Recent Results from Beam Test of Micromegas TPC

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On behalf of the LCTPC Collaboration

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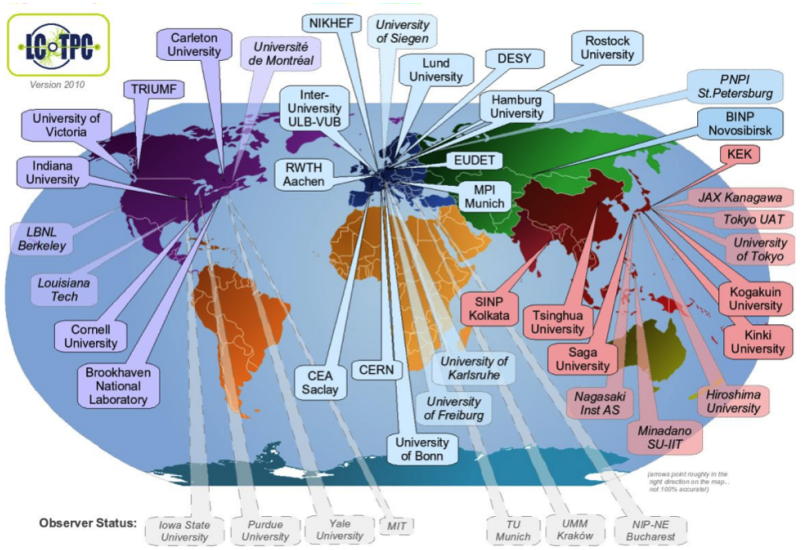


Beam test of 7 MicroMegas (MM) TPC modules at EUDET/AIDA facility at DESY (Feb. 17– Mar. 2, 2014)

- **Involved groups:** Bonn, Brussels, Carleton, DESY, KEK, NIKHEF, Saclay
- **Principal goals:**
  - test of the CO_2 cooling system
  - combine test with 2 Timepix modules

Outline

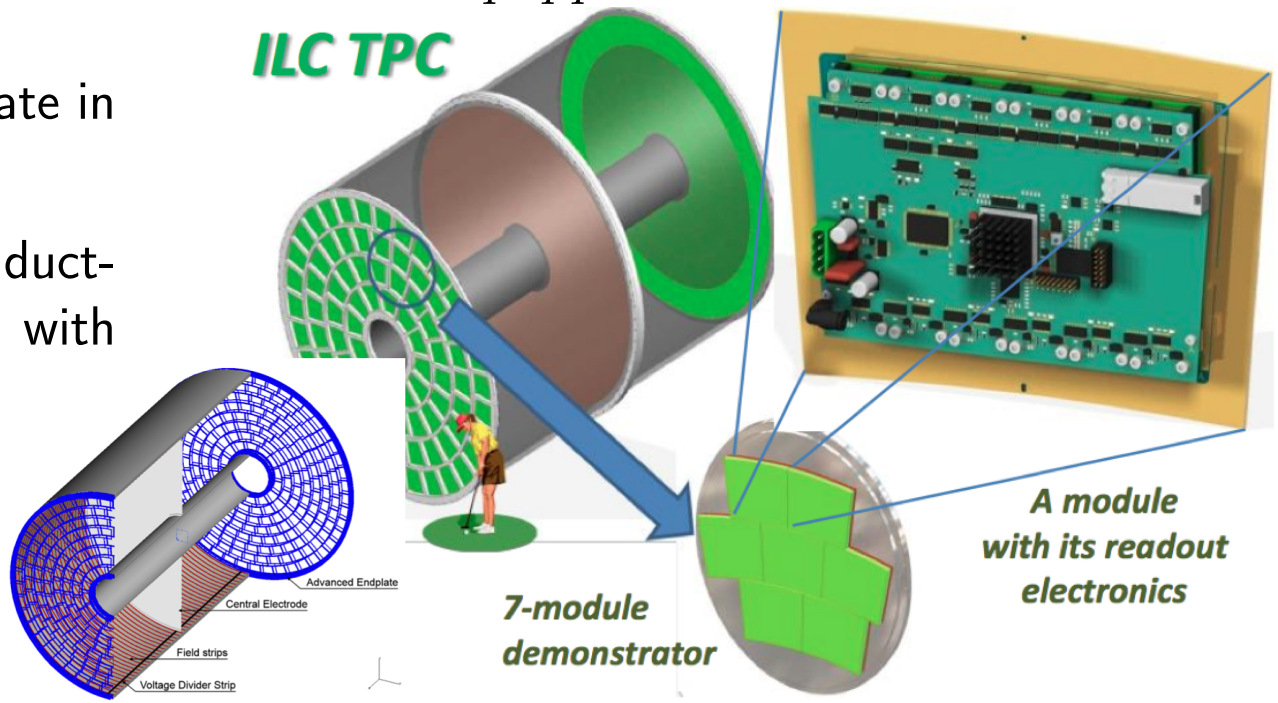
- Facility and Setup
- Readout Scheme
- Trigger and DAQ
- Data Taking
- Dataflow and Analysis
- Results
  - multi-modules studies
  - Timepix results
  - 2-phase CO_2 cooling
- Conclusions

The EUDET/AIDA test beam facility at DESY provide a 6 GeV electron beam

- Setup was designed for a Large TPC Prototype (LPTPC) for the ILC experiment
- LP readout modules operate in a strong magnetic field
  - provides a superconducting solenoid magnet with $\varnothing 85\,\mathrm{cm}$ and a length $\sim 1\,\mathrm{m}$
  - a magnetic field strength of up to **1.25 T**

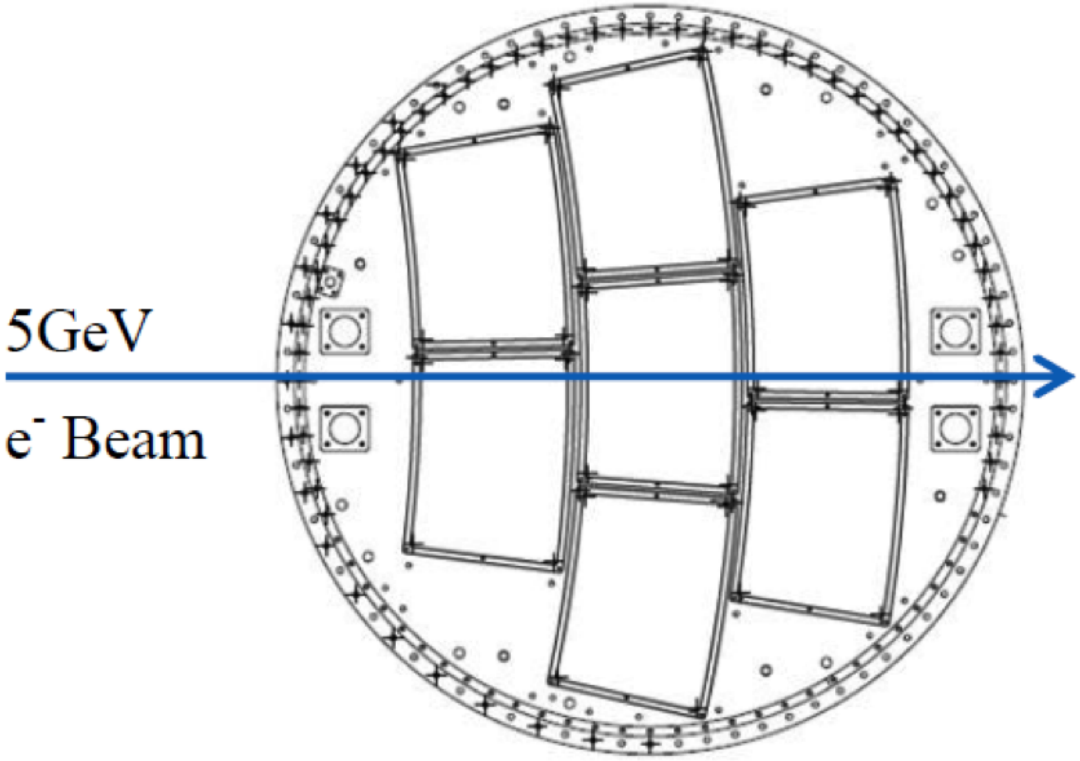
(details in R. Diener talk)

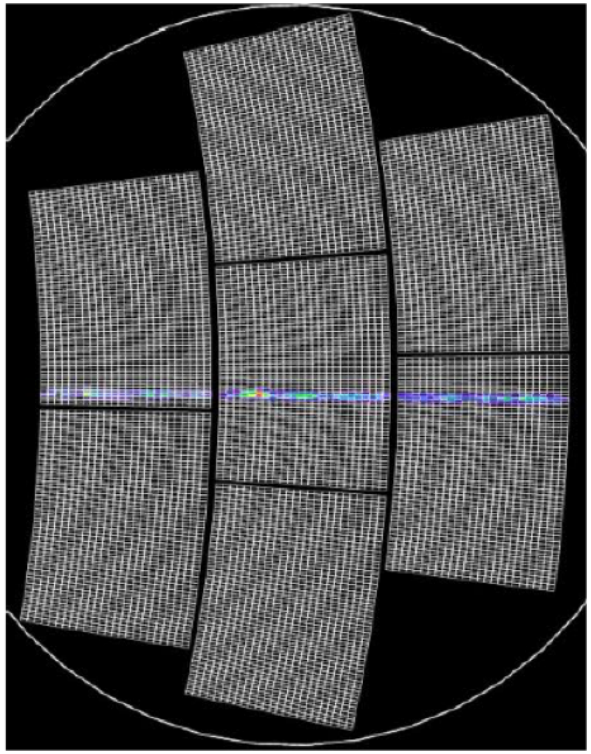
Consists of a field cage equipped with an endplate with 7 windows to receive up to 7 fully equipped identical modules



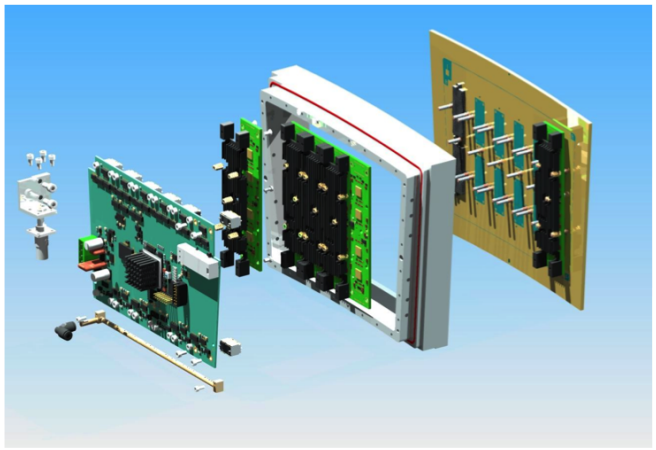
Different layouts are considered for ILD: 4-wheel and 8-wheel scheme

Multi-Module Setup





A multi-module detector sensitive to misalignment and distortions



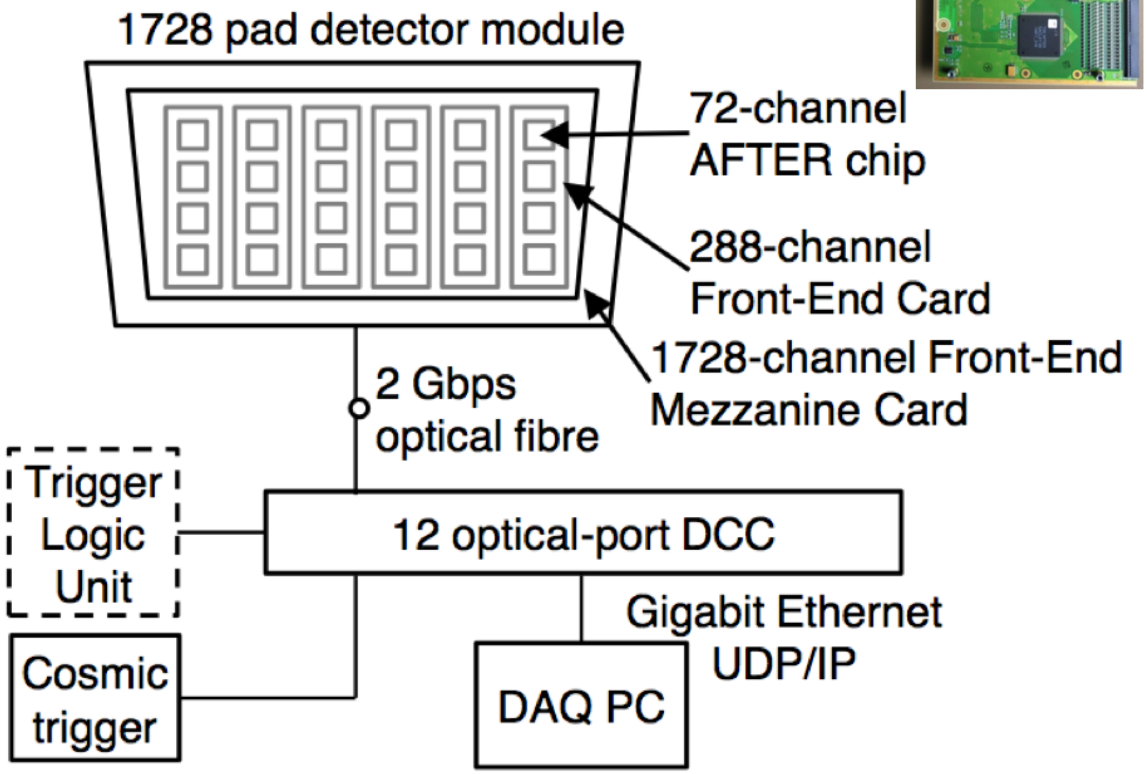
☞ Low material budget is required for ILD-TPC

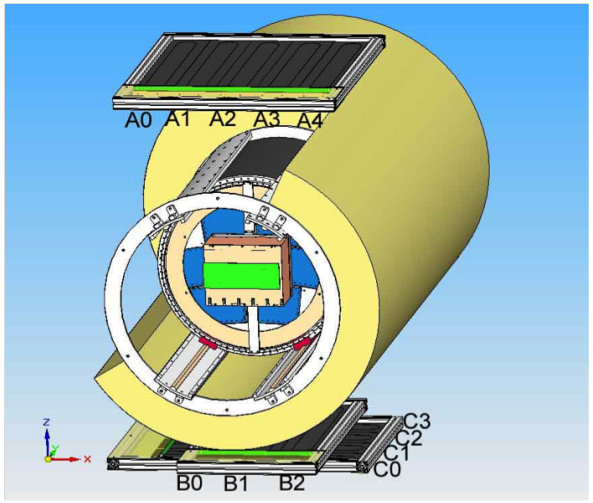
- endplates: $\leq 0.25 X_0$
- current MM module design: $\mathbf{d/X_0 \simeq 0.24}$

Readout system for the MM prototype TPC is conceptually identical to what is deployed in the T2K experiment

(more advanced electronics is being prepared with the SALTRO-16 chip)

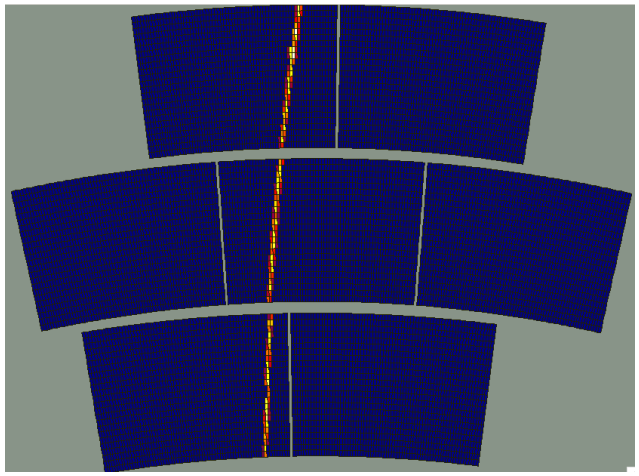
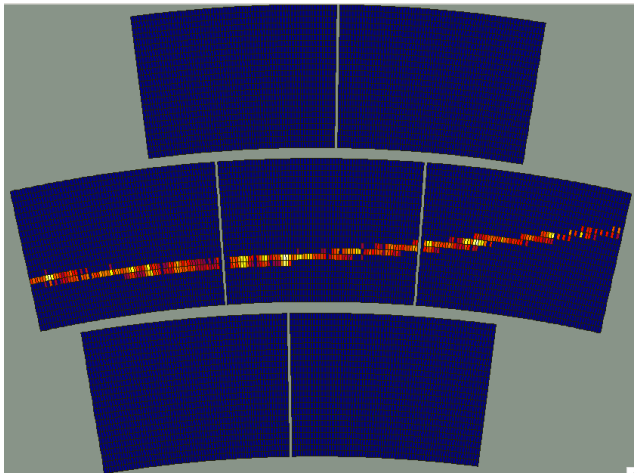
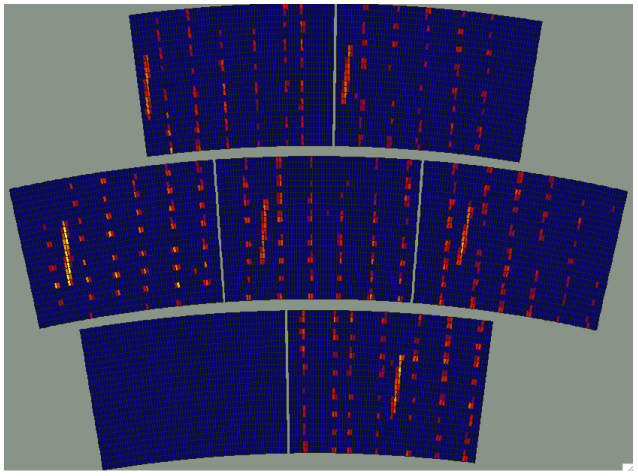
- **72-channel AFTER chip**
  - charge signal amplification
  - shaping (100 ns)
  - waveform sampling in a 511-time-bin SCA
- 4 AFTER chips are mounted on a Front-End Card (FECi)
- 6 FECi are digitalized and read-out by FE Mezzanine (FEMi)
- Each FEMi communicates with a Data Concentrator Card (DCC) over duplex optical link
- DCC transfers events to DAQ PC via a Gigabit Ethernet port





- **Beam, Laser, and Cosmic** triggers are deployed
  - A cosmic trigger based on
    - ➔ 12 scintillator plates
    - ➔ readout by silicon PMs
    - ➔ SiPM signal discrimination and coincidence logic with NIM modules
- **DAQ -** *120 Hz maximum event taking rate*
  - 6 AFTER chips are digitized in parallel by 8-channel ADC at 20 MHz
  - 4 sequential iterations are needed to readout a FEMi
  - each iteration takes 79 x 511 clock cycles at 20 MHz
  - irreducible dead-time of **8 ms**

Beam Run (4108) *Cosmic Run (4097)* *Laser Run (4115)*

Data with B=0, 1 T, E=140, 230 V/cm were taken for $\Delta z = 5\,\mathrm{cm}$

- **7 MM modules** with charge dispersion by resistive anode
  - pads of the size 3×7 mm^2
  - 24 rows with 72 pads each
  - 1728 pads per module
- **2 Timepix modules** (integrated MM grid with pixel readout)

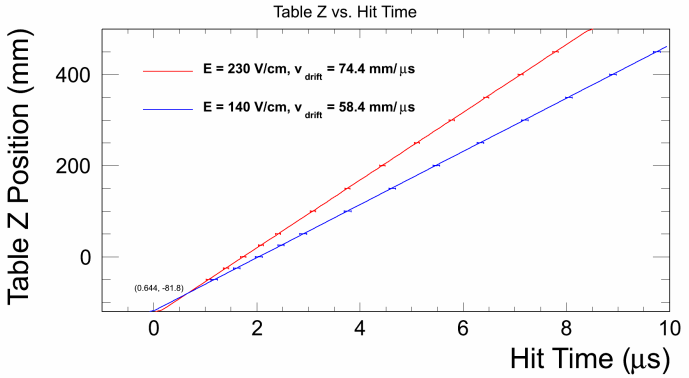
- Prototype operates with T2K gas
  - Ar(95%), CF_4(3%), iC_4H_{10}(2%)
  - gas purity: 60 ppm O_2, 150 ppm H_2O
  - `Magboltz` calculations of V_{drift}(syst.)

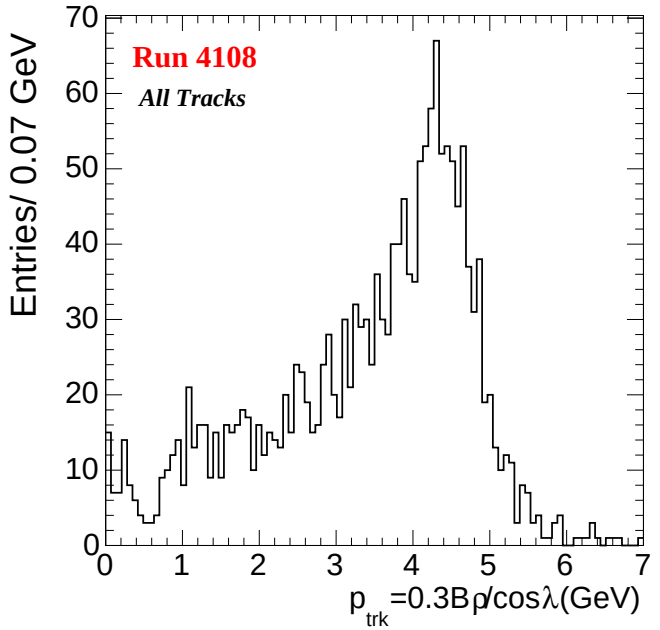
	E=140 V/cm	E=230 V/cm
Data	$58.4 \pm 0.1 \mu m/ns$	$74.4 \pm 0.1\ \mu m/ns$
`Magboltz`	$57.9 \pm 1.0 \mu m/ns$	$75.5 \pm 1.0 \mu m/ns$

Dataflow is organized in two stages: DAQ and analysis

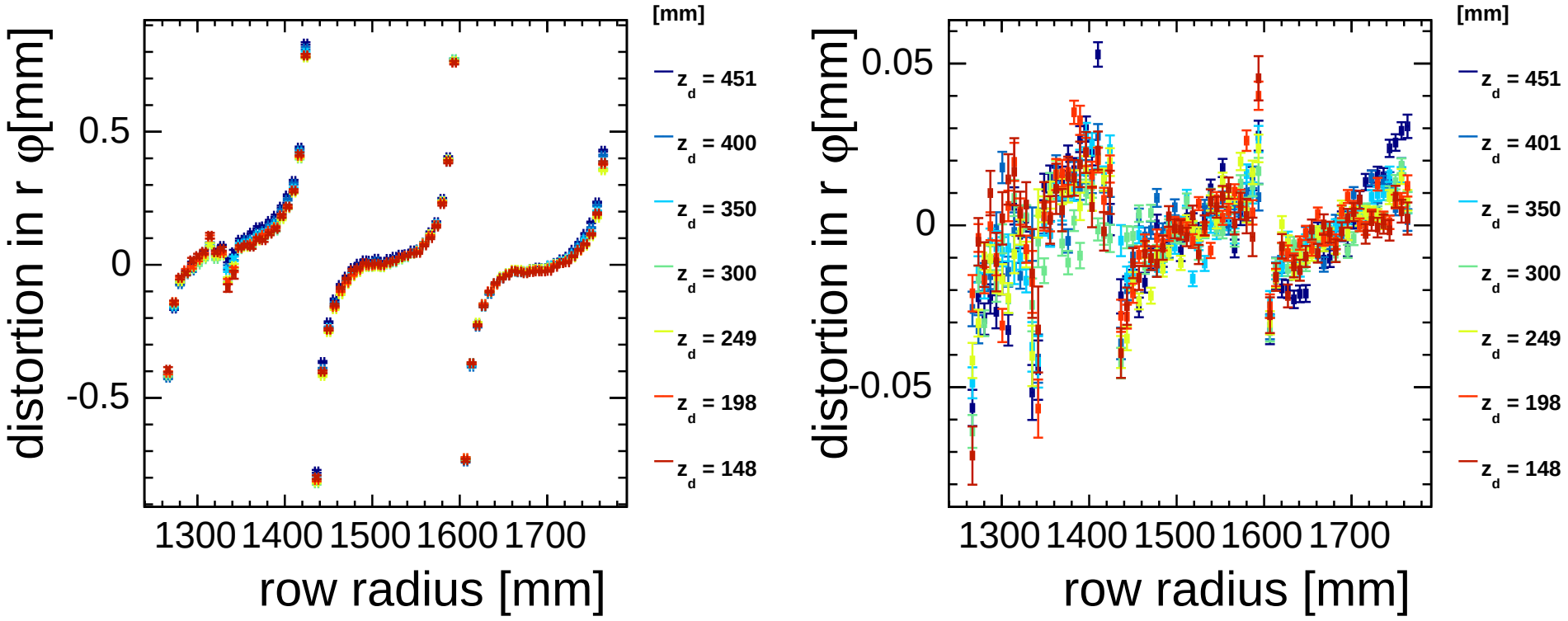
- DAQ software store data in **raw format** (calib. view, event dispay, etc)
  - calibration (pedestal)
  - beam (laser) data taking
  - cosmic runs
  - slow control (temperature)
- Convert raw data in **slcio format**
- Dedicated analysis with **Marlin** framework *(details in R. Diener talk)*
  - subtract pedestals
  - build hits from pulses
  - reconstruct tracks (KalmanFit)
  - analysis (resolution, distortion, etc)

(Time reconstruction in A. Bellerive talk)





Distortions in rφ



Non-uniform E-field near module boundaries induces ExB effects

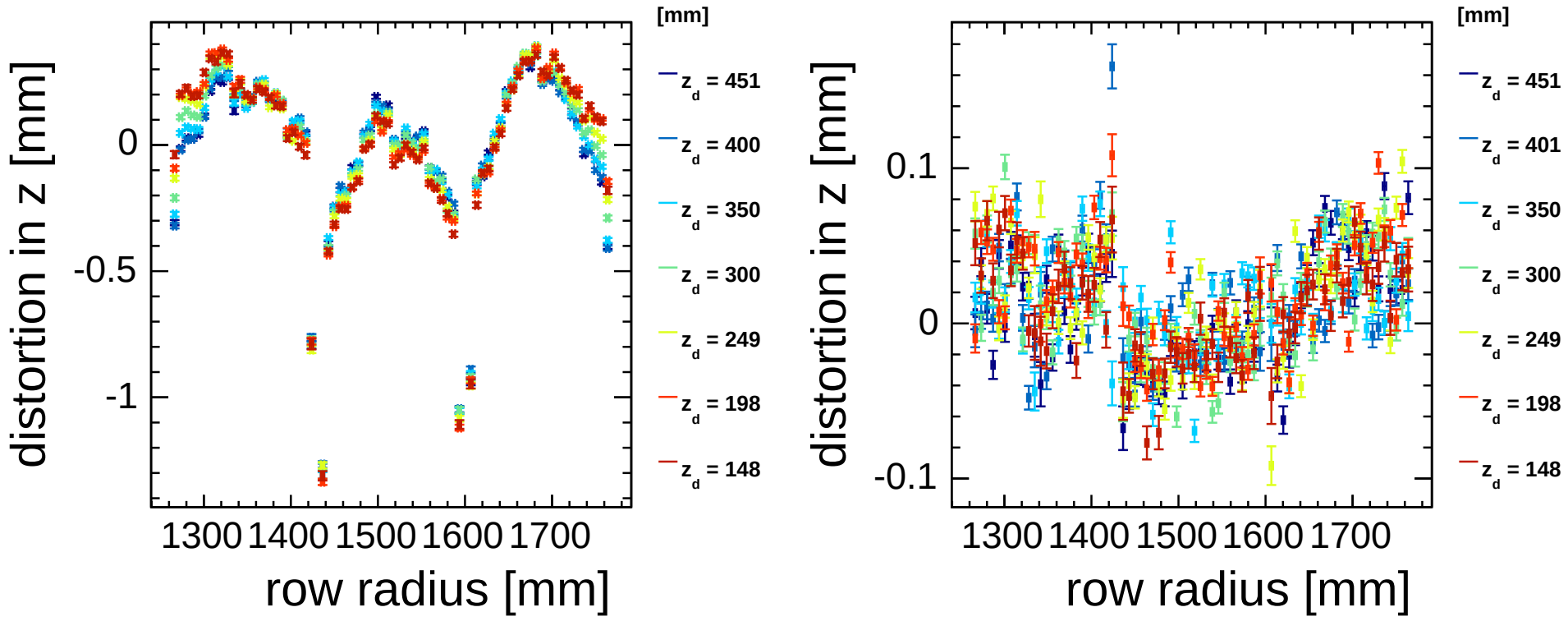
☞ At B=0 T: distortions about 200 μm are due to E only

➠ can be easily pinned down to 20 μm

☞ At B=1 T: distortions about 1 mm are observed

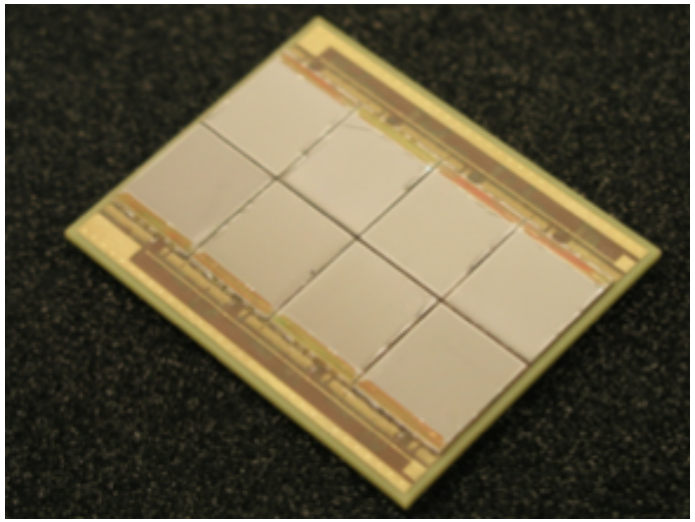
Better than 50 μm distortions remain after corrections at B=1 T

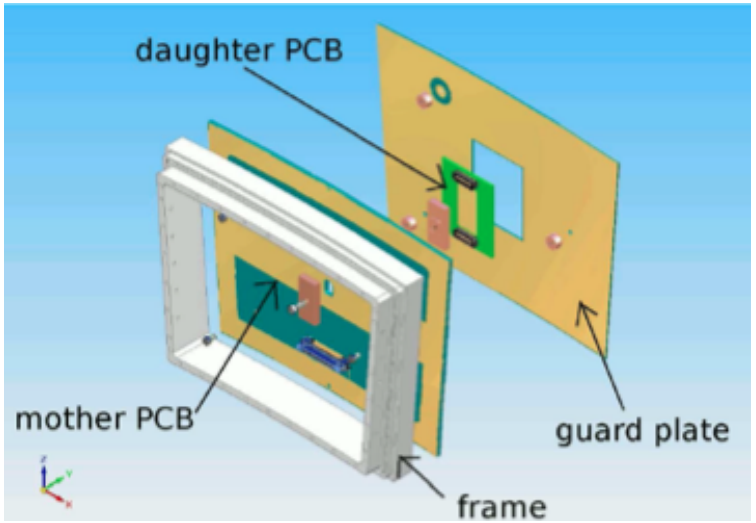
Distortions in z

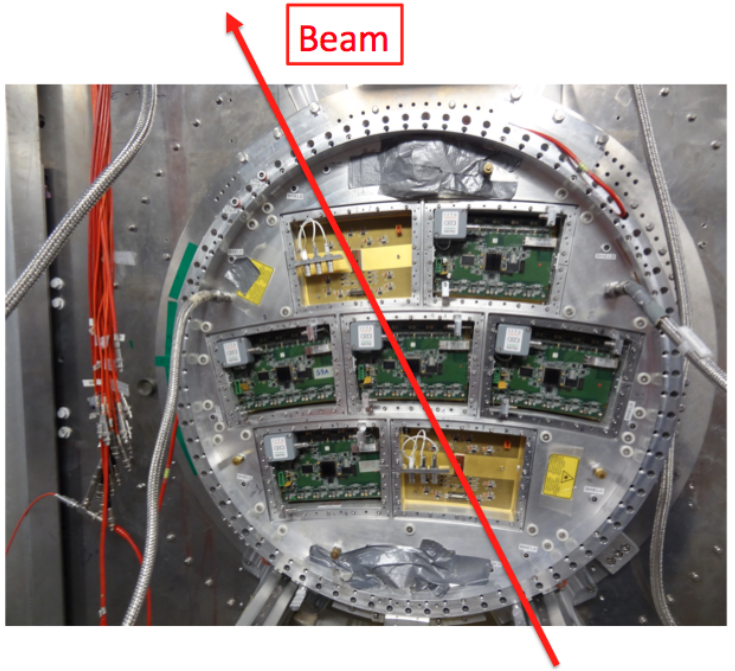


☞ At B=1 T: distortions about 1 mm are observed

Better than 100 μm distortions remain after corrections in z coordinate





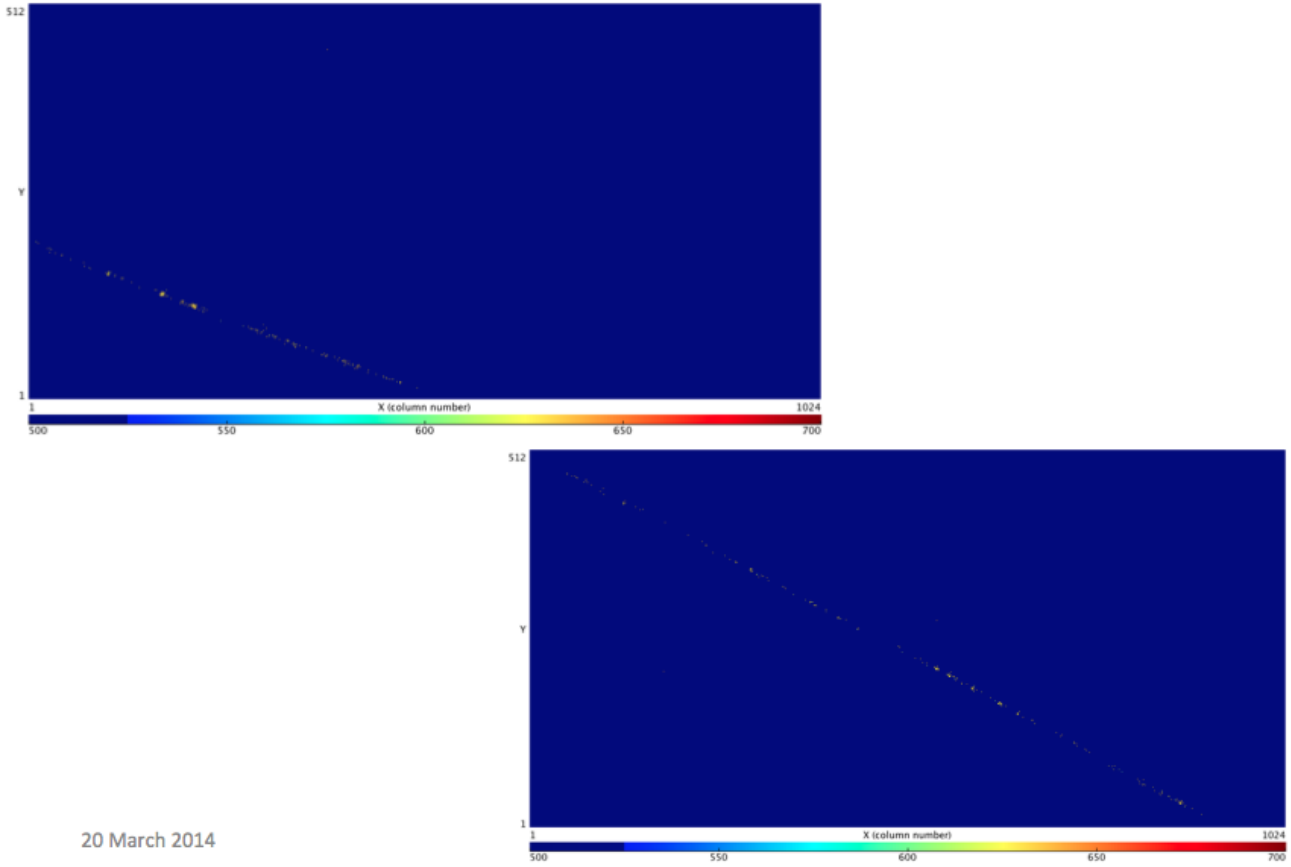


- **Assembly:** 2 Octopus modules
  - 8 InGrids placed on daughter PCB board
- Synchronized readout of **2 Octopus modules and 5 Micromegas modules**

Align the LP in such a way that the beam crosses 2 Octopuses and 1 Micromegas modules

- **Data taking:**
  - B=0 T: 8 runs
  - B=1 T: 17 runs
  - z scan with beam data Δz =5,10 cm
  - $E_{drift} = 140 V/cm$, $V_{oct} = -300 - 330 V$

Stable operation of Octopuses: I~1.2 nA



Data analysis of this beam test setup is on track of preparation

About 26 W power consumption is currently measured per MM module

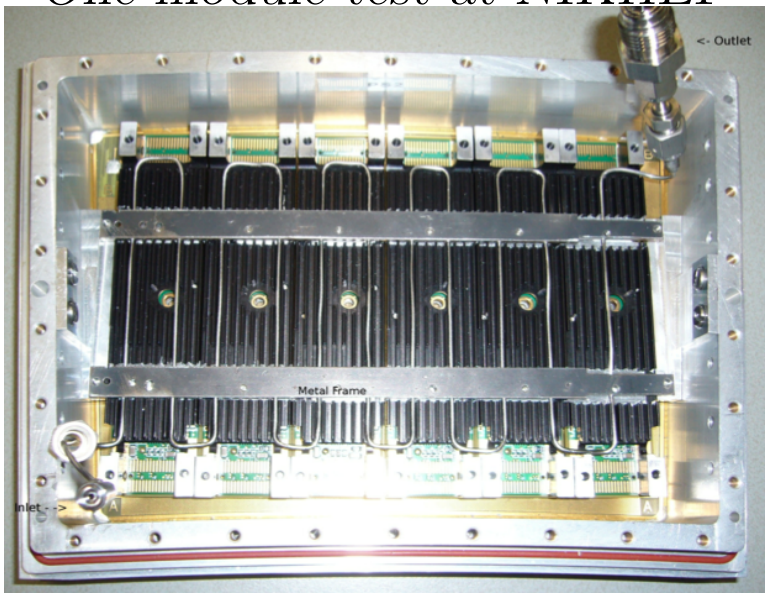
- ☞ Temperature of the circuit rises up to 60°C
  - ➠ cause a potential damage of electronics
  - ➠ covect gas to TPC due to a pad heating

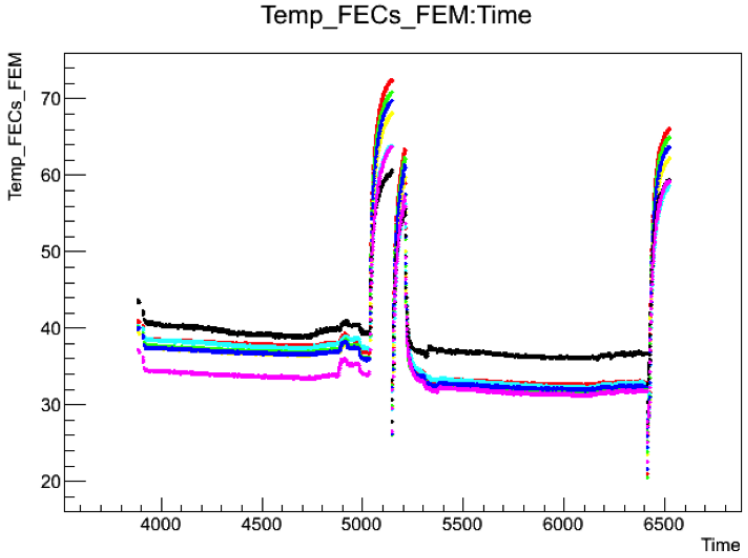
Cooling of the electronic circuit is required!

- ☞ **Principle:** CO_2 has a much lower viscosity and a much larger latent heat than all usual refrigerants
  - ➠ **the two phases** (liquid and gas) can co-exist at room temperature under pressure
  - ➠ very small pipes suffice
  - ➠ hold high pressure with low material budget

It was demonstrated that about 30°C stable temperature is affordable

One module test at NIKHEF

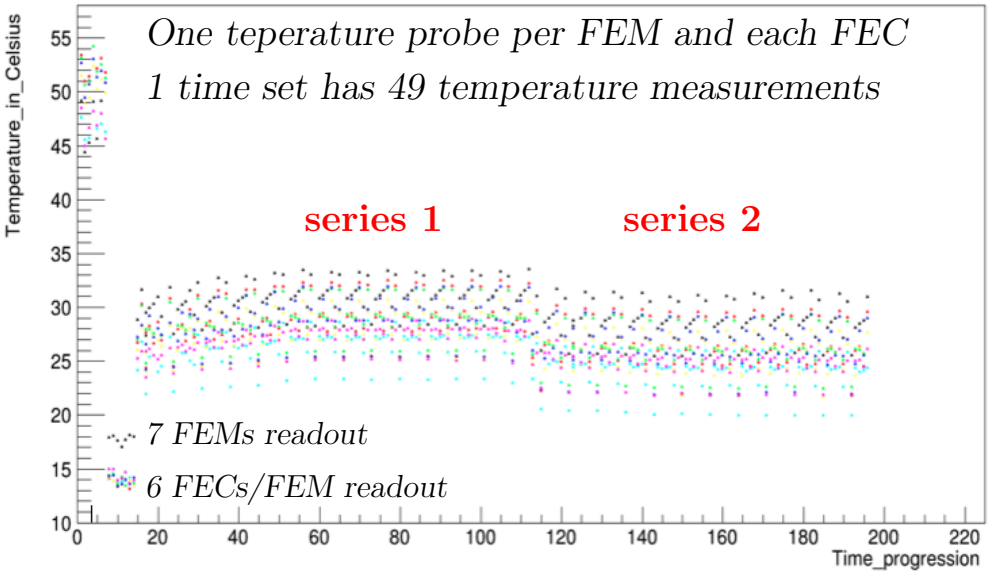


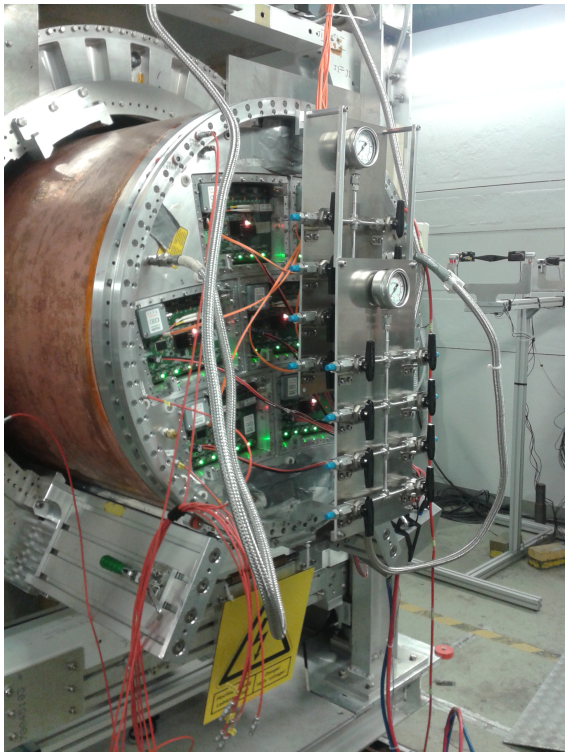


2-phase CO_2 cooling system was designed for the LP setup of the MM mudules

☞ Operation and test conditions:

- ➠ **10°C at P=45 bar** system operation
- ➠ temperature control during different regimes
  - ➔ 5 V LV supply on, no cooling
  - ➔ LV supply off, with cooling
  - ➔ LV supply on, with cooling
  - ➔ 2 series of measurements





About 30°C stable temperture was achieved during operation of 7 MM modules at DESY

Conclusions

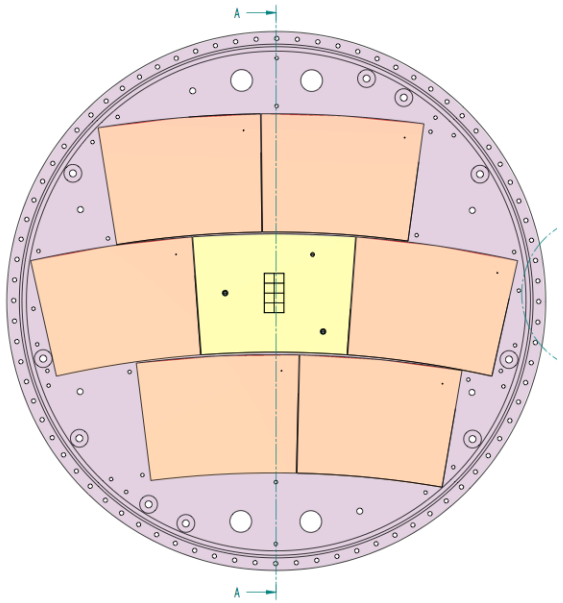
- **The successful beam test within LCTPC collaboration was performed at DESY with EUDET/AIDA facility in February this year**
  - **7 micromegas** fully equipped modules with new CO_2 cooling scheme were tested
  - 3 types of data (**beam, cosmic, laser**) were recorded and analyzed
  - combined test of **2 octopus and 5 micromegas modules** was pursued
  - 2-phase CO_2 cooling allows long-term operation at 30°C of electronic circuit
- Data from Micromegas detectors were analyzed in `Marlin` framework
  - whole analysis chain functions well including Kalman fit
  - multi-module effects (distortions) were estimated at first glance
  - reach better than 50 (100)μm remaining distortions in rϕ (z) after corrections

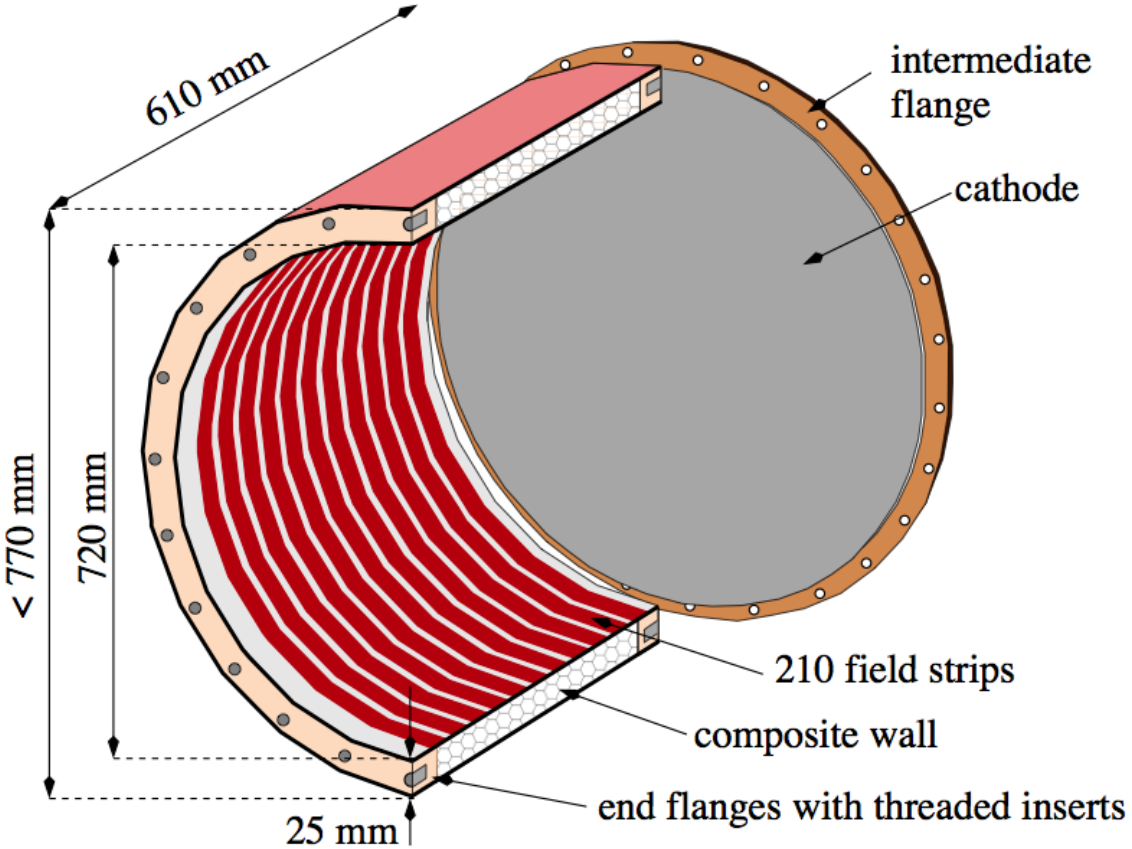
Vast Micromegas R&D program ahead that will profit from further upgrade of the DESY beam test facility

The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project AIDA, grant agreement no. 262025

Backup

- The design of the cage wall was optimized for a low material budget $\mathbf{1.2\%X_0}$
  - an outer diameter of 77 cm and a length of 61 cm and
- Overpressure up to 10 mbar
- Drift field homogeneity $\boldsymbol{\Delta E_r/E \leq 10^{-4}}$





$$\mathbf{E^{max}_{drift} = 350V/cm\ (U_{cathod} = 20\ kV)}$$

Data Concentrator Card (DCC)

- The tasks of the DCC are
  - distribute to the FEMi the 100 MHz clock, trigger and synchronization signals
  - setup run parameters in the front-end electronics
  - aggregate data from FEMi
  - build full events that are transferred to the DAQ PC