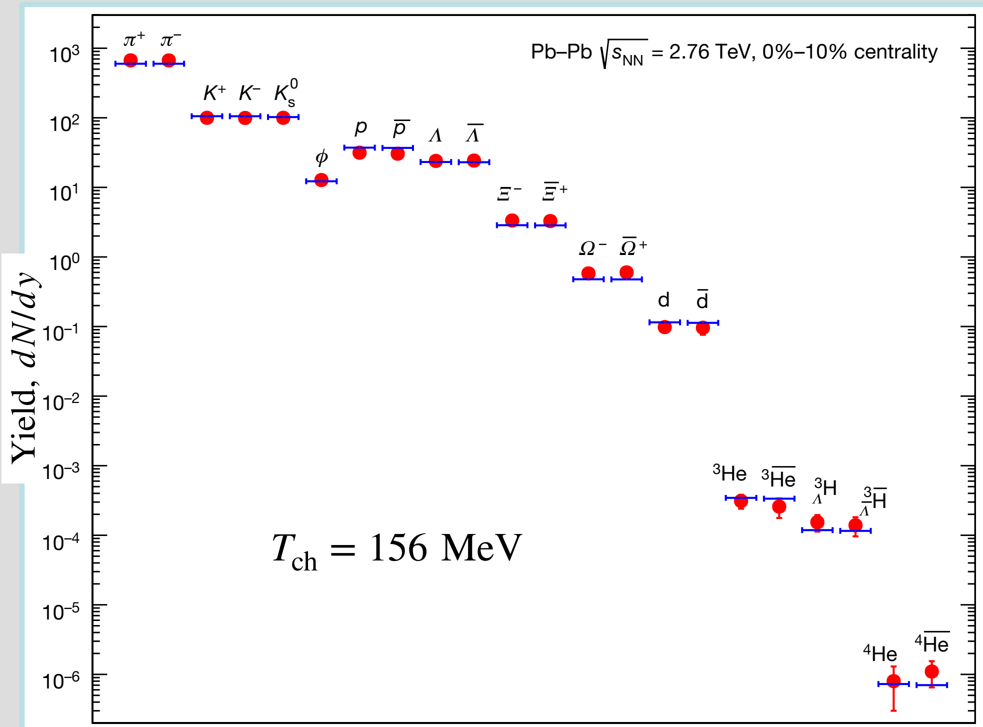
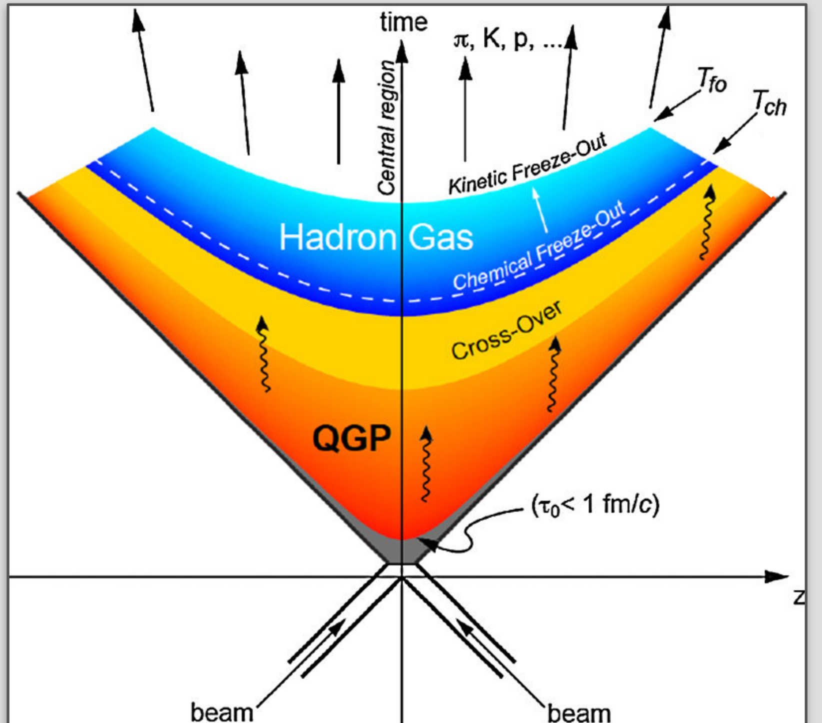
Coalescence as the origin of nuclei in hadronic collisions: evidence from ${}^{3}_{\Lambda}\mathrm{H}$ @ ALICE

Kfir Blum / Weizmann Institute

LHCP 2021

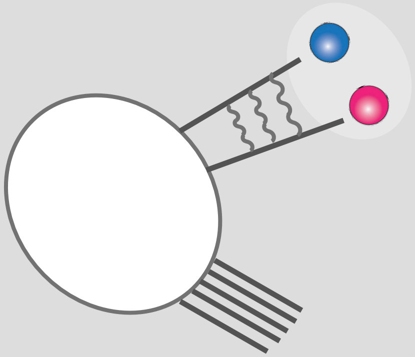
Why does the thermal model work *for nuclei?*





Andronic et al; Nature 561, 321 (2018)

Nuclei can form by coalescence after kinetic freeze out.



Bond et al; Phys.Lett. B71 (1977) 43
Sato, Yazaki; Phys.Lett. B98 (1981) 153
Mrowczynski; J.Phys. G13 (1987) 1089
Scheibl, Heinz; Phys.Rev. C59 (1999) 1585-1602
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

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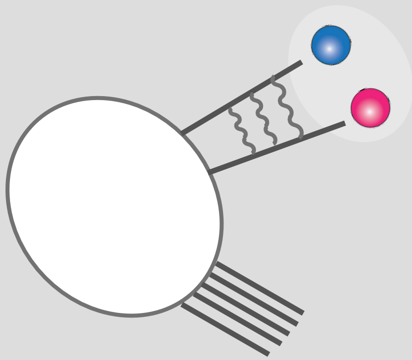
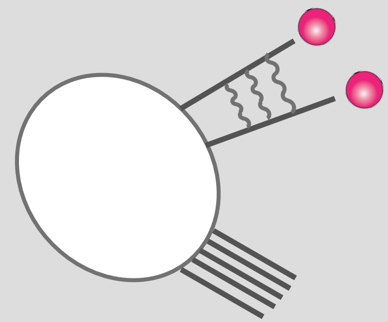
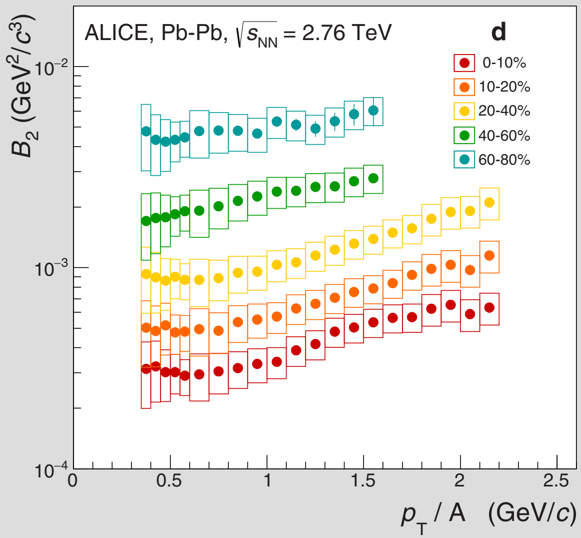
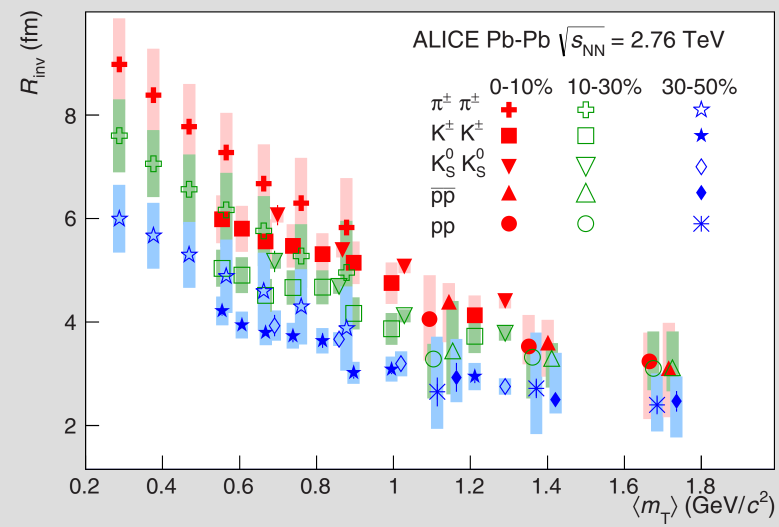




Adam et al; Phys.Rev.C 93 (2016) 2, 024917



Adam et al; Phys.Rev.C 92 (2015) 5, 054908



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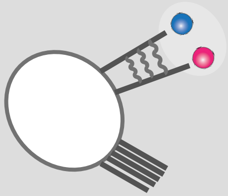
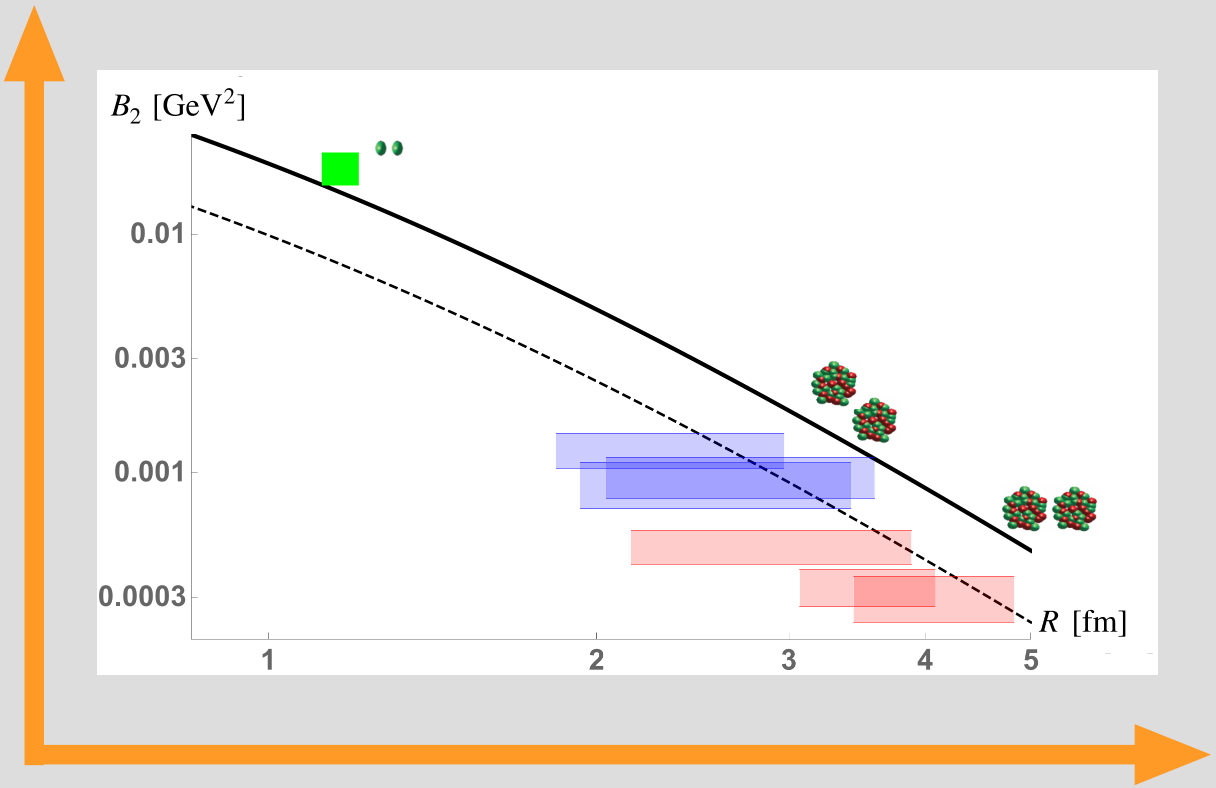
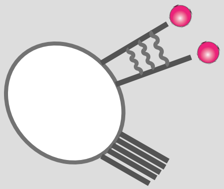


…Works to a factor of ~2





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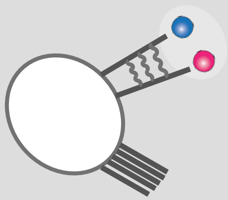

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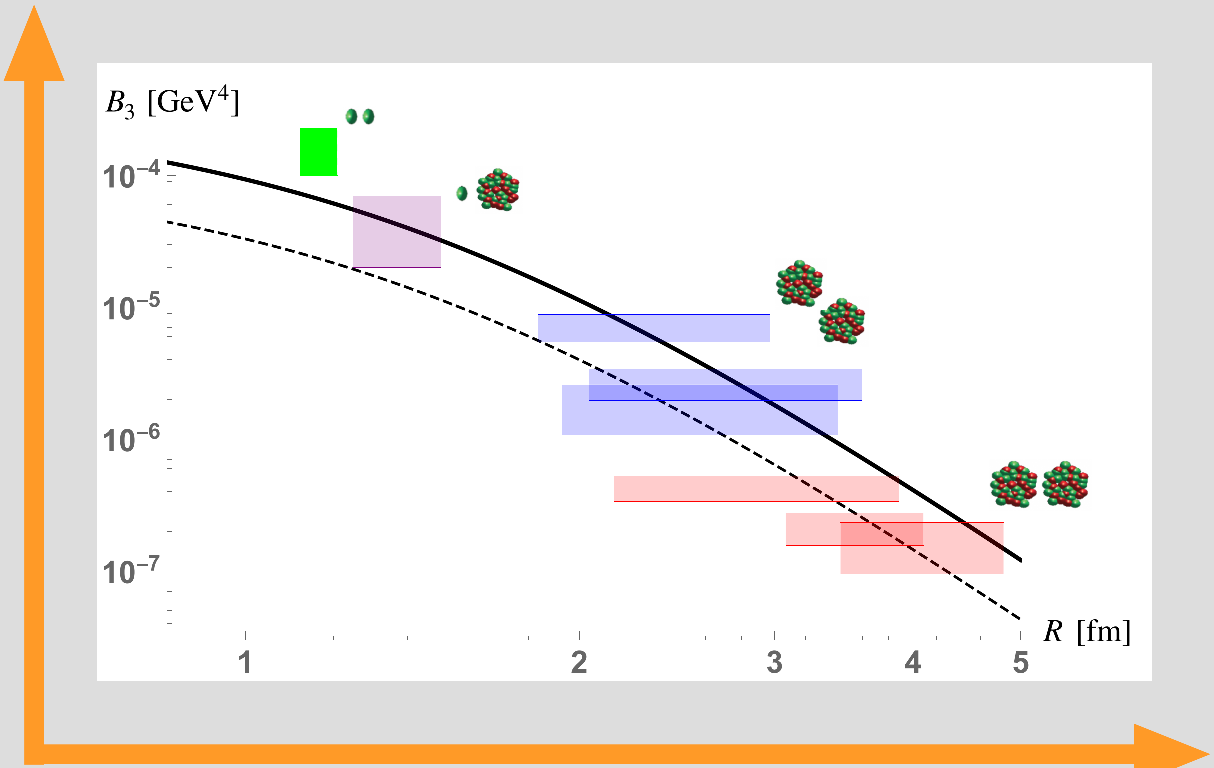
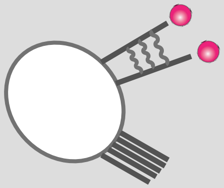
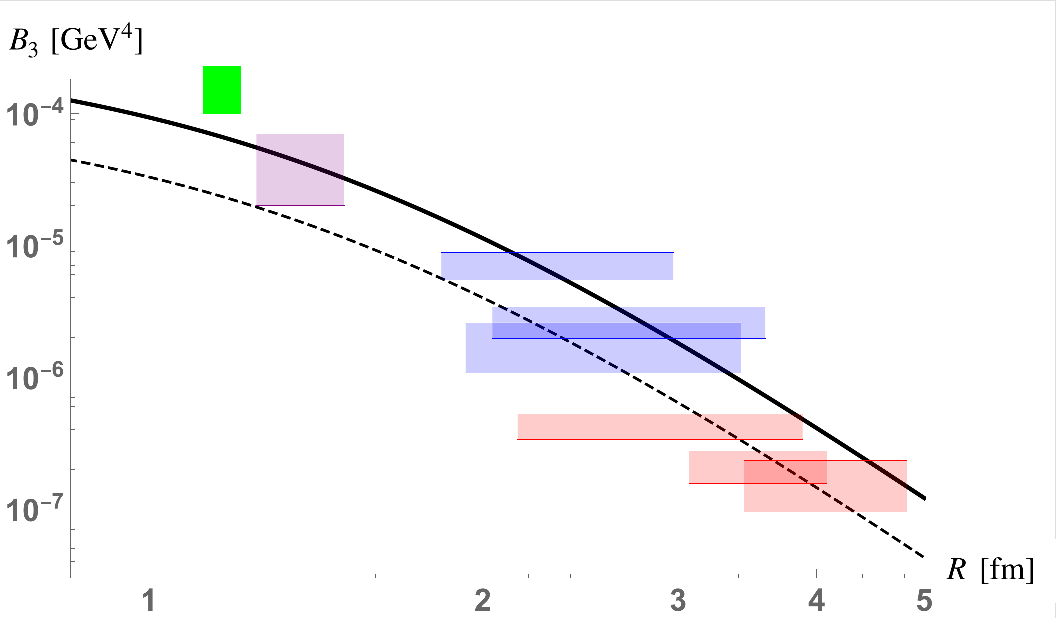




Scaling with system size: $$\frac{\mathcal{B}_A}{m^{2(A-1)}} \approx \frac{2J_A+1}{2^A\sqrt{A}}\left(\frac{mR}{\sqrt{2\pi}}\right)^{3(1-A)}$$



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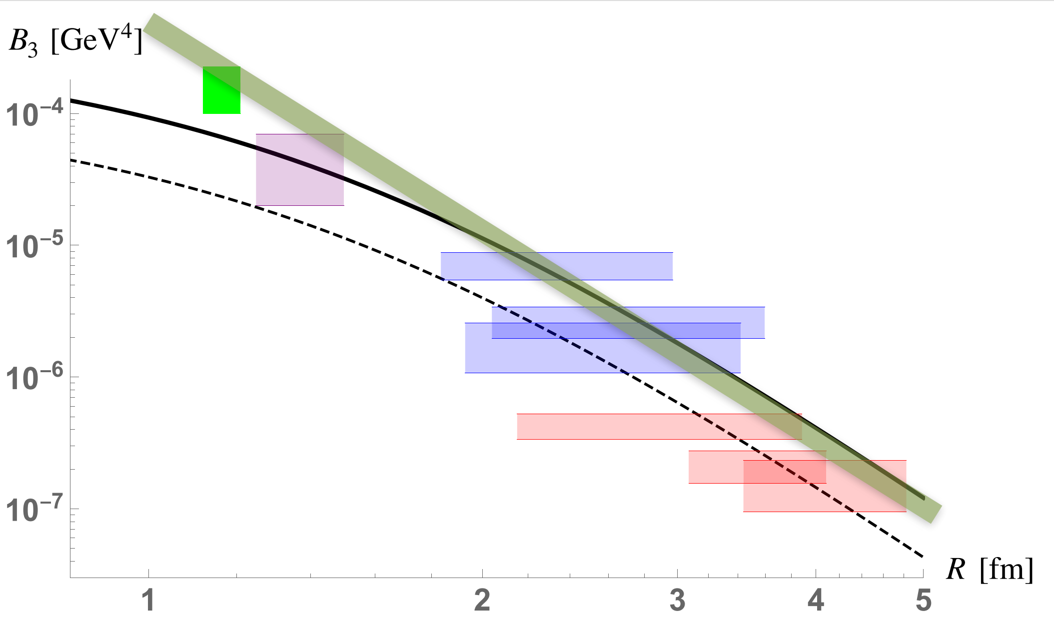

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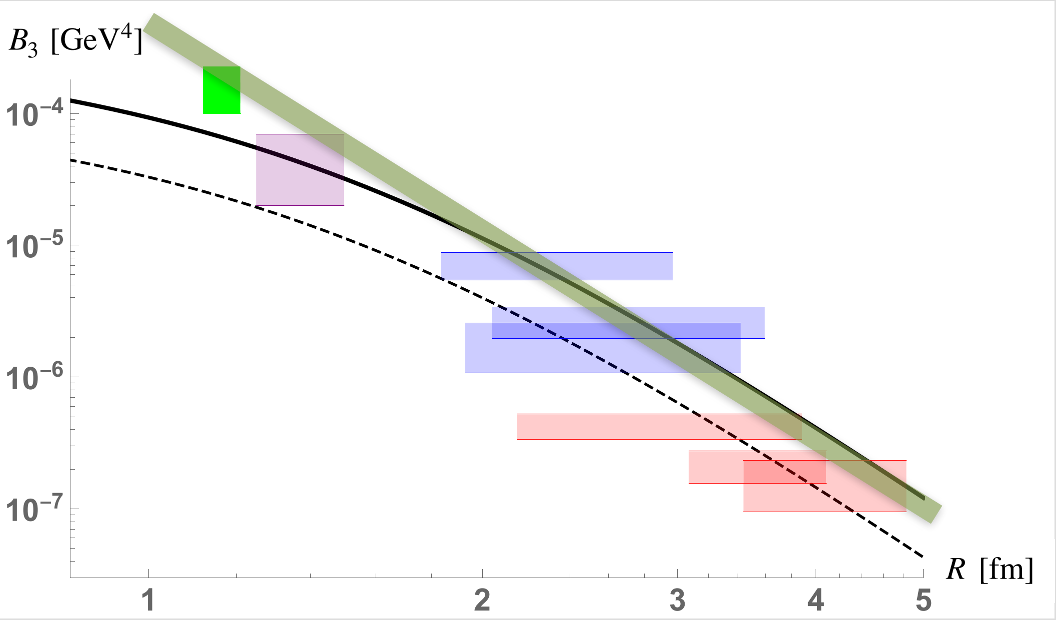

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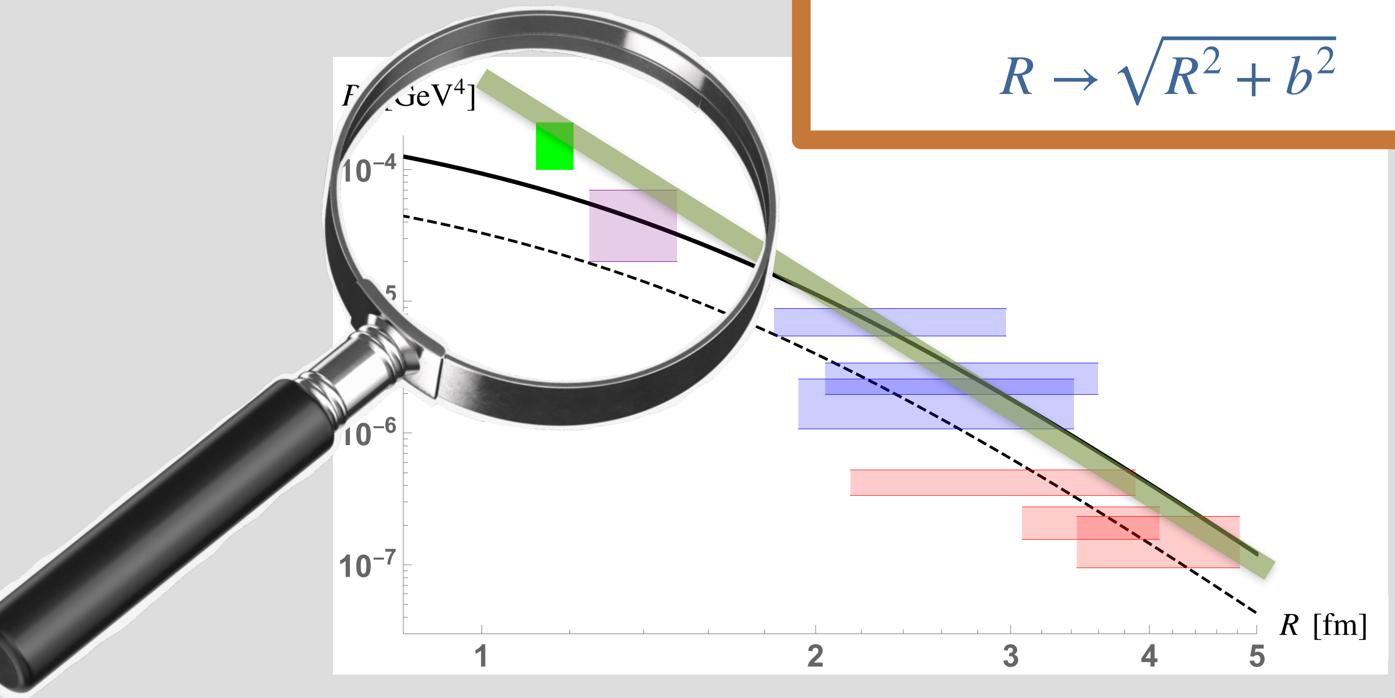
(QM suppression factor):
Clear prediction of coalescence.

$$R \to \sqrt{R^2+b^2}$$



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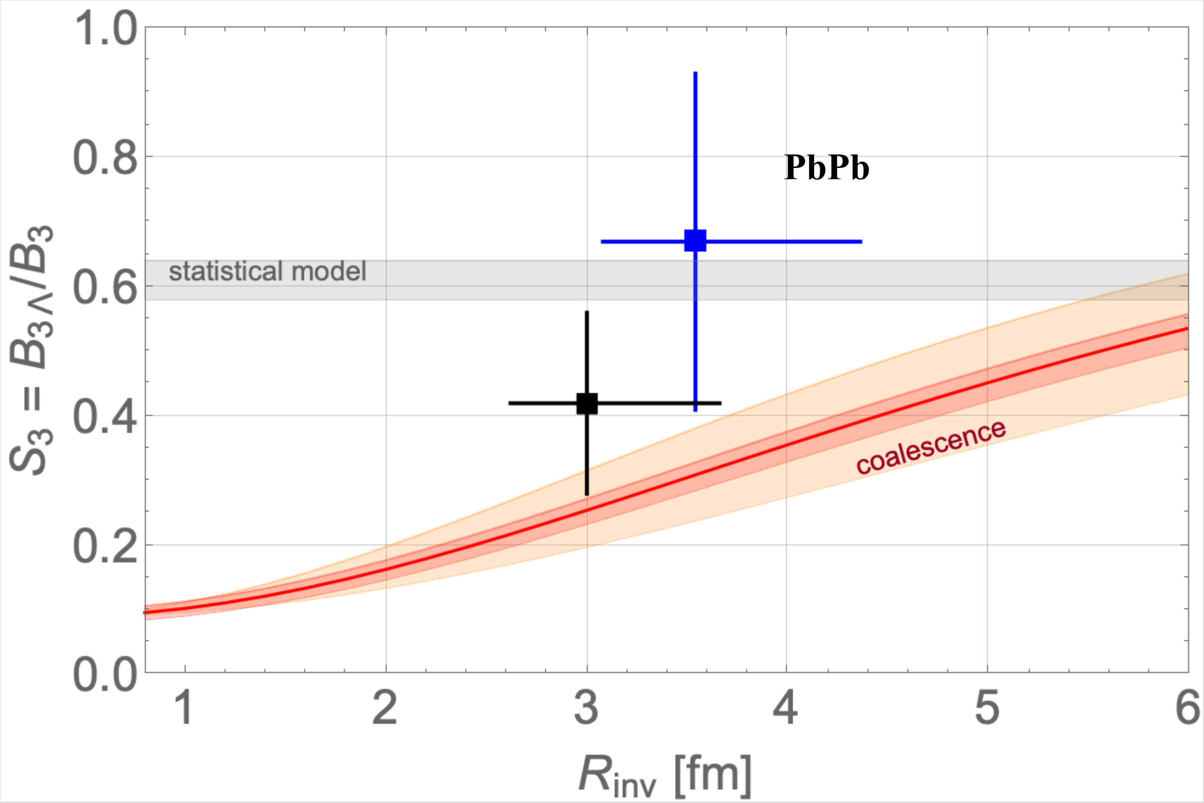
Dream observable: ${}^{3}_{\Lambda}\mathrm{H}$ in pp.

Bellini, KB, Kalweit, Puccio; Phys.Rev. C103 (2021) no.1, 014907 (see Fig.7)

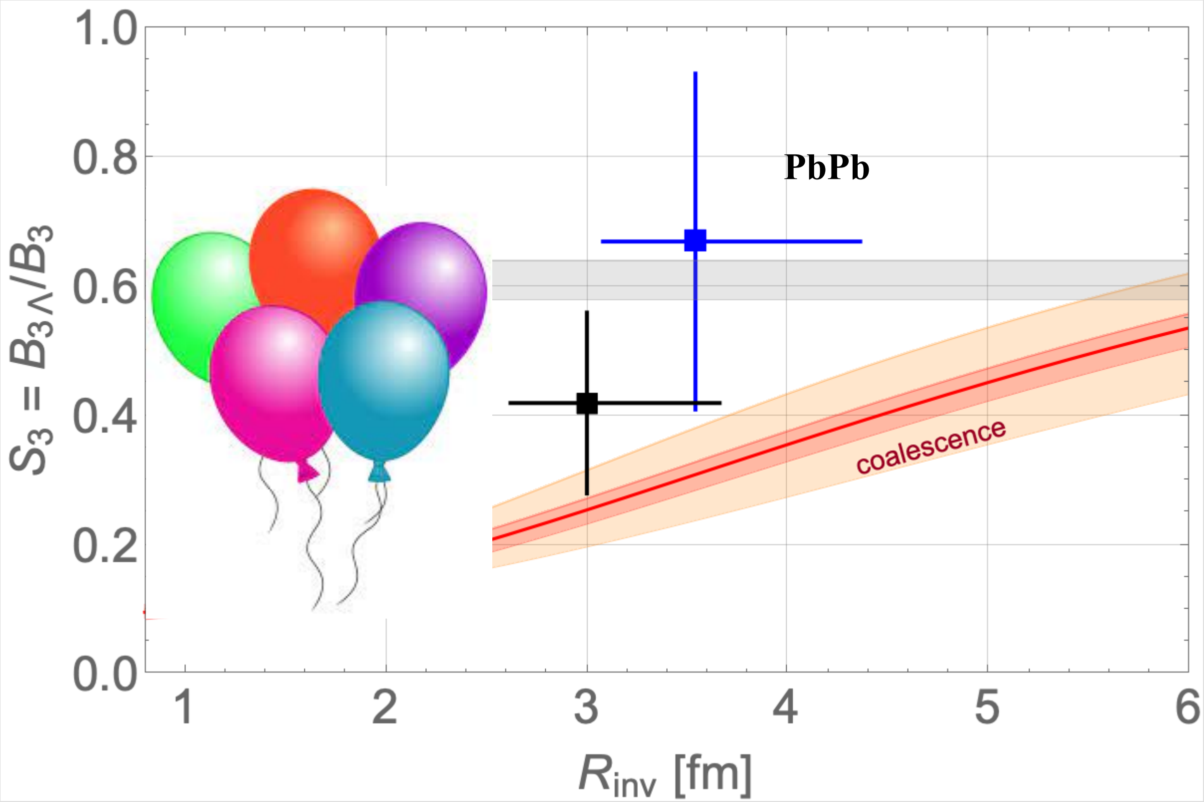
$^{3}_{\Lambda}\mathrm{H}$



pp data: ALICE 2021

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

$^{3}_{\Lambda}\mathrm{H}$



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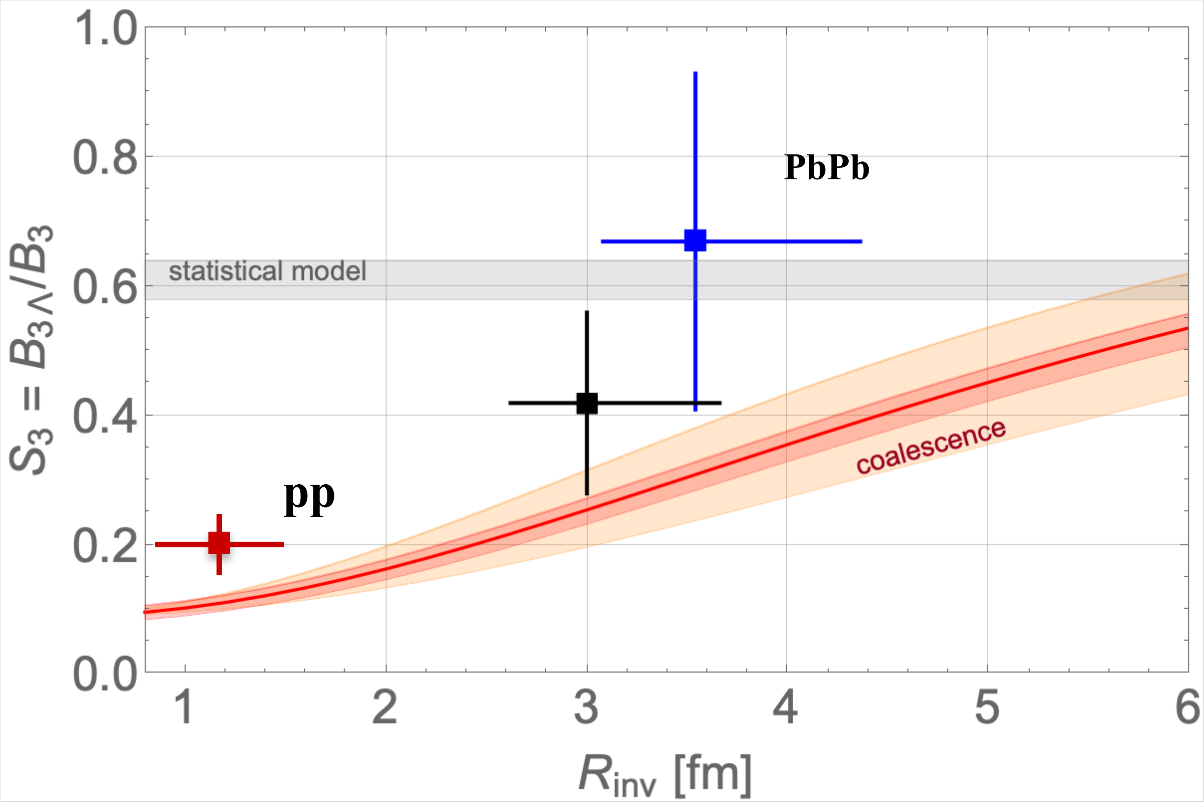

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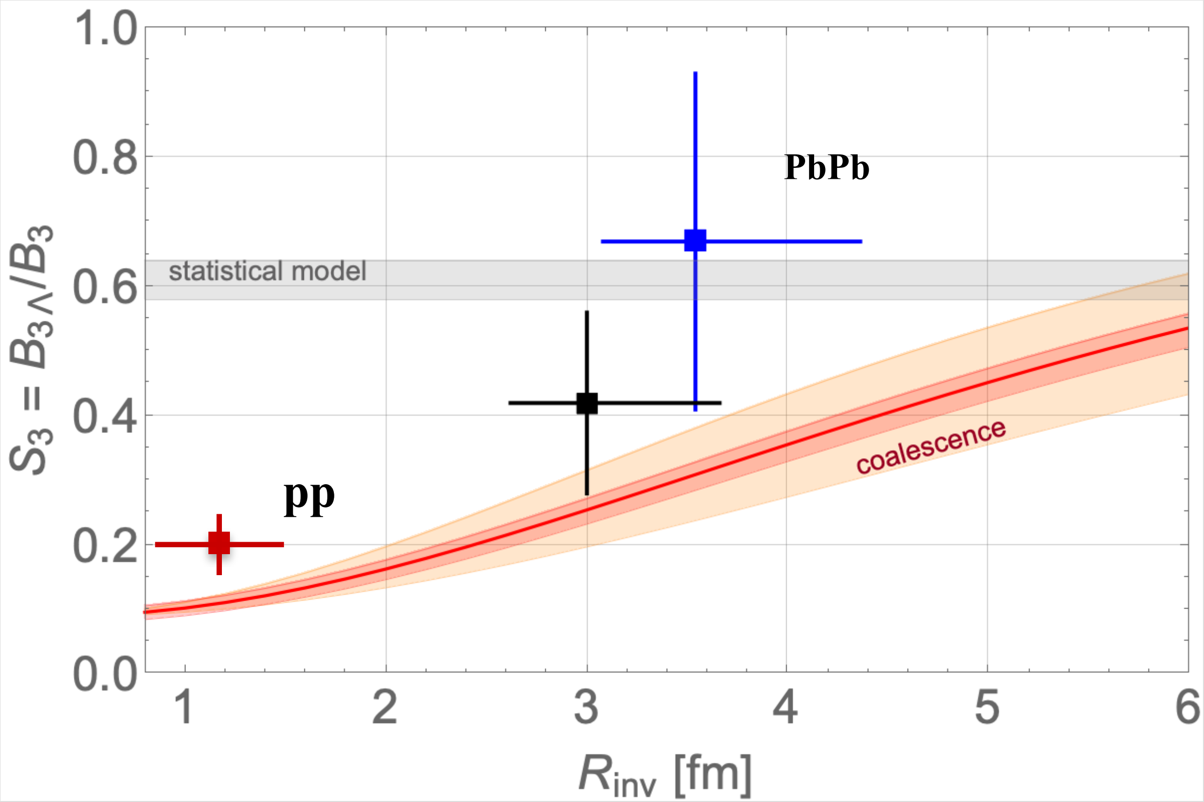

Xtra

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.

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

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_Λ, the answer is:

$$\mathscr{B}_{3\Lambda} = \frac{16\pi^3 \lambda_{3\Lambda}}{\sqrt{3}m^2 \left(b_{pn}^2 + 2R^2\right)^{\frac{3}{2}} \left(b_\Lambda^2 + 2R^2\right)^{\frac{3}{2}}}$$

(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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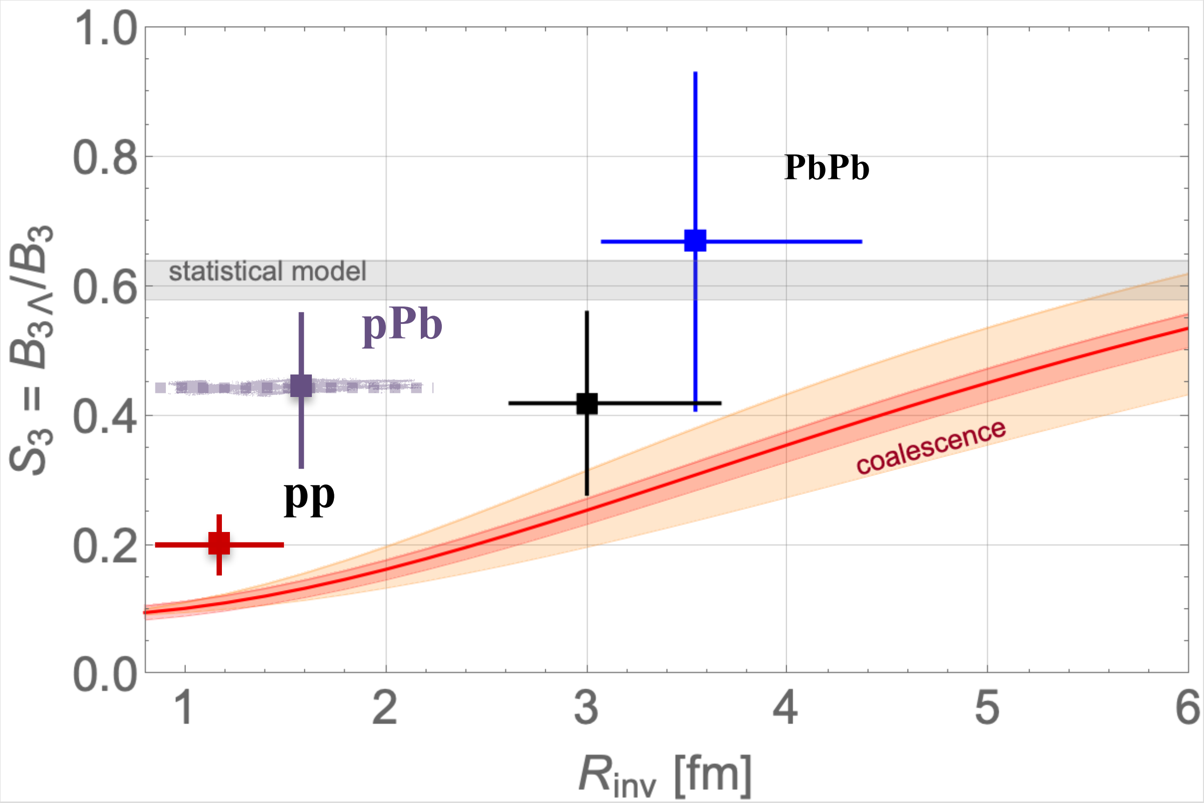

Missing femtoscopy in pPb