

三明康郎 先生 退職記念祝賀会及び最終講義・研究会

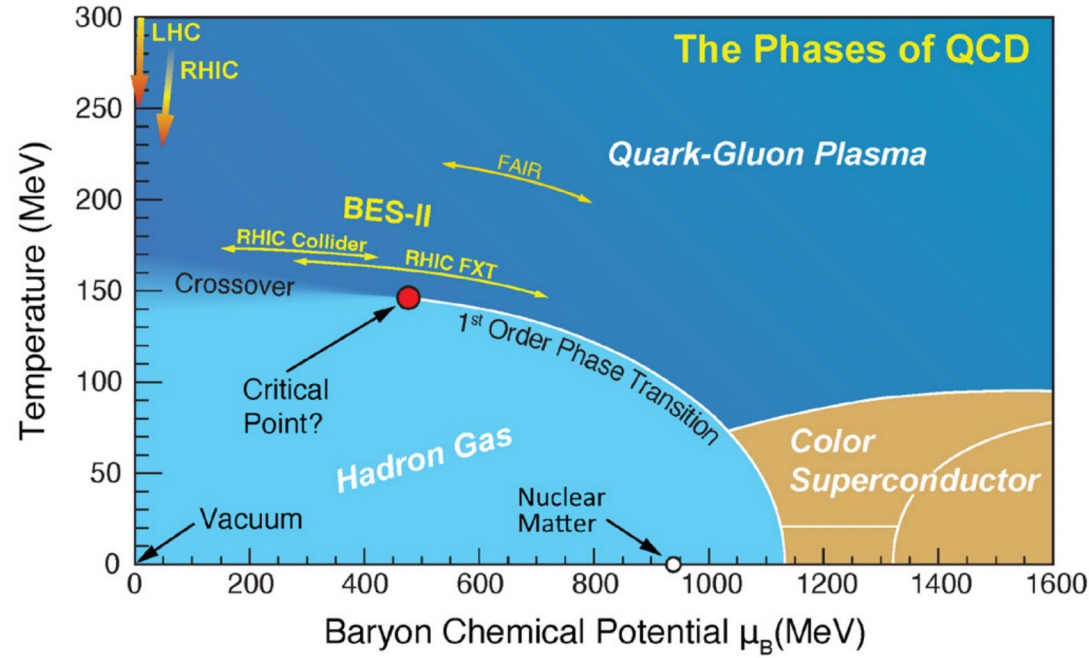
STAR実験から将来へ

QCD相図上の高温領域から高密度領域へ、臨界点・1次相転移の直接観測への挑戦

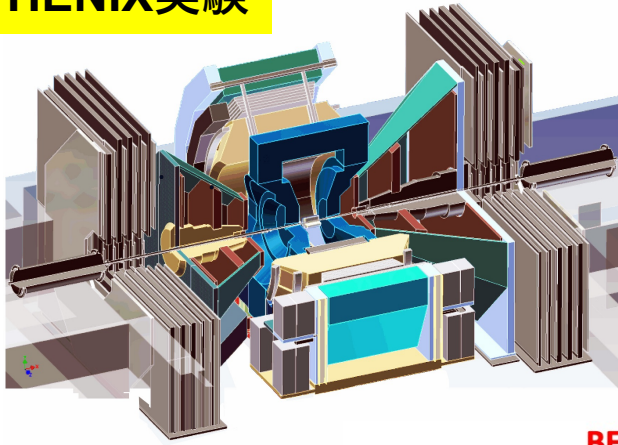
- STAR実験の最近の結果
- 将来計画や希望・夢
- 三明先生とのエピソード

筑波大学 数理物質系 物理学域
宇宙史研究センター クォーク・核物質
高エネルギー原子核実験グループ
江角 晋一

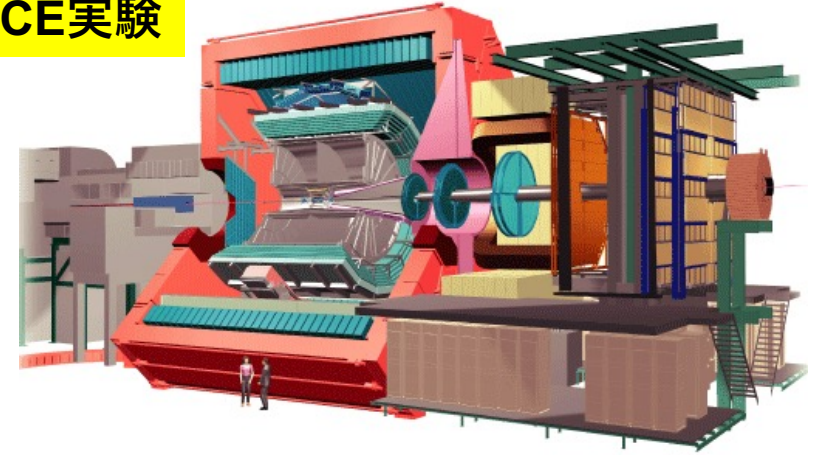
QCD phase diagram and phase structure at high-baryon density



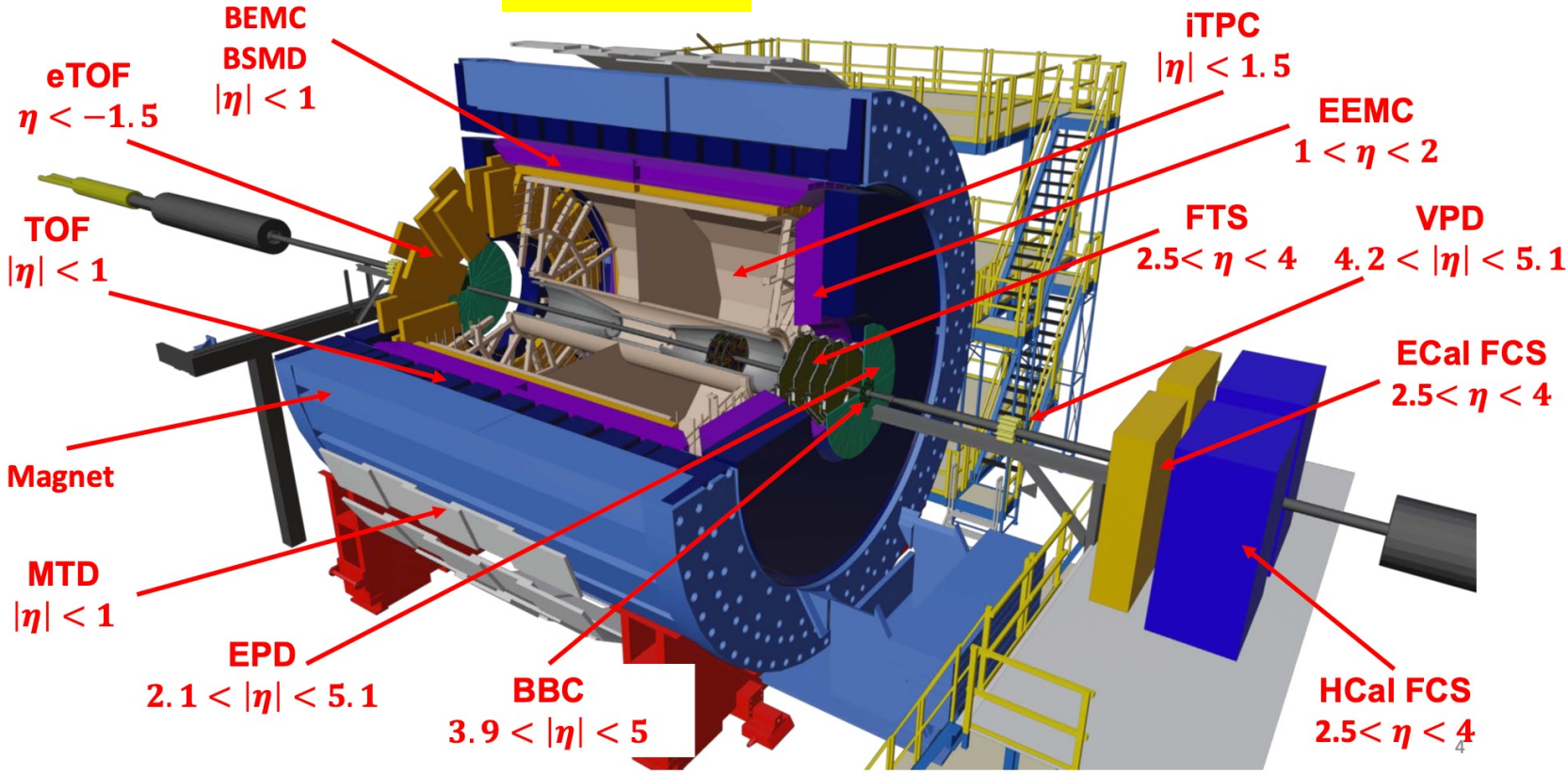
PHENIX実験



ALICE実験

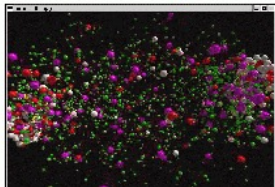
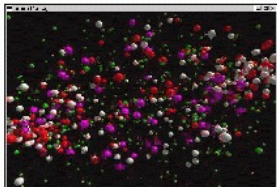
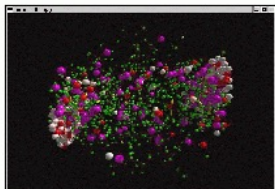
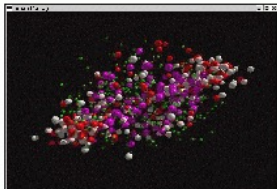
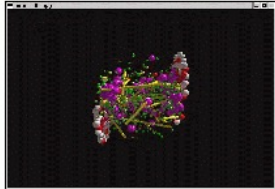
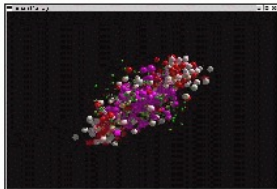
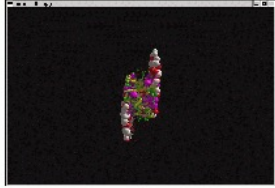
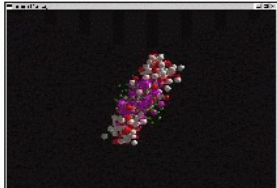
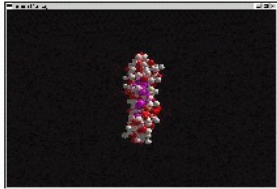
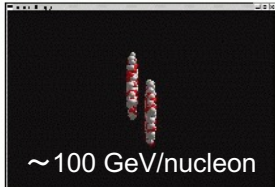
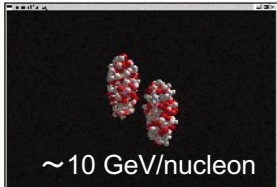


STAR実験

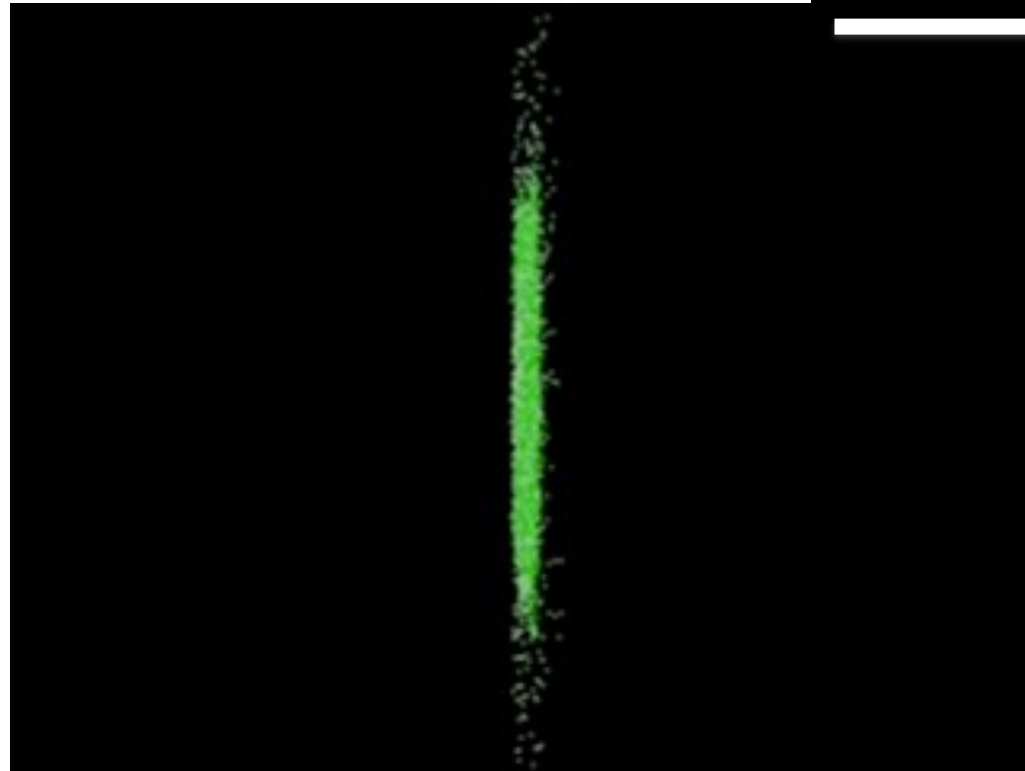
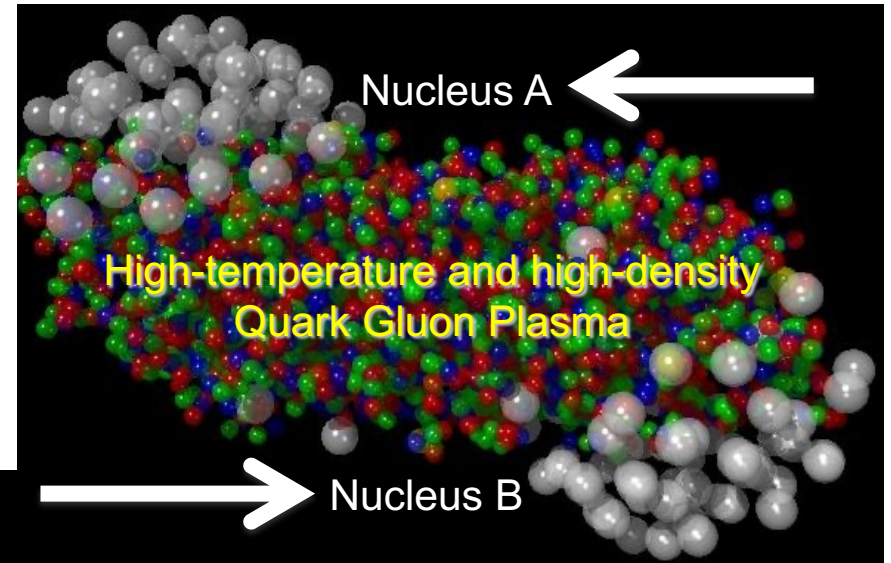


アメリカ
BNL/AGS :
E802/E866

スイス
CERN/SPS :
WA98/NA44

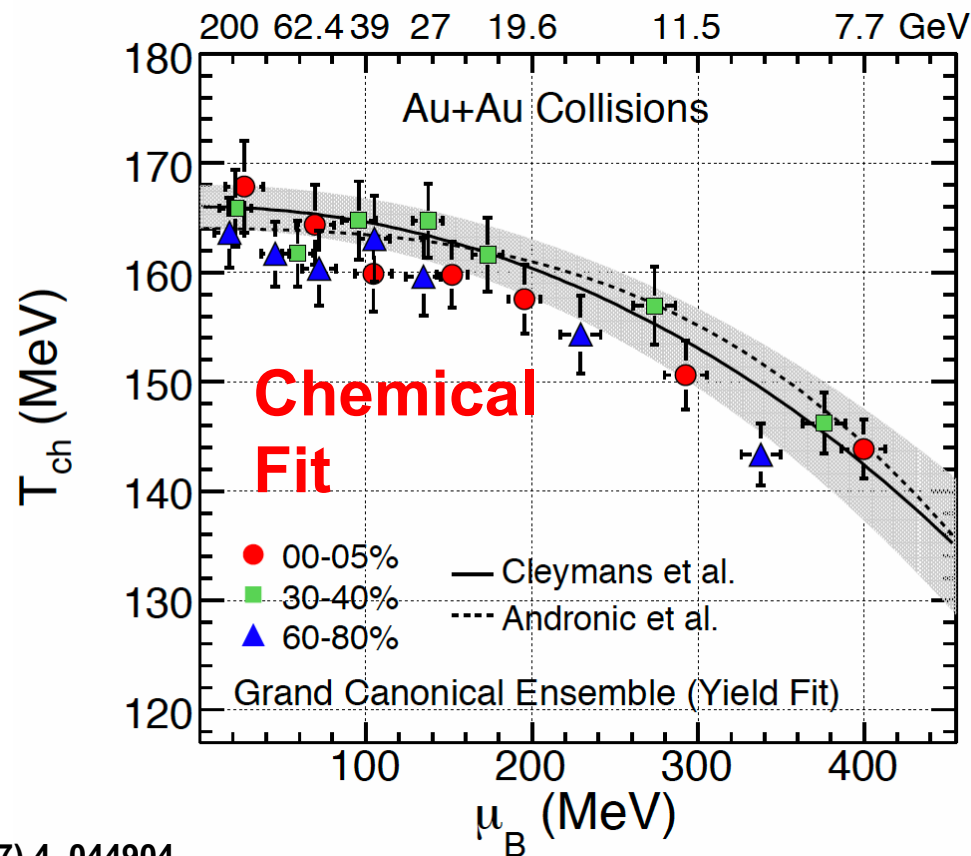
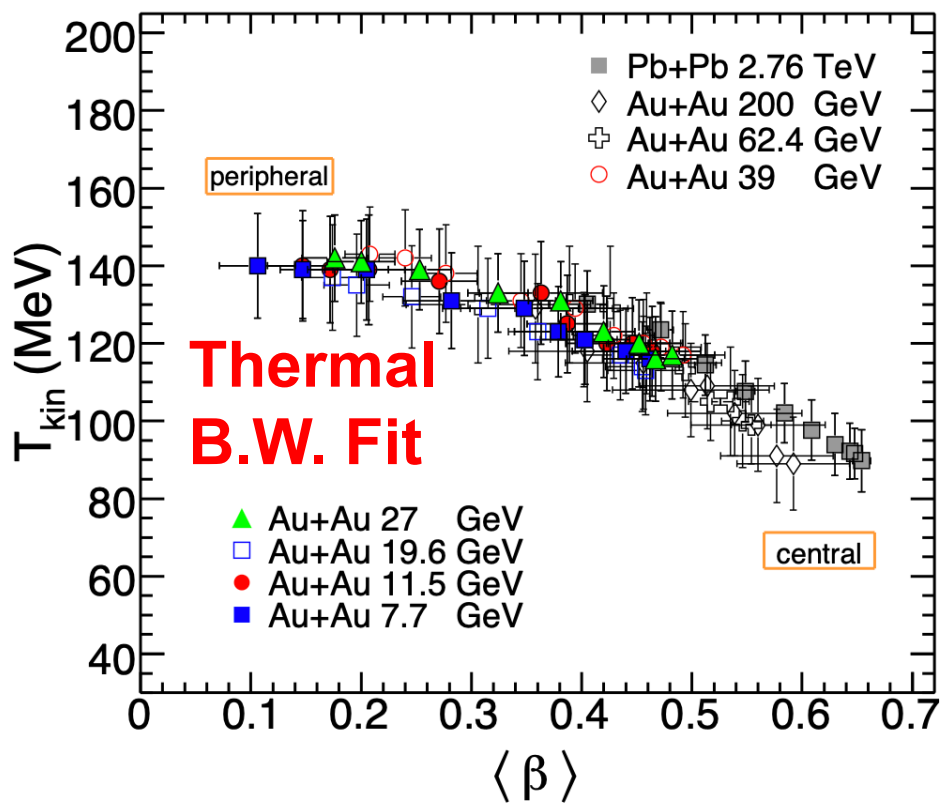


High-Energy Heavy-Ion Collisions and Beam Energy Scan



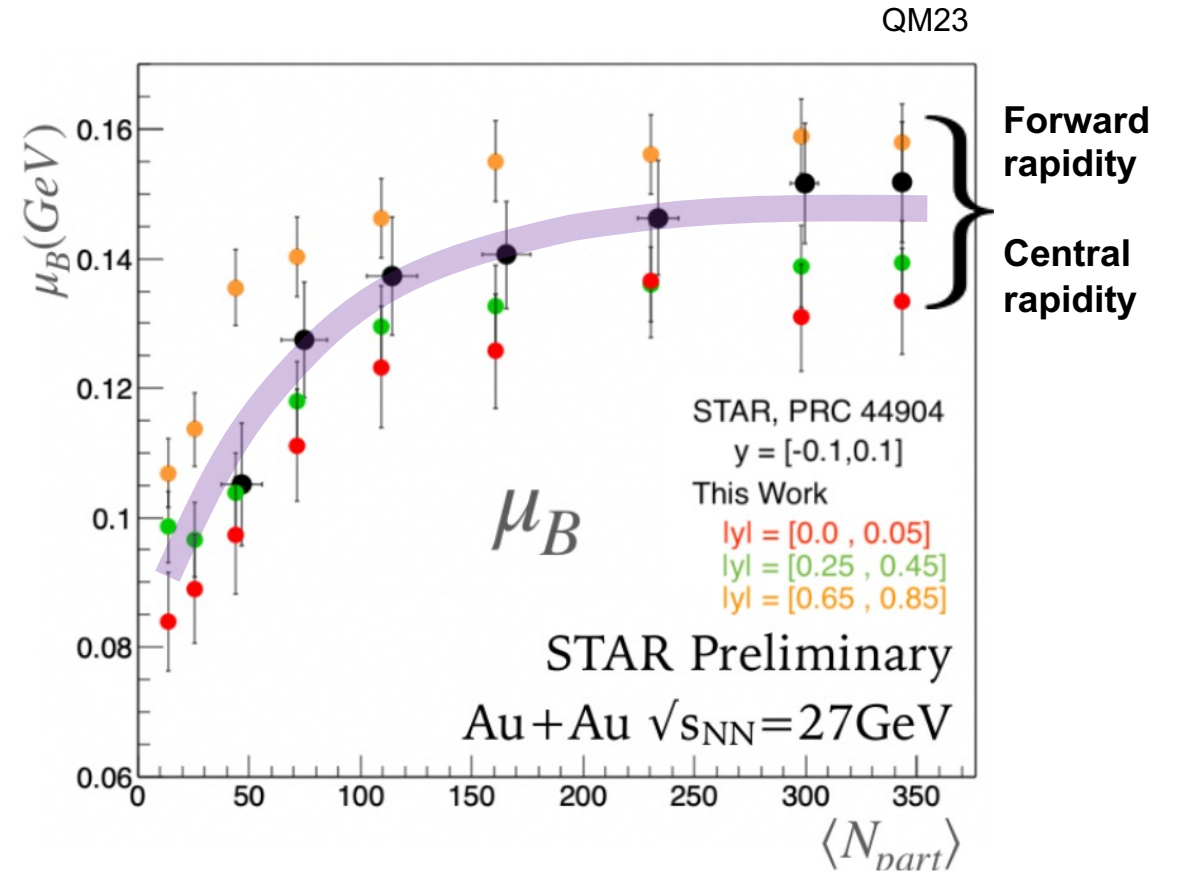
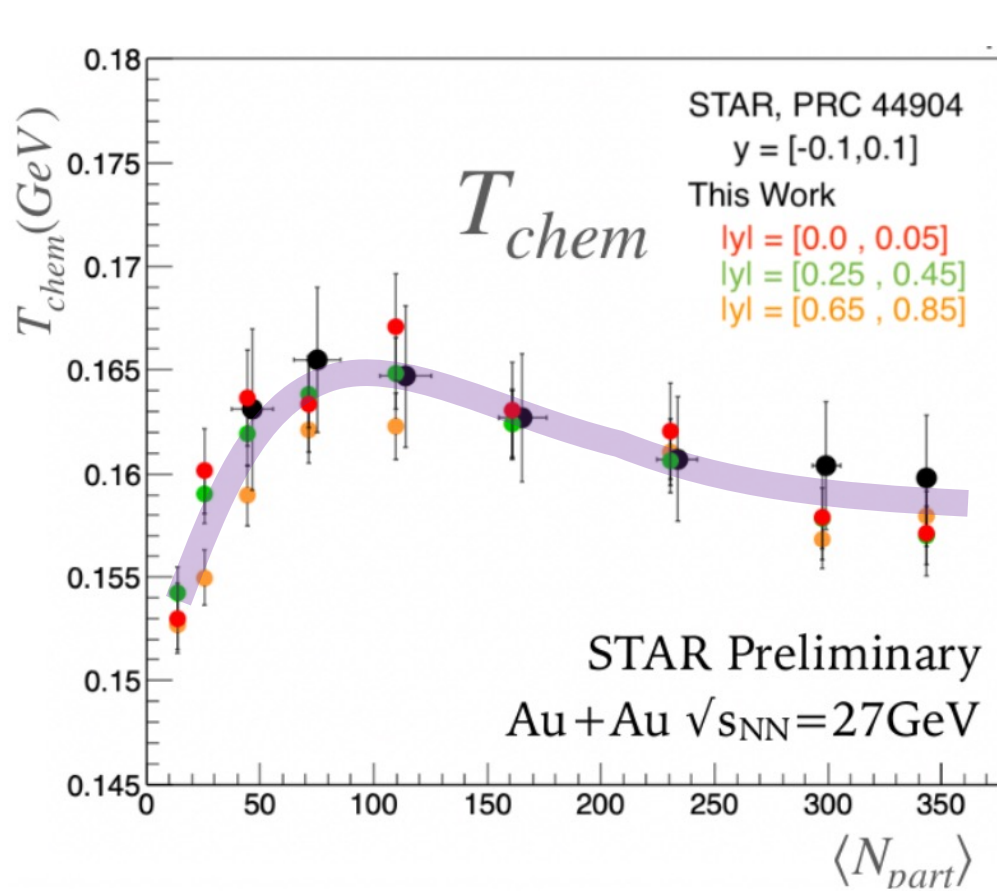
Thermal and Chemical Freeze-out and Collective Flow

- thermal freeze-out, centrality
- chemical freeze-out, beam energy
- light- and hyper-nuclei freeze-out and stopping



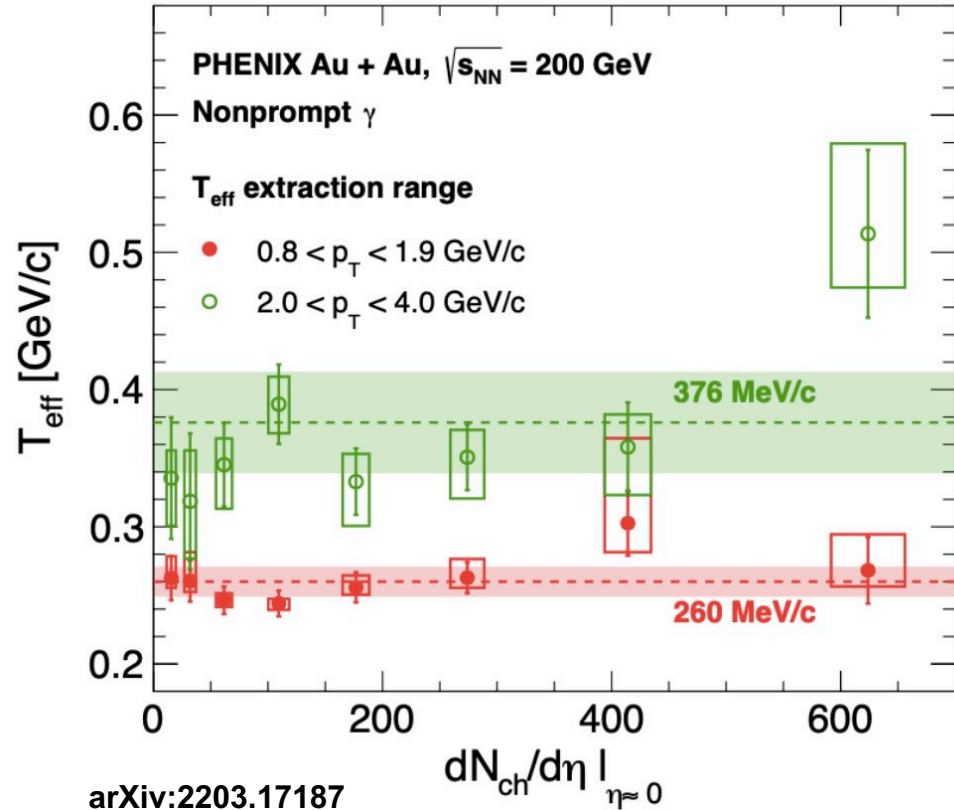
PRC 96 (2017) 4, 044904

Rapidity dependence of the Chemical Freeze-out



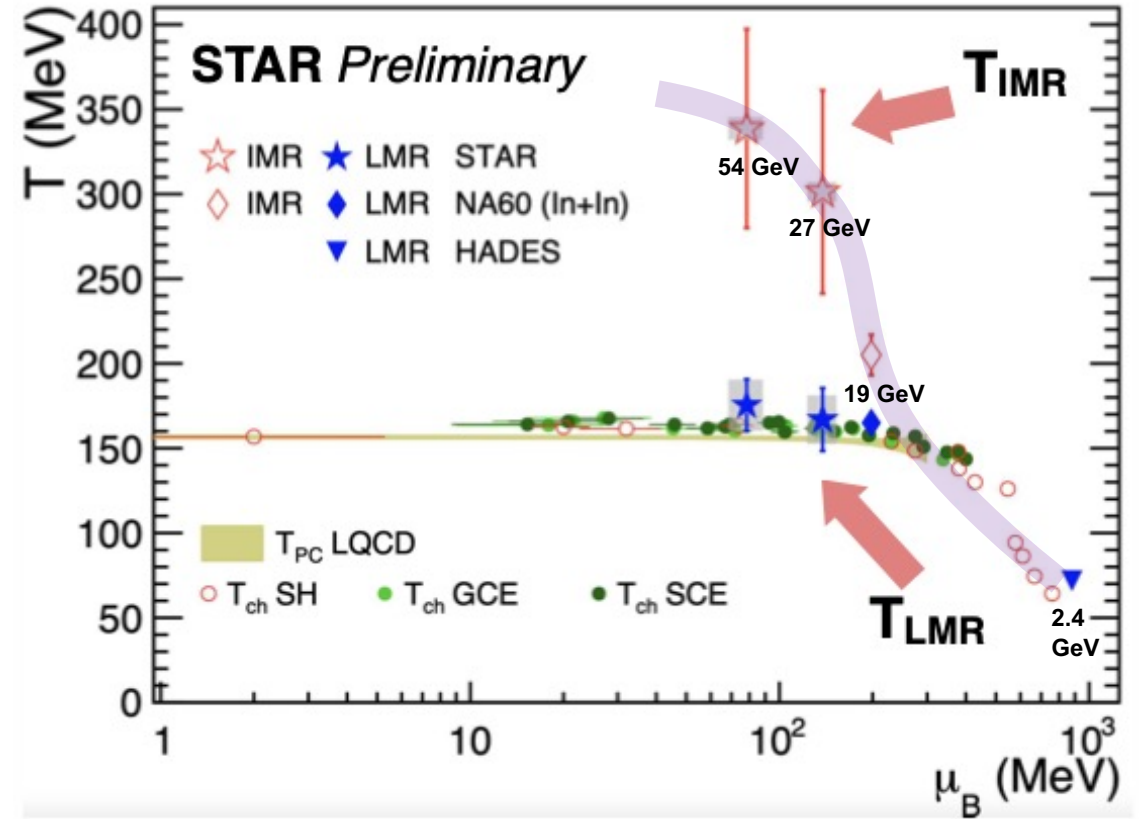
QM23

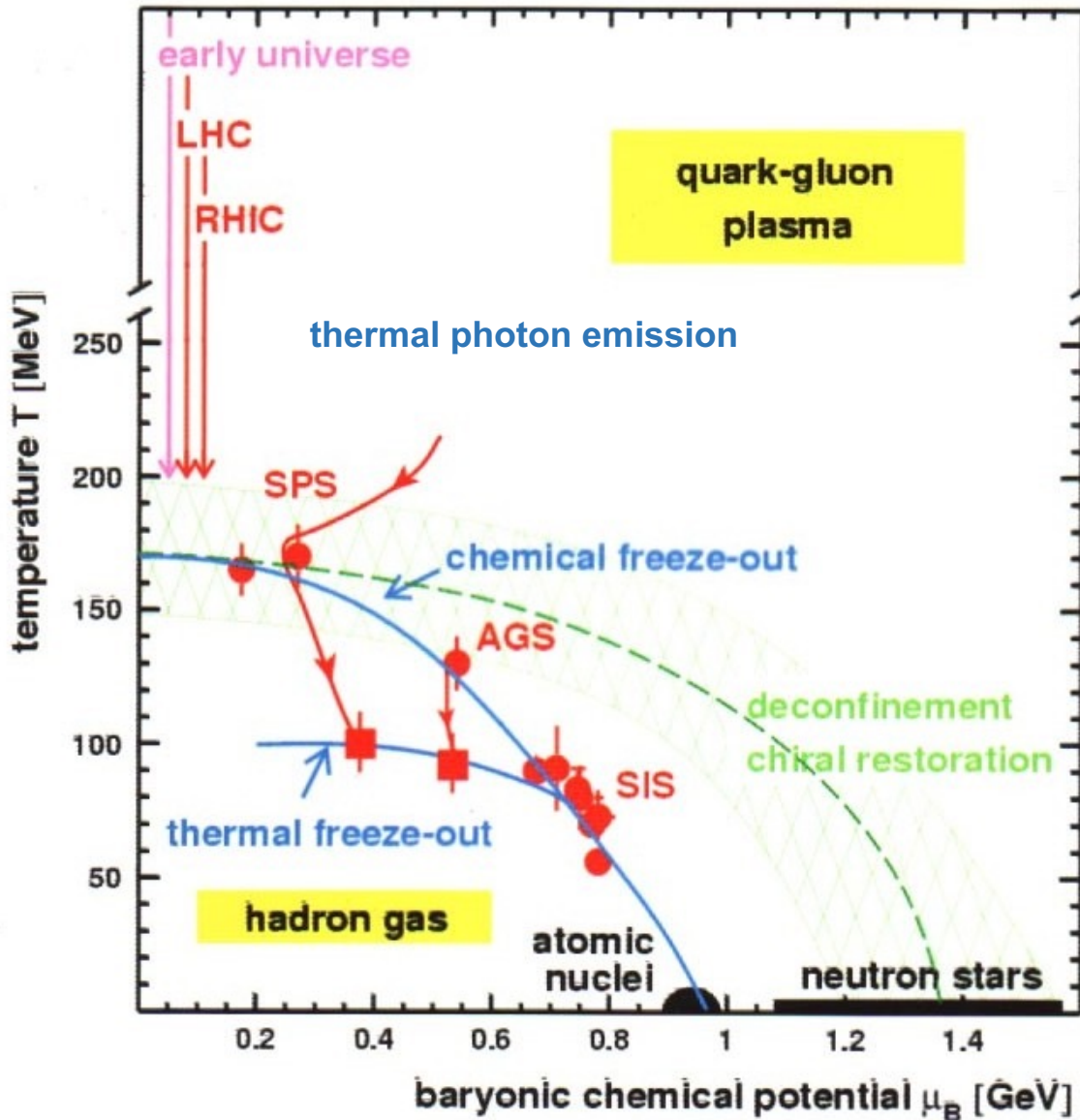
direct photon (hadron decay sub.)
 – QCD prompt photon ($R_{AA} \sim 1$) sub.



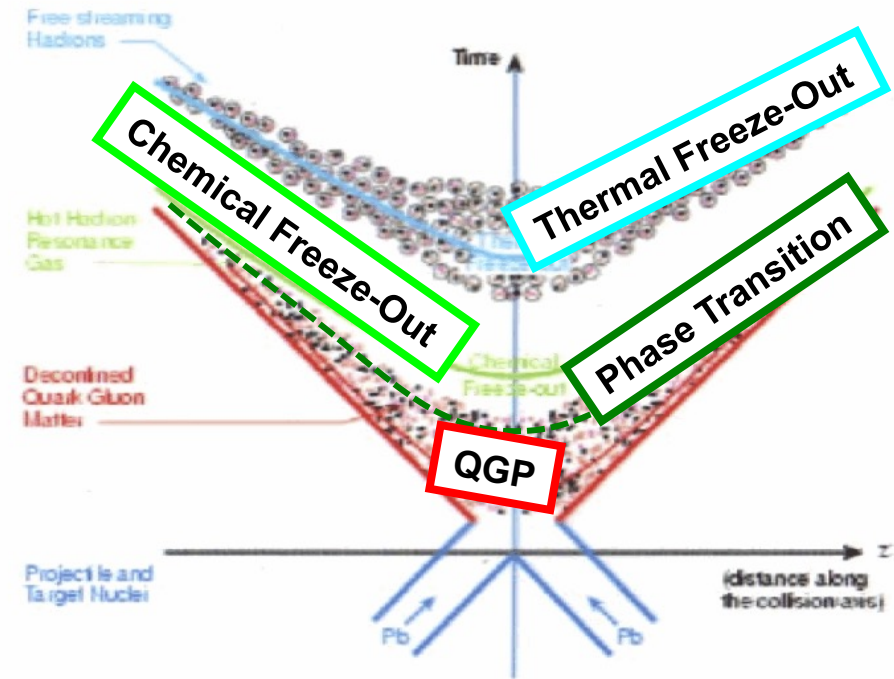
arXiv:2203.17187
 PRL 123 (2019) 022301

temperature via di-lepton





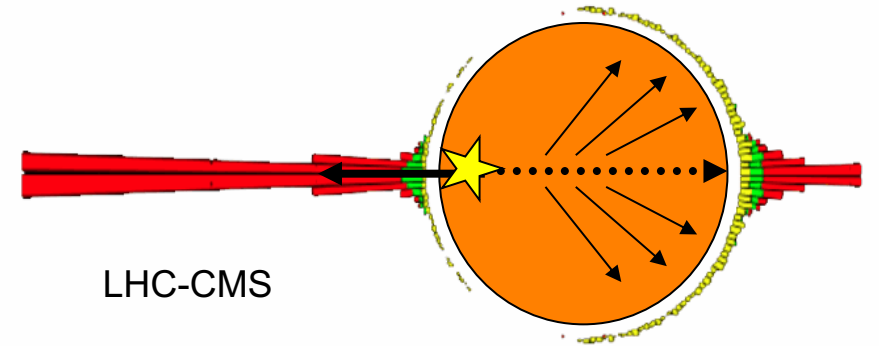
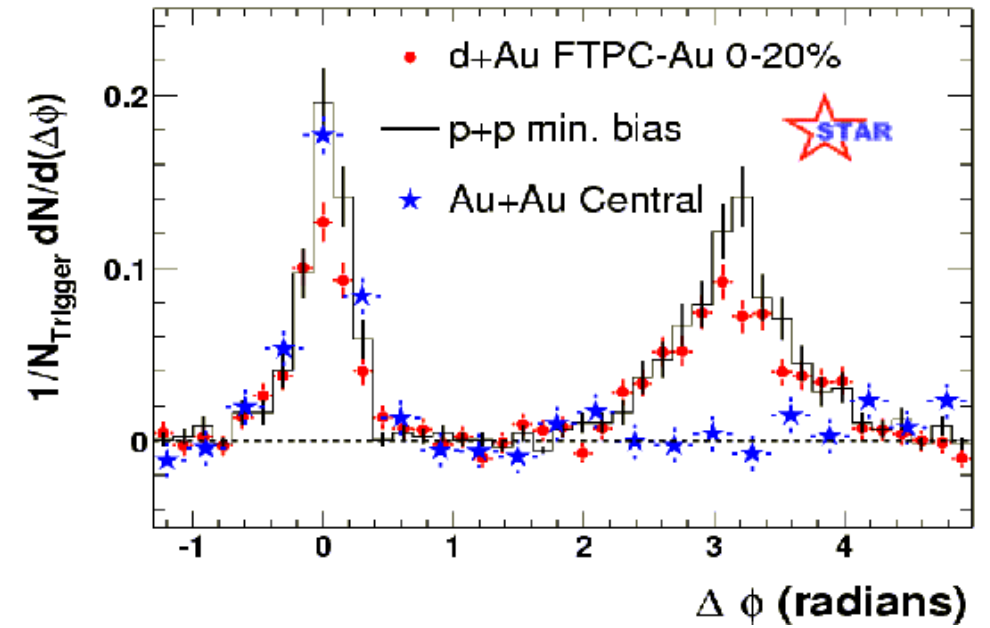
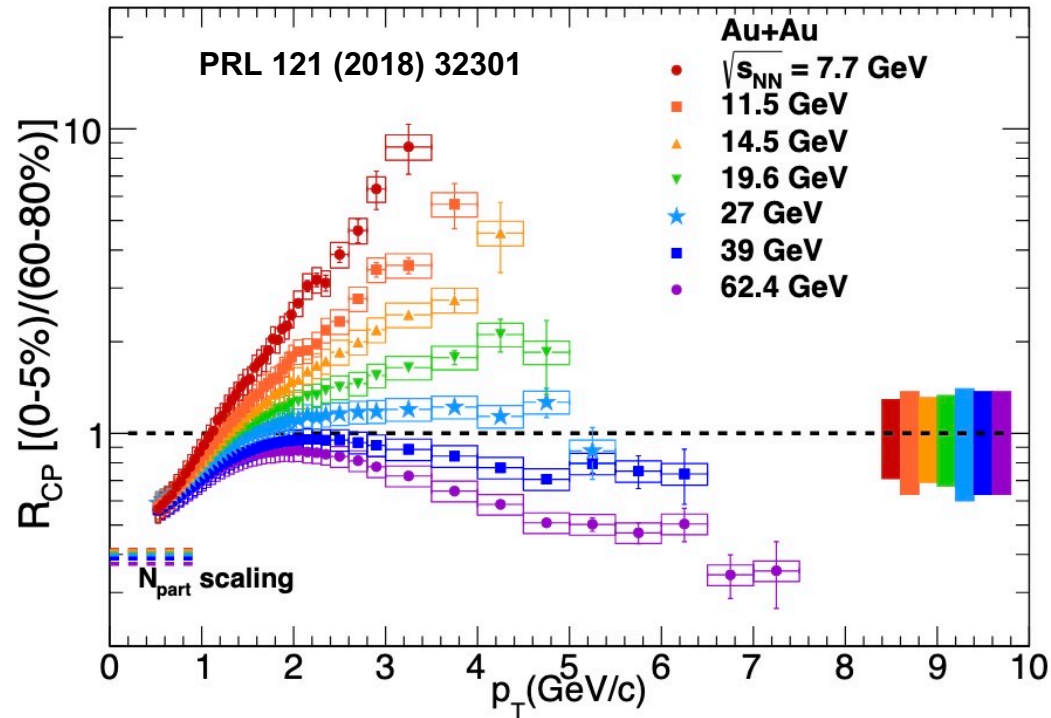
History of QGP evolution with various freeze-out stages and temperatures



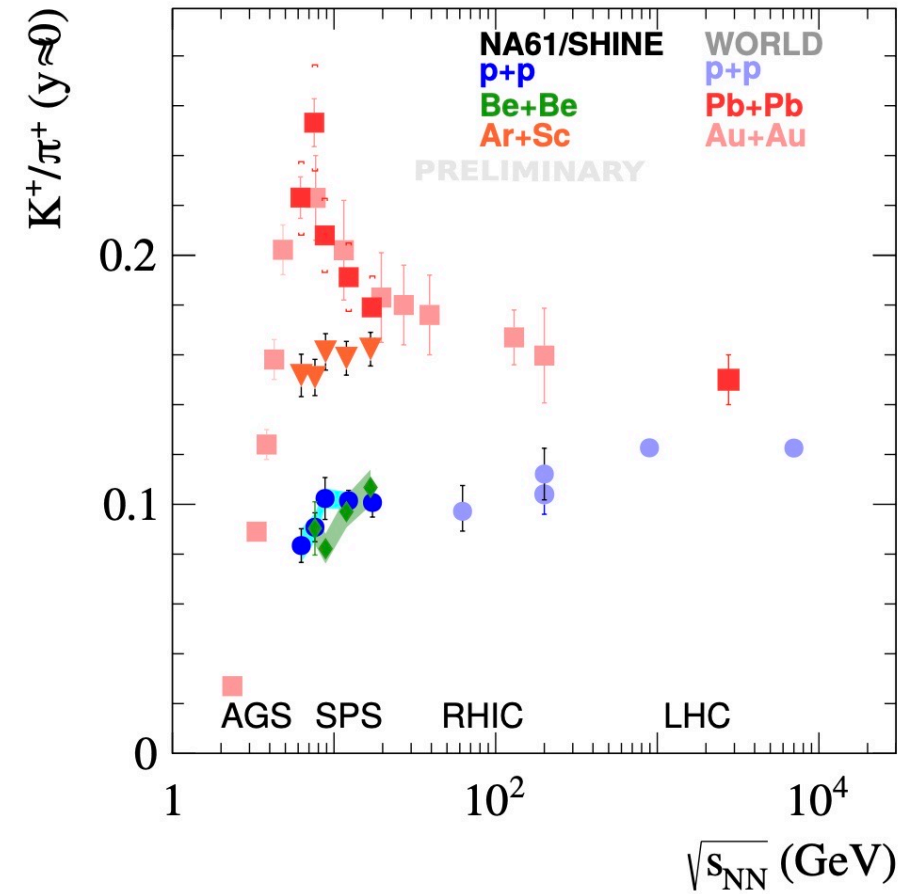
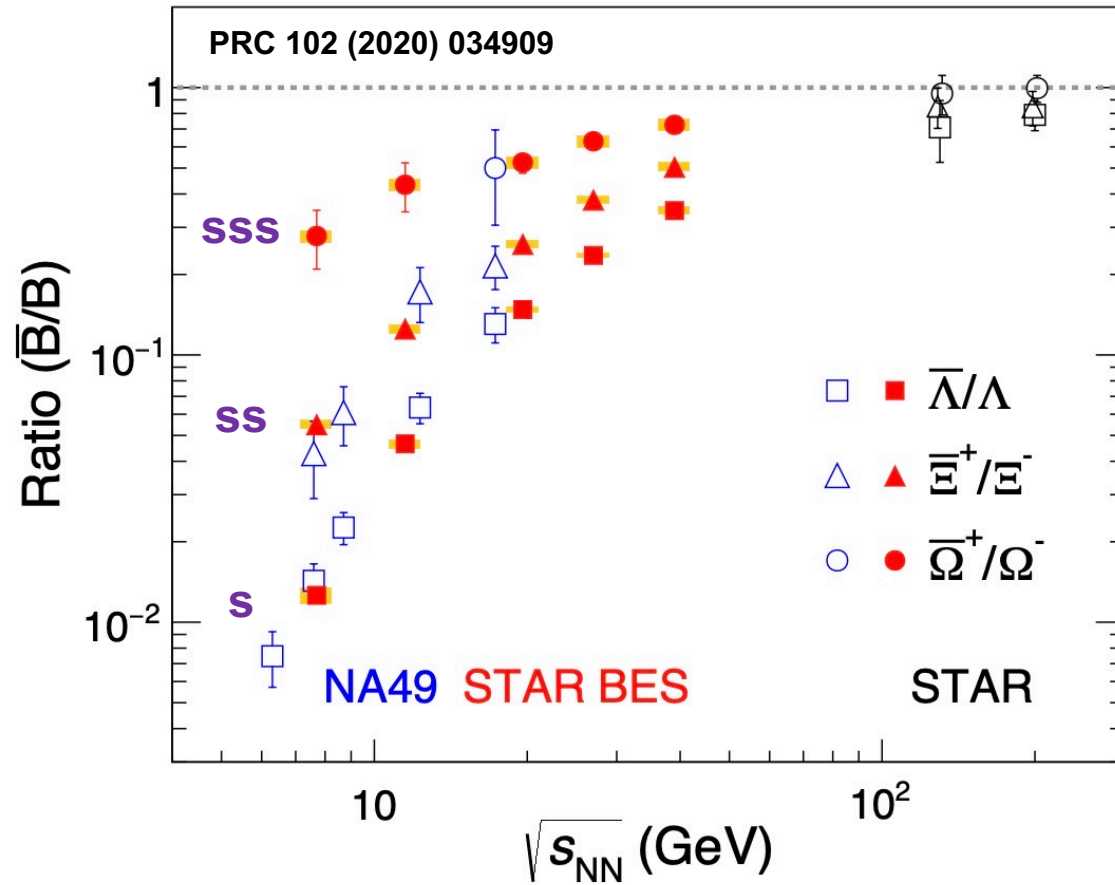
Nuclear Modification, Baryon, Meson, Strangeness and Heavy-quark

PRL 91 (2003) 072304

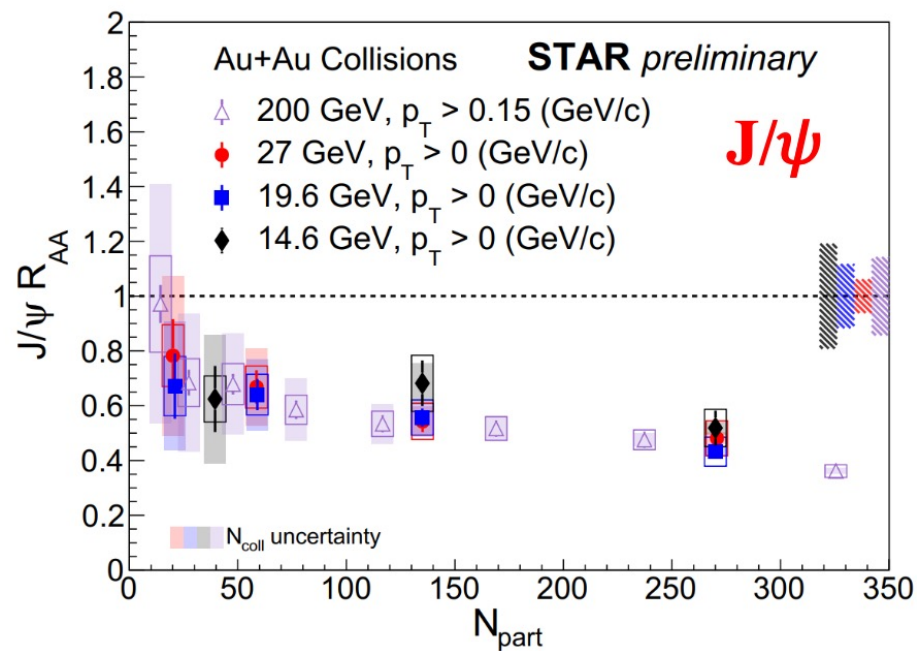
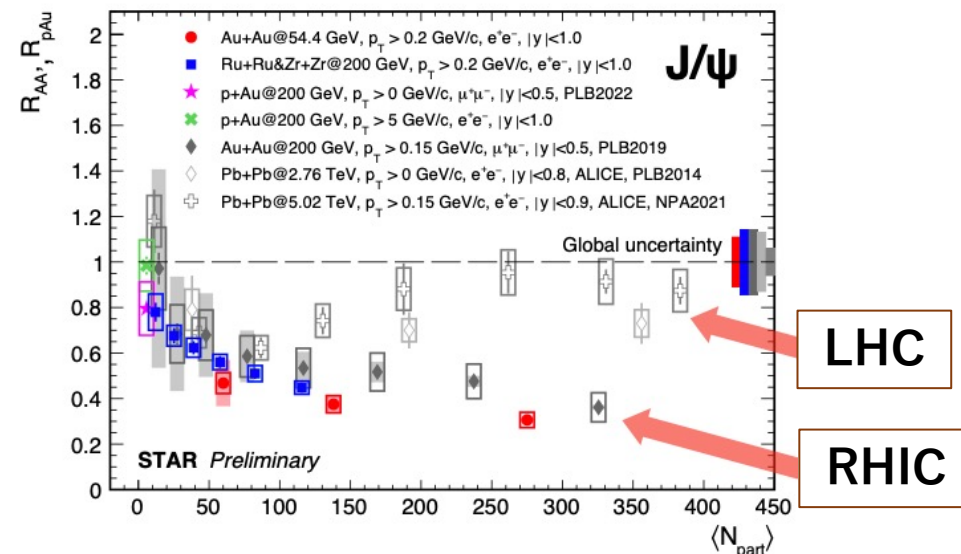
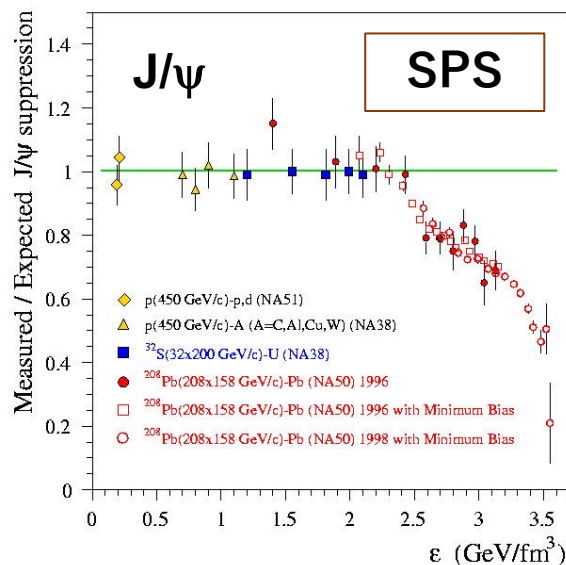
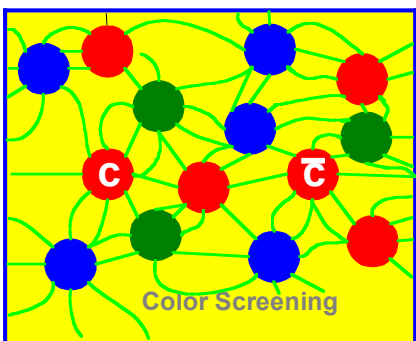
- onset of high p_T suppression, Baryon - meson
- strangeness enhancement, K/pi horn, baryon density
- onset of J/psi suppression, flow of charm quark



Strangeness enhancement and K/pi horn at high-baryon density

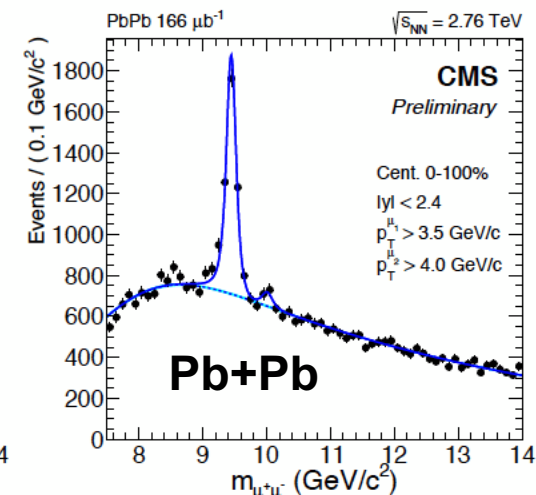
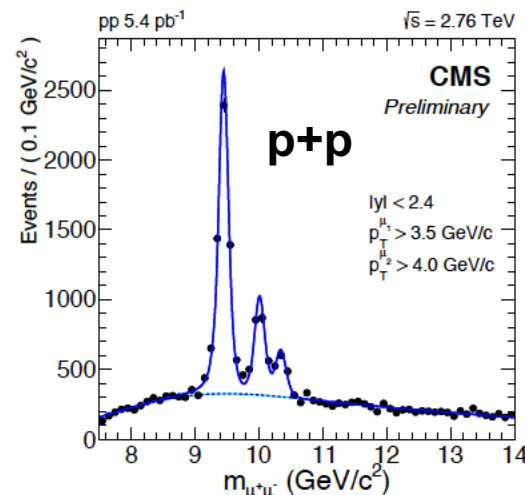


J/ψ and Υ (Upsilon) suppression and regeneration

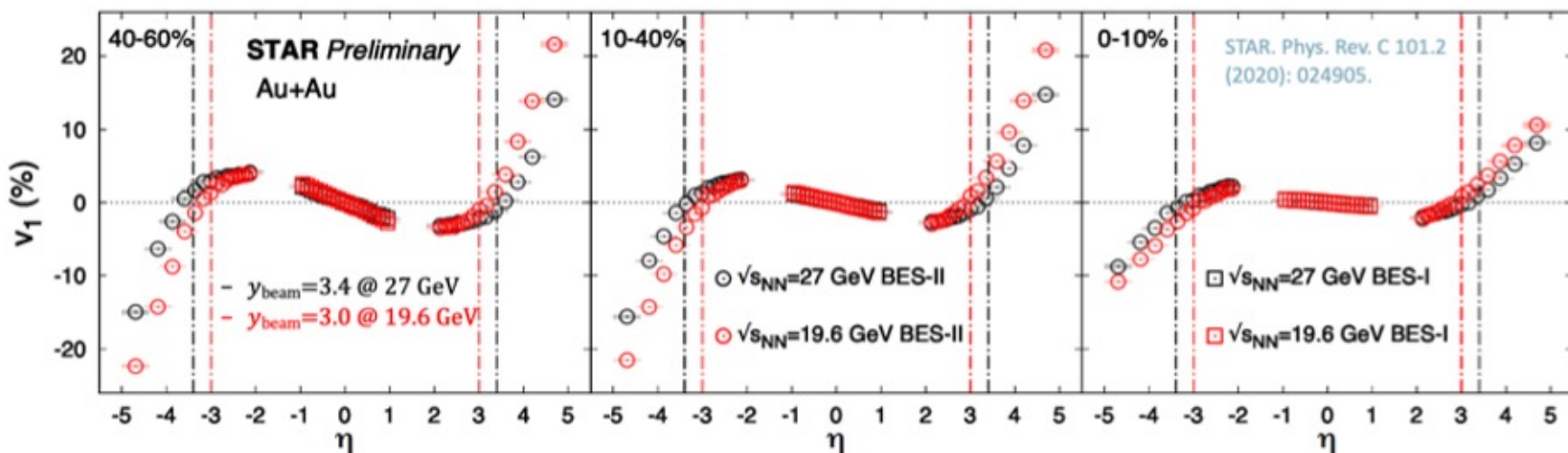
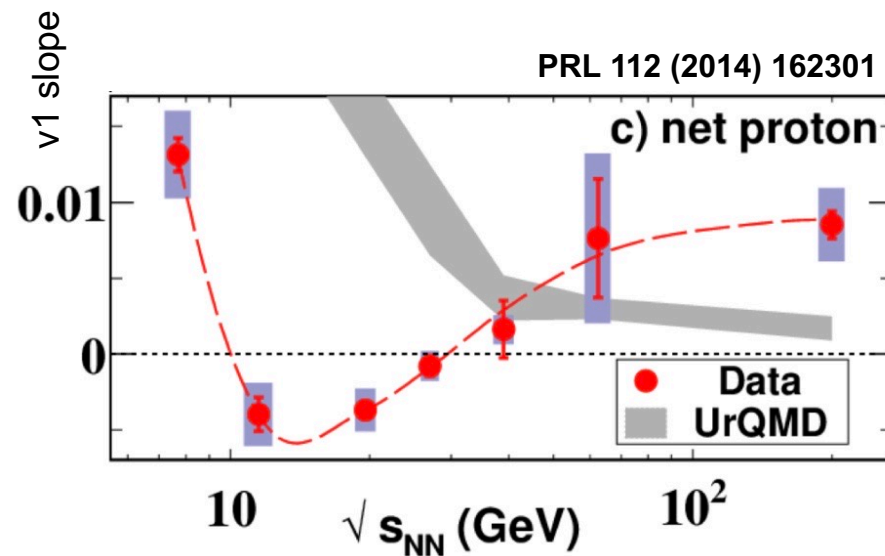
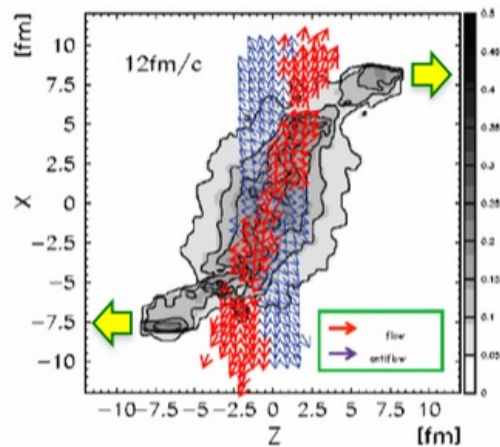
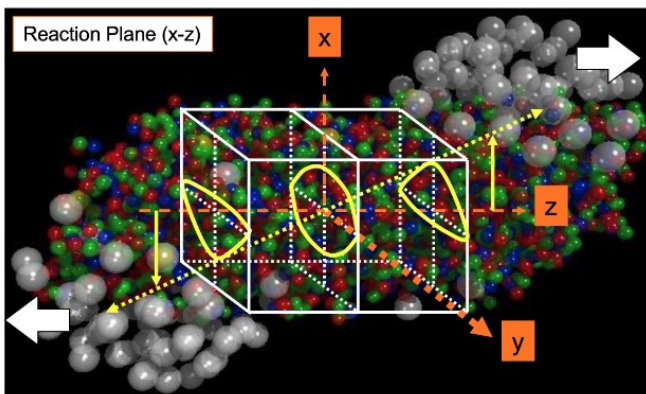


RHIC Beam Energy Scan

Υ (Upsilon) suppression

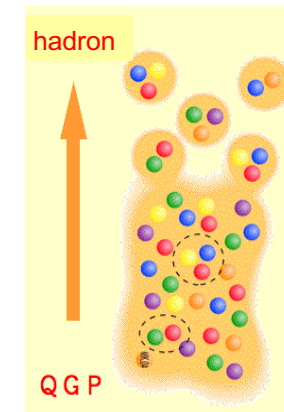
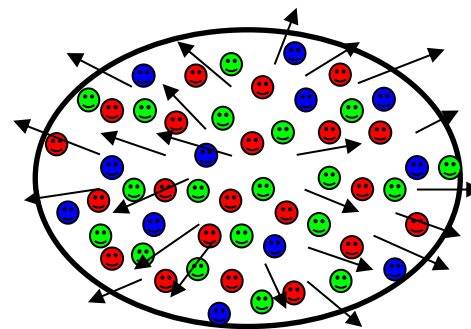
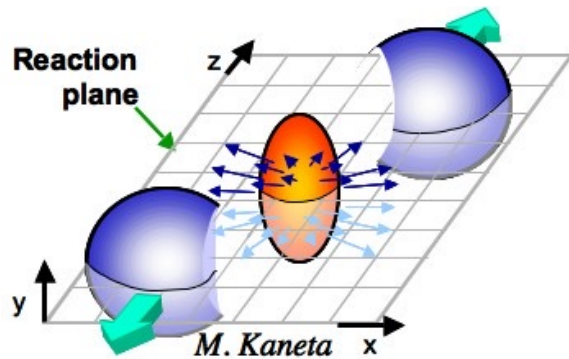


Directed flow v_1

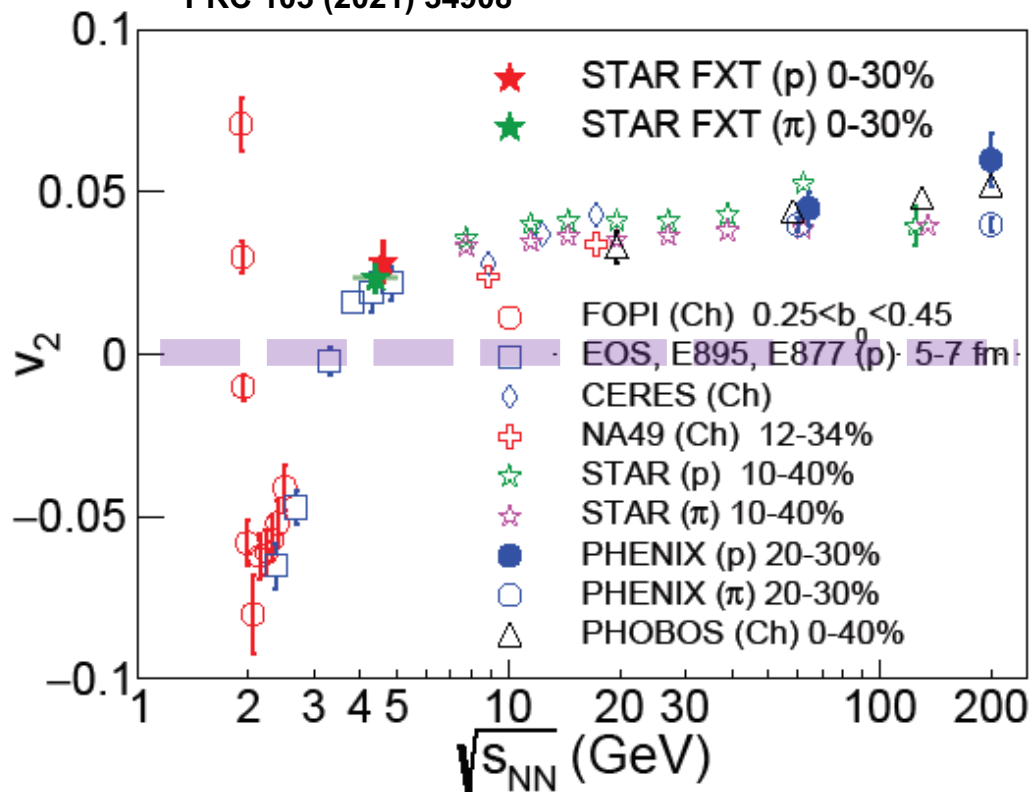


- v_1 -slope, EOS, phase transition
- light- and hyper-nuclei
- v_2 , N_{CQ} -scaling, hadron-parton
- expansion, small system

Elliptic flow v_2

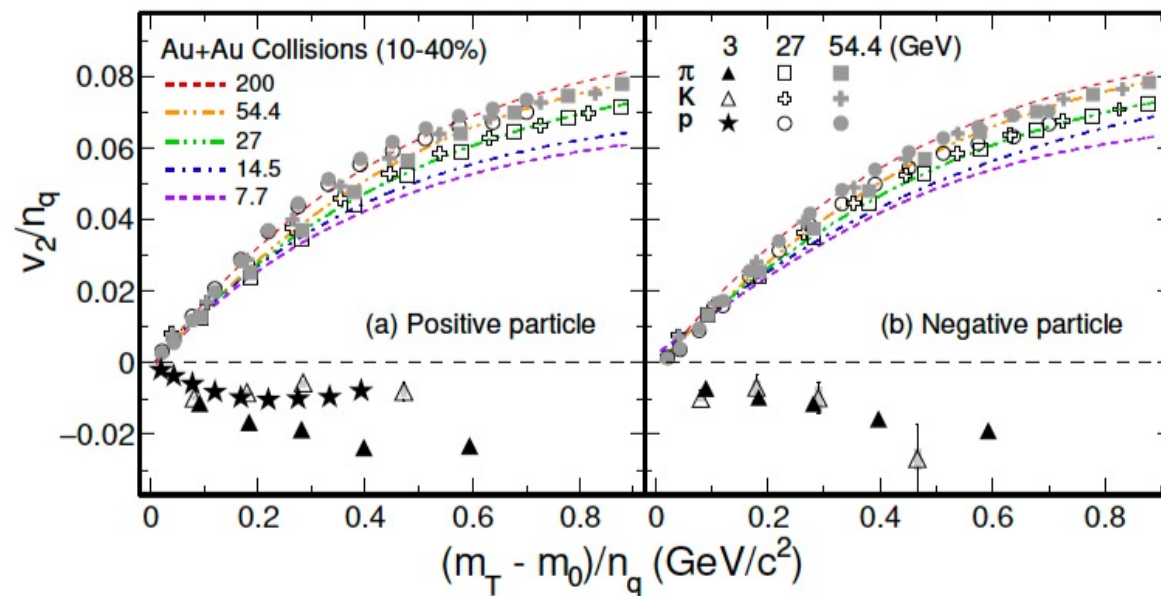


PRC 103 (2021) 34908



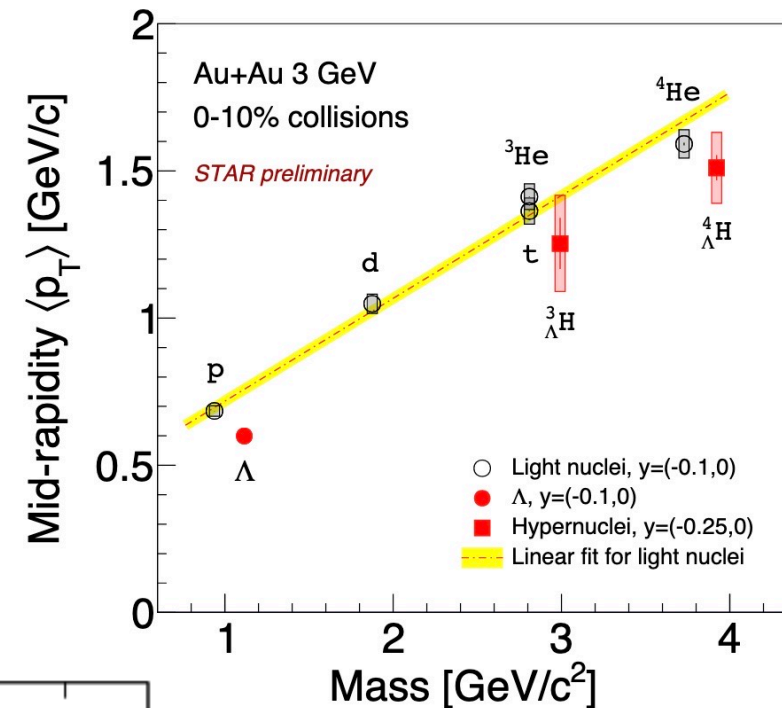
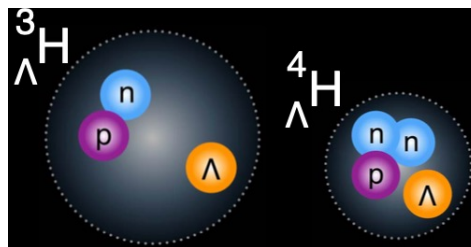
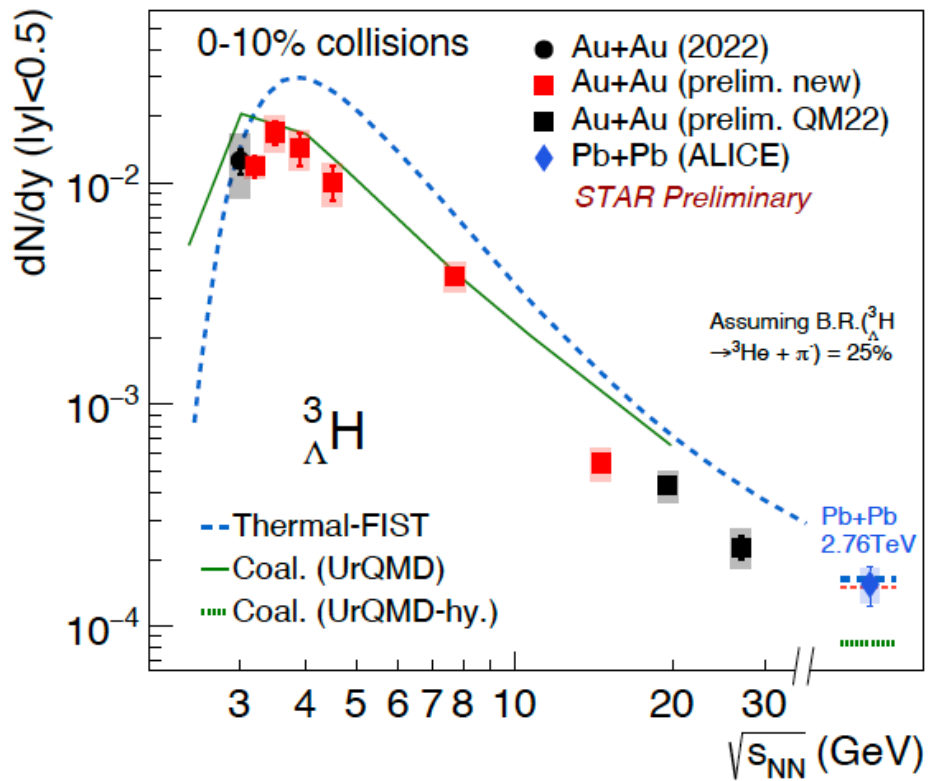
Quark Number Scaling of v_2

PLB 827 (2022) 137003

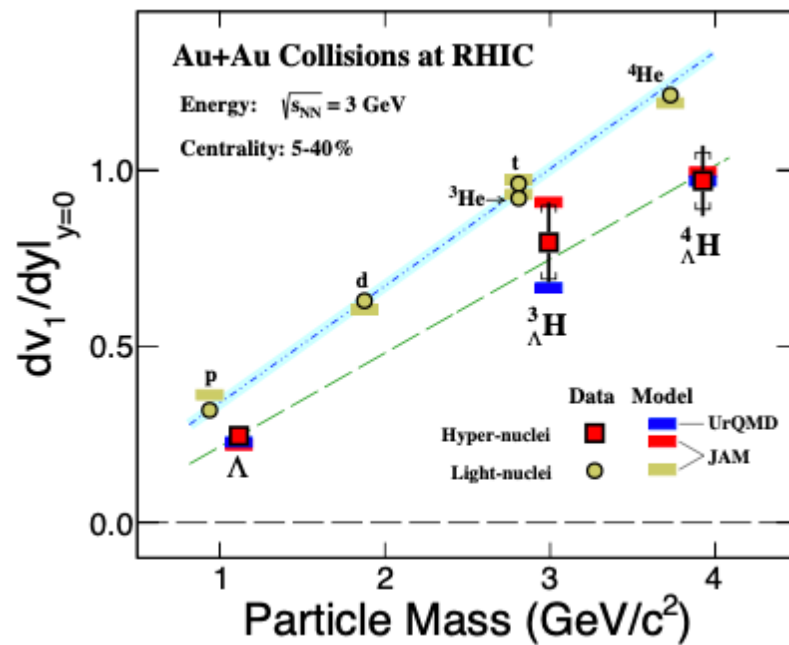


Hyper-nuclei production

QM23

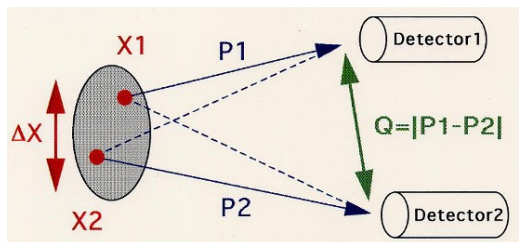


PRL130 (2023) 212301

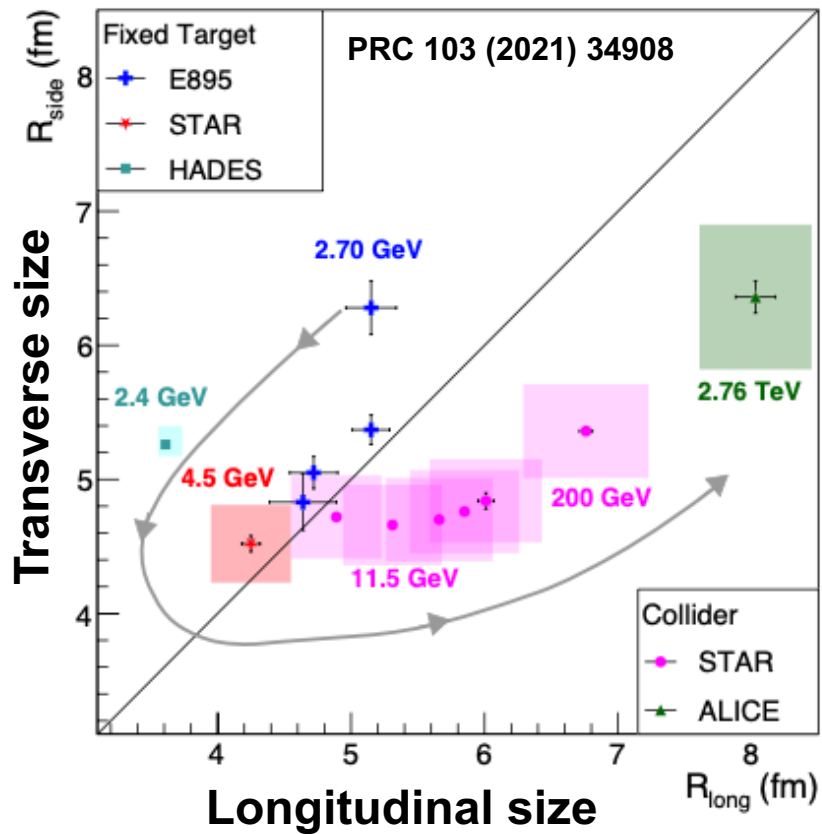


Radial flow and Directed flow of Hyper-nuclei

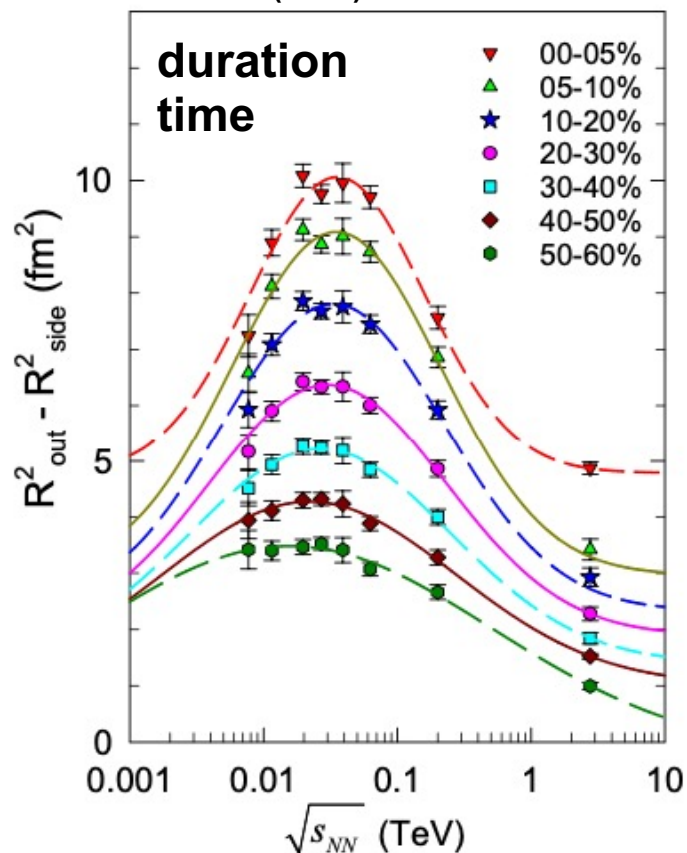
Femtoscscopy and Space-Time Geometry



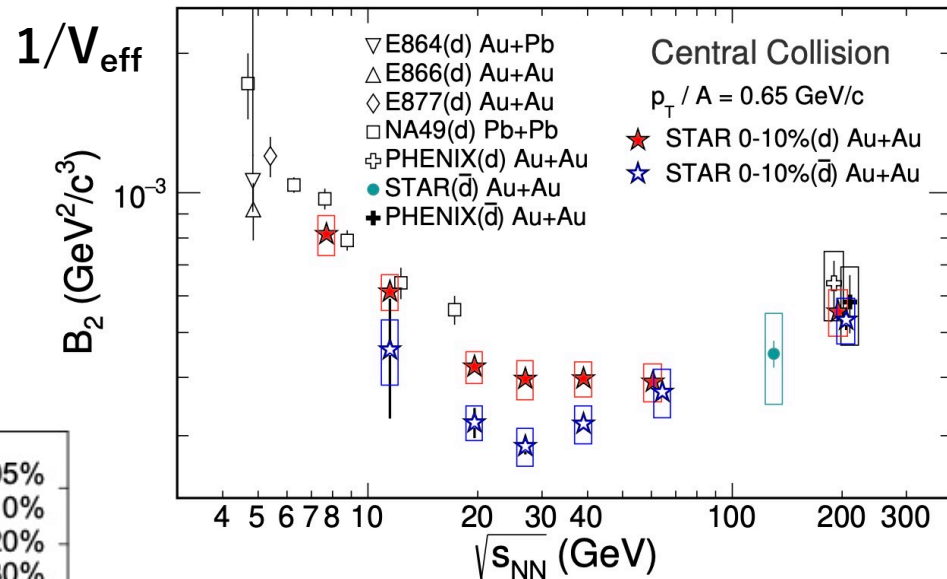
- duration time, size
- source tilt, eccentricity
- dynamical expansion



PRL 114 (2015) 142301



PRC 99 (2019) 064905



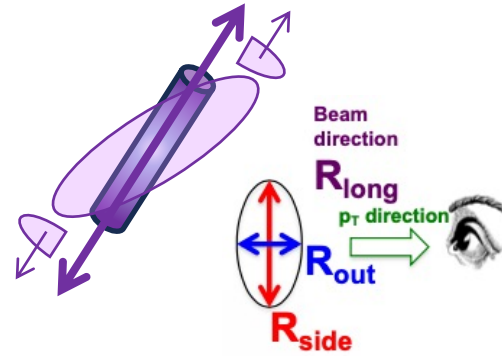
$$E_A \frac{d^3 N_A}{dp_A^3} = B_A \left(E_p \frac{d^3 N_p}{dp_p^3} \right)^Z \left(E_n \frac{d^3 N_n}{dp_n^3} \right)^{A-Z}$$

$$\approx B_A \left(E_p \frac{d^3 N_p}{dp_p^3} \right)^A,$$

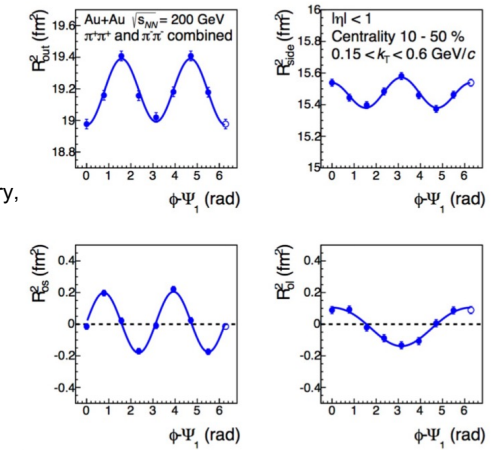
$$B_A \propto V_{\text{eff}}^{1-A}.$$

nucleon correlation volume : V_{eff}

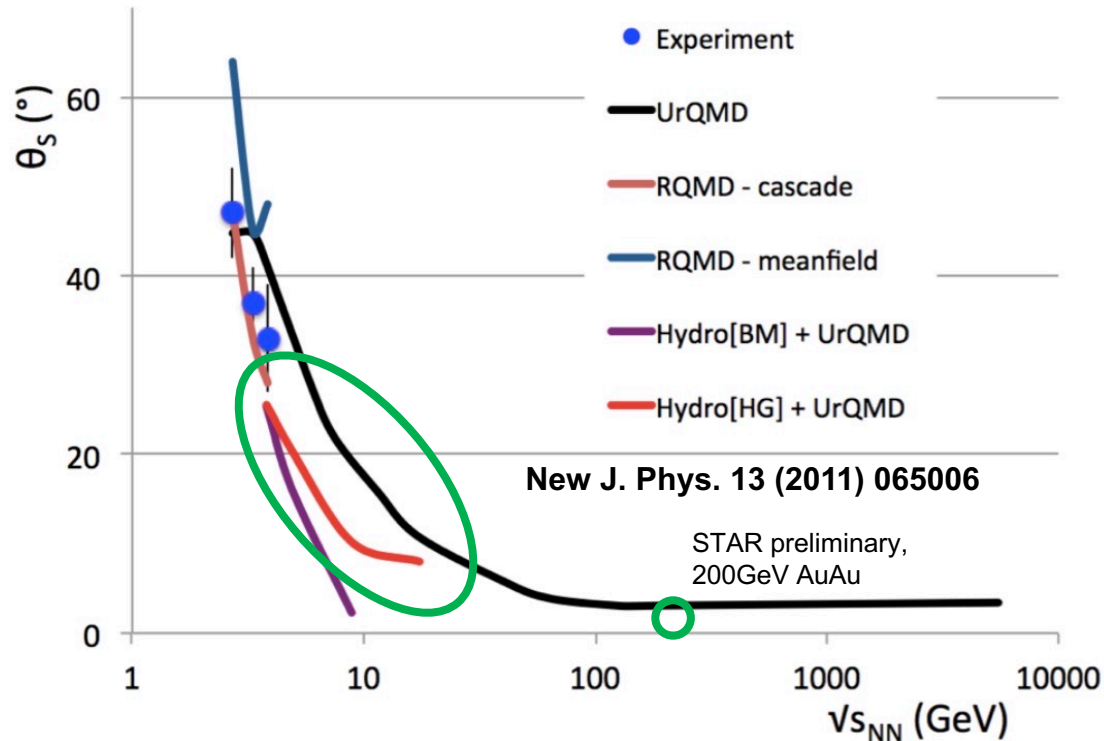
Imaging the 3D geometry at the freeze-out



STAR preliminary,
200GeV AuAu

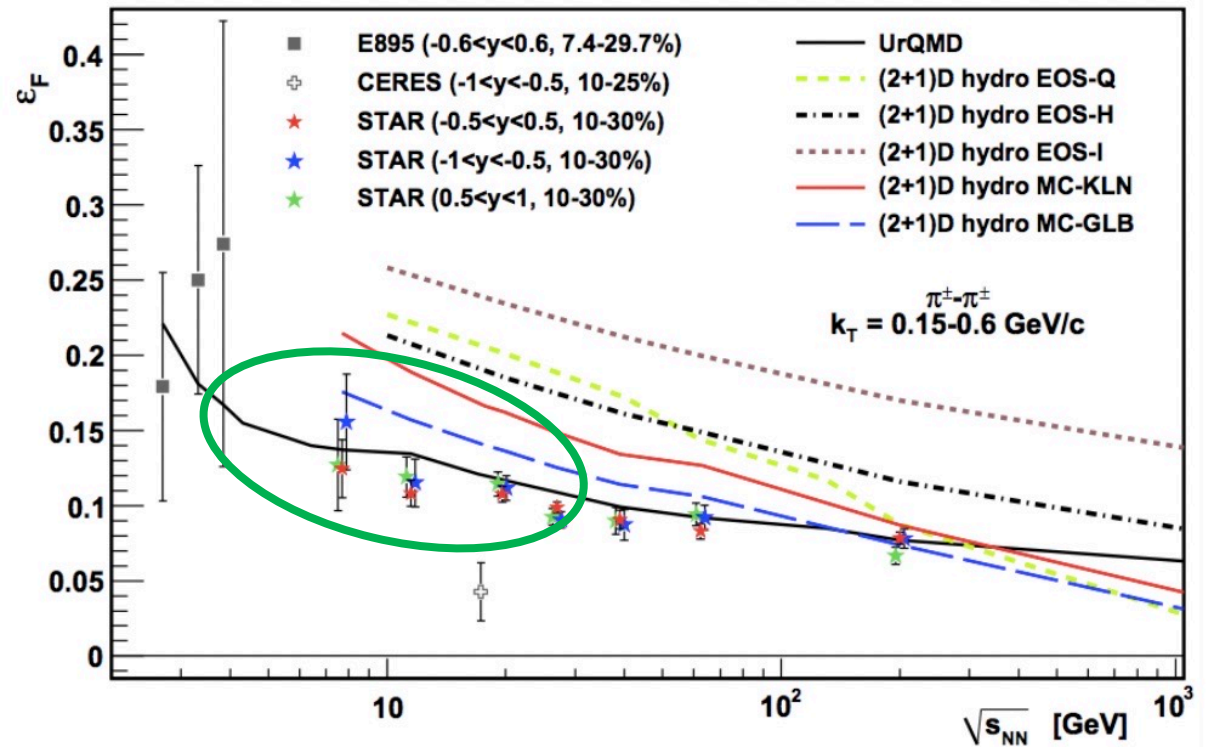


Tilt angle of emission source w.r.t. the beam axis

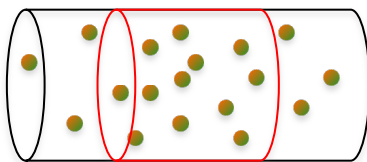


Freeze-out eccentricity

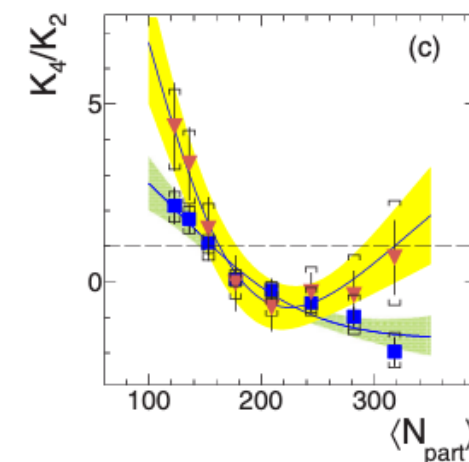
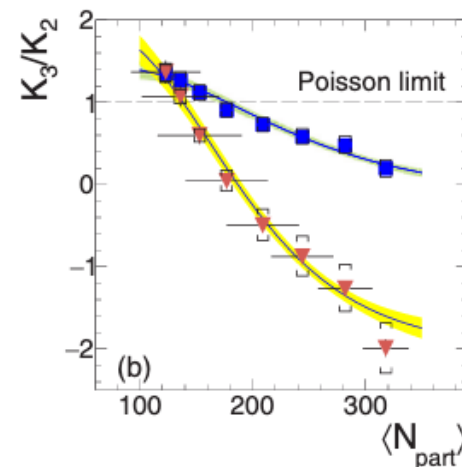
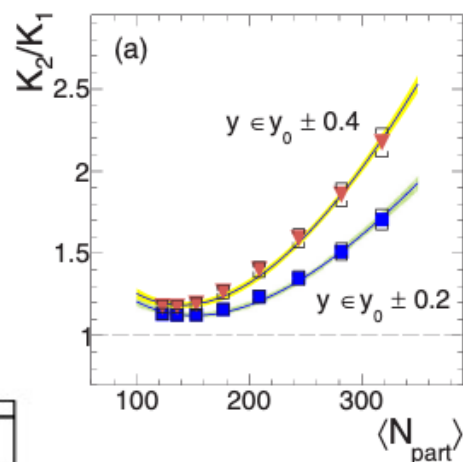
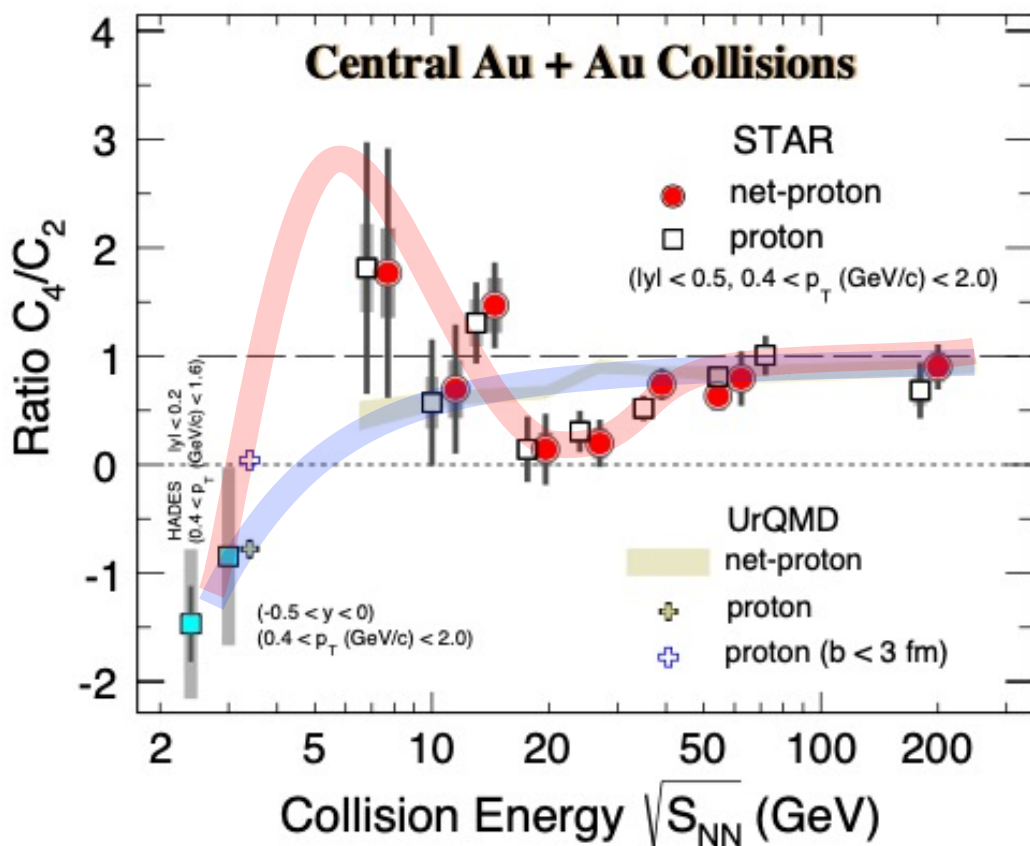
PRC 92 (2015) 14904



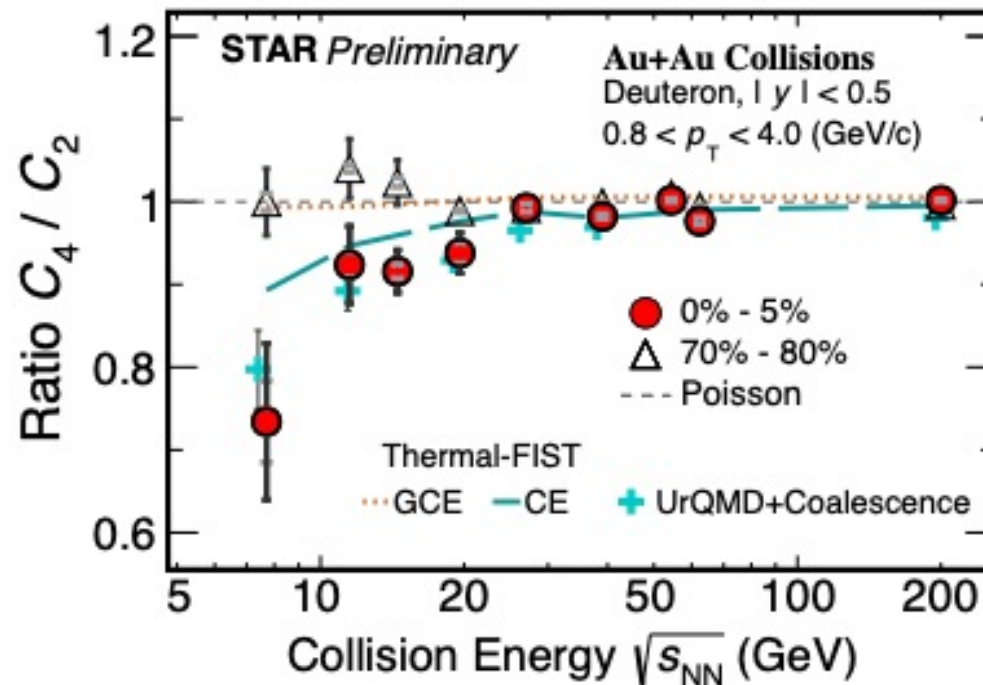
Net-Baryon (conserved number) Higher Order Fluctuation



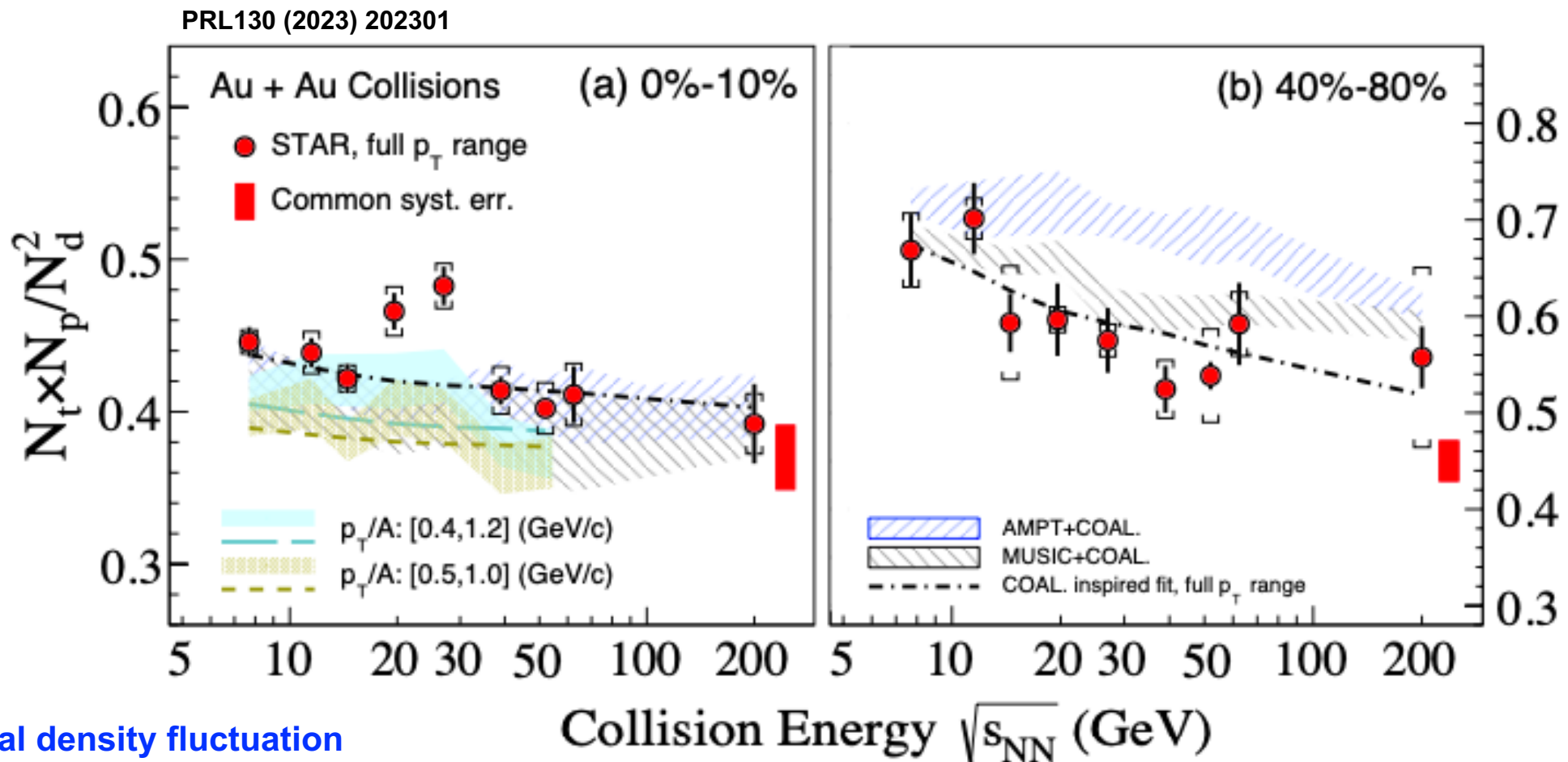
PRL 128 (2022) 202303



arXiv: 2304.10993



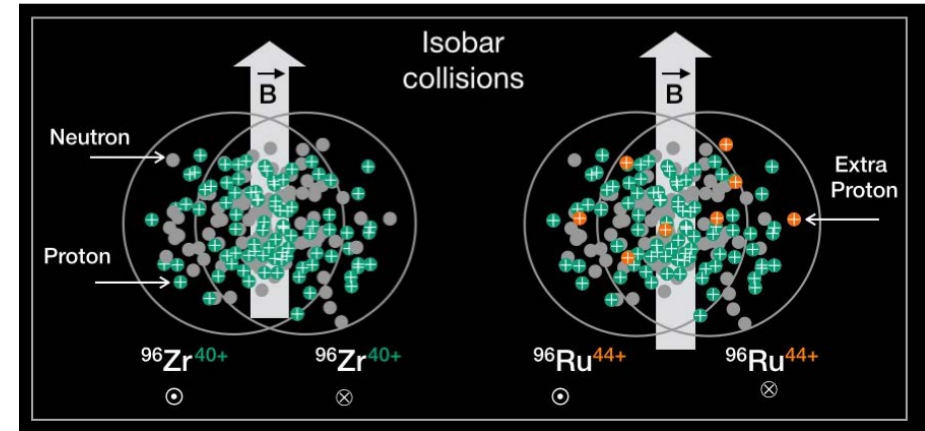
Neutron density fluctuation with Triton production : $(pnn * p) / (pn * pn)$



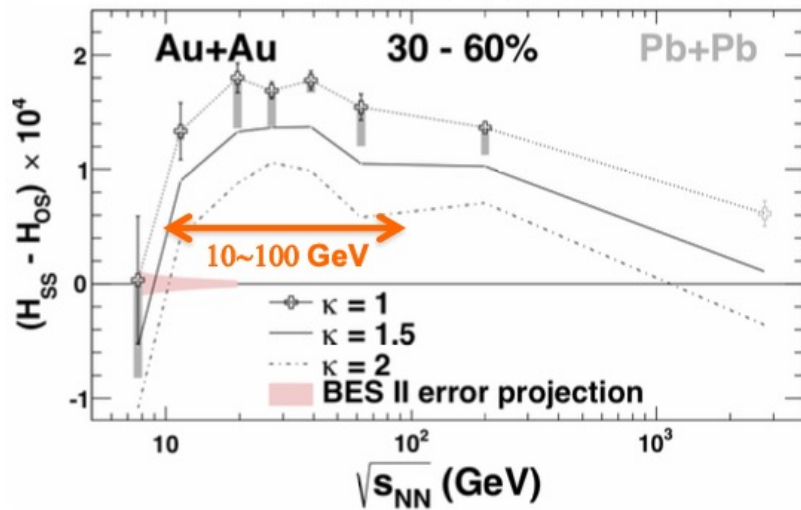
- Local density fluctuation of neutron

Vortical Fluid and Chiral Magnetic Effect

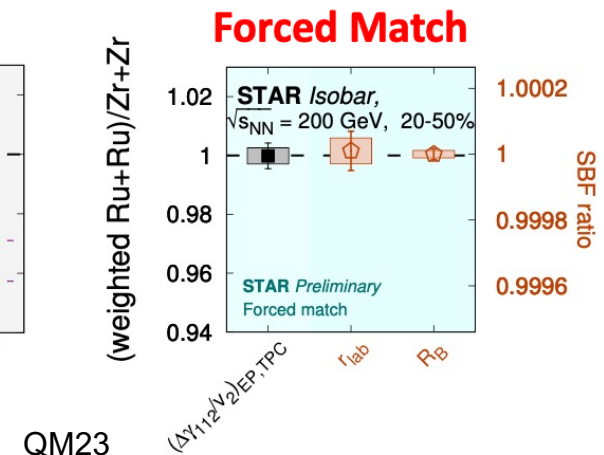
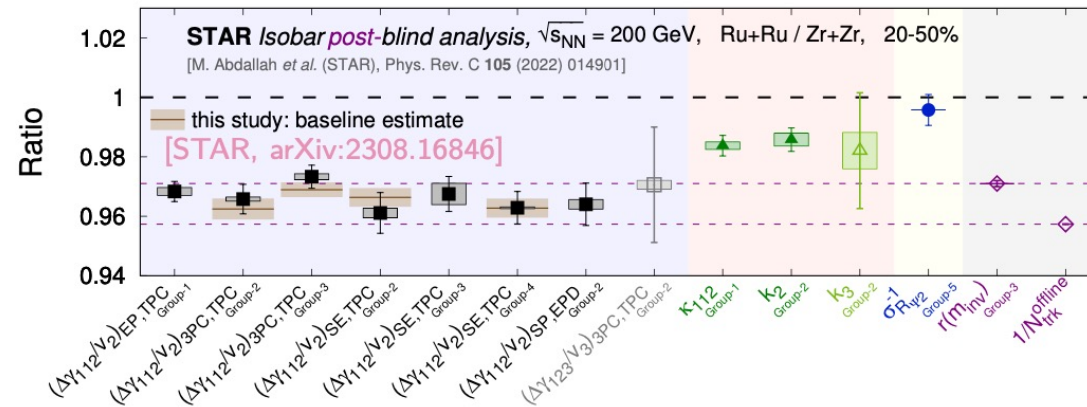
- global and local polarization, spin alignment
- beam energy and centrality dependence
- lambda anti-lambda difference...
- no visible CME signal in isobar blind analysis
- $\Delta\gamma$, ΔS , pair wise or event wise, Δv_1 , Δv_2 ,,,



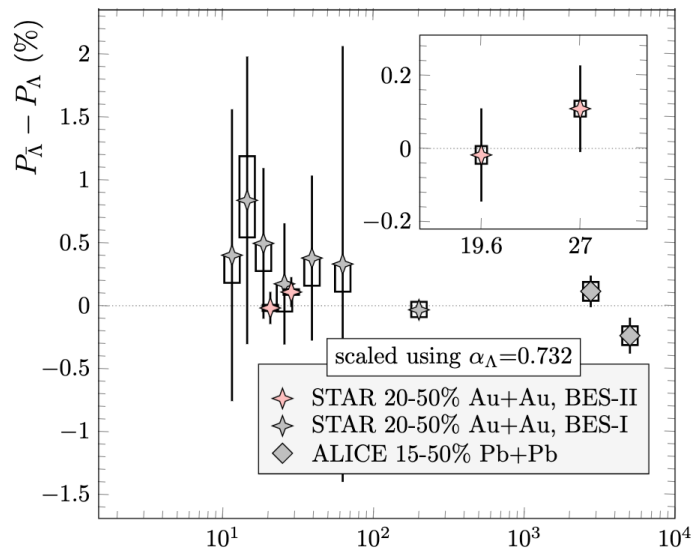
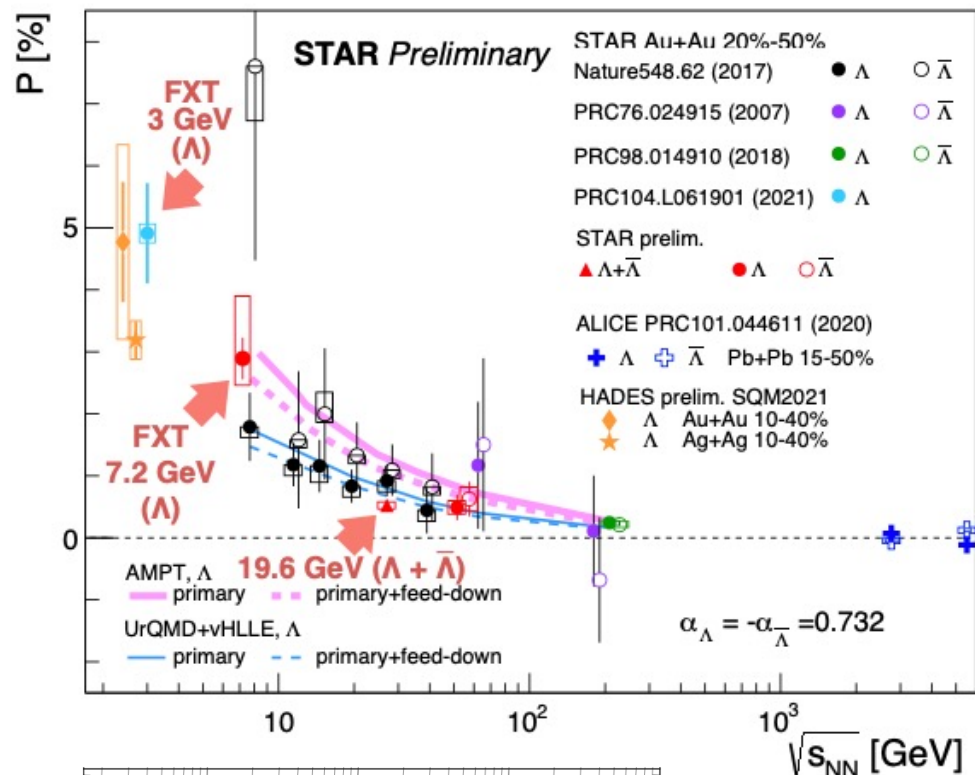
Phys. Rev. Lett. 113, 052302 (2014)



isobar blind analysis completed
(no hint of CME at the moment)



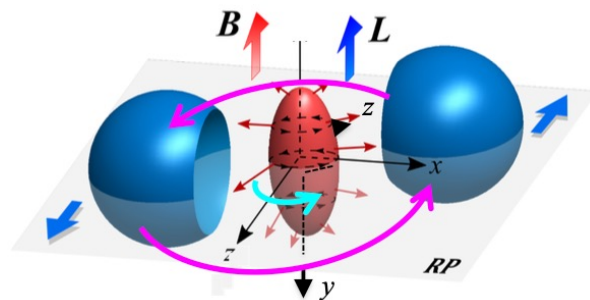
QM23



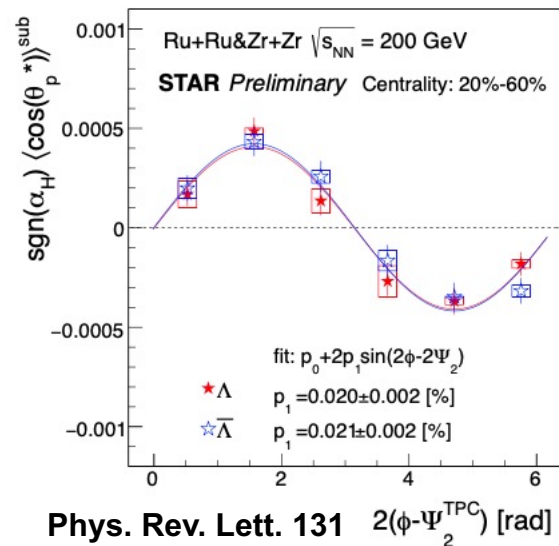
no indication of B-field

Phys. Rev. C 108 (2023) 14910

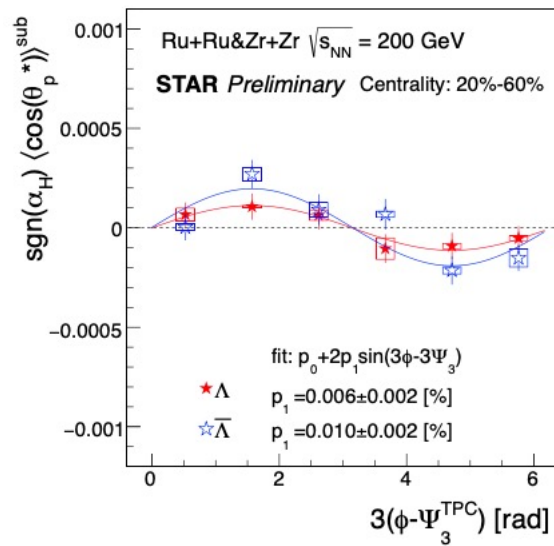
Global and Local Vorticity



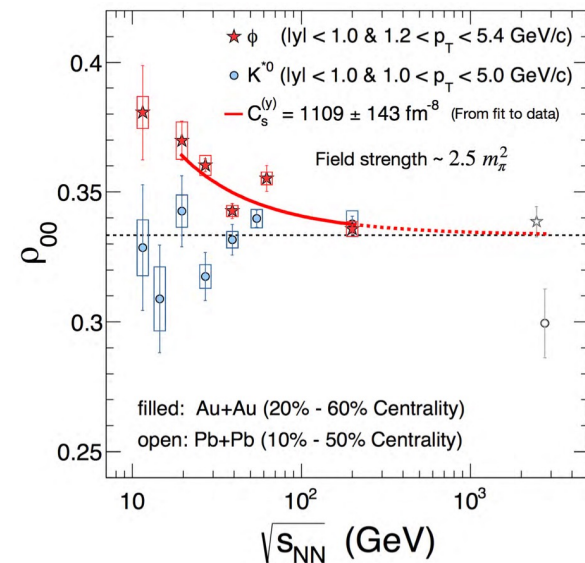
Longitudinal Vorticity by elliptic and triangle flow



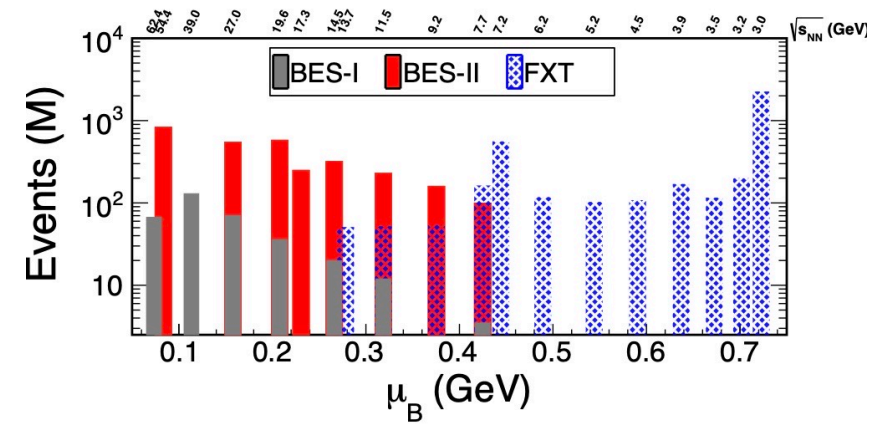
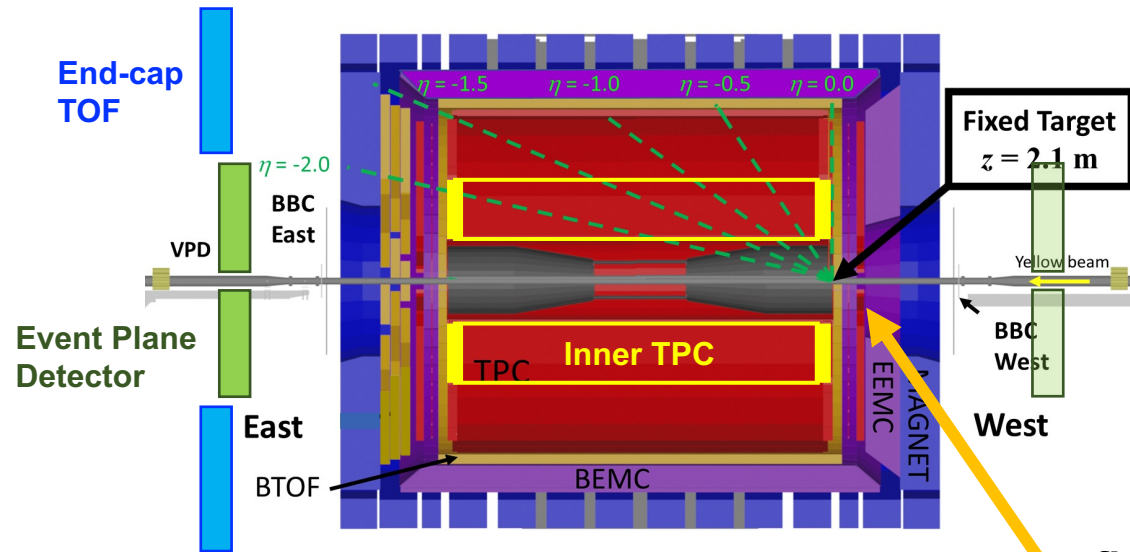
Phys. Rev. Lett. 131 (2023) 202301



Nature 614 (2023) 244

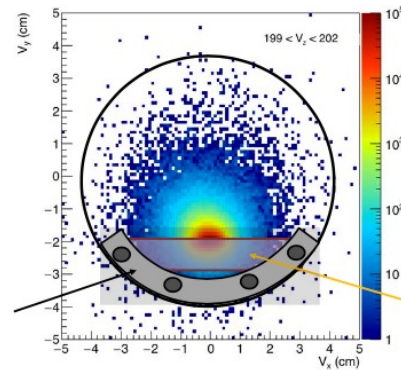
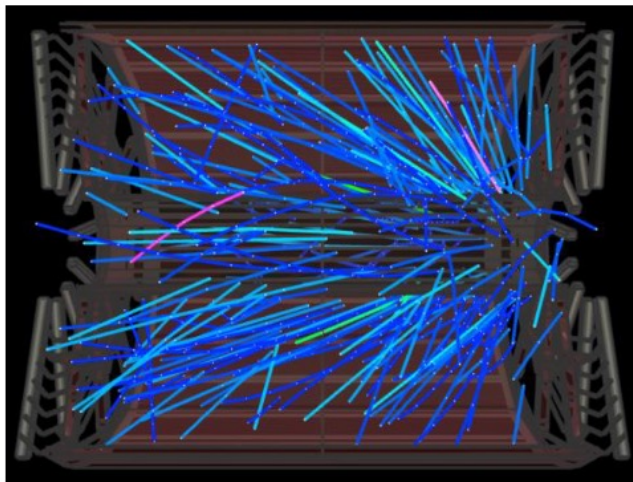


Beam Energy Scan Phase-II at RHIC

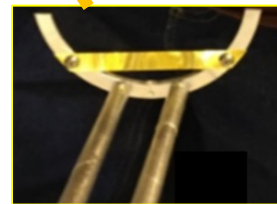


data taken at STAR in BES-II

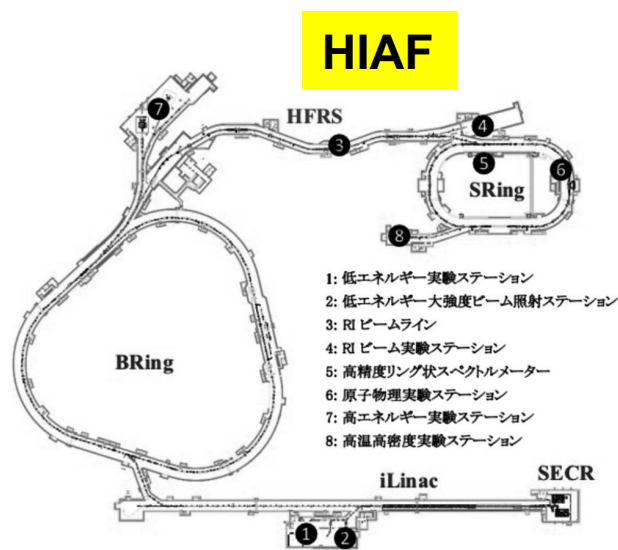
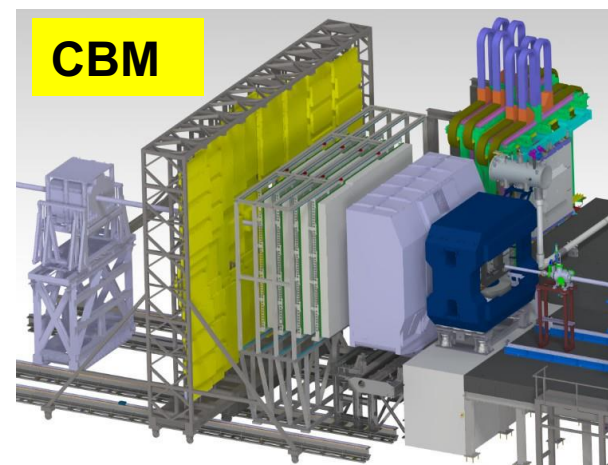
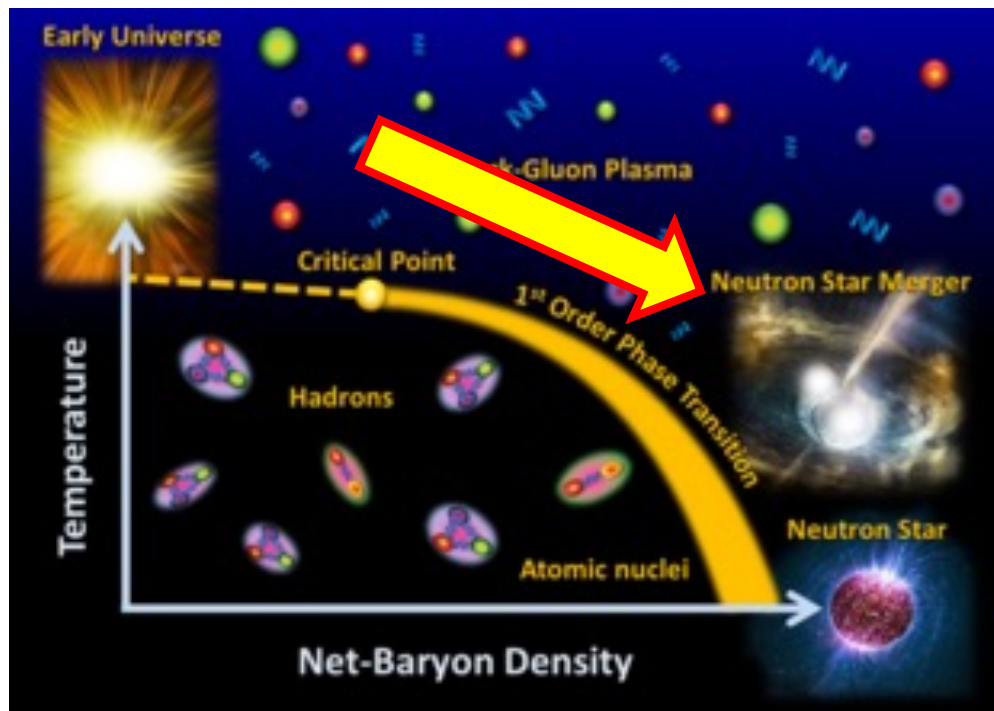
$\sqrt{s_{NN}}$ (GeV)	Beam Energy (GeV/nucleon)	Collider or Fixed Target	$Y_{center\ of\ mass}$	μ^B (MeV)	Run Time (days)	No. Events Collected (Request)	Date Collected
200	100	C	0	25	2.0	138 M (140 M)	Run-19
27	13.5	C	0	156	24	555 M (700 M)	Run-18
19.6	9.8	C	0	206	36	582 M (400 M)	Run-19
17.3	8.65	C	0	230	14	256 M (250 M)	Run-21
14.6	7.3	C	0	262	60	324 M (310 M)	Run-19
13.7	100	FXT	2.69	276	0.5	52 M (50 M)	Run-21
11.5	5.75	C	0	316	54	235 M (230 M)	Run-20
11.5	70	FXT	2.51	316	0.5	50 M (50 M)	Run-21
9.2	4.59	C	0	372	102	162 M (160 M)	Run-20+20b
9.2	44.5	FXT	2.28	372	0.5	50 M (50 M)	Run-21
7.7	3.85	C	0	420	90	100 M (100 M)	Run-21
7.7	31.2	FXT	2.10	420	0.5+1.0+ scattered	50 M + 112 M + 100 M (100 M)	Run-19+20+21
7.2	26.5	FXT	2.02	443	2+Parasitic with CEC	155 M + 317 M	Run-18+20
6.2	19.5	FXT	1.87	487	1.4	118 M (100 M)	Run-20
5.2	13.5	FXT	1.68	541	1.0	103 M (100 M)	Run-20
4.5	9.8	FXT	1.52	589	0.9	108 M (100 M)	Run-20
3.9	7.3	FXT	1.37	633	1.1	117 M (100 M)	Run-20
3.5	5.75	FXT	1.25	666	0.9	116 M (100 M)	Run-20
3.2	4.59	FXT	1.13	699	2.0	200 M (200 M)	Run-19
3.0	3.85	FXT	1.05	721	4.6	259 M -> 2B(100 M -> 2B)	Run-18+21



fixed target at STAR



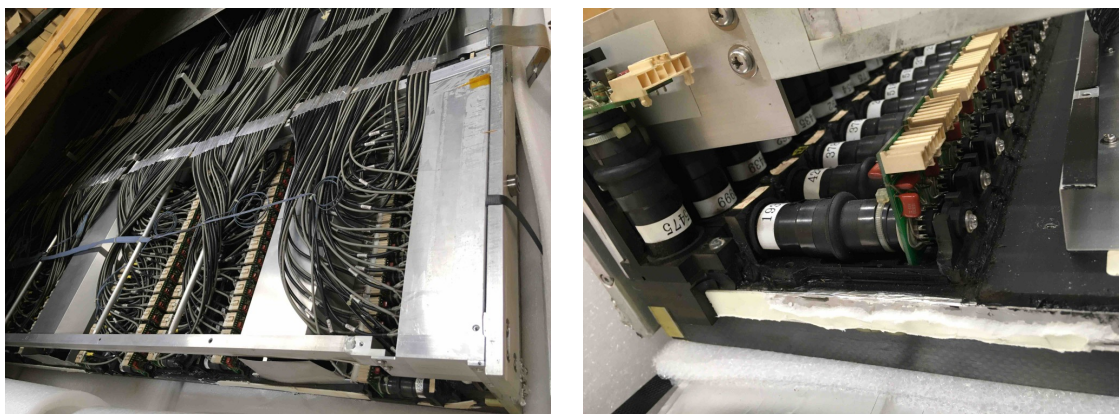
宇宙初期から中性子星内部へ 高温領域から高密度領域へ



J-PARC-HI (KEK/JAEA)



PHENOX TOF検出器の再利用



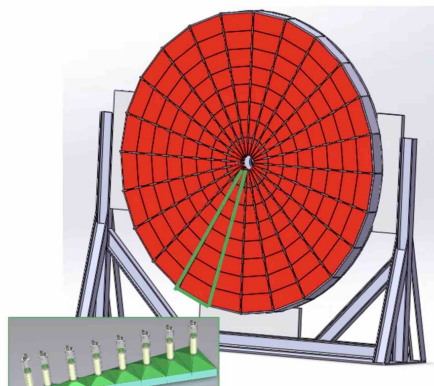
概述 - ZDC探测器介绍

HIAF · HIRFL-CSR · CEE実験



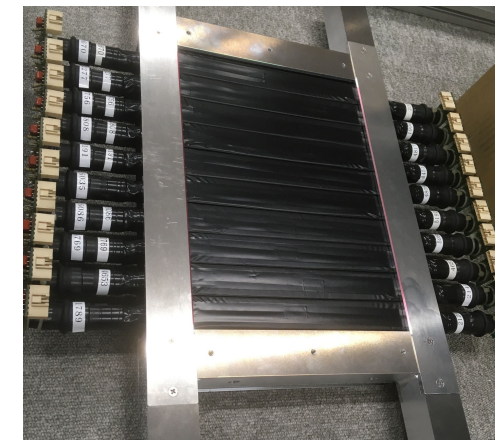
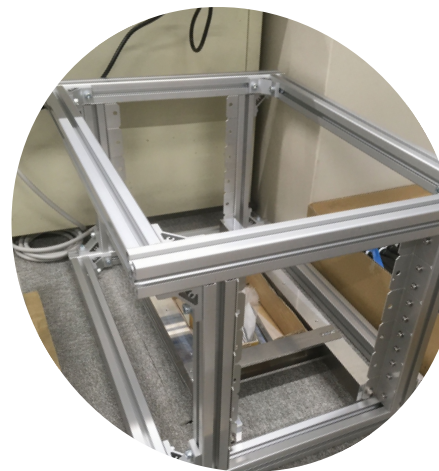
- ZDC探测器安装在CEE的磁铁下游方向，为轮盘结构，前表面距磁铁中心2.95m，束流垂直从轮盘内径里穿过
- ZDC探测器采用“塑闪+光导+真空光电倍增管(PMT)”设计方案
- ZDC探测器测量前向区带电粒子在ZDC里的沉积能量和击中位置信息，确定核碰撞中事件碰撞中心度和事件平面，为CEE以后的物理分析提供基本测量量

ZDC探测器的几何参数	
距磁铁中心距离	2.95 m
ZDC轮盘内径	5 cm
ZDC轮盘外径	100 cm
探测模块数	192 (24扇区 × 8模块/扇区)
电子学道数(双打拿极输出)	384
ZDC主要技术指标	
探测效率	> 95%
通道占有度	< 15%
有效面积	> 1m ²



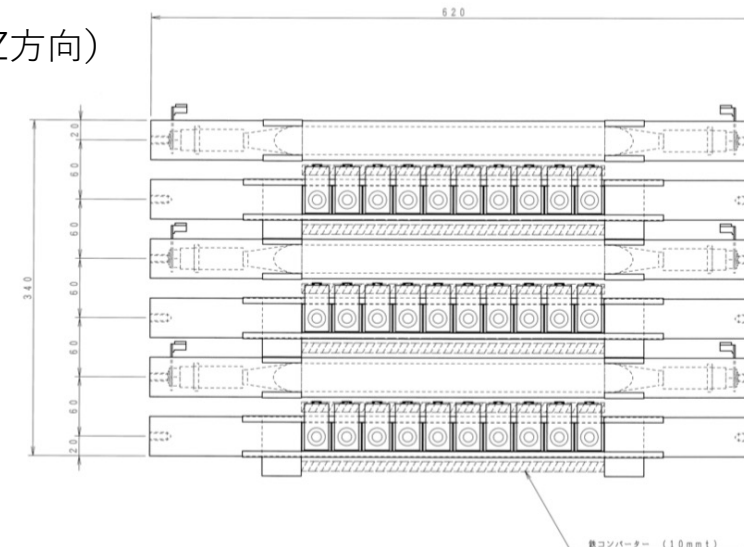
net-proton測定からnet-baryon測定へ

(中性子検出器をCBM・J-PARC-HIへ)



ビーム (Z方向)

X層
Y層
X層
Y層
X層
Y層



三明さんとのエピソード

- 大学院の時の集中講義で
- 三明さんが筑波大におられたので
- どこかの会議へ行った時に、同じホテルの部屋で
- いつも前向きで、とてもユニークな関西人
- 根っからの科学者で、いつも革新的
- 粒子生成、相関、フローから、ジェットへ
- 数理物質系長、研究担当副学長、理事
- 宇宙史一貫教育、研究ユニット招致
- KEKサマーチャレンジ、高校への出前授業
- 科研費申請（STARと臨界点、FoCalと前方）
- 家族想い
- 米びつと犬とPC
- 電話会議とヘビーメタル

