COULOMB DISSOCIATION OF ^{27}P

USC
UNIVERSIDADE
DE SANTIAGO
DE COMPOSTELA

SAÚL BECEIRO NOVO

GENP
Grupo Experimental de Núcleos y Partículas

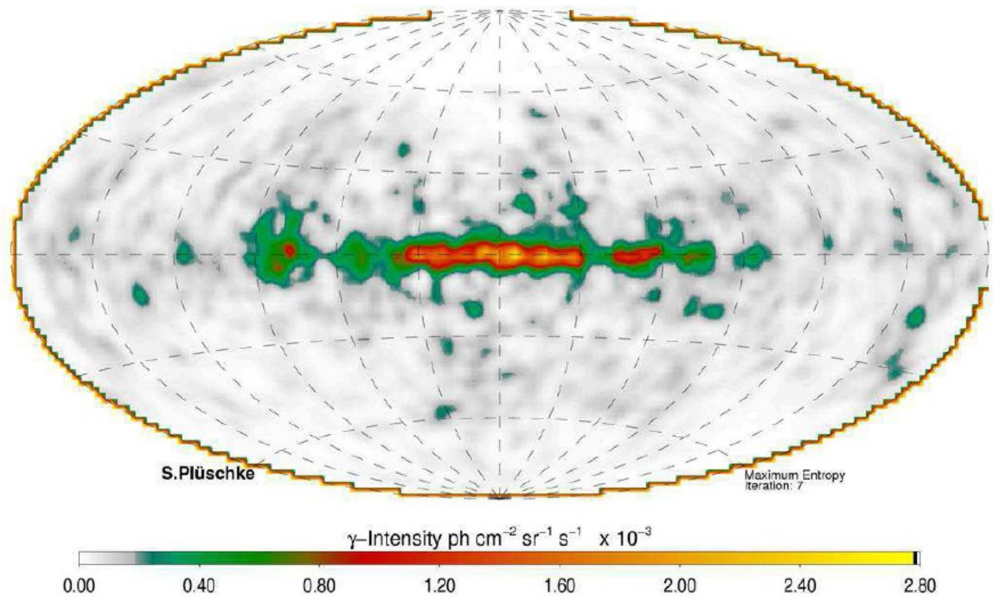
EFN2010

STARS: NUCLEOSYNTHESIS AGENTS

- In 1940's some models assumed that nuclei had been produced in a fireball in the early Universe, however those models failed to explain the experimental observation that stars do not have the same surface composition, suggesting that they must be nucleosynthesis agents

- Cosmic gamma ray measurements help to prove this nucleosynthesis in the stars

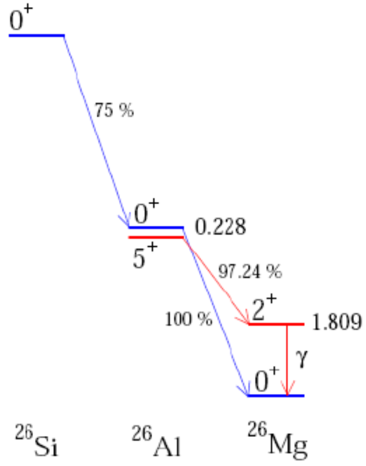
^{26}Al in interstellar medium



-Characteristic γ-lines measurements allow the detection of different nuclei

- The detection of short-life species will clearly show that the nucleosynthesis is still working in stars

- γ-rays from the decay of the unstable ^{26}Al (half life 1,05 million years) were the first evidence of nucleosynthesis still going on in stars.



- A mapping of the Galaxy was done for photons in the region of 1,8MeV (The ^{26}Al decays into ^{26}Mg emitting a photon of 1,809MeV) concluding that ^{26}Al is mainly produced in massive stars and supernovae and novae.

-Nuclear reactions in the neighbourhood of ^{26}Al may help to clarify the scenario

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

GENP Grupo Experimental de Núcleos y Partículas

Production of ^{26}Al through ^{26}Si in rp process

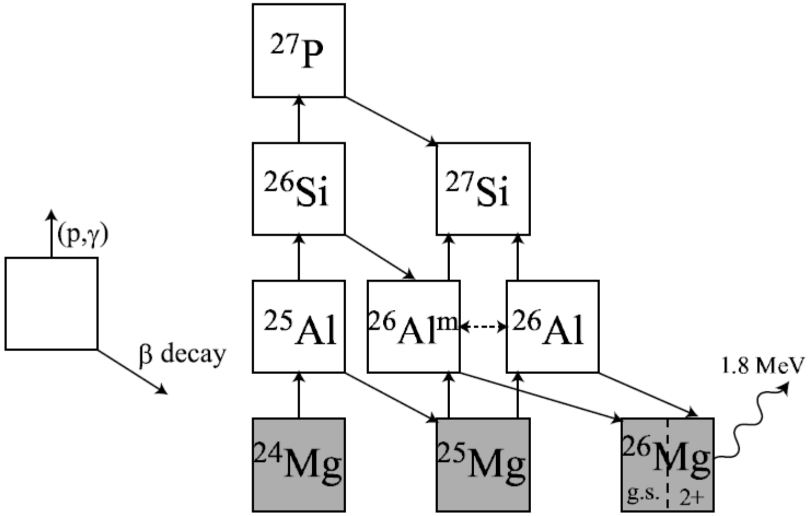
Nucleosynthesis in hydrogen burning scenarios with T>0,3Gk is characterized by rp-process

. ^{26}Al reaction flow: we need to know:

- ^{25}Al and ^{26}Si β+ decay lifetime
- Cross sections: ^{25}Al(p,γ)^{26}Si and ^{26}Si(p,γ)^{27}P

. 3 possibilities after ^{25}Al is produced:

1. ^{25}Al β+ decays to ^{25}Mg (no ^{26}Si produced)
2. ^{26}Si produced via ^{25}Al(p,γ)^{26}Si ->β+ decay to ^{26}Al^m
3. ^{26}Si produced and destructed via ^{26}Si(p,γ)^{27}P



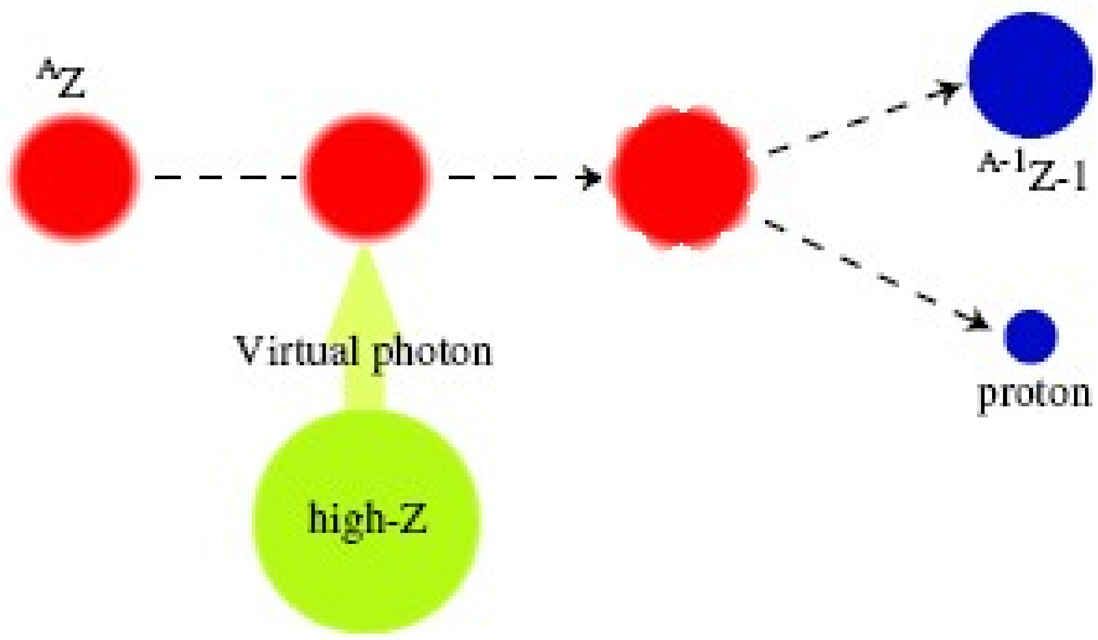
The process 1 occurs if ^{25}Al(p,γ)^{26}Si is slower than the ^{25}Al beta decay. The competition between β+ decay of ^{26}Al and the reaction ^{26}Si(p,γ)^{27}P determine if 2 or 3 proceed

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

GENP Grupo Experimental de Núcleos y Partículas

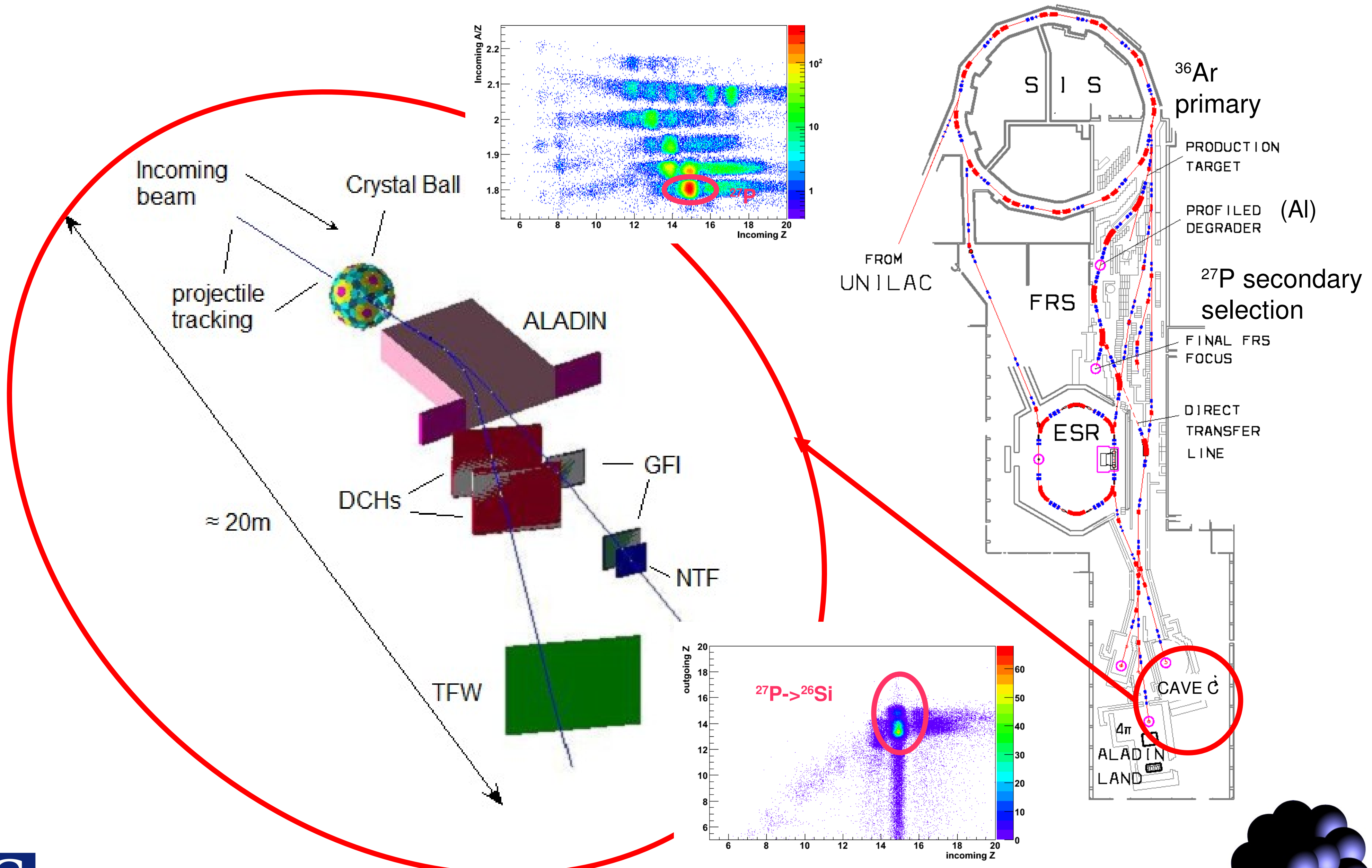
Coulomb dissociation

$^{26}Si(p,\gamma)^{27}P$ direct measurement needs a ^{26}Si beam of 300KeV, whose cross section would be tiny recquiring huge intensities. An indirect method is needed: Coulomb dissociation. In this method, the nuclear Coulomb field is used as a source of the photodisintegration processes. The inverse process is considered γ+a->b+p



Phase volume of (γ,p) is much larger than for (p,γ) -> larger cross section

ALADIN LAND setup at GSI for the C.D.



USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

GENP Grupo Experimental de Núcleos y Partículas

Invariant mass and relative energy

The invariant mass of a multi-particle final state can be expressed as:

$$M = \sqrt{\left(\sum_i E_i\right)^2 - \left(\sum_i \vec{P}_i\right)^2} = E_{decay} + \sum_i m_i$$

In the case of a two-body system de decay energy is exactly the relative energy between both particles, thus, for our reaction:

$$E_{rel} = M - (m_1 + m_2) = \frac{T_1 T_2 \left(\frac{\vec{p}_1}{T_1} - \frac{\vec{p}_2}{T_2}\right)^2}{\sqrt{(m_1+m_2)^2 + T_1 T_2 \left(\frac{\vec{p}_1}{T_1} - \frac{\vec{p}_2}{T_2}\right)^2} + (m_1+m_2)}$$

The study of the relative energy of the outgoing fragments gives then information regarding the excitation states of the incoming nucleus. (Eexc=Erel+Sp, where Sp is the separation energy of the last proton)

Previous results at RIKEN

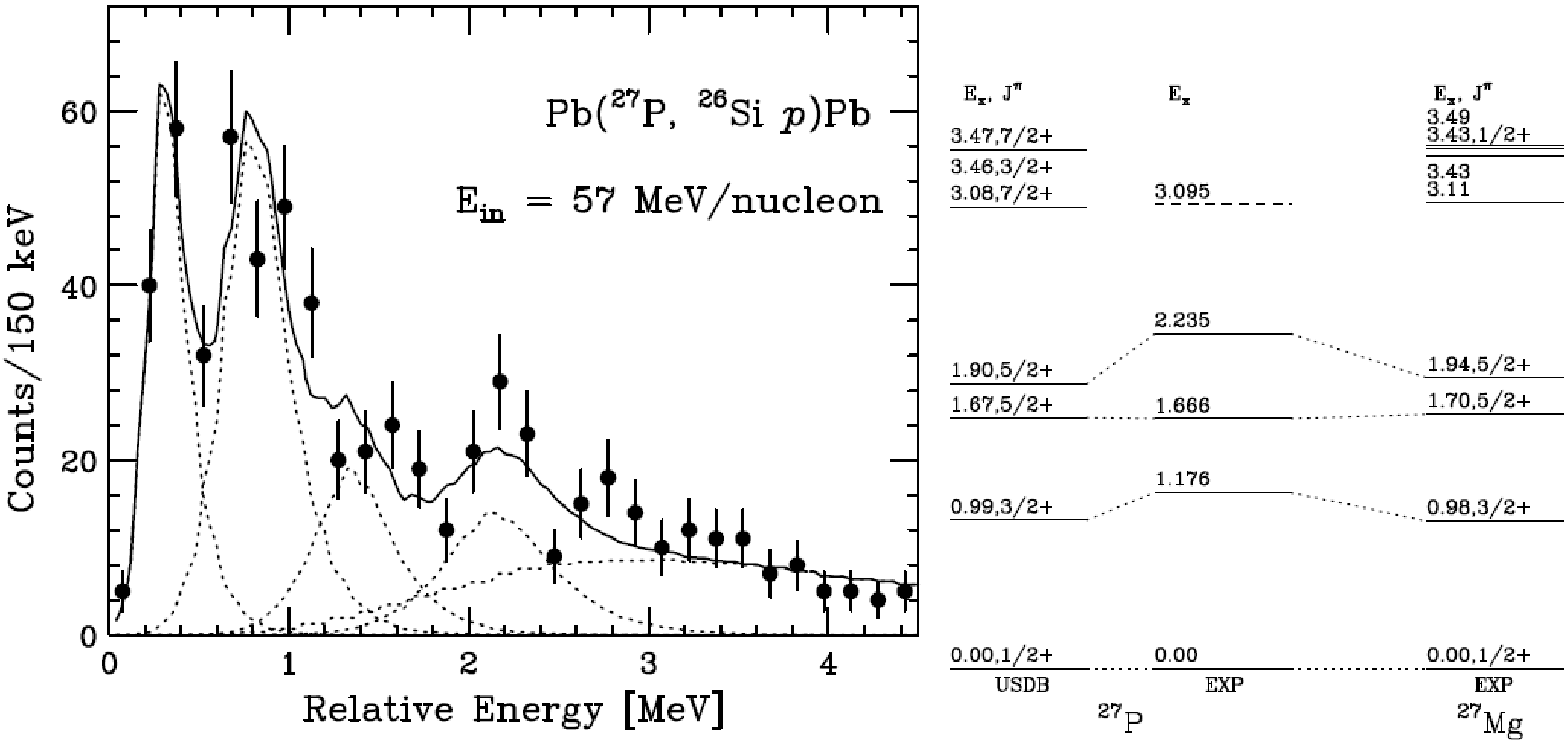
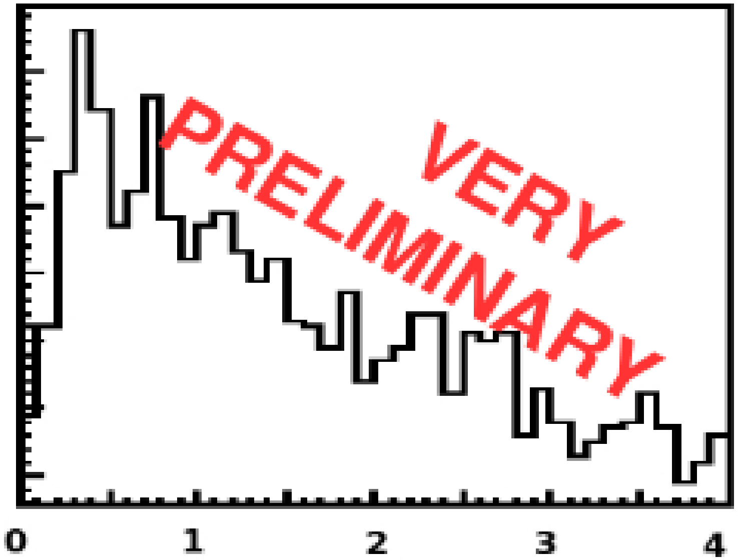


Figure 4.2: Relative energy spectrum of the Pb(^{27}P,^{26}Si p)Pb reaction measured with radioactive ^{27}P beam of 57 MeV/nucleon incident energy. Filled circles shows the experimental data. The solid curve represents the best fit by the five components shown individually by the dotted curves which represent four excited states and a direct capture component.

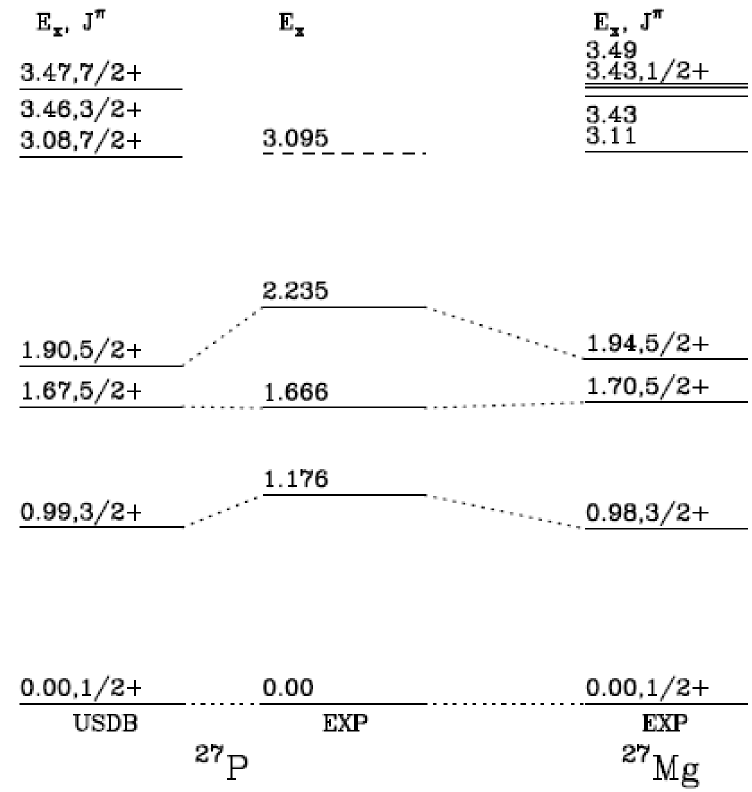
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

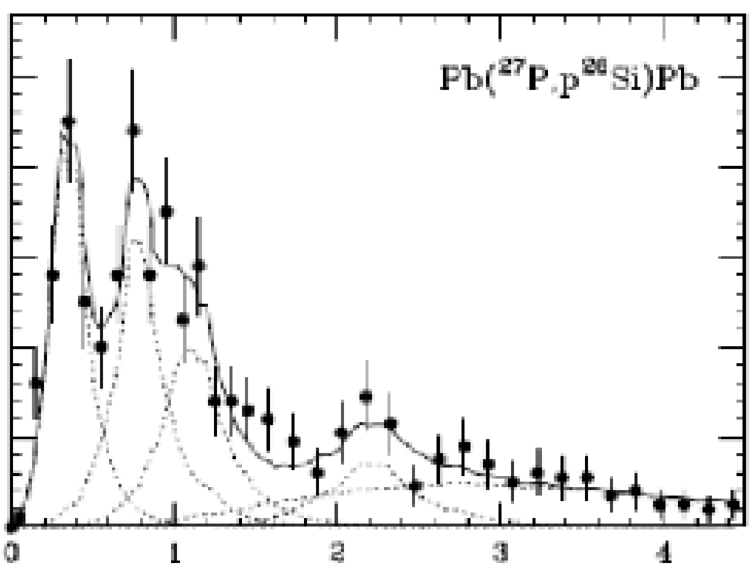
Grupo Experimental de Núcleos y Partículas

Our preliminary results:



@500 AMeV





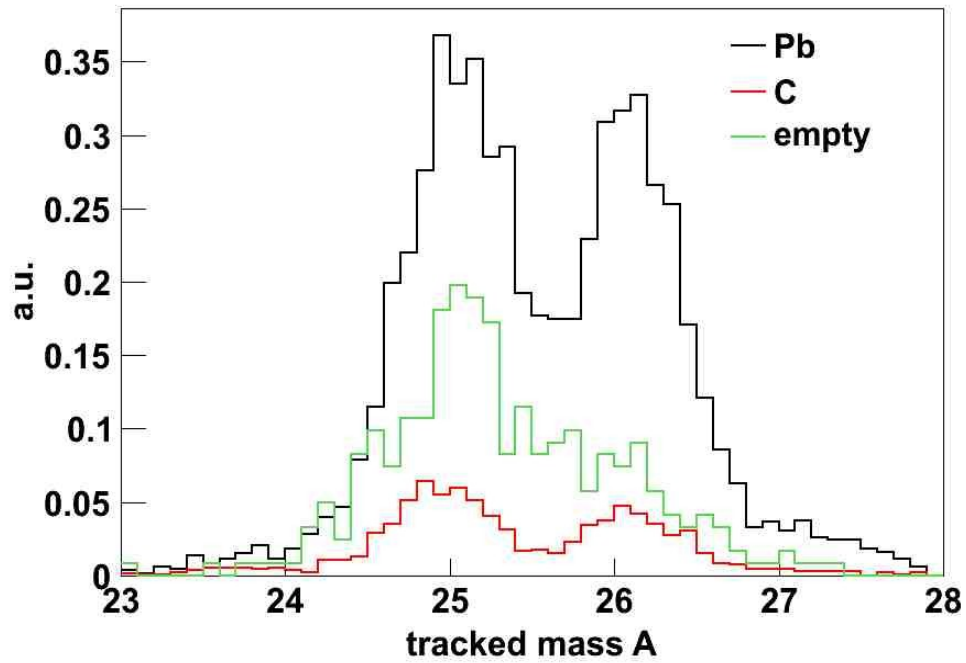
@57 AMeV

Relative Energy (MeV)

The measurement at different energy regimes has shown an important role in previous C.D experiments (^{8}B)

Cross section

To estimate the C.D. cross section the nuclear component and background have to be subtracted. For this measurements with carbon target and empty were performed.



A cross section of 106±5mb was measured (98mb theoretically expected) (S. Typel)

$$\alpha = \frac{A_{proj}^{1/3} + A_{Pb}^{1/3}}{A_{proj}^{1/3} + A_{C}^{1/3}}$$

$$\sigma_{CD} = p_{Pb}\frac{M_{Pb}}{d_{Pb}N_{Av}} - p_C\alpha\frac{M_C}{d_C N_{Av}} - p_{empty}\left(\frac{M_{Pb}}{d_{Pb}N_{Av}} - \alpha\frac{M_c}{d_C N_{Av}}\right)$$

(p_i=ratio of selected events for target i versus incoming ^{27}P and d_i=thickness of target i)

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

GENP Grupo Experimental de Núcleos y Partículas

Summary

^{27}P Coulomb dissociation is a good indirect method for measuring the astrophysical reaction $^{26}Si(p,\gamma)^{27}P$ which is very hard to measure directly in the lab due to the very low cross sections involved.

The reaction is in the production path of ^{26}Al, of great astrophysical interest as it is one of the species which prove that the nucleosynthesis is still going on in stars

The very preliminary relative energy spectra we got looks very promising when compared to previous measurements. Further studies are needed in order to get astrophysical conclusions.

Many thanks to the S223 colaboration

Saúl Beceiro (1), K. Sümmerer (2), D. Cortina-Gil (1)

H. Alvarez-Pol (1), T. Aumann (2), K. Behr (2), K. Boretzky (2), E. Casarejos (1), A. Chatillon (2), U. Datta-Pramanik (3), Z. Elekes (4), Z. Fulop (4), D. Galaviz (5), H. Geissel (2), S. Giron (2), U. Greife (6), F. Hammache (7), M. Heil (2), J. Hoffman (2), H. Johansson (8), C. Karagiannis (2), O. Kiselev (2), N. Kurz (2), K. Larsson (2), T. Le Bleis (2), Y. Litvinov (2), K. Mahata (2), C. Muentz (9), C. Nociforo (2), W. Ott (2), S. Paschalis (10), R. Plag (2), W. Prokopowicz (11) , C. Rodríguez-Tajes (1), D. Rossi (12), H. Simon (2), M. Stanoiu (2), J. Stroth (9), S. Typel (13), A. Wagner (14), F. Wamers (2), H. Weick (2), C. Wimmer (9)

(1) Universidade de Santiago de Compostela, Spain
(2) GSI, Gesellschaft für Schwerionenforschung, Germany
(3) SINP (India)
(4) ATOMKI (Debrecen)
(5) CSIC (Madrid)
(6) Colorado School of Mines (USA)
(7) IPN Orsay (France)
(8) Chalmers I.T. (Sweeden)
(9) Uni. Frankfurt (Germany)
(10) Uni Liverpool (UK)
(11) Uni Krakow (Poland)
(12)University of Mainz (Germany)
(13) GANIL (France)
(14) FZ Rossendorf (Germany)

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

GENP Grupo Experimental de Núcleos y Partículas