Exploring the boundaries between HEP and HIP with jets
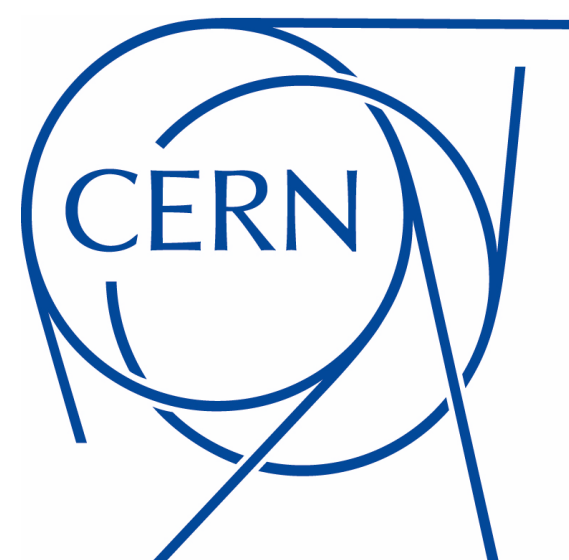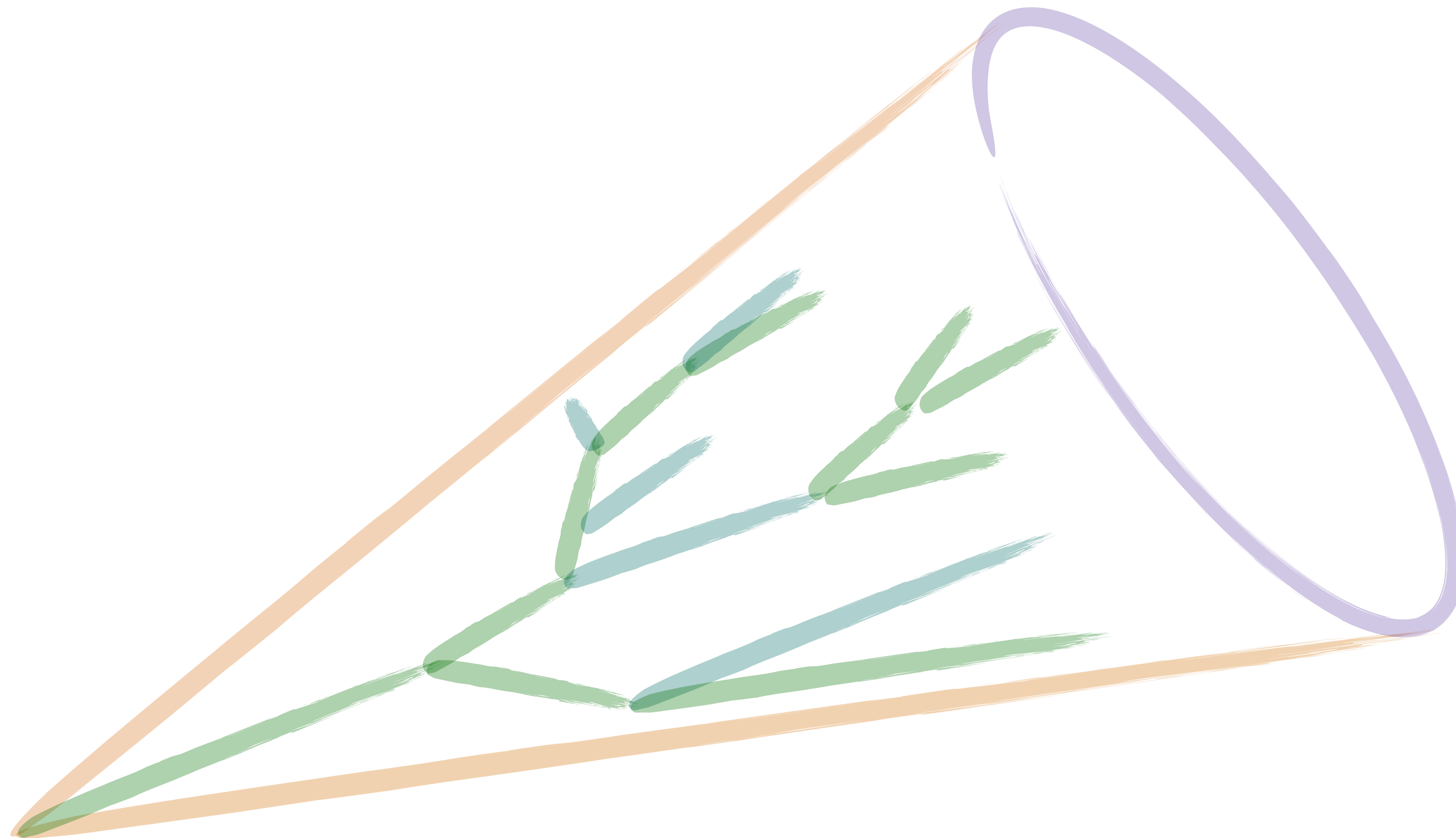
Alba Soto-Ontoso

CERN TH retreat

Les Houches, 7th November, 2022

My research worldline

Sep 2010-June 2015,   **BSc. + MS.c Physics** @University of Sevilla + Granada (Spain)

Sep 2015-June 2018,   **Ph.D** @University of Granada (Spain) + Goethe University (Germany) w/ Javier L. Albacete and Hannah Elfner

Oct 2018-Oct 2020,   **Research Associate** @Brookhaven National Lab (USA) w/ Yacine Mehtar-Tani

Oct 2020-Oct 2022,   **Postdoc** @Institute de Physique Theorique (France) w/ Gregory Soyez

Oct 2022-present,   **Senior fellow** @CERN (Switzerland)

Research interests in a nutshell

Small-x regime

Hints of saturation at LHC energies and cosmic rays

1505.06583
2112.04611

Jets in pp and AA

Jet substructure modifications in the QGP

1904.12815
1911.00375
2005.07584
2009.13667
2103.06566
2106.07402
2111.14768
2205.02861
2210.07901

QCD

Hadronic structure

Proton/nuclear structure pheno impact at colliders

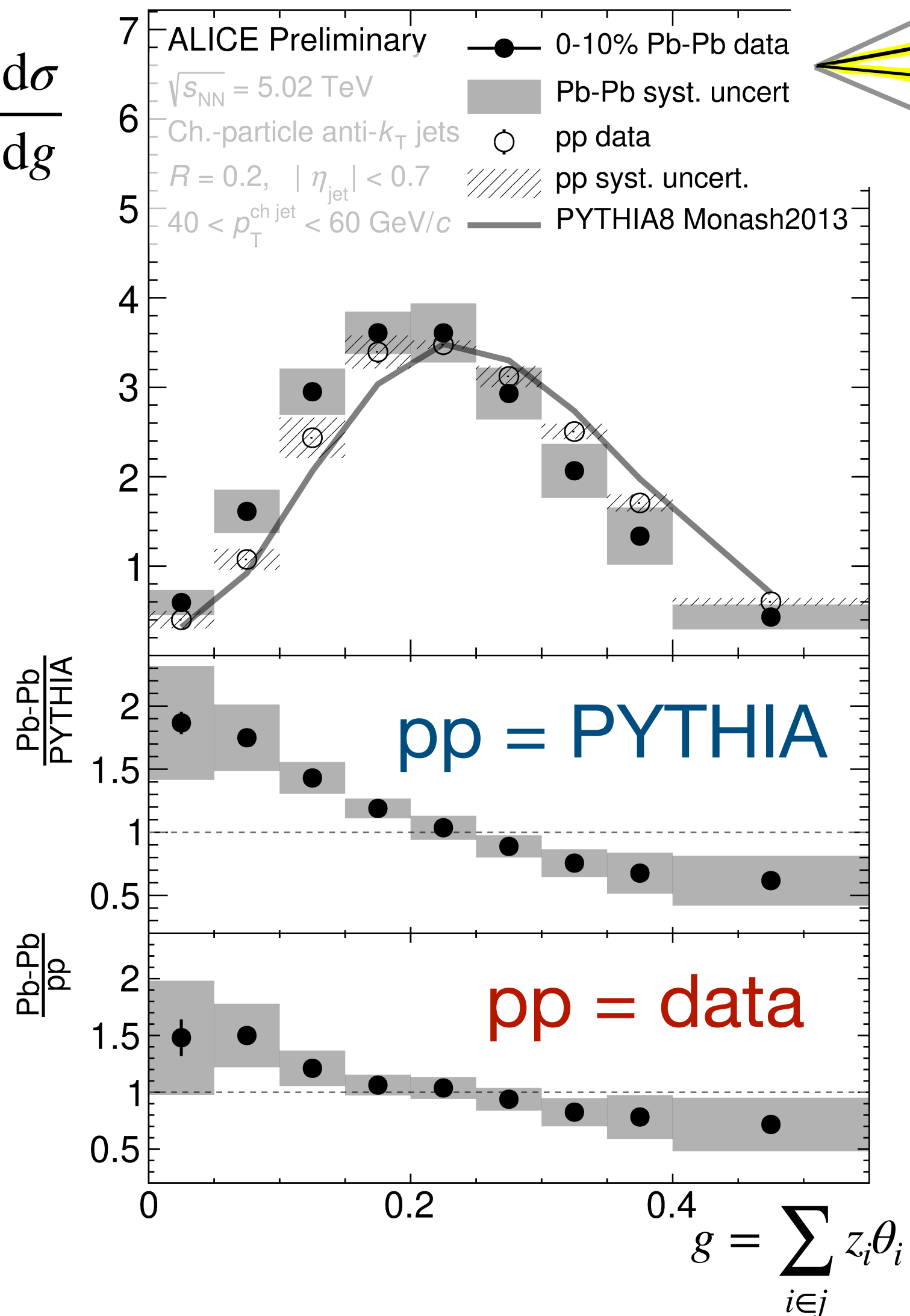1605.09176
1612.06274
1707.05592
1908.10231

Parton showers

PanScales project

2205.02237
2207.09467

ALICE Preliminary
pp $\sqrt{s} = 5.02$ TeV
Charged jets   anti-k_{T}
$R = 0.4$ $|\eta_{\mathrm{jet}}| < 0.5$
$60 < p_{\mathrm{T, ch\ jet}} < 80$ GeV/c

- Dynamical Grooming: $a = 0.1$
- Dynamical Grooming: $a = 1.0$
- Dynamical Grooming: $a = 2.0$
- Sys. uncertainty
- PYTHIA8 Monash 2013

ALICE Preliminary
pp $\sqrt{s} = 5.02$ TeV
Anti-k_{T} charged jets
$R = 0.4$, $|\eta_{\mathrm{jet}}| < 0.5$
$60 < p_{\mathrm{T,ch\ jet}}^{\mathrm{ch}} < 80$ GeV/c

- k_{T}Drop
- timeDrop
- Leading k_{T}
- Leading k_{T} $z > 0.2$

$k_t \sim z p_T \theta$

A precise vacuum benchmark is fundamental for any interpretation of Pb+Pb data

pp = data

$g = \sum_{i \in j} z_i \theta_i$

ALI−PREL−352108
ALI−PREL−503120

(3)

Jet substructure and resummation in heavy-ions: SoftDrop
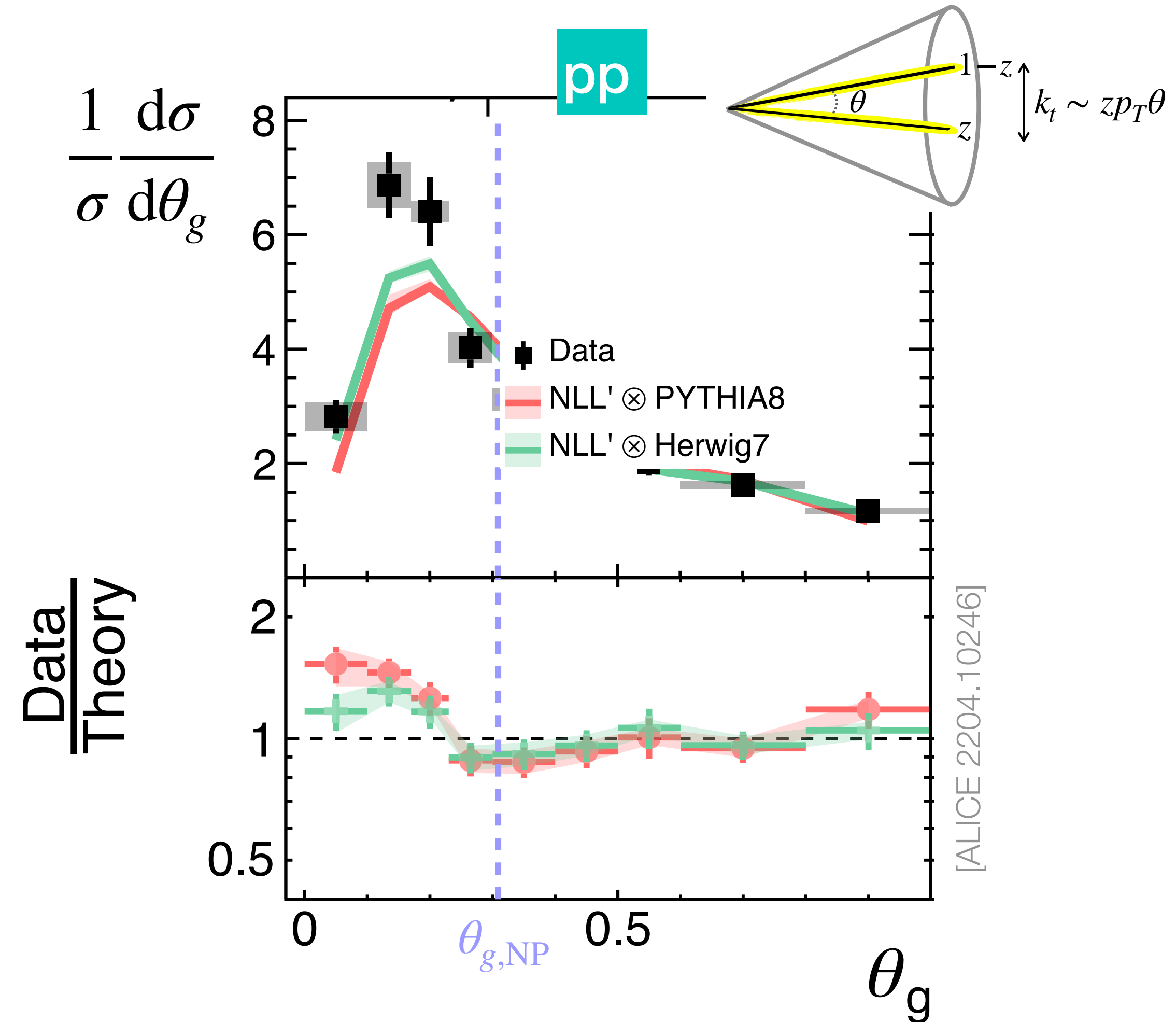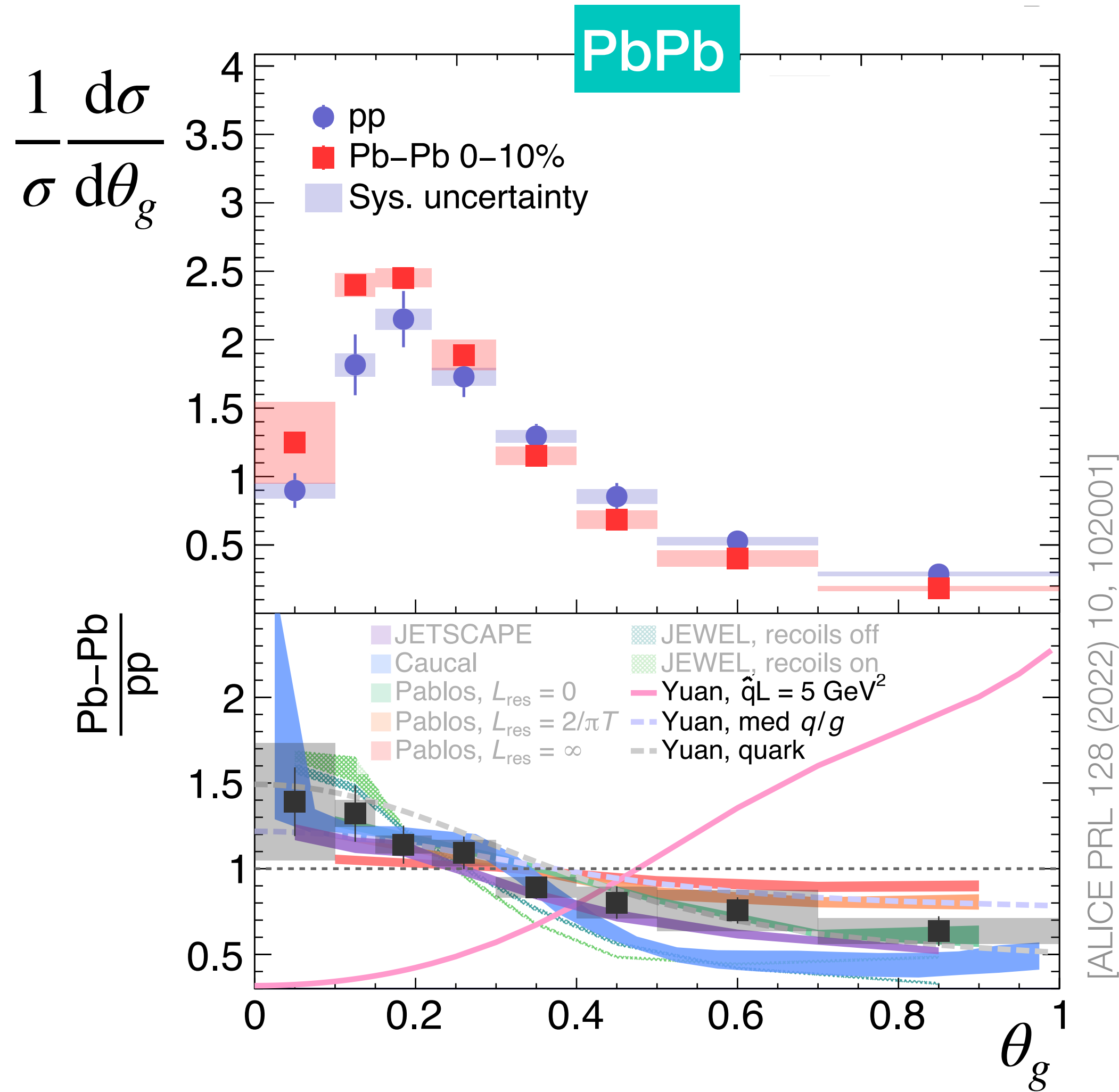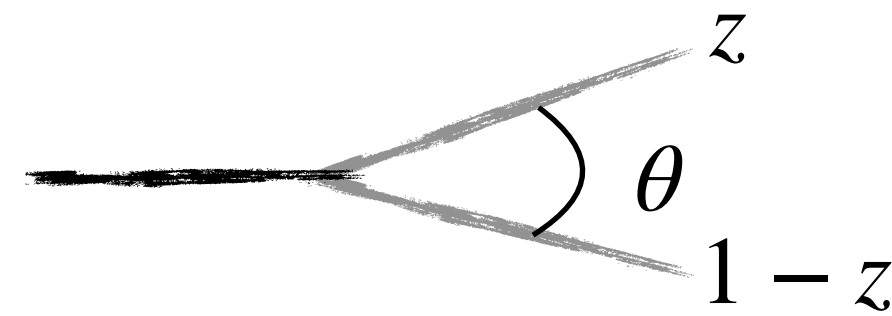

Jet substructure calculations in the medium are still in their infancy

4

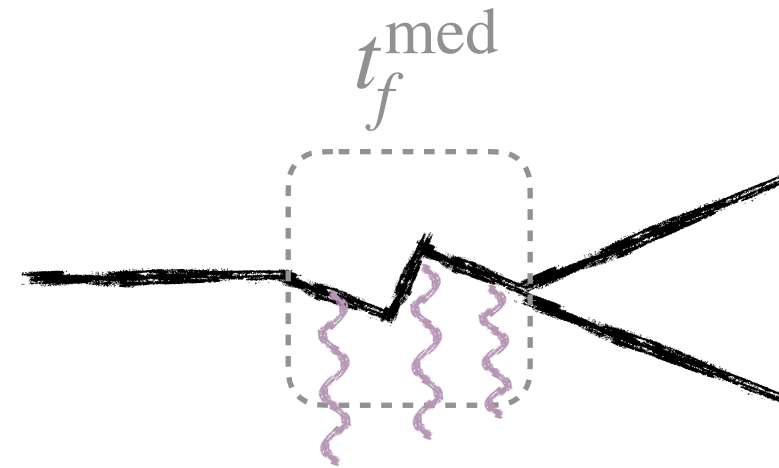# Where do we stand in our understanding of jet-QGP interactions?

Jet evolution in the medium is a multi-scale process: $Q, T, \lambda_{\text{QCD}}, \mu_D, \hat{q} \cdots$

vacuum splittings $t_f^{\text{vac}} \approx (z\theta^2)^{-1}$ $\quad \mathrm{d}P^{\text{vac}} = \dfrac{\alpha_s C_i}{2\pi} \dfrac{\mathrm{d}z}{z} \dfrac{\mathrm{d}\theta}{\theta}$

transverse momentum broadening $\langle k_{t,f} \rangle = \hat{q} t_f \rightarrow t_f^{\text{med}} = \sqrt{\dfrac{2\omega}{\hat{q}}}$

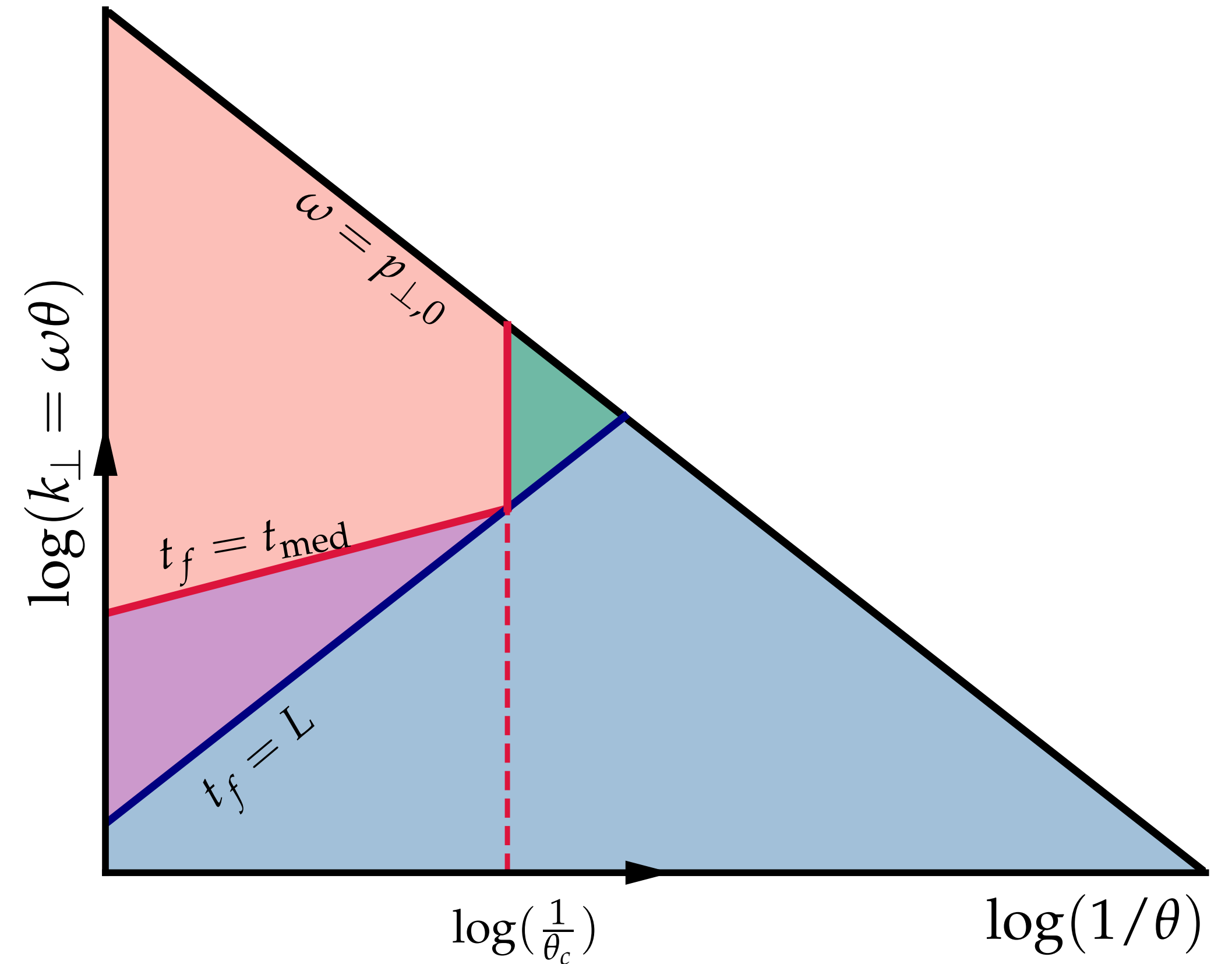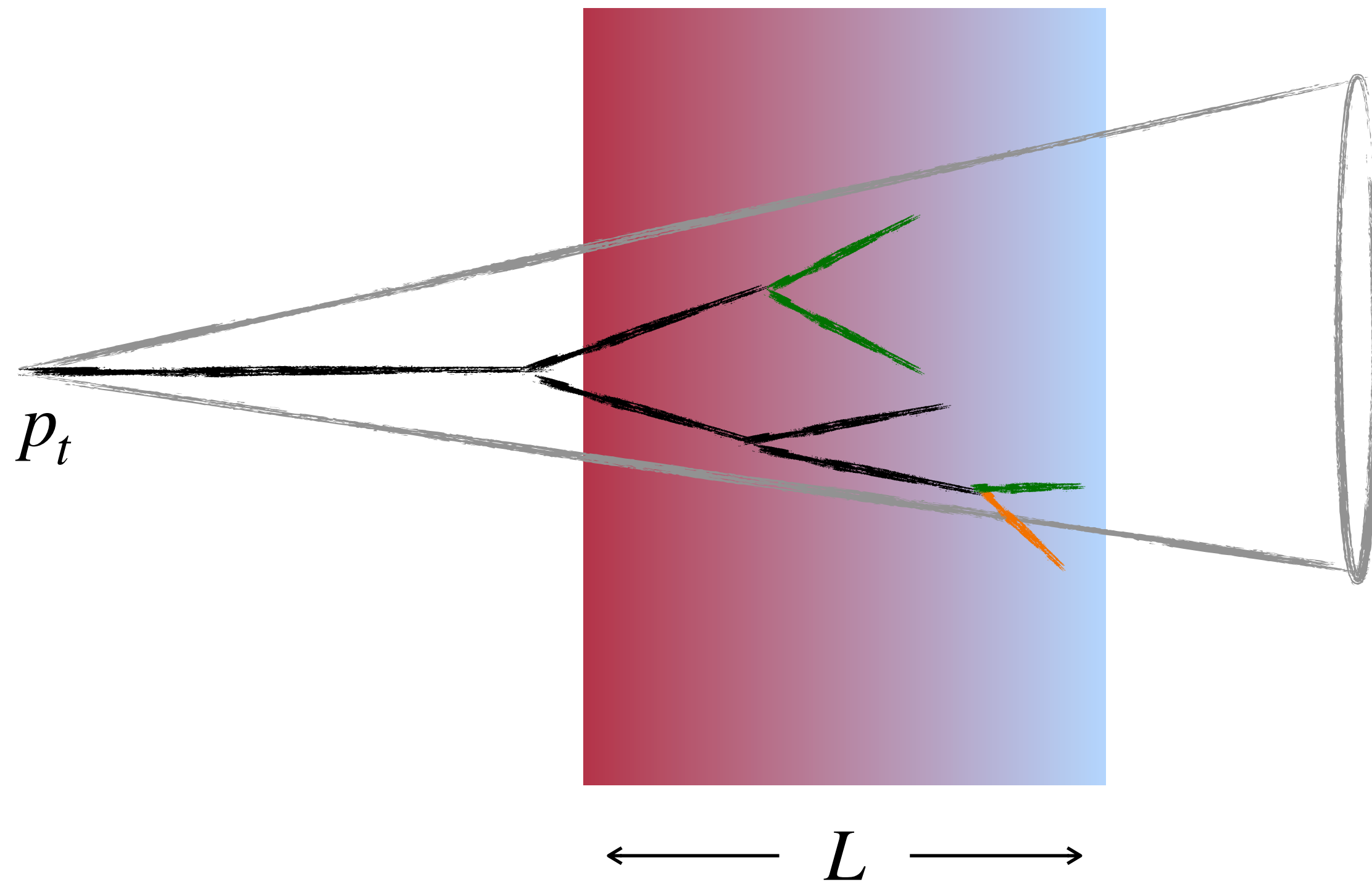At double-log accuracy, in-medium, vacuum-like emissions must satisfy
[Caucal et al. PRL 120 (2018) 232001]
[Expanding media: Caucal et al. JHEP 04 (2021) 209]

$$\boxed{t_f \ll t_f^{\text{med}}}$$

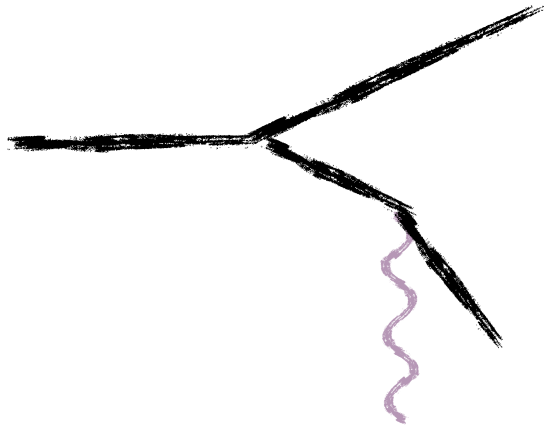How can we test this (DLA) description of the in-medium jet evolution?

1 Extend pp ideas to a heavy-ion context

[Mehtar-Tani, ASO, Tywoniuk PRD 101 (2020) 3, 034004]

Find hardest splitting in the jet
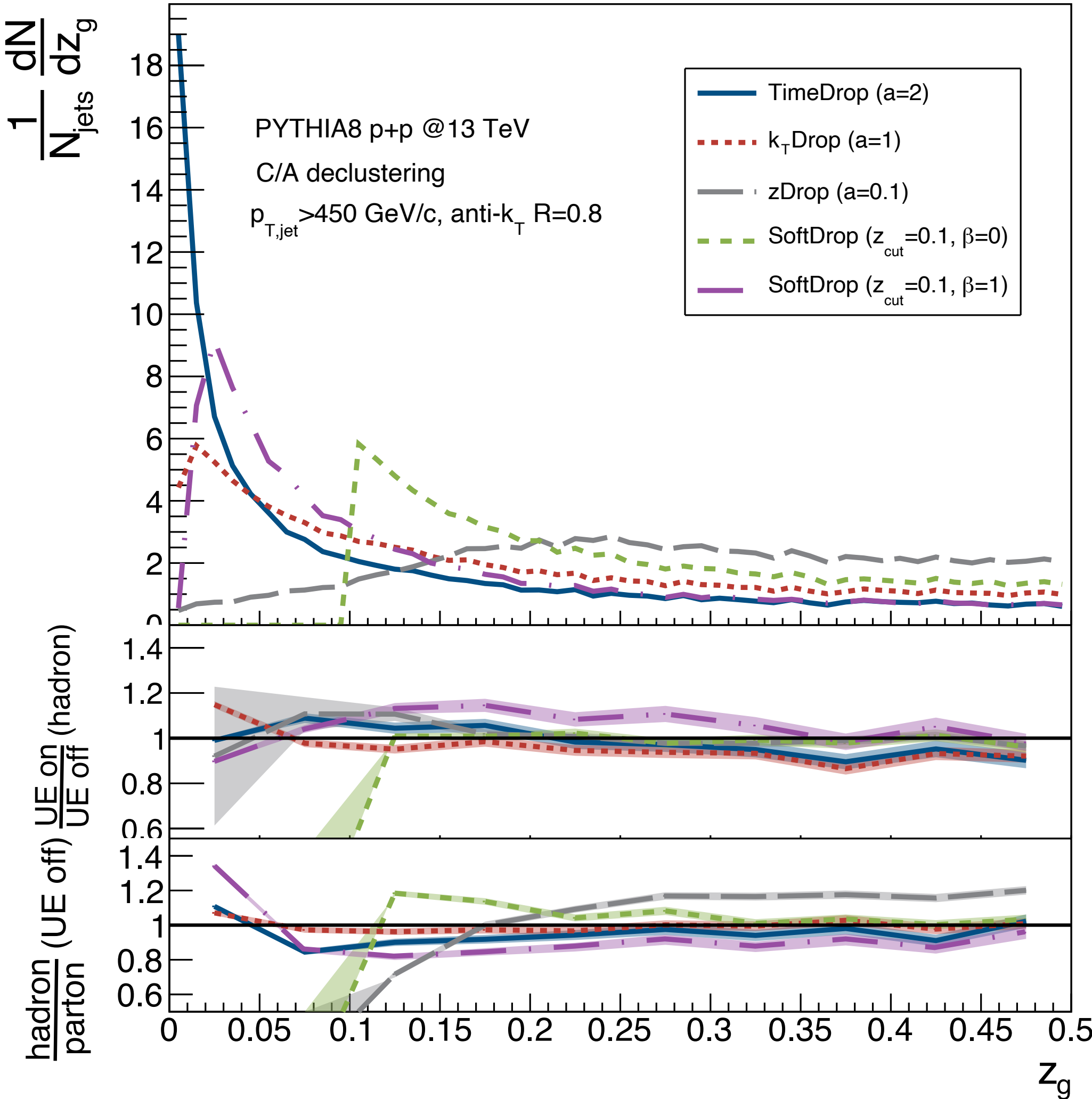
$$\kappa^{(a)} = \frac{1}{p_T} \max_{i \in C/A} z_i(1 - z_i)p_{T,i}(\theta_i/R)^a$$

e.g. $a = 1 \to$ largest-k_t

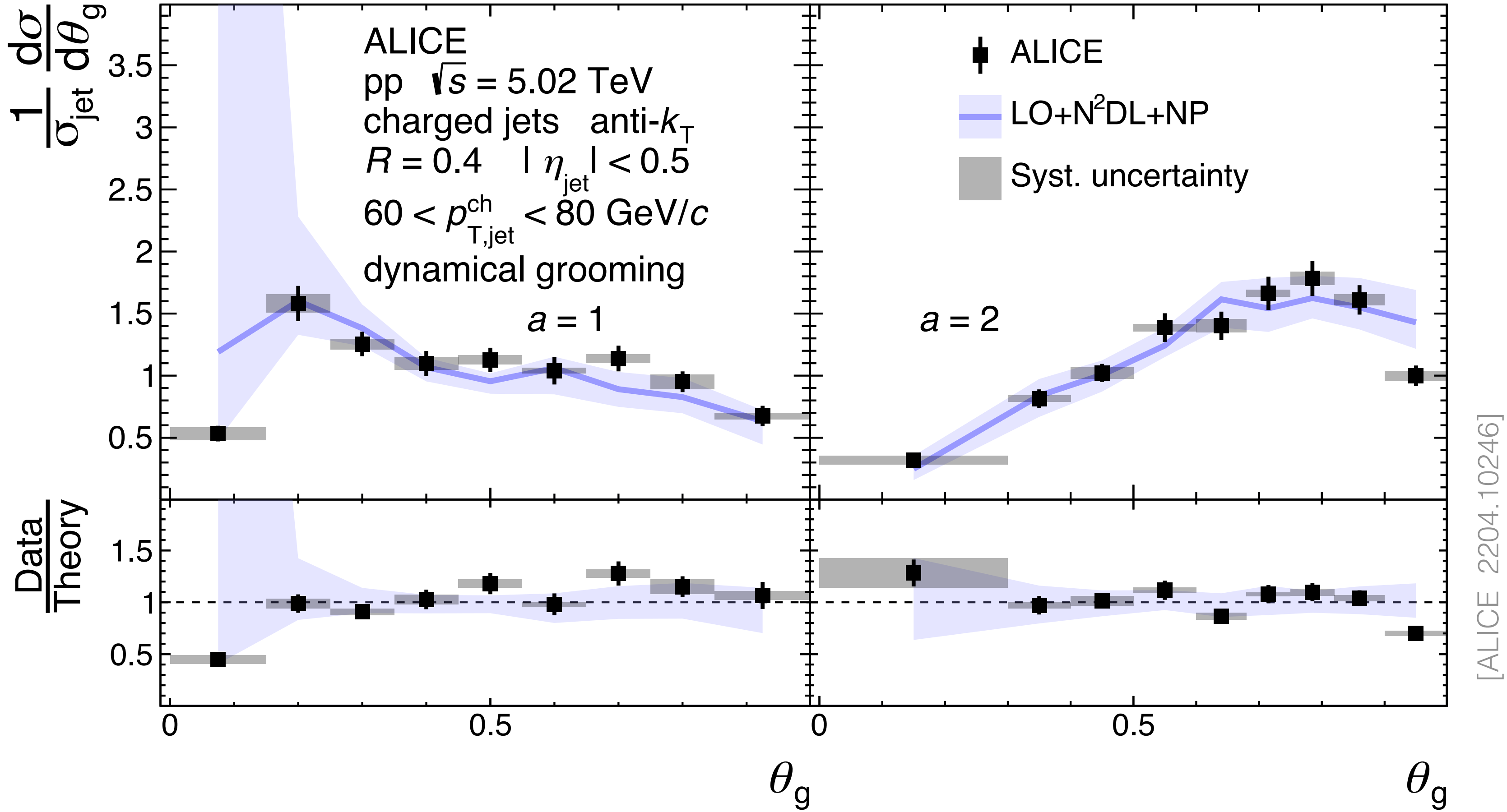$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}k_{t,g}} \propto k_t^{-4}$$

search for Molière scattering

PYTHIA8 p+p @13 TeV
C/A declustering
$p_{T,jet} > 450$ GeV/c, anti-k_T R=0.8

TimeDrop (a=2)
k_TDrop (a=1)
zDrop (a=0.1)
SoftDrop (z_{cut}=0.1, β=0)
SoftDrop (z_{cut}=0.1, β=1)

2 Understand its resummation structure in vacuum [Caucal, ASO, Takacs JHEP 07 (2021) 020]

ALICE
pp $\sqrt{s}$ = 5.02 TeV
charged jets   anti-k_T
R = 0.4 | η_{jet} | < 0.5
60 < $p^{ch}_{T,jet}$ < 80 GeV/c
dynamical grooming
a = 1

a = 2

ALICE
LO+N^{2}DL+NP
Syst. uncertainty

[ALICE 2204.10246]

ALICE p$_t$ reach prevents a pure pQCD description of the data

8

3 Explore its potential to ~~pin down QGP properties~~ [Caucal, ASO, Takacs PRD 105 (2022) 11, 114046]
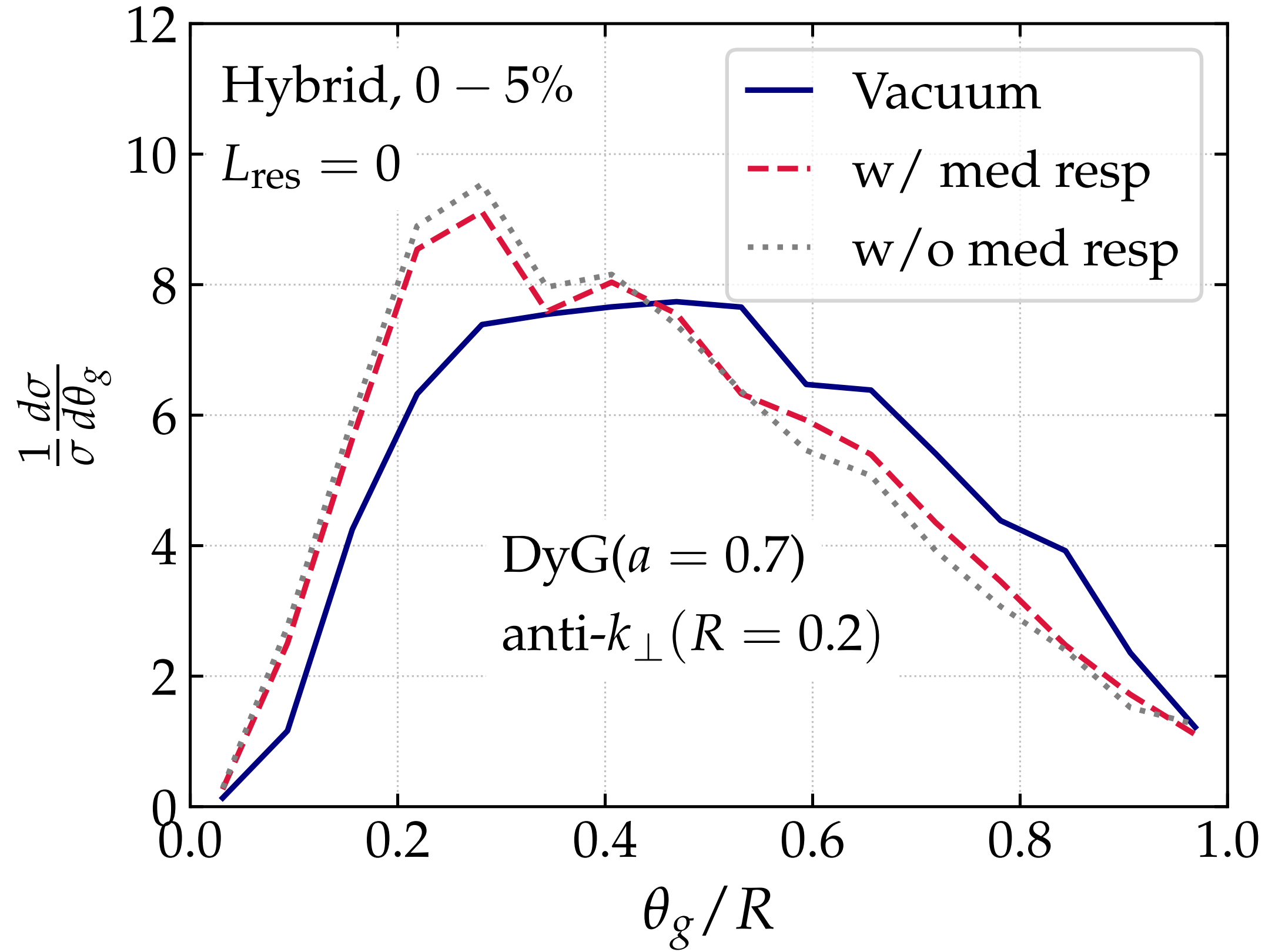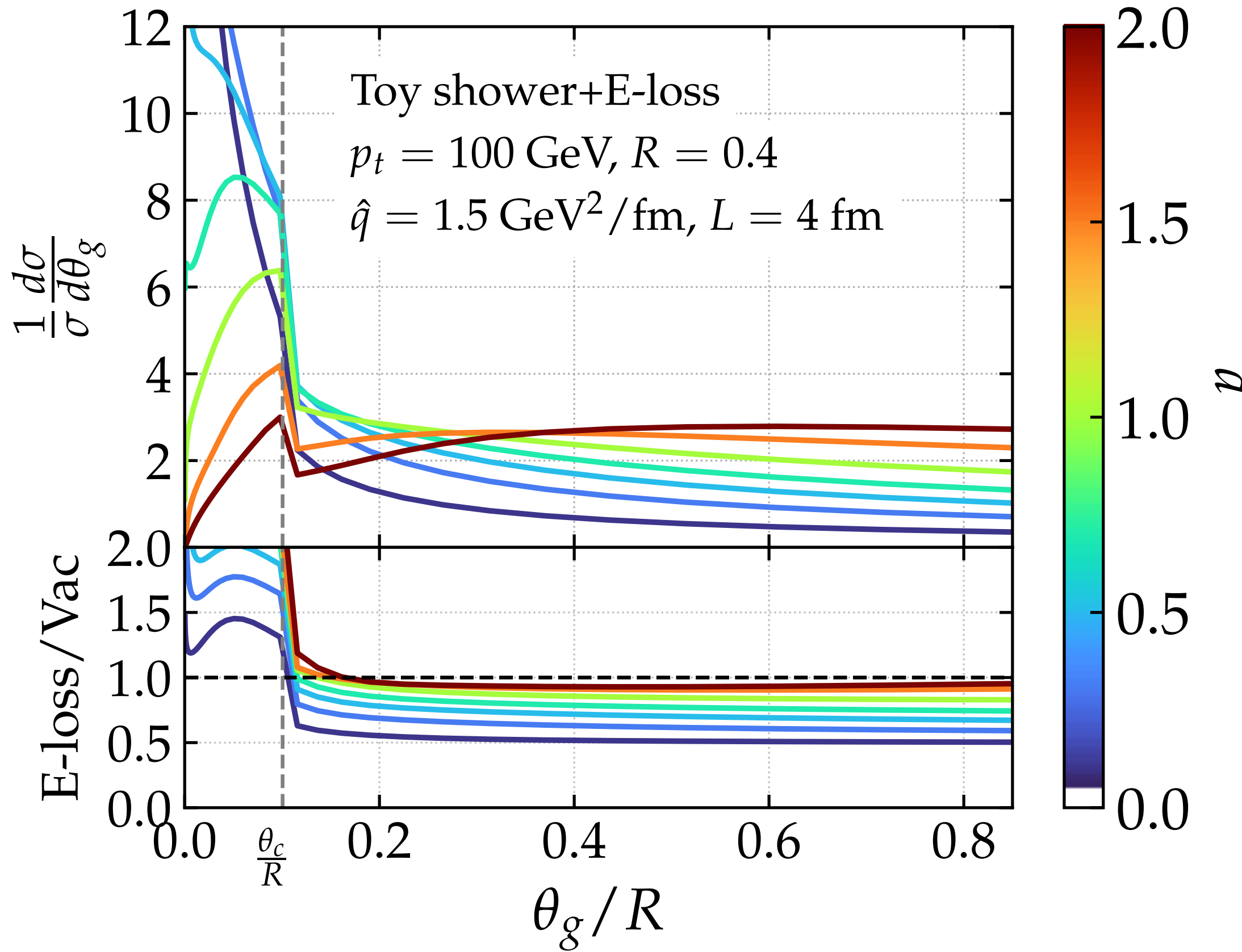
Can we access the QGP resolution angle, θ_c, with dynamical grooming?

Current projects with (~) CERN TH members

A quasi-pure approach to investigate underlying event

Pier Monni +(J. Andersen, L. Rottoli)

PanScales NLL showers including heavy quarks

Gregory Soyez   **Silvia Ferrario Ravasio** +(M. van Beekveld, R. Verheyen)

Lund multiplicity for QCD jets

Gregory Soyez +(R. Medves)

Looking forward to new synergies with CERN TH members