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Letter of Intent for the CERN ^{12}C beam of 86 MeV/N.

Characteristics of the proton emission in Central and Peripheral ^{12}C Induced Heavy Ion Interactions at 86 MeV/N.

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Heavy ion accelerators have during the last decades provided us with a wealth of information about the mechanism in reactions between complex nuclei at low energies. Recently the accelerator facilities in Berkeley and Dubna have opened up the field of heavy ion physics at relativistic energies. However the energy region 20 MeV/N $\leq E_{beam} \leq$ 200 MeV/N is still an unexplored field. A 86 MeV/N ^{12}C beam in the SC at CERN would indeed permit interesting studies of phenomena where the relative nucleon energies are far above the binding energy but still low enough to cause very different phenomena in the overlap region between peripheral and central reactions.

We suggest in this letter an experiment where we want to study proton momentum space spectra in coincidence with residual nuclei in order to distinguish between central and peripheral reactions. A study of two particle correlations and multiplicities are also emphasized.

Some Remarks of the Reaction Mechanisms in the Energy Interval 20 MeV/N to 100 MeV/N.

In the beam energy interval 20 MeV $\leq$ E/N $\leq$ 100 MeV the available energy per nucleon is larger than the binding energy. The relative nucleon velocity (v_{rel}) will in this interval reach the point where it is equal to the Fermi velocity (v_F). At this beam energy the cross term in the expression for the maximum kinetic energy of a nucleon $\varepsilon_{max} = \varepsilon_F + \varepsilon_{beam} + 2\sqrt{\varepsilon_F \, \varepsilon_{beam}}$ contributes most significantly.A process for prompt emission of particles (PEP-jets, Fermi-jets) has been suggested to explain the anomalies in the momentum space spectra of protons at bombarding energies close to the Coulomb barrier. 86 MeV/N is probably too high an energy to study this phenomenon, but if the beam energy could be lowered to values closer to ε_F such a mechanism could be studied with the system presented below.

Two characteristic times are of importance for the reaction mechanism: The passing time, τ_{pass}, and the time for transmitting a disturbance from the interaction region to the rest of the system τ_{sound}. τ_{pass} can be defined approximately as the straight line distance of contact between the ions divided by the average relative speed. τ_{pass} thus depends on the impact parameter and approaches zero for a grazing collision.

τ_{sound} can be defined as the distance of travel for the signal divided by the speed of sound v_s which is $\approx \sqrt{\frac{30}{m_N}}$ c where m_N is the nucleon rest mass.

For a typical central ^{12}C + ^{208}Pb reaction we get

$$\tau_{pass} \approx 2(R_{Pb}+R_C)/v_{rel} = 56 \text{ fm/c}$$

and $\tau_{sound} \approx (R_{Pb} - R_C)/v_s = 28$ fm/c, i.e. $\tau_{pass} > \tau_{sound}$ and there should be time enough to transmit energy to the total system before it goes apart. This should be characteristic for an explosion with a large multiplicity and an almost isotropic angular distribution in the laboratory system of produced light particles. No heavy fragments should be able to survive such a violent process.

For a peripheral $^{12}C + {}^{208}Pb$ reaction the times are:

$$\tau_{pass} \approx R_{Pb} / v_{rel} \approx 20 \text{ fm/c}$$
$$\tau_{sound} \approx 2 R_{Pb} / v_s \approx 92 \text{ fm/c}.$$

Thus we have $\tau_{pass} << \tau_{sound}$ and only a small part of the total volume receives energy before the system disintegrates. This means that two spectators are left with low excitation and a hot "fireball" is produced. The characteristics of such a three-system process are comparatively heavy residuals, evaporation spectra from these and a forward peaked fireball spectrum of light particles.

As a conclusion we state that an identification of the heavy residuals in coincidence with a measurement of the proton spectra (especially the high energy part) could provide us with valuable information about the reaction processes and characteristic times of the reactions. Correlations among the protons themselves are also interesting in order to study two particle processes, like quasi-elastic scattering, and Fermi jets.

Brief Outline of the Experimental Setup.

The experimental setup consisting of detectors and targets will be placed in a vacuum scattering chamber. At this stage we purpose to measure the protons with a telescope consisting of a thin Si transmission detector and a plastic scintillator as a stop detector to permit light particle separation in the proton energy range 30 to 250 MeV. The residual nuclei (e.g. around Carbon or the target element) is proposed to be measured with a telescope consisting of either two Si detector or an ionization chamber combined with a Si detector. The energy range to be covered for the residual nuclei extends from a few MeV to nearly full beam energy.

In the case of an inclusive experiment target thicknesses around 100 mg/cm^2 will be appropriate. In the case where heavy residuals are to be registered as well, the target thicknesses must be reduced by a factor of around 500.

A rough estimate of expected count rates are presented for the case of an inclusive experiment in table 1 below.

The double differential cross sections for ^{20}Ne (250 MeV/N) on ^{238}U were adjusted to the cases presented.*) The beam intensity used is 10^{11} ^{12}C ions per second, the solid angle of the proton telescope 10 msr and the number of atoms $2 \cdot 10^{20}$ cm^{-2}.

Table 1.

Estimated count rates (s^{-1}) for 200 MeV protons in 5 MeV bins at different laboratory angles θ_{lab} for the target elements Al, Fe, U

θ_{lab}	Al	Fe	U
10^{o}	2000	4000	20 000
30^{o}	2000	4000	20 000
60^{o}	150	300	1 500
90^{o}	12	24	120
120^{o}	1	2	10
150^{o}	0.5	1	5
170^{o}	0.2	0.4	2

If one wants to have 10^3 events at 170^{o} this will take 10 min for the U-target, all angles could thus be measured in a little more than 1 hour and all three targets within 3 shifts. For the forward angles a reduction in solid angle or beam intensity will

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*) The cross sections taken from J. Gosset et al. Phys Rev. C16 were used. It should be noted that the absolute normalization may be somewhat overestimated.

be necessary.

For an exclusive experiment the statistics will be decreased since the count rates given in table 1 will be smaller by about a factor 500 due to thinner targets. An additional reduction will result from the coincidence requirement. At present it is not possible to estimate the beam time in this case. A very rough guess would be around 25 shifts for the case of a U-target.

Finally we want to stress that the above discussed detector setup is only a preliminar outline. Presumtive collaborators are most welcome to join us in an eventual future proposal.