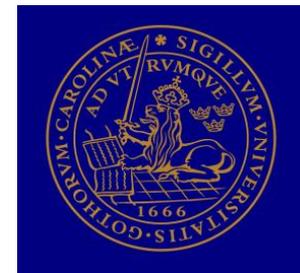
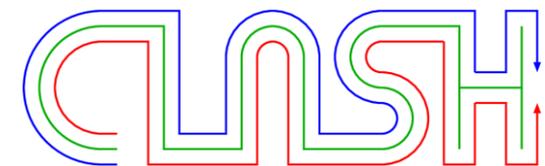


Strangeness production in small systems - from revolution to resolution

Peter Christiansen
Lund University



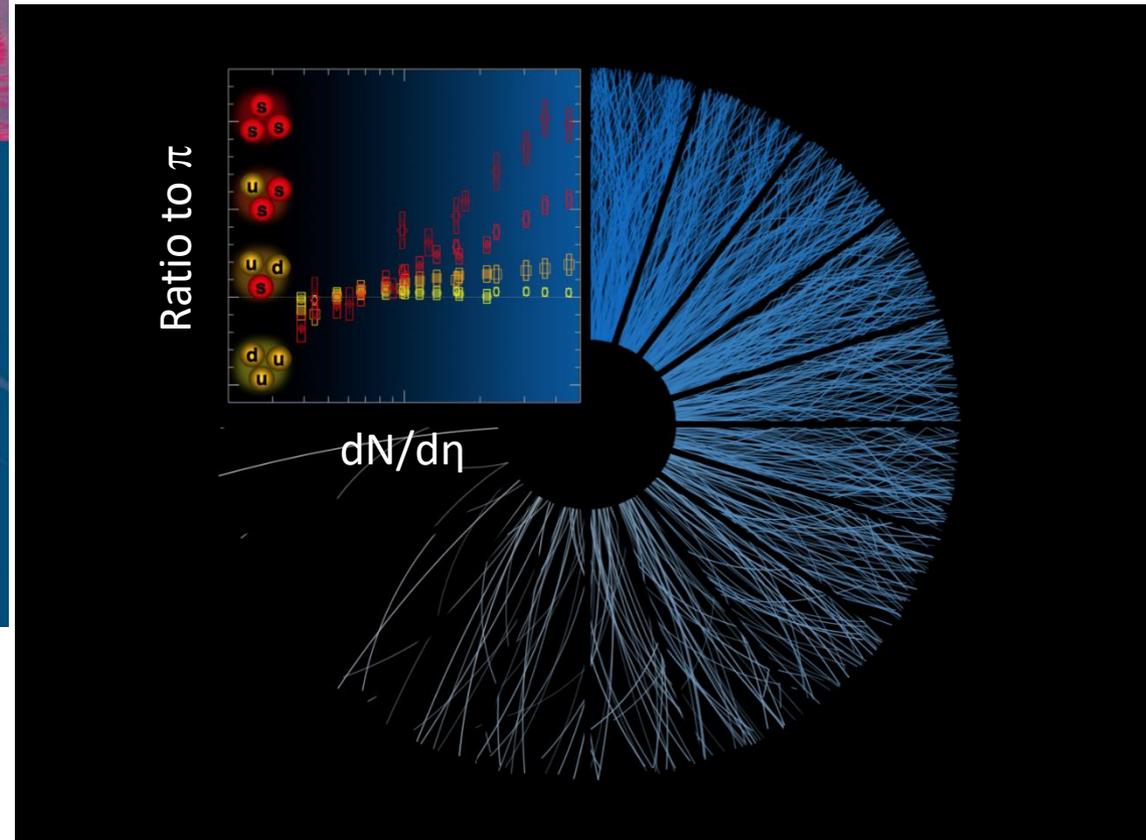
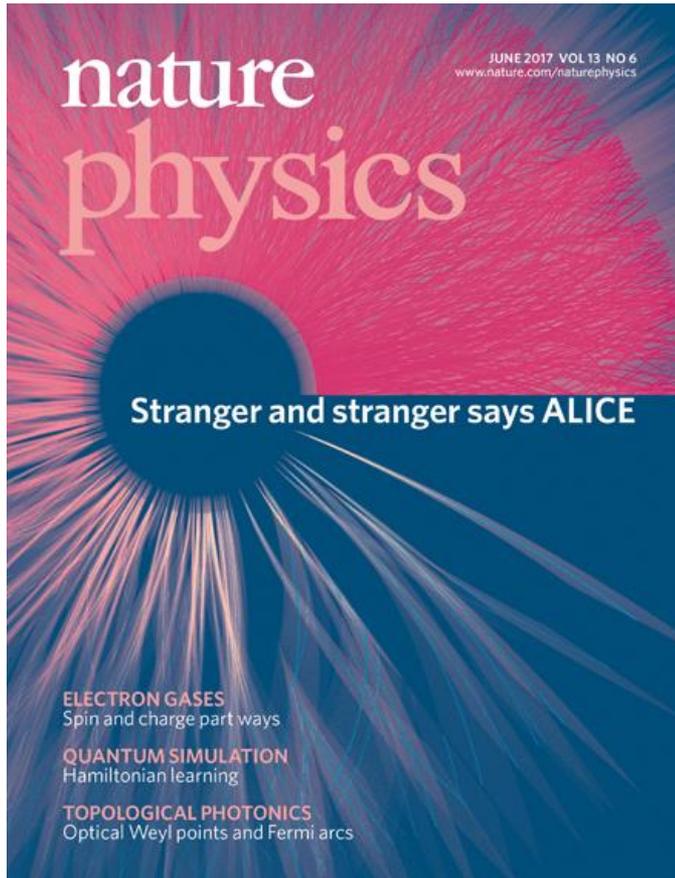
ALICE

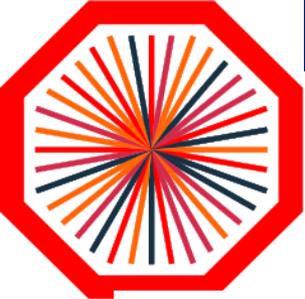




The ALICE revolution: “Stranger and stranger says ALICE”

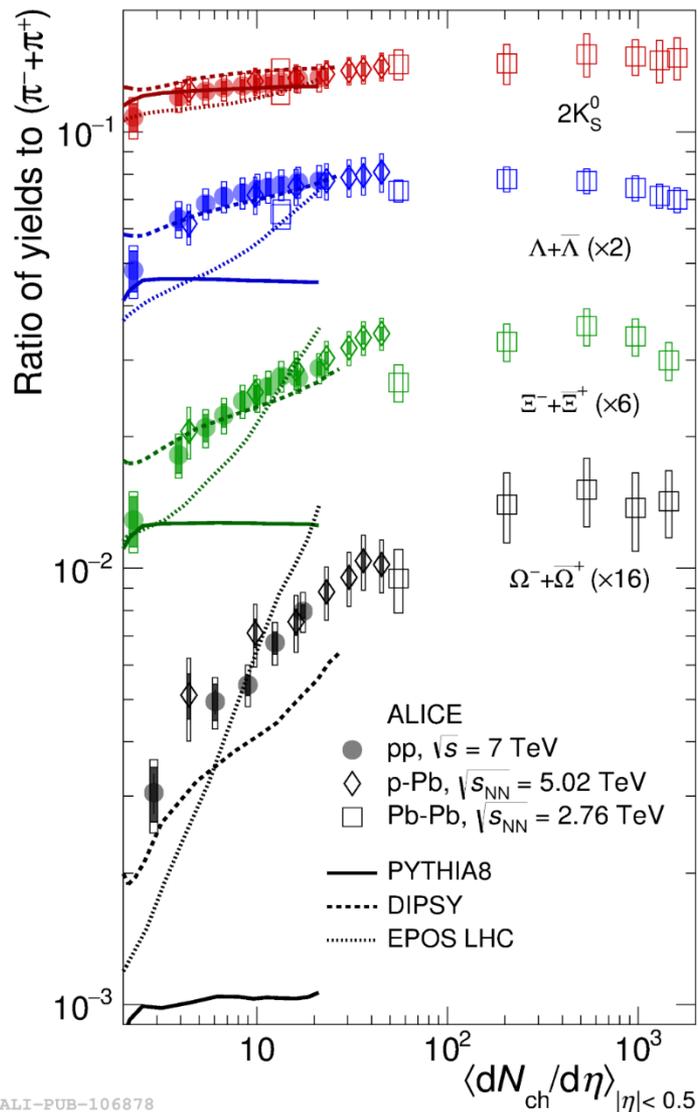
Strangeness: from revolution to resolution (P. Christiansen)



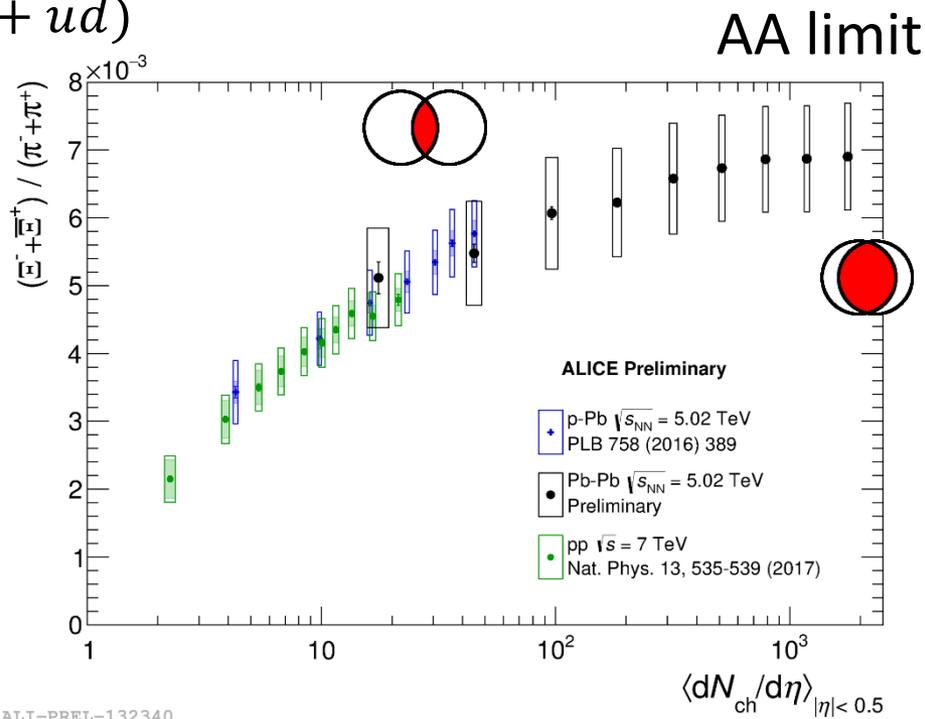


Focus mainly on Ξ in this presentation

Nature Physics 13 (2017) 535

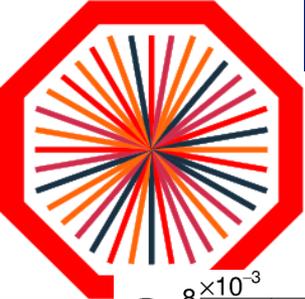


$$\frac{(ssd + \bar{s}\bar{s}\bar{d})}{(\bar{u}d + u\bar{d})}$$



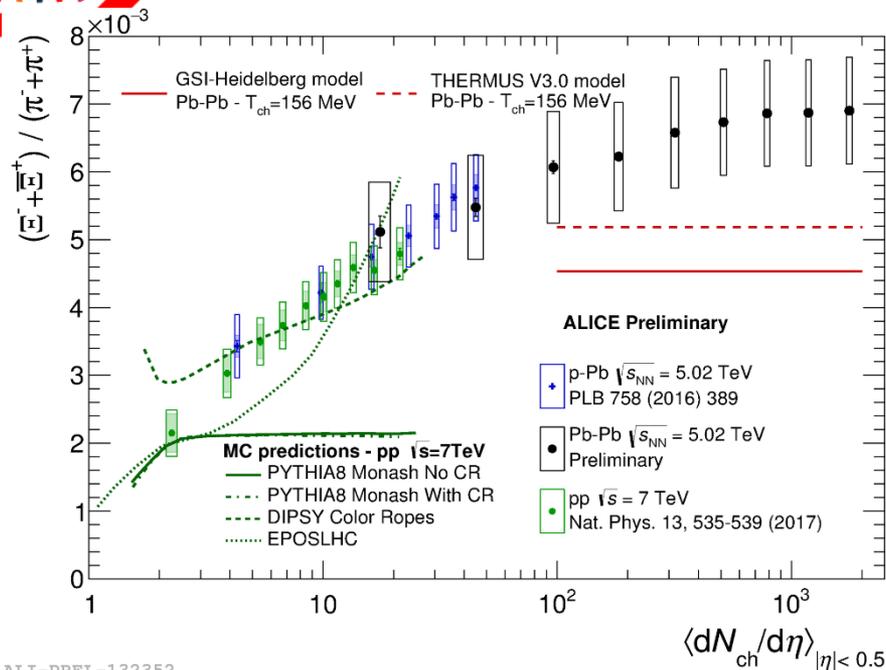
Importantly, even in pp collisions we see a large change

Strangeness: from revolution to resolution (P. Christiansen)



What do the models say?

Strangeness: from revolution to resolution (P. Christiansen)



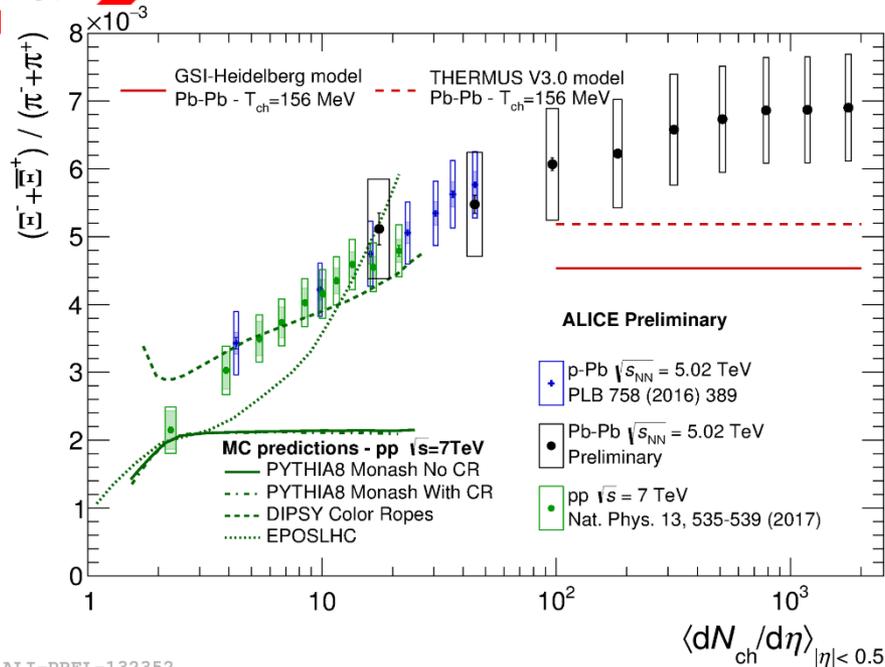
PYTHIA:
 $pp \sim \sum_{MPI} \text{parton-parton interactions}$

predicts “more of the same” as one could expect from asymptotic freedom.

The revolution is that this is wrong!

ALI-PREL-132352

What do the models say?



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pp

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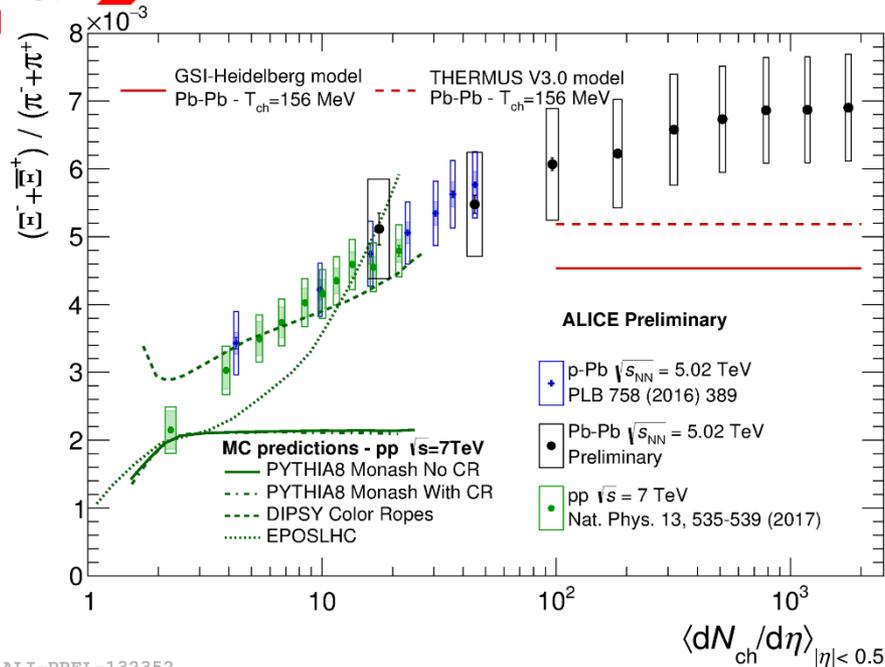
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ALI-PREL-132352

- DIPSY/Angantyr: “Microscopic extension of PYTHIA”
2+ strings can merge into 1 rope \rightarrow Increases string/rope tension
 \rightarrow Enhances production of the heavier strange quarks

- EPOS LHC (and EPOS 3): introduces QGP phase (a la GSI-Heidelberg and THERMUS models). Rise is interplay between corona (“PYTHIA” like) and QGP-like core.

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ALI-PREL-132352

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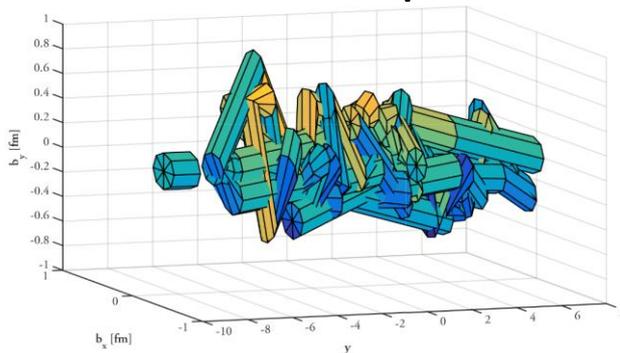


How to make progress?

Microscopic

vs

Macroscopic



Picture from C. Bierlich
(string radii ~ 3.5 times too small!)

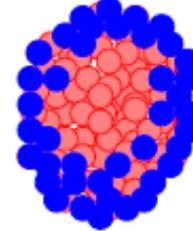


Low mult pp

corona

core

High mult pp



Pictures from K. Werner

- Try to find new observables that can provide differential insights
 - R_T : a tool that can control the Underlying Event (UE)
 - S_O : how similar are events at the same $dN/d\eta$
 - Ξ - π and Ξ -K correlations to trace anti-strangeness

Introduction to R_T

Idea: Martin, Skands, Farrington, Eur. Phys. J. C76 (2016), 1

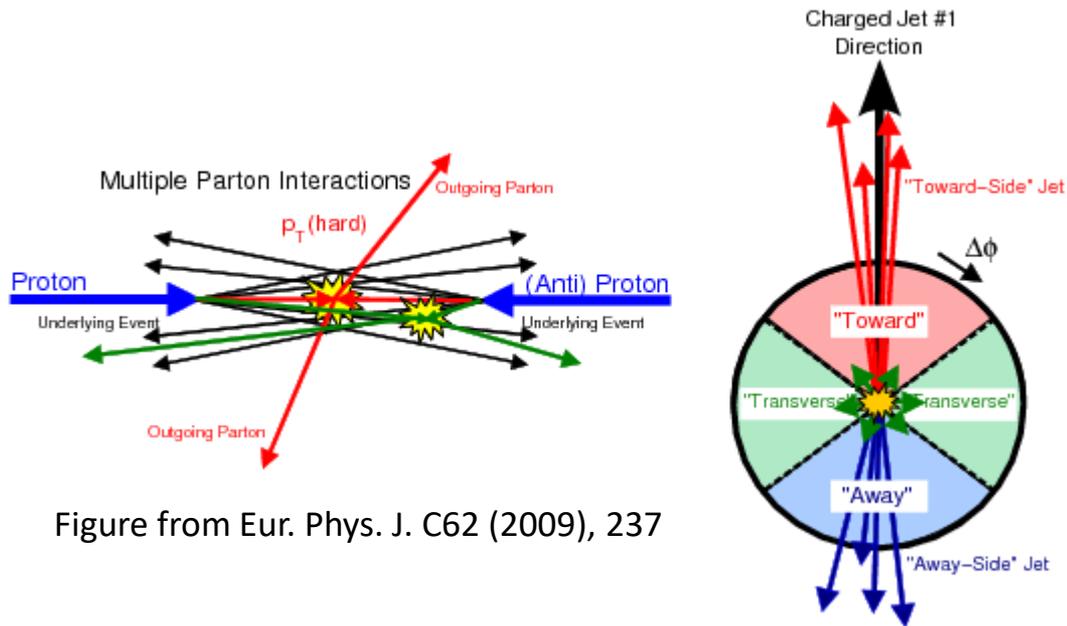


Figure from Eur. Phys. J. C62 (2009), 237





Introduction to R_T

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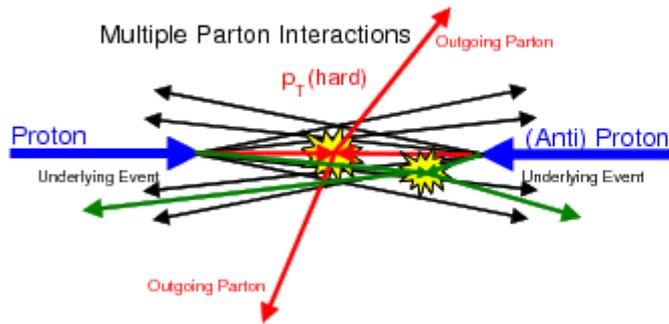
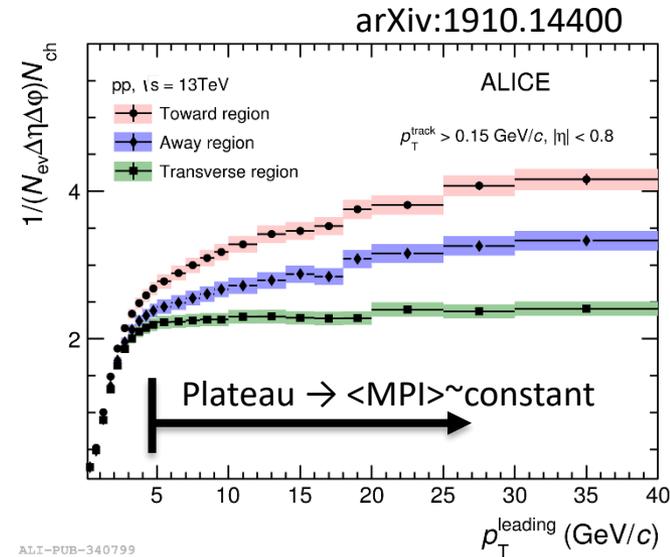
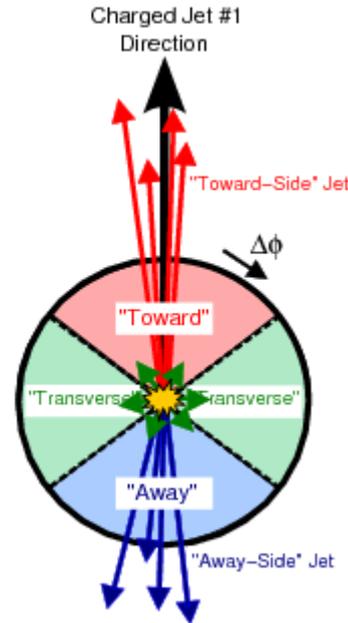
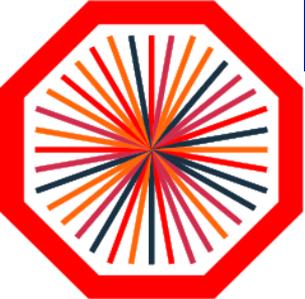


Figure from Eur. Phys. J. C62 (2009), 237



Strangeness: from revolution to resolution (P. Christiansen)



Introduction to R_T

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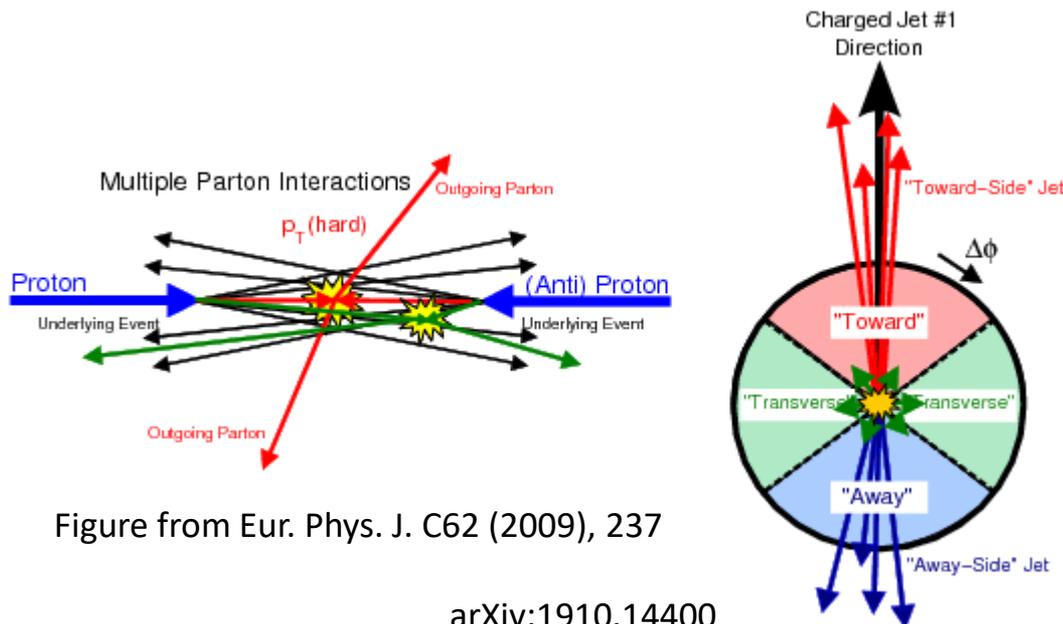
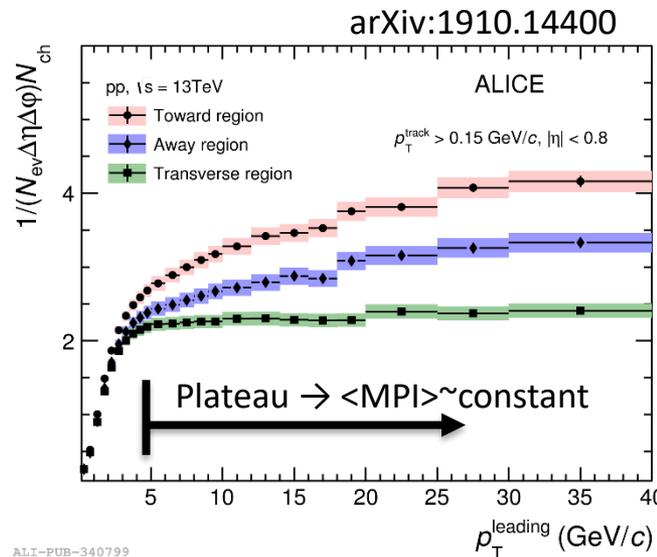
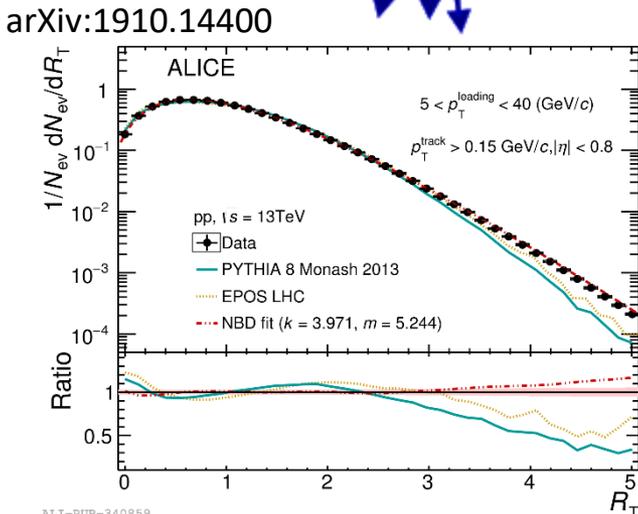


Figure from Eur. Phys. J. C62 (2009), 237



ALI-PUB-340799



ALI-PUB-340859

Define:

$$R_T = \frac{N_{ch}^{Transverse}}{\langle N_{ch}^{Transverse} \rangle}$$

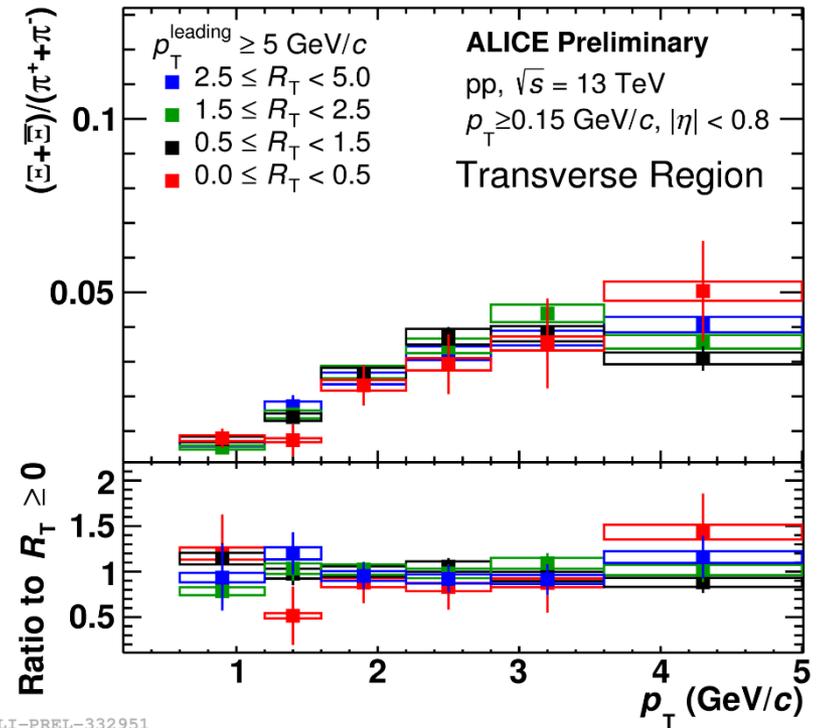
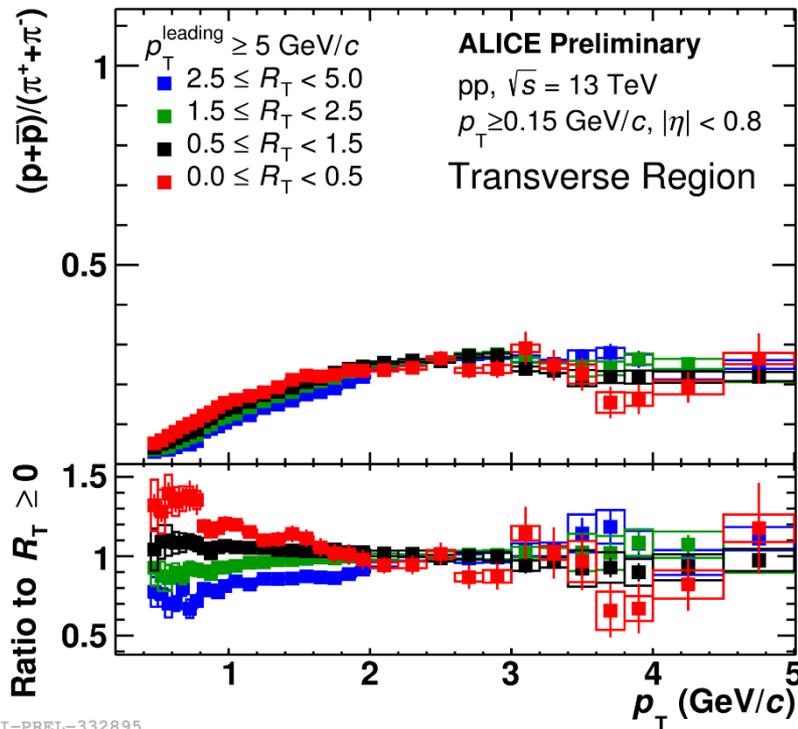
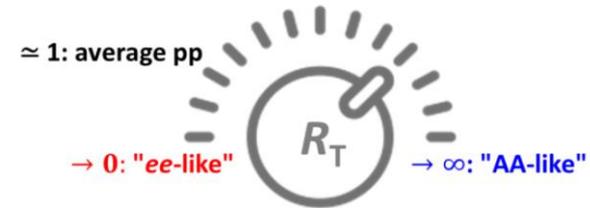
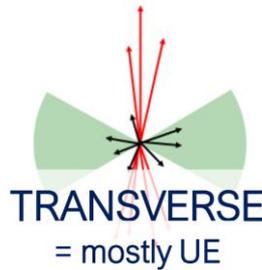
Gives some control over the UE



Strangeness: from revolution to resolution (P. Christiansen)

ρ -to- π and Ξ -to- π ratios vs R_T

Transverse

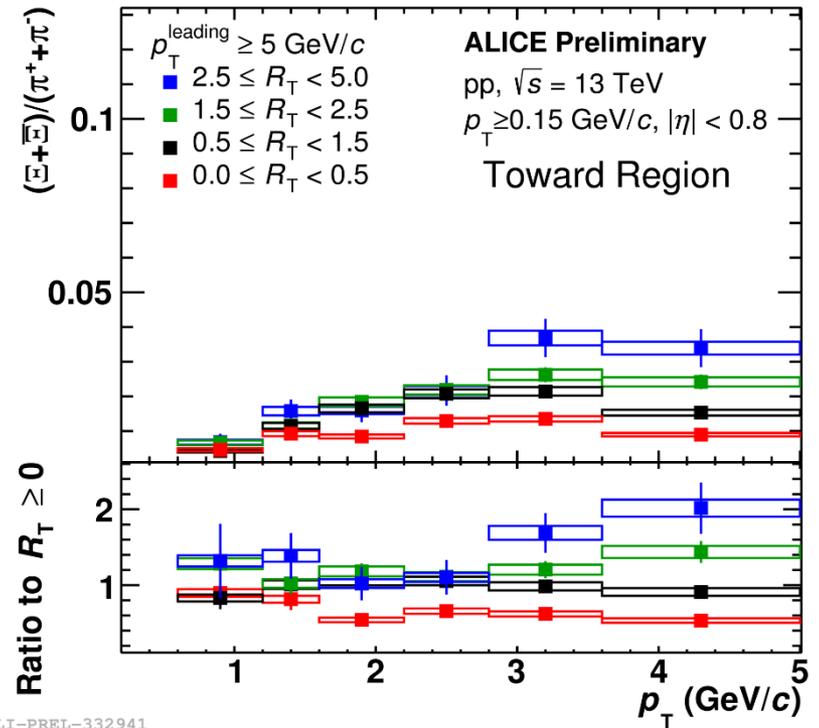
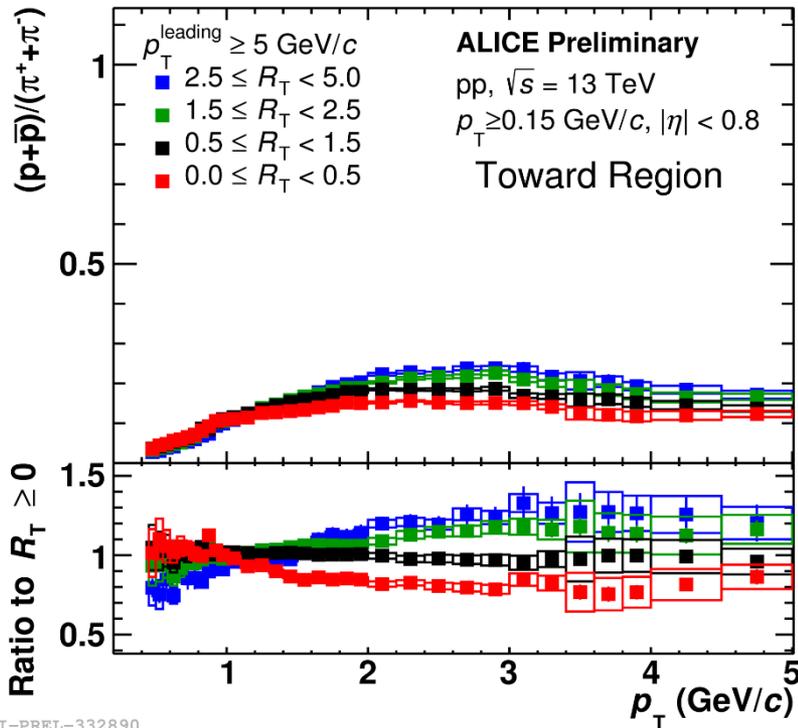
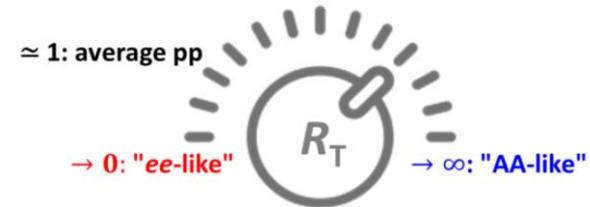
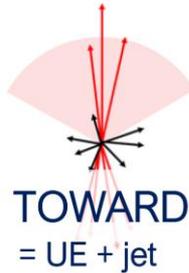


The ρ -to- π decreases at low p_T with increasing R_T , while at high p_T it shows little or no dependence on R_T .

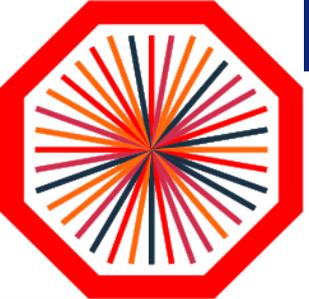
The Ξ -to- π ratio shows little or no dependence on R_T .

ρ -to- π and Ξ -to- π ratios vs R_T

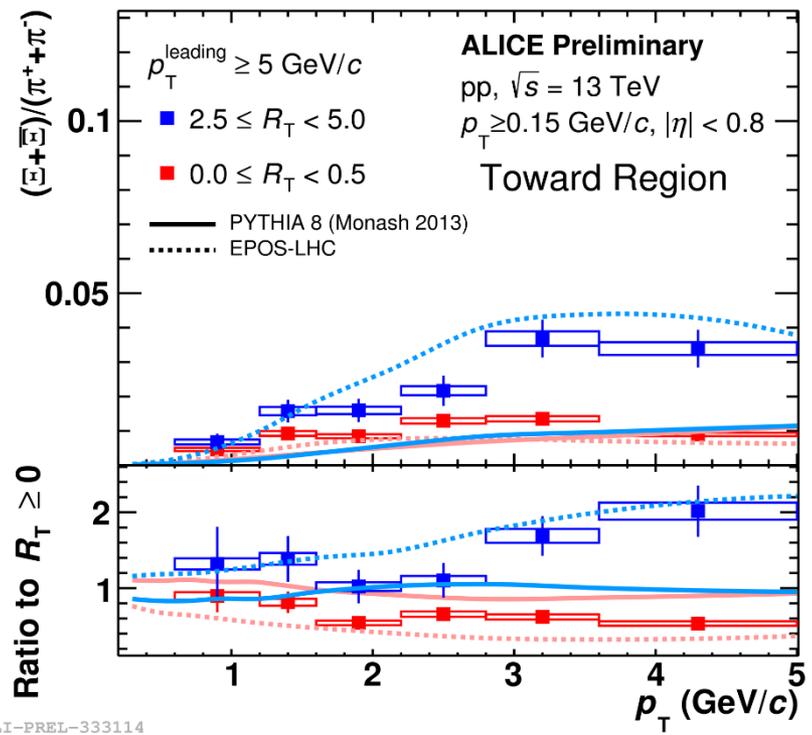
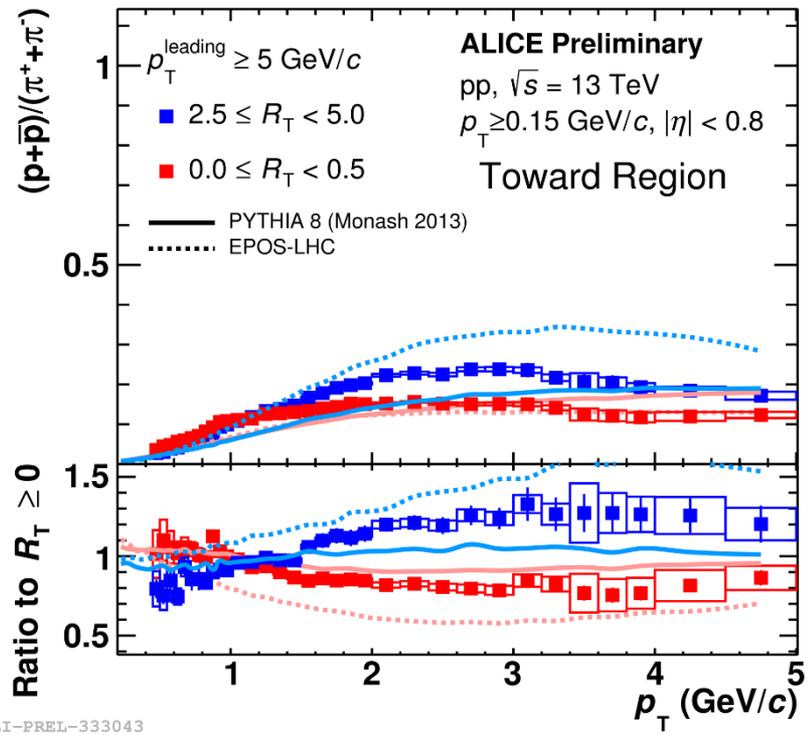
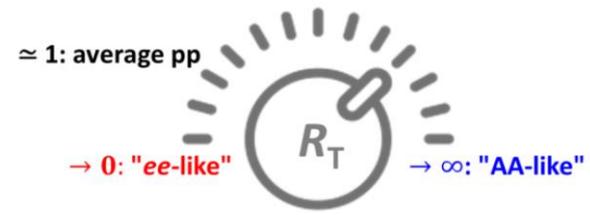
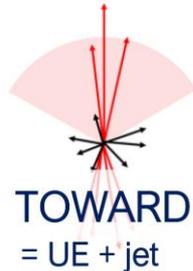
Toward



The ρ -to- π decreases (increases) at low (high) p_T with increasing R_T , a radial flow signature but here likely an interplay between UE and jet. The Ξ -to- π ratio increases with increasing R_T , approaching the "Transverse" value.



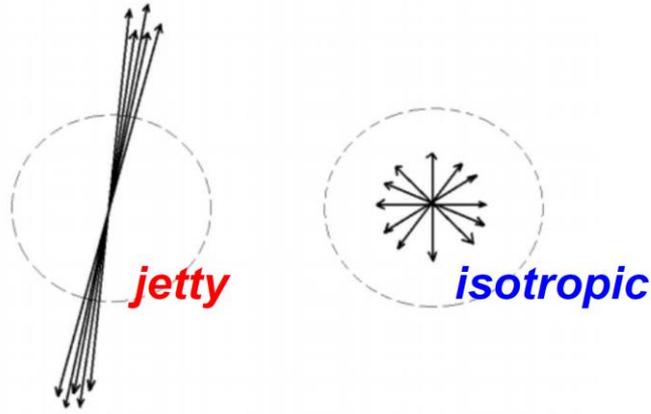
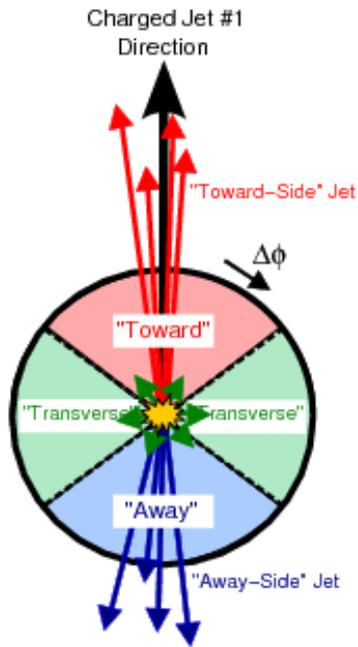
p -to- π and Ξ -to- π ratios vs R_T Toward



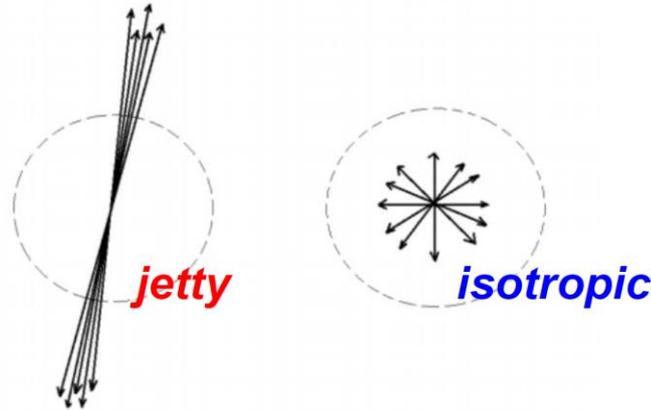
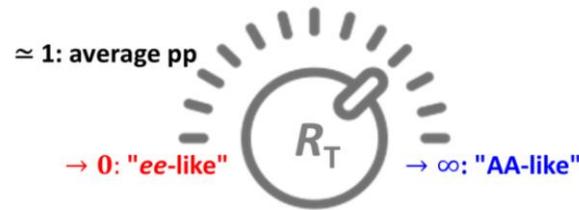
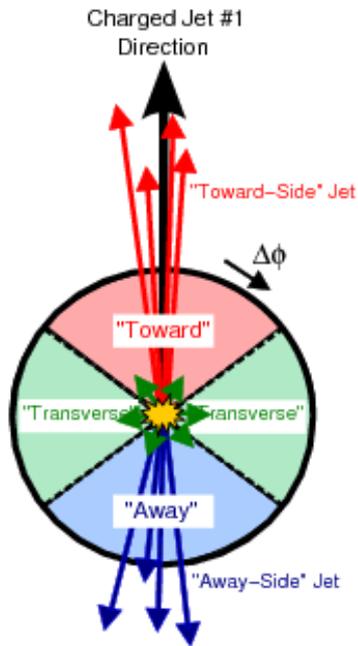
Both models describe well low R_T (jet), suggesting we reach the ee limit.
EPOS LHC does a clearly better job at high R_T as expected.
This indicates a core (Transverse and high R_T) and corona (Towards) picture.

Strangeness: from revolution to resolution (P. Christiansen)

From R_T to transverse spherocity S_0



From R_T to transverse sphericity S_O



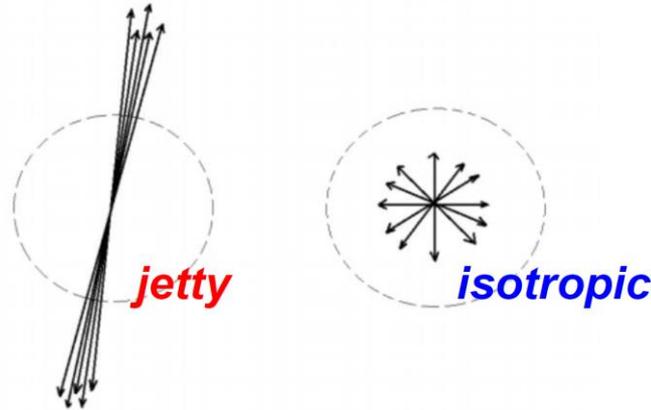
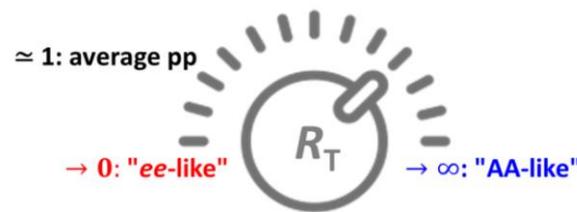
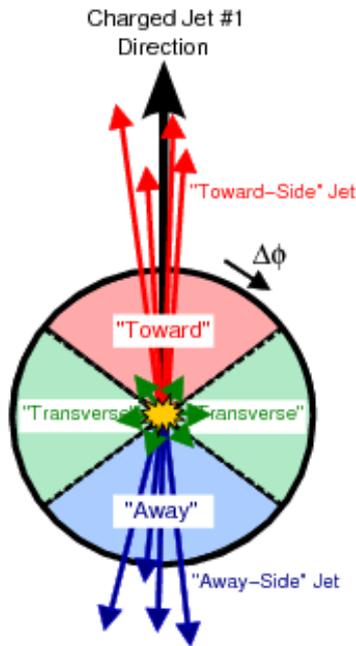
Define the unweighted transverse sphericity:

$$S_O^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\sum_{tracks} |\hat{p}_T \times \hat{n}|}{N_{tracks}} \right)^2$$

Then we can use that as a event classifier.



From R_T to transverse sphericity S_O



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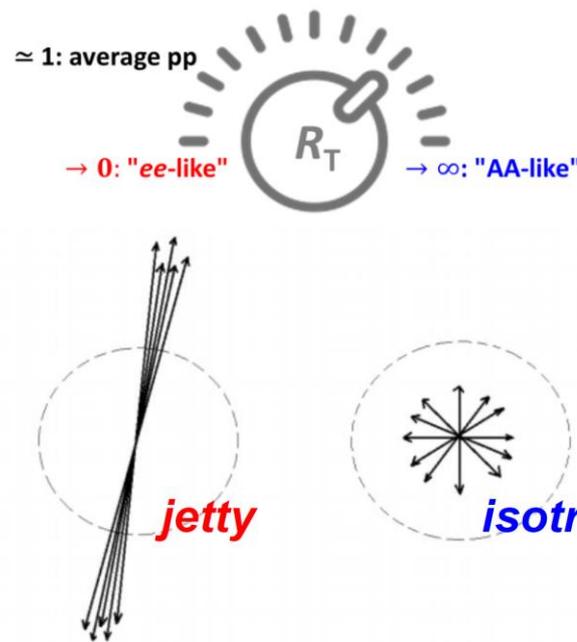
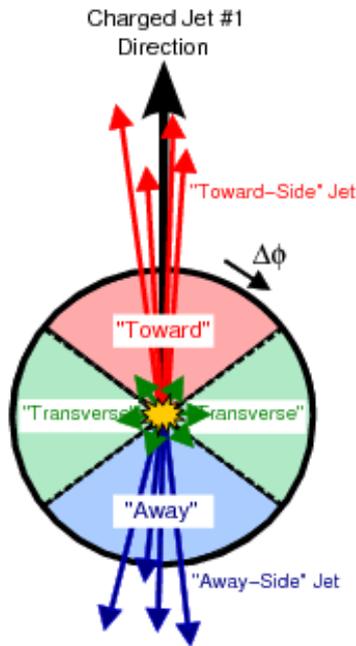
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- So in what way does S_O differ from R_T ?
 - No trigger, but we require 10+ charged tracks
 - We probe the particle production in a full event
 - Testing how homogenous the system is

- Note that we use the unweighted S_O
 - Most other ALICE preliminary results were for the p_T -weighted S_O



From R_T to transverse sphericity S_O



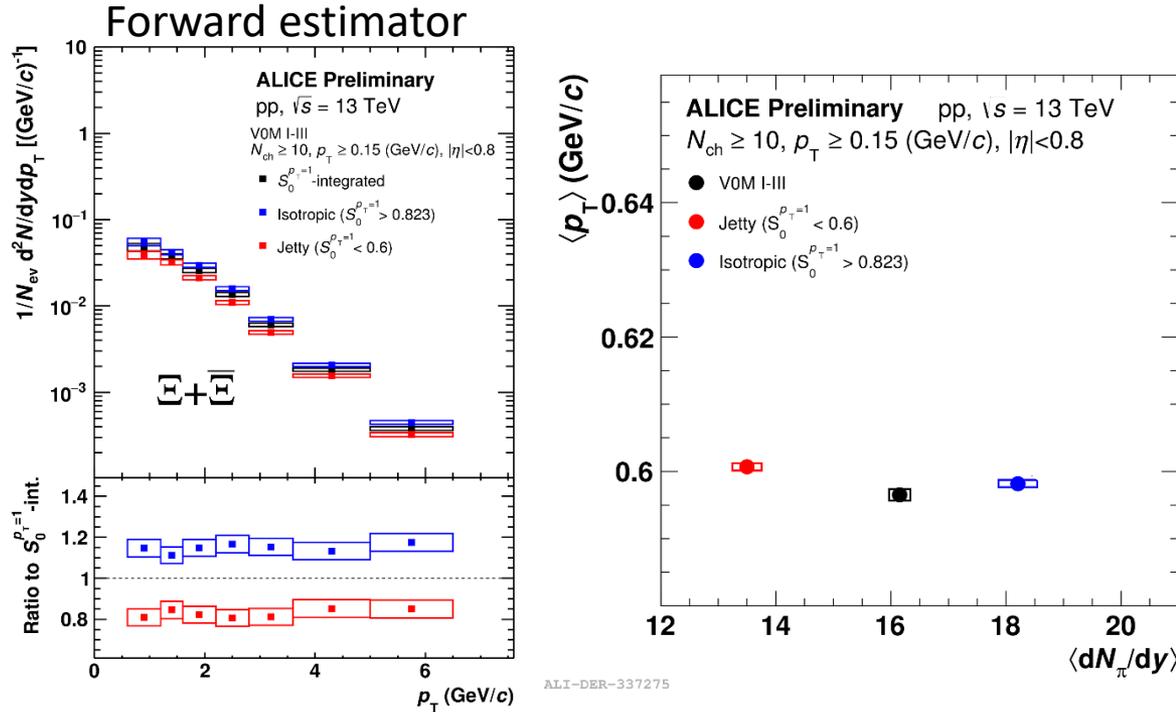
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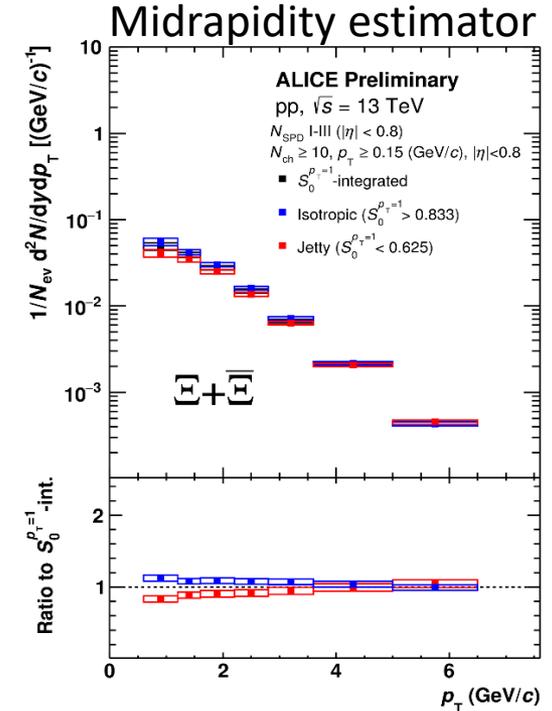
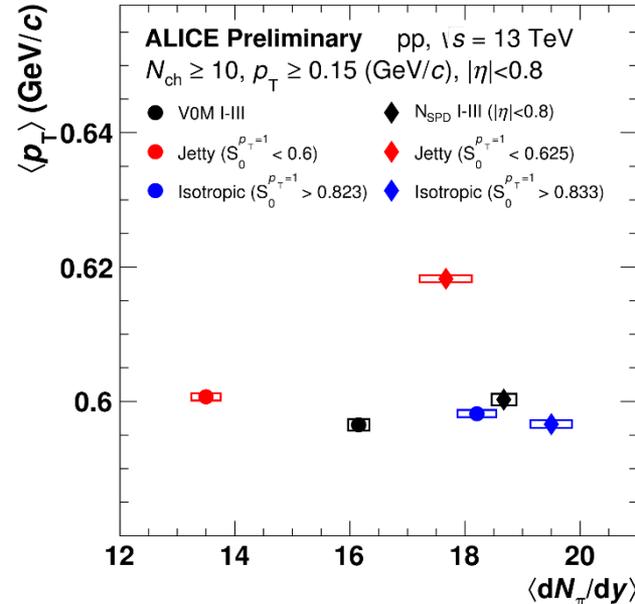
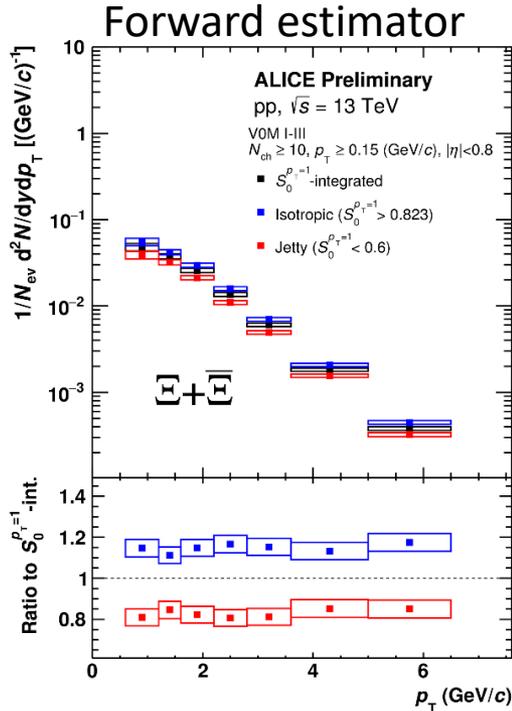
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Dependence on multiplicity estimator

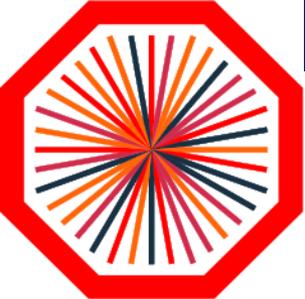


- Forward estimator selects broad range of midrapidity multiplicities
 - S_0 selection mainly selects on multiplicity \rightarrow the spectral shapes are similar \rightarrow hard effects are small for forward multiplicity selection
 - Key to understand $dN/d\eta$ scaling? (hard effects are small)

Dependence on multiplicity estimator

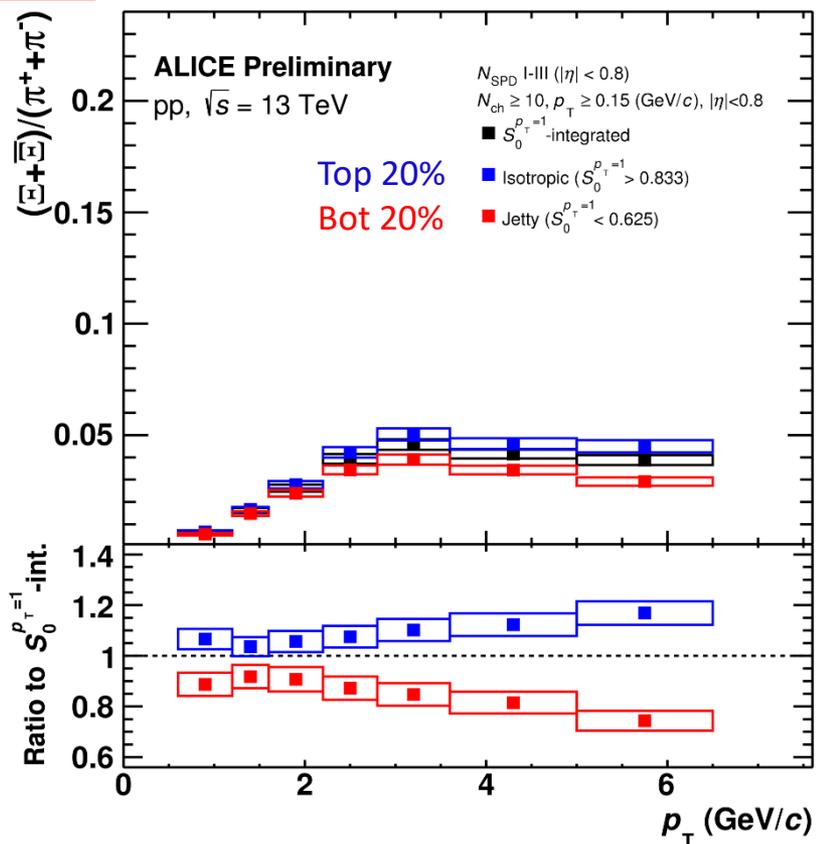


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 - S_0 selection mainly selects on multiplicity \rightarrow the spectral shapes are similar \rightarrow hard effects are small for forward multiplicity selection
 - Key to understand $dN/d\eta$ scaling? (hard effects are small)
- For the midrapidity estimator, the transverse sphericity selection can create subsamples that are significantly harder and softer.



Ξ -to- π ratio for midrapidity estimator

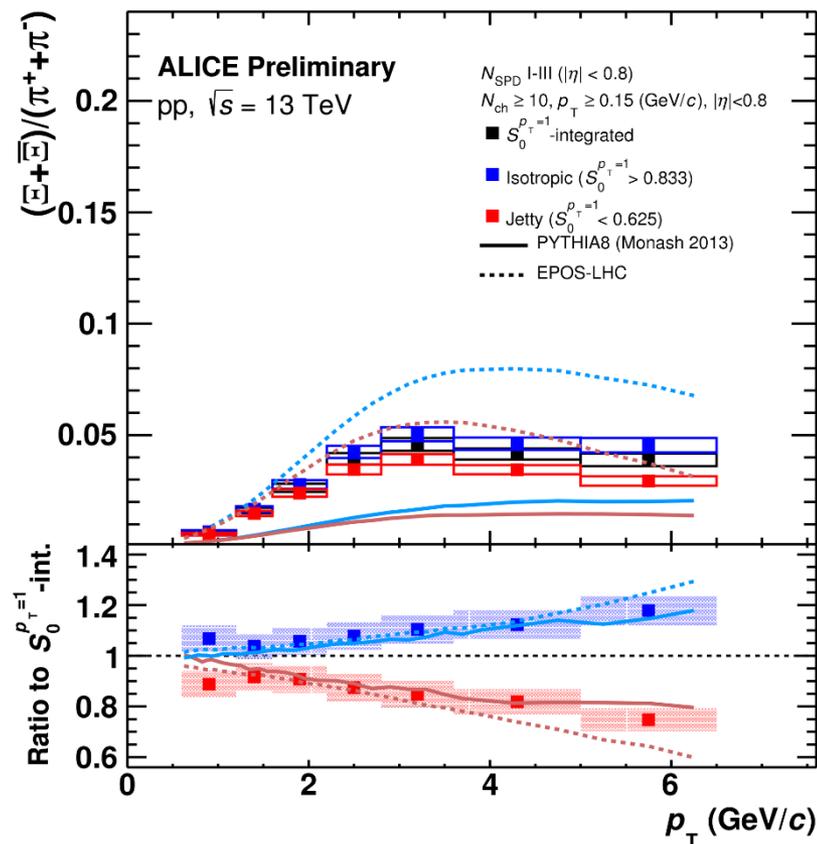
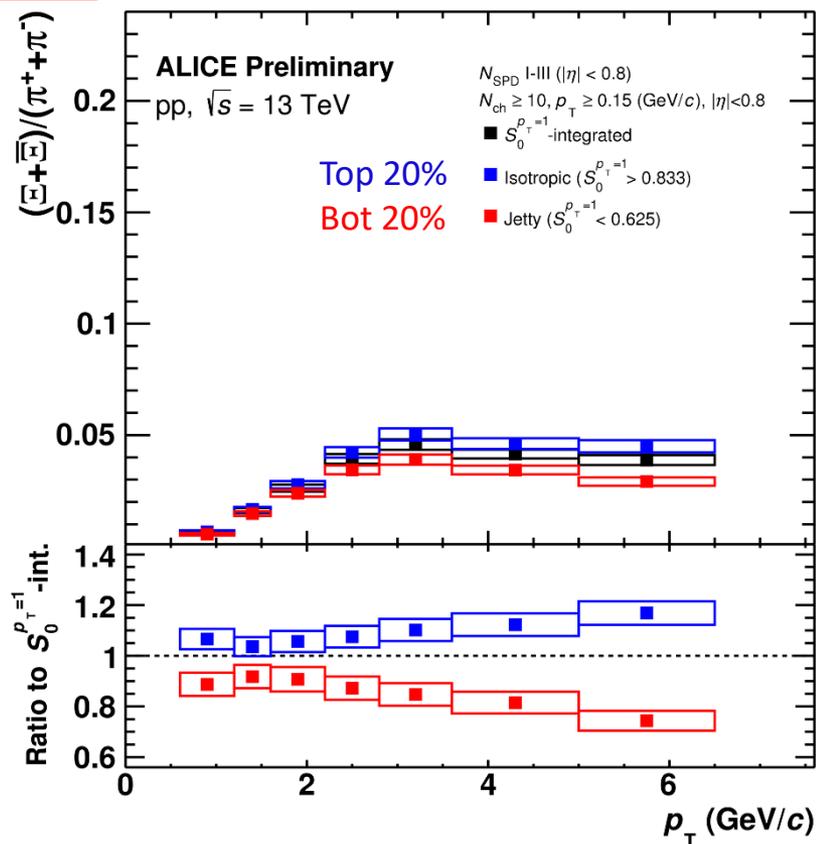
Strangeness: from revolution to resolution (P. Christiansen)



ALI-PREL-335099

Ξ -to- π ratio for midrapidity estimator

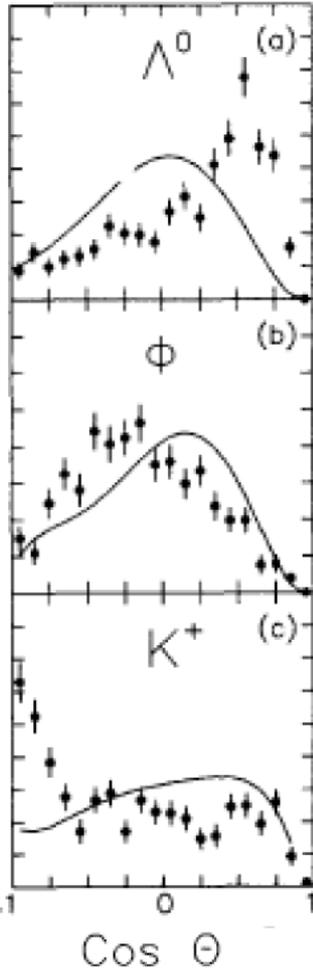
Strangeness: from revolution to resolution (P. Christiansen)



- It seems we can select events with more or less strangeness enhancement \rightarrow to be further investigated and quantified
- The absolute variation is not well described by the models while the relative variation is, except at low p_T

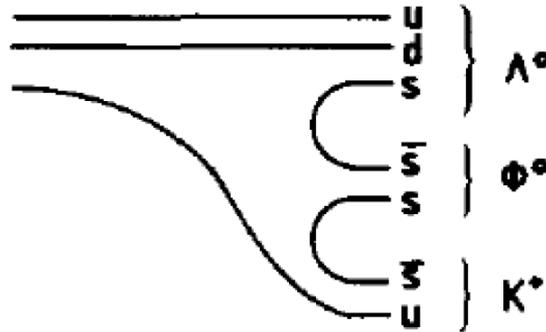
Strangeness correlations: an old idea

Phys.Lett. 163B (1985), 267



**EVIDENCE FOR POMERON SINGLE-QUARK INTERACTIONS
IN PROTON DIFFRACTION AT THE ISR**

R608 Collaboration



Solid lines are calculations
for isotropic phase space

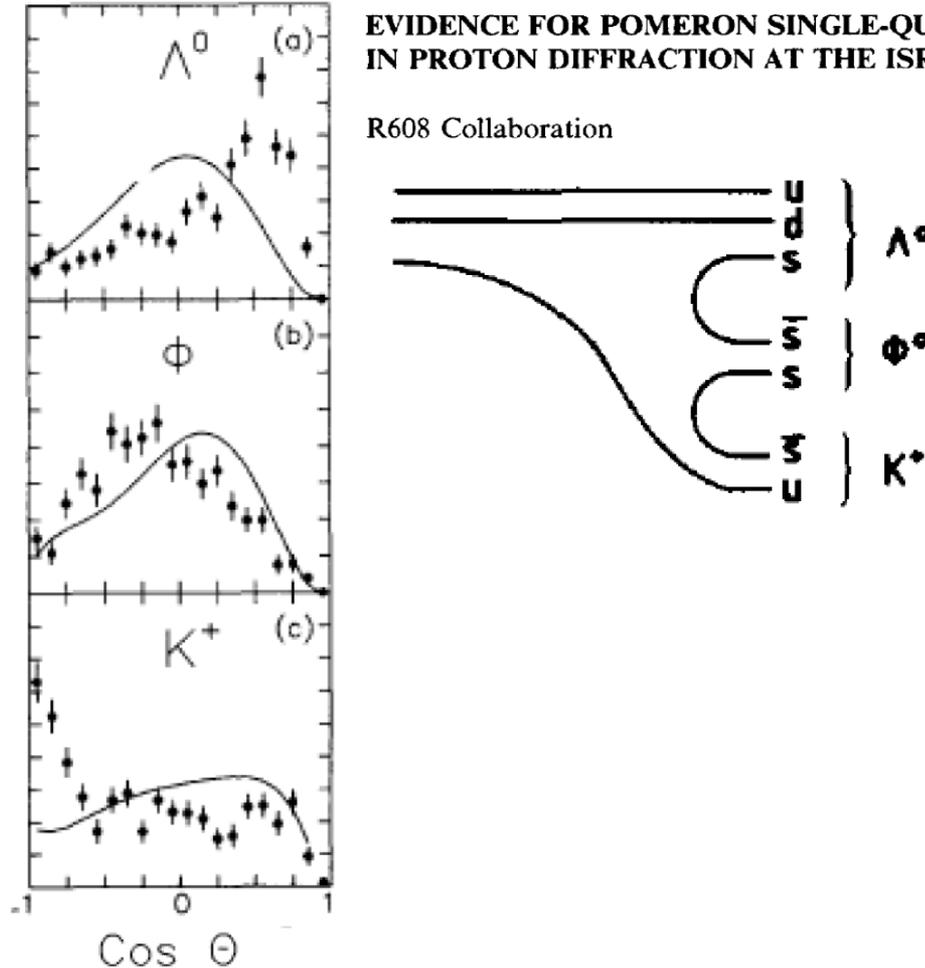


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Phys.Lett. 163B (1985), 267

EVIDENCE FOR POMERON SINGLE-QUARK INTERACTIONS IN PROTON DIFFRACTION AT THE ISR

R608 Collaboration



In pp collisions we can ask the questions:

Where is the anti-strangeness (strangeness) associated with production of Ξ^-/ssd ($\Xi^+/\bar{s}\bar{s}\bar{d}$) recovered?

PYTHIA/Angantyr: expect strangeness to be recovered locally (as shown to the left).

EPOS LHC: expect strangeness enhancement to be associated with a grand canonical (global) reservoir. Microscopic picture?

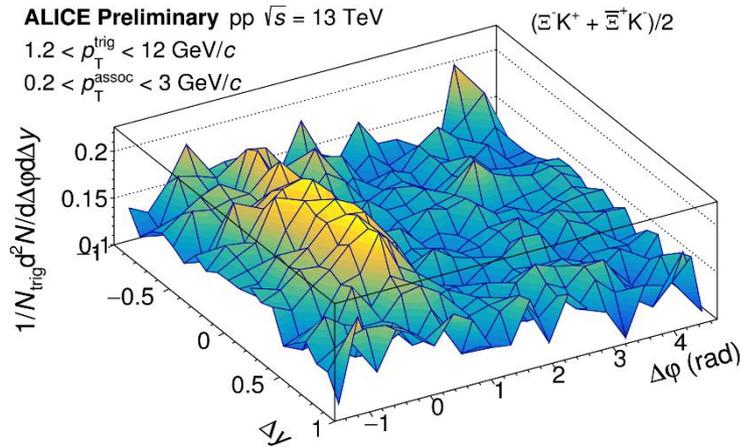
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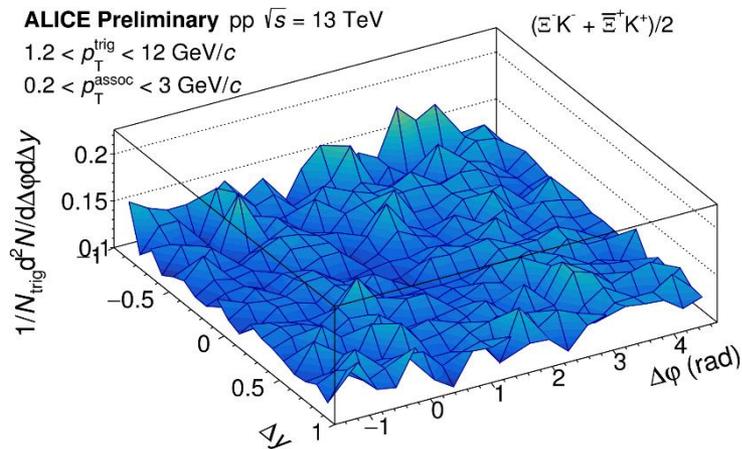


Ξ -K correlation functions

Opposite sign (OS), e.g., $\Xi^-/ssd - K^+/\bar{s}d$



Same sign (SS), e.g., $\Xi^-/ssd - K^-/\bar{d}s$





Ξ -K correlation functions

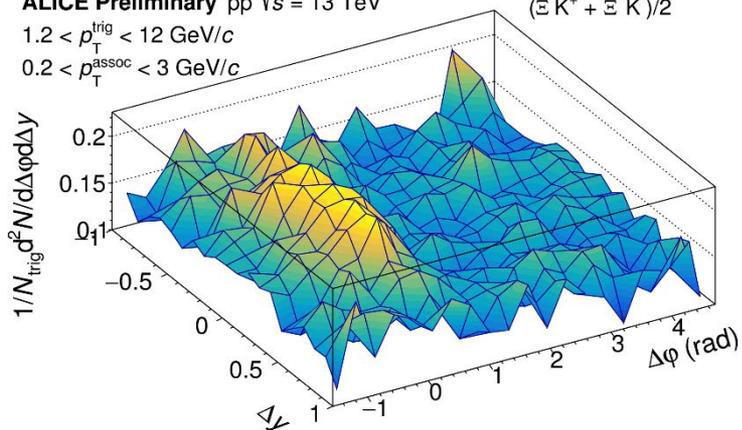
Opposite sign (OS), e.g., $\Xi^-/ssd - K^+/\bar{s}d$

ALICE Preliminary pp $\sqrt{s} = 13$ TeV

$1.2 < p_T^{\text{trig}} < 12$ GeV/c

$0.2 < p_T^{\text{assoc}} < 3$ GeV/c

$(\Xi K^+ + \bar{\Xi} K^-)/2$



ALI-PREL-327500

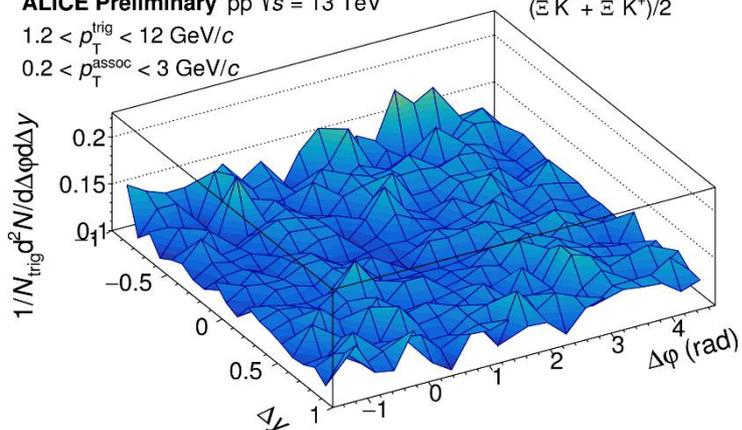
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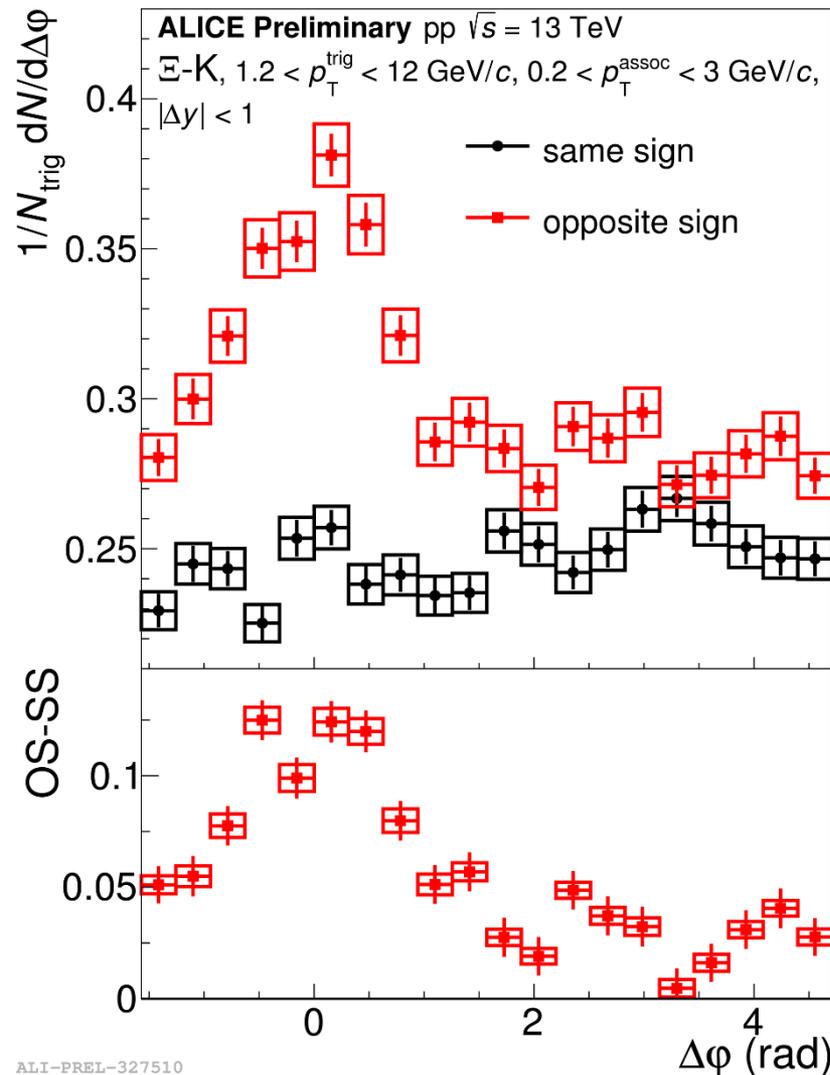
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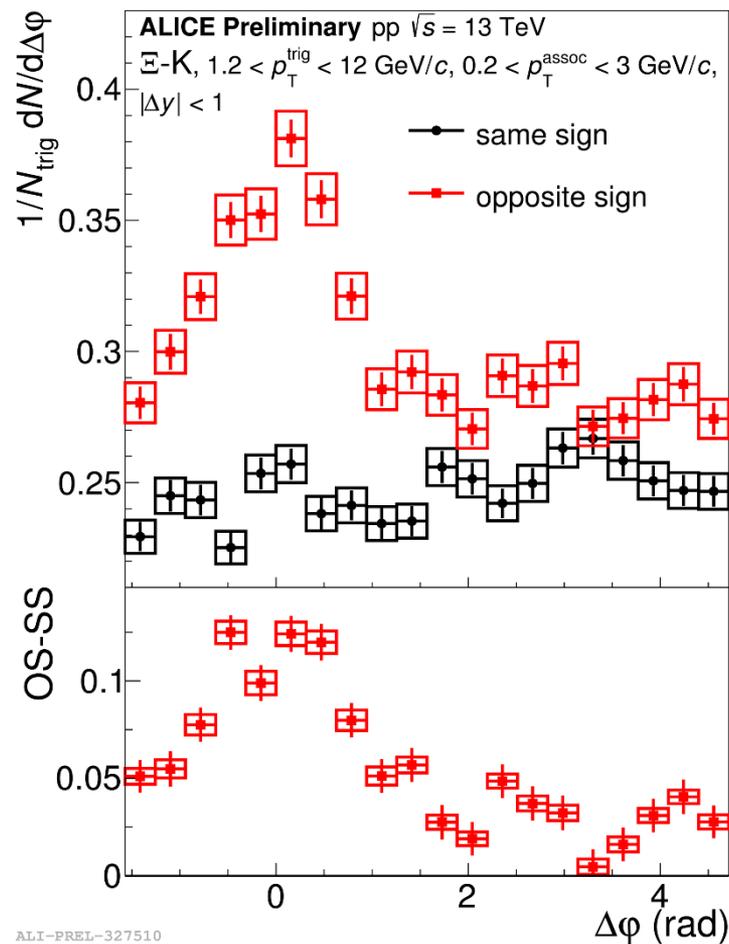
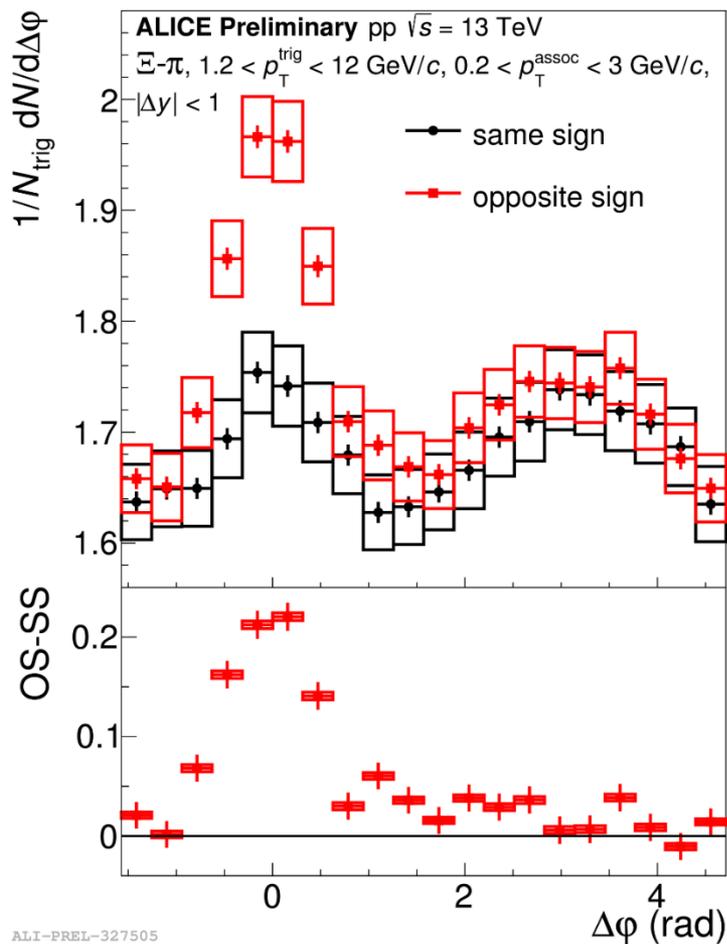
ALI-PREL-327485



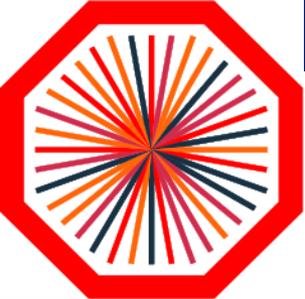
ALI-PREL-327510

Strangeness: from revolution to resolution (P. Christiansen)

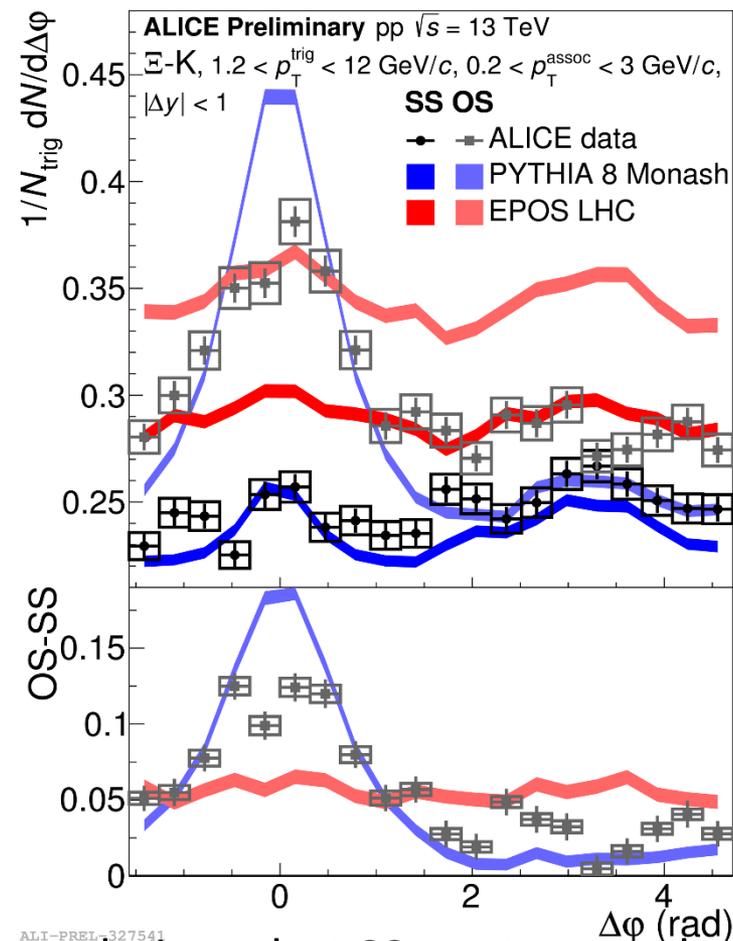
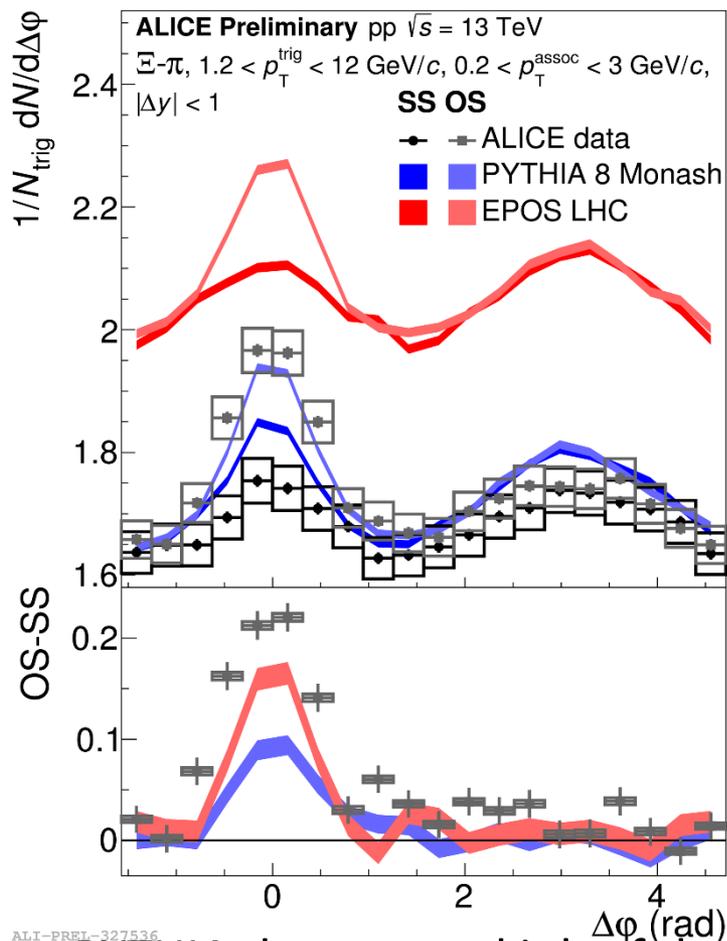
Ξ -K and Ξ - π correlation functions



- One clearly observes a near side peak but there is also evidence for decorrelations



Ξ -K and Ξ - π correlation functions



- PYTHIA does a good job of the OS (UE) correlations, but SS are too weak (strong) for π (K) and away side decorrelations are too weak
- EPOS LHC: in general worse job and too strong strangeness decorrelation



Conclusions

- Many new results on strangeness production in pp collisions. Several interesting indications:
 - The ee limit can be recovered in “Toward” region for low R_T
 - Strangeness enhancement seems to be a UE phenomenon
 - In agreement with AA findings (not covered)
 - Sphericity can select strangeness enhanced or suppressed events
 - Correlations can help identify production mechanism
 - Can we find evidence for deconfinement?
- Several improvements to be done on experimental side
 - But this work would benefit from more models investigating these phenomena in detail

Thank you!

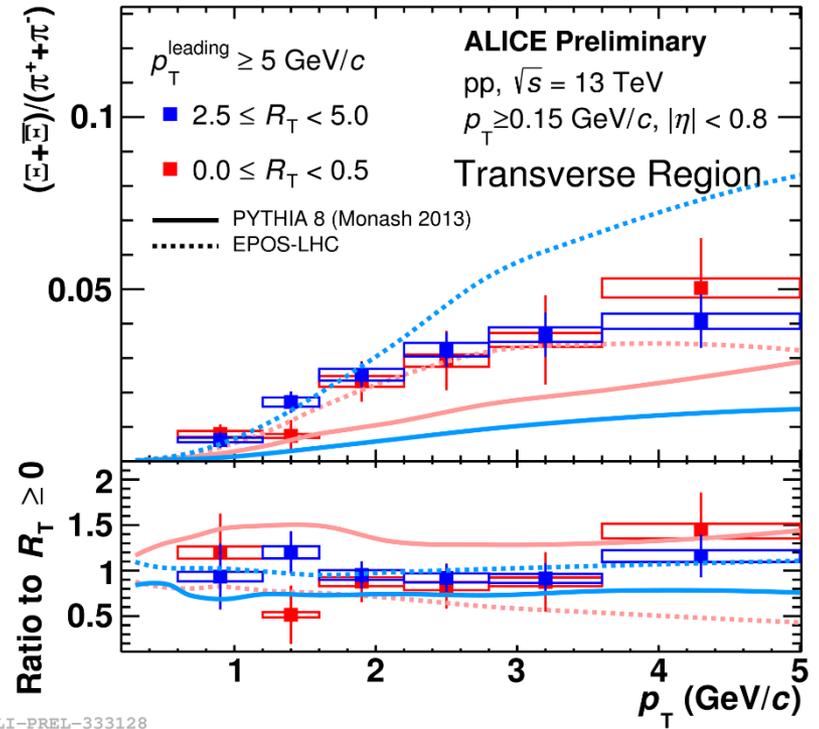
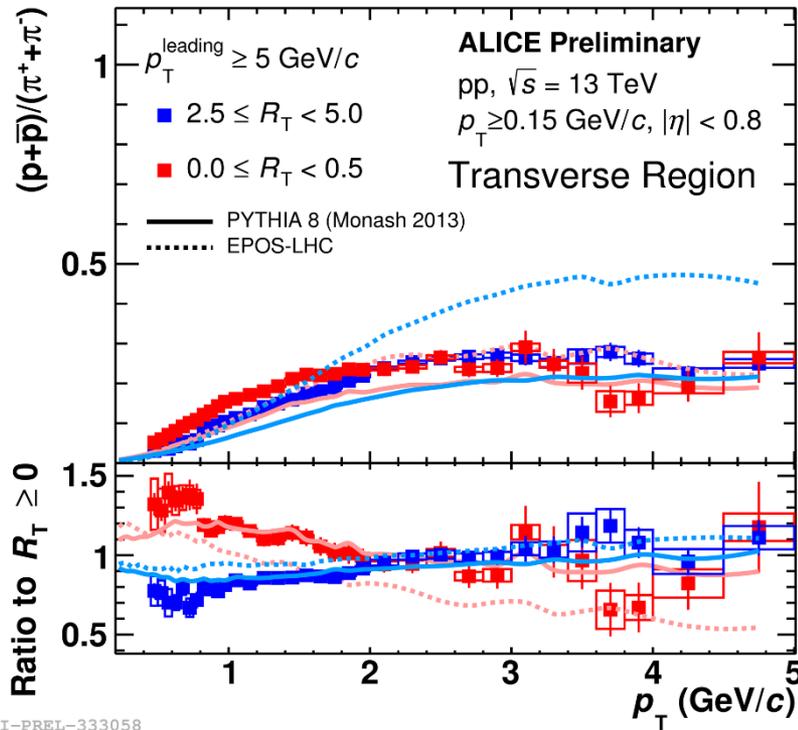
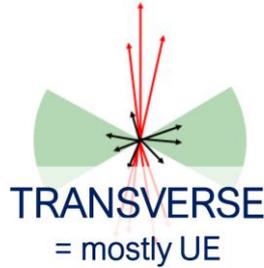
- Many new preliminary results not covered (e.g. π , K , ϕ), see:
 - MPI19: <https://indico.cern.ch/event/816226/contributions/3614931/>
 - MPI19: <https://indico.cern.ch/event/816226/contributions/3603866/>
 - QM19: <https://indico.cern.ch/event/792436/contributions/3533934/>



Backup



ρ -to- π and Ξ -to- π ratios vs R_T Transverse



ALI-PREL-333058

ALI-PREL-333128

PYTHIA8 in general underestimates the ratios, in particular for Ξ -to- π .
EPOS LHC gives a good description at low R_T but underestimates for large R_T ,
in particular for higher p_T .