Strangeness production with respect to high momentum hadrons in pp and p-Pb collisions with ALICE at the LHC

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on behalf of the ALICE Collaboration

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Strangeness in Quark Matter
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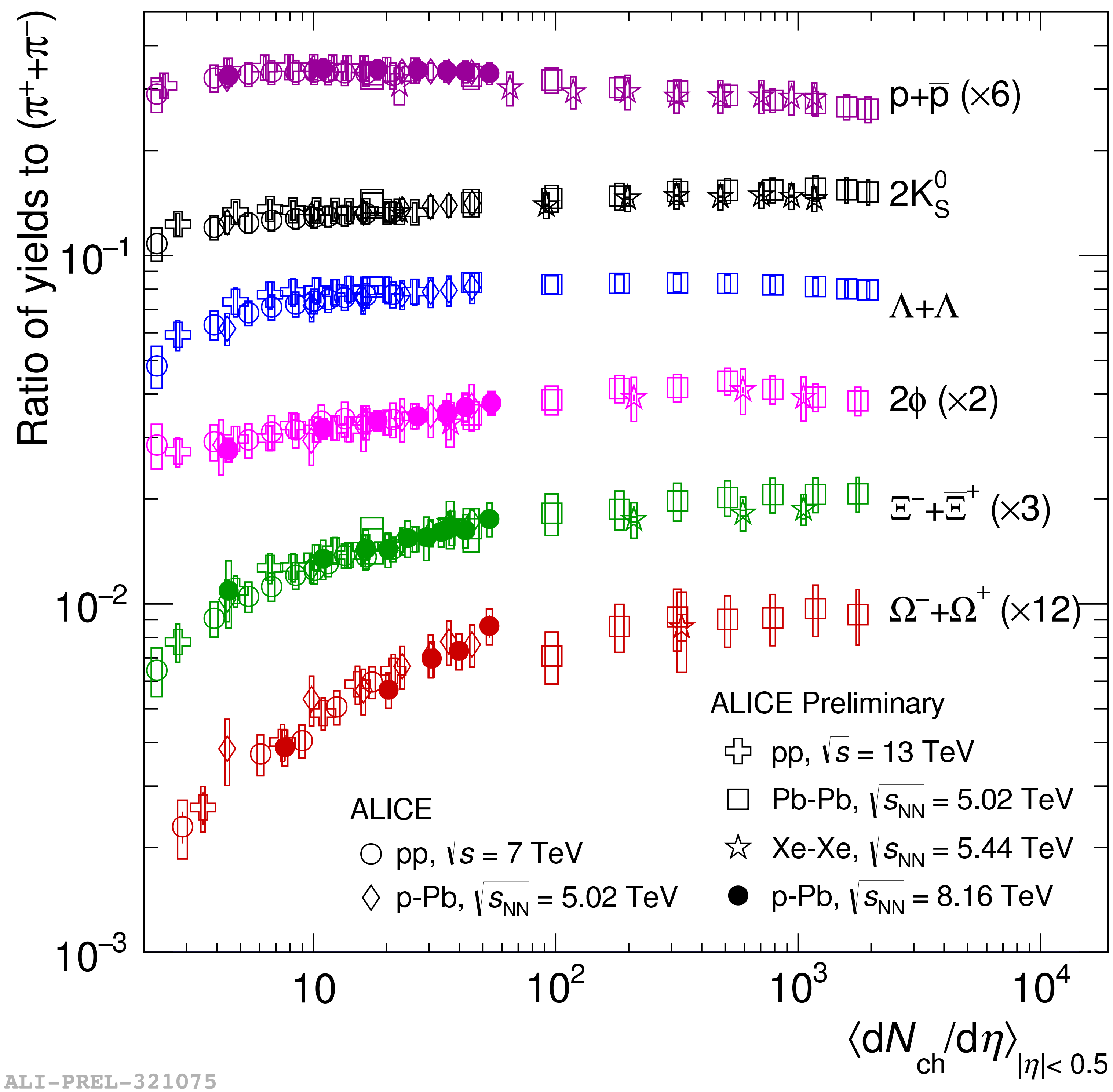
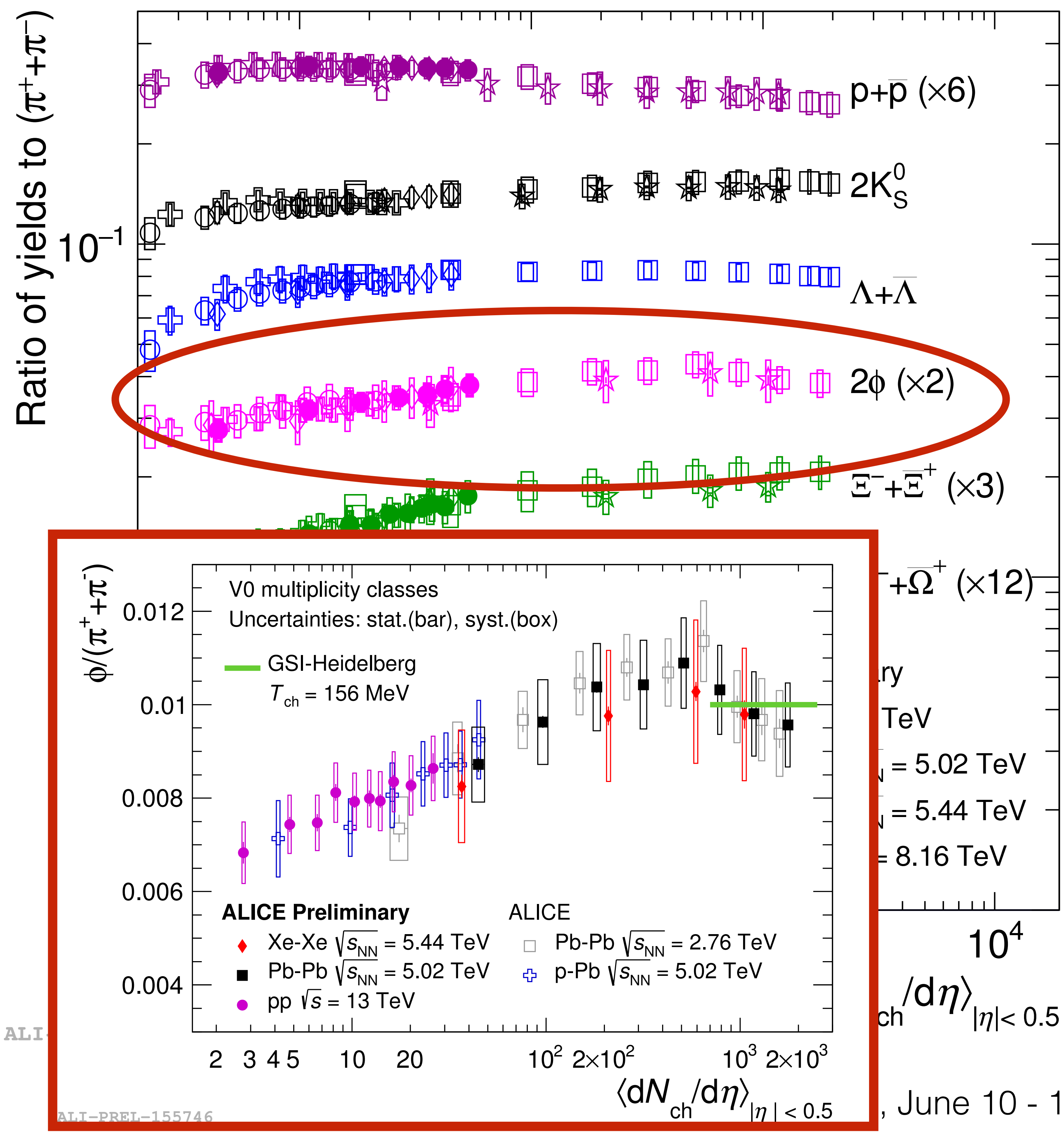
Motivation: Strangeness Enhancement



- Increase in strange particle production as function of multiplicity across all collision systems
- Larger net strangeness -> Larger production increase (ϕ does not behave like s=0 particle!)

ϕ ($s\bar{s}$) → |s|=0
Λ (uds) → |s|=1
Ξ (uss) → |s|=2
Ω (sss) → |s|=3

Motivation: Strangeness Enhancement

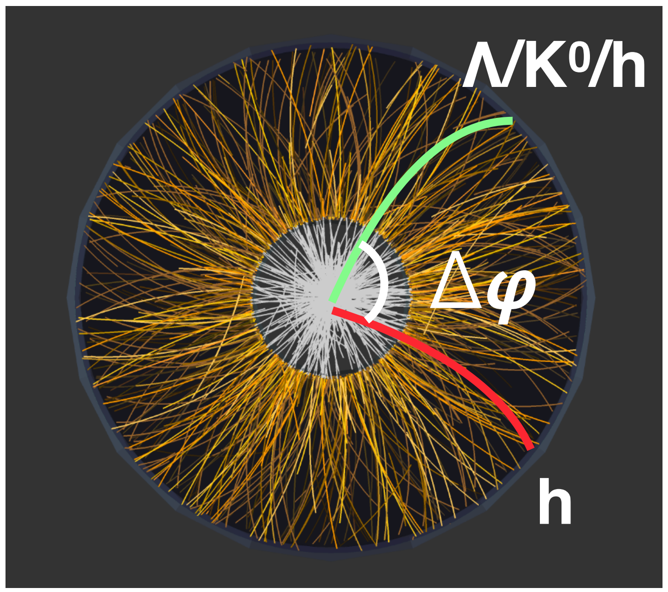


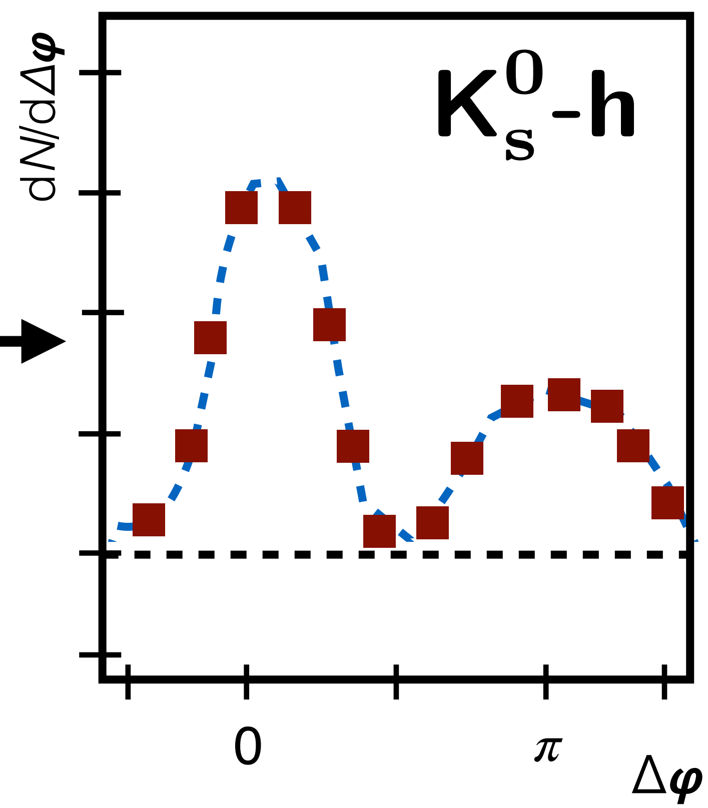
- Increase in strange particle production as function of multiplicity across all collision systems
- Larger net strangeness -> Larger production increase (ϕ does not behave like s=0 particle!)
- Intermediate sized collisions systems (p-Pb, high mult. pp) allow us to study the origin of this enhancement

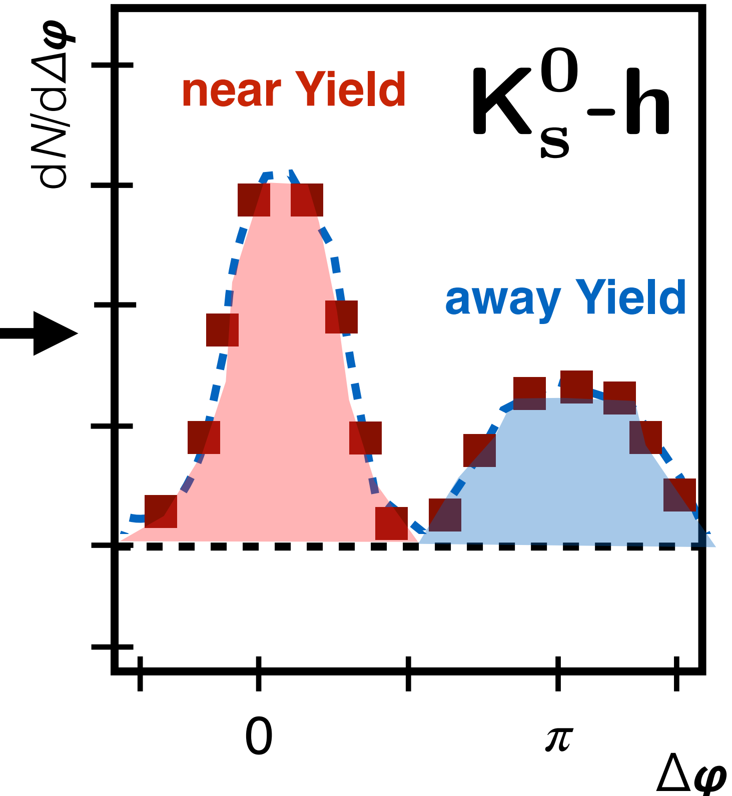
Does the inclusive ratio tell the whole story?

Motivation: Using Correlations to Study Strangeness

Identified Strange Trigger Particles







trigger: $3.0 < p_{T,trig} < 15.0$ GeV/c

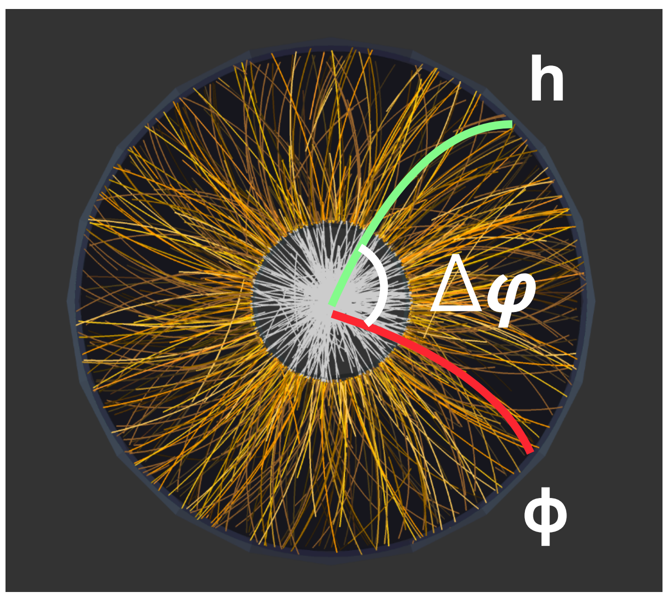
assoc: 1.0 GeV/$c < p_{T,assoc} < p_{T,trig}$

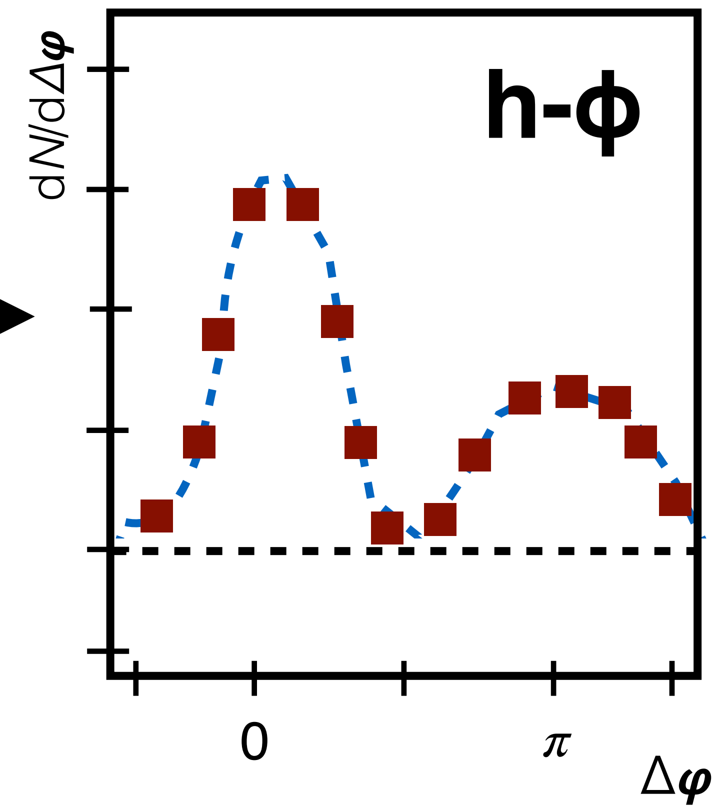
Comparing jet yields with identified strange trigger particle and inclusive charged hadron trigger gives way of studying possible interactions between jet hadro-chemistry and fragmentation.

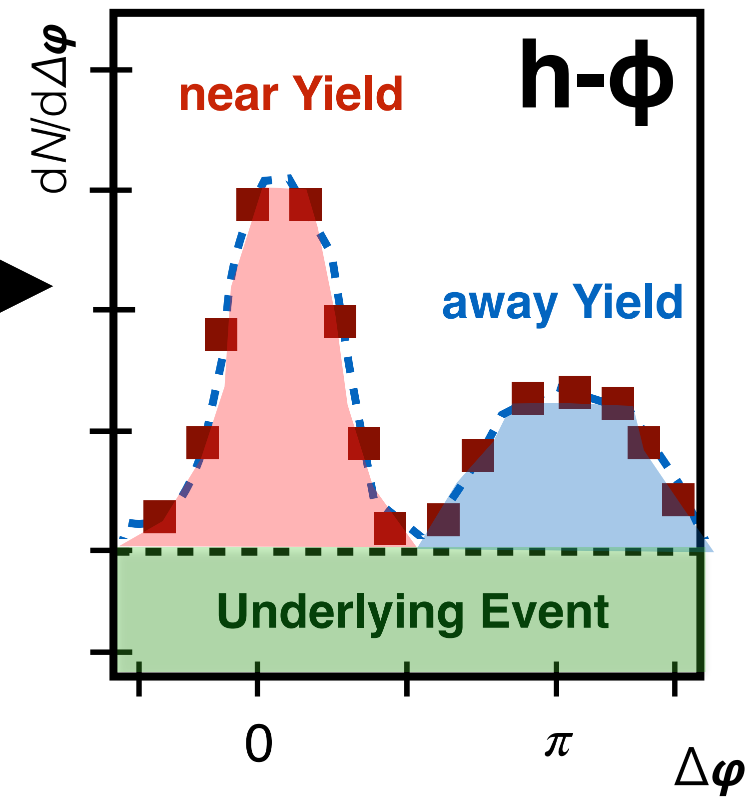
How does jet yield and hadro-chemistry change as a function of multiplicity for jets containing strangeness?

Motivation: Using Correlations to Study Strangeness

Identified Strange Associated Particles







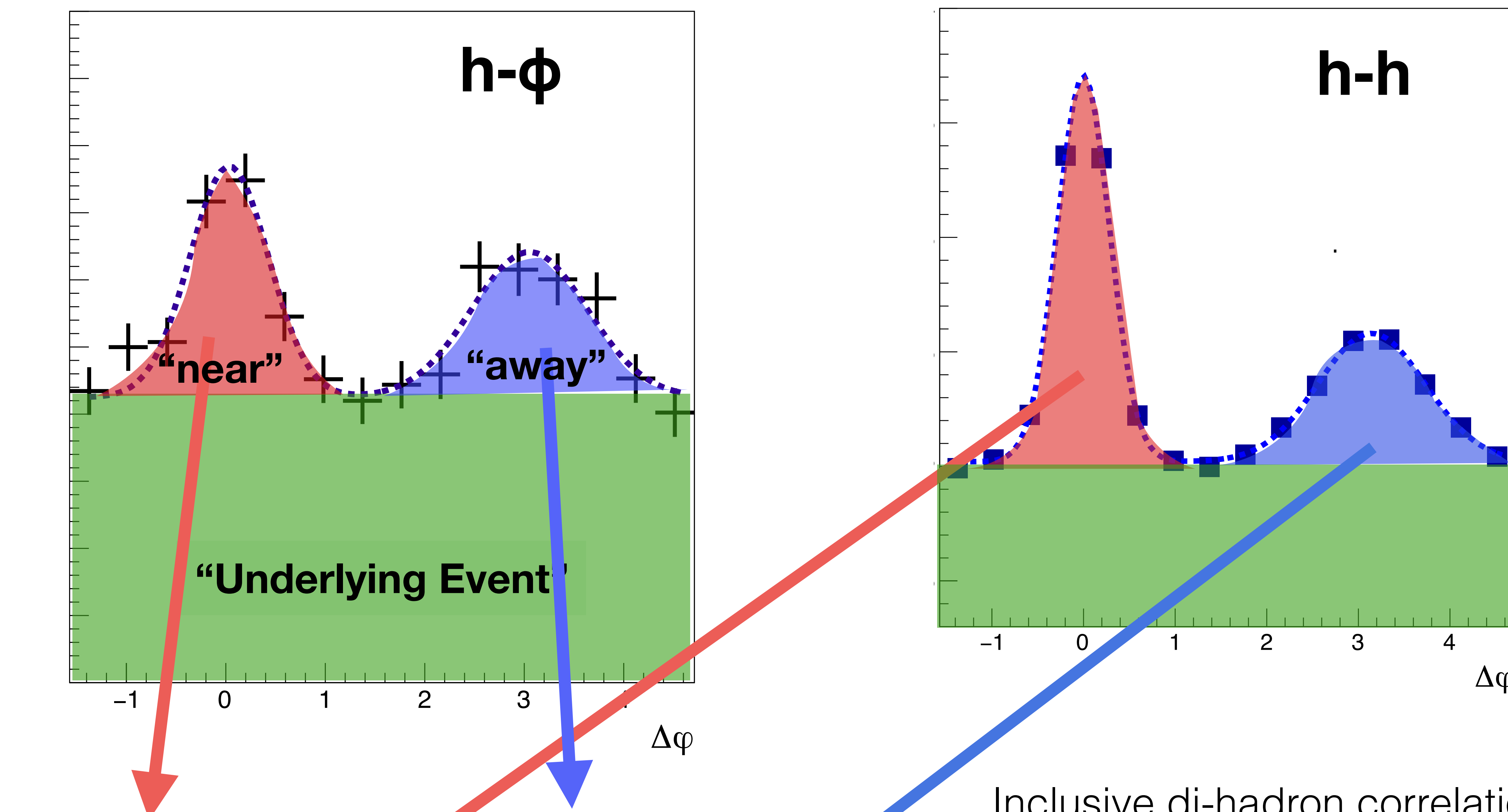
trigger: 4.0 < p_T^h < 8.0 GeV/*c*

assoc: 2.0 < p_T^ϕ < 4.0 GeV/*c*

Measuring the angular correlation between a high p_T hadron trigger (jet proxy) and a ϕ meson gives us a way to separate out **ϕ produced in jets** from **ϕ produced in the underlying event**

How does jet vs. non-jet production affect increase in strangeness?

Extracting Particle Yields from Angular Correlations



$$\left(\frac{(h-\phi)}{(h-h)}\right)_{\mathrm{Near}} \qquad \left(\frac{(h-\phi)}{(h-h)}\right)_{\mathrm{Away}}$$

Inclusive di-hadron correlation allows for direct comparison between strange and non-strange particle production/fragmentation

ALICE Detector

Detectors of interest:

- Inner-Tracking System (ITS)
- Time Projection Chamber (TPC)
- Time of Flight (TOF)

V0: Multiplicity is measured in the forward rapidity region using small angle scintillating detectors

V0A: $2.8 < \eta < 5.1$
V0C: $-3.7 < \eta < -1.7$

ITS: tracking & vertex reconstruction

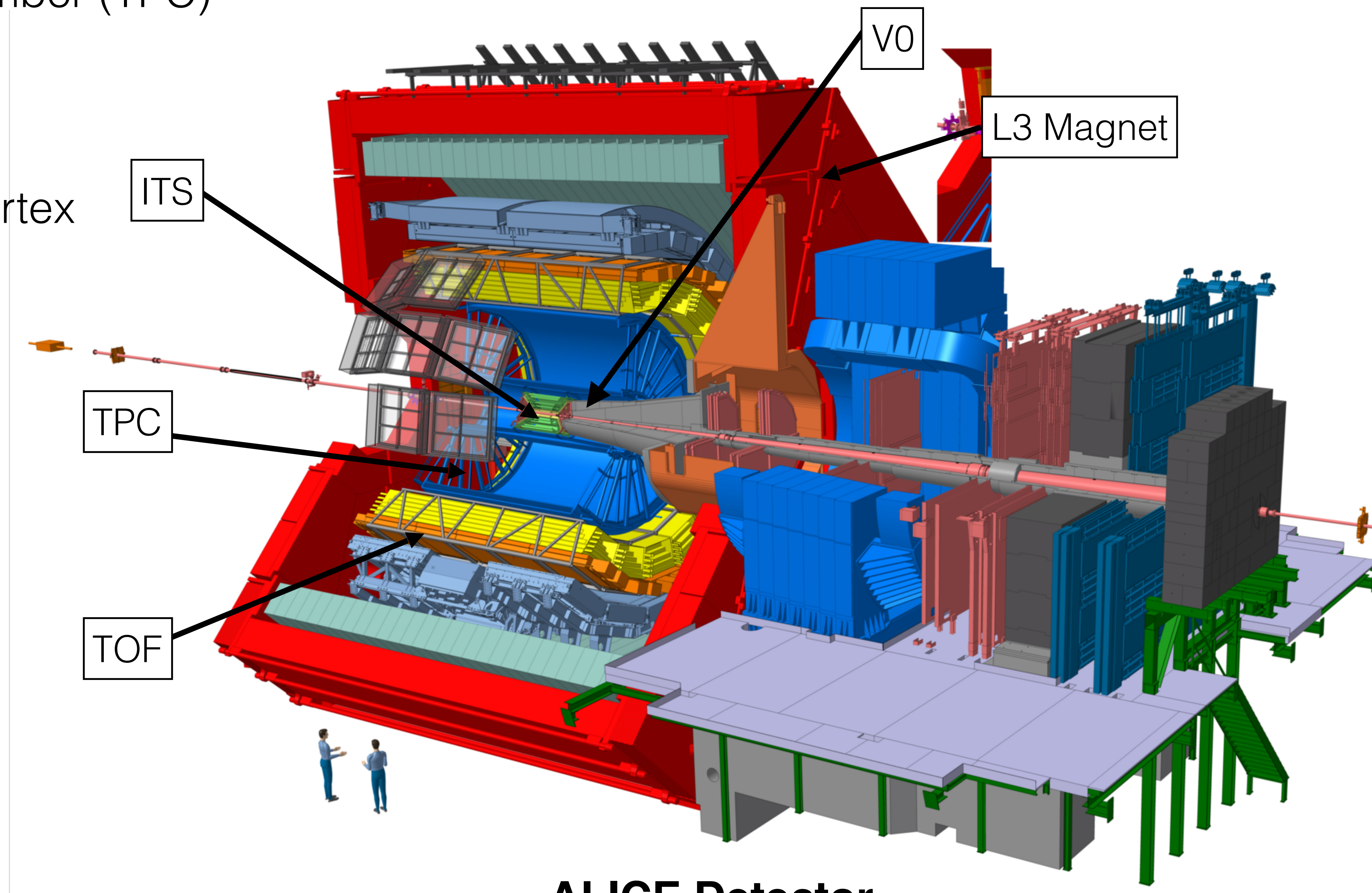
$|\eta| < 0.9$

TPC: tracking & PID

$|\eta| < 0.9$

TOF: PID information

$|\eta| < 0.9$



ALICE Detector

Identified Trigger (K^0_s)

K^0_s-h vs. h-h Correlations in pp at $\sqrt{s_{NN}}$ = 13 TeV

Identified K^0_s Trigger Angular Correlations in pp

Lucia Husova

<u>Poster 156:</u> "Two-particle correlations with high-p_T K^0 mesons in pp collisions at ALICE"

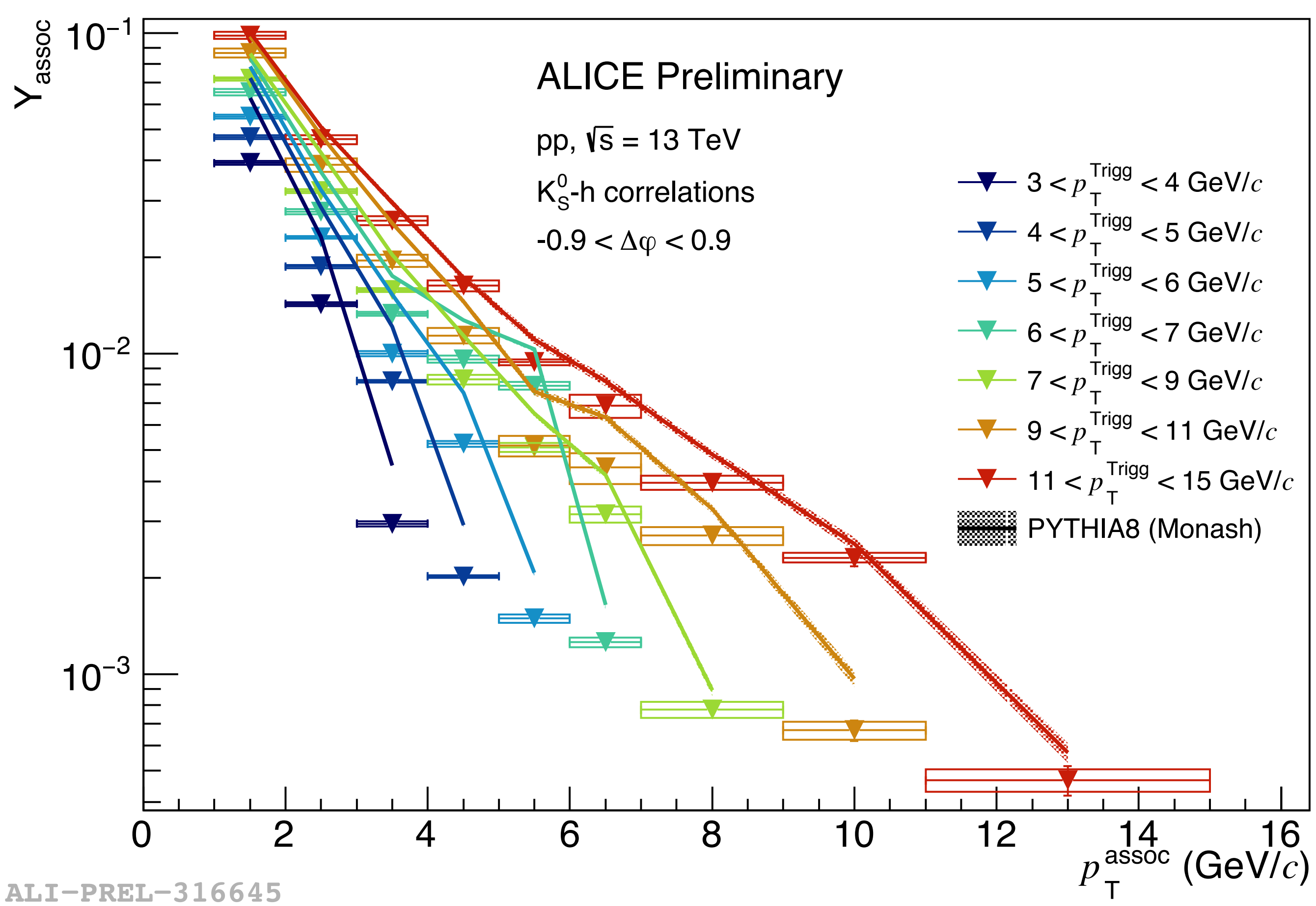
$$K^0_s \longrightarrow \pi^+\pi^-$$

Topological and Invariant mass cuts to identify K^0_s triggers

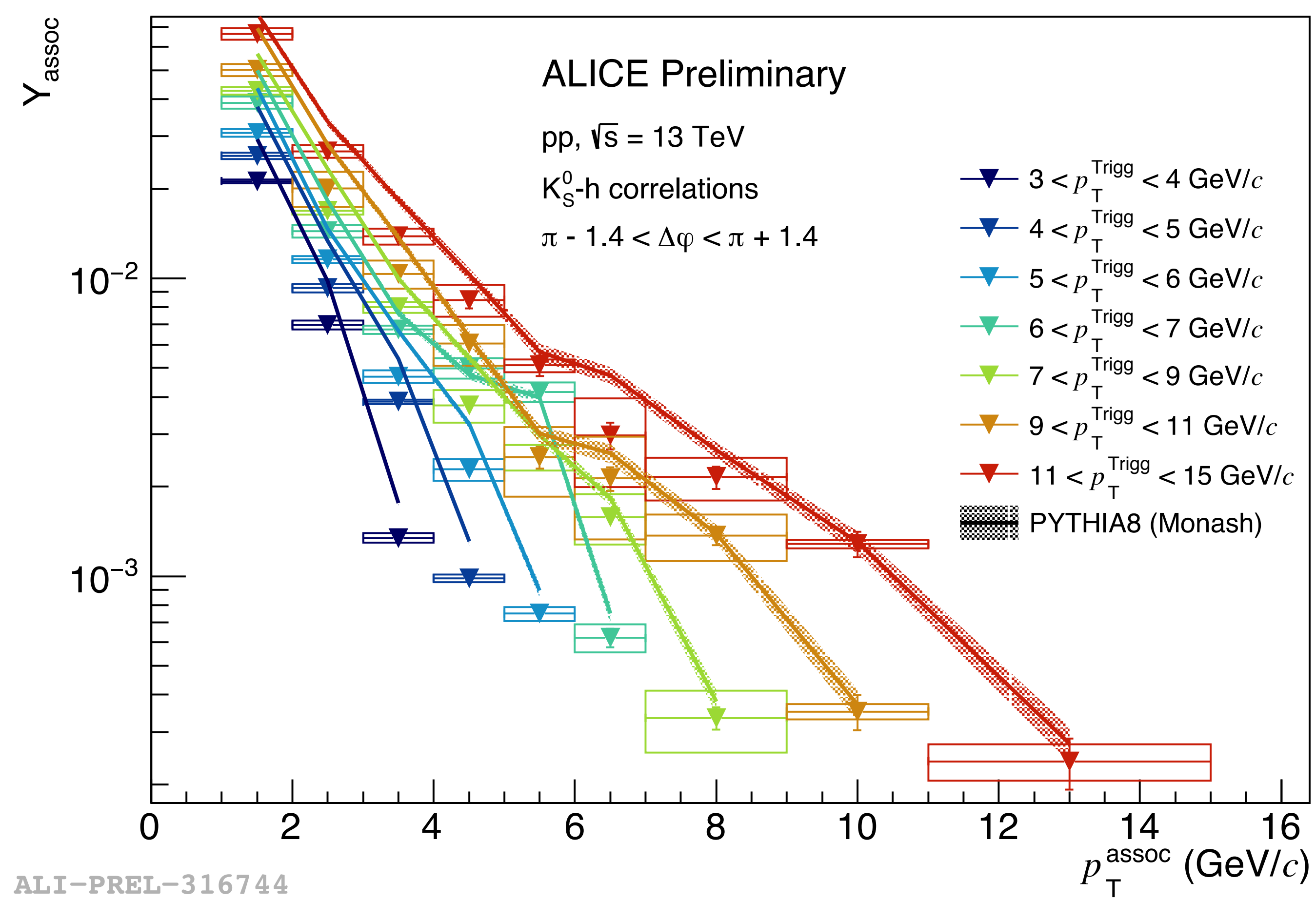
New in ALICE

Pythia describes trend of associated hadron p_T, overestimates near-side yields

Associated Yield vs. p_T^{assoc}



Near-side



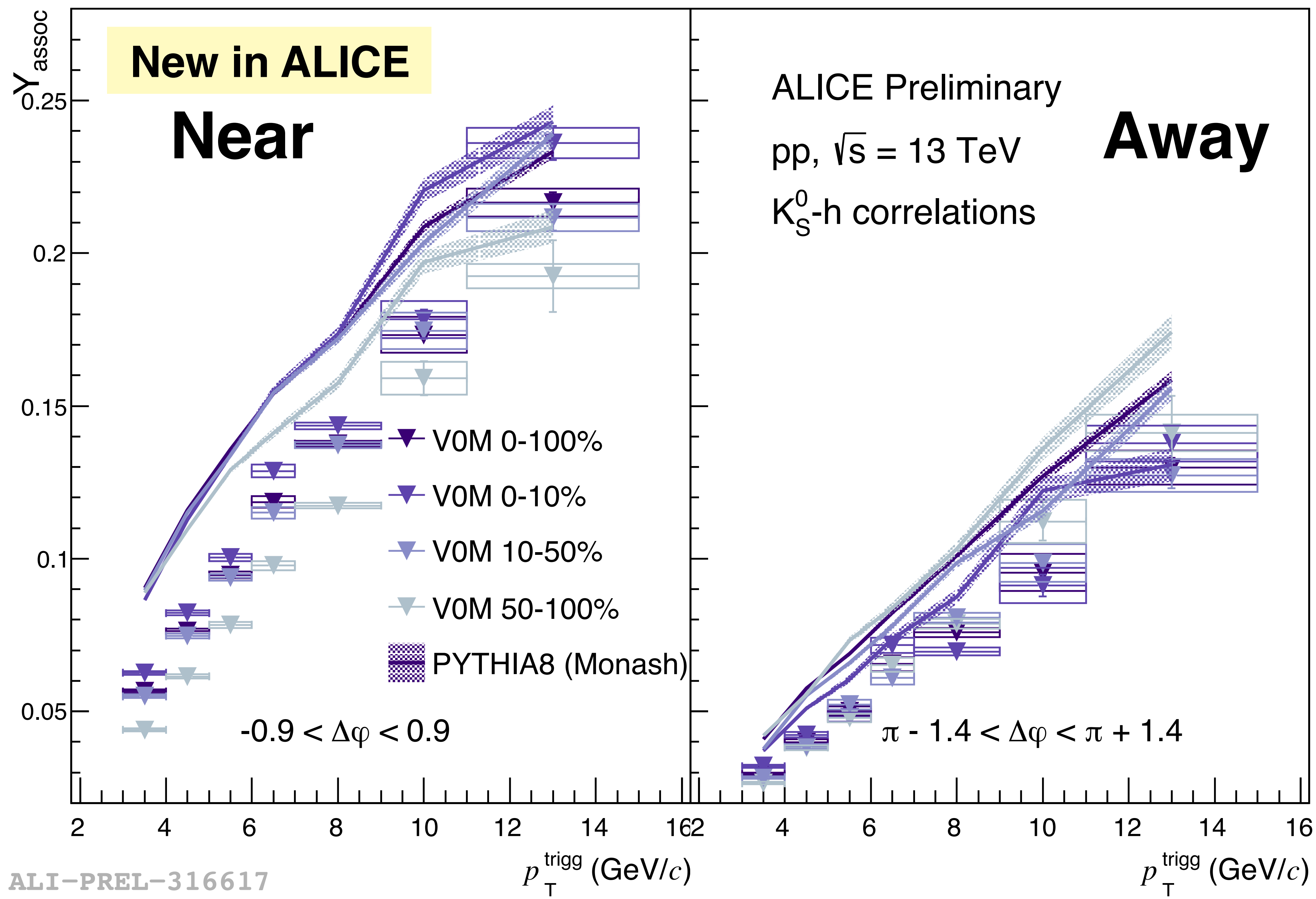
Away-side

Identified K_s^0 Trigger Angular Correlations in pp

Associated Yield vs. p_T^{trig}

Associated yields for trigger p_T cuts measured for different multiplicities.

Pythia matches qualitatively but over predicts near-side yields across all multiplicities

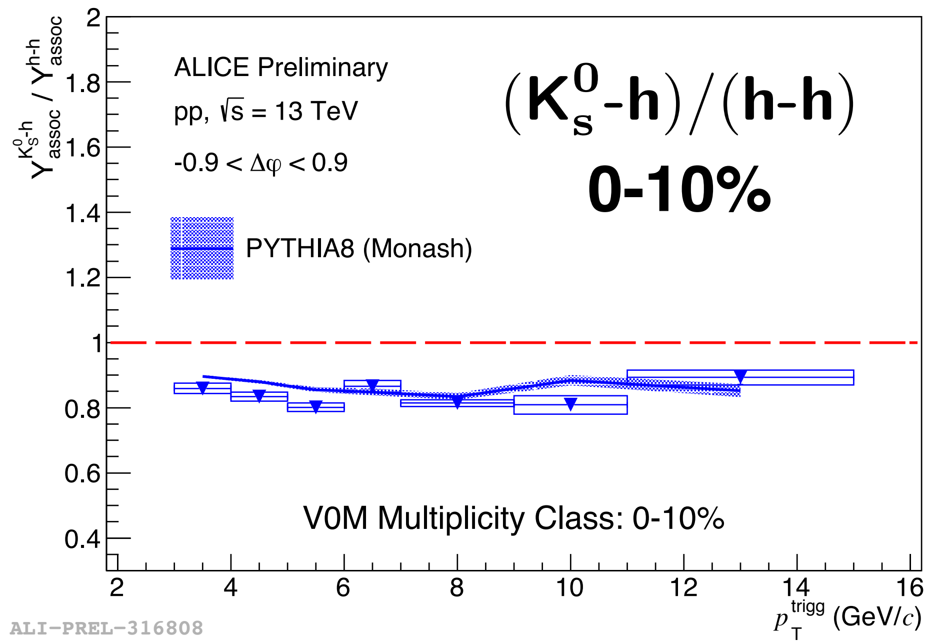


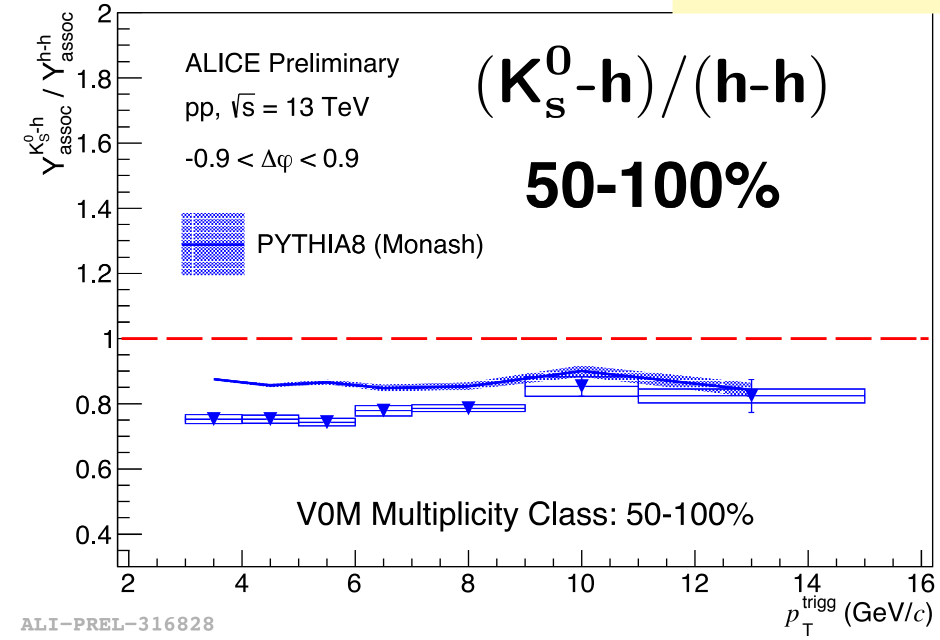
Comparison between K^0_s-h and h-h Correlations

K^0_S-h yields consistently lower than h-h, but ratio is constant across multiplicities and agrees with Pythia

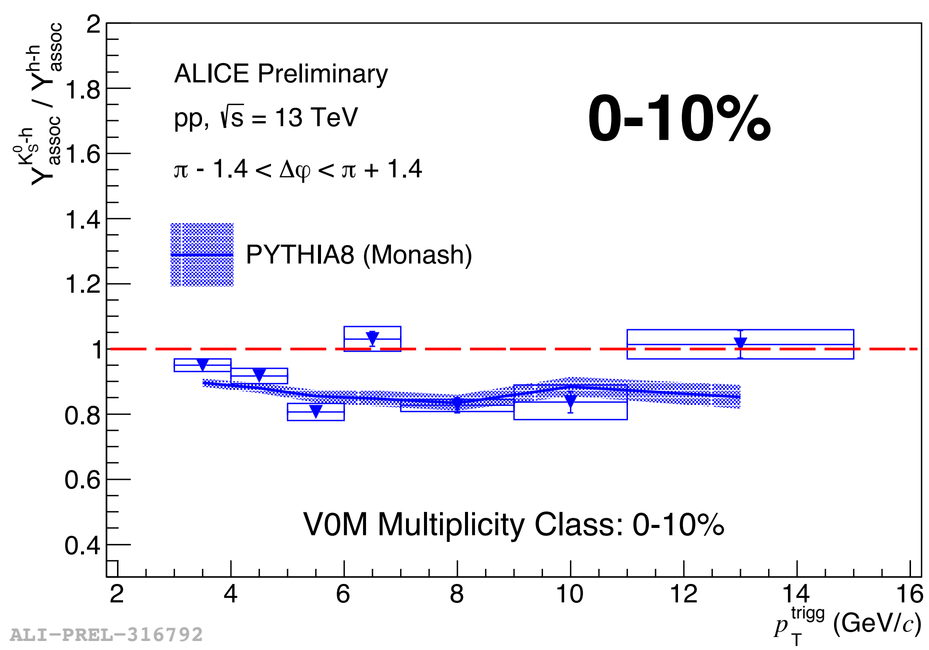
New in ALICE

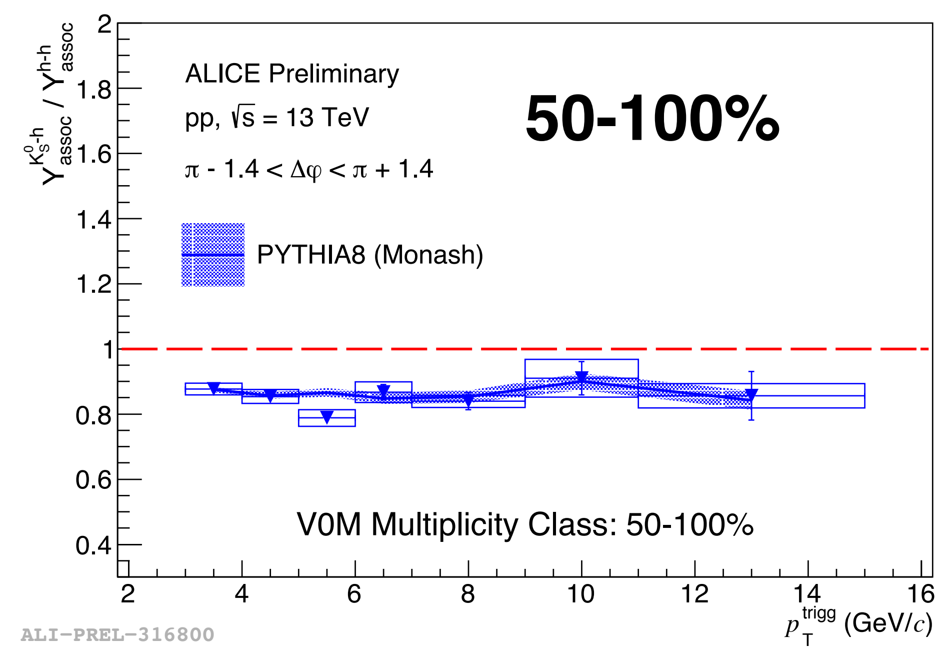
Near-side





Away-side



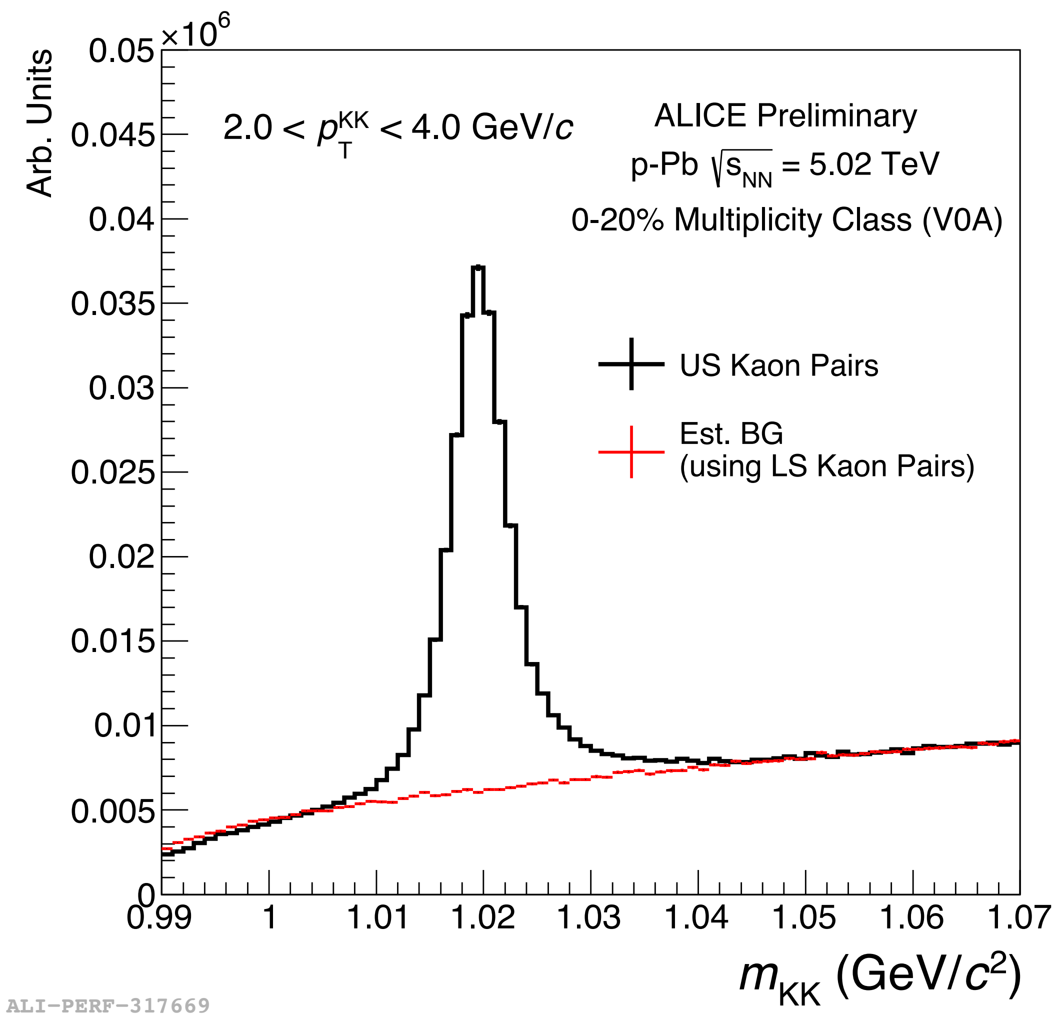


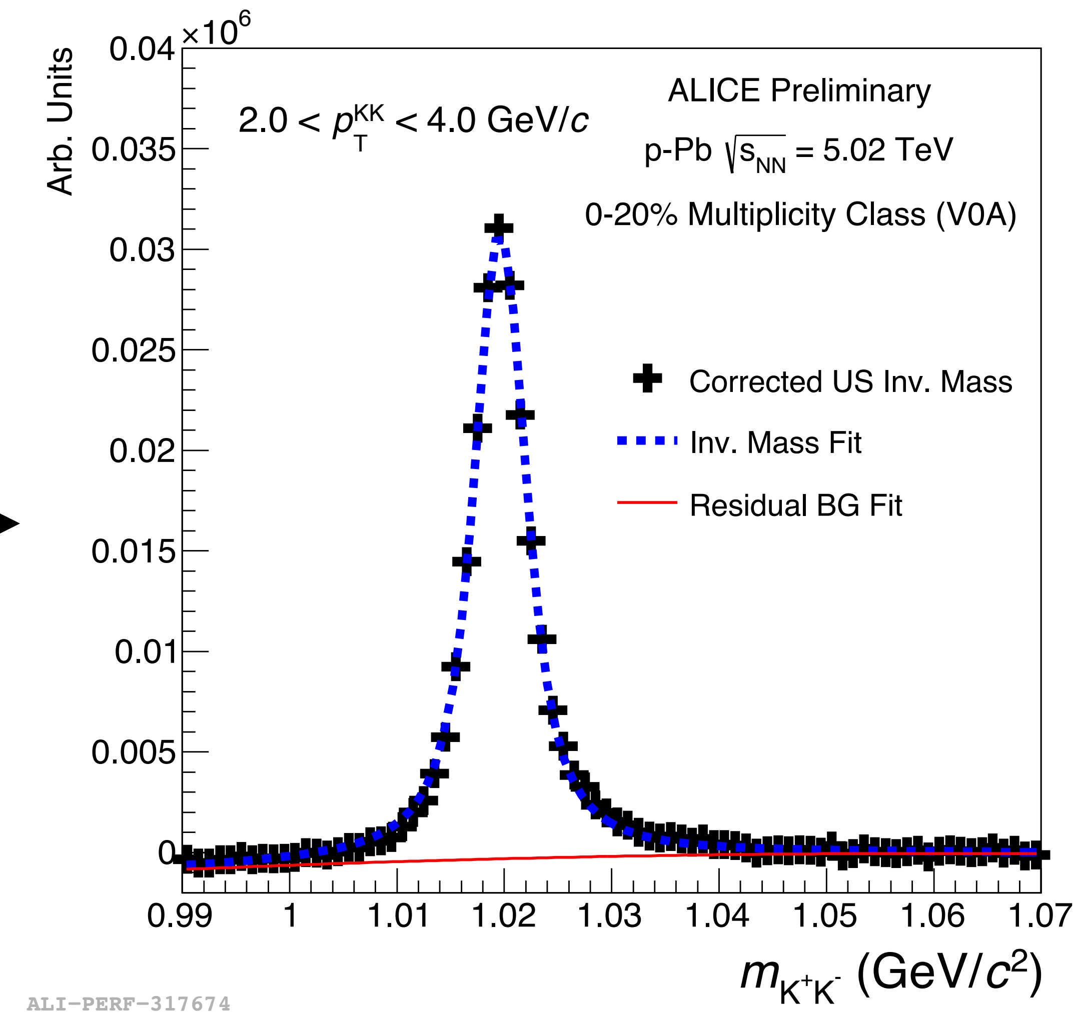
Identified Associated (ϕ)

h-ϕ vs. h-h Correlations in p-Pb at $\sqrt{s_{NN}}$ = 5.02 TeV

h-ϕ(1020) Correlation Measurement

ϕ(1020): **$s\bar{s}$** Main decay of interest: ϕ → $K^+ K^-$ (~49%)





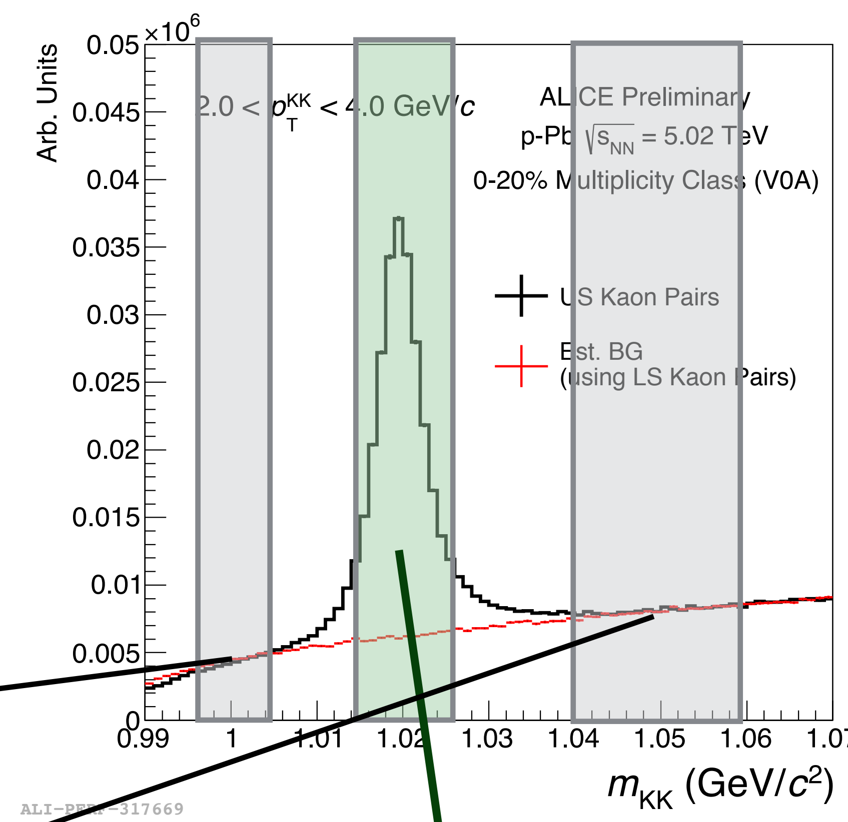
Invariant Mass distribution of unlike sign (US) and like sign (LS) kaon pairs.

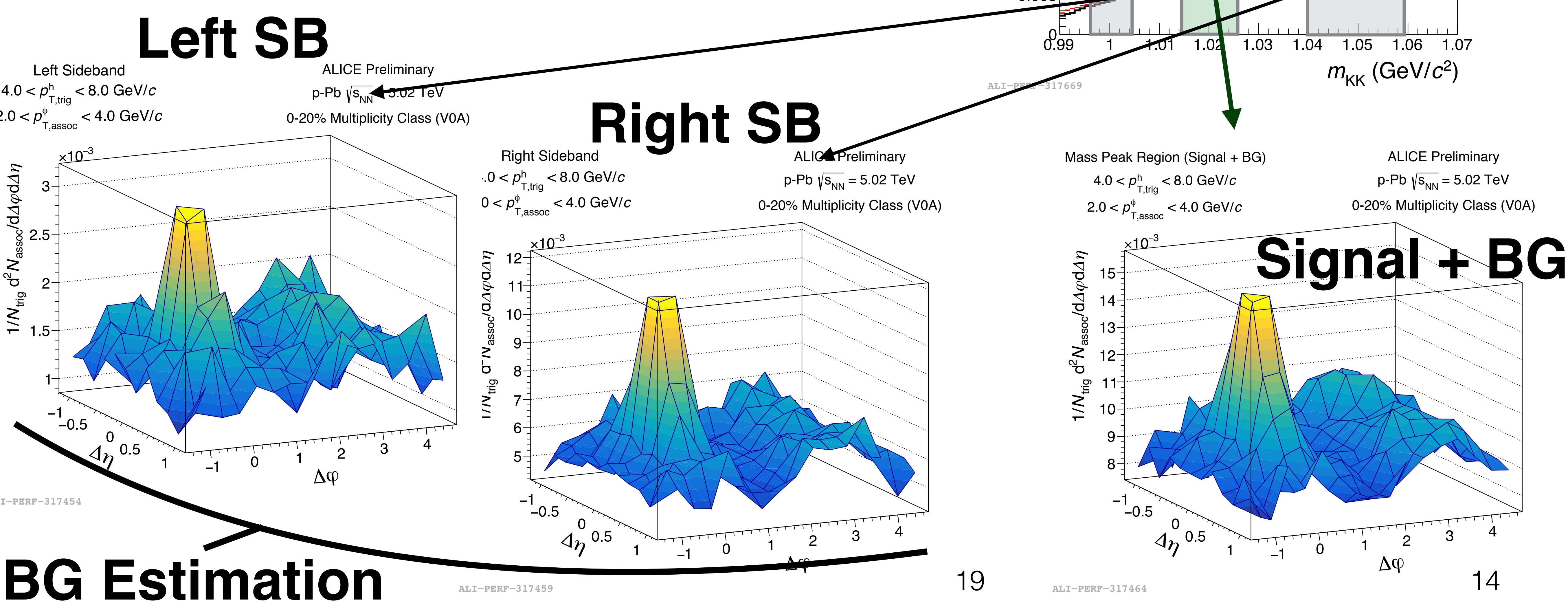
Scaled like sign distribution correctly estimates combinatorial BG under mass peak, gives scale factor for correlation corrections.

Method: Correlation Background Estimation

Correlation contains Signal (h-ϕ) and Background (h-(KK)) components. **Signal/BG ≈ 2.5**

Averaging and scaling correlations in Sideband region (gray) gives estimate of BG in the peak region (green)





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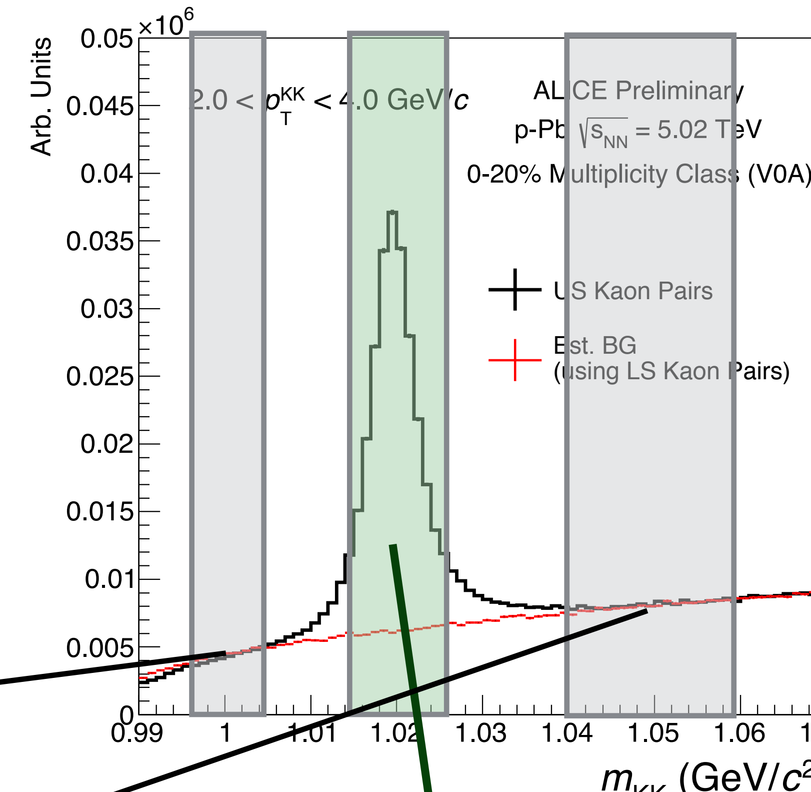
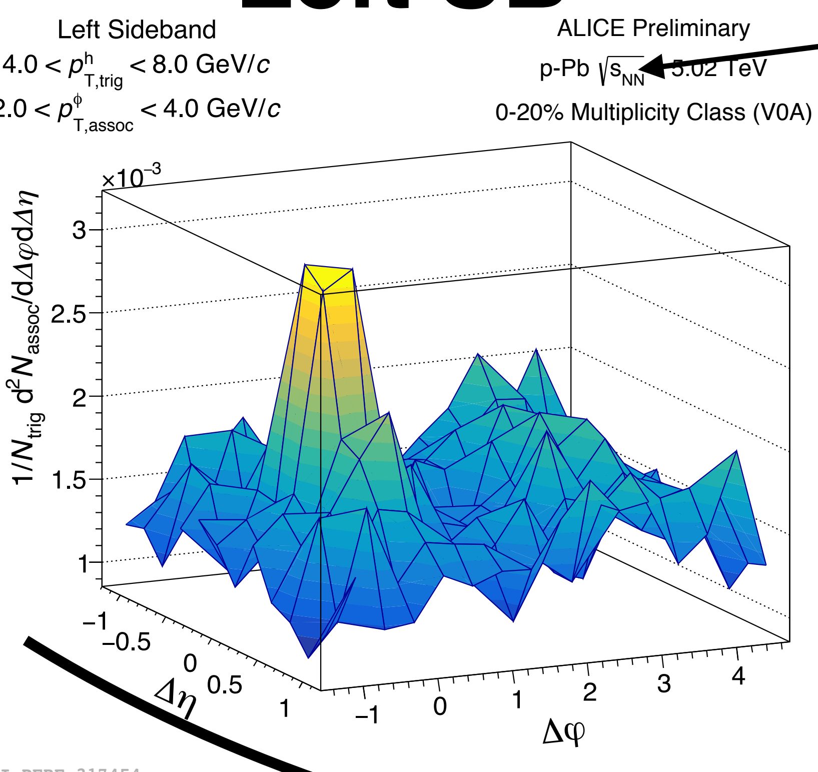
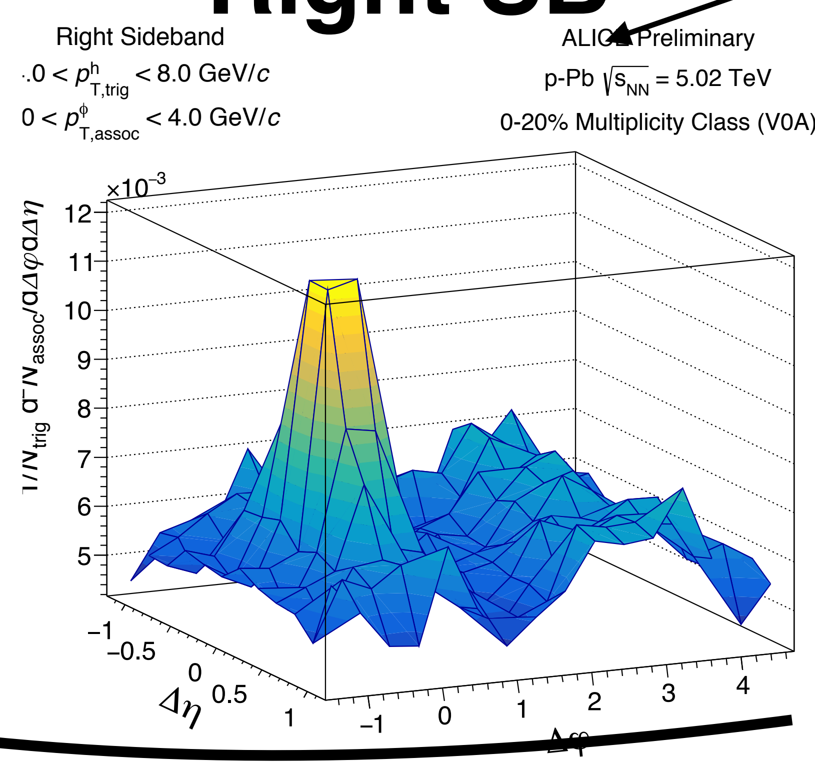
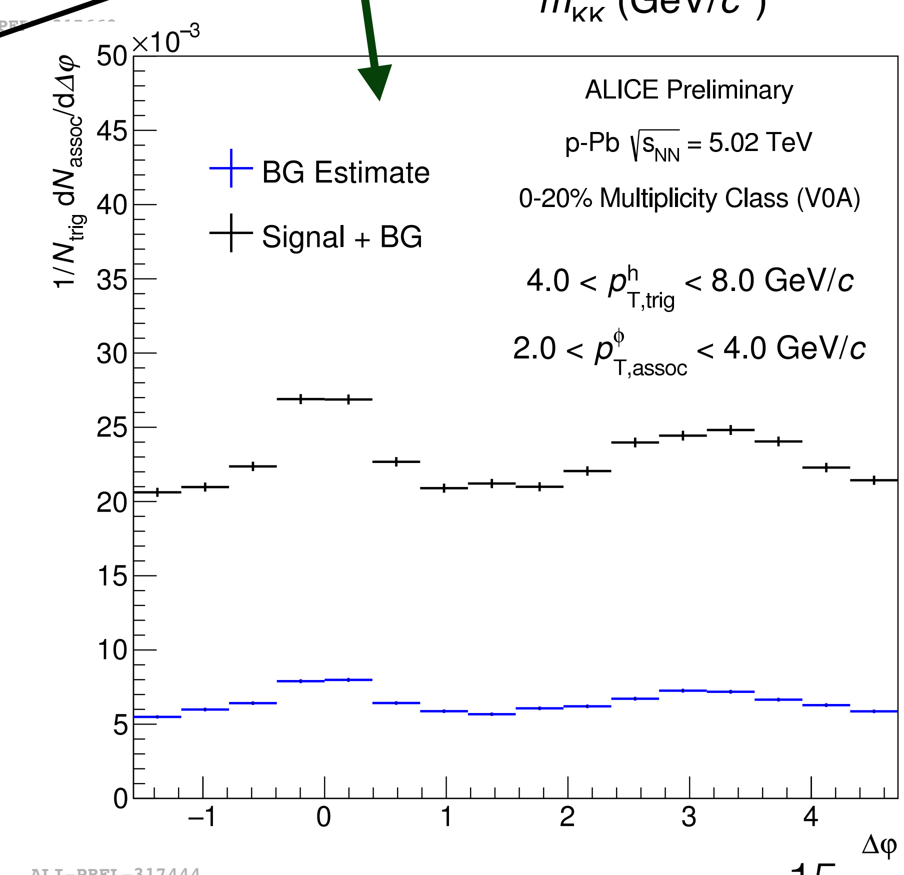


Left SB



Right SB





BG Estimation

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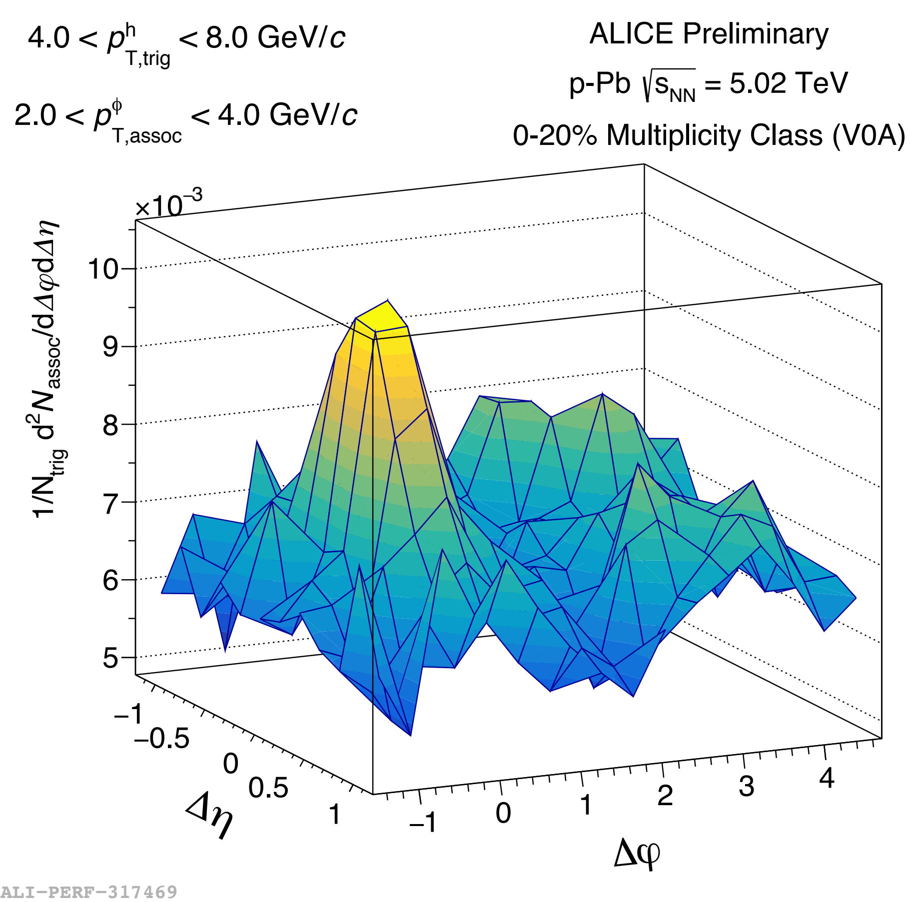
Per-trigger h-ϕ(1020) 2D correlations

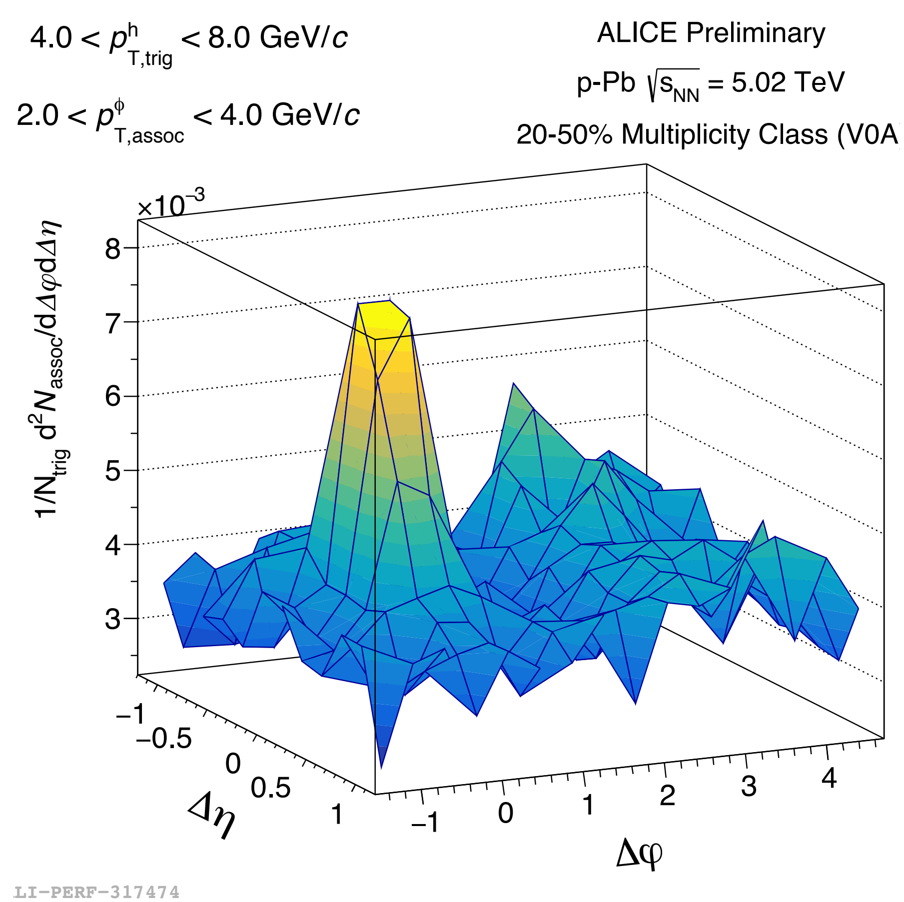
New in ALICE

After h-(KK) background removal, h-ϕ 2D angular correlation measured in 3 different multiplicity bins.

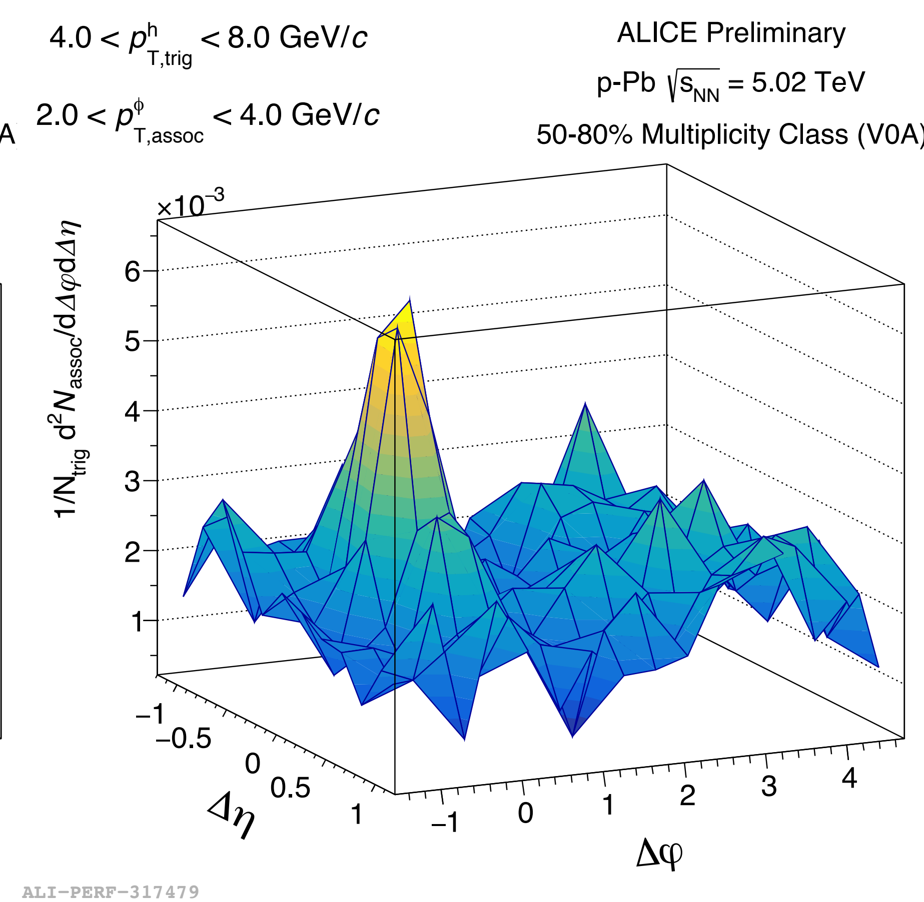
0-20%



20-50%



50-80%



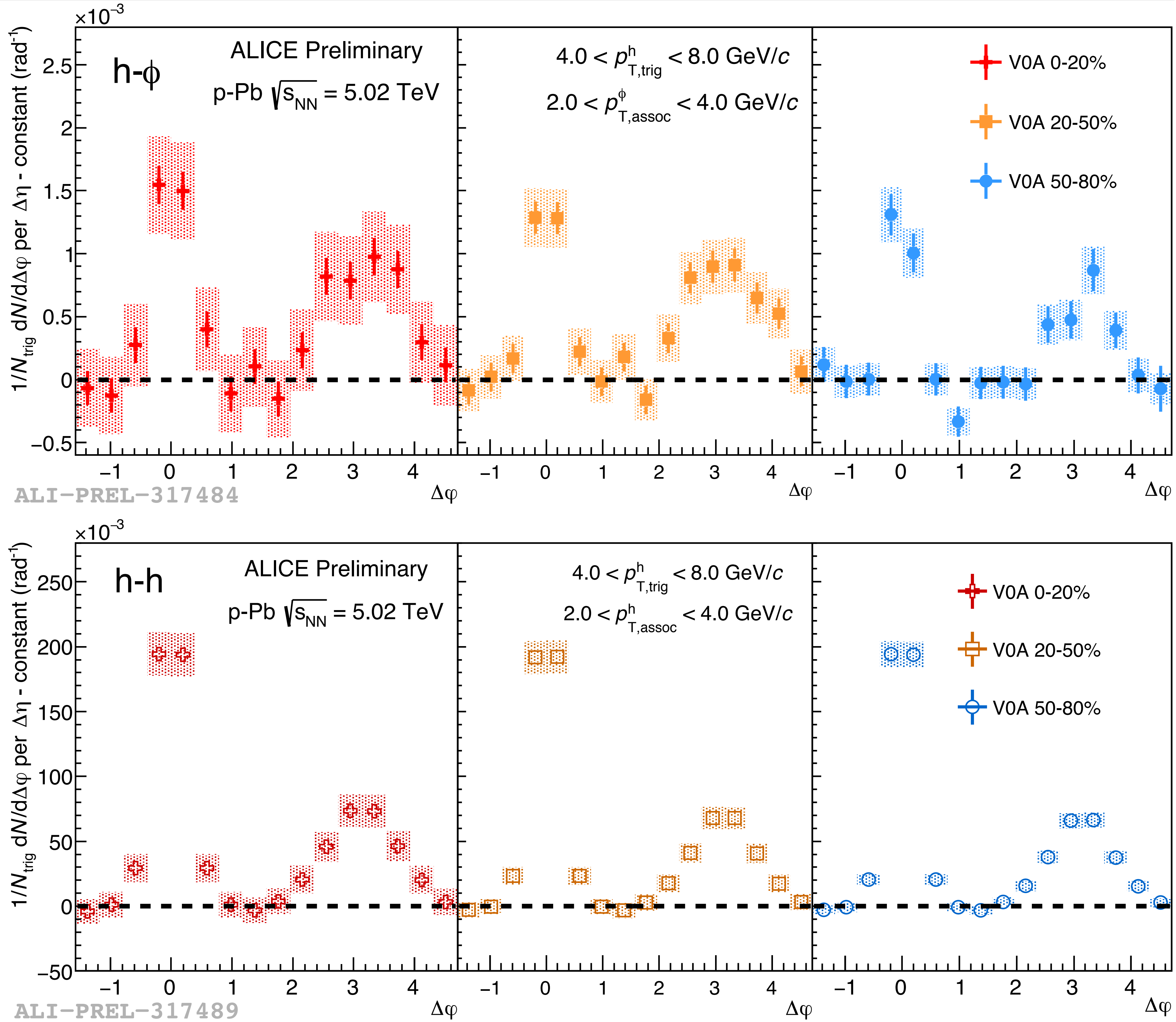
h-ϕ and h-h $\Delta\varphi$ Correlations

New in ALICE

Jet yields extracted from projected 1D $\Delta\varphi$ correlations

“Underlying event” pairs estimated with constant term under jet peaks

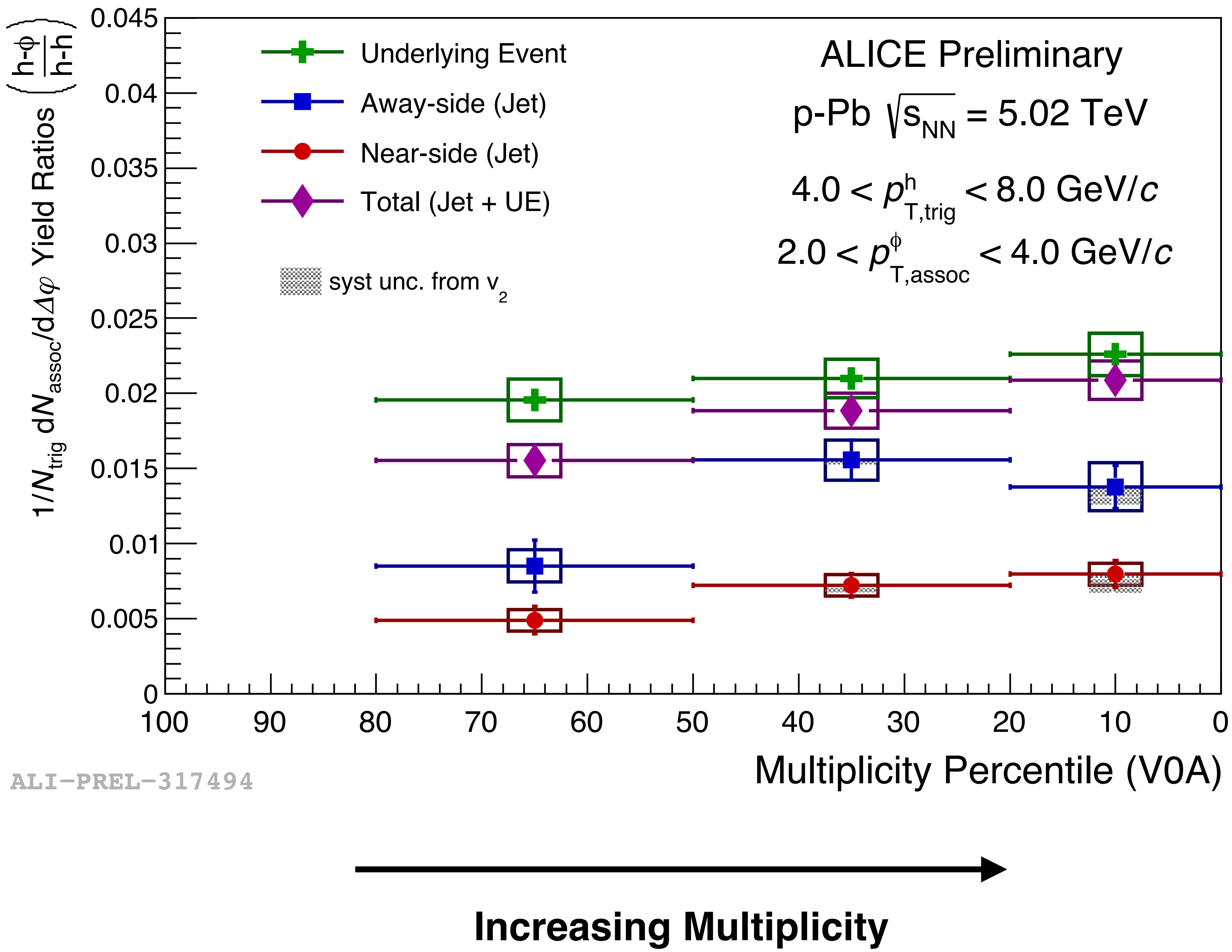
Di-hadron correlations give jet and “underlying event” yields for h-h pairs

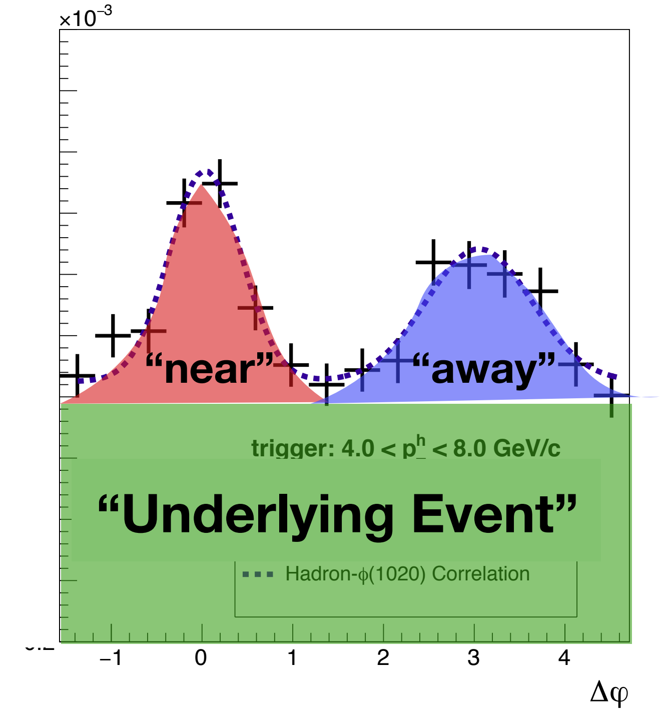


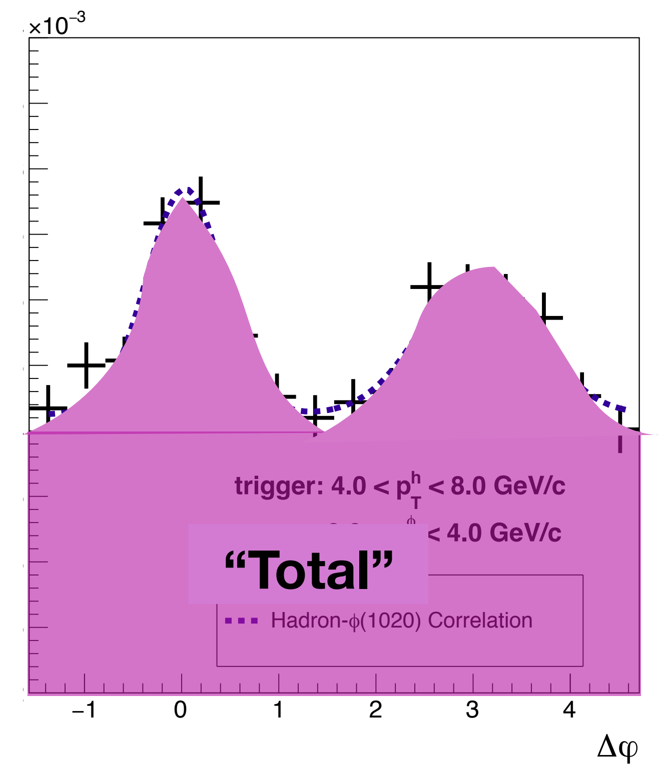
(ϕ/h) ratio in Jet and Underlying Event

New in ALICE

(h-ϕ)/(h-h)



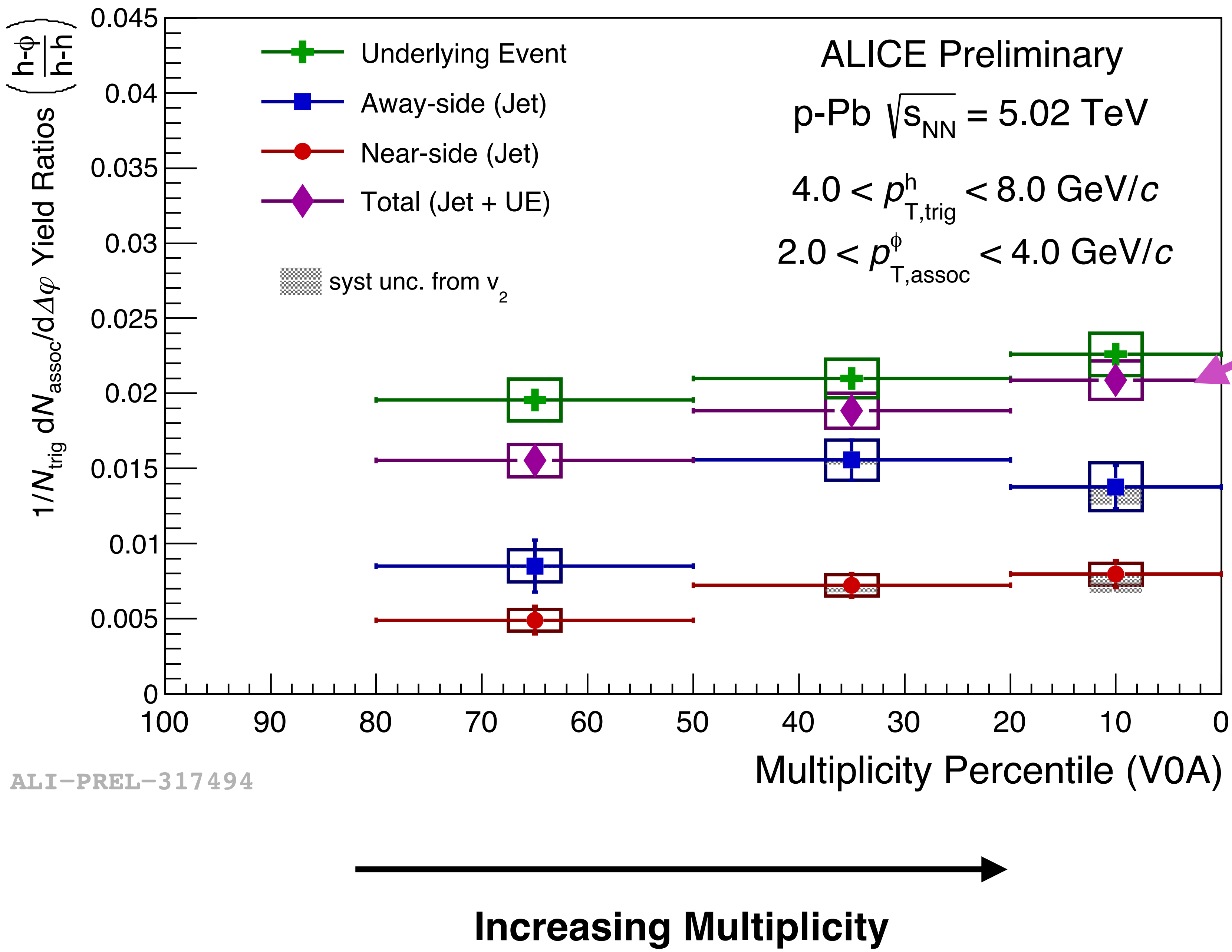




(ϕ/h) ratio in Jet and Underlying Event

New in ALICE

(h-ϕ)/(h-h)

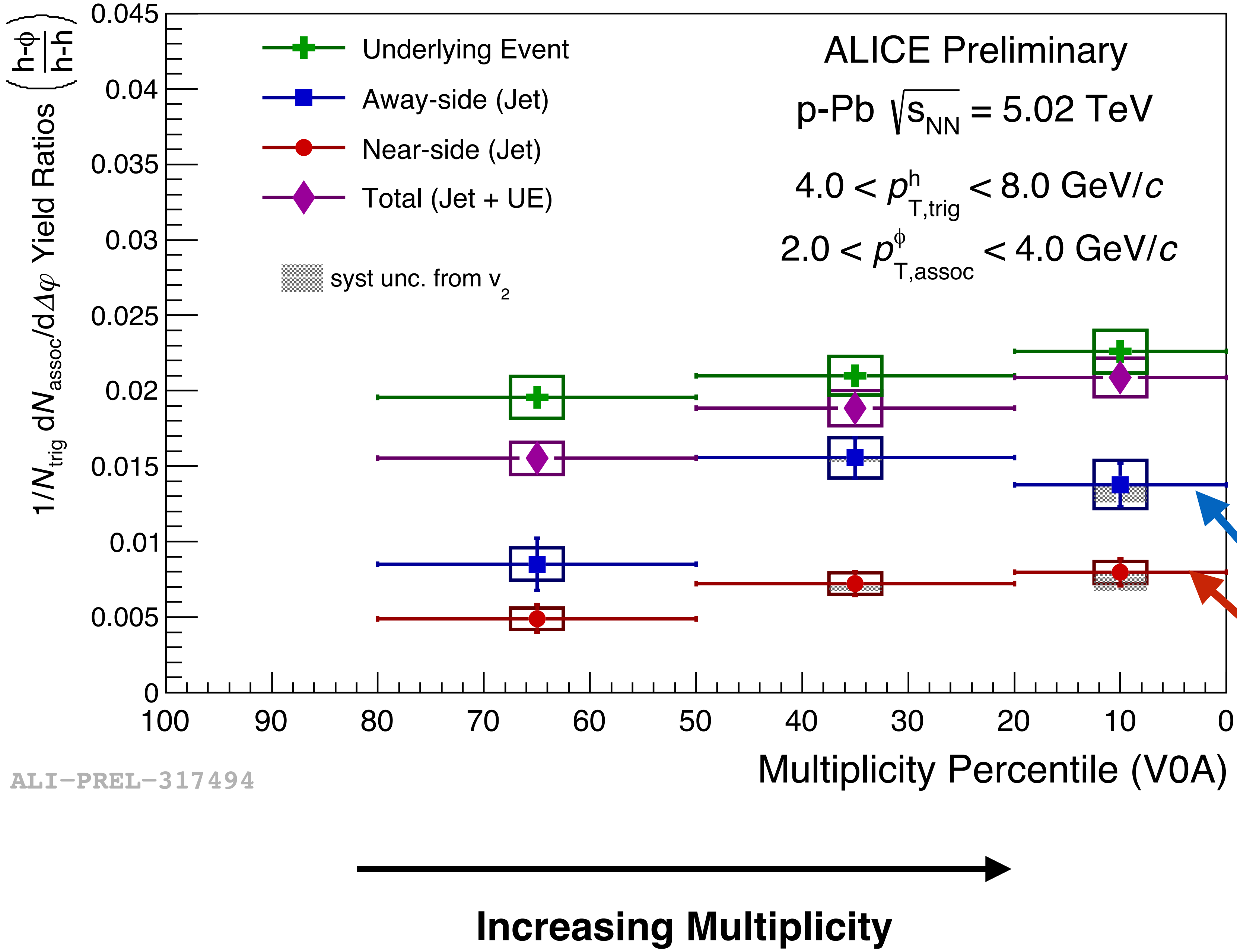


- Total h-ϕ/h-h pairs increases with multiplicity (as seen in inclusive ϕ/π measurement)

(ϕ/h) ratio in Jet and Underlying Event

New in ALICE

(h-ϕ)/(h-h)



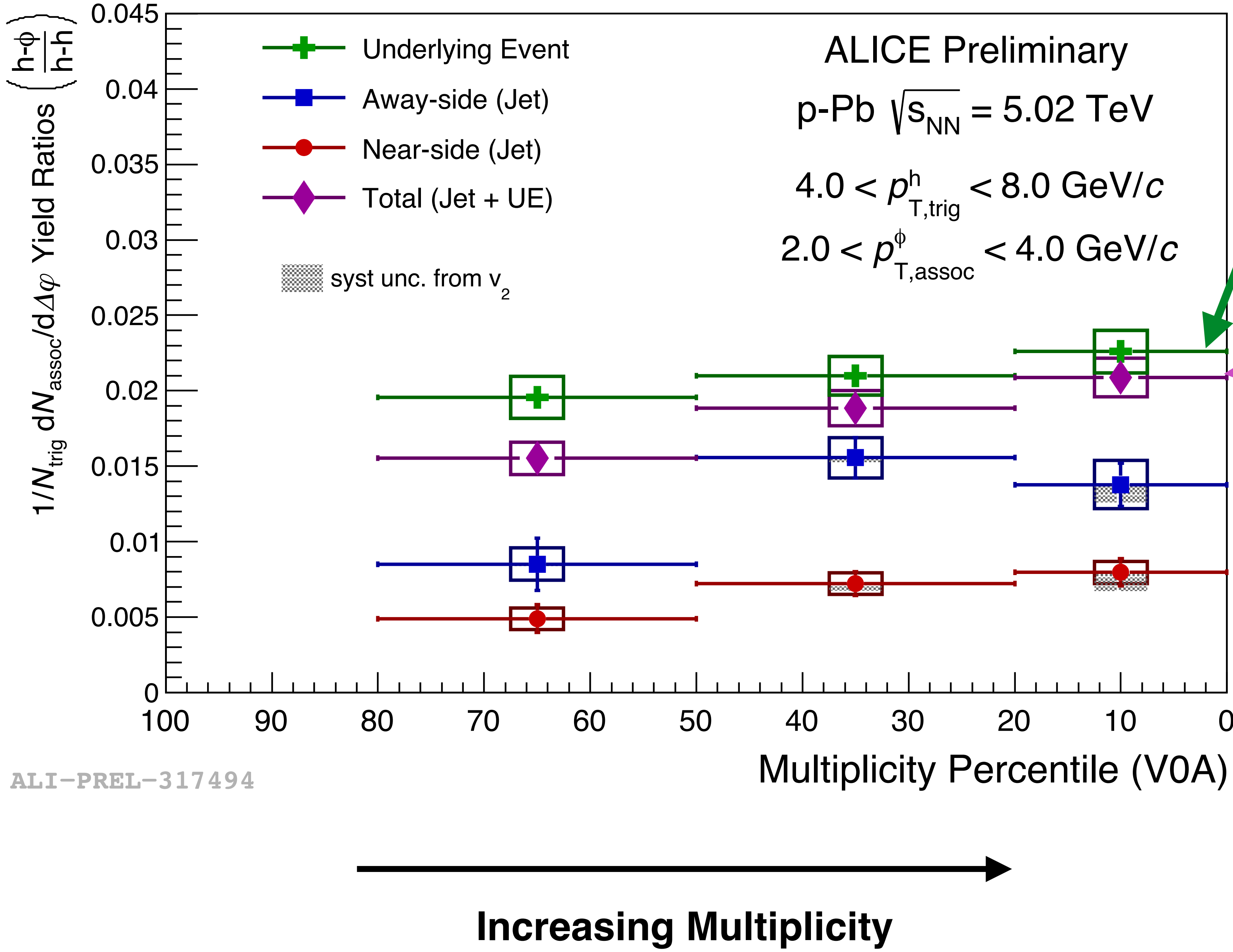
Jets (hard scattering)

- h-ϕ/h-h in **Jets** is lower than inclusive measurement
- Ratio in **Jets** increases with multiplicity (changing jet production? jet-medium interaction?)
- Ratio in Away-side jet is higher than near-side, but increases with multiplicity at same rate

(ϕ/h) ratio in Jet and Underlying Event

New in ALICE

(h-ϕ)/(h-h)



UE (soft production)

- Ratio of h-ϕ/h-h in Underlying Event is systematically higher than Total pair ratio.
- Total pair ratio moves closer to Underlying Event ratio as multiplicity increases (the jet contribution to total pairs decreases vs multiplicity)

Summary

K^0_s-h correlations in pp measured in ALICE

- (K^0_s-h) jet yields overestimated by Pythia, especially at low associated p_T
- (K^0_s-h)/(h-h) jet yield ratios are less than 1 and consistent with Pythia simulations for both near and away-side.
- (K^0_s-h)/(h-h) jet yield ratios show no dependance on multiplicity in pp collisions

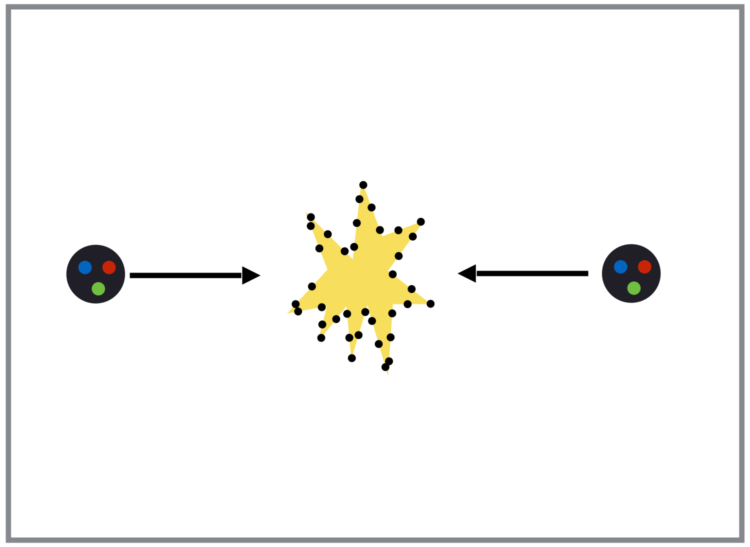
h-ϕ correlations in p-Pb measured in ALICE

- (h-ϕ)/(h-h) total pair ratios show an increase as a function of multiplicity (onset of strangeness enhancement)
- (h-ϕ)/(h-h) pair ratios in jets and in the underlying event are systematically different, and the total pair ratio shifts towards the underlying event ratio as multiplicity increases

Back-up

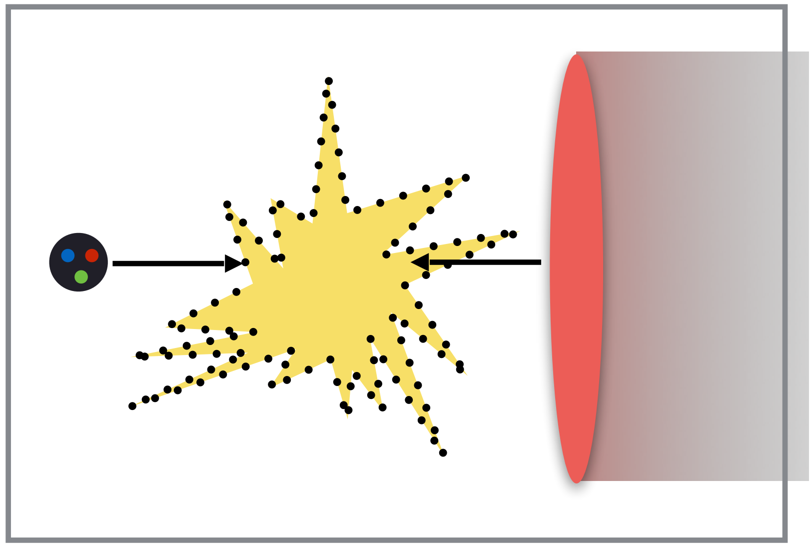
Motivation: Small Systems

pp



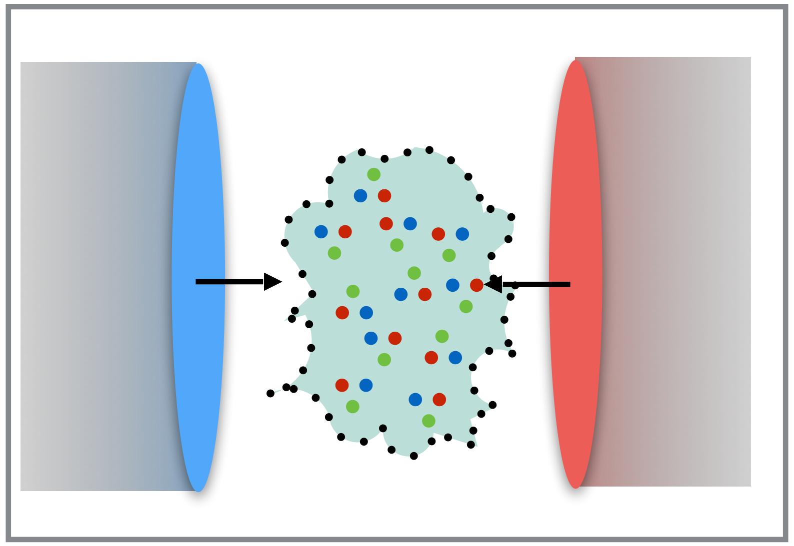
used as reference for p-Pb and Pb-Pb collisions

p-Pb



allows for the probing of nuclear effects present in PbPb but with no(**?**) medium

Pb-Pb



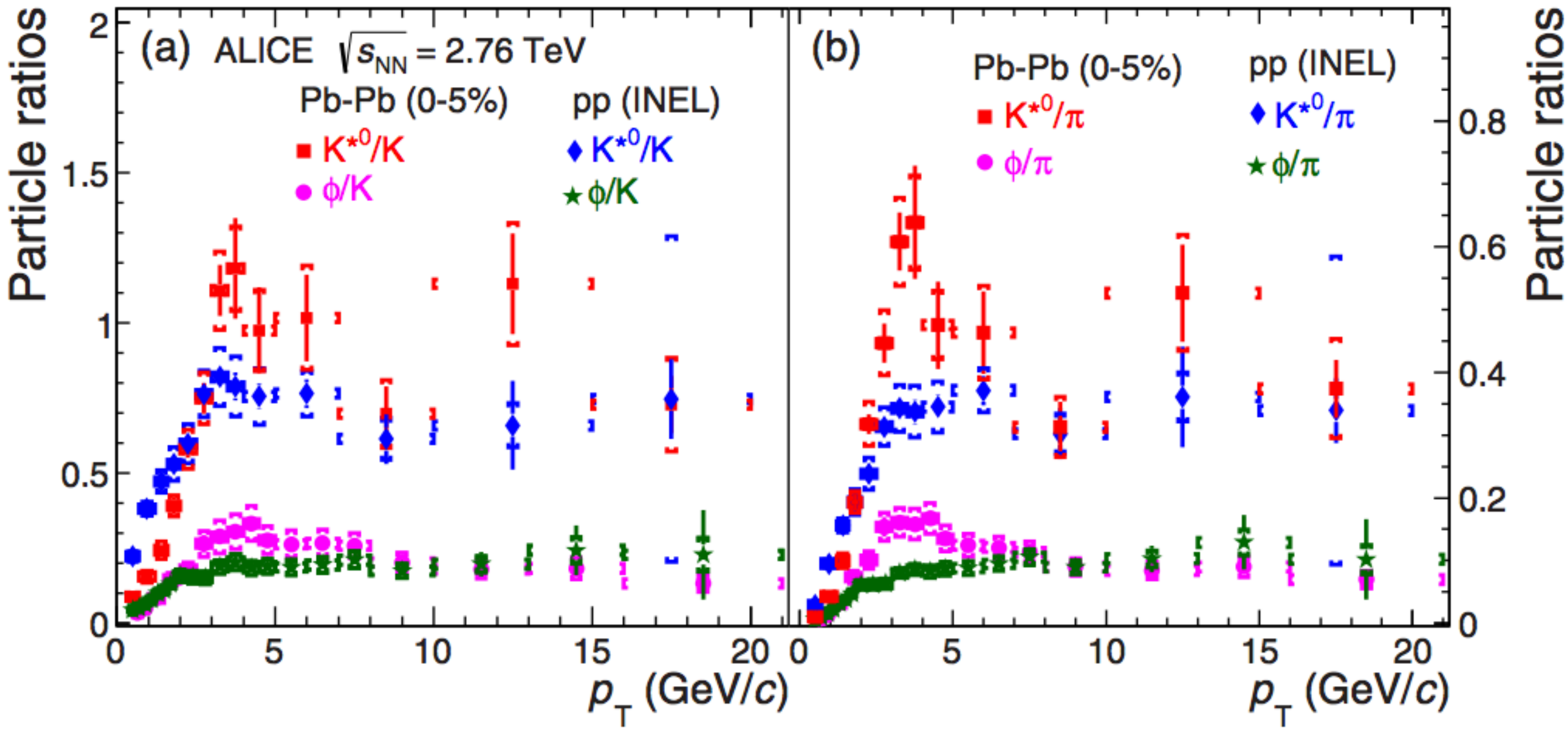
High energy heavy-ion collisions used to study QGP

Increasing System Size →

<u>**Open Question:**</u> Do the signatures of QGP “turn on” only for Pb-Pb? Or is there a smooth transition from pp to Pb-Pb collisions?

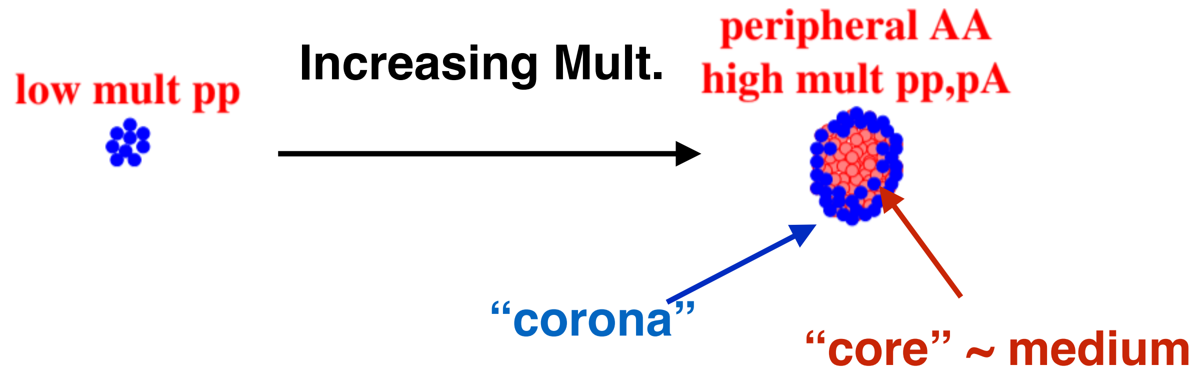
Motivation: Particle Ratio in PbPb and pp

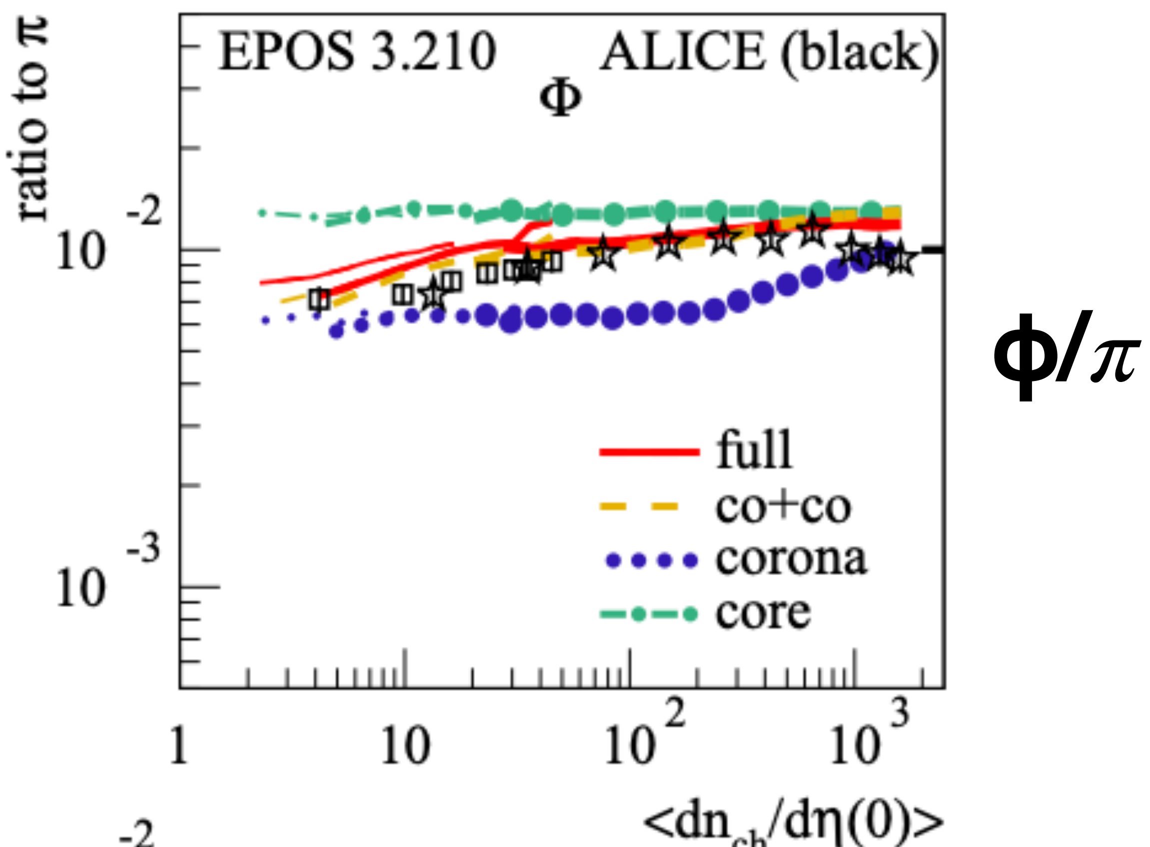
PRC 95 064606 (2017)



High Multiplicity PbPb collisions show the ϕ/π ratio (*right*) is enhanced compared to pp. The enhancement is most present in the ~1-5 GeV/c p_T region, before converging at high p_T for all collision systems/sizes.

Motivation: ϕ/h ratios in p-Pb





Can also be useful to see where this enhancement comes from in theory calculations.

Looking at EPOS, particle ratio in the "core" (hydro) and the "corona" (pp-like) stays mostly flat as a function of multiplicity.

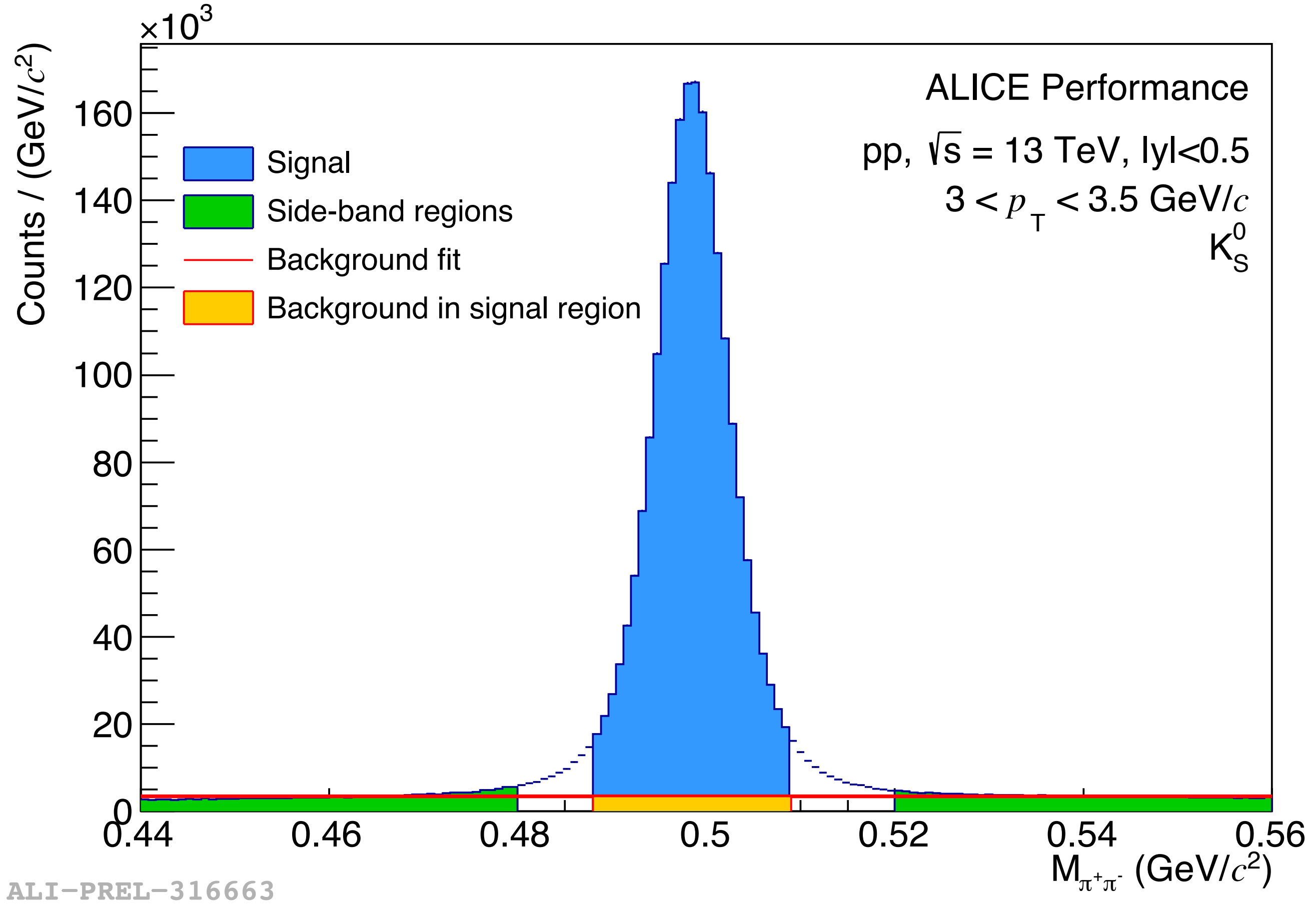
The total ratio still increases as a function of system size due to increased contribution of core

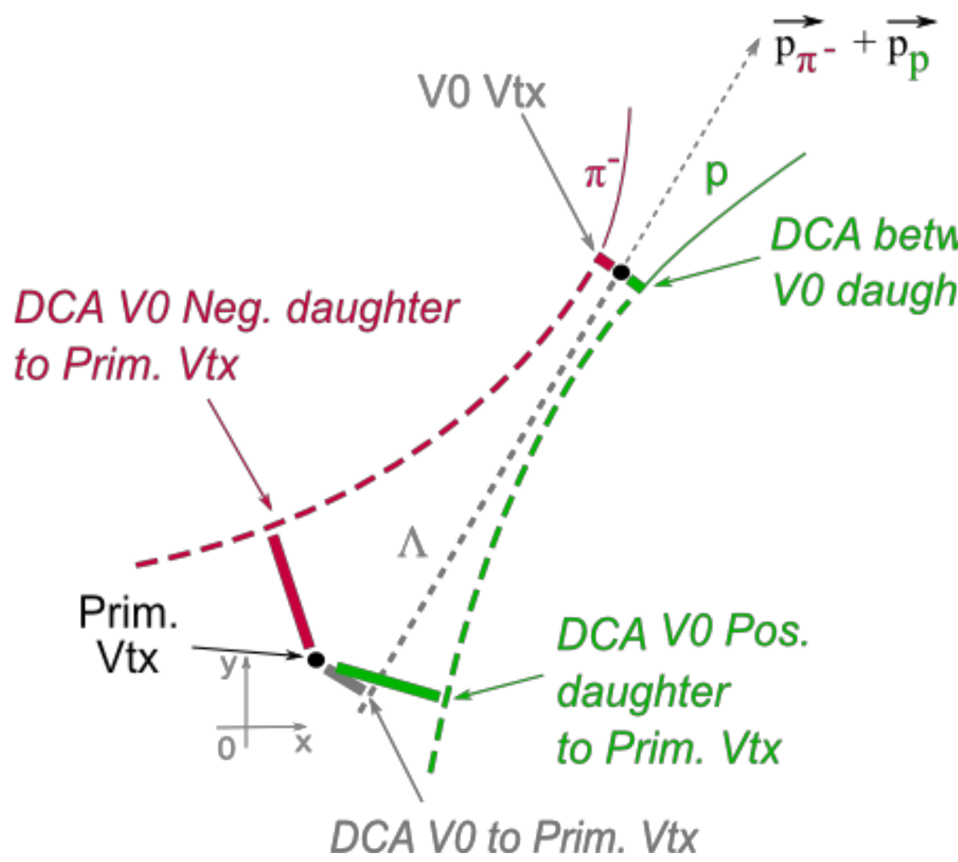
Resonance production in high energy collisions from small to big systems
arXiv:1812.06330v1

Correlated background from fake V^0

$$\frac{dN^{full\ corrected}_{pair}}{d\Delta\varphi}(\Delta\varphi, p_T^{trigg}) = \frac{1}{N^{full\ corrected}_{trigg}}(p_T^{trigg})\left(\frac{dN^{corr}_{pair\ sig}}{d\Delta\varphi}(\Delta\varphi, p_T^{trigg}) - \frac{background}{signal + background}\frac{signal}{integral\ side}\frac{dN^{corr}_{pair\ side}}{d\Delta\varphi}(\Delta\varphi, p_T^{trigg})\right)$$

$$N^{full\ corrected}_{trigg}(p_T^{trigg}) = \frac{signal}{signal + backround} N^{\varepsilon\ corrected}_{trigg}(p_T^{trigg})$$





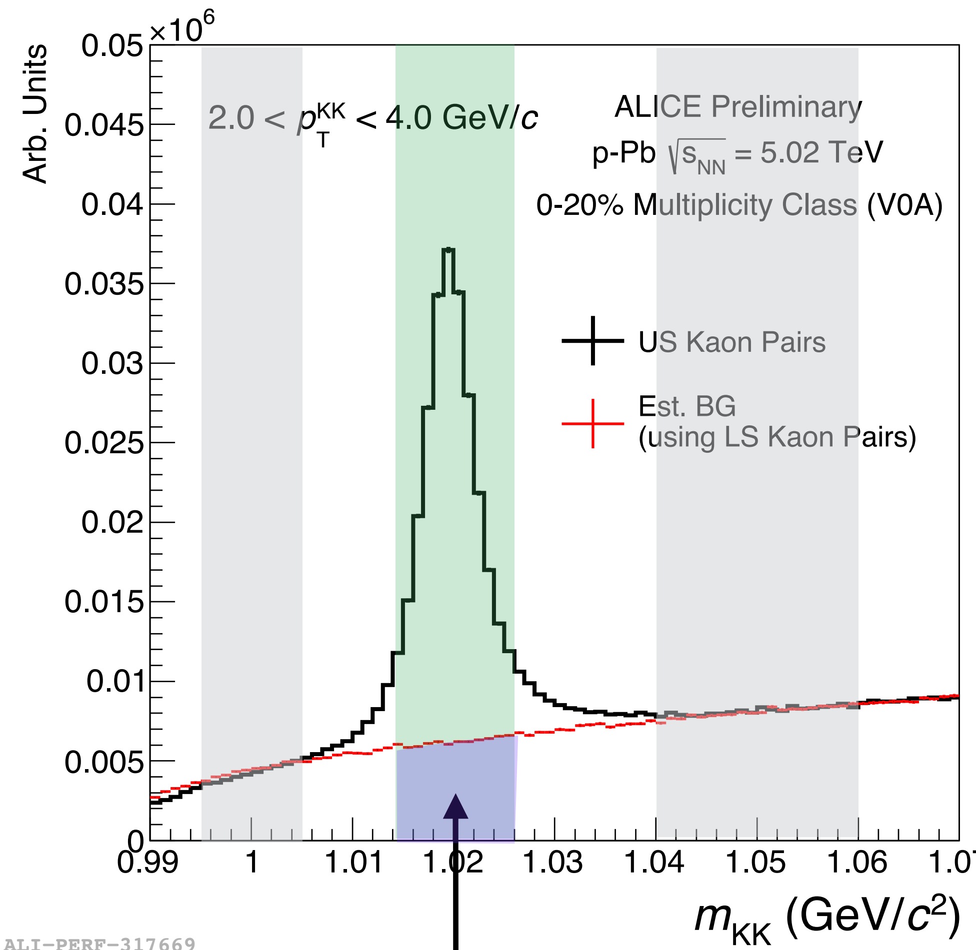
K^0_S purity ~96% across entire trigger p_T range

Method: KK Background Estimation

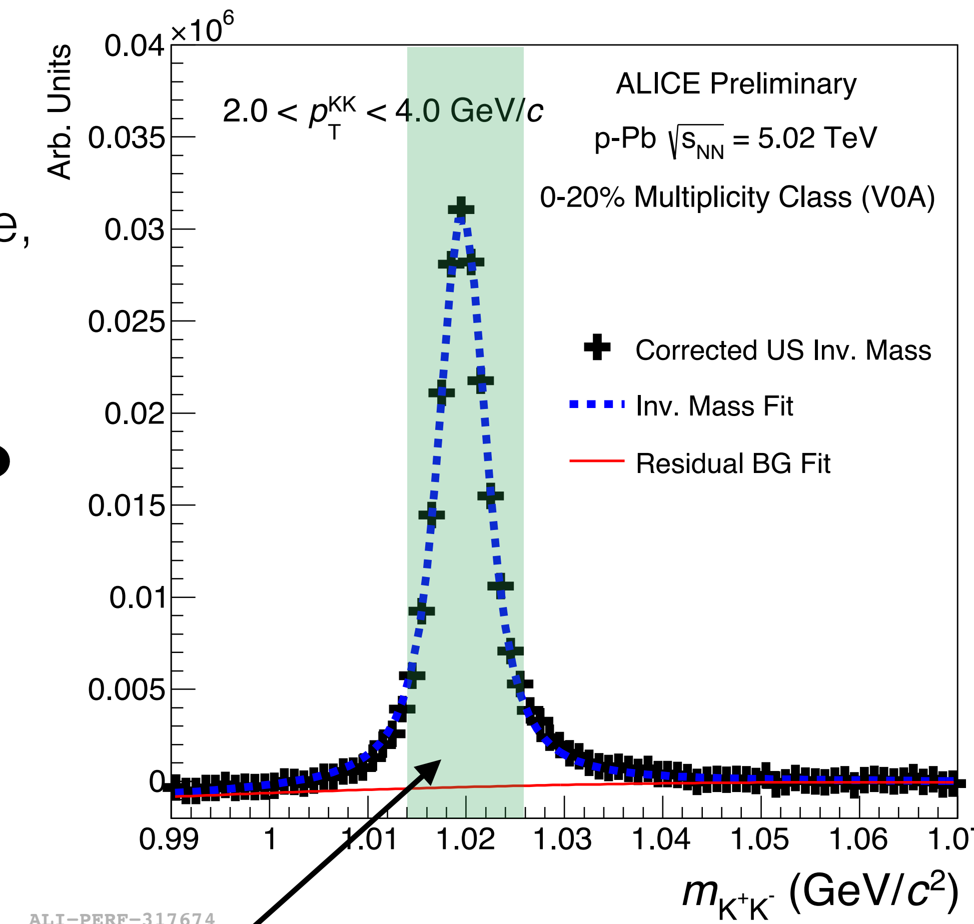
RSB: 0.995 < M_{KK} < 1.005 GeV/c^2

LSB: 1.040 < M_{KK} < 1.060 GeV/c^2

Mass Peak: 1.014 < M_{KK} < 1.026 GeV/c^2



subtract off LS BG estimate, and fit with Voigt + pol2



Amount of BG underneath mass peak:

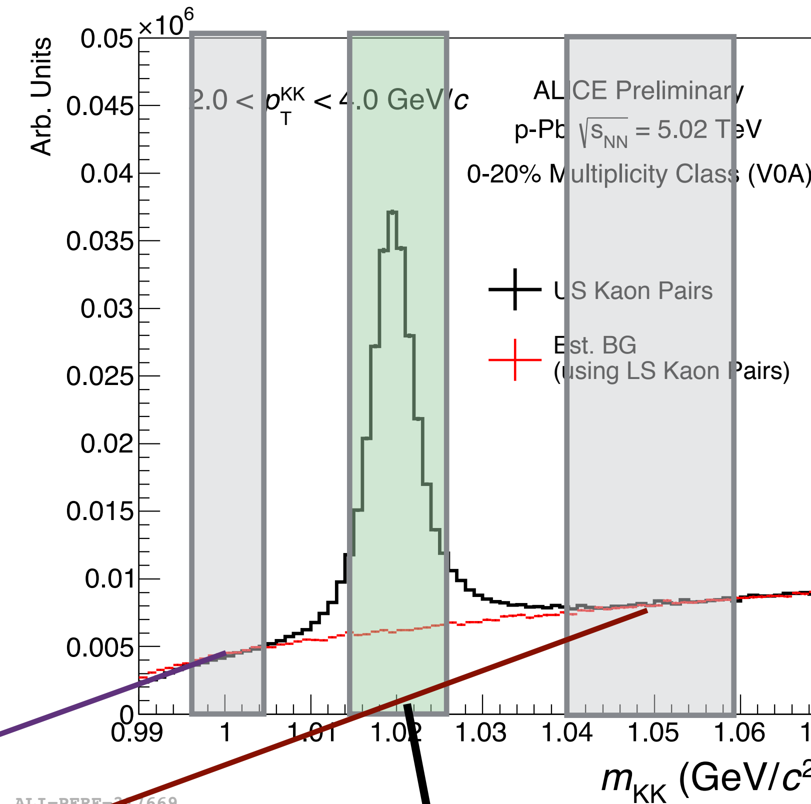
$$(\text{LS Peak Int.}) * \frac{\text{US SB Int.}}{\text{LS SB Int.}}$$

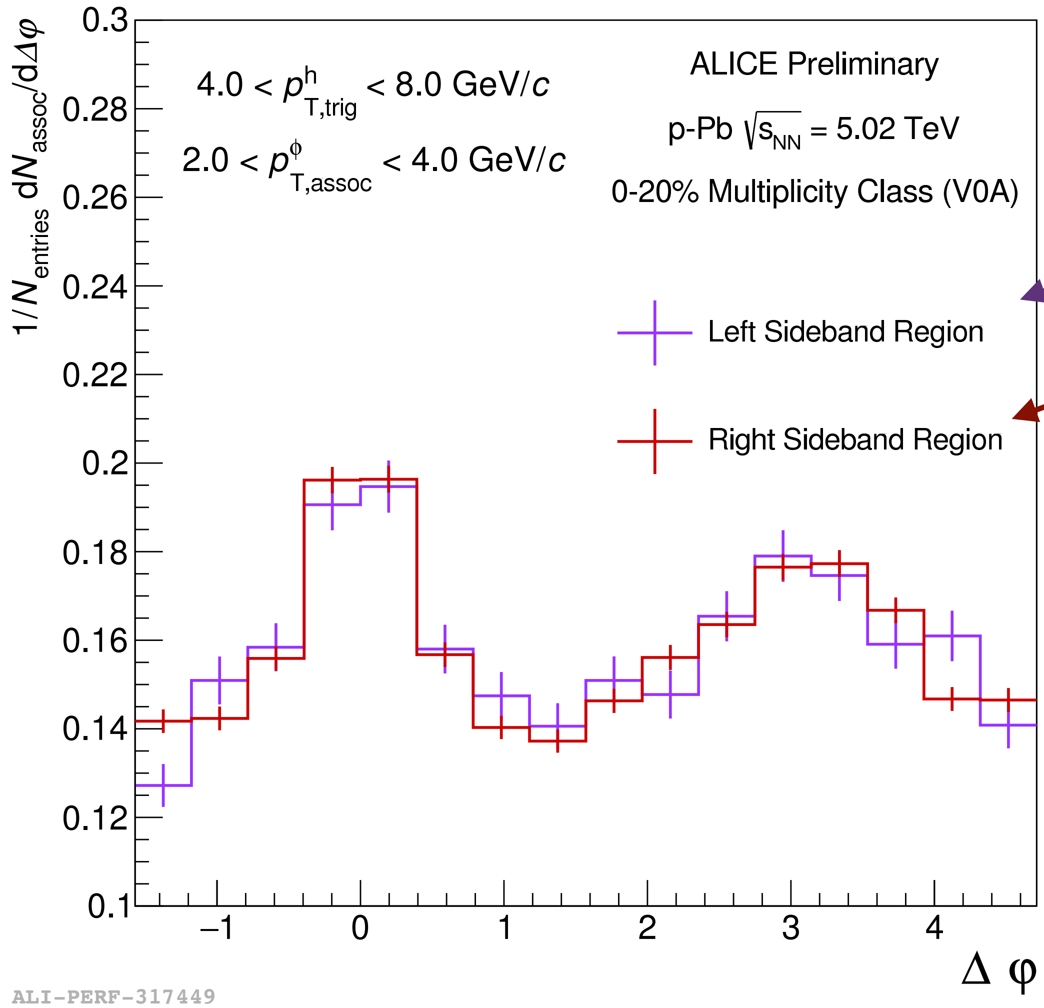
Use mass fit to calculate the percent of signal in the "mass peak" window used (~81%) = (Peak Range Correction)

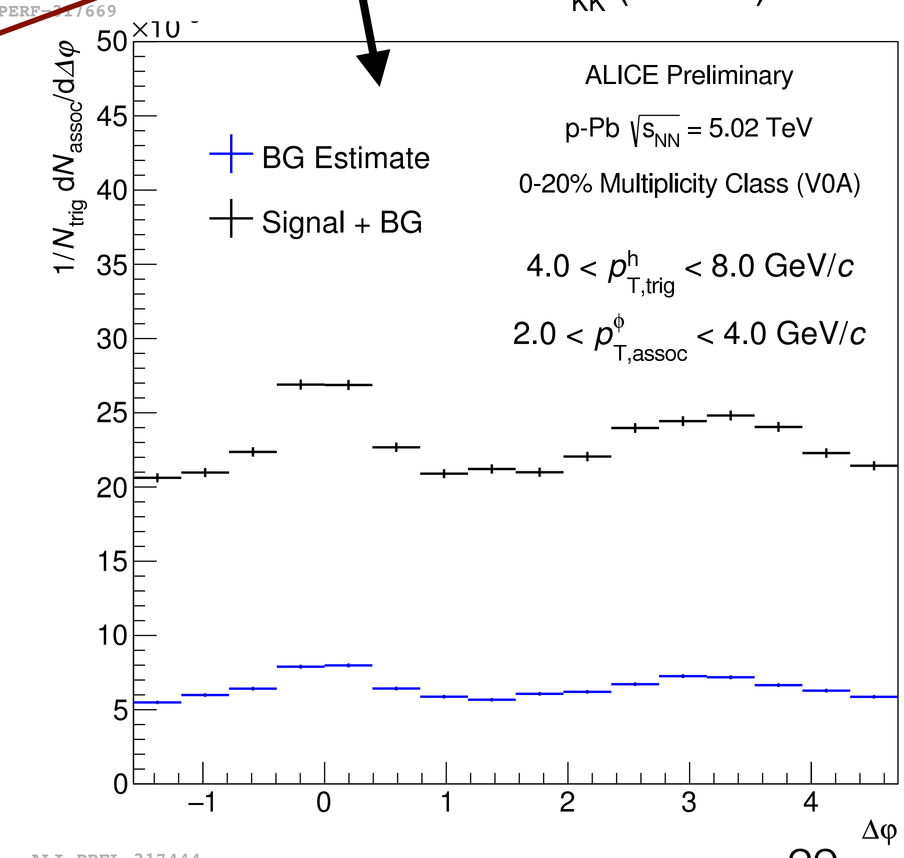
Method: Correlation Background Estimation

Reconstructed ϕ from KK channel, so correlation has Signal (h-ϕ) and Background (h-(KK)) components (Signal/BG ~ 2.5)

Subtracting the scaled, averaged sideband correlations from the correlations in the peak region (green) removes this background.







Per-trigger h-ϕ(1020) 2D correlations

$$C_{trig}^{h-\phi}(\Delta\varphi,\Delta\eta) = (\text{Peak Range Correction}) * \Big(C_{trig}^{h-(USKK\ \text{Peak})}(\Delta\varphi,\Delta\eta) - (\text{LS Peak Int.}) * \frac{\text{US SB Int.}}{\text{LS SB Int.}} * \frac{1}{2} * (C_{trig}^{h-(USKK\ \text{LSB})}(\Delta\varphi,\Delta\eta) + C_{trig}^{h-(USKK\ \text{RSB})}(\Delta\varphi,\Delta\eta)) \Big)$$

with

$$C_{trig}(\Delta\varphi,\Delta\eta) = \frac{1}{N_{trig}^{corr}} \frac{1}{\varepsilon_{trig} * \varepsilon_{assoc}} \frac{B(0,0) * S(\Delta\varphi,\Delta\eta)}{B(\Delta\varphi,\Delta\eta)}$$

where

S(Δ**φ**,Δη) = same event distribution,

B(Δ**φ**,Δη) = mixed-event distribution

N$_{\mathbf{trig}}$ is the total number of trigger hadrons that fall in desired trigger p_T range over all events, corrected for efficiency.