NA64 Search for Dark Photons

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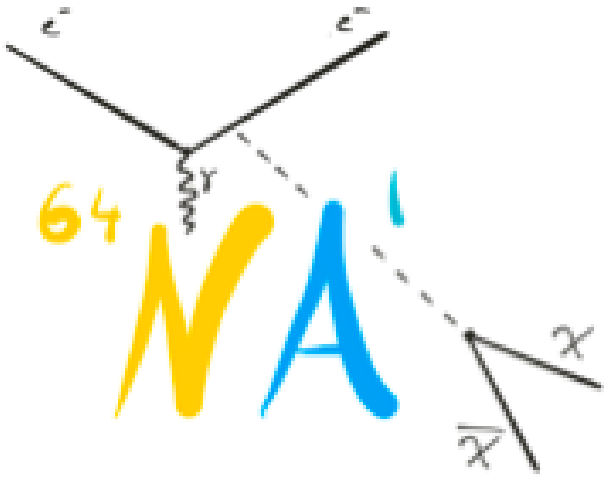

1 Introduction

The NA64 experiment, known as P348 before official approval, was proposed to the CERN SPSC on January 2014 with main goal the search for the following decay modes

$$\begin{aligned} A' &\to invisible \\ A' &\to e^- e^+ \end{aligned} \tag{1}$$

In March 2016 P348 was granted approval by the CERN Research Board and received the title NA64. Since having been promoted, the experiment has been conducting the searches the searches for the processes mentioned above at the CERN SPS. NA64 is a fixed target experiment which utilizes the active beam dump. The detection of rare processes is based on the missing energy techniques.

Such techniques are used for particles whose interaction with the detector is very small, so that they escape the detection and carry away some energy. A significant missing energy in the experiment means that such particles are produced.

The method of the search for the $A' \to invisible$ decay is as follows. If the A' exists it could be produced via the kinetic mixing with bremsstrahlung photons in the reaction of high-energy electrons absorbed in an active beam dump (target) followed by the prompt $A' \to invisible$ decay into Dark Matter particles in a hermetic detector:

$$e^- Z \to e^- Z A' \, ; A' \to \chi \bar{\chi} \tag{2}$$

The experiment employed the optimized 100 GeV electron beam from the H4 beam line at the North Area (NA) of the CERN SPS. The H4 provided an essentially pure e^- beam for fixed-target experiments. The beam was designed to transport the electrons with the maximal intensity up to $\simeq 10^7$ per SPS spill of 4.8 s in the momentum range between 50 and 150 GeV/c that could be produced by the primary proton beam of 400 GeV/c with the intensity up to a few 10^{12} protons on a beryllium target.The main contribution to the the e^- yield from the target was the production of π^0 followed by a process $\pi^0 \to \gamma\gamma \to e^-e^+$. The short-lived π^0 decays inside the target, and the electrons were produced through the conversion of the decay photons in a separate converter. Protons and charged secondaries that did not interact in the convertor are separated from the neutrals be deflecting them in a magnetic field to a thick absorber. The electrons produced in the convertor are transported to the NA64 detector inside an evacuated beam-line tuned to an adjustable beam momentum. The set of specialised detectors is summarised below and a detailed schematic is included in Fig.1

1. Electromagnetic calorimeters ECAL
2. Hadronic calorimeters HCAL
3. Beam counters and Hodoscopes
4. Veto counter
5. Synchrotron radiation counter
6. Decay volume
7. Micromegas tracker MM
8. Straw tube chambers

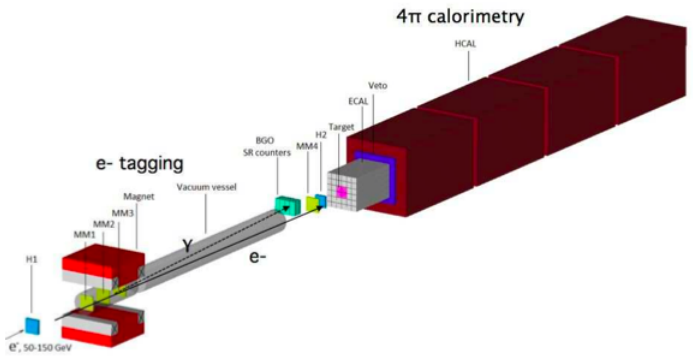

Figure 1: Schematic illustrating the setup of sub-detectors mentioned above.

2 Tasks

1. The purpose of the first task was to provide a report on all sub-detectors and corresponding channels regarding their consistency in measurements and identify problematic equipment. An inconsistent channel was reported by comparing data between runs in the following way. A channel with a $\delta\chi$ ratio greater than 4 was interpreted as inconsistent

$$\delta\chi = \frac{y_1 - y_0}{\sqrt{\delta y_1 + \delta y_0}} \tag{3}$$

where y and δy the channel mean and standard deviation for a particular run respectively. The control was implemented as a program encoded in C++.

Furthermore, the resulting .txt files were stored in a separate directory which permitted online access. A dedicated machine and PHP script were setup to enable online listing and comparison of these results through a PHP interface.

2. The experiment NA64 widely used $\mu^+\mu^-$ events for warious checks. The process

$$e^- Z \to e^- Z\gamma\,; \gamma \to \mu\bar{\mu} \tag{4}$$

was used as a benchmark allowing to verify the reliability of Monte Carlo (MC) simulation and to estimate the corrections to the signal reconstruction efficiency and possible additional uncertainty in the A' yield calculations.

In this next task, the angular distribution of dimuons from the process 4 was studied using MC of 10000 events. This was needed to optimize the design of the tracking system. The angles ($<<1$) between the direction of propagation and both the x and y components of momentum (p_x and p_y respectively) were calculated as follows

$$\frac{p_x}{|\vec{p}|} \tag{5}$$

The MC results are summarized in Fig. 2

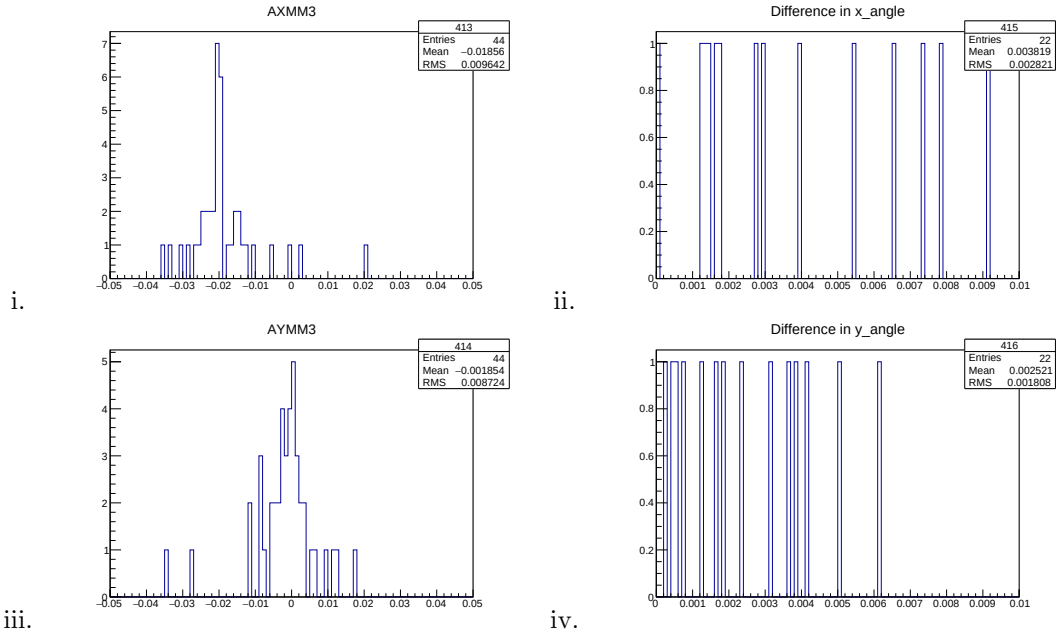

Figure 2: i) Distribution of angles between x-component of momentum and propagation. ii) X-angle between components of dimuon. iii) Distribution of angles between y-component of momentum and propagation. iv) Y-angle between components of dimuon

3. The next task was the extention and further development of the automatic test of commits to the git repository of the package "simulation" that is written for the simulation of signal processes and backgrounds in the NA64 setup and is based on Geant4. The test is run automatically after each

command “git push”. The extention consisted in the addition of the analysis of the root file with histograms created after running several executables of the package “simulation”. The ROOT macro written for this checked that several parameters of the histograms are inside allowed range.