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Observation of the Anomalous Nuclear Enhancement in the Neutral Energy Spectrum in the Central Region of α-α Interactions at $\sqrt{s}$ = 124 GeV at the CERN ISR

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OBSERVATION OF THE ANOMALOUS NUCLEAR ENHANCEMENT IN THE NEUTRAL ENERGY SPECTRUM IN THE CENTRAL REGION OF α-α INTERACTIONS AT $\sqrt{s}$ = 124 GeV AT THE CERN ISR

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Inclusive particle production in proton-nucleus collisions and nucleus-nucleus collisions exhibits an enhancement relative to proton-proton collisions by a factor which has been parameterized as $(A_1 A_2)^\alpha$, where A_1 and A_2 are the number of nucleons in each nucleus. The exponent α varies between 0.8 and 1.3 for inclusive single particle production[1] in the central region and depends on the P_T and type of the produced particle as well as on the center-of-mass energy of the collision.[2]

The anomalous enhancement (α >1) has also been observed for the emission of transverse energy in the central region,[3,4] where the energy is summed over all the particles emitted into a fixed solid angle, typically $\Delta\phi$=2π, Δy=± 1. The variation of α is much larger in this class of experiment, with values as high as α = 2.0 observed at transverse energies up to 80% of the available nucleon-nucleon center-of-mass energy.

In this report, preliminary results are presented for the total neutral energy spectra in the central region from $\alpha\alpha$ and pp collisions at center-of-

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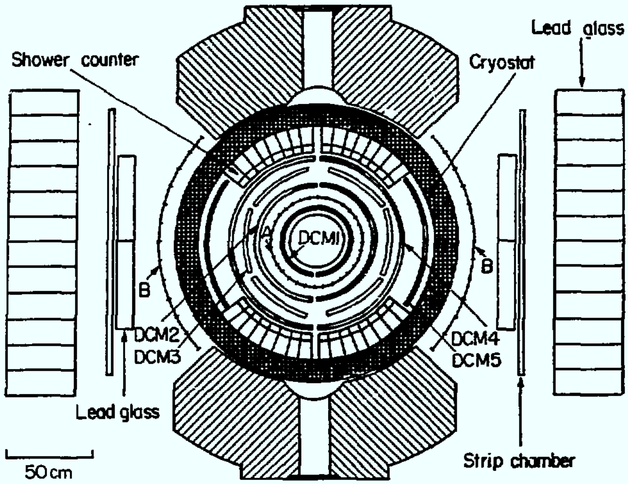

Fig. 1. The apparatus viewed along the beam axis.

mass energies of $\sqrt{s}$ = 31 GeV per nucleon pair. The data were collected in the recent light ion run at the CERN ISR during August 1983. The αα luminosity achieved in this run was 10^{30} cm^{-2} s^{-1}.

The apparatus, shown in Fig. 1, consisted of a superconducting solenoid providing a magnetic field of 1.4 T and enclosing a system of cylindrical drift chambers. Four modules of lead/scintillator shower counters were also located inside the magnet. Each module subtended 50° in azimuth and ± 1.1 units of rapidity *y*, centered on *y* = 0, and was segmented azimuthally into eight counters equipped with phototubes at both ends. The detection of electromagnetic showers was completed by two lead-glass modules located outside the magnet in the angular region not covered by the shower counters. The angular acceptance of each lead-glass array was 57° in azimuth and ± 0.6 units of rapidity, also centered on *y* = 0. The thickness of the lead glass was 21 radiation lengths (r.l.) and that of the shower counters was 14 r.l. The r.m.s. energy resolutions were $(4.3/\sqrt{E} + 2)\%$ and $16\%/\sqrt{E}$, respectively, where E is measured in GeV. A hodoscope of 32 scintilation counters (A), also equipped with phototubes at both ends, was located between the first and second drift chamber modules. The apparatus has been described in more detail elsewhere.[5,6]

To trigger the apparatus, all energies deposited in the shower counters and the lead glass were summed and the total was required to be above a threshold.

The threshold was applied again in the off-line analysis, using more detailed calibration information.

Events due to the occurrence of more than one interaction during the apparatus recording time were rejected. This requirement was necessitated by the high interaction rate at the ISR and the nature of the trigger, which purposely placed little requirement on the pattern of energy deposition. All shower counters were equipped with time-to-digital converters (TDCs). In addition, the scintillator hodoscope (A) which surrounded the interaction region had TDCs capable of recording up to 14 hits per counter end in a time range of 300 ns before and after the nominal event time. The time data from the shower counters and the A scintillators were searched in a range of ± 200 ns (the longest gate time used in the calorimeter). A time cluster was defined as two or more counters firing within a 12 ns interval. If more than one distinct cluster was found, the event was rejected. This method has been shown to work[6] at interaction rates four times higher than those achieved for the $\alpha\alpha$ collisions.

For each shower counter the longitudinal position of the energy deposition was calculated from the time difference or the energy ratio between the two ends. The electromagnetic ("neutral") energy was calculated for each of the individual shower counters and lead-glass blocks, and was simply summed to give the total neutral energy E°_{TOT} for each event. The transverse component of the total neutral energy has not been computed for this preliminary analysis since the charged particle track parameters were not yet available to reconstruct the position of the interaction vertex.

Data samples with four thresholds were used for the $\alpha\alpha$ measurement: 1 GeV, 17 GeV, 23 GeV and 28 GeV. For each data sample, the number of events per GeV of E°_{TOT} was divided by the integrated luminosity L to obtain the spectrum $\frac{1}{L}\frac{dN}{dE^\circ_{TOT}}$ as shown in *Figure 2*. The data from the different samples agree very well and cover a wide range of E°_{TOT} from 1 GeV to 35 GeV. It is noteworthy that the $\alpha\alpha$ data extend to well beyond the incoherent nucleon-nucleon kinematic limit of 31 GeV. The same spectrum measured in proton-proton interactions at the same value of nucleon-nucleon center-of-mass energy, $\sqrt{s} = 31$ GeV, is also shown in the figure. The pp data extend from 5 to 17 GeV.

The ratio of the $\alpha\alpha$ cross section to the pp cross section rises dramatically with increasing E°_{TOT} from a factor of 30 at E°_{TOT} of 5 GeV to a factor of 10,000 at E°_{TOT} of 16.5 GeV. The existence of $\alpha\alpha$ data beyond the nucleon-nucleon kinematic limit indicates the inadequacy of the parameterization $R(\alpha\alpha/pp) = (A_1A_2)^\alpha$ for the E°_{TOT} spectrum. E°_{TOT} is the sum over many

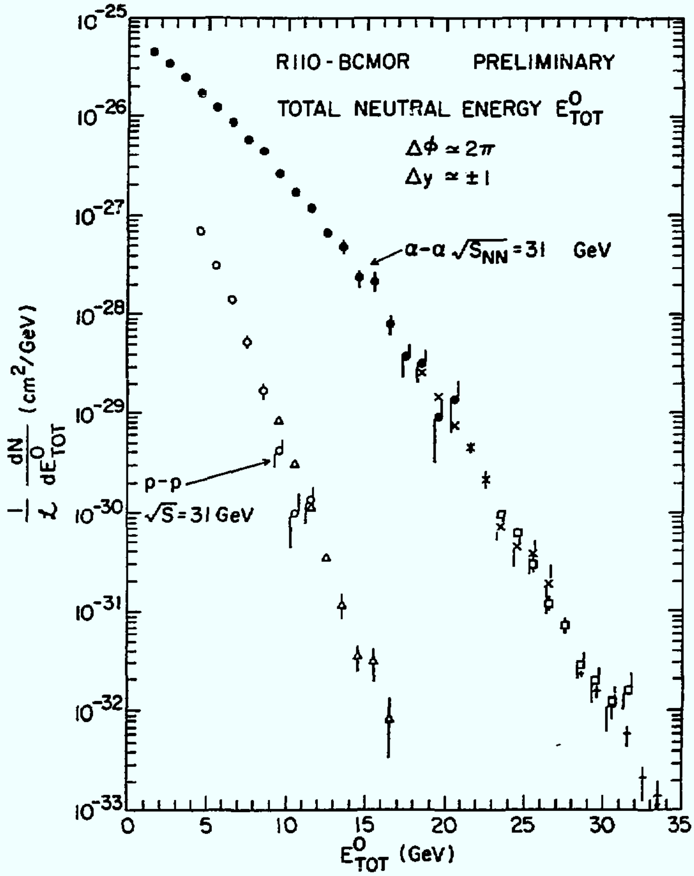

Fig. 2. The spectrum $\frac{1}{L} \frac{dN}{dE^{o}_{TOT}}$ versus the total neutral energy E^{o}_{TOT} observed in the detector, $\Delta\phi = 2\pi$, $\Delta y = \pm 1$ for $\alpha\alpha$ and pp collisions at the same center-of-mass energy per nucleon pair, $\sqrt{s} = 31$ GeV. The thresholds for the data samples for $\alpha\alpha$ are: 1 GeV ●; 17 GeV x; 23 GeV ϕ ; 28 GeV †; and for pp 4 GeV o; 9 GeV Δ.

particles in the detector, so it is directly sensitive to multiple nucleon-nucleon interactions in the colliding α particles. Single particle spectra are sensitive in a different way to multiple nucleon-nucleon interactions and thus provide a complementary probe of nucleus-nucleus collisions. Both these issues will be investigated as the data are further analyzed.

It should be emphasized that the spectra presented in Figure 2 are preliminary. Tracking of charged particles, vertex fitting and looking for clusters in the neutral energy deposition have not yet been attempted. No corrections have been applied for resolution, double hits within the same shower counter or energy deposited by charged tracks in the shower counters or lead glass. These effects are not expected to materially change the conclusions of this paper. The systematic error on the E°_{TOT} scale is estimated to be less than 6%.

A display of a typical $\alpha\alpha$ event with $E^{\circ}_{TOT} \geq 30$ GeV is shown in Figure 3. These events appear to have a much higher charged particle multiplicity than pp events[6] at the same value of E°_{TOT}.

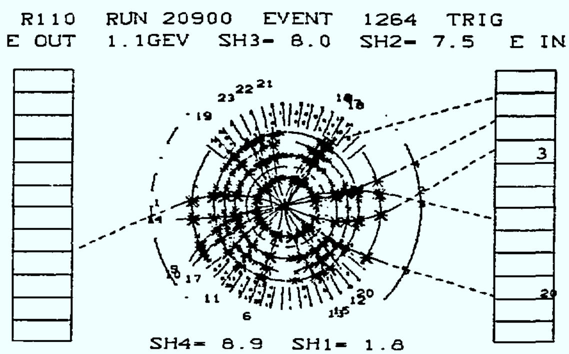

Fig. 3. View of reconstructed event from same perspective as Figure 1. Note that 23 charged tracks have been found.

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