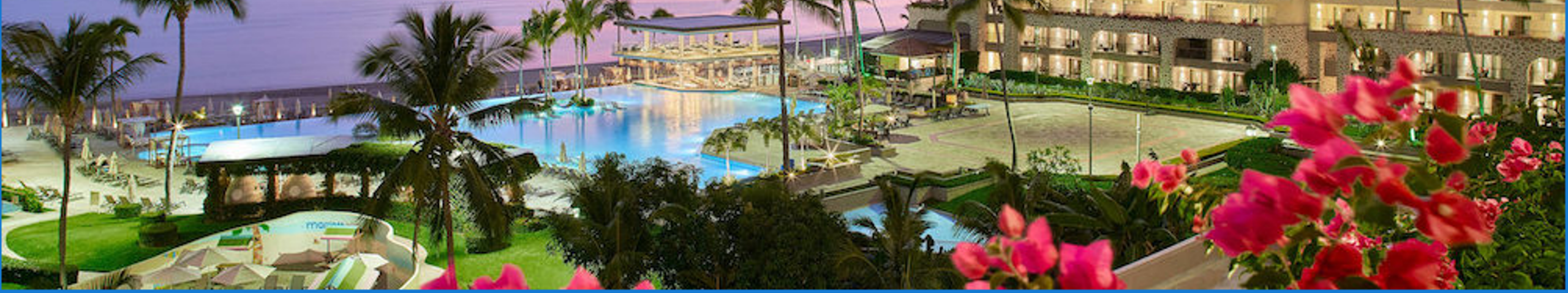

The 37th Winter Workshop on Nuclear Dynamics

Hedgehog events

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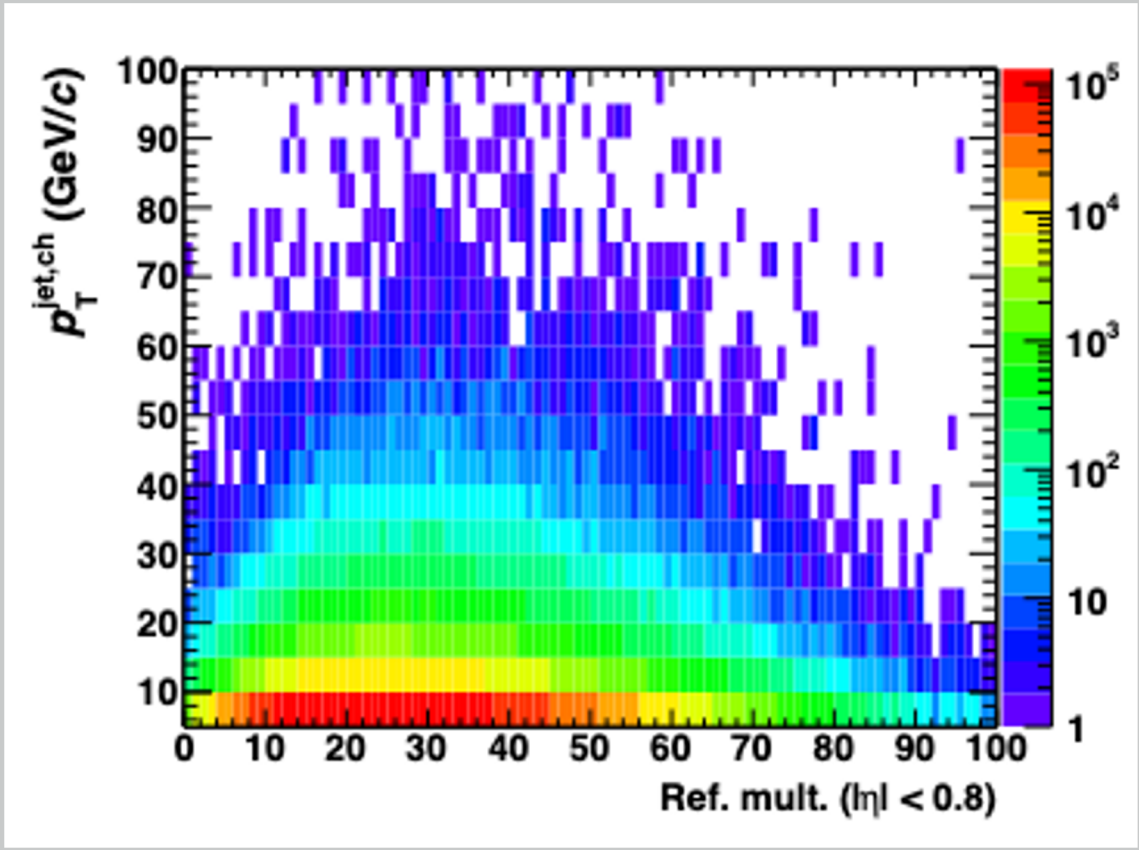
Motivation

- The pp events have shown all the characteristic features of sQGP except for the “energy loss”
- Is there a way to check it?

The forgotten features

- The highest multiplicities do not yield the maximum leading-p_T reach!



ALICE data

Figure from B. Hess PhD thesis:
https://cds.cern.ch/record/2058633/

Strong increase in the high-p_T yields with multiplicity

But observed increase at low momenta – small but real

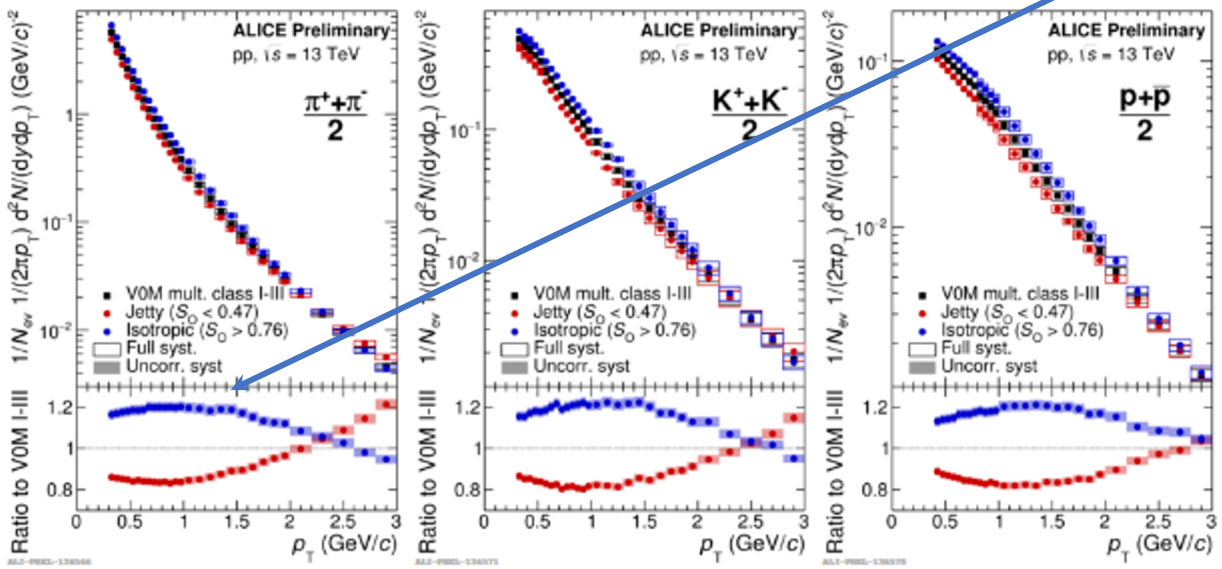
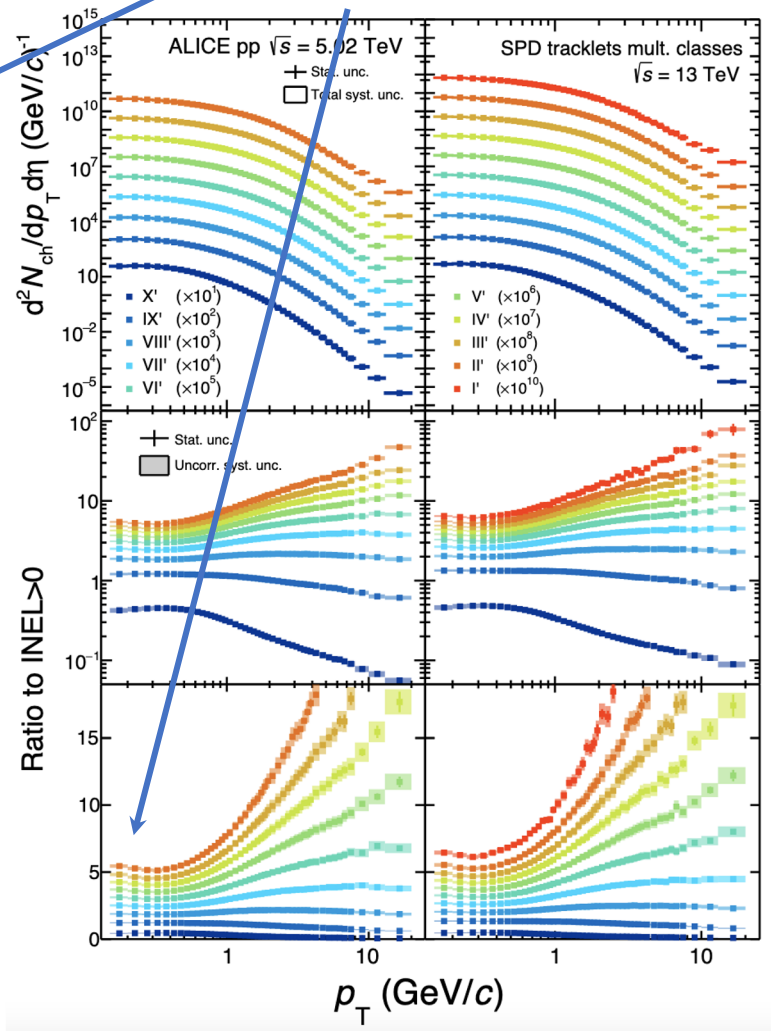


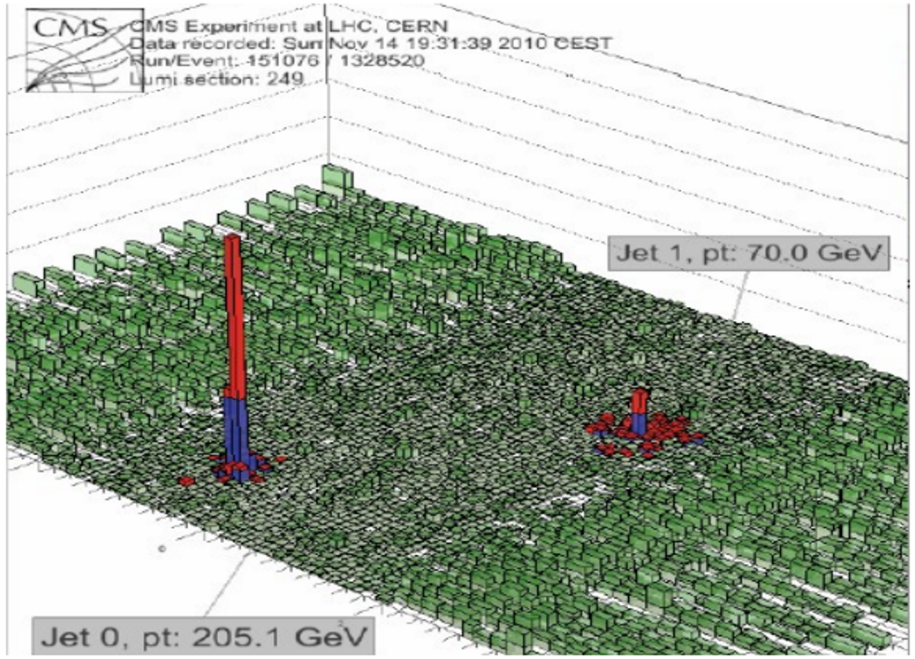
Fig. 2. Top panels: transverse momentum spectra of $\pi^{\pm}$, $K^{\pm}$, and $p(\bar{p})$ in V0M multiplicity class I–III events, jetty events (20% lowest S_O) and isotropic events (20% highest S_O). Bottom panels: ratio of spectra in jetty (isotropic) events to the V0M class I–III.



Many interesting feature at low momenta

ALICE, Eur. Phys. J. C80 (2020) 8, 693

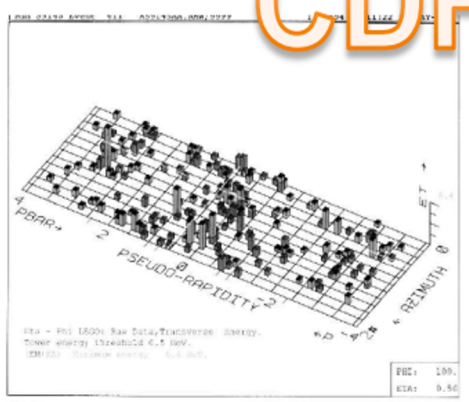
The “energy loss” feature is well established



But, if I can have question: if I have a quenched jet should I allow for the possibility to see both primary jets absorbed?

In that sense let's go back to **prehistory**!

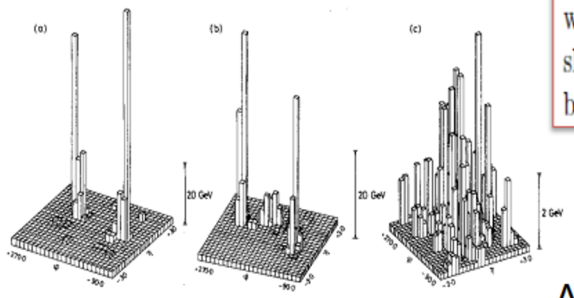
CDF



hriss Quigg: arXiv:1004.0975v1 [hep-ph]

An interesting example—an *atypical* event observed in $\bar{p}p$ interactions at $\sqrt{s}$ = 1.8 TeV by CDF's Run 1 detector, is shown in Figure 3.([3]) This event was accepted by a $\sum E_\perp$ trigger, without any topological requirement. The LEGO® plot shows many bursts of energy: More than a hundred active towers pass the display threshold of 0.5 GeV. The total transverse energy in the event is 321 GeV, but it is not concentrated in a few sprays, it is everywhere. The central tracking chamber records about sixty charged particles.

I am assured that this "hedgehog" event is authentic; it is not merely coherent noise in the counters. The colleague who selected this specimen estimated similar events to be about as common in the online event stream as Z^0 production and decay into lepton pairs: about one in ten thousand triggers. I include this outlier as a reminder that when we think about the strong interactions outside the realm of a single hard scattering, we should think not only about the large diffractive and "multiperipheral" cross sections, but also about less common phenomena.



UA1

Albajar, C., et al. (UA1 Collaboration). Analysis of the Highest Transverse Energy Events Seen in the UA1 Detector at the SppS Collider. Z. Phys. C36 (1987),

- **Conclusion: there are "rare" events in pp collisions that have never been seriously studied!**

Rare events seen also in Generators!

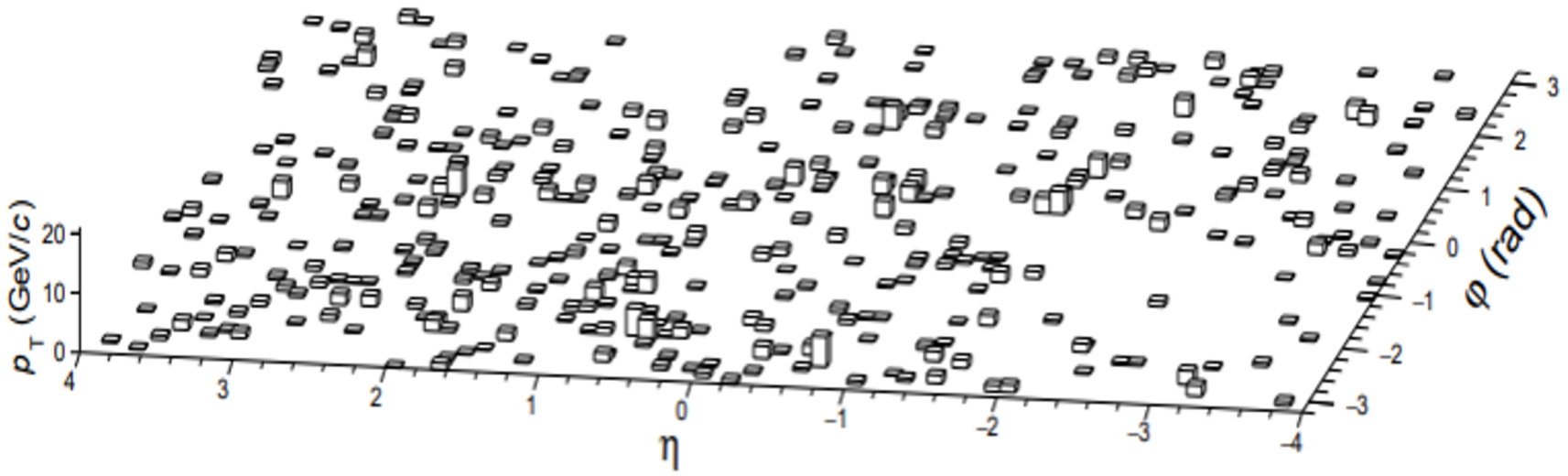
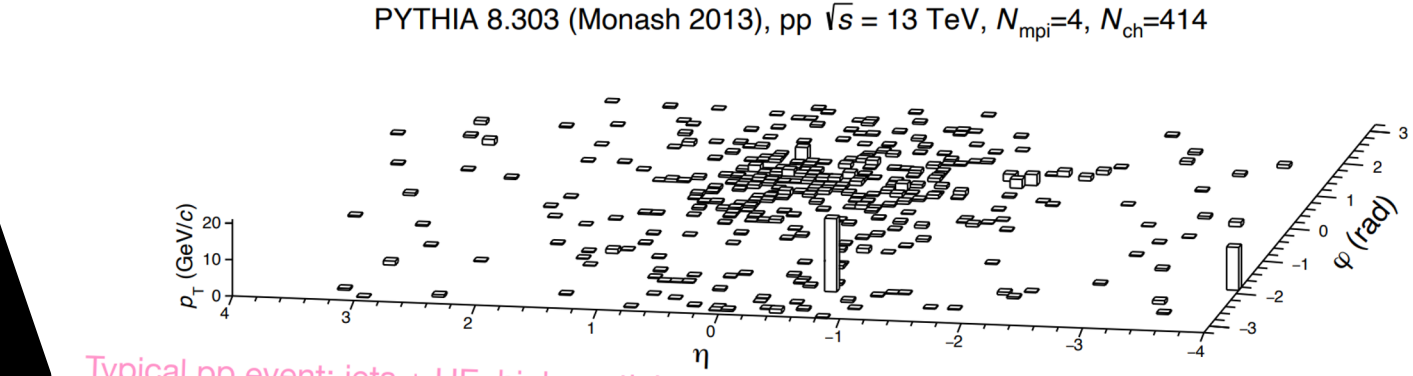


FIG. 1. Event display of a high multiplicity pp collision at $\sqrt{s} = 13\,\text{TeV}$ simulated with PYTHIA 8.303.

And Pythia?!

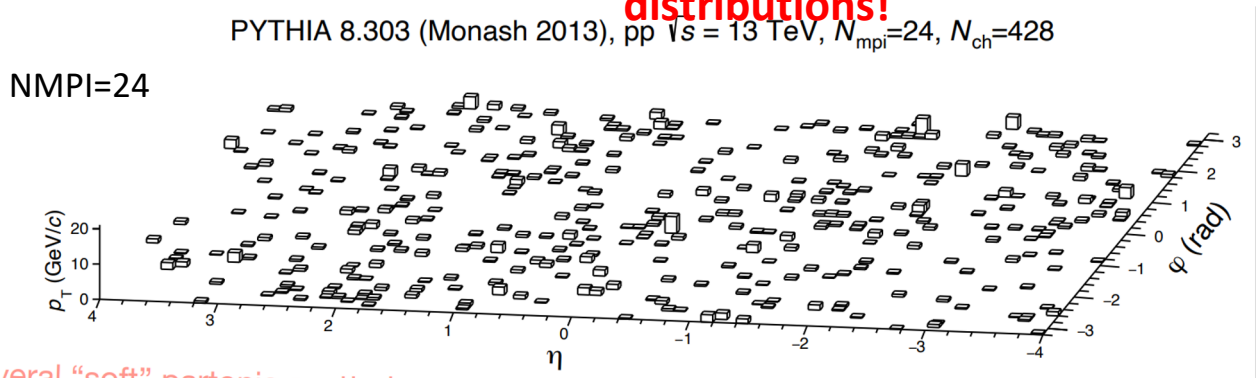
- It has a very distinct behavior depending on the number of multiple parton interactions (MPI)

NMPI=4



Typical pp event: jets + UE, high particle density at mid-pseudorapidity

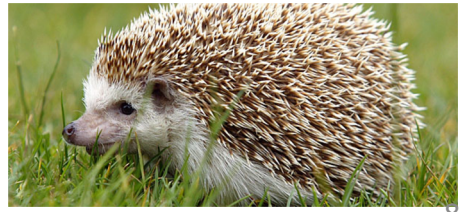
Same multiplicity – completely different distributions!



NMPI=24

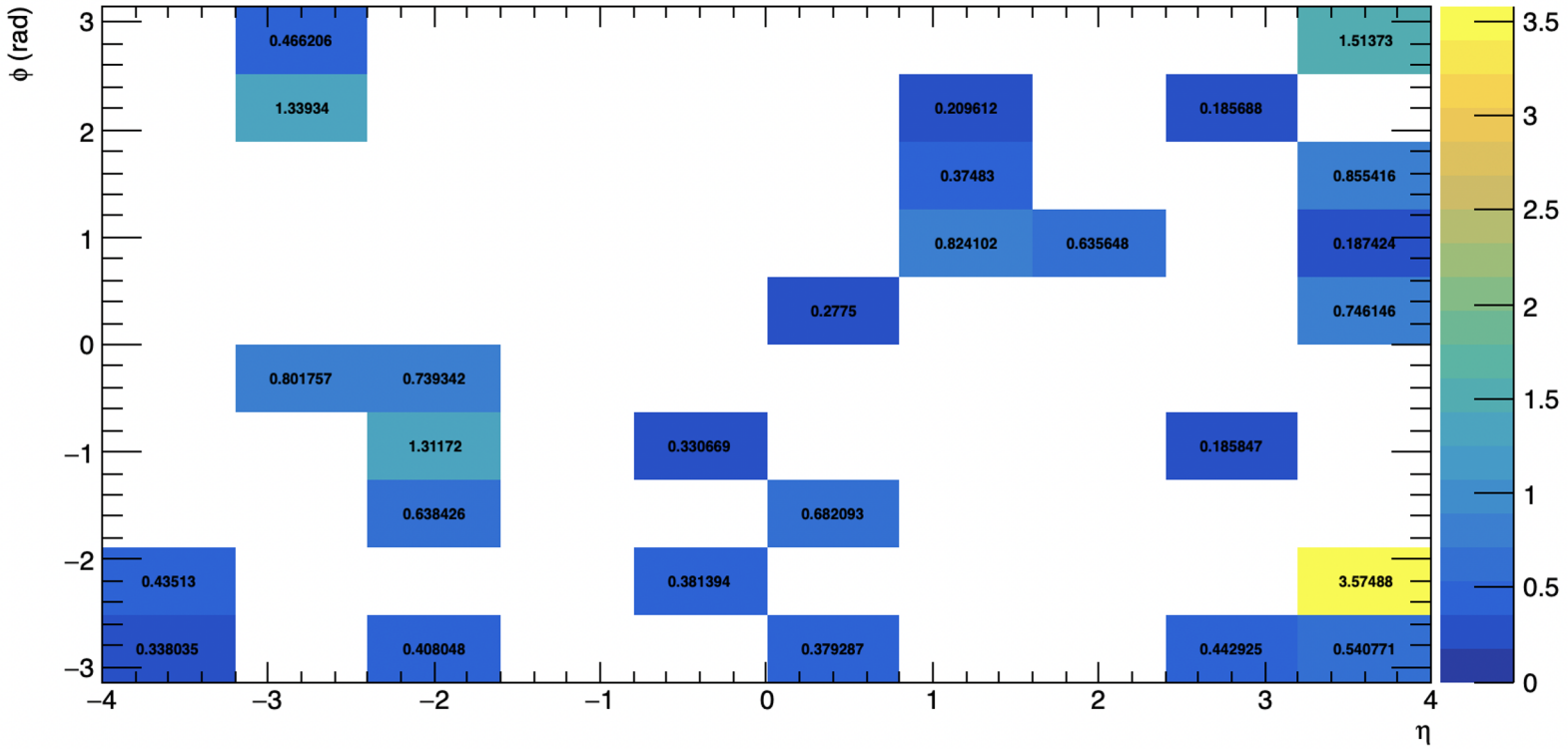
Several “soft” partonic scatterings, roughly flat pseudorapidity distribution

Absence of high pts!



Can we trigger on rare events?

YES!



A grid in eta-phi is built (10x10)

The average p_T is determined in each cell ($0.15<p_T<20$ GeV/c): $\langle p_T \rangle = \sum \langle p_T \rangle^{cell}/100$

The relative sigma is determined as follows: $\rho = \sigma_{\langle pT \rangle}/\langle p_T \rangle$

For events having p_Ts isotropically distributed in η-ϕ (high occupancy), the relative sigma (ρ) is expected to be small

flattenicity

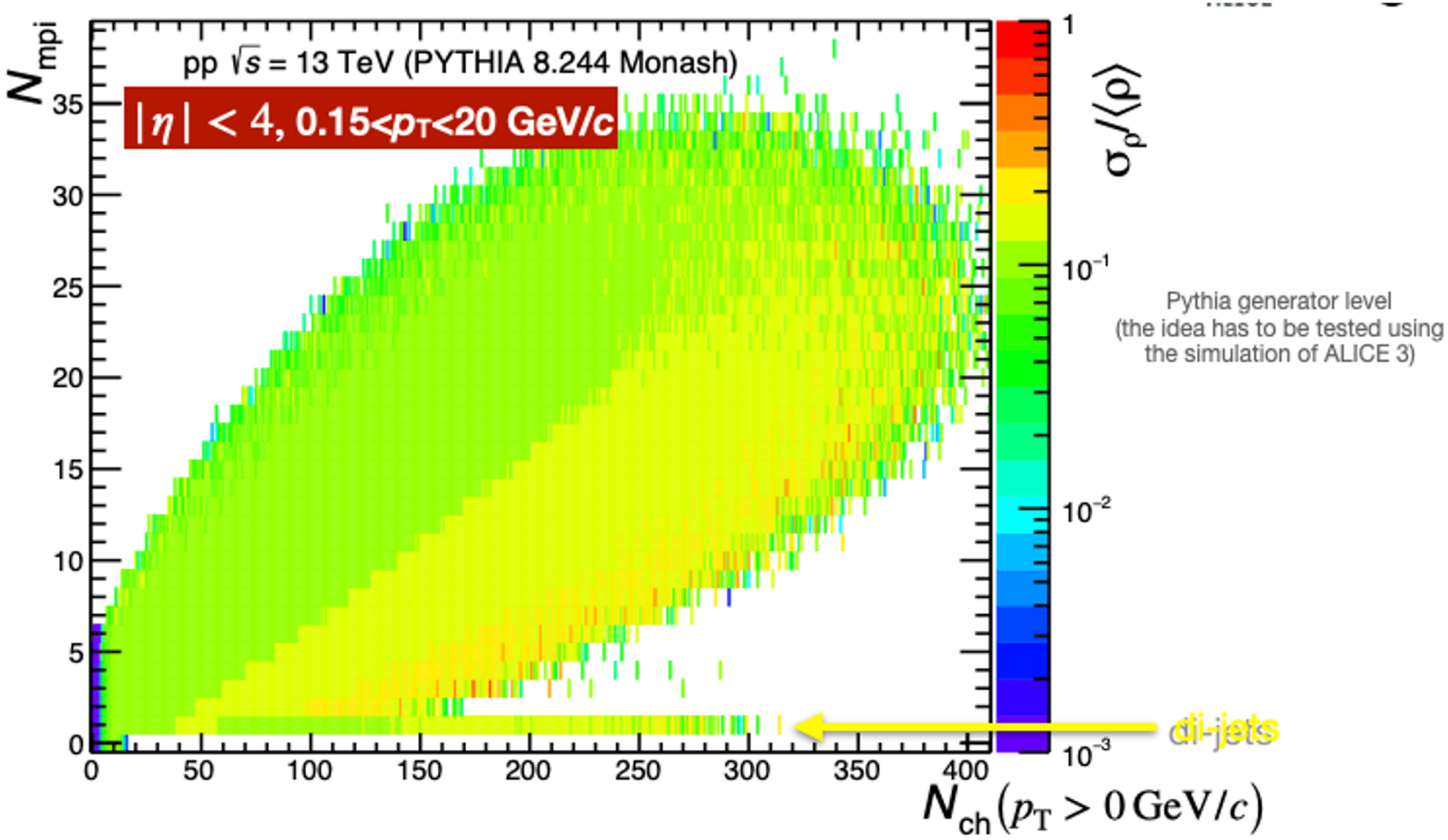
We define a new event structure parameter. We open the possibility to identify and isolate very rare event. It is more detailed than the sphericicy/spherocity/R_T parameters

By selecting the events using the two parameters: sigma and <pt>

One can perfectly well observe the evolution of the events from a jetty form to the hedgehog type!

An impressive distribution!

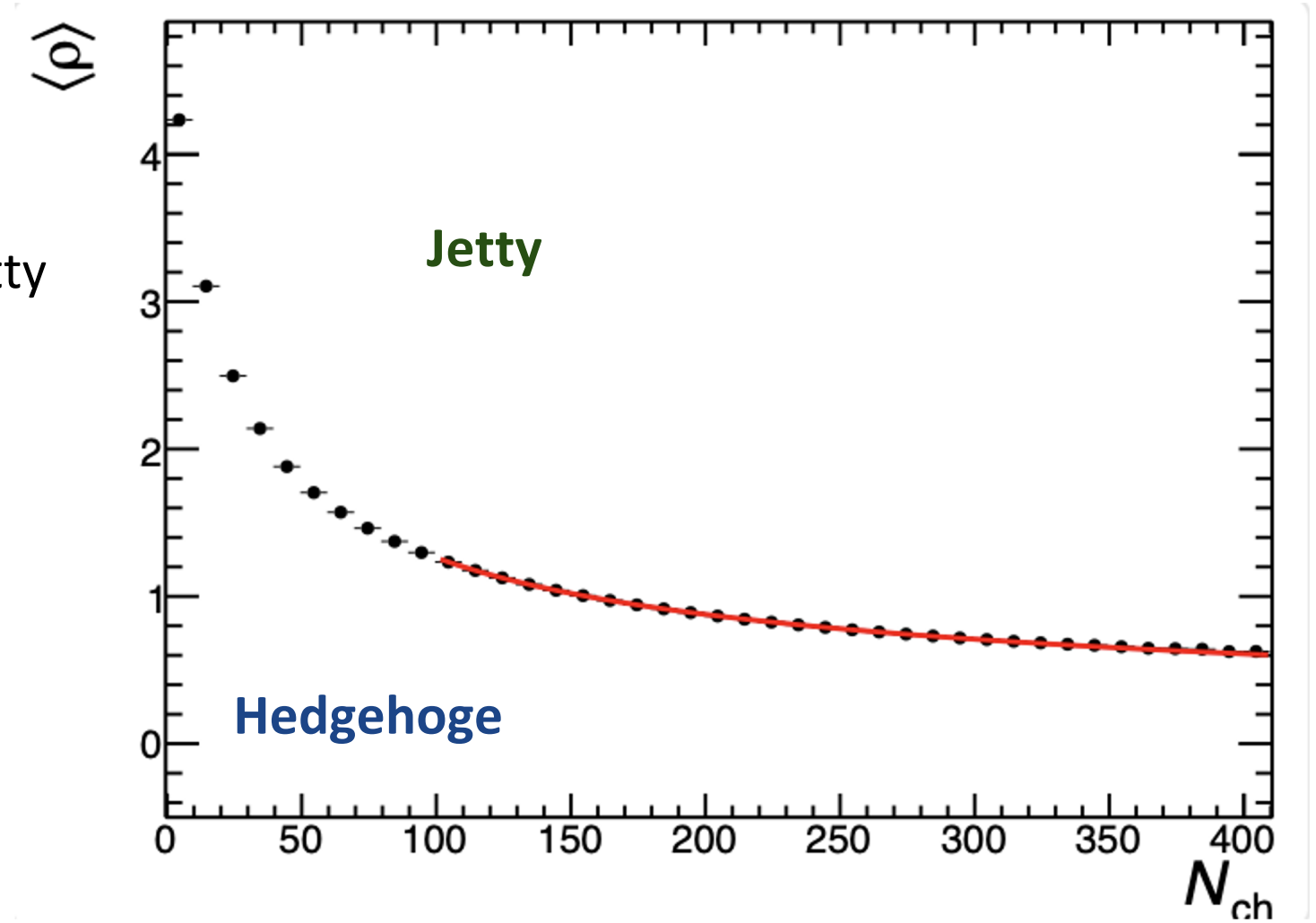
Very large distribution in the number of MPIs
Usually the high multiplicity and high MPI region is not investigated!



Flattenicity vs Nch

Essentially the part above the curve is the phase space for jetty events and the one below for hedgehog events

The probability for hedgehog events at multiplicity 150 ($|\eta|$<1.2) is ≈10^{-4}



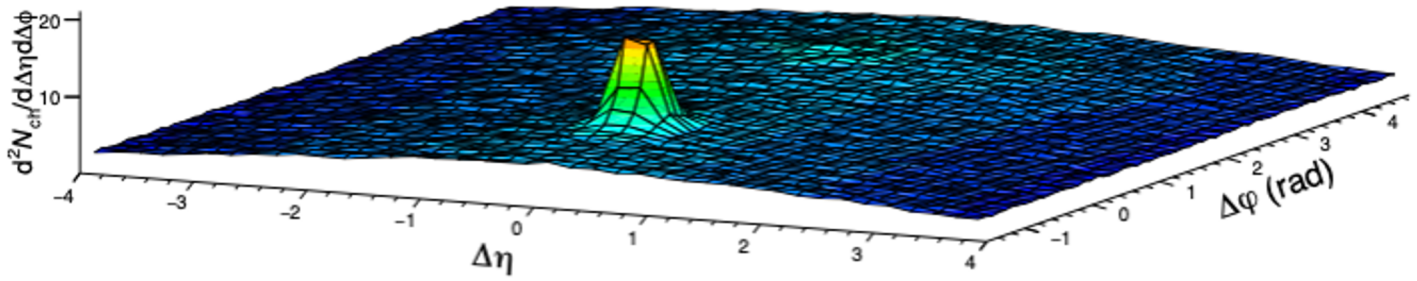
Dial your favorite event!

- **By choosing the trigger we can identify very rare events for study**

High $\langle p_T \rangle$ fluctuations

PYTHIA 8.303 (Monash 2013), pp $\sqrt{s}$ = 13 TeV

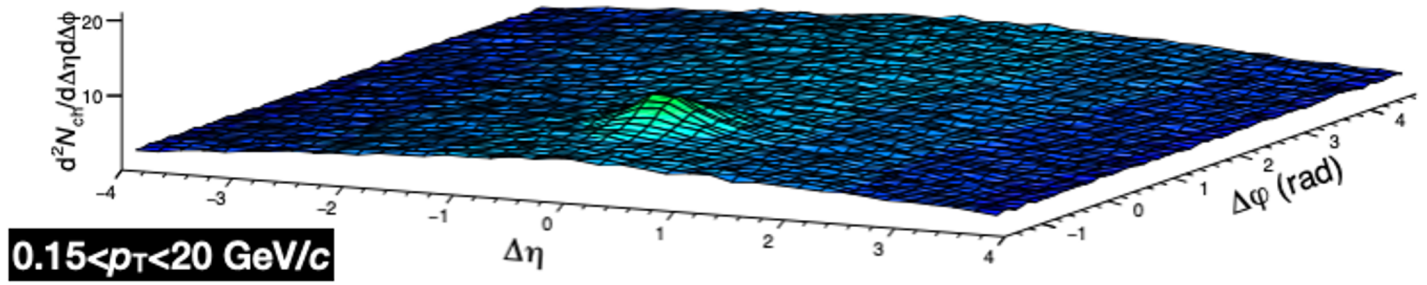
$|\eta|<4$, $0.15 \le p_T < 20$ GeV/c, $N_{ch}>300$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=9 GeV/$c$



Low $\langle p_T \rangle$ fluctuations

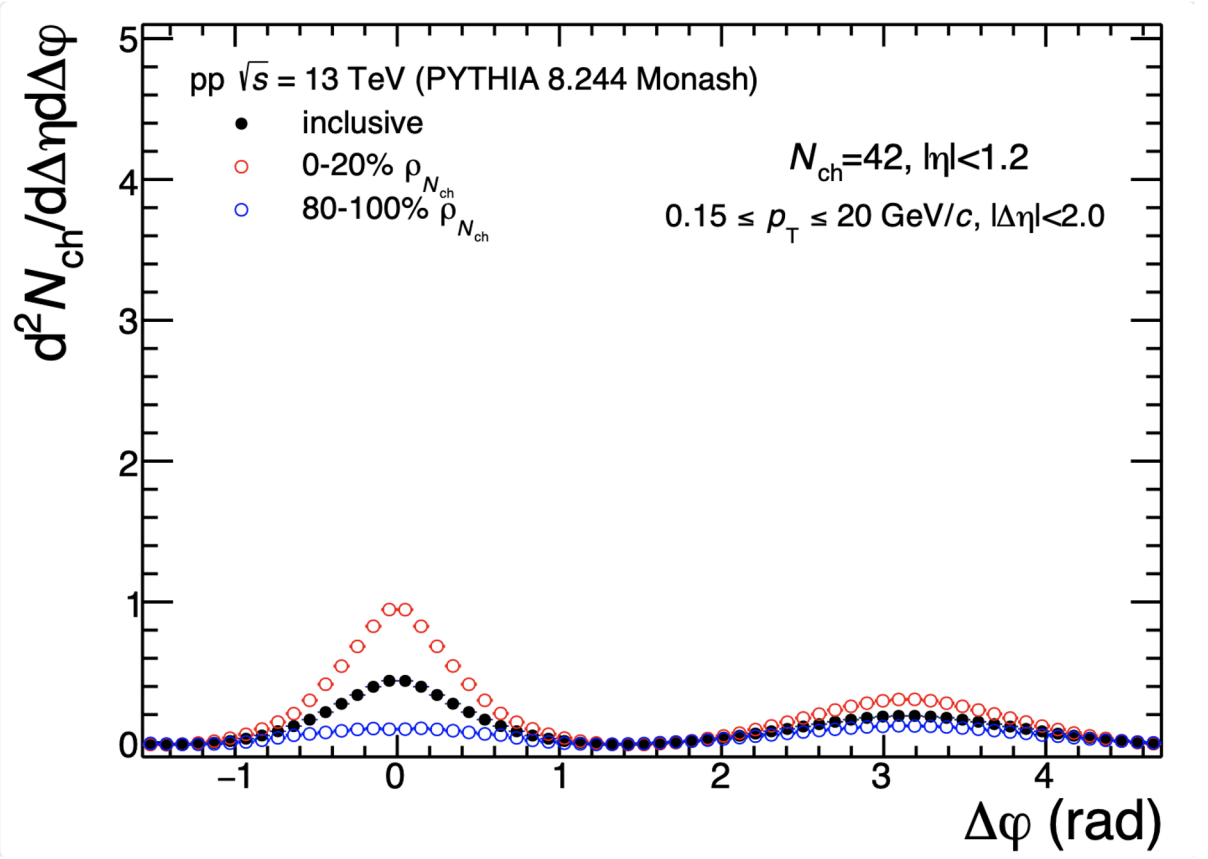
PYTHIA 8.303 (Monash 2013), pp $\sqrt{s}$ = 13 TeV

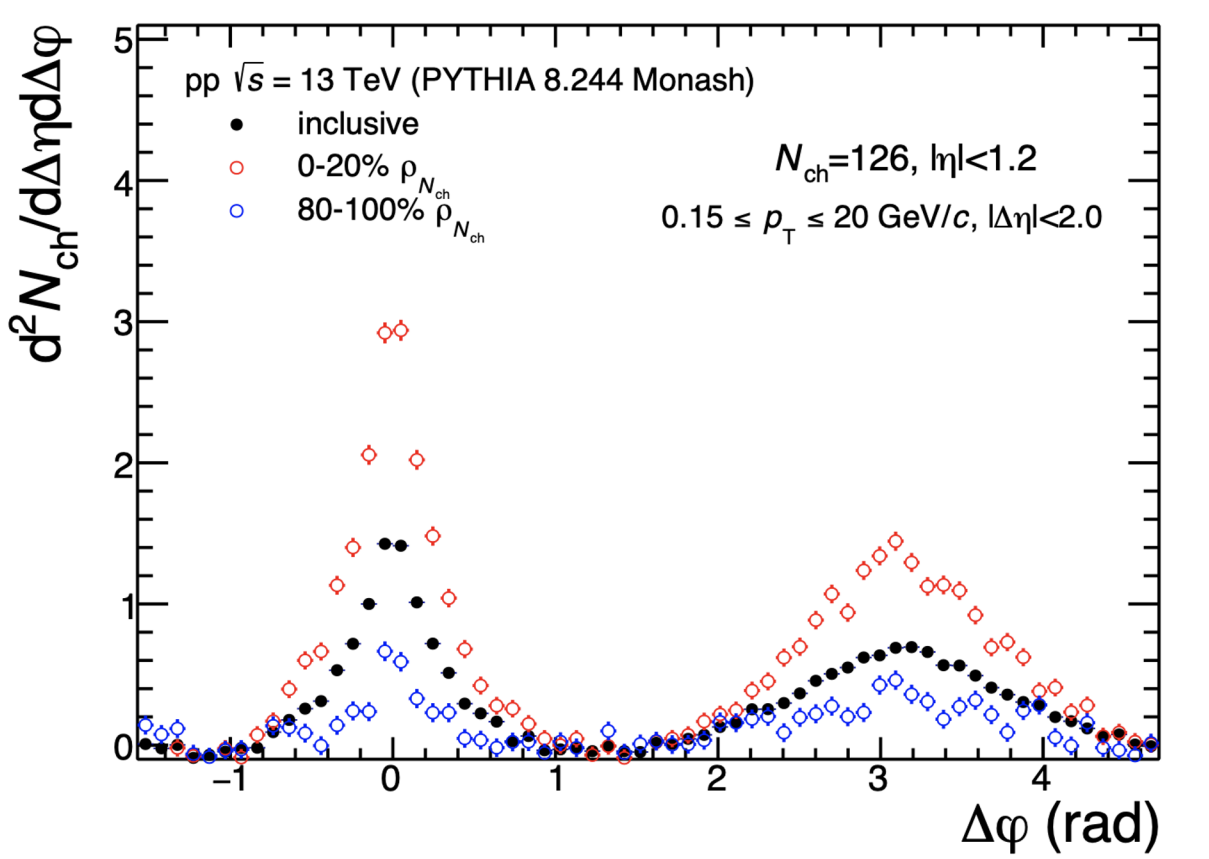
$|\eta|<4$, $0.15 \le p_T < 20$ GeV/c, $N_{ch}>300$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=4 GeV/$c$



High multiplicity pp collisions

Hedgehog events can be tagged even at low multiplicities!





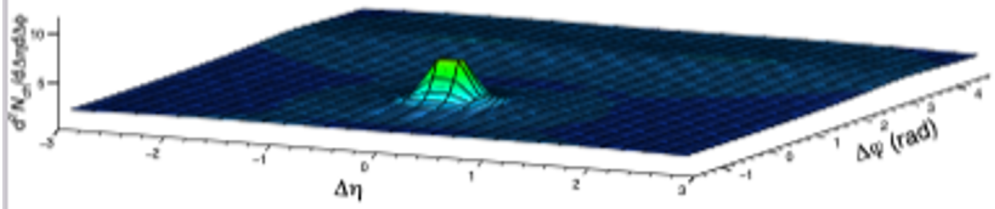
Do other generators predict hedgehog events?

We show that all the event generators do predict Hedgehog events

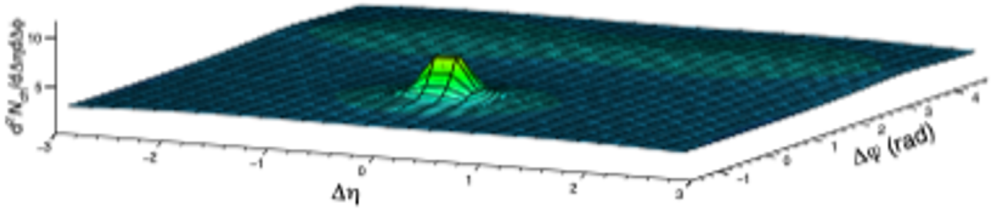
The predictions are not equal for all the generators - it would open the possibility for a comparison among the generators

Di-hadron correlations (jetty): several MC generators

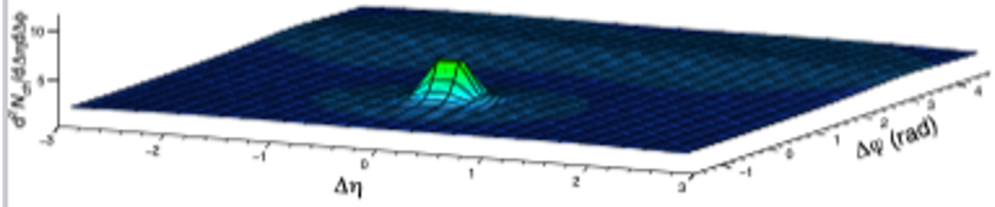
Pythia Monash, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=6 GeV/$c$



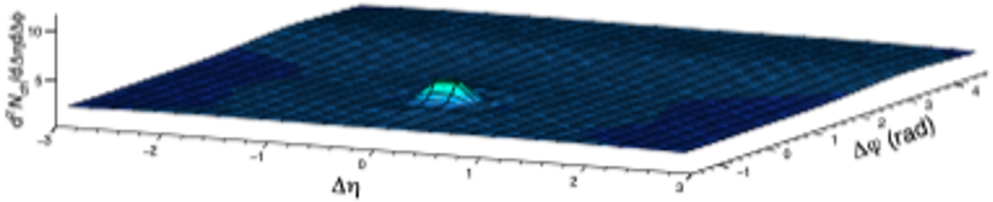
Pythia Monash noCR, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=6 GeV/$c$



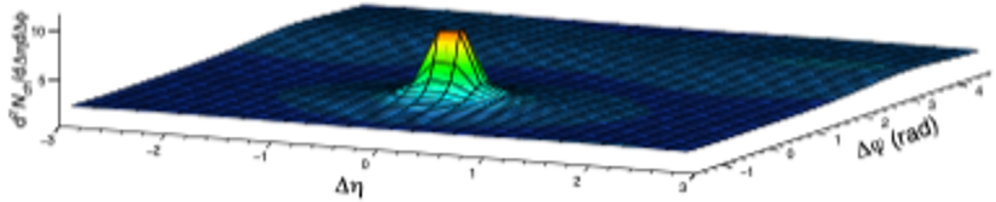
Pythia Monash ropes, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=7 GeV/$c$



Epos LHC, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=6 GeV/$c$



AMPT, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle>1.15$, $\langle p_T^{trig}\rangle$=7 GeV/$c$

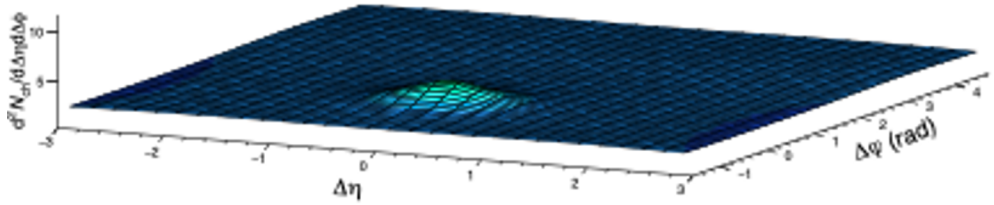


Leading jet peak is model dependent, in particular EPOS LHC gives a "suppression effect"

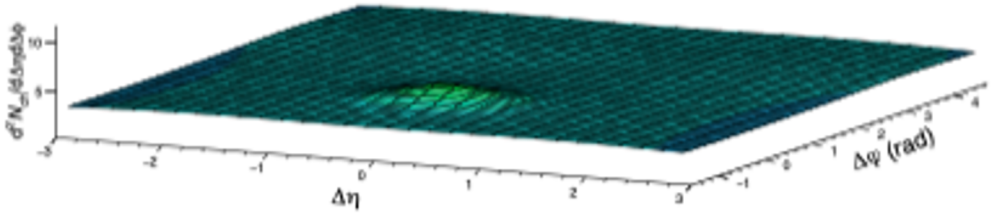
High multiplicity $N_{ch} \geq 100$ ($|\eta| < 4$), jet-like structure ($\rho/\langle\rho\rangle > 1.15$)

Di-hadron correlations (hedgehog): several MC generators low

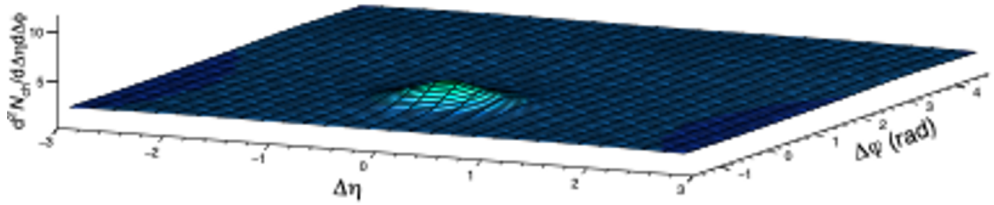
Pythia Monash, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=3 GeV/$c$



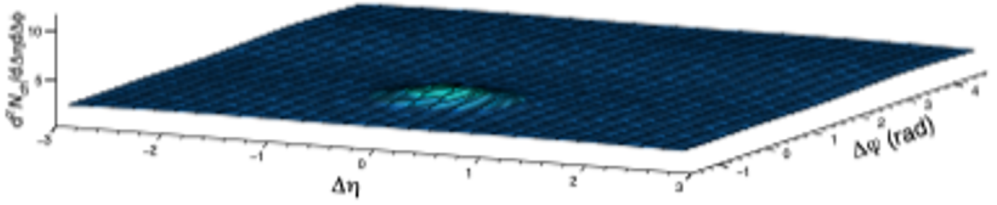
Pythia Monash noCR, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=2 GeV/$c$



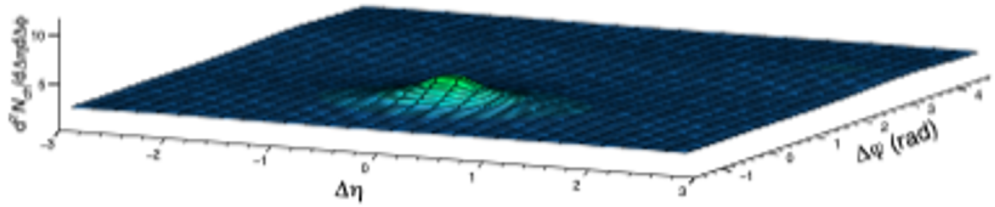
Pythia Monash ropes, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=3 GeV/$c$



Epos LHC, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=3 GeV/$c$



AMPT, pp $\sqrt{s}$ = 13 TeV
$|\eta|<4$, $0.15\leq p_T<20$ GeV/c, $N_{ch}>100$, $\rho/\langle\rho\rangle<0.85$, $\langle p_T^{trig}\rangle$=3 GeV/$c$



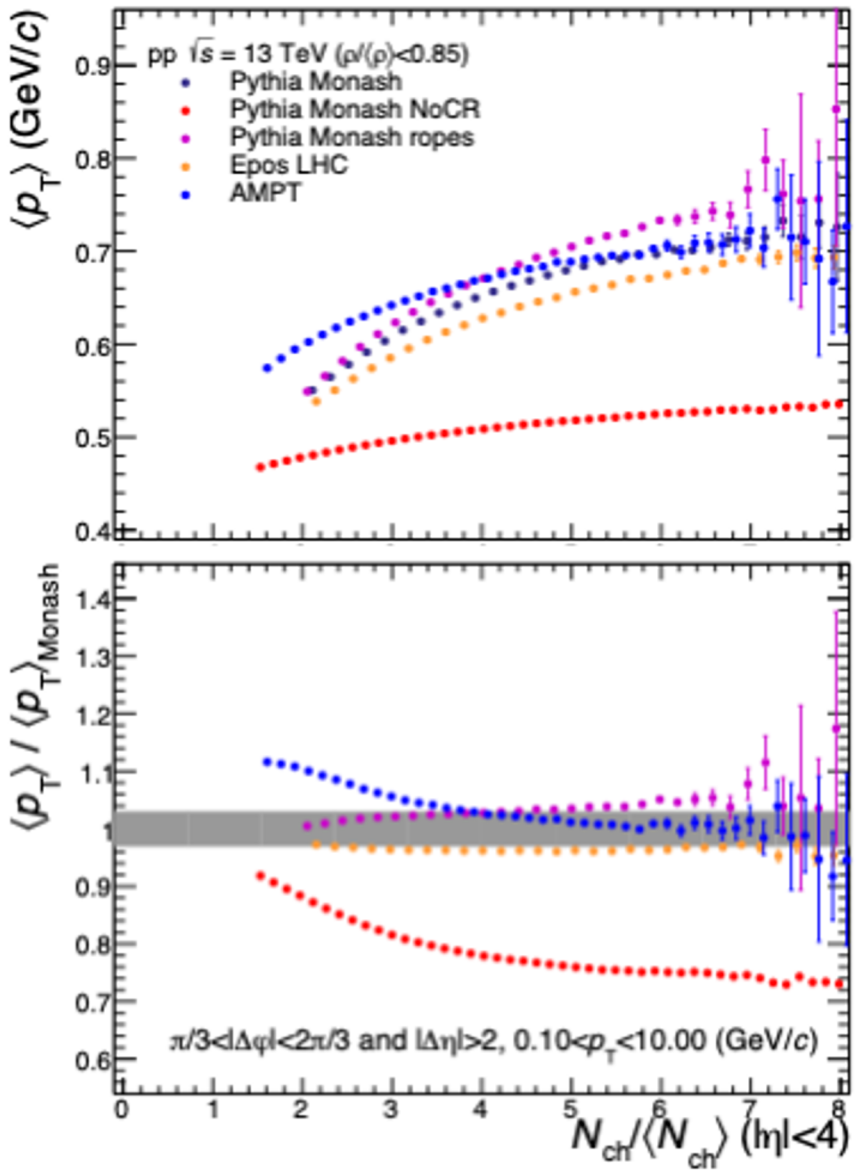
We can find hedgehogs like events in all event generators

High multiplicity $N_{ch} \geq 100$ ($|\eta| < 4$), isotropic distribution of p_T ($\rho/\langle\rho\rangle < 0.85$)

All MC generators predict the existence of hedgehog events!!!

The details of the predictions varies from one generator to another so that experimental comparison with MCs offers the possibility to tune the generators

Average pT in hedgehog pp collisions



Low ρ (hedgehog)

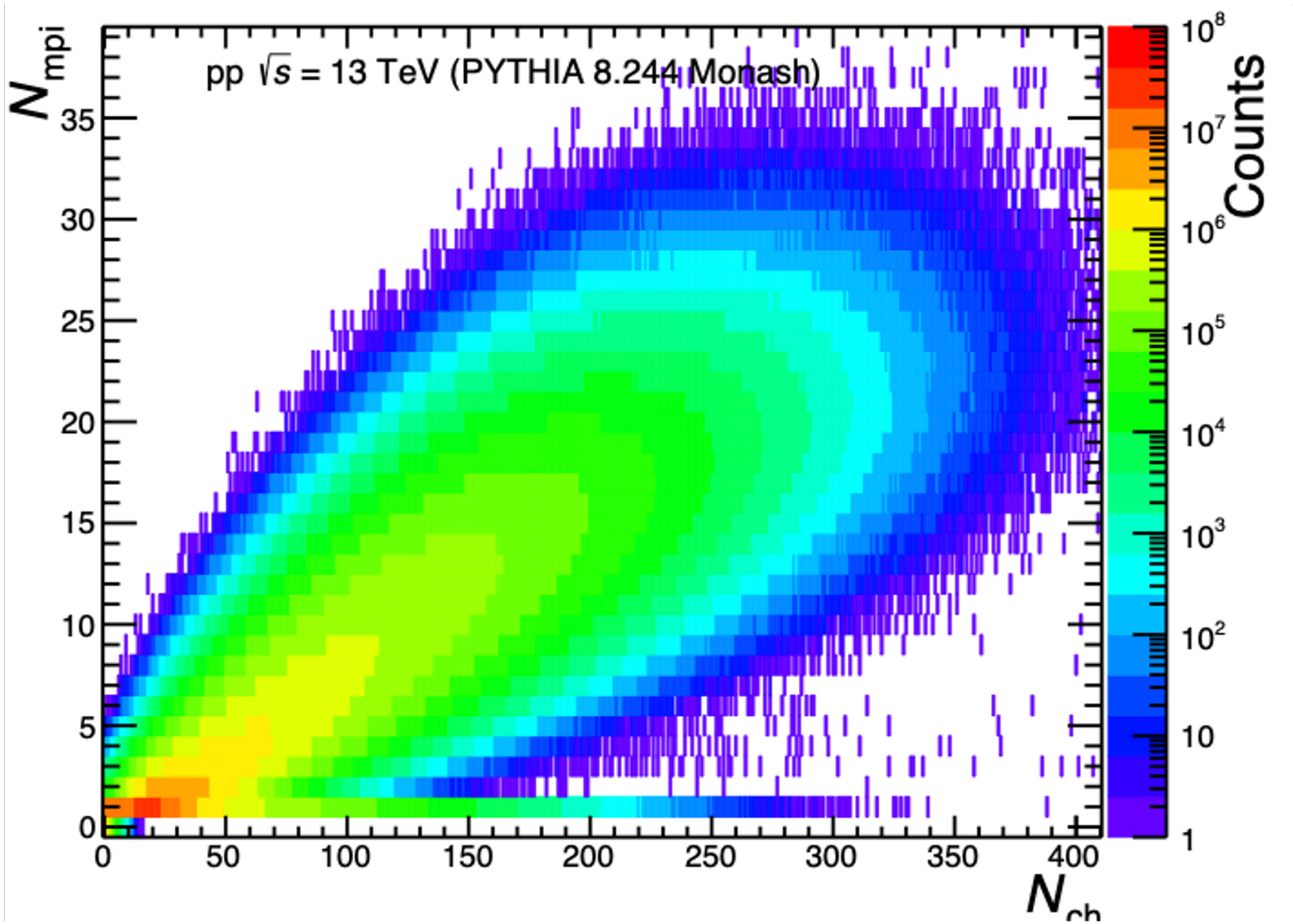
Slightly better discrimination power between CR vs ropes
Good discrimination power between Pythia and AMPT

Summary

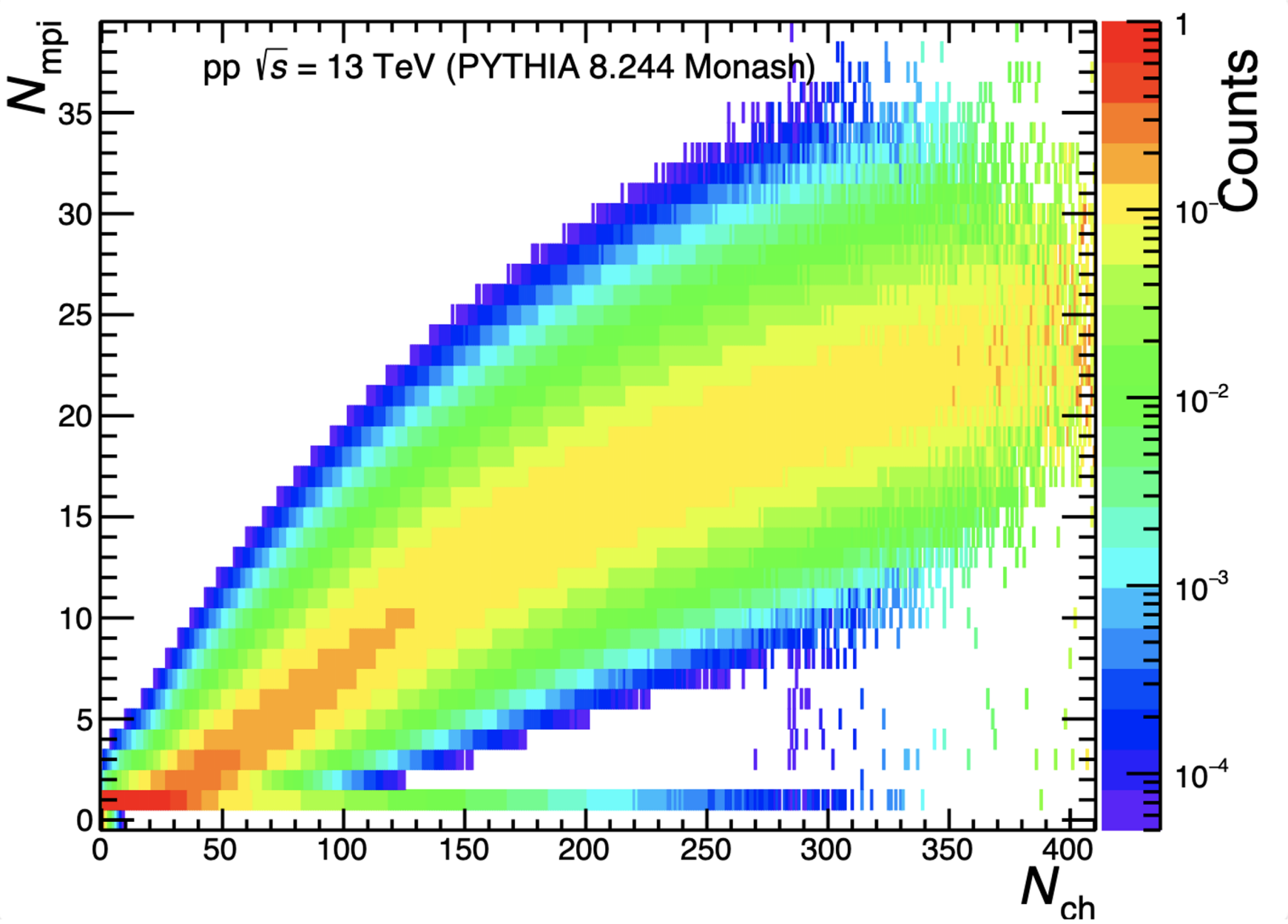
- We define a new event structure - **flattenicity**- to isolate hedgehog events. The quantity **ρ**, which measures how isotopic the event is, has been defined and tested using different MC generators
- MC generators predict different features of hedgehog-like events (di-hadron correlations and average p_T)
- We propose to measure di-hadron correlations, and average transverse momentum, for hedgehog and jetty like events.

The hedgehog events may shed light to the long search for "energy loss" like effects in pp and open a new way to study pp collisions

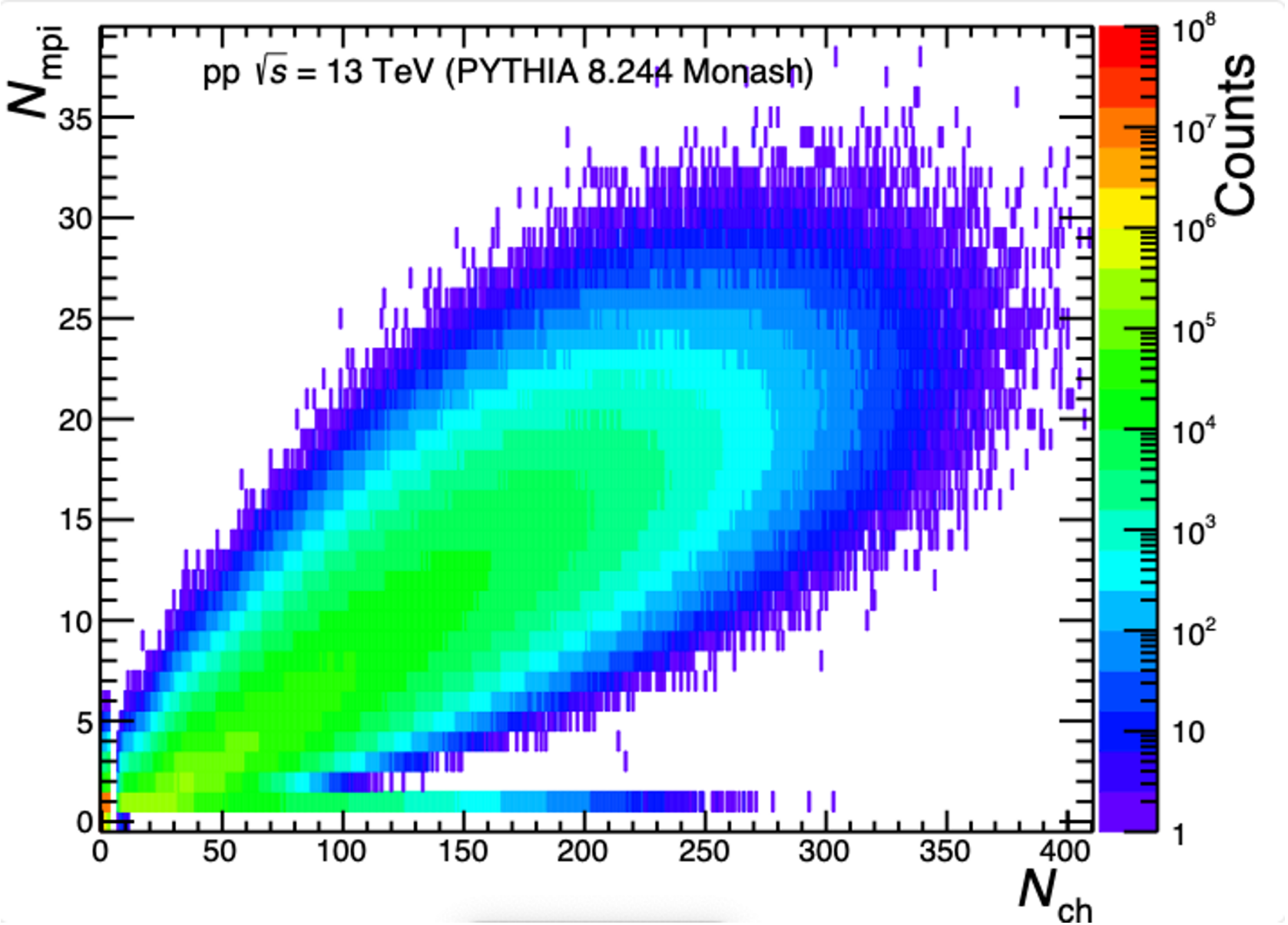
MPI vs Nch (all)



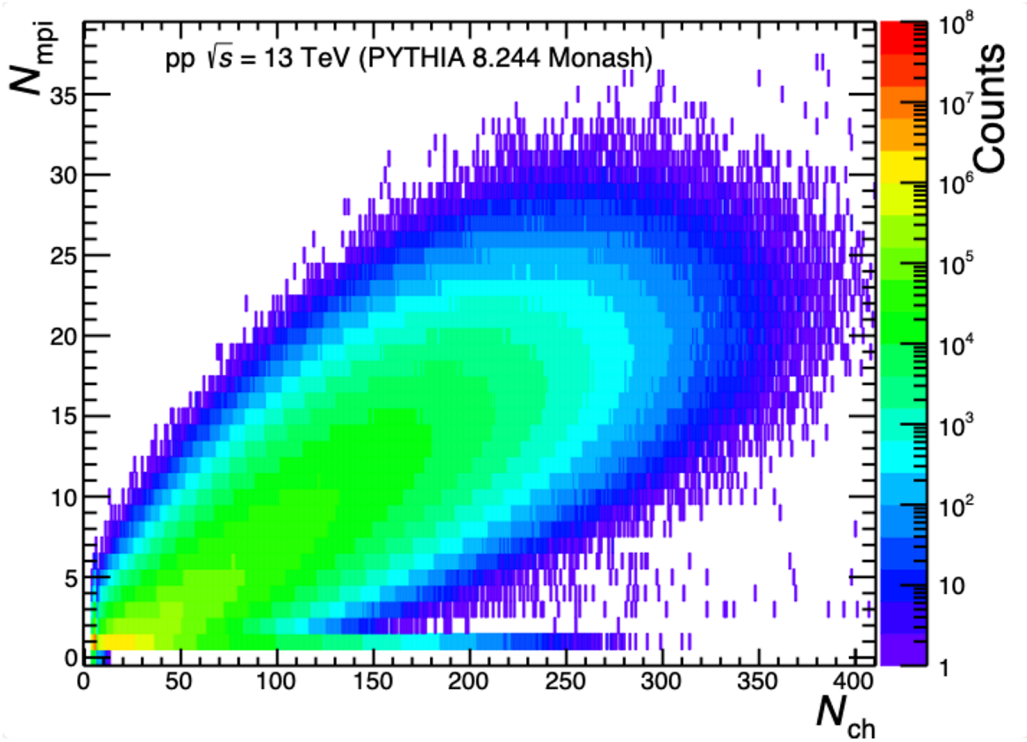
Probability of MPI vs Nch (all)



MPI vs Nch (hedgehog, low rho)



MPI vs Nch (jetty, high rho)



MPI vs Nch (hedgehoge, low rho)