Jets in QCD Matter

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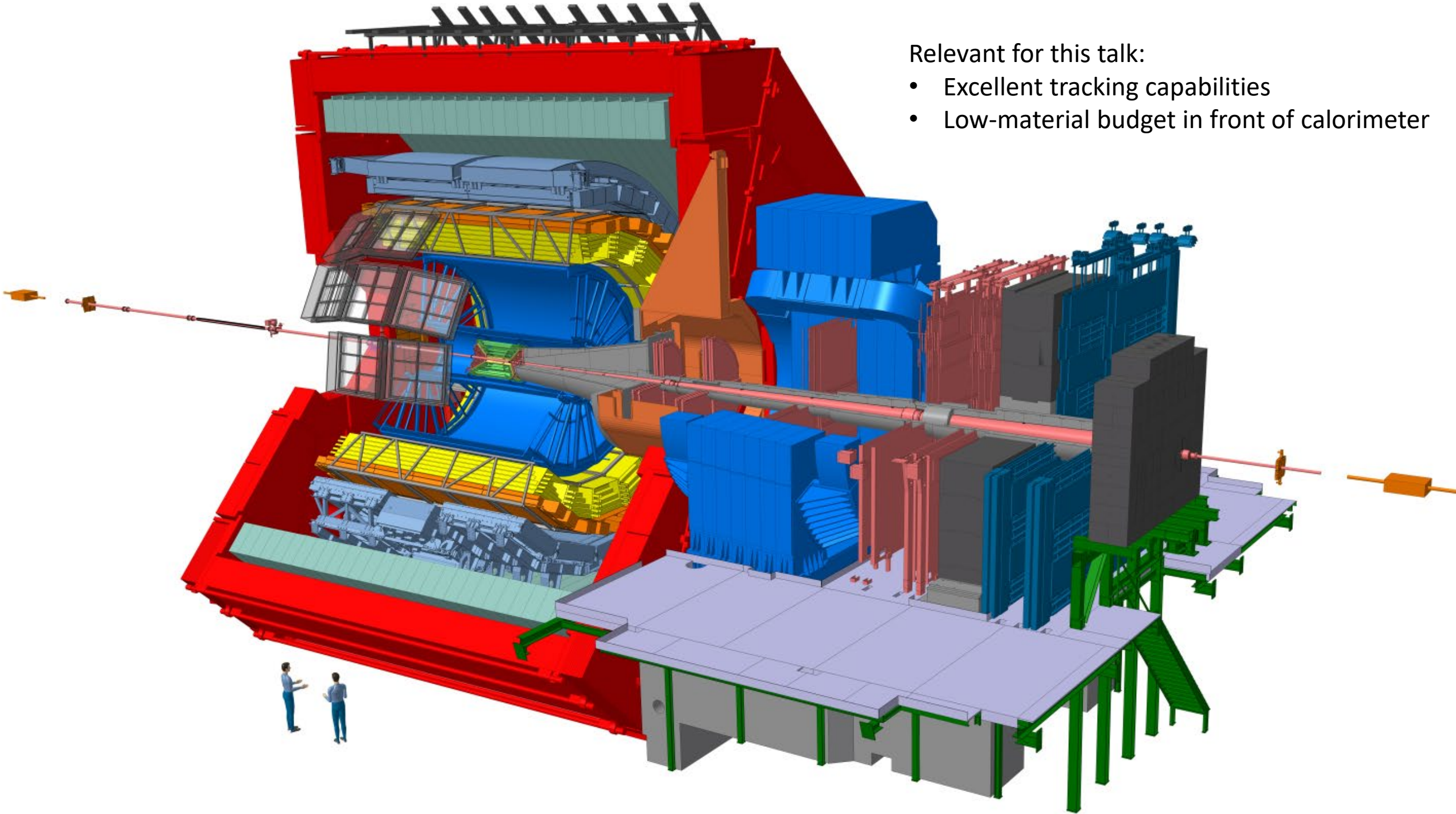
8th Workshop of the APS Topical Group in Hadronic Physics, Denver, CO, April 2019

Outline

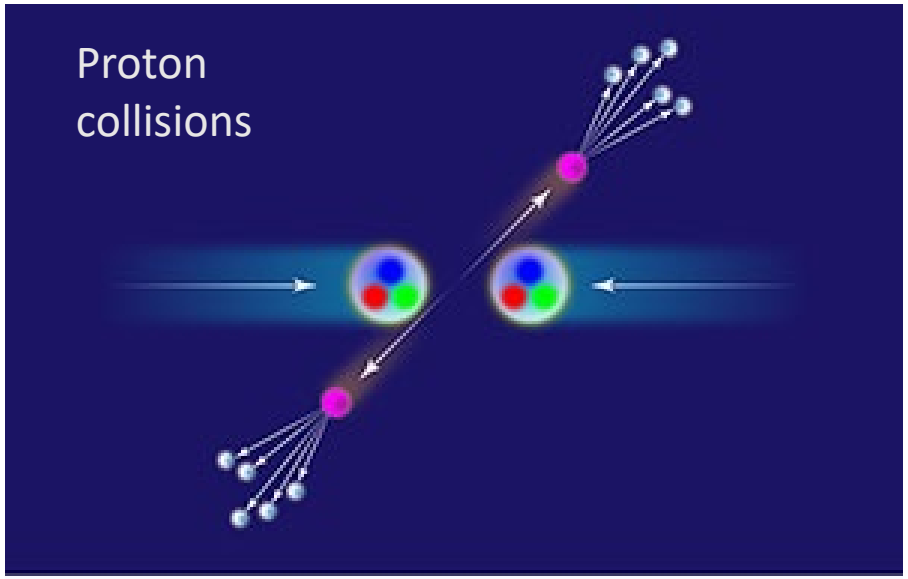
- jets in hot QCD matter with ALICE
- jets in cold QCD matter with ALICE

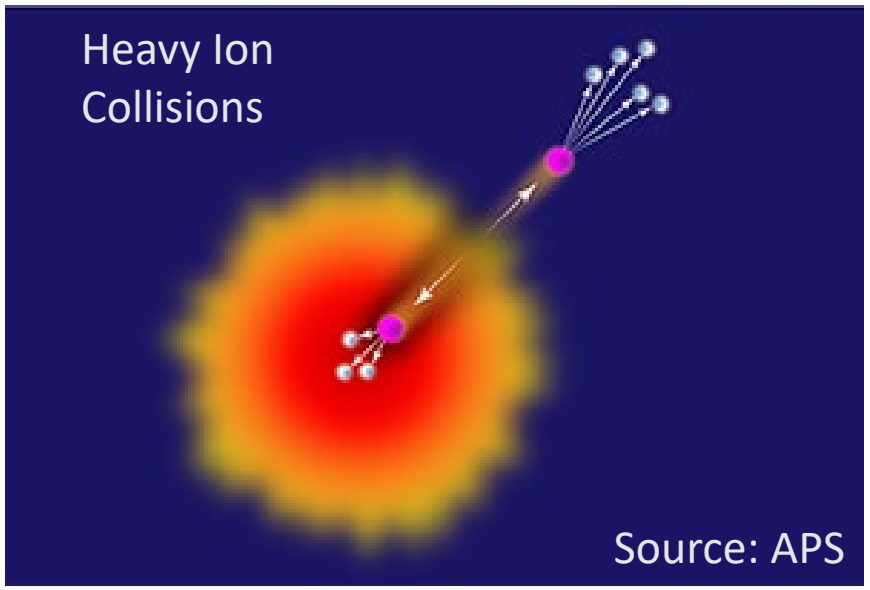


Relevant for this talk:

- Excellent tracking capabilities
- Low-material budget in front of calorimeter

Jet probes of quark-gluon plasma (QGP)

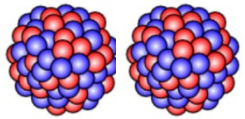


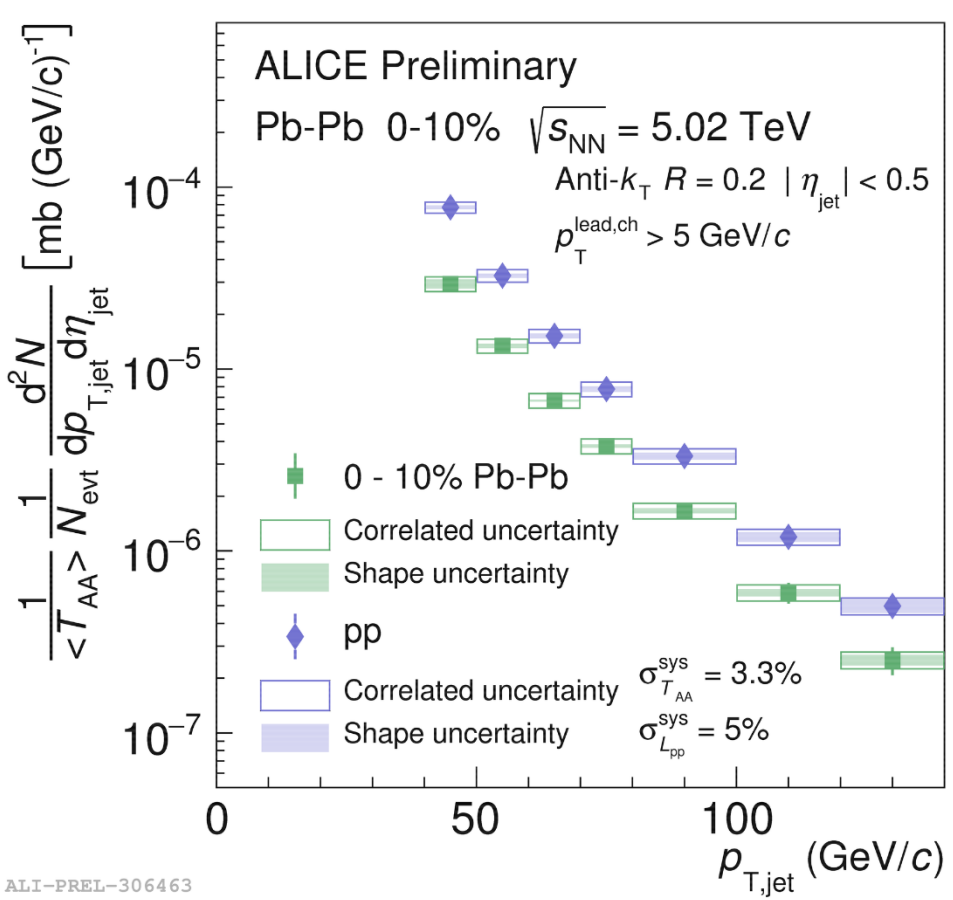


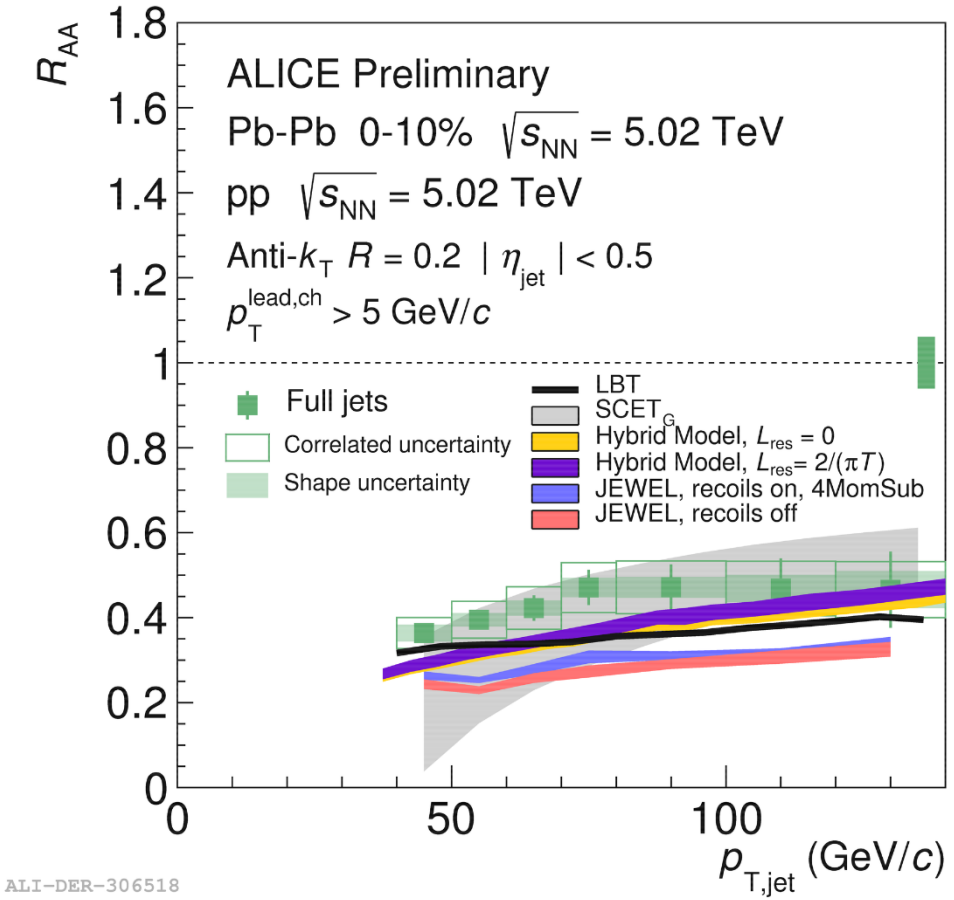
Control

Jet-QGP interactions

Jet spectra measurements



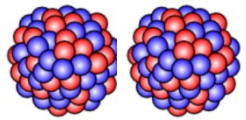




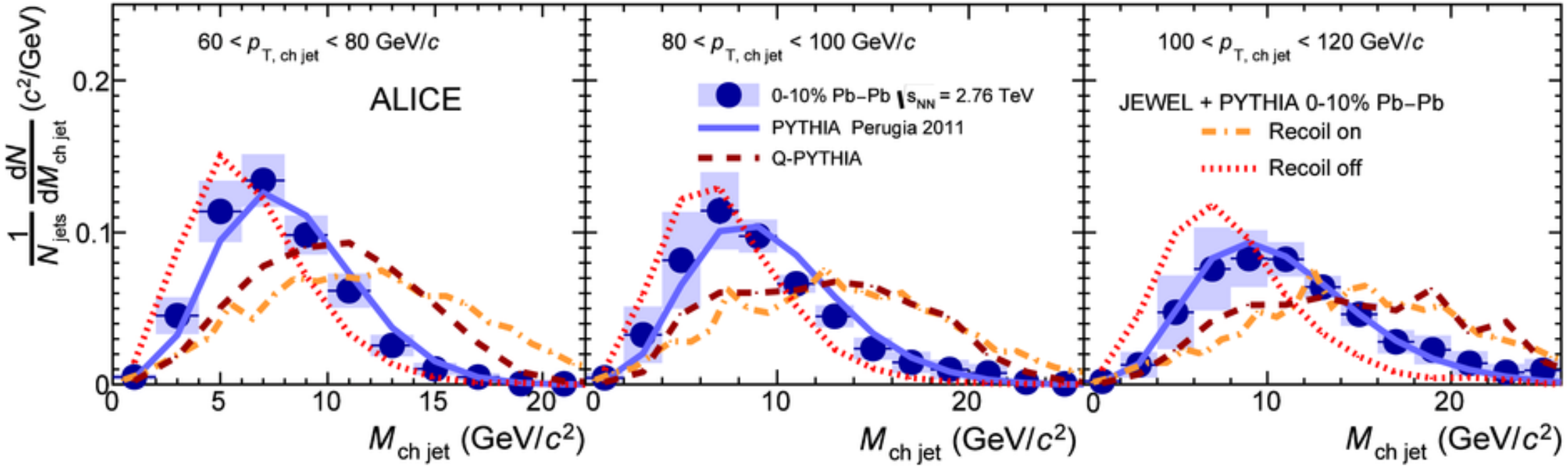
- Jets strongly suppressed in central Pb-Pb collisions
- Models that vary widely in the physics can all describe data within errors (☹)

Jet mass in Pb-Pb

$$M_{Jet} = \sqrt{E_{Jet}^2 - p_{Jet}^2} \propto Virtuality$$

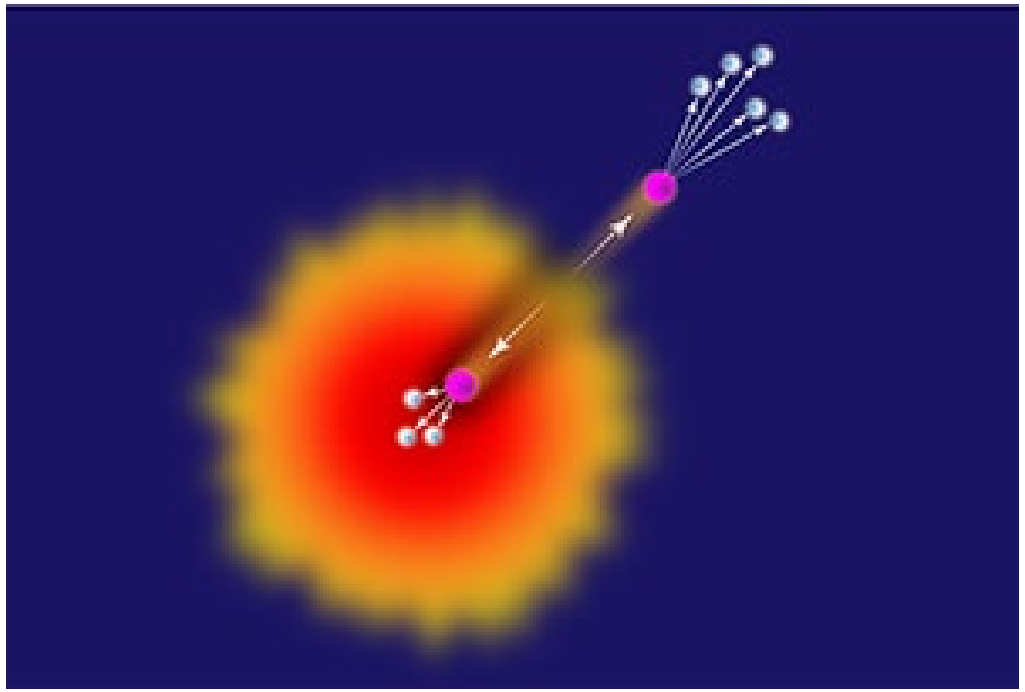


[Phys. Lett. B 776 (2018) 249](#) (first measurement)

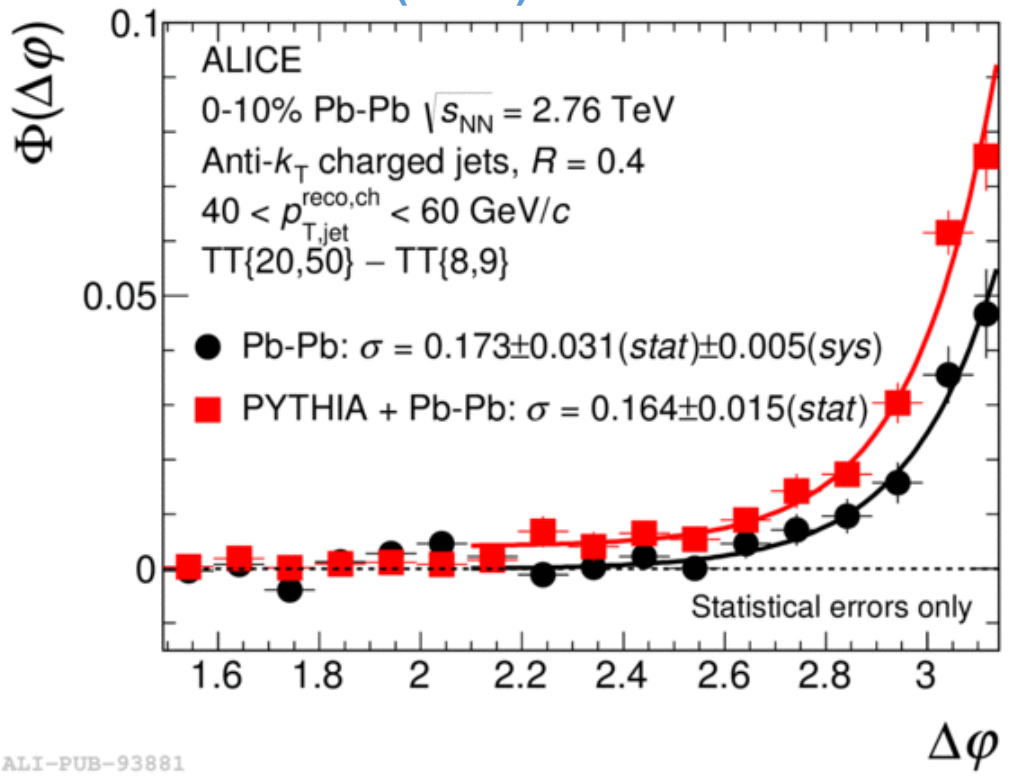


Models with energy loss miss data badly,
PYTHIA (pp) describes it fairly well

Search for jet scattering off quark-gluon plasma



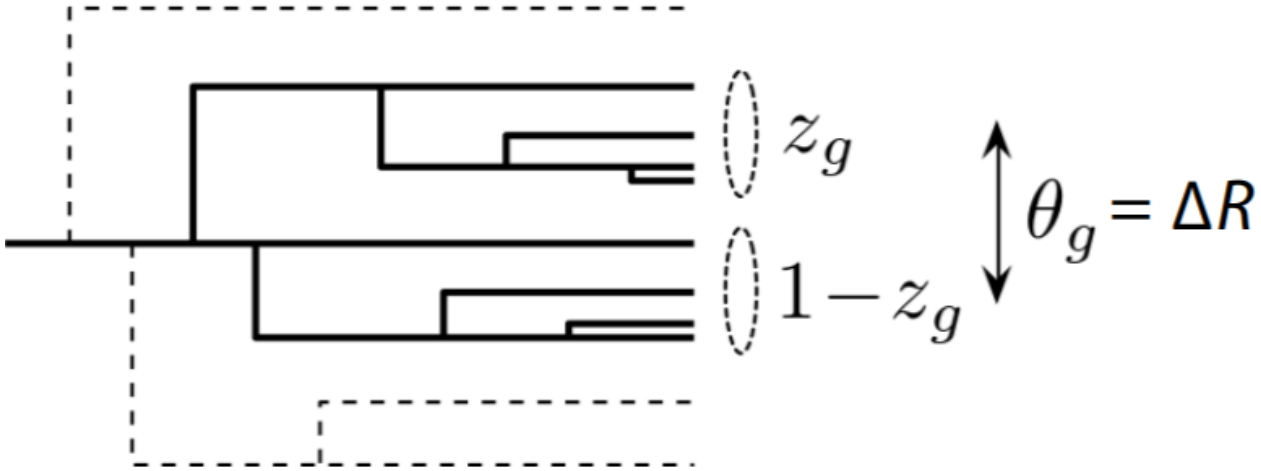
JHEP 09 (2015) 170



- Large-angle scattering off QGP not yet observed with current precision
- High-Luminosity LHC will provide percent-level precision arXiv:1812.06772

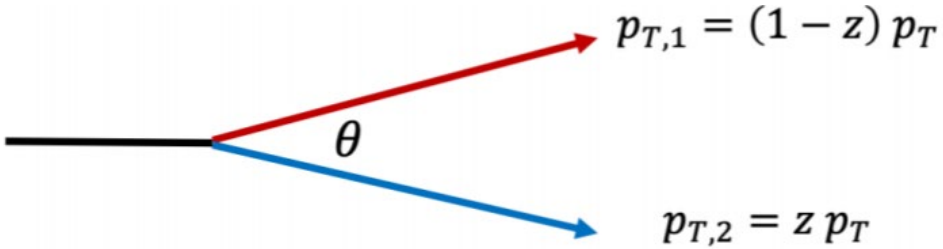
Deconstructing jets

A. Larkoski et al., Phys. Rev. Lett. 119, 132003 (2017)

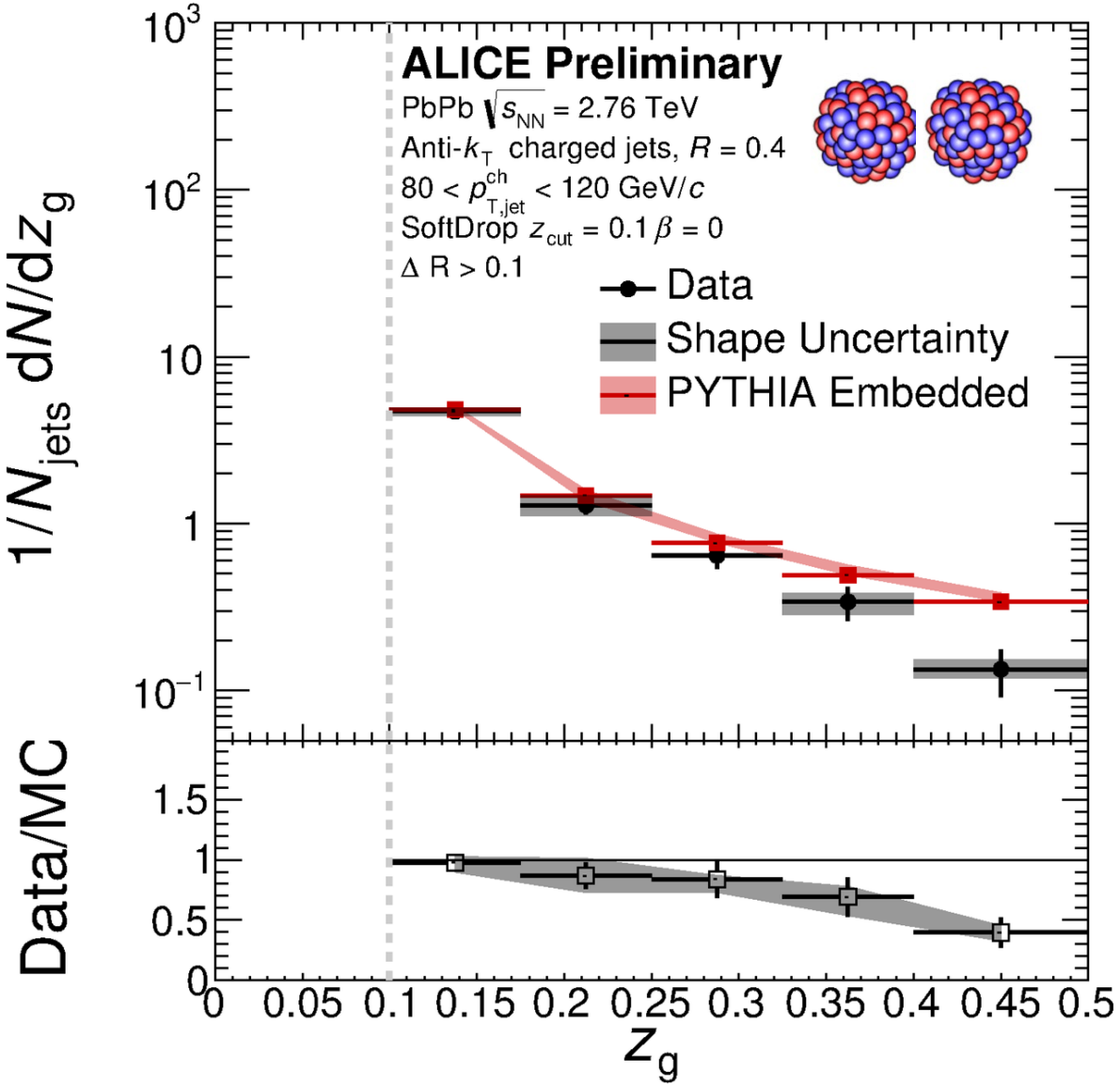


"Shared Momentum Fraction" Zg

Found to converge to Altarelli-Parisi splitting functions



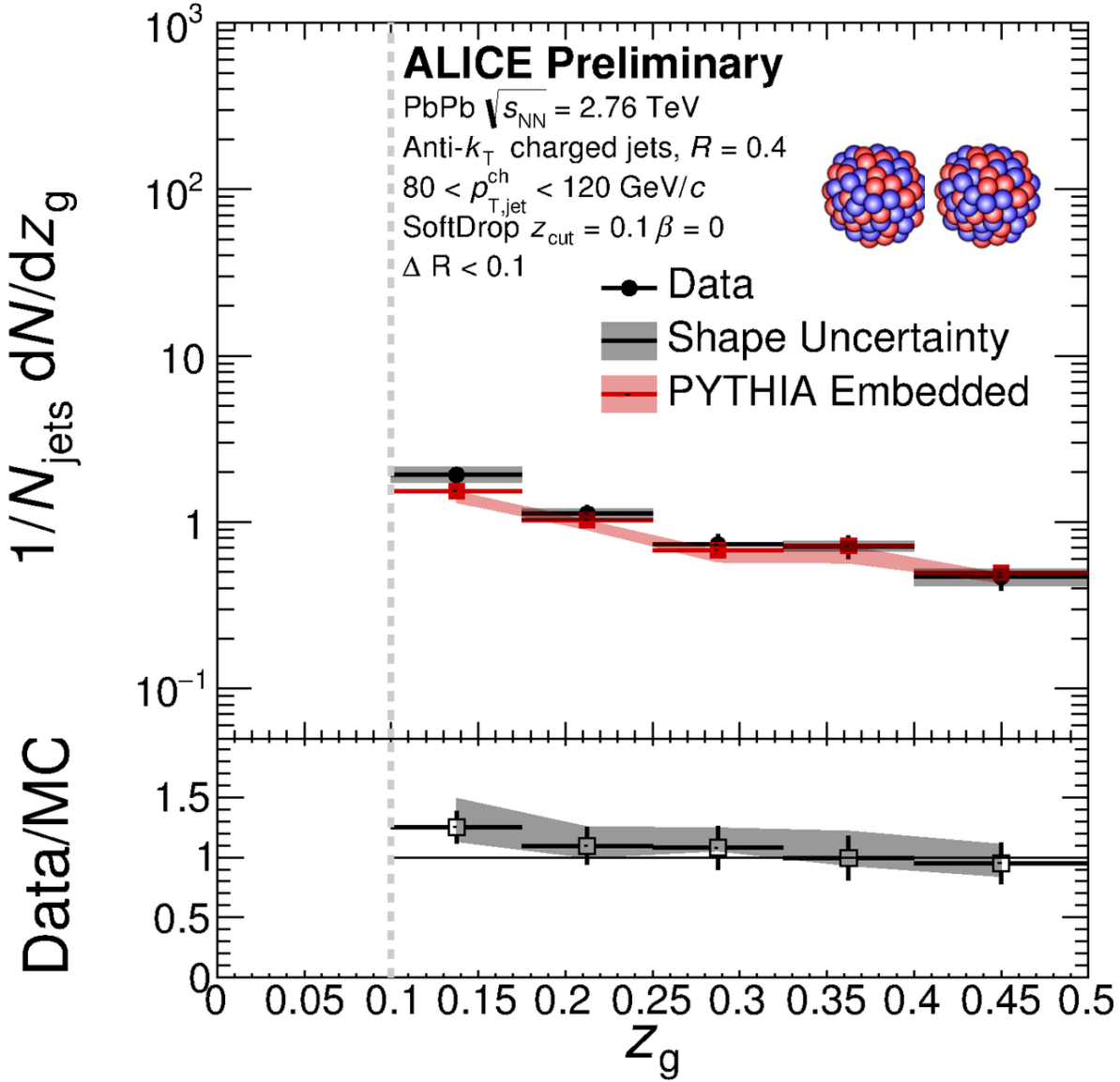
Shared-momentum fraction for well-separated sub-jets



$$\Delta R > 0.1$$

Significant modification
for symmetric configurations

Shared-momentum fraction for collinear sub-jets

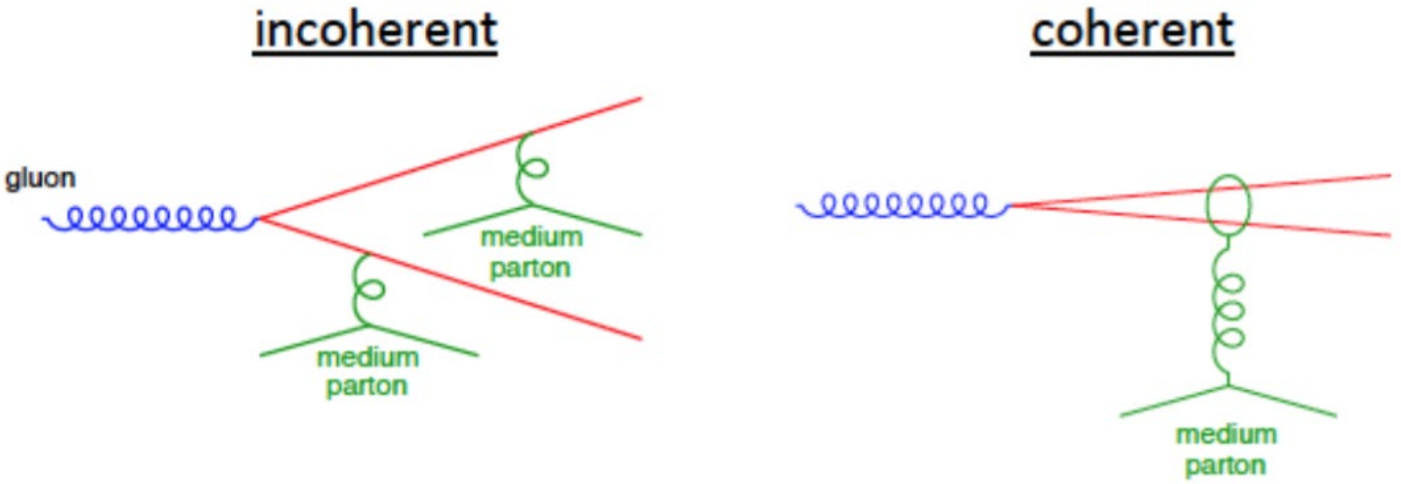


$$\Delta R < 0.1$$

No significant modification

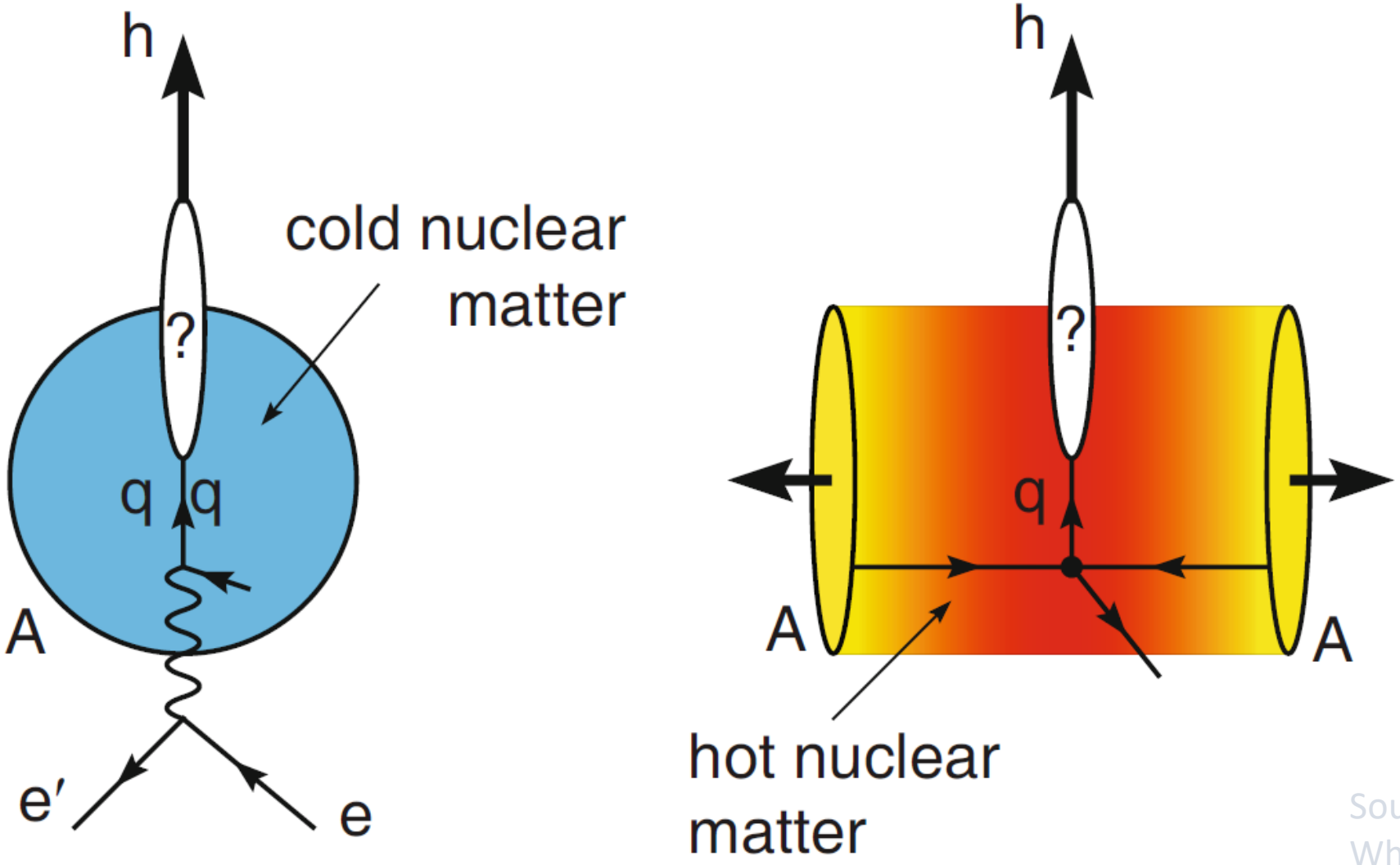
“Color coherence”???

J. High Energ. Phys. (2017) 2017: 125



- Potentially yet another interesting QCD-in-matter effect (adding to color transparency, LPM, etc.)

Quark propagation in “QCD matter”



Source: EIC White paper

“QCD Matter” in diverse type of experiments

eA **pA** **pA and AA**

- CLAS12, SeaQuest, COMPASS, NA61 **(fixed target)**
- ALICE, ATLAS, CMS, LHCb and PHENIX, STAR **(collider)**

Future : The Electron-Ion Collider

Theory of quark interactions with QCD matter has more than 20 years of development

Radiative energy loss and p(T) broadening of high-energy partons in nuclei
R. Baier (Bielefeld U.), Yuri L. Dokshitzer (INFN, Milan), Alfred H. Mueller (Columbia U.), S. Peigne, D.
Published in **Nucl.Phys. B484 (1997) 265-282**
CU-TP-760, BI-TP-96-26, LPTHE-ORSAY-96-61
DOI: 10.1016/S0550-3213(96)00581-0
e-Print: **hep-ph/9608322** | **PDF**

References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
ADS Abstract Service

Detailed record - Cited by 1042 records 1000+

Multiple collisions and induced gluon Bremsstrahlung in QCD
Miklos Gyulassy (Columbia U.), Xin-nian Wang (LBL, Berkeley). Jun 1993. 47 pp.
Published in **Nucl.Phys. B420 (1994) 583-614**
CU-TP-598, LBL-32682
DOI: 10.1016/0550-3213(94)90079-5
e-Print: **nucl-th/9306003** | **PDF**

References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
KEK scanned document; ADS Abstract Service

Detailed record - Cited by 698 records 500+

Heavy quark colorimetry of QCD matter
Yuri L. Dokshitzer (Paris U., VI-VII & Orsay, LPT), D.E. Kha
Published in **Phys.Lett. B519 (2001) 199-206**
LPT-ORSAY-01-58, BNL-NT-01-9
DOI: 10.1016/S0370-2693(01)01130-3
e-Print: **hep-ph/0106202** | **PDF**

References | BibTeX | LaTeX(US) | LaTeX(EU) | Harv
ADS Abstract Service

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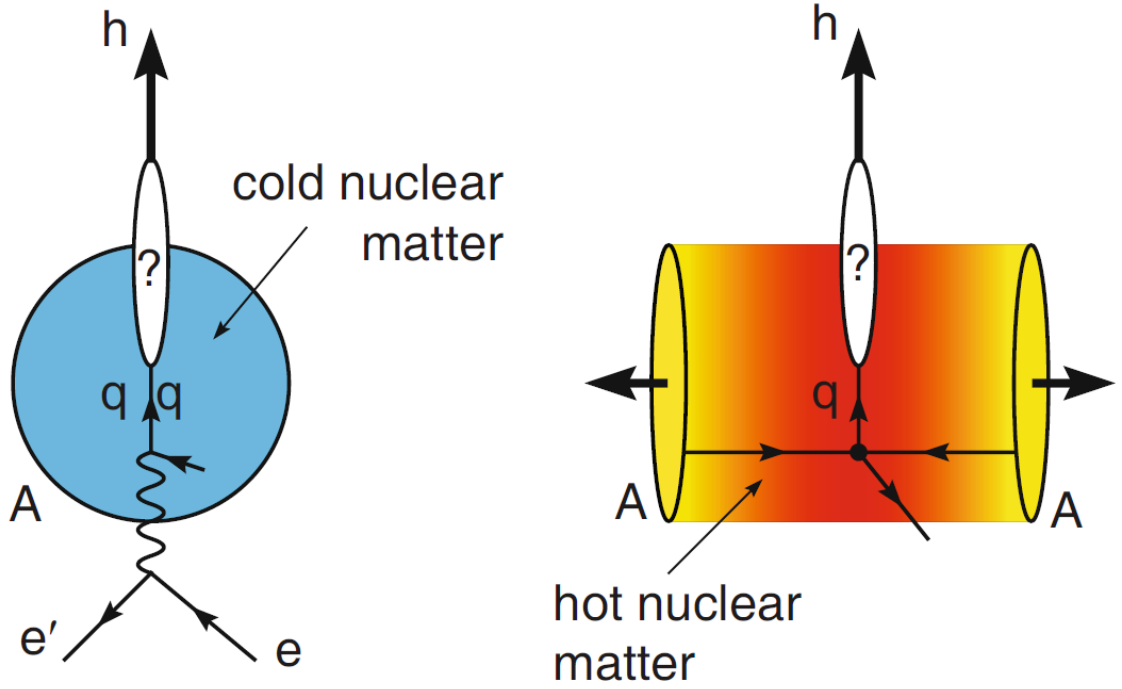
Theory applies to both:



EIC will be the fusion point of two distinct communities

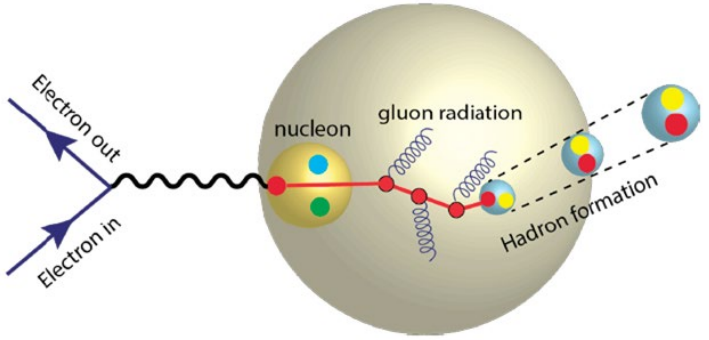
"The realization of an EIC would unify the U.S. QCD community, which at present is two distinct research communities studying hadronic physics and heavy ion physics"

The National Academies of Sciences,
An Assessment of U.S.-Based Electron-Ion Collider Science

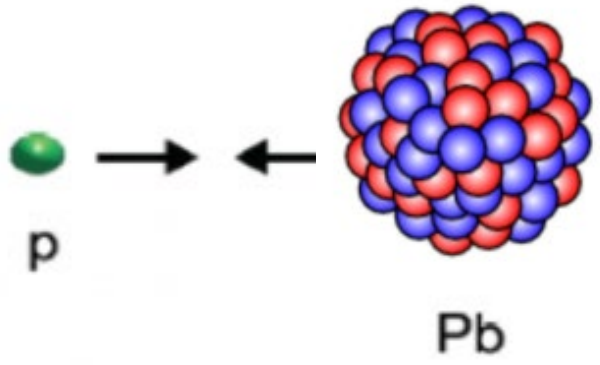
Jefferson Lab

BROOKHAVEN NATIONAL LABORATORY

A NATURAL FUSION POINT IS =

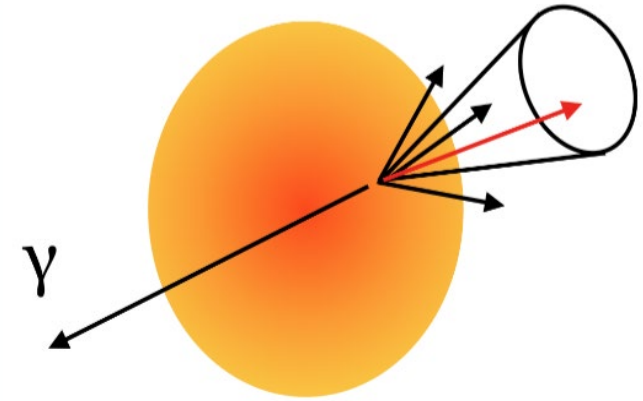


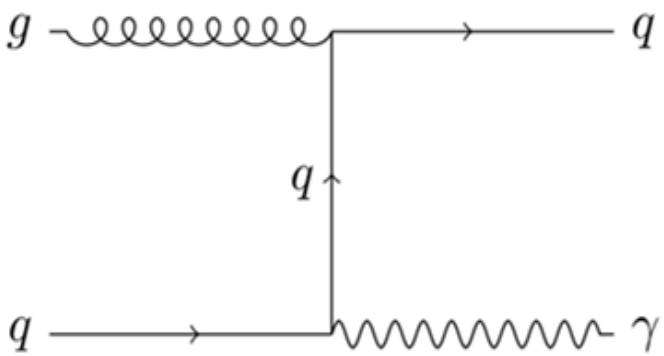
Proton-lead collisions at the LHC
→ a gateway towards EIC Physics

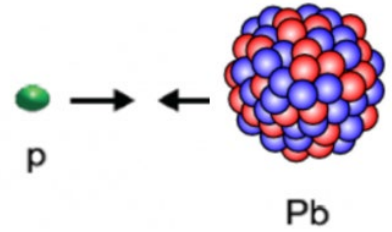


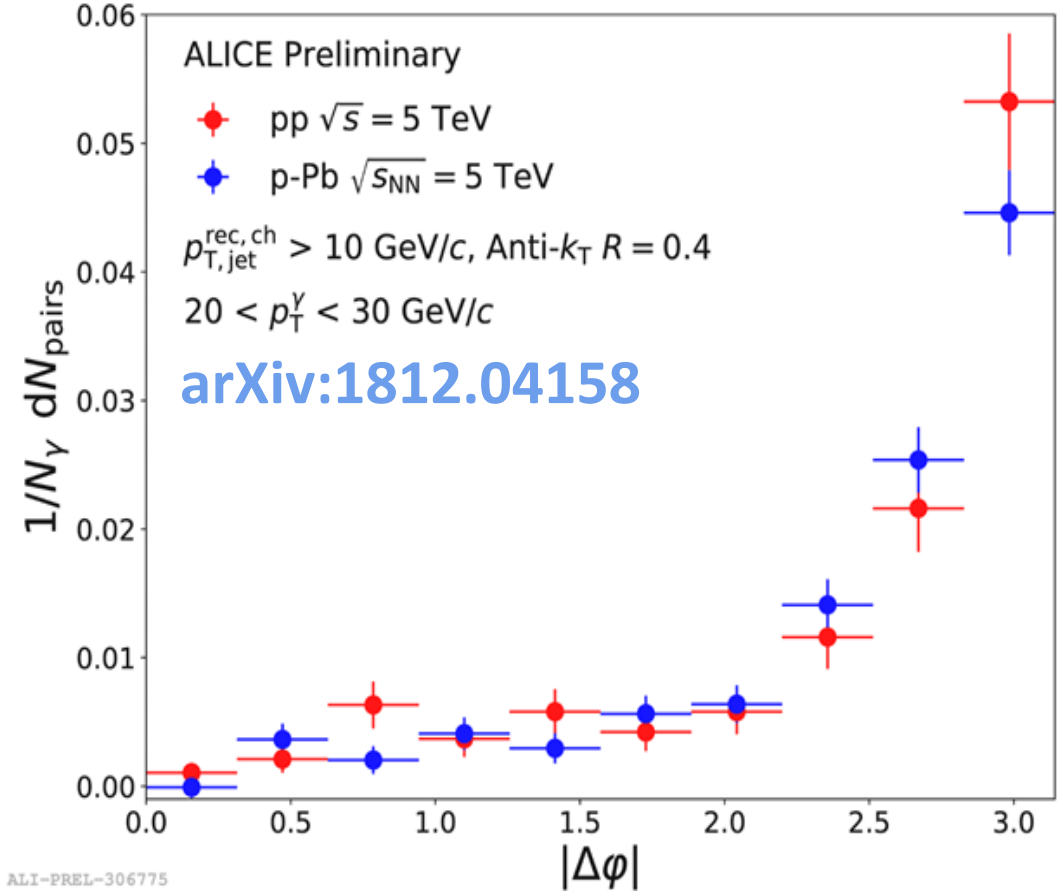
- In 2013, the LHC delivered them at a center-of-mass energy of 5 TeV
- Our “probe” is in itself complicated, and we do not control kinematics. Electron beams would be better.

Photon-jet correlations



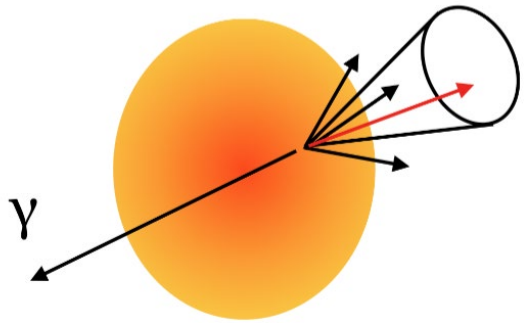




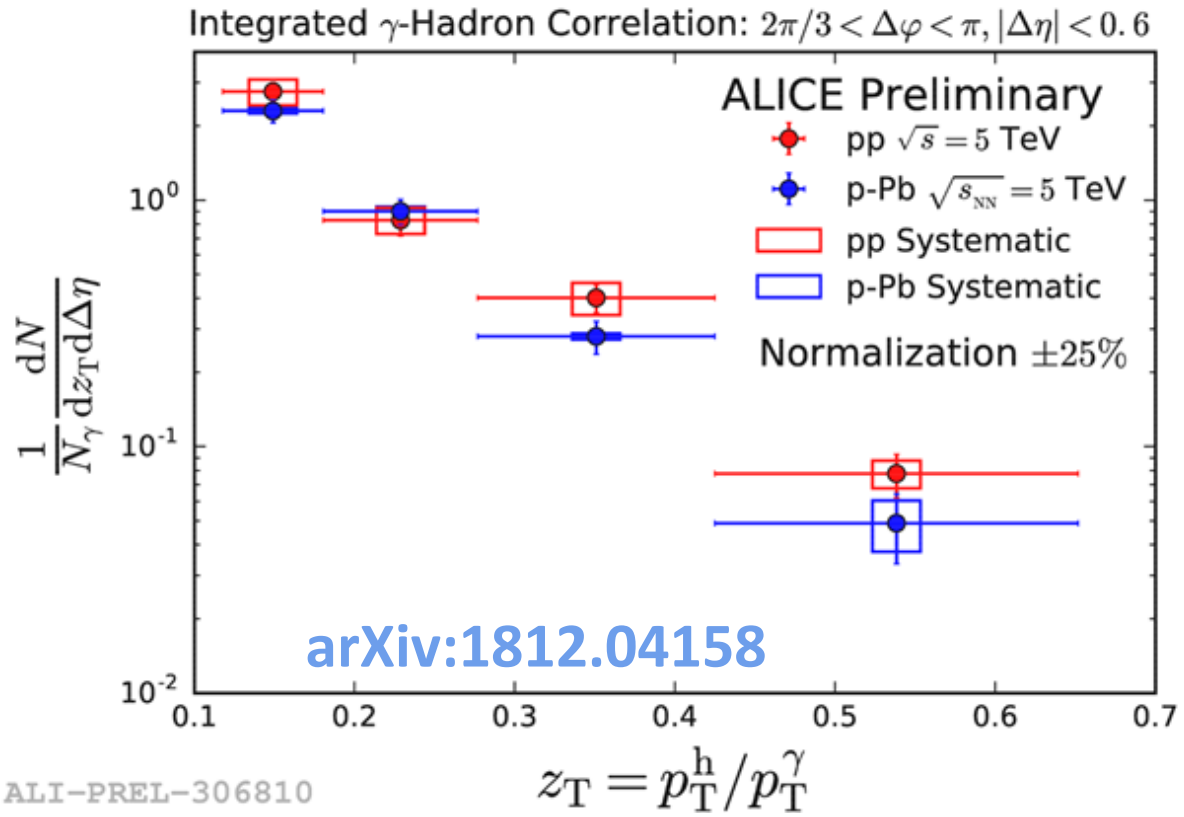


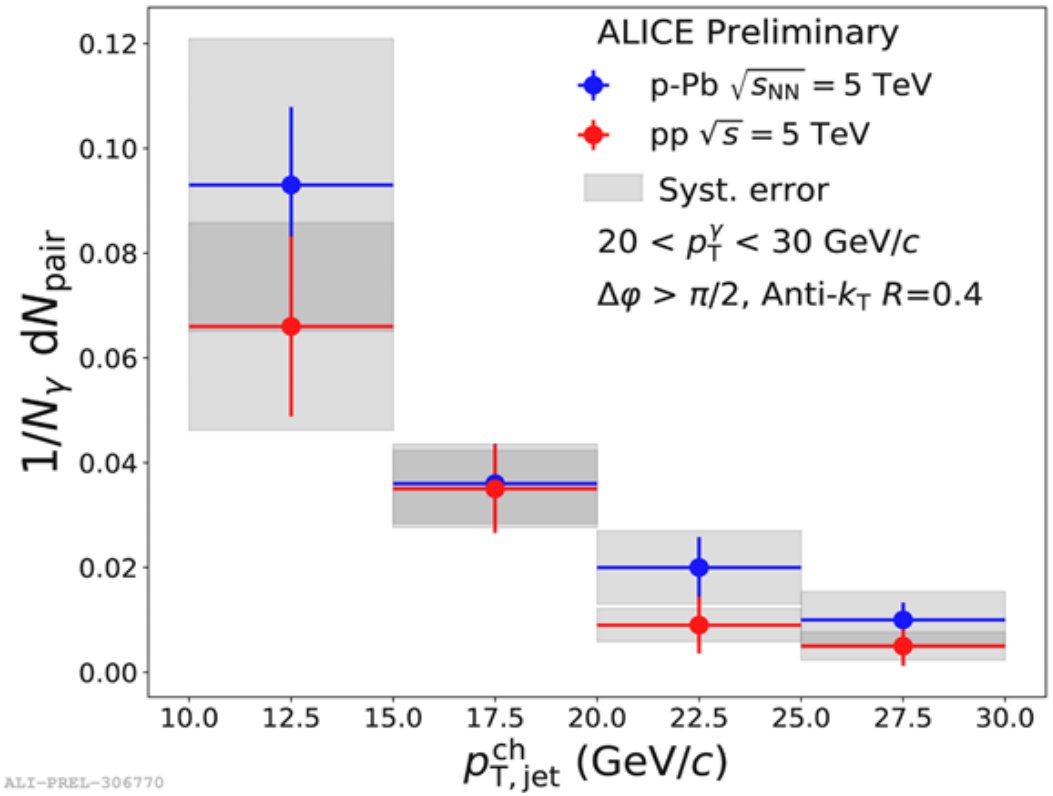
We constrain quark kinematics by measuring photon (mimicking electrons in DIS)

Hadrons spectra



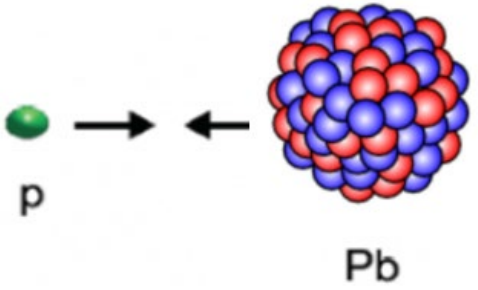
Jet spectra

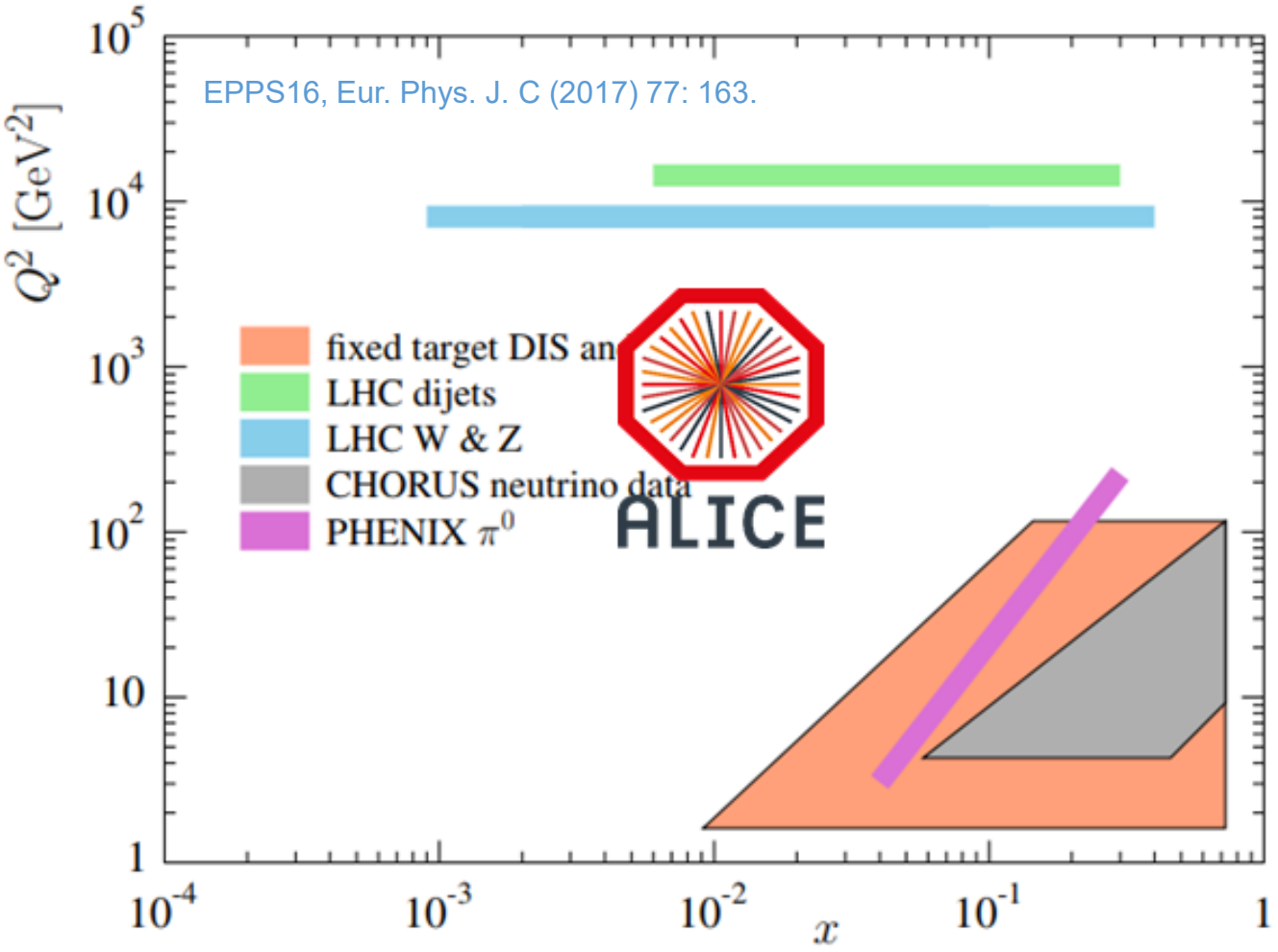




p-Pb data agree with pp collisions within errors

Photons measured with ALICE access a poorly explored region

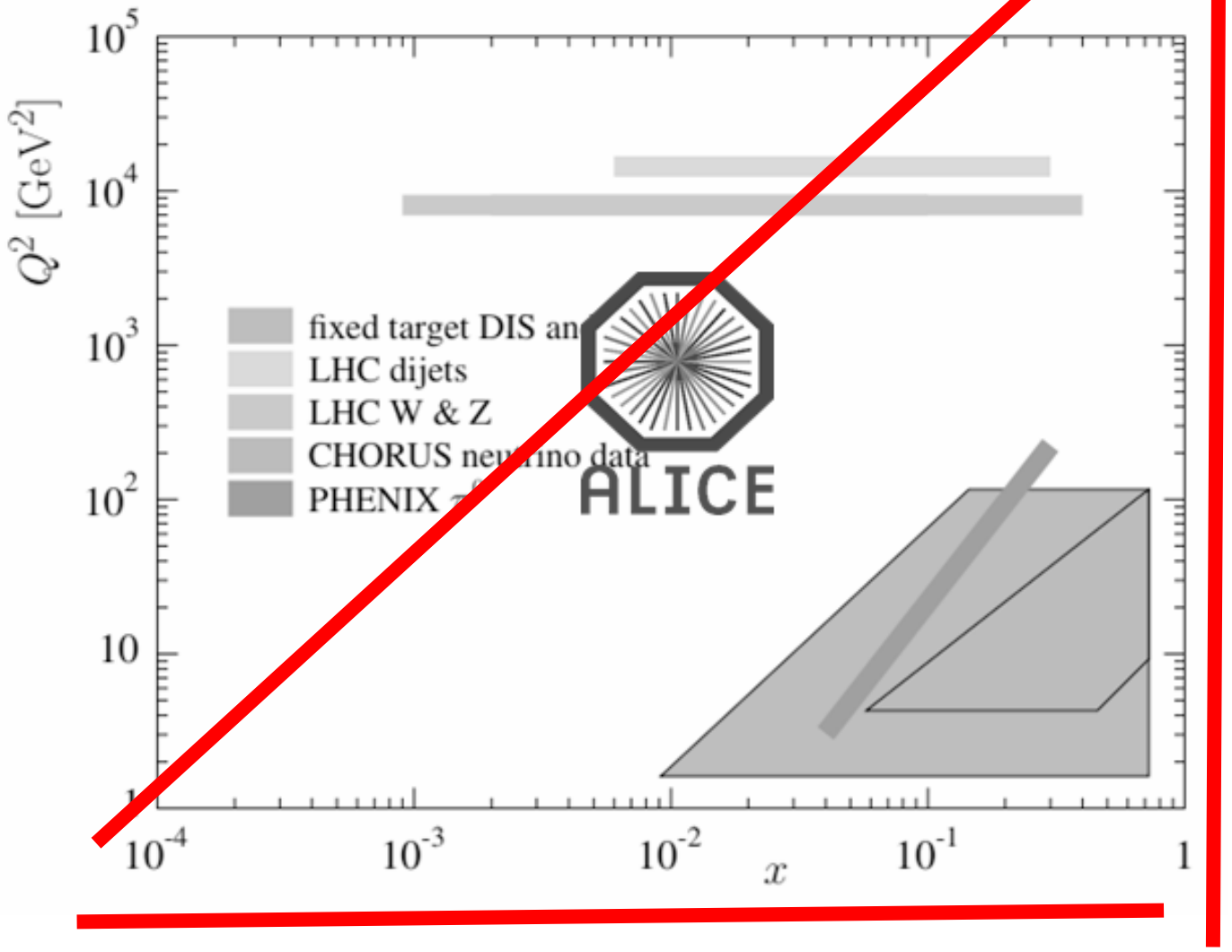




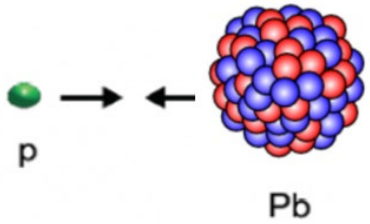
$$x \sim \frac{2p_T}{\sqrt{s}}$$

$$Q^2 \sim p_T^2$$

EIC coverage with $\sqrt{s} = 100$ GeV

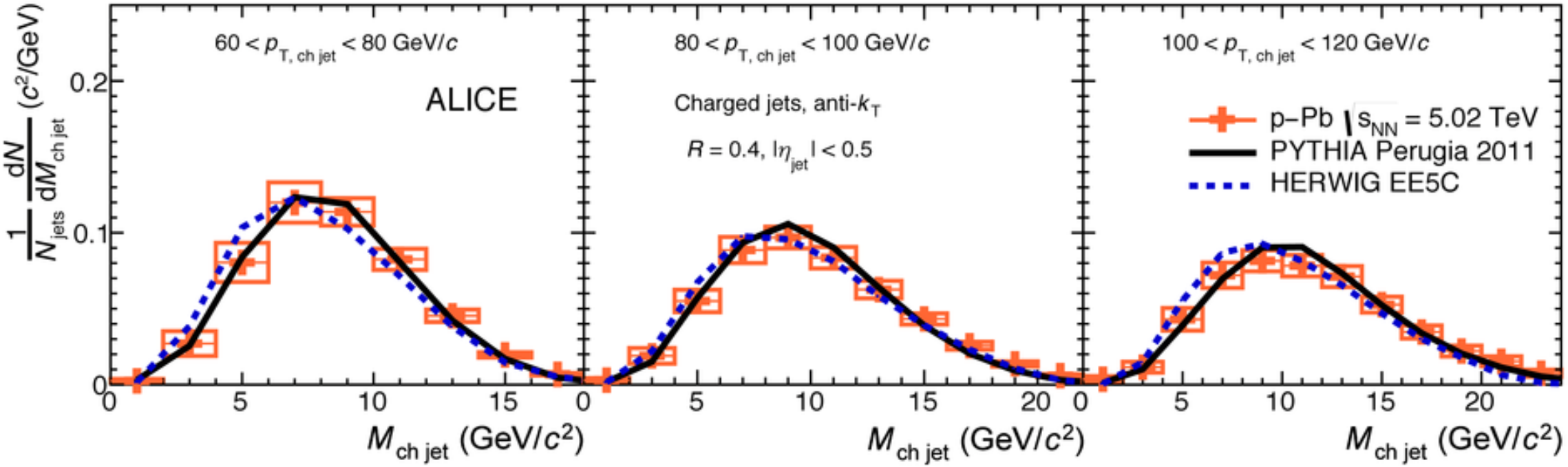


Jet mass in pA collisions



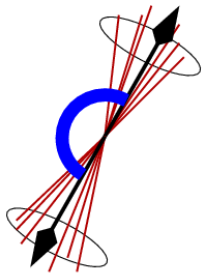
[Phys. Lett. B 776 (2018) 249](#) **(first measurement)**

$$M_{Jet} = \sqrt{E_{Jet}^2 - p_{Jet}^2} \propto Virtuality$$

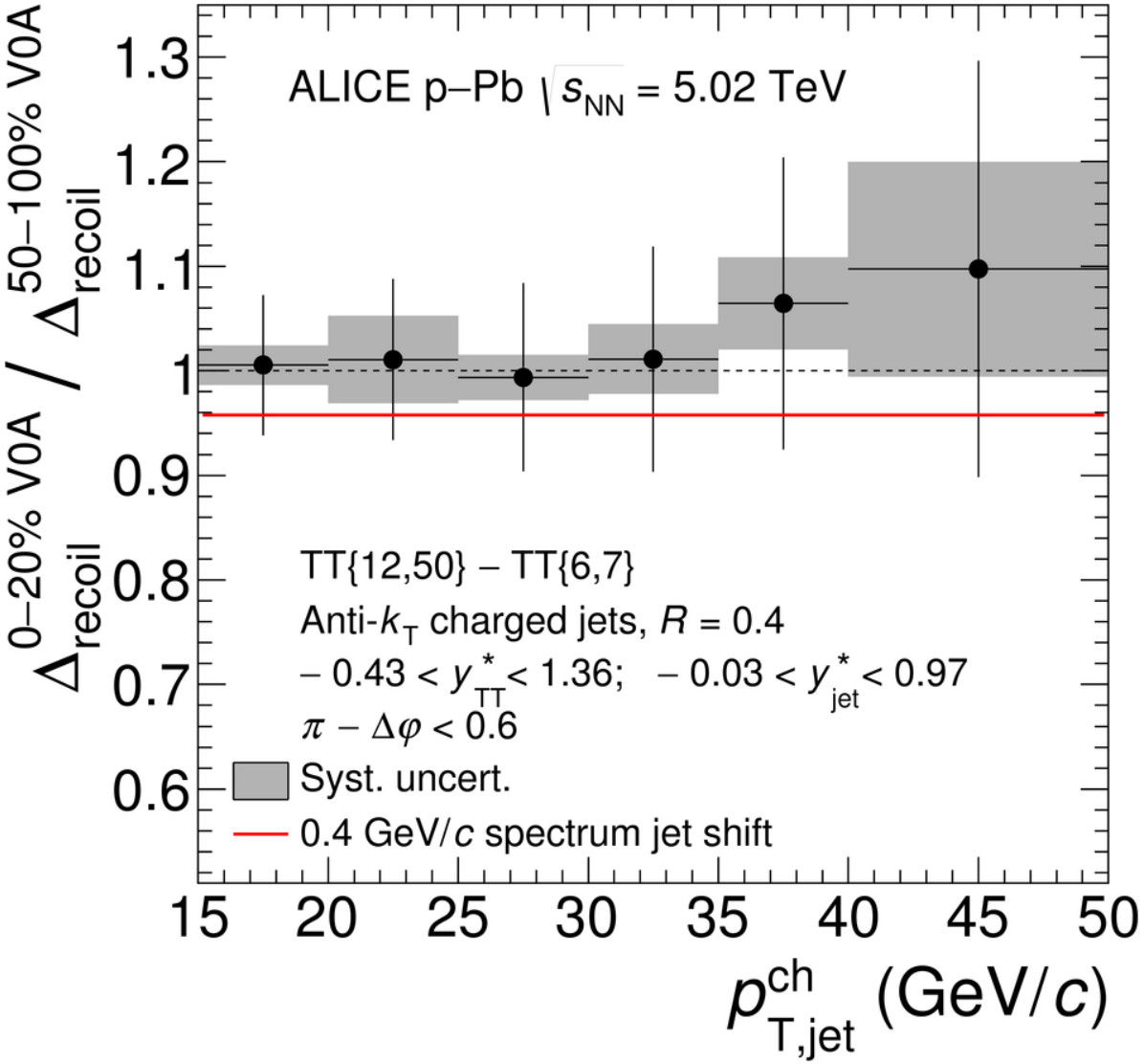


No strong modifications observed with respect to reference (PYTHIA)

Constraints on jet quenching in p-Pb collisions

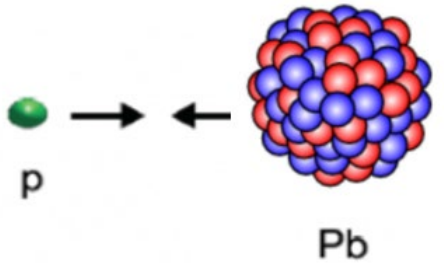


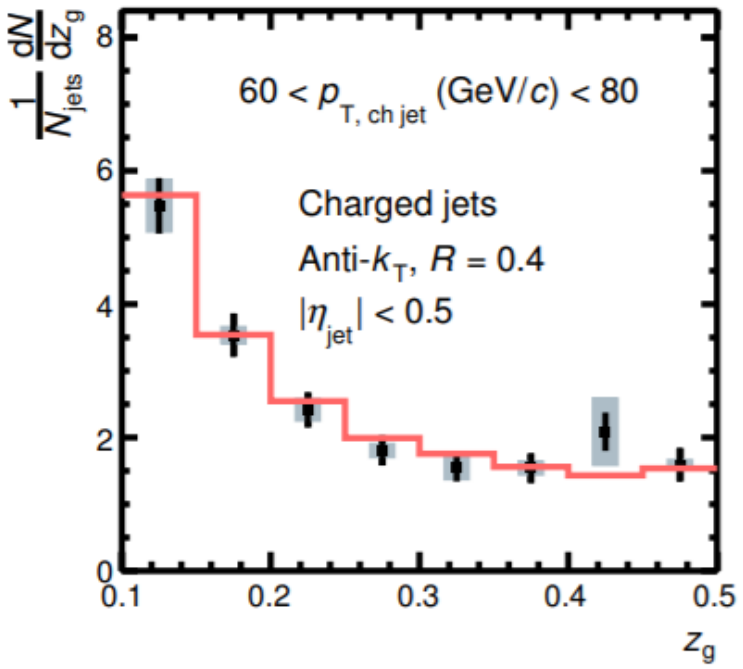
Phys. Lett. B 783 (2018) 95

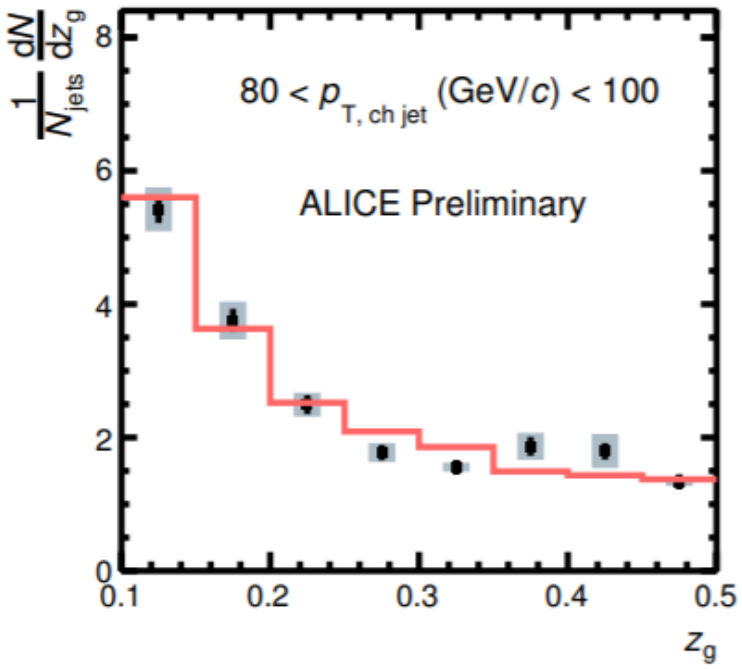


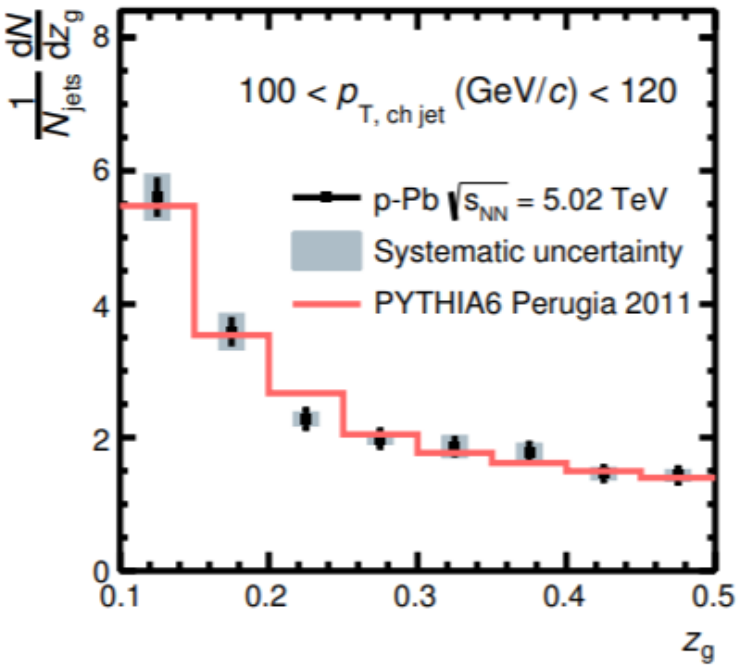
- Coincidence hadron—jet measurements in p-Pb collisions are used to constrain possible energy loss in p-Pb collisions.
- ΔE < 400 MeV at 90% CL

Shared-momentum fraction in p-A collisions







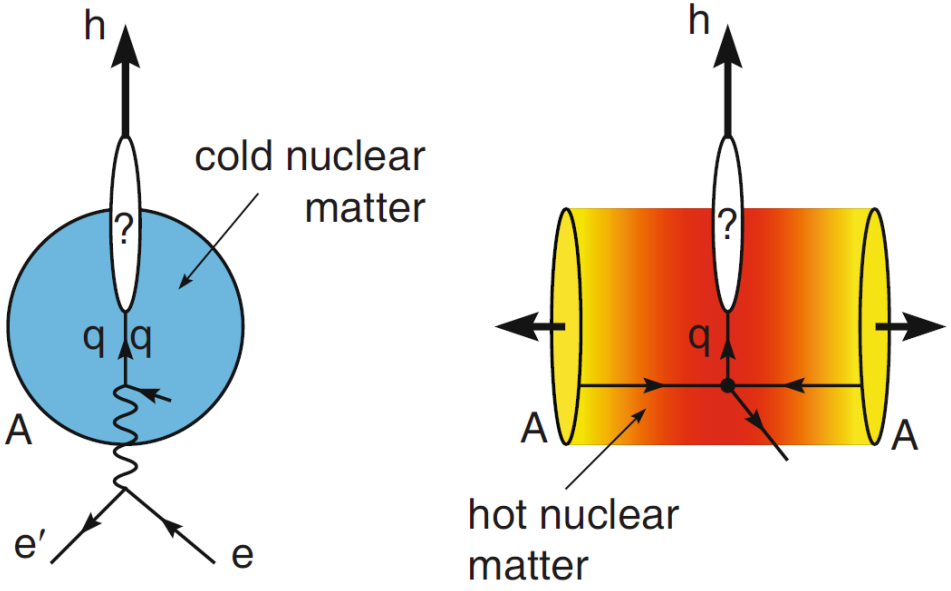


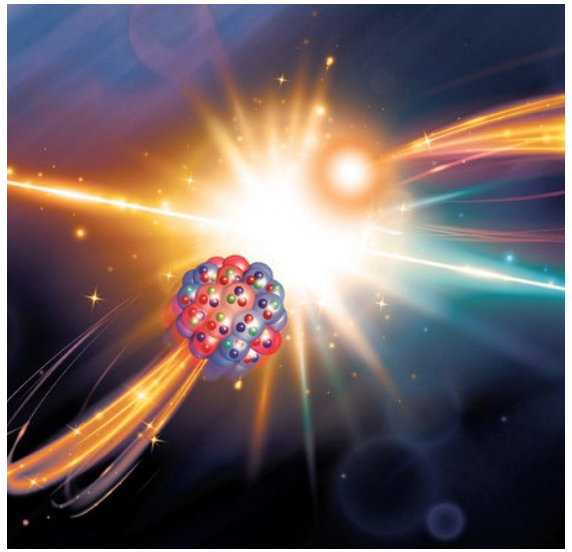
ALI-PREL-120123

- No strong modifications observed with respect to reference (PYTHIA)

Summary

- Jets can be used to probe the Quark-Gluon Plasma. Exciting new tools are jet substructure (coming from HEP)
- No strong modification of jet production in p-A collisions within our precision.
- QCD matter physics bridges JLAB and RHIC/LHC communities.
- The physics of QCD matter can be studied precisely and in controlled way at the EIC. 20+ years of theory and all LHC jet physics developments





Backup