M.Sc. PROJECT REPORT

PARALLEL PLATE ANALYSER FOR HIGHLY CHARGED IONS

Submitted by

ANJU
M.Sc. (Physics) Final Yr.
1994

Under the Supervision of

Prof. B.P. Singh
Nuclear Science Centre

Department of Physics
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C E R T I F I C A T E

Certified that the work reported in present Project Report **"PARALLEL PLATE ANALYSER FOR HIGHLY CHARGED IONS"** has been done by Anju under my supervision and it has not been submitted elsewhere for any degree.

B.P. Singh

Prof: **B.P. Singh**
Nuclear Science Centre

ACKNOWLEDGEMENT

It has been a fortunate opportunity to work under the supervision of Prof. B.P. Singh. I express my deep gratitude to him for his guidance and interest shown in every stage of my work. I would like to thank to the Director of NSC who allowed me to work at his centre and provided me necessary help.

I am very grateful towards all physics department staff especially to the Head of the Department for their kind help.

I am also thankful to my friend Usha for her help in completing the project.

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INTRODUCTION

Experimental studies in various areas of nuclear science and applications of nuclear techniques to other branches of science involve the detection of charged particles and quite often also the measurement of their characteristics. In general it covers the variety of energetic charged and uncharged particles. The charged particles include the electrons, protons, alpha particler and other energetic atomic ions usually referred as heavy ions.

Electrostatic energy analysers works on the principle that path of the charged particles in an electric field is dependent on the particles energy. There are four different types of electrostatic analysers i.e. Parallel Plate, spherical, cylinderical and cylinderical mirror analyser. In this we are using Parallel Plate analyser for deflection. And after deflection the charged particles are detected by Parallel Plate Avalanche Counter (detector).

Interaction of fast moving ion with a gaseous target results the scattered projectile beam having a distribution of charge states which can be separated out by passing the scattered beam through the set of Parallel Plates across which an electric field is applied. These can be detected by the Parallel Plate Avalanche detector.

PARALLEL PLATE ELECTROSTATIC CHARGE SELECTOR FOR HEAVY IONS

When a fast moving (Mev/amu) ion interacts with a geseous target. then this results the scattering projectile beam having a distribution of charge states. These charge states can be separated out by passing the scattered beam through a set of parallel plates across which the electric field is applied.

A Parallel Plate Electrostatic Deflector Assembly has been designed and tested successfully at Nuclear Science Centre. The assembly consists of a set of parallel plates (40 cm in length. 6 cm distance between the plates and 2.5 cm the width of the plate) housed in a 6" beam pipe. The high voltage feedthru is detachable and insulated from the housing by a Teflon cylinder surrounding it. Fig. 1 shows the beam line assembly for housing the Deflector plates. The vacuum sealing between the beam pipe in which the plates are housed and the teflon cylinder is provided by a Wilson seal arrangement which helps in adjusting the separation between the two plates. The Wilson seal arrangement is shown in fig. 2 . The sealing between the high voltage feedthru and the teflon cylinder is provided by a single O ring which helps to reduce the length of the trapped air column.

The assembly after the 6" beam pipe can be bent using a bellow (4") so that the beam after deflection follows the central trajectory. The different charge states of the scattered projectile beam that have been separated out by the assembly are detected by a Parallel Plate Avalanche detector placed about 120 cm from the end of the plates.

When the deflected particles are directly goes through the detector, then this may cause damage to detector. To overcome this damage the Aluminium slits are placed just near to the detector.

The assembly of Parallel Plate Electrostatic Deflector was tested for its performance of bending the main beam, as the voltage on the two plates was increased from 0 KV to ± 20 KV using P.V.G. and Glassman Power supplies. The beam used was 49 MeV Si 6^+. The gap between the plates was 2.4 cm. Two Al strips (one 35 mm and other 10 mm wide) insulated from each other and at a distance of 113.5 cm from the end of the plates.

I am thankful to M.J. Singh, S.K. Goel, R. Shanker and A.K. Sinha in helping and giving information about parallel plate electrostatic charge selector for heavy ions.

BEAM LINE ASSEMBLY HOUSING THE DEFLECTOR PLATES

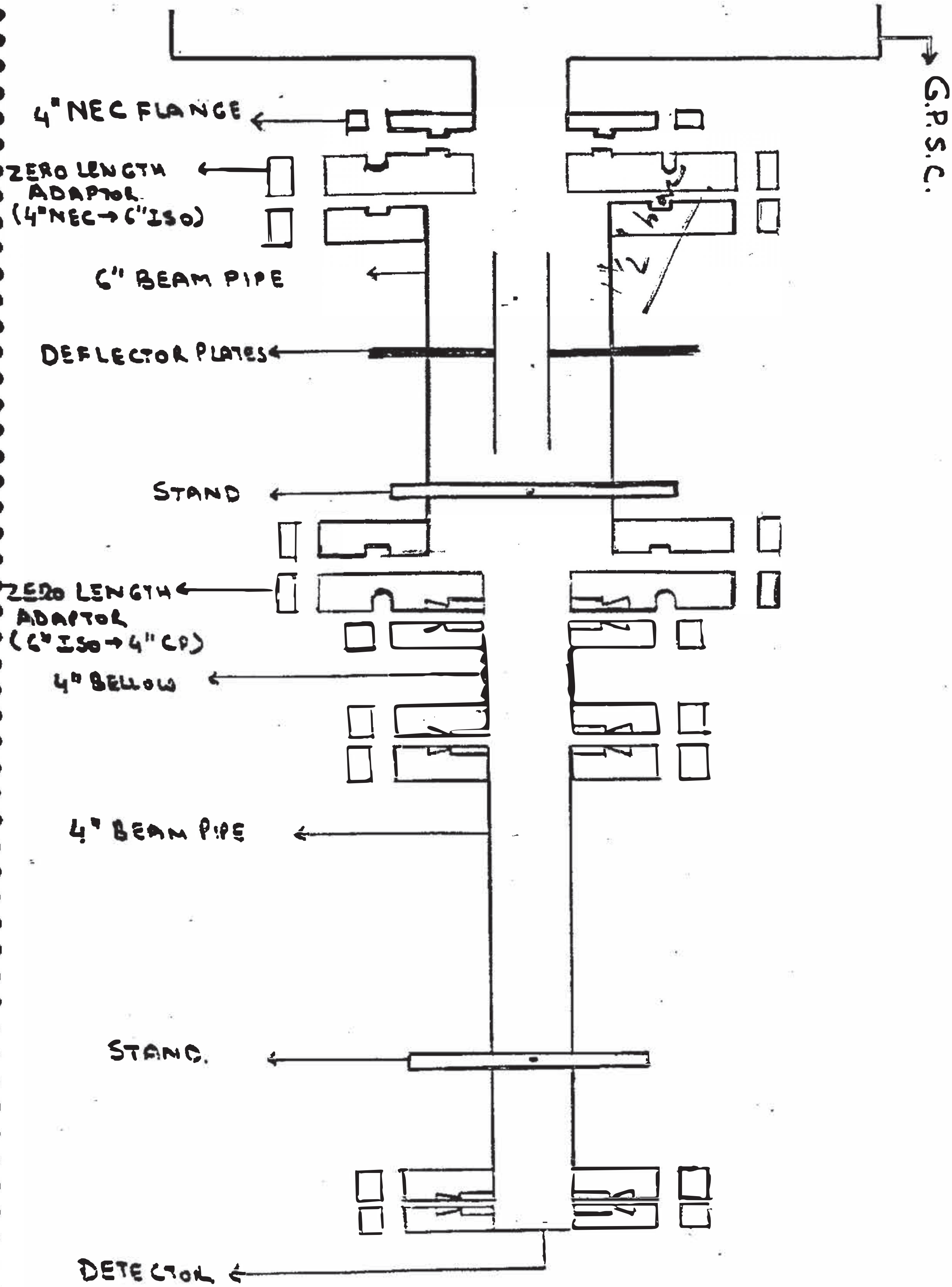


Fig: 1

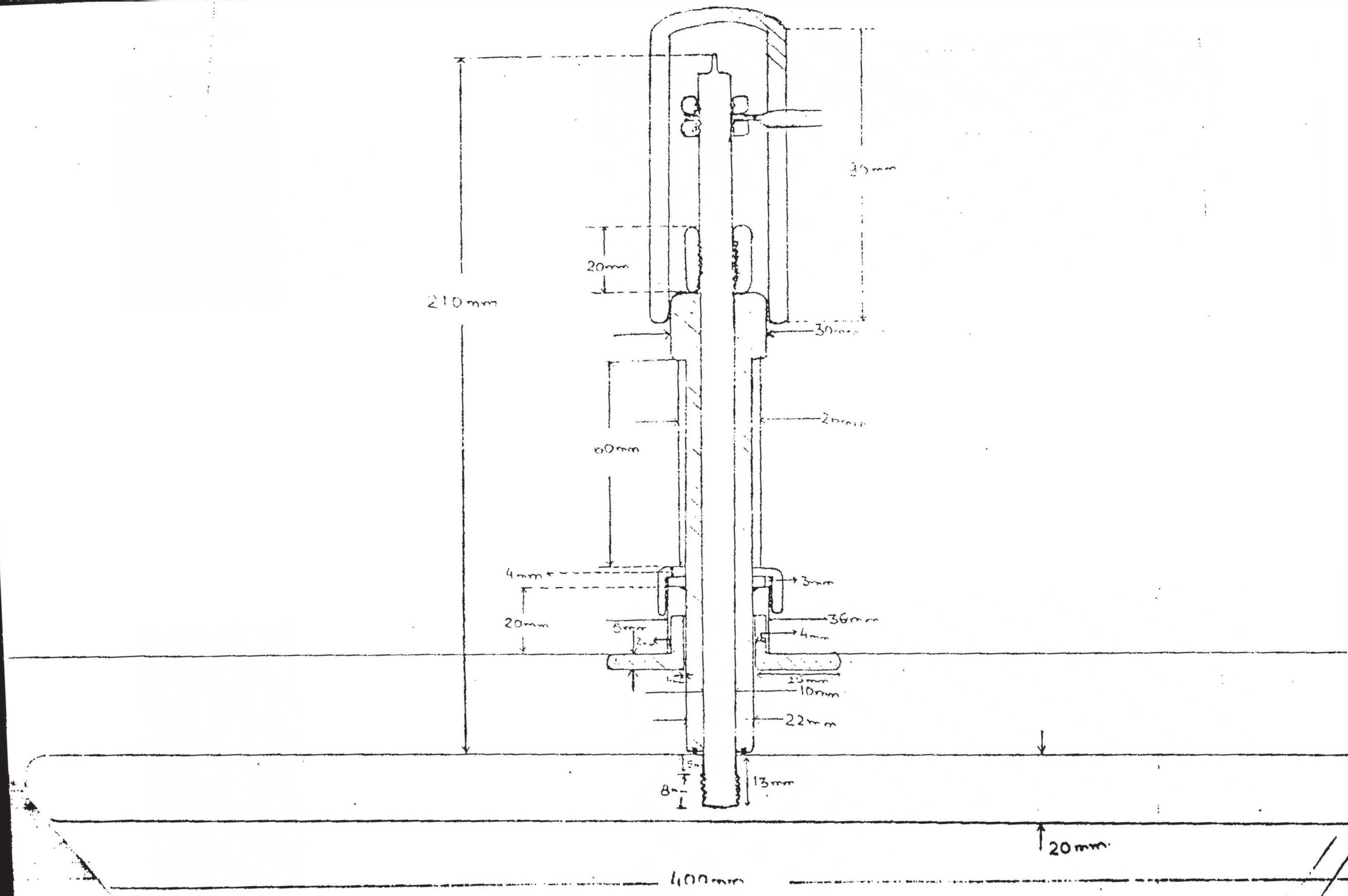
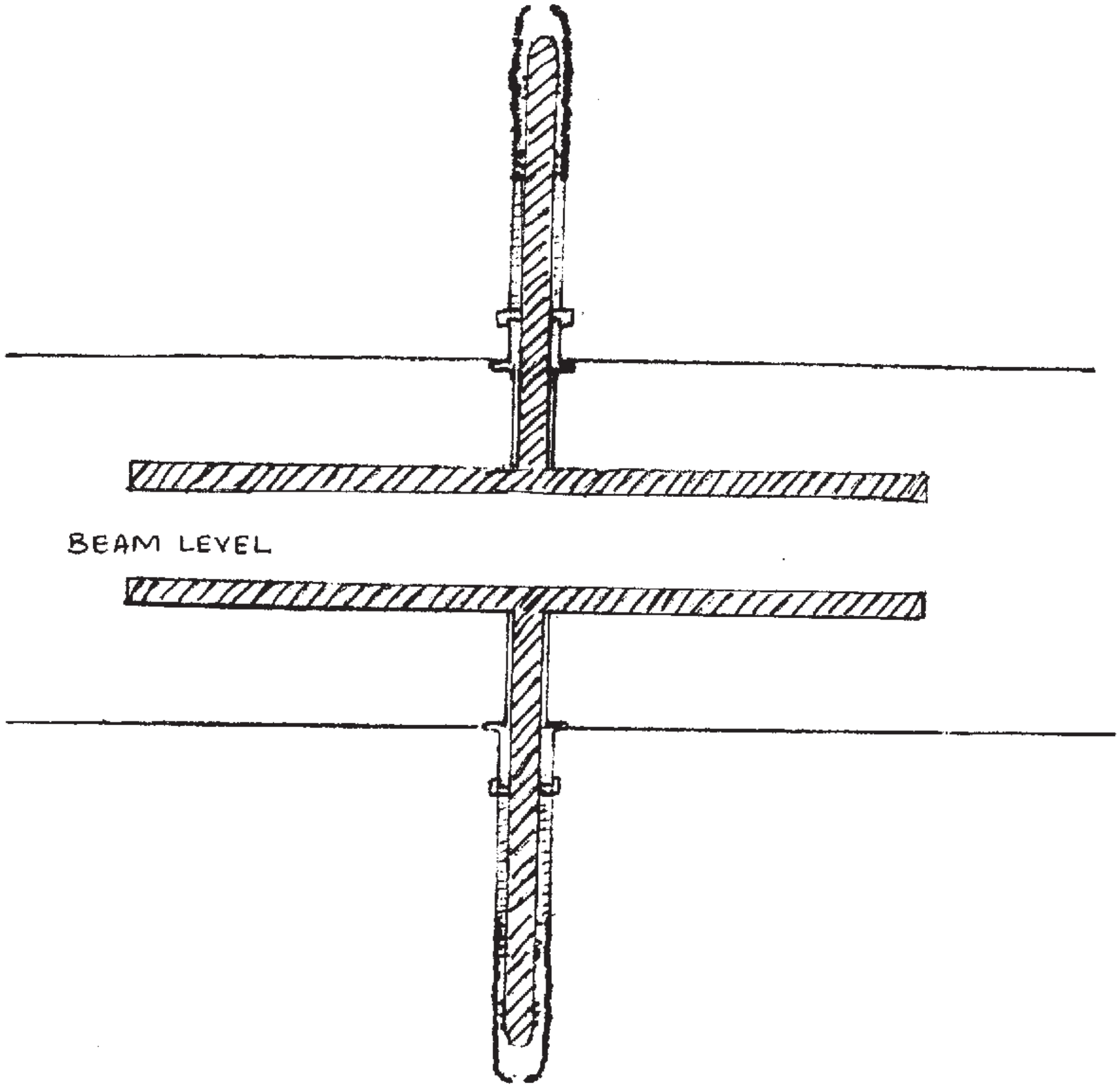


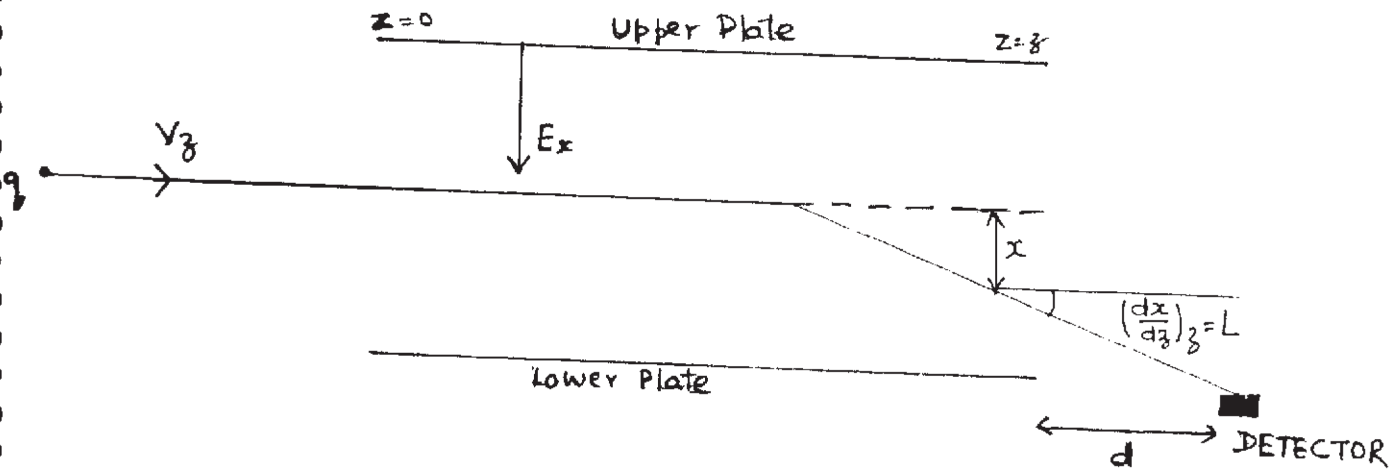
Fig: 2 The Wilson Seal arrangement between 6" beam bibs and Teflon cylinder



SECTIONAL VIEW OF DEFLECTOR PLATES HOUSED IN 6"BEAM PIPE

Fig: 3

NET-DEFLECTION



DERIVATION

$$F = ma \quad \text{—— (1)}$$

$$qE = m\frac{d^2x}{dt^2} \quad \text{—— (2)}$$

$$m\left(\frac{d^2x}{dz^2}\right)\left(\frac{dz}{dt}\right)^2 = qE$$

$$m\frac{d^2x}{dz^2}V_z^2 = qE \quad \text{—— (3)}$$

where $V_z^2 = \left(\frac{dz}{dt}\right)^2$

From equation (3) we have

$$\frac{d^2x}{dz^2} = \frac{qE}{mV_z^2} \quad \text{—— (4)}$$

$$\frac{d}{dz}\left(\frac{dx}{dz}\right) = \frac{qE}{mV_z^2}$$

$$\frac{dx}{dz} = \frac{qE}{mV_z^2} z + c \quad \text{------ (5)}$$

where c is the constant of integration

At $z = 0$

$\frac{dx}{dz} = 0$

$\therefore c = 0$

And we have

$$\frac{dx}{dz} = \frac{qE}{mV_z^2} z d \quad \text{--- (6)}$$

Again integration

$$x = \frac{qE}{mV_z^2} \cdot \frac{z^2}{2} \quad \text{—— (7)}$$

Total deflection $[X] = \left(\frac{dx}{dz}\right) + (x)$ —— (8)

$$X = \frac{qE}{mV_z^2} z \cdot d + \frac{qE}{mV_z^2} \frac{z^2}{2}$$

$$= \frac{qE}{mV_z^2} \left[z \cdot d + \frac{z^2}{2} \right]$$

$$X = \frac{1}{2R.E} [E] [z^2 + 2 d . z]$$

where

$mV_z^2 = T$

$R.E = \frac{2T}{q}$

$\therefore$ Deflection

$$X = \frac{1}{2R.E} [E] [z^2 + 2 . d . z]$$

NET DEFLECTION $\quad 'X' = \frac{1}{2RE}[E][\ell^2 + 2d\ell]$

RE = Electrical Rigidity of the particle beam = $\frac{2T}{q}$

T = Energy of the beam (MeV)

q = Charge state of the Ion undergoing Deflection

E = Electric field $\left(\frac{KV}{m}\right)$

<u>Example:</u>

If the length of the plates = 40 cm

Electric field = 12 kv/cm

Distance of the Detector from the end of the plates = 100 cm

$$\text{Deflection } X = \frac{12 \times (1600 + 8000)}{2 \times 1000} \frac{1}{(RE)}$$

$$X = 57.6 \times \frac{1}{(RE)}$$

$$= 57.6 \times \frac{1}{2 \times \frac{40}{10}} = \frac{57.6}{8}$$

$$= 7.2 \text{ cm}$$

PARALLEL PLATE AVALANCHE COUNTER

Introduction

Paralled Plate avalanche counters (PPAC) are a known instrument for precise timing measurements in nuclear physics.

PPAC has two important goals :-

1. They can built at low cost with large dimensions
2. Show timing performance.

For light particles the ionization is rather low so that solid state detectors are better suited. In heavy ion physics solid-state detectors have some serious disadvantages and this type of gas counters offers the possibility of building large area detectors with good time resolution.

Principle of Operation

A PPAC consists of two thin properly strectched metalized plastic foils mounted paralled to each other. The gap between the foils should be kept as small as possible to achieve good time resolution. A high voltage is applied between two planes. The ionizing particles to be detected traverse the counter perpendicular to the planes and produce electron-ion pairs in the counting gas. In the hmogenous strong electric field secondary ionization sets in immediately and an avalanche of the Townsend type will be formed. The number of secondary electrons is given by

$$n(d) = n_0 e^{\alpha d} \qquad -(1)$$

with

n_0 = Number of primary electrons

d = Drift path

α = first Townsend Coefficient

α is the mean ionization probability per unit path length and is a function of the reduced field strength E/P

$$\frac{\alpha}{P} = A \exp\left\{-B/\left(E/P\right)\right\}$$

P is the gas pressure, A & B are constants of the specific gas.

At low pressure rather high values can be reached for the reduced field strength ($E/p \sim 500$ V/cm torr). This gives a gas gain up to 10^4. Primary electrons produced near the cathode contribute most to the signal, as seen from eq. (1). The signal has an amplitude of a few mV consists of two parts:

a) a fast rising component ($tr \sim 2$ns) due to the motion of the electrons.

b) and d times higher, slowly rising component ($tr \sim 1\ \mu s$) stemming from the positive ions with their much lower drift velocity.

Only the fast component is used for timing measurements, the slow part of the signal is differentiated out in the input network of the preamplifier.

CONSTRUCTION

Fig : 4 shows one of the PPACs. Two foils of 2.5 μm Hostaphon evaporated with conductive Au-layer ($30 \mu g/cm^2$, $R \sim 1 \Omega /cm^2$) are glued with epoxy onto the frames of plexiglass. The gap between the foils should be very uniform to achieve a good homogeunity of the counter across the surface. This was simply achieved by machined spacers and a very thin homogenous layer of glue between foil and frame. The attractive electrostatic forces only play a role in counters with surfaces of some hundred cm^2.

If the PPAC is used as a transmission counter, the foils should be as thin as possible. Foils of FORMVAR or VYNS can be made much thinner than the commercially available Hostaphon foils, but we found it rather difficult to evaporate larger areas (>20 cm^2) with low resistive metal layer. It has been possible to produce VYNS foils (~ 60 $\mu g/cm^2$) and to metalize them for surfaces up to 55 cm^2. In order to avaid edge effects the edge of the foil which is glued on the frame was not evaported. The electrodes were contacted using conductive glue. Three types of PPACs were constructed and investigated:-

a) A small one with circular shape (diameter 10 mm) for test purposes. It is used to scan the timing properties across the surface of larger PPACs its gap was (normally) 1mm, tests were also made with a gap of 2mm.

b) A long counter with a sensitive area of $2x26\ cm^2$. The signal is taken from the 2 cm side. Gap distances of 4,2 and 1 mm has been used.

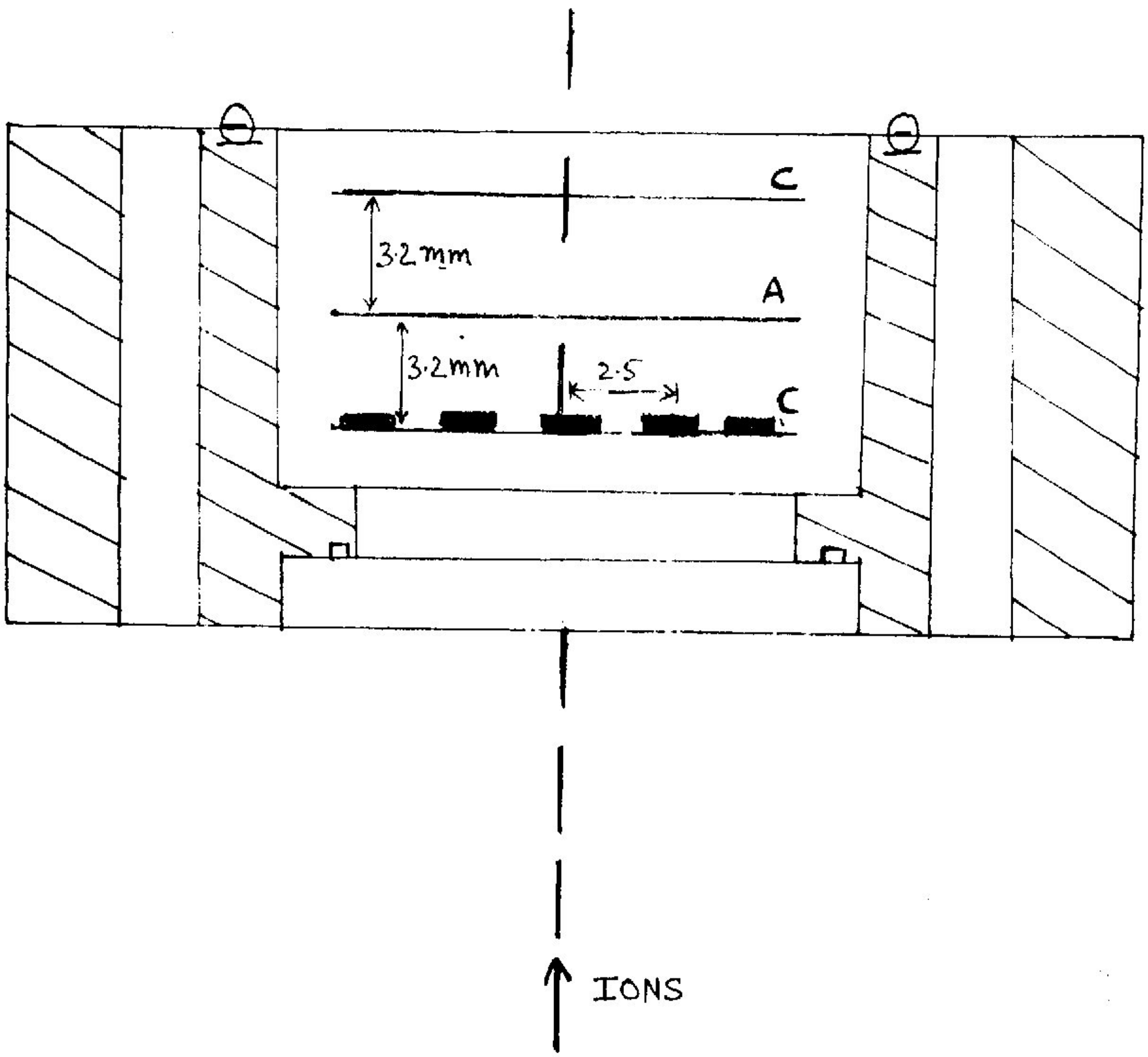
c) A large area PPAC with an active surface of $24x23\ cm^2$. In this case metal layer is divided into five strips separated by 1 mm. The signals were processed separately for each strip. The gap is 2 mm. a smaller distance between the two foils was not possible due to the strong electrostatic forces.

WORKING

Low pressure Avalanche Counters are used for a variety of applications, primarily as timing detectors. It was found that the PPACs work best in the pressure range of 8-15 torr. At lower pressures, the primary ionization gets too low, at higher pressures the foils which keep the pressure have to be considerably thicker.

Usually the PPACs was operated at 10 torr. The i-butylen was used in PPACs because of its cheapness and easy handling.

Parallel Plate Avalanche Counter was fabricated and tested at NSC. The counter was having thin foils as the



Schematic of the PPAC

Fig : 4

electrodes. It consits of an anode, made of double sided aluminized layer, 1 µm thick, sandwiched between two cathodes. One of the cathodes and aluminum deposited in 2.5 mm wide strips on mylar and the other was a plain aluminized mylar. The strips were connected to a resistor chain and provided the position sensing plane. The foils were mounted on to 1.6 mm thick pcbs. The electrodes were housed in a 30 -mm thick. 4" standard NEC flange with a diameter 100 mm step machined out. Spacing between the electrodes was 3.2 mm. The detector was tested with 252 Cf source and give the position resolution. Tests are in progress to improve the resolution by increasing the gap between the electrodes.

When measuring the time resolution between two PPACs the two counters are sitting in the same gas flow in order to ensure that both counters experience the same pressure. Small charges in the gas pressure have no effect on the timing between these two counters. The gas inlet and outlet is regulated by needle valves.

I like to express my thanks to J.J. Das, D.O. Kataria, Jaipal, N. Madhavan of Nuclear Science Centre in giving the information and data of the Parallel Plate Avalanche Counter.

APPLICATIONS

Such a set up can be used for

(1) ATOMIC PHYSICS EXPERIMENTS

(2) NUCLEAR PHYSICS EXPERIMENTS

(1) ATOMIC PHYSICS :

In ion atom collision the different charges state of the scattered projectile can be separated using this set up.

This set up is used for studing the Recoil ion charge state distributions and their production cross-sections for the processes like direct ionisation, electron capture and electron loss which occur during the interaction of fast moving heavy ions with gaseous targets.

For a 40 Mev Si^{10+} beam a separation of 8 mm between different scattered charge states is possible.

(2) NUCLEAR PHYSICS:

Such a set up can be used for Nuclear fusion experiments.

140 Mev $Ti^{10+} \longrightarrow {}^{58}Ni$

(i) Electrical rigidity of beam is 18.4 Mev/q and net deflection is 3.08 cm.

(ii) Electrical rigidity of the fusion products is 2.8 Mev/q and the net deflection is 11.04 cm. Thus the beam like and fusion products can be well separated using this set up.

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