EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN / SPSC 2000–025
SPSC / M654
May 15, 2000

MEMORANDUM

Further information concerning P316

The NA6i Collaboration

This memorandum provides additional information on the proposed NA6i experiment, SPSC-P316, addressing some questions raised in the SPSC meeting of March 28, 2000.

1 Introduction

In this text we will address the following questions raised in the SPSC meeting of March 28, concerning the P316 (NA6i) proposed experiment:

1. What nucleus should be used as intermediate mass ions? Silver is not appropriate, from the machine point of view.
2. Juergen Knobloch, from CERN/IT, would like to have more details on the reconstruction CPU and data storage that NA6i expects from IT Division.
3. In what concerns the mass window 400–650 MeV, is it possible to conceive a special dedicated setup with a reasonable dimuon acceptance down to p_{T} values below 500 MeV/c?
4. How well can the background subtraction procedure be handled, in the intermediate mass region (IMR) and in the low mass region (LMR)?
5. Is the running of heavy ions at the SPS compatible with the "medium term plans" of CERN?
6. Will the Alice1 pixel readout chip work? Will it work in time to have a first proton run at the end of 2001?

2 Intermediate mass ion beam

In the P316 proposal we mentioned Ag as a possible "intermediate mass ion beam". We have learned from Lau Gatignon that the ion source experts think that Silver does not make a good ion beam, because:

- Its melting point is higher than for Pb and therefore the oven has to be refurbished (reconditioned) typically every 2 weeks instead of once per ion run.
- It is only 53 % isotopically pure. Either one has to find and buy isotopically pure silver (like is done for lead, 52 % pure normally) or admit a factor 2 or more loss in beam intensity.

According to the same people, a better material, from the source point of view, would be Indium, which is 96 % isotopically pure and has a melting point similar to lead.

For the physics motivation of NA6i, Indium is a perfectly good nucleus and we can easily have a Indium target 99.999 % pure (Z=49, A=115). Goodfellow, for instance, sells such material and the target system could be made in one of the NA6i institutes.

We prefer to work with spherical nuclei to make our life easier in terms of interpretation of the results. In Phys. Rev. 101 (1956) 1131 it is said that "asphericity is unimportant" for Indium. They use a spherical nuclear density distribution. The deformation parameter is 0.068 for Indium and (for comparison) is 0.28 for U-238. In summary, everything seems to be fine with Indium-Indium collisions.

Following this discussion, we have asked Marzia Nardi (a collaborator of Helmut Satz) for new calculations of the expected J/ψ suppression pattern in the case of In-In collisions. These new calculations [1] show that the In-In system is actually preferable to the previously mentioned Ag-Ag case. In fact, according to the latest deconfinement model of Satz and Nardi, the drop due to the melting of the χ_c charmonium state should happen in Ag-Ag for rather central collisions, too close to the edge of available phase space, i.e. collisions with an impact parameter $b = 0.5$–1 fm. The higher value of A (the mass number) for In, 115 instead of 108, increases the explorable range of "centrality" (energy density, density of produced partons, etc). According to the same model, the step due to the melting of the χ_c should happen for collisions with an impact parameter $b = 2.0$–2.5 fm. These new calculations can been seen in Fig. 1, where the Pb-Pb case is also included, for comparison. For simplicity, all calculations were done for the same beam energy, 160 GeV per incident nucleon.

In our proposal (see Figure 2.8, page 10) we mentioned that the critical conditions for χ_c melting were reached, in Ag-Ag collisions, already at $b = 4$ fm. Those figures were produced in 1997, using the assumption that the number of percolating partons was proportional to the number of nucleon-nucleon collisions. It was later on realised that this first idea is incompatible with other experimental results, in particular with the fact that the number of produced hadrons is linearly proportional to the number of wounded nucleons. The new model uses the number of wounded nucleons, and not the number of nucleon-nucleon collisions, to determine the number of liberated partons. Since the number of wounded nucleons does not grow as fast as the number of nucleon-nucleon collisions, with respect to the nucleus size and to centrality, the number of parton clusters needed to start perculation is only reached in more central collisions than previously anticipated, making the Ag-Ag system less interesting than the In-In system to study the onset of the χ_c melting.

The specific prediction, from the new calculations, we are now aiming at probing in NA6i is that the first step in the J/ψ suppression pattern should occur in In-In collisions of $b = 2$–2.5 fm. These calculations have been done for 160 GeV. However, from the point of view of the open charm studies, we want to run at the highest possible energy allowed, since the charm cross section grows quickly with energy in this energy range. For the In ion beam this means an energy per nucleon of $Z/A \times 450$ GeV, i.e. 192 GeV per nucleon.

In summary, the old model used an assumption that, in view of the present knowledge, seems less natural. From this discussion we see that a specific deconfinement model, where the new phase sets in due to perculation of parton clusters and which properly describes the existing Pb-Pb data, makes two different predictions for lighter collision systems by using different scaling laws for the production of partons. This shows that the existing data is insuficient and emphasises the need for the new measurement to clarify the underlying physics.

3 Reconstruction CPU and data storage

In the P316 proposal, at the end of page 40, we wrote that "the reconstruction of the data collected in 30 days of running can be done in less than 3 months using the equivalent of around 50 of the currently available 400 MHz commodity PCs." We will now explain in some detail how we reach this number.

Our running scenario is 5 weeks of ion beam, at 75 % running efficiency, and a trigger rate of 4000 events per burst. This leads to 450 million events on tape at the end of each ion run (2002 and 2003). We will not reconstruct the pixel data of all these events, since a first pass on the data from the muon spectrometer alone will probably eliminate almost 50 % of the events. But in the following we will assume that we will reconstruct all events, just to be conservative in our estimate.

The present event simulation and reconstruction software takes about 7–8 seconds per average Pb-Pb collision for the full procedure, including generation of the kinematics, digitisation in Geant, etc. The simulation part alone takes about 4 seconds of that time, certainly not to take into account when we read raw data files. Furthermore, the code has many (time consuming) cross checks, for our own learning curve, and is not optimised for speed. We believe that the final data reconstruction code will take less than 1 second to fully reconstruct one average Pb-Pb collision. Note that in 2002 we plan to run with In-In collisions, with less tracks to reconstruct. Anyway, we assume 1 second per event, to be on the safe side.

These simulations have been done using a DEC workstation PWS433. This is a 13.9 SpecINT95 CPU. We assume that the data reconstruction will be done in CPUs made available to us by the IT division, in the years 2002–2004, and we take as unit the 400 MHz Pentium II CPUs, of 17–18 SpecINT95 units.

This means that we will need $450 \times 10^6 \times 14/18$ seconds (i.e. around 130 months) to reconstruct all the events in a single 400 MHz PC. In other words, we will need the equivalent of 50 such PCs for 2.7 months. This is similar to the CPU power allocated to the CERES experiment already this year, and should be a minor addition to the computing needs of IT in 2.5 years from now. The corresponding values for the proton runs are negligible and the Monte Carlo simulation jobs will be distributed among the several institutes of the collaboration, including Lyon and Lisbon. Furthermore, after the first reconstruction pass, the analysis of the data will be mostly done in the outside institutes of the collaboration.

Of course, we will need the general support already provided by IT to our collaborators, like AFS space, accounts in the PLUS cluster, etc., basically at the level already provided today for the NA50 collaboration. This is necessary for code development and distribution, as well as for the work of the CERN members of the collaboration.

In what concerns permanent data storage, at 20 kbyte per average event the 450 million events per ion run correspond to 9000 Gbyte of storage space needed per year. Assuming that the price of permanent storage (tapes) will be 2.1 CHF per Gbyte in mid 2002, we will spend 20 kCHF per year. We have included this expense in the running budget of the experiment, to be financed by the NA6i institutes.

One last word on the data rate. At 4000 events collected per burst, three bursts per minute, and 20 kbyte per average event, we reach a data rate of the order of 240 Mbyte per minute or 4 Mbyte per second. We would like to use the same CDR link as presently used by NA48 (our neighbours in ECN3), which has sustained data rates of around 20 Mbyte/s in the last three years, over periods of three months per year, without any major problems.

4 Improved setup for low mass and p_T dimuons

As described in the proposal (page 41), we intend to use a hadron absorber made of Al_2O_3 and C, followed by 20 cm of Fe, for all the data sets, to minimise the turn over time between a first week devoted to low mass dimuon physics and the following four weeks of open charm and charmonia physics. Indeed, the only changes between setups are the ACM field and the beam intensity, parameters that can be changed in a few minutes.

With respect to the setup described in our proposal for the low mass dimuon physics, considerable gain in acceptance for low mass and low p_T dimuons can be obtained by running the muon spectrometer with a lower magnetic field, keeping the same absorber configuration. Reducing the current in the magnet down to 1500 A, for instance, will keep lower momenta muons in the geometrical acceptance of the chambers and trigger hodoscopes located dowstream of the magnet. The trigger rate can be kept below the DAQ saturation limit by appropriately reducing the beam intensity.

The acceptance of the spectrometer is shown in Fig. 2 as a function of p_T for dimuons of mass 500 MeV, for different currents in the ACM magnet. We can see that the acceptance for low p_T dimuons increases by a factor around 5 when using a current of 1500 A instead of the value 3000 A.

We have also looked into the trigger logic. A significant fraction of good low mass dimuons fail to satisfy the present trigger conditions (the R1–R2 coincidence) because they suffer some multiple scattering crossing the hadron absorber. The present trigger conditions are optimised for the studies of the J/ψ and higher masses, where the multiple scattering in the hadron absorber plays a minor role. In principle, it should be possible to open slightly the road allowed for the muons in the R1 and R2 trigger hodoscopes. For a given scintillator slab of R1, the normal trigger of NA50 requires that the muon goes through the corresponding slab of R2 or through the next one, closest to the beam axis: $Slab(R1) - Slab(R2) = 0$ or $+1$. If we allow also the case -1, we increase the number of (good) accepted events, by about a factor of 2 in the low p_T region, as can been seen in Fig. 2. This modification imposes non trivial changes to the trigger electronics and further studies are needed to evaluate if it is feasible or not, given the limited resources at our disposal.

In summary, the low p_T acceptance for dimuons with a mass of 500 MeV can be increased by a factor around 5 decreasing the ACM current from 3000 A to 1500 A. This factor becomes around 10 if also the trigger logic is changed to allow one more R1/R2 combination. Other factors should come from a better adjustment of the matching χ^2 cut at low p_{T}, but this requires further optimisation of the event selection strategy.

Before proposing a final distribution of beam time between the "low mass resonances setup" and the new "500 MeV setup" we need to clarify a few points, including the maximum event rate allowed by the new DAQ system. Limiting the trigger rate to 4000 events per burst, with a 17 % interaction lenght target, and $I_{\mathrm{ACM}} = 1500$ A, we expect around 1000 signal events per day, in the mass window 250–680 MeV, for In-In collisions at a beam intensity of 1.7×10^7 ions per burst. For the case of Pb-Pb collisions, the beam intensity must be reduced to around 0.5×10^7 ions per burst, leading to 300 signal events per day.

5 Background subtraction procedure

The basic problem concerning the background subtraction when using a mixed event technique is the normalisation of the fake background sample. In the context of the NA50 studies of the intermediate mass region, which have revealed a significant excess maybe due to an increase of the charm contribution, the normalisation used in the background subtraction is obtained through a detailed Monte Carlo simulation. In our experiment we will have a measurement that allows to verify these simulations, using the matching χ^2 distributions of prompt dimuons and of π or K muon pairs. Indeed, these distributions are quite different, as can be seen in Fig. 3. Selecting events with a large matching χ^2 we can build an event sample essentially free of signal events, both with opposite-sign and with like-sign muon pairs, from where we can verify the normalization of the background sample. The fact that muons resulting from pion decays have matching properties closer to prompt muons than those coming from kaon decays introduces a second order difference in the event samples of different muon charges (there are more K^+ than K^- mesons being produced). But this slight "bias" is accountable by Monte Carlo simulation and has nothing to do with pair kinematics or possible phase-space edge correlations.

The normalization of the like-sign background sample, cross checked in this "clean background sample" can then be used in the extraction of the signal from the prompt opposite-sign dimuon sample. Similar procedures of selecting a "pure sample of background events" have been very useful in understanding the background subtraction in CERES.

6 Heavy ions at the SPS after year 2000

We understand this question in the following sense: given the fact that RHIC is about to start, can we still justify having a heavy ion physics program at the CERN

SPS? Is the NA6i proposed experiment competitive with respect to the RHIC experiments? We firmly believe that the answer to these questions must be yes. The NA6i experiment will address physics questions that will keep the CERN programme very competitive with respect to the RHIC experiments.

In what concerns open charm, the RHIC experiments (Phenix) will do a dilepton measurement similar to the one NA50 has done up to now in the SPS. An estimation of the charm production cross section will be derived assuming that the dilepton spectra is dominated by charm meson decays. Clearly, the muon track offset measurement of NA6i will bring into play a new dimension that is absent in the (first generation of) RHIC experiments.

In what concerns the charmonia measurements, it will take several years before the measurements of Phenix can compete with the collected data of NA38, NA50 and NA6i. We are no longer looking for the existence of J/ψ suppression, we are pursuing a deeper study of the underlying physics mechanisms. We already understood the reference (Drell-Yan and p-A data) and the signal (Pb-Pb data). Now we want to interfere with the signal to see what is the physics "scaling" variable that determines the observed behaviour. Furthermore, at RHIC energies the beauty production cross section cannot be neglected and even if all the directly produced charmonia states will be suppressed in Au-Au collisions, as is predicted by the model of Satz and collaborators, the detector will still measure a certain amount of J/ψ mesons, coming from decays of beauty mesons. Unless the Phenix detector is upgraded with a high granularity vertex detector, to identify displaced vertex J/ψ events (as planned for ALICE, using the pixel layers and the TRD), there will not exist in the near future a measurement of the beauty production yield in Au-Au collisions at RHIC. In this case the understanding of the measured J/ψ yield will remain limited by the uncertainty in the contribution from this feeddown. Are the observed J/ψ mesons due to the unsuppressed directly produced J/ψ's, or are they due to B decays?

Finally, we recall the discovery potential of NA6i in what concerns the production of thermal dimuons, directly radiated from the free quarks of the quark gluon plasma. It is clear that the volume of the matter produced at RHIC energies is much bigger than at the SPS. The matter will certainly be hotter and will live longer, producing more thermal dileptons (and photons). On the other hand, the level of background dileptons will also increase, even faster (including a big fraction from charmed meson decays). Given the fact that the RHIC experiments (Phenix) cannot separate prompt dileptons from charm decays, it is quite likely that the experimental conditions at the SPS, in the NA6i experiment, end up being more suitable to search for electromagnetic radiation from the QGP. In other words, after the subtraction of the background component and of the Drell-Yan dimuons (extrapolated with some uncertainty from the barely existing high masses), the resulting signal in Phenix will be dominated by charm decays, making the extraction of the "thermal dilepton yield" as difficult as in the analysis of the present NA50 data.

It seems appropriate to quote in this context a few statements made recently by Berndt Muller, after CERN's Press Release: "If CERN has seen the QGP, the matter that will be created at the colliders will be quite different, much hotter and denser and less baryon rich. It will be virtually impossible to study the same domain of matter at RHIC and thus to establish the truth of the picture described in the [press release] document." In other words, we cannot close the SPS and hope that RHIC will do the details. RHIC sits in a different region of the $T - \mu$ plane and, if the conclusions from the SPS data are correct, it will be nearly impossible to study onset phenomena at RHIC. The study of the QCD phase transition requires having a few data points on each phase, and we now understand that the SPS happens to be in the appropriate energy range. We close our answer quoting B. Muller in a workshop on Heavy Ion Physics, held in Lisbon on April 14: "As a matter of principle, how can a facility that makes a billion dollar discovery 'walk away' from the exploration of the new physics, if more, and novel, experiments can be done?"

7 Status of the Alice1 pixel readout chip

The design of the Alice1 readout pixel chip is finished, including all the verification steps that could be done at CERN. In the first two weeks of May, the three microelectronics design engineers involved at this stage have worked with the specialists from the wafer foundry in order to clear the fault messages that resulted in the final, formal checking process. The production of the silicon wafers will take around 6–8 weeks. Once the chips are received at CERN, some first measurements will be immediately done and we should know if the chip is properly working by end of July.

This chip has been designed by the same people that designed the previous pixel chip generations, in RD19, for WA97/NA57. All those chips have worked on the first attempt. It is clear that the Alice1 chip is much more complex and there is some probability that this time things will not work on the first silicon. On the other hand, the use of commercial CMOS technology allows a relatively fast cycle, and if something should be changed, a new design could be submitted in a few months.

Our first milestone is the commissioning run, with protons, at the end of 2001. For this run we only need a partial telescope, with less than 30 chips, that should come from the on-going "engineering run". If some things go wrong and we get a major delay, we would have to postpone the first run to early 2002, still with protons. Unless we find major problems to debug, we believe that we will be ready in time for a first ion run at the end of 2002.

References

[1] M. Nardi, private communication, May 2000.

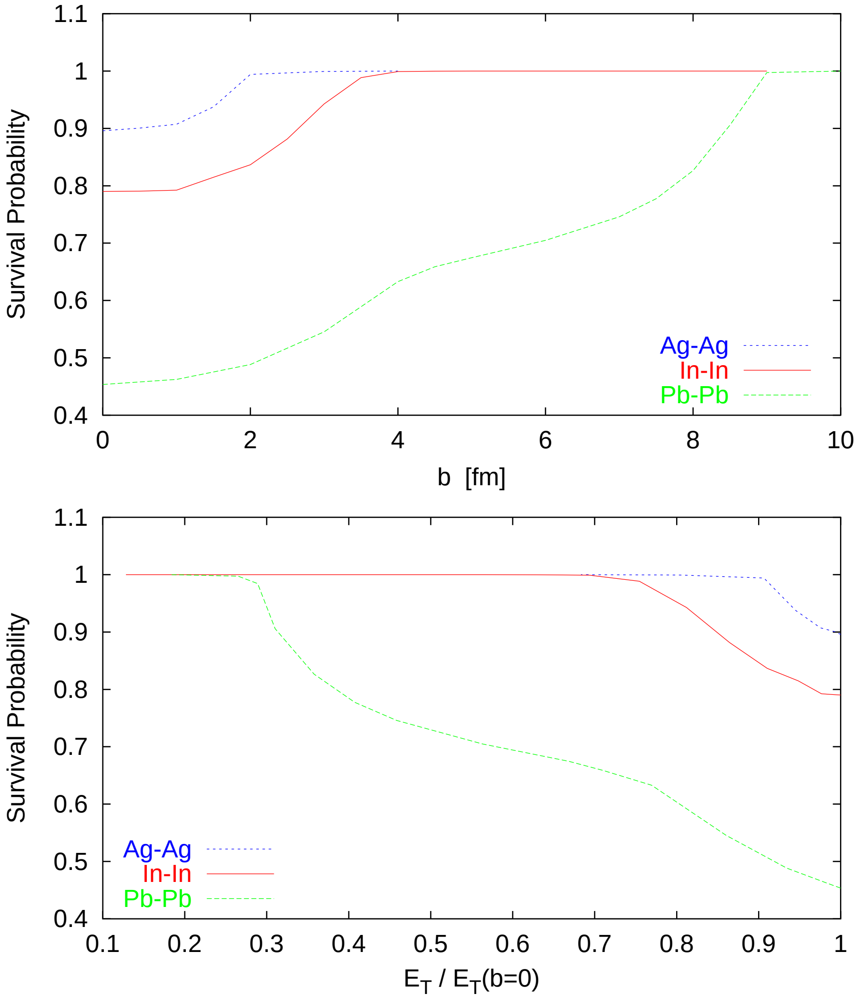

Figure 1: Survival probability for J/ψ production in In-In, Ag-Ag and Pb-Pb collisions, at 160 GeV per incident nucleon, versus impact parameter (top) and transverse energy (bottom), normalised to the $E_{\rm T}$ released in a central collision. The calculations were done by M. Nardi.

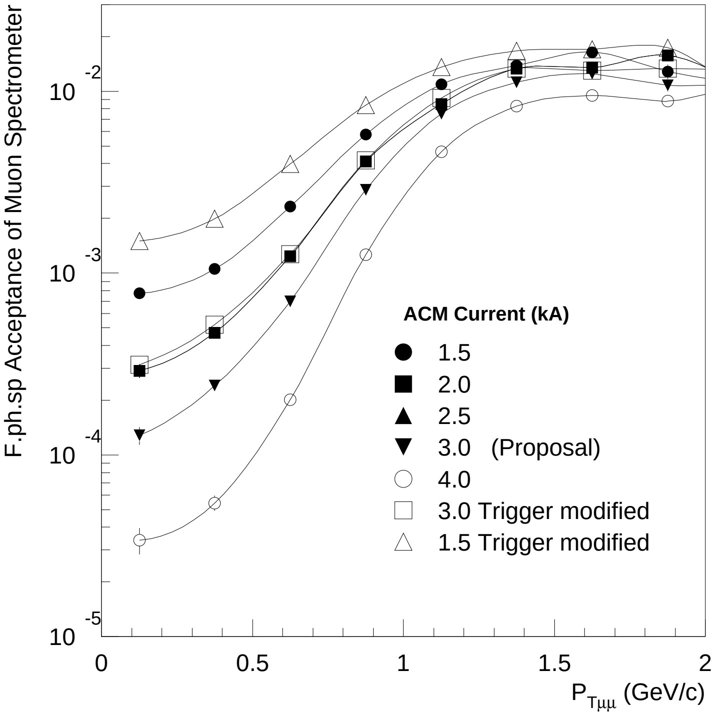

Figure 2: Acceptance of 500 MeV mass dimuons as a function of p_{T} for different ACM currents and R1–R2 trigger conditions. The acceptance values are calculated with respect to the full phase space.

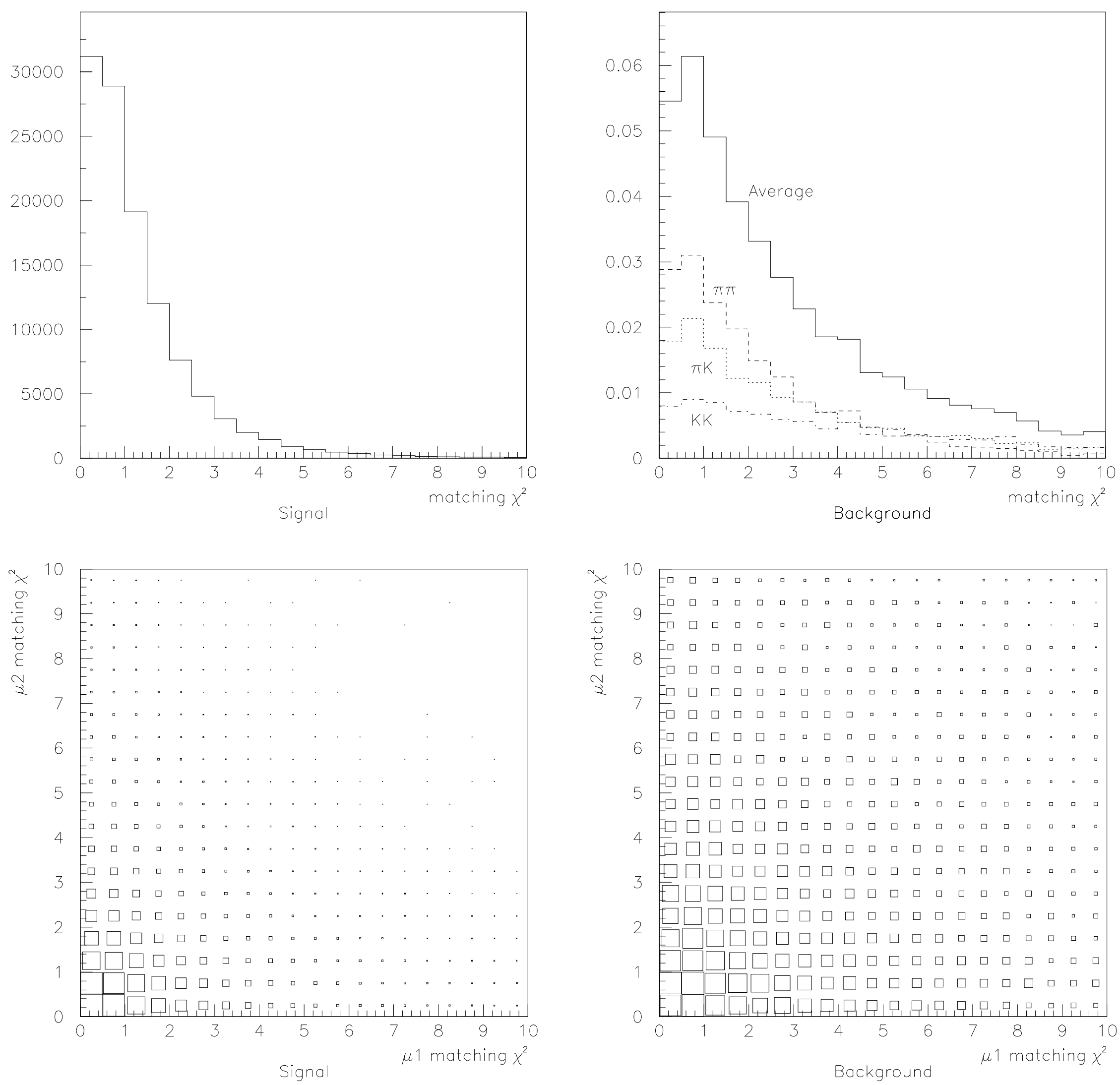

Figure 3: Matching χ^2 distributions for the prompt dimuons (signal, left) and for π or K muon pairs (background, right). A selection on the basis of the matching χ^2 of both muons (bottom figures) leads to a “clean event sample” of background events.