# Inverse kinematics thick target method in order to investigate alpha-clustering in $^{212}$Po

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IV International Conference on

**Nuclear Structure and Dynamics • NSD2019**

*May 13-17, 2019 • Centro Culturale Don Orione Artigianelli, Venice • Italy*

# Outlook

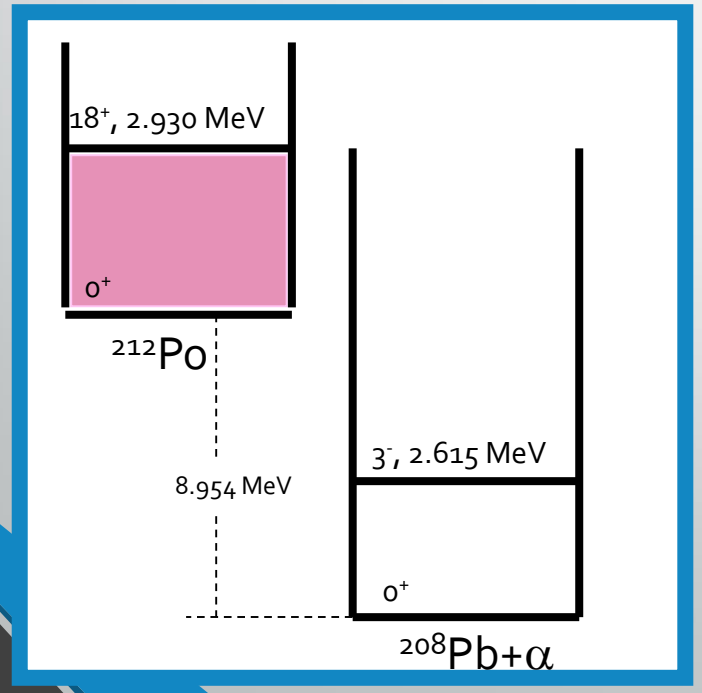
- A bit of History on nuclear clustering: **$^{212}$Po** case
- Resonant Elastic Scattering by using **Inverse Kinematics Thick Target Method** with heavy ions and time-of-flight technique
- **POLONIUM** experiment at INFN-LNS: $^{4}$He($^{208}$Pb,$\alpha$)$^{208}$Pb measurement
- Stopping power measurement of $^{208}$Pb on Helium gas
- Elastic scattering preliminary results
- Conclusions

# A bit of History

At the dawn of nuclear physics, the **α-particle was considered to be one of the basic building block** of nuclei (**cluster model**). Opposite to that picture, there was the single particle description of nuclei based on the hypothesis of a mean field for all nucleons (**shell model**).

A strong revival of the α-cluster model was in the 1960's for the understanding of the structure of light nuclei.

**A big interest has been devoted recently to heavy ions cases like $^{212}$Po**
(*see for review Zhongzhou Ren, Bo Zhou* ***Alpha-clustering effects in heavy nuclei*** *Front. Phys., 13 (2018), Article 132110*)




**Discovery of low-excited negative parity states in $^{212}$Po in the $E_x$ region below 3 MeV with very enhanced $E_1$ transitions by using $^{208}$Pb($^{18}$O,$^{14}$C)α transfer reaction.**

*A. Astier et al. PRL 104 (2010) 0427701*

These states are fingerprints of the α-$^{208}$Pb structure.

*Y.Suzuki and S. Ohkubo PRC 82 (2010) 041303(R)*

This experimental evidence has to be attributed to the strong contribution of an α-$^{208}$Pb($3^-$,2.615MeV) clustering.

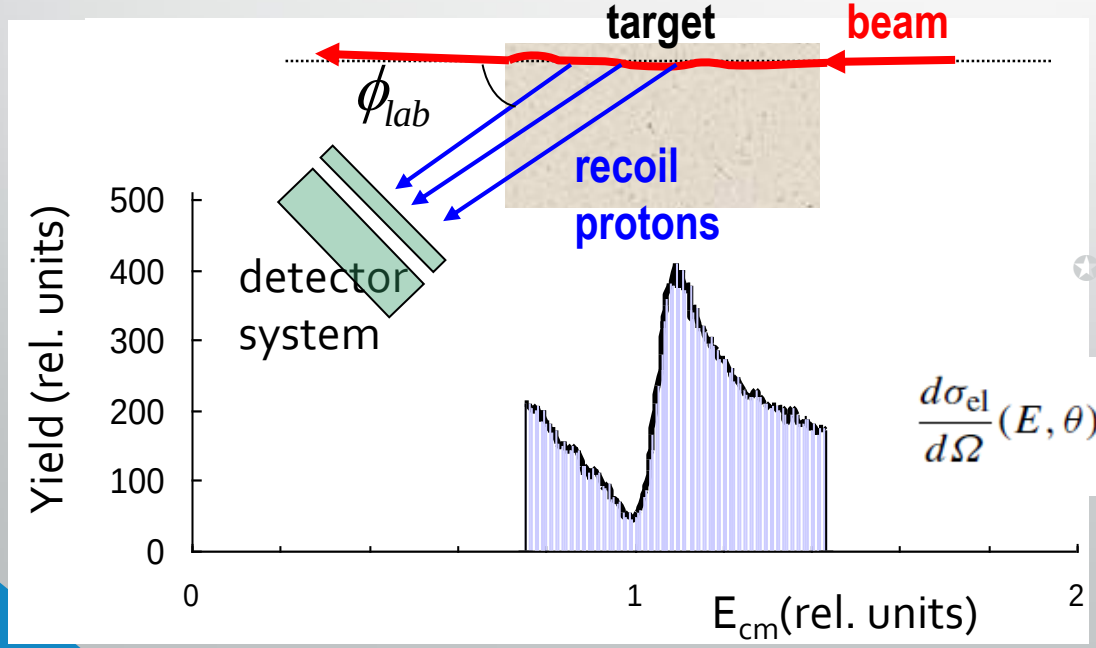
# Resonant elastic scattering by using the inverse kinematics thick target method

K. P. Artemov et al. Sov. J. Nucl. Phys. 52 (1990) 408
*V. Z. Goldberg et al. Phys. Rev. C 69 (2004) 024602*
*C. Angulo et al. PRC 67 (2003) 014308*

- Slowing-down of beam energy by using target **stopping power,**

provides a wide and continuous excitation function with a single beam energy.

- inverse kinematics → forward focused recoil particles (negligible energy loss in the target)
- recoil particle spectra → information on the resonance energy, orbital momentum, and particle width




- Interference effects are reflected in the spectrum

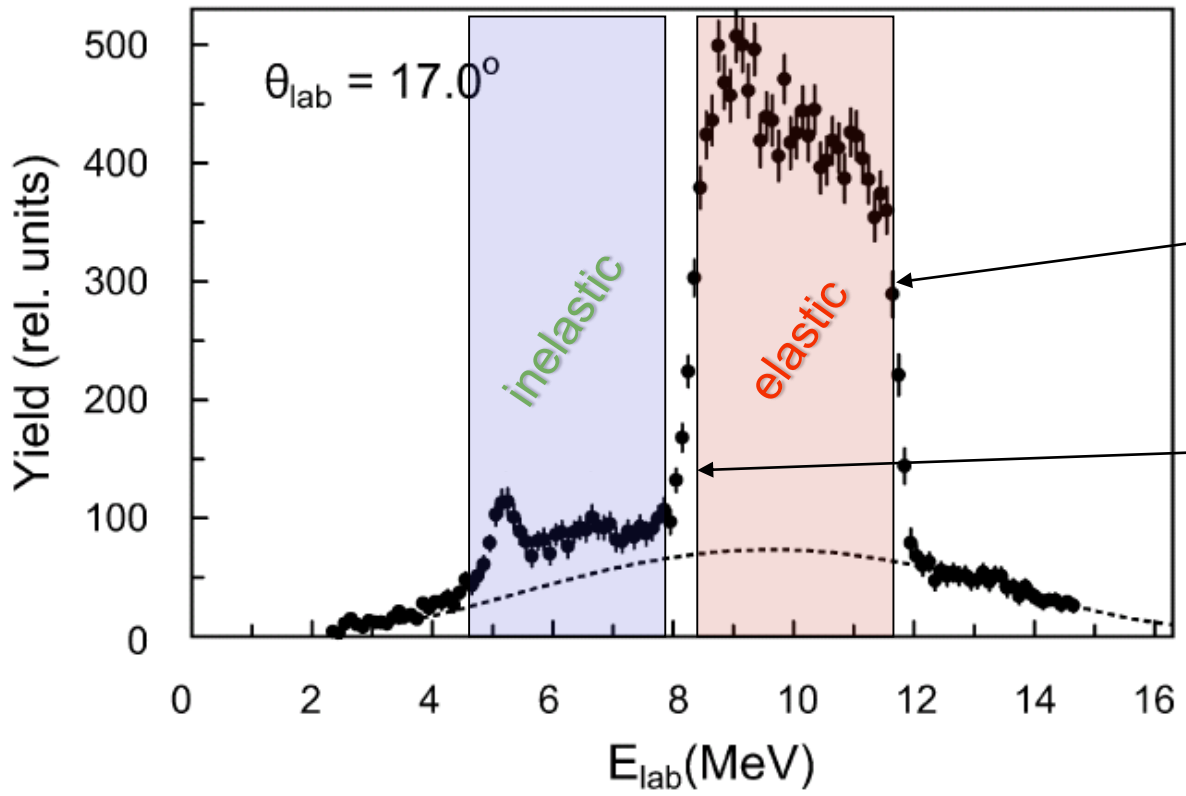
$$\frac{d\sigma_{el}}{d\Omega}(E,\theta) = \frac{1}{2}\sum_{\nu,\nu'}\left|f^{N}_{\nu,\nu'}(E,\theta) + f^{C}(E,\theta)\delta_{\nu\nu'}\right|^2$$

# 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

66 MeV $^{18}$Ne beam on a 2 mg/cm$^2$ $(CH_2)_n$ target to study ***H($^{18}$Ne, p)$^{18}$Ne$_{(g.s.)}$ and H($^{18}$Ne, p)$^{18}$Ne*$_{(2+,\ 1.887\ MeV)}$***



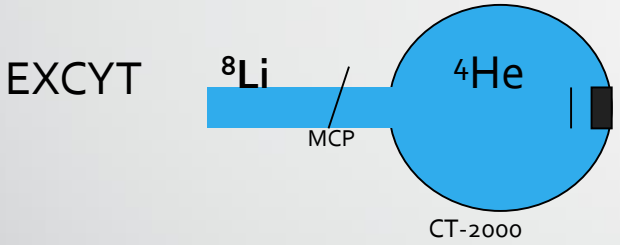

**High energy edge**: *first target layer* reaction induced at the initial $E_{beam}$

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

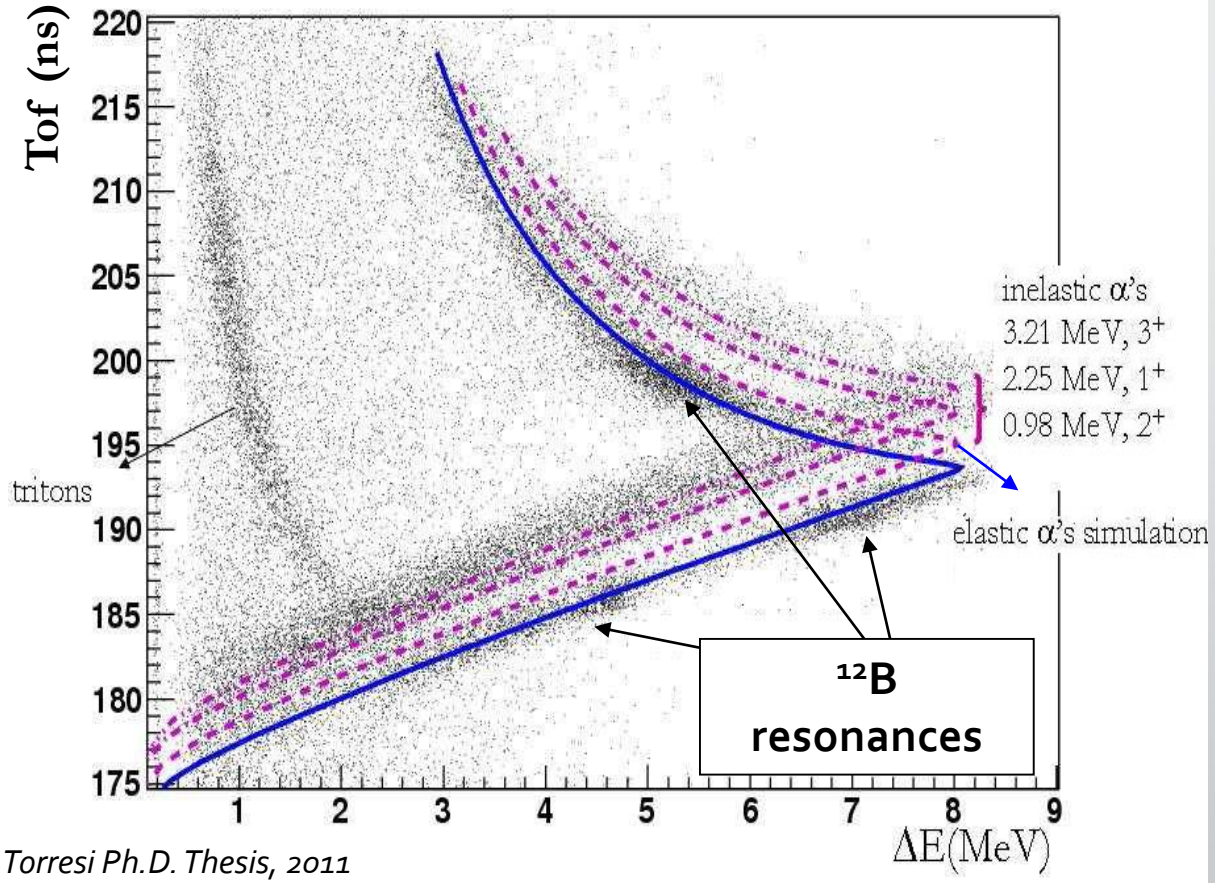
Pellegriti et al. PLB*659 (2008) 864*

# Disentangling elastic from inelastic events by using **extended** infinite thick target and **Time of Flight**

M. Zadro et al, NIM B 259 (2007) 836
Elastic scattering excitation function for the system $^{9}Be + \alpha$

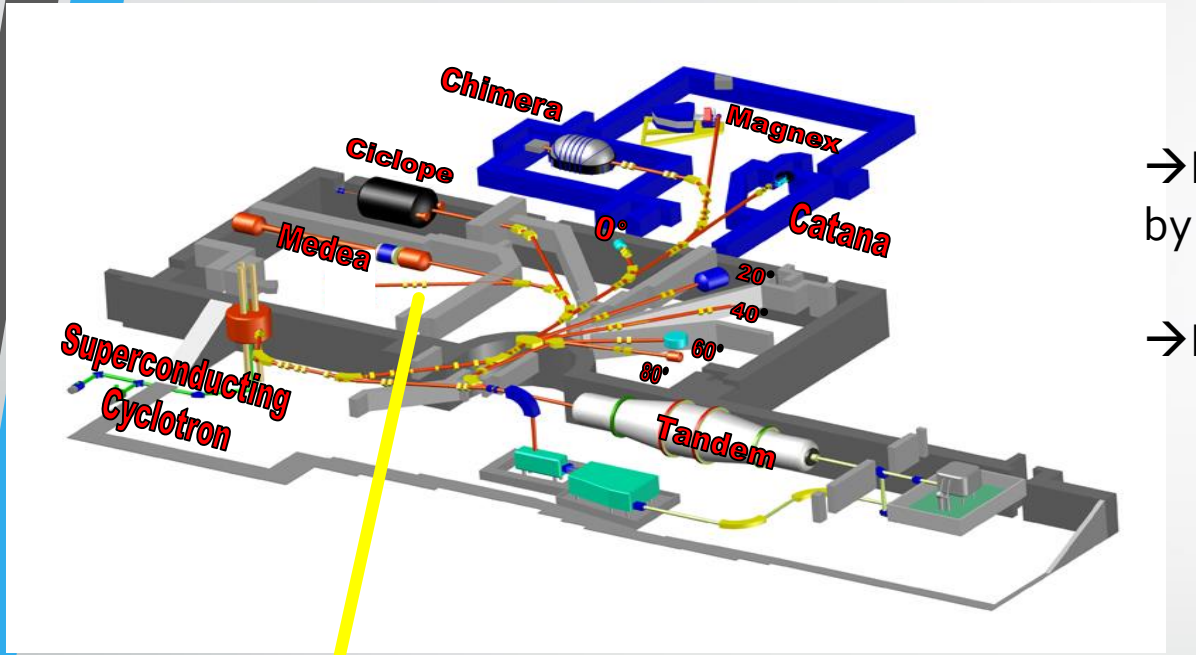



**$^{8}Li+^{4}He$ elastic scattering to investigate $^{12}B$**




*D. Torresi Ph.D. Thesis, 2011*

# **POLONIUM** experiment at INFN-LNS (C134 LNS proposal)




→First $^{208}$Pb beam produced by Serse source and accelerated by the LNS Cyclotron at 10.1 A MeV

→Experiment hosted in Sala Medea – linea ex-neutroni

beam line assembled for the experiment

Faraday cup  Line valve

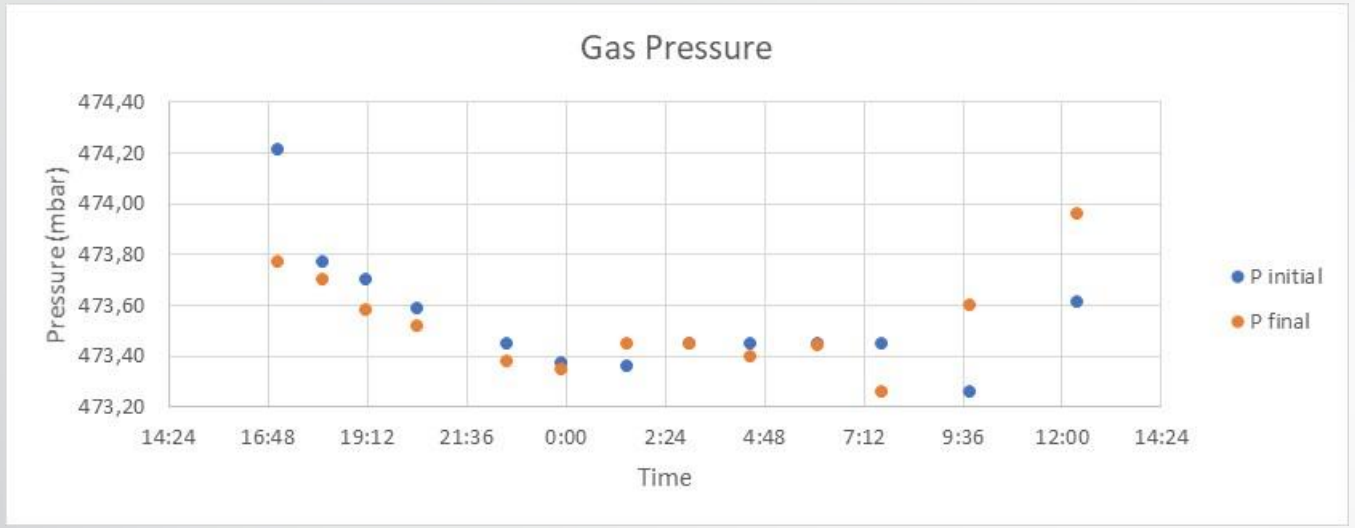
# Experimental apparatus

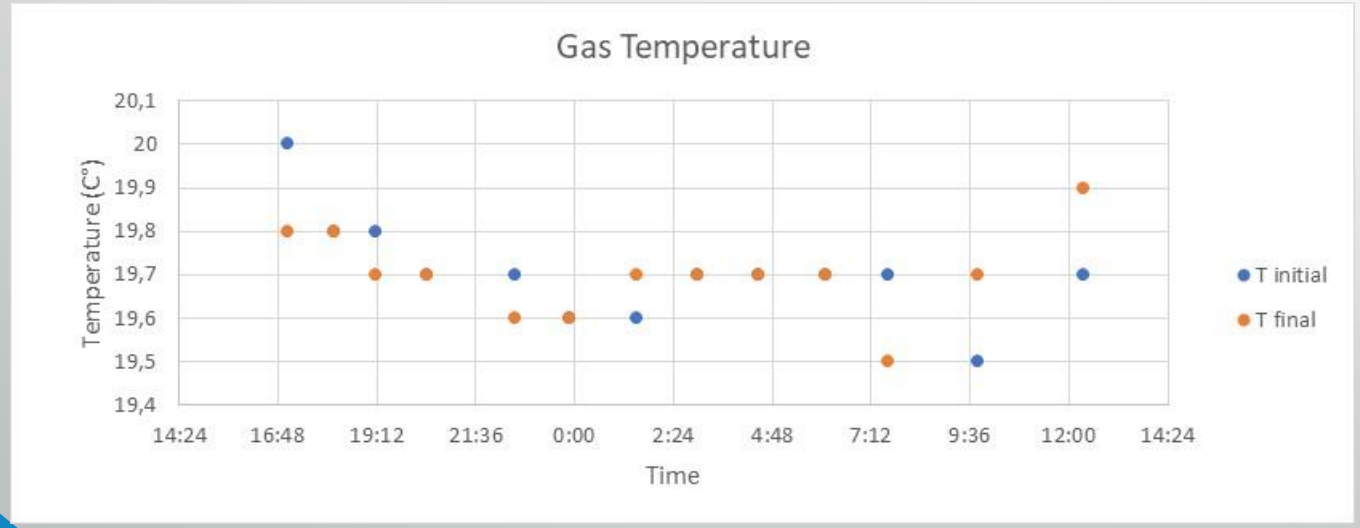




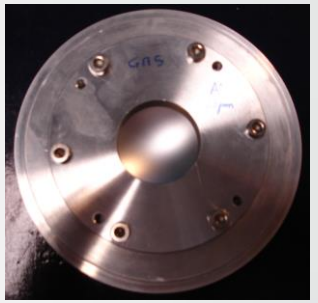

$E_{^{208}Pb\ (after\ Al\ window)}$= 1588MeV
$^{4}$He gas target lenght= 1834 mm
$P_{^{4}He\ gas}$=473 mbar

Pressure variation ~ 0.2% in one day
and correlated with temperature variation

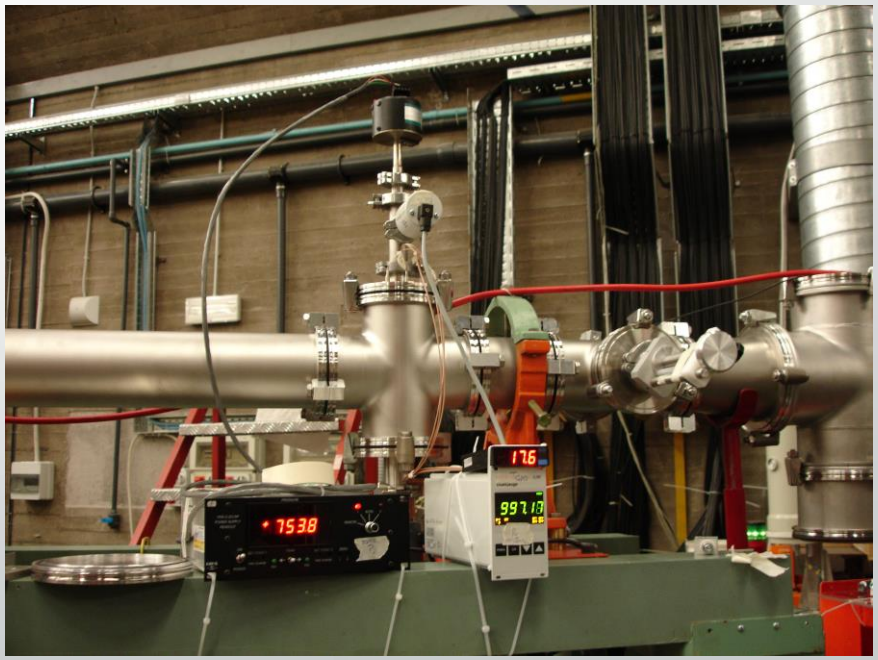



Al window
thickness= 20µm

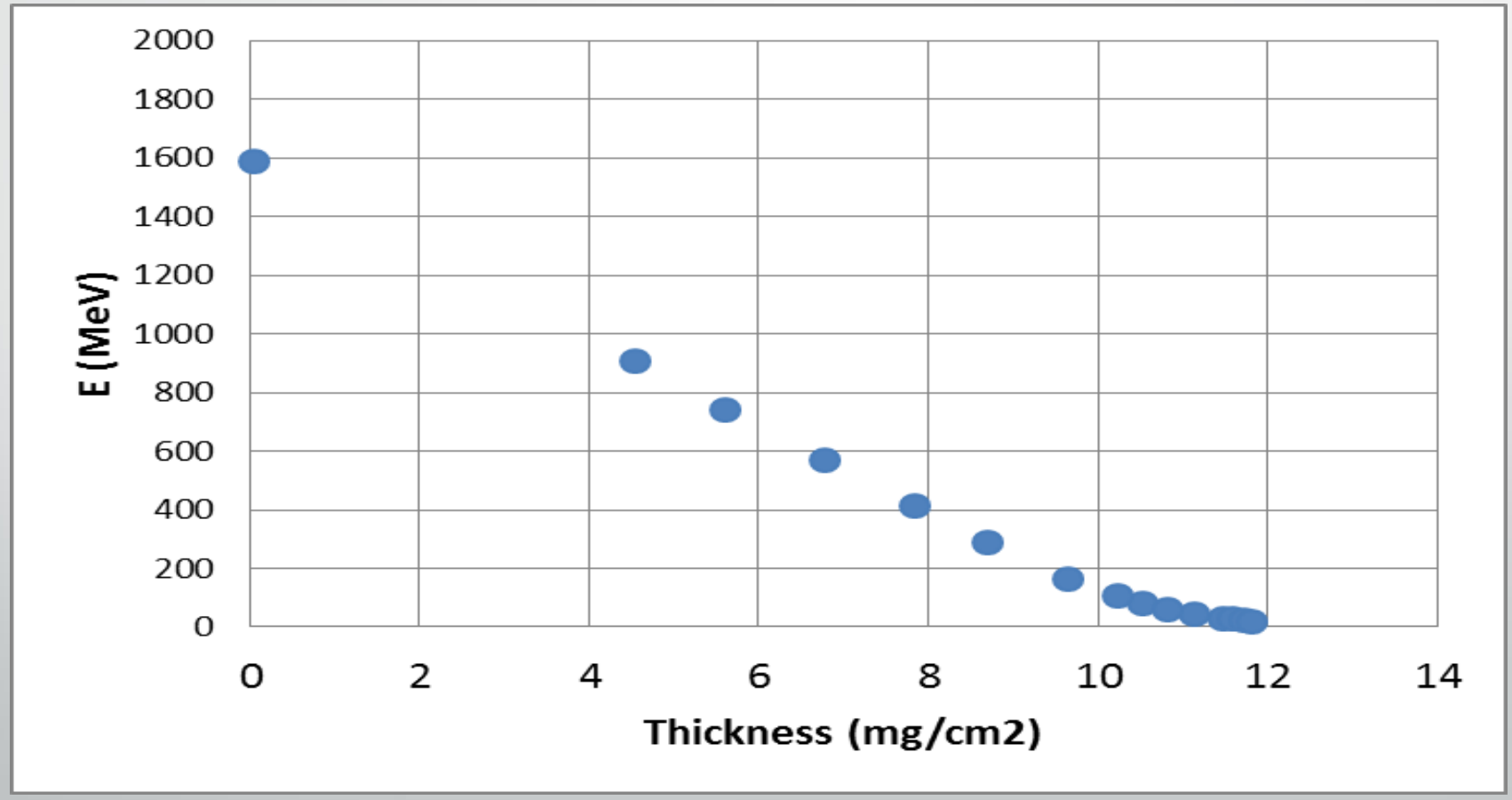


Al window holder designed by N. Salamone (LNS)

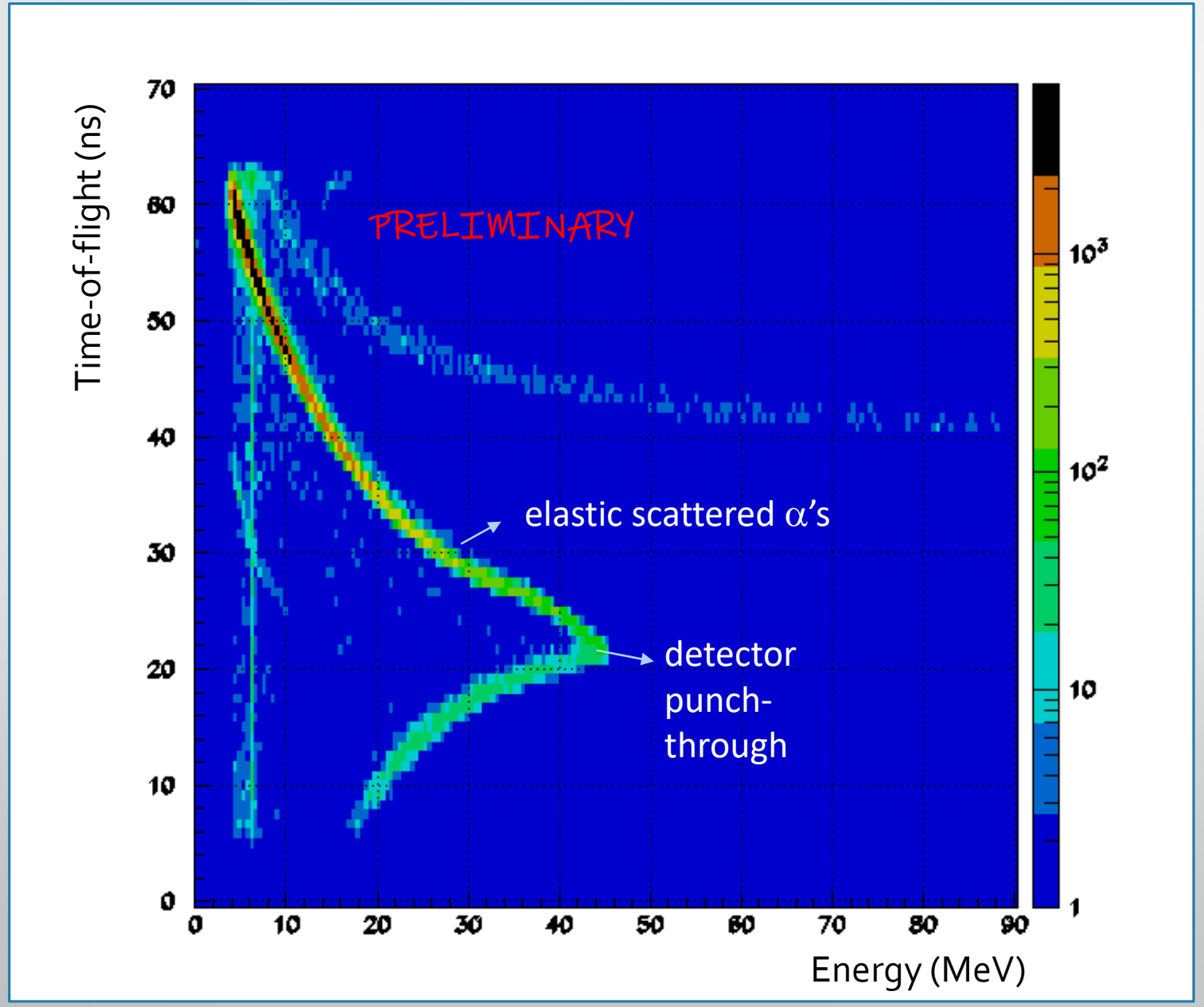


Pressure sensor: Absolute gauge MKS Baratron 122A
Temperature sensor: Pt100 probe

# Stopping power measurement of $^{208}Pb$ on $^{4}He$ gas



# Energy vs time-of-flight



# Conclusions - Remarks

- Inverse Kinematics Thick Target method has been successfully applied to study cluster structures in heavy nuclei
- $^{208}Pb$ stopping power measurements on $^{4}He$ gas
- Preliminary results of excitation function of $^{212}Po$ in the energy range from 2.5 to 11 MeV

To be done:

- Analysis to be completed with full statistics and energy loss corrections
- Monte Carlo simulation of the experiment
- R-matrix fit in order to extract resonances parameters


# Collaboration

**M.G. Pellegriti, A. Musumarra, M. De Napoli, A. Di Pietro, P. Figuera, M. Fisichella, C. Maiolino, D. Santonocito, V. Scuderi, E. Strano, D. Torresi**