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GuyPai

Instituto de Ciencias Nucleares

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In collaboration with A. Ortiz, P. Christiansen, I.Maldonado and E. Cuautle,

Simulation from D. B. Leinweber, hep-lat/0004025 gluon action density: 2.4 x 2.4 x 3.6 fm





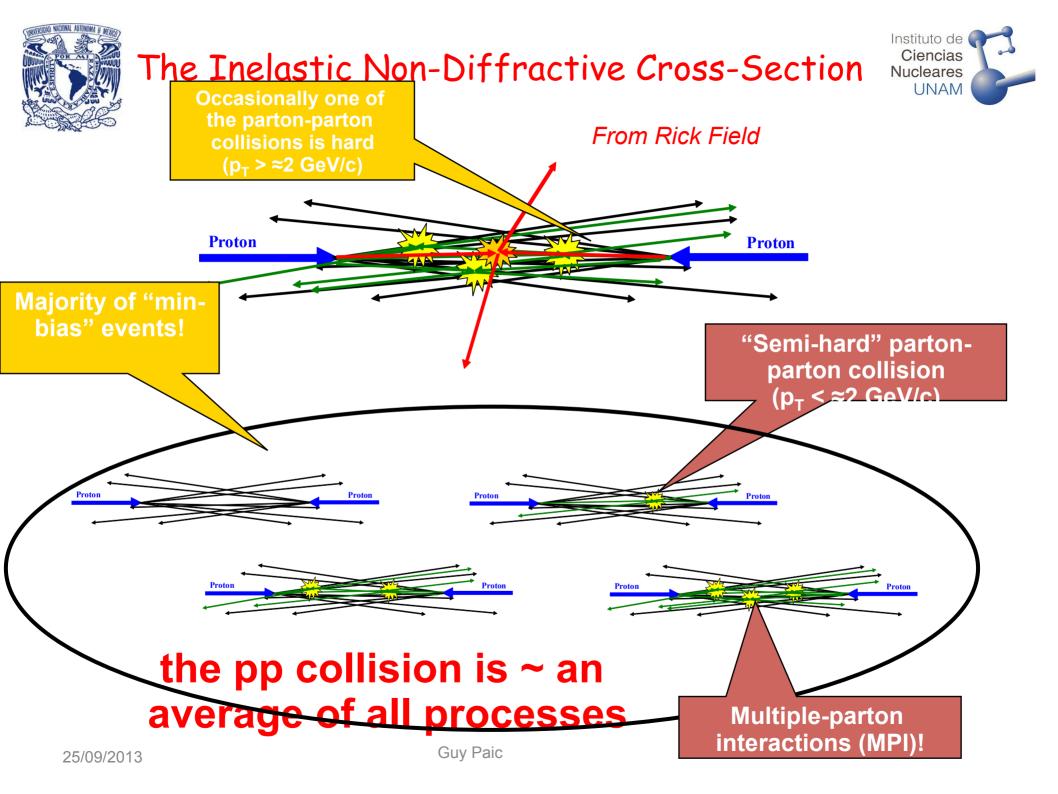
The message

- the LHC has allowed us to investigate the pp collisions in great details: an opportunity we have not yet fully exploited
- In spite of the good statistics we remain steadfastly in the averaging process
- applying the analysis of the event structure of pp events in function of multiplicity may have relevance to heavy ion results on parton energy loss
- The hydrodynamic flow confronted with partonic level interactions like color reconnection in pp sharpens the debate





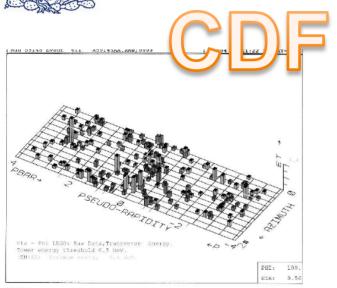
Underlying event in Pythia: MPI (CR), ISR, BR



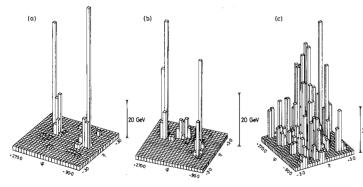


earlier experiments: how wrong we can





Chriss 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.

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),





Introducing the event structure variable transverse velocity



The transverse sphericity

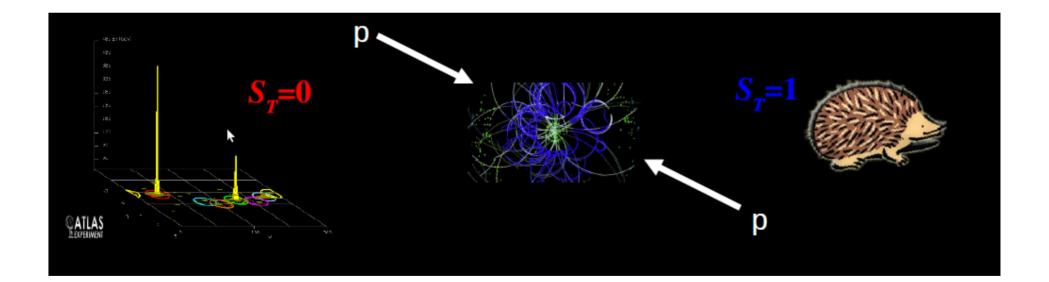


from a pencil to a hedgehog

Transverse Sphericity: $\mathbf{S_{xy}^{L}} = \frac{1}{\sum_{i} p_{Ti}} \sum_{i} \frac{1}{p_{Ti}} \begin{pmatrix} p_{xi}^2 & p_{xi}p_{yi} \\ p_{xi}p_{yi} & p_{yi}^2 \end{pmatrix}$

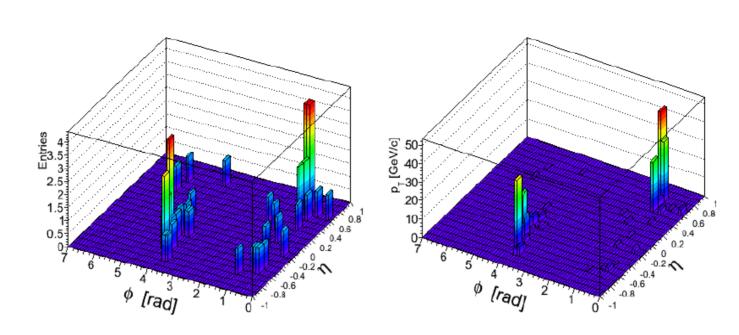
$$S_T \equiv \frac{2\lambda_2}{\lambda_2 + \lambda_1}$$

Remarks: linearized version, IR&C safe





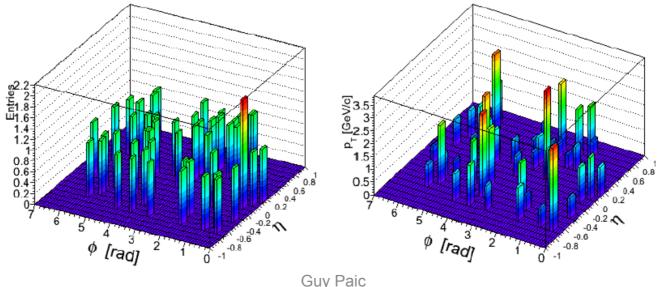


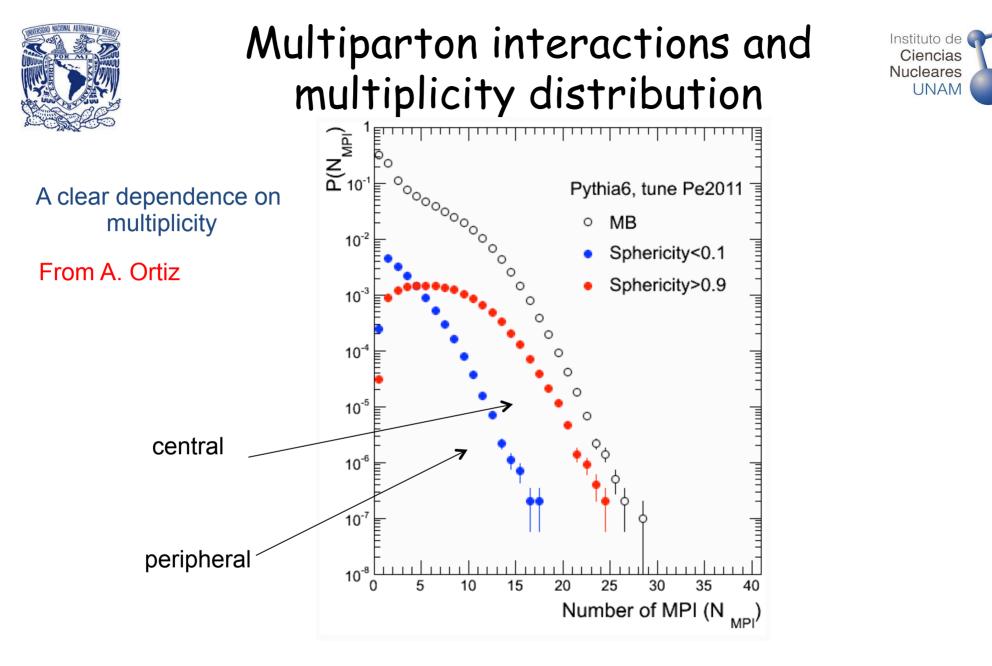




pp @ 7 TeV |η|≤0.8, p_{_}≥0.5GeV/c

Transverse Sphericity: 0.95 Multiplicity: 51

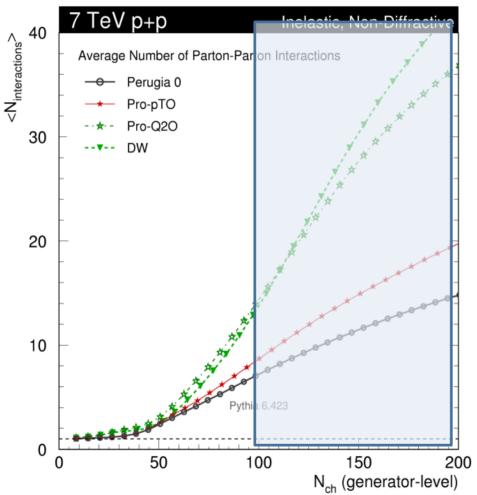




What can be expected in the tail of the MPI/multiplicity? Collectivity?



http://home.fnal.gov/~skands/leshouchesplots/lhc07m-19-1.png



The multiplicity is strongly dependent on the MPI

dependent on the MPI At low multiplicity the effect is negligible.

We need to study the high multiplicities in detail!

Note: the MB is dominated by the low multiplicities. Not seeing the high multiplicities occults the importance of MPI

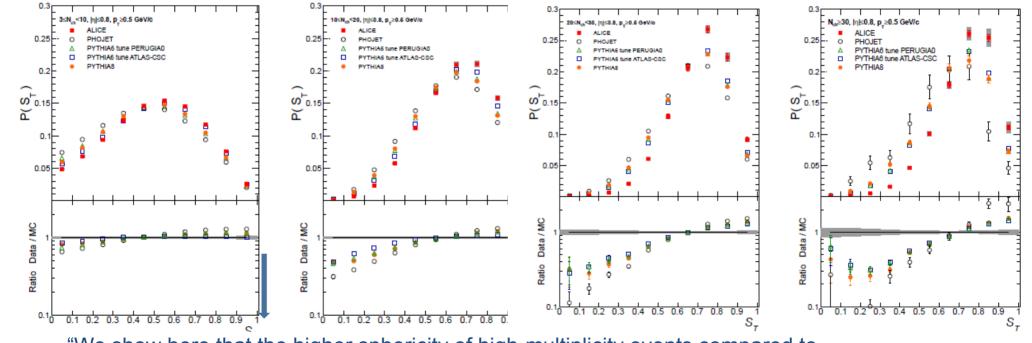




The sphericity spectrum in bins of multiplicity

The general trend with multiplicity is trivial: more multiplicity – > sphericity rises Detail: do the generators reproduce the trend? Actually not! sphericity spectra CROSS the experimental spectrum at ST of ≈ 0.5 at low multiplicity and 0.7 at the highest multiplicities

ALICE Collaboration Eur.Phys.J. C72 (2012) 2124



"We show here that the higher sphericity of high-multiplicity events compared to MC predictions is due to an apparent reduction of the relative jet yields in such type of events" (*from properties in low and high multiplicity events in p-p collisions at 7 TeV CMS Collaboration* CMS-PAS-FSQ-12-022







 Can we talk of "fluctuations" in the pp events or we do have two very distinct mechanisms which may be connected with the number of multiparton interactions and or centrality dependence of the pp collisions (like in heavy ions)?





The next big question: is flow existing in pp collisions?

Ortiz et al. Phys. Rev. Lett. 111, 042001 (2013)

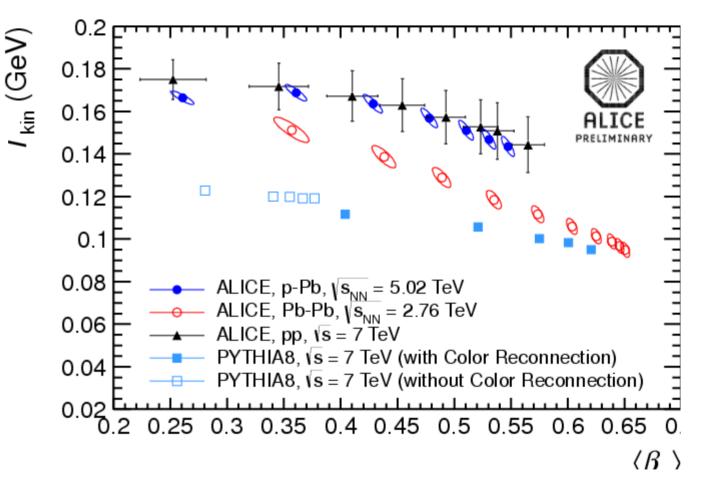




From pp to PbPb not much change!

Blast wave model: thermalized volume elements, expanding in a common velocity field Parameters: T_{kin} , $\beta_T = \beta_S \cdot (r/R)^n$

Can the theory coherently explain???





Color reconnection



In Pythia, the final step at parton level before the hadronization is the color **reconnection** CR, its aim is to describe the hadronization of a many parton system in a single event with multiple hard sub collisions.

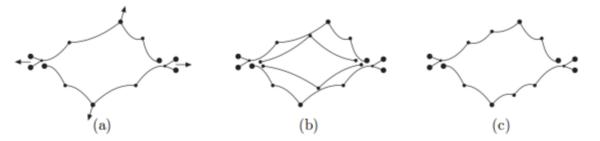


Fig. 2. (a) In a hard gluon-gluon subcollision the outgoing gluons will be colourconnected to the projectile and target remnants. Initial state radiation may give extra gluon kinks, which are ordered in rapidity. (b) A second hard scattering would naively be expected to give two new strings connected to the remnants. (c) In the fits to data the gluons are colour reconnected, so that the total string length becomes as short as possible.

Toy model of (non-perturbative) color reconnections, applicable to any final state

> at hadronisation time, each string piece has a probability to interact with the vacuum / other strings:

- $P_{reconnect} = 1 (1-\chi)^n$ $\chi =$ strength parameter: fundamental reconnection probability (free parameter)
- n = number of multiple interactions in current event (\sim counts # of possible interactions)

G. Gustafson, Acta Phys.Polon.B40:1981-1996,2009

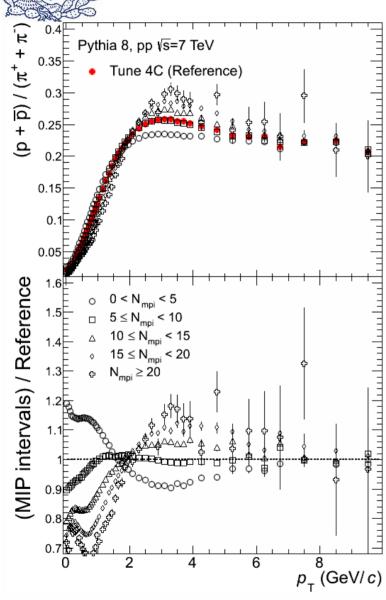




Effect of multiparton interactions and color reconnection on observables with identified hadrons

Guy Paic

$p/\pi vs p_T$ and MPI



The dependence with MPI (multiplicity) resembles the evolution of the p/pi vs p_{T} from peripheral to central Pb-Pb collisions. p/H Krakow, 0-5% HKM, 0-5% Fries et al., 0-5% 0.8 0.6 **→ 0-5%** 0.4 → 20-30% 0.2 0.5 0 1.5 2 2.5 3 3.5 4.5 p₁ (GeV/c)

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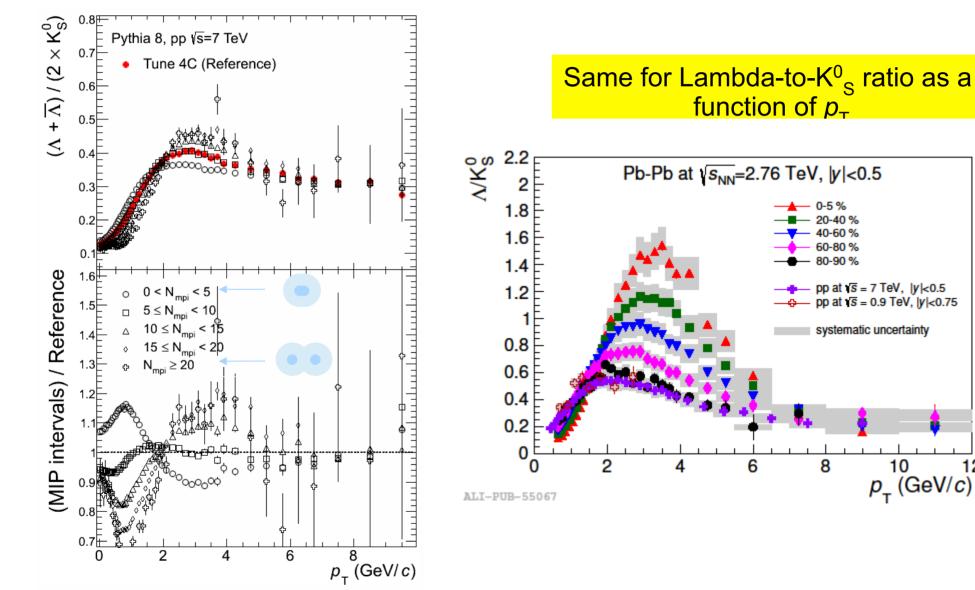
ALICE Collaboration, http://arxiv.org/abs/1303.0737



Λ/K_{S}^{0} vs p_{T} and MPI



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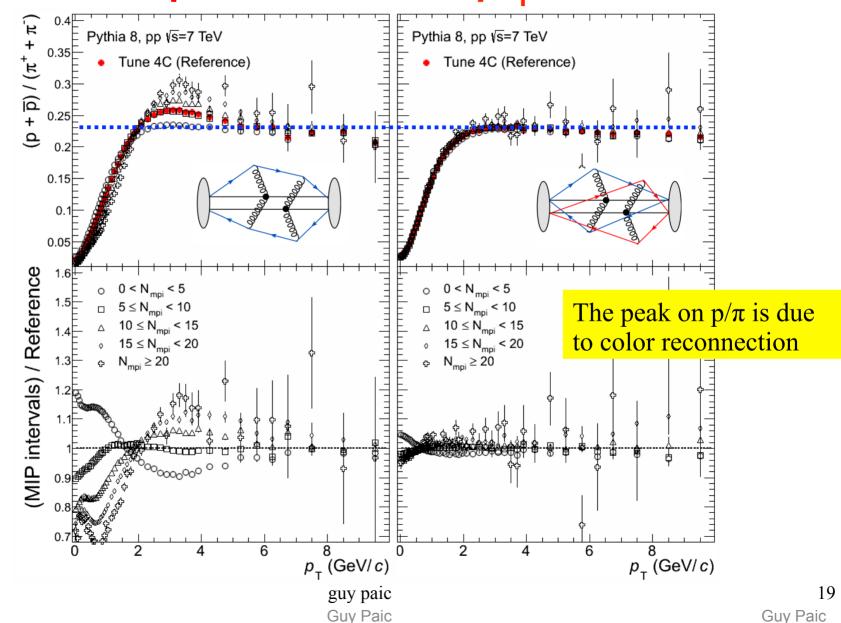


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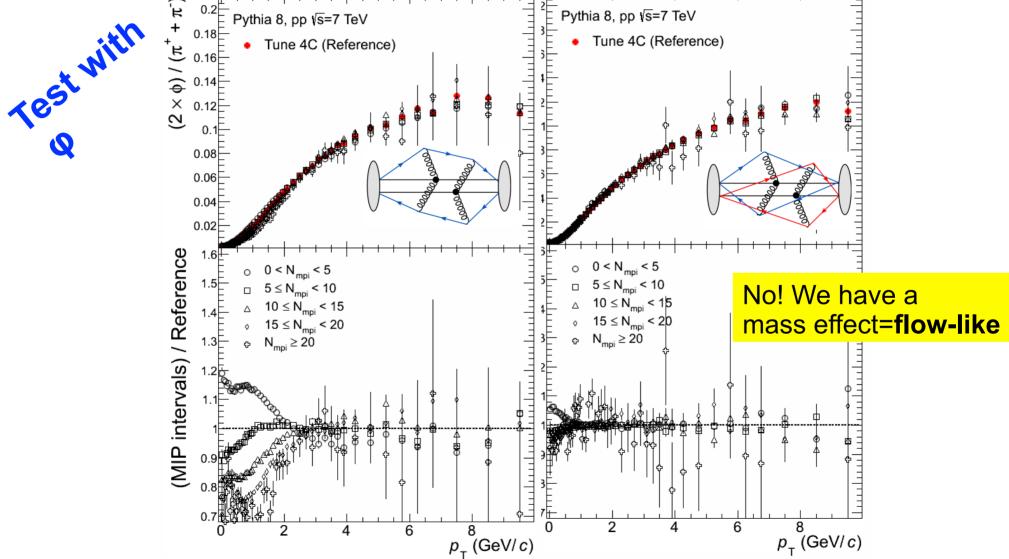
25/09/2013

Effect of CR on the p/π ratio vs p_{τ}











Other observables with identified hadrons

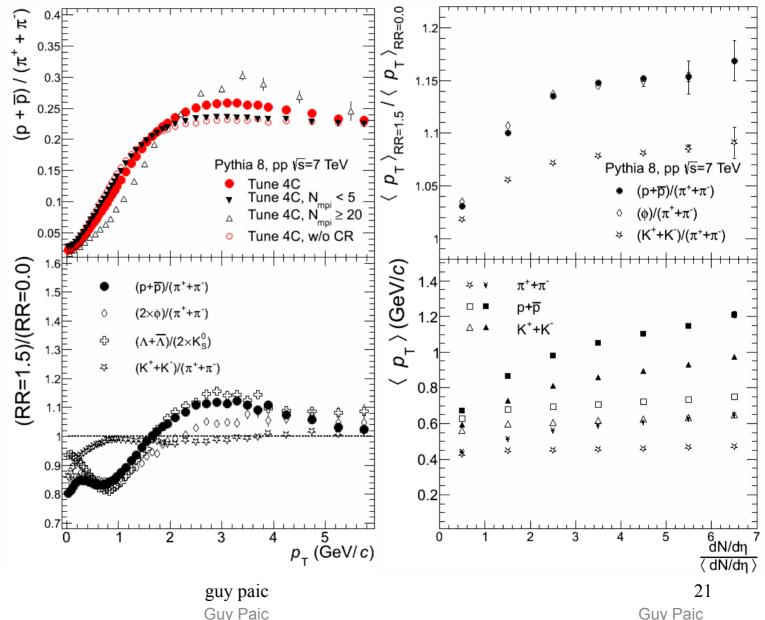


The behavior of the double ratios indicates that we have a mass effect since the ϕ/π and the p/ π ratios exhibit a much larger "bump" than the K/ π ratio.

We know that Pythia underestimates the strange particle production, specially at intermediate p_{T} . To avoid this problem we can look at the $< p_{T} > vs$ Nch.

4/17/2013

25/09/2013



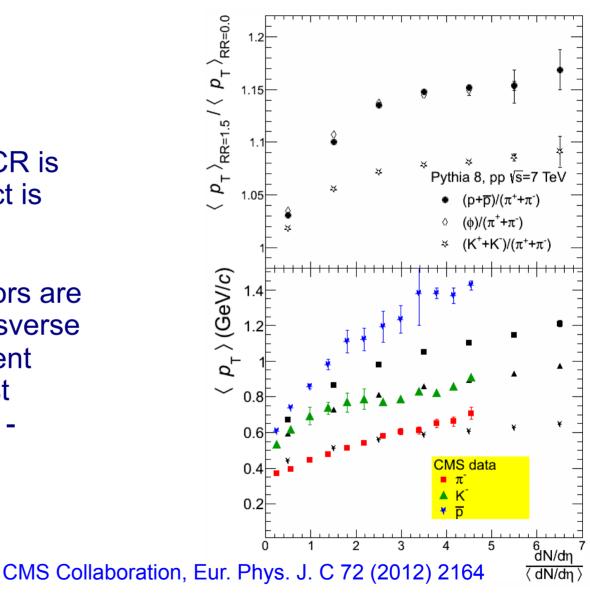


$< p_{T} >$ as a function of multiplicity



Pythia describes the data when CR is implemented, *i.e.* a flow-like effect is necessary.

So far we know that MC generators are too hard, very jetty-like. See transverse sphericity as a function of the event multiplicity. More MPI activity best describes data -> more isotropic ->larger flow-like effect.









- For the first time (unknown to the author of Pythia 8) we have proven that color reconnection does produce effects similar to flow but only up to a limit in pt.
- The effect of the CR does weaken at higher momenta as also requested by the data,
- The fact of having some kind of collectivity without the introduction of often complicated hydrodynamics arguments (thermalisation, temperature time sequence etc) seems interesting and its application to heavy ion collisions could be full of surprises!!





speculations

- we seem to have pinpointed a mechanism that can generate flow like patterns. However a priori I do not see a mechanism that prevents having something similar – a color reconnection that throws particles in eta.
- Ridge? The ridge spectra lie in the same pt range where CR is present





- The similarities observed in the p/pi and T-beta behavior asks an obvious question: is all what we have seen and liked so far in heavy ion already present in pp!?
- One of the "sacred cows" of the field is the parton energy loss...
- If one takes a view from the side of pp one may say that the effect is already seen in pp!!

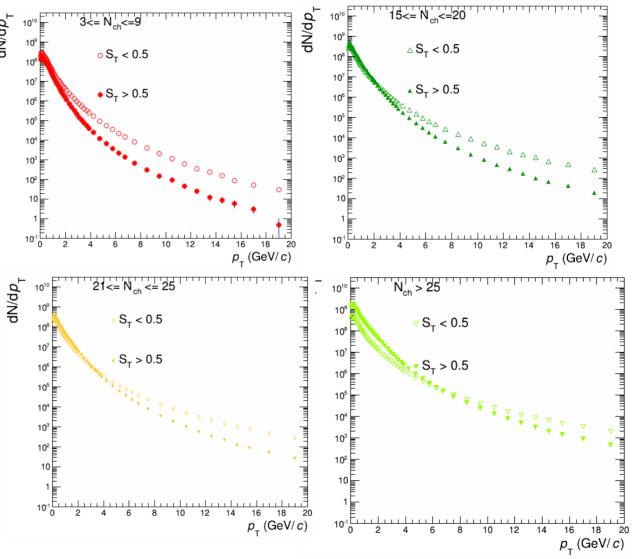




Comparison of high and low sphericity spectra in Pythia 8 4C

By now it is well established by LHC experiments that in high multiplicity events the jets are **suppressed** at high multiplicities in pp collisions

We have made a simulation with Pythia 8. The simulations show the same trend although in real data it is yet more marked...



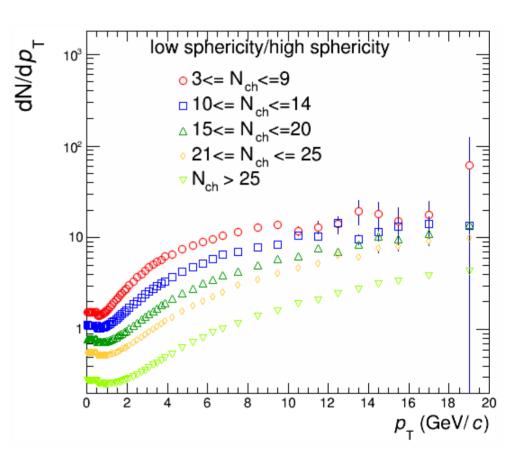


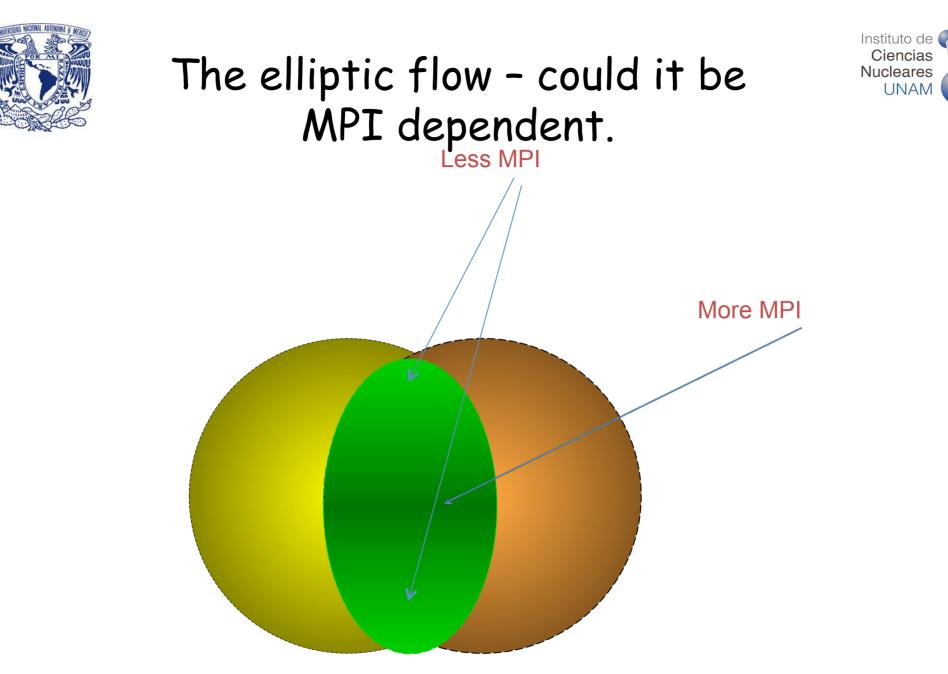


Ratio of low sphericity to high sphericity pt spectra

The ratios show an interesting pattern that bears some similarities to what is observed in Heavy ion collisions and is attributed to parton energy loss

Are we witnessing two different mechanisms of suppression or we witness the same in pp and heavy ions???



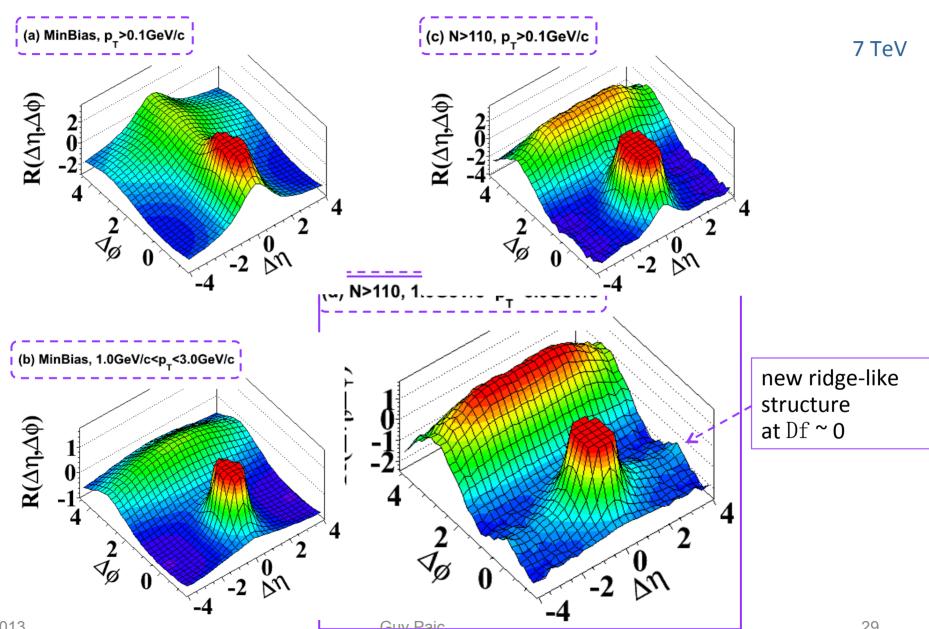


One should take in account that also the initial state is different with respect to the number of interaction if a collective effect like MPI and color reconnection takes place it should be taken into account. ^{25/09/2013} Guy Paic



Long-range near-side angular correlations









Final comments

- We have seen that the pp collisions should be studied not only in minimum bias and/or multiplicity – the event shapes should be taken into account
- Some features of the heavy ion collisions can be observed in the pp collisions at high multiplicity
- The pp collisions with a good statistics should be planned for the next LHC run in 2015 in good conditions with low pileup and high stats top reach higher multiplicities

