DEUTSCHES ELEKTRONEN-SYNCHROTRON
INSTITUT FÜR HOCHENERGIEPHYSIK

DESY 93-199
December 1993

Scintillating Fiber Target Detectors for Future Generation Neutrino Experiments

R. Nahnhauer
Deutsches Elektronen-Synchrotron DESY
Institut für Hochenergiephysik IfH, Zeuthen

ISSN 0418-9833

PLATANENALLEE 6 - 15738 ZEUTHEN

To be sure that your preprints are promptly included in the
HIGH ENERGY PHYSICS INDEX,
send them to (if possible by air mail):

DESY
Bibliothek
Notkestraße 85
22603 Hamburg
Germany

DESY-IfH
Bibliothek
Platanenallee 6
15738 Zeuthen
Germany

DESY 93-199
December 1993

ISSN 0418-9833

SCINTILLATING FIBER TARGET DETECTORS FOR FUTURE GENERATION NEUTRINO EXPERIMENTS

R. NAHNHAUER

Deutsches Elektronen-Synchrotron DESY
Institut für Hochenergiephysik IfH, Zeuthen

Contribution to the
Workshop on Scintillating Fiber Detectors–SCIFI93,
Notre Dame, 1993

SCINTILLATING FIBER TARGET DETECTORS FOR FUTURE GENERATION NEUTRINO EXPERIMENTS

R. NAHNHAUER

Deutsches Elektronen-Synchrotron DESY
Institut für Hochenergiephysik IfH, Zeuthen

Since the first successful application of a scintillating fiber detector for particle tracking and electron identification in the UA2 experiment [1], many projects were aimed at improving this technology further [2-14]. Besides particle tracking, also other types of particle measurements can profit from the use of fibers. Well known are the good energy resolution of spaghetti–type calorimeters [15] and the fast response of fiber trigger systems [16]. In each of these fields however, alternative techniques are available or under development. By contrast, a unique application of fiber technology is the construction of fiber targets. Hereby, for the first time massive, active, high resolution target detectors become feasible [5]. They are highly demanded in particular in neutrino physics experiments [17-22].

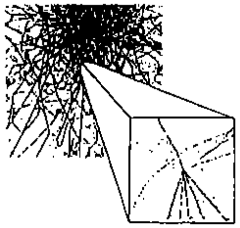

Figure 1: Reaction of a 300 GeV τ–neutrino with a nucleon in a 2 × 2 × 100 cm^3 block of scintillating fibers of 20 μm diameter (Monte Carlo–simulation, dimension of zoom, 2 × 2 mm^2)

Due to the weak interaction of of the neutrinos, large target masses are required in order to achieve resonable interaction rates, even at high energies. High resolution is needed to observe the decay of short living particles like the τ–lepton produced in ν_τ charged current interactions, which has never-been seen up to now, or to observe charm and beauty mesons and baryons. Decaying after 10^{-12} – 10^{-13} seconds the impact parameter of the secondary particles from these decays is typically some hundred microns. An active target is useful to trigger on rare reactions within a large background. In fig. 1 the working principle of such a detector is illustrated. The 20 μm diameter of the scintillating fibers allows clearly to resolve the vertex structure of a ν_τ–interaction, with less resolution it would be hidden by a bulk of shower particles. One observes the transverse image of the interaction with a particle jet opposite to a kink track – the image of a τ decaying to a muon.

The MOON-Project

In choosing between the different possibilities to build a large fiber target, we propose to make maximum use of the evident modular structure of such a device and build a MOdular– Omnipurpose–Neutrinodetector. The basic element of such a device is shown in fig. 2.

A photomultiplier provides information for fast triggering and calorimetry. The image intensifier chain with CCD readout allows precise vertex reconstruction and tracking and identifies low energetic particles by range. Energy determination down to 500 keV seems to be in reach with 100 μm fibers [20]. Impact parameter resolution would be better than 200 μm and track resolution below 100 μm [10]. The same basic detector could be used, with different arrangements of modules, at low and high energy neutrino sources for various different fundamental experiments. Already with a few blocks first interesting physics investigations are possible [20].

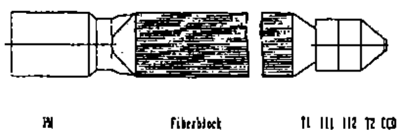

Figure 2: Module of the MOON–detector with $5 \times 5 \times 100$ cm^3 fiber block, photomultiplier at left side and image intensifier plus CCD at right side.

Dedicated experiments to search for ν_τ interactions could be done with 500–1000 modules in fixed target beam dumps [17,18] or at hadron colliders [21], allowing not only to observe the interactions of the ν_τ but also to evaluate it's properties. It would be possible e.g. to register about 10 000 ν_τ-interactions per year if such a detector is run at the LHC. At a nuclear power station one would be able to reach a new order of precision for the limit on the magnetic moment of the $\bar{\nu}_e$. As a by-product, sensitive tests of the Standard Model would be possible by means of neutrino-electron scattering data, improving the presently available statistics by orders of magnitude [20]. Sensitive neutrino oscillation searches could be done both at low and at high energies [17-19].

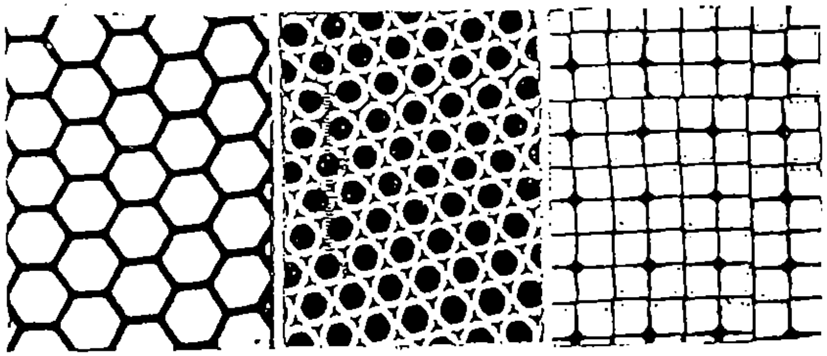

Figure 3: Cross section of coherent multifiber bundles a.) 30 μm plastic fibers, b.) 20 μm glass capillaries, c.) 20 μm scintillating glass fibers (from ref. 20)

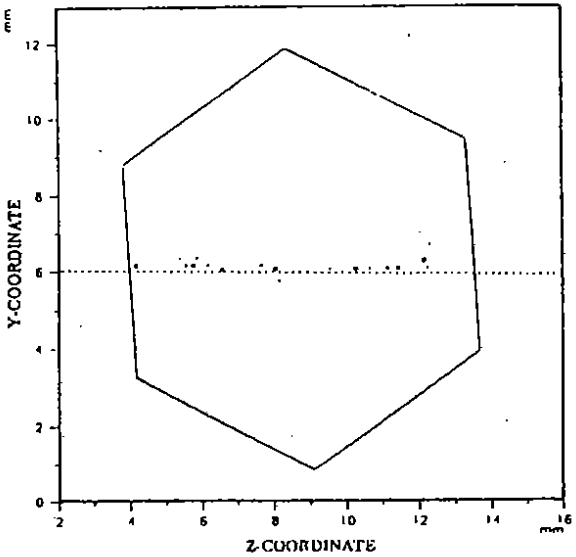

Figure 4: Image of a 5 GeV/c π^- crossing a hexagonal capillary bundle of 100 μm capillary diameter –.dashed line: prediction of the track from a silicon microstrip telescope (from ref. 10)

The technical parameters to construct the proposed detector are in reach of existing technology. Several firms provide suitable fibers and there is already a choice between different basic options (see fig. 3). In particular capillaries filled with liquid scintillators are under extensive study [3, 5-7, 10]. As an example the track of a 5 GeV π^- in a 100 μm capillary target filled with PMP doped methyl-naphtalene is shown in fig. 4. The fiber readout is done in this case with a 3-stage image intensifier chain and a CCD. The CCD time response and dead time of about 10 msec and 1 μsec respectively fit well to low rate neutrino experiments while collider applications would require additional effort.

In summary, the proposed detector would allow to carry through an interesting neutrino physics programme over a period of several years, using different neutrino sources. It's modular type of construction would allow adjustment to varying technical standards and available budgets. Already with a few modules interesting physics could be done.

Acknowledgement

I thank J. Bähr, H. E. Roloff and P. Söding for interesting discussions about the topic and critical reading of the manuscript.

References

1. R. Ansorge et al., *NIM* **265** (1988) 33.
2. Proceedings "Scintillating Fiber Workshop", Blossin 1990, Ed. R. Nahnhauer.
3. A. Artamonov et al., *NIM* **A 300** (1991) 53.
4. H. Akbari et al., *NIM* **A 302** (1991) 415.
5. S. V. Golovkin et al., *NIM* **A 305** (1991) 385.
6. J. Bähr et al., *NIM* **A 306** (1991) 169.
7. M. Adinolfi et al., *NIM* **A 311** (1991) 91.
8. M. Atac et al., *NIM* **A 314** (1992) 56.
9. D. Bernard, *NIM* 315 (1992) 43.
10. J. Bähr et al., *NIM* **324** (1993) 145.
11. B. Abbot et al., *NIM* **327** (1993) 319.
12. M. de Jong et al., *CERN-PPE* /93-131 (1993)
13. C. d' Ambrosio. S. Qian *NIM* **A 335** (1993) 341.
    C. d' Ambrosio et al., *NIM* **A 322** (1992) 20.
14. J. Bähr et al., this Proceedings "High Precision particle tracking with a fiber detector at the HERA ep-collider"
15. D. Acosta et al., *NIM* **A 308** (1991) 481.
16. K. Kuroda et al., *NIM* **A 300** (1991) 259.
17. K. Winter, *Acta Physica Hungeria* 68 (1990) 135.
18. R. Nahnhauer, V. Zacek, *CERN-PPE* /90-138.
19. D. Frekers, *Nucl.Physics B* (Proc. Suppl.) 31 (1993) 334.
20. G Zacek, *CERN-PPE* /91-06.
21. D. Denegri, *Proc. "LHC-Workshop"*, Aachen 1990, Ed. G. Jarlskog, D. Rein, V.1, p. 56
22. F. Vannucci, *LPNNE 9301* (1993)