SEGMENTED ZERO DEGREE DETECTOR FOR COULOMB EXCITATION EXPERIMENTS WITH RADIOACTIVE NUCLEAR BEAMS

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Coulomb scattering is a very important tool for studying nuclear structure. In general, the projectile scatters of the target and it may get excited through nuclear or Coulomb interaction. For small scattering angles (e.g. $\theta_{max} = 4^0$) Coulomb excitation dominates and we can neglect the nuclear contribution. Detection of beam particles at small angles in coincidence with signals from the NaI(Tl) array will allow us to separate Coulomb excitation from nuclear excitation.

Since nuclear fragmentation beams, such as those produced in the A1200, may contain more than one isotope we need to identify them on event-by-event basis. For the identification of the isotope of interest several techniques can be used. A time of flight (TOF) method in combination with an energy loss measurement and knowledge of the magnetic rigidity ($B\rho$) of the A1200 allows the identification of the beam particle before the target. The TOF method is based on the measurement of velocity of the projectile nucleus using the time signals from two spatially separated detectors. In our case we have a thin plastic scintillator after the A1200 focal plane and PIN silicon detector located before NaI(Tl) array. The last detector is also used for the energy loss measurements (δE), which uniquely defines the atomic number of the nuclear fragment. Simultaneously, we also need to know the isotopic composition of the beam after the target because nuclear reactions can take place in the target. Such information is necessary for the identification of gamma rays from the isotope of interest. For this purpose we have to measure energy loss and total energy of each nuclear fragment. A combination of two plastic scintillators with different time characteristics is a very convenient choice because δE and E signals can be easily distinguished through pulse shape discrimination.

Recently, we built a Zero Degree Detector (ZDD) for Coulomb excitation experiments, (Fig. 1.)

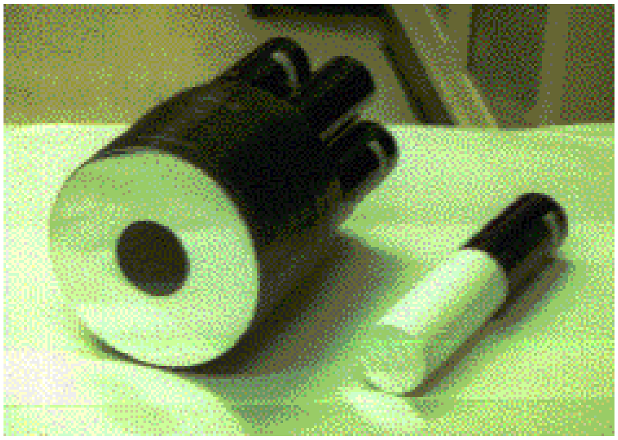

Fig. 1: The Segmented Zero Degree Detector.

The detector is made of thick slow plastic scintillator (BC 444) and thin layer (0.6 mm) of fast plastic scintillator (BC 400). The Z measurement, in our detector, is based on the fact that energy losses in the thin absorbers are small and velocity of the projectile (β) is roughly const. The mean energy loss, by the fully stripped nucleus, can be approximated by the Bethe-Bloch formula [1]:

$$\delta E = 2\pi N_a r_e^2 m_e c^2 \rho (z/a)(Z/\beta)^2 x \,,$$

with $2\pi N_a r_e^2 m_e c^2 = 0.1535$ MeVcm^2/gm, ρ, z and a are properties of the absorbing material and x is the absorber thickness. For example, while passing through the thin fast plastic scintillator, ^{40}Ar ions with energy 100MeV/A will lose 4.45MeV/A and ^{26}Ne ions with the same energy will lose only 2.5 MeV/A. The thin fast plastic is glued to the thick slow plastic scintillator. That layer of glue represents the detector's "dead volume", which is ≤ 0.15 mm. For identification of fragments in the ZDD, the target can not be too thick (thickness of the Au target should be ≤ 700 mg/cm^2). This requirement reduces the number of excitations to the fraction of the primary beam nuclei. Moreover, we know that Coulomb excitation cross sections increase rapidly with θ_{scat} and our maximum beam-rate is limited by the fragments which pass target without interaction. So, one has to detect scattered nuclei separately from the rest. The simple solution of this problem is a segmented ZDD. The outer detector consists of a cylinder with a hole and the inner detector is also a cylinder, which can be installed into that hole. The total length of the detector is 153.0 mm. The inner and outer radii of the outer detector are 27.9 mm and 83.8 mm, respectively. The radius of the inner detector is 26.7 mm. The outer detector is viewed by the 6 PMTs (9807B02) placed in the hexagonal order and inner detector has one PMT. PMTs were attached by using F113 epoxy. For the improving of light collection 2 μm of Al were deposited on the front part of the ZDD. Teflon tape and BC-620 reflective paint were also used on the side of the detector. A special support system, which allows adjustment of the ZDD position with respect to the beam, was also built, see fig. 2.

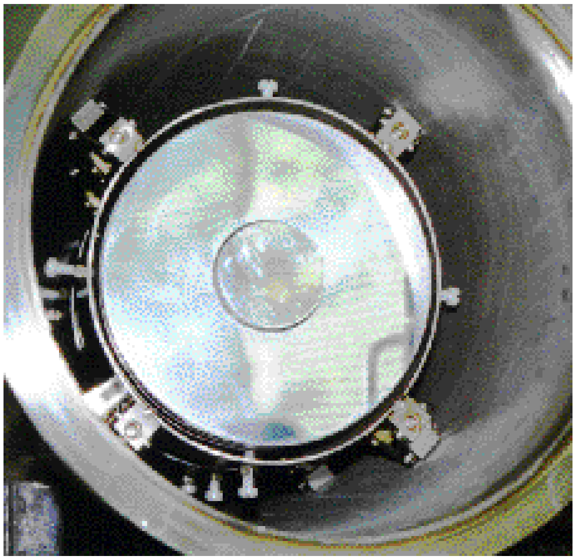

Fig. 2: The Segmented ZDD installed in the beam pipe.

In addition, a water cooling system was installed to cool down the PMT voltage dividers because the detector operates in a vacuum. For a typical experiment [2] the inner detector is sensitive to the nuclei with $\theta \leq 1^0$ and the outer one for $1^0 \leq \theta \leq 4^0$. In order to get the same scattering angles in the c.m. system as for small ZDD one has to place big ZDD at the bigger distance from the target. This substantially reduces the radioactive background in the NaI(Tl) array arising from beam stopping in the ZDD. First beam tests demonstrated the importance of gain matching for the PMTs.

References

1. W.R.Leo, Techniques for Nuclear and Particle Physics Experiments, Springer-Verlag Berlin Heidelberg, 1994.
2. H.Scheit et al., Phys. Rev. Lett. 77, 3967 (1996).