3 FINUDA

Nuclear physics topics will be investigated by the FINUDA (standing for *FIsica NUcleare a* $DA\Phi ne$) experiment[1]. A nuclear physics experiment carried out at an e^+e^- collider sounds contradictory in itself, but this is where the uniqueness of the idea lies [15]: charged kaons from ϕ decays are used as a monochromatic, slow (127 MeV/c), tagged, background-free, high-counting rate beam on a thin target surrounding the beam pipe. The possibility of stopping low-momentum monochromatic K^- with a thin target (typically $0.5\,g\,cm^{-2}$ of ^{12}C) is unique to $DA\Phi NE$: K^-'s can be stopped with minimal straggling very near the target surface, so that outgoing prompt pions do not cross any significant amount of the target and do not undergo any momentum degradation. This feature provides unprecedented momentum resolution as long as very transparent detectors are employed before and after the target.

The FINUDA detector is optimized to perform high-resolution studies of hypernucleus production and non-mesonic decays[16], by means of a spectrometer with the large acceptance typical of collider experiments. Furthermore, contrary to fixed-target experiments, the direction of the K^- is competely tagged by the detection of the K^+ and viceversa.

Negative kaons stopping inside the target produce a Y-hypernucleus ($Y = \Lambda, \Sigma, ...$) via the process

$$K^-_{stop} + \ {}^{A}Z \rightarrow \ {}^{A}_{Y}Z + \pi^-,$$

where the momentum of the outgoing π^- is directly related to the level of the hypernucleus formed (two-body reaction). In the case of Λ hypernucleus formation, the following weak-interaction 'decays' are strongly favored in medium-heavy nuclei

$$\Lambda + n \rightarrow n + n \qquad\qquad \Lambda + p \rightarrow n + p,$$

with the nucleus undergoing the reactions

$${}^{A}_{\Lambda}Z \rightarrow \ {}^{(A-2)}Z + n + n \qquad\qquad {}^{A}_{\Lambda}Z \rightarrow \ {}^{(A-2)}(Z-1) + n + p,$$

which are interesting for studying the validity of the $\Delta I = 1/2$ rule.

Besides studies on hypernucleus spectroscopy, interest exists for K-N interactions at low energy [17], and for the measurement of the KN scattering length for kaonic-hydrogen X-rays [18]. There exist interesting similarities in the expected rates between FINUDA and the proposed facility at the BNL AGS, where the (K^-, π^o) reaction, complementary to FINUDA's (K^-, π^-) is studied with K^- at rest; both experiments have a design energy resolution below 1 MeV fwhm and a comparable hypernuclei production rate. However, AGS operates with extracted beams at a high rate ($2 \times 10^4 s^{-1}$ stopped K^-) and low geometrical acceptance (about 20 msr), while FINUDA's flux, at initial $DA\Phi NE$ luminosity, is two orders of magnitude lower, and the acceptance is 2 orders of magnitude larger. The AGS choice of considering neutral prompt pions is dictated by their use of thick targets, which makes the resolution for emerging prompt charged pions much worse than for neutral pions.

[1]FINUDA is on Internet `http://www.lnf.infn.it/esperimenti/finuda/finuda.html`

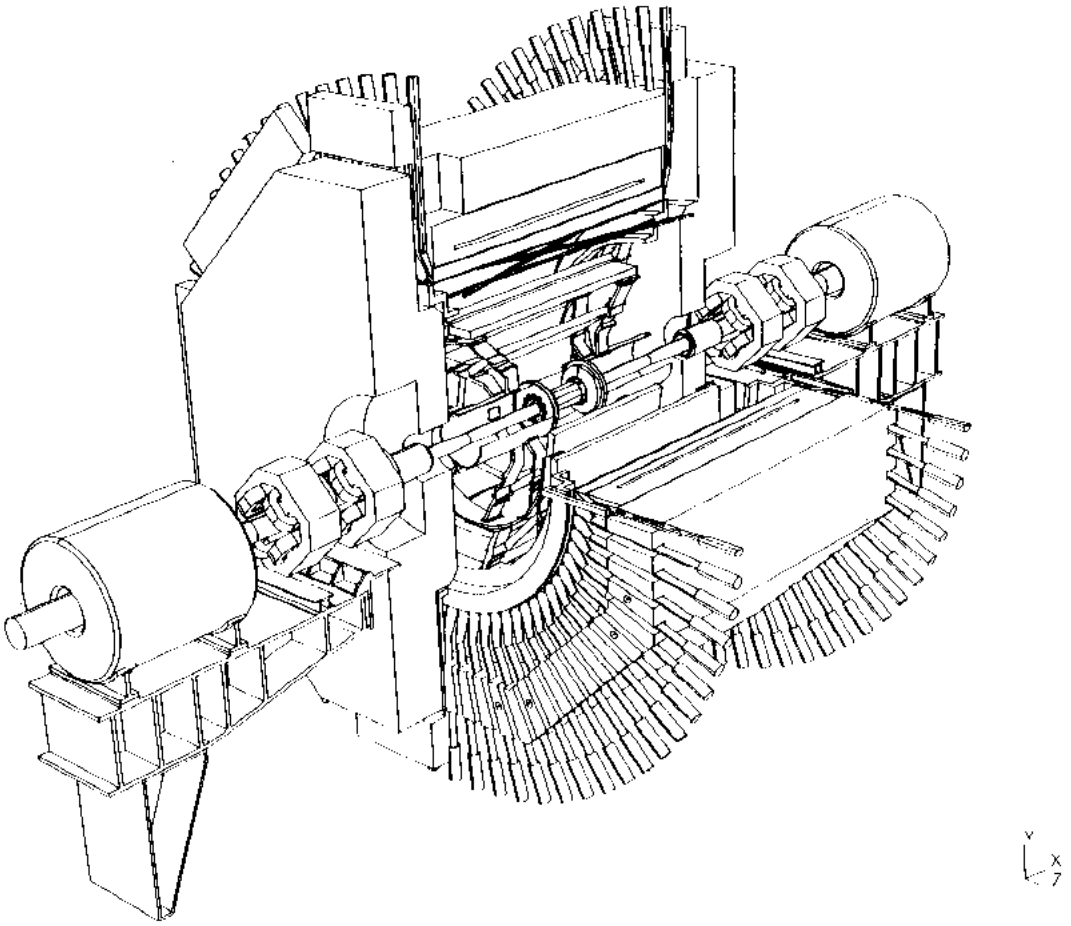

Figure 2: Cut-out view of the FINUDA spectrometer, showing also a section of the $DA\Phi NE$ beam pipe and compensating quadrupoles.

Following the initial idea [15], FINUDA was formally proposed in May 1993 [19], rapidly approved, and funded at the end of 1993. A technical report[20] is to appear shortly as a LNF preprint. For a recent review see [21].

3.1 The Apparatus

FINUDA (fig.2) is a magnetic spectrometer with cylindrical geometry, optimized in order to have large solid-angle, optimal momentum resolution (of the order of 0.3 % fwhm on prompt pions) and good triggering capabilities. The geometrical acceptance is approximately $135^0 \leq \vartheta \leq 45^0$, thus naturally rejecting e^+e^- background from Bhabha scattering.

FINUDA consists of (fig.3) an interaction/target region, external tracker, outer scintillator array, and superconducting solenoid. The (K^+, K^-) pairs from ϕ decay emerge from the interaction region, whose dimensions are $\sigma_x = 2$ mm, $\sigma_y = 0.02$ mm, $\sigma_z = 3$ cm. The (K^+, K^-) pairs follow a $sin^2\vartheta$ law, with ϑ the angle relative to the z-axis.

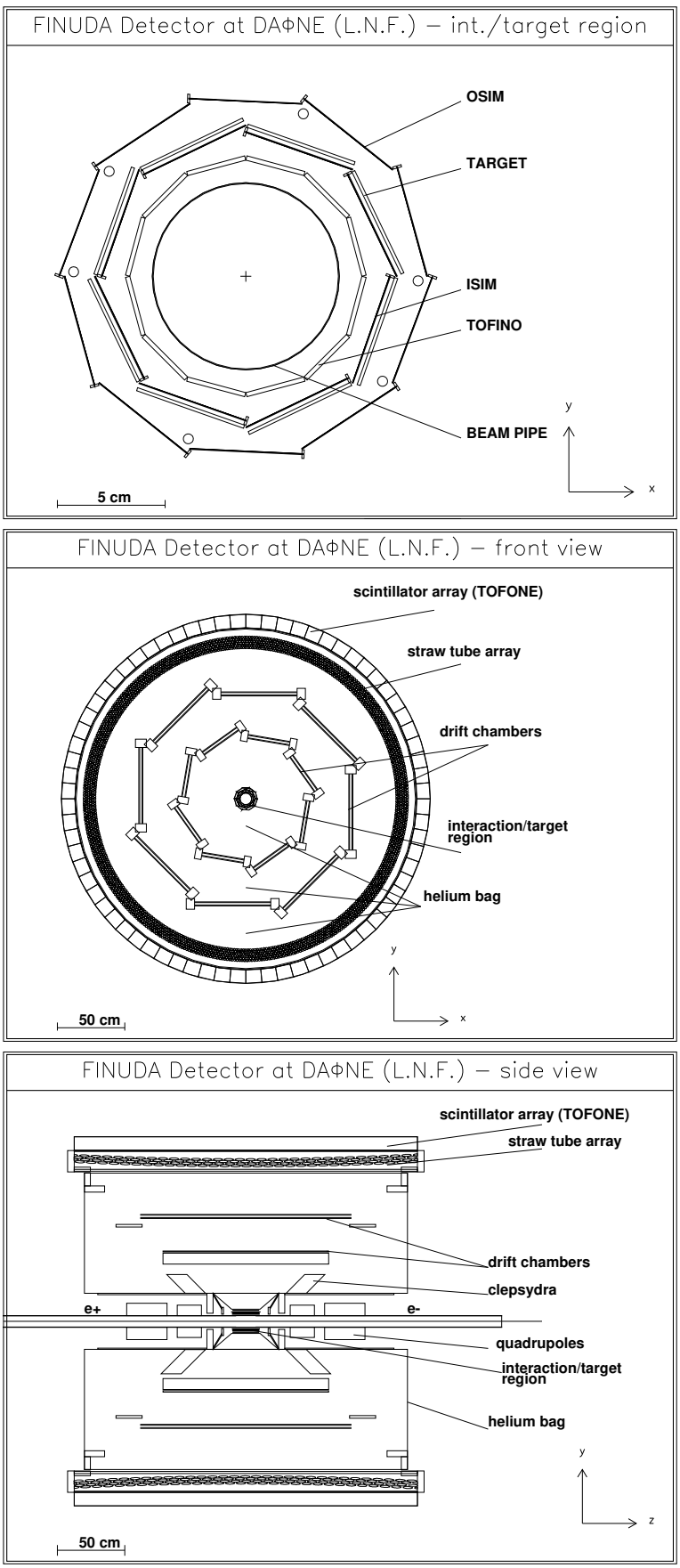

Figure 3: Interaction/target region (top); sketch of the FINUDA detector front view (center); and side view (bottom). *Clepsydra* is the support structure sustaining the detectors.

The FINUDA magnet is a superconducting solenoid whose magnetic axis is along the beam direction; it provides a highly uniform $B_{max} = 1.1$ T magnetic field (max disuniformity of 5% at the outer edges of the tracking volume). The tracking volume is generated by rotating a trapezium with bases of about 20 cm and 180 cm, and a height of about 120 cm. The iron yoke has an octagonal shape, with two endcaps that can be opened vertically to access the detector.

The cylindrical interaction/target region of FINUDA (fig.3) consists of the beam pipe, a scintillator barrel (TOFINO), an internal octagonal Si microstrip array (ISIM), and the nuclear stopping target. The above arrangement must:

1) identify (K^+, K^-) pairs from ϕ decay for triggering by exploiting the back-to-back event topology and by identification through ionization energy loss $-(dE/dx)$ (TOFINO);
2) measure the (K^+, K^-) coordinates before the nuclear target with $\sigma \sim 30 - 50 \mu m$, provide particle identification by $-(dE/dx)$, and have triggering capabilities (ISIM);
3) stop the monochromatic K^- as near as possible to the external surface of the target;
4) measure the lifetime of hypernuclear states (TOFINO);
5) be radiation hard to cope with damage caused by Bhabha- and Touschek-scattered beam particles.

The thicknesses needed for the inner detectors are determined by the requirement of stopping the K^- as close as possible to the outer surface of the target, taking also into account its energy straggling and $\sin^2 \vartheta$ angular distribution. The target's octagonal shape allows one to use different materials simultaneously. The length of the interaction/target region is determined by the requirement of accepting all the (K^+, K^-) pairs emitted from 45° to 135° along the z-coordinate from -3.5 cm to $+3.5$ cm, which corresponds to the fwhm of the (e^+, e^-) interaction region. The resulting length of the target will be 17 cm and will allow an acceptance for (K^+, K^-) of more than 90%.

The TOFINO consists of 12 strips, each 2.0 mm thick, 14 cm long and 2.5 cm wide, subtending a polar angle $\Delta\varphi = 30°$. The strips are arranged following a circumference of radius 5.5 cm and are read by hybrid photo multiplier tubes (HPMT). The HPMT's operate in the 1.1 T-magnetic field and are very compact.

The two silicon microstrip arrays ISIM (in the interaction/target region) and OSIM (in the outer tracker) are composed of 18 modules in total. Each module is made of three $300 - \mu m$-thick, $52.6\, mm \times 65.4\, mm$ double-sided (ρ and φ strips) Si wafers bonded together. The pitch is 50 μm, and the strip width 6 μm for a total of 4×10^4 strips. The external tracker, which consists of a ten-sided outer silicon microstrip detector (OSIM), two sets of planar low-mass drift chambers (LMDC) immersed in a He atmosphere, and an array of straw tubes (ST), has to:

1) measure the position of the prompt 270 MeV/c π^- from the hypernucleus production very close to the target, thus determining the position of the K^- stopping point and thereby correcting for the energy lost in the thin target, with a consequent improvement in momentum resolution (OSIM);
2) measure the second and third space points of the prompt π^- trajectory in the (ρ, φ) plane, with high resolution and maximal transparency (LMDC);
3) measure the fourth space point with good accuracy, and independently of the incident angle of the track due to the curvature caused by the magnetic field (ST).

The LMDC are two sets of planar drift chambers using a He-based gas mixture, each one with a $(1230 \times 396) mm^2$ (inner chambers) and $(1870 \times 686) mm^2$ (outer chambers) area. Measurement of the coordinate along the wire is made by means of charge division.

The ST array is composed of 2424 0.03-mm-thick aluminized mylar straws with an inner diameter of 15 mm, and a length of 255 cm. The straws are arranged in three superlayers, each one formed of two layers staggered by approximately half the diameter. The inner superlayer is axial, the two outer superlayers are stereo oriented at $\sim \pm 13^0$.

Finally, the outer scintillator array (TOFONE) will provide a fast logic signal for the DAQ trigger (multiplicity and coincidence of the prompt π^- with the TOFINO signal) and neutron detection (with a $\sim$15% efficiency). The TOFONE is composed of 72 slabs of plastic scintillator, 255 cm long and 10 cm thick, with read-out at both ends by 90^o deflector prisms and lightguides funnelling the light signal to photomultipliers located in a low-field region outside the magnet.

3.2 Status of Subdetectors

3.2.1 Interaction/target Region

After tests with cosmic rays, the NE104 scintillator was selected for the internal scintillator barrel (TOFINO), since it provides light output in excess of 50 pe/mip. Two HPMT sample prototypes under test gave a 50 ps time resolution. Final assembly is scheduled by November 1995. Delivery of about 100 silicon wafers for the ISIM/OSIM detector is due by April 1995. Two full modules will be ready for testing at CERN and TRIUMF in September 1995.

3.2.2 Outer Tracker and TOF System

A $(115 \times 57)\, cm^2$ prototype low-mass drift chamber has been tested at CERN with a 5 GeV/c pion beam and a $He{-}iC_4H_{10}$ (70%-30%) gas mixture[22]. The space resolution was measured to be better than $100\, \mu m$ along the whole drift cell, with 98% average efficiency, while the coordinate along the wire was measured by charge division with a resolution of 0.61% of the wire length. Assembly of the detector is scheduled from May to December 1995.

An 8-channel straw tube prototype was tested at CERN with mip's in May 1994 using DME, and attained a $40 - \mu m$ space resolution [23]. A 160-channel prototype with axial and