Transverse momentum fraction of strange hadrons in mini-jets in pp collisions

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- Motivation
- Experimental setups & analysis approach
- Results
- Summary and outlook

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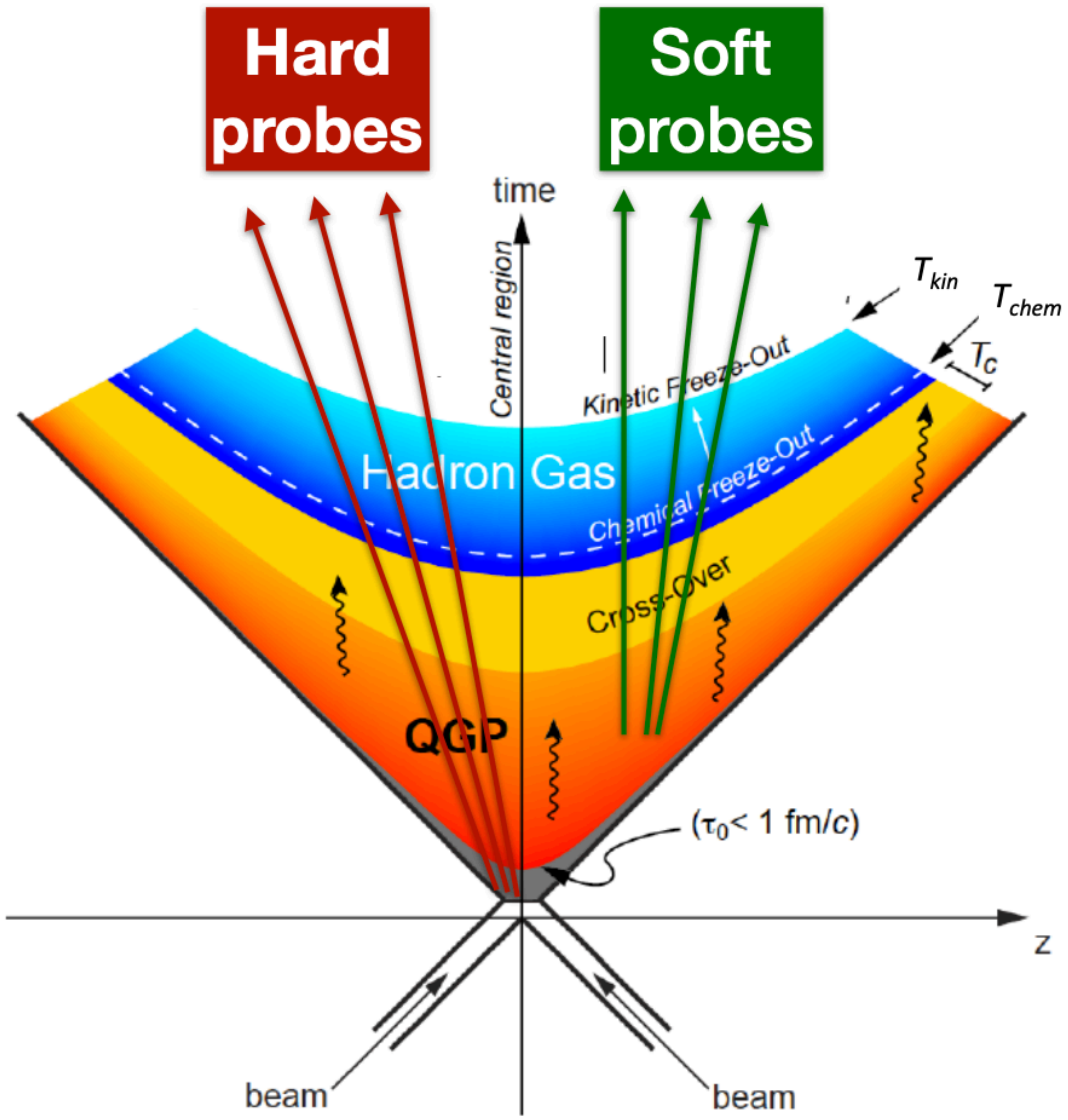
Quark-gluon plasma



- Heavy-ion collisions probe the strongly-interacting matter — the quark-gluon plasma (QGP) under extreme conditions of high temperature and energy density
- **Hard probes** created at the initial stage of the collision
  - ➡ Jet, heavy-flavor quarks
- **Soft probes** created in the "fireball"
  - ➡ Collective expension

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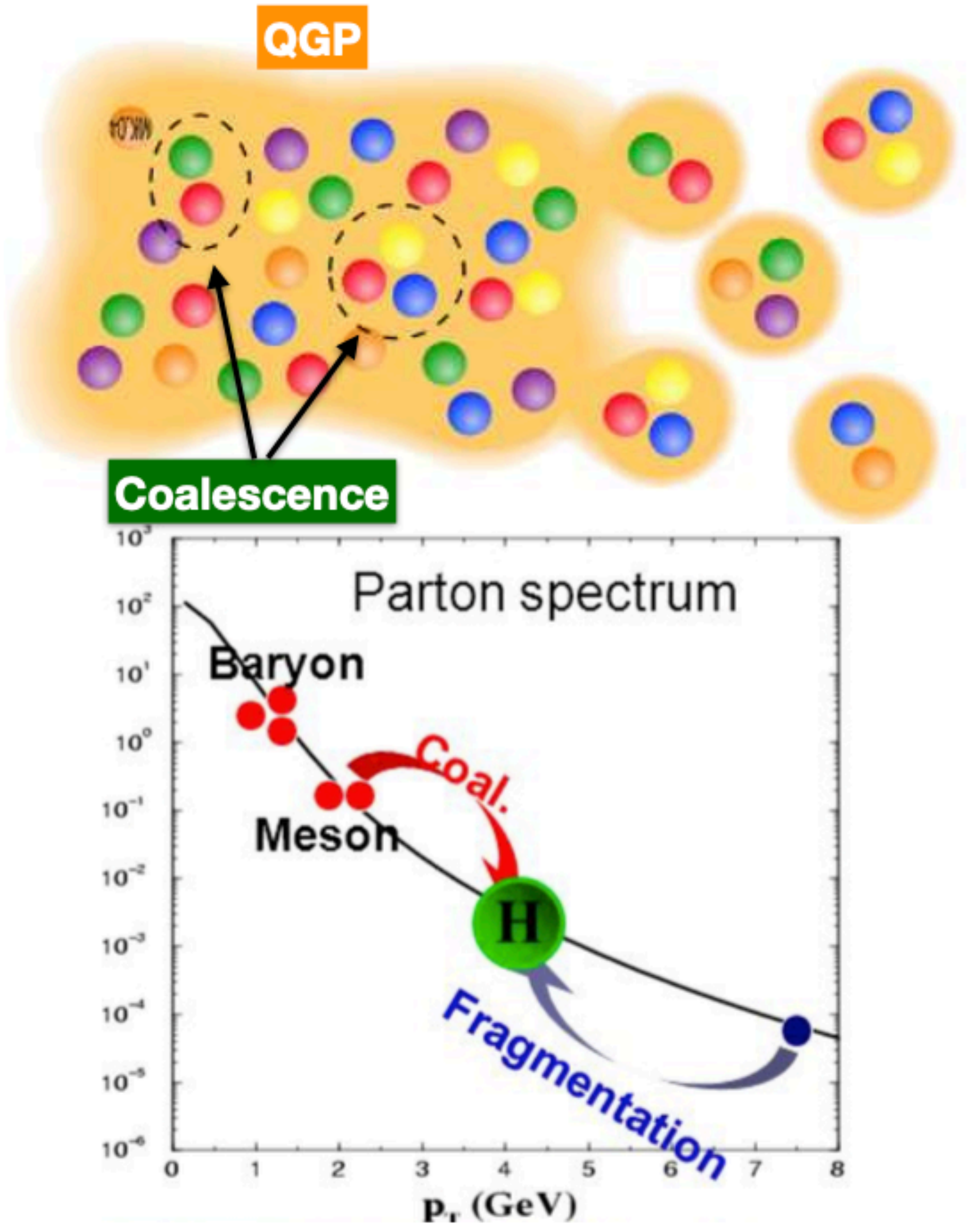
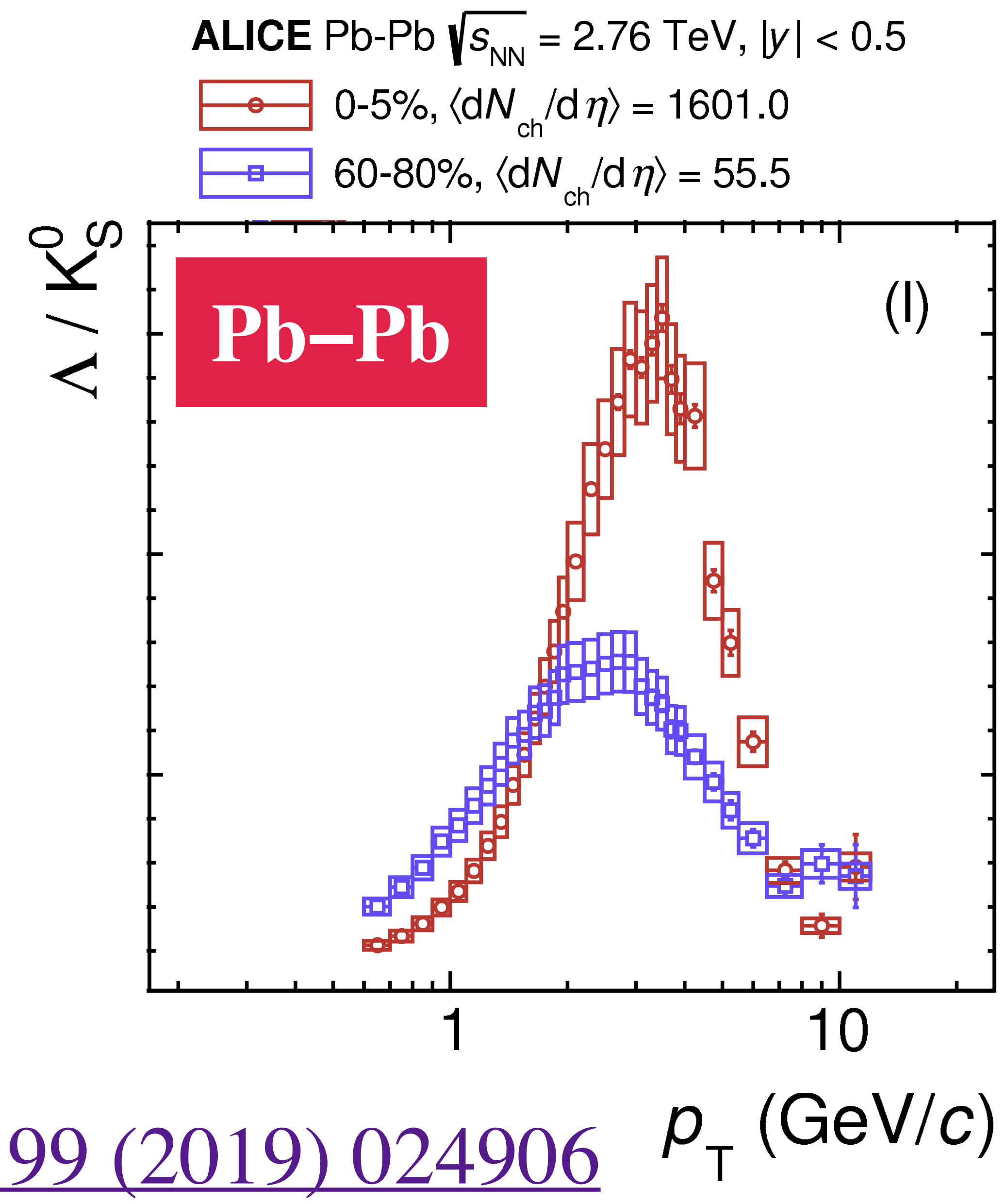
The hadronization in QGP



Rapp *et al. Phys. Lett.* **B655** (2007) 126
Greco *et al. Phys.Rev.* **C92** (2015) 054904
Ko *et al. Phys. Lett.* **B792** (2019) 132

- **Fragmentation** — hadrons from high p_T (hard) partons
- Coalescence/recombination — hadrons formation via (di-)quark combination in the QGP medium
  - $p_{T,hadron} \simeq n\, p_{T,parton}$, n = 2 (meson), 3(baryon)
  - Sensitive to baryon and meson species
  - Baryons from lower momenta partons (denser)

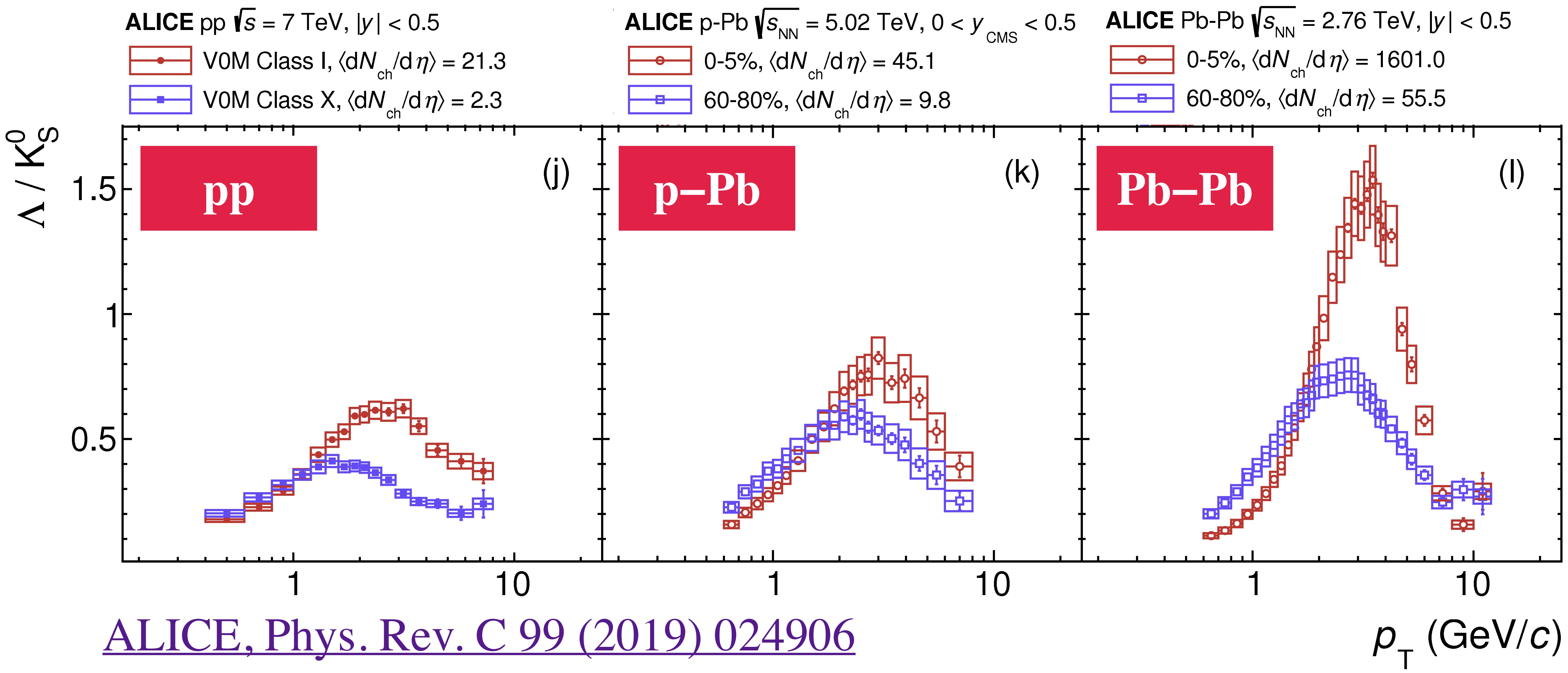
Strange baryon-to-meson enhancement



ALICE, Phys. Rev. C 99 (2019) 024906

- Baryon-to-meson ratio (Λ/K^0_S) increases at intermediate p_T in central Pb–Pb collisions compared to peripheral ones
  - ➡ Interplay of radial flow and coalescence
  - ➡ Reflect QGP effects in heavy-ion collisions

Strange baryon-to-meson enhancement



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- Baryon-to-meson ratio (Λ/K^0_S) increases at intermediate p_T in central Pb–Pb collisions compared to peripheral ones
- Λ/K^0_S ratio enhancement is observed in different collision systems (pp, p–Pb and Pb–Pb) at high multiplicity

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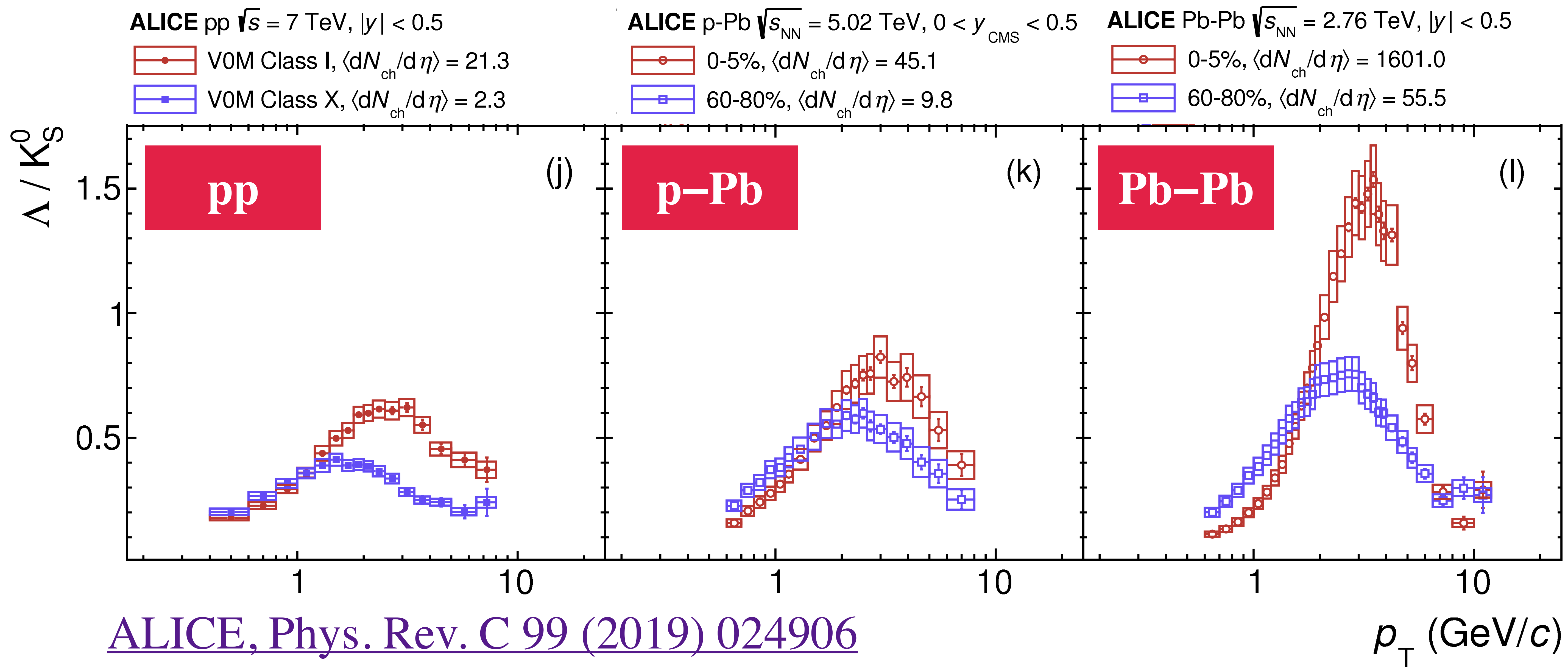

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- Baryon-to-meson ratio (Λ/K^0_S) increases at intermediate p_T in central Pb–Pb collisions compared to peripheral ones
- Λ/K^0_S ratio enhancement is observed in different collision systems (pp, p–Pb and Pb–Pb) at high multiplicity
- To constrain hadronization mechanisms in all systems, it's important to separate particles from hard and soft processes ☞ Using jets to tag the hard processes

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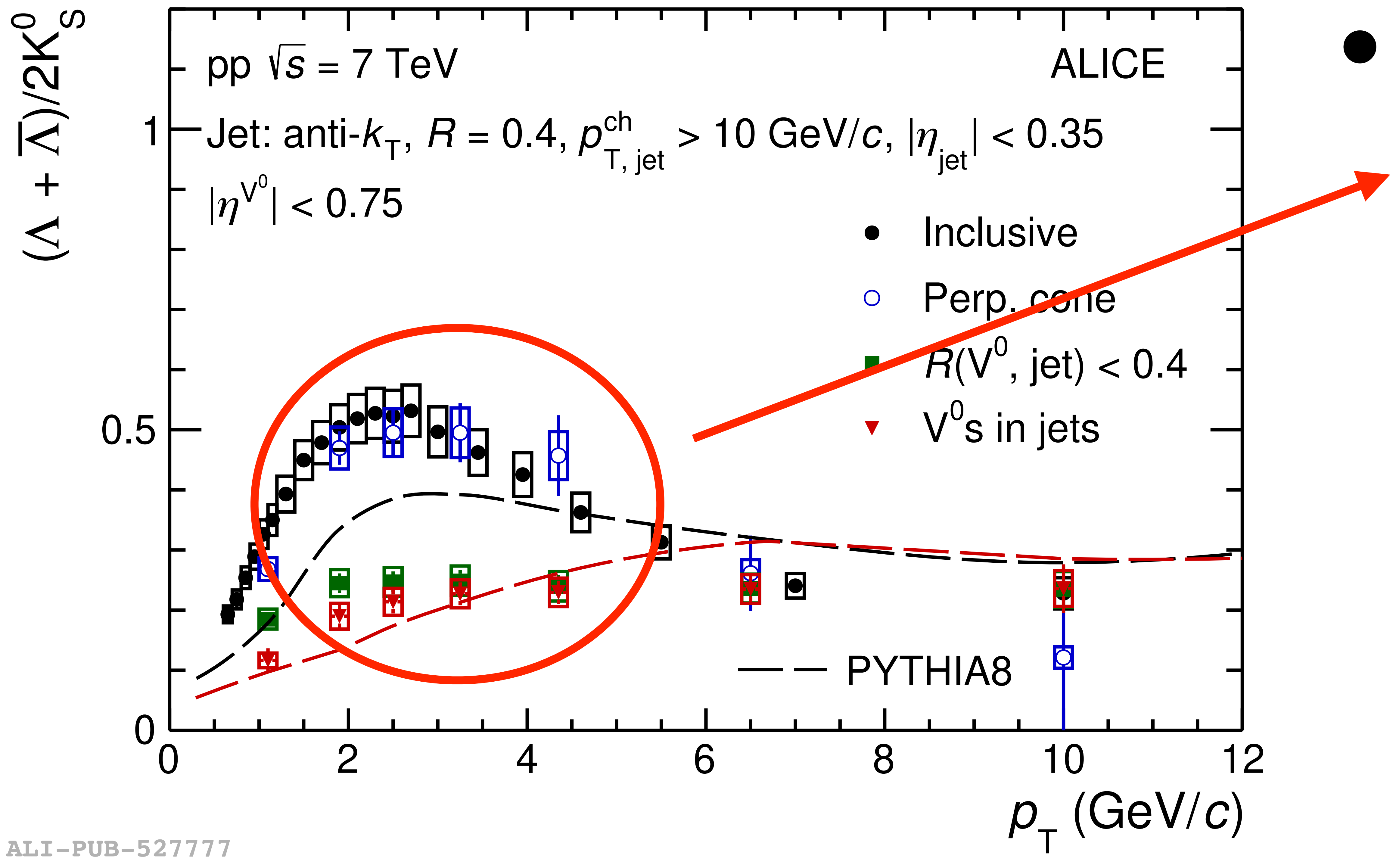
Strange particle production in jet

ALICE, Phys. Lett. B 827 (2022) 136984



- Strange baryon-to-meson ratio enhancement observed in UE (compared to in jet production) at intermediate p_T in small systems
  - ➡ Suggests that the enhancement is not attributed to the jet fragmentation
  - ➡ However, particles produced in the hard process don't necessarily be within high energy jets

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Strange particle production in jet

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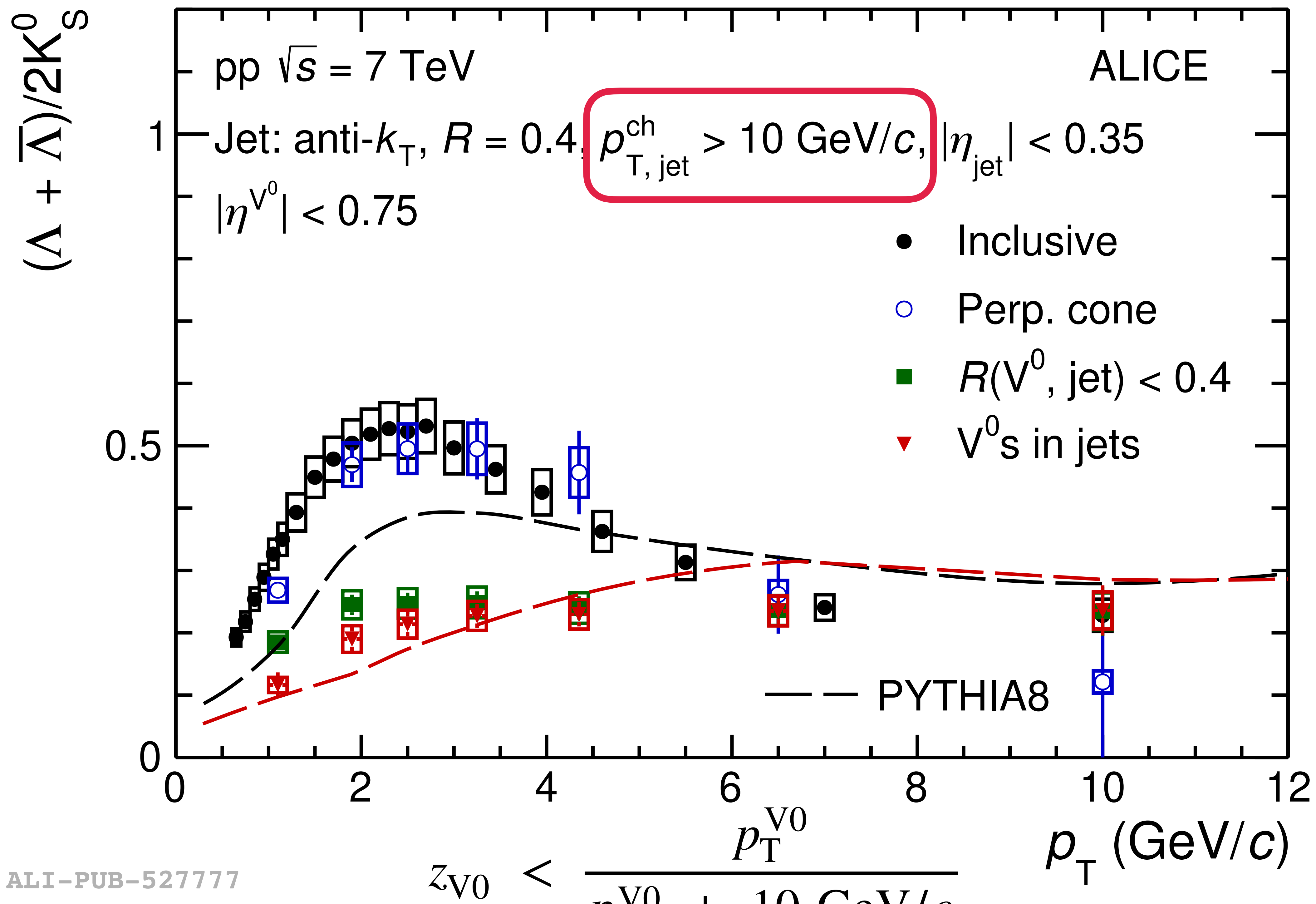

$$z_{V0} < \frac{p_T^{V0}}{p_T^{V0} + 10\ \mathrm{GeV}/c}$$

$z < 0.09$ → $z < 0.5$

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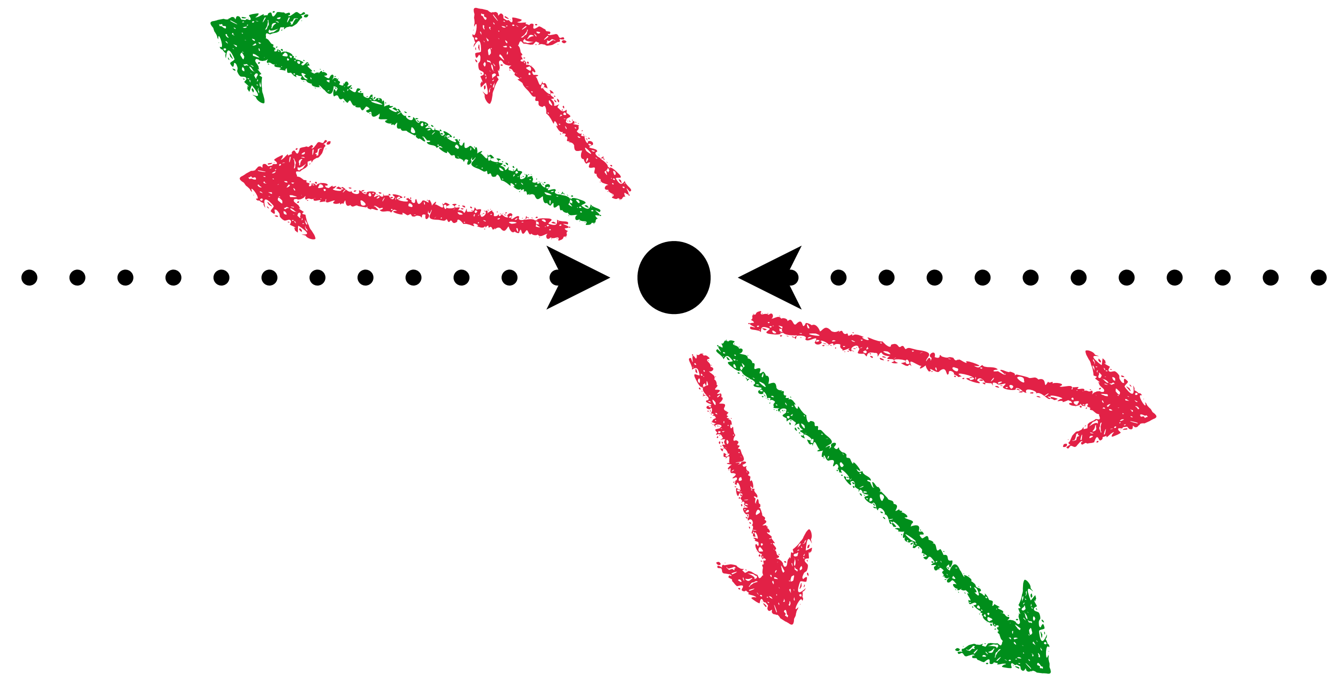
$$z = \frac{p_T^{S}}{p_{T,jet}}$$

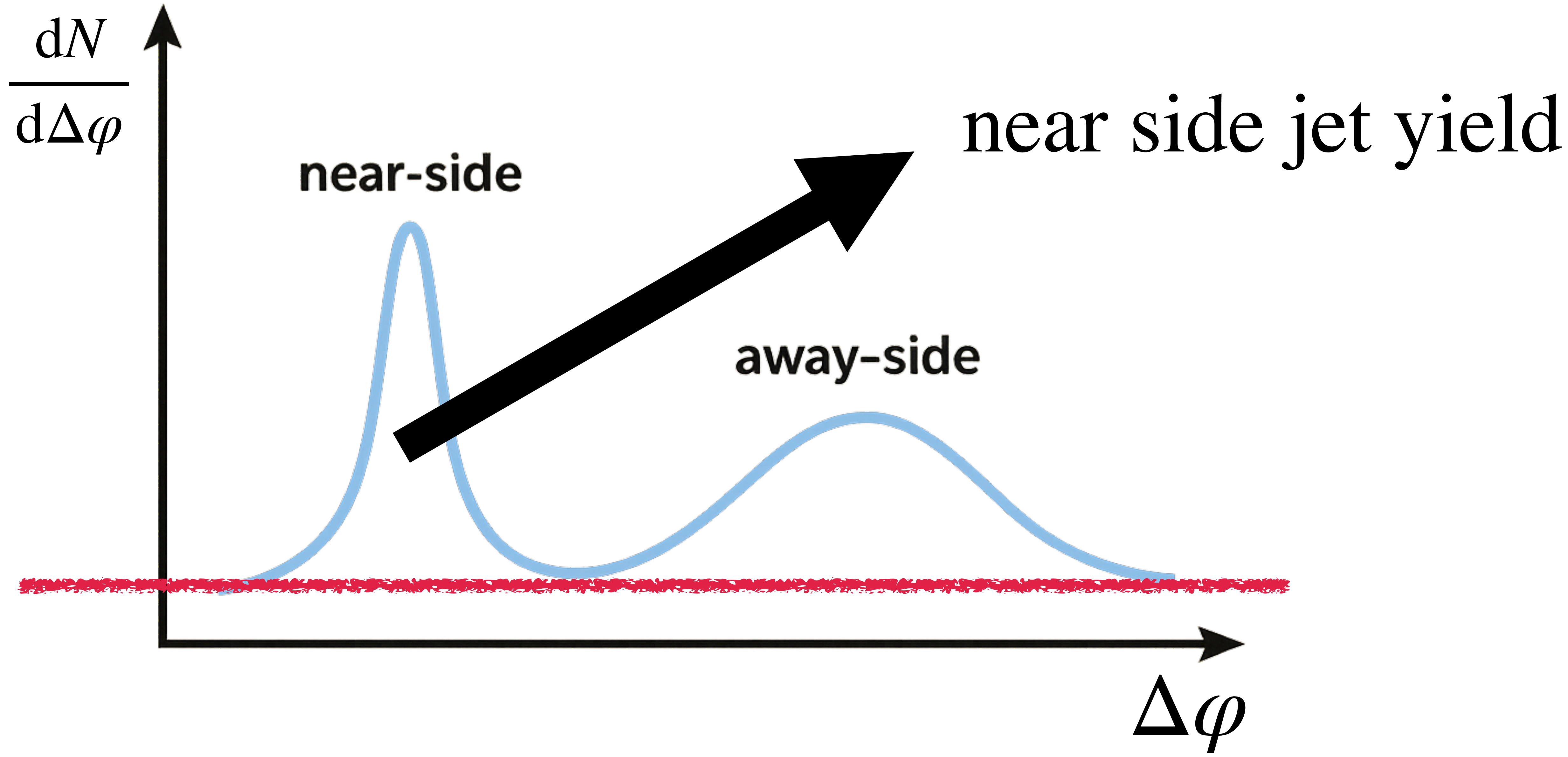
- Strange particle-jet association depends also on momentum fraction z
- Using a two-particle angular correlations method

Two particle angular correlation

- **Correlation function:**

$$C\left(\Delta\eta,\,\Delta\varphi\right) = \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2N}{\mathrm{d}\Delta\varphi\mathrm{d}\Delta\eta}$$





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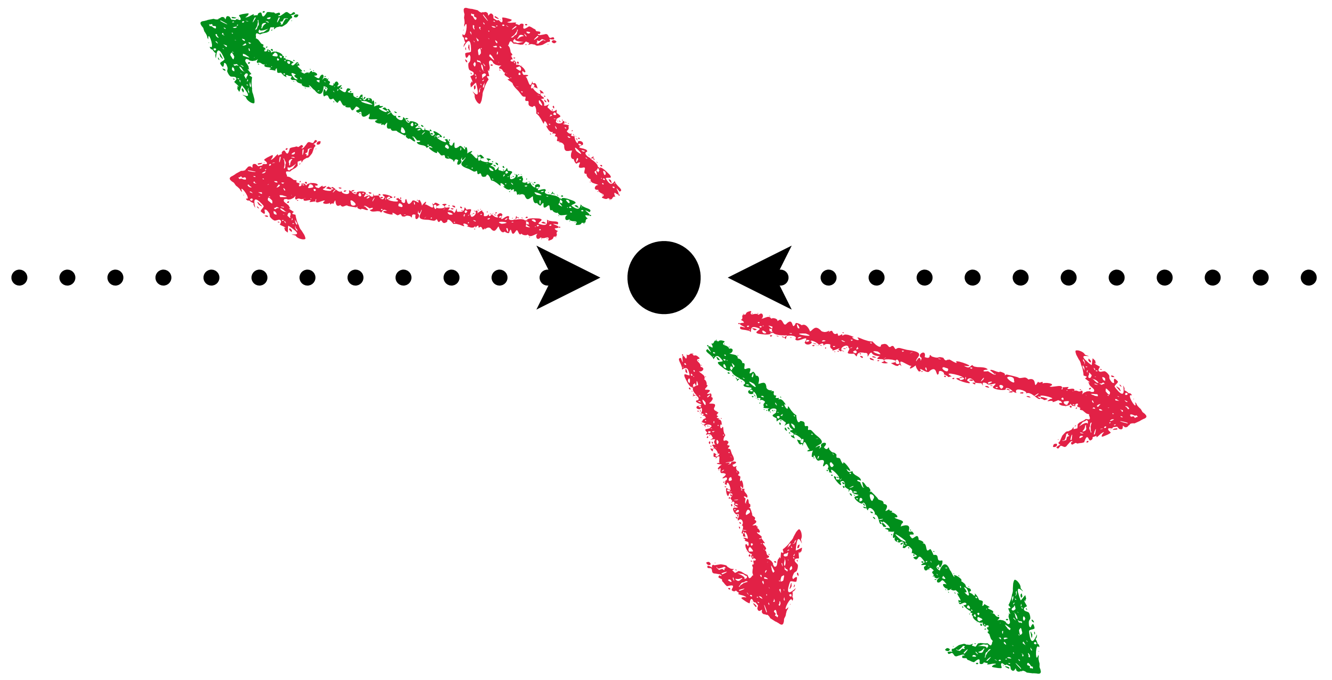

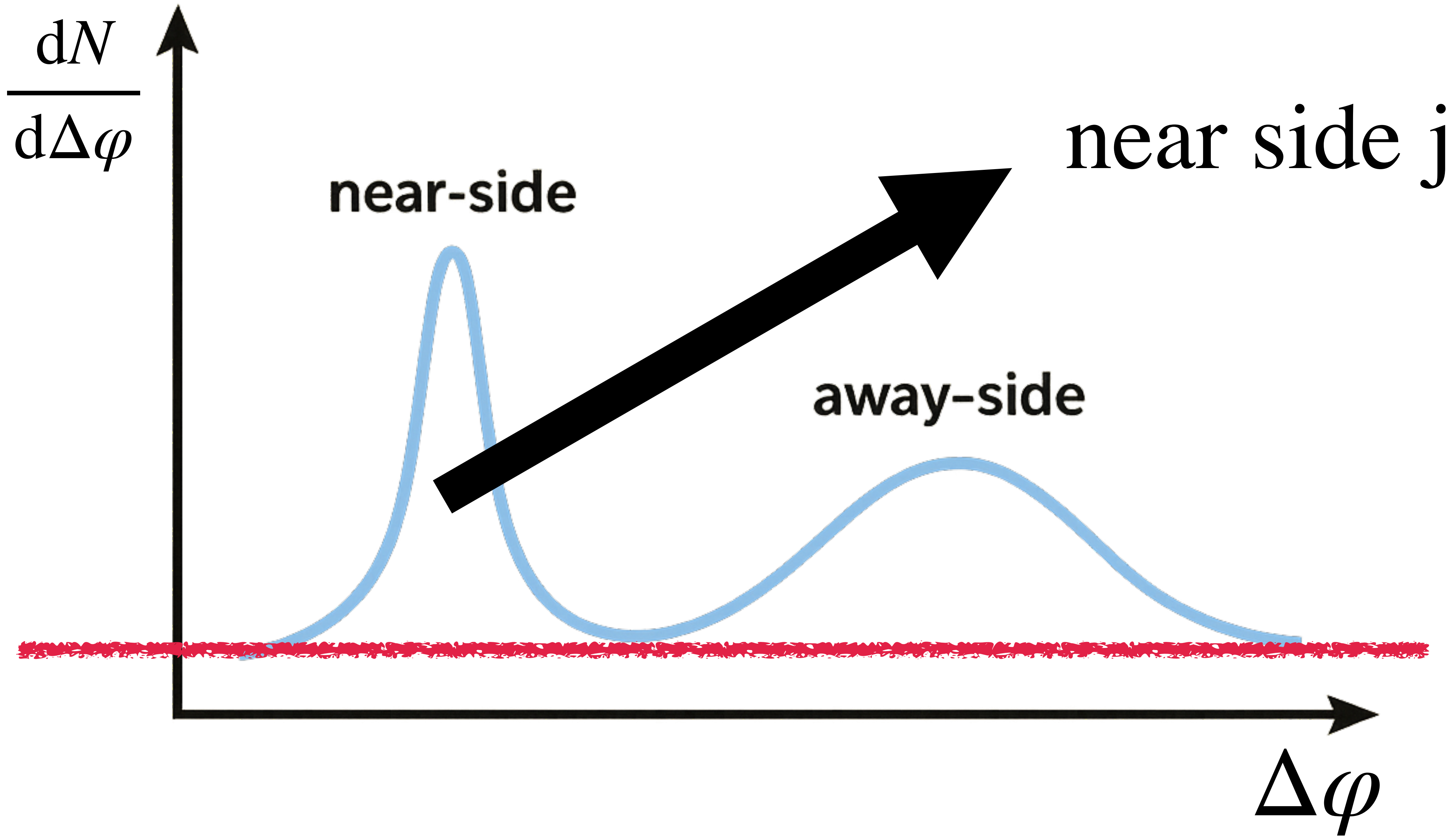

near side jet yield

?

$$z=\frac{p_{\mathrm{T}}^{\mathrm{s}}}{p_{\mathrm{T,jet}}}$$

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Two particle angular correlation

- **Correlation function:**

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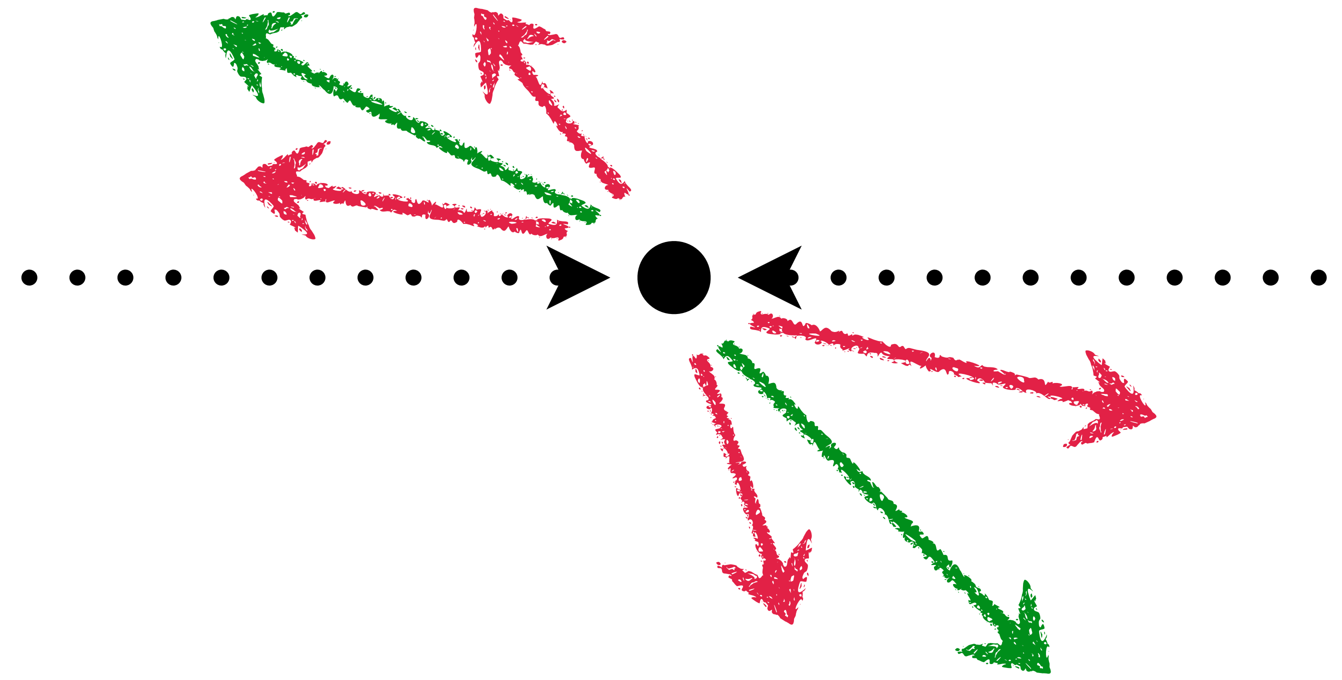

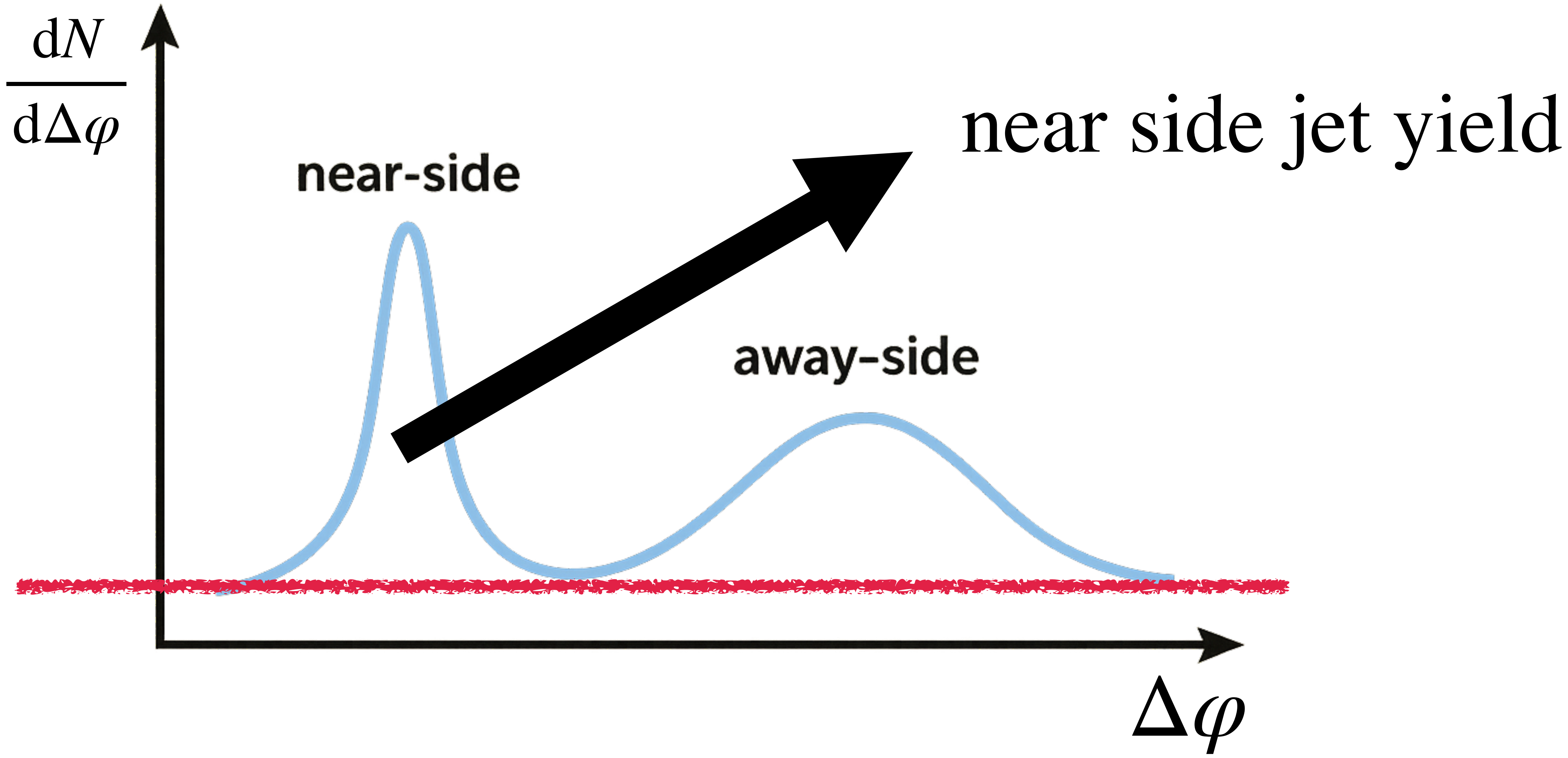

$$\langle z \rangle = \frac{p_{\mathrm{T}}^{\mathrm{S}}}{p_{\mathrm{T,jet}}} = \frac{p_{\mathrm{T}}^{\mathrm{S}}}{p_{\mathrm{T}}^{\mathrm{S}} + \sum_{p_{\mathrm{T}}}^{\mathrm{NS}}}$$

$p_{\mathrm{T,jet}}$ represented by the sum p_{T} of the near side associated particles and the trigger particle

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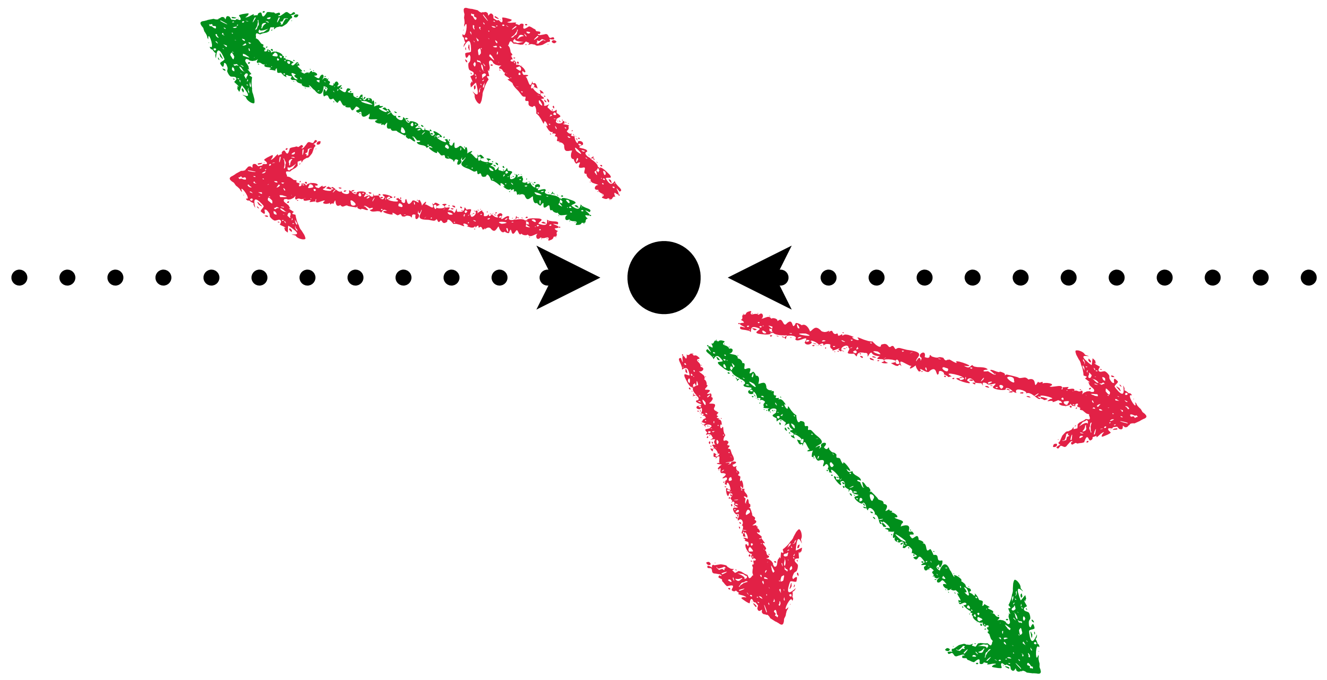
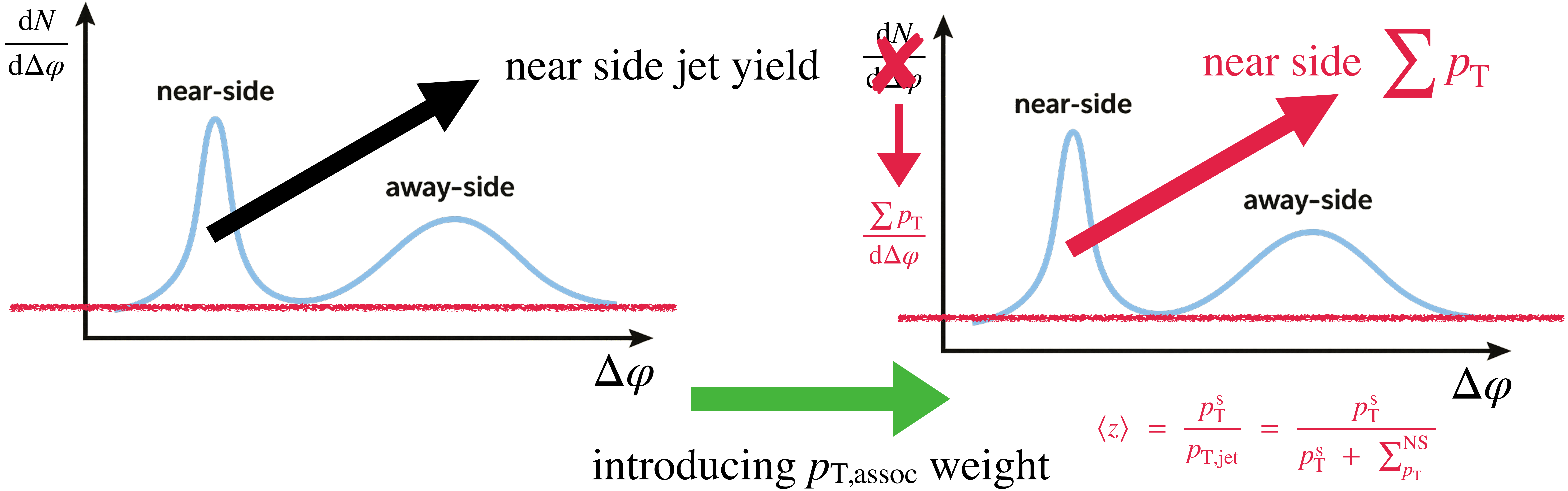
p_T weighted two particle angular correlation

- **p_T weighted correlation function:**

$$C_{p_T \text{ weighted}}\left(\Delta\eta,\ \Delta\varphi\right) = \frac{1}{N_{\text{trig}}}\frac{d^2\sum p_T}{d\Delta\varphi d\Delta\eta}$$





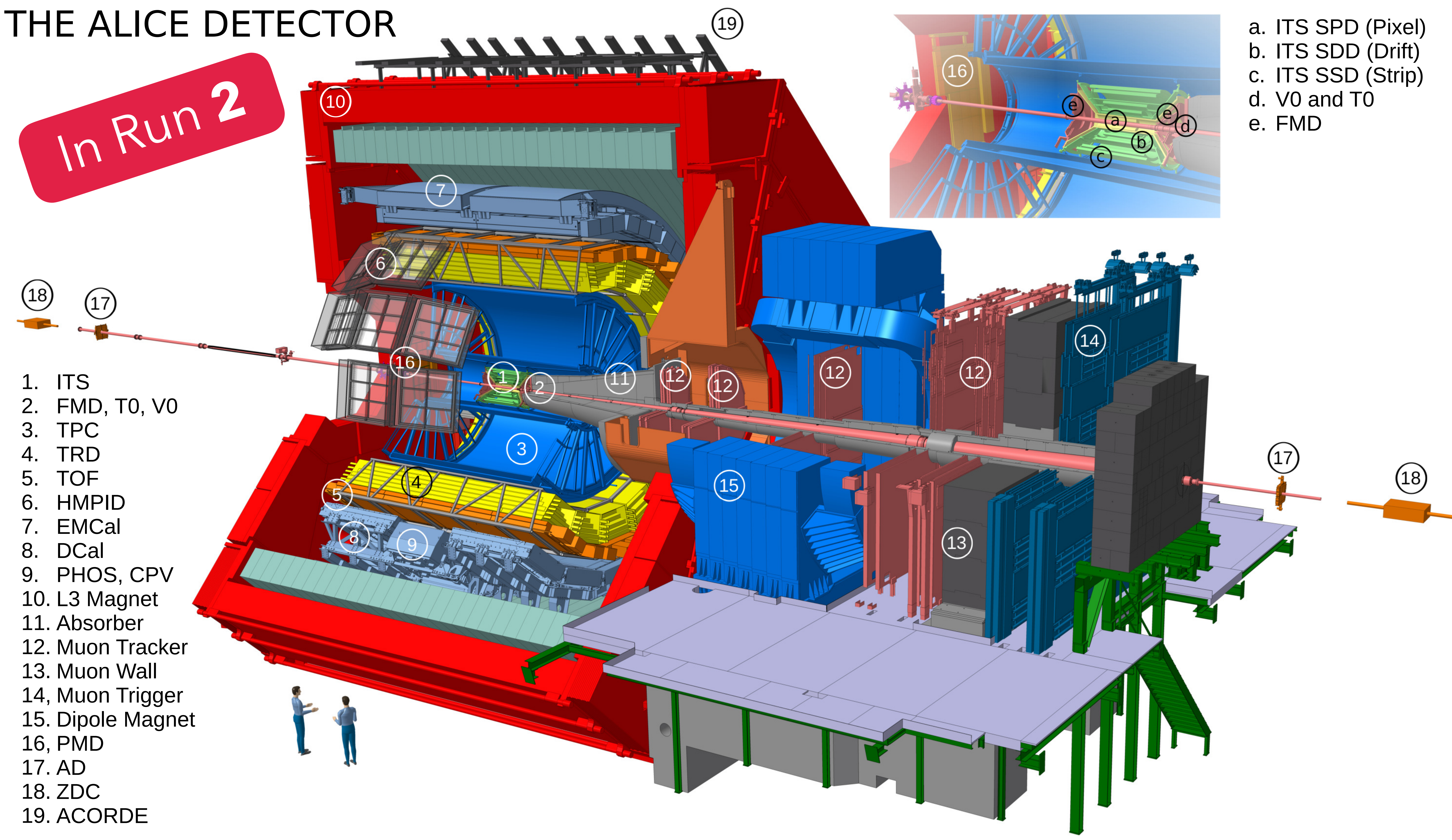
$$\langle z\rangle = \frac{p_T^S}{p_{T,\text{jet}}} = \frac{p_T^S}{p_T^S + \sum_{p_T}^{NS}}$$

Experimental setup

- **V0A and V0C (V0)**
  - V0A: $2.8 < \eta < 5.1$, V0C: $-3.7 < \eta < -1.7$
  - Event trigger and multiplicity determination
- **Inner Tracking System (ITS)**
  - $|\eta| < 0.9$
  - Vertex reconstruction and event trigger
- **Time Projection Chamber (TPC)**
  - $|\eta| < 0.9$
  - Charged-particle tracking and identification
- **Time Of Flight (TOF)**
  - Charged-particle identification

Data samples & analysis setup

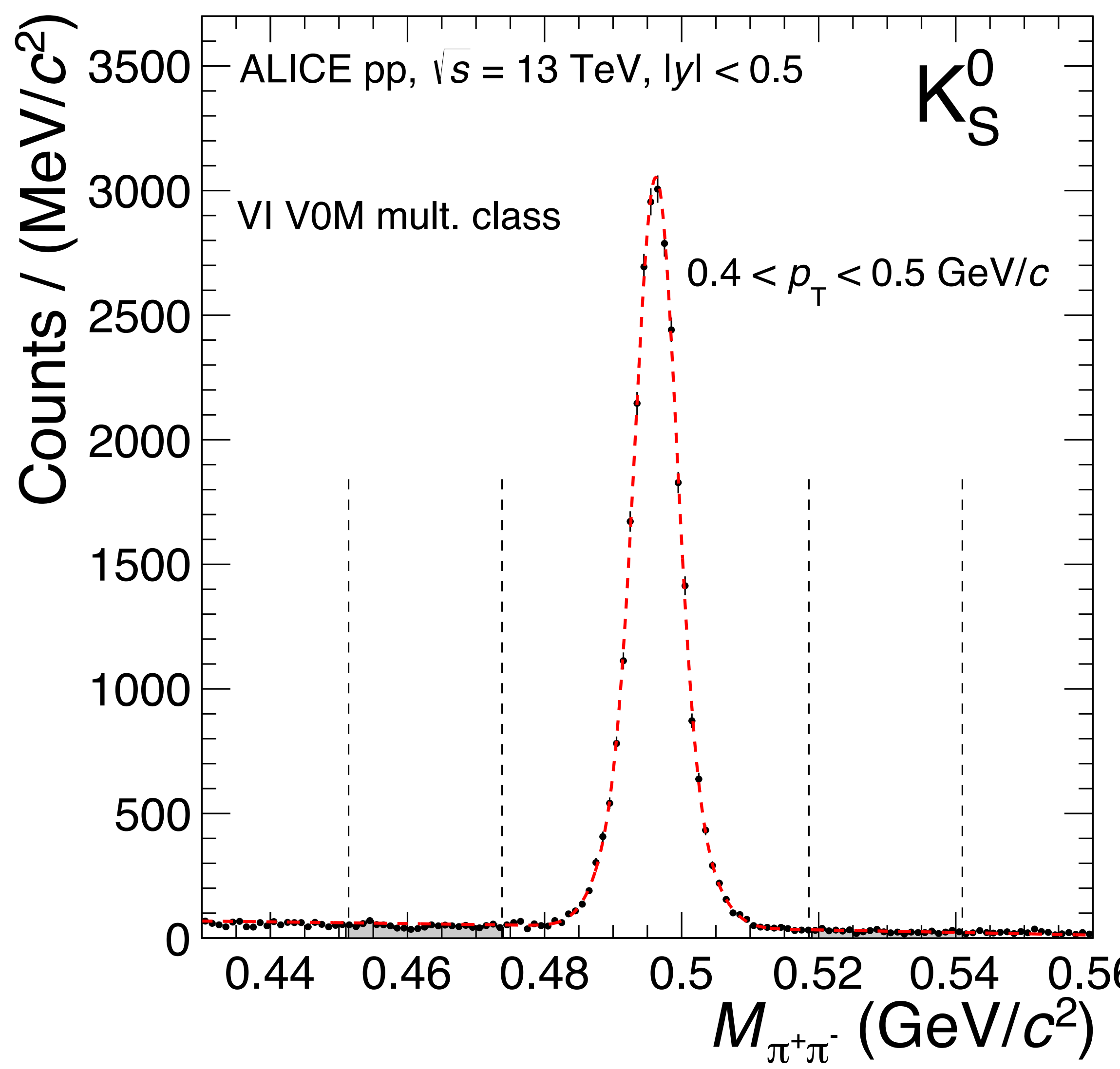
- pp at $\sqrt{s}$ = 13 TeV
- Standard event selections, $|z_{vtx}| < 10$ cm, IB and OOB pileup rejected



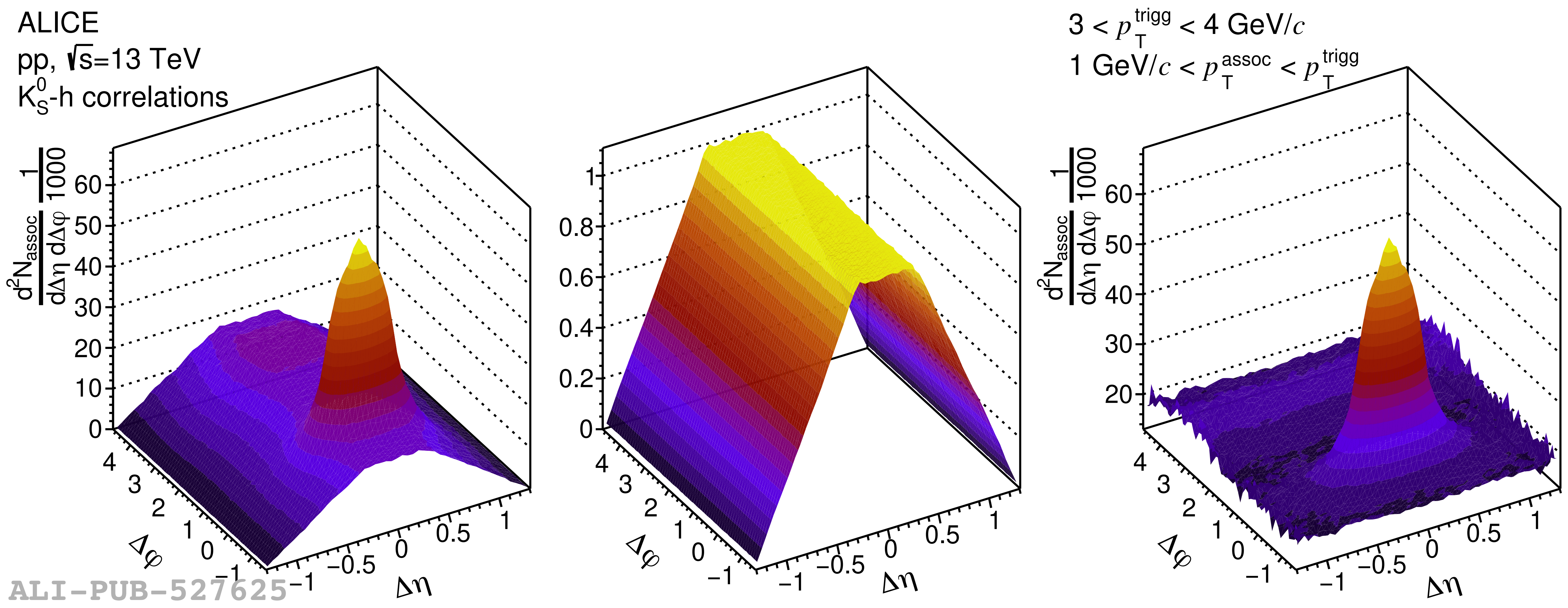
Analysis approach

- **Trigger particles**: strange particles (K^0_S, Λ, $\overline{\Lambda}$)
  - Pairs of tracks with proper charge-sign combination and PID
  - Topological and kinematical selections (e.g. DCA…)
- **Associated particles**: charged primary particles
- Raw correlation function
  - ➡ Jet yield ($\sum p_{\mathrm{T}}$) obtained by applying acceptance and inefficiency corrections, and uncorrelated bkg subtraction

ALICE, Eur. Phys. J. C80 (2020) 167



ALICE, Eur. Phys. J. C 81 (2021) 945



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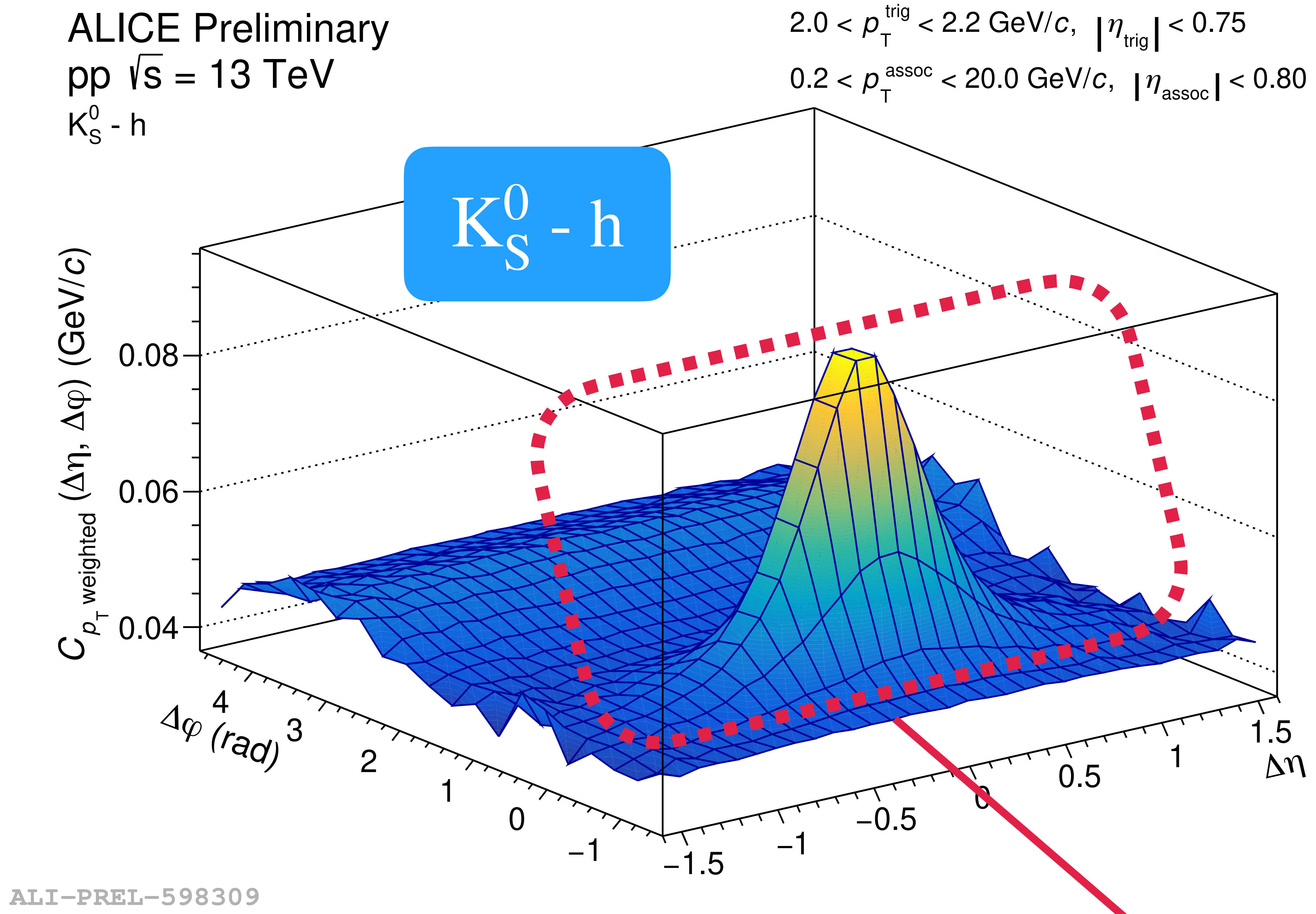
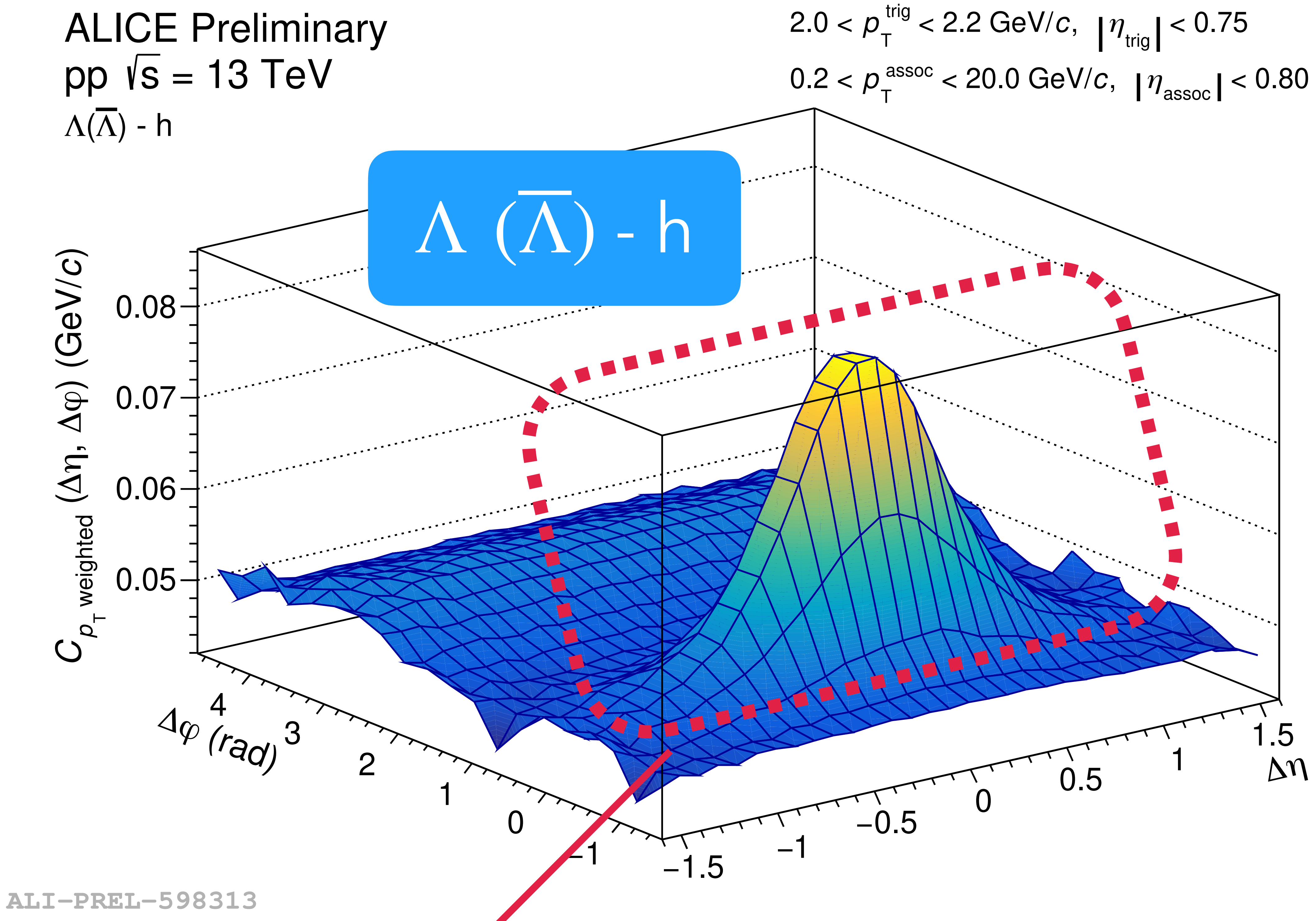
Combined p_T weighted correlation function





Fully corrected p_T weighted correlation function for strange meson K^0_S (left) and baryon $\Lambda(\bar{\Lambda})$ (right)

$$\langle z \rangle = \frac{p_T^S}{p_{T,jet}} = \frac{p_T^S}{p_T^S + \sum_{p_T}^{NS}}$$

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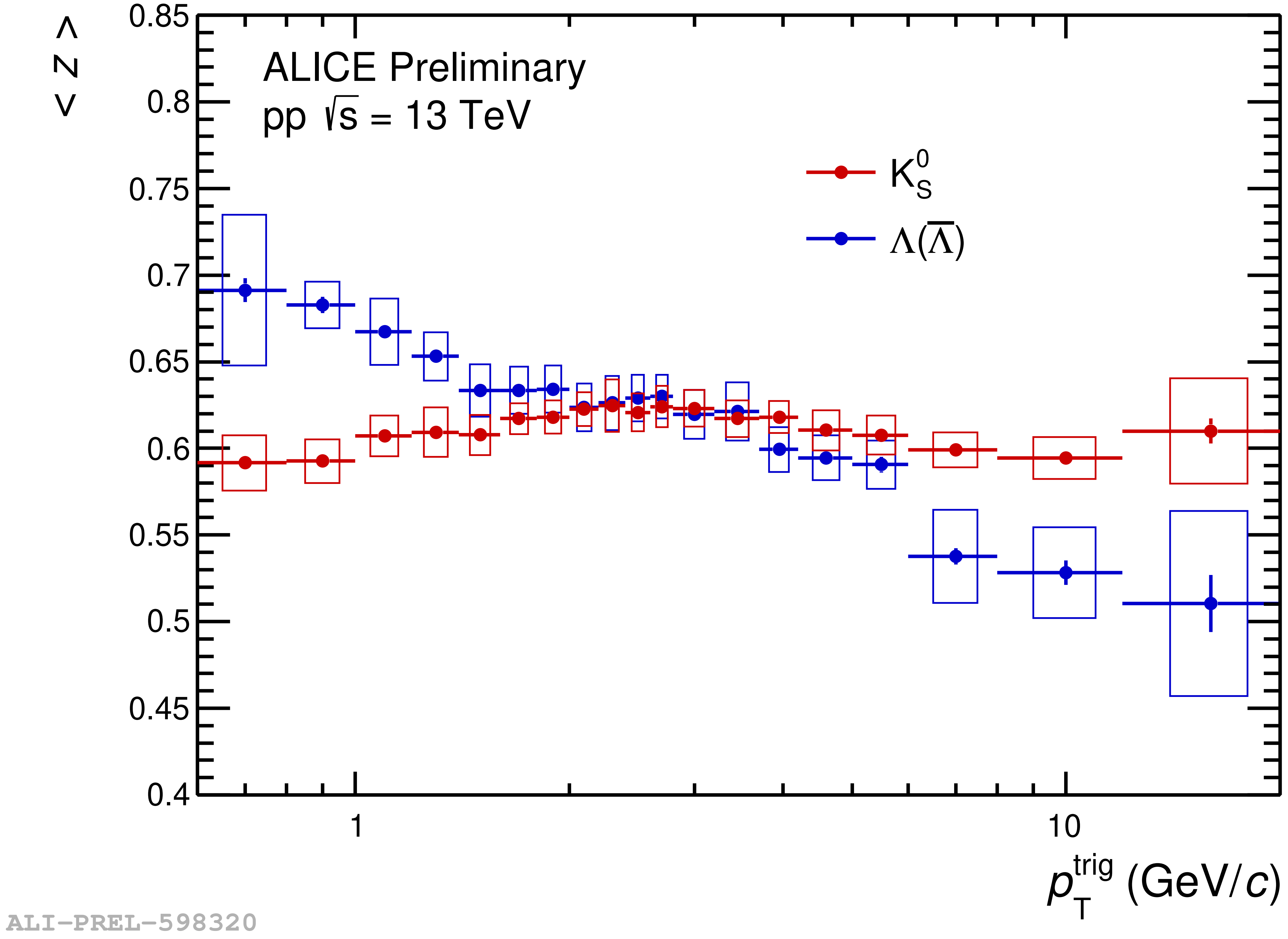
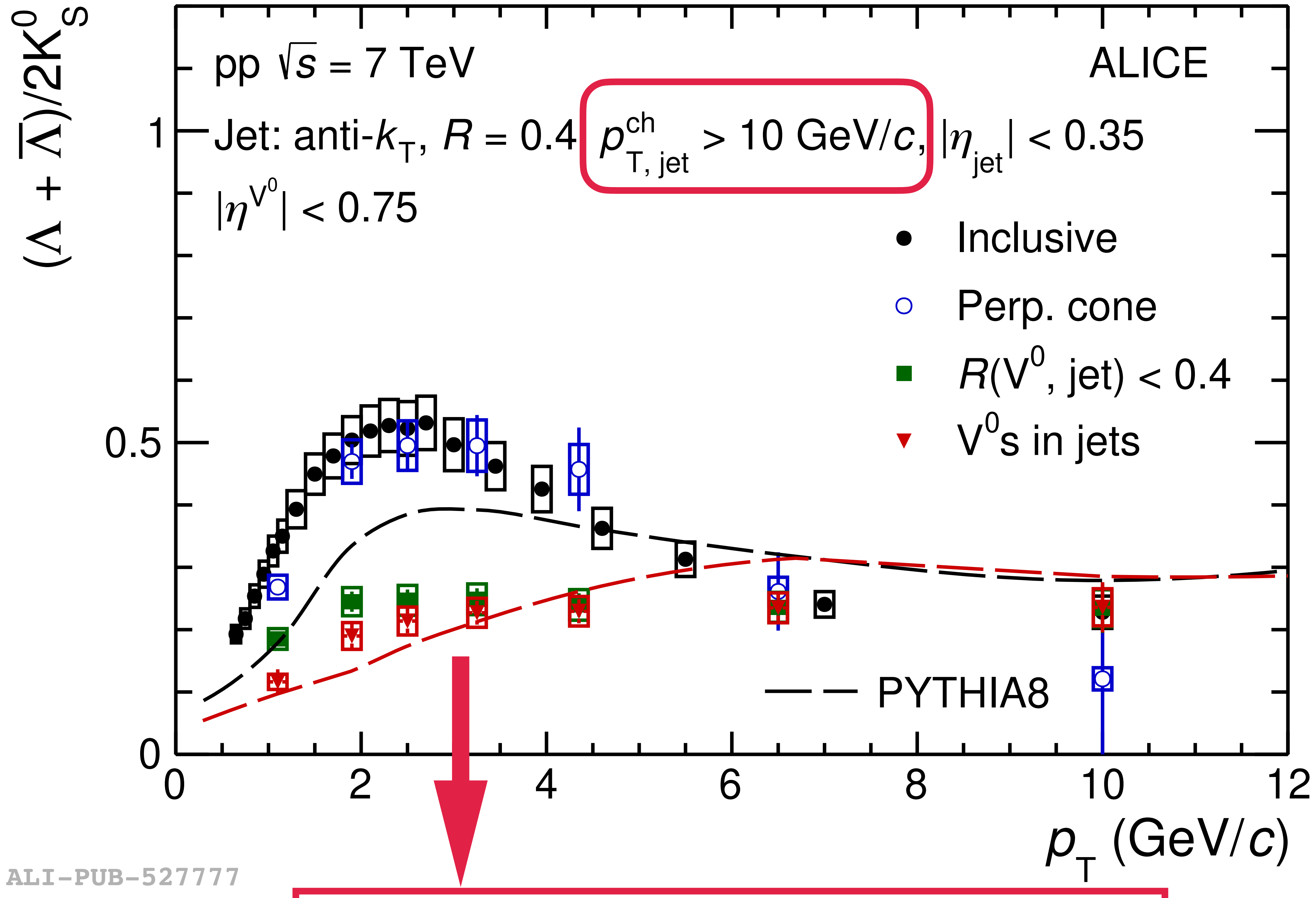
Results - < z >

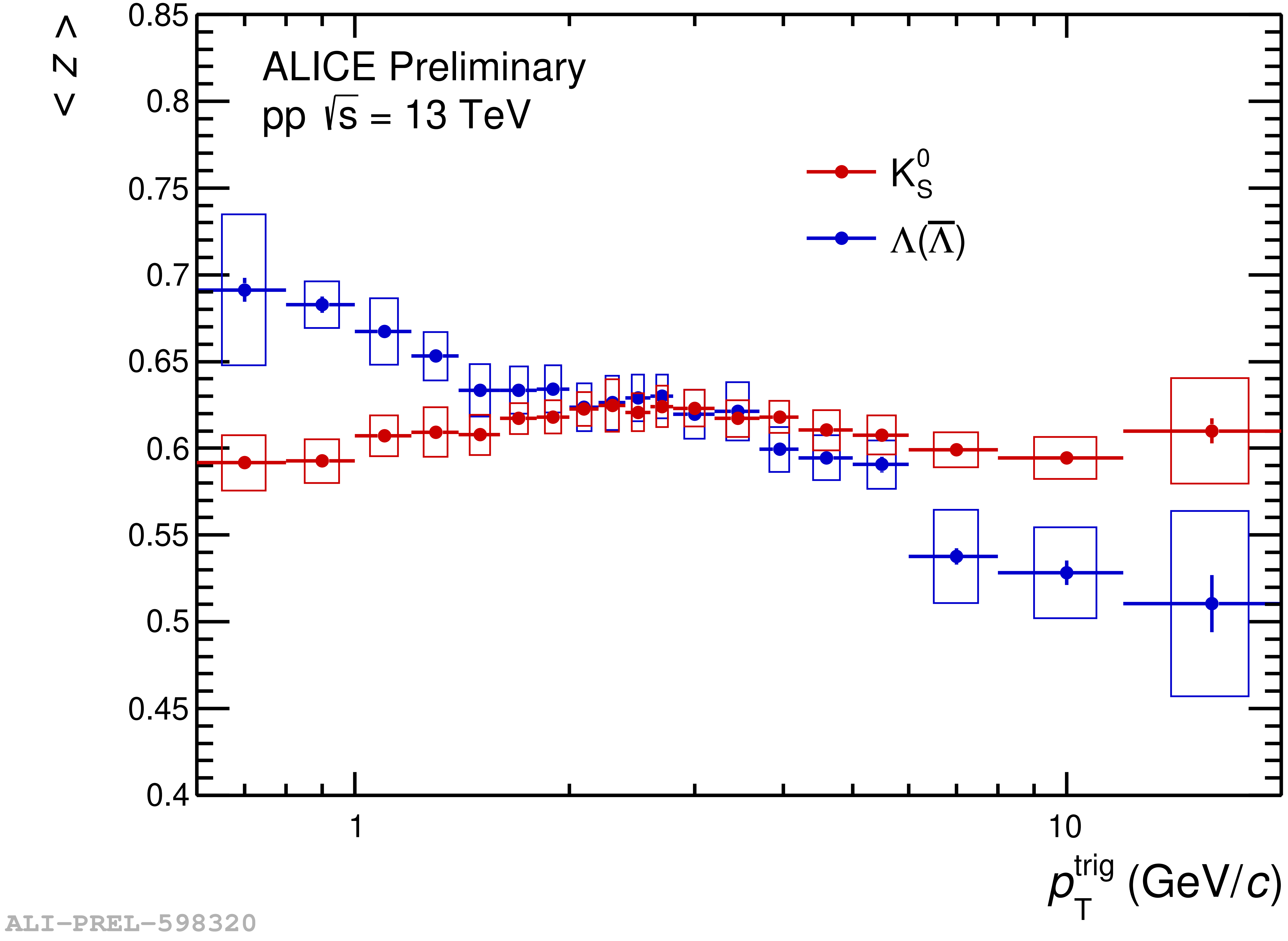




$p_{T,jet} \sim 3/0.6$ GeV/c = 5 GeV/c

- Results suggest that the strange particles take large fraction (high $< z >$) from the originated (relative) low energy partons
  - When comparing the in-jet and out-of-jet strange particles production, we are actually measuring particles with different $<z>$

Results - < z >



- At high p_T, expected to be the leading particle effect
- $< z >$ doesn't change too much, no indication of a significant change of fragmentation properties
- The increasing for Λ $(\overline{\Lambda})$ (from intermediate p_T to low p_T) due to either the fragmentation is harder for Λ $(\overline{\Lambda})$ in this region, or more isolated Λ $(\overline{\Lambda})$ production contribution in this region

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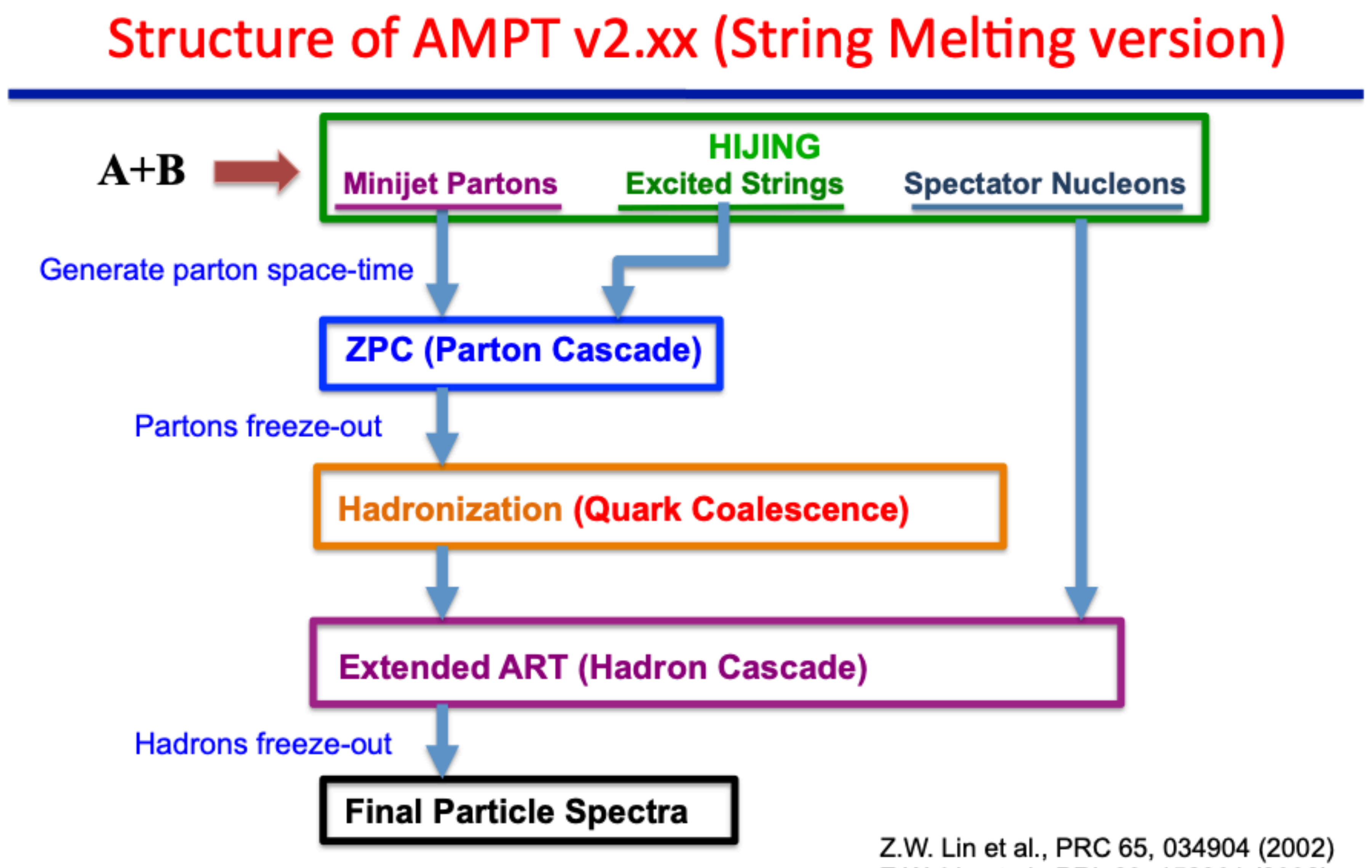
MC models

PYTHIA8.3

Monash

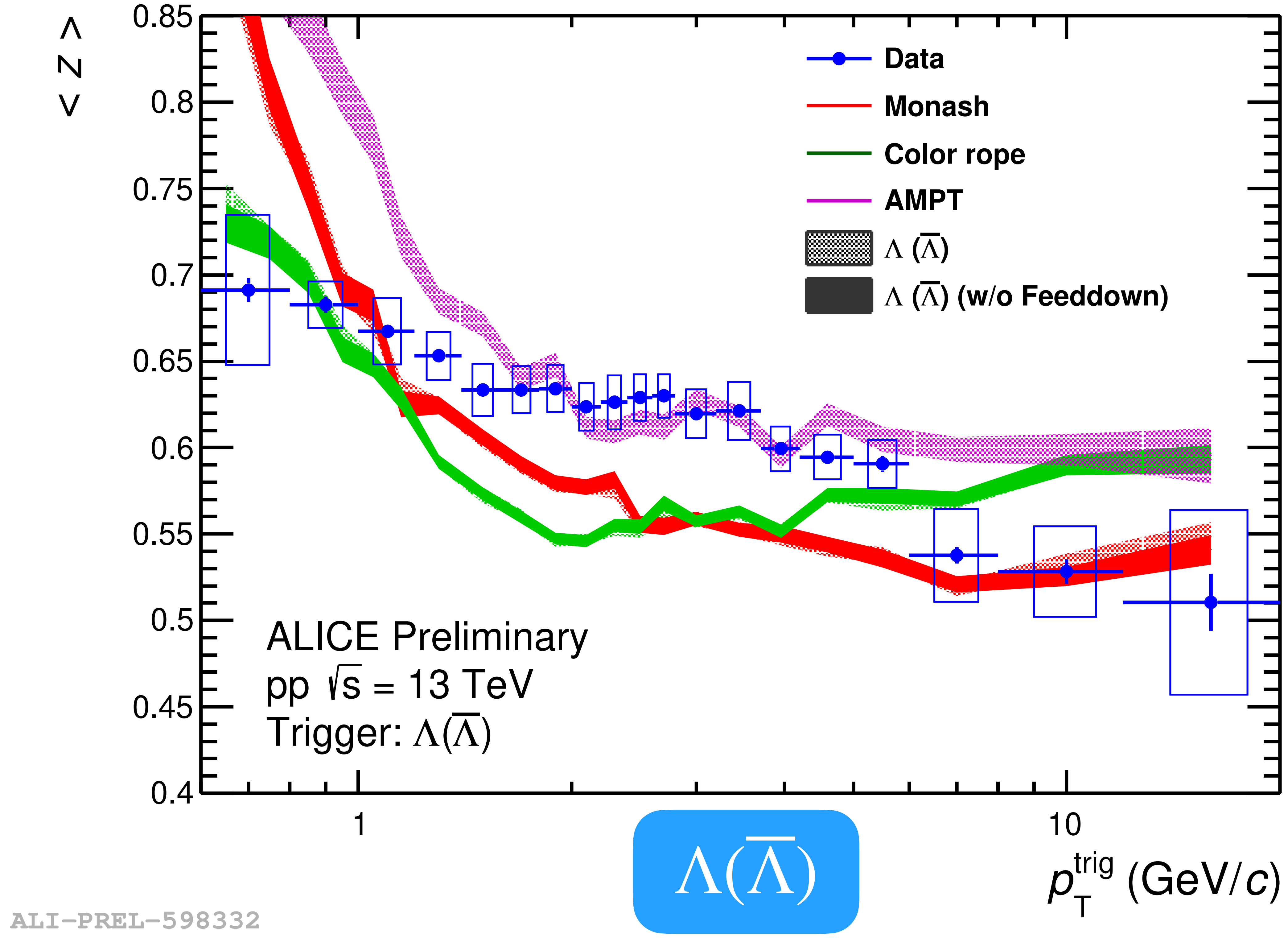
Color Rope

A Multi-Phase Transport (AMPT) model



Z.W. Lin et al., PRC 65, 034904 (2002)
Z.W. Lin et al., PRL 89, 152301 (2002)

Results - < z > compared with predictions

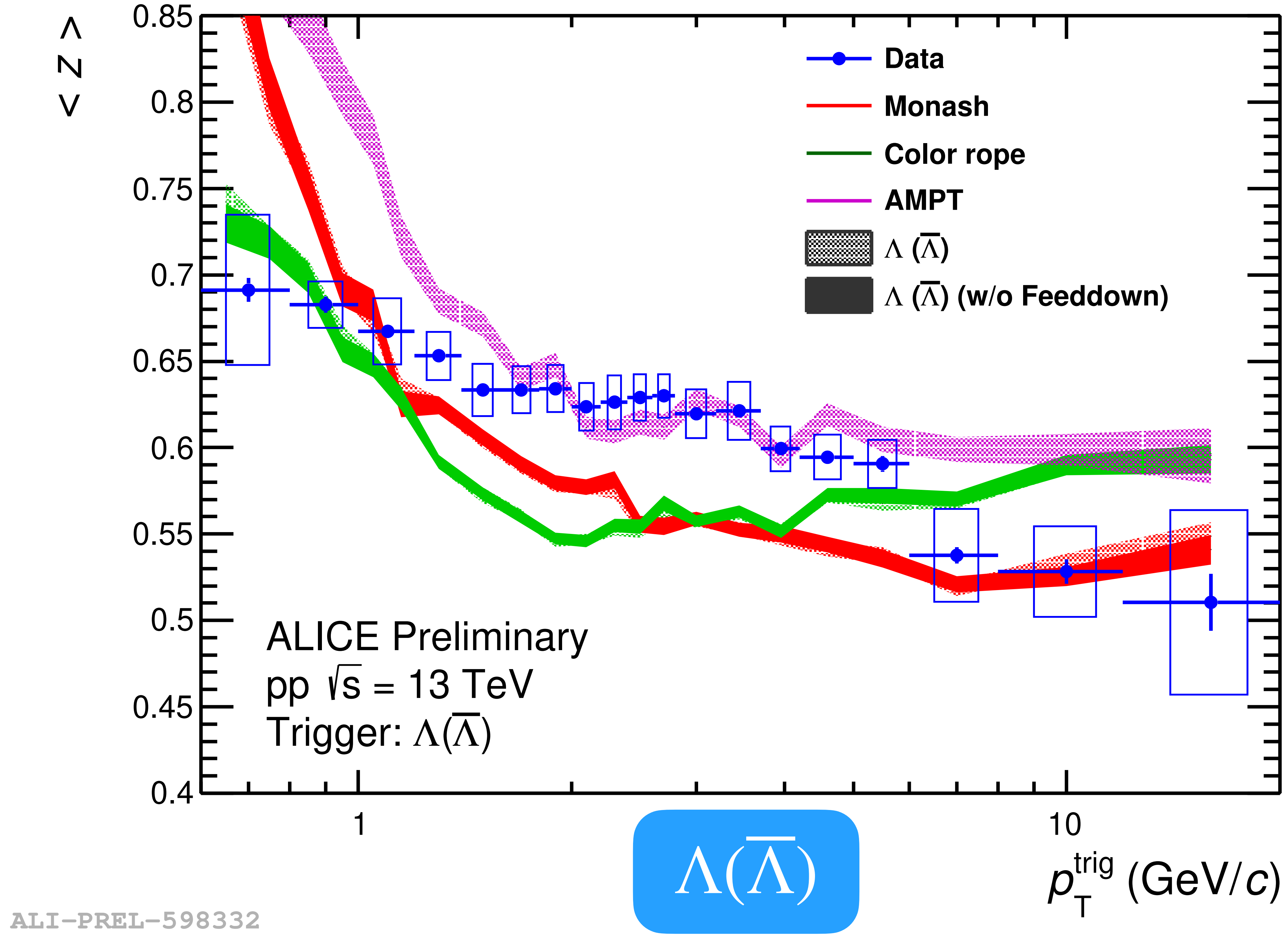


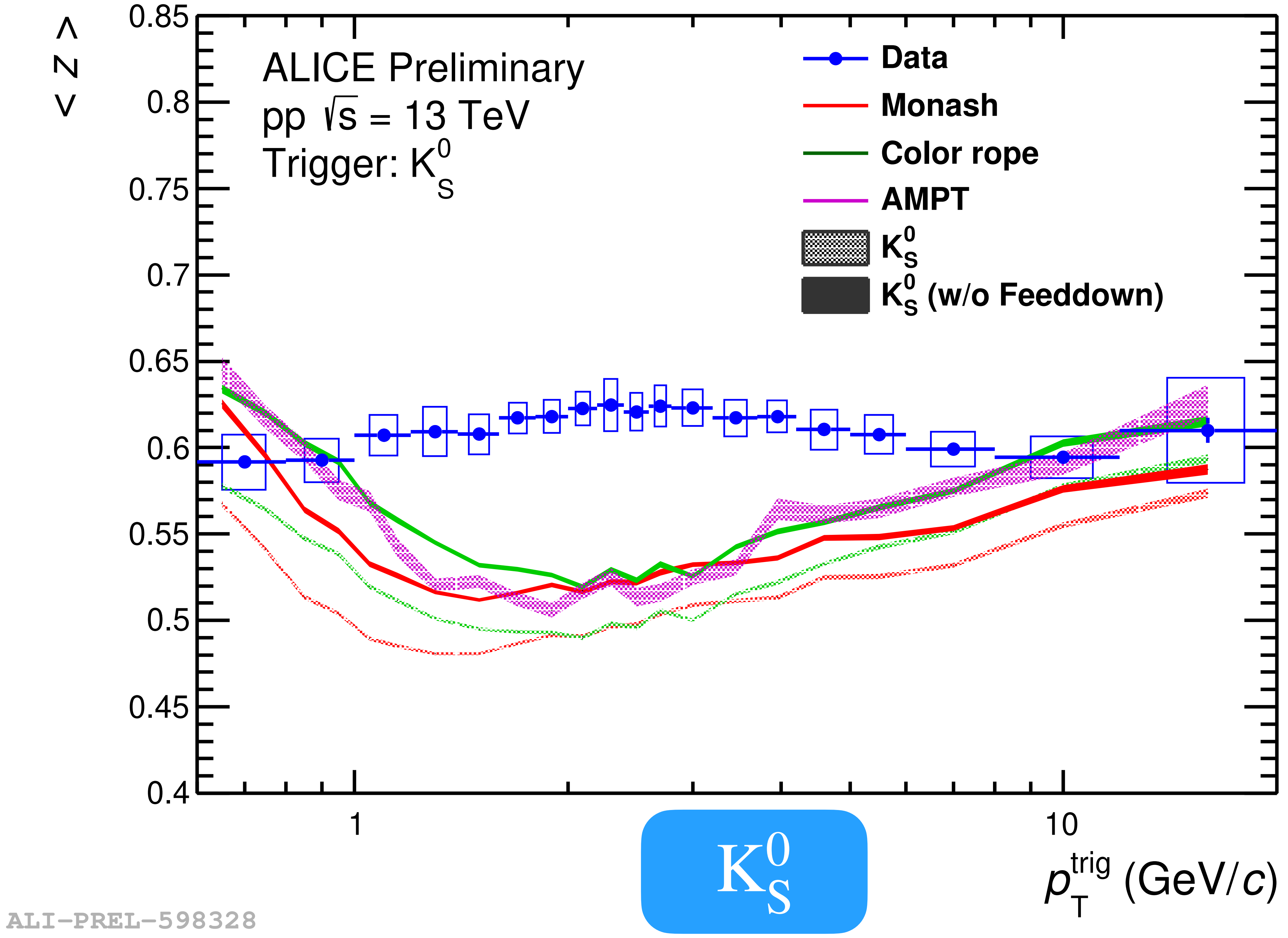
$\Lambda(\overline{\Lambda})$

$\Lambda\ (\overline{\Lambda})$:

- PYTHIA8 and AMPT only catch the shape for $\Lambda\ (\overline{\Lambda})$, not able to describe the magnitude
- No significant effect from feed-down from multi-strange particles

Results - < z > compared with predictions





K_S^0:

- PYTHIA8 and AMPT can NOT even catch the shape
- 10% decrease from resonance feed-down

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Summary and outlook

Summary:

- The first measurement of the strange particle's p_T fraction in mini-jets in pp collisions at $\sqrt{s}$ = 13 TeV, and a novel p_T weighted correlation method is presented
- Strange particles are more likely coming from (relative) lower-energy partons with high z than from an average fragmentation of higher-energy partons
- Neither PYTHIA8 (fragmentation) nor AMPT (coalescence) can well describe data, providing new constraints on models

Outlook:

- Extend the measurement to multi-strange particles
- Investigate the multiplicity dependence of the transverse momentum fraction for (multi-) strange particles

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Between

IOPP, Central China Normal University

and

IP2I, Université Claude Bernard Lyon 1

PhD candidate:

- Lang XU

Thesis title:

- Study of strange particle production in jets with ALICE at the LHC

Thesis supervisors:

- Cvetan Valeriev Cheshkov from IP2I, UCBL; Xiaoming Zhang from IOPP, CCNU

Topics:

- The novel measurement of the transverse-momentum fraction of (multi-) strange particle in (mini-)jets

Thanks for listening!

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Backup