A Large Ion Collider Experiment

European Organisation for Nuclear Research

Two- and Three-Particle Jet-like Correlations in the ALICE Experiment at the LHC

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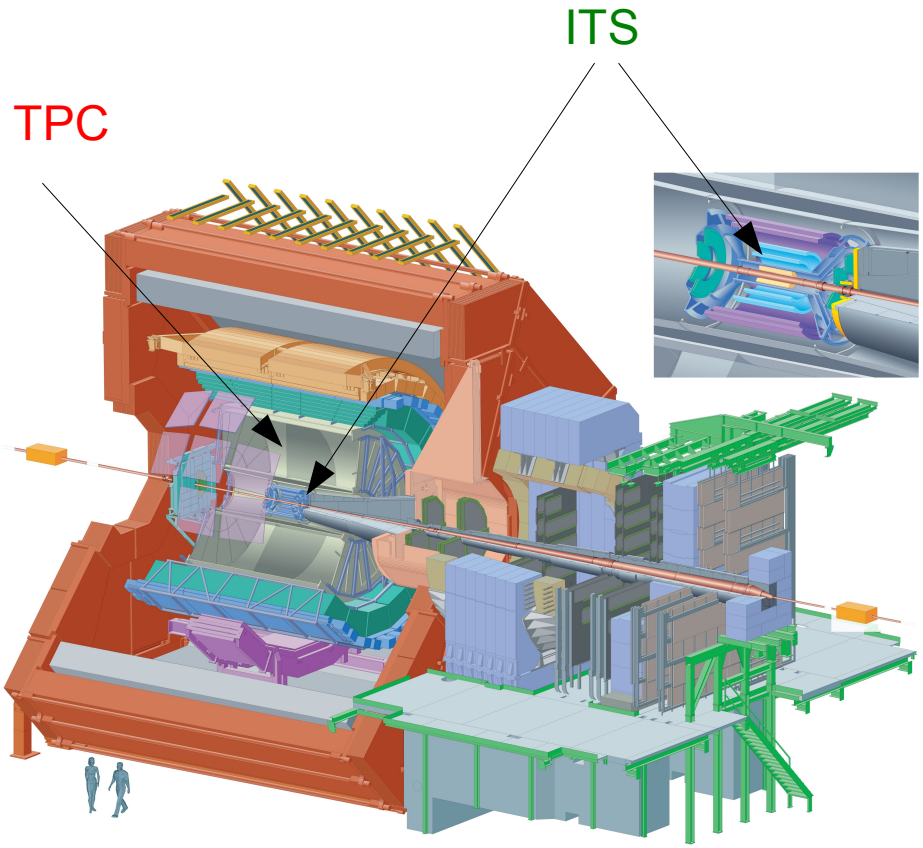
FRANKFURT AM MAIN

Outline

- Motivation
- 2-Particle Correlations
  - $\Delta\phi$
  - $\Delta\phi$–$\Delta\eta$
  - j_T and k_T
- 3-Particle Correlations
  - $\Delta\phi$–$\Delta\phi$
- Summary

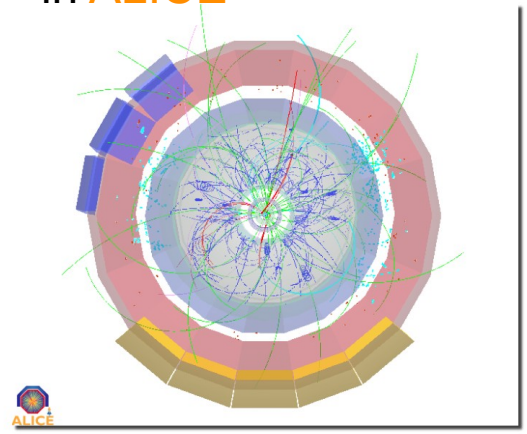
ALICE Experiment

- A Large Ion Collider Experiment
- Dedicated heavy-ion experiment at the LHC.
- Analysis uses chaged tracks in:
  - Time Projection Chamber
  - Inner Tracking System
    - Silicon pixel, strips and drift.



Motivation

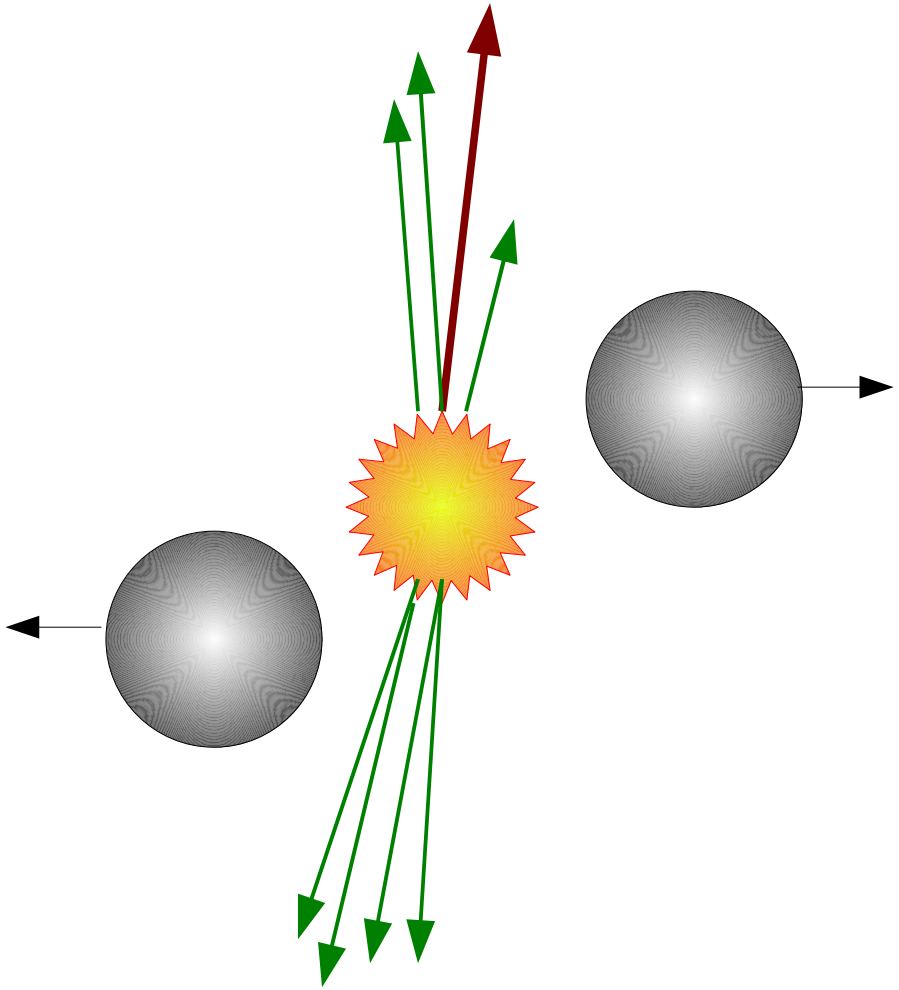
7 TeV *pp* Collision in ALICE



- Heavy-ions:
  - Probe medium created using jets:
    - Modification of medium by the jet.
    - Modification of jet by the medium.
    - At prior experiments interesting effects seen:
      - Energy loss and away-side suppression
      - Near-side ridge
      - Conical emission
- *pp* Collsions:
  - Reference for heavy-ion data
  - Study jet properties.

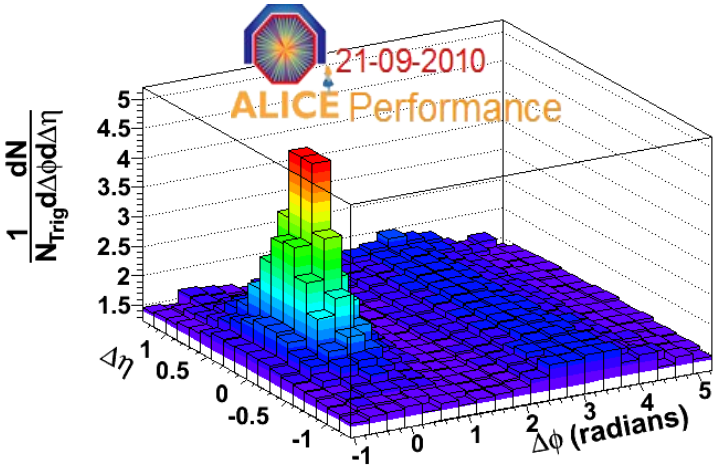
Jet-Like Correlations

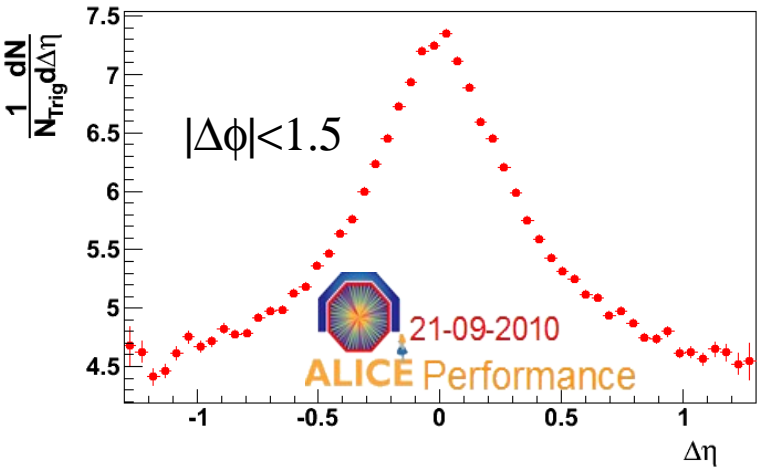
- Study angular correlations between intermediate and high p_T trigger particles and lower p_T associated particles.
- $\Delta\phi=\phi_{Trigger}-\phi_{Associated}$
- $\Delta\eta=\eta_{Trigger}-\eta_{Associated}$

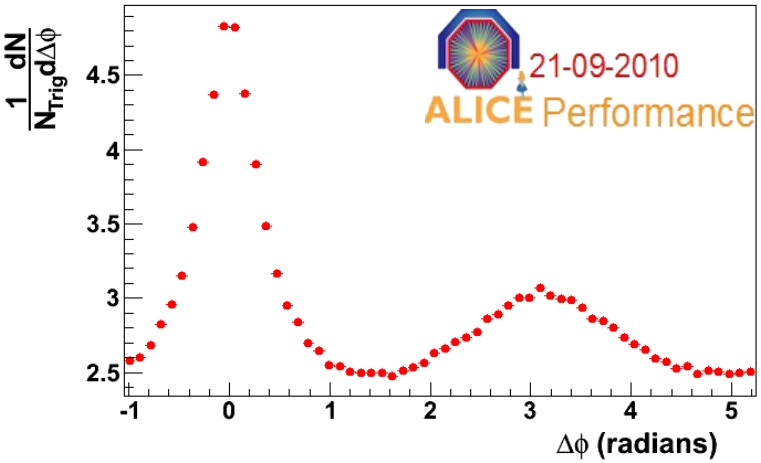


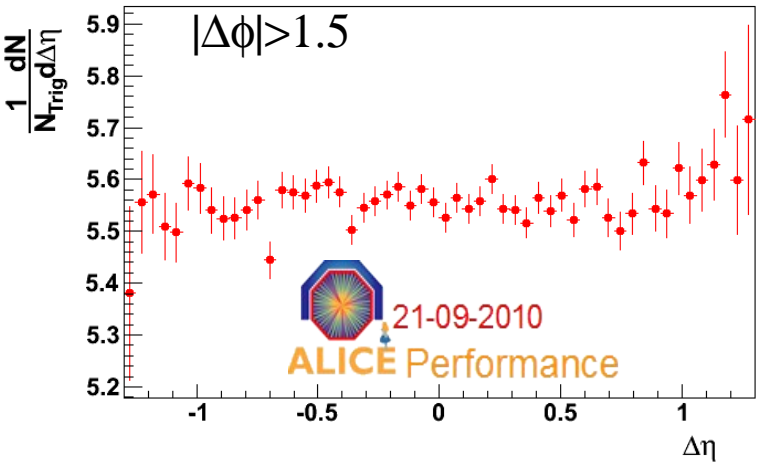
Unsubtracted Correlations

7 TeV *pp*
$4<p_T^{Trigger}<6$ GeV/c
$0.25<p_T^{Assoc}<4$ GeV/c
$|\eta^{Associated}|<0.8$





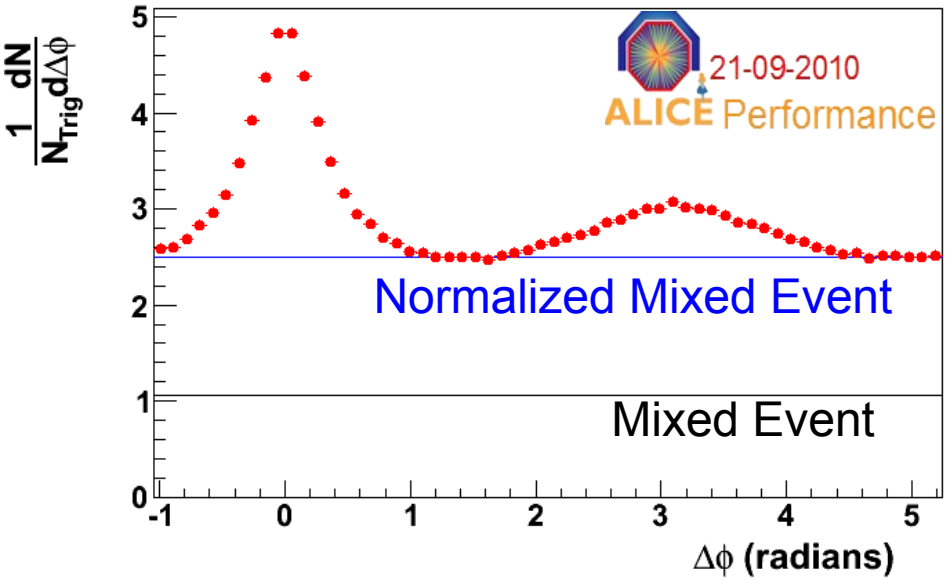


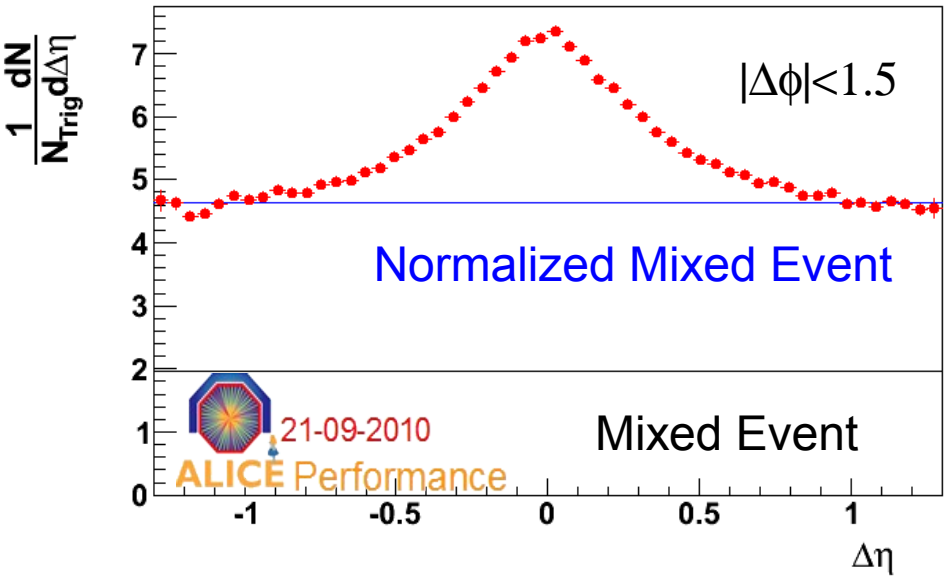


- Single particle efficiency corrected.
- Mixed event acceptance corrected.

Background Subtraction

7 TeV *pp*
$4<p_T^{Trigger}<6$ GeV/c
$0.25<p_T^{Assoc}<4$ GeV/c
$|\eta|<0.8$



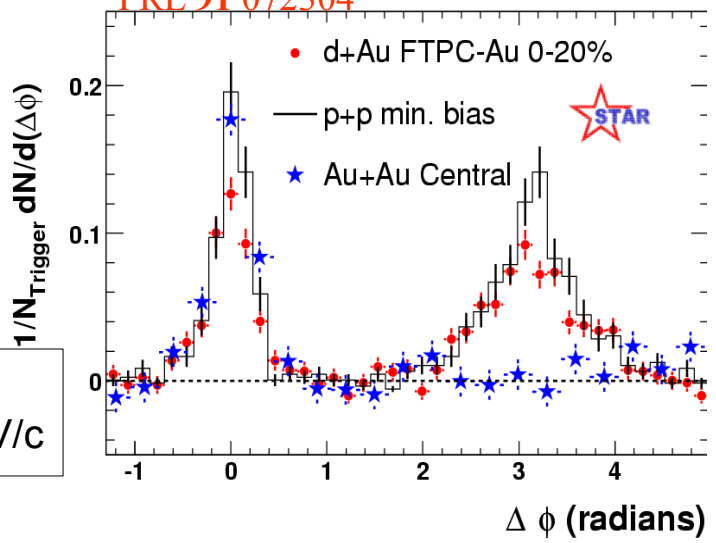


- Background from mixed events.
- Triggering biases background level.
- Jet signal positive definite
  - Maximum level of background is Zero Yield At Minimum.
- Normalizing to
- $|\Delta\phi\pm1.5|<0.2$ radians.

Prior Experiments
Away-Side Suppression

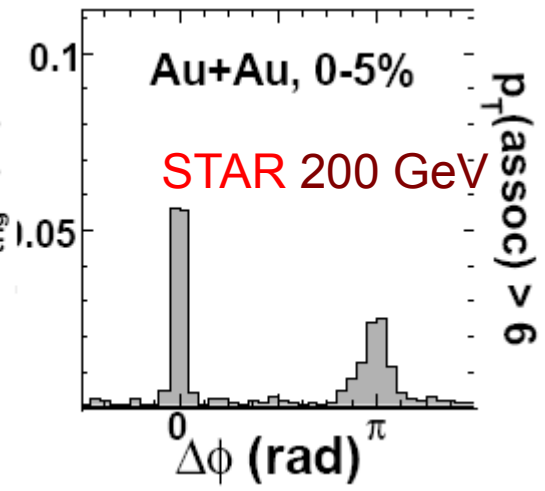
PRL **90** 082302
PRL **91** 072304

STAR 200 GeV



4<p_T^{Trig}<6 GeV/c
2<p_T^{Assoc}<p_T^{Trig} GeV/c

PRL97 162301

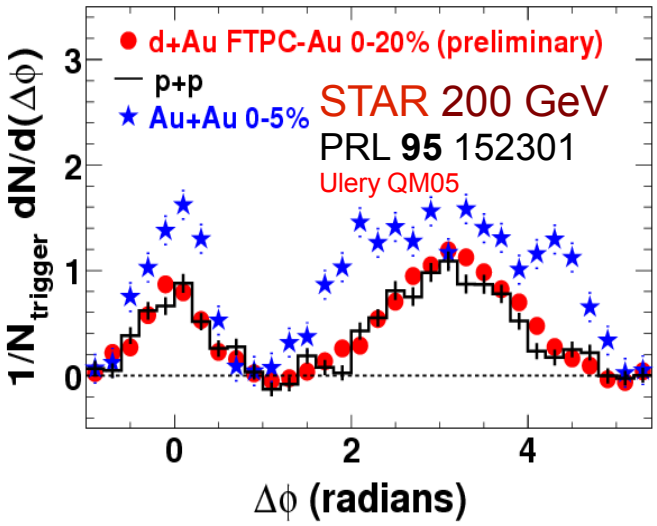


8<p_T^{Trig}<15
p_T^{Assoc}>6 GeV/c

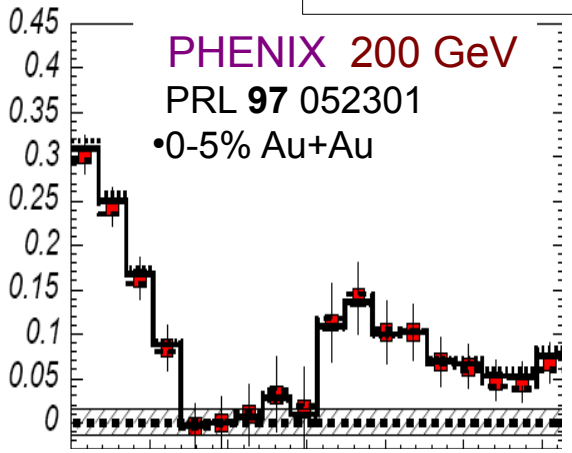
- Away-side in central Au+Au was found to almost entirely disappear for intermediate (~2 GeV/c) p_T associated.
- Returns (but suppressed relative to d+Au) for high p_T associated.

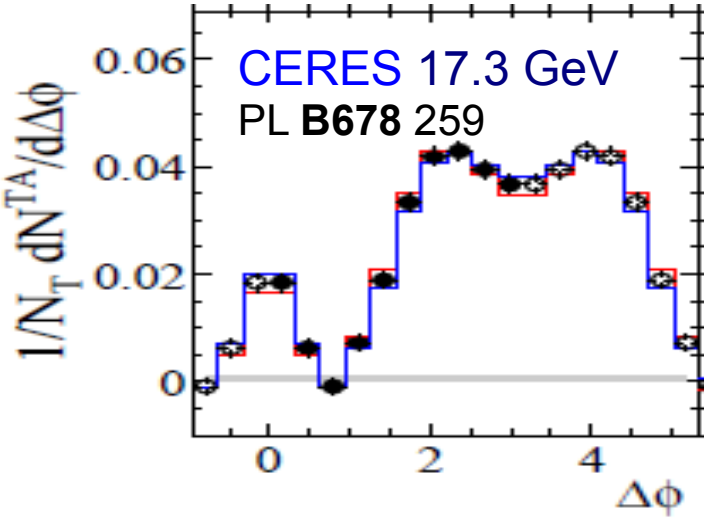
Prior Experiments
Away-side Modification

$4<p_T^{Trig}<6$, $0.15<p_T^{Assoc}<4$ GeV/c



$2.5<p_T^{Trig}<4$, $1<p_T^{Assoc}<2.5$ GeV/c



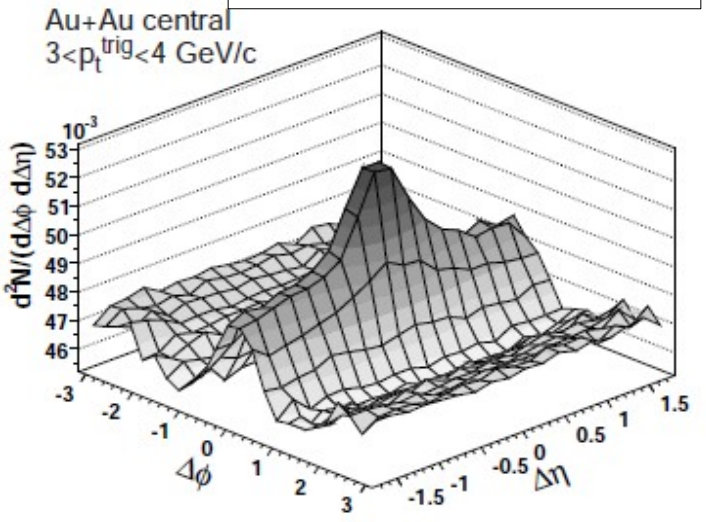


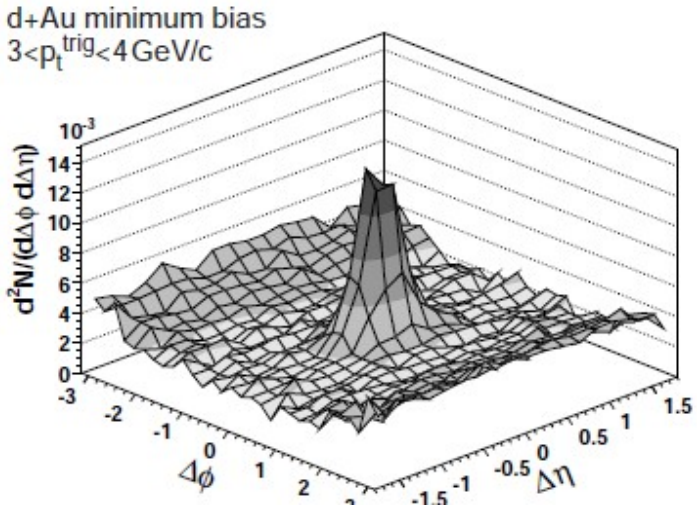
- Enhanced and broadened away-side in heavy-ions for low and intermediate p_T.
- Even dipped for associated ~1 GeV/c

Prior Experiments
Ridge

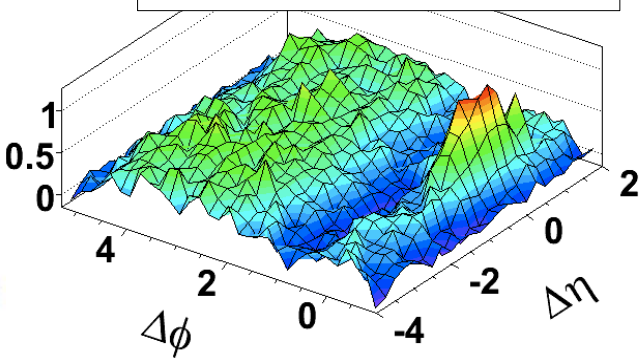
STAR
PRC 80 64912
0-10% Au+Au, d+Au
$3<p_T^{Trigger}<4$ GeV/c
$p_T^{Assoc}>2$ GeV/c

200 GeV





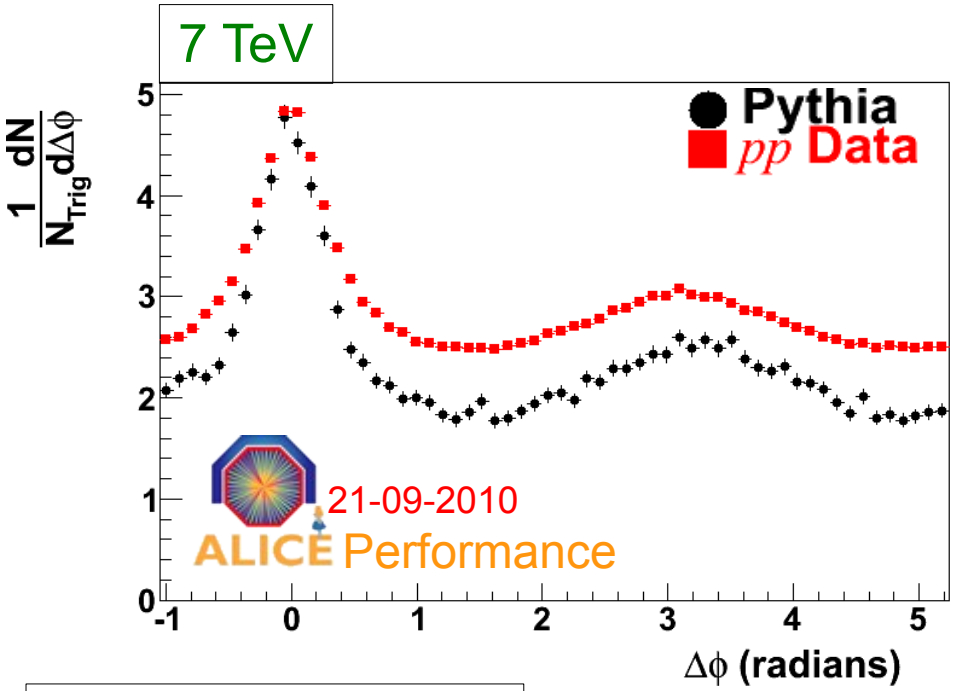
PHOBOSPreliminary
Wenger, QM08
0-30% Au+Au
$p_T^{Trigger}>2.5$ GeV/c
$p_T^{Assoc}>0.02$ GeV/c

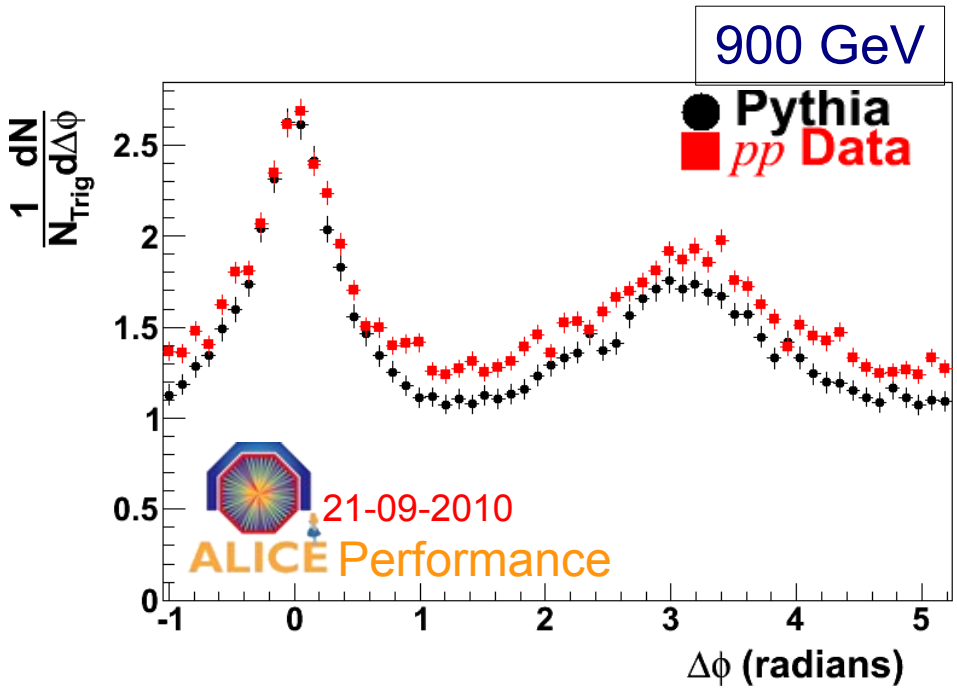


- Near-side ridge correlated in azimuth but not pesudorapidity seen in heavy-ions.
  - Not present in minimum bias d+Au

Pythia Comparison Unsubtracted

$4<p_T^{Trigger}<6$ GeV/c
$0.25<p_T^{Assoc}<4$ GeV/c
$|\eta|<0.8$



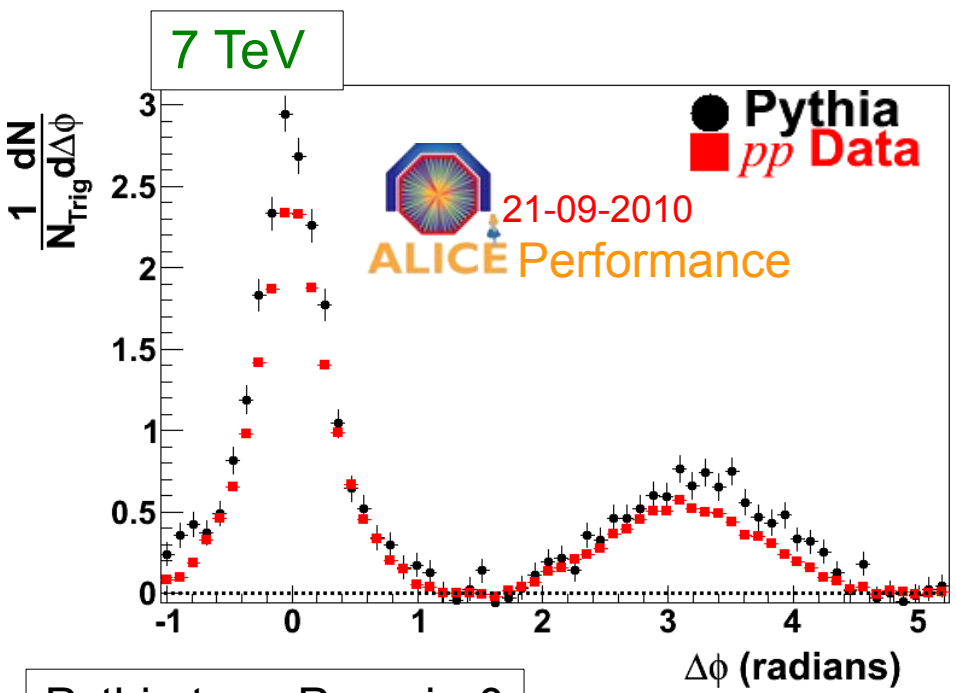


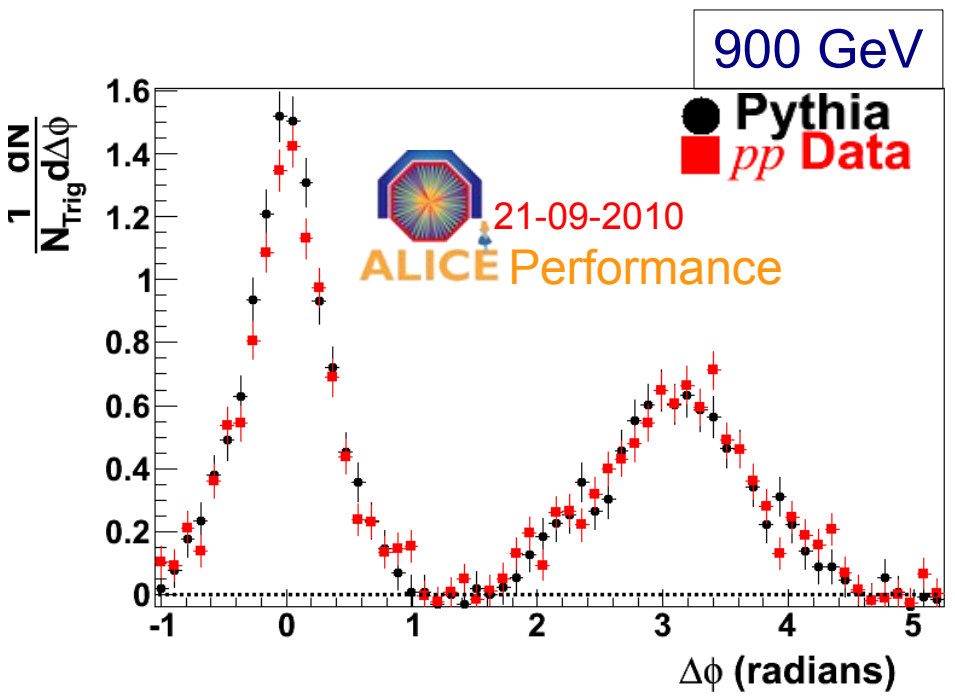
Pythia tune Perugia-0

- Perugia-0 tune of Pythia has less particles in triggered events then the data.

Pythia Comparison

$4<p_T^{Trigger}<6$ GeV/c
$0.25<p_T^{Assoc}<4$ GeV/c
$|\eta|<0.8$





Pythia tune Perugia-0

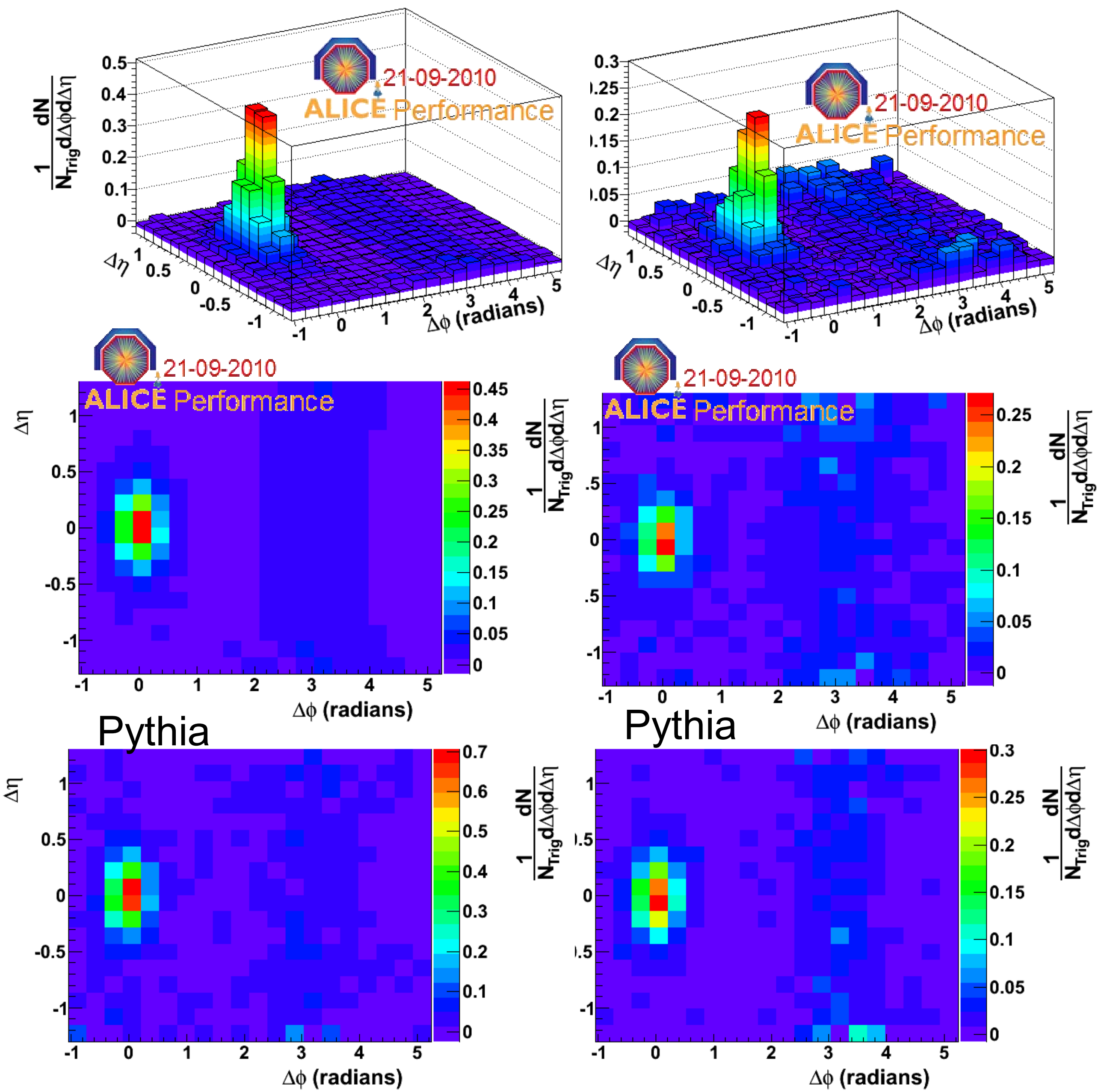
- Near-side peak increases with energy.
- Pythia reproduces 900 GeV fairly well.

2-D Comparison

$3 < p_T^{Trigger} < 4$ GeV/c
$2 < p_T^{Assoc} < 3$ GeV/c

7 TeV

900 GeV



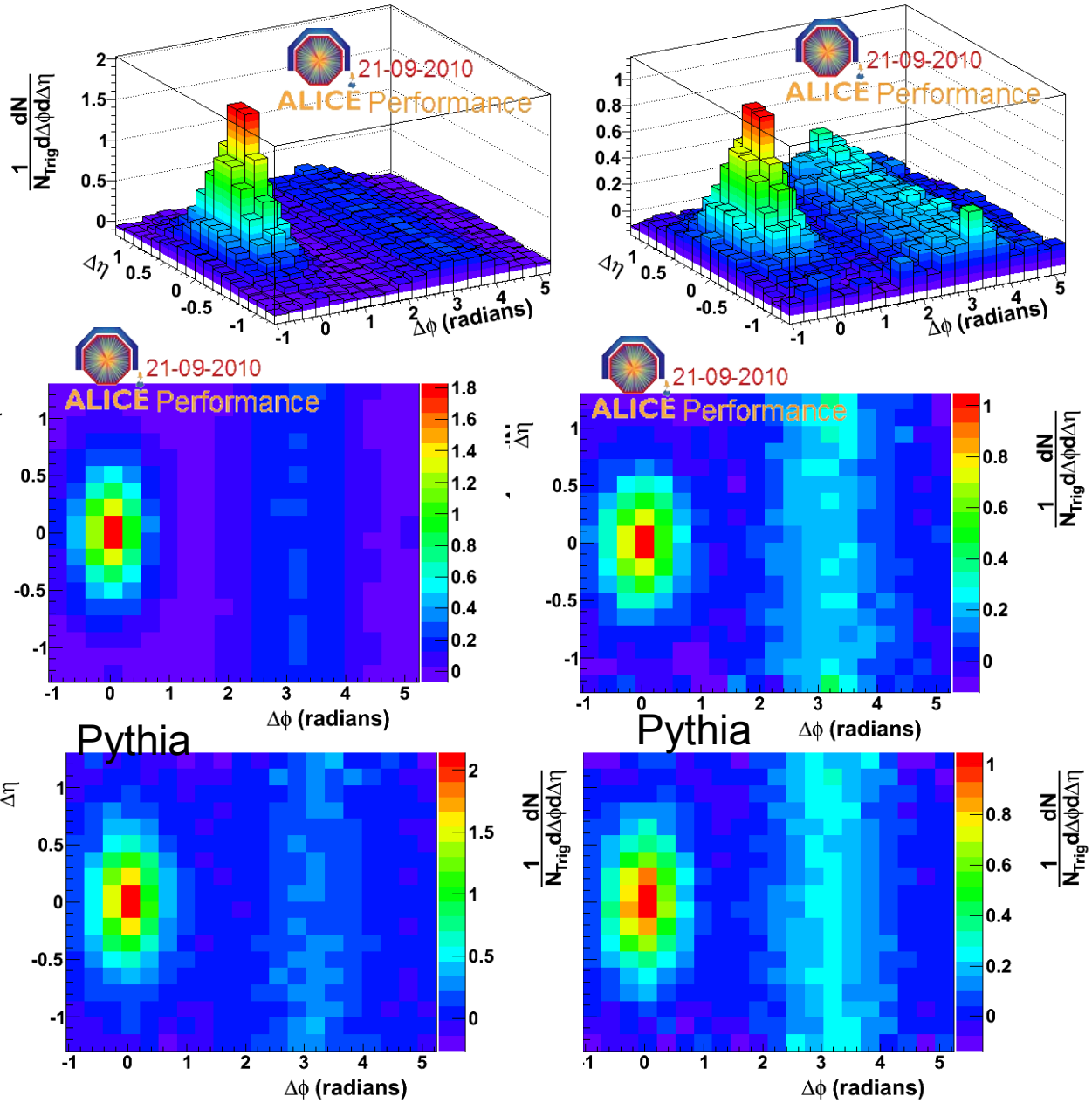
- No "ridge" structure present in minimum bias *pp*.
- Data is similar to Pythia.
    - Near-side peak larger in Pythia at 7 TeV.

2-D Comparison

$2.5<p_T^{Trig}<20$ GeV/c
$0.25<p_T^{Assoc}<2.5$ GeV/c

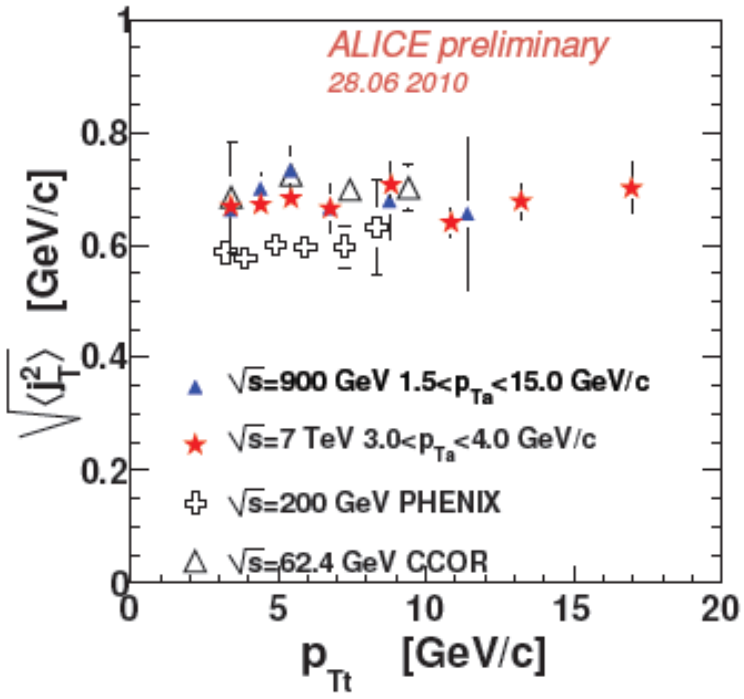
7 TeV

900 GeV



- No "ridge" structure for low-p_T associated in minimum bias *pp*.

Jet Fragmentation Transverse Momentum

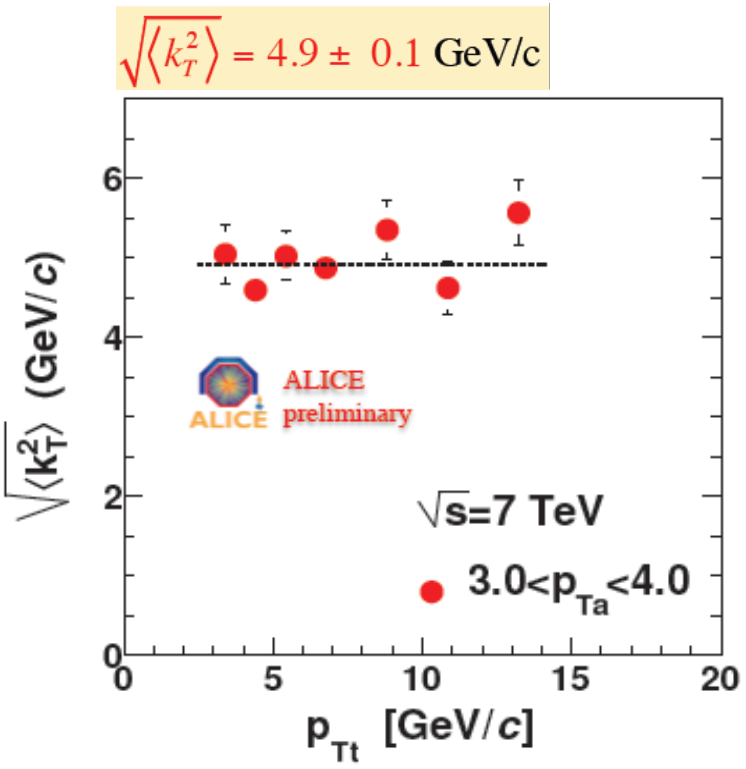


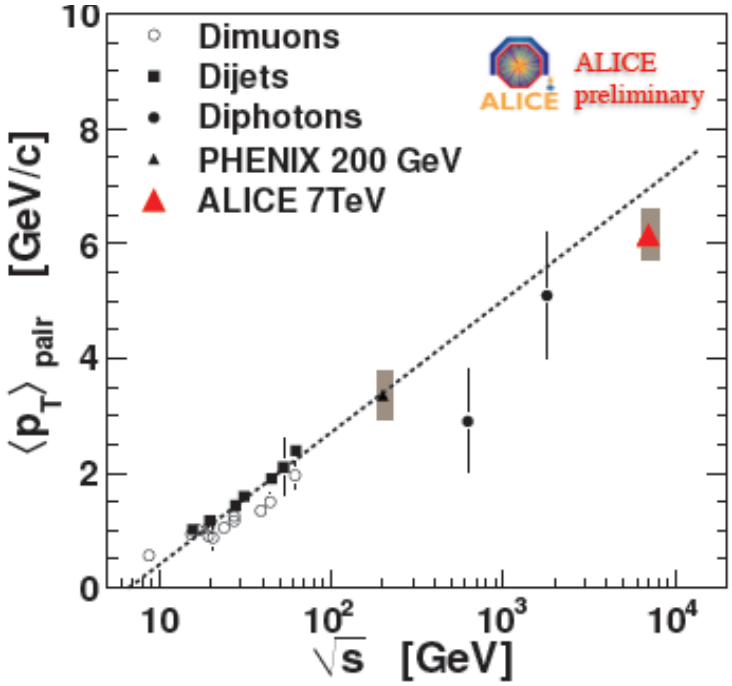
$$\sqrt{\langle j_T^2 \rangle}_{900\ \mathrm{GeV}} = 678 \pm 12\ \mathrm{MeV/c}$$

$$\sqrt{\langle j_T^2 \rangle}_{7\ \mathrm{TeV}} = 673 \pm 5\ \mathrm{MeV/c}$$

- p_T of jet particles perpendicular to the jet-axis.
- No significant p_T dependence.
- No significant energy dependence.
- Only statistical errors shown.

k_T

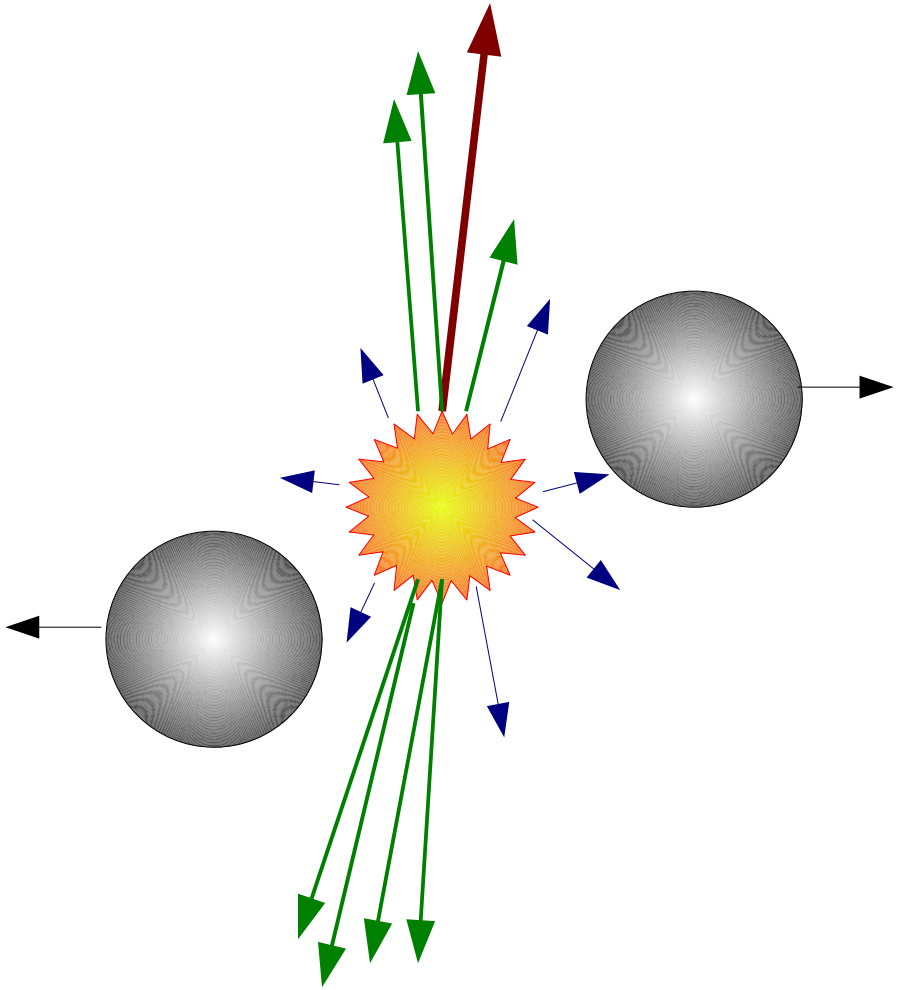




- k_T is initial transverse momentum of the partons in the hard-scattering
- Statistical errors only.

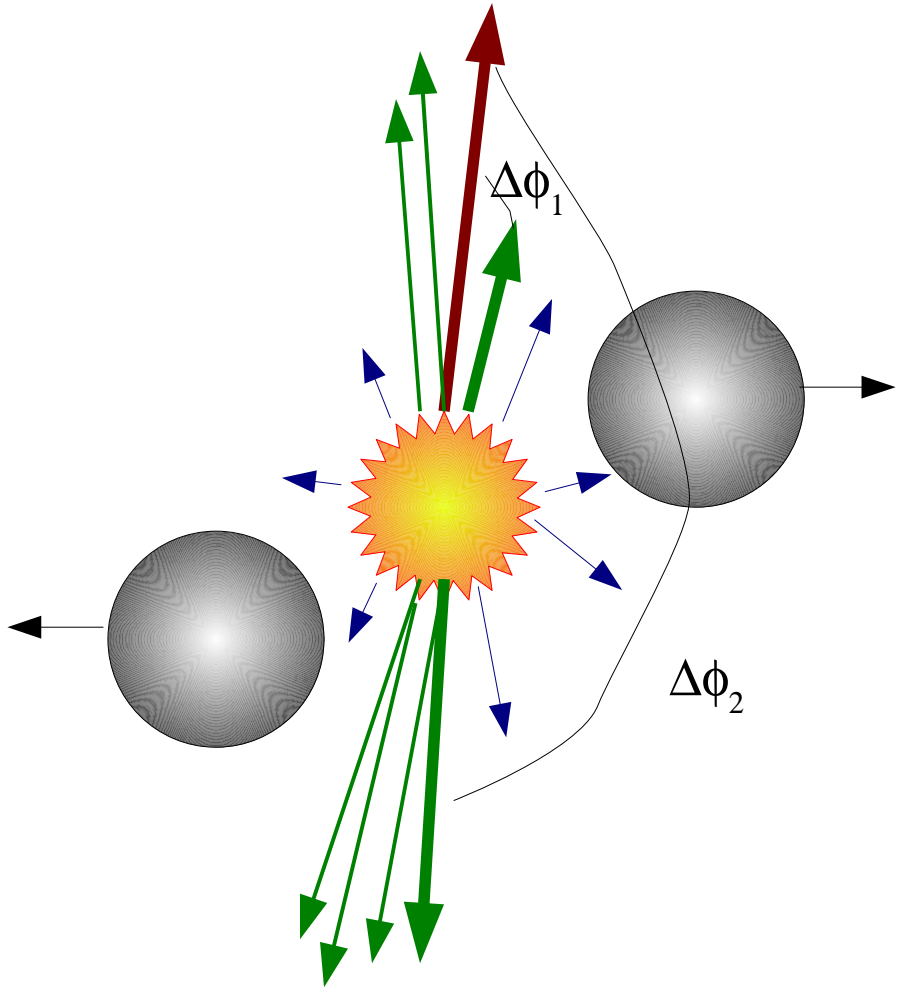
3-Particle Correlations

- Select an intermediate or high-p_T trigger particle.
- Look at relative angles between trigger and 2 other particles.
- $\Delta\phi_1 = \phi_{Trigger} - \phi_{Associated,1}$
- $\Delta\phi_2 = \phi_{Trigger} - \phi_{Associated,2}$



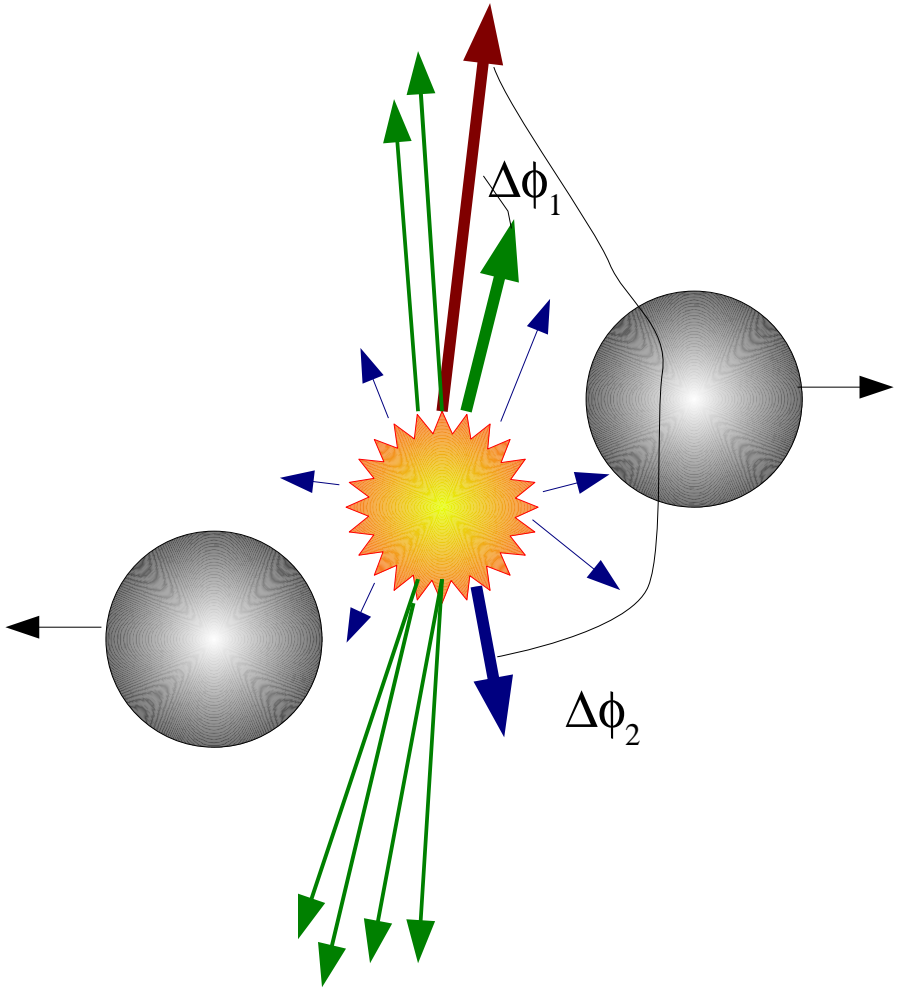
3-Particle Correlations

- Select an intermediate or high-p_T trigger particle.
- Look at relative angles between trigger and 2 other particles.
- $\Delta\phi_1 = \phi_{Trigger} - \phi_{Associated,1}$
- $\Delta\phi_2 = \phi_{Trigger} - \phi_{Associated,2}$
- Both particles from jet.
  - Our signal.



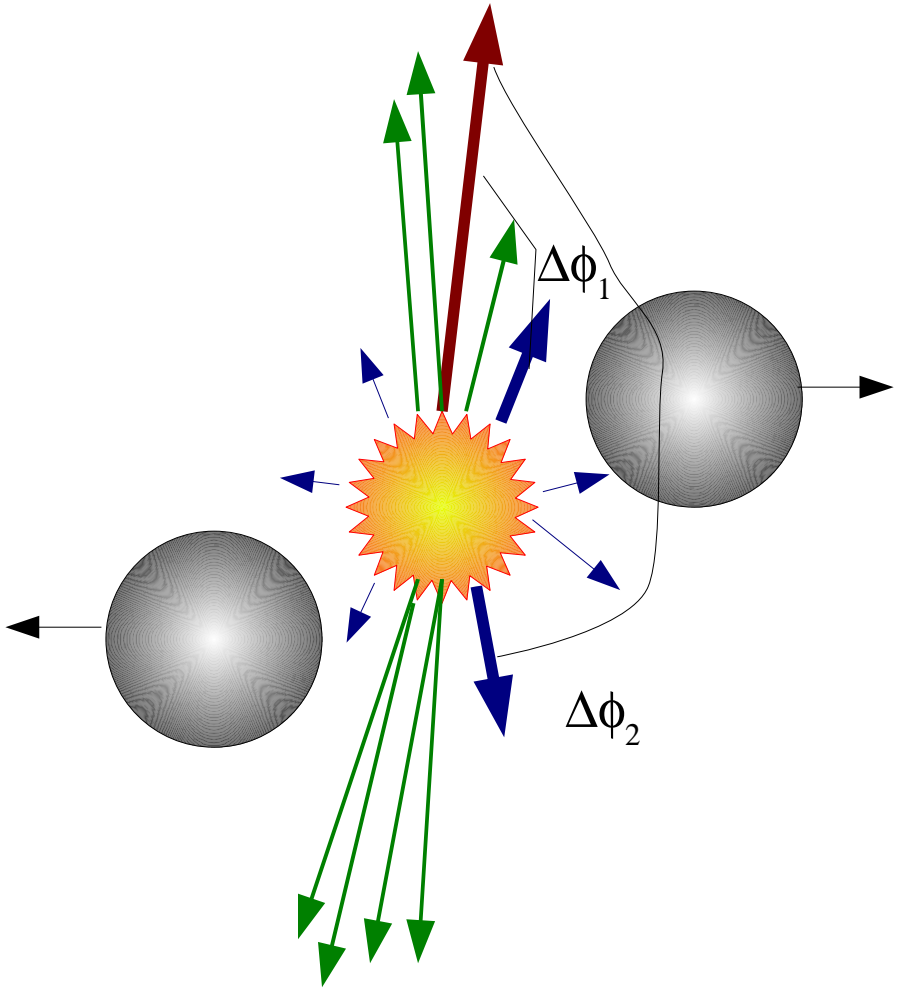
3-Particle Correlations

- Select an intermediate or high-p_T trigger particle.
- Look at relative angles between trigger and 2 other particles.
- $\Delta\phi_1 = \phi_{Trigger} - \phi_{Associated,1}$
- $\Delta\phi_2 = \phi_{Trigger} - \phi_{Associated,2}$
- 1 from jet and 1 from background.
  - Hard-soft background

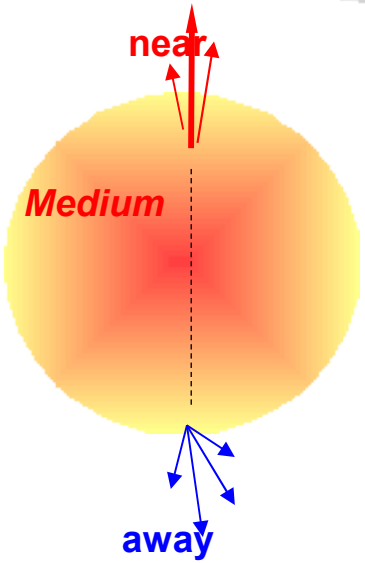


3-Particle Correlations

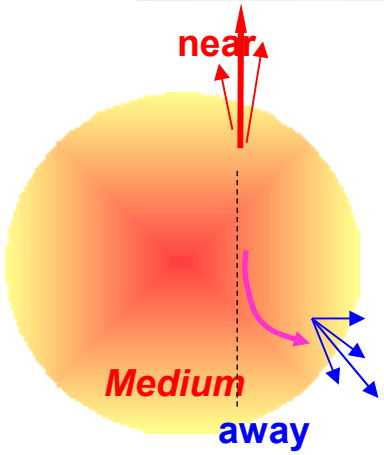
- Select an intermediate or high-p_T trigger particle.
- Look at relative angles between trigger and 2 other particles.
- $\Delta\phi_1 = \phi_{Trigger} - \phi_{Associated,1}$
- $\Delta\phi_2 = \phi_{Trigger} - \phi_{Associated,2}$
- Both from background.
  - Soft-soft background



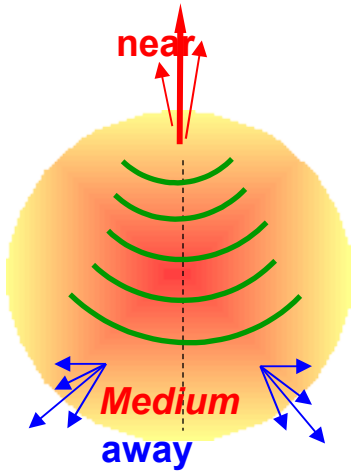
Δϕ–Δϕ 3-Particle Correlations



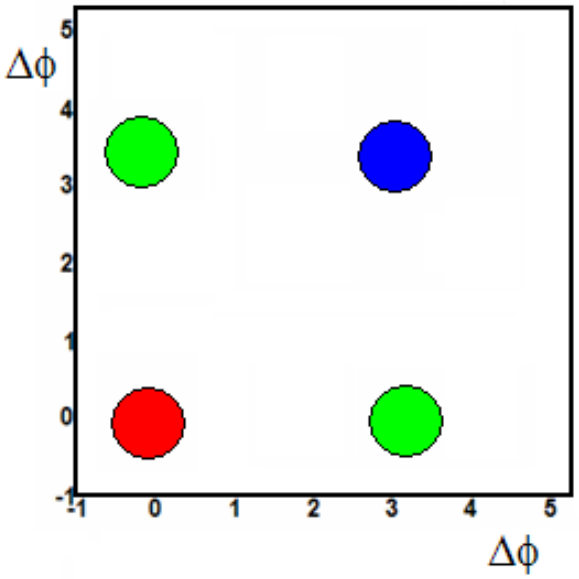
di-jets

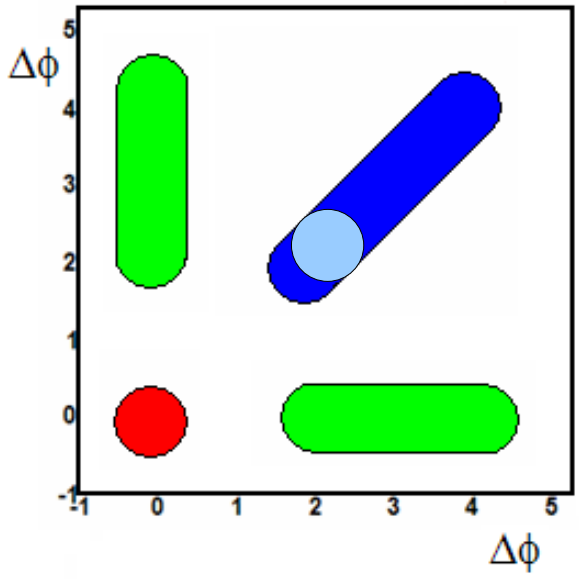


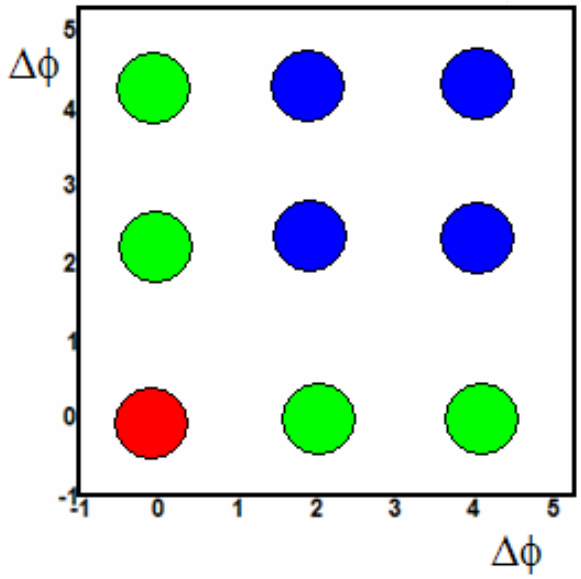
deflected jets, k_T



Conical Emission





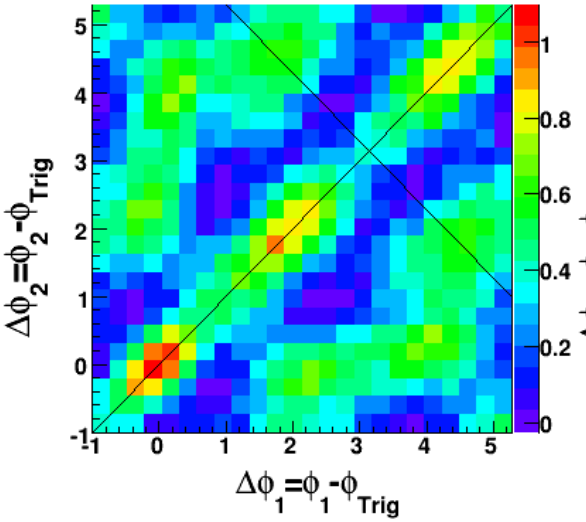


Prior Experiments

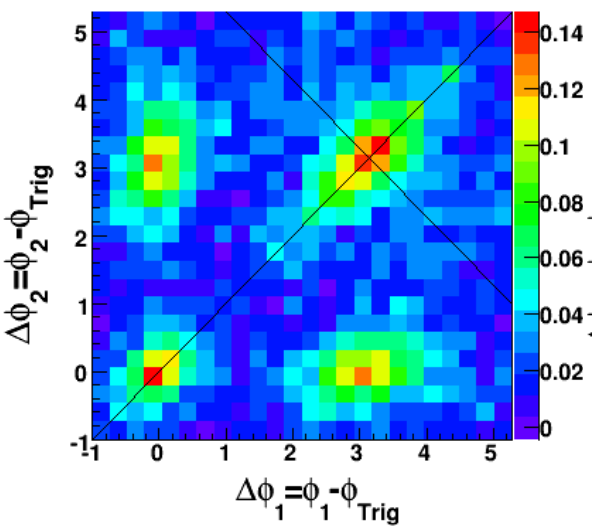
$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

200 GeV
STAR PRL 102:052302

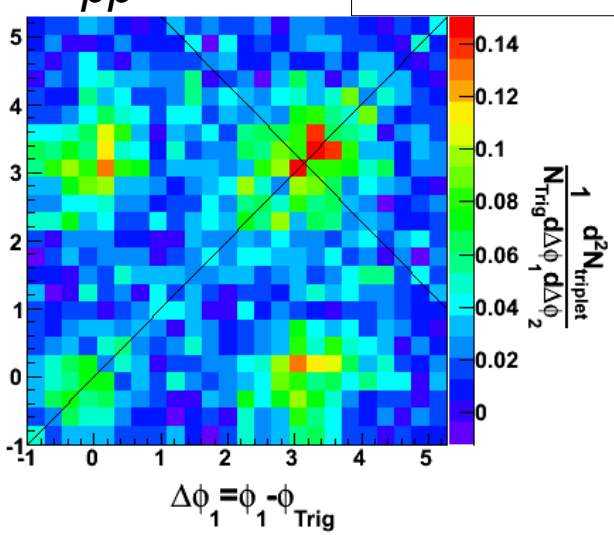
Au+Au 0-12%



d+Au



pp



- Conical emission seen in heavy-ion collisions at RHIC.
  - Not seen in *pp* or d+Au.

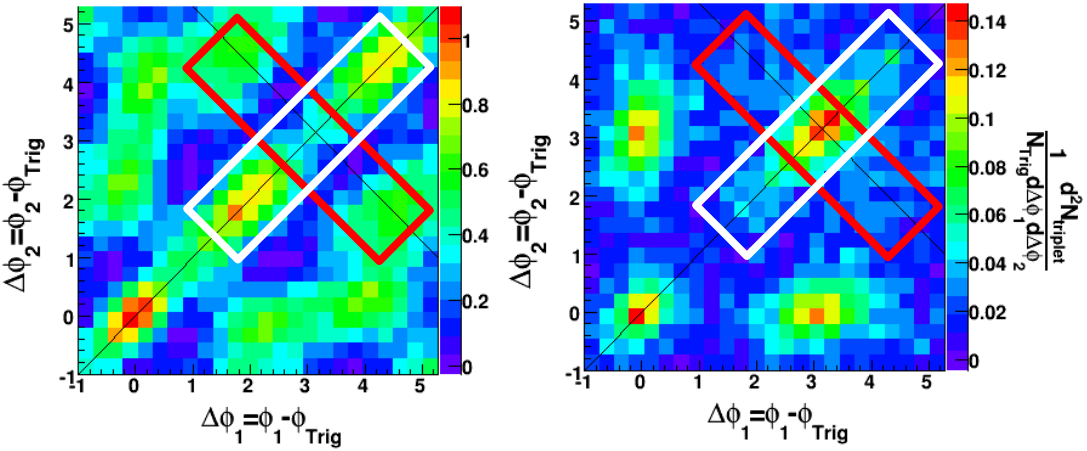
Prior Experiments

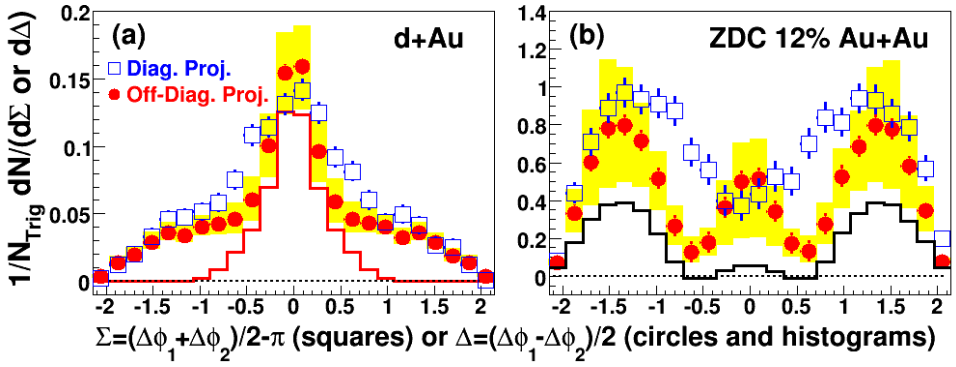
$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

200 GeV
STAR PRL 102:052302

Au+Au 0-12%

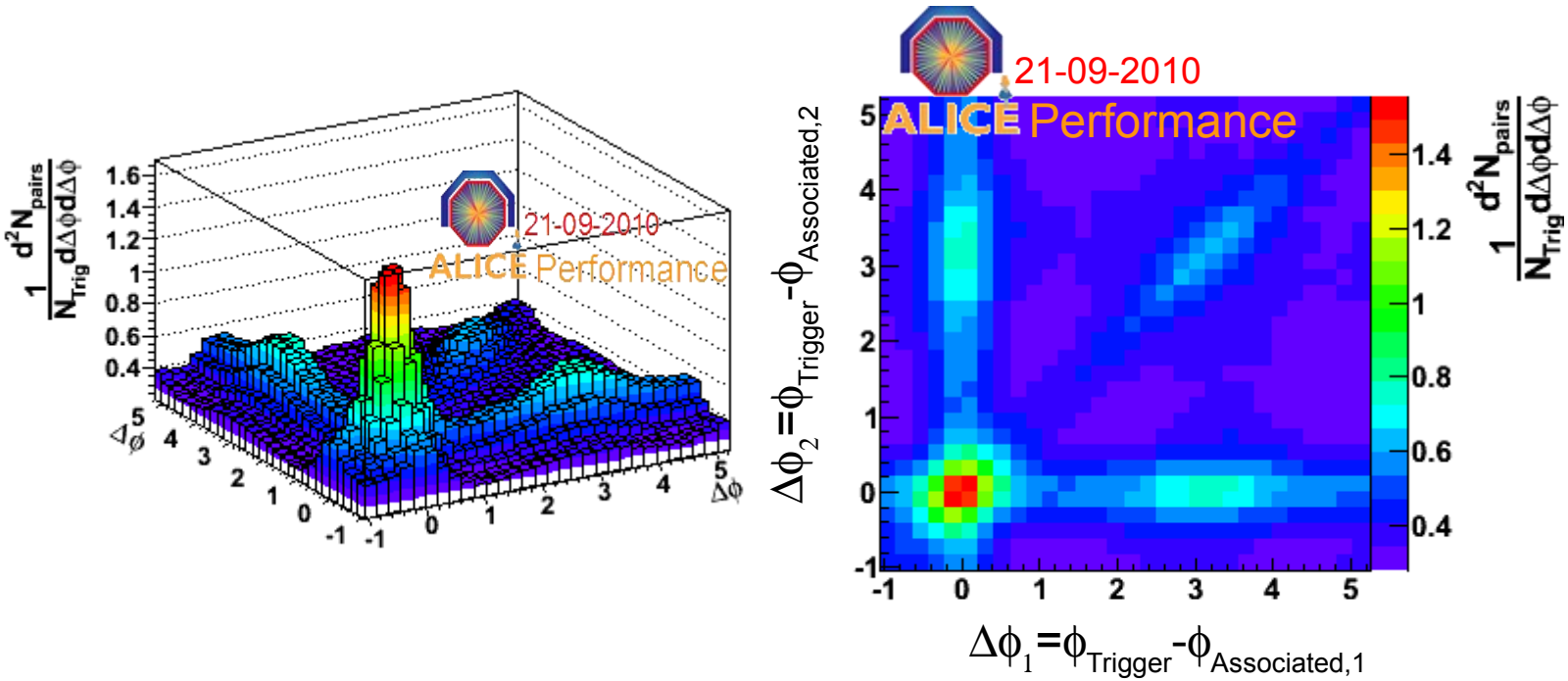
d+Au





- Conical emission seen in heavy-ion collsions at RHIC.
  - Not seen in *pp* or d+Au.

Unsubtracted Signal

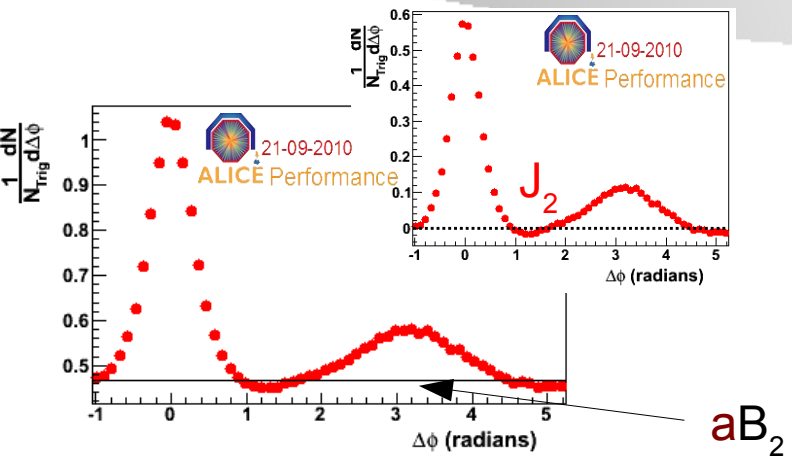


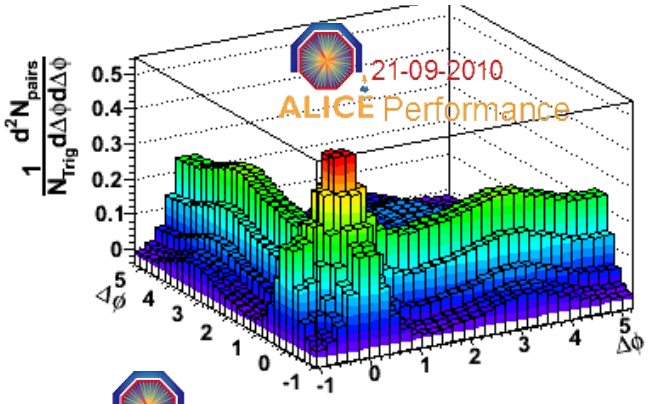
7 TeV *pp*
$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

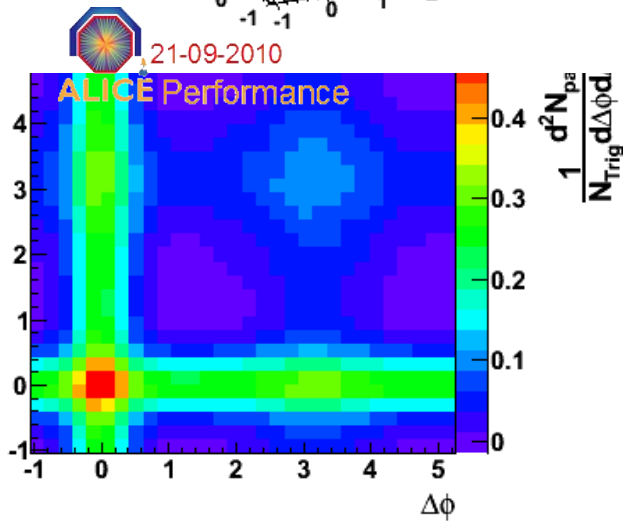
- Contains:
  - 3-particle correlations
  - 2-particle correlations
  - Uncorrelated particles

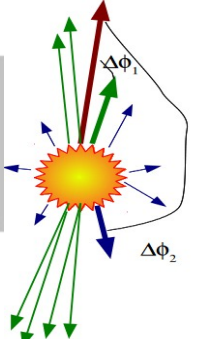
7 TeV *pp*
$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

Hard-Soft Background





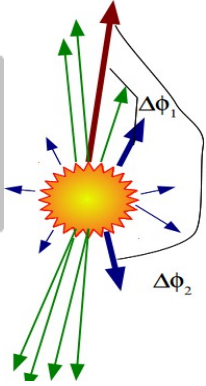


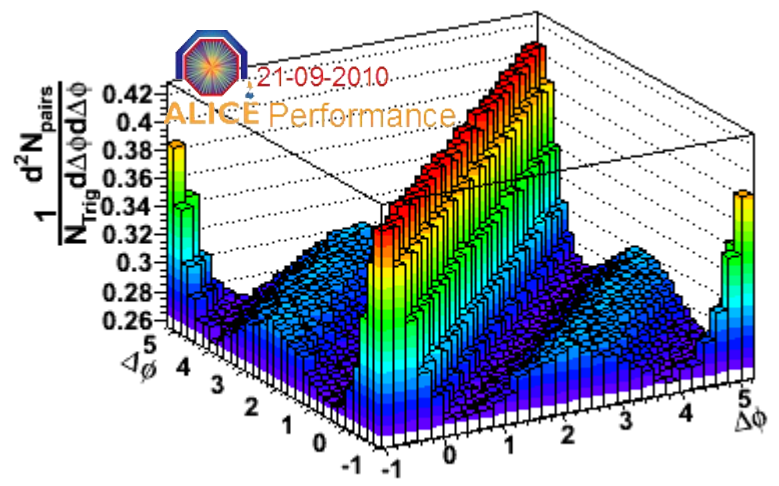


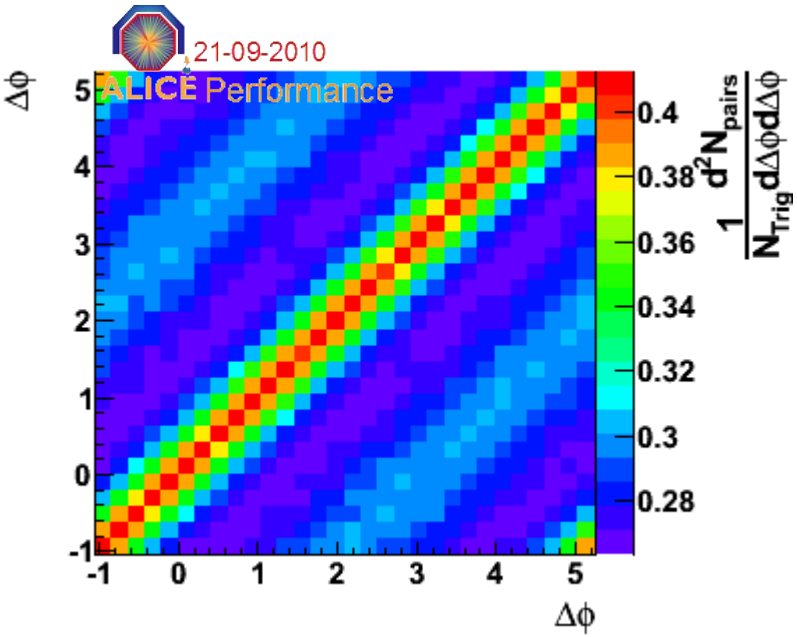
- 1 particle jet-like correlated with trigger and 1 from background.
- Constructed from 2-particle correlation and its background.
- $J_2(\Delta\phi_1)\otimes aB_2(\Delta\phi_2)+J_2(\Delta\phi_2)\otimes aB_2(\Delta\phi_1)$
- a from 3-particle ZYAM

7 TeV *pp*
$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

Soft-Soft Background



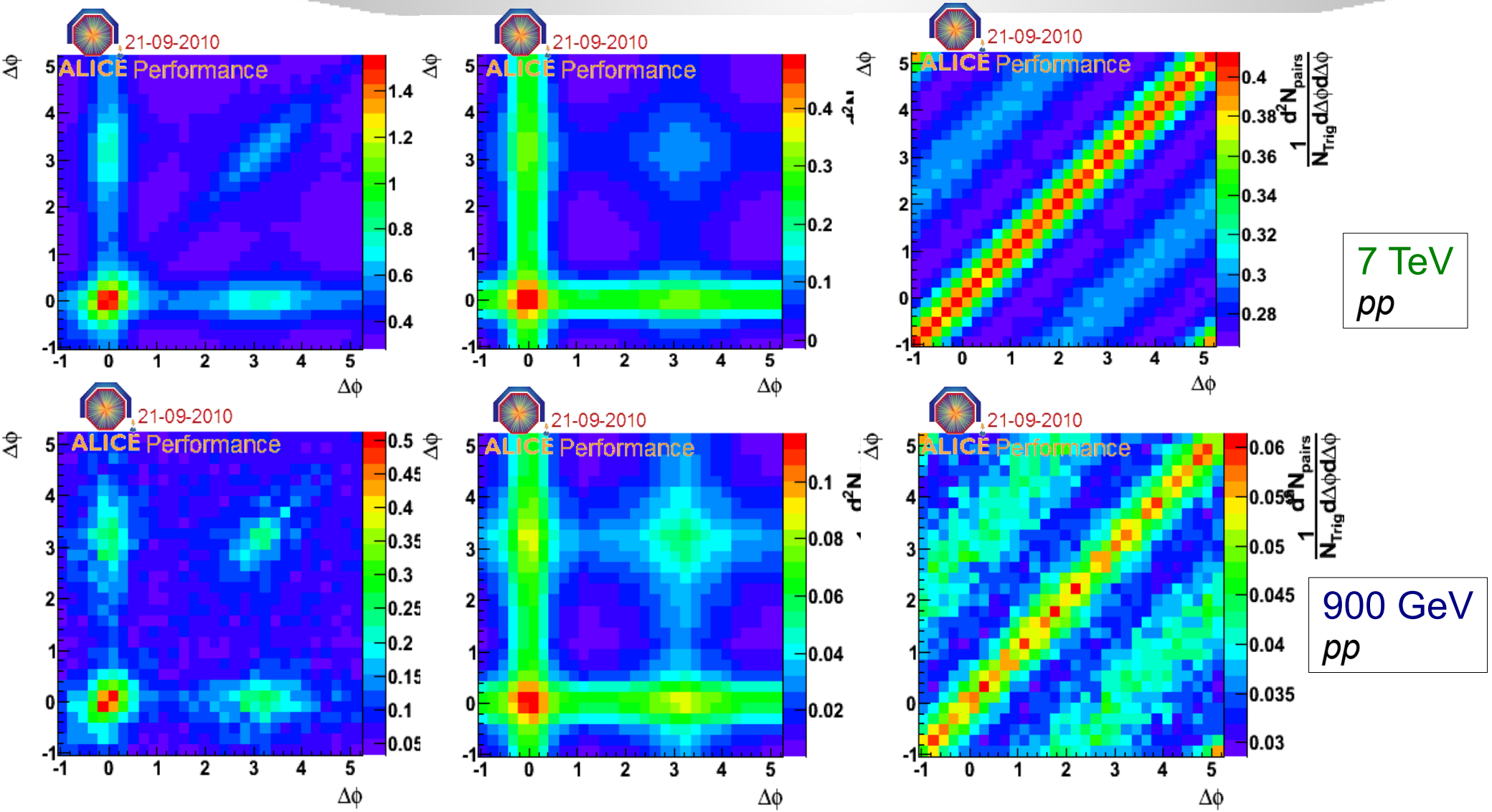




- Uncorrelated background and correlations independent of trigger.
- Constructed by mixing trigger with pairs of associated.
- Normalized by a^2b.
  - a from 3-particle ZYAM
  - $b=\frac{\langle N(N-1)\rangle/\langle N\rangle^2 \quad Triggered\ Events}{\langle N(N-1)\rangle/\langle N\rangle^2 \quad Mixed\ Events}$

Terms

$3<p_T^{Trig}<4$ GeV/c
$1<p_T^{Trig}<2$ GeV/c

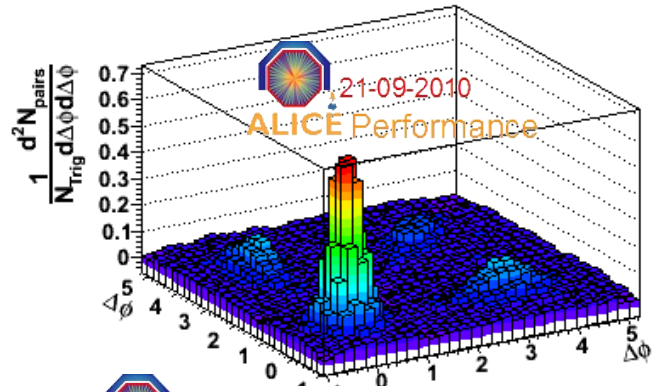


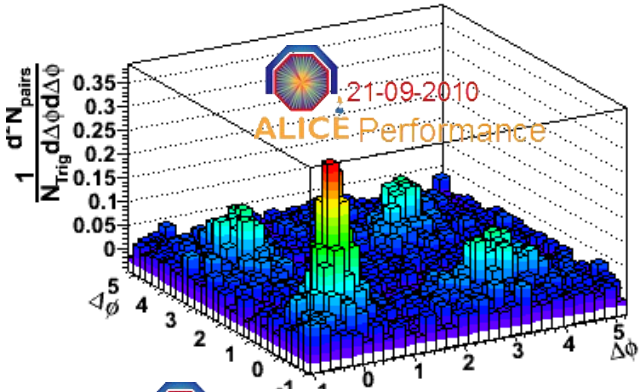
Raw Signal – Hard Soft – Soft Soft

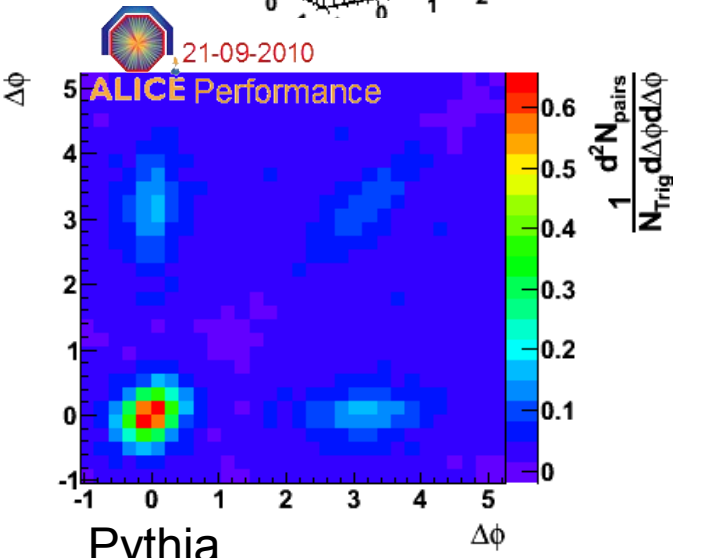
7 TeV

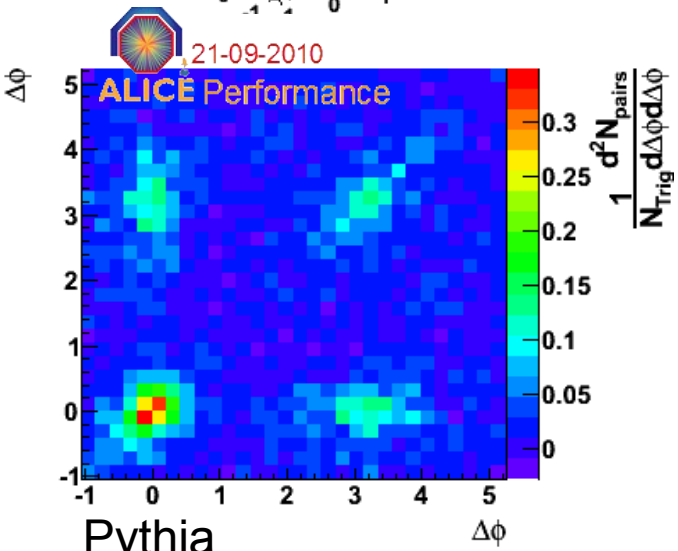
900 GeV

$3<p_T^{Trigger}<4$ Gev/c
$1<p_T^{Assoc}<2$ GeV/c

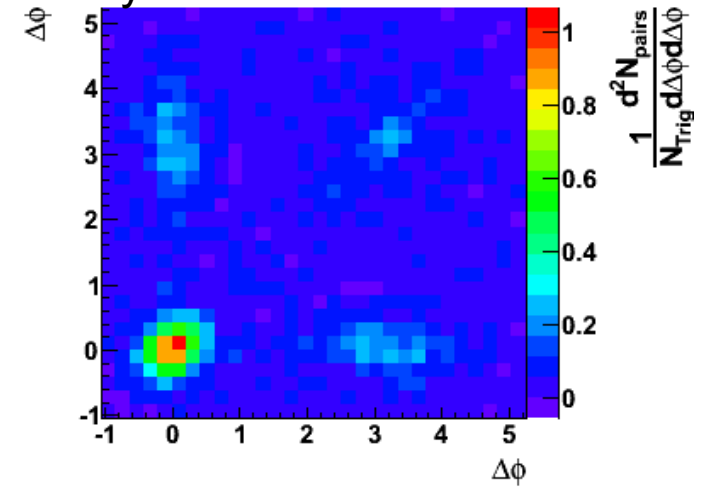




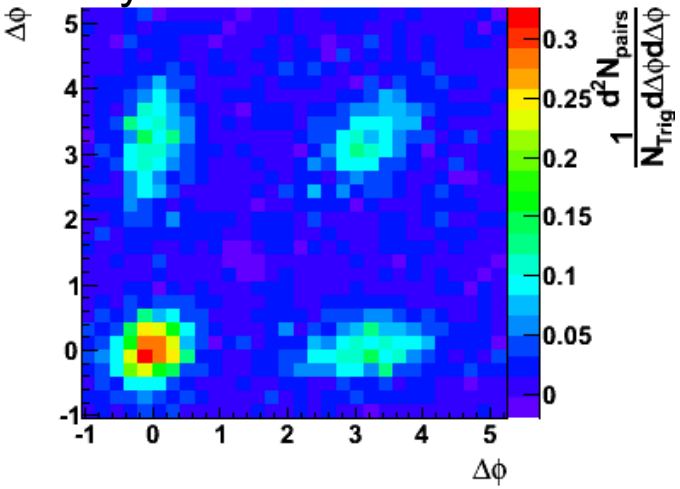




Pythia

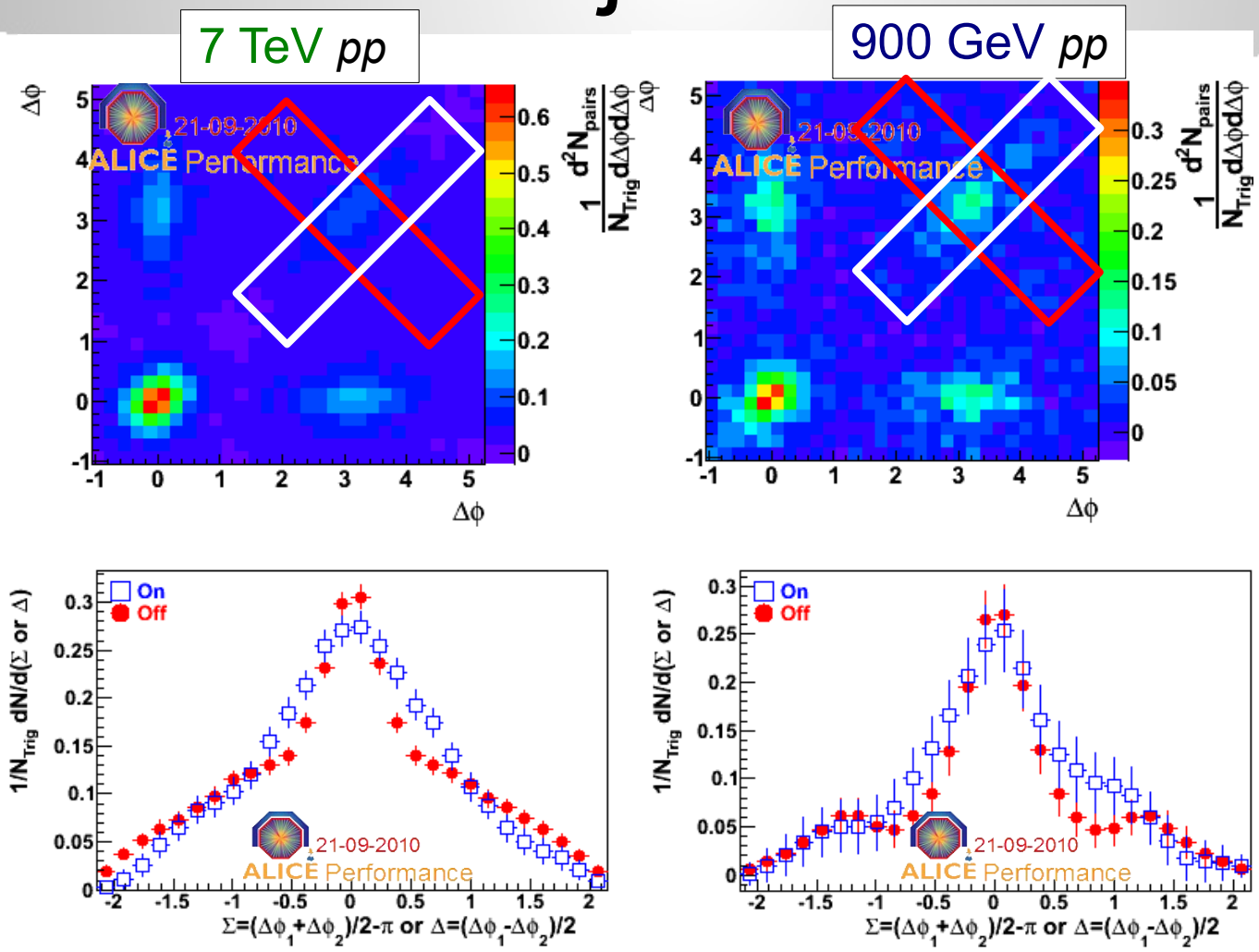


Pythia



- Background Subtracted
  - No evidence of conical emission in minimum bias *pp*.
  - Broadening along $\Delta\phi_1=\Delta\phi_2$ diagonal.

Projections



- Similar away-side projections for both energies
- Broadening consistent with k_T broadening seen

Summary

- **2- and 3-particle jet-like correlations** studied in ALICE in *pp* collisions at √s=900 GeV and 7 TeV.
- These analyses will be performed on heavy-ion data when available and *pp* provides a base line.
- No indication of medium modification in minimum bias *pp* collisions.
- Jet properties extracted from *pp* collisions:
  - Jet fragmentation transverse momentum measured.
  - Initial parton transverse momentum measured.
  - Away-side peak broadening from k_T like effect.