Alternative to the two-component ansatz and implications for small collision systems

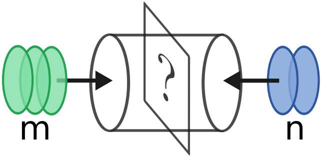
J.S. Moreland, J.E. Bernhard, S.A. Bass | July 15, 2015

Correlations and Fluctuations in p+A and A+A Collisions

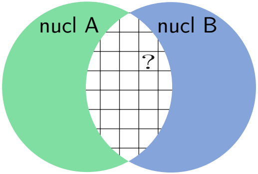
Supported by NNSA Stewardship Science Graduate Fellowship

Thinking of initial conditions as a mapping

Side view



Beam view



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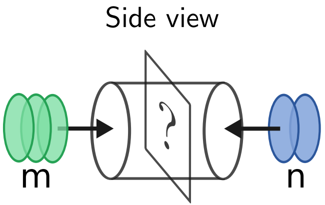

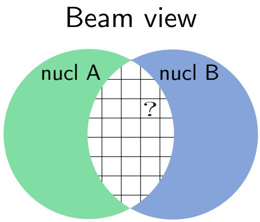

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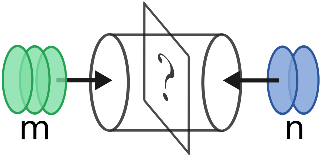

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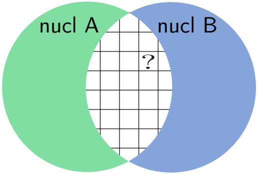

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Fundamental assumption

There exists a single (possibly energy dependent) mapping from nuclear thickness to entropy density: $dS/dy|_{y=0} \propto f(T_A, T_B)$

Continuous function of two variables... where to begin?

- For all its shortcomings, the wounded nucleon model is remarkably successful at describing soft particle production
- Mapping must respect basic physical constraints, e.g. symmetric and monotonic in T_A, T_B

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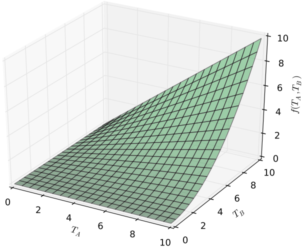

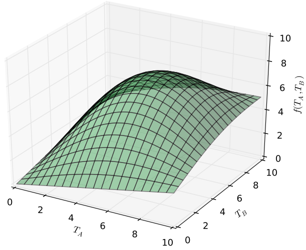

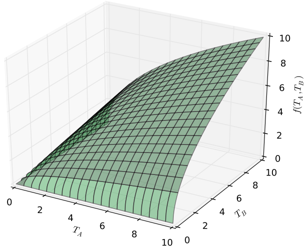

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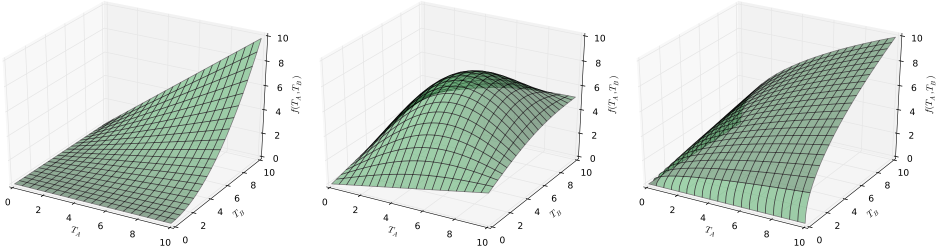

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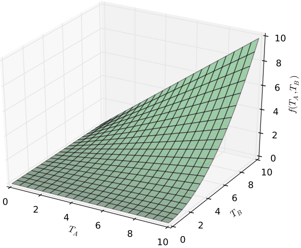

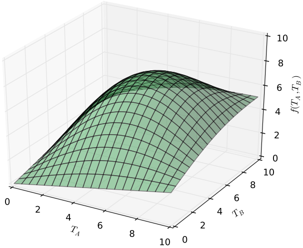

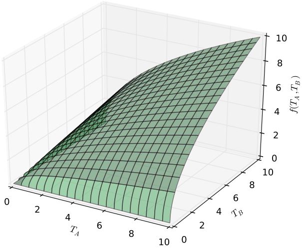

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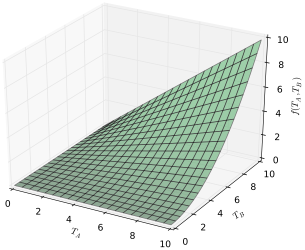

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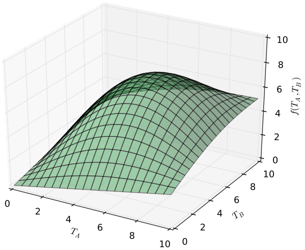

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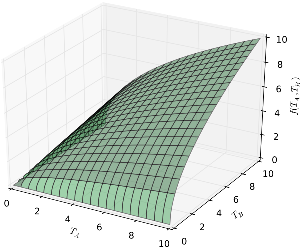

plausible

Parameterizing entropy deposition

Historically started with wounded nucleon model,

$$dS/dy|_{y=0} \sim \frac{T_A + T_B}{2}$$

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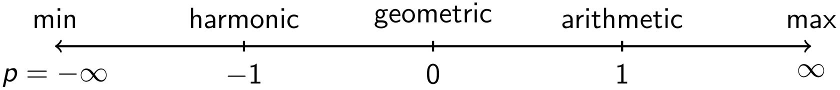
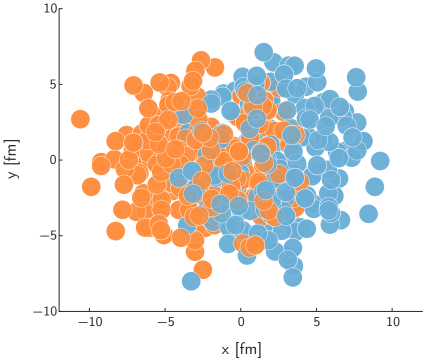
In this work we replace the arithmetic mean with a generalized mean,

$$dS/dy|_{y=0} \propto \left(\frac{T_A^p + T_B^p}{2}\right)^{1/p}$$



TRENTo – new parametric model for entropy deposition

1. Sample nucleon coordinates



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1. Sample nucleon coordinates
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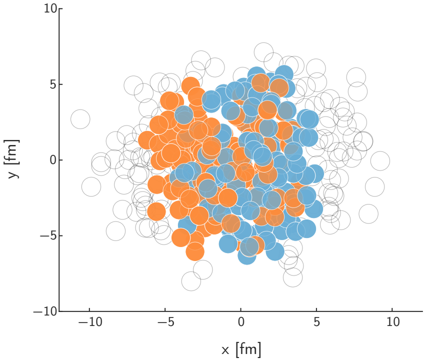

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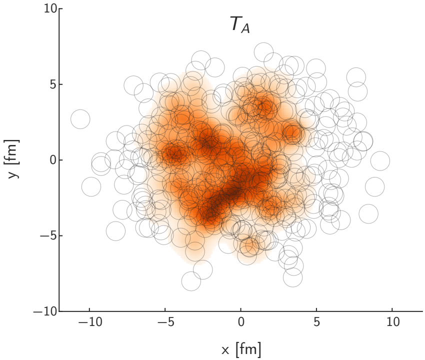

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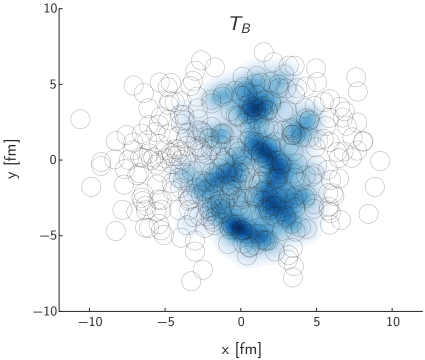

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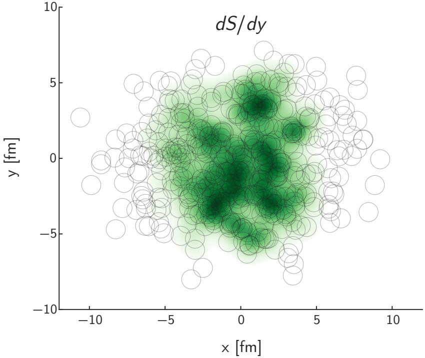

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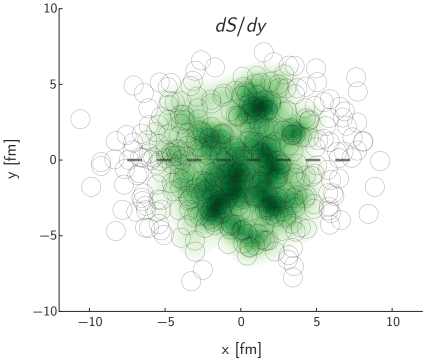

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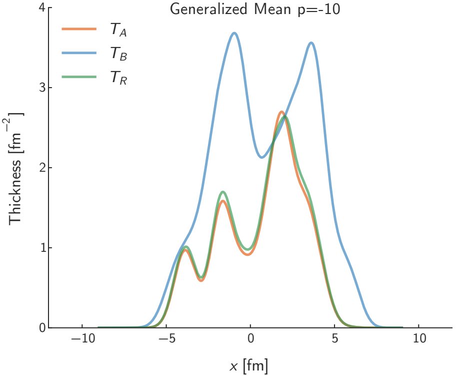

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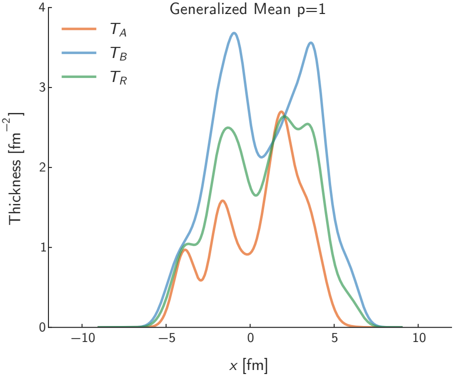

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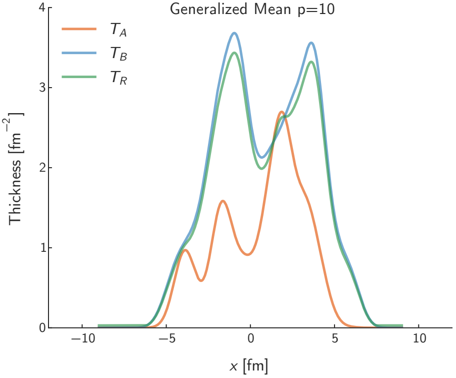

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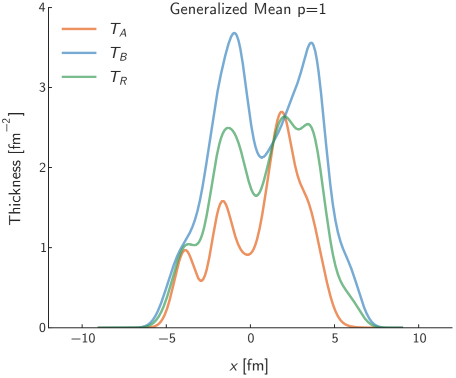


"Thickness Reduced Event-by-event Nuclear Topology"

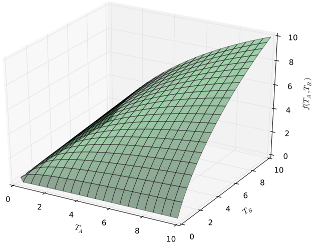
Demonstrating the flexibility of the ansatz

- For $p = 1$ model reduces to a wounded nucleon model (exact)
- for $p = -0.65$ model replicates the KLN mapping to $\mathcal{O}(1\%)$

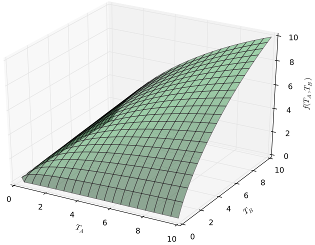
$$\frac{dN_g}{d^2 r_\perp dy} \sim Q^2_{s,min} \left(2 + \log \left(\frac{Q^2_{s,max}}{Q^2_{s,min}} \right) \right), \quad Q^2_s \sim T$$

Drescher, Nara Phys. Rev. C **75**, 034905 (2007)

KLN mapping

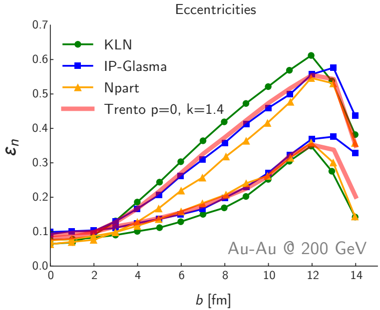


Generalized mean p=-0.65



Demonstrating the flexibility of the ansatz

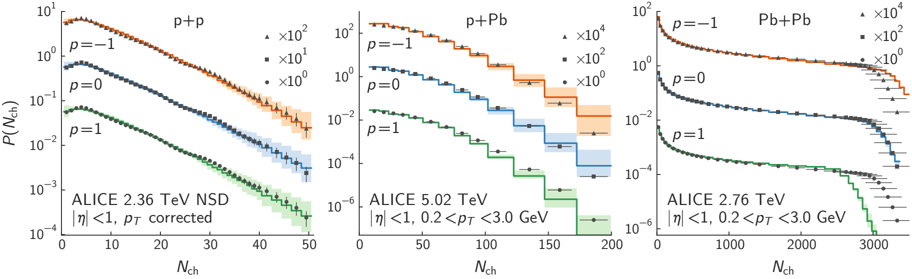
- $p \approx 0$ mimics the IP-Glasma model
- Similar harmonics and multiplicities right: eccentricity vs impact param.
- More on this later in the talk ...



Schenke, Tribedy, Venugopalan
Phys. Rev. Lett. **108**, 252301 (2012)

Opportunity: Constrain the generalized mean parameter p via systematic model-to-data comparison to simultaneously extract the QGP viscosity and initial conditions

Testing parameterization against measured multiplicities



TRENTo model plotted against LHC multiplicity distributions

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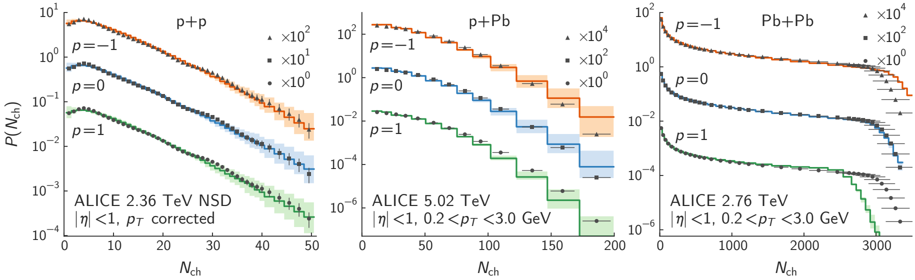

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- Lines indicate different values of the generalized mean (annotated)

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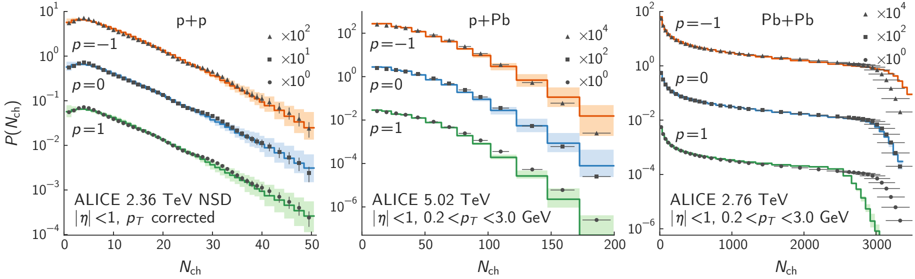

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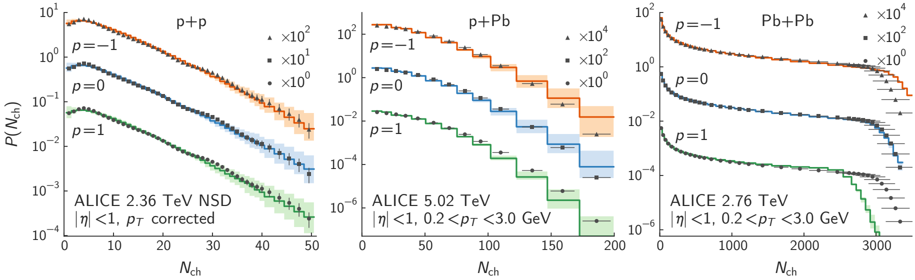

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- Norm is varied to account for differences in energy and kinematic cuts

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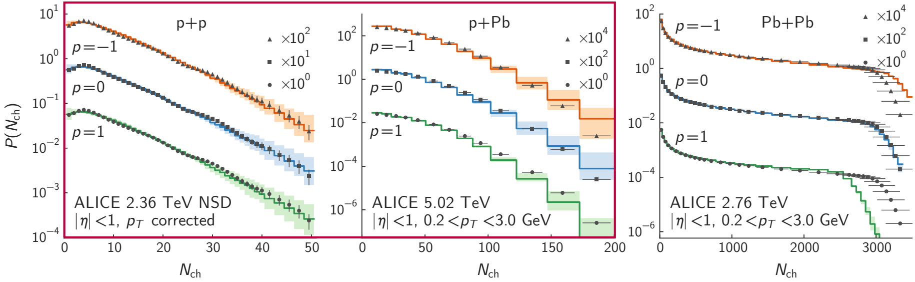

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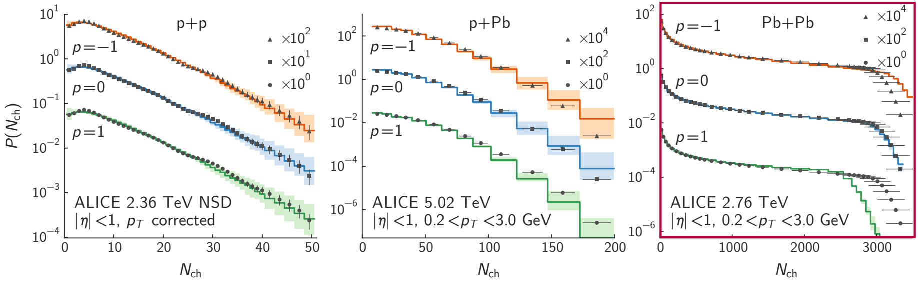

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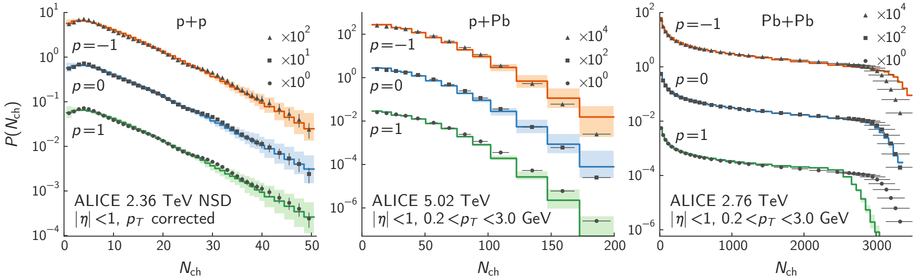

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- Normalizations provide further constraints on allowable parameters:

p	k	p+p norm	p+Pb norm	Pb+Pb norm
+1	0.8	9.7	7.0	13.
0	1.4	19.	17.	16.
−1	2.2	24.	26.	18.

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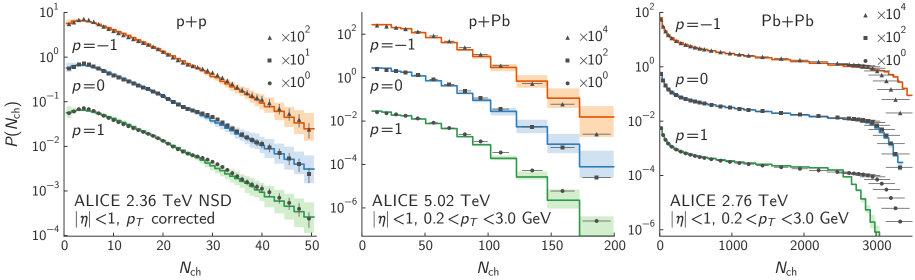

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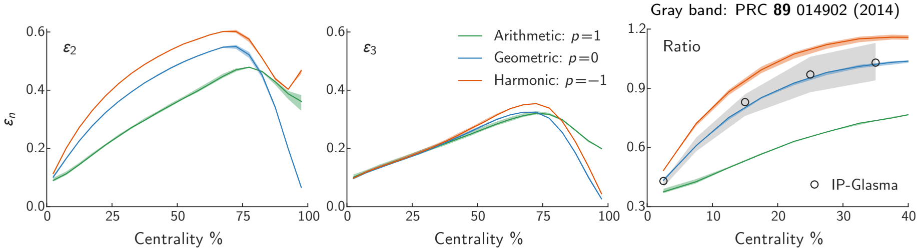
Testing parameterization against flow constraints



TRENTo Pb+Pb eccentricity harmonics: $\varepsilon_n e^{in\phi} = -\frac{\int dx\, dy\, r^n e^{in\phi} s(x,y)}{\int dx\, dy\, r^n s(x,y)}$

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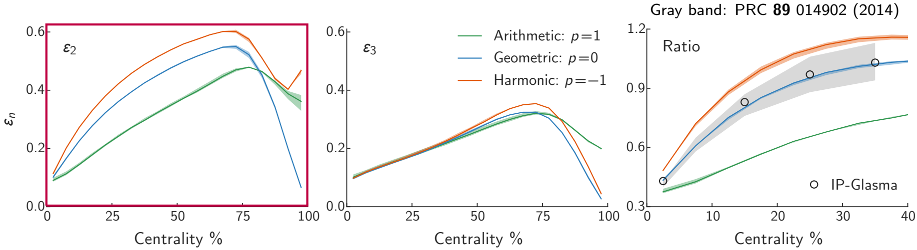

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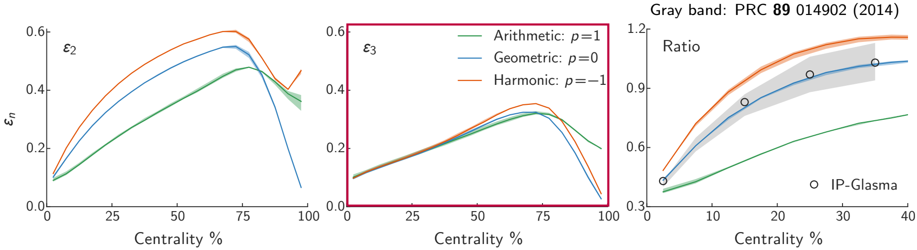

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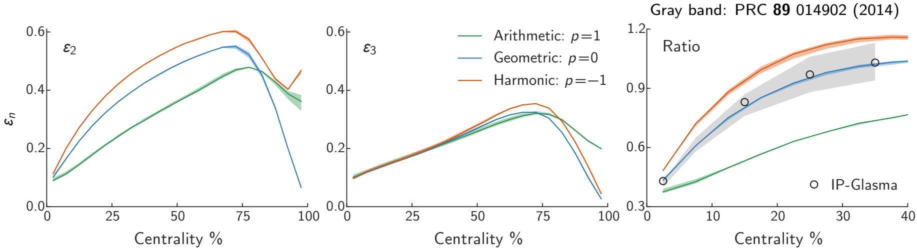

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- Varying fluctuation parameter by ±30% has negligible effect on eccentricity harmonics, i.e. p+p fluctuations are sub-leading effect.

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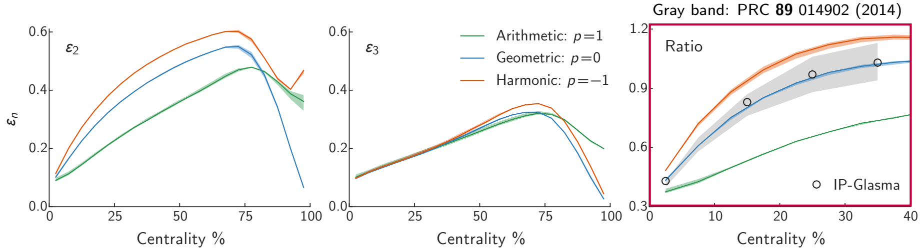
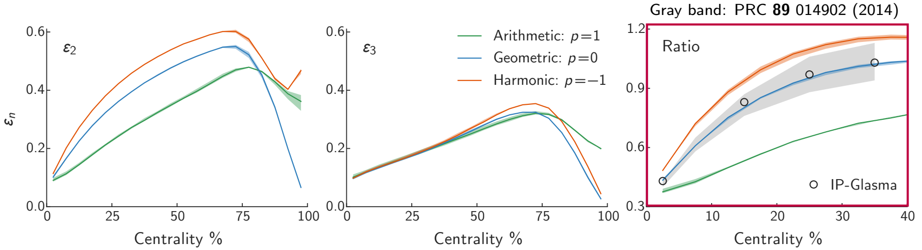


Ratio of $\varepsilon_2/\varepsilon_3$ strong discriminator for initial condition models.
Easy to fit v_2 by varying η/s... hard to fit v_2 and v_3 simultaneously.

Testing parameterization against flow constraints



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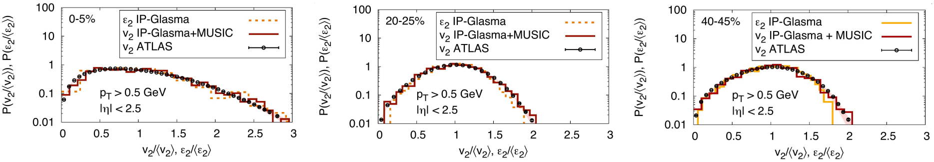
Easy to fit v_2 by varying η/s... hard to fit v_2 and v_3 simultaneously.

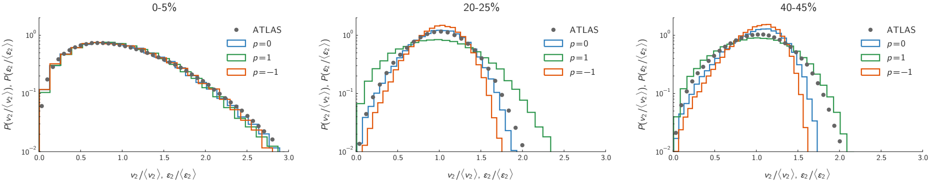
- Gray band from Retinskaya, Luzum, Ollitrault, allowed region for eccentricity ratio $\sqrt{\langle\varepsilon_2^2\rangle}/\sqrt{\langle\varepsilon_3^2\rangle}^{0.6}$ determined using measured flows and linear response $v_n \propto \varepsilon_n$.
- Eccentricity ratio prefers geometric mean and mimics IP-Glasma
  Both multiplicities and flows in agreement, prefer $p \sim 0$ at LHC

Event-by-event flow distributions

Top: IP-Glasma $\varepsilon_2/\langle\varepsilon_2\rangle$, and IP-Glasma+Music $v_2/\langle v_2\rangle$ (Bjorn's QM14 talk)

Bottom: TRENTo $\varepsilon_2/\langle\varepsilon_2\rangle$ for different values of the generalized mean





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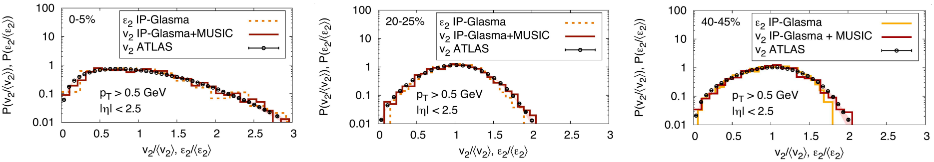
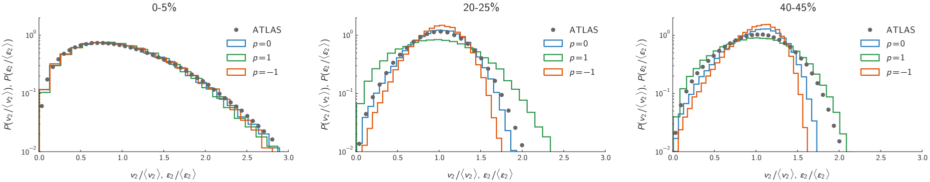
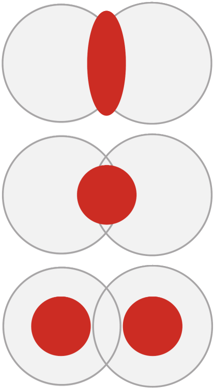




Generalized mean parameter strongly affects eccentricity distribution shape. Preliminary results (no hydro) consistent with $p \approx 0$. Consistent with harmonic ratio and multiplicity constraints shown previously.

Implications for small collision systems

Mapping effect on p+p entropy deposition



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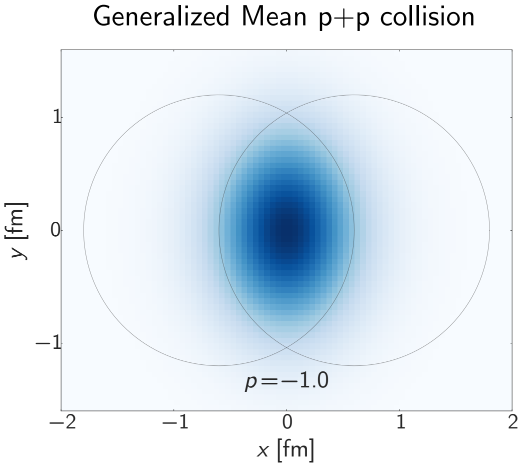

Generalized mean interpolates between distinct deposition schemes

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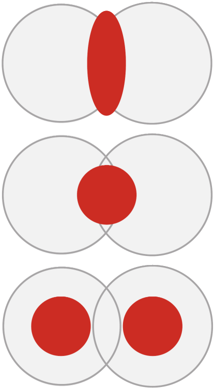

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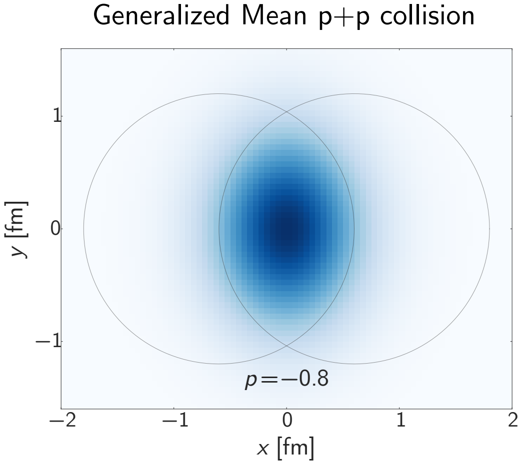

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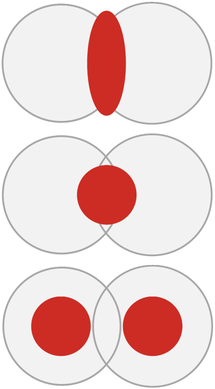

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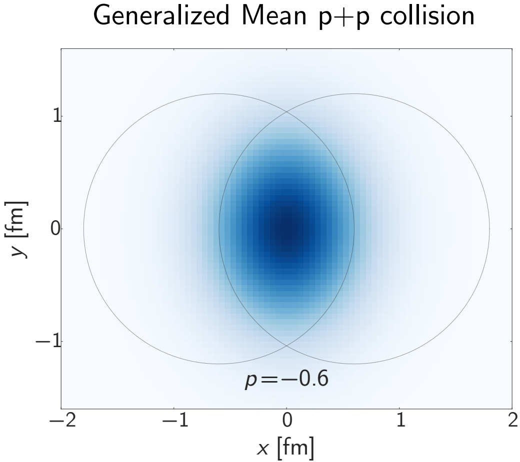

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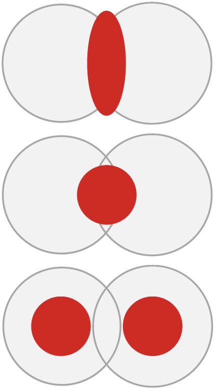

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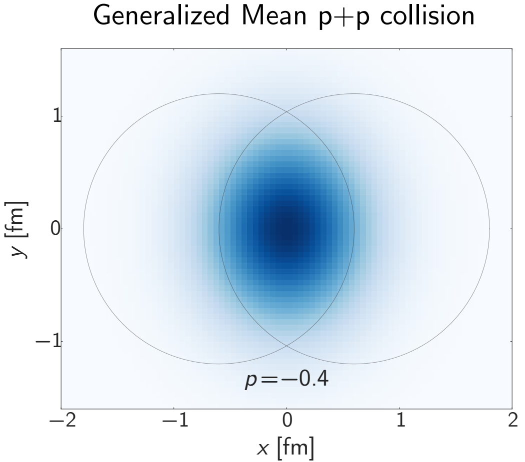

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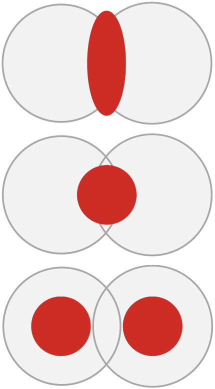

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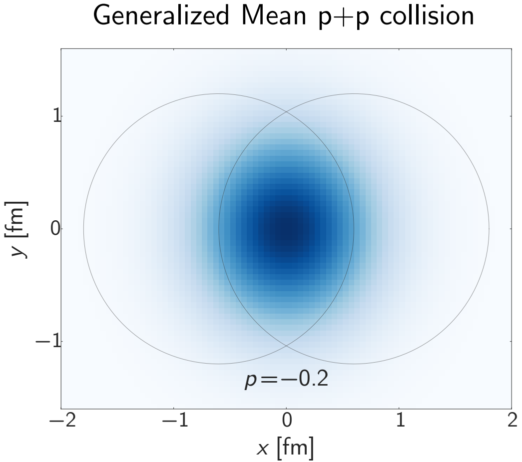

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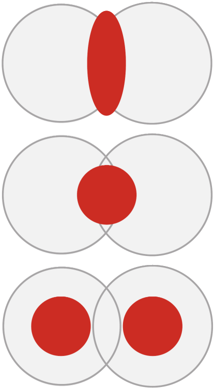

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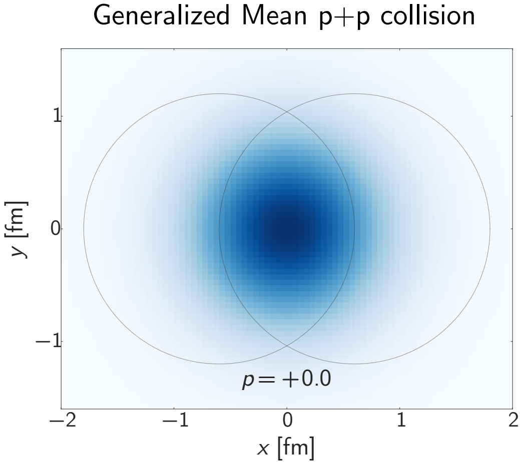

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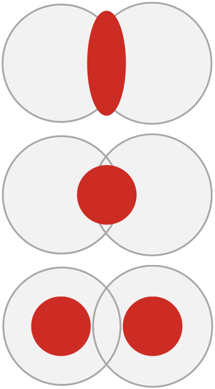

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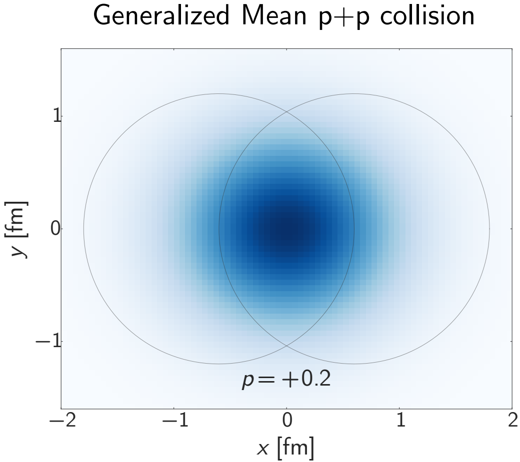

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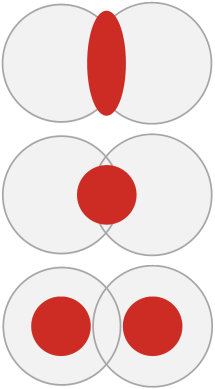

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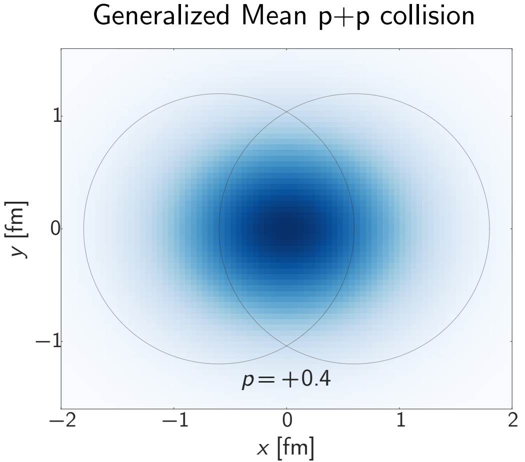

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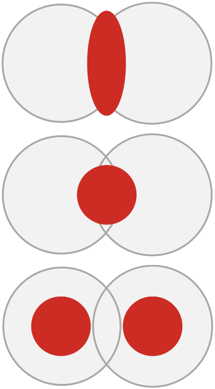

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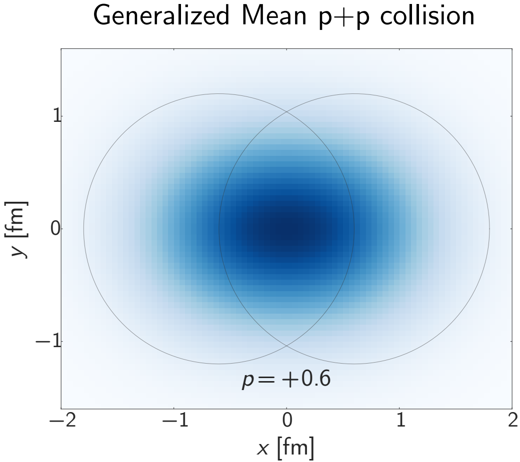

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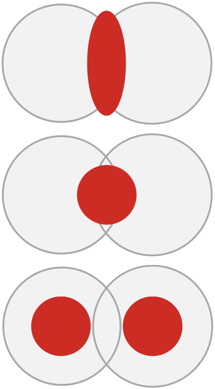

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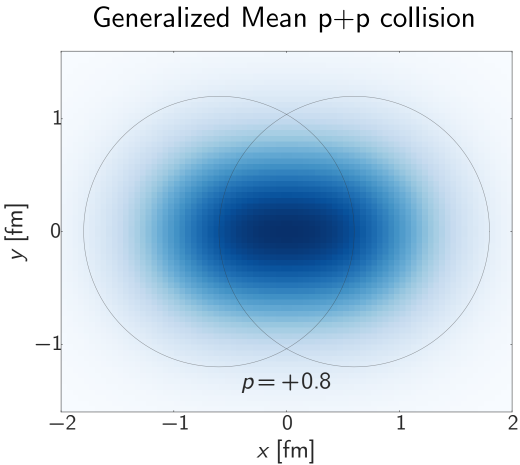

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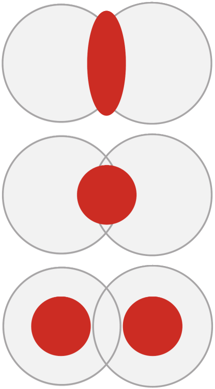

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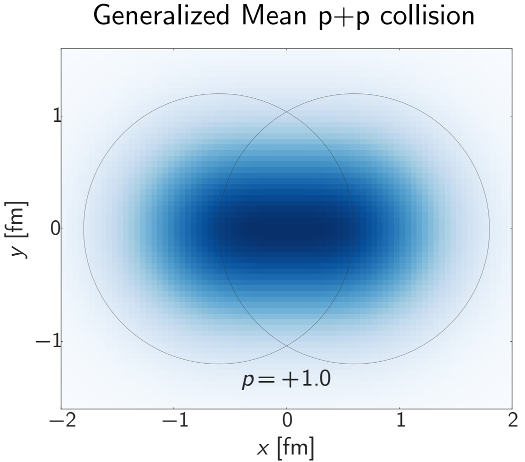
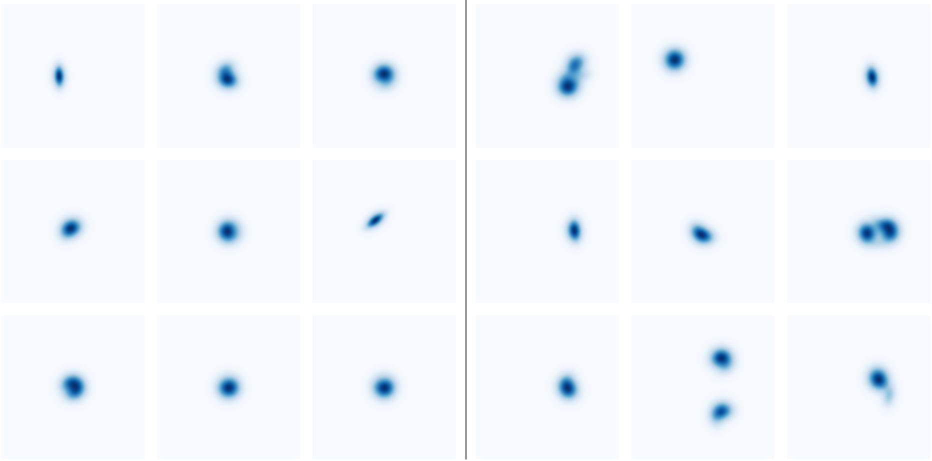
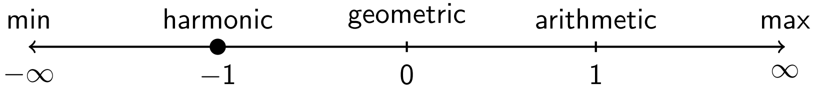
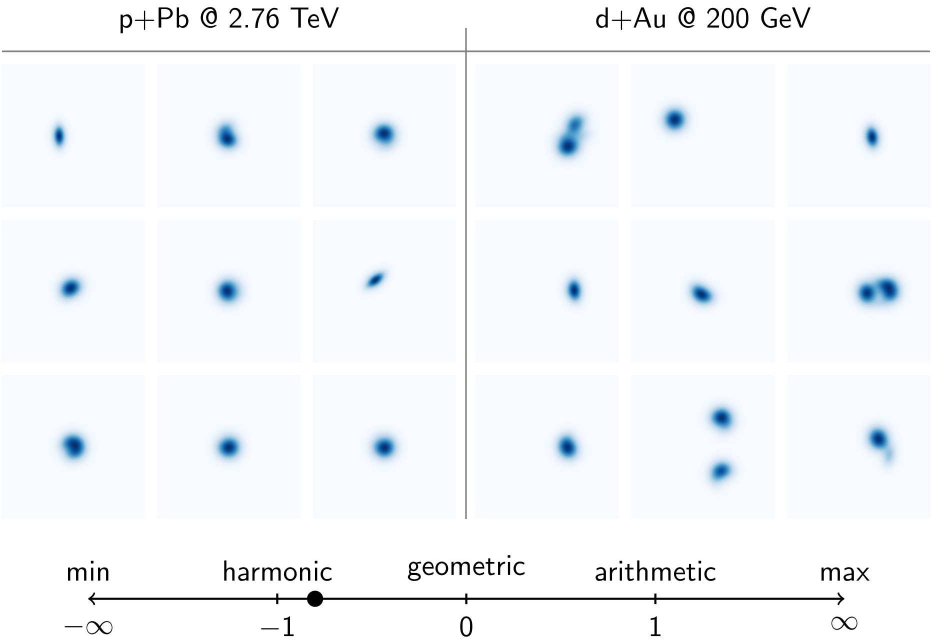


Generalized mean interpolates between distinct deposition schemes

p+Pb @ 2.76 TeV | d+Au @ 200 GeV



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d+Au @ 200 GeV
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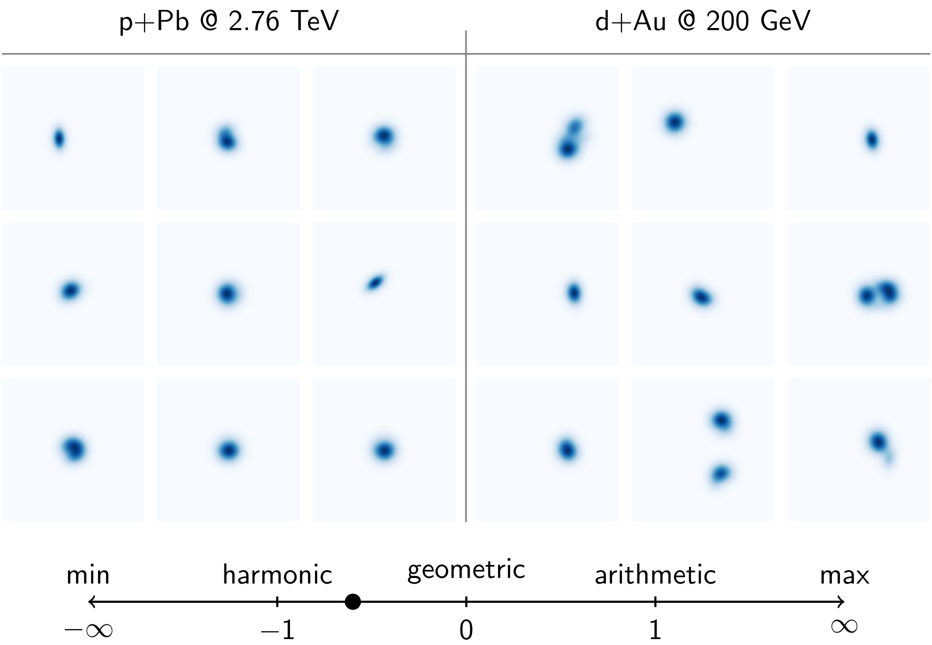
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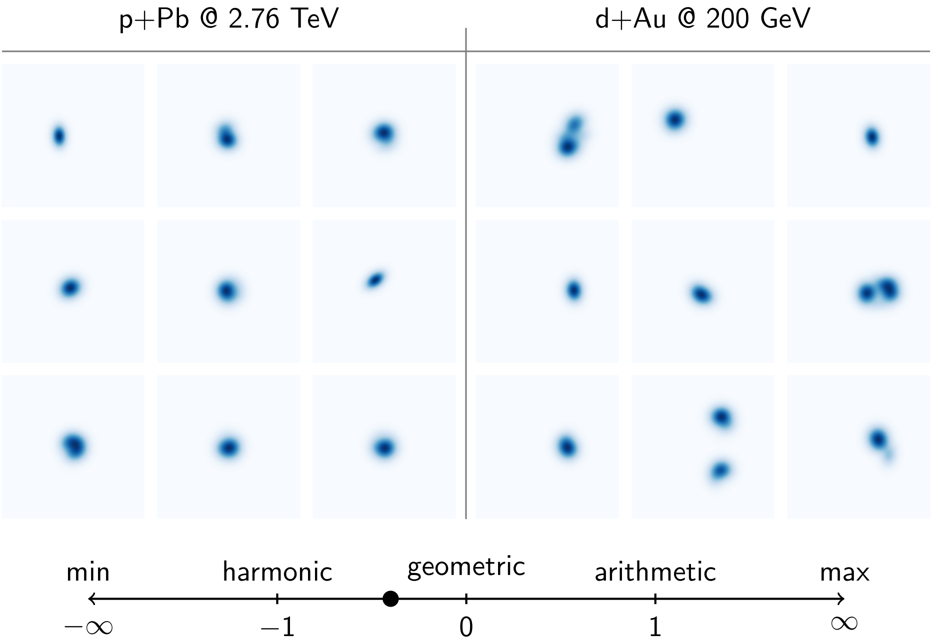

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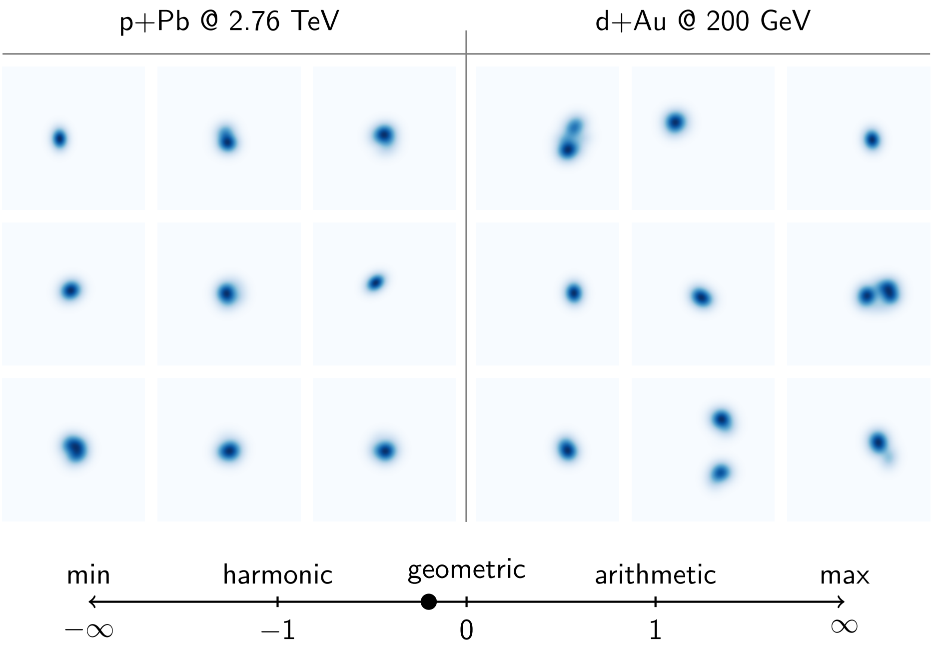

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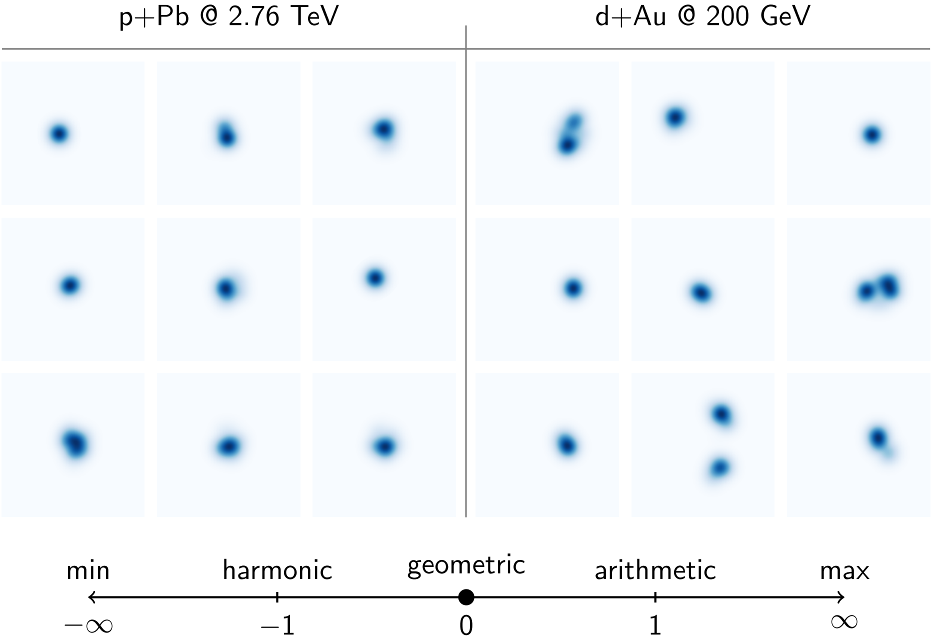
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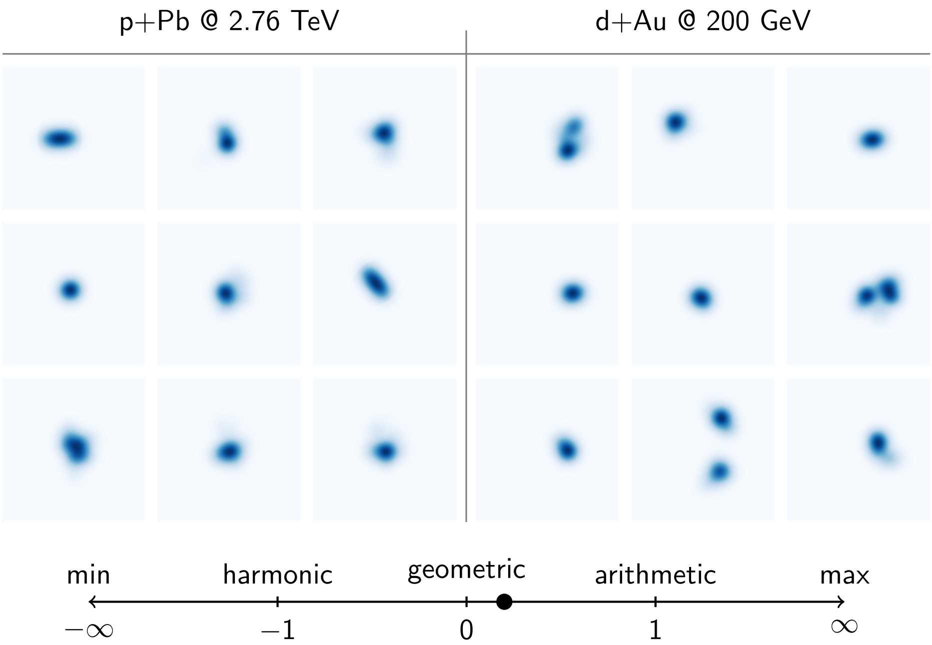
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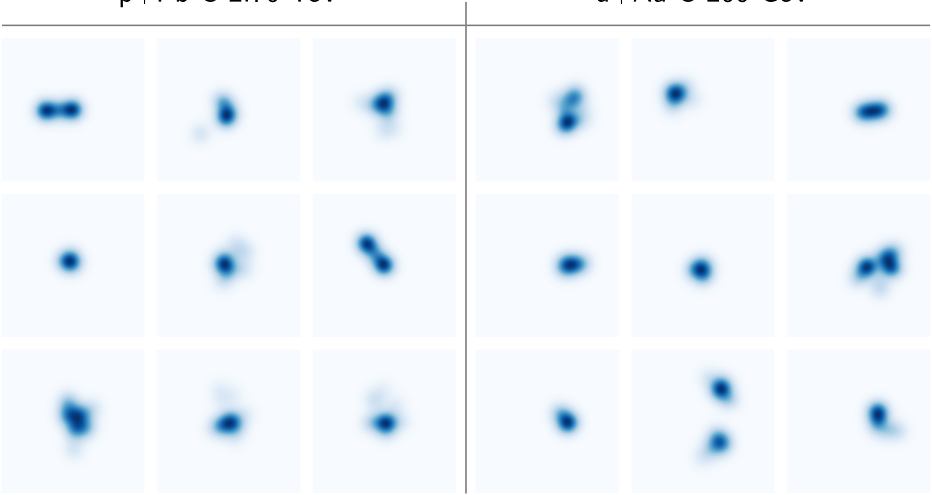

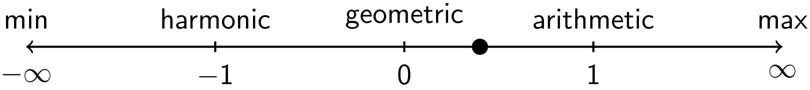

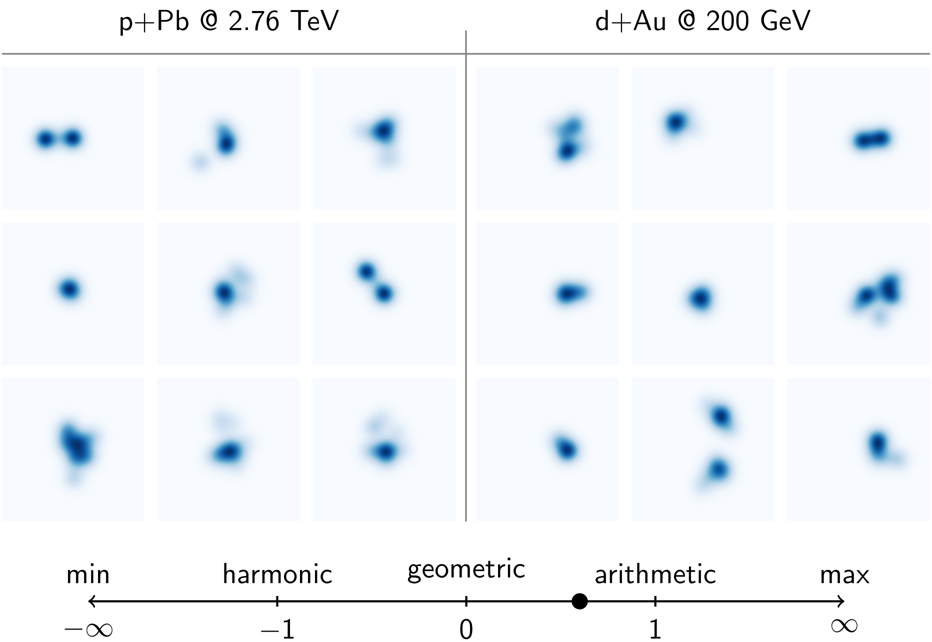
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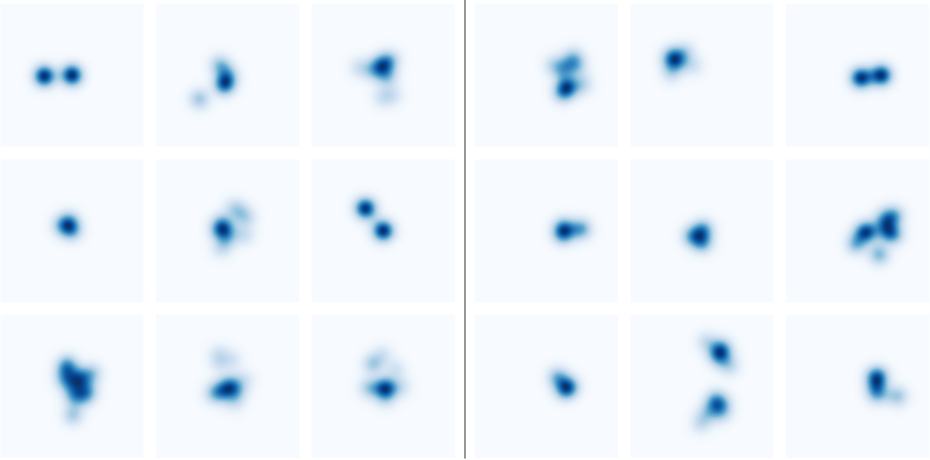

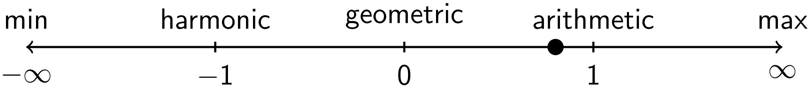

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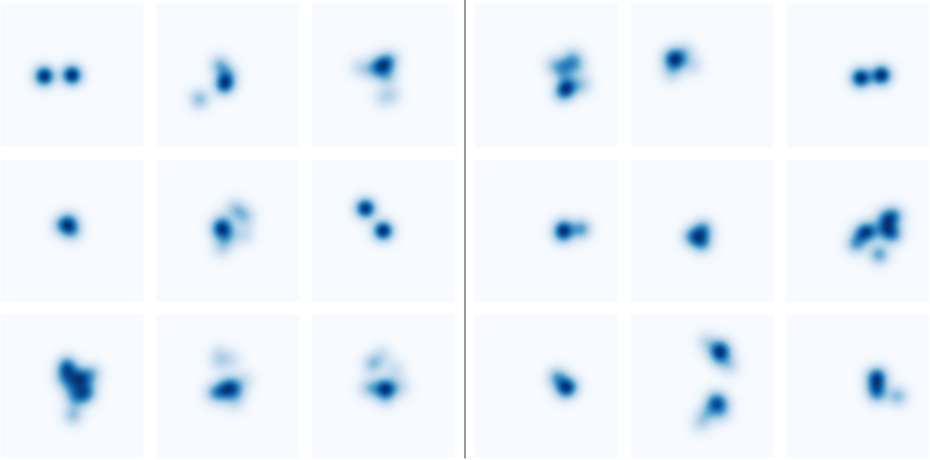
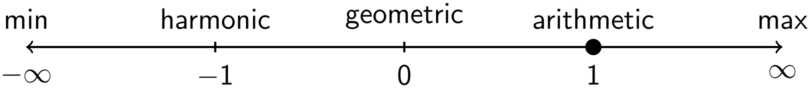
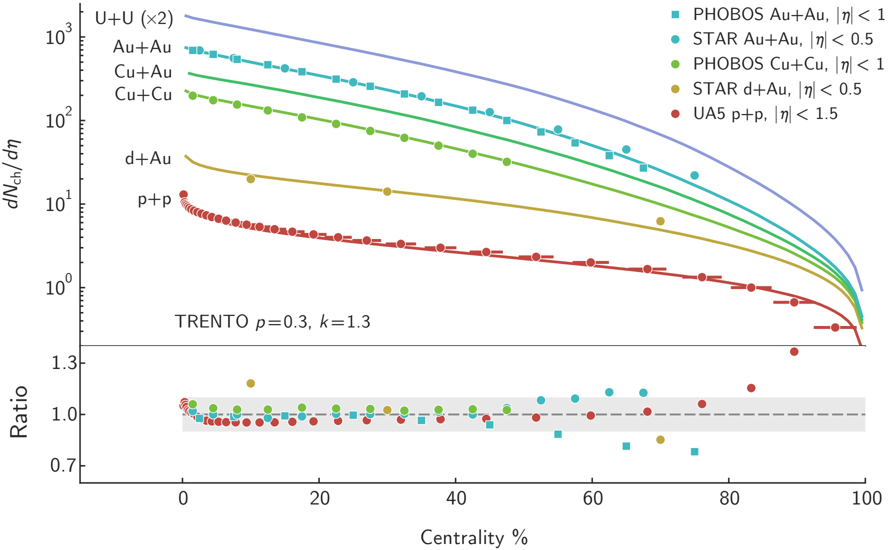




Constraining entropy deposition with multiple systems



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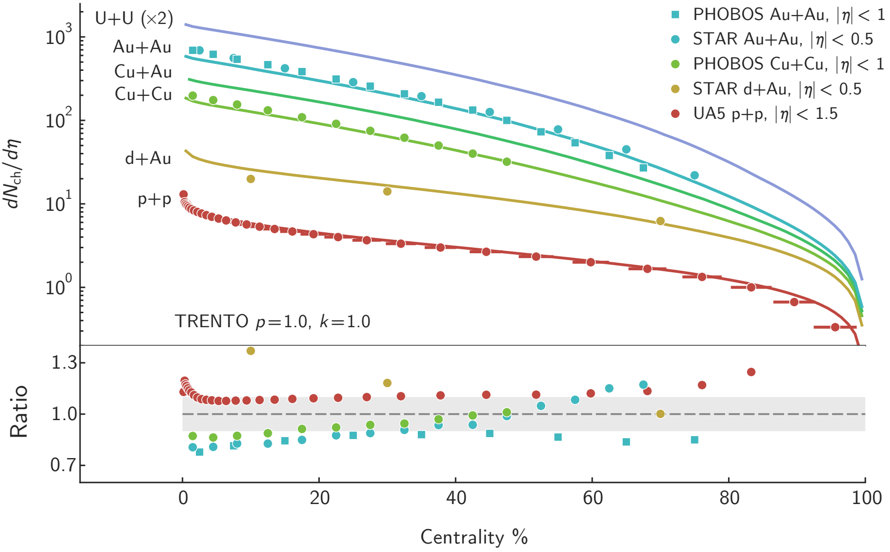

Summary

- Introduce TRENTo, a new parametric model which deposits entropy proportional to the generalized mean of participant matter.
- Model can mimic behaviour of well known initial conditions models such as KLN and IP-Glasma.
- Preliminary results (no hydro!) indicate that the LHC prefers $p \approx 0$ which closely mimics IP-Glasma scaling. RHIC prefers $p \approx 0.3$.
- Model prefers entropy deposition in p+p and p+A collisions which is more eikonal, i.e. localized in p+p overlap region.
- Currently working on embedding model in systematic Bayesian analysis to extract QGP medium and initial state properties simultaneously.

Model available at: `https://github.com/Duke-QCD/trento`