Studying (anti)deuteron formation in heavy ions using an advanced coalescence model

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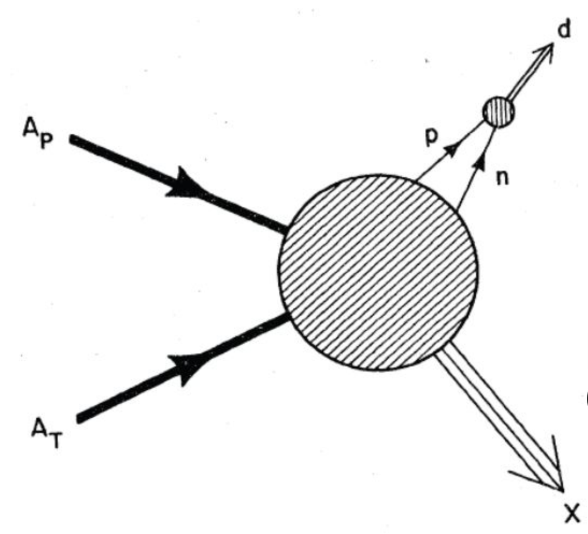
(Anti)nuclei formation using coalescence

- (Anti)protons and (anti)neutrons close in phase-space can **coalesce** and form a nucleus
- Spherical approximation assumption
  - (Anti)nucleons with a relative momentum $k^* < p_0$ coalesce
  - p_0 obtained by fitting measurements
- Advanced coalescence model: ***Wigner function formalism***
  - Assigns a coalescence probability on an event-by-event basis
  - No free parameters



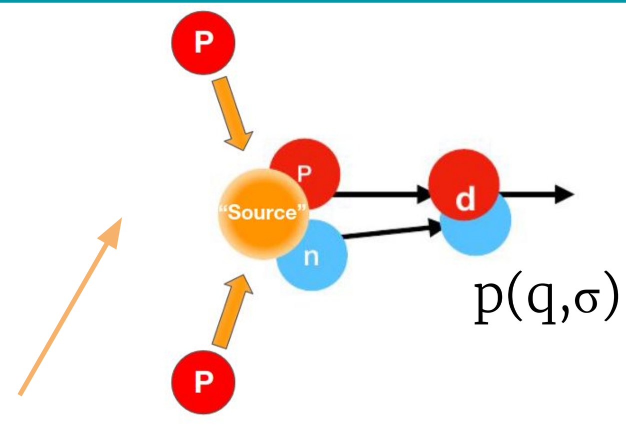
[J.I. Kapusta, Phys.Rev.C 21 (1980)]

Wigner function formalism

- Based on the Wigner function of the deuteron

$$W(x,p) = \frac{1}{\pi\hbar}\int_{-\infty}^{\infty} \psi^*(x+y)\psi(x-y)e^{2ipy/\hbar}\,dy$$

  where ψ is the wavefunction of the deuteron (several options available)
- Projecting the (anti)nucleon density matrix on the deuteron density matrix we have [1]:



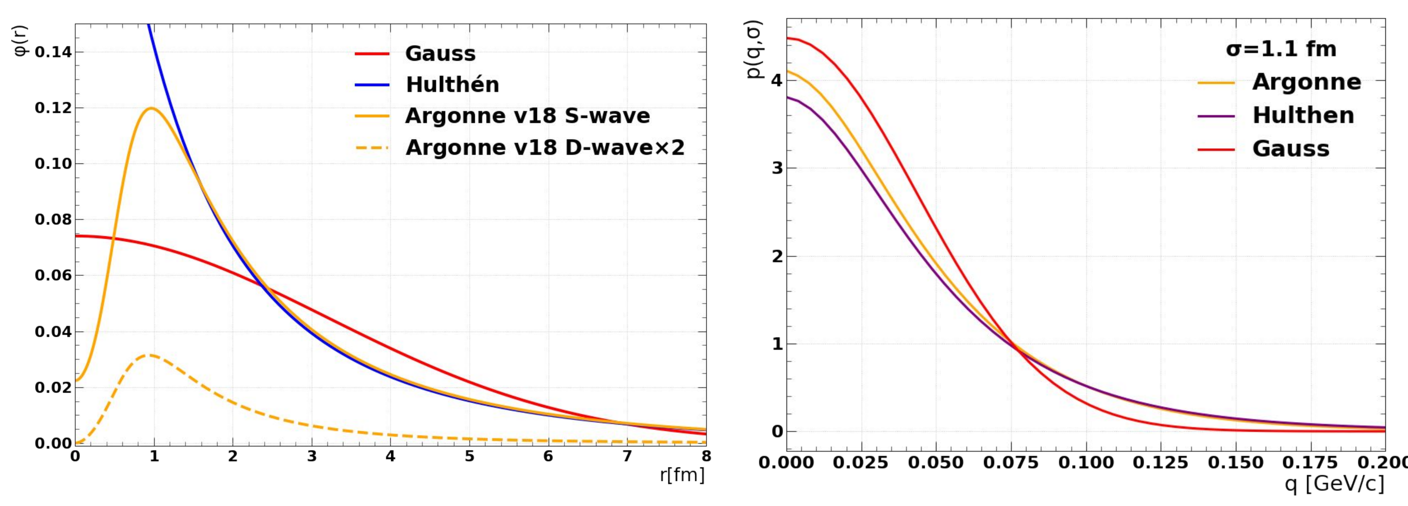
d^3N/dP^3

Repeat for each possible pair in each event

Obtained with **Event Generator** (EPOS3)

$$d^3N/dP^3 = S\int d^3q \int d^3r_p \int d^3r_n\, W(q,r)\; W_{np}(p_n,p_p,r_n,r_p)/(2\pi)^6$$

Deuteron Wigner function — Nucleon phase-space

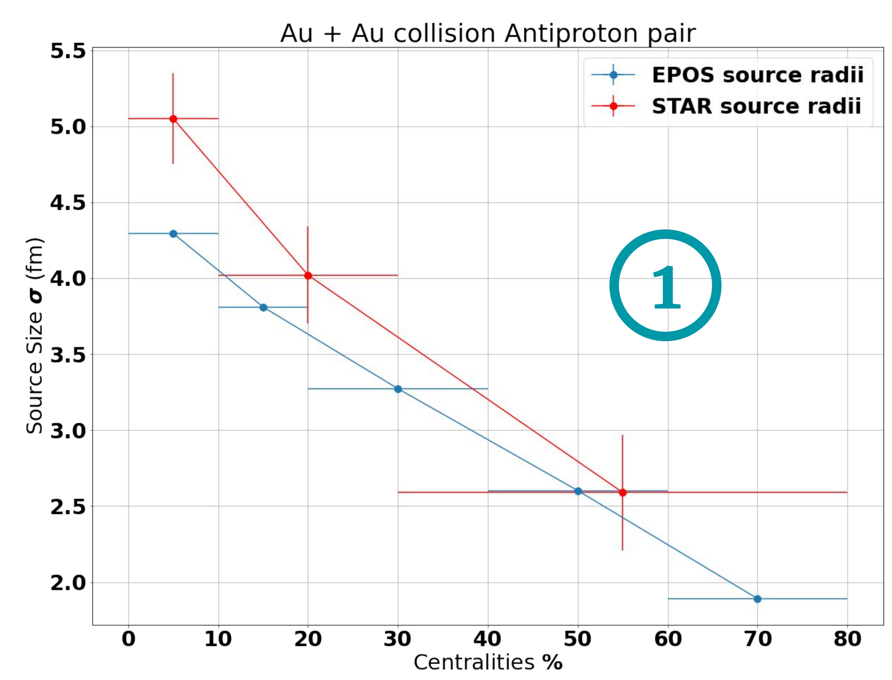


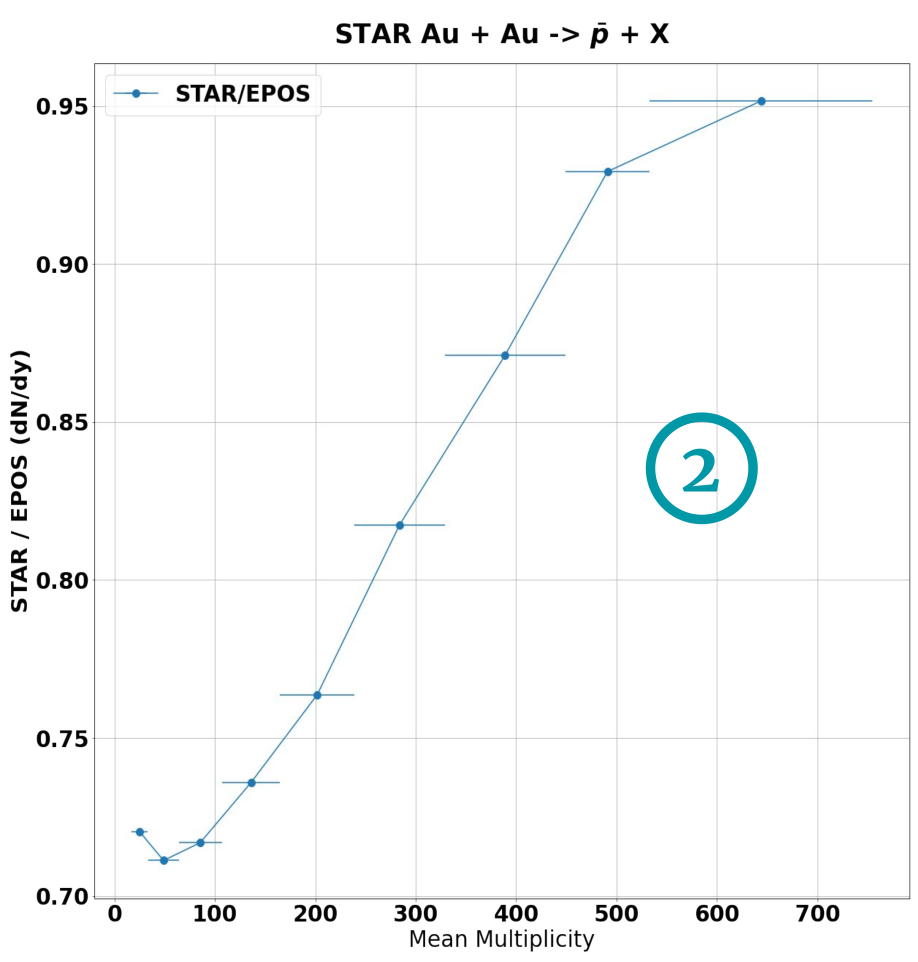
- When assuming a Gaussian source [2] an expression for the coalescence probability p(q,σ) as a function of the relative momentum and size of the emission source can be obtained [3]
- This probability can be applied on each (anti)proton-(anti)neutron pair in each event

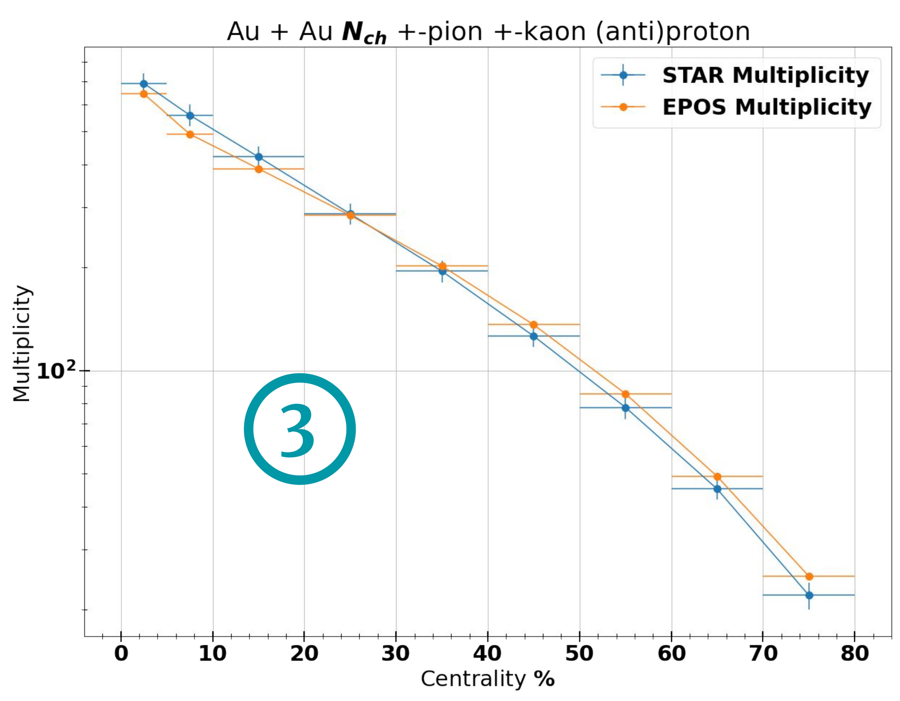
[1] EPJA 56 (2020) 1, 4
[2] PLB 811 (2020) 135849
[3] arXiv:2302.12696

Correcting the event generator

- Event generators are known to not perfectly describe nature → Correct event generator using measurements → source size, momentum distribution, multiplicity
- Source size σ measured in Au-Au collisions at 200 GeV by STAR Collaboration [4] (1)
- Momentum: Use $m_T - m_p$ spectra from [5] to reweight each nucleon for different centralities (2)
- Multiplicity: Choose midrapidity multiplicities to reproduce mean multiplicities measured by STAR [6] (3)



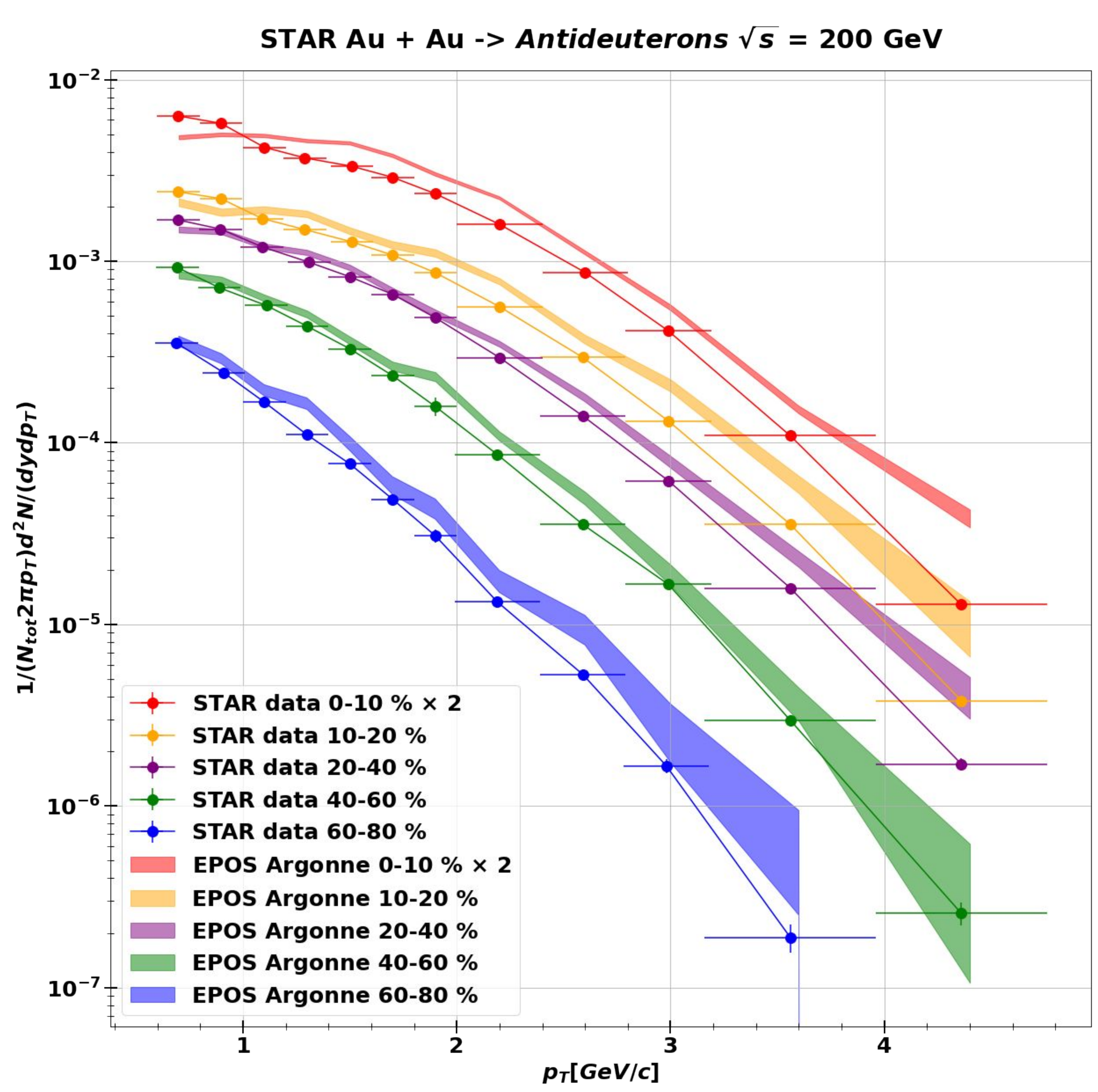




[4] PoS(WPCF2011)006
[5] J. Adams *et al.* , Phys. Rev. Lett. 92, 112301 (2004)
[6] PHYSICAL REVIEW C 79, 034909 (2009)

(Anti)deuteron spectra

- Deuteron predictions with Argonne (best wave function [3])
- Comparison to STAR collaboration data show difference by ~30% [7]
- Model reproduces the shape of the spectrum
- No free parameters
- Further studies
  - improved source models
  - rescattering and absorption effects



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[7] Phys. Rev. C 99, 064905 (2019)