Status of the Analyses for the Proton Higher-Order Fluctuations in the STAR Fixed-Target Program from $\sqrt{s_{NN}} = 3.2$ to 7.7 GeV

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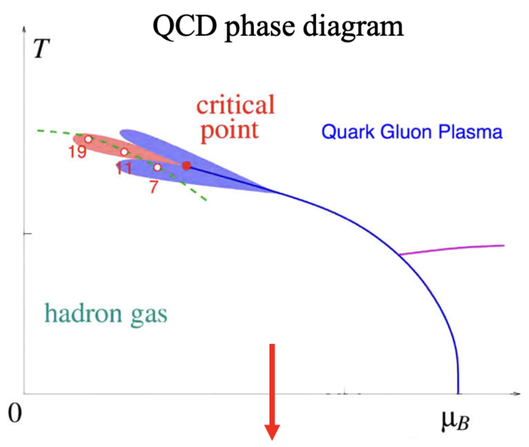
1. Introduction

Critical Fluctuations

- Fluctuations of conserved charges, such as baryon number, expected near critical point
- Proton number is a proxy for baryon number
- Cumulants of net-proton number distributions vs. collision energy are measured
- QCD calculations predict non-monotonic cumulants vs $\sqrt{s_{NN}}$ if close to critical point [1]



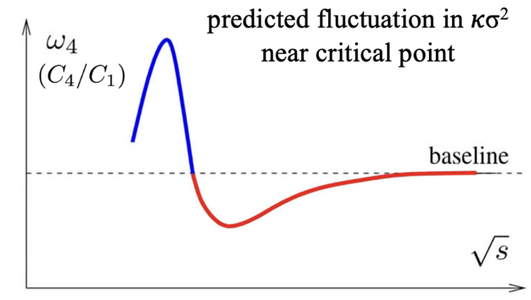
Cumulants and Moments

Cumulants of a distribution are defined as [2]:

- $C_1 = \langle N \rangle \equiv \mu$
- $C_2 = \langle (N-\mu)^2 \rangle \equiv \sigma^2$
- $C_3 = \langle (N-\mu)^3 \rangle$
- $C_4 = \langle (N-\mu)^4 \rangle - 3\langle (N-\mu)^2 \rangle^2$

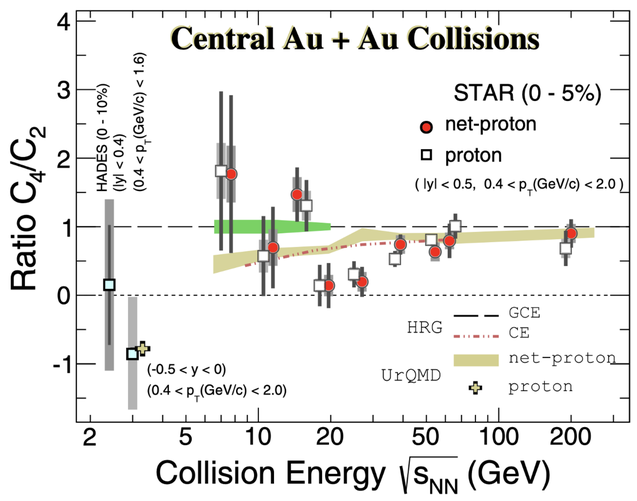
Some standardized moments are:

- $S\sigma = C_3/C_2$ [measures asymmetry]
- $\kappa\sigma^2 = C_4/C_2$ [measures "tailedness"]



Previous Results

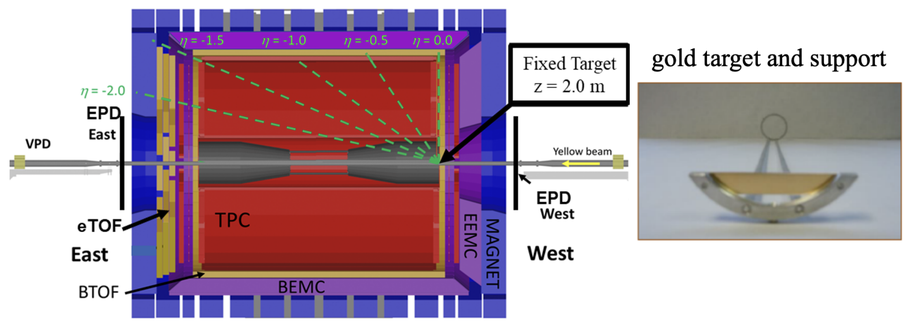
- Non-monotonicity in Beam Energy Scan I net-proton C_4/C_2
- Recent $\sqrt{s_{NN}} = 3$ GeV measurement returns to non-critical baseline [3]
- High-statistics collider data from Beam Energy Scan II will improve measurements from $\sqrt{s_{NN}} = 7.7$-27 GeV
- Fixed-target data will fill the gap between $\sqrt{s_{NN}} = 3$ and 7.7 GeV



2. The STAR Fixed-Target Program

- Relativistic Heavy-Ion Collider (RHIC) luminosity in collider mode is unusable for Au+Au below $\sqrt{s_{NN}} = 7.7$ GeV
- Gold target installed on west end of STAR TPC
- New data from $\sqrt{s_{NN}} = 3.0 - 7.7$ GeV

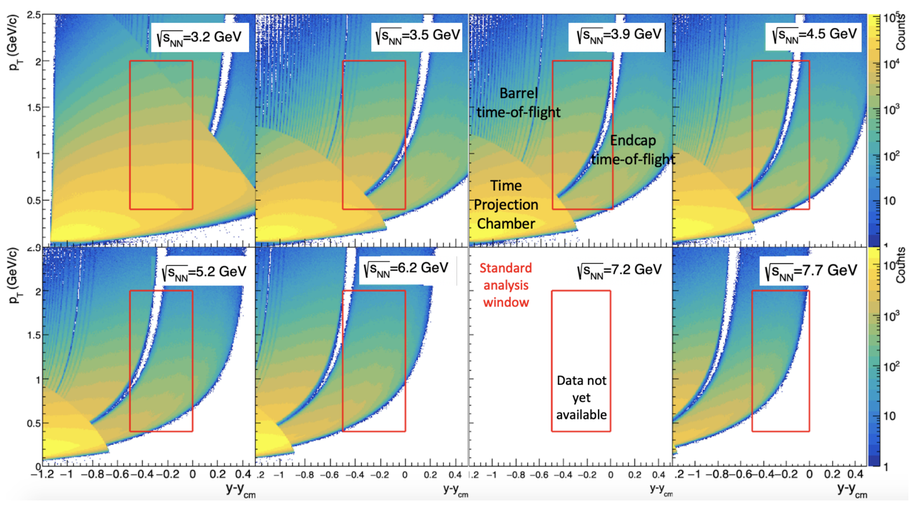
$\sqrt{s_{NN}}$ (GeV)	3.2	3.5	3.9	4.5	5.2	6.2	7.2	7.7
μ_B (GeV)	0.70	0.67	0.63	0.59	0.54	0.49	0.44	0.42
y_{CM}	1.139	1.254	1.375	1.522	1.683	1.867	2.021	2.102
# good evts	201M	116M	117M	108M	103M	118M	317M	113M
produced	yes	yes	yes	yes	yes	yes	no	yes



Challenges

- Acceptance is asymmetric w.r.t. midrapidity
- Limited midrapidity acceptance at higher energies
- Time-of-flight (TOF) required for particle identification

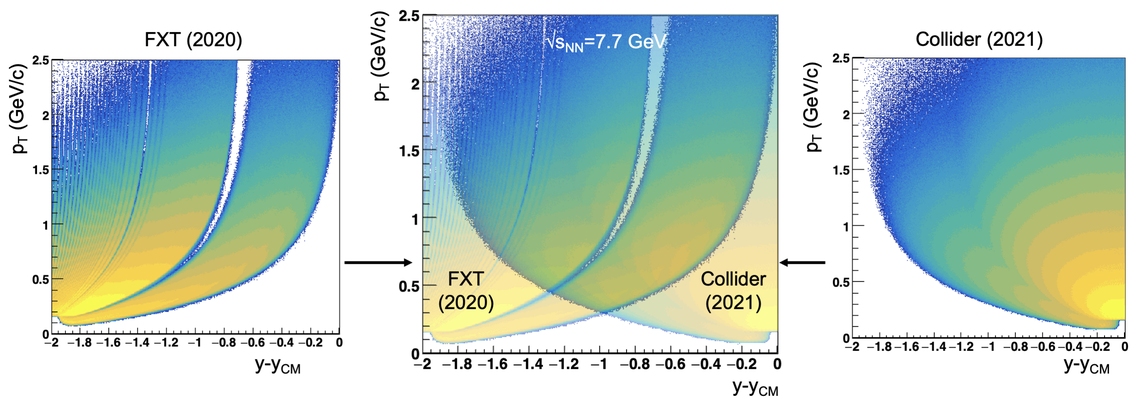
3. Acceptance



- Standard analysis window shown by red box: $0.4 < p_T < 2$ GeV, $-0.5 < y - y_{\rm cm} < 0$
- We have near full acceptance up to $\sqrt{s_{NN}} = 4.5$ GeV
- Analyses at top fixed-target energies must be away from midrapidity

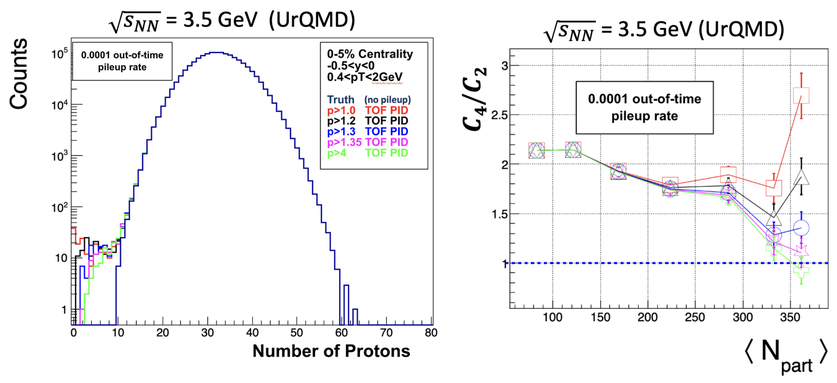
Overlap at $\sqrt{s_{NN}} = 7.7$ GeV

- Data was taken at $\sqrt{s_{NN}} = 7.7$ GeV in both the collider and fixed-target configurations
- There is significant overlap in acceptance for a comparison
- Overlap analysis will increase confidence in fixed-target and collider methodologies



4. Pileup with Time of Flight

- Fixed-target analysis uses TOF and TPC for proton ID
- Centrality determined by TPC multiplicity
- TOF relies on precision timing and often misses protons from pileup with timing offset
- TPC multiplicity includes pileup tracks
- Pileup events classified as central collisions but have few TOF-identified protons
- This causes tail on proton-number distribution, which creates false signal for high-order cumulants



Solution: Reject pileup, do not correct for it. Usual cumulant correction for pileup doesn't fix timing fluctuations

5. Outlook

- Fixed-Target Program extends energy range of RHIC down to $\sqrt{s_{NN}} = 3$ GeV
- Fixed-target proton fluctuations analyses are underway from $\sqrt{s_{NN}} = 3.2$-7.7 GeV
- Overlap acceptance for fixed-target and collider data at $\sqrt{s_{NN}} = 7.7$ GeV allows methodology cross-check
- Reliance on TOF for particle ID makes measurements sensitive to timing fluctuations, which can be managed
- Prior measurements show non-monotonic variation in C_4/C_2 as a function of $\sqrt{s_{NN}}$
- Fixed-target data will add mid-rapidity C_4/C_2 measurements at $\sqrt{s_{NN}} = 3.2$-4.5 GeV to energy scan

References

[1] M. A. Stephanov, J. Phys. G: Nucl. Part. Phys. **38** 124147 (2011).

[2] X. Luo and N. Xu, Nucl. Sci. Tech. **28**, 112 (2017).

[3] M. Abdallah *et al.*, (STAR Collaboration) Phys. Rev. Lett. **128**, 202303 (2022).