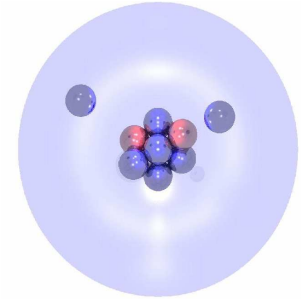
Analysis of breakup channel for the ^{11}Li+^{208}Pb reaction at energies around the Coulomb barrier.

J. P. Fernández-García

Departament of Atomic, Molecular and Nuclear Physics
University of Seville.

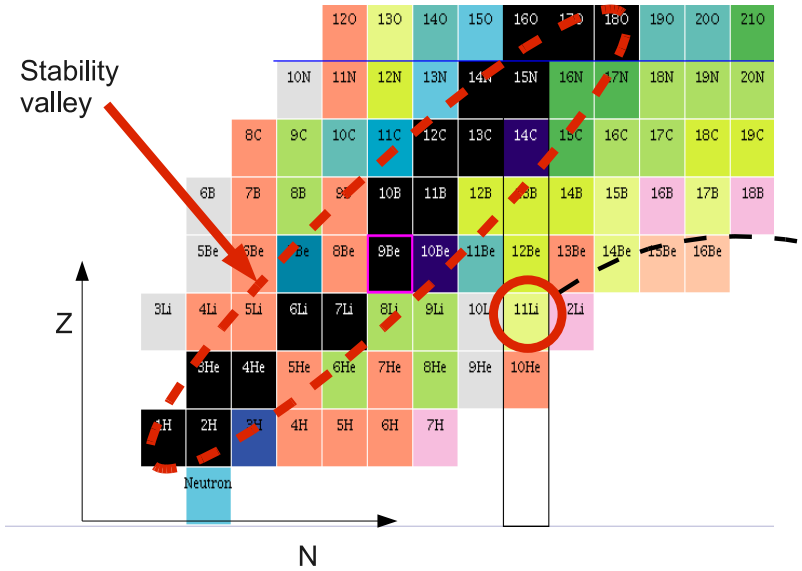


1. Introduction
   - Goals
2. ^{11}Li+^{208}Pb experiment at TRIUMF, Canada
   - Experimental setup
   - Experimental data
   - Theoretical calculations
3. Conclusions

Introduction

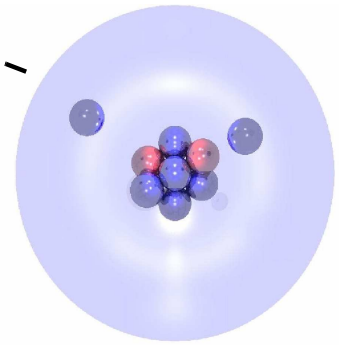
Exotic nuclei: Unstable systems rich in neutrons or protons.

- ^{11}Li system rich in neutrons, half-life $\tau_{1/2}(\beta^-)$= 8.6 ms.
- ^{11}Li halo nucleus, ^{9}Li+n+n



- Weakly bound structure.
- Large systems.

Borromean nucleus

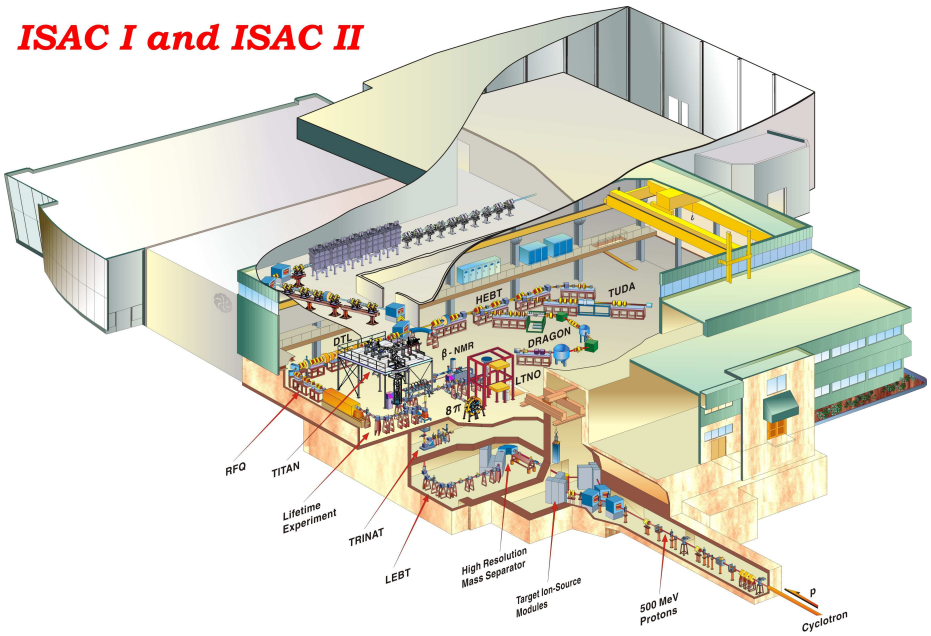


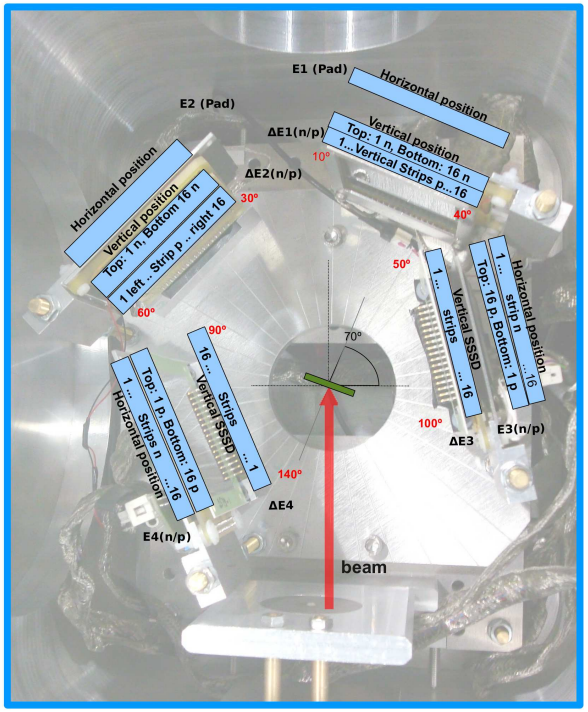
Goals

- To measure elastic and break-up process of the reaction ^{11}Li+^{208}Pb at energies around the Coulomb barrier (24.2 and 29.7 MeV.)
- To understand the dynamics of the reaction induced by weakly bound nucleus, ^{11}Li, on a heavy target.
- To obtain information about the structure of ^{11}Li.

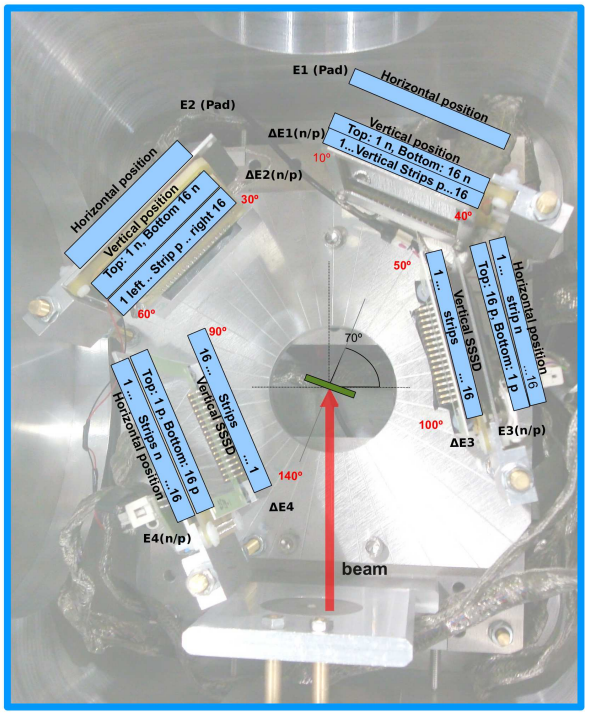
Experiment E1104

^{11}Li+^{208}Pb@24.2, 29.7 MeV - Beam rates 7000 ^{11}Li per second. Oct'08



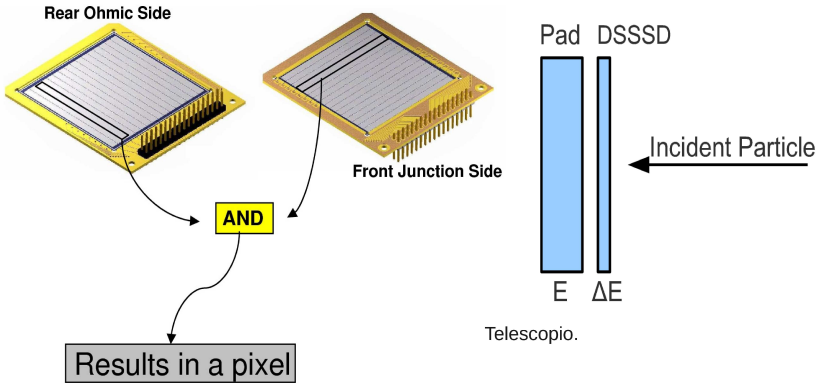


Experimental setup

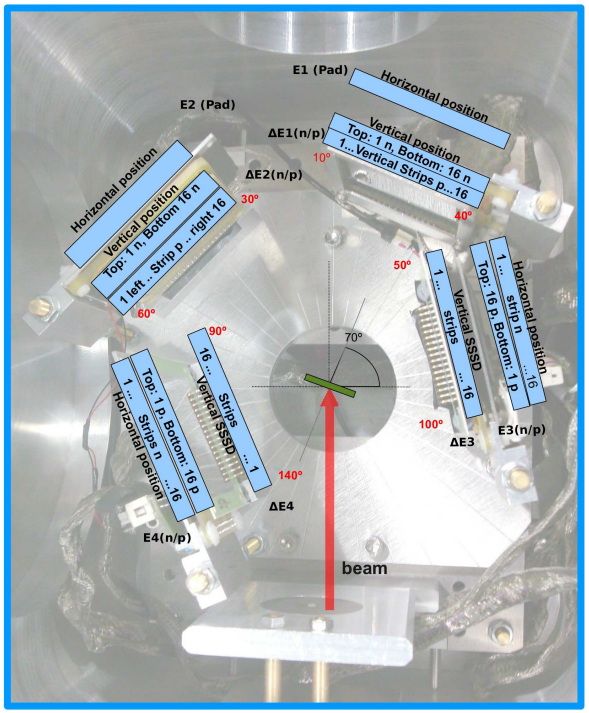


The detection system contained 4 particle telescopes. In the bi-dimensional diagrams ΔE versus E we can separate mass and charge.

- DSSSD (Double Sided Silicon Strip Detector): 16 horizontal x 16 vertical.
- SSSSD (Single Sided Silicon Strip Detector): 16 vertical.



Experimental setup



The detection system contained 4 particle telescopes. In the bi-dimensional diagrams ΔE versus E we can separate mass and charge.

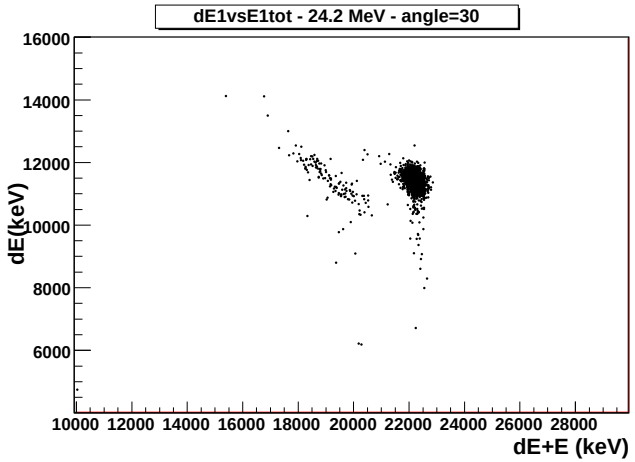
- DSSSD (Double Sided Silicon Strip Detector): 16 horizontal x 16 vertical.
- SSSSD (Single Sided Silicon Strip Detector): 16 vertical.

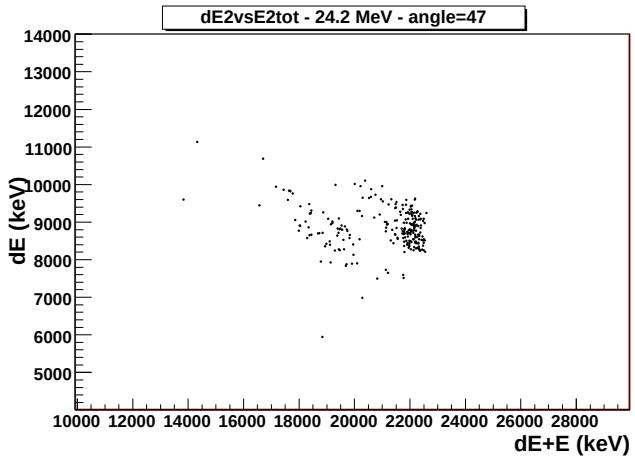
detector	thickness (ΔE+E)	angular range
DSSSD+PAD 1	40 + 500 μm	10°-40°
DSSSD+PAD 2	40 + 500 μm	30°-60°
SSSSD+DSSSD 3	20 + 60 μm	50°-100°
SSSSD+DSSSD 4	20 + 60 μm	90°-140°

Experimental data - ΔE versus E_{tot}

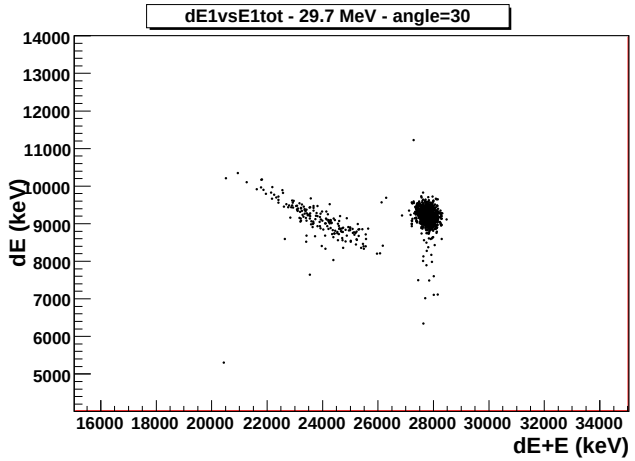
Detector 1 (30°) **Detector 2 (47°)**

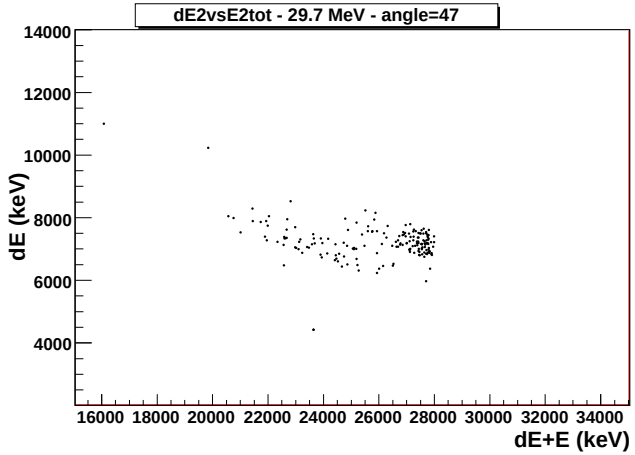
- **24.2 MeV**





- **29.7 MeV**

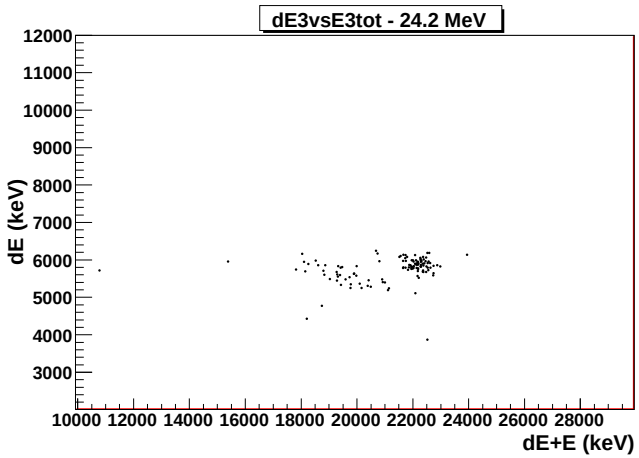


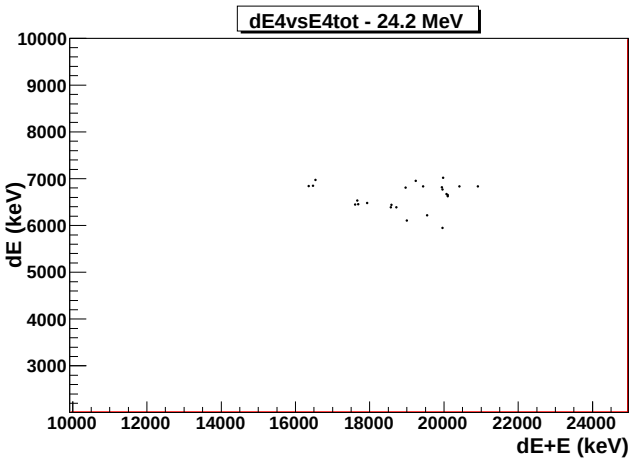


Experimental data - ΔE versus E_{tot}

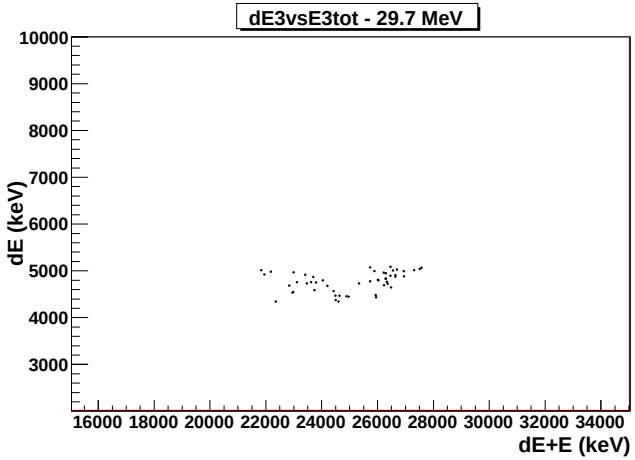
Detector 3 (58°) **Detector 4 (130°)**

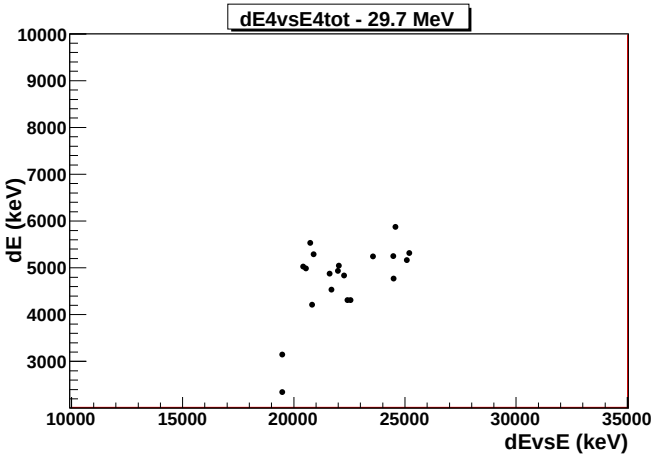
- **24.2 MeV**





- **29.7 MeV**

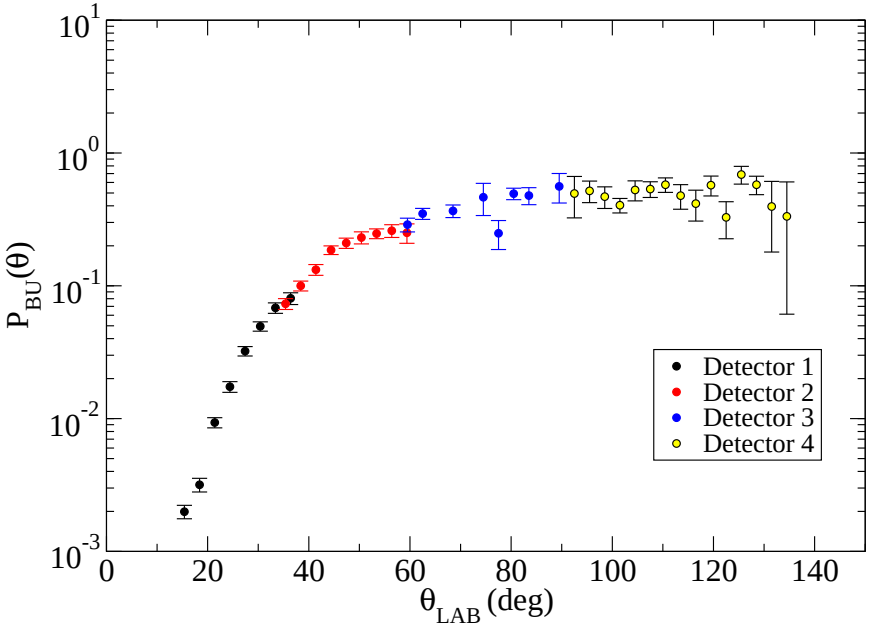




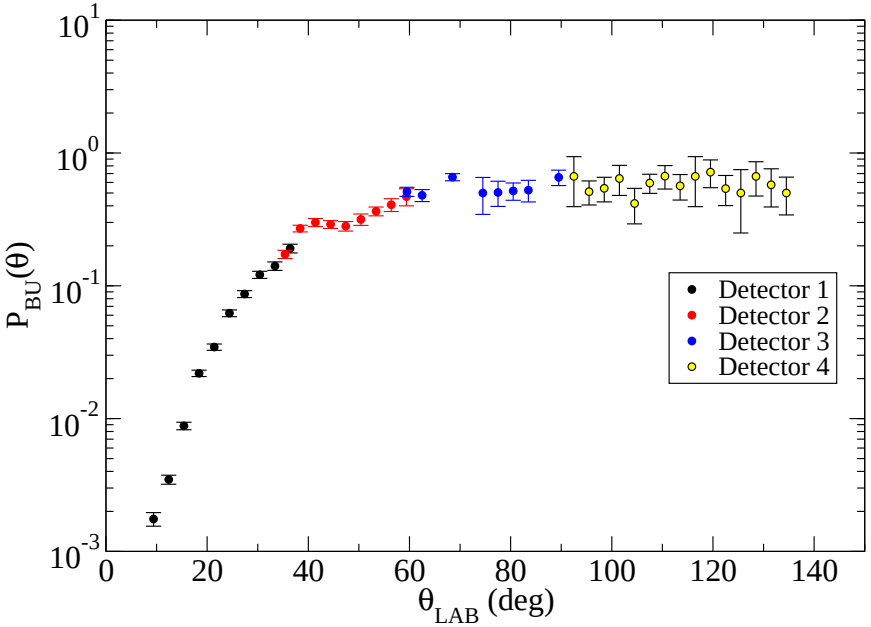
Experimental data - Breakup probability

We defined the breakup probability: $P_{bu} = \frac{N_{bu}}{N_{bu}+N_{elast}}$

24.2 MeV



29.7 MeV



High breakup probability P_{bu} >60%.

Theoretical calculations

1. What mechanism produces the breakup of the nucleus ?
2. What can we learn about the ^{11}Li structure ?

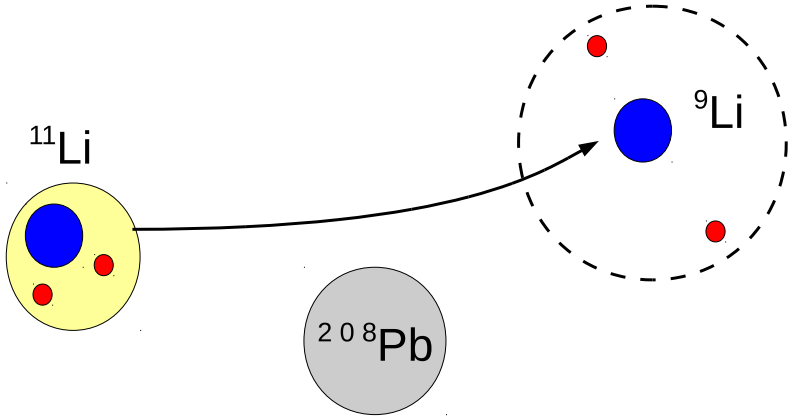
$\Downarrow \Downarrow$

We compare the experimental data with theoretical calculations.

Theoretical calculations

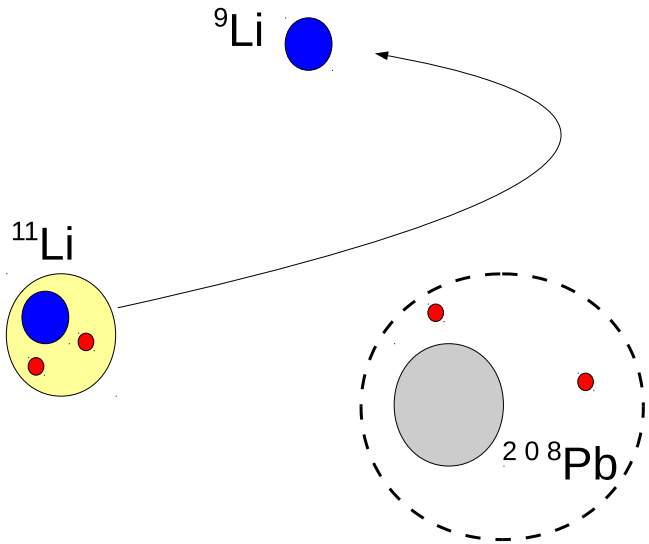
1. What mechanism produces the breakup of the nucleus ?

DIRECT BREAKUP



$$v_{9Li} \approx v_{11Li} \Rightarrow E_{9Li} \approx \frac{9}{11} E_{11Li}$$

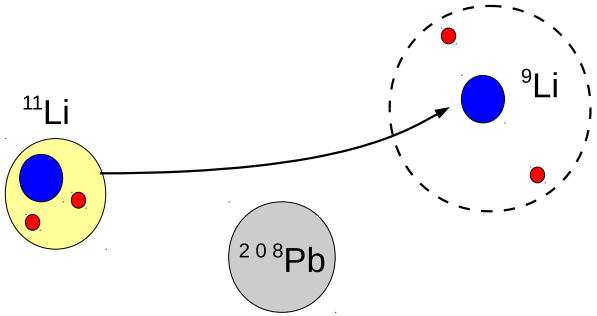
2n TRANSFER



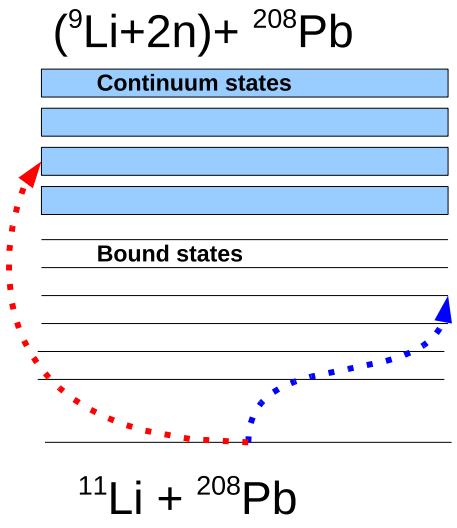
$$E_{9Li} \approx E_{11Li}$$

Theoretical calculations - DIRECT BREAKUP

- **Continuum-Discretized Coupled-Channels calculations(CDCC).** 3-body model.



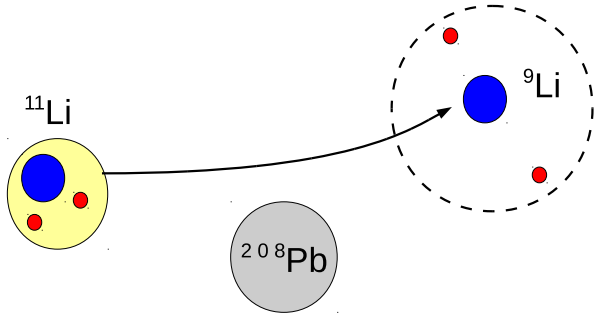
  - The breakup process is treated as an inelastic excitation of the projectile.
  - Di-neutron model (^{9}Li+2n) adjusted to reproduce g.s. rms radius.
  - ^{11}Li structure models predict a dipole resonance at low energies
    - With dipole resonance.
    - WithOUT dipole resonance.



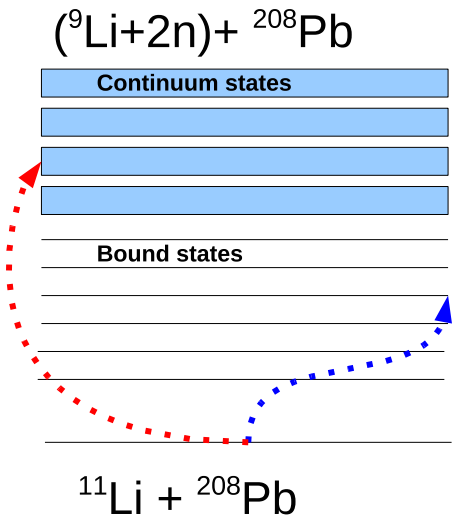
- 4-body model presented by M. Rodriguez-Gallardo.

Theoretical calculations - DIRECT BREAKUP

- **Continuum-Discretized Coupled-Channels calculations(CDCC).** 3-body model.



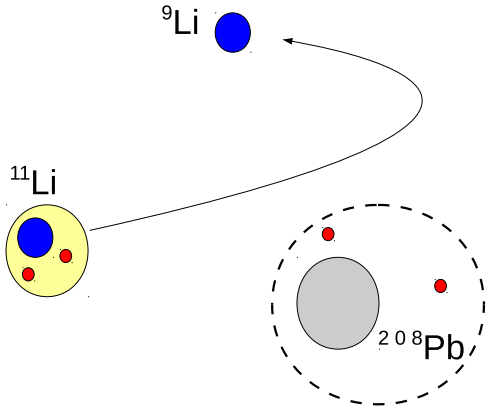
  - The breakup process is treated as an inelastic excitation of the projectile.
  - Di-neutron model (^{9}Li+2n) adjusted to reproduce g.s. rms radius.
  - ^{11}Li structure models predict a dipole resonance at low energies
    - With dipole resonance.
    - **WithOUT dipole resonance.**



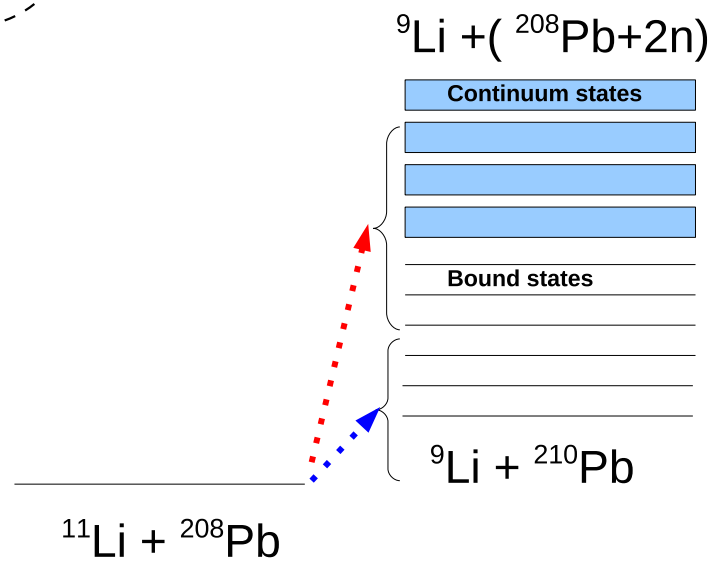
- 4-body model presented by M. Rodriguez-Gallardo.

Theoretical calculations - 2n TRANSFER

- **DWBA.**

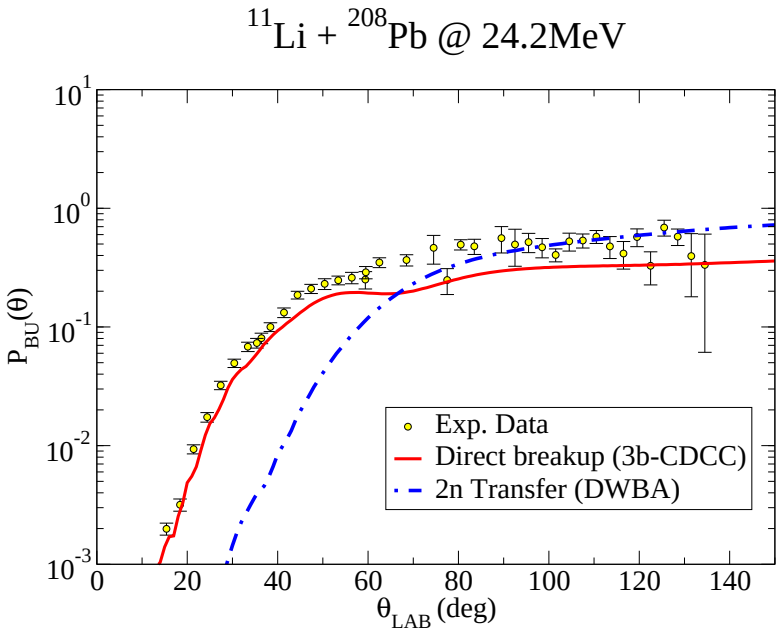


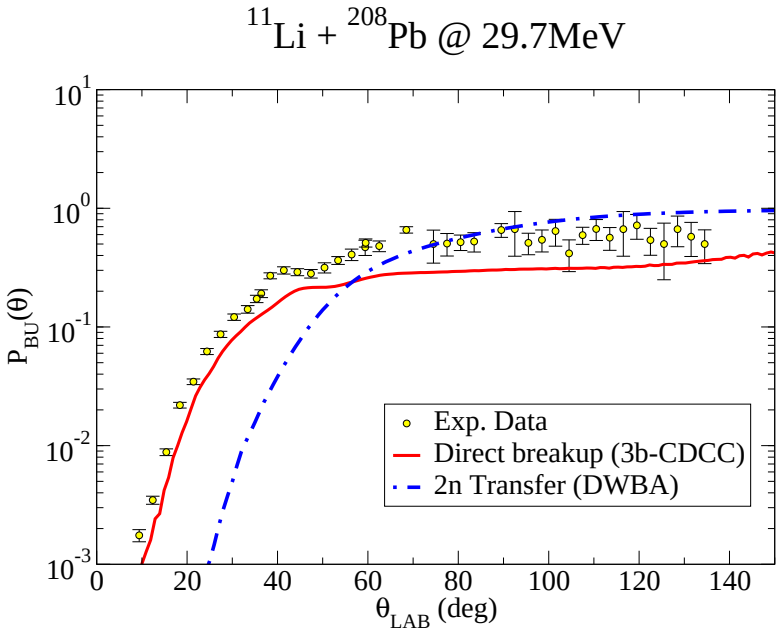
- Assume a neutron transfer mechanism populating bound and unbound states of the target.
- Approximation to 1st order of the nuclear and Coulomb couplings.



Theoretical calculations - Breakup probability

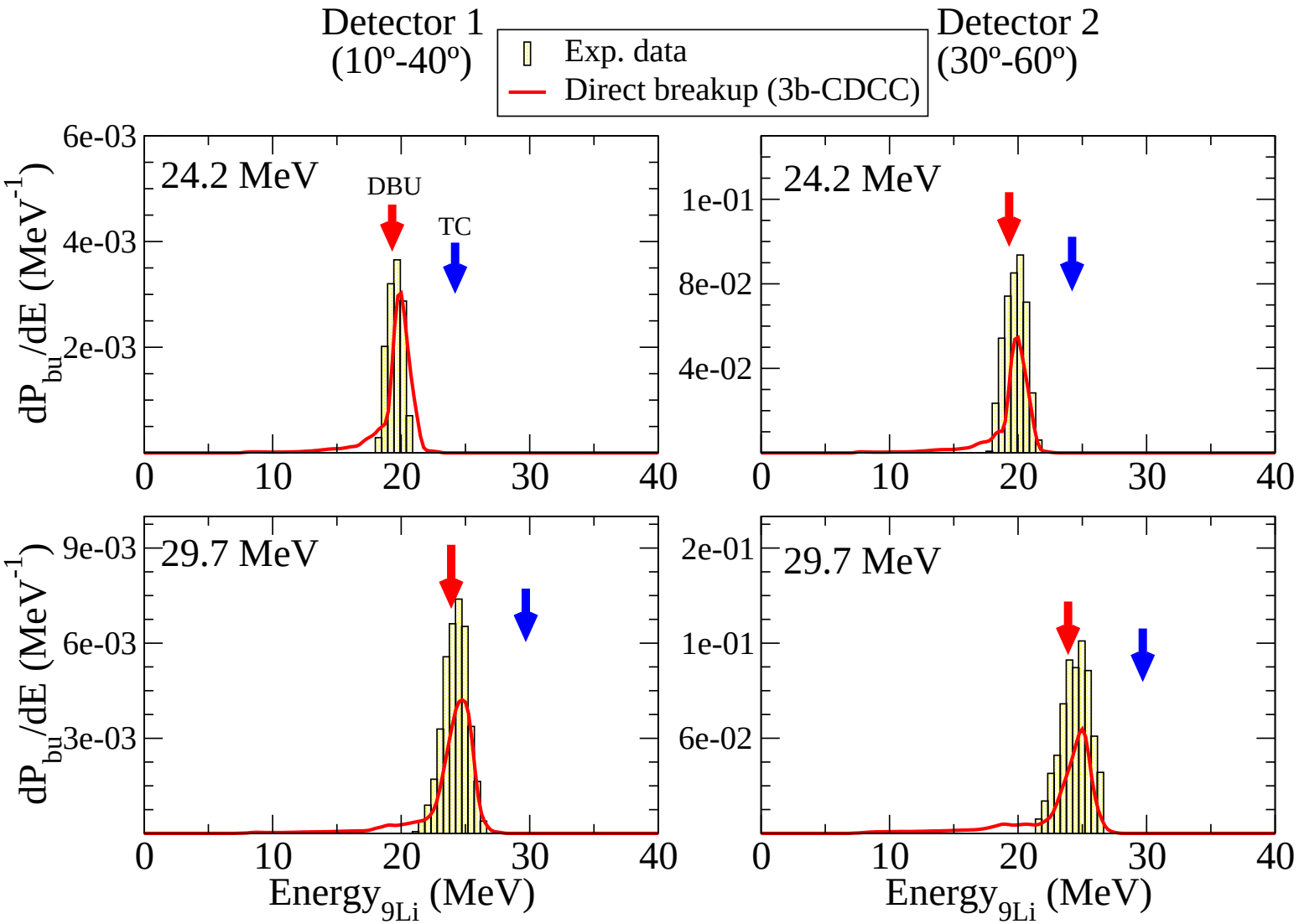
1. What mechanism produces the breakup of the nucleus ?





Present data are consistent with a direct breakup mechanism at small angles

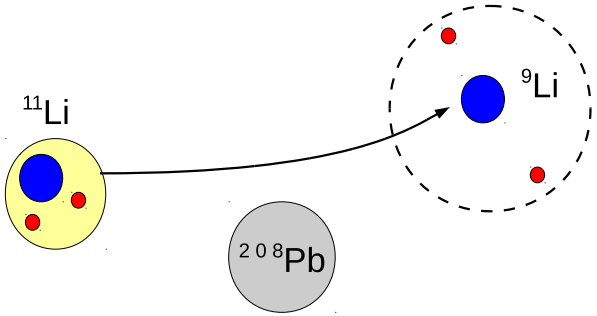
Theoretical calculations - Energy distribution of ^{9}Li fragments



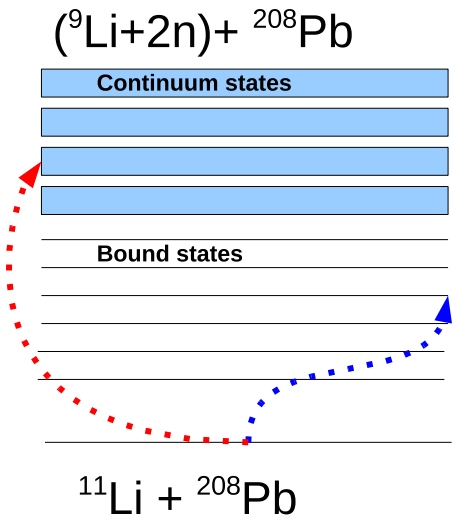
Present data are consistent with a direct breakup mechanism at small angles

Theoretical calculations - Resonance

- **Continuum-Discretized Coupled-Channels calculations(CDCC).** 3-body model.



  - The breakup process is treated as an inelastic excitation of the projectile.
  - Di-neutron model (^{9}Li+2n) adjusted to reproduce g.s. rms radius.
  - ^{11}Li structure models predict a dipole resonance at low energies
    - **With dipole resonance ($\sim$ 0.4 MeV).**
    - **WithOUT dipole resonance.**



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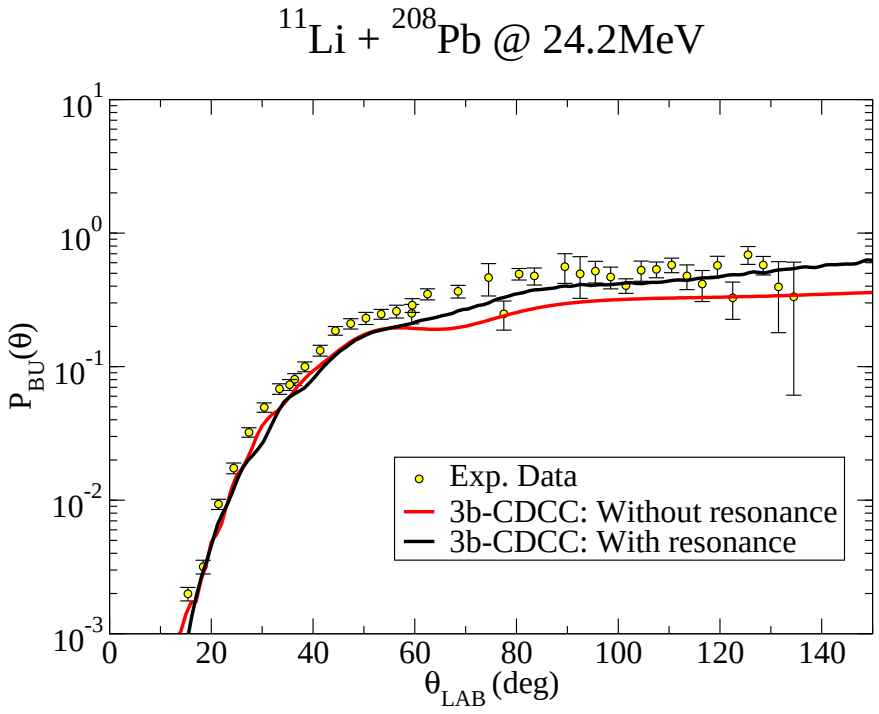
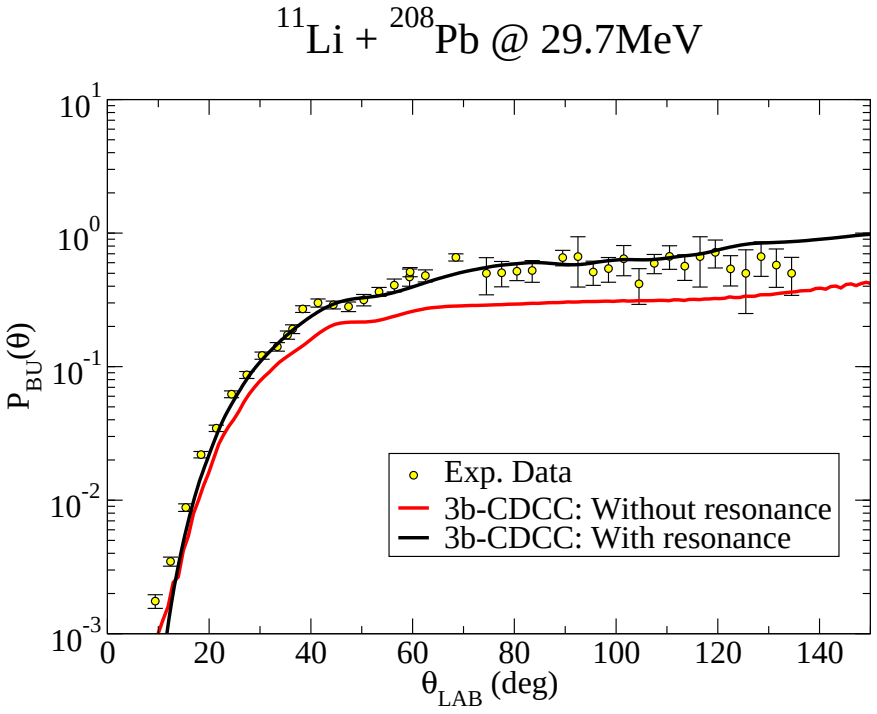
Theoretical calculations - Resonance





Present data supports a dipole resonance at low energies.

Conclusions

- We have measured ^{11}Li on ^{208}Pb at energies around the Coulomb barrier at TRIUMF facility (Canada).
- The set-up allowed us to separate elastically scattered ^{11}Li from ^{9}Li breakup fragments in ^{11}Li+ ^{208}Pb reaction.
- The preliminary data are well reproduced by CDCC calculations, suggesting that, at small angles, these fragments are mainly produced by a direct-breakup mechanism.
- The preliminary data suggest a dipole resonance at low energies.

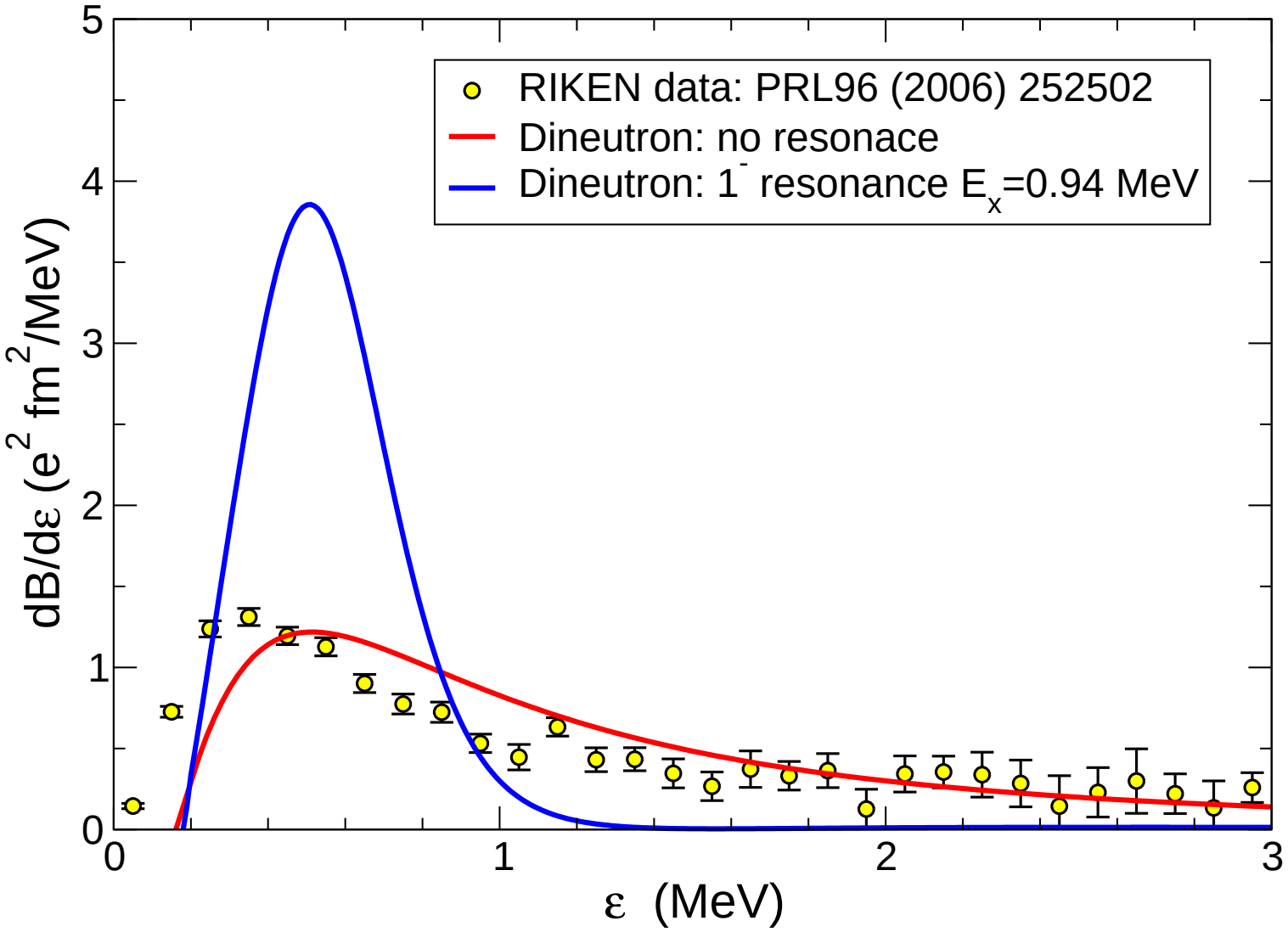
Acknowledgments

E1104 COLLABORATION

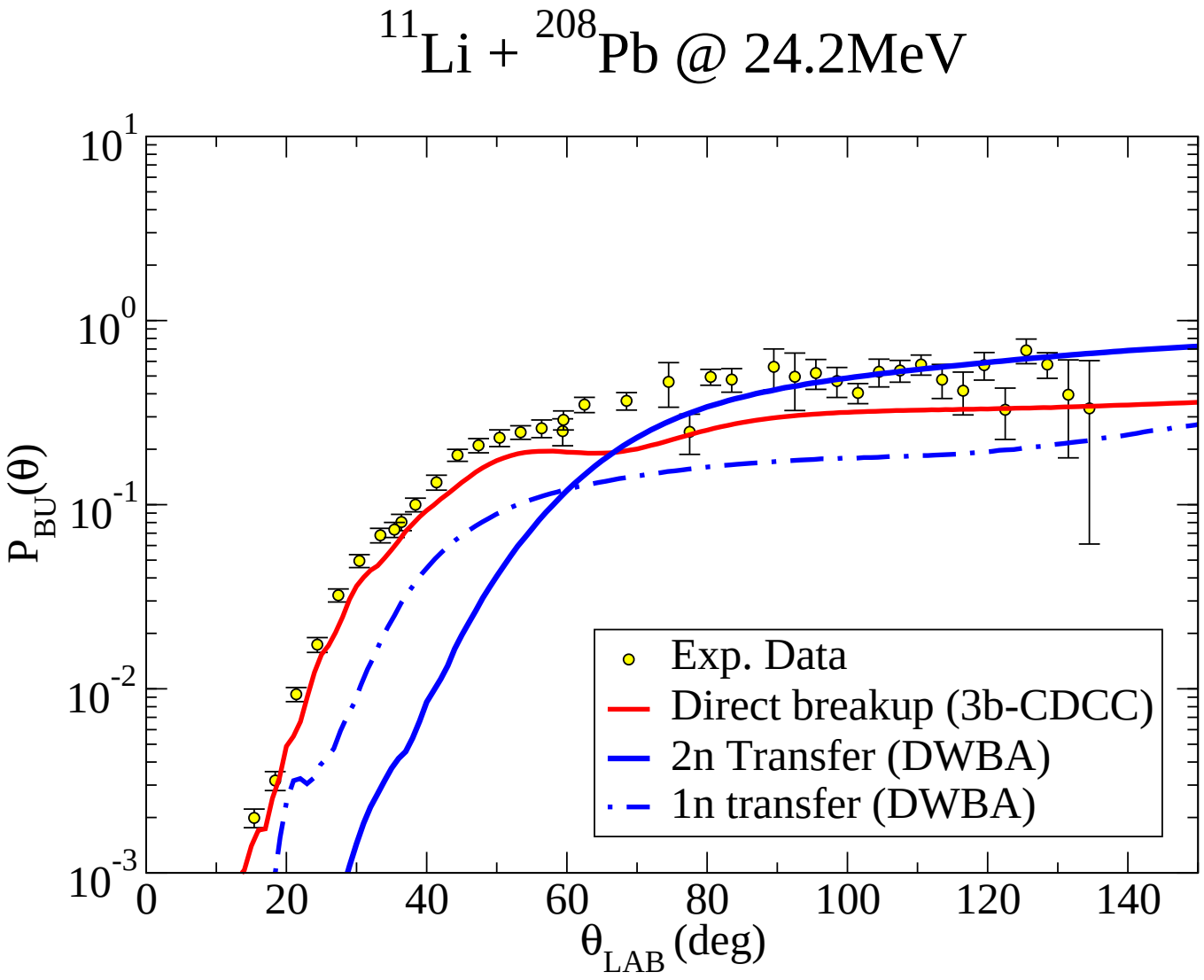
J. P. Fernández-García [a, b], M. Cubero [c, d], J. A. Lay [a], L. Acosta [l], M. Alcorta [c], M. A. G. Alvarez [a, b], M. J. G. Borge [c], L. Buchmann [h], C. A. Diget [f], B. Fulton [f], D. Galaviz [g], J. Gómez-Camacho [a, b], M. Madurga [c], I. Martel [e], A. M. Moro [a], I. Mukha [i,j], T. Nilsson [k], A. M. Sánchez-Benítez [e], A. Shotter [f], O. Tengblad [c] y P. Walden [h]

a Dpto. FAMN, Universidad de Sevilla, 41080 Seville, Spain.
b Centro Nacional de Aceleradores, Universidad de Sevilla, 41092 Seville, Spain.
c Instituto de Estructura de la Materia, CSIC, 28006 Madrid, Spain.
d CICANUM, Universidad de Costa Rica,2060 San José, Costa Rica.
e Dpto. de Física Aplicada, Universidad de Huelva,21071 Huelva, Spain.
f Departament of Physics, University of York, YO 10 5DD Heslington, York, UK.
g CFNUL, Universidade de Lisboa, 1649-003 Lisbon, Portugal.
h TRIUMF, V6T2A3 Vancouver B.C., Canadá.
i GSI Helmholtzzentrum für Schwerionenforshung, 64291 Darmstadt, Germany.
j Instituto de Física Corpuscular, Valencia, Spain.
k Fundamental Physics, Chalmers University of Technology, 41296 Göteborg, Sweden.
l INFN, Laboratori Nazionali del Sud, 95123 Catania, Italy.

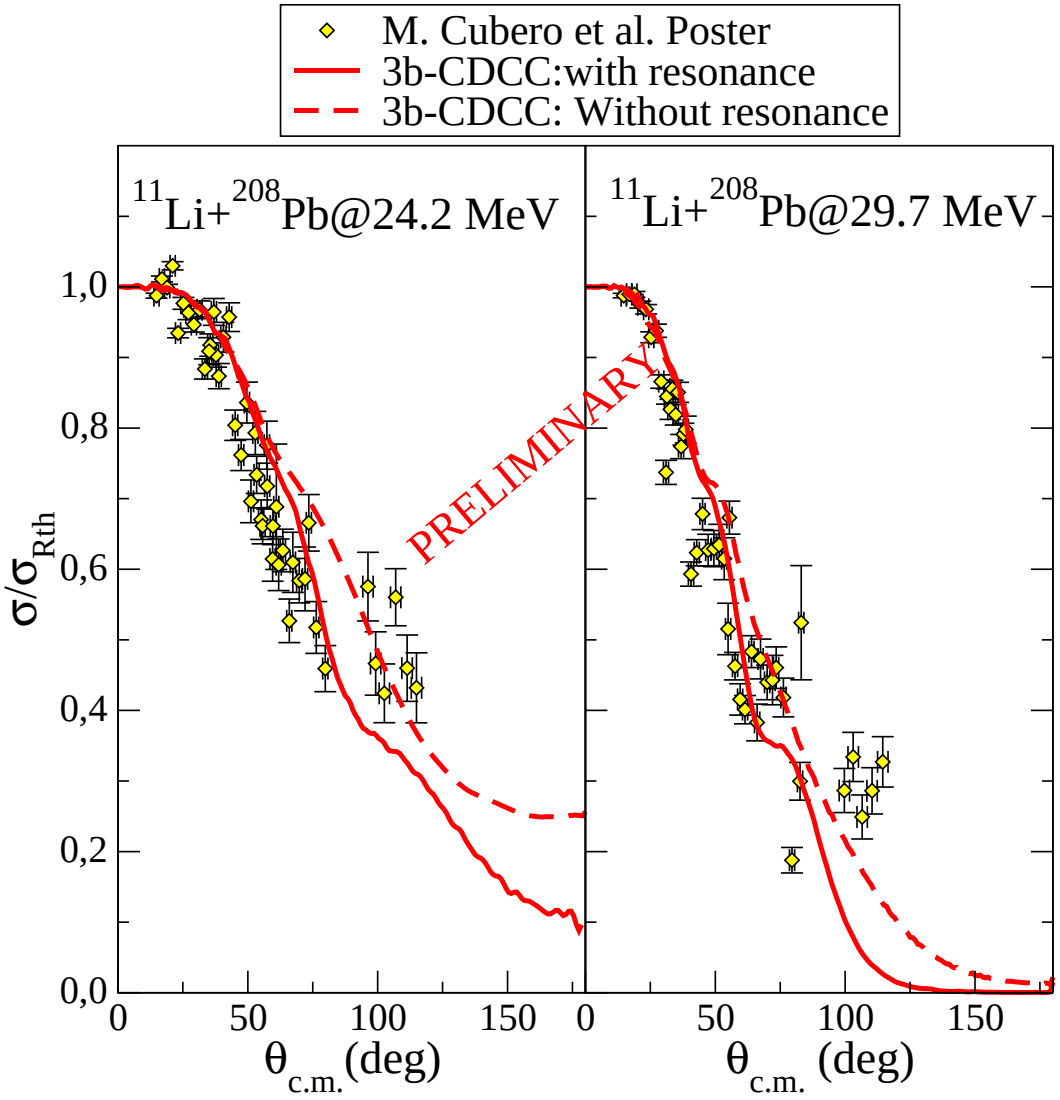
*


RIKEN data: PRL96 (2006) 252502
Dineutron: no resonace
Dineutron: 1⁻ resonance E_x=0.94 MeV
dB/dε (e² fm²/MeV)
ε (MeV)
0
1
2
3
4
5
0
1
2
3

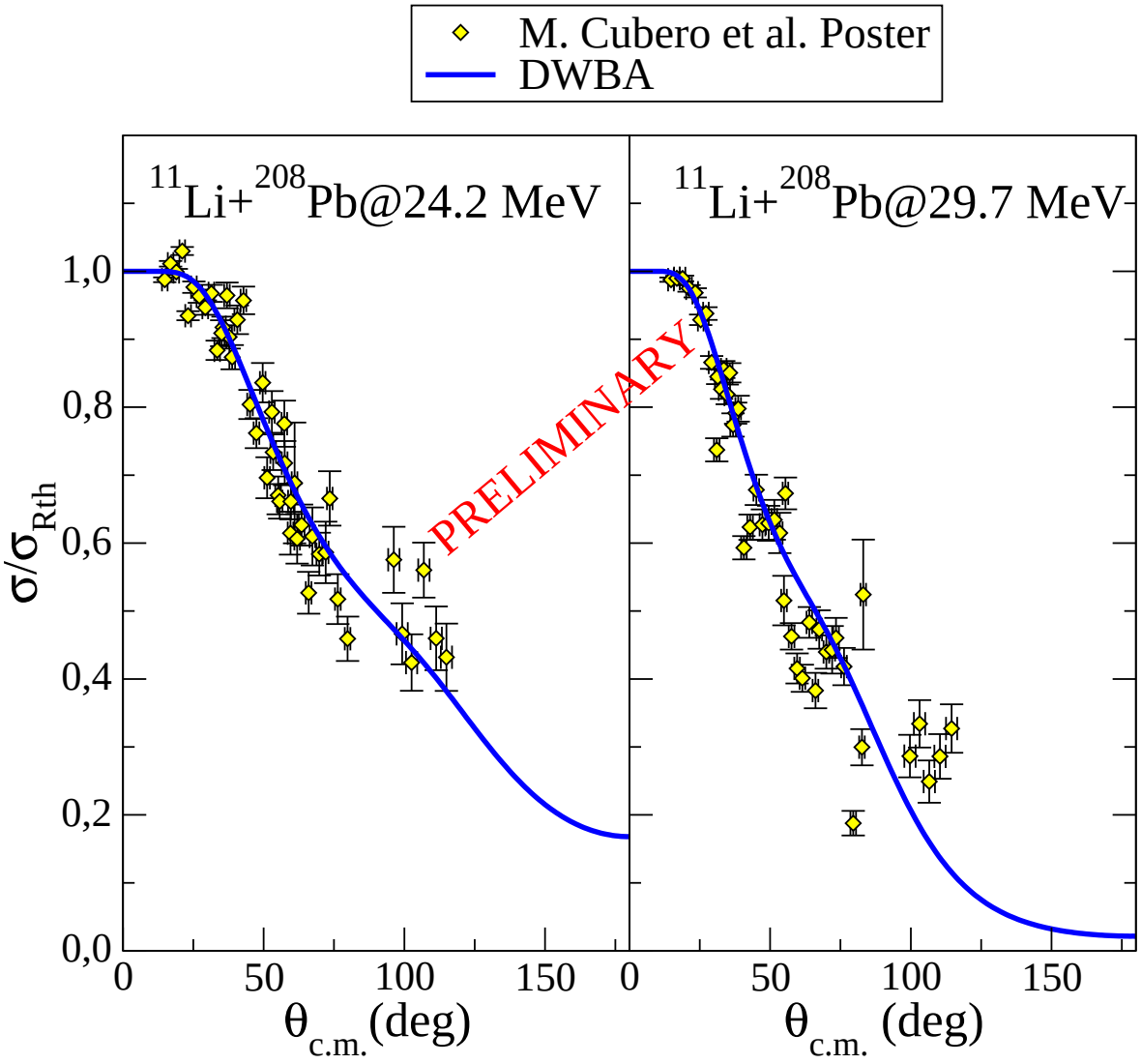
*


^{11}Li + ^{208}Pb @ 24.2MeV
$P_{BU}(\theta)$
θ_{LAB} (deg)
Exp. Data
Direct breakup (3b-CDCC)
2n Transfer (DWBA)
1n transfer (DWBA)

*


M. Cubero et al. Poster
3b-CDCC:with resonance
3b-CDCC: Without resonance
^{11}Li+^{208}Pb@24.2 MeV
^{11}Li+^{208}Pb@29.7 MeV
PRELIMINARY
σ/σ$_{Rth}$
1,0
0,8
0,6
0,4
0,2
0,0
0
50
100
150
θ$_{c.m.}$ (deg)

*


M. Cubero et al. Poster
DWBA
^{11}Li+^{208}Pb@24.2 MeV
^{11}Li+^{208}Pb@29.7 MeV
PRELIMINARY
σ/σ_{Rth}
1,0
0,8
0,6
0,4
0,2
0,0
0
50
100
150
$\theta_{c.m.}$(deg)