Interplay of underlying event and event shape observables in Z-boson events

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The Context

* CDF, CMS and ATLAS have measured observables sensitive to underlying event in Z-boson events at 1.96, 7, 13 TeV.

* CMS and ATLAS have also measured certain event shape observables in Z-boson events at 7 TeV.

* What is lacking in these measurements in terms of measuring the effect of MPI?
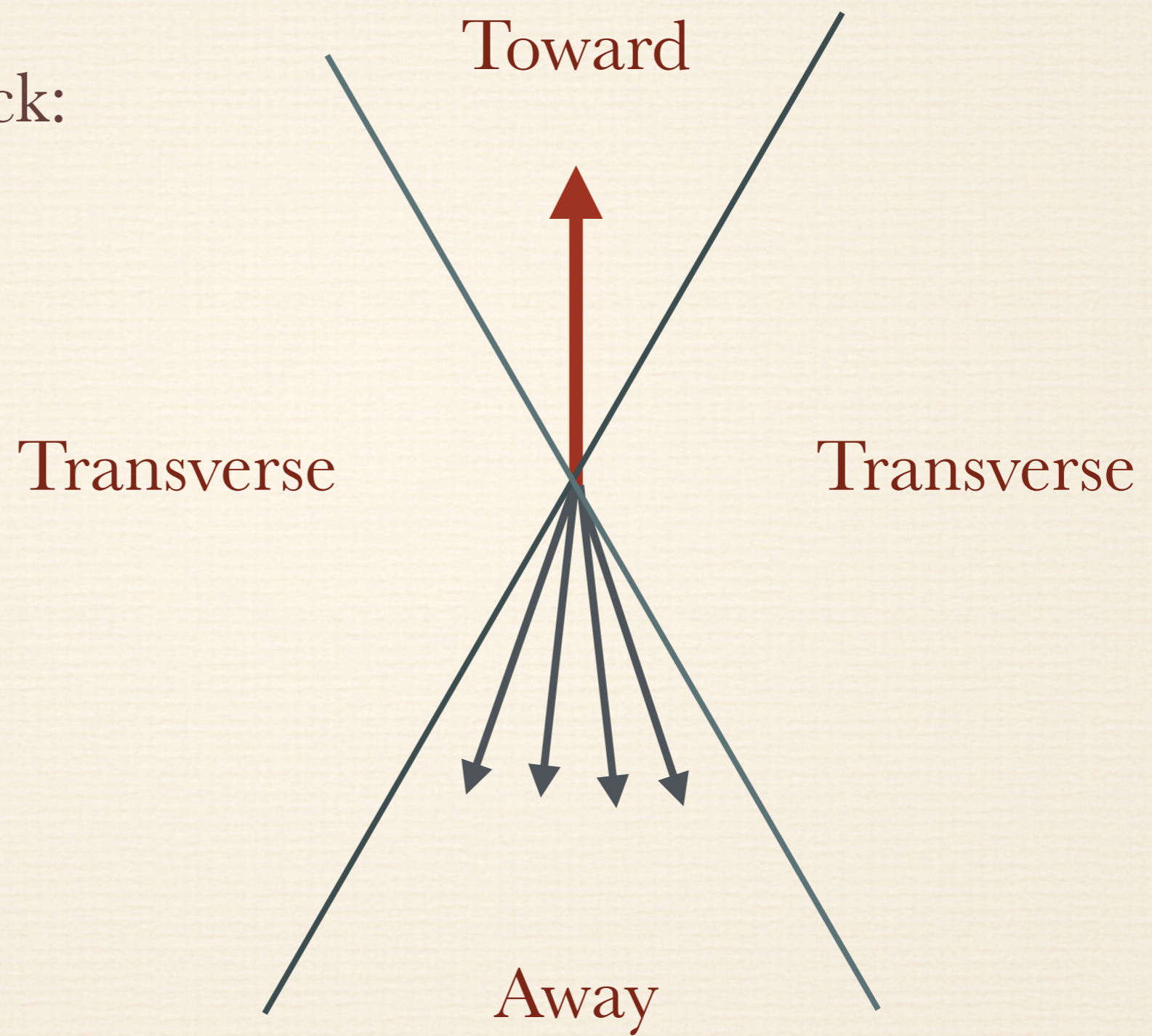
Not your Grandparent's Z

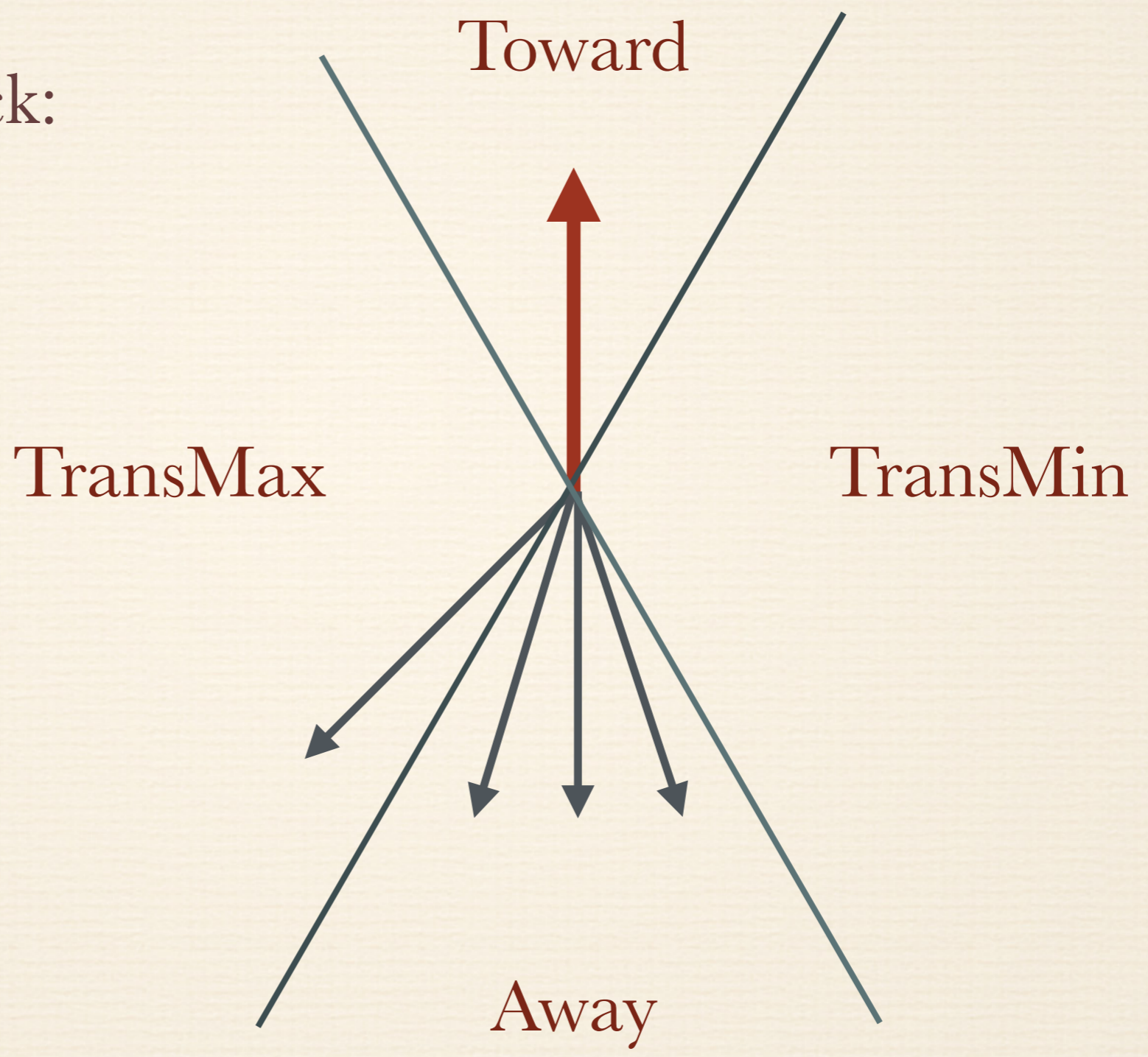When I grew up:
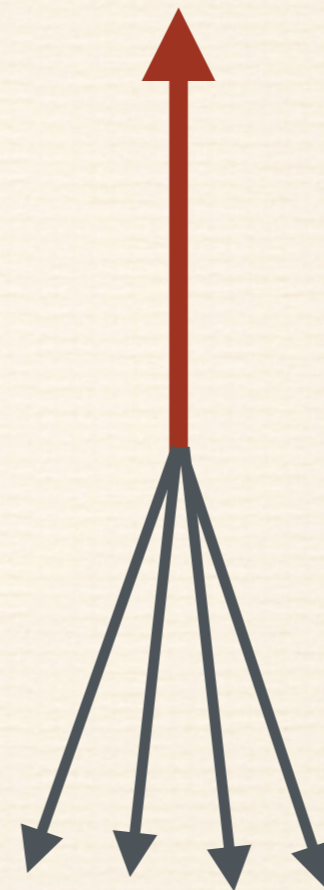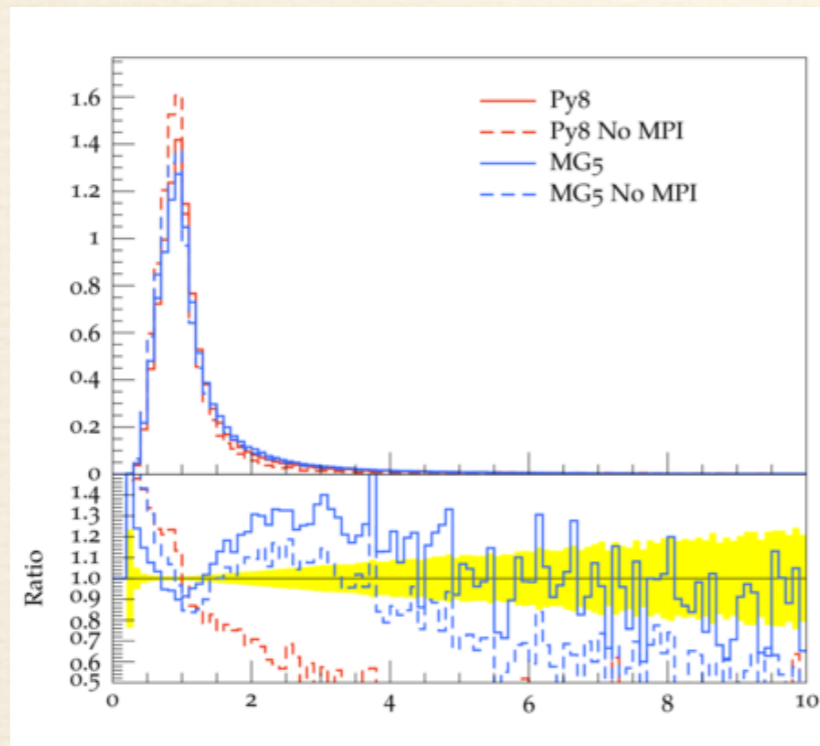
Or:
so-called
Drell-Yan
production

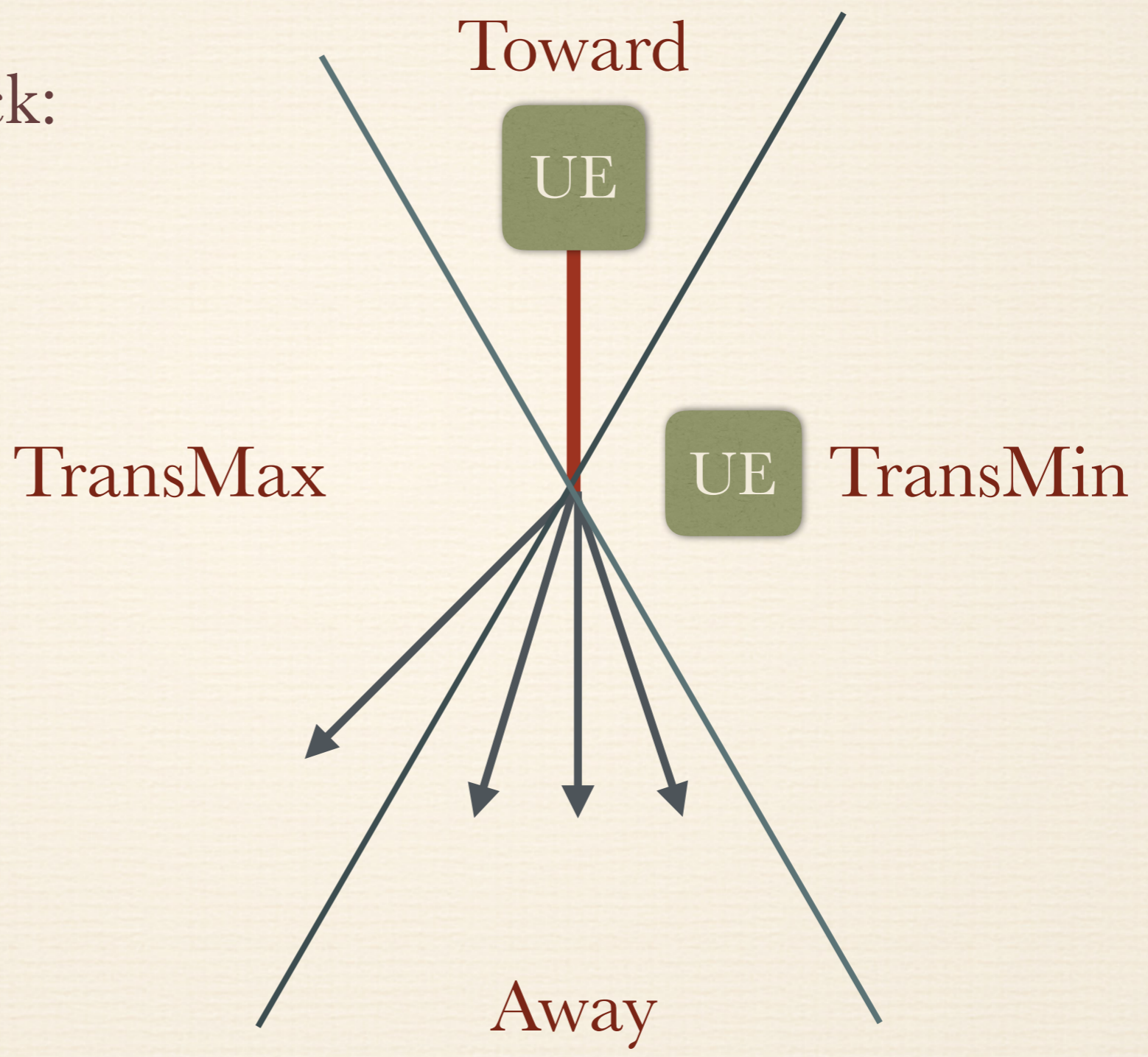# Not your Grandparent's Z

Thus spake Rick:

Toward

Transverse

Transverse

Away

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Not your Grandparent's Z

Thus spake Rick:

Toward

TransMax

TransMin

Away

Not your Grandparent's Z

Thus spake Rick:

Toward

UE

TransMax

UE   TransMin

Away

Not your Grandparent's Z

Thus spake Rick:

Toward

TransMax

TransMin
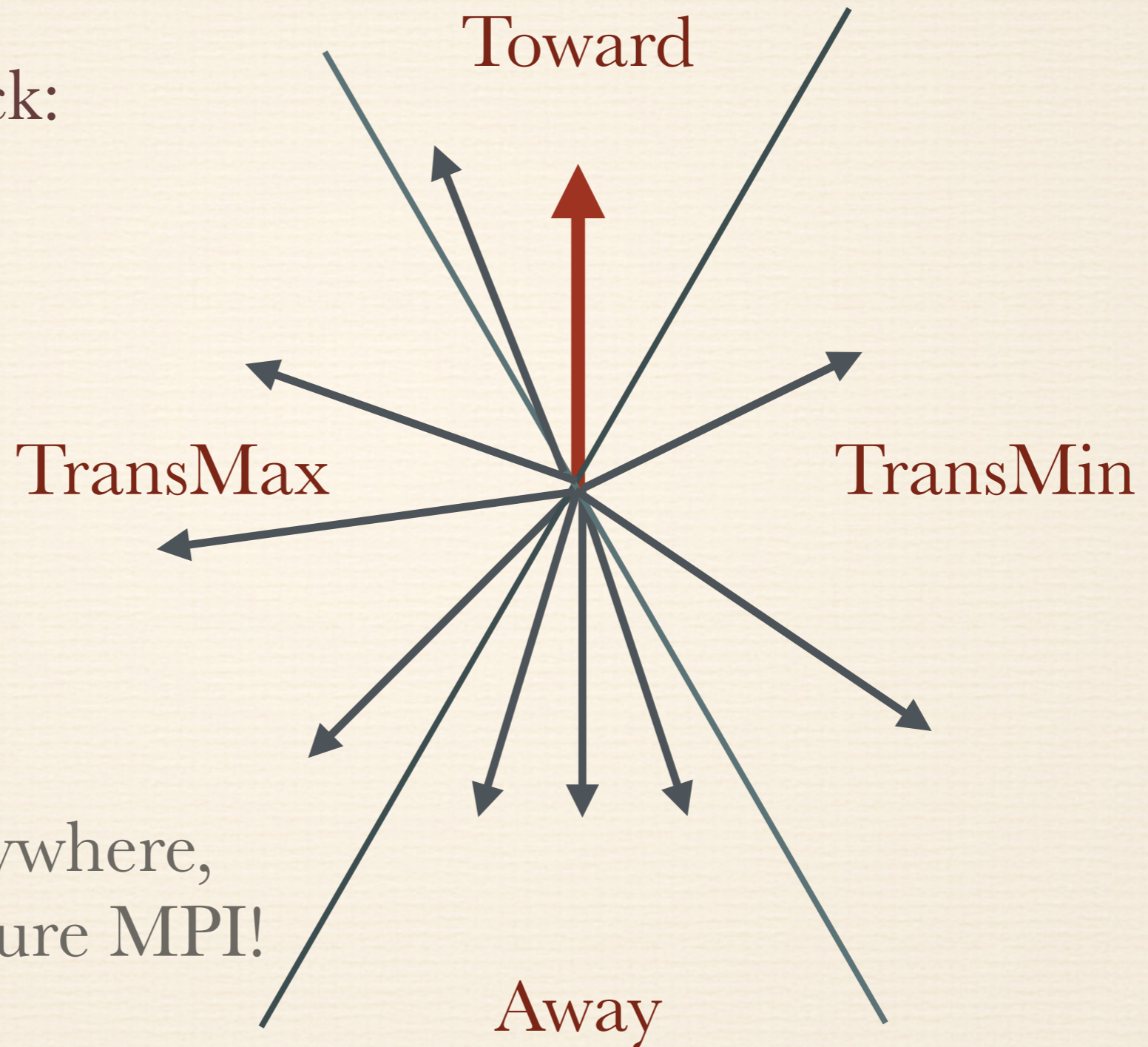
Jets, jets, jets everywhere,
not a place to measure MPI!

Away
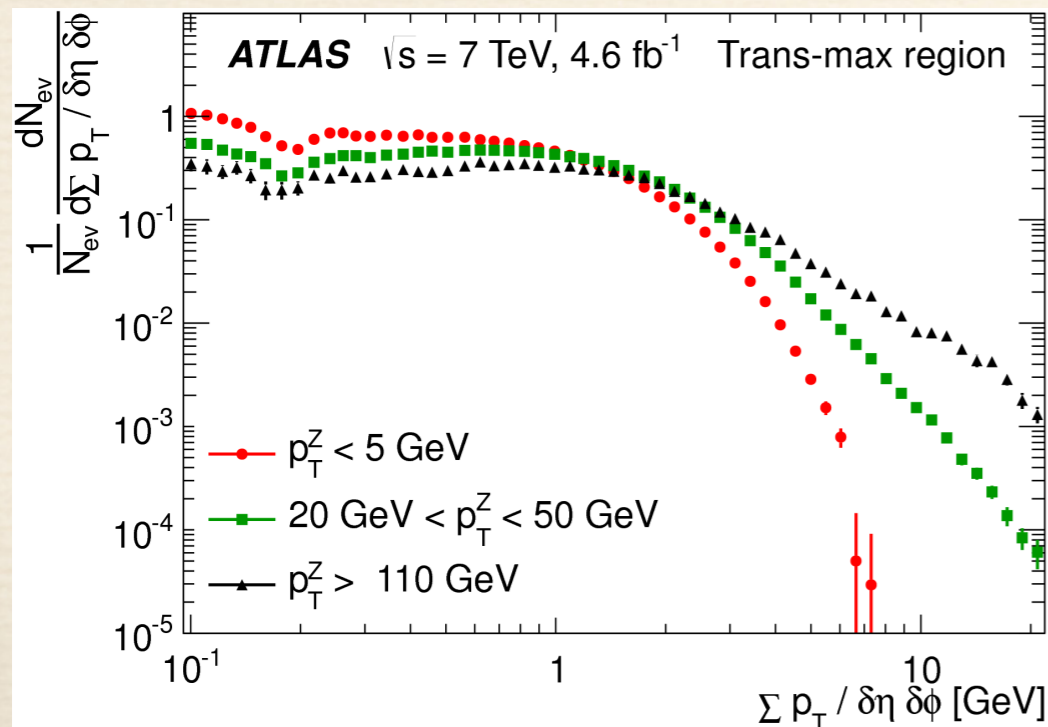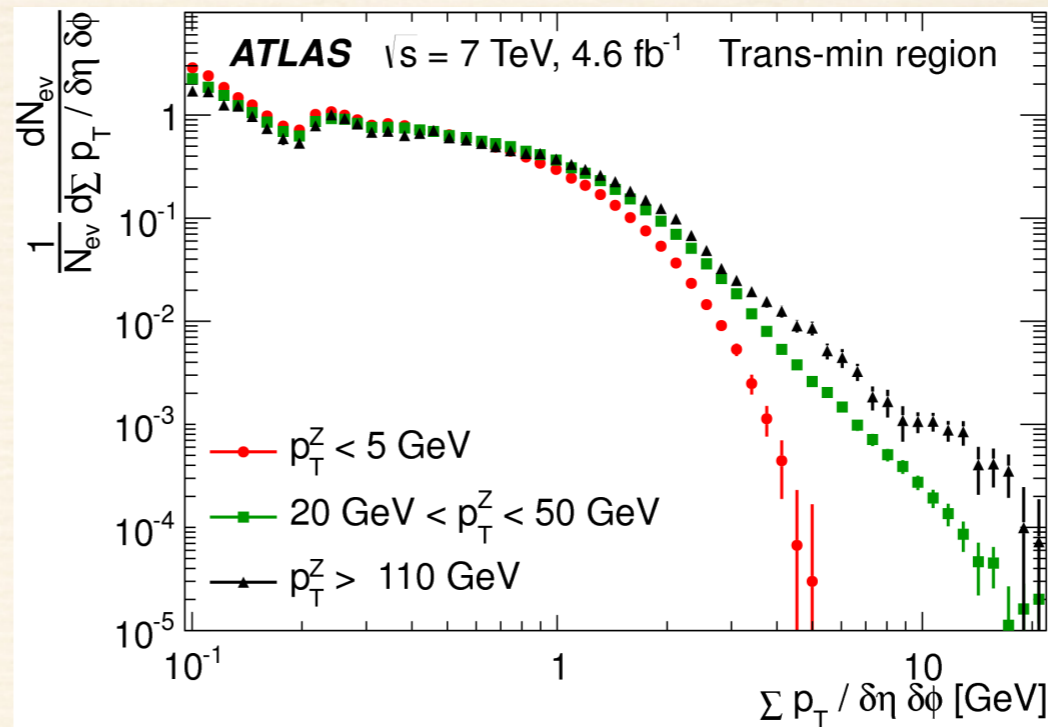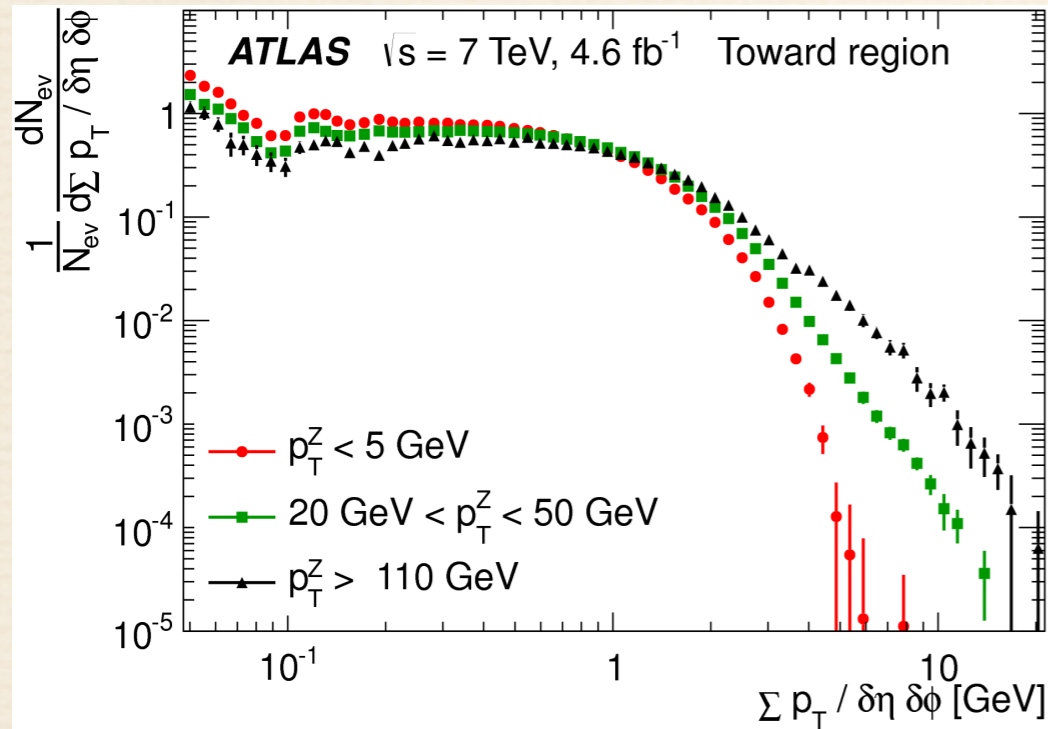
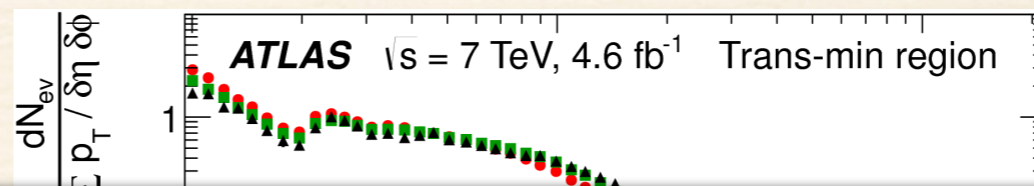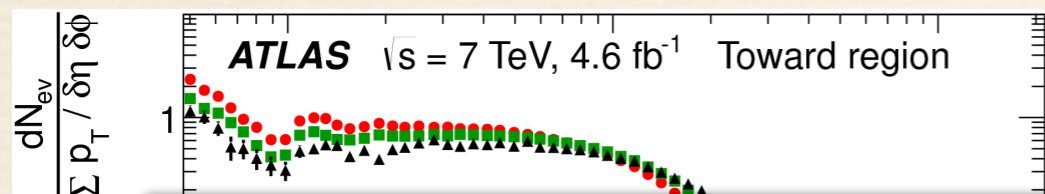# Supported by Data

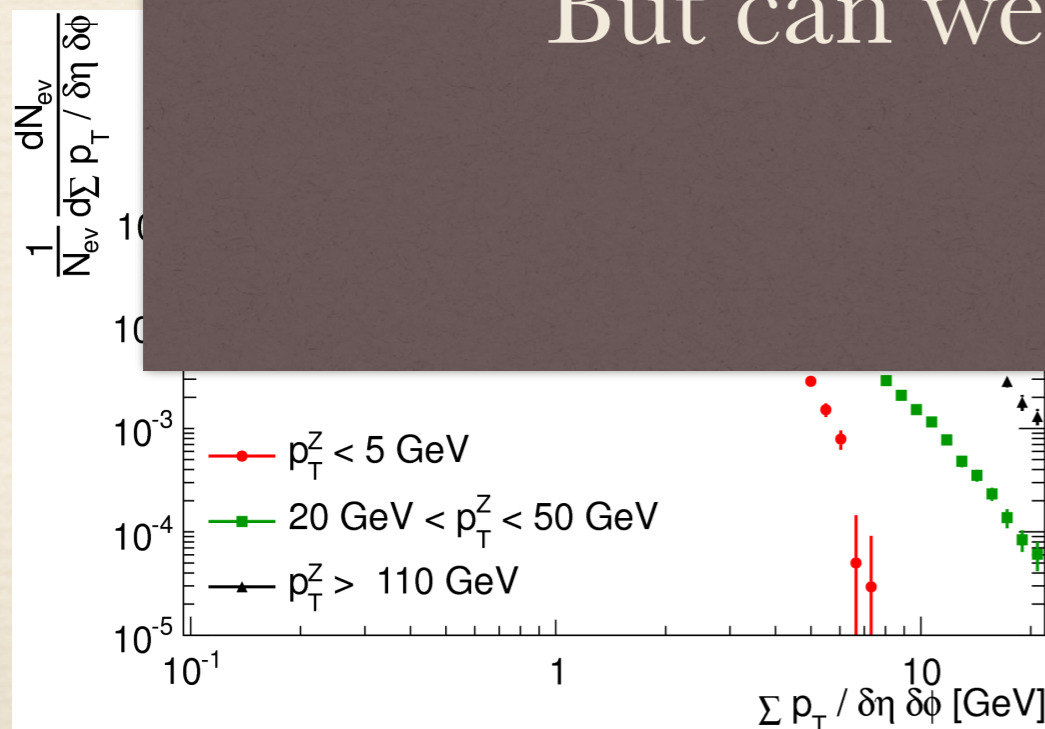In absence of extra activity, there should be no dependence on Z p$_T$.

But there is.

Supported by Data

ATLAS $\sqrt{s}$ = 7 TeV, 4.6 fb^{-1} Toward region

ATLAS $\sqrt{s}$ = 7 TeV, 4.6 fb^{-1} Trans-min region

$\frac{1}{N_{ev}} \frac{dN_{ev}}{d\Sigma\, p_T / \delta\eta\, \delta\phi}$

In busy LHC environment, we can not factorise MPI from extra radiation.

But can we get better sensitivity?

dependence on Z p$_T$.

But there is.

- ● — p$_T^Z$ < 5 GeV
- ■ — 20 GeV < p$_T^Z$ < 50 GeV
- ▲ — p$_T^Z$ > 110 GeV

$\Sigma\, p_T / \delta\eta\, \delta\phi$ [GeV]

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Analysis Setup

- ❖ Generator level study with Zmumu events, using Pythia8 (LO) and MG5 (multileg, upto 3 extra jets) interfaced with Pythia8. Monash tune used in both cases. Also ran both with tuning MPI off in Pythia8.

- ❖ Inclusive distributions, and distributions for zero, one and more than one jet events.

- ❖ Muons from Z-boson are excluded in calculating all observables, and in jet reconstruction.

UE Activity (toward)
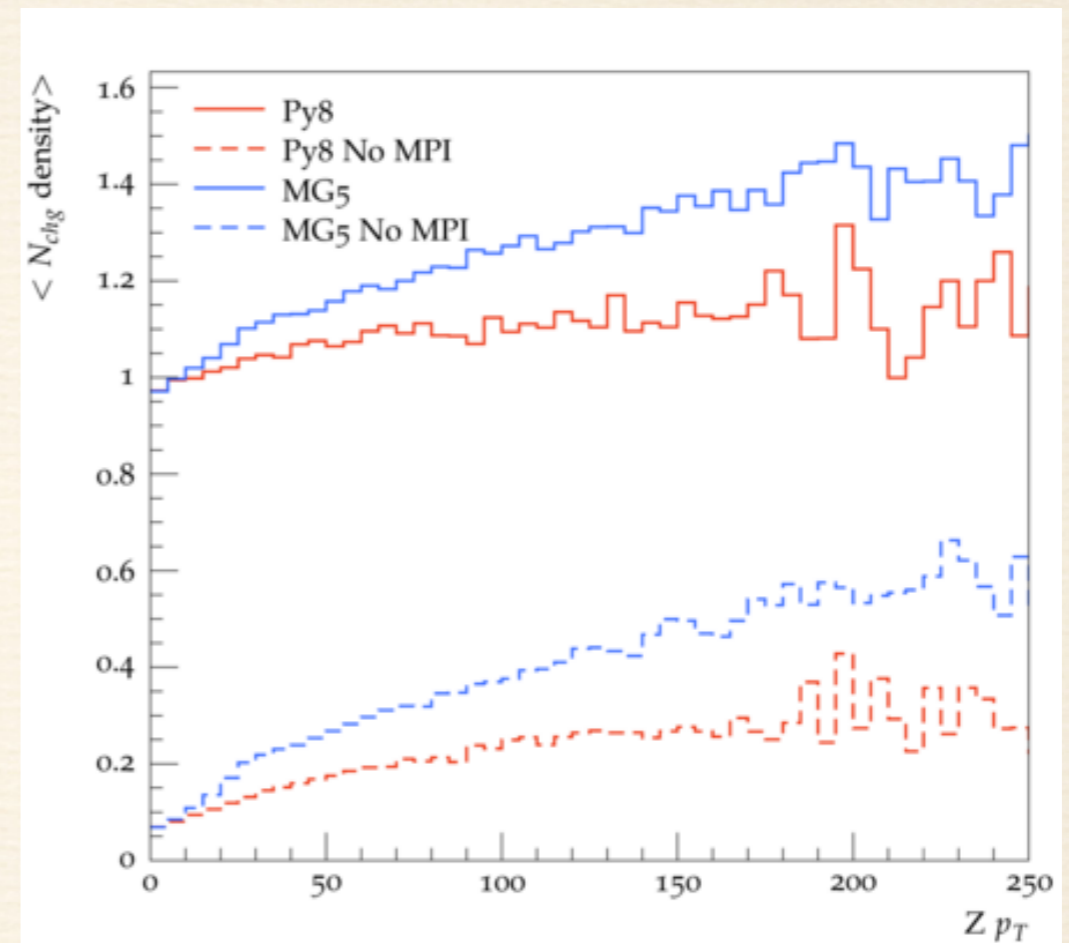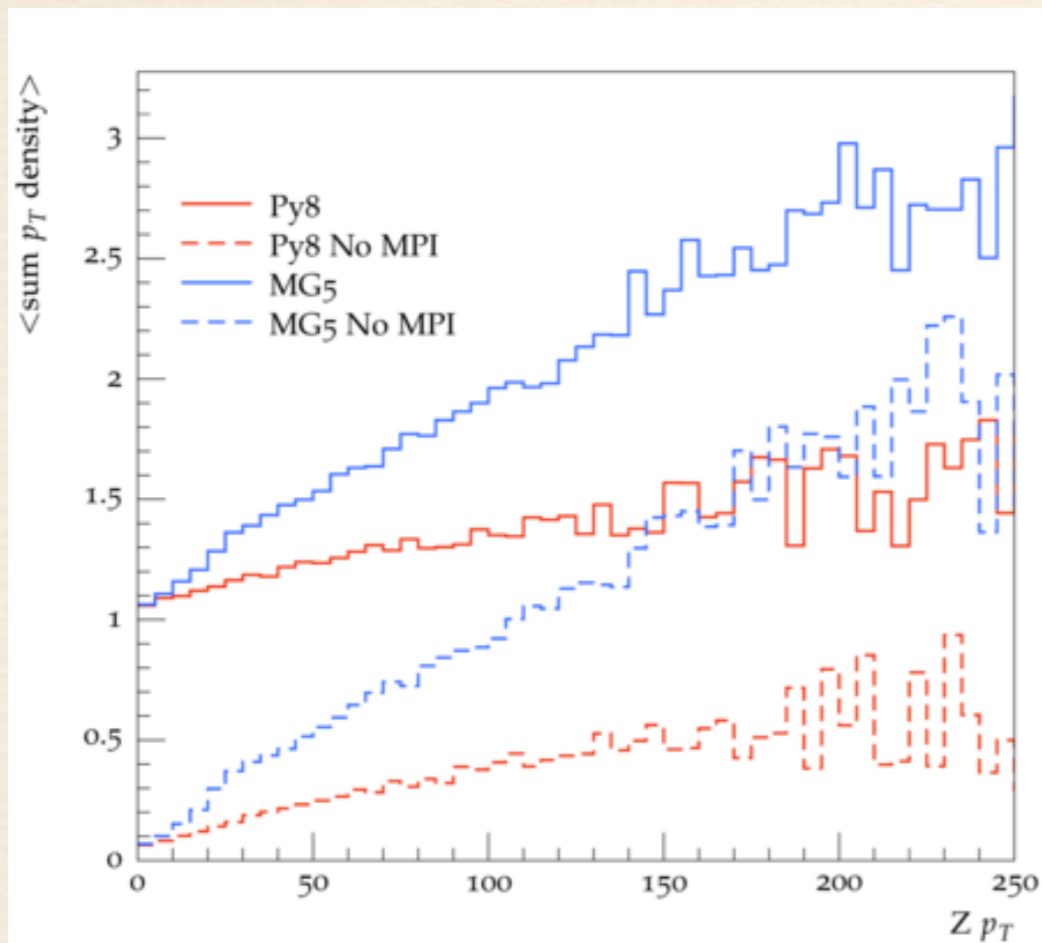
Usual UE profiles, with extra jets producing a lot of activity, MPI shifts them up by a roughly similar amount

Reminder: (transverse) Thrust

T=2/pi $\longrightarrow$ T=1

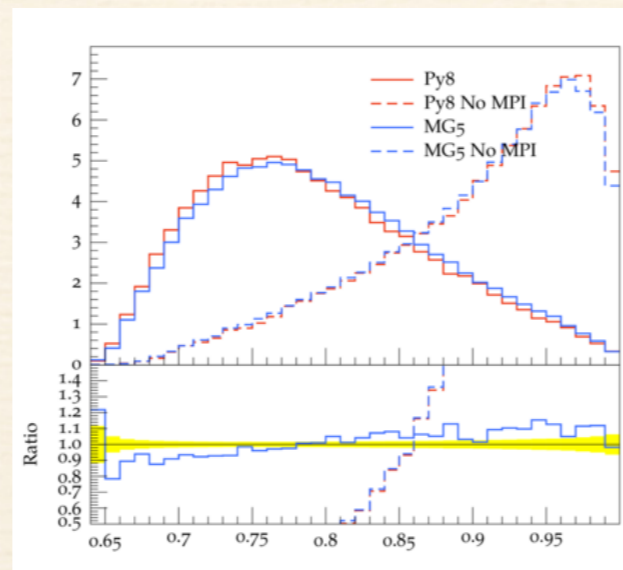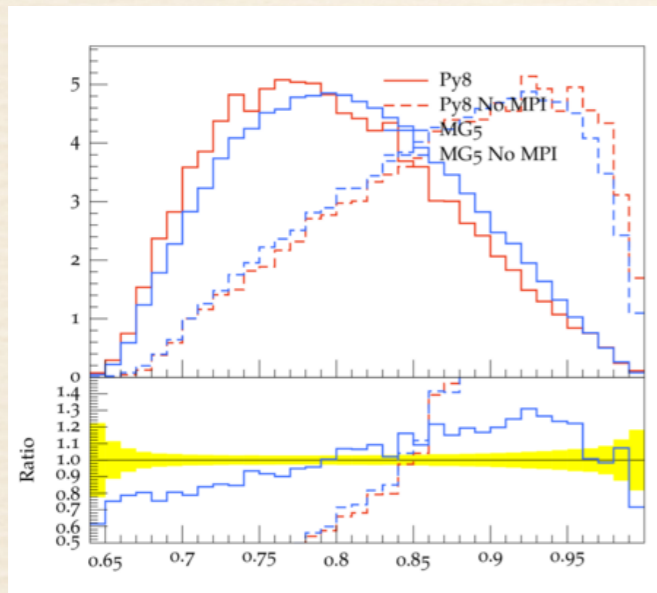Isotropic events

Balanced events

Reminder: (transverse) Thrust
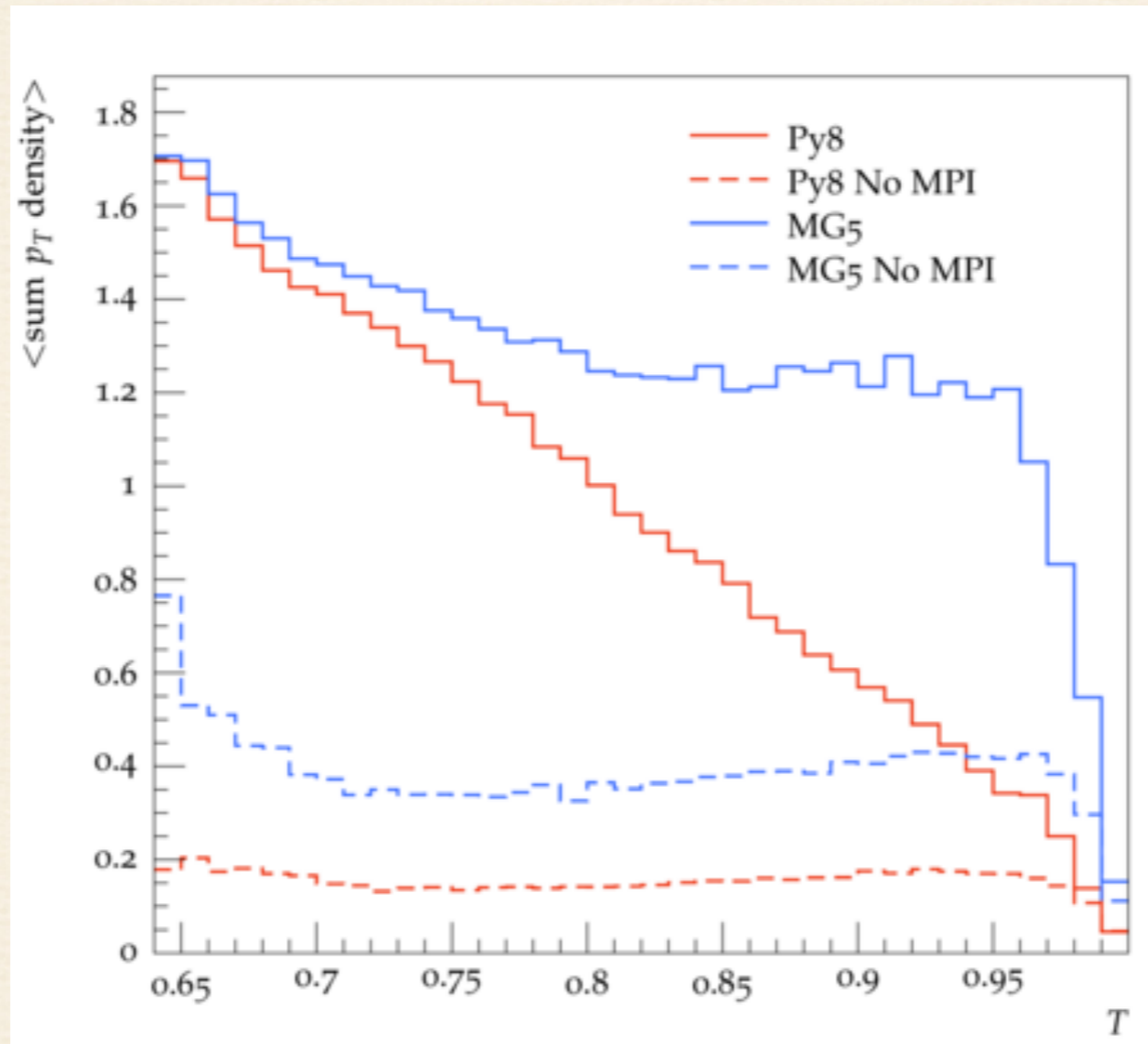
T=2/pi → T=1
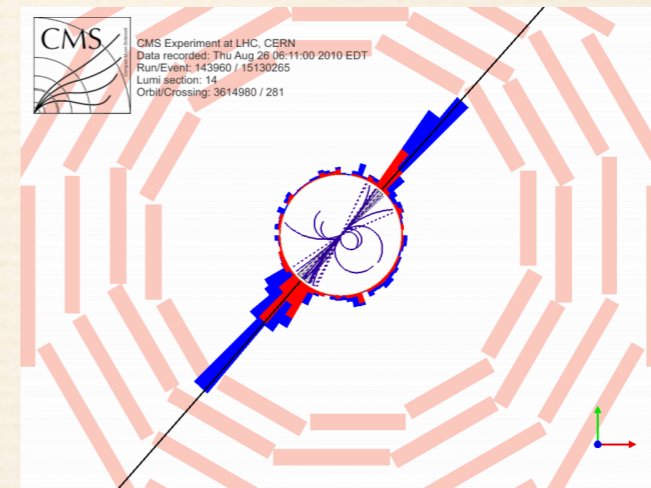
Isotropic events ——→ Balanced events
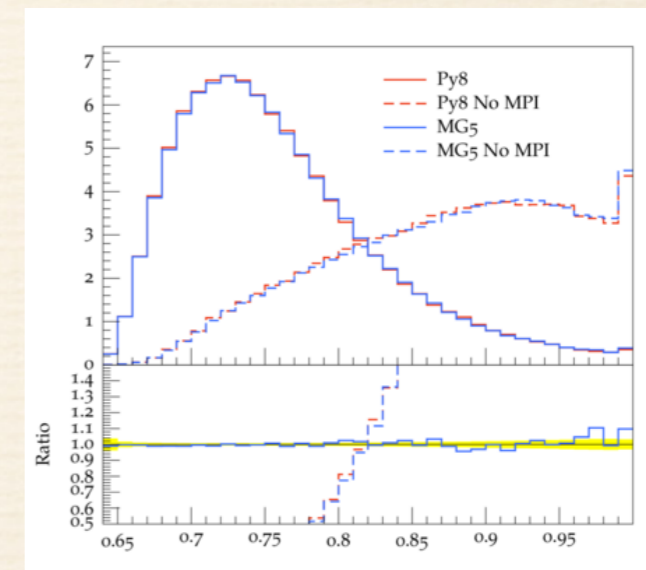
Jet multiplicity ←——

Absence of MPI
=
More balanced

Plot against Thrust (toward)

Same activity for isotropic events. Pythia8 produces more MPI here. Interleaving?

~Flat, extra jets independent of topology
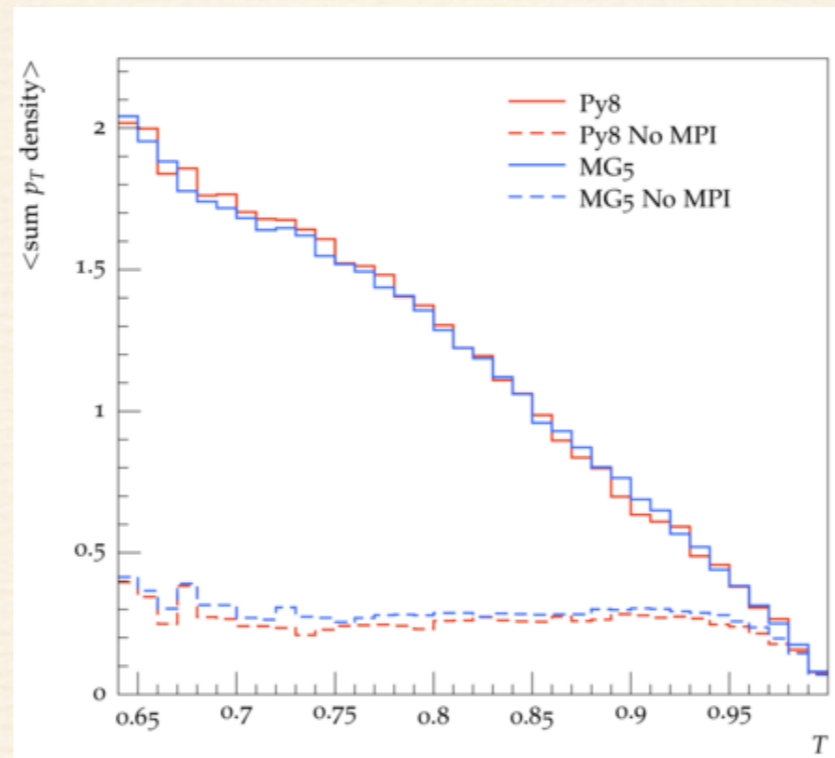

Pythia8 cant keep up just with MPI

Not zero, always extra jets!

Less extra jets in Pythia8 causes much more isotropic events
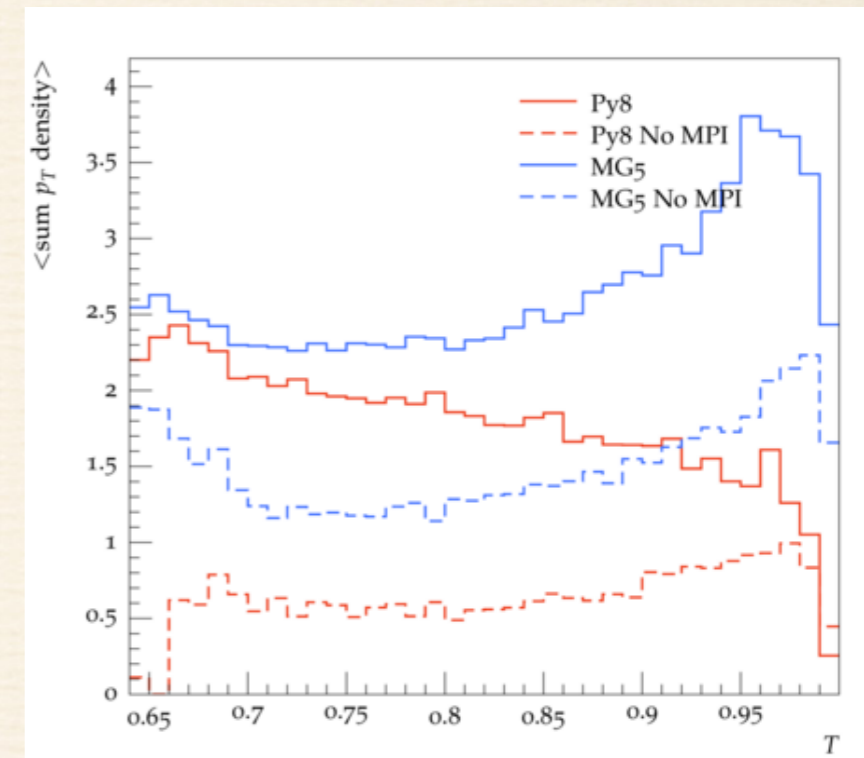No MPI shows the effect of extra jets is a constant shift

Plot against Thrust
for different jet multiplicities
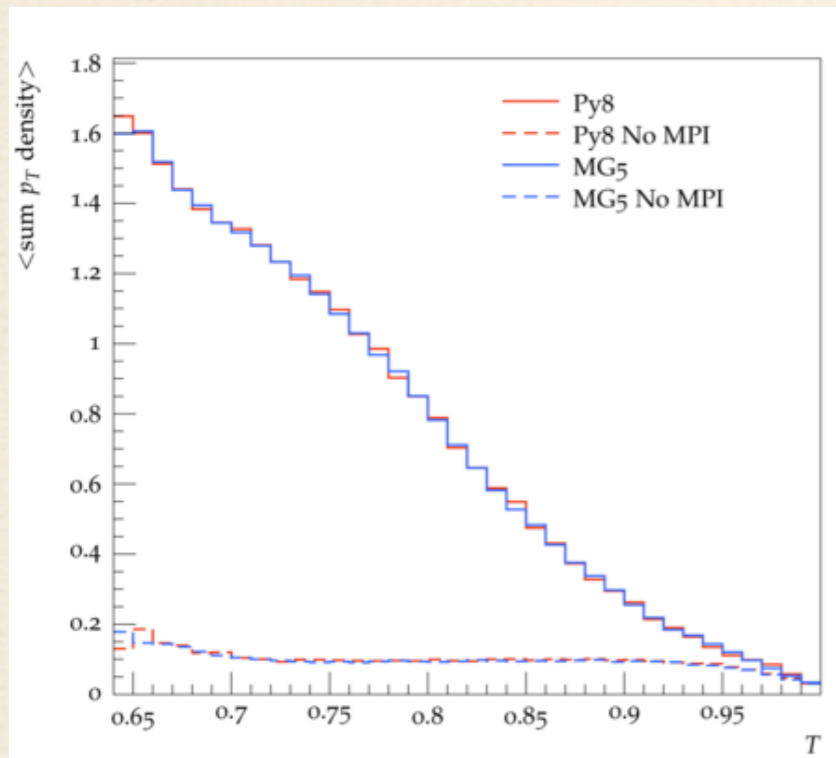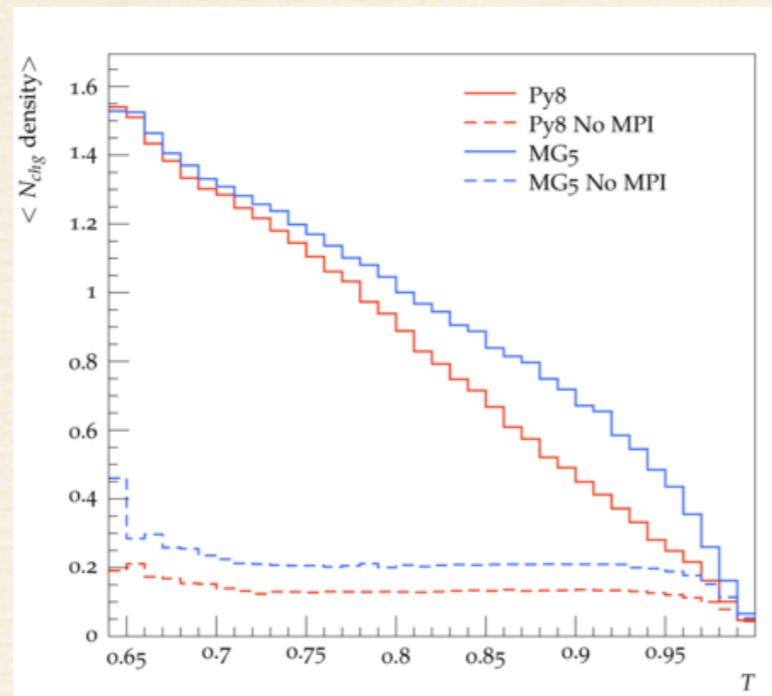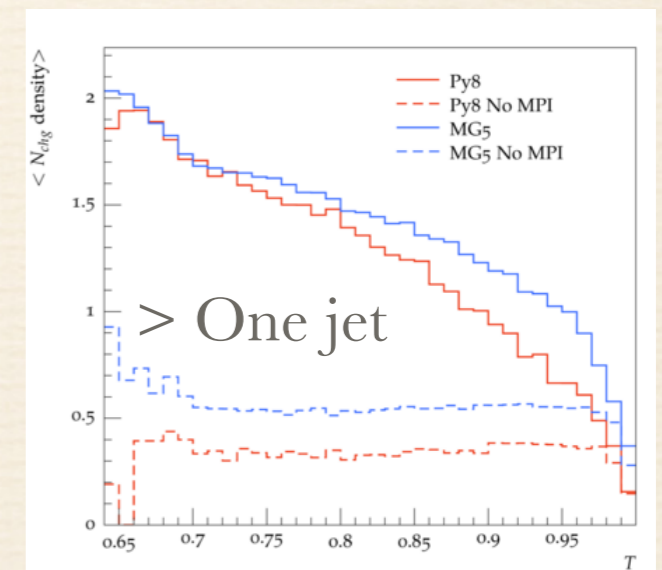

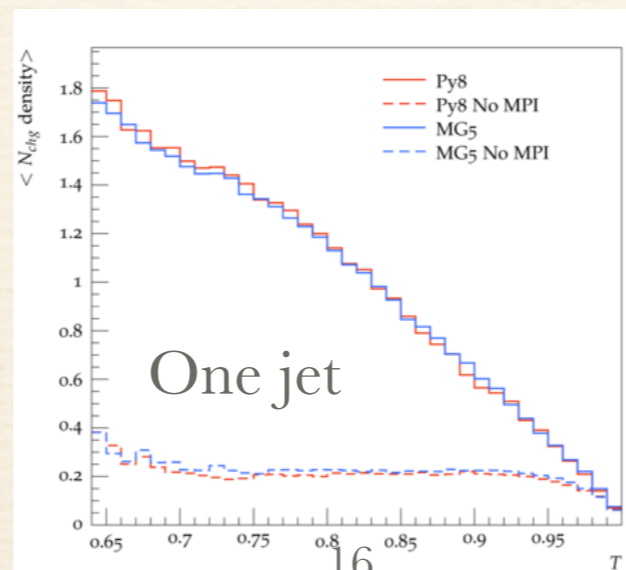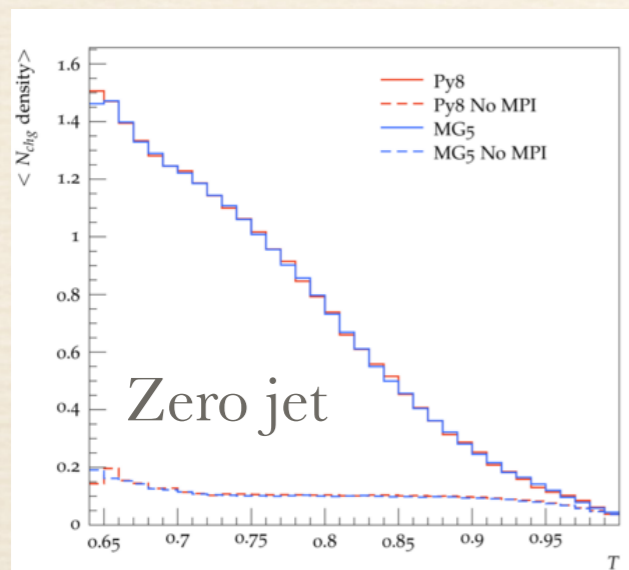Zero jet   One jet   > One jet

The difference comes predominantly from > 1 jet events (as expected)

Similar for Multiplicity

Inclusive

Noticeable difference: activity falls even with extra jets.
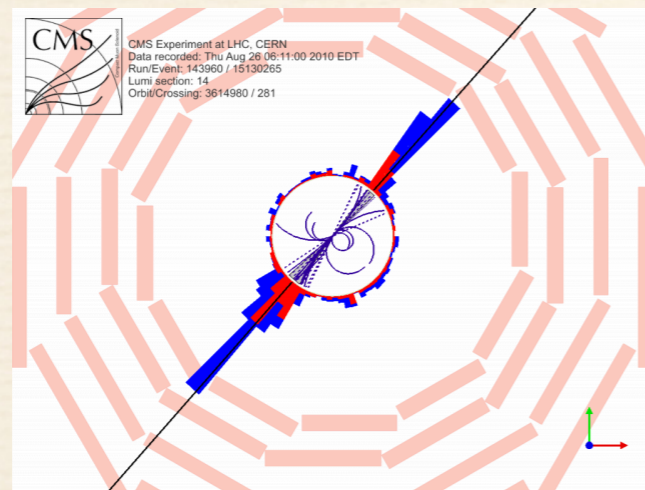So MPI gives softer particles than extra jets?

Zero jet

One jet

> One jet

Reminder: (transverse) Spherocity

S=0 $\longrightarrow$ S=1
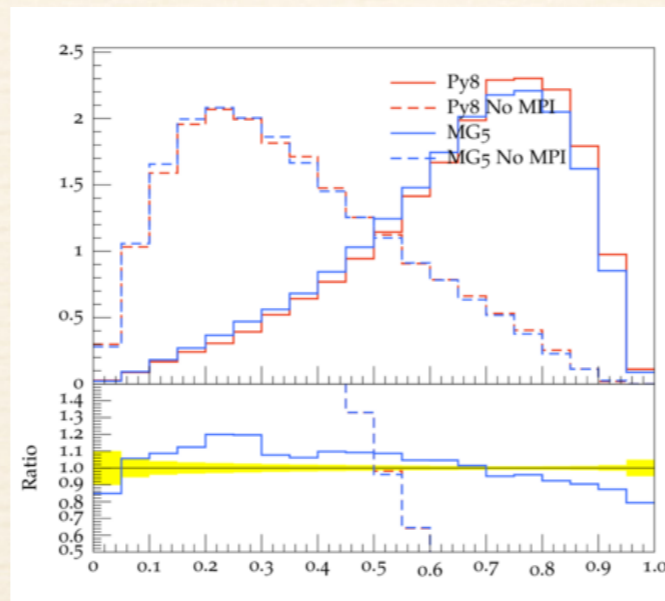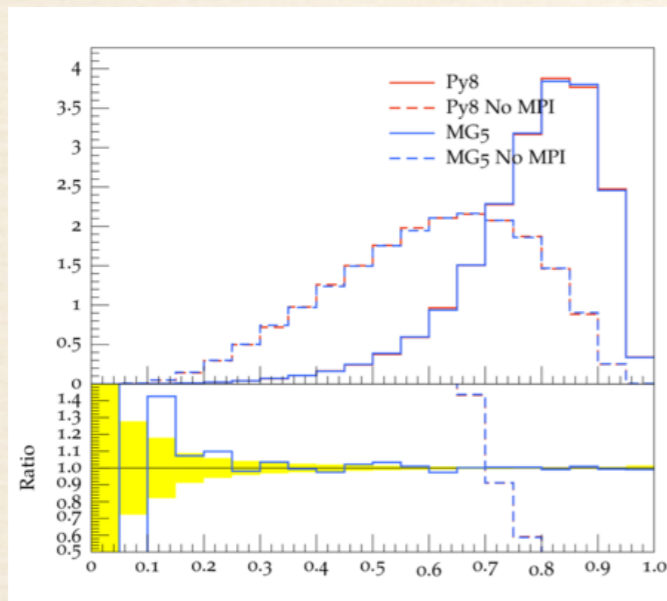
Balanced
events

Isotropic
events

Reminder: (transverse) Spherocity
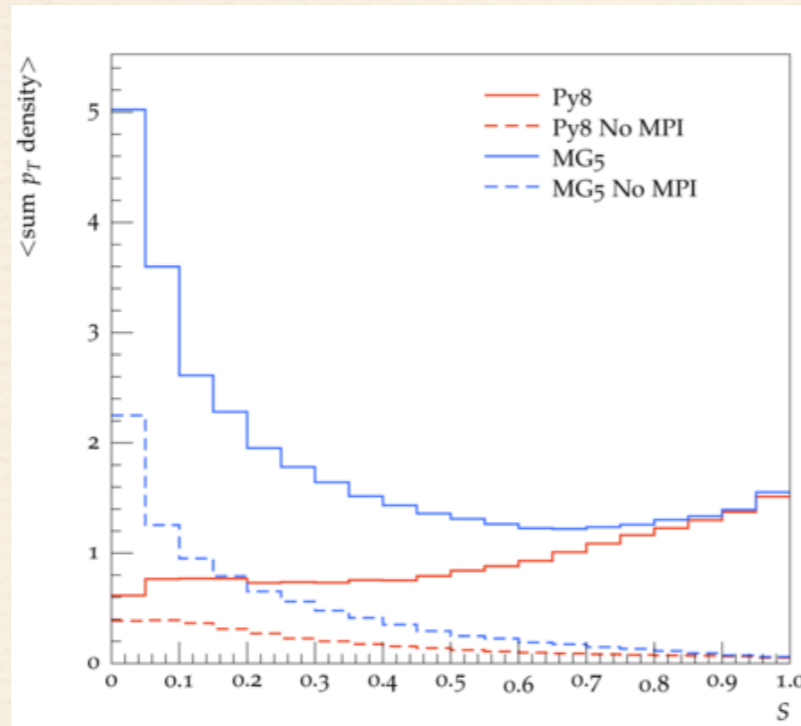
S=0 → S=1

Balanced events   Isotropic events
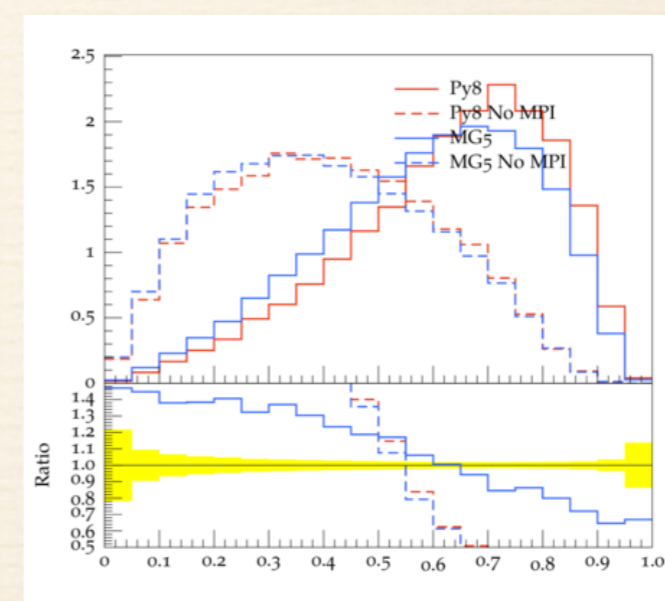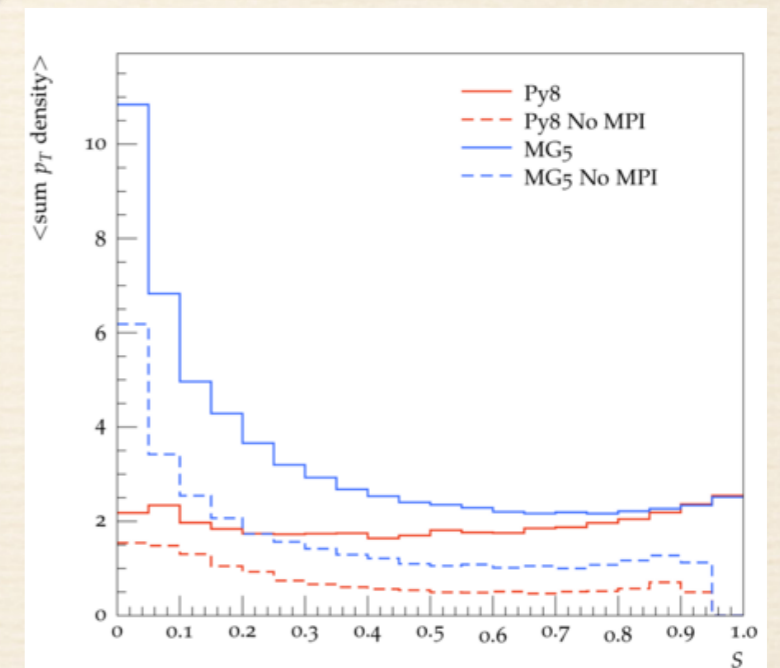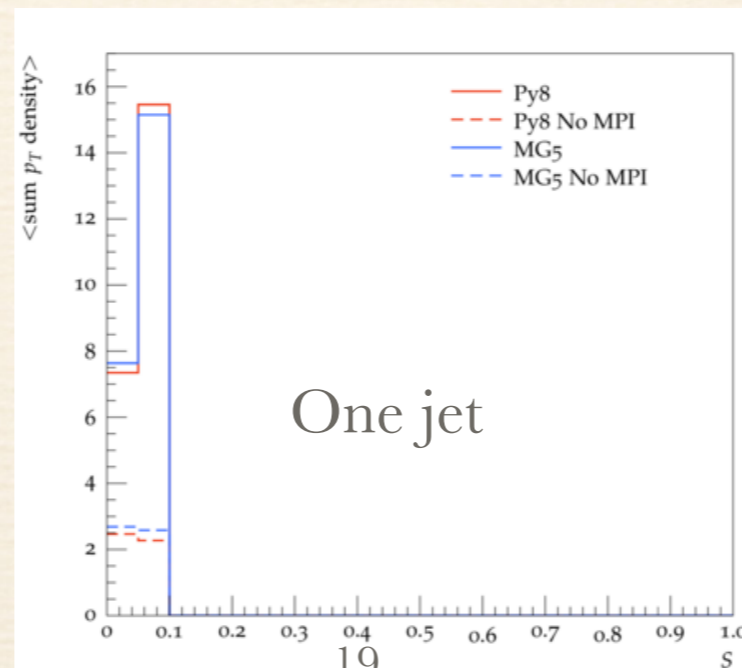

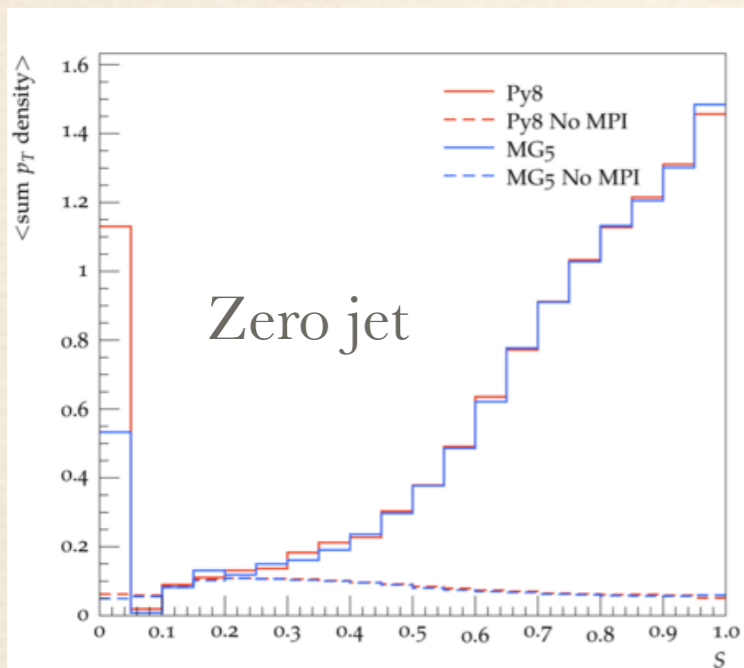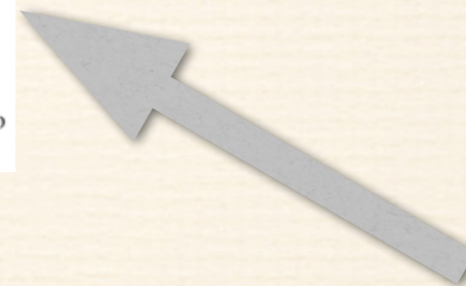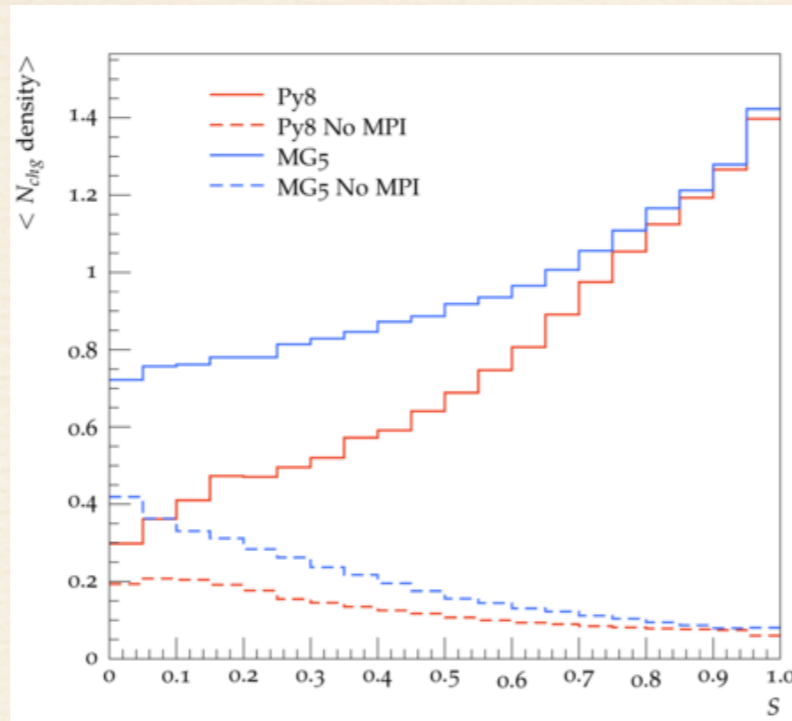Jet multiplicity   Not so sensitive?

Sum p$_T$ against Spherocity

Inclusive

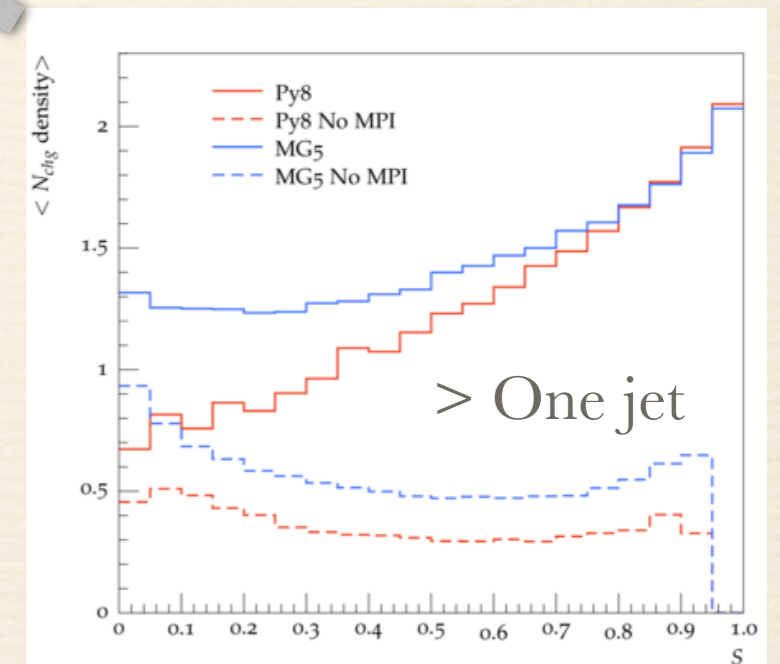Similar behaviour like thrust, slightly less sensitive
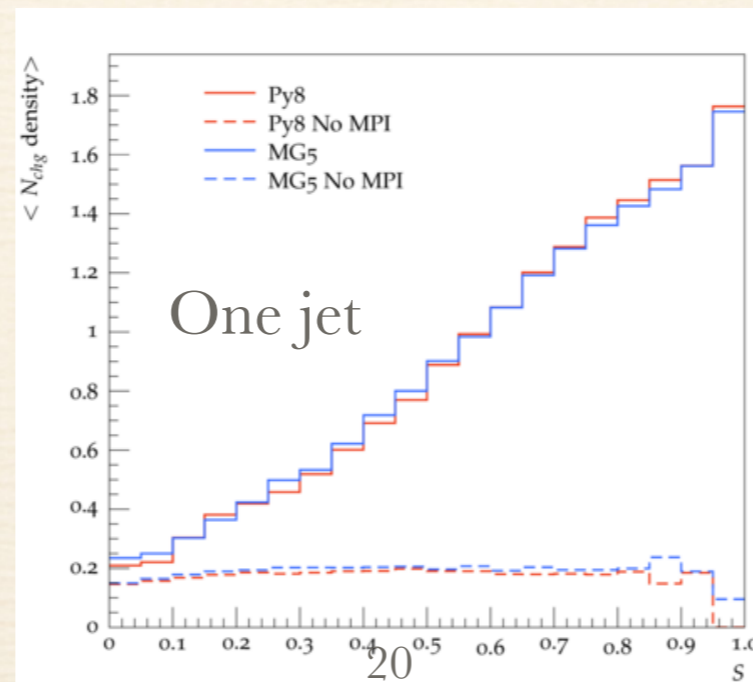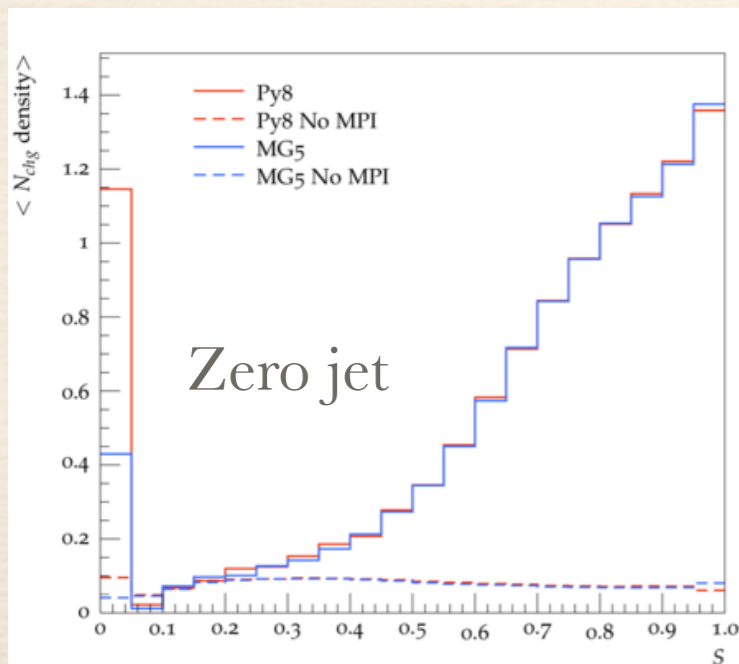

Zero jet
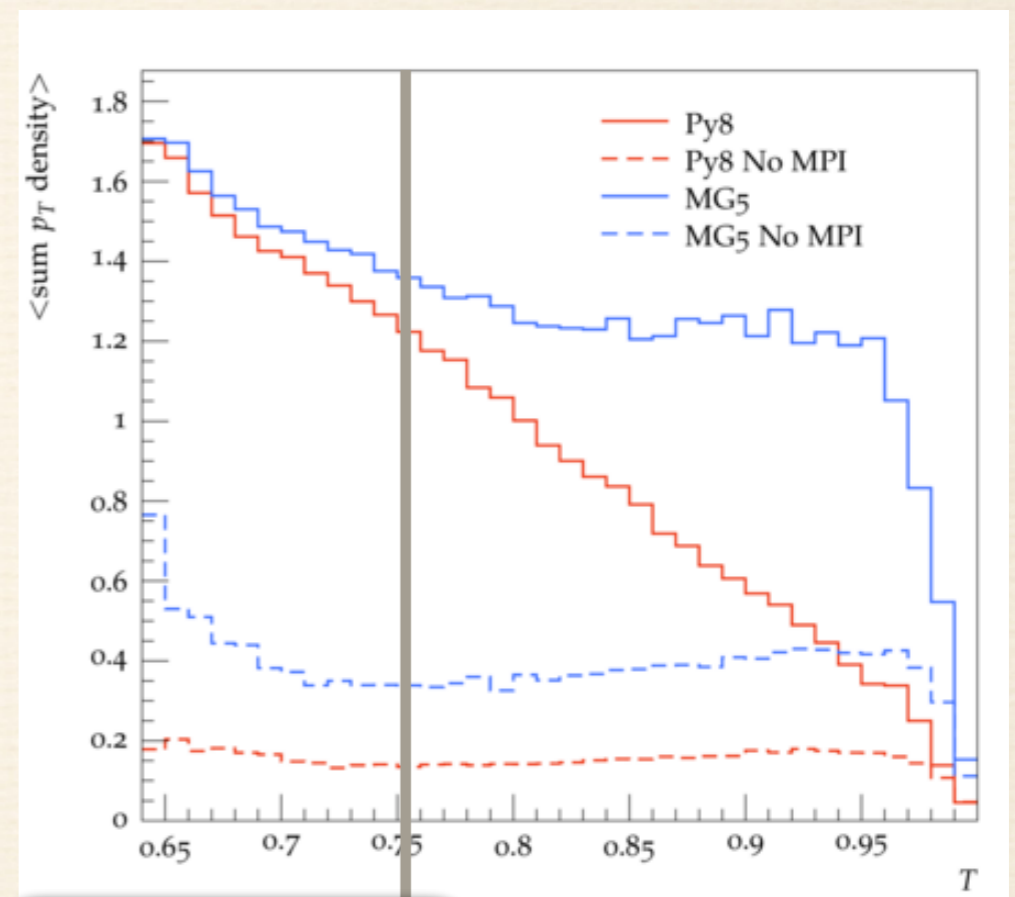
One jet

Multiplicity against Spherocity

Inclusive

Similar behaviour like thrust, slightly less sensitive

Summary

- Attempt to use event topology to better measure MPI.

- Also looked at transverse region, jet effects are more amplified

- Thrust seems more suitable for this purpose.

- Proposal: measure UE activity for T < 0.75 (or S > 0.65) ?

Less effect of extra jets?