Data analysis from the CERN test experiment related to HADES electromagnetic calorimeter

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HADES (High Acceptance Di-Electron Spectrometer)
The purpose of HADES is to study the nuclear matter properties at high densities and temperatures. HADES will provide di-electron data at baryon density and temperature which will enable us to scan a different part of the phase diagram of nuclear matter. The main purpose of study is the medium modification of hadrons properties such as masses and decay widths. In the short life nuclear matter state, just after the heavy ion collision, a lot of particles are created. Light vector mesons like ρ, ω and φ are adapted to scan this state because of their short lifetime. The ρ meson is decaying in about 4.5 x 10^{-24} s, the ω meson is decaying in about 6.6 x 10^{-23} s and the φ meson is decaying in about 1.55 x 10^{-22} s. All these mesons can decay with low probability (10^{-5}) to electron pairs but they will mainly decay to pions. If these light vector mesons decay to pions, the information will be lost because pions will scatter in the ball of fire before they escape. But electrons don’t interact with this matter, so by detecting the electron pair, it is possible to reconstruct the initial meson with intact information. However, because of the low probability of electron pair decay, signal from these particles is affected by a large amount of various particles. Most of these particles are pions and eta mesons.

There are mainly two sources of background in the light vector mesons signal. Neutral pions and eta mesons can decay in electron pair plus one photon called Dalitz decay with a branching rate about 1.2%. These electrons present no interest and must be subtracted from the signal. The main decay of neutral
pions and eta mesons is a pair of photons. By detecting these photon pairs it is possible to calculate the amount of electron pair produced by the Dalitz decay of neutral pions and eta mesons.

The other source of background is charged pions. The RICH detector will detect exclusively electron pairs, but sometimes charged pions will be detected as electrons by the detector. Rho meson, for instance, decays to pion pair with a branching rate of 99.9%. The amount of pions produced is much bigger than the amount of electron pair produced. At low momenta, the discrimination is done by the TOF detector but we need a better discrimination of electron and pions at higher momenta (>500 MeV). All these background corrections will be done by the HADES electromagnetic calorimeter.

**HADES electromagnetic calorimeter**

The aim is to replace the HADES pre-shower detector by the electromagnetic calorimeter. The calorimeter requires about 8 m² and will be placed at 2.40 m from the target with an angle covering of 18° < θ < 45°. Two proposals of detector have been done and one is to take the lead glass modules from the OPAL experiment at LEP and adapt it to HADES. These lead glass modules are Cherenkov detectors. Electrons and gammas will produce some electromagnetic shower by hitting the module and the charged light particles created will emit some Cherenkov light collected by photomultiplier. Pions react in a different way. Electrons and gammas will deposit their whole energy although pions will deposit only a part of it. That is because pions interact with the detector by mean of strong nuclear force and produce hadronic shower and not electromagnetic shower. The size of one module is 42 x 9.2 x 9.2 cm and about 840 of them will be used for the calorimeter. The resolution of the detector is proportional to the inverted square root of the energy and should reach 5% at 1 GeV.

![Figure 2 HADES experiment with actual pre-shower detector](image-url)
The CERN test experiment

Two test experiments were done before the construction. The purpose of MAMI test experiment was to evaluate the resolution of different modules in order to choose the best one. The other test experiment has been done at CERN. The purpose is to check the energy resolution of the detector and evaluate the electron/pion selection.

At the CERN test experiment, detectors are placed in a 4x4 cm beam of electrons and pions with moment from 0.4 to 2.0 GeV/c. The intensity of the beam is 100-1000 particles/bunch, with bunch every 45 seconds. The beam goes through a gas Cherenkov detector which distinguishes pions and electrons. Two modules have been tested and module one was sent to two A/D converters for check. The adc1 is type CAEN A811 and the adc6 is type PA24K.

![Figure 3 The CERN test experiment](image-url)
Data analysis from the CERN test experiment

Figure 4 Distribution of the energy deposited in the detector (adc converter 6) Green curve depicts pions, red curve depicts electrons and black depicts sum of all detected particles.
The Cherenkov gas detector distinguishes pions minuses from electrons. Indeed, at this energy, when electrons go through the detector, Cherenkov light is emitted while pions go through without detection. Then the electron peaks are fitted with a Gaussian curve.

*Figure 5* Fitting of the electron peak for the first module, *adc6.*
The following graphs represent the energy calibration and the resolution of two modules. For the first module, two different A/D converters were used as described above. In all the following graphs, for the energy calibration, the fitting is done with an exponential function. For the resolution, the fitting is done by a $k/\sqrt{E}$ function.

**Detector 1, adc 6**

**Detector 1, adc 1**

**Detector 3, adc 3**
The results seem correct, the exponential and $k/\sqrt{E}$ dependencies are respected. The resolution on the third detector at 400 MeV seems to be a bit low. However, on all these spectra, we can notice that the resolution of the detector is worse than the expected resolution. At 1 GeV, a resolution of 5% is expected. This can be an effect of a bad fitting for electron peak. Indeed, as one can see, electron peaks are not totally Gaussian. The fitting was tried with other functions like Gaussian + exponential or Gaussian + polynomial.

![Figure 2 Fitting of an electron peak with an exponential + Gaussian function](image)

![Figure 3 Fitting of an electron peak with a 2nd degree polynomial + Gaussian function](image)

The fitting with these new functions is not acceptable, it moves the peak to the low energy and the fitting of the low energy tail is strangely angular. New functions should be used for best fitting but this non expected resolution can be due to the electronic devices.
The electron/pion separation is done by counting the amount of pions out of the electron peak divided by the whole amount of pions.

![Figure 8 Electromagnetic Separation function of the Energy.](image)

**Figure 8 Electron/Pion Separation function of the Energy.**

*Blue depicts Det.1 adc1, red depicts Det.1 adc6 and green depicts Det.3 adc3*

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<th>Energy (MeV)</th>
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<th>Det 3 adc 3</th>
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*Electron/Pion separation values with statistical error.*

To conclude, the energy resolution of this detector is good and probably should be improve with better electronic. The most important result is the electron/pion separation. Indeed, results show really good separation, much better than the actual pre-shower detector. These results are very promising and an electromagnetic calorimeter with lead glass modules from OPAL experiment is a practical, feasible and really efficient proposal to improve the results of HADES.