The SPS Physics Programme

Emmanuel Tsesmelis
EST Division

Abstract

The physics programme of the SPS is discussed as far as approved and its possible evolution up to 2005, the first year of the LHC, is sketched. The programme includes fixed-target experiments and detector test beams, particularly for the LHC experiments. The approved fixed-target programme consists of the two main experiments NA48 and COMPASS and of the continuation of the heavy-ion projects NA45, NA49, NA50 and NA57. Possibilities also exist for a next generation of neutrino and kaon experimentation.

This report provides a brief overview of the physics case for such a programme, outlining where possible its beam requirements.

1 INTRODUCTION

The physics programme of the SPS, carried-out in its large experimental halls in the North and West Areas, will most likely continue its fixed-target activities in the years leading up to the start of the LHC. Figure 1 summarizes present projections for the SPS scientific programme up to the years of LHC physics exploitation.

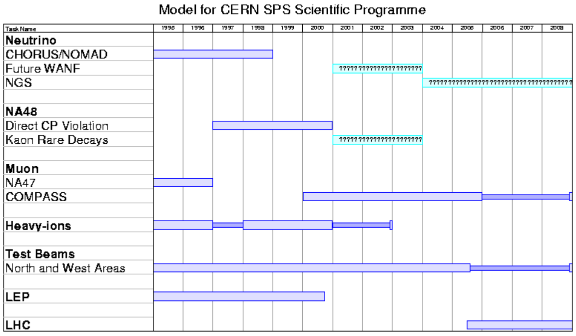


Figure 1: SPS scientific programme projection. (The narrower bands indicate possible periods during which the respective projects may continue while the periods with the question marks refer to projects which have not yet been approved. Due to the fire at the SPS, there was no heavy-ion run in 1997).

In addition to the number of proton fixed-target lines used for LHC test beams, the North Area also houses the two approved SPS experiments NA48 [1] and COMPASS [2]. The former is in the data-taking phase of its production run to measure the direct CP violation parameter $\mathrm{Re}(\epsilon/\epsilon^{'})$, while studies are also in progress to gauge the sensitivity of an upgraded set-up to measure rare decays of the $\mathrm{K_L}$ [3]. COMPASS, which plans to start data-taking in the year 2000, aims to study the spin structure of nucleons using muons and to embark on a programme of hadron spectroscopy.

The heavy-ion programme of the SPS is also located in the North Area. Its aim is the study of strongly interacting matter at extreme energy densities. Experiments NA45 [4], NA49 [5], NA50 [6], and NA57 [7] are in progress, while NA52 [8] finished its data-taking phase at the end of 1998.

Moreover, the smaller experiments NA53 (electromagnetic dissociation of target nuclei by Pb^{208} projectiles) [9], NA54 (determination of cross-sections of fast-muon-induced reactions to cosmogenic radionuclides) [10] and NA59 (a study of the use of a crystal as a quarter-wave plate to produce high energy circularly polarized photons) [11] have been approved to run in the North Area.

With the termination of the two major heavy-ion experiments at the end of 1996 and of the CHORUS [12] and NOMAD [13] neutrino experiments at the end of 1998, the physics activities in the West Area will in future focus on providing test beams, especially for the LHC experiments. Experimental designs for a next generation of neutrino oscillation experiments, based on an upgraded West Area Neutrino Facility (WANF) at either a short-baseline or medium-baseline are being studied. The TOSCA collaboration proposes to build a high-sensitivity short-baseline experiment to search primarily for $\nu_\mu \to \nu_\tau$ oscillations [14] while the proponents of the designs presented in I217 [15] and ICARUS [16] propose to locate a detector on the Jura mountain range to study the LSND neutrino oscillation result.

If approved, the long-baseline option of a Neutrino beam to Gran Sasso (NGS) [17] will be derived using a proton extraction from LSS4 of the SPS ring, sending neutrinos in the direction of the far laboratory. This project is discussed in another presentation at this workshop [18].

This document is organized as follows. Section 2 describes the ongoing and planned proton fixed-target activities while the heavy-ion programme is treated in section 3. The conclusions are given in section 4.

2 PROTON FIXED-TARGET

2.1 CP Violation

NA48 The origin of CP violation is one of the fundamental questions of particle physics. In the Standard Model of electroweak interactions, CP violation is accommodated naturally by the mixing of weakly interacting quark doublets as described by the Cabibbo-Kobayashi-Maskawa formalism.

In addition to the CP violating effects generated by this state mixing, CP violating effects may be induced through virtual transitions involving heavy quarks and is referred to as direct CP violation. If they exist, direct CP violation should not occur according to the super-weak model.

However, direct CP violating effects should appear in the decay of neutral kaons into pion pairs. The aim of the NA48 experiment is to study direct CP violation in the neutral kaon system by comparing the rates of the two CP violating decay modes of the $\mathrm{K_L}$ with the corresponding modes of the $\mathrm{K_S}$. This will lead to a measurement of the direct CP violating parameter $\mathrm{Re}(\epsilon/\epsilon^{'})$ by measuring the double ratio

$$\left| \frac{\eta_{00}}{\eta_{+-}} \right|^2$$

where

$$| \eta_{00} |^2 = \frac{\Gamma(\mathrm{K_L} \rightarrow \pi^0\pi^0)}{\Gamma(\mathrm{K_S} \rightarrow \pi^0\pi^0)}$$

and

$$| \eta_{+-} |^2 = \frac{\Gamma(\mathrm{K_L} \rightarrow \pi^+\pi^-)}{\Gamma(\mathrm{K_S} \rightarrow \pi^+\pi^-)}$$

and which is equal to

$$1 - 6\,\mathrm{Re}(\epsilon/\epsilon^{'}).$$

If the CKM matrix is indeed the source of CP violation, the parameter $\mathrm{Re}(\epsilon/\epsilon^{'})$ derived from the above ratio R is expected to be non-zero.

Evidence for direct CP violation has been reported earlier by the NA31 collaboration [19] with a value of $\mathrm{Re}(\epsilon/\epsilon^{'}) = (23.0 \pm 6.5) \times 10^{-4}$. The E731 experiment at Fermilab [20] has reported a value of $\mathrm{Re}(\epsilon/\epsilon^{'}) = (7.4 \pm 5.9) \times 10^{-4}$, which neither contradicts nor confirms the NA31 result.

The goal of NA48 is to measure $\mathrm{Re}(\epsilon/\epsilon^{'})$ to a precision of 2×10^{-4}. This can be achieved by improving the error sources of the previous experiments:

- Better statistics due to a factor of 10 improvement in the beam intensity compared to NA31. NA48 expects to accumulate 10^6 decays in the limiting mode $\mathrm{K_L} \rightarrow \pi^0\pi^0$. A pipelined, high-rate trigger and readout system has also been developed to handle these higher rates.

- By running the $\mathrm{K_L}$ and $\mathrm{K_S}$ simultaneously in the same fiducial volume and distinguishing between the two by tagging the protons producing the $\mathrm{K_S}$ component, leads to negligible differences and variations in detection efficiencies for the $\mathrm{K_L}$ and $\mathrm{K_S}$ decays, resulting in improved systematic uncertainties.

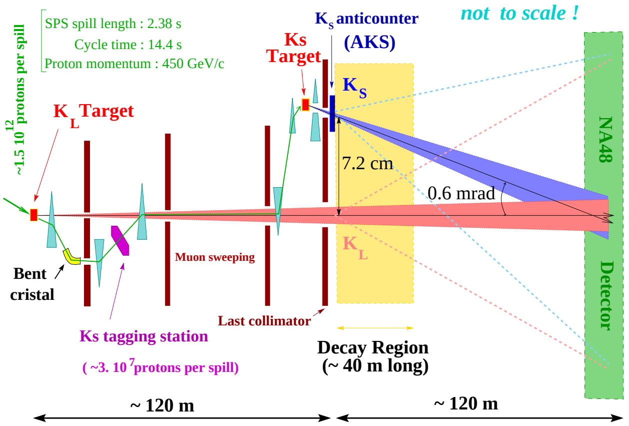


Figure 2: The NA48 beam line.

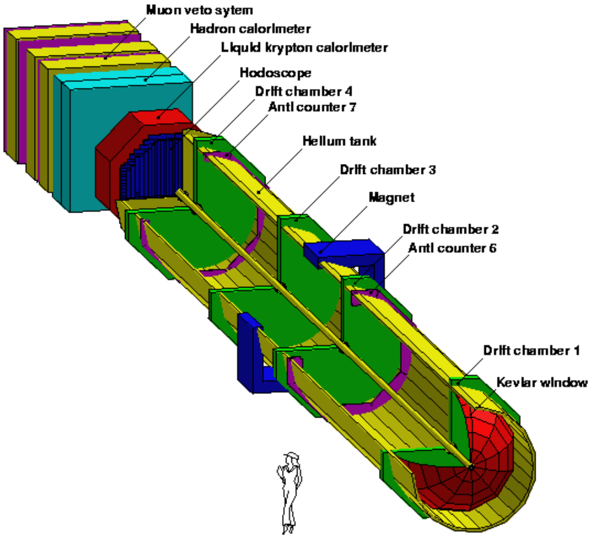


Figure 3: The NA48 detector.

- The high resolution magnetic spectrometer used for the $\pi^+\pi^-$ decays reduces the background from the residual three-body decays $\mathrm{K_L} \rightarrow \pi e \nu$ and $\mathrm{K_L} \rightarrow \pi^+\pi^-\pi^0$.

- A high resolution liquid krypton calorimeter reduces the background from $\mathrm{K_L} \rightarrow 3\pi^0$ to the neutral pion decays.

The NA48 beam line (K12) and detector are shown in Figures 2 and 3, respectively.

The short-term plans of the collaboration include the continuation of the production run in 1999 and 2000 for the measurement of $\mathrm{Re}(\epsilon/\epsilon^{'})$ under the same beam conditions of supercycle length, duty cycle and proton intensity on T10 (of $\sim 1.5 \times 10^{12}$ protons per pulse derived from $\sim 5 \times 10^{12}$ protons per pulse on T4) as in 1998. For the latter part of the 2000 run, systematic checks of the kaon beams are planned, which may require proton intensities on T4 of up to $\sim 1 \times 10^{13}$ protons.

NA48RD Alternative approaches to the study of direct CP violation at the SPS are being discussed. The rare decay modes of the $\mathrm{K_L}$

$$\mathrm{K_L} \rightarrow \pi^0 \mathrm{e}^+ \mathrm{e}^-$$

and

$$\mathrm{K_L} \rightarrow \pi^0 \mu^+ \mu^-$$

are predicted within the Standard Model to have direct CP violating amplitudes which may be larger than their CP conserving and indirect CP violating counterparts. Furthermore, the rare decay mode

$$\mathrm{K_L} \rightarrow \pi^0 \nu \overline{\nu}$$

is theoretically precisely predicted and is virtually a pure direct CP violating decay, allowing the clean determination of the height of the unitarity triangle, the parameter in the Standard Model which determines the size of all CP violating observables.

If approved, NA48RD might be proposed to run in two phases. In the year 2001, the collaboration would run the NA48 spectrometer with no major upgrade but with a proton intensity on the T4 target of $\sim 1 \times 10^{13}$ protons per pulse and with an increased $\mathrm{K_L}$ beam acceptance. The search would start with the more accessible channels like

$$\mathrm{K_L} \rightarrow \pi^+ \pi^- \mathrm{e}^+ \mathrm{e}^- .$$

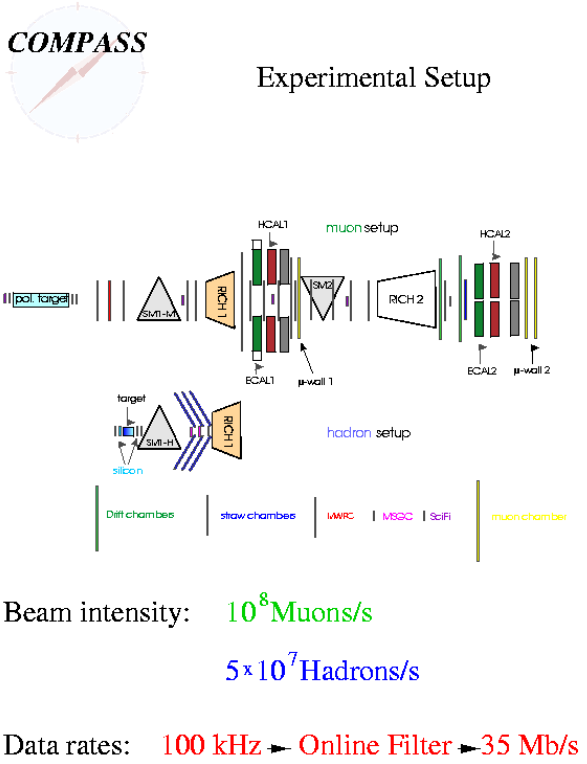
After upgrading the beam and the NA48 spectrometer to include a TRD, NA48RD might then run as of 2002 with a proton beam intensity on the T4 target of $\sim 1.5 \times 10^{13}$ protons per pulse, allowing the continuation of the study of the rare decay channels mentioned above. The preferred supercycle is similar to that for the present heavy-ion programme, i.e. a flat-top at 400 GeV/c of ~ 5 s duration.

2.2 *COMPASS*

The main goal of COMPASS is the study of hadron structure with polarized muon beams of between 100 and 200 GeV/c and the study of hadron spectroscopy with hadron beams of up to 300 GeV/c.

After confirmation of the original EMC result by SMC, the SLAC experiments E142, E143 and E154, and by the HERMES experiment at DESY, it is now firmly established that the spin content of the nucleon is not entirely due to the spin of the quarks. In one explanation of this effect, the polarized gluons lower the quarks' contribution to the nucleon spin.

A key feature of the experiment will be the production of a large sample of open charm particles via photon-gluon fusion when a polarized muon beam is incident on a polarized target. Measuring the asymmetry in this charm production will result in $\Delta \mathrm{G}/\mathrm{G}$, the gluon polarization in a longitudinally polarized nucleon, being known to a precision of 10%.


COMPASS

Experimental Setup

Beam intensity: 10^8Muons/s

5×10^7Hadrons/s

Data rates: 100 kHz ► Online Filter ►35 Mb/s

Figure 4: The COMPASS detector.

The hadron programme comprises a study of the production and decay properties of charmed particles. The knowledge of the semi-leptonic decay widths is one of the important issues in charm physics as it tests the theoretical predictions of charmed baryon decays. In addition, COMPASS will be able to study the spectroscopy of gluonic systems in central production via Pomeron-Pomeron scattering and Primakoff scattering with various probes.

The proposed spectrometer is shown in Figure 4 and consists of particle identification detectors and calorimeters able to stand the high beam intensities. A fully pipelined readout scheme to handle the expected trigger rates of about 100 kHz is foreseen.

The measurements will be performed with high intensity beams in the upgraded M2 line of the SPS (see Figure 5), which will provide $\sim 1 \times 10^8$ muons per second and $\sim 5 \times 10^7$ hadrons per second. Assuming that the preferred SPS supercycle is the same as that for NA48RD above and the highest muon momentum of 200 GeV/c, the number of protons per pulse on the T6 target which are required to reach the above muon flux is $\sim 1.2 \times 10^{13}$. This number can be relaxed for lower muon momenta.

COMPASS was approved in February 1997 and the technical run foreseen for 1999 will be followed by five years of data-taking, commencing with the muon programme in 2000.

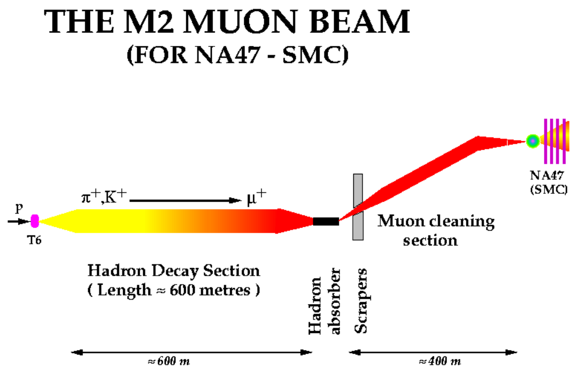
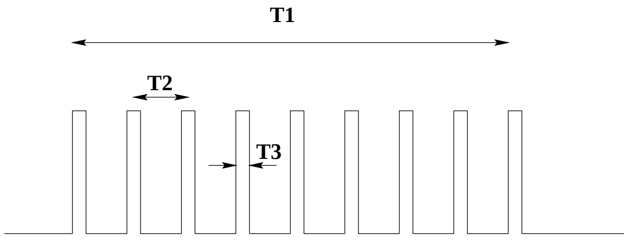


Figure 5: The M2 beam line used previously by SMC. The design for COMPASS is based on an upgraded version of this beam.



Priority 1

T3 < 3 ns	< 1 ns, as it will be at LHC
T2 = 25 ns	stable, with precise clock

Priority 2

<Nparticles>/bunch < 1	assumed to be Poisson-like
T1= slow extraction spill	correlated with <Nparticles>

Figure 6: The requested beam structure for the 25 ns bunched test beam. T1 refers to the overall slow-extraction duration, T2 to the bunch spacing and T3 to the bunch width.

2.3 Test Beams

The physics programme of the SPS will maintain its test beam activities in both the North and West Areas for the LHC detectors. This work has proven crucial in the R&D and prototyping phases of the LHC detectors and will continue to be extensively required during the production and calibration periods leading up to the start of the LHC. In addition, test beam availability will be required even after the completion of detectors, in order to check their stability and to test future improvements.

The tests require large permanent installations on a number of SPS beam lines, with the associated infrastructure and with beam conditions matching the specific needs of energy, particle type and intensity for each sub-detector. Secondary beams derived from a proton beam of 450 GeV/c extracted over about 2.5 s are well-matched to the requirements of the LHC detector studies. To minimize the waiting time between bursts, the present duty cycle of $\sim 17\%$ should be maintained. These test beams will be derived from the T1 target in the West Area and from the T2 and T4 targets in the North Area. After NA48 has completed its approved programme in 2000, the proton momentum may be lowered to 400 GeV/c in order to improve the duty cycle and to reduce the CERN energy budget. This will also allow to meet the requirements on the average proton current of the future neutrino beams since the repetition rate can be increased (see Section 2.4).

The SPS beam lines also serve the test beam needs of experiments running at outside laboratories, such as DESY, SLAC, and Gran Sasso as well as for space-borne detectors such as GLAST and ACCESS.

In addition, ATLAS and CMS have requested the provision of test beams with a 25 ns bunch structure in order to verify the electronics and detector designs under realistic LHC operating conditions. This work will allow the detector and trigger/DAQ groups to study strategies for setting up the timing of the trigger system together with the detector and will enable the former to study detector-related effects such as pile-up and occupancy. The desired beam structure is shown in Figure 6. The momentum of the primary proton and secondary particle beams should remain similar to what is provided under the standard test beam conditions. The secondary beam spot should preferentially have dimensions $10 \times 10\ \mathrm{mm}^2$ but $100 \times 100\ \mathrm{mm}^2$ would also be satisfactory.

The first of these 25 ns tests is planned for the beginning of the 2000 SPS proton fixed-target run. Such a beam will be used simultaneously in both the West and North Areas of the SPS.

2.4 Neutrino Oscillations

One of the most interesting questions in particle physics is whether neutrinos have a non-vanishing mass. A massive neutrino would be a direct indication of physics beyond the Standard Model, thus representing a milestone in particle physics. Moreover, a massive neutrino would have implications for cosmology and astrophysics as neutrinos are likely candidates for the hot component of dark matter and are plausible candidates to explain the solar neutrino deficit and the atmospheric neutrino problem. Due to their small value, neutrino masses are probably out of reach of direct measurements and their study via neutrino oscillations is the only way to address this question.

In the first approximation, neutrino oscillations occur between two different neutrino flavours and are described by the mixing parameter $\sin^2 2\theta$ and the mass-squared difference $\Delta \mathrm{m}^2$. The sensitivity of the experimental searches to these parameters depends on the neutrino energy E and on the distance L of the detector from the neutrino source. For experiments at high-energy accelerators, there are three categories of interest: short- $(\mathrm{L} \sim 1\ \mathrm{km})$, medium- $(\mathrm{L} \sim 10\ \mathrm{km})$ or long- $(\mathrm{L} \sim 1000\ \mathrm{km})$ baseline experi-

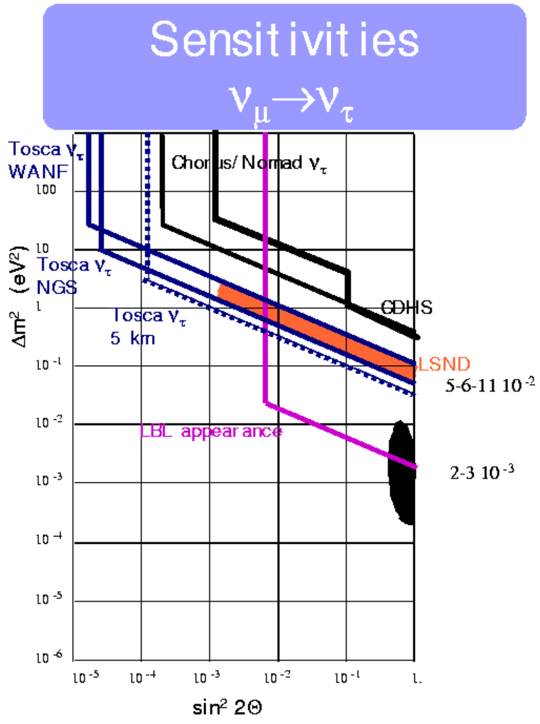


Figure 7: The projected TOSCA exclusion region for a run of three or four years at the WANF and NGS, respectively.

ments. (This paper discusses the first two types of experiments while the long-baseline option, as described by the Neutrino beam to Gran Sasso (NGS), is covered in another talk in this workshop [18]).

The TOSCA collaboration has proposed a high-sensitivity short-baseline experiment to search for $\nu_\mu \rightarrow \nu_\tau$ oscillations. This experiment would extend the sensitivity range of the CHORUS and NOMAD searches towards both smaller mass differences and smaller mixing and will build on the expertise on nuclear emulsions and electronic spectrometers acquired from these previous experiments. The experiment would exploit the direct detection of the τ^- decay topology with a kinematical analysis of the candidate events. The projected exclusion plot is given in Figure 7.

A study has also been made of locating TOSCA at 5 km from the source, at the foot of the Jura mountains. Such an experiment would be sensitive to the LSND result in the scenario that this effect is due to $\nu_\mu \rightarrow \nu_\tau$ oscillations. As is also shown in Figure 7, TOSCA is sensitive to the entire parameter space of the LSND result assuming the $\nu_\mu \rightarrow \nu_\tau$ hypothesis.

TOSCA was initially planned for the WANF. Running at the WANF would enable the experiment to re-use most of the existing infrastructure, thereby resulting in an earlier start of physics and in much-reduced costs. However, this experiment is also feasible in the NGS beam, albeit with more technical restrictions on the detector technologies, plus the need to contruct the necessary new civil engineering and infrastructure at the near site on the NGS line.

In addition, a neutrino facility based on the WANF and with a neutrino detector at the location where the SPS neutrino beam emerges from the Jura mountains at 17 km from the source has been put forward by the I217 and ICARUS collaborations. This would provide the opportunity to perform a medium-baseline programme in search of $\nu_\mu \rightarrow \nu_\tau$ and $\nu_\mu \rightarrow \nu_\mathrm{e}$ oscillations in the parameter space of the LSND result.

ICARUS has proposed to locate one LAr module of 600 t (400 t fiducial mass) at a medium-baseline site at the Jura. Such a detector would be able to probe both $\nu_\mu \rightarrow \nu_\mathrm{e}$ and $\nu_\mu \rightarrow \nu_\tau$ oscillations. The I217 collaboration also favours a detector based on the same technology. Should this technique not be available, then a fine-grained calorimeter could be developed. The sensitivity of ICARUS to $\nu_\mu \rightarrow \nu_\mathrm{e}$ oscillations is shown in Figure 8, together with the result from LSND.

A new WANF programme would require the highest possible neutrino flux, coming in turn from an intense primary proton beam. Unlike the case for the NGS, which is planned for a fast-extraction on a graphite target, the WANF will continue to be based on a fast-slow extraction on a beryllium target, which provides the benefit of additional protons on the same cycle as the slow-extraction.

An example of the SPS supercycle suggested to be used in conjunction with these experiments is shown in Figure 9 and is similar to that proposed for the NGS. Assuming a maximum of 4.8×10^{13} protons per SPS cycle for a run of 200 days at a global machine efficiency of 55% would result in an integrated proton intensity of 4.3×10^{19} per year. Exchanging the beryllium target with one based on graphite increases this to 5.0×10^{19} protons since the full SPS intensity could be extracted on such a target per cycle.

These neutrino experiments could be performed in the WANF before the NGS starts. If approved, the proposed WANF experiments could, therefore, run between the years 2001 and the NGS start-up, which could be expected in 2004 or, more likely, in 2005.

3 HEAVY-IONS

The aim of the SPS heavy-ion programme is the study of strongly interacting matter at extreme energy densities. Statistical QCD predicts that at sufficiently high densities a phase transition from hadronic matter to a plasma of deconfined quarks and gluons will occur. This transition is predicted to have taken place, in the opposite direction, at $\sim 10^{-5}$ s after the Big Bang.

The attainment of the QCD phase transition will result in a number of signatures which are accessible to laboratory studies. Experiments at the SPS are investigating the pre-

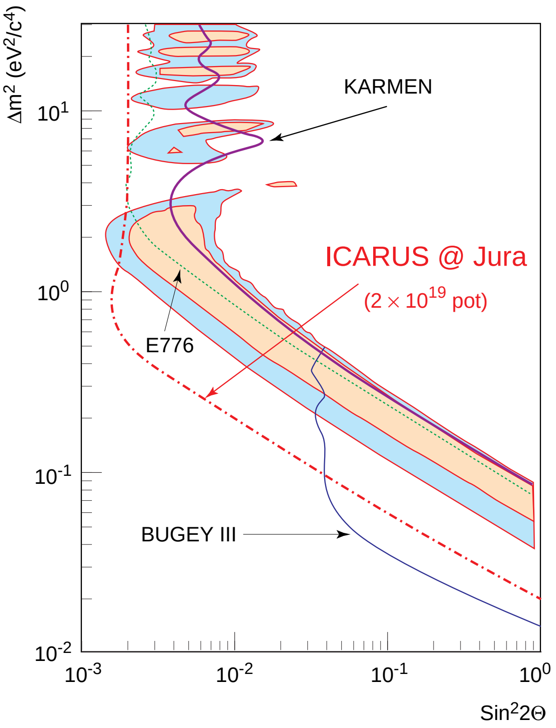


Figure 8: ICARUS sensitivity at a possible Jura medium-baseline site. The plot is for one 600 t module. The shaded regions represent the LSND allowed regions (at 90% and 99% confidence).

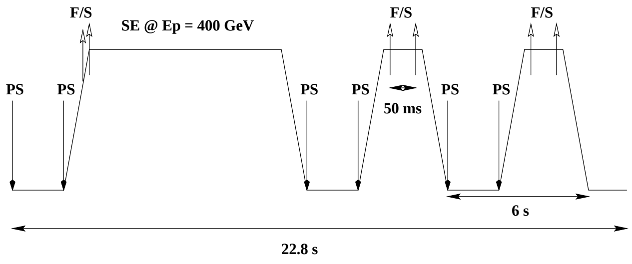
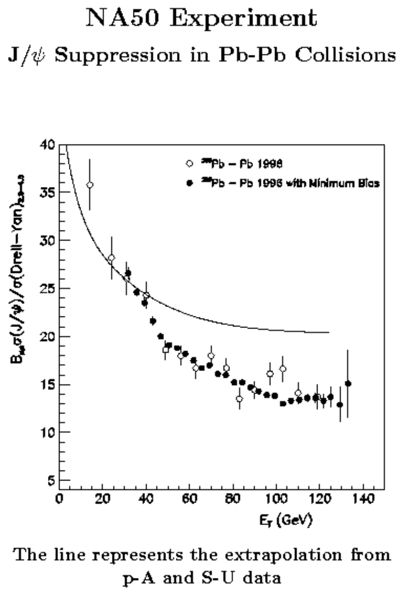


Figure 9: Possible SPS cycle for future neutrino experiments at the WANF.



NA50 Experiment

J/ψ Suppression in Pb-Pb Collisions

The line represents the extrapolation from p-A and S-U data

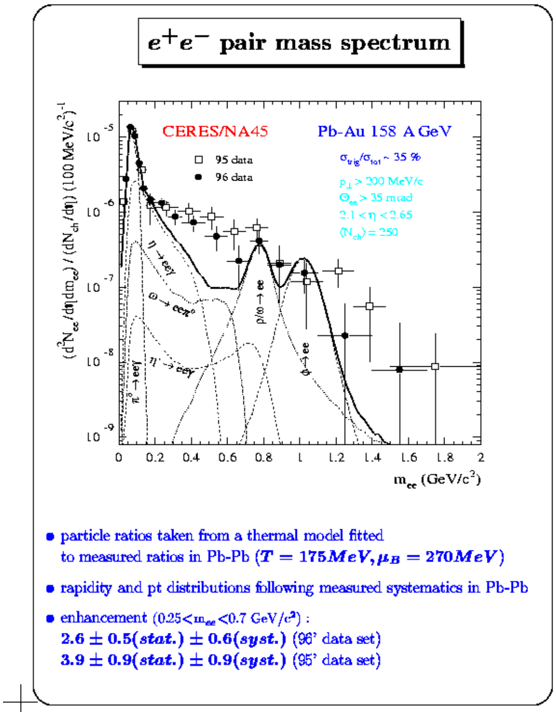
Figure 10: Anomalous J/Ψ suppression measured by NA50.

dicted suppression of J/Ψ production, the excess emission of lepton pairs below the ρ resonance, the enhanced production of strange and, in particular, multi-strange hadrons, the thermal and chemical distributions of hadrons produced in an expanding system and the production of strangelets.

The most notable achievements of the SPS heavy-ion programme were discussed at a recent workshop at Chamonix [21] and a selection of some of the conclusions is given below:

- The earlier evidence for an anomalous mechanism of J/Ψ suppression in Pb+Pb collisions has been confirmed by a new analysis of the data taken by the NA50 collaboration in 1996. The new analysis is based on the comparison of the J/Ψ cross-section with the Minimum-Bias cross-section instead of with the Drell-Yan cross-section used earlier. Figure 10 shows that the $\mathrm{E_T}$ dependence of J/Ψ suppression is different from that observed in lighter systems.

- The analysis of Pb+Au data taken by the NA45 experiment in 1996 confirms the excess yield of $\mathrm{e^+e^-}$ pairs with an invariant mass above twice the π mass and below the ρ resonance. Figure 11 shows the $\mathrm{e^+e^-}$ pair mass spectrum.


e^+e^- pair mass spectrum

- particle ratios taken from a thermal model fitted to measured ratios in Pb-Pb ($\boldsymbol{T = 175 MeV, \mu_B = 270 MeV}$)
- rapidity and pt distributions following measured systematics in Pb-Pb
- enhancement (0.25<m_{ee}<0.7 GeV/c^2) :
  $\mathbf{2.6 \pm 0.5(\mathit{stat.}) \pm 0.6(\mathit{syst.})}$ (96' data set)
  $\mathbf{3.9 \pm 0.9(\mathit{stat.}) \pm 0.9(\mathit{syst.})}$ (95' data set)

Figure 11: e^+e^- pair mass spectrum measured by NA45.

- Data collected in Pb+Pb collisions by the WA97 collaboration show an enhanced production of strangeness, carried mostly by kaons and hyperons, relative to that measured in p+Pb collisions. The enhancement grows with increasing strangeness content culminating in an enhancement of a factor of 15 for the $\Omega + \overline{\Omega}$ yield. Figure 12 shows the strangeness enhancement as measured by WA97. The experiment NA57 will extend the scope of WA97 by investigating the beam energy dependence of the multi-strange particle production and by determining the baryon density at central rapidity from the measurement of positive and negative multiplicities and correlating it with the strange particle yield. NA57 had their first run in 1998.

- Earlier results from the NA49 collaboration yield additional evidence for the quark-gluon plasma. Figure 13 shows the measured strangeness-to-pion ratio, which is expected to become constant after the quark-gluon plasma equilibration.

The high-energy Pb-ion beams of the SPS have been at 158 A GeV/c. However, the experiments NA45, NA49 and NA57 have requested a run with Pb-ions at 40 A GeV/c for the 1999 SPS ion run. This will enable these collaborations to study the characteristics of hadron production and lepton pair continuum in a regime where the ratio of baryon density to energy density is increased by a factor of three

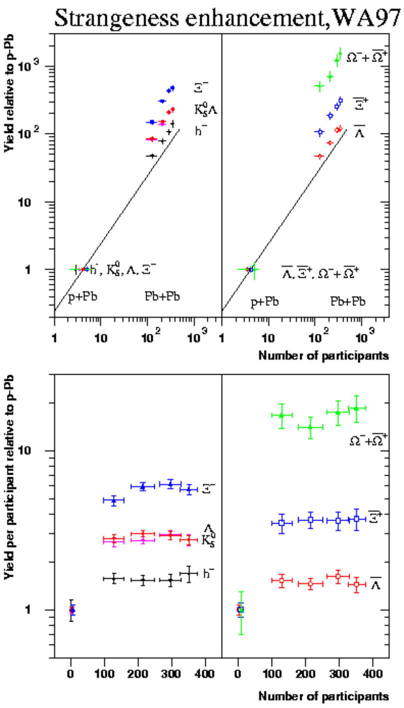


Figure 12: Strangeness enhancement measured by WA97.

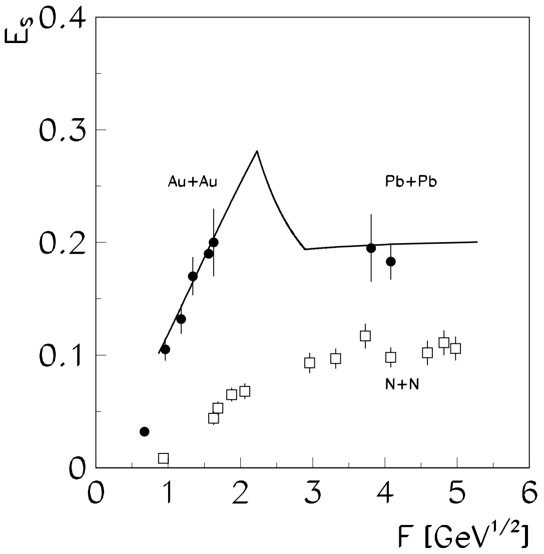


Figure 13: Strangeness-to-pion ratio measured by NA49. The value of F is a measure of the normalized collision energy, which in turn is related to the temperature of the fireball. The line drawn between F=2 and F=3 is the result of one interpretation of the physics in this unprobed region.

compared to the higher SPS energy. Given the physics motivation to study the intermediate region between F=2 and F=3 in Figure 13, and of the successful SPS machine development at this lower momentum, the entire 1999 Pb-ion run is planned for 40 A GeV/c.

Due to the limited acceptance of the NA50 spectrometer when running with Pb-ion beams of 40 A GeV/c, the collaboration requests to maximize the time at 158 A GeV/c to increase its statistics and improve on the systematics. A run with Pb-ion beams at 158 A GeV/c forms, therefore, the default conditions for the run in 2000.

A future possibility for the SPS Pb-ion programme includes a run at 80 A GeV/c, which may be required to study the phase transition region fully. In addition, the measurement of open charm production would provide information on the early phases of the collision and is directly linked to the two open questions of anomalous J/Ψ suppression and the enhancement of the dilepton continuum below the J/Ψ mass.

4 CONCLUSIONS

This report summarizes the physics programme of the SPS for the years leading up to the exploitation of the LHC. During these years, the SPS will maintain a vigorous scientific programme of proton and heavy-ion fixed-target activities, in addition to serving as an injector to LEP in the years 1999 and 2000.

Discussions are also underway in the respective communities and scientific committees to consolidate this programme. Examples of which include the next generation of neutrino experimentation, a study of rare decays in the K_L sector and the extension of the heavy-ion experiments to study open charm.

5 ACKNOWLEDGEMENTS

I would like to thank the workshop organizers sincerely for their kind invitation to provide an overview of the SPS physics programme and for the wonderful setting and atmosphere of the workshop. I would also like to thank Niels Doble, Lau Gatignon and Kurt Hübner for their comments and suggestions.

6 REFERENCES

[1] NA48 Collaboration, CERN/SPSC/90-22/P253, CERN/SPSC/90-39/P253 Add. 1, CERN/SPSLC/91-58/M479, CERN/SPSLC/93-11/M517, CERN/SPSLC/94-12/M533.

[2] COMPASS Collaboration, CERN/SPSLC/96-14/P297, CERN/SPSLC/96-55/M592, CERN/SPSLC/96-30/P295 Add. 1.

[3] P. Debu, private communication.

[4] NA45 Collaboration, CERN/SPSLC/94-1/P280, CERN/SPSLC/95-20/M542, CERN/SPSLC/96-35/P280 Add. 1.

[5] NA49 Collaboration, CERN/SPSLC/91-31/P264, CERN/SPSLC/91-52/P264 Add. 1, CERN/SPSLC/97-26/M601, CERN/SPSLC/98-4/P264 Add. 2

[6] NA50 Collaboration, CERN/SPSLC/91-55/P265, CERN/SPSLC/91-55/P265 Rev., CERN/SPSLC/96-29/M581 CERN/SPSLC/97-22/P265 Add. 1, CERN/SPSLC/98-8/M606.

[7] NA57 Collaboration, CERN/SPSLC/96-40/P300.

[8] NA52 Collaboration, CERN/SPSLC/92-16/P268, CERN/SPSLC/95-72/M570.

[9] NA53 Collaboration, CERN/SPSLC/92-67/P273.

[10] NA54 Collaboration, CERN/SPSLC/95-8/P286.

[11] NA59 Collaboration, CERN/SPSC/98-17/P308.

[12] CHORUS Collaboration, CERN/SPSC/90-42/P254, CERN/SPSC/97-14/M598.

[13] NOMAD Collaboration, CERN/SPSLC/91-21/P261 NOMAD Collaboration, J. Altegoer *et al* , Nucl. Instr. and Meth. A 404(1998)96.

[14] TOSCA Collaboration, CERN/SPSC/97-5/I213, CERN/SPSC/98-20/I213 Add. 1, CERN/SPSC/98-29/M616.

[15] I217 Collaboration, CERN/SPSC/97-23/I217, CERN/SPSC/99-5/M628.

[16] ICARUS Collaboration, CERN/SPSLC/96-58/P304.

[17] Conceptual Technical Design: The CERN Neutrino beam to Gran Sasso, CERN 98-02 and INFN/AE-98/05, May 1998.

[18] E. Weisse, The CERN Neutrino beam to Gran Sasso, these proceeedings.

[19] NA31 Collaboration, G. D. Barr *et al* , Phys. Lett. B 317(1993)233.

[20] E731 Collaboration, L. K. Gibbons *et al* , Phys. Rev. Lett. 70(1993)1203

[21] B. Müller and P. Braun-Munzinger, Status Report of the Relativistic Heavy-ion Programme at the CERN SPS, Chamonix, September 1998.