The Status of MPGD-TPC R&D
By
the LCTPC Collaboration

The Monthly Meeting
of
The ILC Physics and Detector group of Japan
on
May 22, 2014 at KEK

T. Matsuda
KEK/IPNS

As I reported some months ago, we had the LCTPC Review by the ECFA Detector R&D Panel on 4 November 2013.

For this review, we wrote a report on our R&D activities for ILC (ILD) TPC, summarizing (a) the achievements, (b) the remaining issues, and (c) a preliminary plan and schedule of the engineering design of the ILC (ILD) TPC. The engineering study (c) was/is supposed to start by an official GO sign of the ILC in Japan which was (I think) expected in 2013 but has been obviously delayed by at least two years.

At KEK, we submitted our 5 years (from 2013) budget request, somehow responding to a request by our KEK DG. However this budget has also not been realized. The KEK budget for ILC physics and detectors studies in 2014 is in fact very limited.

In this conditions, we may focus only on (b); the remaining issues which have been left behind from our R&D studies of MPGD-TPC.

R&D for MPGD TPC

Achievements

We have demonstrated through the LP TPC beam tests at DESY:

(1) The basic performance of the MPGD TPCs, in particular, the pad readout options, satisfy the basic requirements for ILD TPC at ILC:

- **MWPC option ruled out,**
- **Micromegas option w/o resistive anode ruled out,**
- **The best possible spatial resolution understood by the analytic formula,**
- **Spatial resolutions by GEM-TPC and Micromegas TPC w/ resistive anode measured at 1T and extrapolated to 3.5T,**
- **Single-electron spatial resolution of the digital TPC measured, and,**
- **Extrapolation confirmed (< 60cm drift) at 4T in the DESY 5T magnet.**

(2) How to build important components of ILD TPC:

- **Thin field cage**
- **Light endplate (Al)**
- **MPGD TPC modules**
- **Experience of the operation of LP TPC**

R&D for MPGD TPC
After ILD DBD for ILC

There are, however, a few important basic issues still remain to be addressed before the detector proposal for ILC

Otherwise, we are entering the phase toward the final design of the ILD TPC.

The earliest schedule (next slide) of the construction of ILD detector shown in the ILD meeting at Cracow (Sept 2013) looks very tight though it may deeply depend on the political situation.

Remaining R&D Issues

Before entering the engineering design of ILD TPC, we still need to study the following issues:

A) Ion gate: the most urgent issue,

B) Some issues with MPGD technologies and MPGD modules,

C) Local distortions of MPGD modules,

D) Demonstration of power pulsing (with the S-ALTRO16 electronics)

E) Cooling of readout electronics and temperature control of TPC

F) Measurement of basic parameters and demonstration of the performance of MPGD TPC in 3.5T magnetic field. Also some engineering issues to be confirmed in the high magnetic field.

G) A common analysis method and software: for a better understanding of the beam test results by different MPGD technologies (the technology prioritization in a few years time).

Remaining Issues

Ion Gate: The most urgent issue

***We need a ion gate*:** To prevent the backflow of positive ions from the gas amplification region of the MPGD modules to the drift space of TPC. Distortions by the primary ions at ILC are still negligible.

***Options of ion gate*:**

GEM gate: A simulation has shown that the ion stopping power is sufficiently high → < 10**-4 at around 10V reversed biases →
We are still be better to measured it!
Electron transmission: Can be high with large optical opening → >80%?
Mechanically most friendly to the current MPGD modules.

Traditional wire gate: Known to work with high electron transmission (LEP etc.),
Distortion due to the radial wires?
Mechanical issues exist to mount on the MPGD module.

Wire mesh or grid: A solution never have been tested.
High ion suppression with reasonable reverse volatge?
Mechanical issues exist to mount it on the MPGD module.

Medium size Gate GEM of about 80% optical transmission have been fabricated in Japan by two different fabrication processes. A measurement of the electron transmission has been measured for one type of the product. Nest measurement is scheduled in July.

→ Report by Ikematsu sama.

Remaining Issues

MPGD technologies and MPGD modules

Micromegas module w/ resistive anode: Possible signal pileup in the resistive anode at the ILC environment ? → No real action yet!

We need a confirmation by simulation that the performance of the Micrormegas with the resistive anode would not be deteriorated by the signal pile up in the resistive anode in the ILC environment. The real charges of Micromegas spread in the resistive anode toward the sides of the resistive anode with some time delays. When many hits, the pads see induced charge of the sum of the current. The pile up depends how the induced signals of different origins might overlap each other in "one event frame" of TPC (typically in the order of 1 μs).

GEM modules: Are the current modules reliable enough for the ILD TPC?

HV connections to GEMs (Need more HV connections to suppress distortions.
→Trying a new miniature connection scheme. No move by DESY.
GEM stretching and GEM flames → Treatment of the module boundaries. No answer yet. → A mock up of "next " Asian module.
Micro discharge of the Asian GEM → Still under test. (DESY module using the CERN standard GEM have seen no micro discharge.)

InGrid module: An early transition to Timepix 3 necessary.

For all modules: A design with the gate!

Remaining Issues

Local Distortion

All current LP modules see large distortions; The old TPC problem in the new regime.

We need to minimize the distortions in the hardware level, and, then correct remaining distortions by software.

(1) Distortions due to specific module structures

Micromegas module: Grounded guard structure around the module. To be modified only in next module. No move yet!!

Asia GEM module: Large gaps of the segmented electrodes on the top surface of GEM (Removed. Still see some distortions partially due to the larger gaps on the bottom surface of the GEMs?)

(2) Distortions at the module boundary and the 1mm gap:

E-field calculation and simulation (done so far by the DESY group!) can suggest solutions to reduce the distortion. Then confirm the solutions by either beam tests or laser- beam tests (at KEK).

(3) Develop software to correct remaining distortion after (1) and (2)

Some deterioration of the spatial resolution will remain after the correction.

A global distortion of a few mm level at LP TPC is confirmed by monitoring the patterns on the cathode plane shined by a laser due to the non uniform magnetic field of PCMAG. Also the current LP filed cage has some imperfection and a alignment problem to the magnetic filed. DESY is now working.

Remaining Issues

Cooling and Temperature Control of TPC endplate

Two phase CO2 (2PCO2) cooling for ILD TPC endplates:

Installing readout electronics directly on the MPGD module while we keep the pad plane of the module at a given TPC temperature. The temperature control of the pad plane of the module and a proper cooling of electronics become important. 2PCO2 cooling has advantages of constant temperature and high pressure and compact cooling circuit.

(1) Set up two small 2PCO2 cooling units for test at KEK and DESY (currently at NIKHEF) in the beginning of 2014 → Done!

(2) The first cooling test of the T2K electronics on the Micromegas modules soon. → The set up was very primitive but successful!

(3) Mock up cooling tests for the S-ALTRO16 electronics in "early" 2014?

(4) It is very good that people are starting to think about the advanced endplate seeing the complicated implementation of S-ALTRO16 electronics, and the usefulness of the 2PCO2 cooling. However no immediate solution for the implemented-cooling pad-plane. The ceramic CB is expensive and limited to a size of 10cm x 10cm.

Thermal design of the whole ILD TPC :

ILD TPC design has no thermal jackets on the field cages to minimize the material budget. Addressed in the final design of ILD TPC? No action yet!

Remaining Issues

<u>Power pulsing and power delivery</u>

Need power pulsing even for low readout electronics at ILD TPC:

(1) Power pulsing of SALTRO16 chip has been demonstrated in the chip test.
The reduction factor expected for the ILC bunch structure was around 30.
(2) Power pulsing in LP TPC beam test by SALTRO16 electronics is foreseen.

The power delivery issue has not been addressed so far:

Should be studied together in the design of the final readout electronics for the ILD TPC.

Remaining Issues

Demonstrations in the 3.5T magnetic field

Tests in the 3.5T magnetic field:

(1) Confirmation of performance of MPGD TPC and ion gates,
(2) Measurements of basic parameters of TPC gas, and ,
(3) Engineering issues such as possible mechanical vibration due to the power pulsing .

The problem: A high field solenoid need to be found!

The DESY 5T magnet (KOMAG) has been dismantled from the new He line at DESY for some time. We need either to revive the 5T magnet (by moving it to one of our institutes or by a modification), or to find another high field magnet available for us. With our limited human resource, very preferable to set it up in one of our institutes. A solenoid is preferred.

→ An early news of the 4T MRI magnet at ANL (for the g-2 experiment). Can be used at FNAL test beam in future? Can we really use a small 5T magnet at Fujikura? May be we are rather lazy not to look for more possibilities?
→ Not in this year since we do not have sufficient budget!!!

Remaining Issues

<u>Optimization of ILD TPC</u>

Optimization of the ILD detector in coming few years:

Some specific issues for TPC such as dE/dX performance which we have not addressed very well both in measurement and simulation.

→ Optimization general is still in an early stage (I think).

→ Need man power to address the issues!

Final specification of ILD TPC before prioritization of different MPGD technologies in TDR:

The final design of the ILD TPC will be given in TDR in 4 - 5 years. We review our specification of the ILD TPC, based on the results and experience from the LP beam tests. It includes pad size, module size, TPC gas, in particular, in the context of the neutron background, Specifications of TPC readout electronics, calibration and operation of ILD TPC, etc. We need to fully utilize our simulation tool for the optimization.

→ A significant software efforts to come to a common analysis method/software is under way (DESY and KEK people)

→ Now in 5 years or so rather than in 2-3 years?

Toward the Final Design of ILD TPC

Readout Electronics

Our history of TPC readout electronics:

ALEPH electronics (for some small prototype tests)
T2K electronics (for LP TPC)
PCA16 + ALTRO electronics (for LP TPC)
SALTRO16 electronics (for LP TPC)
GdSP? (for ILD TPC)

SALTRO16 chip: ***The first analog-digital integrated chip for low noise application satisfies our specification except the packing density and power consumption (ADC).***

Besides, its hard-wired digital processing not optimized for the MPGD TPC, and the SALTRO development team has been resolved.

The R&D implementation (because of the budget!) of the S-ALTRO 16 is underway by the Lund group. We need to cooperate with them for its test with modules.

***GdSP*:** **New development for a high-density (> 64 ch/chip), lower power chip as the successor of the SALTRO. Situation not very clear now. Need to establish our own group of experts and significant budget urgently.**

Schedule: **With the rapid development of technology and our limited resource, may be realistic to start development after establishment of ILC Lab (in 2017, or, 9 years before the**

Toward the Final Design of ILD TPC

Field cage, endplates and all

R&Ds in LP TPC so far:

Construction of the light and thin field cages for the LP TPC
Construction of the two types of Al endplates for the LP TPC
Some simulation study for the field cage and the Al endplate for ILD TPC
Some study of the TPC support.
Thin central cathode (in prep.)
Tool for the installation of LP module (in prep.)
Laser beam calibration (in prep.)

Many details of the ILD TPC still to be studied for TDR:

Details of mechanical design of ILD TPC and its support,
Design of a support structure for the outer silicon detector on the outer field cage
Structures inside the field cage:
Details of the central cathode electrode and its HV supply, Resistor chains with a cooling and shielding etc.
Thermal design of ILD TPC
Monitoring system
Measures for earthquakes in Japan

We need to activate and enlarge our mechanical group asap.

Toward the Final Design of ILD TPC

Software

So far:

Software packages for the LP beam test with its core package Marlin TPC for reconstruction of TPC tracks and analysis with tools necessary for the data analysis at LP TPC.

Study of the local distortions has been made using CST^{TM} and Garfield++.

In coming few years: need to perform more simulation

Implementation of the resistive anode,
Tracking code for the digital TPC,
More studies of local distortion and its correction,
Simulation studies for the optimization,
Update of background including the neutrons,
Design and methods of TPC calibrations,
Demonstration of actual track reconstruction of events in one full bunch train
,,,,,,

What is missing here is not ideas, but human resource for simulation!

Toward the Final Design of ILD TPC

The earliest timeline?

2014-15 R&D on ion gates and a decision on the ion gate:
2015-17 Beam tests of new LP modules with the gate
2017-18 Prioritization of the MPGD technology and module.

2017(*)	**ILC LAB & ILD detector proposal**
2017-19	**Final design of the readout electronics for ILD TPC and its verifications**
	Design of ILD TPC
2018-19(*)	**TDR for the ILD tracking system:**
2019-23	**Prototyping and production: Electronics (chips→boards)**
	Prototyping and production: Modules
	Production: Field cage/endplate and all others
	All others
2024-25	**TPC integration and test**
2026(*)	**TPC Installation into the ILD detector**
2027	**ILC commissioning**

(*) In this slide we delayed by one year the ILD-ILC schedule shown at the ILD meeting at Cracow (Sept 2013) to be a bit more realistic.

YEAR	MONTH	LEADING INSTITUTE	DESCRIPTION	AMPLIFICATION	ELECTRONICS	REMARKS
2008	11-12	Saclay	One Micromegas module with resistive anode	Micromegas	AFTER (T2K)	First test
2009	02-03	KEK	3 Asian GEM modules without gating GEM and 3000 ALTRO channels	GEM (SciEnergy)	ALTRO	
	04	U Rostock	TDC electronics with one Asian GEM module	GEM (SciEnergy)	TDC	
	04-05		Maintenance of PCMAG			
	05-06	Saclay	Micromegas modules with two different resistive coatings and new T2K electronics Setup and test of laser photo-dot cathode calibratrion	Micromegas	AFTER (T2K)	
	06	U Bonn	TimePix Octoboard with GEM amplification	GEM (CERN)	TimePix	
	06		Installation of PCMAG on movable stage Installation of ext. Si-Tracker support structure			
	07	U Rostock	TDC electonics with one Aisian GEM module Studies of ALTRO readout with one Asian GEM module	GEM (SciEnergy)	TDC / ALTRO	
	07-08		Finalizing installation of PCMAG on movable stage			
	08	Victoria, Saclay	Laser photo-dot cathode calibration using Micromegas module	Micromegas	AFTER (T2K)	
	09	U Bonn	Small area GEM module, read out with ALTRO electronics	GEM (CERN)	ALTRO	
	11	Saclay	Test of external Si-Tracker with Micromegas module	Micromegas	AFTER (T2K)	
2010	03	Saclay	Micromegas module using the movable stage of the PCMAG	Micromegas	AFTER (T2K)	
	03	KEK	Three Asian GEM modules with ALTRO readout	GEM (SciEnergy)	ALTRO	
	09	KEK	Three Asian GEM modules with ALTRO readout	GEM (SciEnergy)	ALTRO	
	12	Saclay/Nikhef	Ingrid Octopuce test in large prototype	Micromegas	Timepix	
2011	04	DESY	First test of DESY GridGEM module (B=0T)	GEM (CERN)	ALTRO	
	05	Saclay	Test of integrated electronics on a Micromegas module Installation of new cosmic trigger logic	Micromegas	AFTER (integrated)	
	06-07	DESY	DESY GridGEM module	GEM (CERN)	ALTRO	
	07		PCMAG dismounted and shipped to Japan for cooling modification			
2012	03		Return of modified PCMAG to DESY			
	03-06		Installation and tests of new PCMAG cooling using closed circuit cryo coolers			
	07	Saclay	Test of 6 Micromegas modules with integrated electronics	Micromegas	AFTER (integrated)	
	09	DESY	New iteration of DESY GridGEM module; test with 3 modules	GEM (CERN)	ALTRO	
	11-12	KEK	Test of 3 Asian GEM modules	GEM (SciEnergy)	ALTRO	
2013	01-02	Saclay	Test with 7 Micromegas modules with integrated electronics	Micromegas	AFTER (integrated)	
	02-03	DESY	DESY GridGEM; test with 3 modules	GEM (CERN)	ALTRO	
	03-04	U Bonn	Test of two TimePix Octoboards: one with GEM and one with Ingrid amplification; new scalable readout	GEM/Micromegas	TimePix	
	05-06	Lund, Saclay, U Bonn, DESY	Micromegas modules with ALTRO electronics	Micromegas	ALTRO	
	11	DESY	Laser photo-dot cathode calibration using 3 GridGEM modules	GEM (CERN)	ALTRO	
2014	02	Saclay DESY Nikhef	7 Micromegas modules with TRACI 2PCO2 cooling Laser photo-dot calibration with 7 modules 5 Micromegas modules combined with 2 Octopuce modules	Micromegas	AFTER (integrated) TimePix	

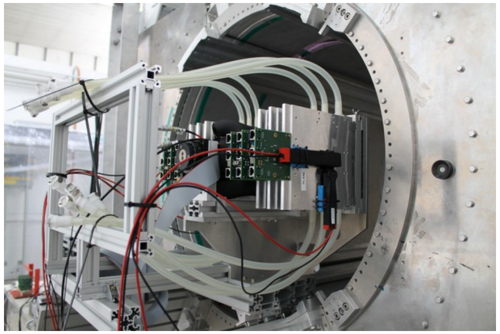
DESY Testbeam Schedule 2013 - Version 25 of December 19th 2013

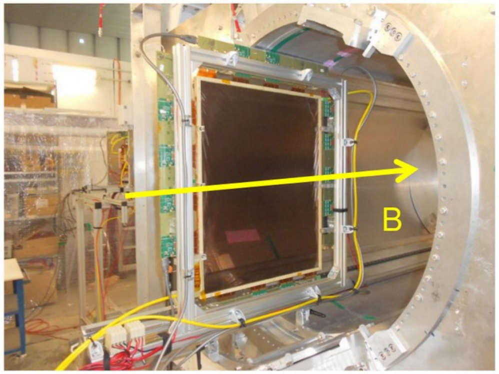
Ralf Diener, Norbert Meyners, Marcel Stanitzki - DESY Test Beam Coordinators

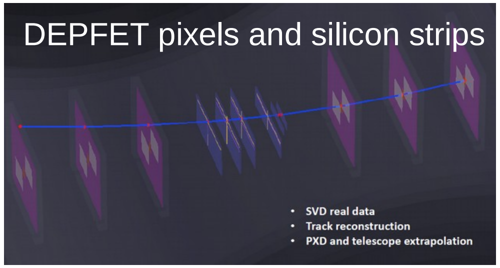
	Week		TB21		TB22		TB24/1		TB24	
			DATURA	none	ACONITE/ANEMONE	CAL	EUDET in PCMAG	PCMAG	none	
	2		---	---	---	---	---	---	---	
14-Jan-13	3		---	ITER	Tele setup					
21-Jan-13	4		X0		---	CALICE AHCAL	---	---	---	
28-Jan-13	5		CMS Pix-irrad	---	---	CALICE AHCAL	---	TPC MMG	ECAL	
4-Feb-13	6		CMS Pix-fwd	---	---	---	---	TPC MMG	---	
11-Feb-13	7		CLICpix	---	---	---	LorAngle	---	---	
18-Feb-13	8		---	SiW ECAL	---	---	LorAngle	---	---	
25-Feb-13	9		---	Sc ECAL	---	---	---	DESY TPC	---	
4-Mar-13	10									
11-Mar-13	11		ALICE ITS	---	MuPix	---	---	DESY TPC	---	
18-Mar-13	12		CMS Pix-irrad	---	APIX PPS	---	---	DESY TPC	---	
25-Mar-13	13		CMS Pix-KA	---	APIX PPS	---	---	LCTPC Time	---	
1-Apr-13	14		CMS Pix-ro	---	APIX IBL	---	---	LCTPC Time	---	
8-Apr-13	15		X0	---	APIX DBM	---	LorAngle	---	---	
15-Apr-13	16		ITER							
22-Apr-13	17		ILCPOL	---	Tele study		SBS GEM	---	---	Announced
29-Apr-13	18		ILCPOL	---	---	RD50	SBS GEM	---	---	
6-May-13	19		DEPFET	---	---	RD50	LorAngle	---	---	
13-May-13	20		FE-I4	---	COMPASS-II	---	---	GridPix	---	
20-May-13	21		CMS Pix-ro	---	---	CALICE AHCAL	---	---	Belle 2 PID	
27-May-13	22		X0			CALICE AHCAL				
3-Jun-13	23		CLICpix	---	---	CALICE AHCAL	---	LCTPC Time	---	
10-Jun-13	24		CMS Pix	---	MuPix	CALICE AHCAL	---	ATLAS MMG	---	
17-Jun-13	25		ALICE ITS	---	APIX 3D	---	---	---	AIDA	
24-Jun-13	26		CMS Trk II	---	DIA-SiGe	---	---	---	AIDA	
1-Jul-13	27		---	SiW ECAL	---	CAL MMG	---		---	
8-Jul-13	28		---	SC ECAL	---	CAL MMG	---	---	XFEL	
15-Jul-13	29		APD	---	APIX 3D	---	---	---	Gossipo	
22-Jul-13	30		CMS Ph2	---	---	CALICE AHCAL	---	---	Gossipo	
29-Jul-13	31		CMS Pix	---	ALICE ITS	---	Surveying			
5-Aug-13	32		Telescope MD	---	APIX IBL	---	LorAngle	---	---	
12-Aug-13	33		CMS high rate	---	APIX PPS	---	LorAngle	---	---	
19-Aug-13	34		CLICpix	---	APIX PPS	---	---	---	PICSEL	
26-Aug-13	35		CLICpix	---	FCAL	---	---	---	PICSEL	
02. Sep 13	36		BRM Maintenance				PCMAG stage work			
09. Sep 13	37									
16. Sep 13	38		CMS Pix	---	XFEL	---			---	
23. Sep 13	39		ALICE ITS	---	ALICE ITS	---			Belle 2 PID	
30. Sep 13	40			---		---			---	
07. Okt 13	41		ALICE ITS	---	MuPix4	---	LorAngle	---	---	
14. Okt 13	42		CMS TrkPh2-J							Announced
21. Okt 13	43		CLICpix	---	---	CALICE AHCAL	LorAngle	---	---	
28. Okt 13	44	no beam 2/11/2013	CMS FPIX	---	---	GSI-DIRC	LorAngle	---	---	
04. Nov 13	45		CMS Pix	---	---	GSI-DIRC	LorAngle	---	---	
11. Nov 13	46		ALICE ITS	---	APIX PPS	---	LorAngle	---	---	
18. Nov 13	47		CMS TrkPh2-E		APIX PPS		DESY-TPC			
25. Nov 13	48		CMS TrkPh2	---	APIX PPS	---	Belle-II Installation			
02. Dez 13	49		CLICpix	---	APIX PPS	---				
09. Dez 13	50		SiPM	---	---	CALICE AHCAL				
16. Dez 13	51	End of beam 20/12/2013 1300	ALICE ITS	---	X0	CALICE AHCAL				
23. Dez 13	52									
					2014					
6-Jan-14			FCAL	---	---	CALICE AHCAL	Belle II VXD			
13-Jan-14	3		FCAL	---	---	CALICE AHCAL	Belle II VXD	---	---	
20-Jan-14	4		SBS GEM	---	APIX 3D		Belle II VXD	---	---	
27-Jan-14	5		SBS GEM	---	DIAPIX		Belle II VXD	---	---	Announced
3-Feb-14	6		LHCb VELO	---	MuPix	---	LorAngle	---	---	
10-Feb-14	7		LHCb VELO	---	ATLAS Strip	---	---	---	PLUME	
17-Feb-14	8		ATLAS Lucid	---	ATLAS Strip	---	---	LCTPC Time	---	
24-Feb-14	9			SiPM	APIX PPS	---	---	LCTPC Time	---	

Testbeam T24/1 Usage

- Also besides LCTPC high demand on beam time at DESY II in 2013/14
- ATLAS upgrade:
  - Measurement of Lorentz angle and charge collection efficiency of 12 silicon microstrip test sensors for the phase2 upgrade
    - First use of EUDET/AIDA 6 layer pixel telescope in PCMAG
    - 18 weeks of beam time in 2013/14
  - Micromegas chambers for Small Wheel upgrade
    - 10 days beam time
- GEM tracker chambers for SBS @ JLAB
  - $40x50\ cm^2$ triple GEM modules, magnetic field up to 500 Gauss
  - 2 weeks beam time
- Belle II Vertex detector
  - Integration test including DAQ, slow control, interlock systems and $2PCO_2$ cooling
  - 6 weeks setup, 4 weeks beam time







TB24/1		TB24
EUDET in PCMAG	PCMAG	none
---	---	---
---	---	---
---	TPC MMG	ECAL
---	TPC MMG	---
LorAngle	---	---
LorAngle	---	---
---	DESY TPC	---
---	DESY TPC	---
---	DESY TPC	---
---	LCTPC Time	---
---	LCTPC Time	---
LorAngle	---	---
SBS GEM	---	---
SBS GEM	---	---
LorAngle	---	---
---	GridPix	---
---	---	Belle 2 PID
---	LCTPC Time	---
---	ATLAS MMG	---
---	---	AIDA
---	---	AIDA
---		---
---	---	XFEL
---	---	Gossipo
---	---	Gossipo
Surveying		
LorAngle	---	---
LorAngle	---	---
---	---	PICSEL
---	---	PICSEL
PCMAG stage work		

		Belle 2 PID

LorAngle	---	---
LorAngle	---	---
LorAngle	---	---
LorAngle	---	---
LorAngle	---	---
DESY-TPC		
Belle-II Installation		
Belle II VXD		
Belle II VXD	---	---
Belle II VXD	---	---
Belle II VXD	---	---
LorAngle	---	---
---	---	PLUME
---	LCTPC Time	---
---	LCTPC Time	---

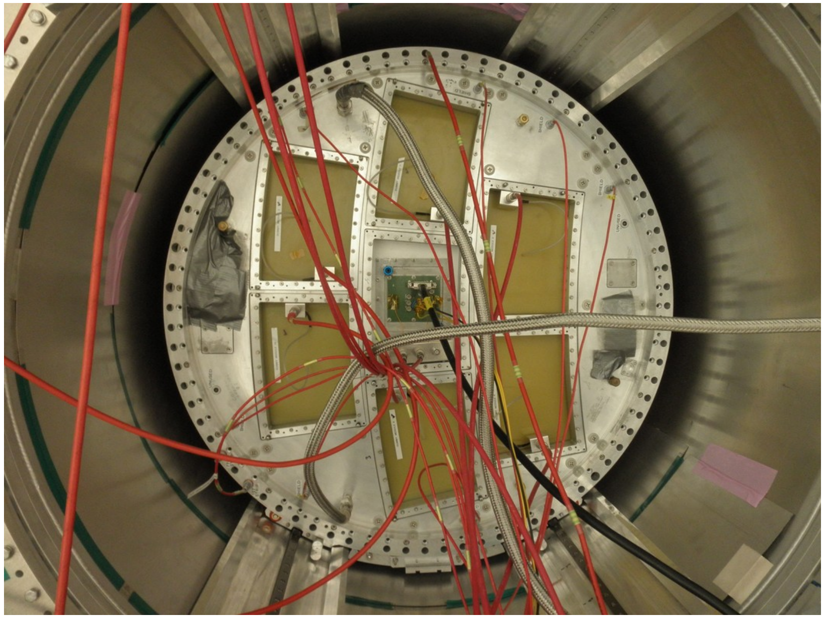
LCTPC Setup at the DESY Testbeam

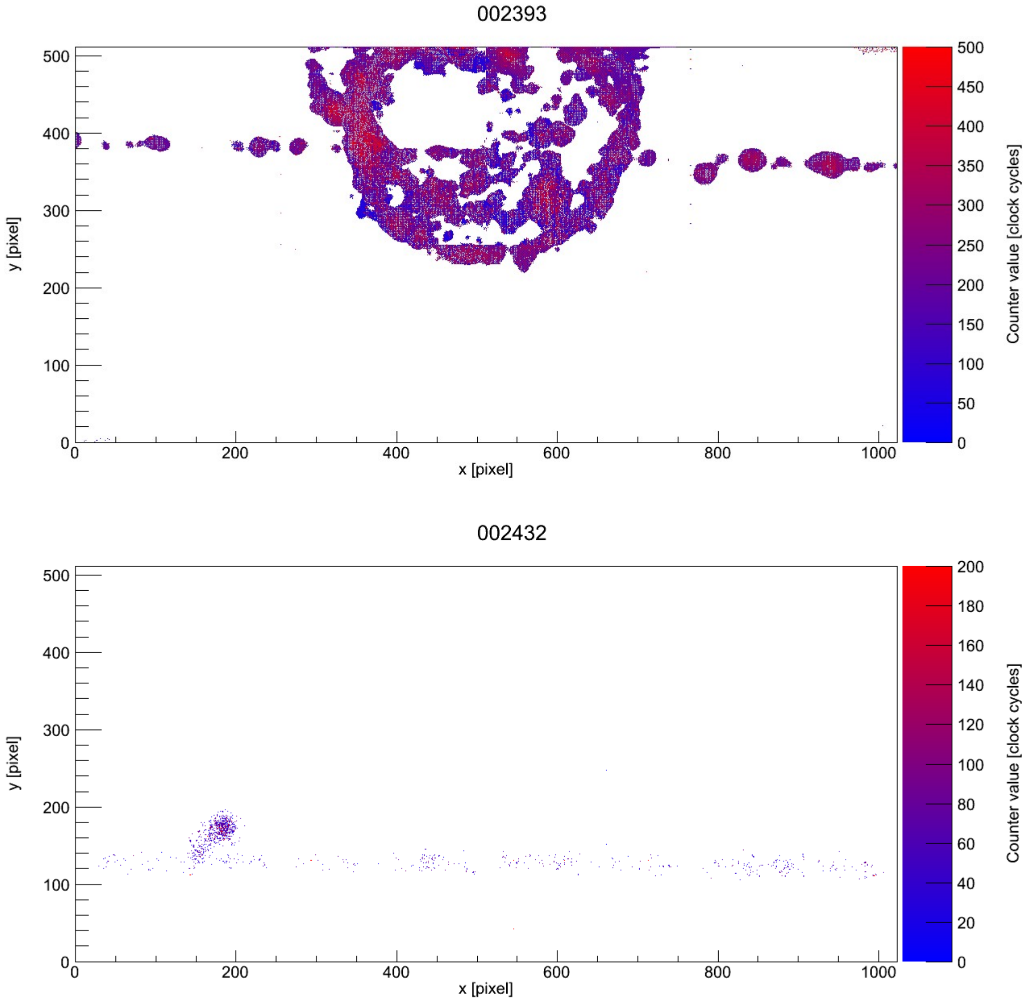
AWLC 14, Fermilab

14.05.2014, R. Diener, DESY

U Bonn TimePix Modules

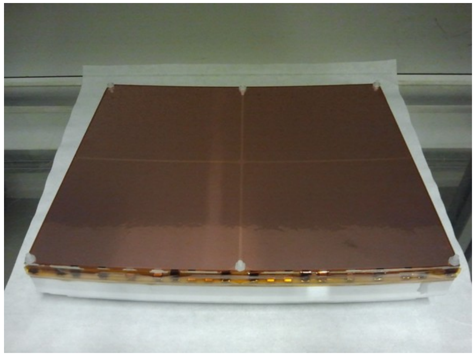
- TimePix Octoboards, 2 modules:
  - Ingrid Octoboard (Micromegas post-processed, pixel aligned on TimePix chip)
  - Triple GEM amplification above TimePix Octoboard
  - New (scalable) readout system
  - 2 weeks beam time

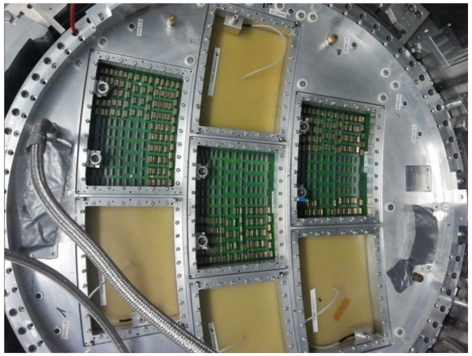




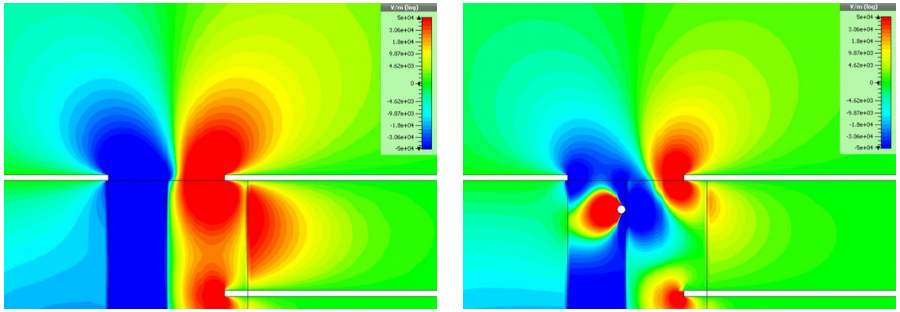
DESY GEM Modules

- 3 readout modules with triple GEM amplification with pad readout (ALTRO)

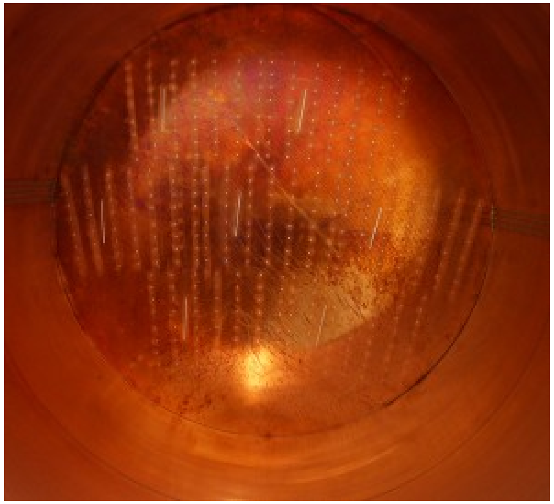




- Guard ring to minimize field distortions at module boarders



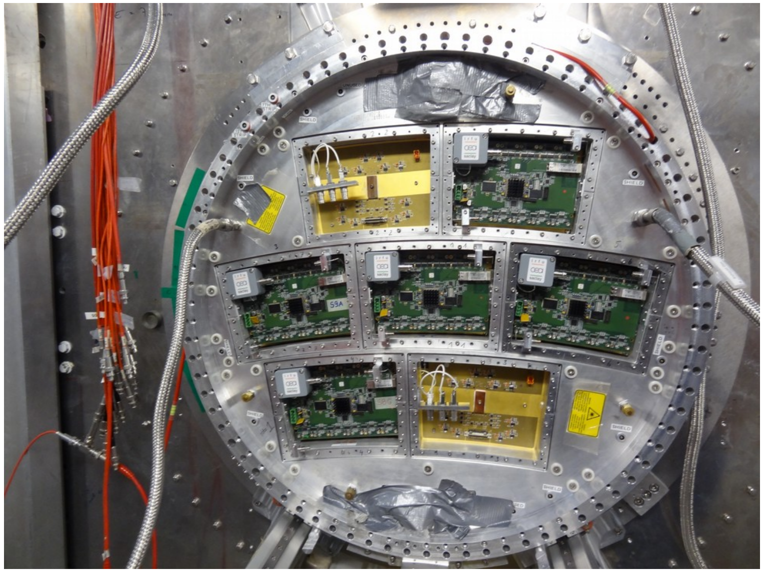
- Measurements of laser photo dots for field distortion studies

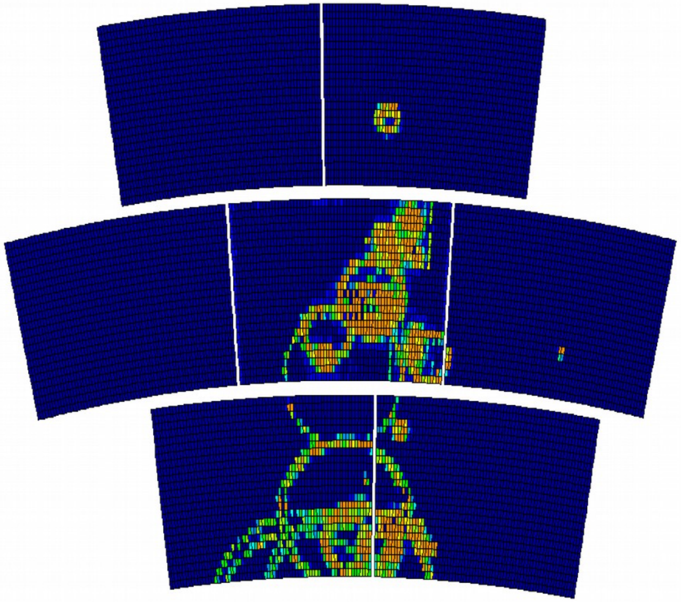


- 4 weeks beam time
  + 1 week laser measurements
- See also next presentation

Micromegas Modules

- 7 modules with Micromegas amplification
  + resistive layer to spread charge on pad layer
- Integrated AFTER readout





- 5 weeks of beam time
  - 4 weeks with integrated readout
    - 2 weeks with new 2PCO_2 cooling
      (incl. combined tests with 2 Octopuce modules & laser data taking)
  - 1 week with ALTRO readout
- More in A. Bellerives and S. Ganjours presentations

TRACI 2PCO2 Cooling

- TRACI: **T**ransportable **R**efrigeration **A**pparatus for **C**O2 **I**nvestigation
  - Very large latent heat and heat capacity makes CO_2 an excellent cooling medium
  - Room temperature operation avoids water condensation
  - High pressures (~60 bar at 20ºC)
  - Low viscosity allows very small pipe diameter
  - Easy & safe to operate
- TRACI 2a build by Nikhef/CERN and acquired by our KEK colleagues for LCTPC
- This system works with a Lewa pump (instead of Gather gear pump):
  - More reliable operation
  - Performance degradation at colder temperatures: less cooling power (not relevant for LCTPC setups)
- First operation at testbeam in February successful

About 26 W power consumption is currently measured per MM module

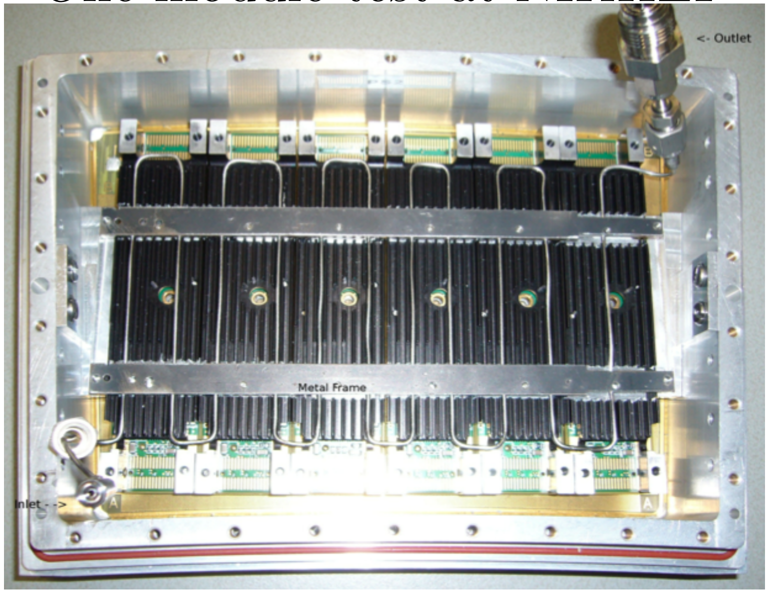
- Temperature of the circuit rises up to 60°C
  - cause a potential damage of electronics
  - covect gas to TPC due to a pad heating

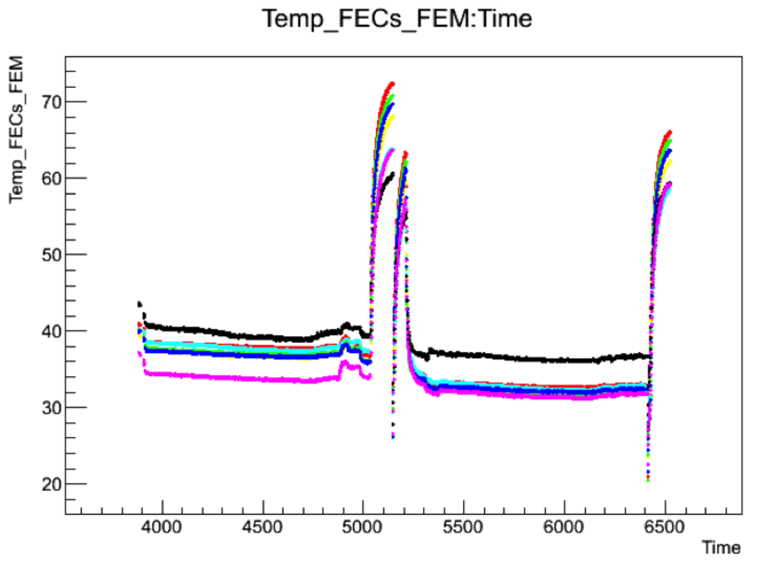
Cooling of the electronic circuit is required!

- **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

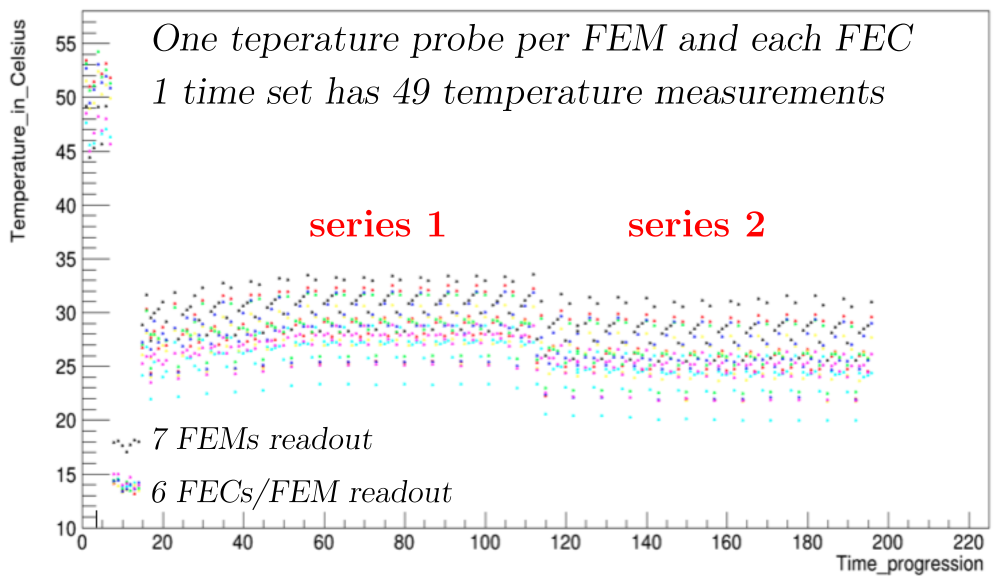
One module test at NIKHEF

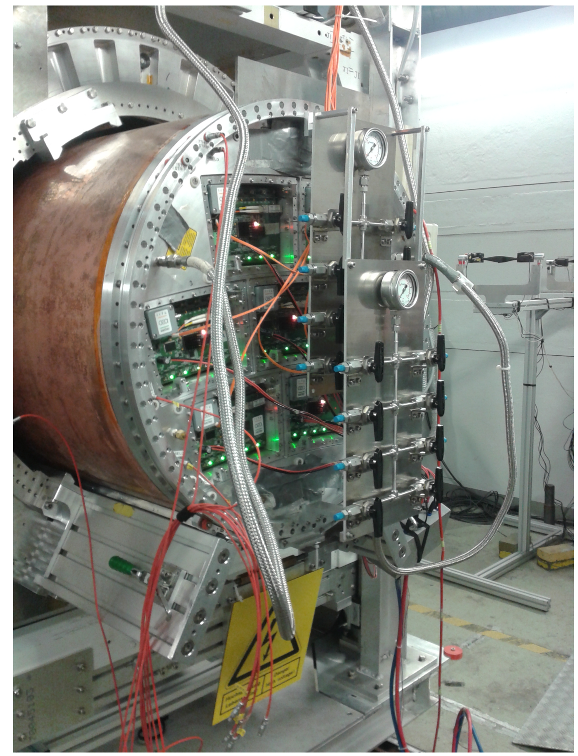




2-phase CO_2 cooling system was designed for the LP setup of the MM mudules

- 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



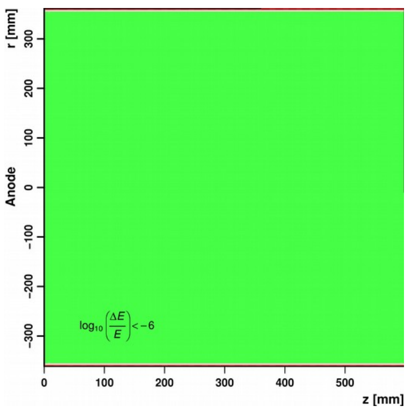


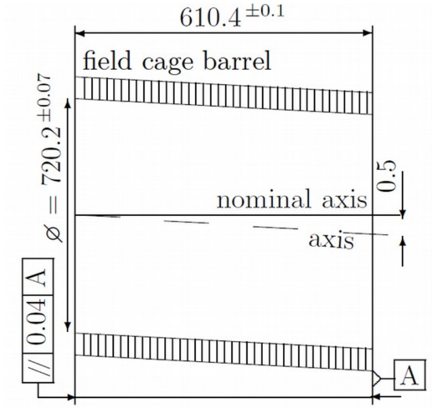
About 30°C stable temperture was achieved during operation of 7 MM modules at DESY

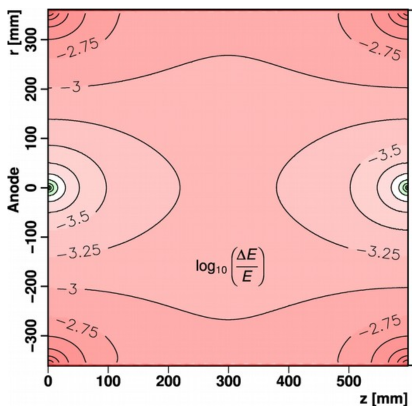
Status and Outlook

- DESY II test beam unavailable at least till autumn 2014
  - Currently maintenance and improvements ongoing
    - Cleaning up, updating equipment, more Ethernet/power plugs
    - Flat floor coating, IP cameras in all areas, lasers for alignment
    - Several “machine” improvements: new targets, shielding, counters, vacuum pumps, …
  - At re-start first slots for high priority users: ATLAS phase 1, Belle II, ...

- LCTPC: building tests for second LP field cage construction started
  - Improve mechanical accuracy
  - Only small changes to principal layout
    - HV connection
    - Test to replace glass fiber by Aramid paper (smaller X_0)







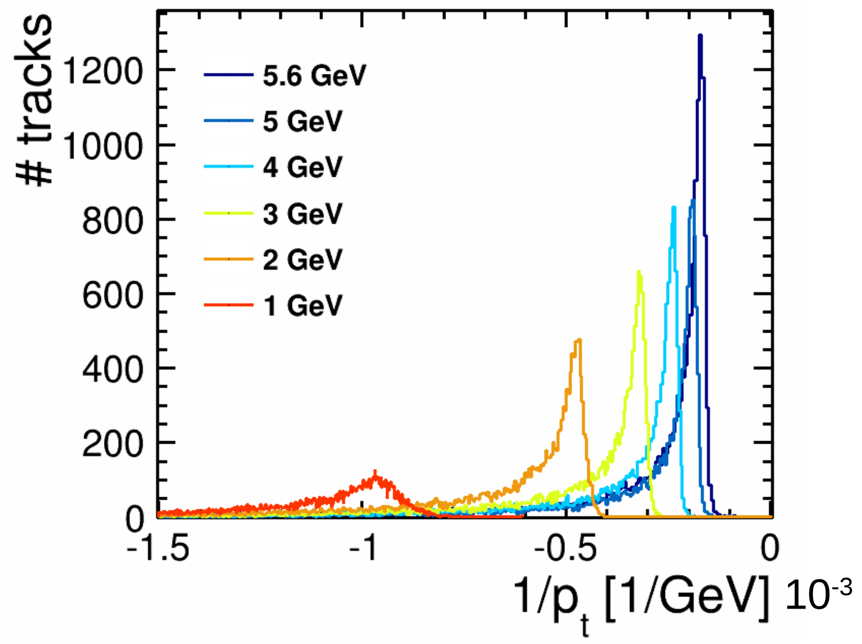
- Efforts ongoing for an external reference tracking detector

Motivation Si-Tracker Reference

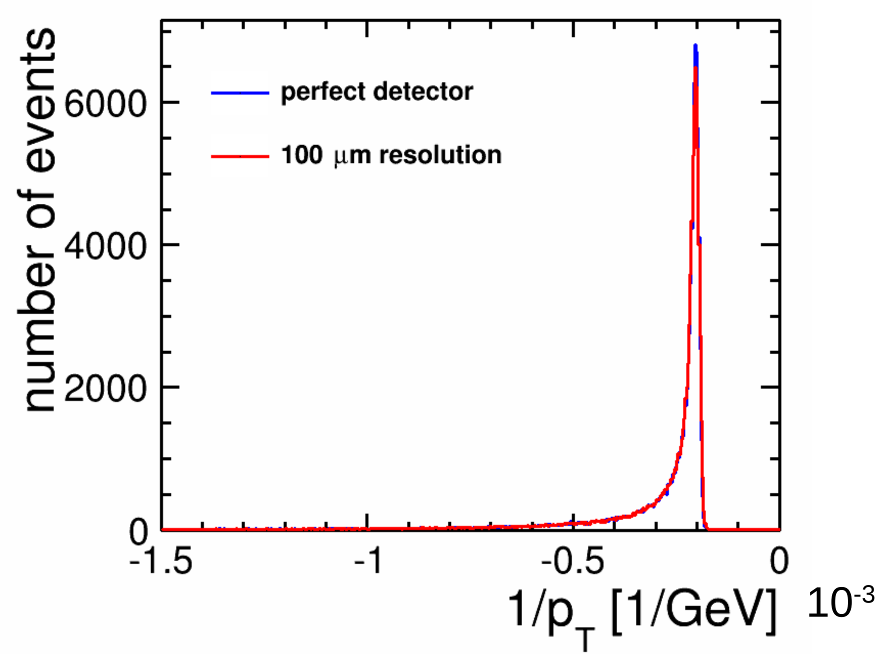
- Determine momentum resolution of the detector
  - Gluckstern formula:

$$\sigma_{p_T} = \sqrt{\frac{720}{n+4}} \frac{\sigma \cdot p_T^2}{0.3 B L^2} \quad \text{(m, GeV/c, T))}$$

  - Field inhomogeneities and distortions impact the momentum determination



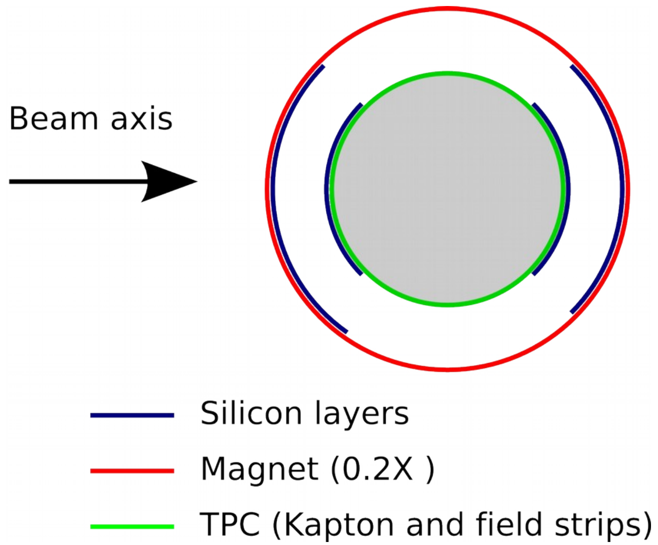
- Broad energy spectra created by:
  - Energy spread of the beam
  - Energy loss in the magnet



- External silicon tracker needed to do momentum studies

External Si-Tracker Reference

- Simple Geant 4 Simulation
  - Magnet: rad. length equivalent
  - TPC made from Kapton and field strips to match rad. length
  - 4 silicon layers (250µm)



  - Reality not so perfect: more material, distance of Si layers smaller, alignment...

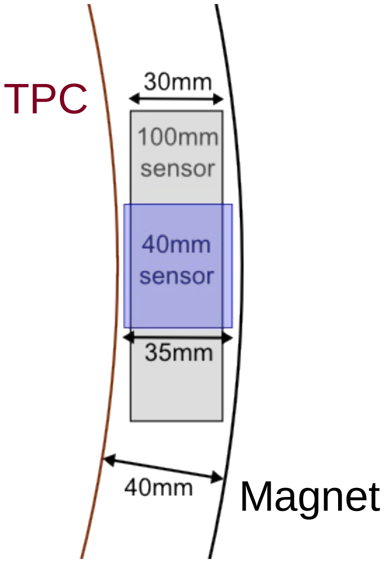
- Included effects:
  - Multiple scattering
  - Beam spread
  - Detector resolution
  - TPC hits: 100µm, every 6mm

- Simulation Results:

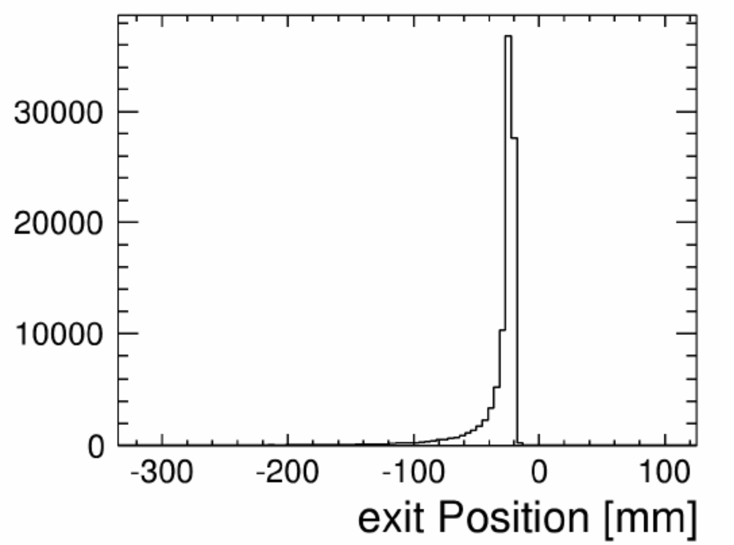
Detector	$\sigma(\Delta pt/pt2)$ [10^{-6} MeV^{-1}]
perfect TPC	4.77
perfect Si tracker	2.95
Si σ_{point} = 5µm	3.23
Si σ_{point} = 10µm	3.88
Si σ_{point} = 15µm	4.76
Si σ_{point} = 25µm	6.76

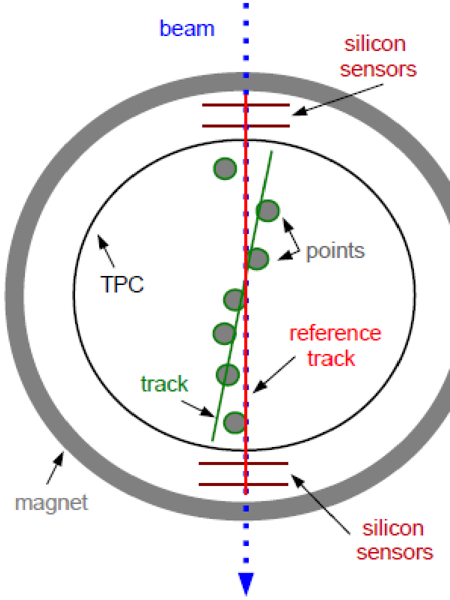
External Si-Tracker Reference

- 2 layers in space between TPC and magnet
- Need to cover about 10cm at exit point



Exit position of beam at 1T for 5GeV electrons

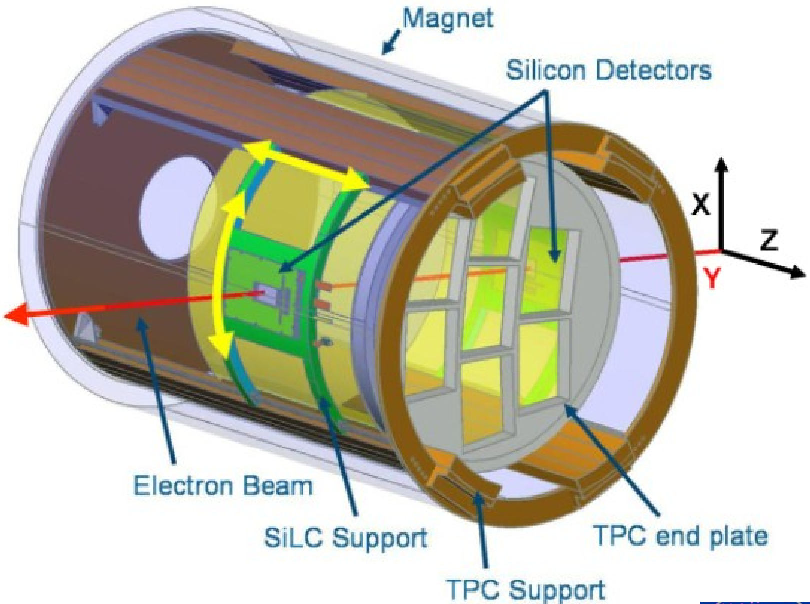


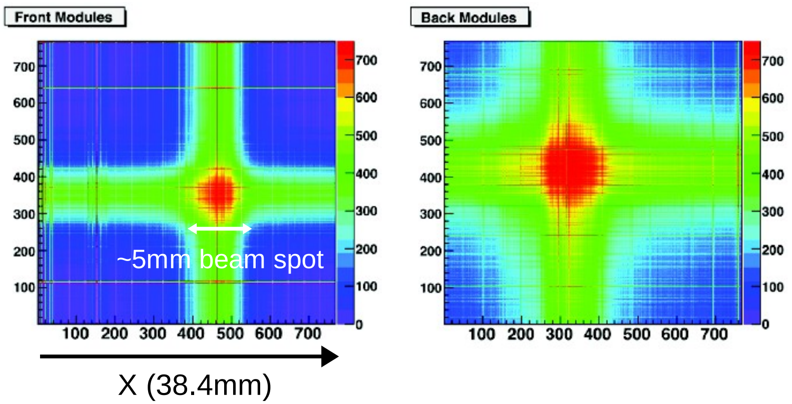


- Si-Tracker high priority for LCTPC (essential for momentum studies)
- Current efforts: AIDA 2 (Horizon2020) proposal
  - 4 layers of Silicon sensors (single sided strip detectors)
    e.g. 10x10cm^2, strip pitch 50µm
  - Small stereo angle between two adjacent layers:
    high precision measurement in phi, with additional low precision z measurement

Previous Si-Tracker Reference

- In 2009, a setup from HEPHY with two double layers was tested with one Micromegas module
  - Single sided strip sensors
  - Readout pitch 50µm
    → spatial resolution better than 10µm
  - Sensor area ~100x200mm, but only 768 strips connected → width 38.4mm
  - DAQ from CMS test setup
  - Mounted on an adjustable support





  - System unfortunately not available anymore

Recent Results from Beam Test of Micromegas TPC

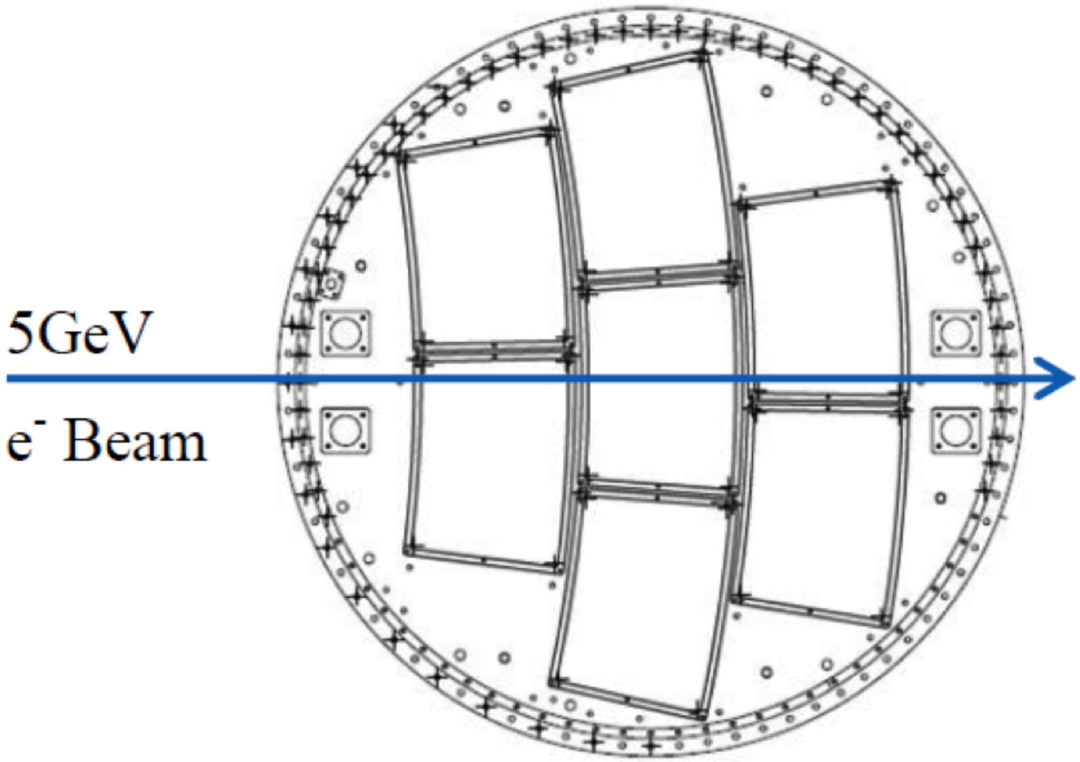
Serguei GANJOUR

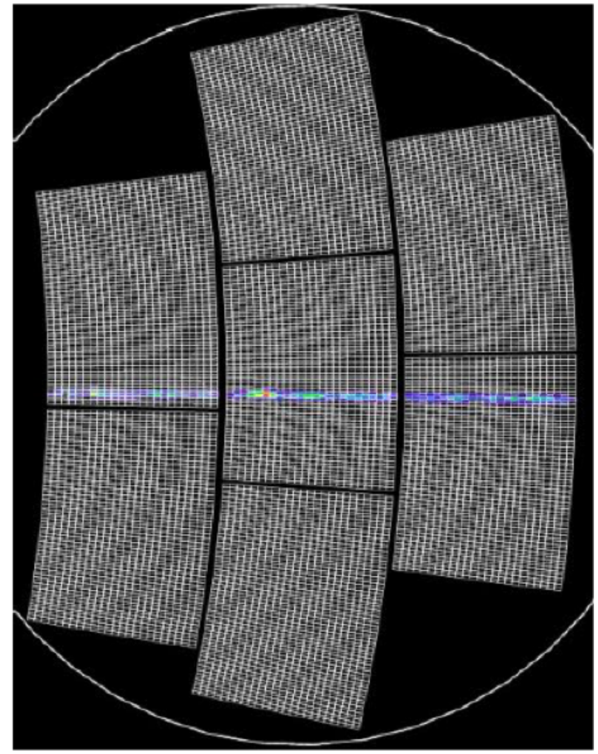
CEA-Saclay/IRFU, Gif-sur-Yvette, France

On behalf of the LCTPC Collaboration

Americas Workshop on Linear Colliders 2014
FNAL
May 12-18, 2014

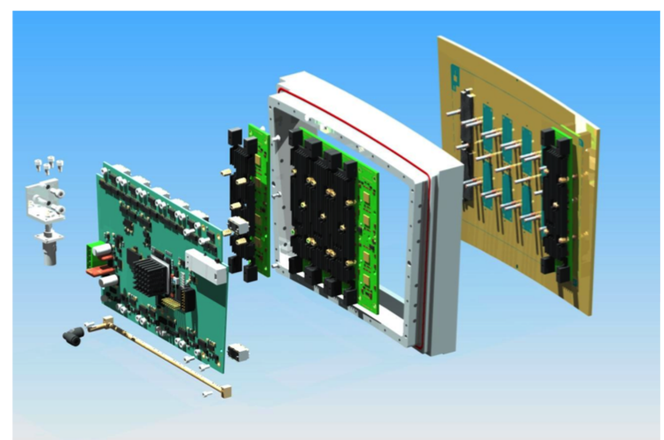
Multi-Module Setup



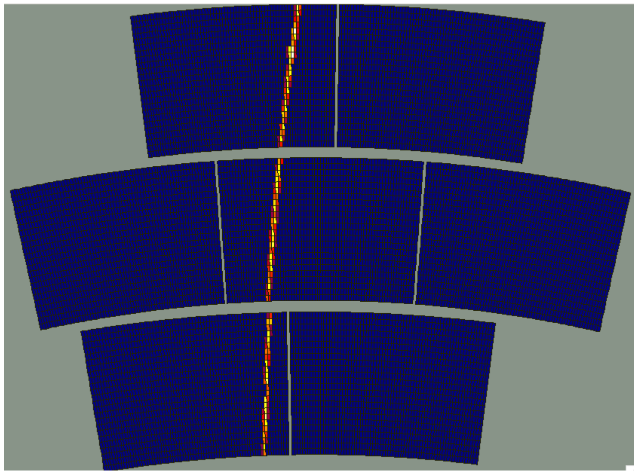


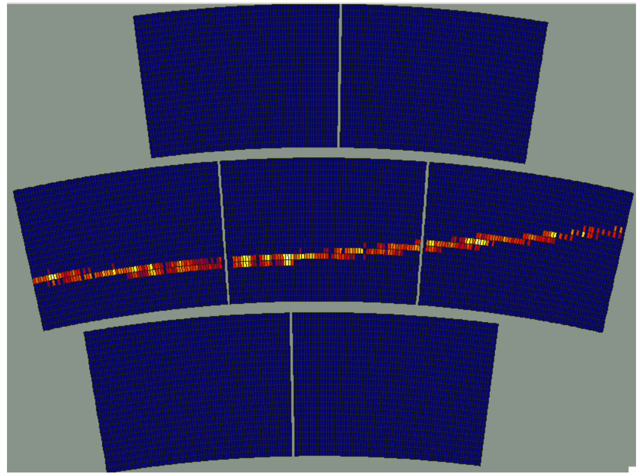
A multi-module detector sensitive to misalignment and distortions

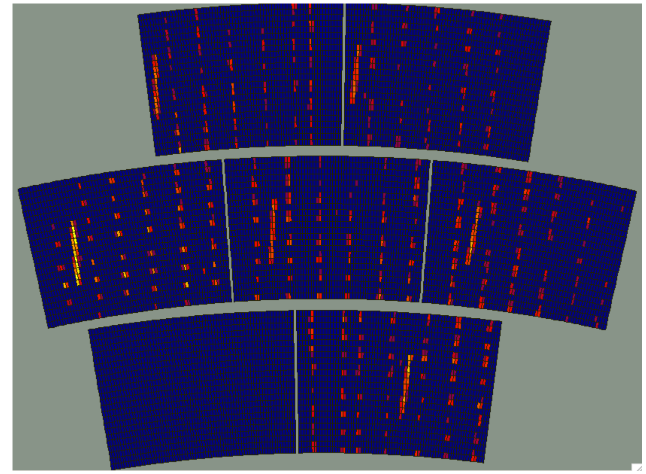
- ☞ Low material budget is required for ILD-TPC
  - ➠ endplates: $\leq \mathbf{0.25X_0}$
  - ➠ current MM module design: $\mathbf{d/X_0 \simeq 0.24}$



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





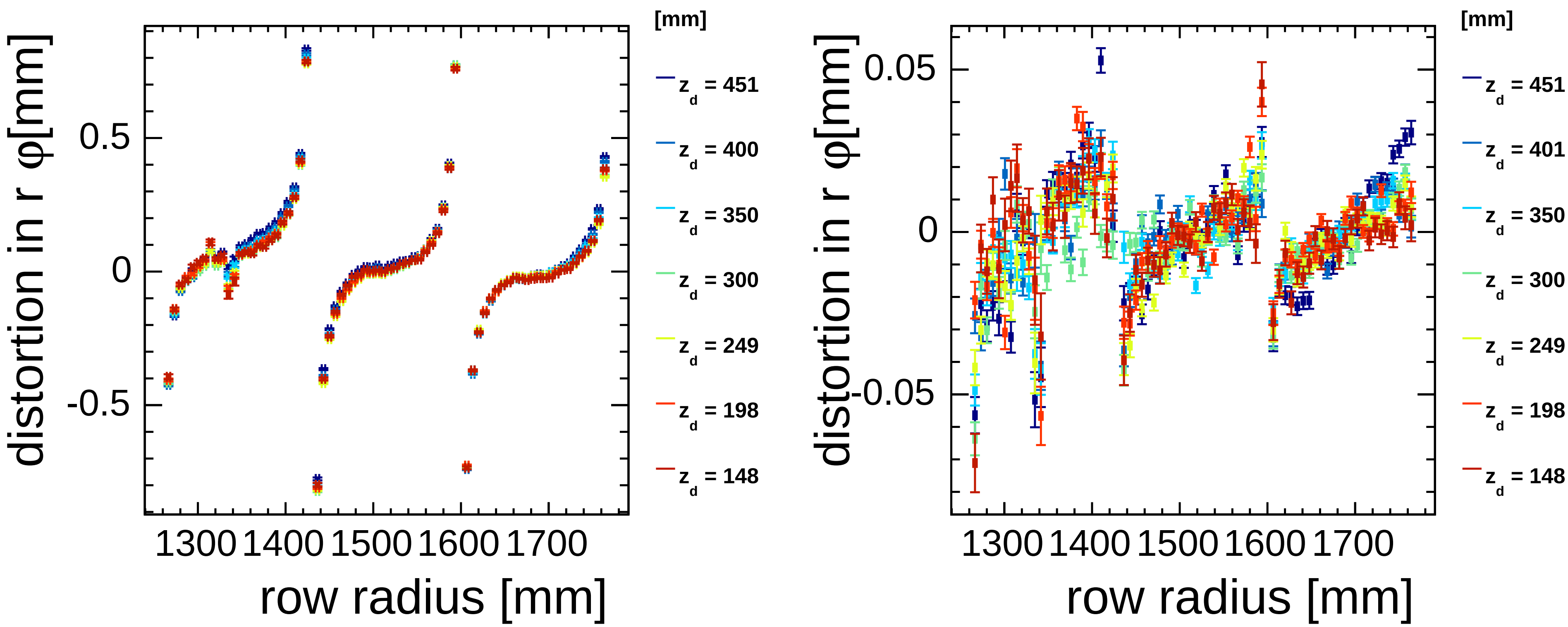


Data with B=0, 1 T, E=140, 230 V/cm were taken for $\Delta z = 5\,\mathrm{cm}$

- **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.)

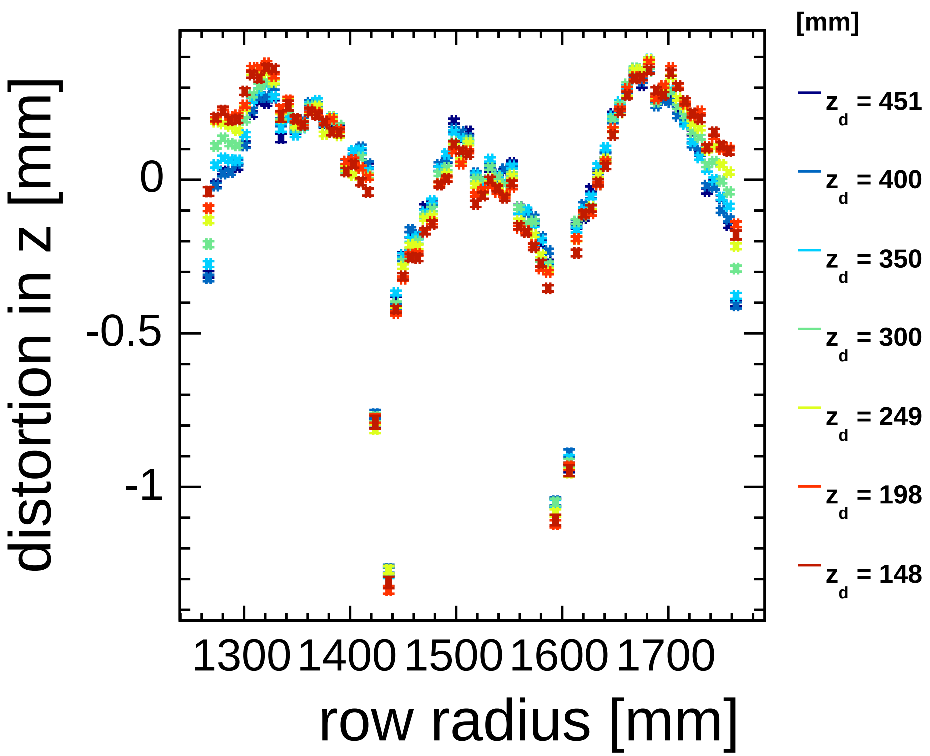
	E=140 V/cm	E=230 V/cm
Data	$58.4 \pm 0.1\mu m/ns$	$74.4 \pm 0.1\ \mu m/ns$
Magboltz	$57.9 \pm 1.0\mu m/ns$	$75.5 \pm 1.0\mu m/ns$

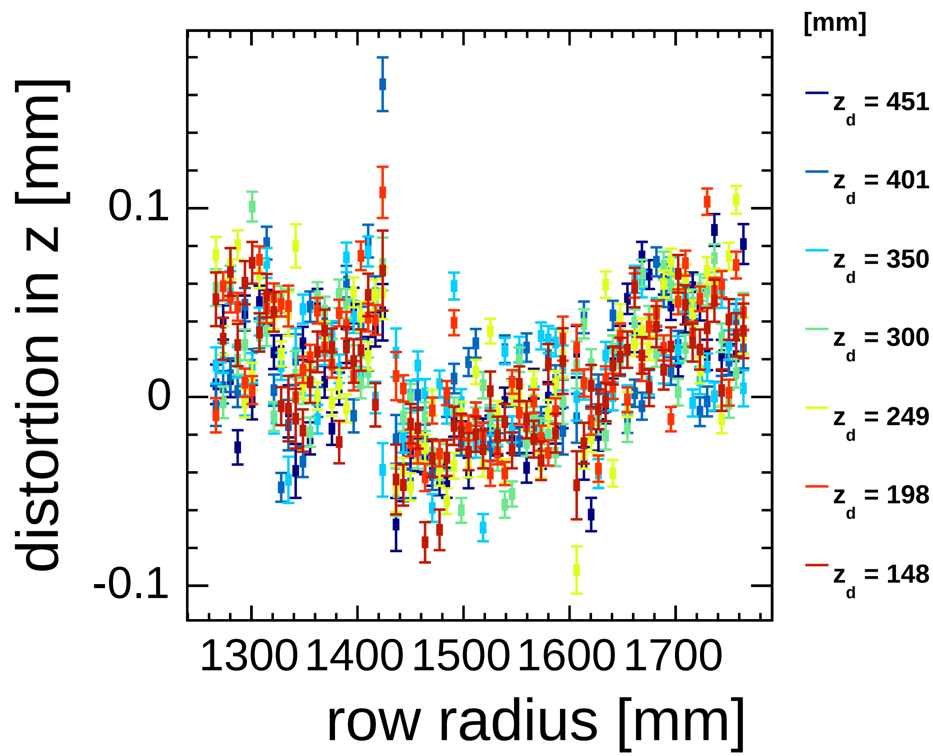


Non-uniform E-field near module boundaries induces ExB effects

- 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





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

Better than 100 μm distortions remain after corrections in z coordinate

GEM TPC Studies
Reconstruction, Corrections, Analysis

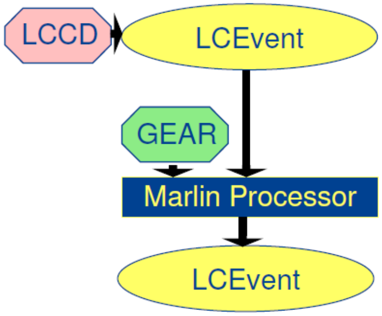
AWLC 14, Fermilab

14.05.2014

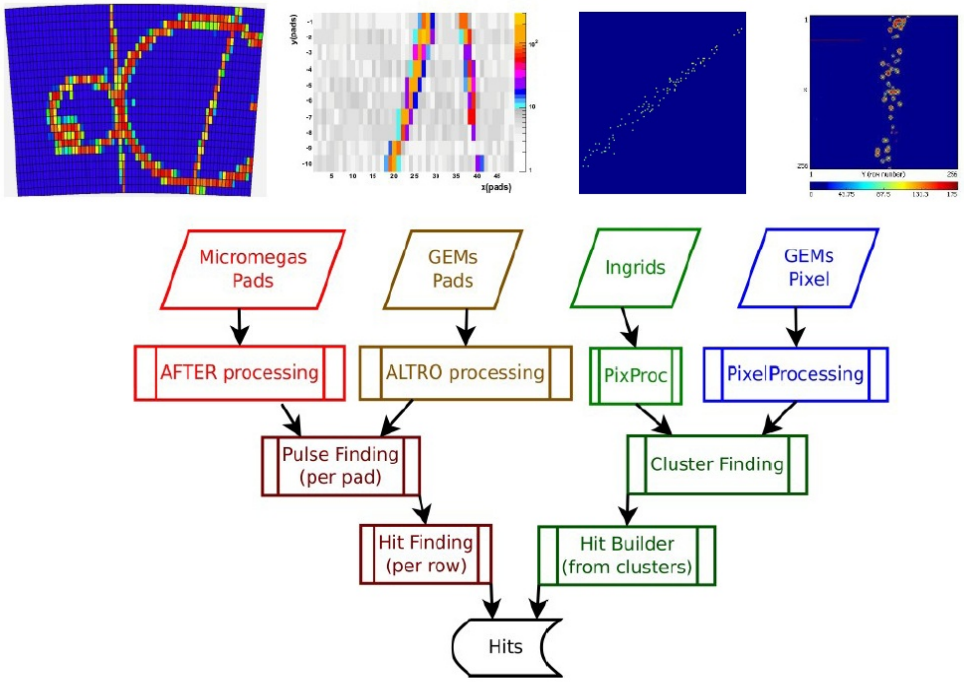
R. Diener, C. Kleinwort, F. Müller, A. Münnich, K. Zenker
DESY

LCTPC Software Overview

- Reconstruction, Simulation, Analysis based on common ILC software tools
  - LCIO
  - Marlin
  - LCCD
  - Gear

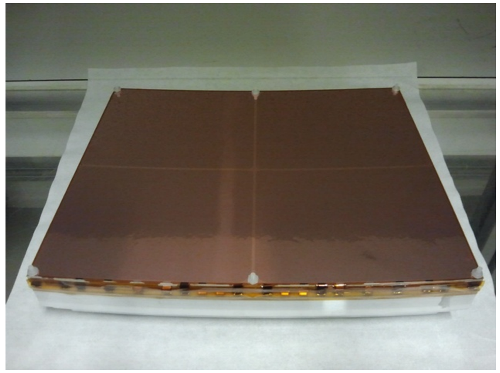


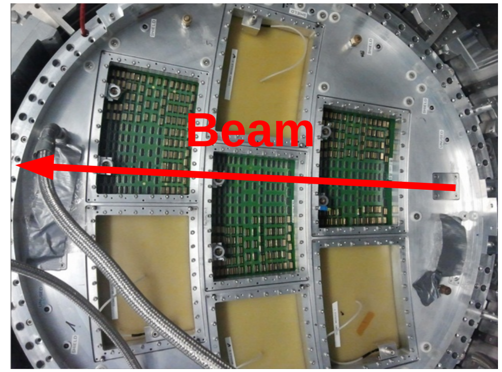
- Software package of LCTPC: MarlinTPC https://znwiki3.ifh.de/MarlinTPC/MarlinTPC
  - Reconstruction processors
  - Conditions handling
  - Simulation (coarse to detailed)
  - Common analysis for standard plots
- Data
  - Testbeam data stored on Grid storage → accessible by whole collaboration
  - Common conditions database server

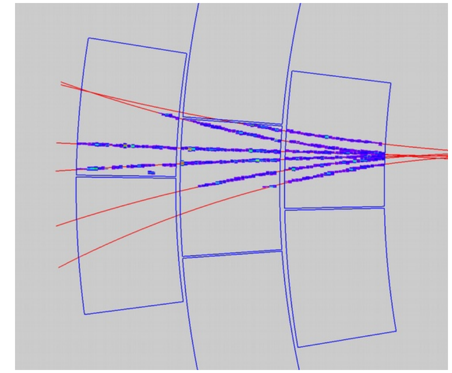


DESY GEM Modules

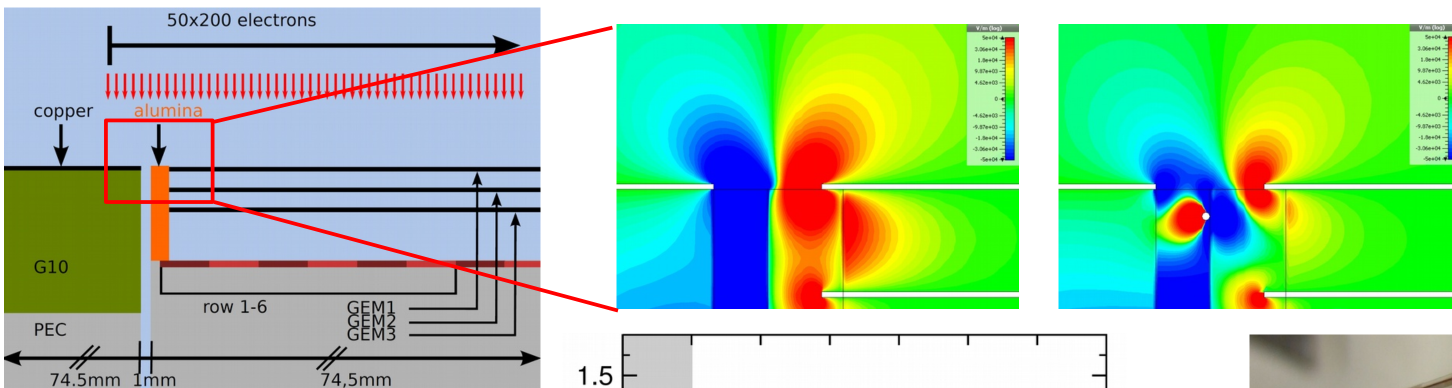
- 3 readout modules with triple GEM amplification with pad readout (ALTRO)
- Pad pitch: 1.25 x 5.85 mm²
- GEMs mounted on thin ceramic grids



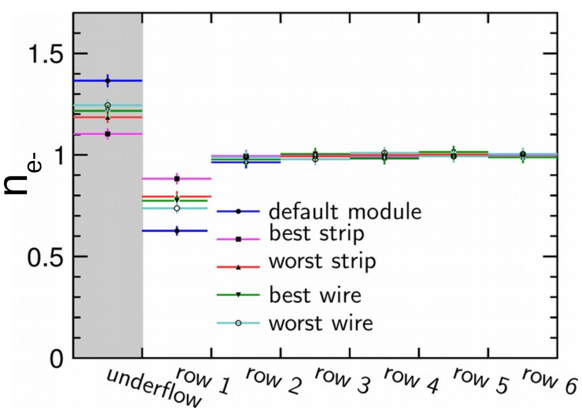


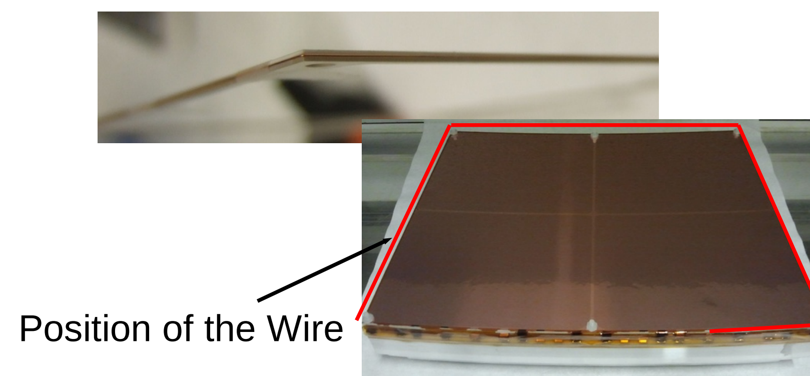


- Guard ring to minimize local field distortions at module borders



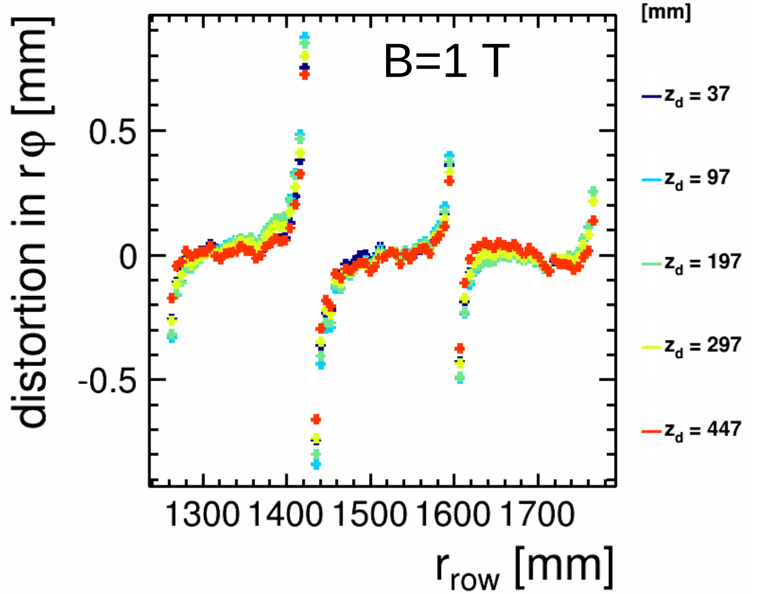
- Retrieve up to 30% collection efficiency in the first row

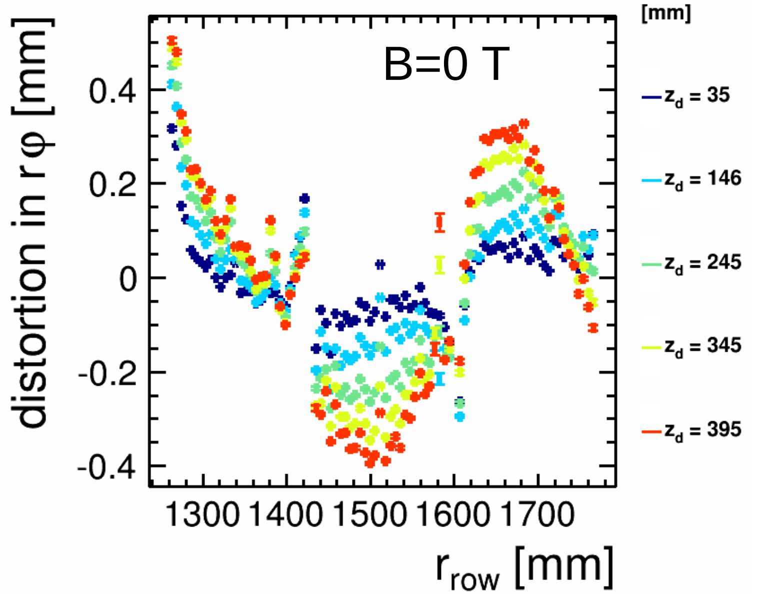




Field Distortions

- Field distortions originate from:
  - Inhomogeneities of drift and magnetic field
    - → ExB effects
- Working hypothesis:
  - Largest influence from the gap between the modules
    - → Large Distortions at the border of the modules
    - → No (or small) dependence on the drift distance expected …
  - … but seen in 0T data sets
- Drift dependence needs to be understood

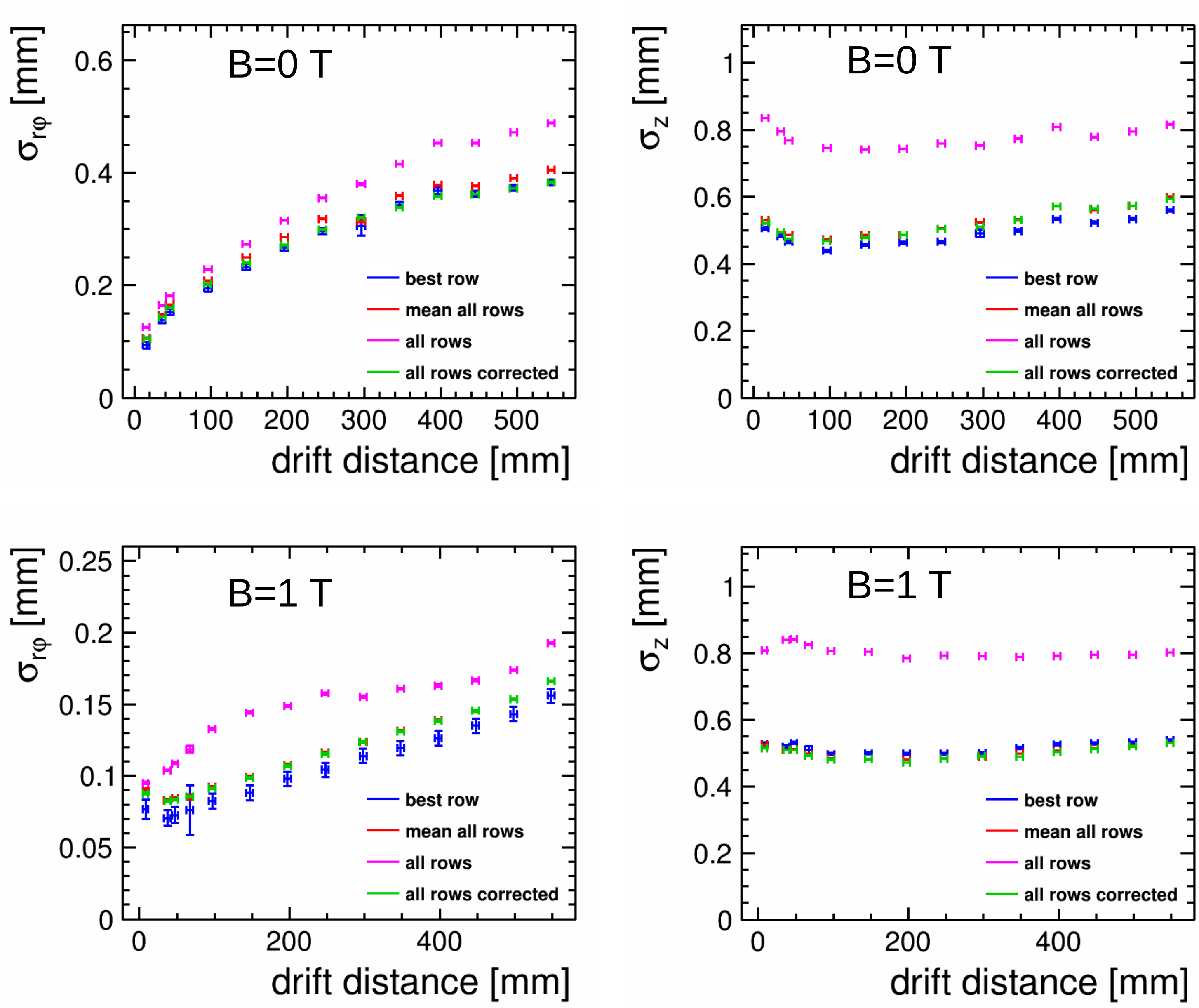




Resolution

- Determined using *Geometric Mean Method*
- Correction of hit positions:
  mean residual deviation to correct for field inhomogeneities

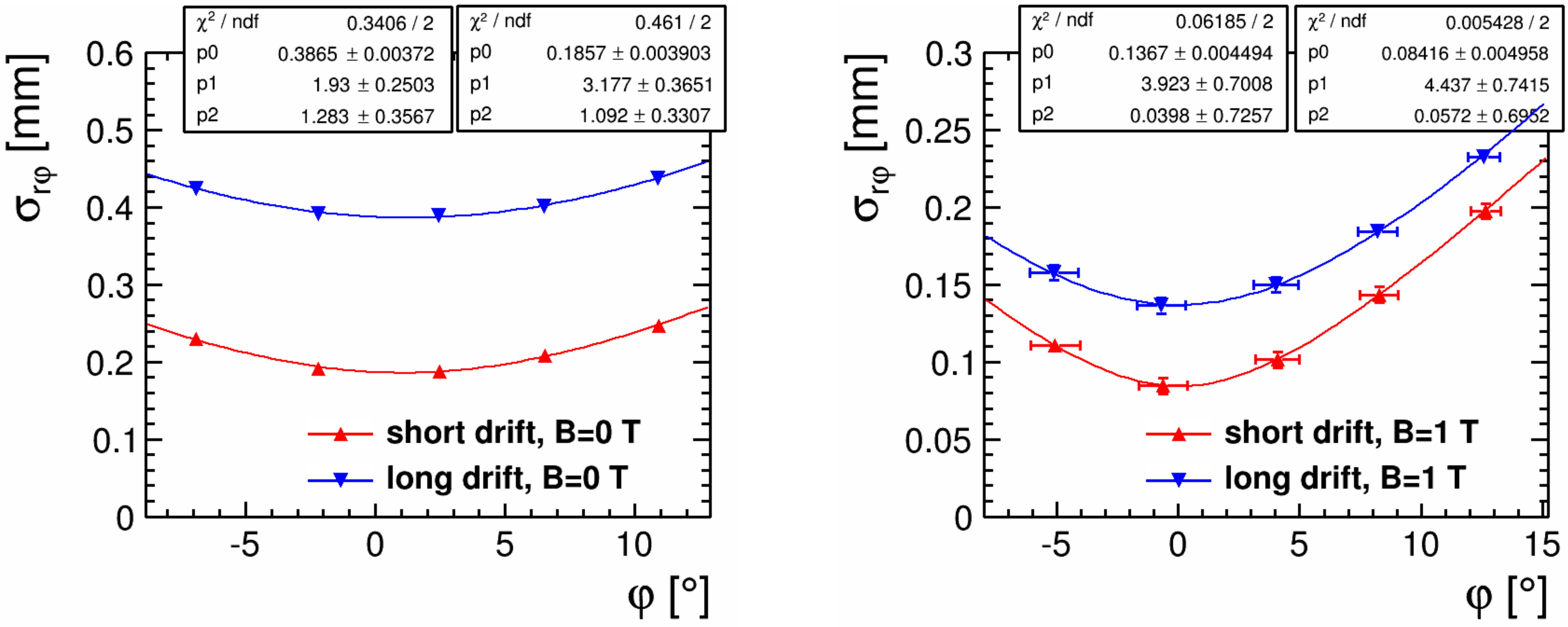
- Behavior as expected
- Only weak drift dependence of σ_z due to read-out electronics limitation



Angular Dependence of Resolution

- Angle: angle between track and pad orientation at the row in question
- Good agreement of theory and data

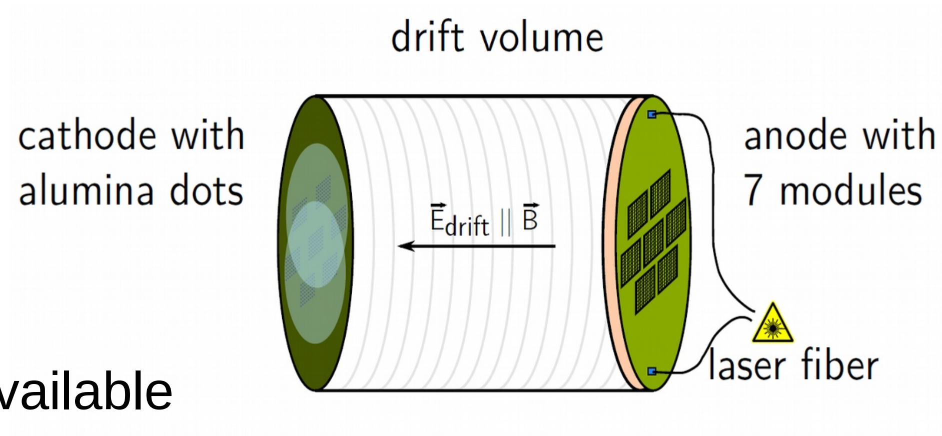
$$\sigma_{r\phi}(\phi,z)=\sqrt{\sigma_{r\phi}^{2}(z)+\frac{L_{pad}^{2}}{12\cdot N_{eff}}\cdot\tan^{2}(\phi-\phi_{0})}$$

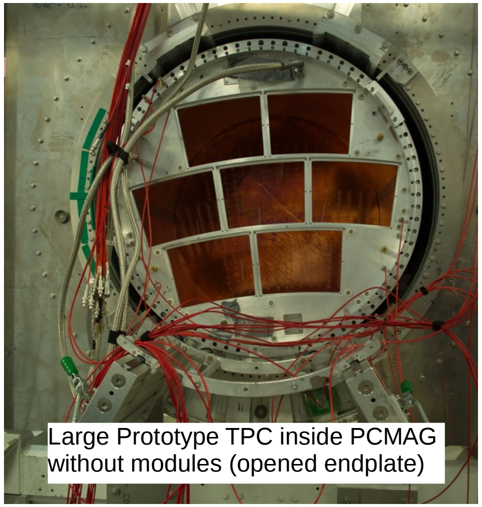


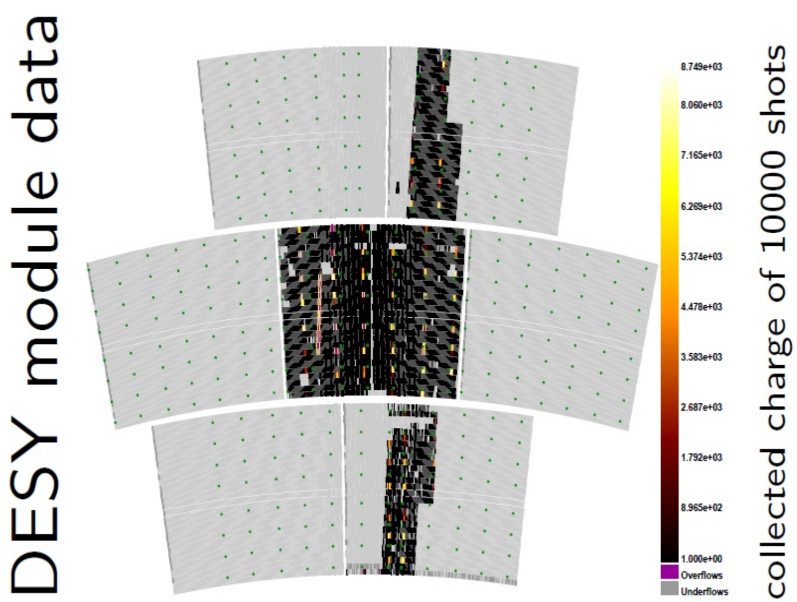
short drift: 50mm; long drift: 500mm

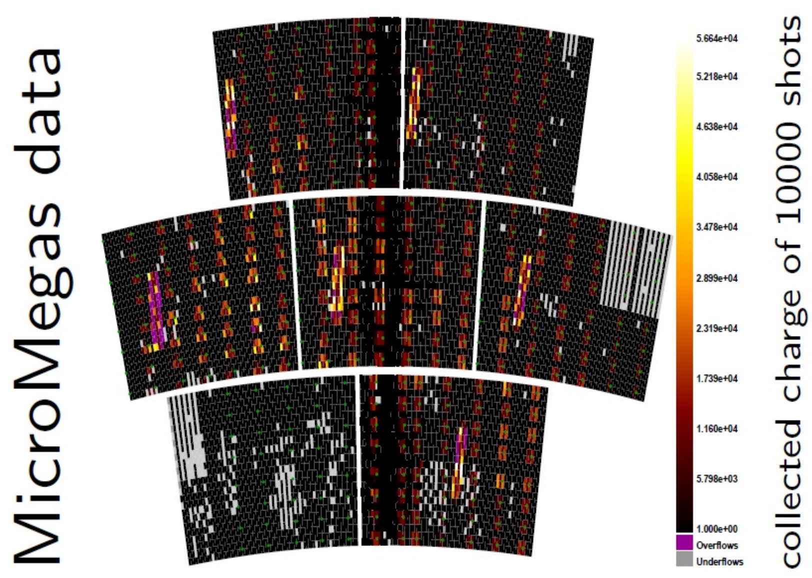
Laser Distortion Measurements

- Global field distortion measurement
  - Laser illuminates cathode pattern
    ↓
    liberates electrons at dots/lines
- Simulation framework available



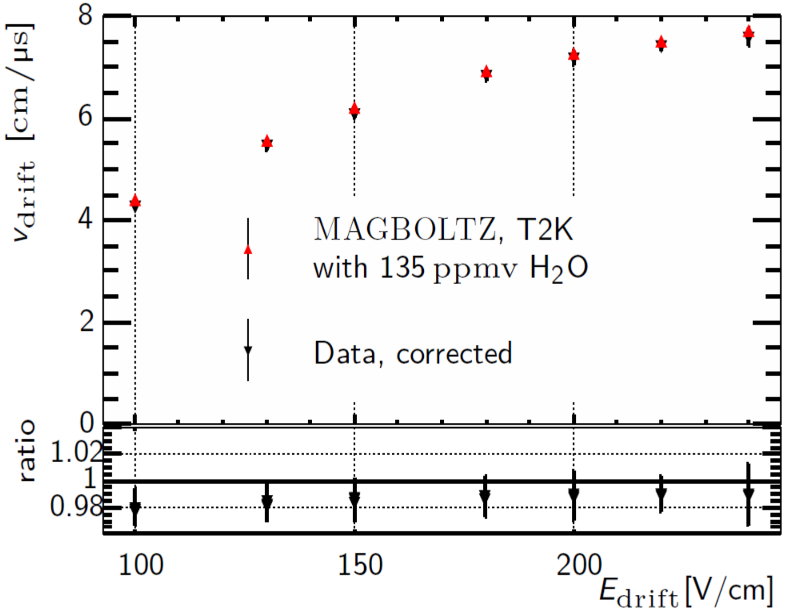

Large Prototype TPC inside PCMAG without modules (opened endplate)

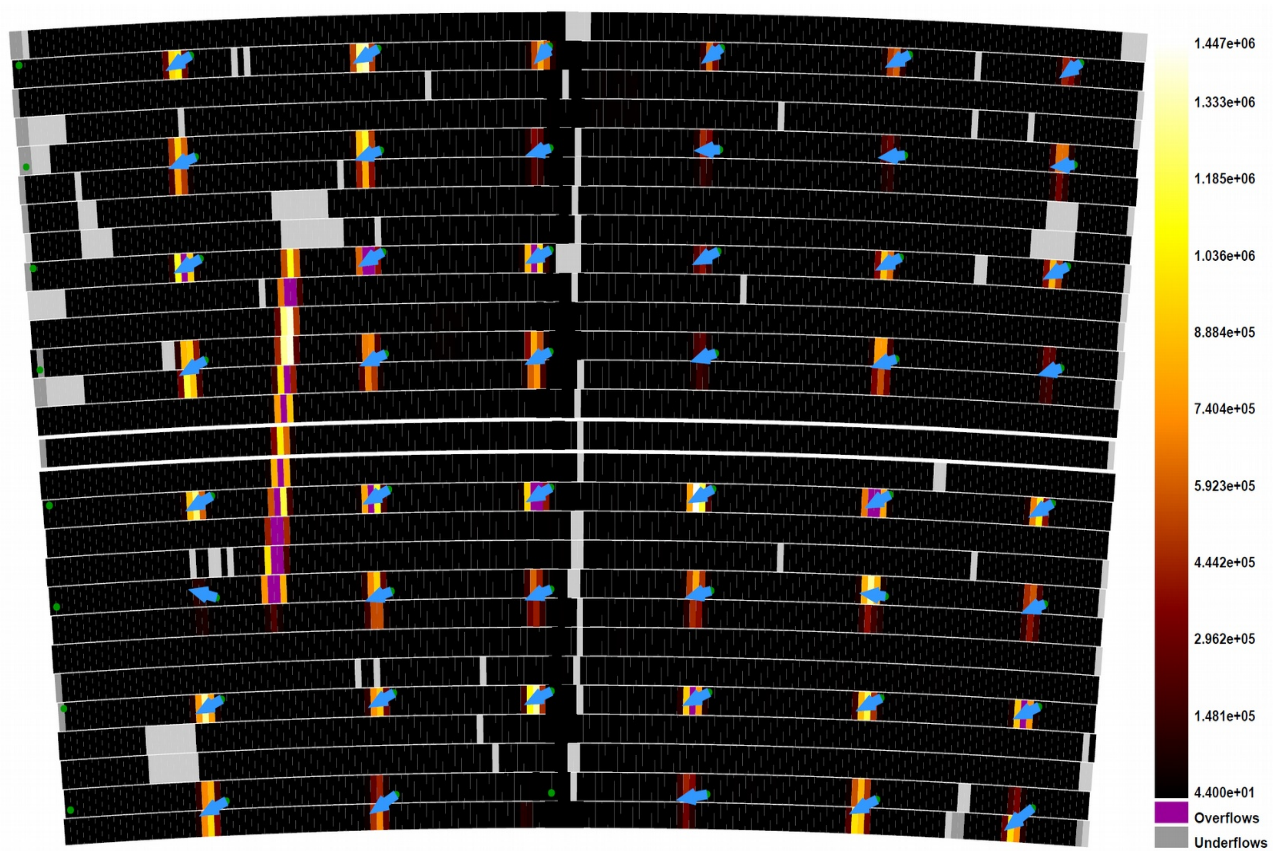




Drift Velocity and Displacement

- Drift velocity agrees well with simulation
- Displacements in the order of
  a few millimeter
- Systematic shift of points in one direction

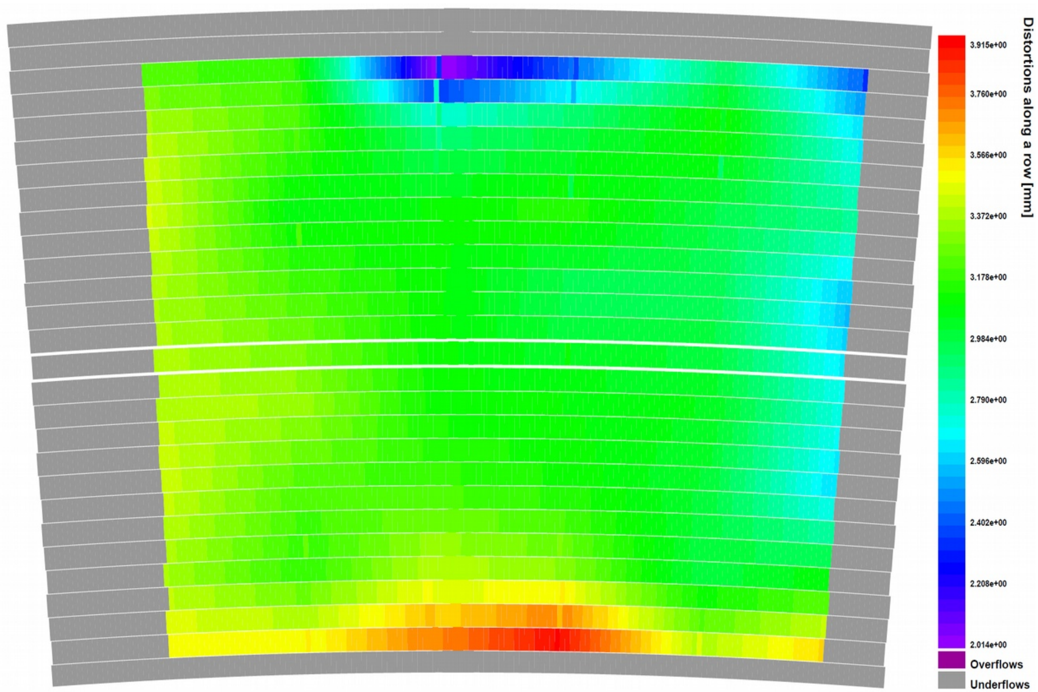




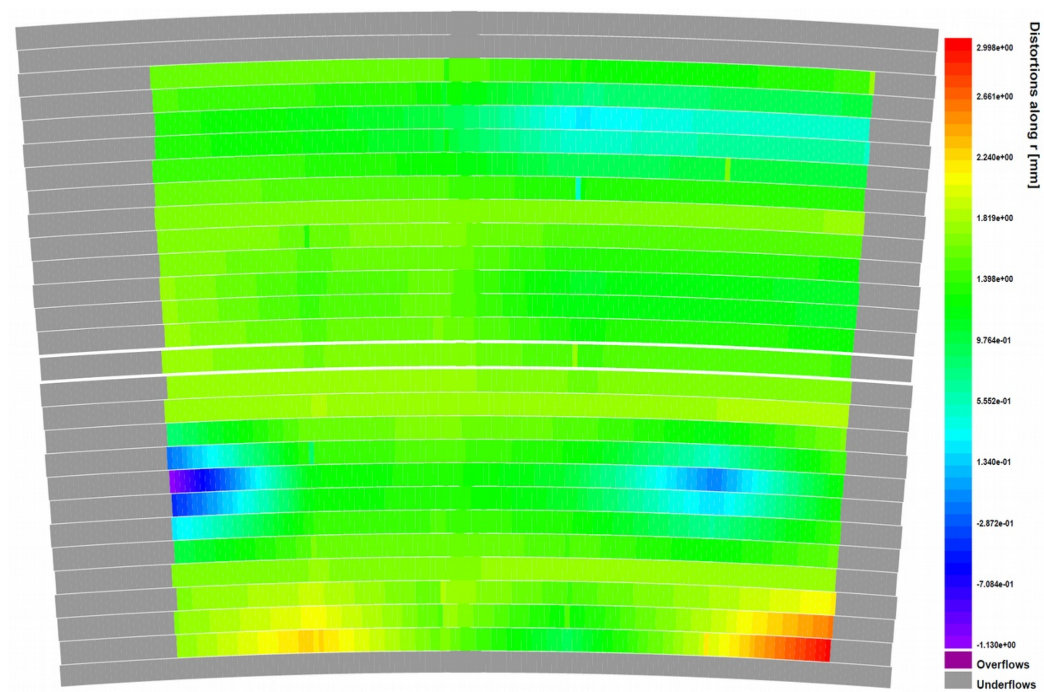
Distortion Maps

- Phi displacements along a row: -2 to +4 mm
- Radial displacements along r: -1.1 to +3 mm

Displacements along a row [mm]



Displacements along r [mm]



Conclusion

- LCTPC software package MarlinTPC well advanced (being constantly improved and extended)
- Standard analysis set defined and implemented
- Fast Hough Transformation and General Broken Lines well suited for reconstruction of testbeam data including alignment

- Analysis of DESY GEM Module testbeam data ongoing
- Distortion corrections and alignment included
  - Drift dependence of distortions needs to be understood

- Global distortion measurements done with laser calibration using GEM and Micromegas setups
- Simulation and analysis framework for distortion maps ready