26th August 2018

The intuitive picture of the coalescence process:

(1) A point-like source:

⇝ If we consider the emission of nucleons from a source $R_{source} < r_{nucleus}$ the question of the coalescence momentum p_0 is straightforward:

a) The most intuitive approach to coalescence is the one via the coalescence mentum p_0: if the momentum difference between the two coalescing nucleons is smaller than p_0, they coalesce.

b) In a point-like emission source, the coalescence momentum p_0 can be approximated by the Fermi-momentum in the nucleus: The question "What is the maximal momentum difference between the two nucleons?" is in this case obviously equivalent to the question "What is the momentum of the nucleons inside ~~the next~~ a bound nucleus?"!

⇝ The Fermi-momentum is – apart from factors related to Fermi statistics – essentially governed by the Heisenberg uncertainty principle:

$$\Delta p \cdot \Delta x \approx \hbar \quad \Rightarrow \quad p_0 \approx \frac{\hbar}{d}$$ where d is the size of the nucleus

With $p_0 \approx \frac{197\ \text{MeV} \cdot \text{fm}}{d}$ we see that for light anti-nuclei like the anti-deuteron or $\overline{^3He}$ with $d \approx 1$-$2\,\text{fm}$, we obtain momenta of the order of 200 MeV. Such a value sounds large at first glance, but the kinetic energy involved in the process

$E_{kin} = \sqrt{p^2 + m^2} - m$ is not large and of the order of a few MeV and thus close to the binding energy.

$\xrightarrow{\text{p.t.o.}}$

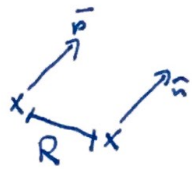
→ As a matter of fact, there are even measurements of the momentum (quantum-mechanically anyway linked to the spatial distribution) of the nucleons inside the nucleus which are of the same order. (There are some details and references in the afterburner public note).

→ For very weakly bound objects like the hyper-triton with 100-200 keV (factor ten smaller than the deuteron!) binding energy and radii of several Fermi, the simple relation

$$p_0 = \frac{\hbar}{d}$$

then yields to very small coalescence momenta and thus via $B_A \sim (\frac{4}{3}\pi p_0)^{A-1}$ to a suppression with respect to smaller/more tightly bound objects.

② An extended source:



→ In an extended source, the suppression due to the maximally allowed coalescence momentum gets overshadowed by the simple penalty factor which requires the nucleons to be close by in configuration space. The length scale is again given by the size of the produced nucleus.

→ However, in heavy-ion collisions, the density of nucleons is also much larger so that in the end, the production of this very weakly bound objects in heavy-ion collisions is favoured.

⇒ The quantum-mechanically correct and mathematically rigorous formulation of the aforementioned effects is given by the Wigner-formalism.