Proton-Muon Energy Correlation in the Crystal Ball

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Measurements of the response of a NaI crystal to protons and muons have been performed, and a nontrivial energy dependence has been observed.

The Darmstadt-Heidelberg Crystal Ball [1], recently upgraded to detect also protons at large scattering angles [2], is the key detector for (p,2p) reaction tagging in experiments with the LAND/R^{3}B setup at Cave C. Measurements of the proton energies are based on calibrations performed with tracked cosmic muons. This is the only readily-available method, but requires a hitherto unknown correlation between the muon and proton energy deposit. Protons at several energies from break-up of the deuteron beam during the S406 calibration experiment for NeuLAND were available, thus a dedicated test setup [3] using one crystal from the Crystal Ball was installed in order to find this correlation.

The test setup was designed to mimic the surrounding Crystal Ball in order to tag muons passing through the crystal in a similar manner as if it was sitting inside the Crystal Ball. Plastic scintillators were used in order to realise this, arranged as shown in Fig. 1. The setup was placed behind the proton arm time-of-flight detector.

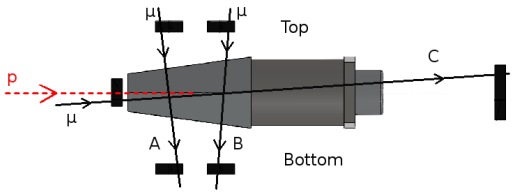

Figure 1: Detector setup. The NaI crystal is 20 cm long and surrounded by 6 plastic scintillators, five of which have an area of 5x5 cm^2 and one an area of 10x10 cm^2, all being 2 cm thick. The solid lines show different muon tracks used for calibration, c.f. Fig. 2.

Both proton and muon energy deposits were measured in the NaI crystal. The muon energy deposits for different pathlenghts, used for calibration by comparison to GEANT3 [4] simulations, are displayed in Fig. 2. The measured proton energy deposits for different beam energies are shown in Fig. 3. While we see the punch-through peak approximately at its expected position (276 MeV), the overall gain is clearly lower for protons compared to muons. An open question is the nonlinear response below punch-through, which is in contradiction to expected behaviour [5]. For details of the analysis see [6].

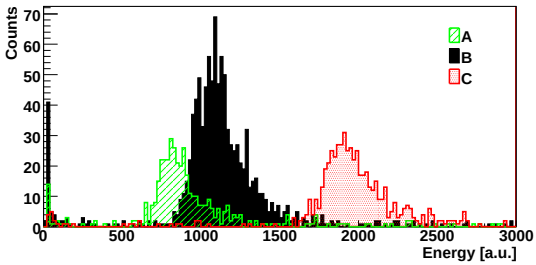

Figure 2: Energy deposited by muons for different paths (A, B, C) through the crystal, as indicated in Fig. 1.

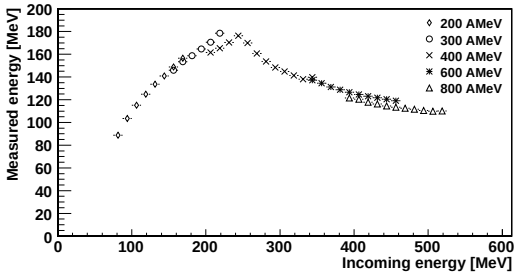

Figure 3: The y-axis, calibrated by muons, shows the proton energy deposit in the crystal. The x-axis displays the energy of the proton derived from its time of flight between the (main experiment) start detector and the scintillator in front of the crystal. The symbols indicate nominal deuteron beam energies.

References

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