NEUTRON PRODUCTION IN EXTENDED CU-TARGETS IRRADIATED WITH RELATIVISTIC ^{12}C-IONS AT DUBNA

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Neutron Production in Extended Cu-Targets Irradiated with Relativistic W-Ions at Dubna

(The complete list of the authors is given on the next page)

Abstract

An extended Cu-target was irradiated with 22 **and 44 GeV carbon ions for about 11,3 and 14,7 h, resp. The upper side of the target was in contact with a paraffin-block for the moderation of seondary neutrons. Small holes in the moderator were filled with either lanthanum** salts or uranium oxid.

The reaction $^{139}La\,(n,\gamma)\,^{140}La \xrightarrow{\beta^-}$ was studied via the decay of ^{140}La (40 h) using radiochemical methods. The results have been published in a "Preliminary Note". The reaction $^{238}U\,(n,\gamma)\,^{239}U \xrightarrow{\beta^-} {}^{239}Np \xrightarrow{\beta^-}$ was studied via the decay of ^{239}Np (2,3 d) as well as the reaction U (n,f) using radiochemical methods. In addition, solid state nuclear track detectors were used for fission studies in gold. Results will be presented.

The yields for the **formation of (n, y) products agree essentially with other experiments on extended targets and carried out at the Synchrophasotron LHE, JINR (Dubna).** To **a first approximation, the breeding rate of (n, y) products doubles when the carbon energy is** increased from 22 to 44 GeV. **If, however, results at 44 GeV** are **compared in detail to those at** 22 **GeV, we** observe an excess of **(37±9)** % in the experimentally observed ^{239}Np-breeding rate over theoretical estimates. **Experiments** using solid state nuclear track detectors are giving similar results. **We present a** conception for the interpretation:

There is the evident comection between "anomalies" we observe in the yield of secondary particles in relativistic heavy ion interactions above a total energy of approx. (35-40) GeV and the increased yield of neutrons in this region.

Neutron Production in Extended Cu-Targets Irradiated with Relativistic ^{12}C-Ions at Dubna

) The October 1992-experiment with 22 GeV and 44 GeV ^{12}C:

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‘publications:
. (Preliminary Results) Preprint E1-93-127, JINR, Dubna (1993)
nd ISOTOPENPRAXIS (in print)
. Final Results:Preprint E1-94-116, JINR, Dubna (1994) and
J. of Radioanalytic and Nuclear Chemistry” to be submitted

I) The December 1993-experiment with 22 and 44 GeV ^{12}C:

J.C. Adloff, M. Debeauvais, CNR; Strasbourg

M. Zamani, Unversity Thessaloniki

. Cui, Huan Hua, Beijing and Marburg

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all “1993” results are preliminary and cannot be quoted

Tolstov's) conjectures concerning subcritical reactors driven by relativistic heavy ions. (Dubna-approach, JINR-Rapid Communications 5 (62) 93 p. 5-15/1993, et cet.):

1. Subcritical reactors driven by relativistic heavy ions allow the construction of commercial nuclear power plants in useful sizes (10-1000) MWe. These nuclear power plants operate without any Tschernobyl risk.

2. When the beam current of relativistic heavy ions is considerably increased, one can think about

TRANSMUTATION

of long-live radioactive waste a' la Bowman (L.A.N.L.)

3. Plan: When one has $2 \cdot 10^{14}$ ions/second of 1.5 AGeV ^{4}He and a subcritical reactor with c=0.98 (neutron multiplication factor), then one can construct a 10 MW(e) nuclear power plant:

Reality: Synchrophasotron (Dubna) has 5=1010 ions/s of 3.5 AGeV ^{4}He

in construction: Nuclotron (Dubna) should have 10^{10} ions/s 6 AGeV ^{4}He

Next phase Nuclotron (Dubna) should have $4 \cdot 10^{11}$ ions/s 6 AGeV ^{4}He

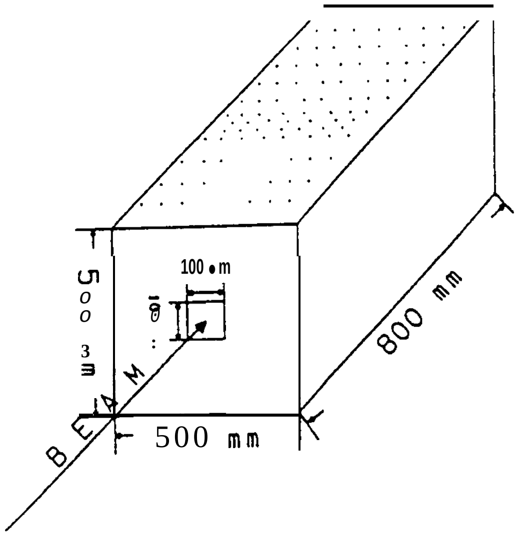
Fig I, Summary of the project **ENERGIJA** in **Dubna**

(Voronko, et al., Atomn. **Energija** (Russian), 68,452 (**90**))

(Reference 6)

1 a)

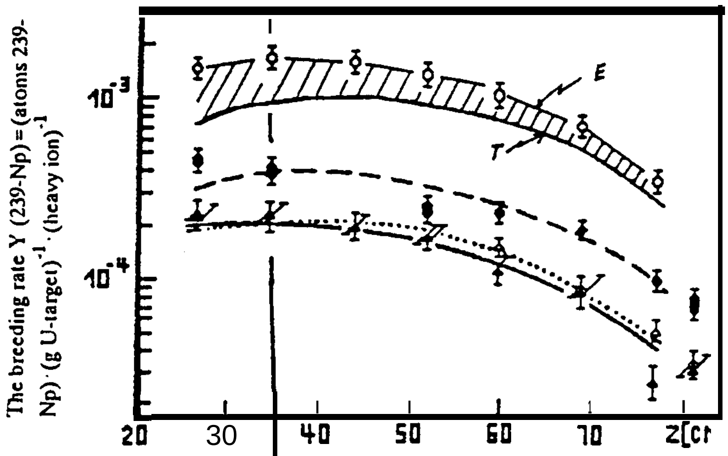
The very massive **Pb-target** (0.5 x 0.5 x 0.8 m^3), irradiated with 3.65 **GeV/u** ions from the **SYNCHROPHASOTRON, JINR, Dubna**



1 b)

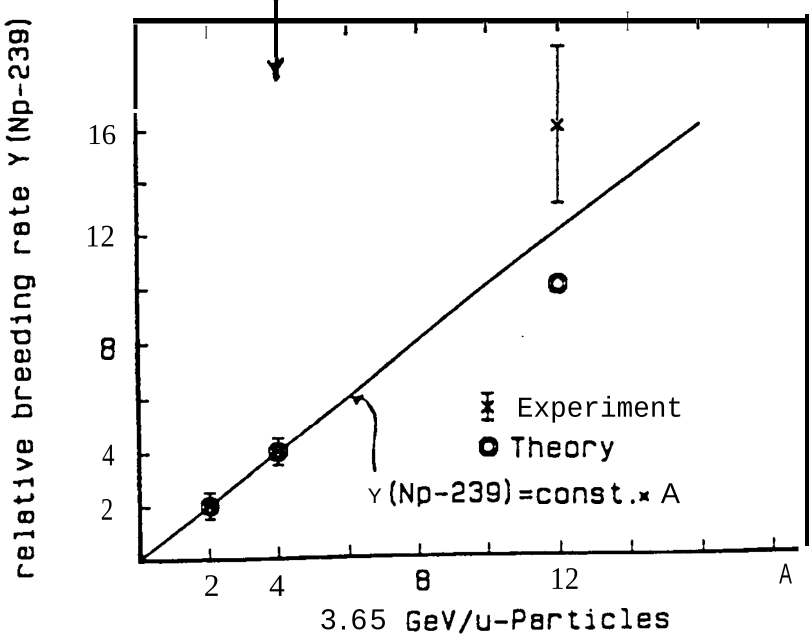
Results for the breeding of ^{239}**Np** in the very massive **Pb-target** (Fig. 1a), as determined along the central beam axis.

Open circles: 3.65 GeV/u ^{12}C, closed circles: 3.65 GeV ^{4}He, open triangle: 3.65 GeV/u ^{2}H, closed triangles: 8 GeV ^{1}H For ^{4}He, ^{2}H, and ^{1}H, the calculations of Y agree with the experiment. For ^{12}C, the calculations (T) are below the experiments (E), as shown by the hatched area.



1 c)

More-than-calculated-breeding (**a possibility**) of ^{239}**Np as** seen in Fig. 1 b. Here we show a "cut" **along** the line Z = 35 cm.



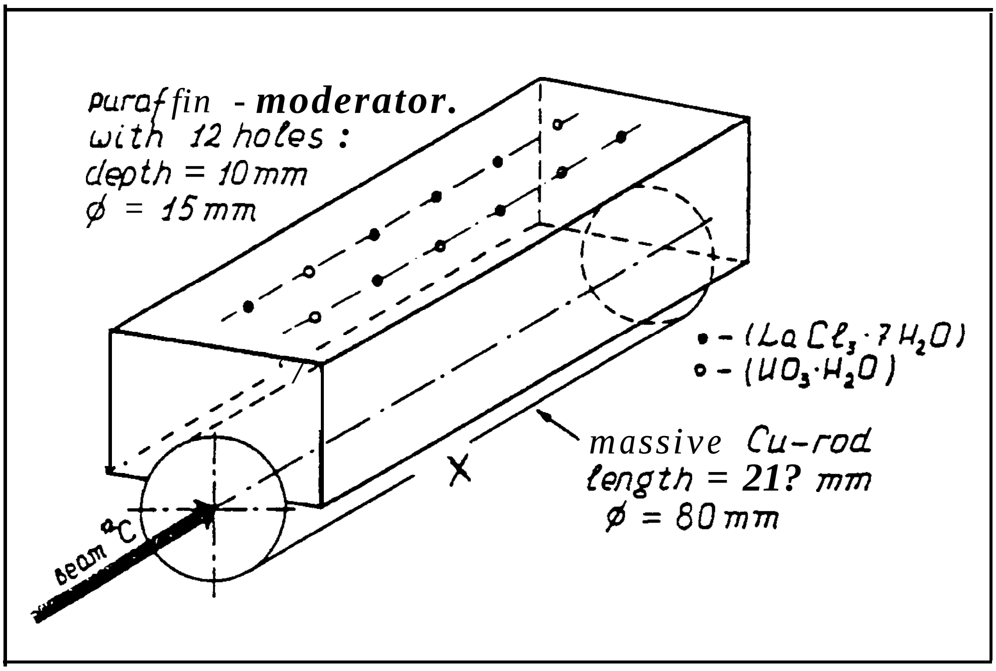


Fig 2: Drawing of the experimental apparatus: a copper rod (ϕ = 8 cm, 1 = 21.7 cm) is covered on its top with paraffin, having in the center a thickness of 6 cm. This paraffin bloc contains tiny holes, filled with ($LaCl_3 \cdot 7H_2O$) and $UO_3 \cdot H_20$) samples.
The position X, 9 cm downstream [he beam entrance into the copper rod, marks the place, where [he auxiliary exposure of a thin Au-layer on mica is carried out on the surface of the copper. Here we study [he fission of Au, as registered in a solid state nuclear track detector.

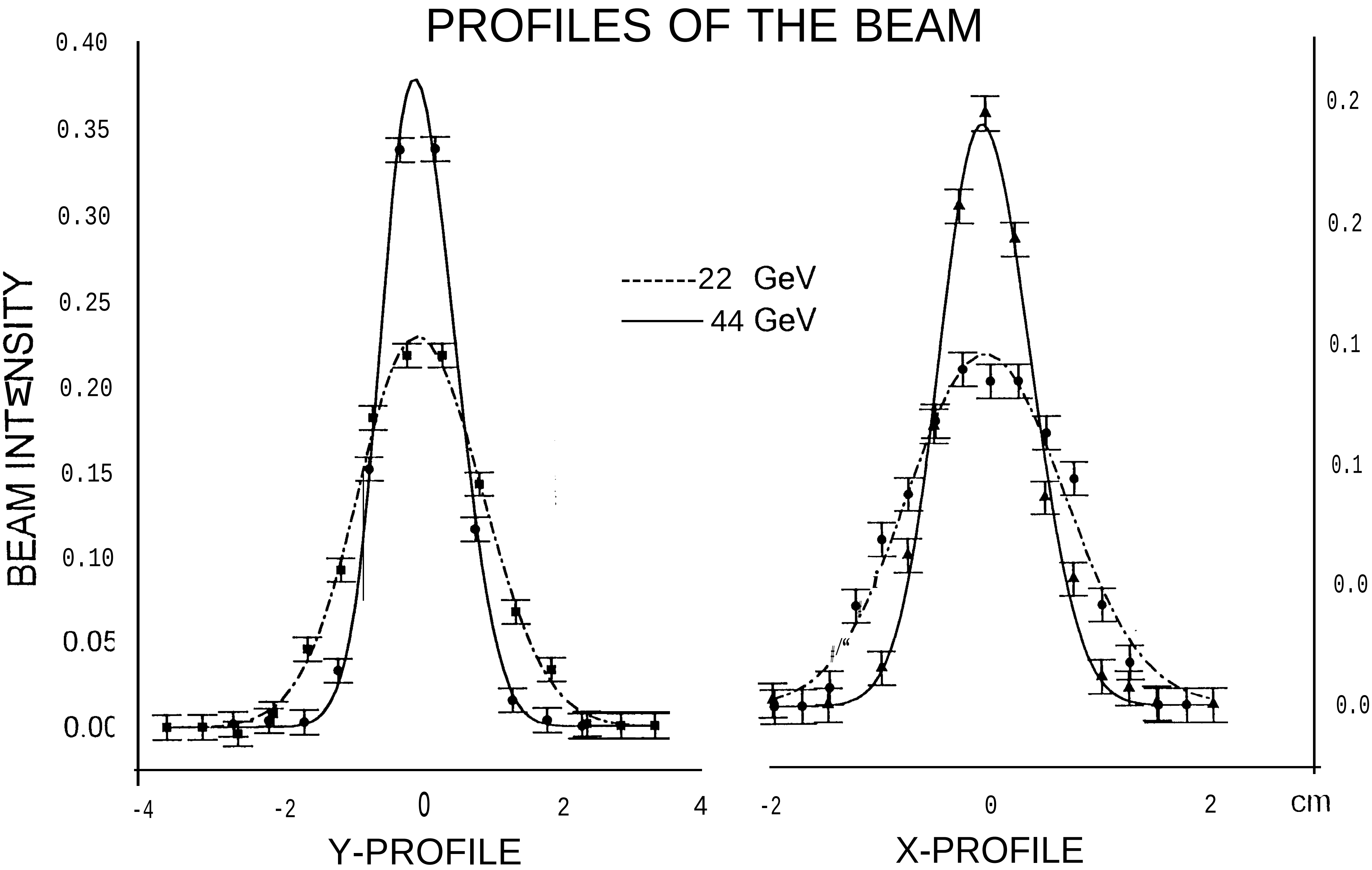
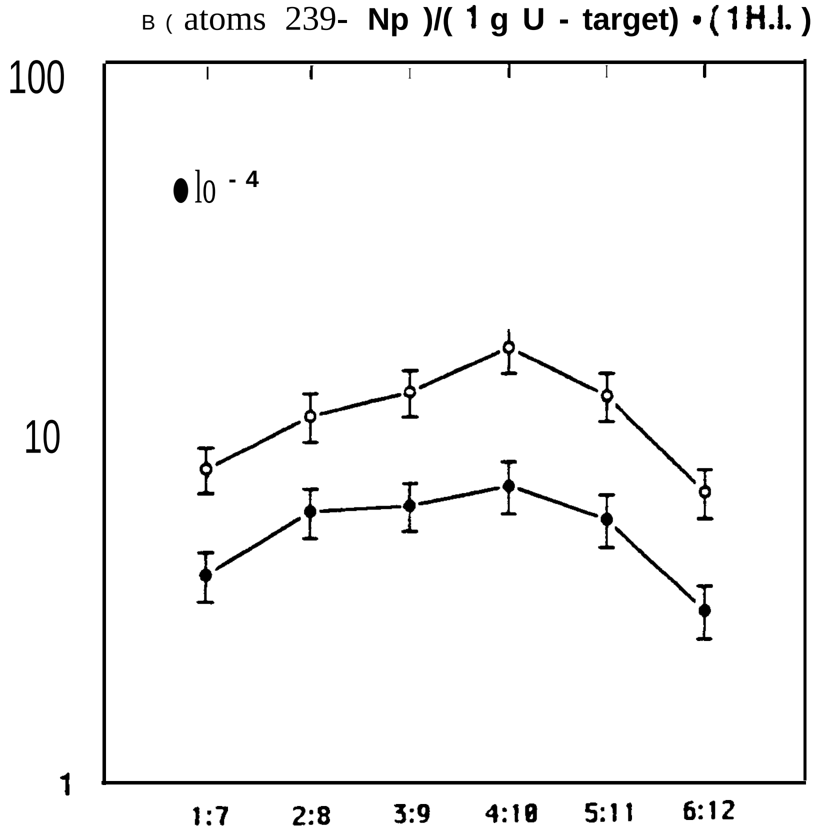


Fig.3: The beam-profiles at 22 GeV and 44 GeV, as observed with nuclear emulsions



Open circles :44 GeV 12-C **Closed circles :22 GeV** 12-C

Fig. 4: Production rates B_{exp} as observed in U-samples shown in Fig. 2. Vial numbers $1 \leq i \leq 6$ have been obtained at 44 GeV, $7 \leq i \leq 12$ at 22 GeV ^{12}C ion energy.

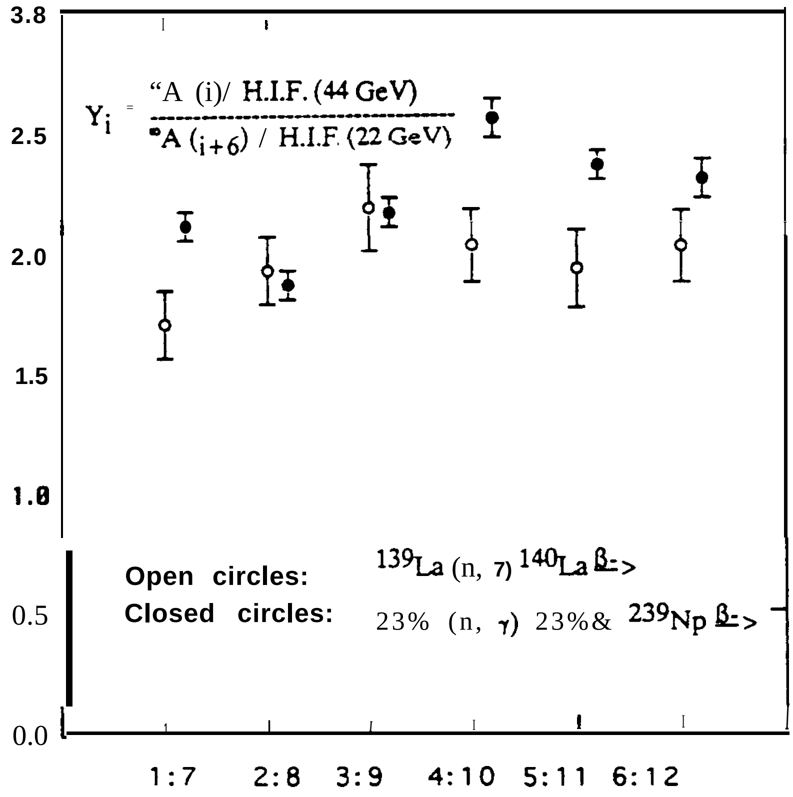


Fig. 5: The ratio Y_i for the reactions ^{139}La (n,γ) and ^{238}U (n,γ). Details are given within the figure and text.

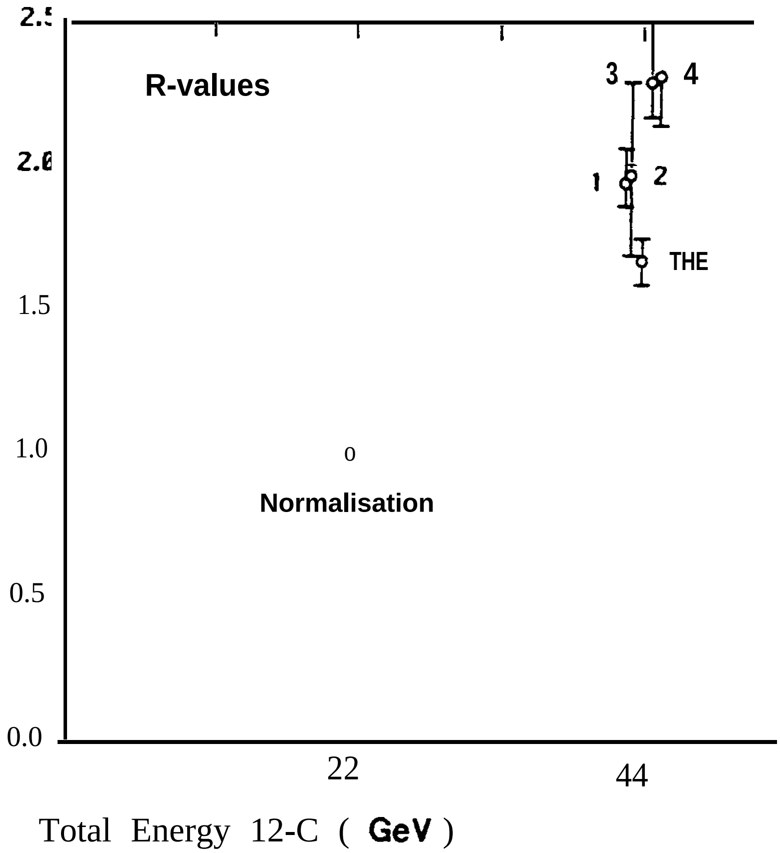


Fig.6: R-values for 44 GeV as compared to 22 GeV ^{12}C-ions (normalisation). The numbers stand for the following experiments:

1. ^{139}La (n,γ) ^{140}La $\xrightarrow{\beta-}$ — R = 1.97 ± 0.10
2. ^{235}U (n,f) ^{140}Ba $\xrightarrow{\beta-}$ — R = 2.0 ± 0.3
3. ^{238}U (n,γ) ^{239}U $\xrightarrow{\beta-}$ ^{239}Np $\xrightarrow{\beta-}$ — R = 2.30 ± 0.12
4. Au + (hadrons, E >30 MeV) --> fission — R = 2.32 ± 0.17

Details are described in the text. (THE) stans for theoretical estimation, R = 1.68 ± 0.08.

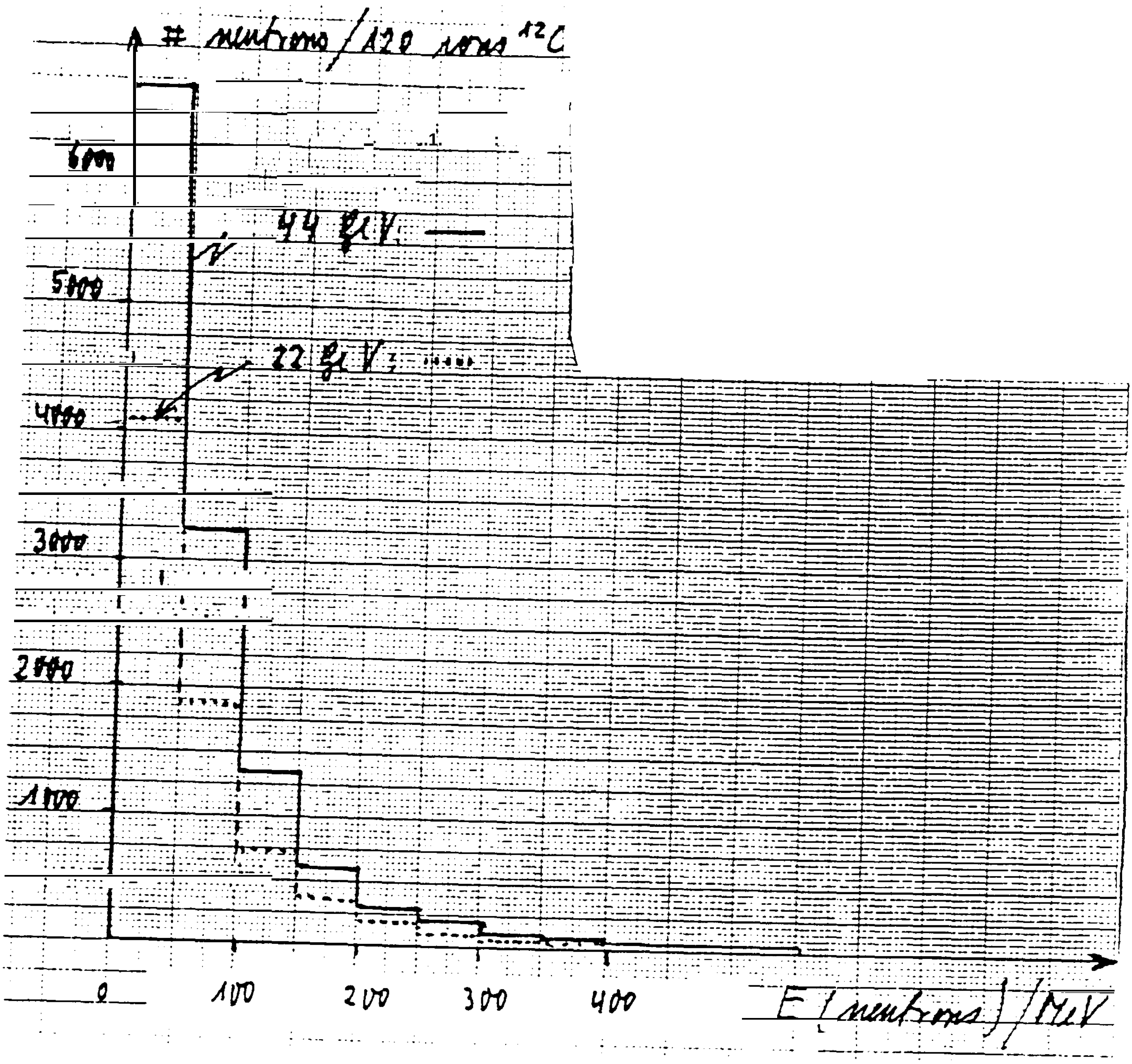
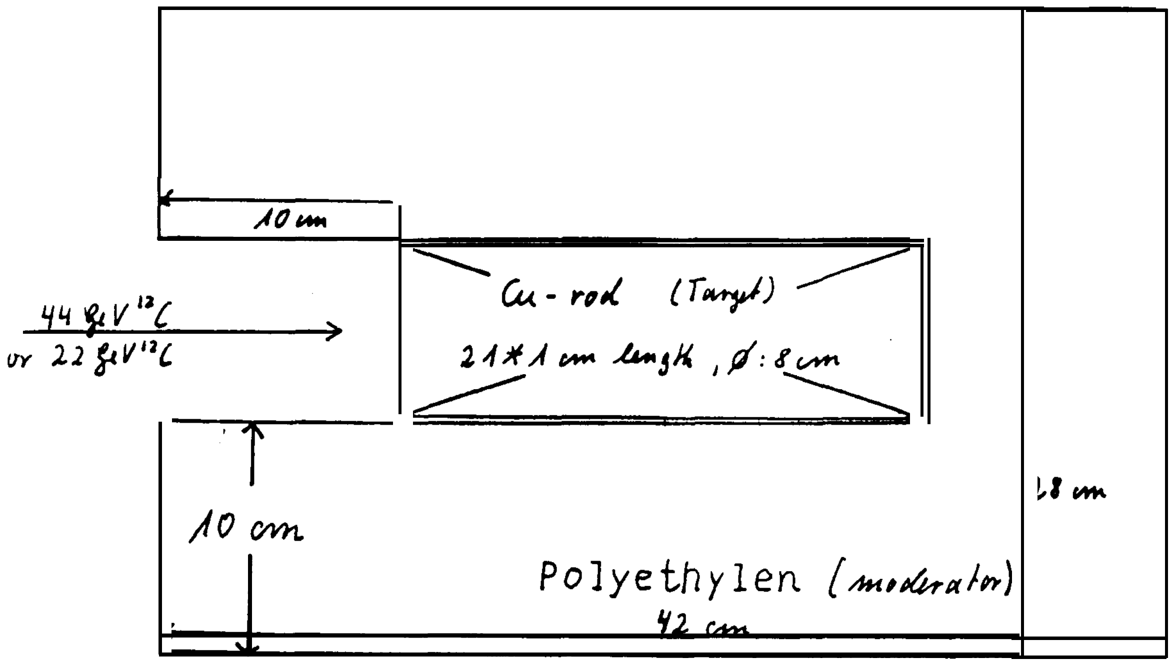


Fig. 7: Neutron spectra of secondary neutrons emitted from the cylindrical surface of the copper target rod, as shown in Fig. 2.

Target (Cu) and Moderator $(-CH_2-)_n$ for the 1993 - Dubna experiment.



Details of this experiment will be published later.

$$R\text{-values} = \left(\frac{\text{effective } \sigma \text{ at 44 GeV } ^{12}C}{\text{effective } \sigma \text{ at 22 GeV } ^{12}C} \right)$$

	1992 Experiment published)	1993 experiment (preliminary) *
CHEMISTRY:		
1) $^{139}La(n,\gamma)^{140}La \xrightarrow[40\,h]{13-}$	1.97 ± 0.11	1.99 ± 0.10
2) $^{238}U(n,\gamma) \ldots ^{239}Np \xrightarrow[2.3\,d]{\beta^-}$	2.32 ± 0.12	1.9 ± 0.2 (low activity)
SSNTD (TRACK-Detectors)		
1) Au + hadron -----> fission (mica detector)	2.32 ± 0.17	2.2 ± 0.2
2) n + H -----> recoil proton (CR-39 detector)	---	2.1 ± 0.2
3) ^{235}U + n -----> fission (macrofol detector)	---	2.2 ± 0.2 at Cu 2.0 ± 0.2 at $(CH_2)_n$
4) Pb + hadron -----> fission (mica detector)	---	2.4 ± 0.2 (in Cu)
THEORY (Dubna)	1.68 ± 0.08	1.64 ± 0.04

* can not be quoted

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