Multiparton picture of elliptic flow decorrelation in rapidity in pp collisions at the LHC

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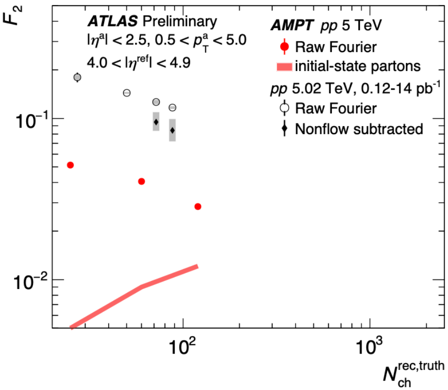


F_2 - (see following) [ATLAS-CONF-2022-020]

flow decorrelation measure between forward and backward $\vec{v}_2$

$F_2 = 0$ - no decorrelation (perfect correlation)

F_2 large - large decorrelation (or small correlation)

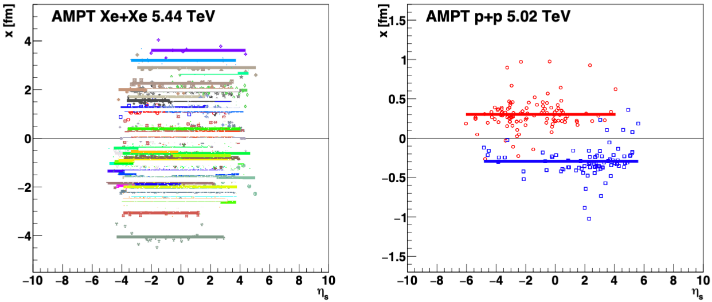
Hitherto unexplained!

Outline

- Strings/flux tubes: FB picture
- Shape-flow transmutation
- FB flow correlation
- Model: multiple strings + fluctuations in hadronization
- F_2 in pp

Strings

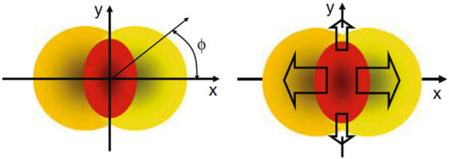
Dual parton, Lund
AMPT [Wu et al. 2018]

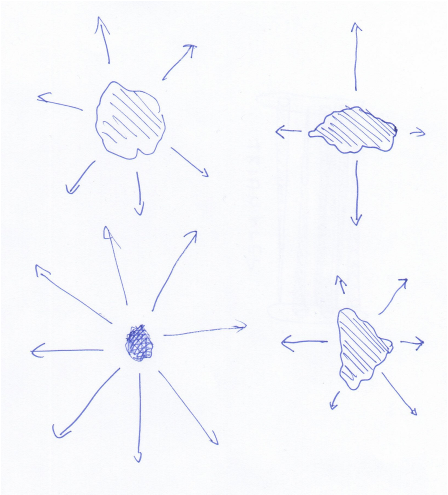


String end-points fluctuate in η_S, shorter strings $\to$ larger FB decorrelation
production of particles from the string, rescattering (!)

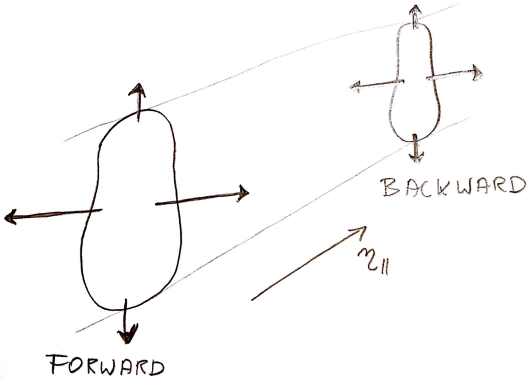
Shape-flow transmutation

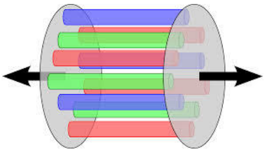
Many particles, rescattering, generation of flow (not necessarily hydro!), $v_2 \sim \epsilon_2$





FB shape similarity → flow similarity → ridges





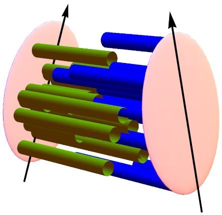
FB similarity is a result of early dynamics and is not obtained from hydro or transport

FB correlations

- One expects substantial FB correlations, e.g., for FB event plane angles (direction of flow), harmonic flow magnitude, or $\langle p_T \rangle$
- Focus on departures from perfect correlations, the torque effect: twisted event-plane angles [Bożek, WB, Moreira 2010]

Fluctuations in energy deposition from each string

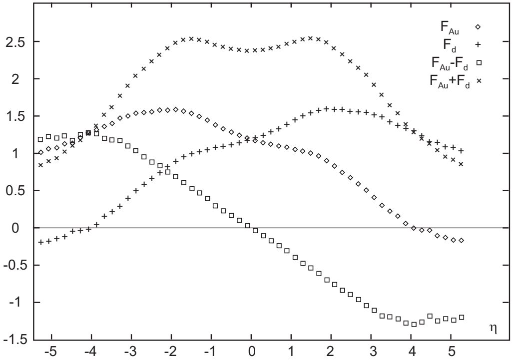
[Brodsky, Gunion, Kuhn, PRL 39 (1977) 1120]
[PB, WB 2015, 2017]



- Position (in spatial rapidity) of one of the string end-points is random
- Results in FB decorrelation

Phenomenological average emission profiles from d-Au

[Białas, Czyż, Acta Phys. Polon. B36, 905 (2005)]

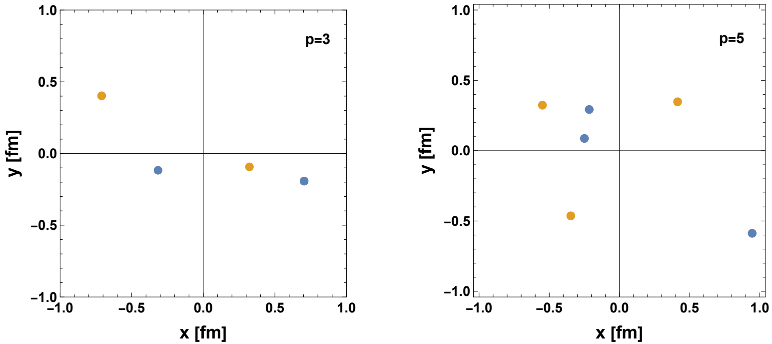


We use uniformly distributed end-points, which yields on the average the triangular distribution, supported phenomenologically

Wounded parton model

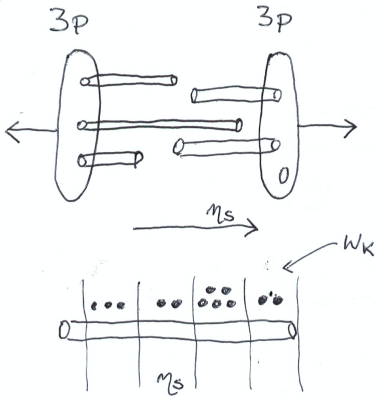
A model of the proton is needed. Recall the near-side ridge in high-multiplicity pp, interperted as a sign of shape-flow transmutation

GLISSANDO 3 with wounded partons for the transverse shape
pp cross section reproduced
We take exploratory cases of 3 and 5 partons per nucleon



Full picture

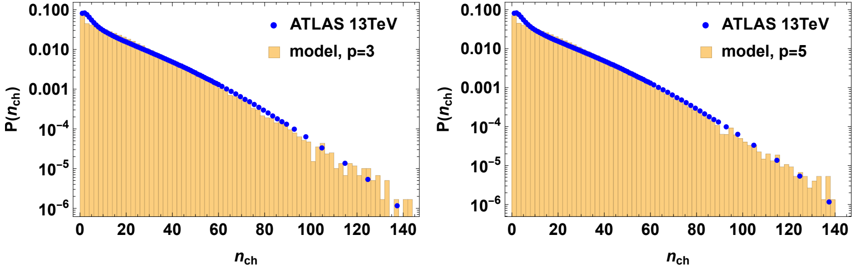
GLISSANDO 3 + strings with fluctuating end points



+ overlaid multiplicity fluctuation in each η bin ($\eta \simeq \eta_s$)

Multiplicity distribution in p-p

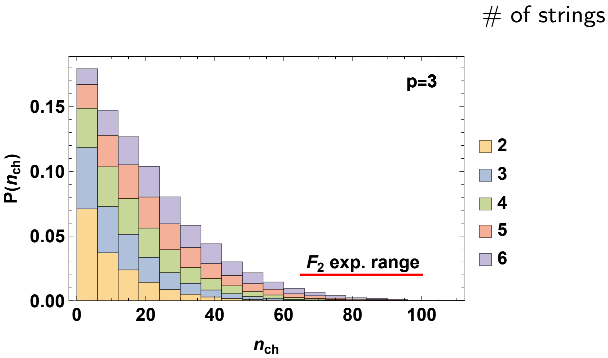
We overlay the distribution $\Gamma(x;\alpha,\beta) \sim x^{\alpha-1}e^{-\beta x}$, with parameters α,β (depending on the collision energy) adjusted to reproduce the height and slope of the tail of the data:



[data: $n_{\rm ch} \geq 1$, $p_T > 500$ MeV, $|\eta| < 2.5$]

Anatomy of the model multiplicity

Tail dominated by numerous strings



higher multiplicity – more strings

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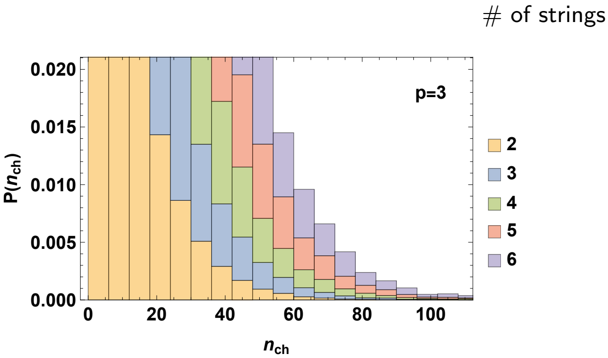

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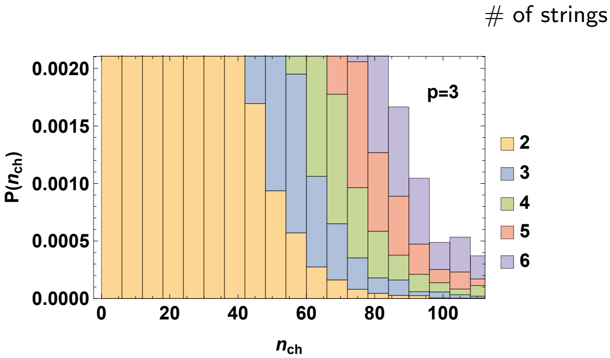

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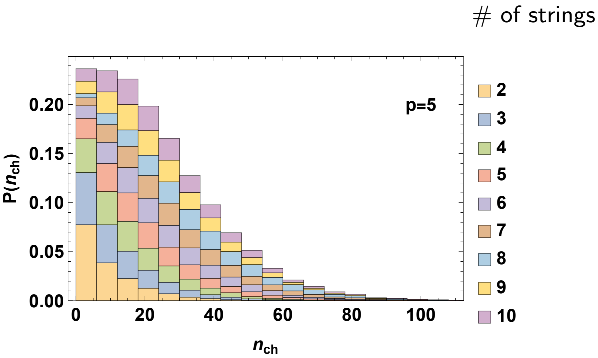

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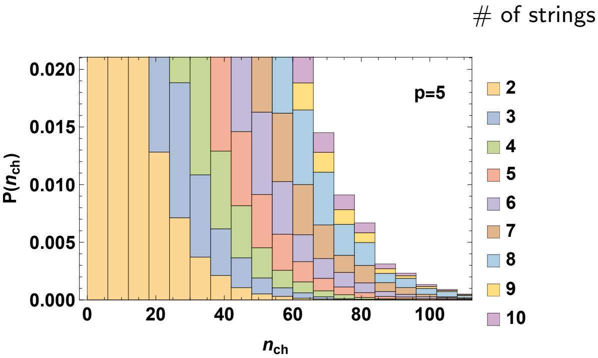

higher multiplicity – more strings

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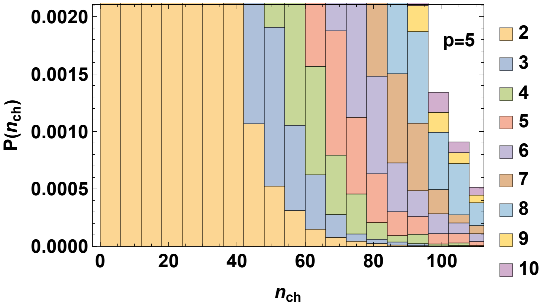


higher multiplicity – more strings

3-bin measure (CMS) of elliptic FB correlations

Need to use measures that cancel trivial decorrelations

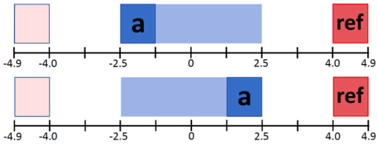
x_k, y_k - transverse coord. (relative to CM) of a piece of string k in an η bin

w_k - weight from overlaid fluctuations

$$\epsilon_2(\eta) = \frac{\sum_k w_k (x_k + i y_k)^2}{\sum_k w_k (x_k^2 + y_k^2)} = \frac{\sum_k w_k r_k^2 e^{2i\phi_k}}{\sum_k w_k r_k^2}$$

$$c_2(\eta, \eta_{\rm ref}) \equiv {\rm Re\ cov}_{ev} \left[\epsilon_2(\eta)\epsilon_2^*(\eta_{\rm ref})\right], \quad r_2(|\eta_a|) = \frac{c_2(-|\eta_a|, \eta_{\rm ref})}{c_2(|\eta_a|, \eta_{\rm ref})}$$

see [CMS 2015]

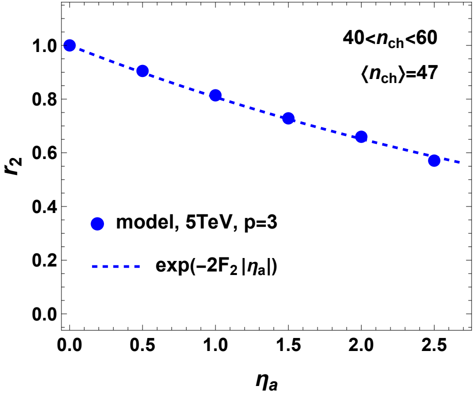


ATLAS measurement

r_2 from v_2 expected to be similar to r_2 from ϵ_2

The slope F_2

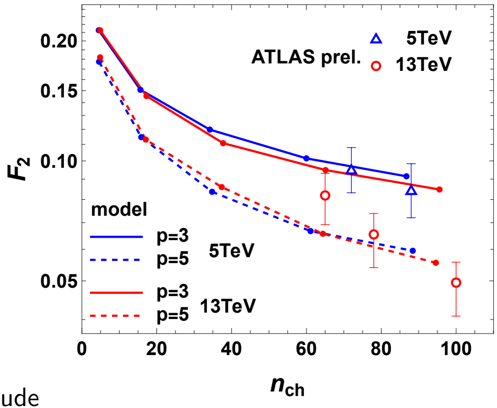
$r_2(|\eta_a|) \simeq e^{-2F_2|\eta_a|}$



F_2 depends on multiplicity

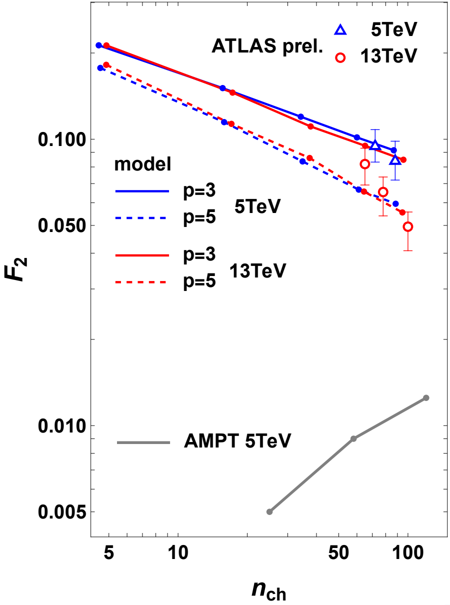
Model vs ATLAS (preliminary)

(sophisticated corrections in the data analysis to get rid of non-flow)



- Right magnitude
- Proper monotonicity in $n_{\rm ch}$
- Essentially no dependence on the collision energy between 5 and 13 TeV
- More partons → reduced F_2, or weaker decorrelation, or more correlation

vs AMPT


ATLAS prel.
5TeV
13TeV
model
p=3
p=5
5TeV
p=3
p=5
13TeV
AMPT 5TeV
0.100
0.050
0.010
0.005
F_2
5
10
50
100
n_{ch}

Conclusions

Basic understanding:

1. Shorter strings $\rightarrow$ more decorrelation (F_2 up)
2. More strings $\rightarrow$ less decorrelation (F_2 down)
3. Fluctuations in hadronization must reproduce multiplicity

Message to take home:

F_2 in high-multiplicity pp collisions hints to multiparton dynamics

Possible improvements of our model:

1. Collisions of n on m partons (Fock components of the proton wave function)
2. More accurate profile of string fluctuations, reference to a_2 coefficient of multiplicity correlations [Rohrmoser, WB, 2019]
3. Robust conclusions should remain

Thanks!

BACKUP

Multiplicity in pp vs models

[ATLAS 2016]