$\Delta\eta$ dependence of net-charge fluctuations in Au+Au collisions from the Beam Energy Scan at the STAR experiment

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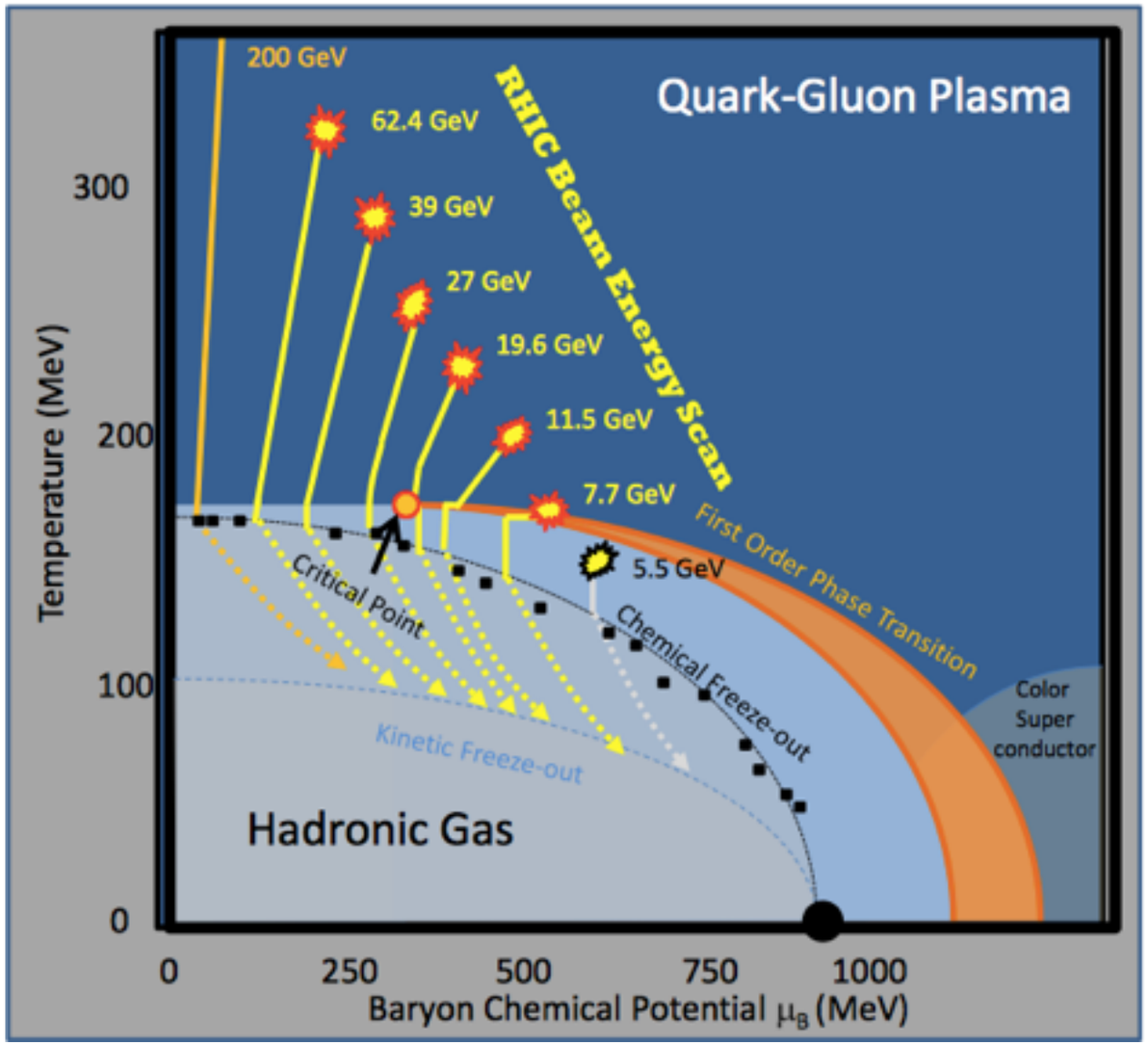
Introduction



QCD phase diagram

Beam Energy Scan (BES1)

2010-2014

Varying the center of mass energy $\sqrt{s_{NN}}$ =7.7, 11.5, 14.5 19.6, 39, 27, 62.4, and 200 GeV in Au+Au collision

"scan"

QCD phase diagram

(small μ_B value at higher beam energy)

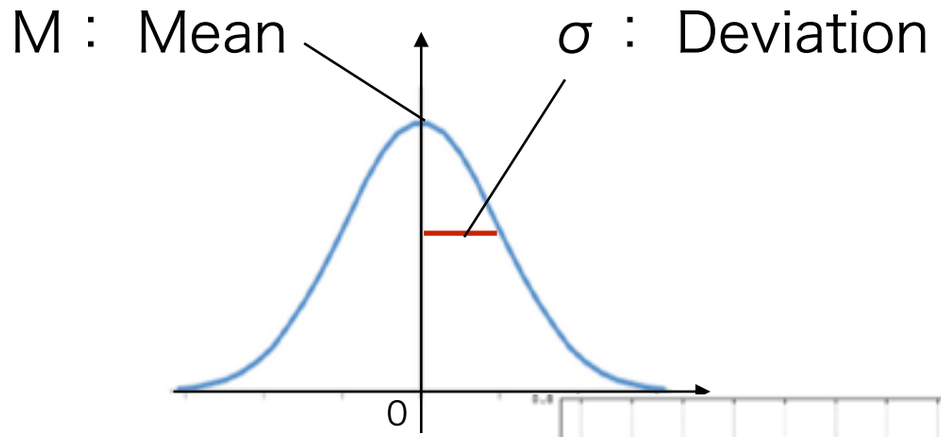
Main goal

- Exploring the QCD phase diagram
- Searching for critical point

Event by Event fluctuation

Event by Event fluctuation is a powerful tool to explore the QCD phase diagram and searching critical point.

N : net charge ⋯ $N_+ - N_-$

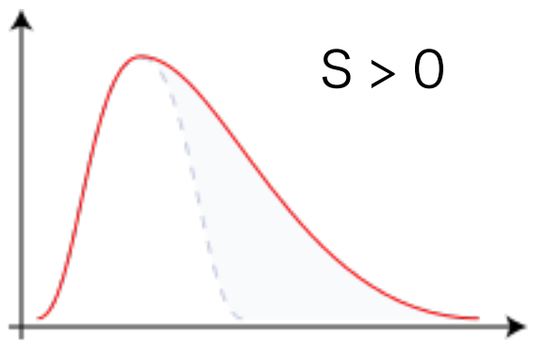


r-th non-central moment is defined by

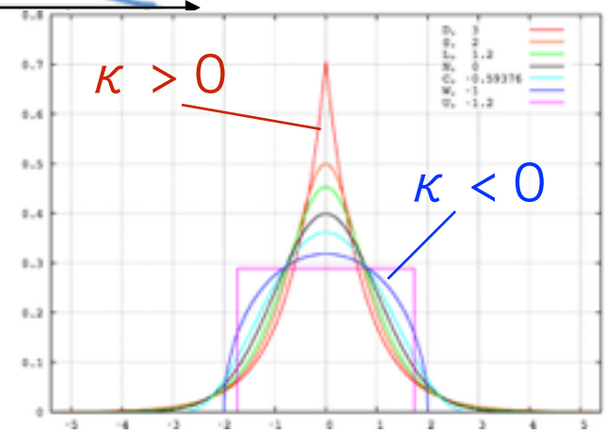
$$\mu_r{}' = \langle N^r \rangle$$

n-th order cumulant is written as

$$c_n = \mu'_n - \sum_{m=1}^{n-1} \binom{n-1}{m-1} c_m \mu'_{n-m}$$



S： Asymmetry



κ ： Peakedness

$$M = c_1 \qquad \sigma^2 = c_2$$

$$S = \frac{C_3}{(C_2)^{3/2}} \qquad \kappa = \frac{C_4}{(C_2)^2}$$

Cumulant ratios (Independent of volume)

$$\frac{\sigma^2}{M} = \frac{C_2}{C_1} \qquad S\sigma = \frac{C_3}{C_2} \qquad \kappa\sigma^2 = \frac{C_4}{C_2}$$

Motivation1

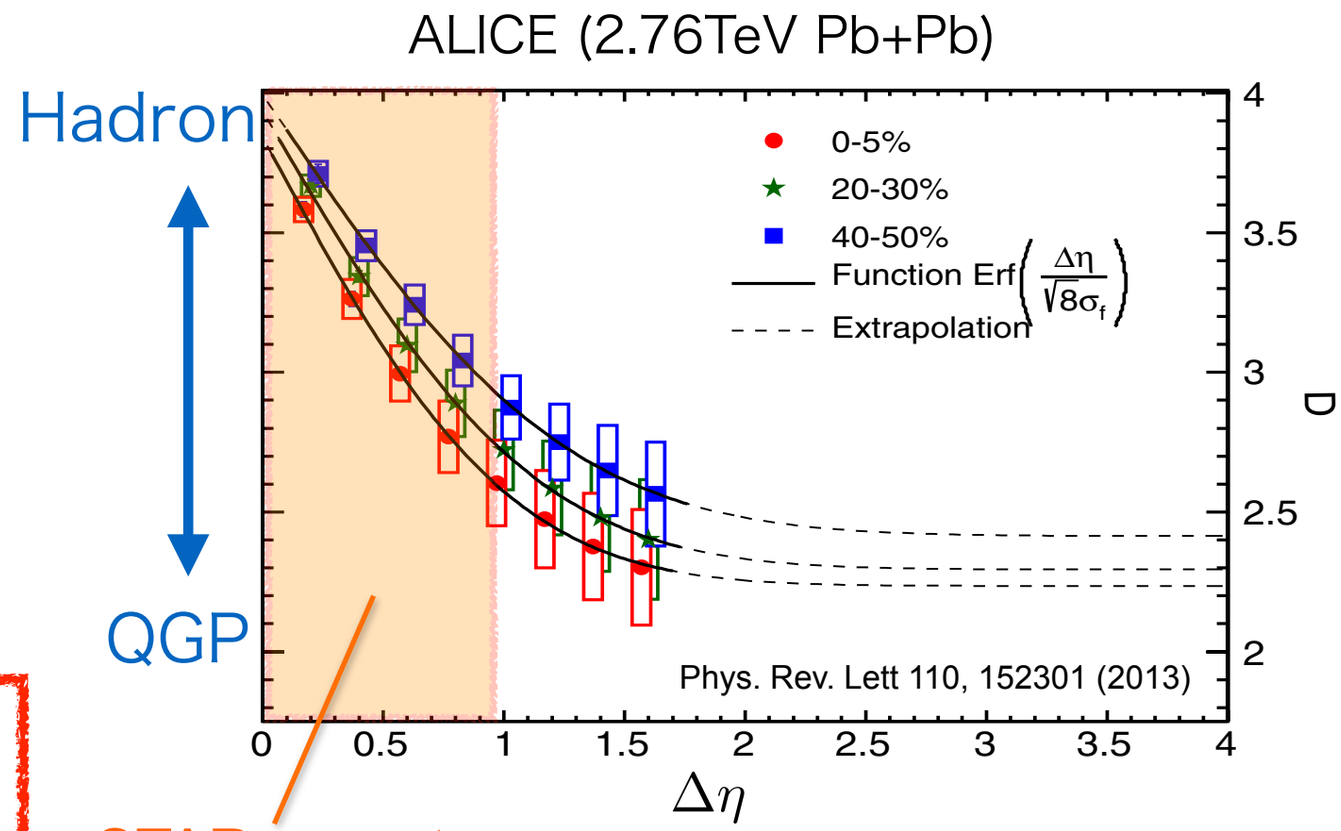
$$D = 4\frac{\langle \delta Q^2 \rangle}{\langle N_{ch} \rangle}$$

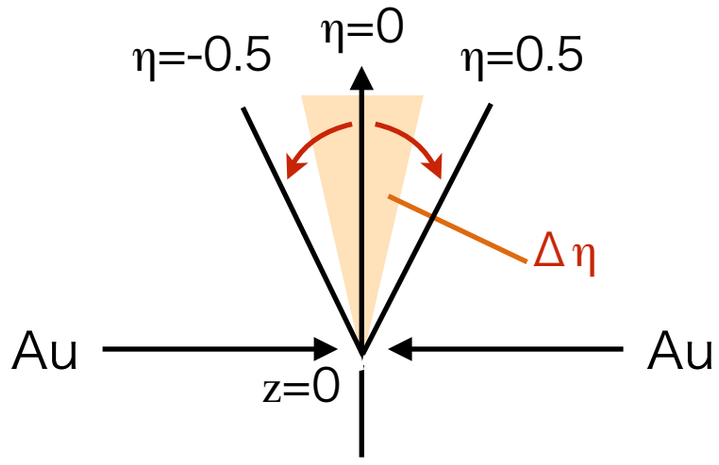
$$Q = N^+ - N^-$$
$$N_{ch} = N^+ + N^-$$

Theoretically

QGP fluctuation : D =1-1.5

Hadron fluctuation : D= 3-4





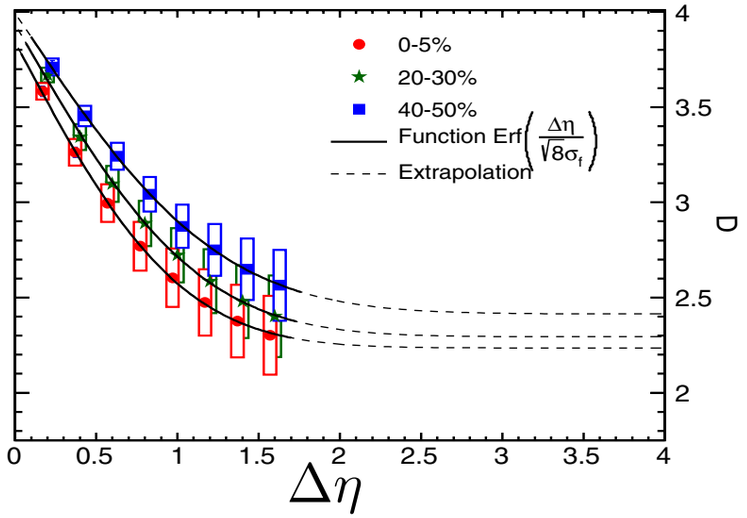
- D-measure decreases with $\Delta\eta$.
- D-measure decreases when going from peripheral to central.

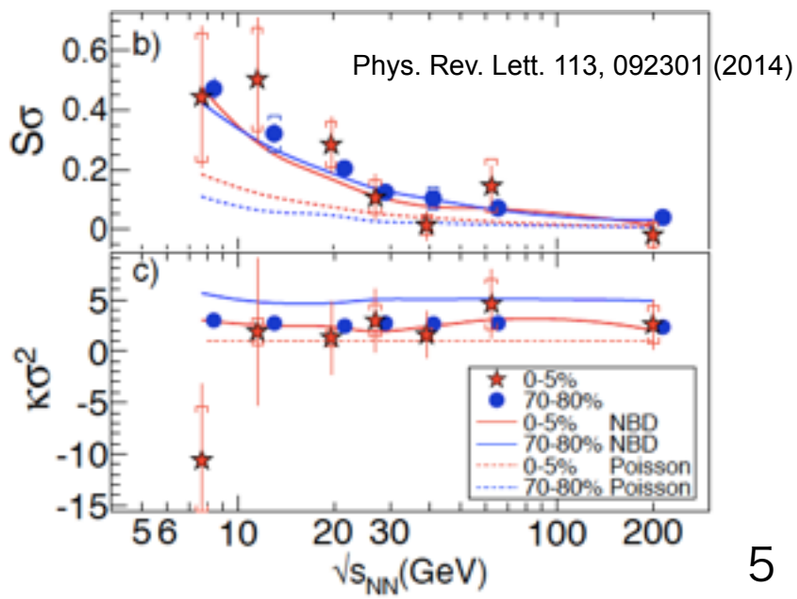
Motivation2

- Interesting results of D-measure as a function of $\Delta\eta$ were measured by ALICE at 2.76TeV.
  → We measured $\Delta\eta$ dependence of D-measure at RHIC BES energies (from 7.7 to 200 GeV).
- $\Delta\eta$ dependence of 3rd and 4th order fluctuation have't been measured yet.
  → We measured $\Delta\eta$ dependence of $S\sigma\,(c_3/c_2)$ and $\kappa\,\sigma^2(c_4/c_2)$.

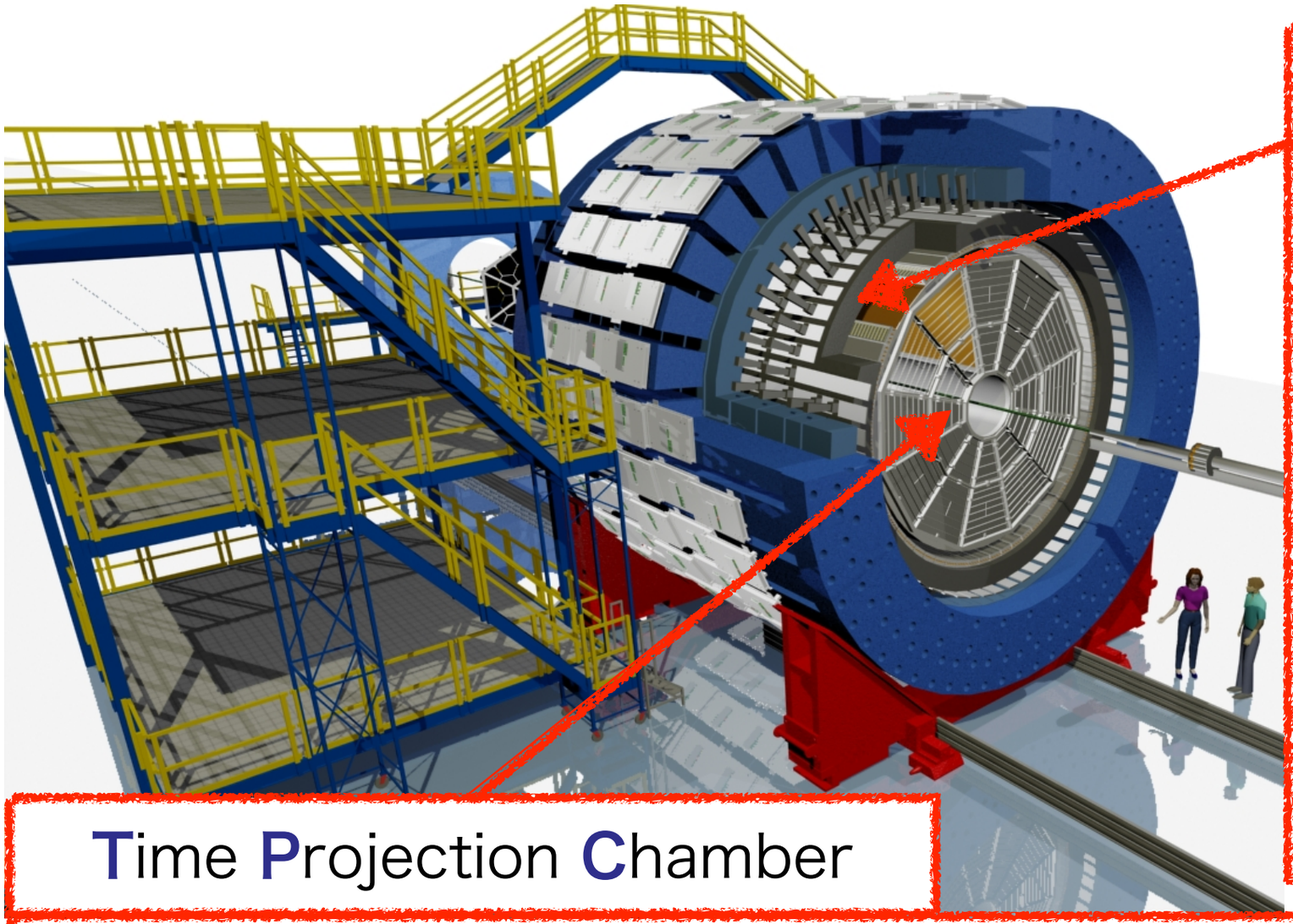
Earlier studies

	$\Delta\eta$	Order
ALICE (2.76TeV)	$\Delta\eta$= 0 to 1.6	2nd (D-measure)
STAR (7.7 to 200GeV)	fixed $\Delta\eta$=1	up to 4th ($S\sigma$, $\kappa\,\sigma^2$)





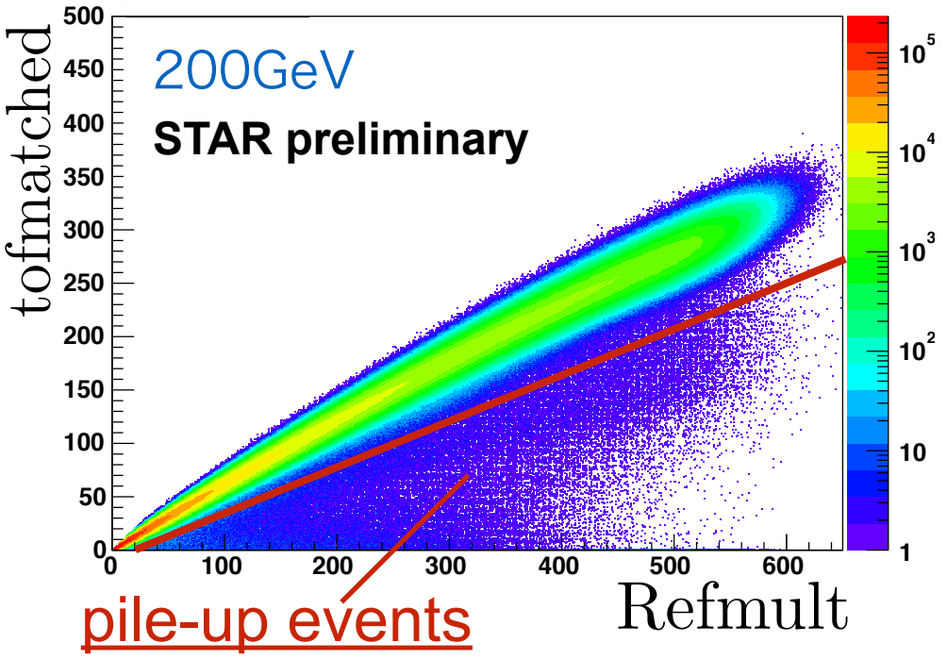
STAR Detector



Time Projection Chamber

Time Of Flight

TOF is used to remove pile-up events.

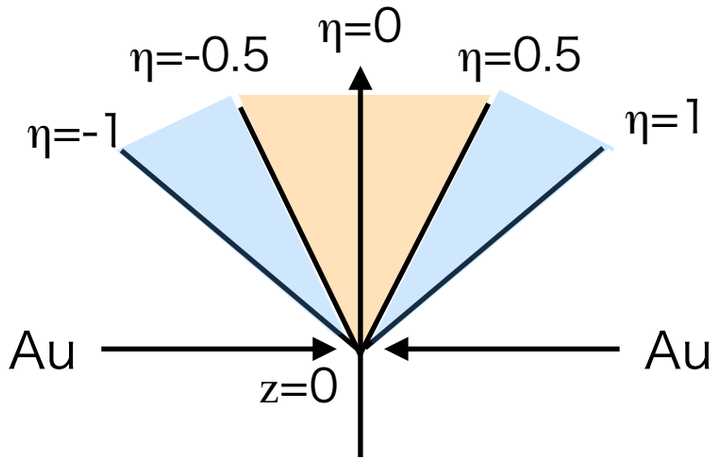


TPC is used to determine centrality and to calculate fluctuation.

Centrality determination (Refmult2) $\quad 0.5 < |\eta| < 1$

net-charge fluctuation calculation

$|\eta| < 0.5 \qquad 0.2 < p_T < 2.0 \ \ \mathrm{GeV}/c$



Using different kinematic window to avoid auto-correlation.

Data set

RHIC STAR experiment, Beam Energy Scan, Au+Au

Energy(GeV)	7.7	11.5	14.5	19.6	27	39	62	200
Event	1.5M	2.5M	12M	15M	28M	74M	46M	87M

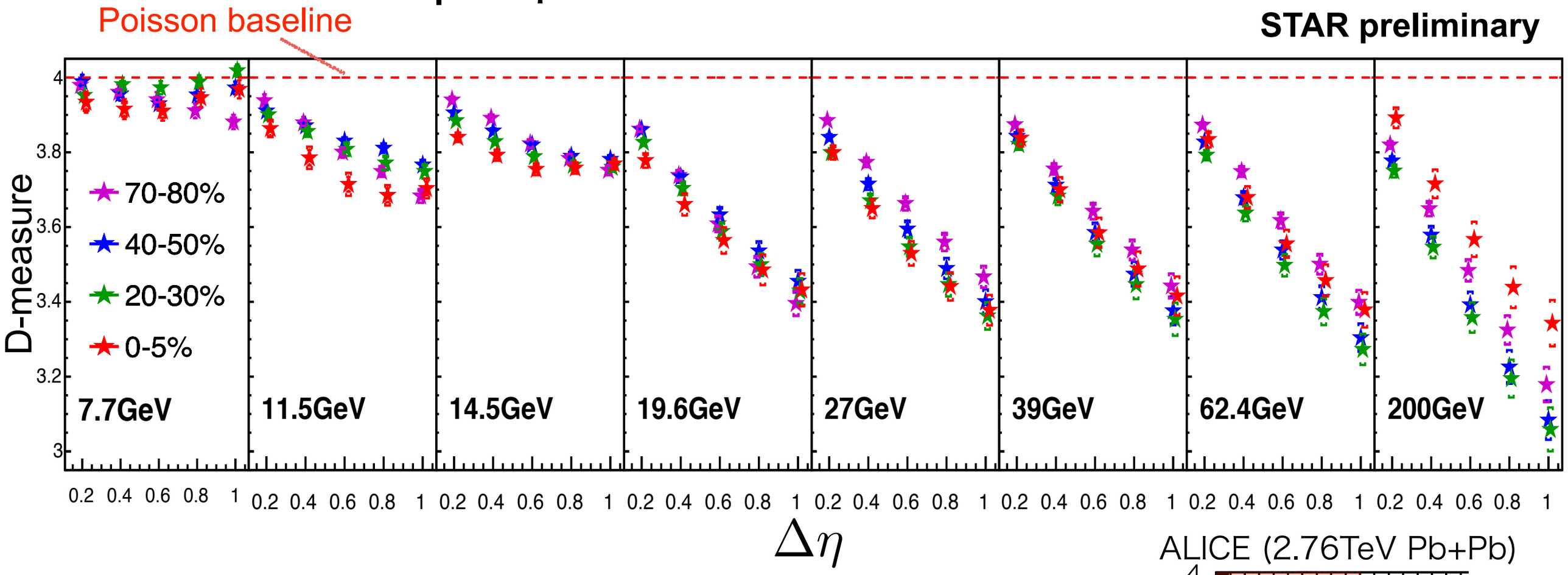
Corrections

- Centrality Bin Width Correction
- Efficiency Correction
- Charge conservation correction (D-measure only)

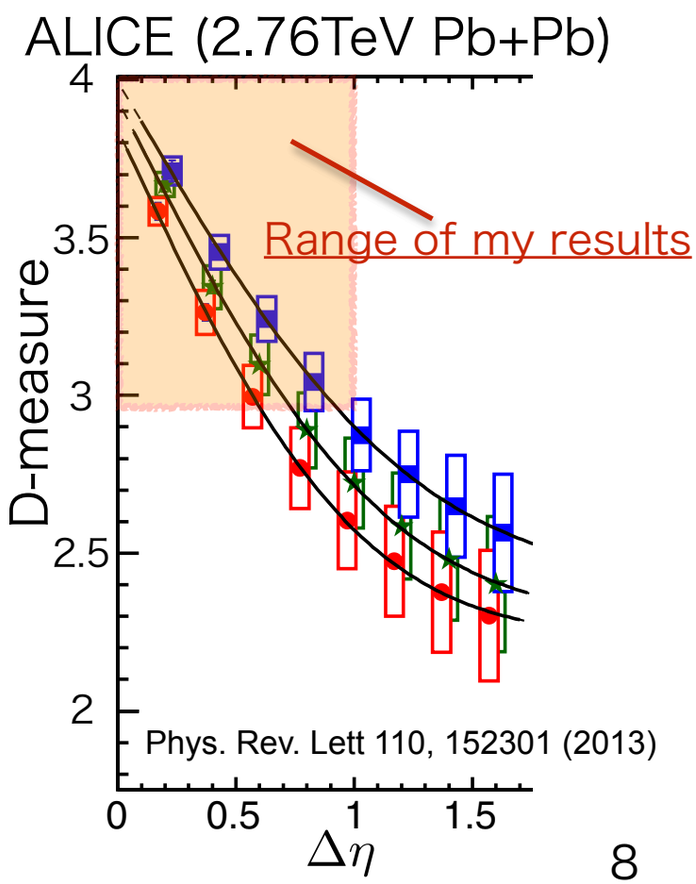
Error estimation

- **Statistical errors**
  Estimated by Bootstrap method (100times)
- **Systematic errors**
  Estimated by varying DCA cut, nHitsFit, nHitsDedx cuts
  and tracking efficiency from -5% to +5%.

Δη dependence of D-measure

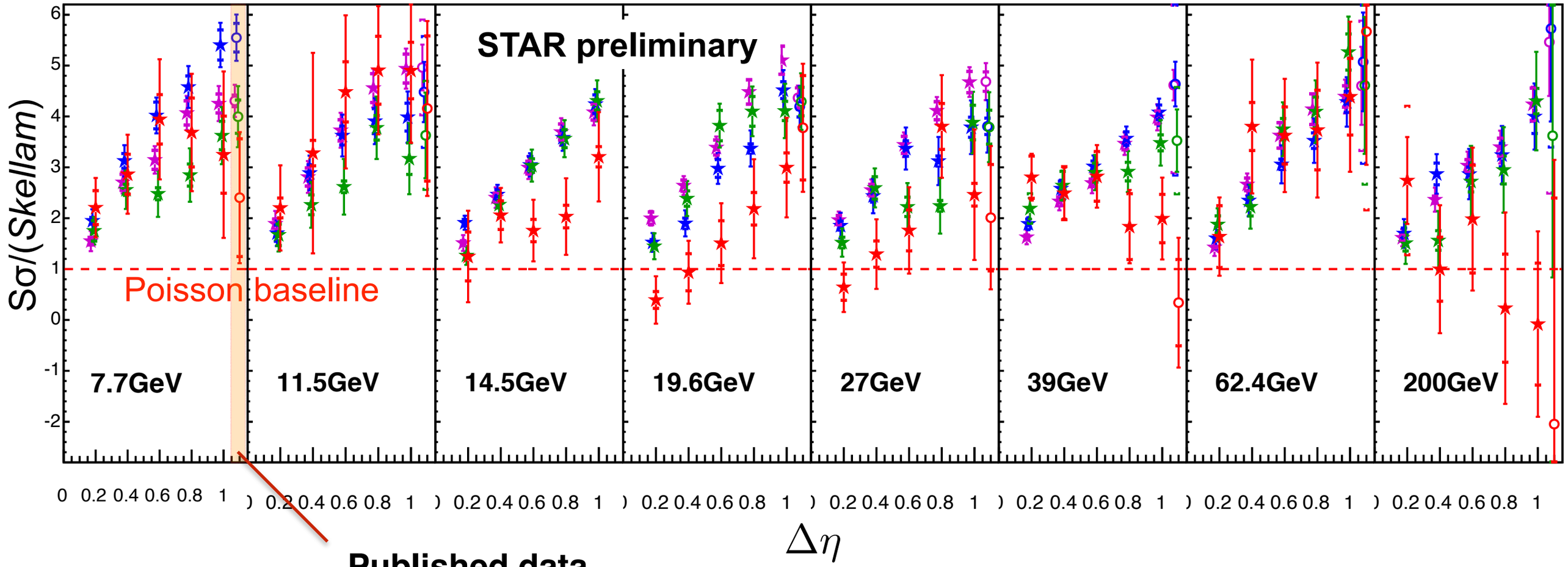


- D-measure is closest to the baseline at $\sqrt{s_{NN}}$=7.7 GeV.
- The deviation gets larger at large Δη and $\sqrt{s_{NN}}$



Consistent with ALICE results

$\Delta\eta$ dependence of Sσ



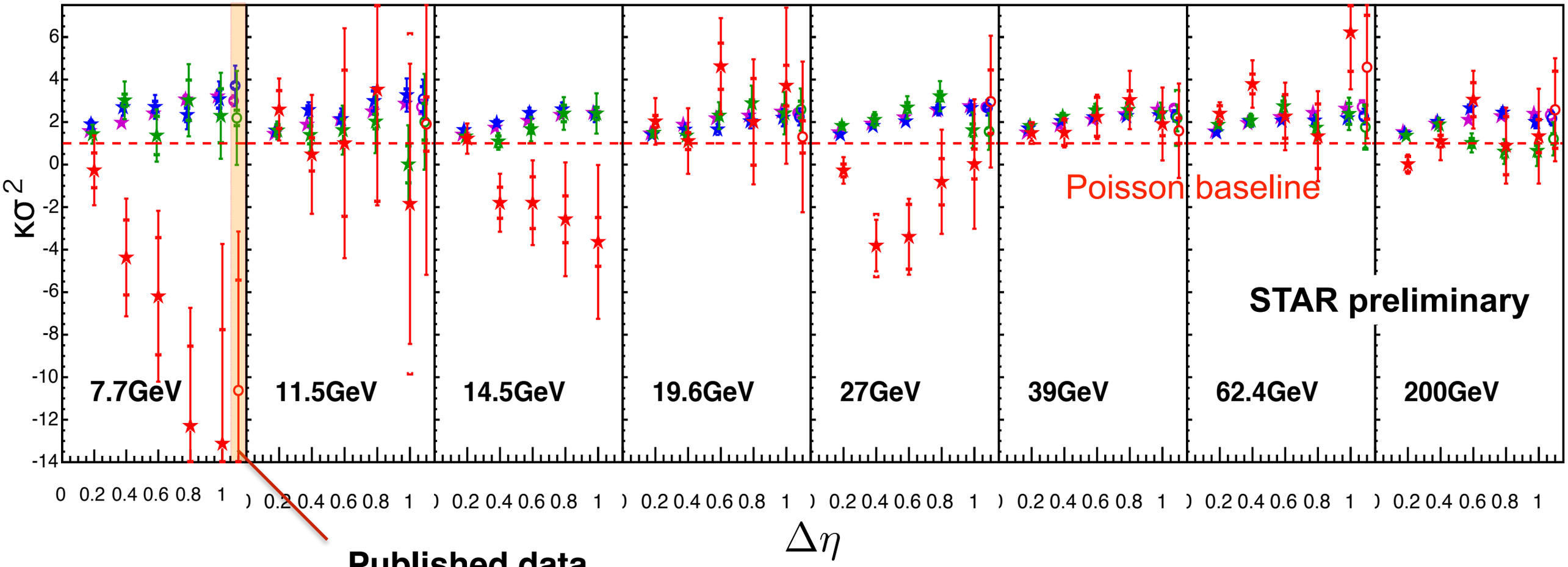
- **Sσ (c_3/c_2)** （Δη=1, shifted to x-axis +0.1, using average efficiency)

- Increase with Δη from poisson baseline for all energies.
  (without 200GeV central collisions)

★ 70-80%
★ 40-50%
★ 20-30%
★ 0-5%
⊖ **Published data**

Phys. Rev. Lett. 113, 092301 (2014)

$\Delta\eta$ dependence of $\kappa\ \sigma^2$



- **$\kappa\sigma^2$ (c_4/c_2)** **Published data** ($\Delta\eta$=1, shifted to x-axis +0.1, using average efficiency)

- Consistent with Poisson baseline in most of energies, but deviations more than 2σ from the poisson baseline are seen at 7.7 and 27GeV.

Summary

- $\Delta\eta$ dependence of net-charge fluctuations (from 1st to 4th order) are measured in Au+Au collisions at BES energies.
- D-measure decreases at large $\Delta\eta$ and $\sqrt{s_{NN}}$ which is similar to ALICE observation in Pb-Pb collisions at 2.76TeV.
- Sσ increase with $\Delta\eta$ from Poisson baseline in all energies. (without 200GeV central collisions)
- $\kappa\,\sigma^2$ is consistent with Poisson baseline in most of the energies, but deviations more than 2σ from the Poisson baseline are seen at 7.7 and 27GeV.

Outlook

- p_T and particle species dependent efficiency corrections.

back up

Correction method

Charge conservation correction have done in order to the charge charge conservation and system size effects.

$$D \quad \Rightarrow \quad D + 4\frac{\langle N_{ch} \rangle}{\langle N_{total} \rangle}$$

Charged multiplicity in measured acceptance

Total charged multiplicity in all acceptance

If this correction is applied,
D-measure become large.

Data set

RHIC STAR experiment, Beam Energy Scan

Au+Au 7.7, 11.5, 14.5 19.6, 27, 39.5, 62, 200GeV

Event selection

|Vz|	<30
|Vr|	<2
|VpdVz-Vz|	<4 (39-200GeV only)
Pile up event cut	Tof matched>0.46*(Refmult)-10

Track cut

Analysis

p_T	0.2 to 2 (GeV)
η	-0.5 to 0.5
nFitPoints	>20
DCA	<1cm
Track Quality Cut	>0.52
nhitsdedx	>10
spallation proton cut	nSigmaProton < 2

Centrality

$\|\eta\|$	0.5 to 1
z-vertex correction	done
DCA	<3cm
nFitPoint	>10