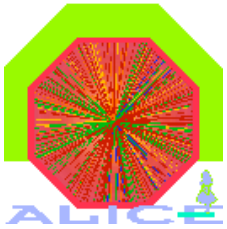


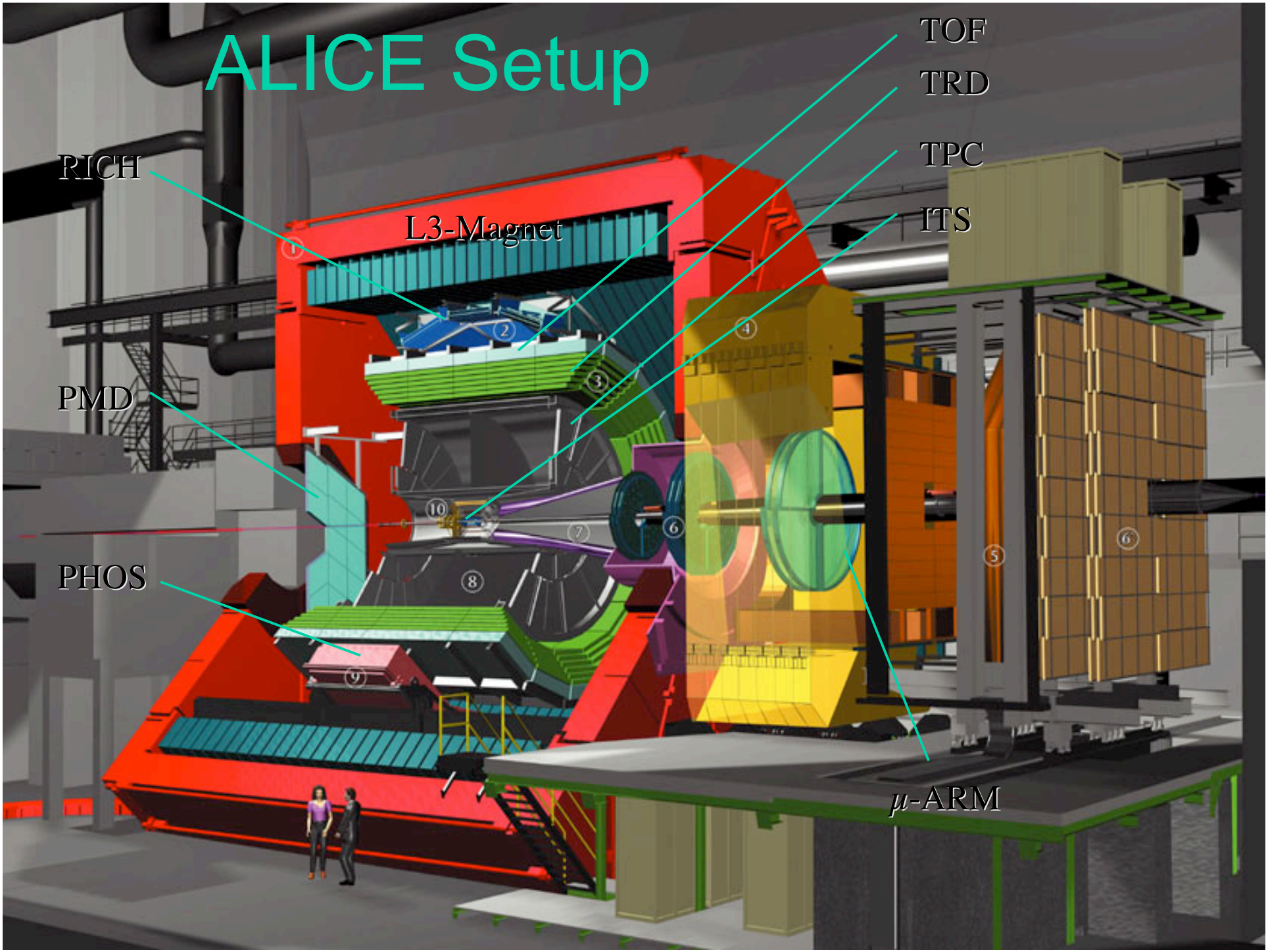
The ALICE TPC
– an innovative device for heavy ion collisions at LHC

bmb+f - Förderschwerpunkt
ALICE
Großgeräte der physikalischen Grundlagenforschung

Bergen, Bratislava, CERN, Copenhagen, Krakow, Darmstadt TU, Darmstadt GSI, Frankfurt, Heidelberg, Lund

Outline:

- **Introduction**
- **Problems and Solutions**
- **TPC parts and their status**
  - **Field cage**
  - **Readout chambers**
  - **Frontend electronics**
  - **Performance**
- **Outlook**


ALICE Setup
TOF
TRD
TPC
ITS
RICH
L3-Magnet
PMD
PHOS
μ-ARM

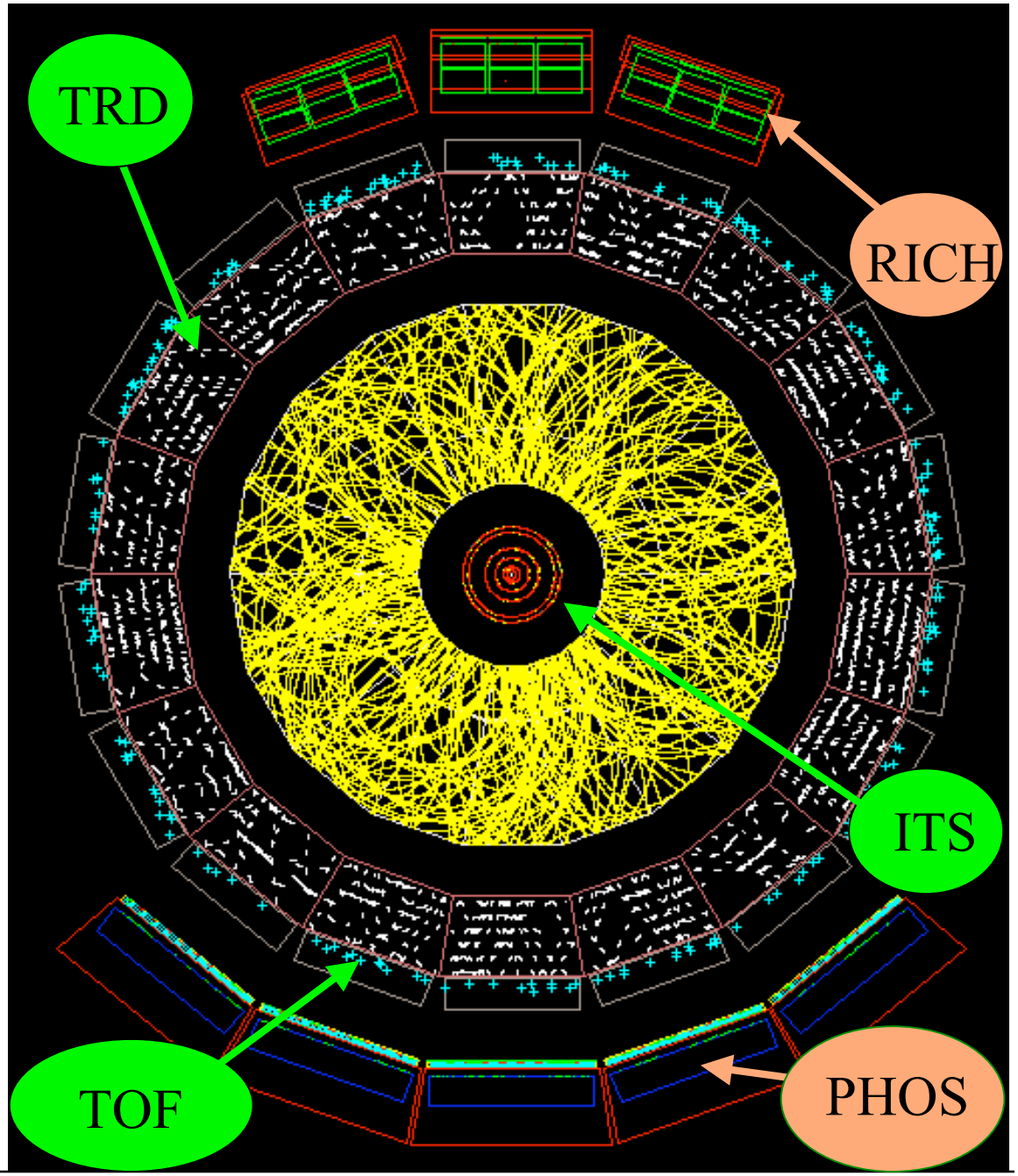
Central event Pb-Pb

@ dN/dy = 8000

- □□ = 2° slice only!

A challenge for

- occupancy
- dE/dx
- tracking
- space charge



The Challenge

- High multiplicity
  - space charge limitations
  - occupancy: large r_{min}
  - optimize track recognition pad sizes
  - FEE: pile-up and baseline problems
- Momentum resolution goal dp/p 1%
  - low multiple scattering in structure and gas
  - drift gas Ne/CO_2 90/10
- Event rate
  - max drift time
- dE-resolution for PID

The Solution and the Consequences

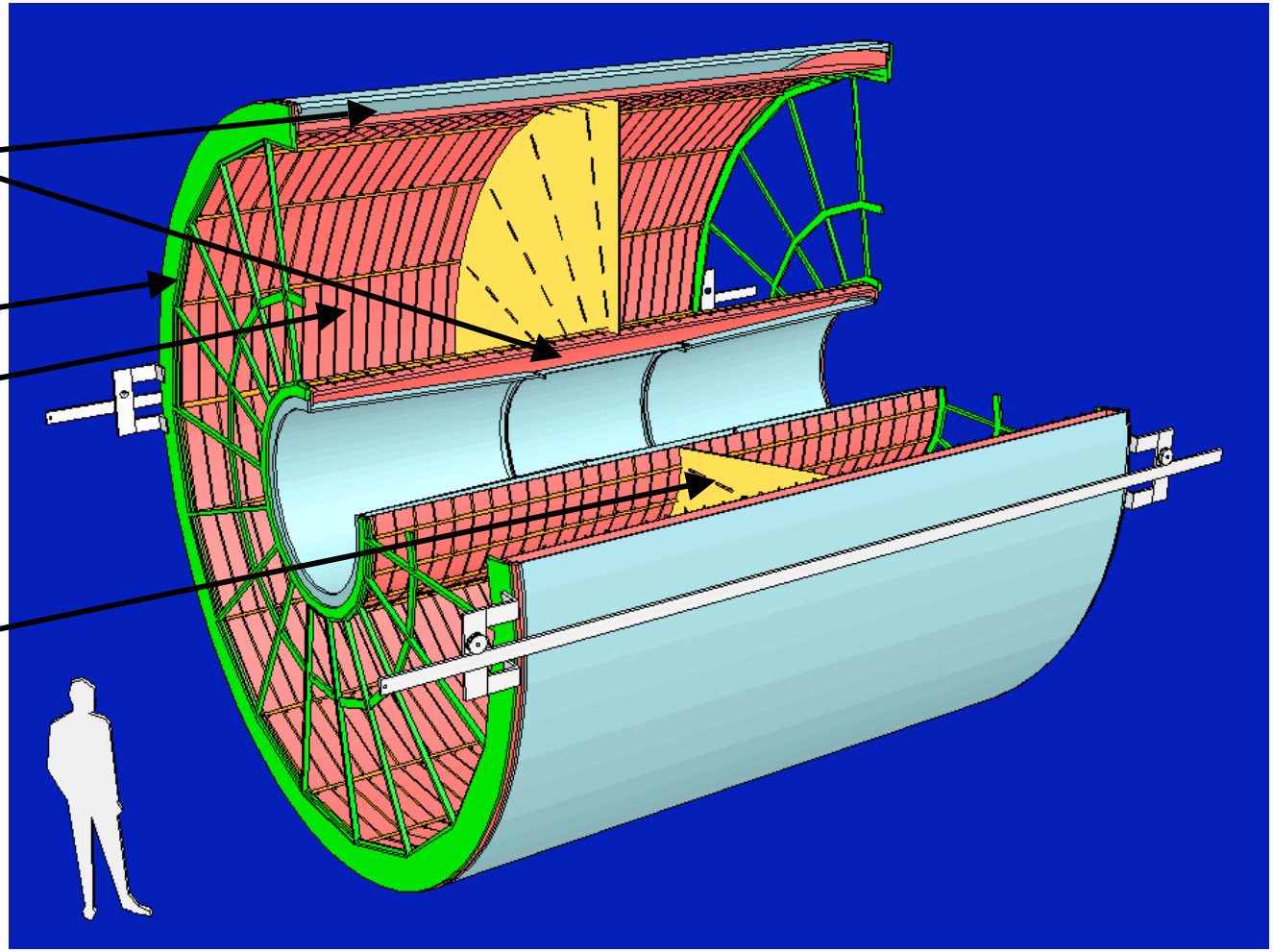
- 'Cold gas', high sensitivity to E and T
  - tolerances $\Delta E/E \leq 10^{-4}$, $\Delta T \leq 0.1$ K
- Low dE/dx: high gas gain needed ($2 \cdot 10^4$ @ 1000 e rms)
- ΔE-resol: 159 samples (= pad rows)
- Minimize FEE channel count:
  - 3 pad sizes: 4 x 7.5, 6 x 10, 6 x 15 mm^2 (pointing to vtx
  - width tuned to pad response function and diffusion
  - $\approx$ 557,568 pad channels
- FEE: digital signal shaping and baseline restoration

TPC Dimensions and Specs

- |□| < 0.9 (full length tracks)
- 845 < r < 2466 mm (cf. STAR: 600 to 1892)
- drift 2 x 2.5 m, 100 kV, 88 □s
- Ne/CO_2 (90/10) (+ probably a few % N_2)
- occupancy 40 to 15% @ dN/dy = 8000
- event rate 100 – 200 Hz
- material budget 3.5 X_0 near □ = 0

TPC Field Cage Overview

- Inner and outer isolation vessels flushed with CO_2
- End plates housing 2x2x18 ROC's
- Field defining system: aluminized mylar strips (166) supported by rods
- Central membrane 100 kV
- 5 x 5.6 m diameter, 88 m^3 volume



Field Cage Assembly

Field Cage Outer Containment Vessel

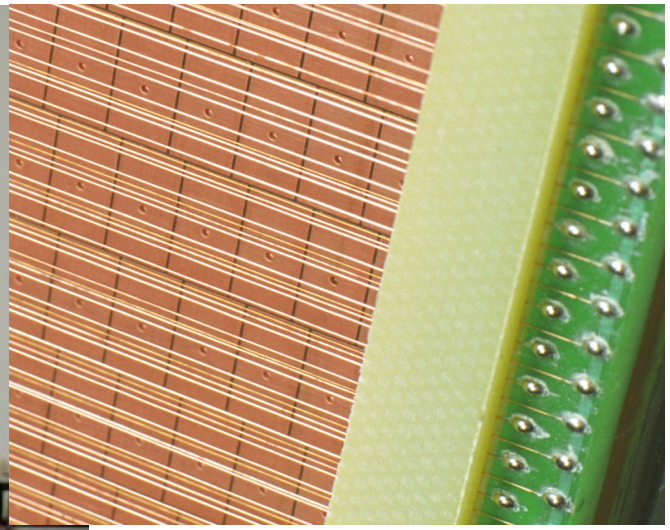
Checking the End Wheel

Field Cage Assembly

Readout Chambers

- 18 sectors each side, 2 chambers/sector
- MWPC's, 557568 cathode pads
- gas gain 2×10^4
- gated
- pad sizes 4x7.5, 6x10, 6x15 mm^2
- 5.7 MHz 10 bit ADC sampling, 512 samples
- position resolution 800 … 1250 □m (r□, z)

Readout Chamber Production Heidelberg/GSI

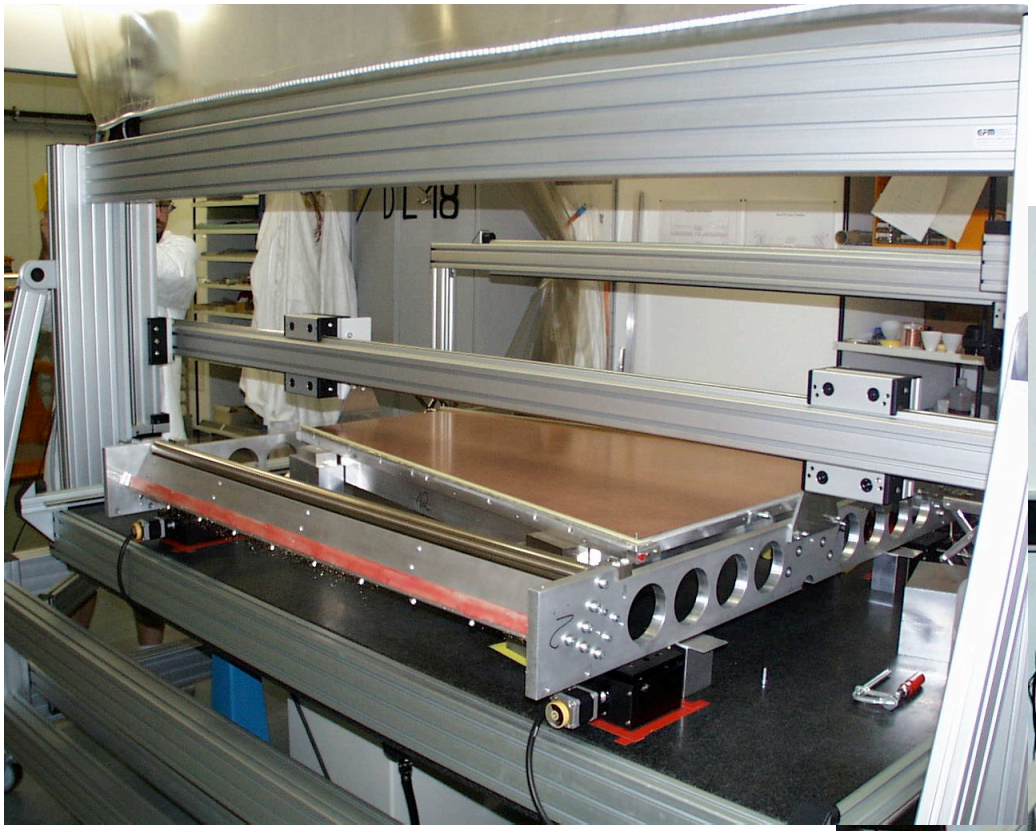


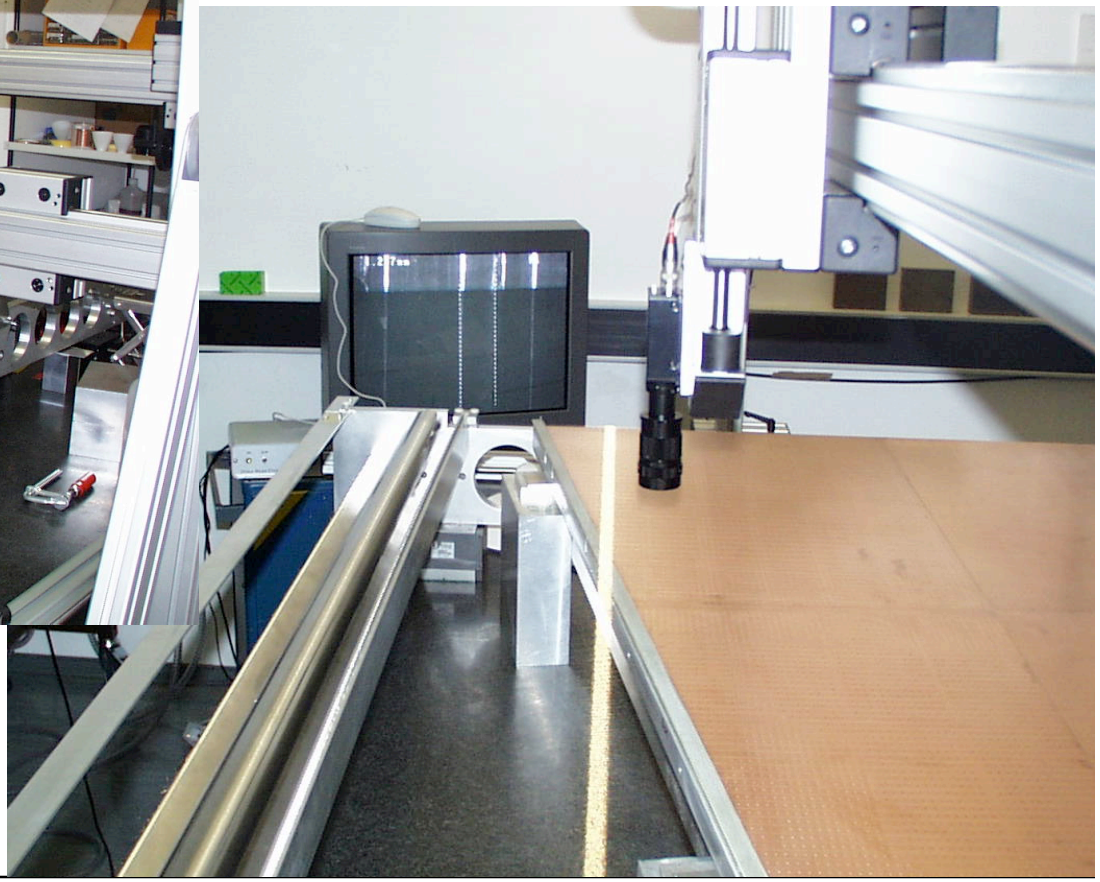
Pads and wires

Adjusting a wire plane before glueing, small chamber type

Readout Chamber Production Heidelberg/GSI

Coarse and fine adjustment of a wire plane, large chamber type

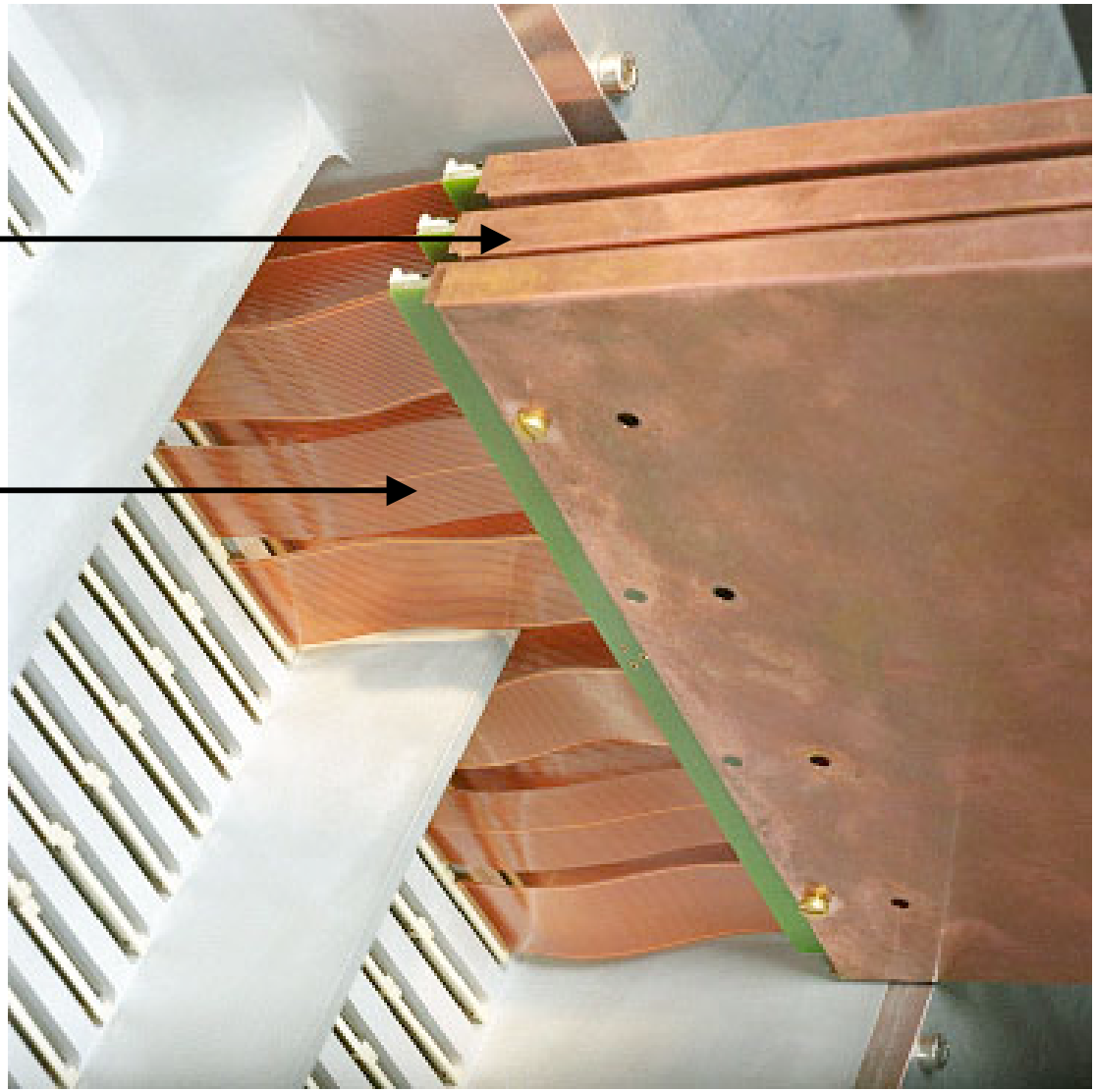




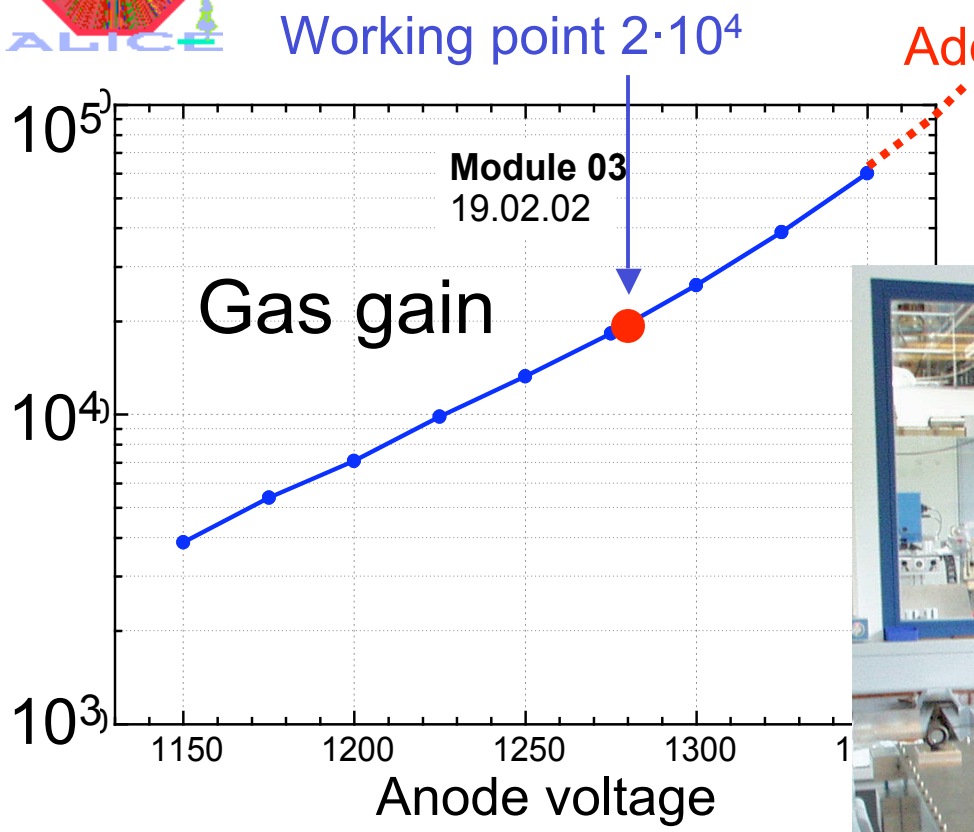
Inner Readout Chamber Connected to Front End Card

FEC in Cu sandwich

6 cables per FEC



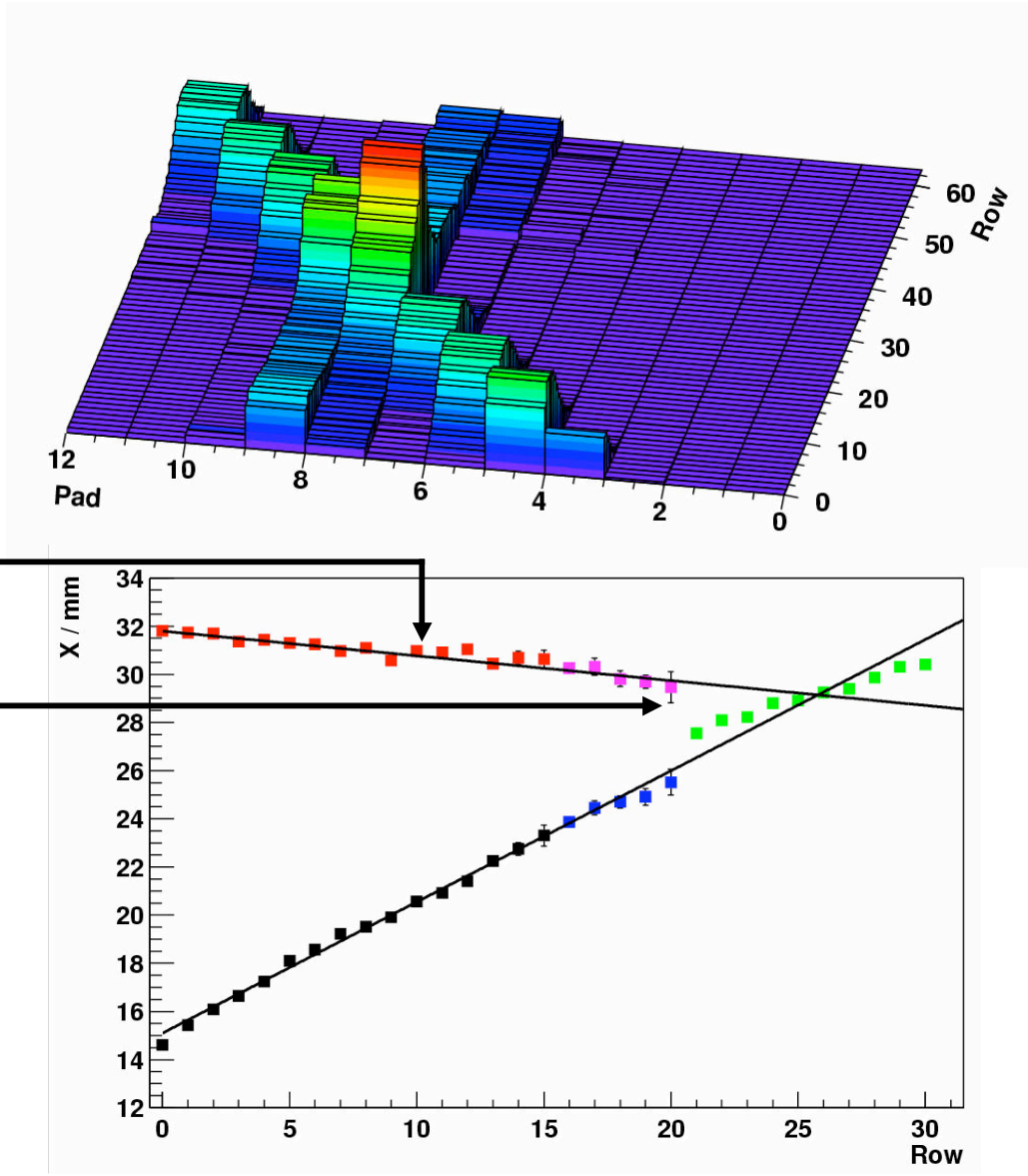
Readout Chamber Test at GSI



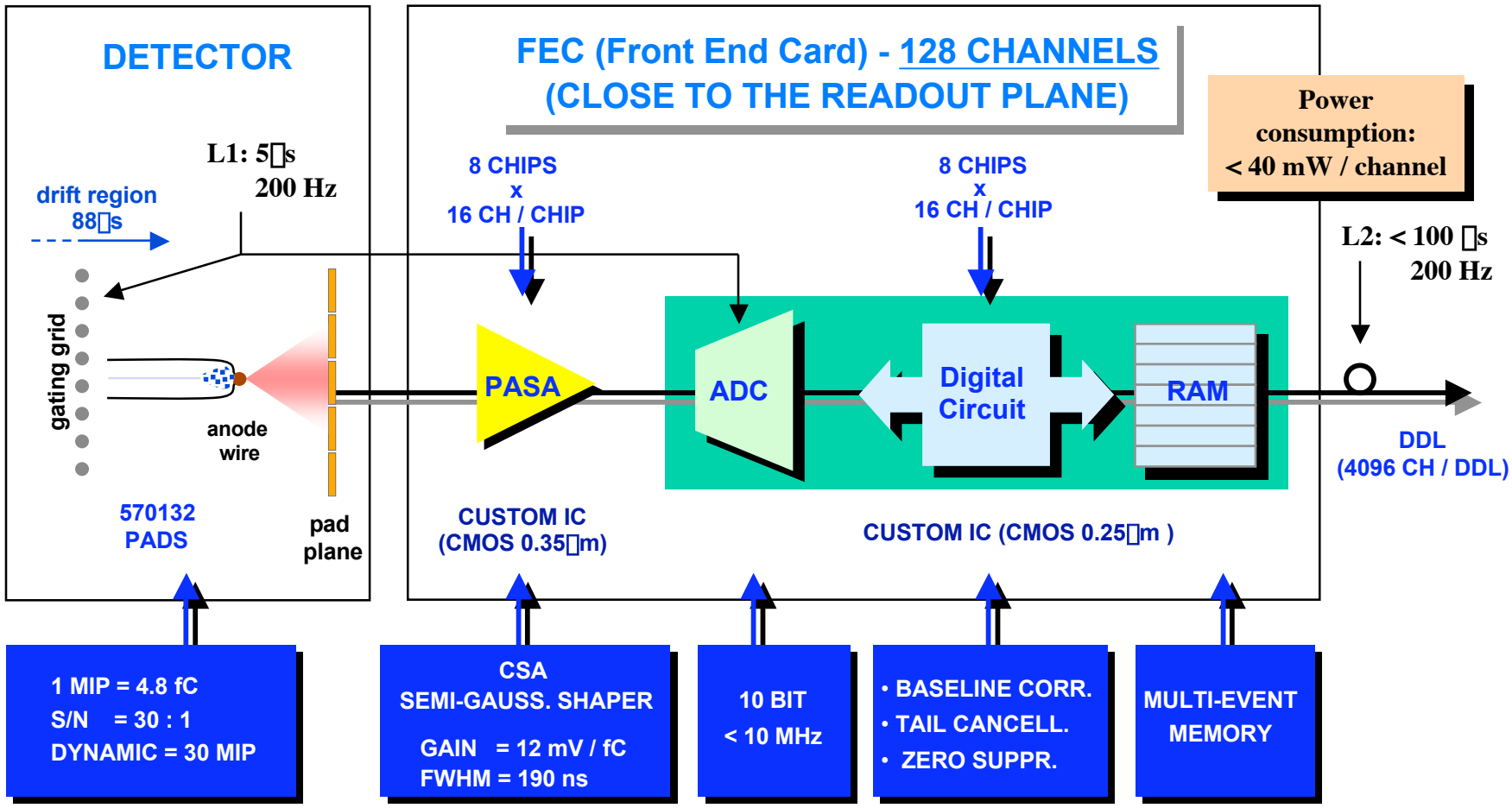
Chamber in test setup

Laser Tracks

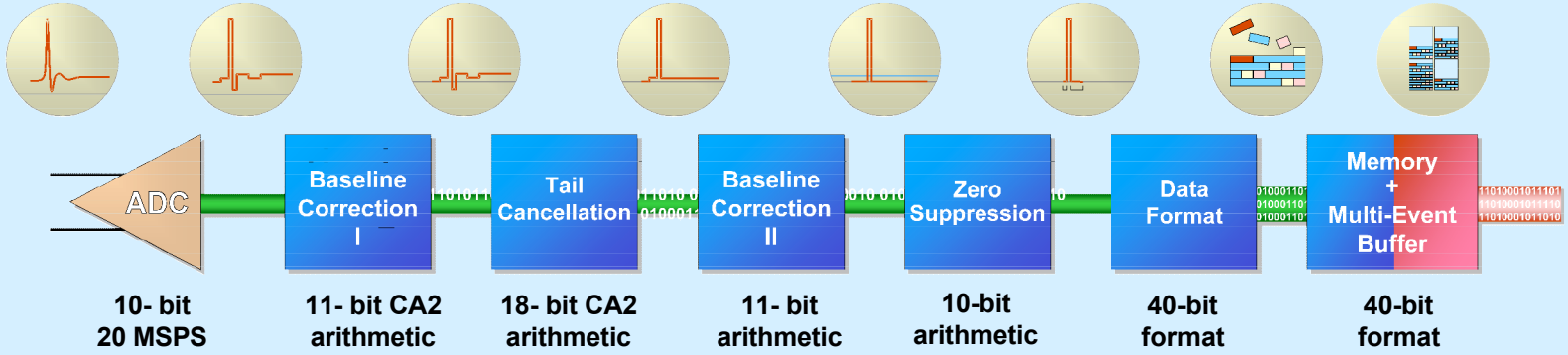
- Pad response function
  □ = 2 mm as expected
- Double track resolution:
  - Separated maxima down to two pad distance
  - Two-gauss fit down to 1 pad



Frontend Electronics: Architecture



ALICE TPC READOUT CHIP – Principle



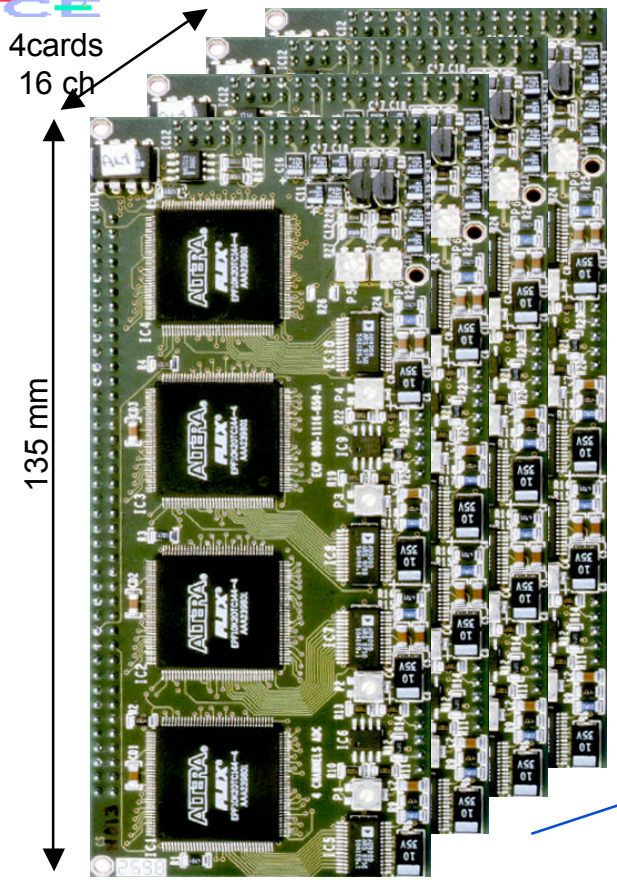
SAMPLING CLOCK up to 20 MHz (5.7 MHz used)

READOUT CLOCK 40 MHz

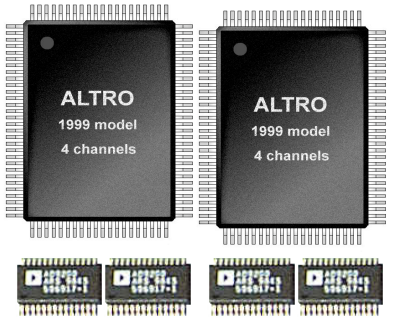
- 16 ADCs and Digital Filter channels in one chip
- Algorithms and parameters reconfigurable

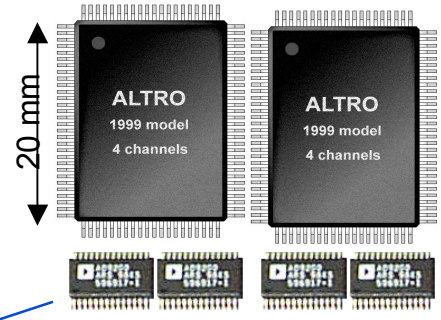
ALTRO Prototyping, a long story

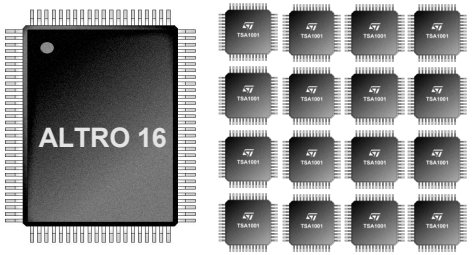
Driving force: Luciano Musa



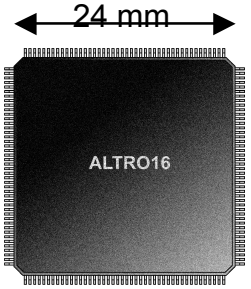
4 PQFP 100
8 SSOP 28







External ADCs (fallback solution)



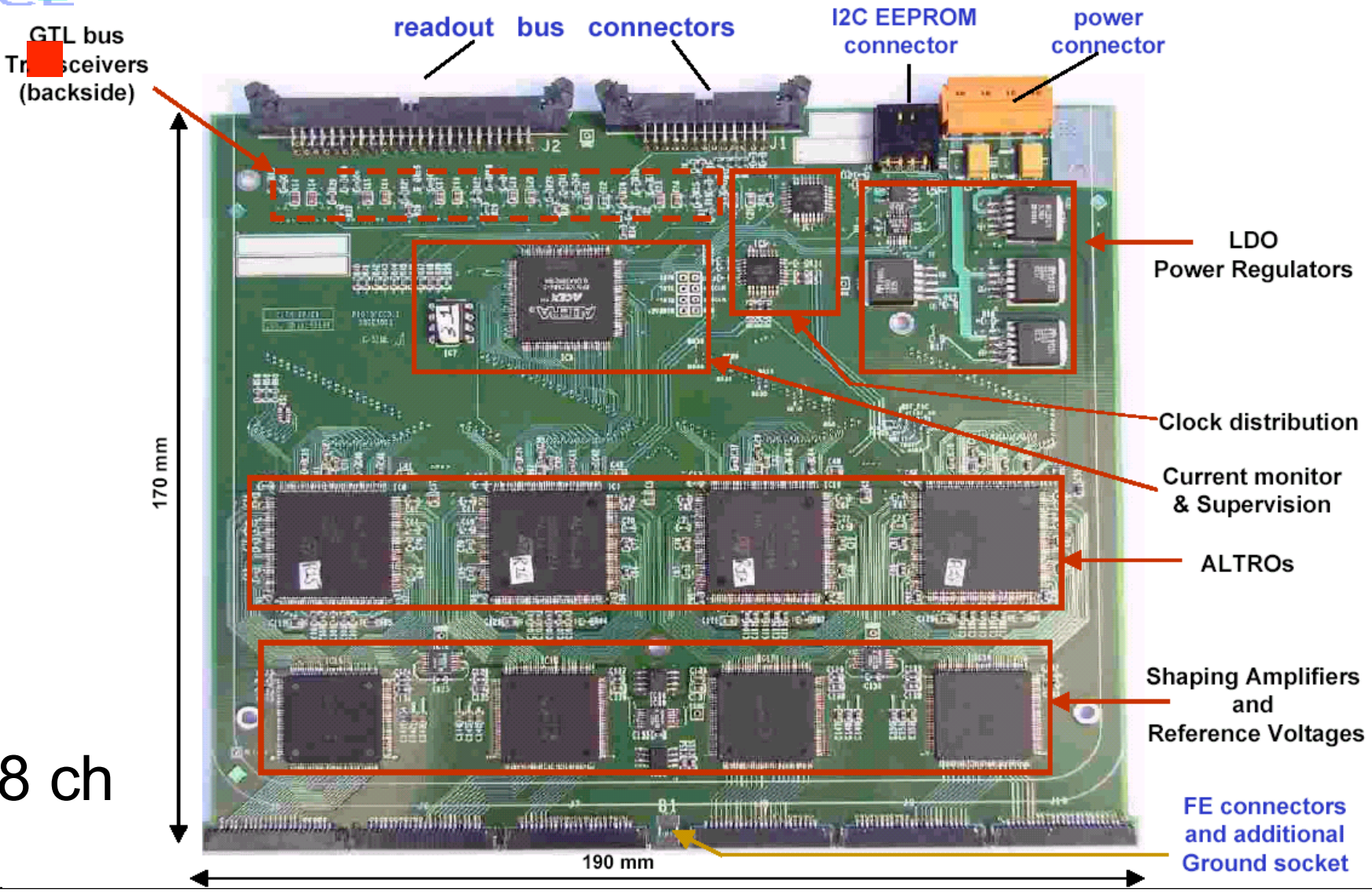
Integrated ADCs

1998
channels per chip: 1
ADC: 1 external
Digital Filter: no

1999
channels per chip: 4
ADC: 4 external
Digital Filter: no

2001
channels per chip: 16
ADC: 16 internal
Digital Filter: yes

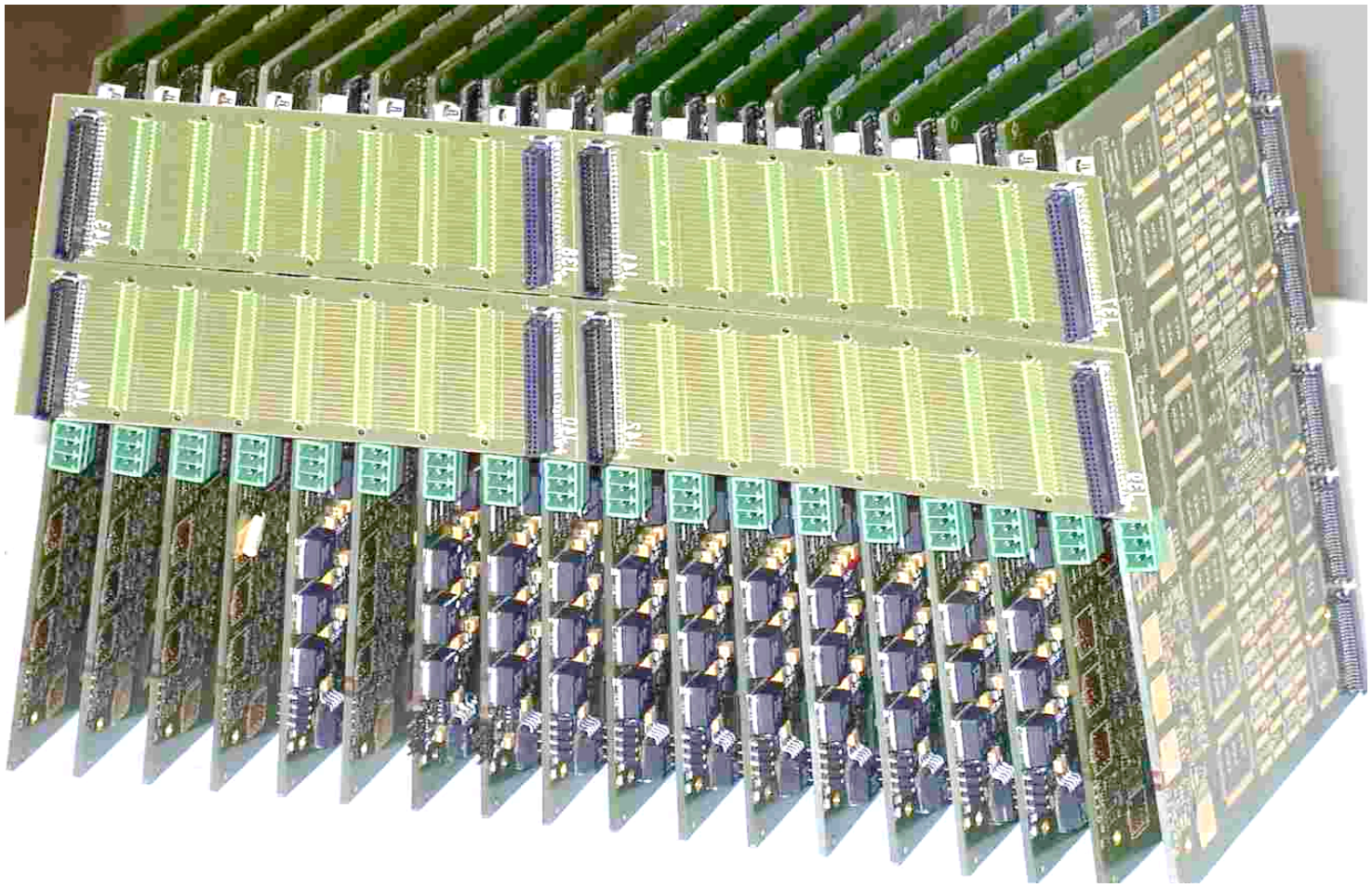
Front-end Card



128 ch

FEE Row with Readout Bus

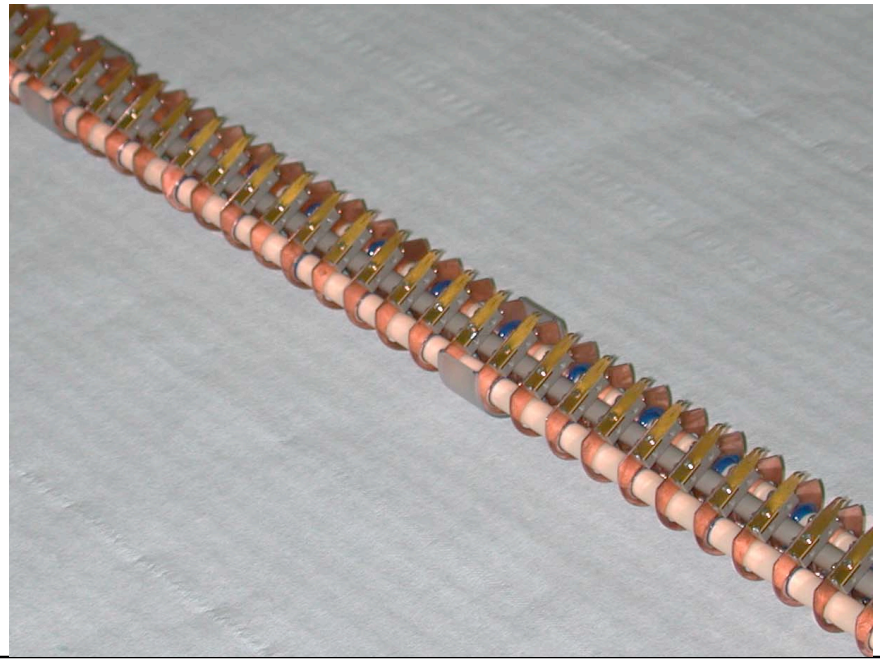
- Innermost row, closest spacing



Cooling:
Temperature Stabilization and Homogeneity

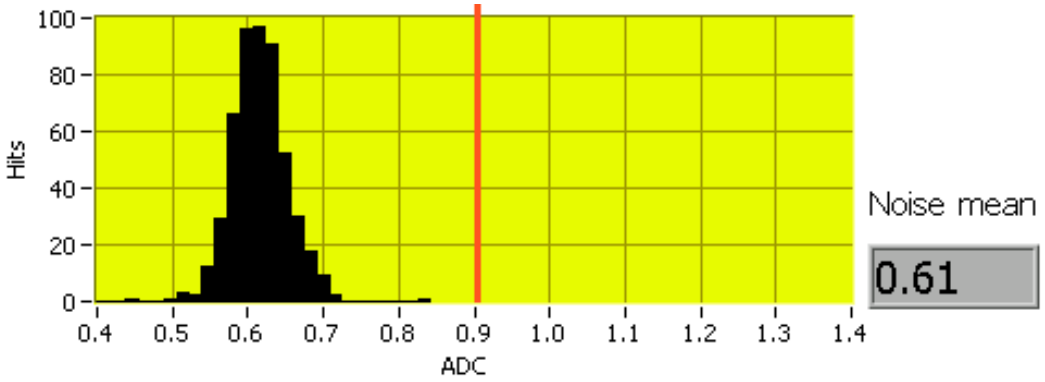
- Clearly a challenging item: we aim at **□T □ 0.1 K**
- Thermal screens toward TRD and ITS
- Readout chamber Al bodies and pad planes: water-cooled
- Water cooling of FEE boards (total power 27 kW)
- Leakless cooling systems

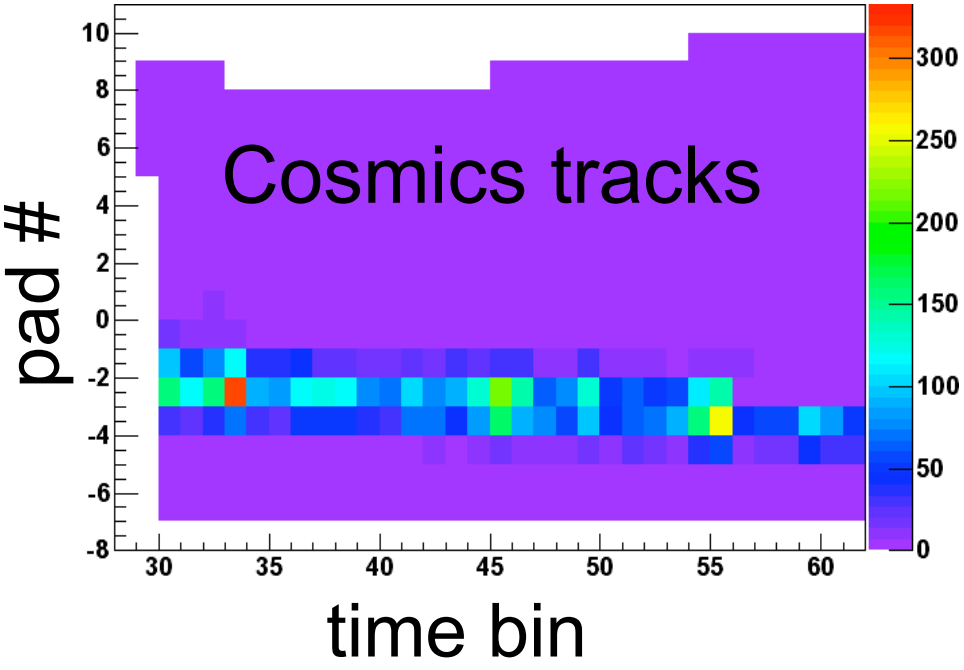
HV resistive divider rod:
4 x 8 W,
water-cooled

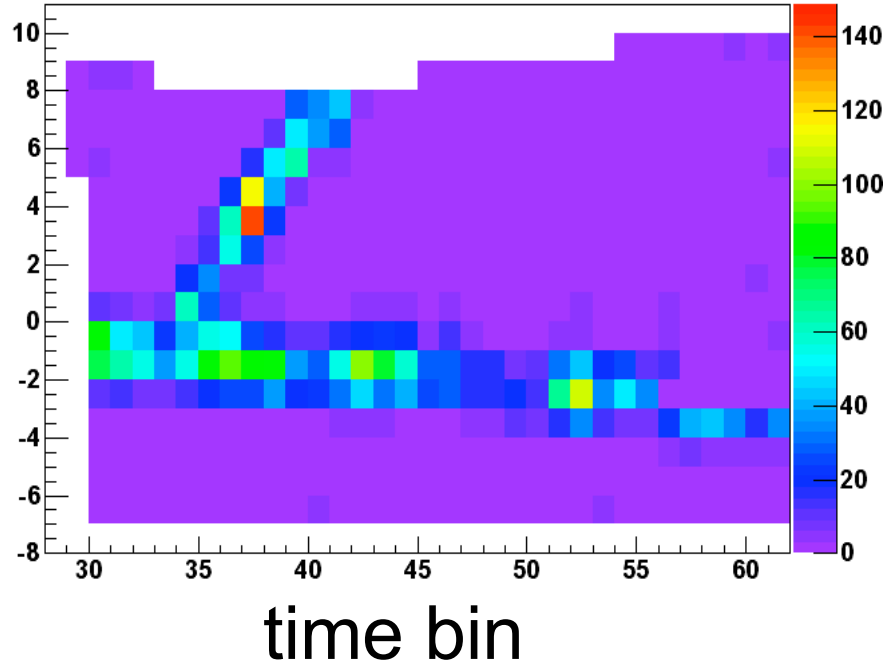


TPC test facility measurements

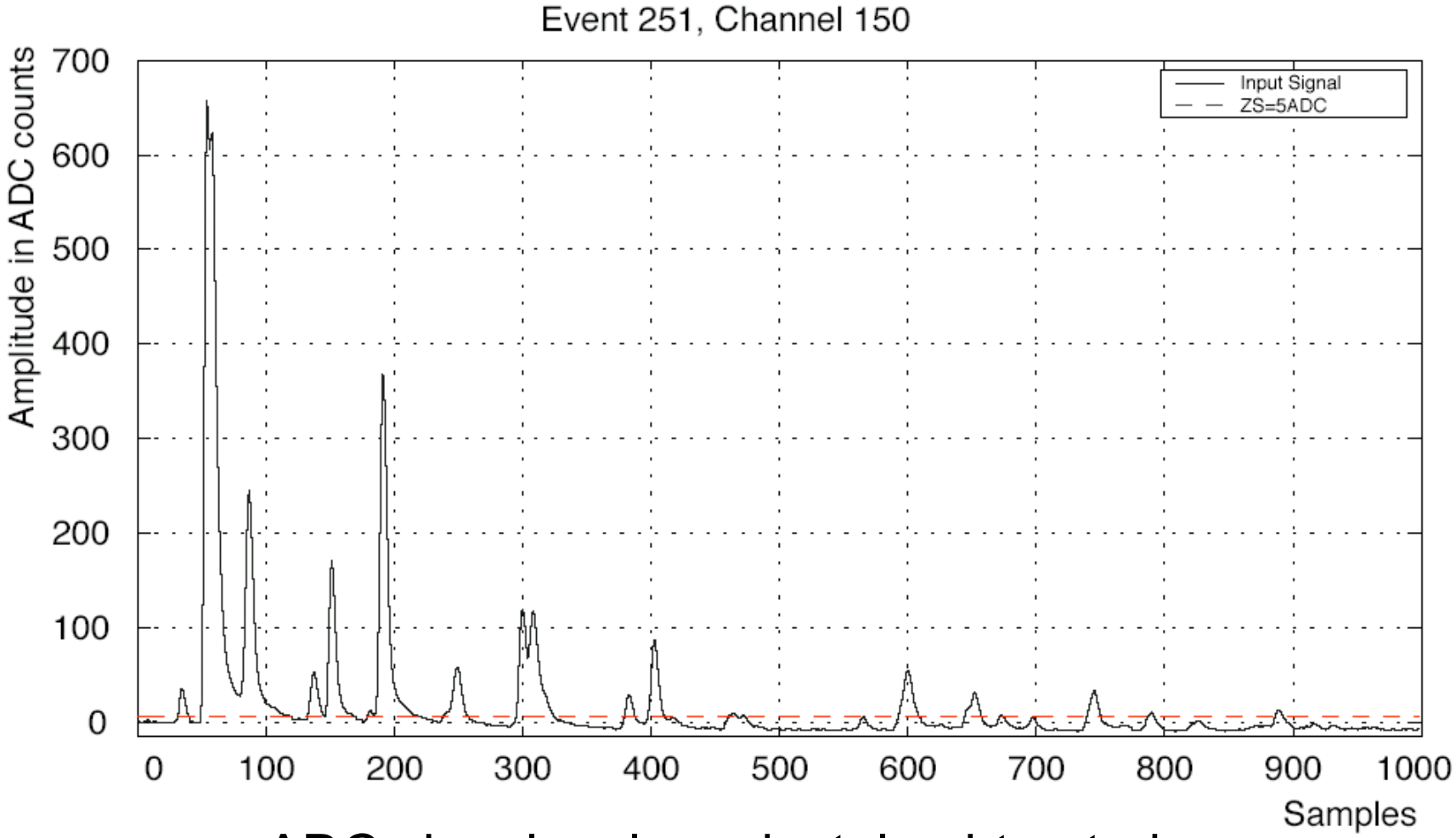
rms noise statistics, mean 700 e





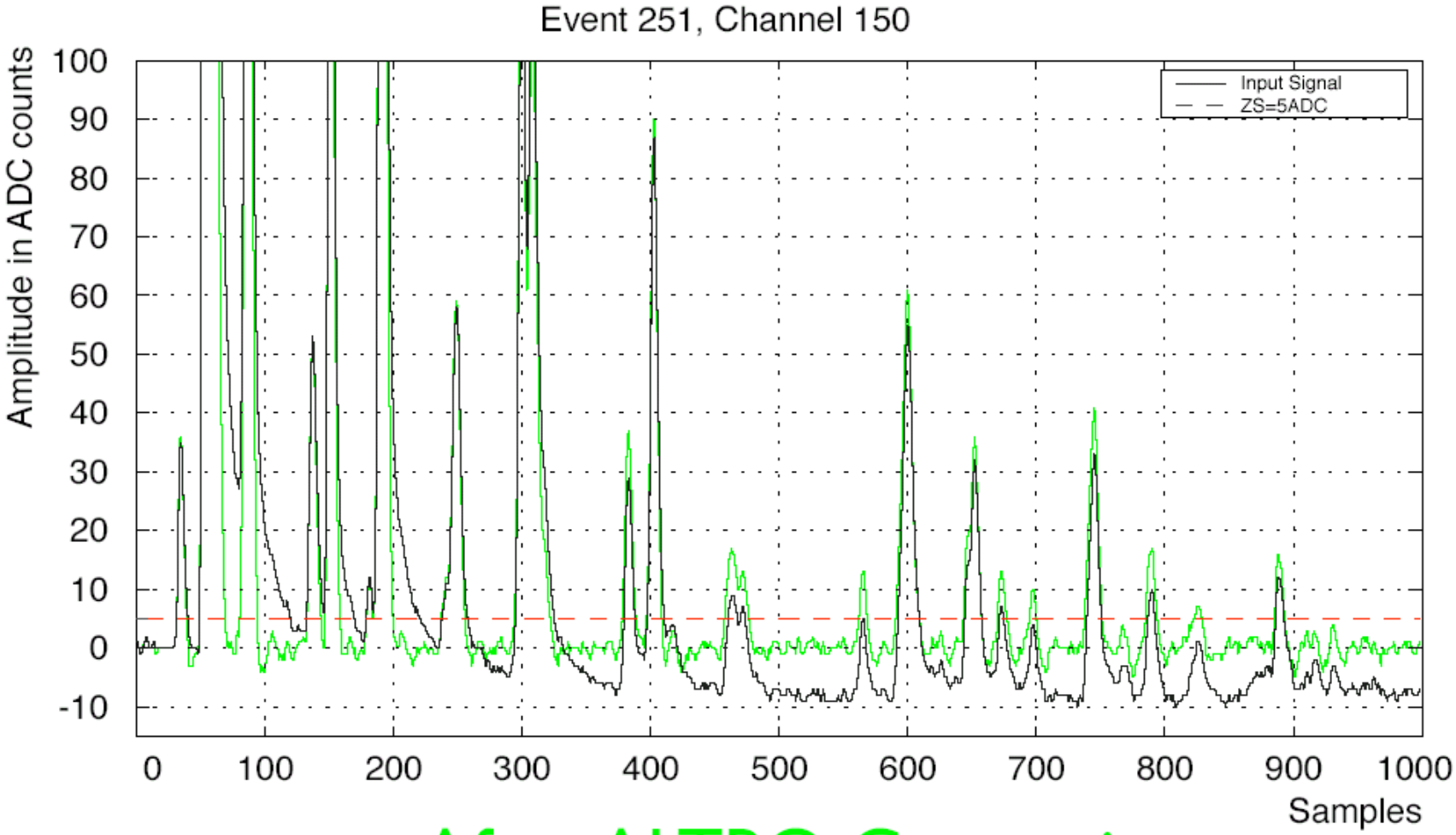


High Occupancy Events from Cosmic Rays

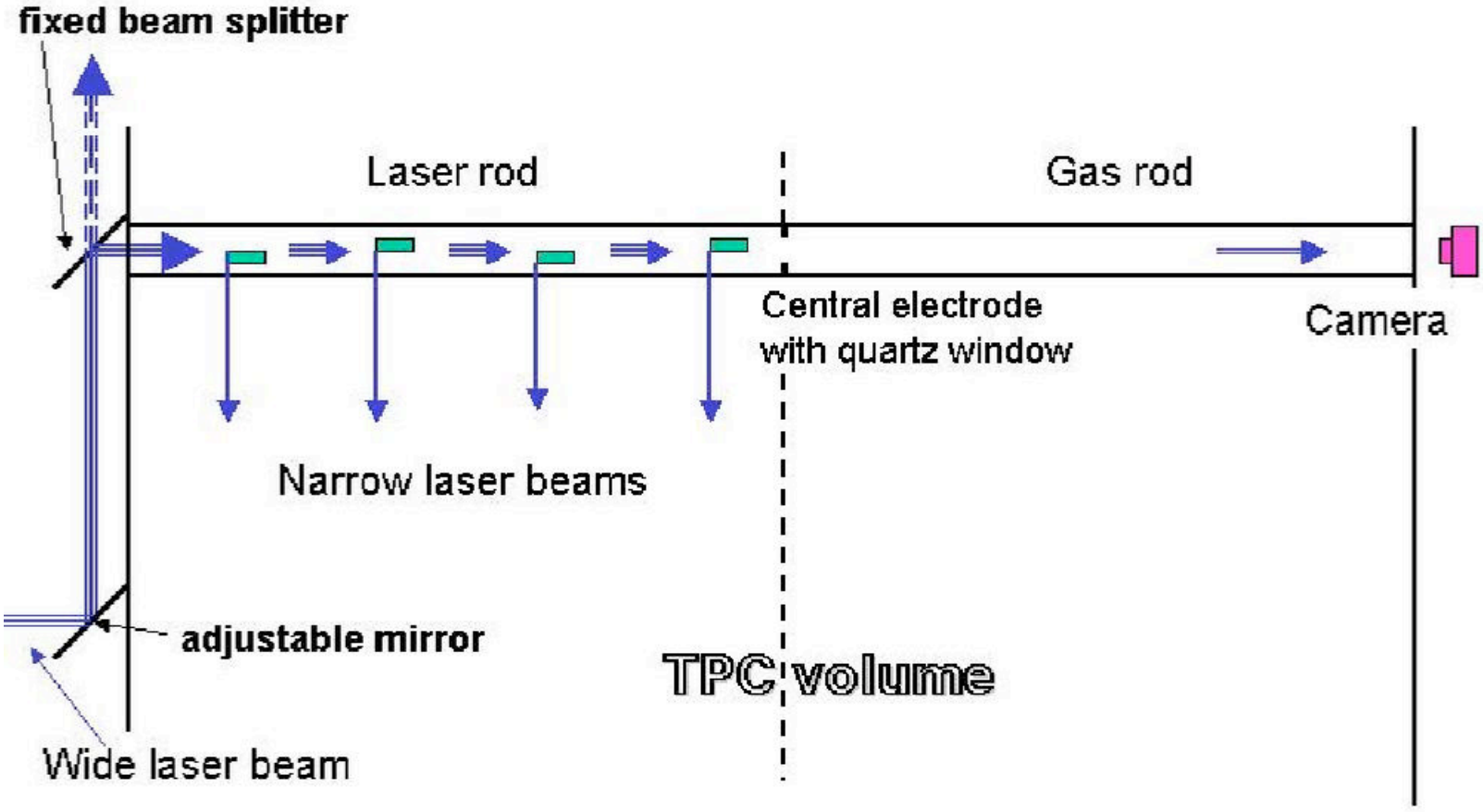


ADC signal, only pedestal-subtracted

ALTRO digital tail cancellation and baseline restoration



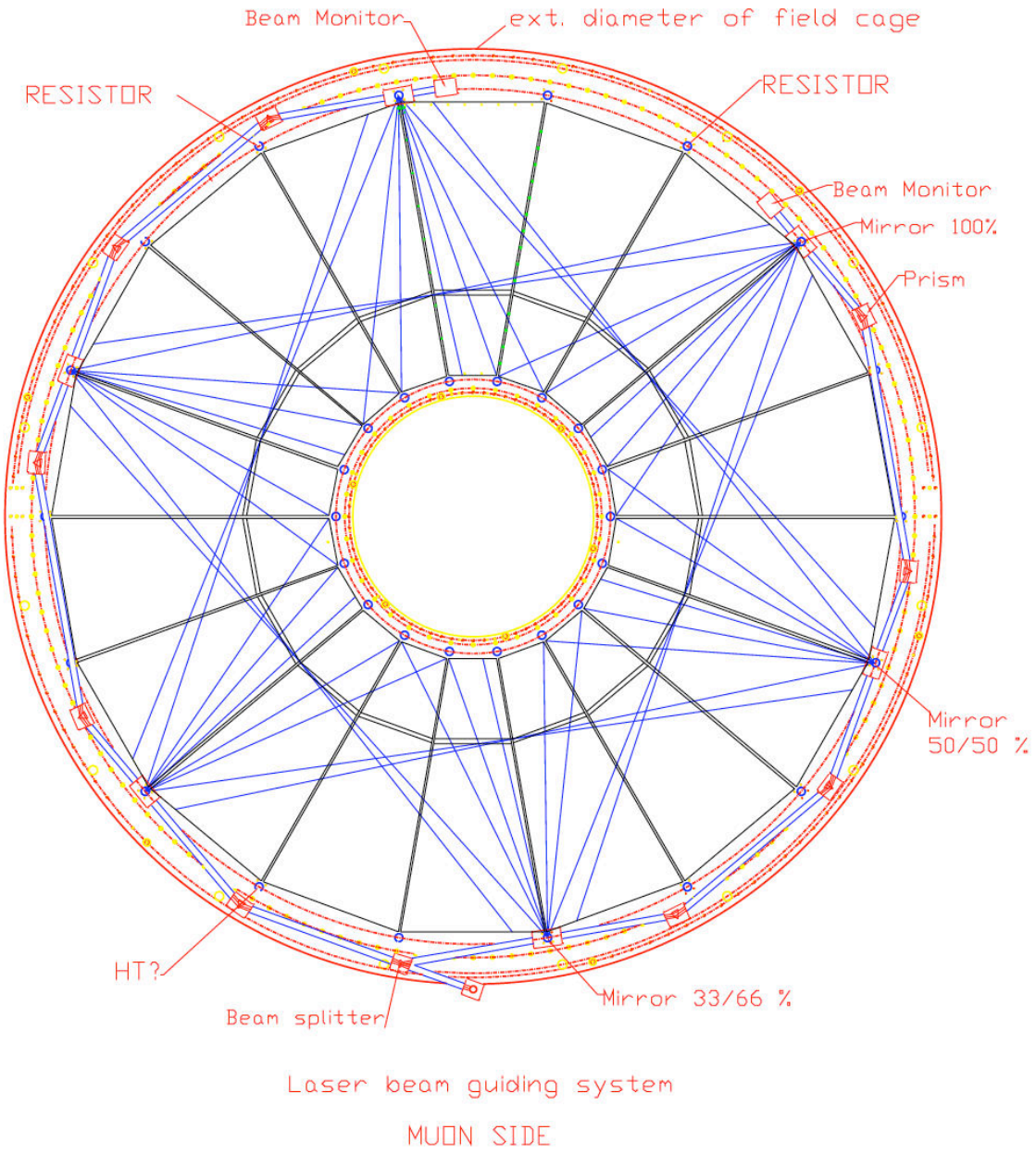
Laser Calibration and Monitoring System Principle



4 micro mirrors along z, alignment check with CCD at other TPC end

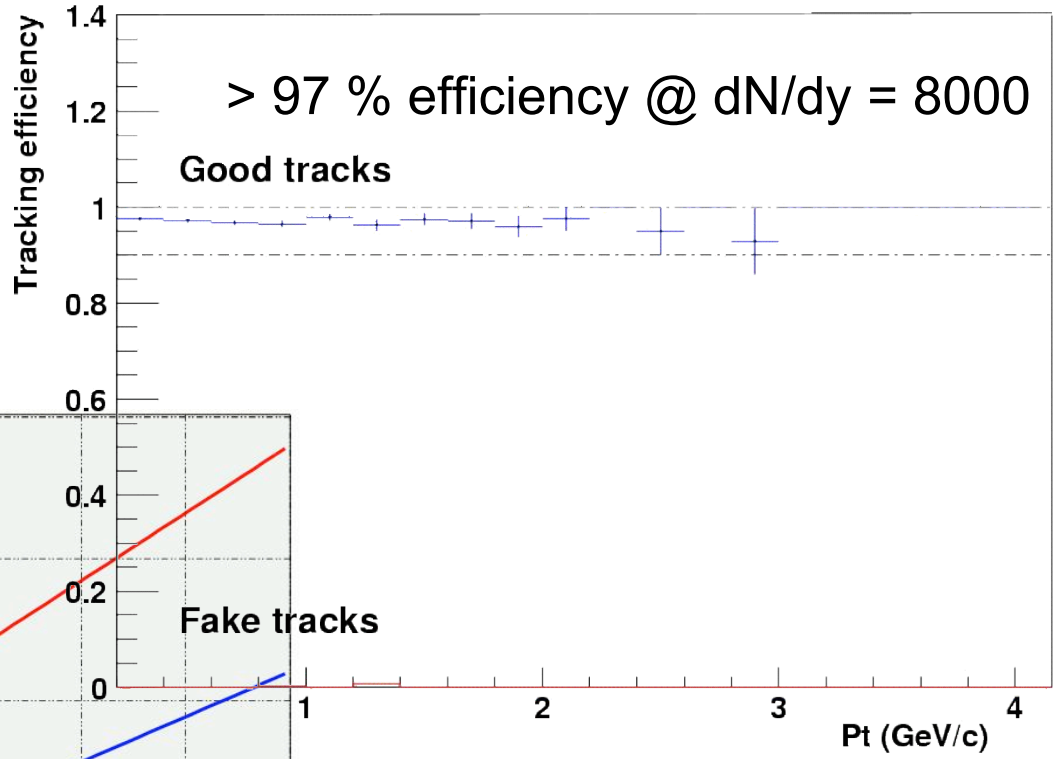
Laser Ray Pattern

- Rays perpendicular to beam axis
- Effective ray ∅ ~1mm
- 2 x 4 z-planes
- Strategic boundary crossings
- Additional signal from central electrode (and pad plane)

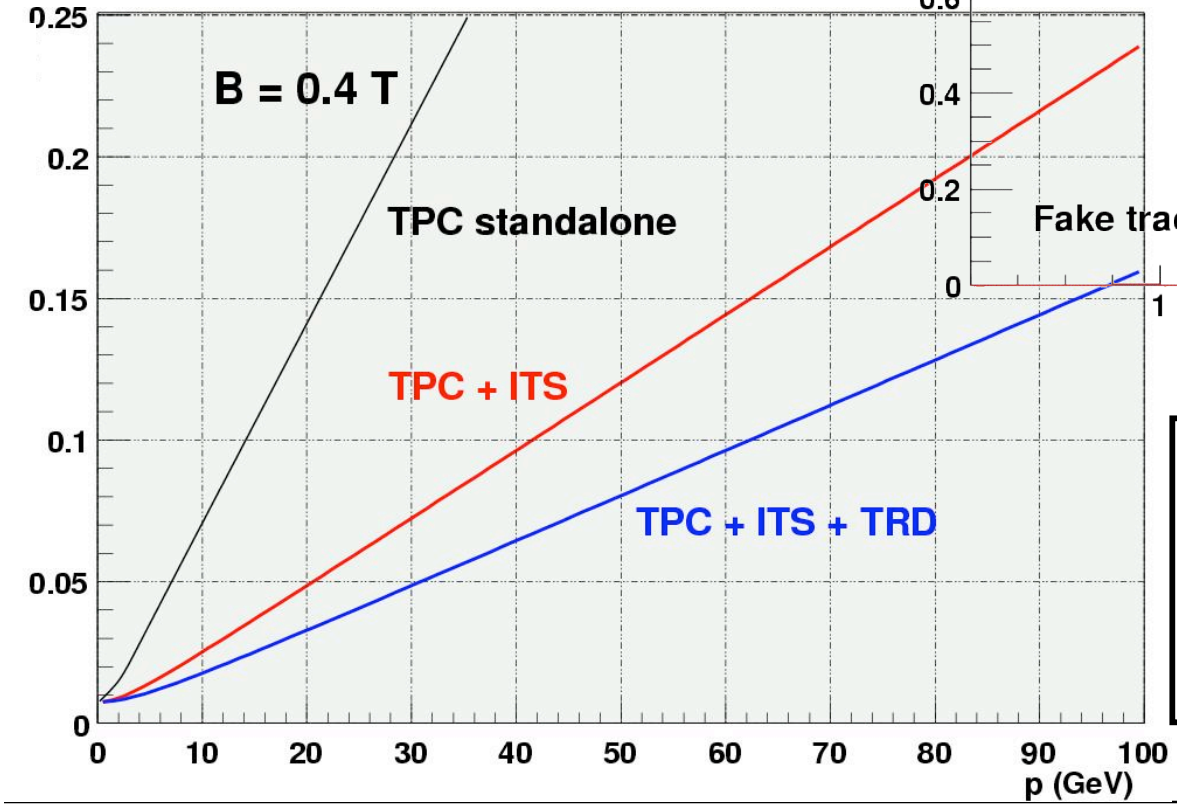


Performance (simulated)

- Note: standard field 0.5 T
- dp/p vs dN/dy: 16% → 9%
  @ dN/dy = 2000



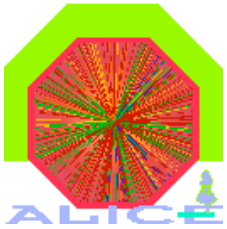
dp/p



- dE/dx resolution
  5.3 – 6.8 %
  depending on multiplicity

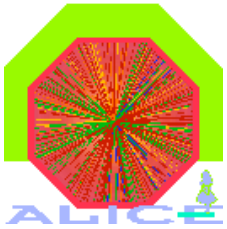
Outlook

- By mid 2004: complete Field Cage assembly and Readout chamber production
- 2004/5: Installation of Readout Chambers and FEE above ground
- 7 month system testing
- March 2006: Installation underground
- 2007 **LHC** start



ALICE TPC Collaborators

T. Alt, Y. Andres, T. Anticic, D. Antonczyk, H. Appelshäuser, J. Bächler, J. Bartke, J. Belikov, N. Bialas, U. Bonnes, R. Bramm, P. Braun-Munzinger, R. Campagnolo, P. Christakoglou, E. Connor, H. Daues, C. Engster, Y. Foka, F. Formenti, A. Förster, U. Frankenfeld, J.J. Gaardhøje, Ch. Garabatos, P. Glässel, Ch. Gregory, H.A. Gustafsson, J. Hehner, H. Helstrup, M. Hoch, M. Ivanov, R. Janik, K. Kadija, R. Keidel, W. Klempt, E. Korna_, M. Kowalski, S. Lang, J. Lien, V. Lindenstruth, C. Loizides, L. Lucan, P. Malzacher, T. Meyer, D. Miskowiec, B. Mota, L. Musa, B.S. Nielsen, H. Oeschler, A. Oskarsson, L. Osterman, A. Petridis, M. Pikna, S. Popescu, S. Radomski, R. Renfordt, J.P. Revol, D. Röhrich, G. Rüschmann, K. Safarik, A. Sandoval, H.R. Schmidt, K.E. Schwarz, B. Sitar, H.K. Soltveit, J. Stachel, T.M. Steinbeck, H. Stelzer, E. Stenlund, R. Stock, P. Strmen, T. Susa, I. Szarka, H. Tilsner, G. Tsiledakis, K. Ullaland, M. Vassiliou, A. Vestbo, D. Vranic, J. Westergaard, A. Wiebalck, B. Windelband



Additional Slides

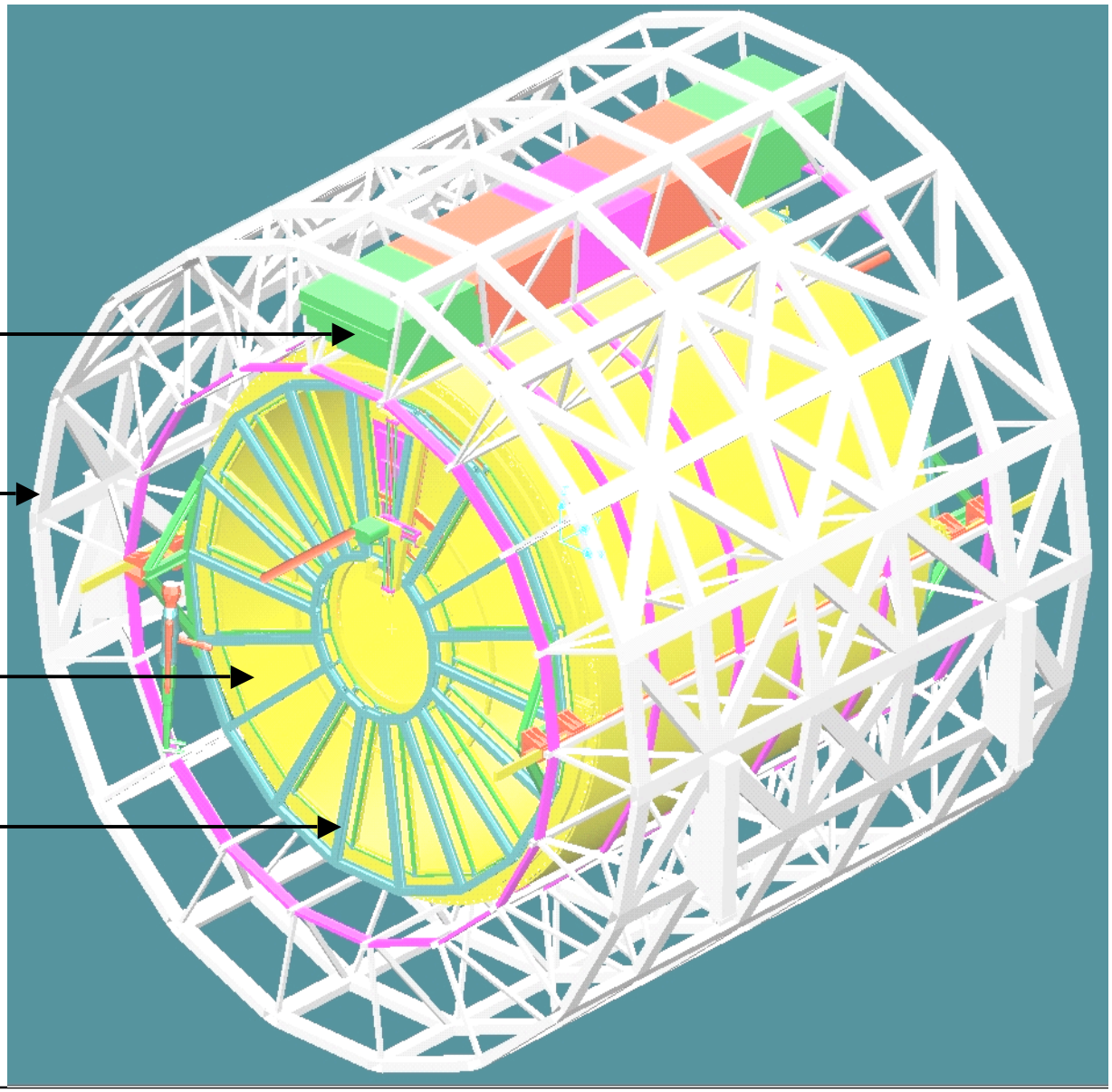
The Environment of the TPC

TRD module

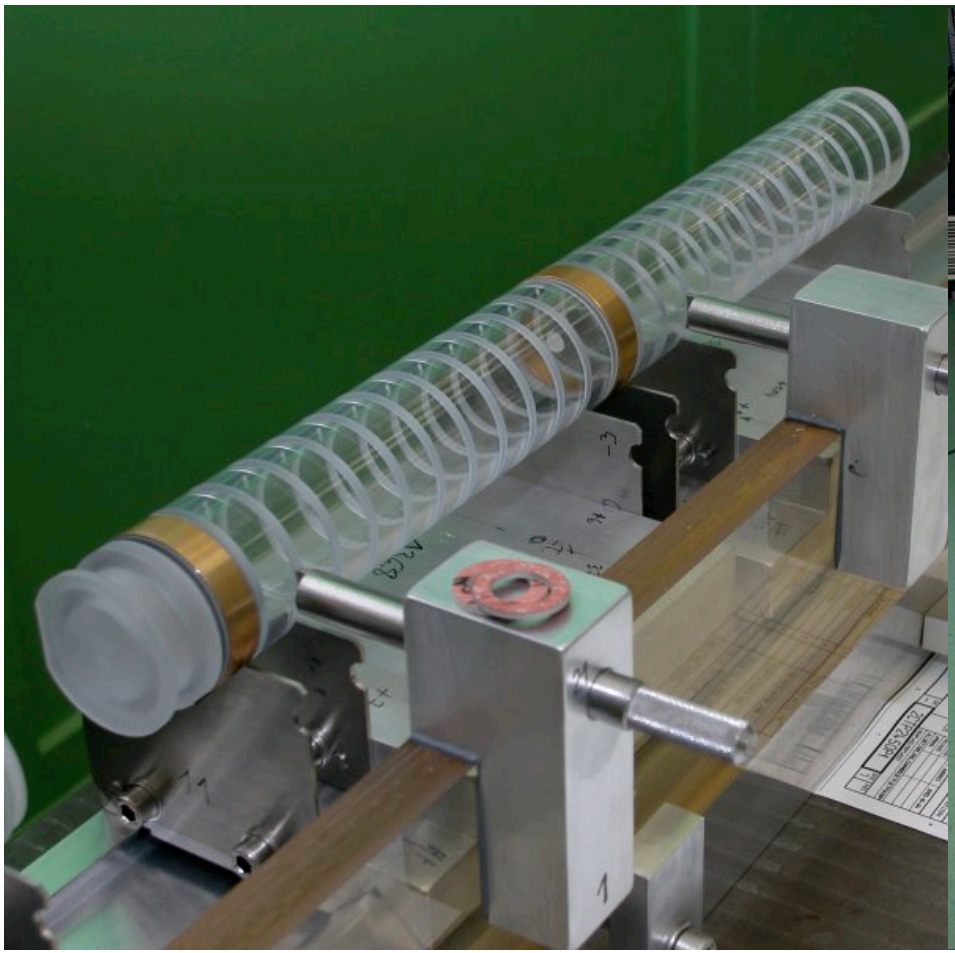
Space Frame

TPC

Service Support Wheel

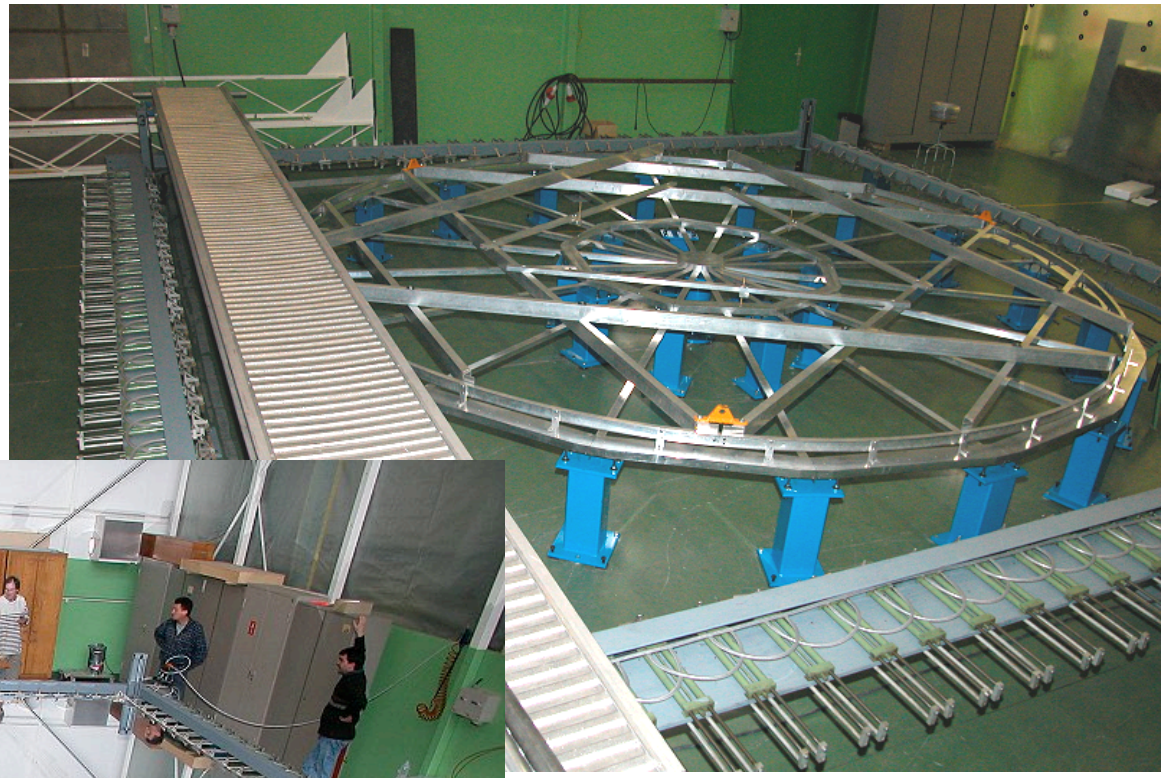


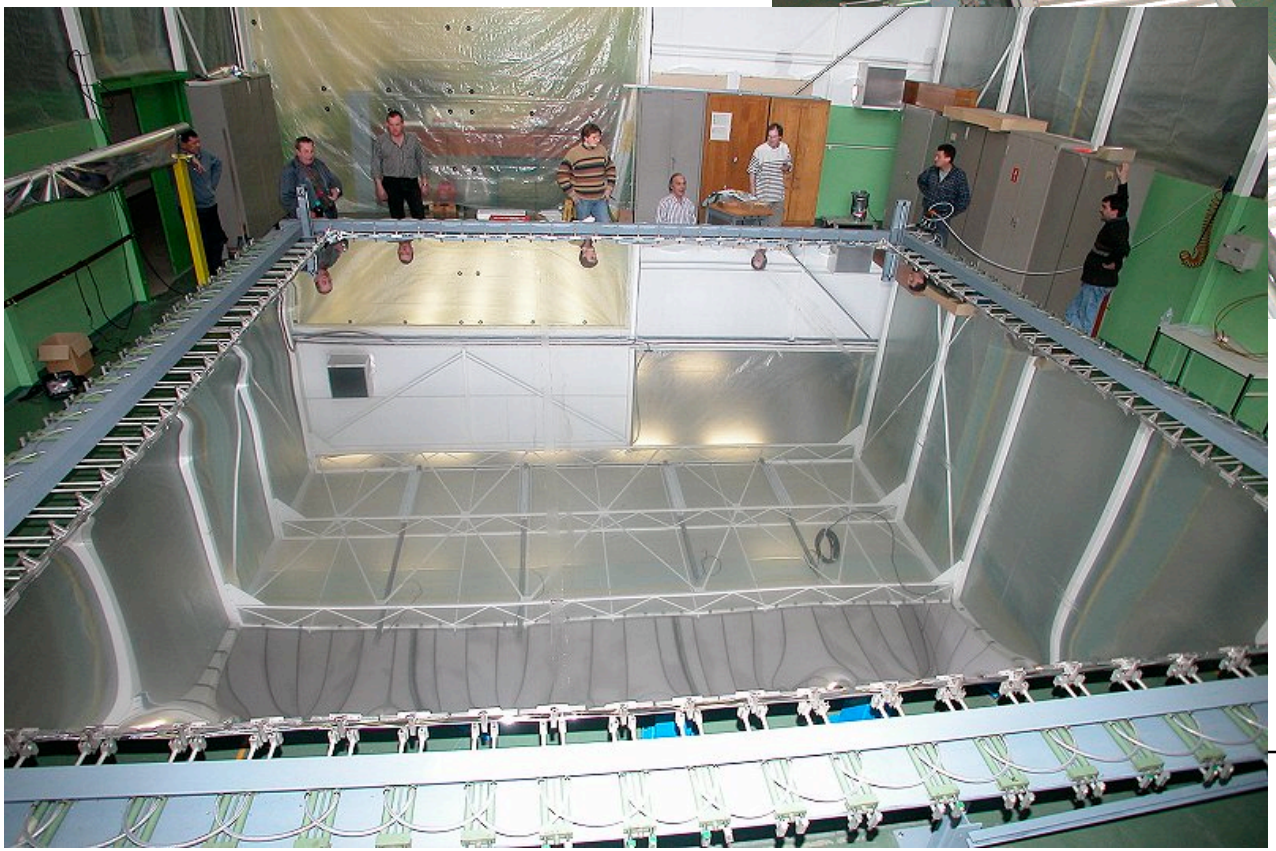
Field Cage: Rod Assembly



Field Cage: Central Electrode

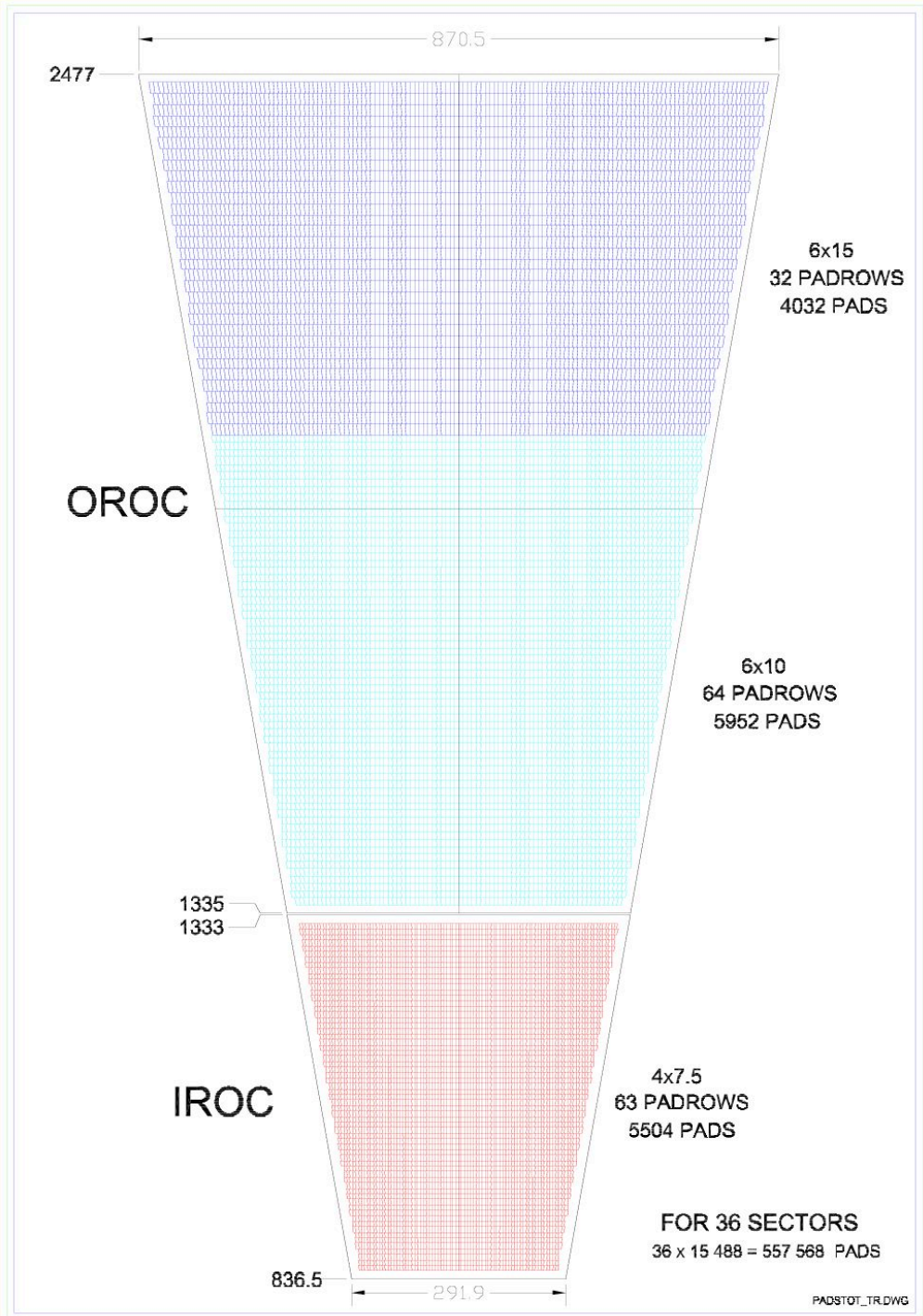
- 6m wide mylar foil, glued from 3 sheets





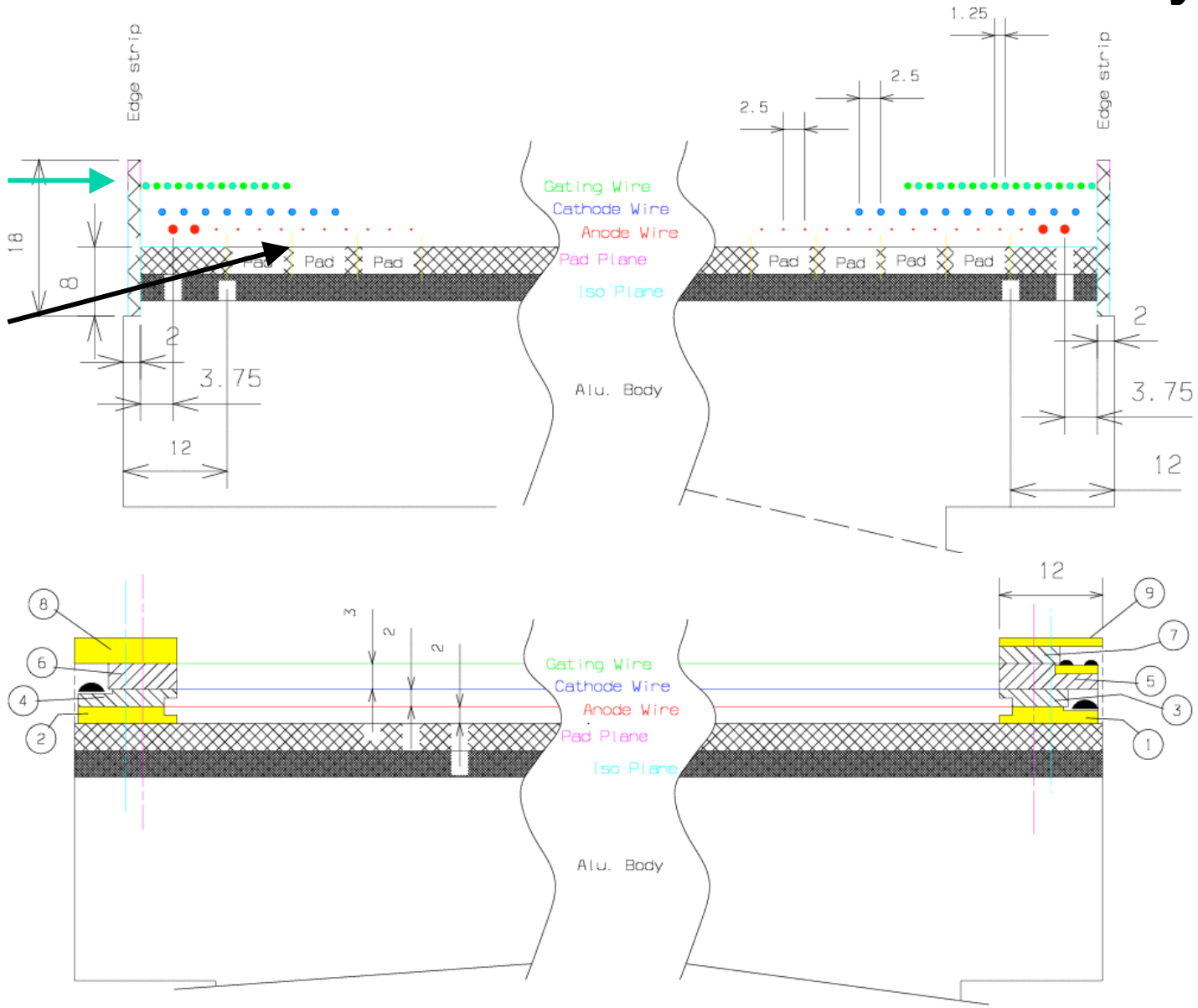
Pad Plane

- optimized pad sizes
  - 4 x 7.5 mm
  - 6 x 10 mm
  - 6 x 15 mm
- segmented: IROC and OROC
- total 557 568 pads



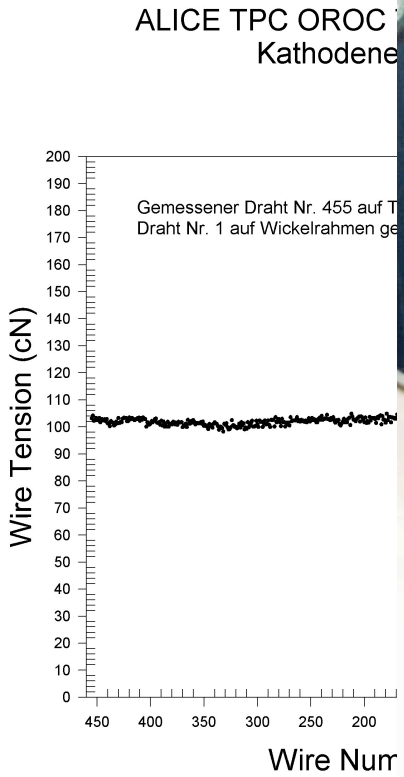
Readout Chamber Wire Geometry

gate wires
cathodes
anodes
pads



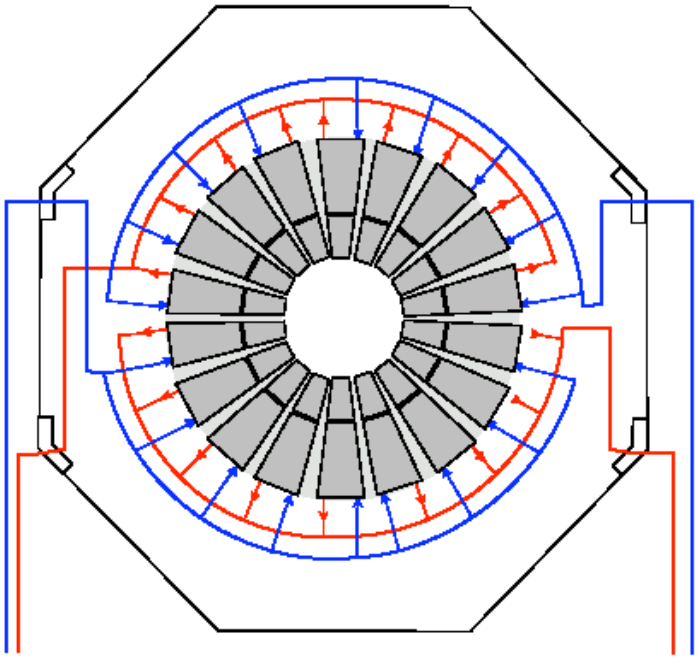
Readout Chamber Production Heidelberg/GSI

Measuring wire tension



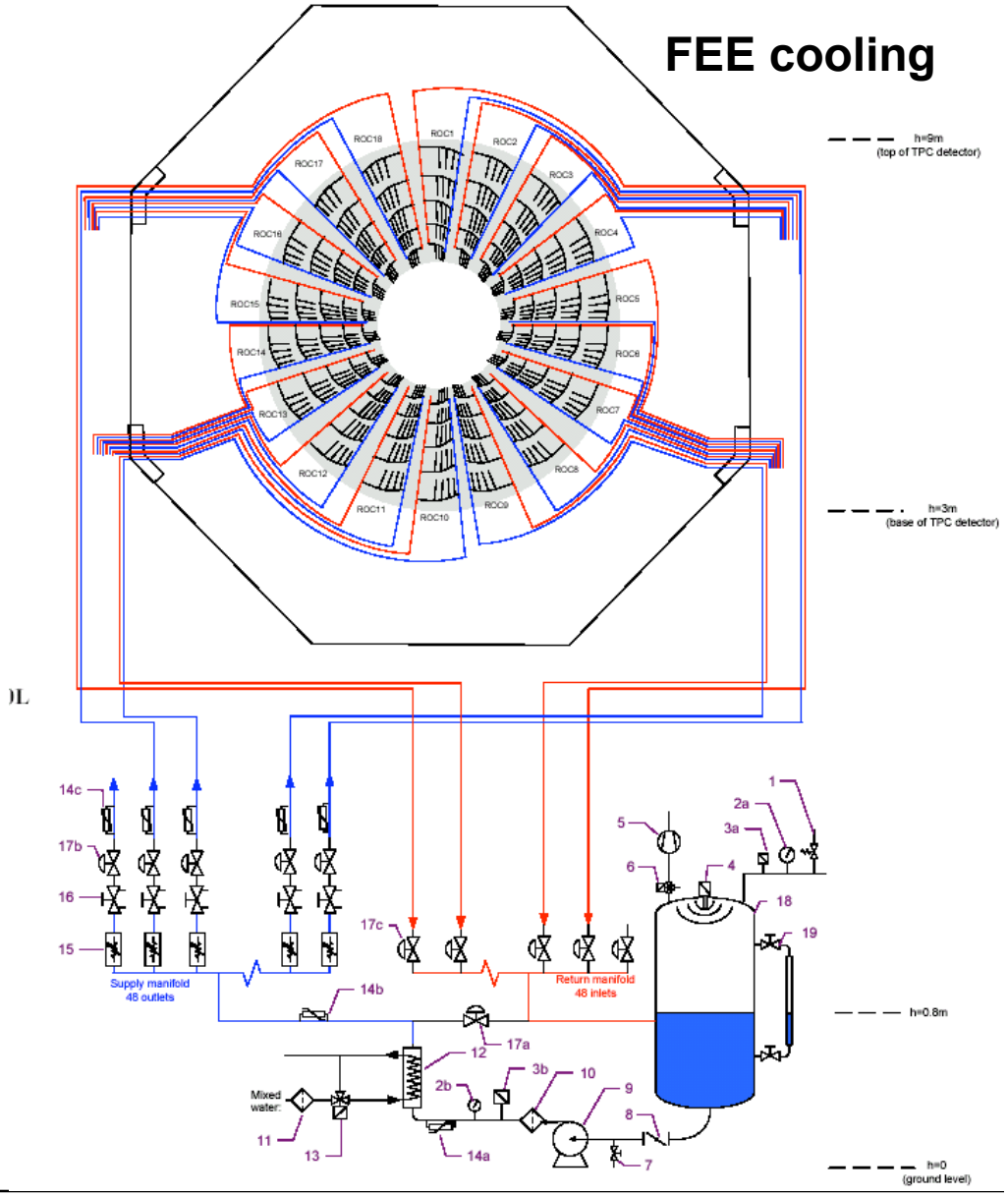
Electronics Cooling

- 27 kW to be removed
- Leakless water cooling systems



ROC padplane thermal screen

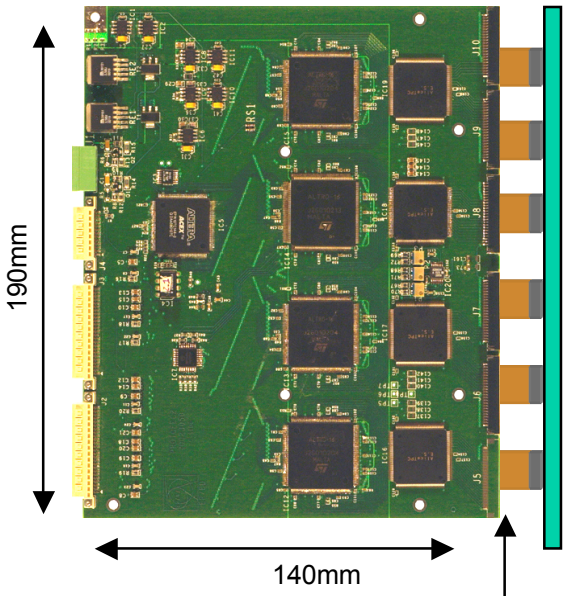
FEE cooling



Mounting FEE

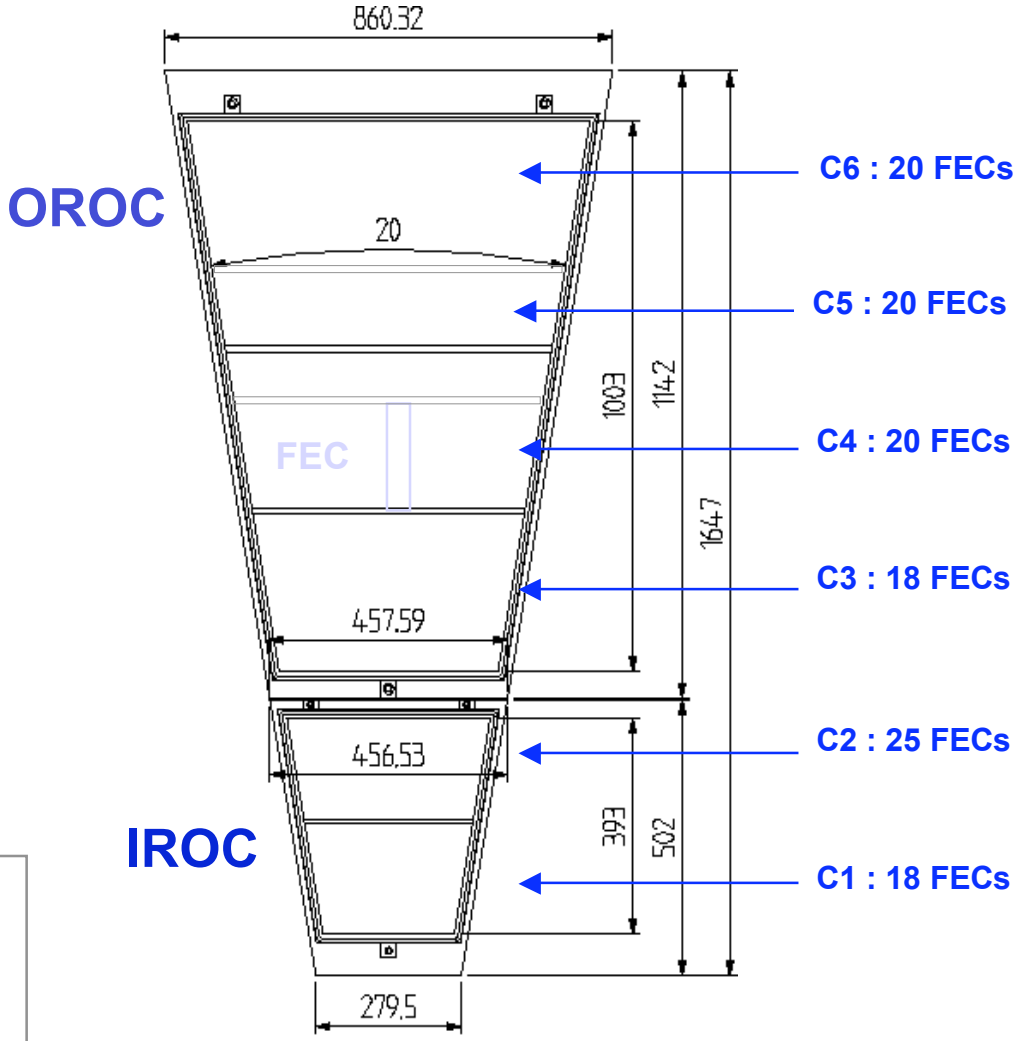
SIDE VIEW

128 channels
Front End Card (FEC)



FRONT VIEW

36 sectors

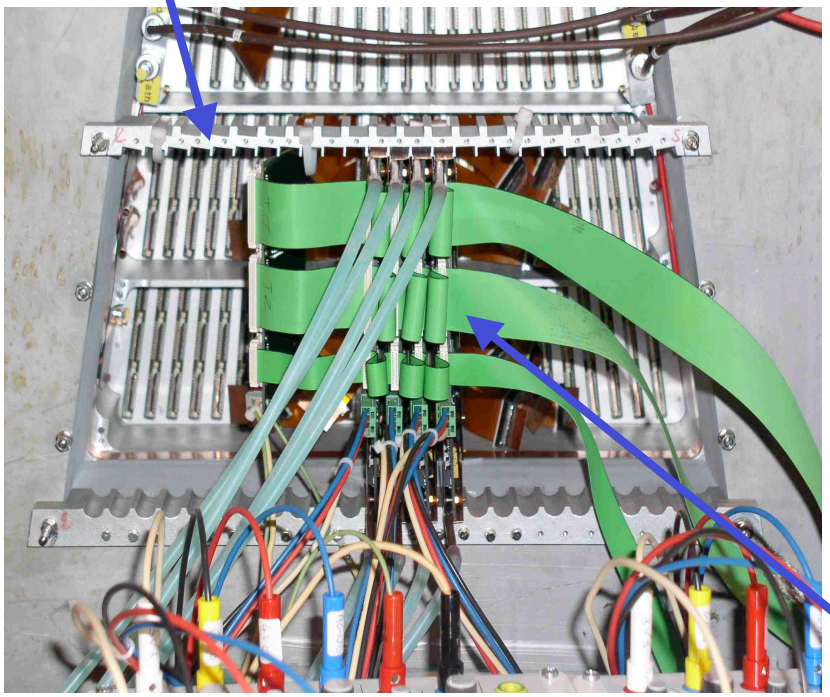


FEE POWER:

- CHANNEL: 40 mW
- BOARD: 6.9 W
- SECTOR: 832 W
- TOTAL: 30.2 kW

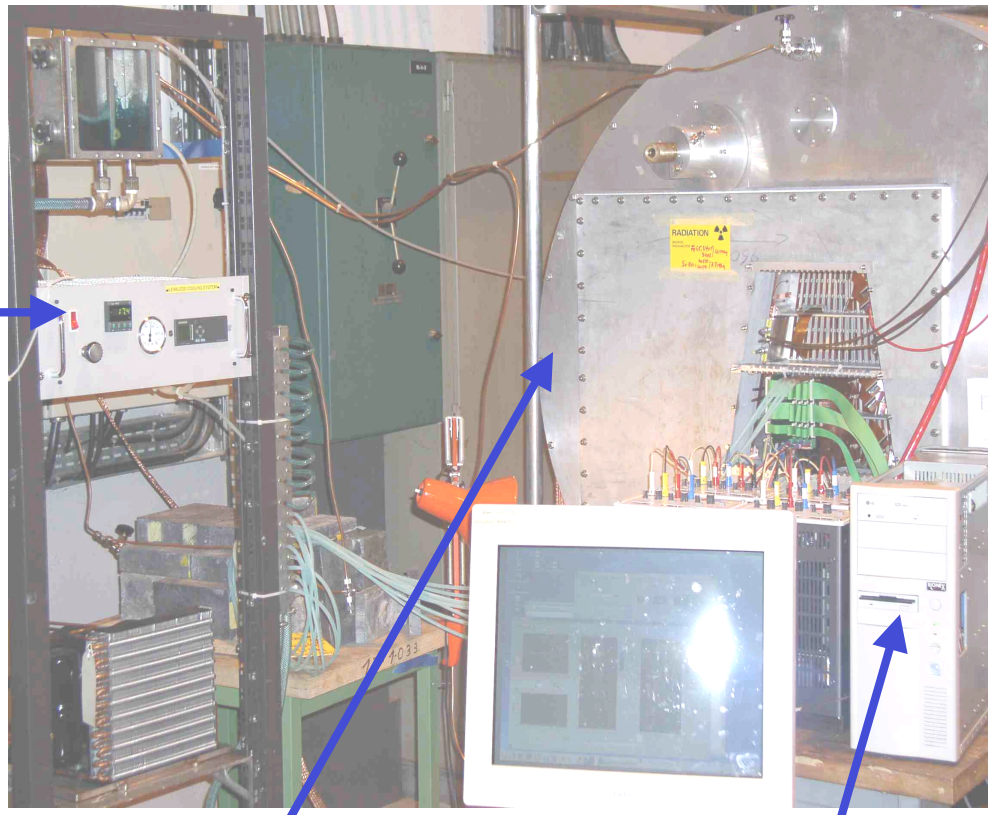
End plate

TPC Test Facility at CERN



Inner Readout Chamber

Cooling System



Field Cage Prototype

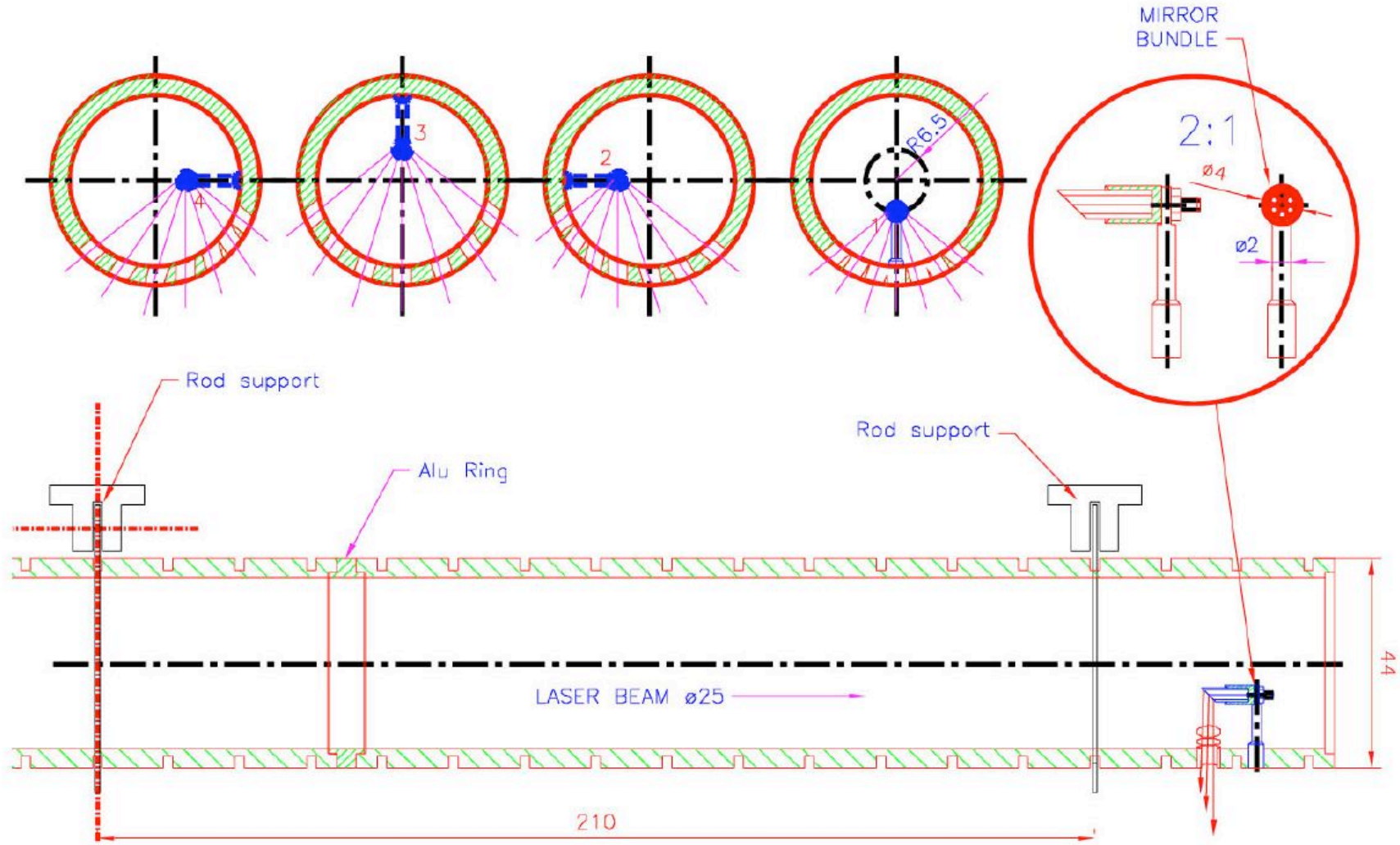
PC with pRCU-I

Close-up of the FECs into the IROC

Laser System: Objectives

- Electronics testing
- Sector alignment
- Drift velocity monitoring
  - Pressure, temperature
  - Temperature gradients (stratification, i.e. up-down)
  - ExB, space charge effects
- Two possible approaches:
  - Relative measurements, rely only on time stability of laser ray position
  - Absolute measurements, requires knowledge of absolute position of laser ray. **More ambitious**

Laser Rod with Mirrors



Laser Spatial Accuracy Goals

- Assembly: angular accuracy ~1 deg.
- Relative angles of micro-mirror rays measured to 50 □rad
- Final position of laser rays:
  - Stable to better than TPC resolution
  - Known to better than TPC resolution via internal calibration with respect to central electrode and ROC (signal from pad plane)
    - Gives **absolute measurement** if E-field is near-perfect

Comparison SPC - RHIC – LHC

Pb+Pb, central	SPS	RHIC	LHC
E_{cm} [GeV]	17	200	5500
dN_{ch}/dy	500	700	2000 - 8000
_ $[Gev/fm^3]_{t_0=1\ fm/c}$	≈2.5	≈3.5	15 - 40
V_{freeze} [fm^3]	≈10^3	≈ $7 \cdot 10^3$	$2 \cdot 10^4$ - $5 \cdot 10^4$
–QGP [fm/c]	<1	1.5 - 4	4 - 10

The LHC is the ideal place to study the QGP:

- hotter - bigger – longer-lived
- ~ 10^4 particles per event: Event-by-event physics