BACKGROUND STUDIES FOR DILEPTON EXPERIMENTS AT THE LHC

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First results from a detector simulation for a heavy ion experiment at the LHC, concerning the combinatorial background of lepton pairs, are presented. The study has been carried out using two samples of 4000 O - O and 1500 S - S central events, obtained from the VENUS 3.11 generator. The framework for future, more detailed studies is described.

1. INTRODUCTION

The present work has been started with the final aim of evaluating the feasibility of a dilepton experiment with heavy ion beams at the LHC.

The first step has been the optimization of the model VENUS [1,2], to get event samples to be used in the simulation. The second step, still in progress, is the development of a detector simulation program, in order to provide a tool for the design of a dilepton experiment. This tool shall be able to estimate backgrounds from conventional sources, and to reproduce the detector response in different experimental configurations.

2. DETECTOR SIMULATION

For the detector simulation, it has been decided to use the GEANT package [3], which has the advantage of a simple definition of the setup, but takes a large amount of CPU time, especially for heavy ion central collisions at the LHC energy, where, before any decay, the total charged multiplicity ranges from 2500 (O-O) to 30000 (Pb-Pb).

The result of the propagation through a boron carbide absorber of a proton-proton event at $\sqrt{s} = 6300$ GeV is shown in fig. 1, while fig. 2 shows the propagation in air of the primary particles produced in an oxygen-oxygen interaction.

3. BACKGROUND TO DILEPTON EXPERIMENTS

3.1 MUONS FROM DECAYS OF PIONS AND KAONS

The starting points for the computation of the number of decays are the pseudorapidity and momentum distributions of pions and kaons at generation. Fig. 3.a and 3.b show respectively $dN/d\eta p$ and $dN/d\eta p_T$ distributions for kaons in
O - O interactions. On the other hand, the definition of the absorber material, shape and position is essential, since it fixes the mean free path of pions and kaons before they undergo an interaction.

The inner shape of the absorber is chosen so that the decay probability be independent of the angle. In particular, for each particle, the mean path \( x \) before the decay is computed as

\[
x = \beta \gamma \tau_0 \ln \left( \frac{1}{1 - pr} \right) = \frac{p}{m} \tau_0 \ln \left( \frac{1}{1 - pr} \right)
\]

where \( p, m, \tau_0 \) and \( pr \) represent respectively the momentum, the rest mass, the lifetime in the rest frame and the decay probability of the particle (which is kept fixed). Then the mean value of this path is computed in different pseudorapidity regions, and the distance of the absorber from the interaction point is given by the difference between this path and one interaction length: so its value depends on the absorber material. The simulation has been carried out for 3 different materials (\( B_4 \), \( Al_2O_3 \) and \( Cu \)), but can be repeated with little effort for other materials. By the way, from here on, the inner shape of the absorber is assumed to be a cylinder.

The absorber position, in principle, should be chosen in order to minimize the number of decays: this of course means that it has to be as close to the interaction point as possible. The absorber has been put at a distance of half an interaction length of \( B_4 \) from the beam axis (16.3 cm). This value is quite reasonable, keeping in mind that in any case the beam pipe radius is of the order of a few centimeters and that the decay path into the absorber would already be dominant with respect to the one in air.

For each particle the decay probability can now be computed as

\[
pr = 1 - \exp \left( -\frac{x}{\beta \gamma \tau_0} \right) = 1 - \exp \left( -\frac{m x}{p \tau_0} \right)
\]

where both the momentum \( p \) and the path \( x \) depend on the emission angle \( \theta \). In particular, \( x \) is given by the sum of two terms: the free path in air and the mean path before the particle interacts in the absorber (one interaction length). As a function of the emission angle:

\[
x = \lambda \mu m + \frac{0.5 \lambda \mu m}{\sin \theta}
\]

Given the branching ratios for the decay channels:

\[
\pi \rightarrow \mu + \nu_{\mu},
\]

\[
K \rightarrow \mu + \nu_{\mu},
\]

1133
the number of decay muons per event and, from kinematics, their 4-momenta are obtained.

At this point, it is possible to impose some cuts on the kinetic energy and on the transverse momentum of the muons, and to get the combinatorial mass spectrum from all the possible opposite sign pairs. Namely, assuming an absorber thickness of 8 interaction lengths, an energy loss of $1.86\text{MeVcm}^2/g(B_1C)$, $1.867\text{MeVcm}^2/g(Al_2O_3)$, $1.67\text{MeVcm}^2/g(Cu)$, and a magnet momentum kick of $0.6\text{GeV}$, all the muons with a kinetic energy below $1.223\text{GeV}(B_1C)$, $1.474\text{GeV}(Al_2O_3)$, $1.820\text{GeV}(Cu)$ and a transverse momentum below $0.6\text{GeV}$ are cut away.

The resulting mass distributions for dimuons are shown in fig. 4 for S-S collisions and a boron carbide absorber (full line). It is evident that the high mass tail of the spectrum is significant. But, looking at the correlation of the pair mass ($M_{\mu\mu}$) with the pseudorapidity interval between the two muons ($\Delta\eta_{\mu\mu}$), one sees that all the high mass dimuons have a large value of $\Delta\eta_{\mu\mu}$ (fig. 5, S S interactions). Now, looking only at the pseudorapidity region $2 < \eta < 3.5$, which is a suitable candidate for a muon spectrometer, the mass spectrum, with the previous cuts, is shown in fig. 4 (dashed line). The mass region of the $J/\psi$ and of the $\Upsilon$ are completely free from this kind of background.

The muons pseudorapidity distributions, after cuts on kinetic energy and transverse momentum, are shown in fig. 6 for different absorbers (O-O interactions).

### 3.2 OTHER BACKGROUNDs

The hadrons which, coming out after the absorber, simulate a muon in the spectrometer are the second main source of problems for a dimuon experiment. These particles, generally referred to as punch through particles, have a very steep dependence on the thickness of the absorber (fig. 7). The requirement of a low level of punch through is in direct conflict with the need of a short absorber for this kind of experiment, to guarantee optimum mass resolution. Therefore, presently available parametrizations, like the one in ref. [4], are not particularly suitable for this purpose, since they are optimized for very thick absorbers and high energy particles. So, it has been decided that a specific simulation should be developed to evaluate the punch through probability for low energy particles and short absorbers: this work is in progress, and we hope to be able to make sensible estimates within a short time scale.

In parallel, we are trying to set up an evaluation of backgrounds also for $e^+e^-$ pairs. In fig. 8 a preliminary estimate of the background from Dalitz decays of $\pi^0$s in O-O interaction is shown. The full line represents the mass spectrum over the whole pseudorapidity range, while the dashed line refers to the pairs in the
interval $-0.5 < \eta < 0.5$. There are no cuts on the momentum. This work is also still in progress.

4. CONCLUSIONS

A program to perform detector simulations for ion-ion interactions at the LHC energy has been set up. This tool will be used to extensively study the various problems connected to the design of a detector for this kind of experiments. As a first step the background to the dimuon spectrum from decays of pions and kaons has been estimated. We are presently working on the problems of punch through and of the combinatorial background for electron pairs. Future developments shall include studies of effects such as the albedo and the lateral leakage from the muon absorber.

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REFERENCES


3) R. Brun et al, GEANT3, CERN DD/EE/84-1.

4) F. Lacava, these proceedings.
VENUS 3.11, $p$-$p$ LHC energy

fig. 1