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THE HEAVY ION PROGRAM AT CERN

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During two periods in 1986 and 1987, oxygen ion beams with energies up to 3.2 TeV will be available at the CERN-SPS. A brief review of the five large heavy ion experiments is presented and the different physics addressed by each of the experiments is discussed.

1. INTRODUCTION

Interest in heavy ion experimments has been growing in the last few years as fixed target experiments at both the CERN SPS and the BNL AGS are preparing to take data. The main physics motivation for the study of heavy ion interactions is to investigate the existence and properties of a new state of matter that is predicted when a region with large energy density is created over a large enough volume. Such a state is supposed to have existed during the time of the creation, but a more practical way to create one in the laboratory is by heavy ion collisions. The best arguments for new physics under these conditions is still that confinement of partons inside a hadron due to the special properties of the surrounding space cannot survive when the density of hadrons is large enough compared to that inside ordinary hadrons. The numerical calculations of QCD support this picture, but do not add much quantitative guidance[1,2] They do, however, confirm the deconfinement of the partons and colour fields within the excited volume. Some of the calculations suggest that first order deconfinement transition with a big latent heat, which could lead to striking phenomena.

These considerations are only relevant to nuclear collisions, if a sufficiently large amount of energy is thermalized and if the state exists for a sufficiently long time. For this reason, most experiments are designed to select events with large energy deposited in a limited rapidity interval. The detectors designed have to work in a high multiplicity environment.

In the first section of the paper we will review briefly the status of the plans to accelerate heavy ion beams at the CERN SPS. In Section 2 we will discuss some of the signatures one is looking for if a quark gluon plasma is created. The main part of this paper will present a brief outline of the five large electronic experiments planning to take data in 1986 and 1987 at the CERN SPS. The experiments we will review are NA34/HELIOS Collaboration,[7] NA35,[8] NA36,[9] NA38,[10] and WA80.[11]

2. CERN HEAVY ION BEAMS

External beams are planned to be available simultaneously in the north and west experimental area. The planned beams will have intensities of 10^4 to 3×10^7 nucleons per second. The present heavy ion program calls for the acceleration of oxygen ions to a maximum energy of 225 GeV/A with possible beams at lower energies, present plans are to run at 60 GeV/A as well. At the time this summary is being written heavy ion beams have been accelerated to 200 GeV/A extracted and delivered to two experiments in the north area. The pleasant surprise was the cleanliness of the beams delivered to the experimental targets. They did not have large contaminations of alhpa particles or other lower A nucleons as feared by some.

The injector preaccelerator for ^{16}O ions was installed at CERN by a collaboration of GSI-LBL and CERN.[3] The injector is based on a high charge state electron cyclotron resonance (ECR) source constructed by R. Geller, Grenoble. The source will be upgraded in 1987 to the acceleration on ^{32}Si and perhaps ^{40}Ca. The ions from the source are accelerated in Linac 1 to 181 MeV/ion (11.4 MeV/nucleon) and then injected into the booster where they are accelerated to 4.14 GeV (259 MeV/nucleon). From the booster they are fed into the PS where they are accelerated to 10 GeV/

nucleon and passed onto the SPS where they are accelerated to the desired energy and extracted to the different experiments. The extracted energy can vary from 60 to 225 GeV/nucleon. A proposal is now being developed to upgrade the heavy ion acceleration capabilities up to lead beams in the early 1990's.

3. EXPERIMENTAL SIGNATURES

Experimentally what can one expect if and when quark gluon plasma is created in the laboratory? One should keep this information in mind when reviewing the properties of the different experiments, to try and understand the different physics emphasis of the experiments. The basic variable one is dealing with is the density of matter. Experimentally, one is unable to measure the density directly but rather tries to estimate it by measuring the energy in a given rapidity region, and/or the multiplicity in a given rapidity region, as well as the interaction volume by pion interferometry. It is expected that if phase transition actually occurs there will be a sharp break in the distributions of the different QGP signatures.

The global event parameters allow estimating the temperature, size and density of the plasma by measuring inclusive particle spectra and particle interferometry. The long range correlations and the characteristics of first order phase transition are measured via multiparticle correlation in rapidity and energy flow. The indication of phase transition can be detected by means of local charge correlations, as well as particle flavor ratio, in particular, ratio of strange particles. The penetrating probes and more direct information from the plasma will come from the measurement of direct photon production, as well as a virtual photon production.

4. THE CERN EXPERIMENTS

The experimental layout of experiment NA34/HELIOS is shown in Fig. 1. The experiment proposes to investigate in detail the characteristics of ultra-relativistic heavy-ion interactions. The experiment combines 4π calorimeter coverage with measurements of inclusive particle spectra, two-particle correlations, low- and high-mass lepton pairs and photons.

The physics program calls for detailed investigation of events with large transverse energy flow that are most likely to involve thermalization of a significant amount of energy over nuclear volume. The E_T flow is measured in a finely segmented uranium scintillator calorimeter with good energy resolution: $37\%/\sqrt{E}$ for hadrons, $16\%\sqrt{E}$ for electromagnetic shower. In the forward direction a Uranium liquid argon calorimeter is planned for the 1987 running period. The external spectrometer has an azimuthal acceptance of $15^\circ \leq \theta_2$ 45 $\leq 45^\circ$ corresponding to a laboratory rapidity interval of 0.8 to 2, and in ϕ a constant 10 cm gap in the calorimeter will define the acceptance. Thus even for central

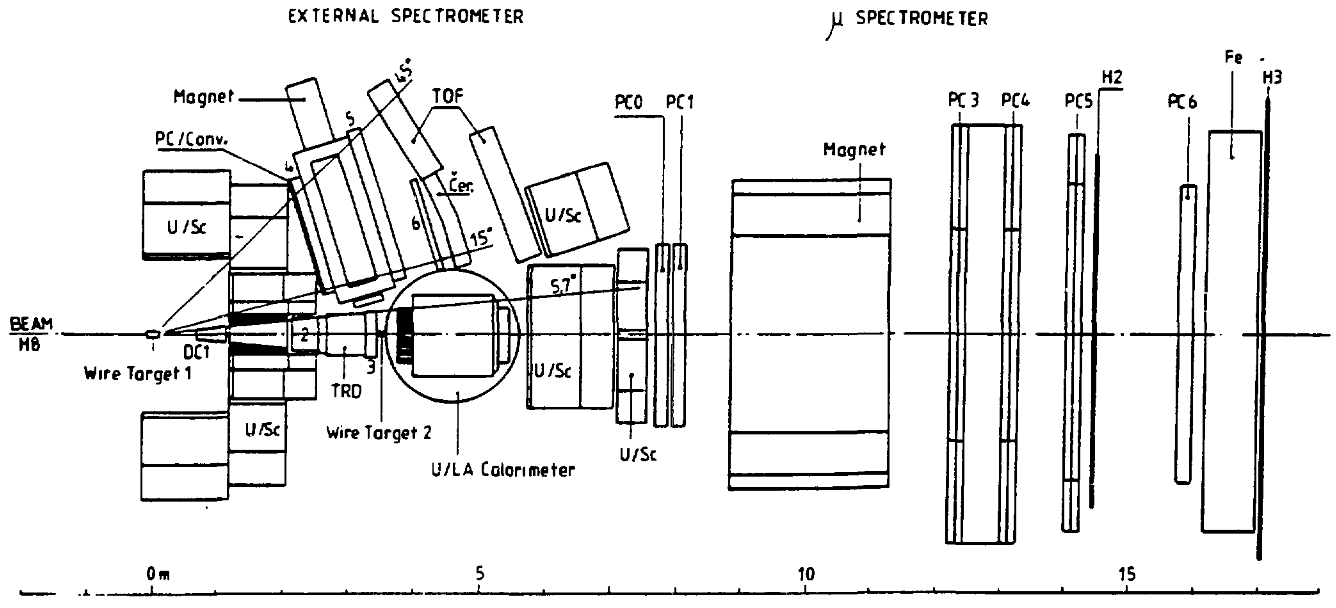


Figure 1: LAYOUT OF EXPERIMENT NA34/HELIOS

^{16}O + Au events at 200 GeV one expects approximately 1-2 charged particles (based on HIJET modeling). The external spectrometer has a weak magnetic field coupled to high resolution drift chambers, giving a $\Delta p/p \approx 1\%$ p (GeV/c). Particle identification is based on time-of-flight hodoscopes and an array of silica aerogel detectors giving p/k separation up to 2.5 GeV and π/K up to 1.5 GeV. The experiment has photon detection capabilities in the external spectrometer, as well as the ability to trigger on converted photons.

Dileptons can be measured in the μ spectrometer which is based on the old NA3 spectrometer. it has been modified extensively to take into account some of the special requirements of the experiment. The experiment will thus be able to measure di-muon in the mass region of a few hundred MeV all the way to the J/ψ. Because of the possible contamination of muon coming from π and K decay, a second multiwire active target will be placed just in front of the foward calorimeter to investigate di-lepton production. The strength of this experiment is clearly in the fact that it will be able to study correlation between the different signatures coupled to a very good measurement of the energy flow.

In Figure 2 we show the layout of experiment NA35. The experimental setup consists of a 2 meter streamer chamber in the vertex magnet and is used to detect all the charge particles emerging from the interaction, as well as the neutral strange particles that decay inside the chamber. The high energy forward going particles are detected by four sets of calorimeters. A highly segmented photon position detector (PPD) is backed by a 240 segmented ring calorimeter that covers one unit of rapidity around mid-rapidity region. An intermediate calorimeter will cover the rest of the forward phase space except for the region around beam rapidity, where a veto calorimeter will detect beam spectators. Thus for each event, charge particle multiplicity, the π^0 multiplicity near mid-rapidity, as well as proton and pion rapidity distributions, and mean transverse momentum for charged pions and strange particle production, all as a function of energy flow can be measured. The unique feature of this experiment is the streamer chamber which will enable them to measure all charged tracks coming out of the interaction.

A possible signature of QGP is a strongly enhanced yield of strange quark pairs. The aim of experiment NA36 is to measure the differential cross sections for the production of neutral kaons, Λ, Ξ, Ω and their anti-particles. In Figure 3 we show a layout of experiment NA36. The neutral strange particle will be measured in a TPC chamber with two-dimensional unambiguous space point tracking sitting inside a long M1 magnet. The TPC sits just off the beam so that only negative tracks are swept into the TPC and no highly ionized beam fragments pass through the TPC. Some charged particle trajectories will be reconstructed and the total energy flow and its fluctuation will be measured in a calorimeter covering the forward center of mass hemisphere. The forward spectrometer apart from the TPC is in a modified EHS configuration. The unique feature of this

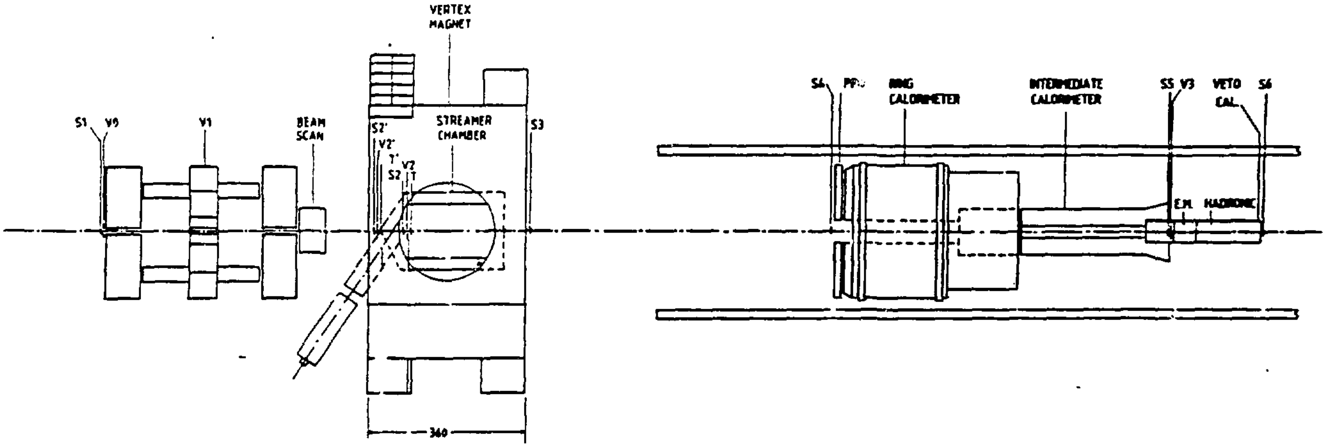
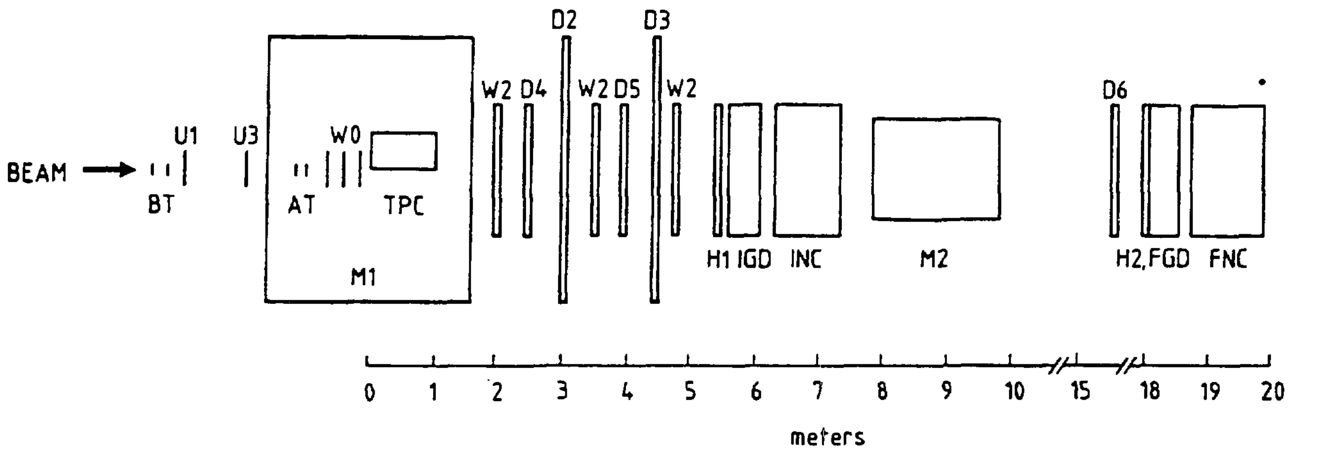


Figure 2: LAYOUT OF EXPERIMENT NA35

experiment is the three-dimensional unambiguous space point tracing permitted by the TPC. They also emphasize more the forward region as compared with other experiments where emphasis is more on the central regions.

In Figure 4 we show the layout of experiment NA38.



BT = beam tag
AT = active target
M1 M2 = magnets
H1 H2 = hodoscopes
IGD, FGD = gamma detectors
INC, FNC = hadron calorimeters

U1, U3 / W0, W2 } prop. wire chambers
D2 - D6 = drift chambers

Figure 3: LAYOUT OF EXPERIMENT NA36

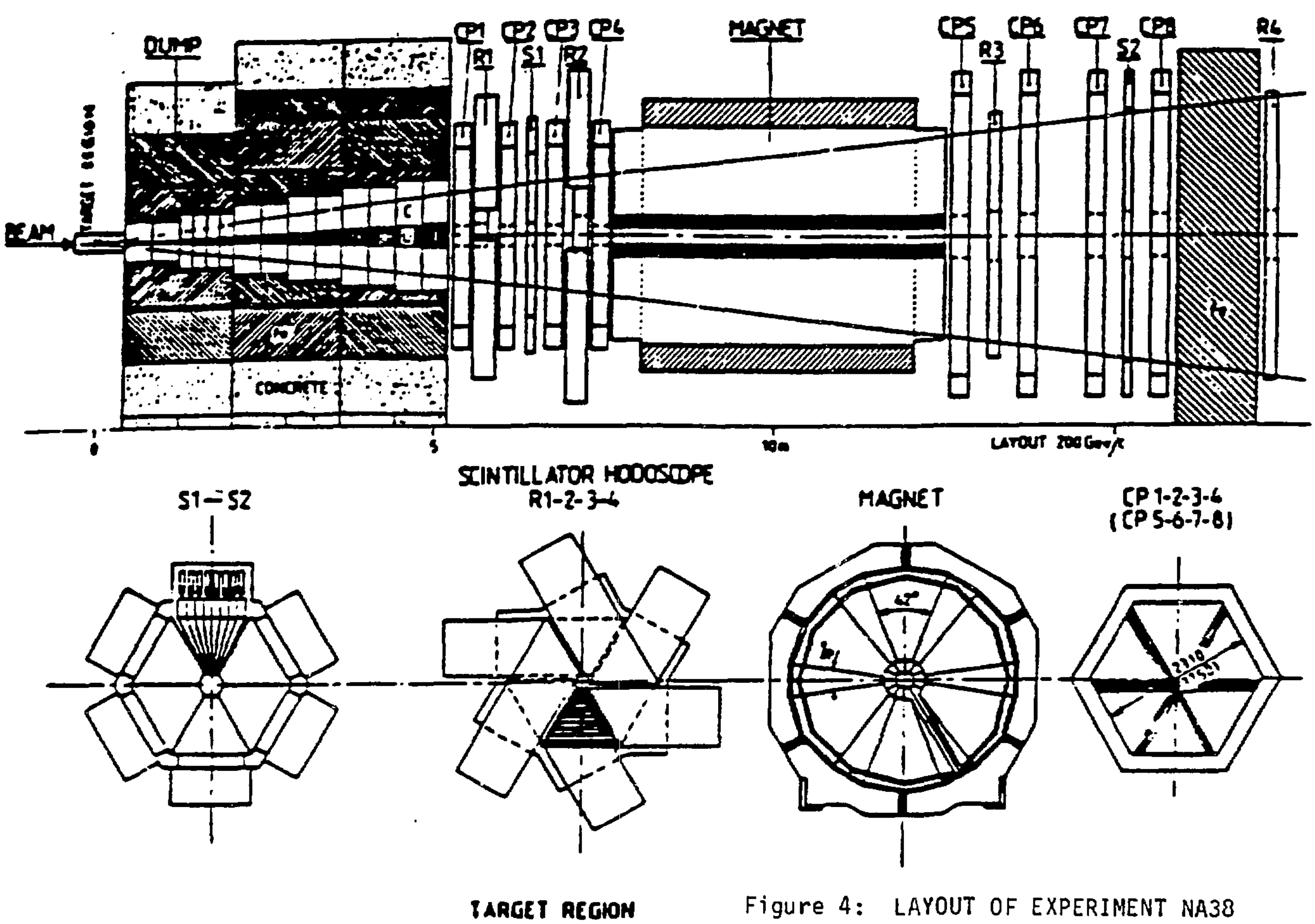


Figure 4: LAYOUT OF EXPERIMENT NA38

The experiment proposes to use a modified NA10 spectrometer which was used to study *di-muon production in high luminosity pA* interaction. An active segmented target and an electromagnetic calorimeter will be added. The thermal di muons are expected to be emitted from the QGP at a reasonably high rate in the region between 1-3 GeV/c transverse mass region and differ from ordinary dimensions in their p_T and rapidity distribution. The emphasis will thus be on measuring the di muons with good mass resolution in correlation to the charge multiplicity and neutral energy flow distributions measured in the electromagnetic calorimeter. The calorimeter is of special design of lead and scintillation fiber structure. The special feature of this experiment has to do with the good di-muon mass resolution, as well as the ability of the experiment to take a high rate.

In Figure 5 we show the layout of Experiment WA80.

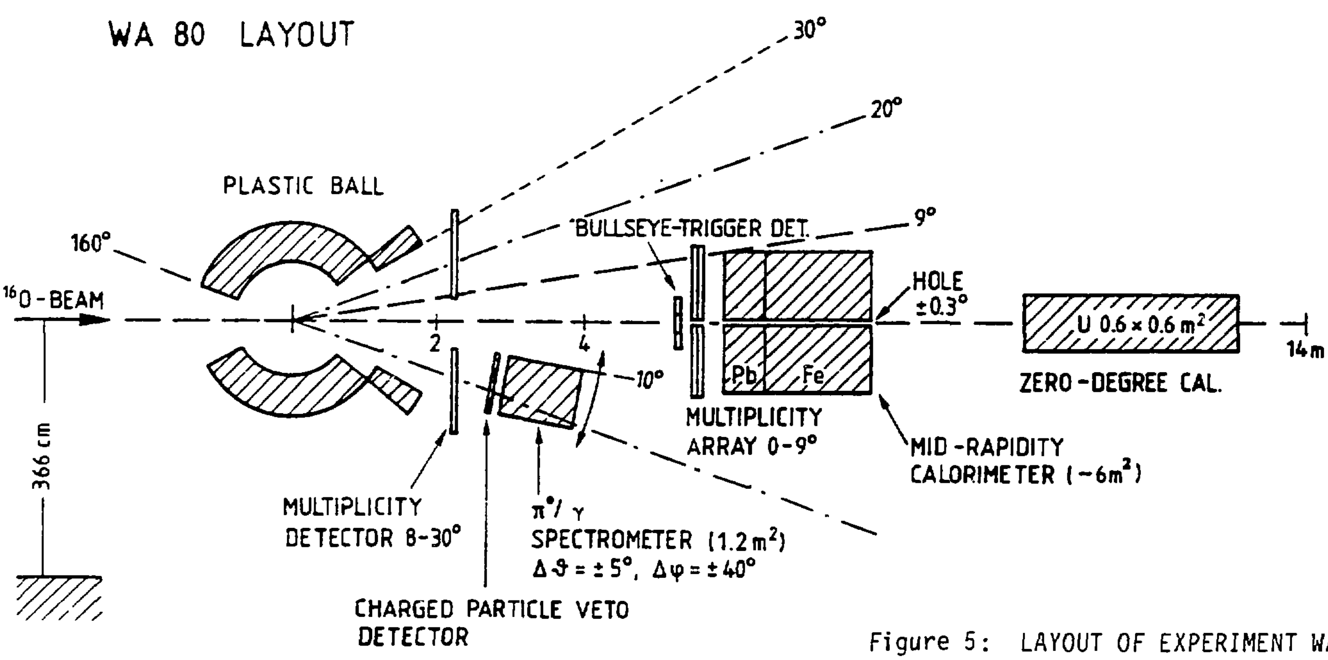


Figure 5: LAYOUT OF EXPERIMENT WA80

The experiment consists of a vertex detector, called the plastic ball, which consists of a 655 module double dE/dx scintillator sphere covering $\theta > 30°$ thus identifying protons, deuterons, tritons, alphas, etc., in the target rapidity domain. The forward angles $\theta < 9°$ are covered by streamer tubes, pad read out array with (25,000 pads), and by two Pb-Fe electromagnetic/hadronic fine granularity calorimeters. In addition, a 1000 segment lead glass calorimeter of sufficiently small granularity to identify π^0 and direct photons at E > 1 GeV covers the $40° > \theta_{cm} > 90°$ center of mass angle. The experiment can thus trigger on high transverse energy and measure charge multiplicity, target fragments, photons and π^0 at high p_T. It has a unique capability in the target region, as well as a very fine multiplicity array counter.

The CERN Heavy Ion Program is thus a very large undertaking involving well over 300 physicists. The utilization of existing equipment enabled the community to mount five large experiments which are complementary to each other in a reasonably short time and with little expense relative to what would have been needed if one would have started from the beginning. We now have to look forward to new and exciting results, hopefully, during 1987.

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REFERENCES

1. See, for example,: Quark Matter Conference at Brookhaven, Nucl. Phys. A418 (1984).

2. Proc. Quark Matter Conf., 4 Springer Lectures Notes in Physics Vol. 221 (1985).

3. Wolf, B.H. et al., GSI Report 86-2.

4. Stock, R., Nucl. Phys. A447, (1985) 371C.

5. Kogut, J.B., Nucl. Phys. 418 (1984) 381C; Muller, B., Springer Lecture Notes in Physics Vol. 225 (1985).

6. Wong, C.W., Phys. A418 (1984) 447C.

7. NA34 Collaboration: Brookhaven Natl. Lab., CERN, Heidelberg Univ., London, Birkbeck College; London, University College; Los Alamos Natl. Lab., Lund Univ., Montreal McGill Univ., Montreal Univ., Moscow Lebedev Phys. Inst., Moscow Eng. Phys. Inst., Novosibirsk Inst. Nucl. Phys., Pittsburgh Univ., Rutherford Appleton Lab., Saclay CEN DPhPE, Stockholm Univ., Tel-Aviv Univ.

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9. NA36 Collaboration: Athens Natl. Tech. Univ., Bergen Univ., Birmingham Univ., Brookhaven Natl. Lab., Carnegie-Mellon Univ., CERN, Chandigarh, Punjab Univ., City College of New York, Cracow Inst. Nucl. Phys., Lawrence Berkeley Lab., Strasbourg Univ., Vienna Akad. Wissensch.

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11. WA80 Collaboration: Darmstadt GSI, Lawrence Berkeley Lab., Lund Univ., Marburg Univ., Munster Univ., Oak Ridge Natl. Lab., Warsaw Univ.