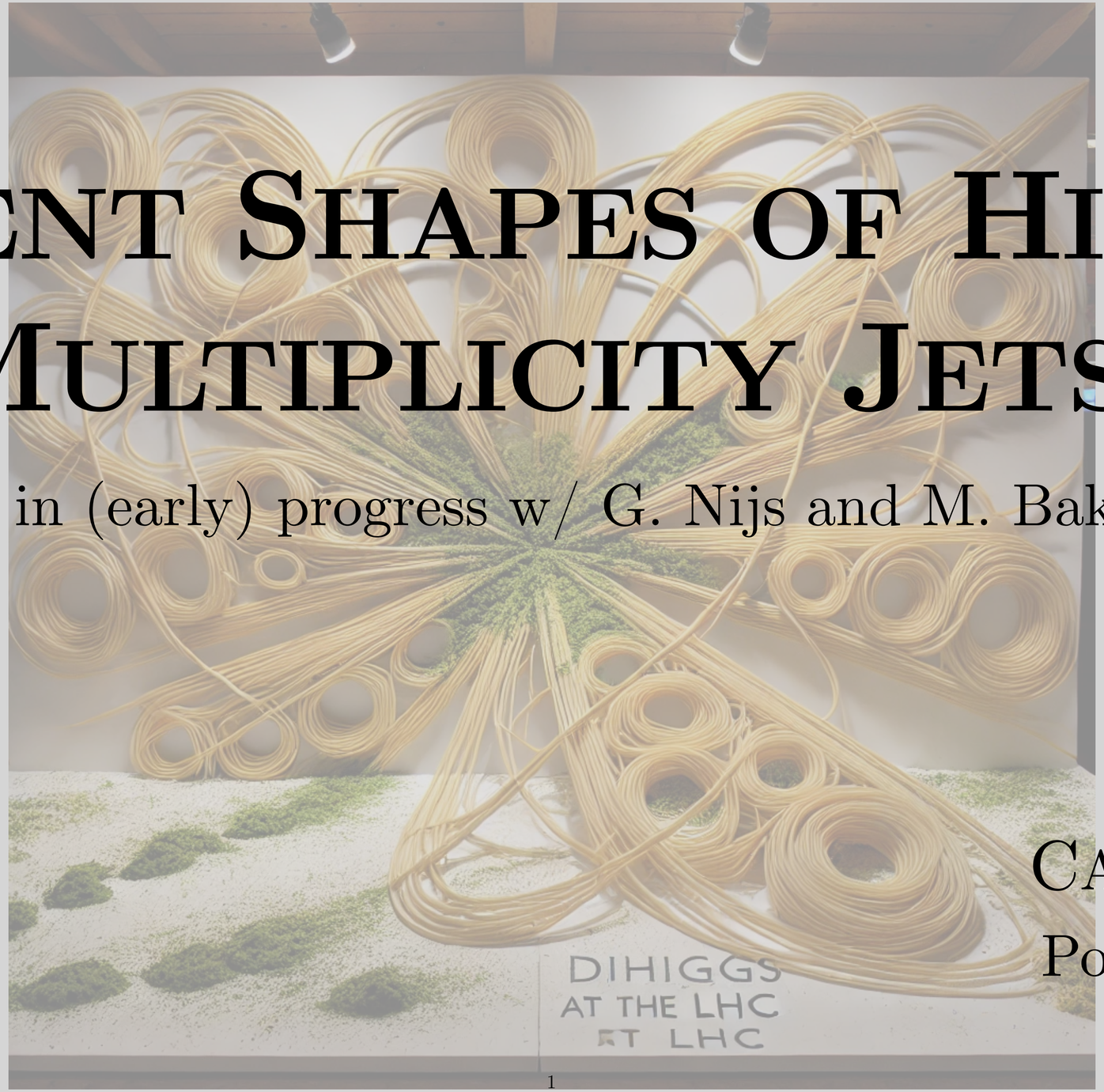
Event Shapes of High Multiplicity Jets

Work in (early) progress w/ G. Nijs and M. Bakker



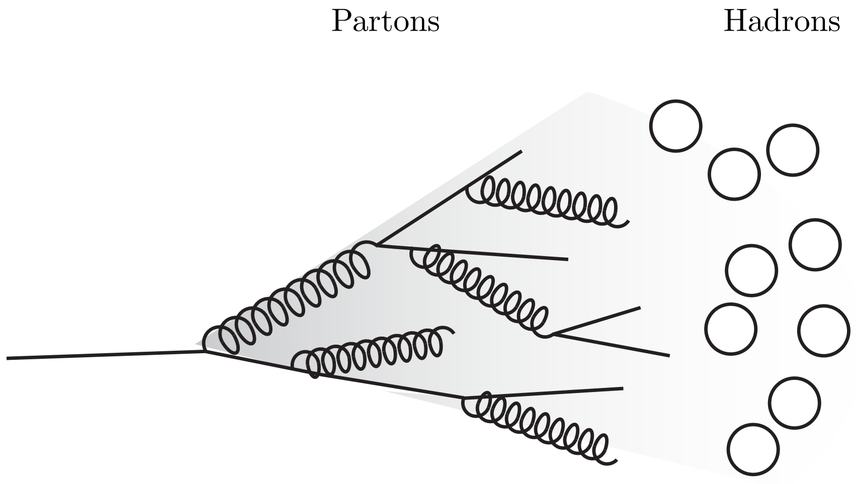
BOOST 2024
Genova, Italy
August 1

Cari Cesarotti
Postdoctoral Fellow
MIT CTP


WHAT IS THIS, A CROSSOVER EPISODE?

High Multiplicity Jets

Problem: High-multiplicity jets are hard to model & simulate



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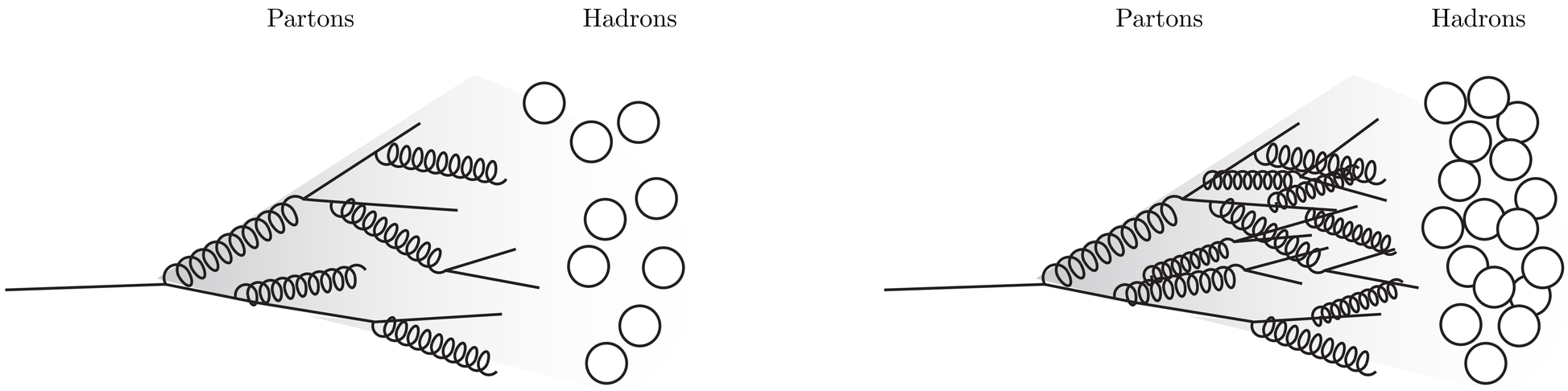
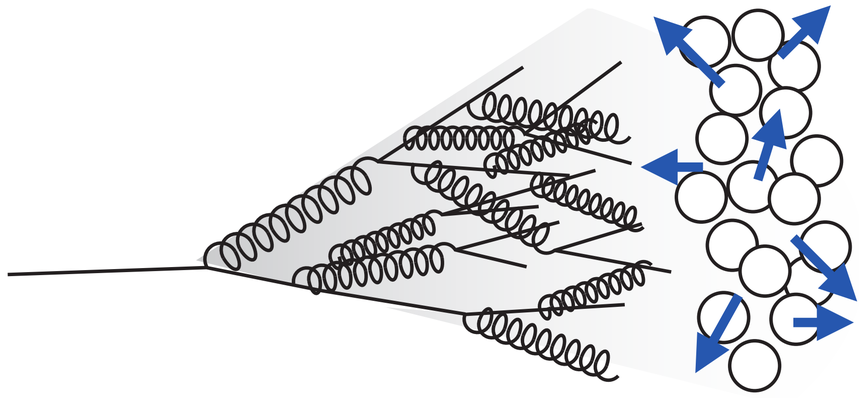


If particle multiplicity is sufficiently high, could new dynamics occur?

High Multiplicity Jets

Could there be rescatterings?



Particles could rescatter, resulting in *non-central* particle correlations

High Multiplicity Jets

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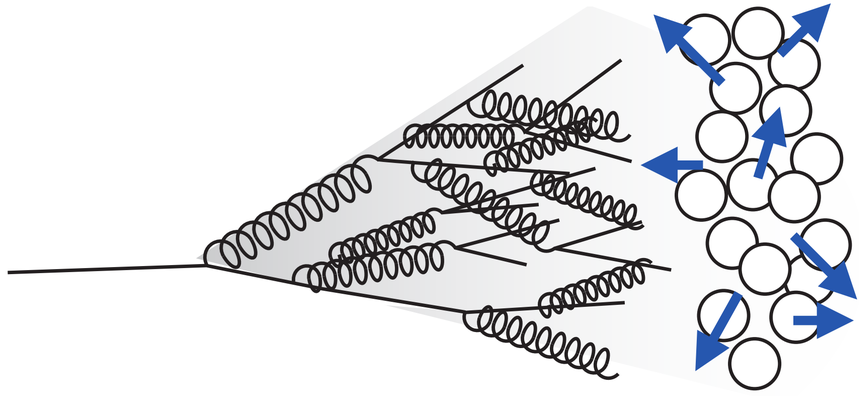
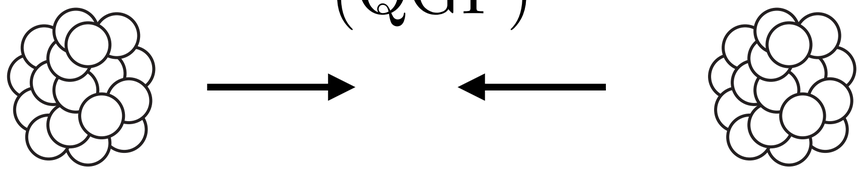
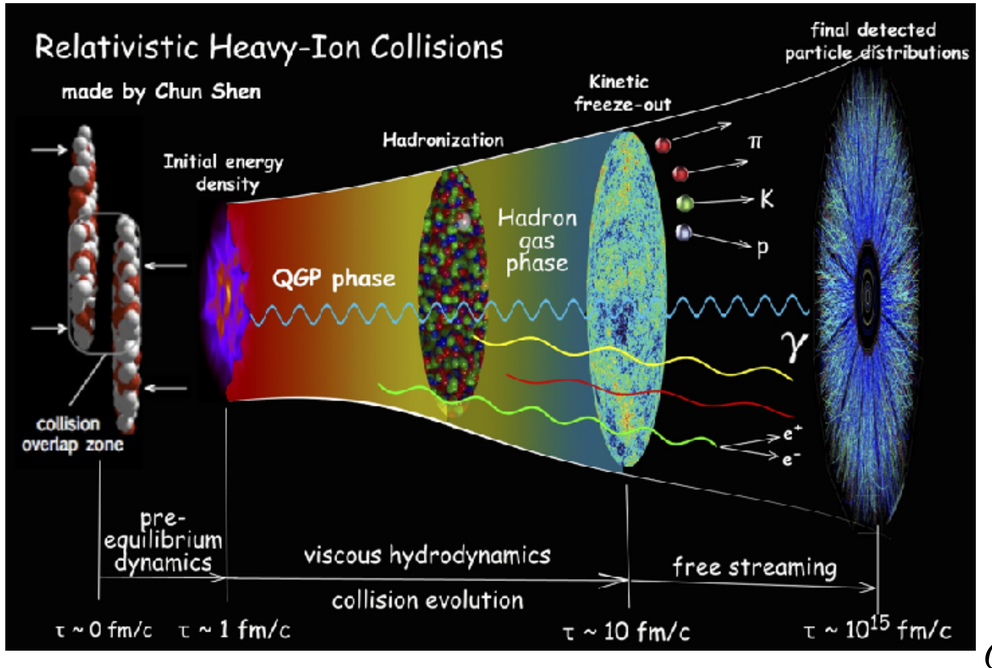


Particles could rescatter, resulting in *non-central* particle correlations

We observe this is PbPb collisions (QGP)



Shen & Sorensen



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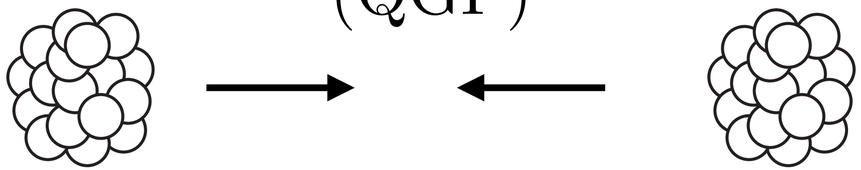
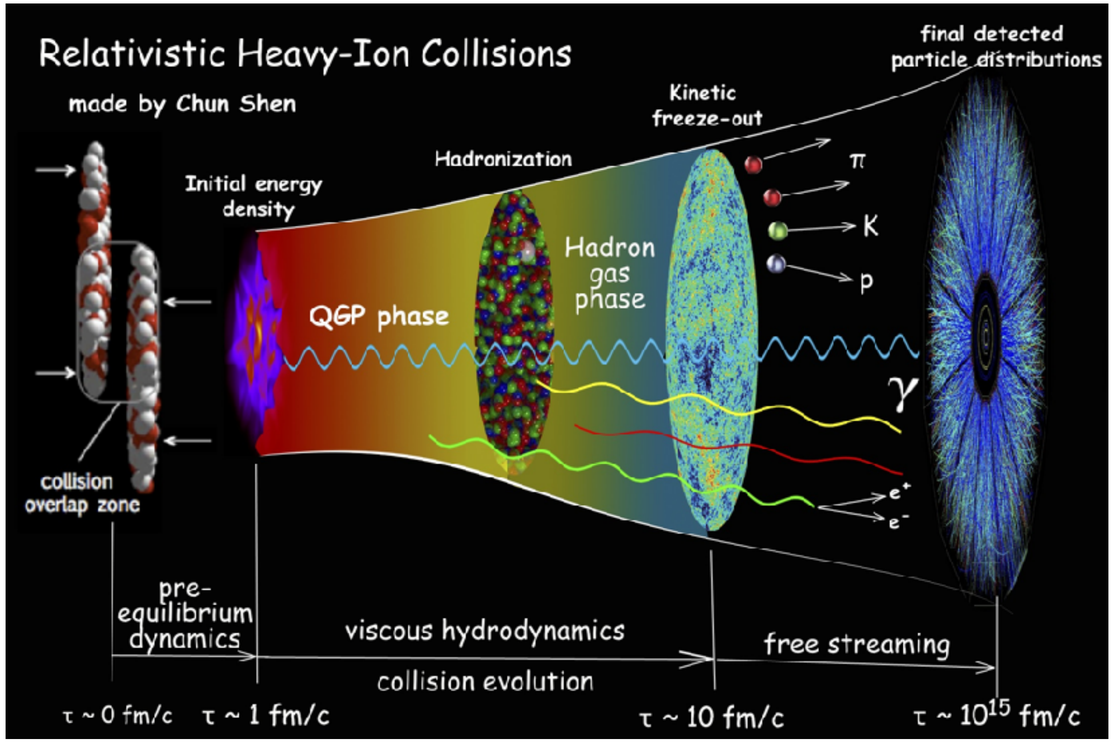
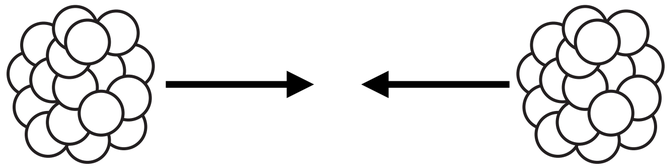


Shen & Sorensen

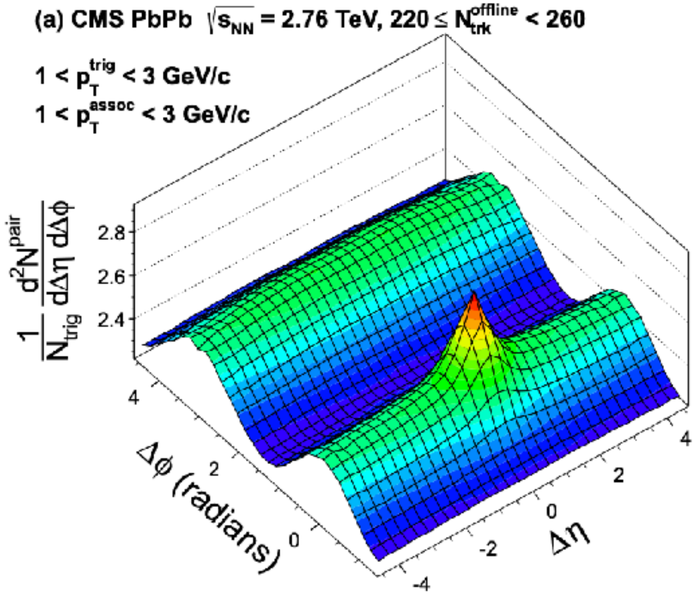


Collectivity & QCD

There are correlations between particles in dense environments

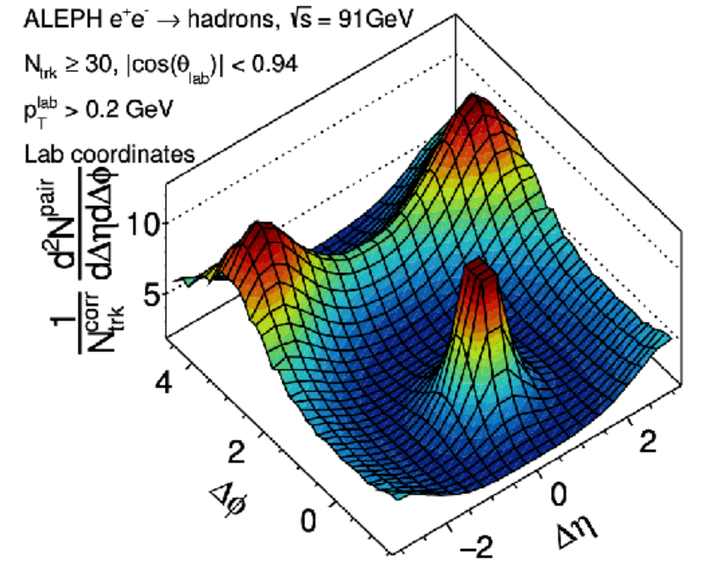


PbPb vs. *ee*



CMS 1305.0609

Badea et al 1906.00489



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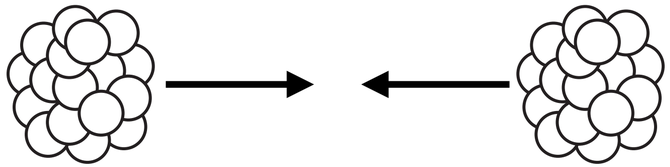

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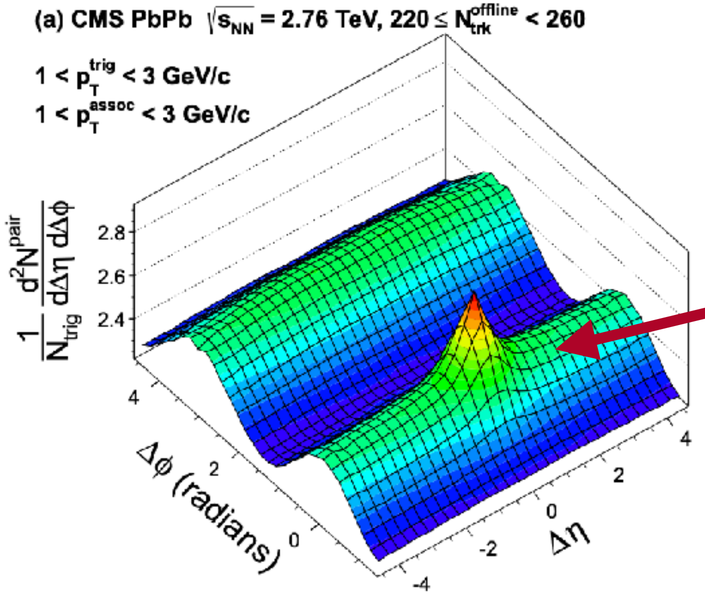
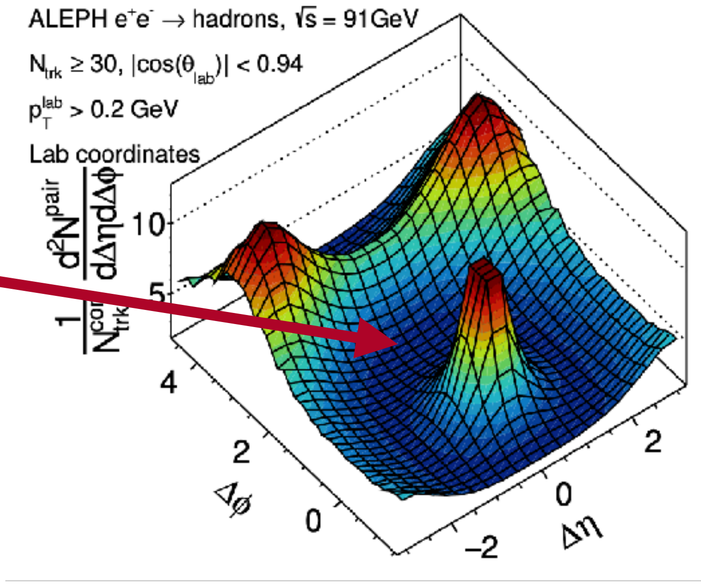


CMS 1305.0609

Particles close to each other because of local reasons (Same jet, boosted decay, etc.)



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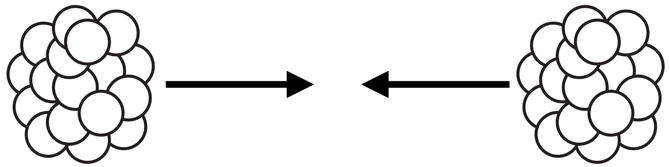

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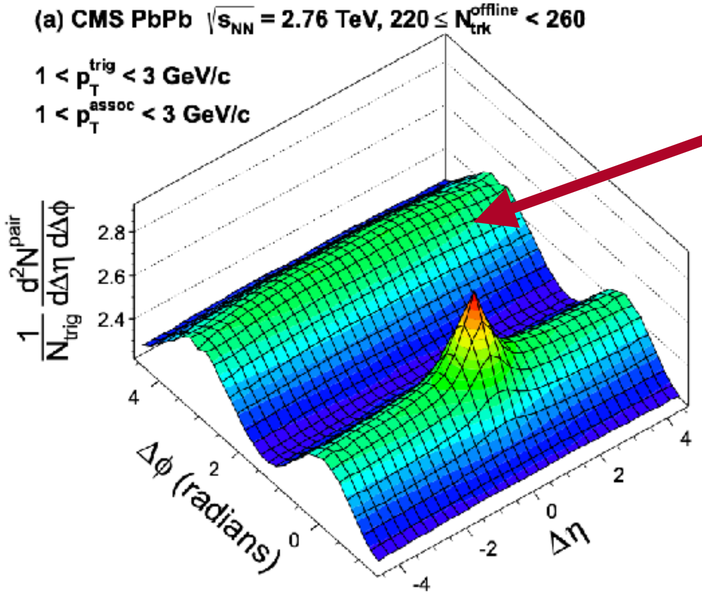
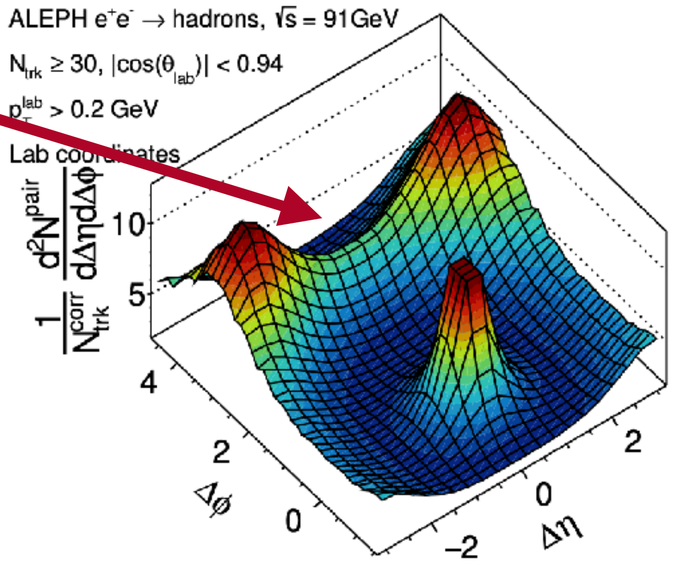


CMS 1305.0609

Back-to-back stuff

Badea et al 1906.00489



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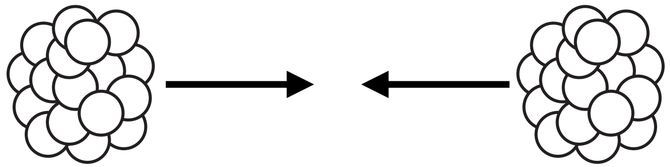

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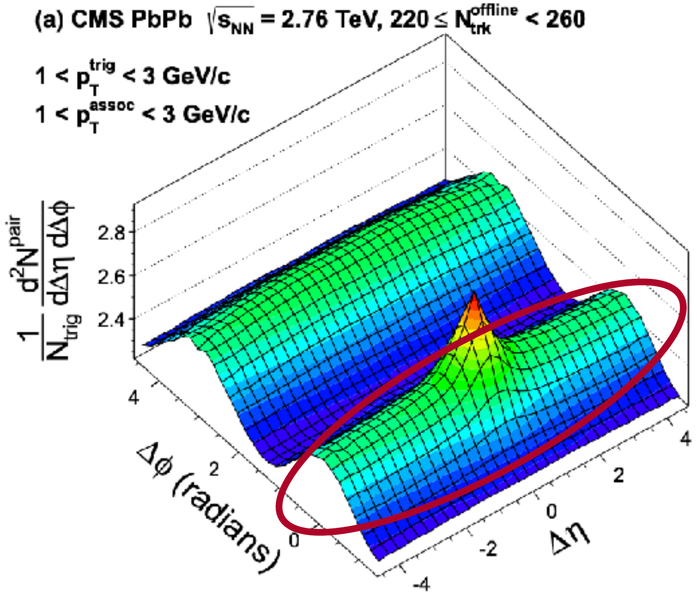
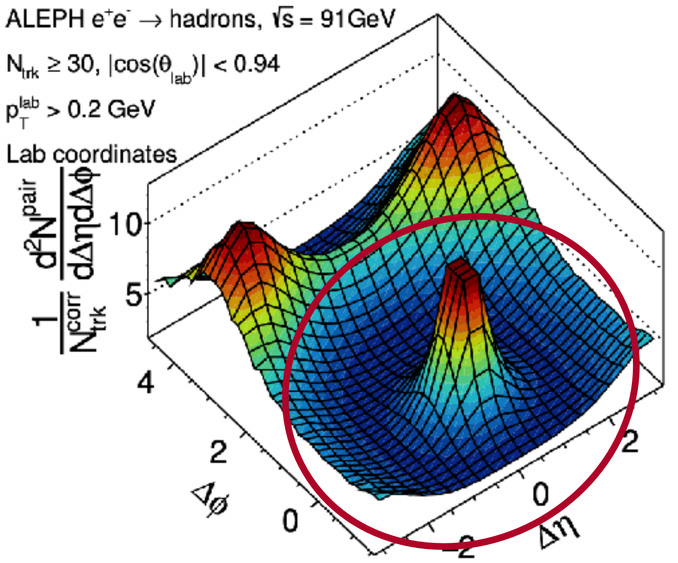


CMS 1305.0609

Collectivity vs. no collectivity
(Evidence of flow?)

Badea et al 1906.00489



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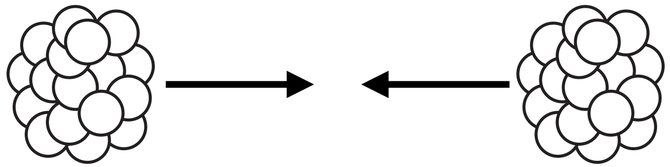
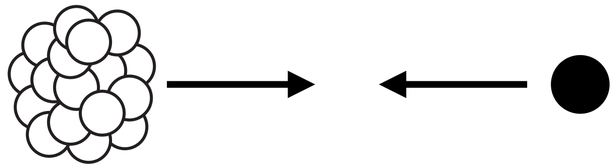
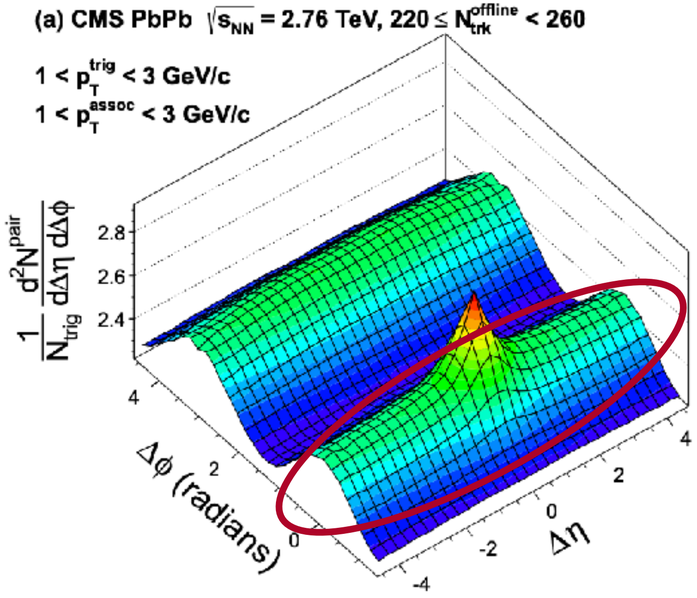
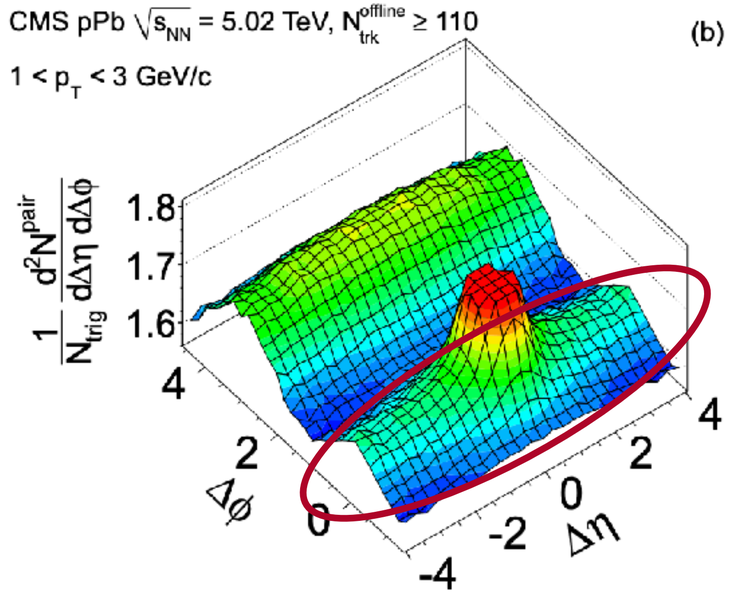






CMS 1305.0609



CMS 1210.5482

Collectivity & QCD

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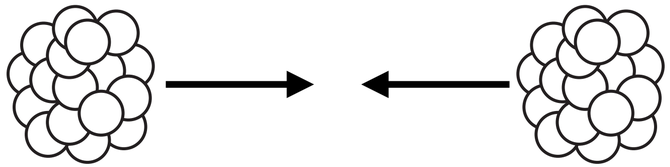

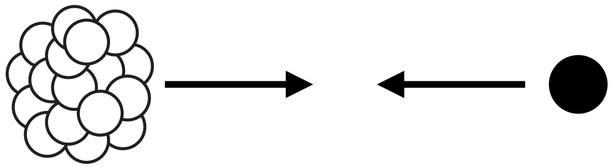

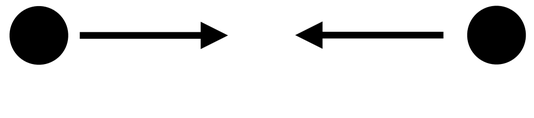

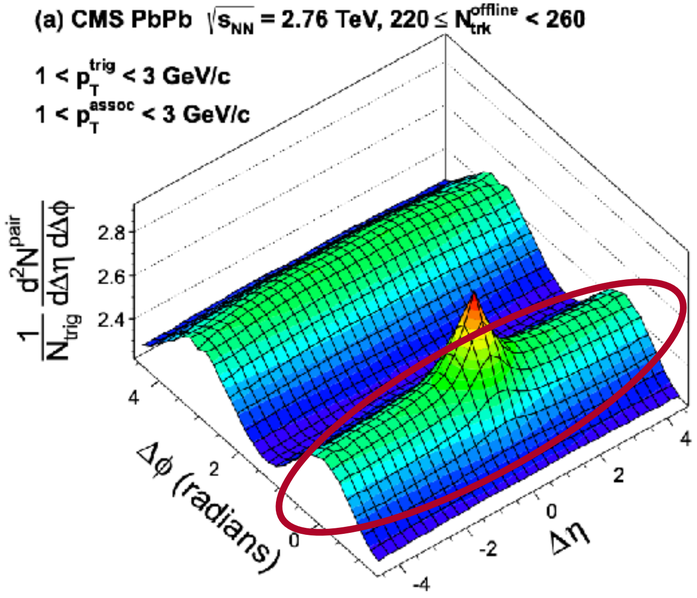

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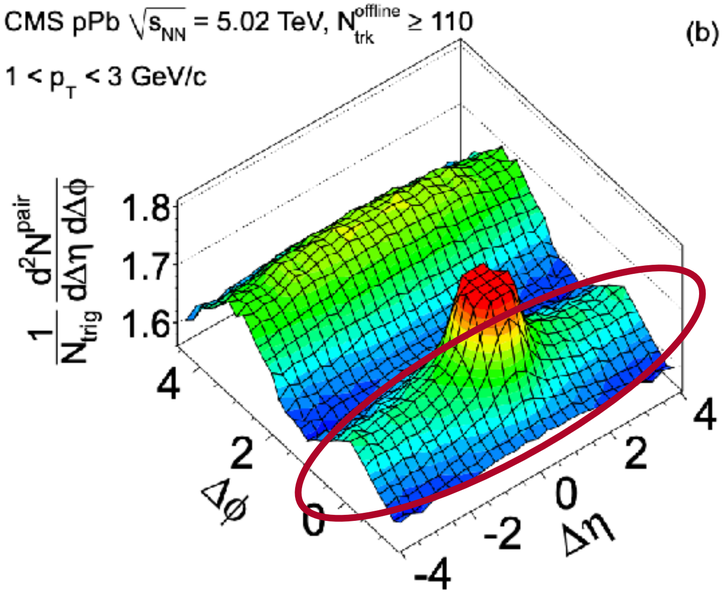

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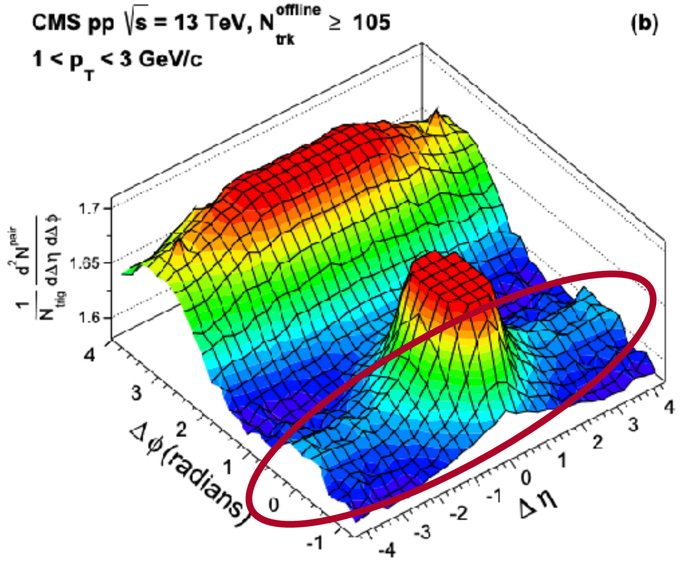

CMS 1510.03068

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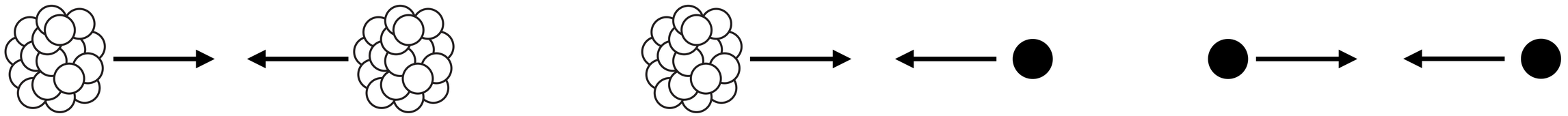


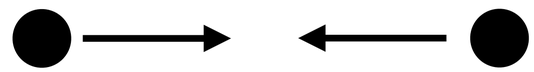
Do QGP arise even in small systems?

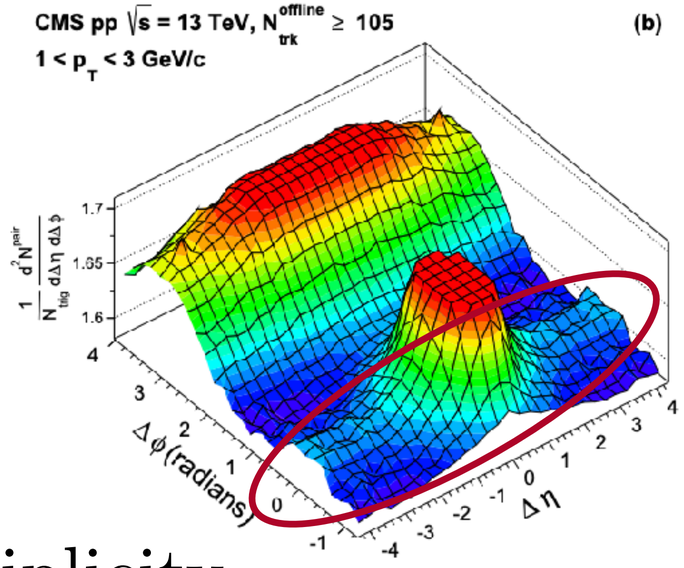
*How small is **too** small?*

Collectivity & QCD

There are correlations between particles in dense environments

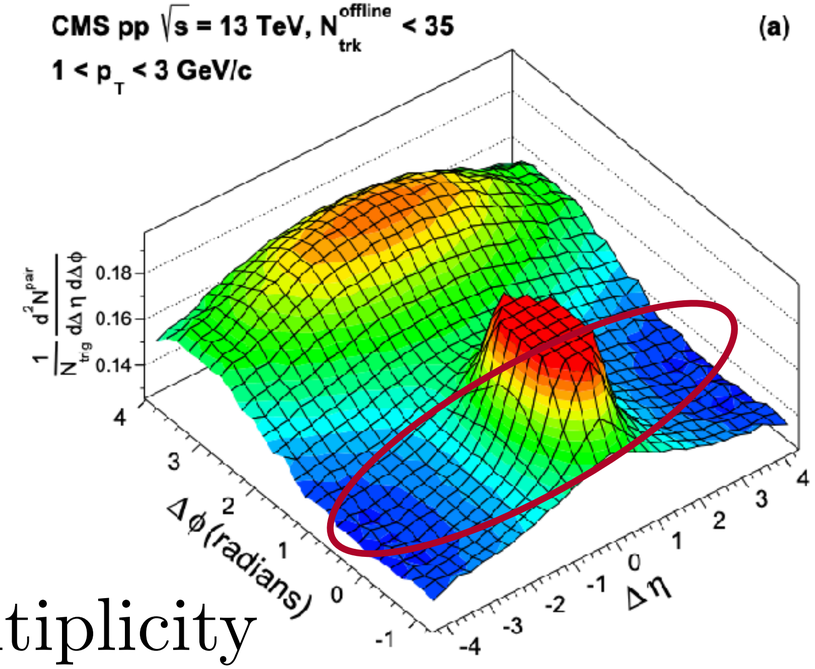
In sufficiently energetic & high multiplicity pp collisions, can QGP form?





High multiplicity

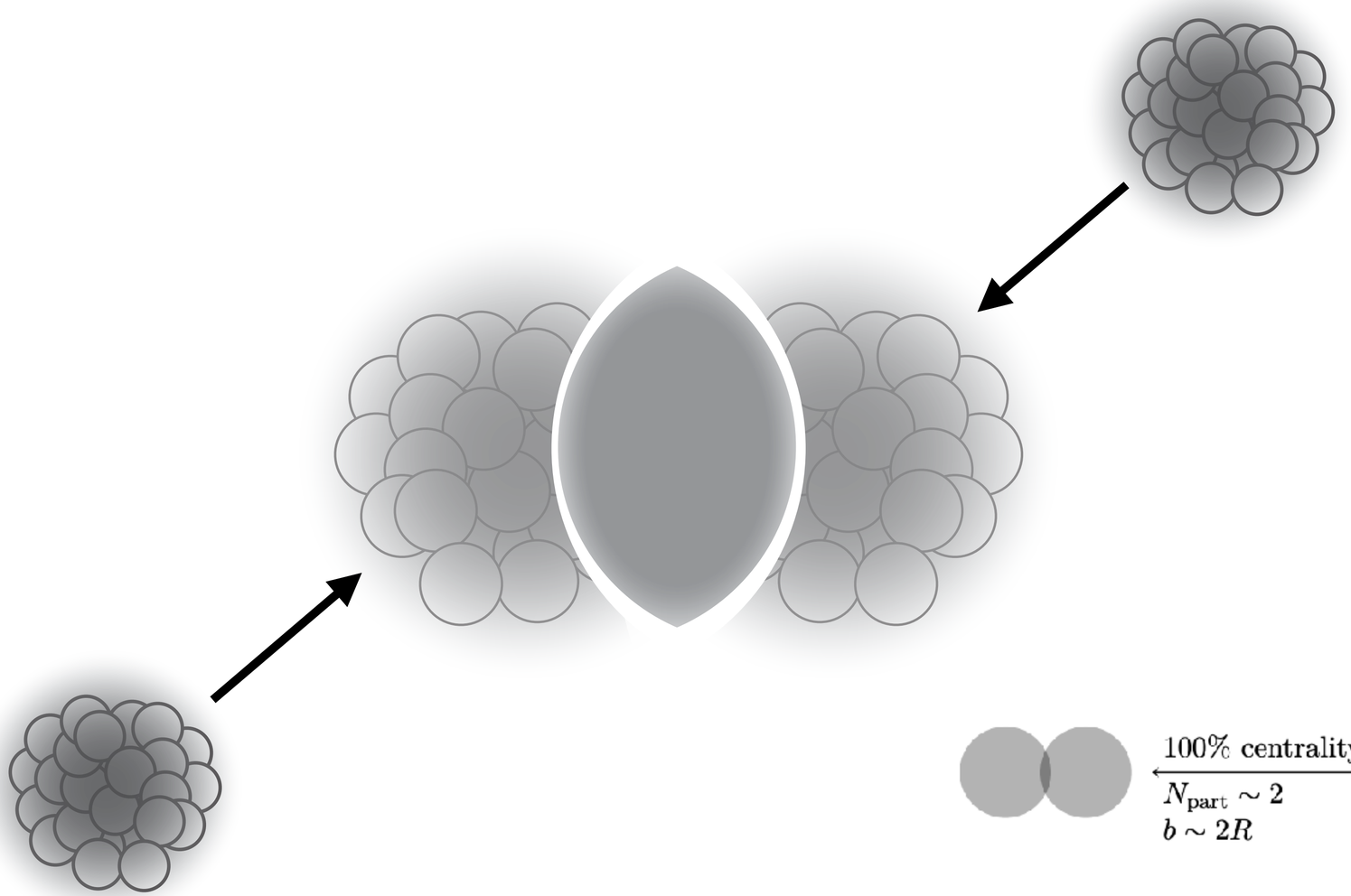
CMS 1510.03068



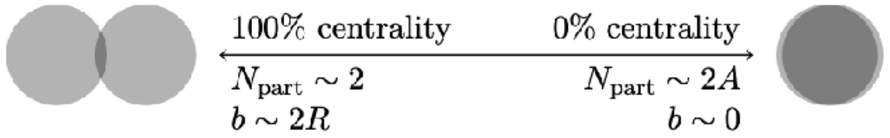
Low multiplicity

Collectivity & QCD

Consider how collectivity arises



Bernhard



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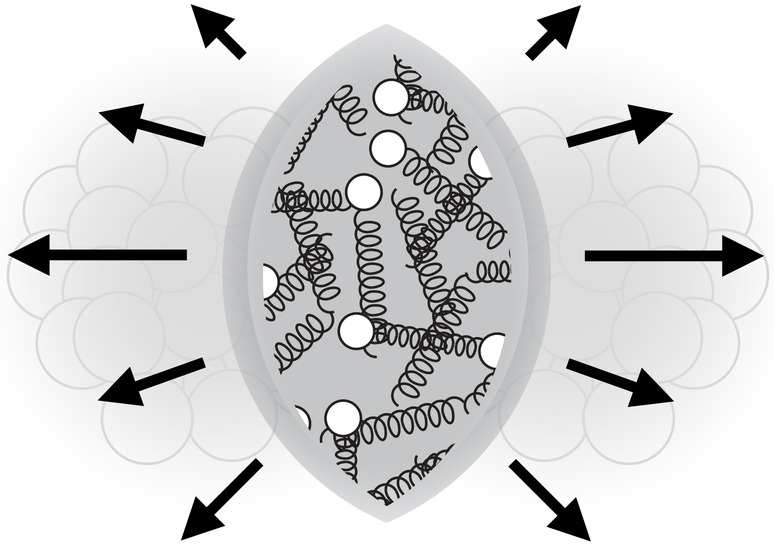
Collectivity & QCD

Consider how collectivity arises

QGP expands anisotropically like a fluid with pressure



Can be modeled with hydrodynamical simulations

Collectivity & QCD

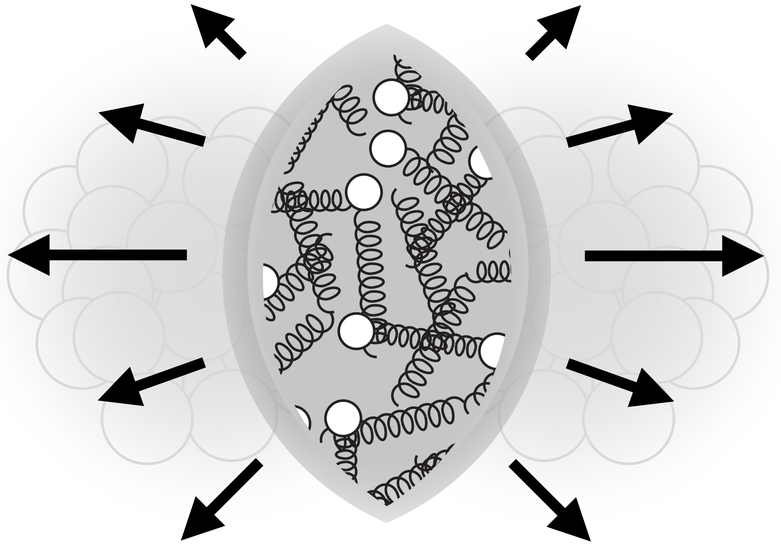
Characterize with *flow coefficients* or *harmonics*

$$\frac{dN}{d\phi} \propto 1 + 2\sum v_n \cos\left(n(\phi - \Psi_n)\right)$$

$$v_n = \langle \cos\left[n(\phi - \Psi_n)\right] \rangle$$

Elliptic flow

$$v_2 = \langle \cos\left[2(\phi - \Psi_2)\right] \rangle$$



$\phi = 0$

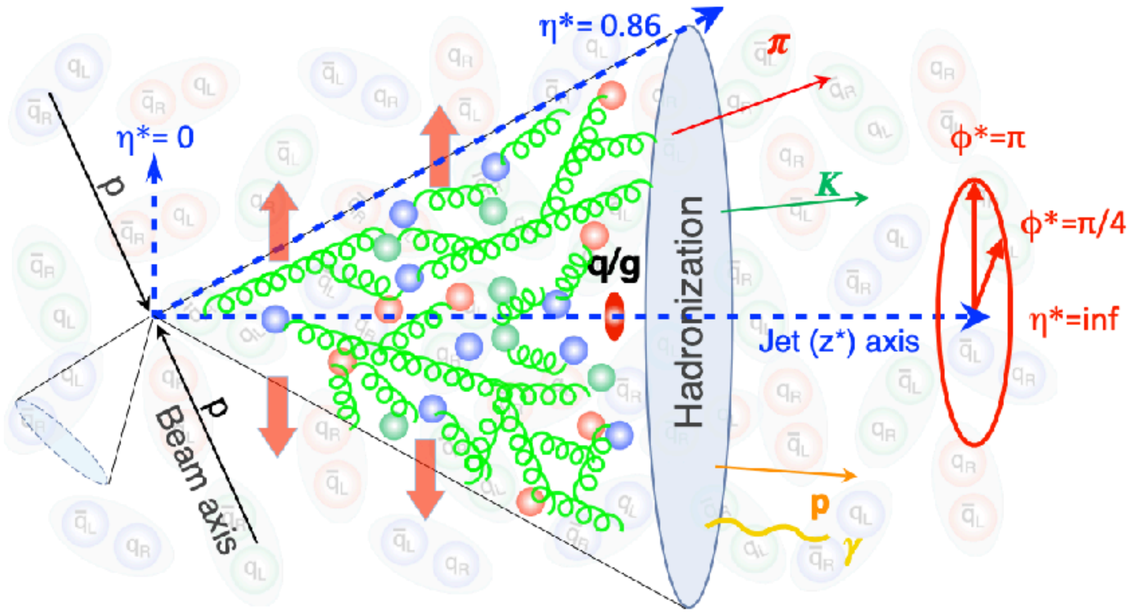
Average over particles in event and centrality bin

Collectivity & Jets

Using these observables, can we see flow in jets?

Instead of almond-shape initial size, what about a jet?

$$\frac{1}{N_{\mathrm{ch}}^{\mathrm{trg}}}\frac{\mathrm{d}N^{\mathrm{pair}}}{\mathrm{d}\Delta\phi^{*}} \propto 1 + 2\sum_{n=1}^{\infty} V_{\mathrm{n}\Delta}^{*}\cos(\mathrm{n}\Delta\phi^{*})$$



CMS 2312.17103

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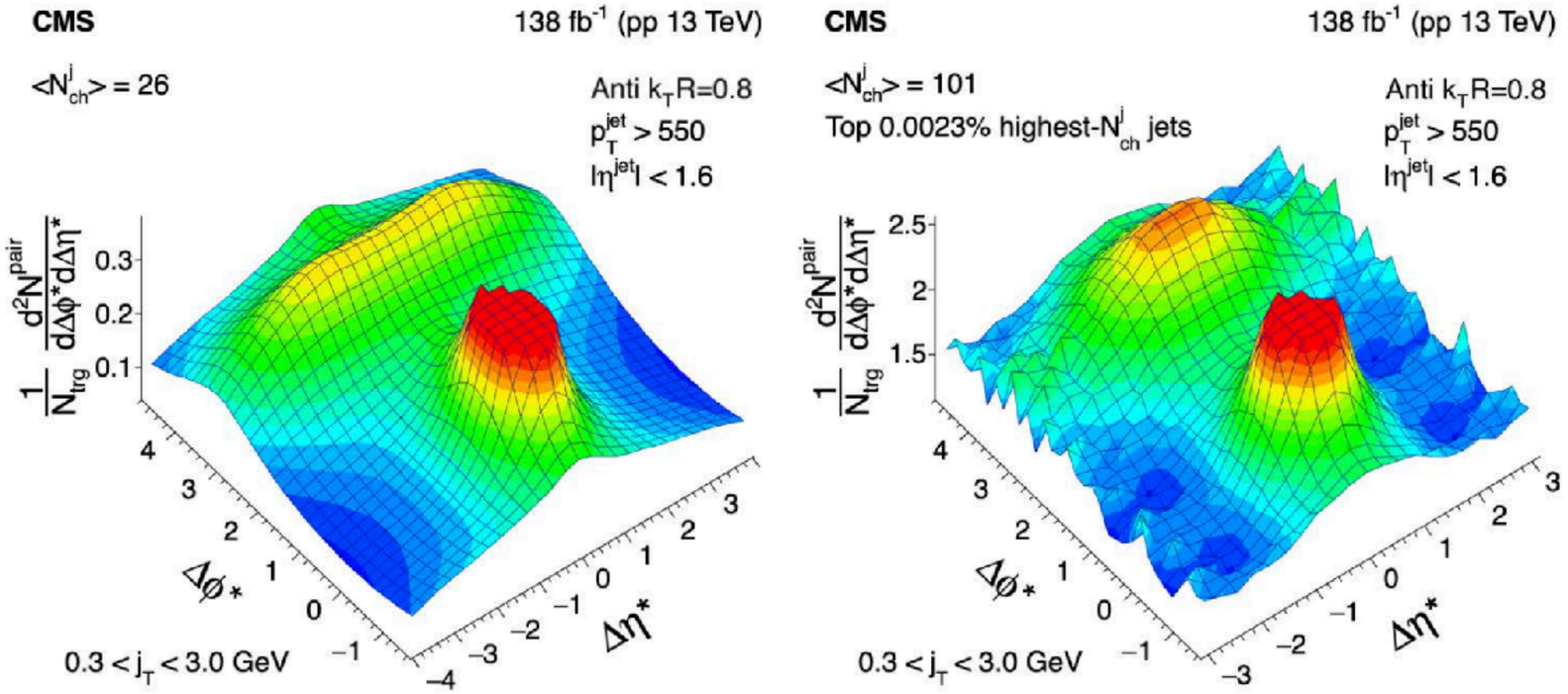
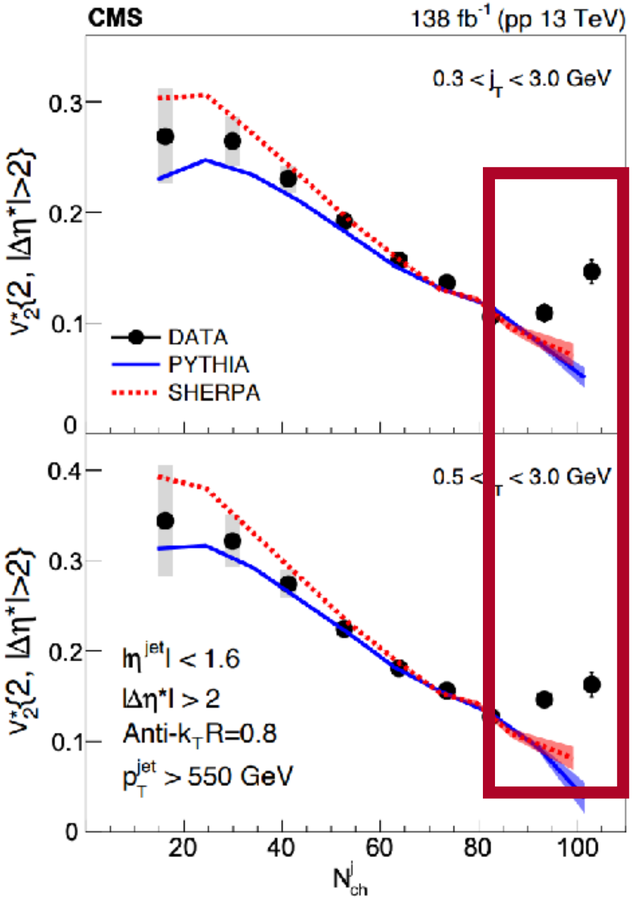




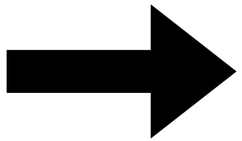
CMS 2312.17103

Outlook

Pipeline for studying hydrodynamics in jets
(Work in progress)

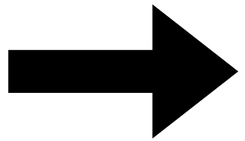
Pythia 8

Simulate CMS jet samples



Trajectum

Apply hydrodynamics to jet constituents



Compute Event Shapes

See if with hydro we can better match data

Pipelin S

s in jets

Pythia 8

Simulate CMS jet samples

Trajectum Code (G. Nijs)

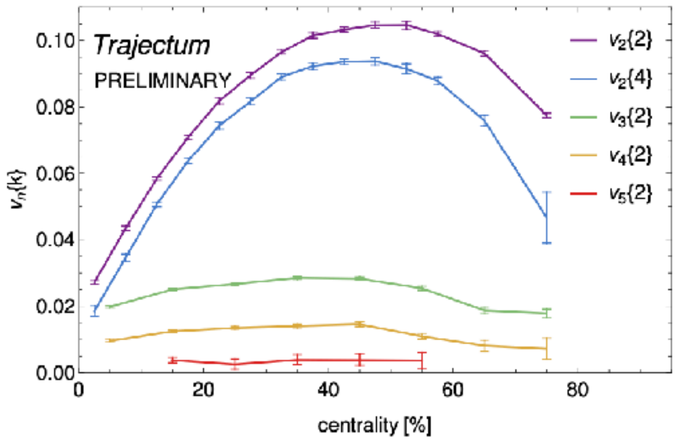
```
#                                                                              #
# References:                                                                  #
# Phys. Rev. C 82 (2010) 014610 [arXiv:1006.5018]                              #
# Phys. Rev. C 82 (2010) 044610 [arXiv:1007.0963]                              #
#------------------------------------------------------------------------------#

#------------------------------------------------------------------------------#
#                            This is Trajectum 2.0                             #
#                                                                              #
#                                Lead developers:                              #
#                       Govert Nijs      Wilke van der Schee                   #
#                                                                              #
#                               Code contributors:                             #
#                    Robin van Bijleveld      Cari Cesarotti                   #
#                        Olaf Massen      Daniel Spitz                         #
#                                                                              #
# If you use Trajectum for a publication, please cite:                         #
# Phys. Rev. Lett. 126 (2021) 202301 [arXiv:2010.15130]                        #
# Phys. Rev. C 103 (2021) 054909 [arXiv:2010.15134]                            #
#                                                                              #
# If you use any of the parameter settings derived from Bayesian analyses as   #
# found in the parfiles/ folder, please cite the corresponding publication and #
# clearly state in your publication where the settings are coming from.        #
#                                                                              #
# Trajectum depends on several libraries shown above. Please follow their      #
# citation requests if you use Trajectum features which rely on these          #
# libraries.                                                                   #
#------------------------------------------------------------------------------#

Initializing event generators:
        Initializing equation of state and transport coefficients... done.
        Initializing hydrodynamics model... done.
        Initializing prehydrodynamic stage model... done.
        Initializing initial conditions model... done.
        Initializing particlization model... done.
        Initializing hard processes... done.
        Quick initialization of other threads... done.
Finished initialization.

Generating entropies for uniformization of entropy distribution:
Running... done.
Process took 0.2 seconds.

Generating events:
Running... 20% (2/10) done                          (4 seconds have passed,
```



CERN

Cesarotti

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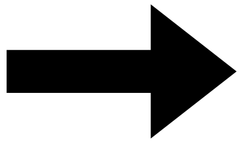
(Work in progress)

Pythia 8

Simulate CMS jet samples



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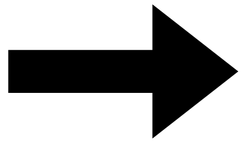

Compute Event Shapes

See if with hydro we can better match data

Compare v_2 to ring EMD?

(See ATLAS 2305.16930)

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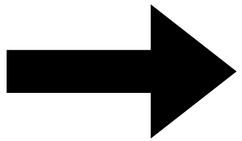
Pythia 8
Simulate CMS jet samples



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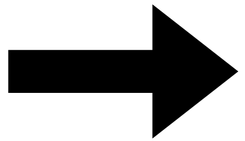

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(See ATLAS 2305.16930)

Could reveal more about the nature of QCD!