Search for QCD Critical Point at RHIC
- A Status Report

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Outline

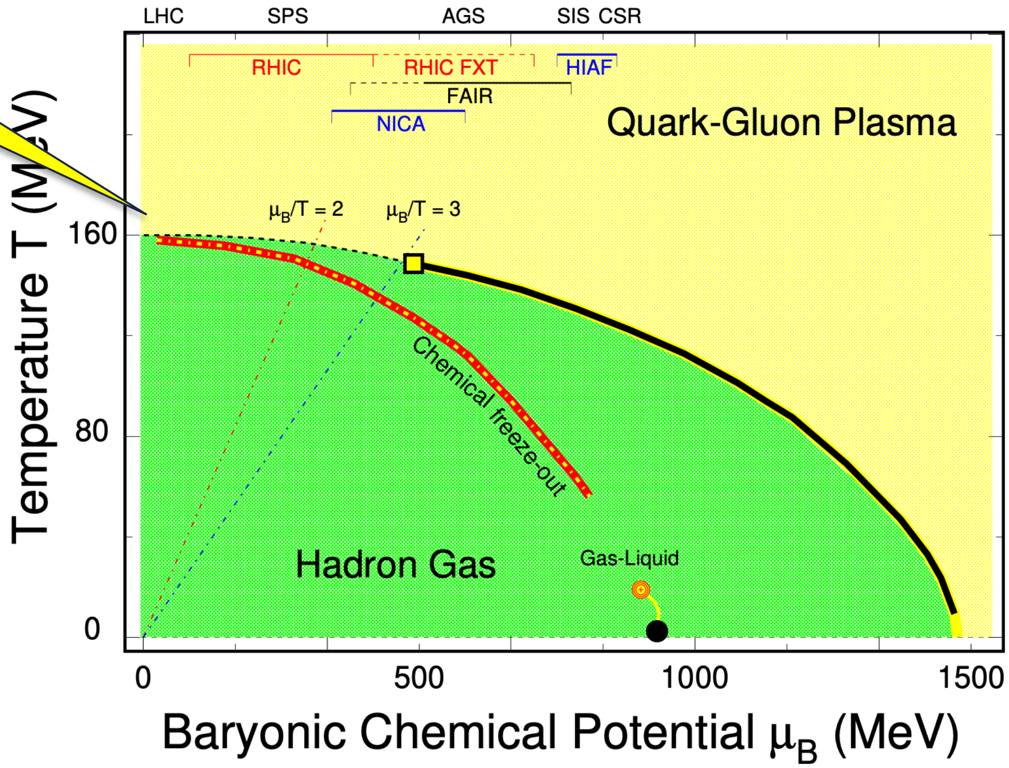
1) **Introduction**

2) Results from RHIC BES
   - (Net-) Proton Distributions
   - Initial Volume Fluctuation at Low Energy Collisions
   - Collectivity

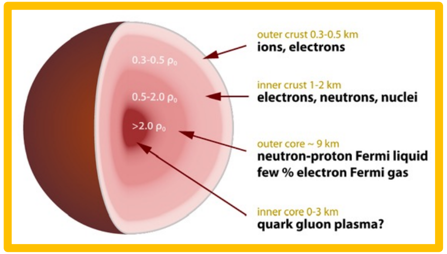
3) Polarization Measurements (?)

Nuclear Collisions and QCD Phase Diagram

Early Universe

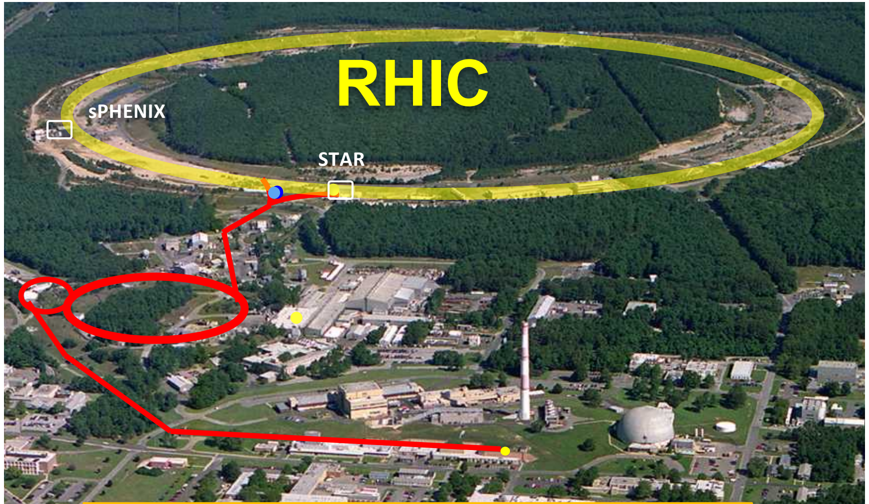


High baryon density:
Inner structure of compact stars



1) RHIC BES: → search for 1^{st}-order phase transition and **QCD critical point**;
2) Baryon interactions (*e.g.* N-N, Y-N) → inner structure of compact stars

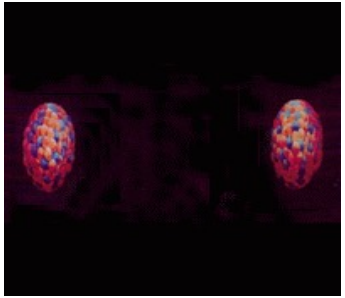
Nuclear Collisions and QCD Phase Diagram



Relativistic Heavy Ion Collider (RHIC)

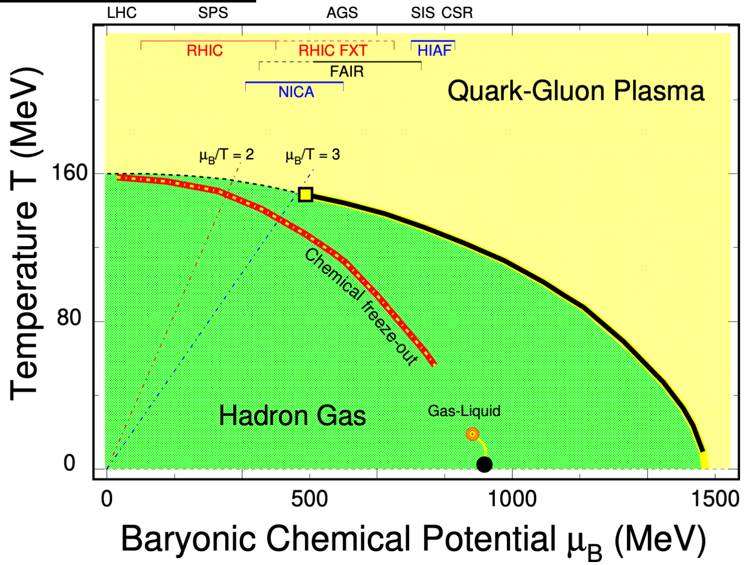
RHIC top collision energies:
- ➢ $\sqrt{s_{NN}}$ = 200 GeV U+U / Au+Au / Zr+Zr / Ru+Ru / O+O
- ➢ $\sqrt{s}$ = 510 GeV p+p

RHIC Beam Energy Scan (BES):
- ➢ $\sqrt{s_{NN}}$ = 200 – 7.7 GeV (collider mode)
- ➢ $\sqrt{s_{NN}}$ = 17.3 – 3 GeV (fixed-target mode)

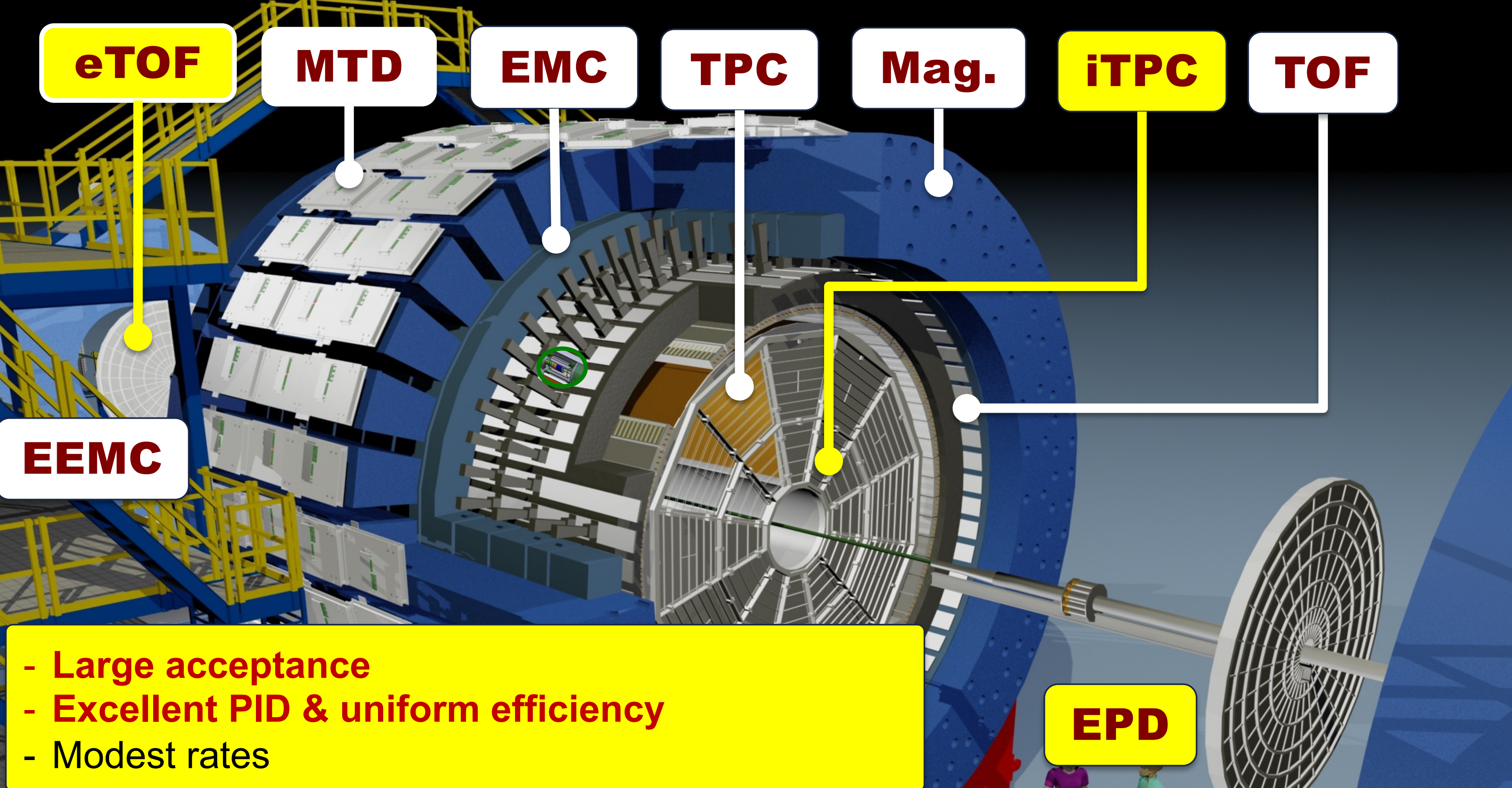


Quark-Gluon Plasma
(QGP)

QCD Phase Diagram

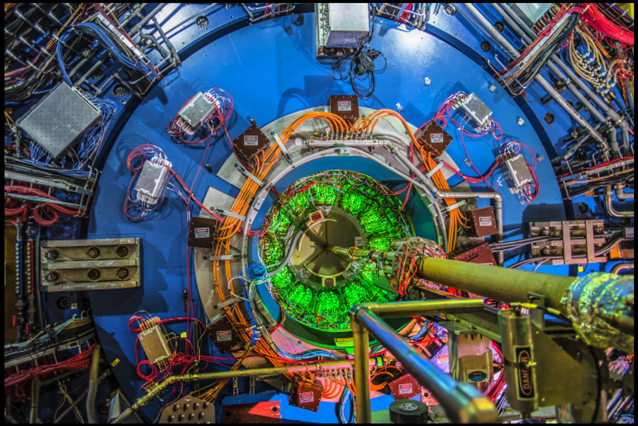


STAR DETECTOR SYSTEM



- **Large acceptance**
- **Excellent PID & uniform efficiency**
- Modest rates

Major Upgrades for BES-II



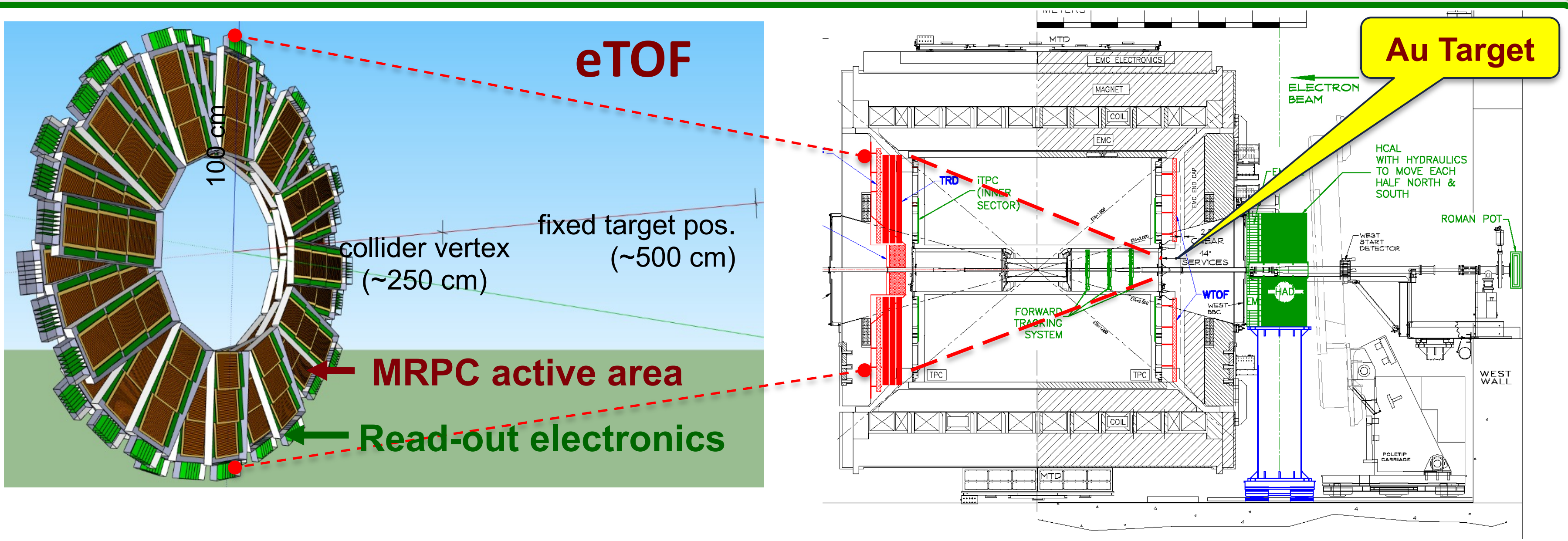
iTPC:
- Improves dE/dx
- Extends η coverage from 1.0 to 1.6
- Lowers p_T cut-in from 125 to 60 MeV/c
- Ready in 2019

eTOF:
- Forward rapidity coverage
- PID at η = 0.9 to 1.6
- **Borrowed from CBM-FAIR**
- Ready in 2019

EPD:
- Improves trigger
- Better centrality & event plane measurements
- Ready in 2018

1) Enlarge rapidity acceptance
2) Improve particle identification
3) Enhance centrality/event plane resolution

iTPC: https://drupal.star.bnl.gov/STAR/starnotes/public/sn0619
eTOF: STAR and CBM eTOF group, arXiv: 1609.05102
EPD: J. Adams, et al. NIM **A968,** 163970 (2020)

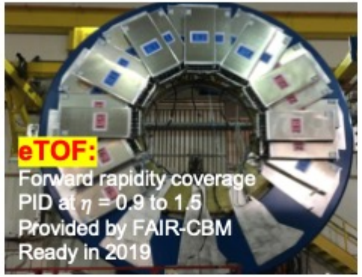


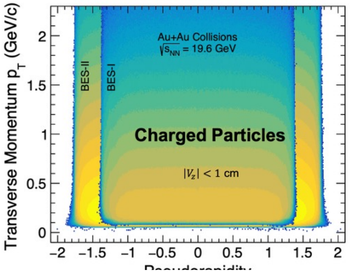
CBM participates in RHIC BES-II in 2019 – 2021:

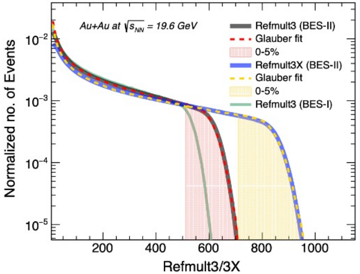
- Complementary to CBM program: $\sqrt{s_{NN}}$ = 3 - 7.7 GeV (**760 ≥ μ_B ≥ 420 MeV**)
- Strange-hadron, hyper-nuclei and fluctuation at the high baryon density region

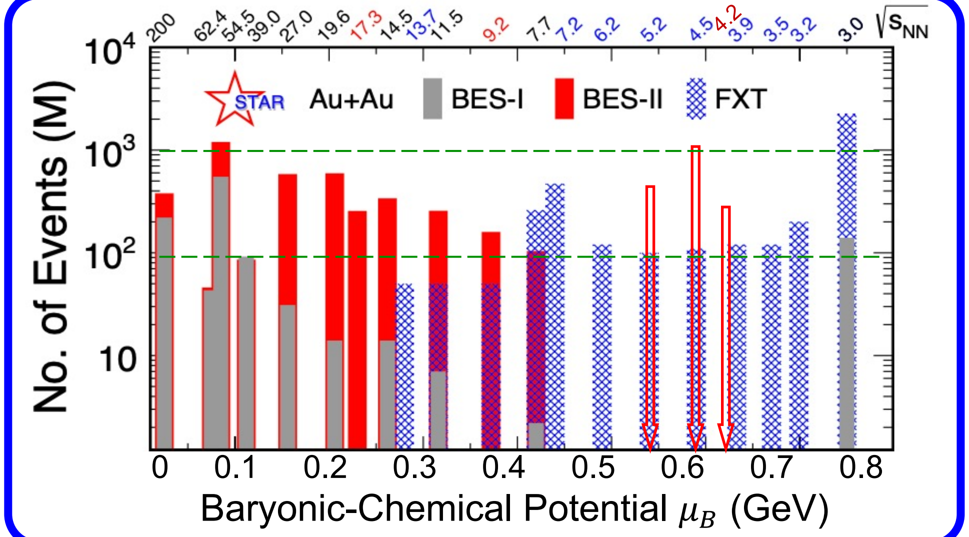
RHIC Beam Energy Scan Program (2010 – 2026)

Detector Upgrades BES-II









(1) Enlarge rapidity acceptance; (2) Improve particle identification; (3) Better centrality/event plane resolution

1) BES-I (2010 – 2014): 7.7, 11.5, 14.5, 19.6, 27, 39, 62.4, 200 GeV;

2) BES-II (2018 – 2026): Collider mode (7.7, 9.2, 11.5, 14.6, 17.3, 19.6, 27 GeV)

FXT mode: (**3.0, 3.2, 3.5, 3.9, 4.2, 4.5**, 5.2, 6.2,…,13.7 GeV)

3) μ_B coverage : $25 < \mu_B < 760$ MeV

STAR BES Data Sets

Au+Au Collisions at RHIC

Collider Runs						Fixed-Target Runs					
	$\sqrt{s_{NN}}$ (GeV)	#Events	μ_B	y_{beam}	run		$\sqrt{s_{NN}}$ (GeV)	#Events	μ_B	y_{beam}	run
1	**200**	900 M	**25** MeV	5.3	Run-10, 19	1	13.7 (100)	50 M	280 MeV	-2.69	Run-21
2	62.4	46 M	75 MeV		Run-10	2	11.5 (70)	50 M	320 MeV	-2.51	Run-21
3	54.4	1200 M	85 MeV		Run-17	3	9.2 (44.5)	50 M	370 MeV	-2.28	Run-21
4	39	86 M	112 MeV		Run-10	4	7.7 (31.2)	260 M	420 MeV	-2.1	Run-18, 19, 20
5	27	585 M	156 MeV	3.36	Run-11, 18	5	7.2 (26.5)	470 M	440 MeV	-2.02	Run-18, 20
6	19.6	595 M	206 MeV	3.1	Run-11, 19	6	6.2 (19.5)	120 M	490 MeV	1.87	Run-20
7	17.3	256 M	230 MeV		Run-21	7	**5.2 (13.5)**	100+**1000 M**	540 MeV	-1.68	Run-20, 25
8	14.6	340 M	262 MeV		Run-14, 19	8	**4.5 (9.8)**	110 +**2000 M**	590 MeV	-1.52	Run-20,25
9	11.5	57 M	316 MeV		Run-10, 20	9	**4.2 (9.12)**	**1000 M**	610 MeV	-1.41	Run-25
10	9.2	160 M	372 MeV		Run-10, 20	10	3.9 (7.3)	120 M	633 MeV	-1.37	Run-20
11	7.7	104 M	420 MeV		Run-21	11	3.5 (5.75)	120 M	670 MeV	-1.2	Run-20
						12	3.2 (4.59)	200 M	699 MeV	-1.13	Run-19
						13	**3.0** (3.85)	**260** + 2000 M	**760** MeV	-1.05	Run-18, 21

Most precise data to map the QCD phase diagram

$$3 < \sqrt{s_{NN}} < 200\ \text{GeV}; \quad 760 > \mu_B > 25\ \text{MeV}$$

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Observables

- **At critical point with an infinite system** correlation length and susceptibilities should diverge

$$\chi_q^{(n)} = \frac{1}{VT^3} \times C_{n,q} = \frac{\partial^n (p/T^4)}{\partial(\mu_q)^n}, q = B, Q, S$$

Conserved Charges q : Net Baryon Number (B), Net Charge (Q), Net Strangeness (S)

Note: Cumulants: C_n ; Factorial Cumulants: κ_n (FC_n)

- **Experimental observables: Conserved quantity distributions**
  1) Sensitive to correlation length (ξ)
  2) Directly related to the susceptibility ratios

$$\langle(\delta N)^3\rangle_c \approx \xi^{4.5}, \quad \langle(\delta N)^4\rangle_c \approx \xi^7$$

$$\kappa_1 = C_1 = \langle N \rangle,$$
$$\kappa_2 = -C_1 + C_2,$$
$$\kappa_3 = 2C_1 - 3C_2 + C_3,$$
$$\kappa_4 = -6C_1 + 11C_2 - 6C_3 + C_4,$$

Measured multiplicity N, $\langle \delta N \rangle = N - \langle N \rangle$

mean: $M = \langle N \rangle = C_1$

variance: $\sigma^2 = \langle (\delta N)^2 \rangle = C_2$

skewness: $S = \langle (\delta N)^3 \rangle / \sigma^3 = C_3 / C_2^{3/2}$

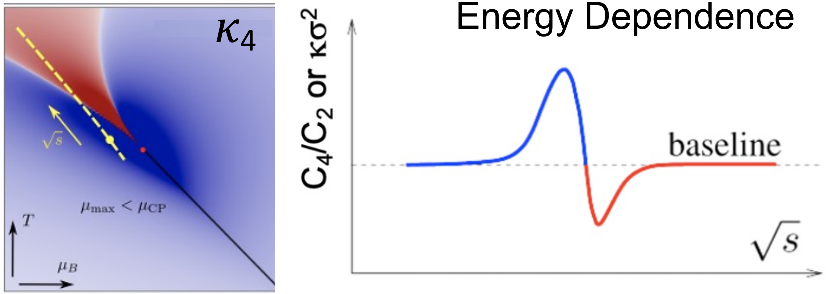
kurtosis: $\kappa = \langle (\delta N)^4 \rangle / \sigma^4 - 3 = C_4 / C_2^2$

Moments, cumulants and susceptibilities:

2nd order: $\sigma^2/M \equiv C_2/C_1 = \chi_2/\chi_1$

3rd order: $S\sigma \equiv C_3/C_2 = \chi_3/\chi_2$

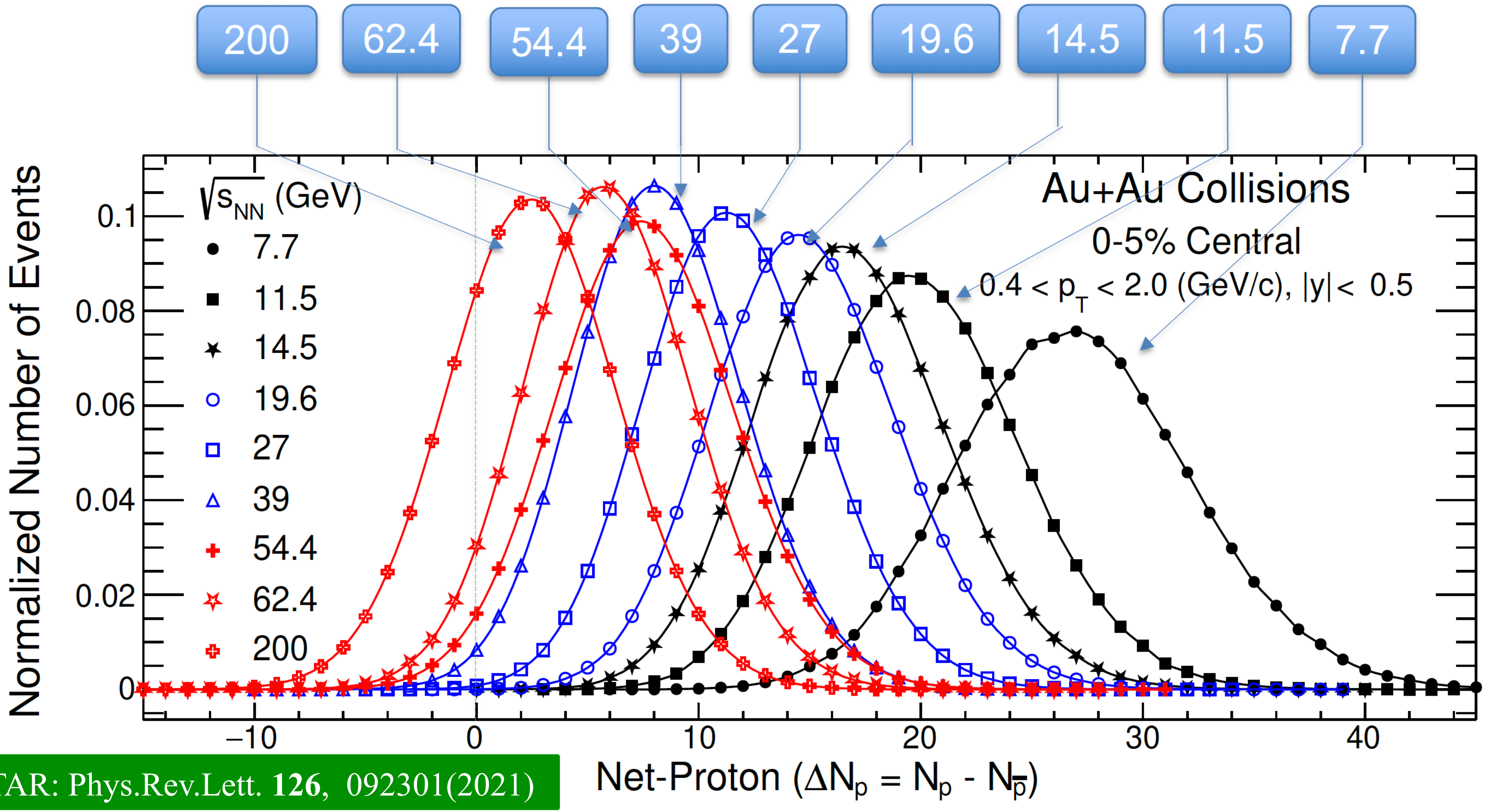
4th order: $\kappa\sigma^2 \equiv C_4/C_2 = \chi_4/\chi_2$



*M. A. Stephanov, **PRL102** (2009) 032301*

*M.A.Stephanov, PRL**102**, 032301 (2009); **107**, 052301 (2011). M.Asakawa, S.Ejiri and M.Kitazawa, PRL**103**, 262301 (2009). Cheng et al, PRD (2009) 074505. F.Karsch and K.Redlich , PLB**695**, 136 (2011). B.Friman et al., EPJC **71** (2011) 1694. S.Gupta, et al., Science, **332**, 1525(2012). A.Bazavov et al., PRL**109**, 192302(12) // S.Borsanyi et al., PRL**111**, 062005(13)*

Event-by-Event Net-Proton Distributions (raw)

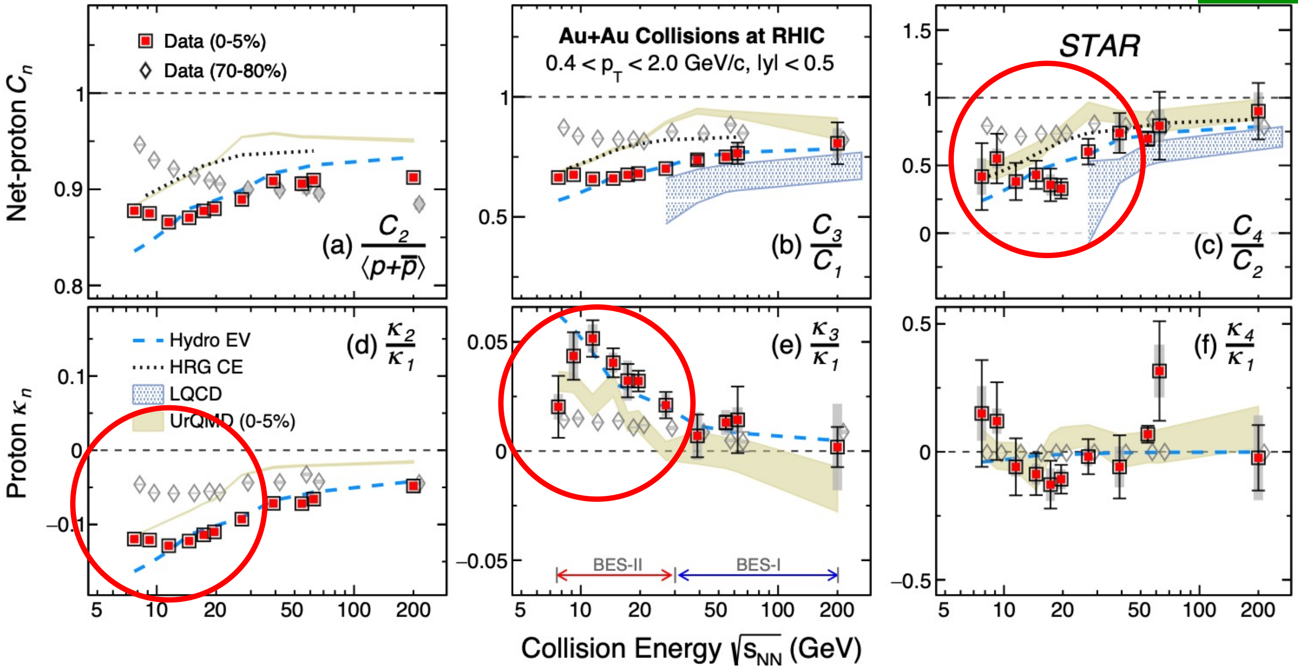


STAR: Phys.Rev.Lett. **126**, 092301(2021)

Energy Dependence (collider)

Au+Au Collisions at RHIC

STAR: PRL**135,** 142305(2025)



1) **UrQMD:** (hadronic transport calculations and the results are analyzed in the same way as data.) S. Bass *et al*., Prog. Part. Nucl. Phys., **41**, 255 (1998);

2) **HRG CE:** P.B. Munzinger *et al.* Nucl. Phys. **A1008**, 122141(2021);

3) **Hydro:** HRG CE + EV, V. Vovchenko *et al*., Phys. Rev. **C105**, 014904 (2022).

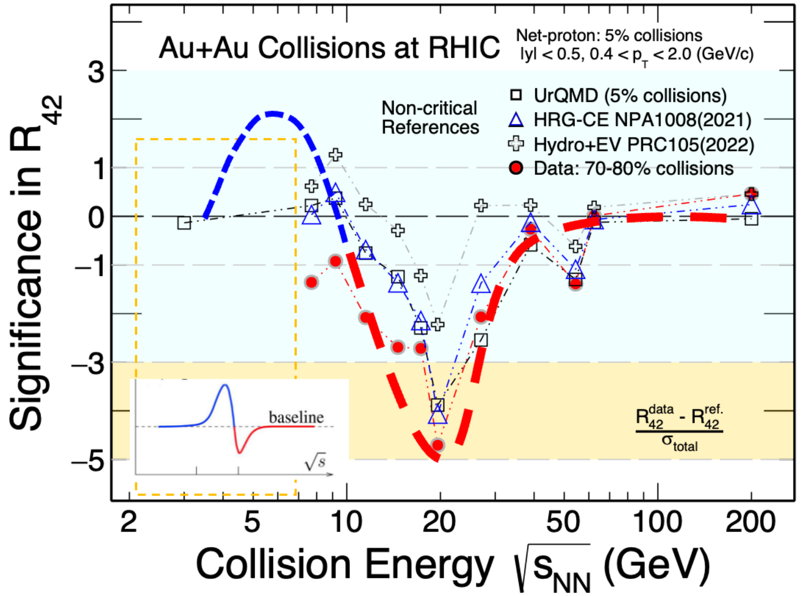
4) **LQCD:** (done for net-baryon) A. Bazavov *et al.,* Phys. Rev. D101, 074502 (2020). arXiv : 2407.09335

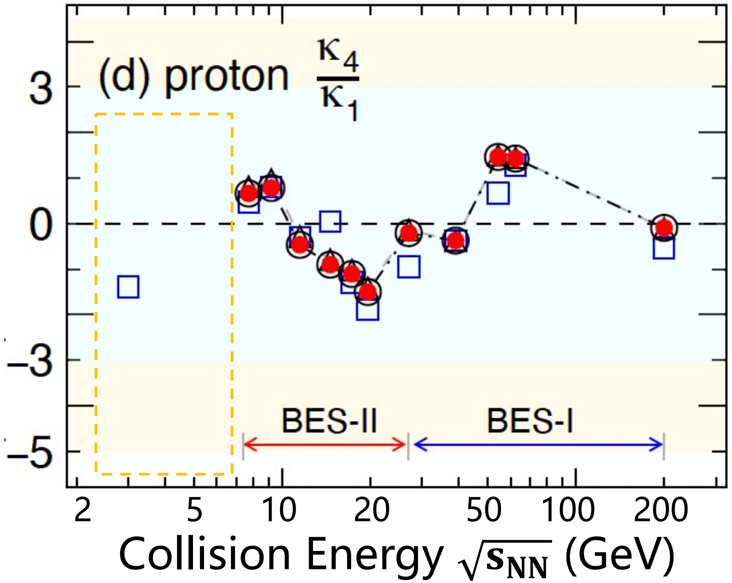
1) The energy dependence is reproduced by most calculations at high energy;

2) Deviations appear below $\sqrt{s_{NN}} < 35$ GeV

Significances at the 4TH Orders

0-5% Au+Au Collisions at RHIC



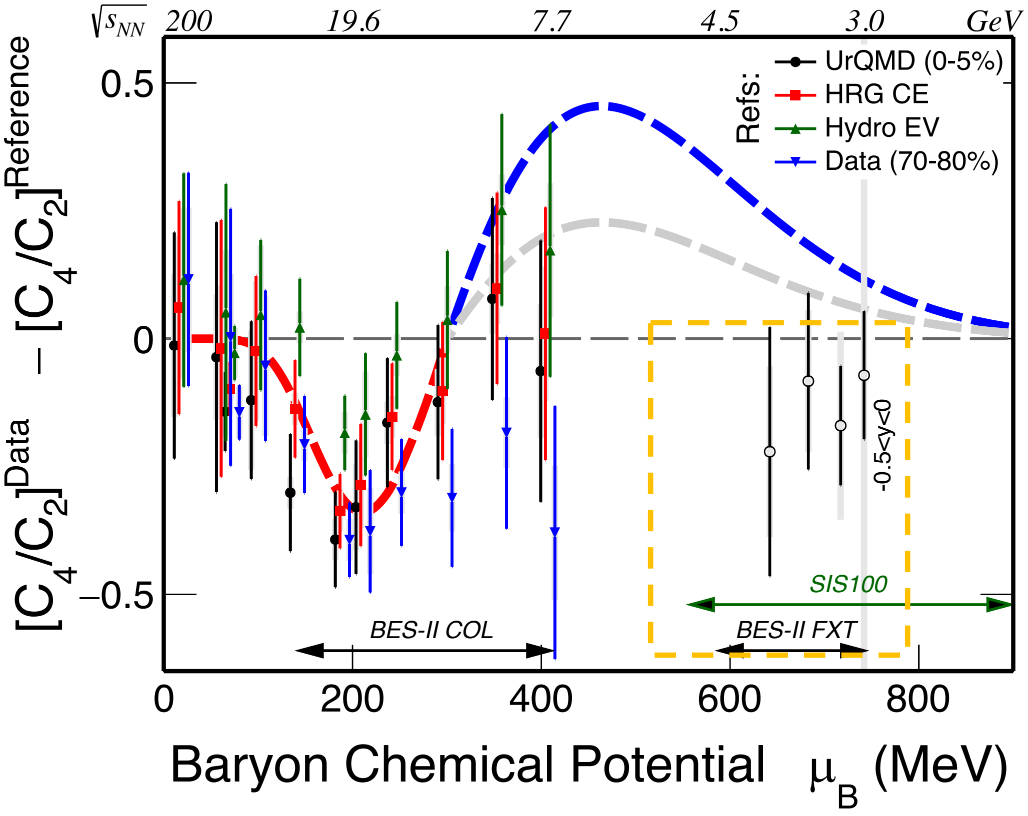


$$Significance = \frac{Data - Reference}{\sqrt{\sigma^2_{data} + \sigma^2_{reference}}}$$

STAR: PRL**135,** 142305(2025)

Significant deviations from non-critical references are observed!

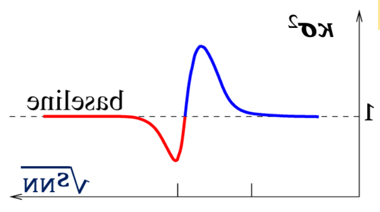
Search for the QCD CEP



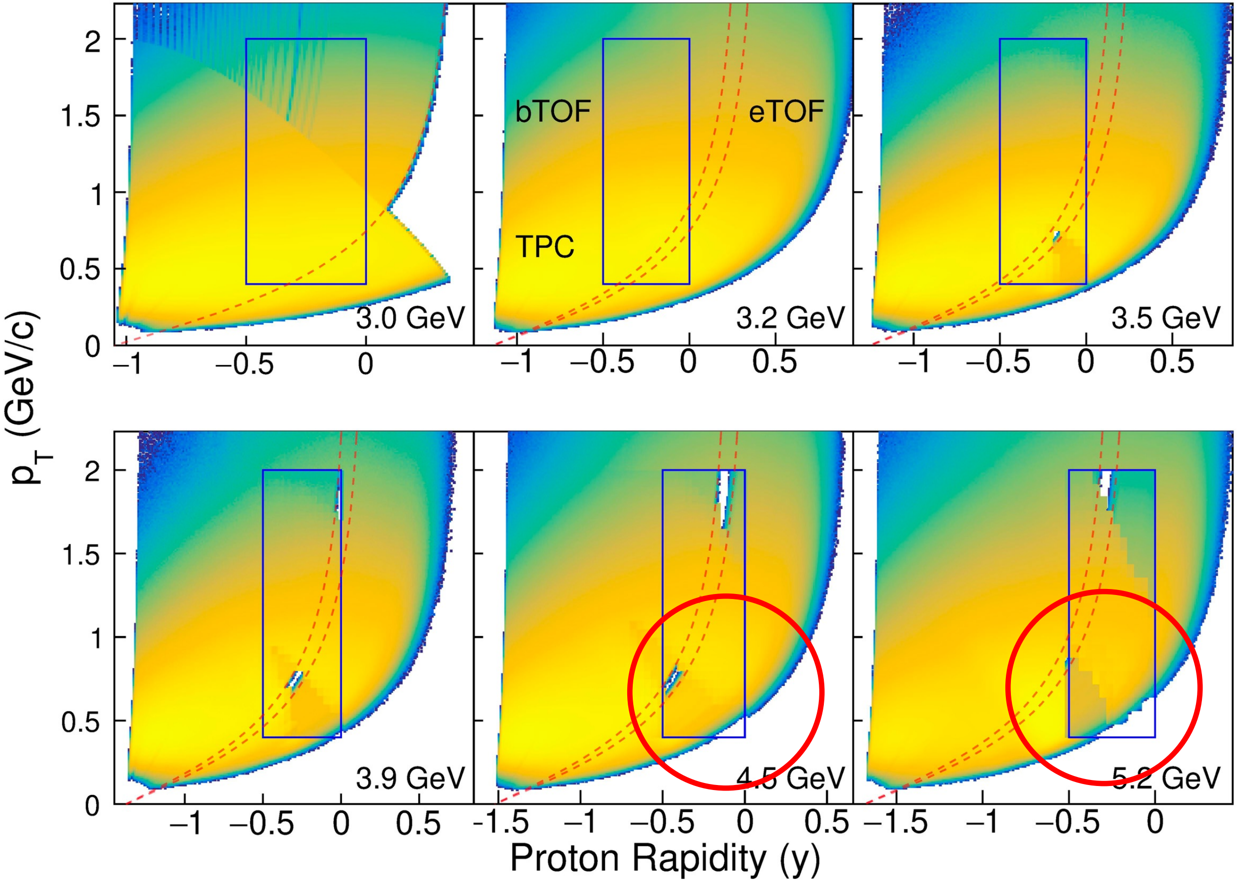
M. Stephanov: Phys.Rev.Lett. 107, 052301 (2011)
P. Braun-Munzinger et al. Nucl.Phys. A1008, 122141 (2021)

$$R_{42}^{data} - R_{42}^{reference}$$

1) Clear minimum at 19.6 GeV is seen;
2) Experimental data between 3 – 8 GeV are crucial;
3) STAR FXT data and CBM at FAIR are important for the search of QCD critical point



Proton PID and Acceptance in FXT

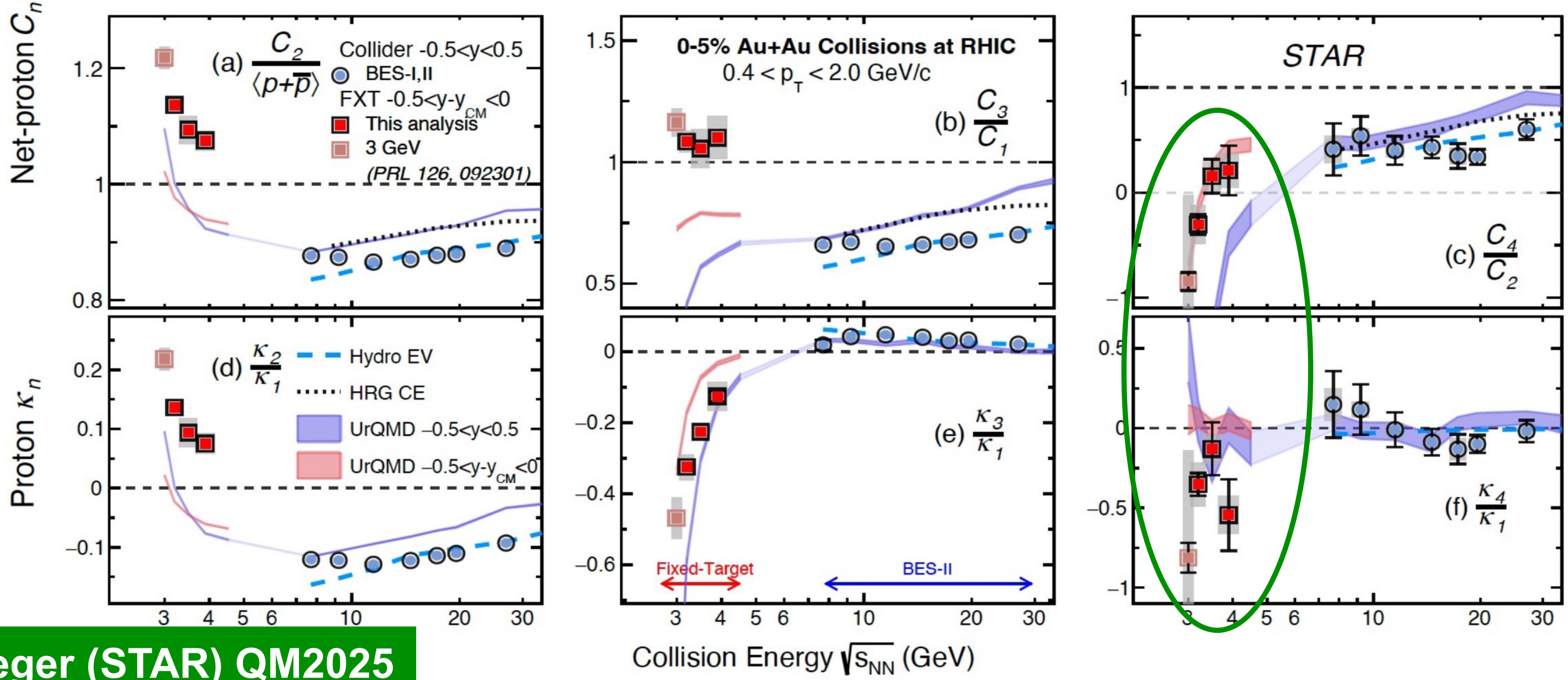


1) TPC, iTPC, bTOF, eTOF are used in the FXT program;

2) Lossing mid-y acceptance for energy higher than 4.5 GeV!

3) Analysis is focused on the mid-y region (-0.5 < y 0)

(Net-) Protons from FXT Program



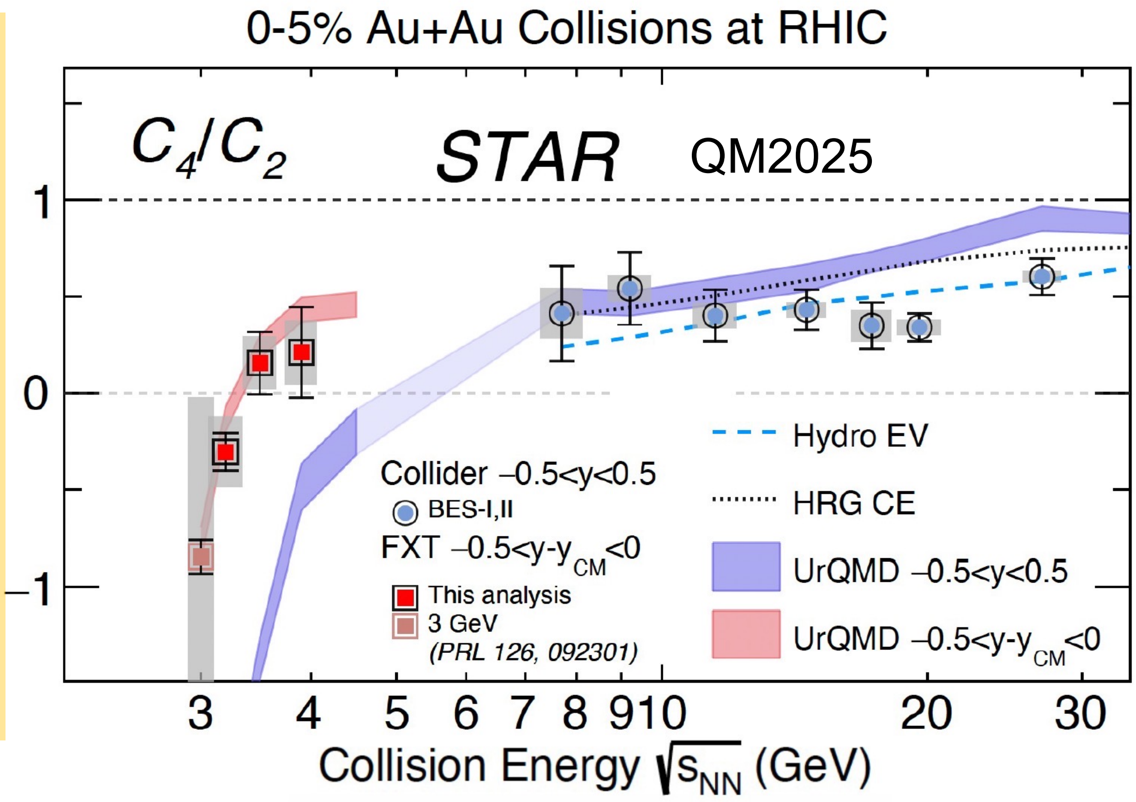
Z. Sweger (STAR) QM2025

At 3.0 – 3.9 GeV central collisions (0-5%, -0.5<y<0):

1) Change of trends and increase above unity for 2nd and 3rd order cumulants;
2) Deviations from UrQMD calculations is seen around 4 GeV in the FXT region

(Net-) Protons (C_4/C_2) from FXT

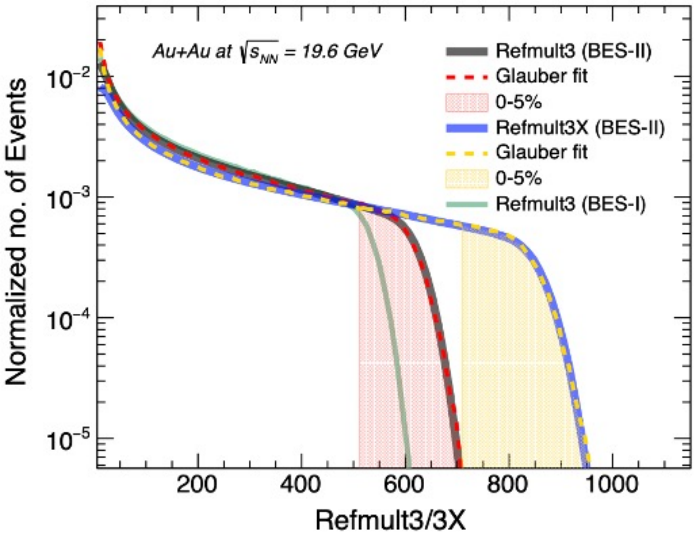
1) Collider mode: |y| <0.5
   FXT mode: -0.5 < y < 0.0
2) 3.0, 3.2, 3.5 and 3.9 GeV data were shown at QM2025
3) Data and UrQMD calculations are consistent for the FXT results. However, at the lowest energies, values of C_4/C_2 become negative: Centrality resolution issue

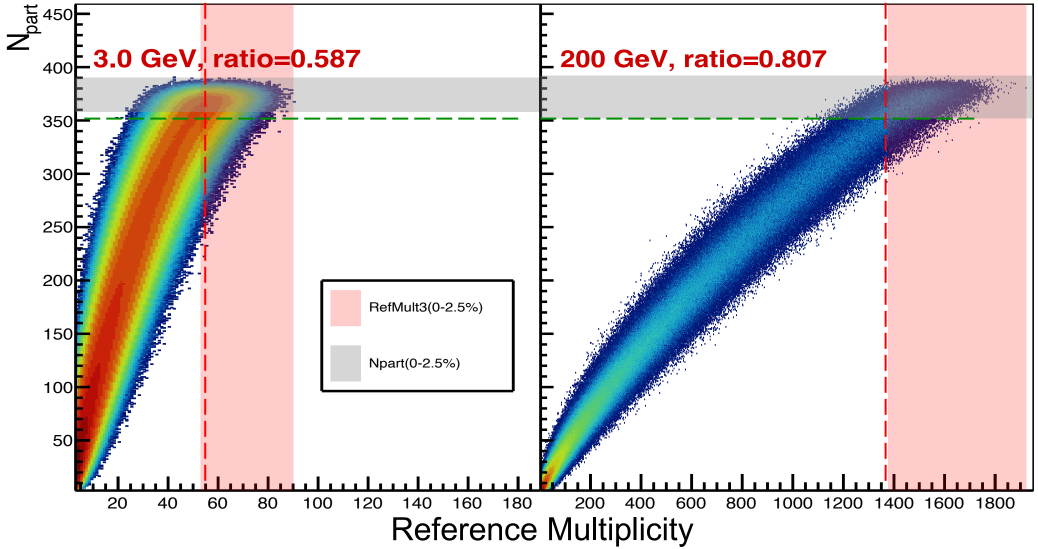


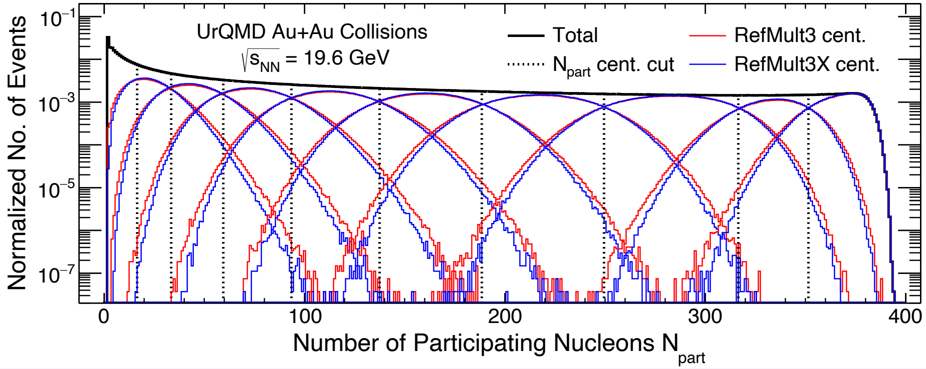
STAR 3GeV data:
Phys.Rev. C107, 024908 (2023)

Z. Sweger: (STAR) QM2025

Collision Centrality Determination



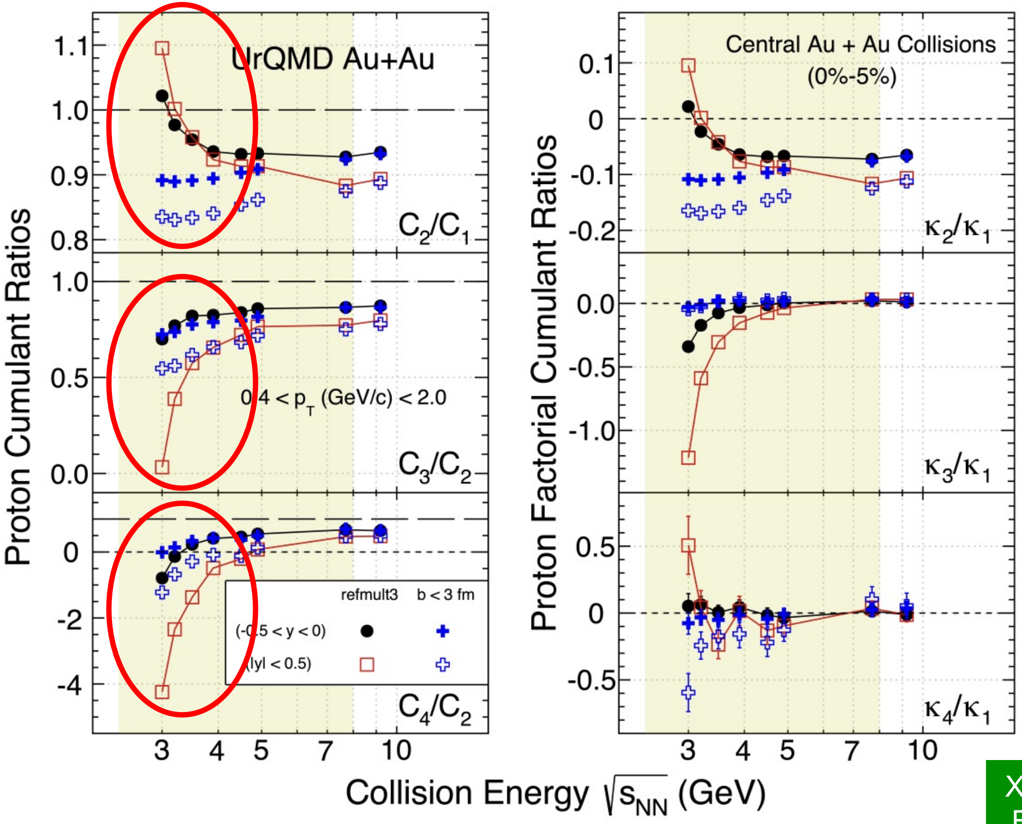




UrQMD3.4 simulation:

1) The lower the collision energy, the smaller of the measure reference multiplicity;
2) The higher the RefMult, the better the centrality determination → **the smaller the initial volume fluctuation**

Initial Volume Fluctuations



1) **Initial Volume Fluctuation**: The collision centrality is determined by charged particle multiplicities.

2) Simulations indicate that effects of the initial volume fluctuations becomes stronger at lower collision energies, which leads to the observed rapidly increase or decrease of κ_2/κ_1 and κ_3/κ_1;

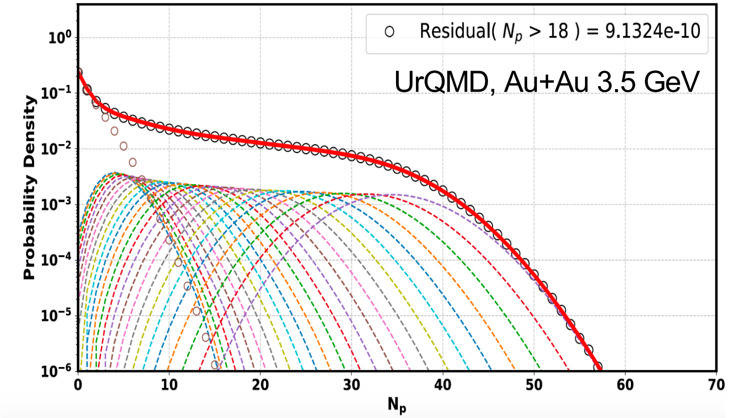
3) At lower energies, as the centrality resolution becomes poorer, initial volume fluctuations become more significant

X. Zhang, Y. Zhang, XFL, N. Xu, Chin. Phys. C 50, 011003 (2026)
B. Friman, V. Koch, arXiv : 2511.11869

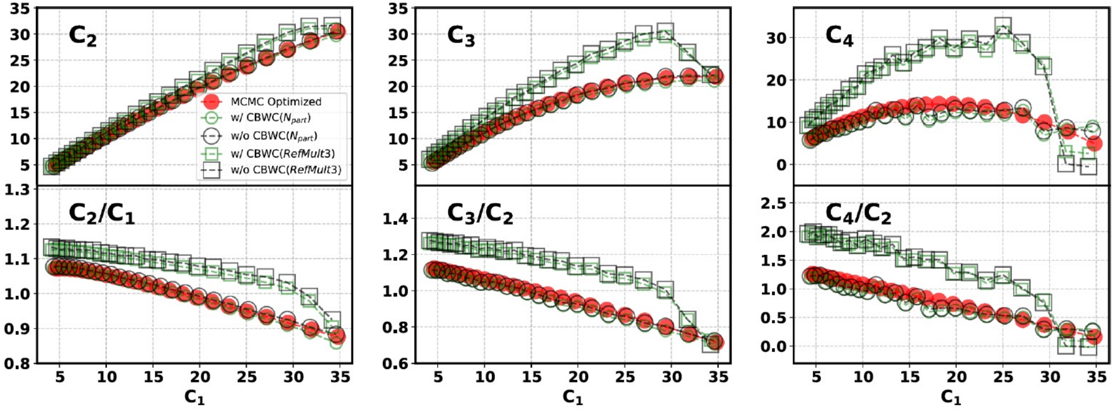
A New Approach

ZH. Wang, XF. Luo, Phys.Lett. **B871**, 139984(2025)

New



UrQMD, Au+Au 3.5 GeV



Edgeworth expansion :

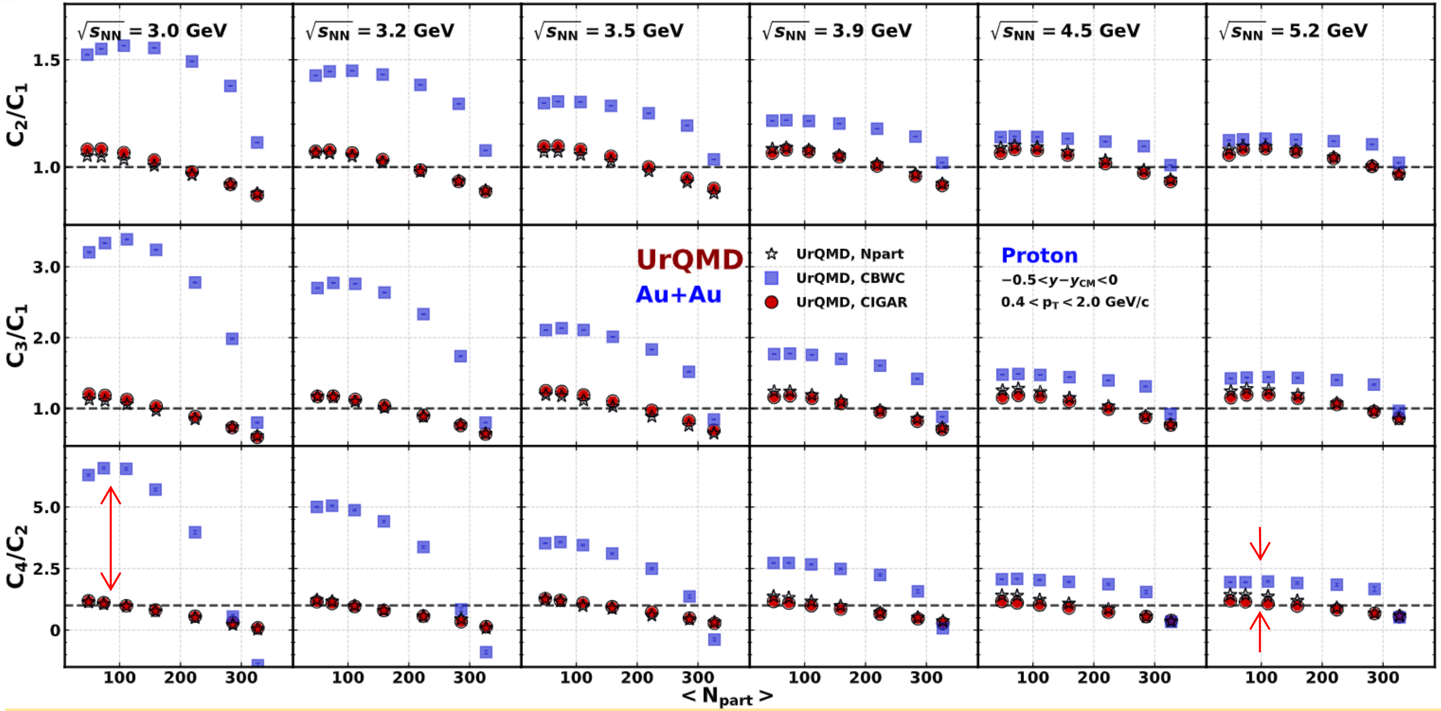
$$\sigma p(\sigma x) = Z(x)\left\{1 + \sum_{s=1}^{\infty}\left[\sigma^s \sum_{\{k_m\}} He_{s+2r}(x)\prod_{m=1}^{s}\frac{1}{k_m!}\left(\frac{S_m+2}{m+2}\right)^{k_m}\right]\right\}$$

where Chebyshev-Hermite polynomials H_{e_n} is defined as: $H_{e_n}(x) = (-1)^n exp(x^2/2)\frac{d^n}{dx^n}exp(-x^2/2)$

Ref. Multiplicity
New approach

1) Using Edgeworth expansion to reconstruct the proton number distribution with cumulant as parameters;
2) Simulations: The new approach is effective to suppress the initial volume fluctuations

More Simulations



Ref. Multiplicity

New approach

Z.H.Wang, X.F.Luo, Phys.Lett. **B871**, 139984(2025)

1) The new approach seems converging to the N_{part}-based centrality results, indicating the method can effectively suppress volume fluctuations. At higher energy, the effect is less;

2) We are working on the associate systematic uncertainties

Summary

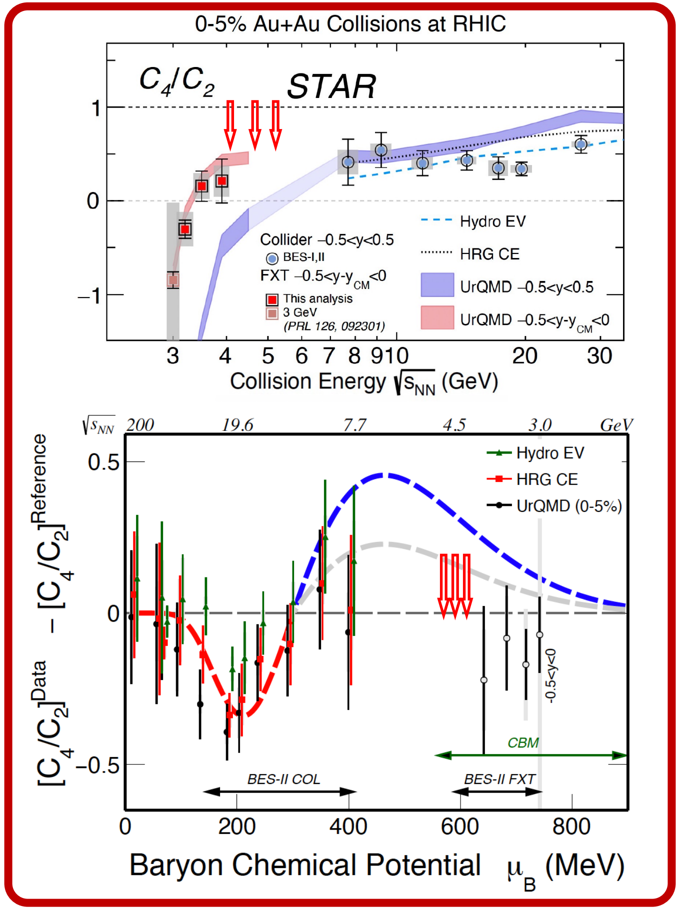
- Precision measurement of (net-)proton fluctuations in Au+Au collisions from RHIC BES-II:

  Collider energies: for net-proton C_4/C_2 in central collisions, deviations of 2-5σ are observed w.r.t non-CP references at 19.6 GeV!

  FXT energies: proton C_4/C_2 in central collisions are consistent with UrQMD calculations at 3.0 – 3.9 GeV while low orders changing trends and deviate from the transport model calculations

- STAR is working on a new analysis framework to determine the collision centrality, in order to suppress the initial volume fluctuation. Reanalyzing all data sets including 4.2, 4.5 and 5.2 GeV Au+Au collisions is under way;

- Modeling with dynamical effects including critical fluctuations and non-equilibrium effects are crucial to understand the experimental data



Collectivity

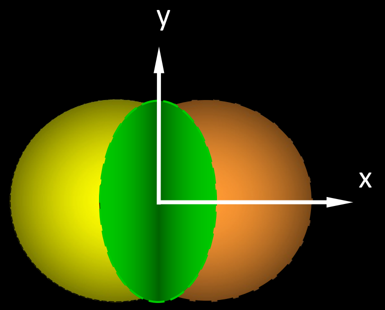
$$\partial_\mu[(\varepsilon + p)u^\mu u^\nu - pg^{\mu\nu}] = 0$$
$$\partial_\mu[s\, u^\mu] = 0$$

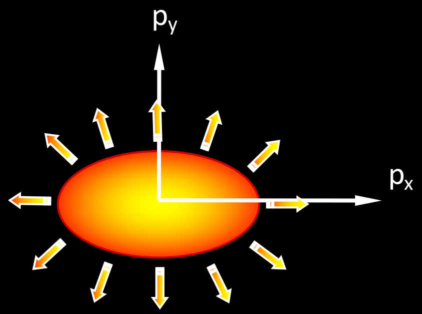
$$\frac{d^2N}{p_T dp_T d\varphi} = \frac{1}{2\pi}\frac{dN}{p_T dp_T}\left\{1 + \sum_{n=1}^{\infty} 2v_n(p_T)cos[n(\varphi - \Psi_R)]\right\}$$

– v_1 Directed flow;
– v_2 Elliptic flow; – v_3 Triangle flow

Anisotropy Parameter v_2

coordinate-space-anisotropy ⇨ momentum-space-anisotropy

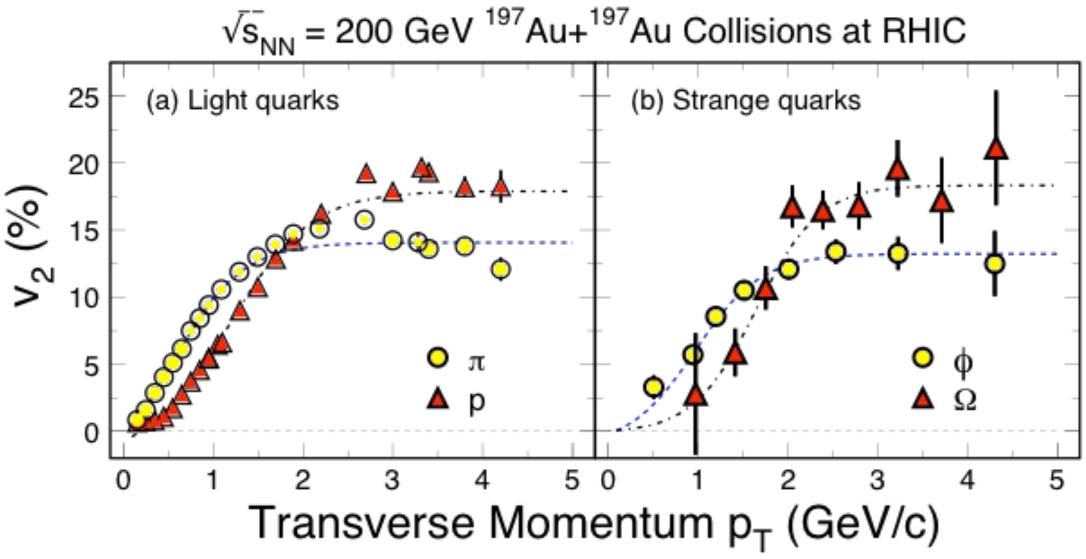




$$\varepsilon = \frac{\langle y^2 - x^2 \rangle}{\langle y^2 + x^2 \rangle} \qquad v_2 = \langle cos2\varphi \rangle, \qquad \varphi = tan^{-1}\left(\frac{p_y}{p_x}\right)$$

Sensitive to initial/final conditions, EoS and degrees of freedom

Partonic Collectivity at RHIC



STAR: PRL**116**, 62301(2016)

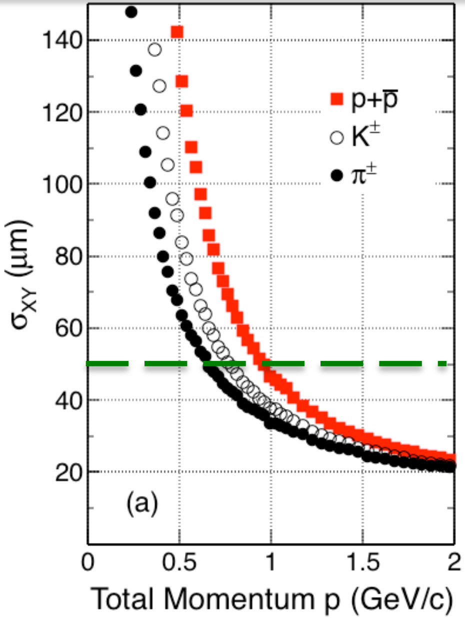
- ✓ Low p_T (≤ 2 GeV/c): hydrodynamic mass ordering
- ✓ High p_T (> 2 GeV/c): ***number of quarks scaling (NCQ)***

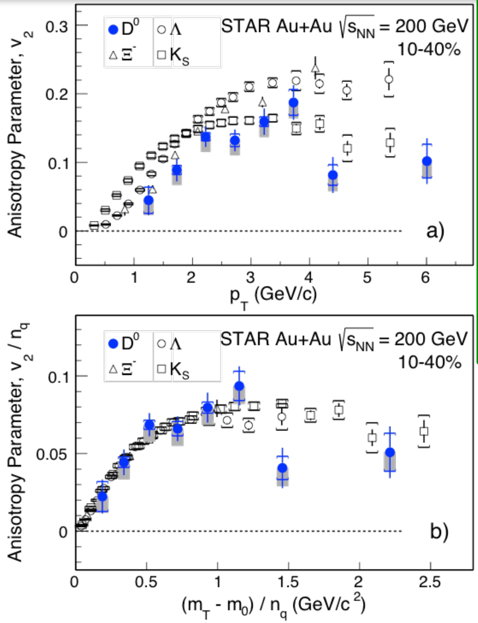
u-, d-, and s-quarks flow!

- ➢ **Partonic Collectivity!**
- ➢ **De-confinement Au+Au collisions at RHIC!**

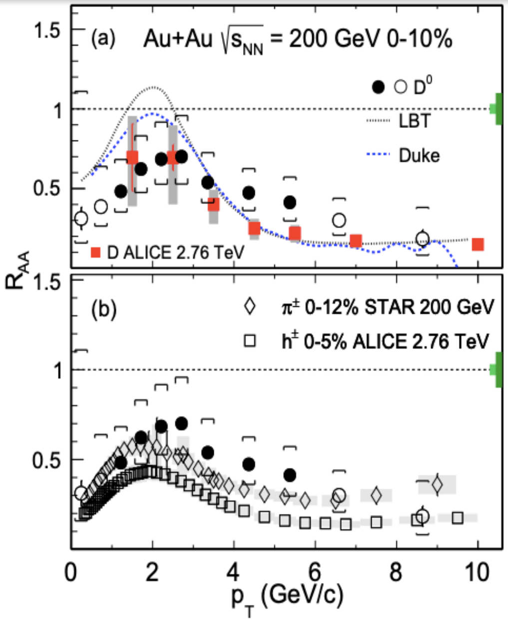
STAR: PRL**116**, 62301(2016)

Heavy Flavor D^0 Collectivity at HRIC





PRL**118**, 212301 (2017)



PRL**113**, 142301 (2014)
PRC**99**, 034908(2019)

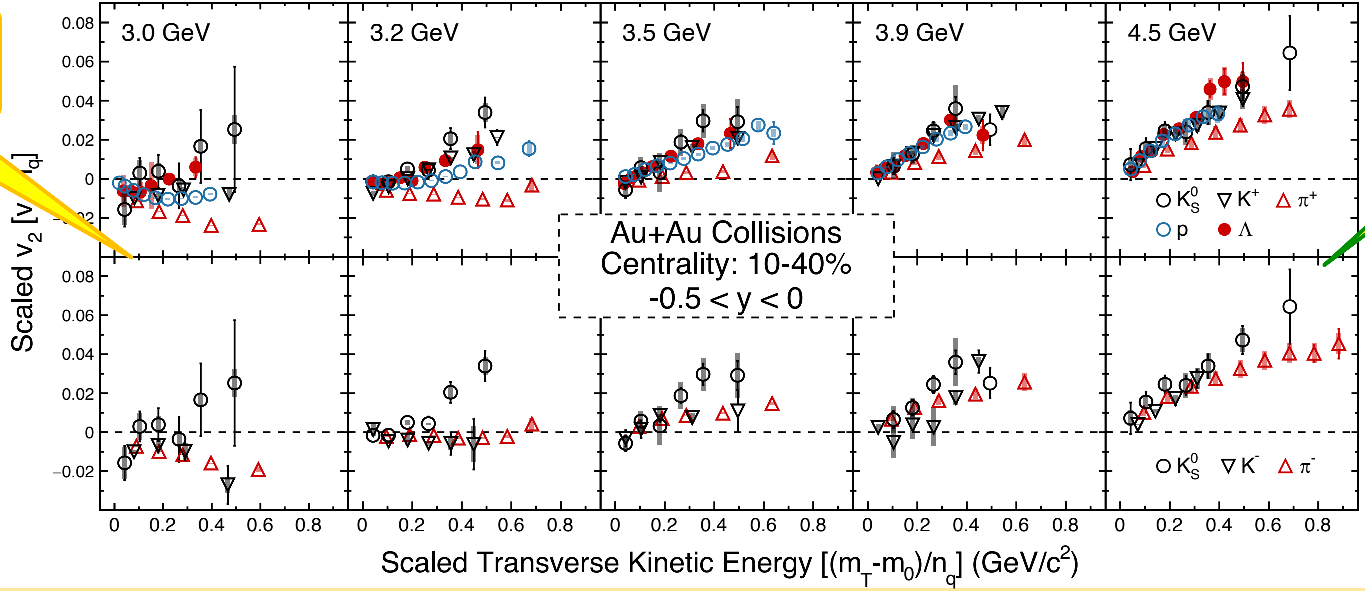
1) First application of MAPS technology in high energy collisions, excellent position resolution;
   - ➢ "These results suggest that charm quarks have achieved **local thermal equilibrium** with the medium created in such (200GeV Au+Au) collisions"
   - ➢ Hadronization via **quark coalescence** process

STAR: PRL**113**, 142301(14); PRC**99**, 034908(19); PRL**118**, 212301(17); PRL**123**, 162301(19); PRL**124**, 172301(20)

Onset of Partonic Collectivity

Hadronic Matter

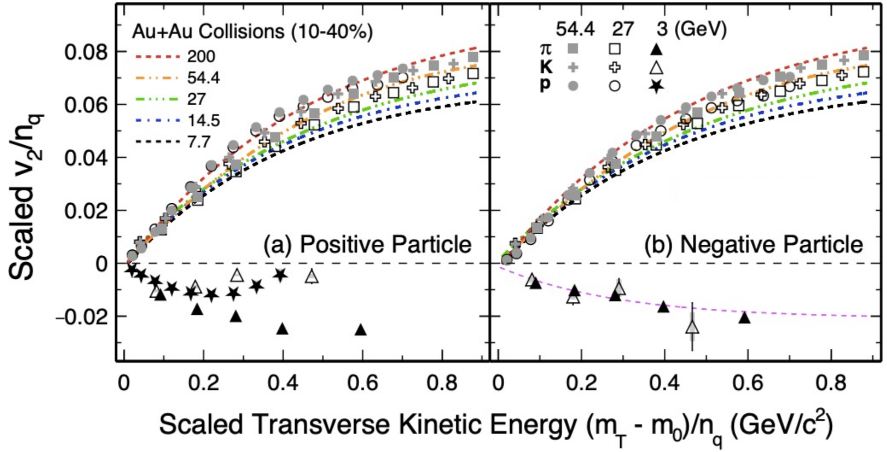
QGP

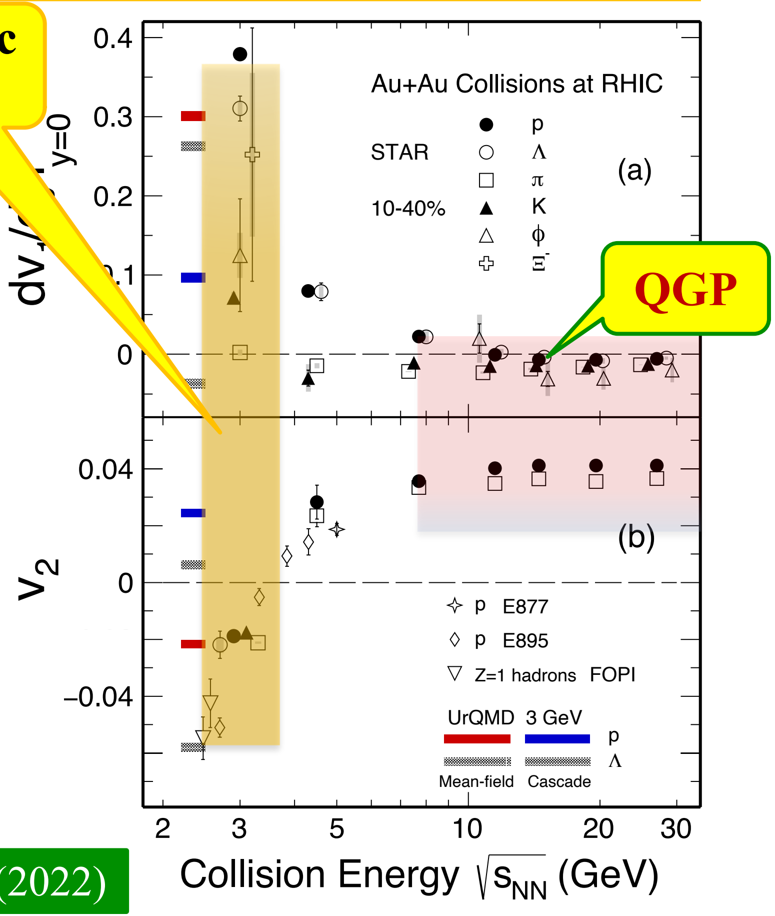


At **3 GeV**, NCQ scaling is absent, hadronic interactions dominant. But the scaling is gradually restored when energy increased to 4.5 GeV !

STAR: PLB**827**, 137003(2022)
PRL**135**, 072301(2025)

Disappearance of Partonic Collectivity

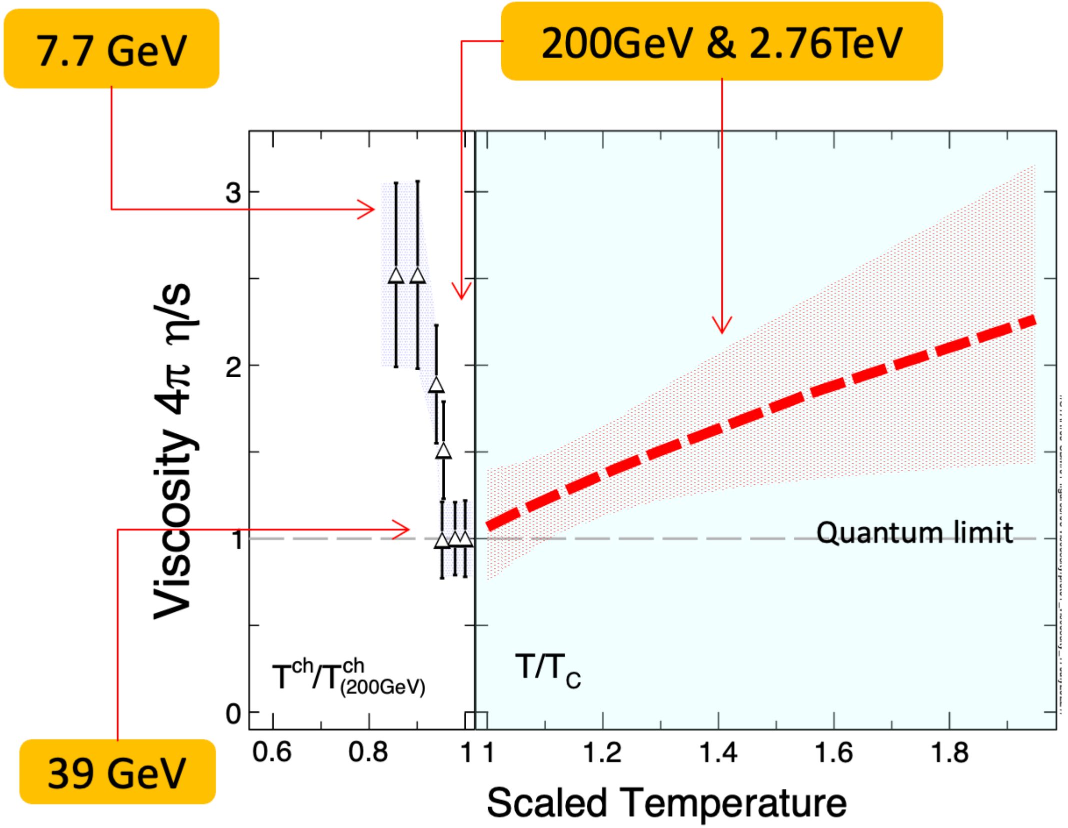




- At **3 GeV**, NCQ scaling is absent;
- Transport model calculations, with baryonic mean field, reproduce both v_1 and v_2 results;
- **hadronic interactions dominant!**

STAR: PLB**827**, 137003(2022)

Equation of State for Strong Interaction



1) Left-plot: Energy dependence of η/s extracted from light-flavor hadron v_2 and v_3. Right-plot: extracted from Bayesian fits to R_{AA} and v_2 at 200GeV collisions;

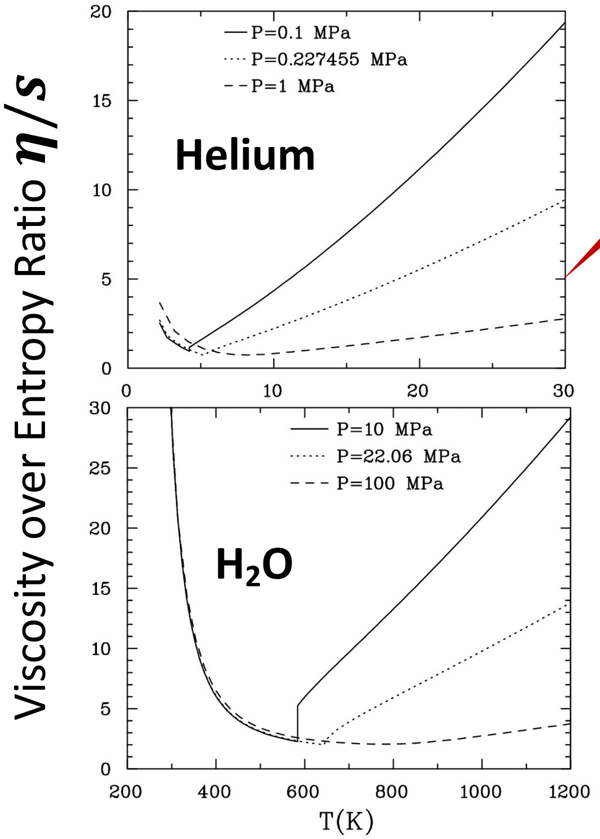
2) Both sides meet at the unity of the scaled temperature;

3) The values of η/s increase quickly below $\sqrt{s_{NN}}$ = 39 GeV → QGP dominants in higher energies;

→ **Evidence of the QCD transition!**

1) L.P. Csernai, J.I. Kapusta, L.D. McLerran, PRL**97** (2006) 152303
2) X.Dong, Y.J. Lee & R.Rapp, ARNPS, **69** (2019) 417
3) J.E.Bernhard, J.S.Moreland & S. Bass, Nat. Phys. **15** (2015) 1113
4) I. Karpenko, P. Huovinen, H. Petersen, and M. Bleicher, Phys.Rev.**C91**, 064901 (2015).
5) G.Nijs, W.van der Schee, U. Gürsoy and R. Snellings, PRL**126**, (2021) 202301
6) P. Braun-Munzinger, A. Rustamov, NX, arXiv: 2601.18666

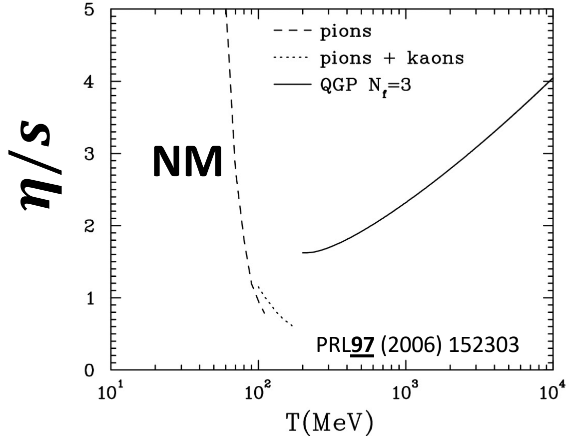
Strongly-Interacting, Low-Viscosity Matter

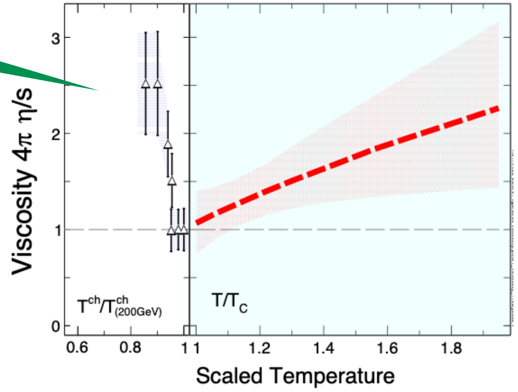


EM interaction
$\eta/s \sim 1$

L.P. Csernai, J.I. Kapusta, L.D. McLerran, PRL**97** (2006) 152303

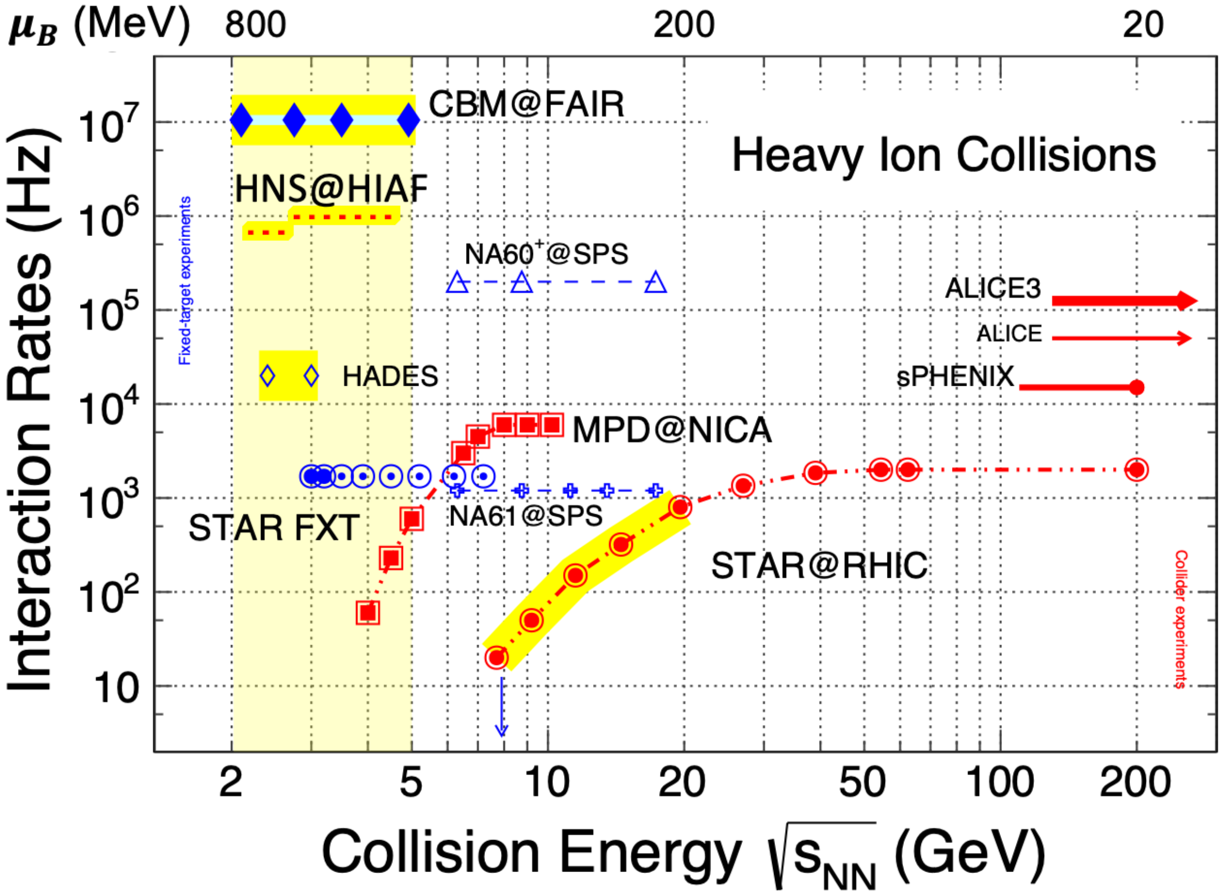
Strong Interaction
$\eta/s \sim 0.1$





- QGP matter in $\sqrt{s_{NN}} \geq 39$ GeV collisions!
- Universal behavior for phase transition!

Future Experiments



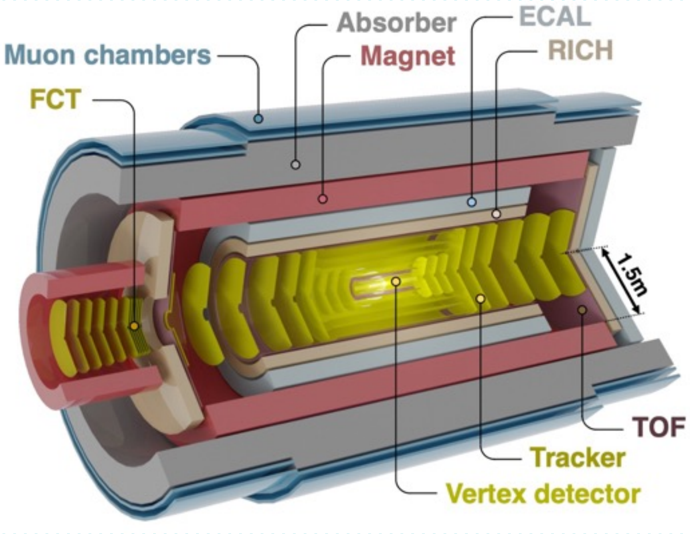
HIAF: 2025

FAIR: 2028

ALICE3: 2034

Future Experimental Opportunities

ALICE3@LHC



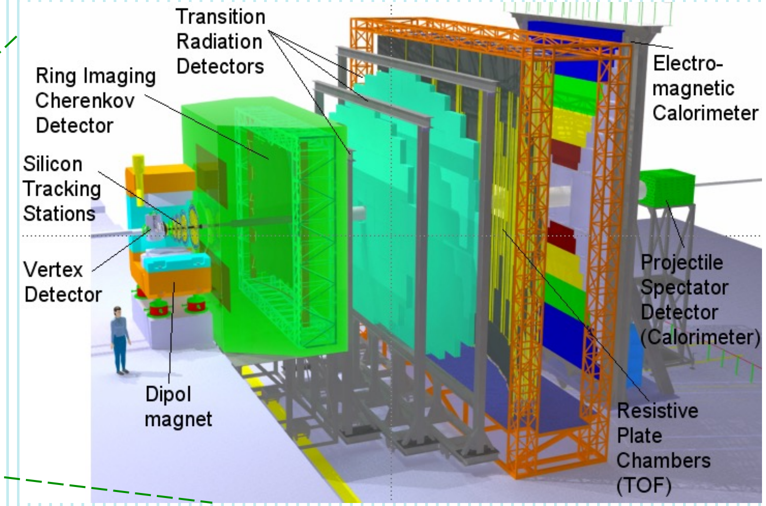
Properties of QGP and Search for CGC!

ALICE FoCAL $x \sim 10^{-6}$

Future Experimental Opportunities

CBM@FAIR

1) **QCD critical point**
2) **High μ_B properties**



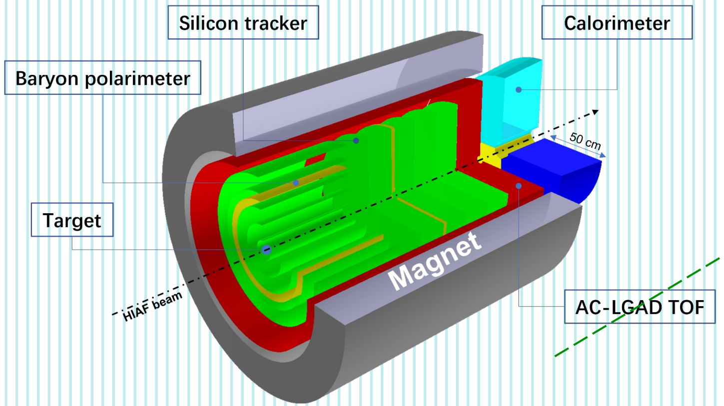
FAIR

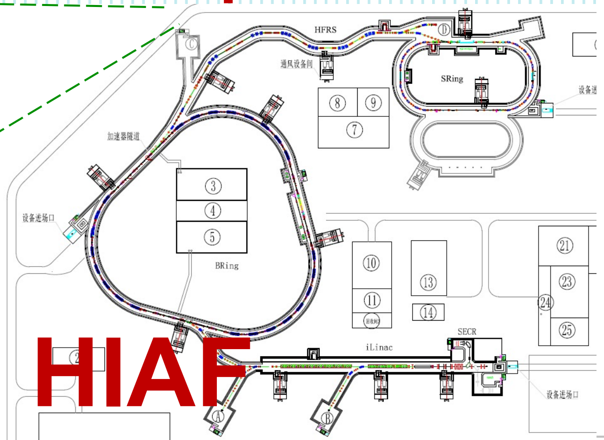
Future Experimental Opportunities

H-NS@HIAF

（超子-核子谱仪）

1) **Polarizations of proton and Λ;**
2) **High μ_B properties and the QCD critical point**





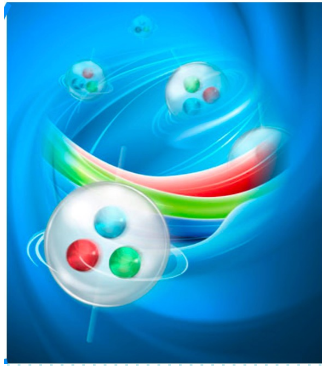
Outline

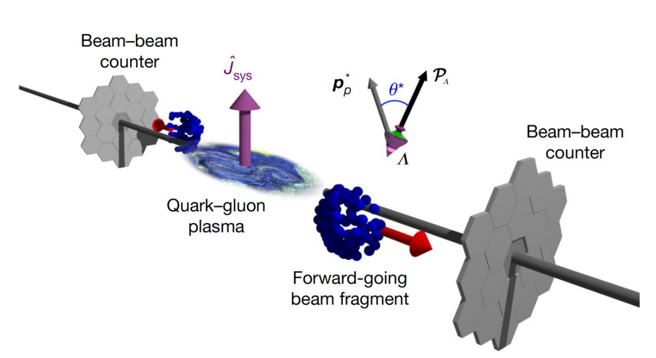
1) Introduction

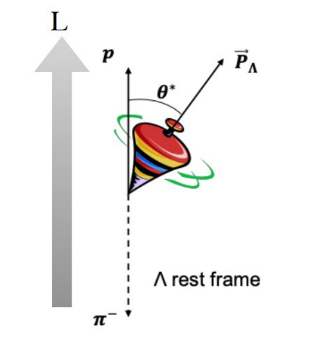
2) Results from RHIC BES
- (Net-) Proton Distributions
- Initial Volume Fluctuation at Low Energy Collisions
- Collectivity

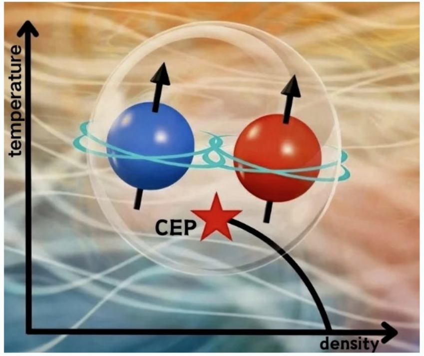
3) Polarization Measurements (?)

Polarization Measurements



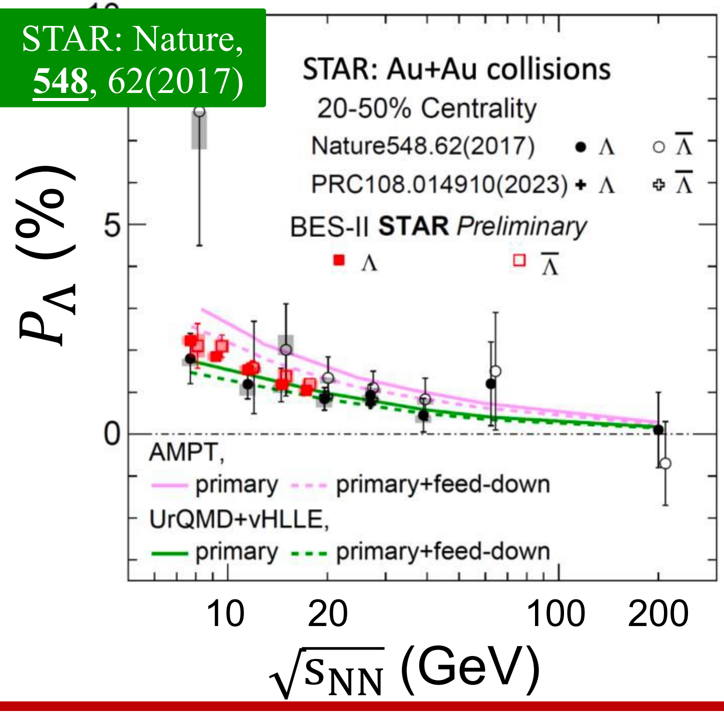


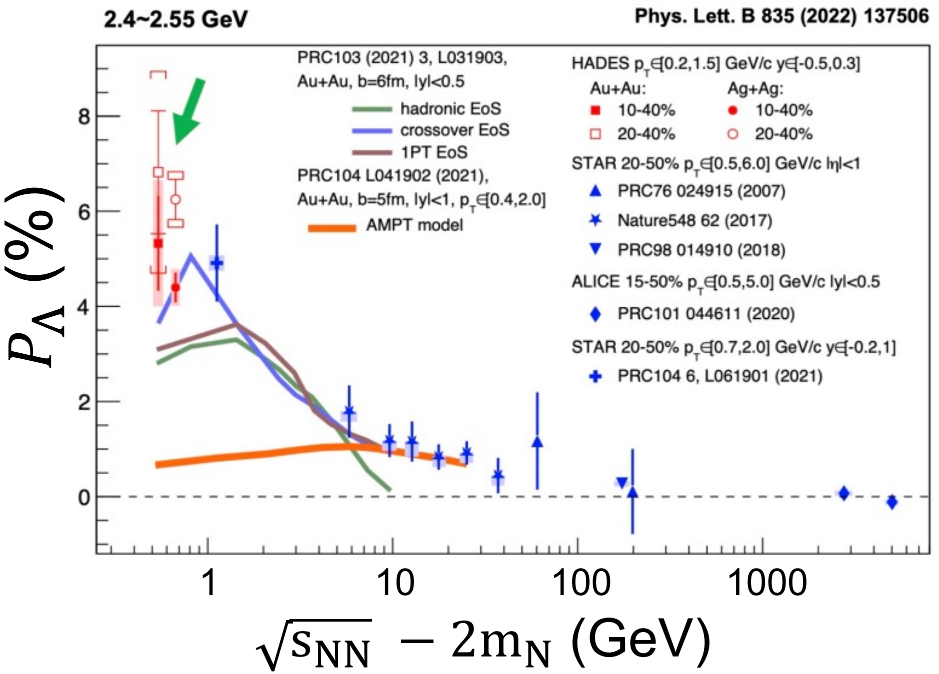




Results on Λ-Global Polarizations

STAR: Nature, **548**, 62(2017)





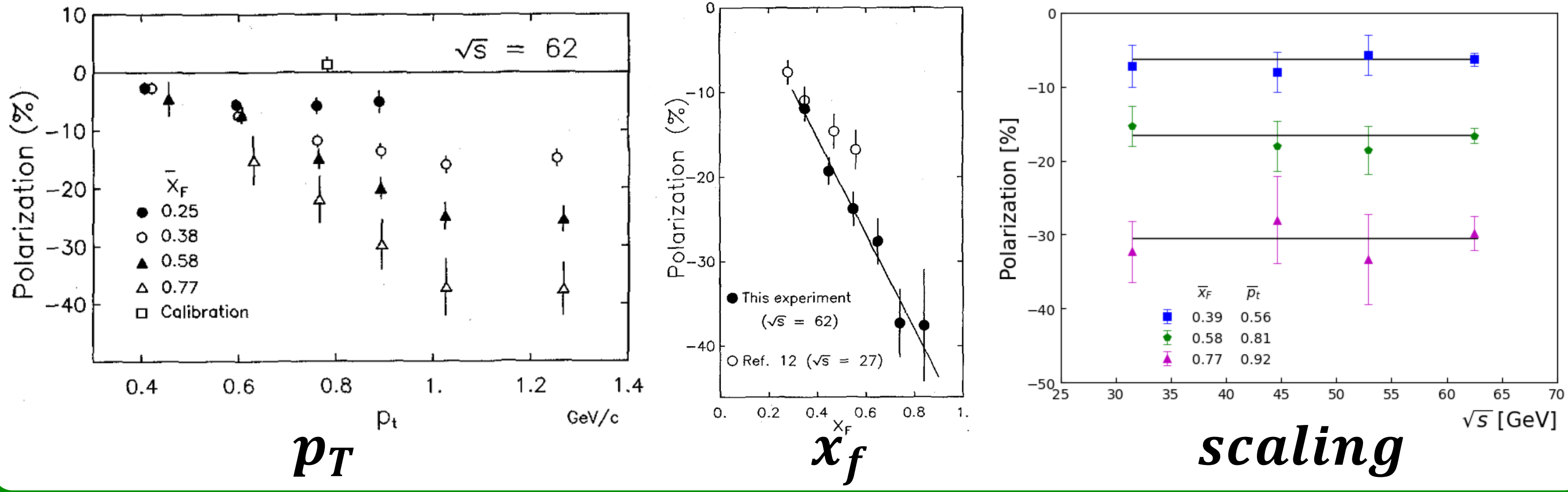
1) Observed Λ-global polarization: along the direction of the total angular momentum and increased as collision energy decreases!
2) No theory fully explain these data, especially at low energies!

$\langle \mathbf{w} \rangle \approx (\mathbf{9} \pm \mathbf{1}) \cdot \mathbf{10^{21}/sec}$

"The most vortical fluid"

Λ –Polarization: x_f- & p_T-scaling (?)

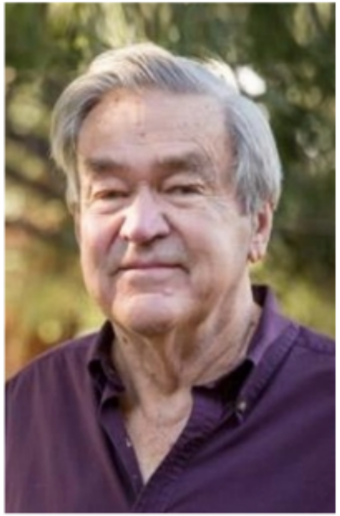
R608: 10.1016/0370-2693(87)91556-5



Questions:

1) Origin of the Λ polarization: **Collision dynamics? Intrinsic spin structure?**
2) In p+A and A+A collisions, both global and local Λ polarization have been observed. What is the relation between those and Λ polarization?

Spin and Strong Interactions



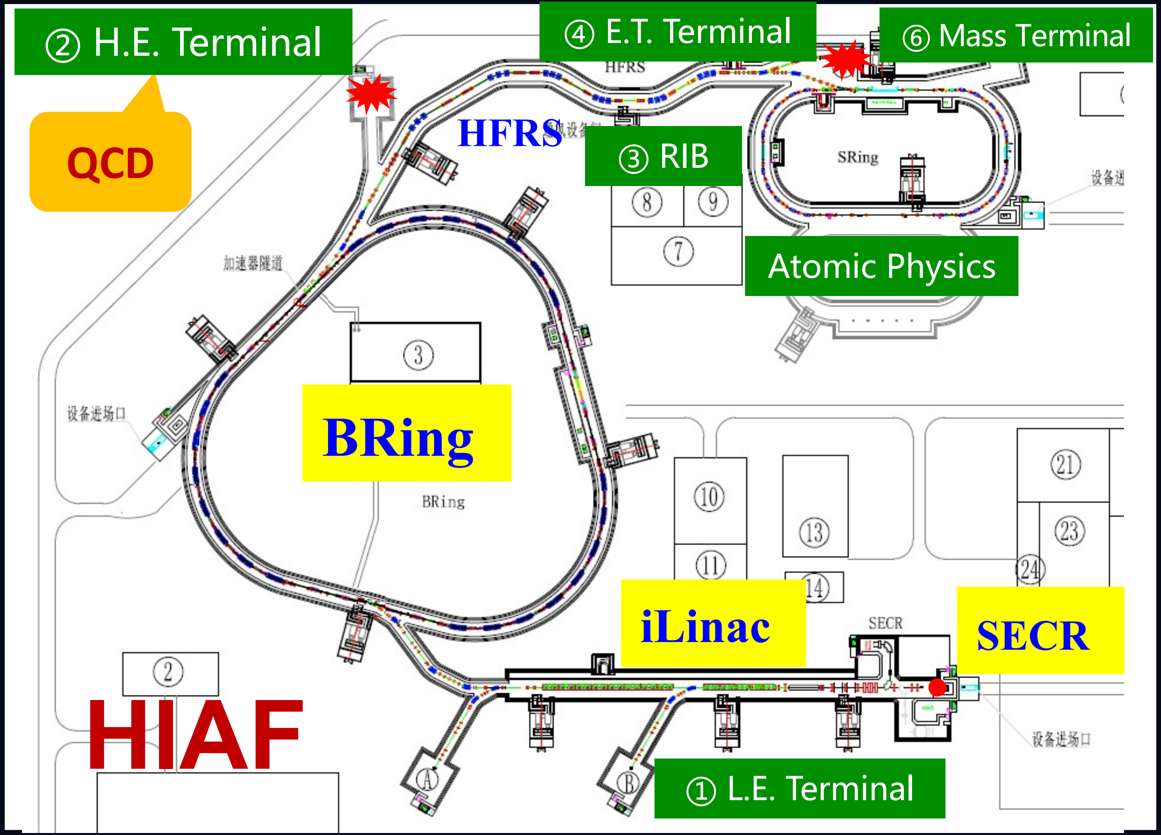
"Polarization data has often been the graveyard of fashionable theories. If theorists had their way, they would ban all experiments involving spin."

James D. Bjorken

Proc. Adv. Res. Workshop on QCD Hadronic Processes, St. Croix, Virgin Islands (1987)

High Intensity heavy-ion Accelerator Facility

(HIAF, Huizhou, China)



HIAF Physics：

(i) Atomic physics;
(ii) Nuclear physics;
(iii) Applied research in biology and material science etc.

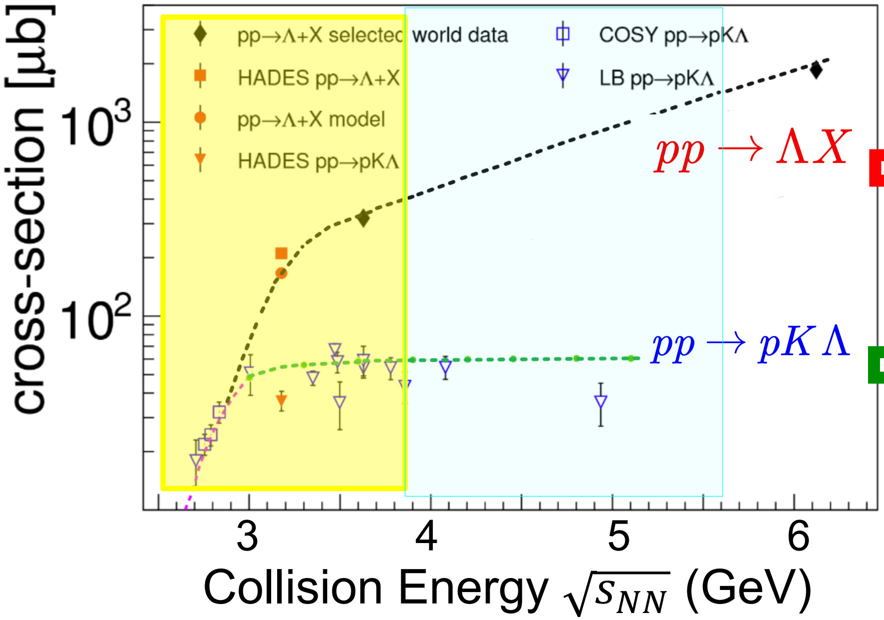
HIAF Commission started in 2025

Science
Volume 390, Issue 6773
Nov 2025

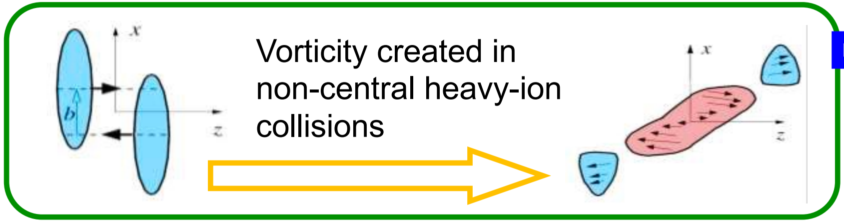
HIAF Beam Parameters

Ion	Intensity (ppp)	Kinetic Energy
$^{238}U^{35+}$	2.0×10^{11}	0.84 (GeV/u)
$^{238}U^{76+}$	5.0×10^{10}	2.5 (GeV/u)
$^{129}Xe^{27+}$	3.6×10^{11}	1.4 (GeV/u)
$^{78}Kr^{19+}$	5.0×10^{11}	1.7 (GeV/u)
$^{40}Ar^{12+}$	7.0×10^{11}	2.3 (GeV/u)
$^{18}O^{6+}$	8.0×10^{11}	2.6 (GeV/u)
protons	5.0×10^{12}	9.3 (GeV/u)
	4.0×10^{14} (HIAF-U, EicC)	32 (GeV/u)

Λ Production and Polarization



HIAF HIAF-U



(1) p + p (A) → $\Lambda + X$

Polarization puzzle:
ZT Liang, and C. Boros, PRL**79**, 3608 (1997); PRD**61**, 117503 (2000). H Dong and ZT Liang, PRD**70**, 014019 (2004); PRD**72**, 033006 (2005).

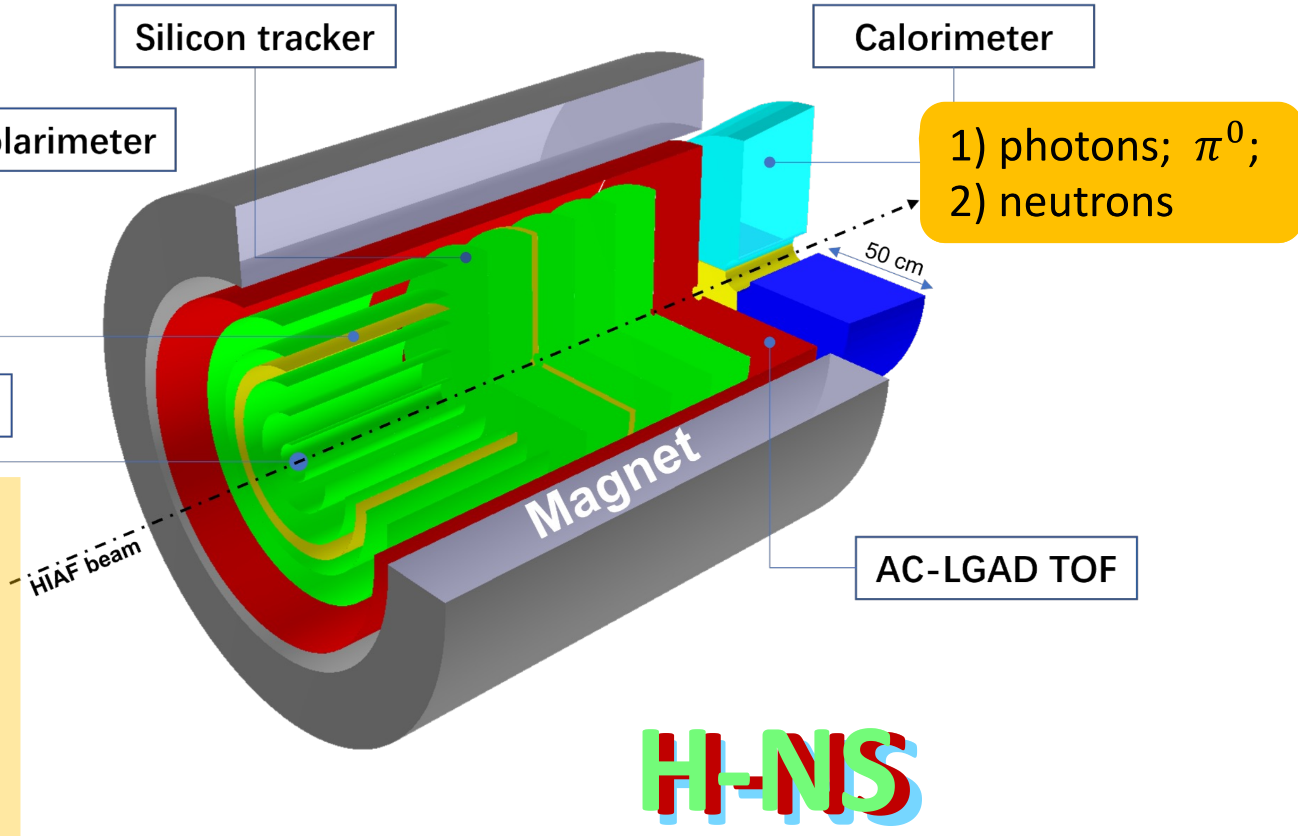
(2) p + p → $\Lambda + K + p$

Exclusive Process:
R Machleidt, K Holinde and C Elster, Phys. Rept.**149**, 1 (1987). BC Liu, BS Zou, PRL**96**, 042002 (2006).

(3) A + A→ $\Lambda + X$

Global Polarizations:
ZT Liang, XN Wang, PRL**94**,102301 (2005); PLB**629**, 20 (2005). JH Gao, *et al.*, PRC**77**, 044902 (2008).

Concept: Hyperon-Nucleon Spectrometer



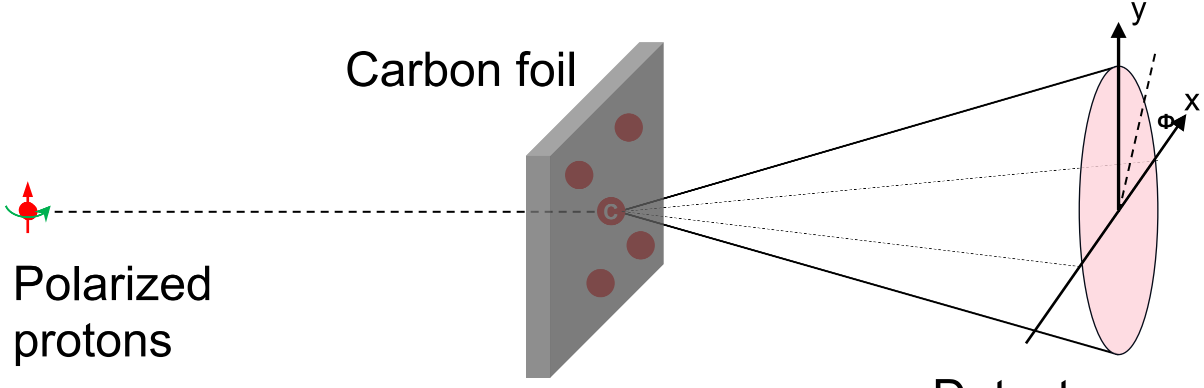
Participating Institutes: ≥ 20 (China), more are welcome!

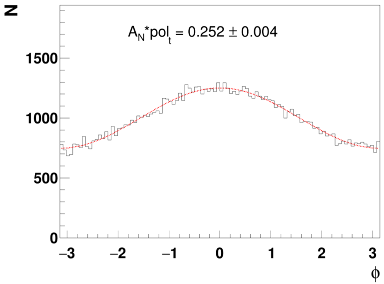
R&D Efforts: (1) Pixel tracker; (2) AC-LGAD; (3) **Baryon Polarimeter;** (4) Target systems; (5) Calorimeter; (6) FEE; (7) DAQ; (8) Magnet; (9) Beam line; (10) Mechanical structure design

Proton Polarimeter

Spin-dependent cross-section of p + p/C scattering:

$$\frac{d\sigma}{d\phi d\cos\theta} = \frac{1}{2\pi}\frac{d\sigma_0}{d\cos\theta}\left[1 + P_y A_N(\theta)\cos\phi\right]$$



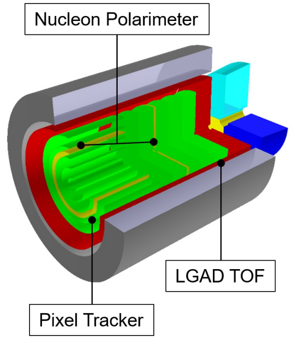


More protons to the left:
Left-right asymmetry

Widely used to measure polarized proton beam (PSI, TRIMUF, LAMPF, COSY, SATURNE, ZGS, KEK-PS, AGS, RHIC …)

Proton Polarimeter:
Yutie Liang: PRD**112**, L031502(2025)

Polarization Observable at H-NS



H-NS

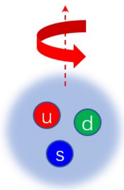
Reaction: p+p

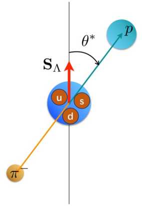
Event rate:1MHz

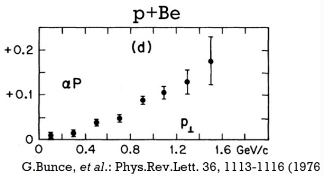
Time: 3 months

- pp → Λ+X N ~ 10^{11}
- pp → p+X N ~ 10^{13}
- pp → pKΛ N ~ 10^{10}

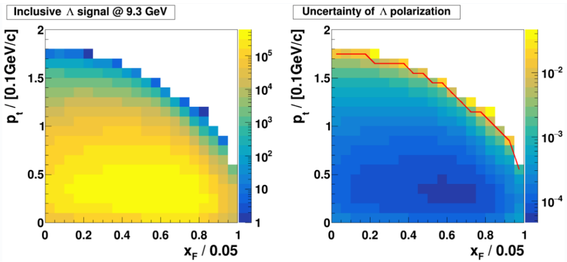
p p → Λ + X $\sigma_{stat.}$ < 0.01 2D:400 bins







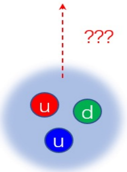
Λ polarization

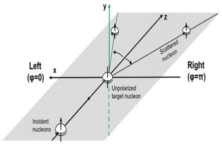


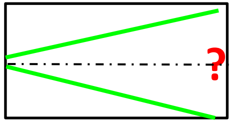
Projection @ H-NS

p p → p + X $\sigma_{stat.}$ < 0.02 2D:400 bins

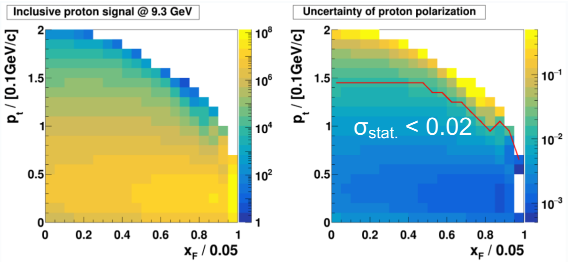
pC scattering ~ $10^{13}*4*10^{-4}$ = $4*10^{9}$





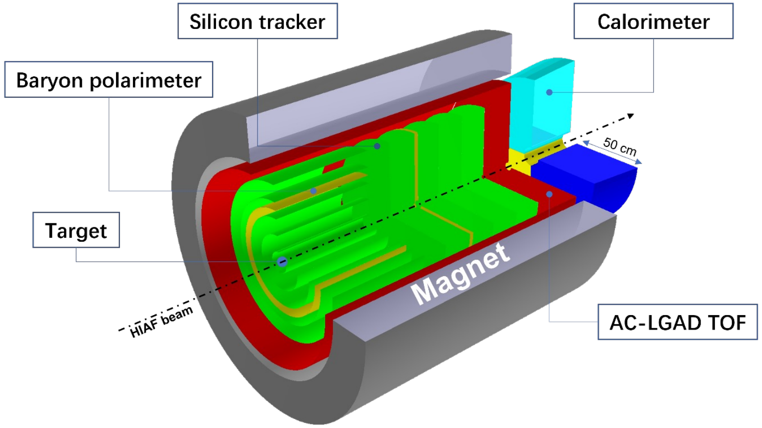


proton polarization



Projection @ H-NS

Hyperon-Nucleon Spectrometer (H-NS)



Participating Institute (21): 北京航空航天大学、北京师范大学、复旦大学、高能物理研究所、国科大、河南师范大学、湖州师范学院、华东师范大学、华南师范大学、**华中师范大学**、**近代物理研究所**、理论物理研究所、南开大学、清华大学、**山东大学**、香港中文大学 (深圳)、原子能研究院、郑州大学、**中科大**、中山大学

Subsystems：Silicon tracker, AC-LGAD, Target, Baryon polarimeter, Calorimeter, Electronics, DAQ, Magnet, Beamline, Mechanics + Engineering

I. Physics：

- Λ production and polarization (p+p)
  - Medium effect (p+A)
  - Global polarization of Λ hyperon (A+A)
- Hadron physics via p+p

II. Community：

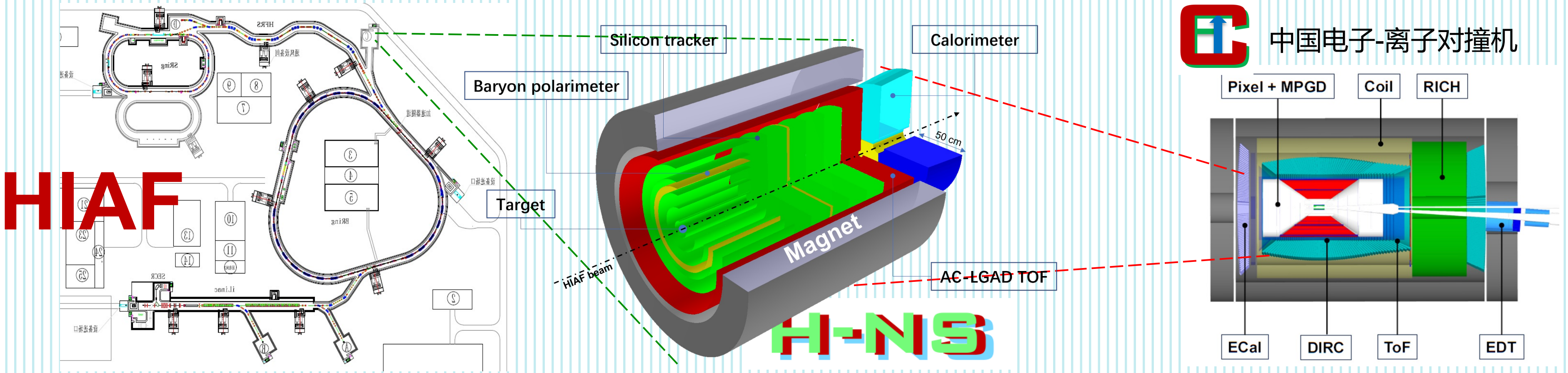
- Supports both communities of hadron structure and heavy-ion physics
- International participations are welcome!

III. Detector R&D

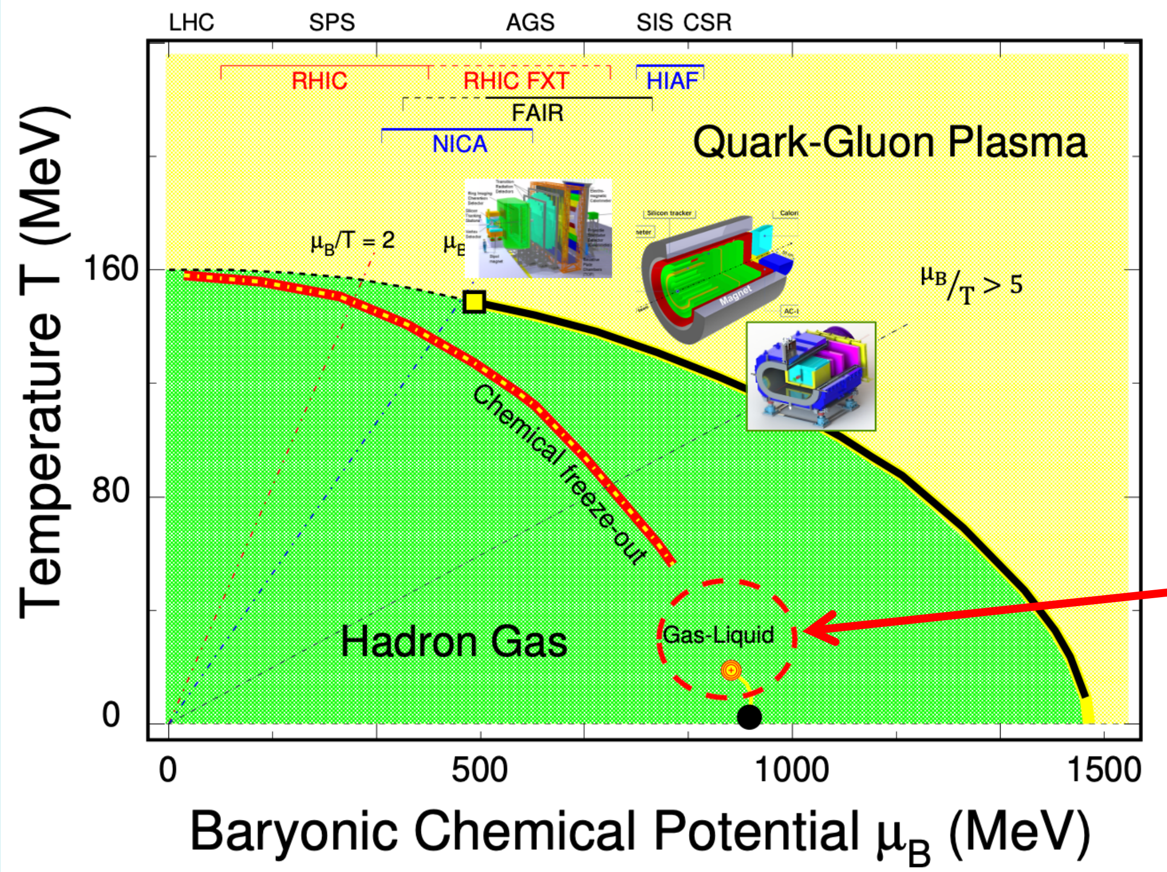
- Many parts are similar for CEPC, H-NS, EicC, and STCF: Save resources!
- H-NS: a detector R&D platform for EicC(½ EicC)

高能强子与核物理@HIAF:

1) **H-NS:** Large acceptance with full azimuthal coverage, High efficiency, Fast DAQ (~1M Hz). Energy scan within 3 – 9.3 GeV/u …
2) **p+p and p+A collisions:** Λ and p polarization, Hadron spectra, Spin structure, Spin-spin correlations, Hyper-nuclei production, BS， …;
3) **A+A collisions:** High μ_B properties: QCD critical point, Global polarizations, …



Nuclear Collisions and QCD Phase Diagram



At $\mu_B = 0$
$(ALICE, ATLAS, CMS, LHCb)$:

1) Property of QGP, smooth crossover transition;
2) Small-x physics: → search for **CGC**

At large μ_B $(CBM, H\text{–}NS, CEE)$ precision measurements:

1) **Search for 1st-order phase transition and QCD critical point;**
2) Polarizations of p & Λ;
3) **EOS with spin degree of freedom**;
4) **The fate of the liquid-gas transition;**
5) Baryon interactions → NN, NY, …

Acknowledgements:

STAR Collaboration

P.Braun-Munzinger, W.J.Fu , X.Dong, S.Esumi, F.Karsch, V.Koch, X.F.Luo, B.Mohanty, A.Pandav, A.Rustamov, K.Redlich, M.Stephanov, J.Stachel, J.Stroth, V.Vovchenko, Y.Zhang

// BLUE: Theory // **RED**: Exp. //

Many Thanks to the Workshop Organizers!

Thank you for your attention!