The ups and downs of building a large detector for Pb-Pb collisions at the LHC

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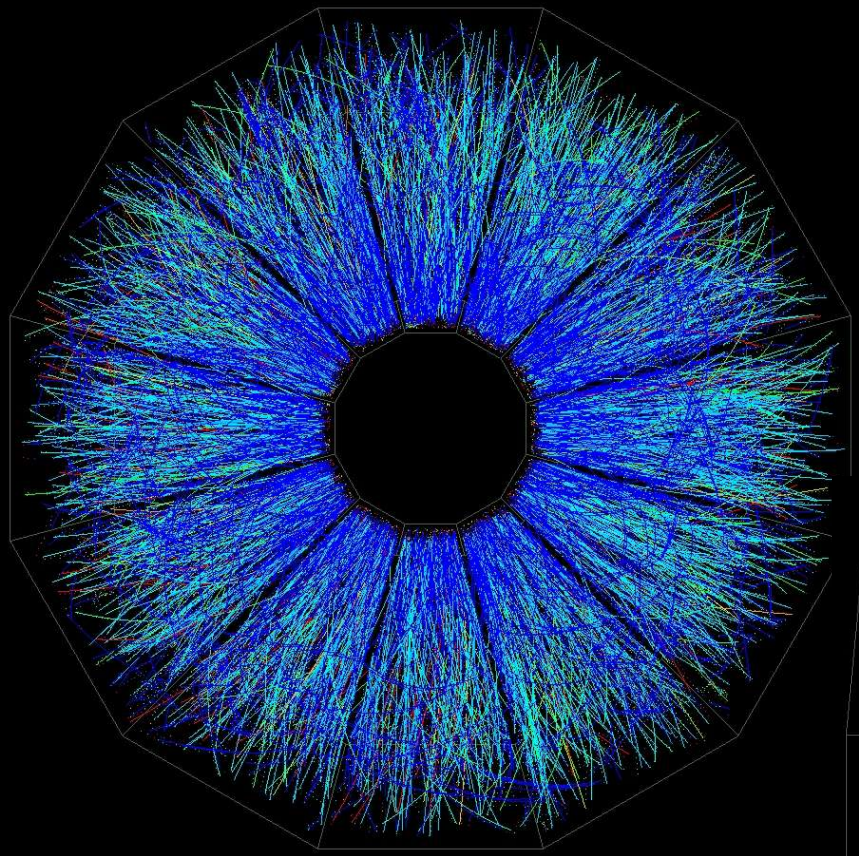
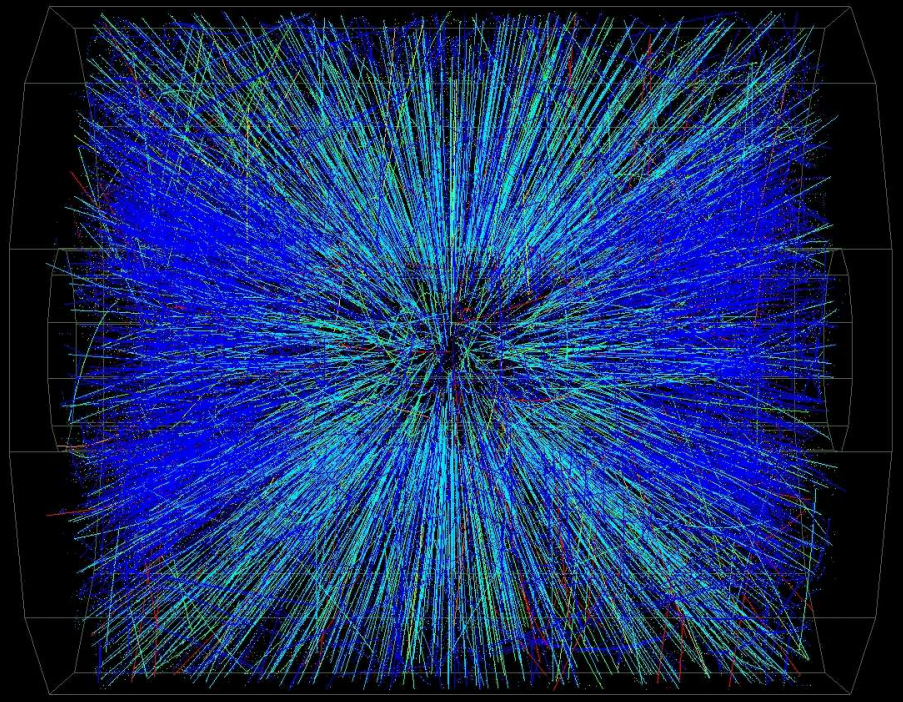
bmb+f - Förderschwerpunkt
ALICE
Großgeräte der physikalischen Grundlagenforschung

Au on Au Event at CM Energy ~ 130 A-GeV



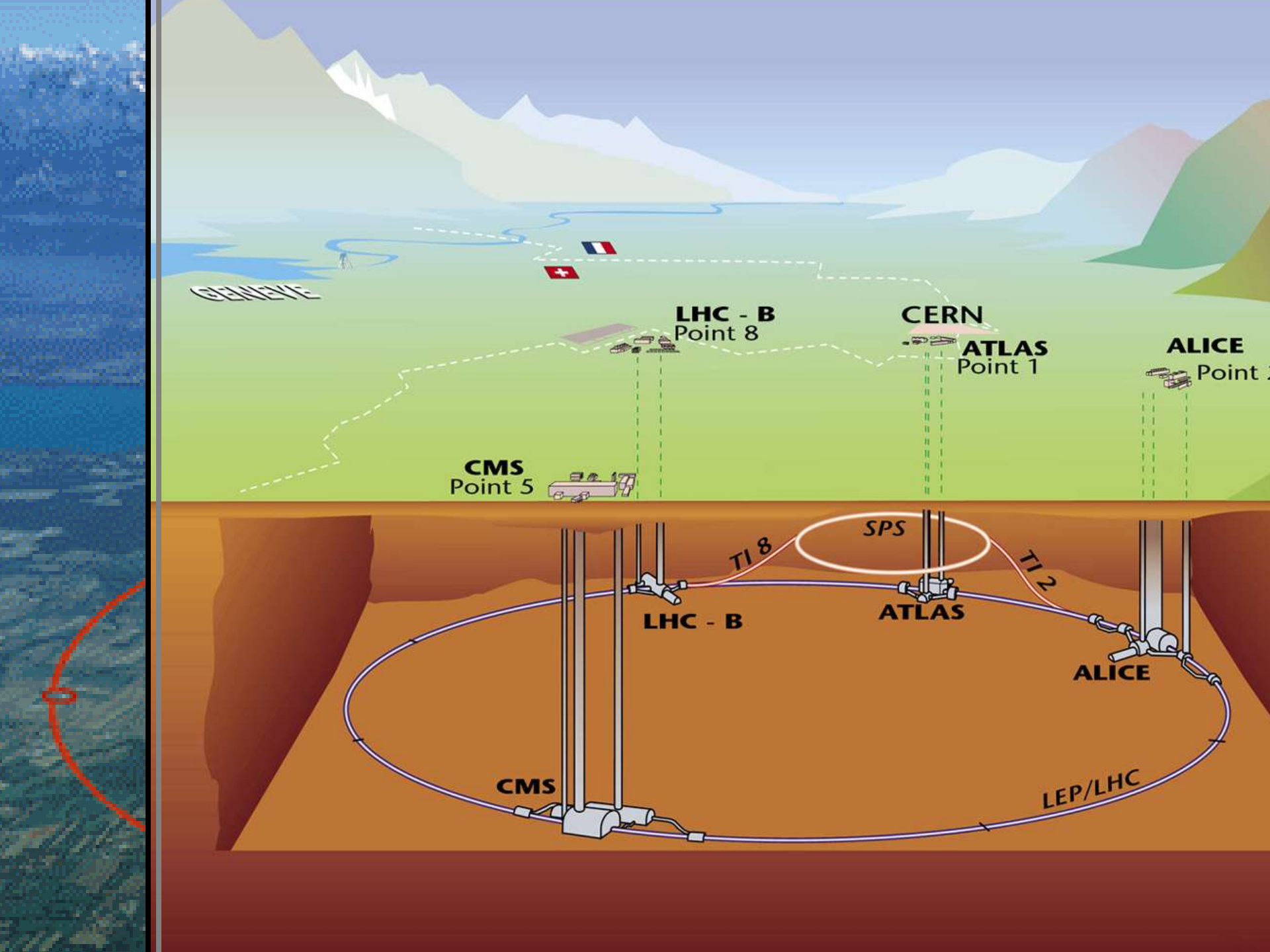
Central Event



the challenge:

Au-Au collisions at RHIC: 6000 produced particles

Pb-Pb collisions at LHC: > 30000 produced particles

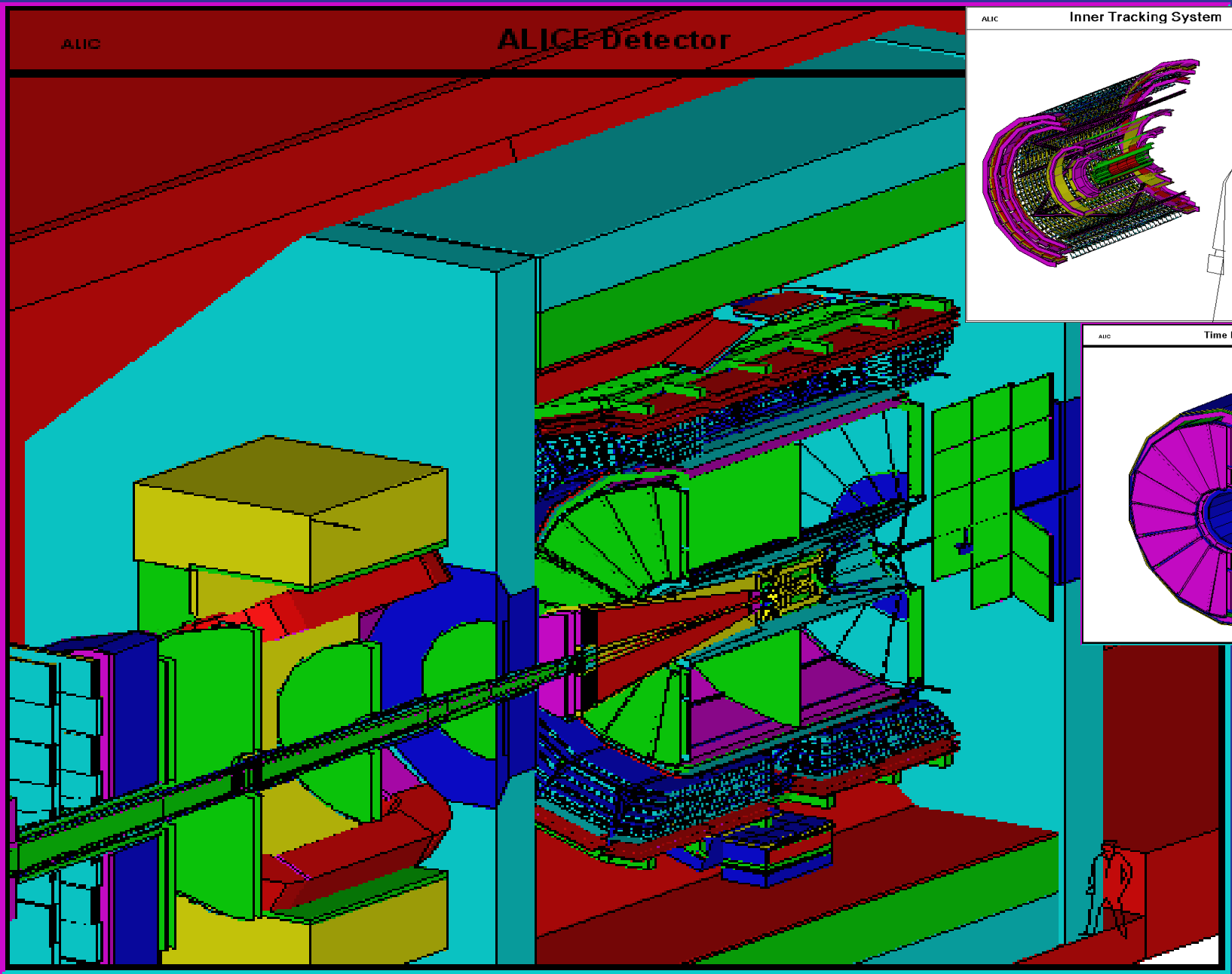

GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC

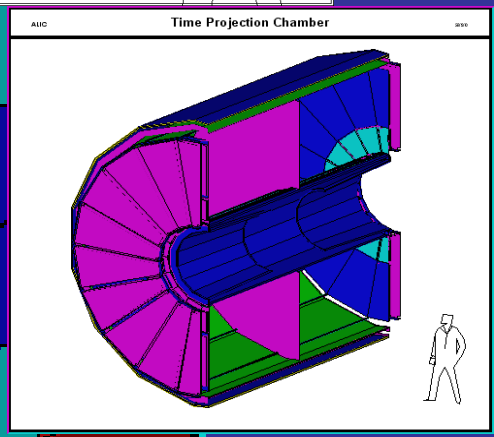
ALICE beim LHC

Bis zu 60000 geladene Teilche

Faktor 25 höher als beim SPS

Computer representation of ALICE





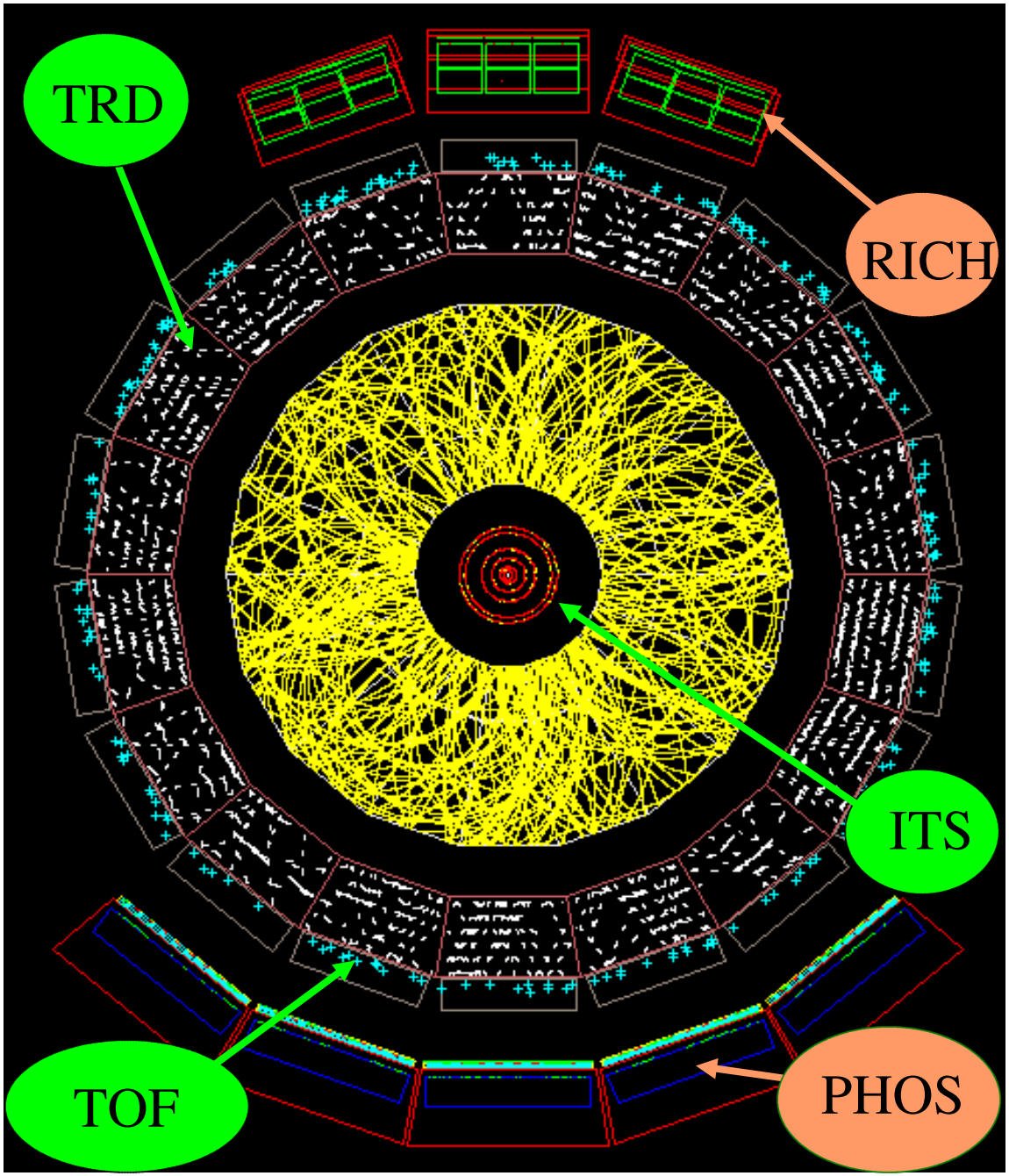
Central event Pb-Pb

@ dN/dy = 8000

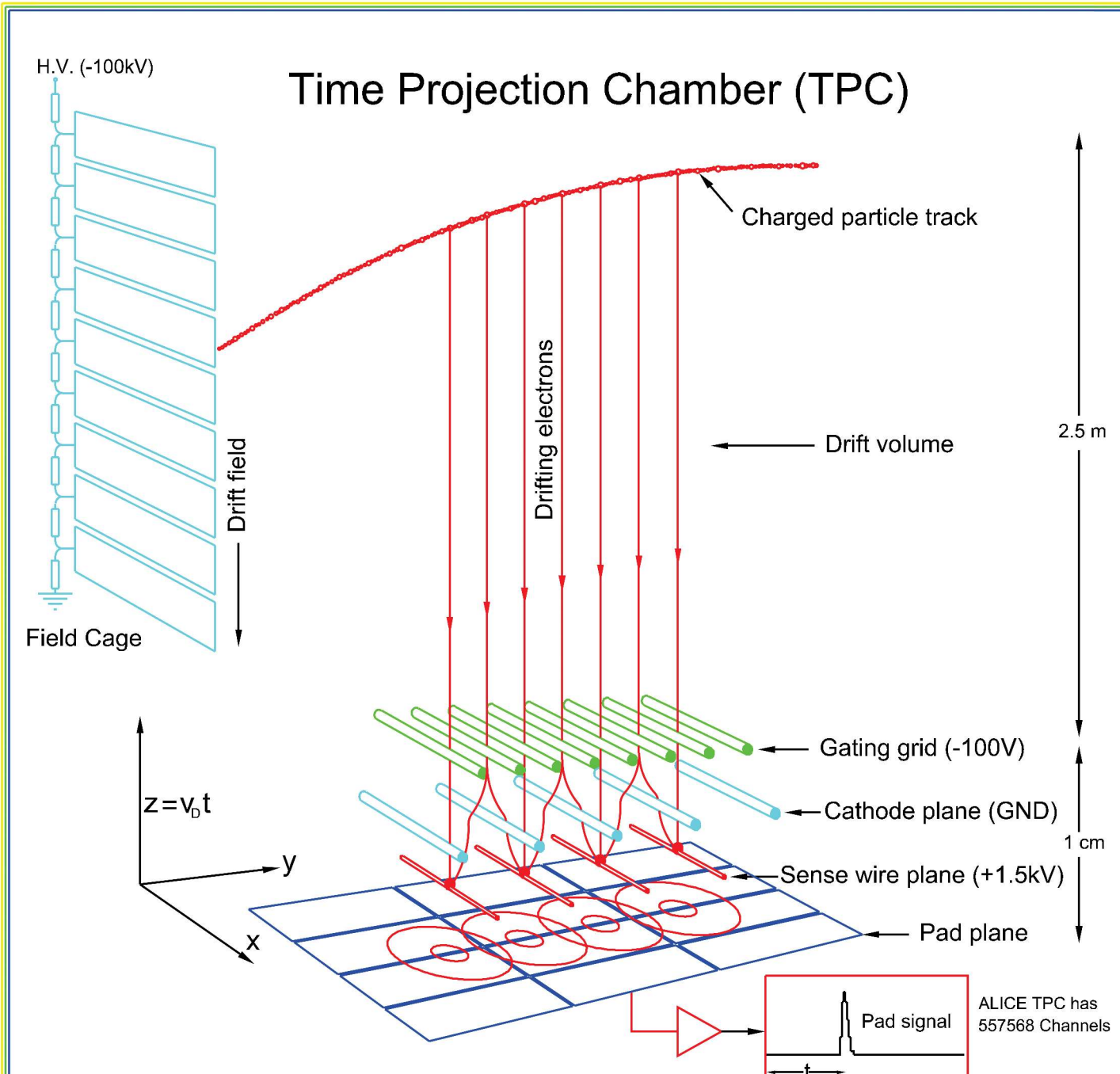
- **$\Delta\theta = 2^{o}$ slice only!**

A challenge for

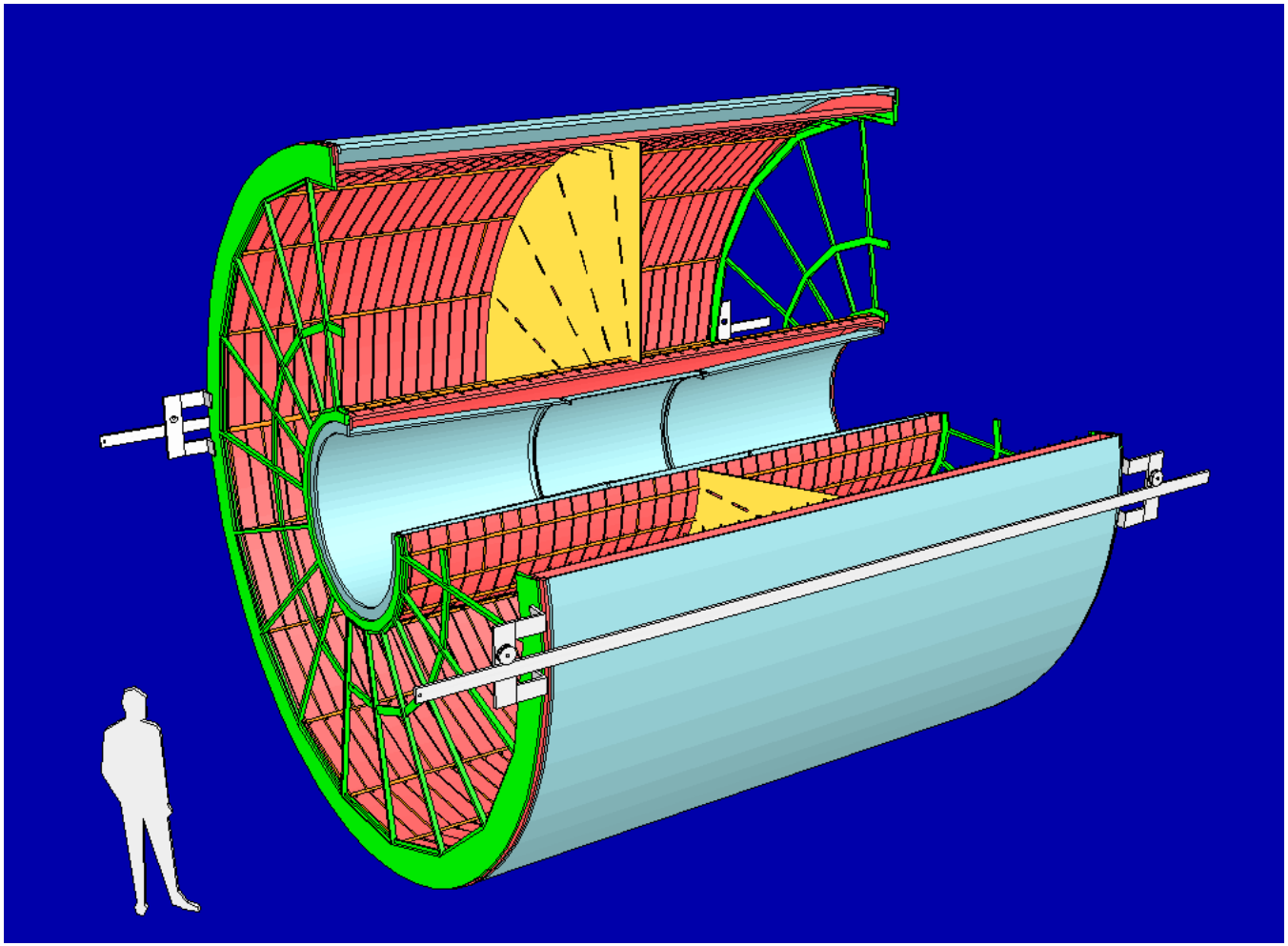
- occupancy
- dE/dx
- tracking
- space charge



the idea: a very large TPC


Time Projection Chamber (TPC)
H.V. (-100kV)
Field Cage
Drift field
Charged particle track
Drifting electrons
Drift volume
2.5 m
Gating grid (-100V)
Cathode plane (GND)
1 cm
Sense wire plane (+1.5kV)
Pad plane
z=v_D t
y
x
Pad signal
t
ALICE TPC has
557568 Channels

schematics of field cage

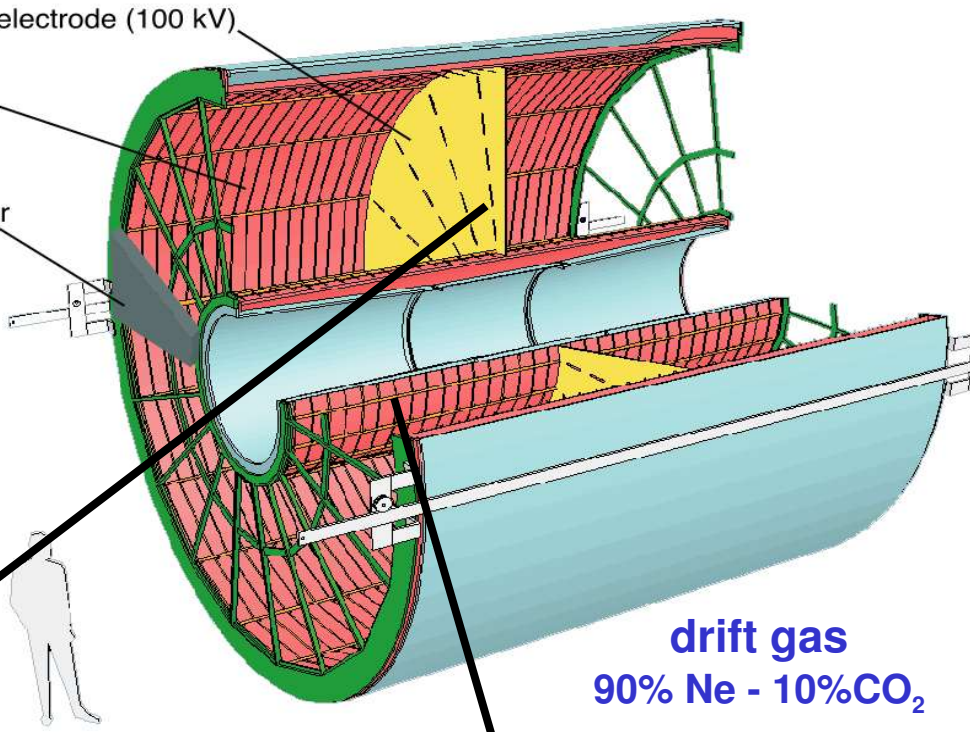


first idea: order the full field cage, made from carbon fiber composites, from industry (Airbus, Boeing, ...)

result of market survey: much too expensive! (4 Meuro vs budgeted 0.8 Meuro)

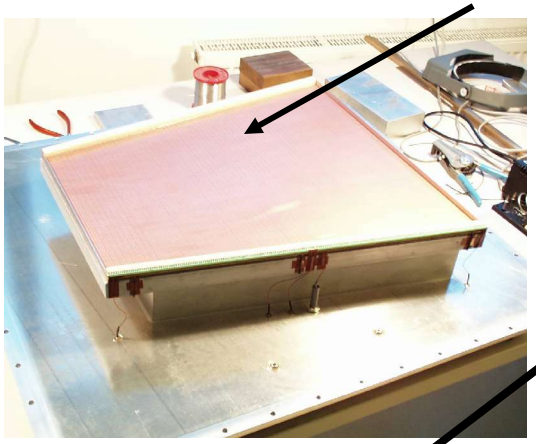
alternative: order components (cheap)
build detector yourself (complicated)

Time Projection Chamber
largest ever: 88 m³, 570 k channels



for tracking and PID via dE/dx

- 0.9 < η < 0.9



drift gas
90% Ne - 10%CO_2

Central Electrode Prototype
25 µm aluminized Mylar on Al frame

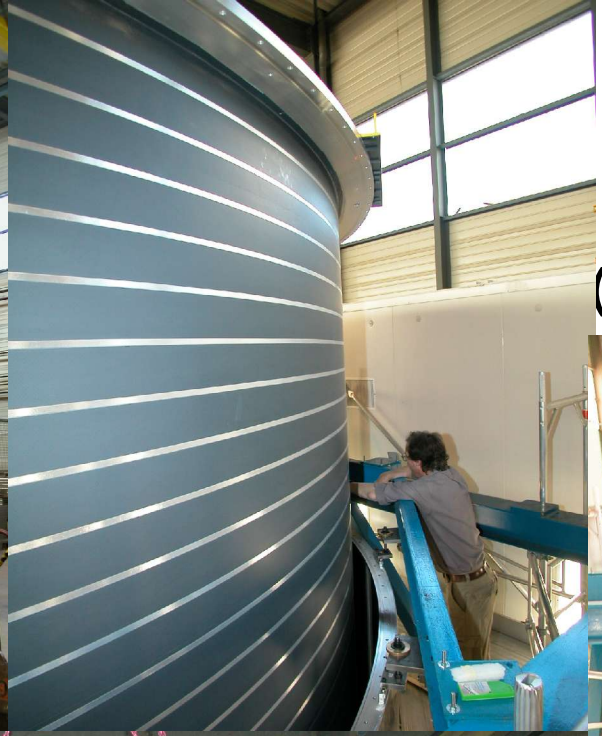
~ 3 m diameter

Field Cage

Inner Vessel

The ALICE TPC becomes real

(outer field cage and end plates)



Field Cage: Central Electrode

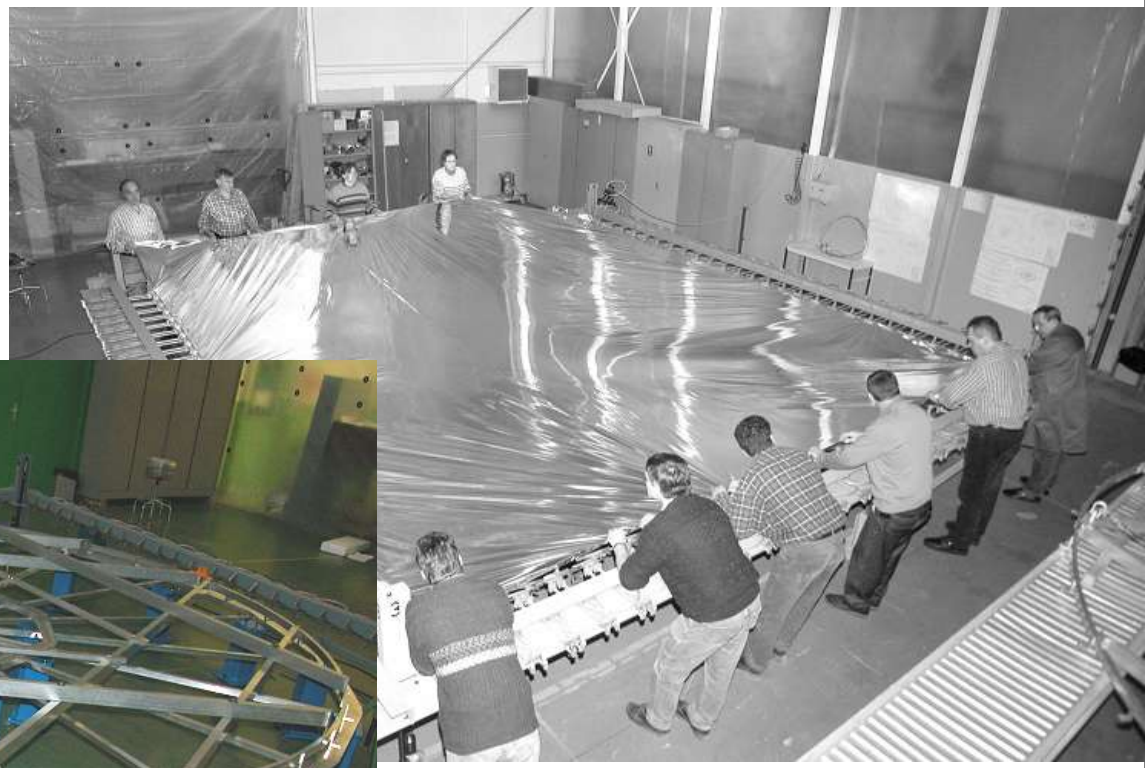
Completed:

- Modification of stretching machine
- Stock of 6m wide glued mylar foil
- Stretching and rupture test
- electrode frames and manipulation tool

Not started yet:

- Production of 3 electrodes (not earlier than needed)

Field Cage: Central Electrode

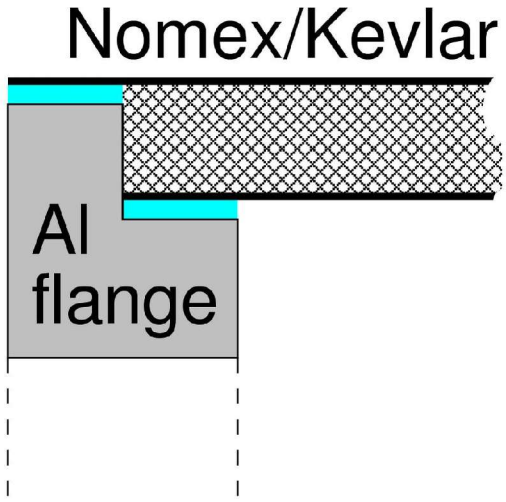


Field Cage Inner Drum

- Delivered by Fischer
- Al strips (ground) prepared

Field Cage: Mounting Rod Supports

Small catastrophy: The Inner FC vessel has to be rebuilt



What happened:

- Leak test: 25 Feb03 --> **leaks at glue joint** between composite and flange
- Ultrasonic test: 27 Feb03 --> **faulty glue bonds**
- First repair by Fischer: 10-14 Mar03, only on outer joint
- Decision to **rebuild**: 24 Apr03, order 6 May03

Consequences:

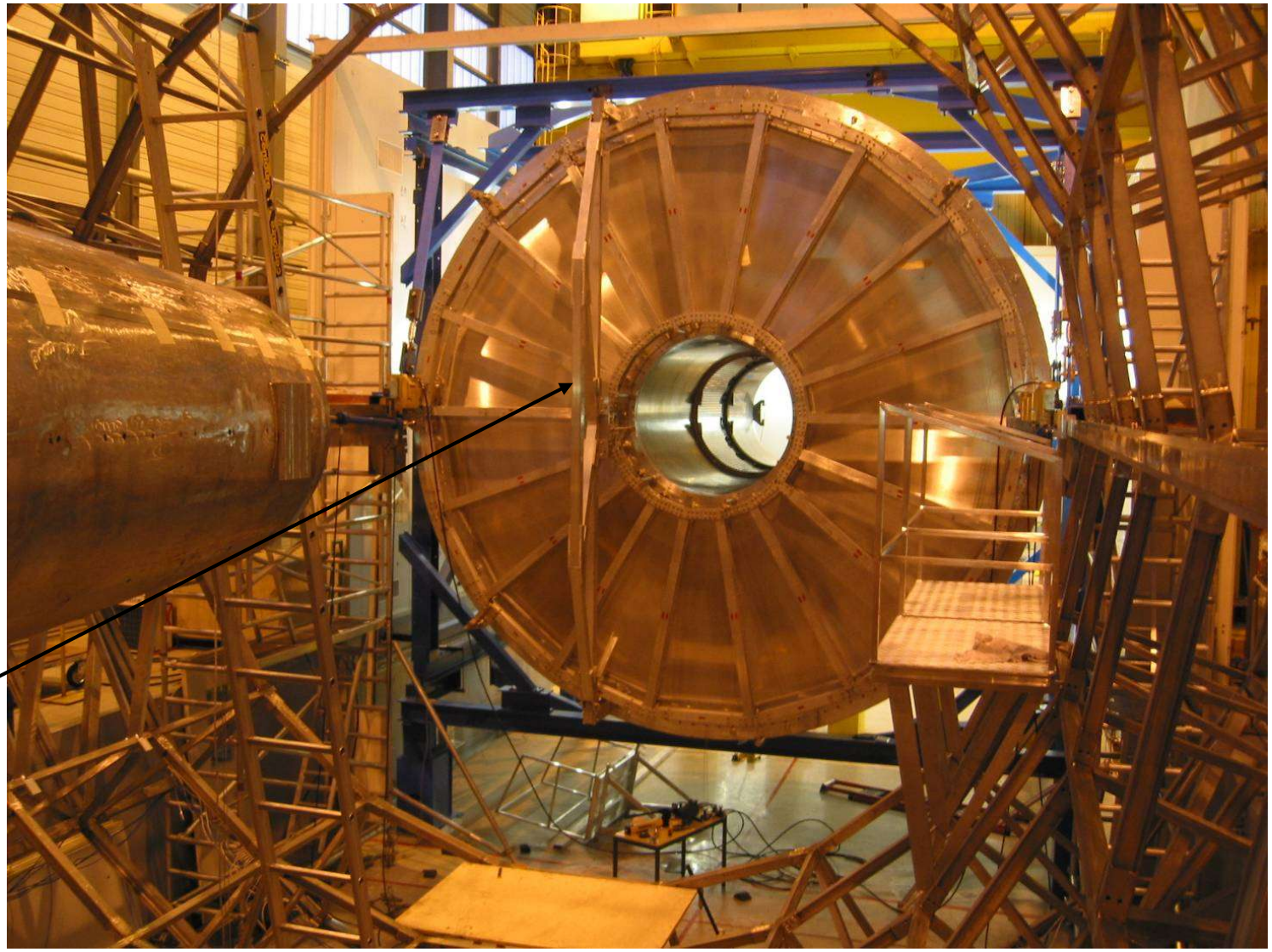
- Repeat work:
  - Assembly at CERN Jul03
  - Leak test, guard rings, vias,
  - Resistor chain, rod supports
- Total delay 7 months, (was luckily only 3.5)
  - Ready to install rods Dec03
  - Complete FC equipment Jul04


Defective vessel

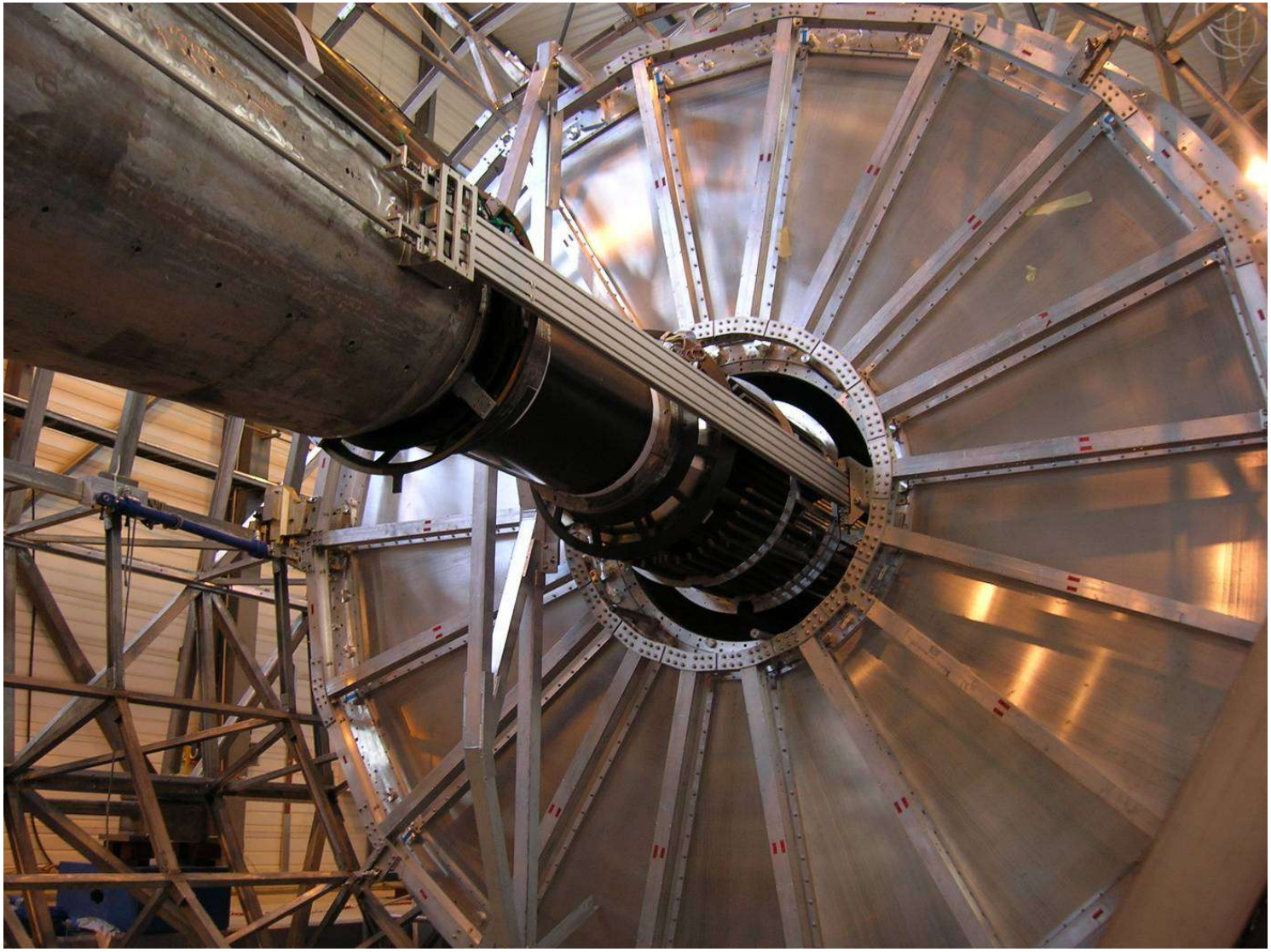

finally complete

ALICE Time Projection Chamber

TPC-ITS Integration Test: Moving TPC into Space Frame



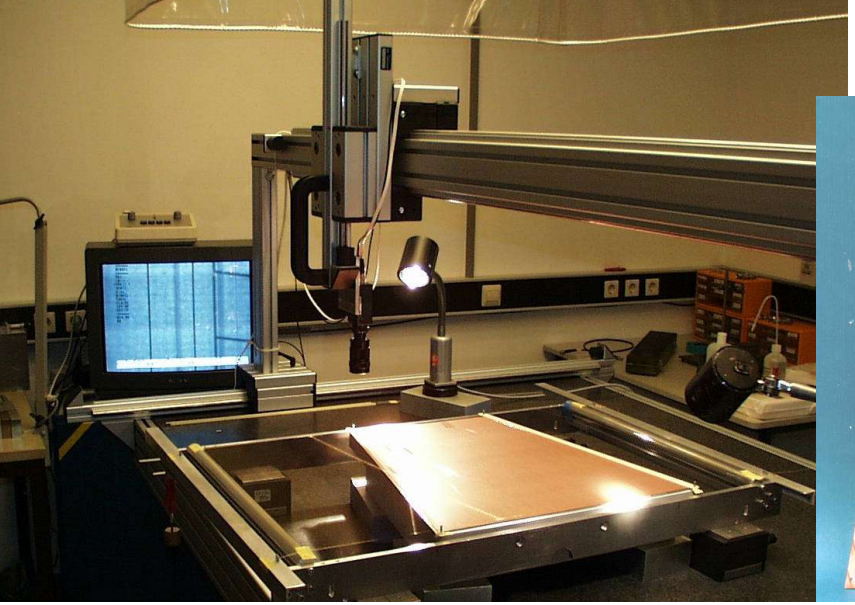
Move TPC to final Position



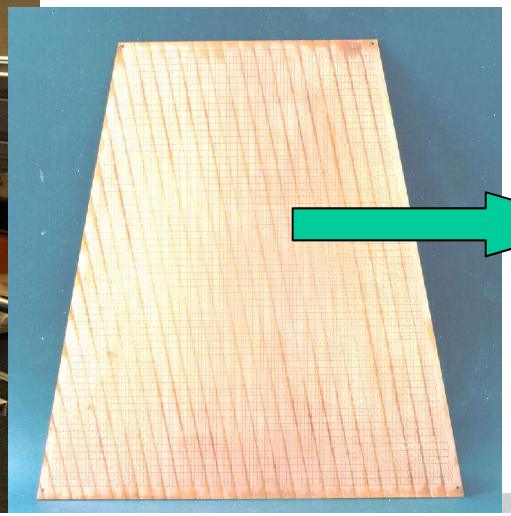
TPC in final position

meanwhile: read-out chamber design

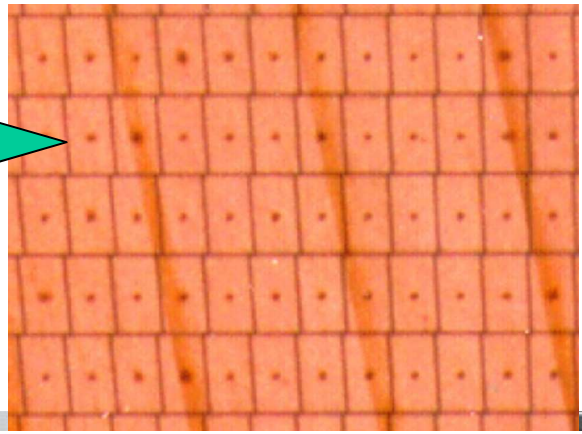
because of large particle density and huge size, need 570000 channels and amplification, can this work?



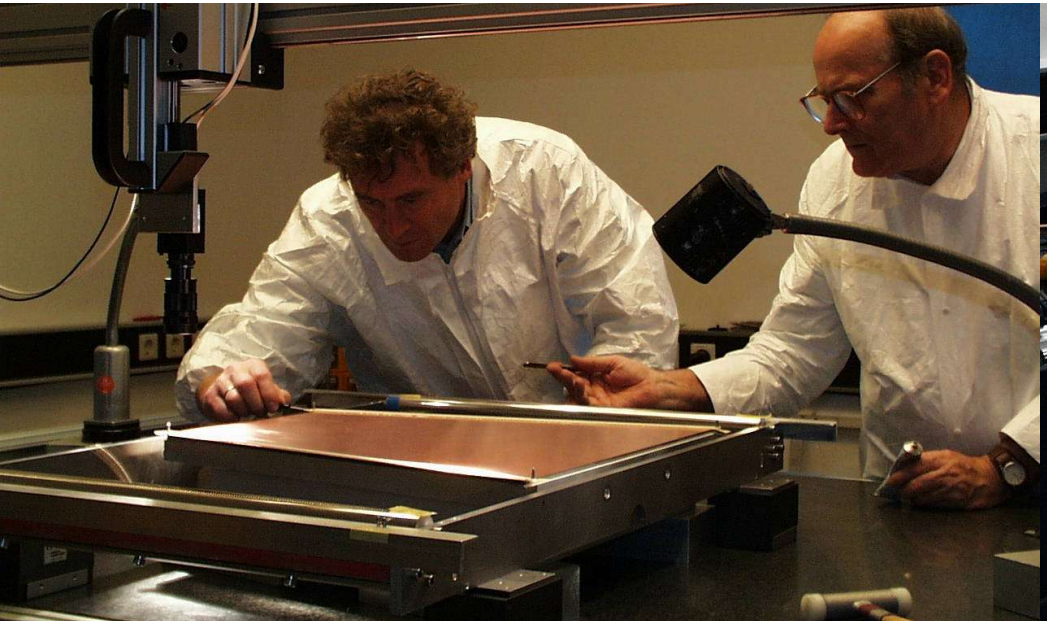
Pad Plane: 5504 pads (4x7.5 mm^2)

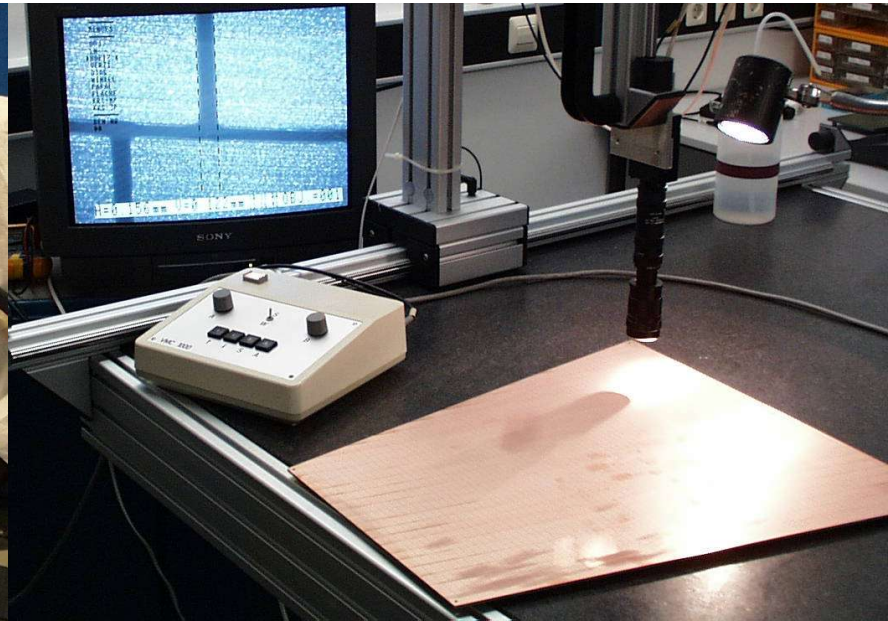


CLOSE-UP ON THE PADS



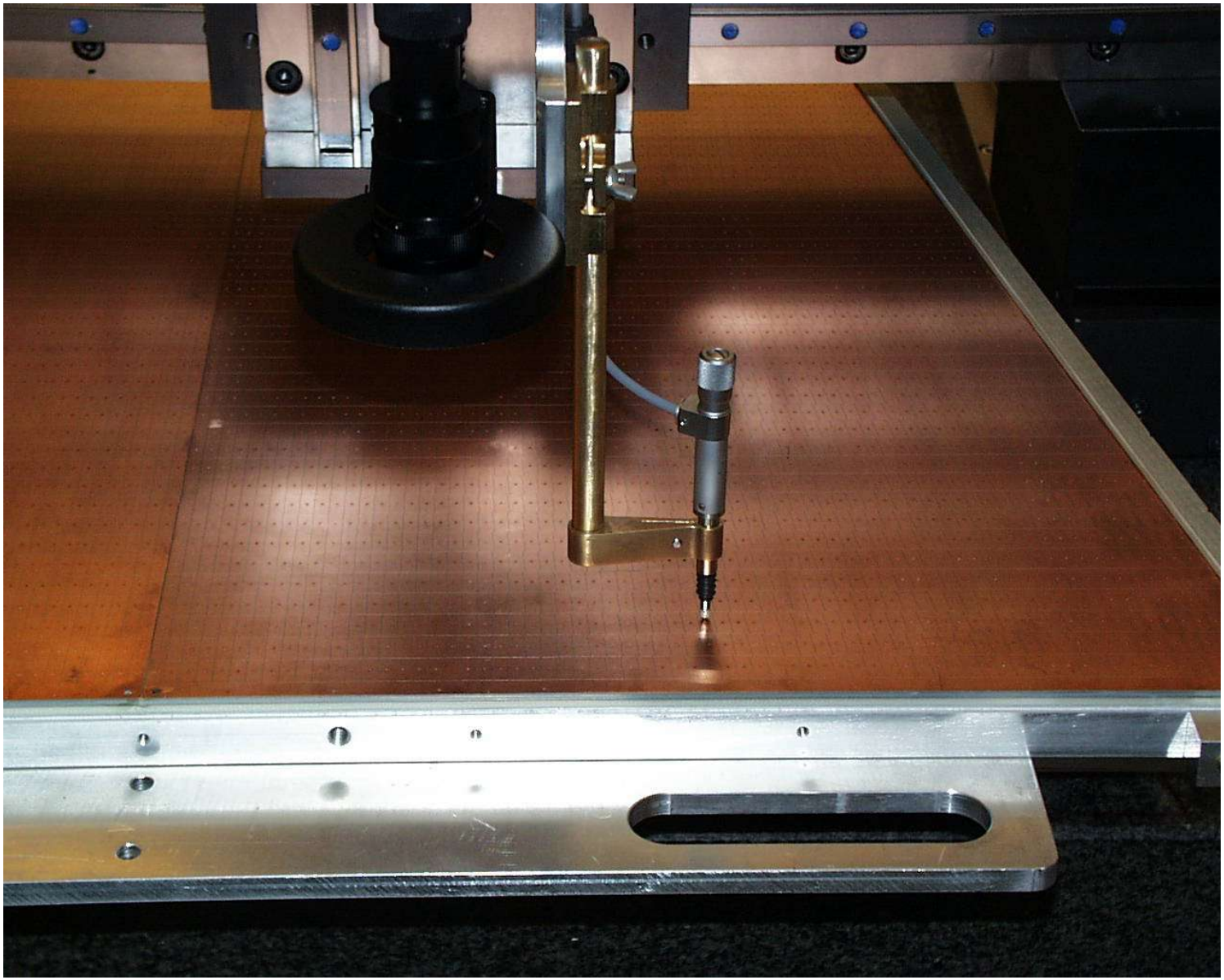
Construction of the TPC readout chambers



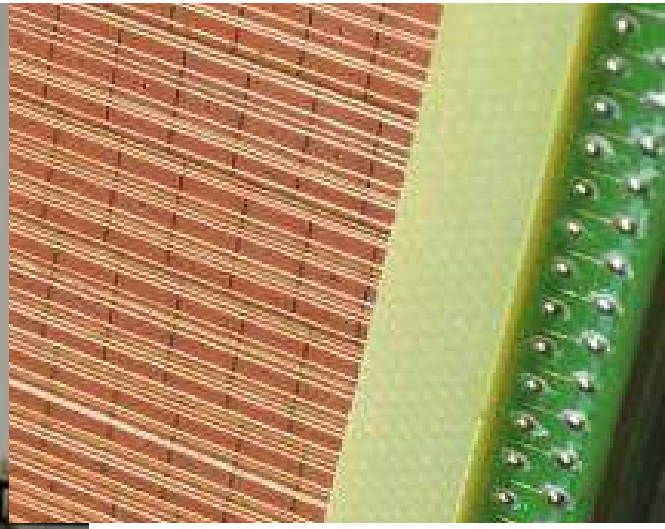


OROC Production Heidelberg/GSI

Survey of planarity and pad geometry



Readout Chamber Production Heidelberg/GSI

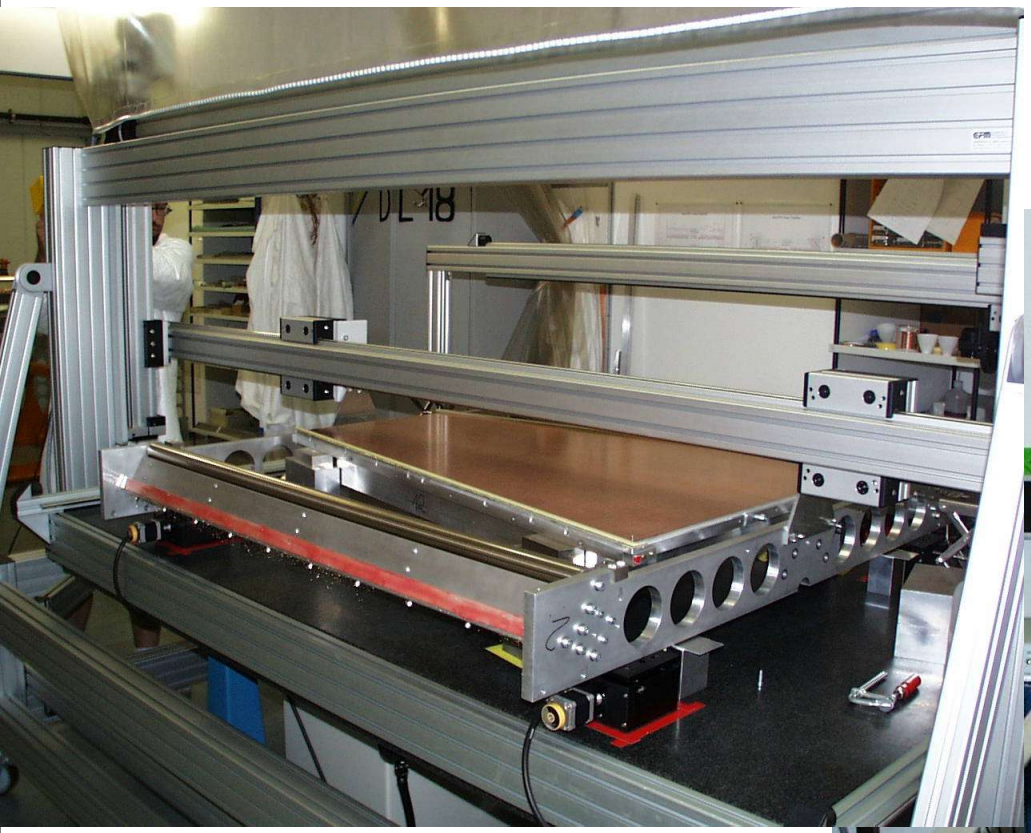


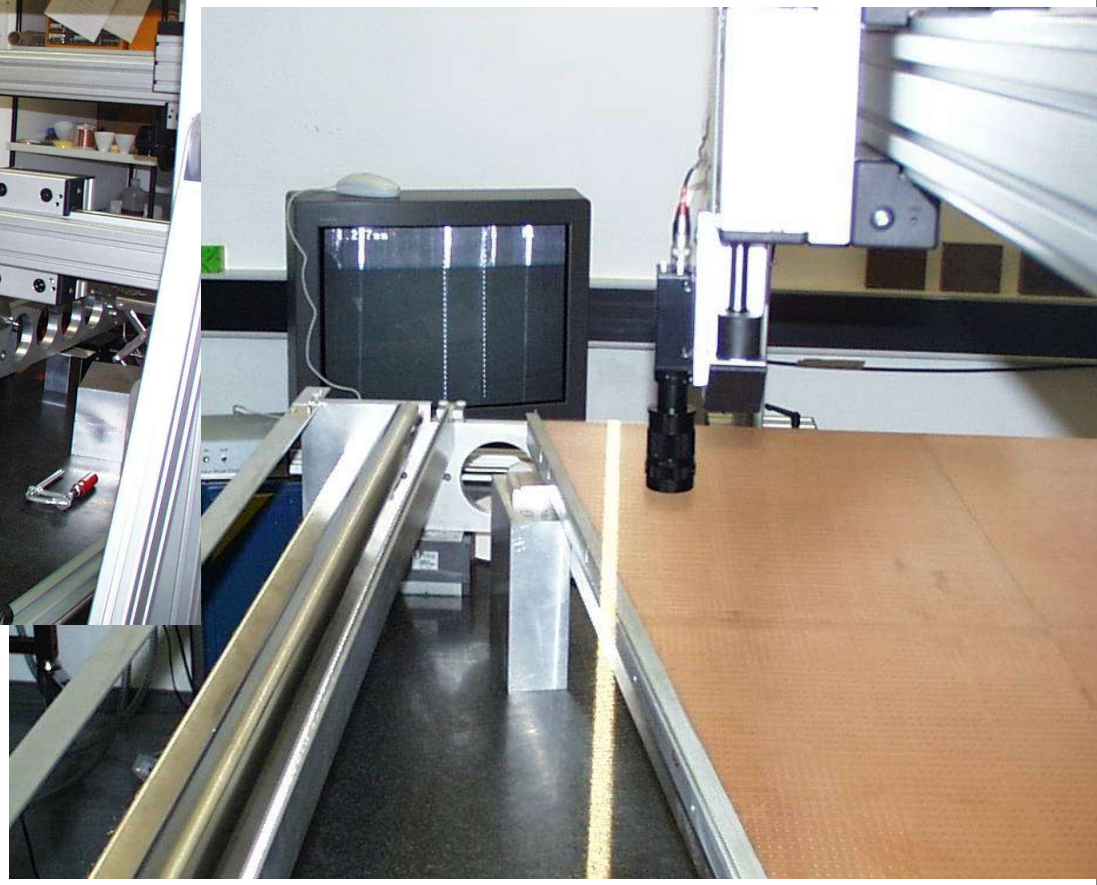
Pads and wires

Adjusting a wire plane before glueing, small chamber type

OROC Production Heidelberg/GSI

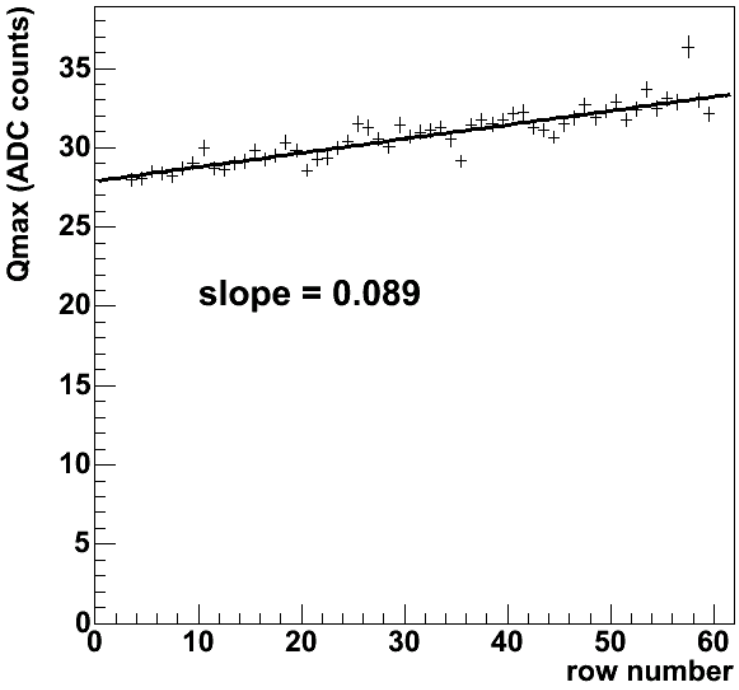
Coarse and fine adjustment of a wire plane

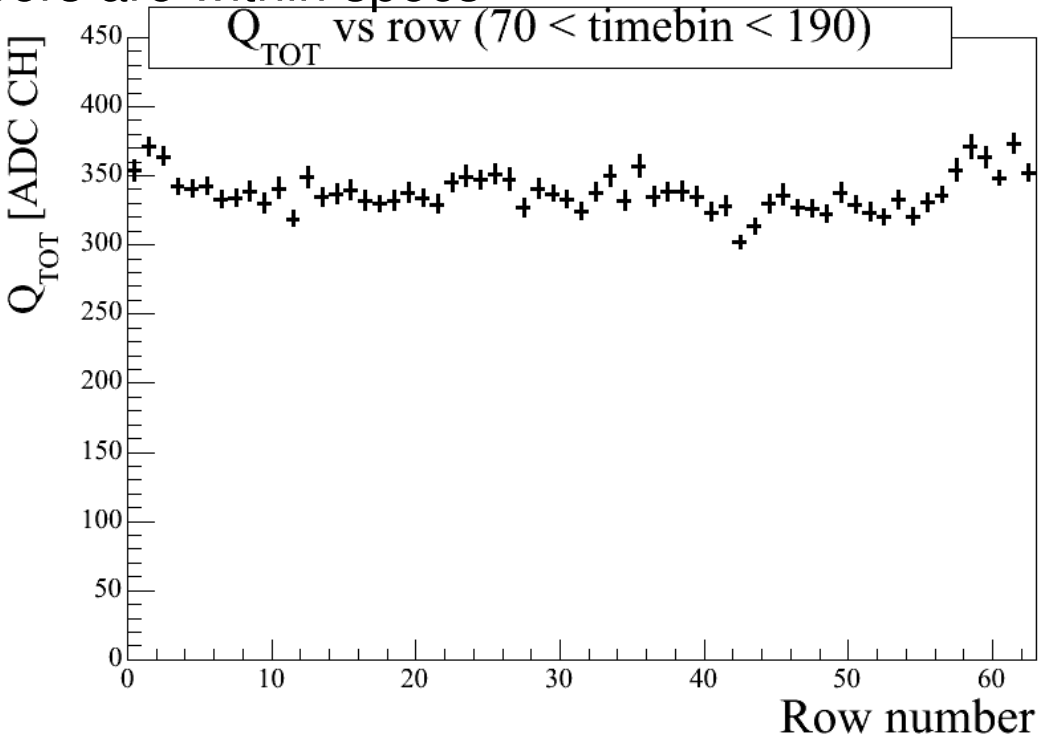




Next big problem:The Gain Variation Story

- Problem traced to pad/anode distance variations of IROC 1
- this chamber was a prototype, should not be installed
- Installed chambers are within specs





IROC 1

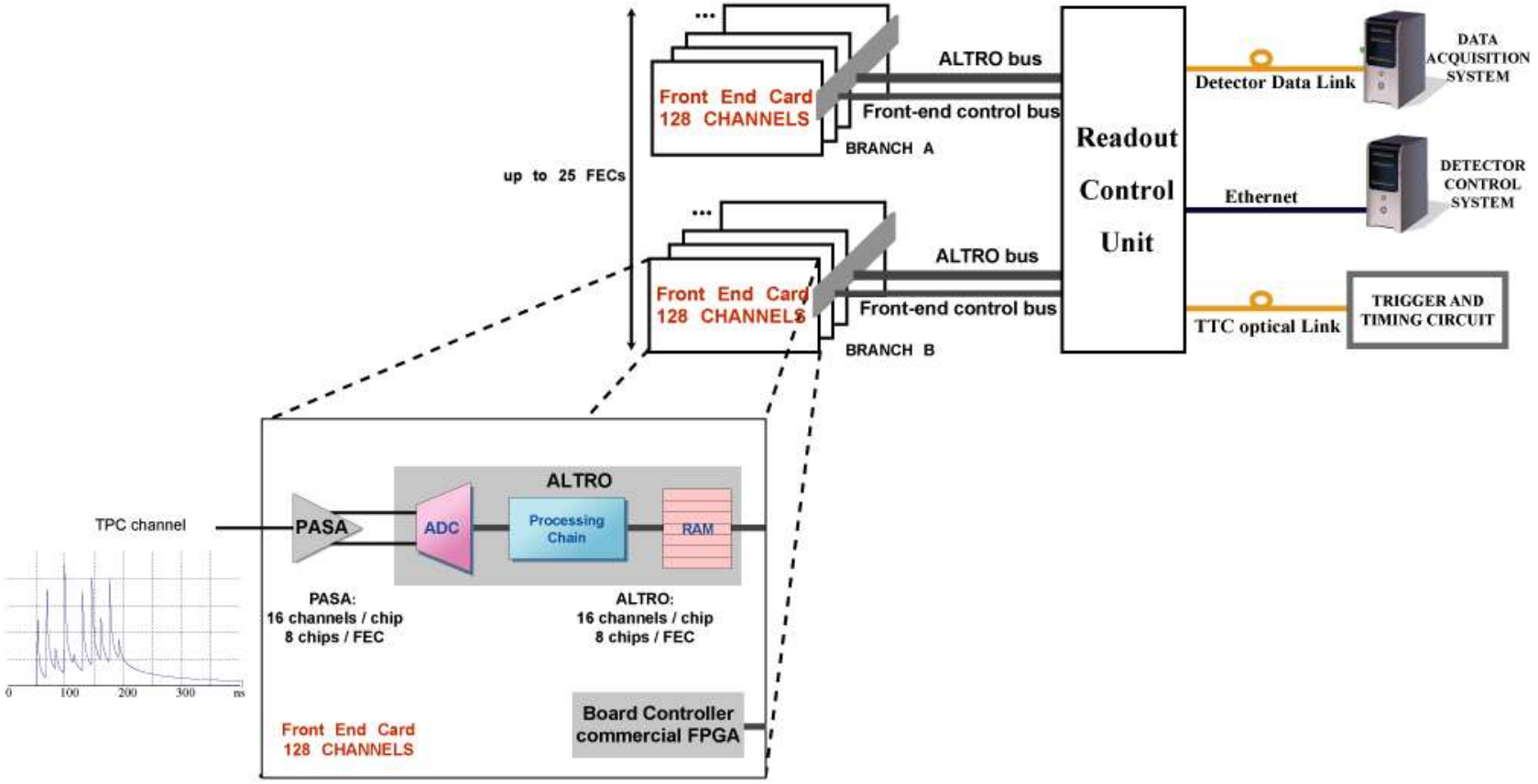
IROC 5

also need electronics for 570000 channels

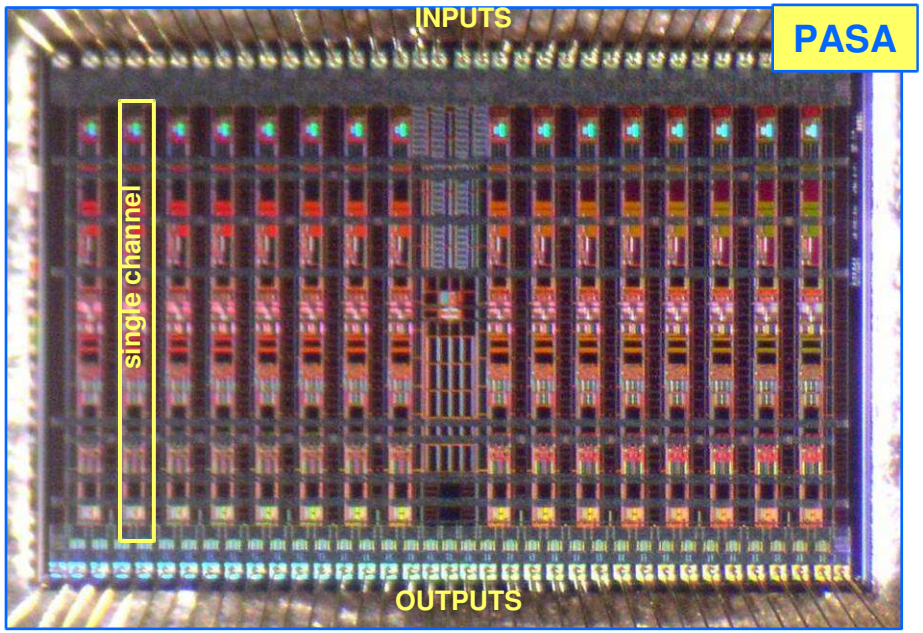
total budget: 4 MCHF
cost/channel: 7 CHF

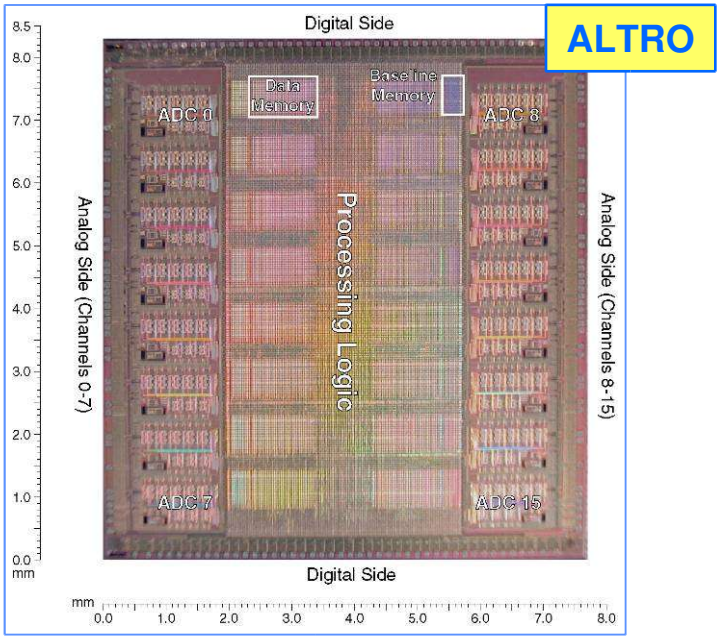
need to design electronics (ASICS)
by ourselves

Each of the 36 TPC Sectors is served by 6 Readout Partitions

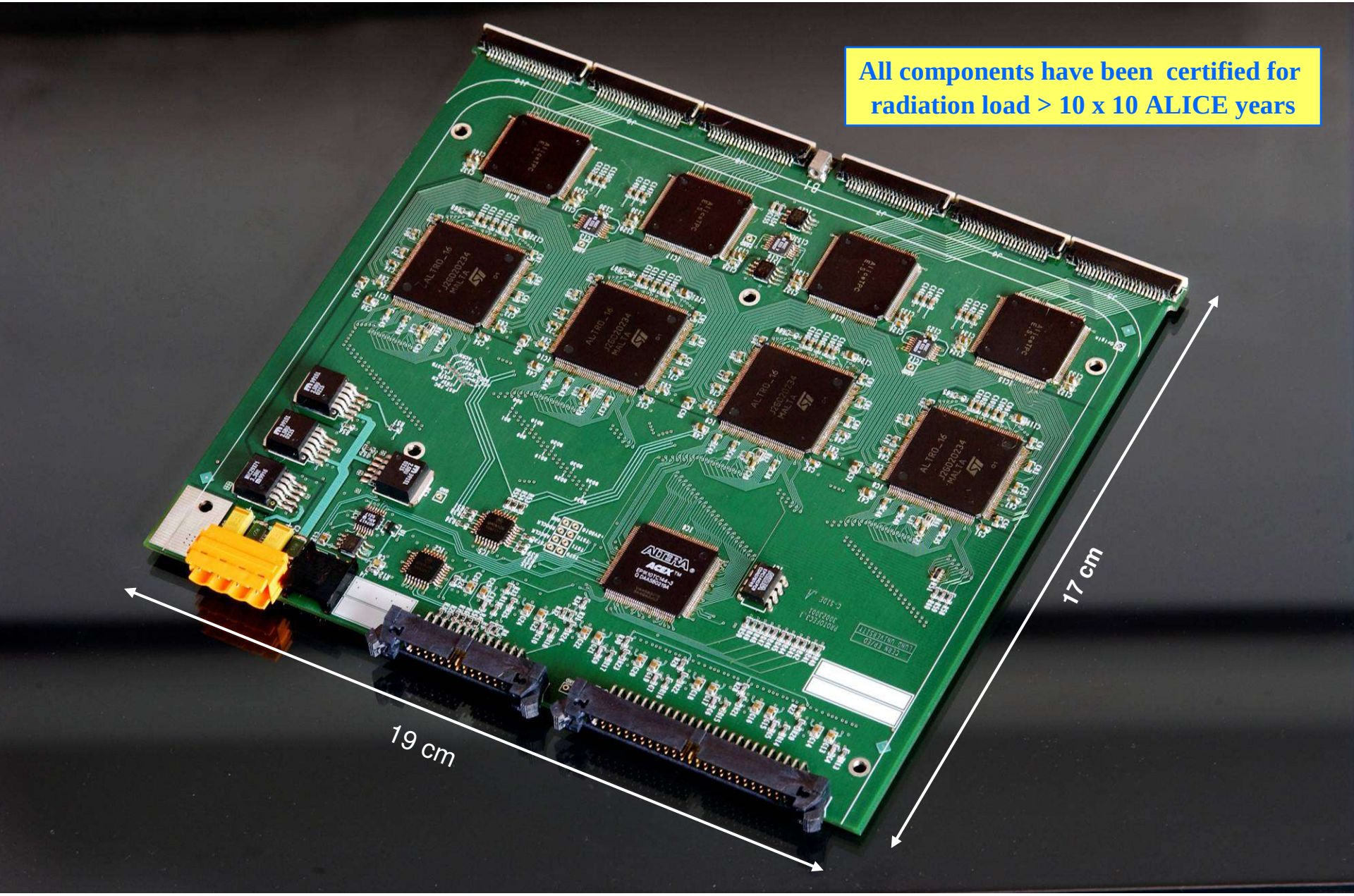


Whole TPC: 4356 Front End Card 216 Readout Partitions





PRODUCTION ENG DATA	PASA	ALTRO
Process	CMOS 0.35 μm	CMOS 0.25 μm
Area	18 mm^2	64 mm^2
Power	11 mW / channel	16 mW / channel
ER Samples	Sep ’03 (500 chips)	Apr ’02 (4K chips)
Mass Production	Jan ’04 (49 Kchips)	Dec ’02 (44 K chips)
Mass Test	May ’04	Feb ’04
Yield	83% - |CG| < 5%, |PT|<5%, |BSL| < 5%	84%

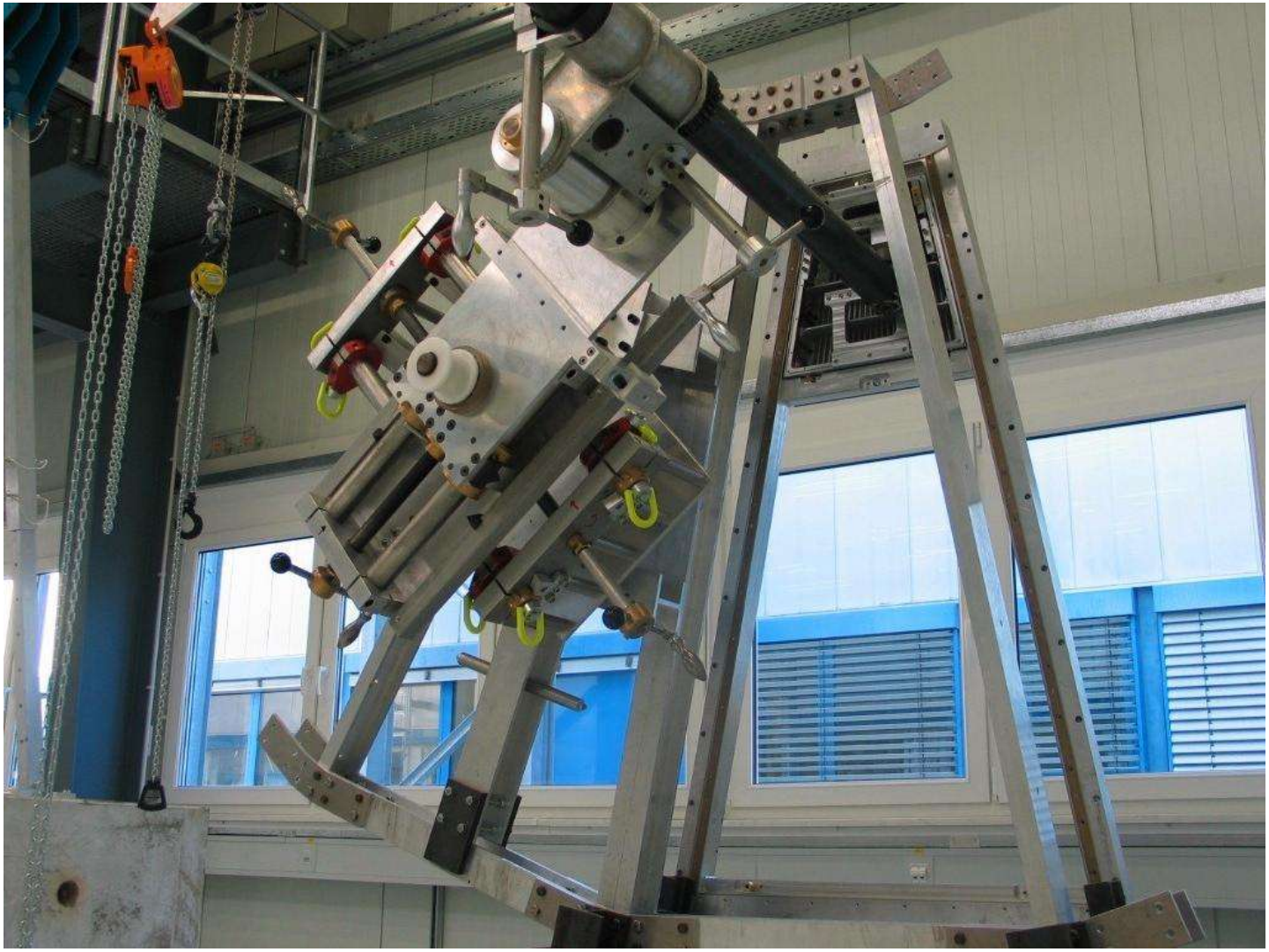

All components have been certified for radiation load > 10 x 10 ALICE years
19 cm
17 cm

note: all 570000 channels need to be tested at 1 min/channel, this implies > 1yr of testing for 3 persons, not acceptable

solution: buy a robot (at Ebay) and program it yourself, testing done in < 3 months

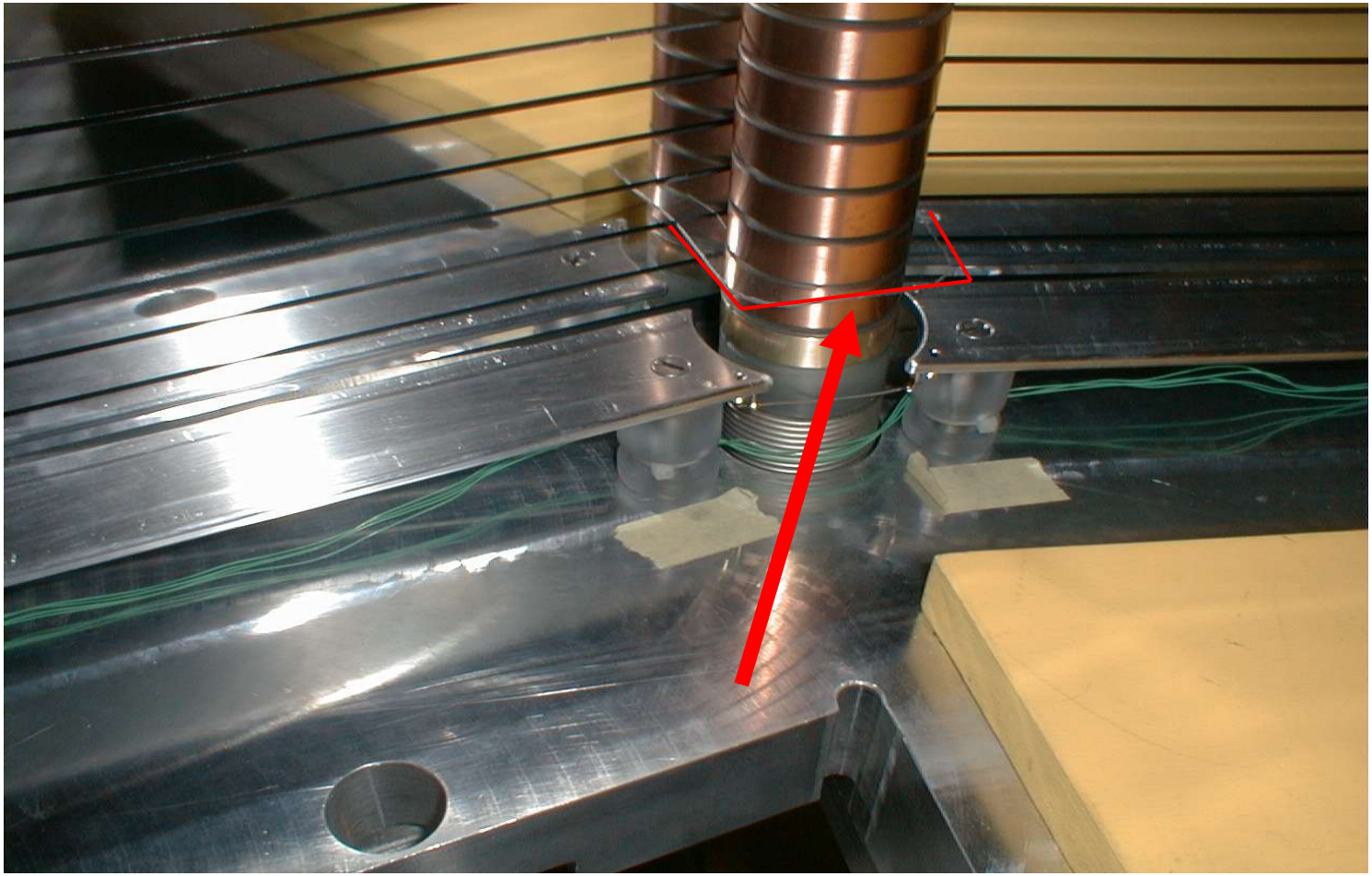
how do we install the read-out chambers?

Chamber Mounting Tool, version 1

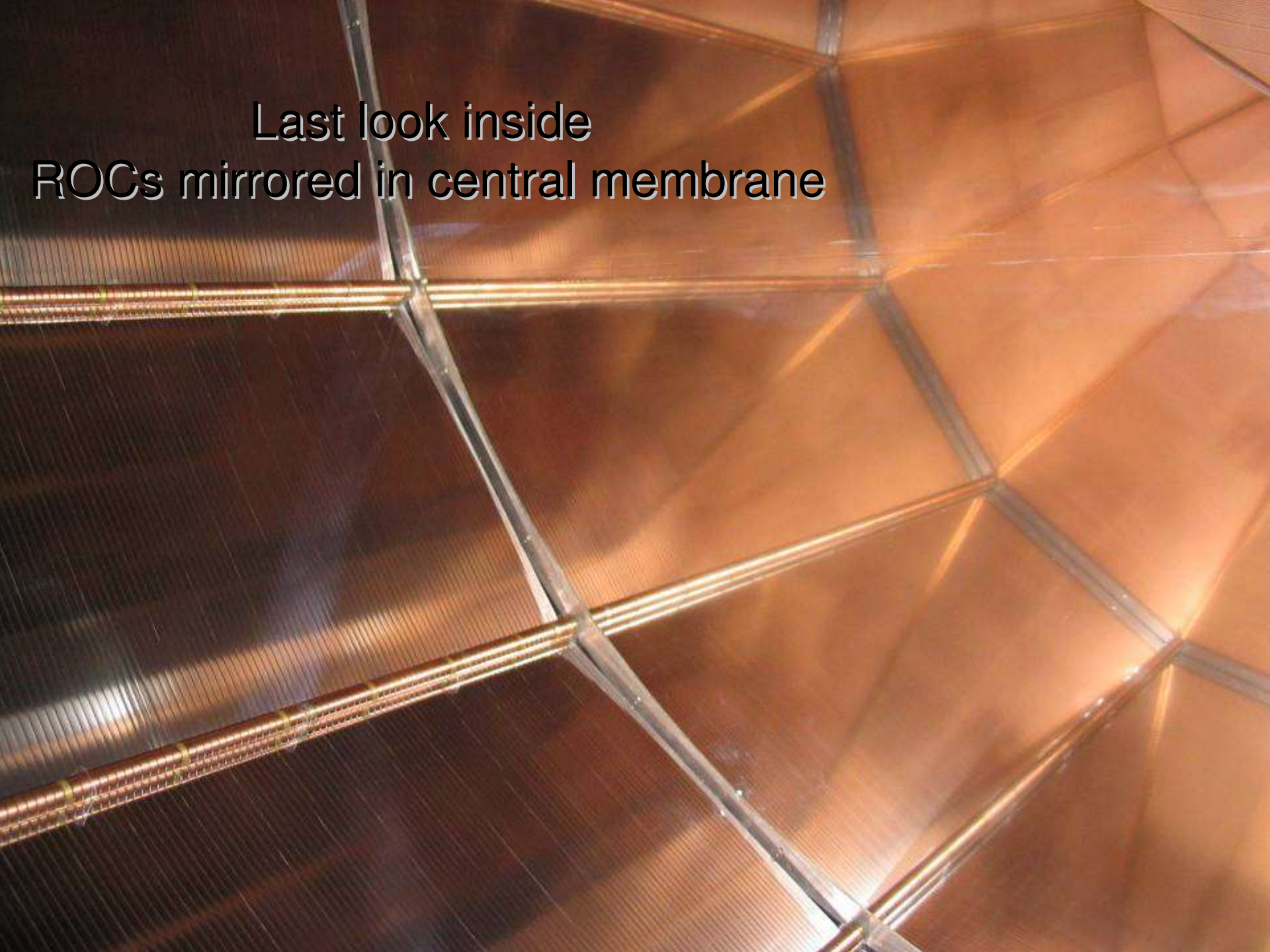


Platform + Mounting Tool in clean room

Critical passage: Inside view



Last OROC

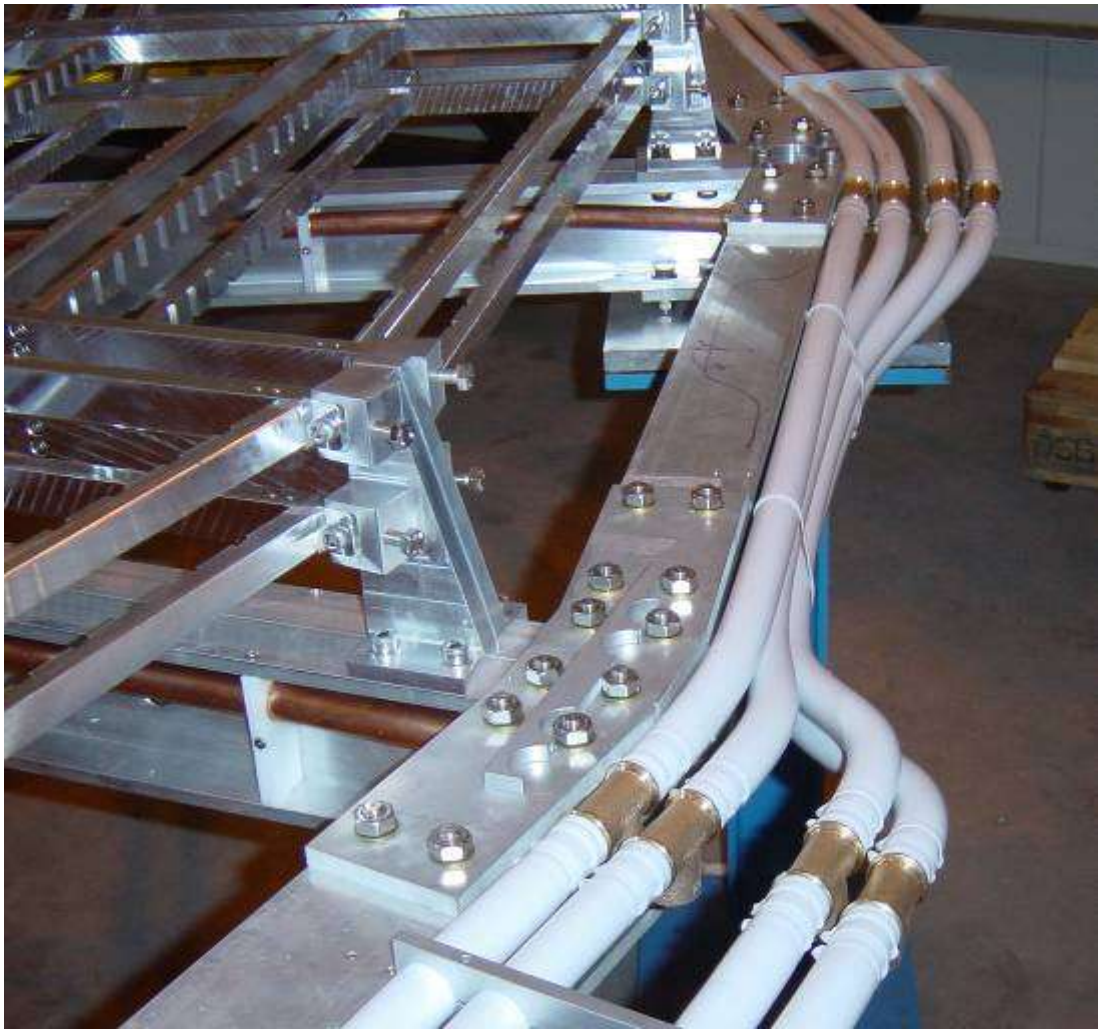

Last look inside
ROCs mirrored in central membrane

the electronics weighs 2 tons

how do we support this?

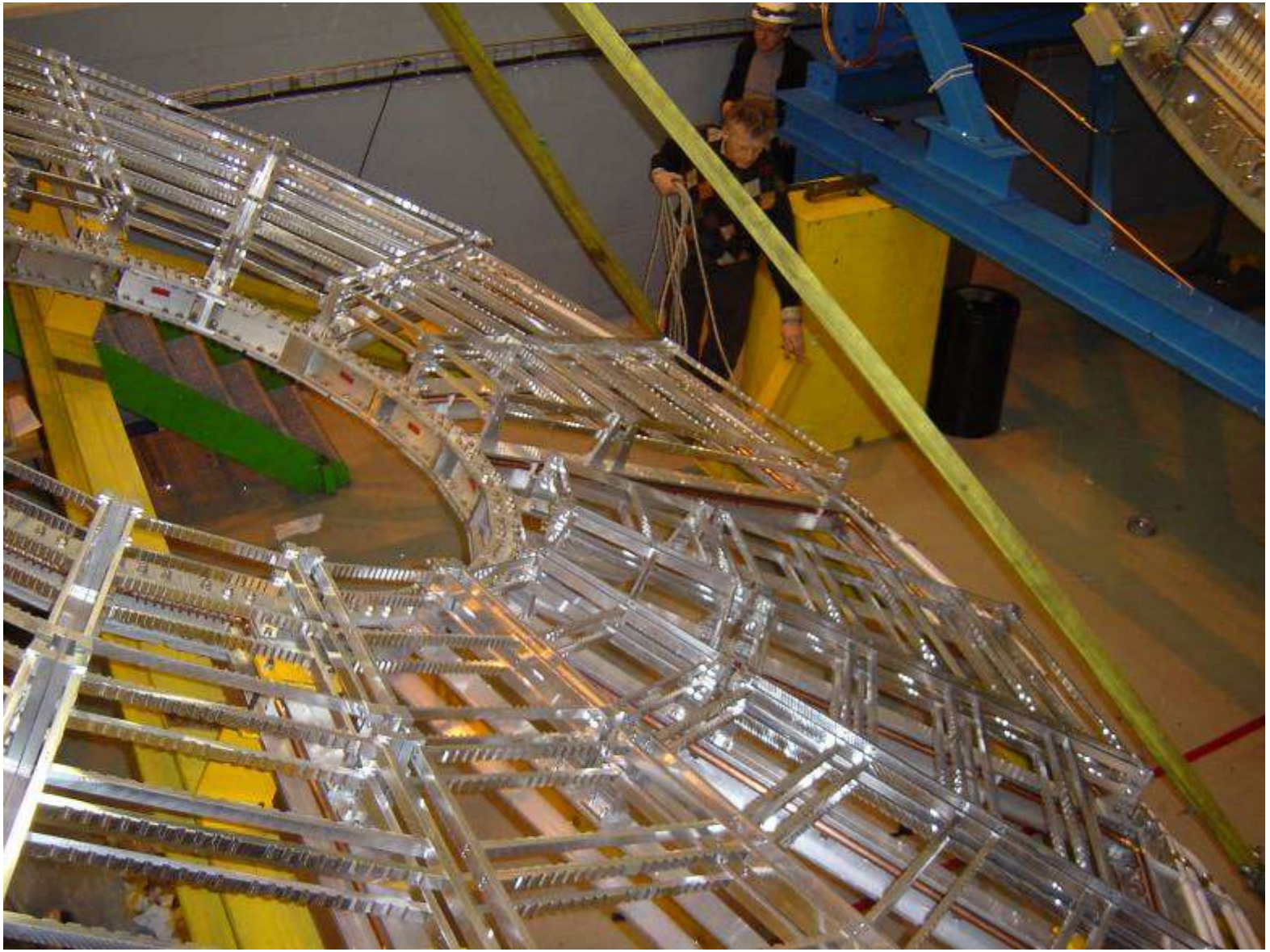
Service Support Wheels

unequipped SSW for integration test



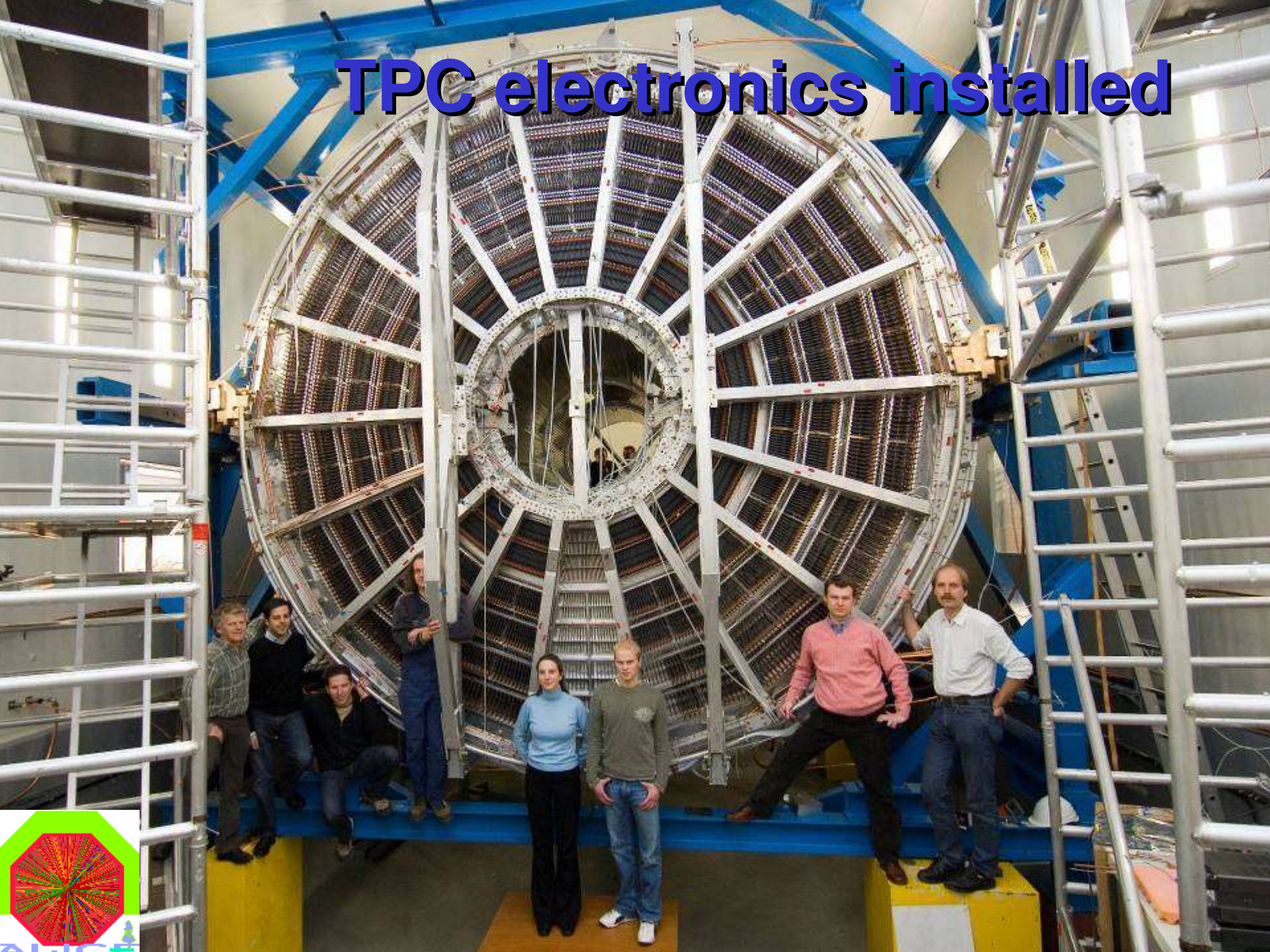
equipped with cooling + FEC frames

SSW installation



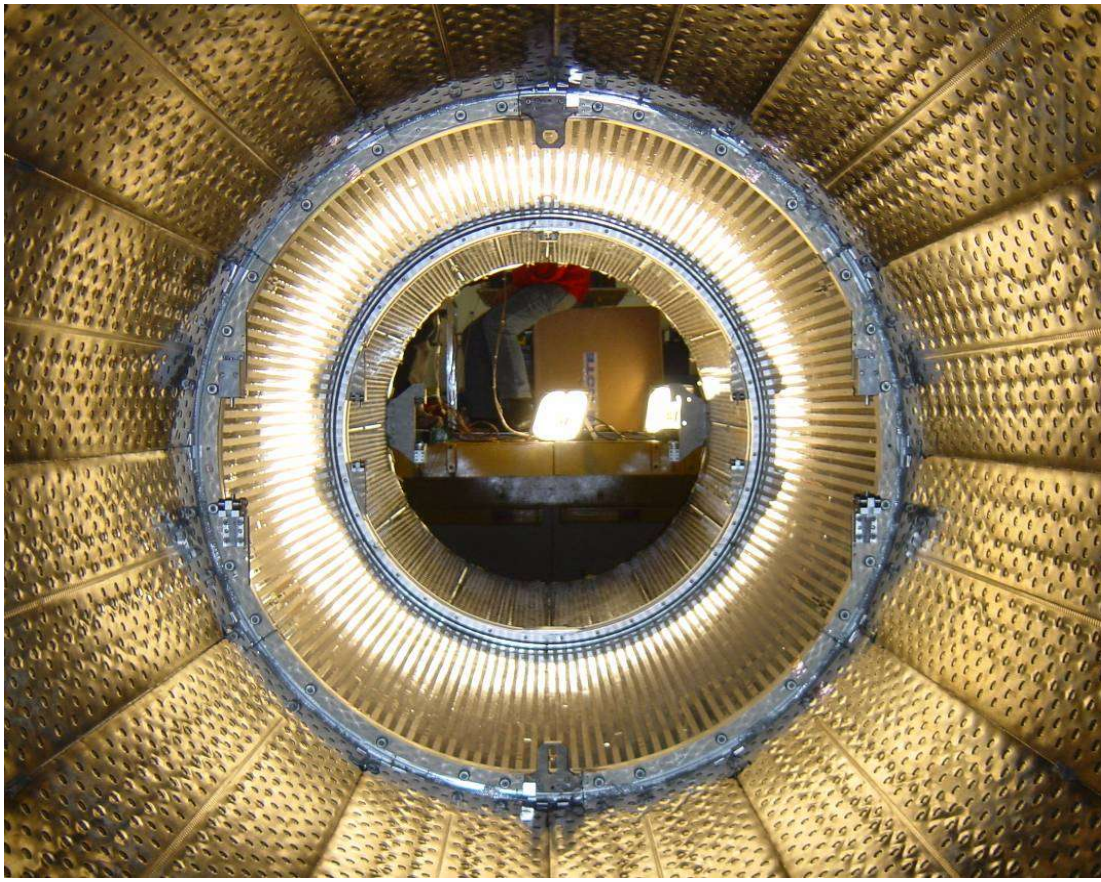
FE Cards Installation highlights

TPC electronics installed



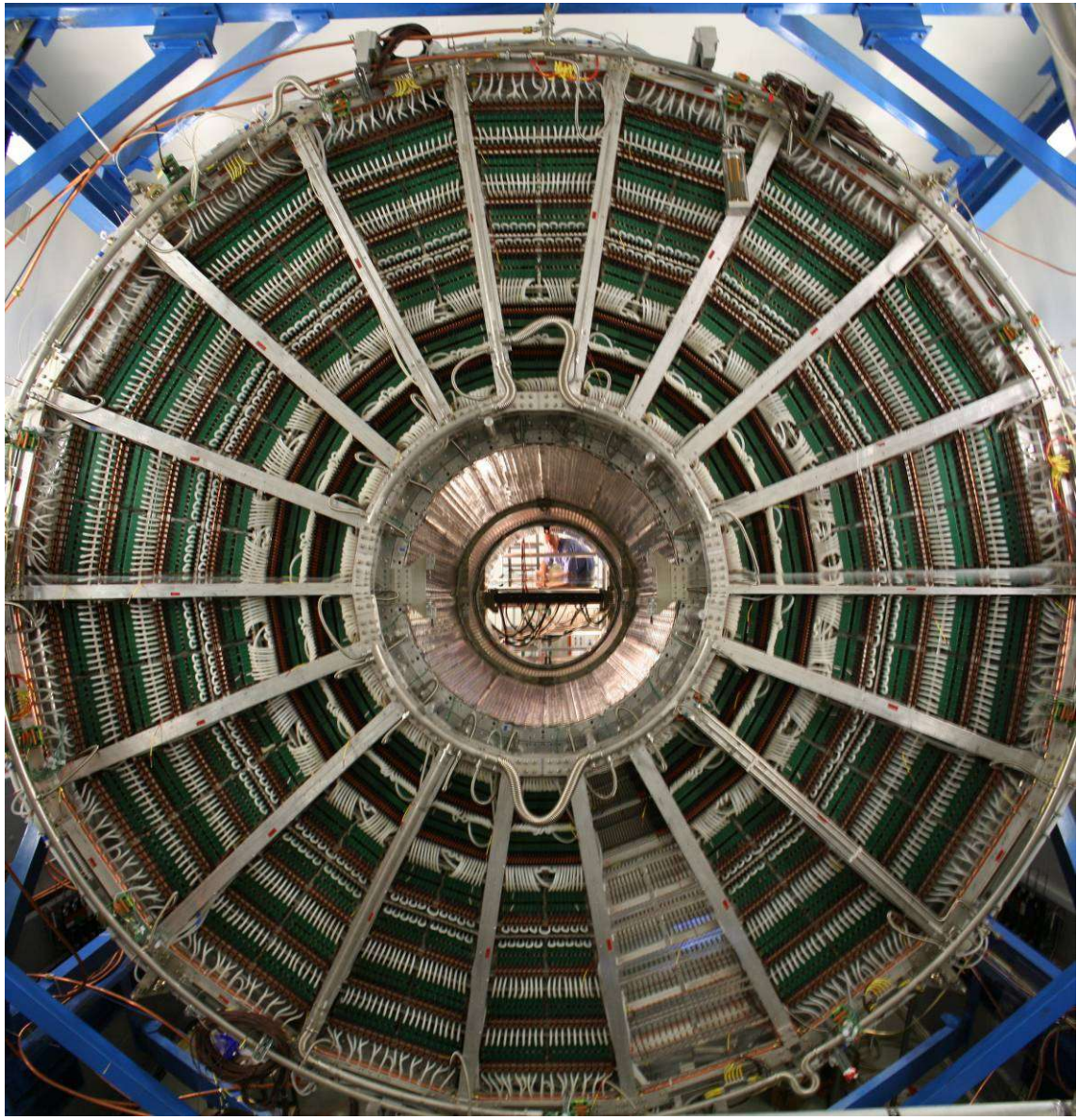
Heat screens

- Inner thermal screen installed, shields from ITS services
- Reminder: no screen towards ITS
- Outer thermal screen:
  - Decision for active screen
  - Design is advanced: fixed to SF from TPC side
  - Offer received
  - Install July/Aug 06, if possible earlier



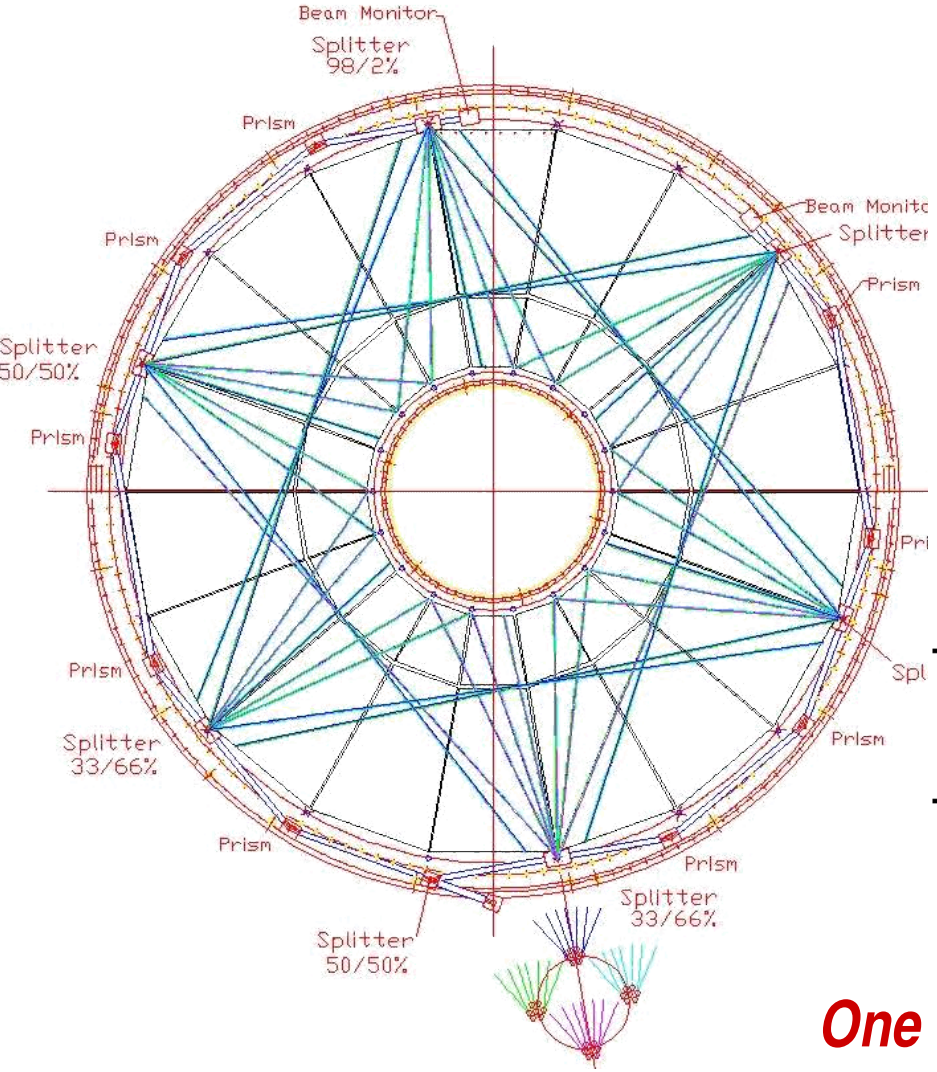
The ALICE TPC has entered the commissioning phase

- 2006/Q1: Frontend electronics installation
  - 72 readout chambers
  - 4356 FEE cards
  - 557,568 channels
  - up to 1000 time bins each
- Commissioning above ground since May
  - Gas system: 95 m^3 $Ne/CO_2/N_2$ (90/10/5), now few ppm O_2
  - test 2 sectors at a time
  - Full data chain
  - Cosmics tracks
  - Laser tracks
  - Noise σ ~ 0.7 – 0.8 ADC cts
- Move to cavern in December

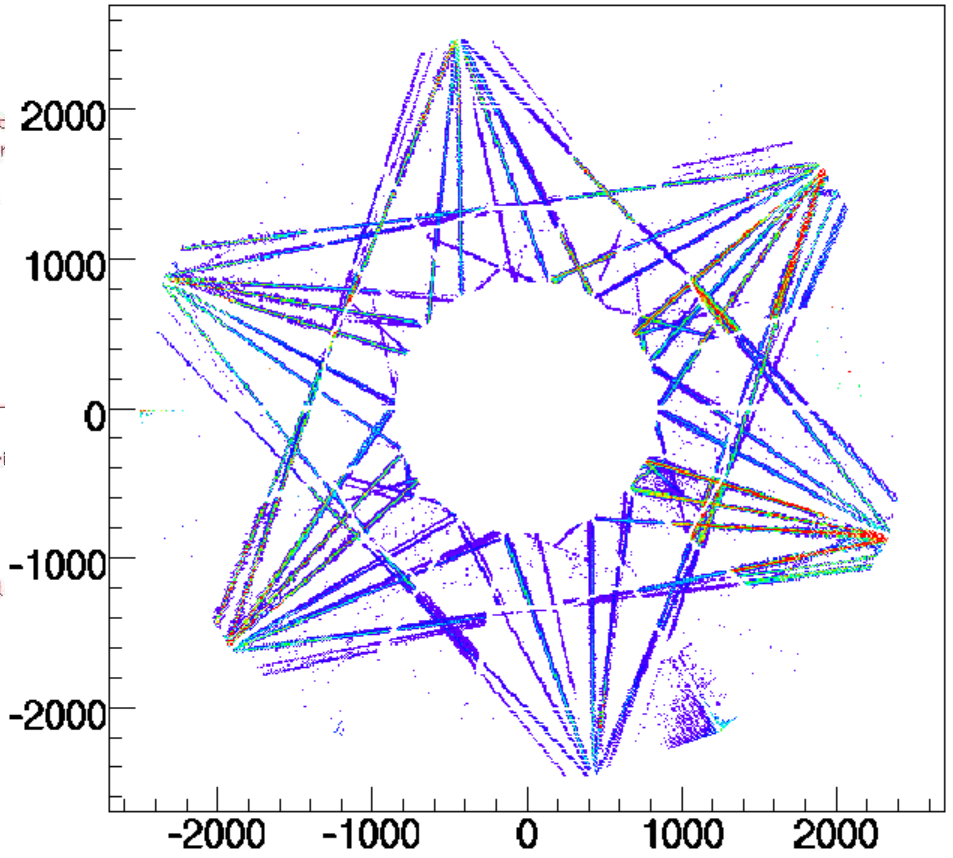


Laser system

Design Side A

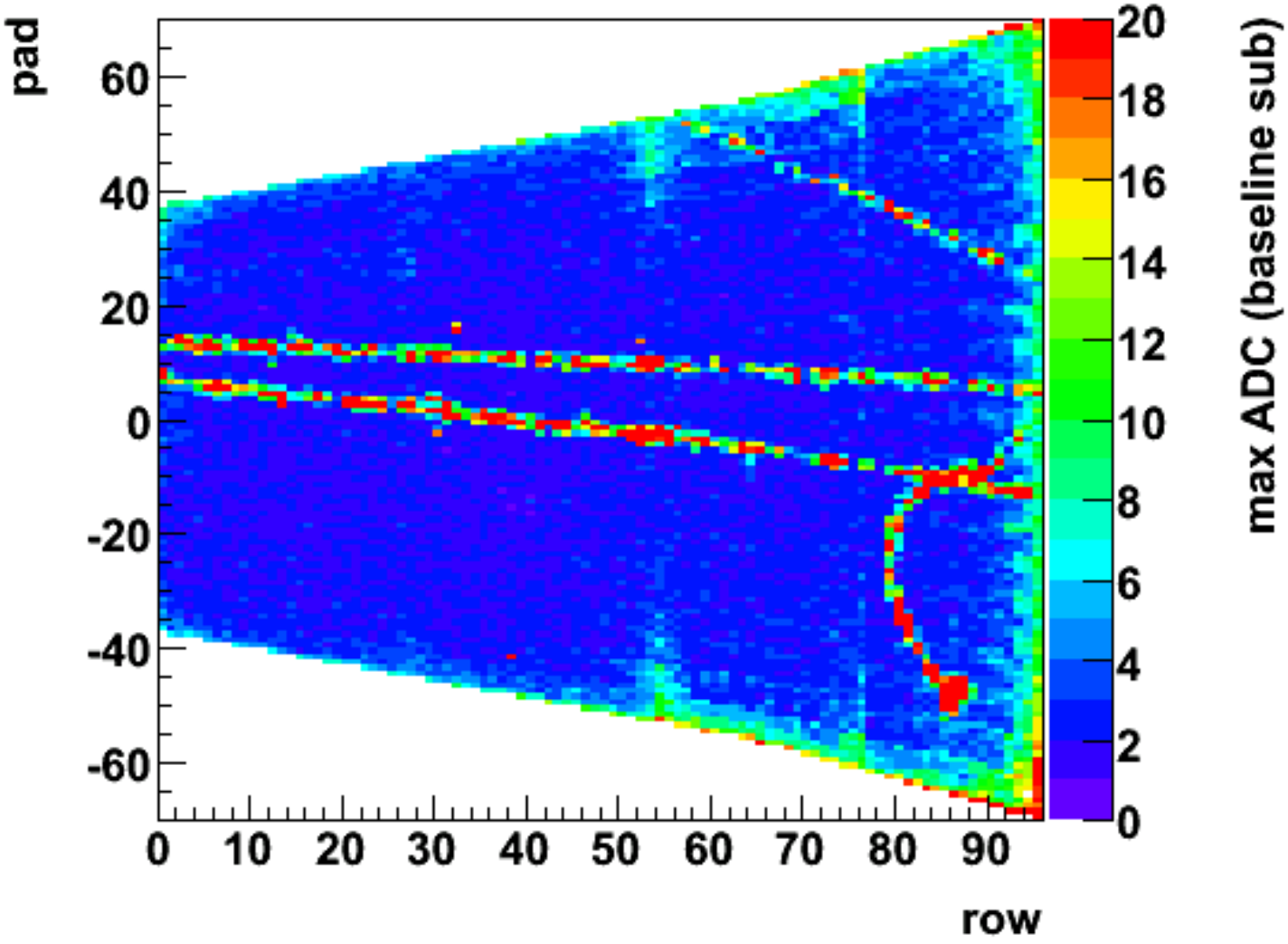


Measured Side A



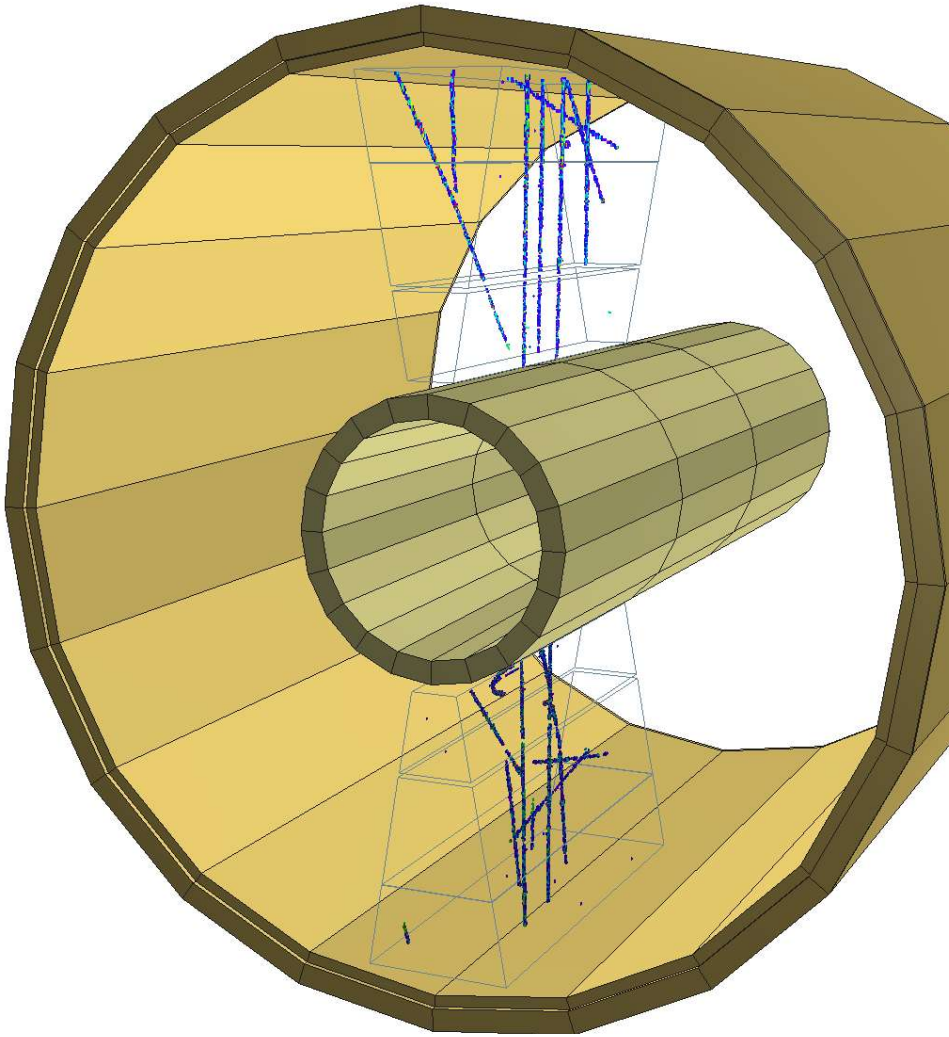
One laser installed on the floor

Cosmic tracks in OROC 13



TPC Status now

- Phase1 of commissioning completed
- tracking performance as in Technical Design Report
- long term tests of detectors and electronics to follow
- installation of TPC into ALICE from Dec. 2006 on



currently:
commissioning will be completed Nov. 06

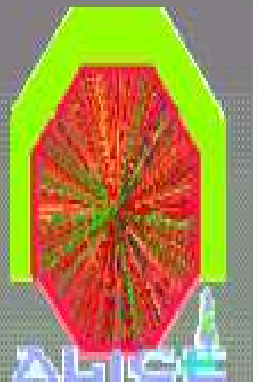
transport TPC into ALICE pit Dec. 06

keep your fingers crossed

ALICE-TPC collaboration:

Bergen, Bratislava, CERN, Copenhagen, TU Darmstadt, GSI Darmstadt,

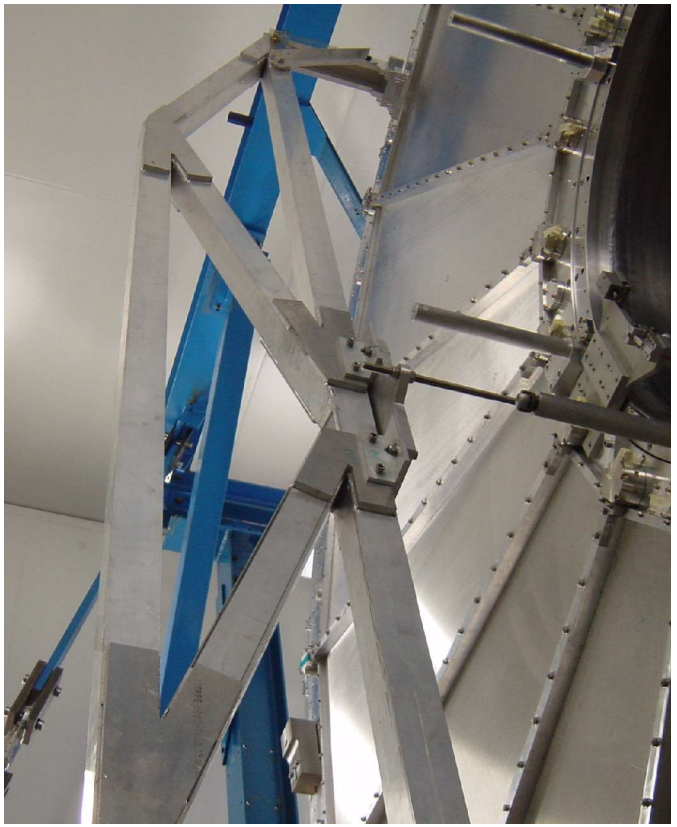
U Frankfurt, Heidelberg KIP, Heidelberg PI, Krakau, Lund

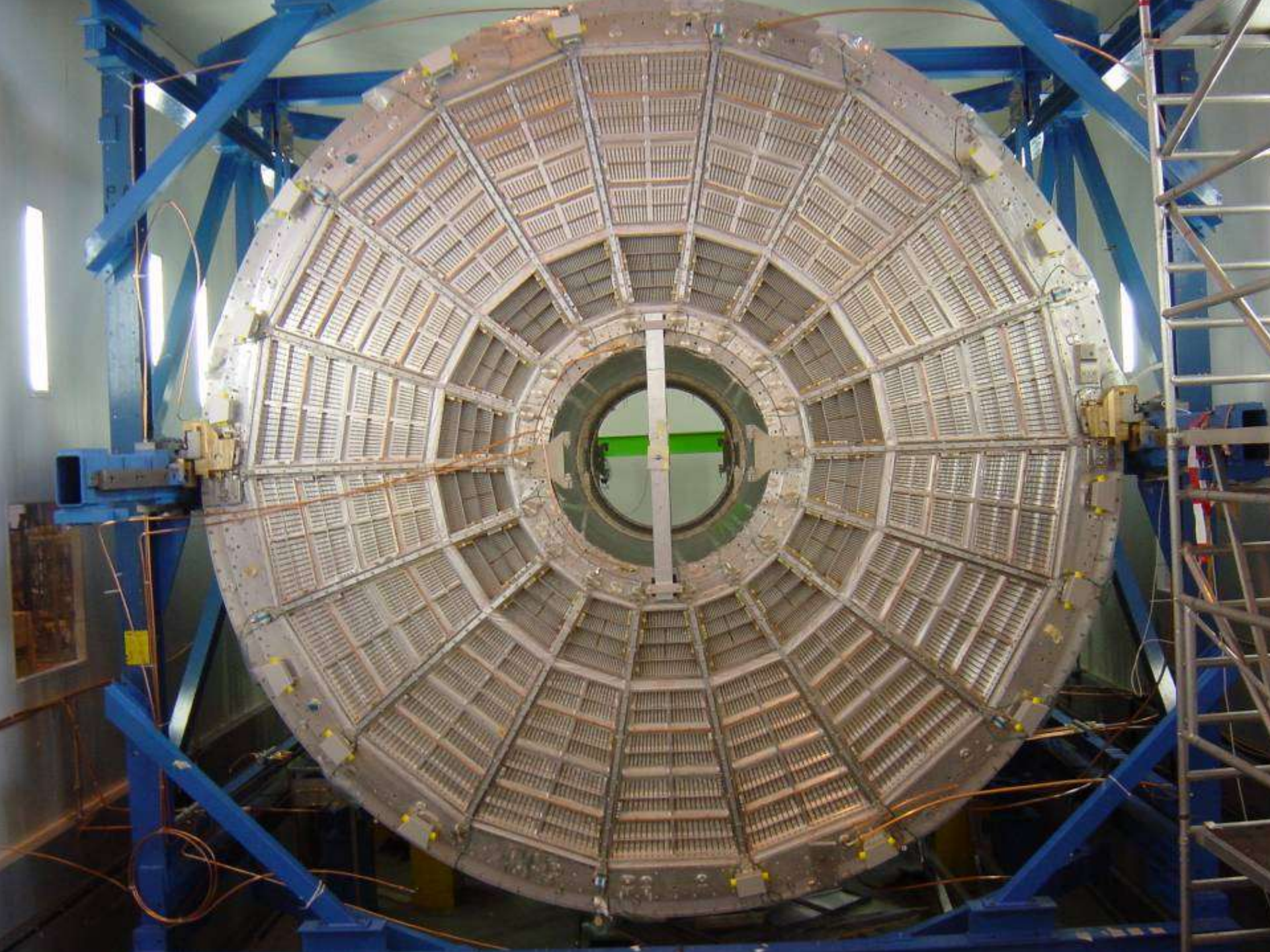


additional slides

Straightening the end plate

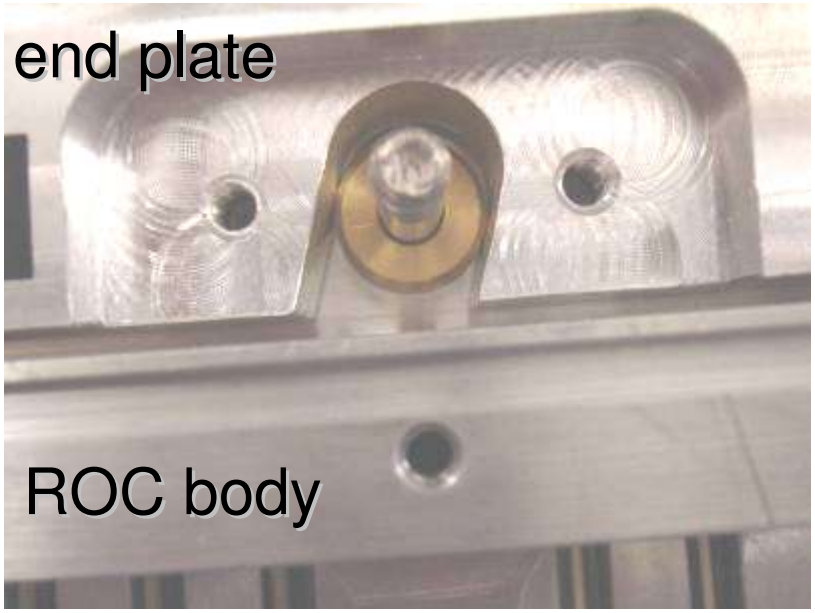
- Decision to use 2 I-bars
- Force needed for flat end plate: F= 2 x 2600 N
- Integration problems with ITS solved (installation situation actually improved for ITS)
- 2nd set of I-bars needed to allow changing between A and C-side (never again allow the endplate to go to its conical shape)
- 2nd set already delivered





Precision Shimming of the ROCs

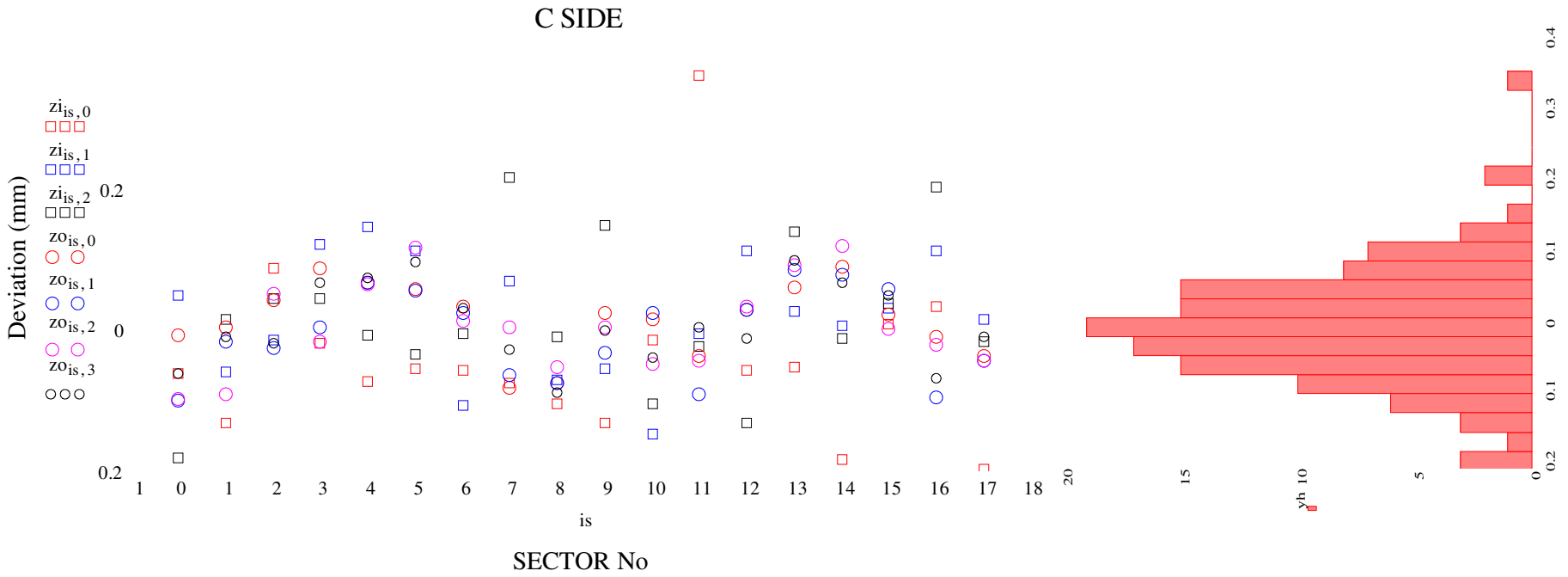
- Steps:
  - survey
  - take out shims
  - machine to correct length
  - reinsert shims
- Overall precision: 200 µm



Mounting point, shim removed

Survey result of ROCs, A-side

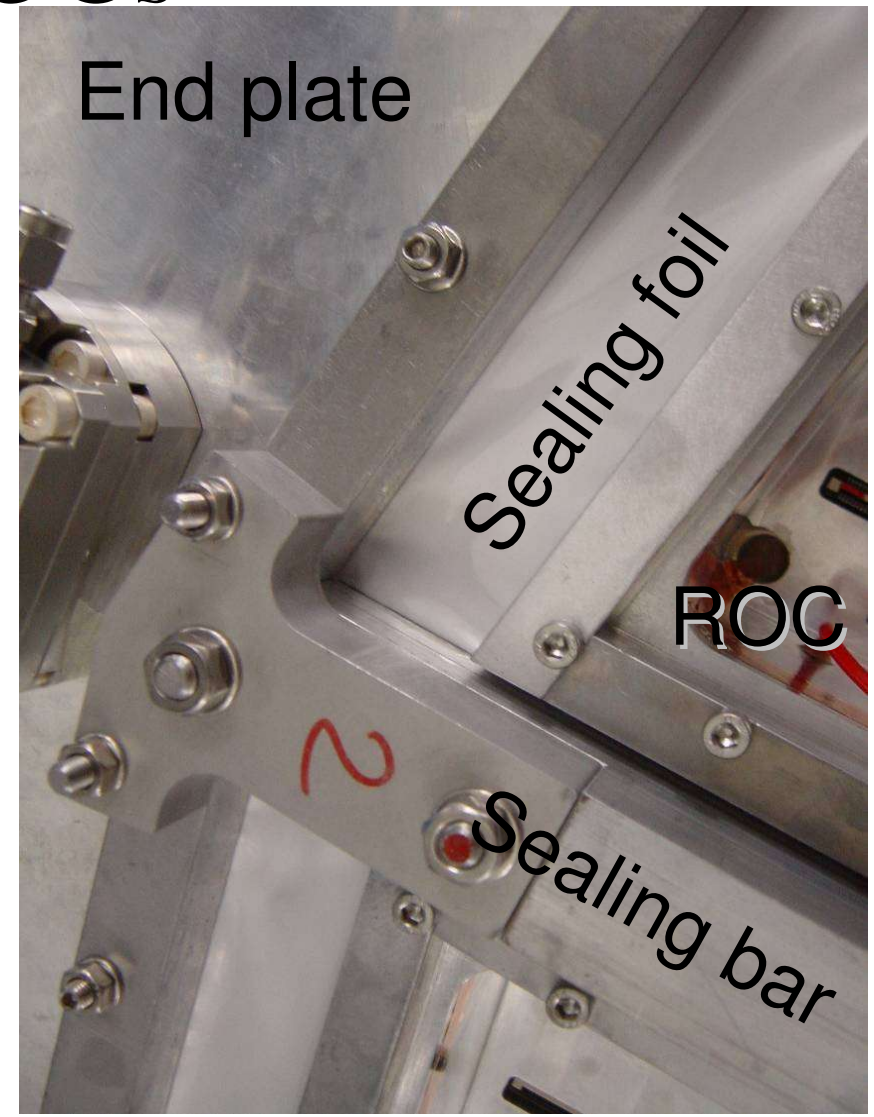
Survey, C-side



- peak-to-peak ± 200 μm
- rms < 100 μm
- one outlier each side

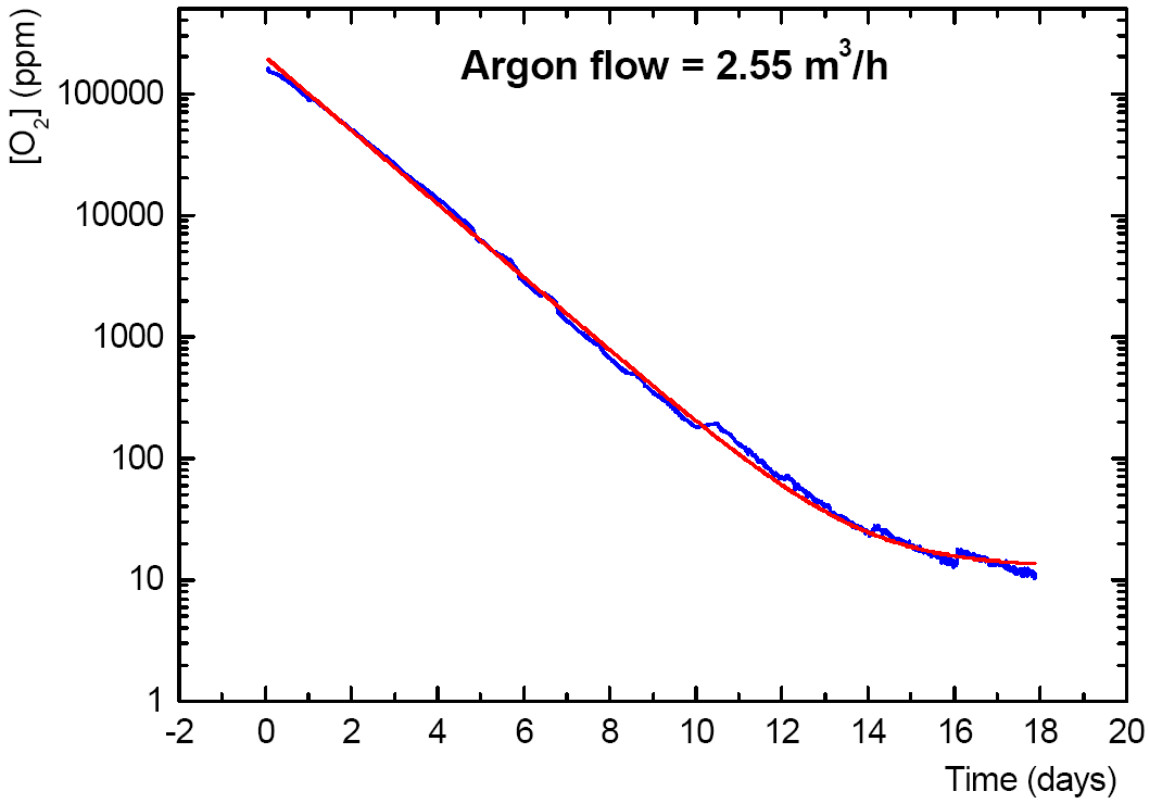
After mounting ROCs

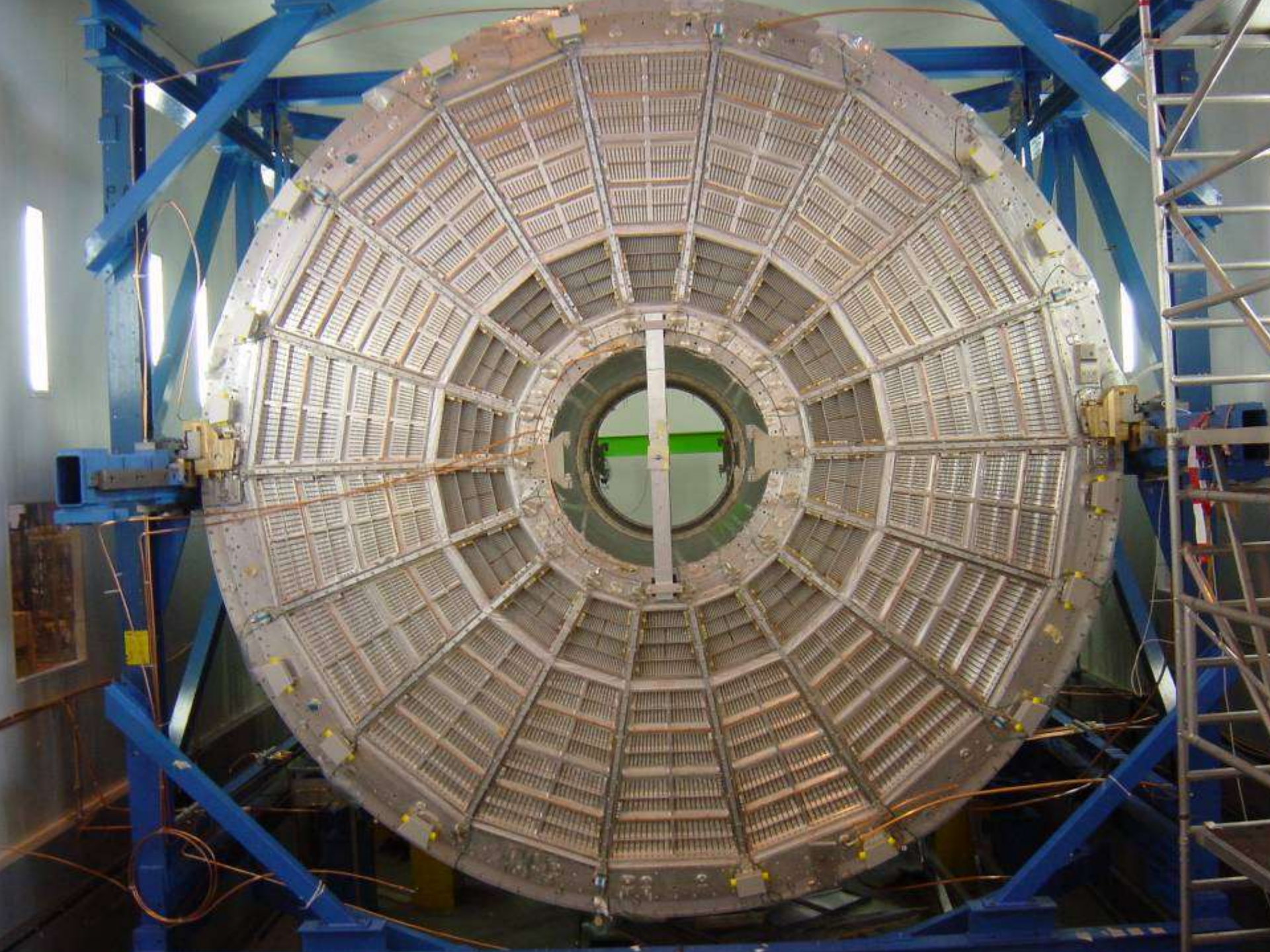
- Sealing chambers
- Leak test
  - He-sniffing
  - One OROC and one seal exchanged
- Argon test



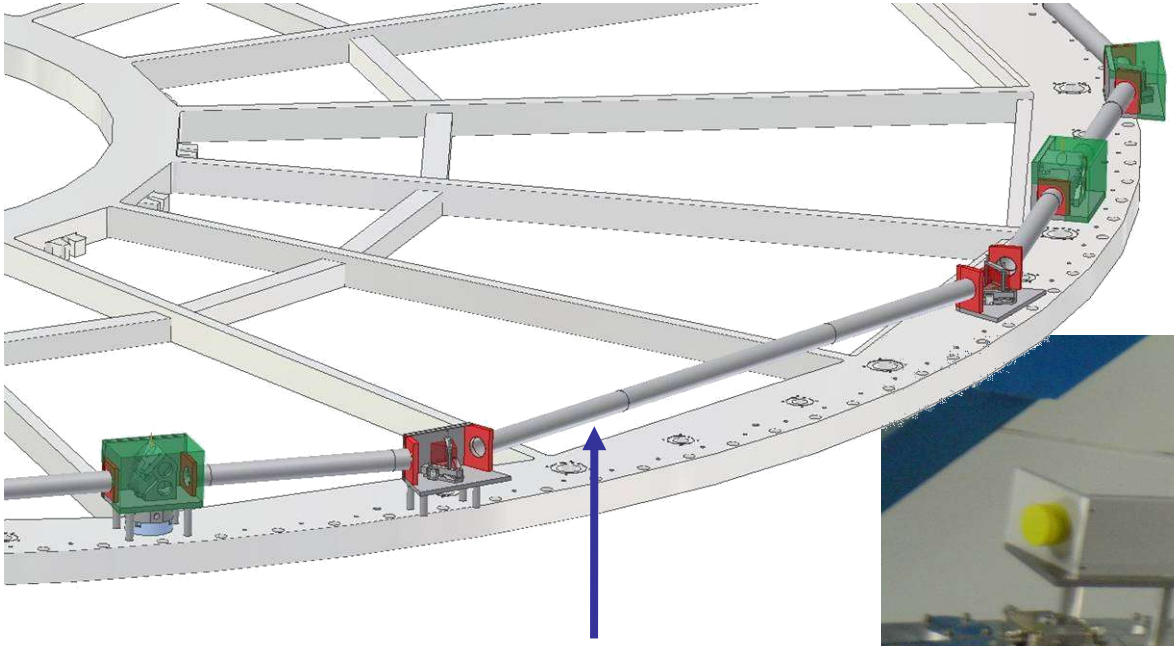
Argon test

- Flow 2.6 m^3/h
- 4x less than with final system → 4x more sensitive
- 11 ppm O_2 reached 24.2.06, still not asymptotic
- extrapolated < 3 ppm for final flow





Laser system optics and mechanics



Safety tube

- Most components installed on end plate
- Alignment and start-up Apr 06

Service Support Wheels (SSW)

- Used ‘bare’ in ITS-TPC integration test
- Services partially preinstalled
  - LV bus bars delayed due to quality problem
- Mounted on Delphi frame rail at end plates
- Load FEC frames to simulate FEC weight (1.1 t each side)
- Alignment of FEC frames to ROCs
- Deformation of wheel < 0.1 mm

SSW sector prototype

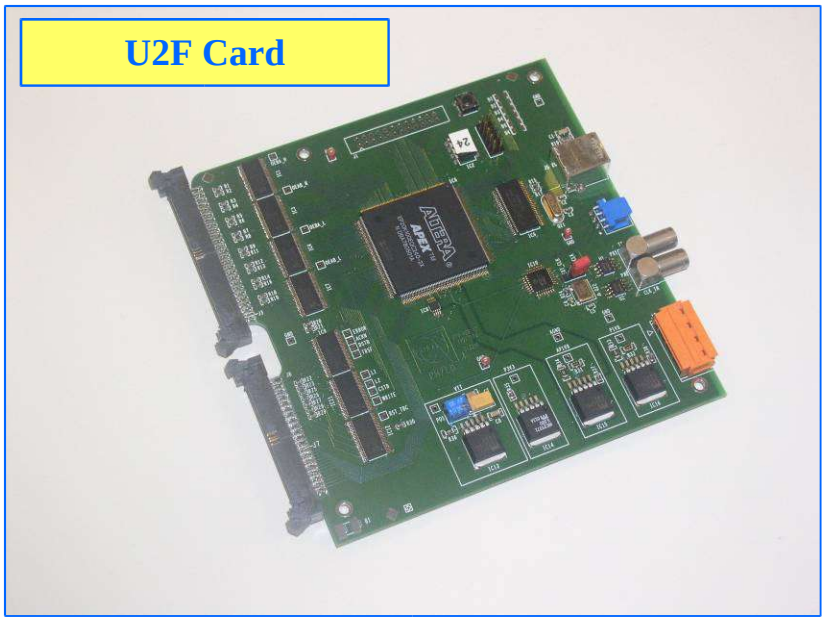
SSW C-side

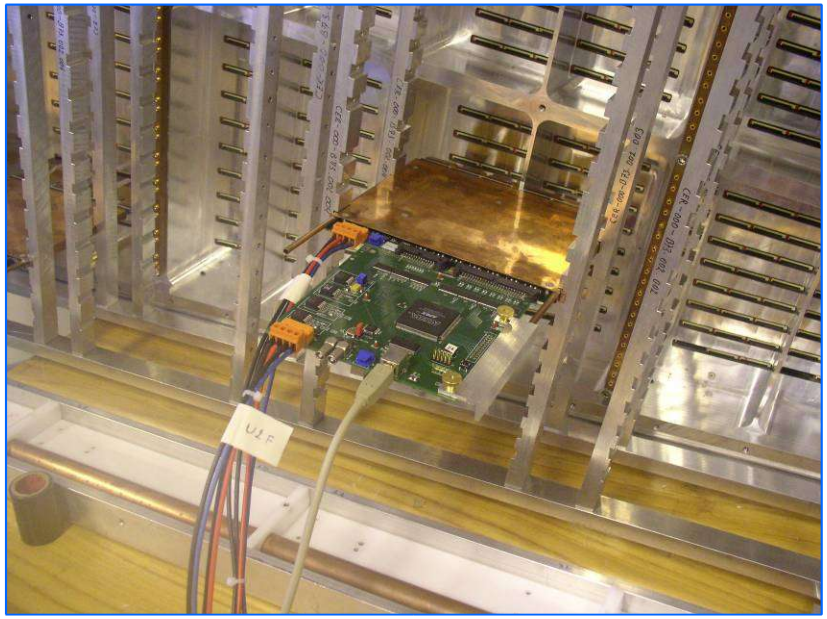
SSW
loaded

FEE installation

During the installation, the FECs are tested individually (stand-alone) by means of a dedicated “mounting test tool”, U2F (USB to FEC interface)

- **Measurement of VCC_A, VCC_D, I_A, I_D and T**
- **Test of all CSRs, Control & Readout path**
- **Readout of trigger related data (pulser)**
- **Connection to the pad plane**



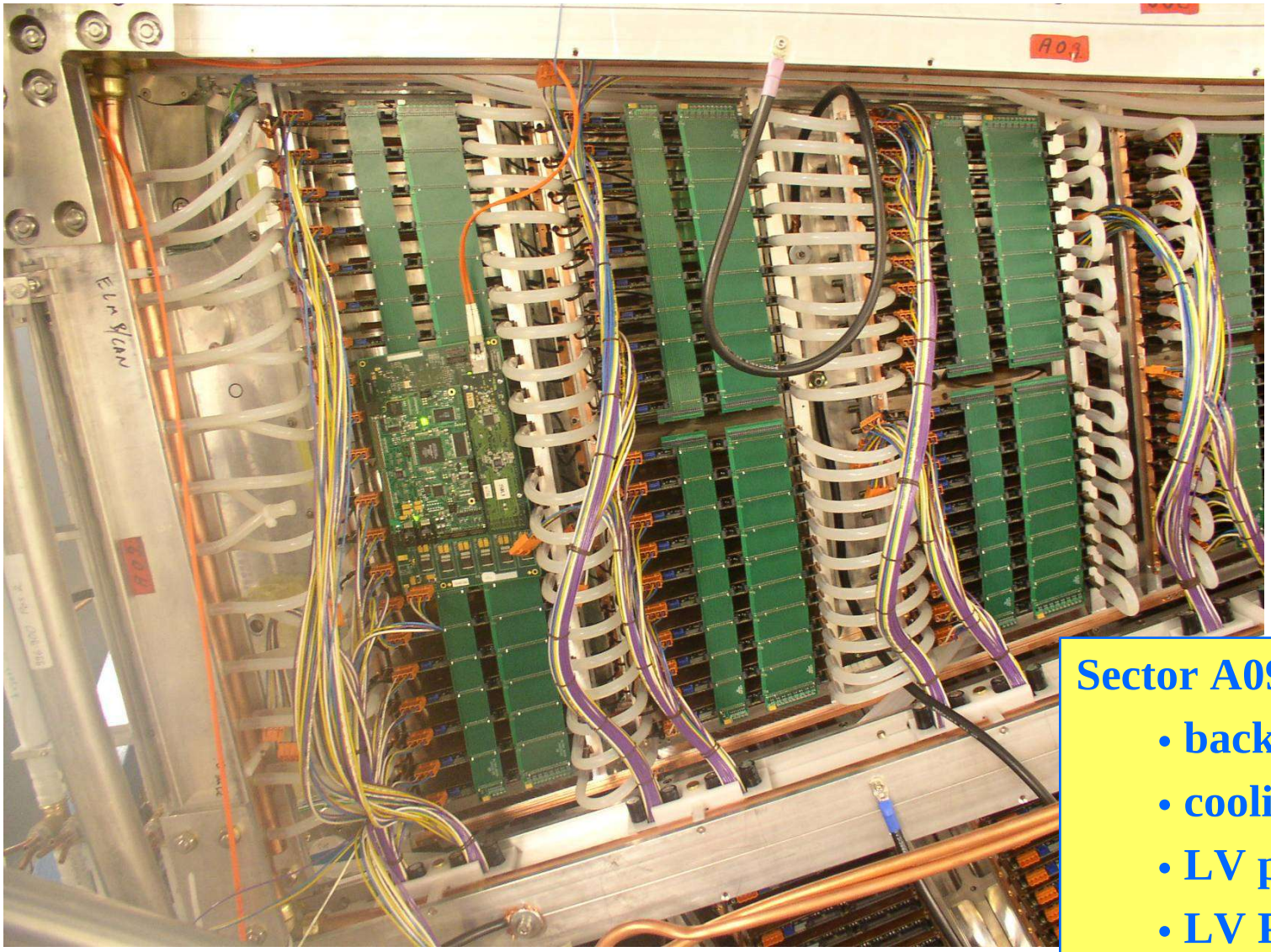


The FEE installation team

TPC A Side
(17th February '06)

FEE installation highlights

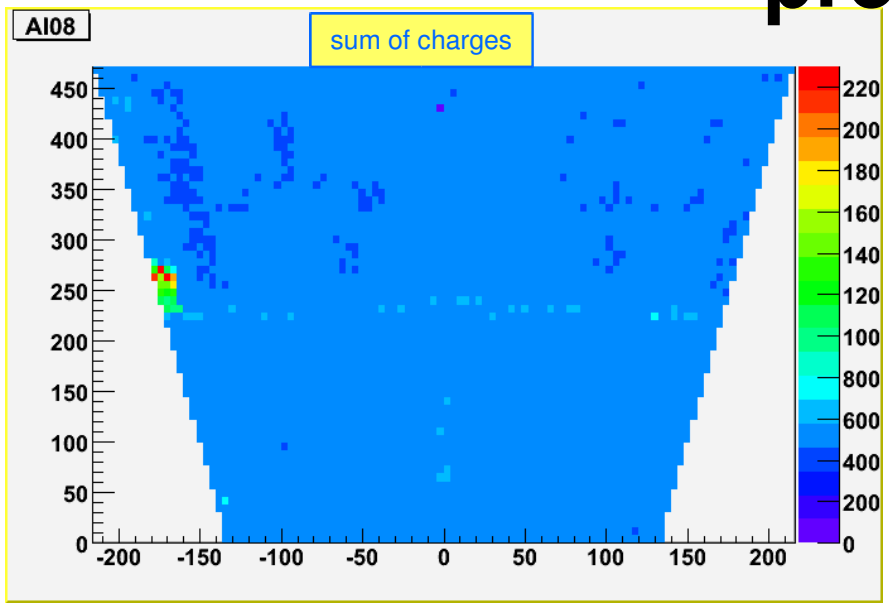
FEE Test Sector A09

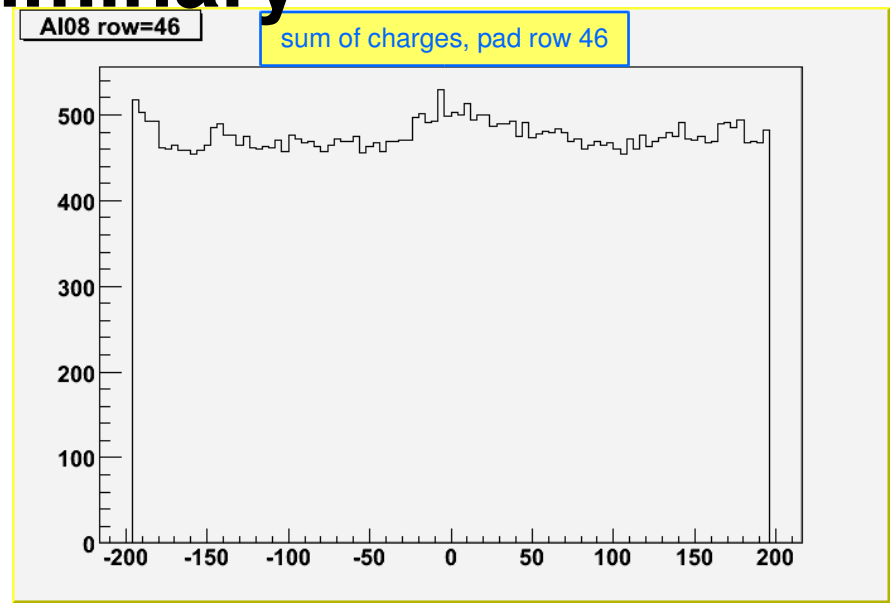


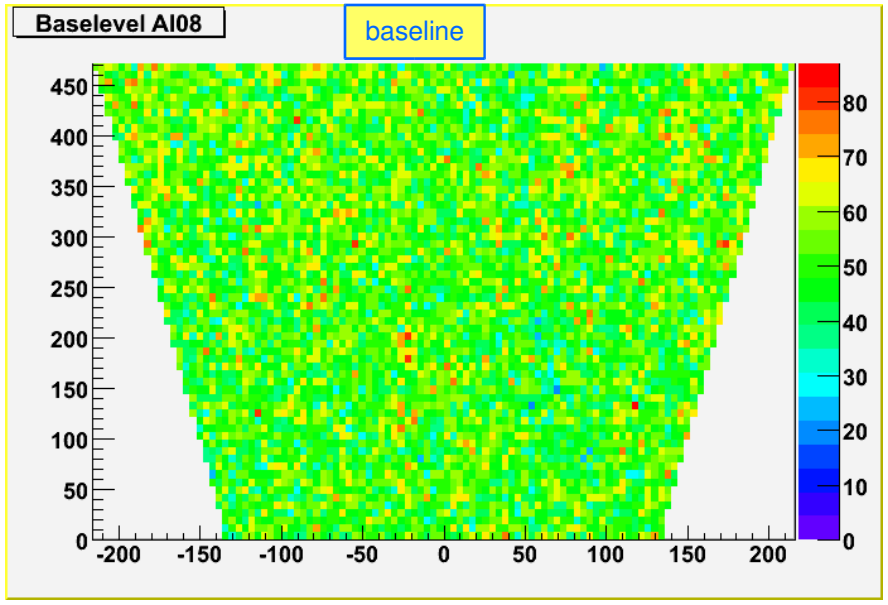
Sector A09 equipped with

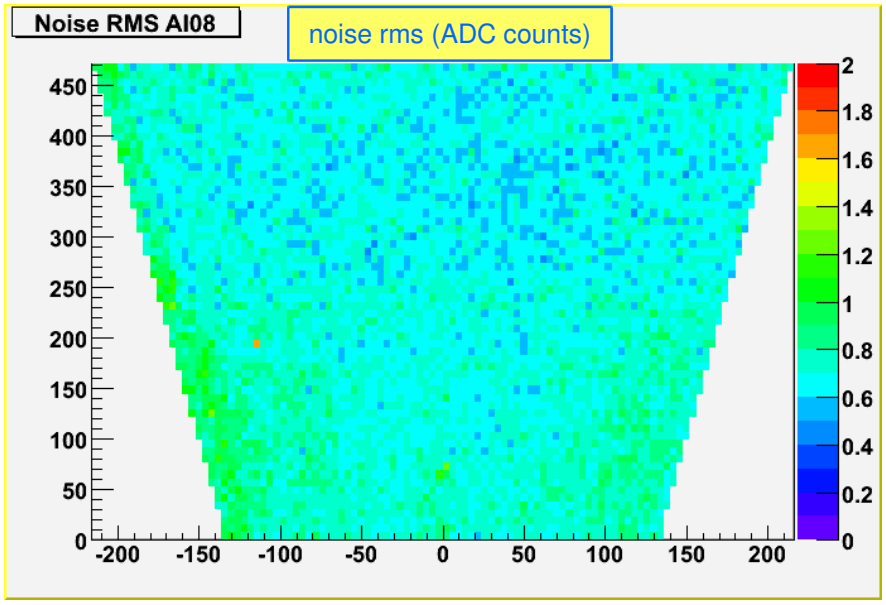
- **backplanes**
- **cooling circuit**
- **LV power rods**
- **LV PS + cables (4 x 40m)**

Test sector IROC results, preliminary

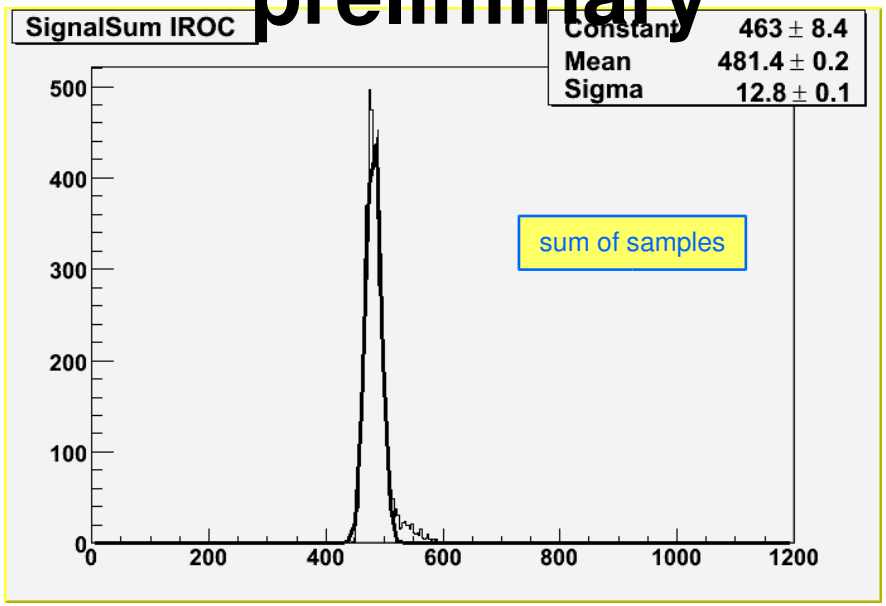


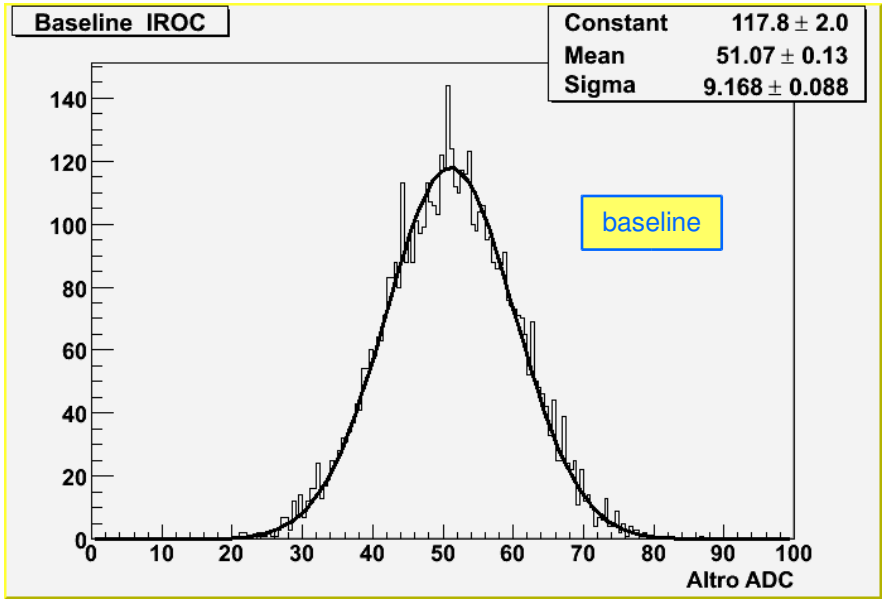


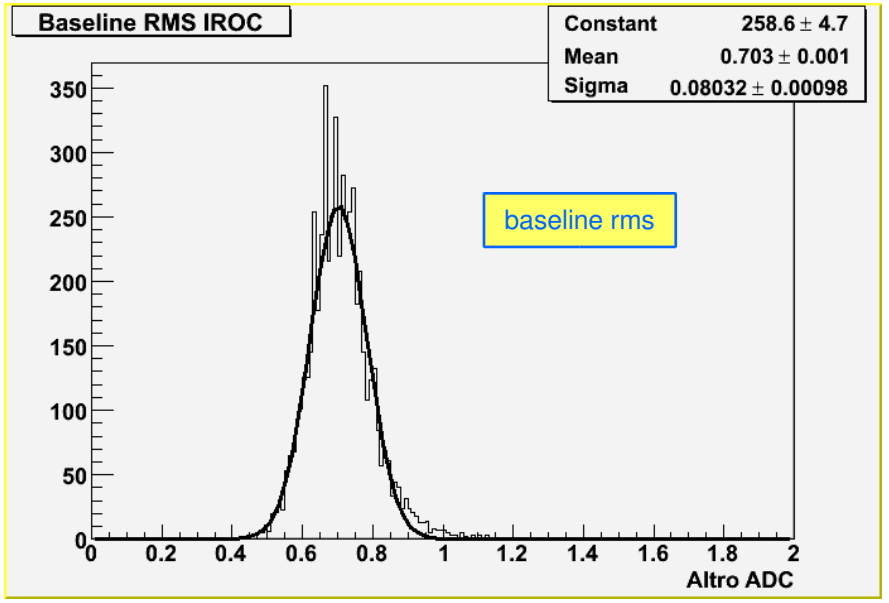




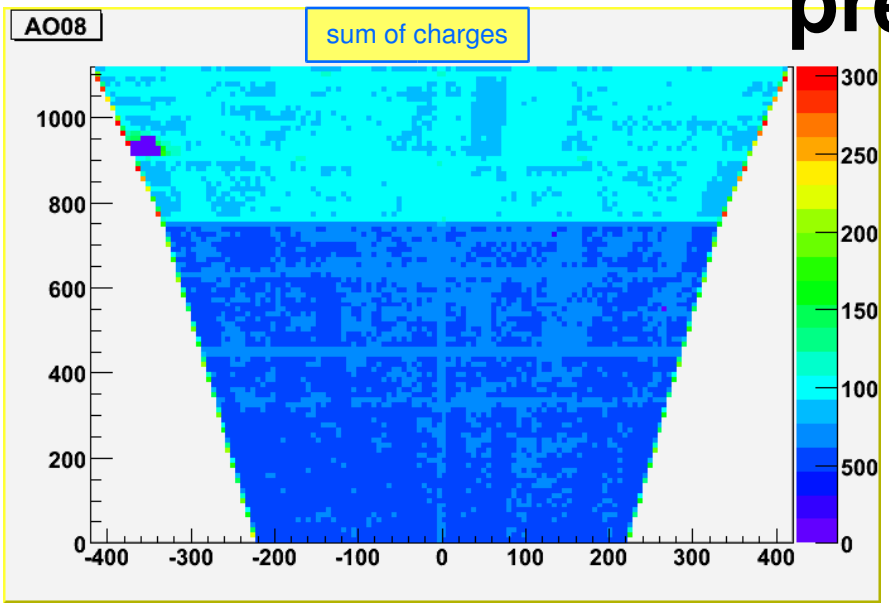
Test sector IROC results, preliminary

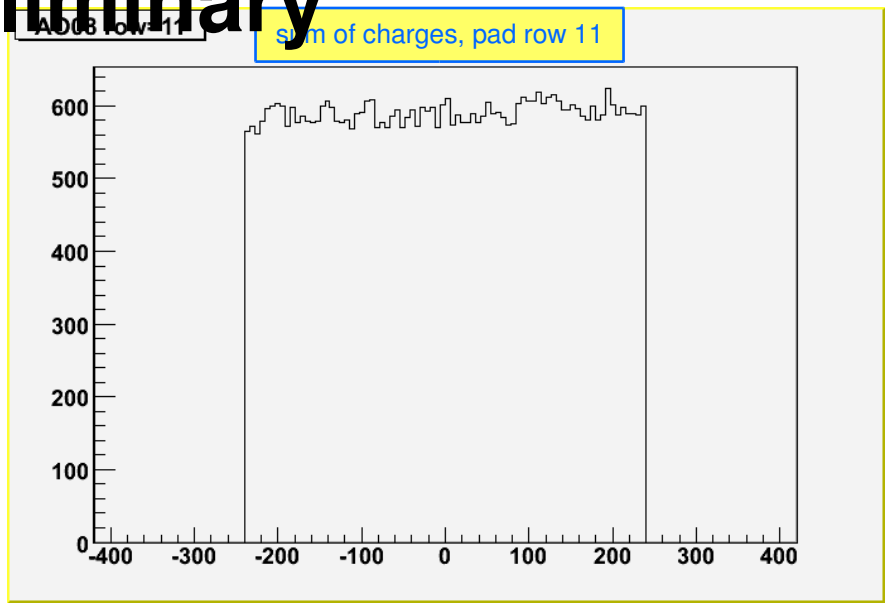


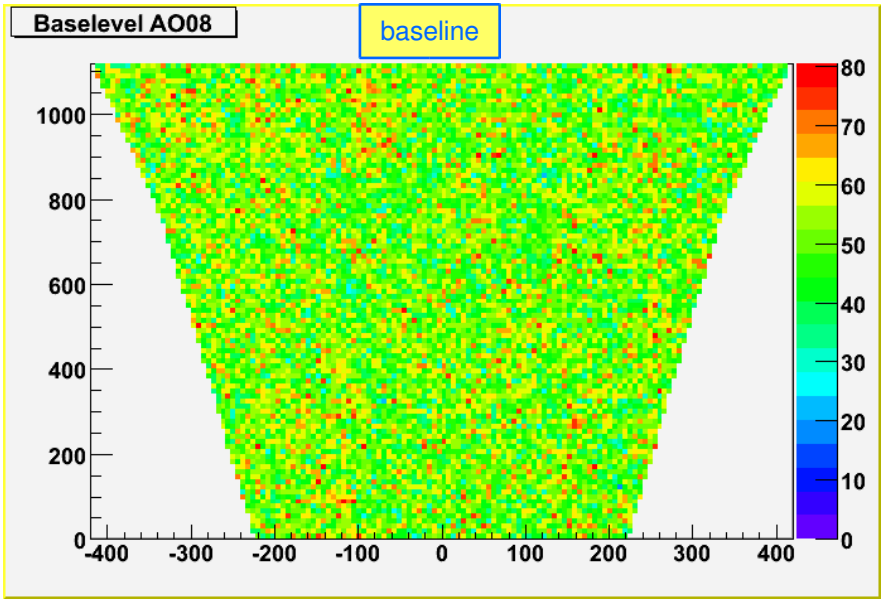


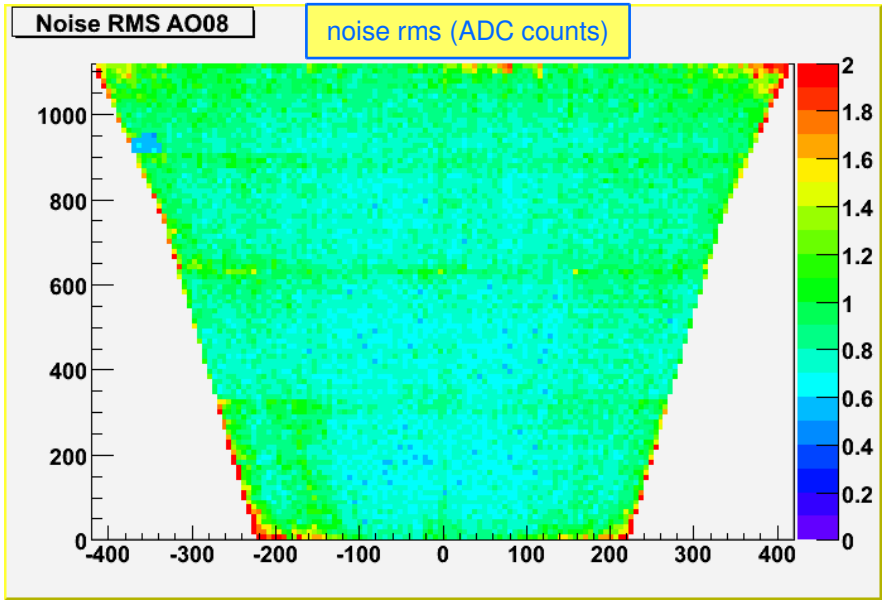


Test sector OROC results, preliminary

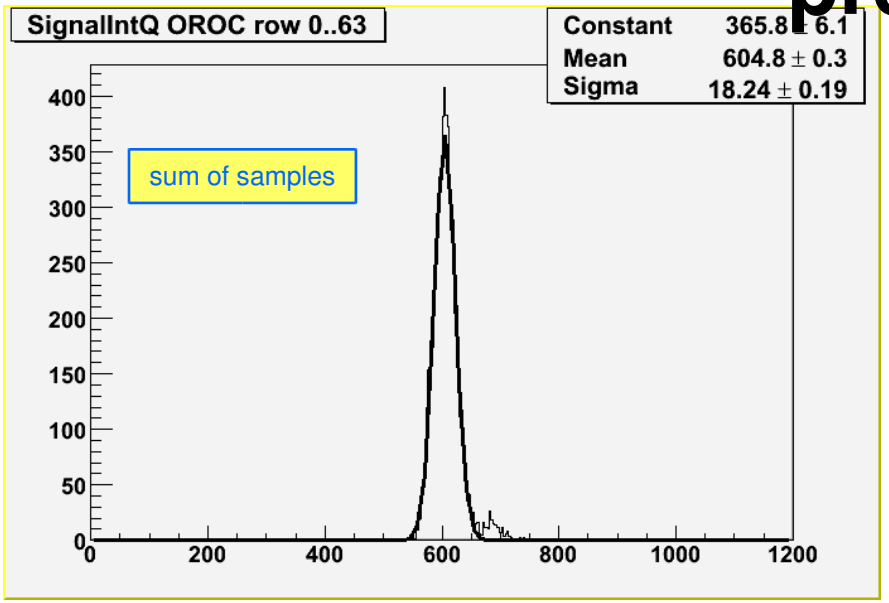


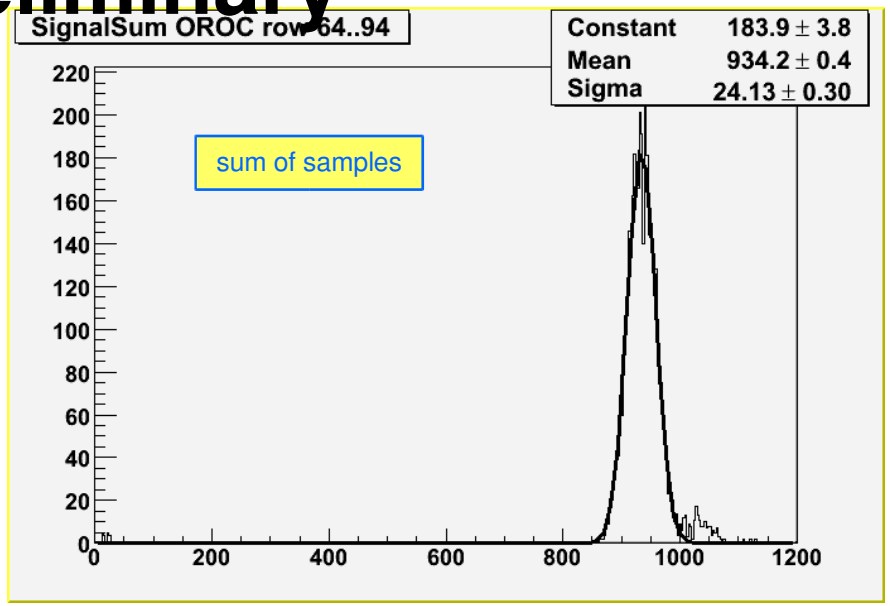


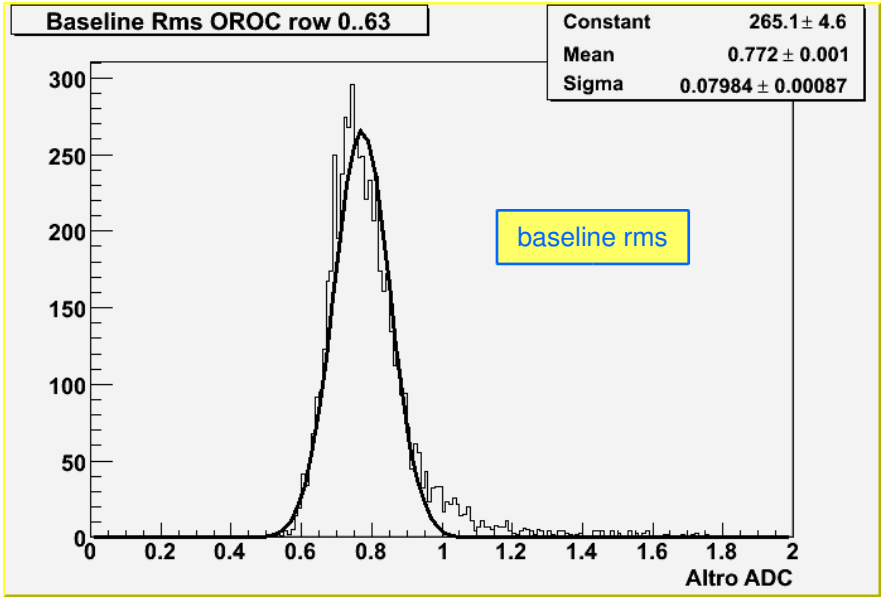


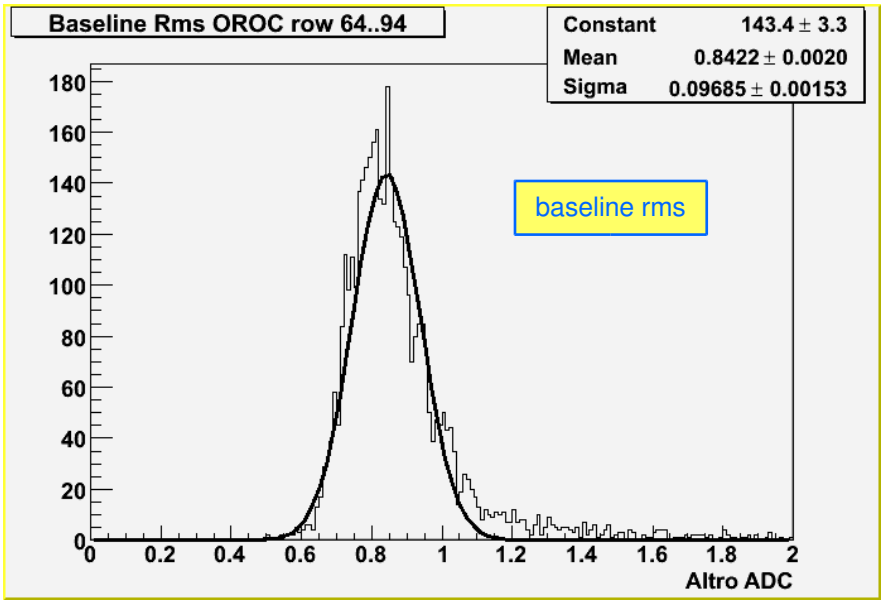


Test sector OROC results, preliminary









Gas system

- Previously commissioned with dummy volumes
- Start pre-commissioning with TPC in SXL2 with final gas mixture in a week

Pre-Commissioning plans, SLXL2

- Commissioning of gas system from 20.3. to ~12.4.
- Commissioning of Field cage, FEE and ROCs
  - DCS system
  - Drift HV
  - Laser
  - ROC HV
  - Gating
  - Readout chain
  - Trigger for cosmics, laser
  - Online monitoring
  - Verify each sector, at least with laser tracks
  - Tracks (laser, cosmics) with 2 sectors (joining, opposite, …)
  - Commissioning of temperature sensors
- Move to UX25: 4.9.06

TPC Summary

- Survey: I-bar and Shimming ROC
- Leak tests
- FEE installation phase till mid Mar 06
- 5 ½ months pre-commissioning
- TPC installation in UX2 Sep 06

-- Spares

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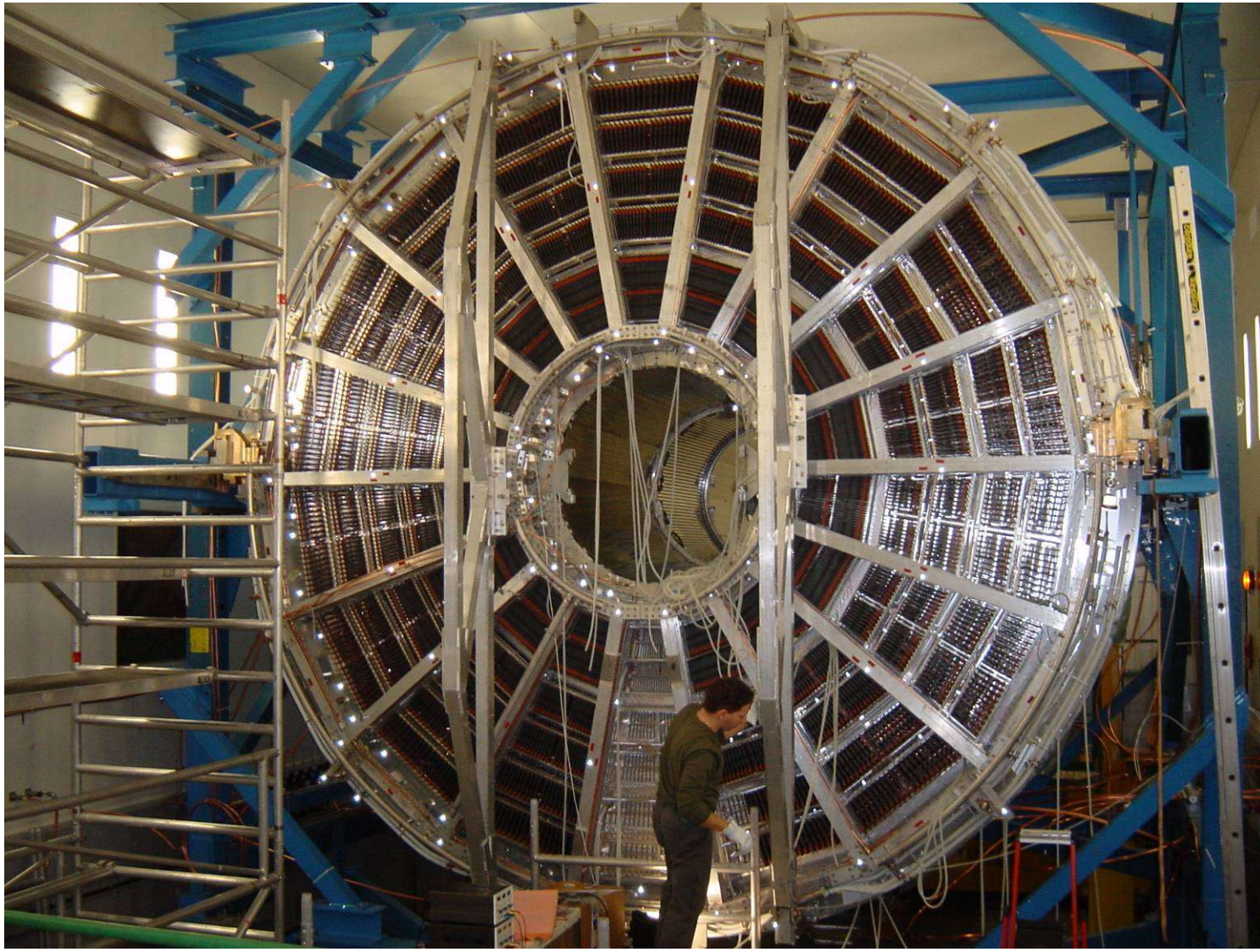
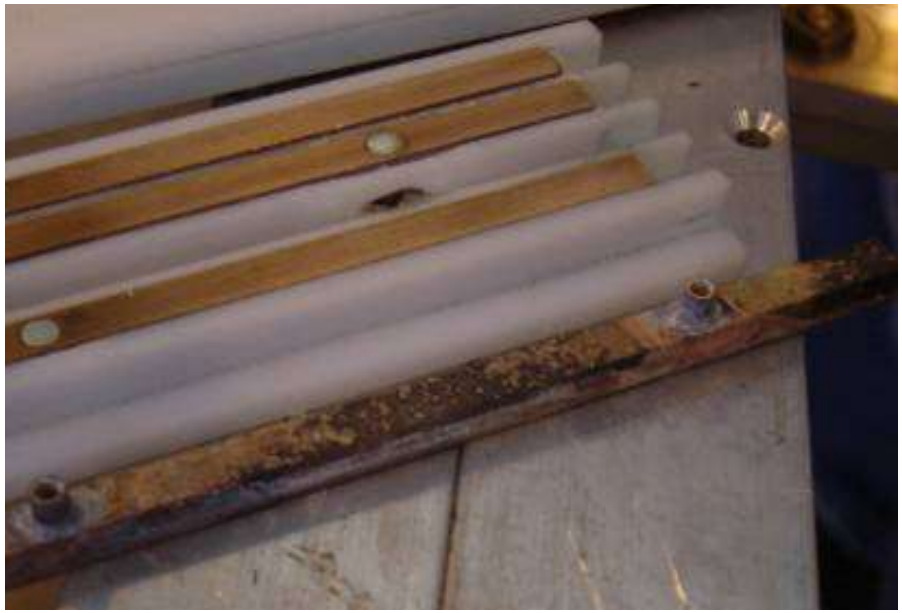
TPC with 2 I-bars



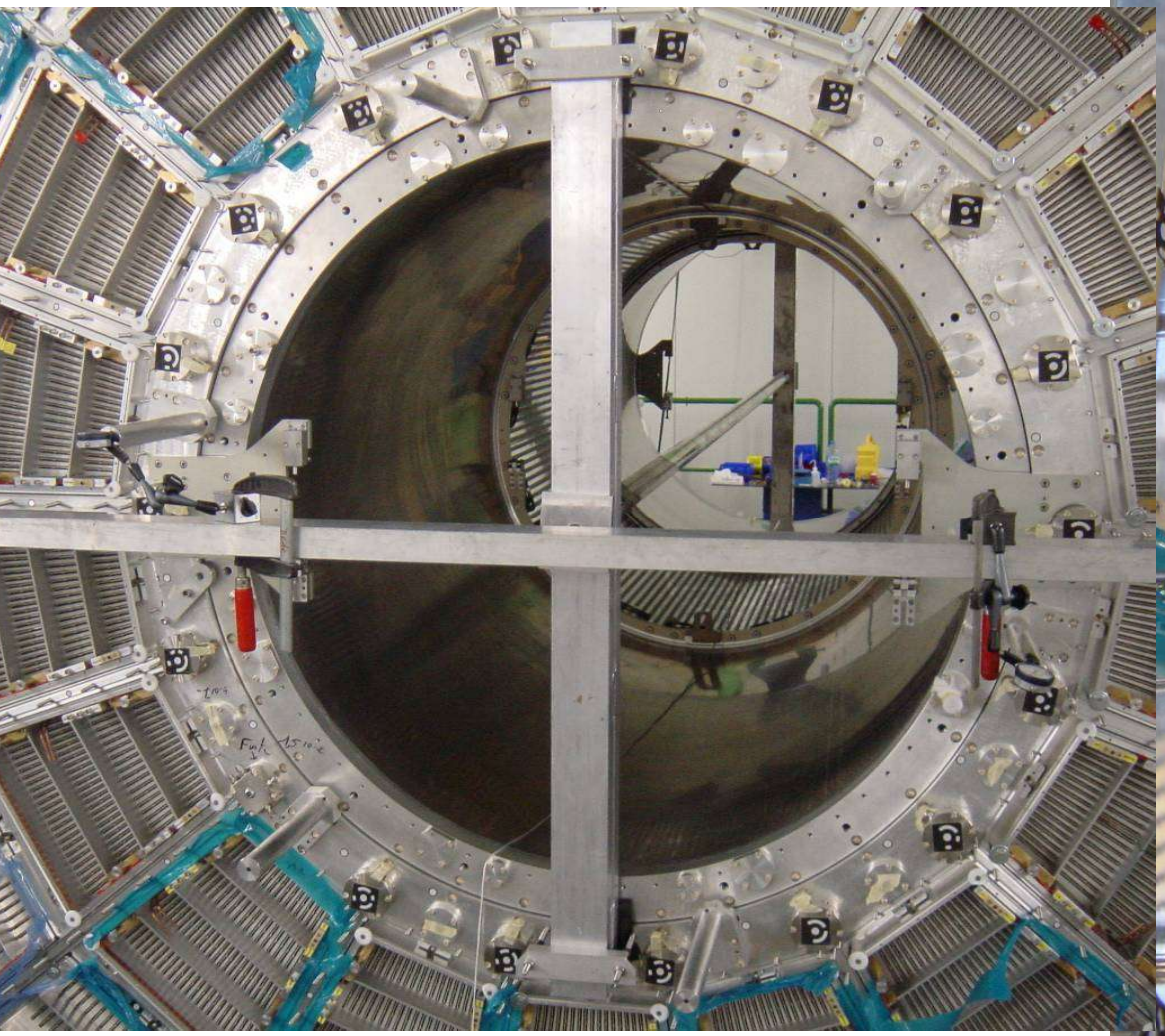
- During ITS installation, I-bars will be on A-side

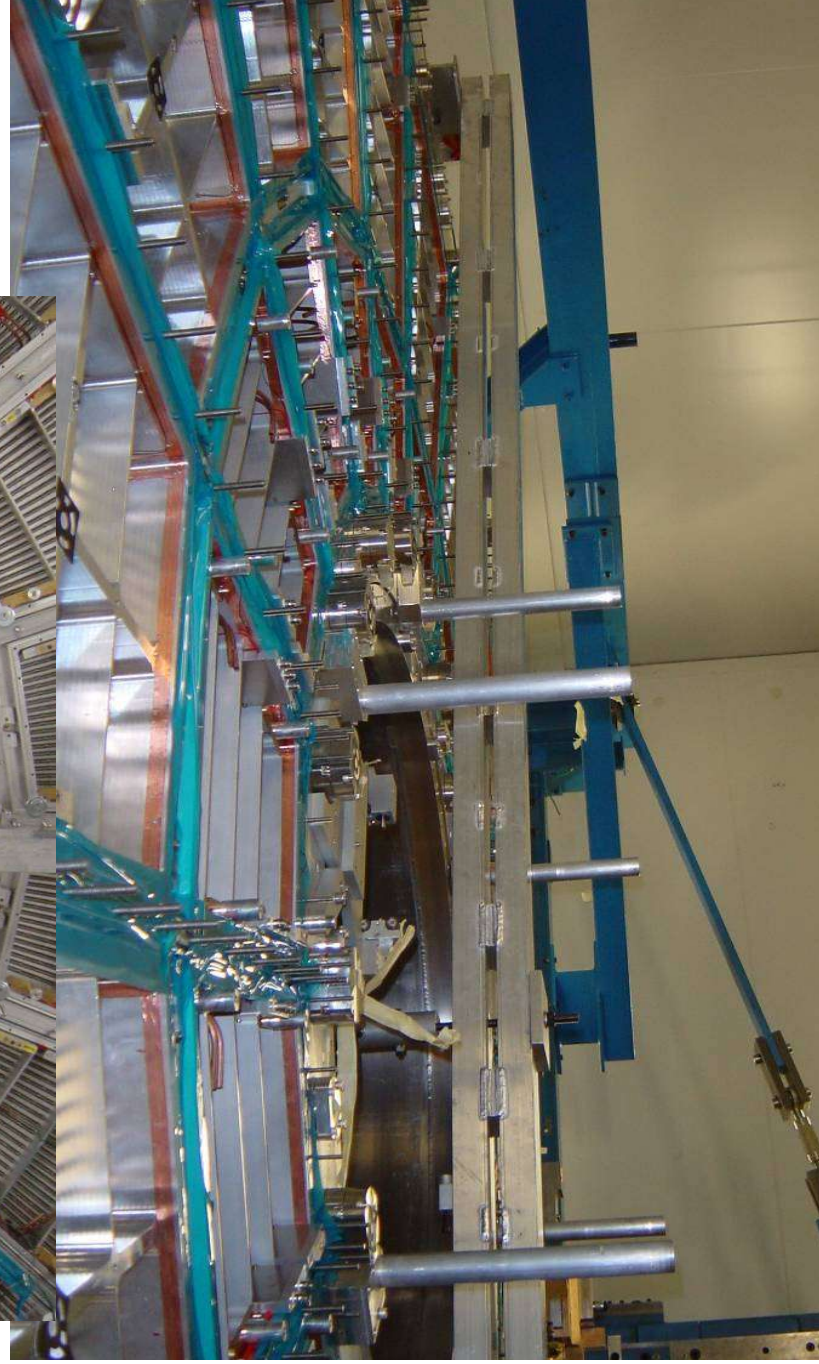
Service Support Wheels (SSW)

- Installation of services into SSW started mid Sep05
- Quality problem detected:
  - LV bus bars: some LV connectors damaged by flux residues and/or excessive temperature
- Repair at company failed, connectors can't be trusted anymore
- New production, will bring completion of SSW to Jan or even Feb06
- Partial recovery of schedule due to the possibility to install LV bus bars after FEE cards, would allow start of FEE installation on one side already late December, almost like foreseen previously



Temporary I-bar





C-side: loaded SSW