^{11}Be Halo nuclei at Isolde.

Alessia Di Pietro
INFN-Laboratori Nazionali del Sud

Outline

- **Overview of previous results.**
- **Description of the Beryllium experiments:**

  ^{9}Be at LNS Catania

  ^{10,11}Be at REX-ISOLDE

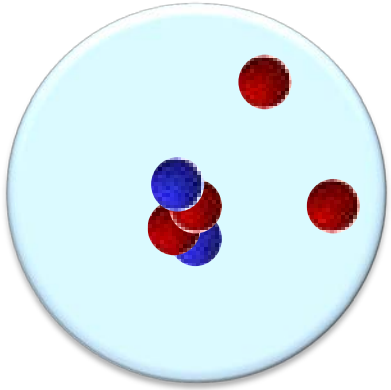
- **Experimental results**
- **Comparison with the calculations**
- **Conclusions and outlooks**

Reaction studies with halo nuclei at low energy.

INTEREST: **elastic scattering and reactions in collision induced by halo and weakly bound nuclei helps to better understand the continuum. Many papers have appeared in the last few years where this topic has been studied theoretically.**

EXPERIMENTAL REQUIREMENTS: **experimentally detailed elastic scattering angular distributions (good angular resolution) as well as other open reaction channels must be measured (large solid angle coverage).**

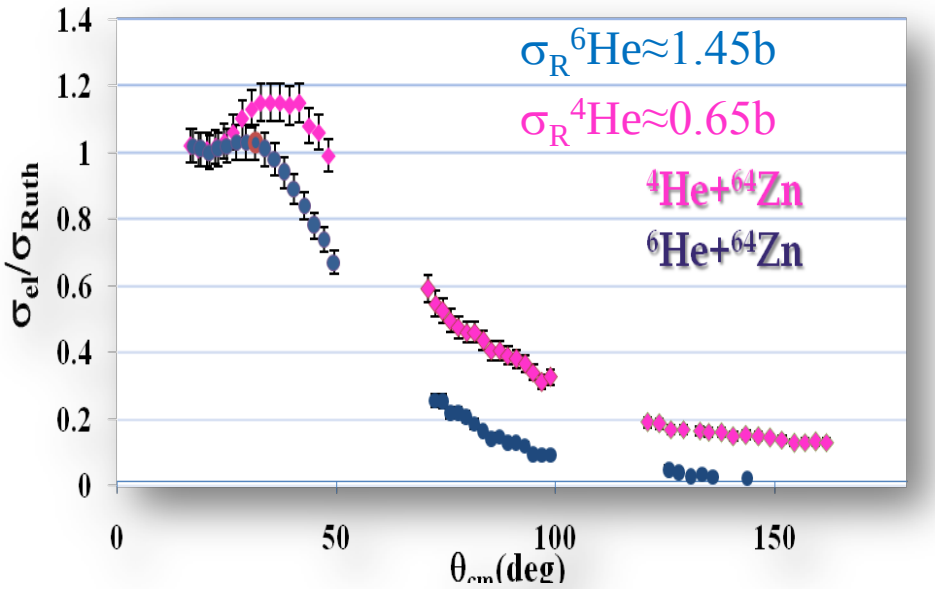
Experimental results obtained mainly with the 2n-halo ^{6}He beam on several targets



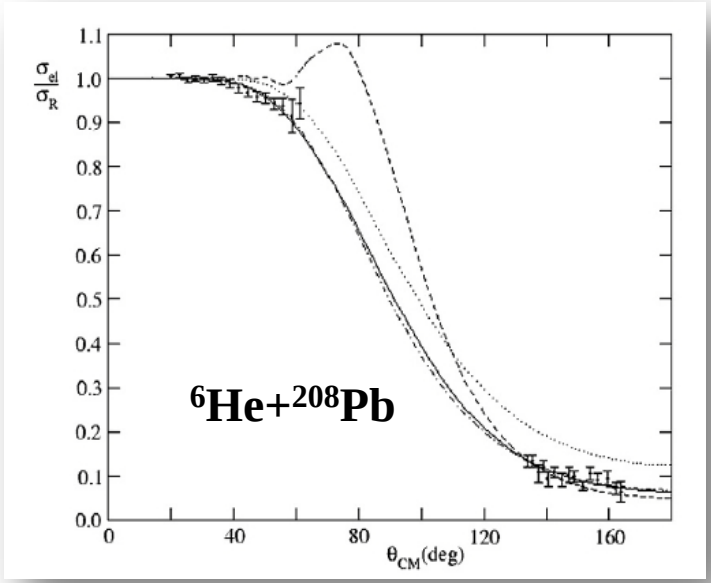
General observations:

- **Dumping of elastic scattering angular distribution**
- **Large total reaction cross sections**
- **Large cross-section for direct processes, saturating most of the σ_R**

Elastic scattering angular distribution with ^{6}He beam



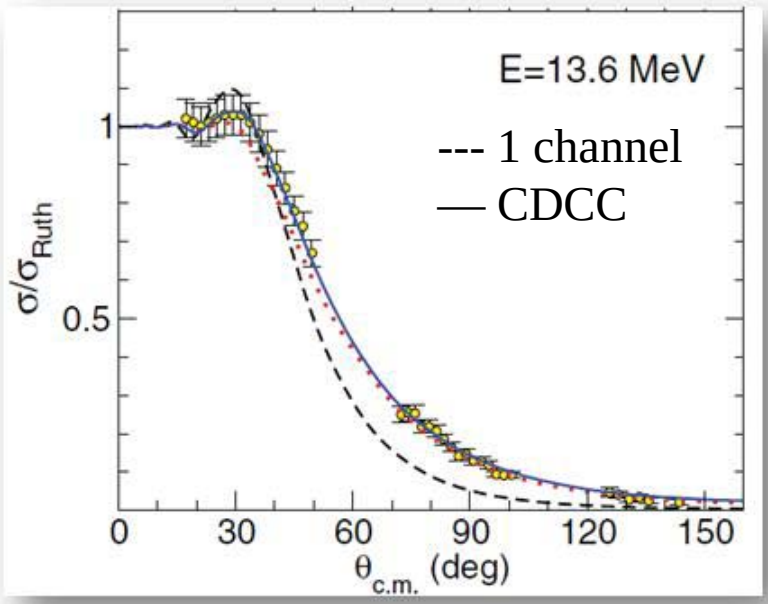
A.Di Pietro et al. PRC 69 (2004) 044613



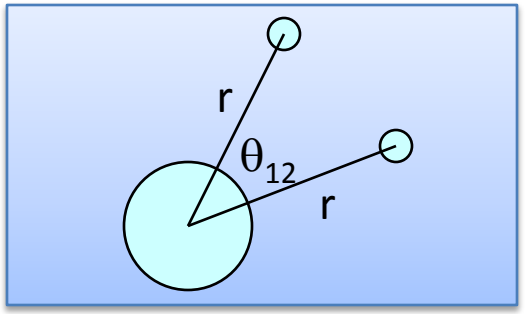
A.M. Sanchez Benitez et al. NPA 803,36,(2008)

Larger total reaction cross-section for ^{6}He induced collision with respect to ^{4}He at the same Ecm.

O.M. fit of elastic A.D.
Large diffuseness
of immaginary part needed .



A. M. MORO *et al. PRC* ***75, 064607 (2007)***

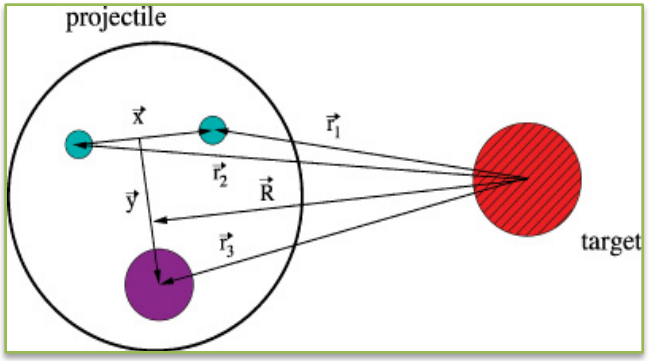


Dineutron model of ^{6}He

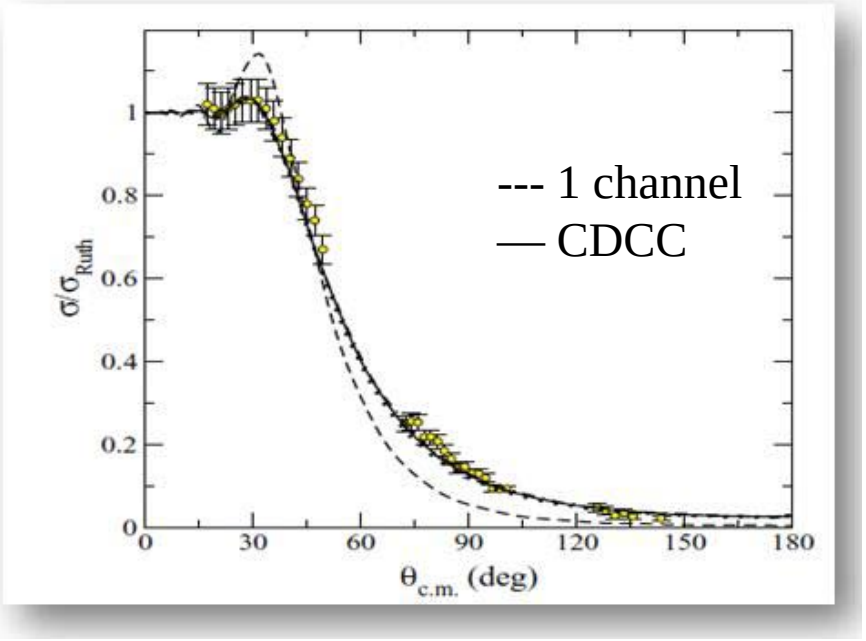
^{6}He+^{64}Zn @ E=13.6 MeV

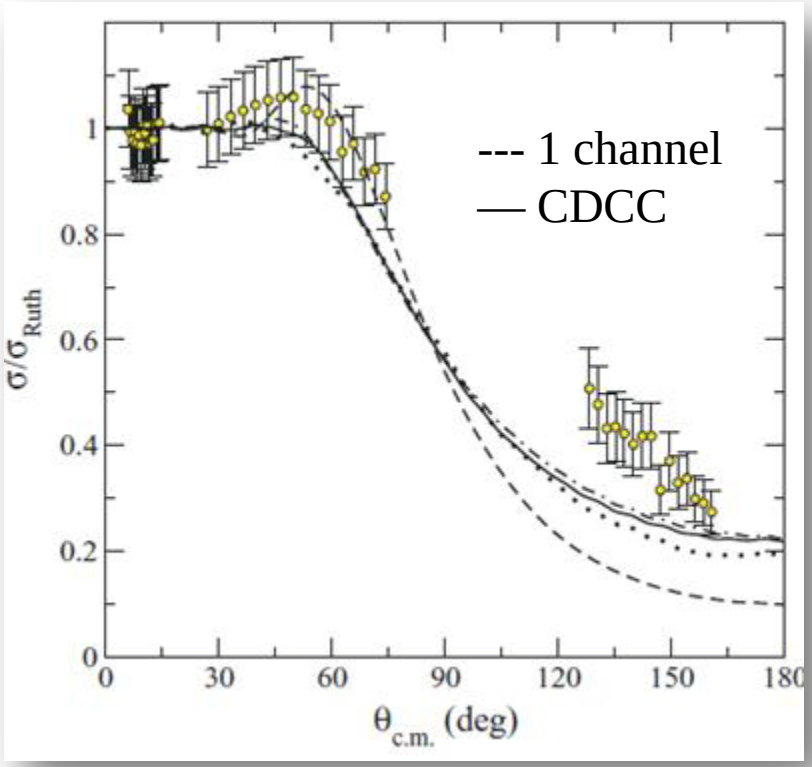
data from A.Di Pietro et al. PRC69(2004)044613

4-body model



M. Rodrìguez-Gallardo et al. PRC 77, 064609 (2008)





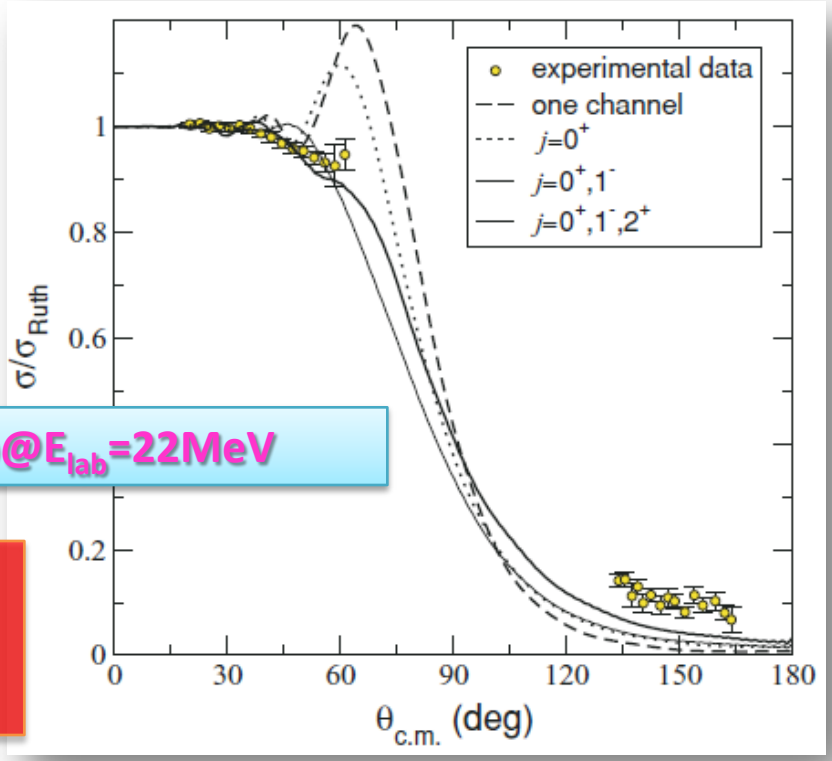
^{6}He+^{64}Zn@E_{cm}=9MeV

M. Rodrìguez-Gallardo et al. PHYSICAL REVIEW C **77, 064609 (2008)**

Experimental data from:

A. Di Pietro et al.PRC69(2004)044613

A. M. Sànchez-Benìtez *et al., Nucl. Phys.* ***A803, 30 (2008)***

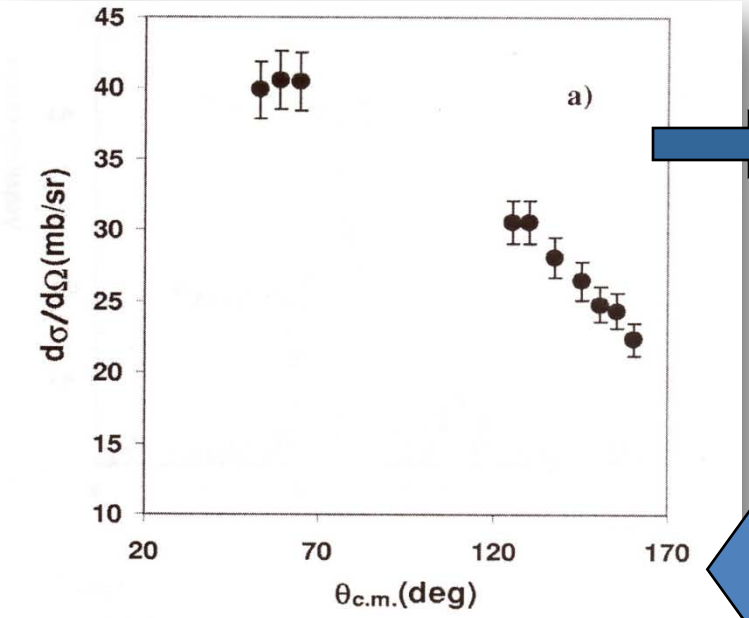


^{6}He+^{208}Pb@E_{lab}=22MeV

Needs to include 1n and 2n transfer coupling effects?

N.Keeley and N.Alamanos PRC 77(2008)054602

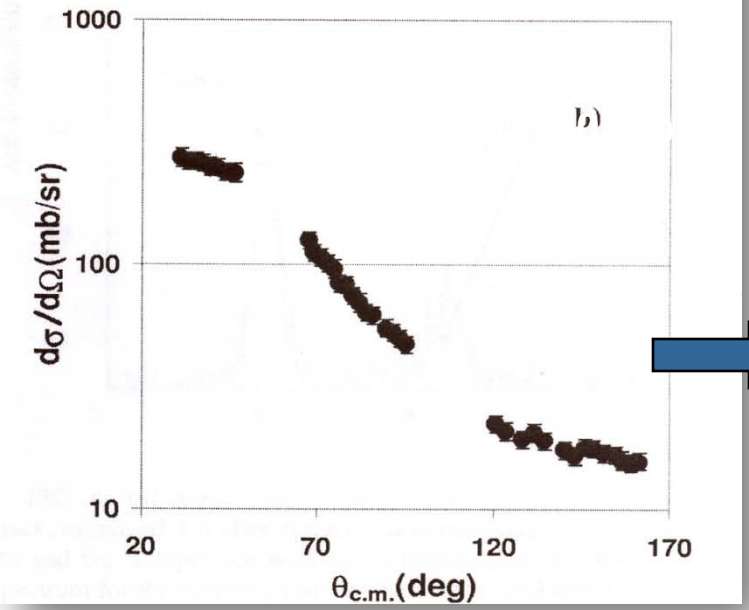
$^{6}He+^{64}Zn$: α-particle angular distribution



$\sigma_{T+bu}/\sigma_R \approx 80\%$

The α particle angular distributions are forward peaked and shift to larger angles when decreasing the beam energy.

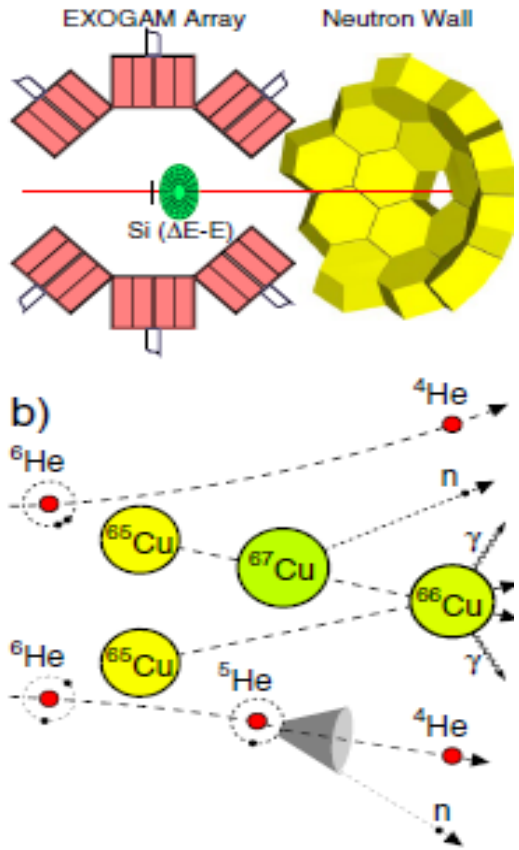
Most of the reaction cross-section corresponds to transfer and break-up events.

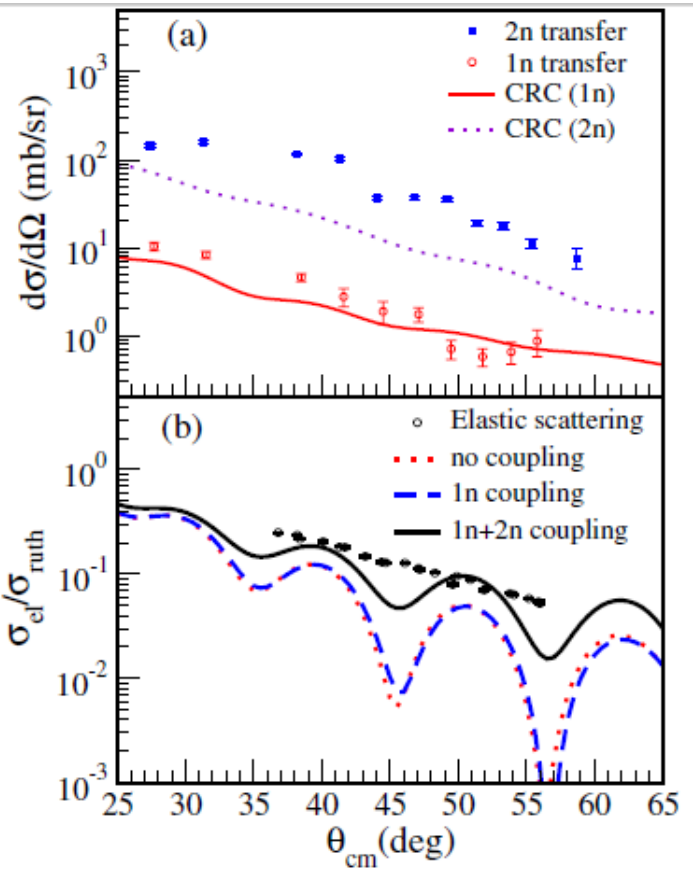


$\sigma_{T+bu}/\sigma_R \approx 80\%$

^{6}He+^{65}Cu: 1*n* and 2*n* transfer reaction @ SPIRAL

α–γ–n coincidence measurement



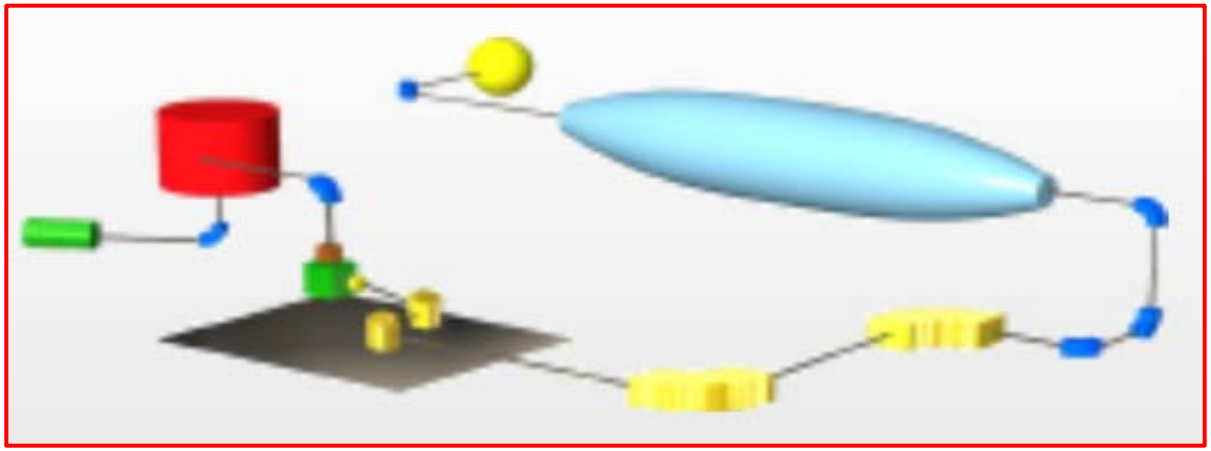


A. Chatterjee et al. PRL **101, 032701 (2008)**

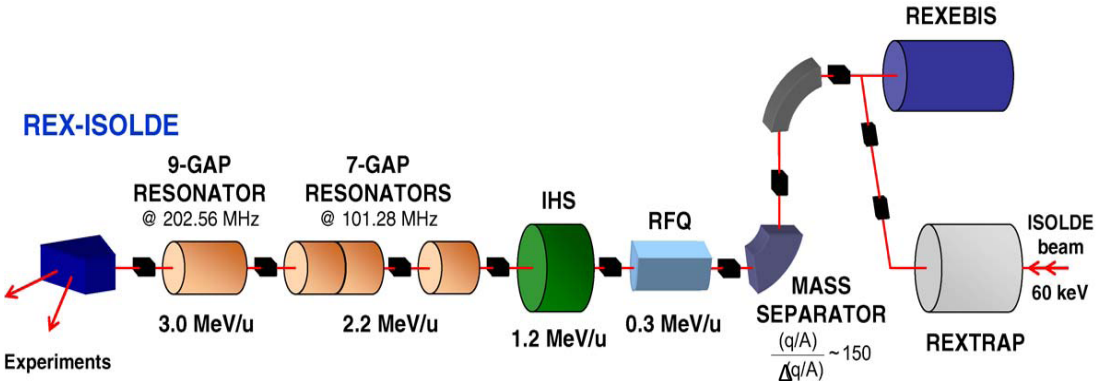
Large cross-section for the 2n transfer. Qualitative agreement with:
P. A. DeYoung *et al.*, *Phys. Rev. C 71, 051601(R) (2005)*

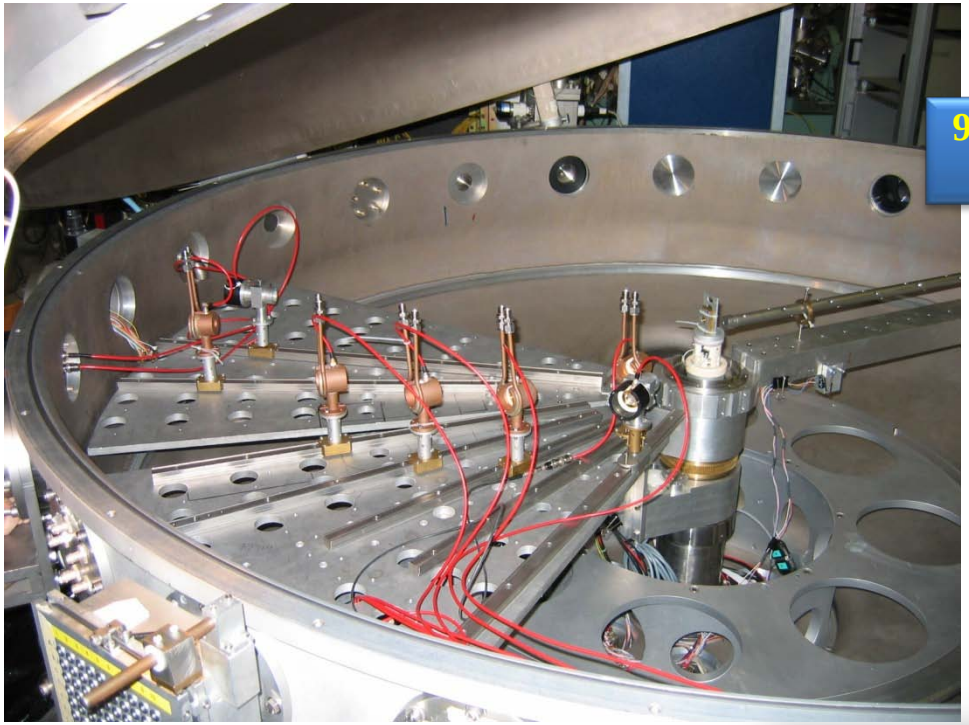
Study of the collisions ^{9,10,11}Be+^{64}Zn at $E_{cm} \approx 24.5$ MeV.
Main aims : elastic scattering, σ_R

^{9}Be @ INFN LNS (Catania)



^{10,11}Be @ REX-ISOLDE (CERN)





$^{9}Be+^{64}Zn$ experiment @ LNS Catania

5 ΔE-E Telescopes

ΔE: 10 μm surface barrier Si detectors

E: 500 μm surface barrier Si detectors

OM fit $^{9}Be+^{64}Zn$

$\sigma_R \approx 1100$ mb

In agreement with

Phys. Rev. C71,034608,(2005)

^{10,11}Be+^{64}Zn @ REX ISOLDE

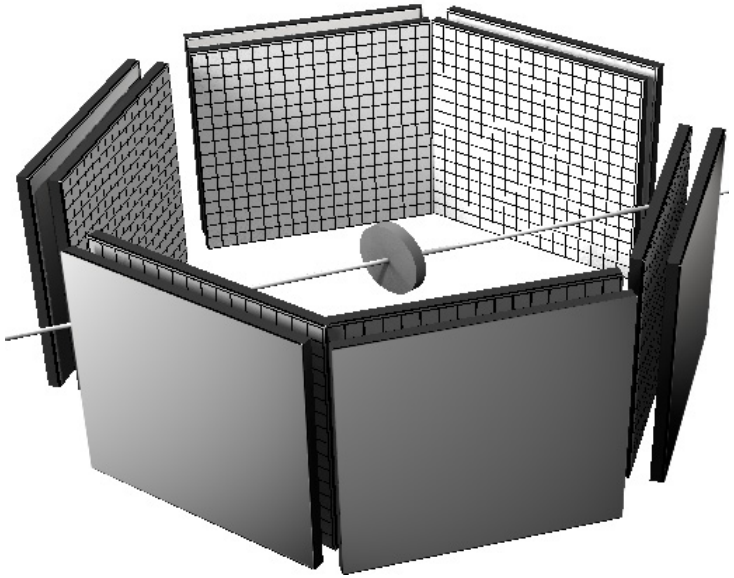
Experimental set-up:

6 Si detector telecopes:

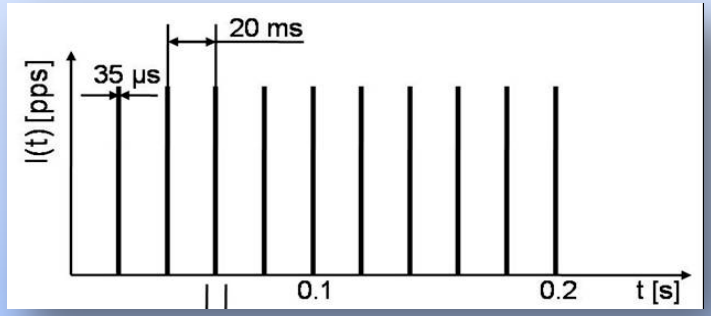
ΔE: 50 μm, 50x50 mm^2 DSSSD detectors

16 +16 strips (256 detector pixels each detector)

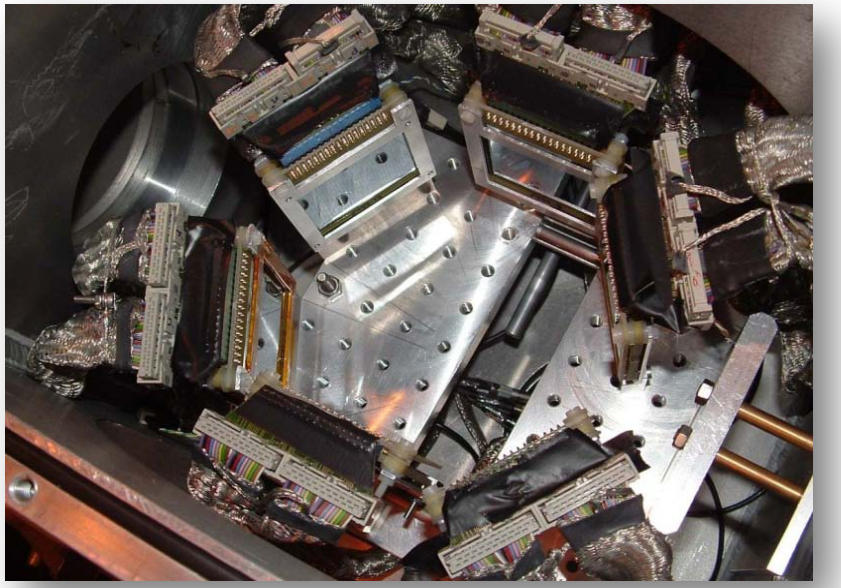
E : 1500 μm 50x50 mm^2 single pad Silicon detectors



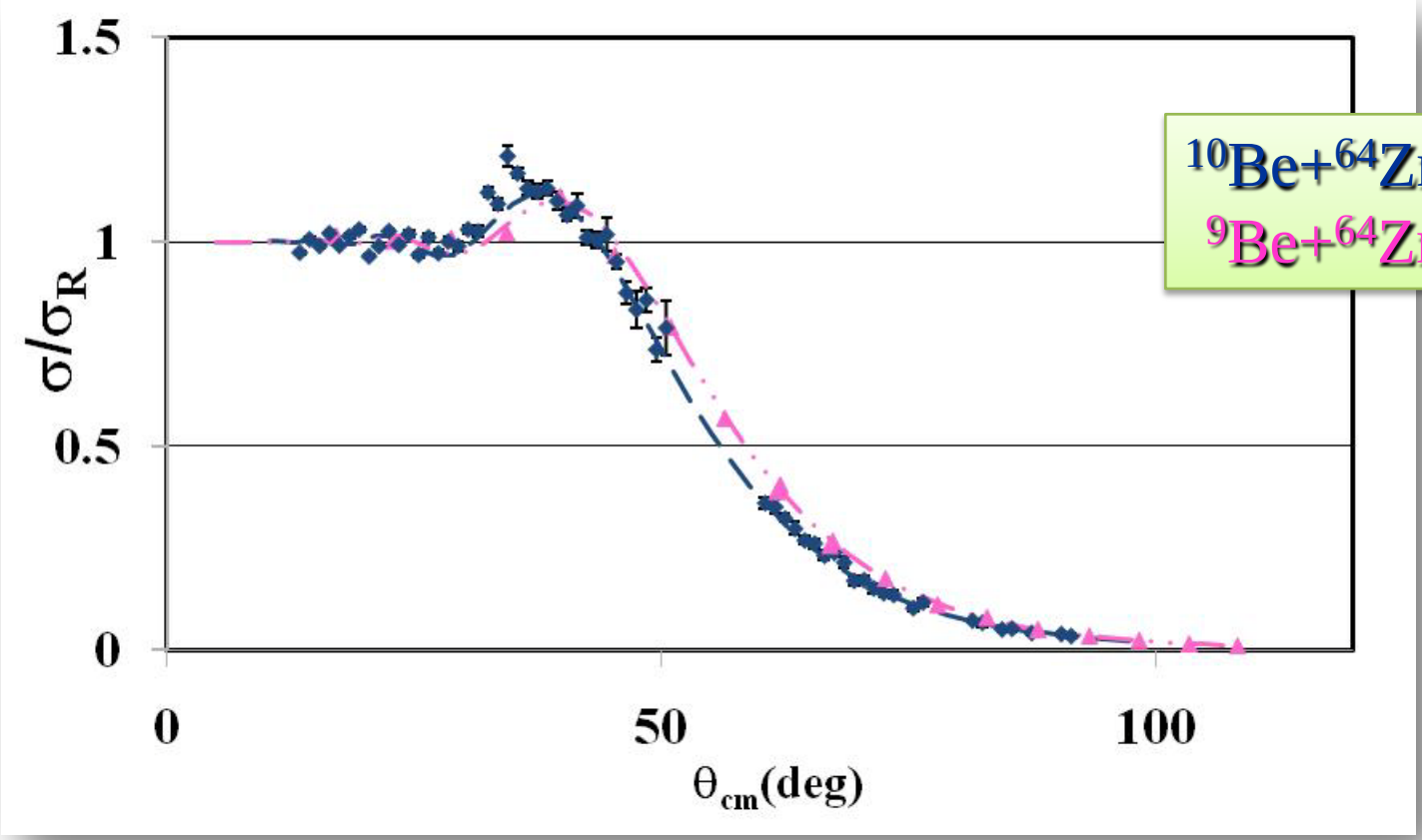
Beam time structure:
low duty-cycle⇒high instantaneous current



Detectors inside the chamber

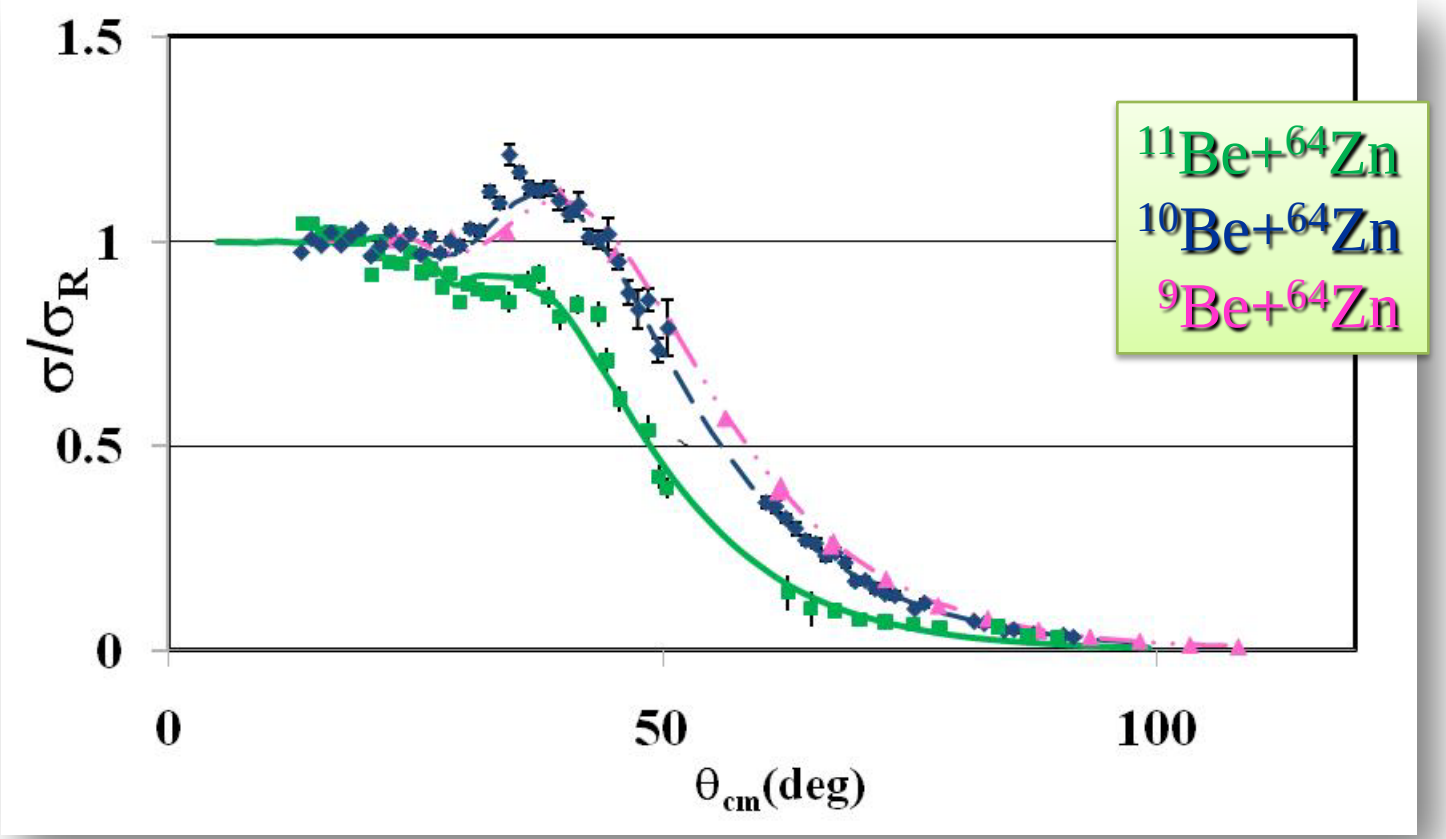


Elastic scattering angular distributions



Reaction cross-section
σ_R ^{9}Be≈1.1b σ_R ^{10}Be ≈1.25b

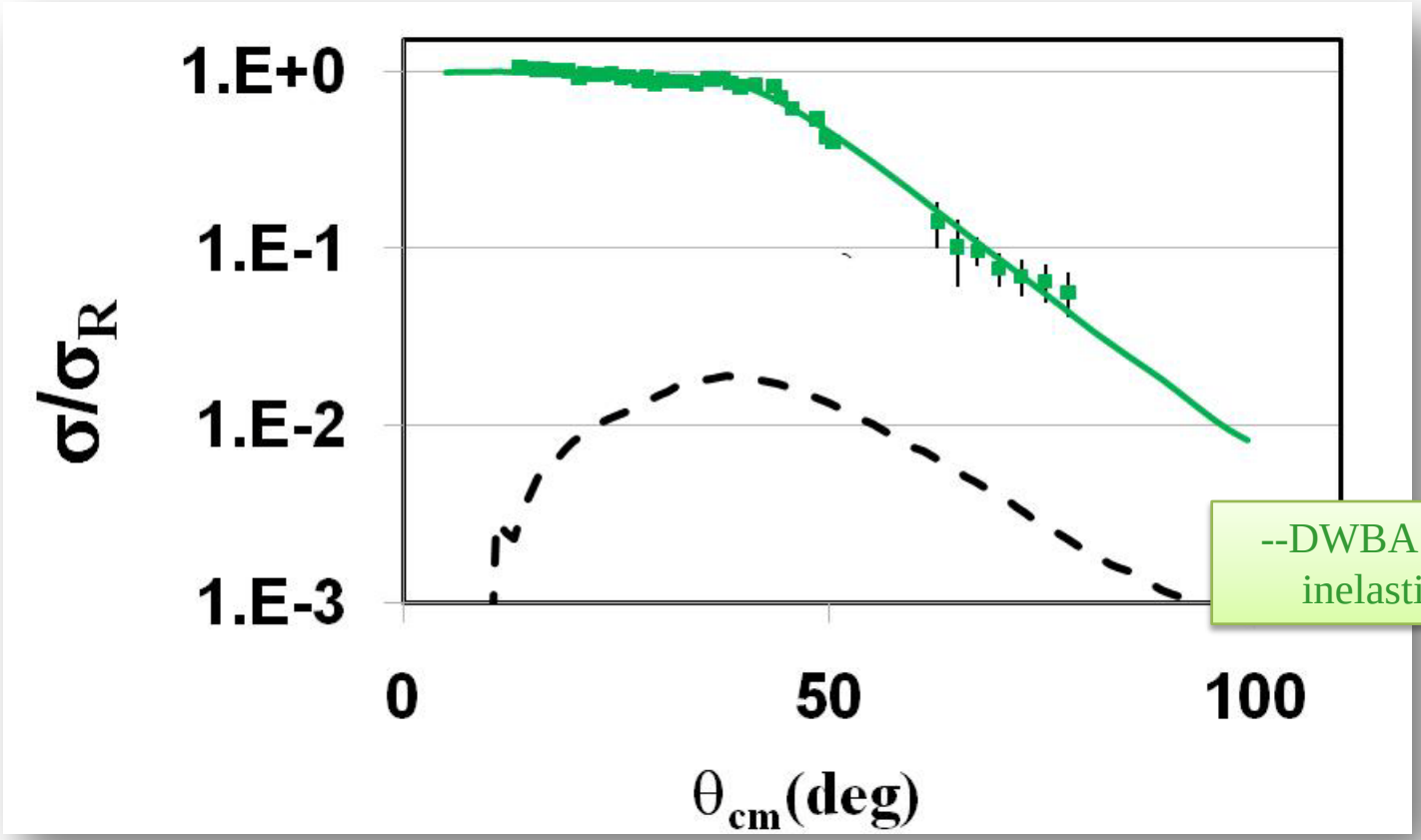
Elastic scattering angular distributions



Reaction cross-section
σ_R ^{9}Be≈1.1b σ_R ^{10}Be ≈1.2b
σ_R ^{11}Be ≈2.7b

A. Di Pietro et a. Phys. Rev. Lett. 105,022701(2010)

$^{11}Be+^{64}Zn$



--DWBA calculation of inelastic scattering

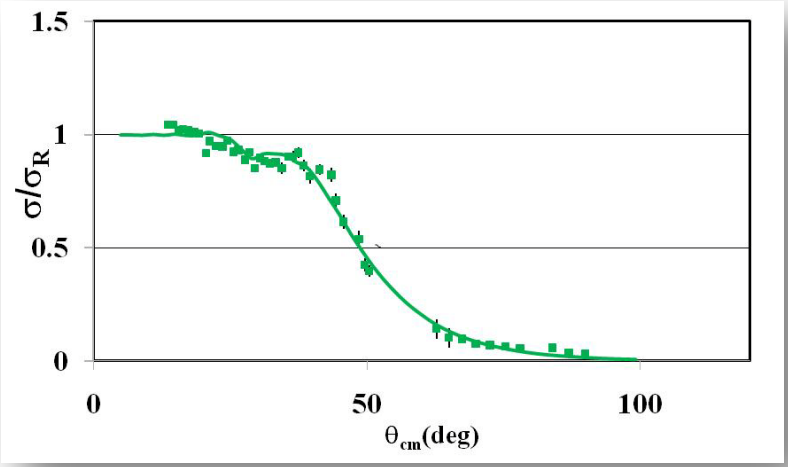
A. Di Pietro et a. Phys. Rev. Lett. 105,022701(2010)

^{11}Be Optical Model analysis:

Adopted procedure:

- volume potential responsible for the core-target interaction obtained from the ^{10}Be+^{64}Zn elastic scattering fit.
- a complex DPP is added. The DPP potential is a surface term having the shape of a W-S derivative with a very large diffuseness.

^{11}Be diffuseness parameter of the DPP potential: a_i=3.5fm

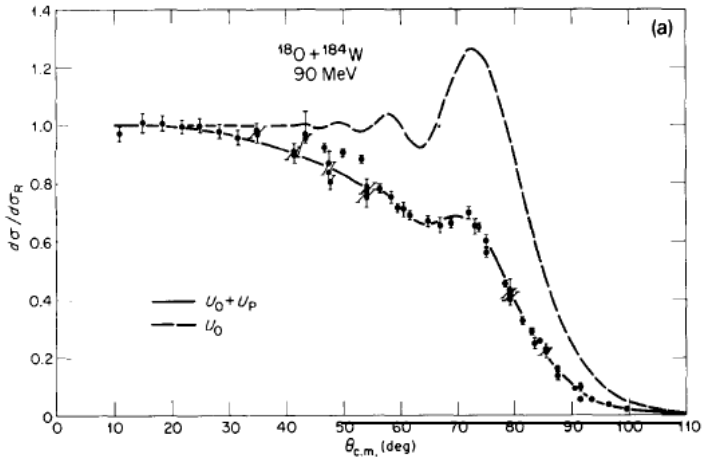


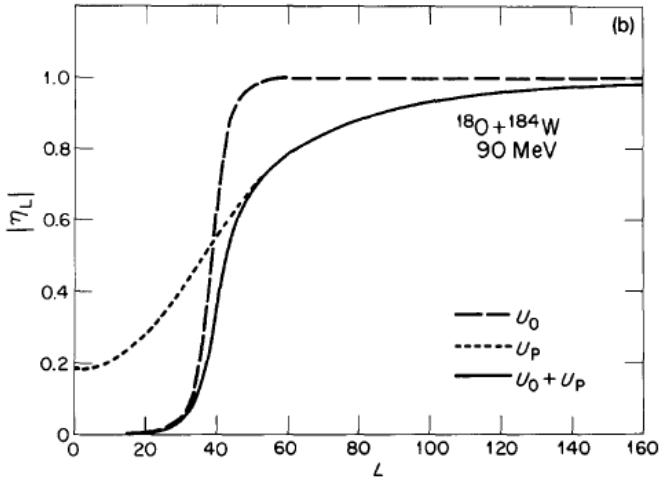
The long range part of the OP due to coupling to break-up ⇒ damping of elastic cross-section at all angles for which the nuclear interaction is felt.

Results in agreement with A.Bonaccrso and F.Carstoiu NPA 706(2002)322

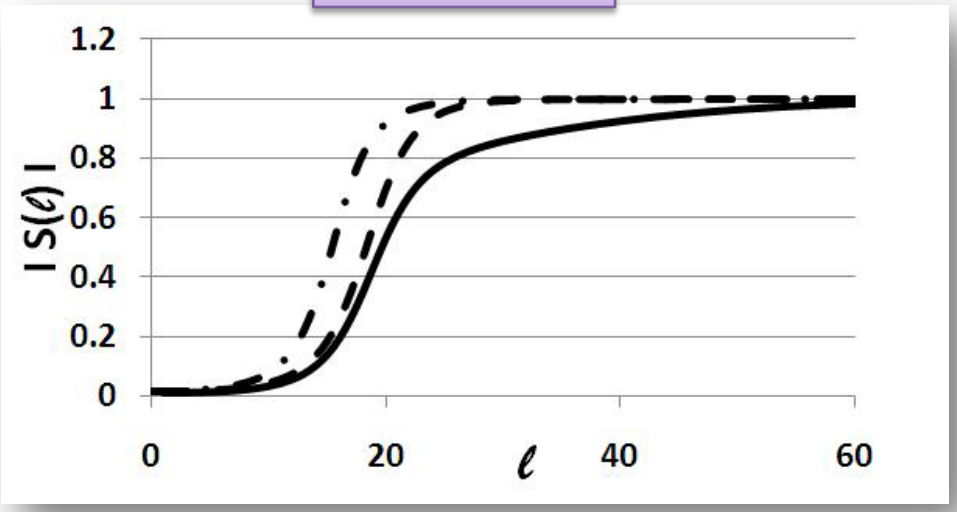
Absorption in high partial waves causes cross-section to fall below Rutherford at forward scattering angles.

$^{18}O+^{184}W$@90MeV W.Love et al. Nucl.Phys.A291(1977)183





$^{9,10,11}Be+^{64}Zn$



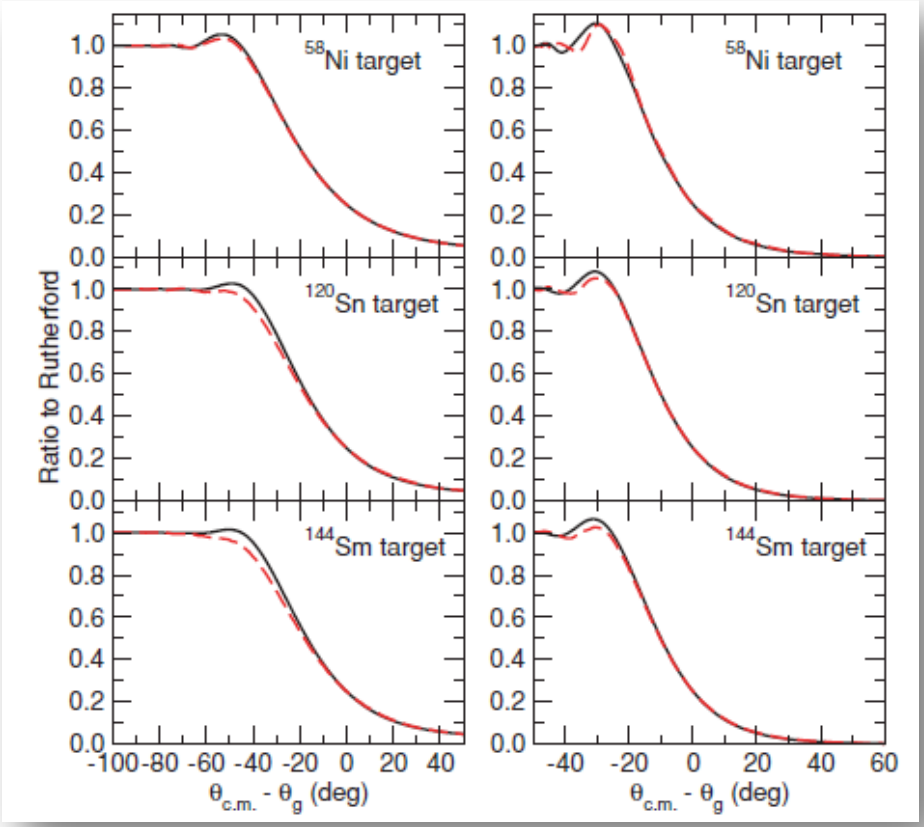
$^{9}Be+^{64}Zn$

$^{10}Be+^{64}Zn$

$^{11}Be+^{64}Zn$

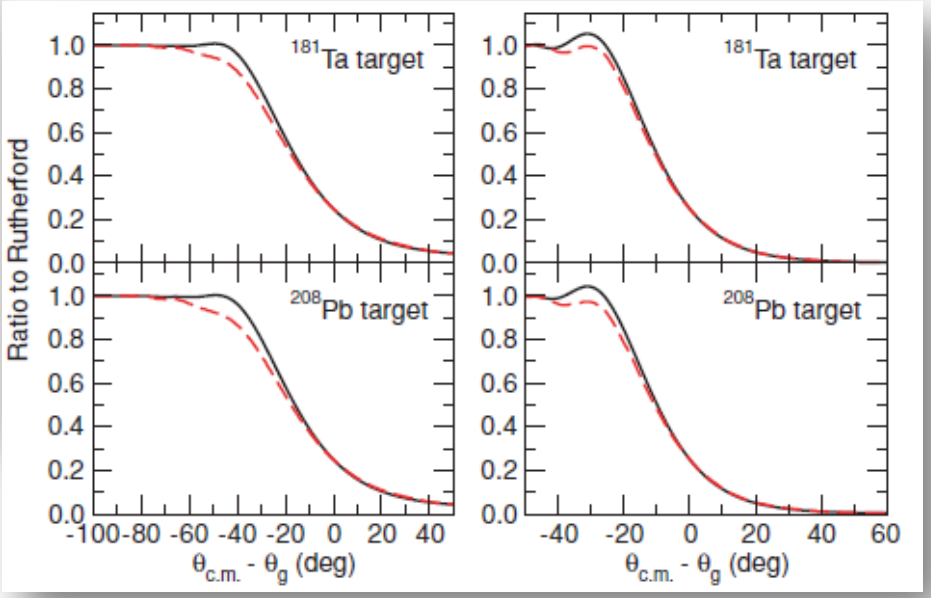
Effect of coupling to Coulomb dipole break-up as a function of the target charge for ^{6}He induced collision at energy around the barrier.

Y. Kucuk et al. PRC 79(2009)067601

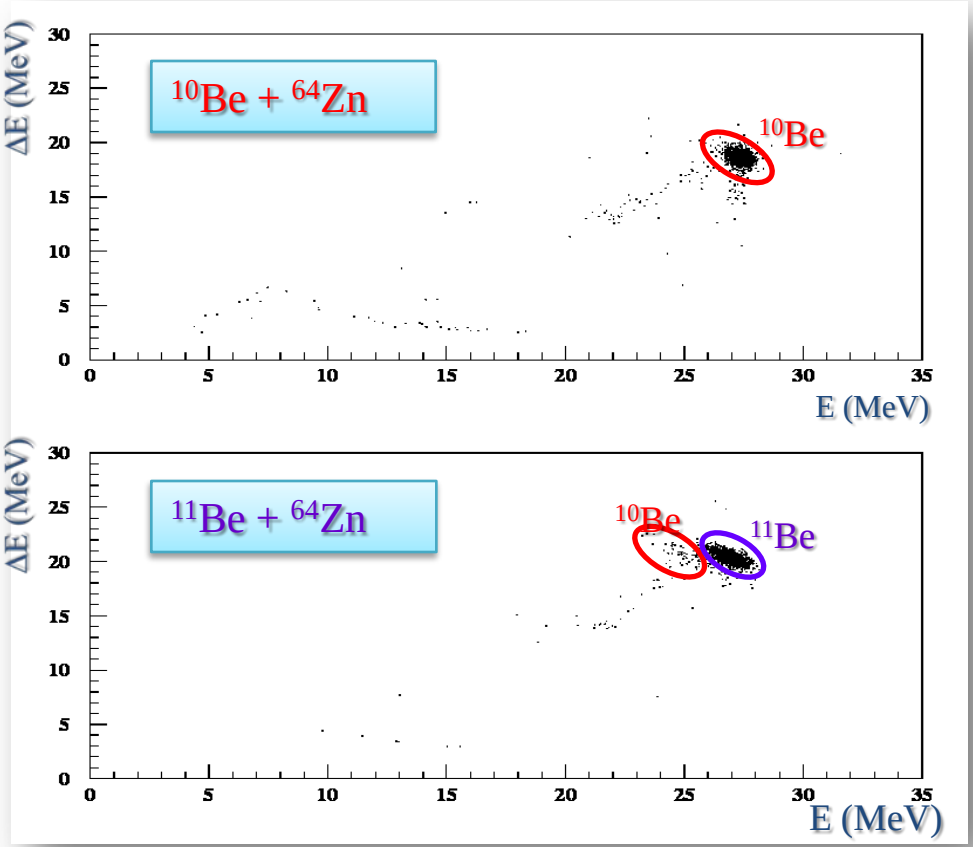


—^{6}Li+A

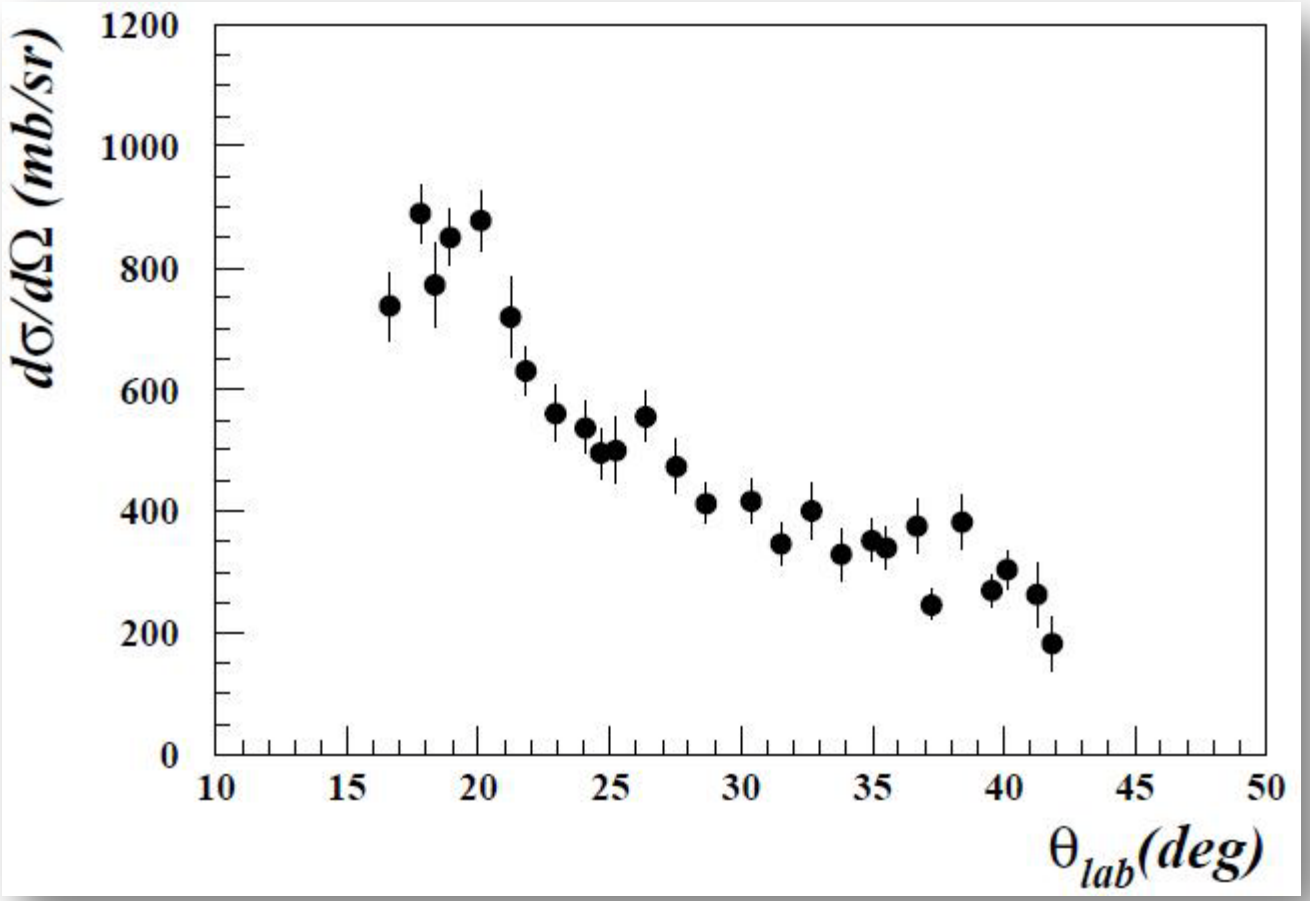
---^{6}He+A



Which processes are contributing to the large reaction cross-section in the ^{11}Be case?



$^{11}Be+^{64}Zn$ BU/Transf. contribution



$\sigma_{BU/TRANSF} \approx 1.1b$

A. Di Pietro et a. Phys. Rev. Lett. 105,022701(2010)

Conclusions

The collisions ^{9,10,11}Be + ^{64}Zn have shown:

✓Damping of elastic cross-section for the reaction induced by the ^{11}Be nucleus when compared with both ^{9}Be (S_n=1.67 MeV) and ^{10}Be (S_n=6.8MeV).

✓Surface type DPP with large diffuseness needed to fit the ^{11}Be data.

✓The total reaction cross-section for ^{11}Be induced reaction is much larger than for the other two Be isotopes $\sigma_{rea}(^{11}Be) > 2\ \sigma_{rea}(^{9,10}Be)$.

✓Evidence for the presence of a large yield of transfer and/or breakup events in the ^{11}Be induced collision with a corresponding cross section $\sigma_{TR\ /\ BU} \sim 1$ barn.

We are involved in a campaign of measurements in Catania to investigate the effect of the low-binding energy on reaction processes at energies below the Coulomb barrier with ^{6,7}Li beams.

Outlooks

- A LoI was submitted to the INTC committee at Isolde to develop a post-accelerated ^{8}B beam to extend these type of studies to p-halo nuclei.

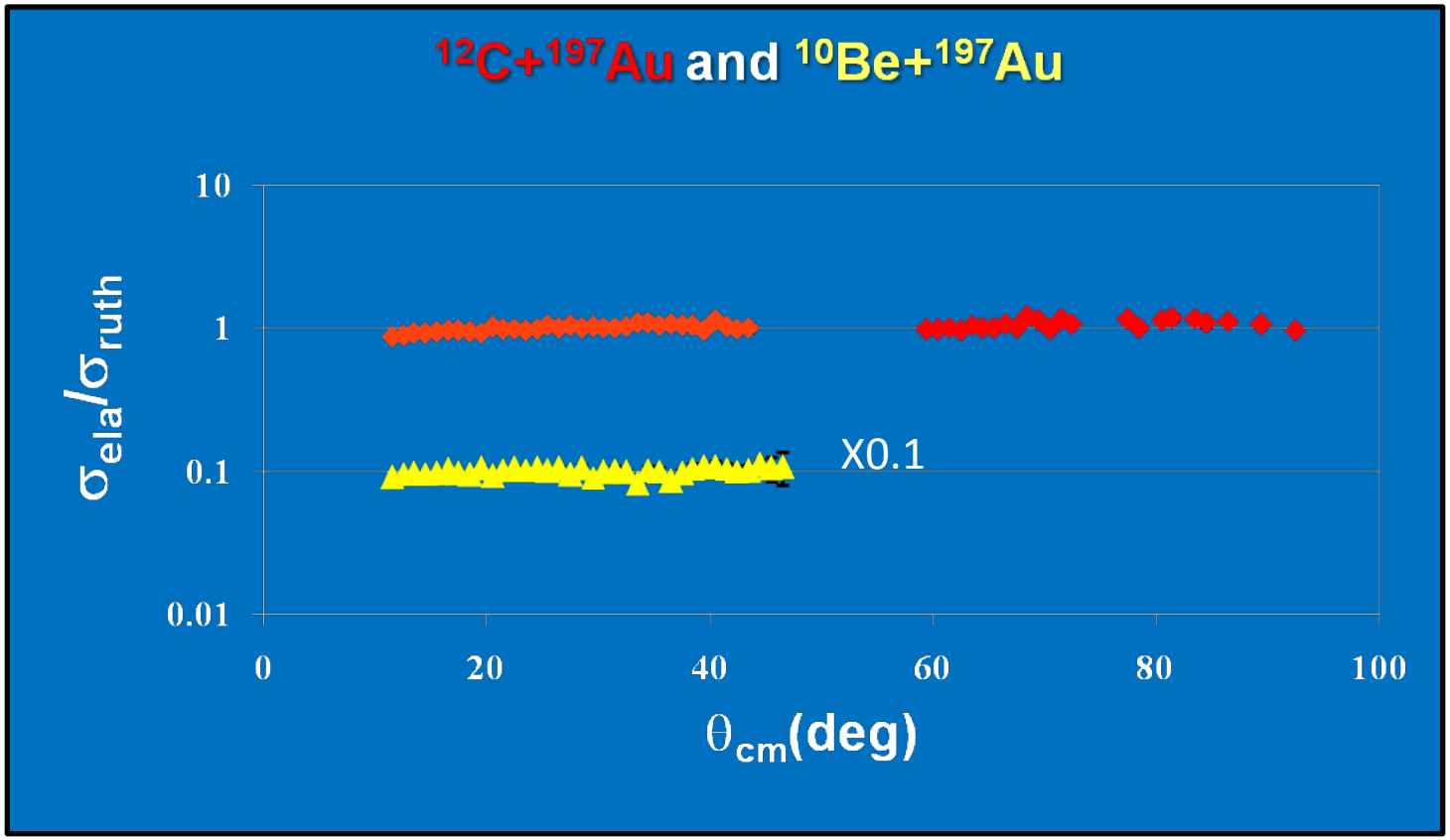
- A collaboration TRIUMF-LNS has been initiated to study the effect of coupling with n-transfer channel with positive Q-value in sub-barrier fusion.
Reactions to be studied ^{6,7,8,9}Li+^{120,119,118,117}Sn.

Collaboration

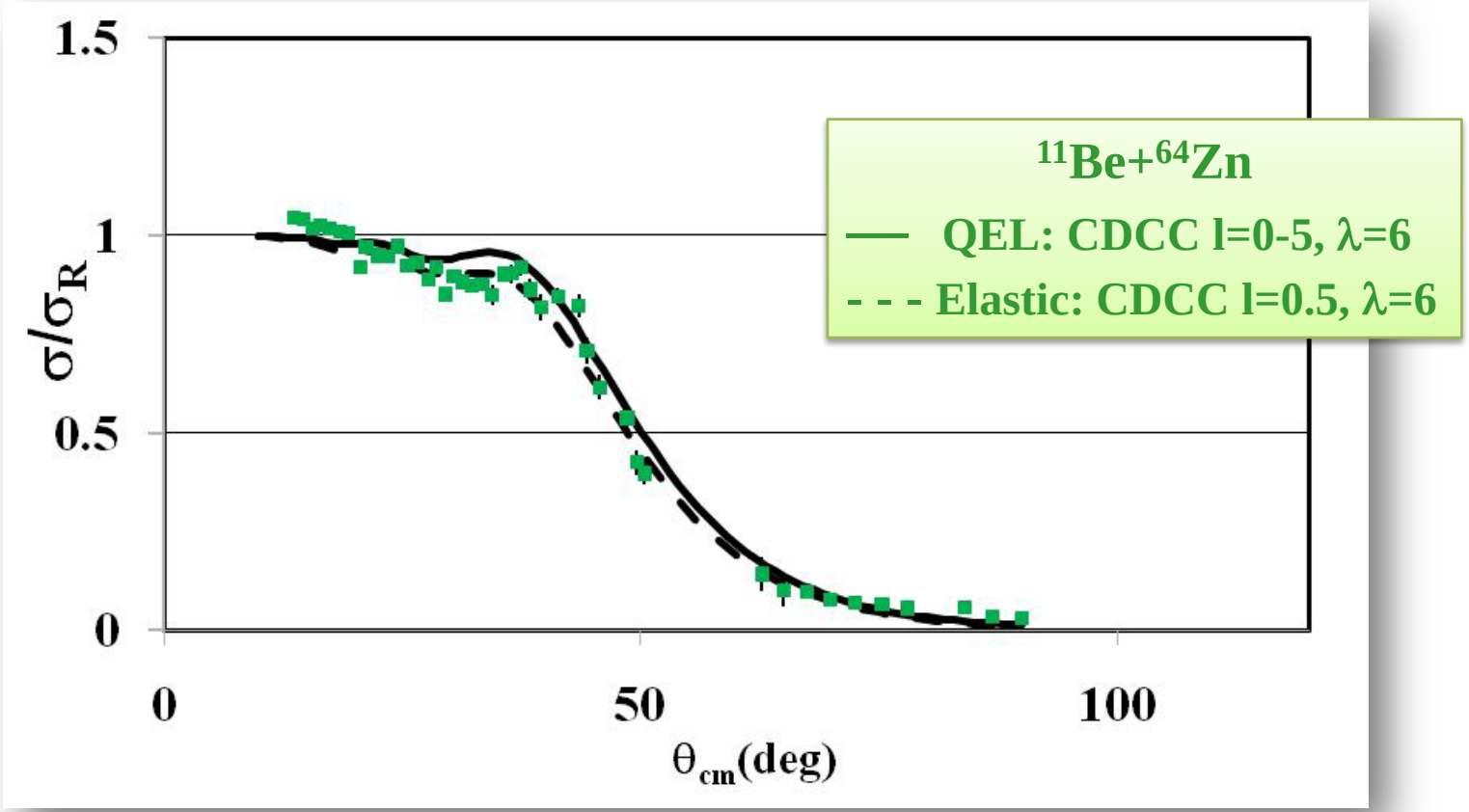
L. Acosta, F. Amorini, M.J.G. Borge, A.D., P. Figuera, L.M. Fraile, J.Gomez-Camacho, H. Jeppesen, M. Lattuada, I. Martel, M. Milin, A.M. Moro, A. Musumarra, M.Papa, M.G.Pellegriti, F. Perez Bernal, R.Raabe, G.Randisi, F. Rizzo, D. Santonocito, G.Scalia, V. Scuderi, O. Tengblad, D.Torresi, A. Maira Vidal, D.Voulot, F. Wenander, M.Zadro

- **INFN-Laboratori Nazionali del Sud and Sezione di Catania, Italy**
- **Dipartimento di Fisica ed Astronomia, Universita' di Catania, Italy**
- **Dipartimento di Metodologie Fisiche e Chimiche per l'Ingegneria, Universita' di Catania, Italy**
- **Departamento de Física Aplicada, Universidad de Huelva, Huelva, Spain**
- **Instituto de Estructura de la Materia, CSIC, Madrid, Spain**
- **CERN, Geneva, Switzerland**
- **Departamento de Física Atomica, Moleculary Nuclear, Universidad de Sevilla, Spain**
- **Ruđer Boskovic Institute, Zagreb, Croatia**
- **Instituut voor Kern-en Stralingsfysica, University of Leuven, Leuven, Belgium**

Rutherford scattering to verify the detector geometry



CDCC calculations



courtesy of A.M.Moro