# Experience with L3 Vertex Drift Chamber at LEP

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Representing

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# Outline

- Introduction
- Design and Construction
- Infrastructure and DAQ
- Detector Performance
- Summary

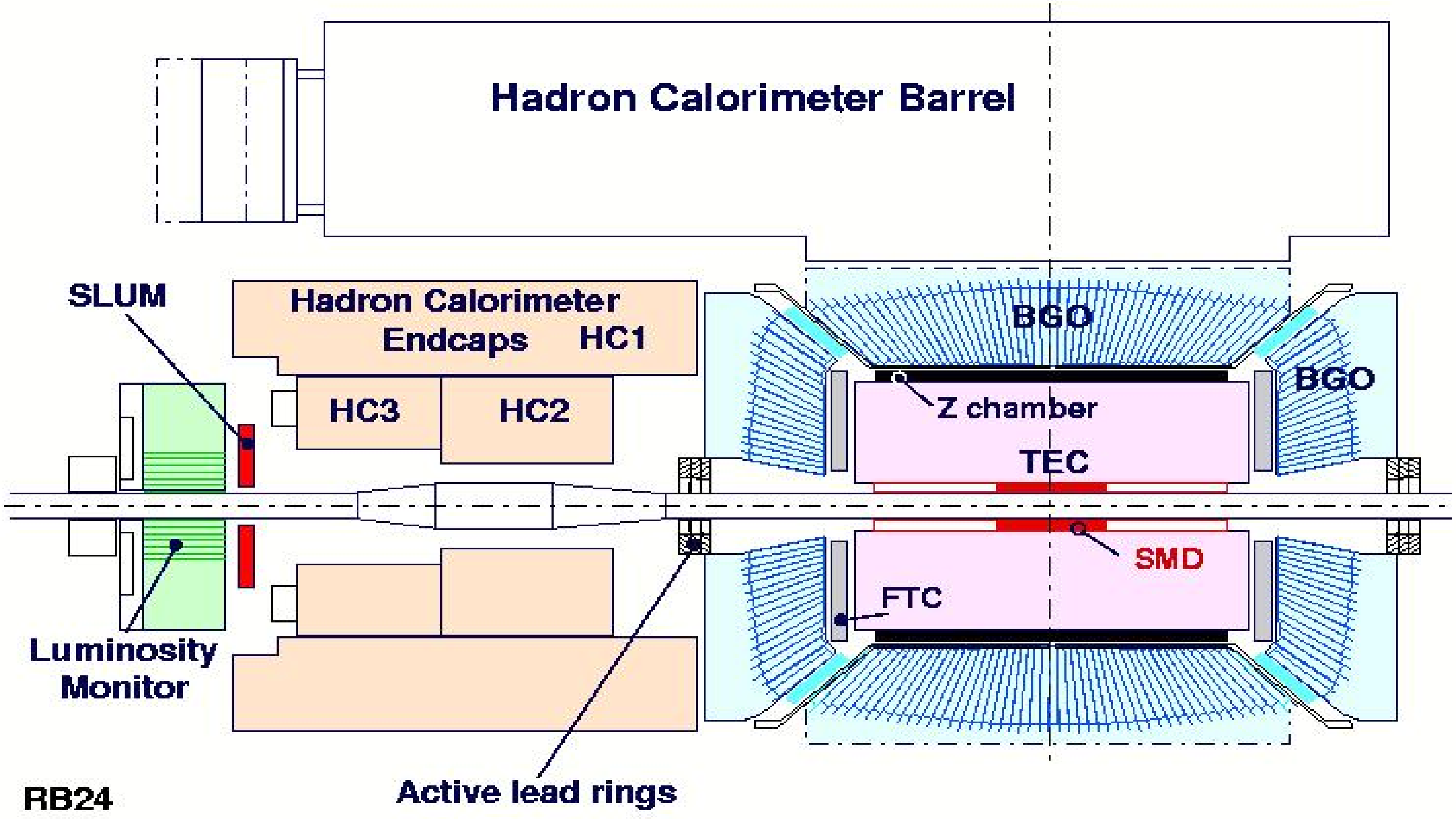
**The talk is a historical overview of the L3 Central Track Detector, its design and performance in the past 11 years, running at LEP.**

# *The L3 Detector*

**The L3 experiment at LEP was designed to study e+e− collisions in the 100 − 200 GeV range with emphasis on high resolution energy measurements of photons, electrons and muons.**

- **Central tracking detector**
- **Electromagnetic calorimeter with BGO crystals.**
  **(accuracy of 1% above 2 GeV; Inner diameter 100 cm !).**
- **Hadron calorimeter with** $(55/\sqrt{E}+5)$**% resolution.**
- **Muon detector of large drift chambers to provide**
  **$\Delta$p/p < 1.5% at p=50 GeV/c.**

# The inner subdetectors of L3



# Main goals of L3 Vertex Chamber

## The main physics goals set for the L3 central track detector were:

- Detection of charge particles and precise measurement of their tracks
- Determination of the transverse momentum and the sign of charge for particles up to 50 GeV/c.
- Reconstruction of the interaction point (primary vertex) and secondary vertices for particles with lifetime greater than $10^{-13}$ s.
- Determination of the charge multiplicity of the events.
- Minimum material between the interaction point and BGO detector for clear separation of photon from electron showers in BGO.
- A double track resolution better than 500 μm.

**The space available for the tracker with these requirements was cylinder with radius of about 45 cm and a total lever arm for coordinate measurements of about 37 cm.**

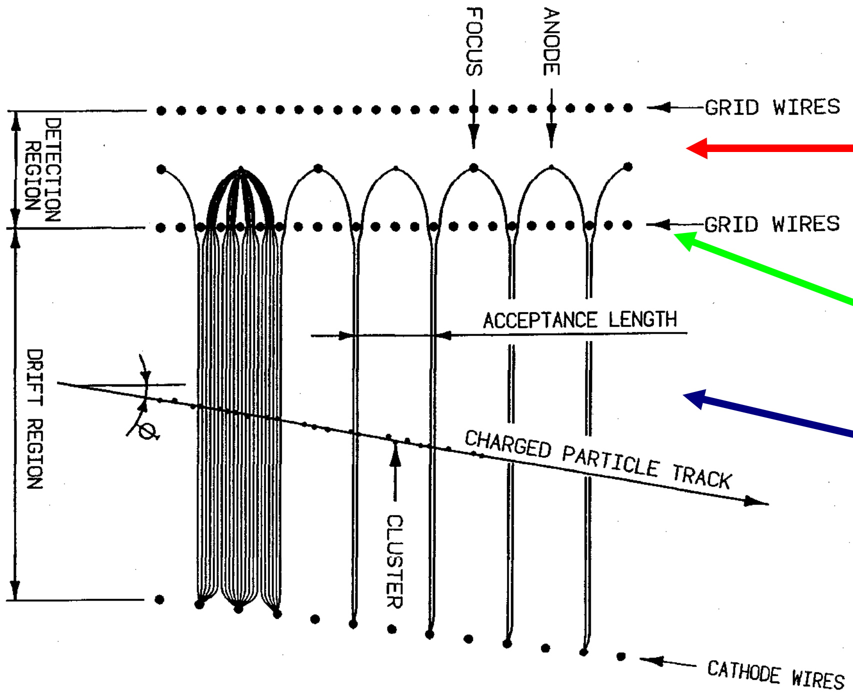
**The charge identification of 50 GeV/c particles with lever arm of 37 cm requires at least 50 coordinate measurements with 50 μm spatial resolution.**

# Time Expansion Chamber Principle

1985

**The principle chosen for the L3 Central tracker was a drift chamber, operated in "Time Expansion" mode.**

**[A.H. Walenta. IEEE Trans. Nucl. Sci. NS−26(1979)]**




$$v_{drift} = (E.T/p).f$$

**The time expansion Chamber (TEC) has high electrical field amplification region (detection gap at the sense wires (anodes) and focus plane,**

**separated by grounded grid wire plane from**

**the low field drift region between the grid wire plane and the cathode wire plane.**

**The gas mixture chosen was: 80% $CO_2$ and 20% $iC_4H_{10}$, at an absolute pressure of 1.2 bar. The electron characteristic energy remain constant at its thermal value up to high electric field strengths. This implies a low longitudinal diffusion at low drift speed.**

**The drift velocity depends linearly on the electrical field (*E*) in the drift region, the gas pressure (*p*), the iso−butane content (*f*) and the absolute gas temperature (*T*).**

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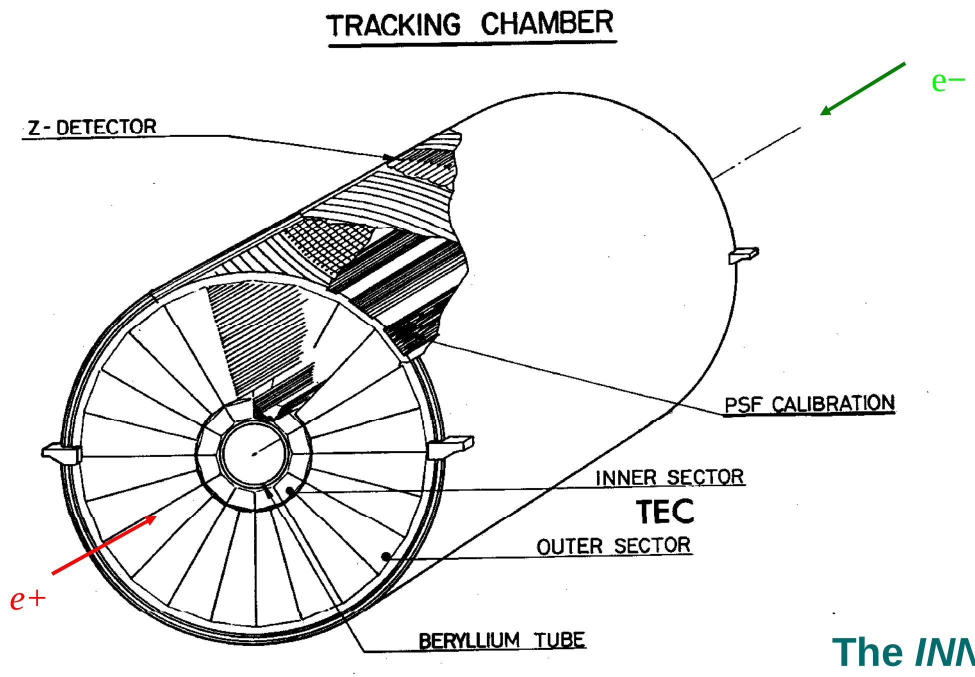
# L3 Time Expansion Chamber



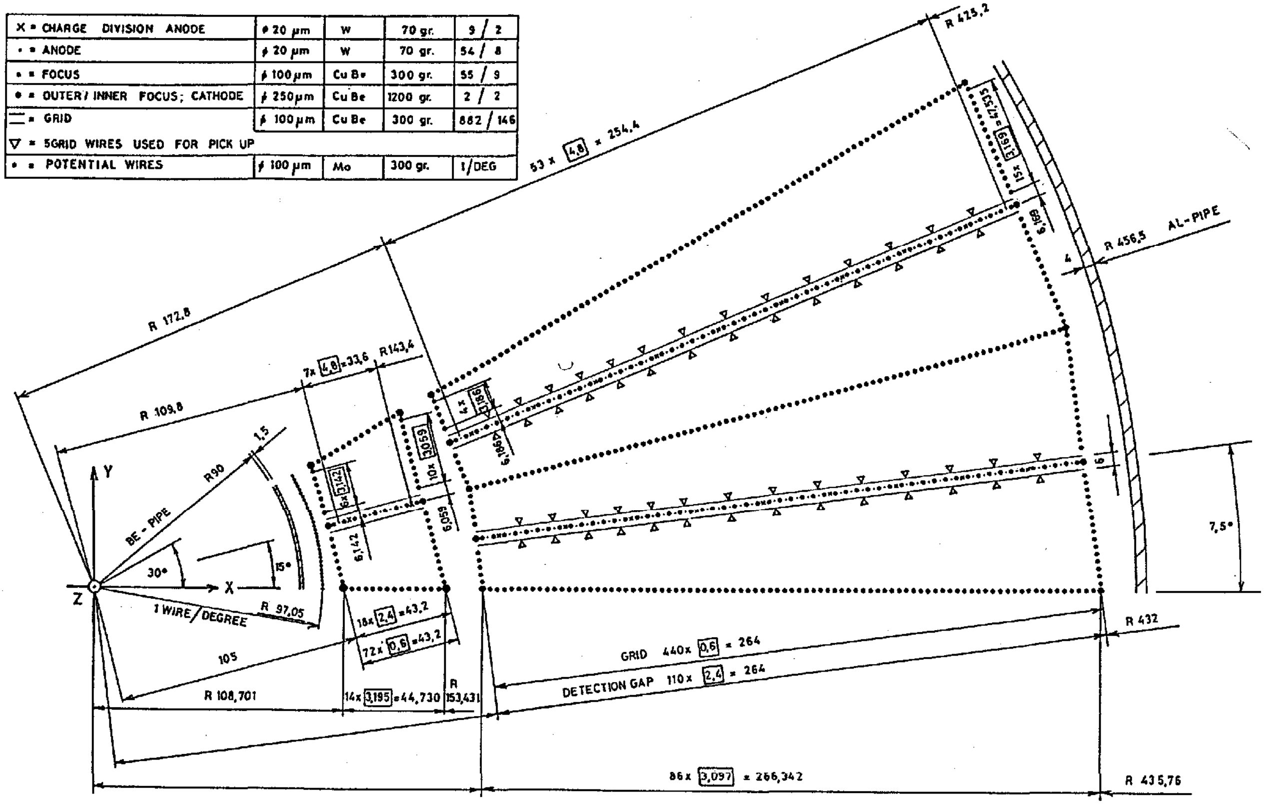

**General view of the L3 central track detector.**

**The TEC wire configiration forms two concentric cylindrical drift chambers: *INNER* and *OUTER* TEC.**

**The *INNER* TEC consists of 12 sectors, while the *OUTER* TEC consists of 24 sectors. All sectors have a common gas volume and are electrically independent.**

# *Structure of the TEC sectors*

| | | | | |
|---|---|---|---|---|
| X = CHARGE DIVISION ANODE | ⌀ 20 μm | W | 70 gr. | 9 / 2 |
| • = ANODE | ⌀ 20 μm | W | 70 gr. | 54 / 8 |
| • = FOCUS | ⌀ 100 μm | Cu Be | 300 gr. | 55 / 9 |
| ● = OUTER / INNER FOCUS; CATHODE | ⌀ 250 μm | Cu Be | 1200 gr. | 2 / 2 |
| ═ = GRID | ⌀ 100 μm | Cu Be | 300 gr. | 882 / 146 |
| ▽ = 5GRID WIRES USED FOR PICK UP | | | | |
| • = POTENTIAL WIRES | ⌀ 100 μm | Mo | 300 gr. | 1/DEG |



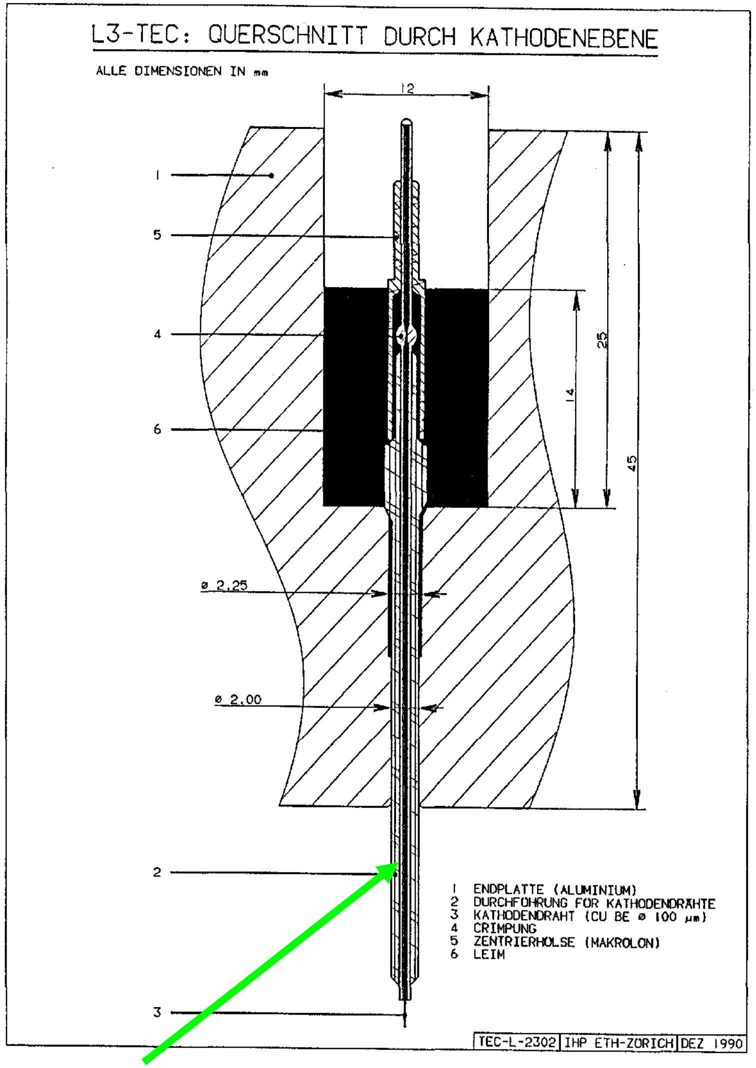

**The total axial tension at p=1200 mb abs. is about 7540 kg.**

| Wire type | Diameter um | Number per sector | Material | Tension [gr] | Total number | Comment |
|---|---|---|---|---|---|---|
| Anode | 20 | 54/8 | W | 70 | 1296/96 | W:Rh=97:3% |
| Focus | 100 | 55/9 | CuBe | 300 | 1320/108 | Cu:Be=98:1.8%, Ni,Co 0.2% |
| Cathode | 100 | 139/51 | CuBe | 300 | 3336/612 | All wires are gold−plated |
| Grid wires | 100 | | CuBe | | 22880 | |

# TEC anode functions. Feed−throughs

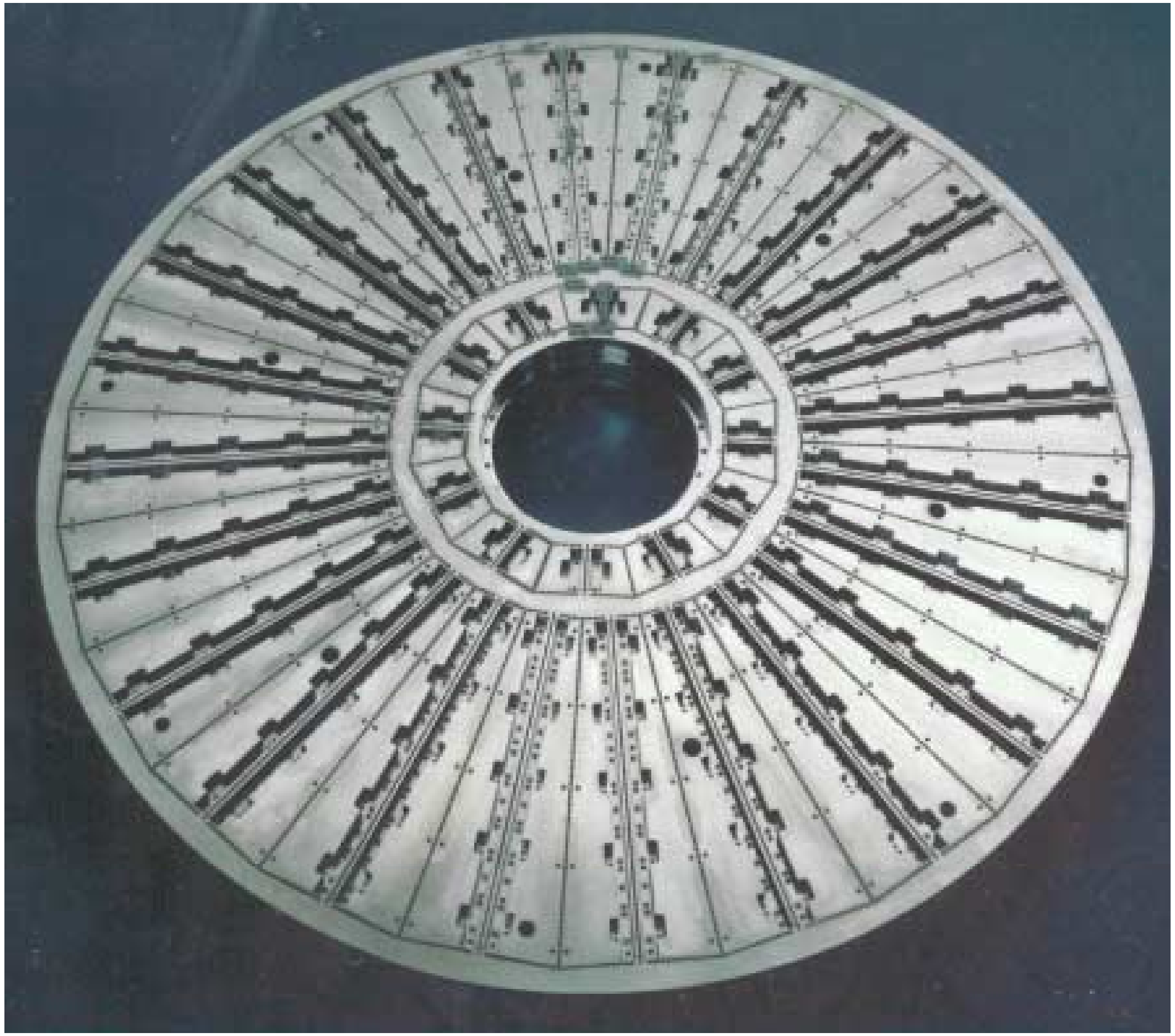
**The anodes are divided into three groups:**

- **Standard anode: Read out at one end and optimized for high resolution *r*φ measurement.**
- **Charge Division: Identical to the standard anodes, but read out at both ends to provide a *z*−coordinate as well as *r*φ measurement.**
- **Pick−up: Two groups of five isolated wires from the grid wire plane on both sides of an anode which are read−out to solve the left−right ambiguity.**




**The single wires are kept in position by feed−thoughts in the holes of the end plates. (Insulation material: Rynite; stand up to 20kV).**

# TEC Mechanical construction



One of the TEC end plates

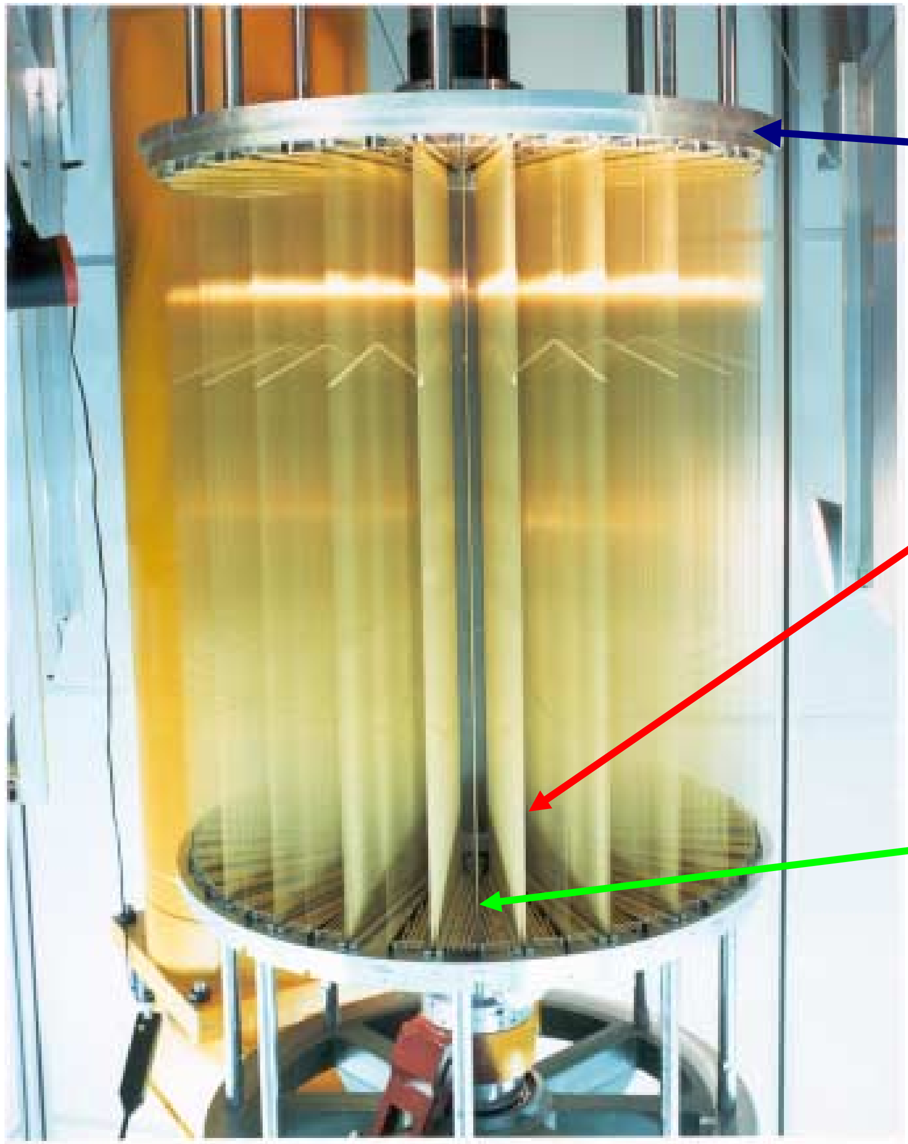
- Two solid up to 4.5 cm thick (mean 2.8 cm) Aluminium end plates with 10 μm precision for all holes for the feed−througths.
- Outer cylinder: 4 mm Aluminium 913 mm diameter.
- Inner cylinder: 1.5 mm Beryllium 180 mm diameter.

Chamber length 1260 mm
Volume 610 l.
7% R.L. (at $\theta = 0$) .

## Mechanical precision:

- Single wire positon < 50 μm
- Wires in the grid plane < 5 μm
- End−plates torsion < 0.08 mrad
- End−plates are parallel within < 50 μm

# *TEC with all wires on wireing stand*

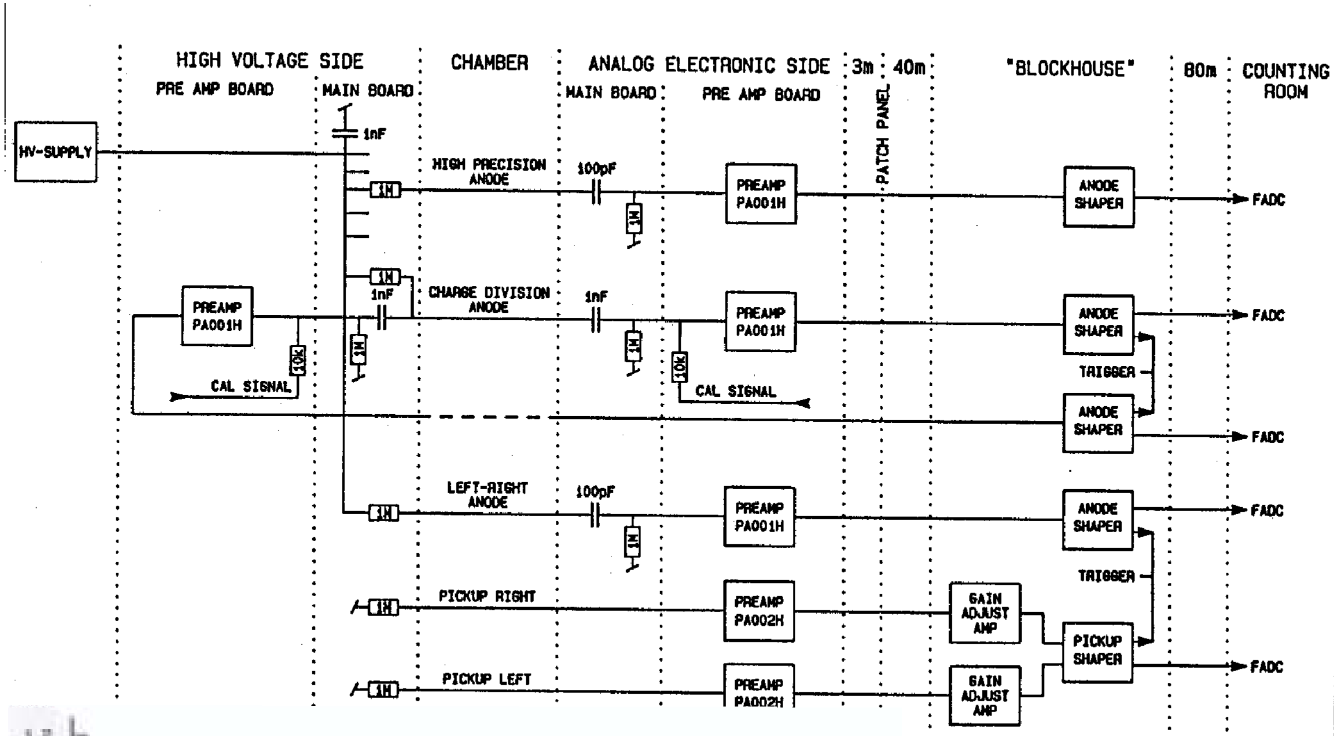


TEC end plate

Detection gap with two grounded wire grid planes and anode/ focus wire plane

Cathode wire plane

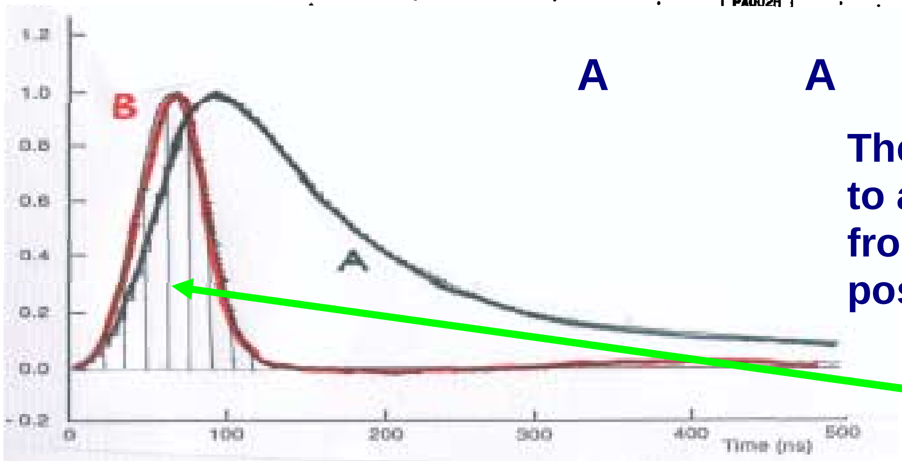
# TEC analog readout electronics




A A B

Front−end preamplifiers with gain 280.

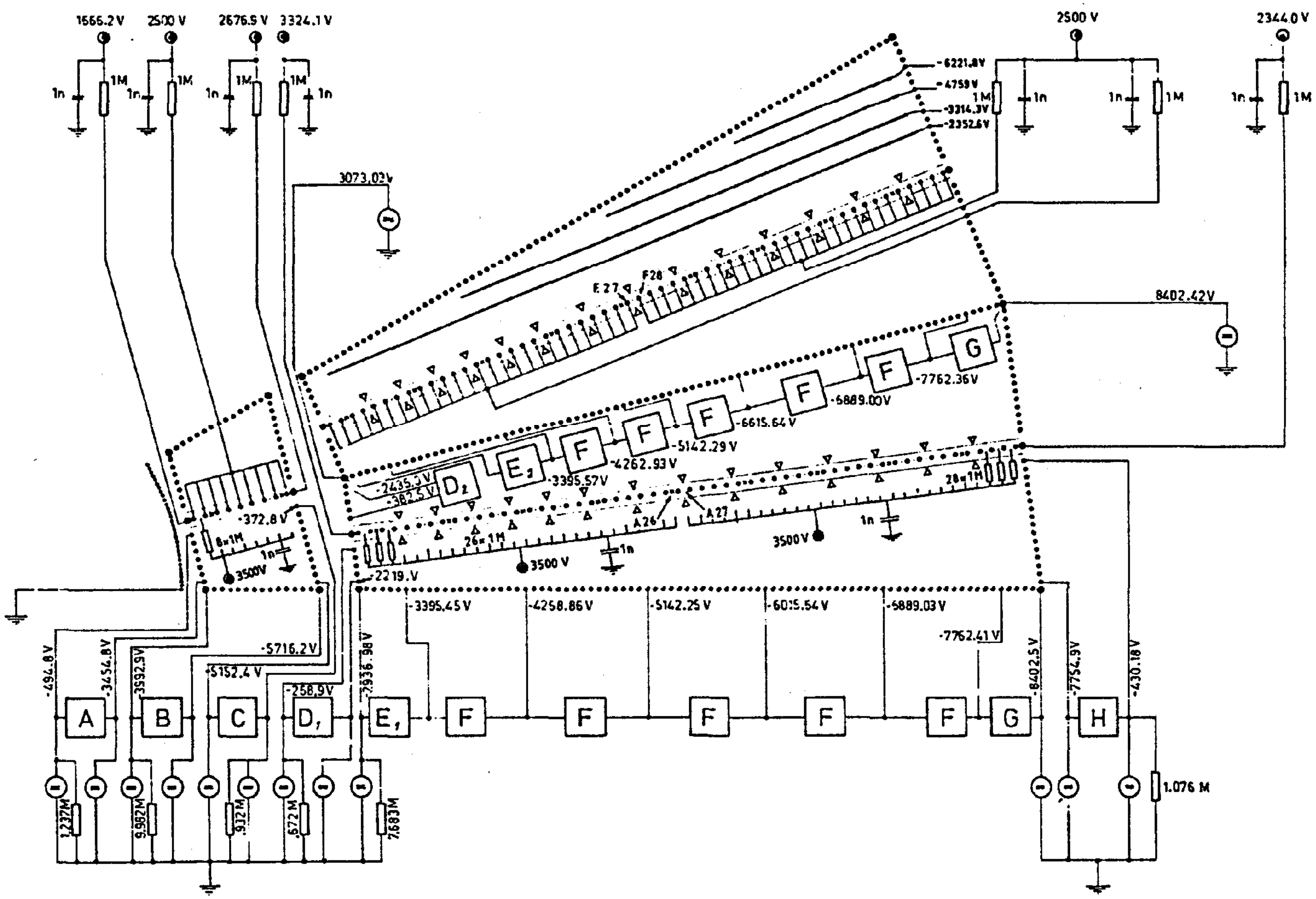
Shaper modules with gain 100.




The shaper module cut the ion tail of the anode pulse to apply the ’COG’ method to the digitized signals from the FADC for precise determination of the pulse position, thus improving the spatial resolution.

$$t_{COG} = \sum t_i . U_i / \sum U_i$$

# TEC High Voltage Connections

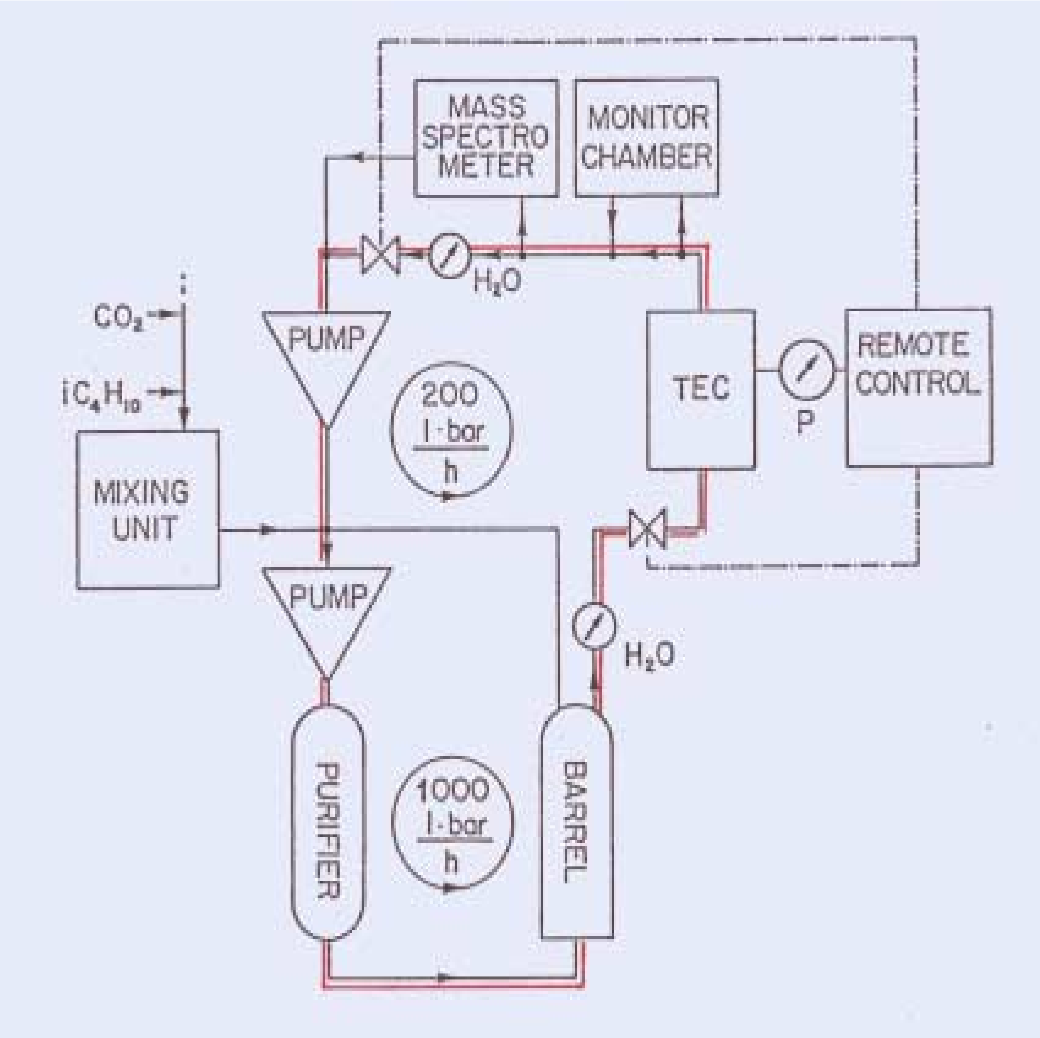



**The deviation of the voltages in all pins of cathode and field shape wire planes, due to the precise resistor chains (A, B, C, D, E, F), is less than 0.05%.**

**The E−field strength in the drift region is 910 V/cm.**

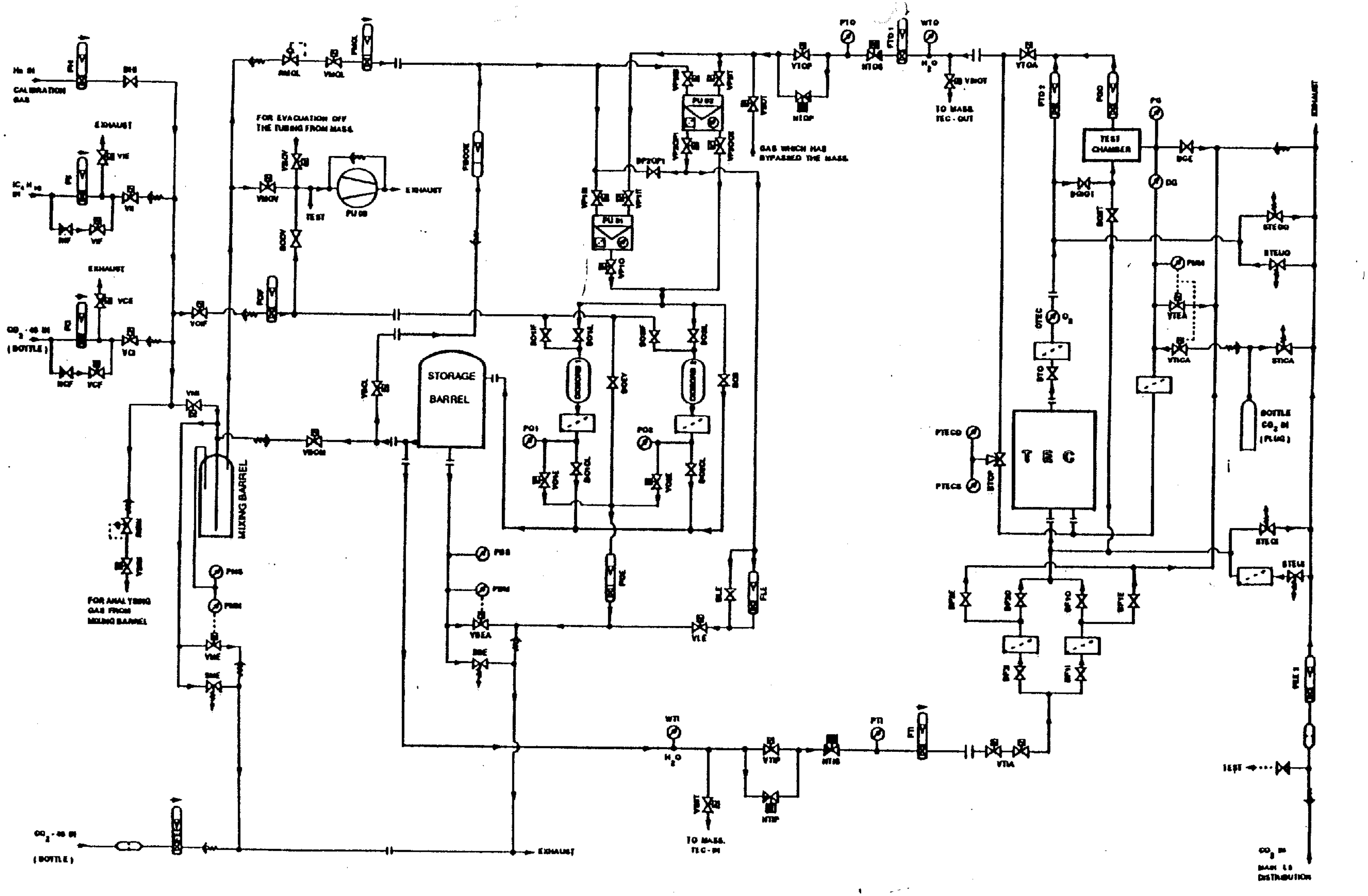
**TEC HV connections  for anode−focus and cathode−field shape frames in the inner and the outer sectors. Long term stability of all voltages for the E−field in the drift region is better than 0.05% (Novelec HV PS) and better than 0.1% for the E−field in the detection gap (anodes and focuses) −( CAEN HV PS).**

# Gas System

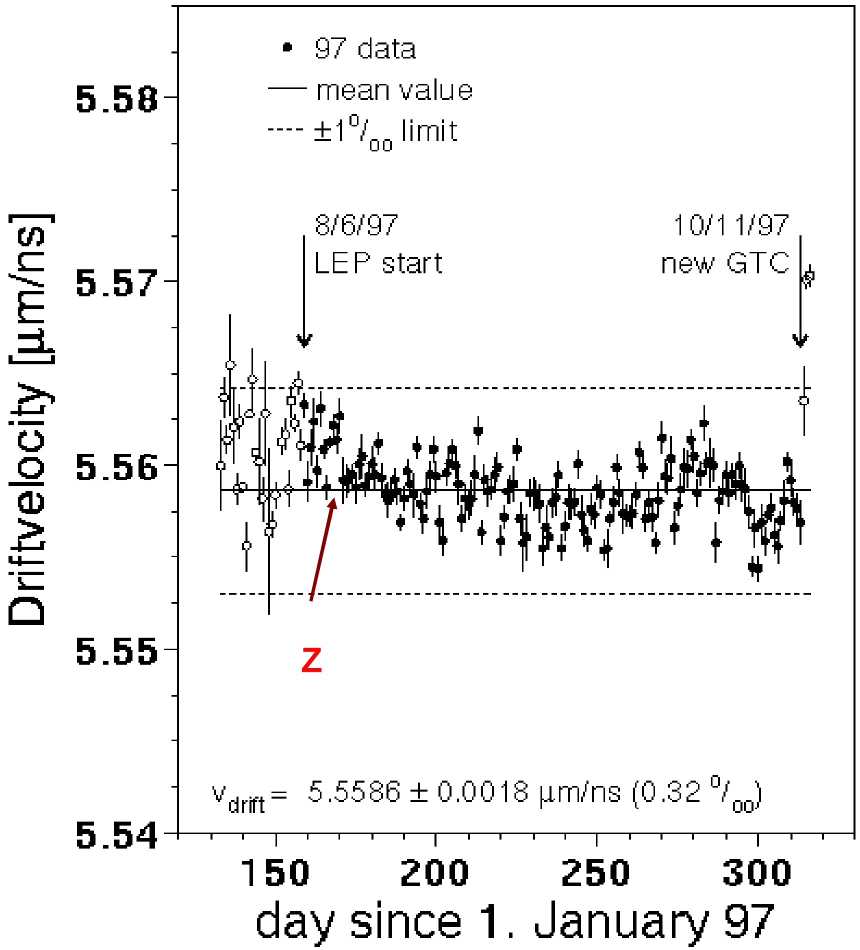


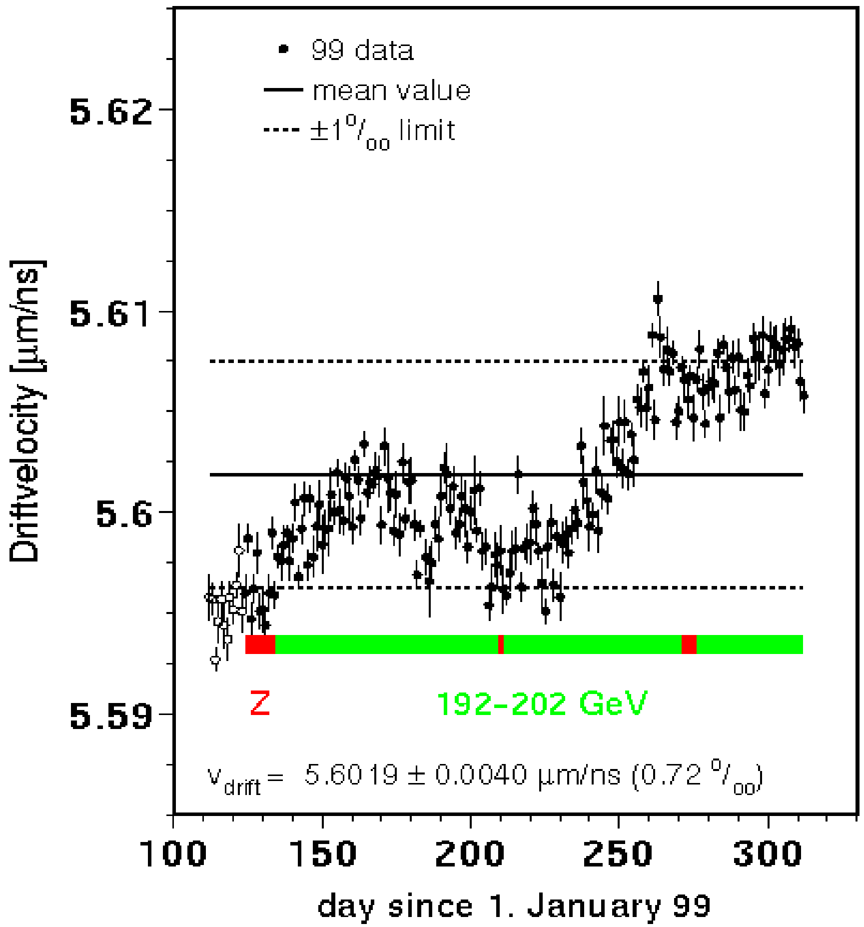

- Operates in closed loop to guarantee long term stability.
- Gas mixture 80% carbon dioxide and 20 % isobutan.
- Gas pressure 1200 mb abs. , stability better than 0.1%.
- The mixture in the storage barrel circulates through several filters and an Oxysorb purifier to keep the oxygen content below 1.5 ppm.
- Stability of the gas mixture < 0.1%.
- The purified gas passes through TEC at a flow of 150 l bar/h.
- Small drift chamber, based on the 'time expansion principle' monitors changes in drift velocity.
- Gas quality is monitored by mass spectrometer.
- Oxygen content in the mixture is < 1.5 ppm i.e. free of electronegative oxygen contamination.

# Real TEC Gas System



# Estimated drift speed by test chamber

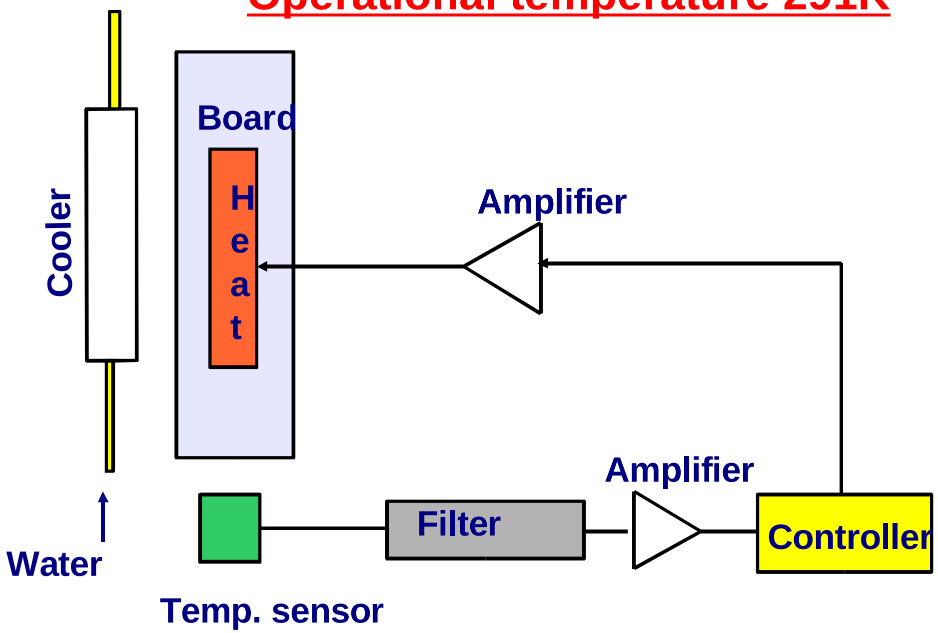


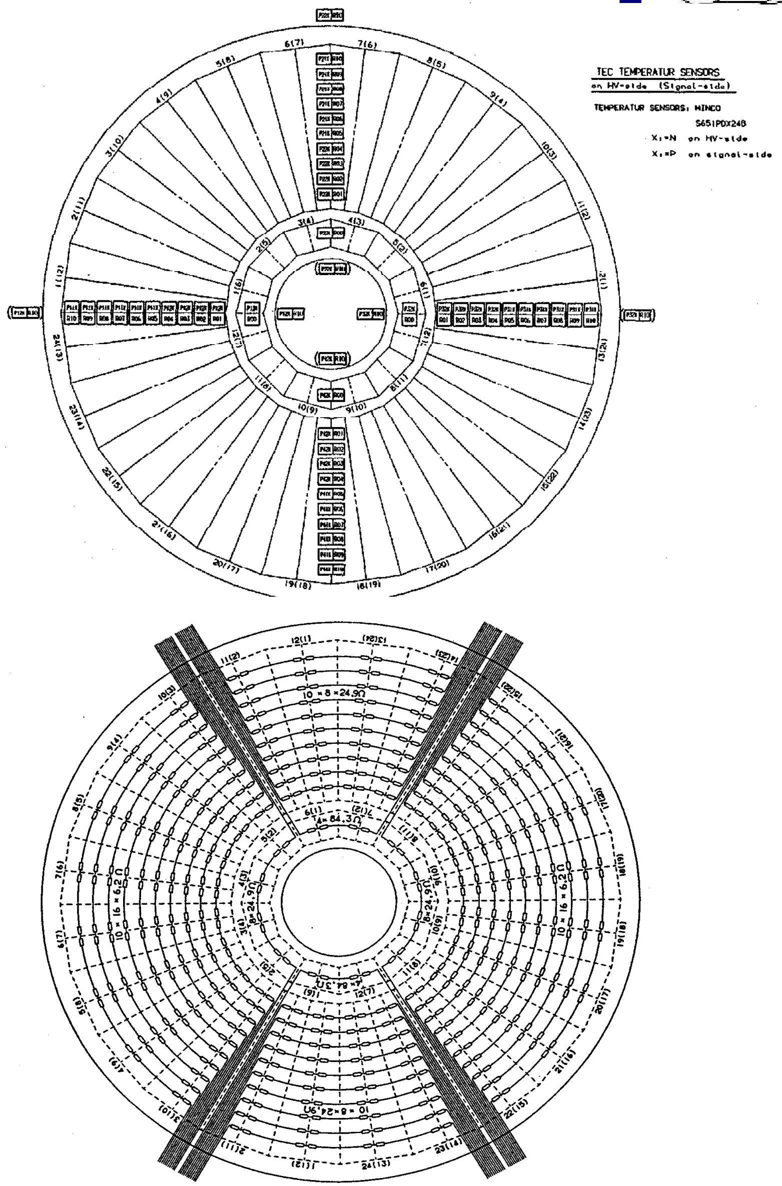




**The estimated drift velocity from the TEC gas test chamber proofed that the gas parameters are well kept within 0.1% limit during the whole data taking period in one year.**

# TEC temperature System

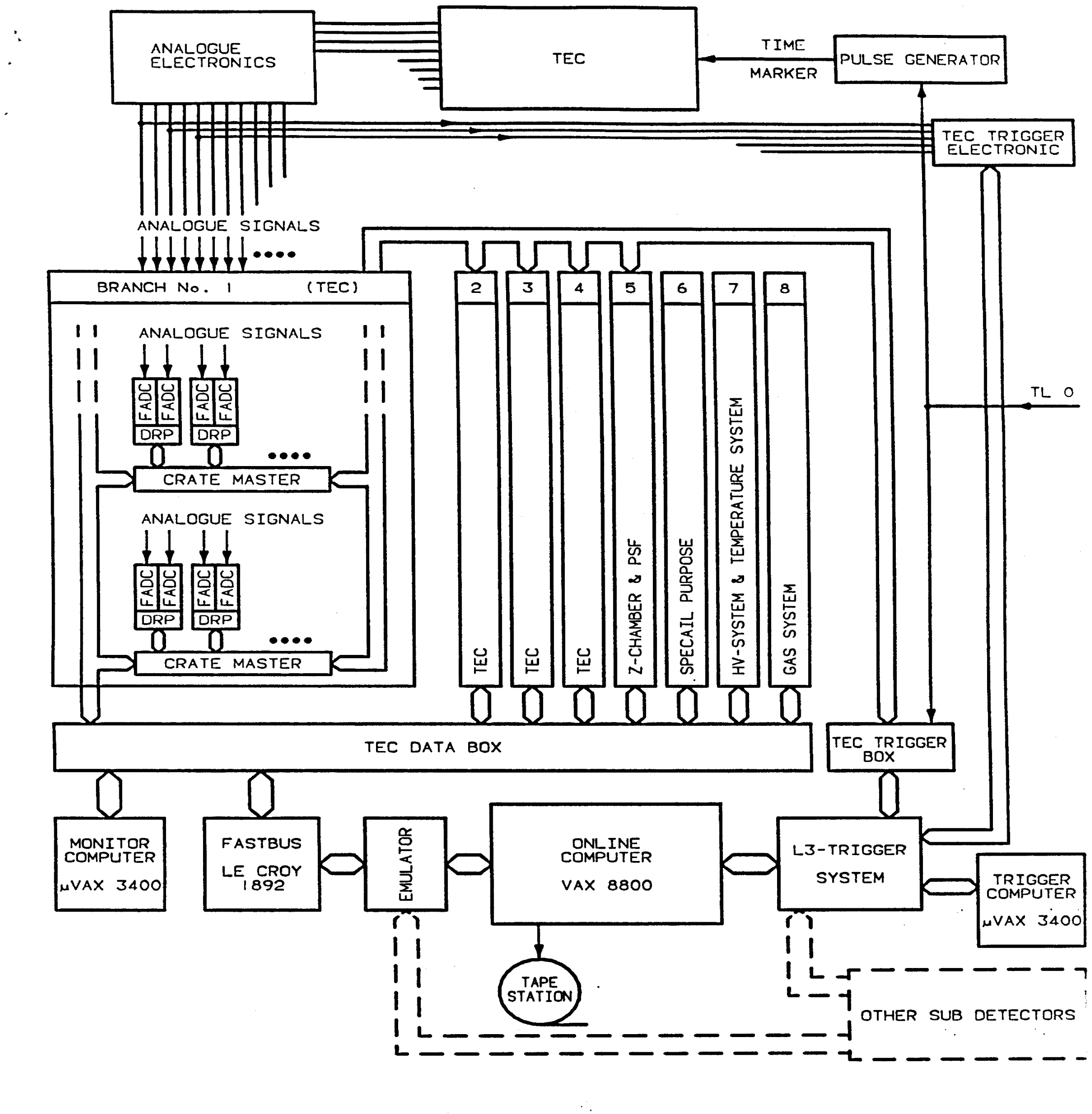
## Operational temperature 291K



**The long term temperature stability on both endplates as well as on the beryllium pipe and outer Al cylinder was kept better than 0.2$^{o}C$ (<0.1%).**

# TEC Data Acquisition System



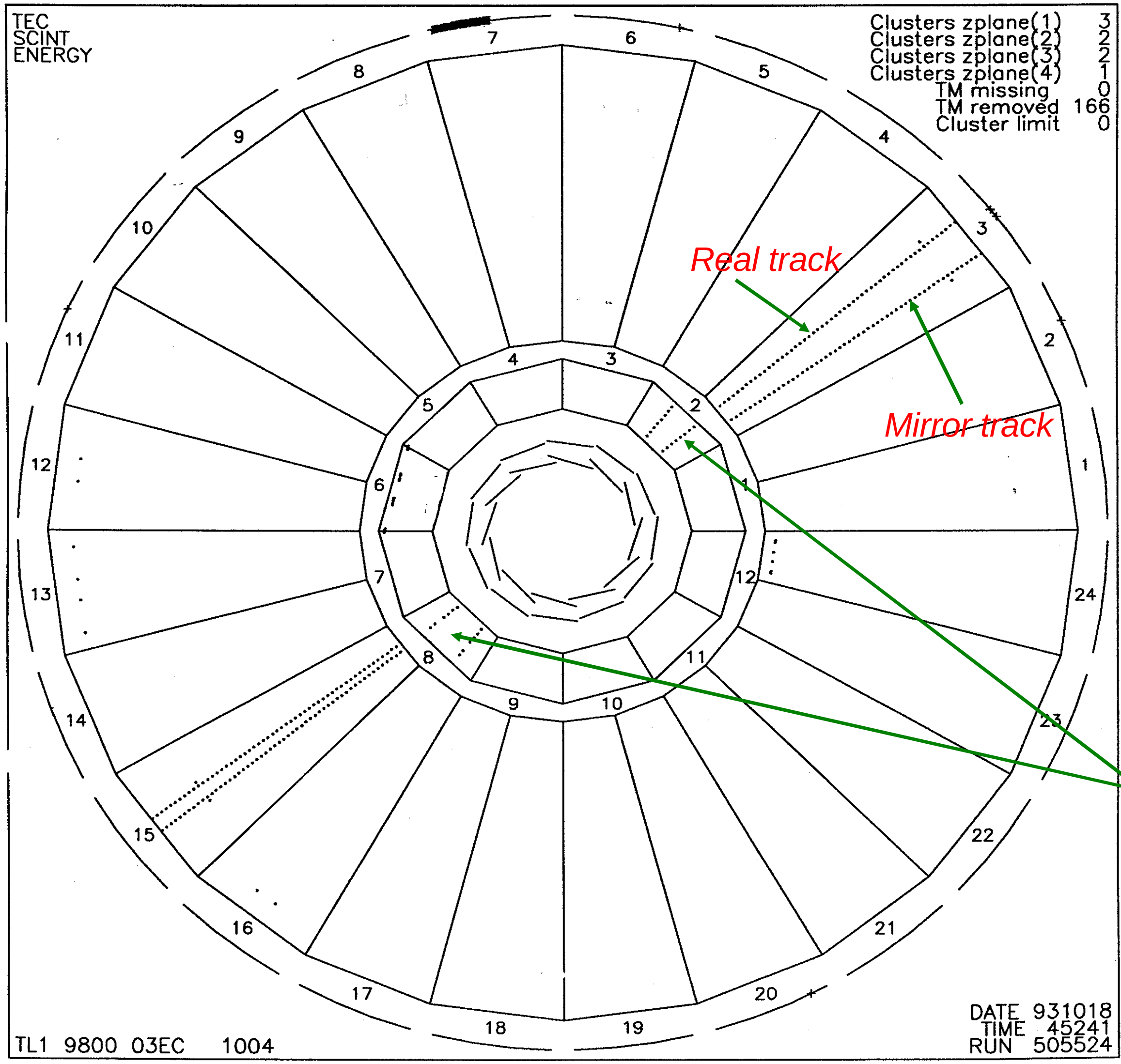

**The DAQ is a multi−branch, multi−crate VME system with the following main elements:**

- **2016 Flash Analog to Digital Convertors (FADC) with 6 bits ADC chip, running with 100MHz clock rate and digi−tazing analog signal in time interval of 10.24 μs in bins of 10 ns.**

- **Data Reduction Processor (DRP) running a program for an essential compression and reduction of the data and calculating pulse parameters** $( t_{COG} , U_{max}, \int U_i dt )$

**[V. Commichau *et al.* NIM A294, (1990), 554 ]**

# Dimuon raw data event (Online)



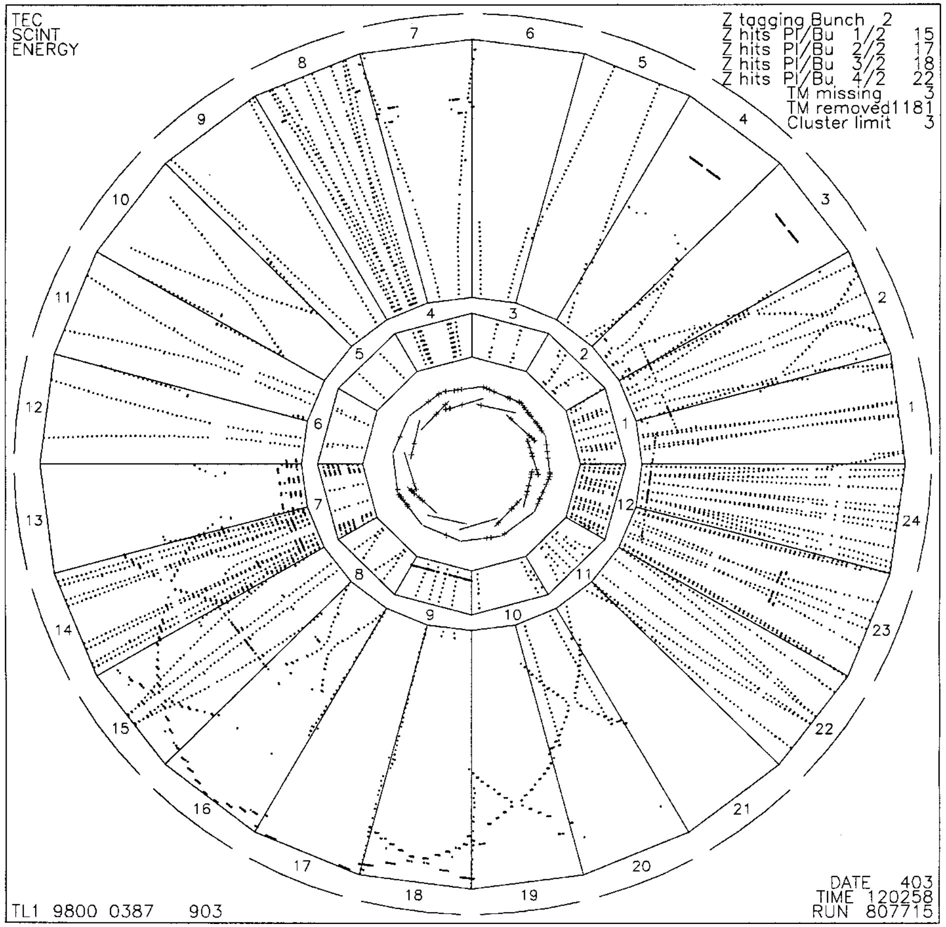

Z ⟶ μ+μ−

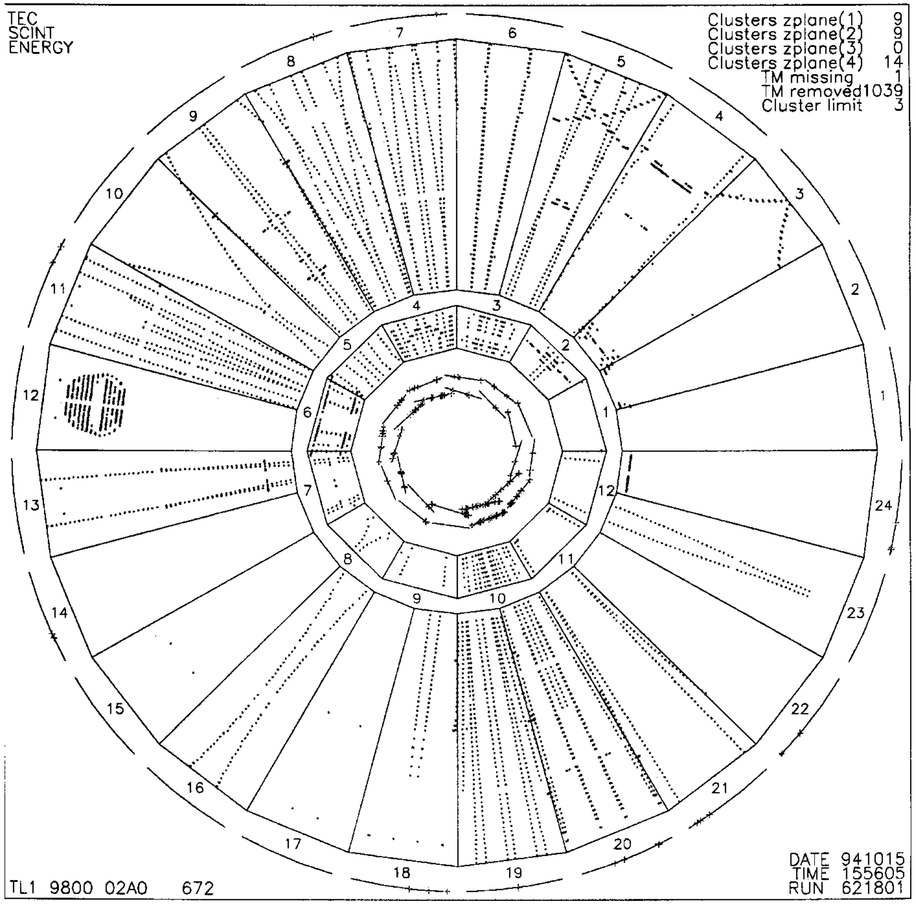
**Di−muon and di−electron events have been used for TEC calibration.**

**During the high energy LEP runs each year there were special Z runs for calibration just before the start and at the end of the data taking period.**

**The left−right ambiguity for most of the tracks is resolved by "track matching" between inner and outer TEC**

# Jet raw data events (Online)

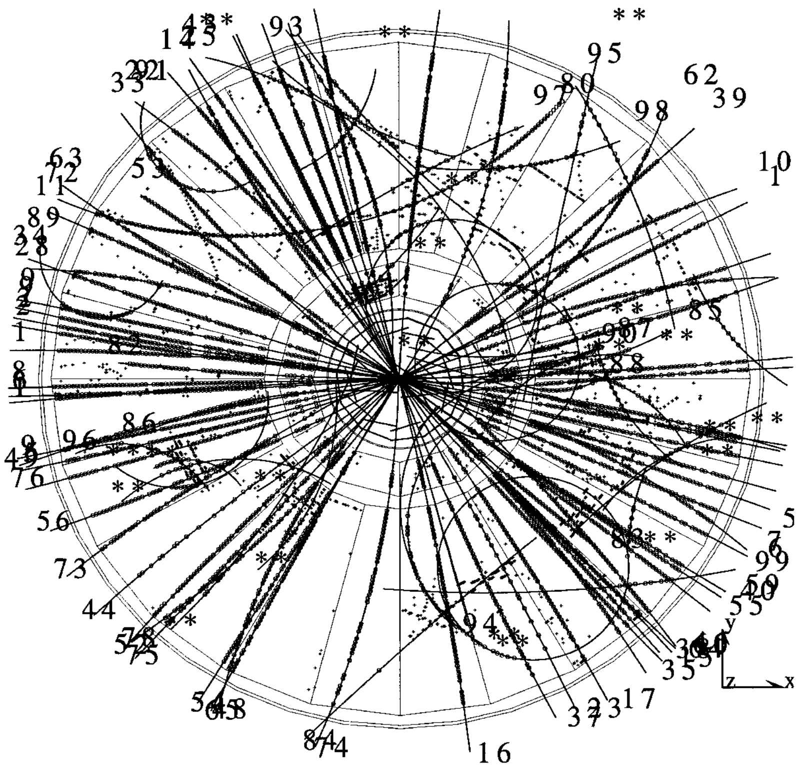



**Due to the trigger and low background conditions at LEP the reconstruction and event identification was straightforward.**

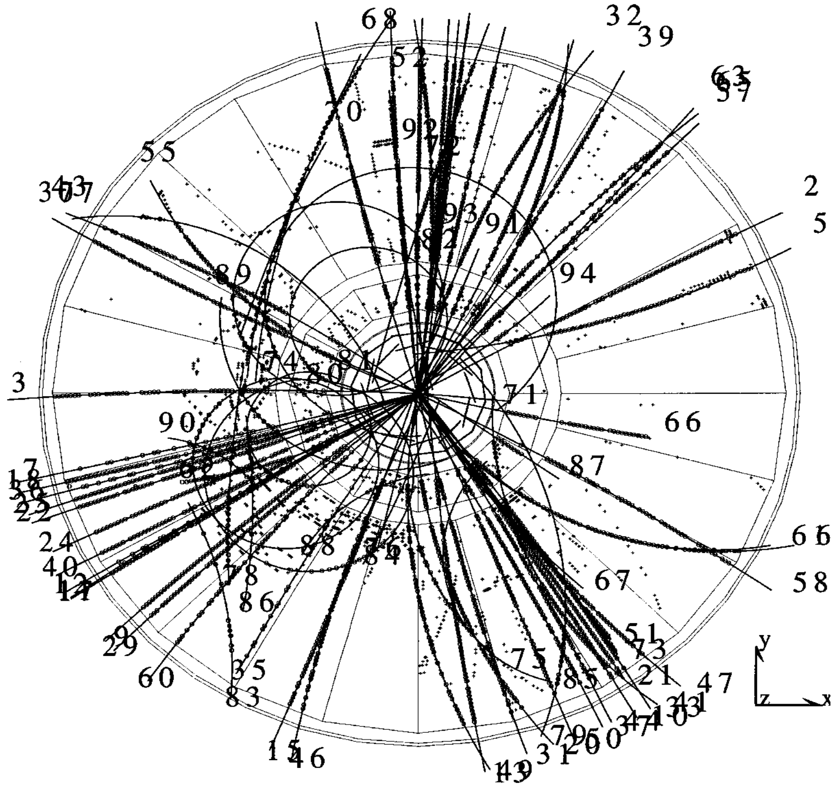
# *Two multi−jet reconstructed events*

**Run #** **713409** **Event #** **1841** Total Energy : 132.38 GeV



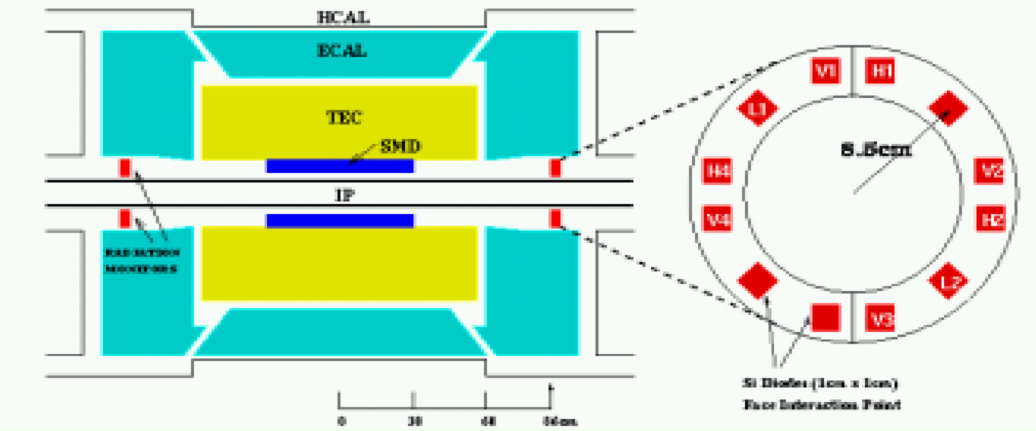
| | | | | | |
|---|---|---|---|---|---|
| **Transverse Imbalance :** | .0797 | | **Longitudinal Imbalance :** | -.1742 | |
| **Thrust :** | .7446 | **Major :** | .4736 | **Minor :** | .2588 |
| **Event DAQ Time :** | *980808 105142* | | | | |

**Run #** **725508** **Event #** **4386** Total Energy : 148.88 GeV

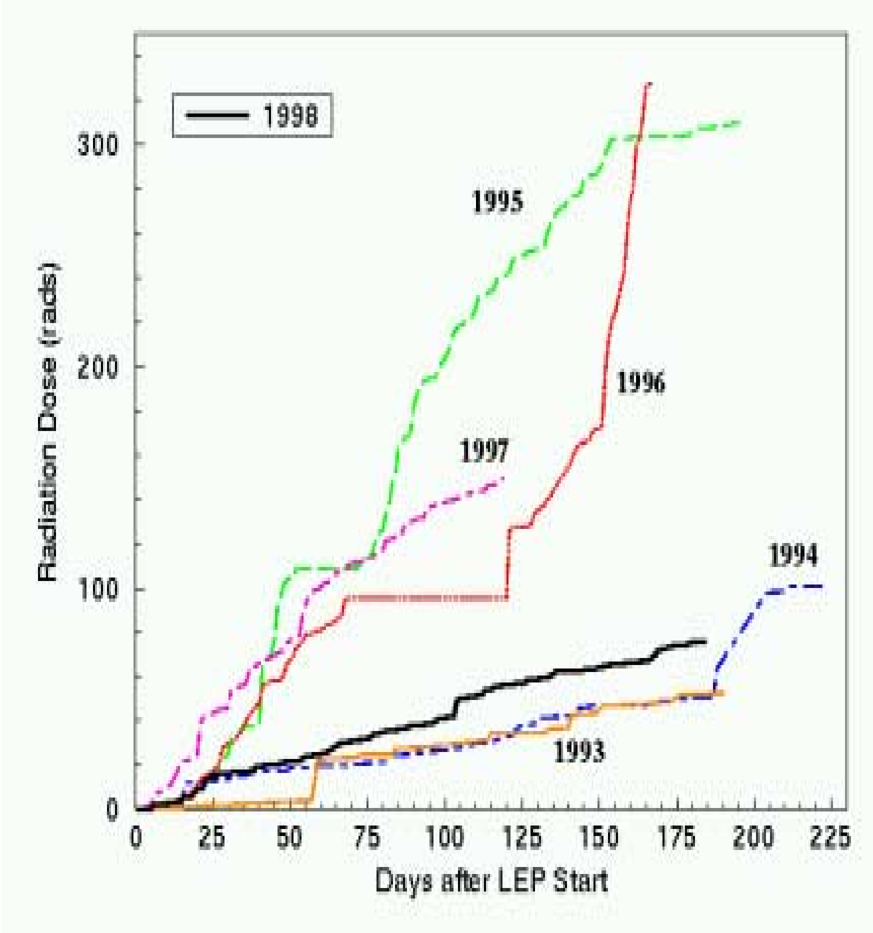


| | | | | | |
|---|---|---|---|---|---|
| **Transverse Imbalance :** | .1230 | | **Longitudinal Imbalance :** | -.0493 | |
| **Thrust :** | .6875 | **Major :** | .5791 | **Minor :** | .2087 |
| **Event DAQ Time :** | *980926 133412* | | | | |

# Radiation and backgrounds at LEP−P2




*The layout and position of the L3 radiation monitor*

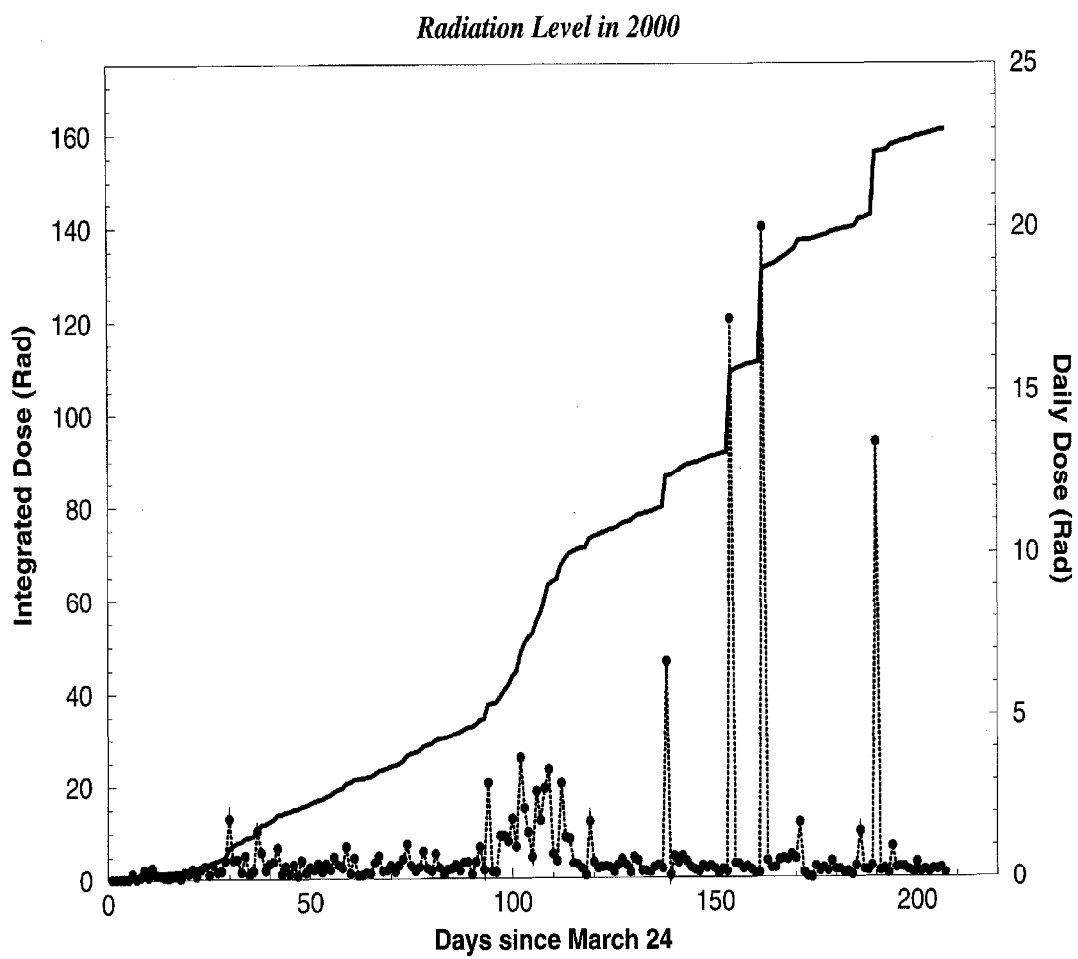



*The integrated dose at LEP−P2 in 1993−1998*

**The integrated radiation dose for 11 years in the central region of L3 is estimated to about 2300 rad.**

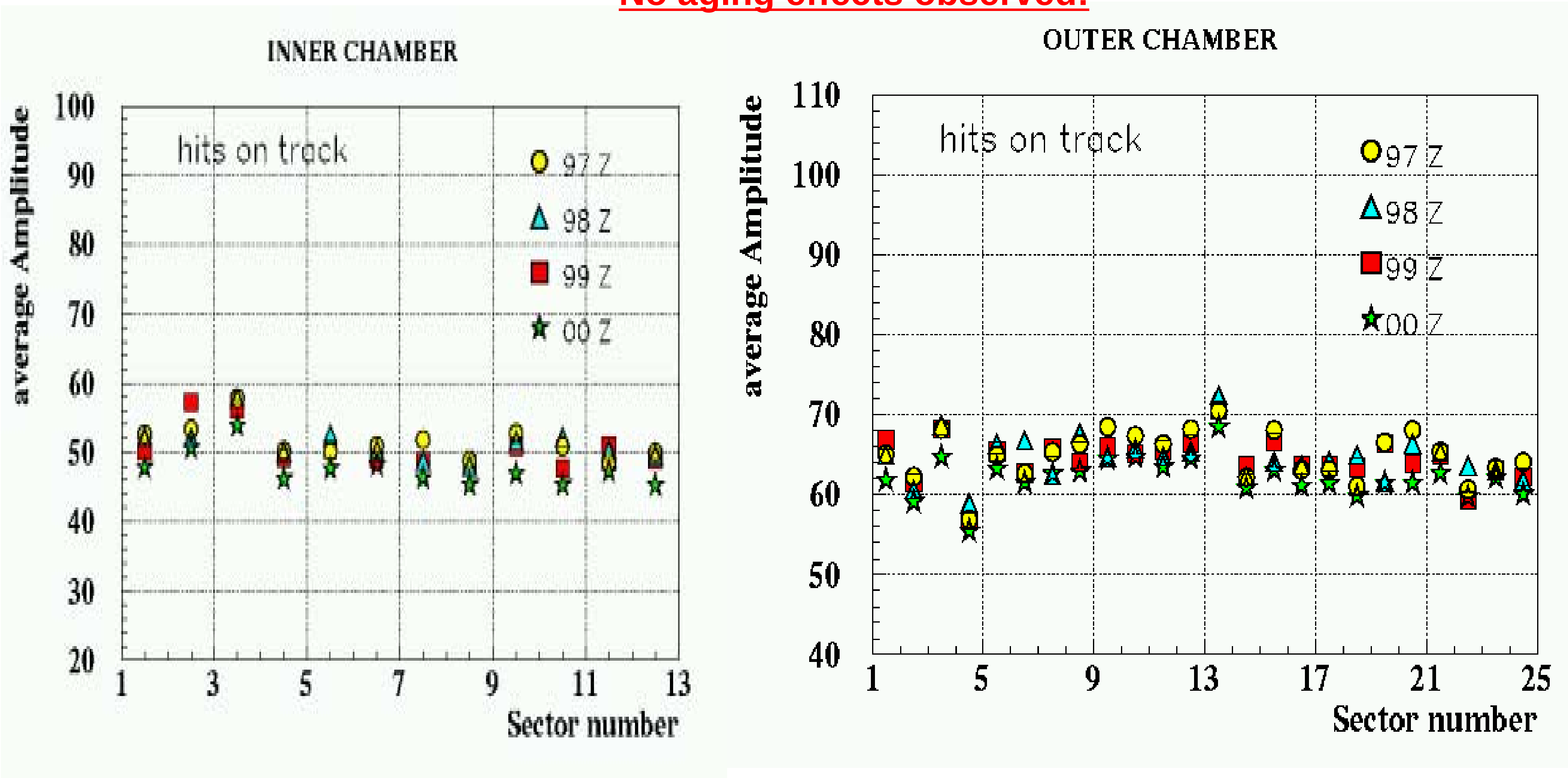
**The radiation received on the anode wires, estimated from their integrated counting and track rates, the initial number of electrons from the acceptance region (~30) and gas amplification (~50000) is ~ $10^{-4}$ C/cm.**

# Radiation and backgrounds at LEP−P2



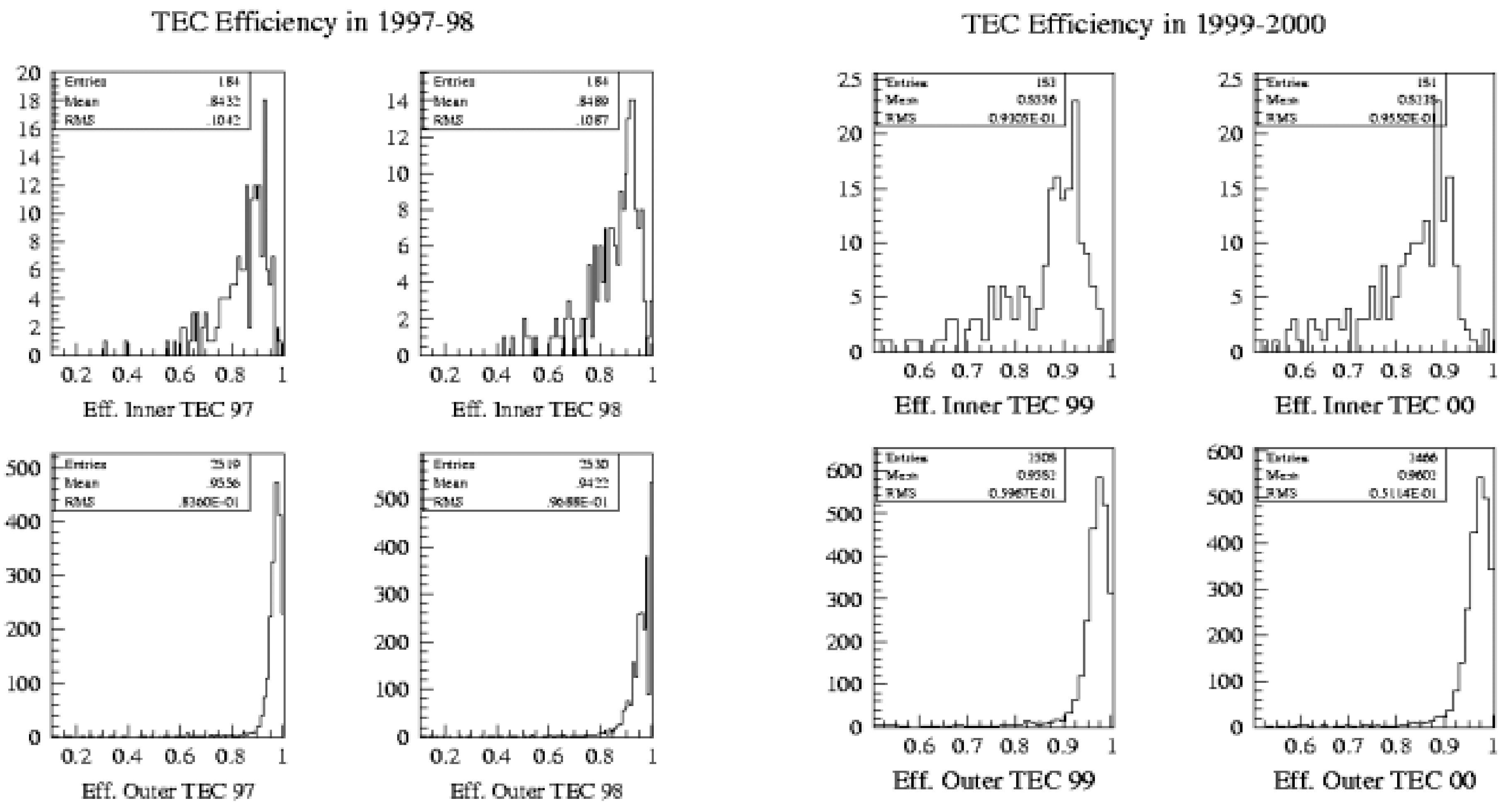
# TEC pulse amplitude

**No aging effects observed!**




**The anode pulse amplitudes in inner and outer TEC sectors remain unchanged during the whole period of 11 years running the detector at LEP.**

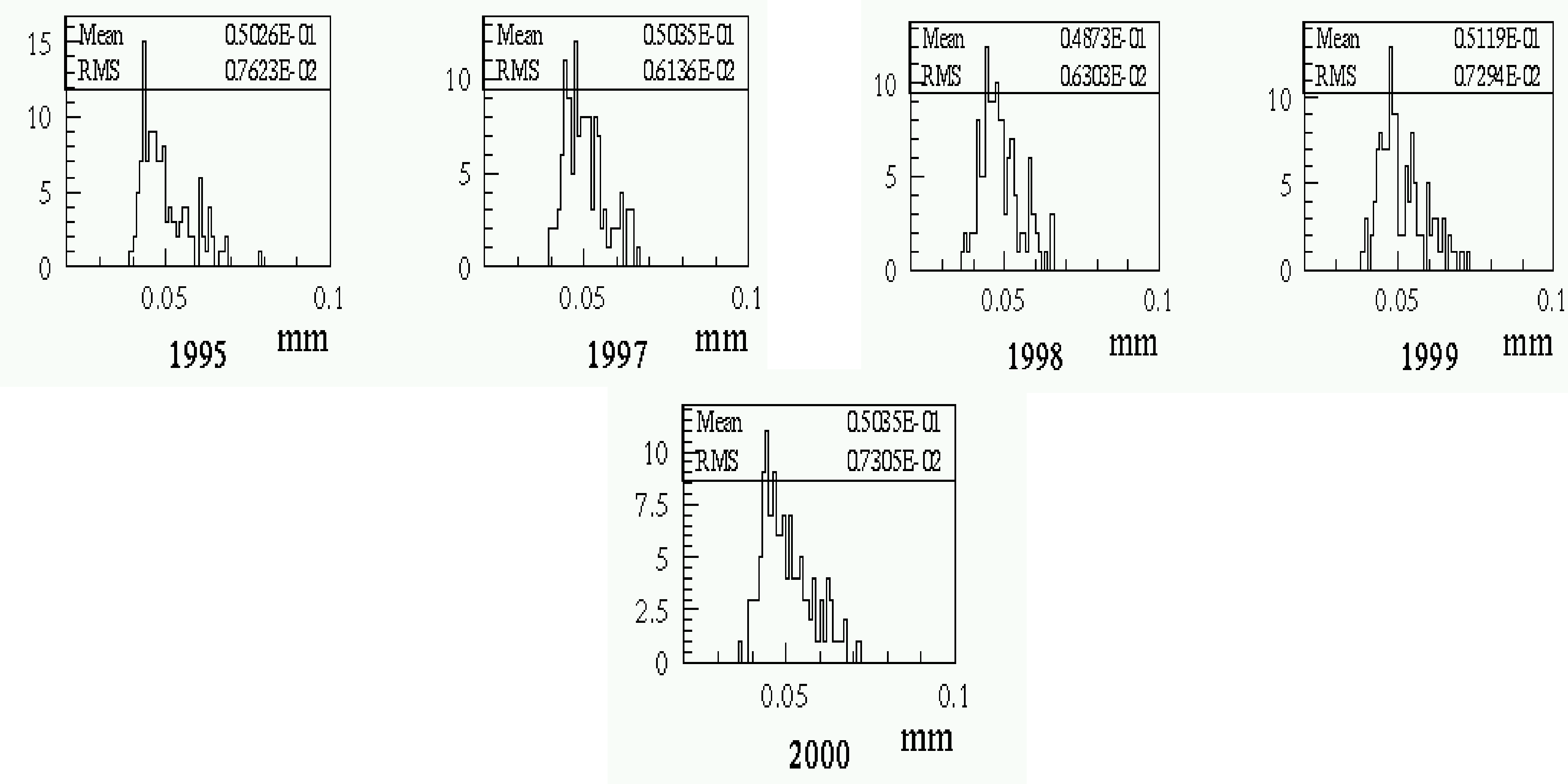
# Single wire efficiency 1977−2000




**The single wire efficiency for all TEC sectors remained constant.**

# Single wire resolution 1995 − 2000

TEC Single Wire Resolution at 10 mm




**No degradation of the single wire resolution was observed.**

**Mean value for whole running period : 50 μm.**

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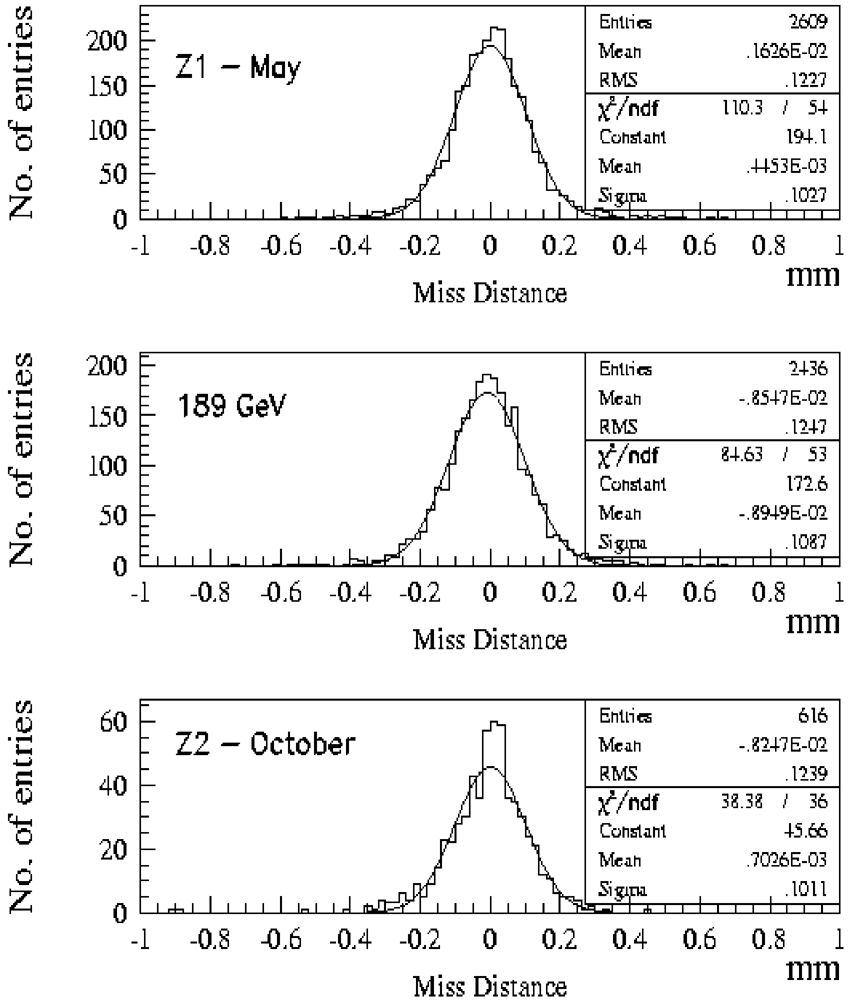
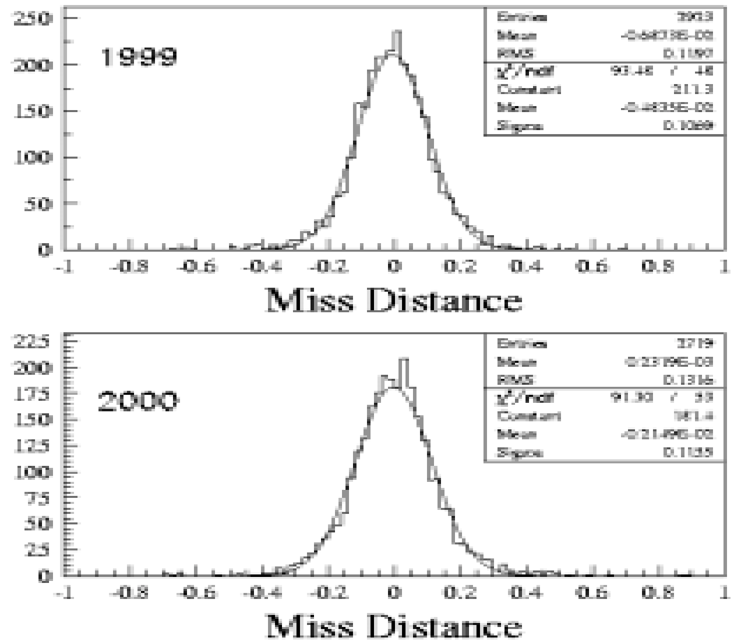
# TEC DCA resolution 1998−2000

TEC DCA Resolution 1998

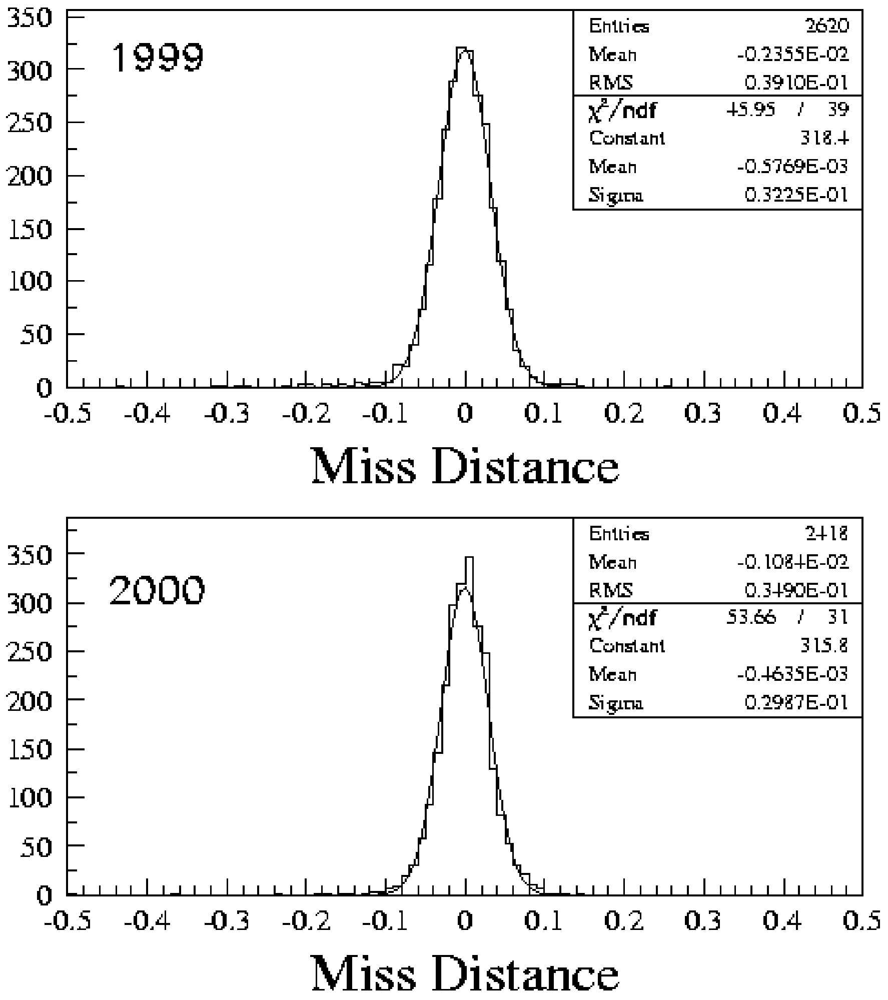



DCA Resolution 2000 - TEC

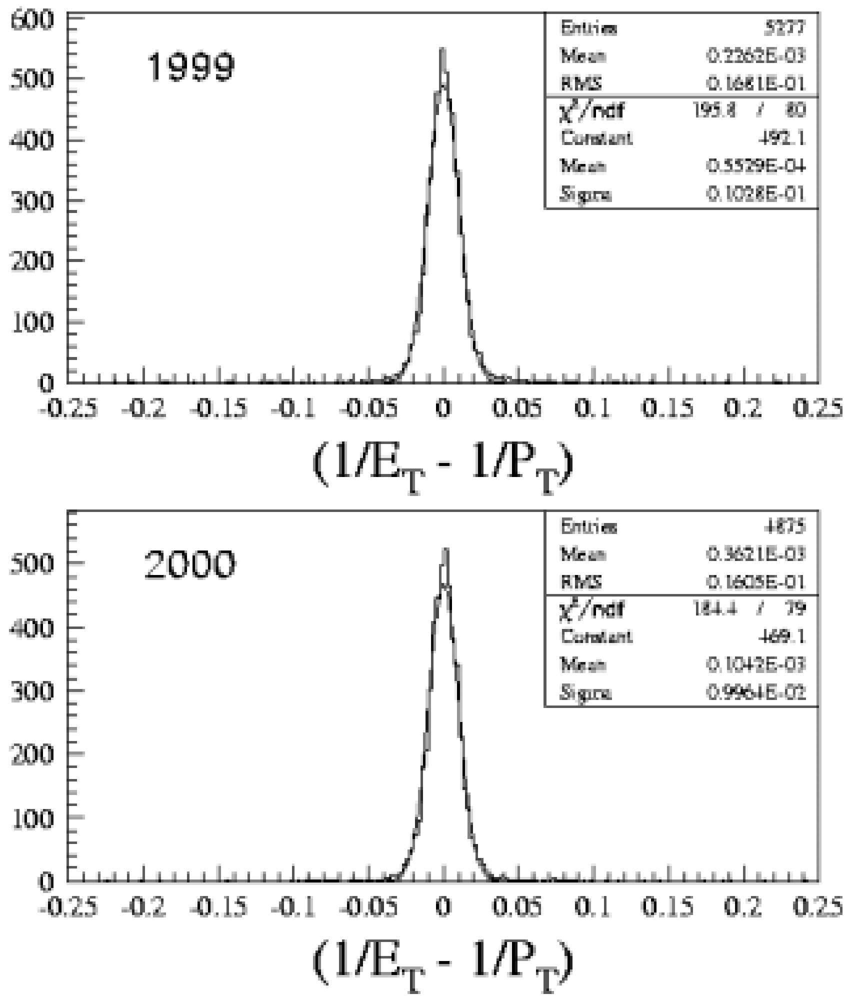


# TEC DCA and pt resolution with SMD

DCA Resolution 2000 - TEC+SMD




1/Pt Resolution 2000 - TEC+SMD



# TEC people

**Construction and Performance of the L3 Central Tracking Detector**

**TEC paper submitted to NIM:**

F. Beissel, A. Böhm, K. Bosseler, C. Camps, V. Commichau, M. Deutschmann, H. Frohn, D. Jansen, P.Göttlicher, J. Grooten, K. Hangarter, U. Herten, H. Liebmann, J. Mnich, M. Möller, R. Pahlke, W. Reuter, N. Rieb, U. Rinsche, S. Röhner, J. Rose, K. Quadflieg, P. Schmitz, R. Schulte, S. Schulte, K. Schultze, T. Spickermann, R. Starosta, H. Szczesny, M Sassowsky, M. Tonutti, H. Virnic T. Winands
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# Summary

- A drift chamber, based on the Time Expansion principle has been designed, build and used in the period 1990−2000 as a Vertex track detector of L3 Experiment at LEP.
- The Chamber has the following main characteristics:

| | |
|---|---|
| Single wire resolution | 50 μm |
| Double track resolution | 500 μm |
| Vertex (DCA) resolution | 125 μm |

Transverse momentum resolution $dp_t / p_t^2 = (2.06 \pm .06).10^{-2} (GeV/c)^{-1}$

- As a result of the chamber design and maintenance of the infrastructure (gas system, HV−system, temperature system) the drift velocity stability and thereby the Time−to−Space relations were kept during the whole running period of TEC at a level of 0.1%.
- No indication of aging has been observed in the whole period of running,
- The data from the L3 Time Expansion Chamber have played essential role in all results from the L3 Experiment.