net-proton moments compared to "IRV" cumulant arithmetic

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bulkcorr PWG meeting

July 3, 2013

Backstory in recent bulkcorr presentations:

http://wjllope.rice.edu/fluct/protected/moments_20130417.pps
http://wjllope.rice.edu/fluct/protected/moments_20130626.pps

"Sampled singles" breaks the intra-event correlations "numerically/stochastically"
The stability of the sampled singles results *vs.* the TRandom3 seed is greatly improved by "oversampling," with the only expense being CPU time.

This sampled singles approach breaks any existing intra-event correlations between Np and Npbar by construction.
…Excellent reproduction of the experimentally measured net-p moments products.

There is however an approach to calculate the moments products that also assumes the absence of intra-event correlations that requires no sampling.

This approach is based on the additive properties of cumulants.

Introduction

We are interested in measuring $S\sigma$ and $K\sigma^2$ for net-protons here.
These quantities are related to the cumulants, C_k, as follows.

$S\sigma = C_3/C_2$ and $K\sigma^2 = C_4/C_2$ (C_1=mean, C_2=variance)

where C_k is a "cumulant."

A feature of cumulants is their additivity for pairs of independent random variables.
i.e. given independent random variables u and v, then

$$C_k(u+v) = C_k(u) + C_k(v)$$

But here, we are interested in $S\sigma$ and $K\sigma^2$ for **net-p**, *i.e.* "u-v" with u=Np and v=Npbar

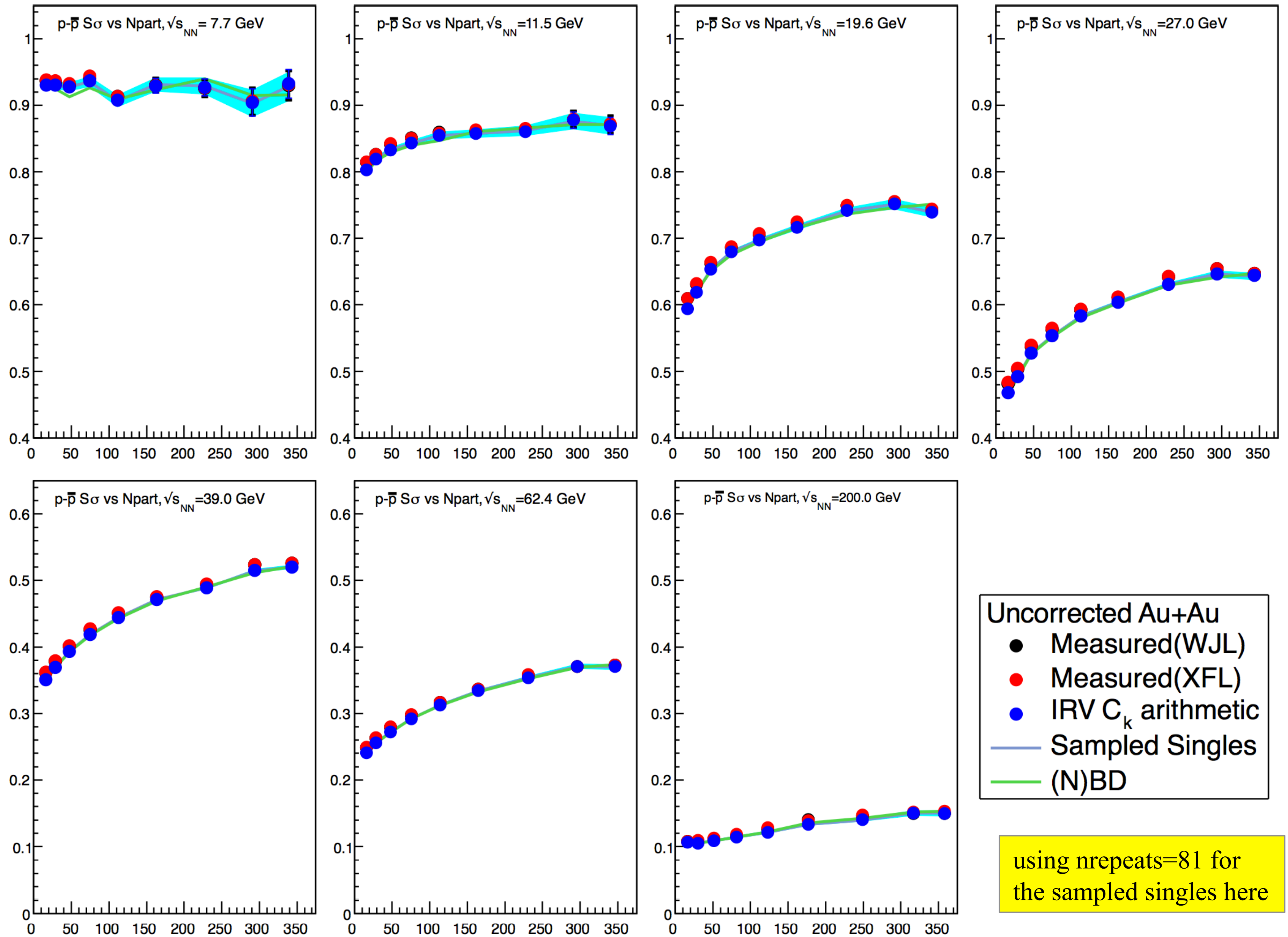
In this case, $C_k(u-v) = C_k(u) + (-1)^k \times C_k(v)$
This relation will only hold if u (Np) and v (Npbar) are random and independent variables.

So, here I'll calculate $S\sigma$ and $K\sigma^2$ using the values of $C_k(u-v)$ via $C_k(u)$ and $C_k(v)$

Tests the importance of intra-event correlations of Np and Npbar that requires no stochastic sampling. The information used here comes only from the singles distributions.

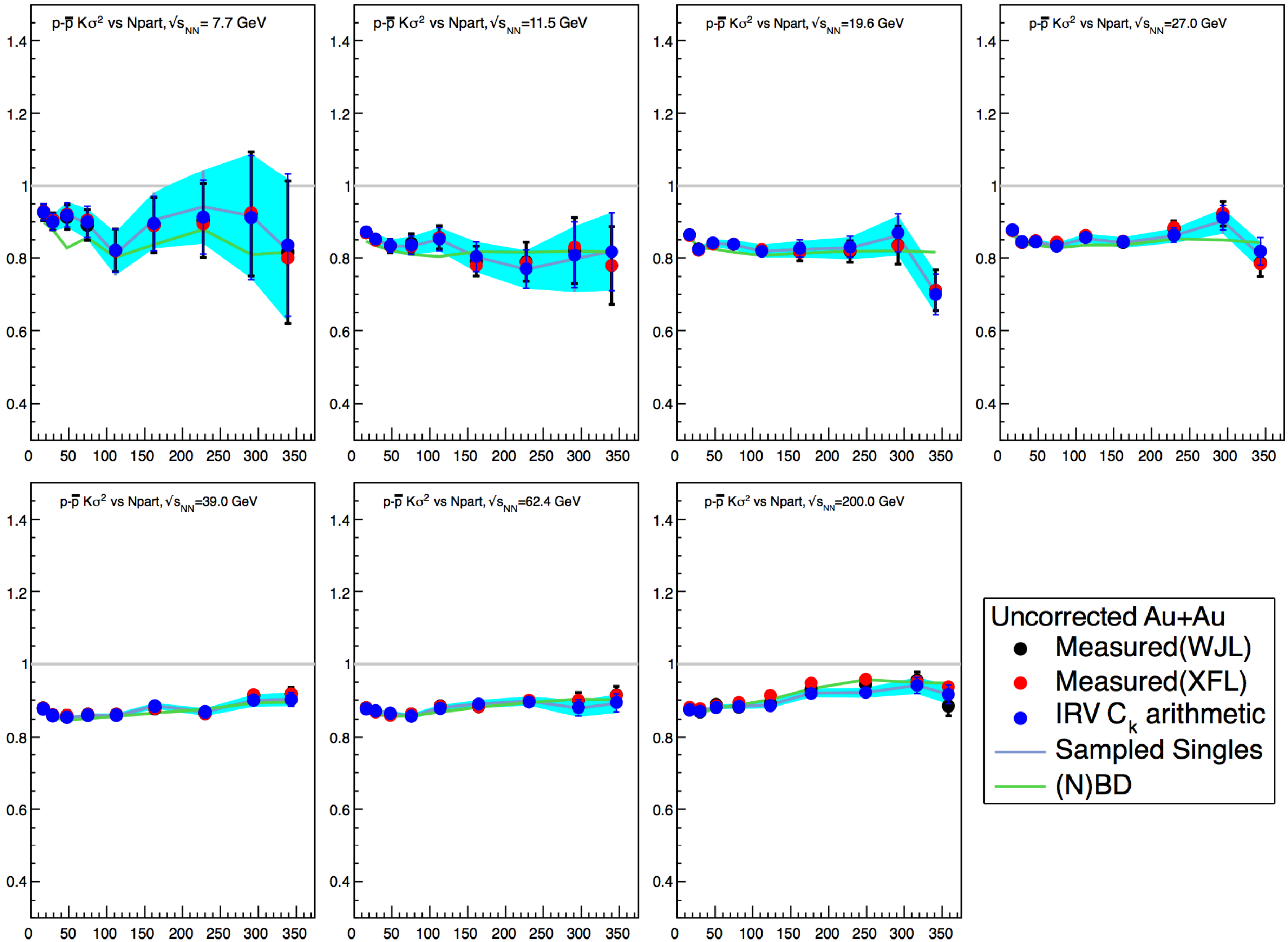
How does this approach compare to the sampled singles approach? and to the data?

Efficiency-uncorrected net-p Sσ vs centrality by $\sqrt{s_{NN}}$

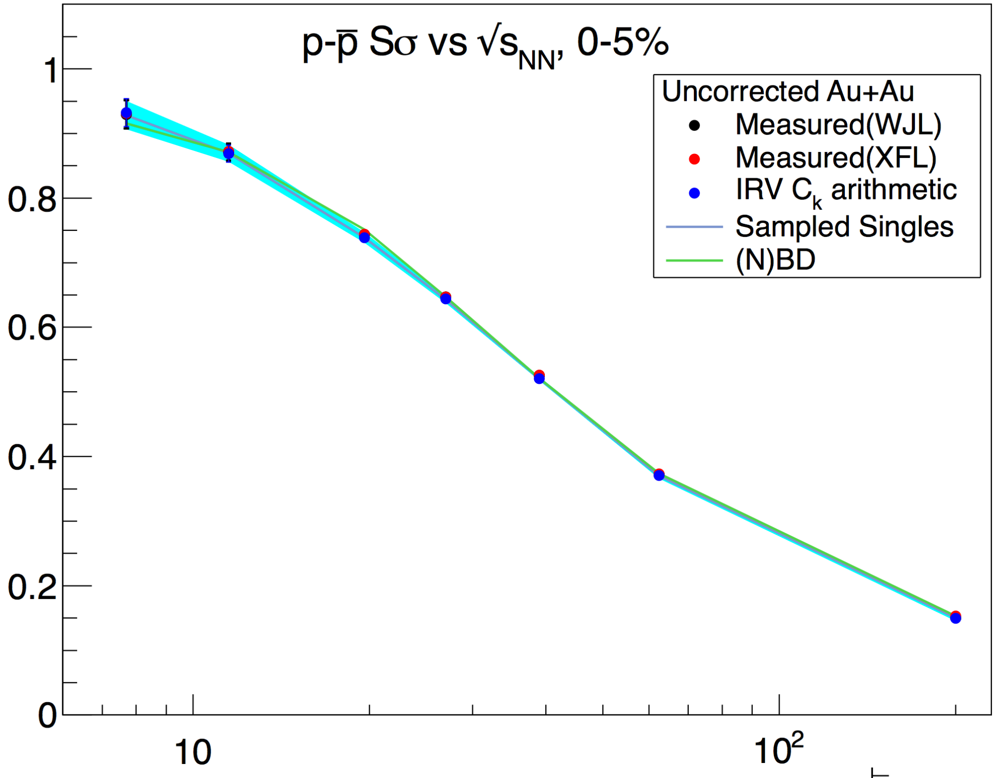


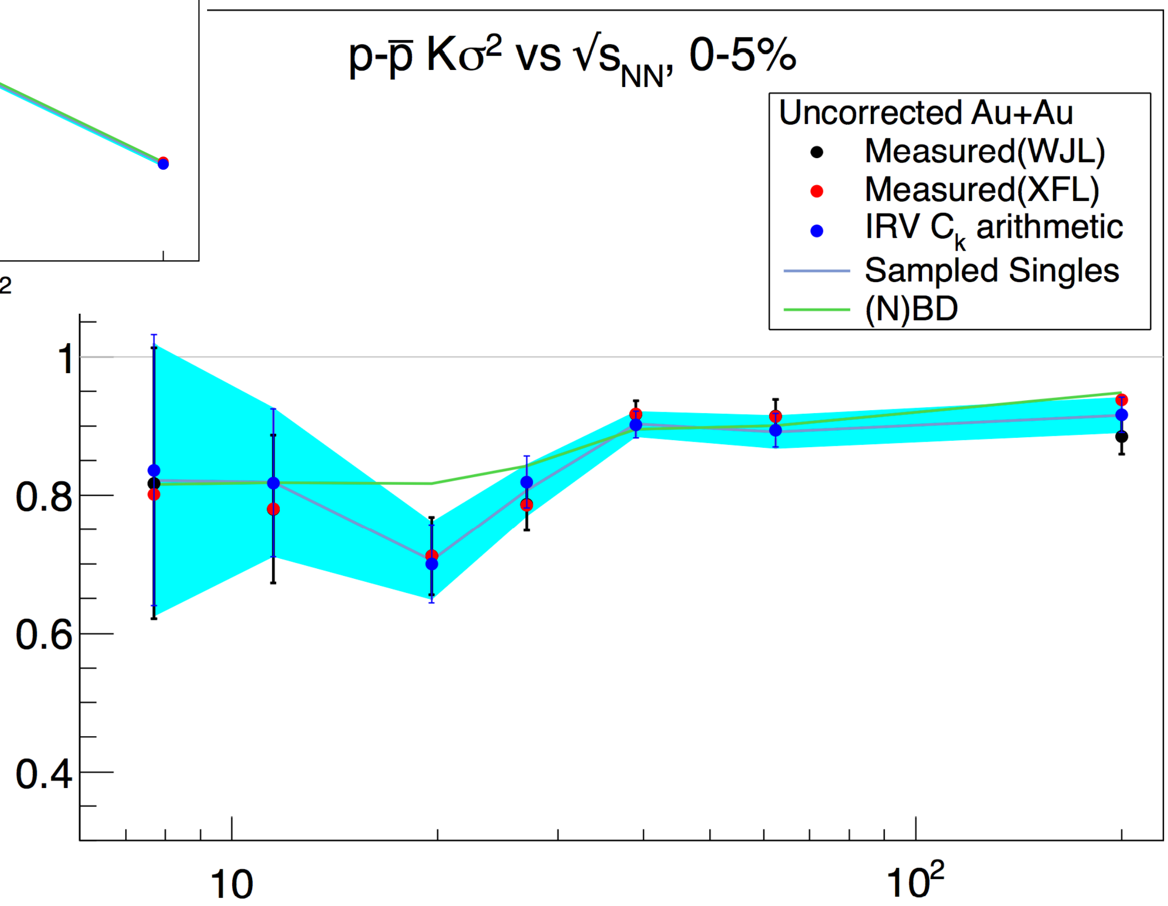
using nrepeats=81 for the sampled singles here

Efficiency-uncorrected net-p $K\sigma_2$ vs centrality by $\sqrt{s_{NN}}$

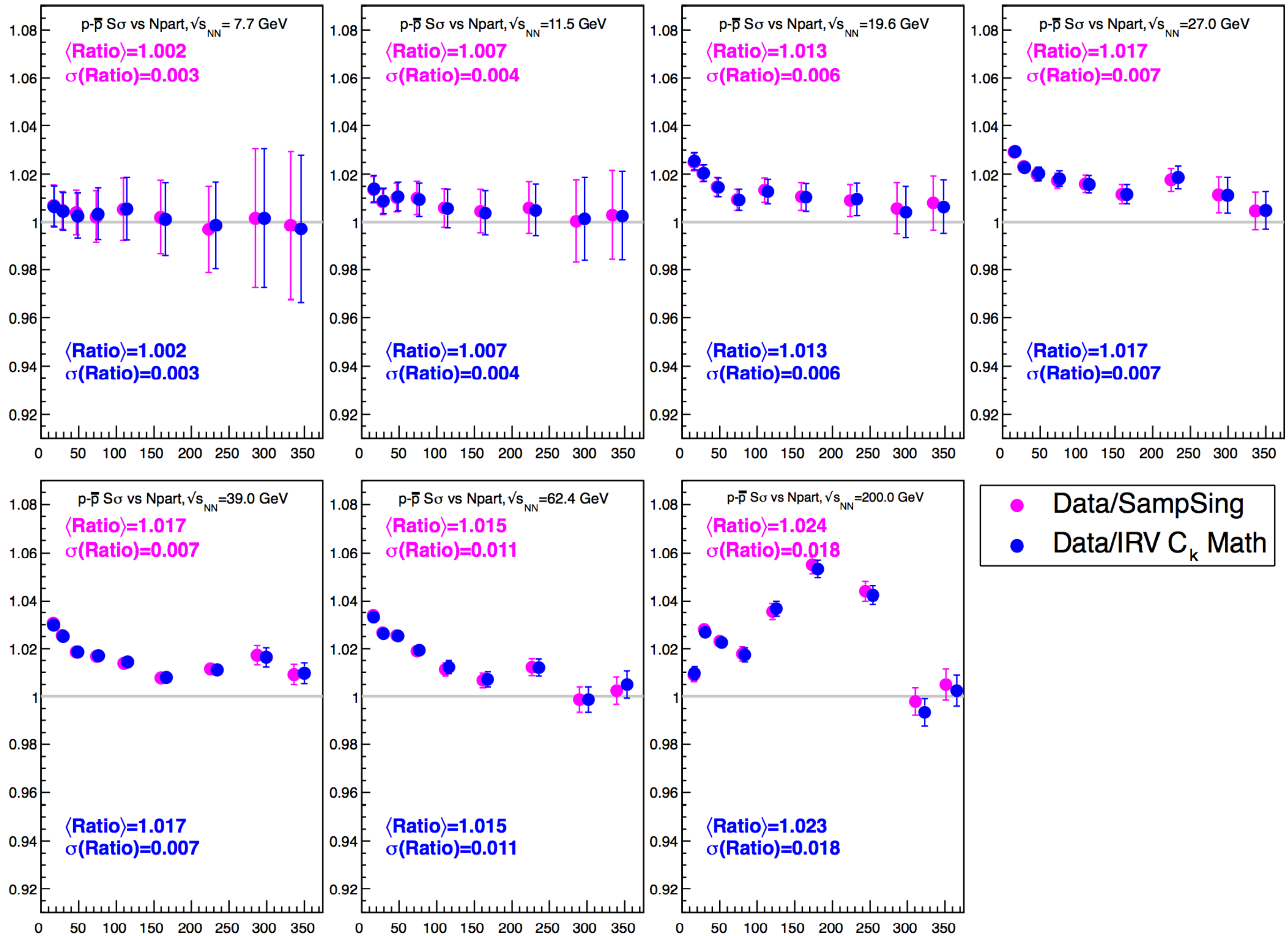


Efficiency-uncorrected net-p Sσ and Kσ² vs $\sqrt{s_{NN}}$ for 0-5% centrality

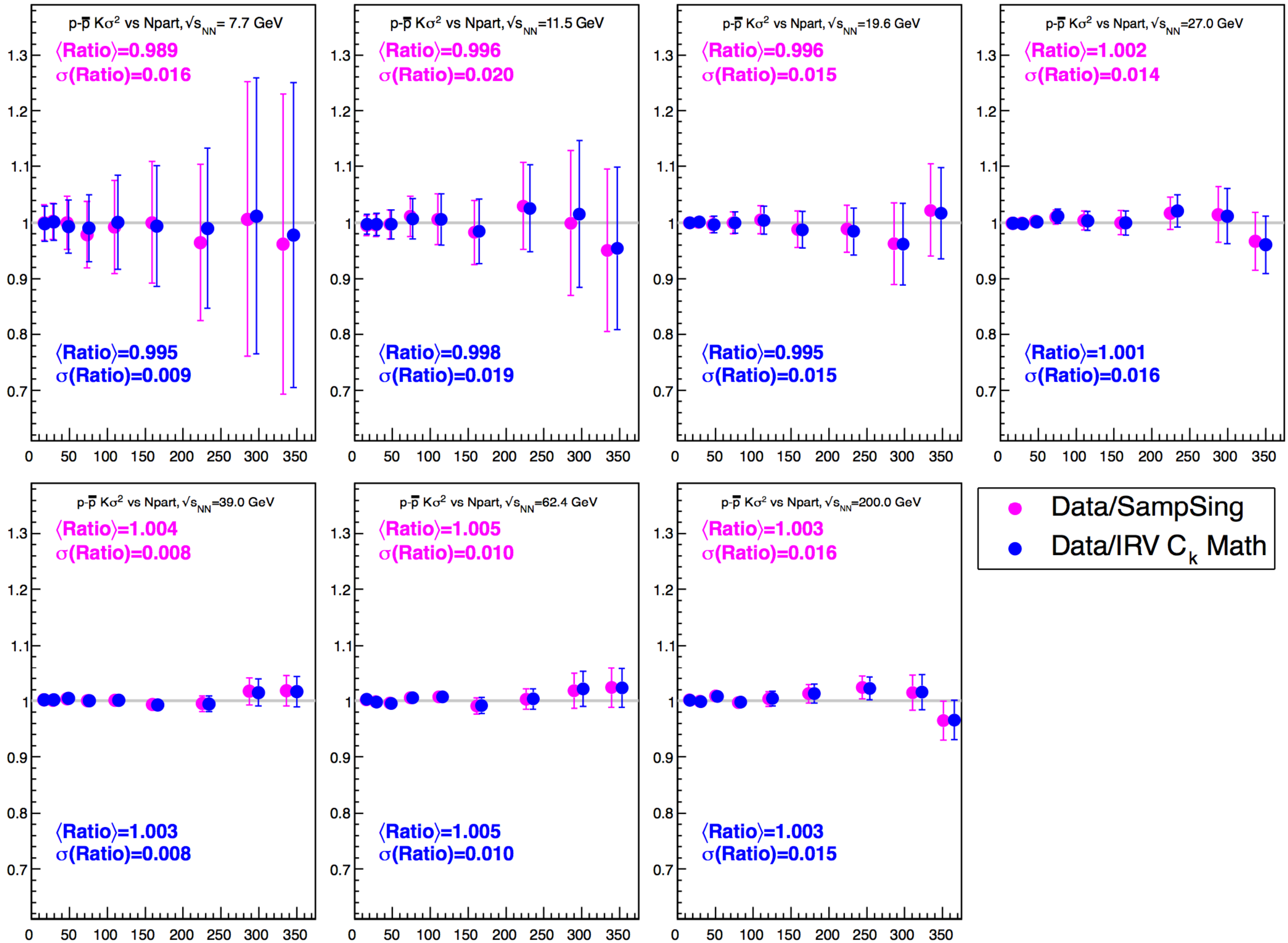




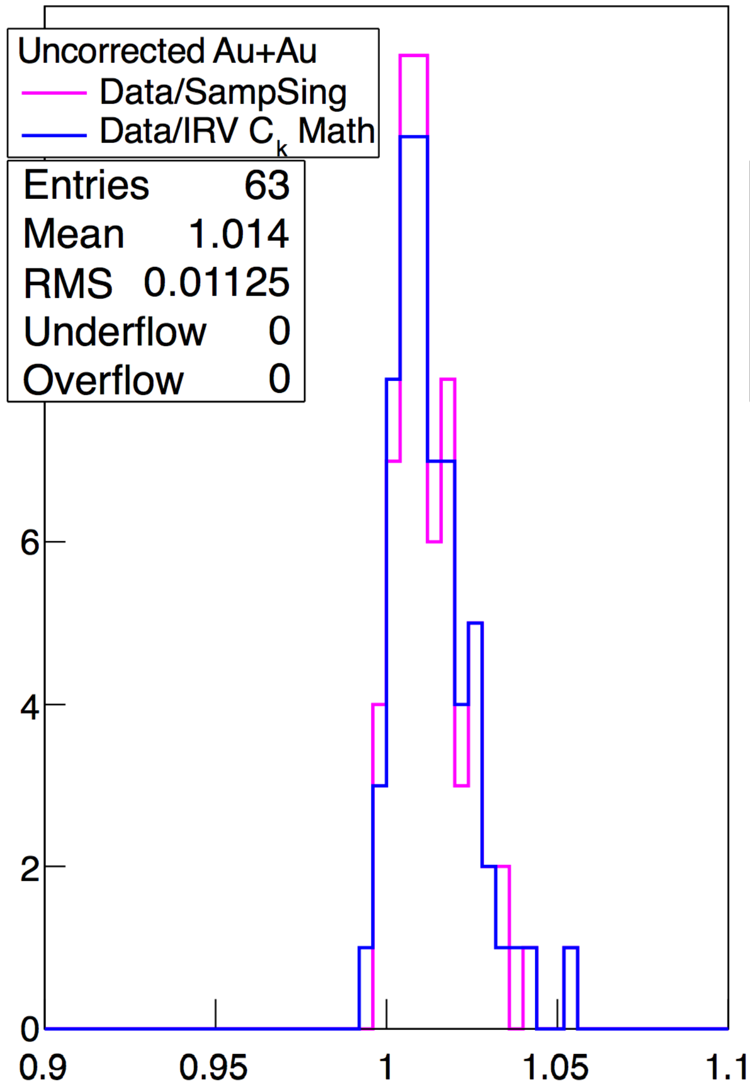
Sσ Ratios

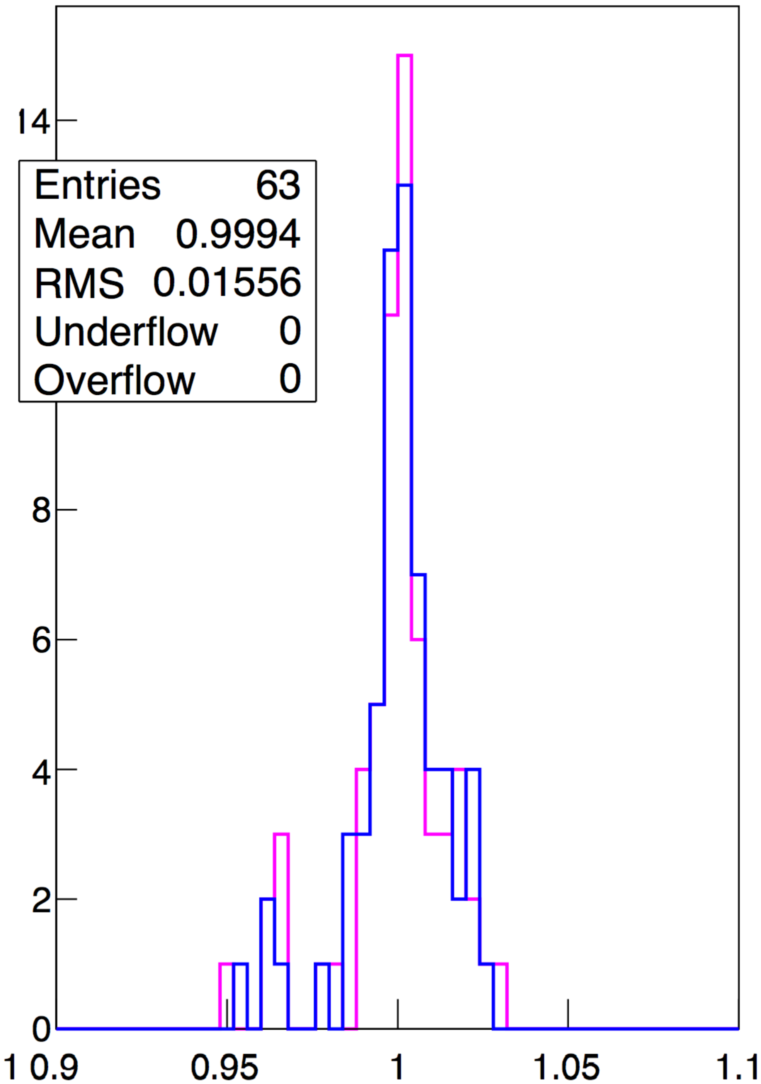

p-p̄ Sσ vs Npart, √s_NN= 7.7 GeV
⟨Ratio⟩=1.002
σ(Ratio)=0.003
⟨Ratio⟩=1.002
σ(Ratio)=0.003
p-p̄ Sσ vs Npart, √s_NN=11.5 GeV
⟨Ratio⟩=1.007
σ(Ratio)=0.004
⟨Ratio⟩=1.007
σ(Ratio)=0.004
p-p̄ Sσ vs Npart, √s_NN=19.6 GeV
⟨Ratio⟩=1.013
σ(Ratio)=0.006
⟨Ratio⟩=1.013
σ(Ratio)=0.006
p-p̄ Sσ vs Npart, √s_NN=27.0 GeV
⟨Ratio⟩=1.017
σ(Ratio)=0.007
⟨Ratio⟩=1.017
σ(Ratio)=0.007
p-p̄ Sσ vs Npart, √s_NN=39.0 GeV
⟨Ratio⟩=1.017
σ(Ratio)=0.007
⟨Ratio⟩=1.017
σ(Ratio)=0.007
p-p̄ Sσ vs Npart, √s_NN=62.4 GeV
⟨Ratio⟩=1.015
σ(Ratio)=0.011
⟨Ratio⟩=1.015
σ(Ratio)=0.011
p-p̄ Sσ vs Npart, √s_NN=200.0 GeV
⟨Ratio⟩=1.024
σ(Ratio)=0.018
⟨Ratio⟩=1.023
σ(Ratio)=0.018
Data/SampSing
Data/IRV C_k Math

Kσ² Ratios


p-p̄ Kσ² vs Npart, √sNN= 7.7 GeV
⟨Ratio⟩=0.989
σ(Ratio)=0.016
⟨Ratio⟩=0.995
σ(Ratio)=0.009
p-p̄ Kσ² vs Npart, √sNN=11.5 GeV
⟨Ratio⟩=0.996
σ(Ratio)=0.020
⟨Ratio⟩=0.998
σ(Ratio)=0.019
p-p̄ Kσ² vs Npart, √sNN=19.6 GeV
⟨Ratio⟩=0.996
σ(Ratio)=0.015
⟨Ratio⟩=0.995
σ(Ratio)=0.015
p-p̄ Kσ² vs Npart, √sNN=27.0 GeV
⟨Ratio⟩=1.002
σ(Ratio)=0.014
⟨Ratio⟩=1.001
σ(Ratio)=0.016
p-p̄ Kσ² vs Npart, √sNN=39.0 GeV
⟨Ratio⟩=1.004
σ(Ratio)=0.008
⟨Ratio⟩=1.003
σ(Ratio)=0.008
p-p̄ Kσ² vs Npart, √sNN=62.4 GeV
⟨Ratio⟩=1.005
σ(Ratio)=0.010
⟨Ratio⟩=1.005
σ(Ratio)=0.010
p-p̄ Kσ² vs Npart, √sNN=200.0 GeV
⟨Ratio⟩=1.003
σ(Ratio)=0.016
⟨Ratio⟩=1.003
σ(Ratio)=0.015
Data/SampSing
Data/IRV Ck Math

Ratios Summary: 7 $\sqrt{s_{NN}}$ values × 9 centrality bins = 63 ratios total





Sampled Singles and IRV C_k Math reproduce experimental Sσ to ~1.5%, with rms~1.1%

Sampled Singles and IRV C_k Math reproduce experimental Kσ^2 to <0.1%, with rms~1.5%

Focussing on 0-5% at 19.6 GeV….

Now we know that there is no aspect of the net-proton moments products that cannot be understood in terms of the p and pbar multiplicity distributions themselves.

That is…

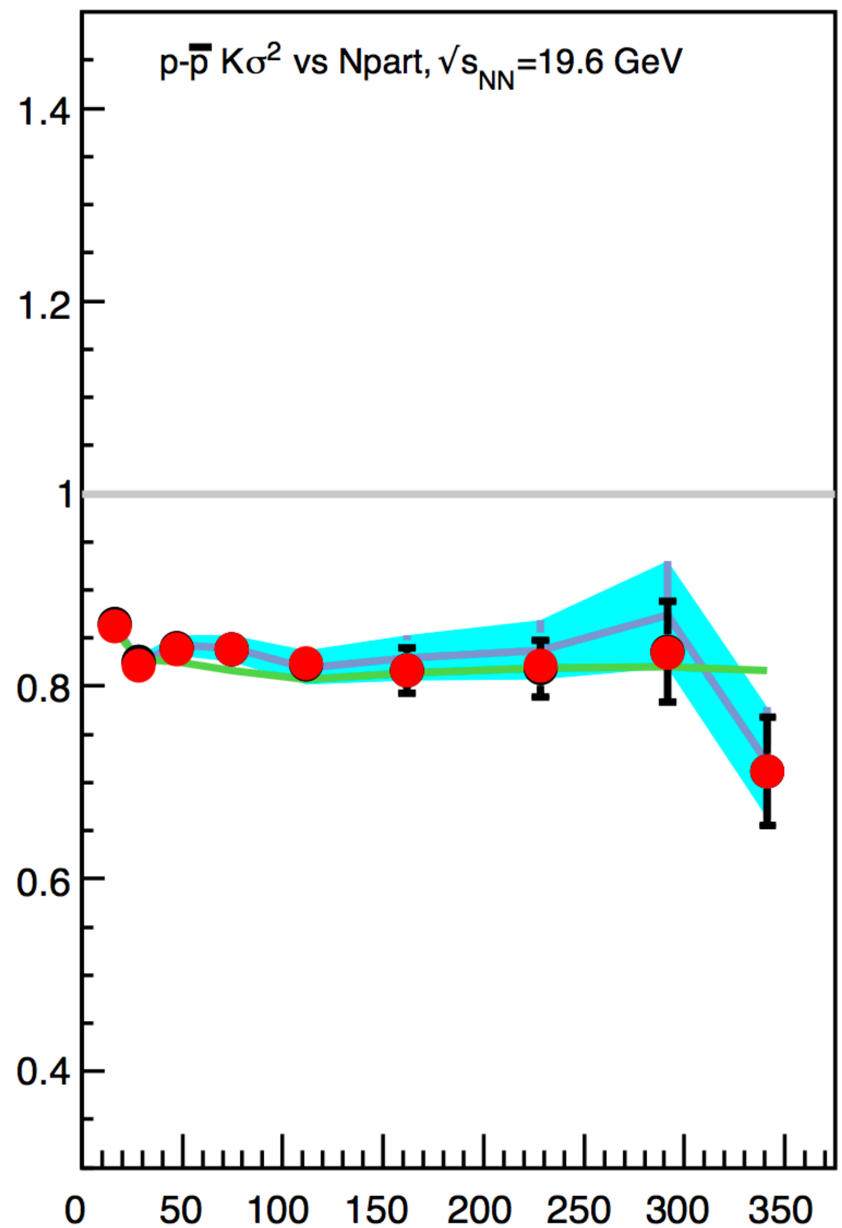
$K\sigma^2$(net-p)

$= C_4(\text{net-p})/C_2(\text{net-p})$

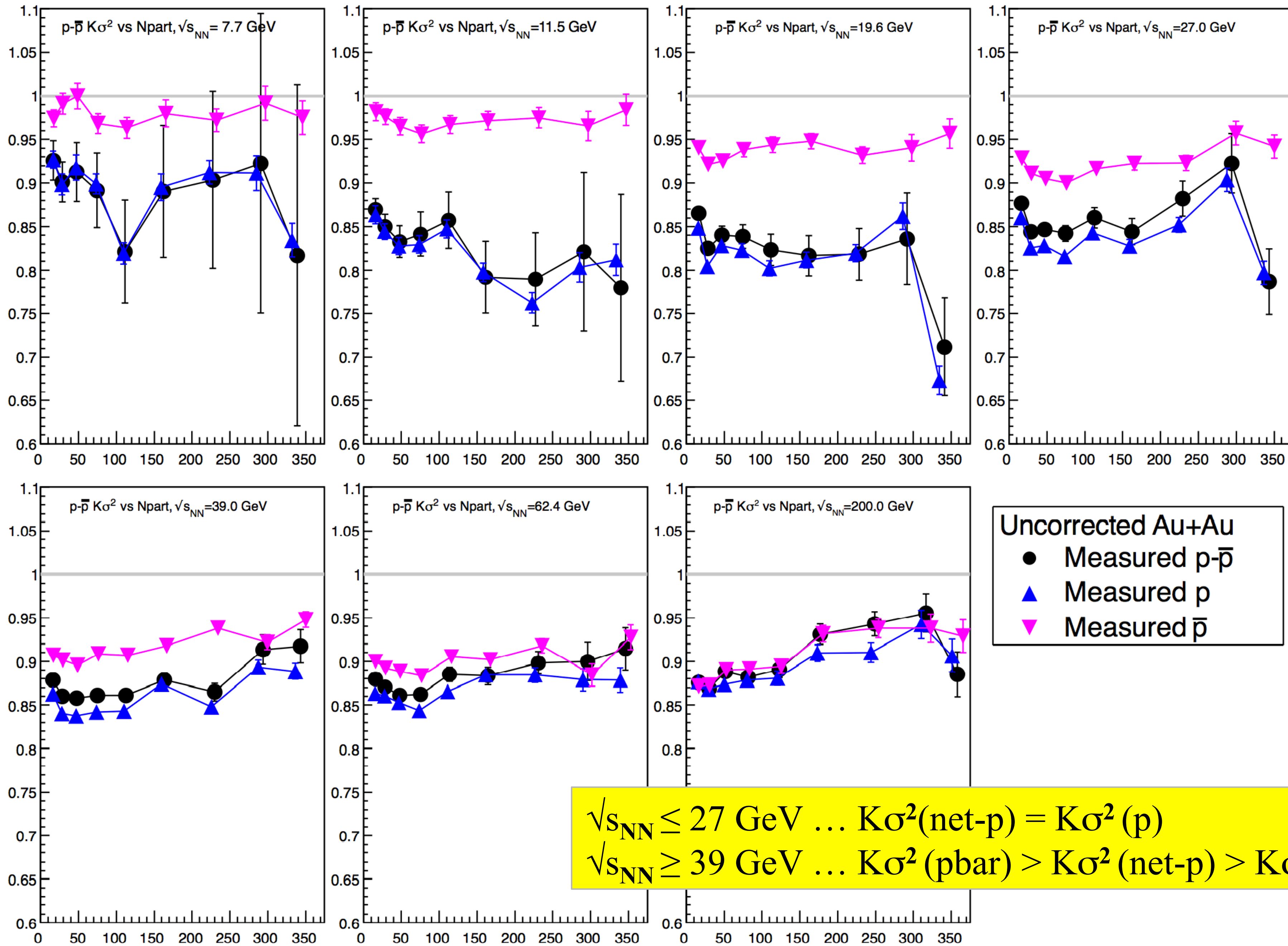
$= [C_4(p)+C_4(\text{pbar})] / [C_2(p)+C_2(\text{pbar})]$

Four terms there.

Are the experimental values of $K\sigma^2$(net-p) driven by all four terms equally?



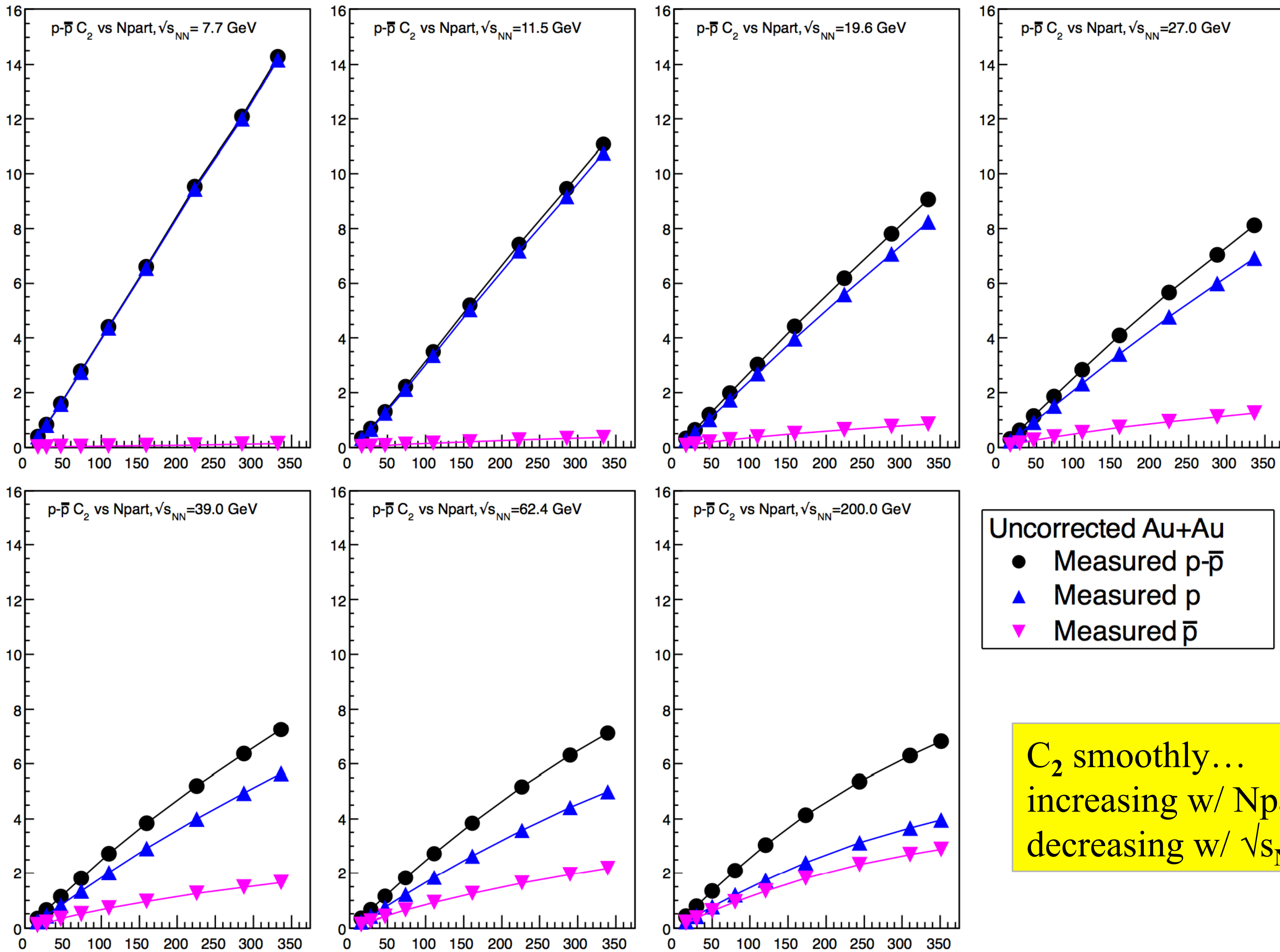
Charge-separated $K\sigma^2$ *vs.* centrality by $\sqrt{s_{NN}}$



$\sqrt{s_{NN}} \leq 27$ GeV … $K\sigma^2$(net-p) = $K\sigma^2$ (p)

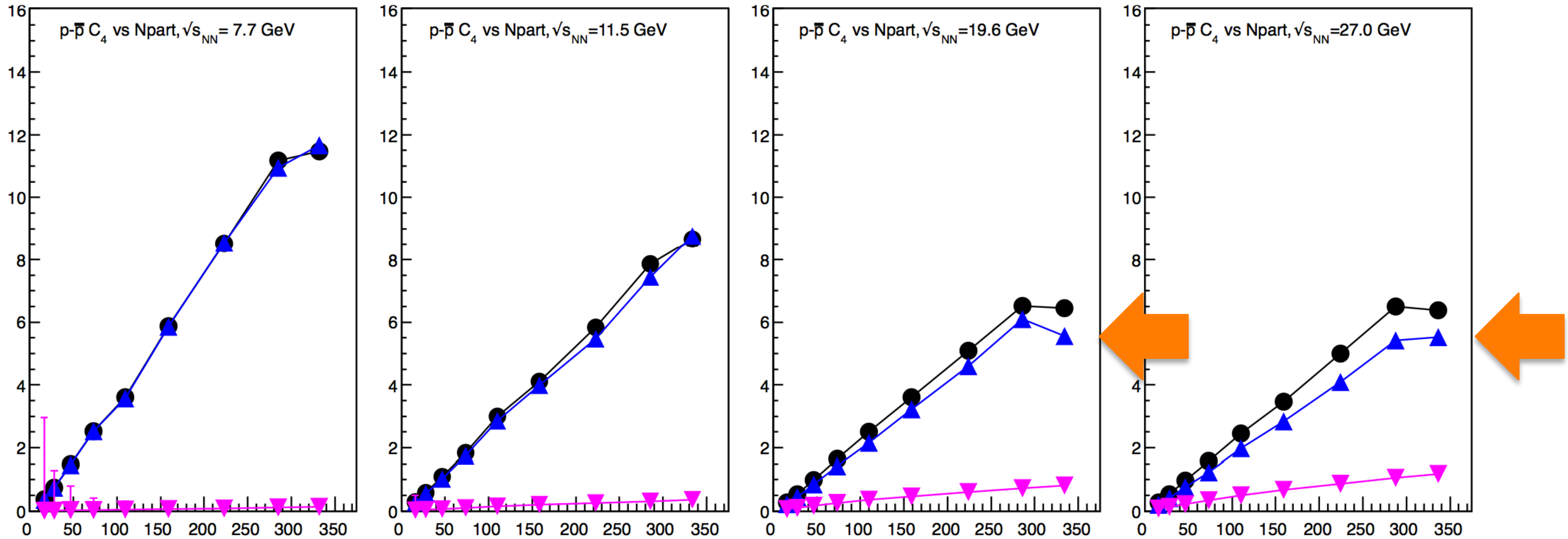
$\sqrt{s_{NN}} \geq 39$ GeV … $K\sigma^2$ (pbar) > $K\sigma^2$ (net-p) > $K\sigma^2$ (p)

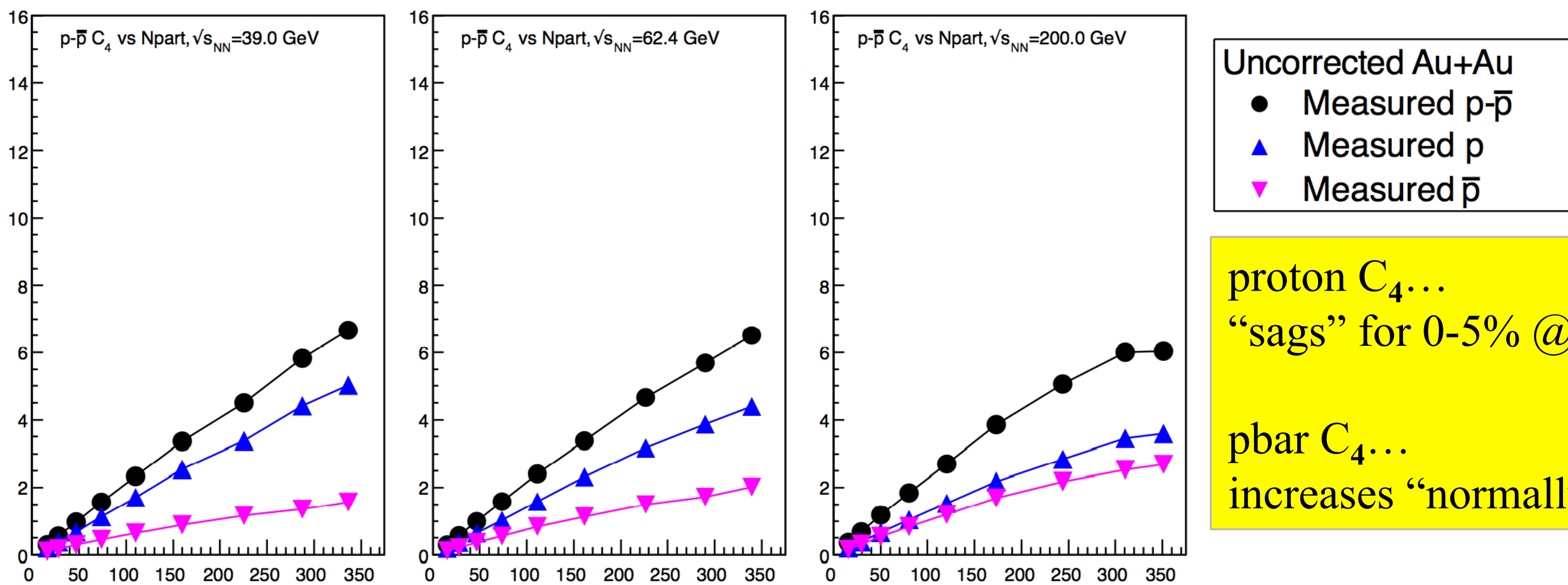
C_2 (variance) *vs.* centrality by $\sqrt{s_{NN}}$



C_2 smoothly…
increasing w/ Npart
decreasing w/ $\sqrt{s_{NN}}$

C_4 *vs.* centrality by $\sqrt{s_{NN}}$





proton C_4…
“sags” for 0-5% @ 19&27

pbar C_4…
increases “normally”

Summary

Sampled singles approach reproduces the experimental data points when "oversampled"

One can also calculate the values of $S\sigma$ and $K\sigma^2$ assuming Np and Npbar are random and independent via the additivity properties of cumulants.

This approach requires no sampling.

The "IRV" (independent random variable) cumulant arithmetic reproduces the
- (oversampled) sampled singles results, which is stochastic.
- the experimental values.

This should lend confidence to the sampled singles approach
and underscore the unimportance of (Np,Npbar) intra-event correlations to net-p moments

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Re: the "apparent dip" for 0-5% and 19.6 & 27 GeV….

Perfectly reproduced by the Sampled Singles and IRV C_k arithmetic approaches…
Seems to come entirely from the proton C_4… proton C_2 increases ~normally
(N)BD does not show this dip – but note that the input to the (N)BD is C_1 and C_2…

$$K\sigma^2(\text{net-p}) = C_4(\text{net-p})/C_2(\text{net-p})$$
$$= [C_4(p)+C_4(\text{pbar})] / [C_2(p)+C_2(\text{pbar})]$$

I am now exploring some of these same aspects with UrQMD, including efficiencies…

BACKUP SLIDES

C_k from net-p paper

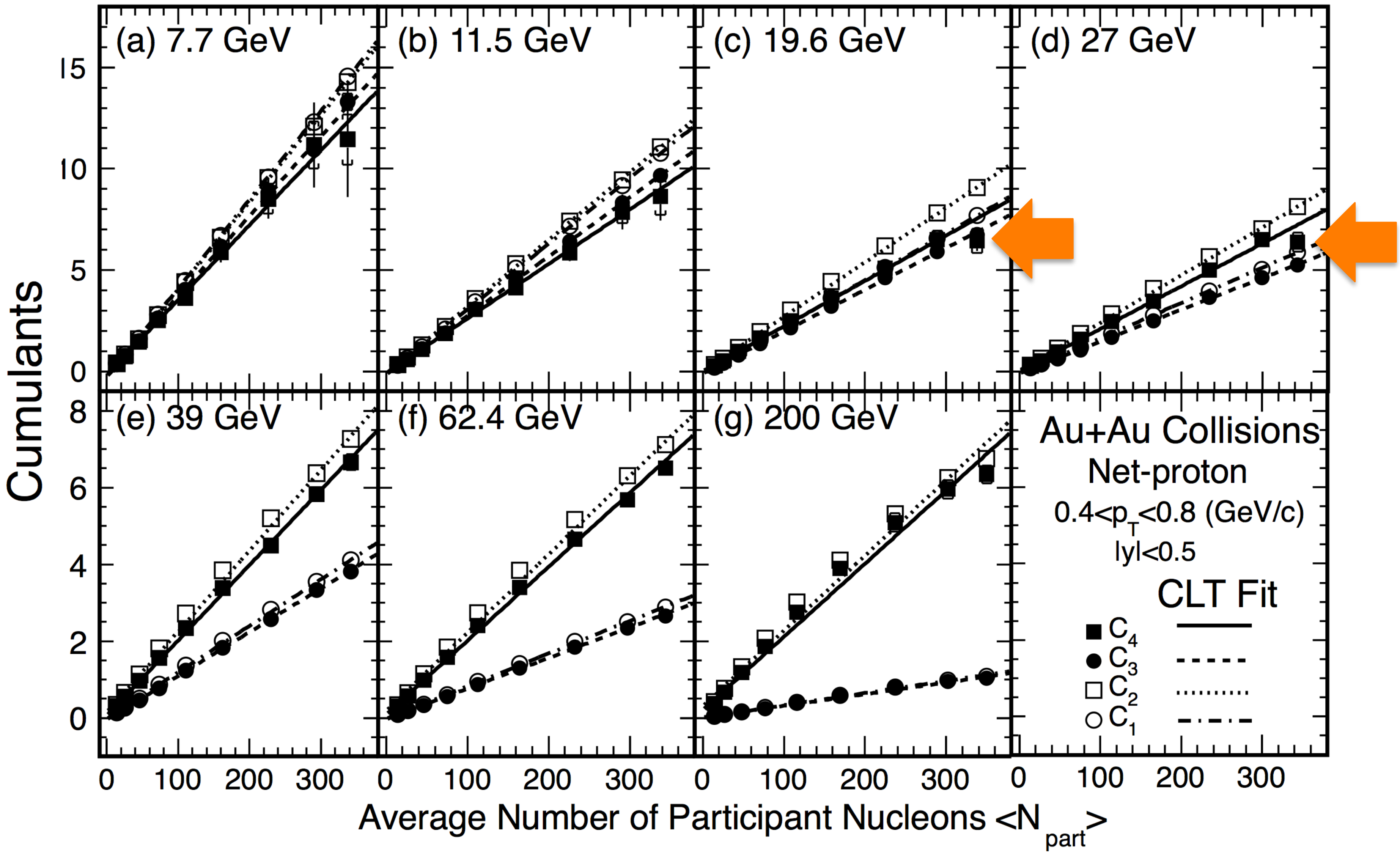
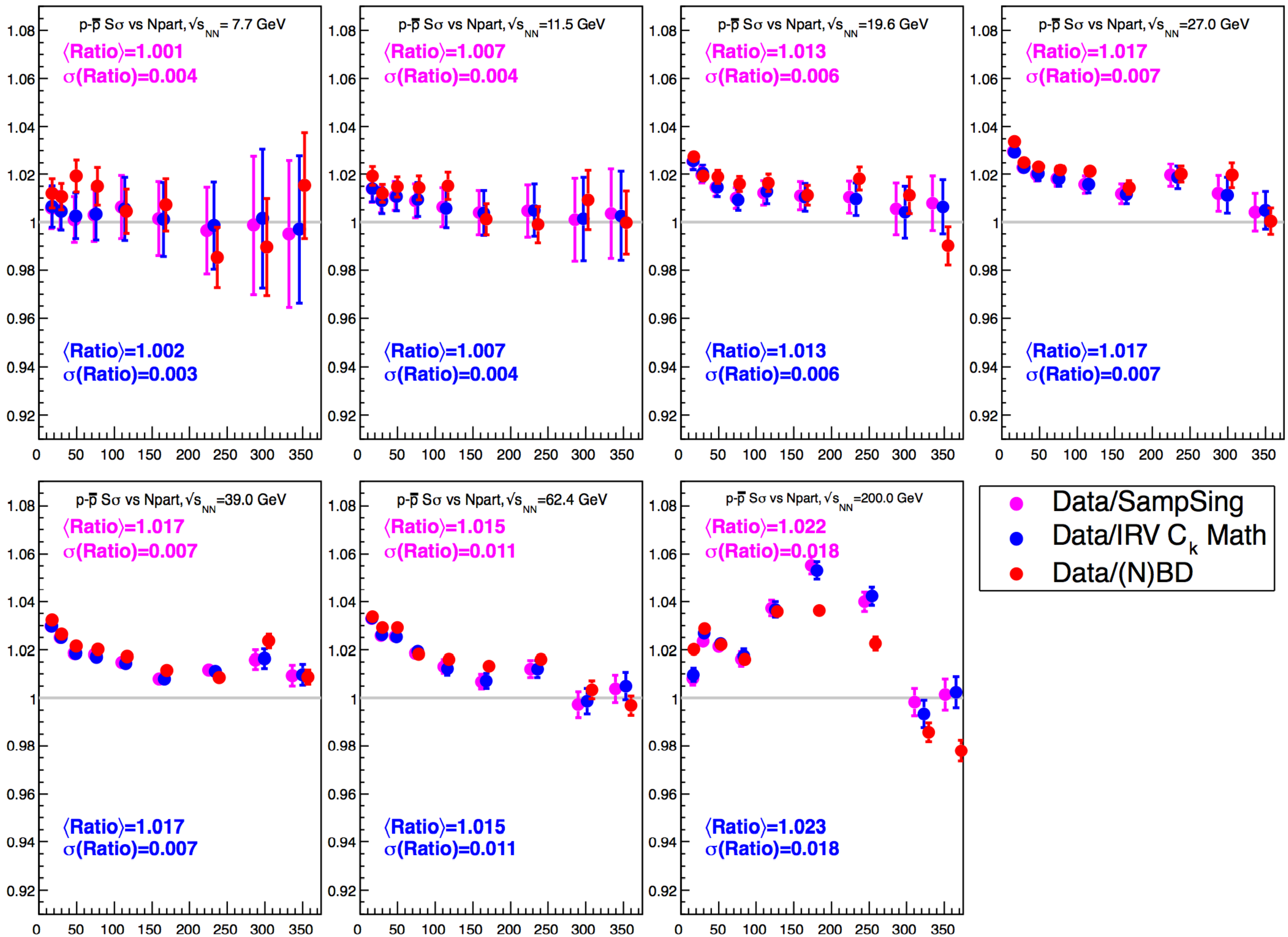
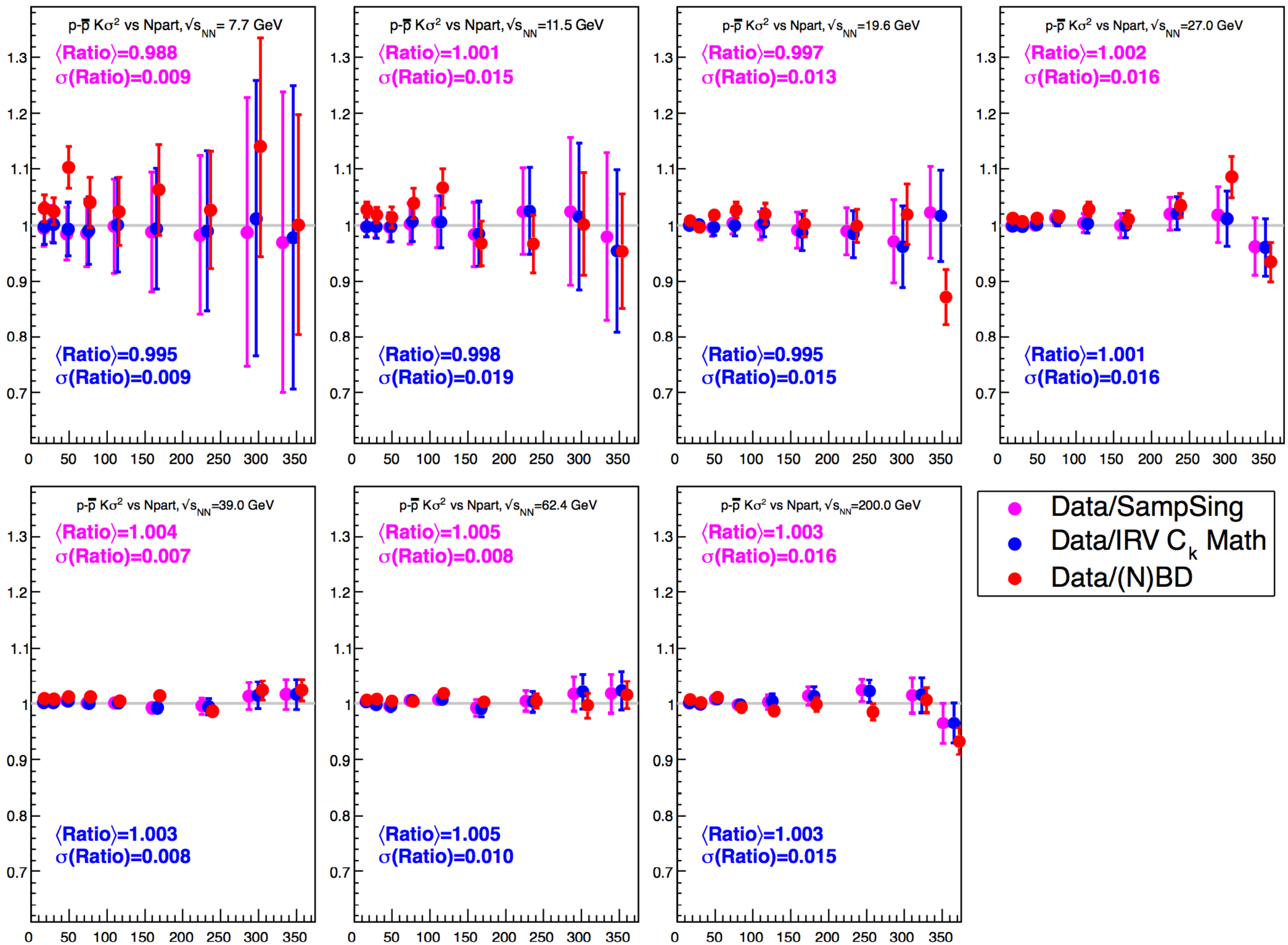


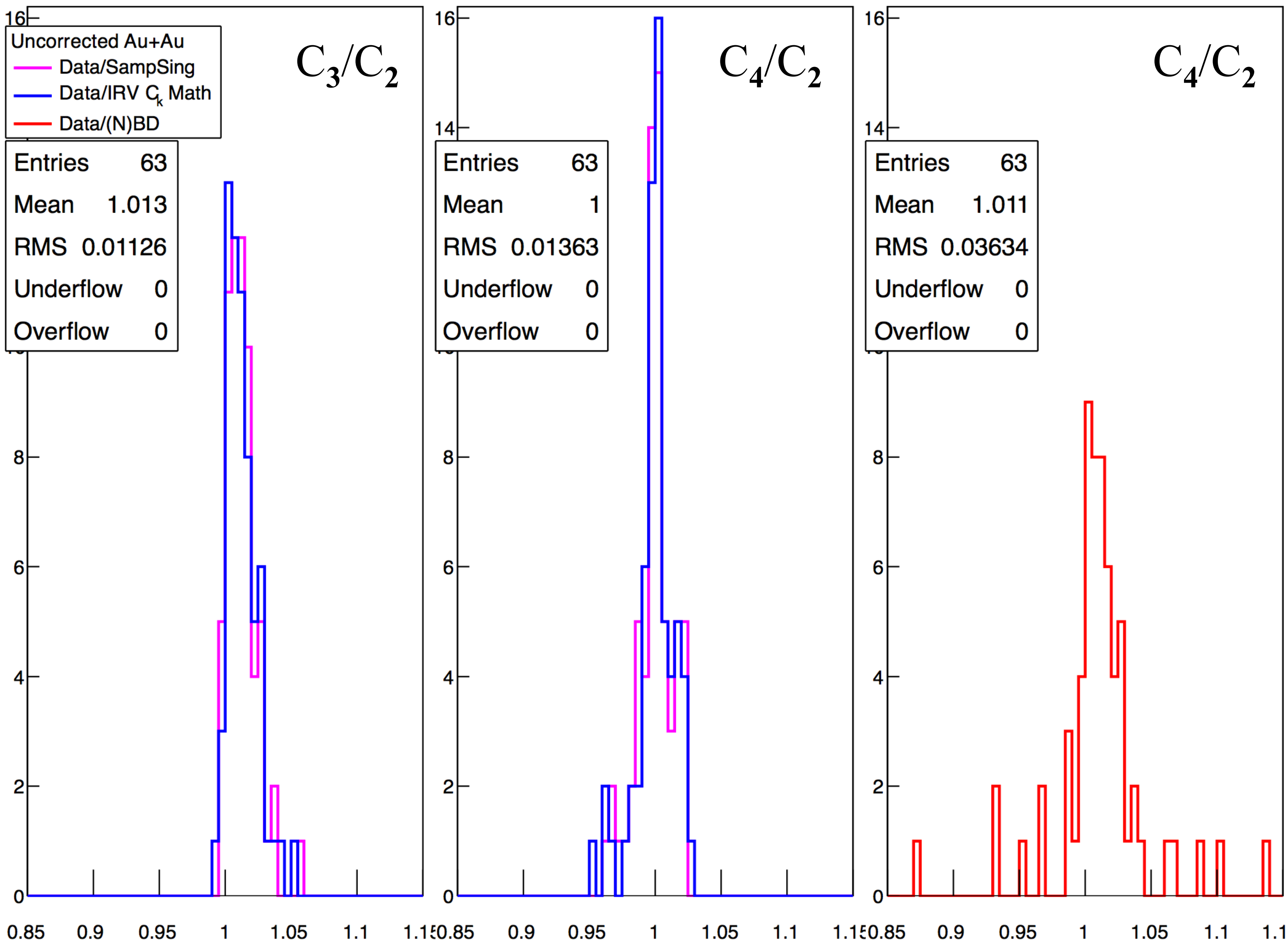
FIG. 2: Centrality dependence of the cumulants of ΔN_p distributions for Au+Au collisions at $\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27, 39, 62.4, and 200 GeV. The lines indicate the linear fits. Error bars are statistical and caps are systematic errors.

Sσ Ratios including (N)BD

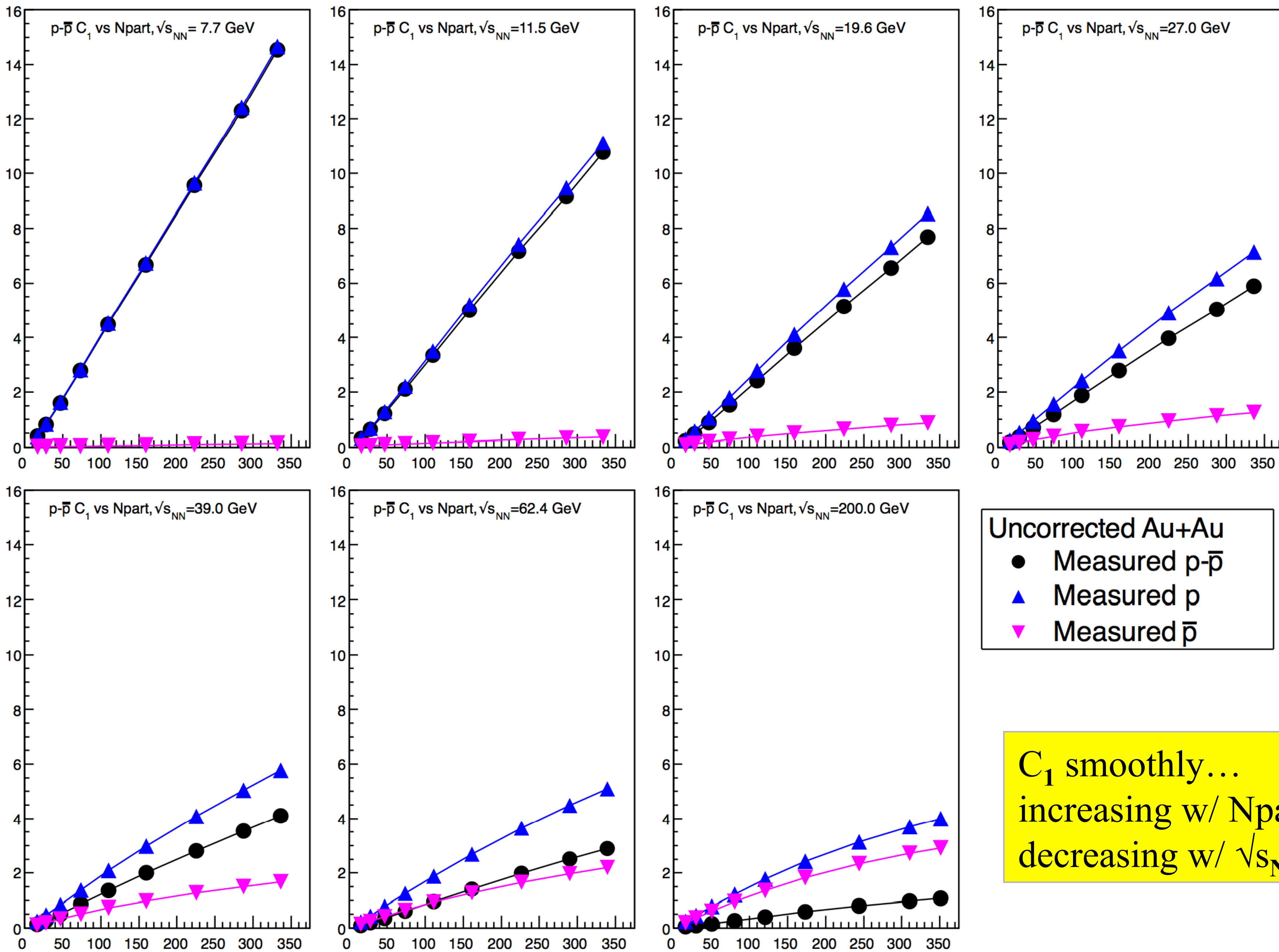


Kσ² Ratios including (N)BD



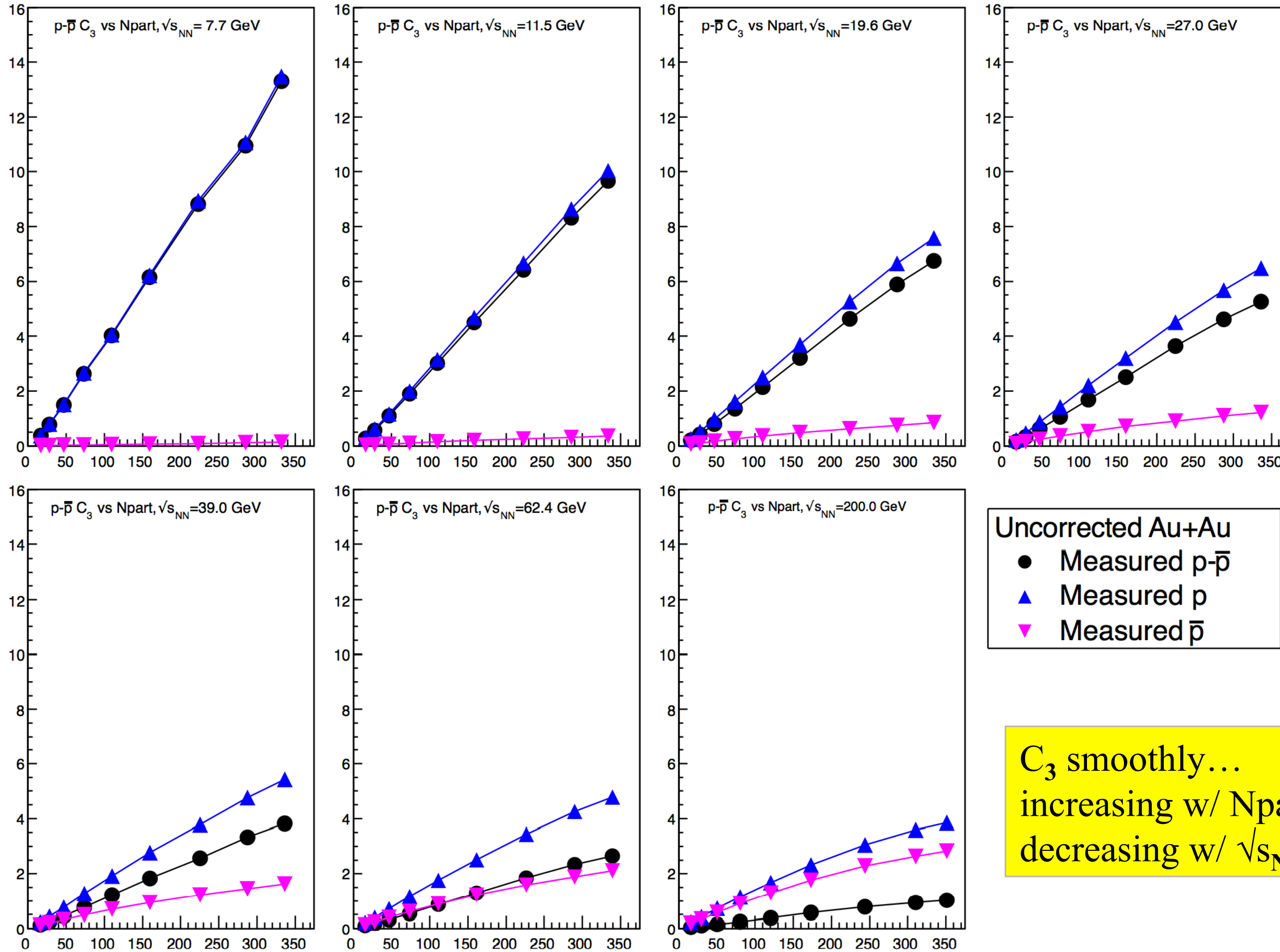

Uncorrected Au+Au
Data/SampSing
Data/IRV C_k Math
Data/(N)BD
C_3/C_2
Entries 63
Mean 1.013
RMS 0.01126
Underflow 0
Overflow 0
C_4/C_2
Entries 63
Mean 1
RMS 0.01363
Underflow 0
Overflow 0
C_4/C_2
Entries 63
Mean 1.011
RMS 0.03634
Underflow 0
Overflow 0

C_1 (mean) *vs.* centrality by $\sqrt{s_{NN}}$



C_1 smoothly…
increasing w/ Npart
decreasing w/ $\sqrt{s_{NN}}$

C_3 *vs.* centrality by $\sqrt{s_{NN}}$



C_3 smoothly…
increasing w/ Npart
decreasing w/ $\sqrt{s_{NN}}$