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Exploring ^{12}B Structure by ^{8}Li-α Resonant Elastic Scattering

IV French-Italian meeting of the Associate European Laboratory (LEA-COLLIGA)
INFN Laboratori Nazionali di Legnaro, 18-19 November 2010

Outlook

motivations

- Exotic clustering
- g.s. behaviour of Boron isotopes
- ^{12}B : exicited ^{8}Li-α cluster states

- Inverse kinematics resonant elastic scattering
- Inelastic scattering contaminations

experimental method

set-up

- ^{8}Li @ EXCYT
- ^{8}Li-α experiment
- Preliminary results

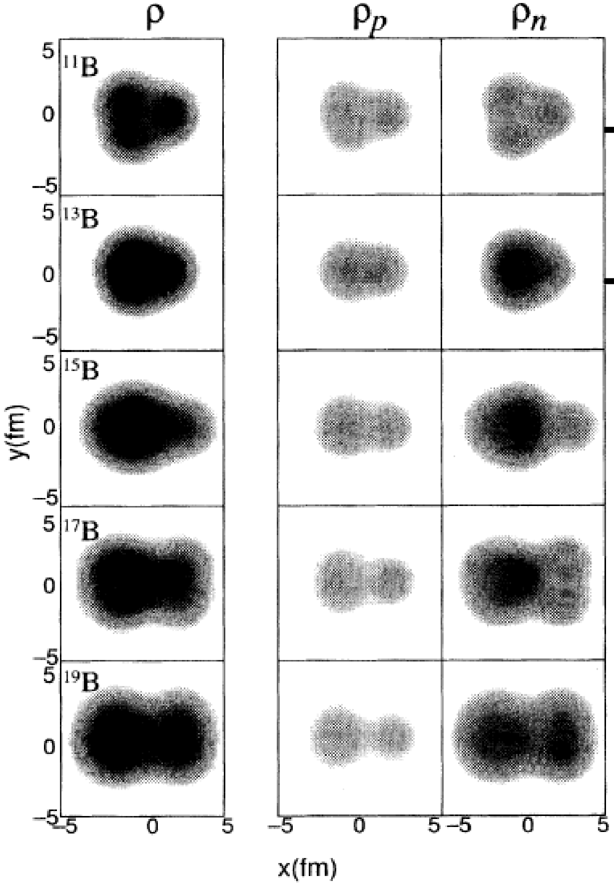
Exotic Clustering

description of unstable nuclei as di-nuclear structures

Clustering in neutron rich nuclei

Matter density distribution in Boron isotopes ground states (AMD calculations): drastic changes in the isotopes structure with the increasing number of neutrons

Odd-even B isotopes



$\alpha - {}^{7}$Li structure

$^{12}B = \alpha + {}^{8}Li$

spherical structure, single particle

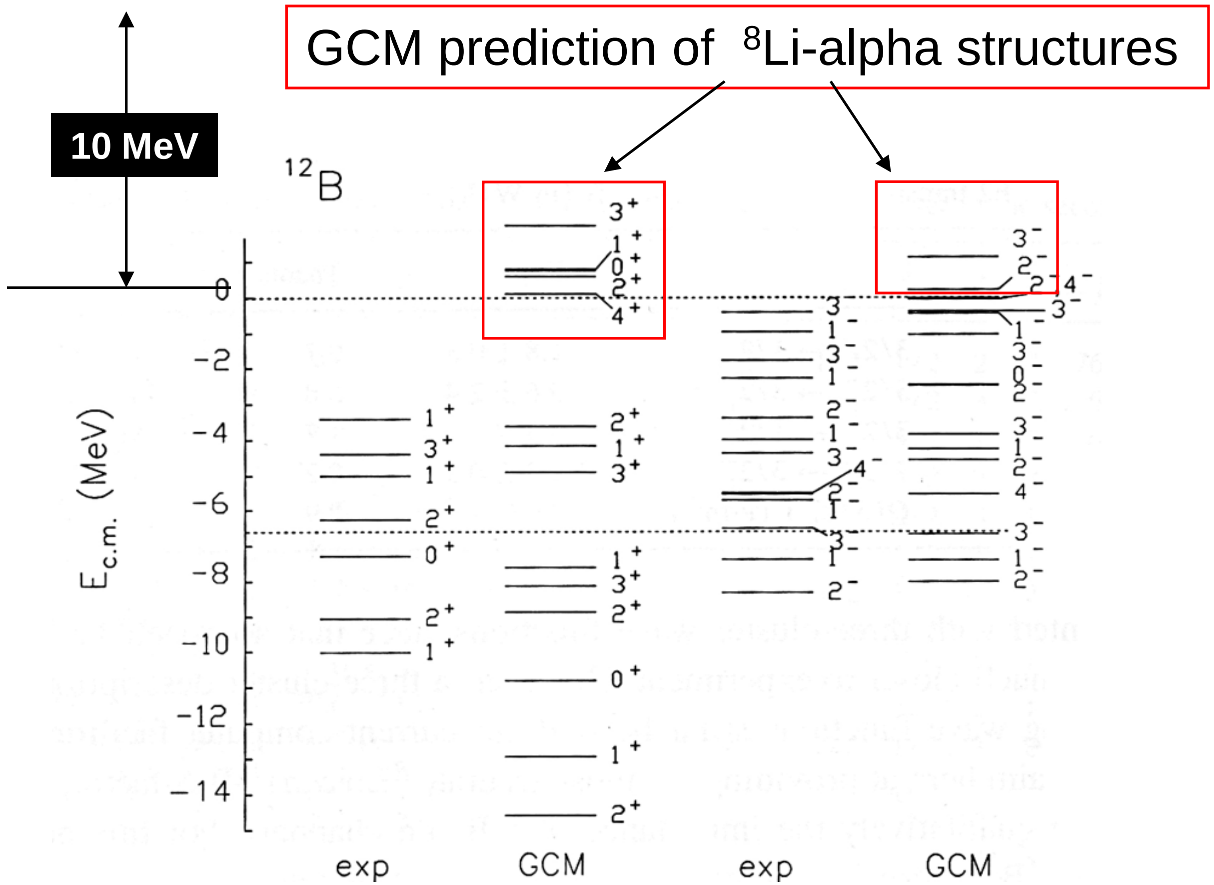
Neutron magic number N=8

prolate di-nuclear structure

Y. Kanada-En'yo and H. Horiuchi PRC 52 (1995) 647

^{12}B

Search for ^{8}**Li-α** configurations of ^{12}**B** states above the α-decay threshold



P. Descouvemont, NPA 596 (1996) 285

Thick Target Inverse Kinematic resonant elastic scattering method

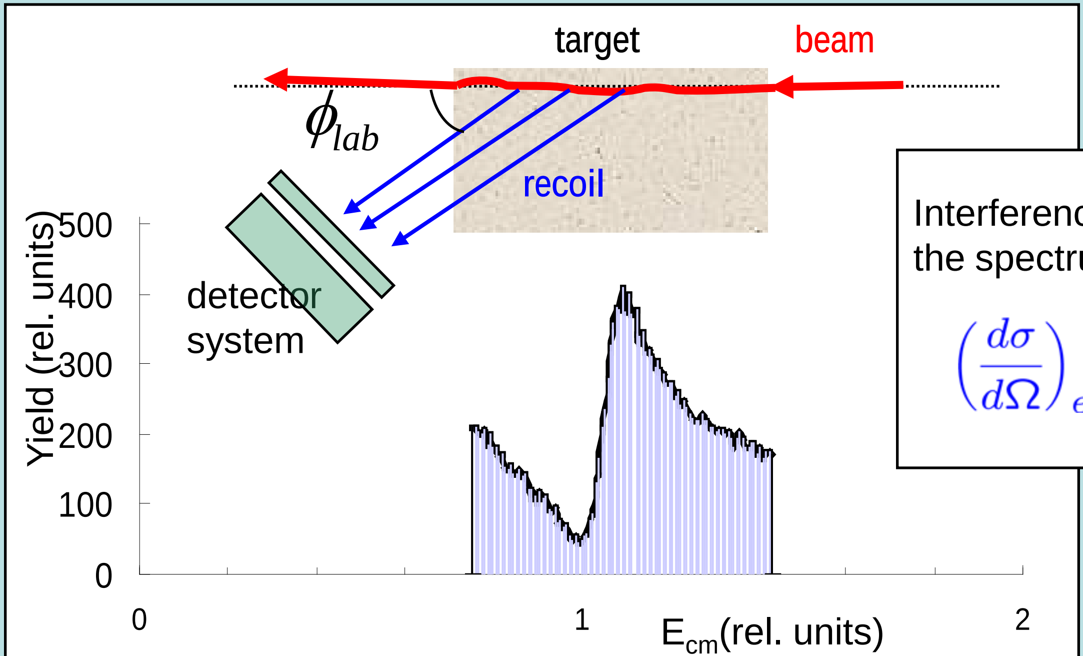
K. P. Artemov et al.
Sov. J. Nucl. Phys. 52, 408(1990)

Y+p→**X***→p+Y

• beam energy loss in the target → wide range for E_{cm}

• inverse kinematics → forward focused recoiling protons (negligible energy loss in the target)

• proton spectra → information on the resonance energy, orbital momentum, and proton width



Courtesy of C. Angulo

Interference effects are reflected in the spectrum shape:

$$\left(\frac{d\sigma}{d\Omega}\right)_{elas} = |f_N + f_C|^2$$

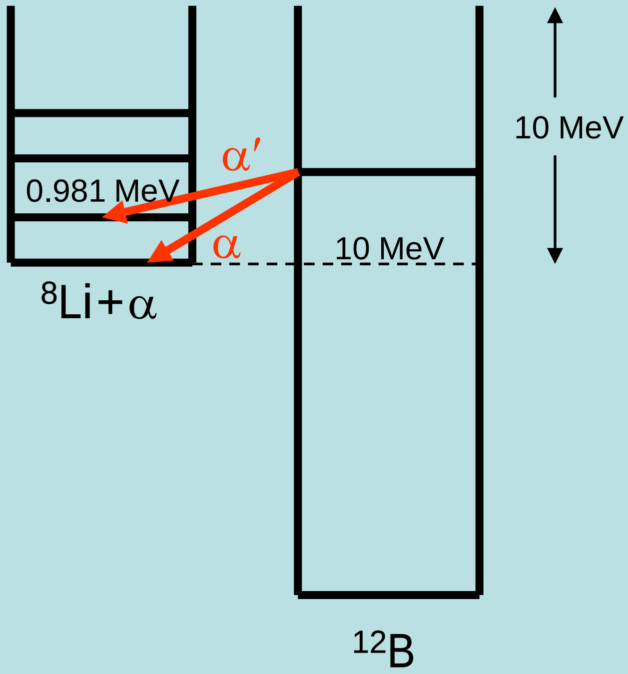
Knowledge of stopping power is required!!

Inelastic scattering contamination in thick target experiments

E_{cm} larger enough to open inelastic channels

↓

recoil spectra with elastic and inelastic event at the same energy



solutions → Choice of the target thickness

→ Time of flight measurement (extended target)

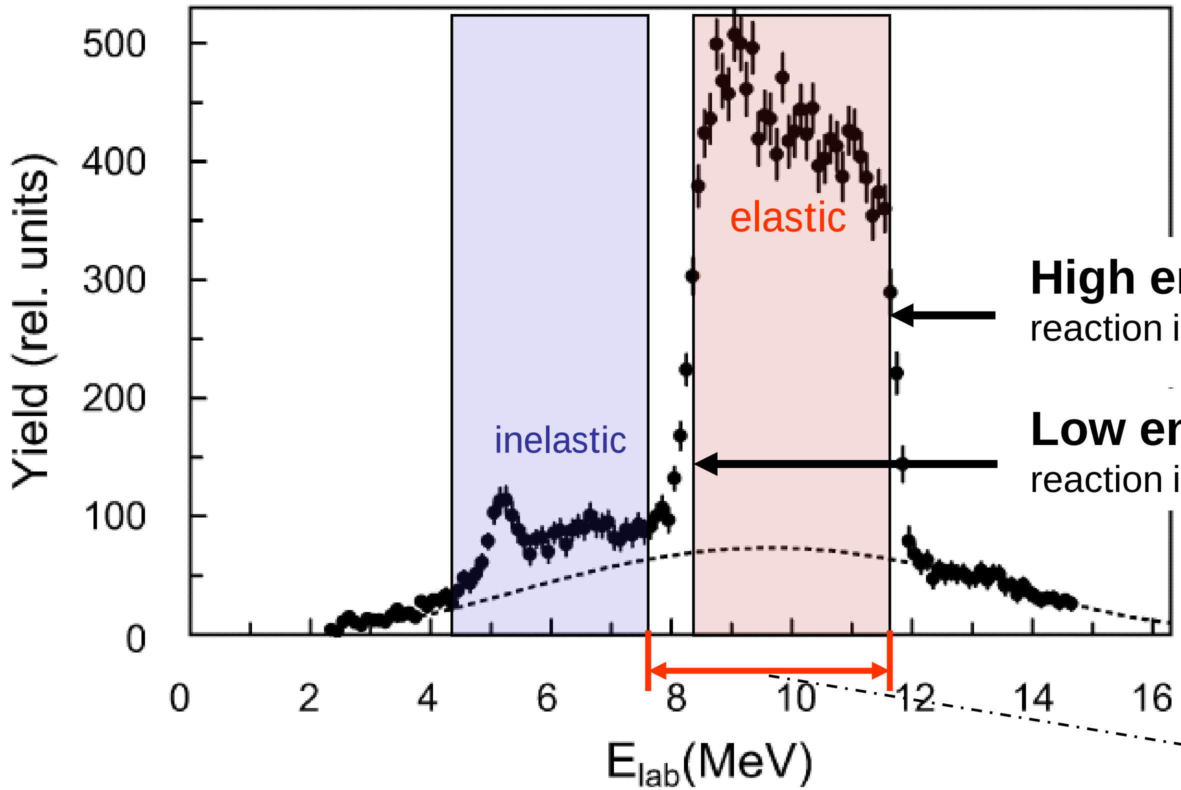
The choice of the target thickness

- A **very thick target** → general overview of level scheme
- A **thinner target** → less straggling and more precise information on the investigated state

In general the target thickness and initial beam energy must be adapted to the experimental goal

$^{18}Ne+p \rightarrow ^{19}Na^* \rightarrow p+^{18}Ne$

66 MeV ^{18}Ne beam on a **2 mg/cm² $(CH_2)_n$ target**



High energy edge: *first target layer* reaction induced at the initial E_{beam}

Low energy edge: *last target layer* reaction induced at $E_{beam}-E_{loss}$

related to the energy position of the beam excited state

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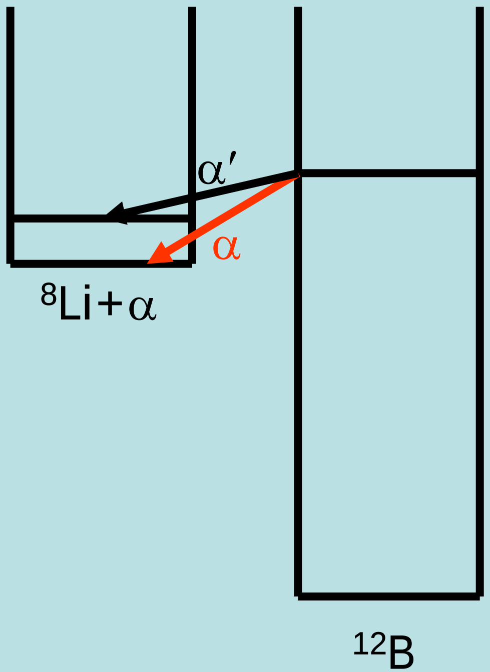
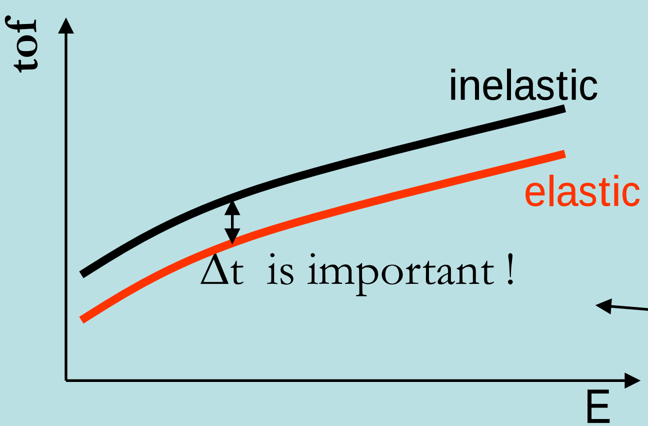
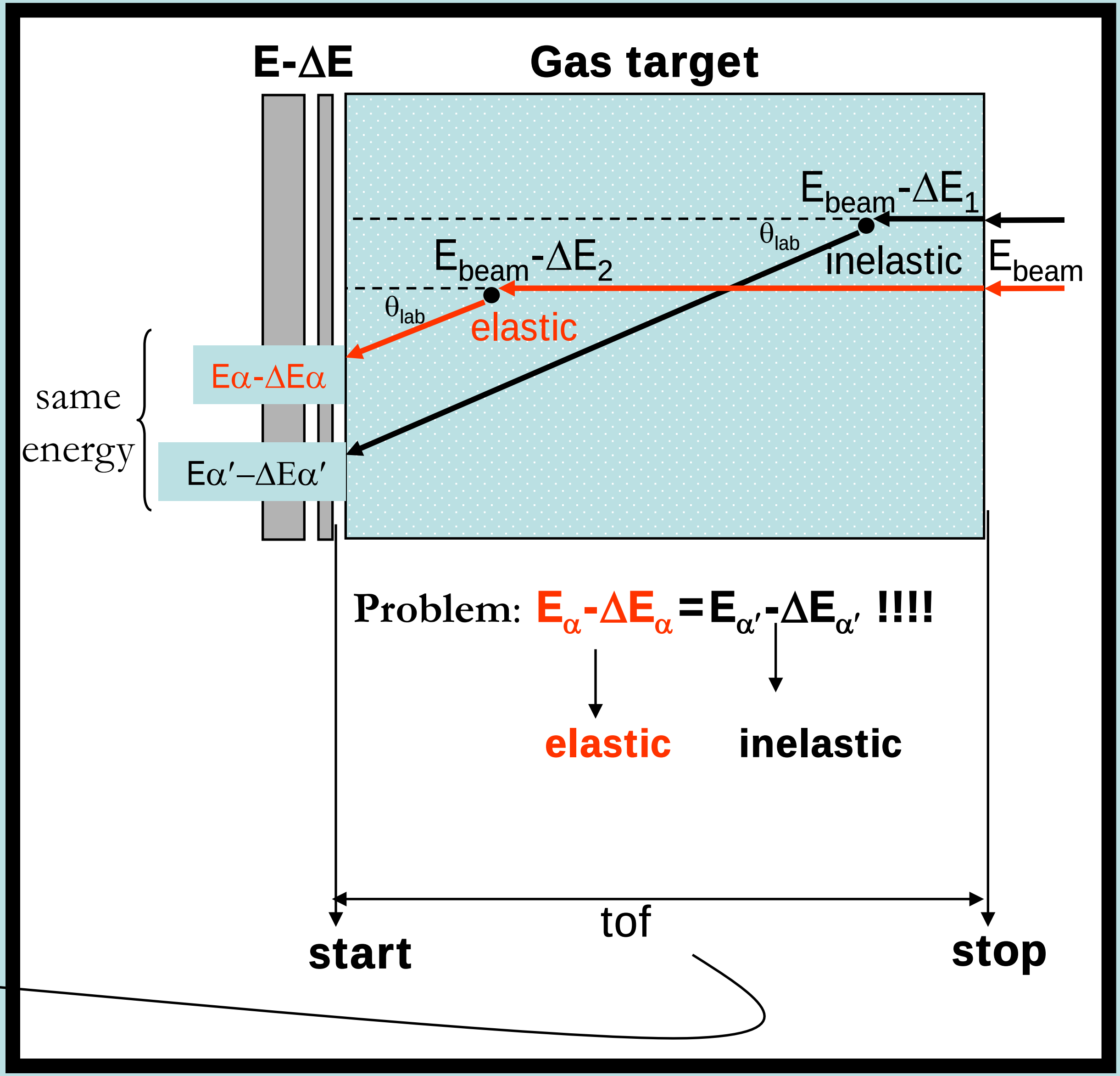
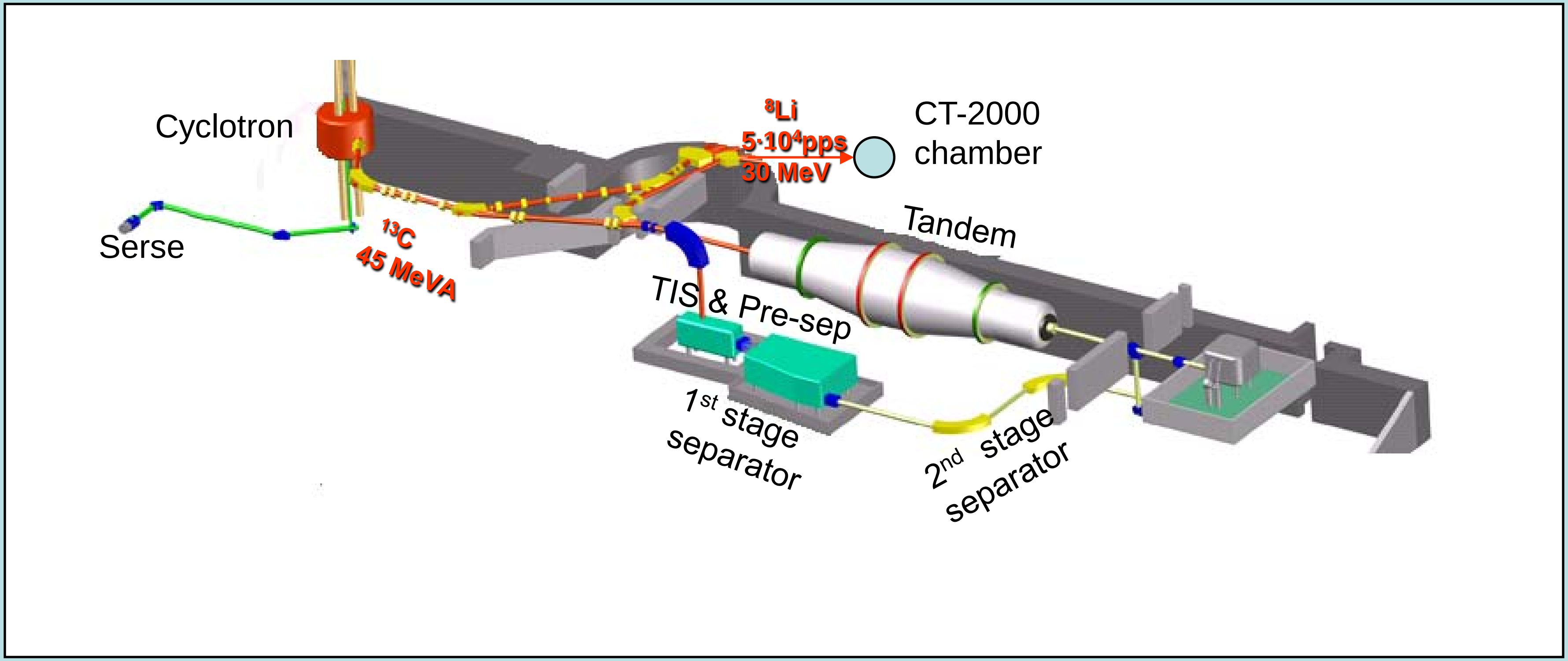
Time of flight and extended and infinite thick target



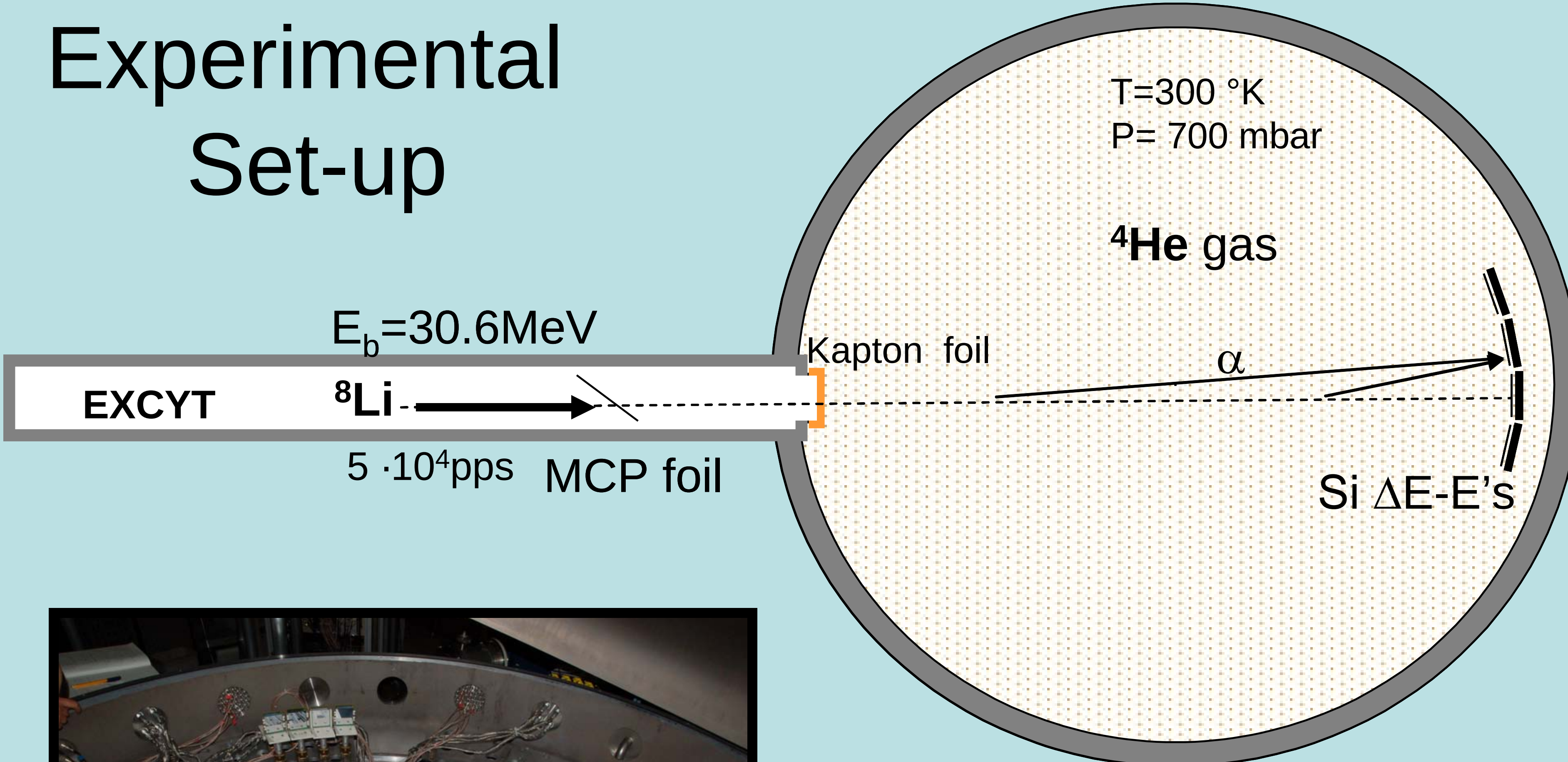


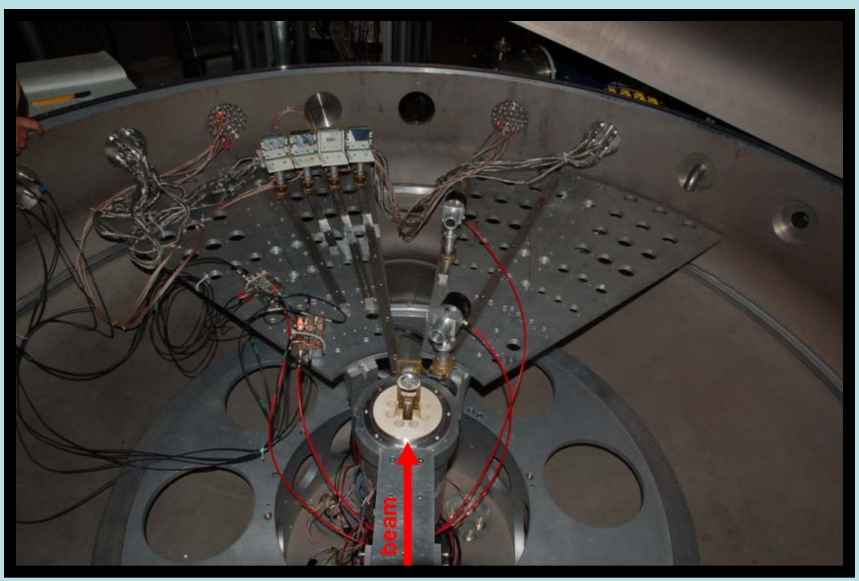


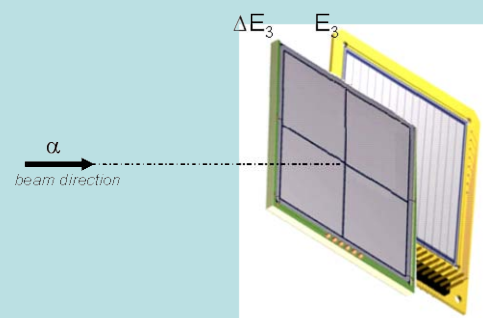
^{8}Li @ EXCYT, INFN-LNS Catania



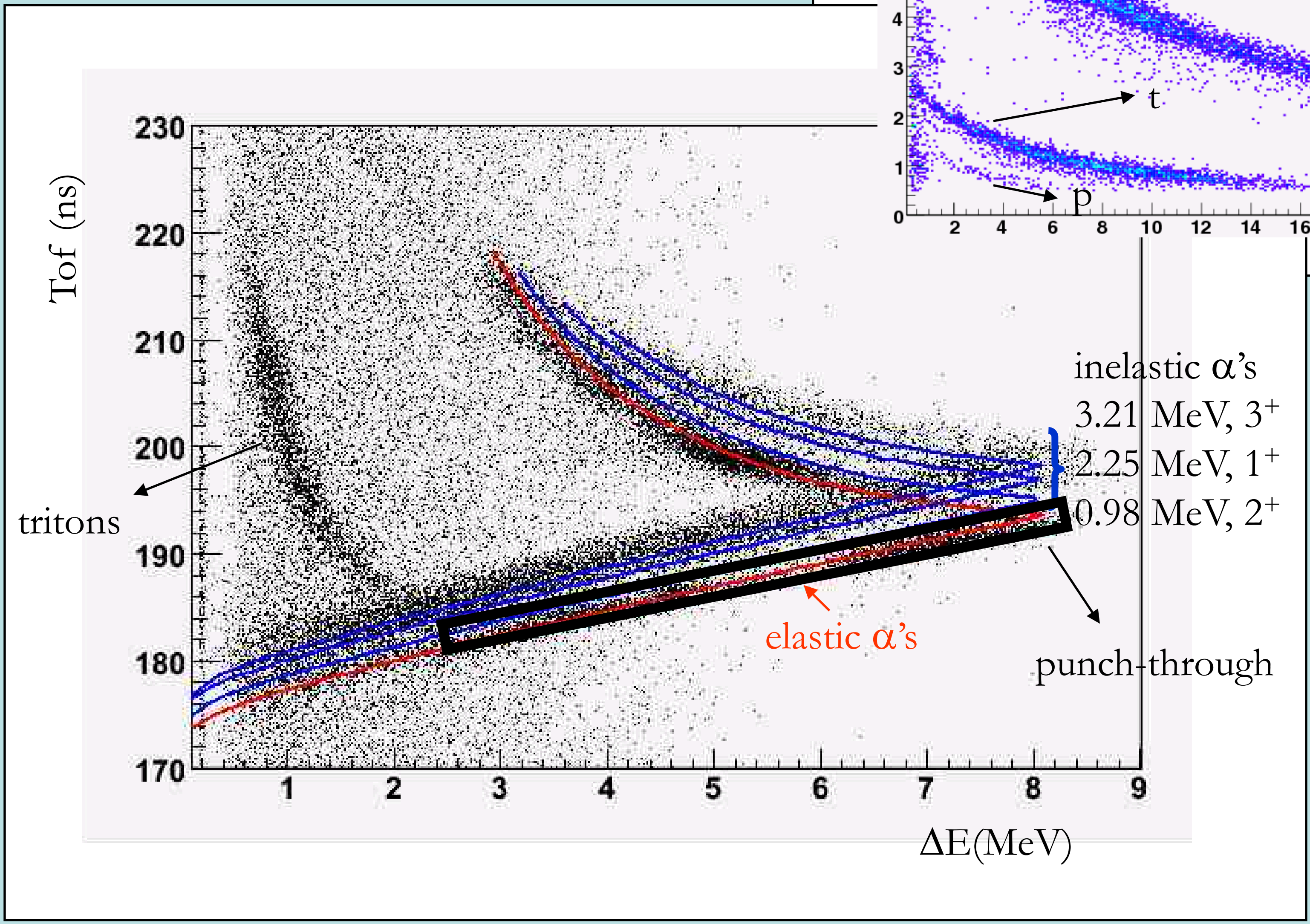
Experimental Set-up

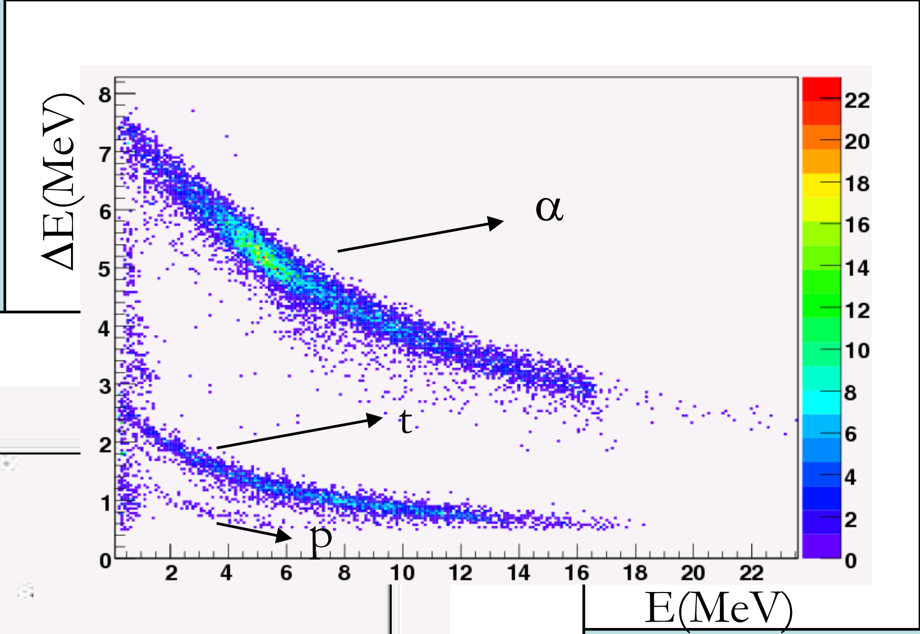






Preliminary Results

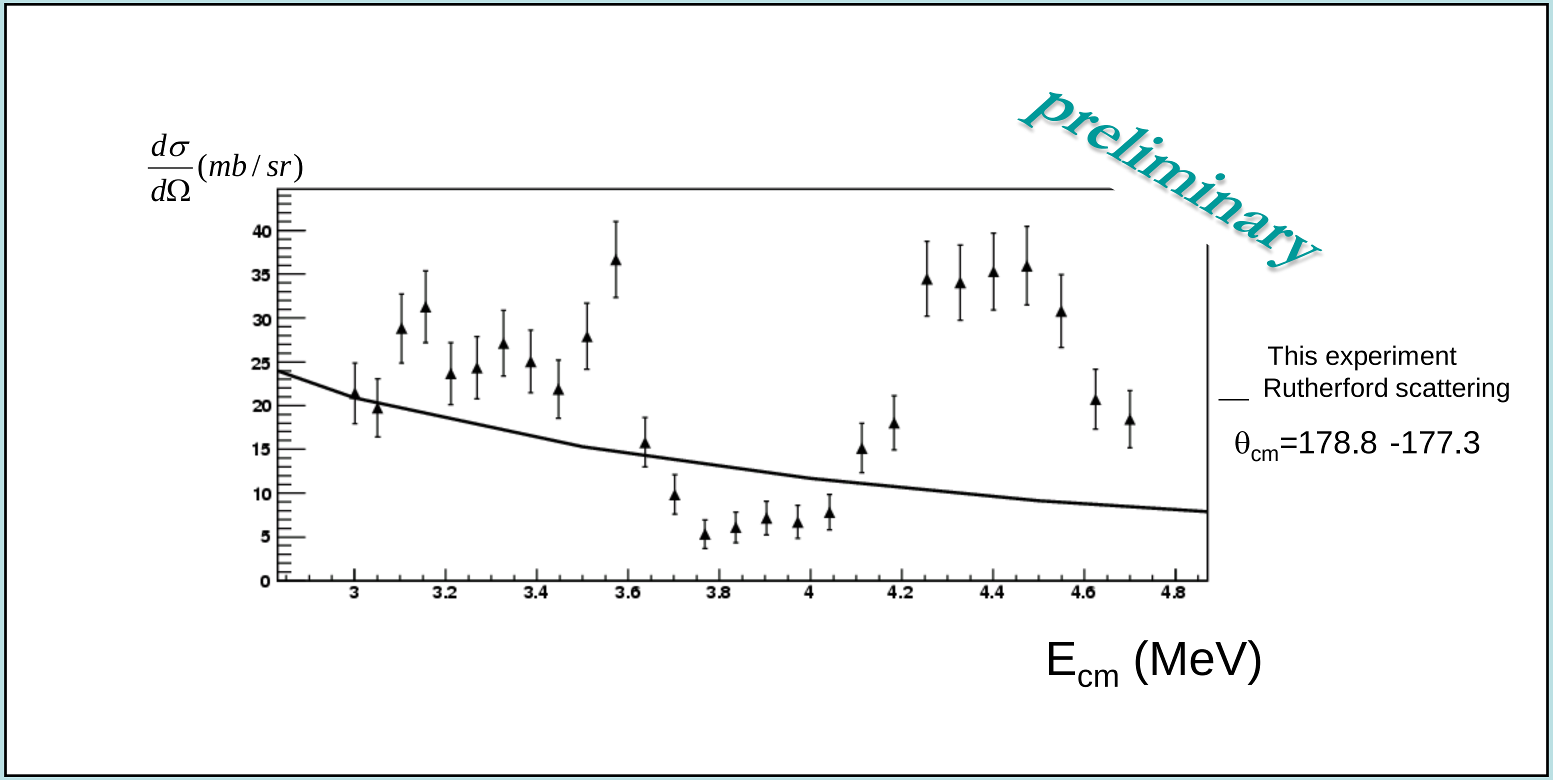




^{8}Li-α elastic cross-section

^{4}He stopping power for α and ^{8}Li

α detected position and energy ⟶ E_{cm} and θ_{cm}



Monte Carlo to evaluate experimental resolution

R-matrix analysis → E_R, $\Gamma\alpha$

Conclusions

^{8}Li+^{4}He→^{8}Li+α has been studied by using a beam energy of E=30.6 MeV

The **TTIK** experimental technique with the **tof measurement**
allows discrimination between elastic and inelastic (or other) scattering

^{8}Li-alpha elastic scattering cross section has been obtained around θ_{cm}**= 180**

Evidence for **large resonances** in the elastic cross section

FUTURE ANALYSIS:

Monte Carlo Simulation including:

→beam profile (experimental collimation)

→energy and angular straggling for beam and recoil particles

R-matrix analysis to obtain the resonance parameters

Collaboration

D.Torresi[a,b], L. Cosentino[a], A. Di Pietro[a], C. Ducoin[c], M. Lattuada[a,b], T. Lonnroth[d], P. Figuera[a], M. Fisichella[a], C. Maiolino[a], A. Musumarra[a,e], M.G. Pellegriti[a,b] M. Papa[d], M. Rovituso[b], V. Scuderi[a,b], G. Scalia[b], D. Santonocito[a], M. Zadro[f]

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f) Ruđer Boskovic Institute, Zagreb, Croatia

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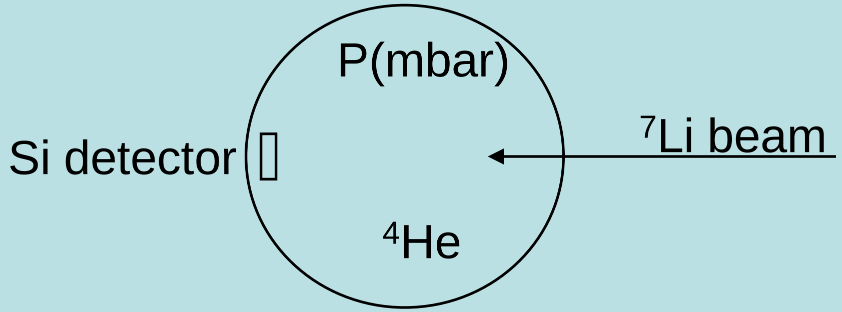
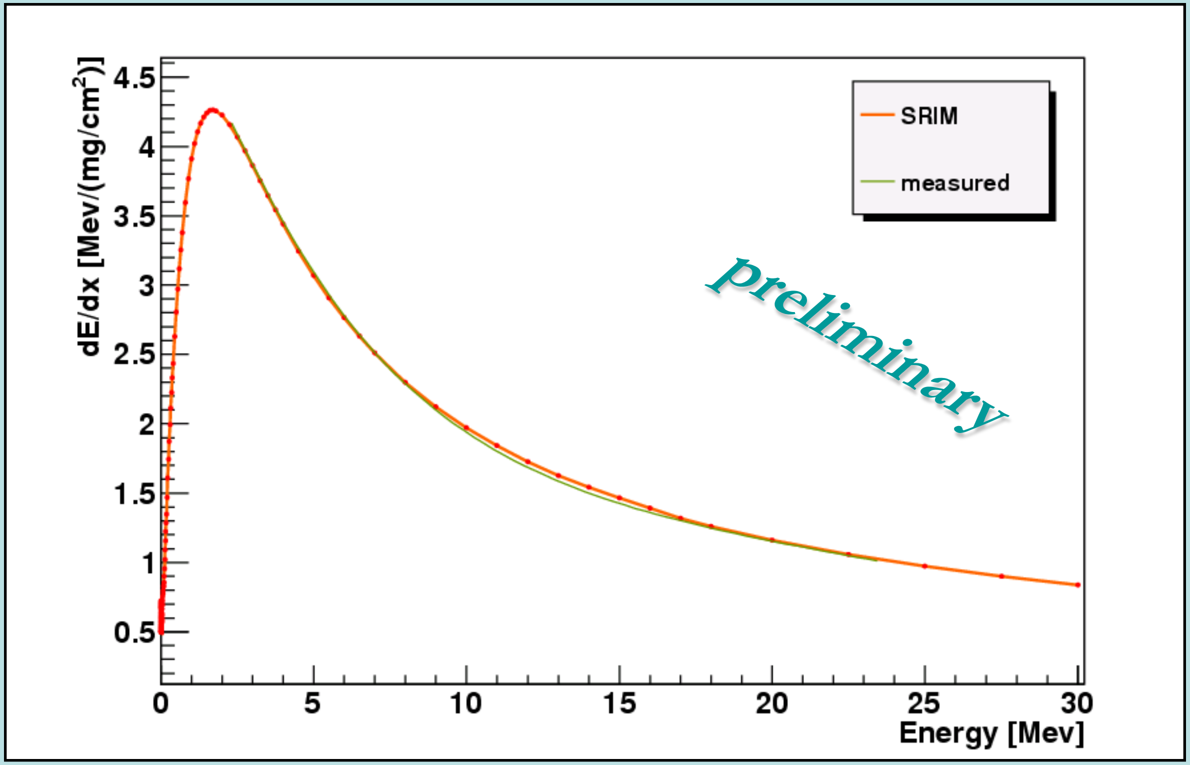
Stopping Power measurements

Measurement of the reasidual beam energy as a function of P





How to extract the resonance parameters from the experimental data:

The R-matrix formalism

A.N. Lane and R.G. Thomas, Rev. Mod. Phys. 30 (1958) 257-353.

The differential cross section ⟷ The collision matrix U_ℓ ⟷ The R-matrix R(E) / The phase shift δ_ℓ

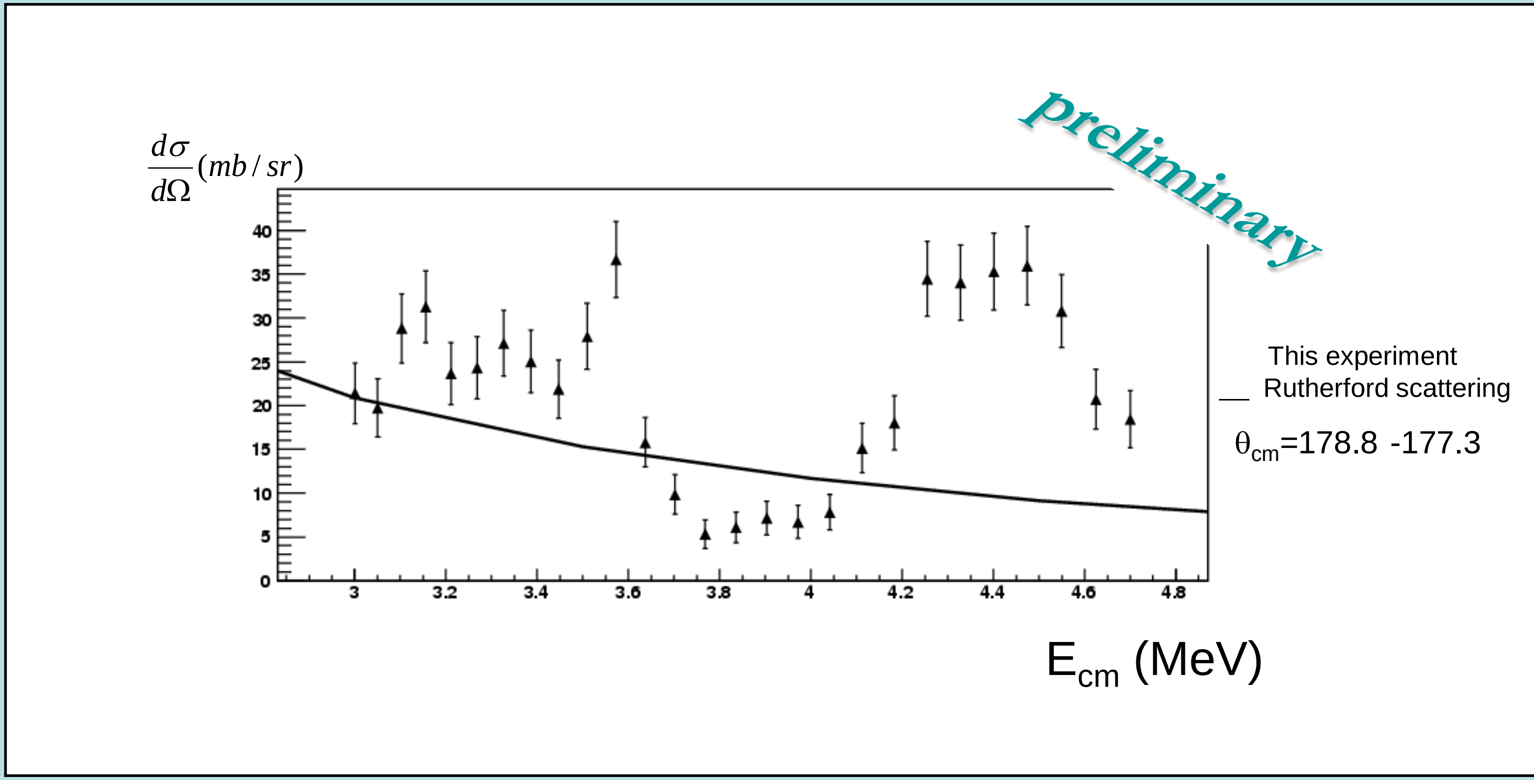
$$\frac{d\sigma(\theta)}{d\Omega} = \frac{1}{4k^2}\left|\sum_\ell (2\ell+1)(1-U_\ell)P_\ell(\cos(\theta))\right|^2$$

$$U_\ell = \frac{I(ka)}{O(ka)}\frac{1-L^\star R(E)}{1-LR(E)} = \exp(2i\delta_\ell)$$

With the R-matrix for λ poles defined as: $$R(E) = \sum_\lambda \frac{\gamma_\lambda^2}{E_\lambda - E}$$

Pole parameters (calculated or formal)		Resonance parameters (observed or experimental)
$E_\lambda, \gamma_\lambda^2, \Gamma_\lambda$	are related to	$E_R, \gamma_R^2, \Gamma_R$

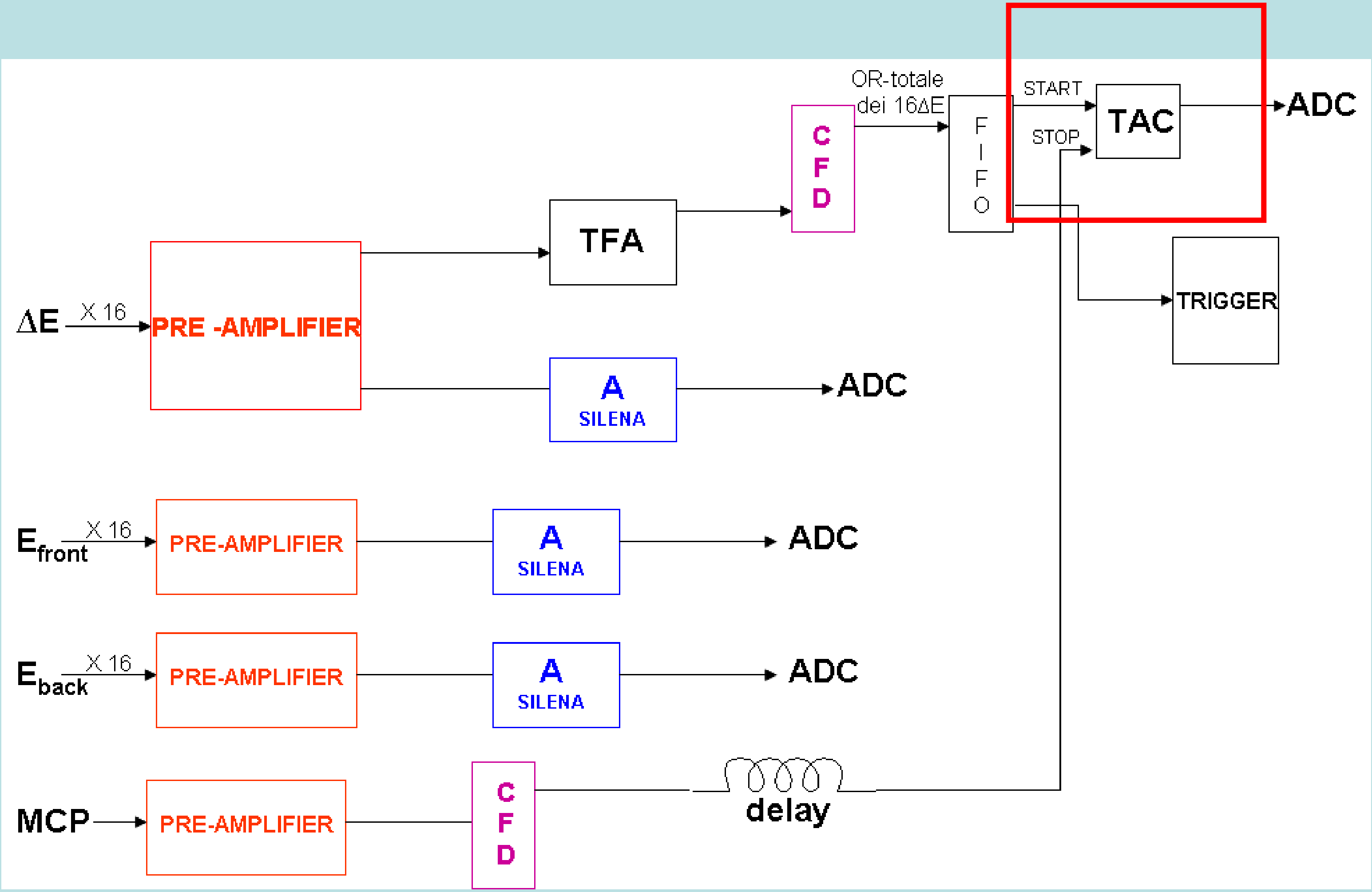
^{8}Li-α elastic cross-section



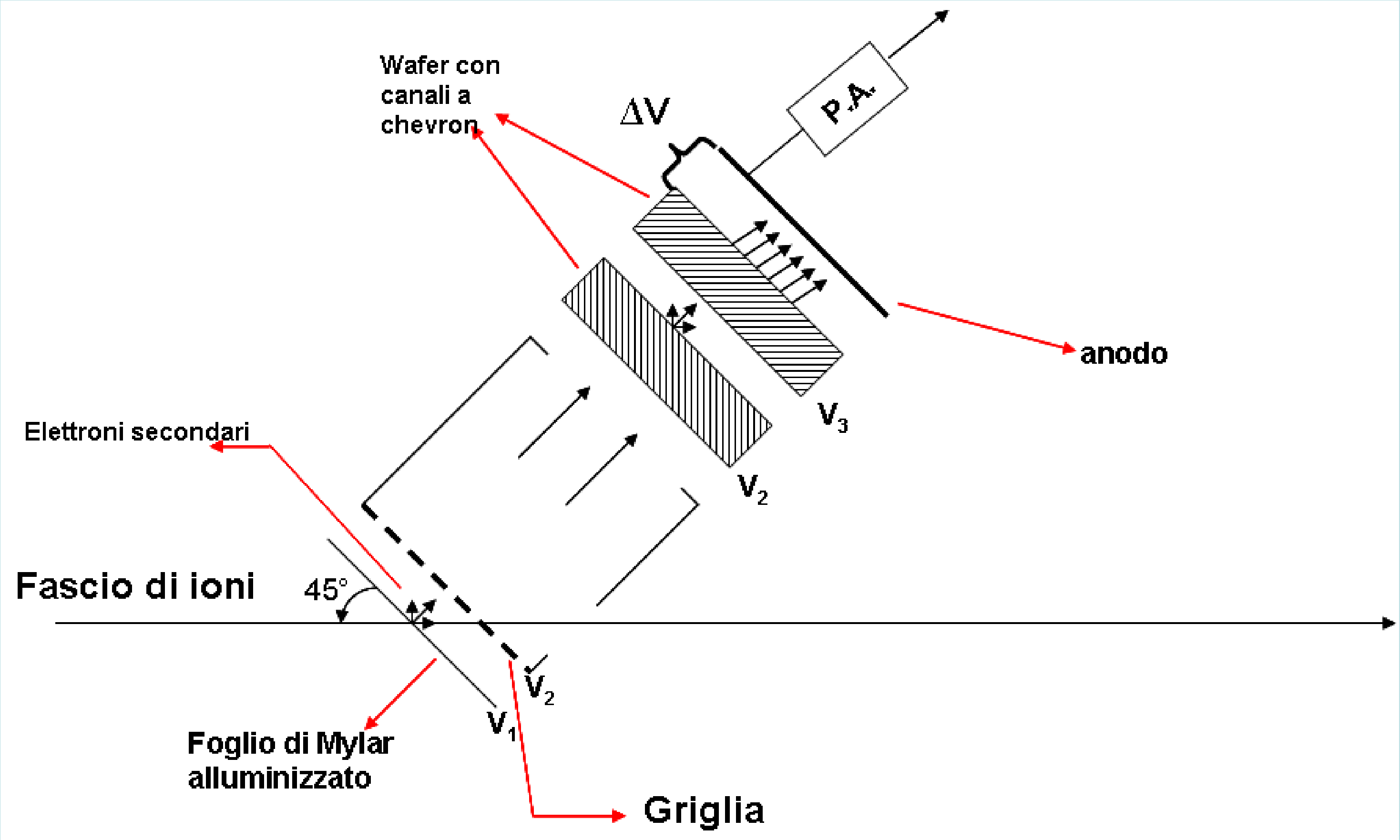
1	12.75 ± 50	$0^{+}; T = 2$	85 ± 40	^{9}Be(^{7}Li, α)^{12}B	^{14}C(p, ^{3}He)^{12}B	
2	13.33 ± 30		50 ± 20	^{9}Be(^{7}Li, α)^{12}B		
3	(13.4 ± 100)		broad			^{10}B(t, p)^{12}B
4	14.82 ± 100	$(2^{+}; T = 2)$	≤ 200		^{14}C(p, ^{3}He)^{12}B	
5	15.5			^{9}Be(^{7}Li, α)^{12}B		

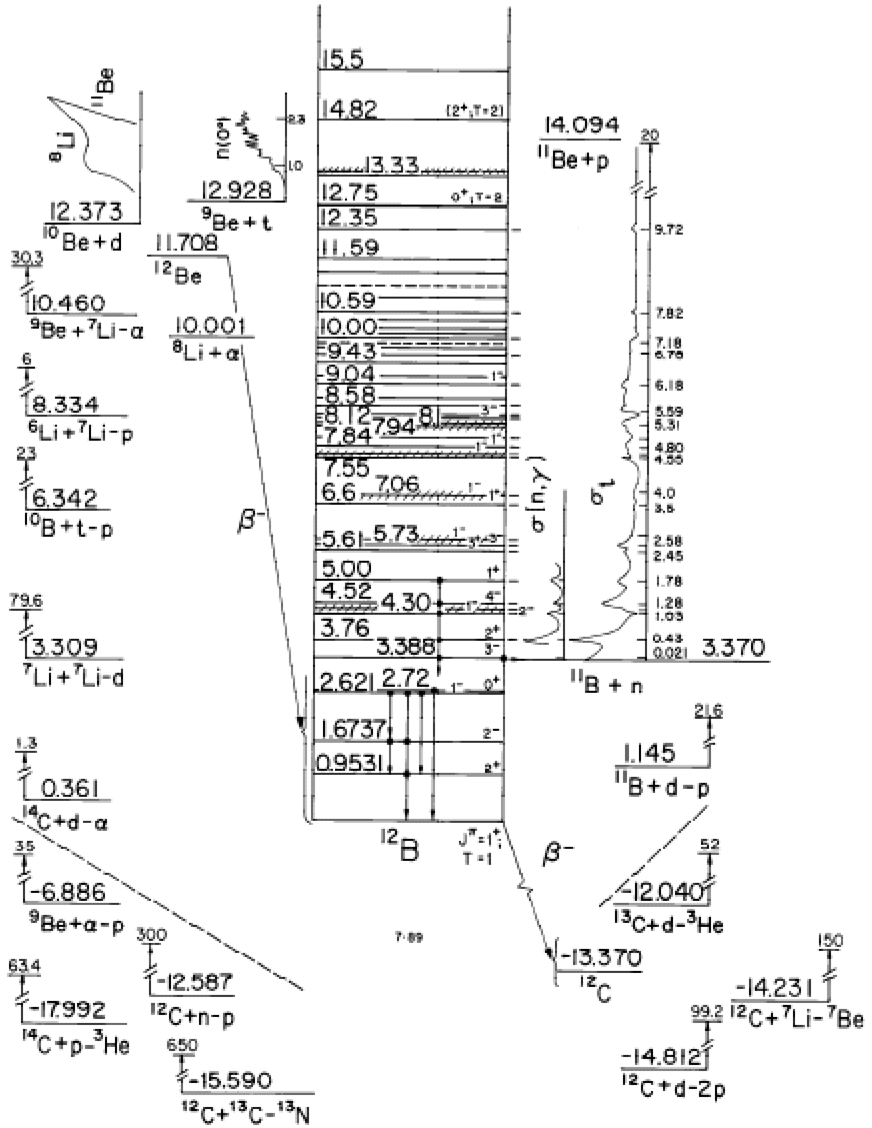
http://www.tunl.duke.edu/nucldata/HTML/A=12/12B_1990.shtml#28

Time measurement



Microchannel Plate



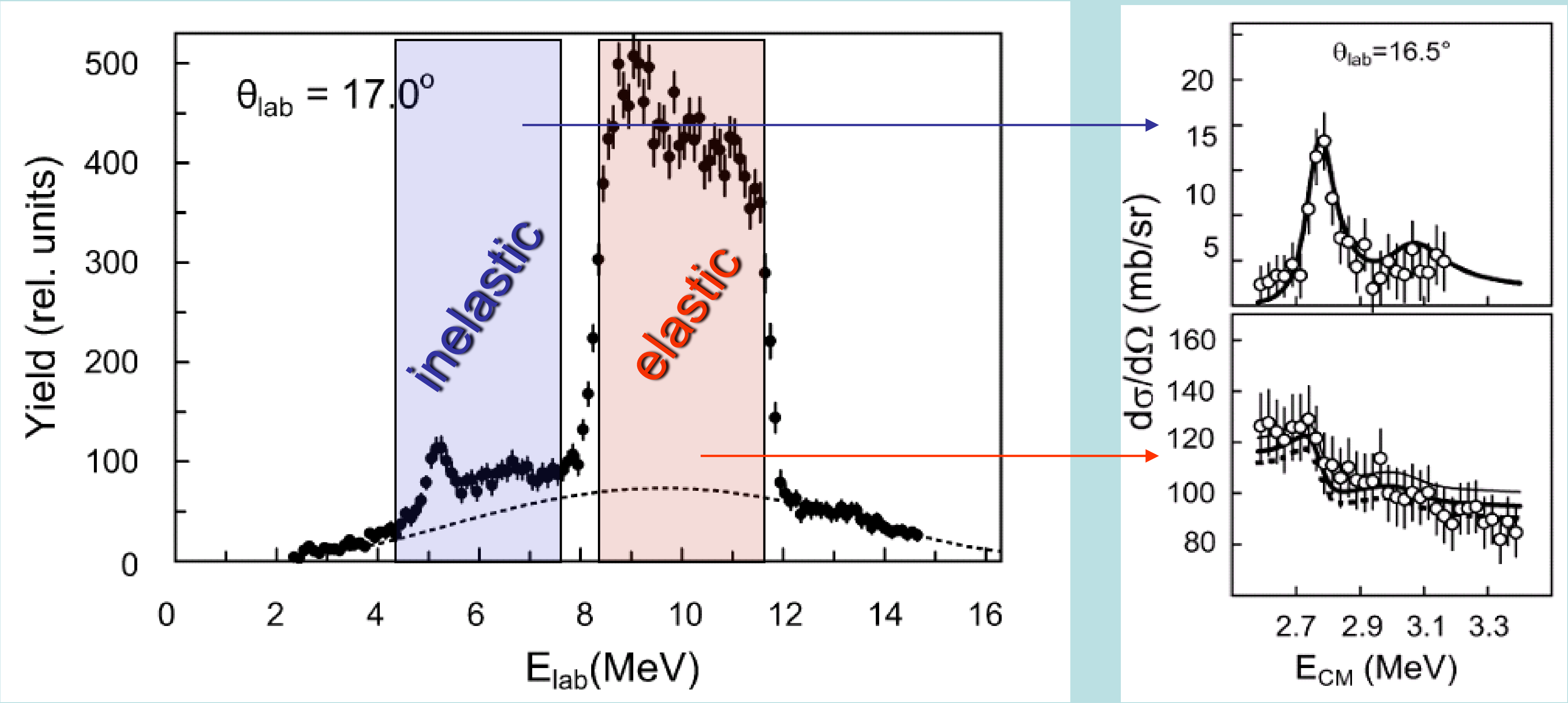


15.5
14.82
(2+,T=2)
13.33
12.75
0+,T=2
12.35
11.59
10.59
10.00
9.43
9.04
8.58
8.12
7.94
8.1
7.84
7.55
7.06
6.6
5.61
5.73
5.00
4.52
4.30
3.76
3.388
2.621
2.72
1.6737
0.9531
12B
Jπ=1+; T=1
β-
14.094
11Be+p
3.370
11B + n
σ(n,γ)
σt
20
9.72
7.82
7.18
6.78
6.18
5.59
5.31
4.80
4.55
4.0
3.5
2.58
2.45
1.78
1.28
1.03
0.43
0.021
21.6
1.145
11B+d-p
52
-12.040
13C+d-3He
-13.370
12C
150
-14.231
12C+7Li-7Be
99.2
-14.812
12C+d-2p
8Li
11Be
12.373
10Be+d
12.928
9Be+t
11.708
12Be
30.3
10.460
9Be+7Li-α
10.001
8Li+α
6
8.334
6Li+7Li-p
23
6.342
10B+t-p
79.6
3.309
7Li+7Li-d
1.3
0.361
14C+d-α
35
-6.886
9Be+α-p
300
-12.587
12C+n-p
63.4
-17.992
14C+p-3He
650
-15.590
12C+13C-13N
7-89

The choice of the target thickness

$^{18}Ne + p \rightarrow ^{19}Na^* \rightarrow p + ^{18}Ne$

66 MeV ^{18}Ne beam on a **2 mg/cm^2 $(CH_2)_n$ target**



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