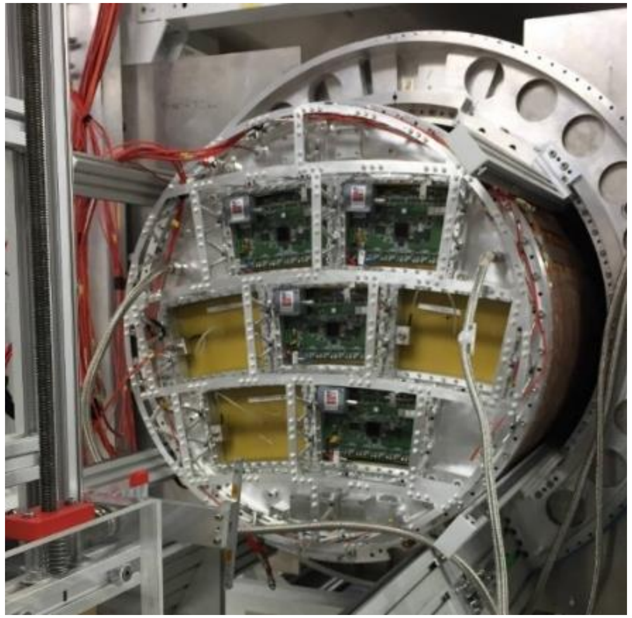
LCWS2021
International Workshop on Future Linear Colliders

March 18, 2021

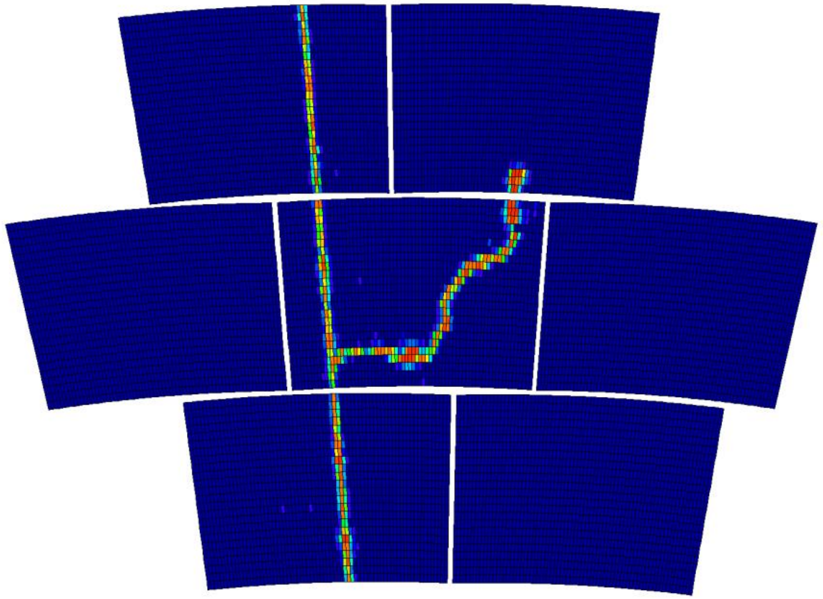
Results from a beam test of four 'Encapsulated Resistive Anode Micromegas' modules



Paul Colas

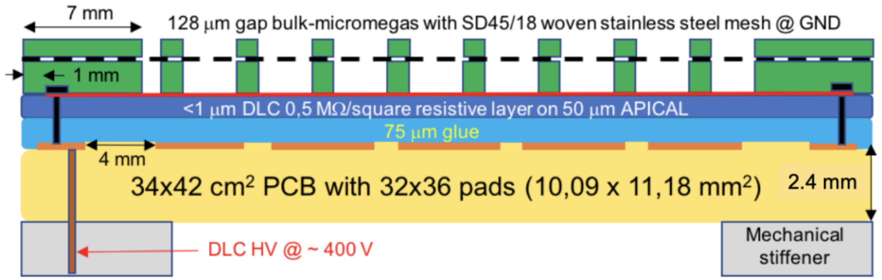
CEA/Université Paris-Saclay

LC-TPC



- **TPCs for ILC and T2K**
- Requirements from physics:
  - ILC mainly point resolution (100 µm at all drift distances) and 5% dE/dx resolution
  - T2K : mainly dE/dx resolution (8%) and point resolution better than 700 µm
- Use of Diamond-Like Carbon (DLC) in Micromegas TPCs to
  - Stabilize Micromegas
  - Spread the charge to improve point resolution and save electronic channels

Charge spreads according to a diffusion equation, parameter RC of the resistive-capacitive continuous network. R sheet resistivity (per square), and C capacitance per unit of surface



$$C = \frac{\varepsilon_0 \ \varepsilon_r}{d}$$

$$\frac{\partial \rho}{\partial t} = \frac{1}{RC}\left[\frac{\partial^2 \rho}{\partial r^2} + \frac{1}{r}\frac{\partial \rho}{\partial r}\right]$$

$$\Rightarrow \rho(r,t) = \frac{RC}{2t} e^{\frac{-r^2 RC}{4t}}$$

RC ~100 ns/mm² allows spreading over a few mm² in the integration time of the electronics of O(100 ns)

M.S. Dixit et.al., NIM A518, 721 (2004) , M.S. Dixit & A. Rankin, NIM A566, 281 (2006)

ERAM

- Improvement to the simple resistive anode
  - Mesh at ground : same potential as surrounding mechanics (module frames) : more uniform field, less distortions near edges
  - Thus DLC needs to be encapsulated, i.e. covered along the borders by 5 mm wide photoresist
  - This provides more operational flexibility : the DLC voltage can be tuned independently for each module, and even set to zero (in case of a short circuit) while the neighbor is at 400 V, without distorting the drift field.

Many tests in recent years

Beam test at DESY in 2015 (LCTPC, 2 DLC modules)

Cosmic-ray test at Saclay in 2017 (T2K)

Beam test at CERN in August 2018 (T2K)

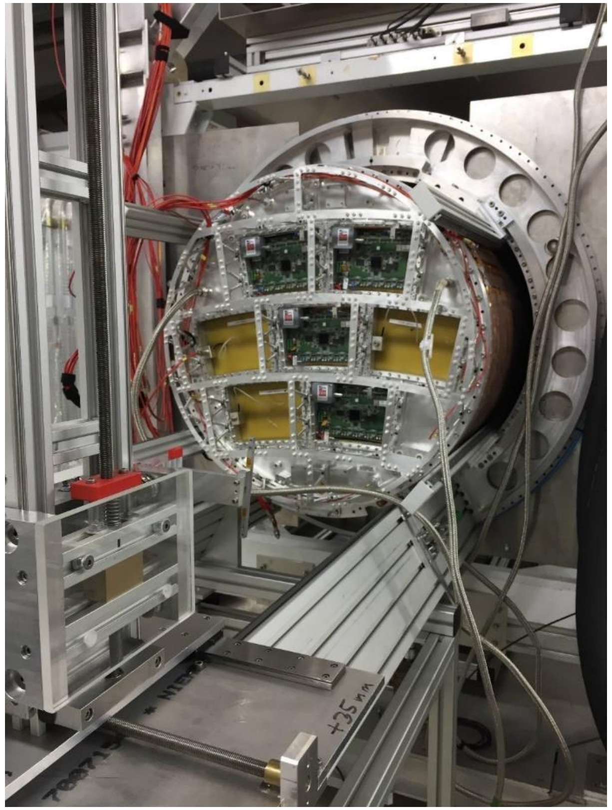
Beam test at DESY in November 2018 (LCTPC)

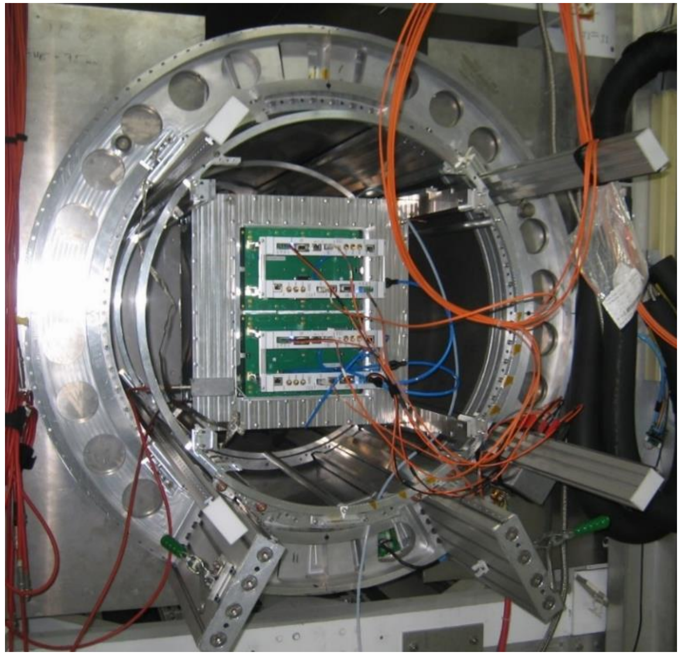
Cosmic-ray test in Saclay since January 2019 (LCTPC/FCC)

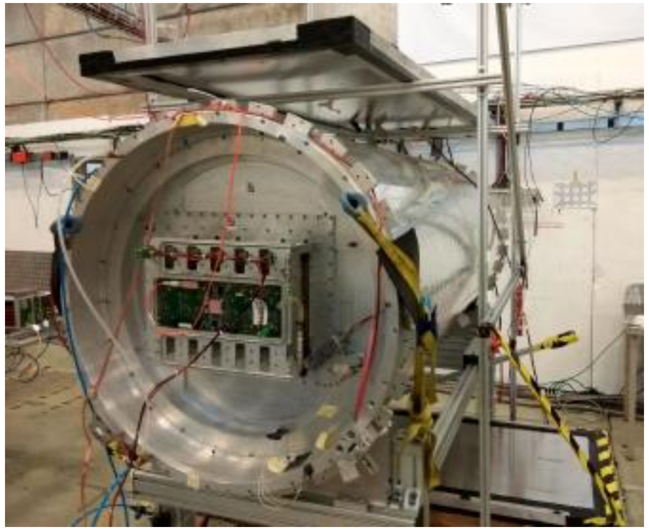
Beam test at DESY in June 2019 (T2K)

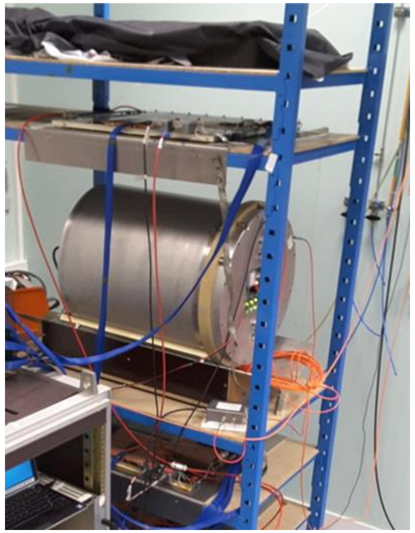
Cosmic test at CERN since December 2019 (T2K)

Cosmic tests in Saclay during the covid year (T2K) (4-6 modules)

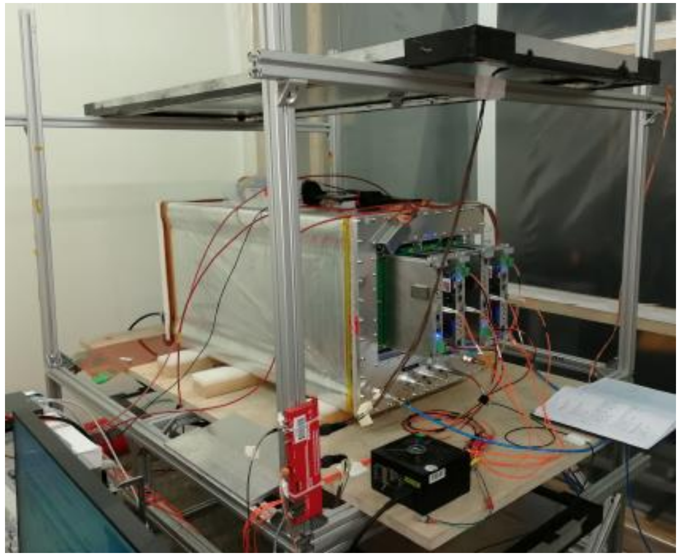






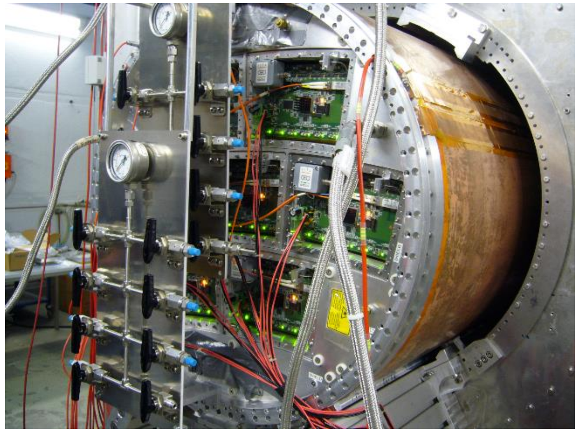


5 TPC of 15, 58, 60, 100 and 150 cm length with 1000 to 2000 channels
All with DLC charge spreading

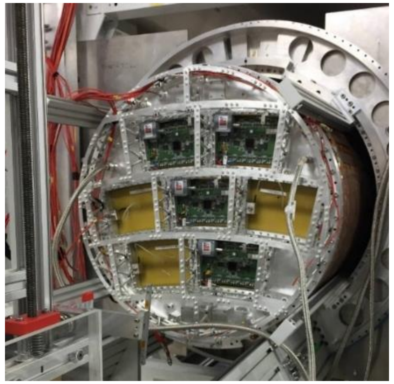


Overal conclusion : extremely reliable and stable operation

7 modules readout by Micromegas and cooled with 2PCO2 : beam test in 2015



4 modules with new ERAM scheme : tested in November 2018.



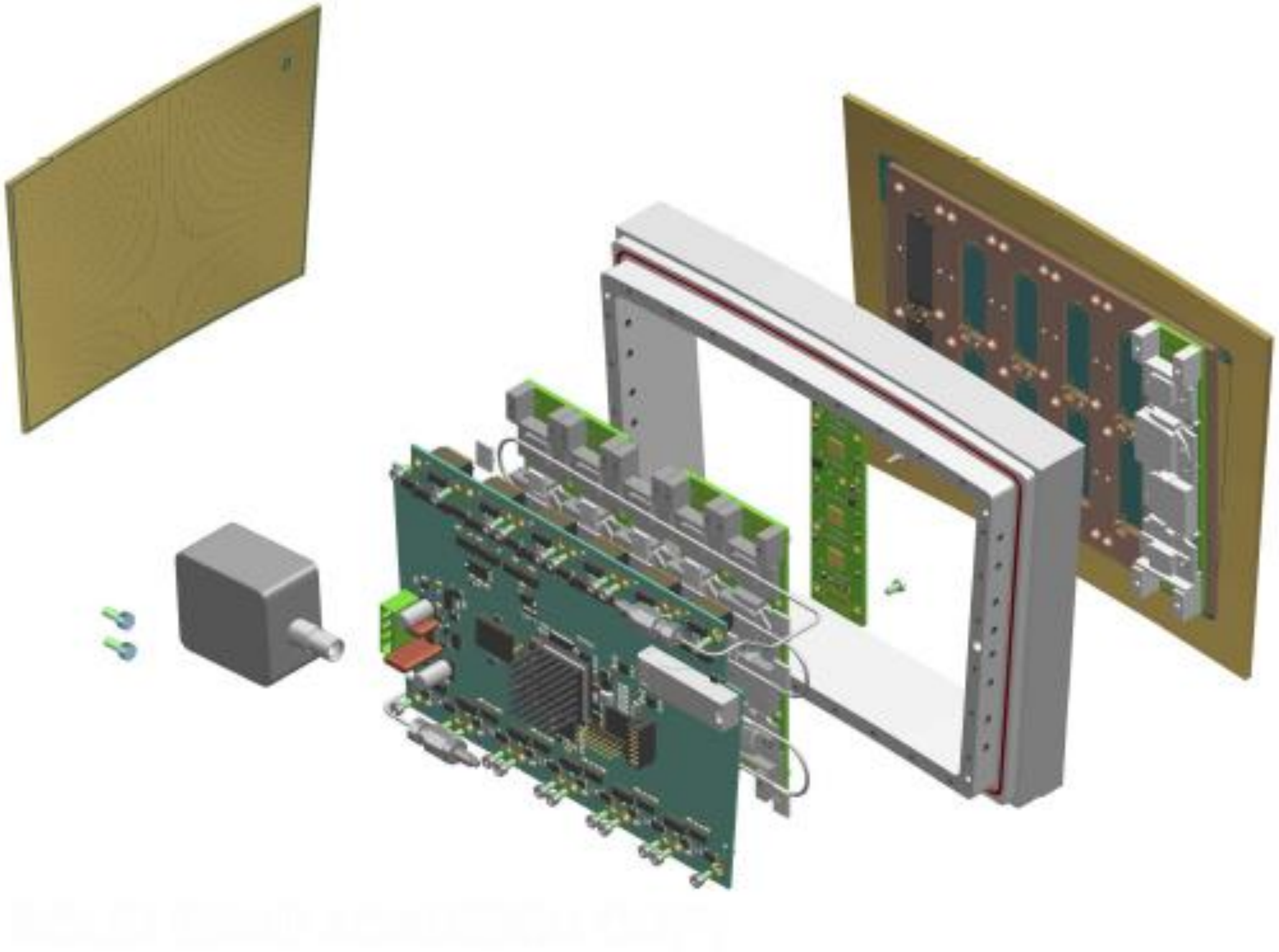
Cosmic test in Saclay (B. Tuchming) since January 2019, still on-going, with few months shutdowns for winter and summer breaks and Covid 19 shutdown. Re-started in September 2020.

Micromegas modules

Since 2008 we built and tested every year Micromegas modules with an AFTER-based readout electronics. Since 2013 this electronics and its cooling are fully integrated.

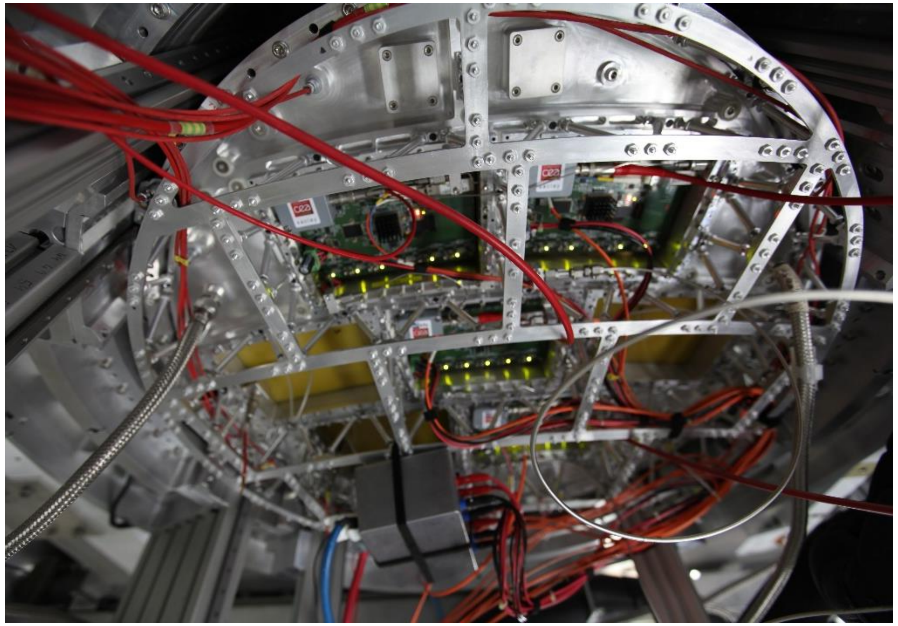
LV supply
HV supply
Double fibre for data flow
2-phase CO_2 cooling

72x24 pads of 3x7 mm²



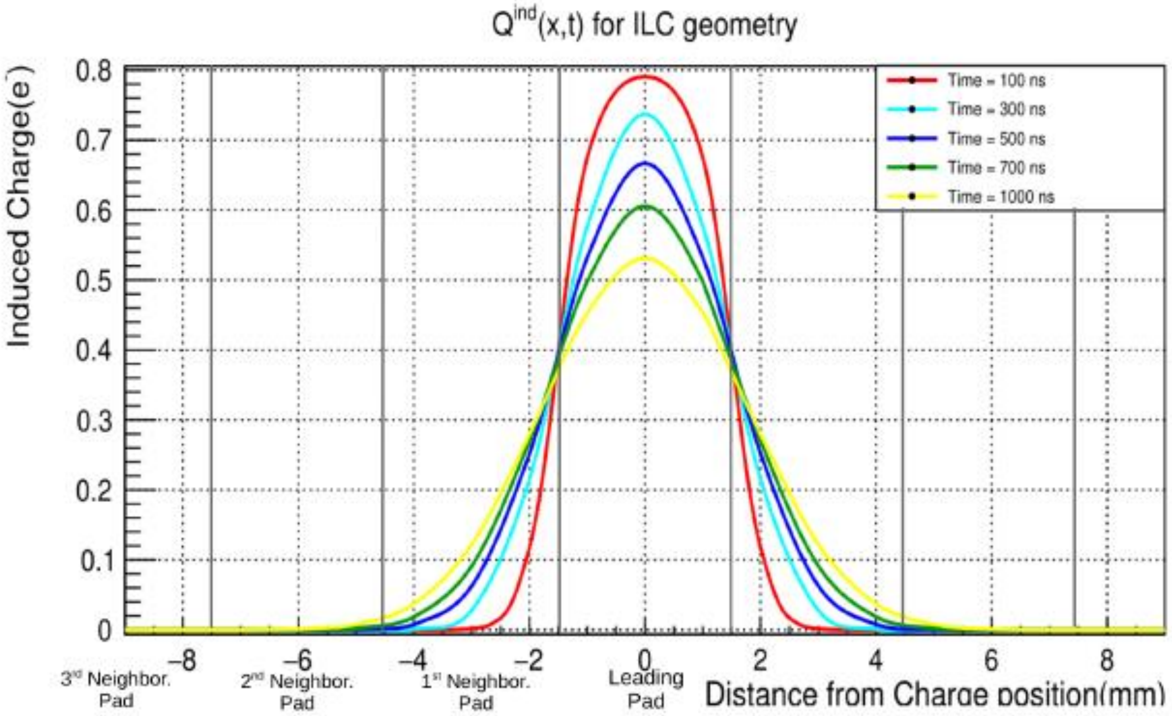
M. Riallot

We used the tracks from the beam test to check the module alignment and assess the accuracy of the spaceframe.

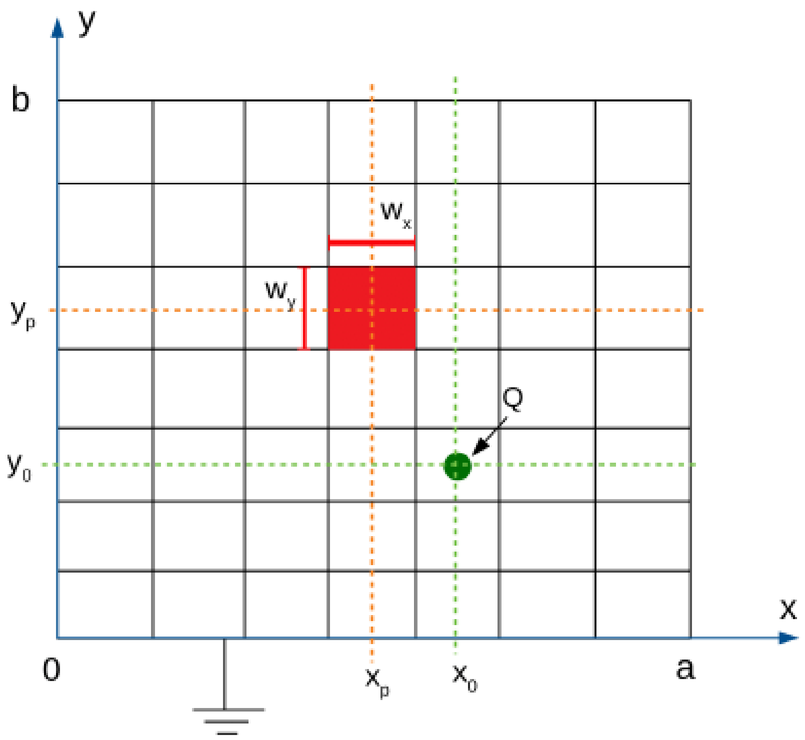


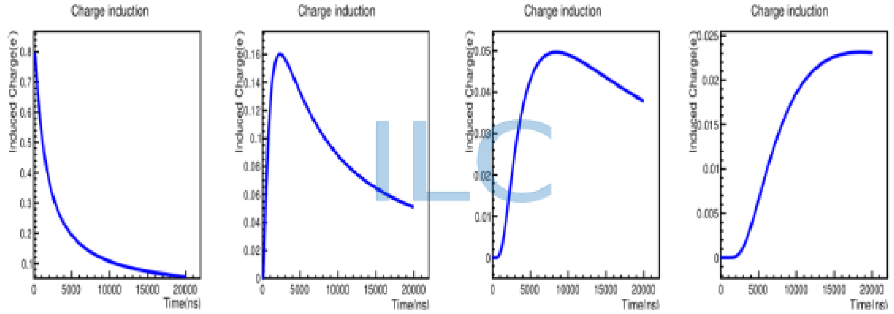
Calculations of charge spreading

Werner Riegler calculated the induced charge vs time and position when you deposit a given charge at a given point (for the time being the charge is assumed to be deposited fully at t=0)



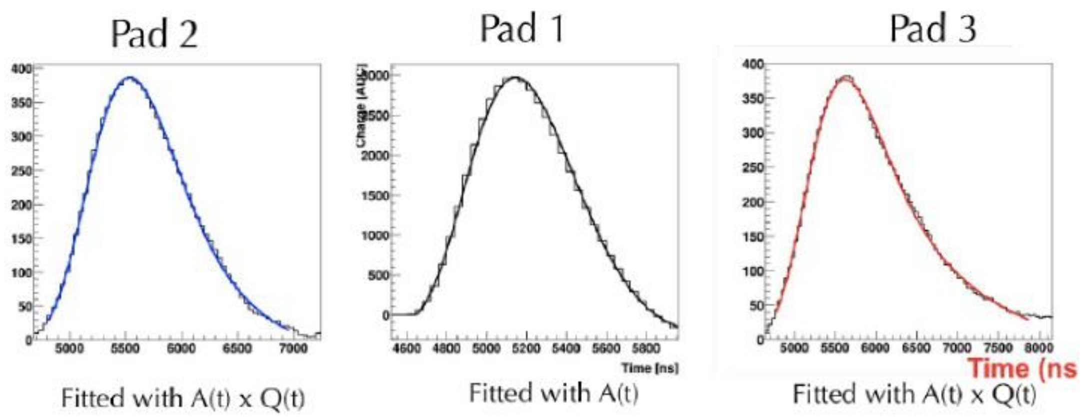
(a) $Q^{ind}(x,t)$ plots for a 7-pad segment of ILC module

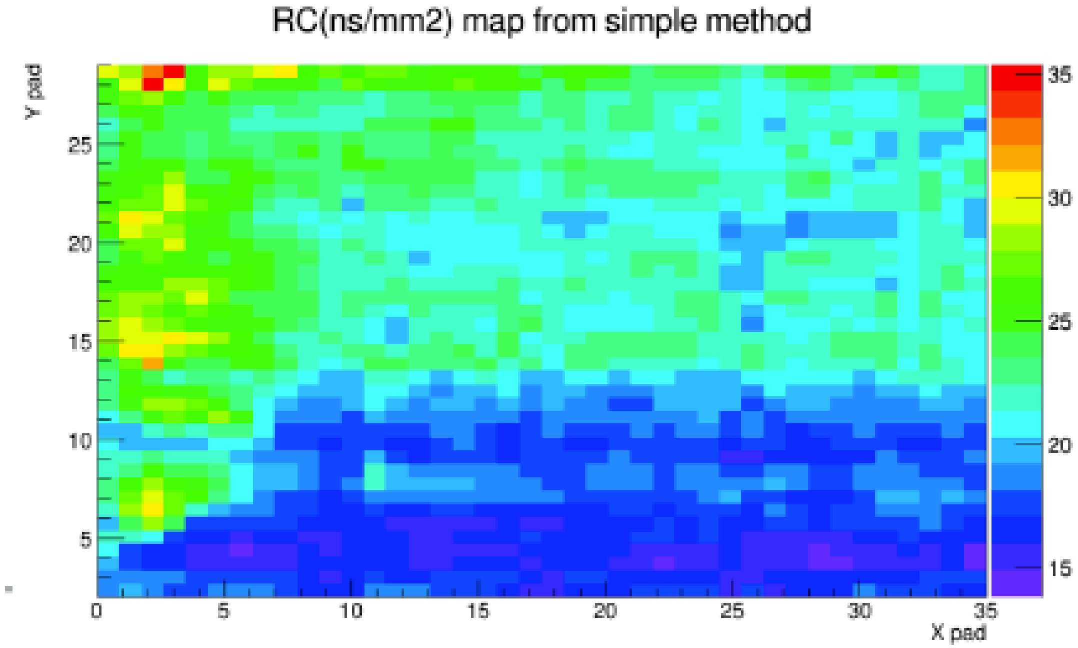




Studies of charge spreading in T2K

Using the signal shape measured in the leading pad and in neighbouring pads, the RC value is assessed and an RC map is obtained.





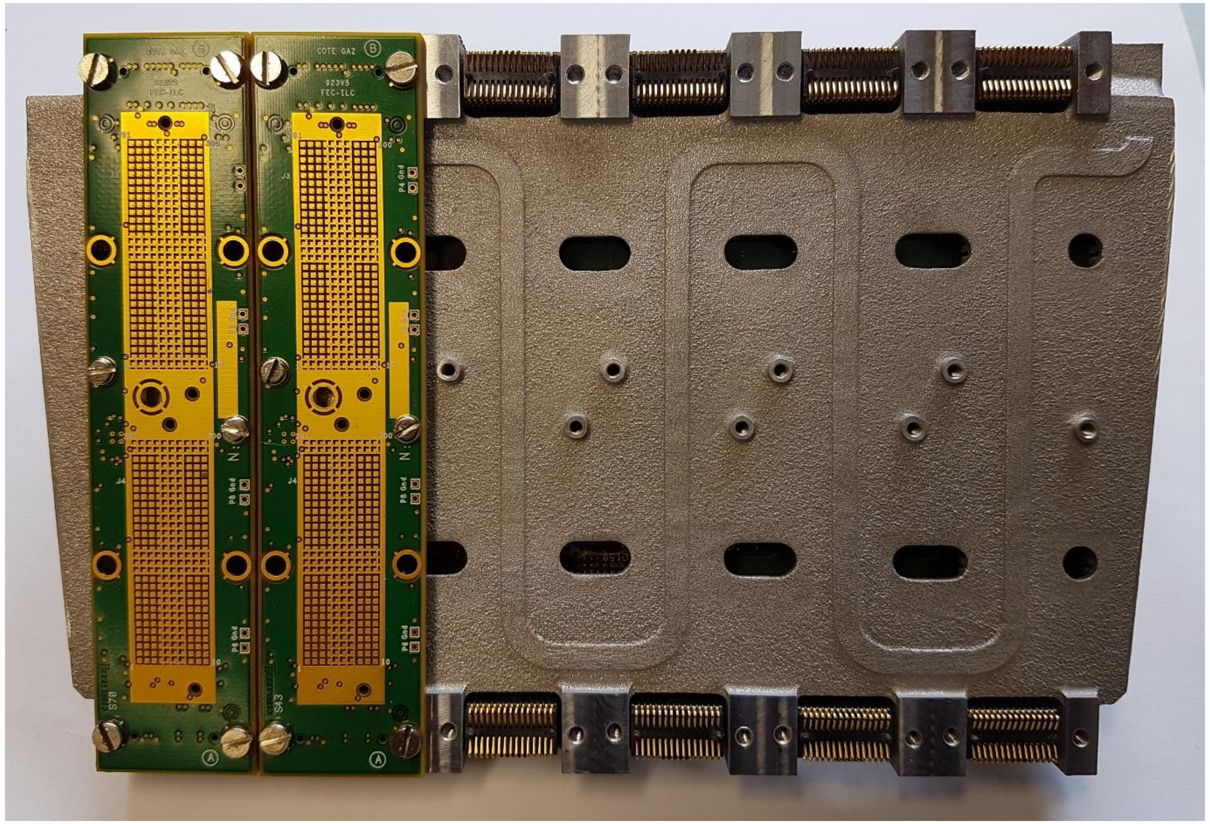
S. Hassani, S. Emery

The relation $$\sigma(t) = \sqrt{\frac{2t}{RC}}$$

Is used to relate RC with the width of the charge distribution at a given time t

3D printed cooling plate

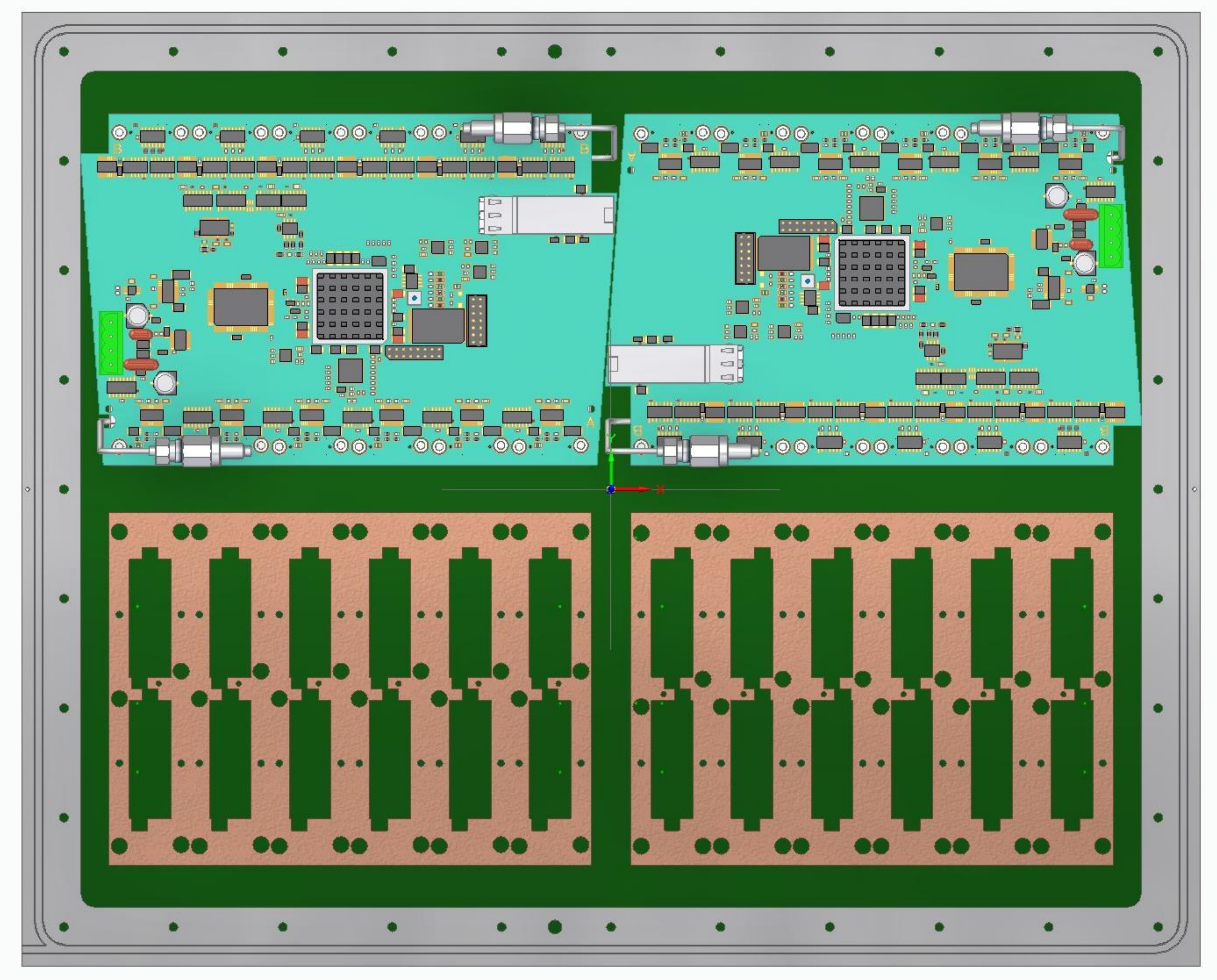
The 2-phase CO2 cooling has been demonstrated on the 7 modules Micromegas setup in 2015.
We now have a 3D-printed board in Aluminum, ordered just before the confinement and delivered the first week after.
Mechanical tests have been performed.
A test under pressure is being prepared.
We plan to make a cooling test at DESY with TRACI, with the electronics but with no beam in Q2 2021 if possible.



D. Attié, P. C., S. Ganjour, M. Riallot, O. Tellier

A supermodule for SAND using the LCTPC integrated AFTER electronics (up to 6912 pads)
42cm x 34 cm

This is about the size required for ILD.



M. Riallot

Status of the Micromegas paper

Analysis in principle completed (but checks are needed). All plots are almost final. The text requires polishing before being sent to all participants in the beam test*, and then to all LCTPC.

26 pages
14 figures
37 references

*D. Attié, M. Riallot, X. Coppolani, S. Emery, Huirong Qi, J. Timmermans, in addition to the 5 editors

A Time Projection Chamber with Micromegas-based Readout

Editors: Paul Colas, Keisuke Fujii, Serguei Ganjour, Tomohisa Ogawa, Maxim Titov

January 8, 2021

Abstract

A Micromegas-readout Time Projection Chamber (TPC) was proposed for the central tracking at the International Large Detector (ILD) - a detector concept for the International Linear Collider (ILC). Module prototypes were built and subjected to beam tests, in an attempt to validate the design of Micromegas readout with a resistive anode. This work was carried out in the DESY Test Beam facility, consisting of a 5 GeV electron beam and a field cage with its ancillaries, built for the Linear Collider TPC (LCTPC) collaboration. The results of these beam tests are given in this paper, and extrapolated to the conditions of operation at the future Linear Collider.

Contents

Main results

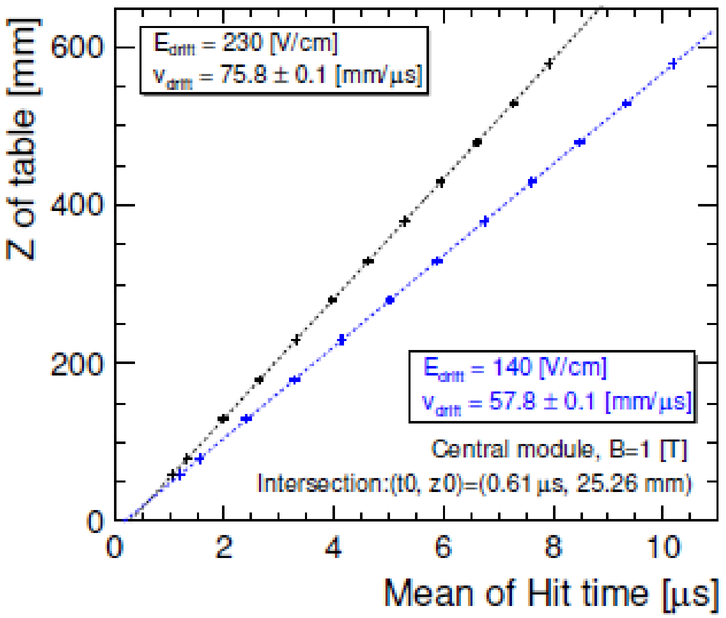
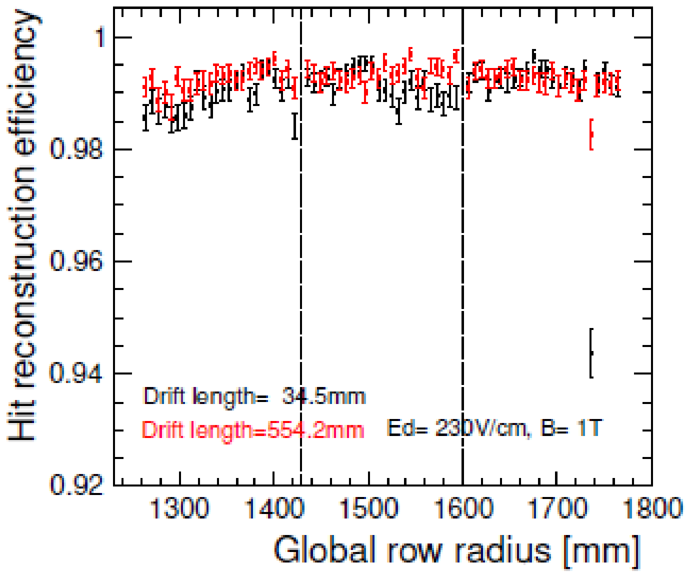
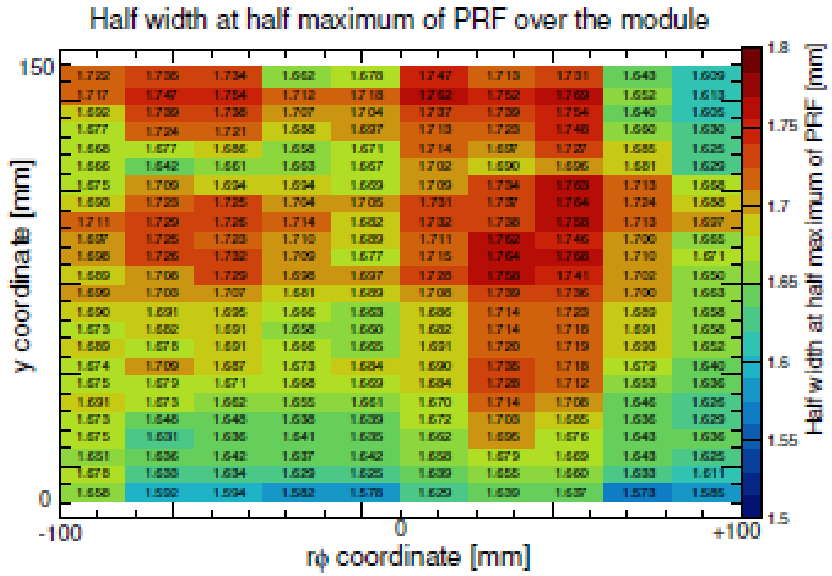


Table 3: The table shows the estimated reference parameters and drift velocity measured with the central module in different run periods, in which the gas condition is complemented below. E_d is the setting value for the drift field. v_{sim}, D_t and D_l are simulated values using Magboltz version 9.0.1 [27].

B[1) [T]	z_0 [mm]	t_0 [μs]	E_d [V/cm]	v_{drift}^{meas} [mm/μs]	$v_{drift}^{simu2)}$ [mm/μs]	D_t, D_l[3) [μm/$\sqrt{cm}$]
1	25.3±3.0	0.61±0.05	140	57.78±0.10	57.7	74.9, 308.3
			230	75.75±0.13	75.5	93.6, 230.0
0	27.4±3.0	0.65±0.05	140	57.98±0.10	57.2	308.7, 308.9
			230	75.85±0.13	75.2	308.3, 230.0

[1) Conditions during the data taking : temperature: 16 °C, system pressure: 1015 hPa, H_2O: 100 ppm, O_2: 60 ppm.
[2) Statistical errors are negligible.
[3) Simulated values with Magboltz, where statistical errors are at the 1% level.





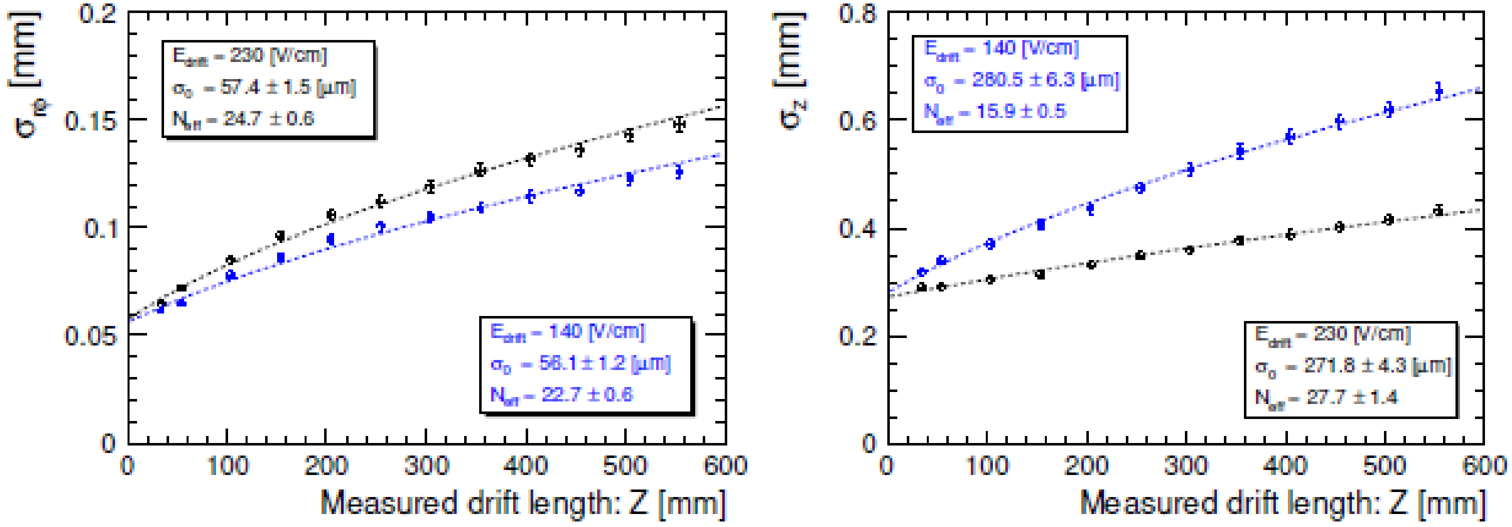
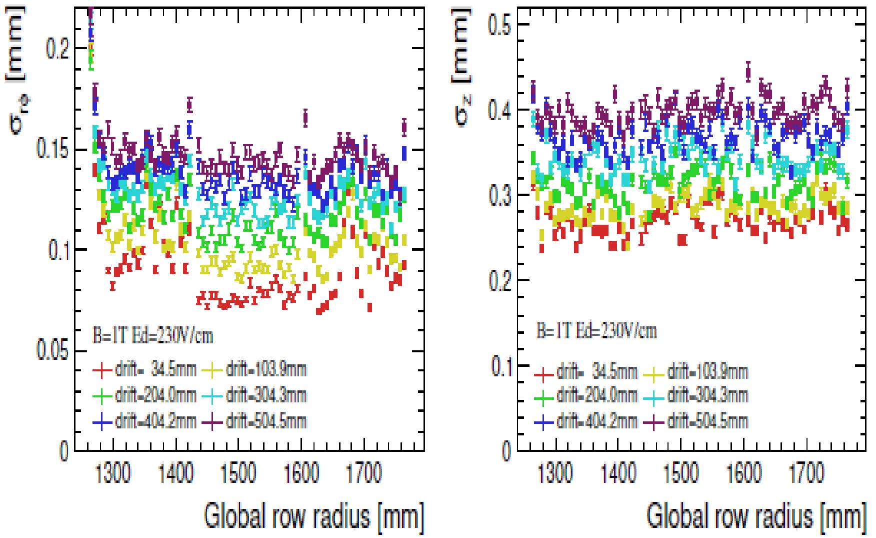
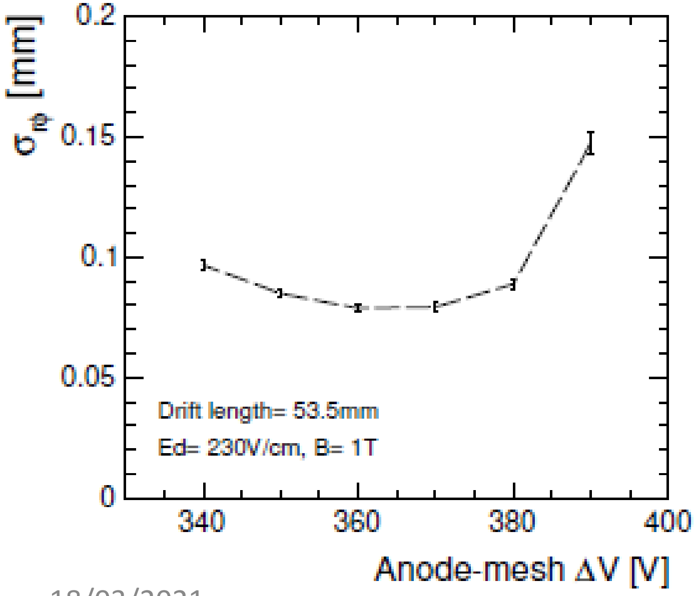
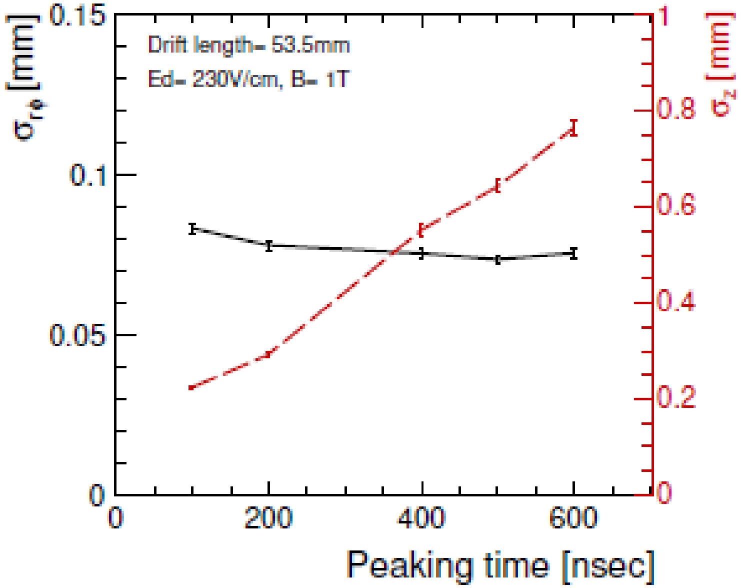


Figure 8: The distributions of the $r\phi$ and z resolution as a function of the measured drift length. A black and blue colors respectively show two different drift fields of 140 and 230 V/cm. The points are an average over 24 pad-rows of the central module.

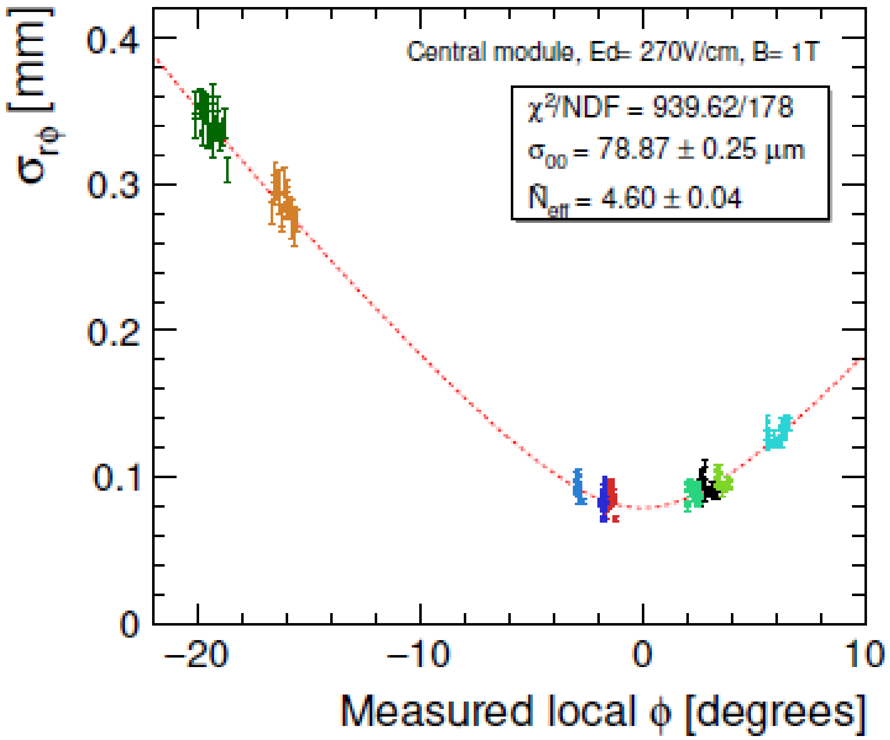




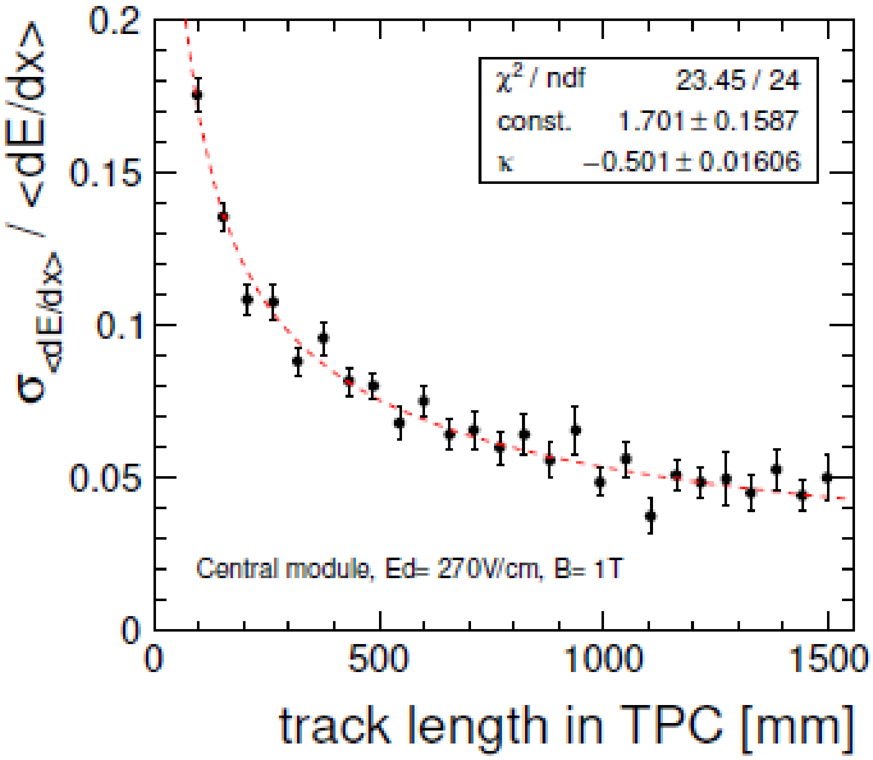


Space resolution

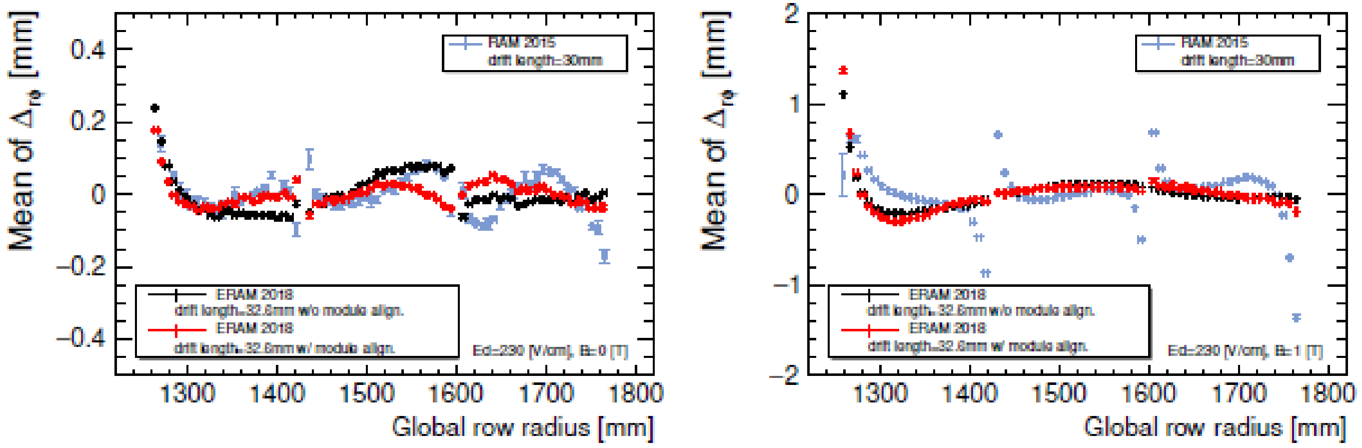
Angular dependence of the resolution and fit of the effective number of clusters (4.60 +- 0.04)



dE/dx resolution

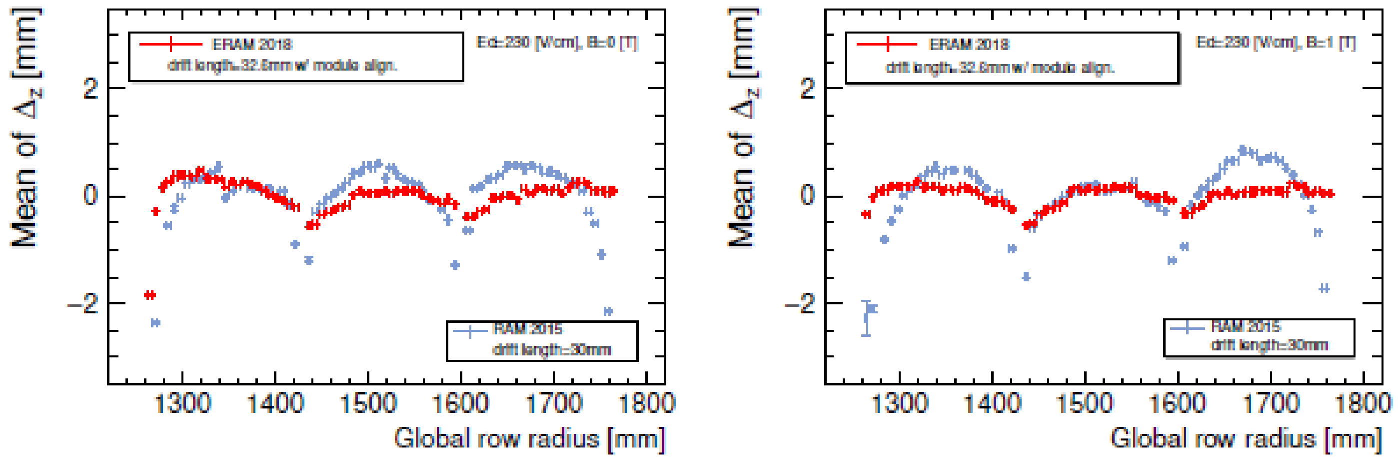


Analysis by Tomohisa Ogawa.
Very good agreement with Jurina Nakashima (previous talk)



r-phi distortions

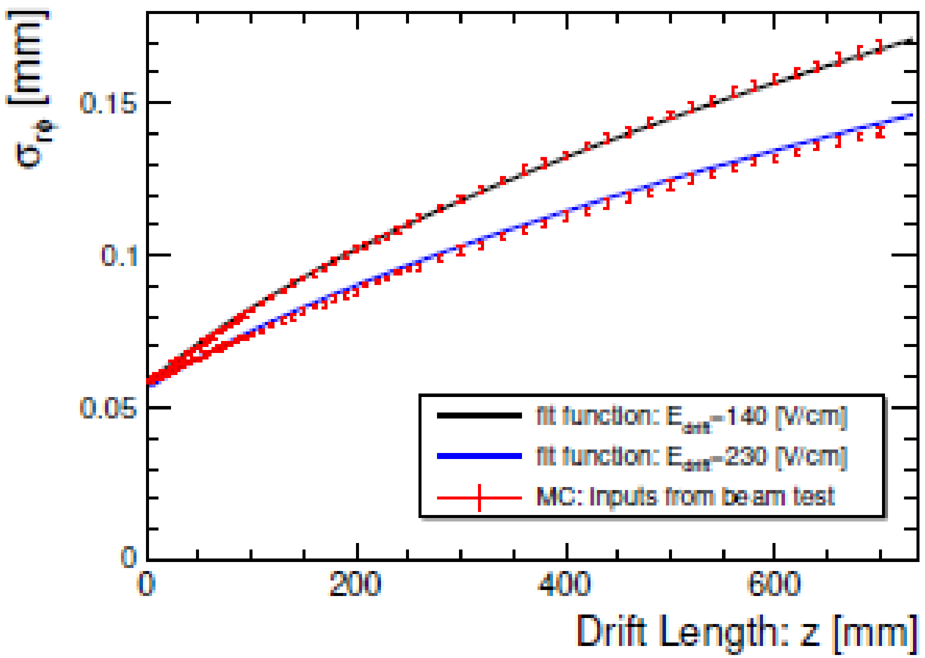
Figure 10: The plots show the mean residual in rϕ over three modules, as a function of the row radius. Left : B=0 and right : B=1 T.

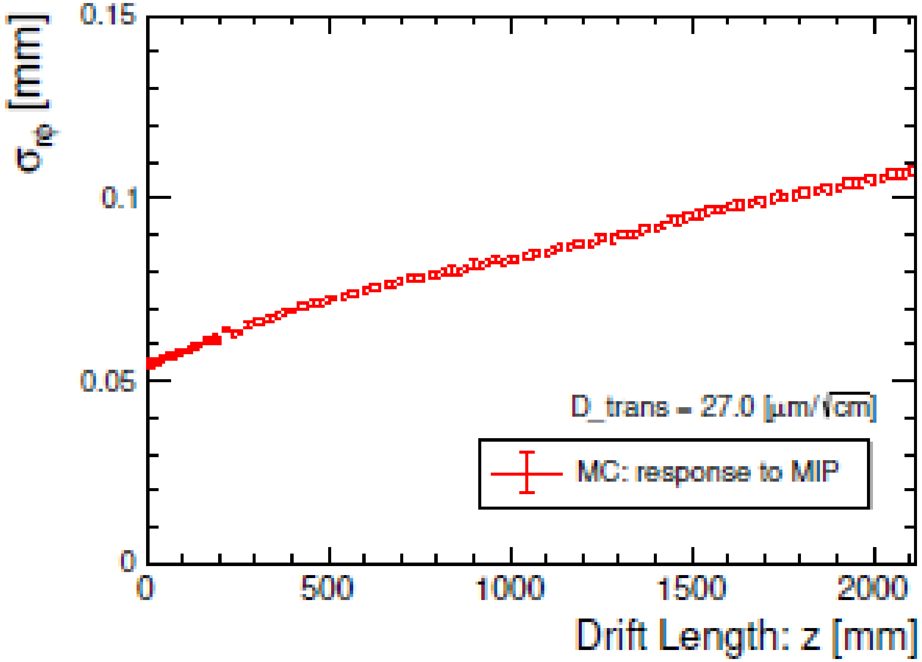


Z distortions

Figure 11: The plots show the mean residual in z over the three modules. Left B=0 and right : B=1 T. In blue are the data from 2015 and in red for 2018, with the new grounding scheme.

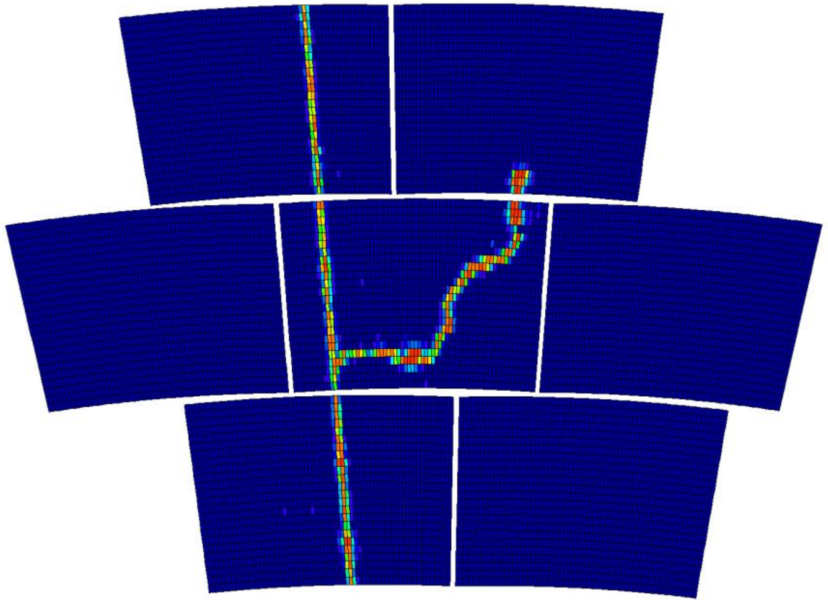
Extrapolation to ILC conditions (MIPs, 3.5T, drift up to 2.1 m)

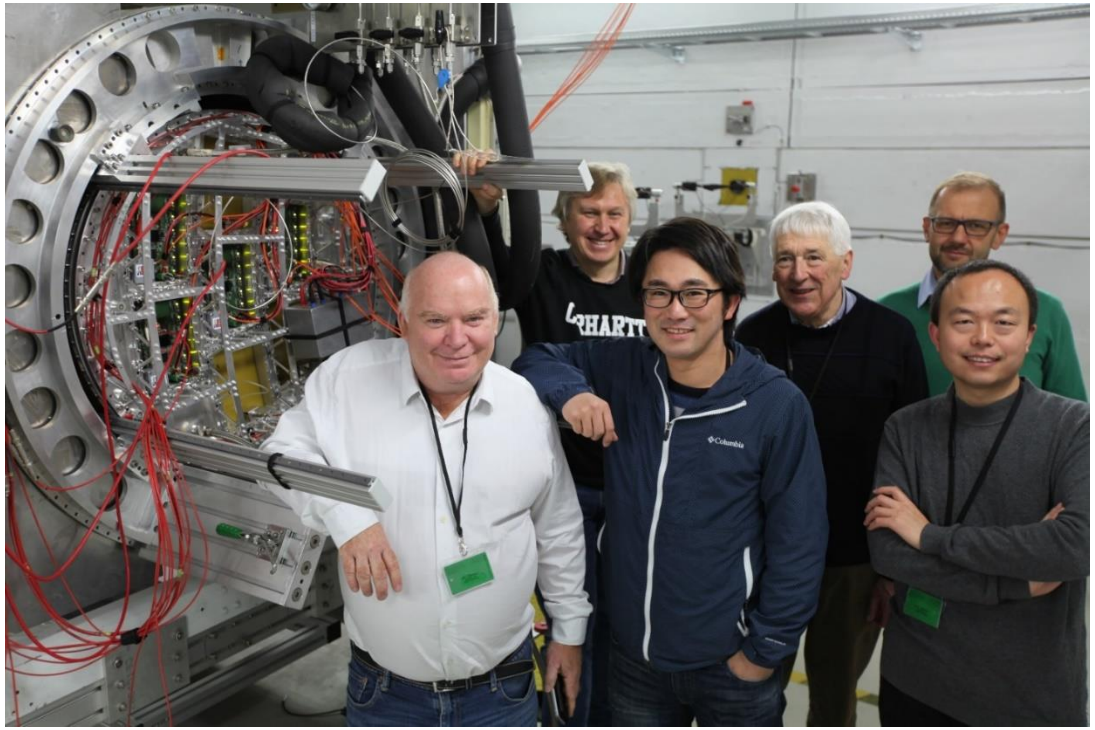




CONCLUSIONS

Despite very difficult conditions, several achievements were done in 2020.
Rarity of funding for ILC is compensated by activating synergy with T2K and SAND.
Look forward to a boost in the IDT era.





Thanks to my LCTPC colleagues, especially
D. Attié, S. Ganjour, T. Ogawa, M. Riallot, X. Coppolani,
S. Emery, Huirong Qi, J. Timmermans, M. Titov,
R. Diener and O. Schäfer
And to my T2K and SAND colleagues