Coalescence as the origin of nuclei in hadronic collisions:

evidence from $^3_\Lambda$H @ ALICE

Kfir Blum / Weizmann Institute

LHCP 2021
Why does the thermal model work for nuclei?

Nuclei can form by coalescence after kinetic freeze out.

Bond et al; Phys.Lett. B71 (1977) 43
Lednicky; Phys.Part.Nucl. 40 (2009) 307

KB, Takimoto; Phys.Rev. C99 (2019) no.4, 044913
Bellini, KB, Kalweit, Puccio; Phys.Rev. C103 (2021) no.1, 014907
Coalescence calibrated from femtoscopy


KB, Takimoto; Phys.Rev. C99 (2019) no.4, 044913

Adam et al; Phys.Rev.C 93 (2016) 2, 024917

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KB, Ng, Sato, Takimoto; Phys.Rev.D 96 (2017) 10, 103021
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...Works to a factor of ~2
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Scaling with system size:

$$\frac{\mathcal{B}_A}{m^{2(A-1)}} \approx \frac{2J_A + 1}{2^A \sqrt{A}} \left( \frac{mR}{\sqrt{2\pi}} \right)^{3(1-A)}$$
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Wave function effect (QM suppression factor)
Clear prediction of coalescence.

\[ R \rightarrow \sqrt{R^2 + b^2} \]
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Want the smallest \( R \), and the largest \( b \).
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Dream observable: \( {}^3\Lambda H \) in pp.
Bellini, KB, Kalweit, Puccio; Phys.Rev. C103 (2021) no.1, 014907  (see Fig.7)
pp data: ALICE 2021

SQM2021, Pietro Fecchio, May 21, 2021
https://indico.cern.ch/event/985652/contributions/4305115/
$\Lambda H$

$S_3 = \frac{B_3}{B(\Lambda)}$

$R_{inv}$ [fm]
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Xtra
There is no such thing as “2 body” vs. “3 body” coalescence. There is only one meaningful coalescence computation.

It is approximate in splitting FSI from a “hard source”, a splitting that has no clear small expansion parameter (that I know of). Probably not very accurate. Probably does catch basic scaling, coalescence-femtoscopy, etc.

\[
\frac{dN_{3\Lambda}^{\Lambda H}}{d^3P} = \frac{2s_{3\Lambda H}^{\Lambda H} + 1}{(2\pi)^3} \int d^4x_p \int d^4x_n \int d^4x_\Lambda \int d^4x'_p \int d^4x'_n \int d^4x'_\Lambda \times \\
\Psi_{3\Lambda H}^{*}(x'_p, x'_n, x'_\Lambda) \Psi_{3\Lambda H}^{\Lambda H}(x_p, x_n, x_\Lambda) \rho_{p_p, p_n, p_\Lambda}(x_p, x_n, x_\Lambda; x'_p, x'_n, x'_\Lambda)
\]

If the spacetime representation of the density matrix is approximately isotropic Gaussian, and if we approximate the nucleus wave function as a product of Gaussians with scale radii \( b_{pn}, b_\Lambda \), the answer is:

\[
\mathcal{B}_{3\Lambda} = \frac{16\pi^3 \lambda_{3\Lambda}}{\sqrt{3m^2 \left(b_{pn}^2 + 2R^2\right)^{\frac{3}{2}} \left(b_{p}^2 + 2R^2\right)^{\frac{3}{2}}}} \quad \text{(Bellini, KB, Kalweit, Puccio; Phys.Rev. C103 (2021) no.1, 014907)}
\]

Source chaoticity \( \lambda_{3\Lambda} \) measures, alongside other factors, whether the density matrix is factorisable. (In general, it should not be.) It is rarely targeted by femtoscopy analyses: they should measure it.

Using a full numerical wave function corrects this at the level of a factor of 2 or so.
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Missing femtoscopy in pPb