A Cherenkov detector as a possible TOF detector for the Super-FRS

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In order to separate and identify fragmentation products with the Super-FRS (SFRS) [1] at FAIR a high resolving power detection system is required for position and Time-of-Flight (TOF) measurements. In order to separate the heaviest ions with masses of 200u and 201u with an energy of ~1GeV/u at the distance of 52 m from the middle plane FMF2 to the final FMF4 a detection system with $\sigma\sim$54 ps time resolution is required. Along with a fast timing response the detector has to satisfy requirements of the harsh environmental surroundings of the SFRS. The rate of particles at FMF2 is expected to be up to 10^7 ions/spill (spill=500 ns÷10 s). This requires a highly radiation resistant material.

In many relativistic heavy ion experiments gaseous [2] or solid [3], [4] Cherenkov radiator materials are used for particle identification and energy measurements. The application of gaseous or liquid active materials allows to refresh them by circulation and therefore greatly reduces the degradation of the performance due to aging after exposure to the high ion rates. Typically the refractive index (n) of gases equals to 1.0003 at normal ambient conditions and is pressure depended. Even for the maximum ion energy at the SFRS that does not allow to reach the Cherenkov threshold velocity of photon creation $\beta = \frac{1}{n}$, where $\beta = 1/\sqrt{1-\gamma^2/2}$. To measure Cherenkov photons with heavy ions of 400 MeV/u, a radiator material with n≈1.5÷2 is required. In order to achieve this for gases one has to increase significantly its pressure what makes it impossible to easily use them under usual experimental condition. Fig. 1 illustrates the dependency of the refractive index on wavelength for several materials with the corresponding threshold velocity.

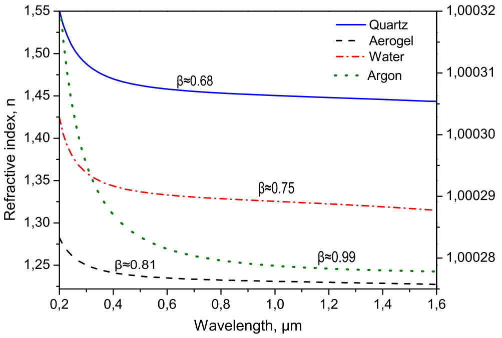

Figure 1: Refractive index as a function of wavelength for materials commonly used as Cherenkov radiators. Left ordinate shows n for argon. The threshold velocity β is indicated for n at 589 nm.

Consequently, for a future TOF detector an Iodine Naphthalene liquid ($C_{10}H_7I$) radiator with n=1.705@589nm is proposed. The liquid is kept in a cuvette made out of float/quartz glass and glued together with an optical glue. The entrance and exit window of the cuvette will be coated with Al to act as a mirror for the Cherenkov photons. To be sure that the $C_{10}H_7I$ does not react with the optical glue several samples from fused silica have been glued and stored for several months in the liquid as well as heated and shaken. The transmission spectra were measured with an UV spectrometer before and after an exposure to light and contact with optical glue (Fig. 2). No change of the transmission has been recorded after contact with the glue.

As an example after pathing of ^{59}Ni ion with an energy of ~400 MeV/u about $3{\cdot}10^4$ Cherenkov photons are created. The measurement of the efficiency of the liquid radiator was performed with cosmic muons as a reference to 2 plastic scintillators and equals to 24%. The detection efficiency of Cherenkov photons was investigated as well by the GEANT based Monte Carlo simulations. PMTs for photon detection and several concepts of redout system were tested. First test of the prototype detector will be performed early 2014 at the SIS/GSI.

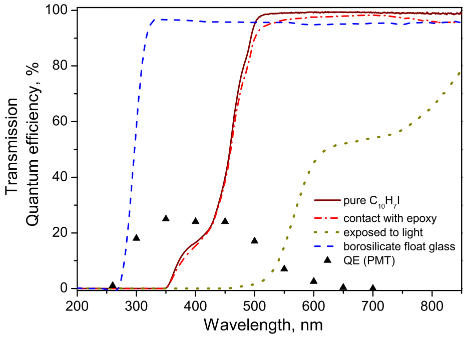

Figure 2: UV transmission spectra of $C_{10}H_7I$ liquid before and after exposure to light and contact with optical glue as well as of borosilicate float glass and quantum efficiency (QE) of the photomultiplier tube (PMT).

References

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