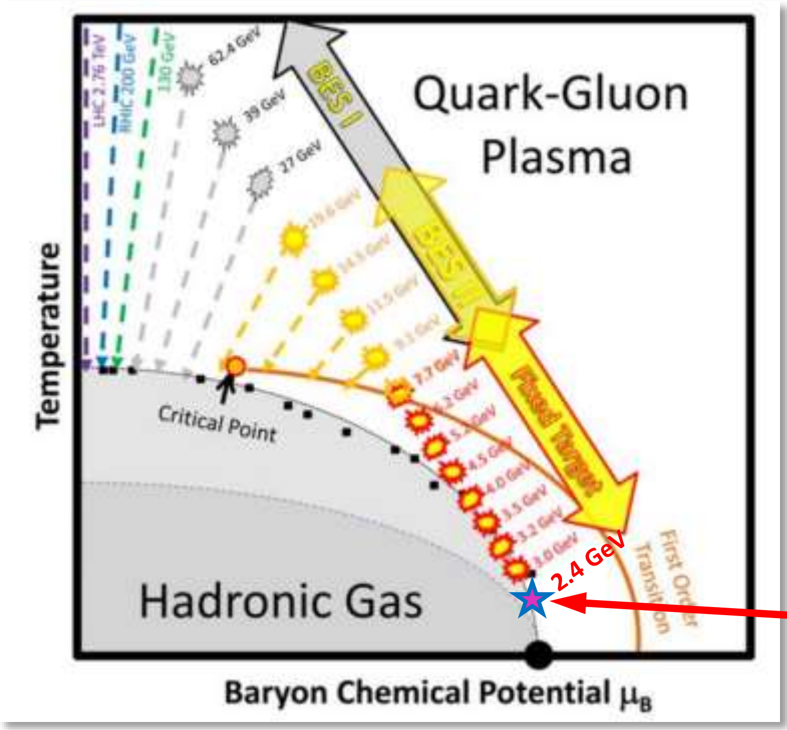
Critical fluctuations studied with HADES

30/11/2021 **FANI-2021** | R. Holzmann (GSI) for the HADES collaboration

Exploring the QCD phase diagram through HI collisions



- proton detection in HADES
- centrality estimators
- cumulants & correlators
- **volume fluctuation corrections**
- conclusions & outlook

HADES Au+Au at $\sqrt{s_{NN}} = 2.41$ GeV

→ Adamczewski-Musch et al. PRC 102 (2020)

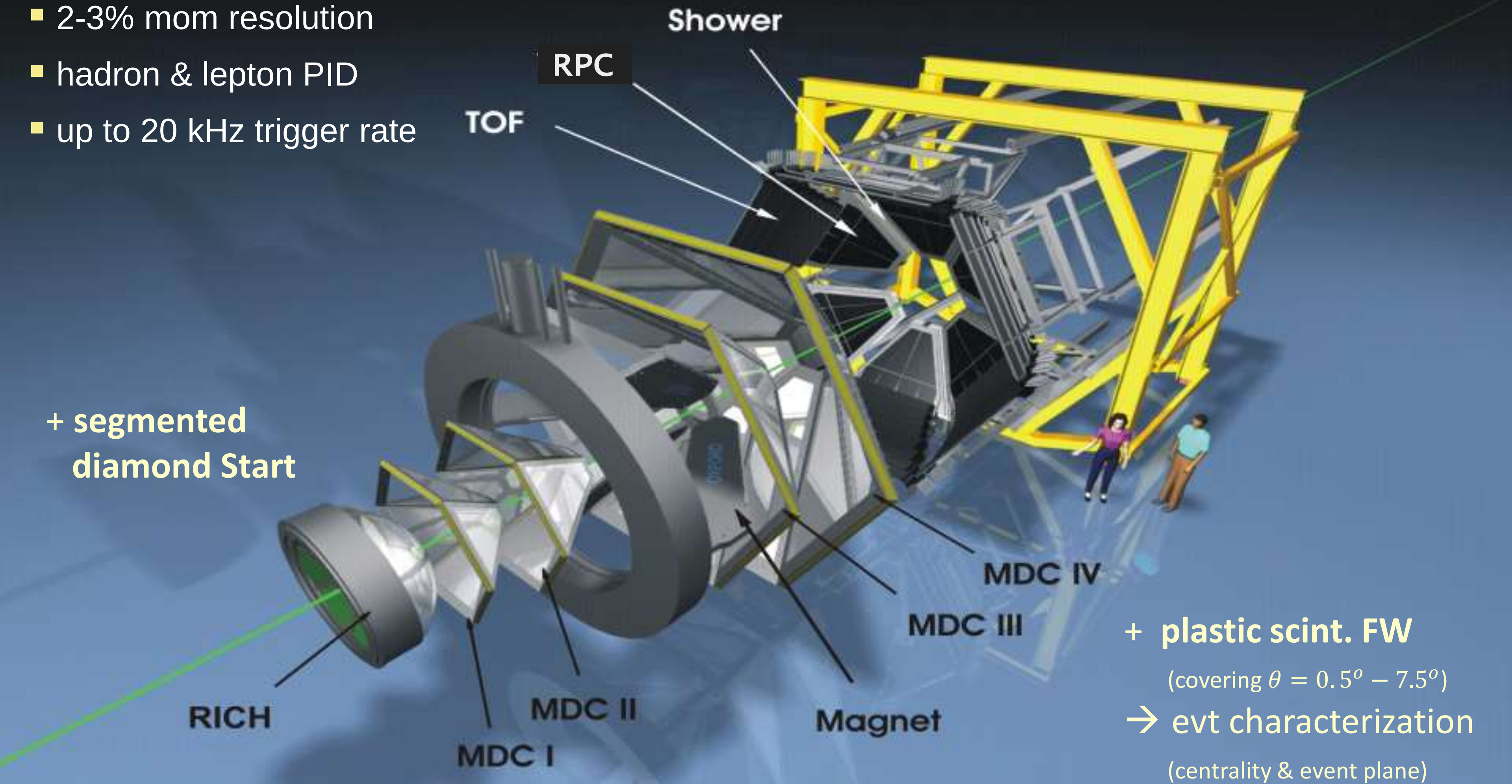
Ag+Ag at $\sqrt{s_{NN}} = 2.55$ GeV

→ analysis in progress …

The HADES detector at GSI

High Acceptance DiElectron Spectrometer
(setup used in Au+Au run)

- large acceptance
- 2-3% mom resolution
- hadron & lepton PID
- up to 20 kHz trigger rate



\+ **segmented diamond Start**

\+ **plastic scint. FW**

(covering $\theta = 0.5^o - 7.5^o$)

→ evt characterization

(centrality & event plane)

Event cleaning in HADES

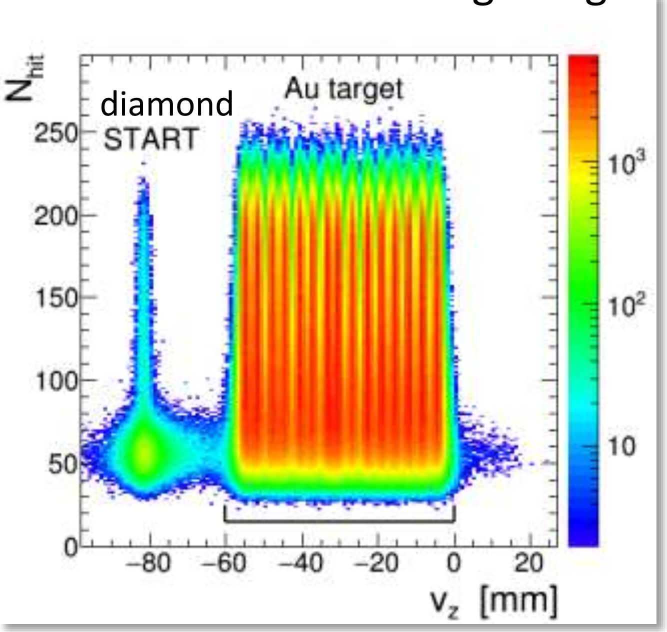
Segmented gold target:

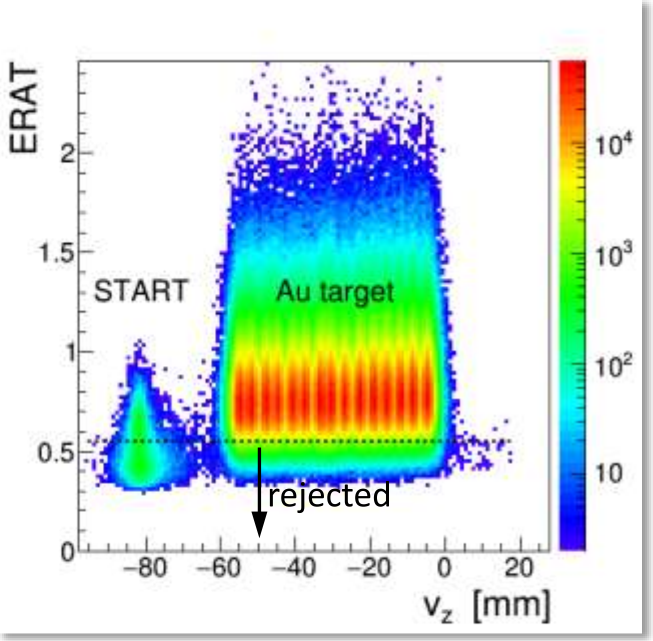
- ^{197}Au material
- 15 discs of Ø = 2.2 mm mounted on kapton strips
- Δz = 3.6 mm
- 2.0% interaction prob.

Kindler et al.,
NIM A 655 (2011) 95

Remove Au+C bkgd on the kapton with a cut on $ERAT = \sum E_t / \sum E_l$

Event vertex cut on target region



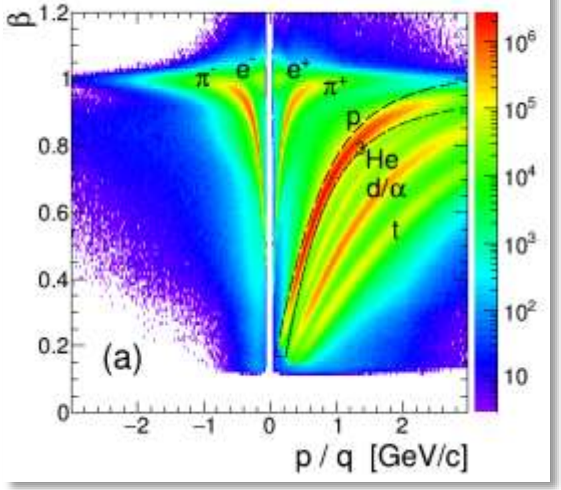


→

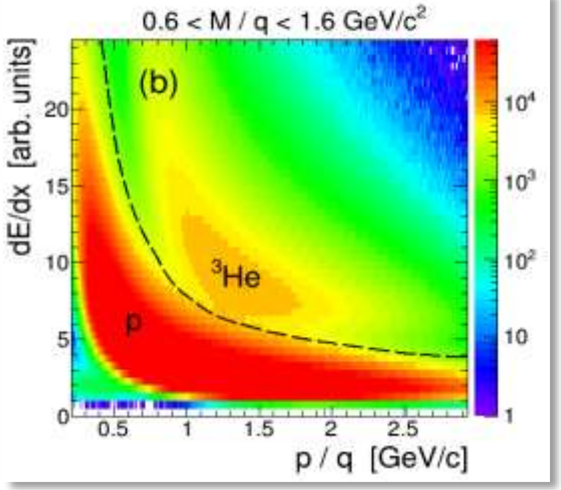
beam direction

Particle ID in HADES

velocity vs. p/q



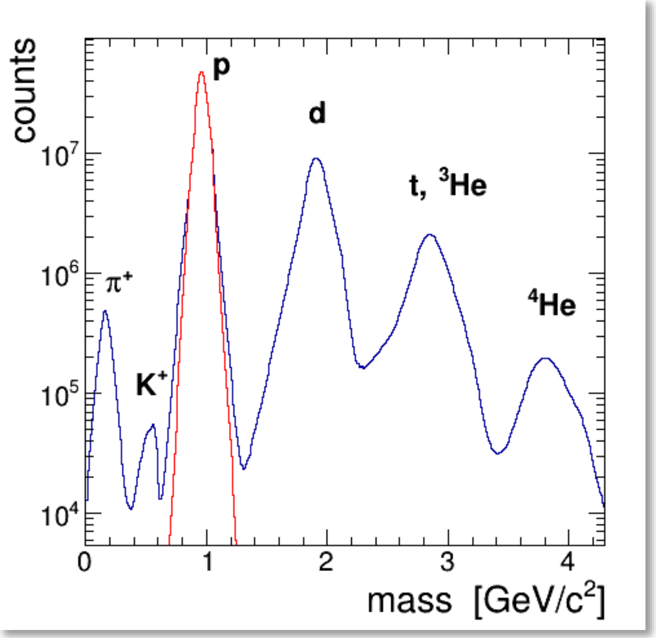
MDC dE/dx vs. p/q



Hadron ID based on

- ToF
- momentum
- dE/dx

Mass spectrum and accepted protons



Proton fluctuation signal purity

within same evt

- Proton pid impurities $\leq \mathbf{10^{-3}}$
- Weak decays, e.g. $\Lambda \rightarrow p + \pi^-$, $\Sigma \rightarrow p + \pi^-$ $\leq \mathbf{6.5 \cdot 10^{-4}}$
- Knock-out (spallation) protons $\leq \mathbf{3 \cdot 10^{-3}}$
  - from secondary reactions in target / target holder
  - 50% pp, 45% np, <5% πp (Geant3 + GCalor)

different evt classes

- Au + C reactions on target holder (8μm kapton) foils $\leq \mathbf{10^{-3}}$
  - suppressed by trigger & centrality selection
  - asymmetric rapidity distribution $y > y_0$
- Event pile-up (central evt + min. bias evt) $\leq \mathbf{3 \cdot 10^{-5}}$

relative contribution

Centrality selection with the Forward Wall

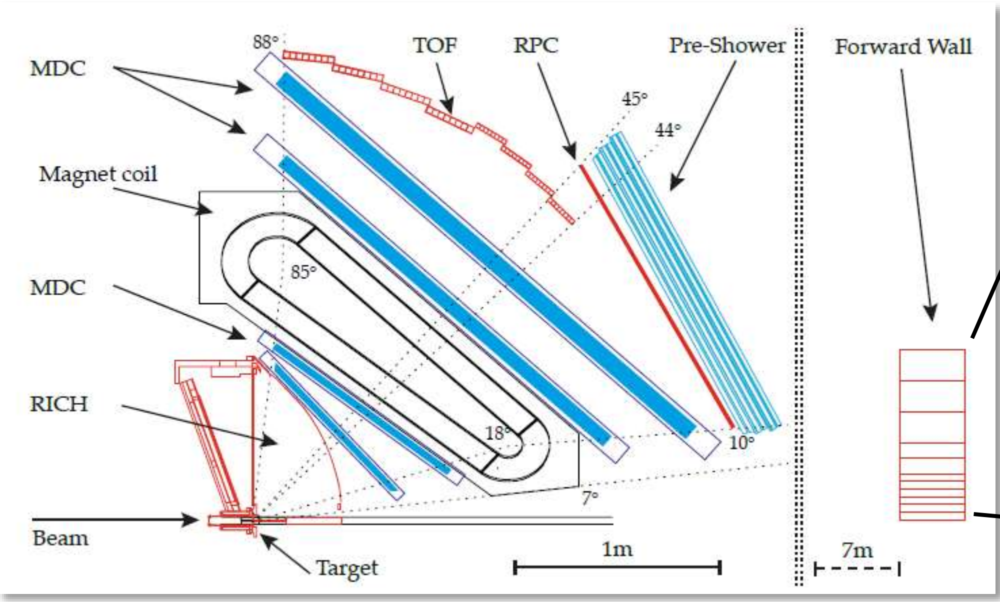
In 1.23 GeV/u Au+Au collisions:

- protons & clusters dominate
- centrality selection based on
  - hit mult in TOF & RPC
  - or track mult
  - or **FW sum of charges**

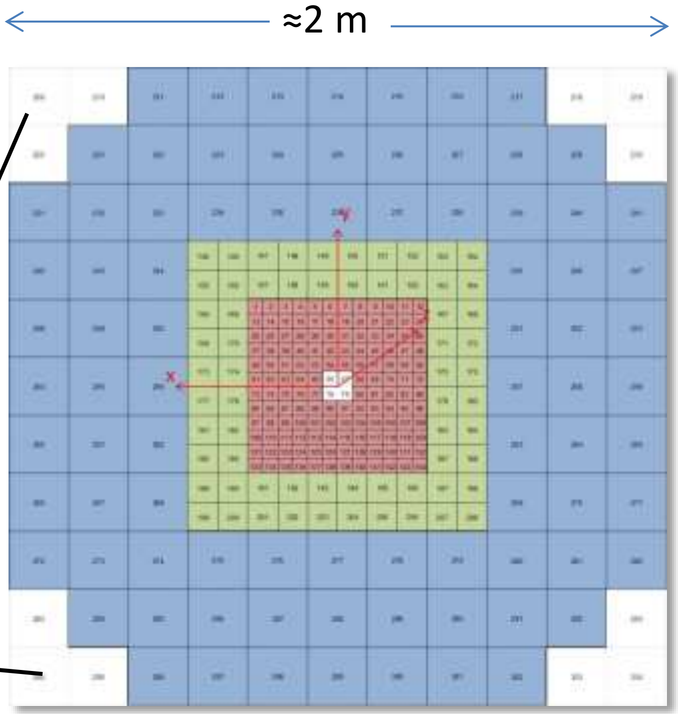
    ➔ reduce auto-correlations!

FW made of plastic scintillator tiles covering polar angles $\theta = 0.5^o - 7.5^o$ i.e. a pseudorapidity of $\eta = 2.7\ - 5.4$ (HADES itself covers $y \approx 0 - 1.8$)

➔ Used for event-plane reconstruction



cross section of 1/6 HADES sector

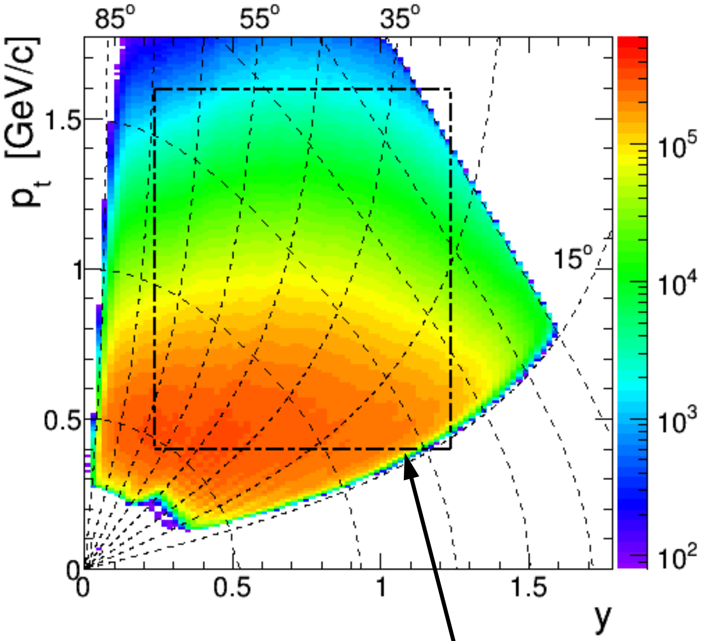


4x4, 8x8, 16x16 cm^2 tiles

Proton distributions in Au+Au at $\sqrt{s} = 2.41\ GeV$

HADES $y - p_t$ coverage for protons

$y_0 = 0.74$

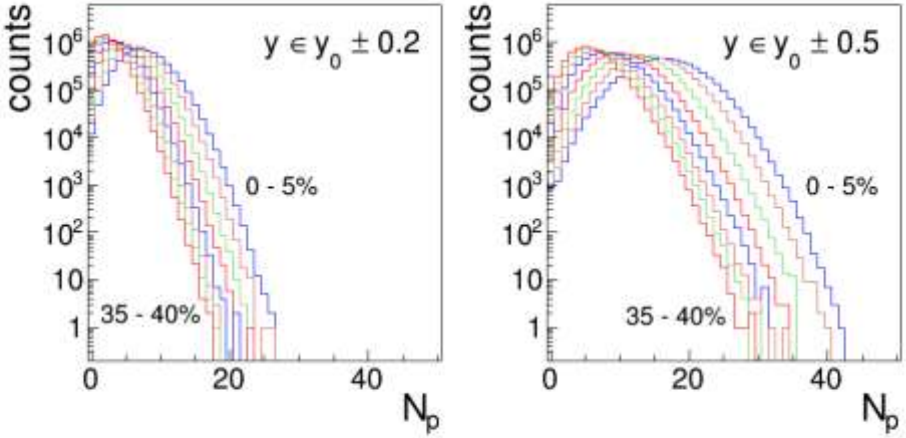


Useful acceptance for fluctuation analysis

$\mathbf{y = y_0 \pm 0.5}$

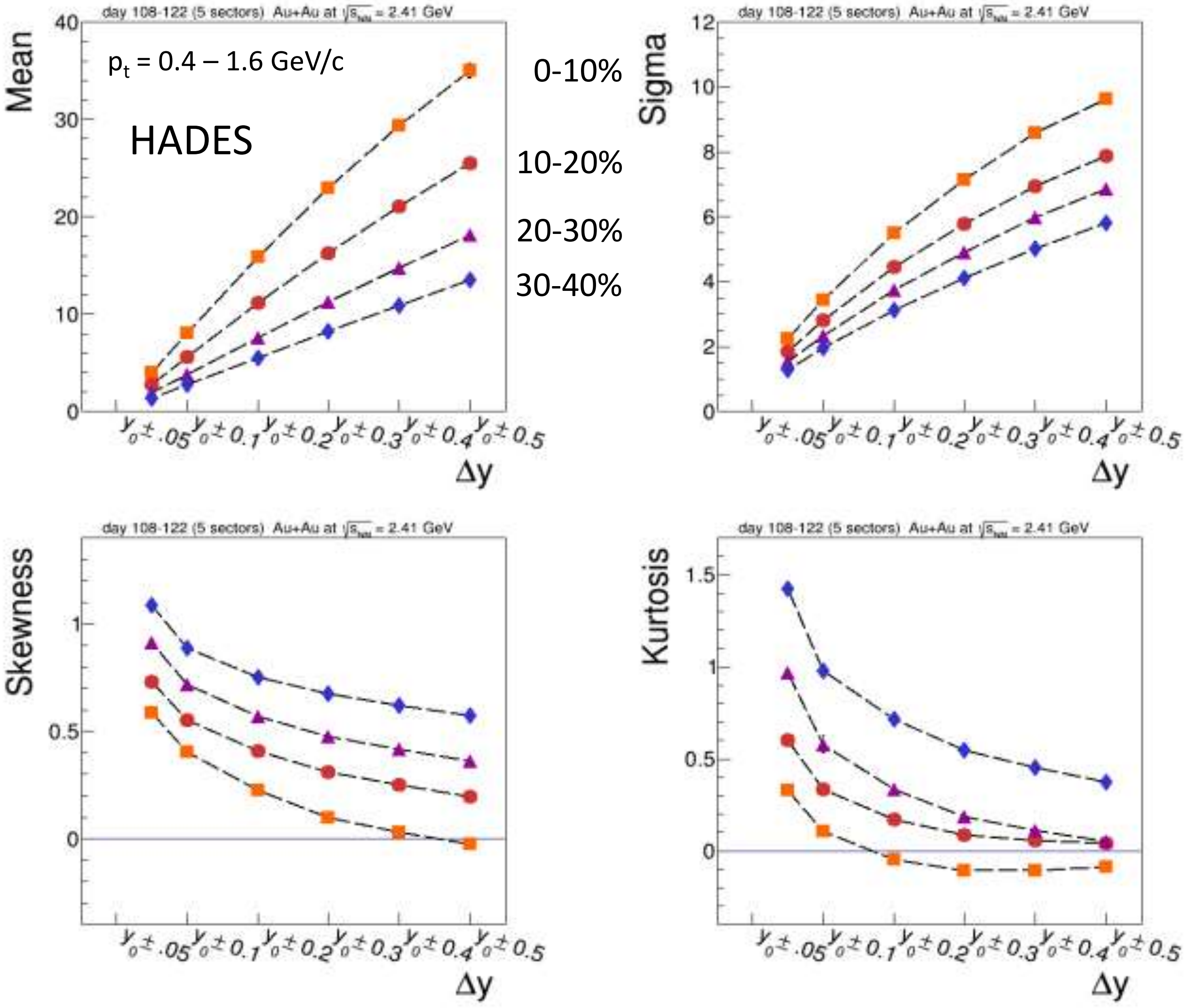
$\boldsymbol{p_t = 0.4 - 1.6}$ **GeV/c**

Proton multiplicity distributions



Analysis based on $1.6 \cdot 10^8$ Au+Au events divided into 5%-centrality bins in the range of the 0 - 40% most central events

E-by-E efficiency-corrected moments in Au+Au



From the moments
we can calculate

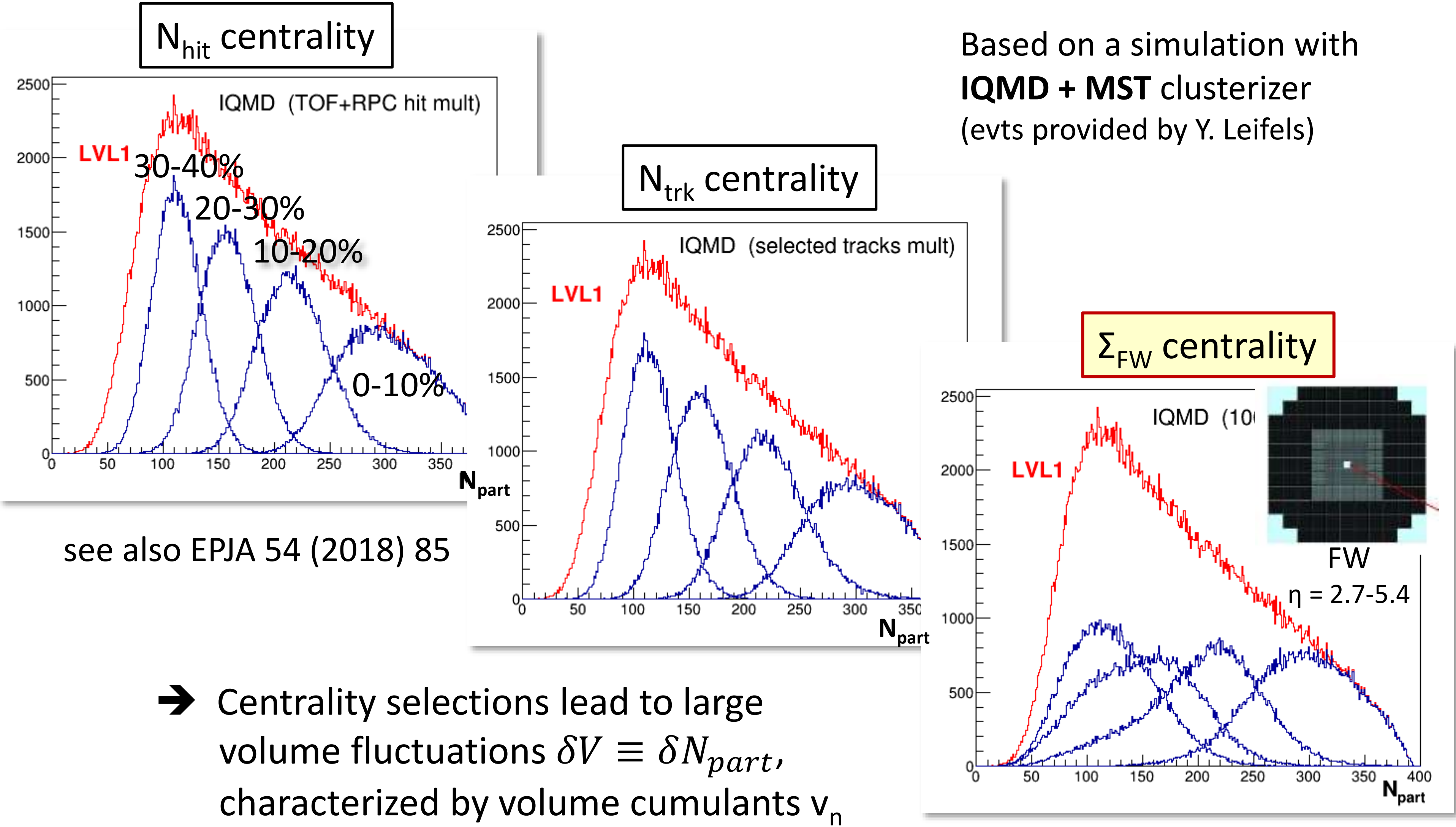
- factorial moments
- cumulants
- reduced cumulants
- factorial cumulants
- etc.

but …

… are dominated by
e-by-e variations
of the source volume!

Centrality estimators in HADES

Based on a simulation with **IQMD + MST** clusterizer
(evts provided by Y. Leifels)


N_{hit} centrality

N_{trk} centrality

Σ_{FW} centrality

see also EPJA 54 (2018) 85

➔ Centrality selections lead to large volume fluctuations $\delta V \equiv \delta N_{part}$, characterized by volume cumulants v_n

➔ We use FW for fluct. analysis

Volume fluctuation corrections (VFC)

V. Skokov, B. Friman & K. Redlich PRC 88 (2013), A. Rustamov et al. NPA 960 (2017), Sugiura, Nonaka & Esumi PRC 100 (2019), Esumi & Nonaka NIM A987 (2021)

Averaging the volume-dependent proton distribution moments

$$< N_{prot}^{n} > = \int P(V) \; \underbrace{\sum N_{prot}^{n} P\left(N_{prot} \middle| V\right)}_{< N_{prot}^{n} >_{V}} dV$$

one obtaines volume contributions to the observed reduced cumulants ***c***$_n$:

observed **true**

$$c_1 = \kappa_1 \tag{1}$$

$$c_2 = \kappa_2 + \kappa_1^2 v_2 \tag{2}$$

$$c_3 = \kappa_3 + \kappa_1^3 v_3 + 3\kappa_1 \kappa_2 v_2 \tag{3}$$

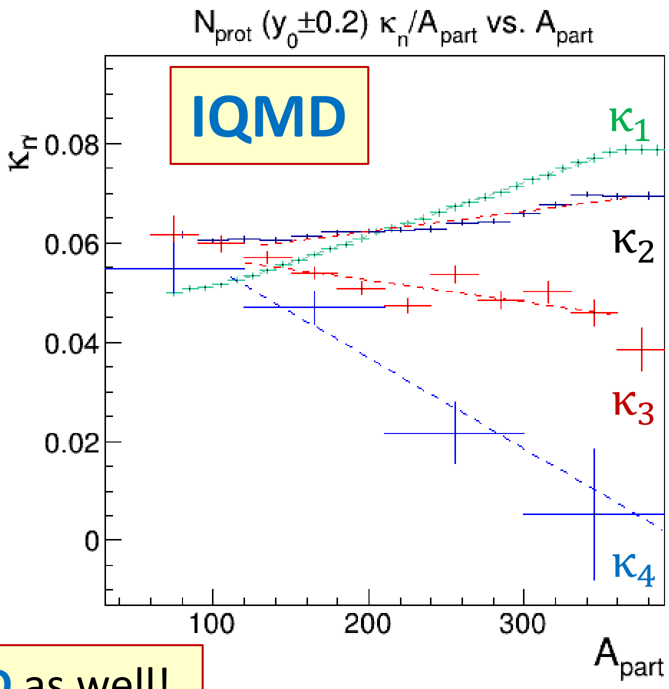
$$c_4 = \kappa_4 + \kappa_1^4 v_4 + 6\kappa_1^2 \kappa_2 v_3 + \left(4\kappa_1 \kappa_3 + 3\kappa_2^2\right) v_2 \tag{4}$$

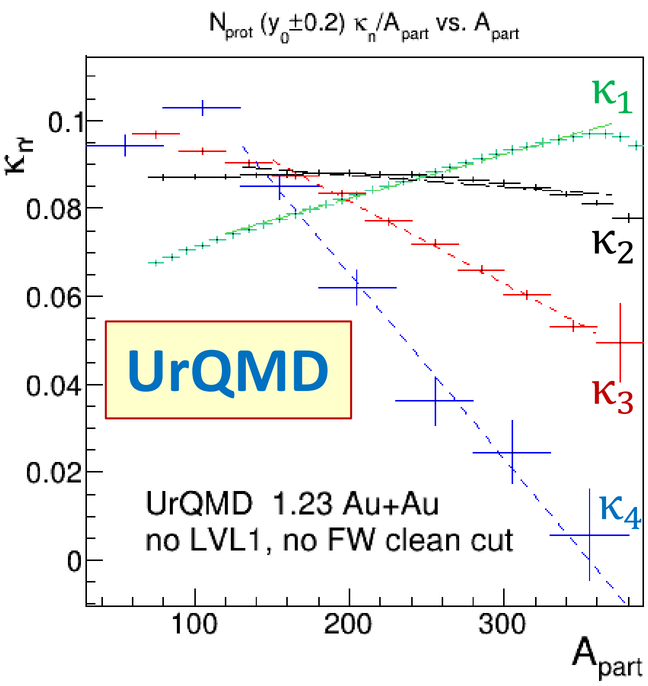
where κ_n are true reduced cumulants, c_n are observed cumulants and v_n are volume cumulants, and assuming all κ_n are constant!

Reduced proton cumulants in transport models

See also Sugiura, Nonaka & Esumi
PRC 100 (2019)

Definition: $\kappa_n = K_n/V$ with $V = A_{part}$





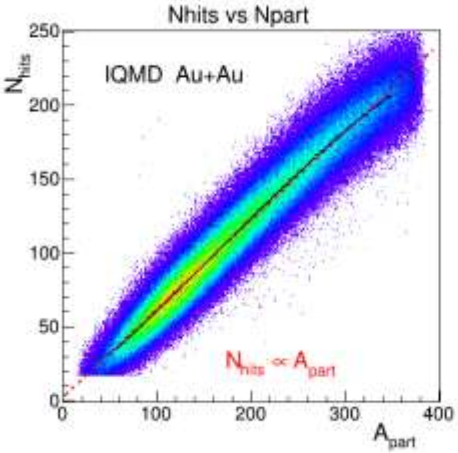
→**HSD** as well!

→ Skokov et al. assumption (κ_n = cst) is not fulfilled!

→ Extend formalism to NLO: $\kappa_n \to \kappa_n + \boldsymbol{\kappa'_n} \cdot (V - \bar{V})$
and N2LO: $\kappa_n \to \kappa_n + \boldsymbol{\kappa'_n} \cdot (V - \bar{V}) + \boldsymbol{\kappa''_n}\,(V - \bar{V})^2$

details given in Adamczewski-Musch et al. PRC 102 (2020)

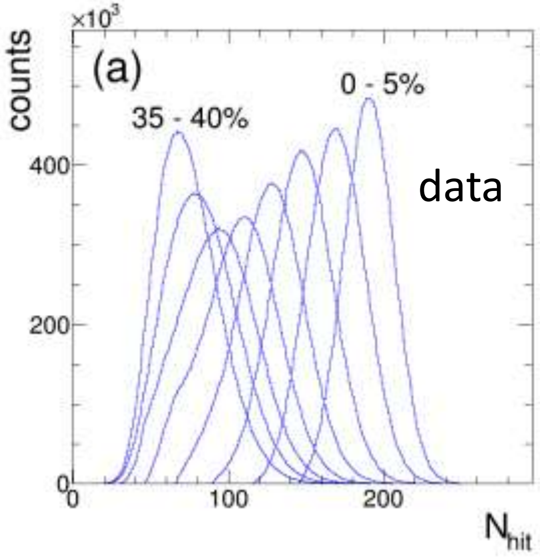
Ad-hoc approach: N_{hit} as a proxy for N_{part}



IQMD simulation shows that N_{hit} is proportional to N_{part}

→ use N_{hit} as proxy for vol. flucs.
i.e. rescale & adjust the $\boldsymbol{v_n}$

Observed N_{hit} distributions (selected on FW)

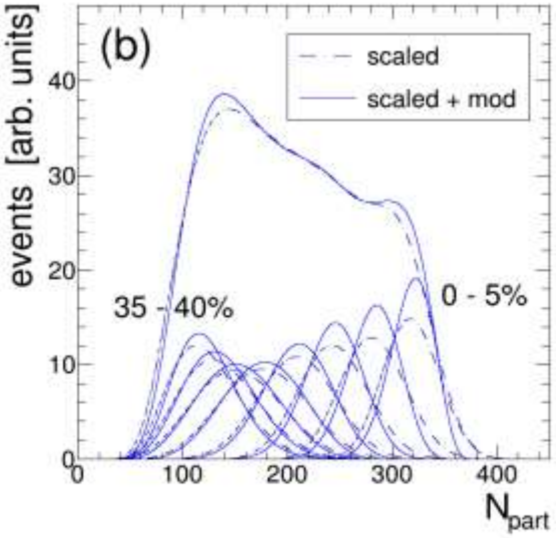


fit IQMD cumulants to adjust scaled $\boldsymbol{v_n}$

morph N_{hit} into N_{part}

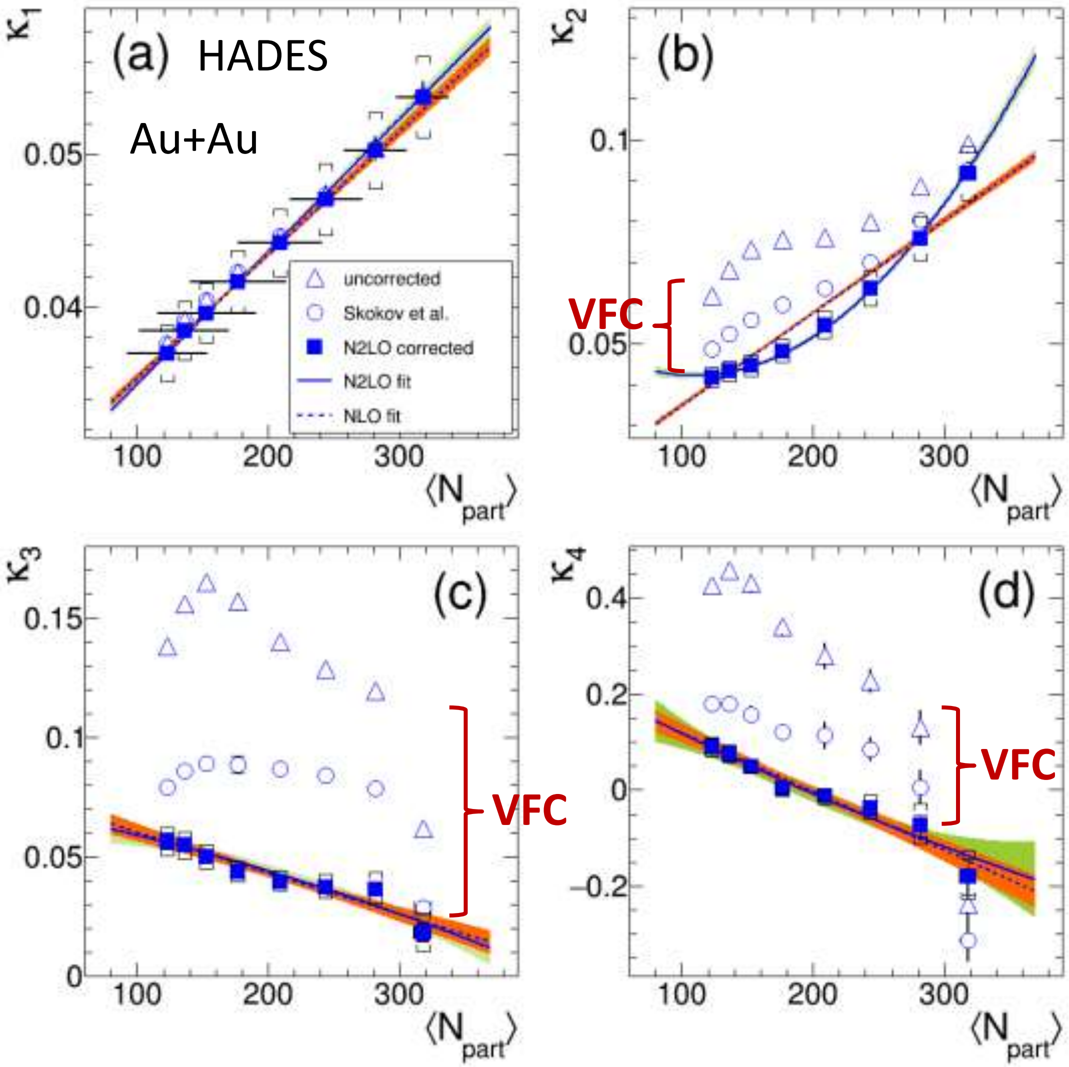
PRC 102 (2020) 024914

Reconstructed N_{part} distributions



Reduced proton cumulants in Au+Au data: $y = y_0 \pm 0.2$

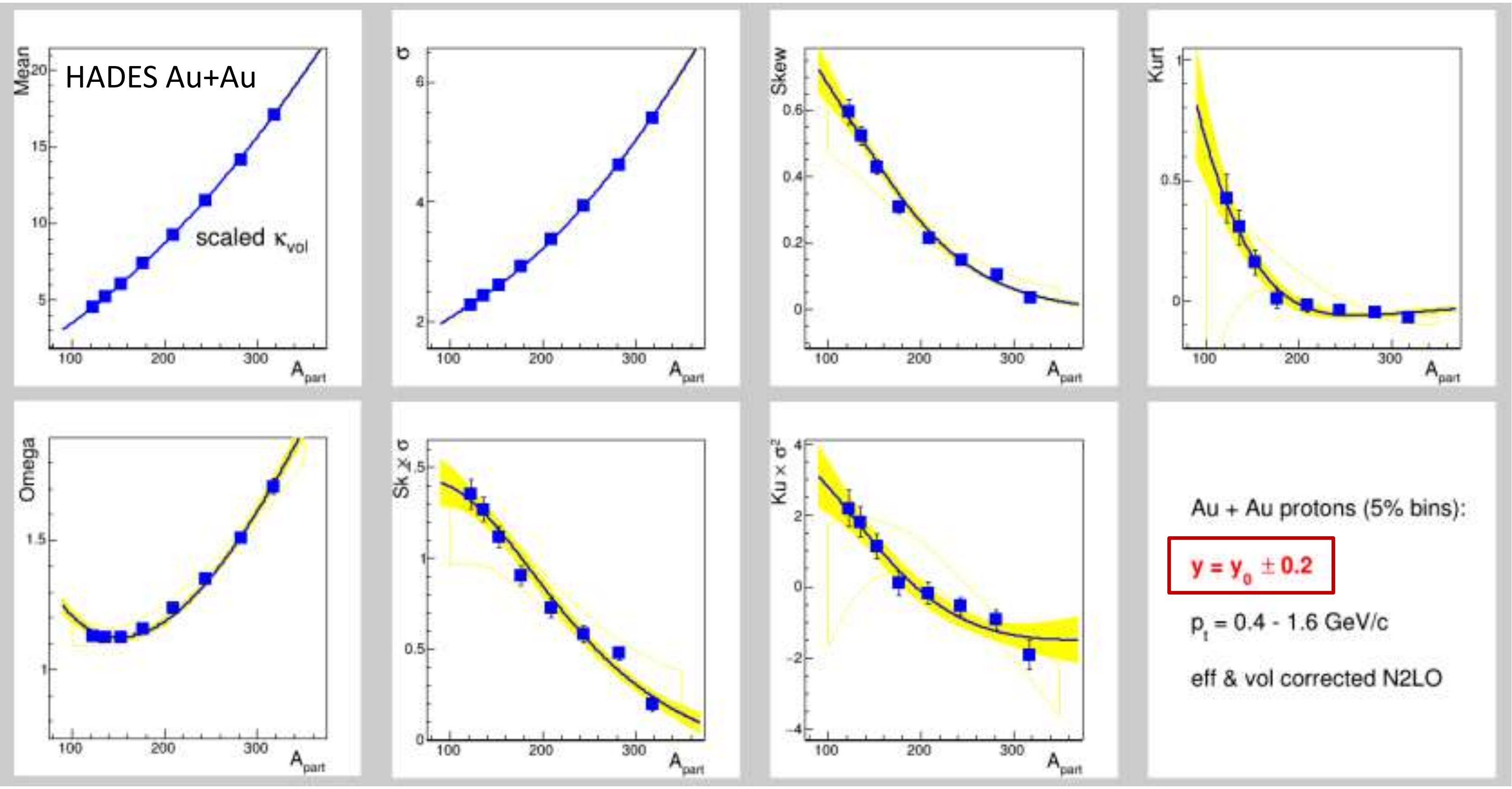
effect of volume fluctuation corrections



- Vol. fluct. Corr. (**VFC**) are important!
- NLO terms are needed!
- Eventually, also N2LO terms

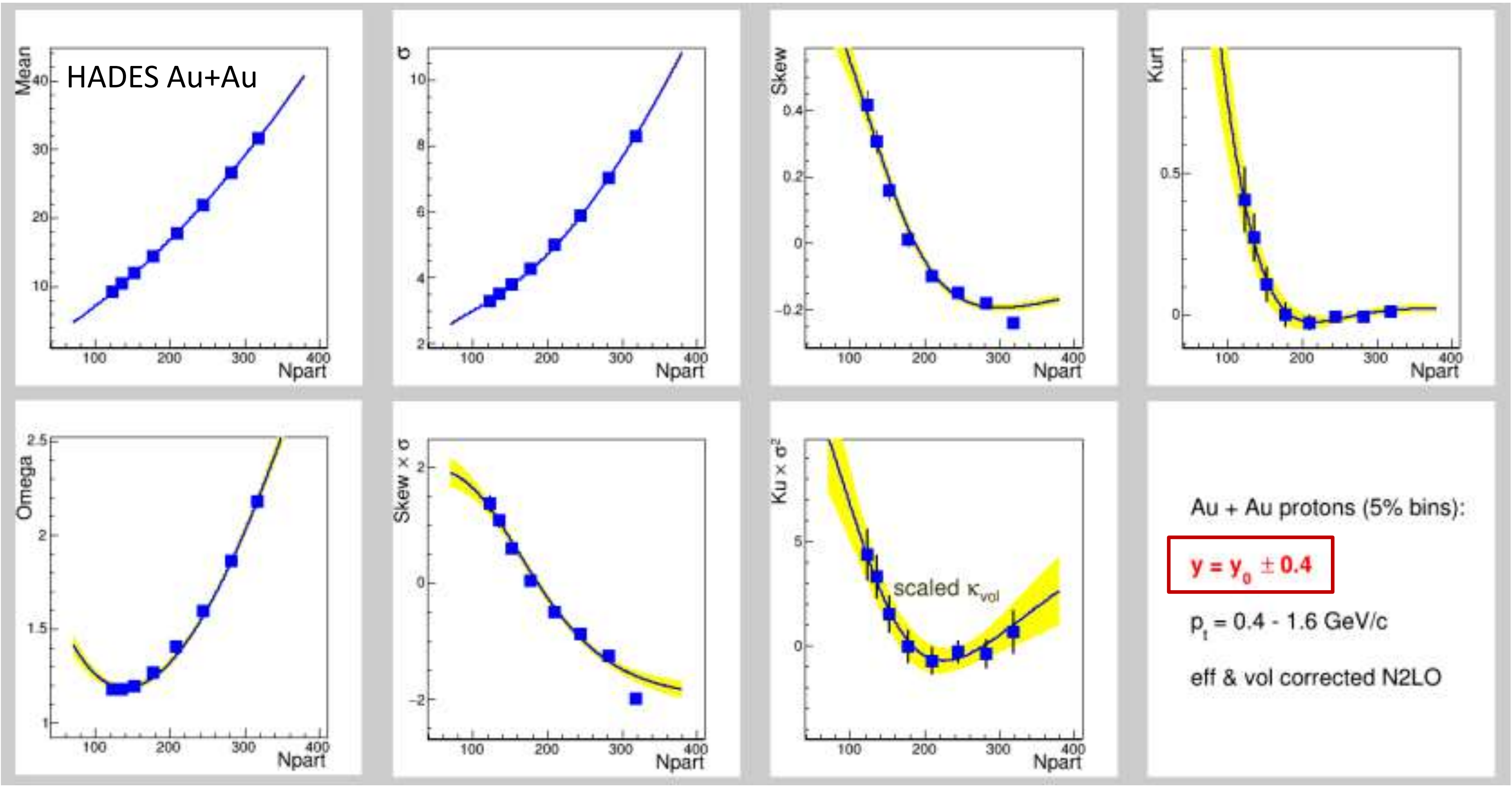
Volume correction of proton nb. moments:

IQMD scaled & adjusted N_{hit} κ_{vol}



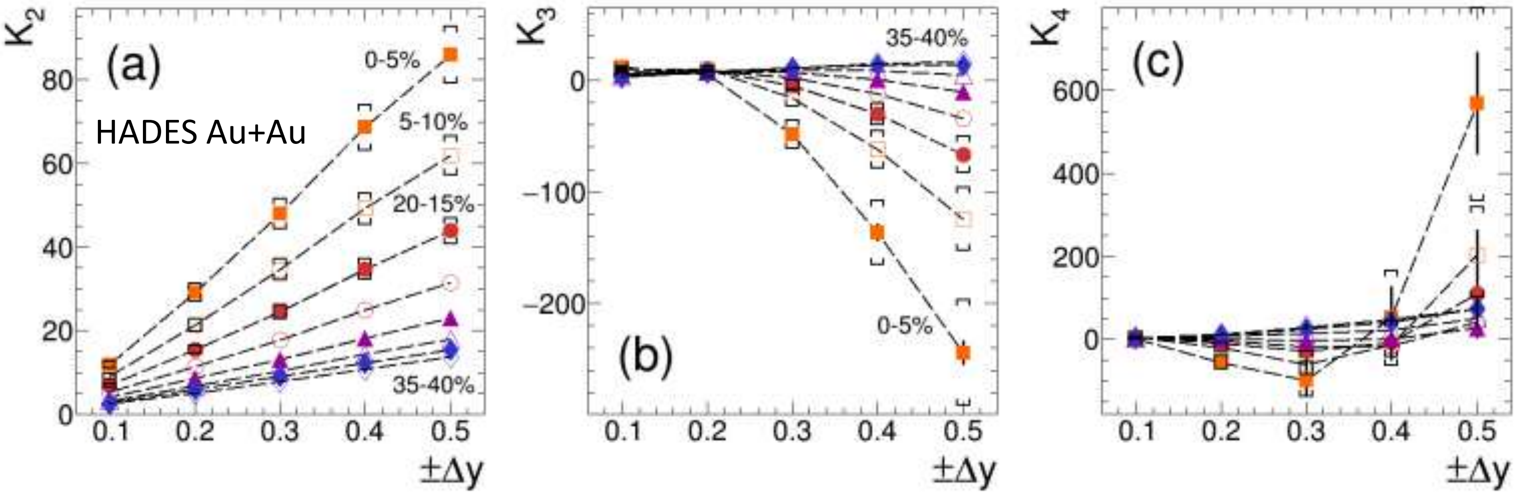
HADES, PRC 102 (2020)

Volume correction of proton nb. moments: IQMD scaled & adjusted N_{hit} κ_{vol}

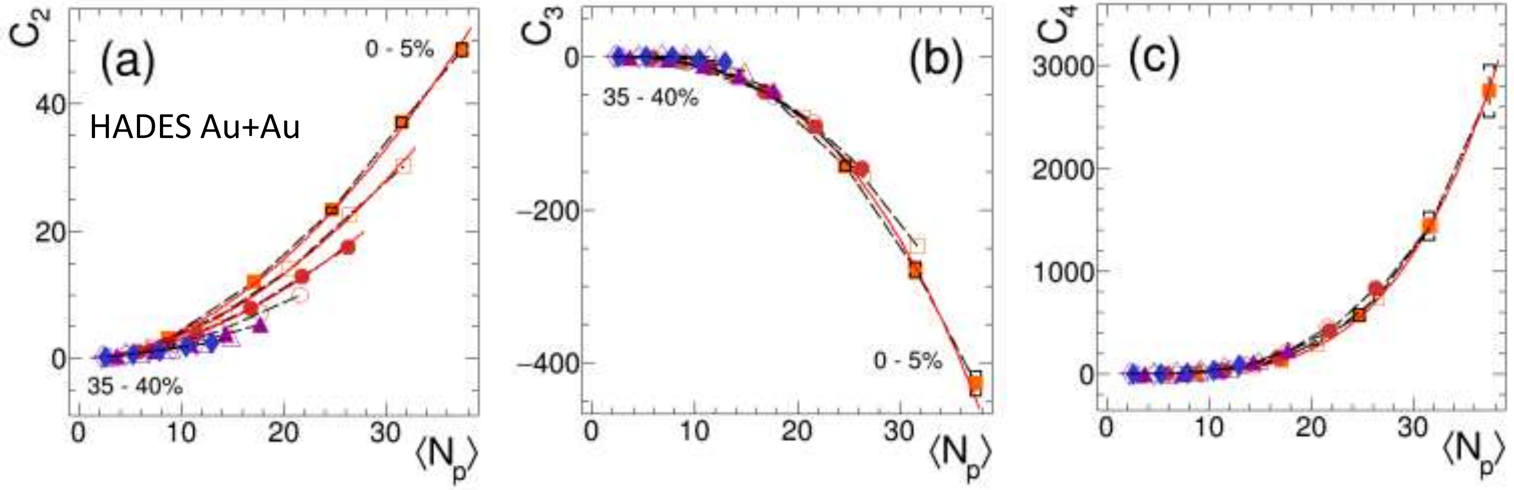


HADES, PRC 102 (2020)

Au+Au data: N2LO corrected cumulants & correlators



eff. & vol.
corrected
proton-nb
cumulants



correlators
a.k.a factorial
cumulants

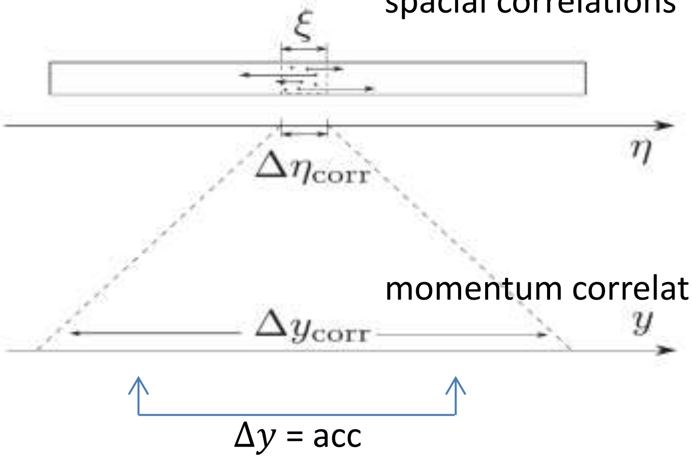
<N> scaling of volume-corrected correlators C_k

B. Ling & M. Stephanov PRC 93 (2016)

consider two extreme scenarios:

(1) $\Delta y_{\mathrm{corr}} \ll \Delta y \quad \rightarrow \quad C_n \propto \Delta y$

(2) $\Delta y_{corr} \gg \Delta y \quad \rightarrow \quad C_n \propto (\Delta y)^n$

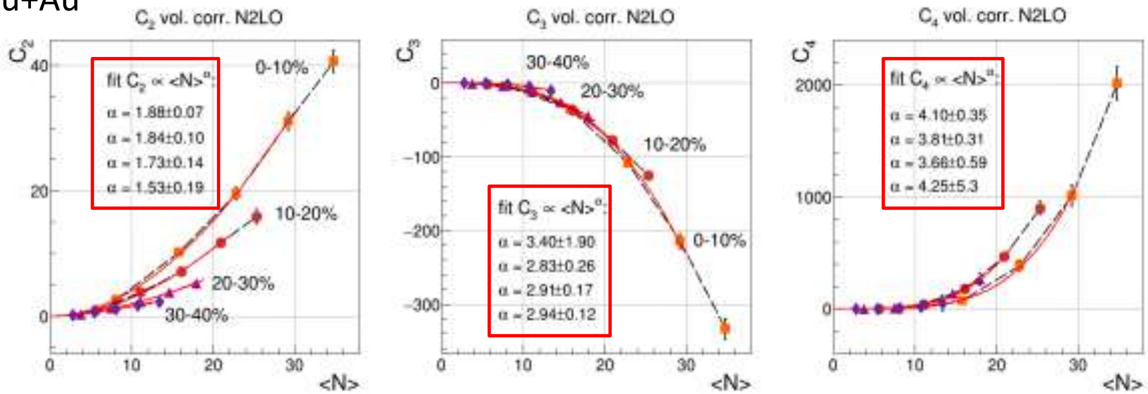


spacial correlations

momentum correlations

Δy = acc

HADES Au+Au

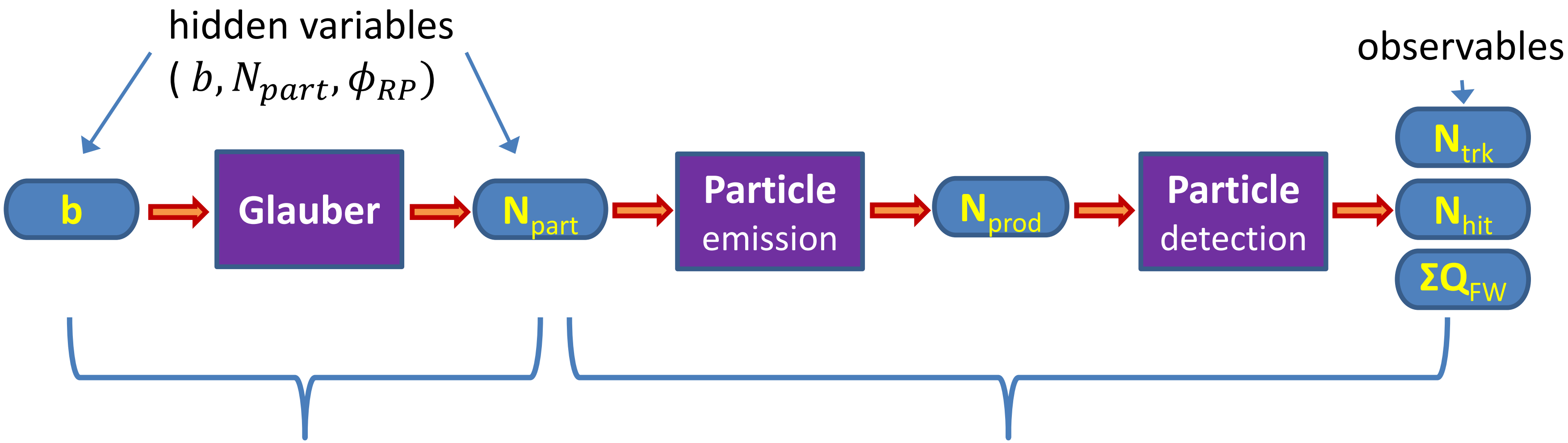


HADES Au+Au

10% centrality bins

➔ observed scaling favors long-range correlations $(\Delta y_{corr} > 1)$

Alternative N_{hit} → N_{part} transformations based on a Glauber Monte Carlo



hidden variables

(b, N_{part}, ϕ_{RP})

observables

b → **Glauber** → **N_{part}** → **Particle emission** → **N_{prod}** → **Particle detection** → **N_{trk}**, **N_{hit}**, **ΣQ_{FW}**

A minimal model:

b → **Glauber MC** → **N_{part}** → **Generic randomizer** → **N_{hit}**

e.g. Poisson(λN_{part}) x ($1 - \alpha N^2_{part}$)

→ compute the $\kappa(N_{part})$ from the $\kappa(N_{hit})$ and expand N_{part}

→ do a Bayesian reconstruction of the N_{part} distribution

True Poissonian process: N_{hit} = Poisson(λN_{part})

Applying **total cumulance** to
$X = N_{hit}$ = Poisson($X|_{Z=N_{part}}$)
we obtain an analytic relation between the cumulants of N_{hit} and N_{part}:

$$\kappa_n[N_{hit}] = \sum_{i=1}^{n} \lambda^i \, S_2(n,i) \, \kappa_i[N_{part}] \qquad (1)$$

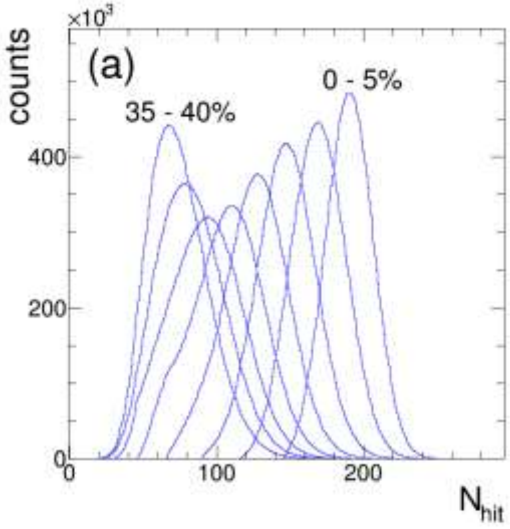
See also
Broniowski & Olszewski, PRC95 (2017)

With the inverse:

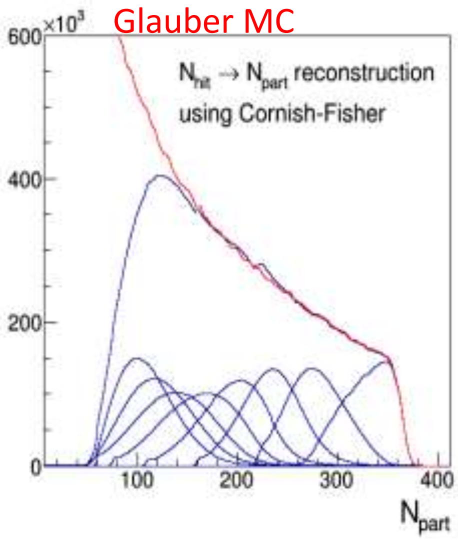
$$\kappa_n[N_{part}] = \sum_{i=1}^{n} \lambda^{-i} \, S_1(n,i) \, \kappa_i[N_{hit}] \qquad (2)$$

where S_1 and S_2 are Stirling numbers

Observed Au+Au N_{hit} distributions



Poisson

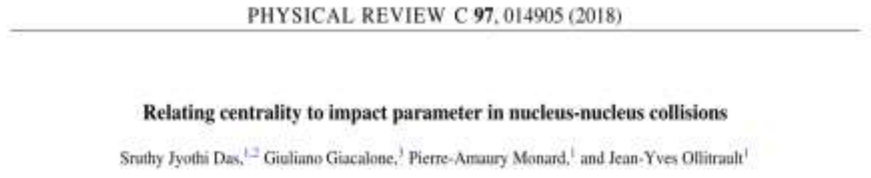

Glauber MC

N_{hit} → N_{part} transformation using total cumulance

+

Cornish-Fisher expansion of the N_{part} distributions

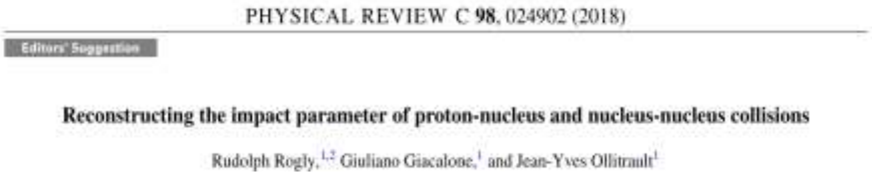
Bayesian reconstruction of centrality



PHYSICAL REVIEW C **97**, 014905 (2018)

Relating centrality to impact parameter in nucleus-nucleus collisions

Sruthy Jyothi Das,[1,2] Giuliano Giacalone,[1] Pierre-Amaury Monard,[1] and Jean-Yves Ollitrault[1]



PHYSICAL REVIEW C **98**, 024902 (2018)

Editors' Suggestion

Reconstructing the impact parameter of proton-nucleus and nucleus-nucleus collisions

Rudolph Rogly,[1,2] Giuliano Giacalone,[1] and Jean-Yves Ollitrault[1]

Ollitrault et al.

- validated with simulations and applied to LHC data

PHYSICAL REVIEW C **104**, 034609 (2021)

Model independent reconstruction of impact parameter distributions for intermediate energy heavy ion collisions

J. D. Frankland,[1,*] D. Gruyer,[2] E. Bonnet,[3] B. Borderie,[4] R. Bougault,[2] A. Chbihi,[1] J. E. Ducret,[1] D. Durand,[2] Q. Fable,[2] M. Henri,[1] J. Lemarié,[1] N. Le Neindre,[2] I. Lombardo,[5] O. Lopez,[2] L. Manduci,[2,6] M. Pârlog,[2,7] J. Quicray,[2] G. Verde,[5,8] E. Vient,[2] and M. Vigilante[9]
(INDRA Collaboration)

INDRA collab.

- validated with low-energy GANIL data $E_{beam} < 100$ MeV/u

Apply Bayes' theorem →

$$\boxed{P(B|A) = P(A|B)\,P(B)/P(A)}$$

Setting $A = N_{hit}$, $B = N_{part}$ with

$P(B|A)$ ↔ prob of N_{part} for given N_{hit} ← to be reconstructed
$P(A|B)$ ↔ prob of N_{hit} for given N_{part} ← Glauber fit to N_{hit} data
$P(A)$ ↔ min bias N_{hit} distribution ← data
$P(B)$ ↔ min bias N_{part} distribution ← Glauber

minimal model (Glauber MC)

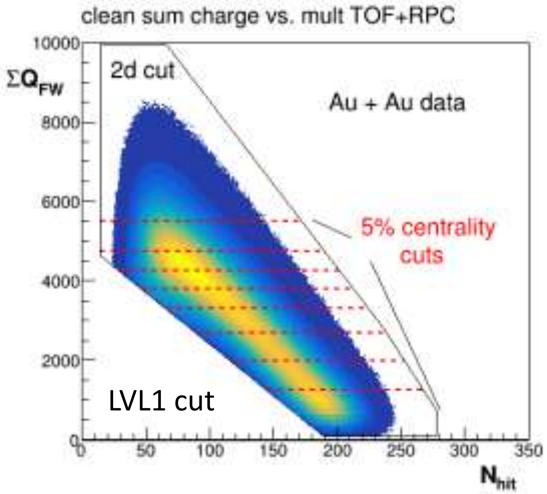
Glauber-based Monte Carlo of Au+Au data

for details, see HADES centrality paper EPJA 54 (2018)

HADES data with 5% centrality cuts on FW signal

Au+Au data

- LVL1 trigger
- cleaning cuts



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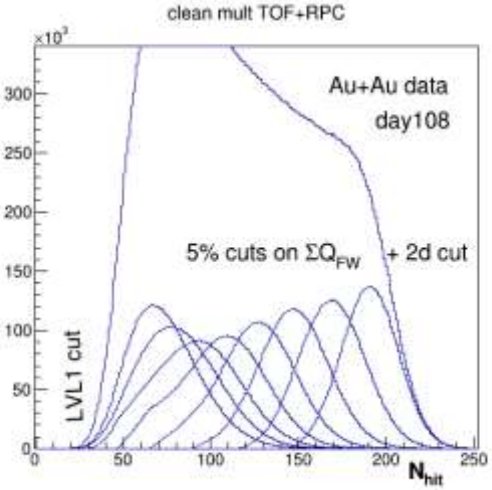
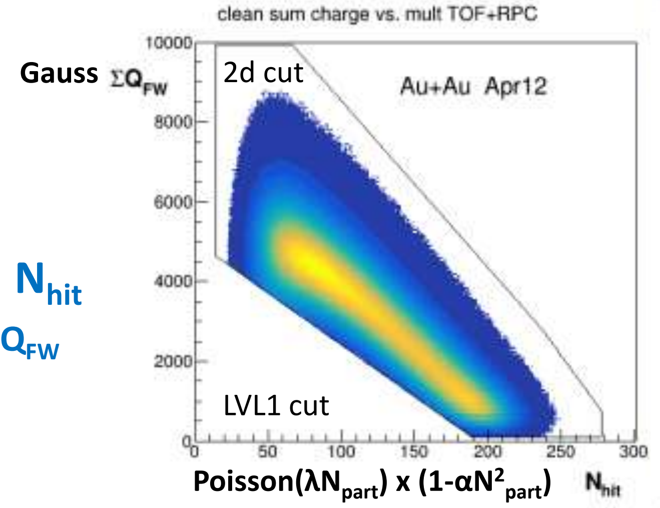
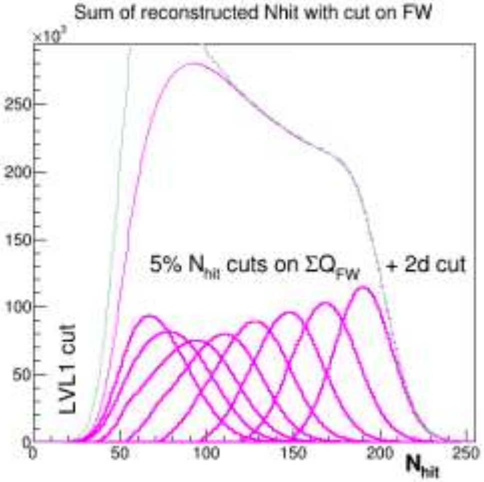


Monte Carlo

- Glauber
- Poissonian $\mathbf{N_{hit}}$
- Gaussian $\mathbf{\Sigma Q_{FW}}$



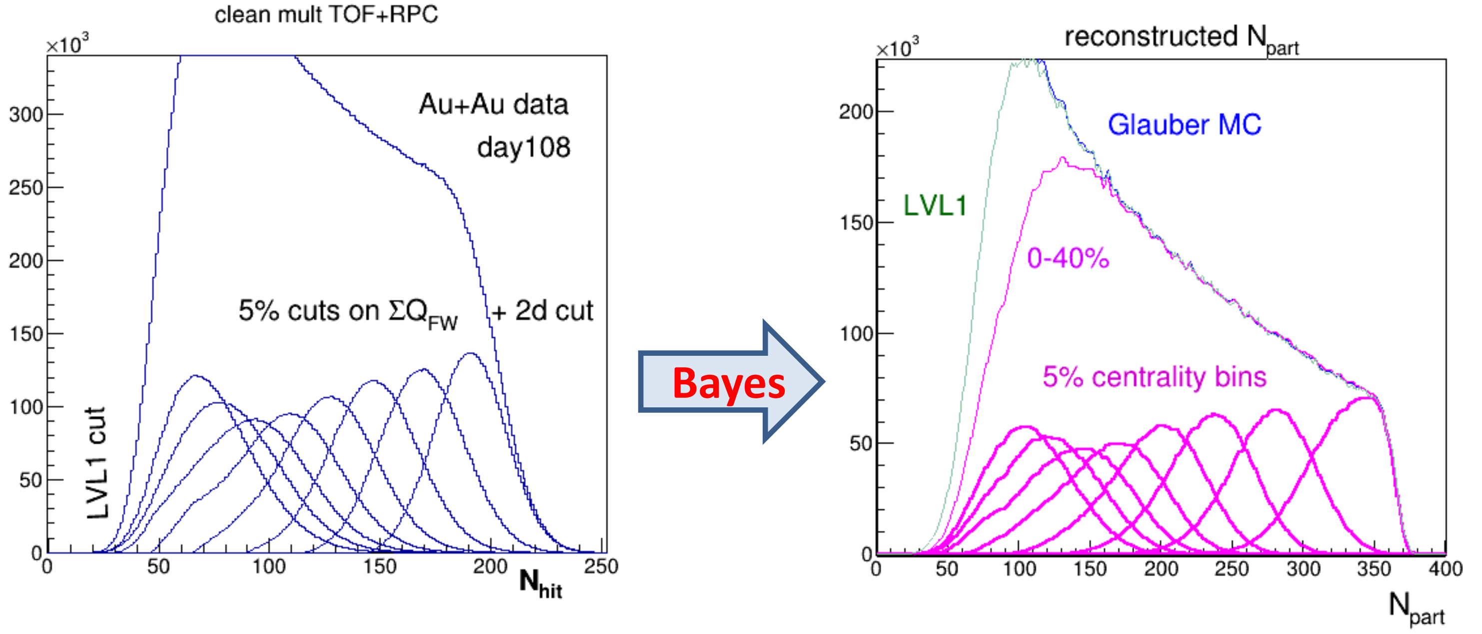
➔



Bayesian reconstruction of centrality

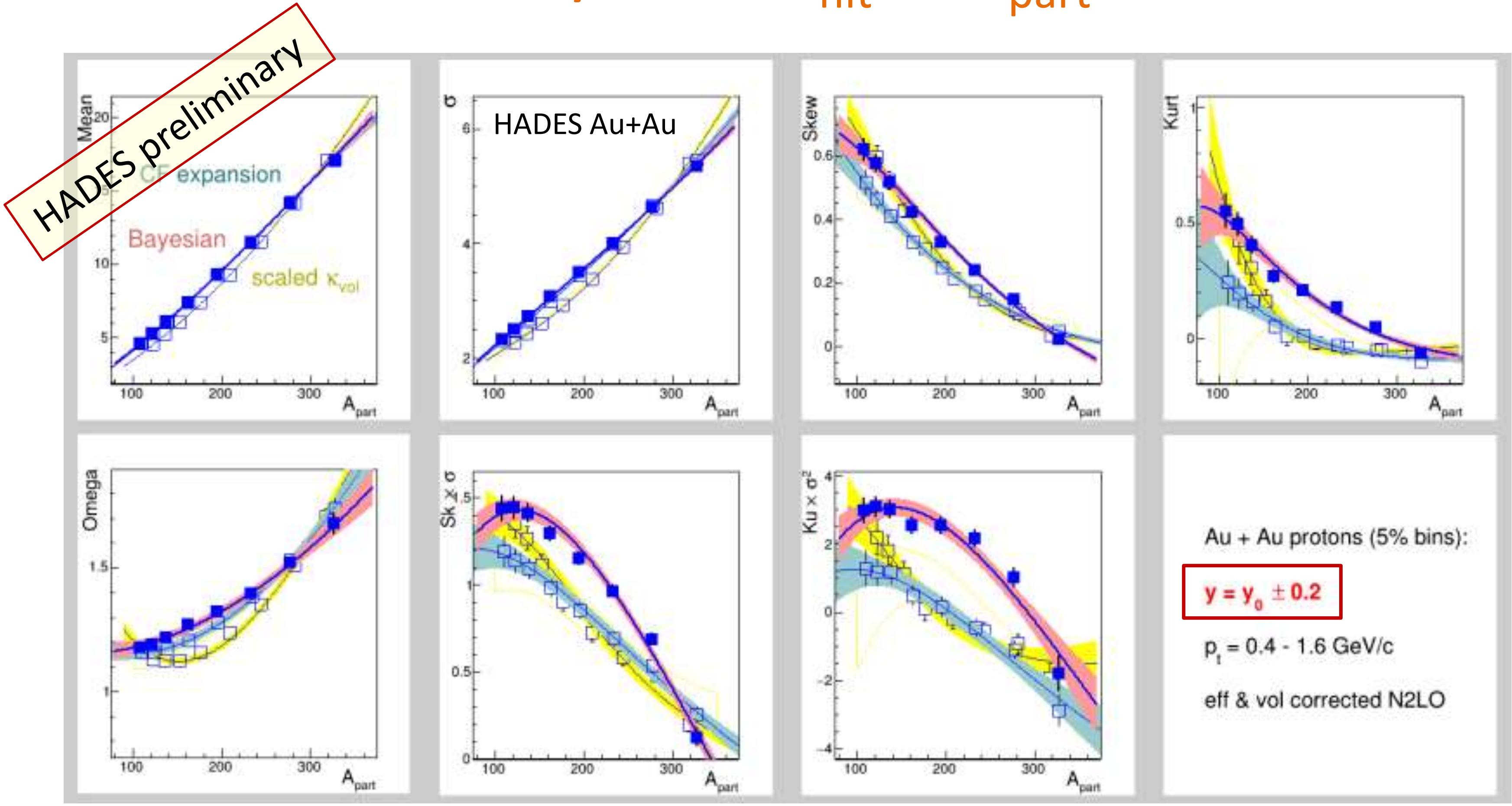
For the N_{hit} → N_{part} reconstruction we follow Frankland et al. PRC 104 (2021):

$$P(N_{part}|FW_c) = \frac{\sum_{N_{hit}} P(N_{hit}|N_{part})\, P(N_{part})\, w(FW_c \,\&\, LVL1 \,\&\, 2D)}{\sum_{N_{hit}} P(N_{hit}|FW_c)}$$



Volume correction of proton nb. moments:

Bayesian $N_{hit} \rightarrow N_{part}$

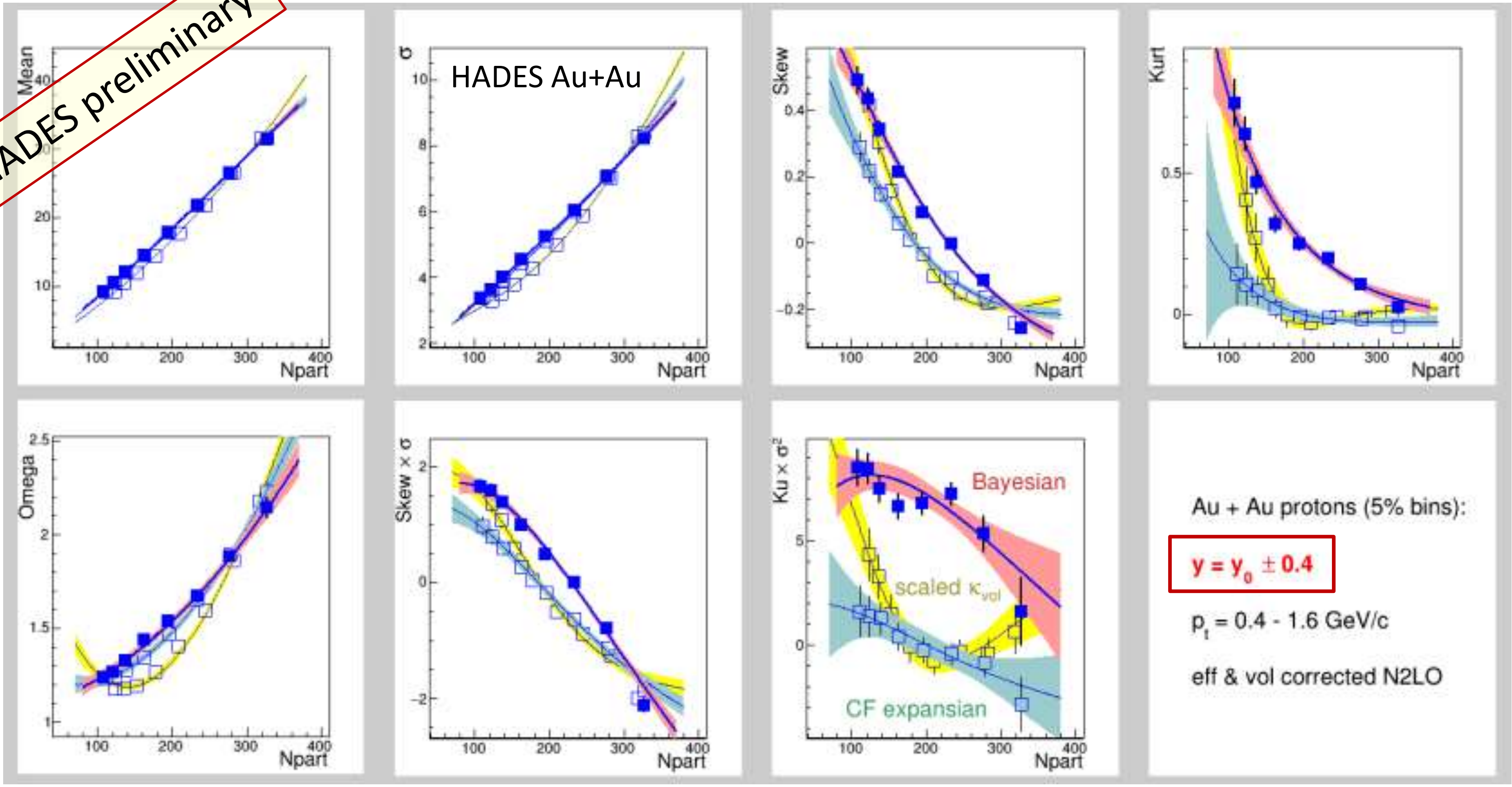


HADES re-analysis November 2021

Volume correction of proton nb. moments:

Bayesian $N_{hit} \rightarrow N_{part}$

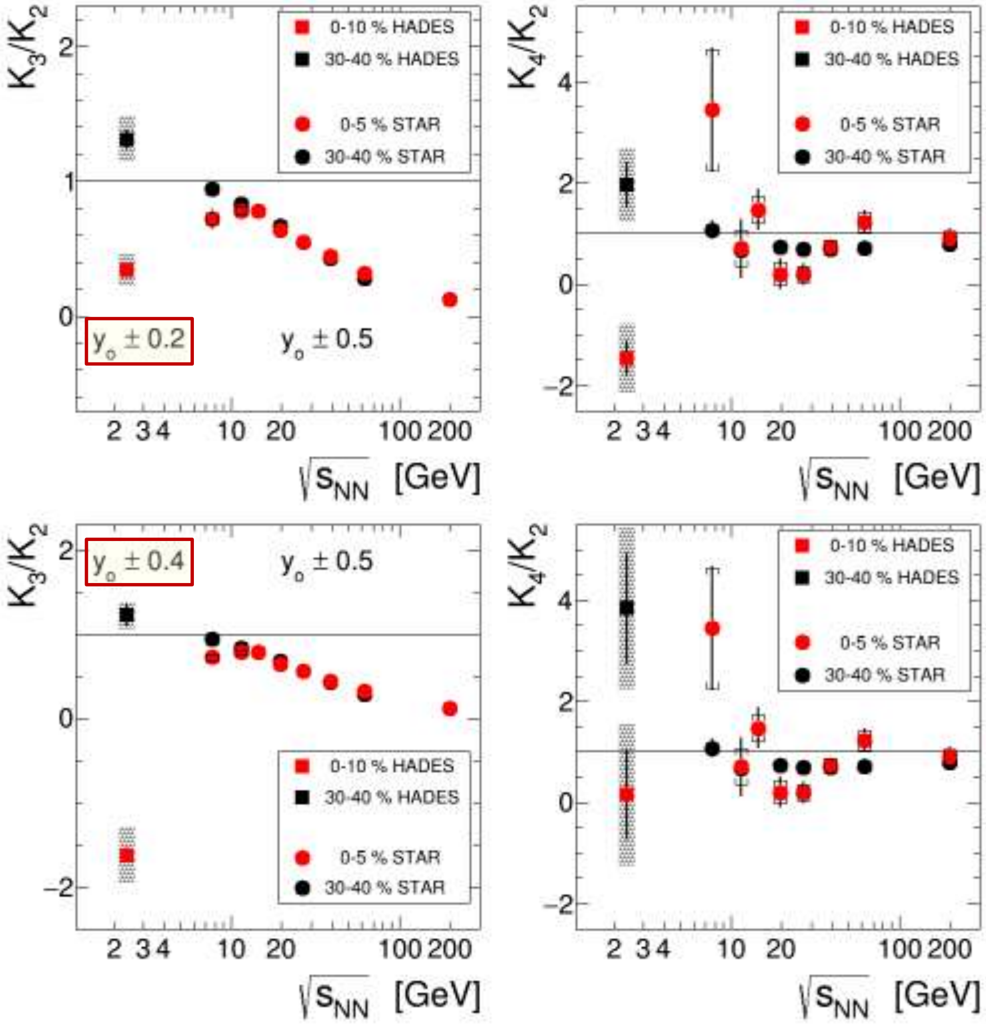
HADES preliminary



HADES re-analysis November 2021

HADES vs STAR: status of 2020

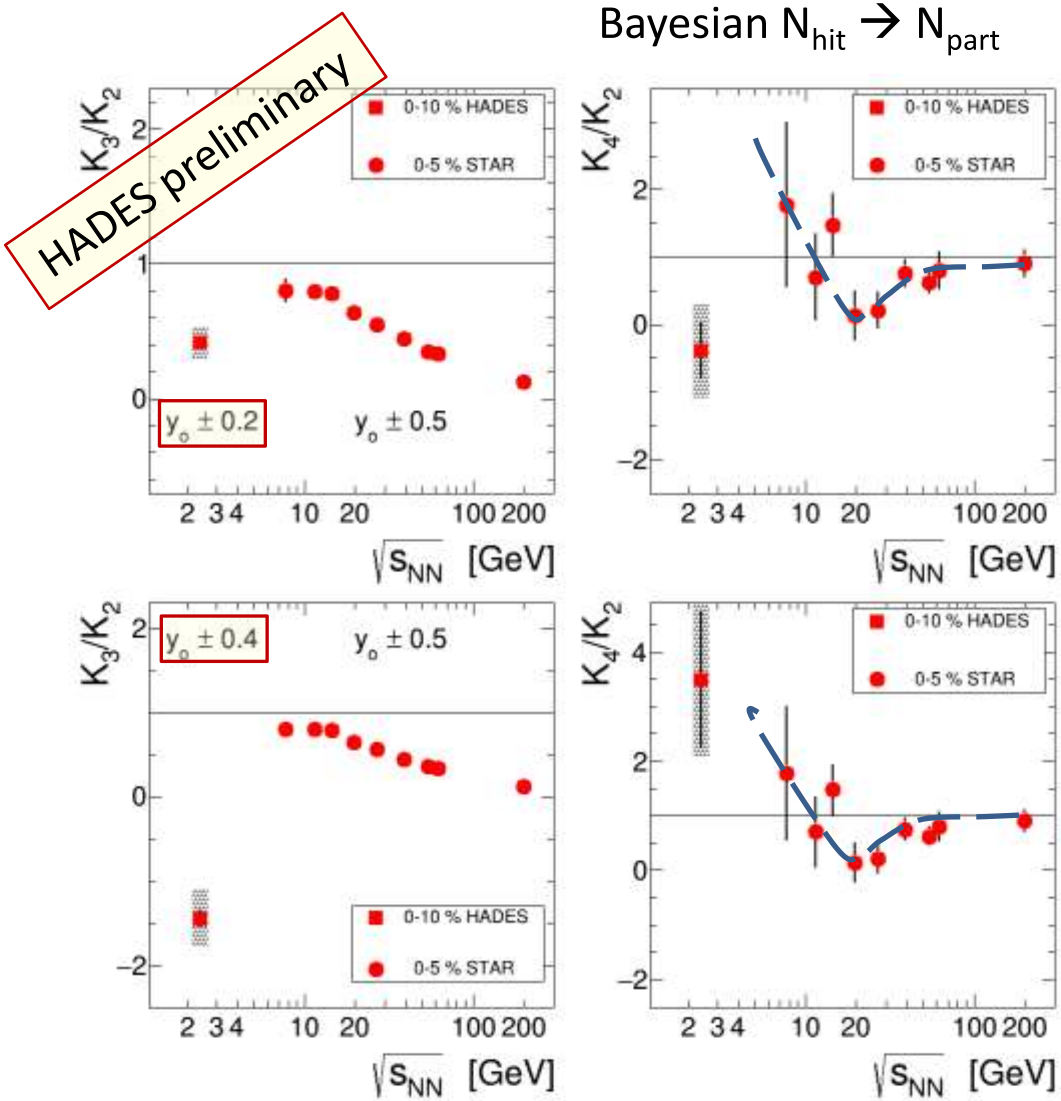
IQMD rescaled N_{hit} (used in HADES PRC 102 paper)



Note that STAR updated their data in 2021!
→ PRL & PRC 104

Comparison with STAR 2021

Bayesian N_{hit} → N_{part}

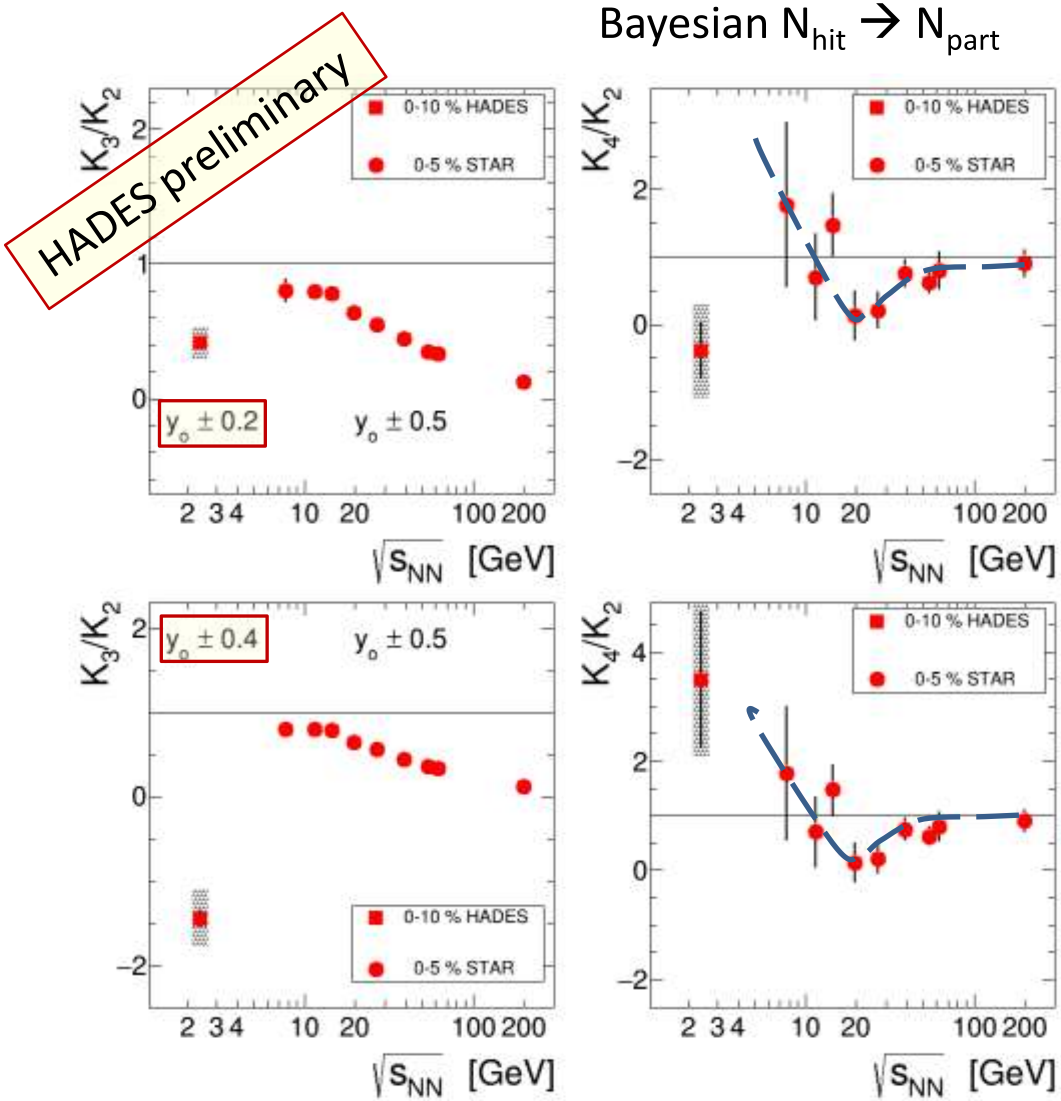


STAR sees a „non-monotonic“ trend of K_4/K_2 with N_{part} which they interpret as a sign of possible critical behavior

PRL (2021), PRC 104 (2021)

Comparison with STAR 2021

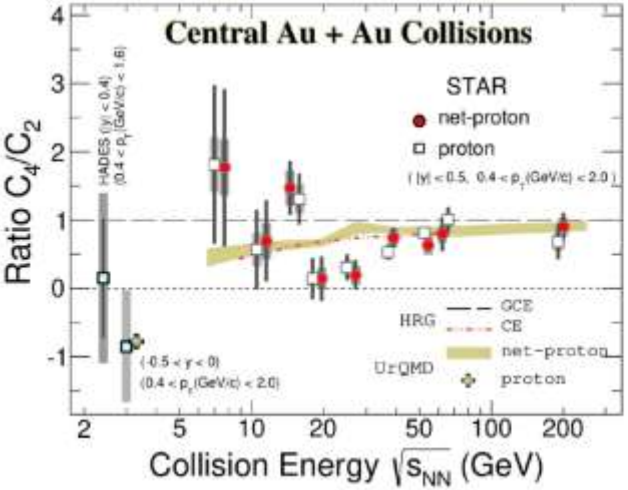
Bayesian N_{hit} → N_{part}



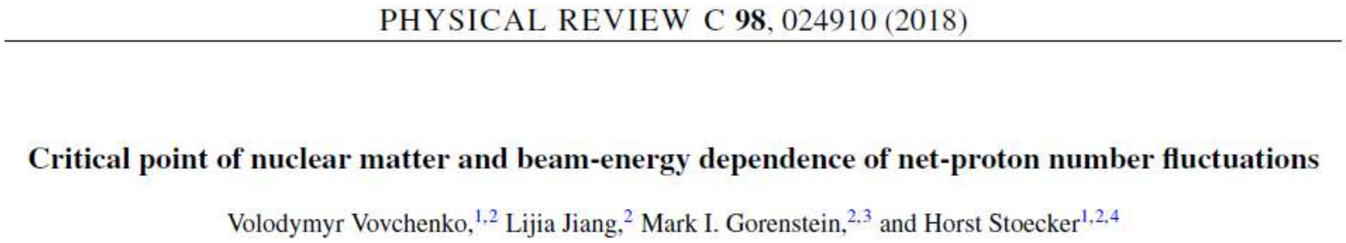
STAR sees a „non-monotonic“ trend of K_4/K_2 with N_{part} which they interpret as a sign of possible critical behavior

PRL (2021), PRC 104 (2021)

STAR 3 GeV result:



Hadron Resonance Gas + van der Waals forces



PHYSICAL REVIEW C **98**, 024910 (2018)

Critical point of nuclear matter and beam-energy dependence of net-proton number fluctuations

Volodymyr Vovchenko,[1,2] Lijia Jiang,[2] Mark I. Gorenstein,[2,3] and Horst Stoecker[1,2,4]

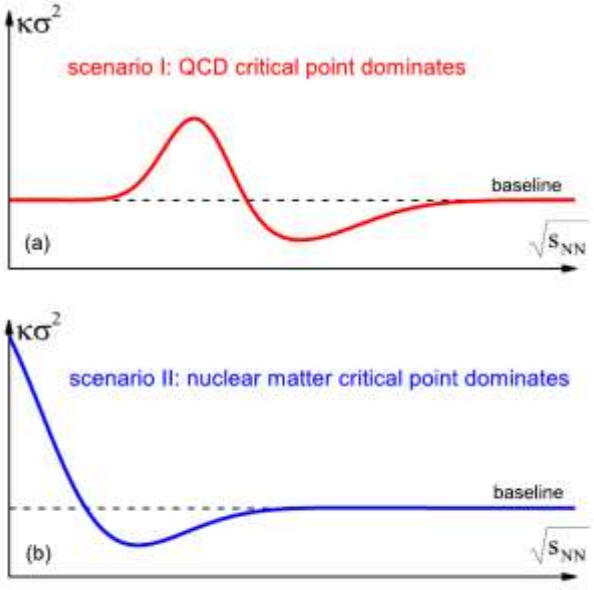
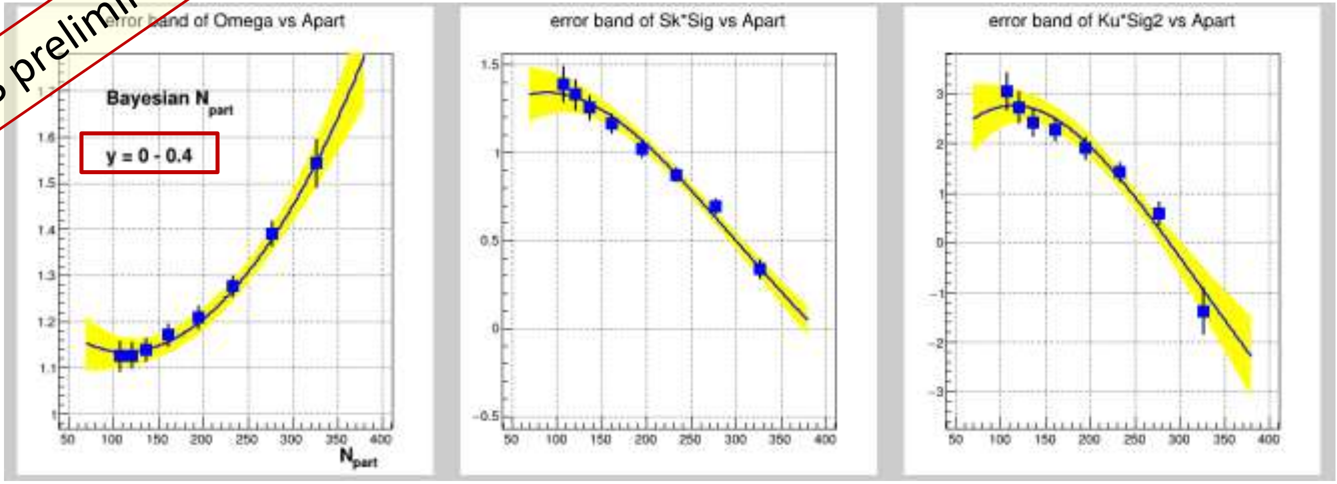


Fig. 3

Proton cumulants: forward vs backward rapidities

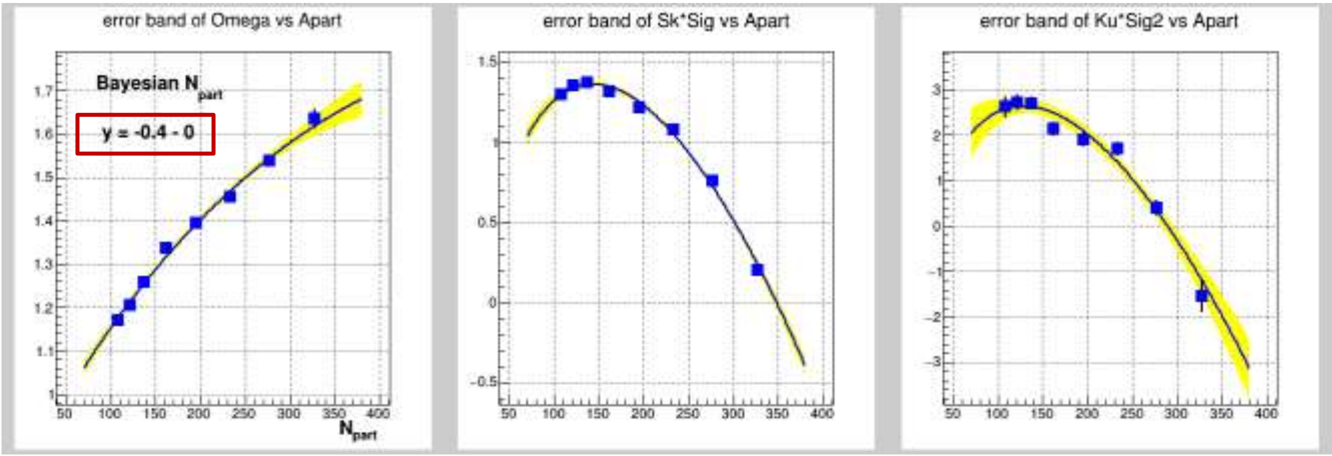
Bayesian $N_{hit} \rightarrow N_{part}$

HADES preliminary



HADES Au+Au

forward rapidities



HADES Au+Au

backward rapidities

HADES re-analysis November 2021

→ **Systematics!**

Summary and Outlook:

- Analyzed proton number fluctuations with HADES in 1.23 AGeV Au+Au collisions

- Applied full (N2LO) volume corrections to observed proton cumulants using different $N_{hit} \rightarrow N_{part}$ transforms

- Found indications for strong long-range correlations (>1 in rapidity)

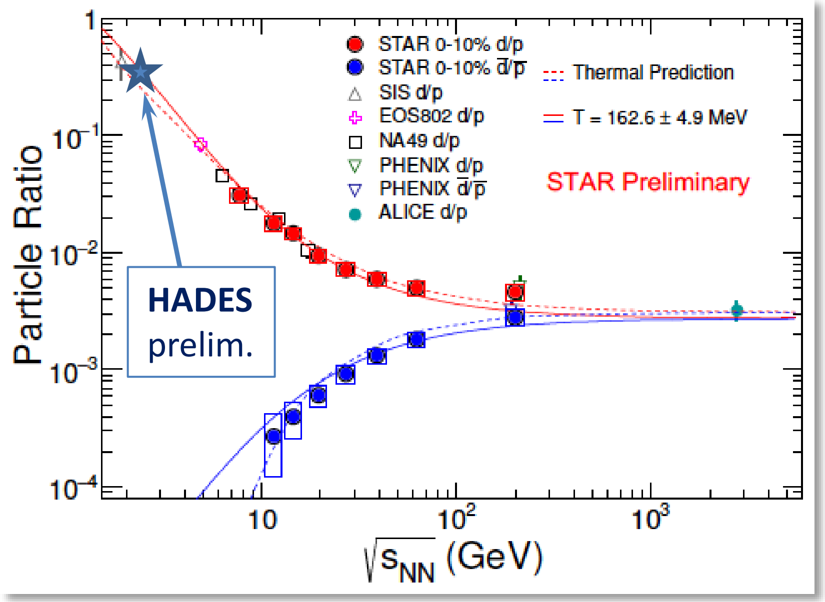
→ absolutely need to control volume corrections!
→ remnant effects of liquid-gas phase transition?
→ bound vs free protons?

→ very high-statistics Ag+Ag data are available for analysis
→ beam-energy scan <1 AGeV (SIS18) & >2 AGeV (SIS100)

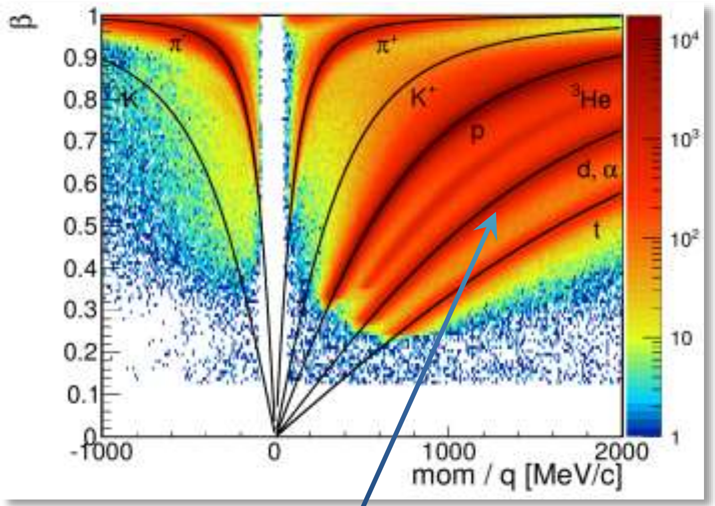
Extra slides

How do bound protons contribute?

Systematics of d/p from STAR collaboration (QM2017)



HADES 1.23 GeV/u Au+Au data



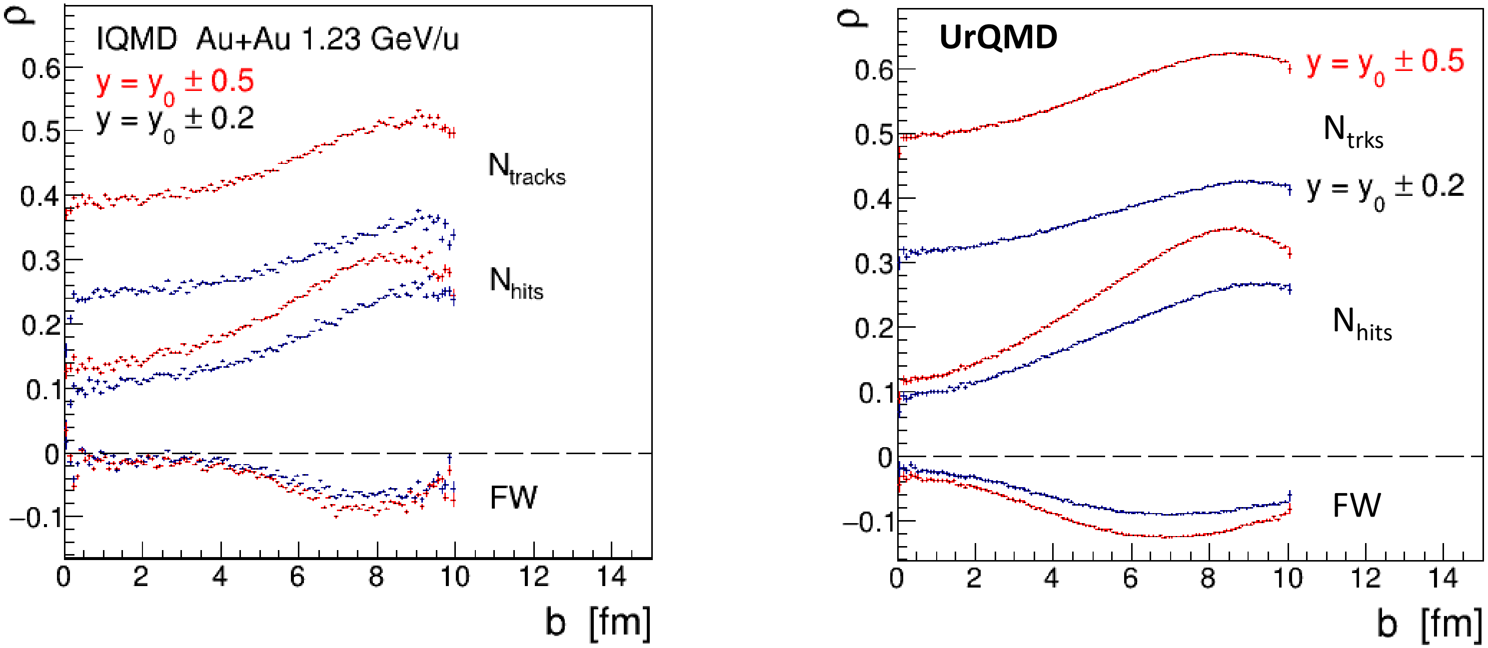
d/p ≈ 0.37 in 0-10% most central

Large fraction of protons are bound in nuclei: d, t, He, etc.

How do they contribute to proton-number fluctuations?

➔ Investigation of light nucleus production in Au+Au is ongoing (M. Szala & M. Lorenz)

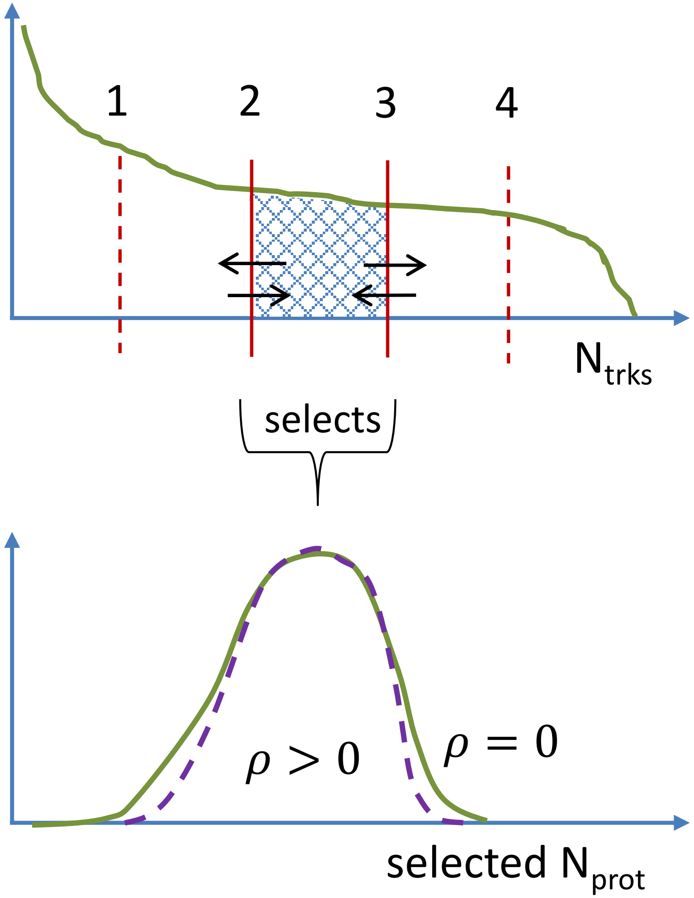
Correlations of N_{prot} & centrality selection



Pearson's linear correlation coefficient: $\rho_{xy} = \frac{cov(x,y)}{\sqrt{var(x)\,var(y)}}$

→ Non-zero correlations have a damping effect volume fluctuations!

Correlations & volume fluctuations

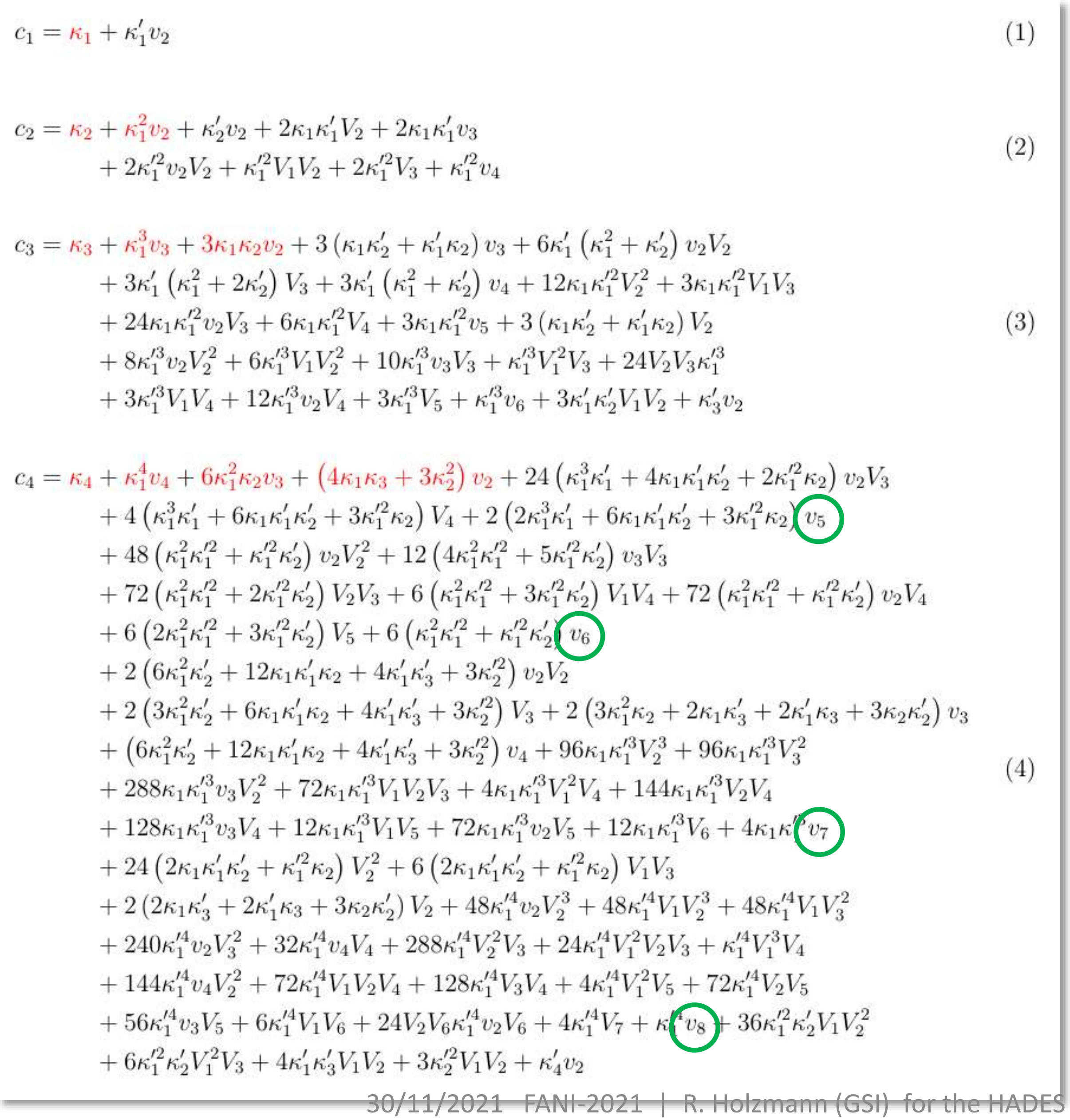


A centrality selection on nb. of tracks is problematic

If N_{trks} and N_{prot} are correlated, a cut on N_{trks} will reduce the width of the selected proton distribution

Volume fluctuation cumulants v_n are modified by correlations!

Extended (NLO) Skokov volume corrections



$$c_1 = \kappa_1 + \kappa_1' v_2 \tag{1}$$

$$\begin{aligned} c_2 = {} & \kappa_2 + \kappa_1^2 v_2 + \kappa_2' v_2 + 2\kappa_1\kappa_1' V_2 + 2\kappa_1\kappa_1' v_3 \\ & + 2\kappa_1'^2 v_2 V_2 + \kappa_1'^2 V_1 V_2 + 2\kappa_1'^2 V_3 + \kappa_1'^2 v_4 \end{aligned} \tag{2}$$

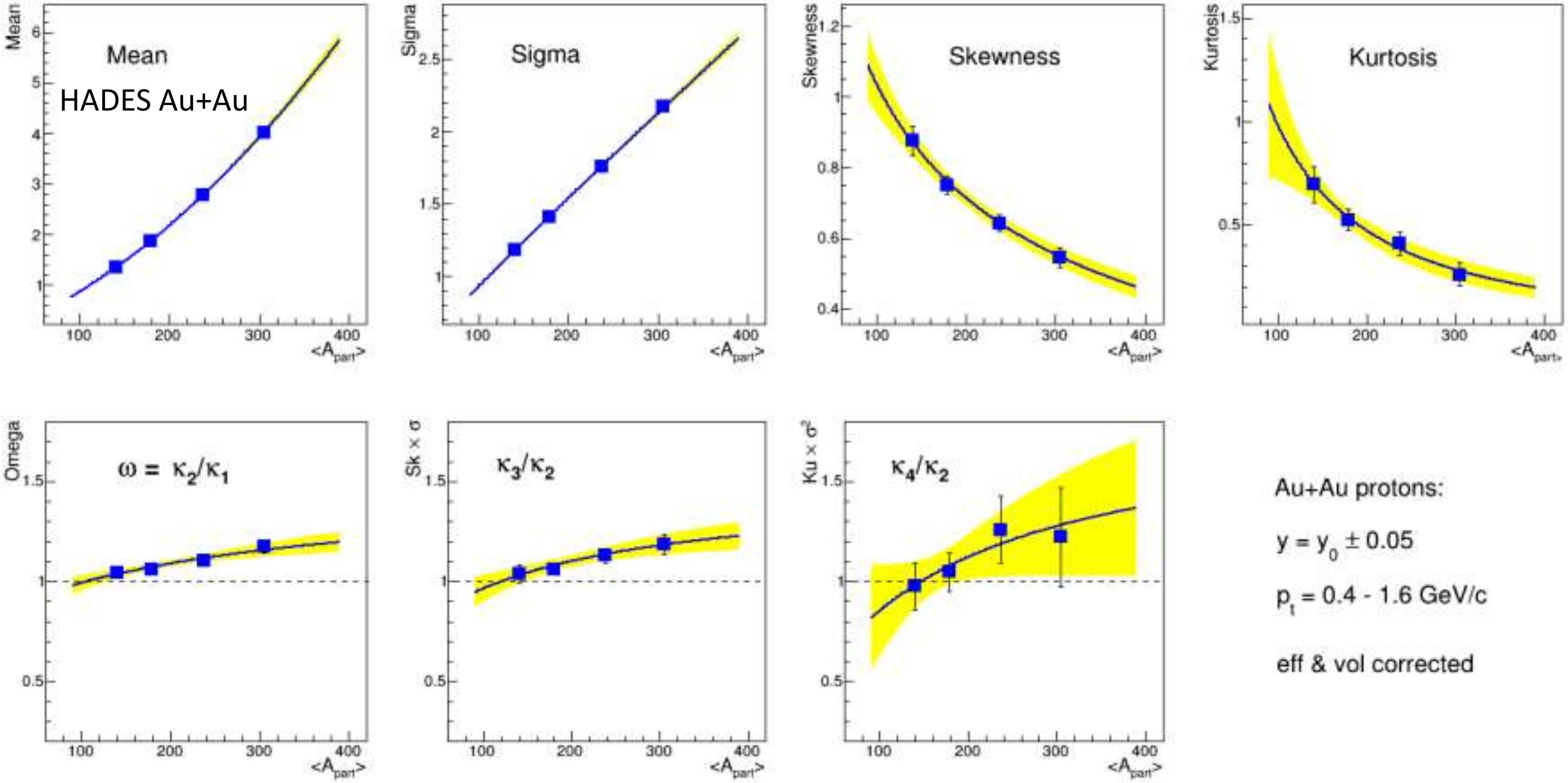
$$\begin{aligned} c_3 = {} & \kappa_3 + \kappa_1^3 v_3 + 3\kappa_1\kappa_2 v_2 + 3\left(\kappa_1\kappa_2' + \kappa_1'\kappa_2\right) v_3 + 6\kappa_1' \left(\kappa_1^2 + \kappa_2'\right) v_2 V_2 \\ & + 3\kappa_1' \left(\kappa_1^2 + 2\kappa_2'\right) V_3 + 3\kappa_1' \left(\kappa_1^2 + \kappa_2'\right) v_4 + 12\kappa_1\kappa_1'^2 V_2^2 + 3\kappa_1\kappa_1'^2 V_1 V_3 \\ & + 24\kappa_1\kappa_1'^2 v_2 V_3 + 6\kappa_1\kappa_1'^2 V_4 + 3\kappa_1\kappa_1'^2 v_5 + 3\left(\kappa_1\kappa_2' + \kappa_1'\kappa_2\right) V_2 \\ & + 8\kappa_1'^3 v_2 V_2^2 + 6\kappa_1'^3 V_1 V_2^2 + 10\kappa_1'^3 v_3 V_3 + \kappa_1'^3 V_1^2 V_3 + 24 V_2 V_3 \kappa_1'^3 \\ & + 3\kappa_1'^3 V_1 V_4 + 12\kappa_1'^3 v_2 V_4 + 3\kappa_1'^3 V_5 + \kappa_1'^3 v_6 + 3\kappa_1'\kappa_2' V_1 V_2 + \kappa_3' v_2 \end{aligned} \tag{3}$$

$$\begin{aligned} c_4 = {} & \kappa_4 + \kappa_1^4 v_4 + 6\kappa_1^2\kappa_2 v_3 + \left(4\kappa_1\kappa_3 + 3\kappa_2^2\right) v_2 + 24\left(\kappa_1^3\kappa_1' + 4\kappa_1\kappa_1'\kappa_2' + 2\kappa_1'^2\kappa_2\right) v_2 V_3 \\ & + 4\left(\kappa_1^3\kappa_1' + 6\kappa_1\kappa_1'\kappa_2' + 3\kappa_1'^2\kappa_2\right) V_4 + 2\left(2\kappa_1^3\kappa_1' + 6\kappa_1\kappa_1'\kappa_2' + 3\kappa_1'^2\kappa_2\right) v_5 \\ & + 48\left(\kappa_1^2\kappa_1'^2 + \kappa_1'^2\kappa_2'\right) v_2 V_2^2 + 12\left(4\kappa_1^2\kappa_1'^2 + 5\kappa_1'^2\kappa_2'\right) v_3 V_3 \\ & + 72\left(\kappa_1^2\kappa_1'^2 + 2\kappa_1'^2\kappa_2'\right) V_2 V_3 + 6\left(\kappa_1^2\kappa_1'^2 + 3\kappa_1'^2\kappa_2'\right) V_1 V_4 + 72\left(\kappa_1^2\kappa_1'^2 + \kappa_1'^2\kappa_2'\right) v_2 V_4 \\ & + 6\left(2\kappa_1^2\kappa_1'^2 + 3\kappa_1'^2\kappa_2'\right) V_5 + 6\left(\kappa_1^2\kappa_1'^2 + \kappa_1'^2\kappa_2'\right) v_6 \\ & + 2\left(6\kappa_1^2\kappa_2' + 12\kappa_1\kappa_1'\kappa_2 + 4\kappa_1'\kappa_3' + 3\kappa_2'^2\right) v_2 V_2 \\ & + 2\left(3\kappa_1^2\kappa_2' + 6\kappa_1\kappa_1'\kappa_2 + 4\kappa_1'\kappa_3' + 3\kappa_2'^2\right) V_3 + 2\left(3\kappa_1^2\kappa_2 + 2\kappa_1\kappa_3' + 2\kappa_1'\kappa_3 + 3\kappa_2\kappa_2'\right) v_3 \\ & + \left(6\kappa_1^2\kappa_2' + 12\kappa_1\kappa_1'\kappa_2 + 4\kappa_1'\kappa_3' + 3\kappa_2'^2\right) v_4 + 96\kappa_1\kappa_1'^3 V_2^3 + 96\kappa_1\kappa_1'^3 V_3^2 \\ & + 288\kappa_1\kappa_1'^3 v_3 V_2^2 + 72\kappa_1\kappa_1'^3 V_1 V_2 V_3 + 4\kappa_1\kappa_1'^3 V_1^2 V_4 + 144\kappa_1\kappa_1'^3 V_2 V_4 \\ & + 128\kappa_1\kappa_1'^3 v_3 V_4 + 12\kappa_1\kappa_1'^3 V_1 V_5 + 72\kappa_1\kappa_1'^3 v_2 V_5 + 12\kappa_1\kappa_1'^3 V_6 + 4\kappa_1\kappa_1'^3 v_7 \\ & + 24\left(2\kappa_1\kappa_1'\kappa_2' + \kappa_1'^2\kappa_2\right) V_2^2 + 6\left(2\kappa_1\kappa_1'\kappa_2' + \kappa_1'^2\kappa_2\right) V_1 V_3 \\ & + 2\left(2\kappa_1\kappa_3' + 2\kappa_1'\kappa_3 + 3\kappa_2\kappa_2'\right) V_2 + 48\kappa_1'^4 v_2 V_2^3 + 48\kappa_1'^4 V_1 V_2^3 + 48\kappa_1'^4 V_1 V_3^2 \\ & + 240\kappa_1'^4 v_2 V_3^2 + 32\kappa_1'^4 v_4 V_4 + 288\kappa_1'^4 V_2^2 V_3 + 24\kappa_1'^4 V_1^2 V_2 V_3 + \kappa_1'^4 V_1^3 V_4 \\ & + 144\kappa_1'^4 v_4 V_2^2 + 72\kappa_1'^4 V_1 V_2 V_4 + 128\kappa_1'^4 V_3 V_4 + 4\kappa_1'^4 V_1^2 V_5 + 72\kappa_1'^4 V_2 V_5 \\ & + 56\kappa_1'^4 v_3 V_5 + 6\kappa_1'^4 V_1 V_6 + 24 V_2 V_6 \kappa_1'^4 v_2 V_6 + 4\kappa_1'^4 V_7 + \kappa_1'^4 v_8 + 36\kappa_1'^2\kappa_2' V_1 V_2^2 \\ & + 6\kappa_1'^2\kappa_2' V_1^2 V_3 + 4\kappa_1'\kappa_3' V_1 V_2 + 3\kappa_2'^2 V_1 V_2 + \kappa_4' v_2 \end{aligned} \tag{4}$$

Where the v_n are reduced volume, i.e. N_{part}, cumulants, and the κ_n and κ_n' are obtained by fitting eq. (1) - (4) to the measured proton cumulants c_n

Note that v_n terms appear now up to 8th order!

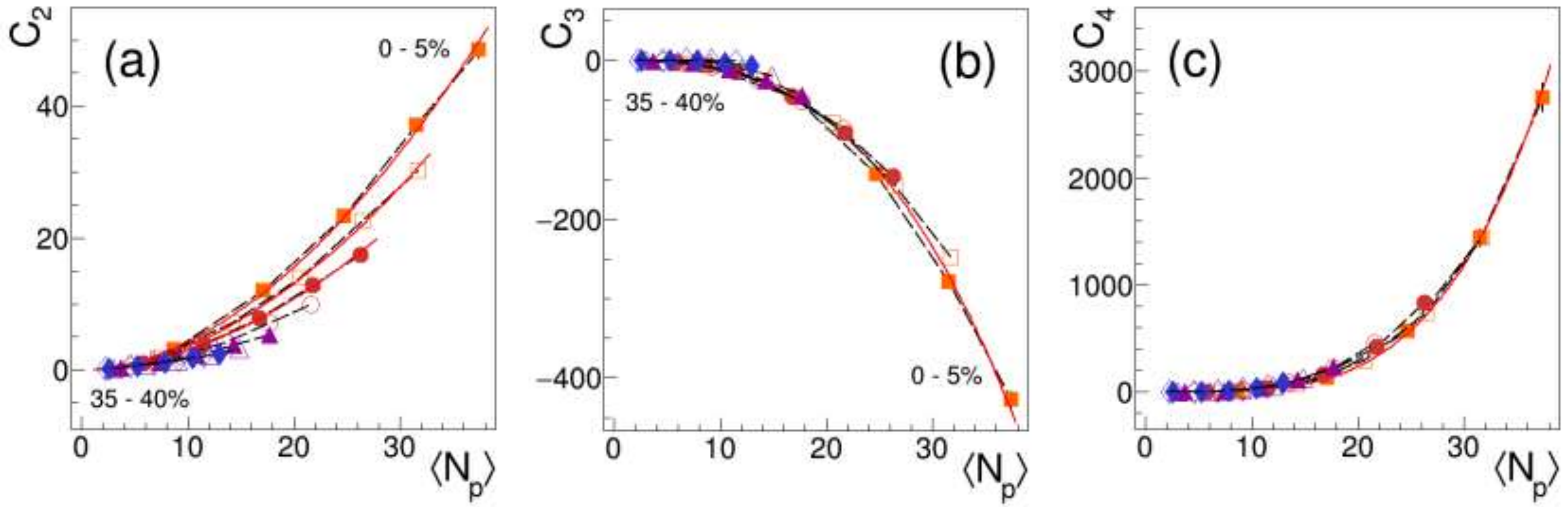
NLO corr. proton moments in Au+Au data: $y = y_0 \pm 0.05$



➔ approaching Poisson limit
in narrow phase-space bin!

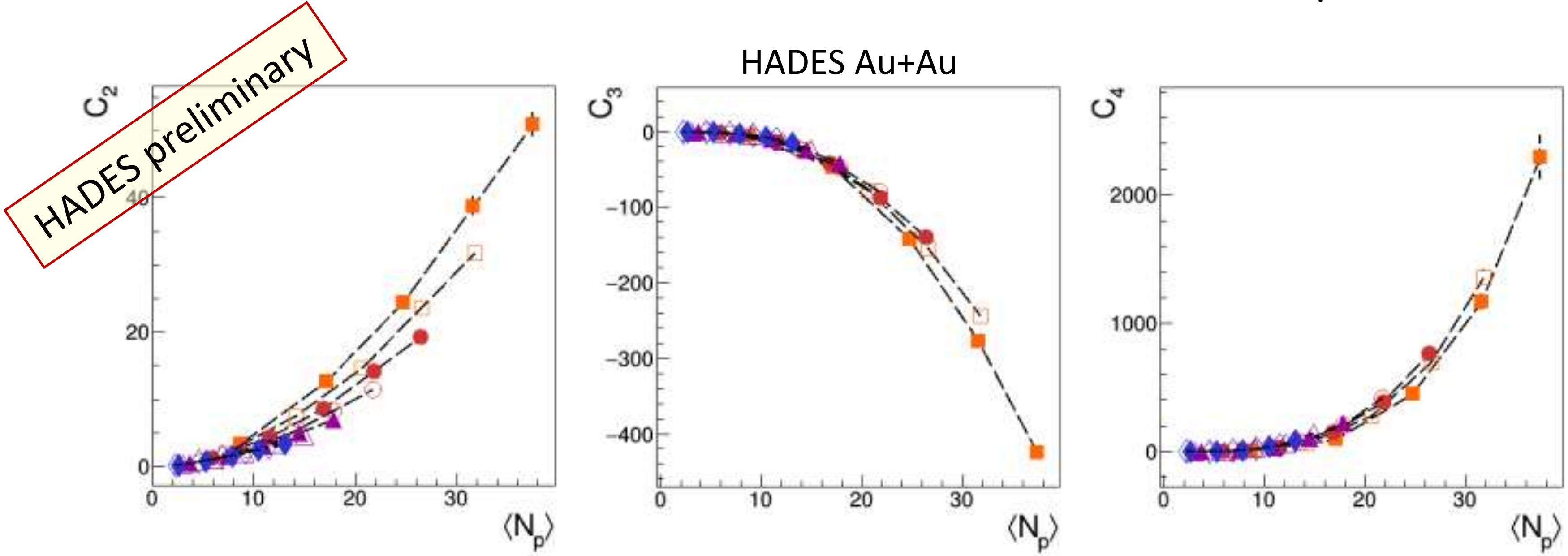
Re-analysis of the proton fluctuations: proton correlators (IQMD based N_{part})

HADES Au+Au



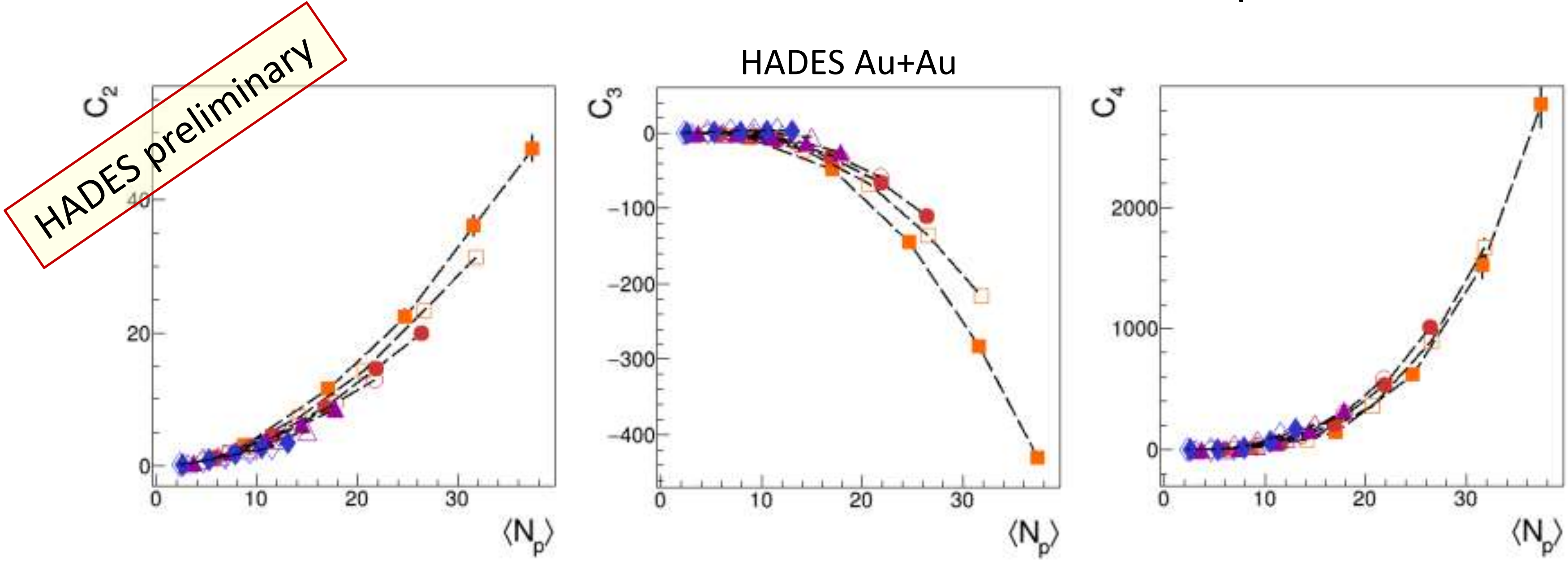
As published in PRC 102 (2020)

Re-analysis of the proton fluctuations: proton correlators (Poisson+CF of N_{part})



The n-particle correlators are very robust!

Re-analysis of the proton fluctuations: proton correlators (Bayesian N_{part})



HADES Au+Au

HADES preliminary

The n-particle correlators are very robust!!