中国物理学会高能物理分会
HIGH ENERGY PHYSICS BRANCH OF CPS

Multi-Point Energy Correlators in Photon-Tagged Jet Production

Main focus: three-point energy correlators of photon-tagged jets in Pb+Pb collisions

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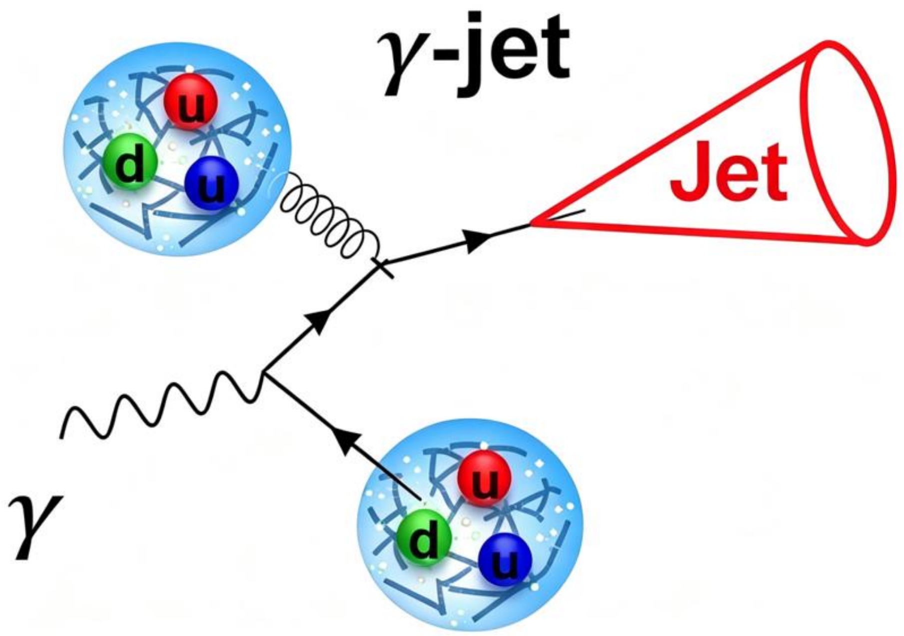
Outline

Introduction: gamma-tagged jets as calibrated probes

> Prompt photon calibrates the initial hard scale.

> Tagged jet probes energy loss and medium response.

> Jet energy flow is redistributed by the medium.



What we measure

Energy correlations among particles inside reconstructed jets.

What we want

How the medium redistributes jet energy across angular scales.

Gamma-jets provide a calibrated probe for studying medium-induced changes in jet energy flow.

Introduction: from EEC to EEEC

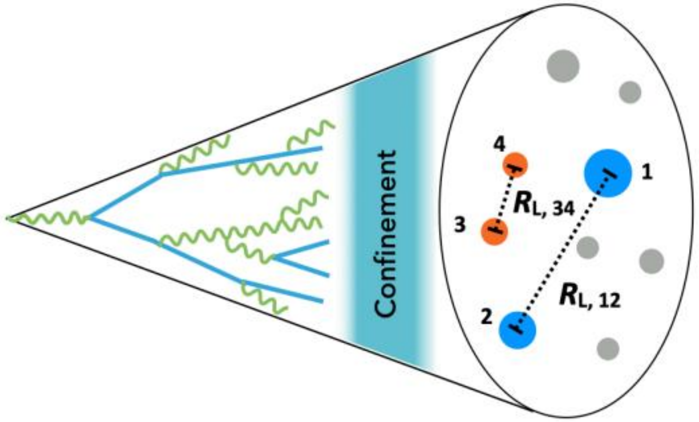
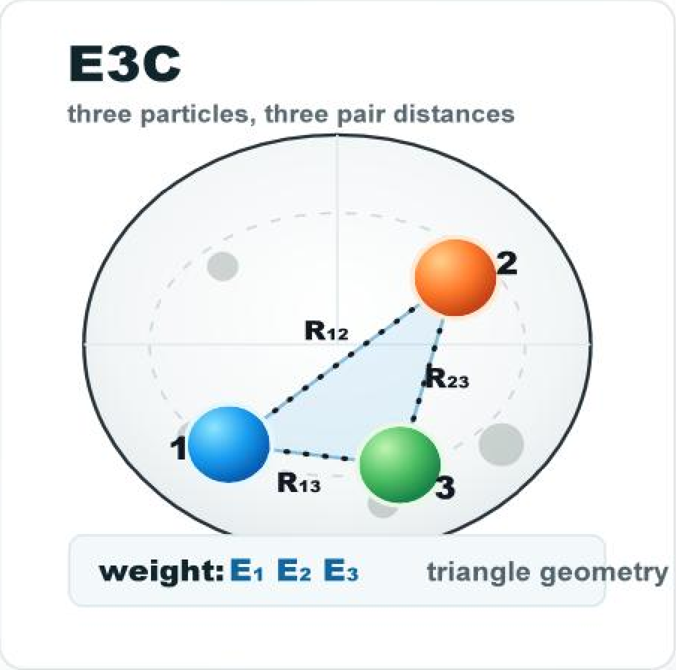


Figure from ALICE Collaboration, arXiv:2409.12687 [hep-ex] (2024).



$$\Sigma_{\mathrm{EEC}}(R_L) = \frac{1}{N_{\mathrm{jet}} \cdot \Delta} \int_{R_L-\frac{1}{2}\Delta}^{R_L+\frac{1}{2}\Delta} \sum_{\mathrm{jets}} \sum_{i,j} \frac{p_{T,i}p_{T,j}}{\left(p_T^{\mathrm{jet}}\right)^2} \times \delta(R'_L - R_{L,ij})\, dR'_L.$$

$$R_{ab} = \sqrt{(\eta_a - \eta_b)^2 + (\phi_a - \phi_b)^2}\,.$$

$$\Sigma_{\mathrm{E3C}}(R_L) = \frac{1}{N_{\mathrm{jet}} \cdot \Delta} \int_{R_L-\frac{1}{2}\Delta}^{R_L+\frac{1}{2}\Delta} \sum_{\mathrm{jets}} \sum_{i,j,k} \frac{p_{T,i}p_{T,j}p_{T,k}}{\left(p_T^{\mathrm{jet}}\right)^3} \times \delta(R'_L - R_{L,ijk})\, dR'_L.$$

$$R_L \geq R_M \geq R_S$$

EEC: two-point correlation

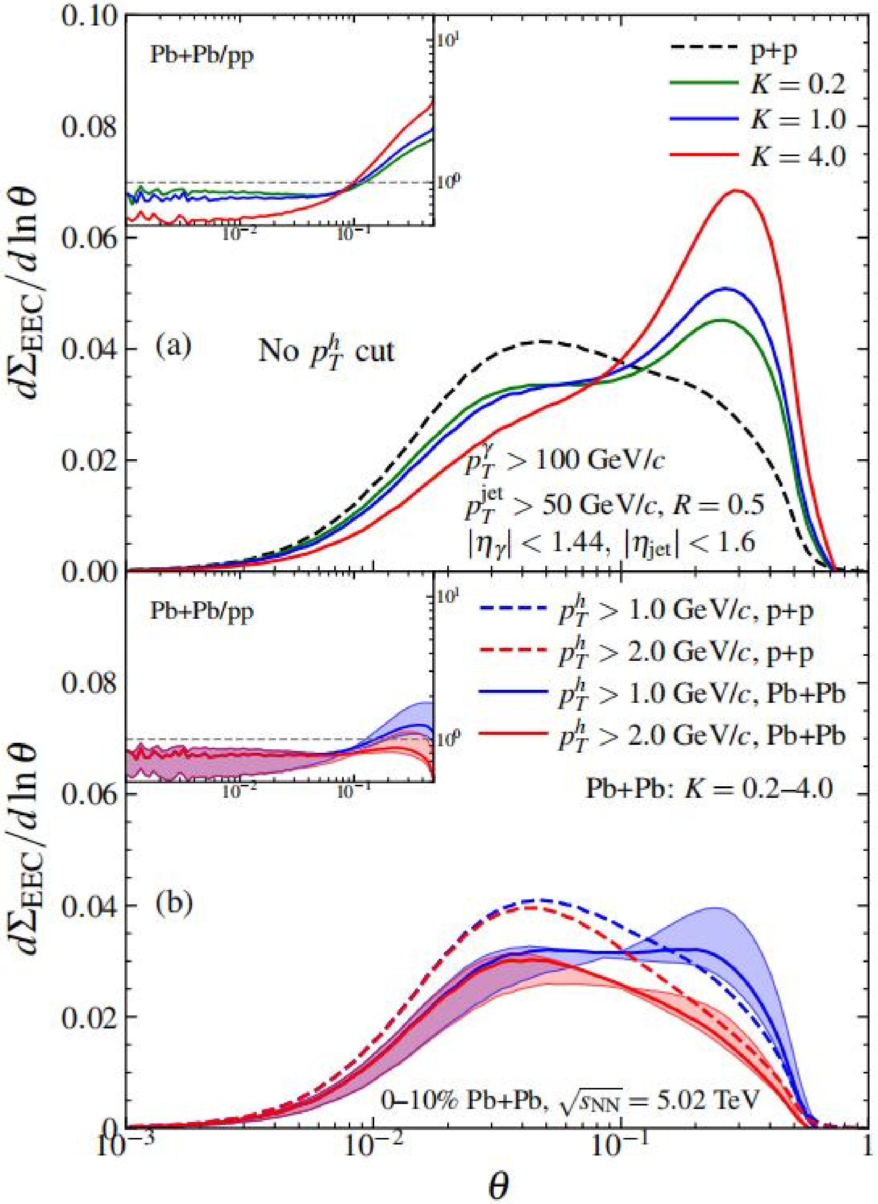
Measures energy flow as a function of one angular distance.

EEEC: three-point correlation

Three ordered distances encode the triangle scale and shape.

Why EEEC?

Different medium components may populate different three-particle geometries.



Reference: Yang, He, Moult, Wang, Phys. Rev. Lett. 132, 011901 (2024).

Previous EEC study

LBT reproduces the EEC:
<u>small-angle suppression and broad-angle enhancement.</u>

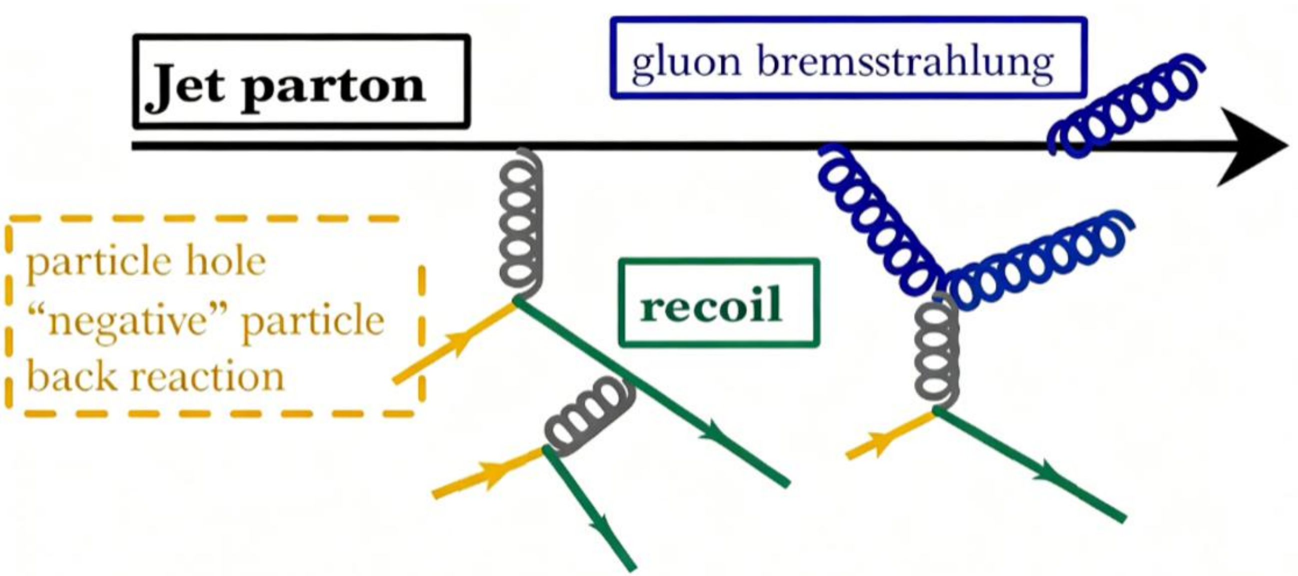
Limitation

EEC no full three-particle geometry.

Next step

Use EEEC

Methodology: Linear Boltzmann Transport (LBT) Model



$$\mu_D^2 = \frac{3}{2} K g^2 T^2$$

K changes the Debye screening mass and the typical momentum-transfer scale, while the scattering rate is fixed at K = 1.

S — **shower partons**

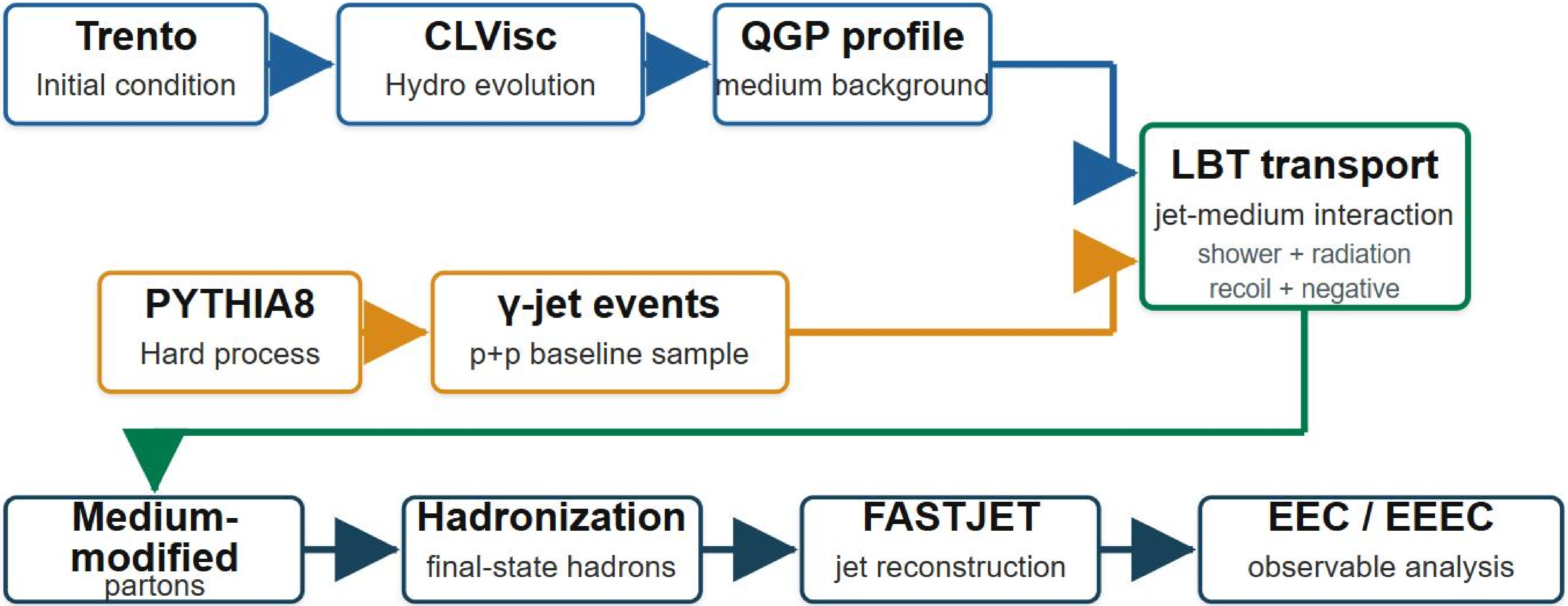
R — **medium-induced radiated gluons**

M — **medium response: recoil + negative partons**

LBT Code: A Color Tracking LBT Model, https://github.com/dyczzz/A-Color-Tracking-LBT-Model

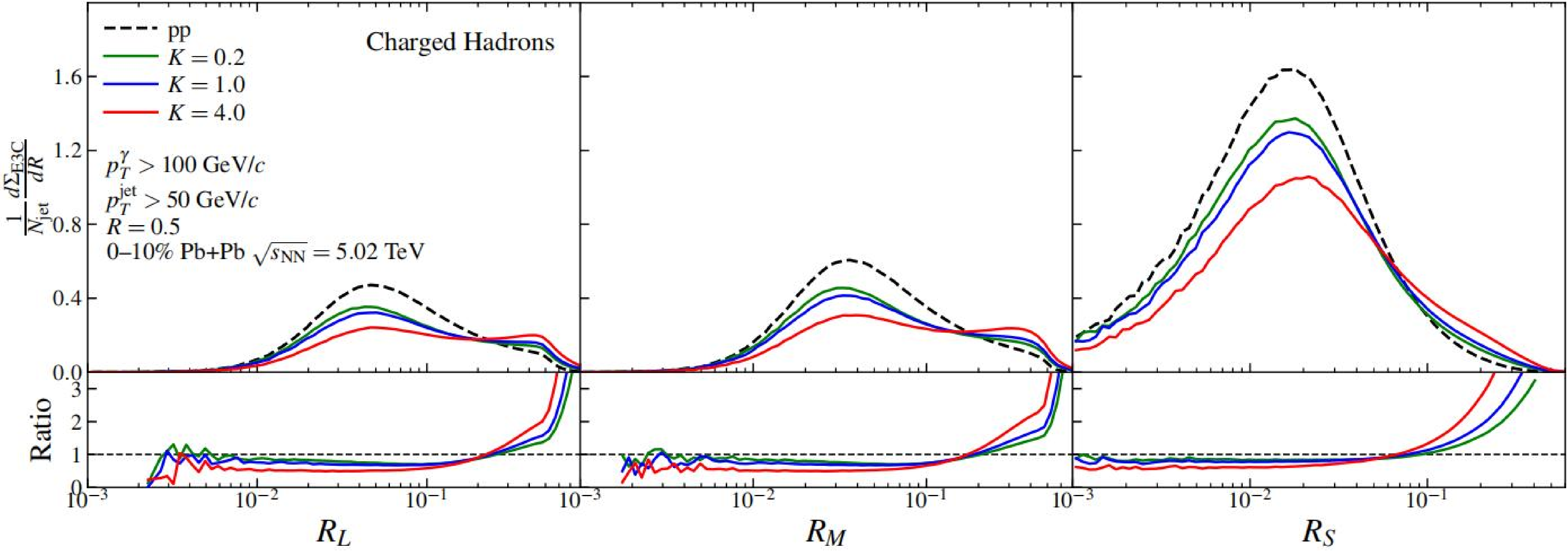
J. Auvinen et al, Phys. Rev. C **82** 024906 (2010); X. F. Guo and X.N. Wang, Phys. Rev. L **85** 3591 (2000); Y. Dang, W.-J. Xing, S. Cao, and G.-Y. Qin, arXiv:2602.10395 [nucl-th] (2026).
B.W. Zhang, E. Wang, and X.N. Wang, Phys. Rev. L **93** 072301 (2004); Y. Y. He et al, Phys. Rev. C **91** 054908 (2015); T. Luo et al, Phys. Rev. C **109** 034919 (2024).

Methodology: LBT Workflow



LBT combines the hydrodynamic QGP background with PYTHIA γ-jet events; evolves <u>shower, radiation, recoil, and negative partons</u> through the medium; followed by hadronization, FASTJET reconstruction, and EEEC analysis.

EEEC projections at different angular scales



Distributions differ among R_L, R_M, and R_S, the same modification like EEC: small-angle suppression and broad-angle enhancement.

LBT component analysis of EEEC

Parton Level

S

shower partons

R

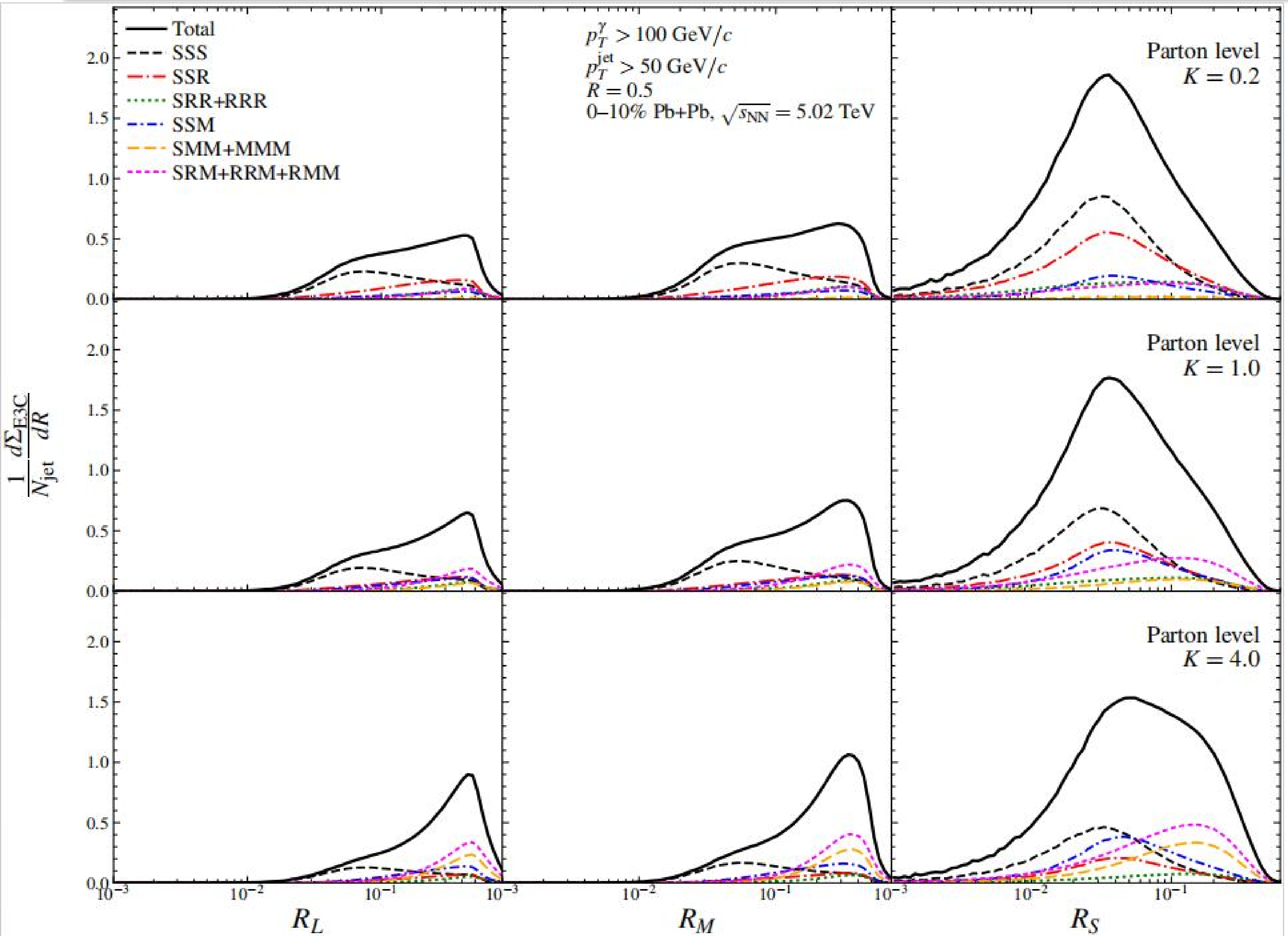
medium-induced radiated gluons

M

medium response: recoil + negative partons

SSS	vacuum-like shower baseline
SSR	one induced radiation gluon correlated with shower partons
SRR + RRR	radiation-dominated triplets
SRM + RRM + RMM	mixed radiation-response triplets
SSM	one response parton correlated with the shower
SMM + MMM	response-dominated triplets

Parton-level component decomposition across angular scales



K increase:

M increases, S decreases,

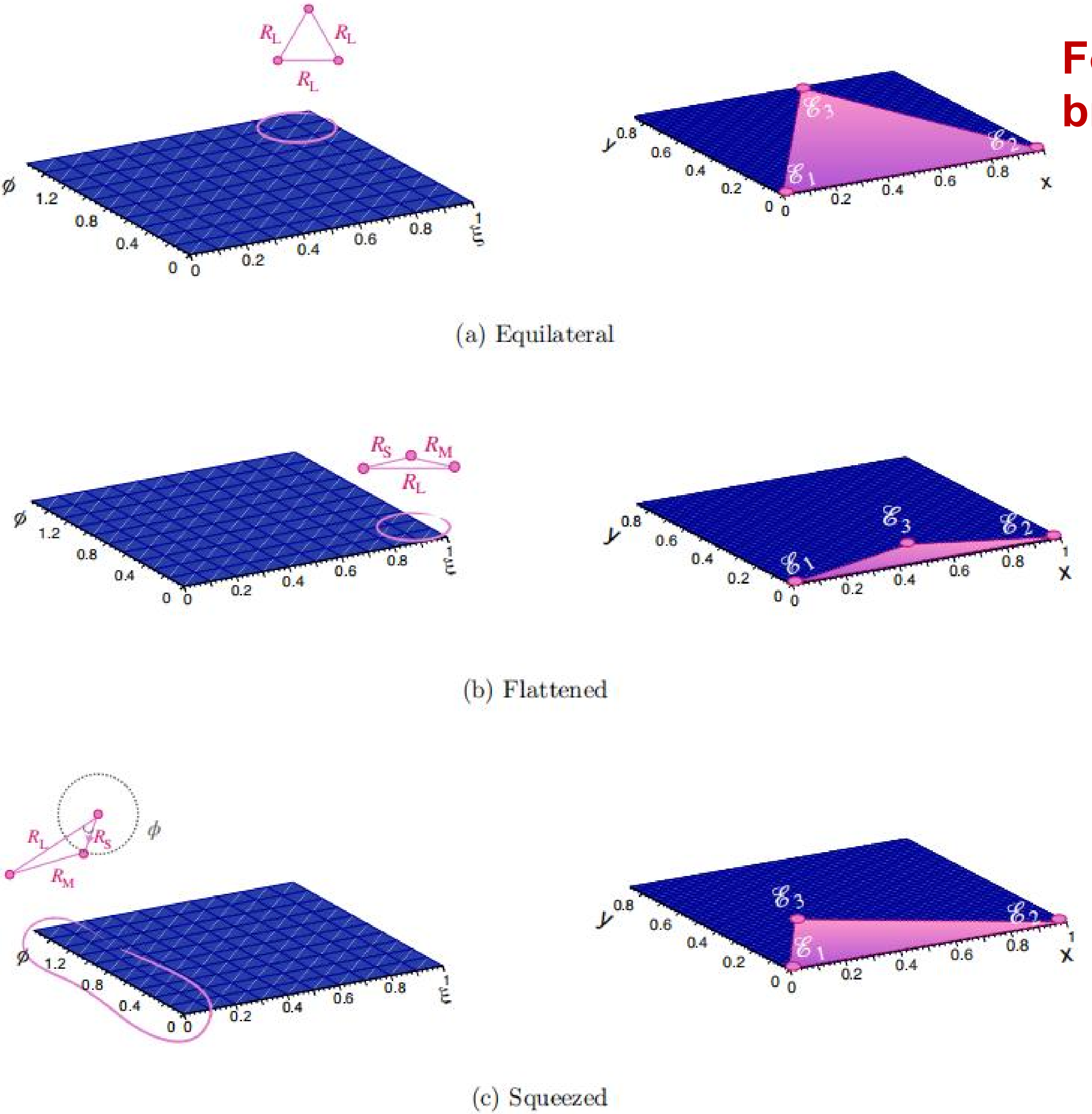
R is relatively stable

Angular scale：

Double-S triplets stay closer to the shower core

Single-S / non-S triplets populate broader angles

Shape-space definition: separate scale from triangle shape

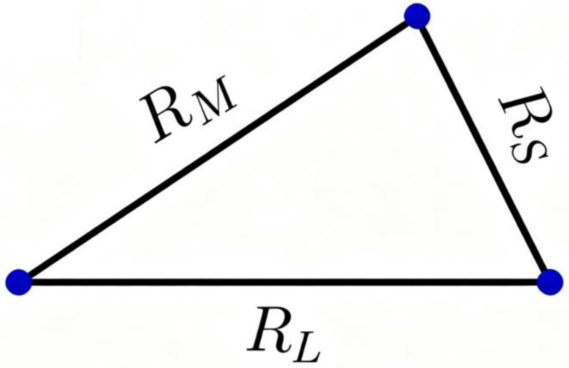


(a) Equilateral

(b) Flattened

(c) Squeezed

Focus on $\xi=1, \varphi=\pi/2, R_L=R_M=R_S$
broad-angle and near-equilateral



ordered distances:
$R_S < R_M < R_L$

shape variables:

$$\xi = R_S / R_M$$

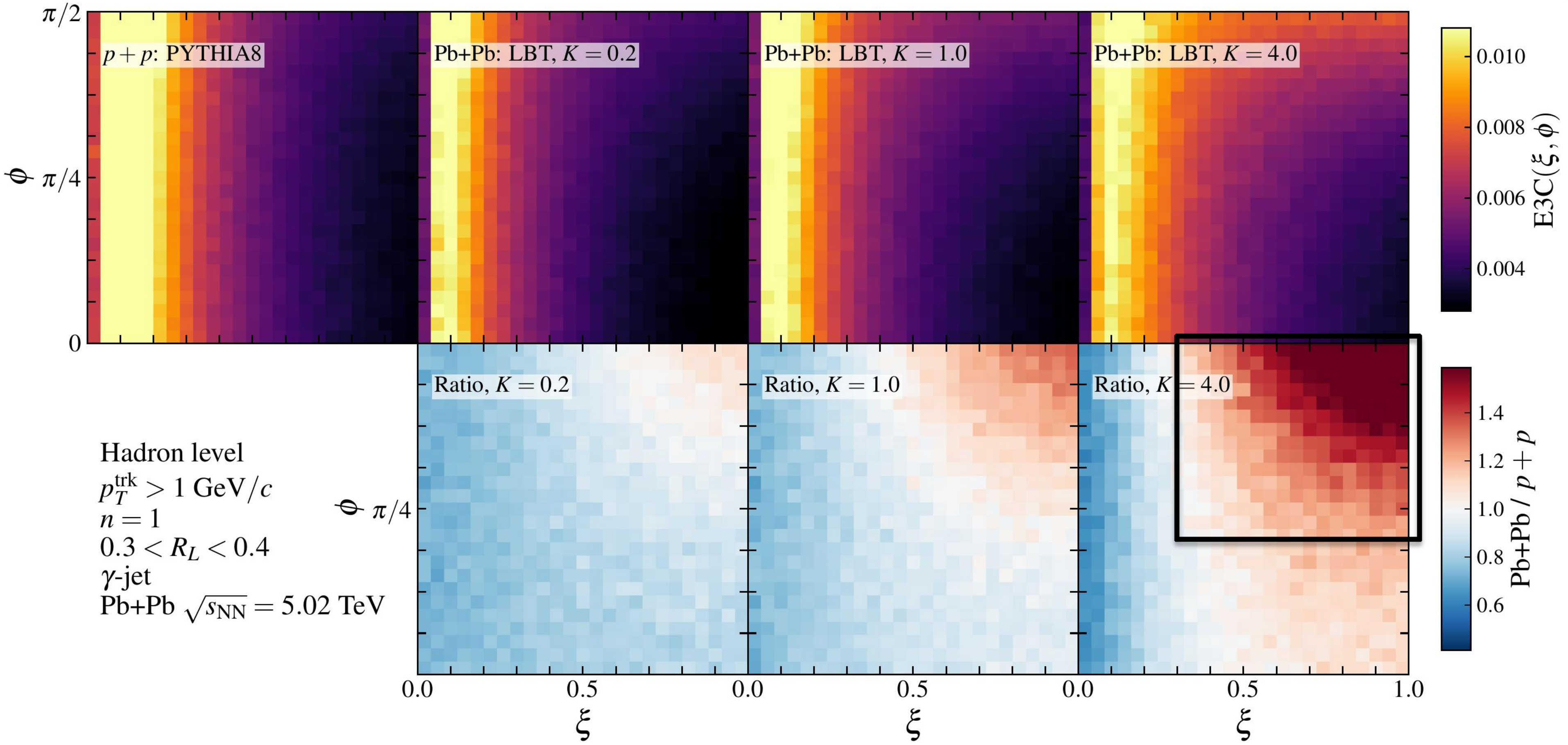
$$\varphi = \mathrm{acrsin}\sqrt{1 - \frac{(R_L - R_M)^2}{{R_S}^2}}$$

Shape can be studied in EEEC.

<u>Fixing R_L</u>, the overall angular scale is fixed, so we can compare different triangle shapes without mixing in scale effects

figure source: Bossi et al., JHEP 12 (2024) 073.

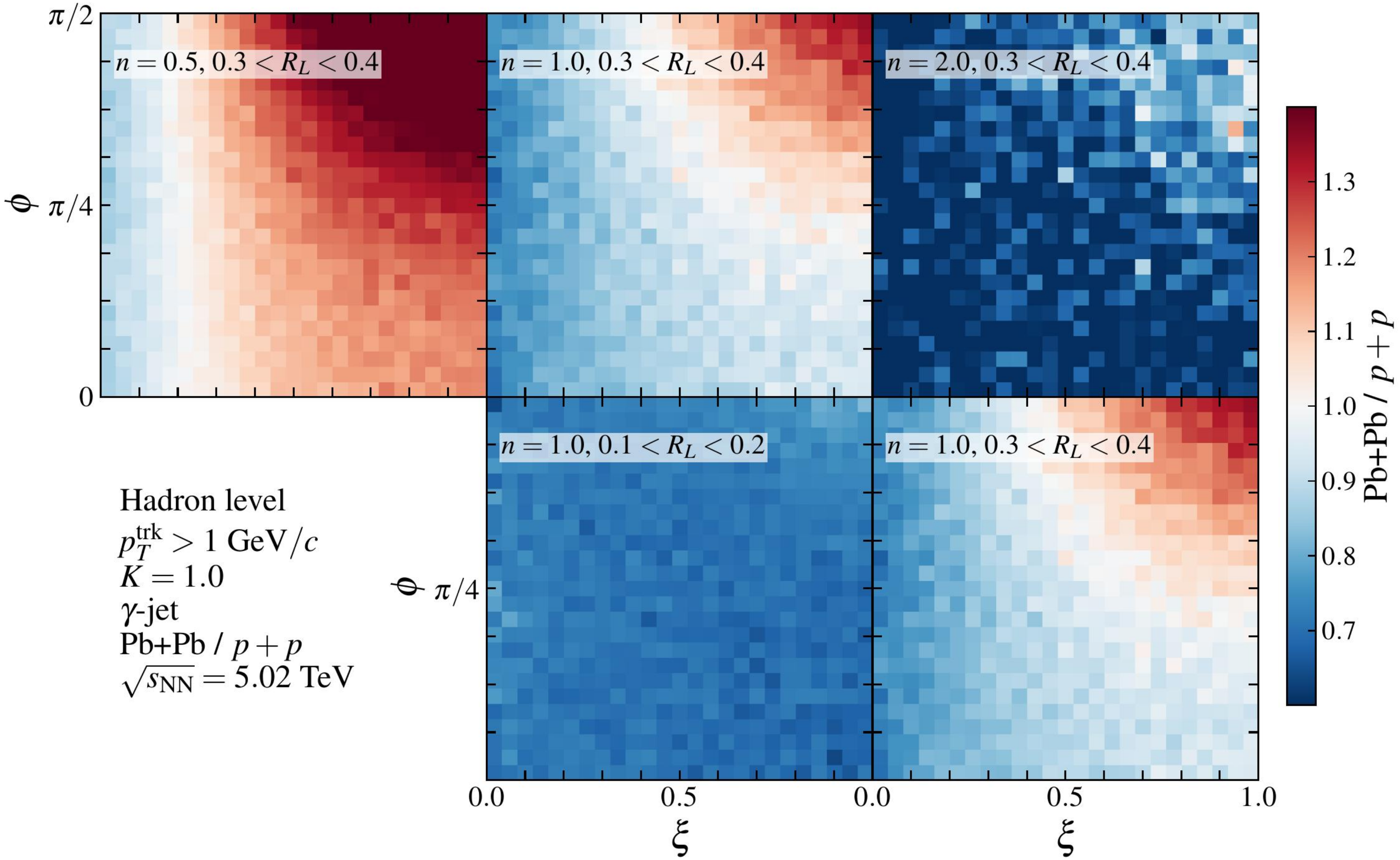
E3C in shape space: absolute yield and AA/pp ratio



Increasing K strengthens the medium modification of EEEC.

Enhancement appears in the broad-angle, near-equilateral region.

Shape-space sensitivity to n and R_L



n = 0.5:
soft enhanced
→ stronger broad-angle enhancement

n = 2:
soft suppressed
→ broad-angle enhancement reduced

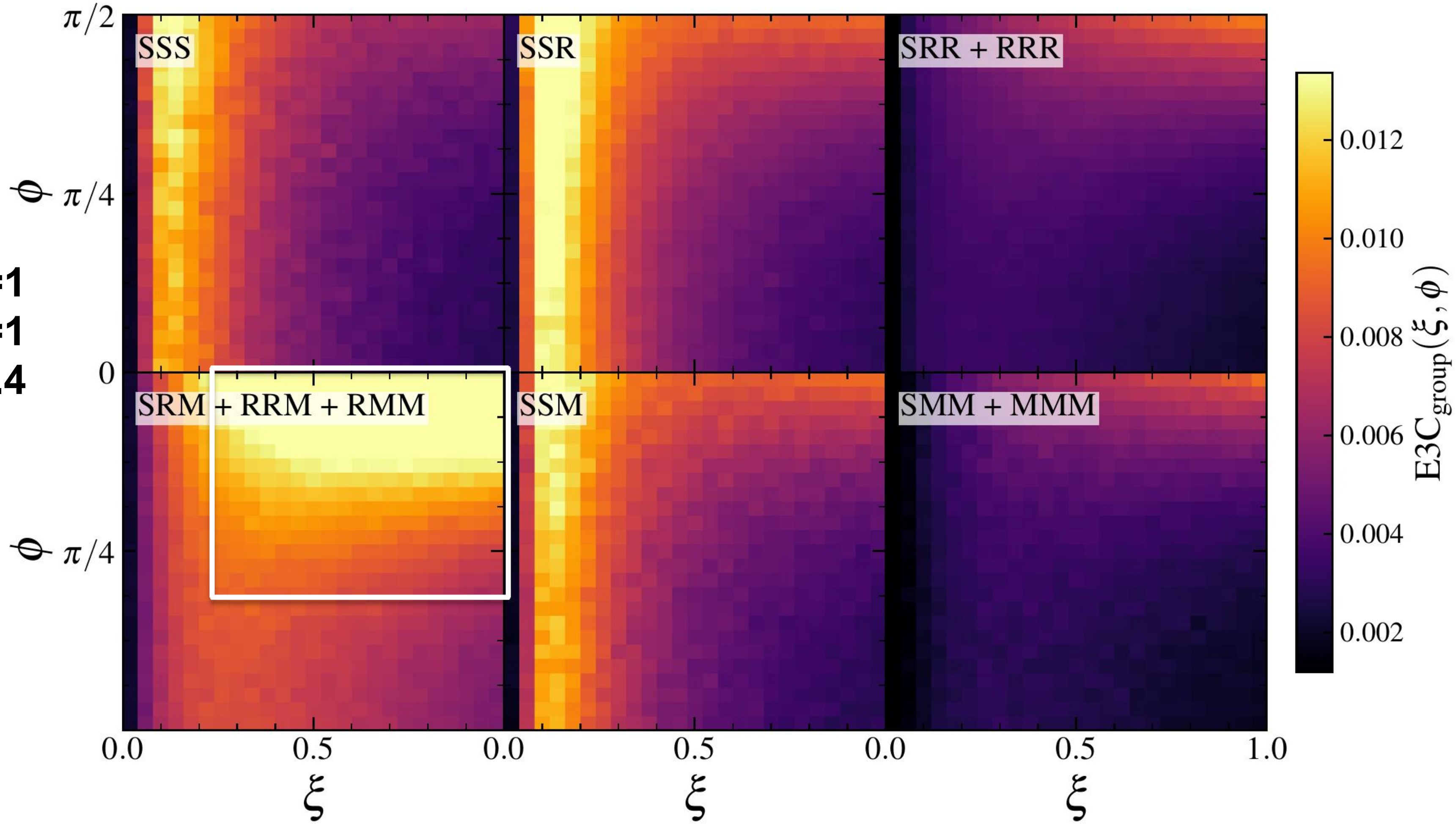
Small R_L:
suppression-dominated

Large R_L:
near-equilateral region enhancement

medium modification:
<u>large R and soft-sensitive</u>

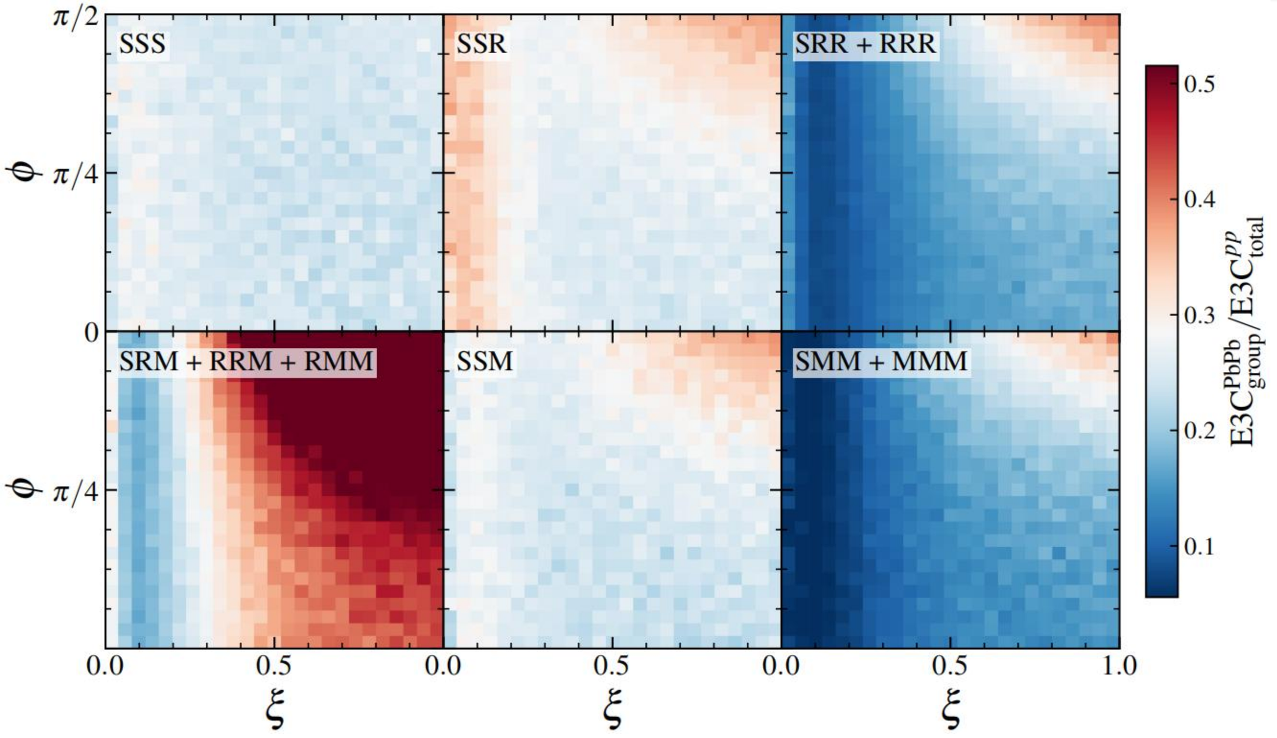
Shape-space component decomposition

n=1
K=1
$0.3<R_L<0.4$

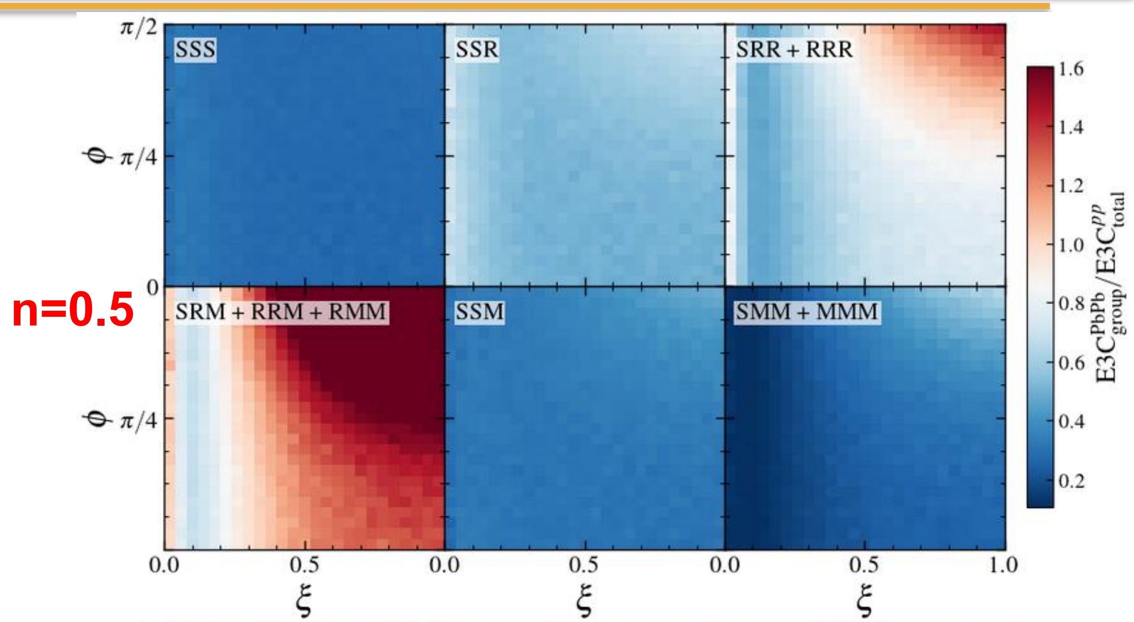


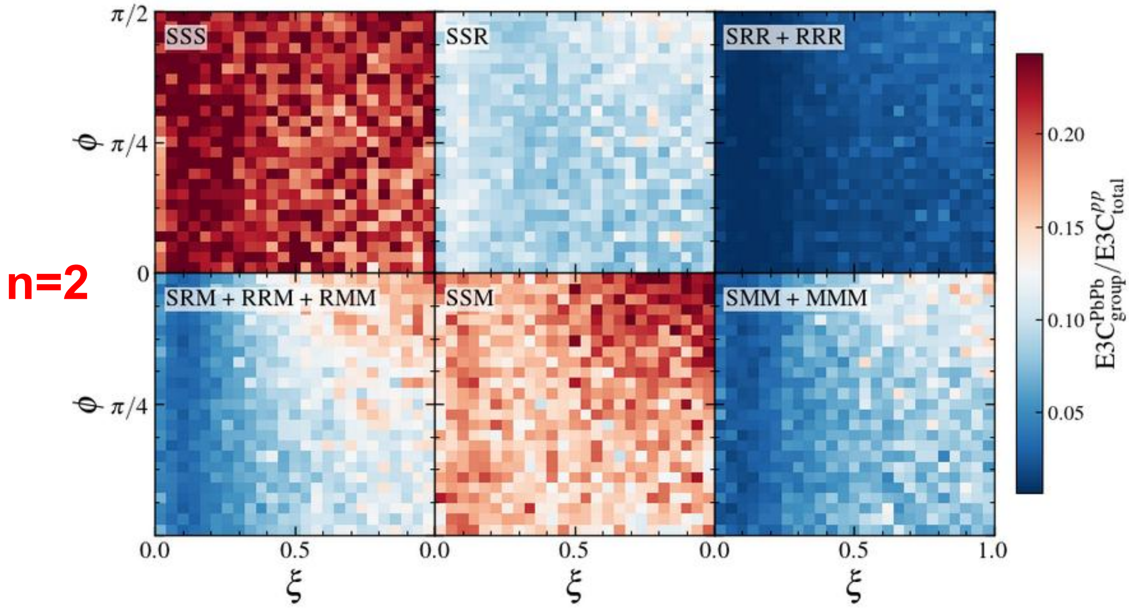
EEEC is most sensitive to <u>mixed radiation-response triplets</u> in the LBT component decomposition.

Shape-space component decomposition



n=1

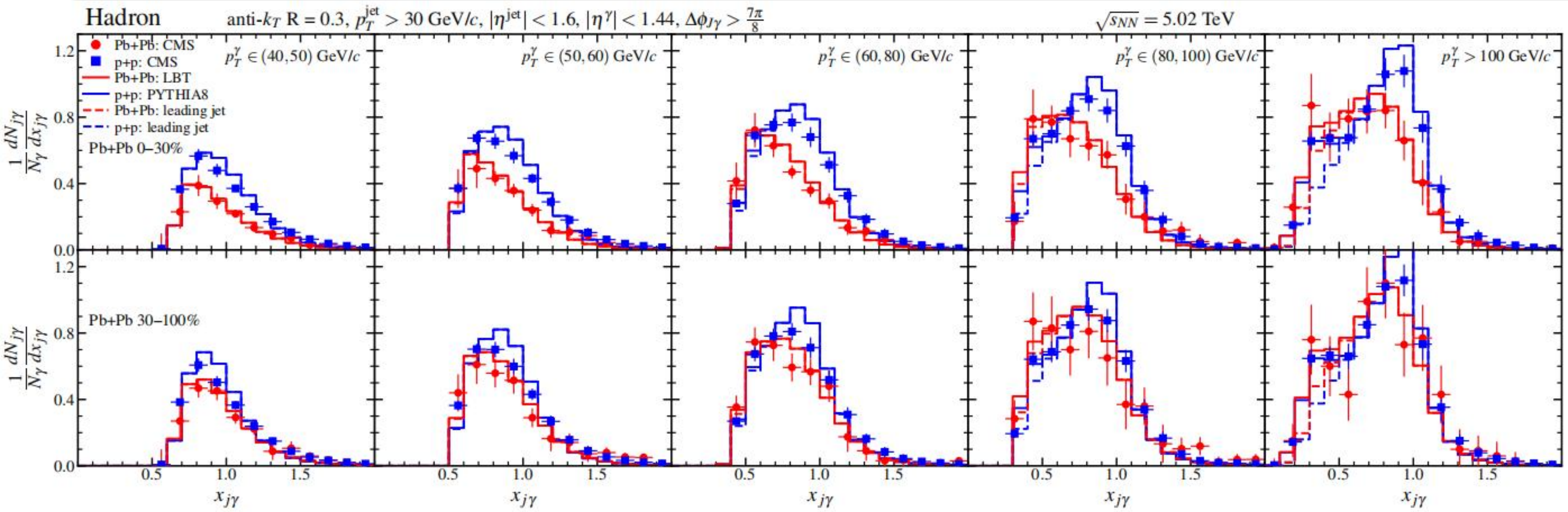


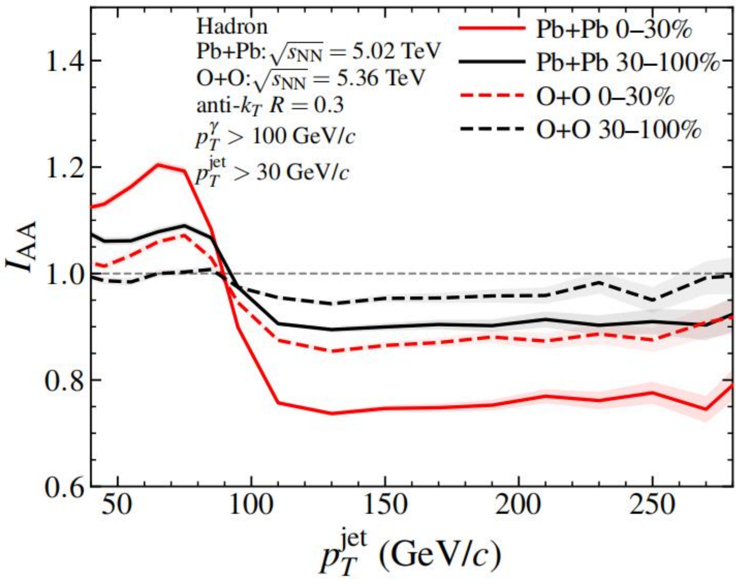


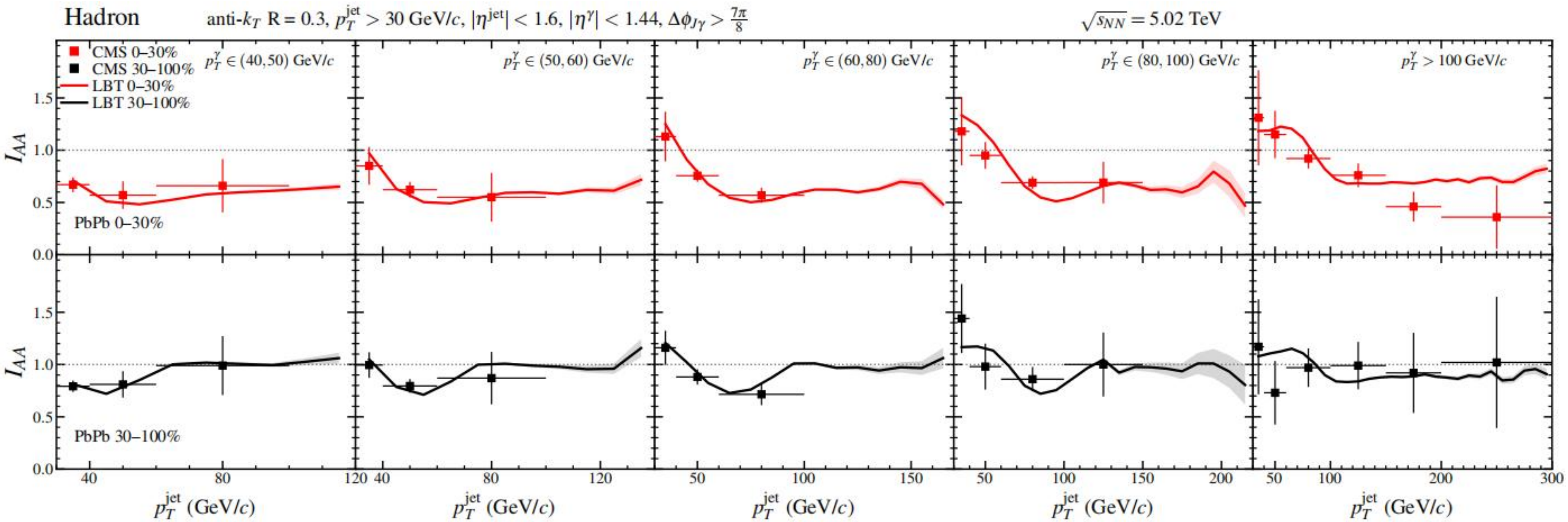
Central result:
Radiation and Medium response both populate broad-angle near-equilateral configurations.

n controls energy weighting:
n = 0.5 enhances softer radiation-related triplets
n = 2 selects harder medium-response triplets

System-Size Dependence



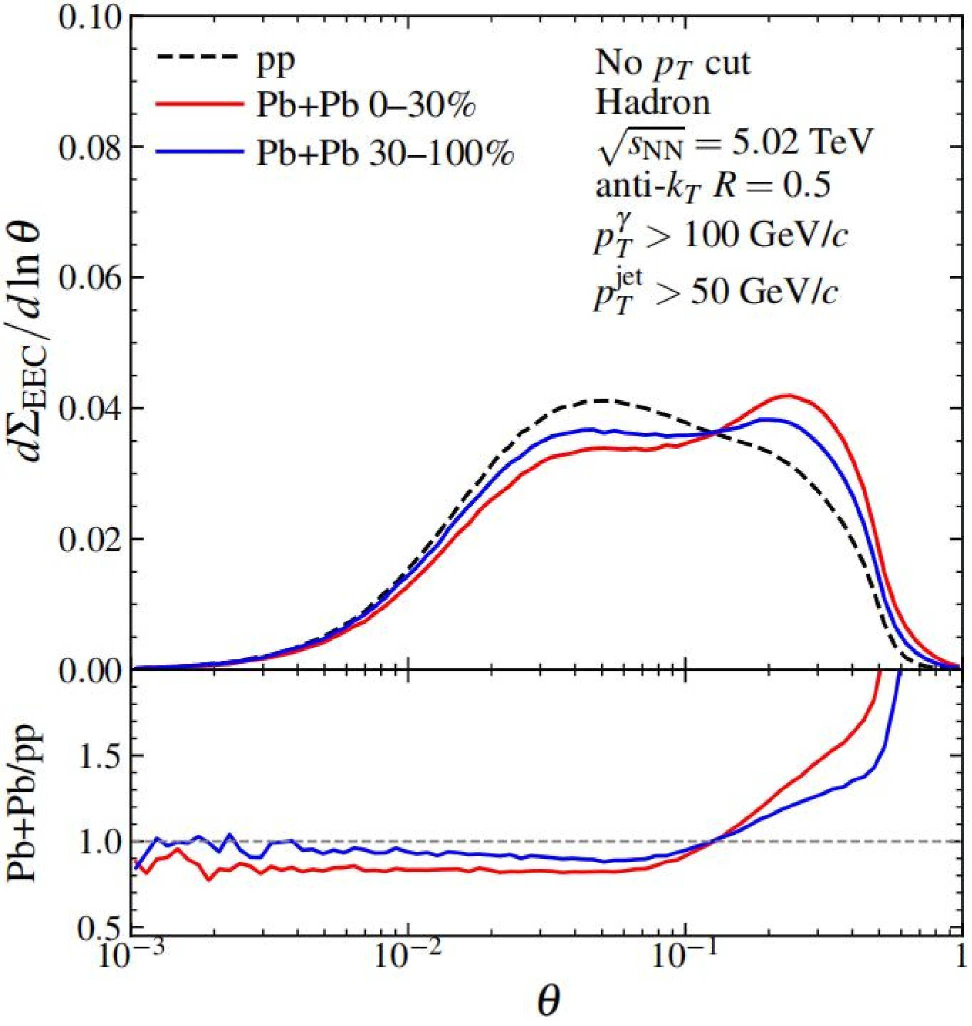


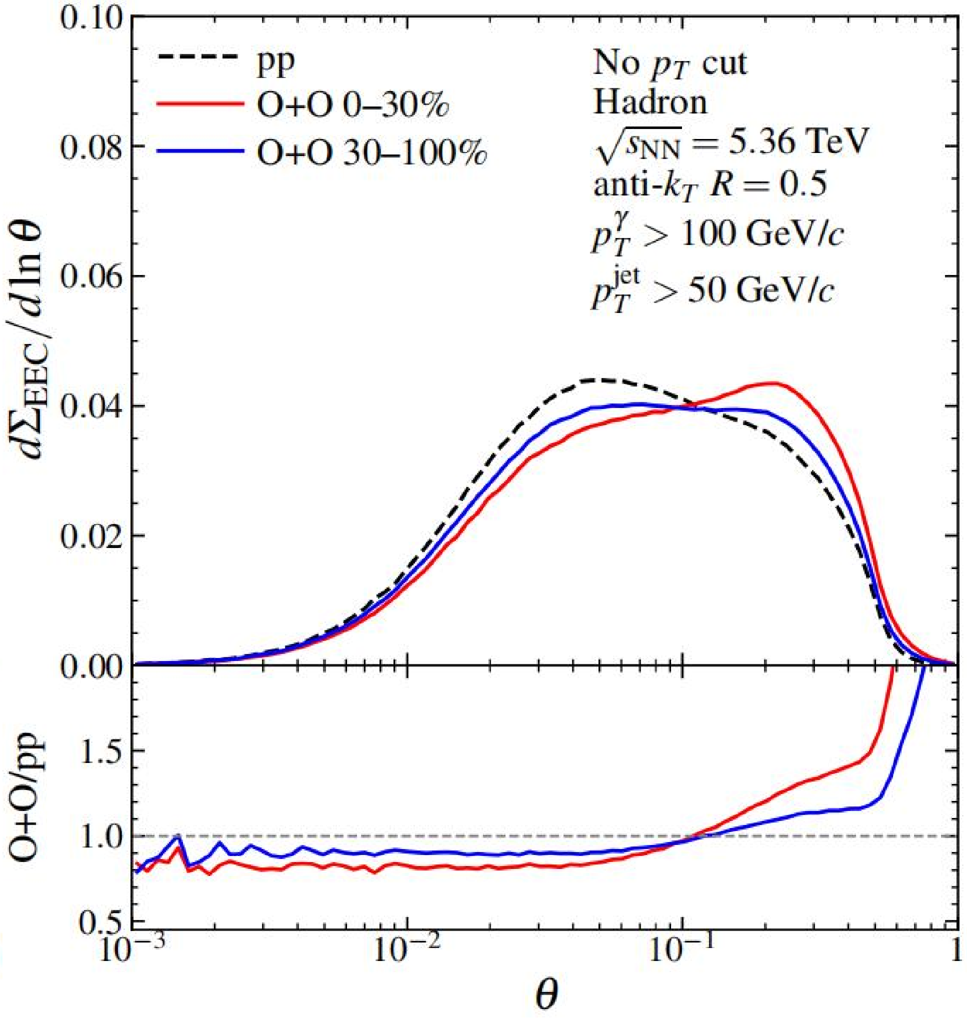


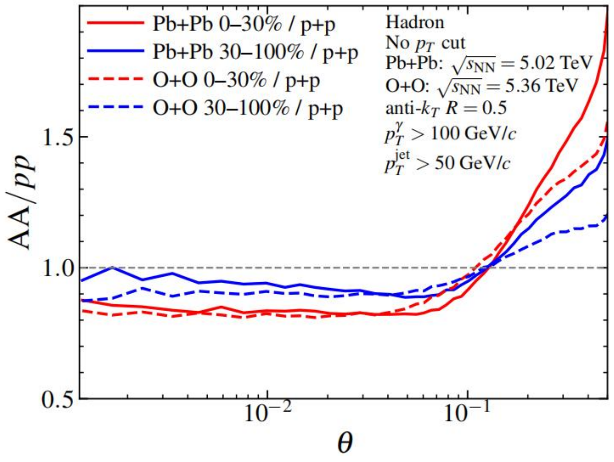
LBT describes CMS γ-jet observables in Pb+Pb collisions.

O+O shows a weaker but still visible γ-jet modification compared with Pb+Pb.

System-Size Dependence







Both Pb+Pb and O+O show the same EEC pattern: small-angle suppression and broad-angle enhancement.
The modification is weaker in O+O.

Summary

✓ EEEC extends EEC from one angular distance to full three-particle geometry.

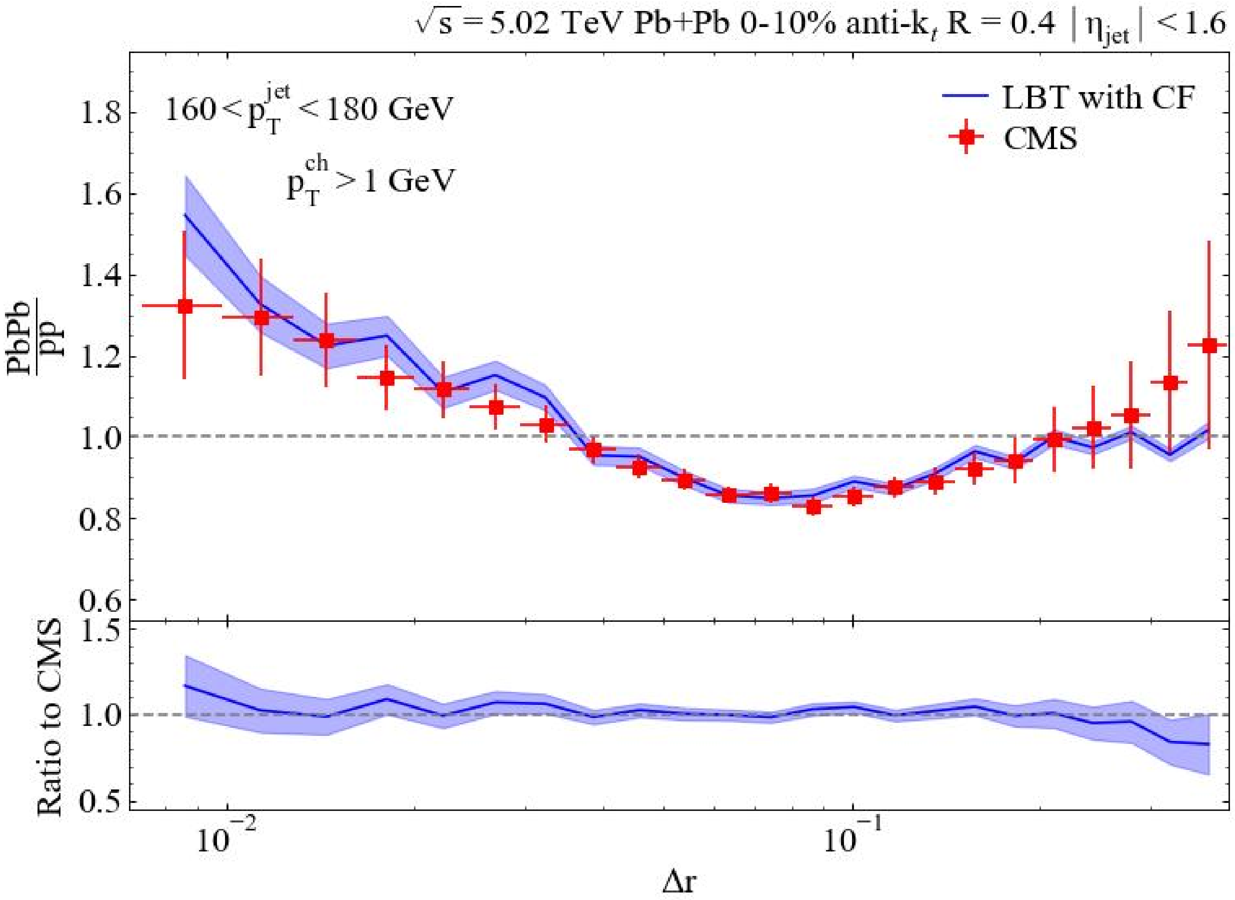
✓ In Pb+Pb, EEEC shows small-angle suppression and broad-angle, near-equilateral enhancement.

✓ Component decomposition shows a shift from shower-correlated triplets toward radiation and medium-response-related triplets, especially in broad-angle, near-equilateral configurations.

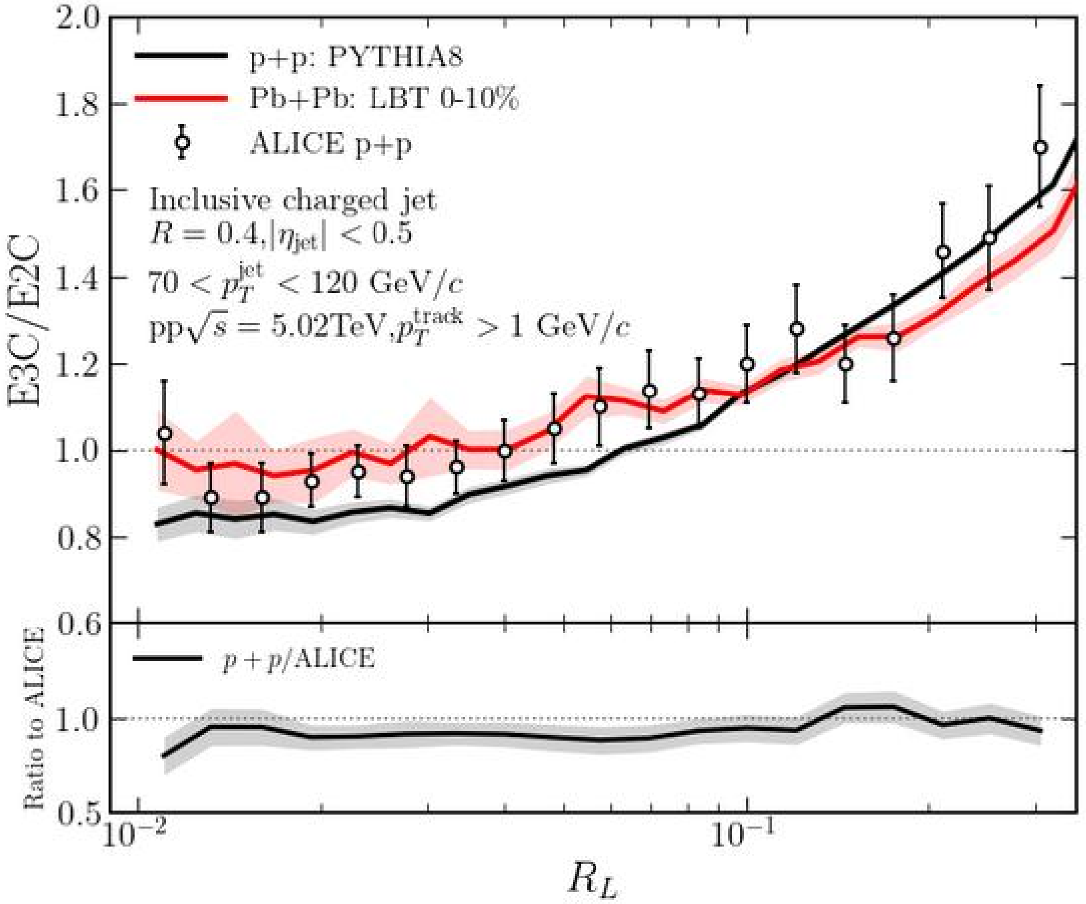
✓ O+O predictions extend the study to a smaller collision system with weaker jet-medium modification.

Thanks for your attention

Backup: LBT comparisons with measured energy correlators



CMS data: CMS Collaboration, Phys. Lett. B 866, 139483 (2025);
LBT calculation/figure courtesy of Cheng Xu.



ALICE pp preliminary data at 5.02 TeV: ALI-PREL-604282.
PYTHIA8 and LBT curves are from this work.

Backup: Radiation versus medium response in shape space