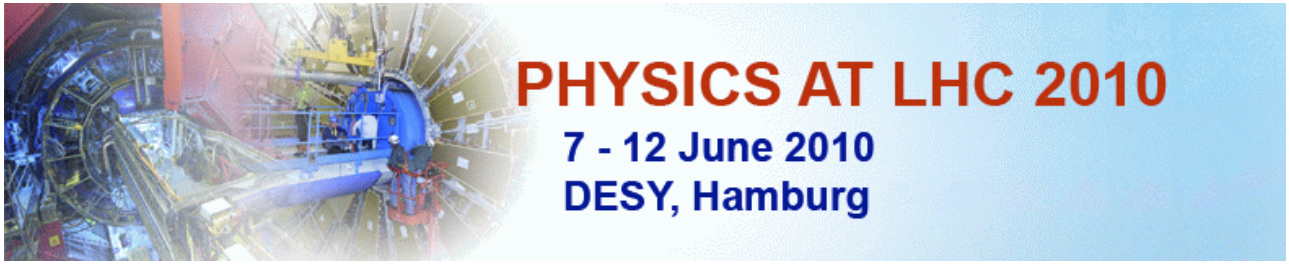
Cluster properties from two-particle angular correlations at CMS

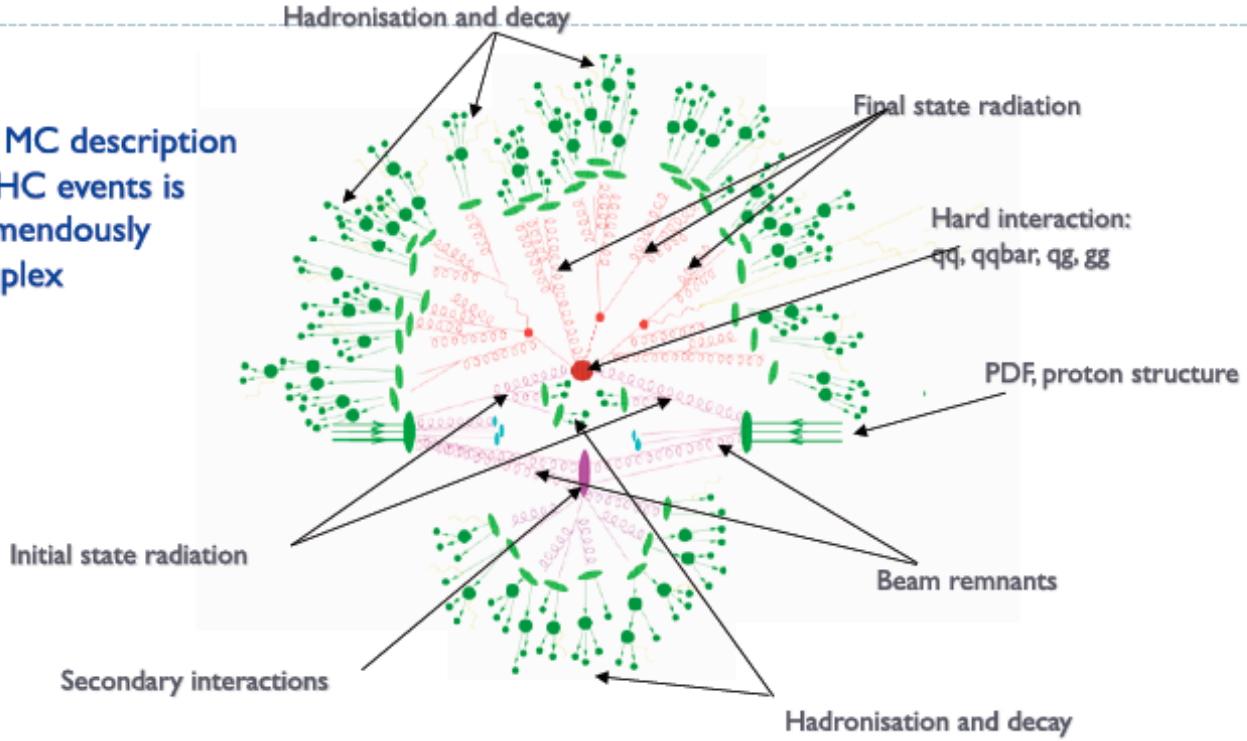
Elisabetta Gallo (INFN Firenze)
On behalf of the CMS Collaboration



A proton-proton collision at LHC

Physics requirements: basics

The MC description of LHC events is tremendously complex



This is a schematization to be able to cut down the problem in pieces and model them in a different way. The "pieces" are correlated !

A proton-proton collision at LHC

Physics requirements: basics

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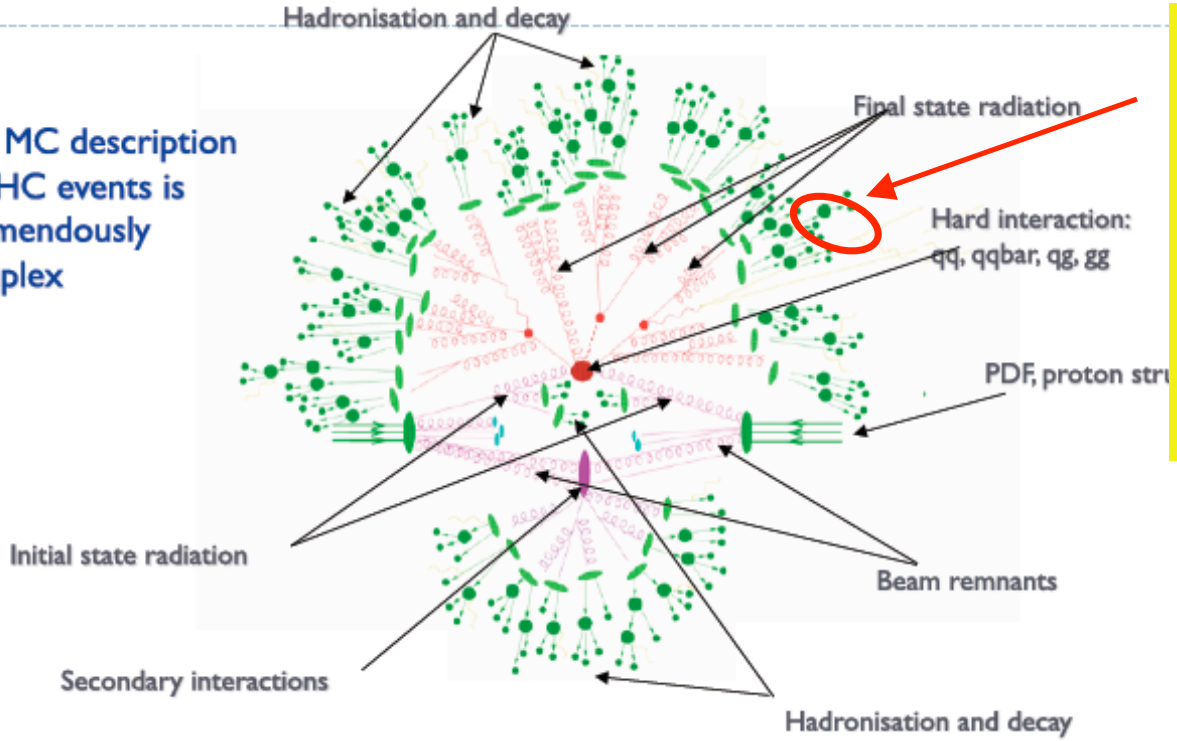


This is a schematization to be able to cut down the problem in pieces and model them in a different way. The "pieces" are correlated !

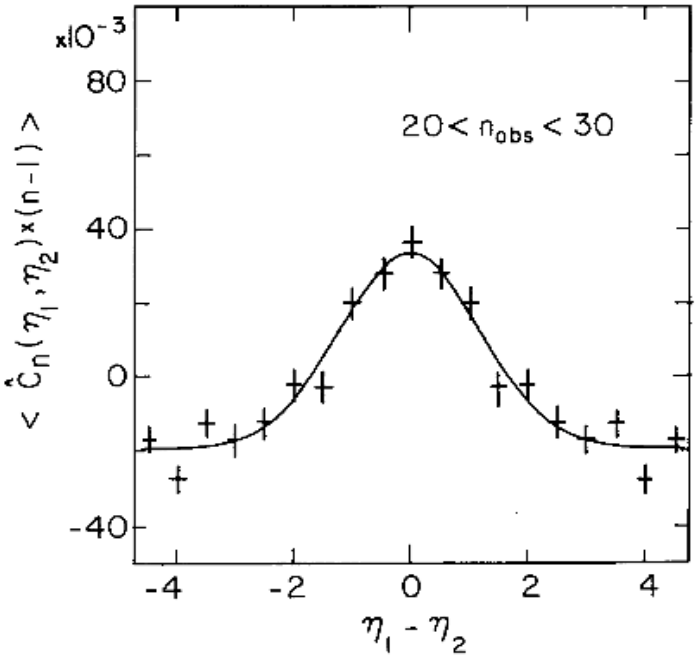
4 7th MCNet Workshop 14/1/2010

Look at two-particle correlations in pseudo-rapidity

Two-particle pseudorapidity correlation functions at colliders

- Extensive studies done at ISR and SPS
- More recently analysis repeated by Phobos in pp collisions at 200 GeV and in heavy-ions collisions
- a quark-gluon plasma could show different properties in the correlations
- Characterize it in terms of a simple ansatz, the Independent Cluster Model (ICM)

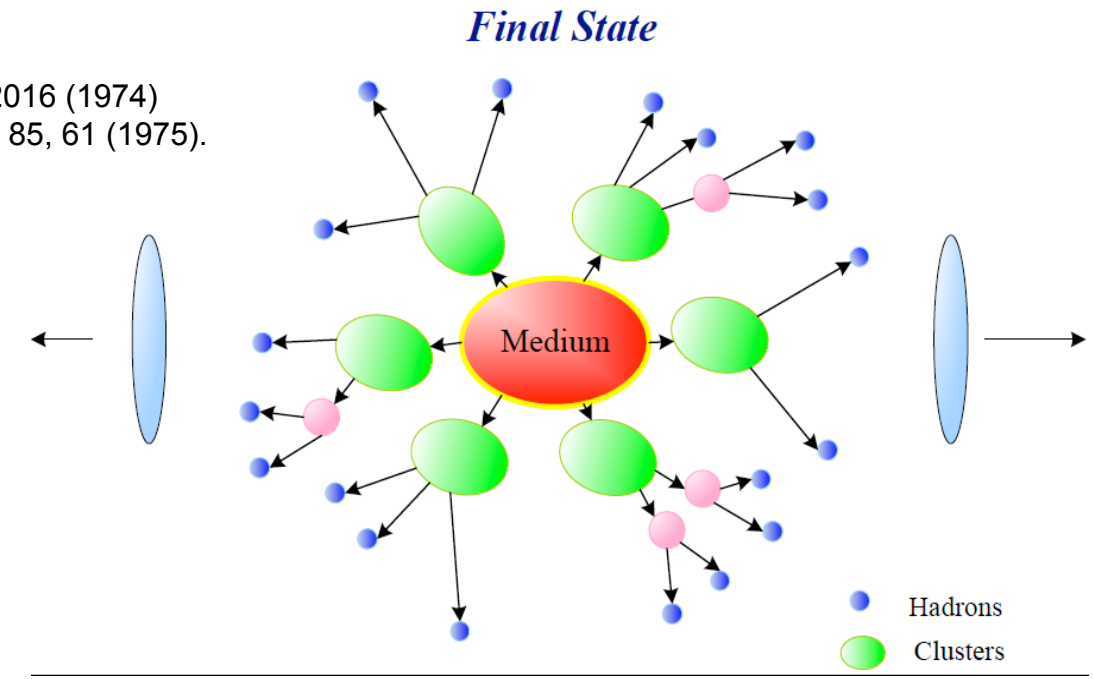
UA5: Phys.Lett.B123:361,1983



UA5: Z. Phys. -Particle and Fields C 37, 191 (1988)
ISR: Nucl. Phys. B 86, 201 (1975)
ISR: Nucl. Phys. B 155, 269 (1979).

The Independent Cluster Model

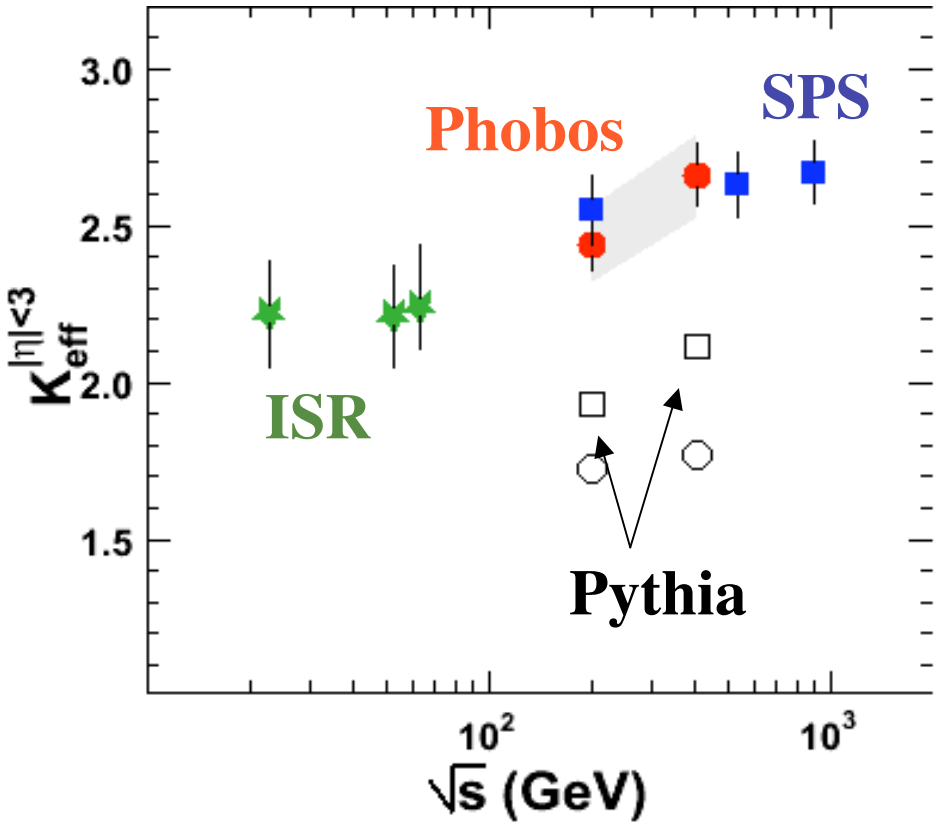
C.Quigg, Phys. Rev. D 9, 2016 (1974)
E. L. Berger, Nucl. Phys. B 85, 61 (1975).



- Clusters are produced independently
- They decay to hadrons in their c.m.s.
- Only two parameters (cluster size and width) to characterize the short-range correlations

The Independent Cluster Model

Energy dependence of cluster size (K_{eff})

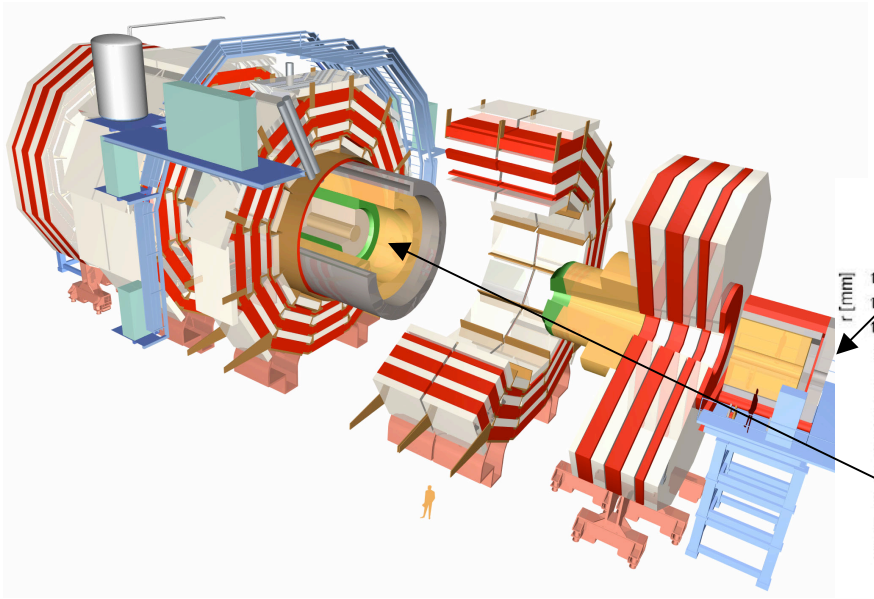


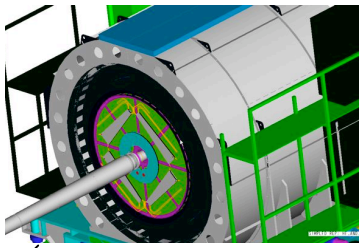
In this talk, CMS results at 900 GeV, 2.36 TeV and 7 TeV

CMS data sample

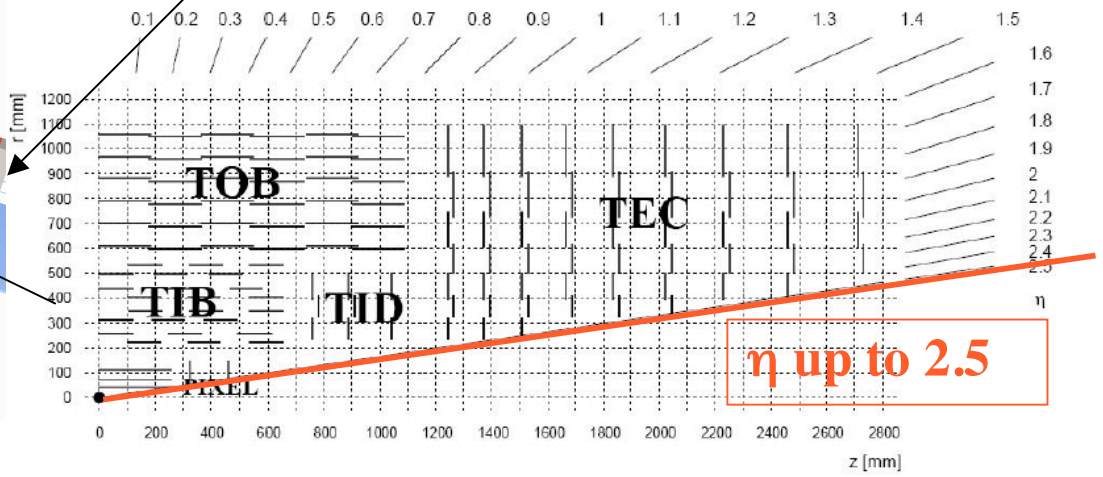
- Non Single Diffractive MinBias data at 900 GeV (~ 170K events), at 2.36 TeV (~11K events) and 7 TeV (~ 150K events)

- Tracks are selected in the kinematic range $0.1\text{GeV}/c<p_T<5\text{GeV}/c$ & $|\eta|<2.4$, at least 3 tracks in the event



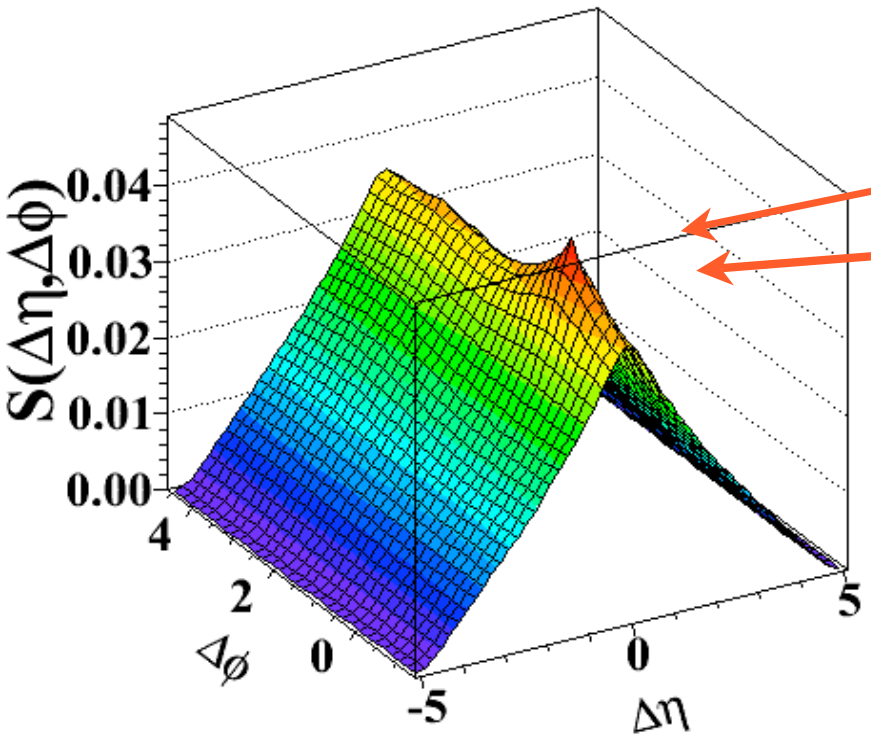


BSC and HF, used to trigger and select NSD events

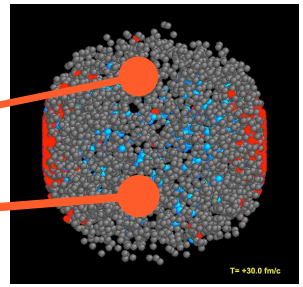


Tracker: selection of charged tracks

Signal distribution



Event 1

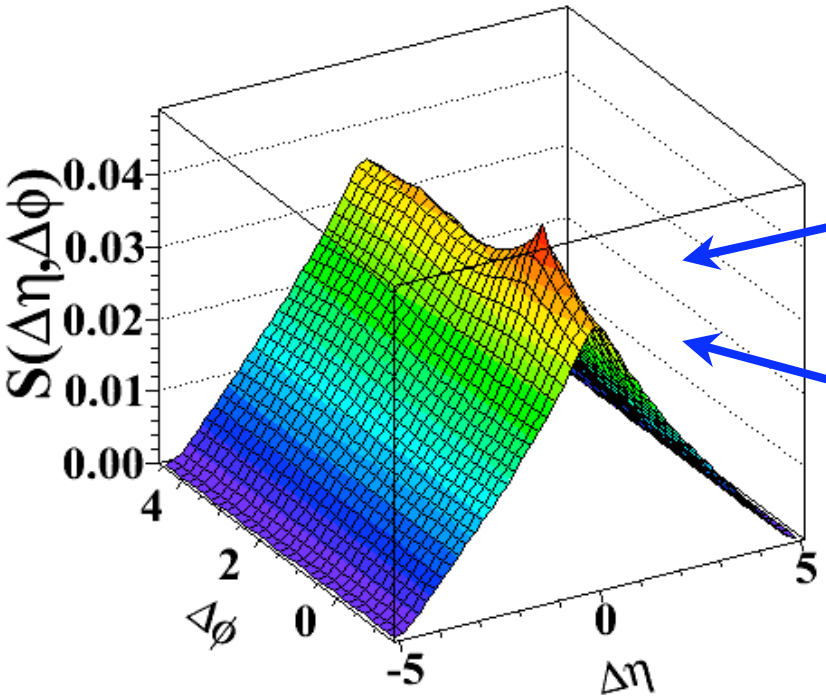


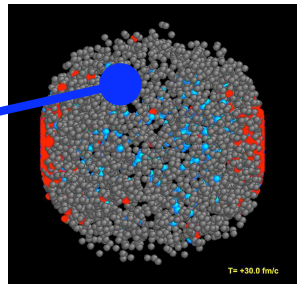
$$\Delta\eta = \eta_1 - \eta_2,$$
$$\Delta\varphi = \varphi_1 - \varphi_2$$

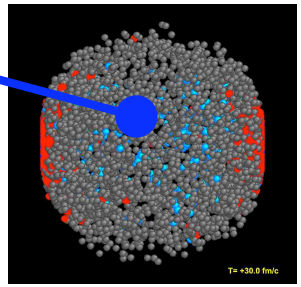
N: total multiplicity
No distinction between
Particle 1 and 2

$$S_N(\Delta\eta,\Delta\varphi) = \frac{1}{N(N-1)} \frac{d^2 N^{signal}}{d\Delta\eta d\Delta\varphi}$$

Background/Reference distribution







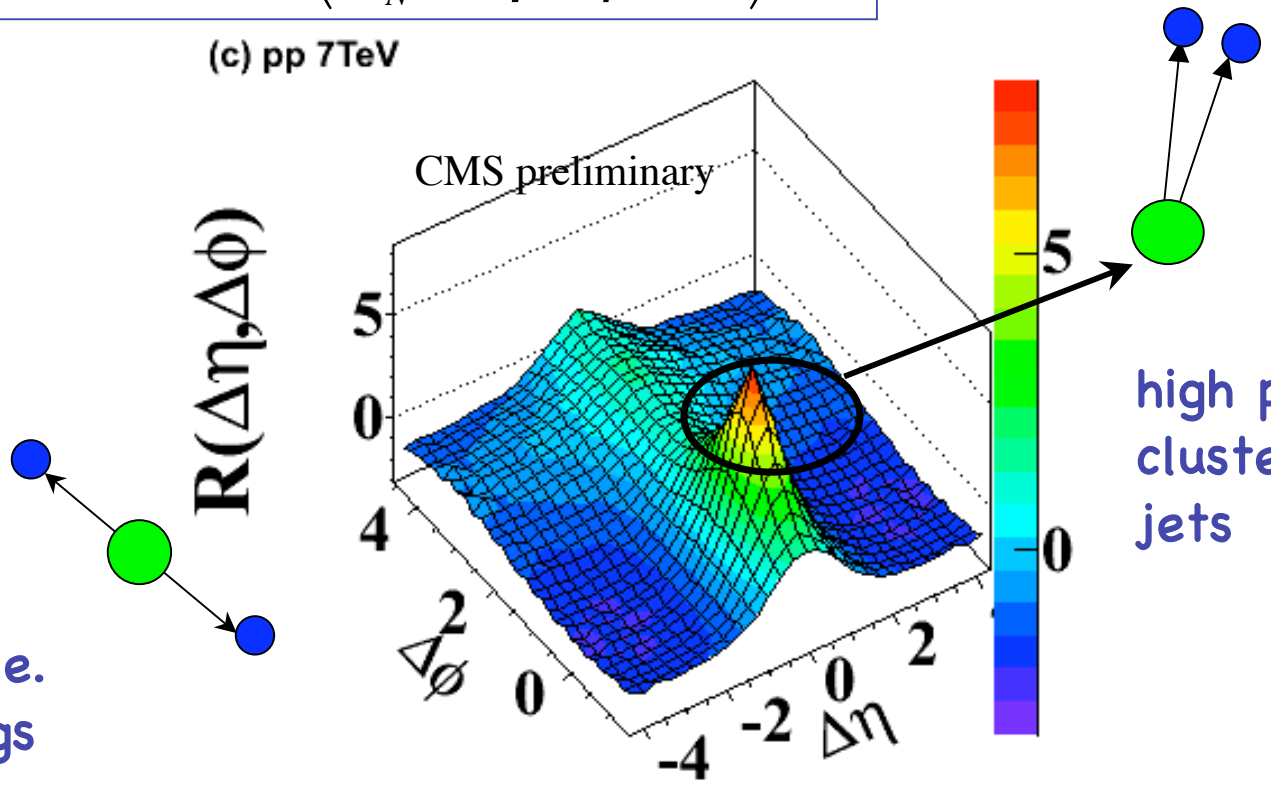
$$B_N(\Delta\eta,\Delta\varphi) = \frac{1}{N^2}\frac{d^2N^{bkg}}{d\Delta\eta d\Delta\varphi}$$

Events are mixed randomly in bins of vertex (0.5 cm) and multiplicity

2D Correlation

$$R(\Delta\eta,\Delta\varphi) = < (N-1)\left(\frac{S_N(\Delta\eta,\Delta\varphi)}{B_N(\Delta\eta,\Delta\varphi)} - 1\right) >_N$$

(Convention used by ISR, UA5 and Phobos)



high p_t clusters, i.e. jets

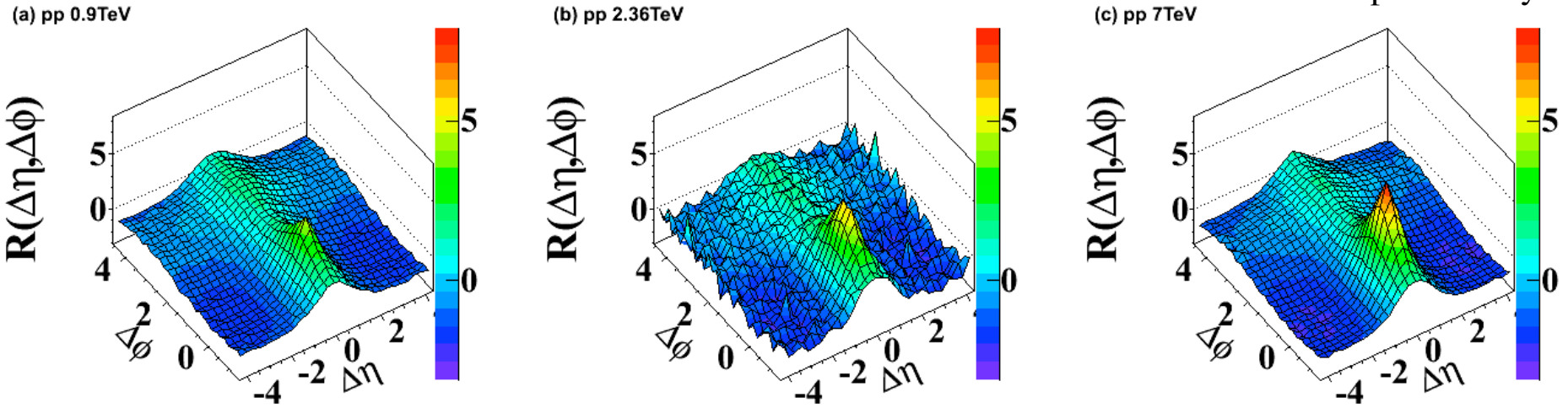
low p_t clusters, i.e. QCD strings

The ratio is calculated in each multiplicity bin. Data corrected for selection and trigger efficiency, many systematics cancel in the ratio

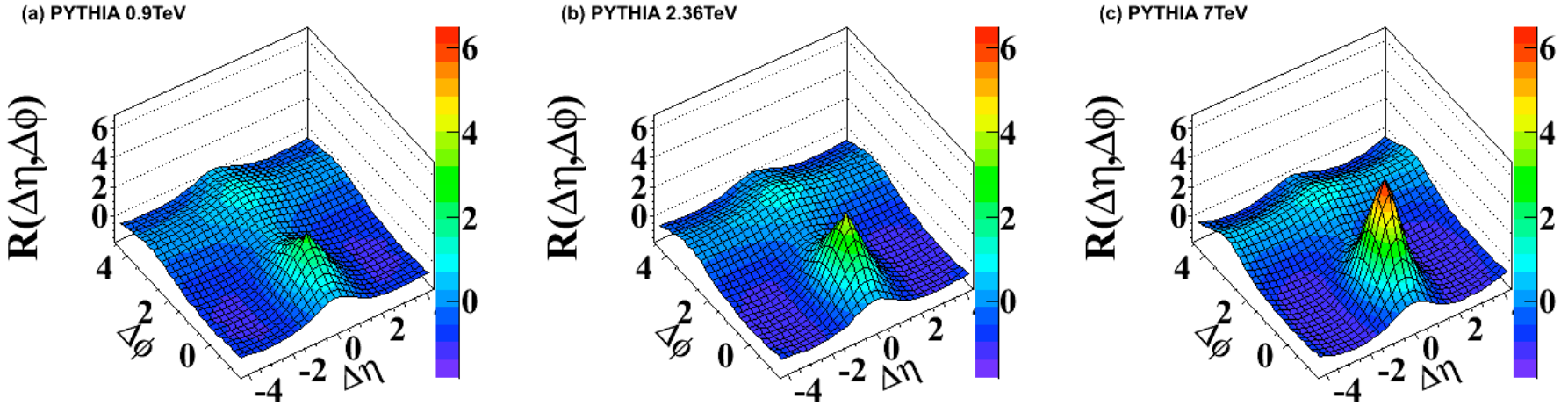
2D Correlation

CMS Data at the 3 c.m. energies

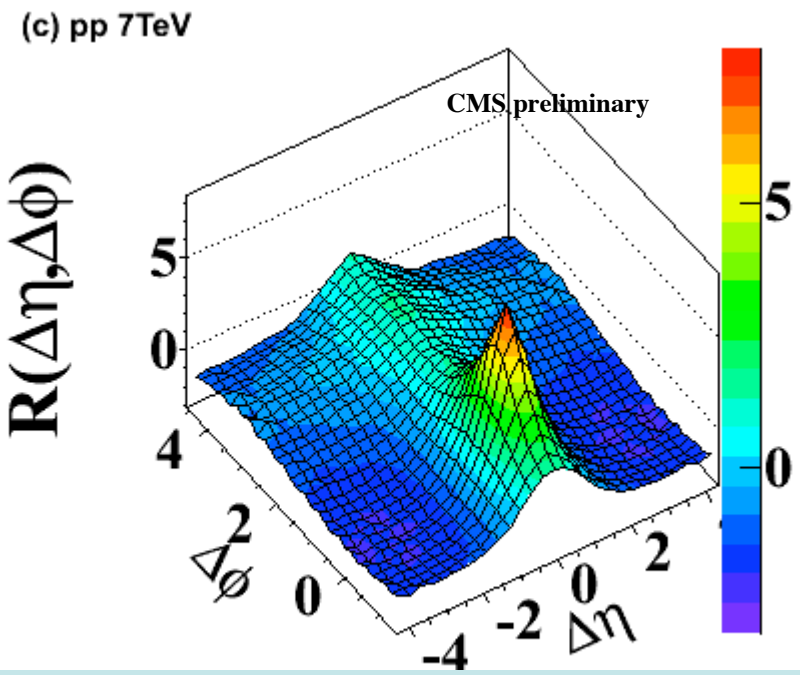
CMS preliminary



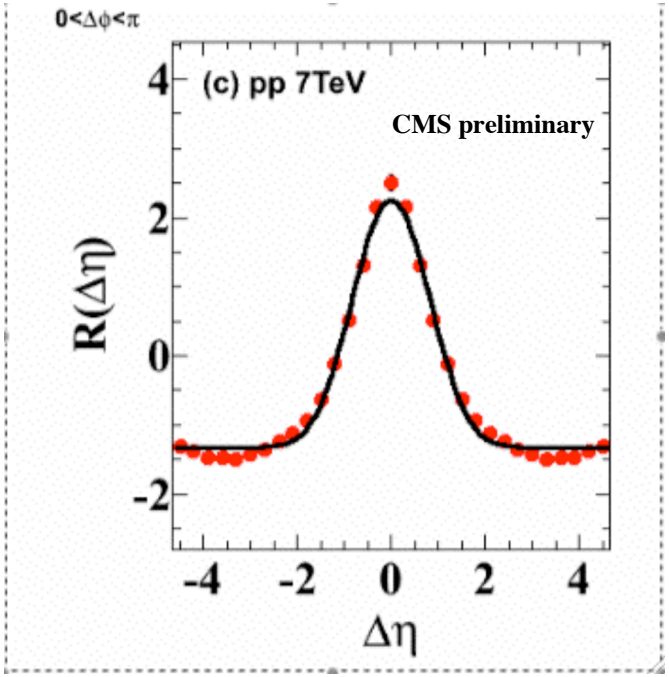
Pythia (D6T) reproduces qualitatively the effect



1D Correlation



averaged over $|\Delta\phi|$ between 0 and π



Can be described in the ICM:

$$R(\Delta\eta) = (K_{eff} - 1)\left[\frac{\Gamma(\Delta\eta)}{B(\Delta\eta)} - 1\right] \qquad \Gamma(\Delta\eta) \propto \exp\left(-\frac{(\Delta\eta)^2}{4\delta^2}\right)$$

(K. Eggert et al., Nucl. Phys. B 86:201, 1975)

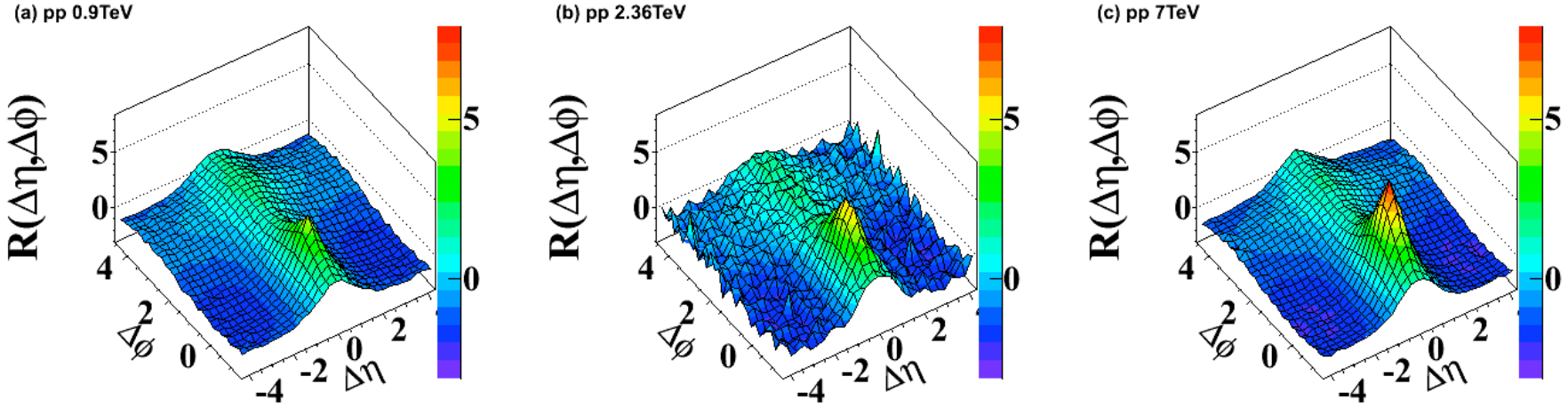
Cluster size (multiplicity)

Cluster width (in $\Delta\eta$)

1D Correlation

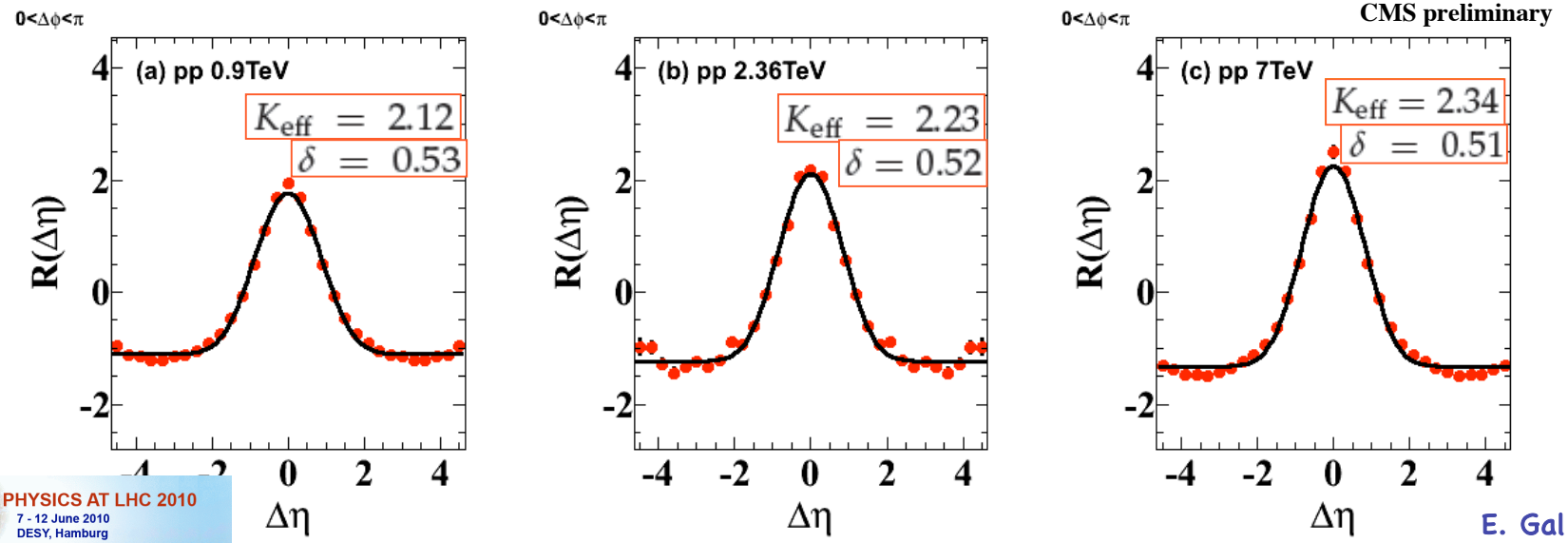
Data at the 3 c.m. energies

CMS preliminary

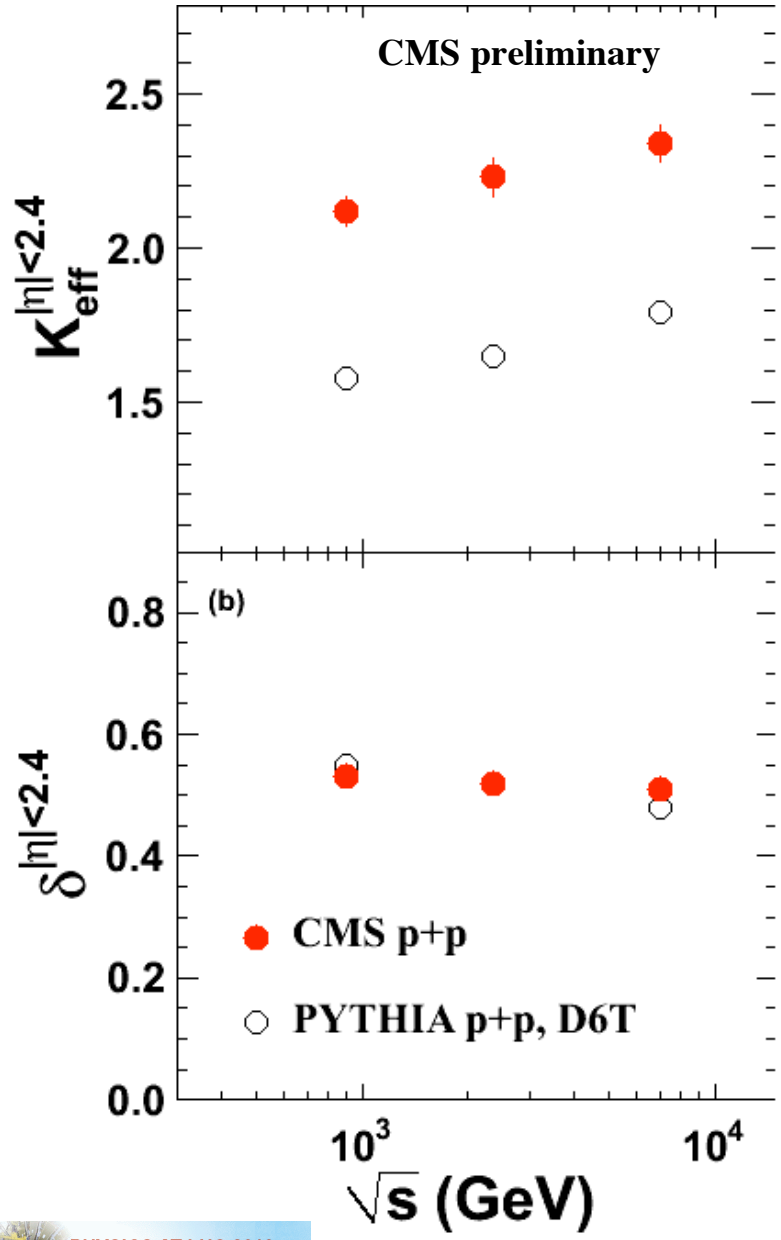


On average every 2-3 charged particles are produced correlated

CMS preliminary



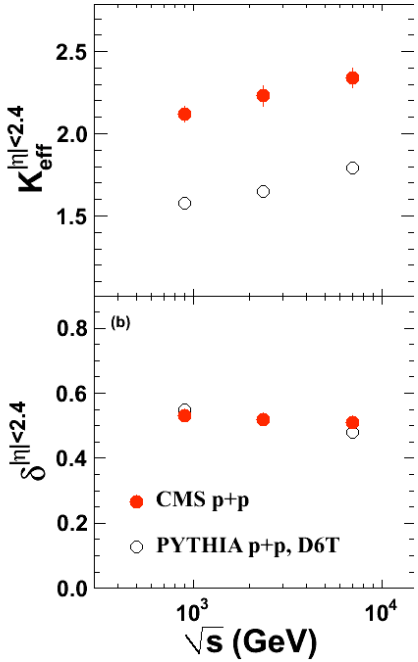
Cluster size and width



- Cluster size K_{eff} increases with energy, Pythia has the right trend but is lower
- Cluster width δ remains constant and is reproduced by Pythia

Cluster size and width

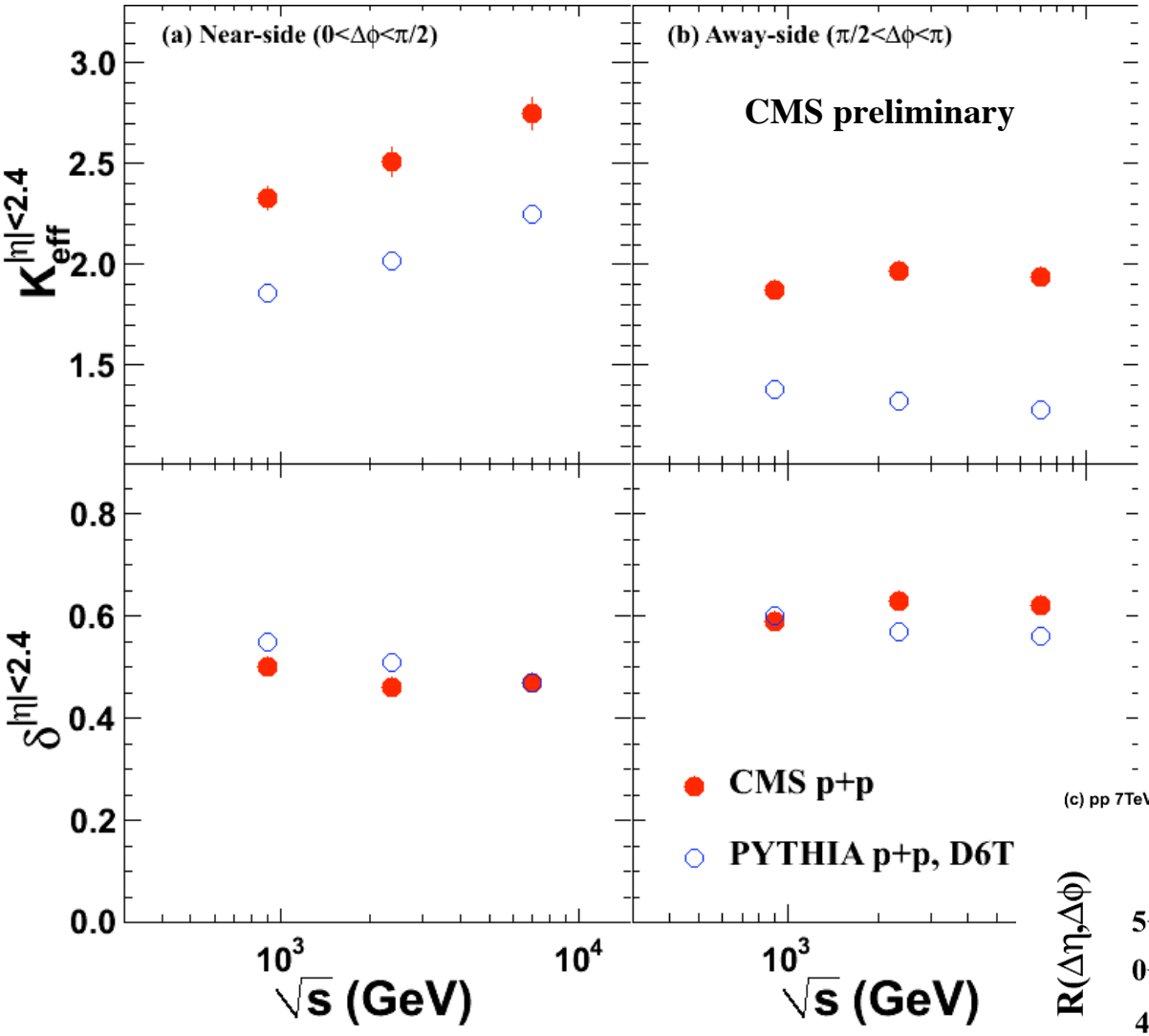
	Systematic uncertainties [%]	
Source	α	δ
Correction on event selection efficiency	2.6	2.8
Correction on tracking/ acceptance efficiency and fake rate	1.3	1.4
Track quality cuts	1.2	1.0
Model dependence on the corrections	2.6	1.3
Total systematic uncertainties	4.1	3.5



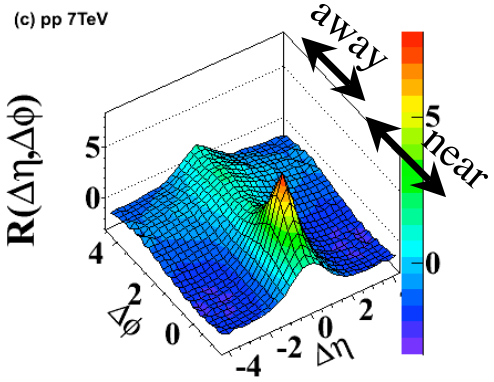
($\alpha=K_{eff}-1$)

$\sqrt{s}$	K_{eff}	δ
0.9 TeV	$2.12 \pm 0.01\,(\text{stat.}) \pm 0.05\,(\text{syst.})$	$0.53 \pm 0.01\,(\text{stat.}) \pm 0.02\,(\text{syst.})$
2.36 TeV	$2.23 \pm 0.02\,(\text{stat.}) \pm 0.05\,(\text{syst.})$	$0.52 \pm 0.01\,(\text{stat.}) \pm 0.02\,(\text{syst.})$
7 TeV	$2.34 \pm 0.01\,(\text{stat.}) \pm 0.06\,(\text{syst.})$	$0.51 \pm 0.01\,(\text{stat.}) \pm 0.02\,(\text{syst.})$

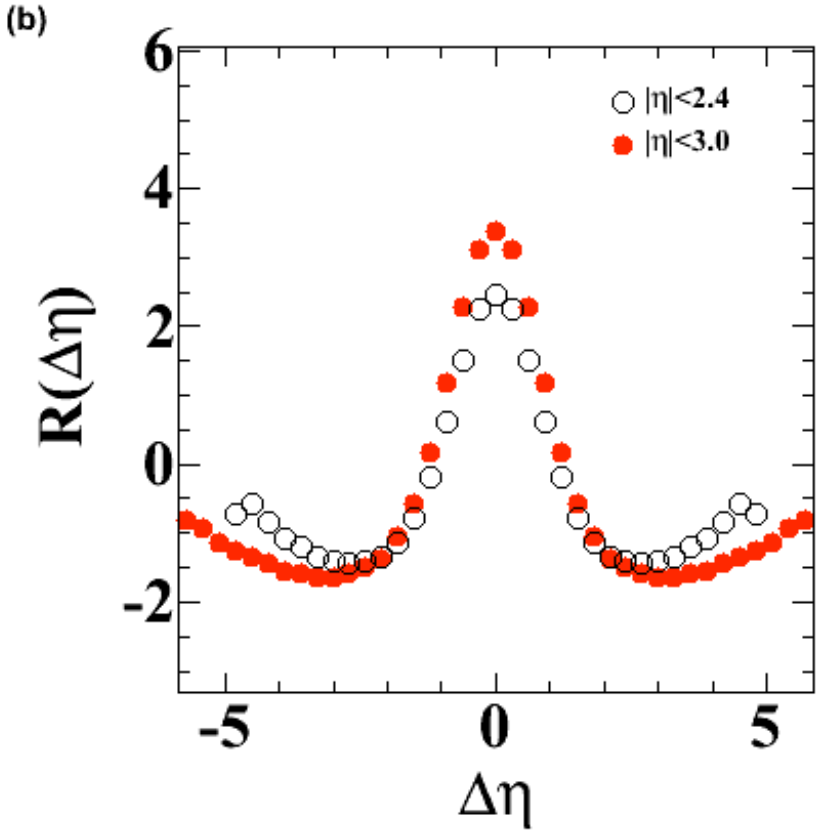
Cluster size and width

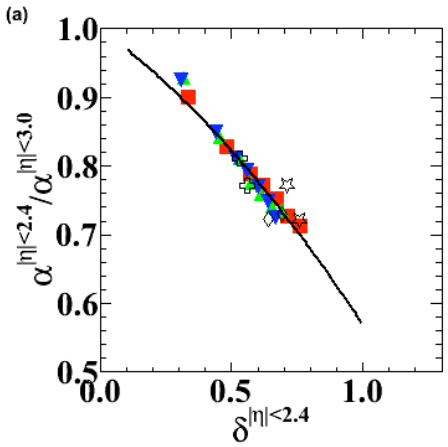


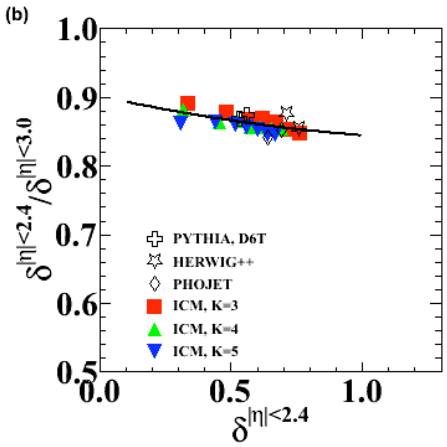
- K_{eff}: Near-side (hard p_t) increases with energy, away-side (soft QCD) remains constant. Pythia has the right trend but is lower
- Cluster width δ remains constant and is reproduced by Pythia



Comparison to other experiments



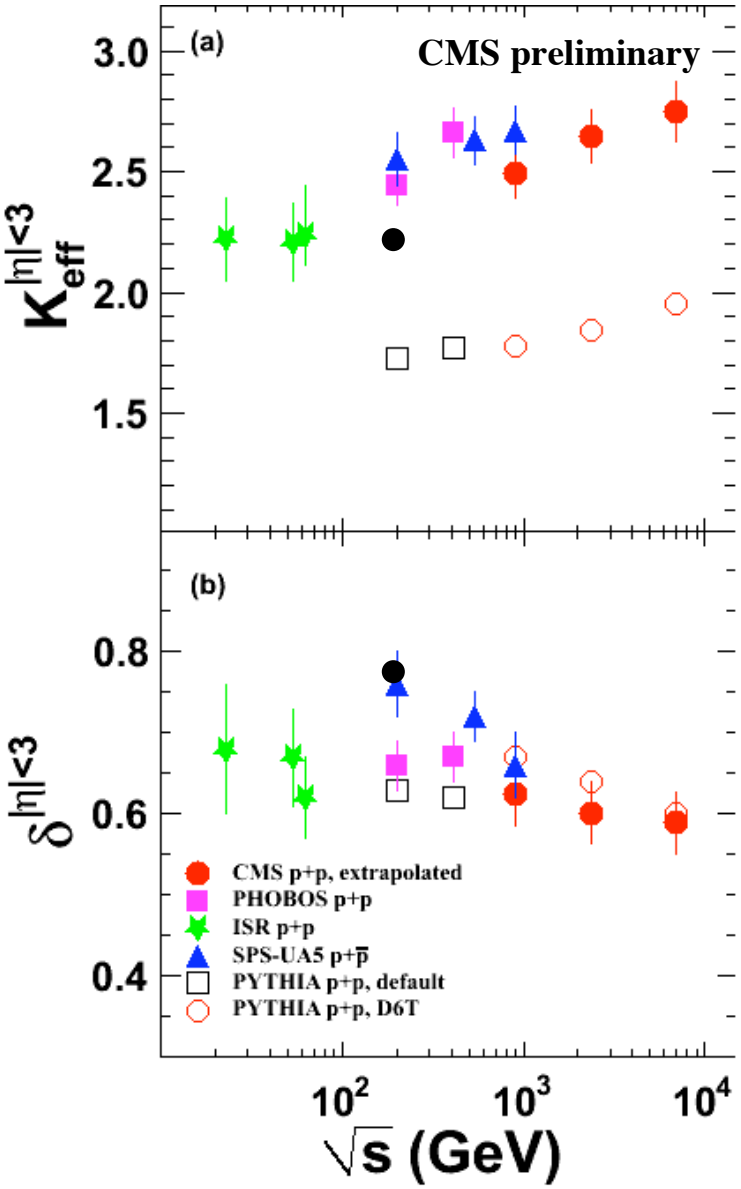




Systematic error due to extrapolation: ~5%

Need to extrapolate to tracks in the kinematic range p_t >0 (use Tsallis function) and $|\eta|<3$

Comparison to other experiments



o the trend with the c.m. energy is confirmed

o CMS points slightly lower than UA5 at 0.9 TeV but compatible

o Pythia lower, results insensitive to different tunes, BEC effect has a negligible effect on the result.

- Heavy ions

Summary

o Short-range two-particle angular correlations have been observed and measured at 0.9, 2.36 and 7 TeV at CMS

o They have been compared to a simple cluster model, the ICM model, determining the cluster size and width.

o The dependence of the cluster size and width is compatible with what found in previous experiments, and not reproduced by Pythia.

o Cluster properties are strongly modified in heavy ions collisions at RHIC. It will be interesting to measure it again in heavy ions collisions at LHC.