R&D Status for Micromegas TPC

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

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

Last beam test of 7 MicroMegas (MM) TPC modules at DESY (Feb. 17– Mar. 2, 2014)

- **Principal goals** of 2014 test beam
  - test of the CO_2 cooling system
  - combined test of 5 MM with 2 Timepix modules

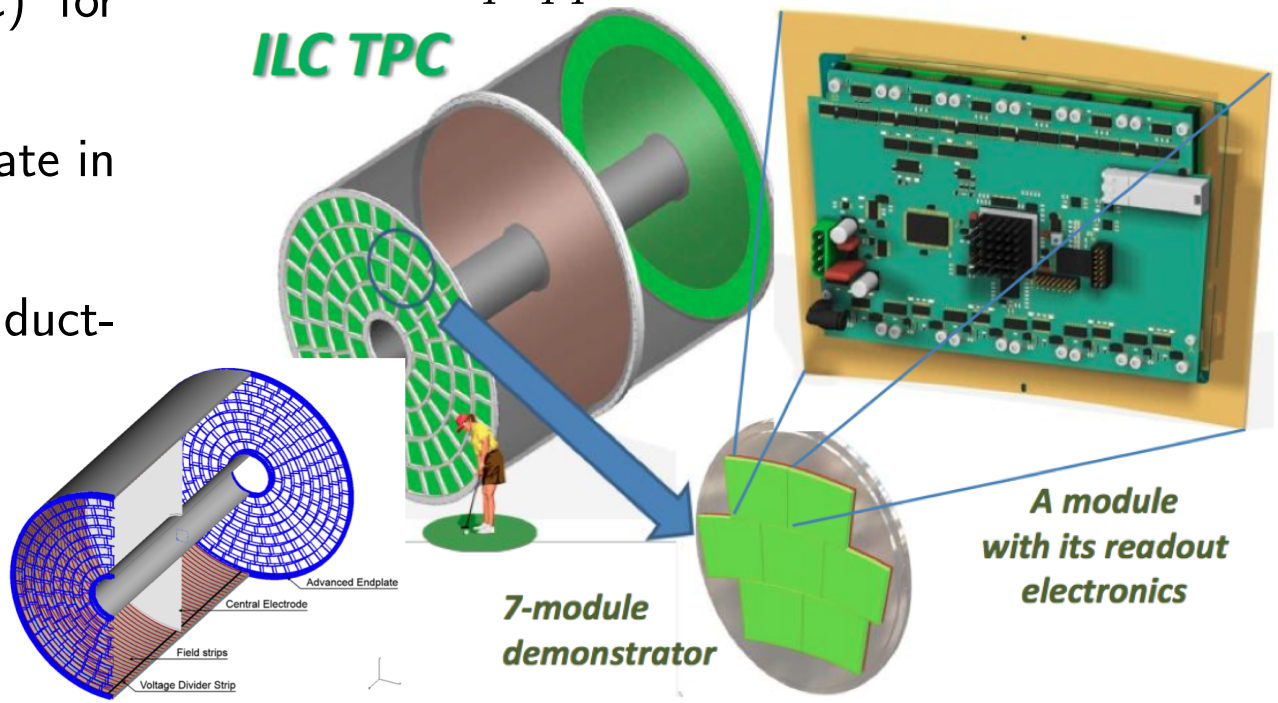
Prehistory of beam tests with MM modules:

- **Mar 2010:** 1 module, start analysis with **FTPC framework**; reanalised with **MarlinTPC framework**
- **May 2011:** cross-talk problem; start using **Marlin framework**
- **Jul 2012:** multimodule setup with 6 fully operated modules; coherent noise
- **Jan-Feb 2013:** multimodule setup with 7 fully operated modules; many disconnected pads; first complete analysis with **MarlinTPC framework**
- **Feb 2014:** same as in 2013 with some pads' connection problem; analysis with **MarlinTPC framework**

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

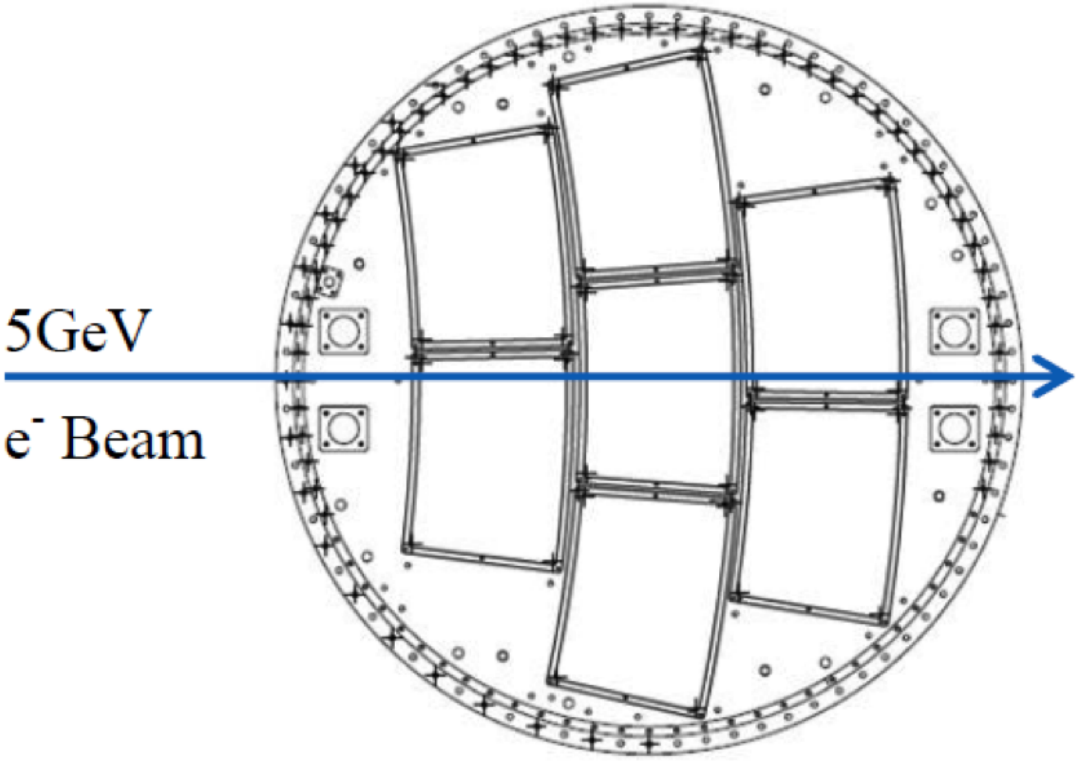
- Setup was designed for a Large TPC Prototype (LPTPC) for the ILC experiment
- LP readout modules operate in a strong magnetic field
  - provides a superconducting solenoid magnet $\varnothing 85\,\mathrm{cm}$ and a length $\sim 1\,\mathrm{m}$
  - a magnetic field strength of up to **1.25 T**

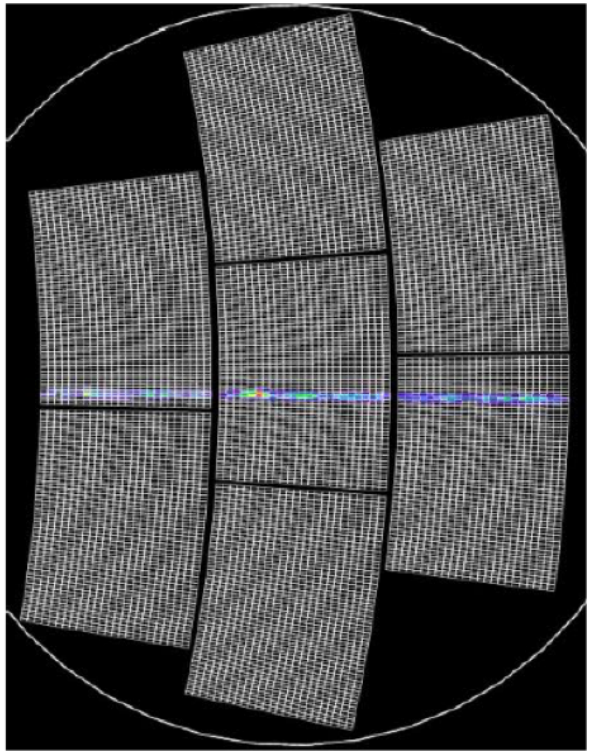
Consists of a field cage equipped with an endplate with 7 windows to receive up to 7 fully equipped identical modules



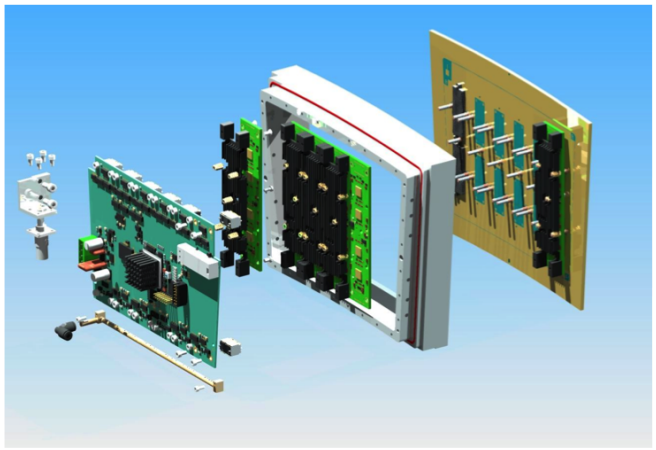
Different layouts are considered for ILD: 4-wheel and 8-wheel scheme

Multi-mudule setup





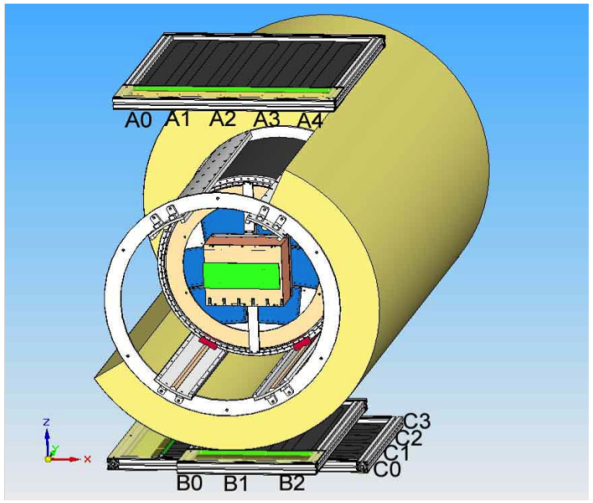
A multi-module detector sensitive to misalignment and distortions



☞ Low material budget is required for ILD-TPC

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

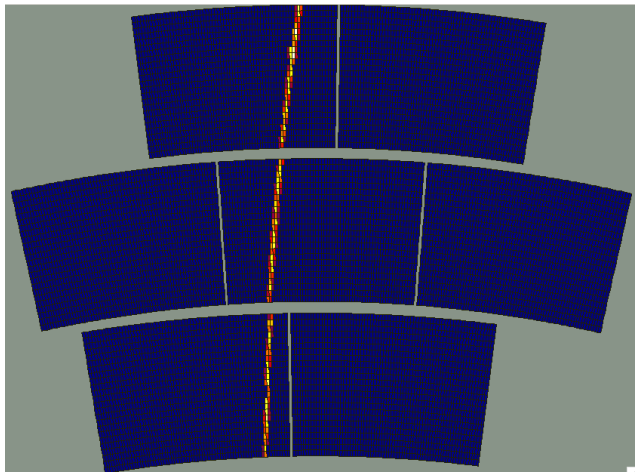
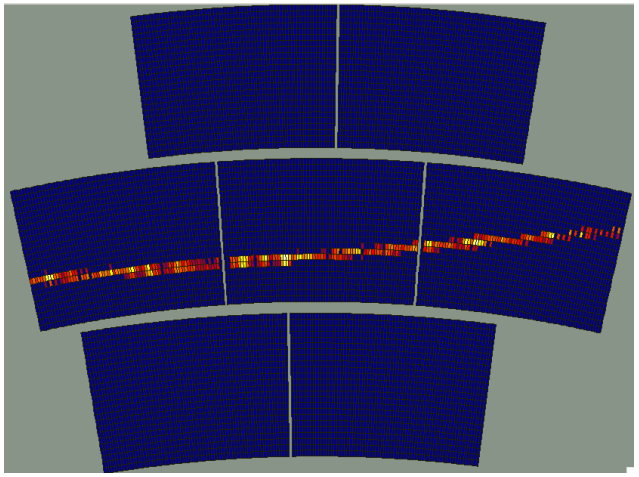
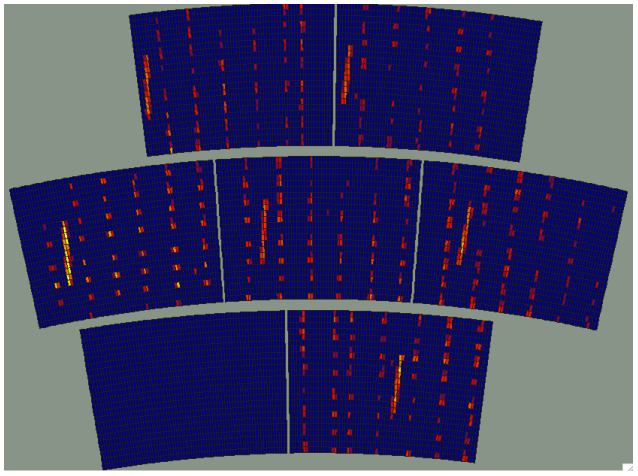
Trigger and DAQ



- **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**

Data Taking 2014

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

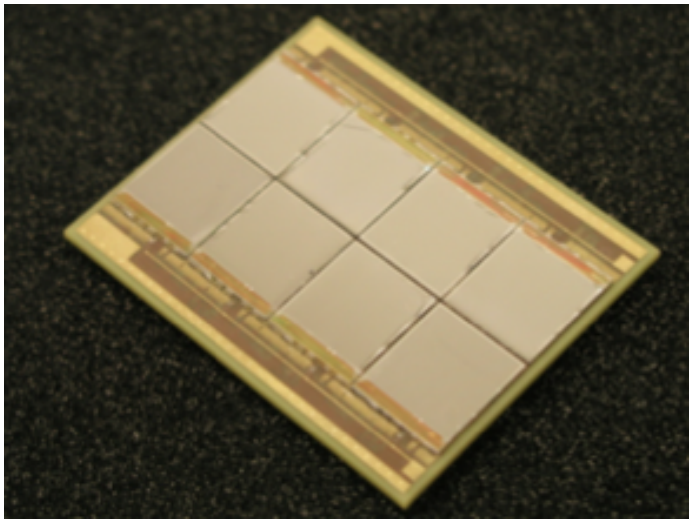




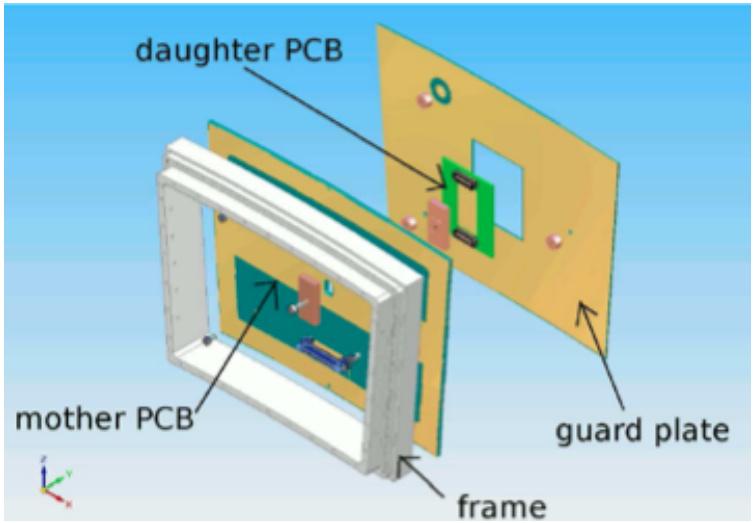
Data with B=0, 1 T, E=140, 230 V/cm were taken for $\Delta z = 5\,\mathrm{cm}$

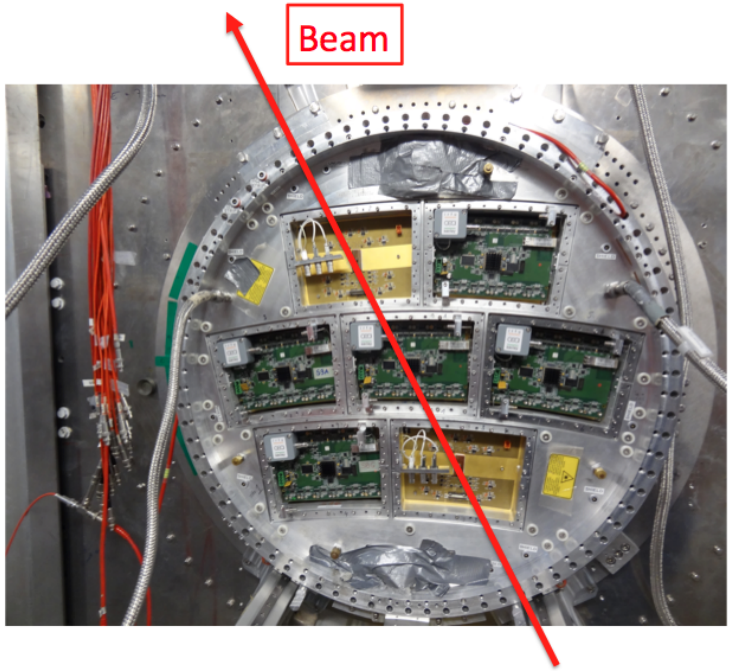
- **7 MM modules** with charge dispersion by resistive anode
  - pads of the size 3×7 mm^2
  - 24 rows with 72 pads each
  - 1728 pads per module
- **2 Timepix modules** (integrated MM grid with pixel readout)

- 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





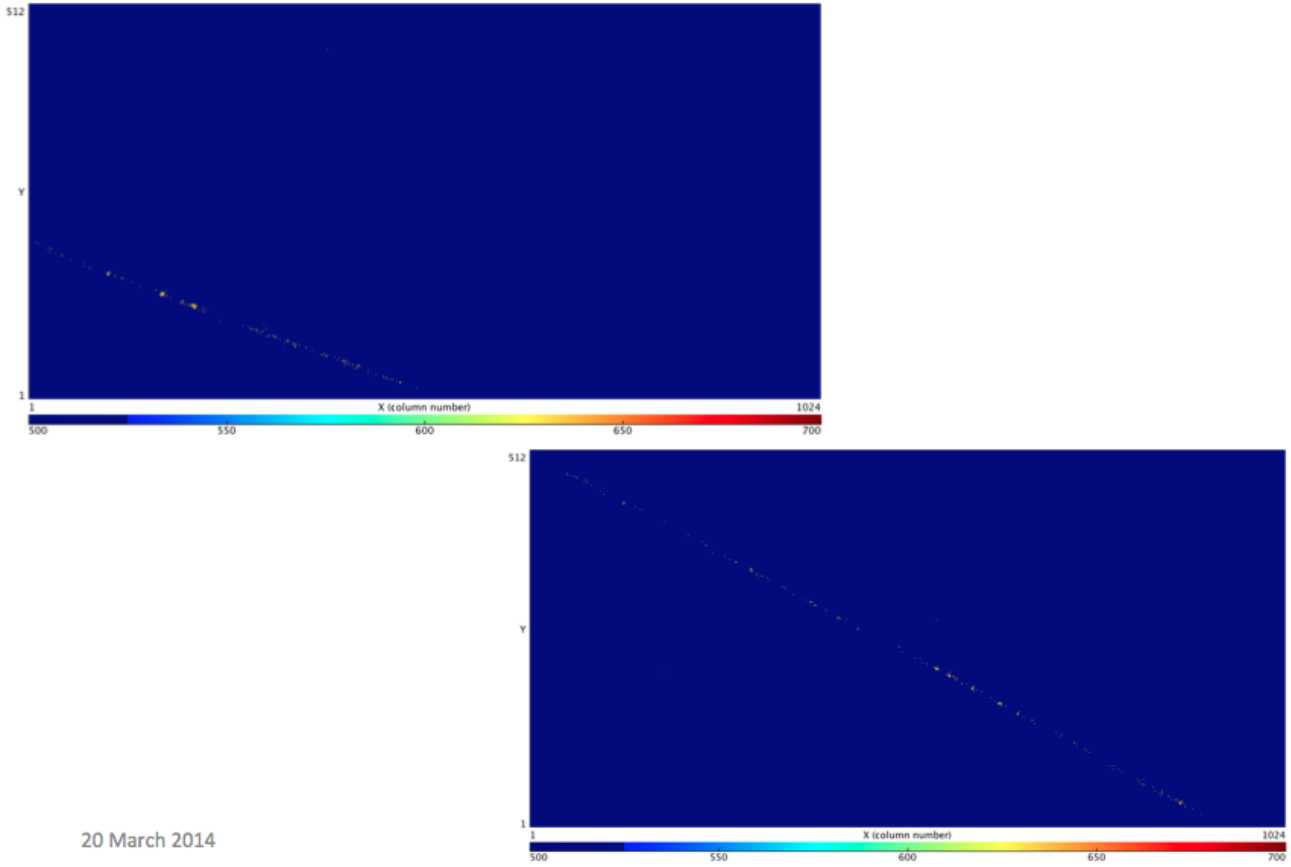


- **Assembly:** 2 Octopus modules
  - 8 InGrids placed on daughter PCB board
- Synchronized readout of **2 Octopus modules and 5 Micromegas modules**

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

2-Phase CO_2 Cooling

About 26 W power consumption is currently measured per MM module

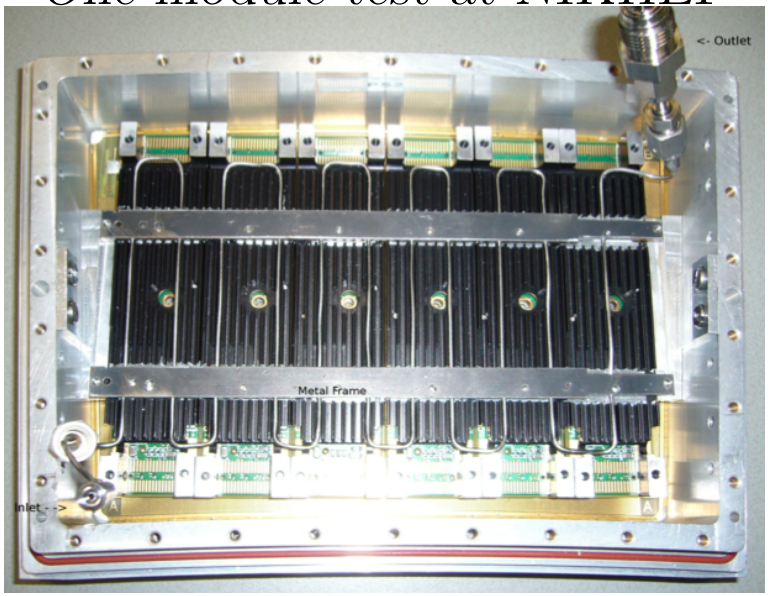
- Temperature of the circuit rises up to 60°C
  - cause a potential damage of electronics
  - covect gas to TPC due to a pad heating

Cooling of the electronic circuit is required!

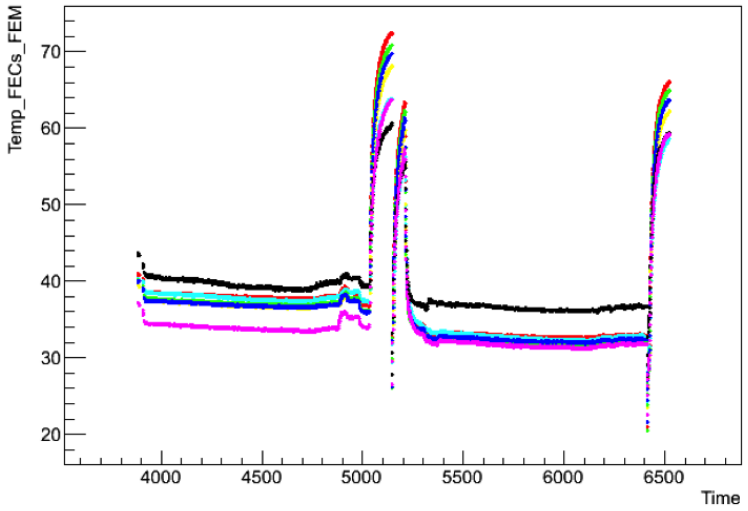
- **Principle:** CO_2 has a much lower viscosity and a much larger latent heat than all usual refrigerants
  - **the two phases** (liquid and gas) can co-exist at room temperature under pressure
  - very small pipes suffice
  - hold high pressure with low material budget

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

One module test at NIKHEF



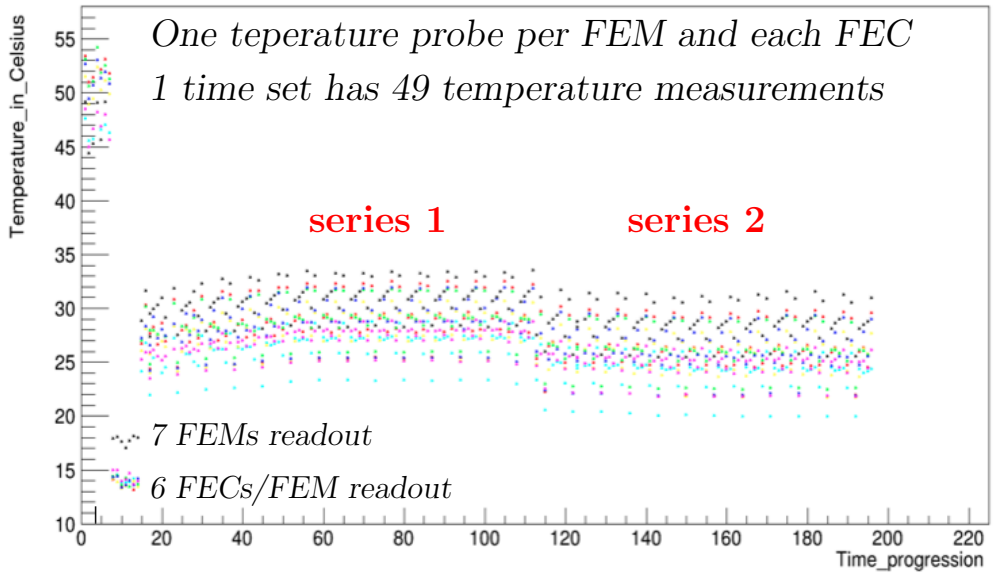
Temp_FECs_FEM:Time

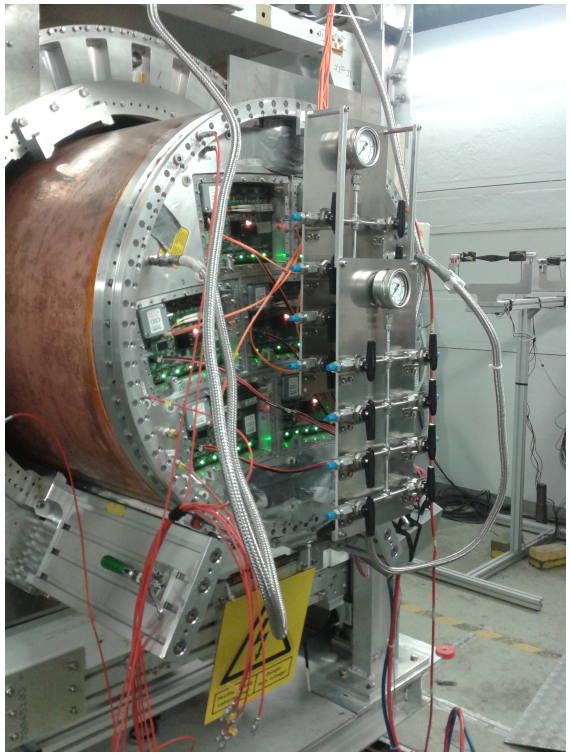


2-phase CO_2 cooling system was designed for the LP setup of the MM mudules

☞ 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



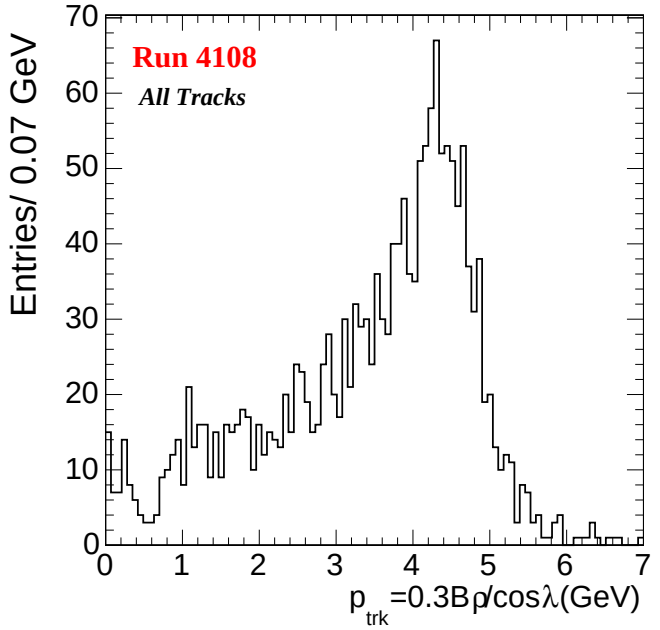


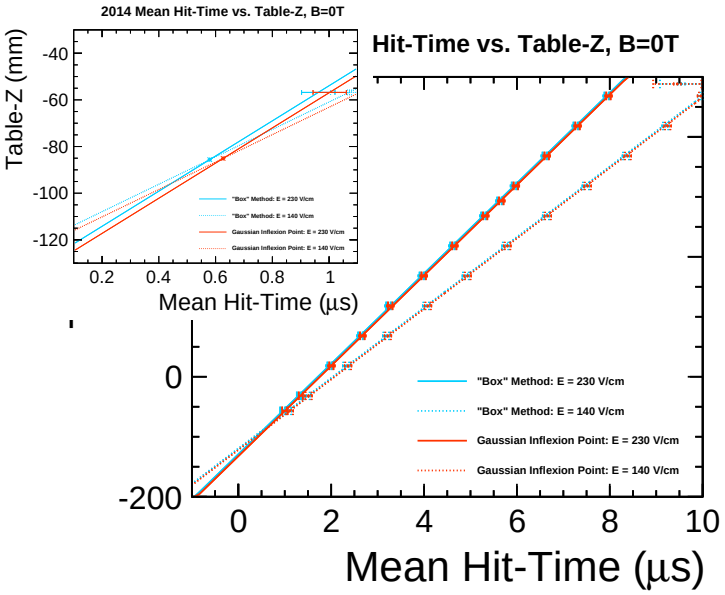
About 30°C stable temperture was achieved during operation of 7 MM modules at DESY

Coherent analysis of all data is performed in MarlinTPC framework

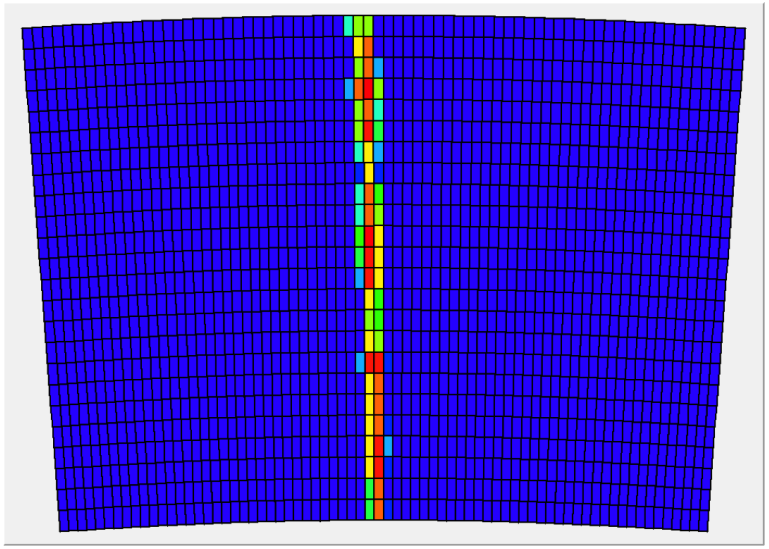
- Dataflow has two major steps: DAQ and Analysis
  - DAQ software store data in **raw format** (calib. view, event dispay, slow control)
  - High level analysis with **MarlinTPC**
    - ➔ subtract pedestals
    - ➔ build hits from pulses
    - ➔ reconstruct tracks (KalmanFit)
    - ➔ analysis (resolution, distortion, etc)

Determine resolution from residuals of the whole 3D track fit, e.g. Kalman algorithm

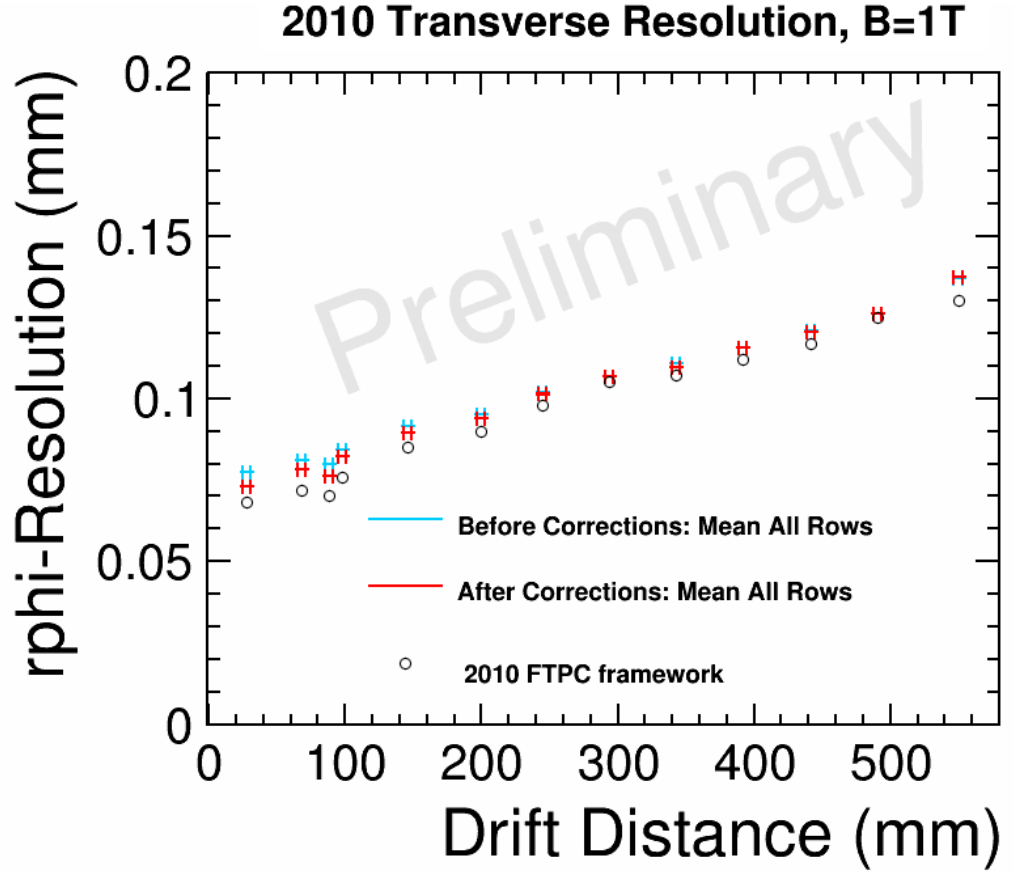




One-Module setup analyzed with both **FTPC and MarlinTPC frameworks**

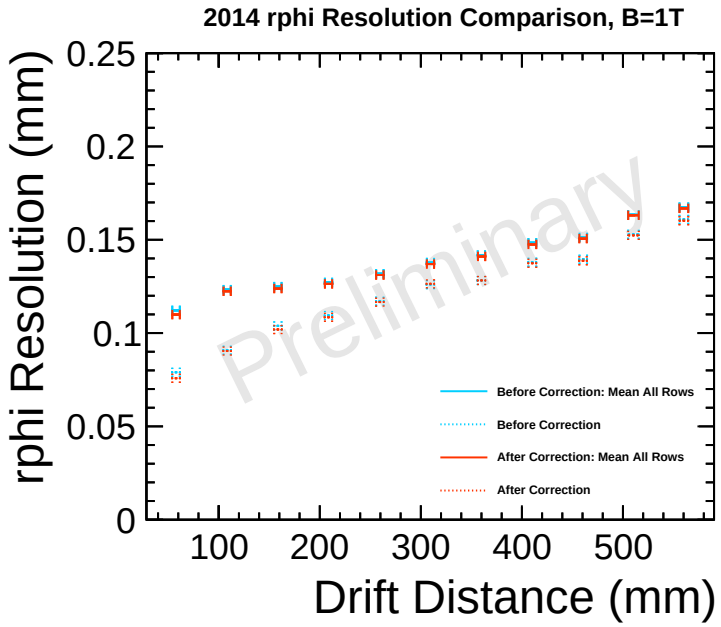


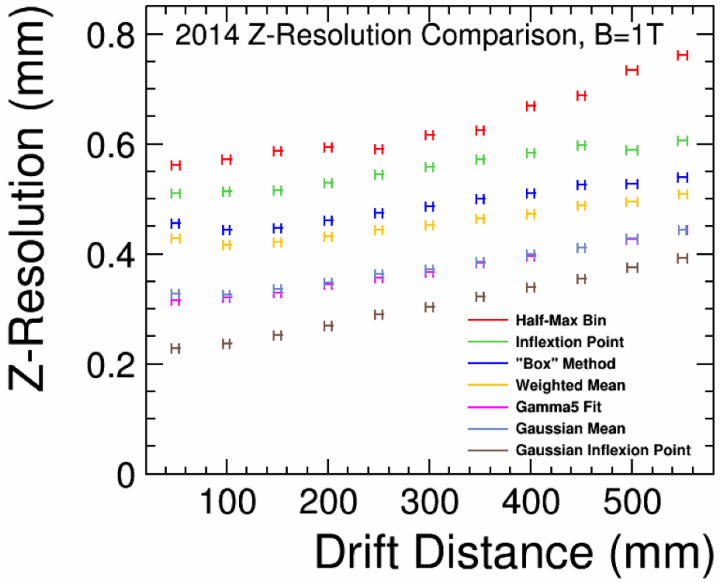
- Deployed simple selections to enrich "**single track**" event content
  - reject multiple-track events
  - require less than 5 hits with more than 40 ADC counts outside 10 central pad lines



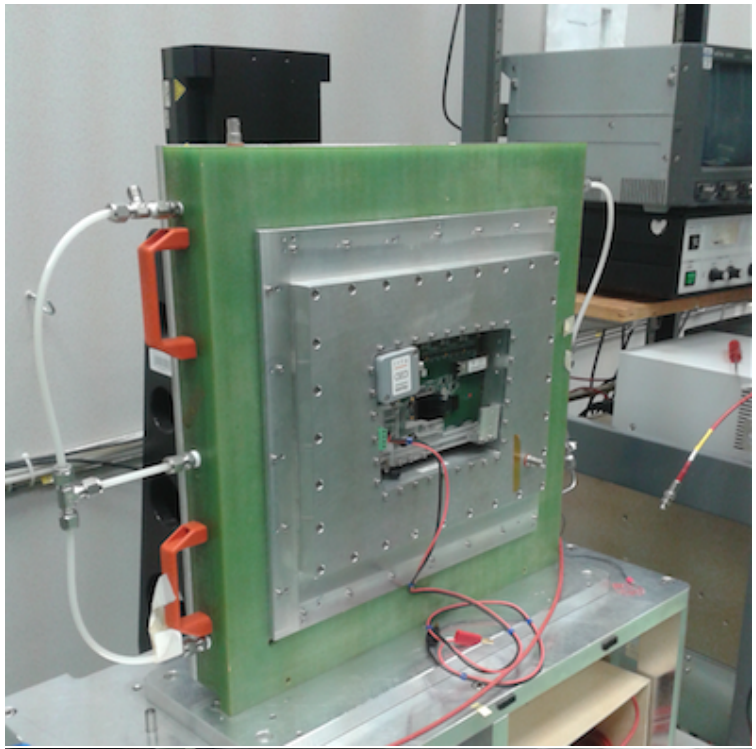
Consistent result with both frameworks

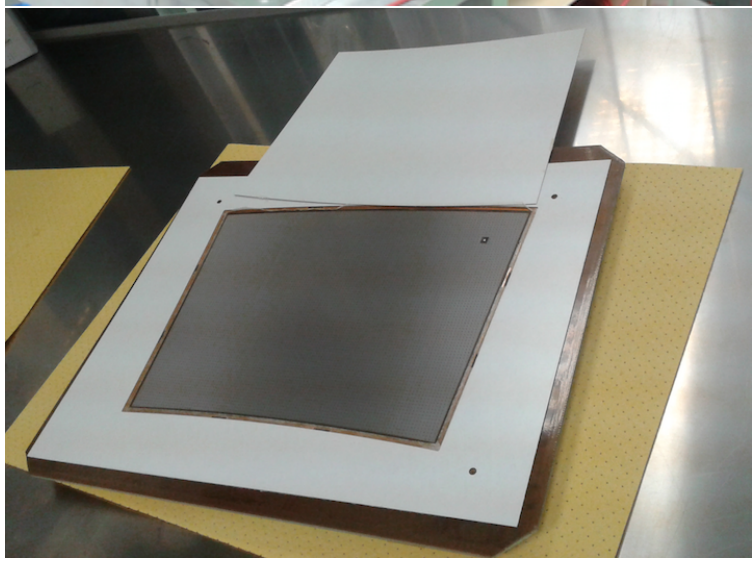
- **Transverse resolution** for 2014 dataset:
  - is in good agreement with 2010 dataset
  - **meets the ILD TPC requirements**
- New estimators (use pulse shape) account possible channel-by-channel shape variation
  - **offers homogeneous z resolution accross the module**
  - absolute z position calibration has to be done separately
  - pulse shape channel-by-channel calibration has to be considered
  - **overkill the ILD TPC requirement!**





- **Next beam test at DESY facility:**
  - **1-15 march, 2015**
- **2 modules with new PCB** is on track of preparation at **CERN test setup**
  - new carbone loaded kapton (CLK) resistive
  - very solid (like diamond), uniform
  - pecisely defined resistivity **(3 MOhm/□)**
- Dedicated calibration using ^{55}**Fe** x-ray source
  - homogeneous gas gain across the module (grid uniformity)





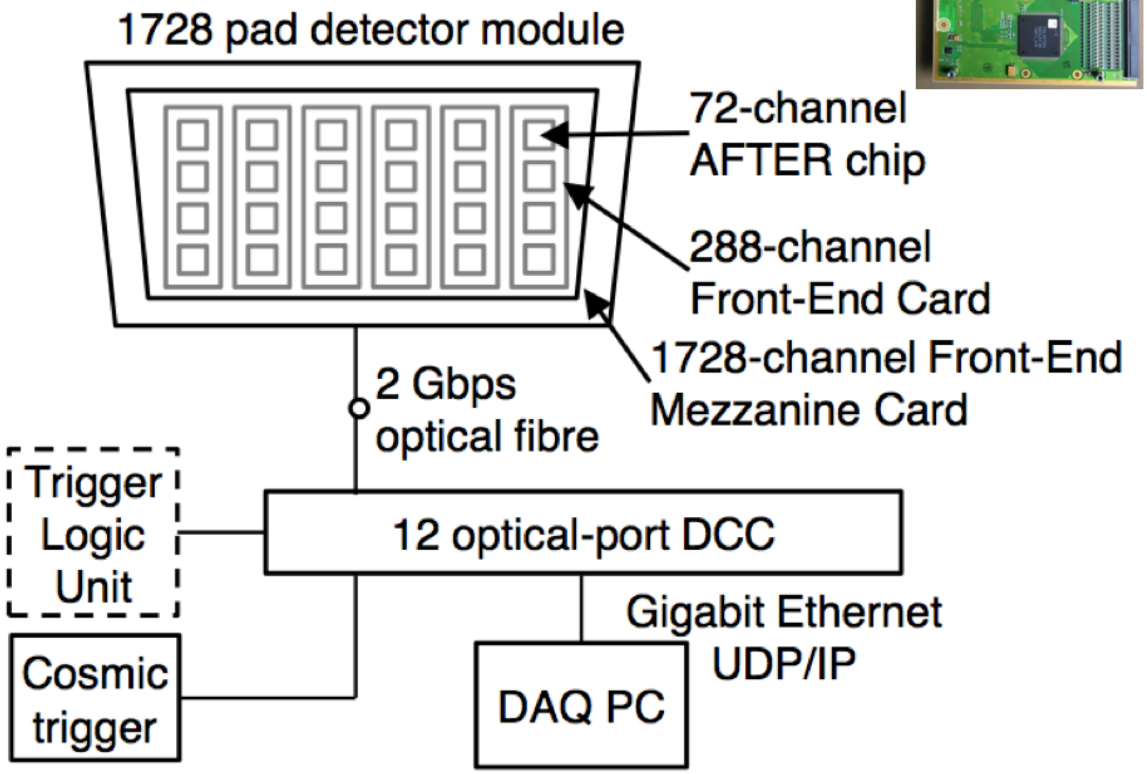
- **The successful beam test within LCTPC collaboration was performed at DESY with EUDET/AIDA facility in February this year**
  - **7 micromegas** fully equipped modules with new CO_2 cooling scheme were tested
  - 3 types of data (**beam, cosmic, laser**) were recorded and analyzed
  - combined test 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
  - meet the ILD TPC requirements for the space resolution
- **Preparation for next beam test 1-15 March, 2015 is ongoing**
  - **whole integration** including cooling and multi-module setup
  - 2 modules with **new PCB** (precisely defined resistivity)
  - scrutiny **multi-module effects** (distortions, alignment)
  - possibly start **gating tests**

Backup

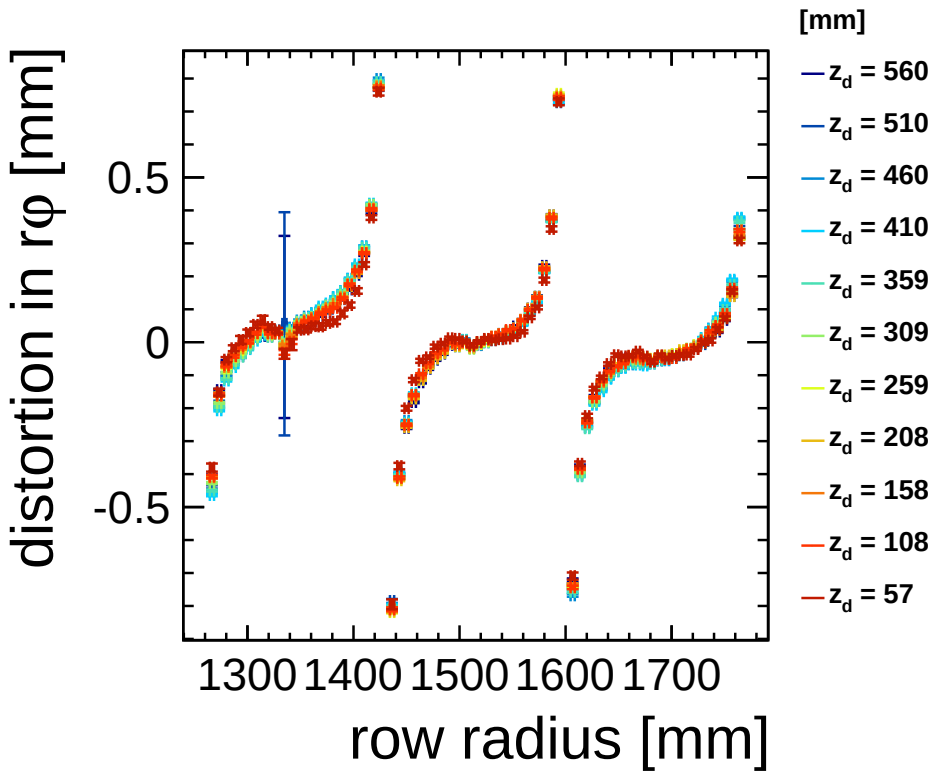
Readout system for the MM prototype TPC is conceptually identical to what is deployed in the T2K experiment

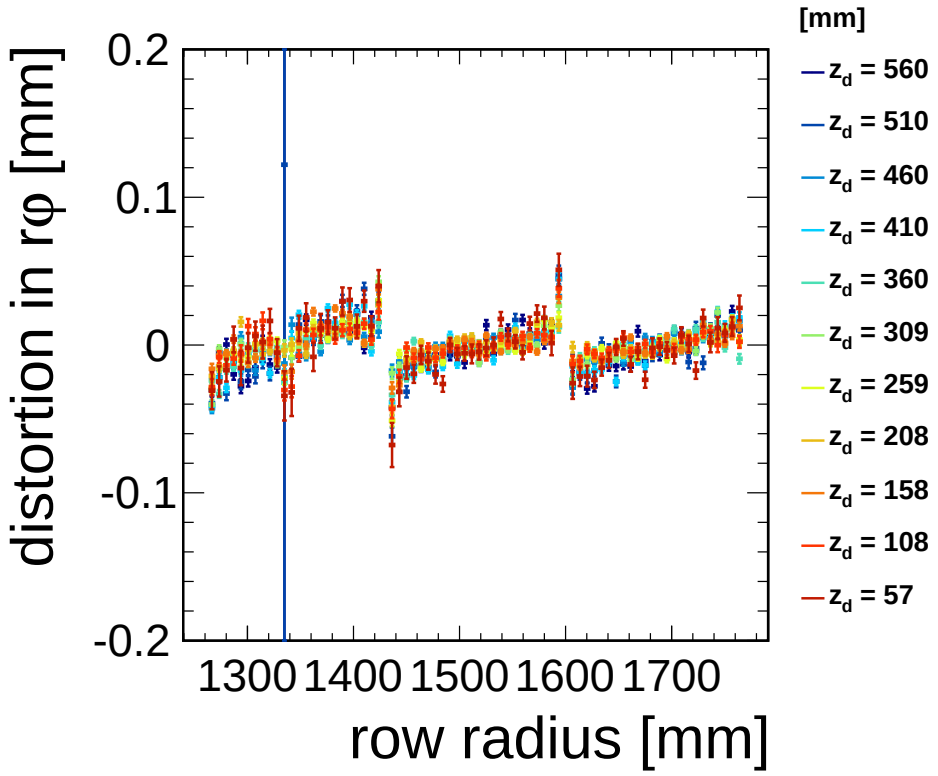
(more advanced electronics is being prepared with the SALTRO-16 chip)

- **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



Distortions in $r\phi$





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

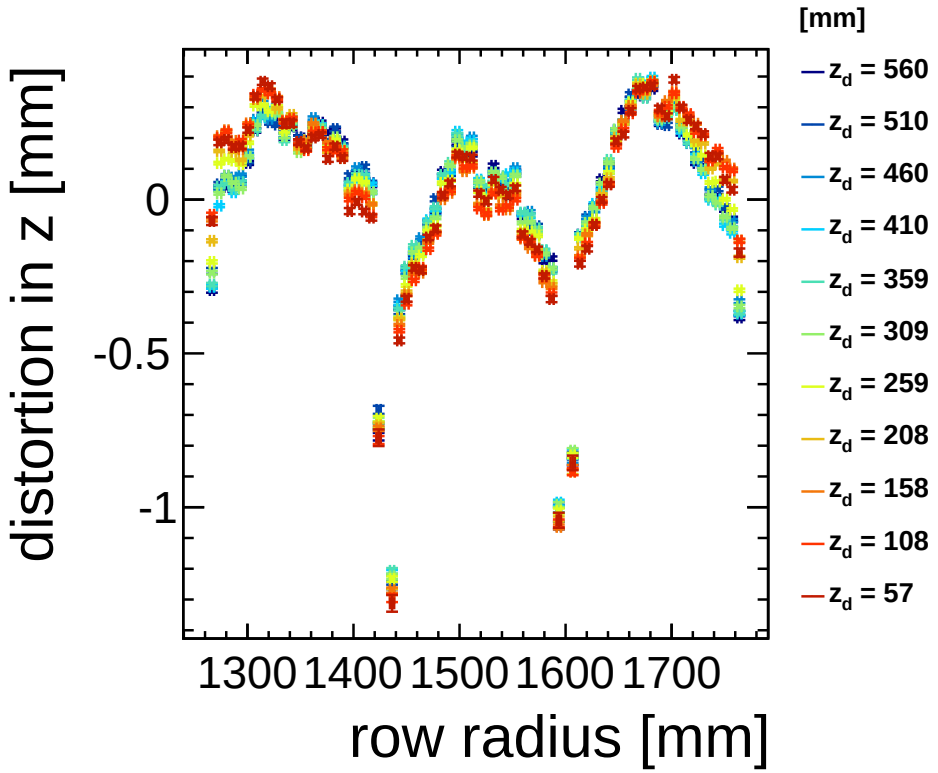
☞ At B=0 T: distortions about 200 μm are due to E only

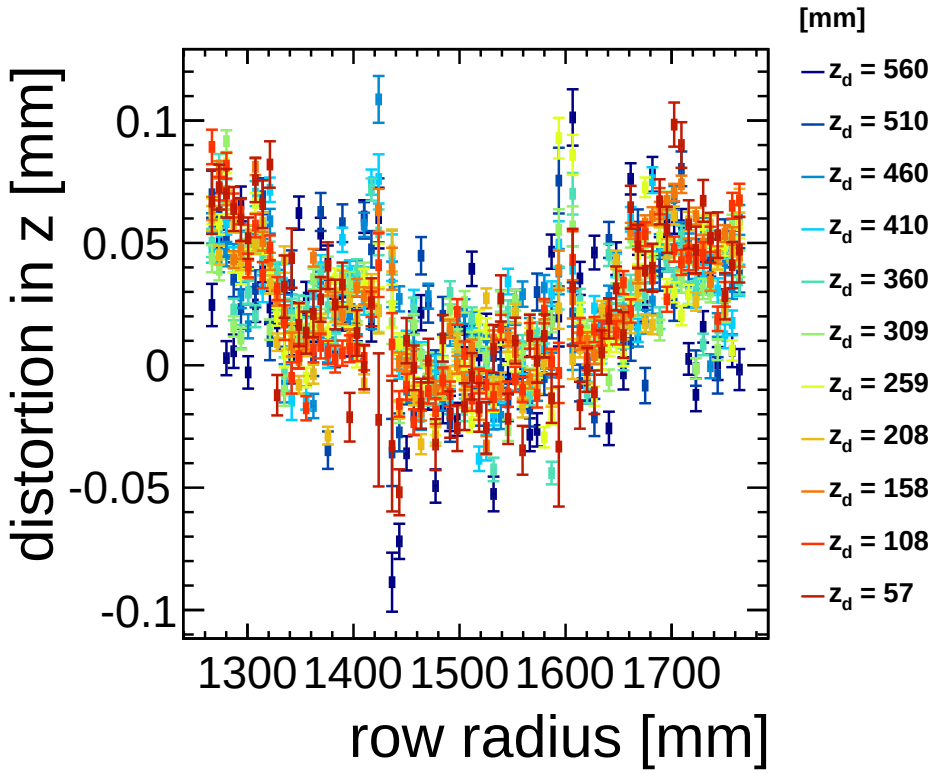
➠ can be easily pinned down to 20 μm

☞ 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