Fragmentation of Relativistic Heavy–Ion Beams in Thick Targets

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To design appropriate shieldings for heavy–ion accelerators the angular and energy distribution of emitted fragments, especially of neutrons, produced by relativistic heavy–ion beams stopping accidentally in components of the beam line has to be known explicitly. Up to now no data concerning the production of neutrons in thick targets are available for projectile ions heavier than ^{131}Xe and specific energies of the primary ions higher than 800 AMeV [1]. Therefore the fragment yields emitted from thick graphite and iron targets, in which 400 AMeV ^{12}C– and 1 AGeV ^{12}C– and ^{238}U–ions were stopped, were studied in Cave B of GSI. The energy and angular distributions of the emitted fragments were measured at small angles (0°–15°) with the LAND, from 0° to 90° with a BaF$_2$–detector–telescope. The BaF$_2$–telescope consisted of a 9 mm thin plastic– and a 14 cm thick BaF$_2$–scintillator with an efficiency for fast neutrons of about 20 % [2].

The detector–telescope was placed in a distance of 5 m behind the target to obtain a satisffying resolution of the time–of–flight measurements. By converting the time–of–flight spectra the energy distributions of neutrons and of charged fragments were derived. In fig. 1 neutron energy spectra emitted from a 20 cm thick iron target in which a 1 AGeV ^{238}U–beam was stopped in a depth of 1.56 cm are compared to Monte Carlo simulations effectuated with the PHITS and the SHIELD code [3].

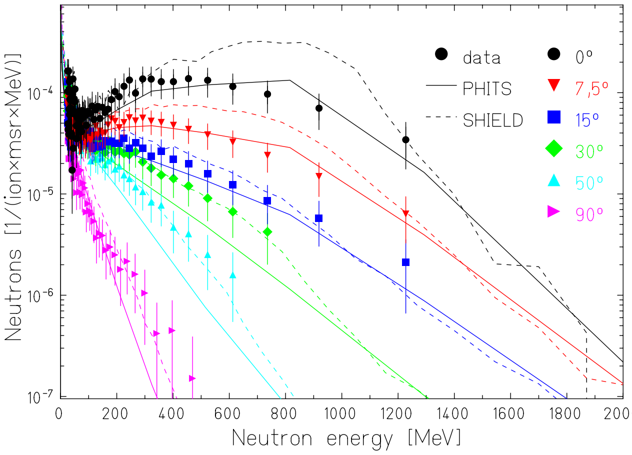

Figure 1: Neutron energy distribution measured behind a 20 cm thick iron target irradiated with 1 AGeV ^{238}U–ions compared to results of the Monte Carlo simulations PHITS and SHIELD.

At small angles the measured spectra show a broad maximum at about half of the energy per nucleon of the primary ions. At larger angles an exponential decay of the energy distribution was observed. These characteristics are explained by the fragmentation process itself. Neutrons emitted in forward direction emerge mainly from projectile abrasion whereas the neutron emission at larger angles is more probable due to the evaporation from the highly excited prefragments. The general features of the measured energy spectra can be reproduced by the Monte–Carlo codes, but there are still discrepancies.

The angular distributions for all fragments are forward peaked. He–ions have a very small, neutrons a broad angular distribution. An overlay of the neutron distributions measured for the three different irradiations is shown in fig. 2.

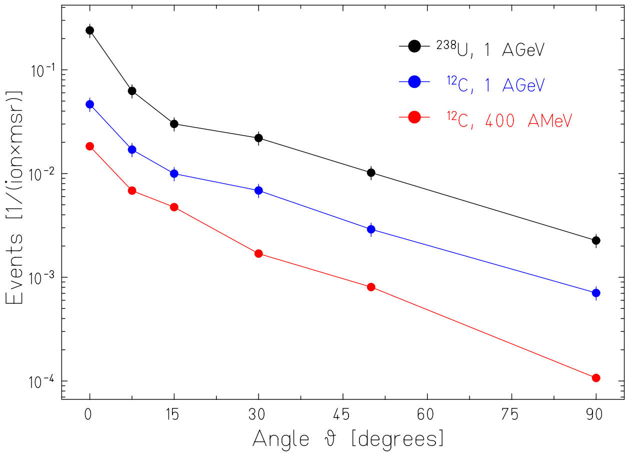

Figure 2: Angular distributions of emitted neutrons for the stopping of 400 AMeV ^{12}C–ions in 20 cm graphite and of 1 AGeV ^{12}C– and ^{238}U–ions in 20 cm iron.

By integrating the angular distributions of fragments emitted from thick graphite and iron targets the total yields were derived, which are listed in tab 1 [4].

Table 1: Fragment yields per primary ion emitted in the forward hemisphere (0°–90°). Uncertainty of yields: 20 %.

projectile	400 AMeV ^{12}C	1 AGeV ^{12}C	1 AGeV ^{238}U
target	20 cm C	20 cm Fe	20 cm Fe
neutrons	6.60	20.9	69.2
H–ions	1.90	2.85	6.80
He–ions	0.34	0.50	0.50

The results confirmed the strong dependence of the yield on the mass and energy of the primary ions which was already observed in former experiments. For the first time these observations could be extended to very heavy primary ions and to relativistic projectile energies. Henceforth shielding calculations can be performed based on experimental data as already done for the future GSI accelerator facility [5].

References

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