BACKWARD EMISSION OF ENERGETIC PROTONS
M. Avan, A. Baldit, J. Castor, G. Chaigne, A. Devaux, J. Fargeix, P. Force,
G. Landaud, G. Roche, J. Vicente, et al.

To cite this version:
M. Avan, A. Baldit, J. Castor, G. Chaigne, A. Devaux, et al.. BACKWARD EMISSION
<10.1051/jphyscol:1984403>. <jpa-00224068>
BACKWARD EMISSION OF ENERGETIC PROTONS


Laboratoire de Physique Corpusculaire, B.P. 45, 63170 Aubière, France
*Institut de Physique Nucléaire, B.P. 1, 91406 Orsay Cedex, France

Résumé - Nous avons mesuré les sections efficaces inclusives de production de protons énergétiques (80-180 MeV) à grand angle (76°, 102°) induites par des protons de 200 MeV frappant des cibles de $^6$Li, $^{27}$Al, $^{28}$Si, $^{58}$Ni et $^{197}$Au. Les données ont été interprétées en utilisant la représentation du "Quasi Two Body Scaling" et également comparées aux prédictions d'un modèle de cascades nucléaires classique.

Abstract - Backward energetic proton inclusive cross sections were measured for 200 MeV protons hitting $^6$Li, $^{27}$Al, $^{28}$Si, $^{58}$Ni and $^{197}$Au targets. The data are analyzed using the Quasi Two Body Scaling picture and also compared with the predictions of a standard cascade code. (Outgoing proton energy : 80-180 MeV ; scattering angle : 76°, 102°).

Backward energetic proton inclusive cross sections were measured for 200 MeV protons on $^6$Li, $^{27}$Al, $^{28}$Si, $^{58}$Ni and $^{197}$Au targets using the Orsay synchrocyclotron accelerator (Fig. 1).

Fig. 1 - Inclusive proton spectra as a function of outgoing proton energy at mean angle (102°) for $^6$Li (o), $^{27}$Al (A), $^{58}$Ni (●), $^{197}$Au (▲).

Such measurements have been performed by other experimentalists with various beams (electrons, protons and heavy ions) in a wide range of energies (100 MeV to 1 GeV/
nucleon) but the measurements of the scattered proton are mostly performed with energy up to half value of the incident energy. In order to study the relevance of the various proposed mechanisms (knock-out on clusters, nuclear cascades, single scattering on nucleons with large Fermi momentum ...), we are studying energetic protons up to the kinematic limit.

The experimental set-up /1,2,3/ needs to have a large acceptance both in momentum (300 - 700 MeV/c) and angle (\( \sim 10^\circ \)). A bending magnet (1 m x 1 m area) with two multiwire proportionnal chambers is sufficient to reconstruct the trajectories (using the beam spot on the target as origin) and provides an energy resolution of 2 MeV (FWHM).

Particle identification is obtained using a Time of Flight Technique. To check all calibrations (momentum, acceptance, efficiency) data at forward angles (18\(^\circ\) - 24\(^\circ\)) were recorded with a CH\(_2\) target to get the free p-p elastic cross section (Fig. 2) before moving the whole system to backward regions (80\(^\circ\) - 110\(^\circ\)).

![Fig. 2 - Proton-proton elastic scattering differential cross section as a function of the scattering angle.](image)

**Fig. 2** - Proton-proton elastic scattering differential cross section as a function of the scattering angle. (•) our data (•) phase shift analysis (200 MeV).

A classical analysis of the backward data is given in term of a standard cascade code /3,4,5,6/. It has been possible to reproduce qualitatively the data obtained with \(^{197}\)Au target and 200 MeV incident protons (Fig. 3).

Unfortunately, when using a Fermi gas model, high nucleon momenta are not included in the calculation. In our case (200 MeV - \(^{197}\)Au), the Fermi momentum distribution is limited to 300 MeV/c.

In the most recent theoretical approach developed by Gurvitz /7,8/ a large amount of data pA → p'X, A\(_1\)A\(_2\) → p'X taken with high incident energy 0.6 - 1.0 GeV/A and 90\(^\circ\) < \( \theta' \) < 180\(^\circ\) (\( \theta' \) scattering angle) shows an universal one nucleon momentum density distribution \( n(k) \) which appears to be the same for medium and heavy nuclei (\( A \geq 20 \)). The Quasi Two Body Scaling (QTBBS) is an interesting approach.

The experimental inclusive cross sections are expressed in terms of on-shell pp, pn cross section and a quantity \( G(k_{\text{min}}) \). \( G(k_{\text{min}}) \), for a single scattering mechanism simply reads:

\[
G(k_{\text{min}}) = \frac{1}{\pi} \int_{k_{\text{min}}}^{\infty} n(k) \, dk
\]

\( k_{\text{min}} \) is the minimum momentum of the struck nucleon N in the reaction p + N → p' + N'.

On Fig. 4, we have plotted (full line) the "universal" \( G(k_{\text{min}}) \) fitting a large amount of high energy data. Clearly a scaling regime is reached.
Fig. 3 - Solid curve - experimental data. Dots with statistical error - predictions of a cascade code.

Fig. 4 - Solid curve is the "integrated distribution" \( G(k_{\text{min}}) \) fitting high energy data. The values of \( G(k_{\text{min}}) \) obtained from: our data (200 MeV proton) for \(^6\text{Li} (\blacktriangledown), \, ^{27}\text{Al} (\blacktriangle), \, ^{58}\text{Ni} (\triangledown) \) and \(^{197}\text{Au} (\blacklozenge) \), at 102°.
Cordell data (180 MeV/nucleon) for \(^{181}\text{Ta} \) at three angles (120° (■), 150° (□) and 90° (×)).
Electron data for \(^4\text{He} (\circ) \) and \(^{14}\text{N} (+) \).
We have also plotted $G(k_{\text{min}})$ extracted from our data /9/ and from other ones /10,11/. A scaling regime is also reached at incident energies of about 200 MeV. However this last regime is different from the one observed above 600 MeV/A (high energies data) /9/.

This may question the existence of a significant amount of a large momentum component in nuclei /9/. Up to now, QTBS theory includes final state interaction but neglects distortion of the incident proton and struck nucleon.

We are at the moment beginning a p-$\gamma$ coincidence experiment. We measure the $\gamma$ ray emitted by the residual nucleus using a High Purity Ge detector in coincidence with the backward scattered proton. The identification of the residual nuclei provides precise informations on the amount of excitation transferred to the system, which in turn should enlighten the interaction mechanisms. Preliminary results are shown in Figure 5 where all the residual nucleus contributions have been added (target $^{28}$Si, scattering angle 76°).

Fig. 5 - Inclusive proton spectrum versus outgoing proton energy (●) - p-$\gamma$ coincidence spectrum versus outgoing proton energy.

REFERENCES
(2) LEBRUN C. et al., Nucl. Instr. Meth., 165 (1979) 409
(6) BARASHENKOV V.S. et al., Nucl. Phys., A187 (1972) 531
(8) GURVITZ S.A., Report WIS-82/7 March-PH 
(9) AVAN M., BALDIT A., CASTOR J., CHAIGNE G., DEVAUX A., FARGEIX J., FORCE P., 
LANAUD G., ROCHE G., VICENTE J., 
J.P. DIDELEZ, F. REIDE 
S.A. GURVITZ, to be submitted to Phys. Rev. 
(10) CORDELL K.R., THORNTON S.T., DENNIS L.C., DOERING R.R., PARKS R.L. and 