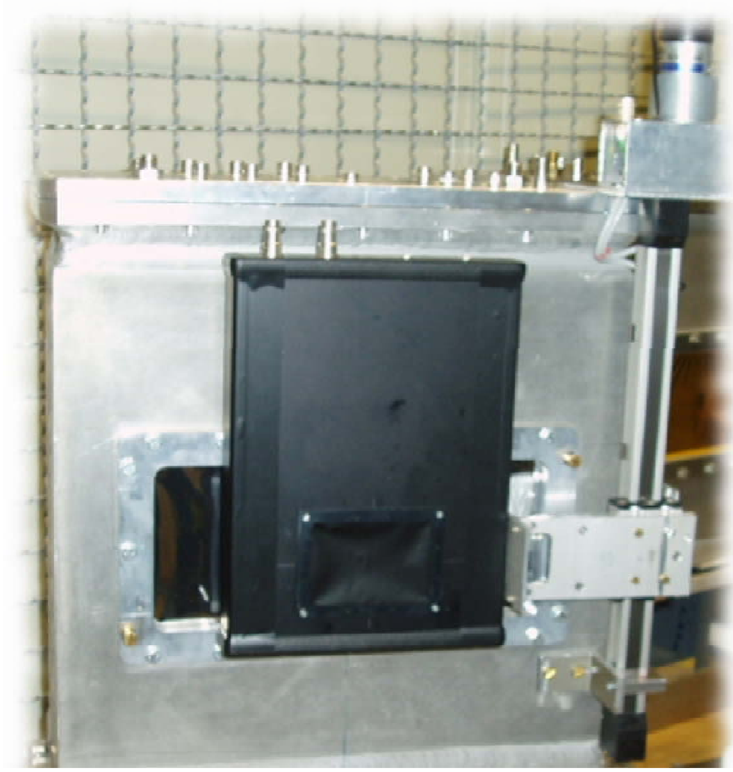
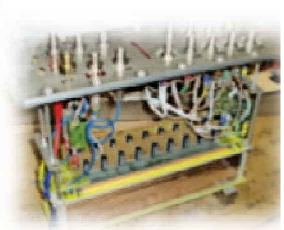
TPC Technical Manual





Development

Time Projection Chambers have been developed at Comenius University in Bratislava as a position sensitive detectors for the Fragment Separator at GSI.

General infos and construction

The Time Projection Chamber has vertical drift respect to the beam direction. The drift space (see Figure 1) is inside a field cage terminated on the lower part by a gating grid. Underneath the grid there are placed four proportional counters with C-pad cathodes.

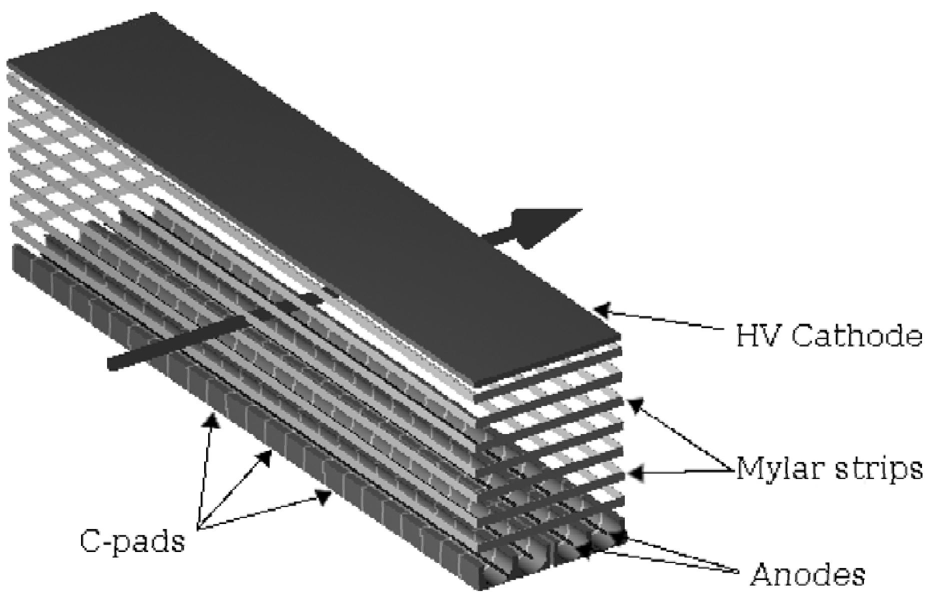


Figure 1: Schematic view of TPC

drift space

The electric field is obtained by applying high-voltage cathode. Mylar strips metalized on both sides surround the drift space. Each mylar strip is 3mm wide and 20μm thick (with 0.5μm Al coating on both sides) and is connected to a high-resistance divider. A voltage up to 400V/cm is applied to the divider and forms uniform electric field inside the drift volume. The electric field strength affects the drift velocity of the electrons. The drift volume is filled with Ar + 10% CH_4 gas (P10) or Ar + 10% CO_2 is used) at normal pressure and room temperature. Several field cages, with different geometry, were made to fulfil experimental demands. The drift volume is 240mm wide, 70mm long and 60, 80, 100, or 120 mm high.

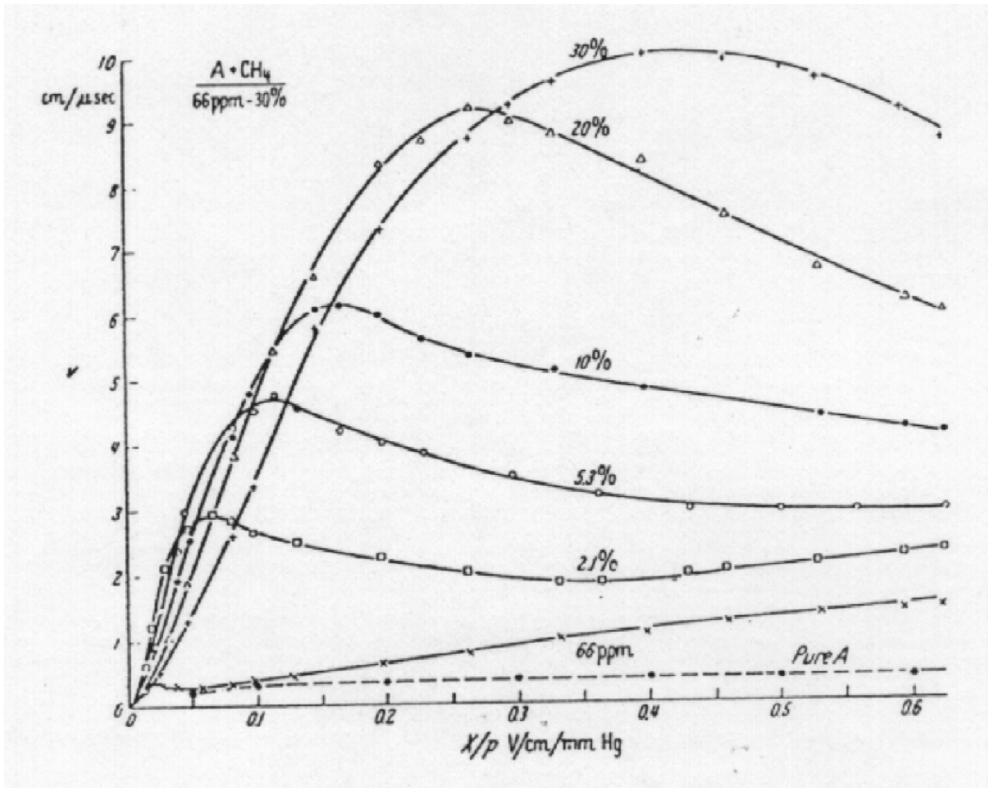


Figure 2: Drift velocity of electrons in Ar + CH4 mixtures

proportional part

The proportional part is placed under the drift space and is separated by a shielding grid. Usually the shielding grid is at negative potential -80 V. The proportional part consists of four anode wires (20 μm in diameter) placed inside C-shaped pad formed cathodes [3]. The C-pads have an inner diameter of 10 mm, an 80° opening angle and are 2.4 mm wide with 0.1 mm pitch. Each C-pad is connected to an integrated passive delay line formed by 9 chips with a total delay of 1350 ns. Each TPC has two independent delay lines.

Typical TPC MOCADI matter:

```
'MATTER'                (mylar as window)
 0   ,214, 1397
 3,  4.191 , 0  , 0 , 0 ,
 0, 0, 0
 0, 0, 0
 1, 1
 0, 0, 0, 0
'COLL'
 1, 0, 0,  10.0,  4.0, 0.0        'SIZE OF TPC1'
*
DRIFT-IN-GAS            (P10 gas in detector)
11.2, 0, 216, 18.300
1, 1
*
'MATTER'                (mylar as window)
 0   ,214, 1397
 3,  4.191 , 0  , 0 , 0 ,
 0, 0, 0
 0, 0, 0
 1, 1
 0, 0, 0, 0
'COLL'
 1, 0, 0,  10.0,  4.0, 0.0        'SIZE OF TPC1'
```

Position measurement

The electron drift time along the field cage is used for measurement of y-coordinate.

$$y = w_d * t_d + y_{off}$$

where t_d is the anode signal, w_d and y_{off} are calibration constants.

The x-coordinate is determined by the measurement of the time difference between the arrivals of the signal from the left and the right side of the delay line.

$$x = w * (t_l - t_r) + x_{off}$$

where w_d and x_{off} are calibration constants.

Each TPC provides two independent x-position measurements and four y-position measurements.

The presence of precise delay line allows precise and unambiguous determination of the position of a passing ion, because the times related to the x- and y-coordinate of the event are correlated by following relation (control sum):

$$t_{CS} = t_l + t_r - 2t_d \tag{1}$$

where t_l and t_r are the times from left and right side of the delay line, t_d is the electron drift time and t_{CS} is the time of the whole delay line.

The use of conditions on the control sum allows to eliminate the noise and the signals coming from delta electrons. The control sum is measured for each anode. The RMS of a control sum distribution is typically $\sigma_{CS} \approx 6\ ns$. This width is due to the two-dimensional (total) resolution of the TPC. For further data processing only those events which fulfil the control sum condition within $3\sigma_{CS}$ are used. The particle position is reconstructed if at least one of the four control sums is within $3\sigma_{CS}$. A typical control sum histogram obtained under the experimental conditions is shown in Figure 3. The efficiency dependence on the beam intensity for Uranium and Xenon beams are shown in Figure 4.

TPC electronics

A block scheme of the electronics is shown in Figure 5.

The signals from the delay lines and the anodes are sent to the preamplifiers (inside the TPC box) and main amplifiers. The amplification gain can be adjusted from 2 to 30. Each signal, after travelling from the experimental area to the FRS Messhuette, is sent to the TPC module (see Figure 6. Here it is spiltted in two branches. The analog branch provides an energy loss measurement. In the digital branch the zero-crosser provides a logical pulse for the stop (start) signal of the time-to-digital converter (TDC). Each zero-crosser has adjustable thresholds. Default values are 100mV for the anodes channels and 125mV for the channels comming from delay lines. The common start (stop) is provided by the FRS trigger. Each TPC module has has 6 channels. For each channels there are 2 time outputs (NIM and ECL).

The threshold, gain and logical signal delay are adjustable for each channel. The front panel has 2 outputs. The OUT1 is the aoutput sent to the

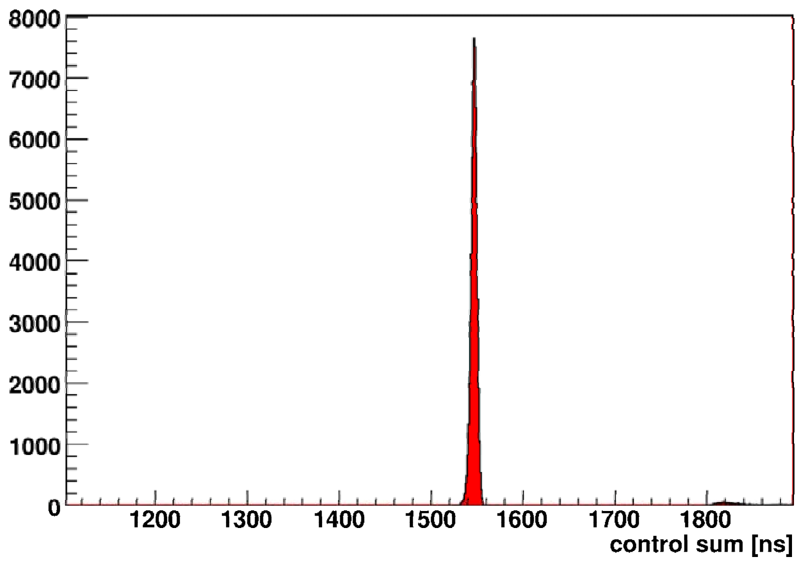


Figure 3: Typical control sum distribution for heavy ion (^{48}Ca) measurement

ADC. The OUT2 is the NIM signal for time branch. On the back side each module has ECL outputs to be directly connected to the TDC.

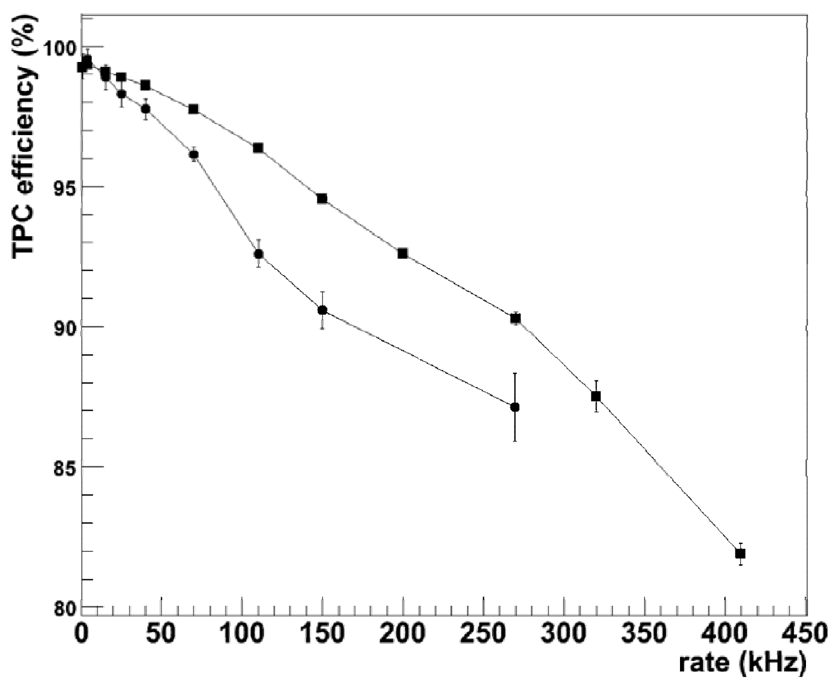


Figure 4: The efficiency of the TPC detector vs beam intensity of Uranium (squares) and Xenon beam(points)

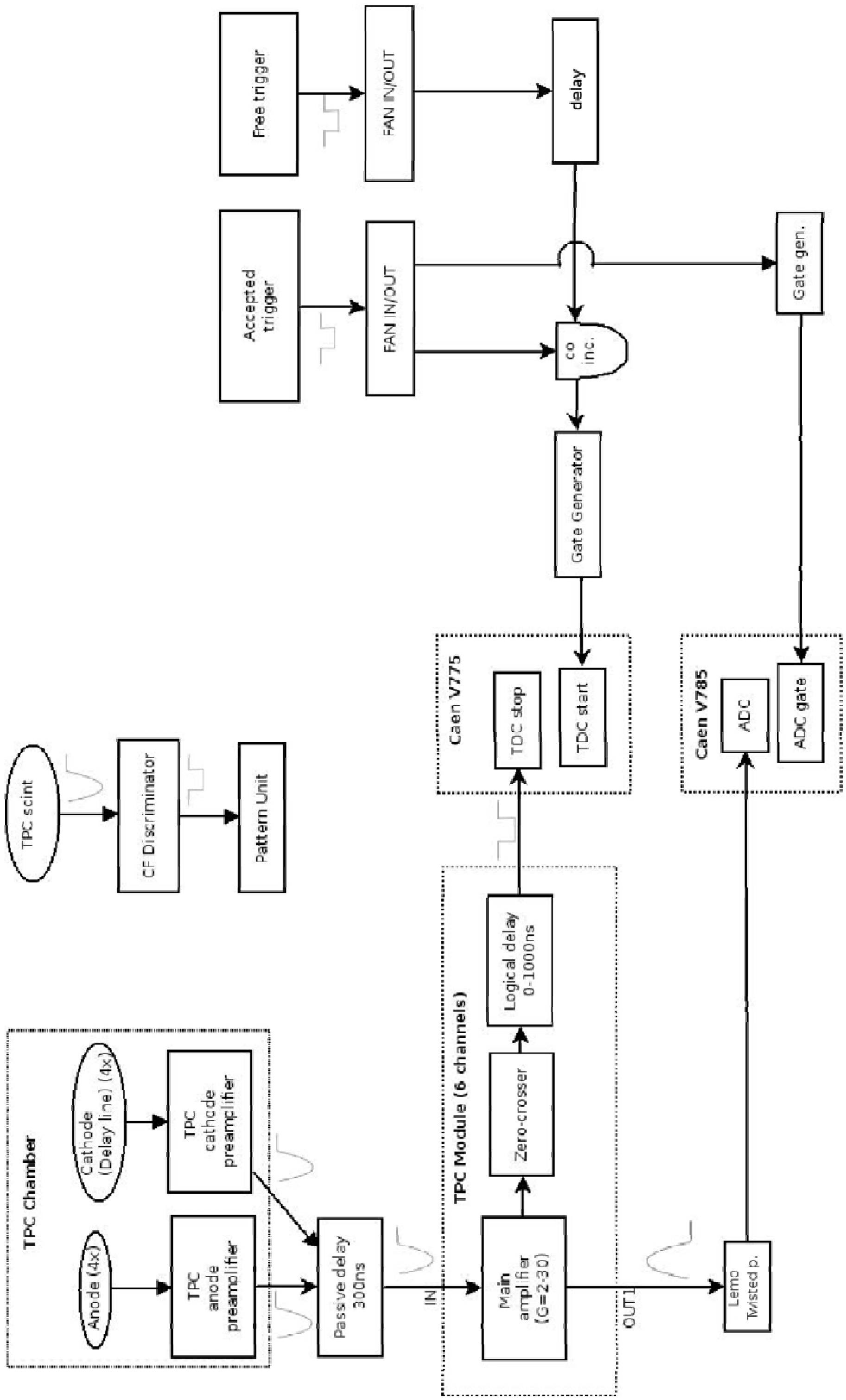


Figure 5: *Block scheme of the TPC electronics.*

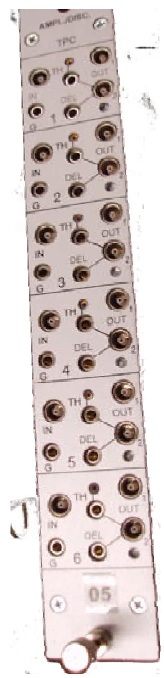


Figure 6: The TPC module

Cabling

High-voltage

Each TPC needs 2 HV Supply. Additional HV is required to use the calibration mask. All of them are in the FRS Messhuette. The grid and the preamplifiers have a special power supplies. The grid voltage connector on the TPC box is labeled as "MR". The connector for drift voltage is labeled as "DRIFT".
For the connection on TPC box see Figure 7.

drift voltage - up to -400 V/cm.
Apply a maximum voltage of **-2400V** for 6 cm drift, **-3200V** for a 8 cm drfit and **-4000V** for a 10 cm drift.

anode voltage - up to 1150V. **Do not apply more than 1200V, otherwise you can destroy the chamber**. The connectors for anode voltages on the TPC box are labeled "VN1" and "VN2".

Additional HV is required to use the calibration mask. All of them are in the FRS Messhuette.

calibration mask - the voltage of the PMT used in the calibration mask depends on the type of PMT installed. The connector for the PMT is on the scintillator box, a black boxsitued on top of the TPC.

Output signals

Each TPC has 9 analog signals, 8 signals from the TPC itself and 1 signal from the calibration scintillator. The 4 anode signals are labeled A11,A12,A21 and A22. The first index refers to the delay line. The 4 signals from two delay lines are labelled DL1, DP1, DL2, DP2, where DL(DP) refers to left(right) side of the delay lines.

To see the actual connection in the ADC and TDC of the TPC crate see the link http://www-w2k.gsi.de/frs/technical/electronics/VMEcrate0.asp .

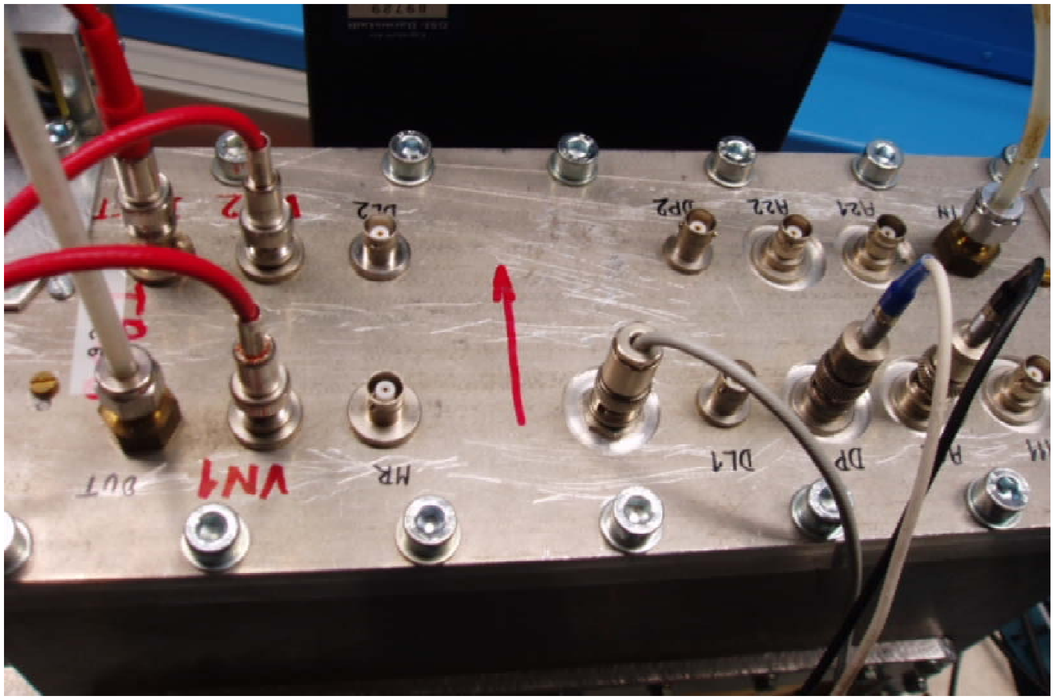


Figure 7: The TPC box connectors

How to start

1. gas - Connect the TPC to the gas system using the connectors "IN" and "OUT" on the TPC box. Usually, the TPC operates at normal pressure with Ar + 10% CH4 gas mixture. The gas "OUT" pipe must be properly connected through the bubble system (see Figure 8), **otherwise the Mylar windows can be damaged.**
Wait 3-4 hours to clean away the rest of air from the TPC box before applying any voltage to TPCs!

2. preamps power supply - turn on the preamps power supplies and check the noise on the scope (approx. -5mV noise fot the anodes, -10-20mV for the delay lines).

3. grid - turn on the grid voltage.

4. drift voltage - gradually increase the drift voltage up to -400 V/cm.

5. anode voltage - slowly increase anode voltage. Starting from 700V it is possible to see on the scope the signals generated by the cosmic background

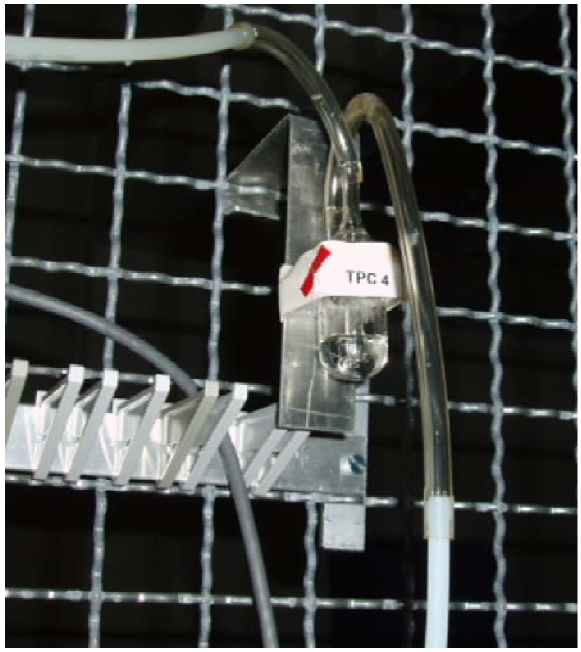


Figure 8: The gas bubble system

particles. At a value of 1000V it is possible to see signals from beta or gamma sources put in front of the Mylar windows. A typical beta signal has an amplitude of 100-150mV and is typically 200ns long. See Figures 9 and 10 for signals coming from cosmic particles and beta source at an anode voltage of 1100V.

Figure 9: signals from cosmic particle, anode signal (up) and delayed signal (down) from delay line

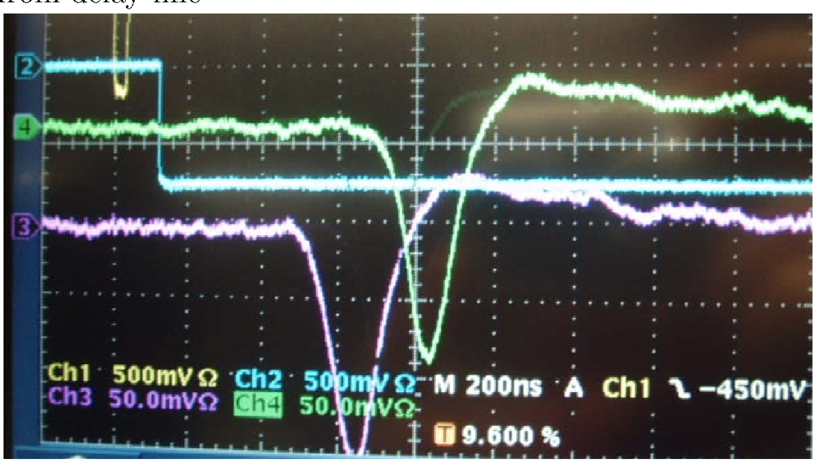


Figure 10: signals from 90Sr beta source : 1st signal from left side (label 3) and 2nd signal from right side (label 4) of the delay line

Gas gain and electronic gain

To operate the TPCs at different ionisation power of the measured ions, one can change the gas gain (anode voltage) and the electronic gain in main amplifiers. The choice of the correct anode voltage depends, of course, on the charge of the ions to detect. The signal from the preamplifier should be 1.8V maximum. Additional amplification can be done using electronic gain in order to cover the full range of the ADC. To operate on the electronic gain is preferable whenever the noise level is small enough, in order to prevent ageing effect on the wires.

Examples of adopted gas and electronic gains at several experiments are shown in the following tables:

E073: primary 238U 1GeV/u, secondary beams: Os, Fr, Ra				
TPC	Anodes HV	el. gain	thresh. anodes	thresh. cath.
TPC23	685 V	10x	100mV	125mV
TPC24	685 V	10x	100mV	125mV
TPC41	690 V	10x	100mV	125mV
TPC42	690 V	10x	100mV	125mV

S322: primary 48Ca 1GeV/u, secondary beams: N,F,O,Mg...				
TPC	Anodes HV	el. gain	thresh. anodes	thresh. cath.
TPC21	880 V	30x	100mV	125mV
TPC22	870 V	30x	100mV	125mV
TPC23	890 V	30x	100mV	125mV
TPC24	880 V	30x	100mV	125mV
TPC41	860 V	30x	100mV	125mV
TPC42	890 V	30x	100mV	125mV

S330: primary 129Xe 1GeV/u, secondary beams: Sn, Tn				
TPC	Anodes HV	el. gain	thresh. anodes	thresh. cath.
TPC41	800 V	10x	150mV	125mV
TPC42	800 V	10x	150mV	125mV

S277: primary 48Ca 452MeV/u, secondary beams: Ti, Cu				
TPC	Anodes HV	el. gain	thresh. anodes	thresh. cath.
TPC21	1070 V	30x	100mV	125mV
TPC22	1070 V	30x	100mV	125mV
TPC23	1070 V	30x	100mV	125mV
TPC24	1060 V	30x	100mV	125mV
TPC41	1140 V	30x	100mV	125mV
TPC42	1080 V	30x	100mV	125mV

S272: primary 40Ar 400MeV/u, secondary beams: Ar				
TPC	Anodes HV	el. gain	thresh. anodes	thresh. cath.
TPC23	790 V	15x	100mV	125mV
TPC24	790 V	15x	100mV	125mV
TPC41	790 V	15x	100mV	125mV
TPC42	790 V	15x	100mV	125mV
TPC43	790 V	15x	100mV	125mV
TPC44	790 V	15x	100mV	125mV

Calibration

The calibration scintillators consist of thin scintillators or scintillating fibres (1mm thick). In a special light frame 3 vertical scintillator fibres are placed at distance of 20mm or 12 mm, horizontal scintillator fibres are placed at distance of 10mm or 6mm.

Output signal from the PMT, after travelling for mthe experimental area to the FRS Messhuette, is sent to a constant fraction discriminator CFD and then to a coincidence circuit, for hardware coincidences, or to the pattern unit for software coincidences. Typical calibration spectra are shown on the Figure 11 and 12.

Calibrations must be done for all drift times and the two delay lines separately. Defocused beam is necessary to have a clear image of the scintillator positions. The scale factors (from ch to mm) are obtained from the distances of the peaks related to the illuminated scintillator fibres. Typical scale factors for delay lines are around 0.07 mm/ns and 0.04-0.05 mm/ns for the drift time.

The absolute offsets are obtained from the central peak position. Final allignment can be obtained running with narrow slits. The calibration parameters must be inserted in the Go4 analysis code, in particular in TFRSParameter.cxx or setup.C file. Some calibration paprameters of old experiments can be found in /d/frs01/profi/sxxx/go4 directories, where sxxx represents the name of the experiment.

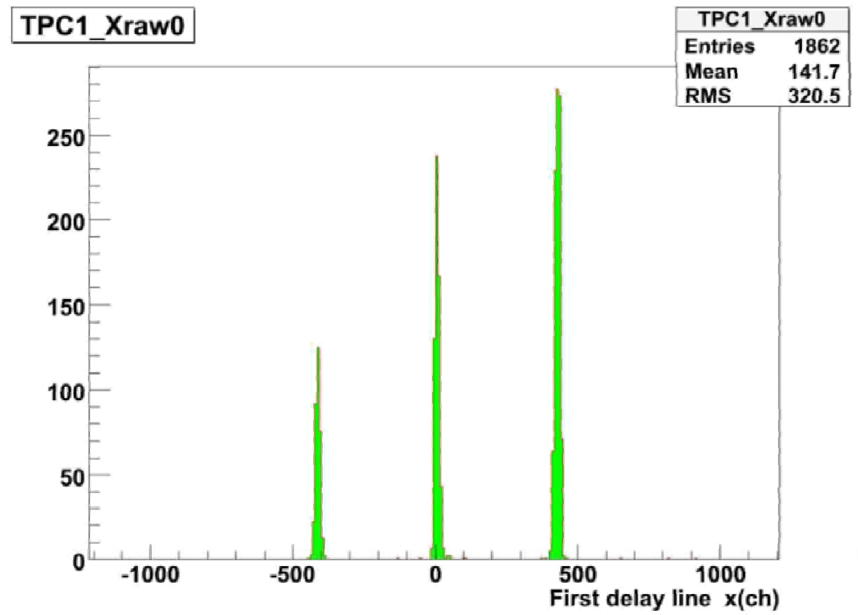


Figure 11: Typical x-position calibration spectrum obtaining by triggering on the TPC mask

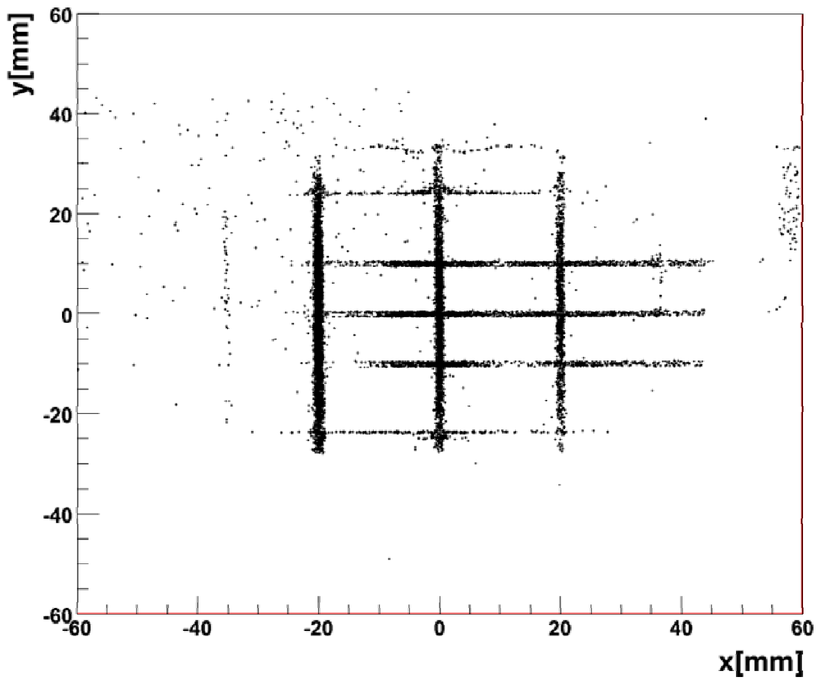


Figure 12: Bidimensional calibration spectrum obtained by triggering on the TPC mask

Figure 13: Photo of the opened TPC scintillator mask