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PROPOSAL

TO STUDY THE NUCLEAR TRANSPARENCY IN α+A REACTIONS AT ENERGIES ≳ 12 GeV/NUCLEON.

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The main goal of the experiment.

A major goal of high energy heavy ion physics is the determination of the nuclear equation of state as a function of temperature and density. The implication of recent theoretical insights gained from relativistic heavy-ion studies have led physicists to believe that the densities and temperatures needed to deconfine quarks from hadrons can be reached with only a ten-fold increase in beam energy beyond that available in today's highest energy heavy-ion accelerators [1]. The most important requirement for a phase transition to quark-gluon matter in head on collisions of two nuclei at 10-15 GeV/nucleon is that the nuclei pile up and stop (in the centre of mass) rather than pass through each other. One can say, with some confidence, that a beam of 10 GeV/nucleon heavy ions on a stationary target would be enough to initiate hadron melting if nuclear transparency is sufficiently low [1]. Otherwise it may be necessary to go to ultrarelativistic energies.

The available information from nucleus-nucleus collisions at laboratory energies > 3 GeV/nucleon is poor and we do not know much about transparency in heavy ion reactions at these energies. That is one important reason in itself for studying nucleus-nucleus reactions at ~ 10 GeV/nucleon.

We propose to measure, event by event, pseudo-rapidity and multiplicity distributions of singly charged relativistic particles ($\beta > 0.7$) globally and in selected regions of rapidity as well as multiplicities or recoiling protons (30-400 MeV) and charged nuclear fragments. These studies will explore the general features of α+A reactions. However, our main goal of the experiment is to measure the transparency of nuclear matter at energies around 10 GeV per nucleon.

Achieving maximum baryon density.

The amount of compression in head-on collisions [2] is expected to grow with increasing energy until it is limited by longitudinal growth and transparency effects. Longitudinal growth refers to the finite amount of time (and therefore distance) required for particle creation. Because of this effect many of the produced particles in interactions between two sufficiently energetic nuclei materialize only when the nuclei have passed through each other.

At low energy an intranuclear cascade is developed in the hit nucleus. In order to produce particles not only in the first generation of the cascade but in all collisions between participating nucleons the incident energy must be above a certain threshold. This is illustrated in Fig. 1 where a comparison between p+nucleus and p+p multiplicities indicates that above 5 GeV the participant nucleons contribute effectively to the particle production, while at energies below ~ 5 GeV only a

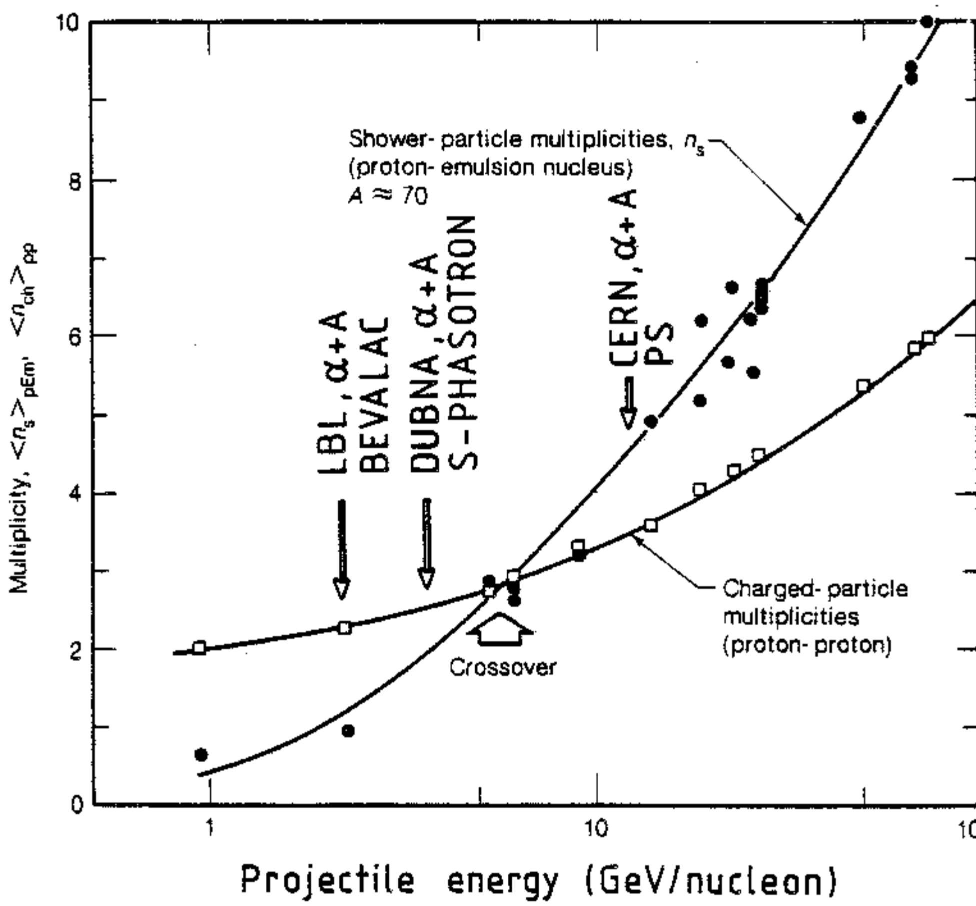

Fig. 1. Shower-particle multiplicities n_s from proton-nucleus collisions, (emulsion nuclei $\langle A \rangle \approx 70$), and charged-particle multiplicities n_{ch} from proton-proton collisions as a function of projectile kinetic energy. Note that the multiplicity from p-nucleus collisions is actually smaller than from pp collisions for incident energies below ~ 5 GeV.

fraction of the participant nucleons contributes because of pion absorption and energy degradation within the nuclear matter involved in the collision.

From studies of p+A reactions at high energies, say > 50 GeV, we know that the nucleus is comparatively transparent and the intranuclear cascade is almost absent.

An interesting dynamical question is then where does the transparency set in? At which incident energies do we active maximum baryon density?

Transparency.
To illustrate the concept of transparency, in the sence we use transparen-

cy here, we show an oversimplified calculation for central collisions.

The inelasticity in nucleon-nucleon collisions is K = 0.5. If we assume that the formation time is shorter than the distances between the hit nucleons, than a nucleon with an incident energy E has an energy EK^{ν} after ν collisions i.e. a 10 GeV nucleon has ~ 600 MeV after 4 collisions. Central α+Ag (Ag is the heaviest target in emulsion) collisions, where each of the incident nucleons collides four times, will not be rare. If the particles are created instantaneously central events will show small transparency and a large intranuclear cascade will be developed. If, on the other hand, the formation time is longer than the distance between the hit nucleons the transparency will be large and the intranuclear cascade comparatively small.

The question about transparency is crucial for heavy ion reaction studies. If the transparency is low at 10-15 GeV per nucleon then very large baryon densities can be achieved in this energy range, maybe enough to produce quark-gluon plasma in U+U collisions [1].

The experiment.

We propose to study the transparency by comparing pseudo-rapidity ($\eta = -\ln \mathrm{tg}\,\frac{\theta}{2}$) densities, $\rho(\eta) = \sigma^{-1} d\sigma/d\eta$, for relativistic ($\beta > 0.7$) singly charged particles (shower-particles) in α+A, p+A and p+p reactions. p+A and p+p distributions can be extrapolated from available data. Similar studies in emulsion showed for the first time (1973) the large transparency in high energy p-nucleus collisions [3].

We also propose to study multiplicity distributions of recoiling protons and nuclear fragments and to compare with p+A reactions at the corresponding energy. Large differences between α+A and p+A reactions will appear if the transparency is low.

In p+A reactions it has been found that the multiplicity of recoiling protons measures the number of participating nucleons [4]. Several models describe this behaviour [5]. We intend to study if a similar strong correlation exists between the multiplicity of recoiling protons and participating nucleons also for α+A reactions and to use this correlation to select central events.

Exposure and beams.

We propose to expose three emulsion stacks to high-energy ($\geq$ 12 GeV/nucleon) alphas available in the August 1983 ISR and PS run in order to investigate α + nucleus reactions.

The beam flux required is ~ 10^4 cm^{-2}, reasonably uniform over 4x10 cm^2.

The conditions for our emulsion exposures will be identical with those for the LBL emulsion experiment proposed for the same run [6]. As soon as the beam is adjusted for emulsion experiments the time for the alignement and the exposure of an emulsion stack is comparatively small (< 1 hour, including the time for enteries).

Emulsion stacks and measurements.

The size of each emulsion stack is 4x10x10 cm^3 and weigh with its assembly and support under 2 kg. The emulsion stacks will be processed in Lund. Scanning and measurements will be performed in all participating laboratories.

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