We need more p+A running before decommissioning RHIC

## *Don't give up on a discovery*

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QCD Town Hall Meeting 2022
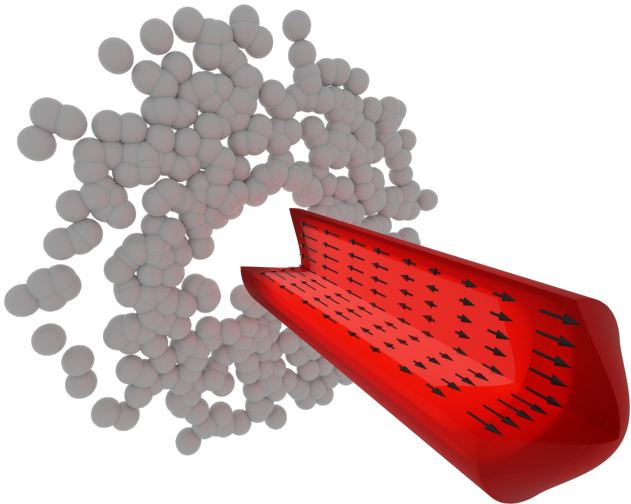
high-stats p+A running may reveal a new fluid phenomenon

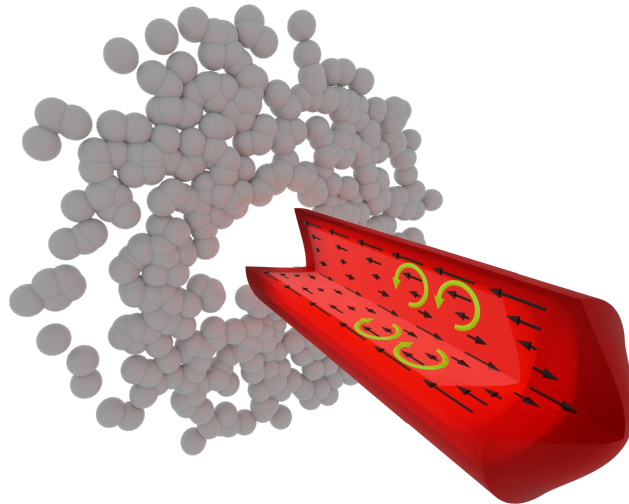Fluid behavior in central p/d/^{3}He+A collisions?

- "QGP" of hadron size?

- Thermalization mechanism?

- Do we understand the non-perturbative sector of our "reference system?"

- Ubiquity of v_n... is there another signature?

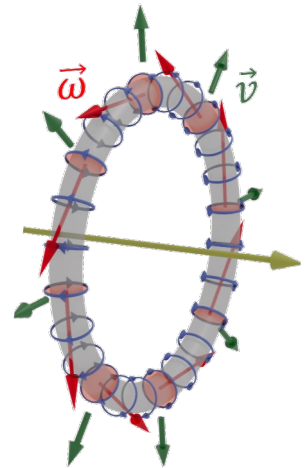Nagle & Zajc, Ann.Rev.Nucl.Part.Sci. (2018)
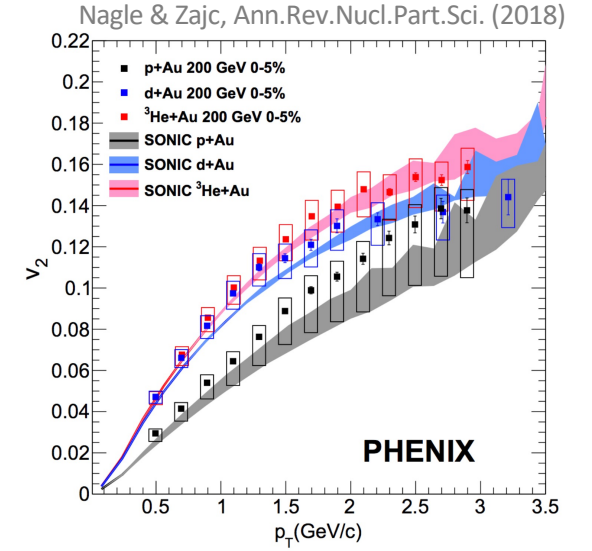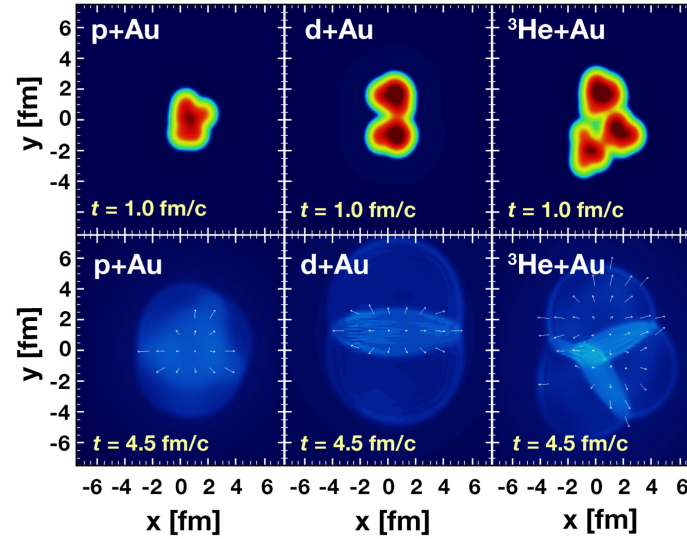
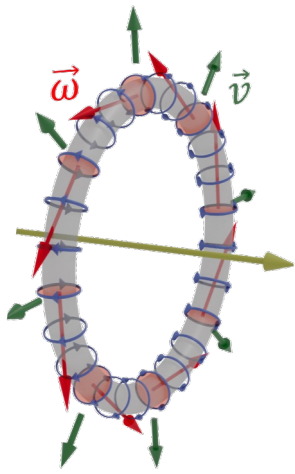Possible p+A scenarios:

Bjorken "flow" $u_z = \eta_s$

Natural response – radial gradient

Consequence:
- Expanding vortical toroid ("smoke ring")

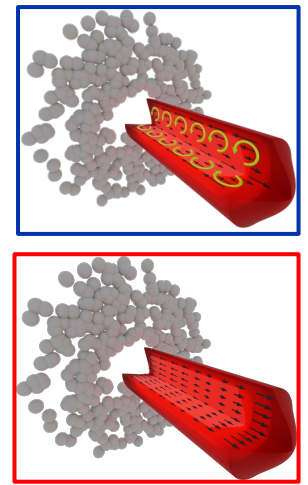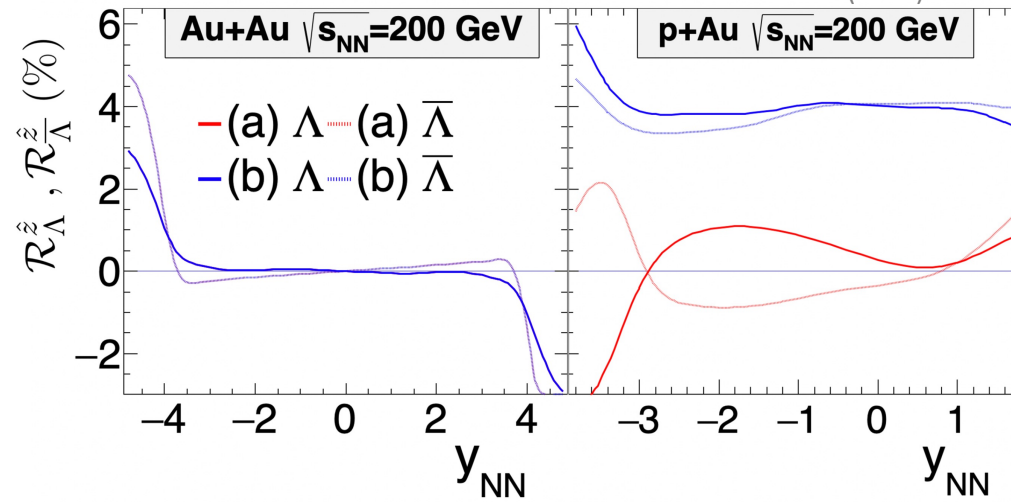Helmholtz, Phil. Mag. (1867). See also Takahashi.Nat. Phys. (2016)

Simple cumulant observable:

$$\overline{\mathcal{R}}_\Lambda^{\hat{z}} = 2 \left\langle \frac{\vec{S}'_\Lambda \cdot (\hat{z}' \times \vec{p}'_\Lambda)}{|\hat{z}' \times \vec{p}'_\Lambda|} \right\rangle_\phi$$

$$= \frac{8}{\pi\alpha} \langle \sin(\phi_p - \phi_\Lambda) \rangle$$

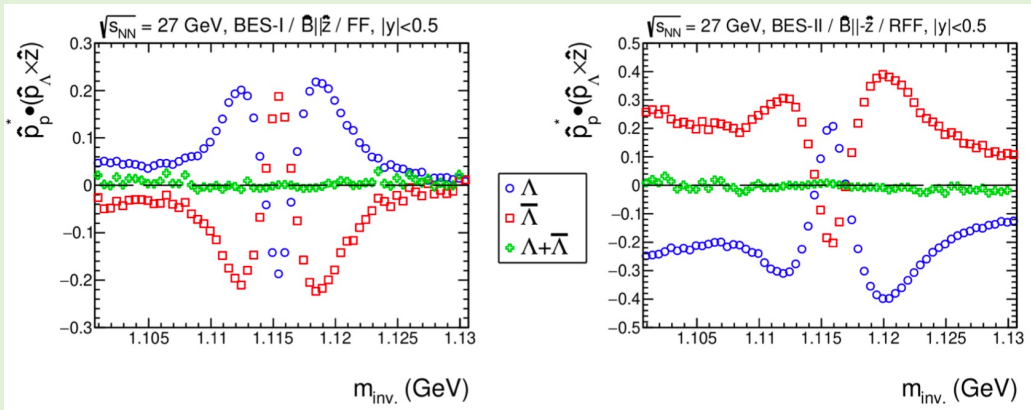signature robust against fluctuating
e-by-e initial conditions
MAL, QM2022; Chinallato et al, in prep.

PRC104 (2021) 011901

Au+Au $\sqrt{s_{NN}}$=200 GeV

— (a) Λ ---- (a) $\overline{\Lambda}$
— (b) Λ ---- (b) $\overline{\Lambda}$

p+Au $\sqrt{s_{NN}}$=200 GeV

$\mathcal{R}_\Lambda^{\hat{z}}$, $\mathcal{R}_{\overline{\Lambda}}^{\hat{z}}$ (%)

y_{NN}

Why not just use the p+A data on tape?
- large, complex detector effects cloud signal.
- *need to measure with both B-field orientations*

$\sqrt{s_{NN}}$ = 27 GeV, BES-I / $\hat{B}\|\hat{z}$ / FF, |y|<0.5

$\sqrt{s_{NN}}$ = 27 GeV, BES-II / $\hat{B}\|$-$\hat{z}$ / RFF, |y|<0.5

$\hat{p}_p^* \cdot (\hat{p}_\Lambda \times \hat{z})$

- Λ
- $\overline{\Lambda}$
- $\Lambda + \overline{\Lambda}$

$m_{inv.}$ (GeV)

Can RHIC measure this?
- Yes. STAR: ~2x500M central events [STAR BUR 2022]
- sPHENIX? probably!

STAR BUR 2022; https://drupal.star.bnl.gov/STAR/starnotes/public/SN0793
See also J. Adams at RHIC Users Meeting https://indico.bnl.gov/event/15479/

Can't you just do the same thing with jets?
- similar phenomenon expected/predicted with
  jets thru QGP, but... different physics
  W. Matioli et al, PLB820 (2021) ;
  Tachibana & Hirano, NPA (2013);
  Betz/Gyulassy/Torrieri, PRC76

→ : flow velocity e (GeV/fm^3)

y (fm)

x (fm)
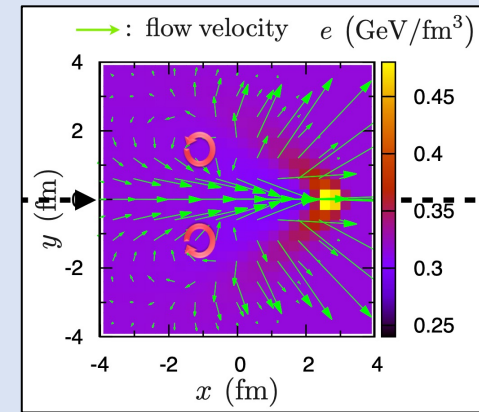
Novel fluid configuration
- unique probe of hydro nature in smallest systems
  - among fundamental open issues at RHIC
  - "bridge" to EIC – collective/bulk sector
- much precision physics remains to be done at RHIC, but...
  ... RHIC remains a **discovery facility** – this would be qualitatively new
- this must not be left on the floor