Low-mass lepton-pair production in p-Be collisions at 450 GeV/c


1 University of Bari and INFN, I-70100 Bari, Italy
2 Brookhaven National Laboratory, Upton, NY 11973, USA
3 CERN, CH-1211 Geneva 23, Switzerland
4 University of Heidelberg, D-69120 Heidelberg, Germany
5 Los Alamos National Laboratory, Los Alamos, NM 87544, USA
6 University of Lund, S-223 62 Lund, Sweden
7 McGill University, Montreal, PQ H3A 2T8 Canada
8 University of Montreal, Montreal, PQ H3C 3J7 Canada
9 Lebedev Institute of Physics, RU-117924 Moscow, Russia
10 Institute of Physics and Engineering, RU-115409 Moscow, Russia
11 Institute of Nuclear Physics, RU-630090 Novosibirsk, Russia
12 University of Pittsburgh, Pittsburgh PA 15260, USA
13 University of Rome 'La Sapienza' and INFN, I-00185 Rome, Italy
14 Rutherford Appleton Laboratory, Didcot OX11 0QX, UK
15 DAPNIA, CE Saclay, F-91191 Gif-sur-Yvette, France
16 University of Salerno and INFN, I-84100 Salerno, Italy
17 University of Stockholm, S-11346 Stockholm, Sweden
18 University of Tel Aviv, Ramat Aviv 69978, Israel
19 University of Turin and INFN, I-10100 Turin, Italy
20 University College London, London WC1E 6BT, UK

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a Now at: University of Lund, S-223 62 Lund, Sweden
b Now at: University of Cambridge, CH-1211 Geneva 4, Switzerland
c Visitor at CERN from Slovak Academy of Sciences, SQ-04535 Kosice, Slovak Republic
d Now at: University of Rome 'La Sapienza' and INFN, I-00185 Rome, Italy
e Now at: University of Ferrara and INFN, I-44100 Ferrara, Italy
f Visitor at CERN from Weizmann Institute, Rehovot, Israel
g Visitor at CERN from Niels Bohr Institute, DK-2100 Copenhagen Ø, Denmark
h Visitor at CERN from Ludwig-Maximilians-Universität, D-W-8000 München, Germany
i Now at: University of Columbia, Nevis Labs., NY 10533, USA
j Now at: University of Kyoto, Kyoto 606, Japan
k Now at: DESY, D-W-2000 Hamburg 52, Germany
l Now at: University of Montreal, Montreal, PQ H3C 3J7 Canada
m Now at: Ecole Polytechnique, F-91128 Palaiseau, France
n Now at: University of Urbino, I-61029 Urbino, Italy
o Now at: DAPNIA, CE Saclay, F-91191 Gif-sur-Yvette, France
p Now at: University of Liverpool, Liverpool L69 3BX, UK
q Now at: Politecnico of Milan, I-20100 Milan, Italy
r Now at: University of Salerno and INFN, I-84100 Salerno, Italy
s Now at: Slovak Academy of Sciences, SQ-04535 Kosice, Slovak Republic
t Visitor at CERN from Institute of Nuclear Study, Tokyo 188, Japan
u Visitor at CERN from NIKHEF-H, NL-1009 DB Amsterdam, the Netherlands
v Now at: LIP, P-1000 Lisbon, Portugal
w Now at: Texas Tech. University, Lubbock TX 79409, USA
x Now at: SAIIC, San Diego, USA
y Now at: Moscow State University, RU-117234 Moscow, Russia
z Now at: Brookhaven National Laboratory, Upton, NY 11973, USA
AA Now at: Institute of Physics, Acad. Sinica, Taipei 11529, Taiwan
BB Deceased
Abstract. We report on the production of low-mass electron pairs and muon pairs in p-Be collisions at 450 GeV/c at the CERN SPS. For both electron and muon pairs the low-mass spectrum can be explained satisfactorily by lepton pairs from hadronic decays, and there is no need to invoke any “unconventional” source. The normalisation of the major hadronic sources is set by the data. The upper limit, at 90% confidence level, on any new source of lepton pairs is \( \sim 20\% \) of the hadronic decay contribution for muons, and \( \sim 40\% \) for electrons.

1 Introduction

The production of low-mass lepton-pairs \( (m_{\text{pair}} < m_\mu) \) in hadronic collisions has been measured in several experiments, stretching back over more than a decade [1]. Despite this considerable amount of experimental effort and data, it has remained unclear whether the production of these pairs matches that expected from “conventional sources”, i.e. hadronic decays, hadronic bremsstrahlung of virtual photons, and Drell-Yan. This uncertainty has been due in large part to inadequate knowledge of the relevant hadronic production cross-sections and of the decay modes into lepton pairs.

Clearly this issue should be settled, since any significant deviation from the level implied by conventional sources could have important implications for the hadronisation process [2]. Furthermore, lepton pairs have been suggested as a signature for quark-gluon plasma formation in relativistic heavy-ion collisions [3]: it is essential then to understand their production level in ordinary hadronic collisions.

In this paper the production of electron and muon pairs, produced in 450 GeV/c p-Be collisions \( (\sqrt{s} \approx 29 \text{ GeV}) \) in the central rapidity region, is compared to the expectation from conventional sources. The most important features of the experimental approach are:

- the analysis of both electron pairs and muon pairs, emphasising different aspects of the detector, producing two essentially independent measurements of lepton pairs;
- the measurement of photons as well as charged leptons, affording direct measurement of certain Dalitz decay modes;
- electron identification by both transition radiation and calorimetry;
- a double measurement of the momentum (or energy) of both muons and electrons;
- a measurement of the total charged multiplicity of the event.

The main result is that low-mass lepton pairs, produced centrally at \( \sqrt{s} \approx 29 \text{ GeV} \), can be accounted for by lepton pairs from the decay of hadrons, and there is no need for any “unconventional” source. Upper limits on any new source are presented.

The plan of this paper is as follows. In Sect. 2 we describe the apparatus, triggering, and data-taking, followed by the event reconstruction and selection in Sect. 3. The analysis is presented in Sect. 4, and in Sect. 5 results are summarised and conclusions are drawn.

2 Apparatus, triggering, and data-taking

2.1 Beam and target

The study of low-mass lepton pairs was one of the prime motivations of the HELIOS experiment, and so the suppression of \( e^+e^- \) pairs from conversions was a key feature of the design. Accordingly, we have used a 4 cm long (10% interaction length) Be wire target of only 125 \( \mu \text{m} \) diameter, in order to minimize the radiation length traversed by photons from the decay of hadrons produced in the interaction.

A special 450 GeV/c proton “micro”-beam was developed for the HELIOS experiment to match the wire target. This beam has excellent momentum resolution \( (\delta p/p < 0.1\%) \), a transverse diameter less than 50 \( \mu \text{m} \) and divergence \( \sim 0.2 \text{ mrad} \) at the target. The intensity was \( \sim 10^6 \) per burst. The targeting of the beam on to the wire worked reliably and stably throughout the experiment.

2.2 Apparatus

The HELIOS spectrometer is situated in the H8 beam line of the CERN SPS North Area. An overview of the apparatus is shown in Fig. 1a. The main components are the electron spectrometer and muon spectrometer covering the forward region \( \theta_{LAB} < 6^\circ \) (i.e. \( \eta_{LAB} > 2.9; \eta_{ppCM} < -0.4 \) ), and calorimetric energy measurement over the full solid angle.\(^{1}\) The characteristics of the main components are given in Table 1, together with references where more details may be found. Features of particular relevance to this analysis are described in the sections on triggering and reconstruction.

2.3 Triggering

Incoming protons are defined by three small scintillation counters (SCbeam) placed 270 cm and 140 cm upstream of the target. Two larger scintillators, with central holes, act as a halo counter (SChalo) and were used in veto. A “valid beam” signal, VB, is \( SC_{beam},SC_{halo} \), combined with suitable timing protection to ensure that there is no second beam particle within a \( -350\text{ns} \) to \( +500\text{ns} \) “before-after” window. The interaction pre-trigger, PRE, consists of VB in coincidence with a charged multiplicity \( \geq 3 \) as seen by the Si-pad detector (Table 1). Further triggering steps are now required to select electron pair and muon pair samples.

2.3.1 Electron trigger

The electron trigger performs the two tasks of identifying electrons and rejecting those from conversions. Very extensive discussions of the electron trigger may be found in theses from the HELIOS experiment [9]. For the data described in this paper, two isolated trigger electrons are required.

\(^{1}\) We use a right-handed co-ordinate system with \( z \) along the beam direction and \( y \) pointing vertically upwards.