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Memorandum

To: Members of the SPS Committee

From: J. Stachel for the CERES/NA45 Collaboration

Subject: Status of the CERES/NA45 experiment

After a brief repetition of the main CERES goals this memo gives an update of the analysis of the data from the 1999 heavy ion run at 40 A GeV/c, the performance of the experiment in the 2000 heavy ion run, and the status of the current analysis.

The main goal of the CERES/NA45 experiment is the measurement of low-mass e^+e^- pairs in proton and ion-induced collisions at the SPS. The main result from this experiment was the observation of a significantly enhanced production of lepton pairs with respect to expectations based on hadron decays, in the mass range $250 < m_{ee} < 700$ MeV/c^2, in ion-induced collisions . To distinguish between different theoretical explanations of the enhancement the experiment was upgraded in 1998 by the addition of a radial TPC with an additional magnetic field to improve the mass resolution in the ρ/ω region to $\Delta m/m < 2\%$.

After a first commissioning run in 1998 the plan was for two production runs in 1999 and 2000, one at 40 A GeV/c beam momentum, the other at the maximum SPS momentum which is for Pb ions 158 A GeV/c. The motivation for the 40 A GeV/c run was to get some discrimination power between effects of temperature and effects of baryon density on the dilepton spectrum.

Analysis of 1999 Run

As described in the status report given in March 2000 the 1999 data taking suffered from problems in the read-out of the experiment. Nevertheless, about 8 Million events were recorded for which typically 50 % of the TPC channels are read-out properly and for which data from the 2 RICH detectors and the 2 Silicon drift chambers are also present. Of these about 6 Million events have been analyzed.

Software was written to automatically recognize problems with corrupted or missing data and to adjust the tracking to this unexpected environment. Then

work started on the calibration of the TPC. This proceeded from March until July 2000 and is not complete. The difficulty lies in the interplay between:

1. The complicated electric field (approximately 1/r but with distortions from the fact that the inner high voltage electrode has cylindrical shape but the 16 read-out chambers at the outside are flat, i.e. generate a polygonal symmetry). We also found an unexpected distortion leading to tracks that curve in theta or radius by order of a centimetre. We have generated a field map that corrects this effect but the physical origin is still under investigation.

2. The inhomogeneous magnetic field generated by two large coils with current in opposite direction leading to strong local variations of the Lorentz angle and therefore also to the need to know very precisely the location and orientation of the TPC relative to the magnet.

3. The choice of the drift gas (Ne/CO_2) and potential on the HV cathode (31 kV) together with the radial geometry (but polygonal at the outside) leading to strong local variations in drift velocity (about a factor of 3 between inside and outside).

4. Small gradients and changes in temperature (measured at the outer surface of the TPC and not in the gas volume) and pressure leading to drift velocity variations.

This explains that the calibration is a rather difficult and time consuming process. Also, any geometrical calibration of the exact placement and orientation of the 16 TPC read-out chambers is complicated by the in 1999 incomplete read-out of the detector.

The calibration process was stopped in July for 2 reasons: intense preparation of the beam time starting with proton running on August 31 and the desire to have physics results from the 99 run for the Quarkmatter conference in January 2001. It is clear that the final resolution can only be achieved once the calibration is completed. But there are a number of interesting physics results even at this intermediate stage of calibration.

At the present stage of calibration it can be seen from the residuals of 'clean' single hits relative to fitted tracks that the local resolution in rϕ (the bend direction) and in r is already at the design values under certain selection criteria. This is the case when we select tracks with a large enough number of hits (at least 16 out of possible 20), in the middle of read-out chambers and without magnetic field and inspect hits not too close to the upstream and downstream ends of the TPC. In that case, one obtains values of 280 μm in rϕ rather independent of r and 740 μm in r averaged over r. The unfinished calibration leads however to systematic dislocations of hits as function of r, ϕ and z, in particular with magnetic field. If these dislocations and the measured width in the distribution of residuals are entered into the Monte-Carlo simulation of the detector a momentum resolution results

that is about a factor 2 worse than the final goal. This momentum resolution reproduces the current measured width of the Lambda (10 MeV).

For the 99 data with 50 % of the channels missing the Monte-Carlo simulations yield a tracking efficiency in the TPC of 73 %. We actually measure from the extrapolation of tracks from the 2 Silicon driftchambers 57 %. The difference is not yet completely understood.

A number of physics results from the 1999 data taking of CERES have already been obtained. They comprise:

- An e^+e^- mass spectrum with a signal of 159 ± 46 pairs above mass $0.2\,\mathrm{GeV}/c^2$ and a signal to background ratio of 1/6. This is above the expectation from hadronic decays.
- Yields and transverse momentum spectra of negatively charged hadrons and the difference between positively and negatively charged hadrons (close to proton distributions) as a function of centrality of the collision.
- Correlations of negatively charged hadrons as function of the relative momentum in the three spacial dimensions and as a function of the pair transverse momentum. This allows extraction of parameters relevant for the freeze-out of hadrons like time scale, geometric dimensions, pion density, and average expansion velocity.
- Analysis of the azimuthal anisotropy of events and extraction of the elliptic flow (2nd moment in a Fourier analysis).
- Analysis of event-by-event fluctuations in the transverse momentum of particles. We find evidence for a small non-statistical fluctuation.
- Yield and spectral distribution of Λ particles.

Performance of Experiment in 2000 Heavy Ion Run

For the heavy ion run in 2000 the read-out of the TPC after the front-end electronics, comprised of preamplifier/shaper and switched capacitor array, was changed because of the problems encountered in the 1999 run. With support from the microelectronics group in the EP division we used a VME based system (FEDC) of flash ADC's and digital chip (ALTRO) for zero-suppression originally designed for ALICE and modified for CERES specific needs. This system will also be used in this year's run of HARP. The system became available 2 weeks prior to the proton run and was complete just before the start of the heavy ion run. It was incorporated into a new data acquisition system without problems. The data acquistion system and it's performance are described in a note (http://www.gsi.de/~misko/ceres/daq/note.html). It allowed to collect on 10 PC's during a 5 s burst 400 events of typically 500 kByte, i.e. 200 MByte, and in the 14 s long burst pause these data were sent via a fast link to an event builder PC in the

Central Data Recording (CDR) facility. While event building of the 10 branches of data and writing to disk occured on one PC data of the next bursts were sent to another of the total of 7 PC's in CDR. On one more PC the tape control script was running. The event rate was limited by the time it took (5ms) to transfer the TPC data from the FEDC to the memory of a read-out PC and therefore the TPC data were distributed over 8 VME crates and sent via MXI interfaces to 8 PC's. After introducing a pipeline scheme, with a beam rate of about 10^6 per burst and about 1000 central triggers, 400 events could be read out with this scheme.

CERES went into routine data taking 4 days after the first Pb beam was in the North Area and collected in total $31 \cdot 10^6$ events with a centrality corresponding to the most central 8 % of the geometric cross section and another $3.5 \cdot 10^6$ events at 25 % centrality. In addition runs without magnetic field, with minimum bias trigger and with lower beam intensity as well as runs without target and laser runs were taken for calibration purposes.

Using the electron pair yield above mass 0.2 GeV/c^2 for the present trigger centrality from the 1996 analysis, the present sample of 8 % centrality collisions corresponds to about 37 k e^+e^- pairs into the CERES acceptance. Assuming, somewhat conservatively, an overall pair efficieny of 20 %, this should lead to 7.5 k reconstructed pairs with mass above 0.2 GeV/c^2. This would assume an efficiency of 77 % for each detector system. The fraction of dead electronics channels was small, 3 and 5 % in the first and second Si driftchamber, 3.6 and 6.5 % in RICH1 and RICH2 and 6.3 % in the TPC. The efficiency will be determined by hit, ring or cluster reconstruction efficiency, tracking efficiency and finally matching of the 3 systems. We think the overall efficiency of 20 % quoted above can be reached. At present it is for the 1999 data sample 10 %.

Analysis of 2000 Data

Analysis of the 2000 data has started at the end of January 2001 after the Quarkmatter conference and related analysis of 1999 data. It is currently ongoing at GSI and Heidelberg and, with smaller teams, at the Weizmann Institute and at Dubna. The first goal is to achieve the design resolution in momentum and to optimize the tracking efficieny and detector geometrical matching. This will take several months from now and after that the various physics analyses can start. At this time also the calibration and new methods developed will be applied to the 1999 analysis. At present a reanalysis of the data from 1996 is ongoing using the mixed event method for subtraction of combinatorial background. This is close to completion. We have also started an investigation into the feasibility of reconstruction of open charm with the CERES apparatus based on 1996 data. If this is encouraging we intend to apply this to the 2000 data with better momentum resolution, better vertex resolution from the Si system because of improved geometry, and better fake rejection using tracks in the TPC vs. hits in a cathode pad chamber for 1996 data.