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'Large' cross section p-p physics with a dedicated detector

The following individuals have studied the question of how best to pursue large cross-section pp physics at the LHC. We conclude that a dedicated experiment is the optimum way of proceeding. It is the hope of the participants that this document, strengthened by the contributions of further collaborators, may form the basis for a future Expression of Interest to be submitted to the LHCC.

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1 Introduction

In the present memorandum, we summarize the results of the discussions which have taken place during the workshop on forward p-p physics held at CERN during the week of 21-25 August, 1995. This workshop followed work along similar lines (CERN/LHCC 95-01) and the encouragement from the LHCC to further investigate the subject of diffractive physics in p-p collisions (CERN/LHCC 95-03). The main physics goals of a full acceptance detector at the LHC were reviewed and possible detector configurations were investigated.

2 Physics goals in p-p collisions at low luminosities

We discussed a physics agenda in p-p collisions which is largely orthogonal to that of the planned major detectors, which focus on rare, high-p_t processes. Instead, the physics agenda for the detector considered includes the complete range of non-perturbative and semi-perturbative QCD processes, which are of considerable intrinsic interest. We considered other interesting and potentially new physics to which such QCD processes might appear as backgrounds. We note that a detector optimized for this physics may also be a good detector for other physics; one example is two-photon physics in p-p and heavy-ion collisions. Much of the physics we considered requires the ability to analyze complex patterns in individual events. Indeed, interesting classes of events, such as those arising from diffractive processes, are defined by their global pattern structure. These criteria place a number of requirements on the detector and the luminosity at which it can operate by effectively defining what we mean by "low" luminosity and "large" cross section. Operation at luminosities of $10^{30} - 10^{31}$, studying processes with cross sections ranging from 90 mb to perhaps 90 pb, was envisaged.

- Soft Physics
  - The measurement of elastic scattering and total cross-section.
  - The study of soft diffraction , including single and double diffraction.

- The study of pomeron-pomeron interactions via triple, and possibly higher order, diffractive processes.
- The measurement of the inclusive distribution of forward reaction products and studies of leading particles. Insight into some strange cosmic-ray phenomena (such as Centauro events, multi-muon bundles, and other anomalies) may be gained by a careful study of the energy flow in the far-forward region.
- The study of meson-meson and meson-nucleon interactions via leading particle tags.
- Pattern analysis, including the search for disoriented chiral condensates and related phenomena, and other correlation studies of multi-particle production.

- Semi-Hard Physics
  - Hard diffraction, including the search for the rise in the cross section with increasing rapidity gap width.
  - Continuation of studies already begun at Hera, Fermilab, and earlier experiments in elucidating the structure of the pomeron gluon and quark structure functions by measuring the rapidity distributions of heavy flavours, jets, and gauge bosons in diffractive events.
  - Related studies, that probe the fractal nature of QCD phase space and the onset of color-coherence effects, including the analysis of multi-jet global patterns and of jets-within-jets.

- Rapidity Gap Tags for New Physics

  In addition to the rapidity gaps generated by the exchange of a color singlet, we also considered those arising from the exchange of gauge bosons.

- Study of the 'Leading Effect' observed in pp interactions at ISR energies

  As demonstrated at the ISR, the investigation of the leading effect allows a direct comparison between hadronic systems produced in many different processes.

- Two-Photon physics

  Intense heavy-ion beams represent a prolific source of quasireal photons. Photoproduction physics, similar to what is done at HERA, can be performed at much larger cms energies. Photon-gluon collisions allow the study of the gluon distributions in ions and protons. While this physics has been considered by ALICE, it does not appear that they will be able to do it without substantial modification of their detector design.

3 Design Philosophy

3.1 Design goals

Collisions at the Large Hadron Collider will produce particles more or less uniformly over a kinematic range of some 20 units of pseudorapidity, from $-10 < \eta < 10$. In order to optimally pursue the physics goals outlined above, a detector is required that covers this entire range as uniformly as possible. We thus proposed as design goals:

- All charged particles of generic pt be observed and their momenta measured as well as possible.
- All photons of generic pt be observed and their energies well- measured.
- Identification of muons be extended into the far-forward regions.
- The physics of rapidity gaps not be compromised.
- The detection and momentum measurement of leading baryons.

3.2 A Dedicated Detector for "Large" cross section p-p physics

The following considerations have convinced us that a "stand-alone" experiment is the optimum way of pursuing our physics agenda. A dedicated detector will permit, among other things,

- a modified machine lattice to match the forward spectrometer in a wider pseudorapidity range;
- a low luminosity compatible with the optimal design of the experiment;
- dedicated running with the full detector from the begining of p-p collisions at the LHC;
- a special high-beta scheme, with beta at the interaction point of 1000 m or more;
- the possibility of complete $\eta - \phi$ coverage;
- a highly specialized beampipe;
- an easier implementation of new ideas.

In CERN/LHCC/95-01, an interest was expressed in pursuing the present physics agenda in the environment of the ALICE detector. Subsequent developments lead to the conclusion that an environment like that of ALICE may not be the best place to do this physics:

- It now appears that an experiment in I4 may be able to cohabit with the RF cavities, thus opening a collision region not thought to be available at the time of CERN/LHCC/95-01.
- A new design for the machine lattice in the vicinity of an intersection point, in which the separating dipoles are placed close to the IP, has been proposed. This enables these dipoles to be used for forward detection. However, this option increases beta min to approximately 10 m, which would result in a substantial reduction in heavy ion luminosity if implemented in the ALICE environment.
- The ALICE proposal to study Debye screening in Heavy-Ion collisions has been given a green light to be implemented in the Alice Technical Design Report. The implementation of this program is likely to seriously compromise the goal of running with both arms of the forward detector in a dedicated fashion from the very beginning of the p-p collisions at the LHC.

- The task of matching forward spectrometer magnets with good acceptance to the ALICE central solenoid appears to be extremely expensive and the goal of uniform coverage over all of h-f space is likely to be seriously compromised.

As a consequence of the above considerations, we believe that a stand-alone experiment should be dedicated to the physics agenda outlined above, probably at the I4 collision point.

4 Forward Insertion

A possible insertion adapted to experiments for the study of forward p-p physics has been described by T. Taylor (Talk at pp Forward Workshop, CERN, August 23, 1995). The principal characteristics are that:

- The inner triplet is exchanged with the beam separating dipoles.
- The first separating dipole (D1) can be split to permit the introduction of detectors.
- Experimental dipoles before D1 can be integrated into the configuration.
- Space for detectors is thereby provided between D1 and D2.
- The beta-value at the interaction point is tunable in either the range of approximately 10m to 60 m, or in the range of approximately 400 m to 1000 m or more.
- A double crossing will be required, but this does not appear to represent any serious problem.
- Most of the details of the proposed insertion, such as position, size and strength of the individual magnets appear to be broadly negotiable at the present time.

An additional consideration, associated with the I4 IP is that the beams are separated by 42 cm at the RF cavities. Among other implications, this permits more space for zero-degree calorimetry than is true at other IP's.

5 Detector Configurations Under Study

Two principal design concepts have been discussed by us, one with and one without a central magnetic field. They are similar in the way that the experimental and the beam separating dipoles are integrated into the forward spectrometer. The measurements of very forward particles are especially difficult since they have to be performed before the particles shower in the surrounding material. The vacuum-chamber architecture, the implementation of "roman pots", and the calorimetry close to the beams each have to be optimized and thus present a major challenge. The radiation hardness of these components will not present a major problem because of the reduced luminosity, if beam-gas interaction and the beam halo can be controlled. We recognize that new magnets for the central region would be prohibitively expensive. Studies were presented on the use of the two NA49 magnets for the forward experimental dipoles. A study of a central magnet, based on the UA1 dipole, was also presented.

5.1 No Central Magnet

In this scenario (fig. 1), the two experimental dipole magnets were placed as close as possible on either side of the Interaction Point. The central detector in this design concept consisted of electromagnetic and hadronic calorimetry covering the central region almost hermetically. Some tracking in the vertex region was included for help in reconstruction of the forward tracks. The advantage of such a design lies in its compactness. The forward machine dipoles were placed close to the Interaction Region. The machine dipole D1 was split into two magnets, the first with an enlarged aperture. Muon identification and momentum measurements was envisaged in the two forward arms.

5.2 Central Magnet

We believe that it is also important to consider the possibility of including a central magnetic field. We considered the possibility of a central dipole . (Other configurations can also be imagined.) The possibility of the UA1 dipole was suggested (fig. 2). Mechanical advantages, among other issues, were discussed. As in the previous case, the experimental forward dipoles were envisaged to be as close as possible to the IP. These would be followed by the beam separating dipoles as above.

Figure Captions

Figure 1. Detector design concept using NA49 dipoles and two machine dipoles in each spectrometer arm. Central tracking and calorimetry with no central magnetic field.

Figure 2. Detector design concept with central tracking and calorimetry using the UA1 dipole and spectrometer arms consisting of the NA49 and machine dipoles.