KEK Preprint 94-70
August 1994
H

Energy Spectra and Angular Distribution of Intermediate Mass Fragments Emitted in Au/Ag(p,X) Reactions with Ep = 12 GeV

(The first result of the KEK - 12 GeV - PS experiments; E288)

K.H. TANAKA, Y. YAMANOI, H. OCHIISHI, H. AKIYOSHI, S. KOUDA,
H. NAKAMURA, S. MORINOBU, Y. TANAKA, K. KIMURA, T. SHIBATA,
Y. SUGAYA, K. YASUDA, H. ITO and T. MURAKAMI

*Presented at the 5th International Conference on Nucleus Nucleus Collisions,
Taormina, Italy, 30 May - 4 June, 1994.
(to be published as a special issue of Nuclear Physics A)*

Energy spectra and angular distribution of intermediate mass fragments emitted in Au/Ag(p,X) reactions with Ep = 12 GeV (The first result of the KEK-12GeV-PS experiment; E288)

K.H. Tanaka[a], Y. Yamanoi[a], H. Ochiishi[b], H. Akiyoshi[b], S. Kouda[b], H. Nakamura[b], S. Morinobu[b], Y. Tanaka[c], K. Kimura[c], T. Shibata[d], Y. Sugaya[e], K. Yasuda[f], H. Ito[f], and T. Murakami[f]

(a) KEK, National Laboratory for High Energy Physics, Tsukuba, 305 Japan
(b) Department of Physics, Kyushu University, Fukuoka, 812 Japan
(c) Nagasaki Institute for applied Science, Nagasaki, 851-01 Japan
(d) Institute for Nuclear Study, University of Tokyo, Tokyo, 188 Japan
(e) Tokyo University of Agriculture and Technology, Tokyo, 184 Japan.
(f) Department of Physics, Kyoto University, Kyoto, 606 Japan

Abstract

The latest results of the first nuclear multifragmentation experiment, E288 [1], at the KEK 12 GeV Proton Synchrotron (KEK-PS) are presented. The energy spectra of intermediate mass fragments (IMFs) were measured inclusively from 30° to 150° with 20° step in the lab. system. Coincidence measurements with one extra IMF emitted toward 90° direction in the opposite hemisphere were performed at the same time. Characteristic sideward flow of IMFs toward 70° direction was found with the usual isotropic component. This isotropic component was strongly suppressed in the coincidence measurement. These facts may indicate the formation of unusually shaped nuclear matter such as an expanding toroid.

1: INTRODUCTION

E288 aims to study the production mechanism of intermediate mass fragments (IMFs) in the light-ion induced reactions at the KEK-PS energies, i.e. an energy range of several GeV/nucleon, where the nuclear multifragmentation is considered to be the main process of the IMF production and several very interesting phenomena have been previously reported by means of inclusive IMF detections[2,3,4].

Nuclear multifragmentation is, so far, usually studied by medium-energy (~100MeV/u) heavy-ion induced reactions. However, we recognized that there are several advantages to use high-energy light-ions as a projectile to study the nuclear multifragmentation as summarized below.

1, Clean reaction kinematics.

IMFs are always originated in the target nucleus. In the case of medium-energy heavy-ion induced reactions, it is, in principle, very hard to identify the origin of fragments whether the target nucleus or the projectile nucleus.

2, Slow source velocity of IMFs.

This is essential to measure the angular correlation, angular distribution of IMFs and to deduce geometric feature of multifragmentation process.

It should be noticed that we can not expect the compression of the nuclear matter in the light-ion induced reactions. This fact will be useful to study pure high-temperature low-density nuclear matter which may appear in a liquid-gas phase transition.

2: EXPERIMENTAL METHOD

In order to measure IMFs cleanly around 12 GeV primary proton beam, we developed large acceptance Bragg Curve Counters (BCCs)[5], which are fairly insensitive to minimum ionizing particles. A BCC is a gas ionization chamber which can determine the Bragg peak height (atomic number) as well as the total energy deposit (kinetic energy) of an incoming IMF simultaneously. Technical details of this BCC system will be described elsewhere[6].

A set of BCCs we developed were mounted on the rotating table in the 1.5m large scattering chamber and covered the angular range from 30° to 150° with 20° step in the lab. system. An extra BCC was set at 90° (lab. system) at the opposite side of the beam axis from the counters set for angular distribution measurements. The coincidence measurements between individual BCC channel were also performed. The intensity of a 12 GeV proton beam we used was approximately 1×10^9/spill. The beam was focused onto the target with a spot of approximately 1cm in diameter. The targets we used were Au and Ag of about 700 μg/cm^2 thickness with 1.5μm Mylar backing.

3: RESULTS AND STATUS

The first data taking for proton induced reactions has just ended in January '94 and an analysis is now in progress. Typical two dimensional plots of Bragg-peak-height ($\sim$atomic number) vs. kinetic-energy of IMFs detected by one of BCCs are shown in Fig. 1. On the Au target the largest atomic number distinguishable reached heavier than Calcium (z=20). The detectable energy range of IMFs in our BCC system was from approximately 1 MeV/u to 5 MeV/u with 200 Torr P10 (Ar 90 % + C_2H_6 10 %) gas.

The energy spectra of Sodium (Na) isotope deduced from the scatter plot at various laboratory angles are shown in Fig. 2. High energy part of the energy spectra increased at the forward angles, which can be understood in usual two-step model. The angular distribution of the Na isotope is shown in Fig. 3 and has a clear peak at around 70° on the simple isotropic component. This 70° peaking was observed at the angular distribution of Oxygen and Silicon isotopes, also. We can learn from the contour plot of invariant cross-section of Na isotopes (Fig. 4) that this characteristic flow toward 70° direction is concentrating at the low energy region, while the high energy parts show the almost isotropic distribution.

The angular distribution of IMFs which coincident with one extra IMF emitted toward the 90° in the opposite hemisphere showed also the 70° peaking but the isotropic component decreased drastically as shown in Fig. 5. This fact suggests that the high multiplicity event of IMFs shows the sideward (70°) peaking and relatively low multiplicity event shows isotropic distribution. Since it is known that higher IMF multiplicity can be related to the small impact parameter in the nuclear reaction[7,8], our experimental result may be interpreted in terms of the formation of unusually-shaped IMF source, such as an expanding toroid.

References

[1] T.Murakami (Spokes Person), KEK-PS Research Proposal E-288, *"Study of Nuclear Multifragmentation with p,d and α beams at the KEK-PS Energies"*.

[2] N.T.Porile et al., Physical review C39(1989)1914.

[3] D.R.Fortney and N.T.Porile, Physical Review C21(1980)2511.

[4] L.P.Remsberg and D.G.Perry, Phys. Rev. Lett. 35(1975)361.

[5] C.R.Gruhn et al., Nucl. Instrm. and Meth. 196(1982)33.

[6] H.Ochiishi et al., to be submitted to Nucl. Instrm. and Meth.

[7] P.Kreutz et al., Nucl. Phys. A556(1993)672.

[8] V.Lips et al., Phys. Rev. Lett. 72(1994)1604.

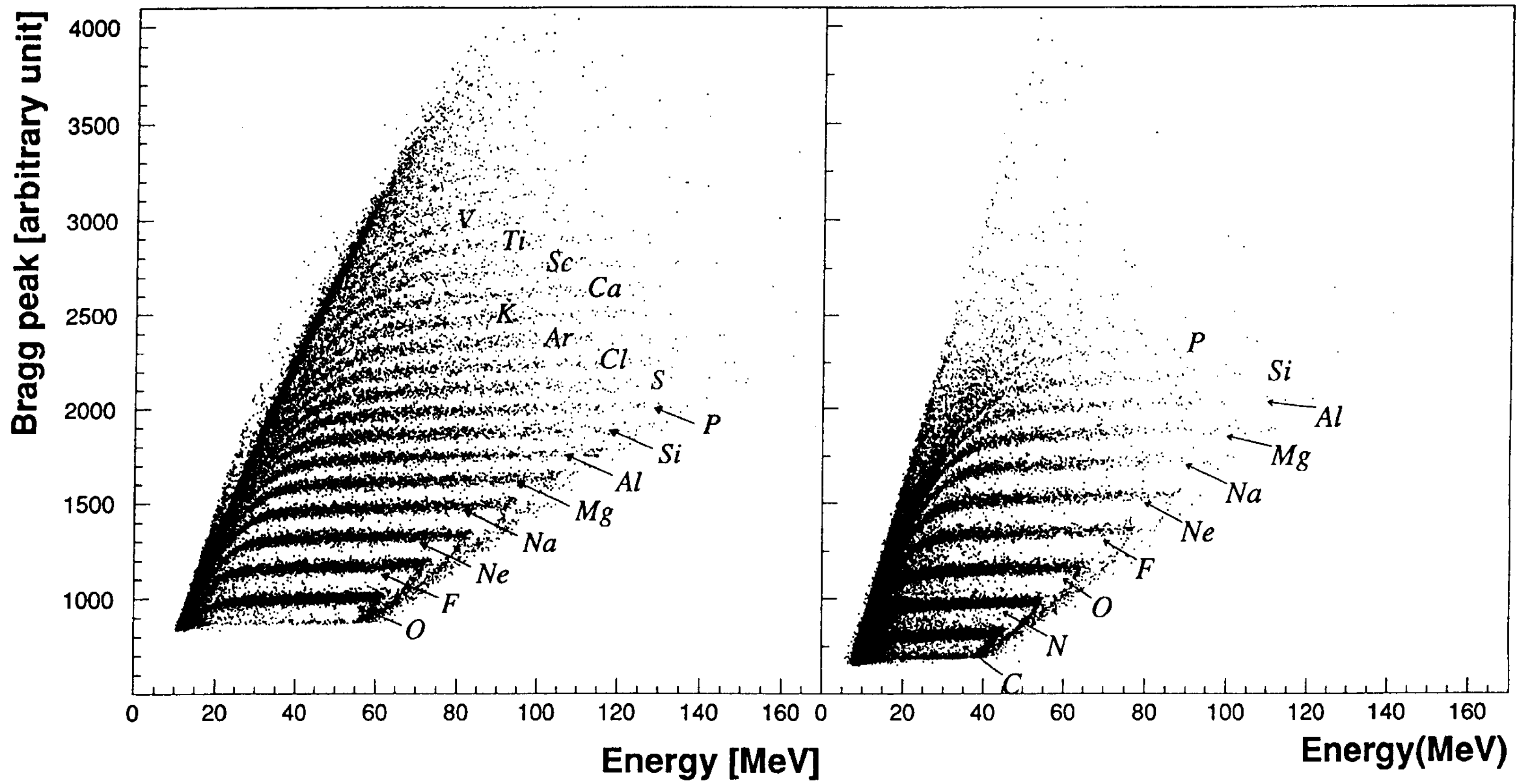

Fig. 1: Typical two-dimensional charge vs. kinetic-energy plots of IMFs produced in the 12 GeV proton induced reactions on $Au_{(Left)}$ and $Ag_{(Right)}$ targets.

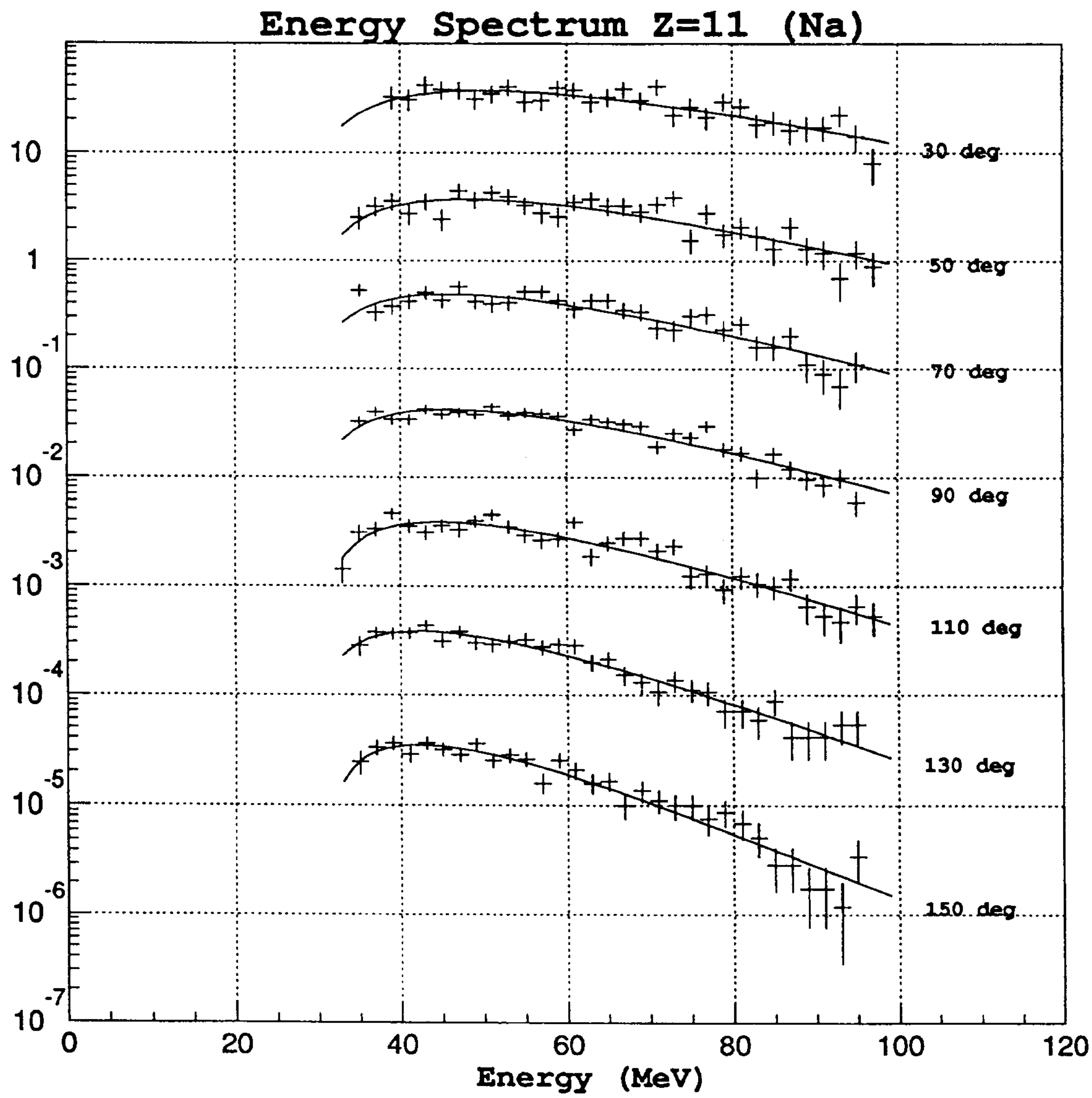

Fig. 2: Energy spectra of Na isotopes produced in Au(p,X):Ep=12GeV reaction at various reaction angles.

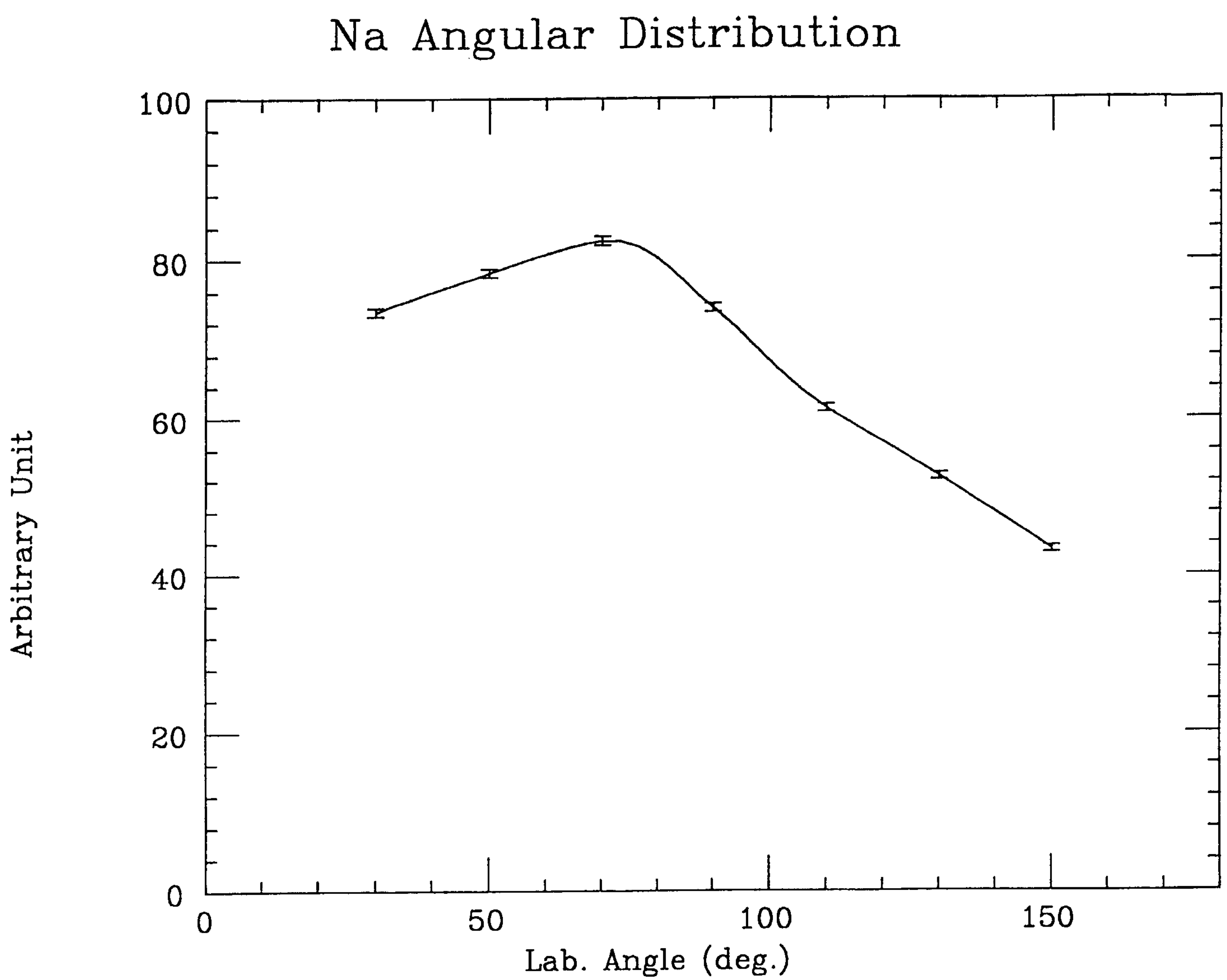

Fig. 3: Angular distribution of Na isotopes produced in Au(p,X):Ep=12GeV reaction.

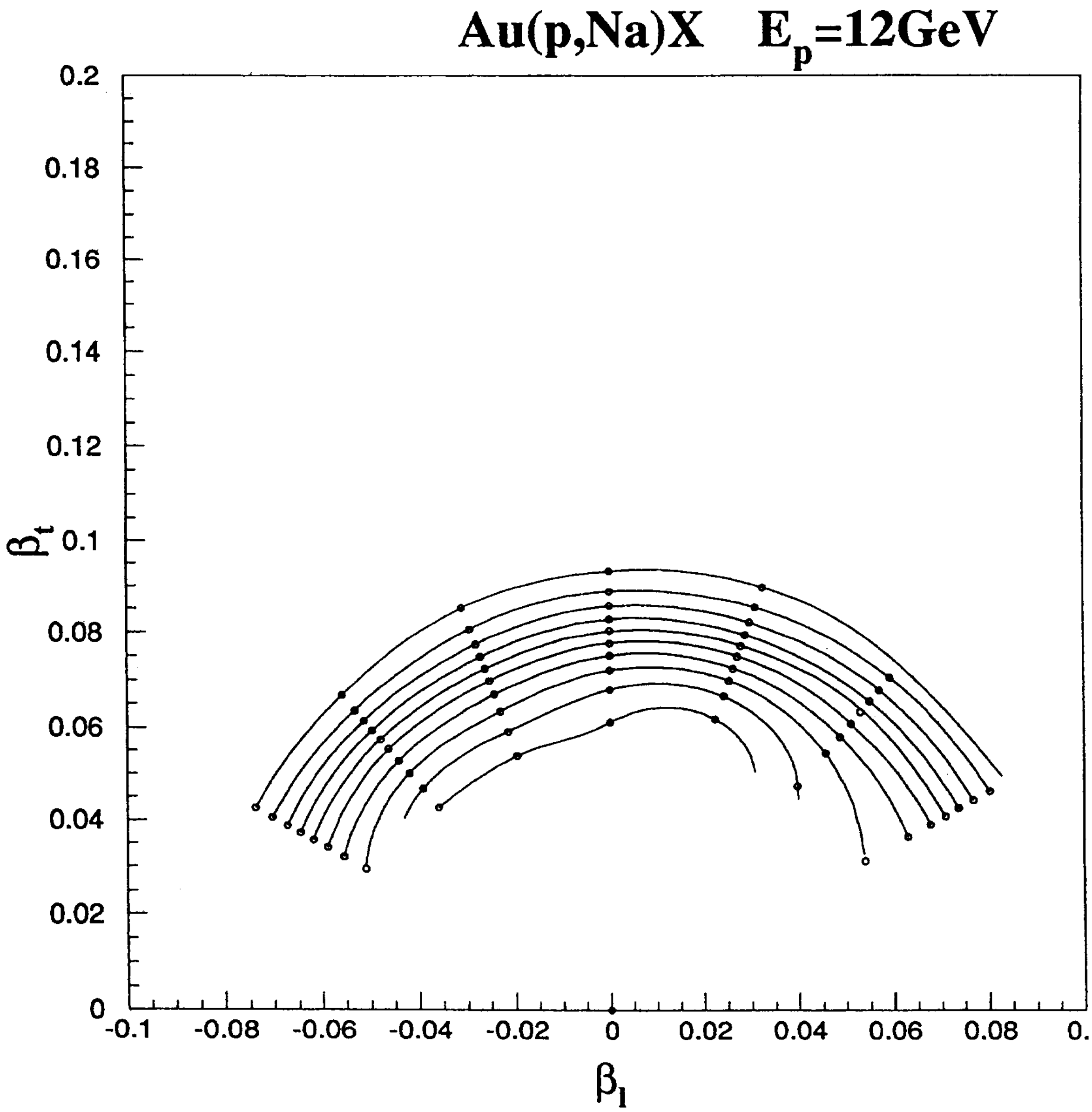

Fig. 4: Contour plot of the invariant cross section of Na isotopes. Horizontal and vertical axes indicate velocity in the beam direction (β_l) and the transverse direction(β_t), respectively. Enhancement can be seen toward the 70° direction at the low energy region.

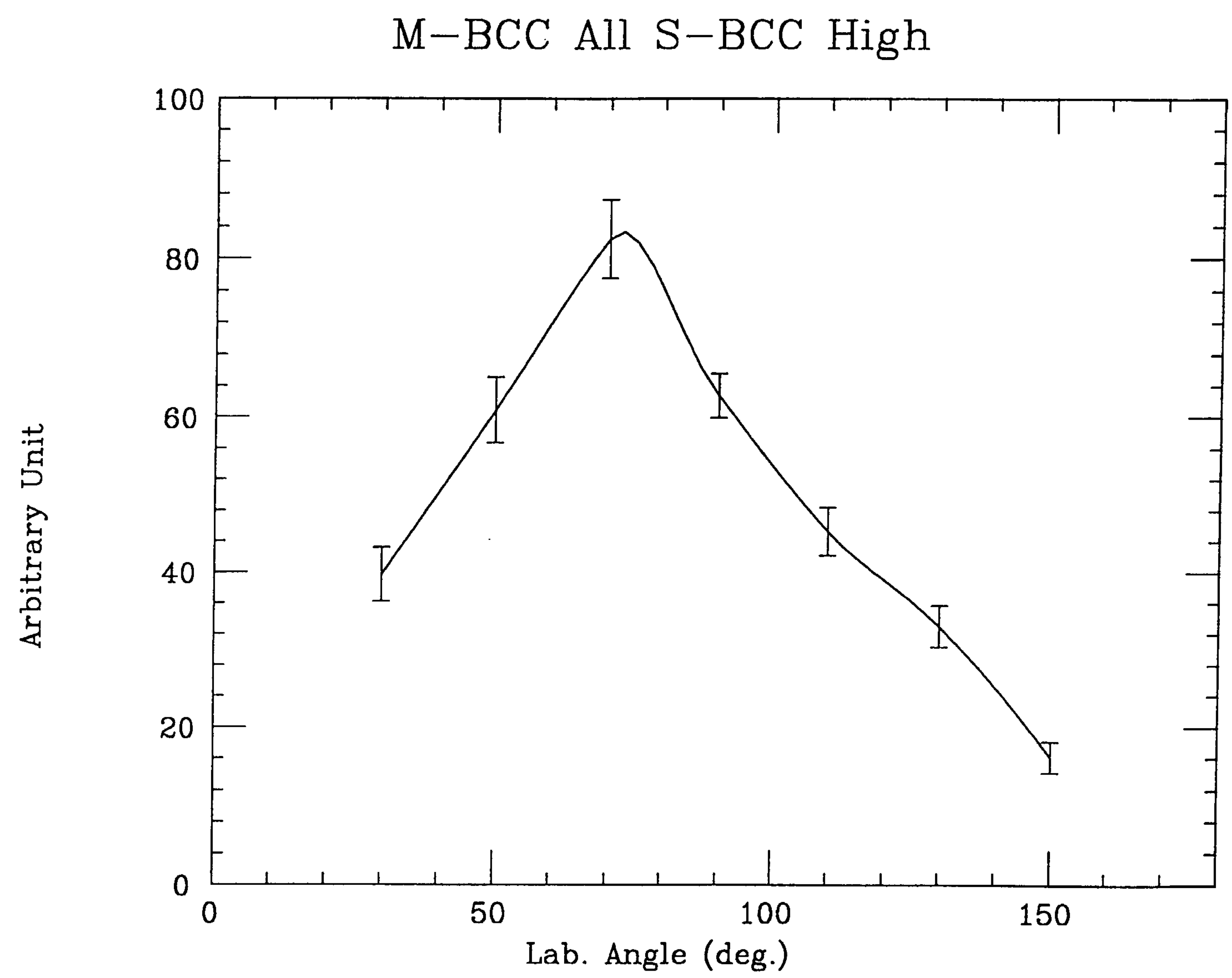

Fig. 5: Angular distribution of IMFs which are coincident with one extra IMF emitted toward the 90° in the opposite hemisphere. Reaction is Au(p,X):Ep=12GeV. Energy of the extra IMF is selected above 1.5 MeV/u to reject the contribution from fission event.