# TPC Large Prototype (LP) Beam Test

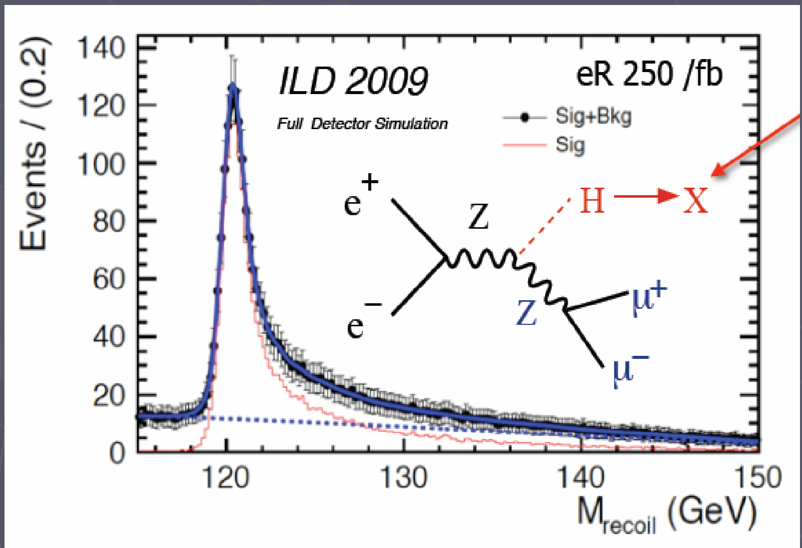
IWLC2010
20 October 2010
Geneva

Takeshi MATSUDA
For
LC TPC collaboration

# Tracking at ILC: High Momentum Resolution

ILC-RDR
LDC LOI

1. **Higgs recoil mass: $e^+e^- \rightarrow ZH\ (Z\rightarrow\mu\mu/ee) + X$:**
   **The beam energy spread dominates when $\delta(1/pt) \leqq 5 \times 10^{-5}$.**
2. **Slepton and the LSP masses though the end point measurement:**
   **$\sigma_M$ (Momentum resolution) ~ $\sigma_M$ (Parent mass) at 1 $ab^{-1}$**
   **when $\delta(1/pt) \leqq 5 \times 10^{-5}$**
3. **$E_{cm}$ determination from $e^+e^- \rightarrow \mu^+\mu^-(\gamma)$**
4. **Rare decay Br ($H \rightarrow\mu\mu$) in $e^+e^- \rightarrow ZH$ and Hvv:**




Higgs mass expected for ILD

## MPGD TPC: Goals

**$\sigma_{r\varphi}$ ≦ 100 μm**
**points/track ~ 200**
**Lever arm ~ 1.5 m**
**High B Field 3.5T (no ExB)**
**Alignment and corrections**

**$\delta(1/p_t) \leqq 5 \times 10^{-5}$**

# Specifications of TPC at ILC (ILD)

ILC-RDR
LDC LOI

TABLE 4.3-5
Goals for performance and design parameters for an LCTPC with standard electronics.

| | |
|---|---|
| Size | $\phi = 3.6$m, L = 4.3m outside dimensions |
| Momentum resolution (3.5T) | $\delta(1/p_t) \sim 9 \times 10^{-5}$/GeV/c TPC only ($\times$ 0.4 if IP incl.) |
| Momentum resolution (3.5T) | $\delta(1/p_t) \sim 2 \times 10^{-5}$/GeV/c (SET+TPC+SIT+VTX) |
| Solid angle coverage | Up to $\cos\theta \simeq 0.98$ (10 pad rows) |
| TPC material budget | $\sim 0.04X_0$ to outer fieldcage in $r$ |
| | $\sim 0.15X_0$ for readout endcaps in $z$ |
| Number of pads/timebuckets | $\sim 1{\times}10^6$/1000 per endcap |
| Pad size/no.padrows | $\sim$ 1mm$\times$4–6mm/$\sim$200 (standard readout) |
| $\sigma_{\rm point}$ in $r\phi$ | $<$ 100$\mu$m (average over $L_{sensitive}$, modulo track $\phi$ angle) |
| $\sigma_{\rm point}$ in $rz$ | $\sim$ 0.5 mm (modulo track $\theta$ angle) |
| 2-hit resolution in $r\phi$ | $\sim$ 2 mm (modulo track angles) |
| 2-hit resolution in $rz$ | $\sim$ 6 mm (modulo track angles) |
| dE/dx resolution | $\sim$ 5 % |
| Performance | $>$ 97% efficiency for TPC only ($p_t >$ 1GeV/c), and |
| | $>$ 99% all tracking ($p_t >$ 1GeV/c) [83] |
| Background robustness | Full efficiency with 1% occupancy, |
| | simulated for example in Fig. 4.3-4(right) |
| Background safety factor | Chamber will be prepared for 10 $\times$ worse backgrounds |
| | at the linear collider start-up |

# TPC R&D by LC TPC Collaboration

**Demonstration Phase**: Small prototype tests

Provide a basic evaluation of the properties of MPGD TPC by using small prototypes, demonstrate that the requirement of the point resolution may be achieved.

**Consolidation Phase:** Large prototype tests (2008- )

Design, build and operate a "Large Prototype" using the EUDET facility at DESY comparing tecnologies and demonstrating the momentum resolution in a way.

**Design Phase:** ILD LOI → ILD DBD → ....

Start working on engineering design of TPC at ILC (ILD).

(LC TPC collaboration: MOU)

## Perform beam tests at all stages.

# Options of MPGD TPC for LC

**Based on the studies with small MPGD TPC Prototypes**

**Analog TPC:**

(1) Multi layer GEM + Narrow (1mm wide) pad readout:
Defocusing by multilayer GEM

(2) MicroMEGAS + Resistive anode pad redaout:
Widening signal by a resistive anode

(3) Multilayer GEM + Timepix
A good efficiency for primary electrons
→ A larger pixel size, but still a higher granularity.

**Digital TPC:**

(4) Ingrid (MicroMEGAS) Timepix: (also the GEM-like structure)
Digital → Free from the gas gain fluctuation
(More information from primary electrons )
Some improvement in the position resolution
Need measurement for long drifts

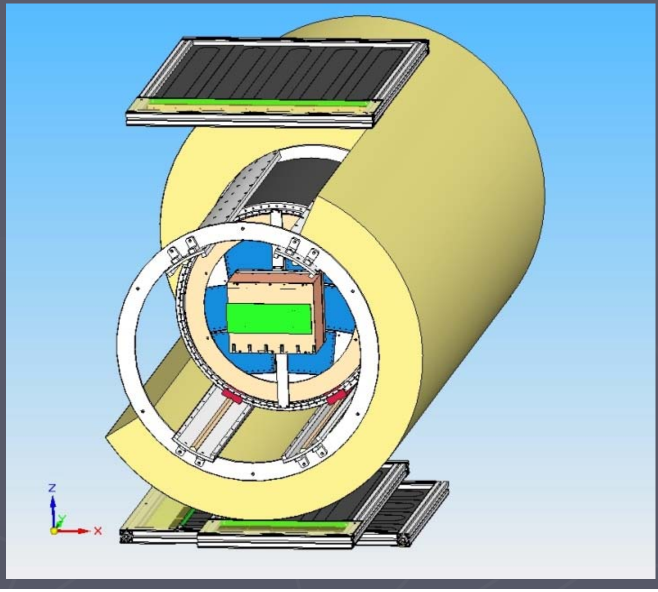
# EUDET TPC Facility at DESY Hamburg

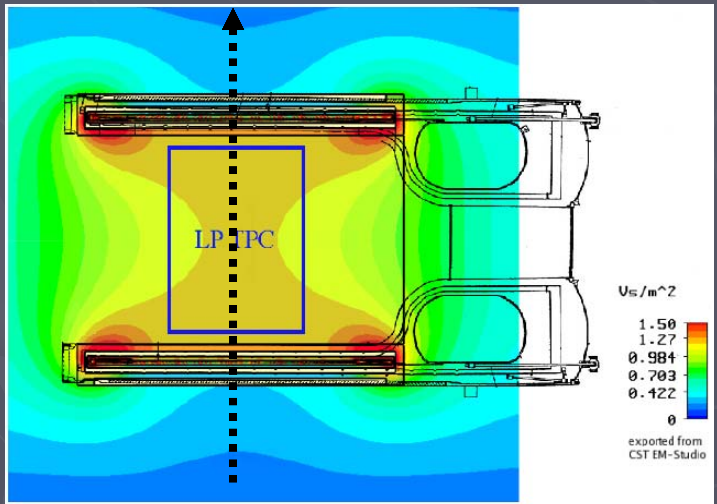
**PCMAG:**

**Open SC magnet (1T) at DEST T24-1 test beam (electron: 1 - 6GeV/c). Coil/cryostat of 20%X0.**

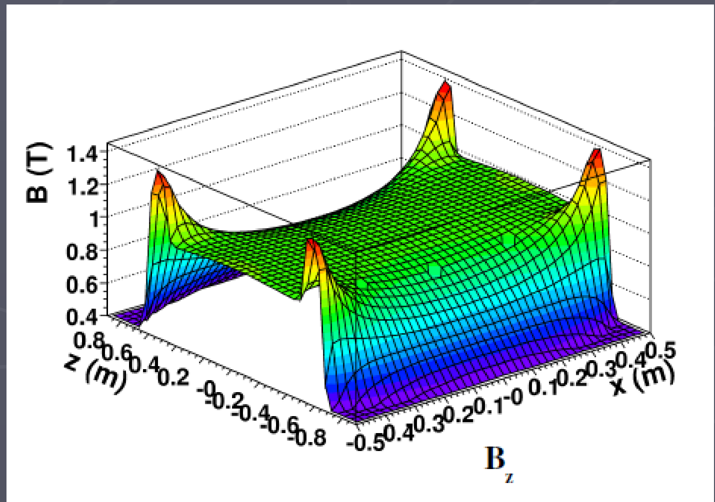
**On a moving stage (2010)**

**Also with a cosmic trigger.**



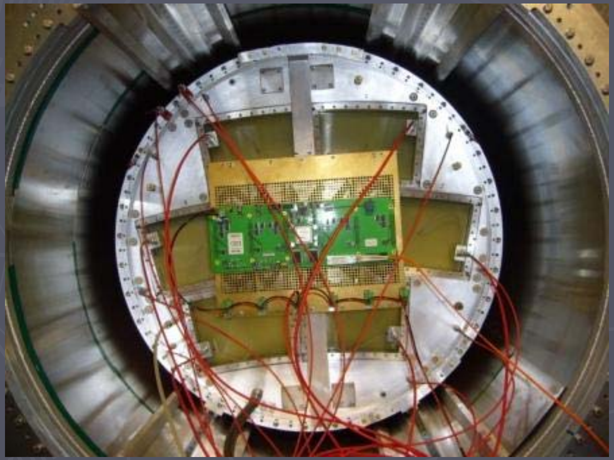




**Non-uniform magnetic filed (on purpose)**

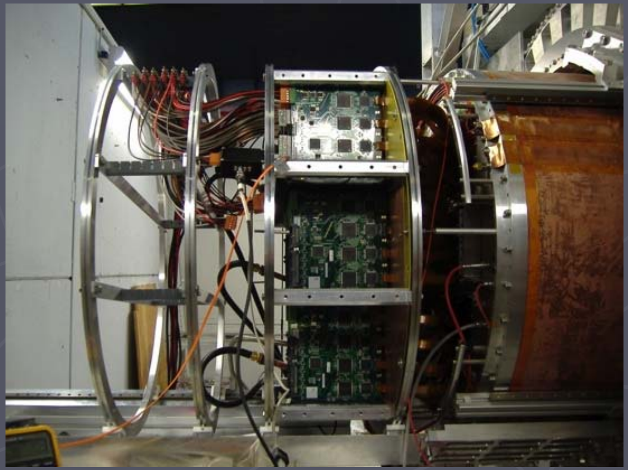



**A field model based on a precision field measurement made in 2007**

# TPC Large Prototype Beam Test (LP1) at DESY T24-1 Beam Line



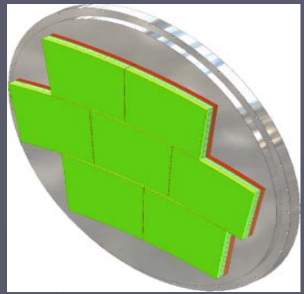
With a MicroMEGAS module readout by T2K electronics



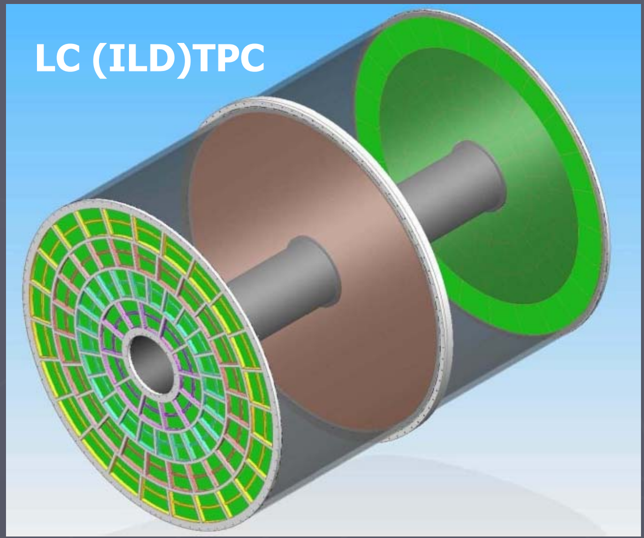
With three GEM modules readout by PCA16-ALTRO electronics

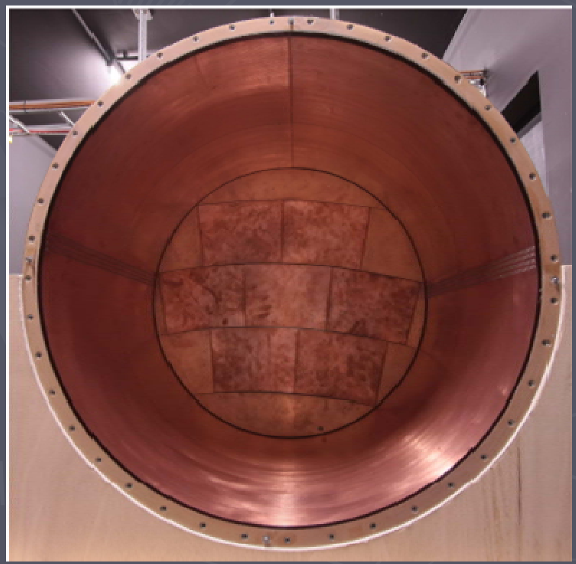
# TPC Large Prototype (LP1)

LP1 Endplate



LP endplate:
A part of LC TPC endplate



LP1 Field cage of L=61 cm, D =72 cm.
1.2% X0 thick (Up to around 20kV).

A cathode with laser patterns for calibration.

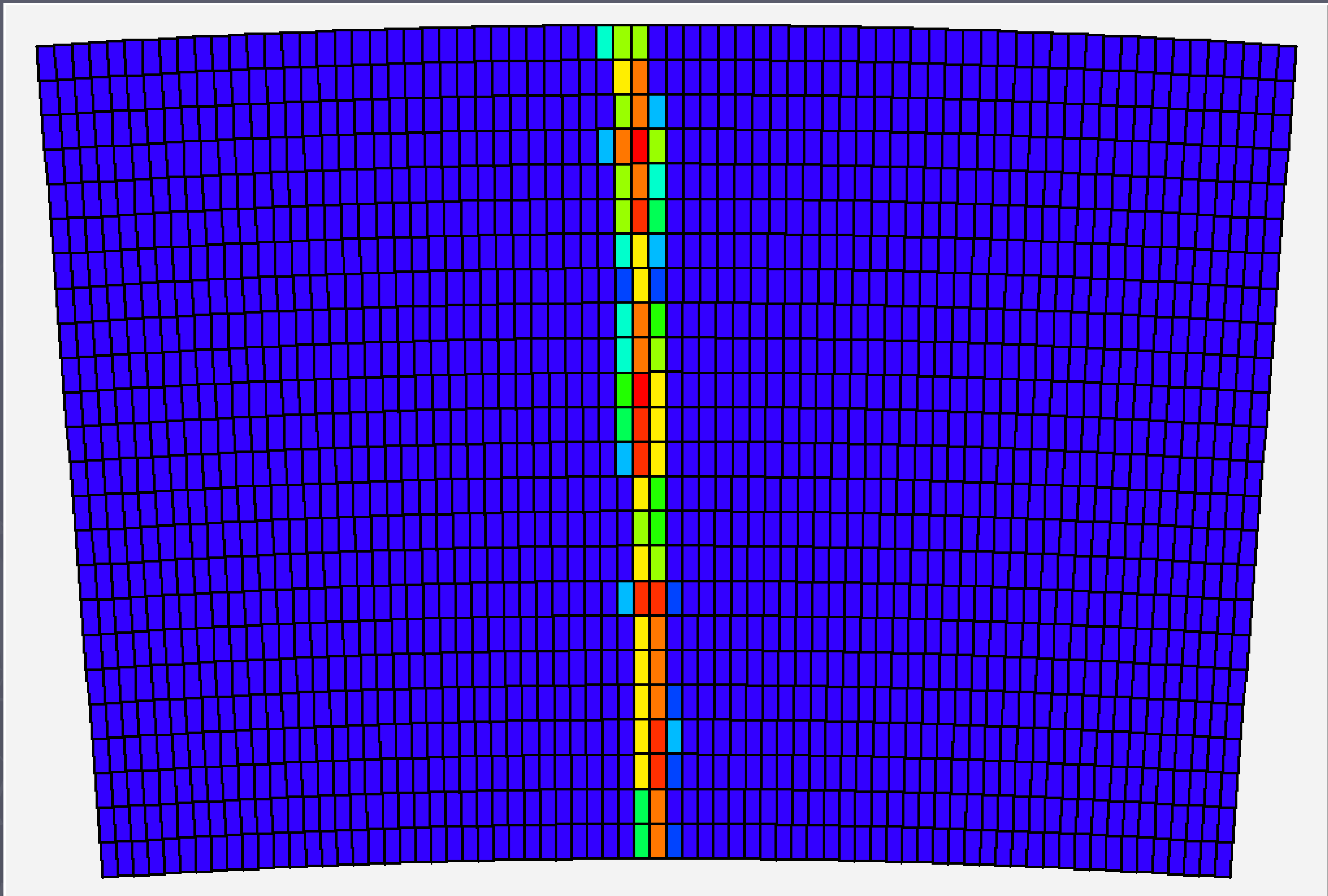
A gas system monitoring temperature, pressure, gas flow, $O_2$ and $H_2O$. (Use premixed gases.)

DAQ and slow monitor

# TPC Large Prototype Tests: LP1

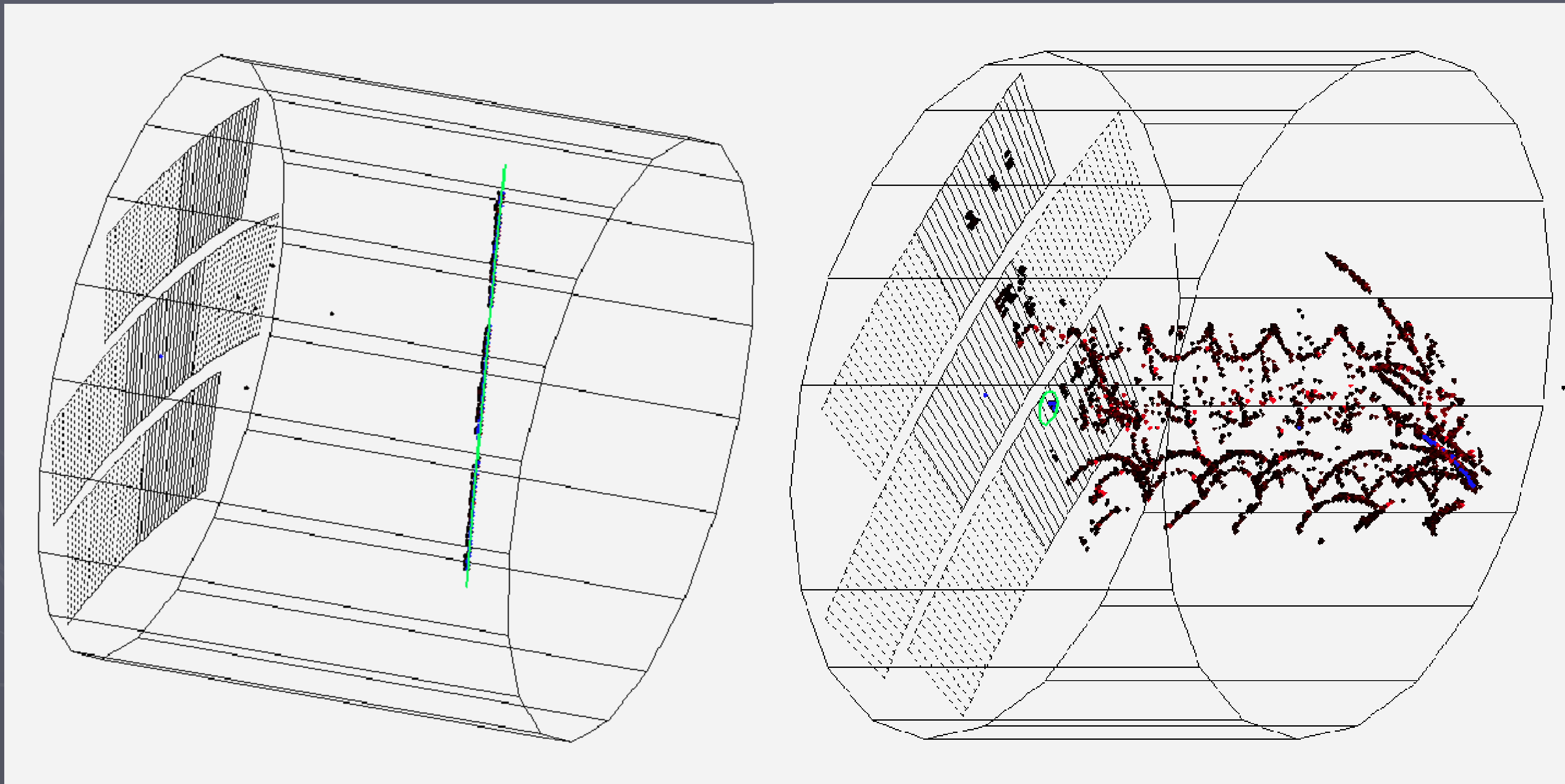
**2008:**
Nov-Dec MicroMEGAS modle w/ resistive anode (T2K electronics)
**2009:**
Feb-Apr 3 Asian GEM Modules w/o Gating GEM (3,000ch ALTRO electronics)
Apr TDC electronics with an Asian GEM Module
Apr-May Maintenance of PCMAG
May-Jun MicroMEGAS w/ two different resistive anodes (New T2K electronics)
Setup and test of laser–cathode calibration
Jun GEM+Timepix (Bonn)
Jun Installation of PCMAG moving stage and SiTR support
July TDC electronics with an Asian GEM module
ALTRO electronics study w/ an Asian GEM module
July-Aug Full installation of PCMAG moving stage
Aug MicroMegas w/o resistive anode with laser-cathode calibration
Sept A Bonn GEM module ( A small aria GEM with ALTRO electronics)
Nov MicroMEGAS with SiTR
Dec MicroMEGAS with the carbon loaded kapton resistive anode.
**2010:**
March MicroMEGAS using PCMAG movable table.
March and Sept 3 Asian GEM modules w/ gating GEM or a field shaper) using the PCMAG movable table (7616ch ALTRO electronic)

# LP1 TPC Events with a MicroMEGAS module



A MicroMGAS module: 24 rows x 72 pads ( 2.7-3.2 mm wide and 7 mm long)

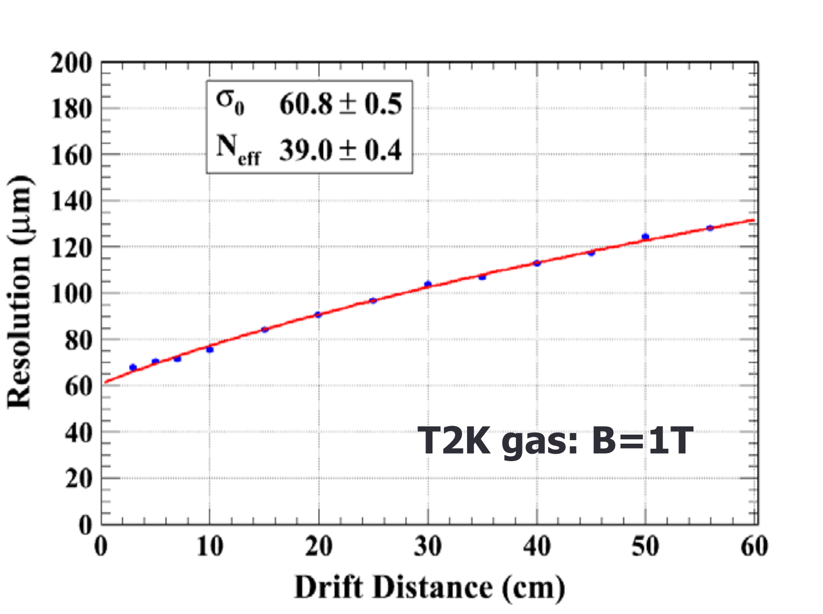
# Events of 5GeV/c Electron Beam
# LP1 TPC with Three GEM modules



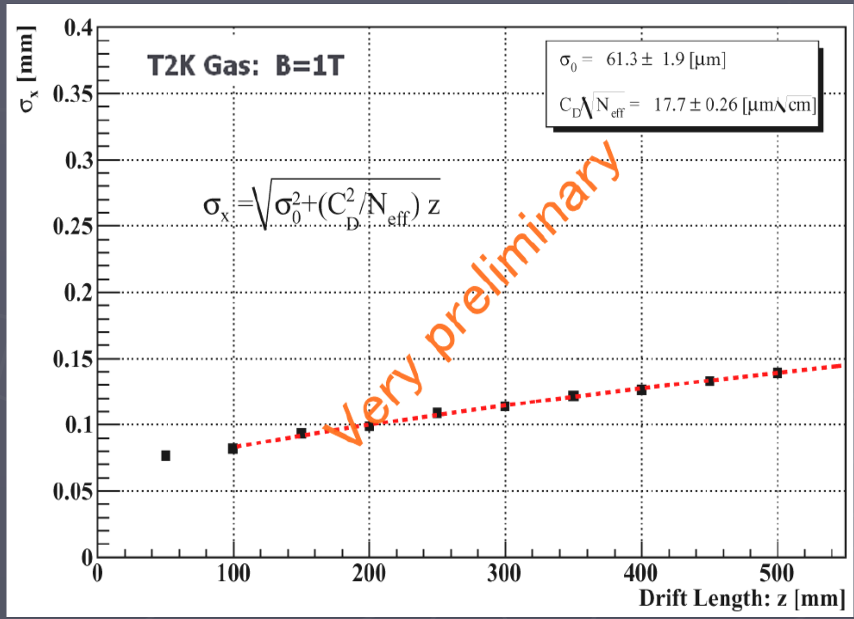
**A typical single track event (left), and an event with many low-energy curling tracks from the TPC cathode plane where a beam electron hits (right).**
**Only a part of the three GEM modules are quipped with readout electronics.**

# TPC Large Prototype Tests: LP1 (2008-2010)

## Some recent results: Point Resolutions




MicroMEGAS module with a carbon-loaded kapton resistive foil (T2K electronics)




GEM module of two layers of 100µmt GEM (PCA16-ALTRO electronics)

**A point resolution of 100µm or better for 2m drift in B=3.5T (ILD TPC)**

(Actually 80µm for the parameters obtained by MicroMEGAS )

# Software Tools

**Tracking software for multi-modules:** Toward Marlin TPC

(a) YokalowMon with Track-Finding Kalman Filter Processor:

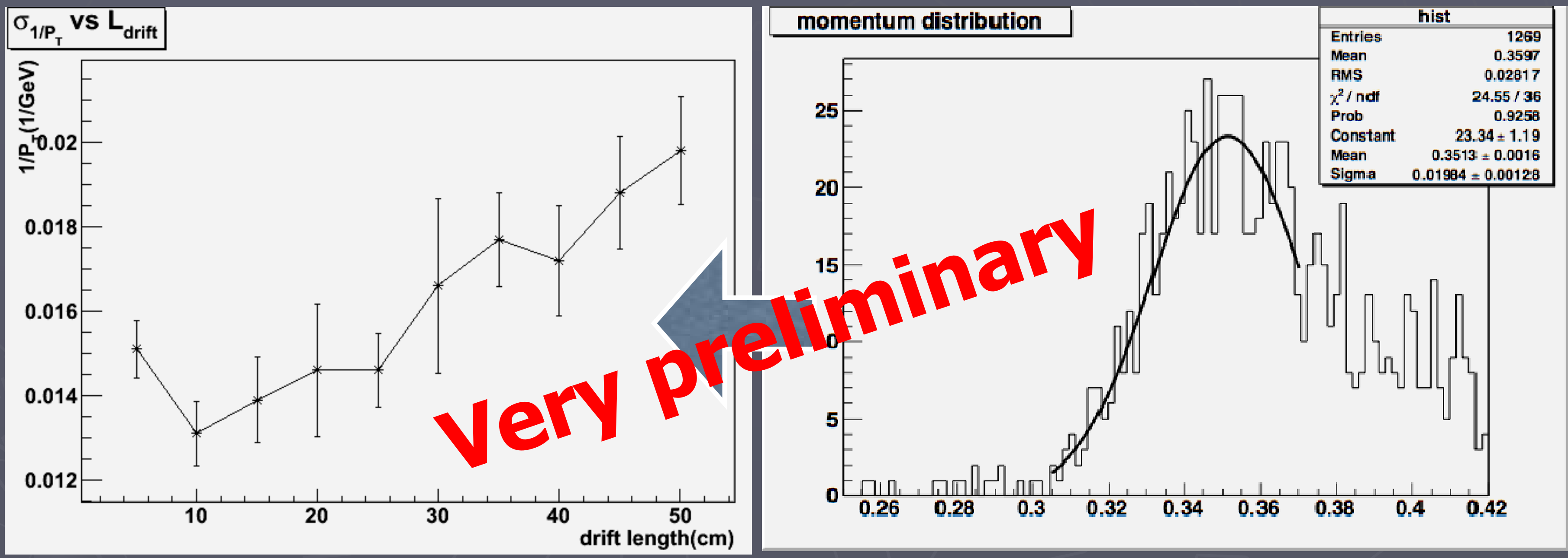
Input data: DAQ format
Use Kalman filter algorithm only in track fitting.

(b) Marlin TPC with Track-Making-Kalman-Filter-Processor:

Input data : LCIO format
Use Kalman filter algorithm both in track finding and track fitting .

**Implementation of the non-uniform magnetic filed:** Now under work!

# An Example of Initial Trials of Multi-module Track Fitting by Marlin TPC




Resolution of $1/P_t$

$1/P_t$ distribution

(No serious selection of tracks, no correction for module misalignment and distortion)

## Point Resolution and Momentum Resolution:
### Current Status of TPC LP1 Beam Test

(1) Point resolution $\sigma_{r\varphi}$: Demonstrated in the LP1

GEM & MicroMEGA with analog readout
T2K gas of low diffusion (high ωτ) in high magnetic fields

(T2K gas: Ar/CF4(3%)/isobetaine(2%))

(2) Momentum resolution: Now!

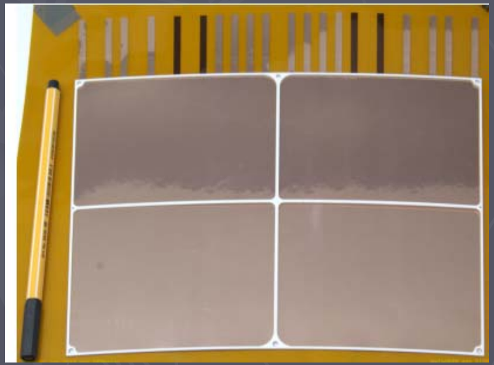
Corrections (Non uniformity magnetic field, alignment etc) to get momentum resolution match to the point resolution.

(3) Other issues:

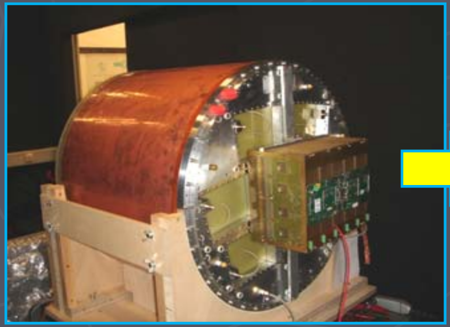
Other requirements
Performance of the digital TPC and others
……

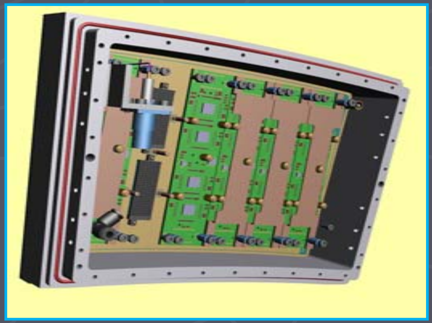
# LP1 Beam Test before 2012

| | |
|---|---|
| **2010:** | |
| **Nov-DEC** | **A prototype of DESY GEM module (A GEM module of three GEM layers supported by thin ceramic spacers)** |
| **2011:** | |
| **Spring** | **A module with 8 Ingrid Timepix (Octopus)**<br>**The first MicroMEGAS module with compact T2K electronics**<br>**More DESY GEM modules** |
| **June-Dec** | **PCMAG modification for "Liq. He less"** |
| **2012:** | **7 MicroMEGAS modules with compact T2K electronics** |



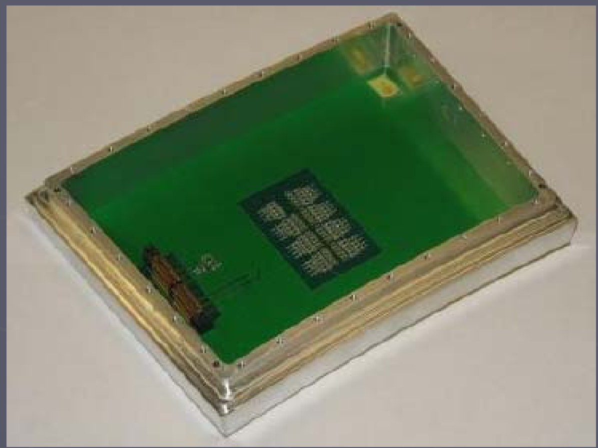
A GEM glued on a thin ceramic Spacer (DESY GEM module )

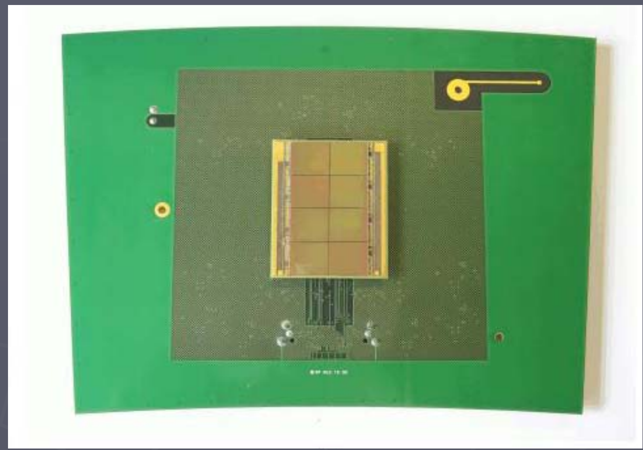


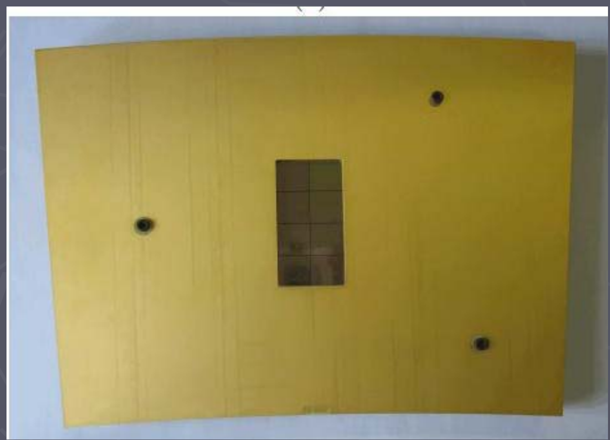


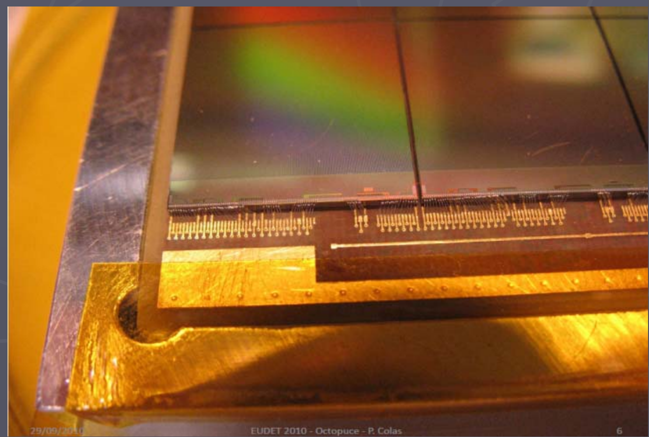
A MicroMEGAS module with compact T2K electronics

# LP1 Module with 8 Ingrid Timepix: Octopus










**To be the first test of the Digital TPC module in LP**

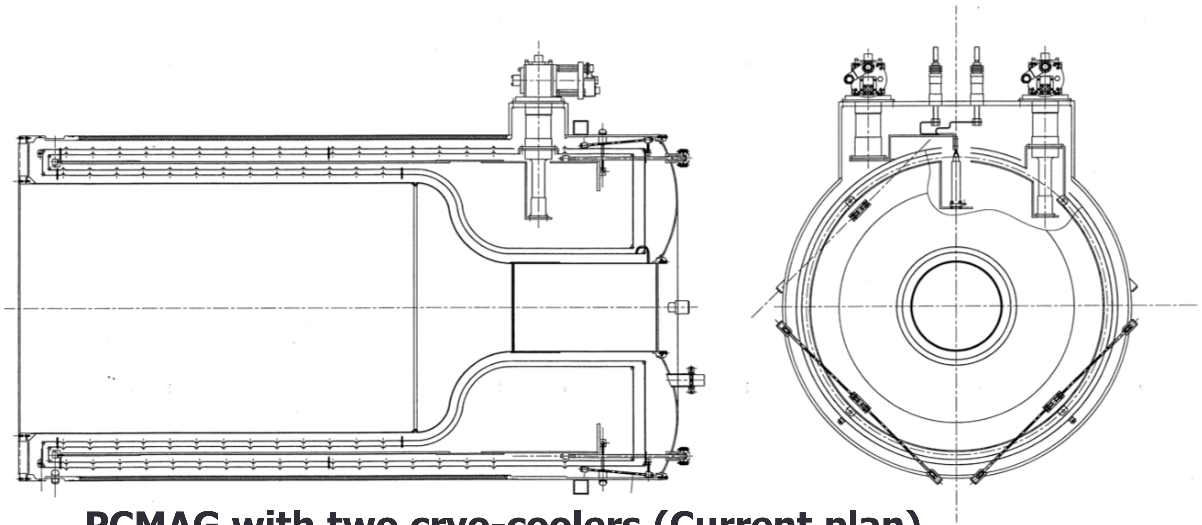
# PCMAG Modification in AIDA/DESY/KEK

## PCMAG without Liquid He (2011)

Safe, easy and efficient operation (by R&D groups)
Portability to bring to any beam line in the world

Save Liquid He (1000L for initial cooling and 250L/week)

Add two cryo-modules (for coil and current leads)
Standard way of operation (no persistent current mode)
Cost of modification: AIDA+DESY+KEK
Tentative Schedule: ready in the beginning of 2012 (6 months)



PCMAG with two cryo-coolers (Current plan)

## TPC Large Prototype Beam Test from 2012: LP1 → LP2

### Advanced endplate:

Material thickness < 25%Xo for PFA

the requirement of 15%$X_0$ may be relaxed to 20-30% based on a recent PFA study of jet energy resolution.

Thin endplate:

Light mechanical-structure of endplate.

LP Modules of high density, low power electronics to match with smaller pads (1 x 4mm): S-ALTRO electronics

Issue of power delivery, power pulsing, and cooling (2-phase CO2) with S-ALTRO mounted in the back of each module (iclude an option of direct mounting on the backside of the pad plane)

### Ion Feed back and Ion disks:

Estimate distortion due to the ion disks

→ Most probably needs a gating device

Options of gating device: Wire gating, GEM gating and others.

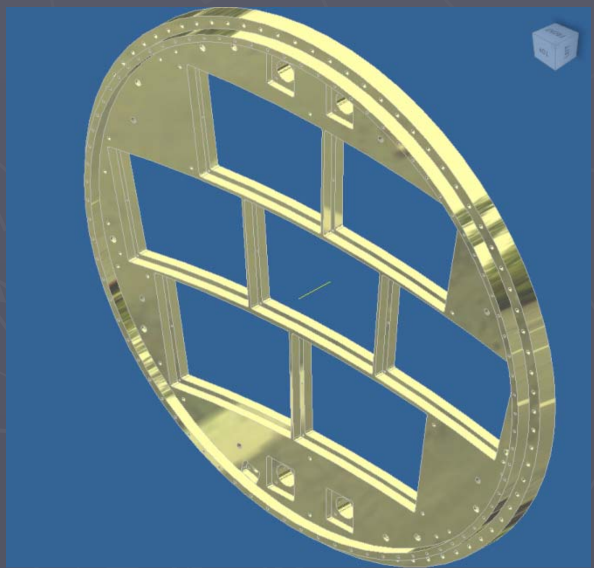
## Advanced Endplate:
## Thinning Endplate Structure (Mechanical)

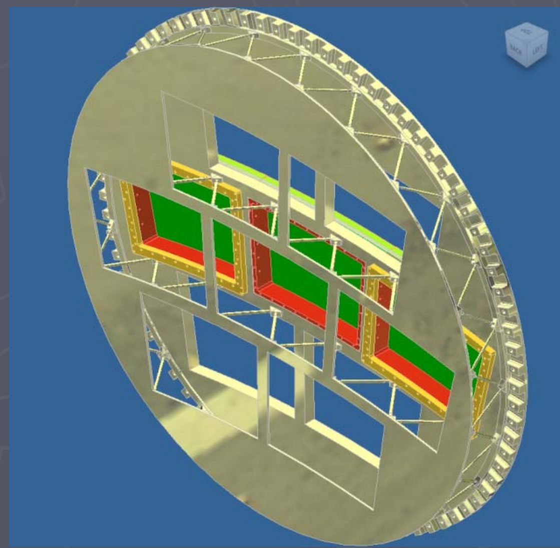
## Demonstration at Large Prototype (LP2)

Compares to **18.87 kg** aluminum for the current LP1 endplate.

2009-03-04, reported on design of the hybrid (aluminum/carbon fiber) design:
**7.35 kg** Aluminum, **1.29 kg** carbon, for LP1, 0.072 $X_0$.

Mass is currently 12kg,
but will be reduced to about **8 kg**
after thinning the uninstrumented areas.

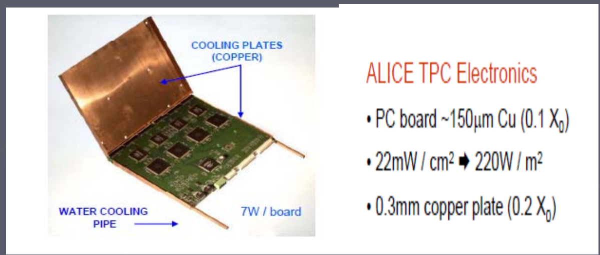


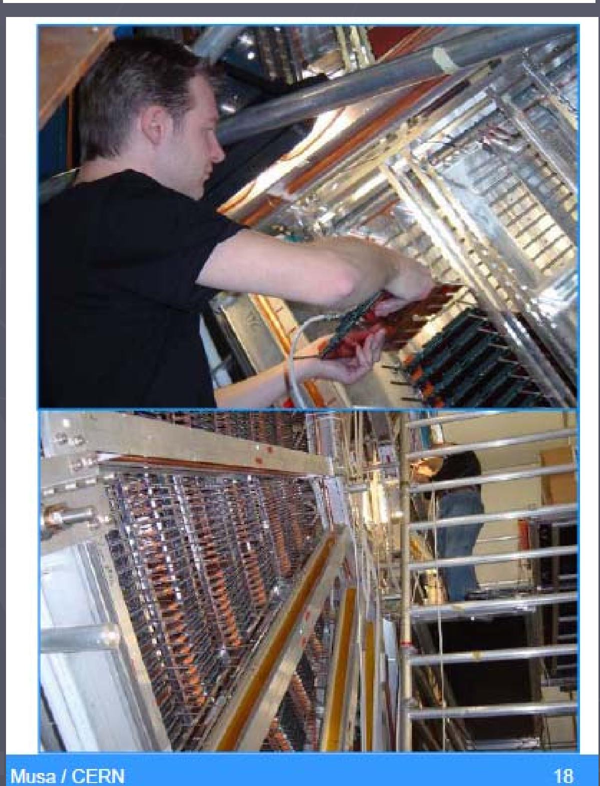


**Also the second filed cage**

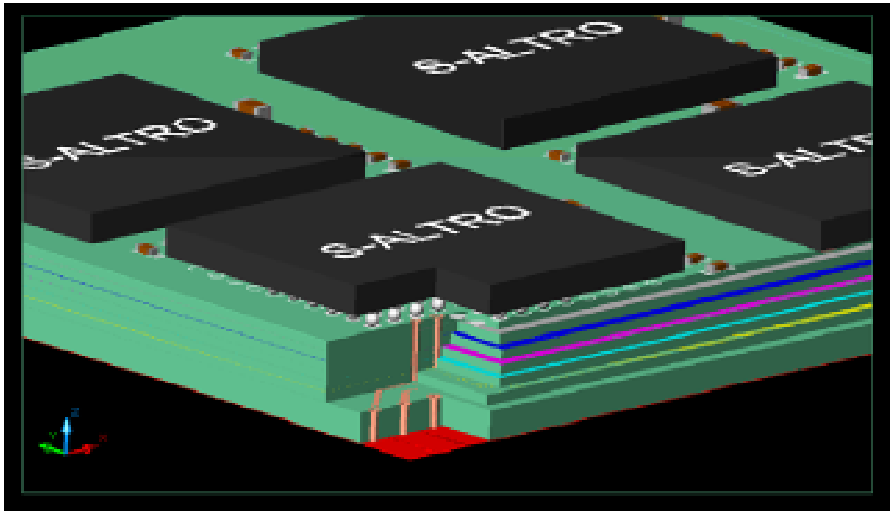
# Advanced Endplate: S-ALTRO

## _High density, low power , low material electronics for TPC




**ALICE TPC**




***The S-ALTRO team at CERN***

P. Aspell, H. Franca Santos, E. Garcia, A. Junique, M. Mager, C. Patauner, A. Ur Rehman, L. Musa

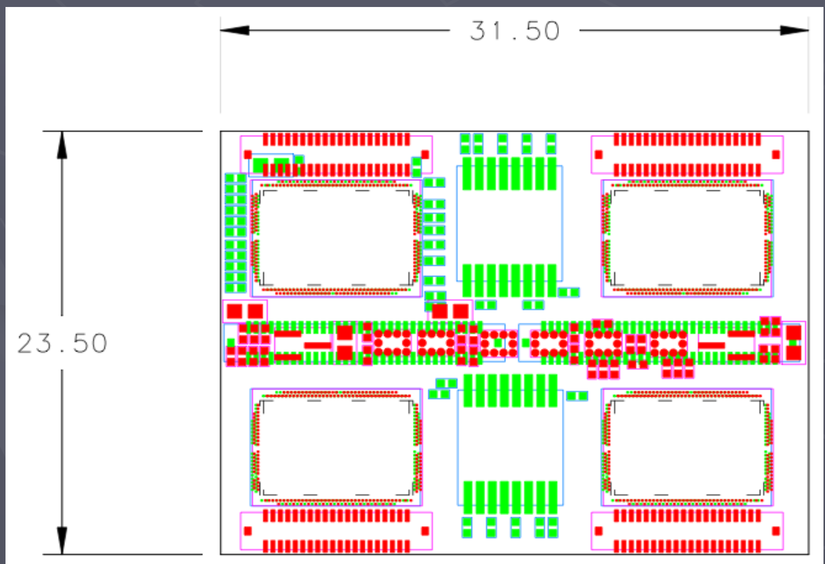
**ILC (ILD) TPC**

# Advanced Endplate:  S-Altro16 in MCM

Avoid the risk of direct bump bonding (at least in the R&D stage) with the relaxed material budget.

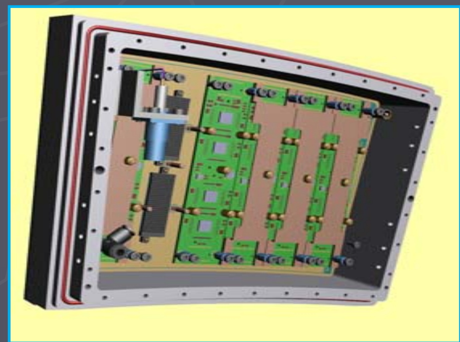
Components in red are facing the pad module whereas component is green are on the opposite side. (Note that the chip frame is the occupied bond-area and not the die size)

The dimensions of the board is compatible with a pad size of 1x6 $mm^2$. Need 64ch chip for 1 x 4mm pads in future.




S-Altro16 MCM

S-ALTRO will be used both for GEM and Micromegas



Bart Verlaat/Nikhef

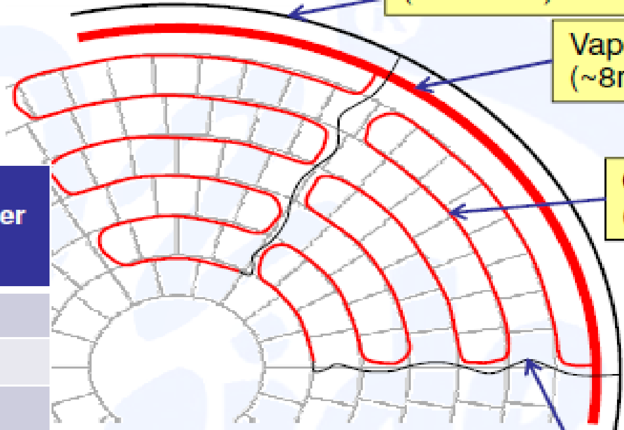
# Advanced Endplate: Cooling

## Preliminary Design Consideration for ILC TPC
## Advantage of thin piping (high pressure)

BVERLAAT@NIKHEF.NL

# TPC end plate cooling tube routing

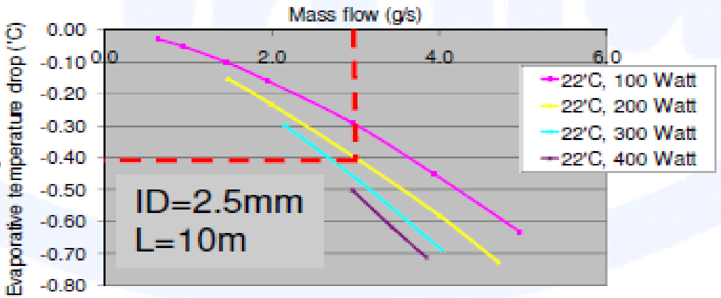
Possible layout of the 6 loops option




| | Qty Frames / loop | Heat load per loop (W) | Tube length (m) | Inner diameter (mm) |
|---|---|---|---|---|
| 1 loop | 200 | 1000 | 48m | 6.2 |
| 2 loops | 100 | 500 | 24m | 4.3 |
| 4 loops | 50 | 250 | 12m | 3 |
| 6 loops | 34 | 171 | 8m | 2.2 |

Similar to AMS-TTCS

AMS test data (2001)
0.4ºC temperature gradient




16

# Advanced Endplate:   Test with a Pad PCB Model

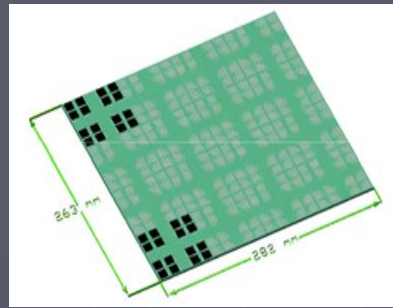
**Test:**

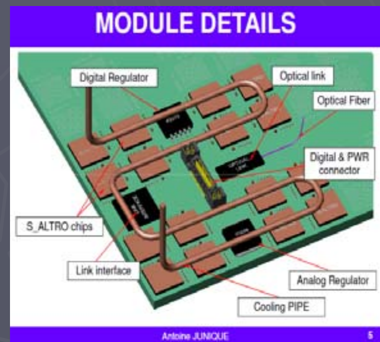
- Power switching
- Power delivery
- Cooling:
- Thermo-mechanical test
- In a high field (DESY 5T magnet, PCMAG, etc.)

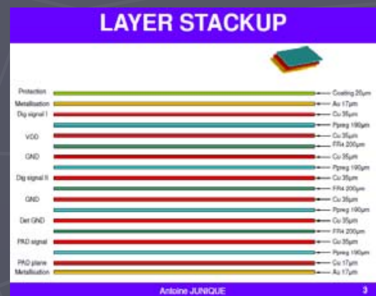
**Pad PCB model with FPGA**

- Realistic design of pad PCB with all components
- 64ch S-ALTROs replaced by proper FPGAs and
  OP amp/ADC as current load and heat source.
- Connect pads to the FPGA analog outputs
- Try cooling by the 2-phase CO2 cooling (NIKHEF)
- Test also on board software/communication
- Test in high magnetic field

**Test Schedule: 2010-2011**





# TPC Large Prototype Beam Test :
# Tentative Schedule

| | |
|---|---|
| **2010-2011** | **Continue LP1 at DESY to complete the measure of momentum resolution and others.** |
| **2011** | **PCMAG modification: Potable PCMAG without Liq. He** |
| **2012** | **Continue LP1while preparing LP2 with advanced endplate at DEST T24-1 beam line.** |
| **2012-** | **LP2 with advanced endplate (at DESY)**<br>**Possibly visit a hadron beam (10-100GeV/c) for a few months .** |

# Some Conclusions

MPGD TPC options at ILC (ILD) TPC provide a large number of space points (200) with the excellent point resolution down to 100microns over 2m drift distance. It is a truly-visual 3D tracker works in high magnetic filed providing the performance necessary for the experimentation at ILC.

The TPC Large Prototype test at DESY (LP1) by LC TPC collaboration using the EUDET facility is being carried out successfully since November 2008.

We look forward to performing momentum measurement in non uniform magnetic field of PCMAG with full length tracks in the multi modules setup in 2010-2012.

From 2012 we hopefully start the beam test (LP2) with the advanced endplate and a proper gating device. The momentum measurement will be improved using a higher energy hadron beam.