Sergei A. Voloshin

Evolution of expectations:

2004-2009: the signal in Au+Au might be about 1/3 of $\Delta \gamma$. We should be able to get "accuracy" of about 10% of $\Delta\gamma$ 2017-2019: the signal is likely less than 10-15%. We should be able to achieve 5% accuracy 2021 - isobars - no (?) signal at the level ~a few %, but it might be larger in AuAu and/or PbPb.

~2025(?) SP/PP and/or ESE < 0.5% in AuAu/ PbPb?





Playing on signal with system size

"Cross-observable-correlation"



Toward 1% precision



$$\frac{(\Delta \gamma/v_2)_{\rm Ru+Ru}}{(\Delta \gamma/v_2)_{\rm Zr+Zr}}$$

STAR \Rightarrow **STAR**: f_{CME} from $\Delta \gamma$, SP/PP

Search for the chiral magnetic effect via charge-dependent azimuthal correlations relative to spectator and participant planes in Au+Au collisions at $\sqrt{s_{NN}} = 200 \text{ GeV}$ STAR Collaboration PHYSICAL REVIEW LETTERS 128, 092301 (2022)

Error bars show statistical uncertainties; the caps indicate the systematic uncertainties.

Implications. Conclusions STAR 🛠

STAR isobars:

- Accurate upper limits for $f_{\rm CME}$ are being evaluated.

Isobar results do not exclude a bigger signal in AuAu. The signal could be significantly smaller in such (relatively small nuclei) collisions

Y. Feng, Y. Lin, J. Zhao, and F. Wang, Phys. Lett. B 820, 136549 (2021),

Should we request for more? $^{136}_{54}$ Ce, $^{136}_{50}$ Xe?

- No CME signature that satisfies the predefined criteria has been observed in isobar collisions in this blind analysis.

The signal could depend strongly on the system size. Calculations by A. Dobrin (private communication)

Isobar run was a real success (not only for the CME search)

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S.A. Voloshin

													61									P11120 -088	-1 S	228	-48	638	PH1155 158	-58	PIII155 458	PH1150 1078	PH1157 24 M	PIII158 108	PHIL59 415M	P111140 928	P111141 2050 M	11142 0.58	Pm143 265D	3Fm144 363.0	17.7 Y
	C		ЛР		P		N	1114	cli	de	C		60								Nd126	Nd127	7 Nd128	Nd129	Nd130	Nd131	Nd132	Nd133	Nd134	Nd135	No 6	Nd137	Nd138	Nd139	Nd140	Md141	Nd142	2 Nd143	Nd
			AN							uc	53		59				Pr121	Pr122	Pr123	Pr124	Pr125	Pr126	Pr127	Pr128	Pr129	^{33 S} Pr130	Pr131	Pr132	Pr133	Pr134	Pr135		Pr137	Pr138	Pr139	^{дун} 7140	272 Pr141	Pr142	238 Pr1
																Ce119	148 Ce120	-0.58 I Ce121	-088 Ce123	128 Cel23	3.38 Ce124	3.14.8 Ce125	428 5 Ce126	31.8 Ce127	32.8 Ce128	400 S	943 Ce130	1£ж Се131	<u>6.5ж</u> Се132	17 м Се133	<mark>24 м</mark> Се134	Ce135	128H	1.45M Ce137	441 H	<mark>.39 м</mark> Ге1 30	ւա Ce140	19.12 н Се141	13.57 3 Cel
													58		1 117	-02.8	-0258	1.1.8	-2 5	385	68	102 8	50 S	31.8	3,53 м	3.5M	25M	102 M	3.51 H	97 м 1 1 2 2	3.16D	17.7 H	0.185	рон 1. 1.26	0251	57.640 D	BB 4 50	32.50LD	11.11
													57		Lall/ -0.58	Lall8	La119 -28	La120 288	5.38	Ear22 8.7 S	La123 178	La124 <1 8	La125 64.8.8	La120 <108	La127 51 M	La128 523 M	La129 11 <i>б</i> м	La130 87 м	Lа131 яж	La1 <i>32</i> 4вн	La133 зяі2 н	La134 645m	La135 19.5H	La130 987 м		.a1.38 190	La139 99910	La140 1 <i>67</i> 81 D	La1 352 F
													56	Ba115 0458	Ba116	5 B a117 1.758	Ba118	Ba119 54 S	Ba120 24 S) Ba121 29.7 s	Ва122 195м	Ва123 27 м	Ва124 плм	Ba125 3.5м	Ва126 100 м	Ва127 12.7 м	Ba128 2.43D	Ba129 223н	Ba130	Ba131 11.500	Ba132	Ba133 9848.9 D	Ba134 2.417	Ba135 6.52	Ba136 7854	3a137 1232	Ba138 n <i>e</i> se	Ba139 выся	Ba1 12.72
													55	Cs114	Cs115	5 Cs116	Cs117	Cs118	3 Cs119	Cs120	Cs121	Cs122	2 Cs123	Cs124	Cs125	Cs126	Cs127	Cs128	Cs129	Cs130	Cs131	Cs132	Cs133	Cs134	Cs135	Cs136	Cs137	Cs138	Cs1
												7	54	Xe113	Xe114	Xe115	Xe116	5 Xe117	7 Xe118	3 Xe119	Xe120	Xe121	Xe122	Xe123	Xe124	Xe125	Xe126	Xe127	Xe128	Xe129	Xe130	Xe131	Xe132	Xe133	Xe134	Ke135	Xe136	Xe137	Xel
7													52	2.74 S I1112	100 s I1113	18 S I1114	59 S 1115	<u>ы s</u> I116	звж 1117	звж 1118	40 м 1119	40.1 м 1120	201 н I121	2лен 1122	1123	і сян I124	1125	¥64 d I126	1,910 1127	26.40 1128	4.071 1129	21 232 1130	26.505 1131	5243D 1132	10.4% 11.33	14н 134	1135	MBIRE	14 08 3
									T-106	T-107	T-108	T-100	T-110	342.8	668 Tr-110	21.8 Tra1.1.2	13M	2.91.8	2 22 M	137M	101 M	BLD X	212 H	<mark>зазж</mark> То121	1327 H	4.1760 D	\$9400 D To 1 2 4	13.11 D	100 To126	<mark>24.59 м</mark> То 1.27	150000 Y	12.36H	802070 D	2295н То131	208н То132	2.5M	6.57 H Tol 34		24.5 S
52									feruo erus	3.1 MS	2.1.8	468	1868	19.38	тепт2 20м	1ентэ 1.7 м	тетт4 152 м	тепт5 58 ж	2.49H	си по тегти си м	600D	тег 19 16ЛЯН	10120 009	1916D	2.55	089	4.74	707	1884	9.35H	31.74	Пет29 Фбж	тет50 34дв	25DM	3204 D	1.5M	10134 41.8 м	1905	
51							Sb103 st.sus	Sb104 0.44 S	Sb105	Sb106 063	5 Sb107	5b108 74 s	Sb109 170 S	Sb110 230 S	Sb111 758	Sb112 51.4.8	Sb113 667 м	Sb114 349 м	Sb115 321 м	Sb116 158 M	Sb117 280 н	Sb118 зем	Sb119 9819 H	Sb120 15вяж	Sb121 5721	Sb122 2.7238 D	Sb123 42.79	Sb124 6020 D	Sb125 279955 Y	Sb126 12.46 D	Sb127 3850	Sb128 9шн	Sb129 440 H	Sb130 99.5м	Sb131 23Л3 м	Ъ132 лям	Sb133 2.5м	Sb134 0.78 s	Sb1 1688
50					Sn100	Sn101	Sn102	2 Sn103	Sn104	Sn105	5 Sn106	5 Sn107	Sn108	Sn109	Sn110	Sn111	Sn112	Sn113	Sn114	Sn115	Sn116	Sn117	Sn118	Sn119 8.59	Sn120	Sn121 27.06 н	Sn122 4ഒ	Sn123	Sn124 5.79	Sn125 964 D	Sn126	Sn127	Sn128 5907 м	Sn129 223 M	Sn130 3.72 м	3n131 508	Sn132 39.7 s	Sn133	Sn1
49				In98	In99	In100	In101	In102	In103	In104	In105	In106	In107	In108	In109	In110	In111	In112	In113	In114	In115	In116	In117	In118	In119	In120	In121	In122	In123	In124	In125	In126	In127	In128	In129	n130	In131	In132	In1.
48		[Cd96	Cd97	Cd98	Cd99	Cd100	0 Cd101	Cd102	2 Cd103	3 Cd104	Cd105	Cd106	6 Cd107	Cd108	Cd109	Cd110	Cd111	Cd112	2 Cd113	Cd114	Cd115	Cd116	Cd117	Cd118	Cd119	Cd120	Cd121	Cd122	Cd123	Cd124	Cd125	Cd126	Cd127	Cd128	Cd129	Cd130	Cd131	
47	A	<u>9</u> 94	-1 s A295	283 Aq96	928 Ag97	163 Ag98	49.1 S Ag99	1.36M Ад100	5.5x Ag101	7.3м Ар102	<mark>ялж</mark> 2 Ар103	55.5м З Ар104	125 Ag105	б.50н 5 <mark>Ар106</mark>	0.89 Ag107	461.4 D Ag108	12.49 Ag109	1280 Ag110	24.13 Ag111	12.22 Ag112	28.73 Ag113	5346н Ар114	7.49 Ag115	2.49н Ag116	<u>ялам</u> Ag117	2 <i>в</i> ум Ag118	nens Ag119	13.58 Ag120	524 S Ag121	2.108 Ag122	1258 Ag123	0658 Ag124	0.506 s Ag125	0.37 s Ag126	0.34 S Ag127	27 s Ag128	020 s Ag129	-0.18 S	
41	15) De	KS 10.2	203 D-0404	51 S	252 Ddi	46.7 S	124 S	2Д ж D-100	ні м Ратоо	12.9 M	657 M	692 ж Раноз	41 29 D	23.96 M	51.859 12-11-06	2.37 м Ра107	48161 D-1102	24.6.S	7.45D	<u>ыю</u> н Ран н	5.37 H	468 Dd113	200 M	2.69 ж Рd115	72.8 S	3.768 Pd117	213 Pd118	123s Pd119	0.78 s Pd120	0.20 s Pd121	02938 Pd122	0.172 S	166 MS	107 MS	79 MS	H MS	46 M.S		
46	6 0.9	5	FU94 908	-108	FU9 122 S		Г U90 17.7 М	21.4 M	3630	BATH	112	16991 D	11.14	22.33	27.33	69000Y	26.46	РС109 13.7012 H	11.72	234 M	21 JBH	538 538	2.42 M	258	1185	4.38	198	0.52 S	0.58	N SE NS	N SEINS	N SUNS	-02 8						
45	R1 >10	h92 виз	Rh93	Rh94 258 S	Rh95 512 м	9.90 M	Rh97 20.7 м	Rh98 8.7 м	Rh99 16.1 D	Rh100 208 H	3.3 Y	207 D	Rh103	42.3 S	Rh105 35.36 H	29 ED S	Rh107 21.7 м	Rh108 168 S	S Rh109 BD S	Rh110	Rh111 11 S	Rh112 3458	2 Rh113 2 HD S	Rh114 1858	0.59 S	Kniio Dess	Rh11/ 0,44 S	Rhiið >ustuns	Knii9 skors	Rh12U Ngang	Rh121 >150NS	Кh122 -£0м8							
44	R1 9 S	u91	Ru92	Ru93 \$9.7 s	Ru94 ม.ย.พ	Ru95	Ru96	Ru97 2.791 D	Ru98	Ru99	Ru100	Ru101	Ru102	2 Ru103	Ru104	Ru105	Ru106	i <mark>Ru107</mark> 3.75м	7 Ru108	Ru109	Ru110	Ru111	Ru112	Ru113	Ru114	Ru115	Rull6 אוסא	Ru117 אוסצוג	Rull8 NS	Ru119 >1 50 NS	Ru120 אום א								
43	Ta	:90	Tc91	Tc92	Tc93	Tc94	Tc95	Tc96	Tc97	Tc98	Tc99	Tc100	Tc101	Te102	Tc103	Tc104	Te105	Tc106	Te107	Te108	Tc109	Te110	Tc111	3.67		1.0													
42	M	o89	Mo90	Mo91	Mc92	Mo93	Mo94	428D Mc95	Mo96	Mo97	Mo98	Mo99	Mo10		Mo10	2 <mark>Mo10</mark>	Mo10	Mo10	5 Mo10	6Mo107	Mo108	Mo109	9 Mo110		Sun	nme	r 20)16		exte	ensi	veo	disc	uss	ion	of r	oos	sibl	e
41	2.11 N	м b88	5.56 H Nb89	15.49 м Nb90	14.84 Nb91	4000 Y Nb92	925 Nb93	15.52 Nb94	Nb95	9.55 Nb96	24.13 Nb97	65.54 H Nb98	Nb99	14 бі м Nb100	и.зм Nb101	67.58 Nb102	ens Nb103	356 S Nb104	BAS Nb105	3.58 5 Nb106	1.09 S Nb107	0.53 S Nb108	0.30 S Nb109		sob	ar r	airs	S:		0/110						о. г			
¥1	14.5	5M -07	213H	14 £0 H	980 Y	3470000	Y 100	20300 Y	34.597 D	23.35H	72.1 M	2.86 S	1508	1.58	7.1 S	1.38 Ze101	1.58 Ze102	498 Ze102	2.958 Zr104	1 III S	330 MS	0.193 S	0.19 8																
40	1.9	ю/ н	Z100 B34D	Z109 7841 H	2190 51.45	11 22	17.15	2195 15000 Y	2194 1738	64 E2 D	2.50	Z197 16.744 H	2198 30.7 S	2.1 S	ZF100 7.1 8	2.3.8	2.9.8	2F105 1.38	128	068	ZT100 >19DNS	2.F107 1.50 MS	ZTIU8 >15DNS			onsi			n:			-I:£	C						
39	Y 14.3	86 4н	Y87 798н	Y88 106650	Y89 100	Ү90 64 ш н	Y91 98.51 D	¥92 3.54 н	Y93 10.18 н	Ү94 18.7 м	Y95 103м		Y97 3.758	Y98 0.548 S	Y99 1.470 S	Y100 735 MS	Y101 0.458	Y102 0.30 s	Y103	Y104 180 MS	¥105 мартя	¥106 >19⊒№	Y107 30 M S	- 1	- Iar	ges	t (re	elati	ve)	cna	arge		rere	nce	}				
38	Sr 64.8	:85 4 D	Sr86	Sr87 7ш	Sr88	Sr89 9.50	Sr90	Sr91	Sr92 2лн	Sr93	Sr94	Si 5	Sr96	Sr97	Sr98	Sr99 0269 s	Sr100	Sr101	Sr102	Sr103	Sr104	Sr105		-	- sir	nilar	TITY	IN SI	nap	e									
37	R	b84	Rb85	Rb86	Rb87	Rb88	Rb89	Rb90	Rb91	Rb92	Rb93	Rb94	Rb 5	Rb96	Rb97	Rb98	Rb99	Rb100	Rb101	Rb102				18	- av	allal	OIIIT	y ar	id p	rice									
36	Market Street	r83	Kr84	Kr85	Kr86	Kr87	Kr88	Kr89	Kr90	4.492 S Kr91	Kr92	Kr93	Kr94	Kr95	Kr96	Kr97	Kr98	Kr99	Kr100	3/ M-S]			-	- po	SSID	ollity	to	acc	eler	ate	(Ia	nde	em,	FR	5)			
00	117 B1	9 182	ஏற Br83	39344D Br84	17.30 Br85	763 м Br86	284H Br87	<u>315м</u> Br88	32.32 S Br89	8.57 S Br90	1.840.8 Br91	1.286.8 Br92	020 S Br93	0.78 S Br94	>£DMS Br95	ы su su su Br96	ы яля Br97	>1 50 MS	>1 5 0 NS																				
35	35.3	ЮН	2.40 H	N DE IE	2.50 M	55.1 S	55.60 8	1629 8	4.40 S	1.51.8	0.541 S	0.343 8	102 MS	πxs	>1 SI NS	>1 SI NS	>1 SI NS																						

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correlations in Xe–Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV

$$\Gamma^{\text{Xe}-\text{Xe}} = sB^{\text{Xe}-\text{Xe}} + bv_2^{\text{Xe}-\text{Xe}},$$

$$\Gamma^{\text{Pb}-\text{Pb}} = sB^{\text{Pb}-\text{Pb}} + bv_2^{\text{Pb}-\text{Pb}},$$

for the second s STAR 🖈 CM

$$\frac{(\Delta\gamma/v_2)_{\text{spectator}}}{(\Delta\gamma/v_2)_{\text{participant}}} = \frac{(\Delta\gamma/v_2)_{\text{ZDC}}}{(\Delta\gamma/v_2)_{\text{TPC}}} = \frac{\Delta\langle\cos(\phi_{\alpha} + \phi_{\gamma})_{\alpha}\rangle_{\alpha}}{\Delta\langle\cos(\phi_{\alpha} + \phi_{\gamma})_{\alpha}\rangle_{\alpha}}$$
$$\frac{(\Delta\gamma/v_2)_{\text{ZDC}}}{(\Delta\gamma/v_2)_{\text{ZDC}}} = 1 + f_{\text{CME}}^{\text{TPC}} \left(\frac{v_2^2}{v_2^2}\right)_{\alpha}$$
$$\frac{(\Delta\gamma/v_2)_{\text{ZDC}}}{(\Delta\gamma/v_2)_{\text{TPC}}} = 200 \text{ GeV} \qquad 0.2 < p_{\text{T}} < 2$$

0.08

Group 4 (also done by group 3)

Ru: 0.101 ± 0.123 (stat.) ± 0.023 (syst.) Zr: 0.009 ± 0.088 (stat.) ± 0.033 (syst.)

 $\gamma_{\beta} - \Psi_1^{\mathrm{W}} - \Psi_1^{\mathrm{E}}) \rangle / \langle \cos(2\phi - \Psi_1^{\mathrm{W}} - \Psi_1^{\mathrm{E}}) \rangle$ $\phi_{\alpha} + \phi_{\beta} - 2\phi_c) \rangle / \langle \cos(2\phi_{\alpha} - 2\phi_c) \rangle$

GeV/c APS DNP meeting, October 11, 2021 page

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S.A. Voloshin

PP/SP,

Tue Jul 9 23:21:18 2019

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WAYNE STATE UNIVERSITY

v_2 {**ZDC**}

Elliptic Flow Fluctuations at Midrapidity using Spectator Neutrons

Cross-correlations, LCC as BG to CME/CMW

Global constraint on the magnitude of anomalous chiral effects in heavy-ion collisions

Wen-Ya Wu^{a,b}, Qi-Ye Shou^{a,b}, Panos Christakoglou^c, Prottay Das^d, Md. Rihan Haque^e, Guo-Liang Ma^{a,b}, Yu-Gang Ma^{a,b}, Bedangadas Mohanty^d, Chun-Zheng Wang^{a,b}, Song Zhang^{a,b}, and Jie Zhao^{a,b}

arXiv:2211.15446v1 [nucl-th] 28 Nov 2022

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Fig. 2. Effect of the radial boost on two particle angular difference in azimuth (left panel) and pseudorapidity (right panel).

Summary

- <u>siCME</u> (si shear induced) A smaller effect but with larger signal/background ratio
- Future highs statistics data: SP/PP and, probably ESE → 0.5% level in AuAu PbPb collisions
- all other approaches seems to have too large "systematic" uncertainty
- larger isobars?

EXTRA SLIDES

LCC \Rightarrow **CME**, **CMW** observables

FIG. 9. Three-particle correlator for the second harmonic, fo positive (red squares) and negative (blue circles) particles. Statistica (systematic) uncertainties are indicated by vertical bars (shade boxes). page 14 Chi retreat UCLA, December 204, 2022

J. Adam et al.* (ALICE Collaboration)

S.A. Voloshín

