INTERNATIONAL SCHOOL OF SUBNUCLEAR PHYSICS

58th Course:
GRAVITY AND MATTER
IN THE SUBNUCLEAR WORLD

ERICE-SICILY: 15 – 24 June 2022

Production of ϕ-meson pairs with ALICE at the LHC: a novel probe for strangeness production

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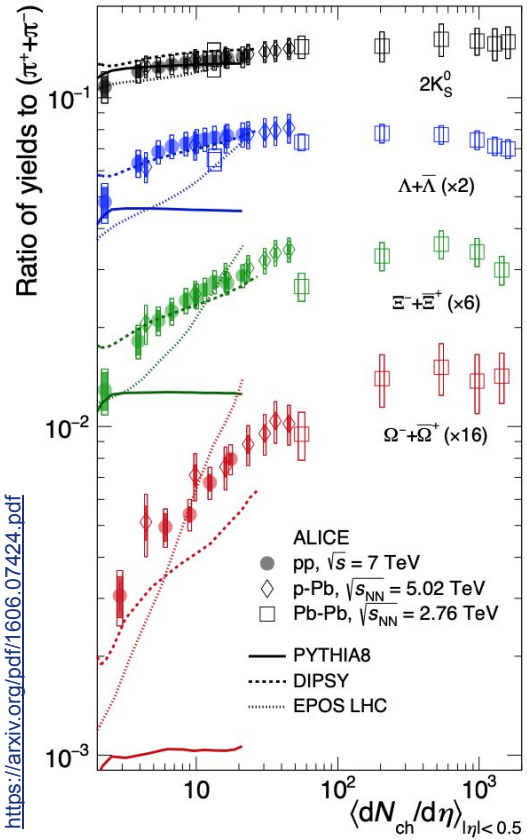
Strangeness enhancement



https://arxiv.org/pdf/1606.07424.pdf

Strangeness enhancement is an increase observed in the ratio of strange hadrons to pions in high multiplicity pp collisions and heavy-ion collisions with respect to minimum bias pp collisions.

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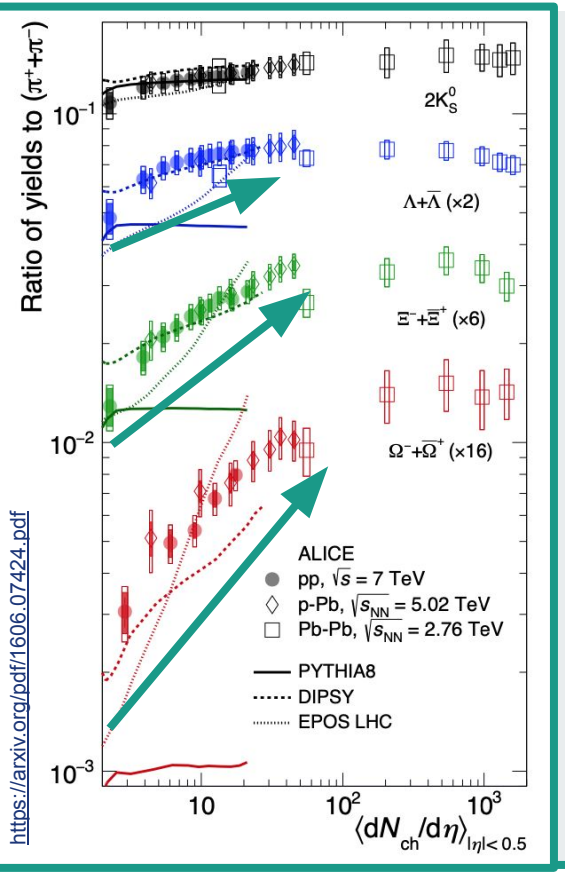

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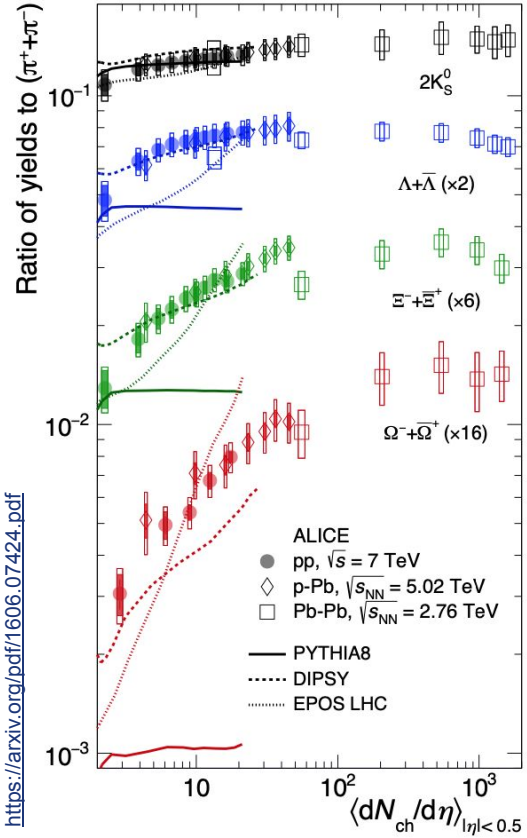
The ratio to pions increases with the multiplicity of an event, with a smooth transition across collision systems

Strangeness enhancement



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In this context, the ϕ meson proves to be a probe of choice: being a $s\bar{s}$ bound state it is only sensitive to strangeness production

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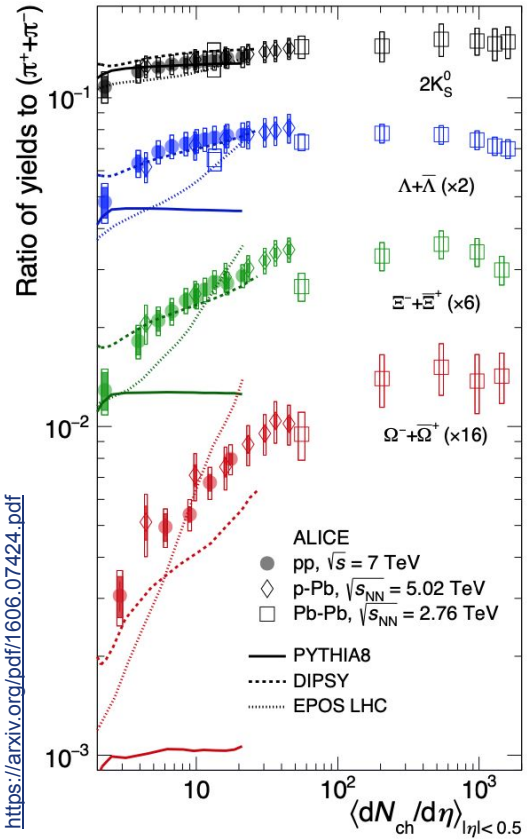

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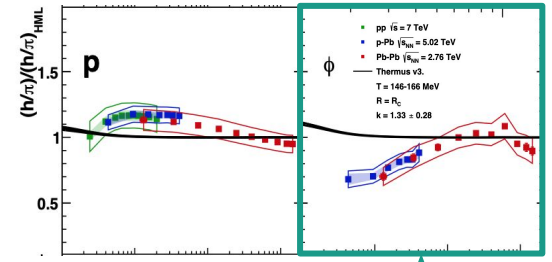
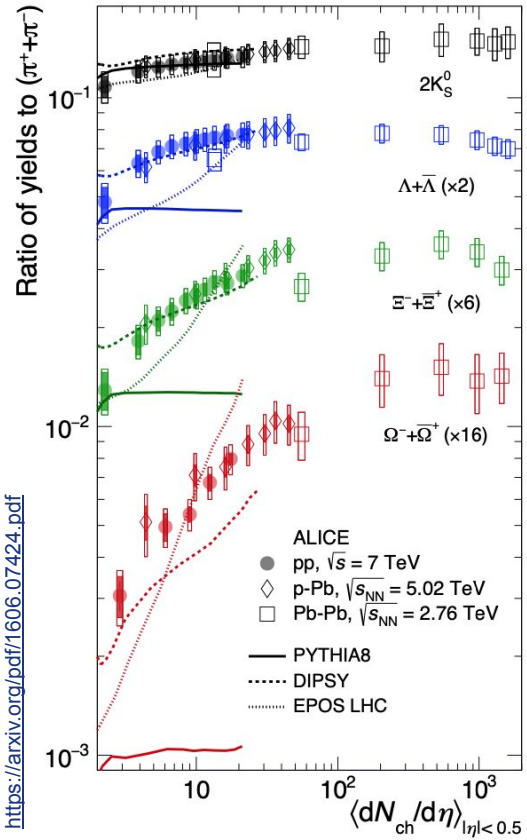
A hint the ϕ meson could help disentangle the nature of strangeness production and enhancement can be seen by the disagreement with the canonical thermal model prediction, an otherwise successful model



V. Vislavicius[1,*] and A. Kalweit[2,†]

https://arxiv.org/pdf/1610.03001.pdf

Strangeness enhancement



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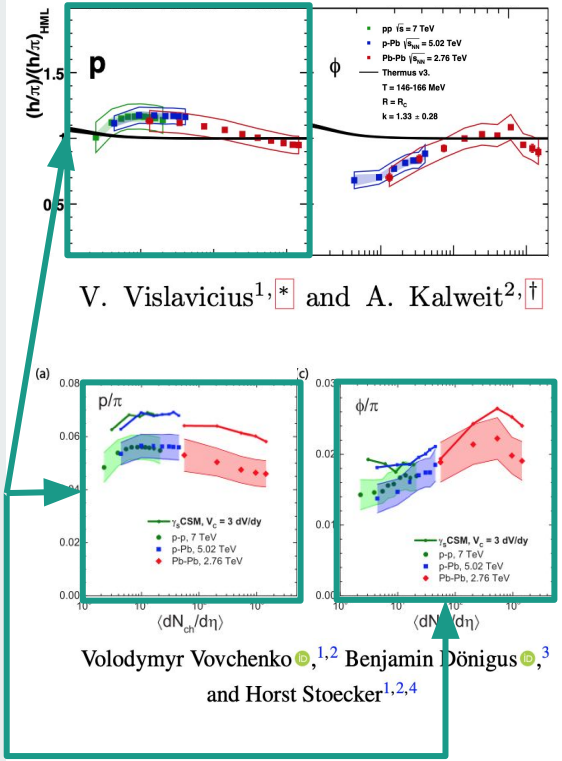
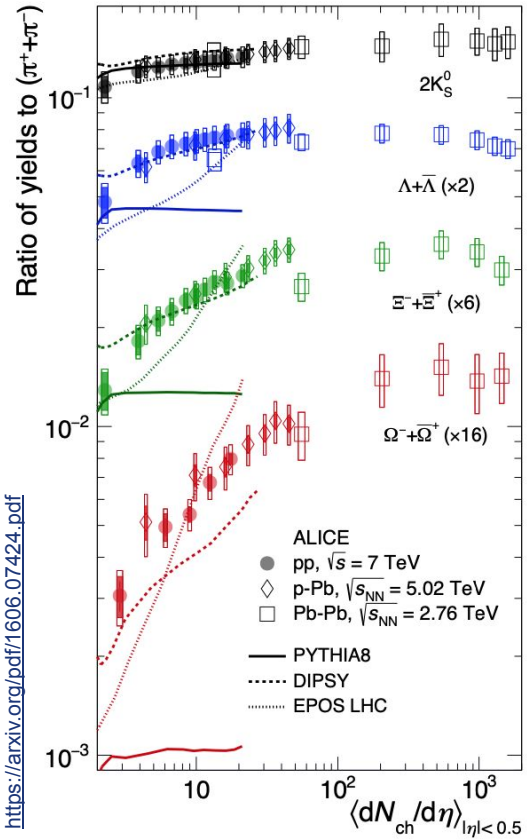
Although recent reformulations of the model predicts more precisely the ϕ meson, they disrupt the prediction for other particles, such as the protons



https://arxiv.org/pdf/1610.03001.pdf

https://arxiv.org/pdf/1906.03145.pdf

Strangeness enhancement



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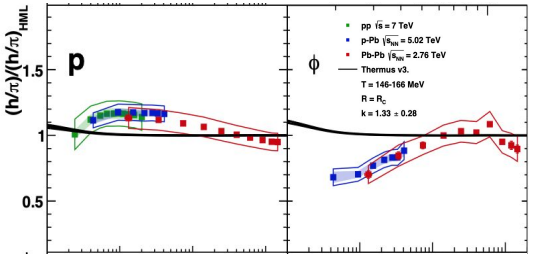
Measurements of ϕ meson production can provide insights into microscopic production models, disentangling the inner workings of this phenomenon by discriminating microscopic production models



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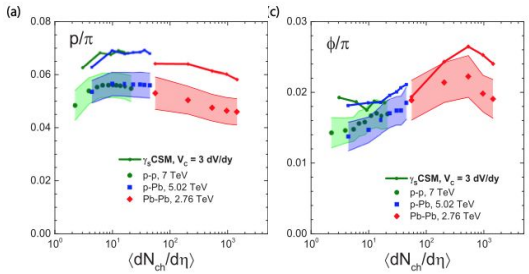

Volodymyr Vovchenko[1,2] Benjamin Dönigus[3] and Horst Stoecker[1,2,4]

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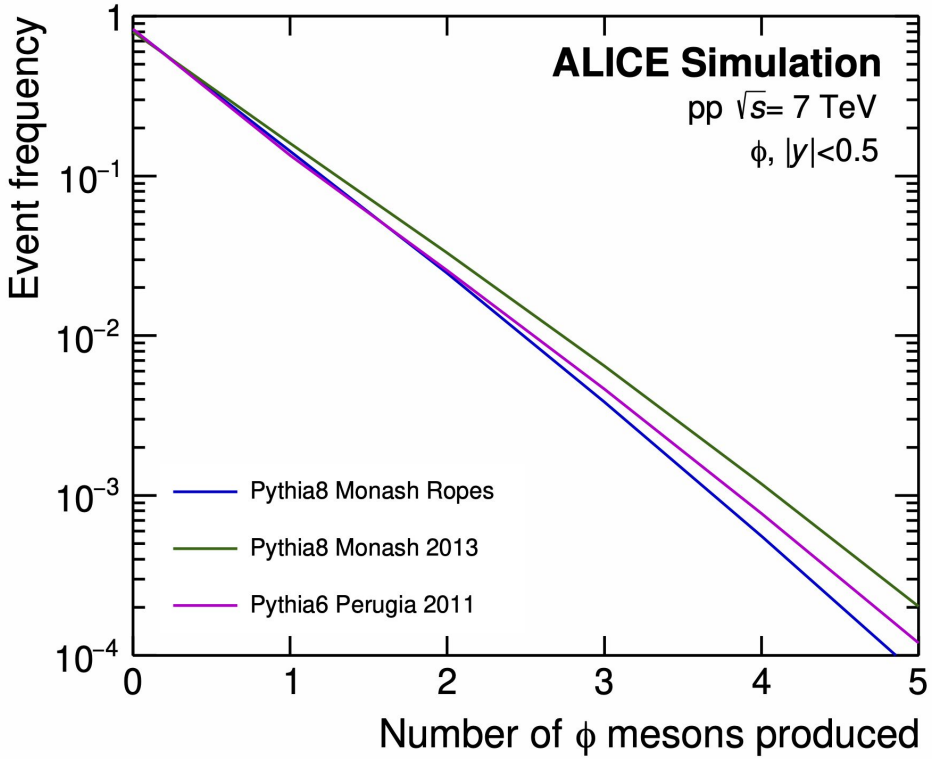
ϕ-meson production



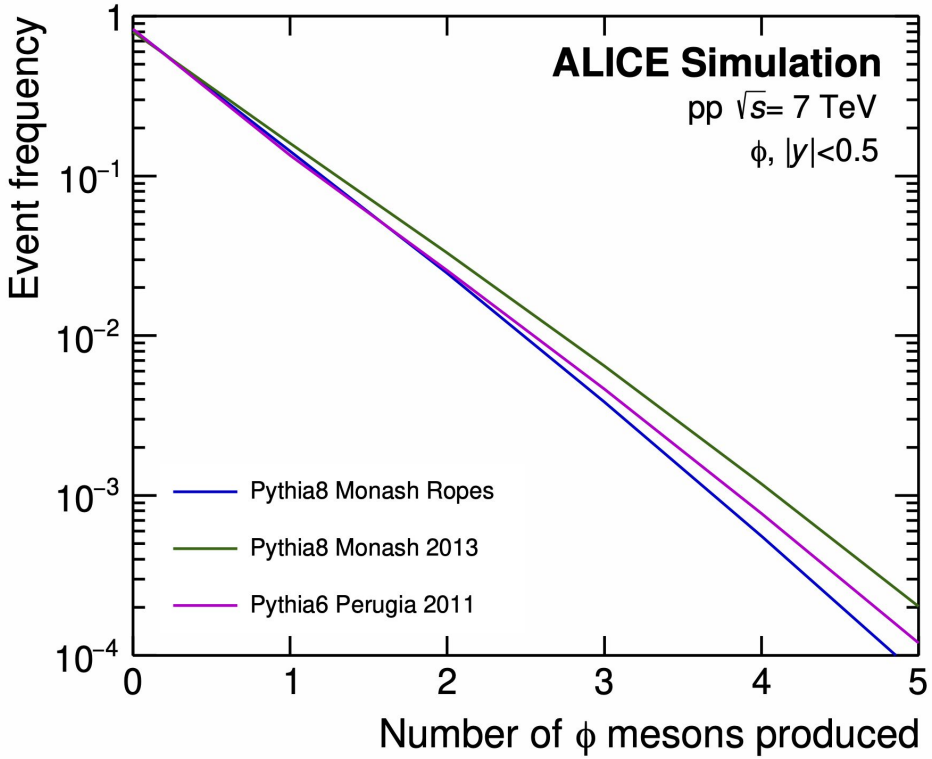
ALI-SIMUL-510293

$\langle Y_\phi \rangle$ Inclusive ϕ meson production

NEW!

$\langle Y_{\phi\phi} \rangle$ Inclusive ϕ-meson pairs production

ϕ-meson production



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$$\mu_\phi = \langle Y_\phi \rangle$$

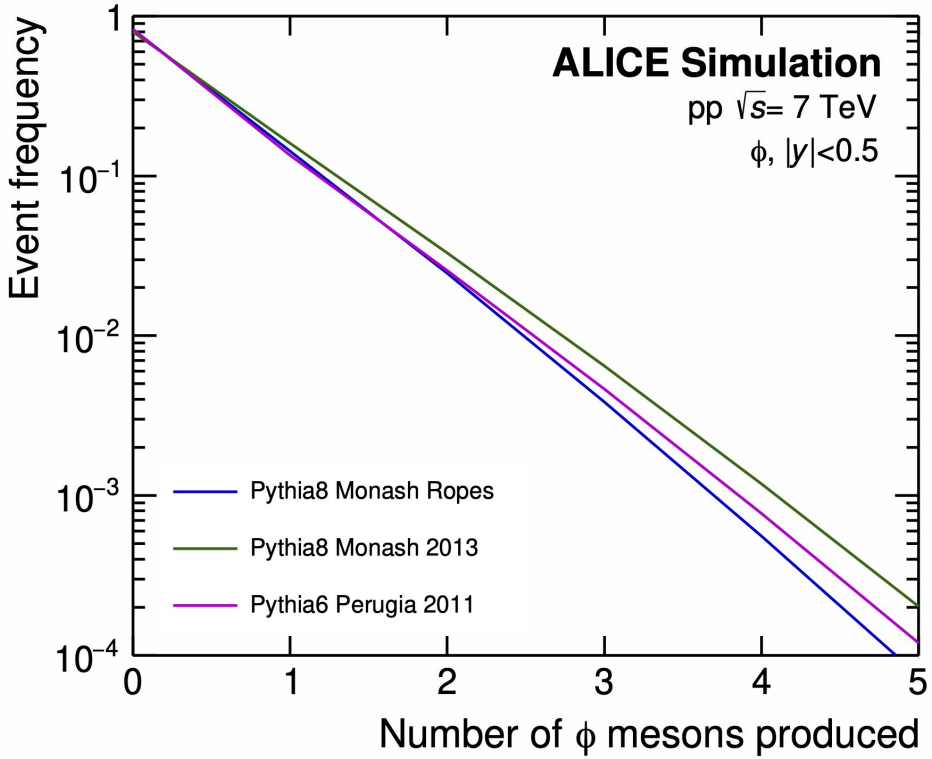
Average yield of produced ϕ-meson

NEW!

$$\sigma^2_\phi = 2\langle Y_{\phi\phi} \rangle + \langle Y_\phi \rangle - \langle Y_\phi \rangle^2$$

Variance of produced ϕ mesons

ϕ-meson production



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Variance of produced ϕ mesons

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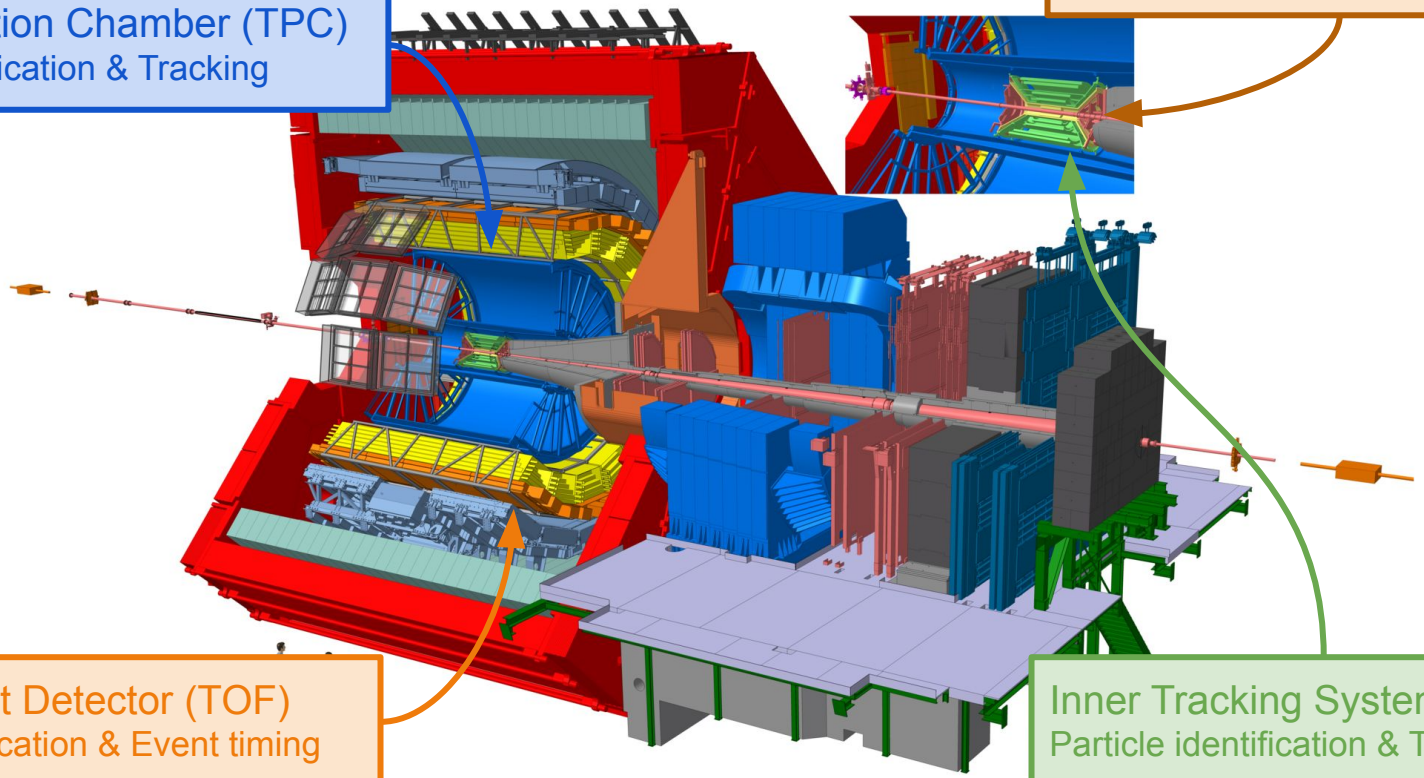
$$\gamma_\phi = \frac{\sigma^2_\phi}{\mu_\phi} - 1 = 2\frac{\langle Y_{\phi\phi} \rangle}{\langle Y_\phi \rangle} - \langle Y_\phi \rangle$$

New way to characterise production

ALICE detector in Run 1&2



Time Projection Chamber (TPC)
Particle identification & Tracking

V0A & V0C
Trigger and multiplicity estimation

Time of Flight Detector (TOF)
Particle identification & Event timing

Inner Tracking System (ITS)
Particle identification & Tracking

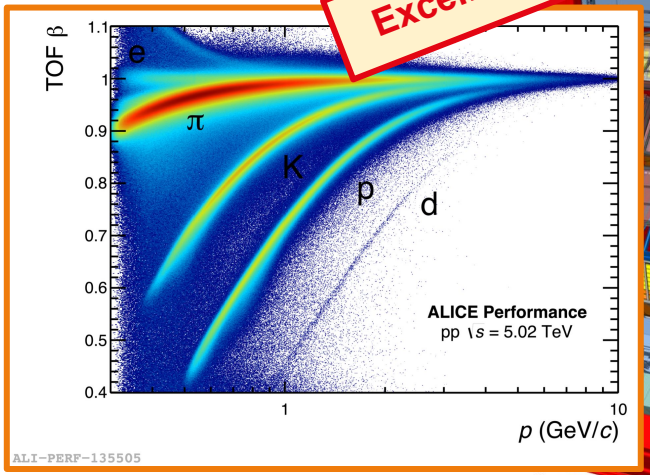
ALICE detector in Run 1&2

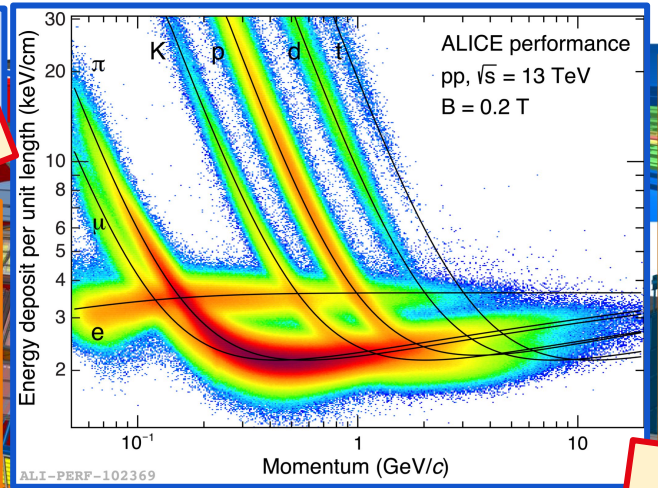
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

INFN ALICE

Time Projection Chamber (TPC)
Particle identification & Tracking

Excellent PID!





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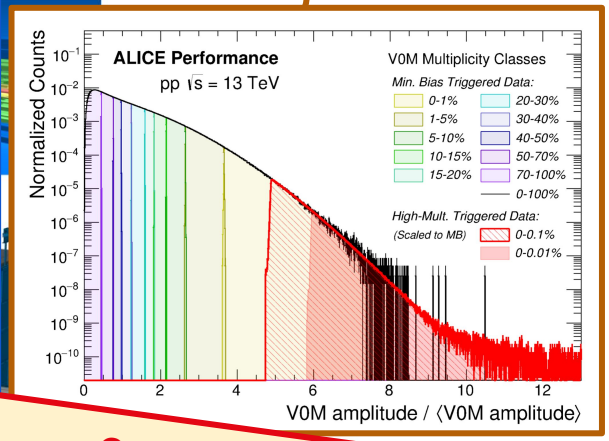
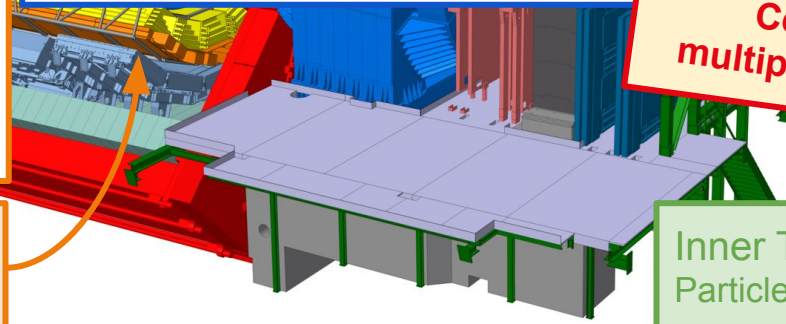


Centrality and multiplicity estimation



Time of Flight Detector (TOF)
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Inner Tracking System (ITS)
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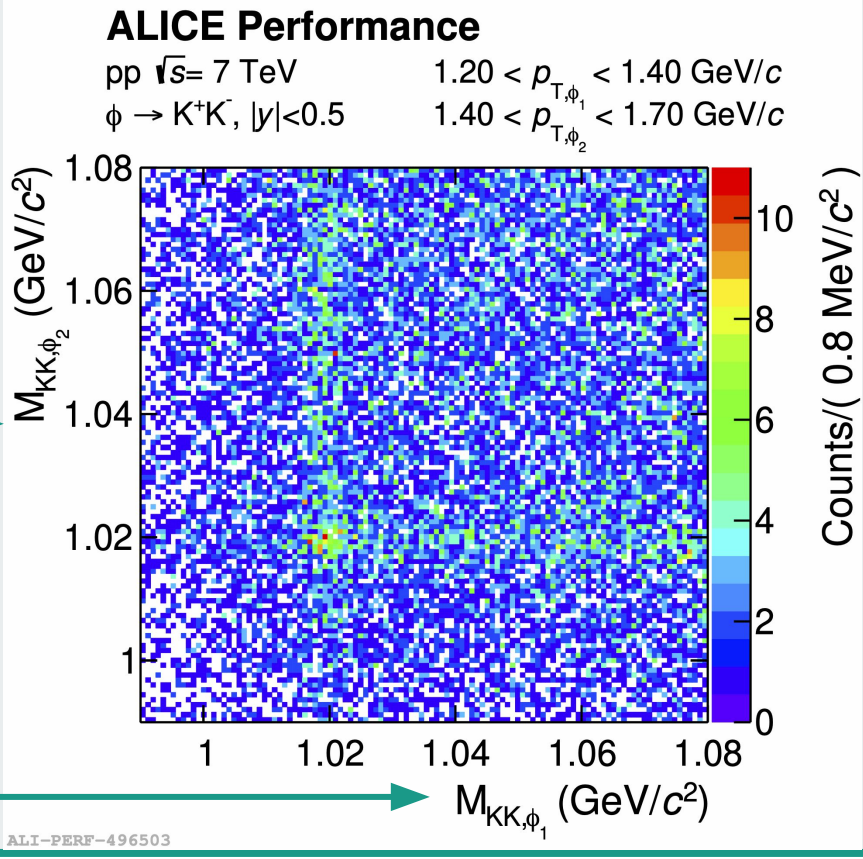
Analysis technique

Two ϕ-meson candidates are paired in a 2D Invariant Mass histogram



Analysis technique

Run 1 data sample

The analysis is differential in transverse momentum

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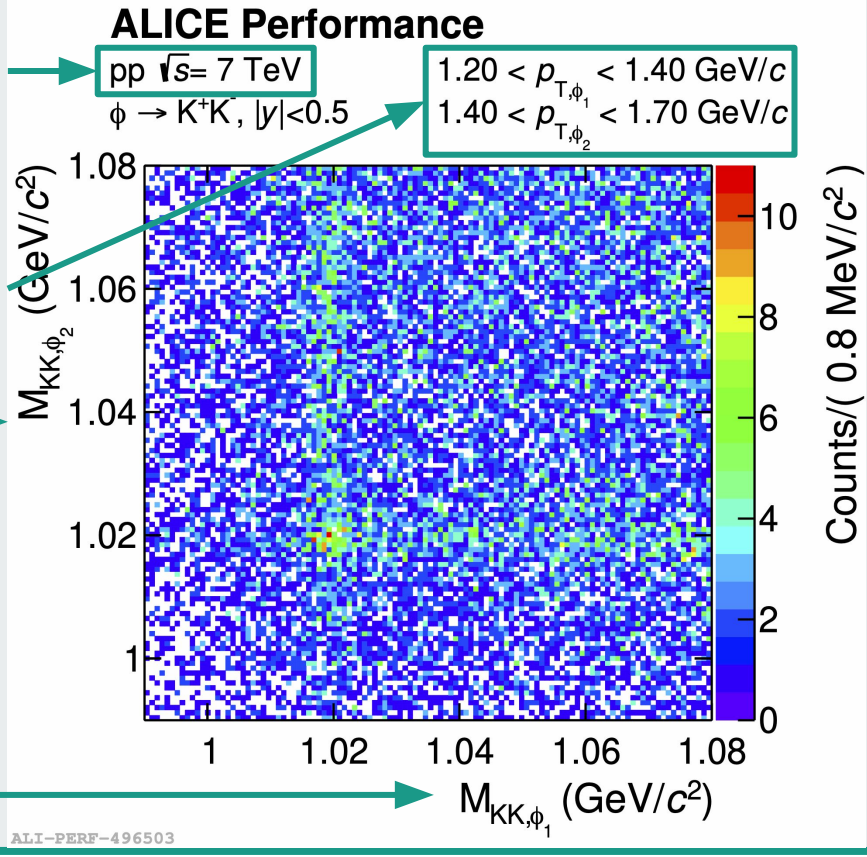

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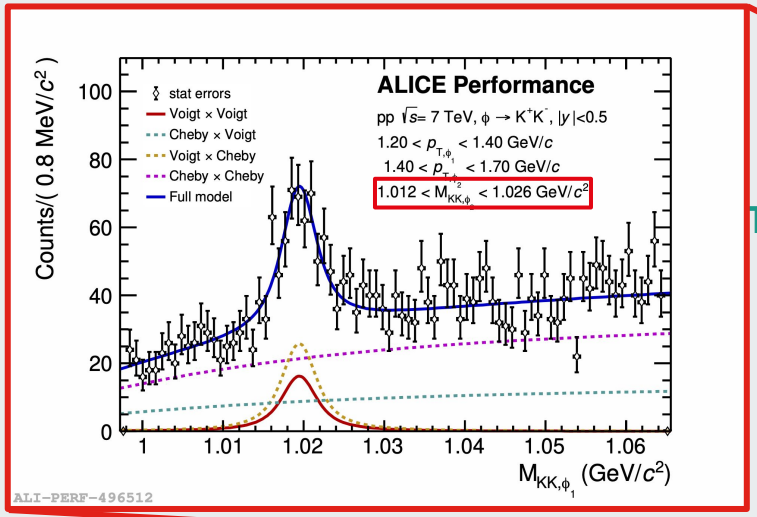

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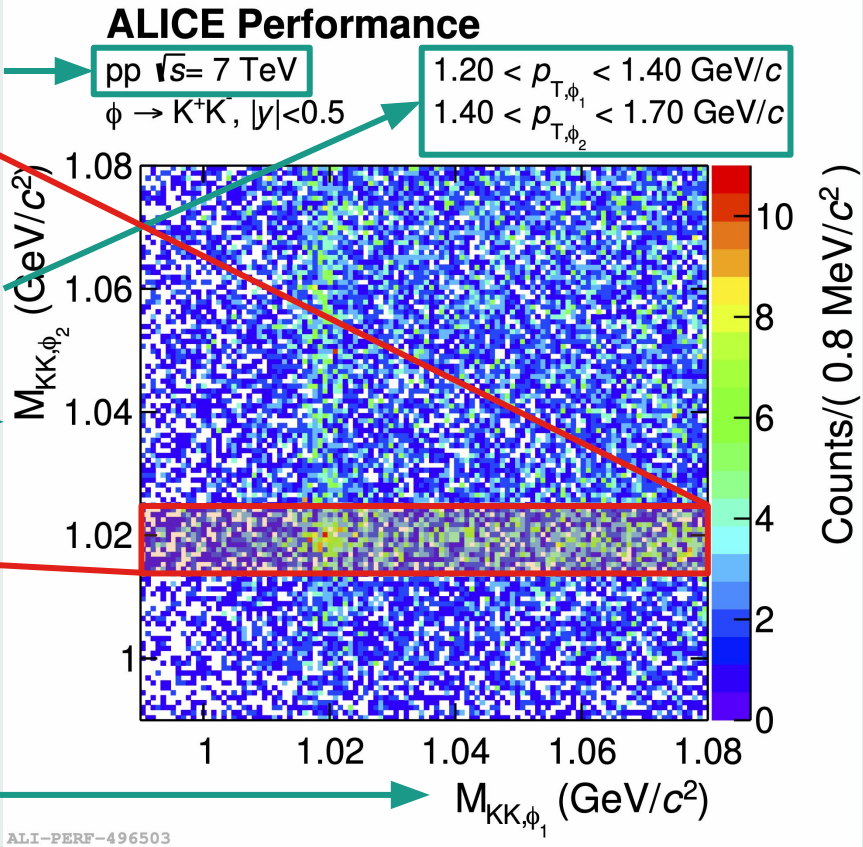

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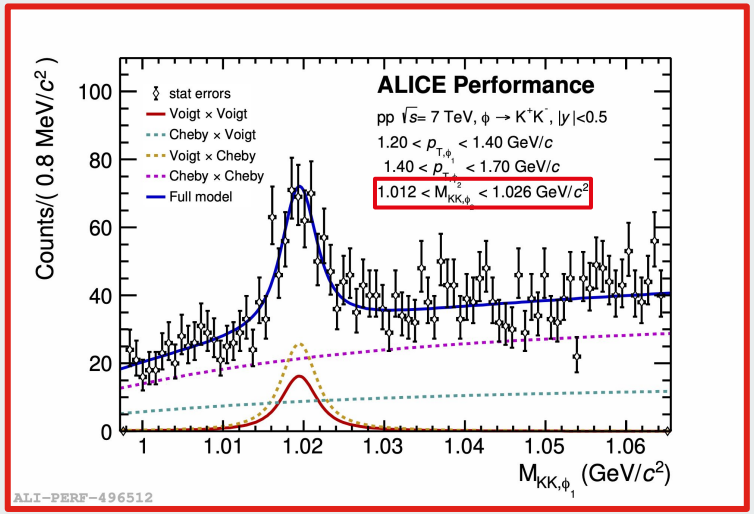

We fit the histogram with a 4-components function, derived from the 1D analysis:

$$f_{1D}(m_1) = S_1 f_{sig}(m_1) + B_1 f_{bkg}(m_1)$$

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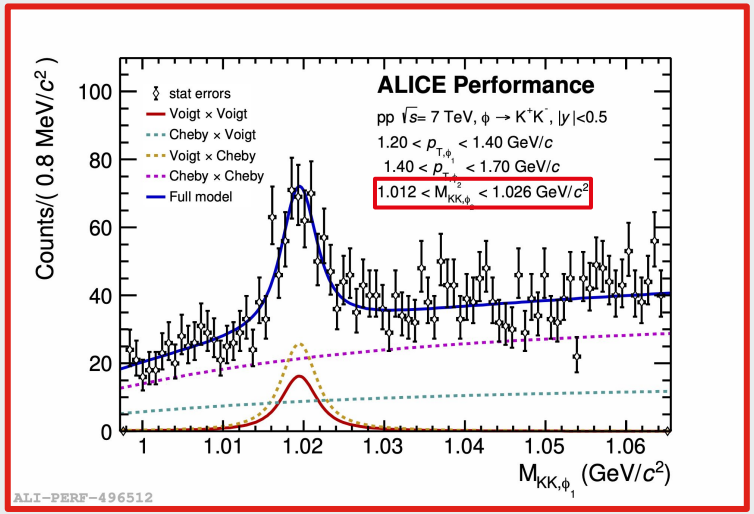

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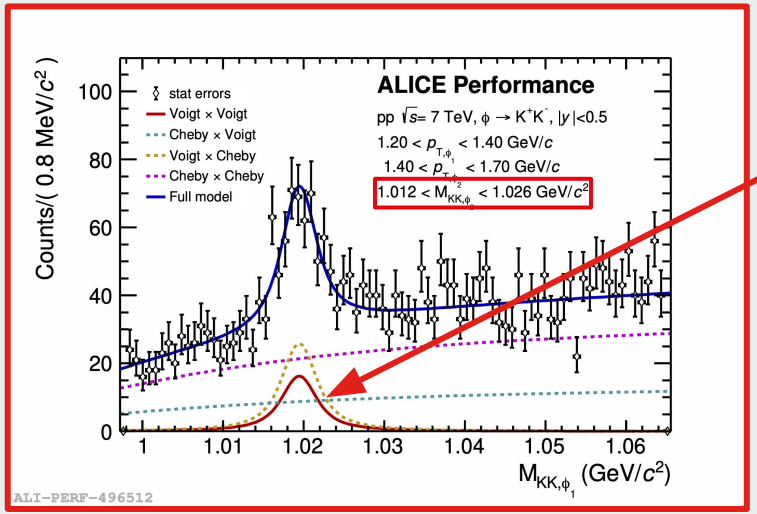

SS $f_{sig}(m_1)f_{sig}(m_2)$ +

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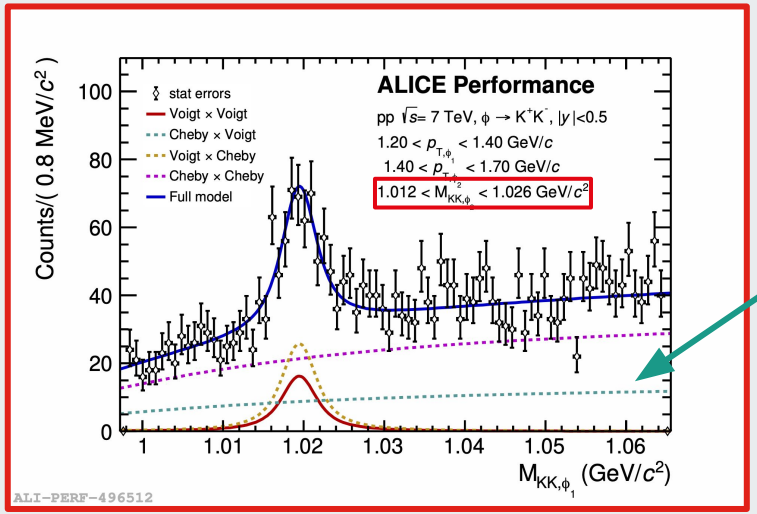
$$f_{2D}(m_1,m_2) = f_{1D}(m_1) \times f_{1D}(m_2)$$

Analysis technique



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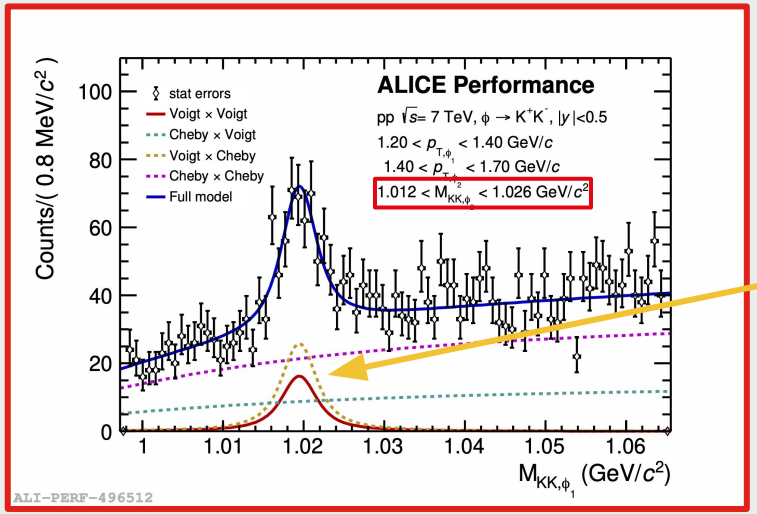

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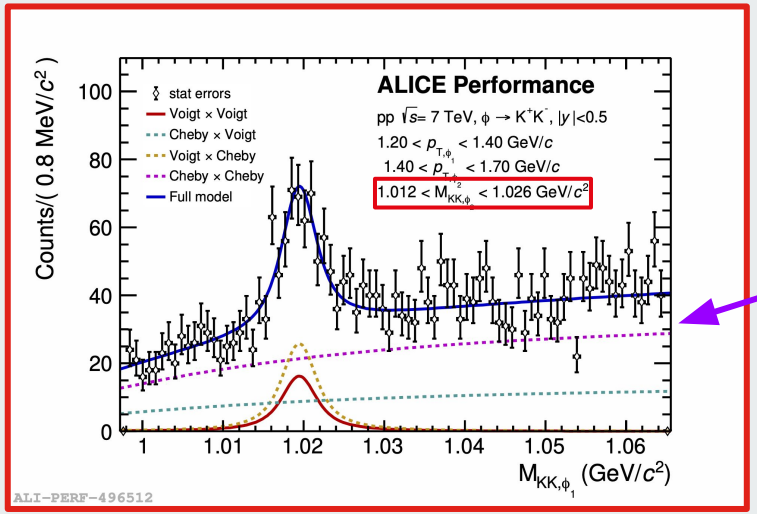

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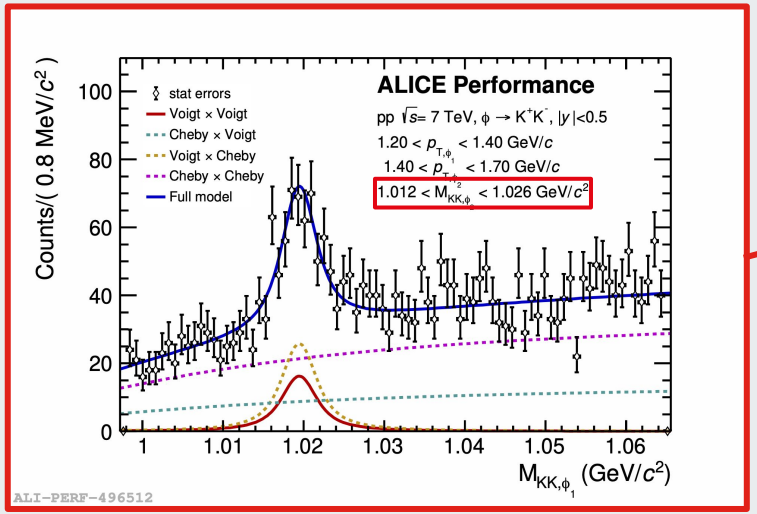
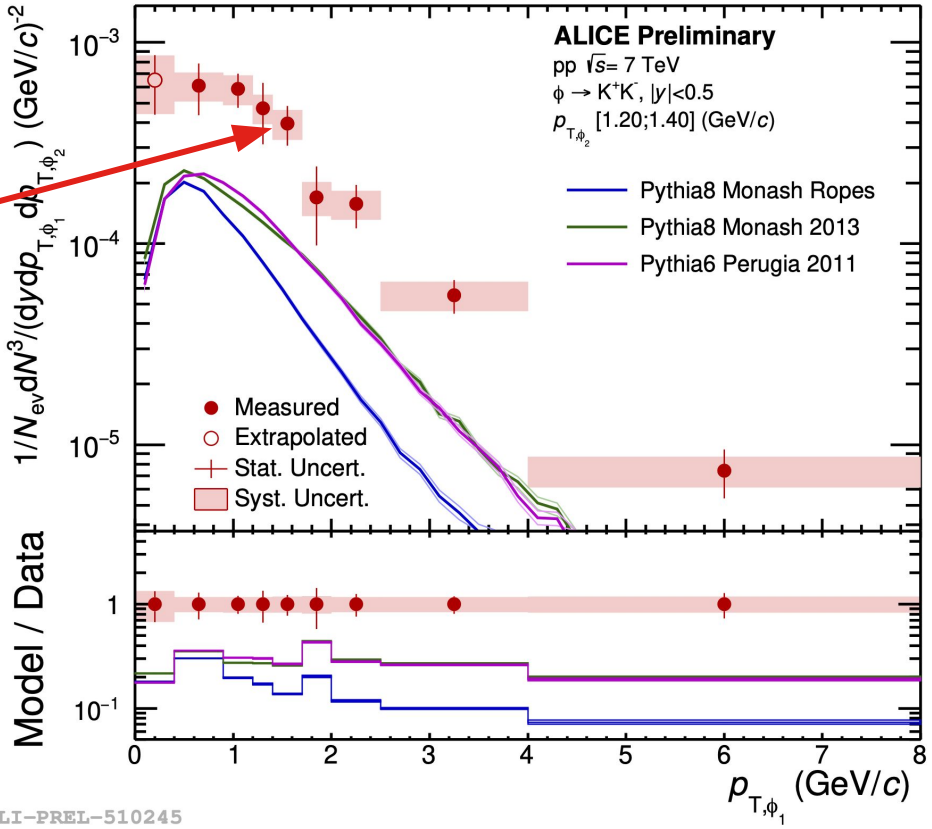
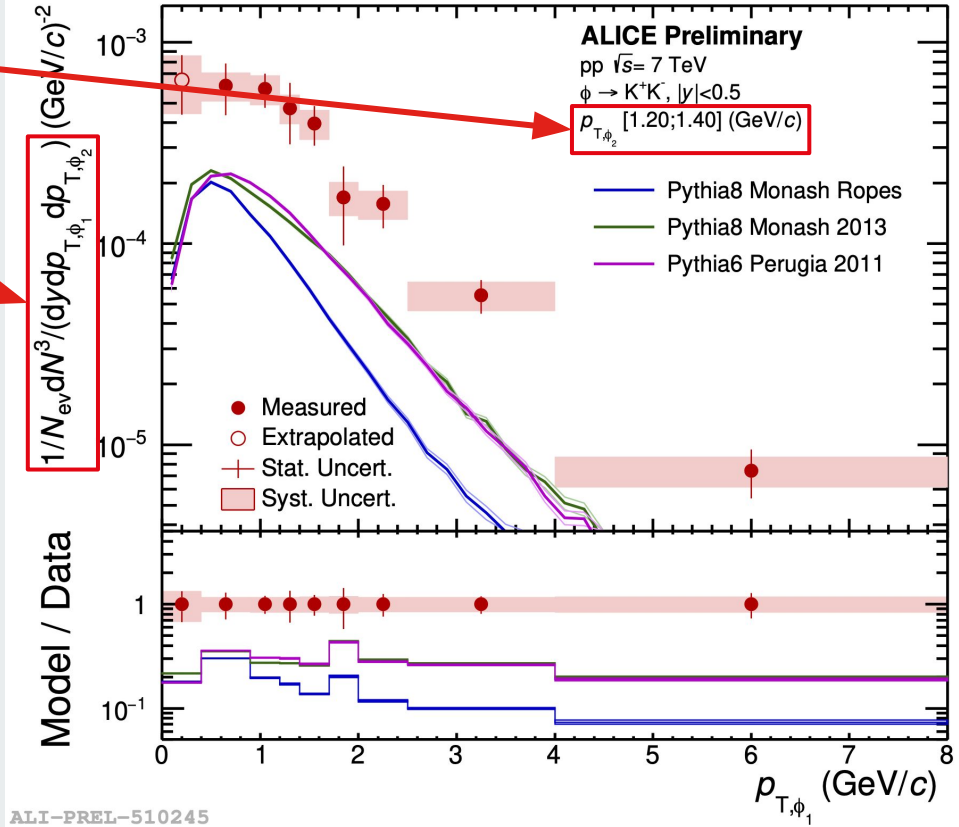
Results


ALICE Performance
pp $\sqrt{s}$= 7 TeV, $\phi \rightarrow K^+K^-$, $|y|<0.5$
$1.20 < p_{T,\phi_1} < 1.40$ GeV/c
$1.40 < p_{T,\phi_2} < 1.70$ GeV/c
$1.012 < M_{KK,\phi_1} < 1.026$ GeV/c^2
stat errors
Voigt × Voigt
Cheby × Voigt
Voigt × Cheby
Cheby × Cheby
Full model
Counts/(0.8 MeV/c^2)
M_{KK,ϕ_1} (GeV/c^2)
ALI-PERF-496512


ALICE Preliminary
pp $\sqrt{s}$= 7 TeV
$\phi \rightarrow K^+K^-$, $|y|<0.5$
p_{T,ϕ_2} [1.20;1.40] (GeV/c)
Pythia8 Monash Ropes
Pythia8 Monash 2013
Pythia6 Perugia 2011
Measured
Extrapolated
Stat. Uncert.
Syst. Uncert.
$1/N_{ev}dN^3/(dydp_{T,\phi_1}dp_{T,\phi_2})$ (GeV/c)$^{-2}$
Model / Data
p_{T,ϕ_1} (GeV/c)
ALI-PREL-510245

Results

Conditional spectra describe how a ϕ meson (ϕ_1) behaves when produced together with a second ϕ meson (ϕ_2) of a given p_T



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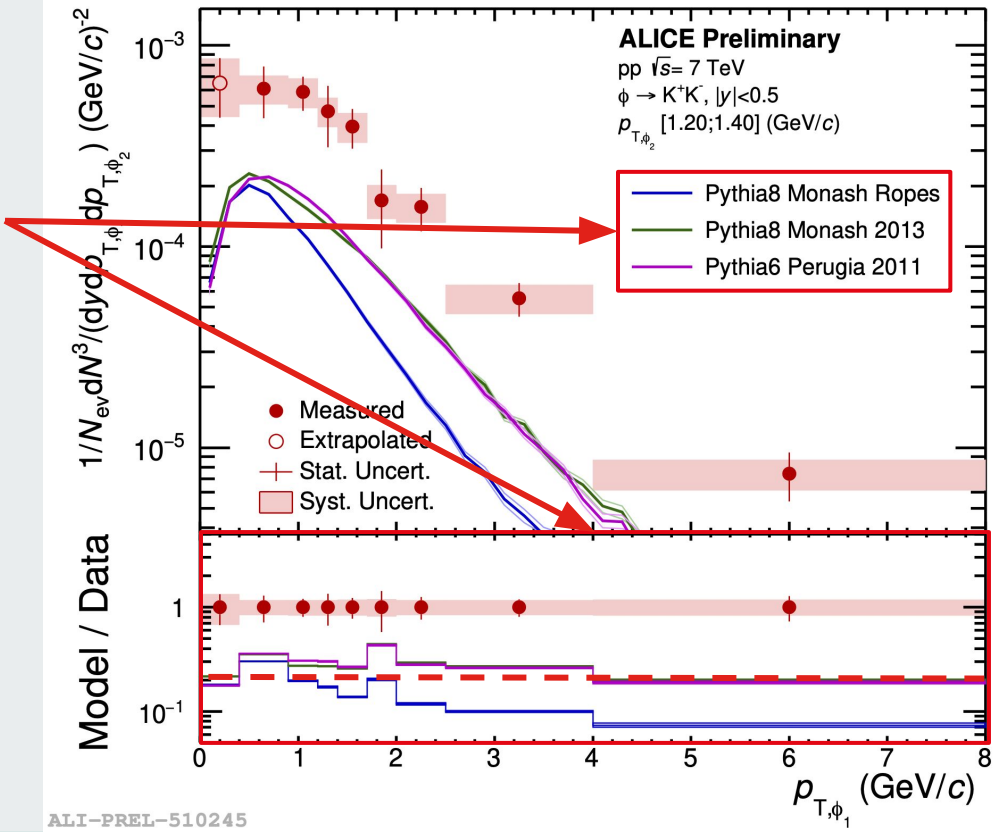
Different Pythia tunes tend to underestimate the conditional Φ-meson production yield



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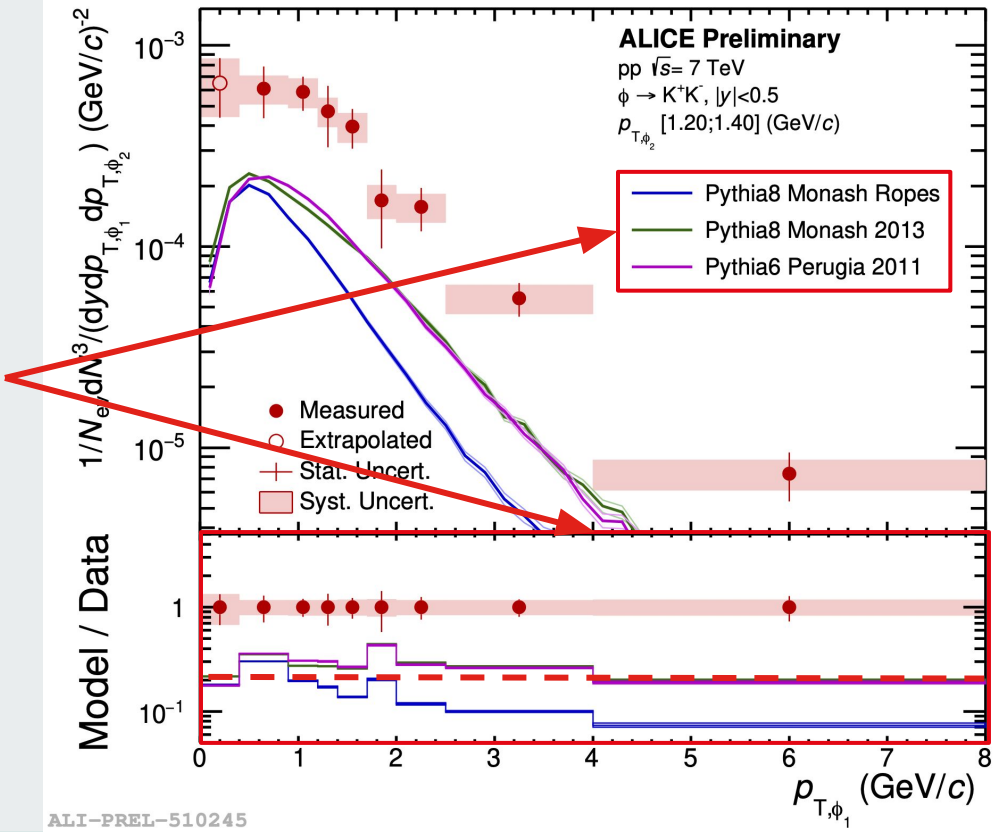
Pythia 6 and 8 tend to correctly predict the spectrum shape, despite their yields are not reproduced



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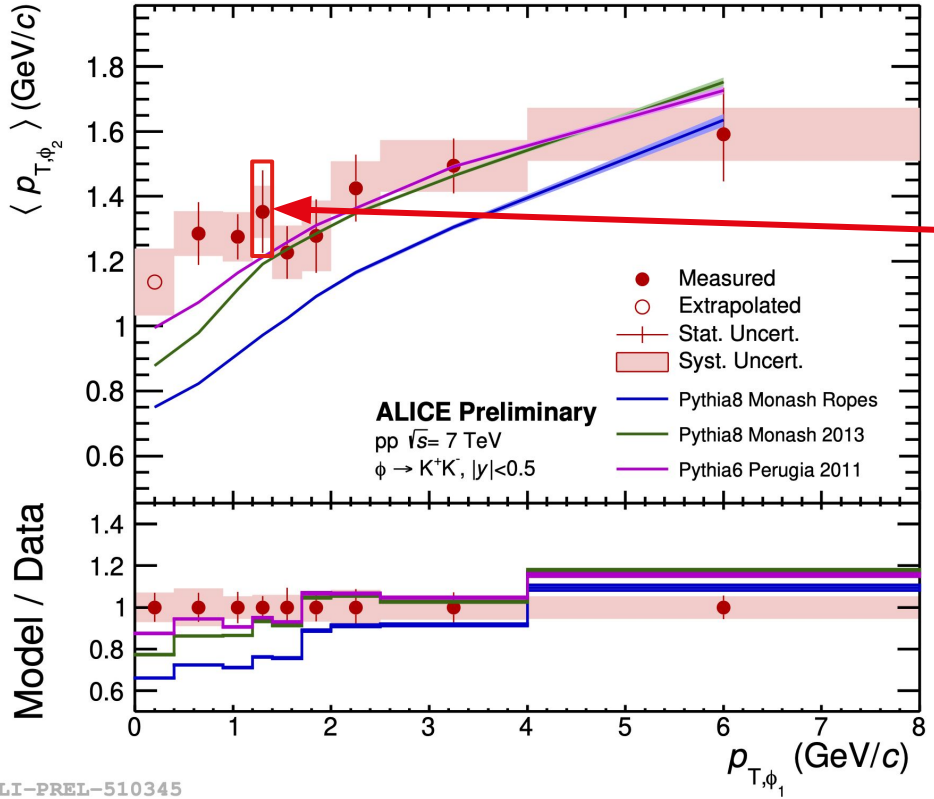
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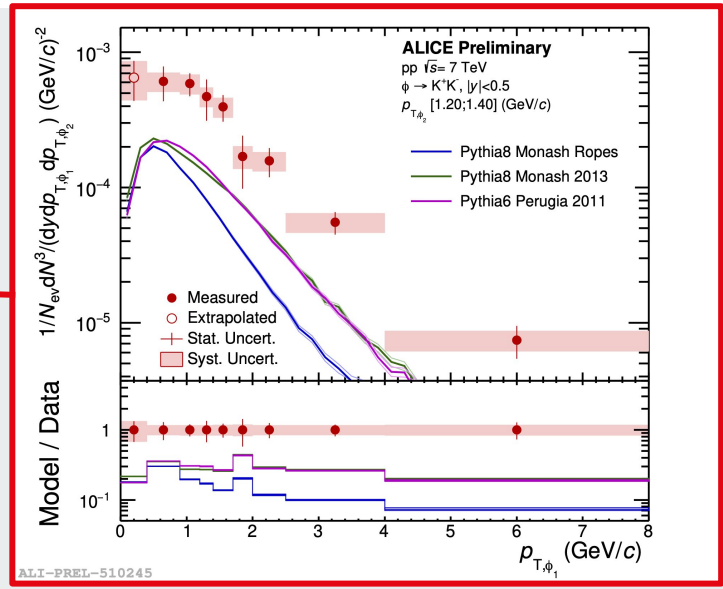
Pythia8 Monash Ropes
Pythia8 Monash 2013
Pythia6 Perugia 2011
Model / Data
p_{T,ϕ_1} (GeV/c)
ALI-PREL-510345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Model / Data
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ALI-PREL-510245

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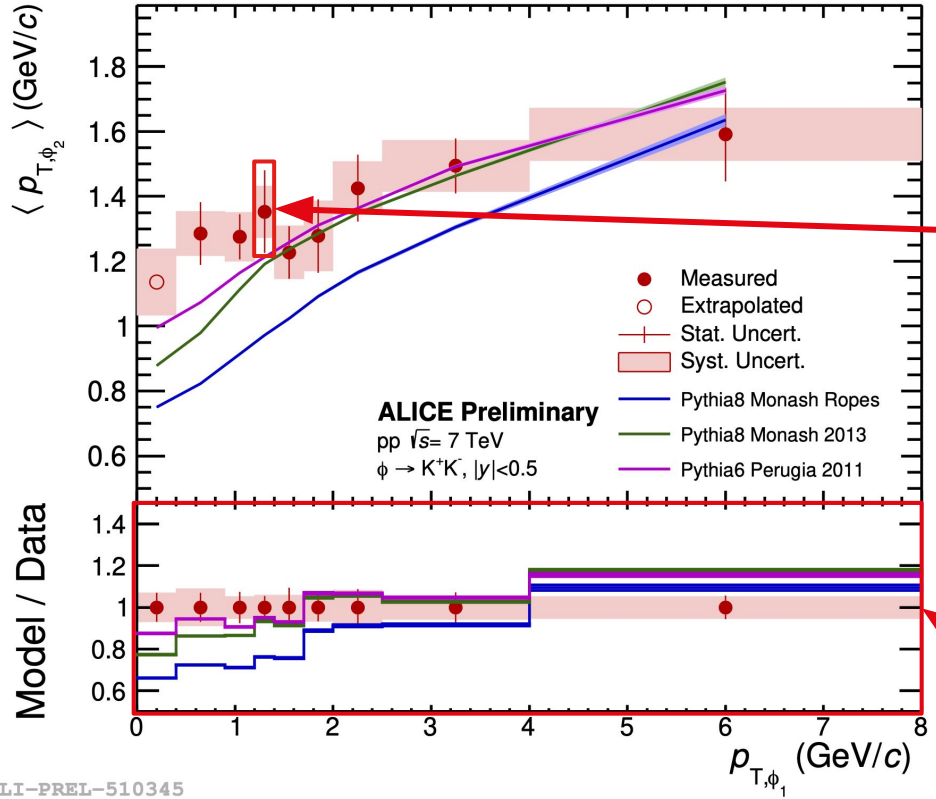
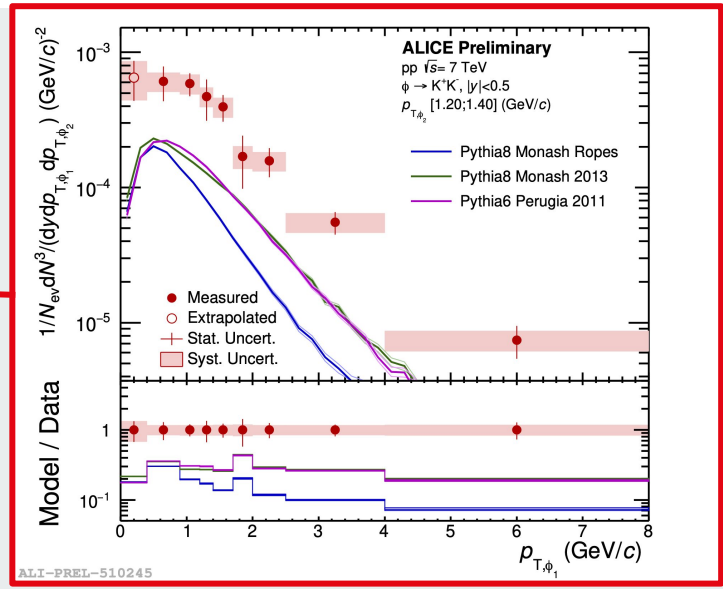
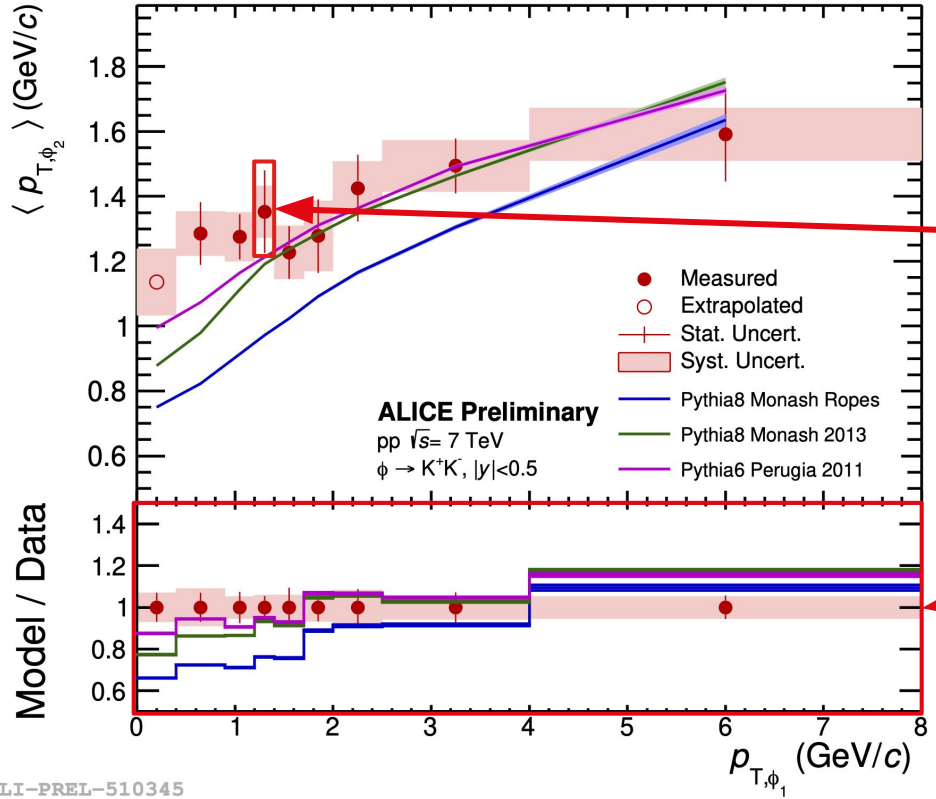
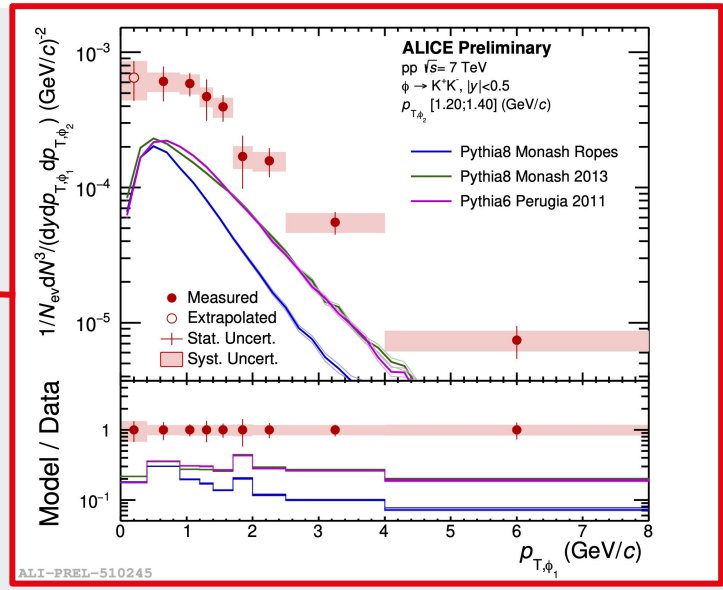




Mean p_T for conditional spectra indicates Pythia models reproduce the shape of the spectra at first order

Results



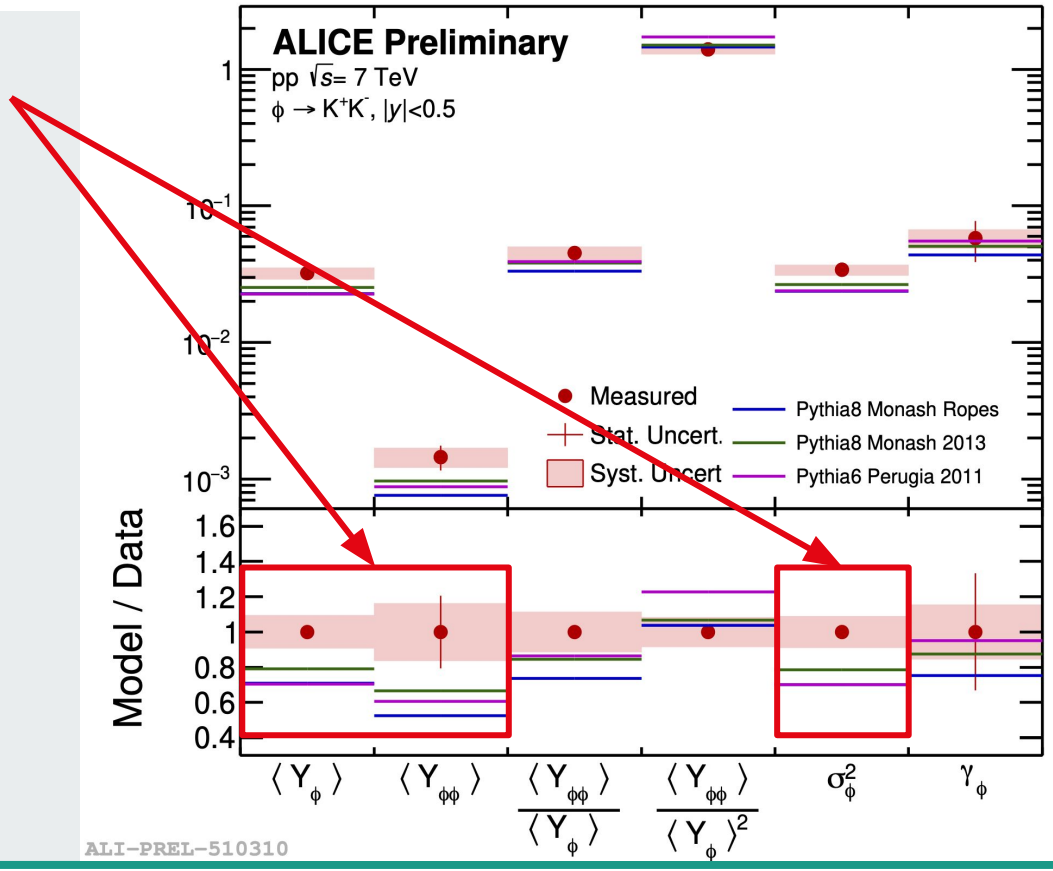


Rope tune of Pythia has a softer spectrum

Mean p_T for conditional spectra indicates Pythia models reproduce the shape of the spectra at first order

Results

Average yield of produced ϕ-meson and ϕ-meson pairs, together with variance are underestimated



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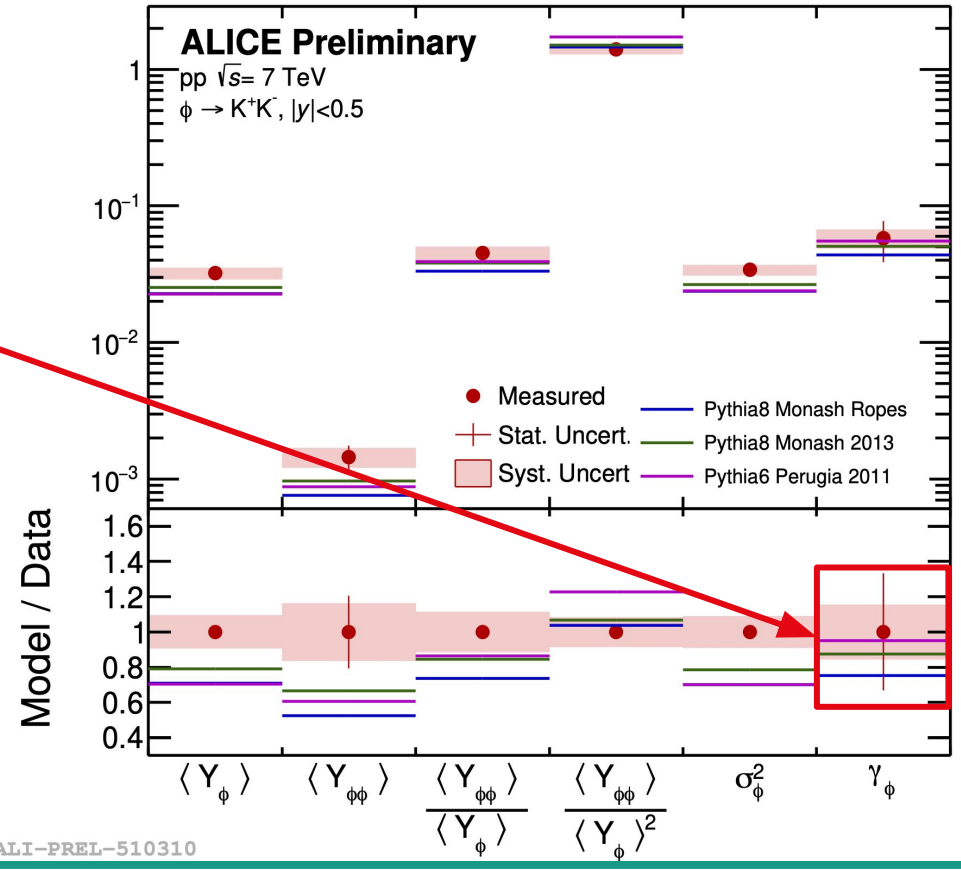
New characterisation technique hint at an accordance of the production statistics, even though the integrated yields are not reproduced

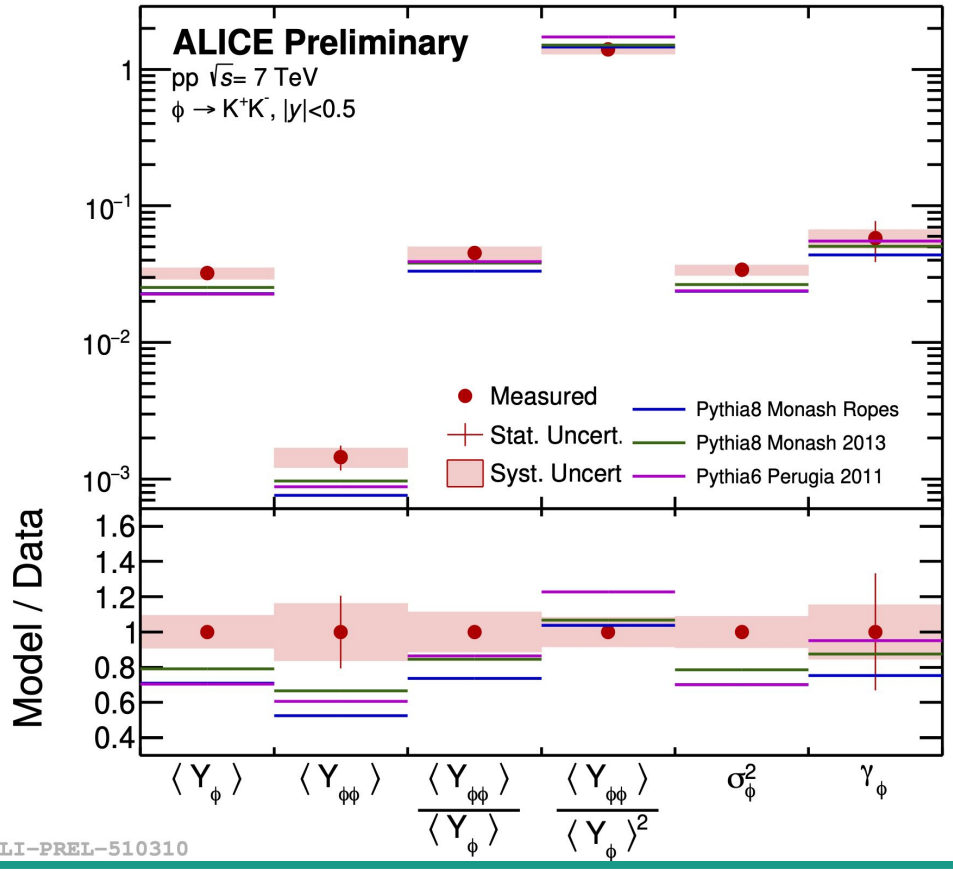


Results

Average yield of produced ϕ-meson and ϕ-meson pairs, together with variance are underestimated

New characterisation technique hint at an accordance of the production statistics, even though the integrated yields are not reproduced

This analysis represents a new way to challenge phenomenological models with a thorough characterisation of resonance and strangeness production



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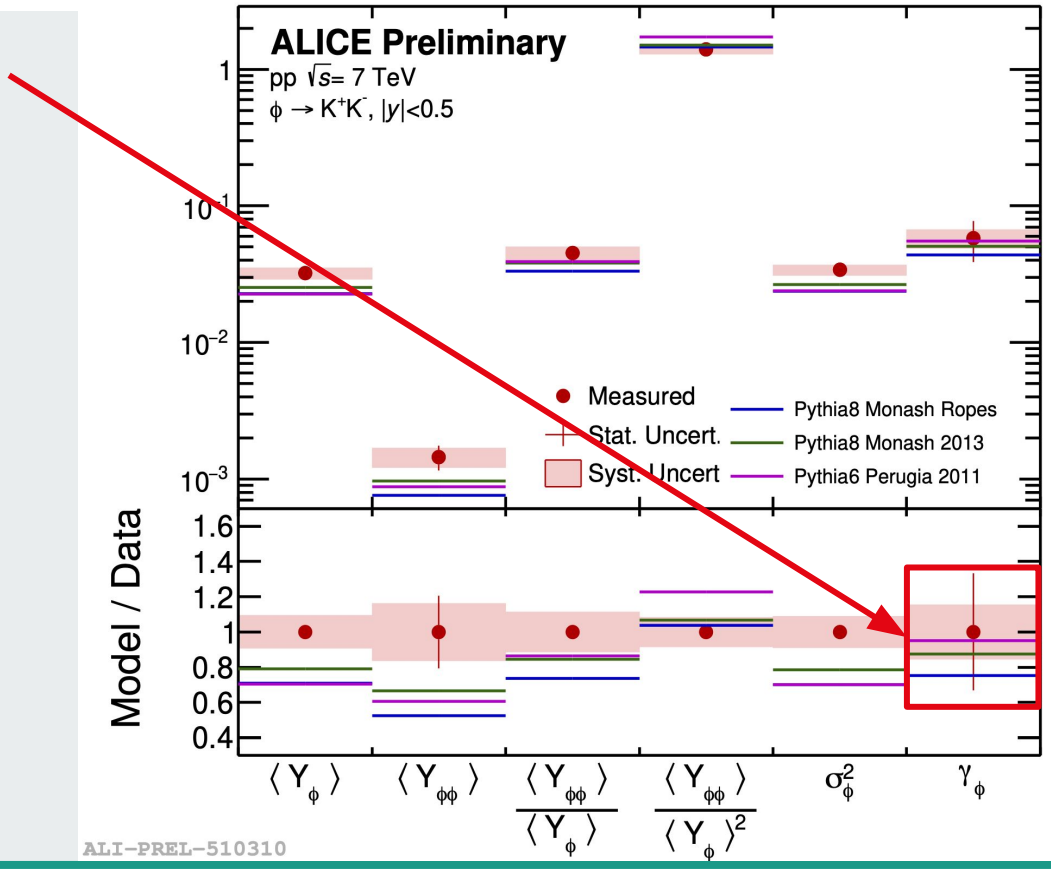
Prospects

Statistical uncertainty is still a limiting factor, more datasets will be included



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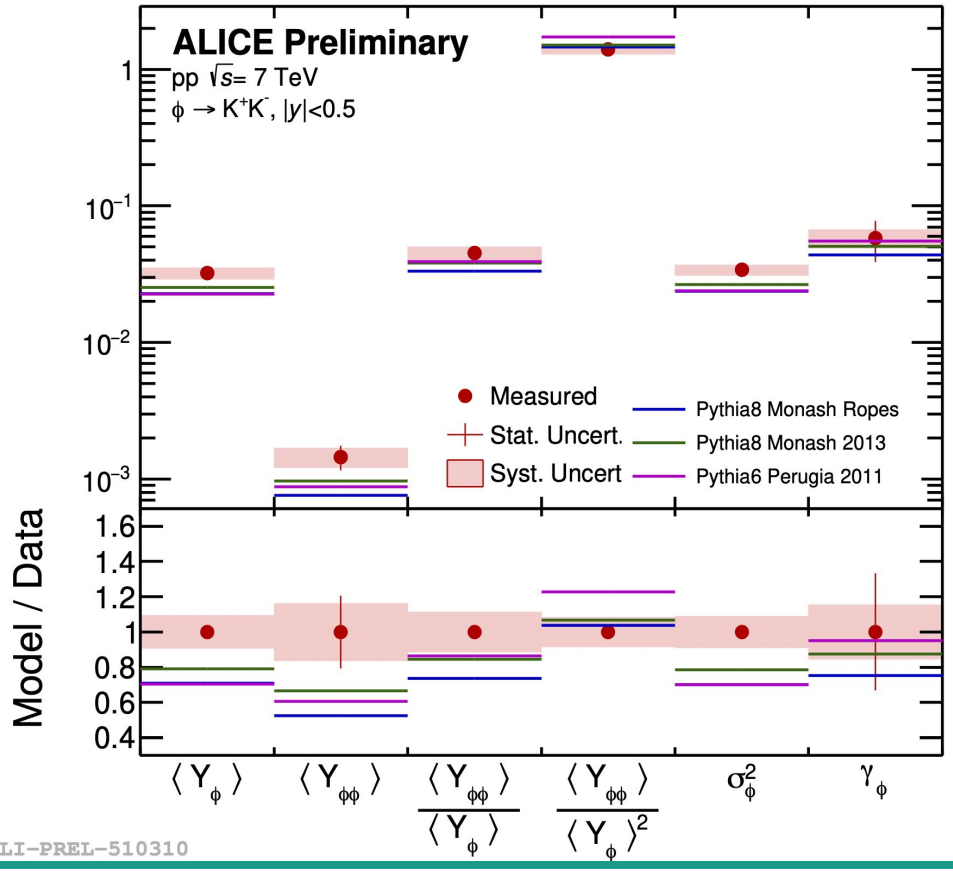
Measurements in p-Pb collisions will give room for a higher multiplicity reach in small systems

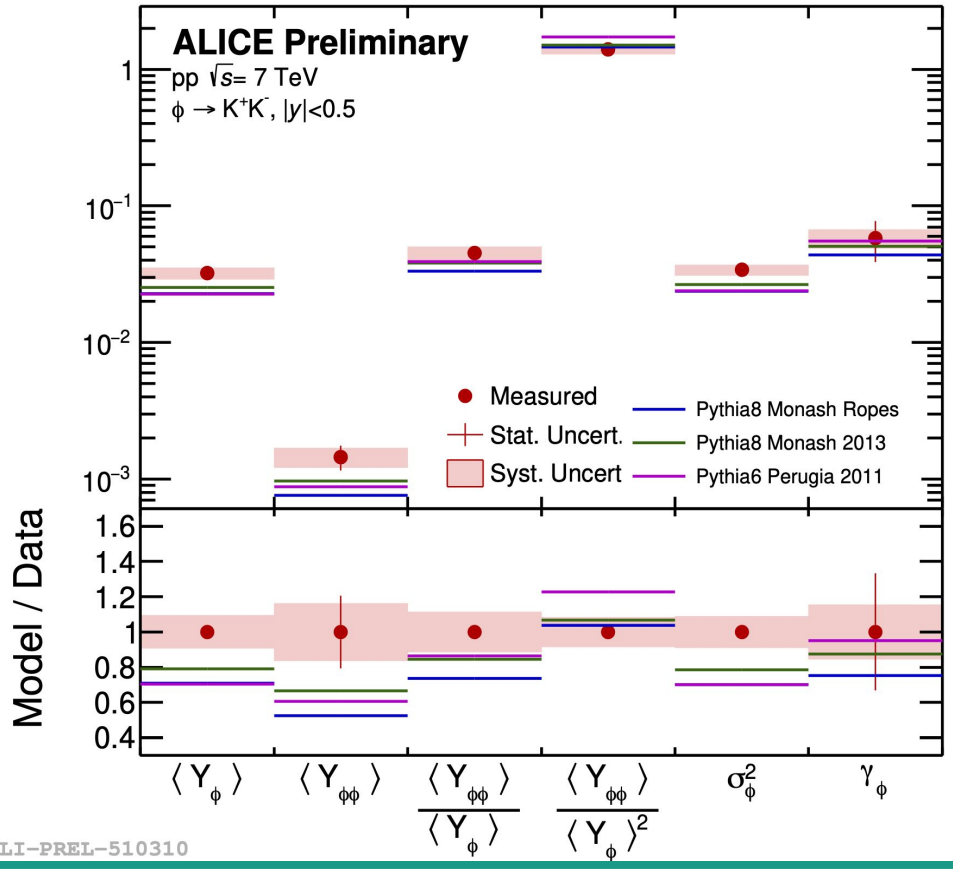


Prospects

Statistical uncertainty is still a limiting factor, more datasets will be included

Measurements in p-Pb collisions will give room for a higher multiplicity reach in small systems

Large data samples foreseen to be collected in Run 3 will further improve the precision of the measurement



Thank you for your attention!
Any questions?