Hellenic Institute of Nuclear Physics

The 4th Workshop on New Aspects and Perspectives in Nuclear Physics

Study of ^{7}Be+^{28}Si at near barrier energies: Elastic scattering and alpha production

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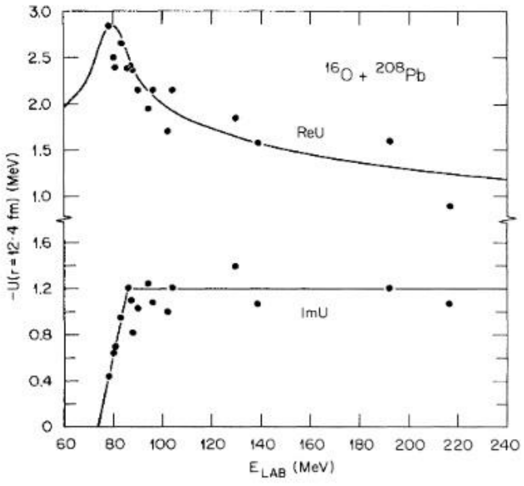
5-6 of May, 2017, Ioannina, Greece

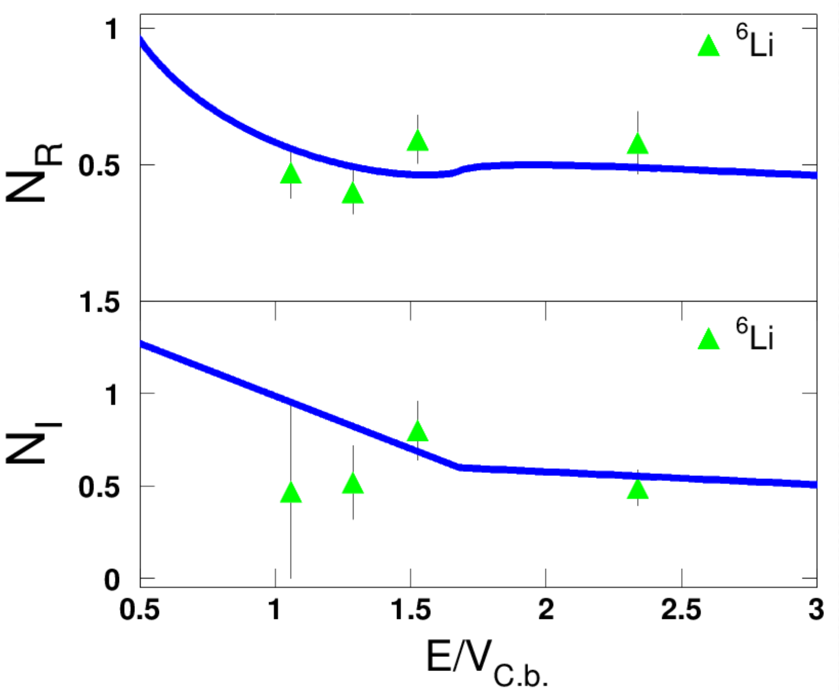
Motivation/Introduction

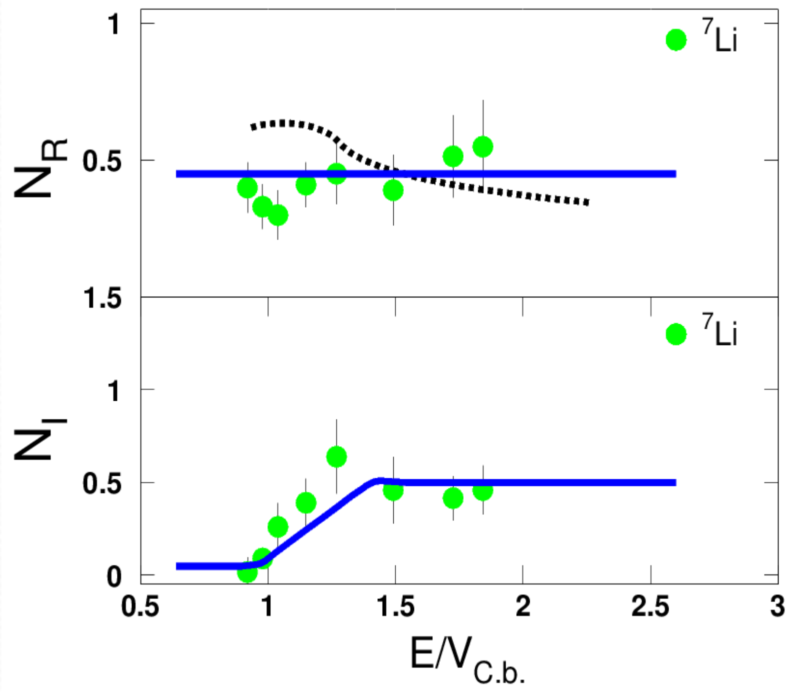
- Elastic scattering is the main tool for probing the optical potential.
- Optical potential: Almost energy independent behavior at energies well above the Coulomb barrier.
- Approaching the vicinity of the Coulomb barrier, the situation is very different.
- Well bound nuclei: Threshold Anomaly (TA).
- The energy dependence of the optical potential deviates from the conventional TA in case of the weakly bound nuclei.

M. A. Nagaragan et al.
PRL 54, 1136 (1985)



Motivation/Introduction



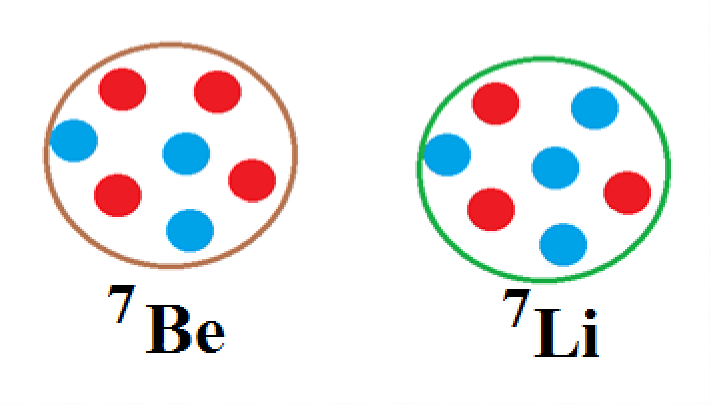


A. Pakou et al., PRC 69, 054602 (2004)

K. Zerva et al., PRC 82, 044607 (2010)

Motivation/Introduction

^{7}Be:The mirror weakly bound radioactive nucleus of ^{7}Li.



Nucleus	Breakup Threshold (MeV)
^{7}Be	1.59
^{6}Li	1.48
^{7}Li	2.45

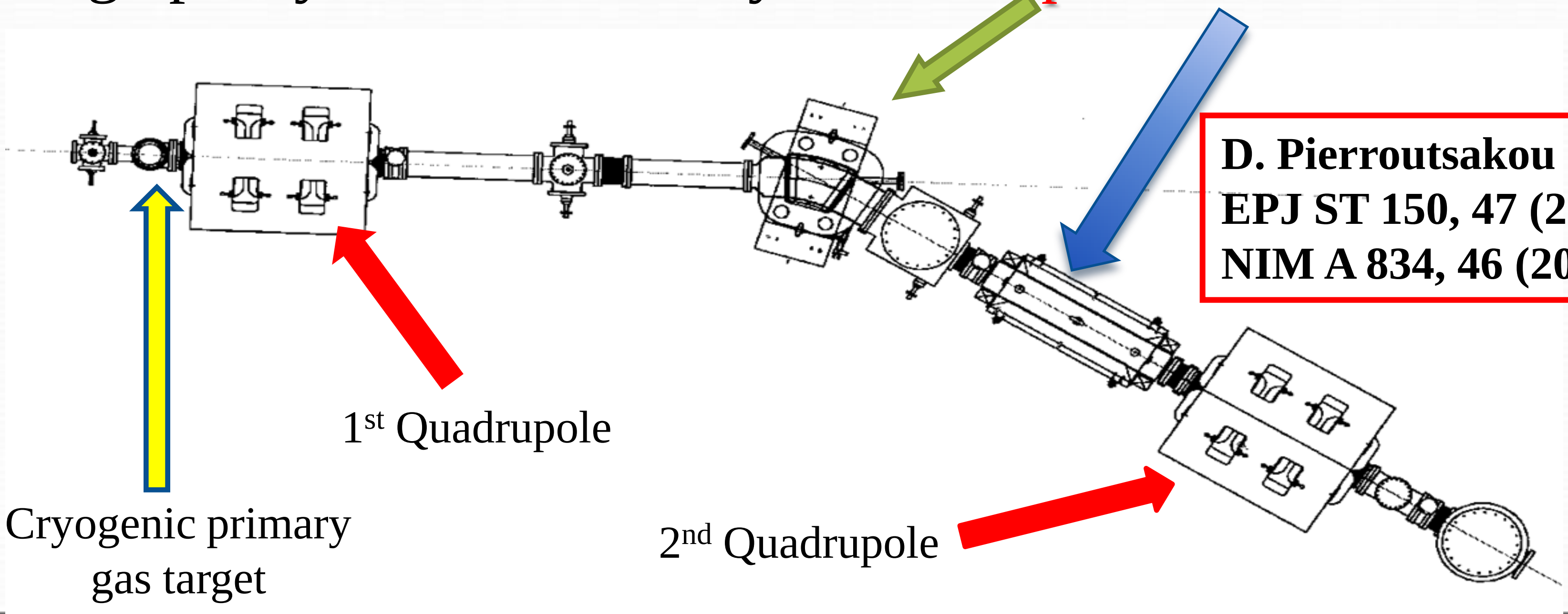
Question: The ^{7}Be nucleus resembles more the ^{7}Li or ^{6}Li?

The Experiment

- This experiment includes the study of **elastic scattering** and the **involved reaction channels** for the system **$^{7}Be+^{28}Si$** at near barrier energies, namely 13.2, 17.2, 19.8 and 22.0 MeV corresponding to (1.14-1.90)$V_{C.b.}$ in order to study the energy dependence of the optical potential as well as the interplay between direct and compound nucleus mechanisms.

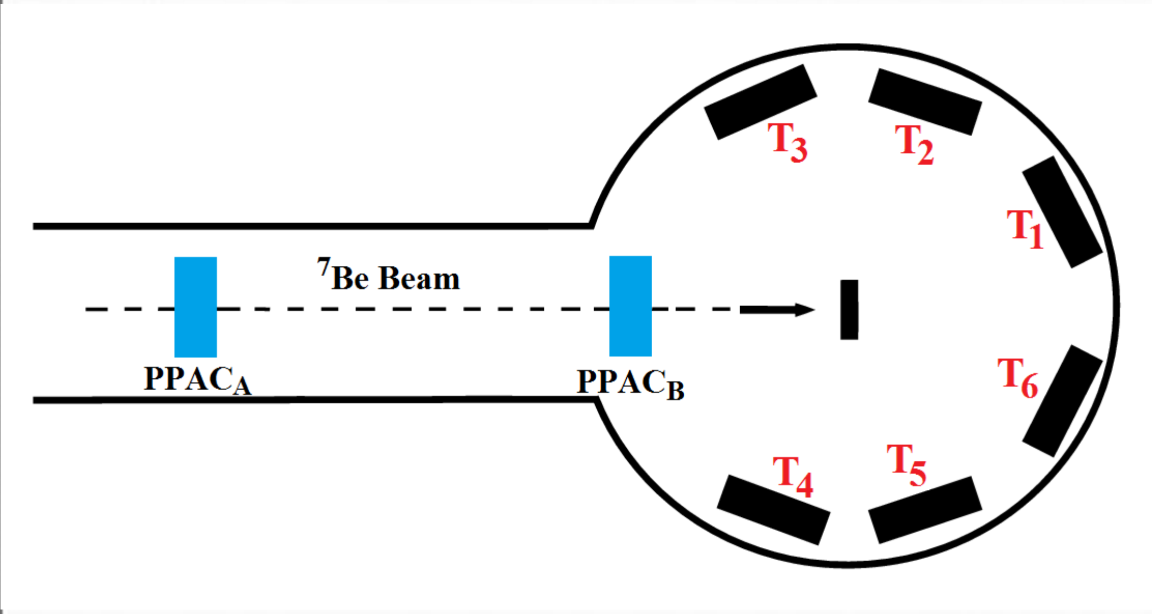
The EXOTIC Facility

- The experiment was visualized at the EXOTIC facility at the Laboratori Nationali di Legnaro (LNL).
- ^{7}Be production: In flight technique via the p(^{7}Li,^{7}Be)n reaction ($Q_{val.}$=-1.64 MeV).
- High purity of the secondary beam: Dipole +Wien Filter.



D. Pierroutsakou et al., EPJ ST 150, 47 (2007)
NIM A 834, 46 (2016)

Experimental Setup



Telescope ID	Angular Range (Degrees)
T_1	13.0 – 41.0
T_2	53.5 – 84.5
T_3	94.8 – 127.2
T_4	96.1 – 126.0
T_5	53.5 – 84.5
T_6	14.2 – 39.8

D. Pierroutsakou et. al., NIM A 834, 46 (2016)

EXPADES Telescopes

ΔE: DSSSD ~55μm

+

E: DSSSD 300 μm

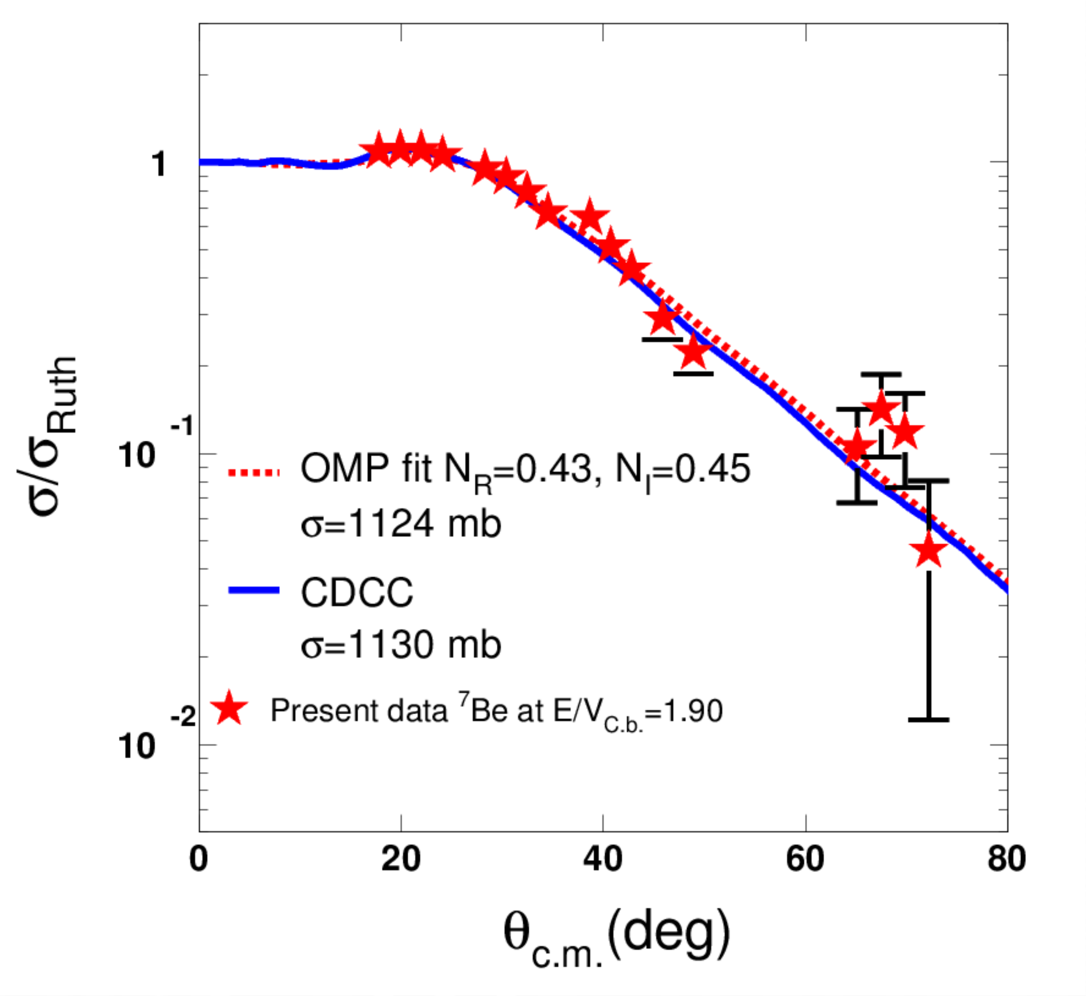
Determination of the elastic scattering differential cross sections

- The analysis of the elastic scattering data was performed by means of an event by event code using the data analysis package ROOT. For that, the information provided by the two $PPAC_S$ and the DSSSD detectors was used, in order to determine in a more accurate way the scattering angle for each event.
- Events with the same angle or with an angle inside the angular range corresponding to a particular strip of each EXPADES detector ($\Delta\theta \sim 2^0$) are summed up.
- The procedure is performed for both the elastic scattering of ^{7}Be on ^{28}Si and ^{208}Pb targets.
- The elastic scattering differential cross sections are obtained through the following expression:

$$\boxed{\frac{\sigma}{\sigma_{Ruth}^{Si}} = \frac{N_{Si}}{N_{Pb}} K}$$

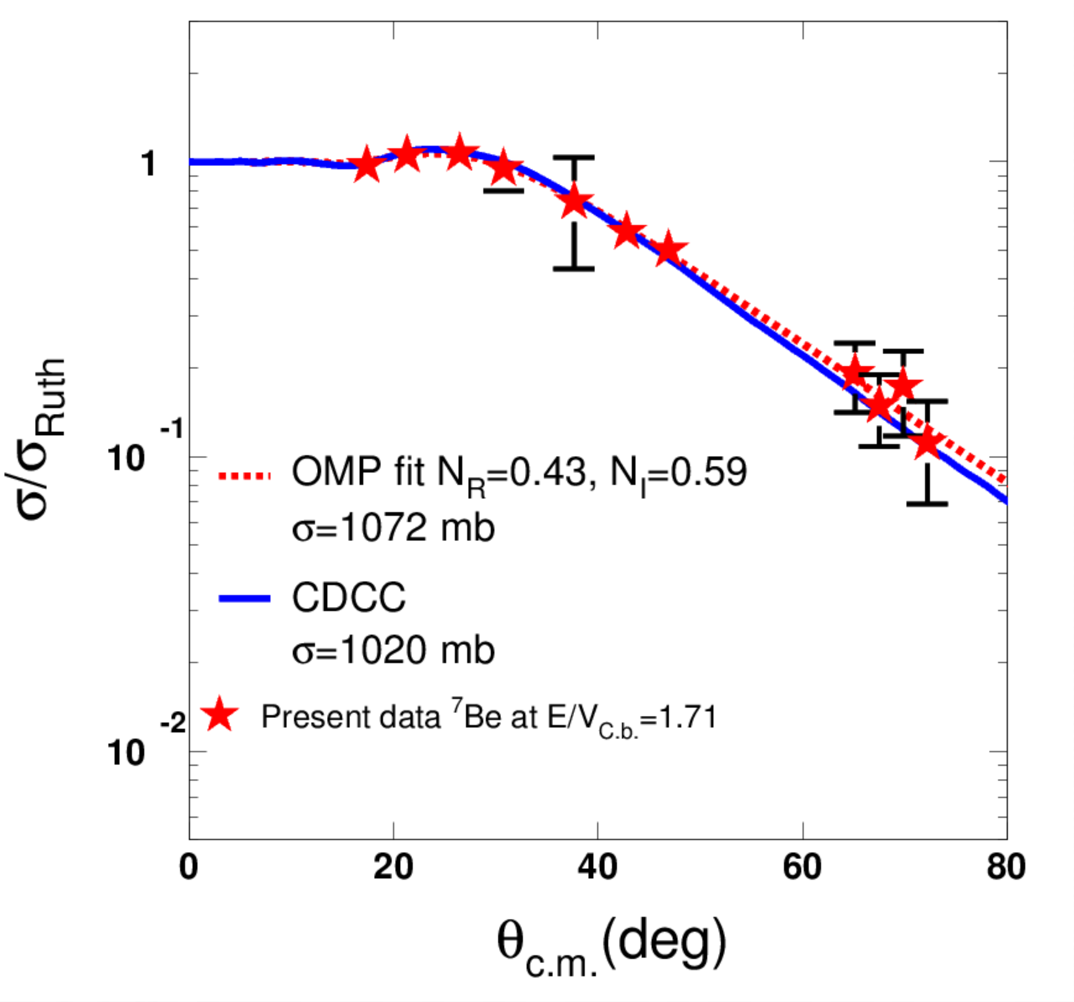
where N_{si} and N_{Pb} are the event by event counts collected with the silicon and lead targets respectively and the constant K is determined assuming that at small scattering angles the ratio between elastic scattering cross sections and Rutherford cross sections is ~1.0.

Elastic scattering data at 22.0 MeV



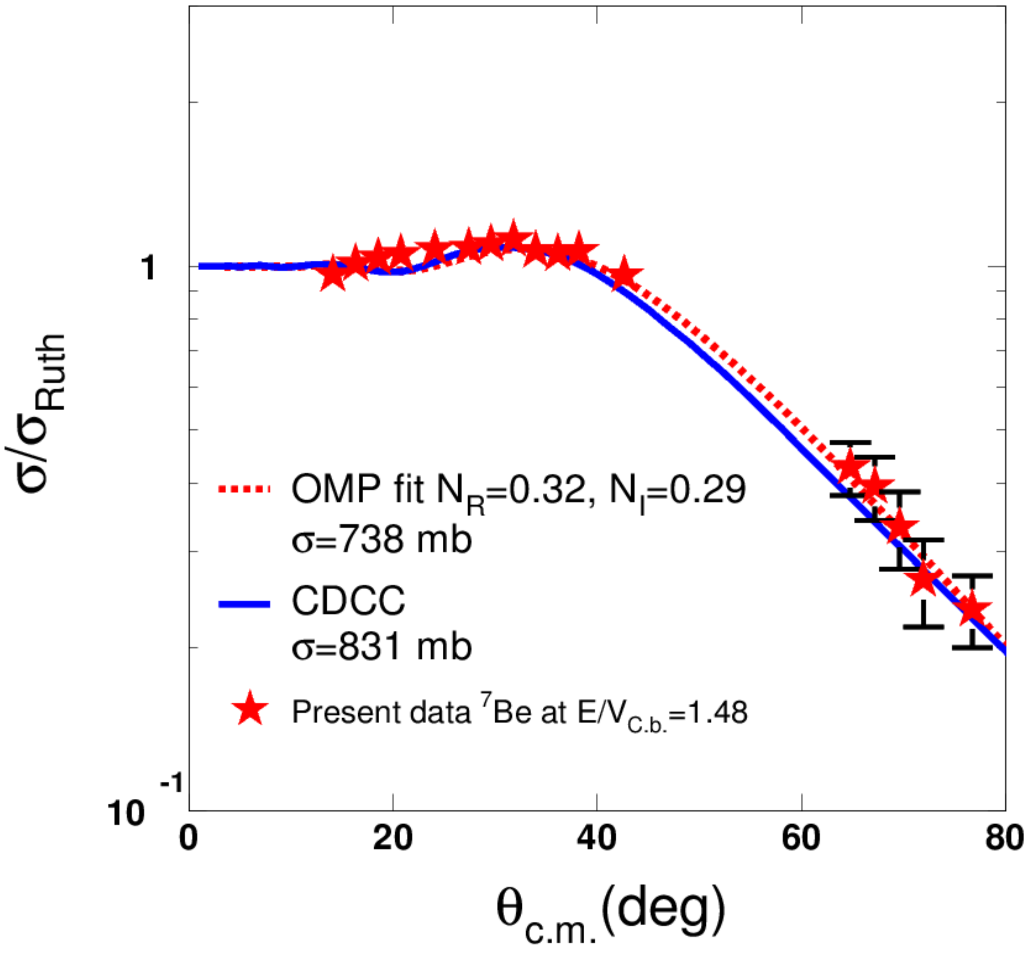
O. Sgouros et al., Accepted for publication in PRC

Elastic scattering data at 19.8 MeV



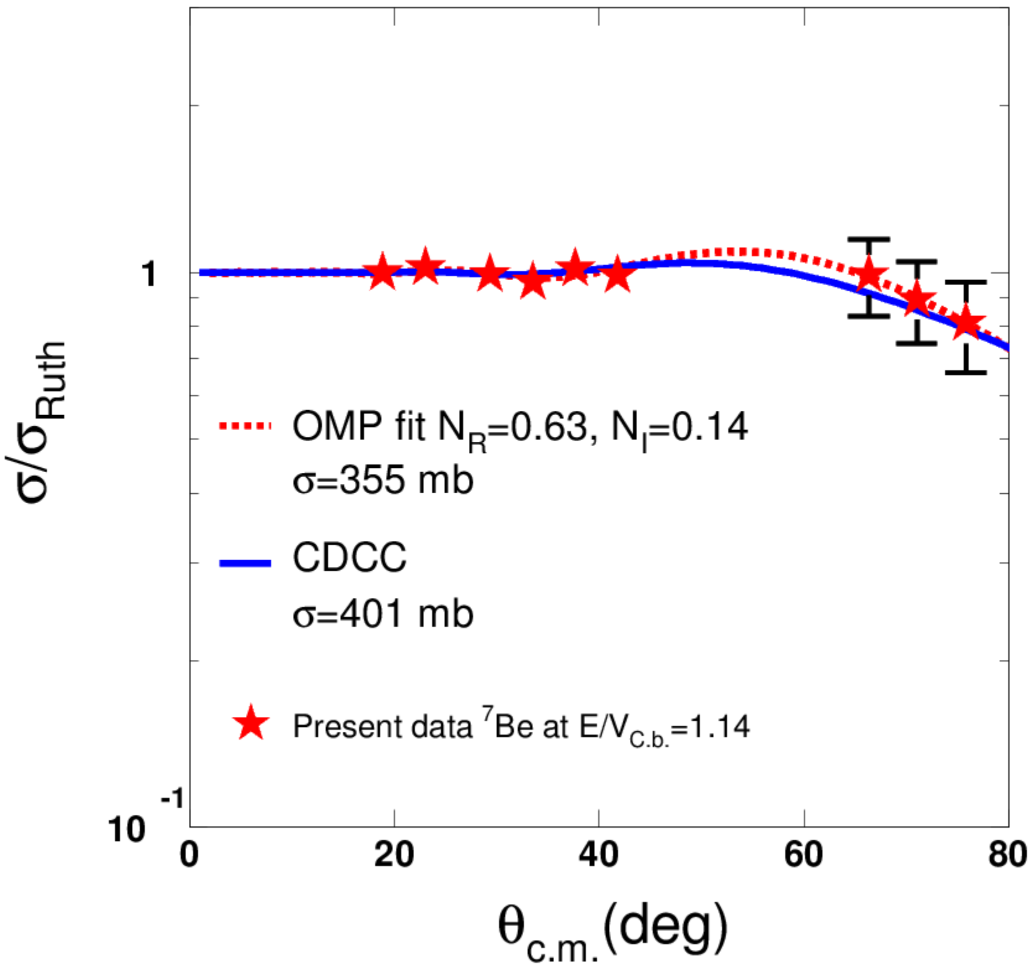
O. Sgouros et al., Accepted for publication in PRC

Elastic scattering data at 17.2 MeV



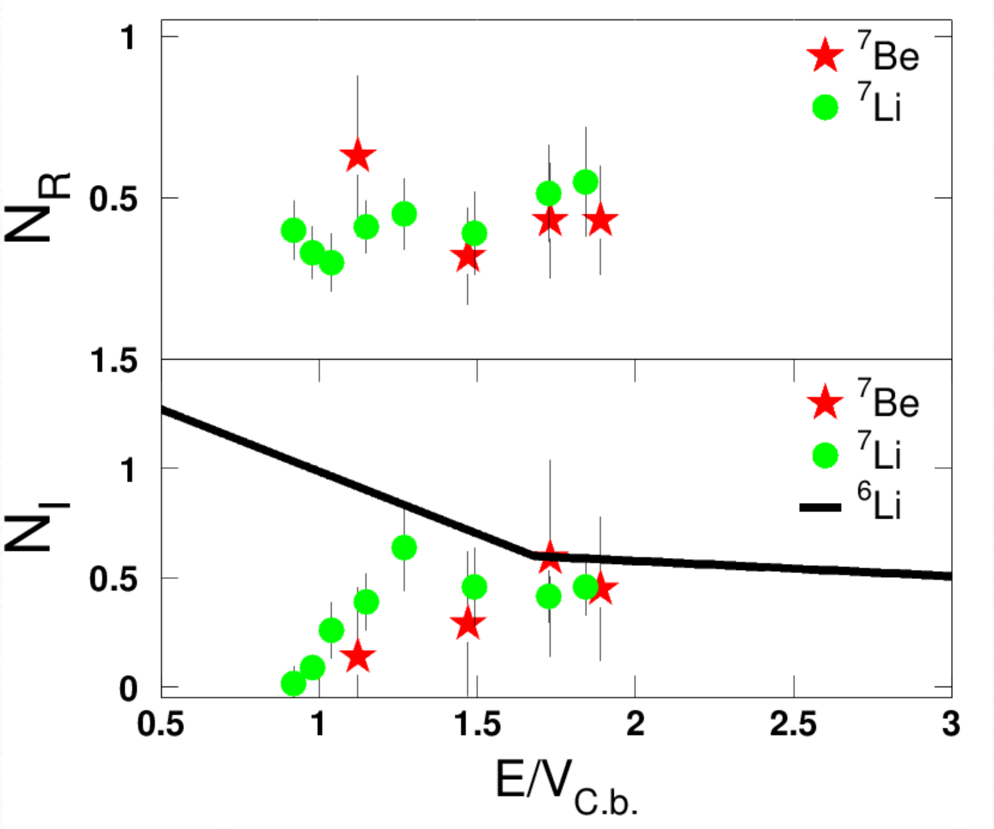
O. Sgouros et al., Accepted for publication in PRC

Elastic scattering data at 13.2 MeV



O. Sgouros et al., Accepted for publication in PRC

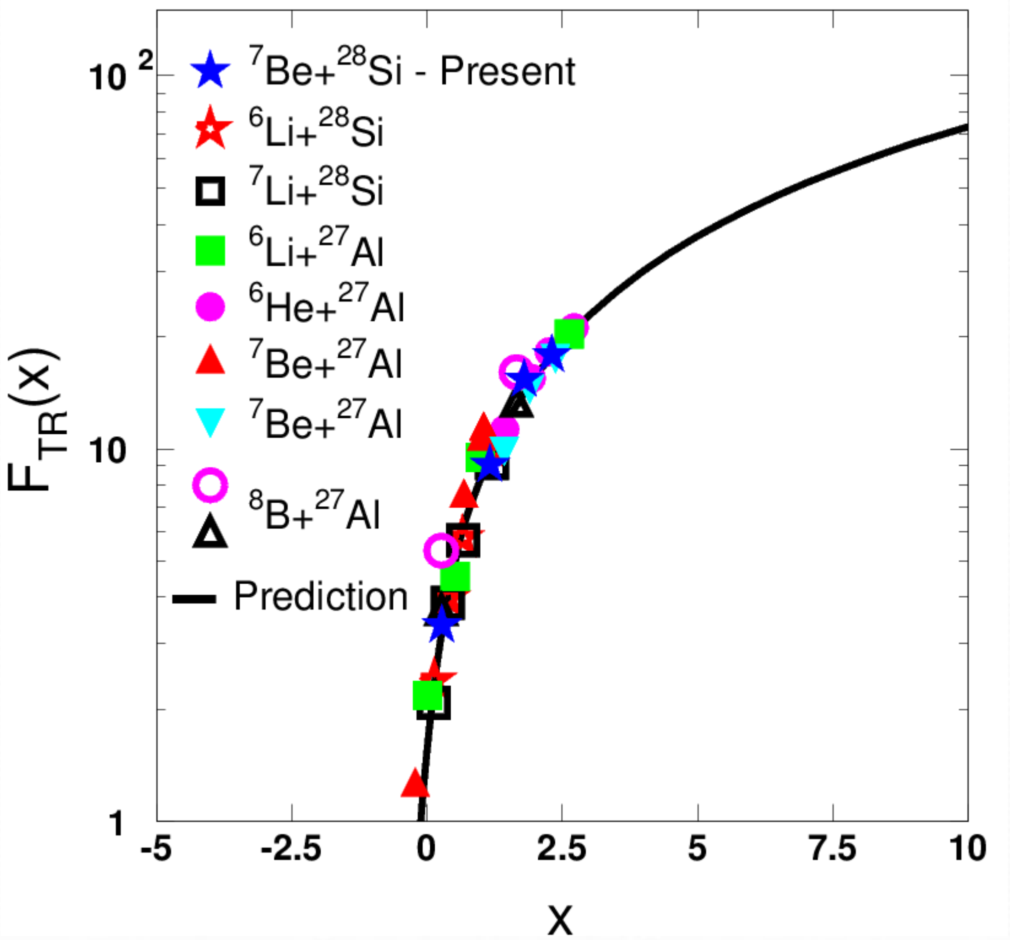
Energy evolution of the optical model parameters



A. Pakou et al.,
PRC 69, 054602 (2004)

O. Sgouros et al.,
Accepted for publication in PRC

Total reaction cross sections



A. Pakou et al., EPJA 51, 55 (2015)

$$\boxed{\sigma_{TR} \rightarrow F_{TR}(x) = \frac{2E_{c.m}}{\hbar\omega R_B^2}\sigma_{TR}}$$

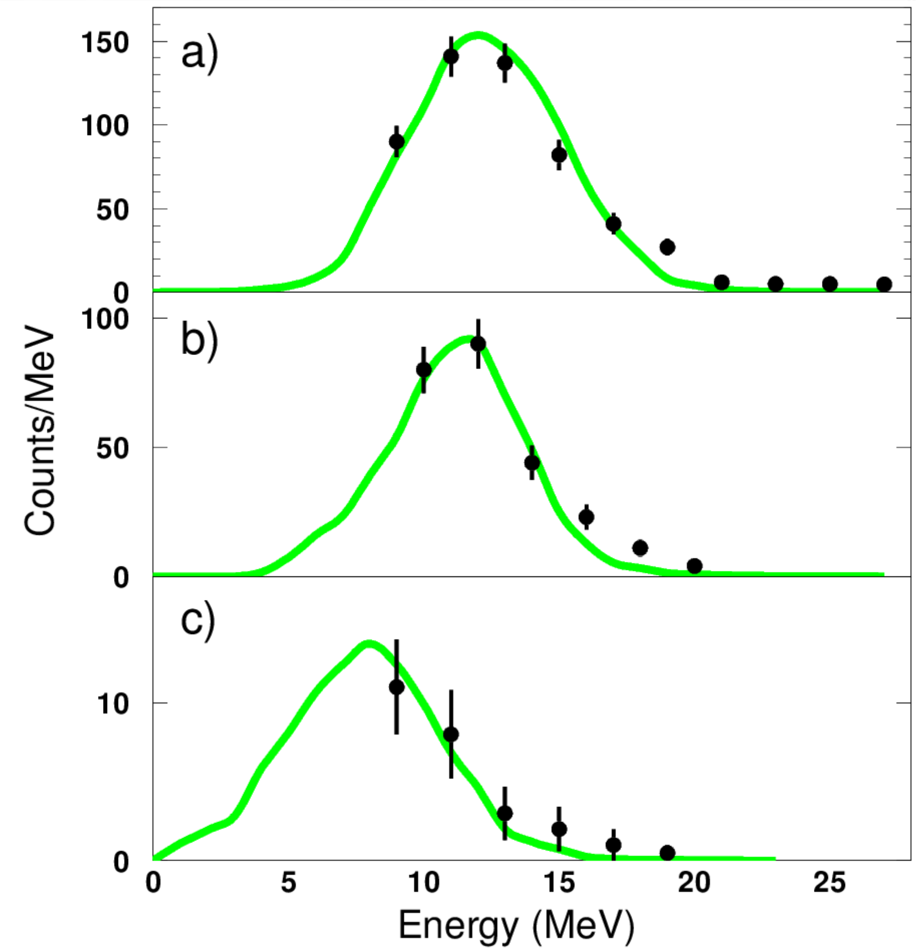
$$\boxed{E_{c.m} \rightarrow x = \frac{E_{c.m} - V_B}{\hbar\omega}}$$

Determination of the reaction differential cross sections

- The ^{3}He and ^{4}He reaction products were well separated via the ΔE-E technique.
- Particles with low energy stop in the first stage of the telescope.

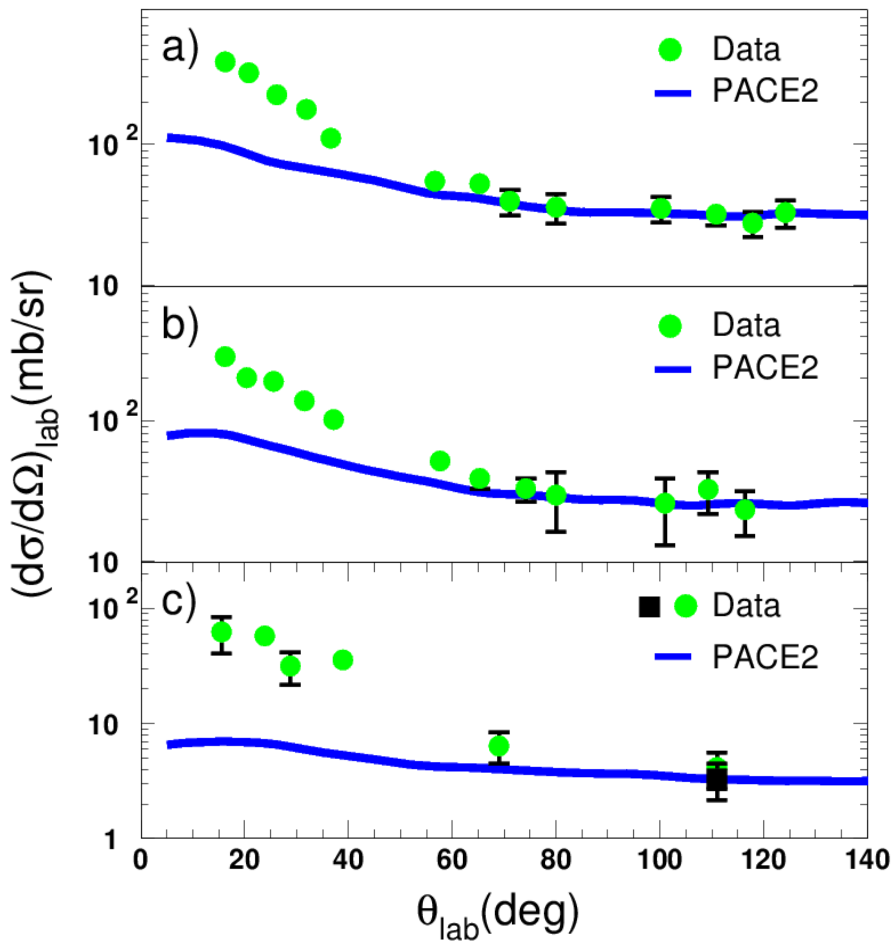
- Such events were retrieved by comparing the experimental energy spectra with the simulated ones.

$$\frac{d\sigma}{d\Omega} = \frac{N}{N_{Pb}} K'$$



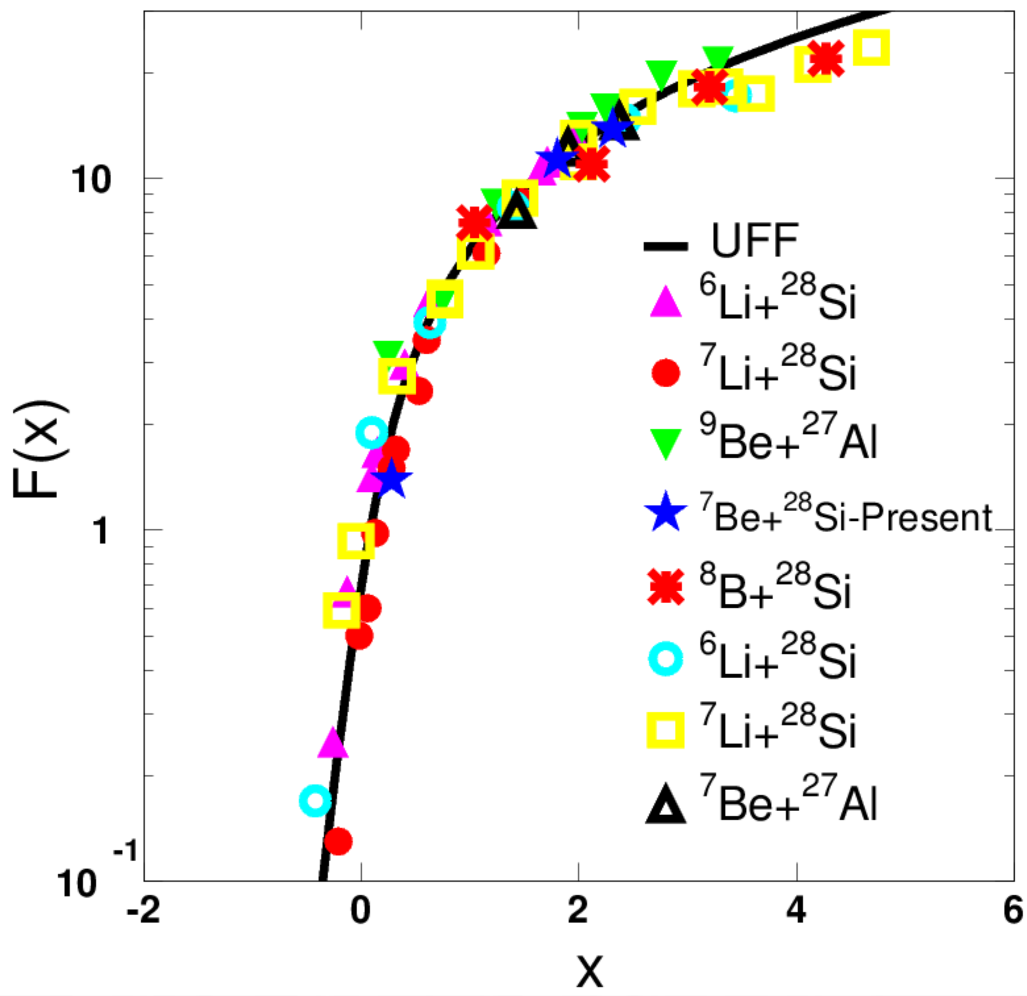
^{4}He angular distribution data

A. Pakou et al.
PRC 71, 064602 (2005)



O. Sgouros et al.,
PRC 94, 044623 (2016)

Fusion cross sections for the system $^{7}Be+^{28}Si$

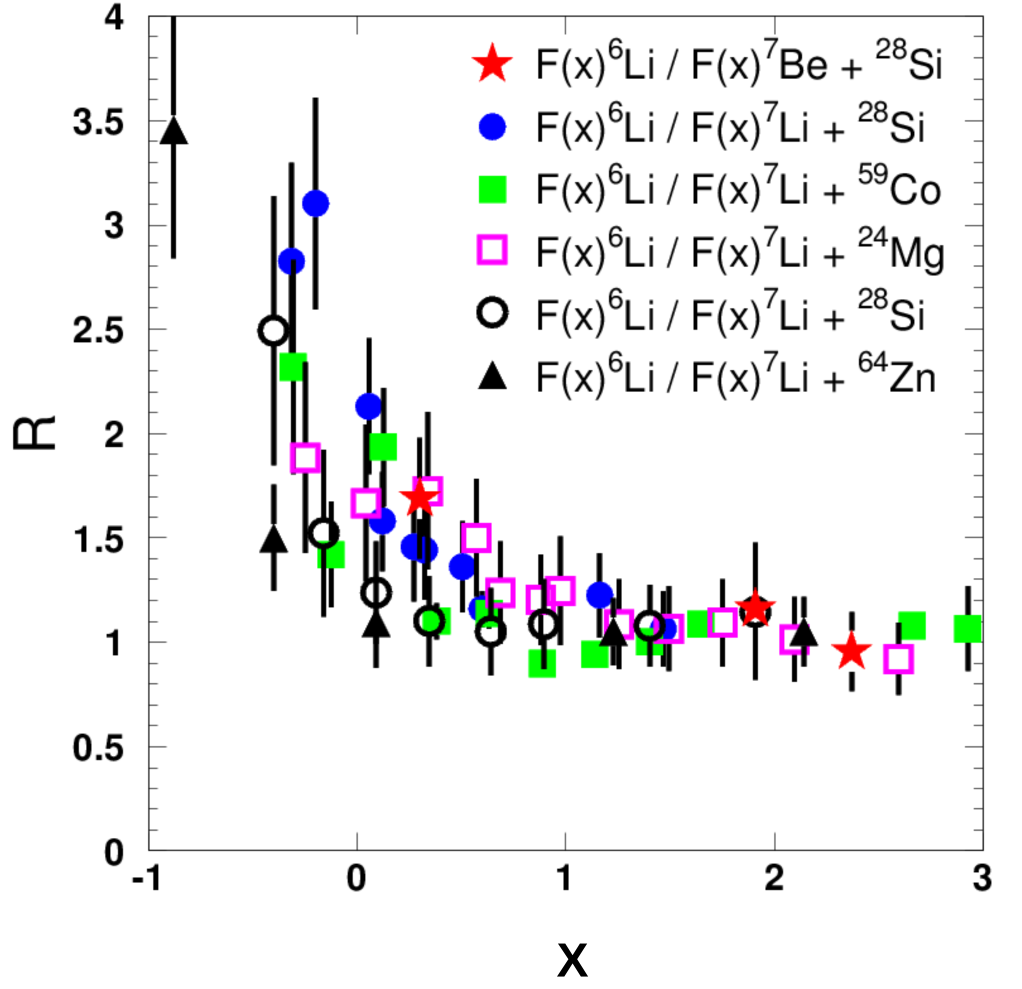


L.F. Canto et al., NPA 821, 51 (2009)

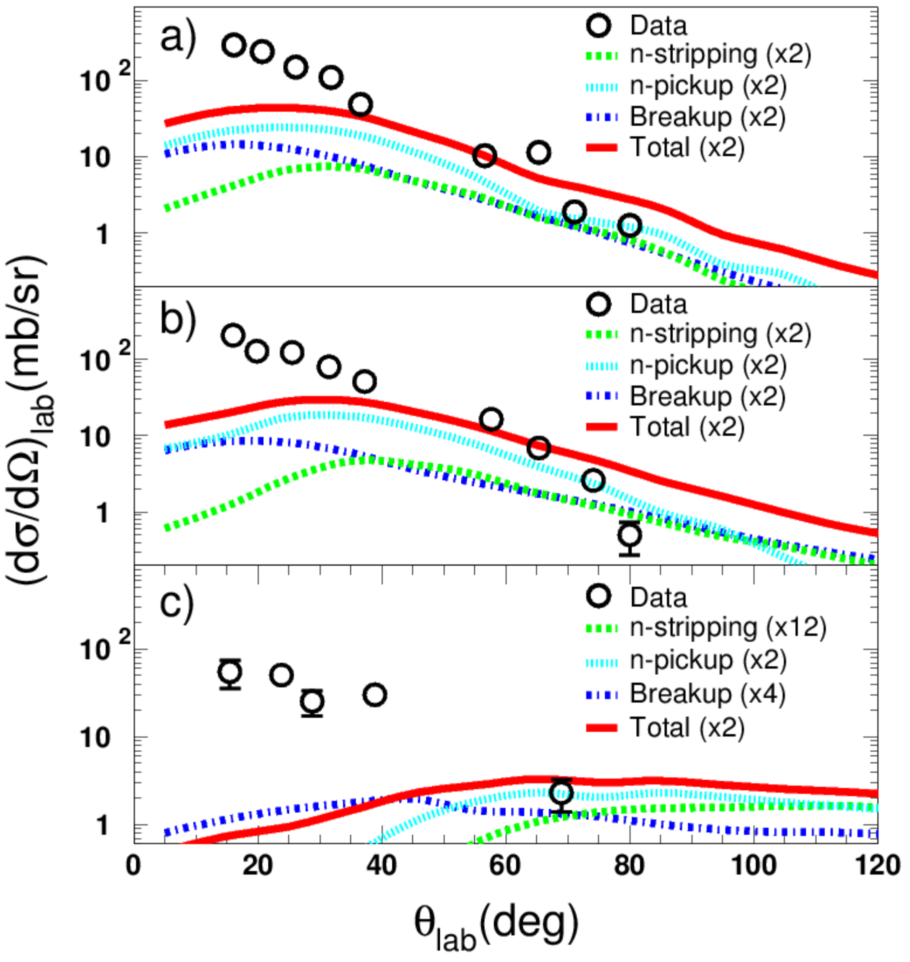
$$\sigma_F \rightarrow F(x) = \frac{2E_{c.m}}{\hbar\omega R_B^2}\sigma_F$$

$$E_{c.m} \rightarrow x = \frac{E_{c.m} - V_B}{\hbar\omega}$$

Ratio $F(x)^6Li/F(x)^7Li, F(x)^7Be$

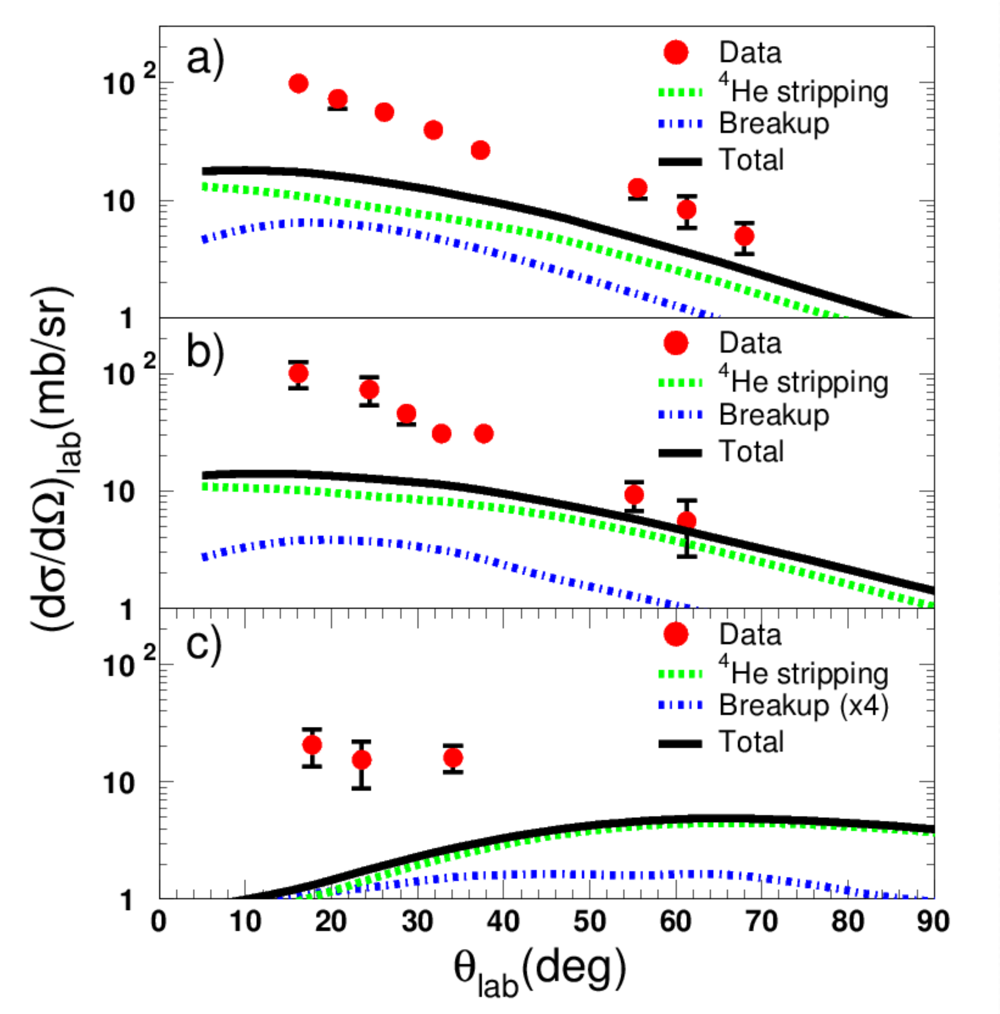


^{4}He production from direct processes



O. Sgouros et al., PRC 94, 044623 (2016)

^{3}He production from direct processes



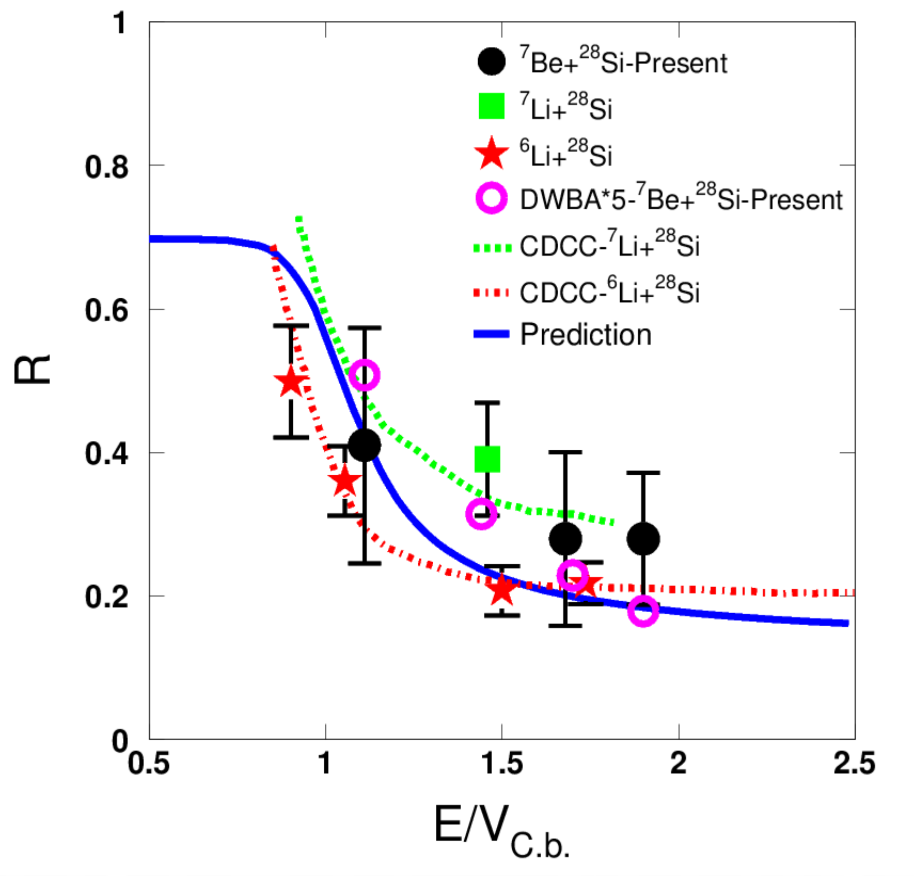
O. Sgouros et al.,
PRC 94, 044623 (2016)

The ratio R= $\frac{\text{Direct reaction cross section}}{\text{Total reaction cross section}}$

A. Pakou et al.
EPJA 51, 55 (2015)

A. Pakou et al.
PRC 69, 054602 (2004)

A. Pakou et al.
EPJA 39, 187 (2009)



O. Sgouros et al.,
PRC 94, 044623 (2016)

Summary and Conclusions

- A global investigation for the system $^{7}Be+^{28}Si$ was performed at near barrier energies namely 13.2, 17.2, 19.8 and 22.0 MeV (1.14-1.90)$V_{C.b.}$.
- The experiment was performed at the EXOTIC facility at LNL.
- Angular distribution measurements for the elastically scattered ^{7}Be ions as well as the light ^{3}He and ^{4}He particles were performed using the detector array EXPADES.
- The elastic scattering data were analyzed in a double-folding framework using the BDM3Y1 interaction and the energy evolution of the optical potential was deduced.
- The large assigned errors in the potential parameters prevent definite conclusions to be drawn solely from elastic scattering data. However, in combination with the fusion data they show a similarity between ^{7}Li and ^{7}Be.
- The trend of the energy evolution of the imaginary part of the optical potential is compatible with the standard threshold anomaly but with a real part which does not obey the dispersion relations.

Summary and Conclusions

- The ^{4}He data were treated in a statistical model framework and the contribution of the direct and the compound nucleus channels to the total alpha production was estimated.
- Taking into account ^{4}He production due to compound processes and alpha particles multiplicities in the compound framework, fusion cross sections were deduced and were found in excellent agreement with the systematic.
- Ratios of fusion functions of ^{6}Li to those for ^{7}Li and ^{7}Be were formed, indicating a hindrance of fusion for ^{7}Li and ^{7}Be with respect to those of ^{6}Li below the barrier.
- Large ^{3}He and ^{4}He yields due to direct processes are inferred and they were attributed to ^{4}He and ^{3}He transfer reactions respectively.
- The ratio R (direct to total) was calculated for the system ^{7}Be+^{28}Si. Data are consistent with previous measurements for ^{6}Li and ^{7}Li on ^{28}Si, exhibiting an increasing behavior of the ratio while approaching the barrier. However, present data follow in magnitude those for ^{7}Li, indicating larger contribution of direct processes for the two mirror nuclei.

Collaborators

- *Physics Department and HINP, The University of Ioannina, Ioannina, Greece*
- *INFN – Sezione di Napoli, Napoli, Italy*
- *Dipartimento di Fisica e Astronomia and INFN – Sezione di Padova, Padova, Italy*
- *Dipartimento di Scienze Fisiche, Universita di Napoli, Napoli, Italy*
- *INFN – Sezione di Milano, Milano, Italy*
- *National Centre for Nuclear Research, Otwock, Poland*
- *Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland*
- *Institute of Accelerating Systems and Applications and Department of Physics, University of Athens, Greece*
- *Departamento de Ciencias Integradas, Universidad de Huelva, Huelva, Spain*
- *Centro de Fisica Nuclear da Universidade de Lisboa, Lisbon, Portugal*
- *Instituto de Fisica, Universidad Nacional Autonoma de Mexico, Mexico D.F, Mexico*
- *INFN, Laboratori Nazionali del Sud, Catania, Italy*