The EURISOL Distributed Facility Initiative

Marek said that one of the goals of EURISOL-DF is to:

Organise **experimental campaigns** using all available observables, techniques, facilities (at least two) and theoretical approaches to answer key questions in nuclear structure…….

have a single entry point for **a significant fraction (up to 50%) of the Radioactive Ion beam-time** dedicated at ISOLDE-CERN, SPIRAL2-GANIL & SPES-INFN for the EURISOL-DF experiments and distributed via the EURISOL-DF Program Advisory Committee;

I would like to take as example Alessia's presentation and say few words toward this direction.

Alessia said that light nuclei is a quantum mechanics laboratory. I presume that all of us we will agree with this statement.

Understanding reaction mechanism(s) for reactions including light exotic nuclei is of paramount importance.

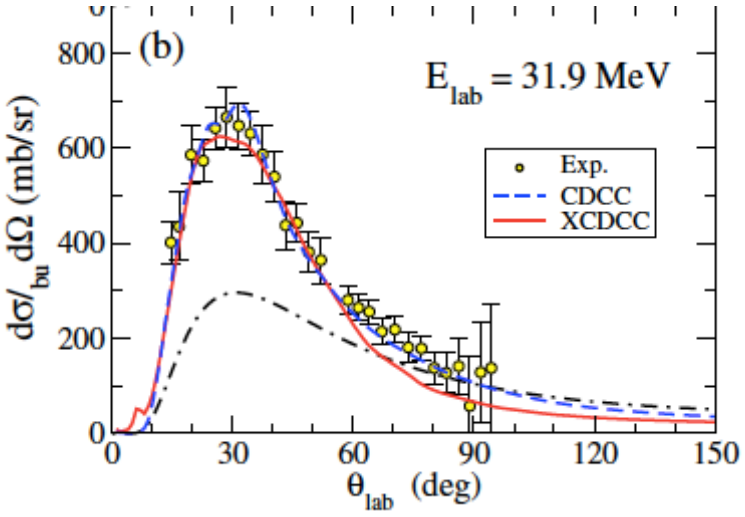
Alessia has done a really great work by measuring reactions involving light exotic nuclei. However as she has shown the problem is complex, the ensemble of the different exit channels was not measured and frequently the statistics, at least of the first (but not only) generation experiments, was not excellent.

Break-up

From Alessia's presentation

^{11}Be+^{197}Au @ TRIUMF

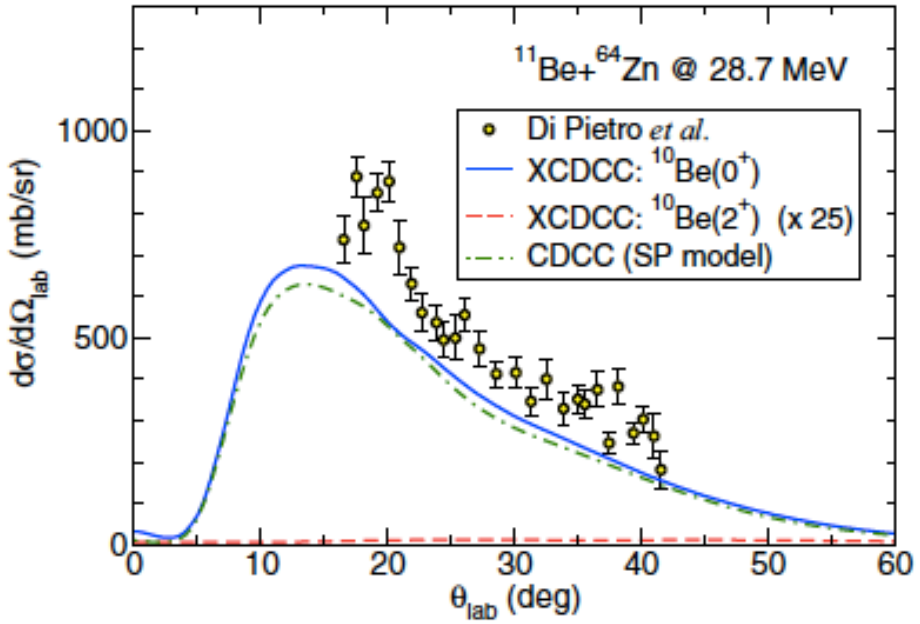
V. Pesudo et al. Phys. Rev. Lett. 118, 152502 (2017)



Coulomb dominated break-up

non-elastic break-up effects important on lighter target

^{11}Be+^{64}Zn @ ISOLDE



R.De Diego et al Phys.Rev. C 95, 044611 (2017)

PHYSICAL REVIEW C **95**, 044611 (2017)

Extracting three-body breakup observables from continuum-discretized coupled-channels calculations with core excitations

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Indeed, if one wants to analyze theoretically elastic scattering or transfer reactions in a discretized channel calculation scheme he has also to know, (it gives confidence to the calculations), the different other reaction channels like break-up channels.

Similarly, if one wants to calculate sub-barrier fusion in a discretized channel calculation scheme, he has to “know” for the considered system elastic and inelastic scattering and also break-up reactions.

This may be the spirit of the EURISOL-DF. Convince experimental teams to collaborate for studding for some well-chosen systems and energies, structure and the reaction mechanism(s).

In the EURISOL-DF spirit, as I can imagine it, experimental teams could establish a gentlemen agreement and collaborate for completely investigating an ensemble of predetermined systems at different experimental facilities and with different experimental set-ups.

Obtaining at different energies and with the necessary statistics the ensemble of the reaction channels is extremely important….Obviously the list of the systems to be studied should be established with the help and the interested theoreticians. But I will say few words concerning theory later on…..

I think that this idea was nicely presented by Maria (Borge) when she said that: not a full instrumentation will give you the full answer…….

I was also amazed by Alesia's statement saying that we may have to revisit the stable systems…..

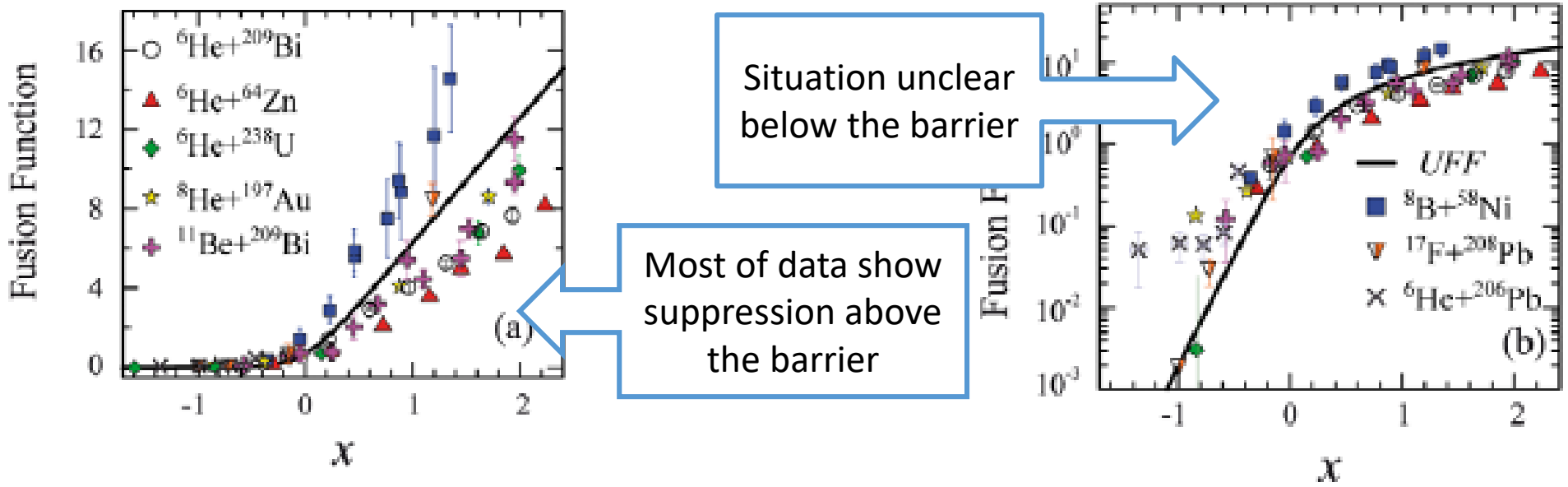
I think that this statement is correct and as an example I would like to quote the SCRIT electron scattering facility which was developed for measuring electron scattering (world's first facility) for short-lived exotic nuclei.

Indeed, the high luminosity which was achieved there is sufficient for determining the nuclear shape with only 10^8 target ions. This advancement enables electron scattering not only from unstable nuclei but also from stable nuclei when necessary.

Sub-barrier fusion

L.F. Canto et al.: NPA 821,51, (2009)

From Alessia's presentation



Besides the interest of investigating sub-barrier fusion of halo nuclei, the sub-barrier fusion dynamics of n-rich nuclei important for nuclear astrophysics studies.

Fusion reactions between n-rich nuclei occur in some explosive scenario (e.g. $^{24}O+^{24}O$ or $^{28}Ne+^{28}Ne$ could provide a significant energy source to drive X-ray super-bursts). How important are the dynamic effects (like coupling to transfer channels) on the fusion process?

Clustering effects do enhance sub-barrier fusion? Do these effects explain the unexpectedly high electron screening potentials found? C. Spitaleri et al. Physics Letters B 755 (2016) 275.

Concerning sub-barrier fusion: We were writing ten years ago with Nick Kelley, Riccardo Raabe and J.L. Sida that :

The total fusion cross-sections for halo nuclei show a suppression with respect to the 'bare' calculations at energies just above the barrier that is probably due to single neutron transfer reactions.

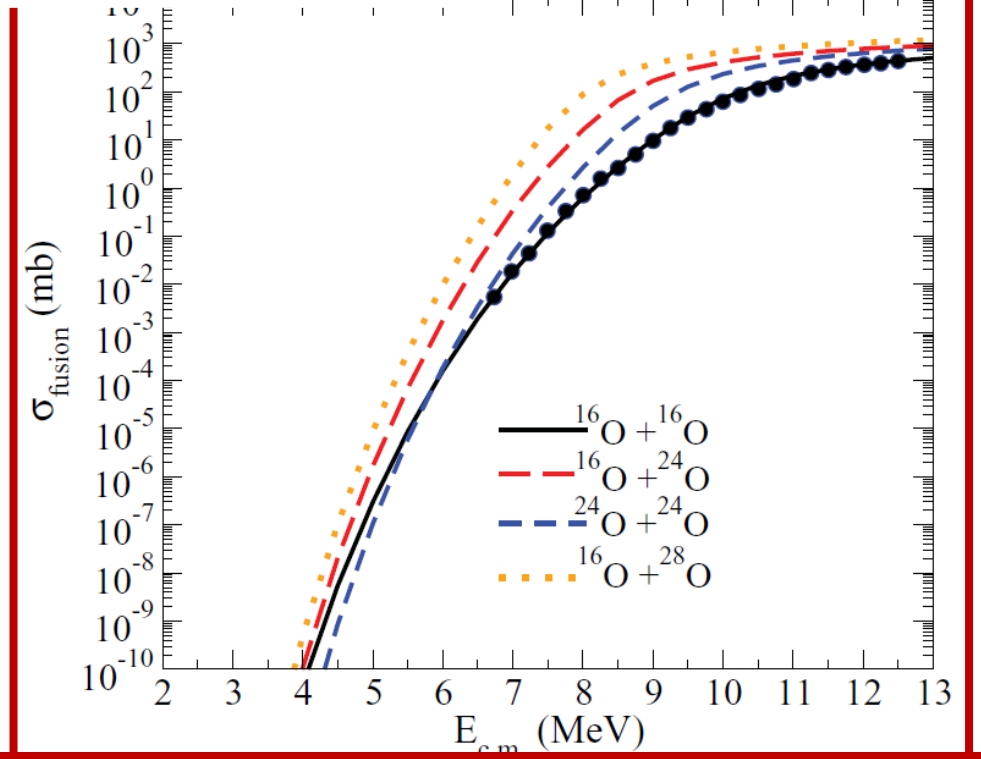
We see once again the interrelation between the different reaction channels. In the same text one can read, the data for total fusion are also consistent with a possible sub-barrier enhancement; however, this observation is not conclusive and other couplings besides the single-neutron channels would be needed in order to explain any actual enhancement….

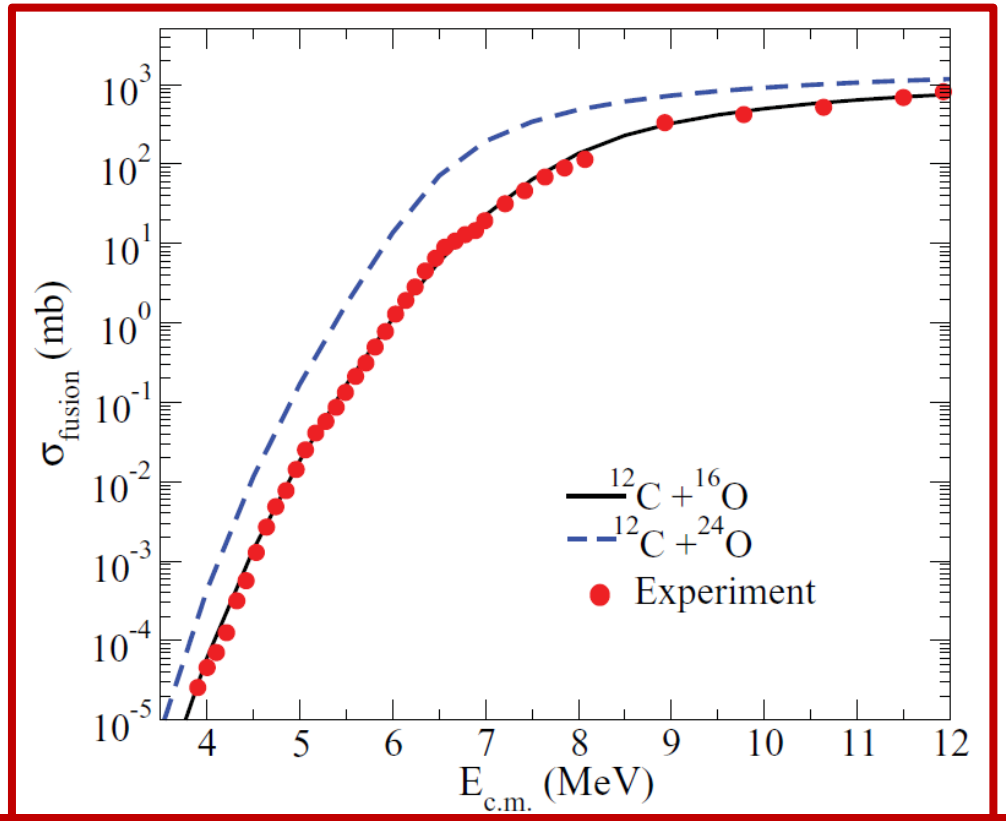
Once again in the EURISOL-DF spirit, as this was discussed previously, experimental teams could (should) collaborate for completely investigating the chosen systems.

Fusion of very neutron-rich nuclei may be important to determine the composition and heating of the crust of accreting neutron stars.

Measurements of sub-barrier fusion for light « exotic » nuclei – $^{16}O+^{16}O$, $^{16}O+^{24}O$, $^{24}O+^{24}O$, $^{12}C+^{16}O$, $^{12}C+^{24}O$…… PRC 85,055801(2012)

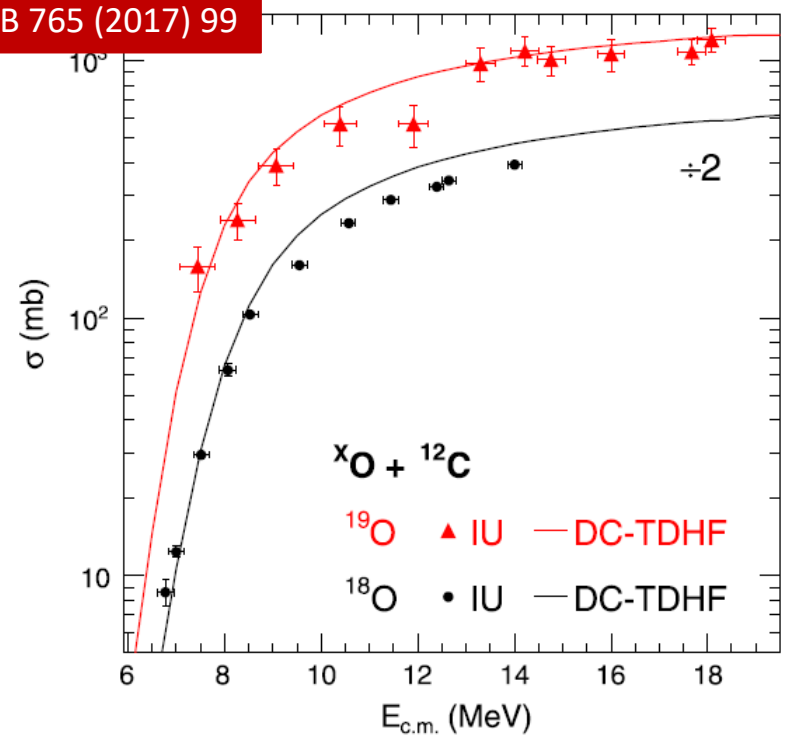
(PRC 85, 055801 (2012))





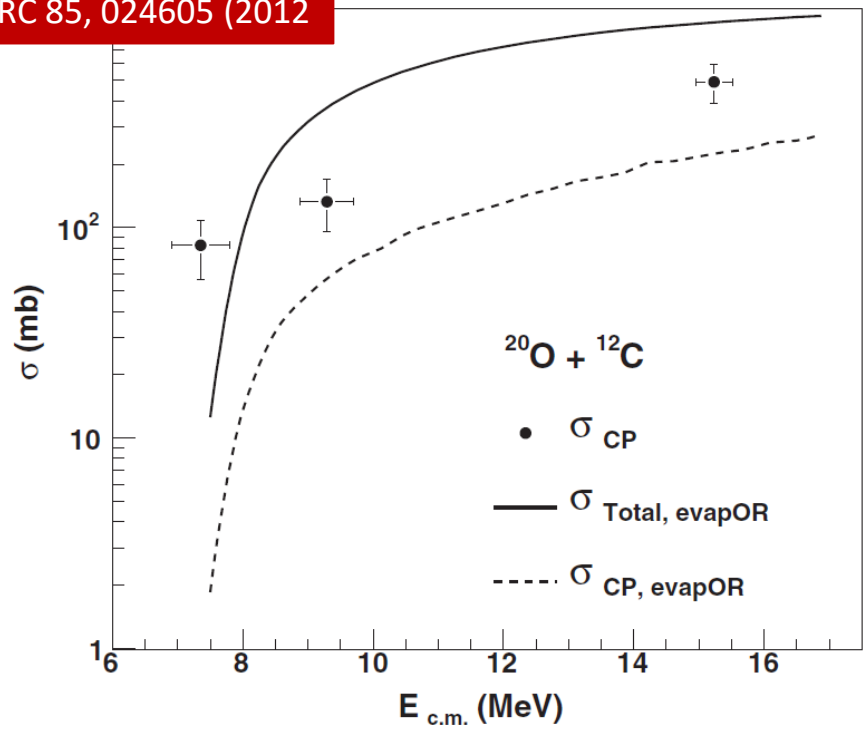
DC-TDHF calculations. TDHF evolution of the nuclear system coupled with density-constrained Hartree Fock calculations to obtain the ion-ion interaction potential. The fusion barrier penetrability is obtained by numerical integration of the two-body Schröndiger equation using the incoming wave boundary condition.

PLB 765 (2017) 99



The description of the fusion excitation function for ^{18}O is notably poor

PRC 85, 024605 (2012



New experiments will be realized at GANIL.

Concerning theory:

We are dramatically missing theoreticians working in the domain of reactions and ultimately theoreticians able to bridge the gap between theoretical structure calculations which are complex and diffusion calculations for which I do believe new methods have to be developed in particular in the case of reactions involving two weakly bound nuclei.

Similar remarks can be made for sub barrier-fusion calculations.

Concerning theory for sub-barrier fusion:

Indeed, In the absence of a practical *ab initio* quantal many-body theory for sub-barrier fusion all approaches involve the calculation of an ion-ion potential barrier, usually as a function of the nuclear separation coordinate *R*, and the solution of the corresponding one-body Schrödinger equation for the transmission probability and the fusion cross sections.

Many of the phenomenological and semi microscopic potentials for fusion utilize the double-folding method which is based on the physical assumption of *frozen densities* or the *sudden* approximation

Let me summarize :

In the EURISOL-DF spirit, as I can imagine it, experimental teams could establish a gentlemen agreement and collaborate for completely investigating an ensemble of predetermined systems at different experimental facilities and with different experimental set-ups.

Produce text-book experimental results (our legacy to the future generations).

But it is as well of paramount importance…. To establishe from the very beginning among the collaborating laboratories the “needs” in theory and eventually hire theoreticians.