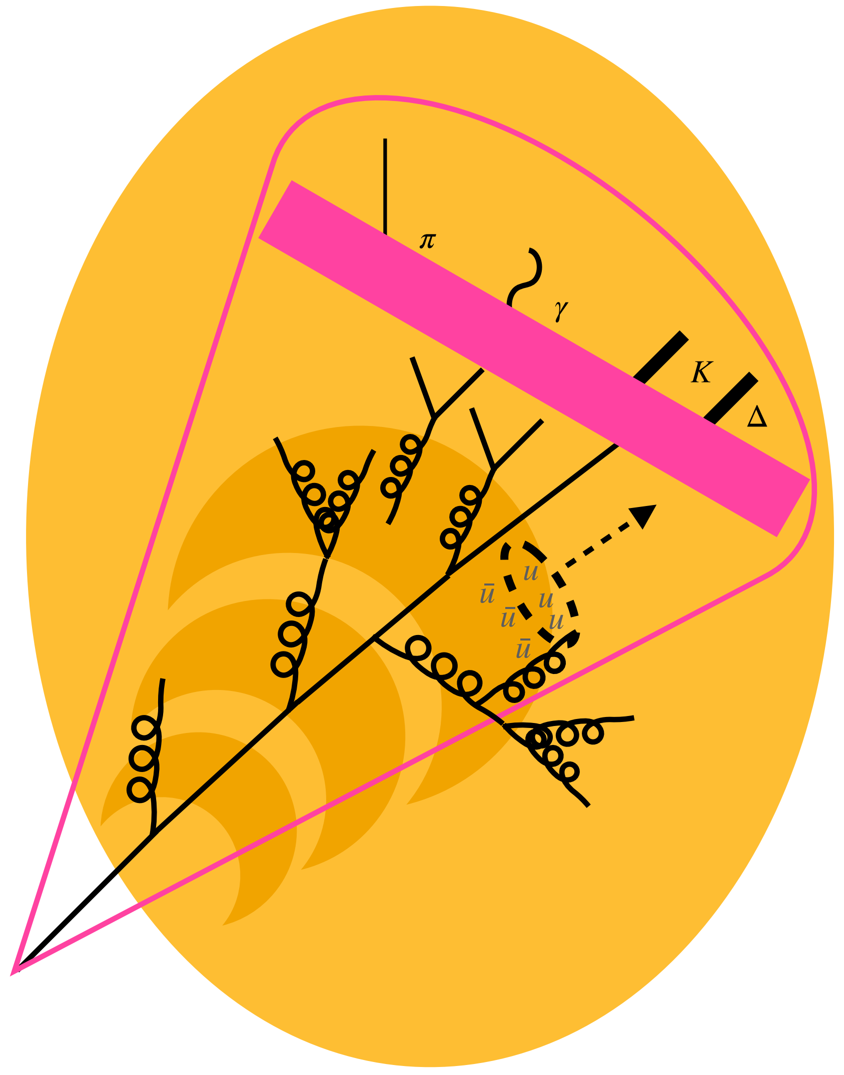
perfectly correlated

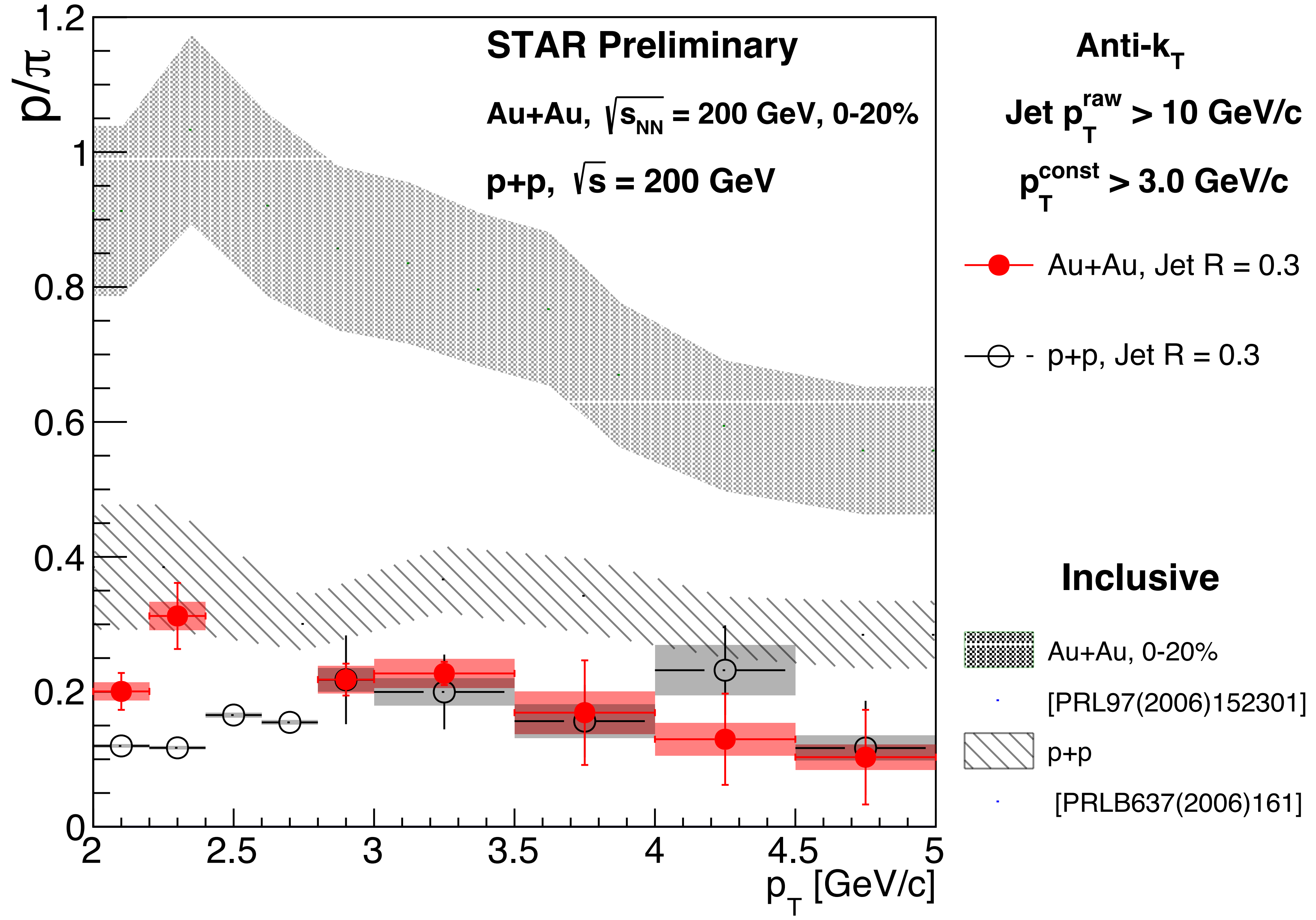
- r_c can probe contribution of string-like fragmentation
- First measurement in pp: Pythia predicts more string fragmentation than supported by data, but difficult to conclude with default Herwig tune

Baryon-to-meson ratios

Signature of medium response?



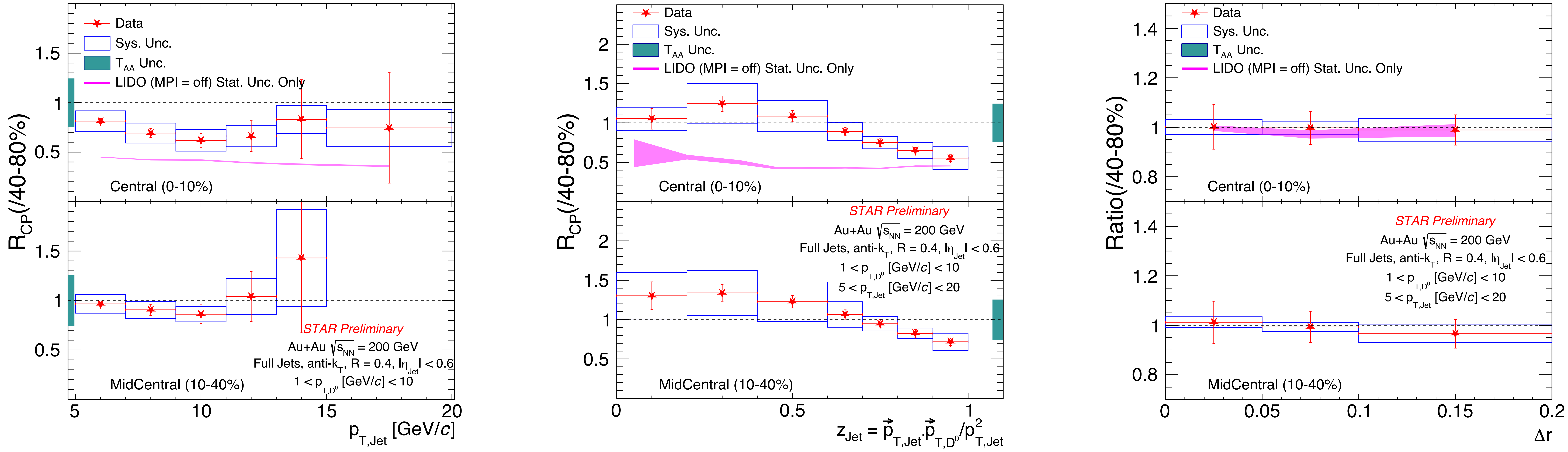




- Possible sign of parton coalescence in jet: enhanced baryon-to-meson ratio in AA
- No observed modification of *in-jet* p/π ratio for R = 0.3 jets

$D^0 = c\bar{u}$

D⁰-jet spectra, profile, fragmentation

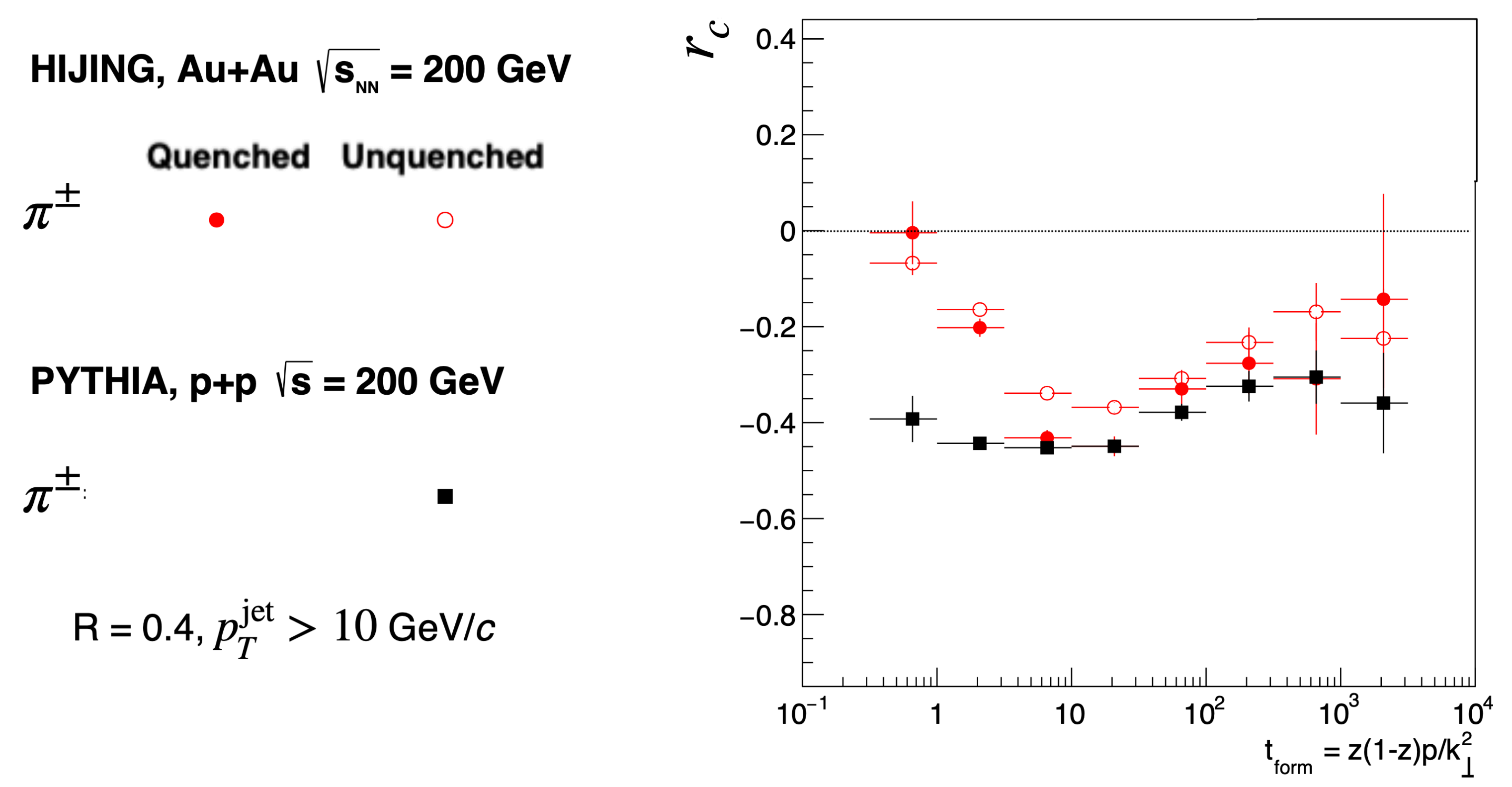


- Testing charm quark energy loss, diffusion, and fragmentation modification
- *Hint of suppression of yield at low-p_T. Hard-fragmenting charm jets are suppressed*. *No diffusion*.
- Model including radiative and collisional energy loss during heavy quark evolution underpredicts central yields — MPI might be important for D^0 p_T this low

Future prospects

Constituent identity

Esha, [Hard Probes 2023]



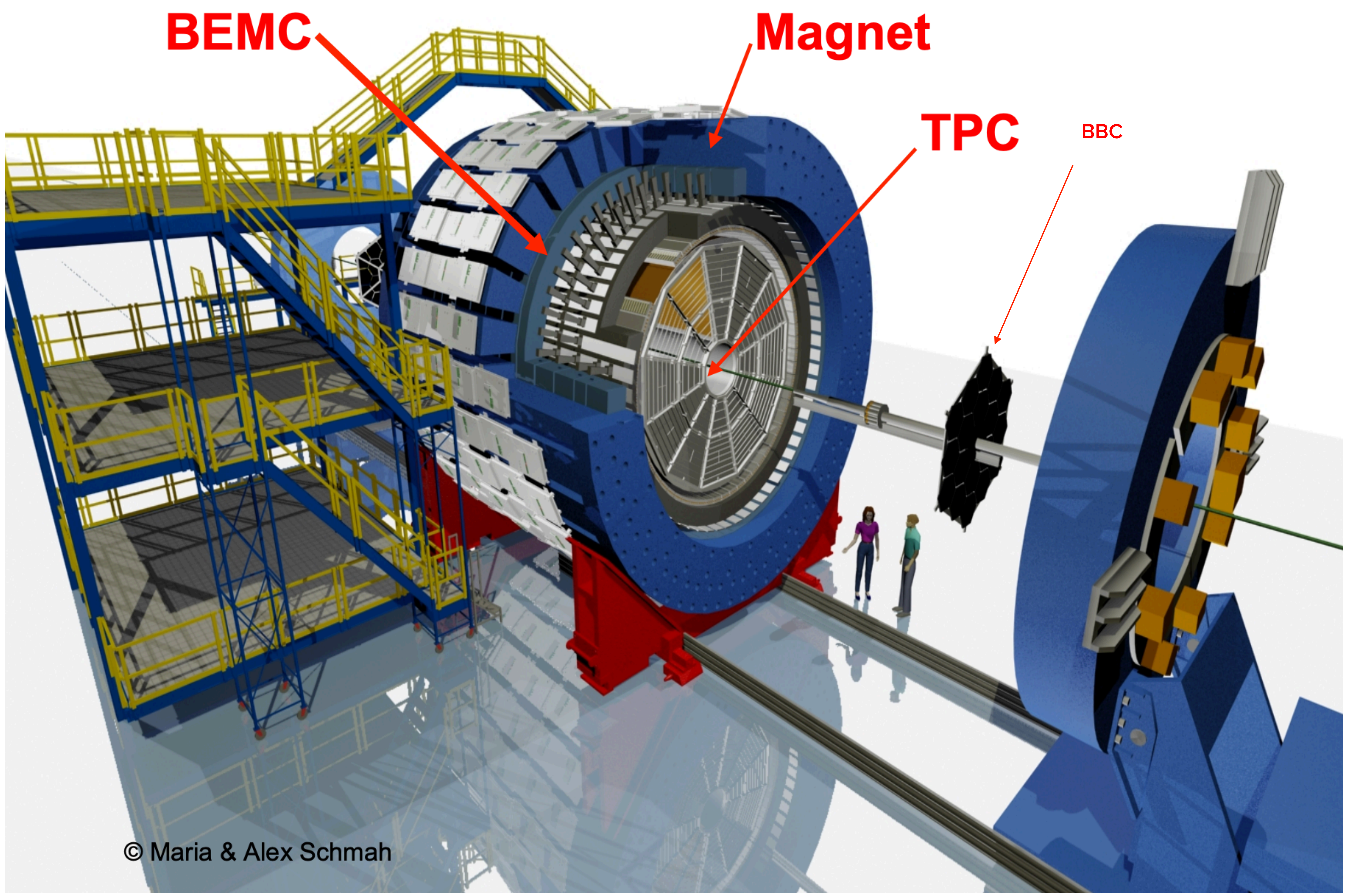
- r_c: extension to heavy-ion collisions underway
- Herwig tune to RHIC kinematics ongoing
- *Baryon-to-meson ratios*: studying dependence on constituent p_T threshold
- *D^0-jet*: adding another dataset to increase statistics; adding generalized angularities; tightening D^0 p_T threshold

What we've learned

- **Precision era of jet substructure**: many-dimensional corrections and correlations, systematically mapping the phase space for QCD radiation in vacuum at lower $\sqrt{s}$
- **First measurements** of new observables **EECs and** r_c separate perturbative and non-perturbative physics cleanly for **improved theoretical control**
- Demonstrated **scaling of quenching** with N_{part} (**~similar energy density**) across collision species; **more energy lost at RHIC** than LHC, relative to jet p_T; **jet profile broadening**, with radiation roughly recovered by ~0.5 radians; and **finite jet** $\mathbf{v_2}$. **No quenching** observed in **pAu** collisions.
- **No medium-induced hadrochemistry** effect observed. **Suppression of jets with hard-fragmenting charm hadrons** but as yet no observed corresponding enhancement of soft-fragmented charm jets or diffusion to broader angles

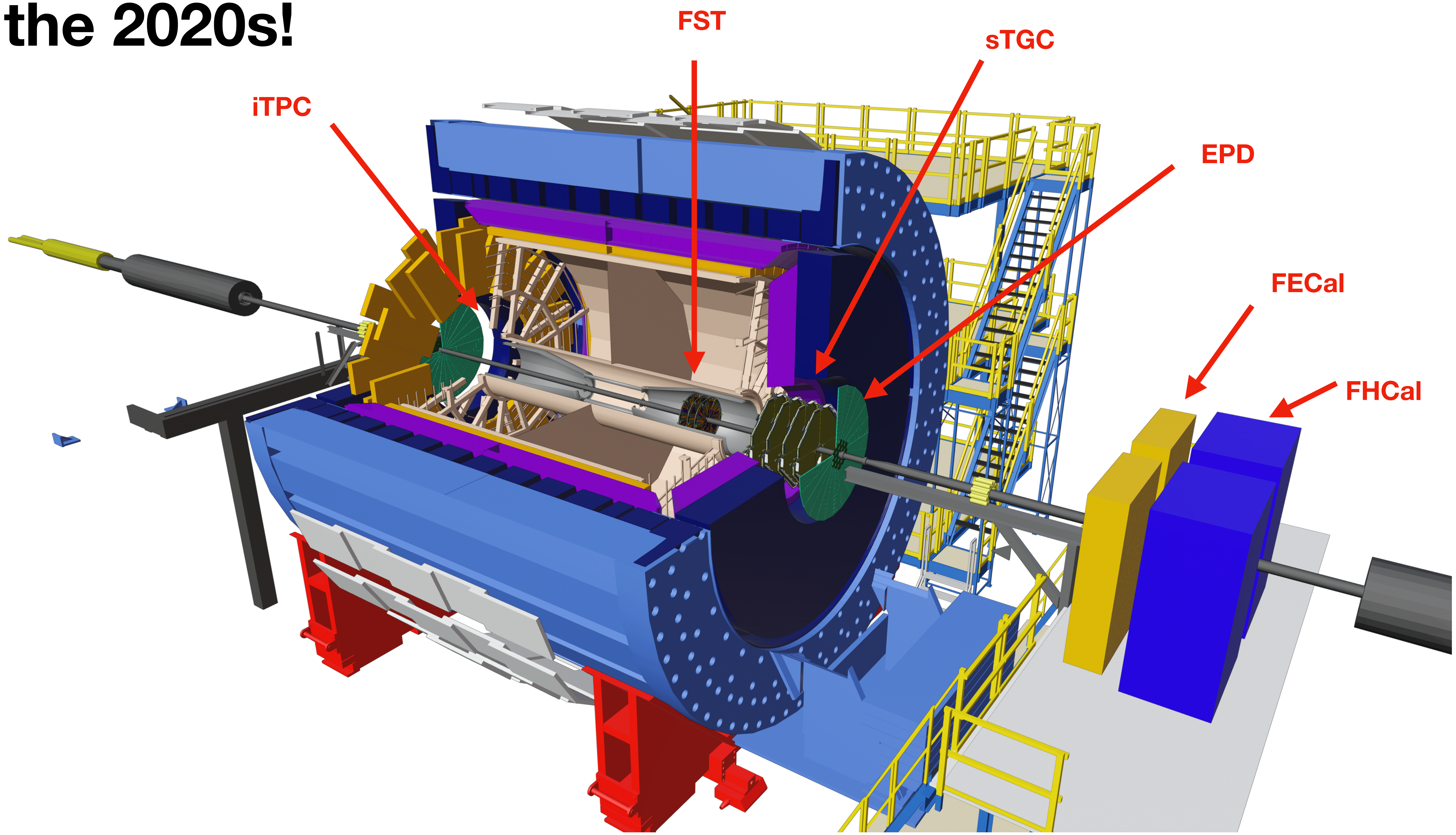
Jets at STAR

In the 2010s



Jets at STAR

In the 2020s!



Precision tracking

Forward jets → different x; q v. g

Unbiased centrality/ EP determination

Etc!

Donate to Maui relief efforts

https://www.hawaiiancouncil.org/helpmaui/

(Direct donate link: https://www.memberplanet.com/s/cnhamembers/kakoomaui)

Backup