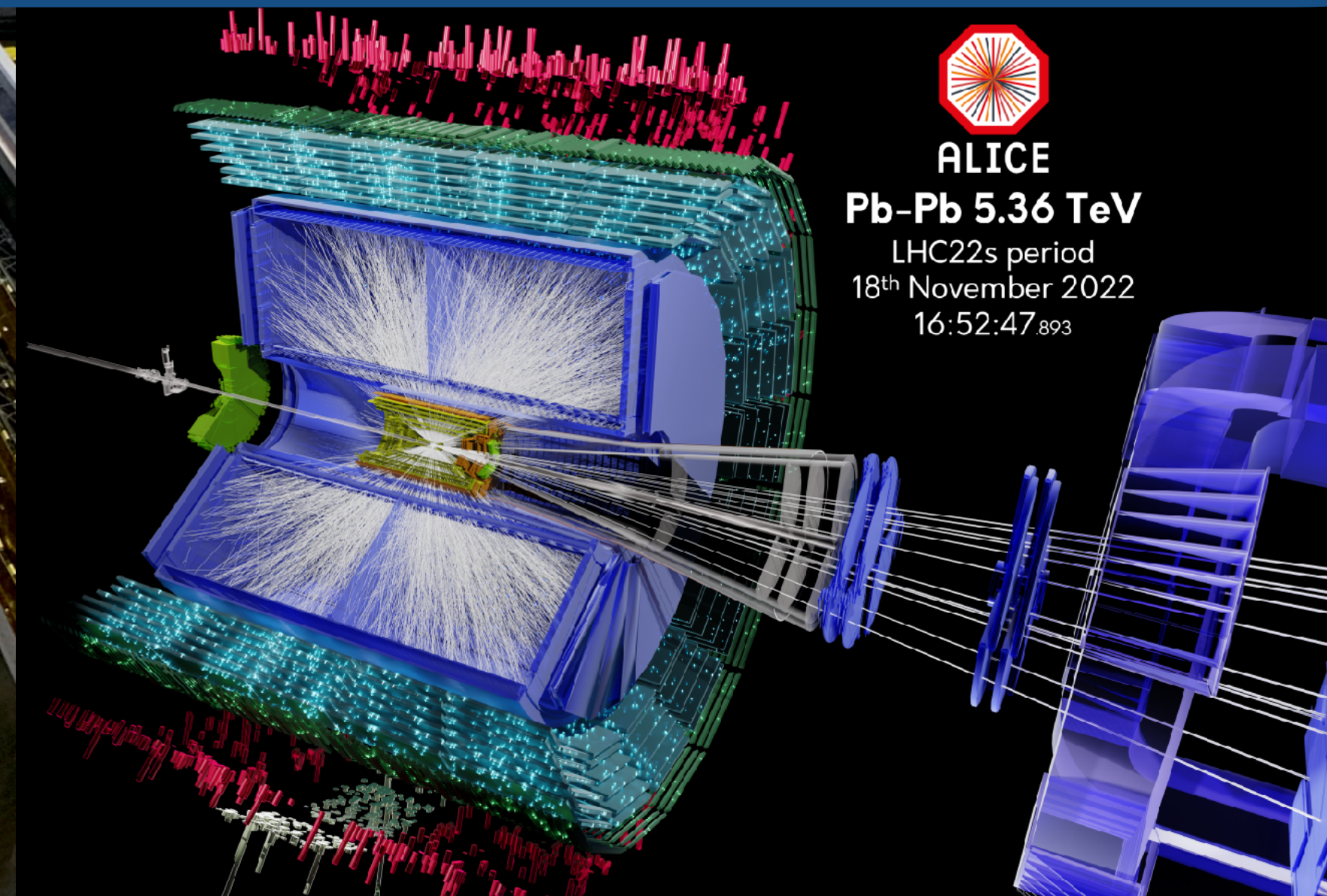
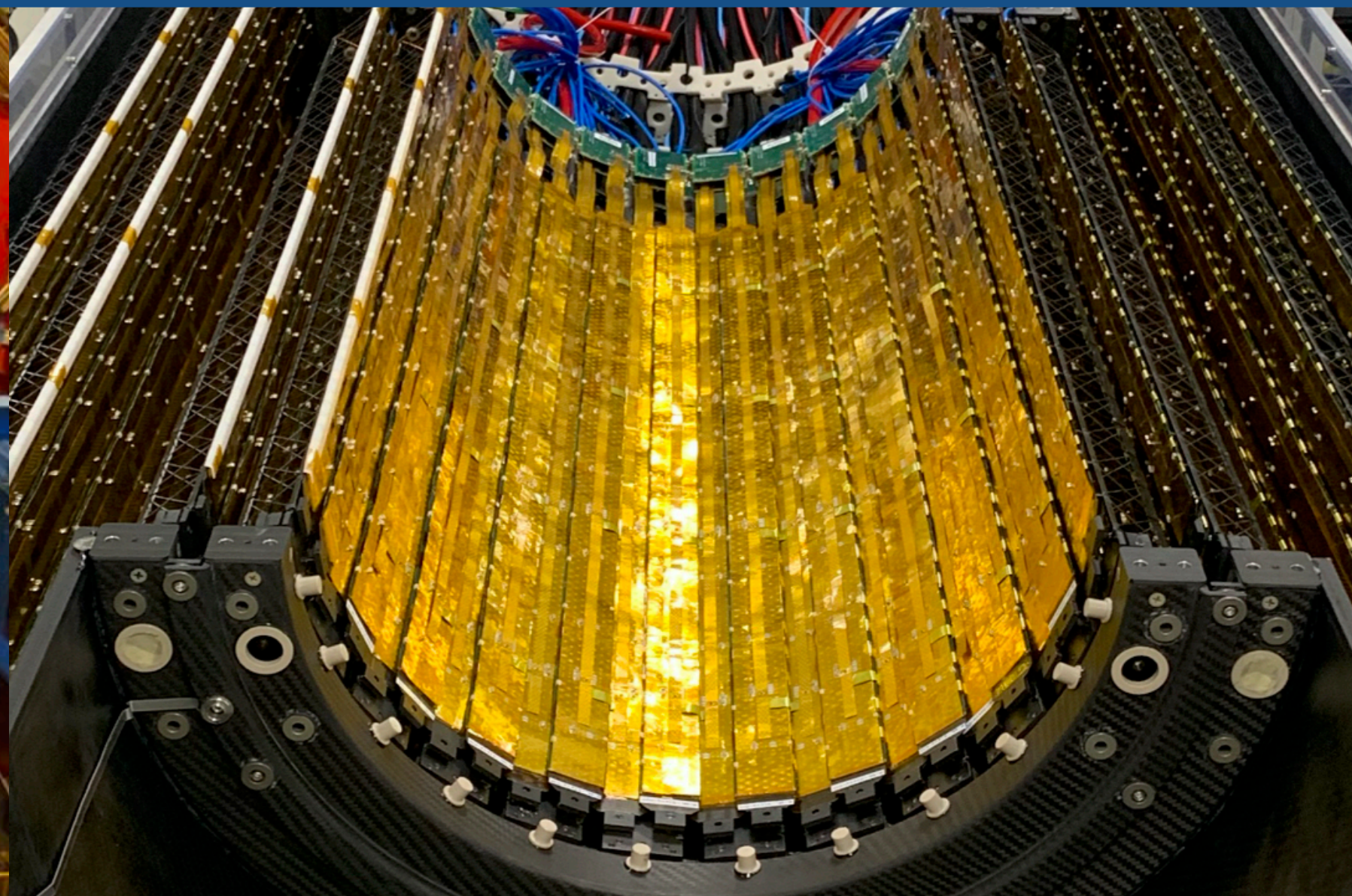
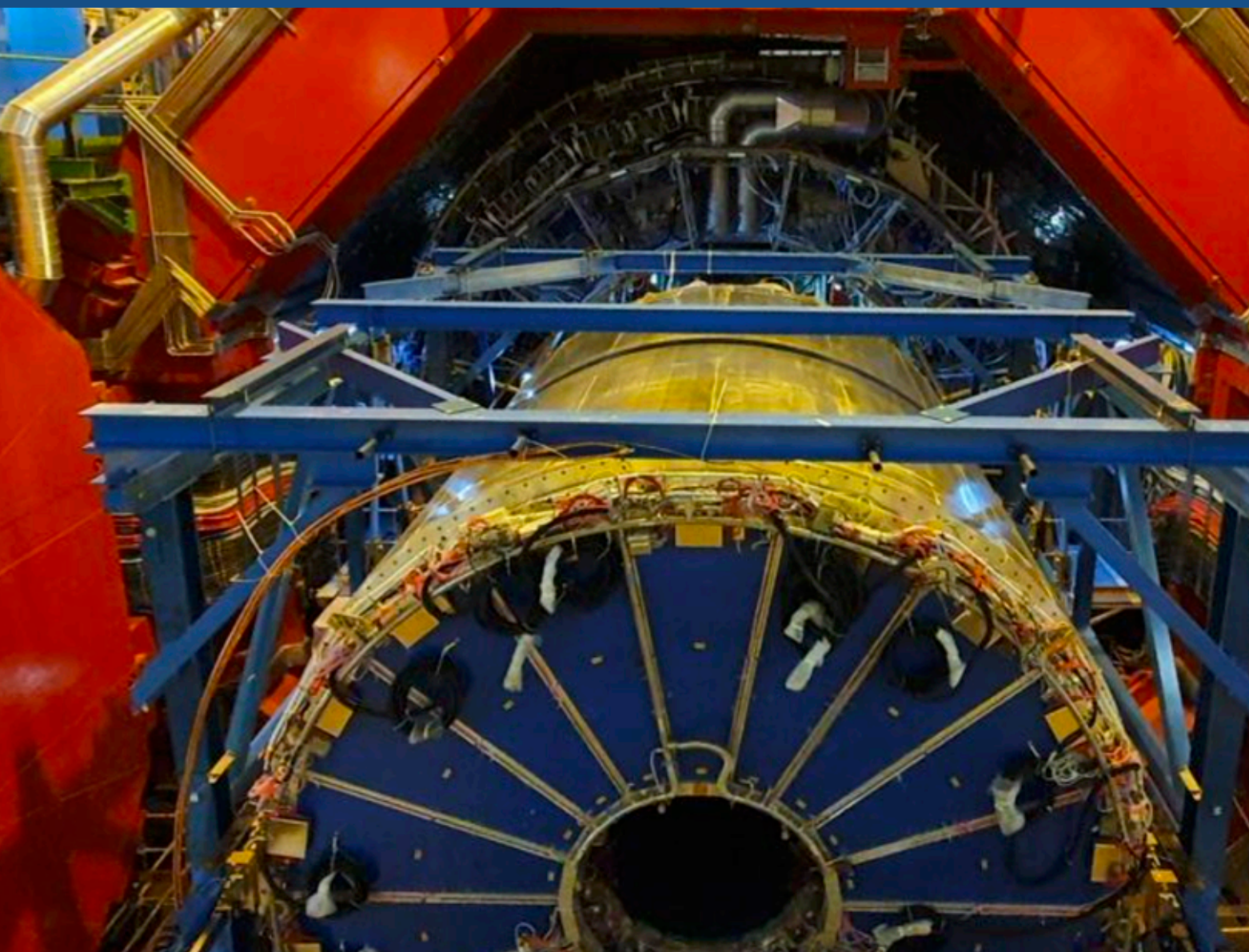


ALICE Highlights

James Mulligan, Lawrence Berkeley National Laboratory
for the ALICE Collaboration



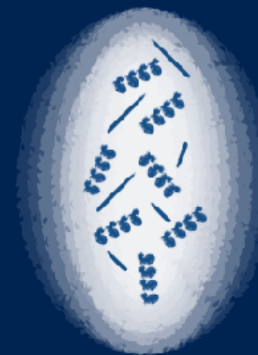
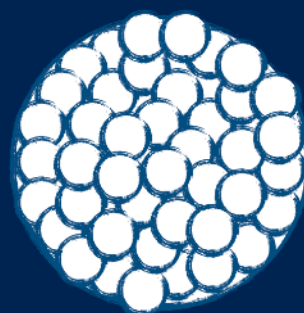
ALICE
Pb-Pb 5.36 TeV
LHC22s period
18th November 2022
16:52:47₈₉₃



11th International Conference on Hard and
Electromagnetic Probes of High-Energy Nuclear Collisions
March 27, 2023



QCD in vacuum



Properties of
nuclei

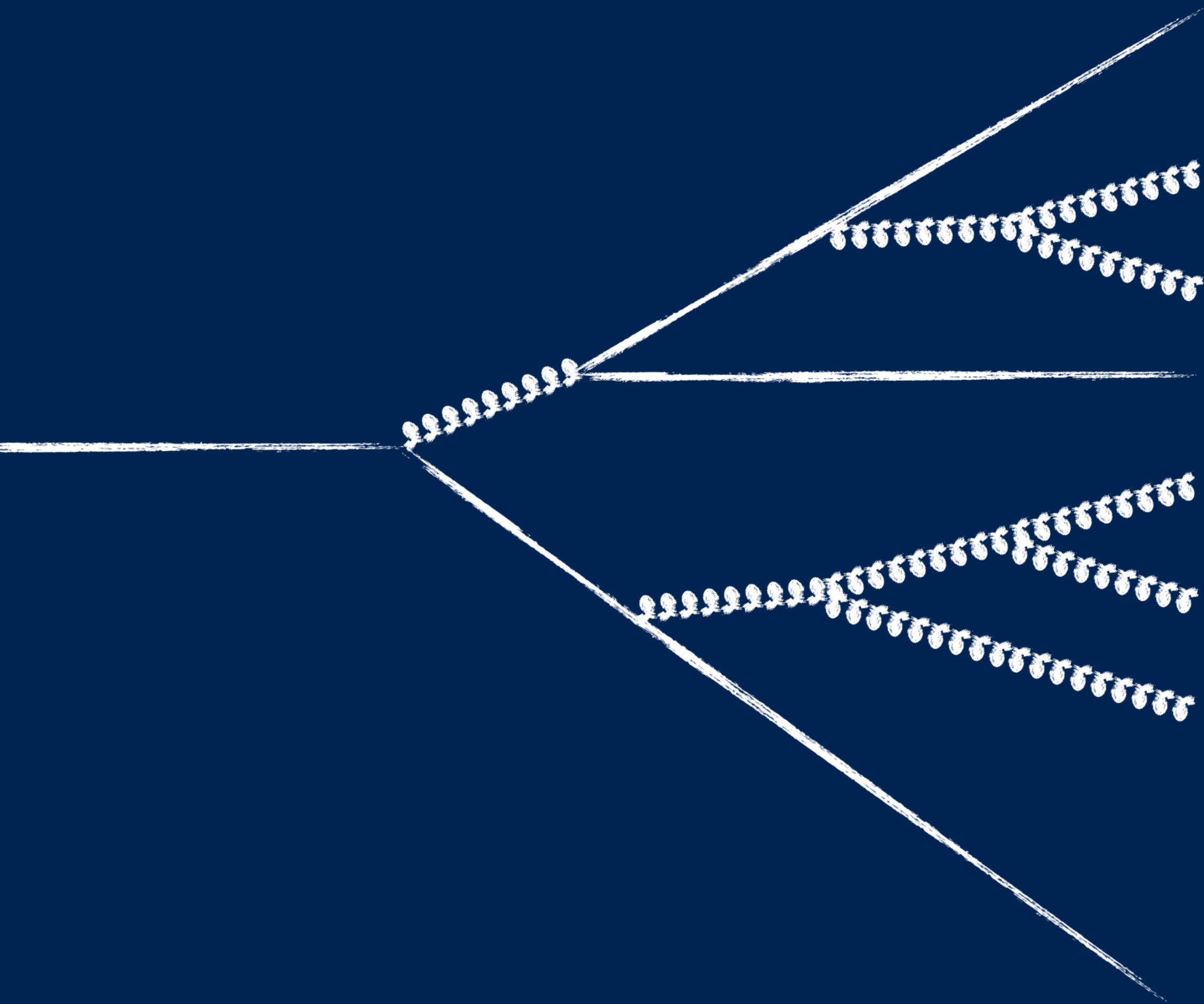
Properties of
QGP

QCD in vacuum

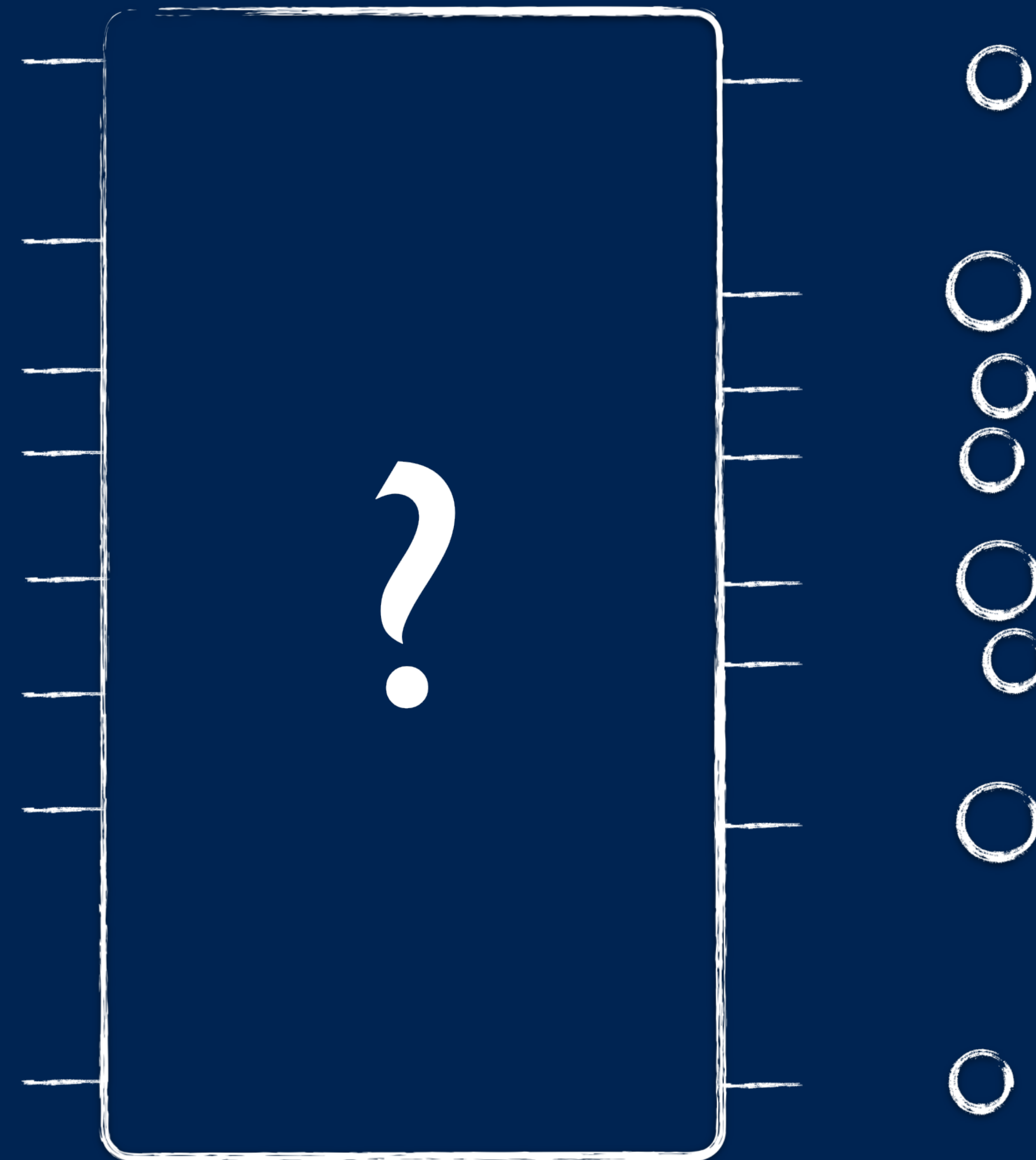


Properties of
nuclei

Properties of
QGP



— Perturbative QCD —



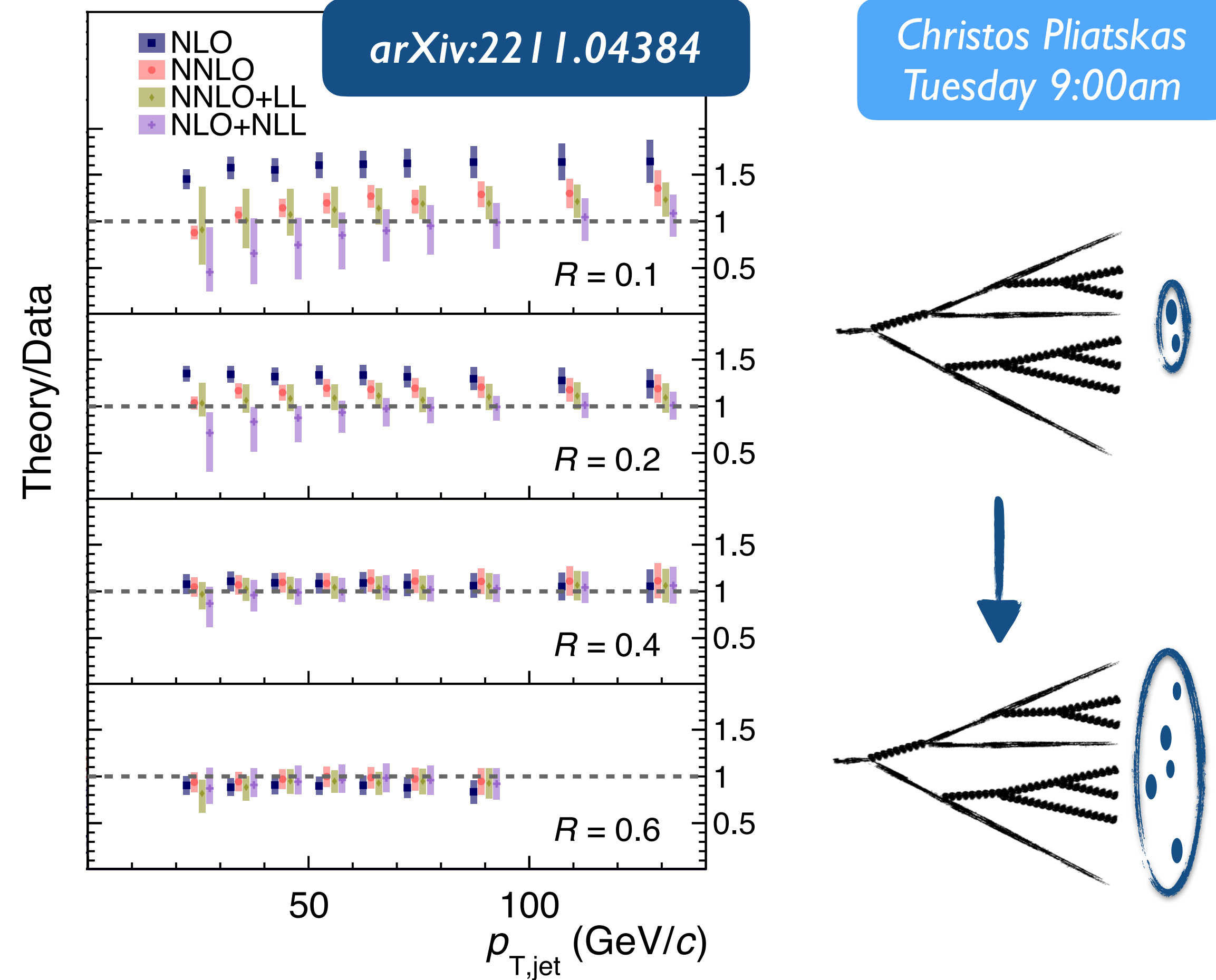
— Hadronization —

How much of the fragmentation process is perturbatively calculable?

Can experiment guide our understanding of the hadronization process?

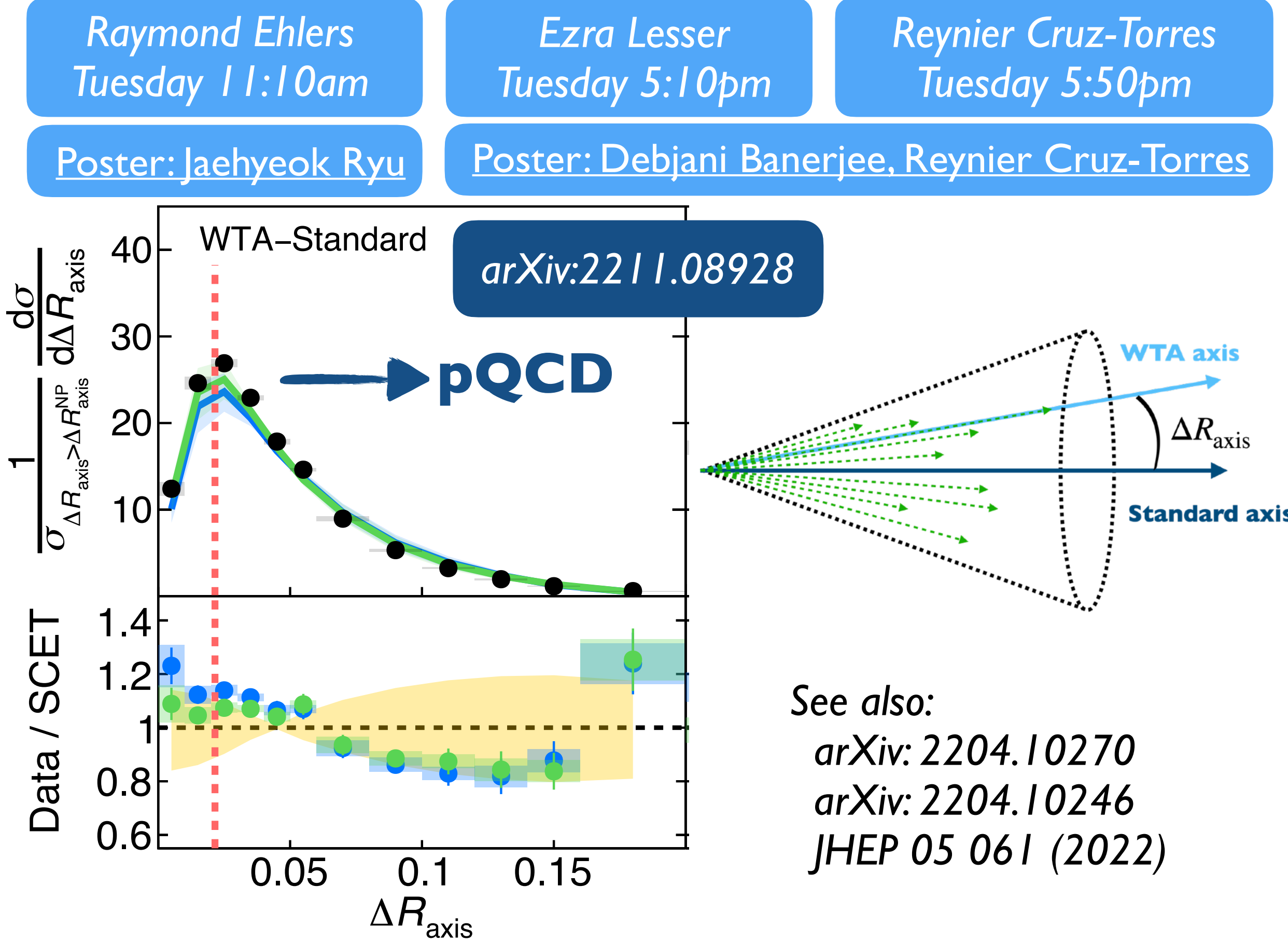
From partons to hadrons

Jet production

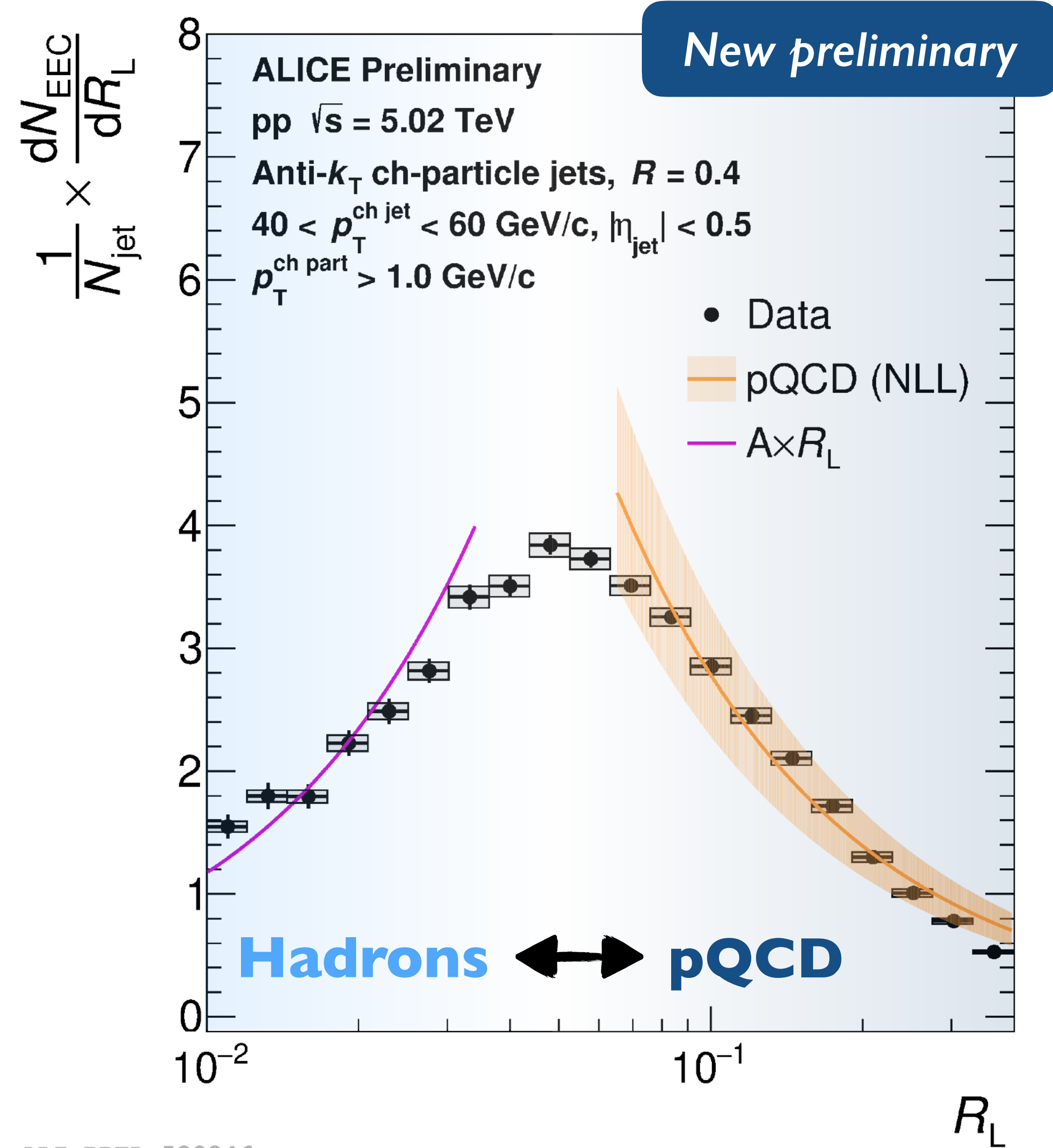


Direct connection of hadrons to pQCD

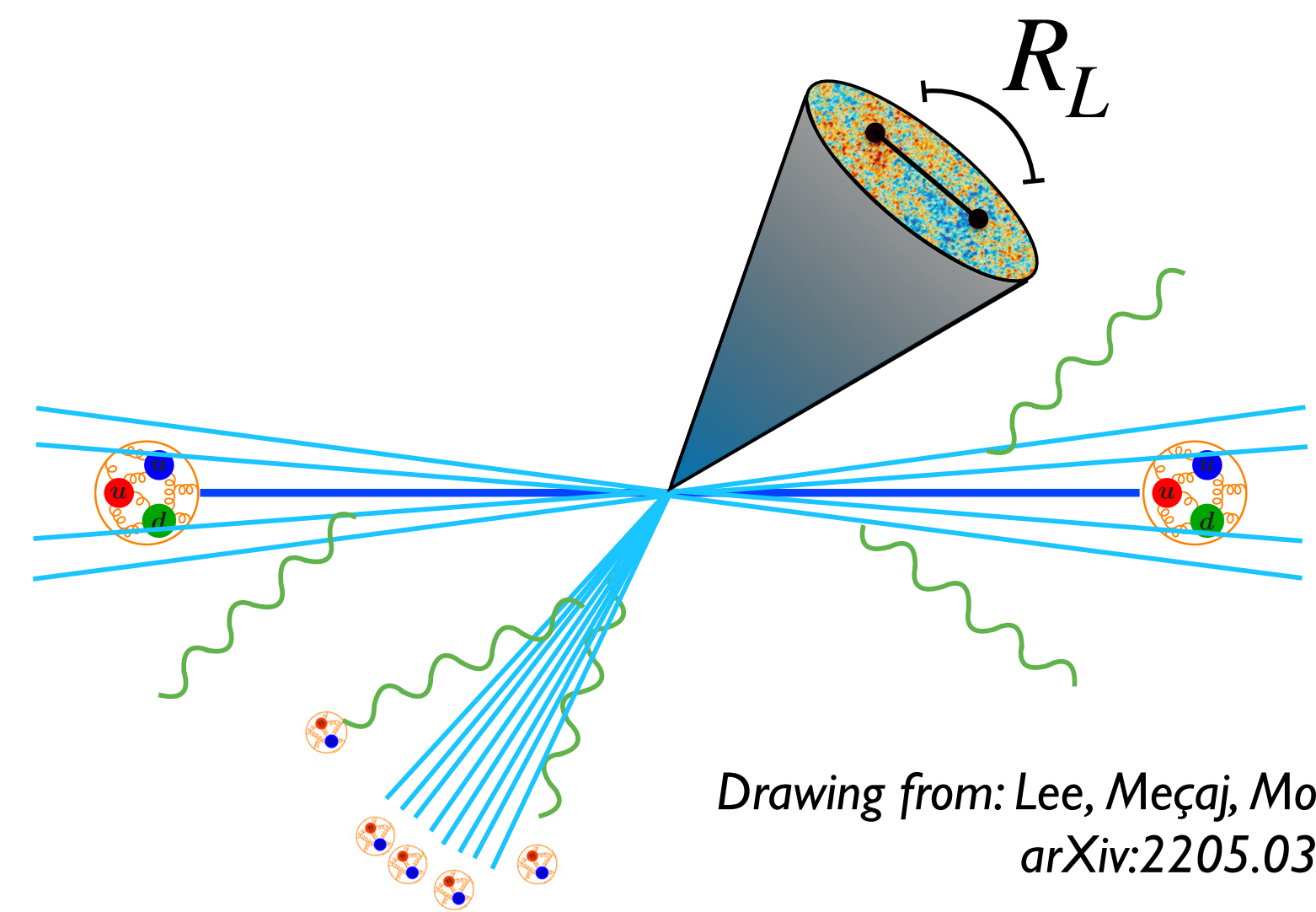
Jet substructure



Mapping the transition from perturbative to non-perturbative QCD



A new type of jet observable:
 N -point angular correlation

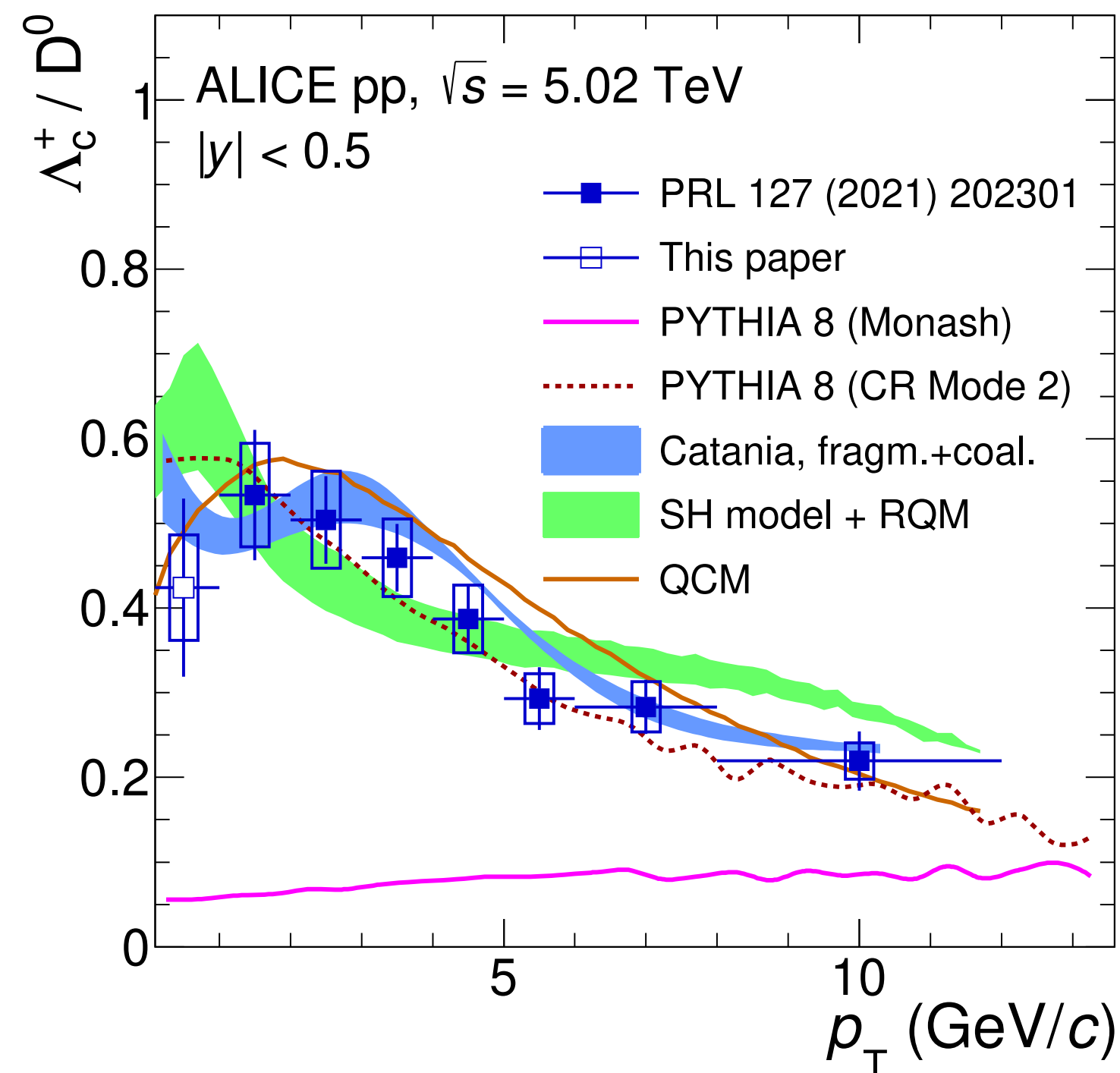


Direct sensitivity to QCD scales
→ Clear separation of perturbative emissions and hadronization

Heavy flavor hadronization

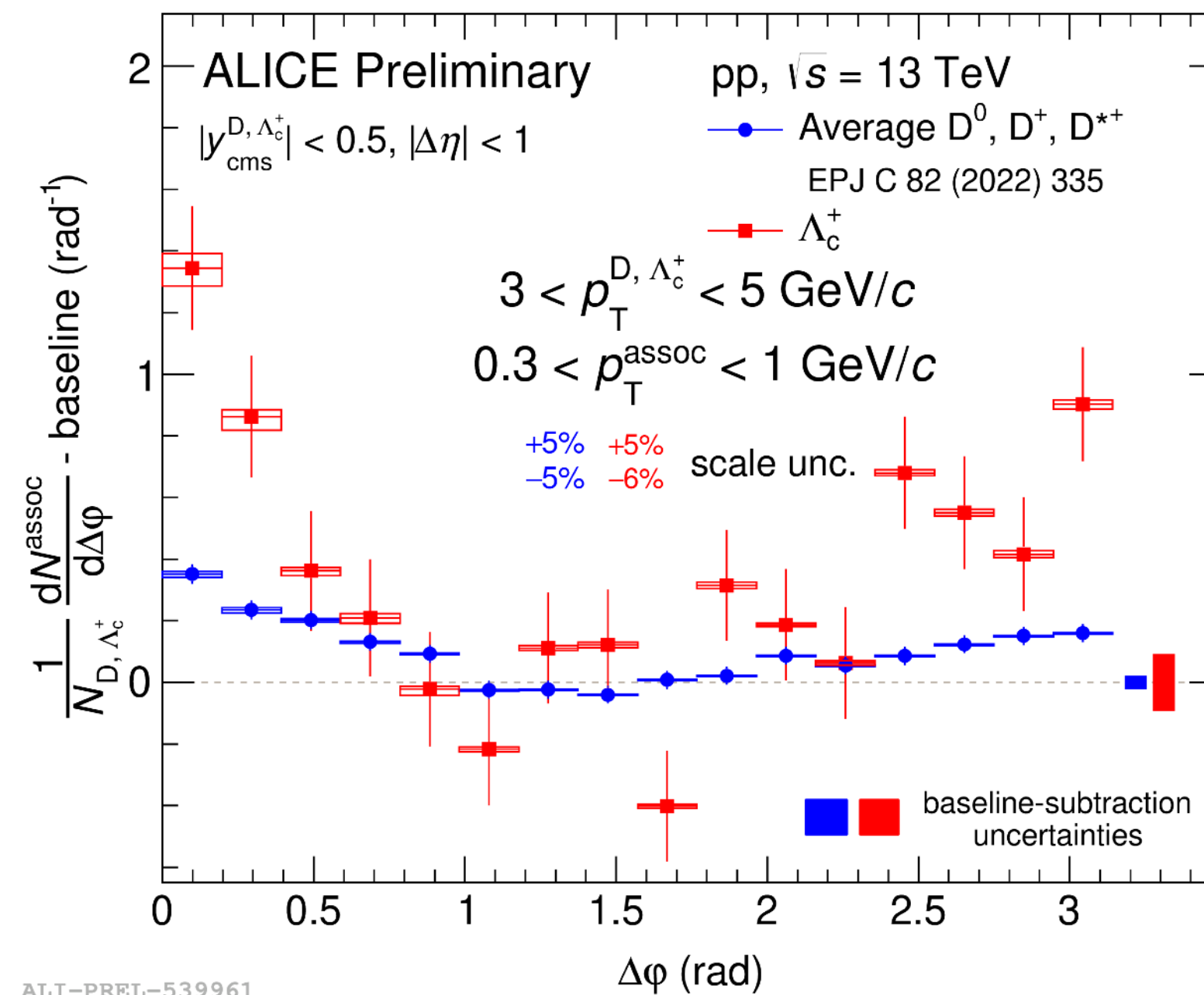
Prompt Λ_c^+ / D^0

arXiv:2211.14032



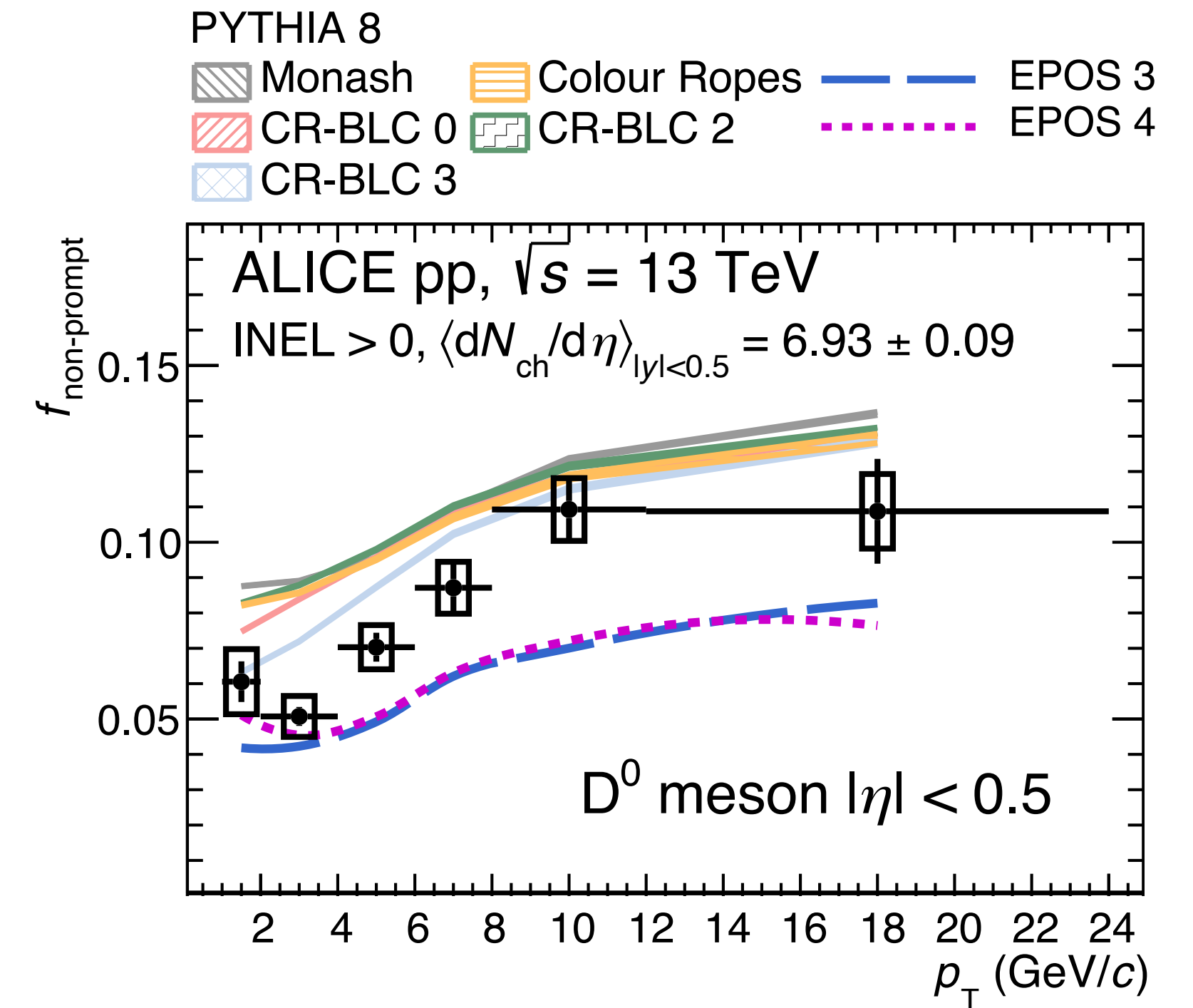
Λ_c^+, D^0 -hadron correlations

New preliminary



Non-prompt / prompt D^0

arXiv:2302.07783



Charm baryon-meson ratios partially explained by models with modified hadronization mechanisms

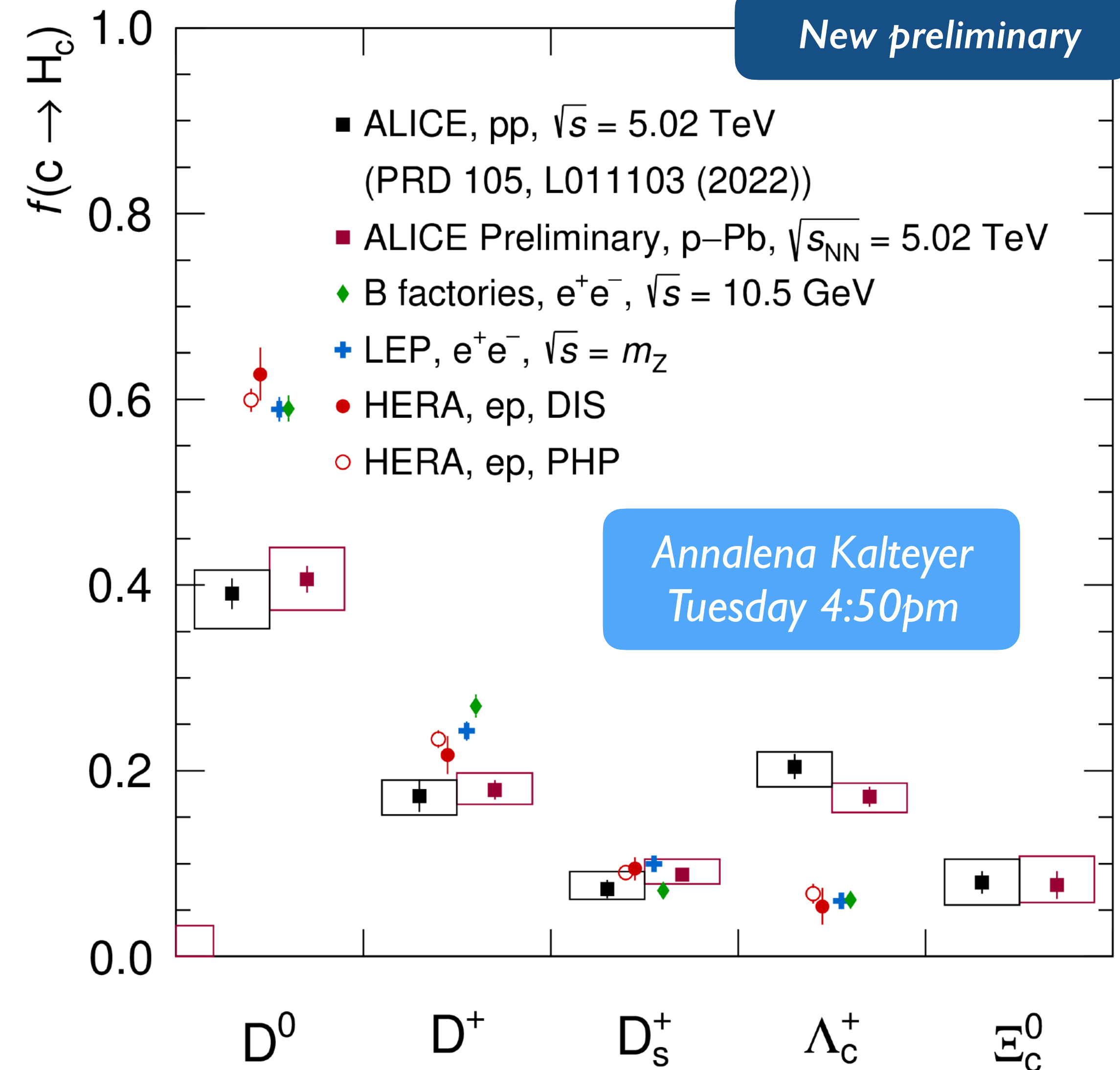
What have we learned about charm hadronization?

- (1) Charm fragmentation fractions differ in pp vs. e^+e^-
- (2) Models that modify hadronization can partially explain data

Exploring the limits of QCD factorization

Additional insight from:

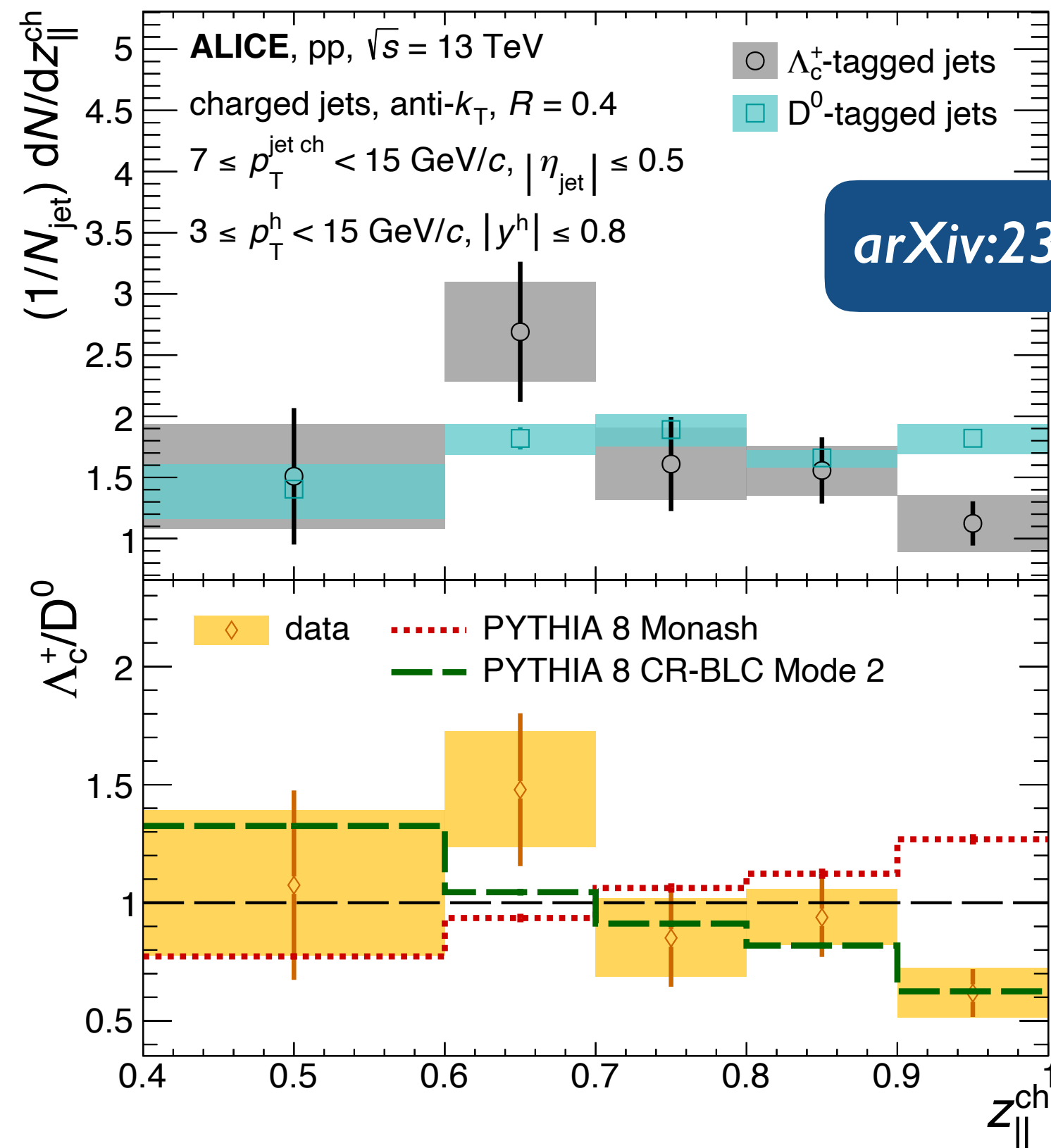
- Charm vs. beauty
- Multi-HF hadrons
- Charm hadrons in jets



ALI-PREL-539822

Charm fragmentation in jets

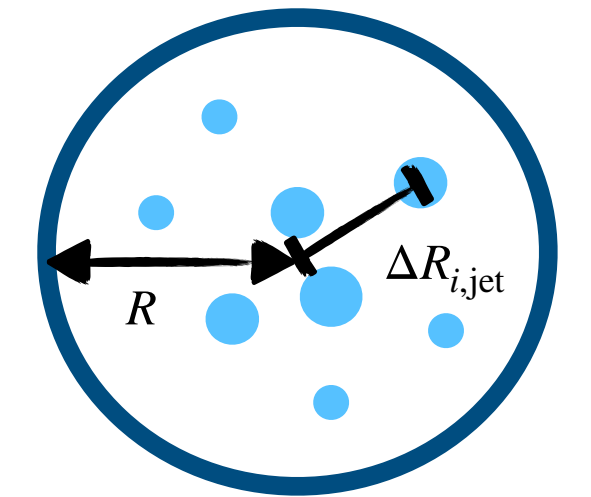
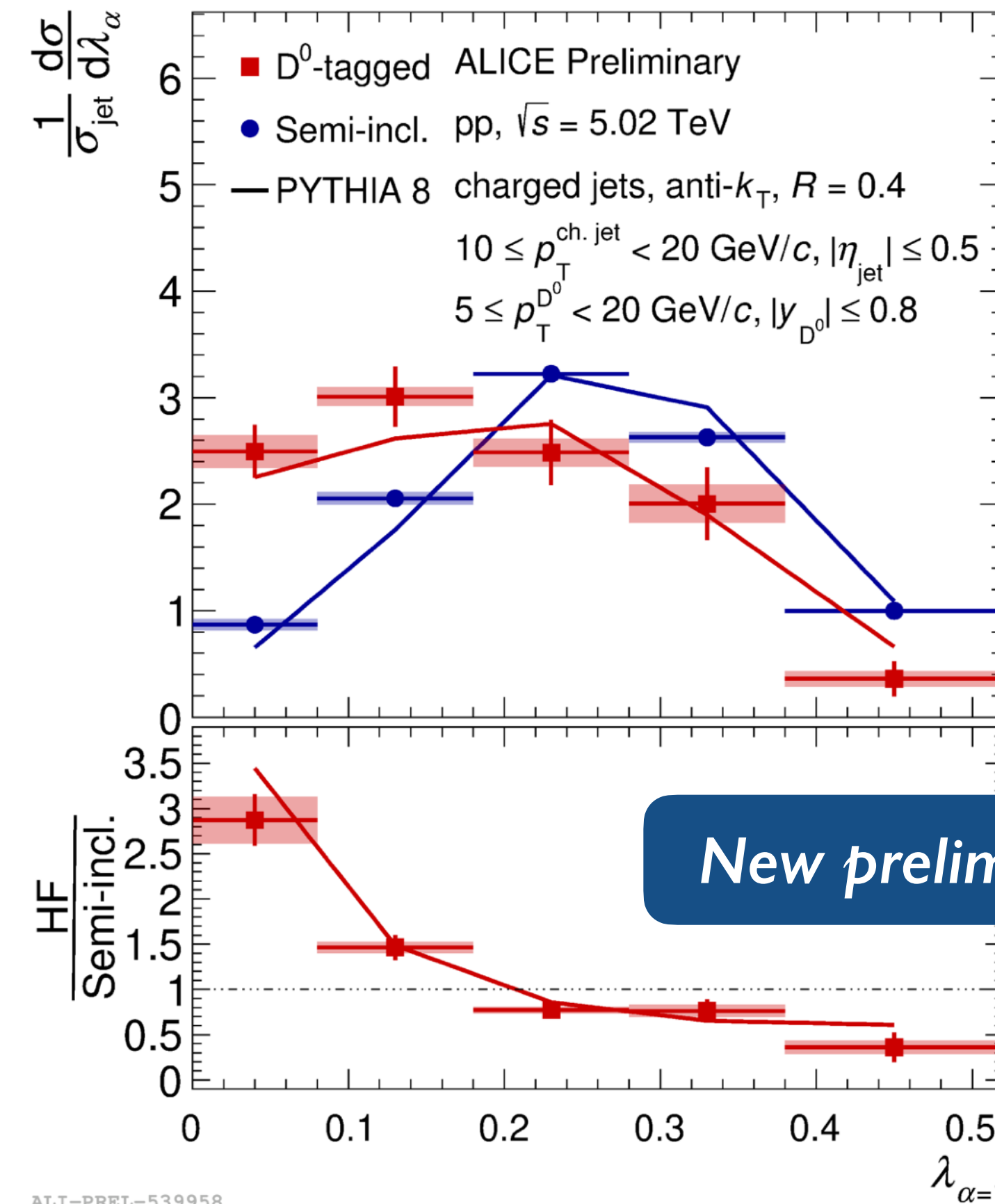
Λ_c^+ vs. D^0 fragmentation $z_{||}^{ch} = \frac{p_{jet} \cdot p_{\Lambda_c^+}}{p_{jet} \cdot p_{jet}}$



arXiv:2301.13798

Softer fragmentation of Λ_c^+

D^0 -jet angularities



$$\lambda_\alpha = \sum_i z_i \theta_i^\alpha$$

New preliminary

ALI-PREL-539958

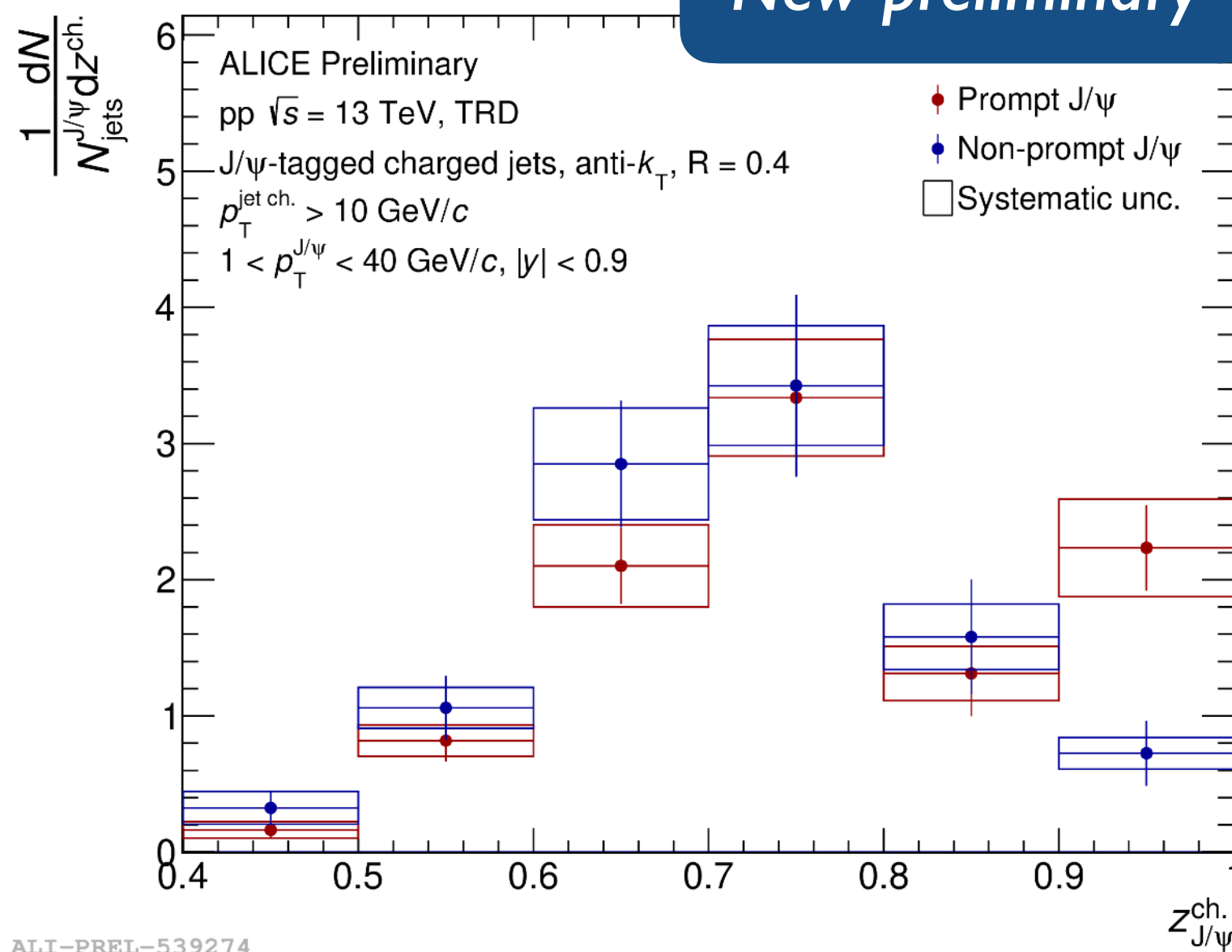
New constraints: mass effects vs. q/g

Identified particles in jets

J/ψ

Ailec de la Caridad Bell Hechavarria
Wednesday 11:30am

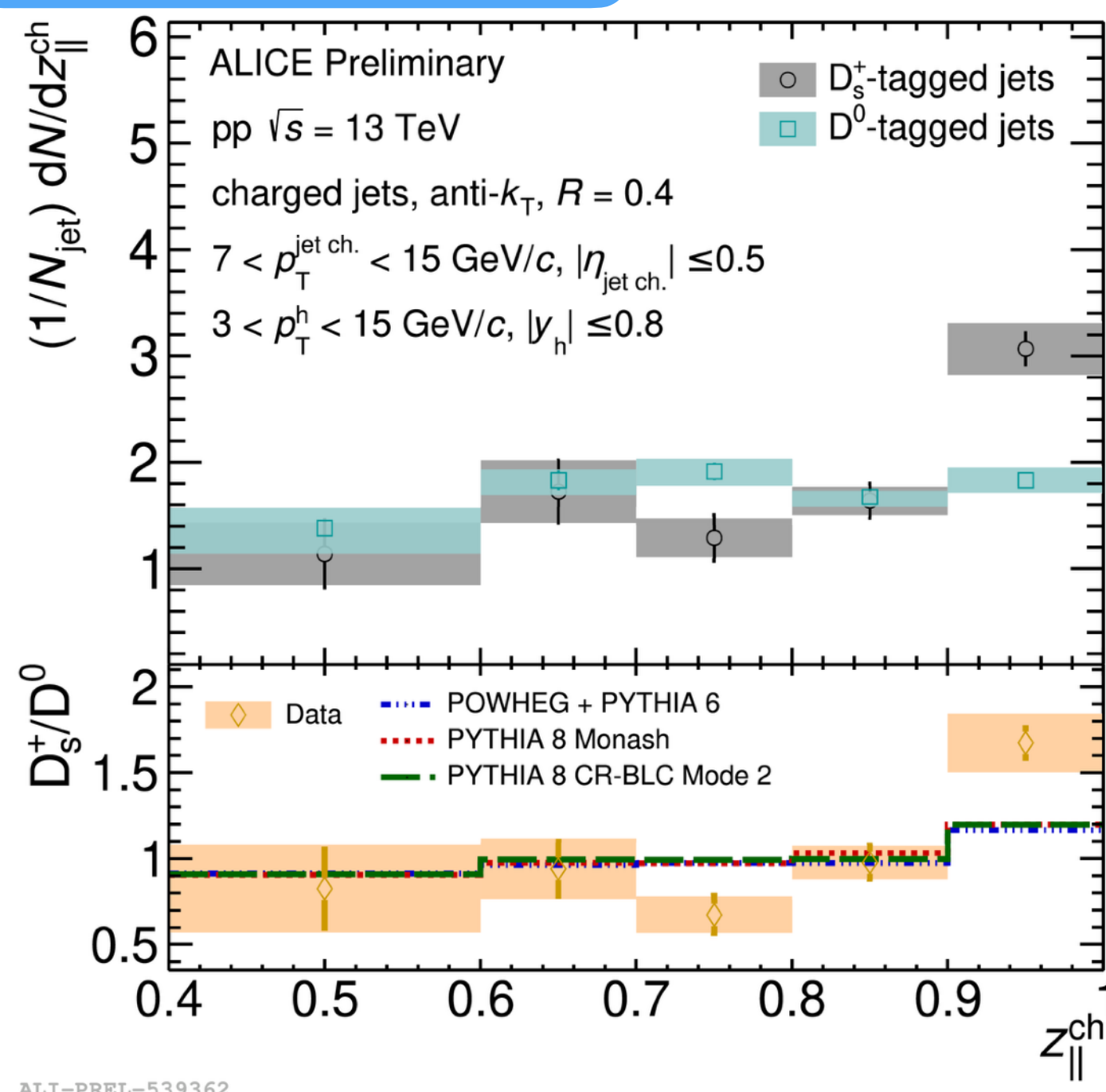
New preliminary



D_s^+

Antonio Palasciano
Wednesday 2:40pm

New preliminary

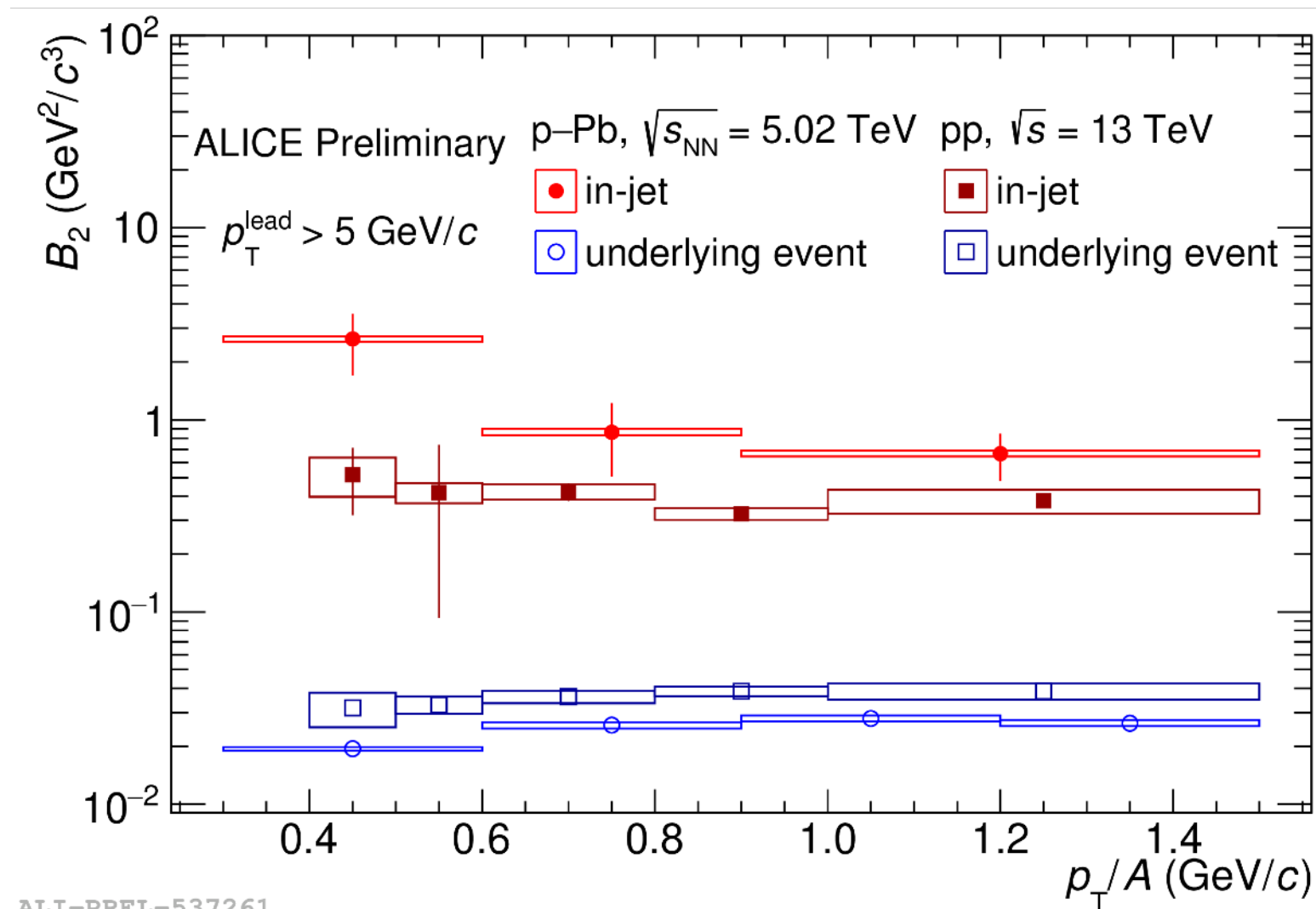


Deuterons

Marika Rasà
Tuesday 5:10pm

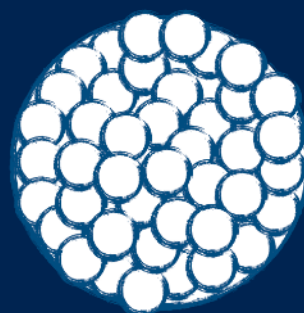
arXiv:2211.15204

New preliminary



Wealth of new experimental constraints on hadronization models

QCD in vacuum

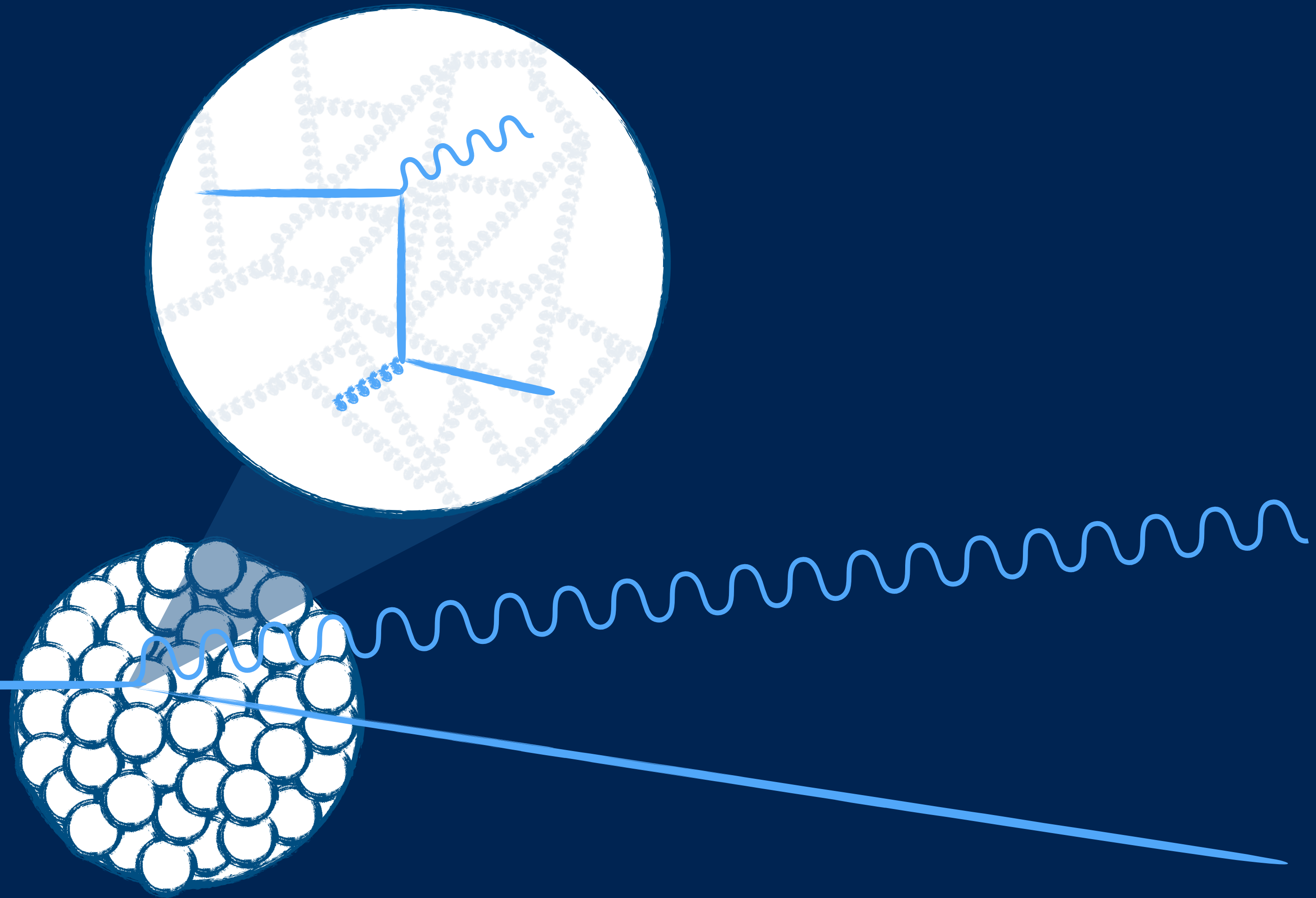


Properties of
nuclei

Properties of
QGP

Can EW probes provide new constraints on nuclear PDFs?

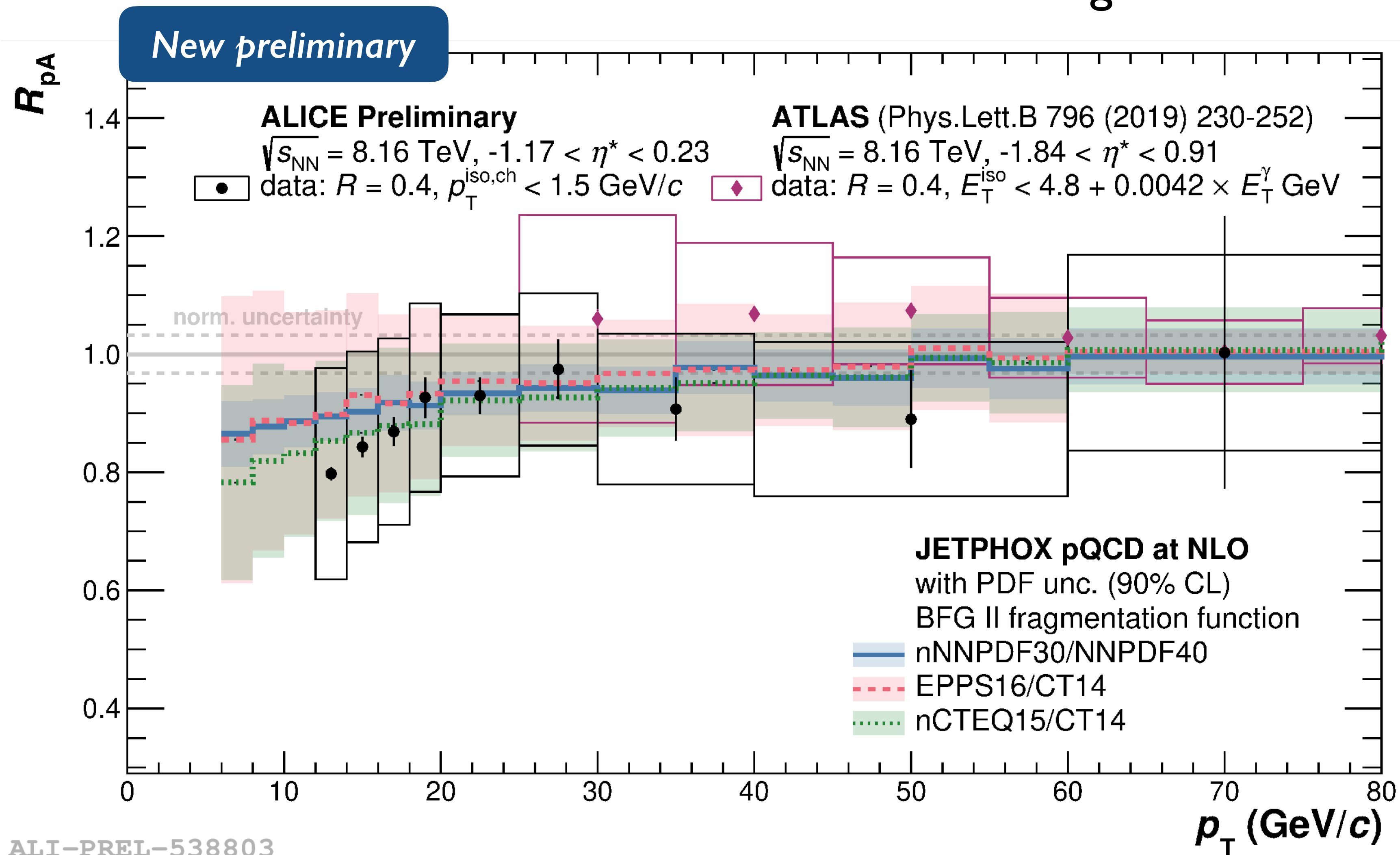
How are gluons distributed in nucleus as a function of x , Q^2 ?



Isolated prompt photons

Florian Jonas
Tuesday 2:00pm

Constrain low- x gluon nPDF



First LHC measurement
of isolated prompt photon
 R_{pA} at $p_T < 20 \text{ GeV}$

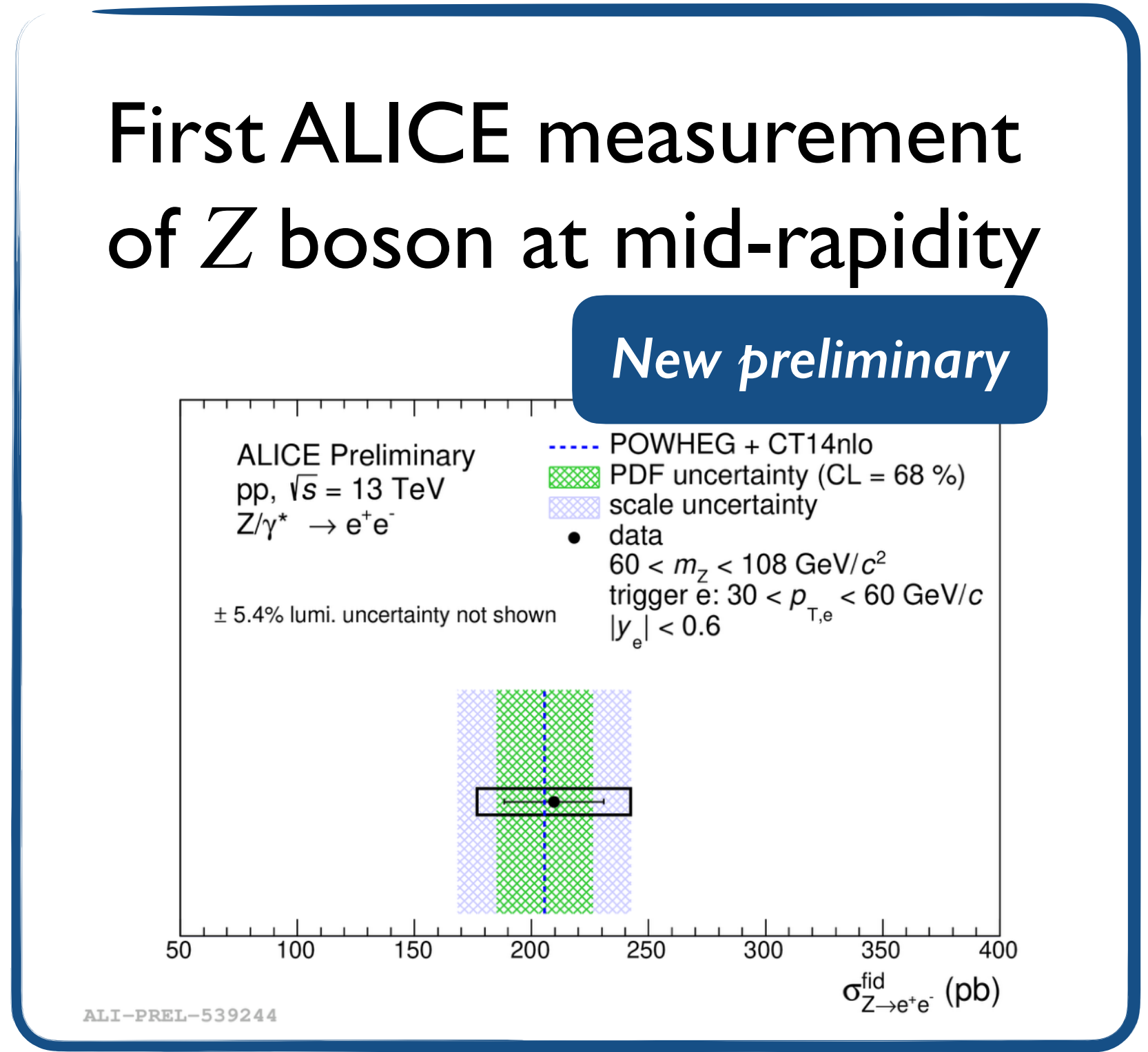
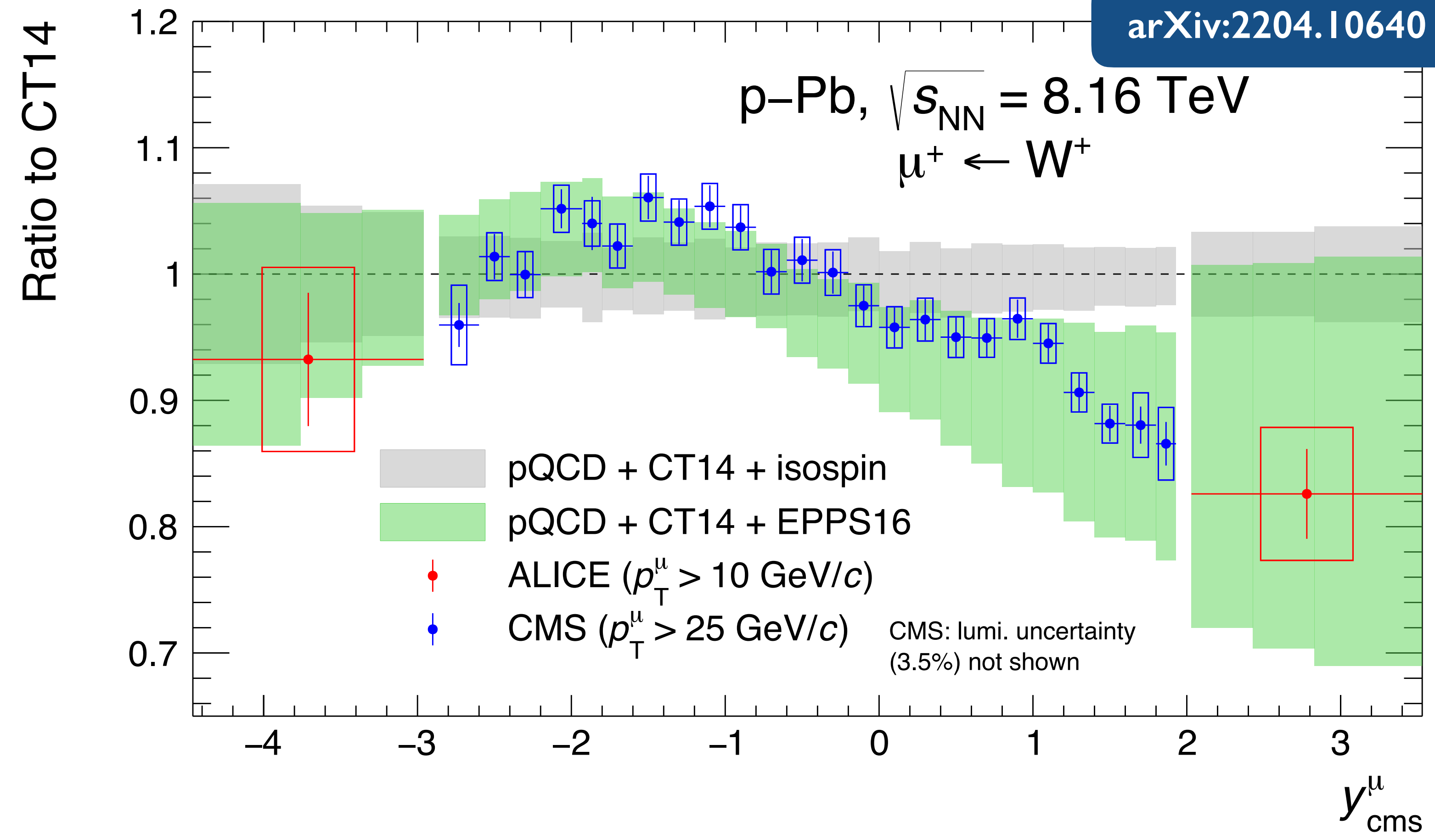
Probing $x \sim 10^{-3}$
Gluon shadowing region

See also: *Inclusive photons*
[arXiv:2303.00590](https://arxiv.org/abs/2303.00590)

W bosons

Constrain low- x light quark nPDF

arXiv:2204.10640

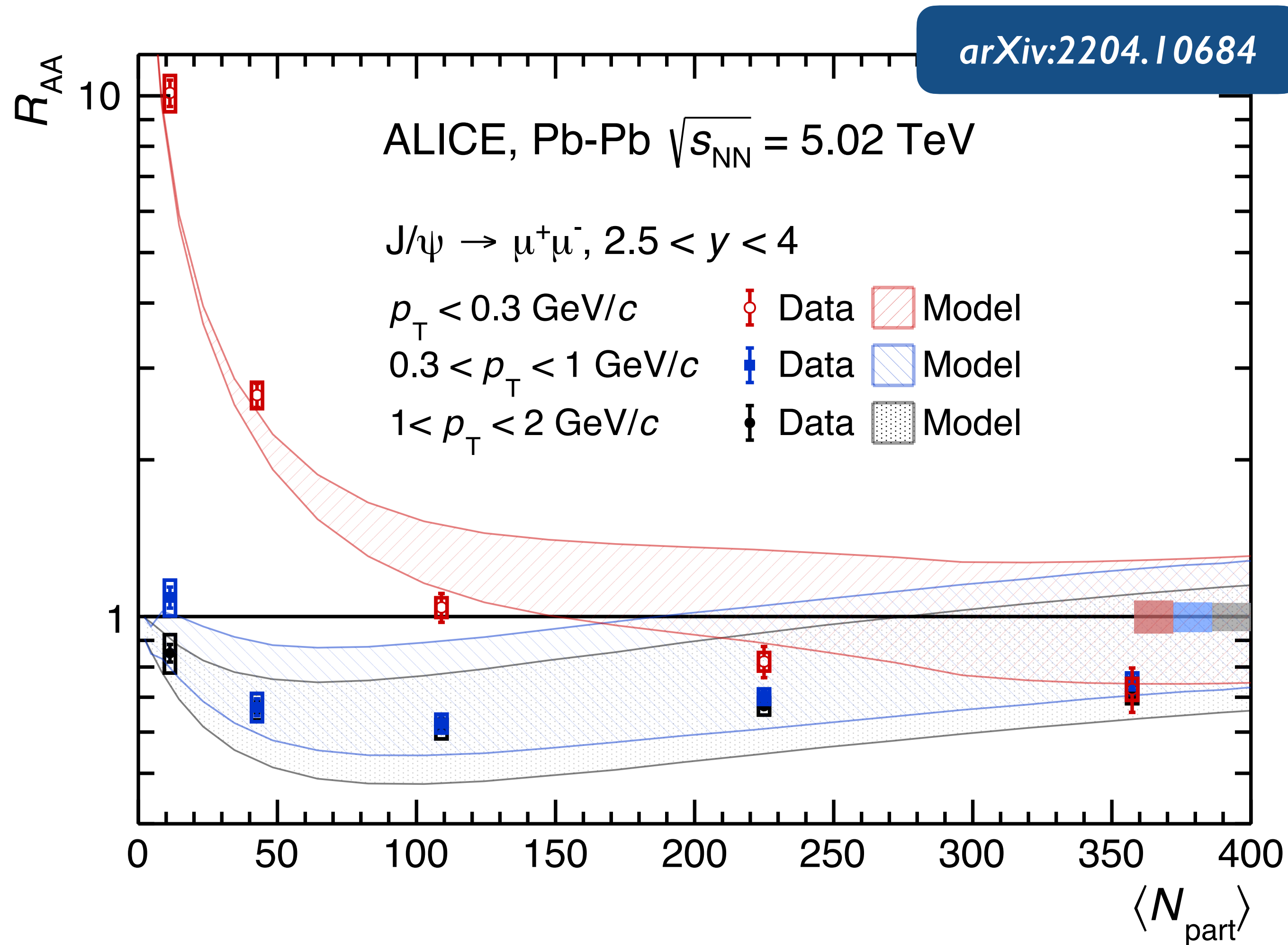


New constraints on nPDFs at forward rapidity $x \sim 10^{-4}$

J/ψ photoproduction

$$\gamma + A \rightarrow J/\psi + A$$

Ionut Cristian Arsene
Wednesday 9:00am

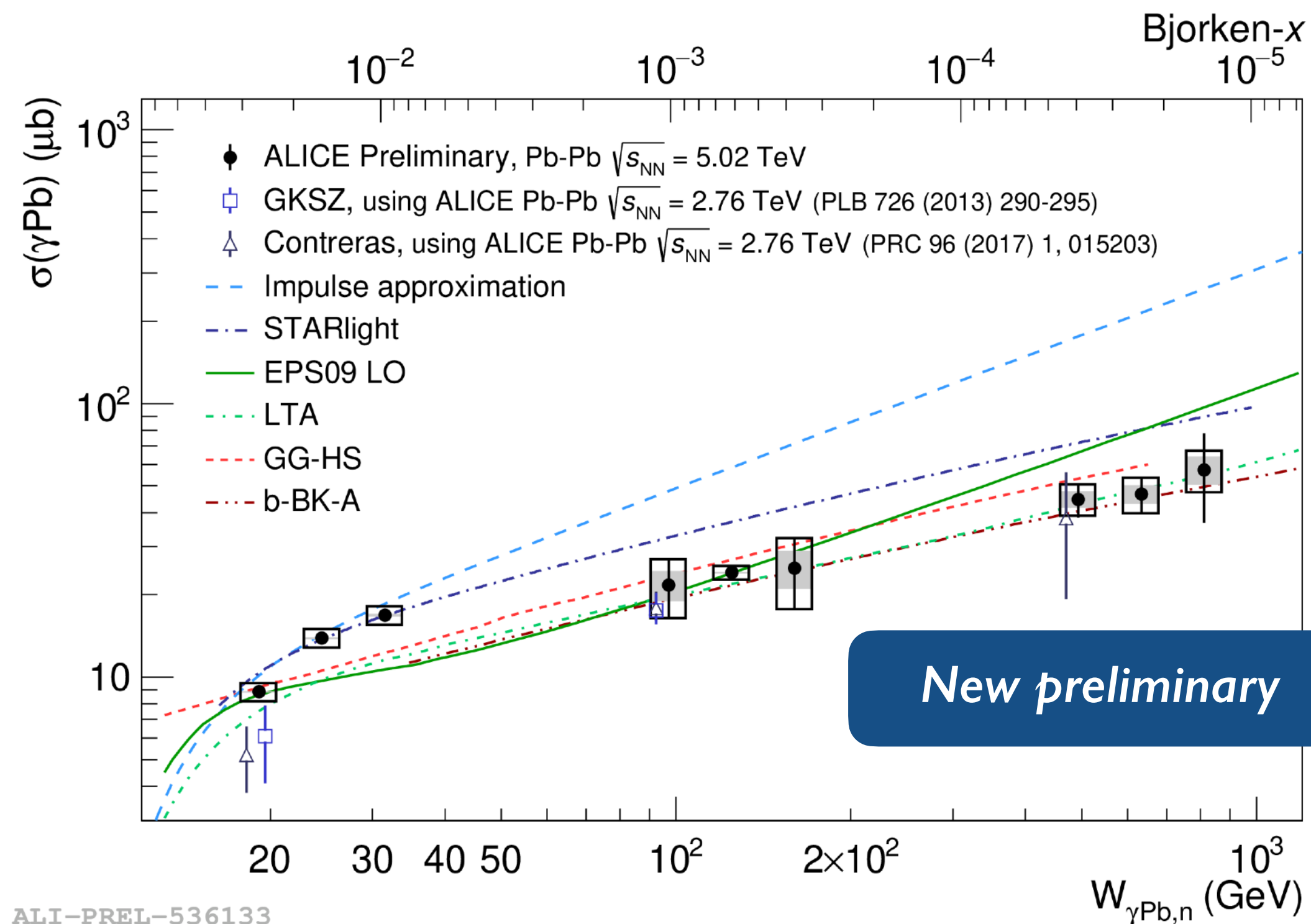


**Coherent photoproduction
in peripheral hadronic events**

Low- p_T excess observed up
to semi-central collisions

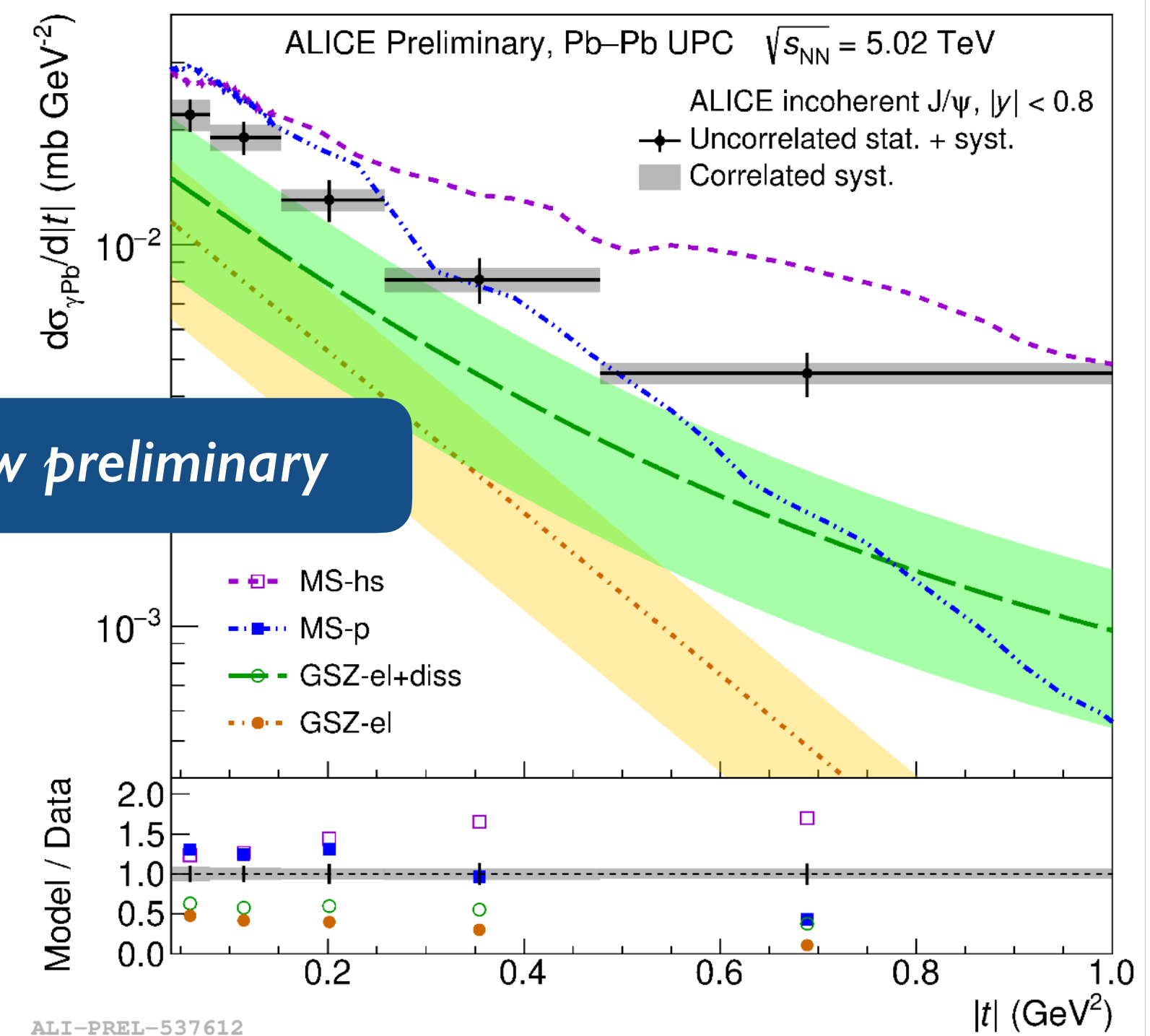
J/ψ photoproduction

Coherent: with neutron emission



Constrain gluon density down to $x \sim 10^{-5}$

Incoherent: t distribution



Probe sub-nucleonic fluctuations

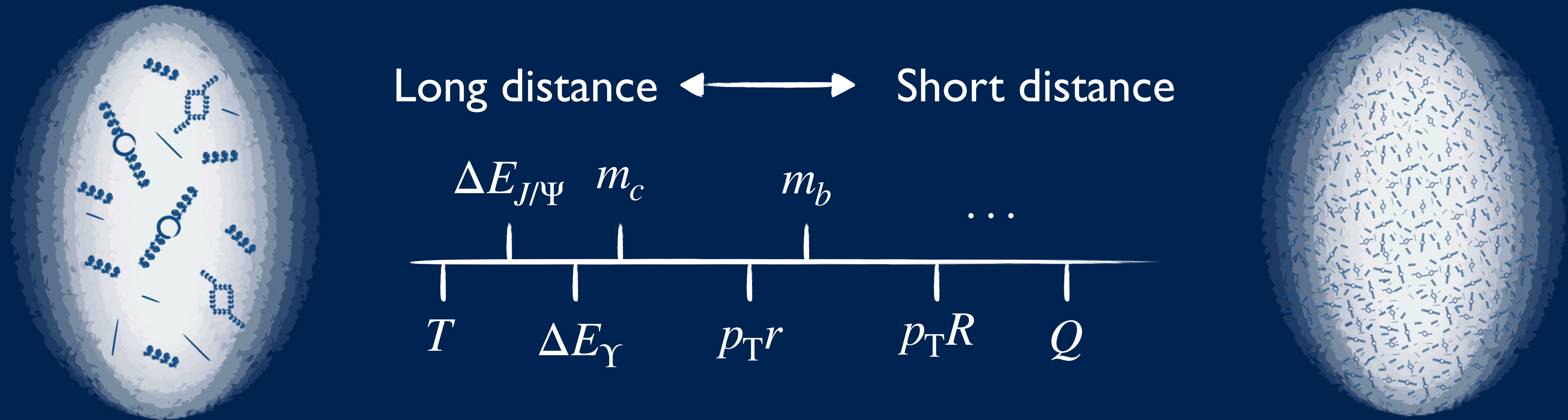
QCD in vacuum



Properties of nuclei

Properties of QGP

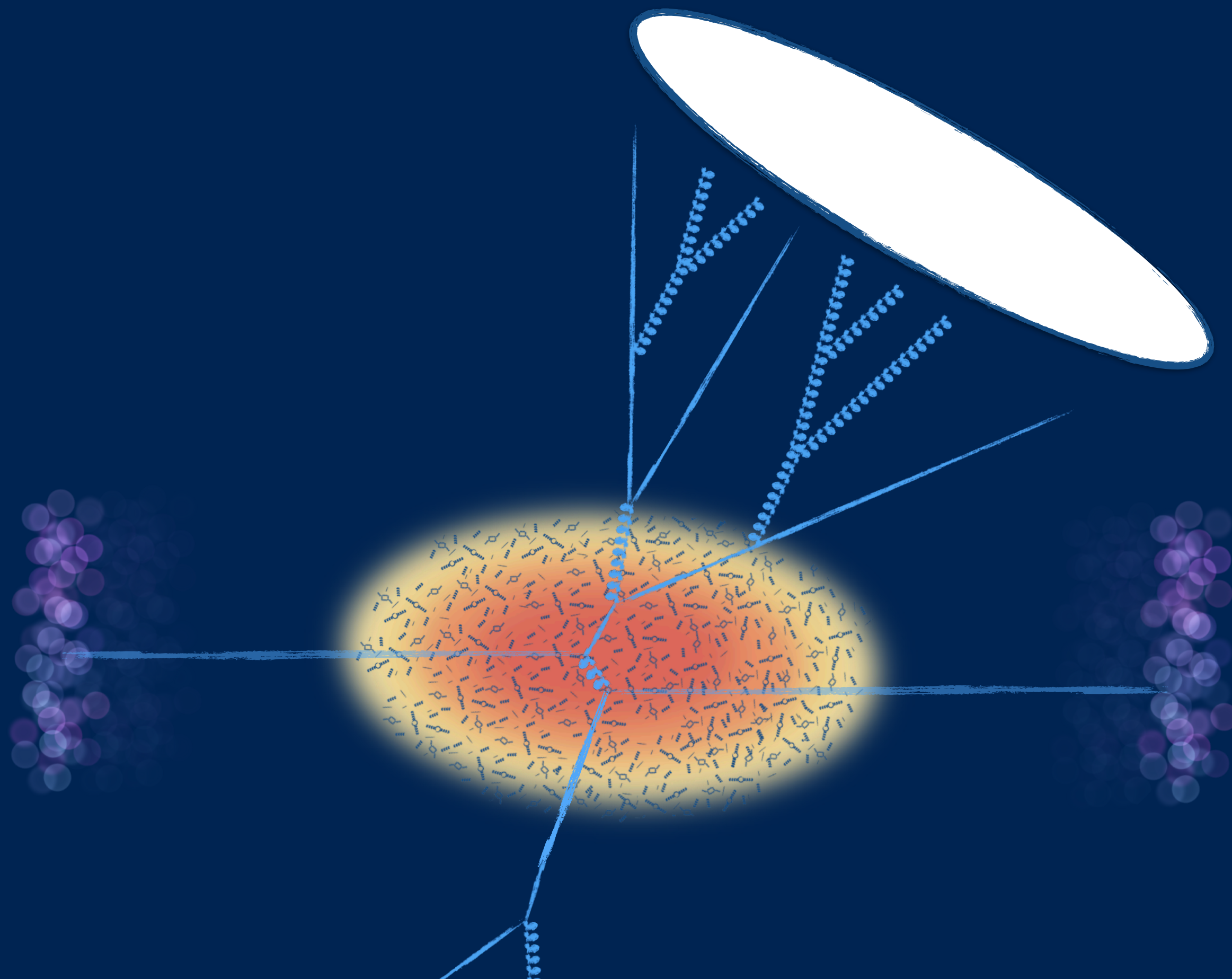
Microscopic properties of the QGP



Variety of probes with complementary strengths

- Resolution scale
- Connection to lattice, pQCD

Which **jet observables** will provide new and interpretable information about the QGP?

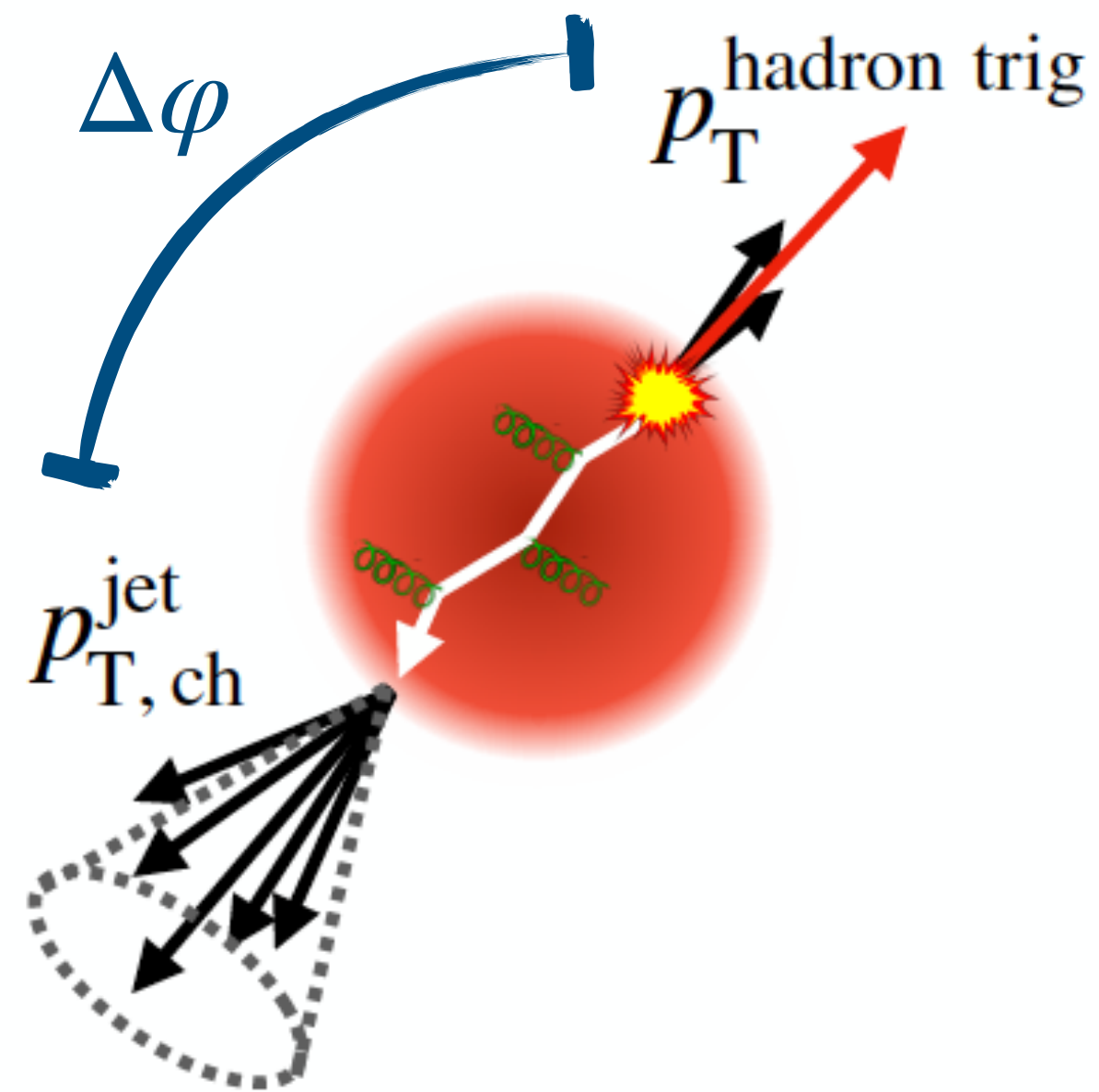


Long distance \longleftrightarrow Short distance

$\Delta E_{J/\psi}$ m_c m_b
| | |
T ΔE_γ $p_{T,r}$... $p_{T,R}$ Q

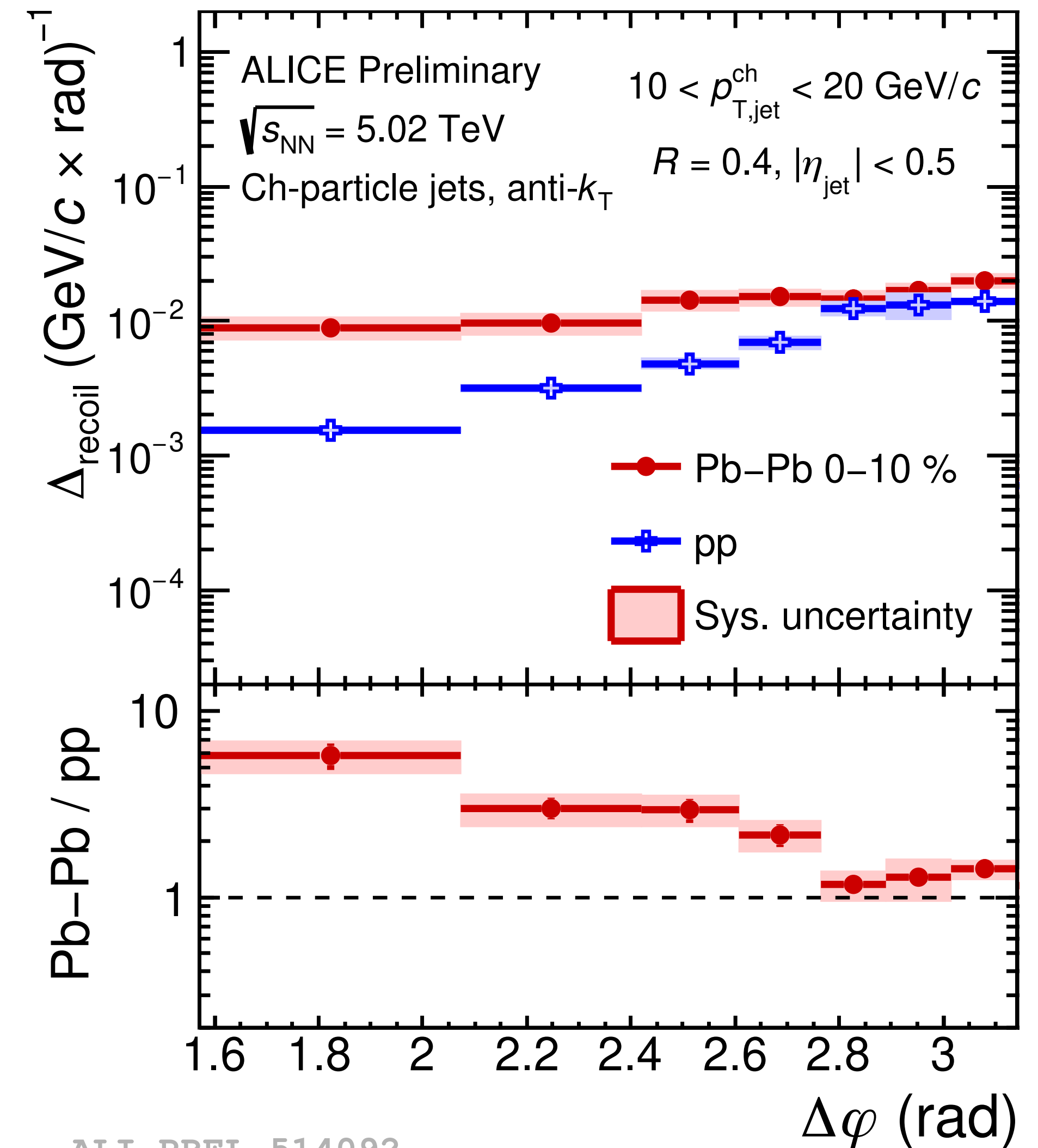
perturbative QCD

Semi-inclusive jet correlations



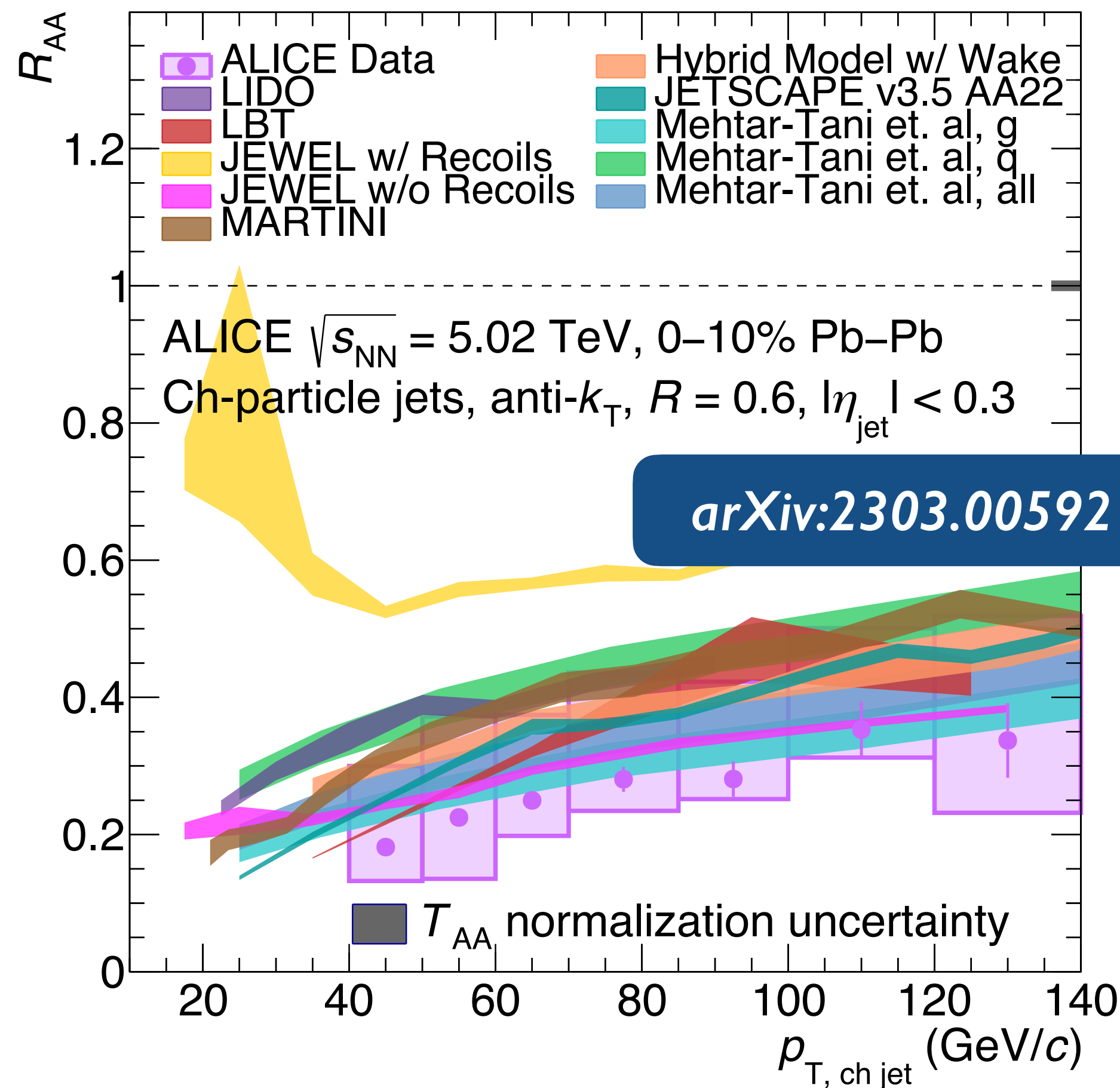
Low- p_T , large- R phase space reveals significant acoplanarity

Models suggest this is due medium response rather than large-angle scattering

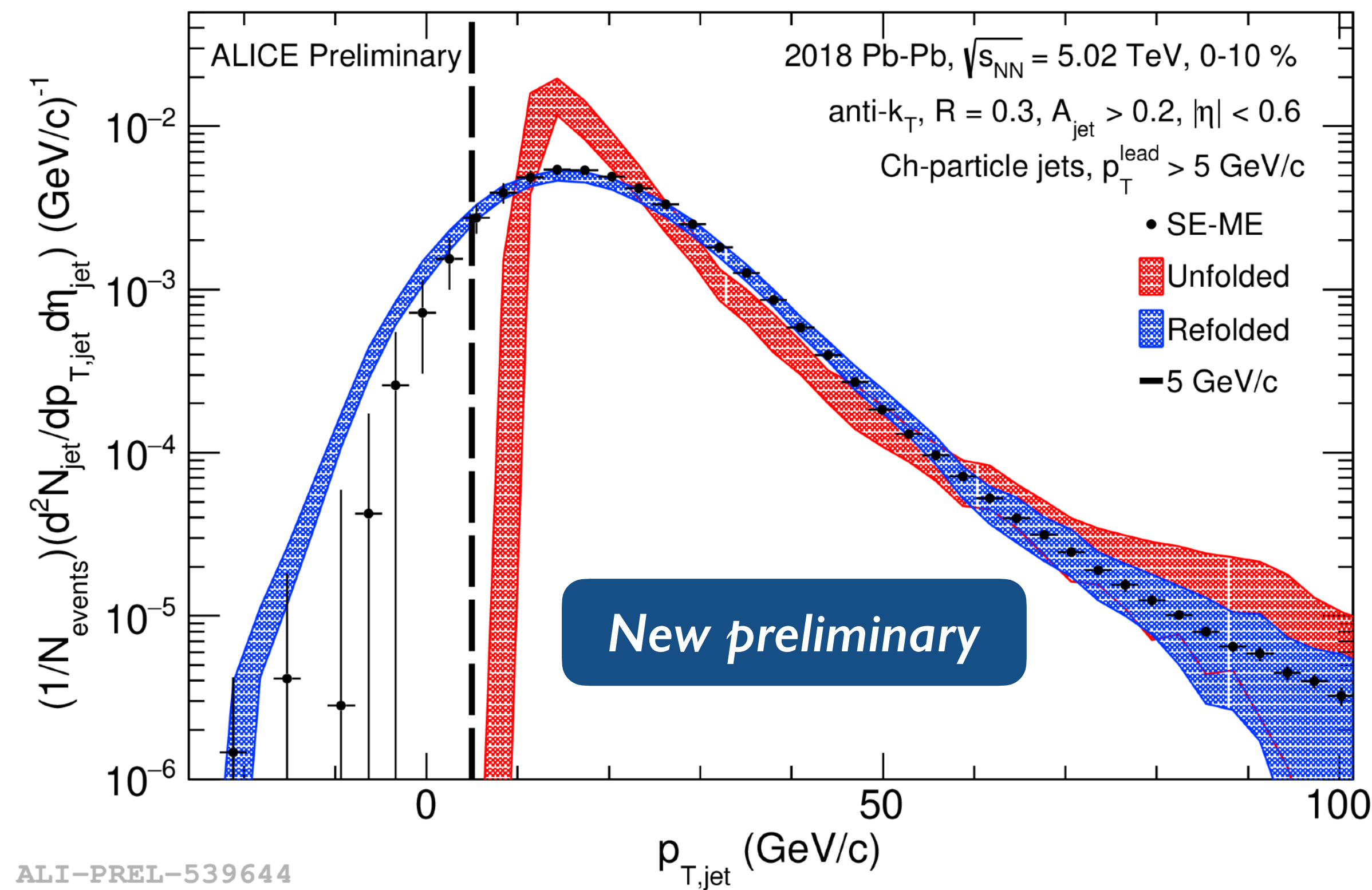


ALI-PREL-514092

ML background subtraction



Mixed event subtraction



Complementary approaches to reach low- p_T , large- R phase space



ALICE

Jet substructure

Focus on observables that are *calculable, corrected, and complementary*

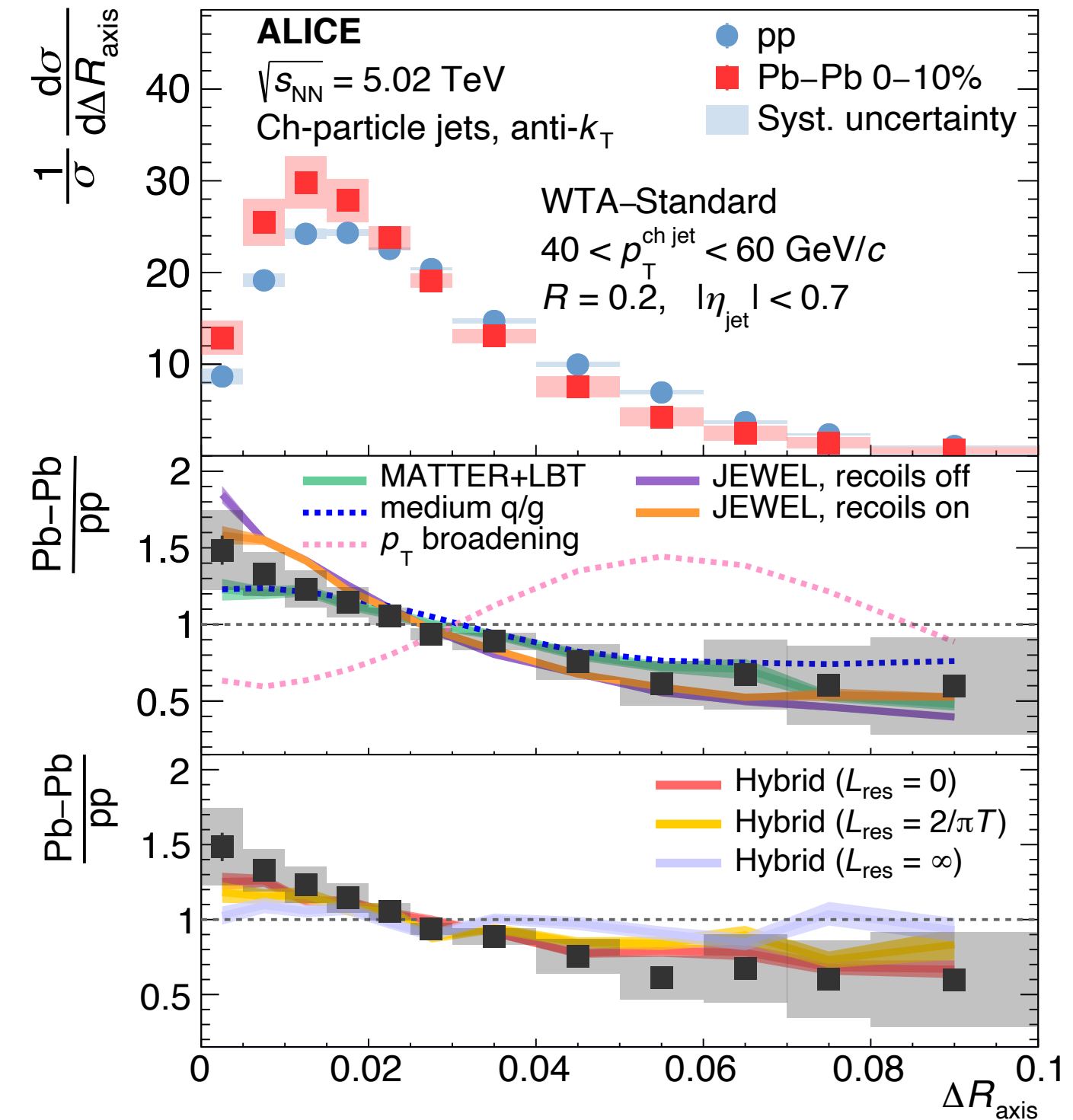


ALICE

Jet axis differences

Reynier Cruz-Torres
Tuesday 5:50pm

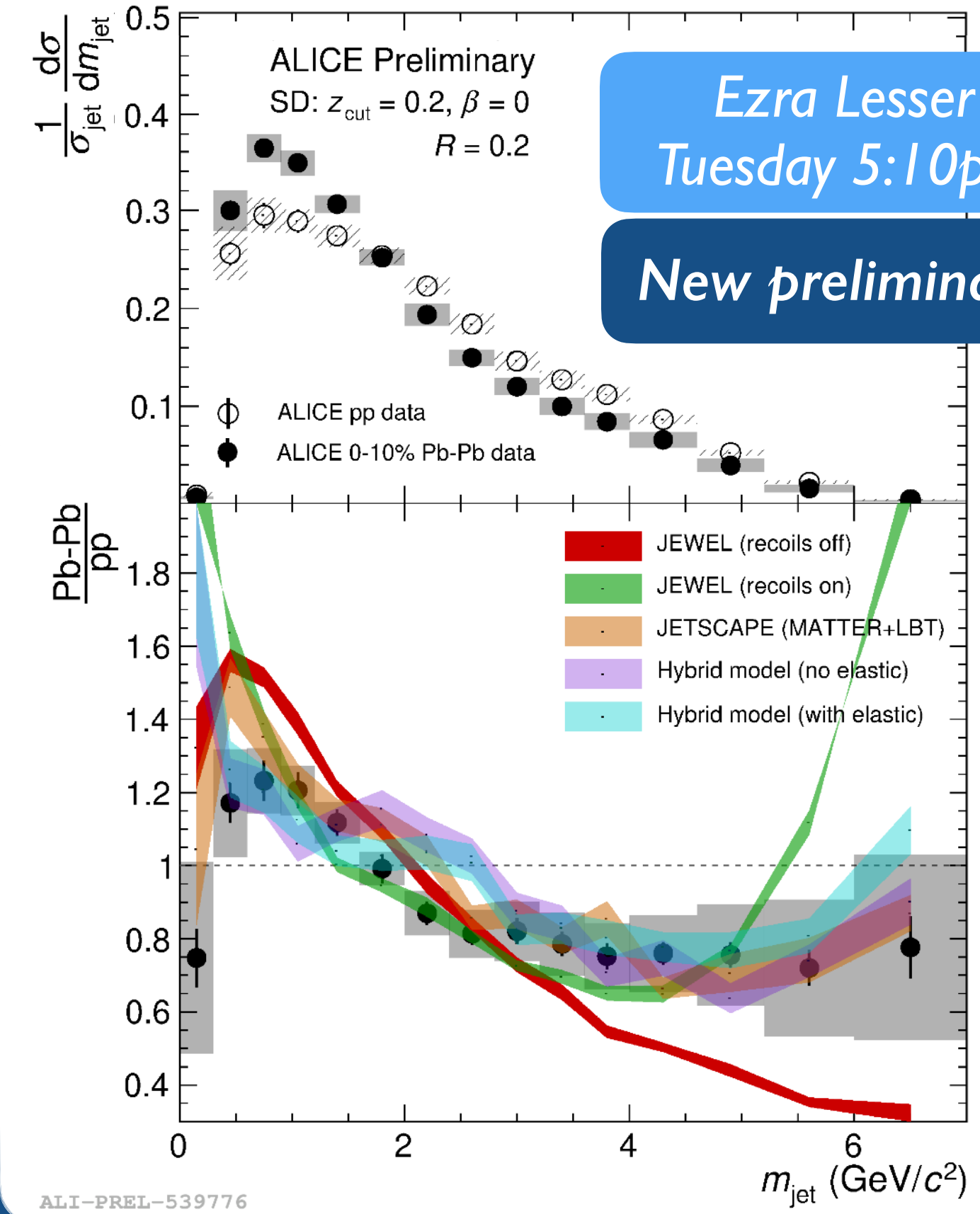
arXiv:2303.13347
arXiv:2211.08928



Jet mass, angularities

Ezra Lesser
Tuesday 5:10pm

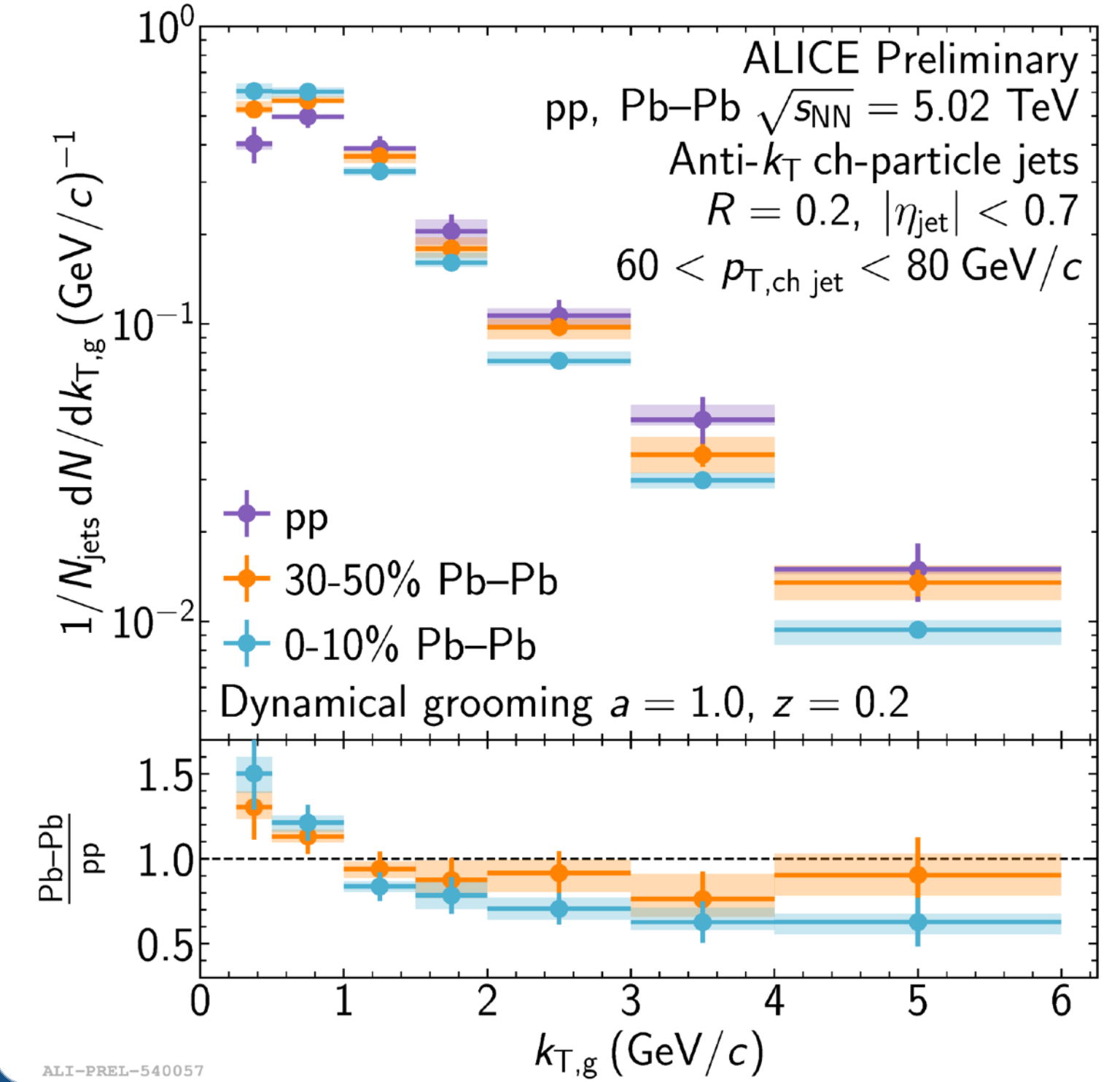
New preliminary



Groomed k_T

Raymond Ehlers
Tuesday 11:10am

New preliminary

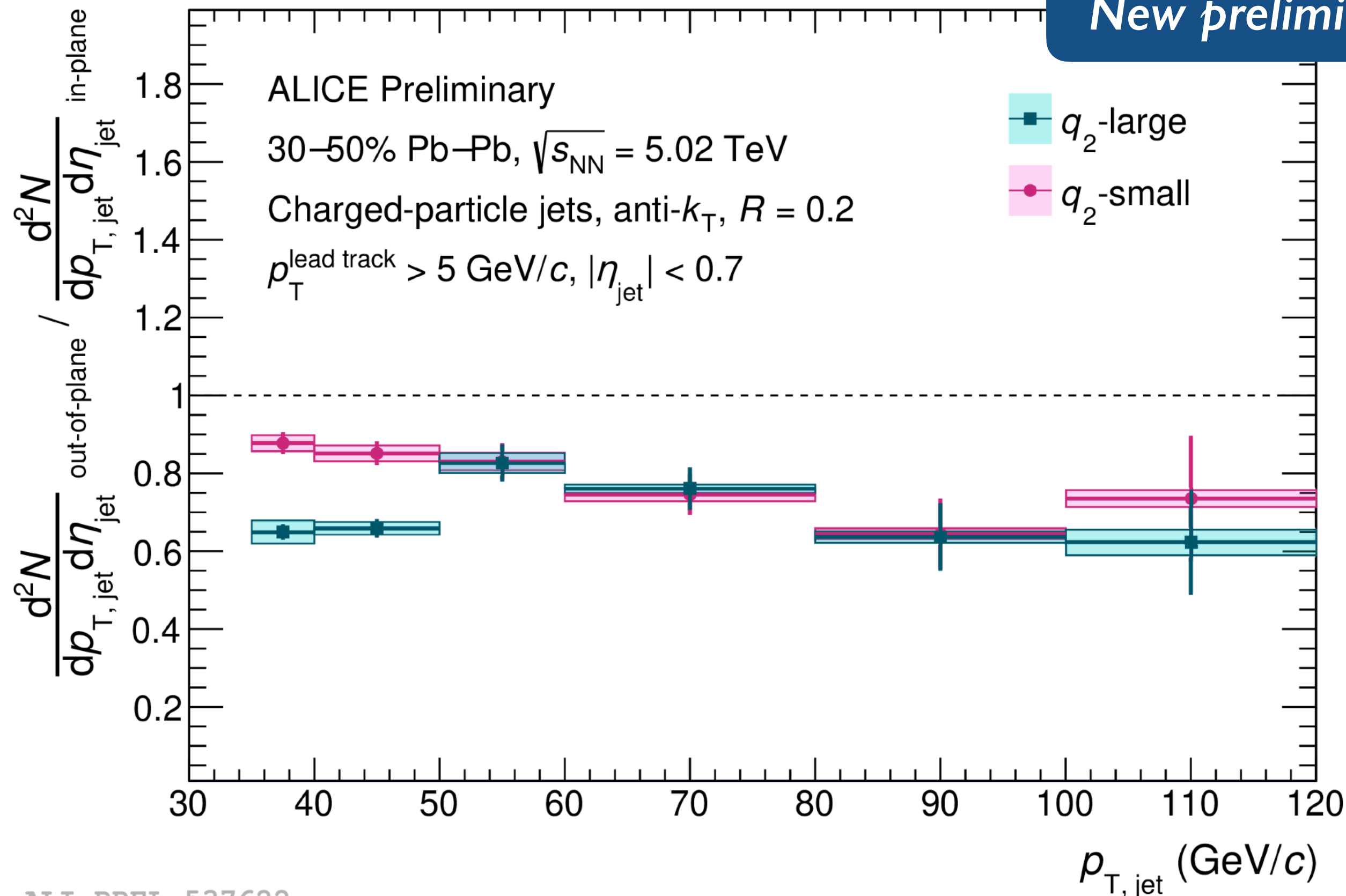


Detailed phenomenology of in-medium fragmentation — connections to QGP resolution length

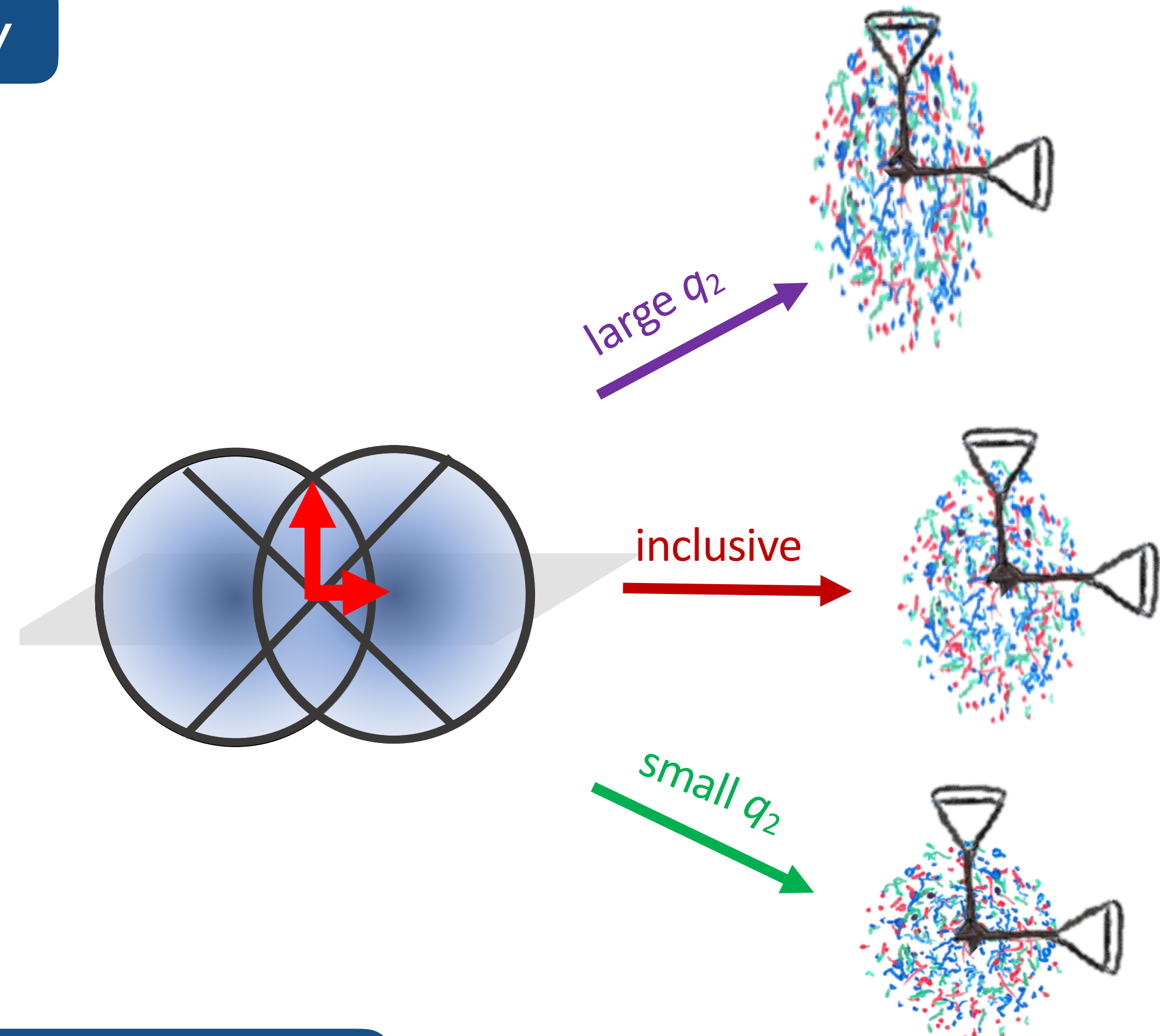
Event shape engineering

Caitlin Beattie
Thursday 10:20am

New preliminary



ALI-PREL-537622

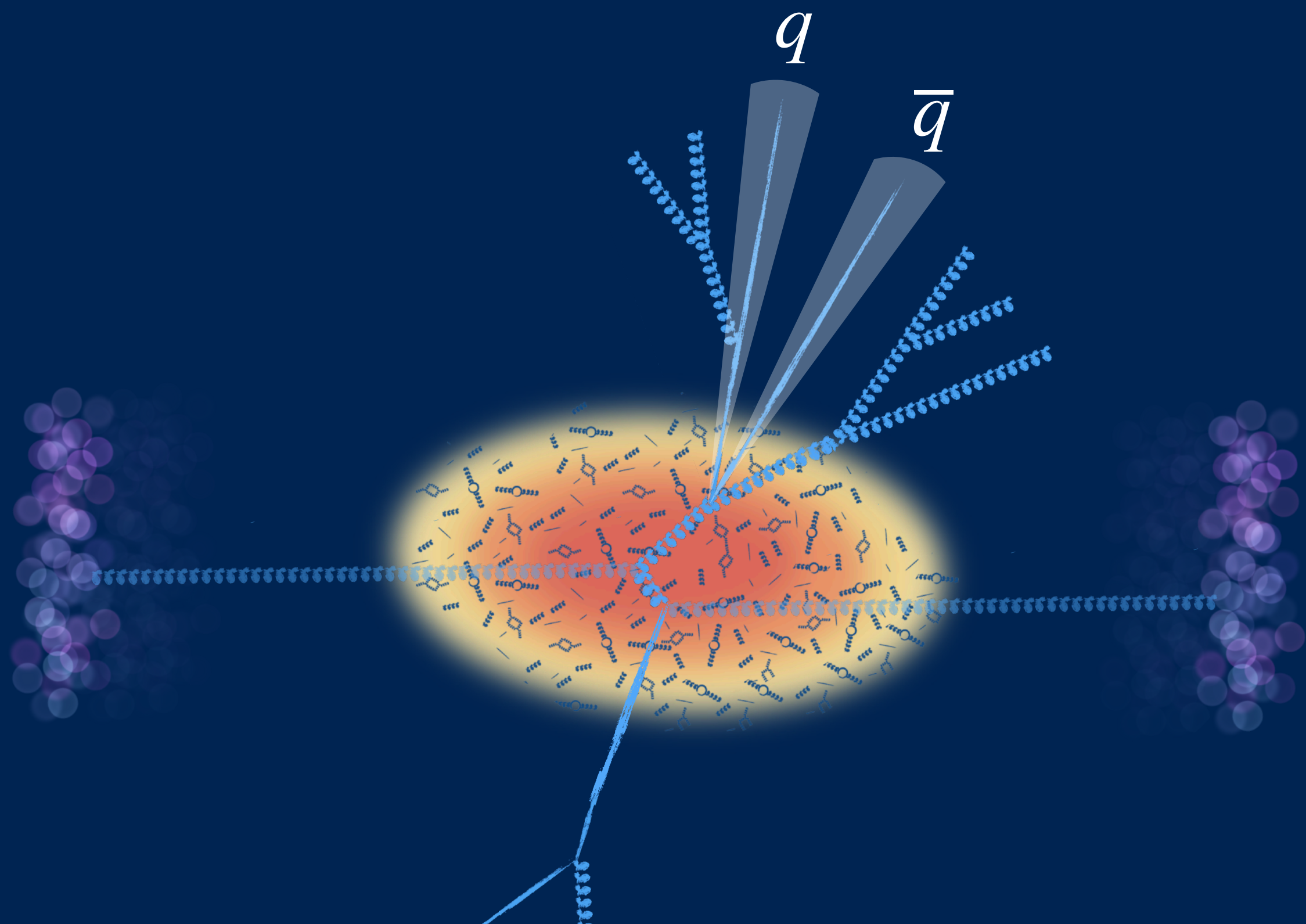


Suppression of out-of-plane jets relative to in-plane jets

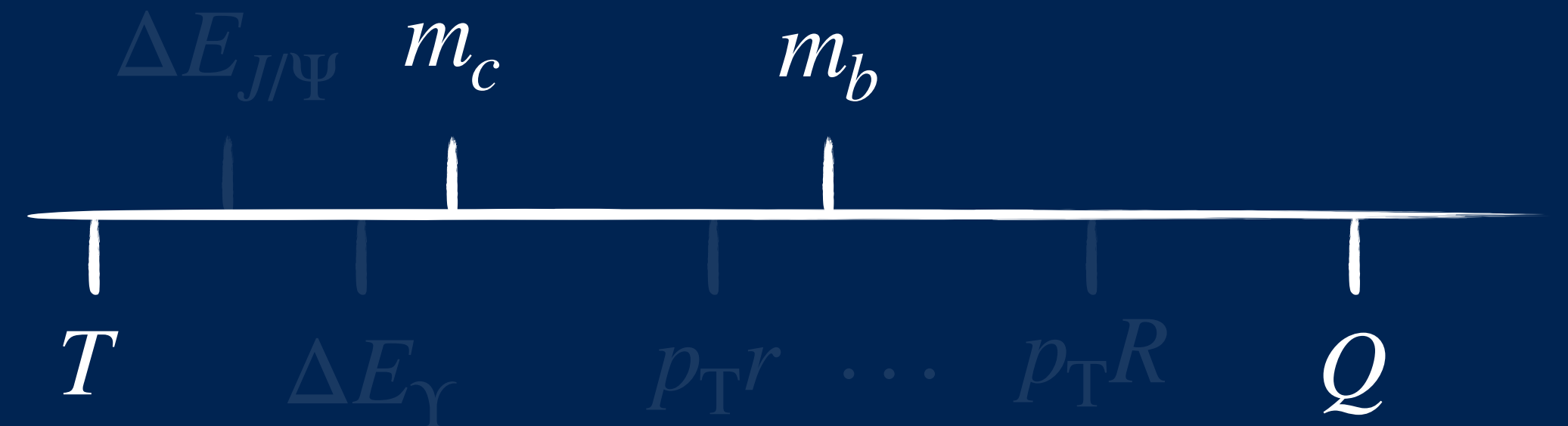
→ Probes interplay of energy loss with expansion of medium

See also: high- p_T v_2
arXiv:2212.12609

Can **heavy-flavor quarks** provide an additional handle on jet-medium interactions?

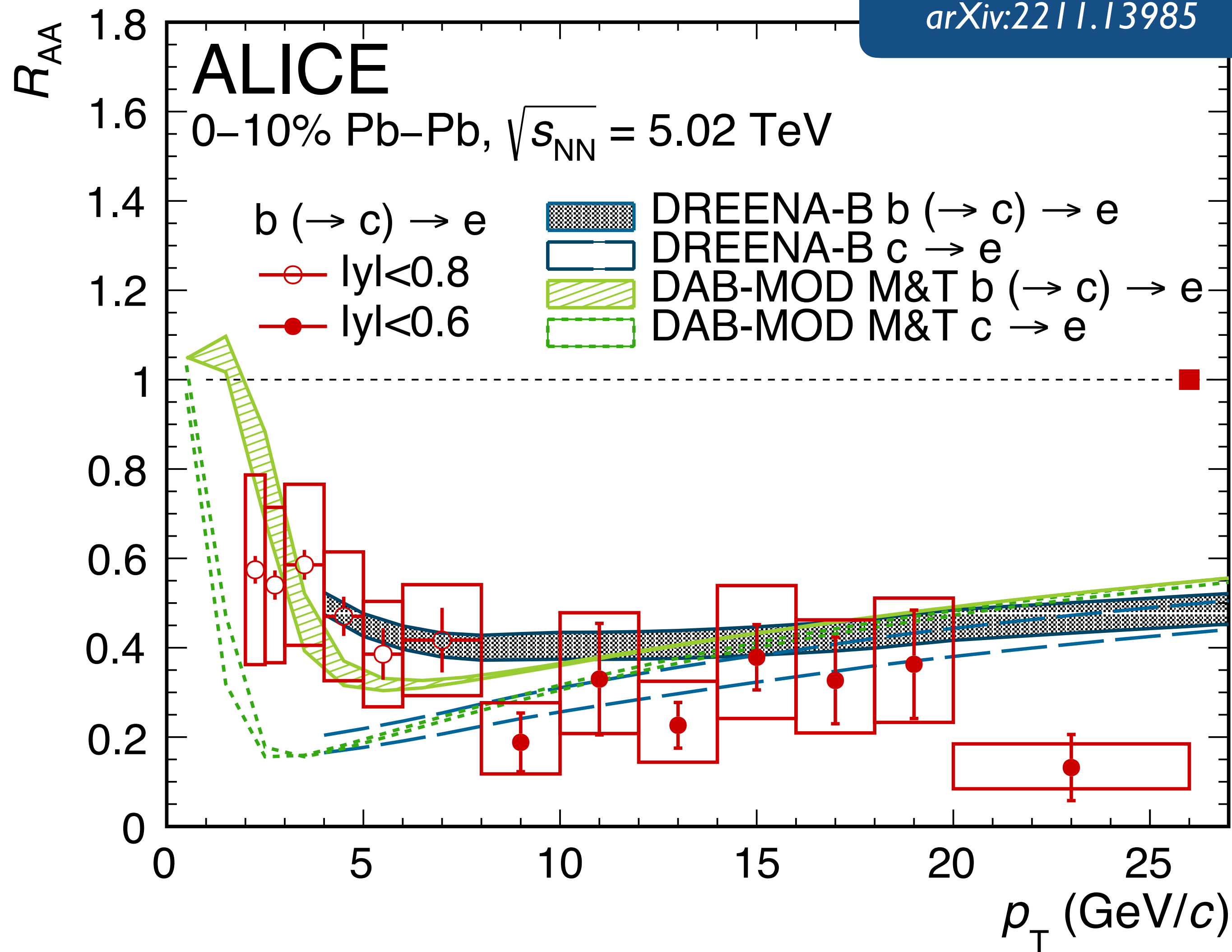


Long distance \longleftrightarrow Short distance



perturbative QCD



arXiv:2211.13985



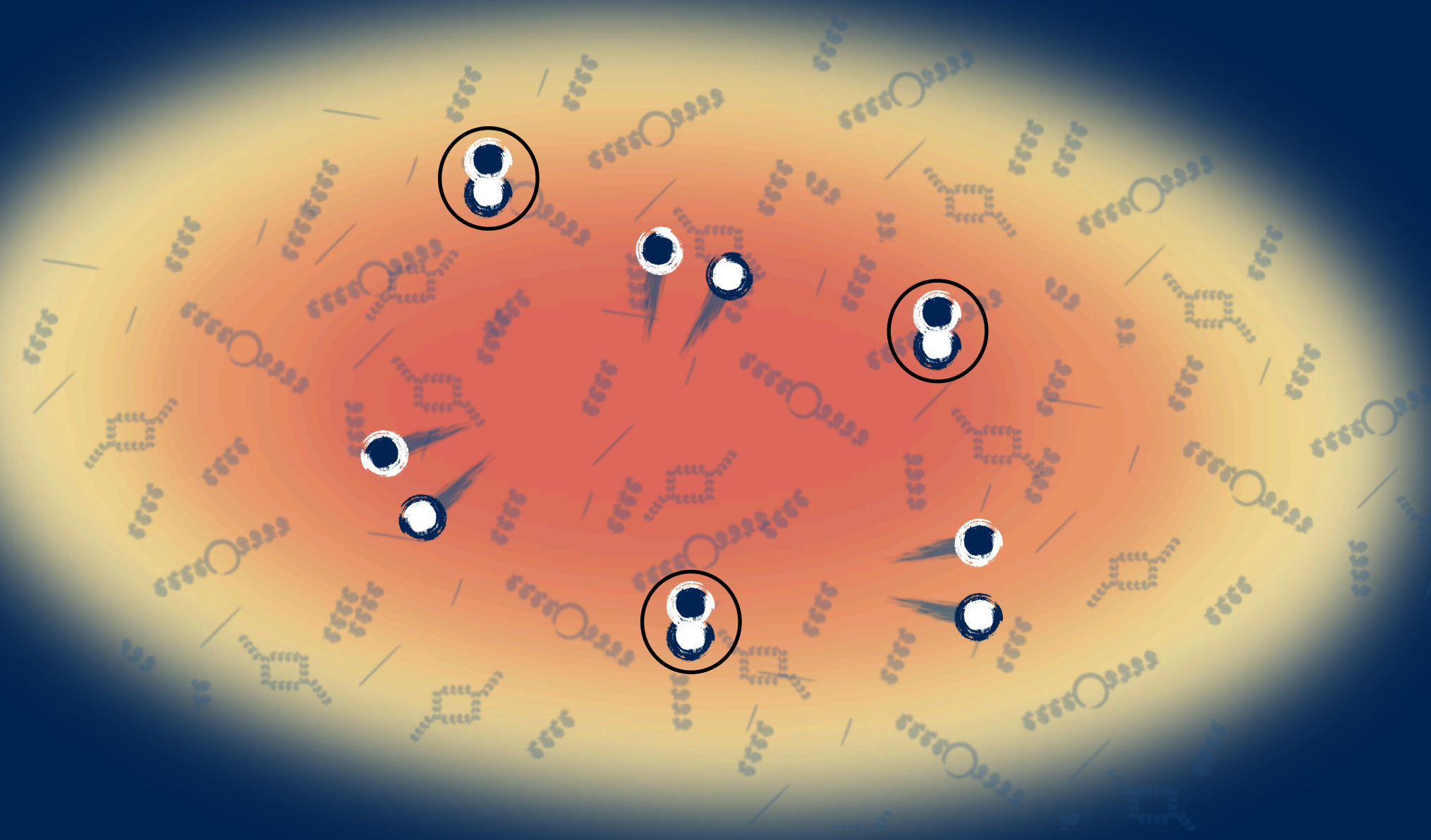
Electrons from b -hadron decays

Consistent with models of b -quark energy loss

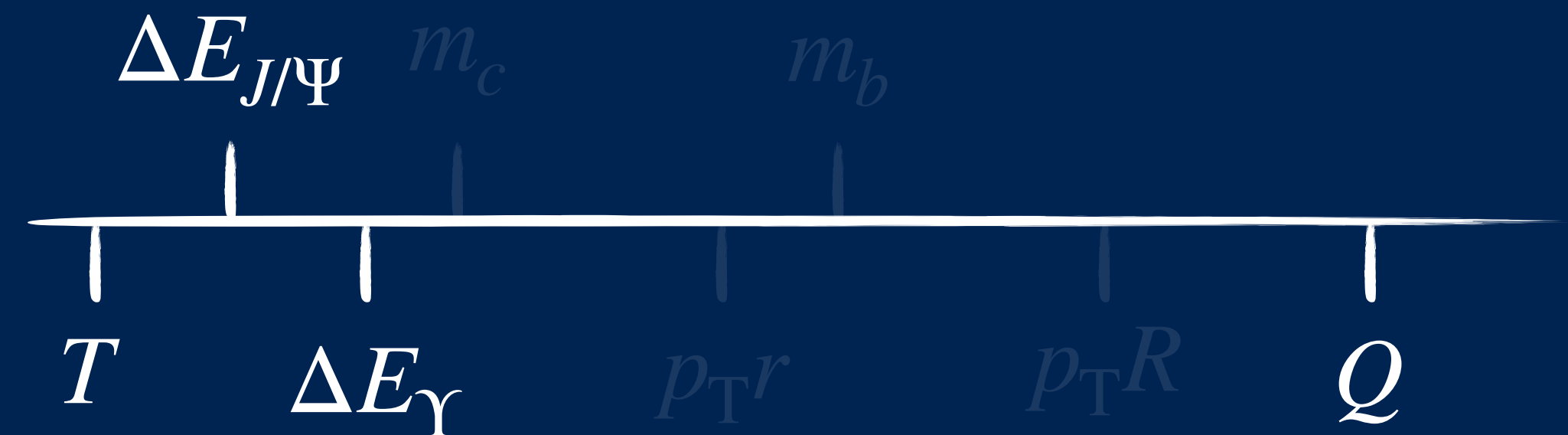
See also:

-  arXiv:2303.13349 $c, b \rightarrow e$ in $pp, p\text{-Pb}$
-  JHEP 12 (2022) 126 Non-prompt D^0 in Pb-Pb

Can the dissociation and regeneration of **quarkonium states** elucidate color screening?



Long distance \longleftrightarrow Short distance



lattice QCD, pQCD

Pengzhong Lu
Tuesday 11:10am

Victor Feuillard
Thursday 9:40am

See also: Inclusive J/ψ
[arXiv:2303.13361](https://arxiv.org/abs/2303.13361)

Charmonium



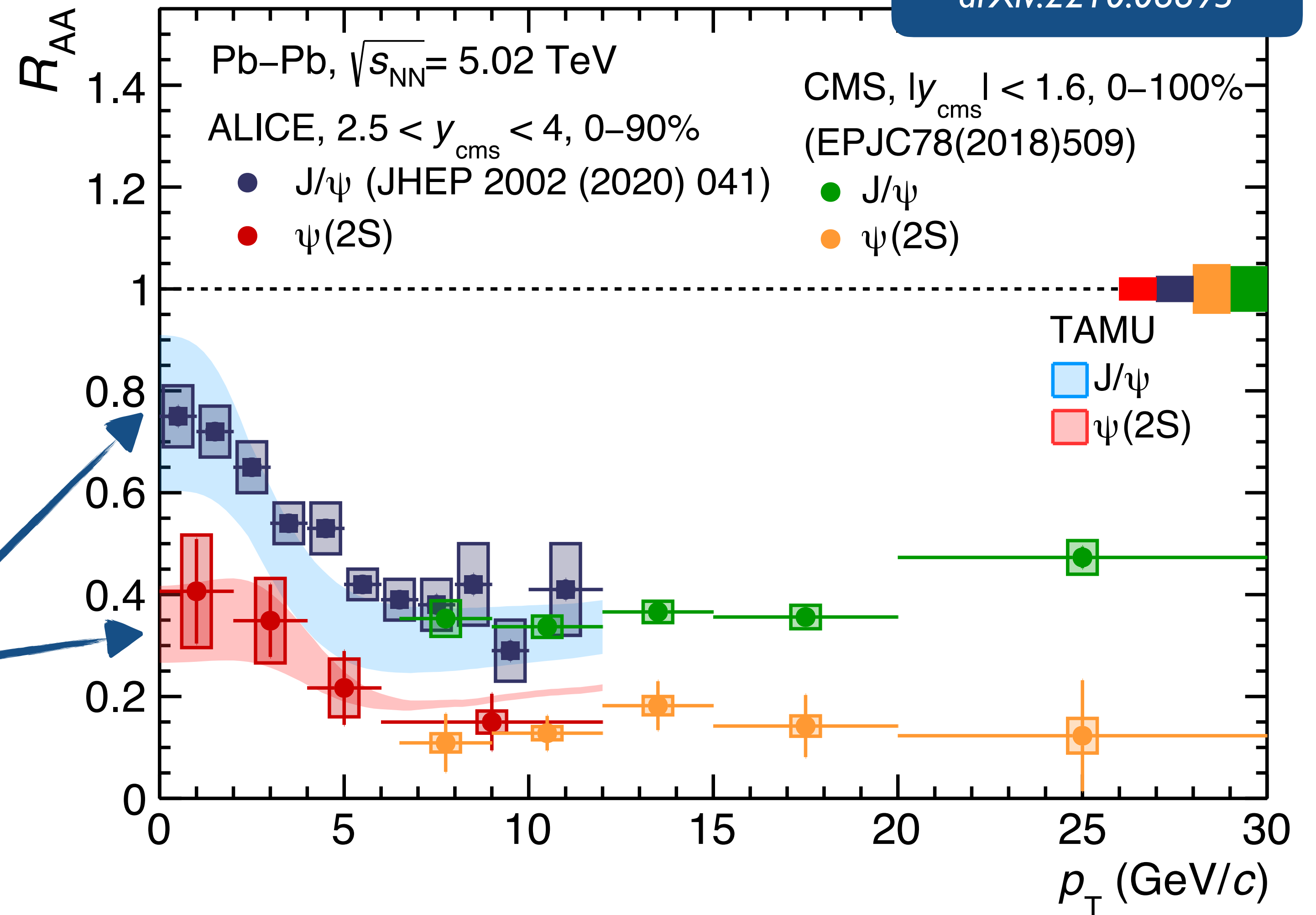
[arXiv:2210.08893](https://arxiv.org/abs/2210.08893)

Measurement of J/ψ , $\psi(2S)$
down to $p_T = 0$

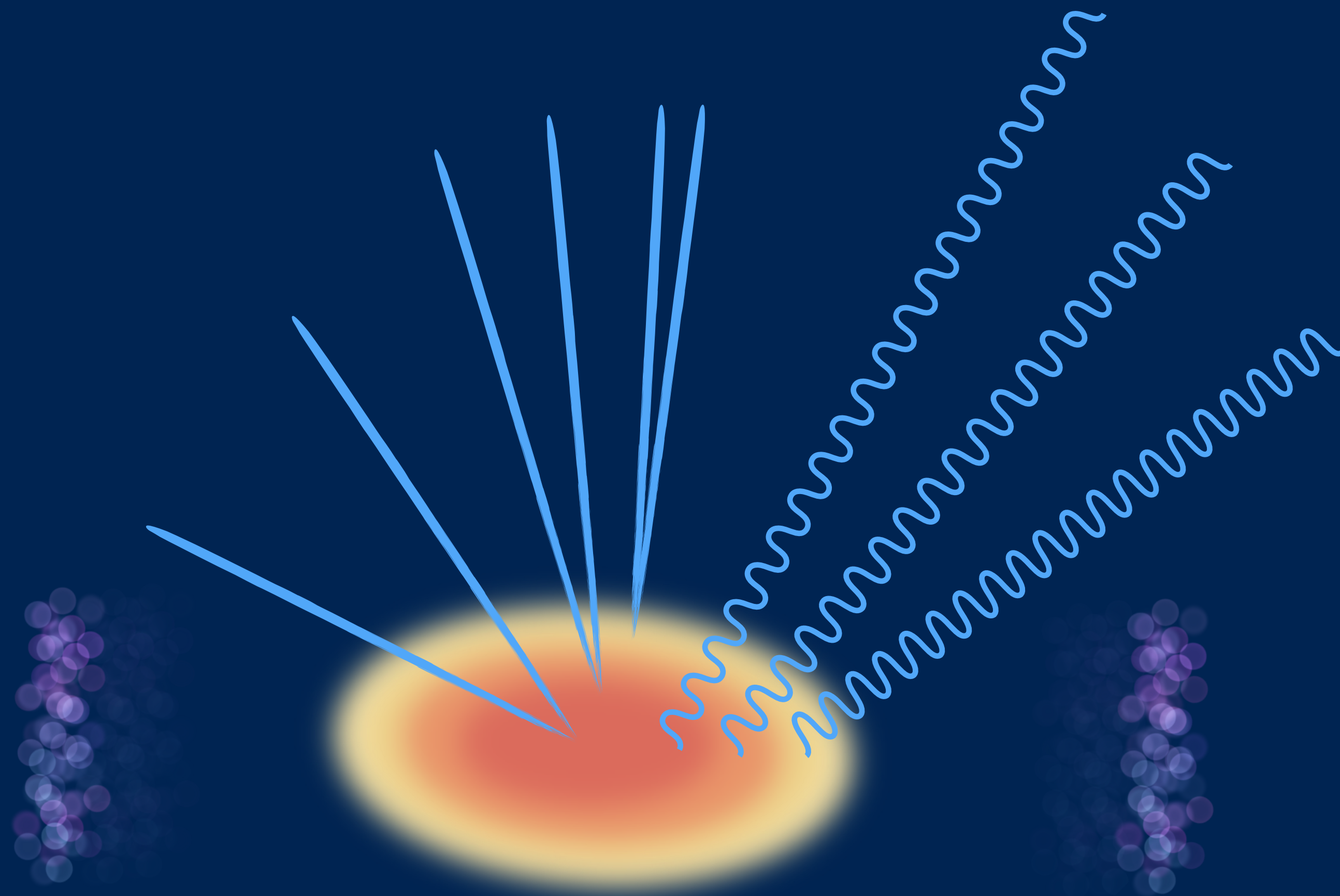
$$R_{AA}^{\psi(2S)} < R_{AA}^{J/\psi}$$

Less suppression as $p_T \rightarrow 0$

Recombination



Bulk properties of the QGP

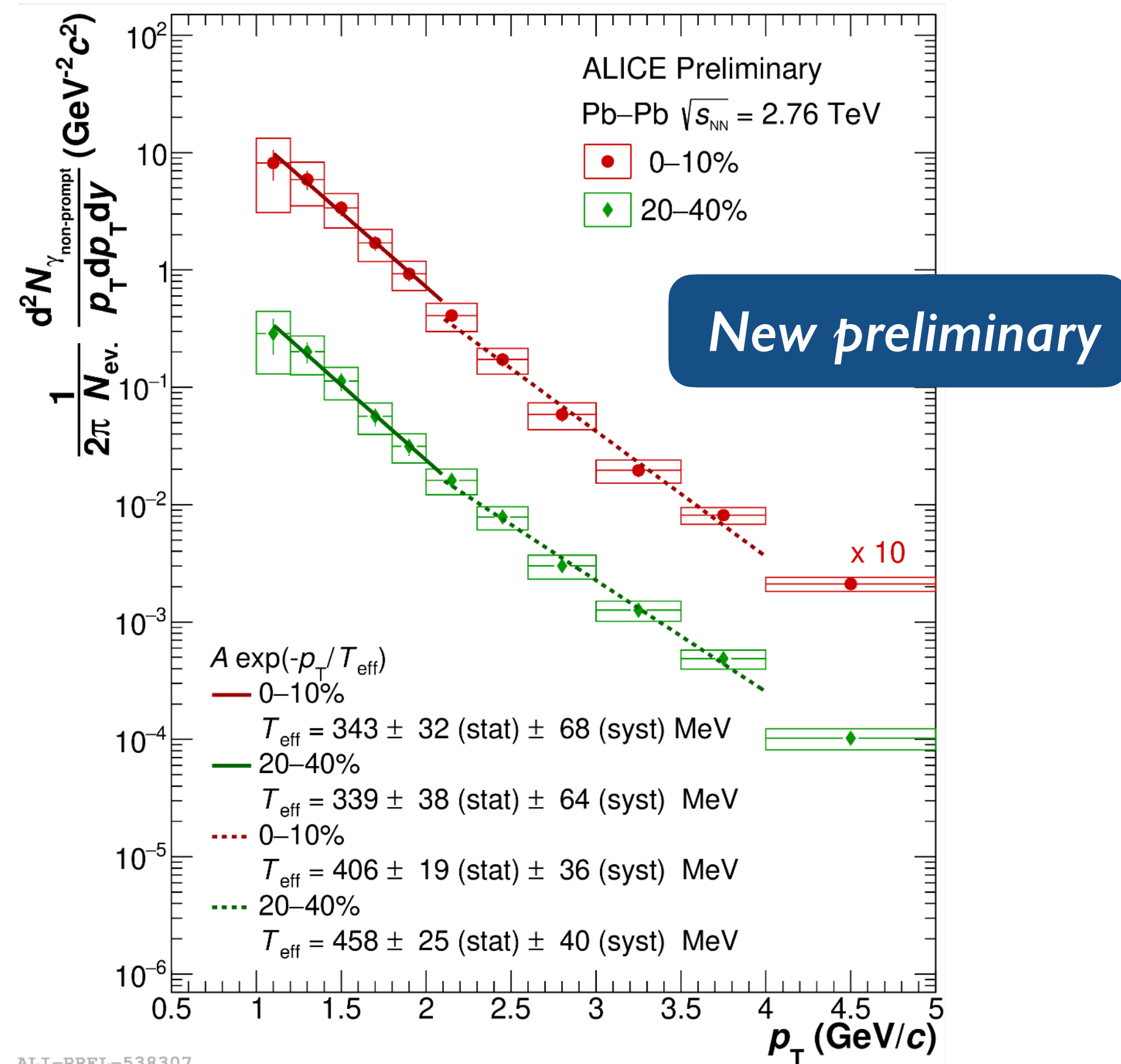


Temperature
B-field
Vorticity

Electromagnetic radiation

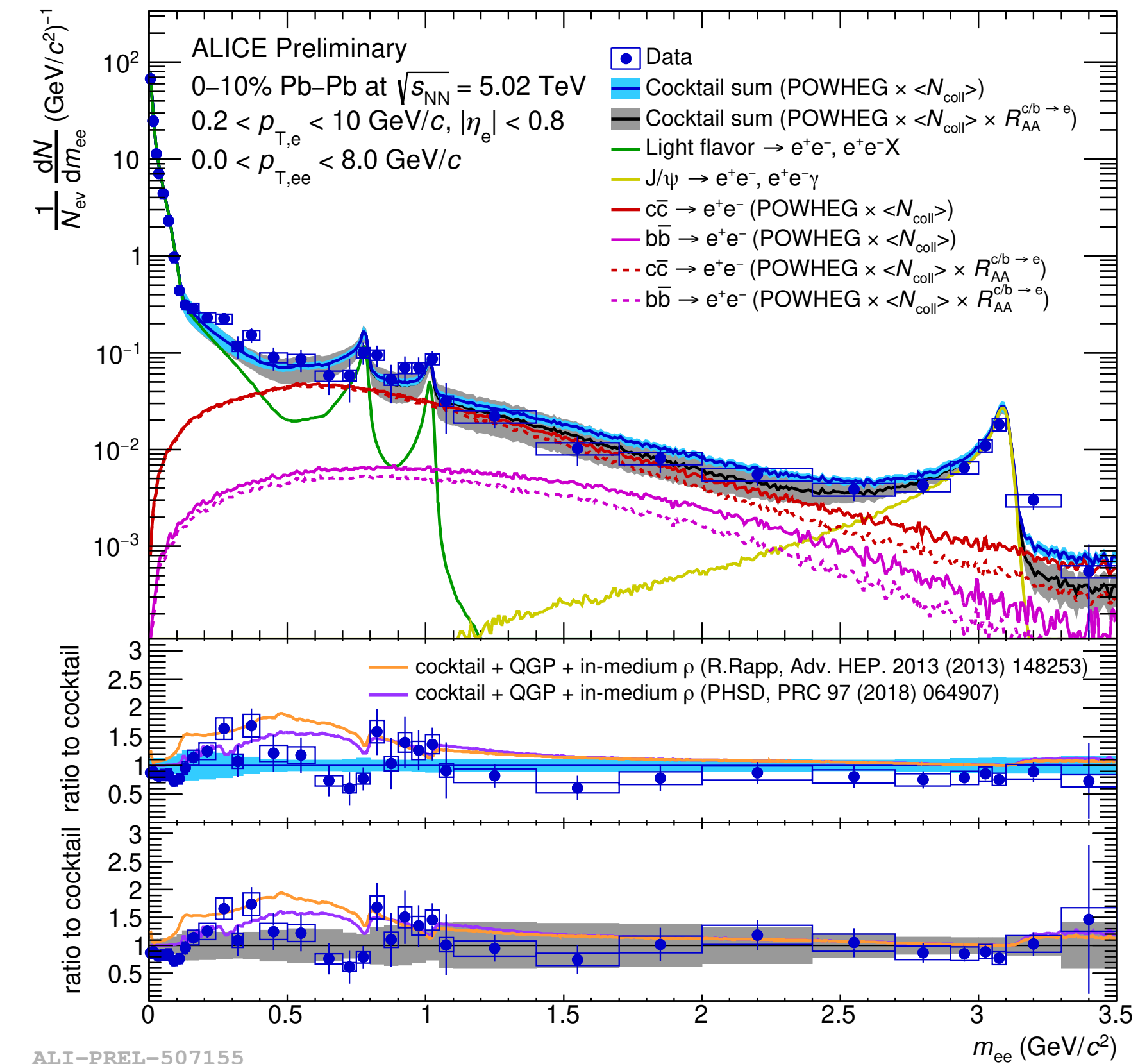
Sensitive to QGP temperature

Photons



Direct photons: extraction of T

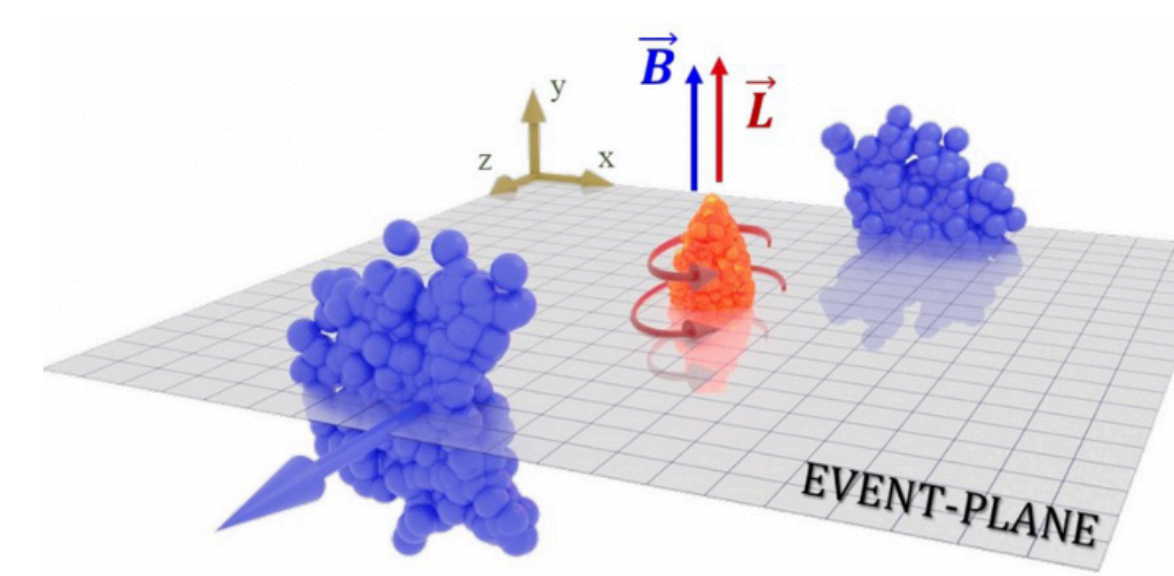
Di-electrons



Hint of low-mass thermal excess

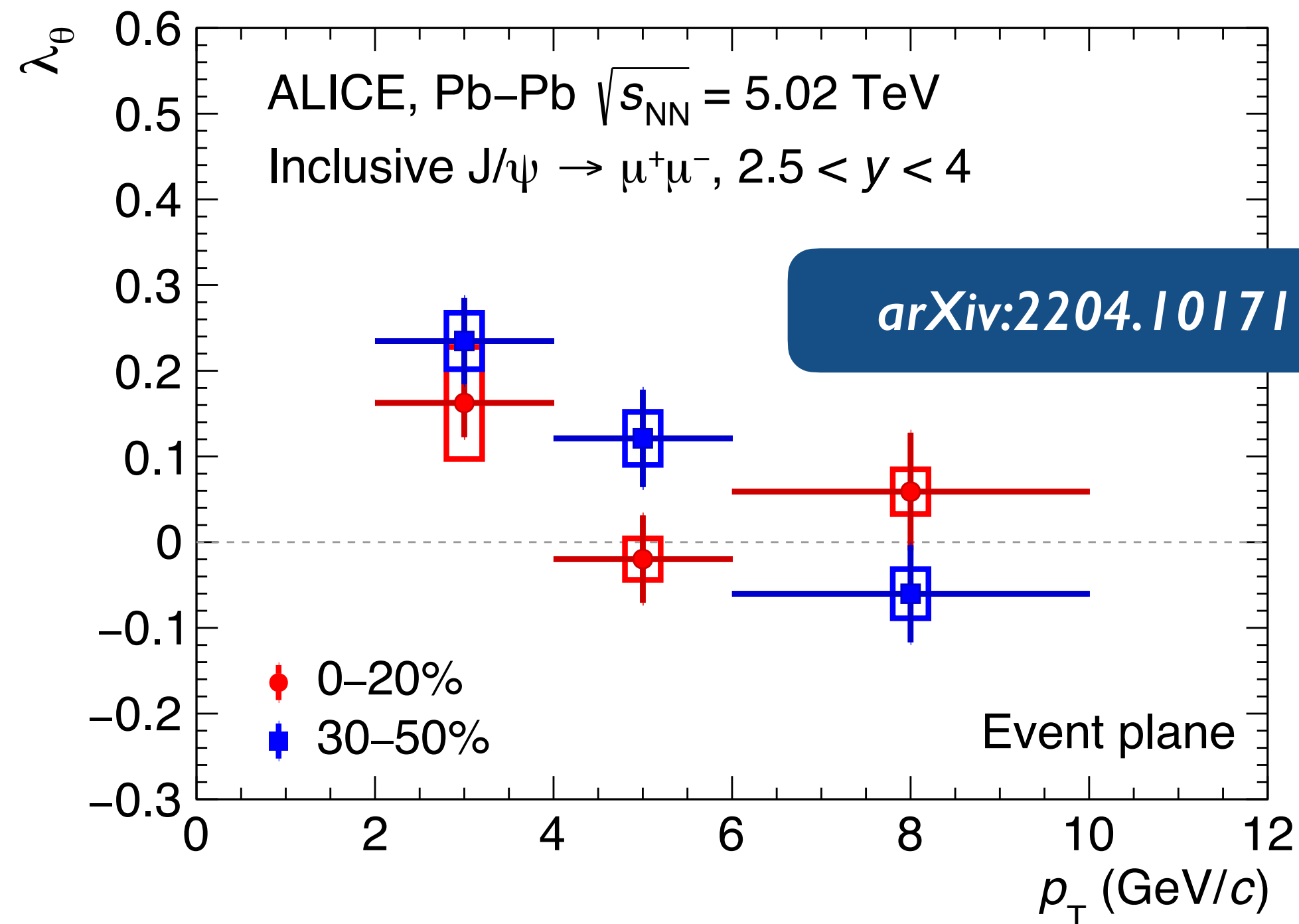
Charm polarization

Sensitive to B -field, vorticity



Quarkonium

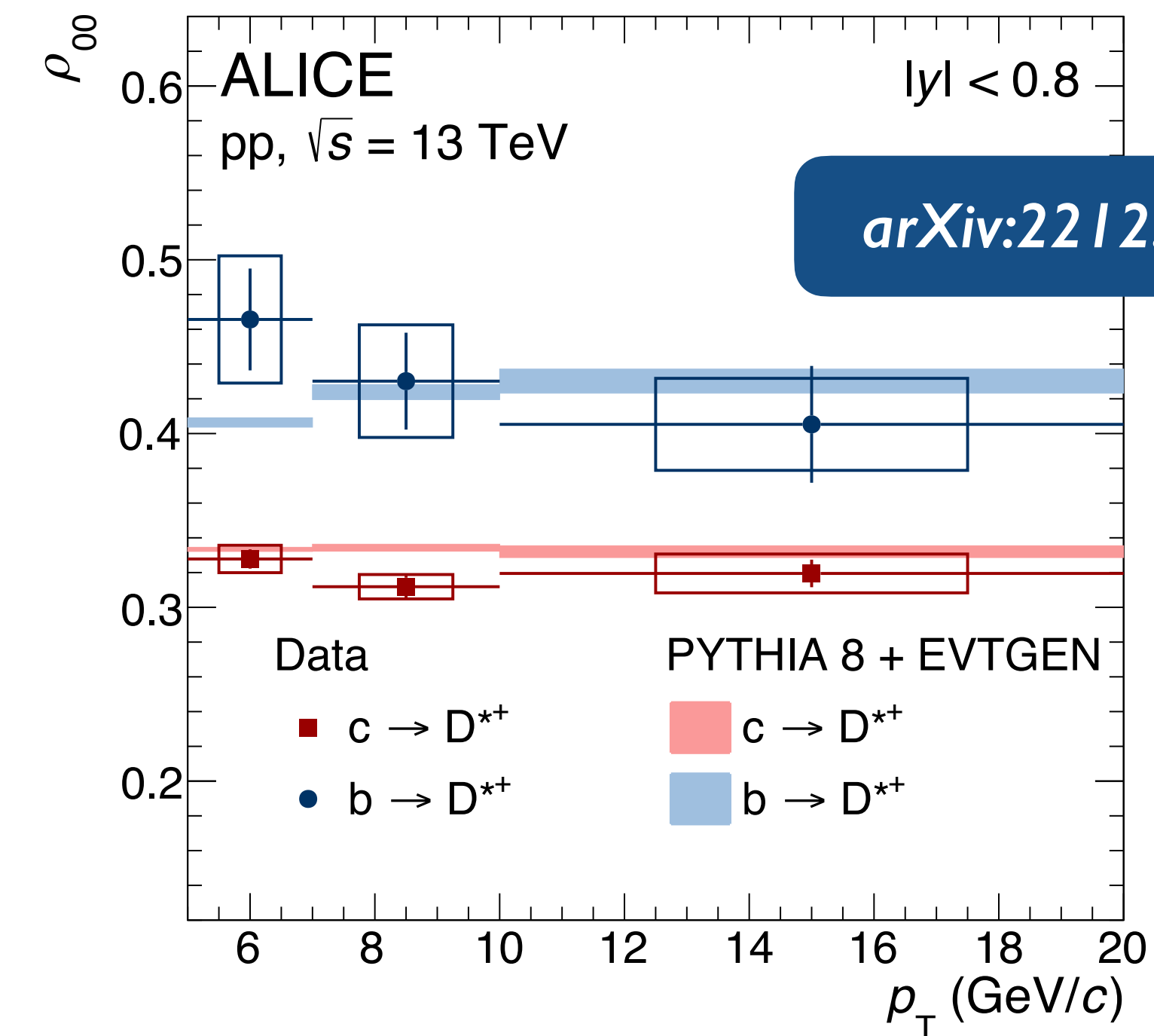
Andrea Ferrero
Thursday 9:00am



Evidence for non-zero polarization

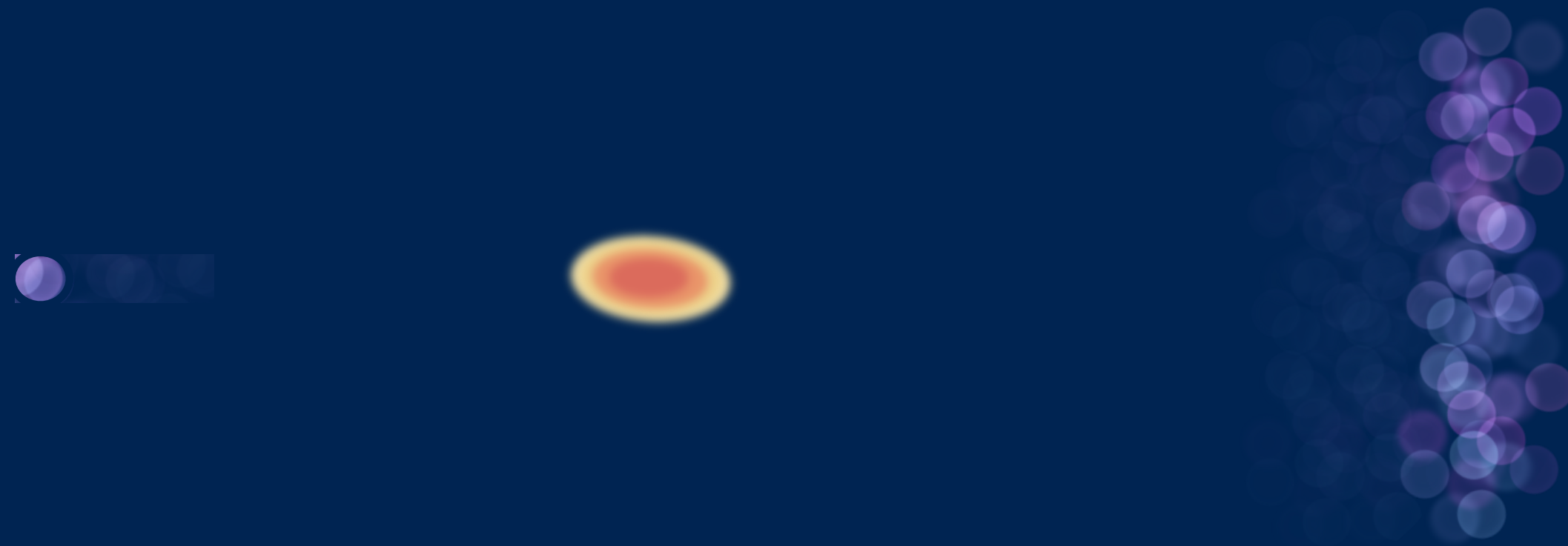
Non-prompt D^{*+}

Stefano Politano
Wednesday 10:00am



Spin alignment in pp baseline

Can we establish the limits of QGP formation by studying **small systems**?

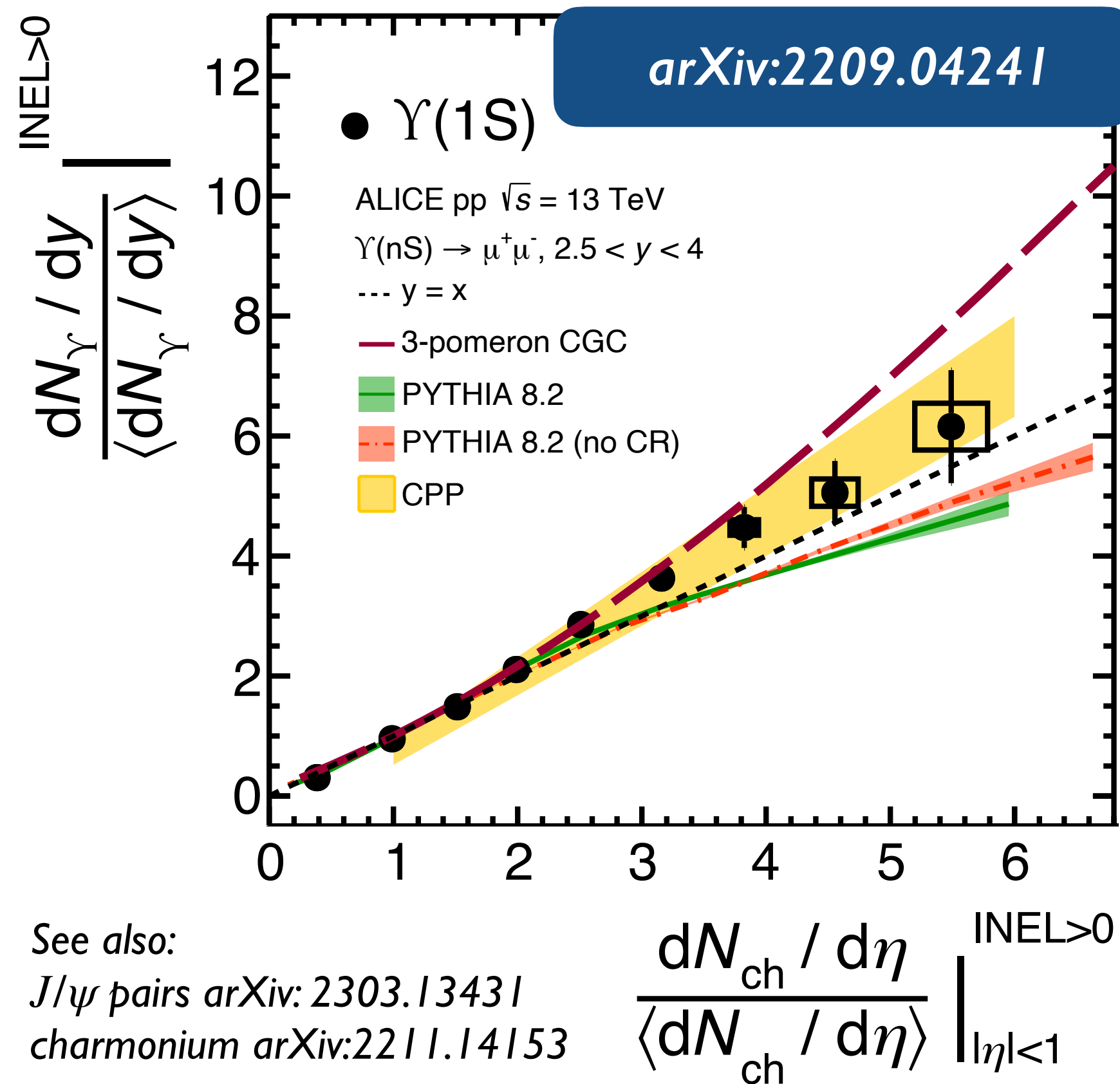


Quarkonia

Ailec de la Caridad Bell Hechavarria
Wednesday 11:30am

Poster: Tabea Maria Eder

Bottomonium at forward y



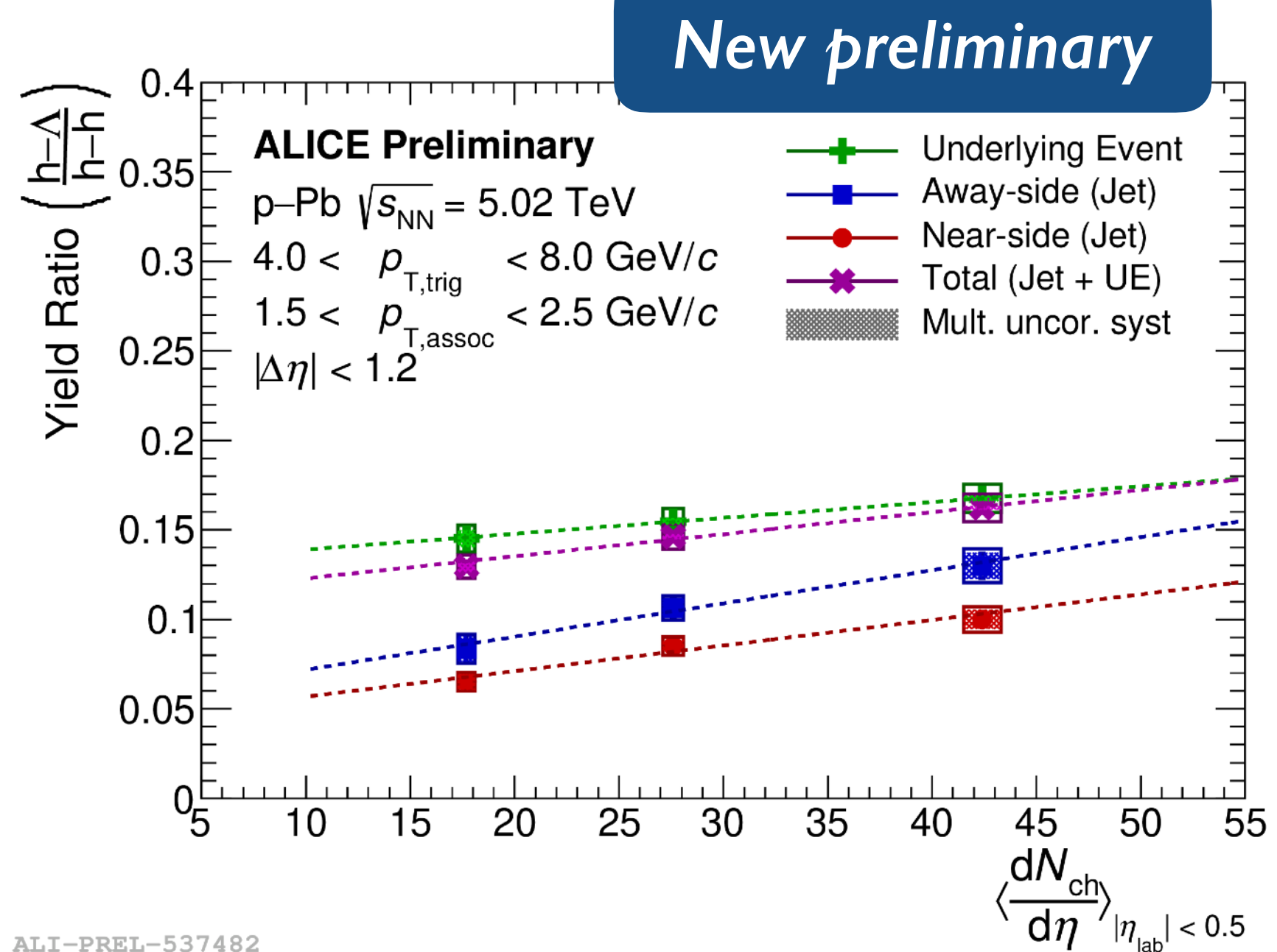
Strangeness

Ishaan Ahuja
Tuesday 9:00am

Ryan Hannigan
Tuesday 5:30pm

Poster: Mustafa Anaam

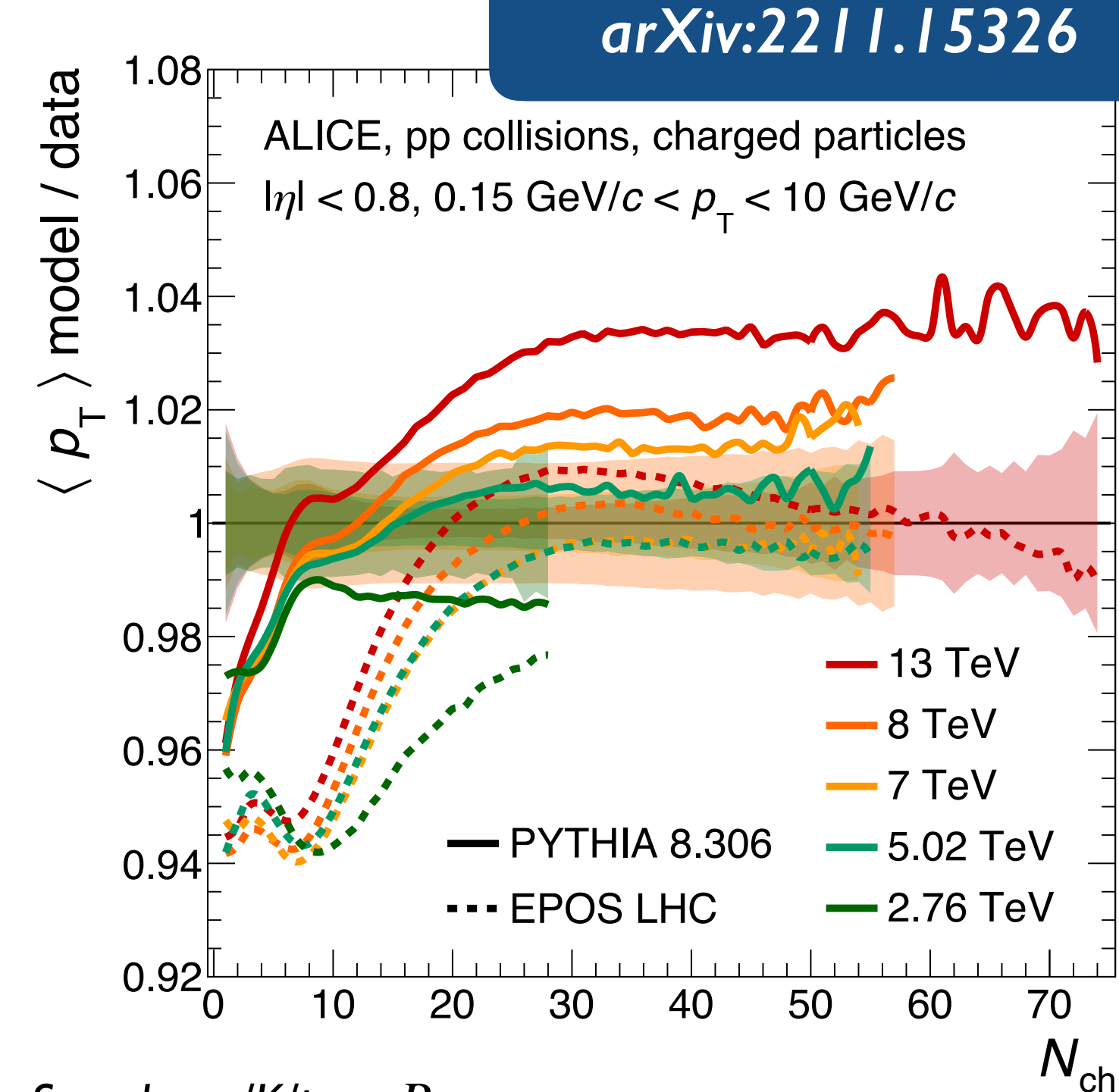
Strange-hadron correlations



Charged particles

Mario Krüger
Tuesday 9:20am

$\langle p_T \rangle, \sigma(p_T)$ vs. N_{ch}

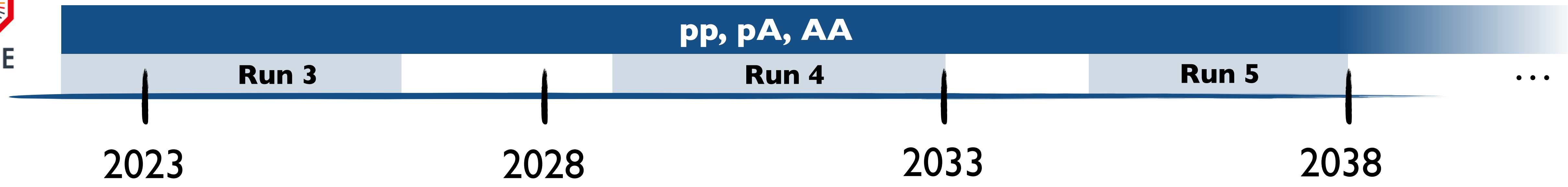


See also: $\pi/K/p$ vs. R_T
 arXiv:2301.10120

The Future



ALICE





pp, pA, AA

Run 3

Run 4

Run 5

2023

2028

2033

2038

...

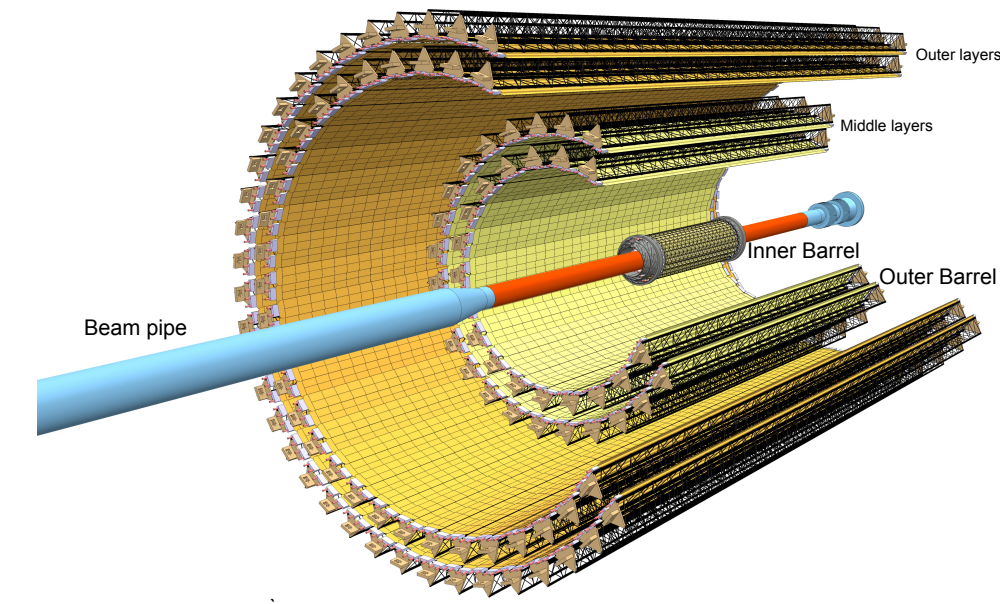
New data: opportunities to study hard probes with ALICE 2

Increased rate capability by 50x

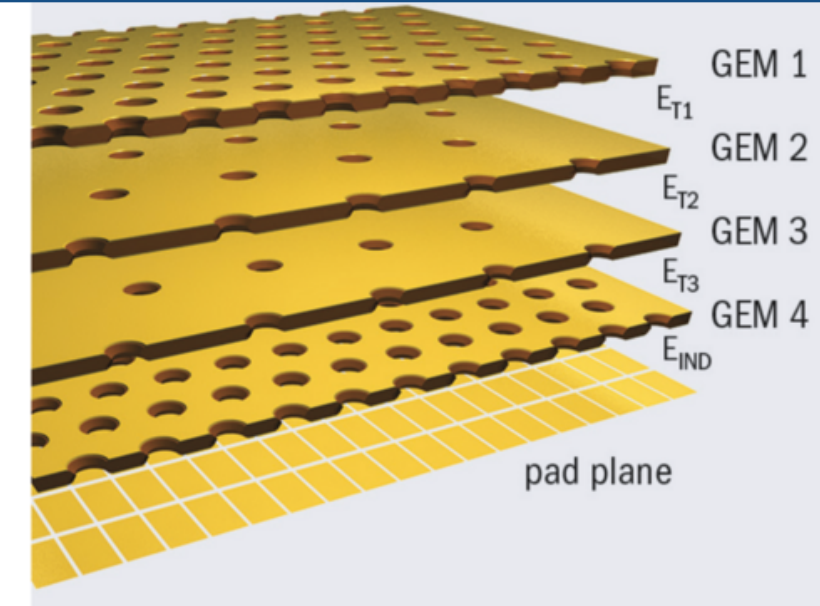
Improved vertex precision by 3-6x

arXiv:2302.01238

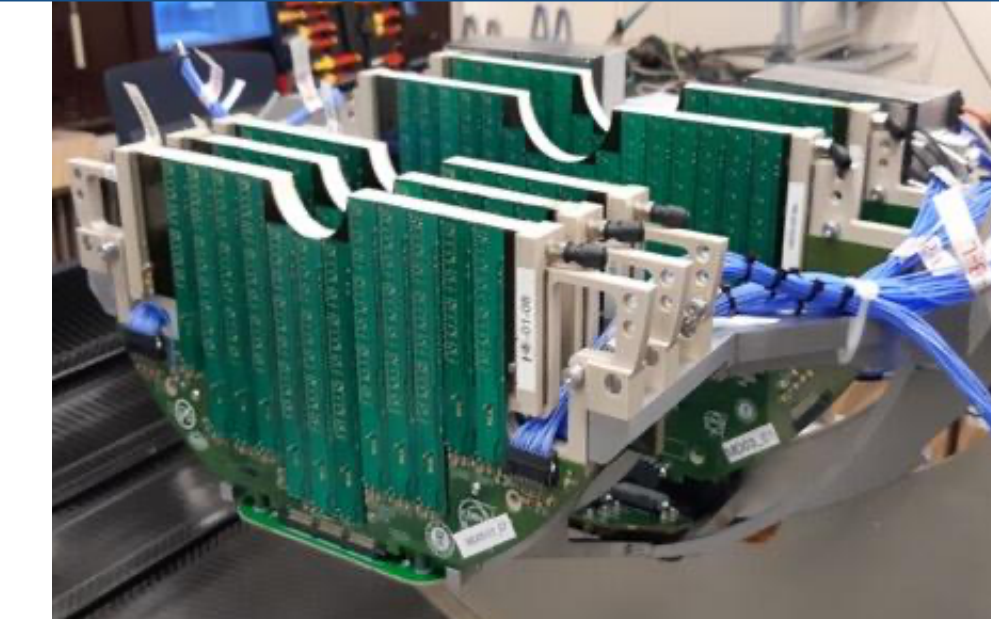
Inner Tracking System



Time Projection Chamber



Muon Forward Tracker



...

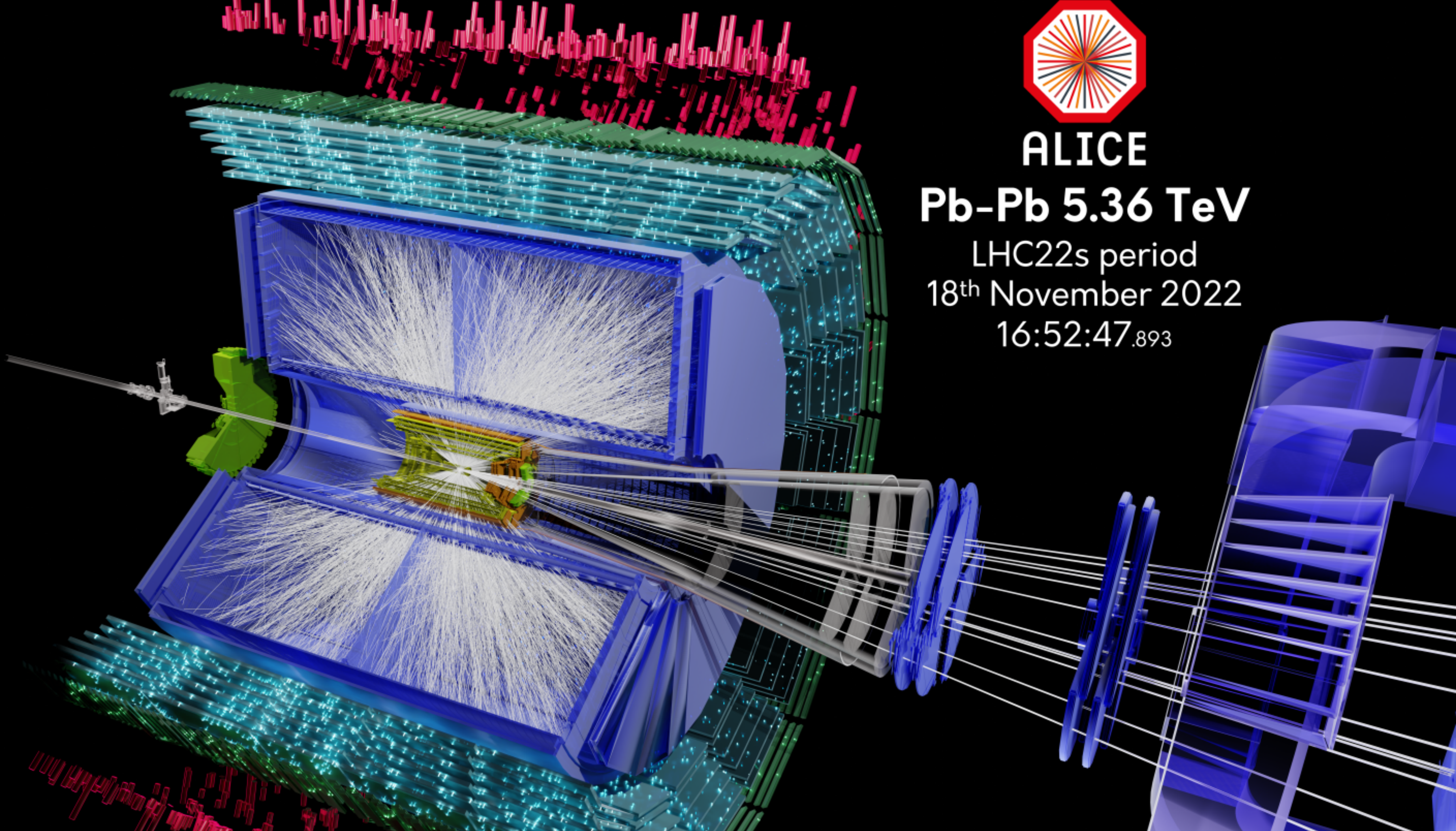


ALICE

Pb-Pb 5.36 TeV

LHC22s period
18th November 2022

16:52:47.893





ALICE

pp, pA, AA

Run 3

Run 4

Run 5

...

2023

2028

2033

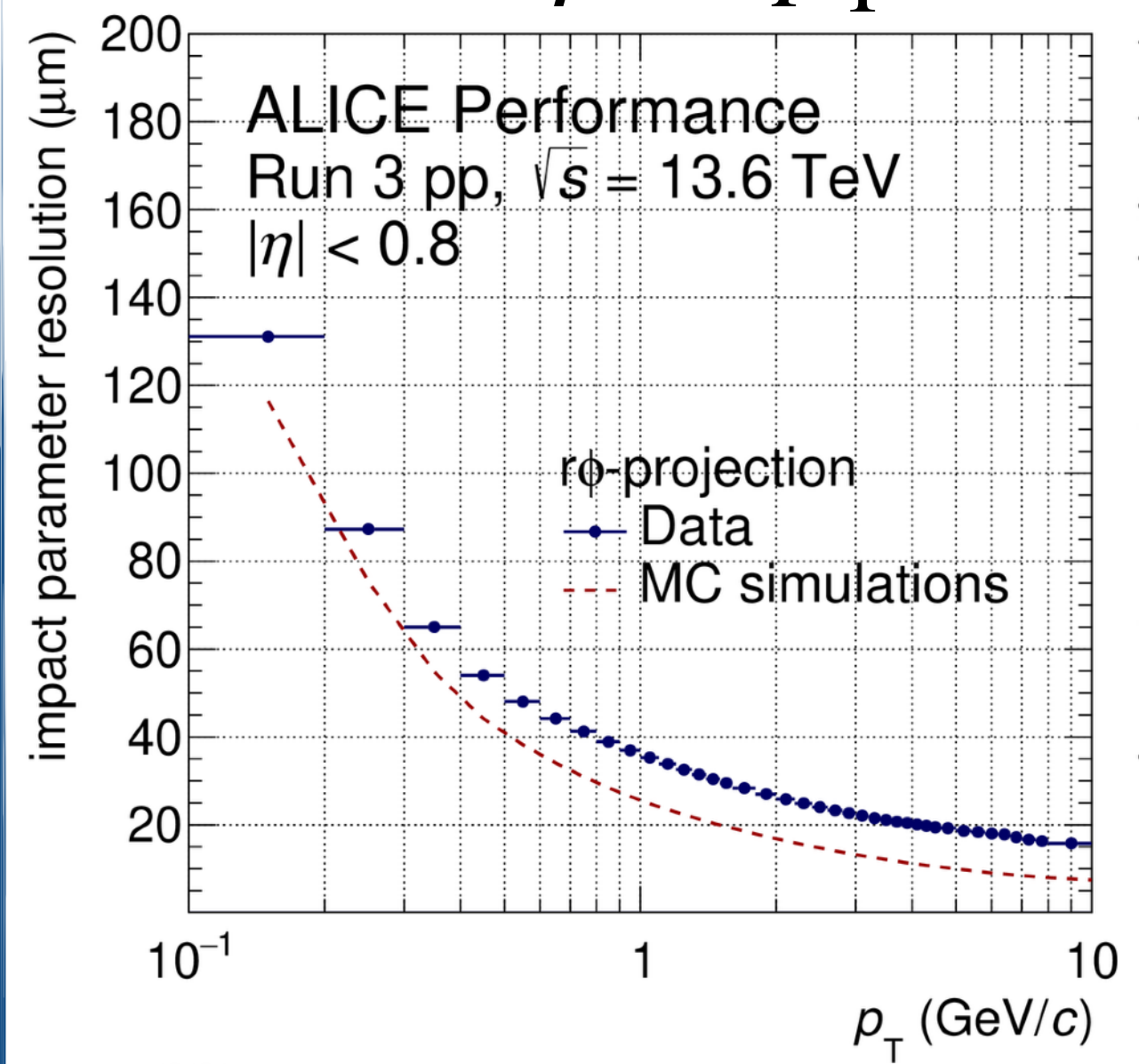
2038

Impact parameter resolution

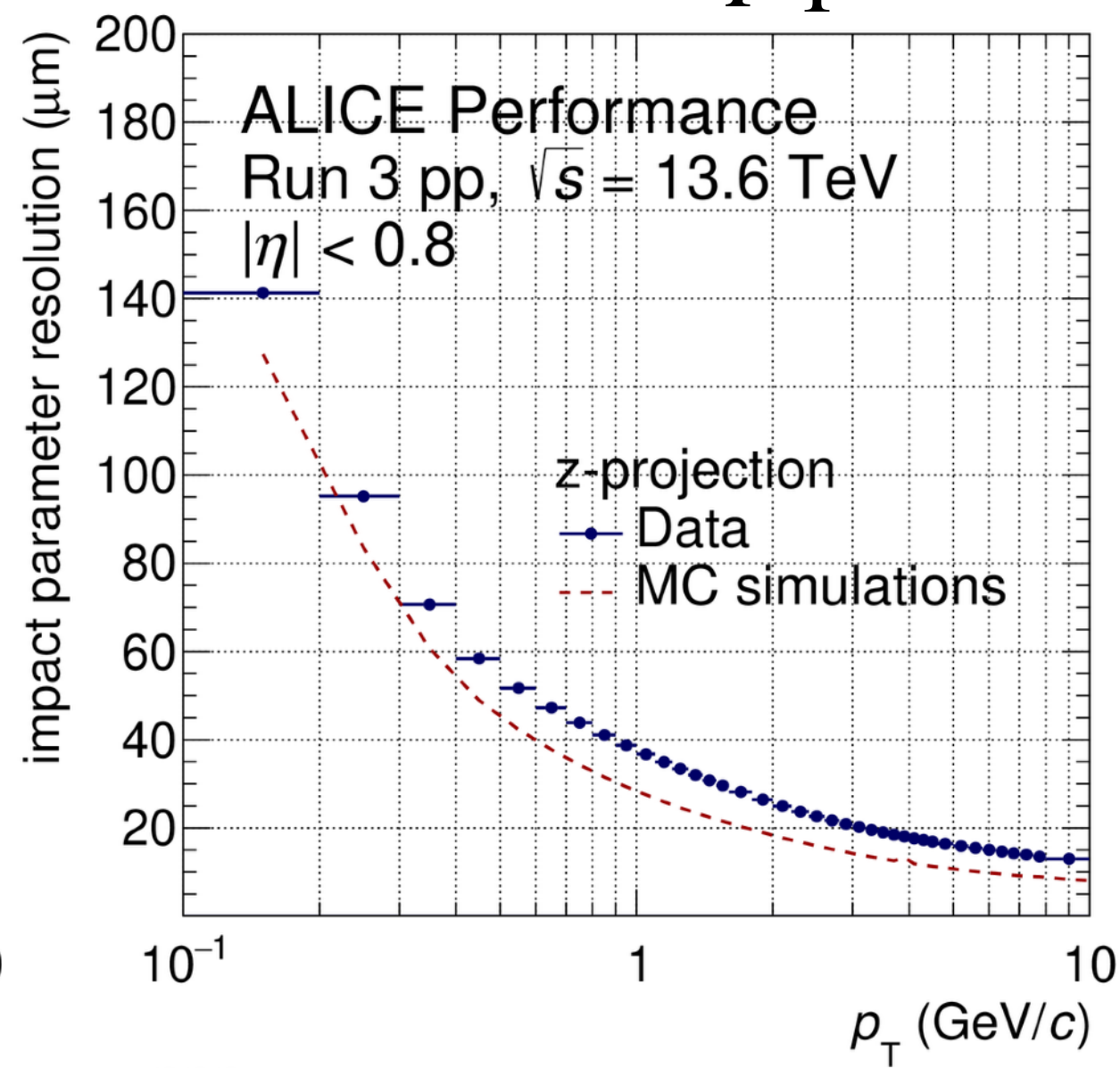
Partial calibration and alignment

$r - \phi$ vs. p_T

z vs. p_T

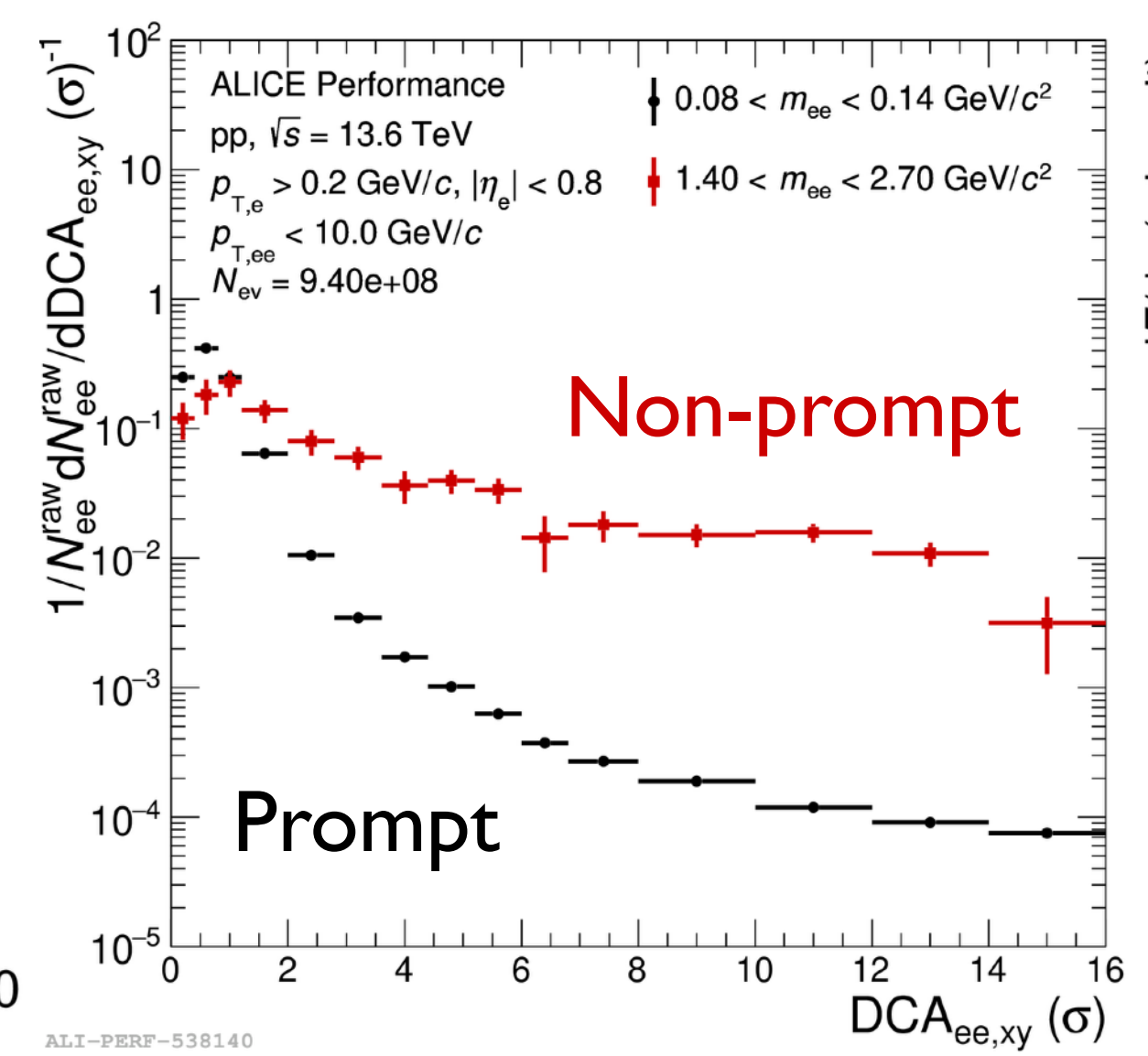


ALI-PERF-535955



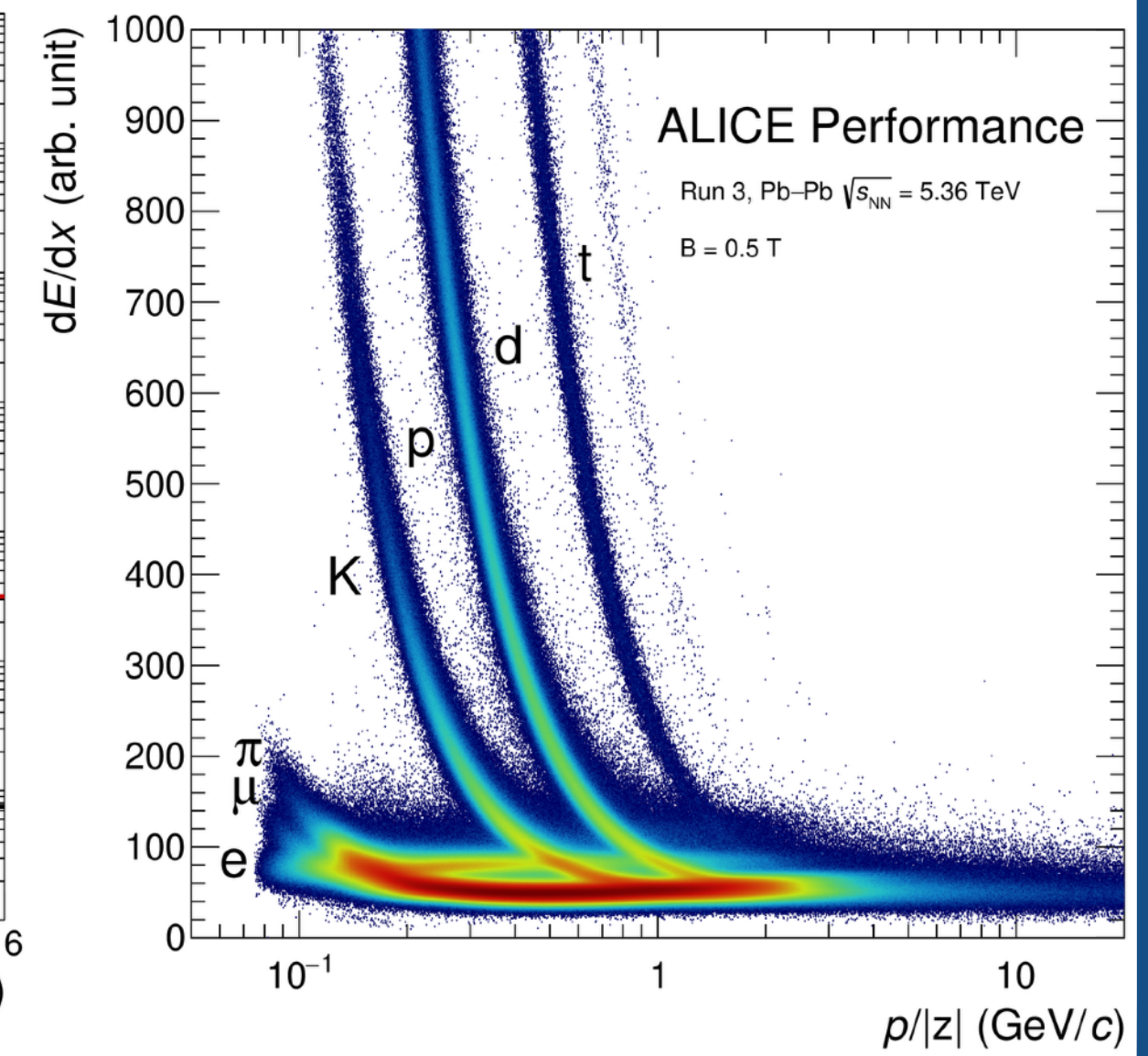
ALI-PERF-535959

Di-electron separation



ALI-PERF-538140

TPC dE/dx



ALI-PERF-529714

Successful commissioning and data-taking in pp collisions and Pb-Pb test run



ALICE

pp, pA, AA

Run 3

Run 4

Run 5

2023

2028

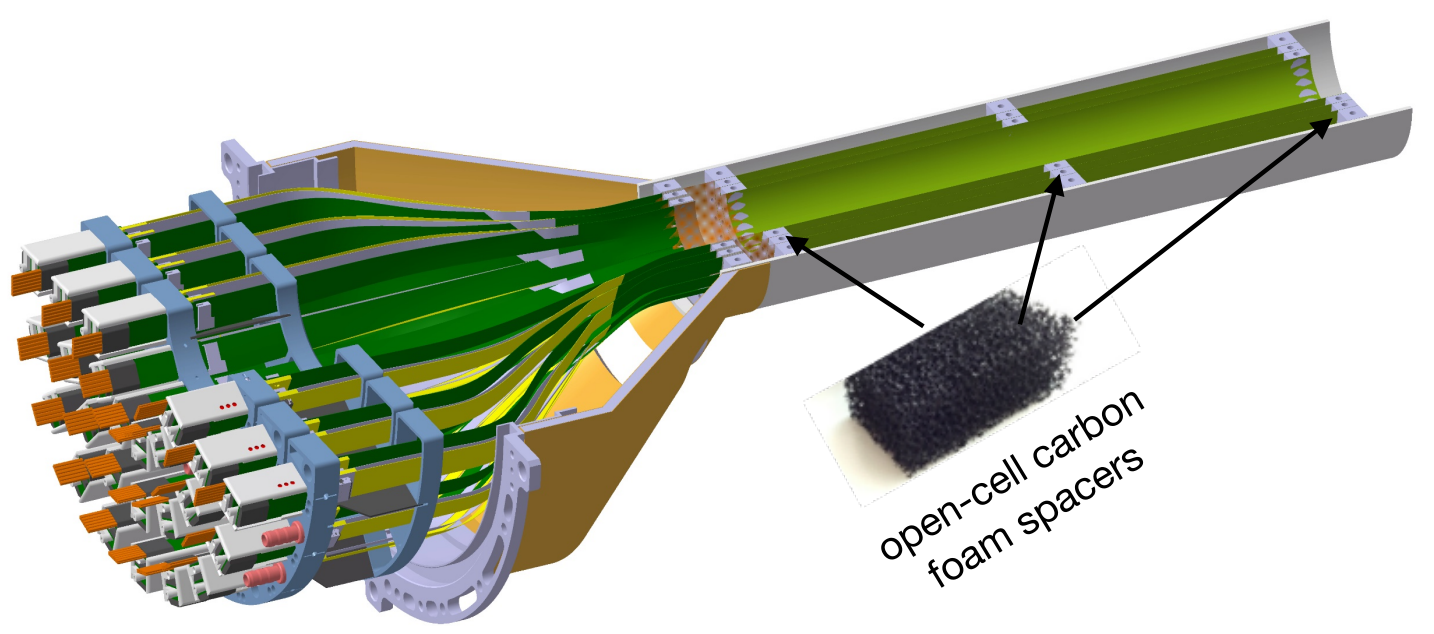
2033

2038

...

ITS 3

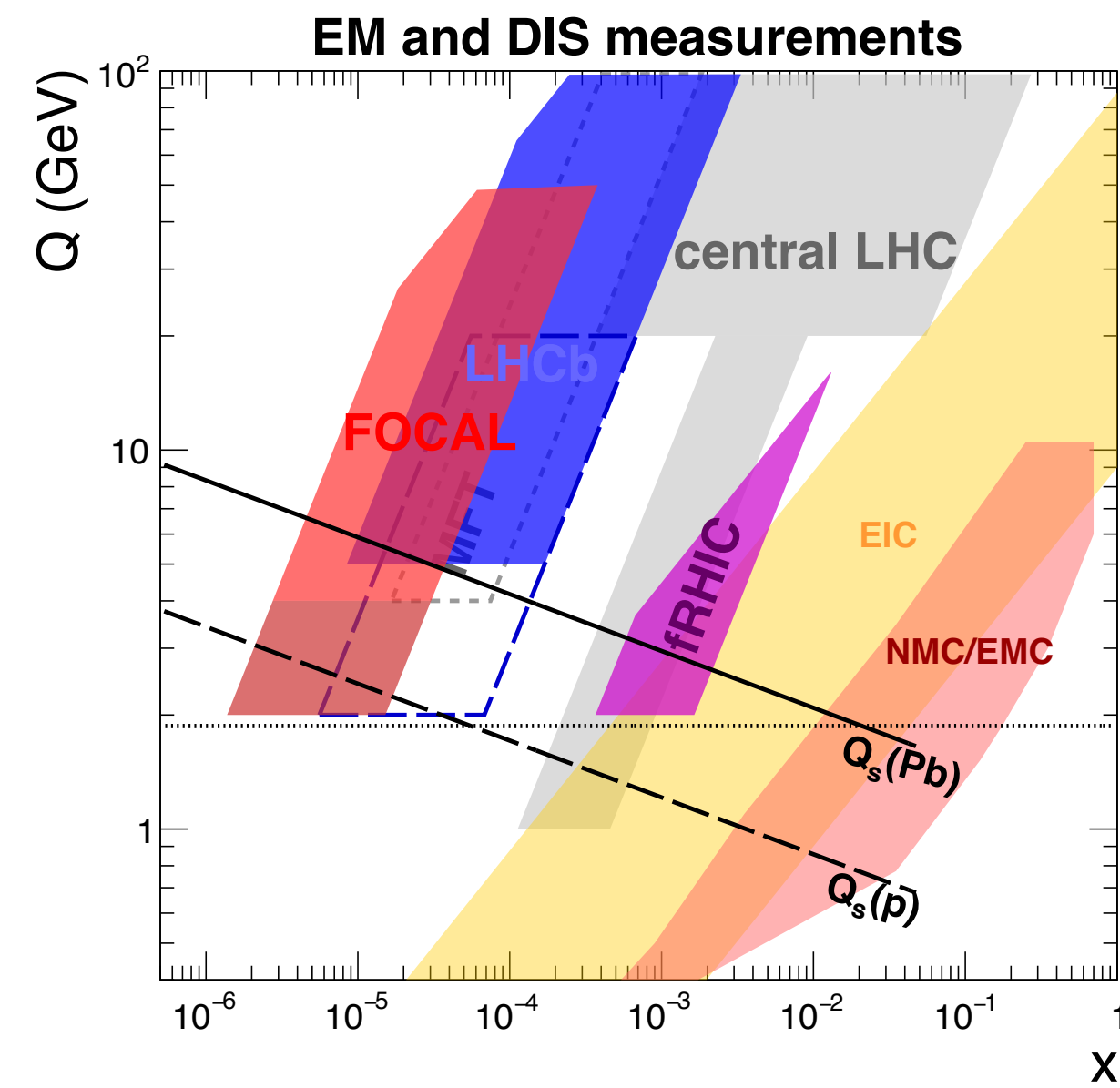
Jory Sonneveld
Tuesday 3:40pm



Ultra-thin cylindrical silicon for inner tracking layers

FOCAL

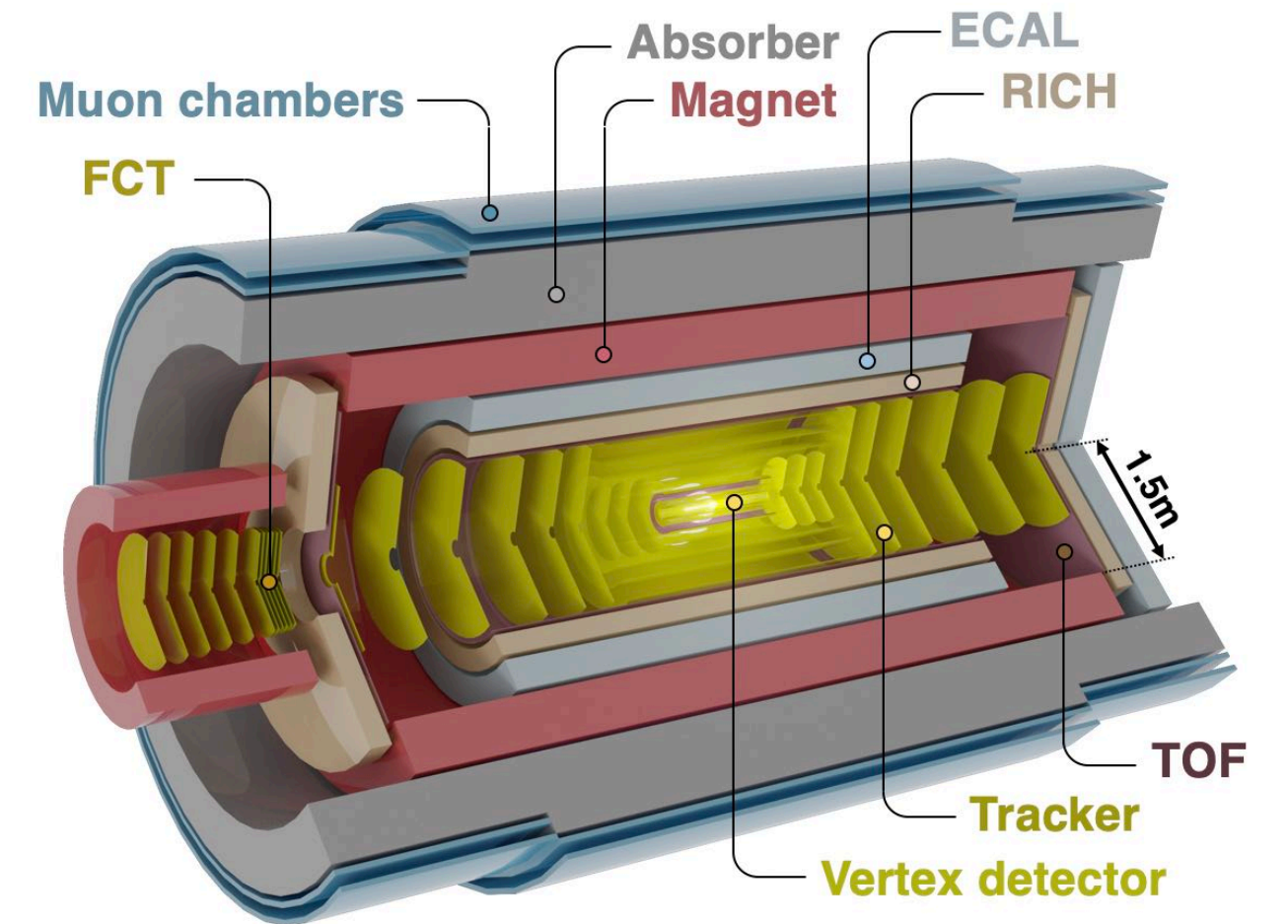
Tatsuya Chujo
Tuesday 3:20pm



Forward calorimeter: non-linear evolution of gluon density at low-x

ALICE 3

Alessandro Grelli
Tuesday 2:20pm



arXiv:2211.02491

Multi-HF hadrons, soft photons, low-mass dileptons, and more

Jets

Transverse momentum (j_T) distributions of charged-particle jet fragments in pp collisions at $\sqrt{s} = 5.02$ TeV, **Jaehyeok Ryu**
Multiplicity dependence of charged-particle jet properties in pp and p-Pb collisions, **Debjani Banerjee, Reynier Cruz-Torres**

HF

Non-prompt D^0 production in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, **Mingyu Zhang**
 Ξ_c^0 via the semileptonic decay channel in pp collisions and in p-Pb collisions, **Sanghoon Lim**
Open heavy-flavour production from the high mass dilepton spectrum in pp collisions at $\sqrt{s} = 13$ TeV, **Michele Pennisi**

Quarkonia

Quarkonium production and flow in small systems, **Tabea Maria Eder**

EM

First results of dielectron analyses in Run 3, **Florian Eisenhut**
Topological separation of dielectron signals in Pb-Pb collisions, **Jerome Jung**
Neutral meson production as a function of multiplicity in pp collisions at $\sqrt{s} = 13$ TeV, **Joshua Koenig**
 $\pi^+\pi^-$ and K^+K^- photoproduction in ultra-peripheral Pb-Pb collisions, **Minjung Kim**
 J/ψ photoproduction and exclusive dimuon production in p-Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV, **Michael Winn**

Strangeness

Particle yield modification in jet-like azimuthal V^0 -hadron correlations in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, **Mustafa Anaam**

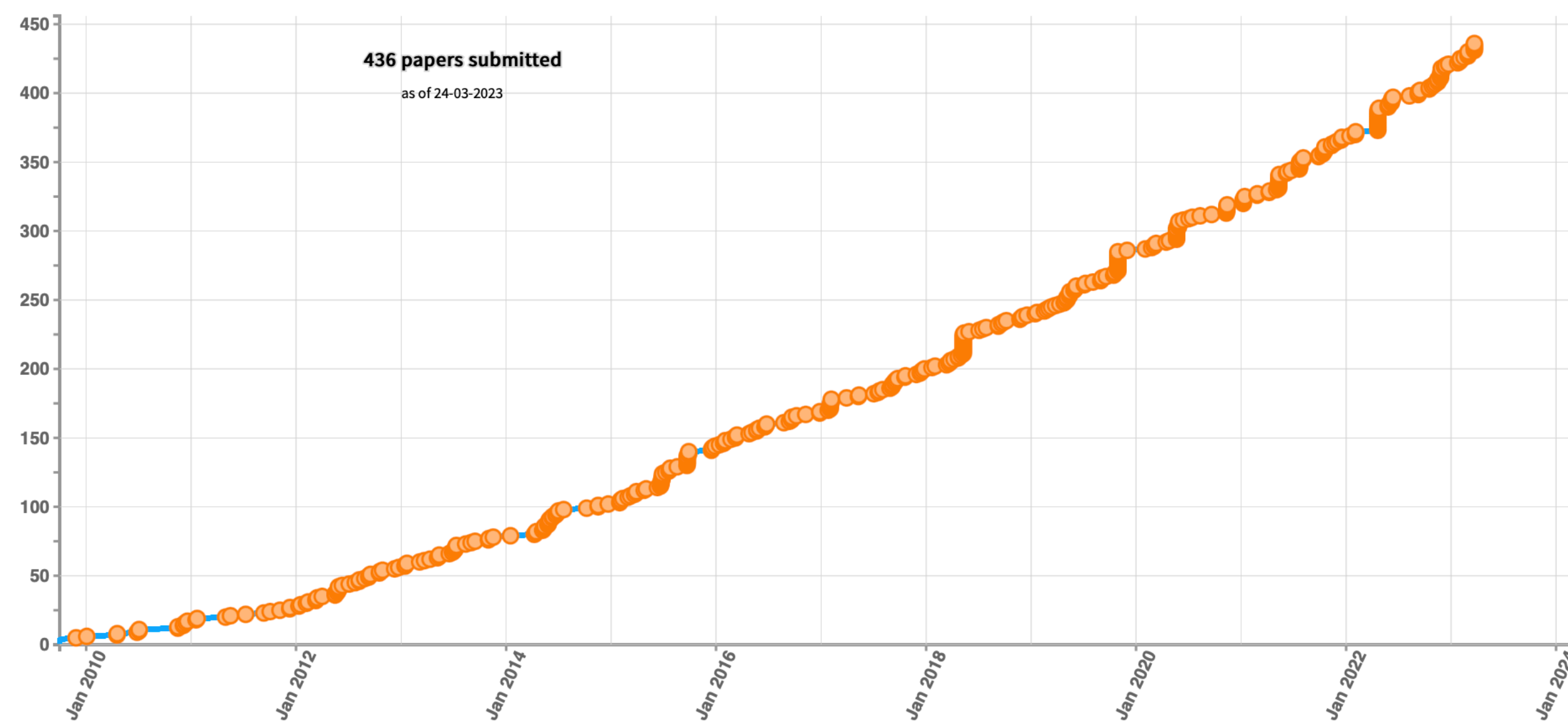
Resonances

ω meson production in pp and p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, **Nicolas Strangmann**
 ω mesons in pp collisions at $\sqrt{s} = 13$ TeV, **Jens Robert Lühder**

ALICE results

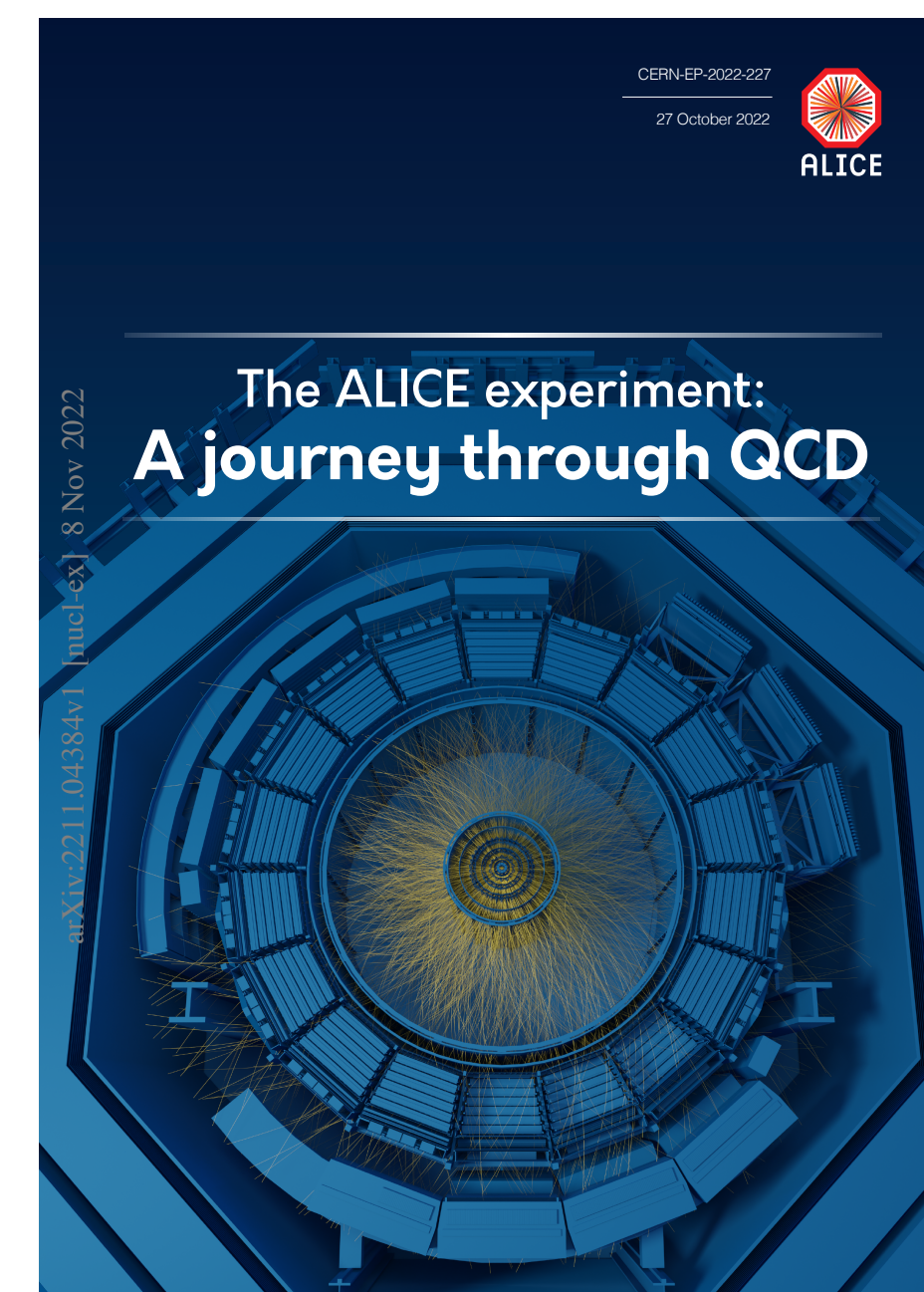
Publications

alice-publications.web.cern.ch



ALICE Review Paper

[arXiv:2211.04384](https://arxiv.org/abs/2211.04384)



Preliminary results

alice-figure.web.cern.ch

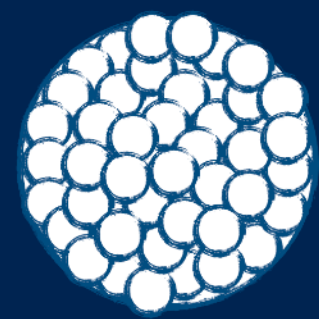
Summary



Novel jet observables

Heavy flavor hadronization

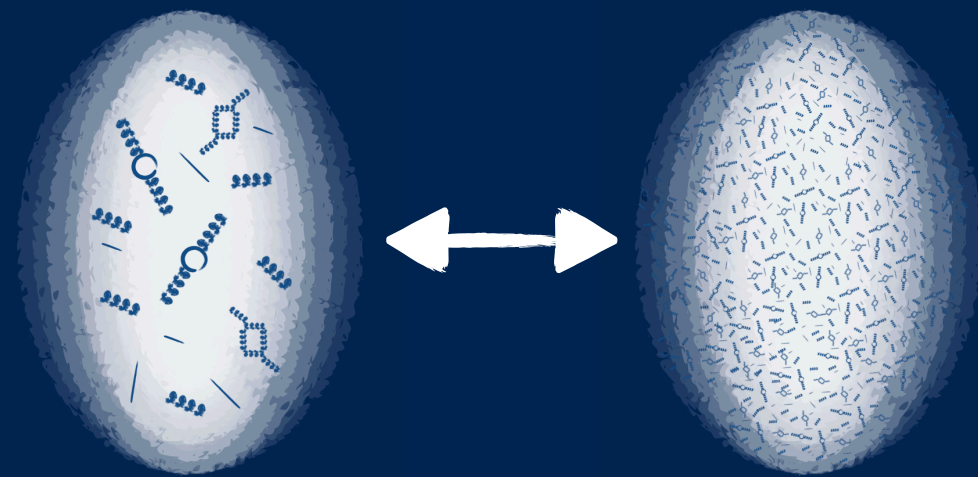
Identified particles in jets



γ, W in p-Pb collisions
 J/ψ in γA collisions



low- x content of nucleus



Microscopic:
jets, HF, quarkonium

Macroscopic:
 $T, B, vorticity$

New clues to understand many-body dynamics of QCD