# The Ridge and Di-hadron Correlations from the Beam Energy Scan

**Liao Song for the STAR Collaboration**

University of Houston

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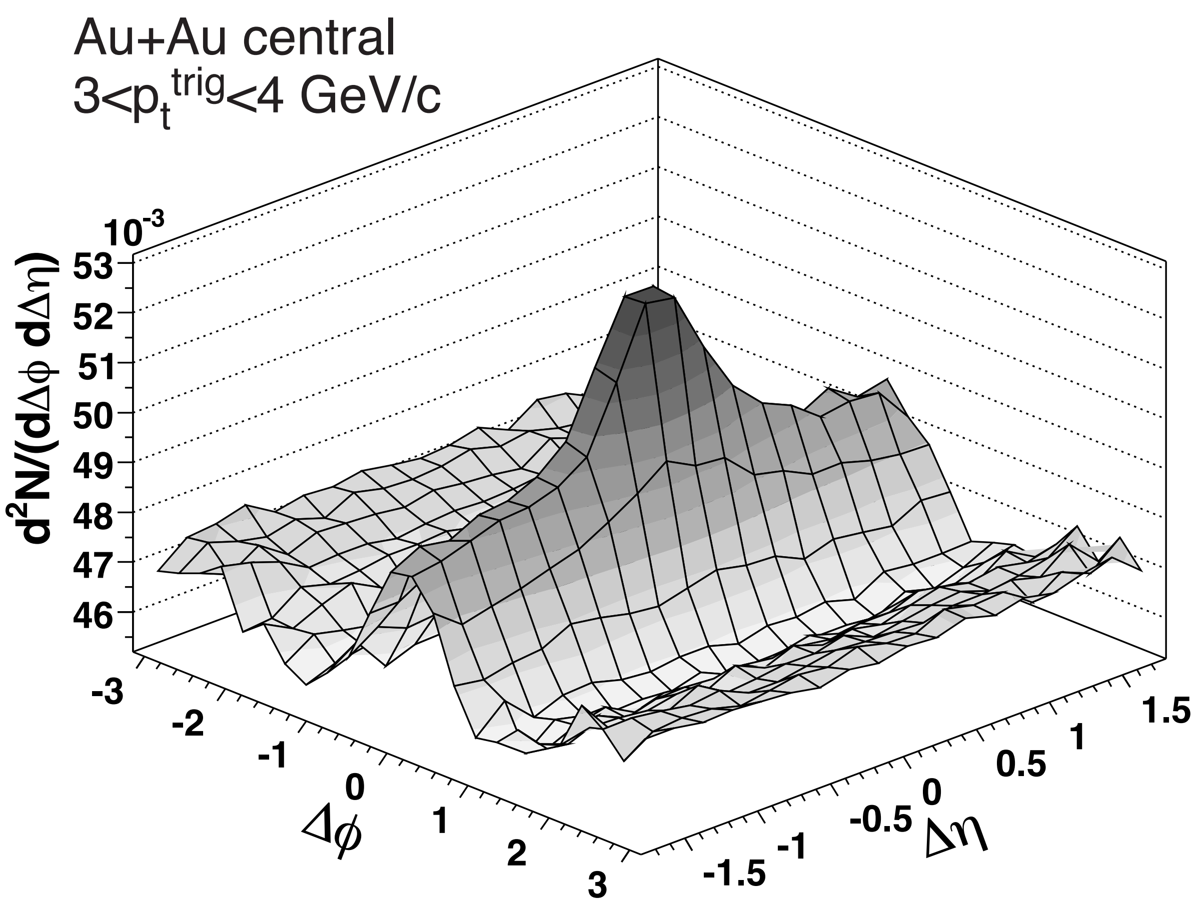
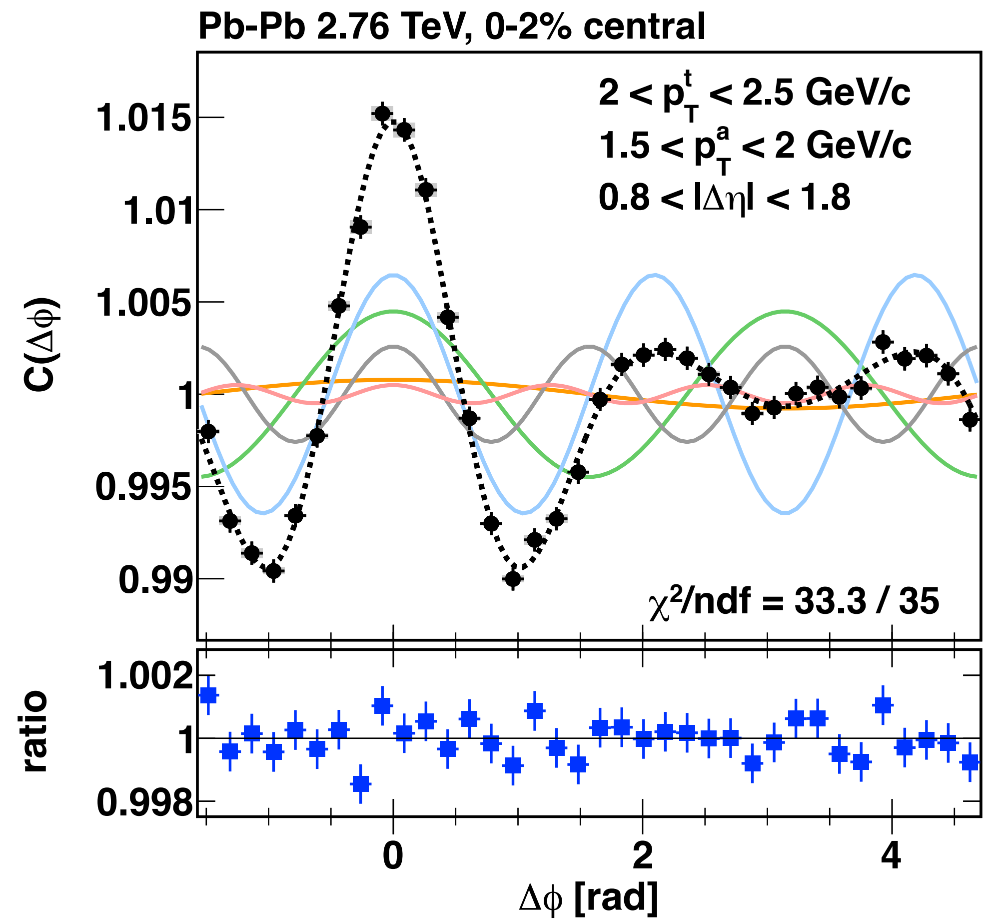
# Di-hadron correlations and ridge

- ★ Different orders of flow harmonics extracted using di-hadron correlations. Two methods used: **Fourier decomposition method** and **Gaussian fitting method**.
- ★ Does the ridge survive in all centralities and collision energies in the BES?

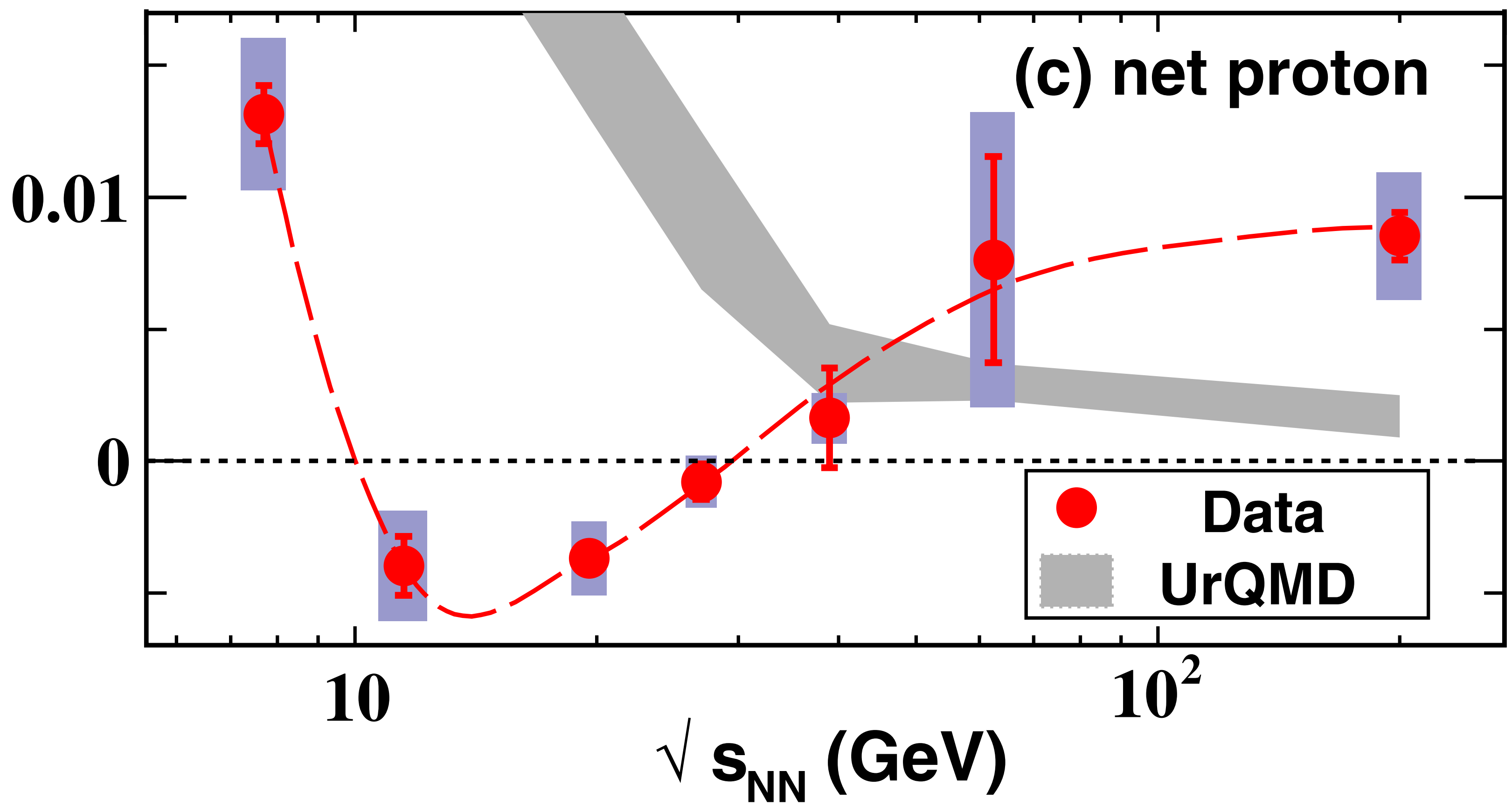



STAR Collaboration, Phys.ReV.C80(2009)064912




ALICE Collaboration PLB 708.(2012)249-264

# $dv_1/dy$ of net proton in the BES




STAR Collaboration,Phys. Rev. Lett. 112 (2014) 162301

- ★ STAR observed double sign change for proton $dv_1/dy$ - Possible signature of 1st order phase transition and softening of the EOS.
- ★ Is there also evidence of this from higher order harmonics $v_2$ and $v_3$ ?
- ★ Auvinen and Petersen (PRC 88 (2013) 064908) suggested $v_3$ could be suppressed relative to $v_2$. Hadronic interactions could wash out the softening of the EOS for $v_2$, making $v_3$ more sensitive to the first order phase transition.

# Data sets and event/track selection

Au+Au $\sqrt{s_{NN}}$ = 7.7 - 39 GeV

| energy(GeV) | vertex z cut | No. Evt |
|---|---|---|
| 7.7 | ±70cm | 4M |
| 11.5 | ±50cm | 12M |
| 14.5 | ±50cm | 20M |
| 19.6 | ±40cm | 36M |
| 27 | ±40cm | 70M |
| 39 | ±40cm | 130M |

Track cuts:

★ |η|<1

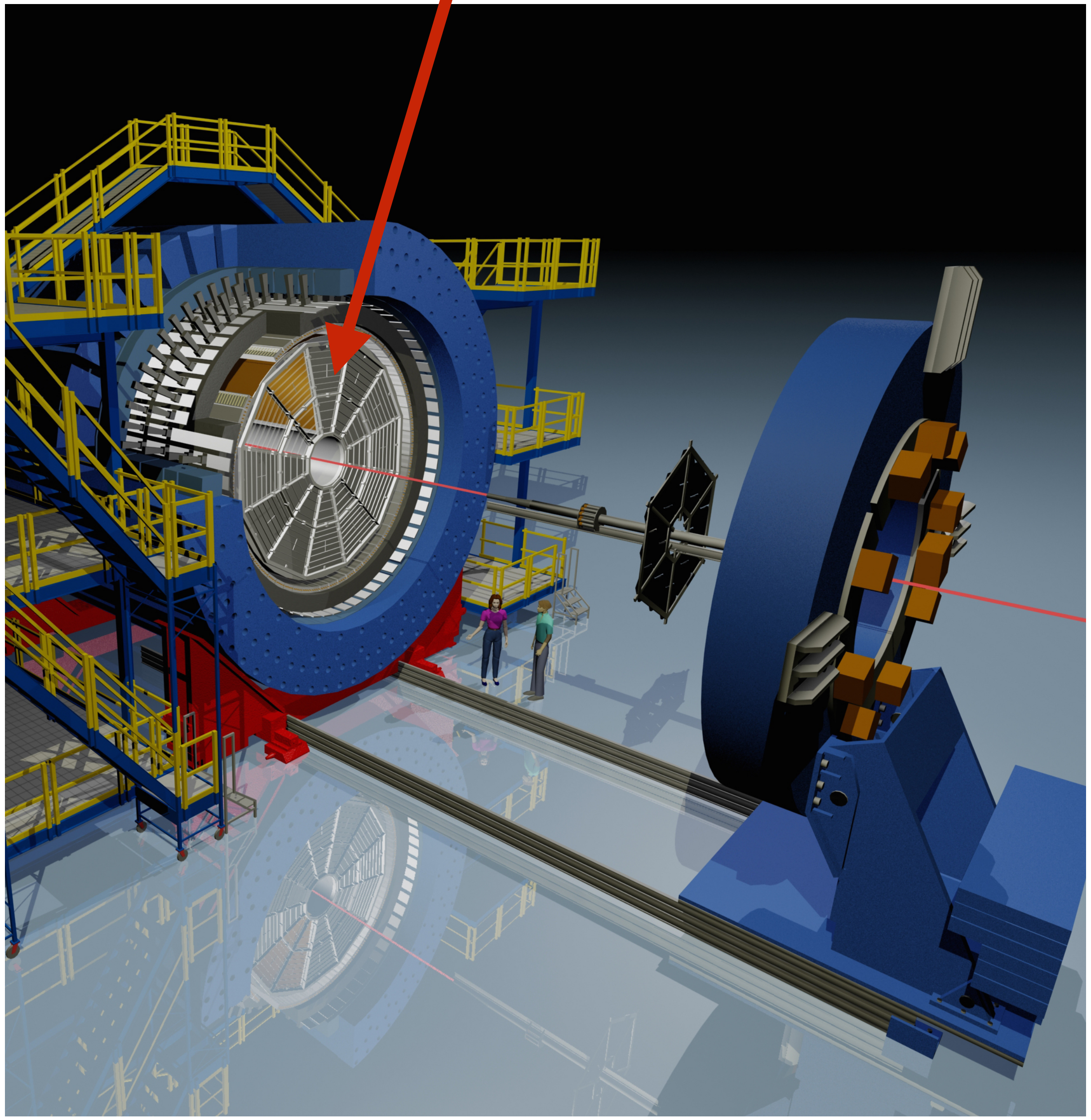
★ 0.2<pT<2 GeV/c

★ number of TPC hits>15

★ fitted hits/maximum possible hits>0.52

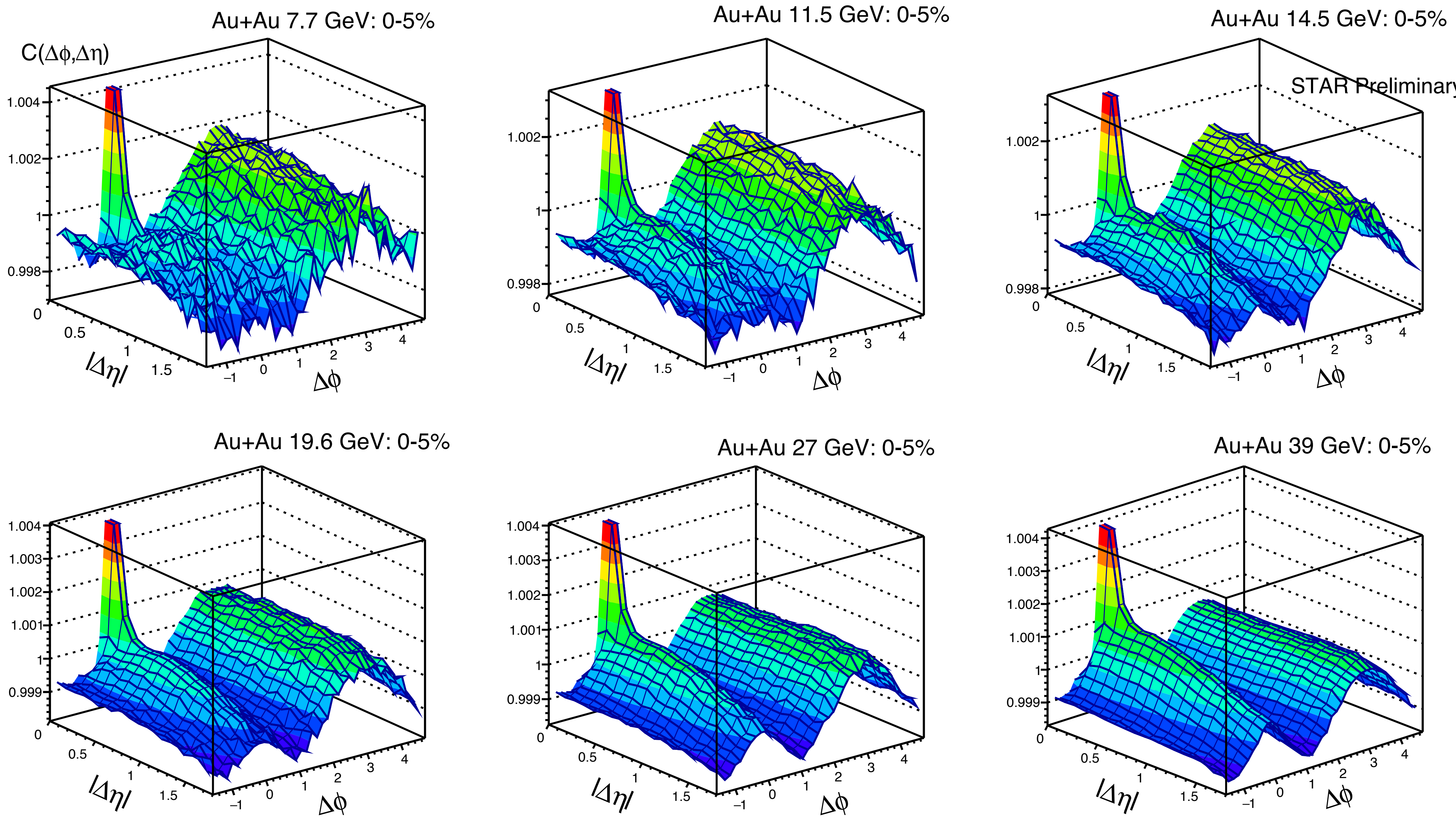
★ DCA<2 cm

TPC: the main detector used in the analysis



the STAR detector

# Di-hadron correlations in BES energies

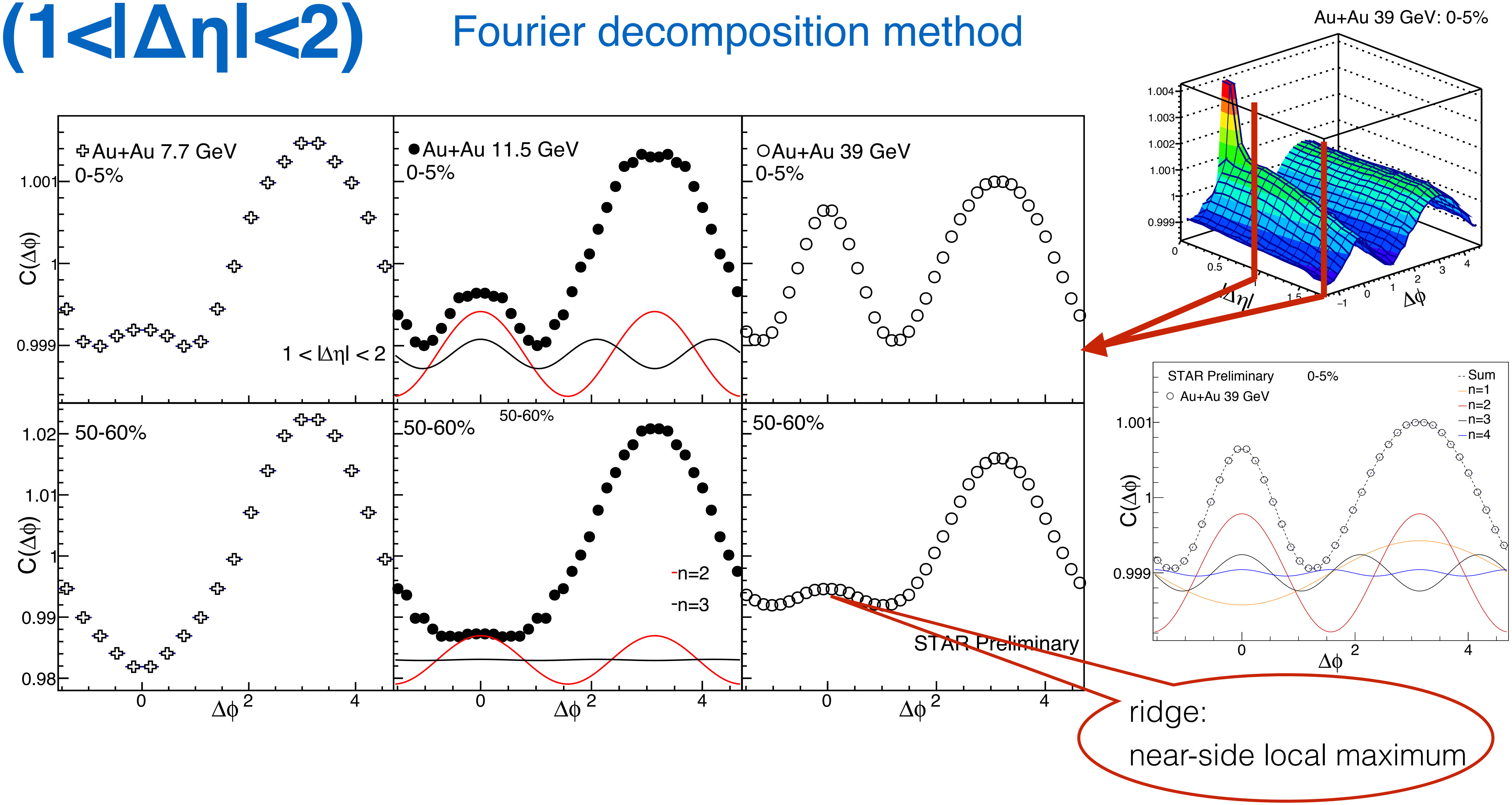



$$C(\Delta\phi,\Delta\eta) = \frac{N_{same}(\Delta\phi,\Delta\eta)}{N_{mixed}(\Delta\phi,\Delta\eta)}$$

To quantify the ridge, we make a projection of ΔΦ for large Δη.

# ΔΦ projection of di-hadron correlations (1<|Δη|<2)

Fourier decomposition method

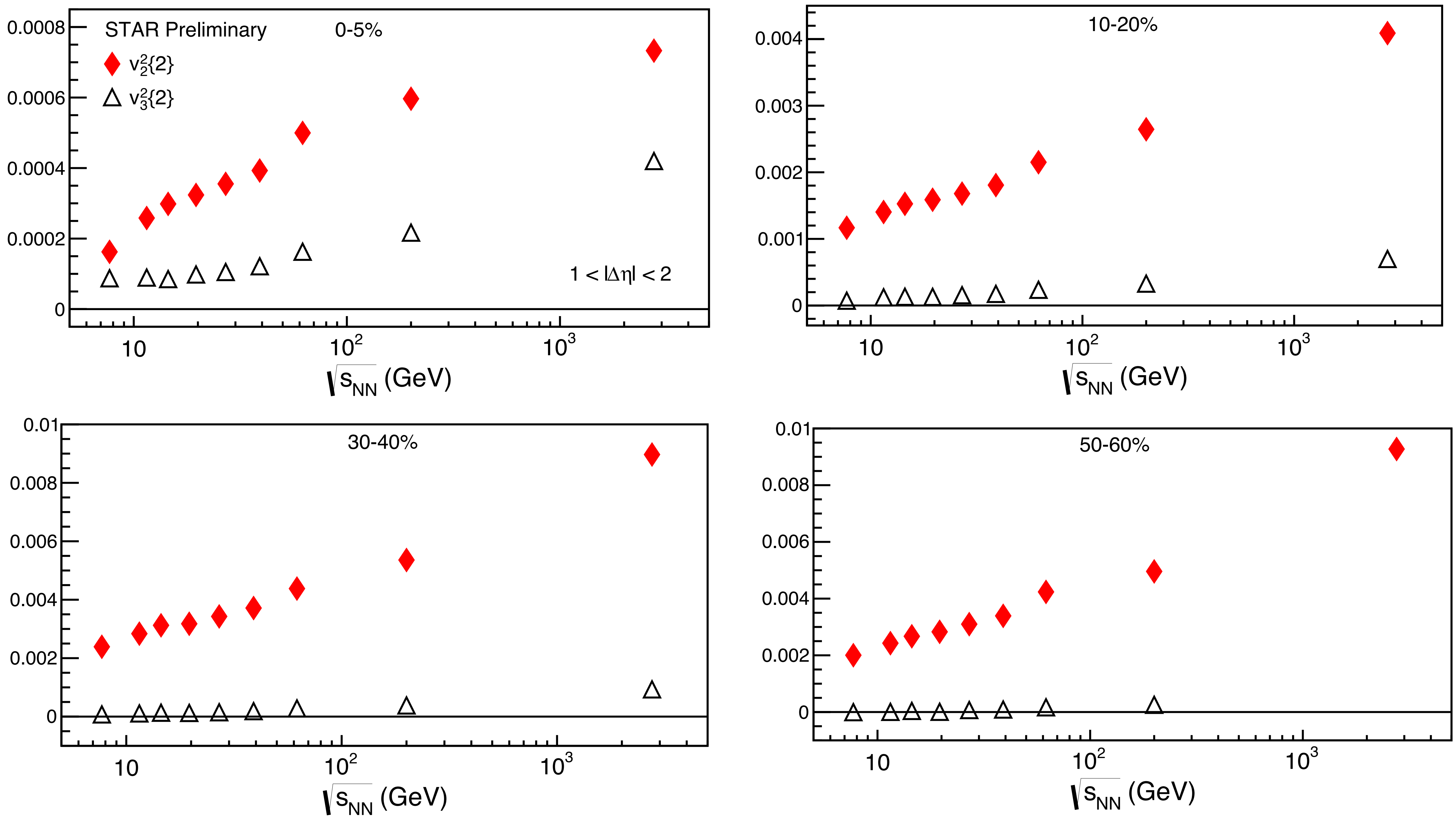



- ★ Near-side ridge persists down to the lowest energies for central collisions.
- ★ Ridge subsides in peripheral collisions at the lowest energies.

# Energy dependence of ridge harmonics

## Fourier decomposition method

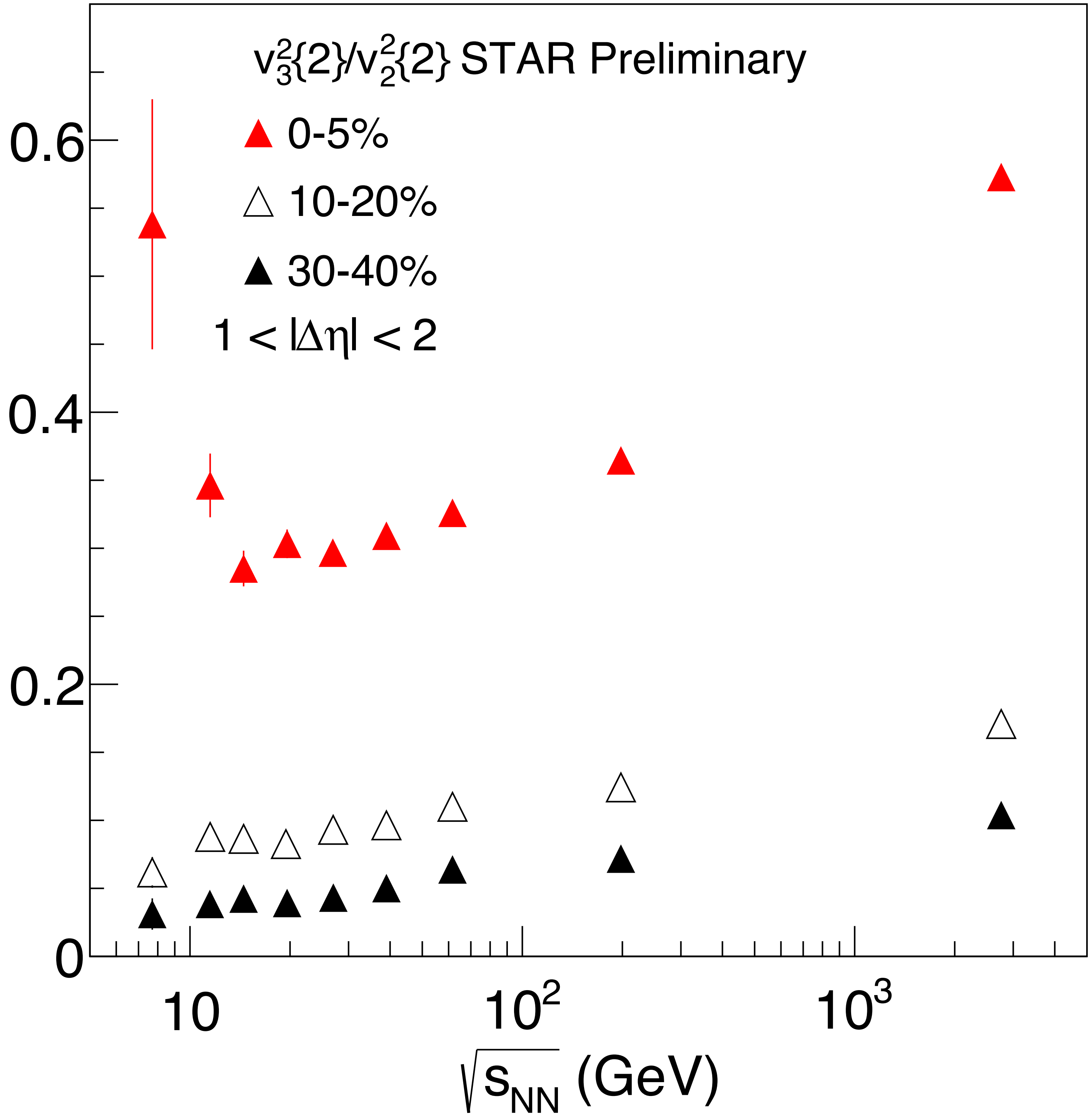
2.76 TeV data from ALICE,
Phys. Rev. Lett. 107, 032301 (2011)




★ Both $v_2\{2\}^2$ and $v_3\{2\}^2$ show monotonically increasing trends vs. the collision energy.

# $v_3\{2\}^2/v_2\{2\}^2$ vs. energy

## Fourier decomposition method

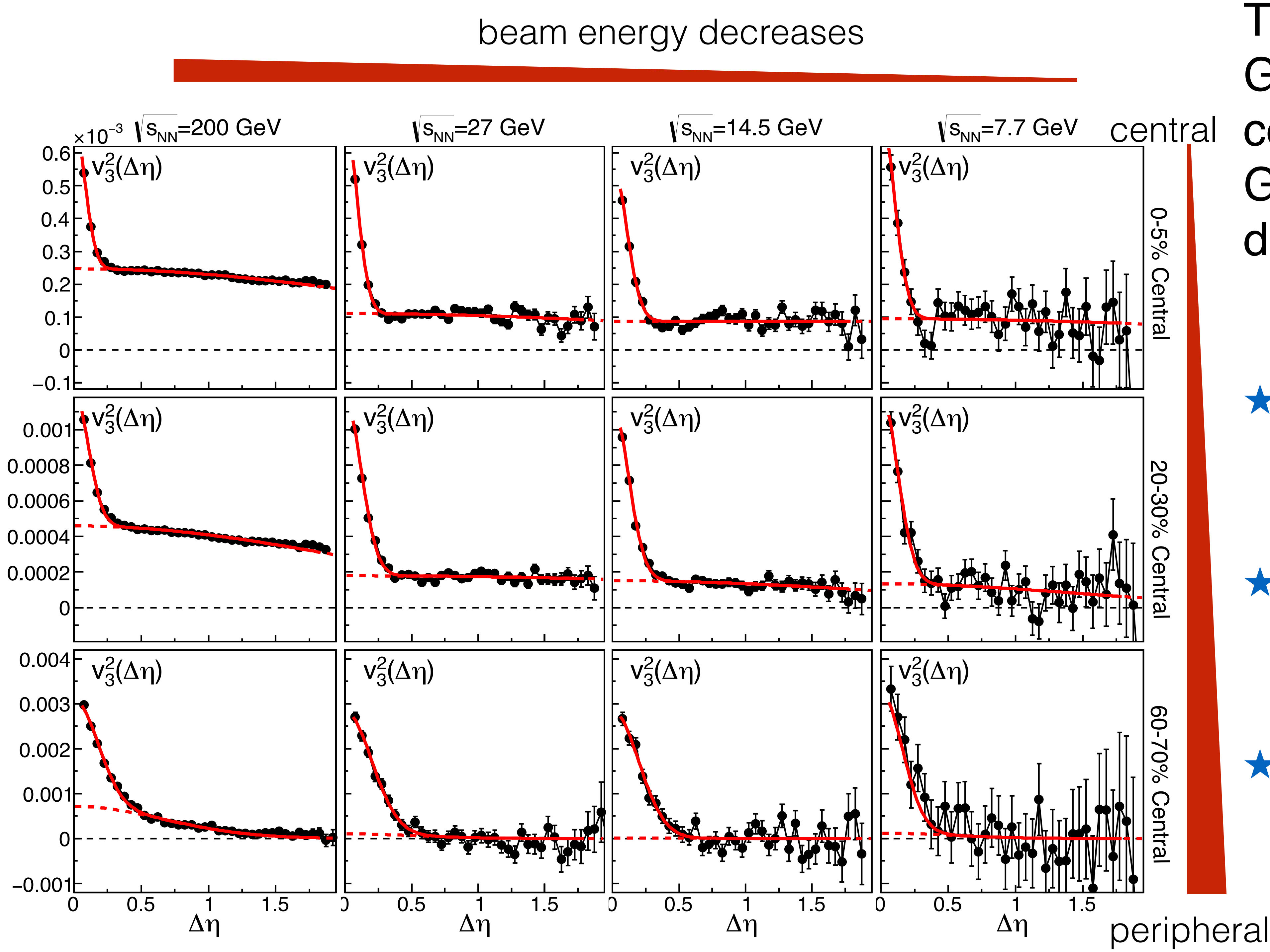



2.76 TeV data from ALICE, Phys. Rev. Lett. 107, 032301 (2011)

- $v_3\{2\}^2/v_2\{2\}^2$ in 0-5% central collisions shows a dip vs. beam energies. It is not seen in all more peripheral bins.
- Next slides will investigate $v_3\{2\}^2$ extracted from Gaussian fitting method.

# Energy and Δη dependence of $v_3\{2\}^2$

## Gaussian fitting method



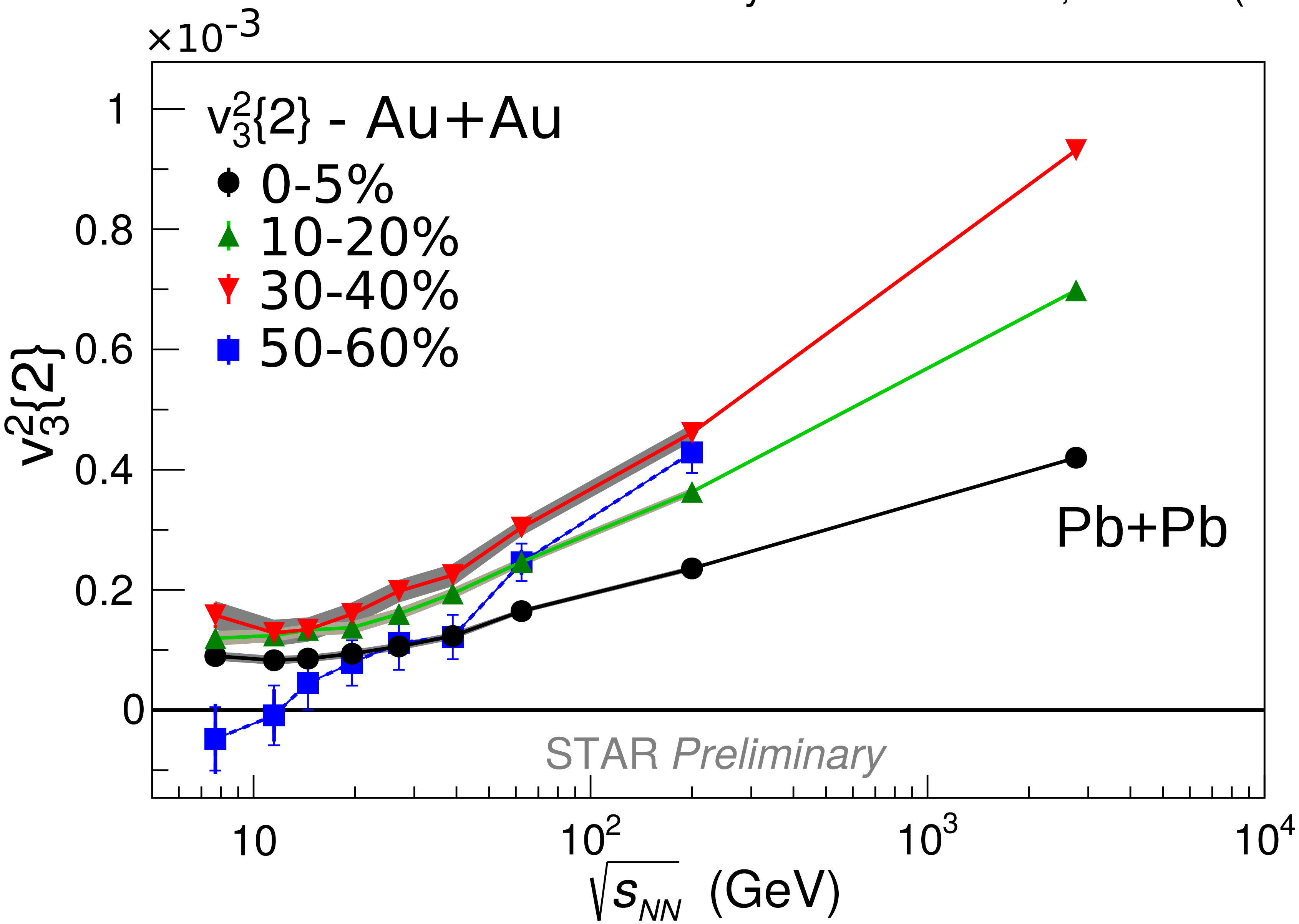

The two component Gaussian fitting range covers |Δη|<2 . The wider Gaussian gives the dashed curve: $v_3\{2\}^2$

- ★ $v_3\{2\}^2$ persists down to lowest energies in central collisions.
- ★ At low energies, $v_3\{2\}^2$ disappears in peripheral collisions.
- ★ Consistent with the Fourier decomposition method shown earlier.

# Energy dependence of $v_3\{2\}^2$

## Gaussian fitting method

2.76 TeV data from ALICE,
Phys. Rev. Lett. 107, 032301 (2011)



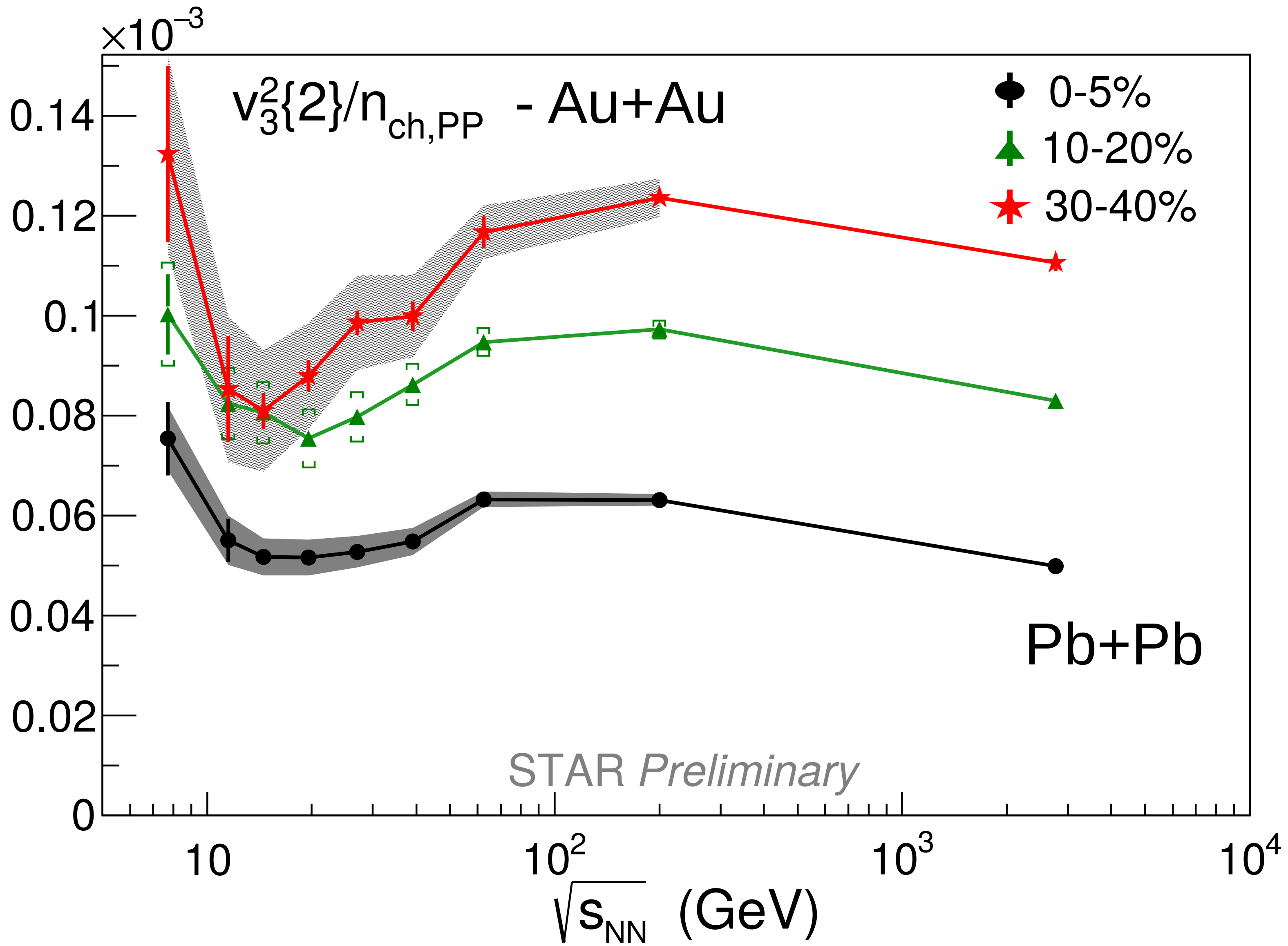

Over the range $-2<\Delta\eta<2$. Short range HBT-like correlations removed

- ★ Strong $v_3\{2\}^2$ even at lowest energies.
- ★ $v_3\{2\}^2$ approximately constant from 7.7 to 19.6 GeV.
- ★ Large increase from RHIC to LHC.

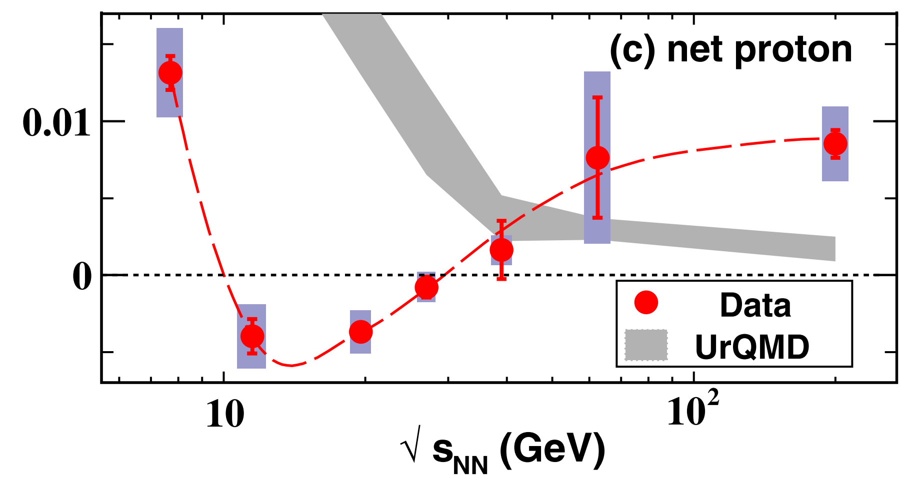
# Energy dependence of $v_3\{2\}^2/n_{ch,PP}$

## Gaussian fitting method

$n_{ch,PP}=(2/N_{part})dN_{Ch}/d\eta$ is the multiplicity per participant pair, used as an estimation of the **density of the system**




- Scaling $v_3\{2\}^2$ by multiplicity reveals interesting trend.
- Minima are prominent for all centrality intervals up to 0-50% most central.
- Dips in $dv_1/dy$ and $v_3\{2\}^2/n_{ch,PP}$ occur around the same beam energy.

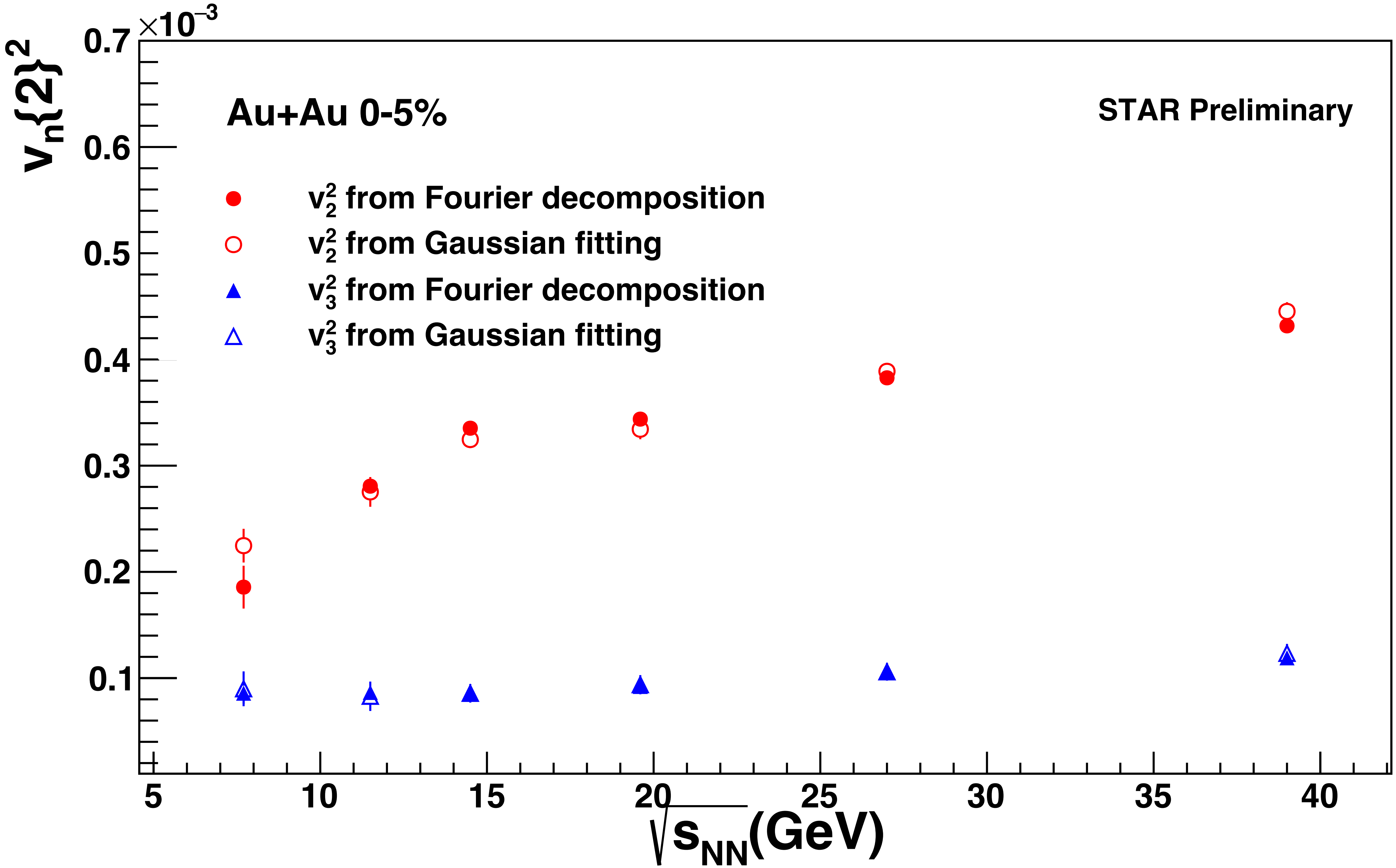


# Summary

- Di-hadron correlations and anisotropic flow coefficients from Fourier decomposition method and Gaussian fitting method were presented. The two methods are consistent.
- Ridge and $v_3\{2\}^2$ persist to lowest beam energies for central Au+Au collisions and become zero for peripheral collisions at the lowest energies.
- Minima observations:
    - Local minimum observed when $v_3\{2\}^2$ is scaled by $v_2\{2\}^2$ only in the 0-5% most central collisions;
    - Local minimum also observed when $v_3\{2\}^2$ is scaled by $n_{ch,PP}$ for all centrality bins in the 50% most central collisions;
    - Both of these minima are in the range of 11.5 to 19.6 GeV in beam energy.

# THANK YOU!

# Backup



Au+Au 0-5%
STAR Preliminary
$v_2^2$ from Fourier decomposition
$v_2^2$ from Gaussian fitting
$v_3^2$ from Fourier decomposition
$v_3^2$ from Gaussian fitting
$v_n\{2\}^2$
$\times 10^{-3}$
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5
10
15
20
25
30
35
40
$\sqrt{s_{NN}}$(GeV)