Measurement of the photon response of $PbWO_4$ and CeF_3 below 1 GeV

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The proposed photon detector for ANKE [1] will be located in the target region in front of the dipole magnet D2 [2]. Limitations in space require the use of a scintillator material with a radiation length as small as possible.

In recent years $PbWO_4$ has been investigated as a high-density inorganic scintillator with good energy resolution for photon detection even at intermediate energies [3]. For high-energy physics it has been chosen by the CMS collaboration at CERN as the material for the electromagnetic calorimeter (about 80000 channels).

	$PbWO_4$	CeF_3
density ρ [g/cm^3]	8.28	6.16
index of refraction	2.16	1.68
radiation length X_0 [cm]	0.89	1.68
Molière radius R_M [cm]	2.2	2.6
major decay constants [ns]	< 20	30
peak wavelength [nm]	420	$310 - 340$
temp. dep. of light yield [%/°C]	≈ -1.9	-

Table 1: Relevant physical properties for $PbWO_4$ and CeF_3.

Recent tests at the photon beam line of the electron accelerator MAMI at the nuclear physics institute of the University of Mainz have been performed in order to evaluate the photon response of $PbWO_4$ and, for the first time, of CeF_3. Both test arrays have a length of at least 16 radiation lengths and a diameter of at least 3 Moliére radii. The properties of both materials are shown in table 1.

Figure 1 shows the resolution of $PbWO_4$, which is better than of CeF_3 (fig. 2) despite its lower light output. However, the CeF_3 crystals (provided by the Crystal Clear Collaboration and ETH Zürich) are prototypes [4] and are not yet optimized like $PbWO_4$ (manufactured by RI&NC, Minsk, Republic of Belraus, and Bogorodistsk Techno Chemical Plant, Russia). The CeF_3 modules consist of 2–4 single crystals and the optical quality differs a lot; some modules are, therefore, very inhomogeneous. The scintillation performance of $PbWO_4$ has been steadily improved by the raw material, crystal growth conditions and suitable dopants (Nb/La) to guarantee radiation hardness.

In fig. 1 a comparison of $PbWO_4$ with the existing BaF_2 modules of the TAPS spectrometer is shown. The two curves correspond to an integration either over the total light output or over the fast component only. Below E_γ=300 MeV the resolution is dominated by the low light yield of the scintillator, but at higher energies the performance gets better due to the high density and short radiation length.

The time resolution (achieved by selecting an impact point between two neighbouring crystals) is $\sigma_t = (1/\sqrt{2}) \cdot 237$ ps $= 168$ ps and $\sigma_t = 130$ ps for CeF_3 and $PbWO_4$, respectively.

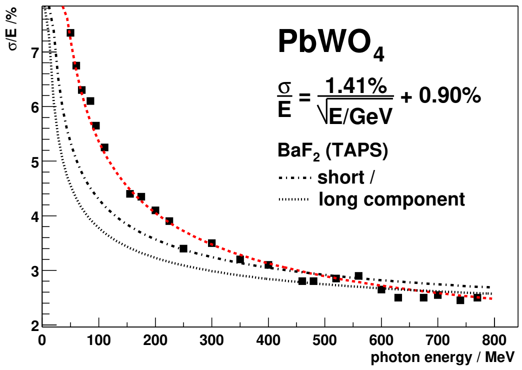

Figure 1: Preliminary test results on the resolution of $PbWO_4$ as obtained in August 2000 at the electron accelerator MAMI of the University of Mainz.

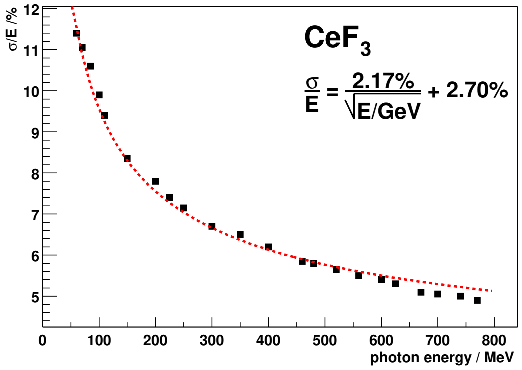

Figure 2: Preliminary results on the resolution of CeF_3.

Radiation resistance has been investigated by the CMS collaboration [5], where this problem is more severe than at COSY. It was found, that the loss in light output due to radiation damage saturates at about 5% at high neutron rates.

All these properties together make $PbWO_4$ most suitable for use in a future electromagnetic calorimeter at ANKE.

References

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