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STUDY OF HIGH ENERGY NUCLEUS-NUCLEUS INTERACTIONS WITH THE ENLARGED NA 10 DIMUON SPECTROMETER

EXPERIMENT NA 38

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I. RESULTS OF THE EXPLORATORY RUNS IN 1986 AND 1987.

In the course of the exploratory ion beam program carried out at CERN in 1986 and 1987, we have accumulated and analysed dimuon events produced near mid-rapidity by Oxygen and Sulfur ions of 200 GeV per nucleon impinging on Uranium and Copper targets. The Oxygen data were taken in a 10 days run at $5*10^7$ ions per burst on average, the Sulphur data in a 13 days run at $(1-2)*10^7$ ions per burst. We also took reference data with 200 GeV incident protons.

A calorimeter measured the electromagnetic transverse energy E_T. Stringent cuts eliminate those events whose transverse energy might be distorted by interactions of additional beam particles. The surviving p-U, O-U and S-U data include 4904, 7225 and 12760 J/Ψ events respectively (dimuon mass between 2.7 and 3.5 GeV/c^2). The ratio of J/Ψ events to the muon pairs in the Continuum is found to decrease by a factor of 2 over the transverse energy range covered by the experiment in ^{16}O-U collisions (see A. Bussière et al., Z. Phys. C, Particles and Fields, 38 (1988) 117; by "Continuum" we mean the dimuons of masses above 1.7 GeV/c^2 excluding the J/Ψ and the Ψ', which are mainly Drell – Yan pairs). A preliminary analysis of the Sulphur data confirms this result, over transverse energies higher by a factor 1.7, which correspond however to similar energy densities. The p-U data have a J/Ψ to continuum ratio which is rather independent of E_T, and which is nearly 3 times larger than the same ratio at the highest E_T Oxygen and Sulphur points.

This decrease of the J/Ψ to Continuum ratio is P_T dependent and is strongest at low P_T (see fig. 1). A possible vanishing of this decrease with E_T somewhere beyond $P_T = 2$ GeV/c is compatible with our limited present statistics.

II. OPEN QUESTIONS, AND PHYSICS PROGRAM FOR 1989 – 1990.

The theoretical models which attempt to explain the E_T dependence of the J/Ψ to continuum ratio (absorption by nuclear matter or by a hot hadron gas; Debye colour screening in a quark – gluon plasma) lead to different predictions for the P_T dependence of the observed effect. Our first priority is therefore to increase significantly the statistics with the Sulphur beam in order to:

1. – Improve the accuracy for the J/Ψ-to-Continuum ratio and its P_T dependence.

2.– Measure more accurately the P_T dependence of the muon pairs in the continuum, which so far does not show any variation with E_T, within experimental errors which are however very large.

3.– Study the behaviour of the Ψ' relative to the J/Ψ.

A second intriguing feature of our data concerns the mass region around 1.2 GeV/c^2 where the cross section appears to increase faster than linearly with the projectile atomic number A_p. This is also the region where the background from meson decays is highest (85% of the opposite sign pairs in S-U interactions, as inferred from the like sign pairs), and must be subtracted with great care.

In particular, correlated meson decay pairs (i.e. pairs occurring only in $+\,-$ and not in $+\,+$ nor $-\,-$ combination) are expected from K^+K^- pairs (strangeness conservation) and from high P_T back-to-back pion pairs. Their contribution to the dimuon signal depends obviously on the extent to which the produced mesons are forced to interact before decaying. We are now in the process of measuring this component with a proton beam, by varying the absorber thickness after the target. Non negligible rates (of the order of 10 % of the genuine dimuon signal in the 1 – 2 GeV/c^2 mass range) are being found.

The extrapolation of these findings to O-U and S-U reactions is not obvious, and analogous measurements with a sulphur beam will be necessary.

III. A NEW CALORIMETER - ABSORBER BLOCK FOR 1989 – 1990.

The main improvement which seems at present possible is a further reduction of the muon decay background by a factor of 2, using a better optimized calorimeter and hadron absorber configuration. This will help in reducing both the systematical error discussed in the preceding section, and the statistical error of the J/Ψ to Continuum ratio which is dominated by the background subtraction. For the absorber, we intend to use larger quantities of BeO which is the densest among the low Z materials ($\rho = 3.0$ g/cm^2). Regarding the calorimeter, copper appears to be a better converter material than Pb since it has the same Moliere radius as Pb (which means that the photon showers will not be wider than in Pb), but it has 2.5 times more interaction lengths for a given number of radiation lengths and will therefore kill many more pions and kaons. The optimal solution should preserve or, if possible, improve the dimuon mass resolution, as well as the quality of the measurement of the neutral transverse energy (the hadronic transverse energy cannot be measured so close to the target, since the widths of the hadron showers are much larger than the rapidity bins). Furthermore, a longer lifetime in the very rough radiation environment of the experiment, and a somewhat wider range in pseudorapidity are being aimed at.

Among several novel calorimeter/absorber configurations which have been studied following the above criteria, the following two versions are the most promising:

1.– a calorimeter similar to the existing one but using Cu instead of Pb, and somewhat shorter (8 instead of 16 radiation lengths);

2.– a sampling calorimeter which occupies only angular domains outside the six circular sectors corresponding to the air gaps of the magnet ("petal calorimeter").

The second solution is sketched in Fig. 2. It is particularly elegant since it decouples to a large extent the two conflicting requirements of having dense but low Z material in front of the spectrometer, and high Z converter in the calorimeter. The incomplete azimuthal coverage of the calorimeter is not dangerous; according to a GEANT3 simulation it results in an acceptable 6 % extra error in the transverse energy. The mass resolution improves appreciably, (40 % at the Φ mass), since the muons in the spectrometer acceptance windows travel through low Z materials only, beginning ideally with 3 interaction lengths of BeO. The rate of decay muon pairs halves since the first 3 L_{int} now lie within 100 cm of the target centre, while in the 1986/87 layout 3 L_{int} occupy 160 cm. Due to multiple scattering in the calorimeter and wide angle K decays, a number of prompt and decay muons do however appear in the active region of the spectrometer after having traversed the calorimeter. This problem is being studied further.

We will choose one solution and finalize the design this summer. The new calorimeter/absorber block will be ready in less than one year. It will then be exposed to an ion beam under conditions which will allow a direct comparison with the data already taken.

We should like to mention that these developments will be directly useful for future experimentation with the proposed heavy ion beam, since the meson decay muons constitute the foremost technical problem for any dimuon experiment using a heavy ion beam.

IV. BEAM TIME REQUEST FOR 1989/1990.

We confirm our request (cf. Memo CERN/SPSC 88-17 SPSC/R74) of

- 34 days with at least 3 10^7 200 GeV/n Sulphur ions per burst in 1989
- 68 days with an intense 200 GeV/n ion beam in 1990.

Our aims for 1989 are

- to study experimentally an improved calorimeter and a compactified hadron absorber configuration;
- to measure the proportion of correlated meson decay pairs in a sulphur beam (by taking complementary data without hadron absorber near the target);
- to accumulate more S-U data of improved quality, benefitting hopefully from a more stable and intense ion source.

Our aims for the requested 1990 run are

- to test an optimized layout defined and built using the results of the requested 1989 run;
- to take those high statistics data which will by then be most useful for a better understanding of the peculiar features of dimuon production in ion-ion collisions.

We recall that we cannot take useful data at 60 GeV/c since the rapidity domain covered by the dimuon spectrometer ($2.8 < \eta < 4.0$) is too far from mid-rapidity at that energy (namely, $\eta = 2.4$); the product cross section times acceptance becomes very small, in particular for the J/Ψ.

We wish also to stress that a rather long ion beam time is needed both to carry out the necessary technical runs and to increase substantially statistics for physics; and that the beam time should be allocated in two parts separated by a prolonged period which is necessary for analyzing and interpreting the data taken in the first period and, if necessary, for modifying the layout of the experiment according to such results before taking the bulk of the data.

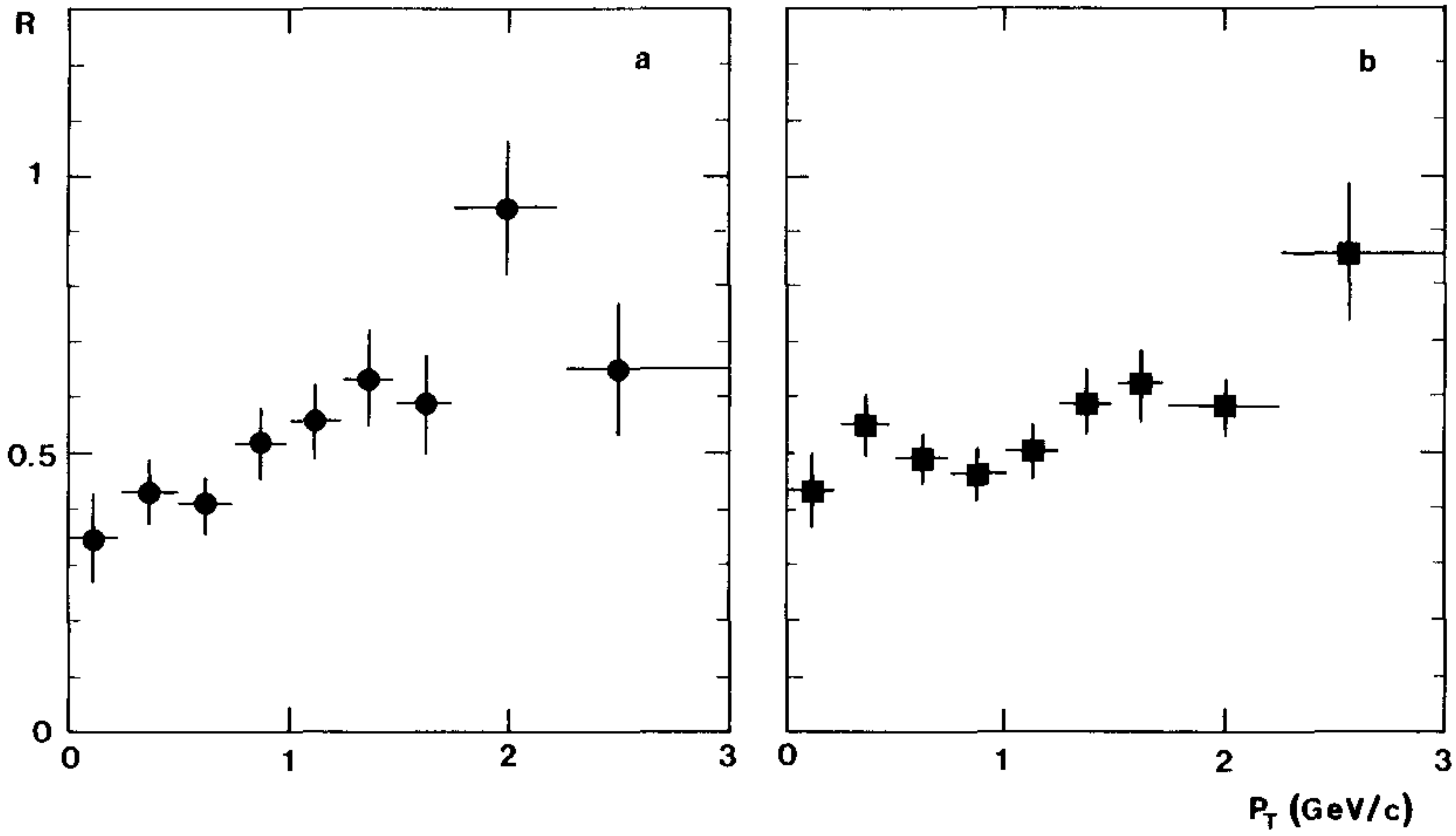

Fig.1 Ratio of P_T distributions of J/Ψ at high and low E_T, for a. oxygen − uranium and b. sulphur − uranium interactions at 200 GeV/nucleon. The extreme E_T intervals used comprise roughly 1/6 of the Continuum events each. The data within E_T bins are normalized in such a way that the analogous ratio for the continuum (integrated over P_T since there the statistics is low) is unity.

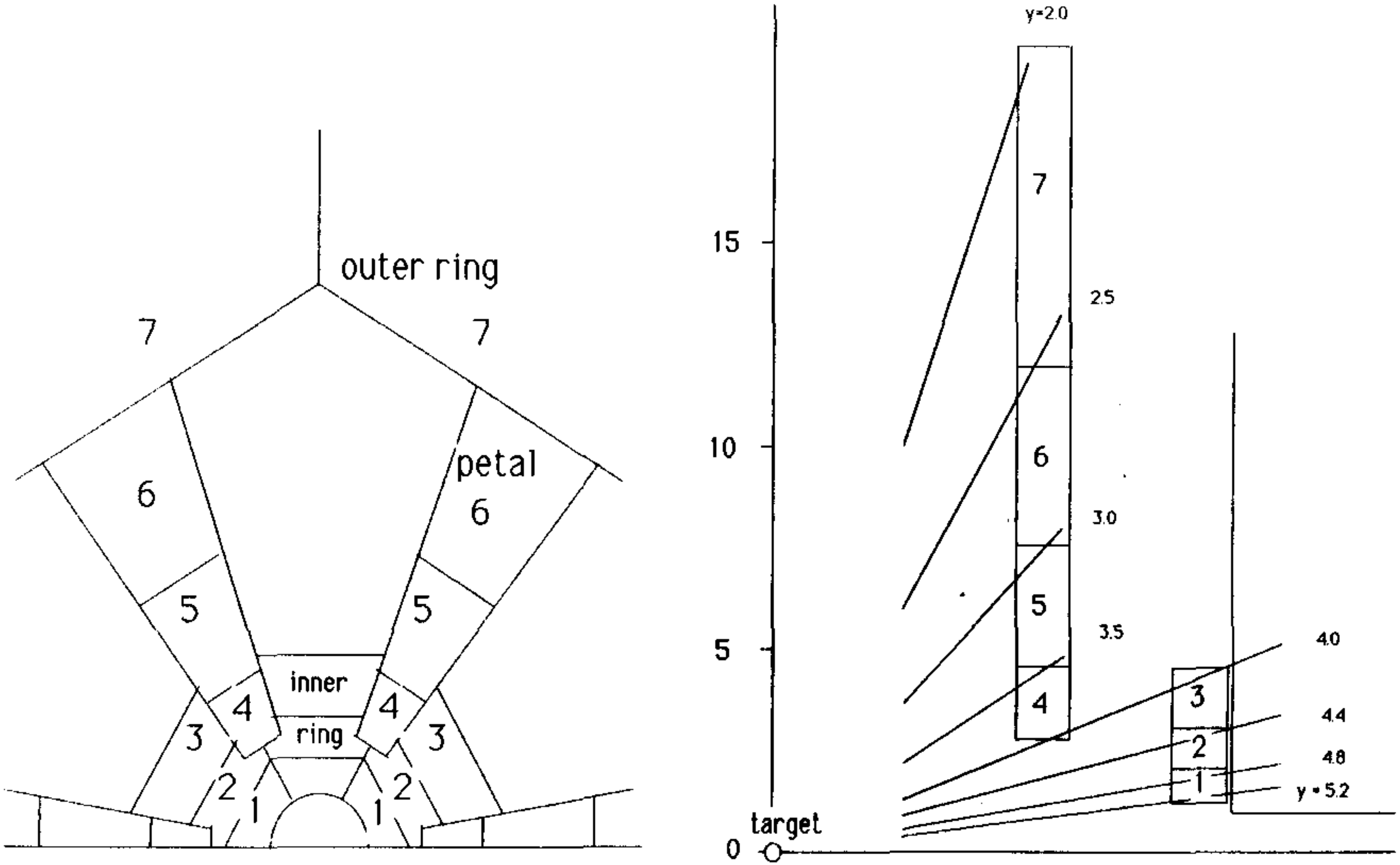

Fig. 2 Schematic front (a) and side (b) view of the Petal Calorimeter, one of the two favored schemes under study. The calorimeter occupies only the angular regions outside the six air gaps of the muon spectrometer magnet. The muon regions (the pentagons in Fig. 2a) are filled with BeO and C (not shown) which absorb efficiently the pions and kaons emitted in the direction of the spectrometer, minimizing at the same time the multiple scattering of the measured muons. The 7 domains in η covered by the calorimeter are labelled, with their limits in η. Note the distorted scale of Fig. 2a.