Round table: Collectivity in Small Systems

Experimental Overview

Wei Li (Rice University)

XII Quark Confinement and the Hadron Spectrum
Aug. 29 – Sep. 3, 2016

Why colliding ultra-relativistic heavy ions?

"In high-energy physics we have concentrated on experiments in which we distribute a higher and higher amount of energy into a region with smaller and smaller dimensions.

In order to study the question of 'vacuum', we must turn to a different direction; we should investigate some 'bulk' phenomena by distributing high energy over a relatively large volume."

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(AA)

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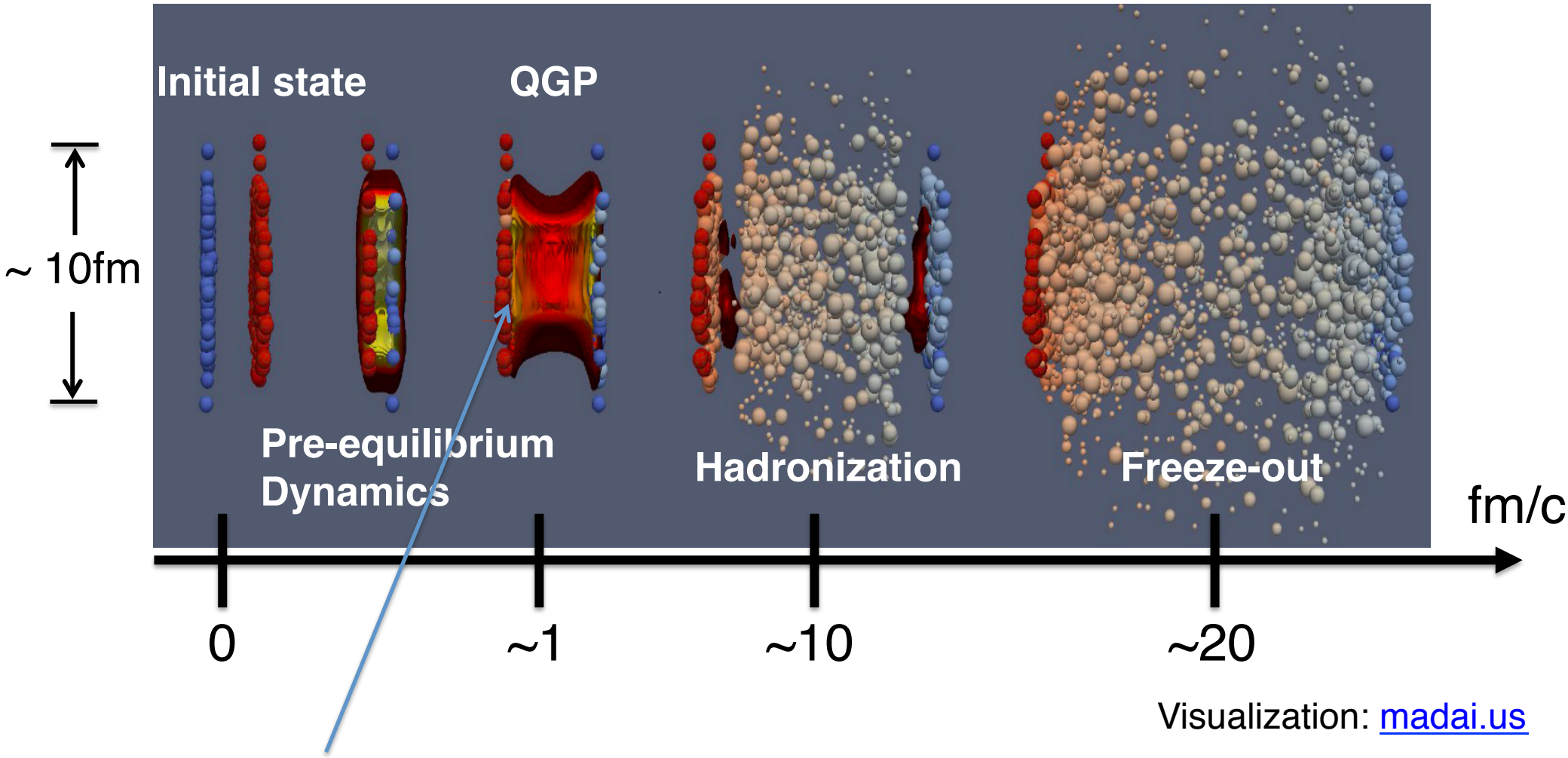
Standard paradigm of a heavy-ion collision

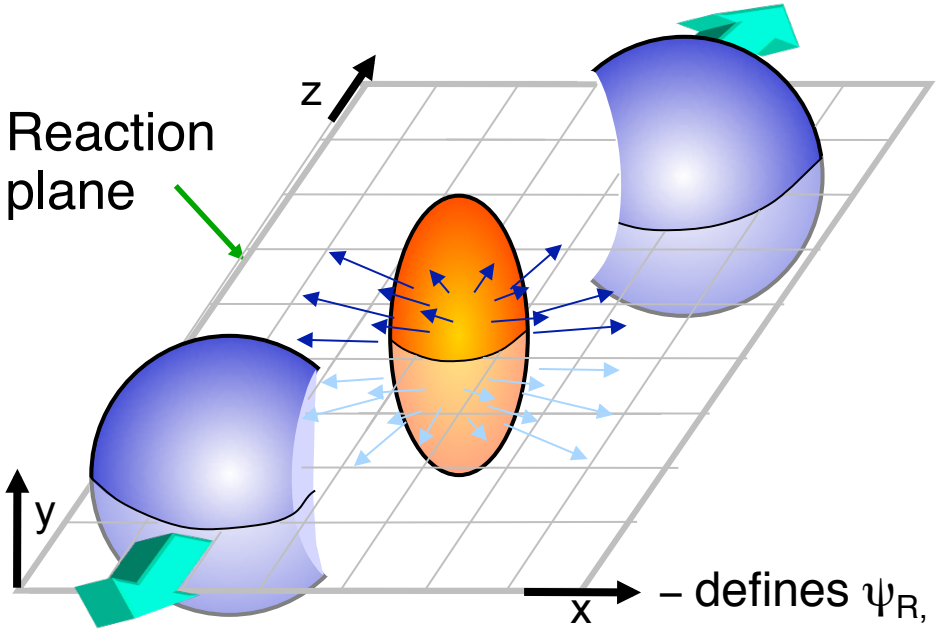


Visualization: madai.us

Discovery of a high temperature, thermalized medium with quark and gluon degree of freedom

Surprisingly, the QGP behaves as a fluid, described by nearly ideal hydrodynamics (very little friction)

Initial-state asymmetry:



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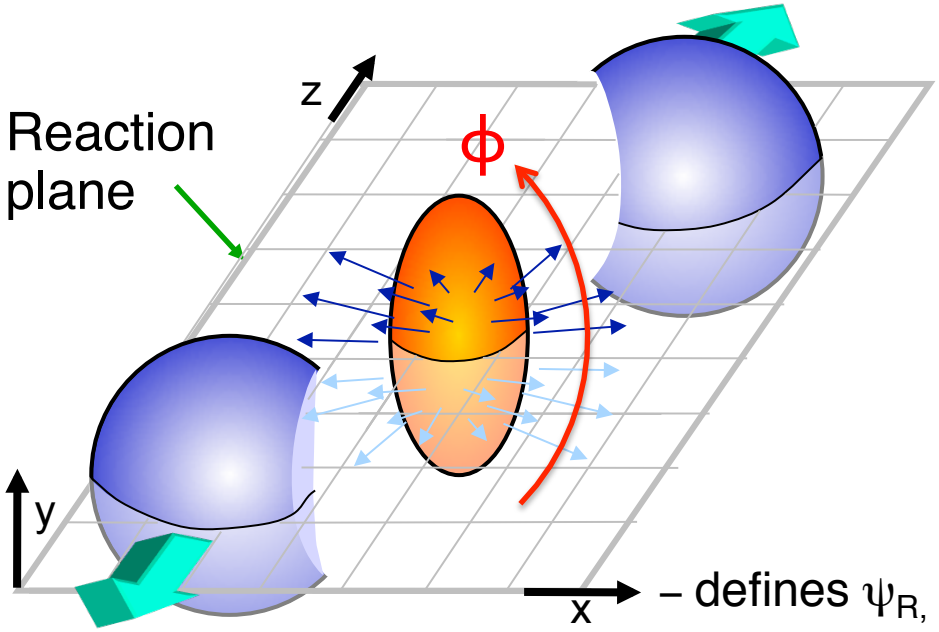

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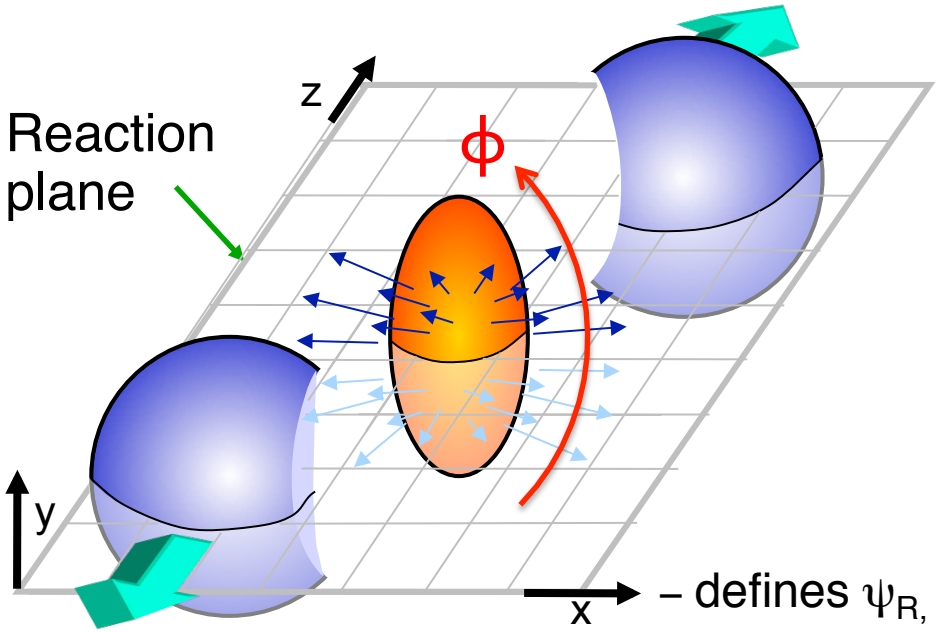
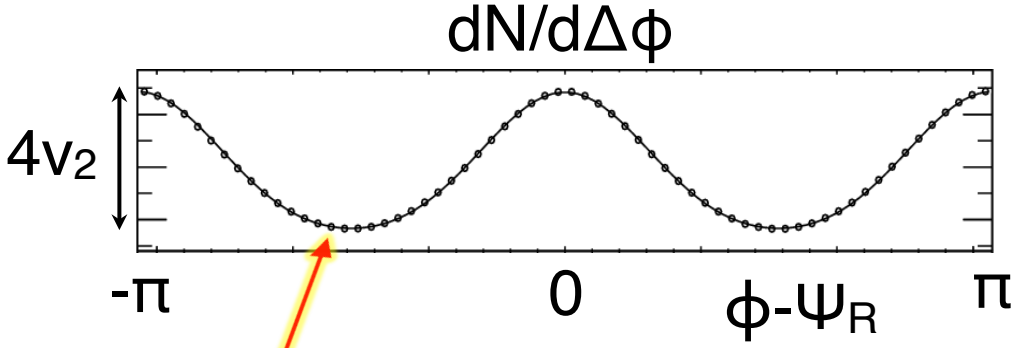


Final-state anisotropy:



$\sim 1 + 2\, v_2 \cos[2(\phi - \Psi_R)]$

"elliptic flow"

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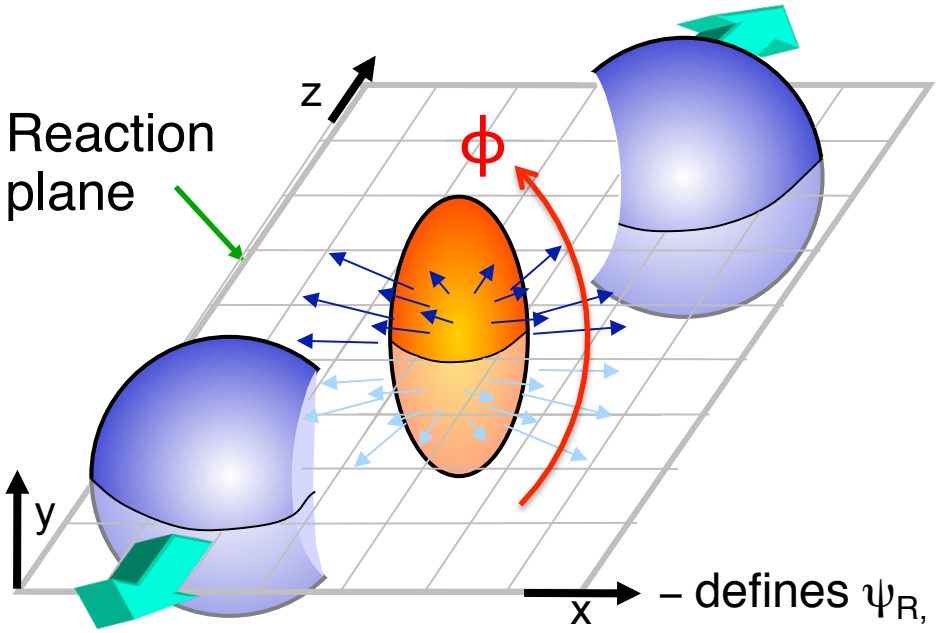

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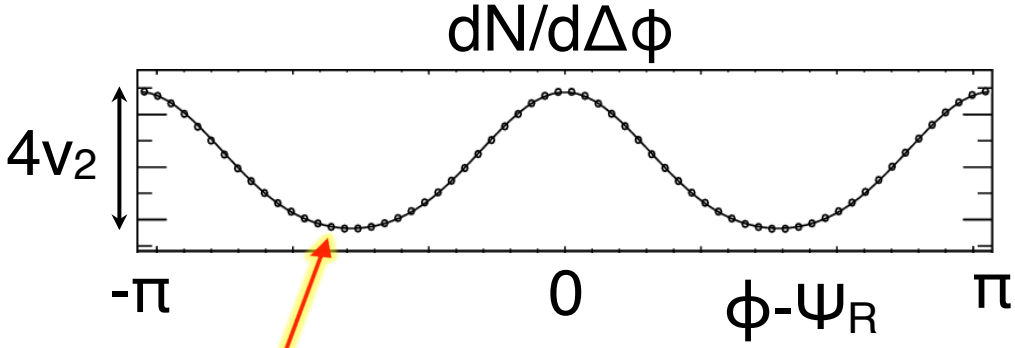

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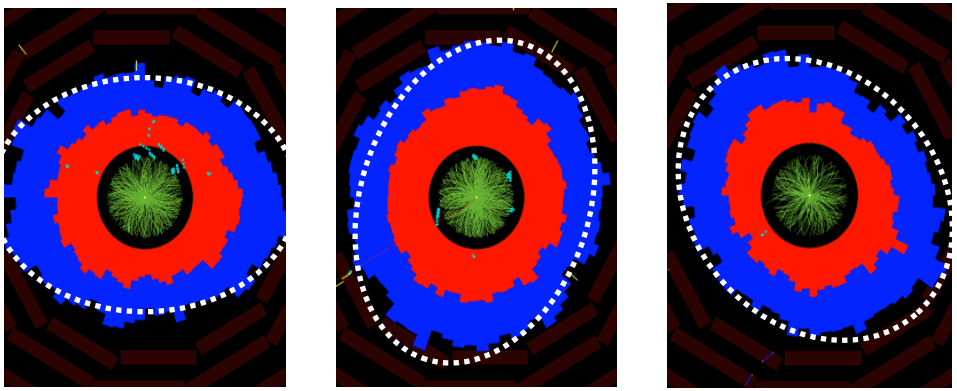
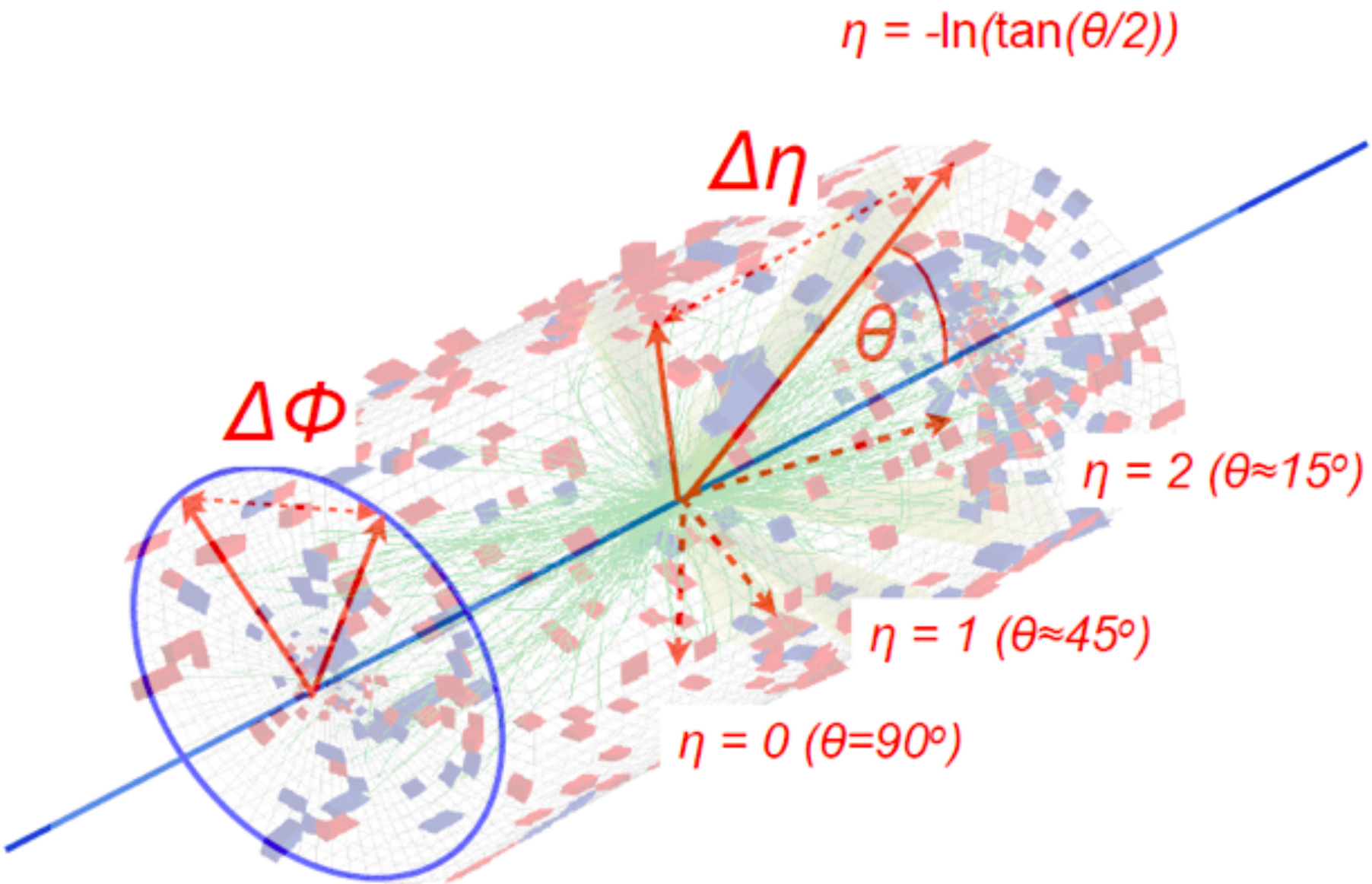
CMS event displays



Flow, two-particle correlations, ridge …



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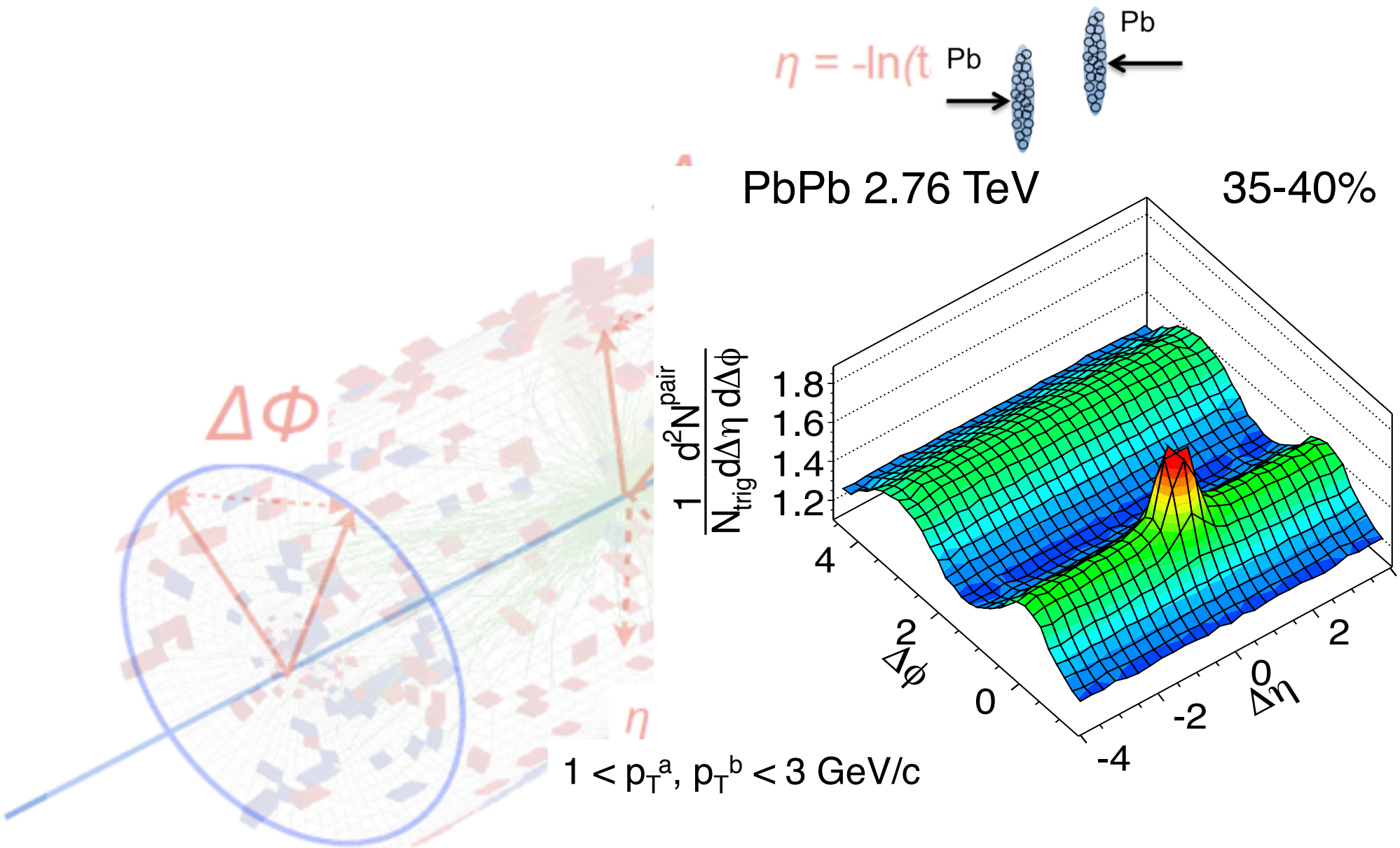

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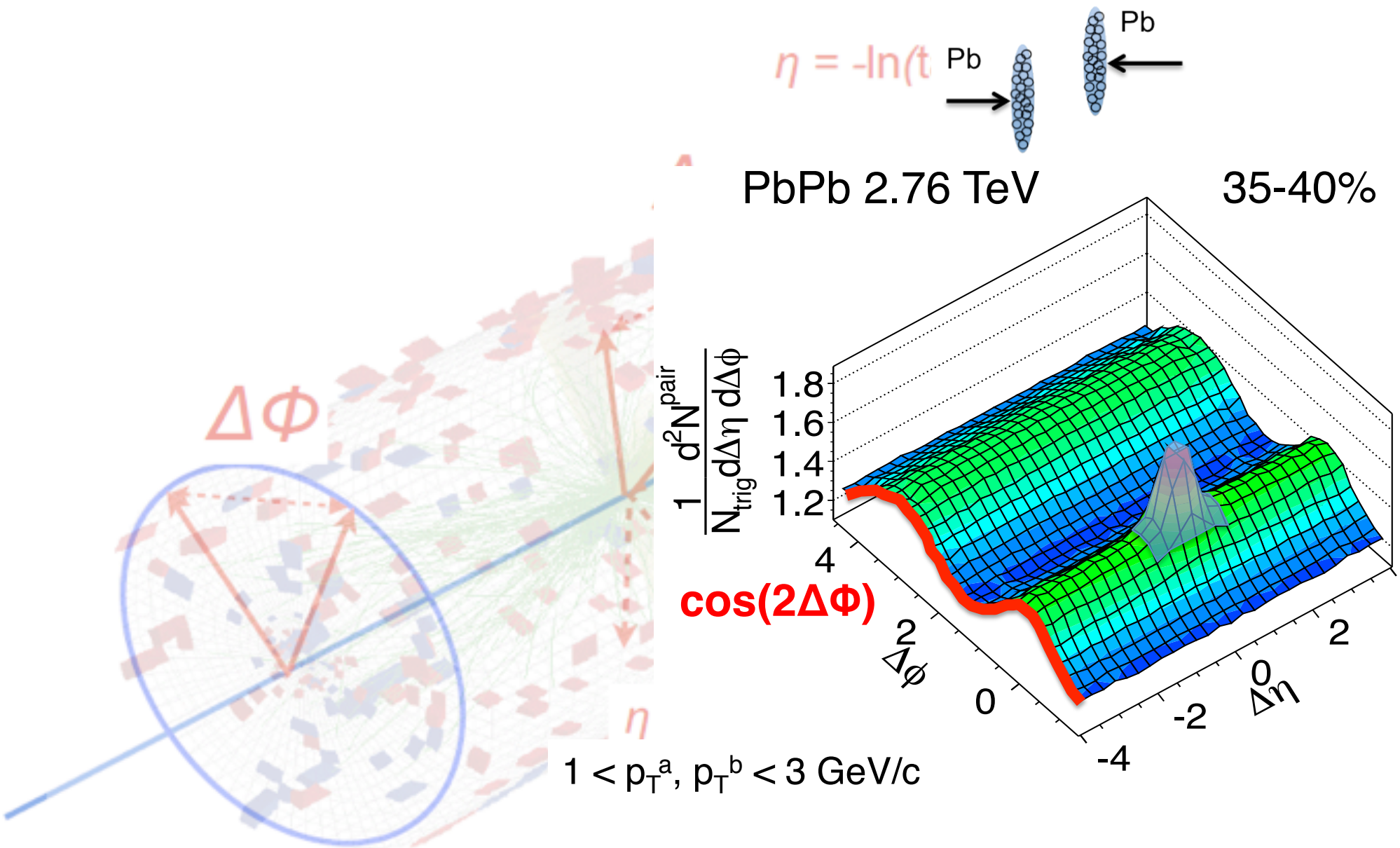

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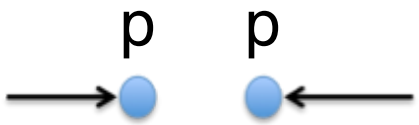
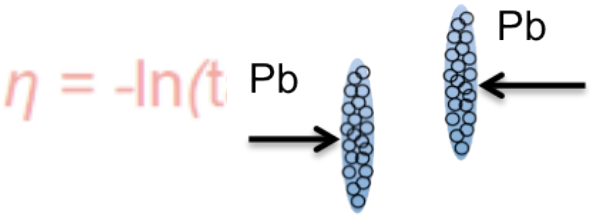
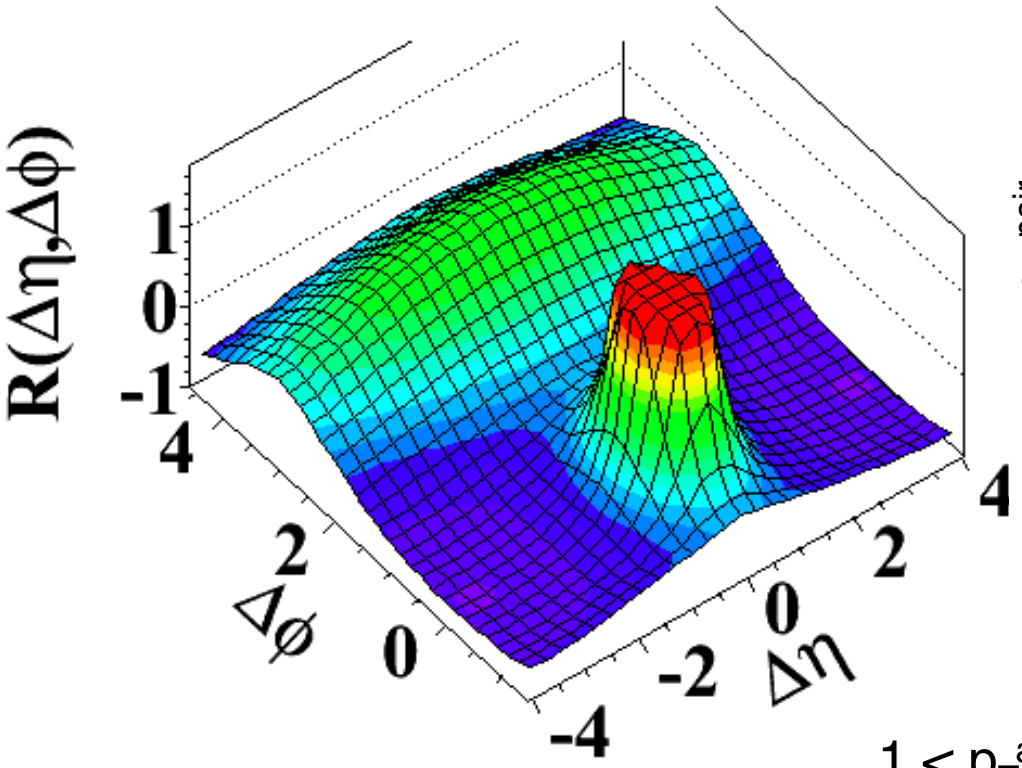
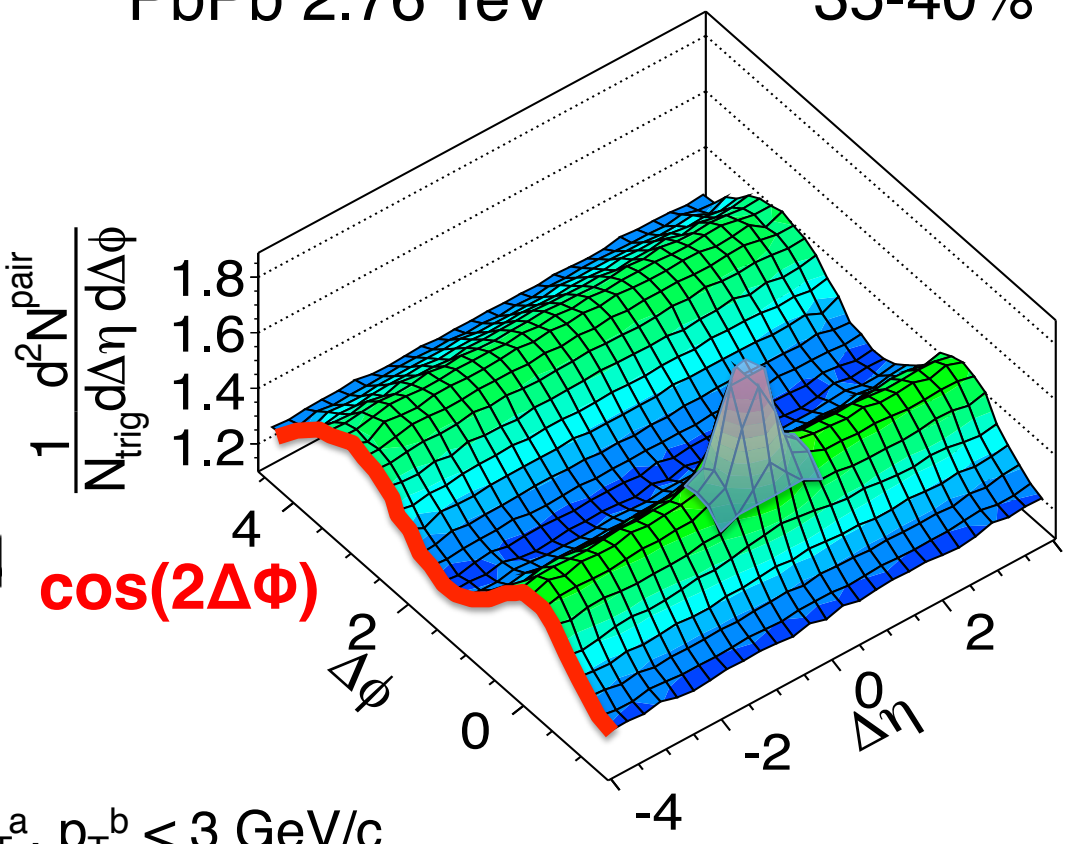




pp 7 TeV, MinBias

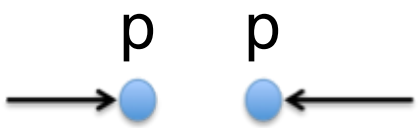
PbPb 2.76 TeV 35-40%

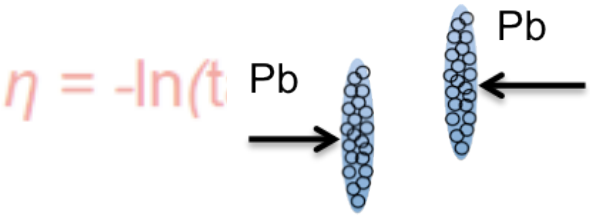




$1 < p_T^a, p_T^b < 3$ GeV/c

Flow, two-particle correlations, ridge …





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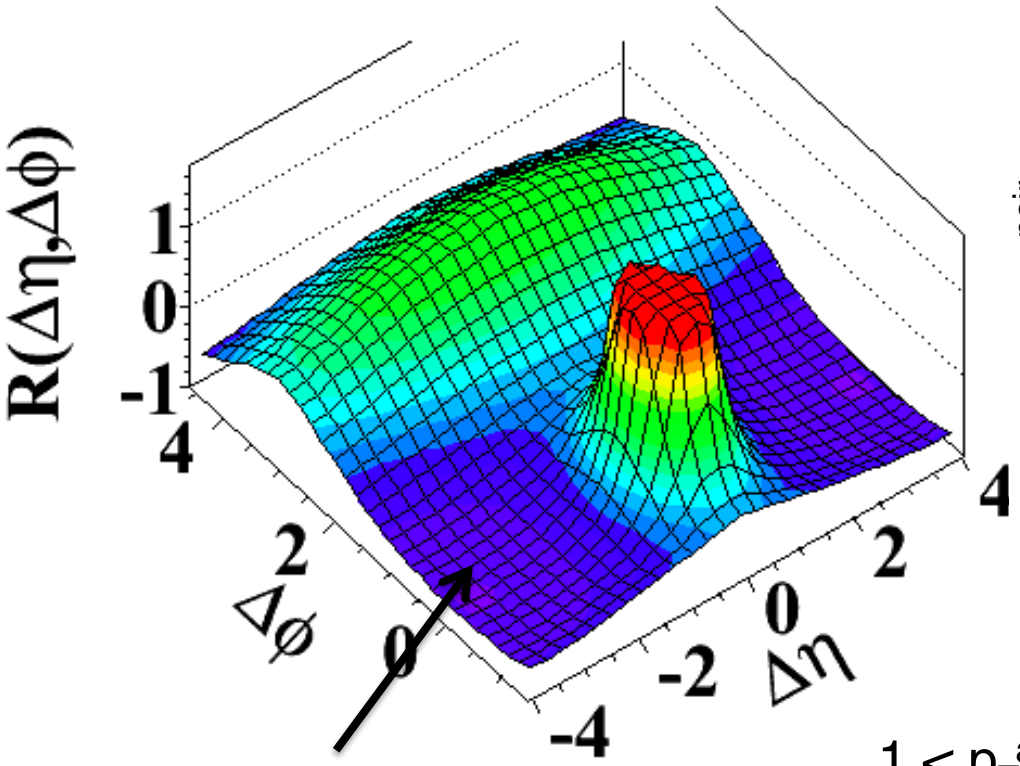

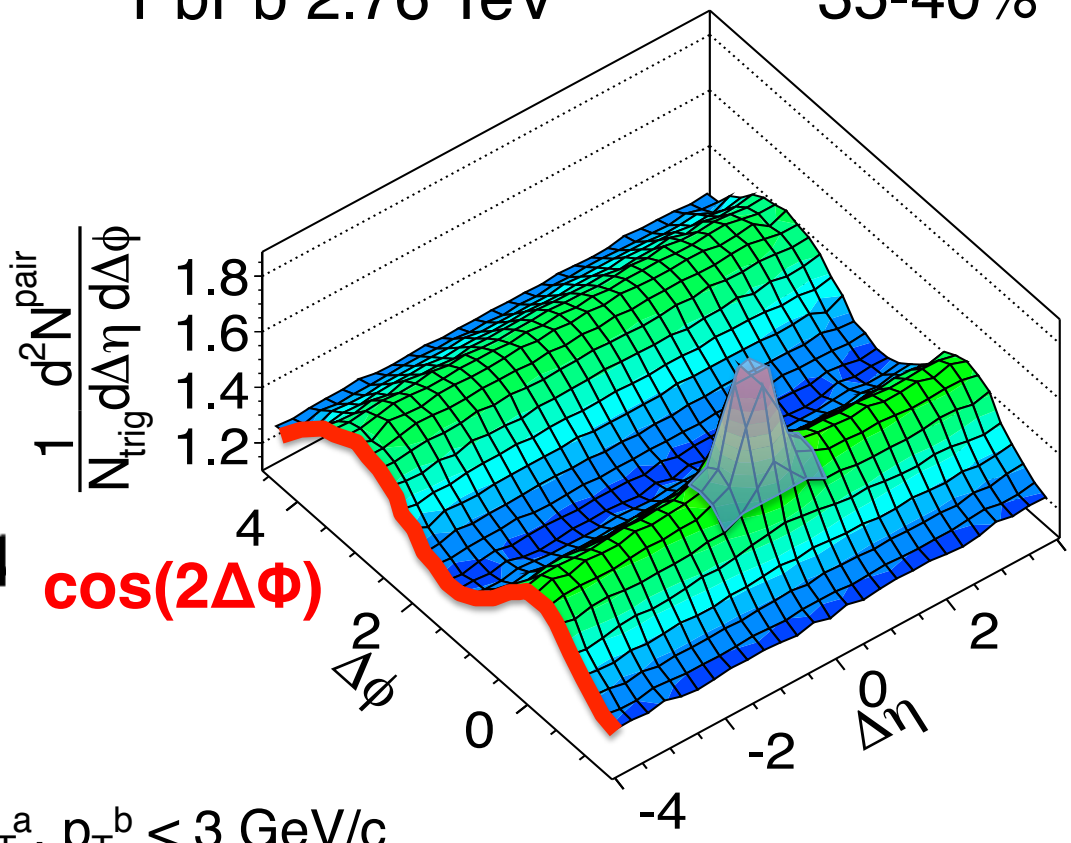

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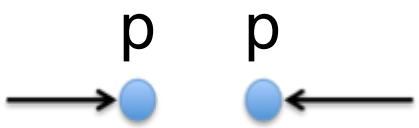
Nothing at ΔΦ ~ 0, |Δη|>2
(Near-side)

Breaking news in 2010!



High-multiplicity pp events

pp 7 TeV, MinBias **<N_{trk} ~ 15>**

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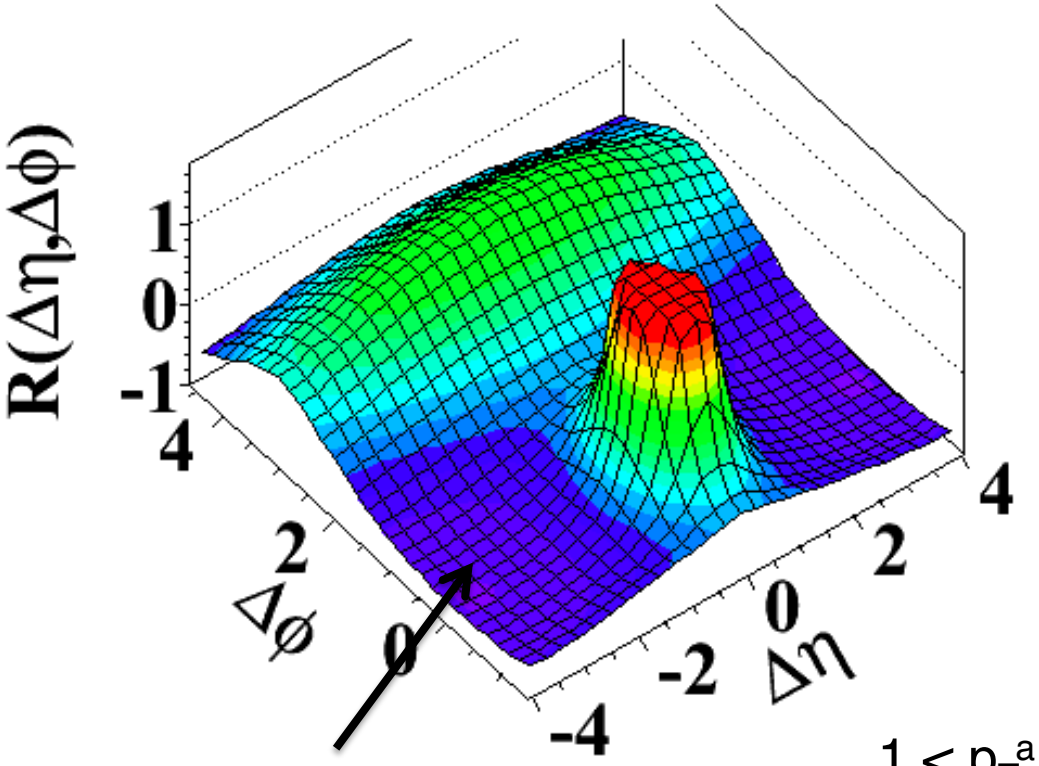

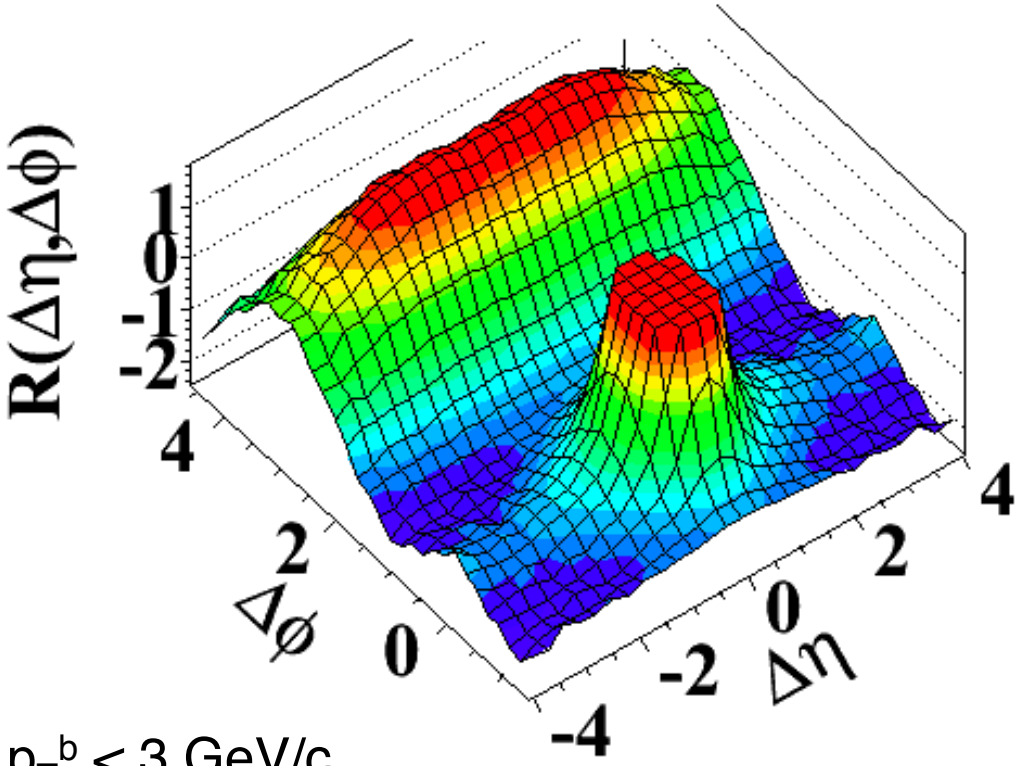

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CMS, JHEP 09 (2010) 091

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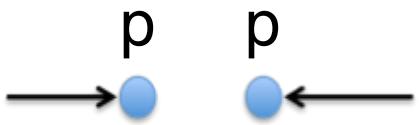

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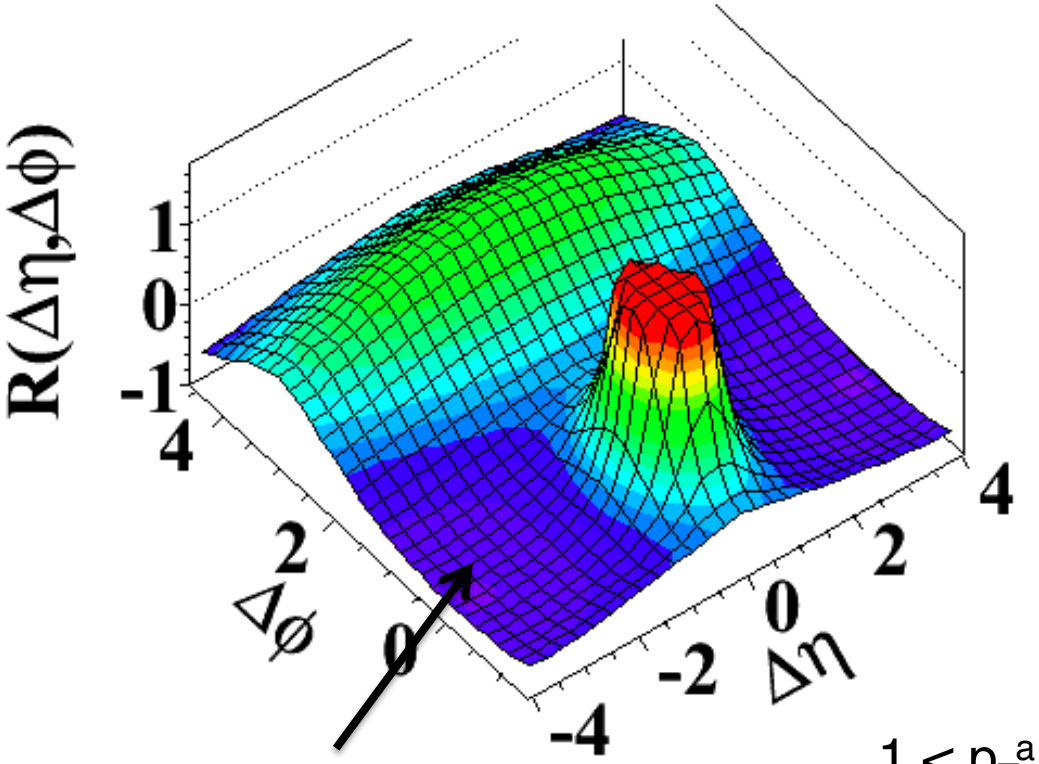

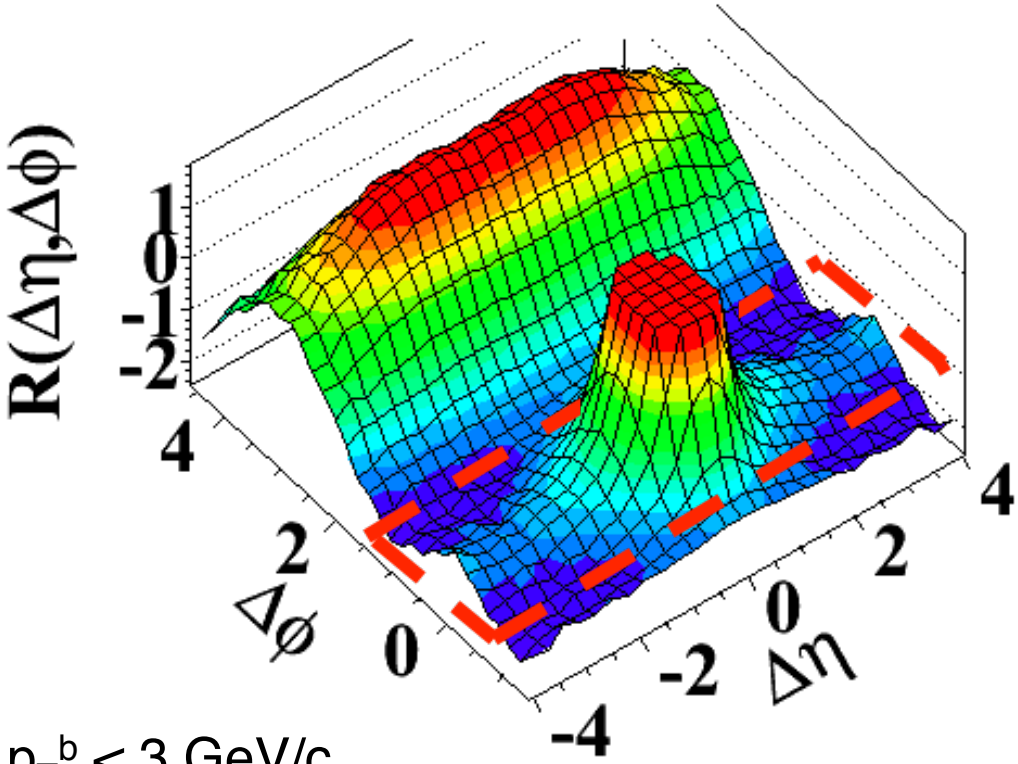

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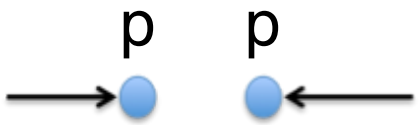

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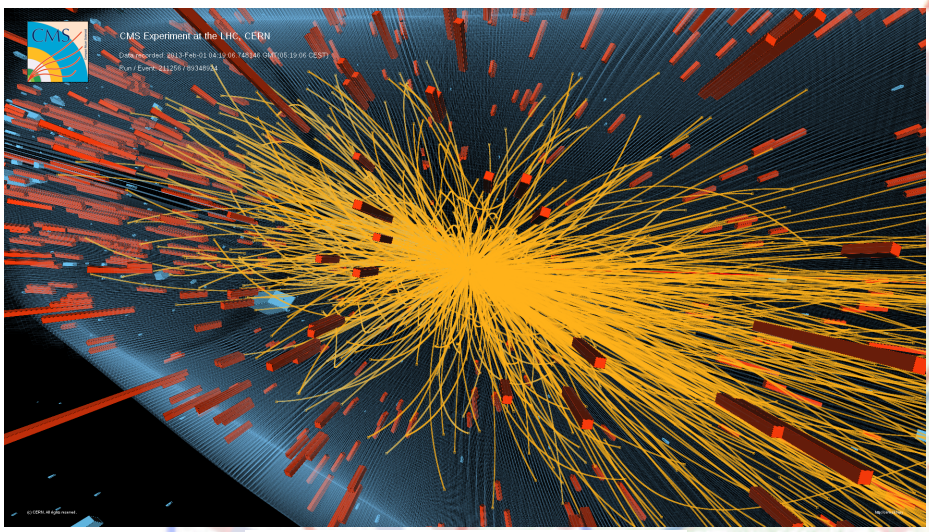

Not a pileup!

10^{-6} – 10^{-5} prob.

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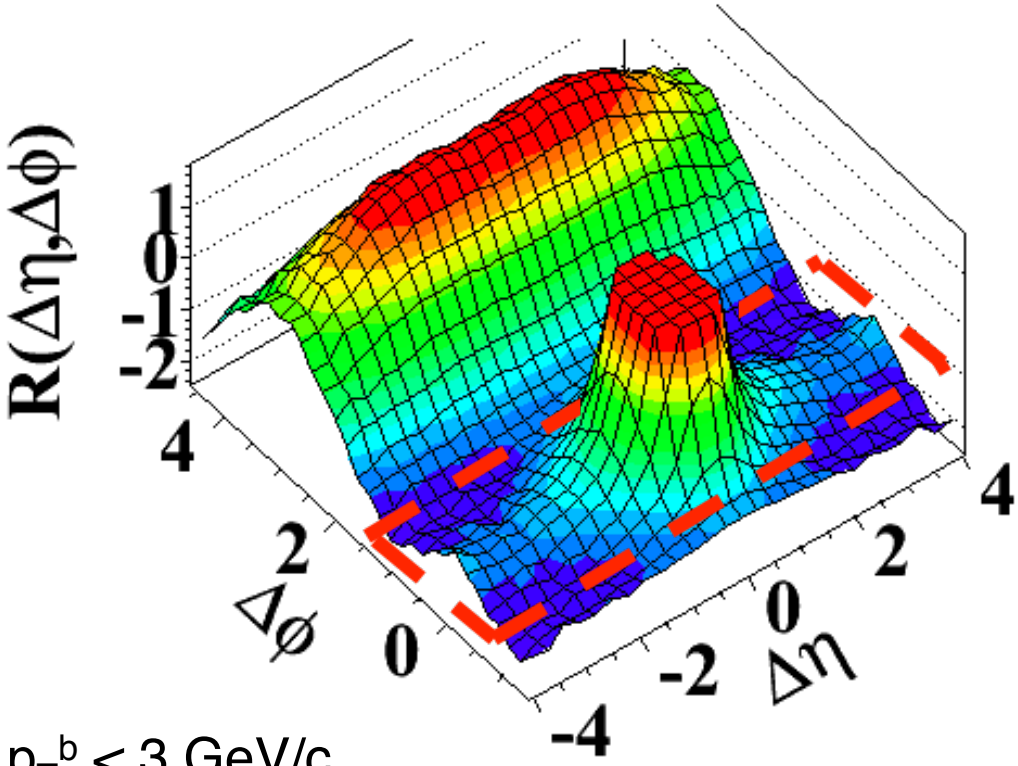

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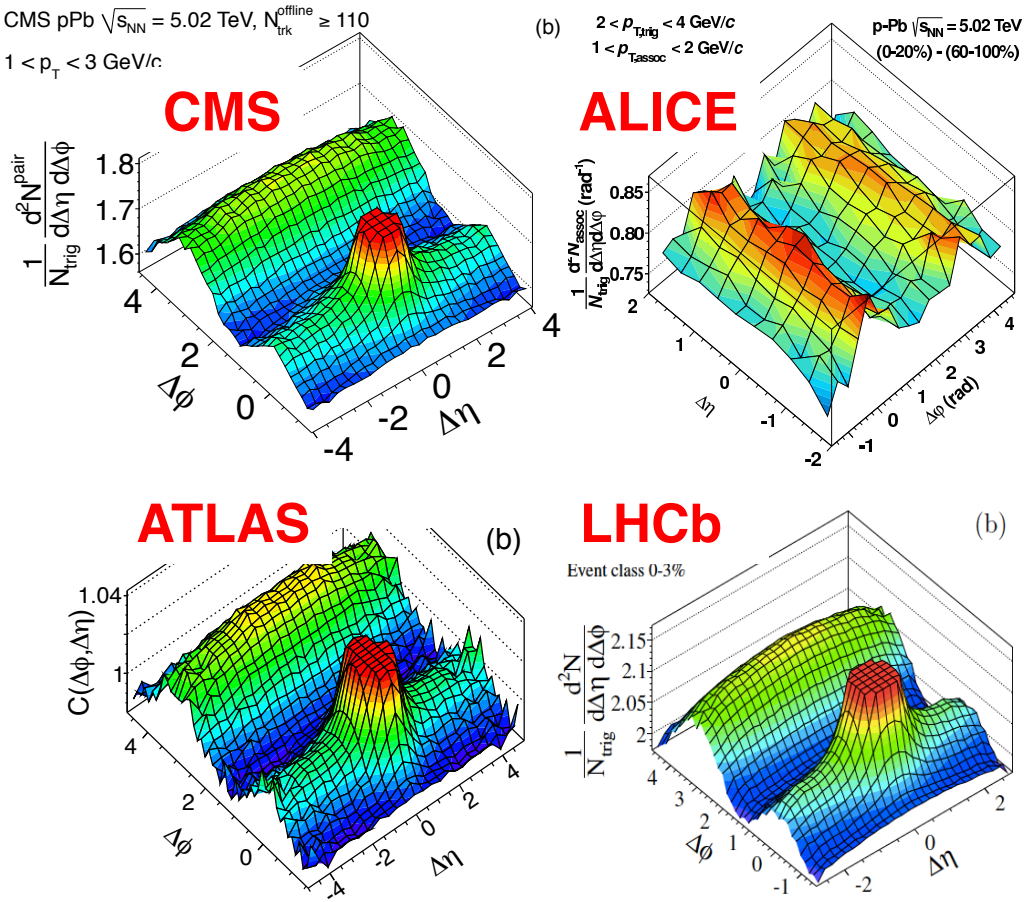
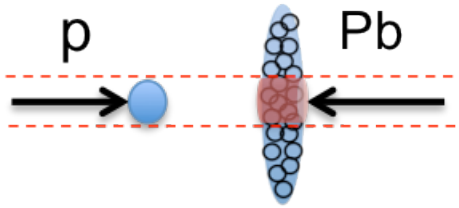
Near-side ridge

“Ridge” tsunami in pPb at the LHC





in 2012

Collective phenomena and QGP fluid in small systems (L ~ 1fm)?!

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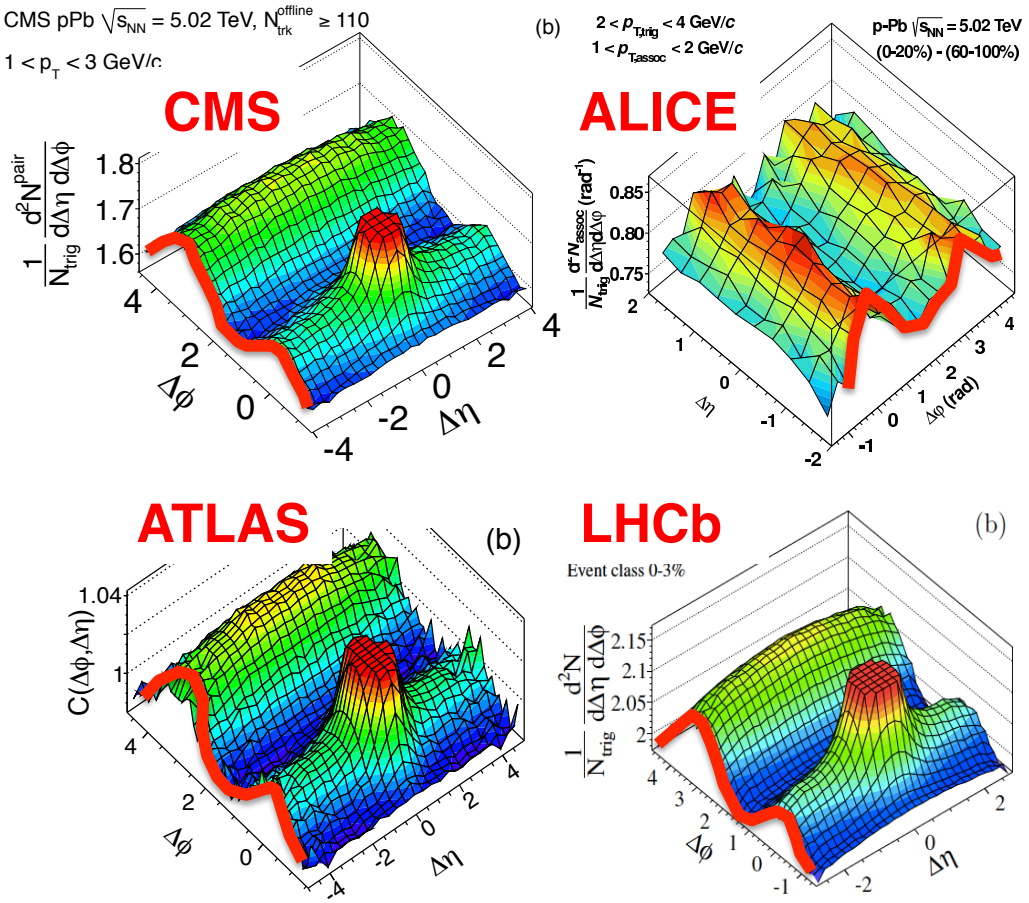
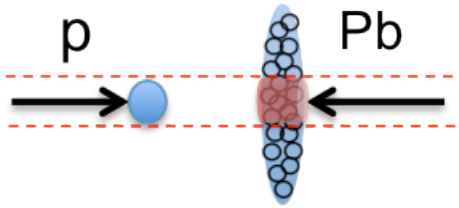
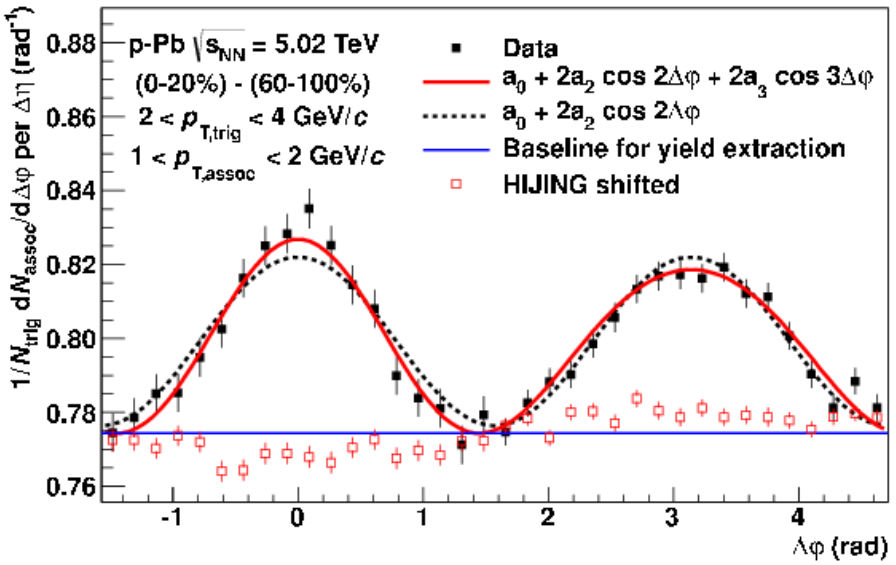




in 2012

“Flow” analysis



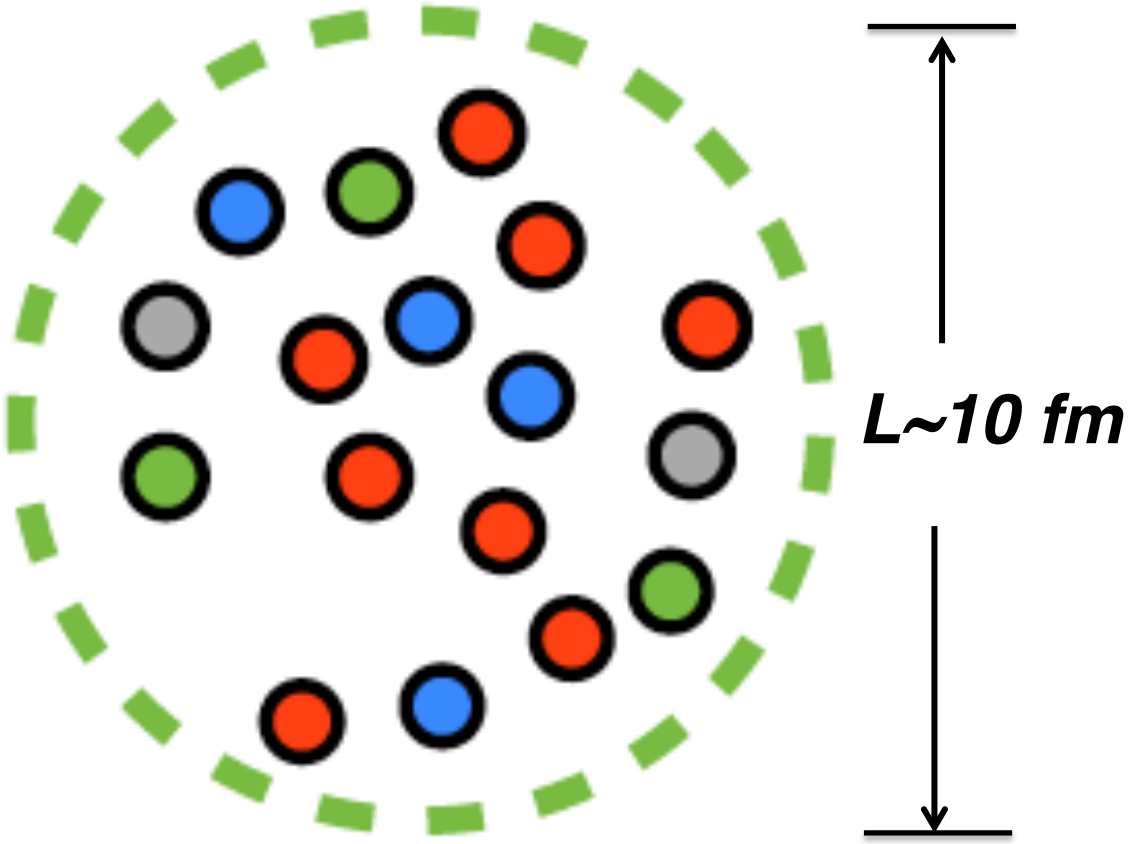
Collective phenomena and QGP fluid in small systems (L ~ 1fm)?!

How small a QGP fluid can be?

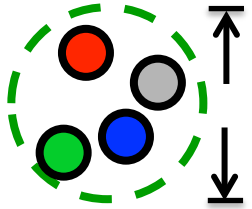
Hydrodynamic applies when:

$$L >> \lambda_{m.f.p.}$$

AA



Too small and dilute?



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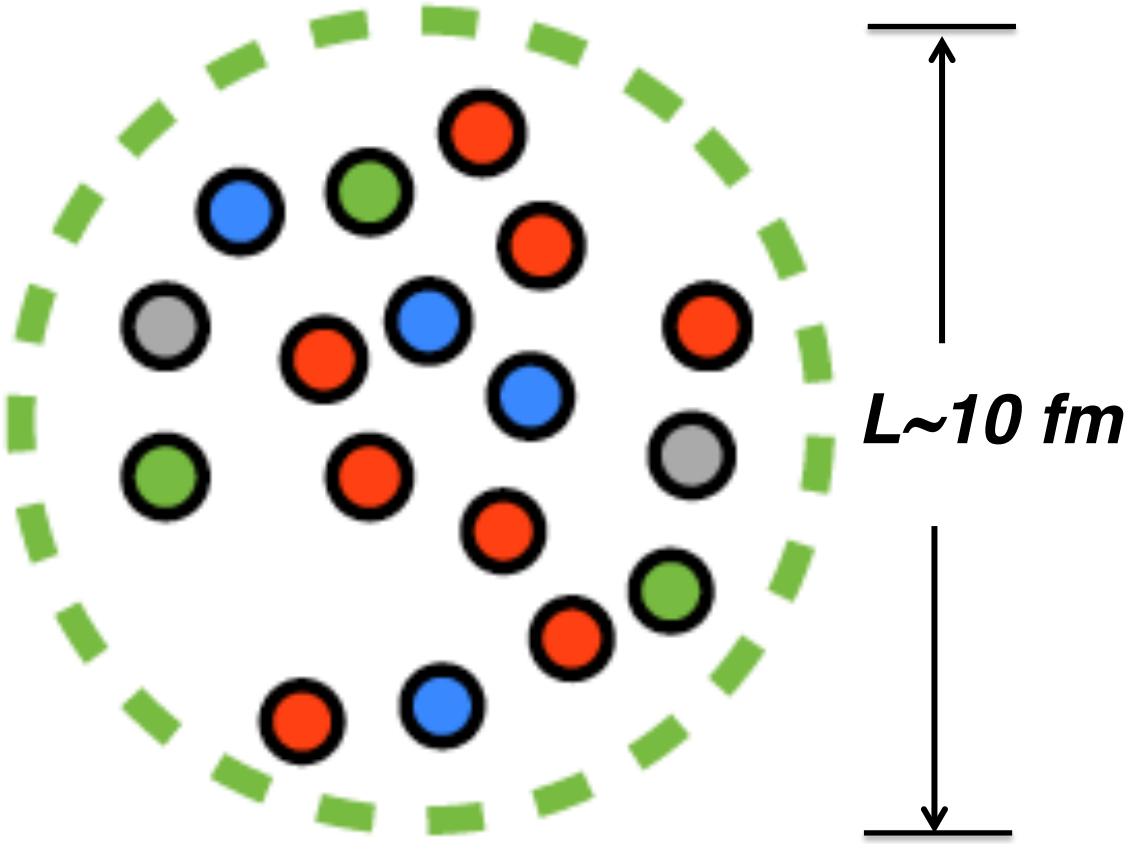
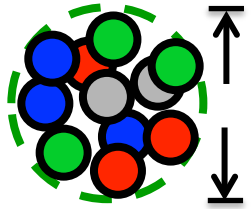


What if making it denser by increasing N_{trk}?



Summary of current status

Almost all signatures of “flow” phenomena now commonly observed in all hadronic systems (pp, pA, AA), at sufficiently high multiplicities.

Some questions:

- ✧ Is QGP fluid created in small systems like pp?
- ✧ Is there a smallest scale of QCD fluid-like system?
- ✧ What’s still needed (experimentally) to reach a definitive conclusion?
- ✧ If everything flows, do we learn anything new about QGP from small systems?