Test Beam 2015 with Micromegas

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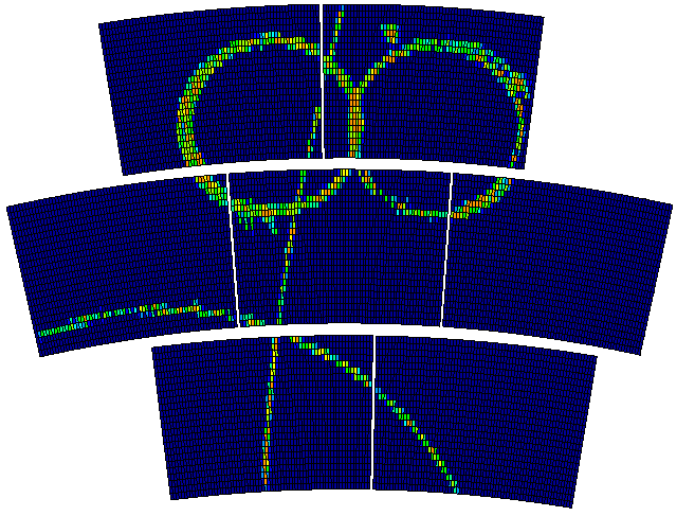

ALCW2015, LCTPC Section
KEK, Japan
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The EUDET/AIDA test beam facility at DESY provide a 6 GeV electron beam

- LP TPC consists of a field cage equipped with an endplate with 7 windows to receive up to 7 fully equipped modules

Last beam test of 7 MicroMegas (MM) TPC modules at DESY (Mar. 1– Mar. 14, 2015)

- **Principal goals** of 2015 test beam
  - to test 5 Carbon Loaded Kapton (CLK) and 2 new Black Diamond (BD) MM modules
  - to gather remaining material aimed for publication this year

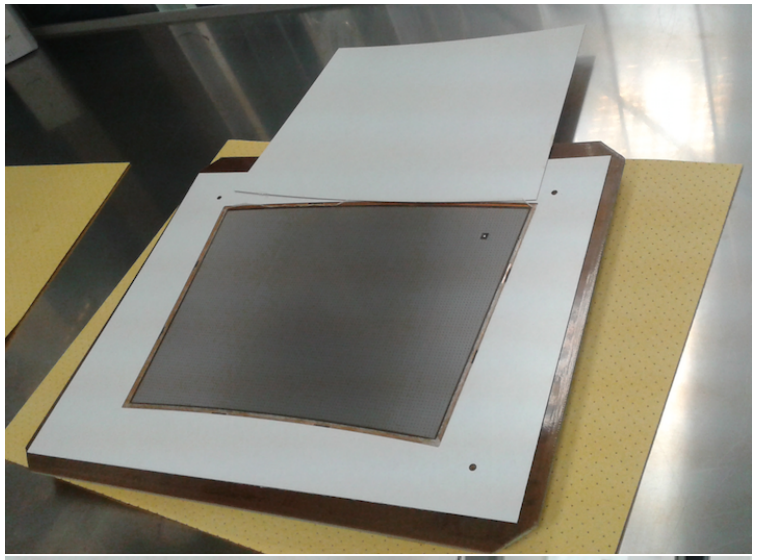
- Valuable help and partial attendance:
  - J. Kaminski (Bonn), K. Fujii (KEK), F. Couderc, B. Tuchming (Saclay)

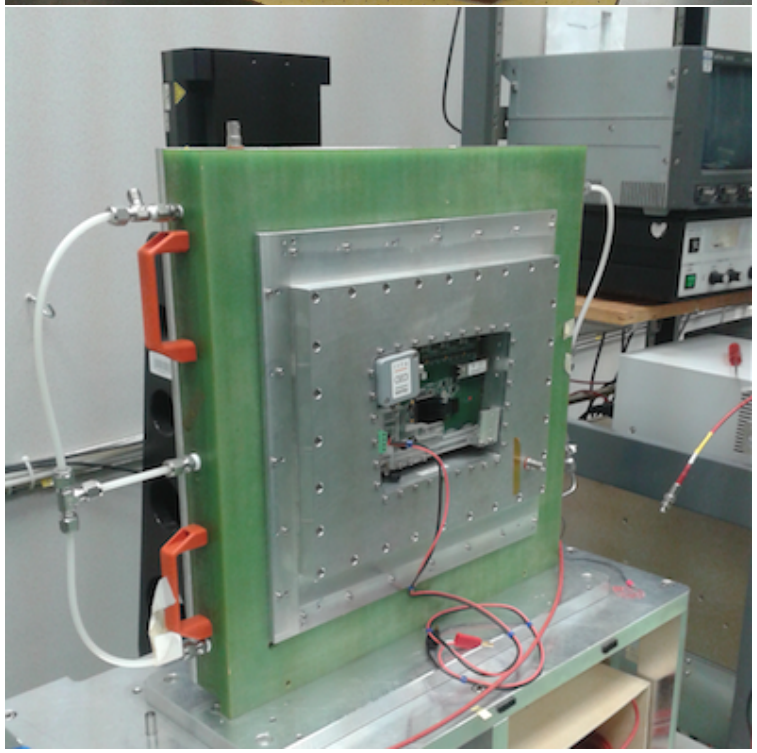
Prehistory of beam tests with MM modules:

- **Mar 2010:** one-module setup
- **May 2011:** cross-talk problem
- **Jul 2012:** multi-module setup with 6 fully operated modules; coherent noise
- **Jan-Feb 2013:** multi-module setup with 7 fully operated modules; many disconnected pads
- **Feb 2014:** same as in 2013 with some pads' connection problem

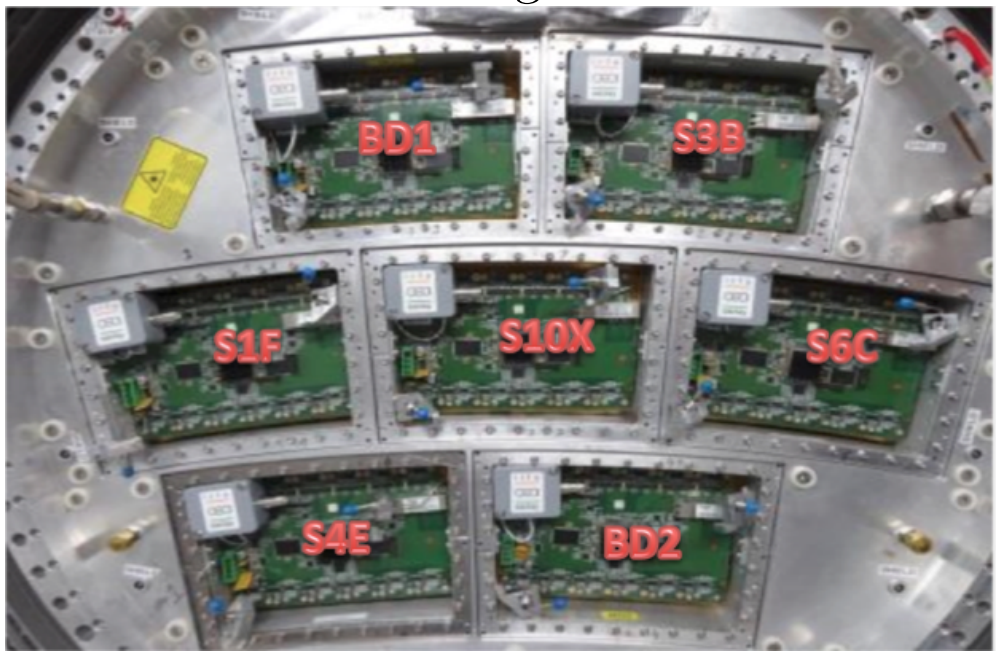
Two new modules were prepared and tested at CERN test setup (Jan-Feb., 2015)

- New type modules: **BD1 and BD2**
  - new PCB with resistive kapton to disperse the charge
  - very solid (like diamond) and uniform
  - pecisely determined resistivity **(5 MOhm/□)**
- Module assembly and test using ^{55}**Fe** x-ray source
  - calibration, pedestal, etc
  - generic test of workability with ZS
  - homogeneous gas gain across the module (mesh uniformity) is foreseen

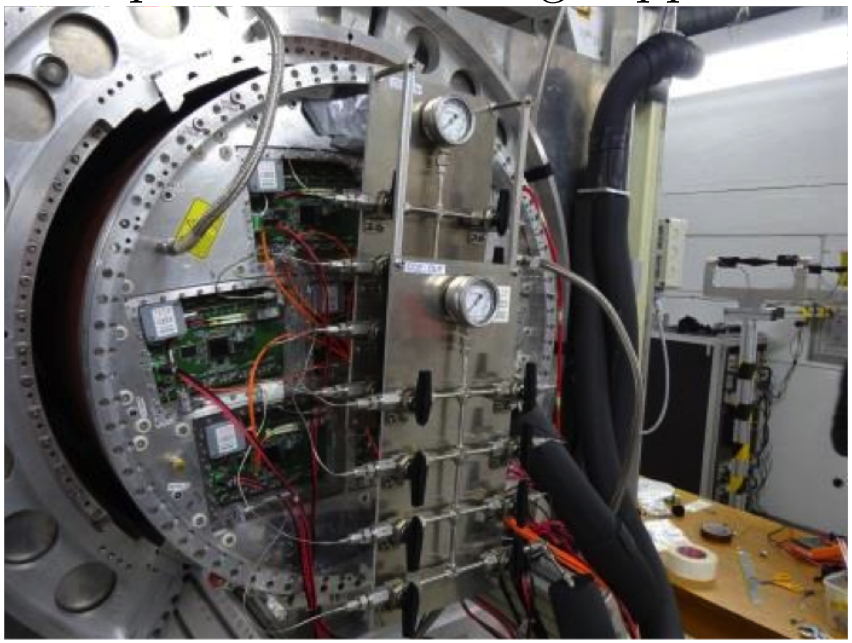




Baseline module configuration for TB2015



2-phase CO_2 cooling support



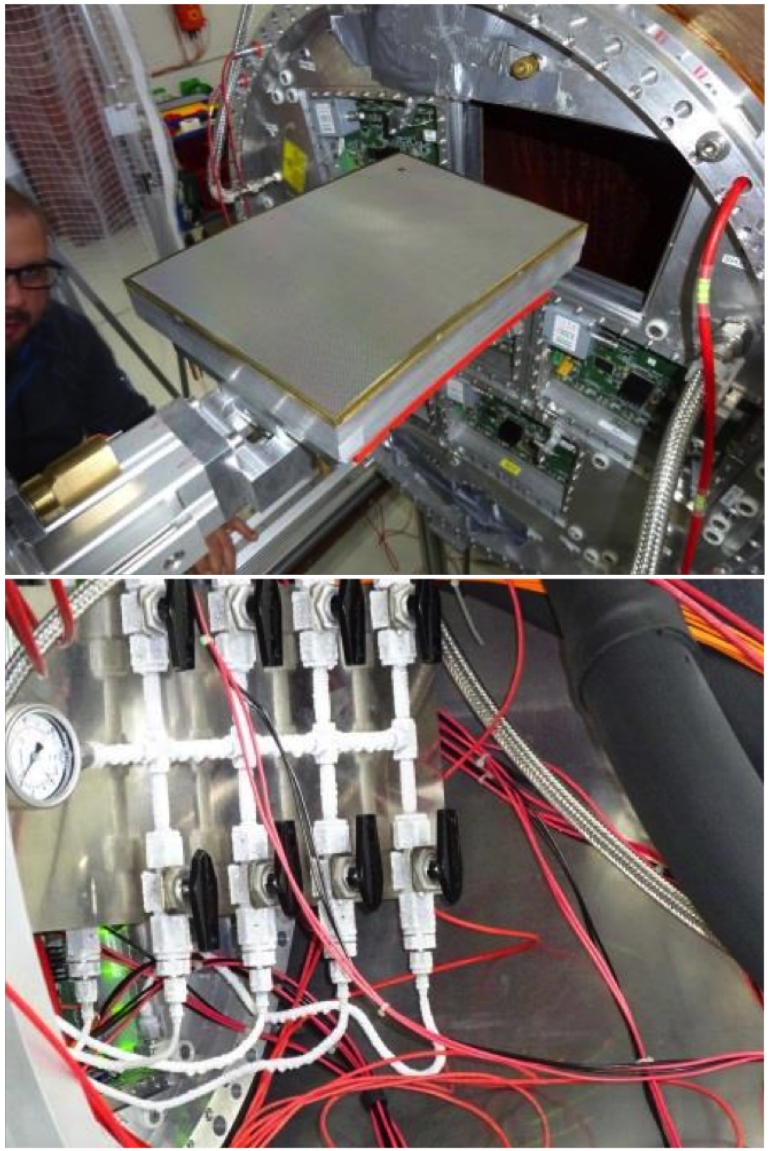
☞ Equipped with 7+2(spare) MM modules for this test beam

☞ Use KEK **cooling plant TRACI** made in NIKKEF for CO_2 cooling

Several minor incidents occured

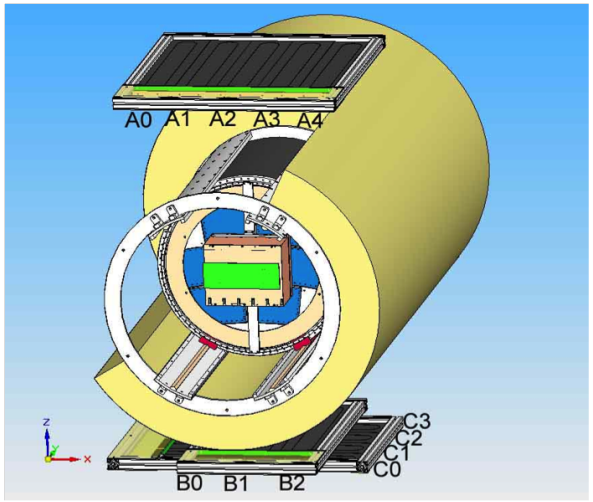
- Delay at the start of the test
  - missing low voltage 30kW supply (found!)
  - broken S8G module while mounting (replaced by S10X)
  - cooling (possibly lack of CO_2 in TRACI)
  - limited BD2 $V_{mesh} = 370$ V (nominal $V_{mesh} = 380$ V)
- **Start beam data taking March 6**
- Dismount module and restart gas flow (March 7-8)
  - continuous sparking broke one module (automtic night cosmic running)
  - replace S5D by S3B

About 3 whole days of data taking with good gas



Frost deposited on the pipes (-10°)

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* (designed and produced at CEA-Saclay)
  - 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**

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

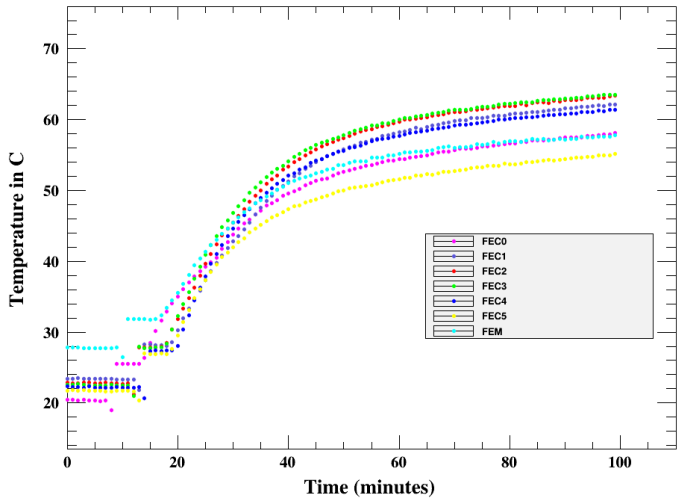
➠ very small pipes suffice

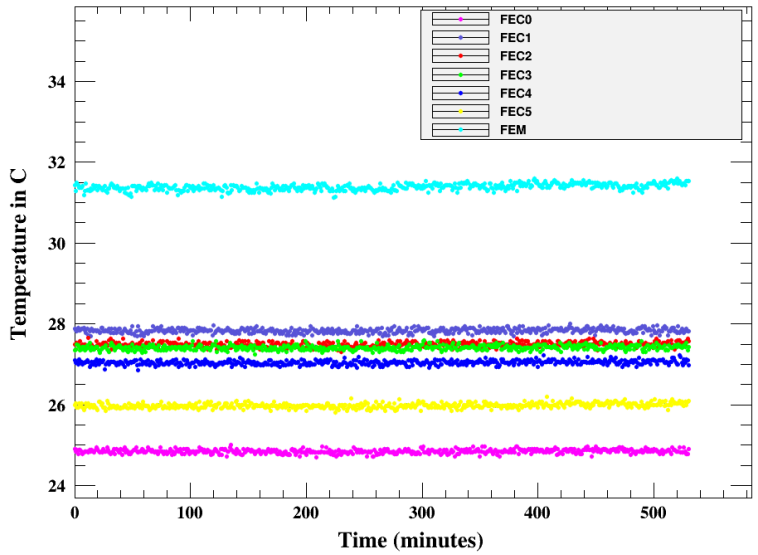
➠ hold high pressure with low material

☞ **10°C at P=45 bar** system operation

About 30°C stable temperature was achieved during operation of 7 MM modules

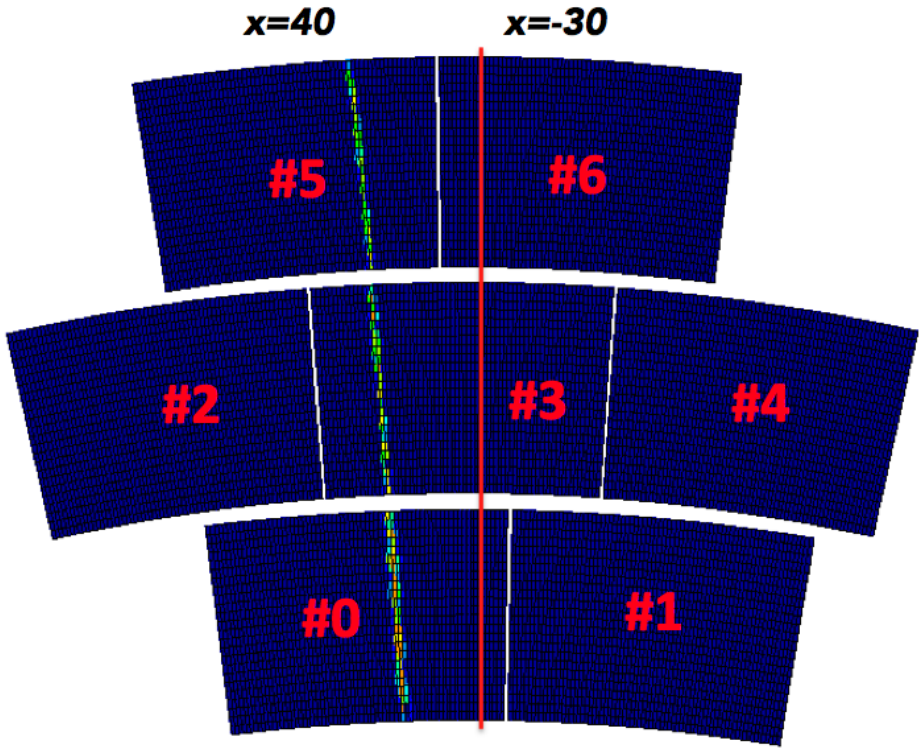
Module 6 (S3B)





- **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
- **Beam data taking program:**
  - magnetic field: B=0, 1 T
  - drift field: E=140, 230 V/cm
  - z-scan [5-50]cm every $\Delta z = 5\,\mathrm{cm}$
  - shaping time τ-scan: 100-1000 ns
  - ZS: 4.5σ (baseline) and 3σ
  - beam energy scan [1-5] GeV
  - varying θ angle up to 30°
- **Cosmic data:** cover a whole LP volume

View from inside

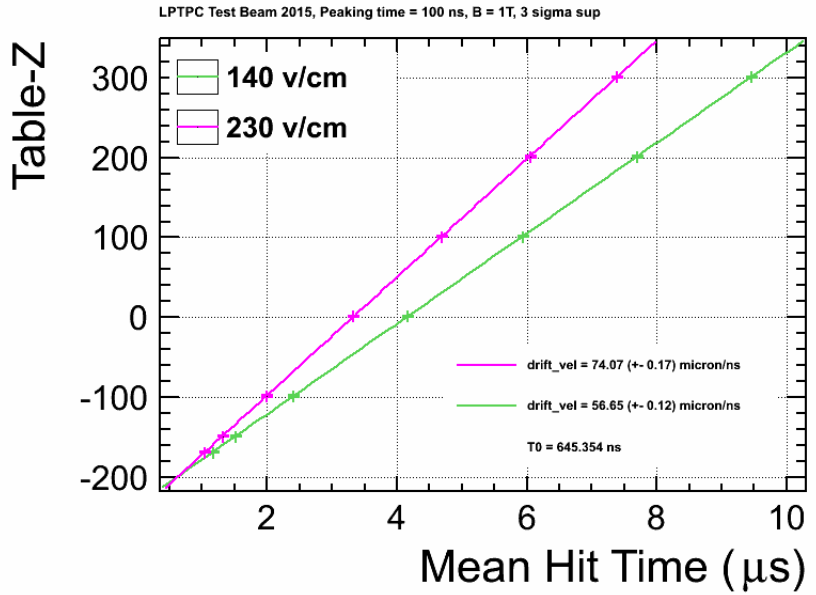


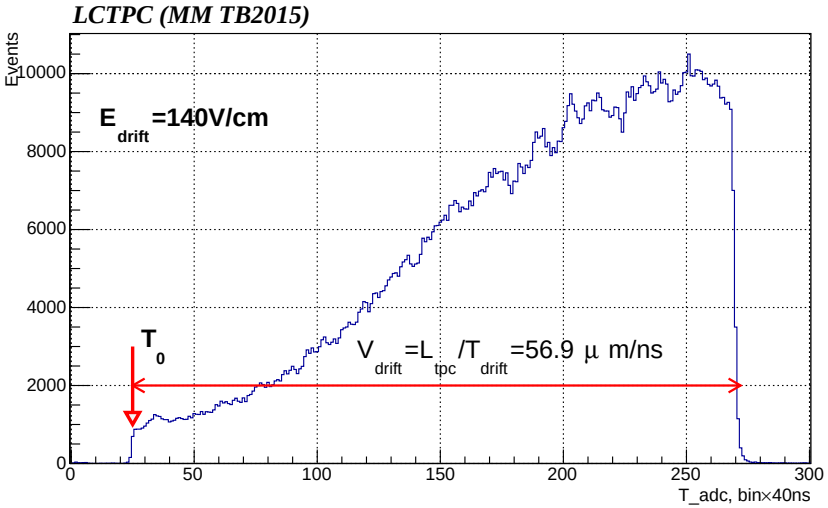
x=40: baseline beam setup
x=-30: complementary beam setup

T_0 *Calibration and Gas Property*

- Prototype operates with T2K gas
  - Ar(95%), CF_4(3%), iC_4H_{10}(2%)
  - gas purity: 60 ppm O_2, 100 ppm H_2O
  - deploy `Magboltz` calculations
- Absolute T_0 calibration:
  - **beam trigger:** dedicated z-scan at $V_{drift} = 140, 230$ V
    - ➔ $T_0 = 645$ns from fit
  - **cosmic trigger:** accumulate a whole LP volume data events
    - ➔ $T_0 = 22 \times 40\text{ns} = 880\text{ns}$

About 250 ns differnce for T_0 between 2 trigger configurations





	E=140 V/cm	E=230 V/cm
V_d `Data`	$56.7 \pm 0.1 \mu m/ns$	$74.1 \pm 0.2\ \mu m/ns$
V_d `Magboltz`	$57.9 \pm 1.0 \mu m/ns$	$75.5 \pm 1.0 \mu m/ns$
$D_\perp$ `Magboltz`	$74.5 \pm 2.5 \mu m/\sqrt{cm}$	$94.8 \pm 3.1 \mu m/\sqrt{cm}$

Future Plans

- We do not plan to make any big hardware investment before beginning of 2017
- We have presently **no intent to take more data** with the same configuration
- However, **several possibilities** are still opened
  - if there is an endplate II to be tested, or
  - if we have an idea of a fixup for distortions
- **Priority in the next two years**
  - to analyze the data
  - to understand distortions systematically
  - to work on simulations
  - publication(s)
- **As far as hardware is concerned**
  - design of a large module with cooling and high channel density
  - gating with a large aperture GEM, by doing back-flow measurements
  - simulating in hardware an ion disk using a UV lamp

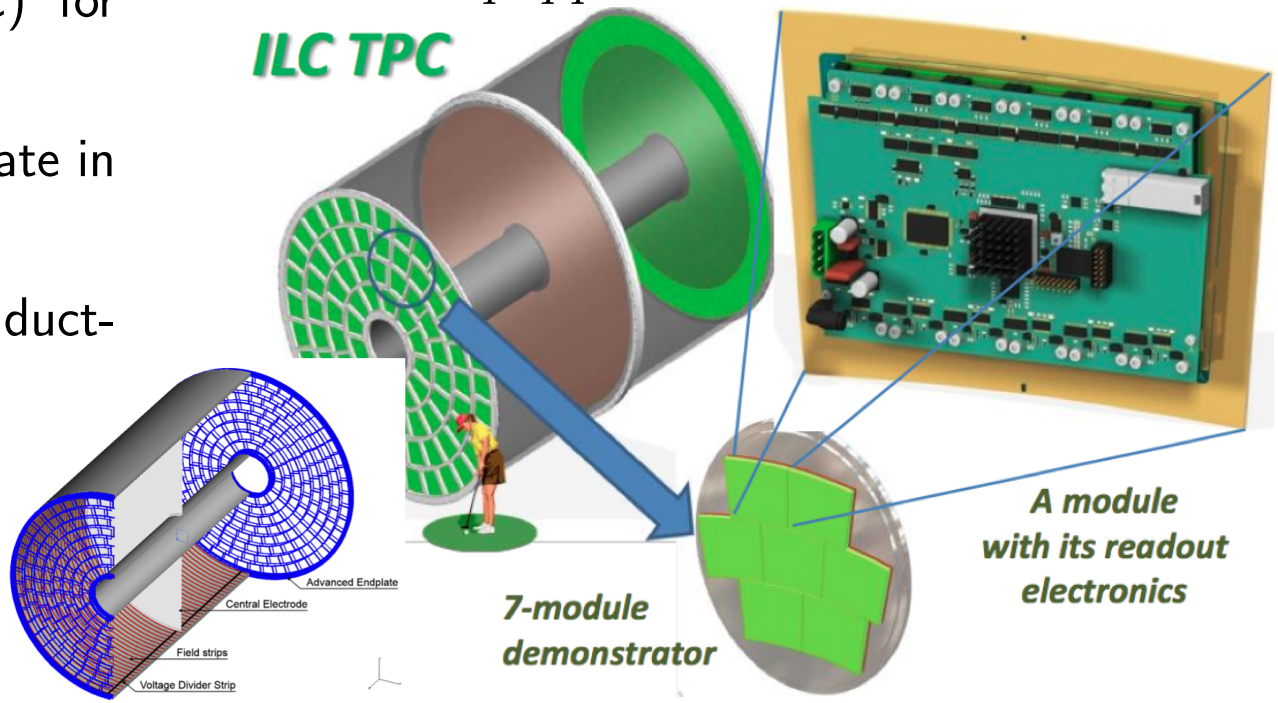
- **A successful beam test within LCTPC collaboration was performed at DESY with EUDET/AIDA facility in March this year**
  - **2 new black diamond (BD) modules and 5 carbon loaded kapton (CLK)** were tested in B=0, 1 T
  - very vast amount of data taken in various configuration were accumulated
  - **(beam and cosmic)** data were recorded and then analyzed
  - 2-phase CO_2 cooling long-term operation at 30°C of electronic circuit was confirmed
- **Publications on behalf of LCTPC collaboration**
  - possibly paper on 2010 one-module setup (could be short)
  - detailed paper on 2015 analysis (possibly within one year)
- **Preparation for next beam tests**
  - module with **common pad structure** is being discussed
  - integration for **gating and ion back flow** tests
  - possibly contribution to endplate II to address distortions

Backup

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

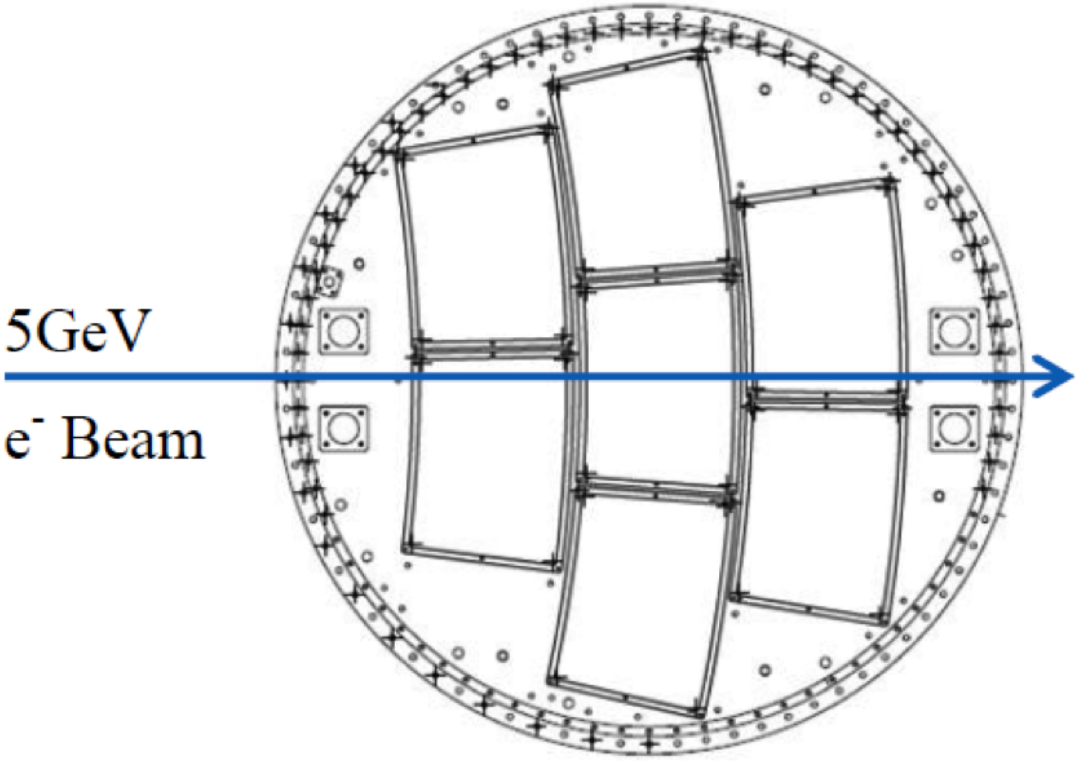
- Setup was designed for a Large TPC Prototype (LPTPC) for the ILC experiment
- LP readout modules operate in a strong magnetic field
  - provides a superconducting solenoid magnet $\varnothing 85\,\mathrm{cm}$ and a length $\sim 1\,\mathrm{m}$
  - a magnetic field strength of up to **1.25 T**

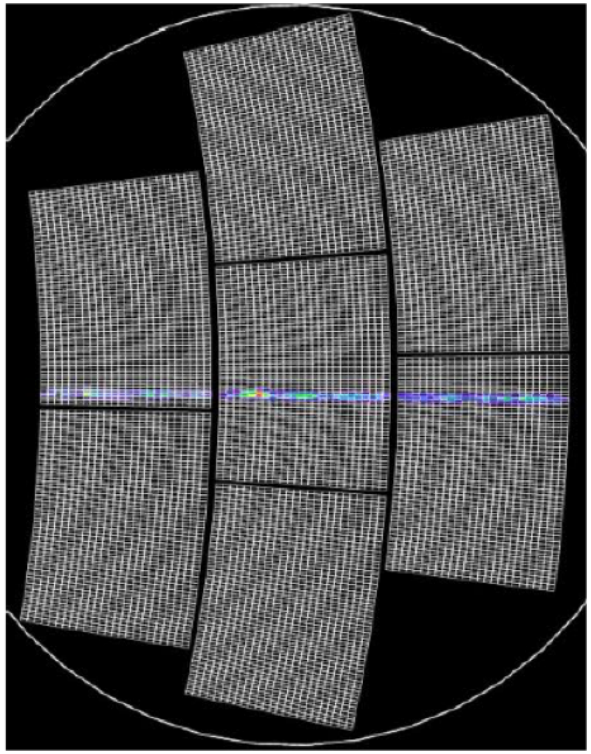
Consists of a field cage equipped with an endplate with 7 windows to receive up to 7 fully equipped identical modules



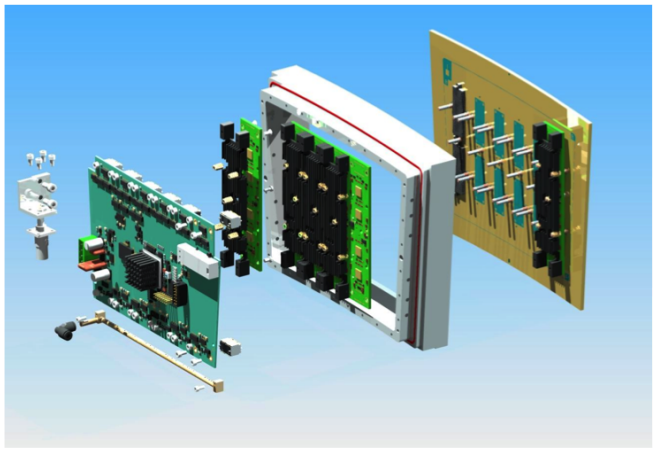
Different layouts are considered for ILD: 4-wheel and 8-wheel scheme

Multi-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

(designed and produced at CEA-Saclay)

- **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