ISOBARIC COLLISIONS AS PRECISION PROBES OF THE DEFORMATION OF ATOMIC NUCLEI

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BACKGROUND

QUADRUPOLE DEFORMATION → BASIC PROPERTY OF NUCLEI

QUADRUPOLE MOMENT:

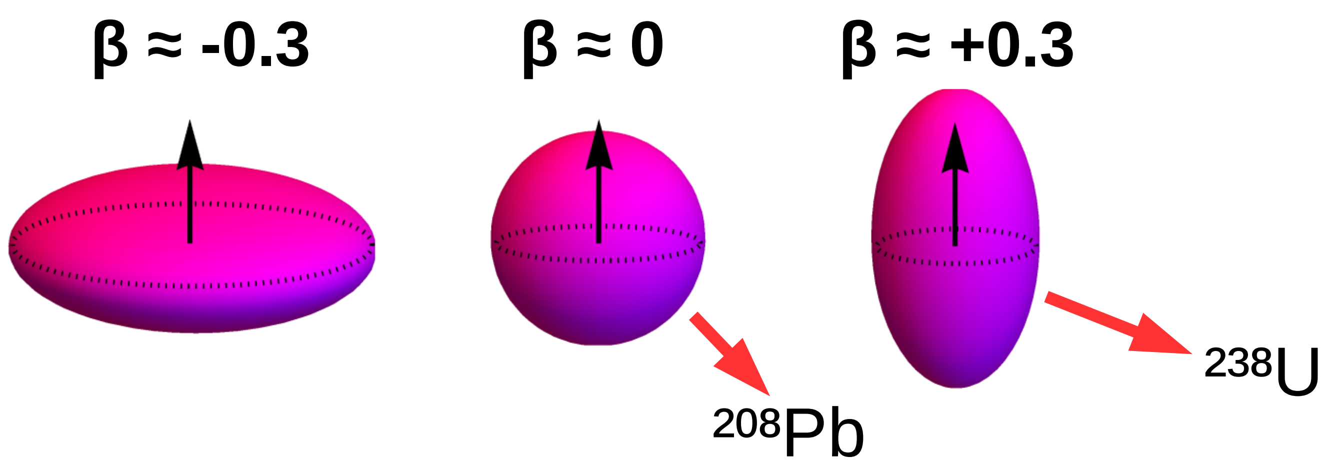
$$Q_2 \propto \langle Y_2^0(\Theta, \Phi) r^2 \rangle \neq 0$$

OVER GROUND STATE

DIMENSIONLESS DEFORMATION PARAMETER:

$$\beta \propto \frac{Q_2}{\langle r^2 \rangle}$$

[Giacalone, **2101.00168**]

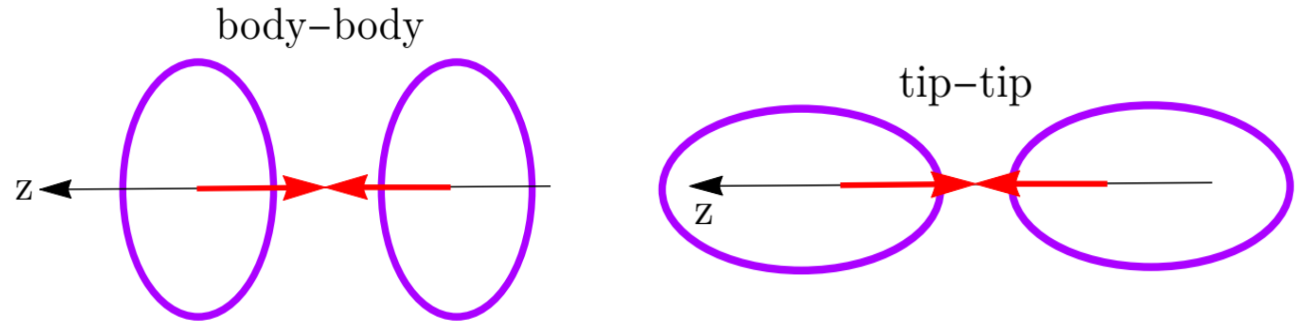


PREDICTED BY NUCLEAR MODELS.

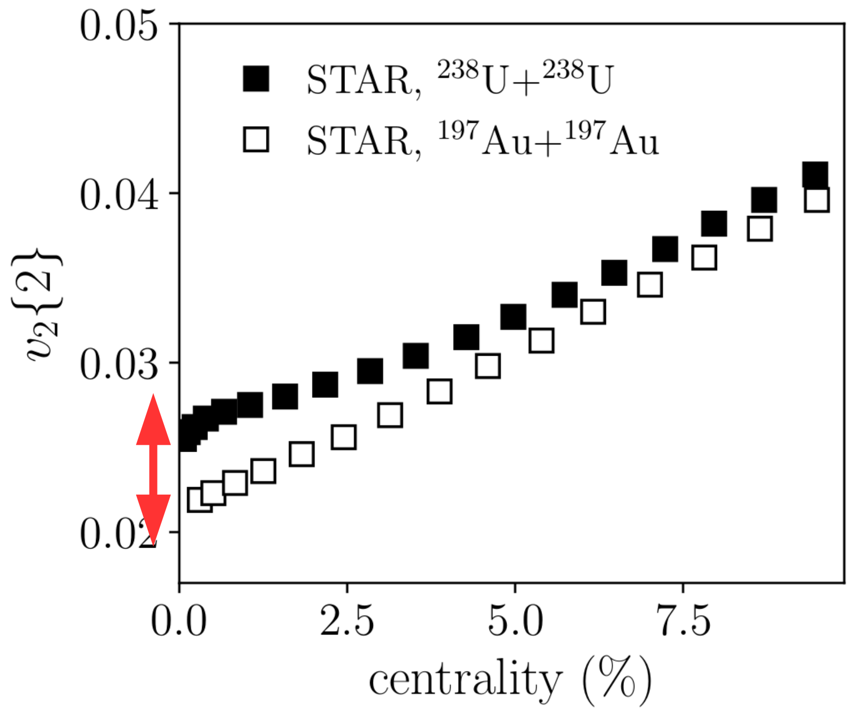
INFERRED FROM LOW-ENERGY EXPERIMENTS.

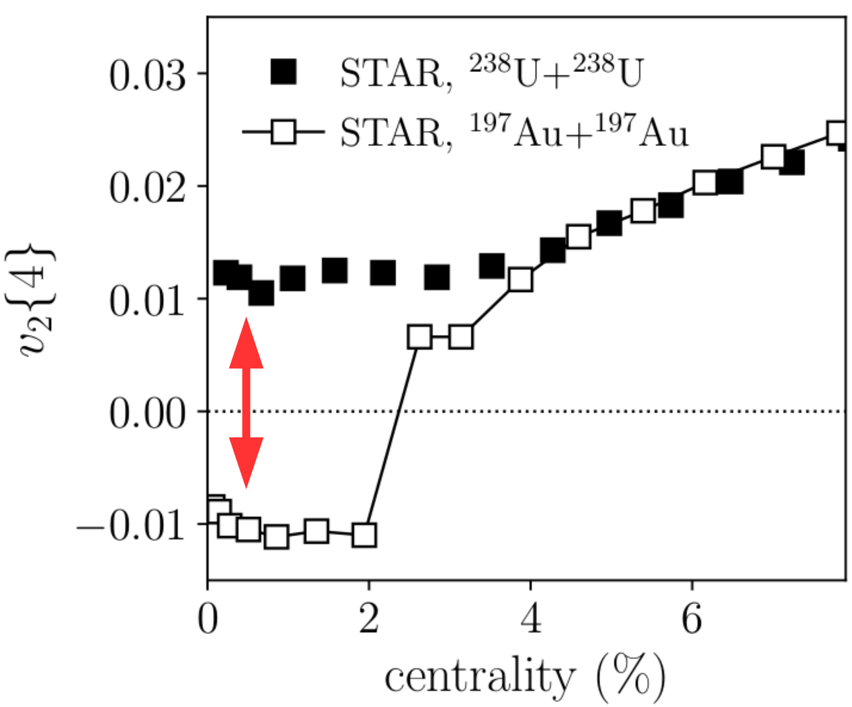
IMPACT IN CENTRAL HEAVY-ION COLLISIONS: REGIONS OF OVERLAP

$^{238}U + ^{238}U$



MANIFESTATIONS IN ELLIPTIC FLOW CUMULANTS.





[STAR Collaboration, 1505.07812] [Giacalone, 1811.03959]

NEW MEANS OF PROBING THE QUADRUPOLE PARAMETER, β.

OUR IDEA FOR ISOBARIC COLLISIONS

IN GENERAL ONE HAS: $v_2 = \kappa_2 \; \varepsilon_2$

κ_2 → **MEDIUM PROPERTIES**

ε_2 → **INITIAL STATE ANISOTROPY**

ISOBARIC (^{96}Ru, ^{96}Zr) SYSTEMS: SAME MEDIUM PROPERTIES.

$$\kappa_2[\mathrm{Ru+Ru}] = \kappa_2[\mathrm{Zr+Zr}]$$

THEREFORE, ONE EXPECTS:

$$\frac{v_n\{2k\}_{\mathrm{Ru+Ru}}}{v_n\{2k\}_{\mathrm{Zr+Zr}}} = \frac{\varepsilon_n\{2k\}_{\mathrm{Ru+Ru}}}{\varepsilon_n\{2k\}_{\mathrm{Zr+Zr}}} \overset{?}{=} 1$$

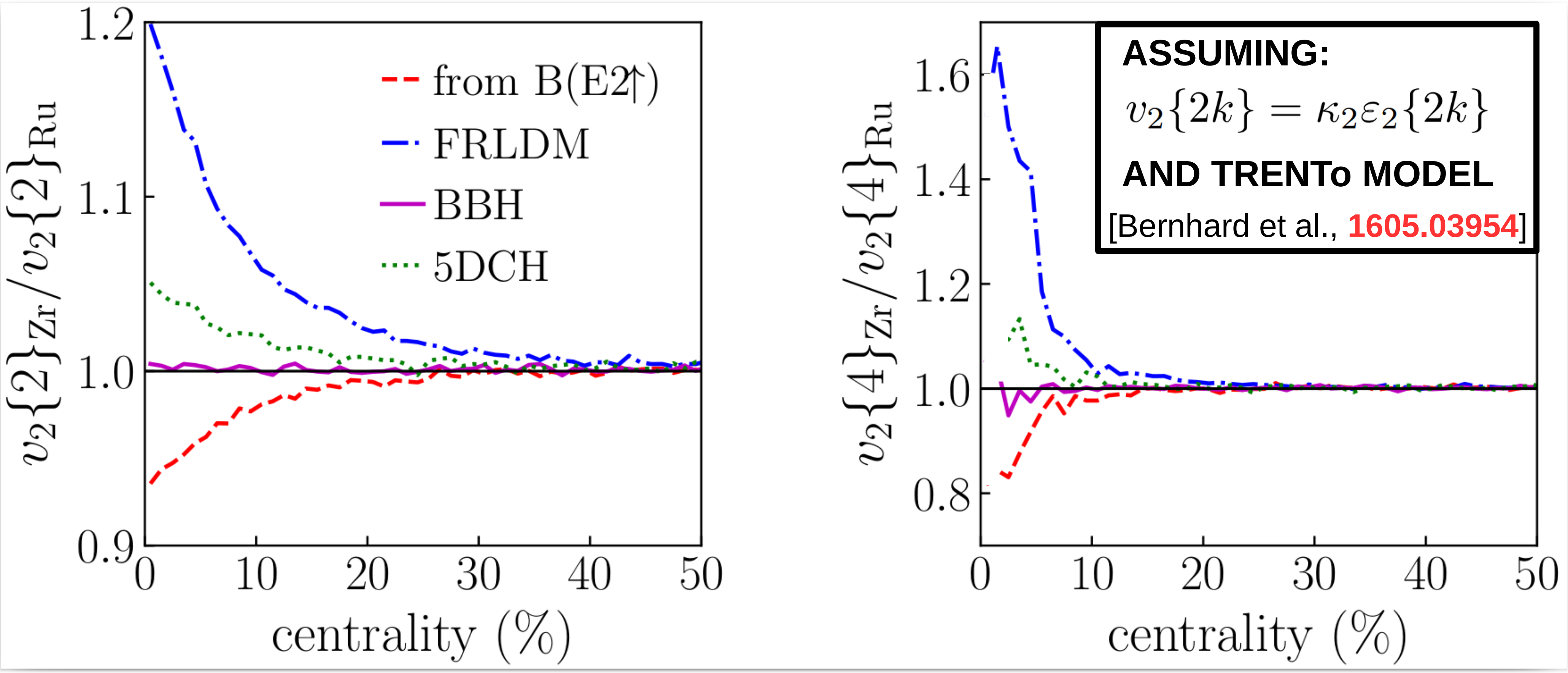
DEVIATIONS FROM 1 DEPEND ON β. TEST OF NUCLEAR MODELS.

- **(measured) transition B(E2) values.** [Pritychenko et al., 1312.5975]
- **Empirical liquid-drop deductions** [Möller et al., 1508.06294]
- **Beyond-mean-field EDF (HFB+SLy4/Gogny D1S).** [Bender et al., nucl-th/0508052] [Bertsch et al., 1010.1876]

model	β_{Zr}	β_{Ru}
from B(E2↑)	0.062	0.154
FRLDM	0.240	0
5DCH	0.151	0.197
BBH	0.020	-0.020

RESULTS

(experimental error in ratios only statistical, i.e., negligible!)



- **These are <u>quantitative predictions.</u>** (up to error in centrality determination)

- **Difference between models much larger than experimental error.**

- **Data serves as <u>precision probe of state-of-the-art nuclear theory</u>.**

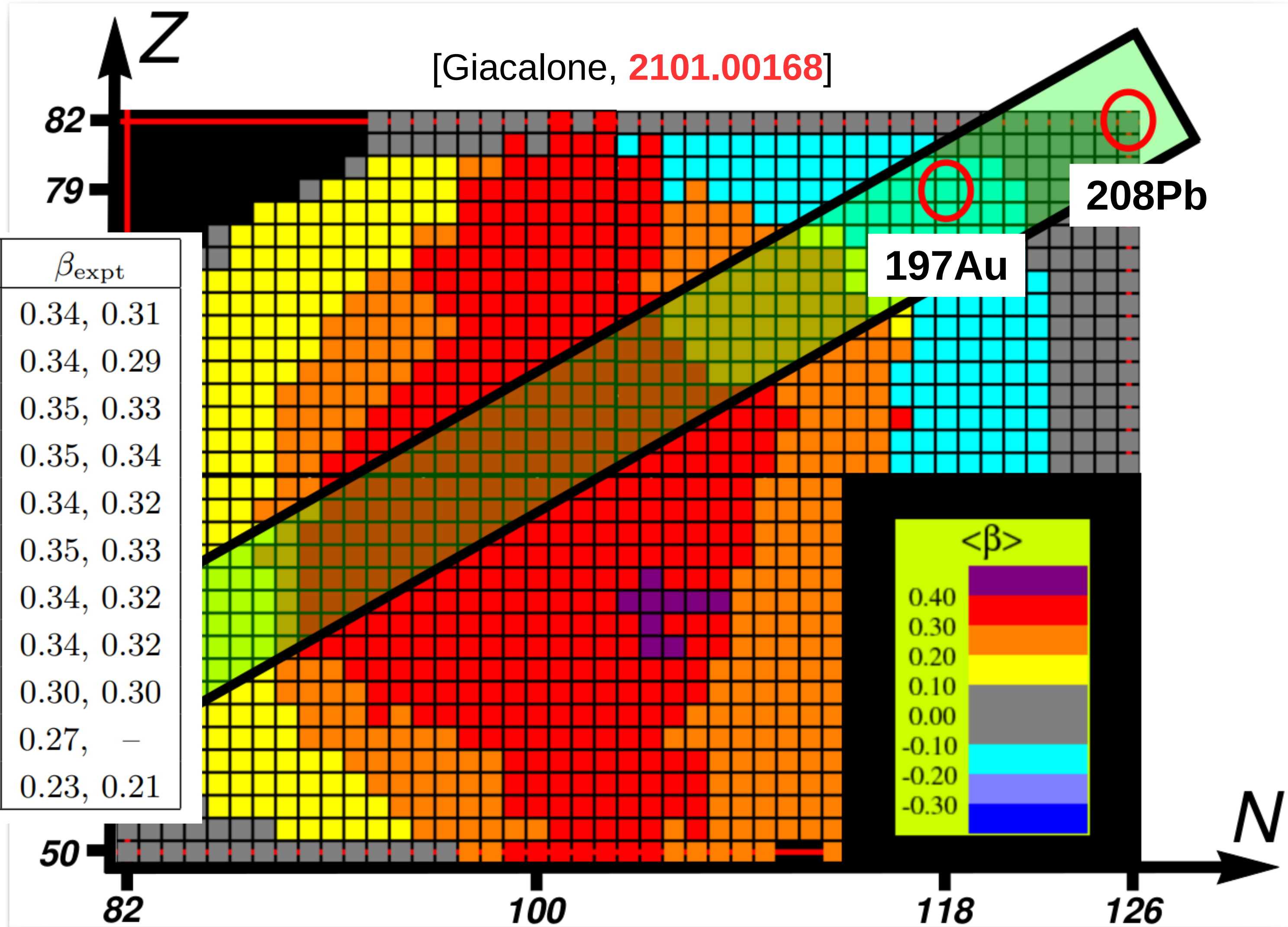
FUTURE

DEFORMATION ACROSS STABILITY VALLEY.
PAIRS OF WELL-DEFORMED ISOBARS ARE IDEAL TO THE PURPOSE.

[Bender, Bertsch, Heenen nucl-th/0508052]

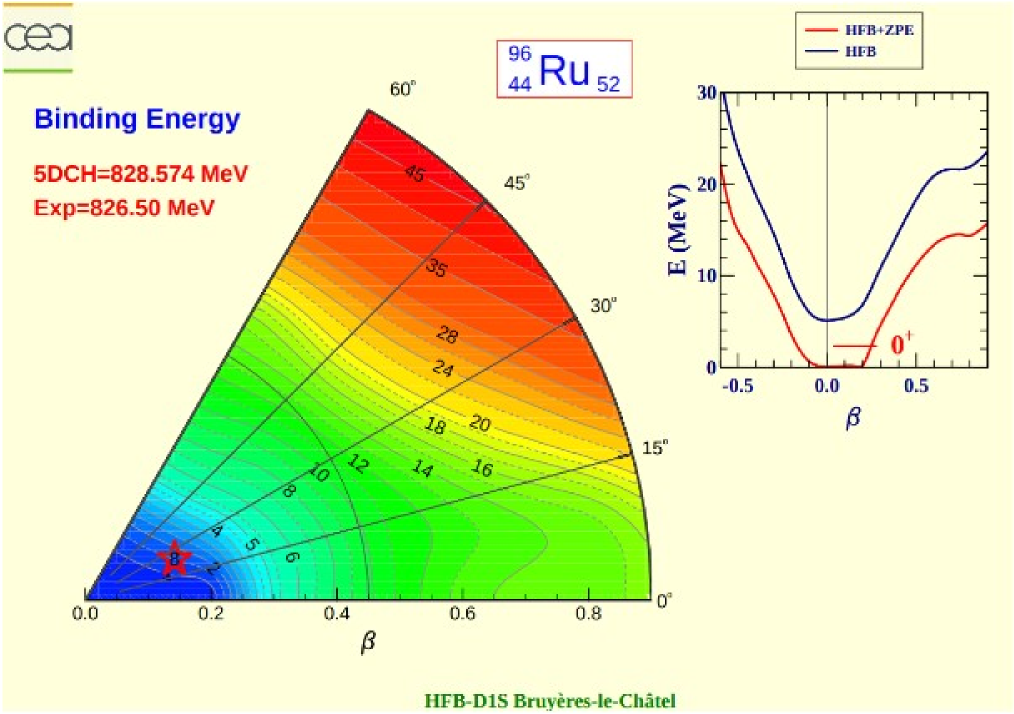
[Pritychenko et al., 1312.5975]

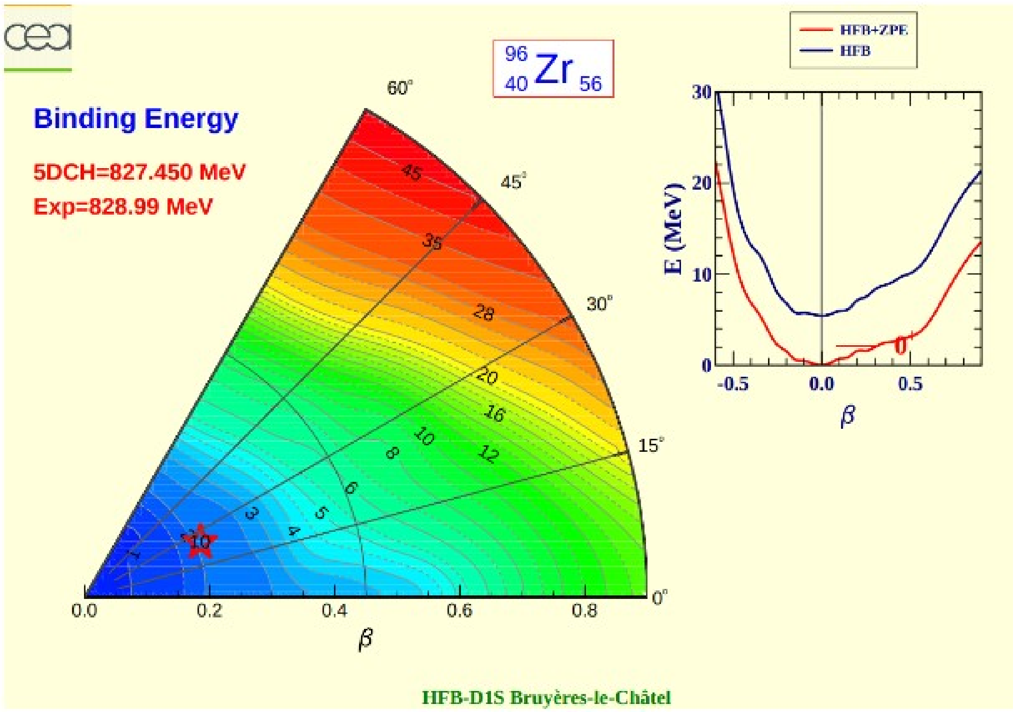
A	isobars	$\beta_{\rm theory}$	$\beta_{\rm expt}$
154	$_{62}$Sm, $_{64}$Gd	0.35, 0.33	0.34, 0.31
156	$_{64}$Gd, $_{66}$Dy	0.35, 0.30	0.34, 0.29
158	$_{64}$Gd, $_{66}$Dy	0.36, 0.34	0.35, 0.33
160	$_{64}$Gd, $_{66}$Dy	0.37, 0.35	0.35, 0.34
162	$_{66}$Dy, $_{68}$Er	0.36, 0.35	0.34, 0.32
164	$_{66}$Dy, $_{68}$Er	0.36, 0.35	0.35, 0.33
168	$_{68}$Er, $_{70}$Yb	0.34, 0.35	0.34, 0.32
170	$_{68}$Er, $_{70}$Yb	0.34, 0.35	0.34, 0.32
176	$_{70}$Yb, $_{72}$Hf	0.31, 0.32	0.30, 0.30
180	$_{72}$Hf, $_{73}$Ta*	0.29, 0.30*	0.27, –
184	$_{74}$W, $_{76}$Os	0.26, 0.24	0.23, 0.21

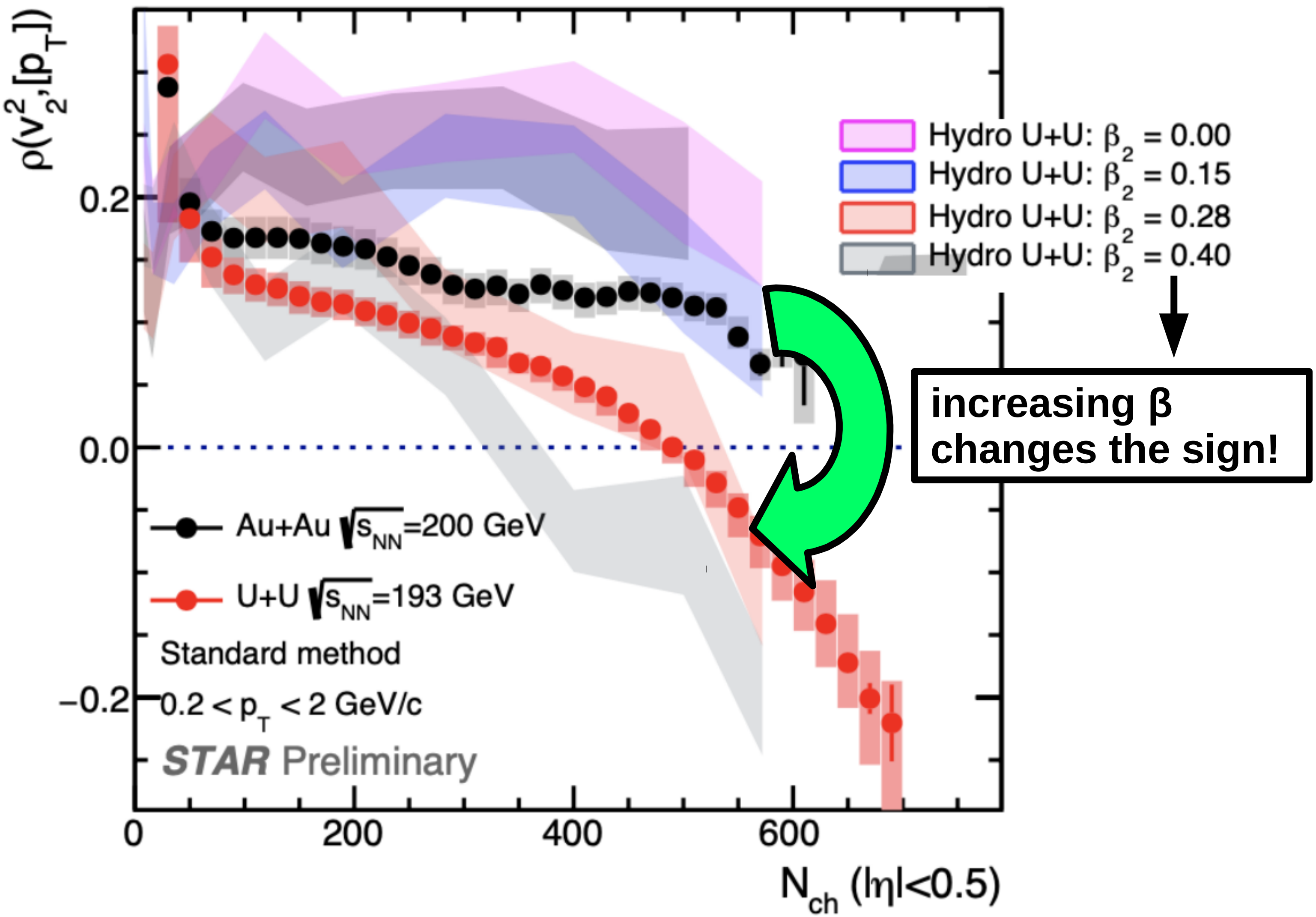


SMALL DIFFERENCES CAN BE SEIZED AT COLLIDERS.
GREAT PHYSICS OPPORTUNITY AT RHIC.

BACKUP


96 44 Ru 52
Binding Energy
5DCH=828.574 MeV
Exp=826.50 MeV
HFB+ZPE
HFB
E (MeV)
0+
β
HFB-D1S Bruyères-le-Châtel


96 40 Zr 56
Binding Energy
5DCH=827.450 MeV
Exp=828.99 MeV
HFB+ZPE
HFB
E (MeV)
0+
β
HFB-D1S Bruyères-le-Châtel


$\rho(v_2^2,[p_T])$
0.2
0.0
−0.2
0
200
400
600
N_{ch} (|η|<0.5)
Hydro U+U: β_2 = 0.00
Hydro U+U: β_2 = 0.15
Hydro U+U: β_2 = 0.28
Hydro U+U: β_2 = 0.40
increasing β
changes the sign!
Au+Au $\sqrt{s_{NN}}$=200 GeV
U+U $\sqrt{s_{NN}}$=193 GeV
Standard method
$0.2 < p_T < 2$ GeV/c
STAR Preliminary