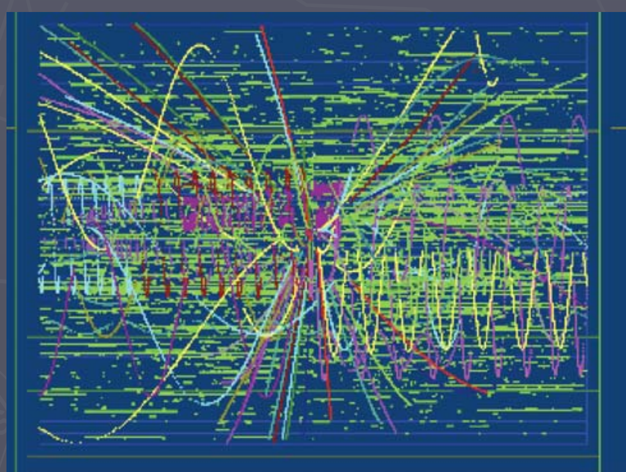
R&D's for Advanced Endplate in 2010 - 2012
(LC TPC Collaboration)

LCWS2010 Tracker Session
27 March 2010

LC TPC Collaboration
Takeshi MATSUDA
DESY/FLC & KEK/IPNS

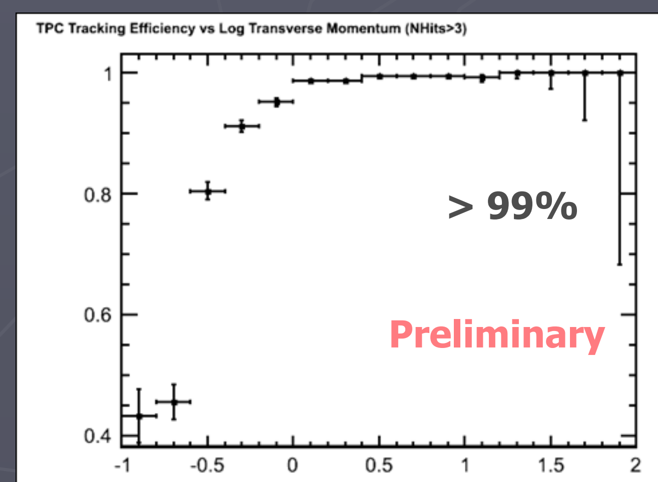
R&D Goals for ILC (ILD) TPC

- **Very high momentum resolution:** $\delta(1/pt) \leqq 9 \times 10\text{-}5$ (TPC alone)
  → 200 position measurements along each track with the point resolution of $\sigma_{r\varphi} \sim 100\mu m$ at 3.5T in a non uniform magnetic field
- **High tracking efficiency down to low momentum in significant backgrounds for PFA**
- **Minimum material of TPC for PFA : 5% X0 in barrel/15% X0 in endplate**



ttbar overlayed with 100BX of pairbackgrounds

->



Tracking efficiency w pair background (S. Aplin & F. Gaede)

Options of MPGD for ILC TPC

Based on the studies with small MPGD TPC Prototypes

Analog TPC: Immediate options if the current ILC schedule

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

(2) MicroMEGAS + Resistive anode pad:
- Widening signal by resistive anode
- 3 mm wide pads currently, but can be narrow as GEM

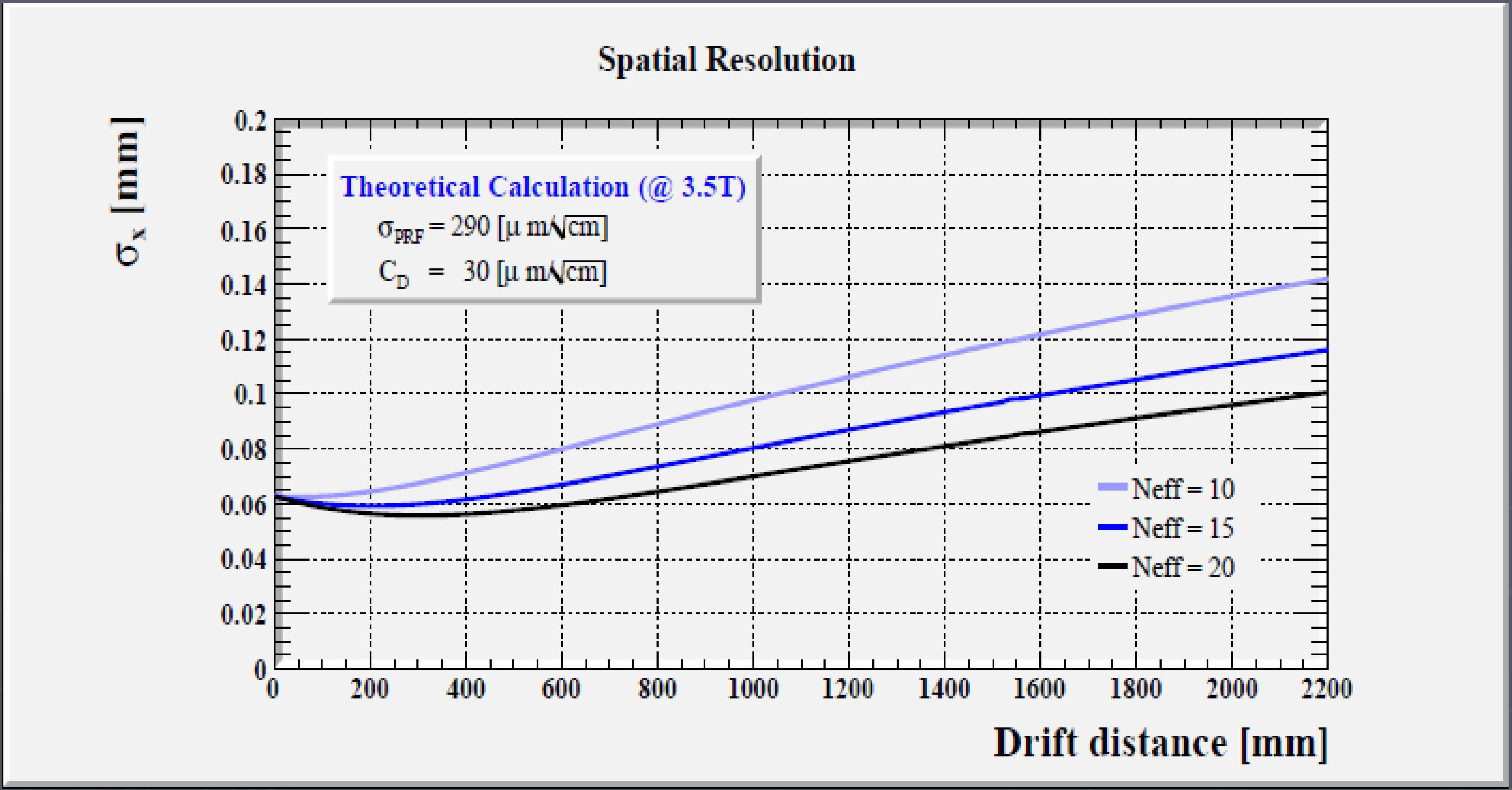
(3) Multilayer GEM + Timepix: "Small pad" analog TPC
- Need to improve the efficiency for primary electrons
- Some advantage for the pad-angular effect

Digital TPC:

(4) Ingrid-MicroMEGAS + Timepix:
- Digital → Free from the gas gain fluctuation
  - More information from primary electrons and
  - Thus better position resolution (to be demonstrated)

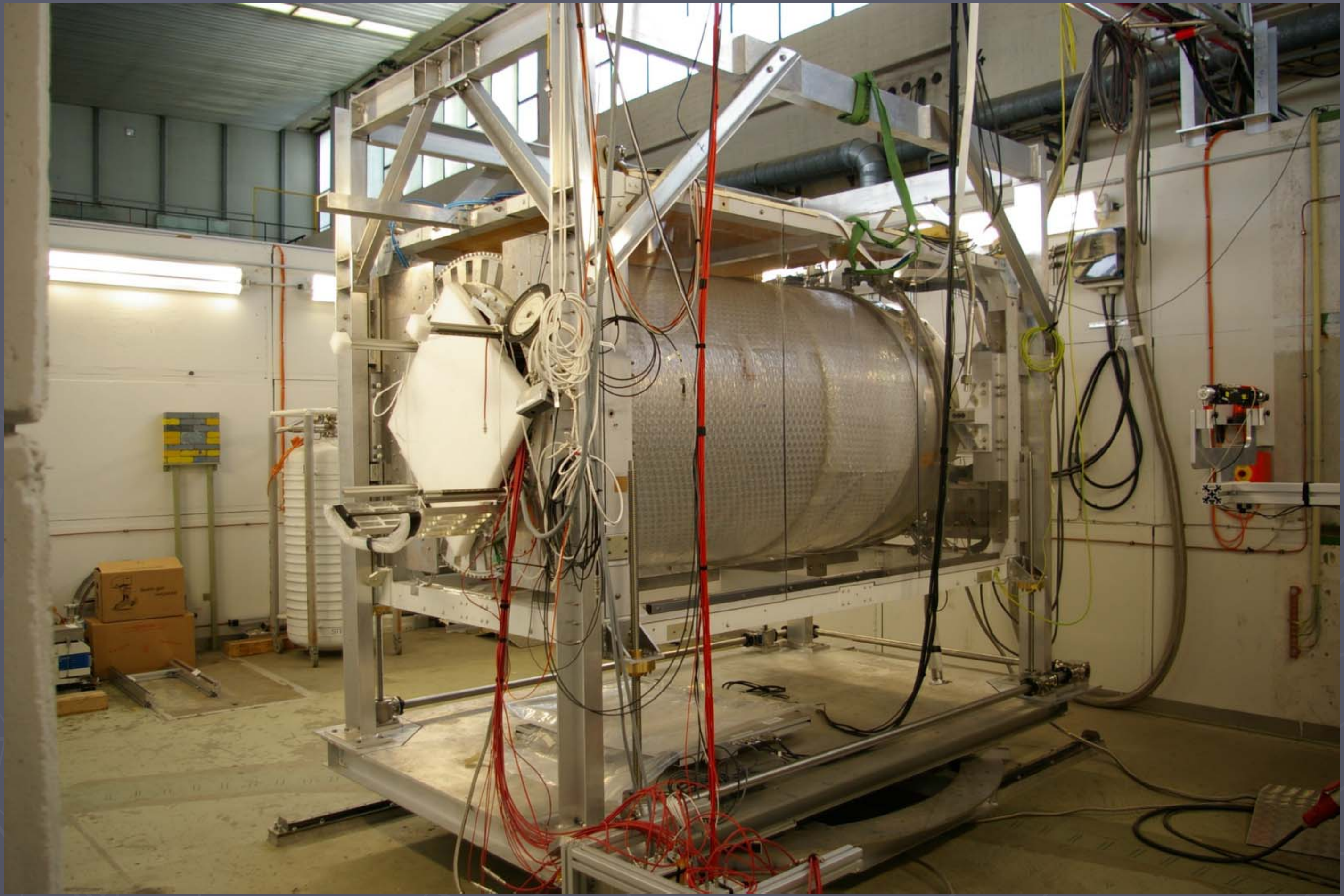
Position Resolution: Neff

Calculation for ILC TPC



These calculations are for GEM with 6mm long pads. The dependence on Neff is similar for MicroMEGAS in large drift distance. Neff, The effcetive number of primary electrons contribute to position resolution, measured both for MicroMEGAS and GEM are around 20 (@1T).

TPC Large Prototype Beam Test (LP1)



LP1 at DESY T24-1 beam area

Please refer to Klaus Dehmelt' stalk

Point Resolution and Momentum Resolution

TPC Large Prototype (LP) at T24-1 beam line at DESY

(1) **Point resolution $\sigma_{r\varphi}$ OK : 2008- 2009**

← MPGD TPC (GEM & MicroMEGA with analog readaout)
← Gas of low diffusion (high ωτ)： Ar:CF4:Isobutene （T2K gas)

Commissioned the TPC LP prototype (@1T PCMAG)
Tested larger area MicroMEGAS (2009) with new resistive anodes, and GEM.
Commissioned two new PAD electronics; ALTRO with new preamp PAC16 and new T2K electronics. Found their excellent performances.
Precision mapping of PCMAG (2008).
Tested MPGD with Timepix readout (digital TPC)
First test of a calibration method of laser–cathode pattern (2009).
First test with Si envelop (2009).

(2) **Momentum resolution : 2010 (-2011)**

Non uniformity magnetic field of PCMAG (in purpose → ILC)
← Distortion of other sources: Field cage, Module and else.
← MPGD Module boundary
← Tracking Software for the non uniform magnetic field
← Performance of the different MPGD modules.

TPC Large Prototype Beam Test: LP1 in 2010

"Demonstrate full-volume trucking in non-uniform magnetic field, trying to provide a proof for the momentum resolution at LC TPC"

2010:

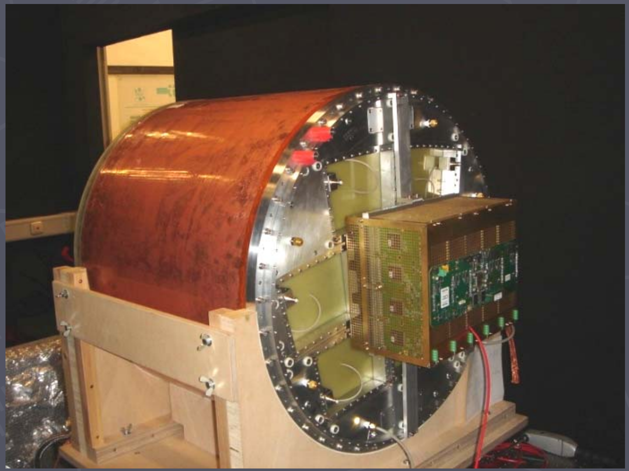
Spring-Summer

3-4 Asian GEM Modules w/ gating GEM   (10,000ch ALTRO electronics)

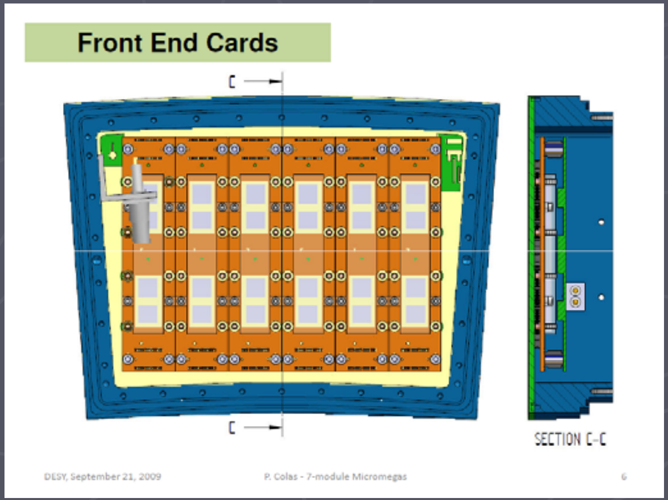
DESY GEM modules (w/ wire gating?)   (10,000ch ALTRO electronics)

Fall   7 MicroMEGAS modules w/ resistive anode (12,000ch T2K electronics)

MicroMEGAS module 2008-2009



Over sized electronic in 2008-2009



MicroMEGAS modules in 2010

(Unfortunately T2K electronics can not be used at ILC TPC!)

TPC Large Prototype Beam Test in 2010-2012

Current Plan: Note that modified since LCWA09

2010 Continue LP1 test at DESY

2011- 2012: Prepare for DBD staying at DESY

→ Limitation using electron beam to measure momentum

→ Make PCMAG to be Liq He less in 2011. Possibility to move LP-PCMAG after 2012.

→ Build a second field cage with some improvement for ILC

→ LP beam test with TPC "Advanced Endplate" hopefully (need resources!)

→ Optional and small scale beam tests at higher energy hadron beams.

To Prepare TPC design for DBD: New Work Package

To prepare for the DBD, this structure will be supplemented with fifth workpackage:

Workpackage (5) LCTPC preparations for DBD	Convener
a) Advanced endcap mechanics + alignment	Dan Peterson
b) Advanced endcap with SAltro, cooling, power pulsing	Luciano Musa
c) Gating device	Akira Sugiyama
d) Fieldcage	Peter Schade/ Klaus Dehmelt
e) ILD TPC Integration	Robert Volkerborn/ Michael Carty
f) LCTPC Software	Christoph Rosemann
g) Testbeams	Takeshi Matsuda

Coveners of the new workpackages overlap significantly with the previous structure because the issues are closely related. The new workpackages are meant to specifically guide the DBD preparations; more explanation is presented in Section 3.3.2.

Two Important R&D Issues for DBD

Advanced endplate:

Requirement: thickness <=15% Xo for calorimetry (PFA)

Still need to be confirmed the requirement by PFA simulation.

Thin endplate:

Light mechanical-structure of endplate.

High density, low power electronics to match with small pads (1 x 4mm): S-ALTRO

Surface-mount of S-ALTRO directly on the back of pad plane of MPGD detector module, and issue of power delivery, power pulsing and cooling (2-phase CO2)

Goal: LP beam test with the advanced endplate (need sufficient funding)

Ion Feed back and Ion disks:

Ion feed back ration and beam backgrounds

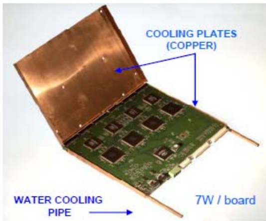
Estimate distortion due to the ion disks.

Options of gating device: Wire gating, GEM gating

Methods of calibration and correction

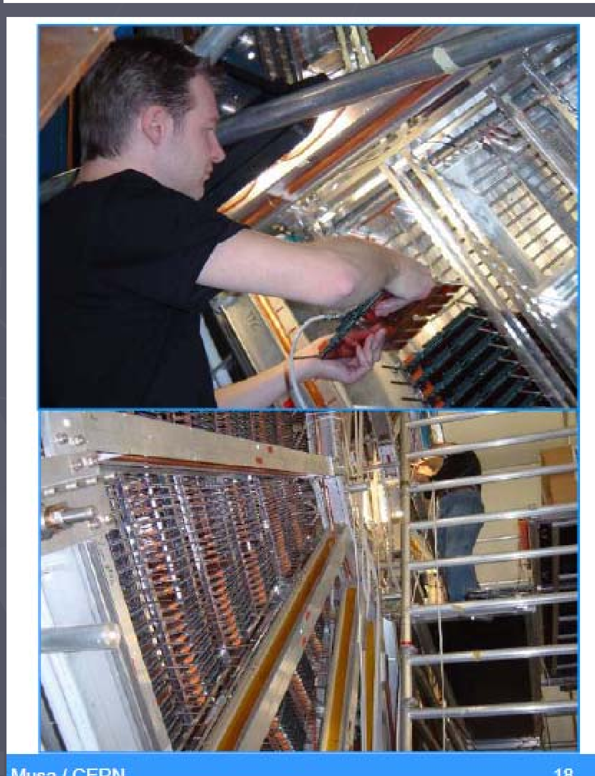
Advanced Endplate: S-ALTRO

High density, low power , low material electronics for TPC

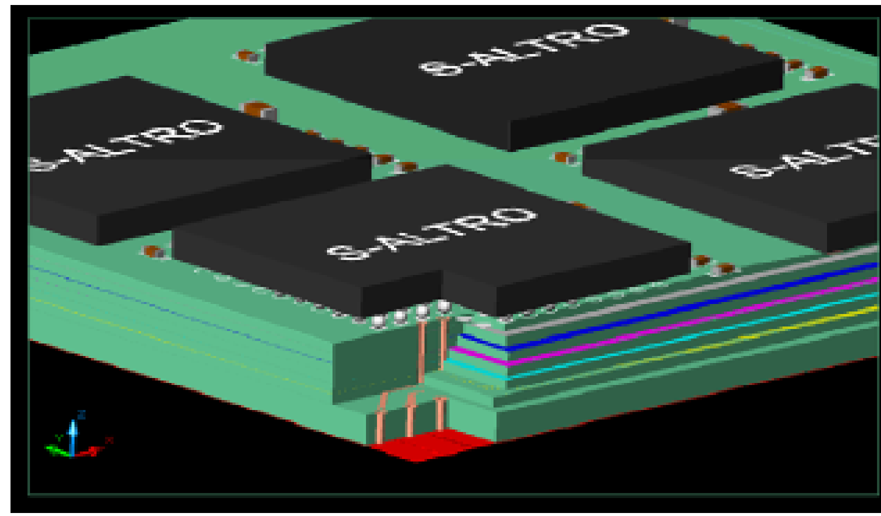


ALICE TPC Electronics

- PC board ~150μm Cu (0.1 X_0)
- 22mW / cm² ➧ 220W / m²
- 0.3mm copper plate (0.2 X_0)



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

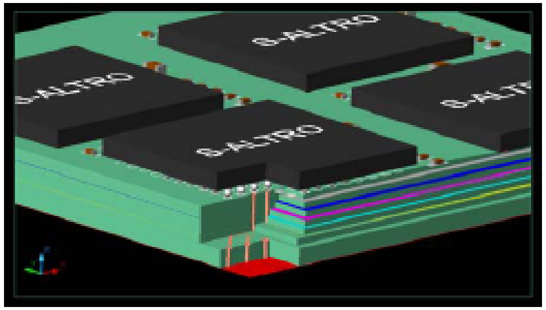
ILC (ILD) TPC

Advanced Endplate: S-ALTRO

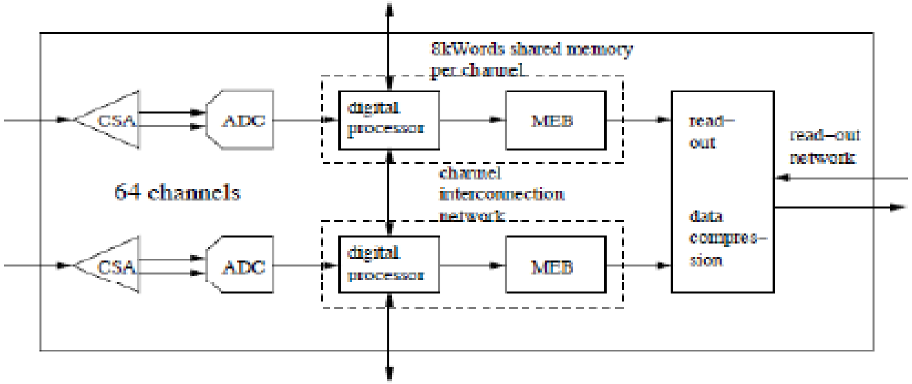
High density, low power electronics for TPC

A multi purpose readout chip for TPC detectors

A multi-purpose readout chip for TPC detectors



- 64 complete readout channels (from detector pad to data link)
- programmable charge sensitive amplifier
  - sensitivity to a charge in the range ~10^2 - ~10^6
  - programmable shaping time in the range 30 to 300ns
- 10-bit 40 MSPS ADCs
- 8k multi acquisition memory per channel (dynamically allocated)
- digital signal conditioning (4th order IIR filter and FIR filter) for baseline correction
- 3-D zero suppression
- lossless data compression
- readout net work controller
- output bandwidth 160 Mbyte/sec



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Advanced Endplate: S-ALTRO

Chip size and Power consumption

L. Musa

Chip size: (*estimate)

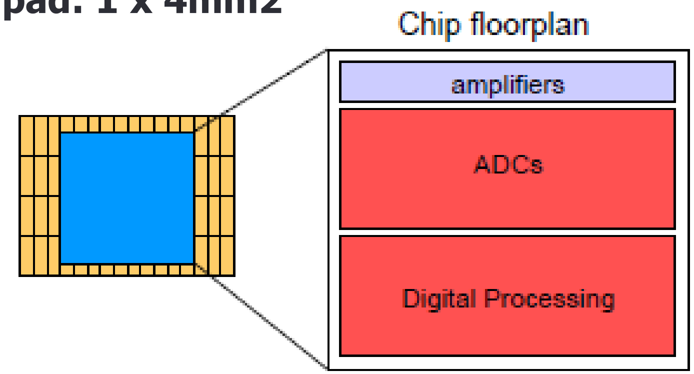
Shaping amplifier 0.2 mm^2
ADC 0.7 mm^2 (*)
Digital processor 0.6 mm^2 (*)
When 1.5mm^2/channel
64 ch/chip ➡ ~ 100 mm^2

PCB board ~ 27 x 27 cm^2
⇨ ~16400 pads or 256 chips/board
Bare die flip-chip mounted or chip scale package
Minimum-size capacitors (0.6x0.3x0.3mm3)
Standard linear voltage regulators
Data link based on ALICE SPD GOL MCM

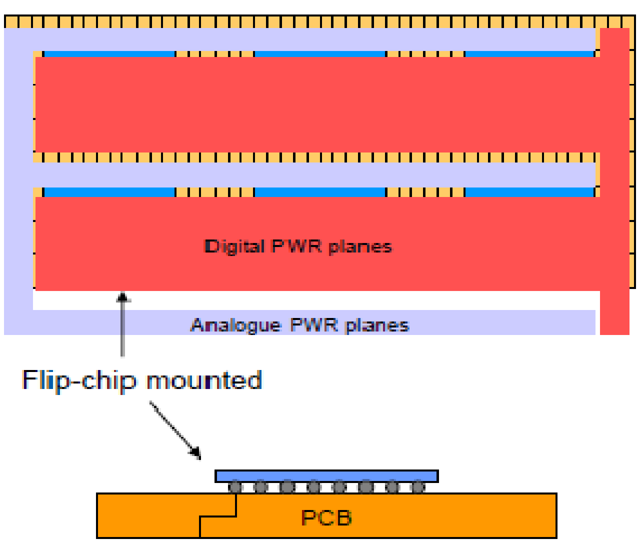
Power consumption: (*) 10 -40MHz

Amplifier	8 mW/channel
ADC	12-34 mW/channel (*)
Digital Proc	4 mW/channel
Power reg.	2 mW/channel
Data links	2 mW/channel
Power reg. eff.	75%
Total	32-60mW/channel (*)
Duty cycle:	1.5% (Electrical duty)
Average power	0.5 mW / channel
	100 -200W/m2 (*)

pad: 1 x 4mm2



PCB topology and layer stack-up



Advanced Endplate: S-ALTRO
Status and Schedule

Status & Plans

Status

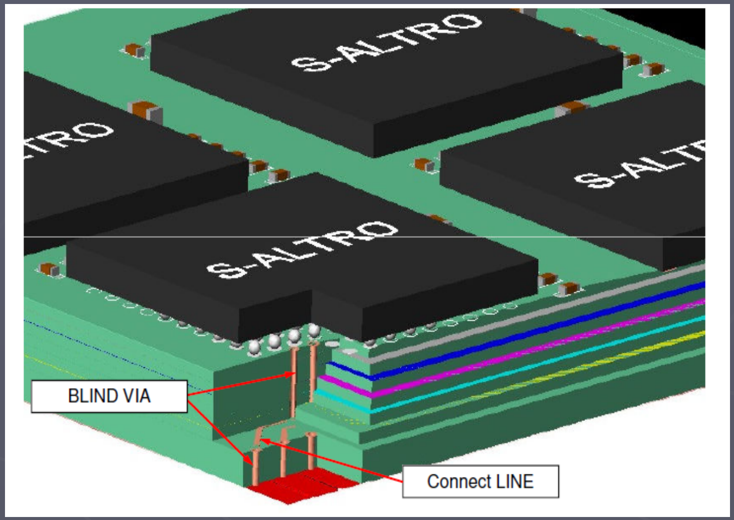
- 2006 12-channel prototype of CSA (no programmability)
- 2007 16-channel prototype programmable (1000 chips for LPTPC @ Desy)
- 2009 2-channel ADC prototype (samples expected in June)
- 08/09 specifications digital blocks and design entry (Verilog) of data processor
- 2009 first design of readout board

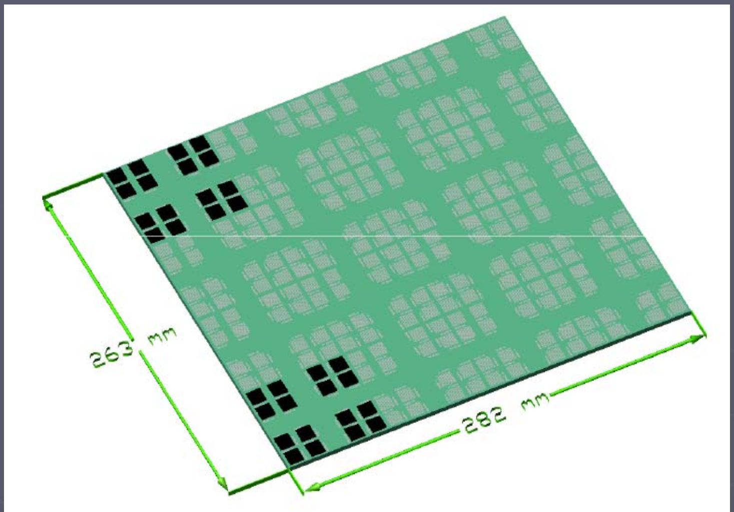
Plans

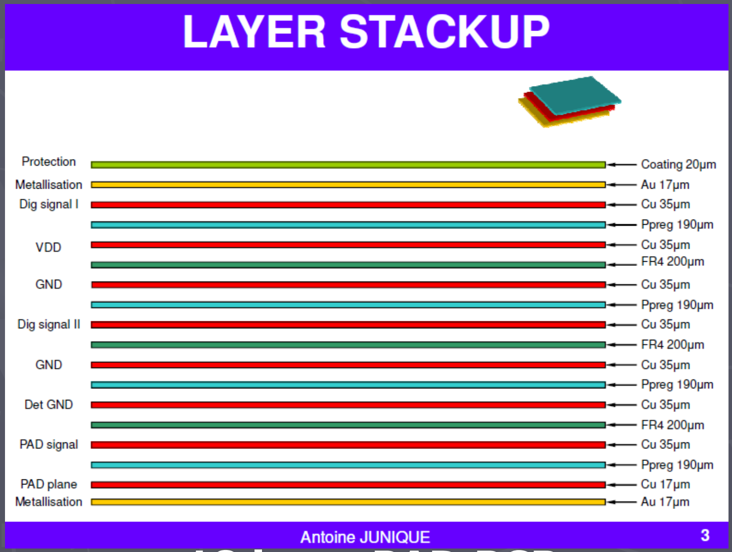
- 2009
  - characterization of ADC samples (Jul – Aug)
  - optimization of ADC design or ADC IP (S3) and migration to IBM 130nm
  - design of 16-channel of complete readout chain (with simplified digital processor)
- 2010
  - characterization of 16-channel prototype
  - decide how to continue the project according to the results achieved

Advanced Endplate: S-ALTRO

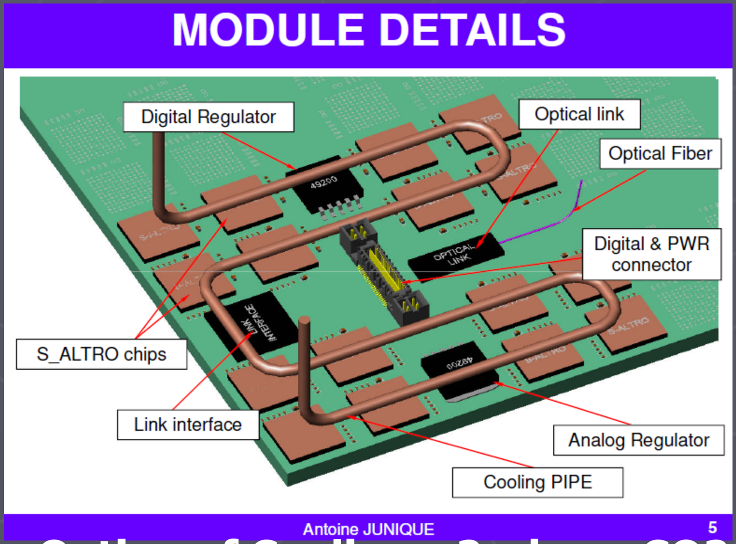
Design of Pad Board







18 layer PAD PCB



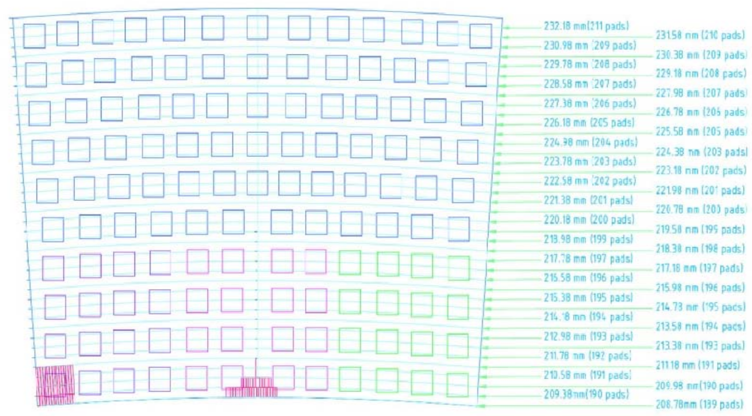
Option of Cooling: 2-phase CO2 cooling/traditional H2O cooling

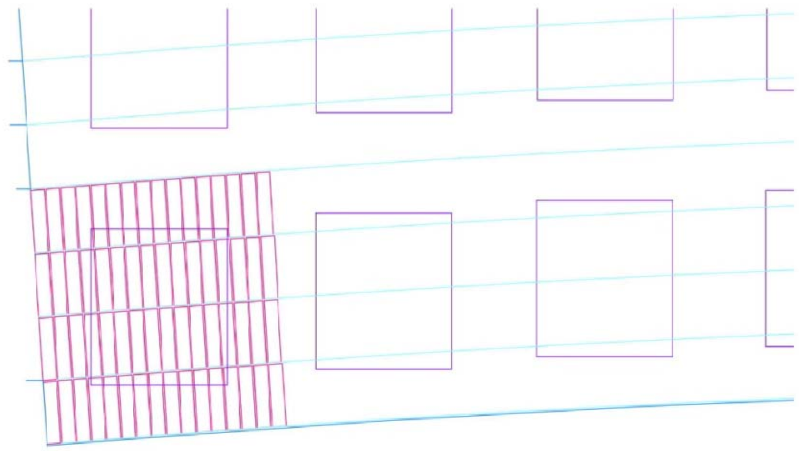
A. Junique

Advanced Endplate: S-ALTRO

Design of Pad Board

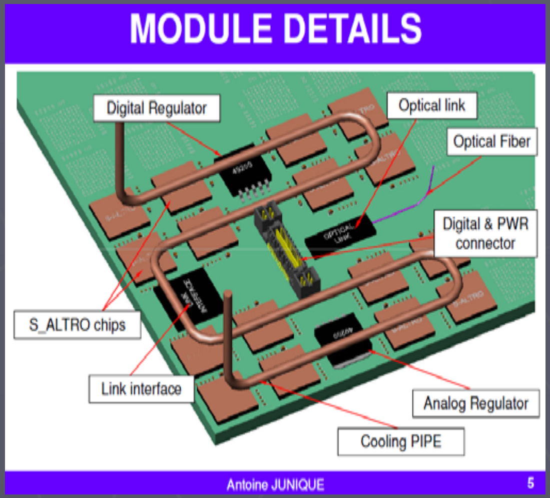
For TPC Large Prototype Module





Advanced Endplate: PCB Test
Test with Dummy Pad PCB

S-ALTRO Team
LC TPC groups



Test:

Power switching
Power delivery
Cooling:
Thermo-mechanical test of pad PCB

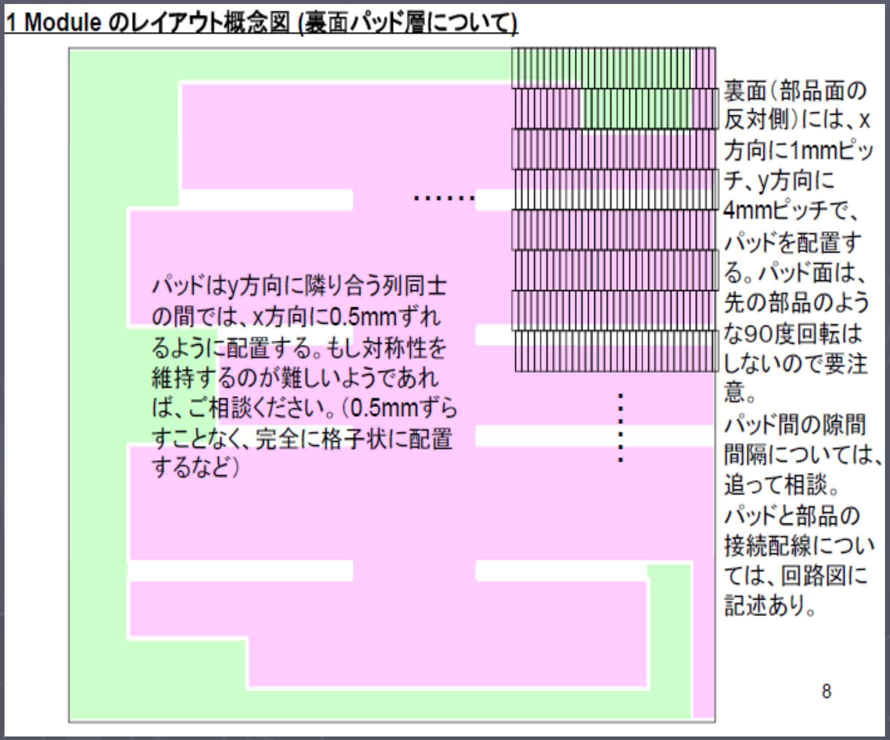
Dummy Pad PCB:

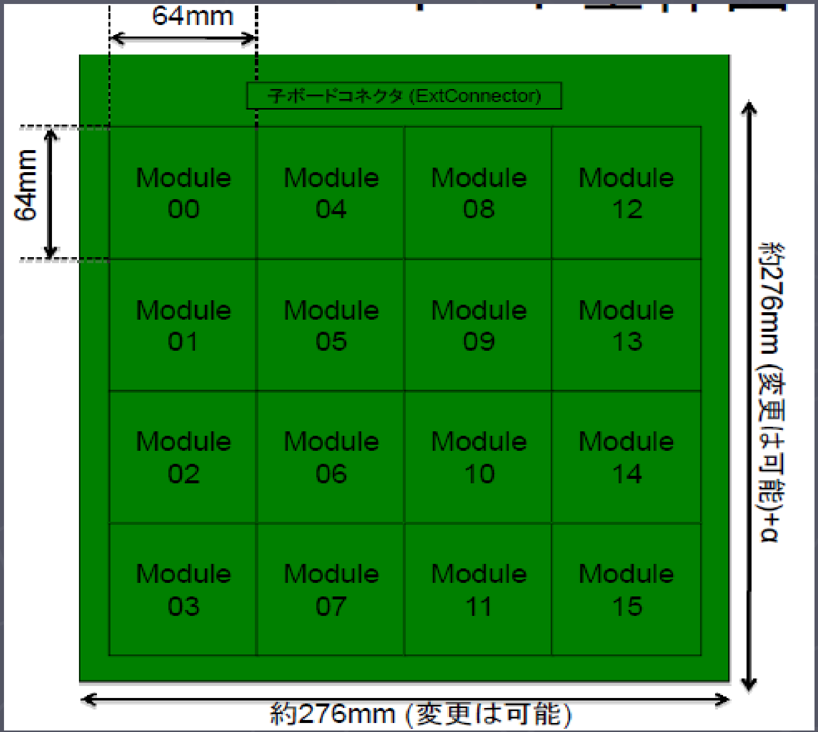
Realistic design of pad PCB with all components
64ch S-ALTROs replaced by proper FPGAs and OP amp/ADC as current load and heat source.
Connect pads to the FPGA analog outputs
Try cooling by the 2-phase CO_2 cooling (AMS and LHCB: Bart Verlaat/Nikhef)
Test also digital software model/communication in FPGA
Test in high magnetic field

Schedule: 2010

Advanced Endplate:　PCB Test
Test with Dummy Pad PCB

S-ALTRO Team
LC TPC groups
T. Fusayasu

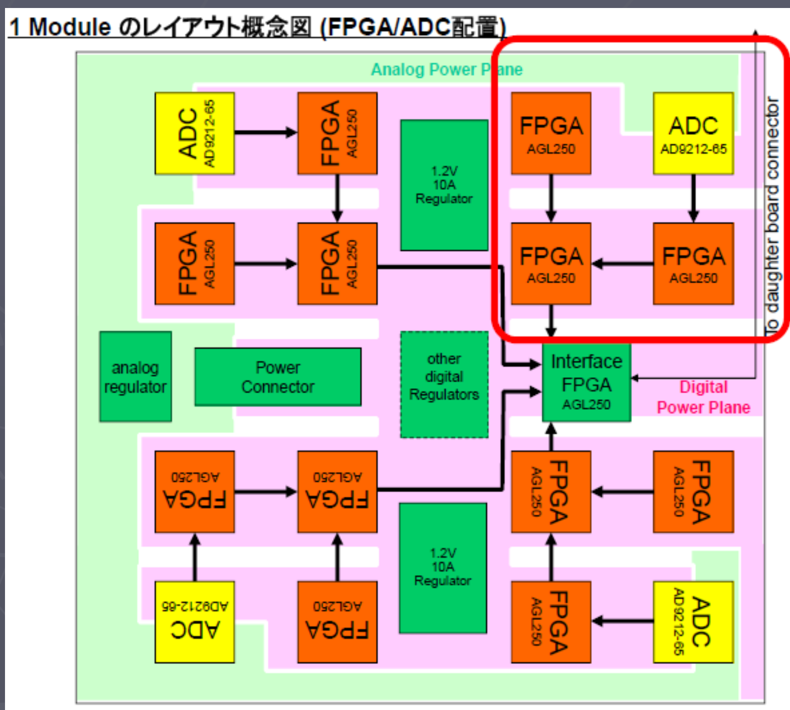


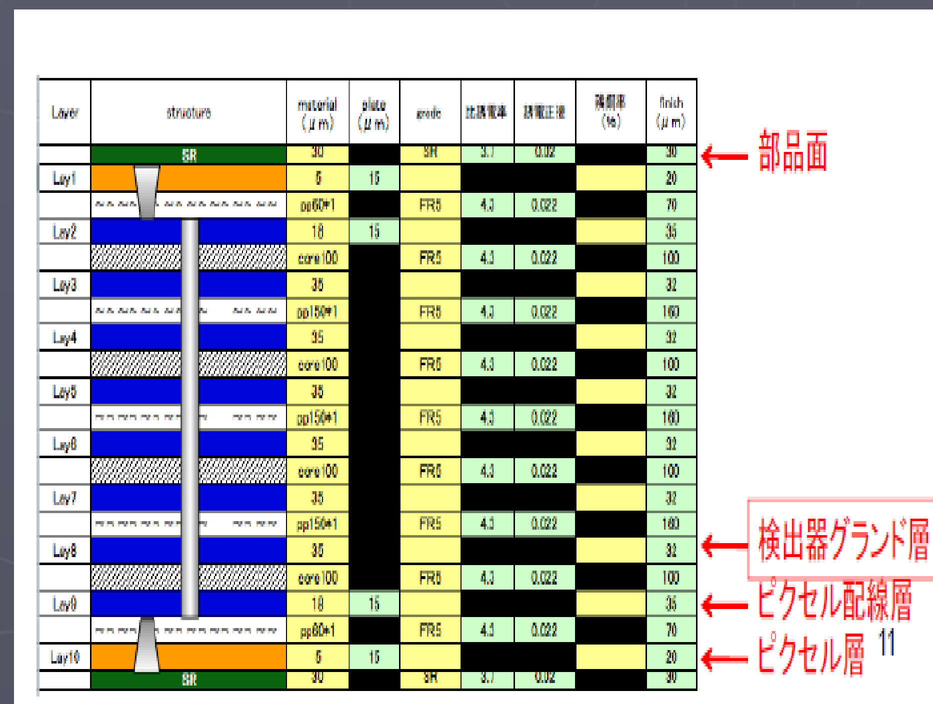


S-ALTRO Team
LC TPC groups
T. Fusayasu

Advanced Endplate: PCB Test

Test with Dummy Pad PCB





Layer	structure	material (μm)	plate (μm)	grade	比誘電率	誘電正接	残銅率 (%)	finish (μm)
	SR	30		SR	3.7	0.02		30
Lay1		5	15					20
		pp60*1		FR5	4.3	0.022		70
Lay2		18	15					35
		core100		FR5	4.3	0.022		100
Lay3		35						32
		pp150*1		FR5	4.3	0.022		160
Lay4		35						32
		core100		FR5	4.3	0.022		100
Lay5		35						32
		pp150*1		FR5	4.3	0.022		160
Lay6		35						32
		core100		FR5	4.3	0.022		100
Lay7		35						32
		pp150*1		FR5	4.3	0.022		160
Lay8		35						32
		core100		FR5	4.3	0.022		100
Lay9		18	15					35
		pp60*1		FR5	4.3	0.022		70
Lay10		5	15					20
	SR	30		SR	3.7	0.02		30

Advanced Endplate: S-ALTRO
Power switching

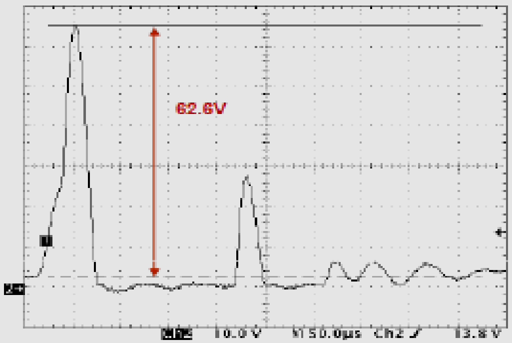
L. Mussa
T. Fusayasu

A case of digital power switching in ALICE

2. Power Pulsing

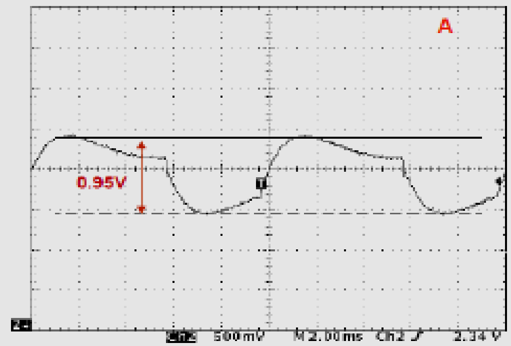
Configuration A
R = 0, C=0

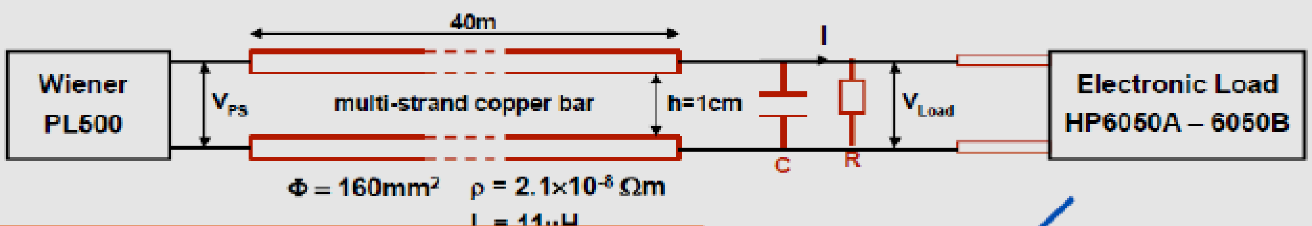
Sudden interruption of current can damage FEE



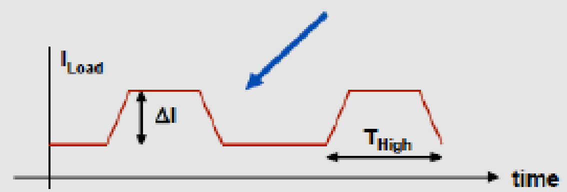
Configuration C
R = 25mΩ, C=70mF

70mF in parallel to load can absorb the large spikes





To be tested with a system very similar to the real (S-ALTRO based) end-plate.



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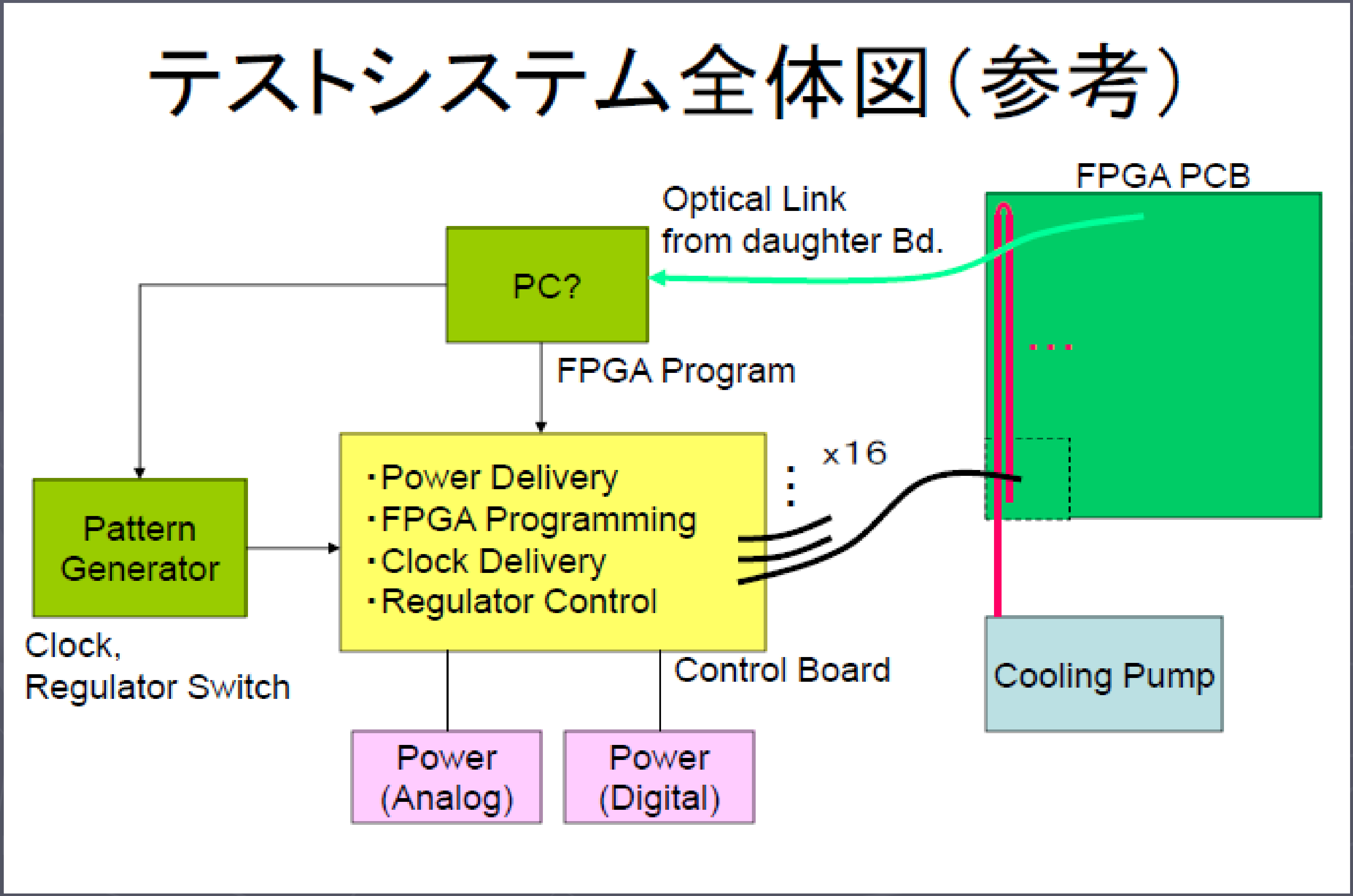
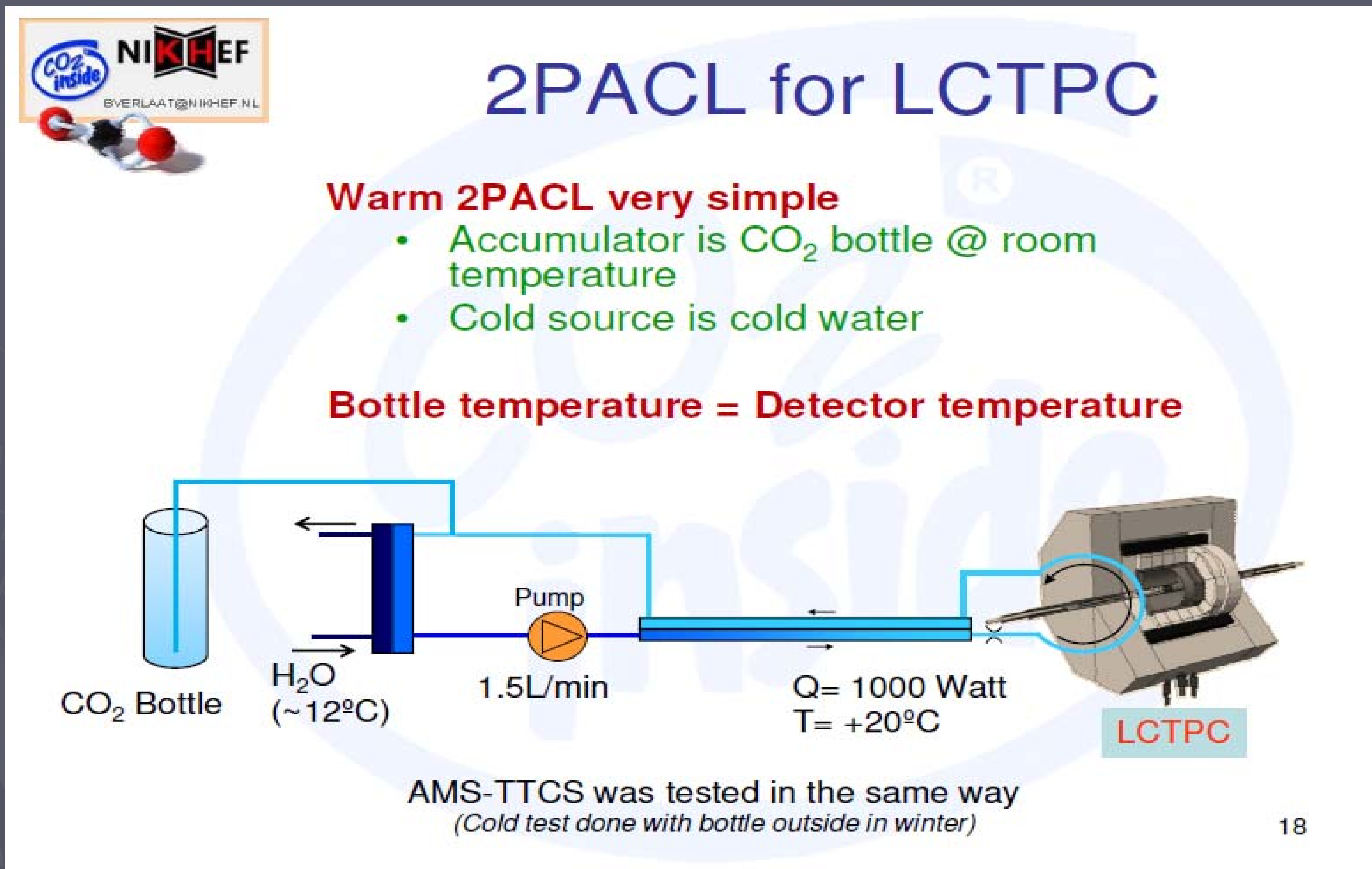
Advanced Endplate: PCB Test
Test with Dummy Pad PCB

S-ALTRO Team
LC TPC groups
T. Fusayasu



Bart Verlaat/Nikhef

Advanced Endplate: Cooling
Option of the 2-phase CO2 cooling



Applied to AMS and LHCb

Bart Verlaat/Nikhef

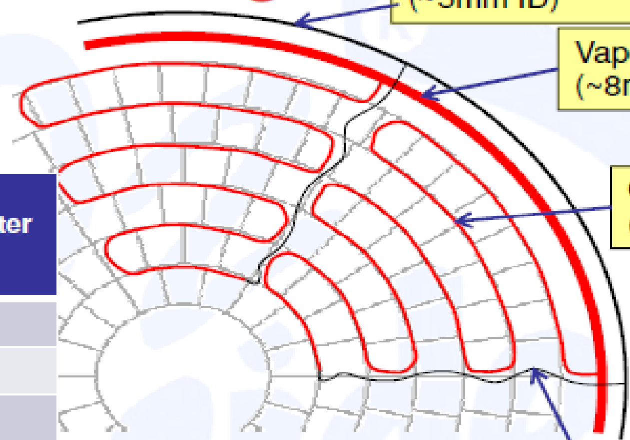
Advanced Endplate: Cooling

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

NIKHEF
BVERLAAT@NIKHEF.NL

TPC end plate cooling tube routing

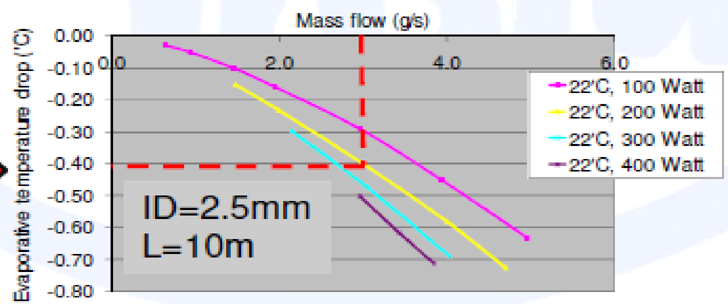
Possible layout of the 6 loops option



	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



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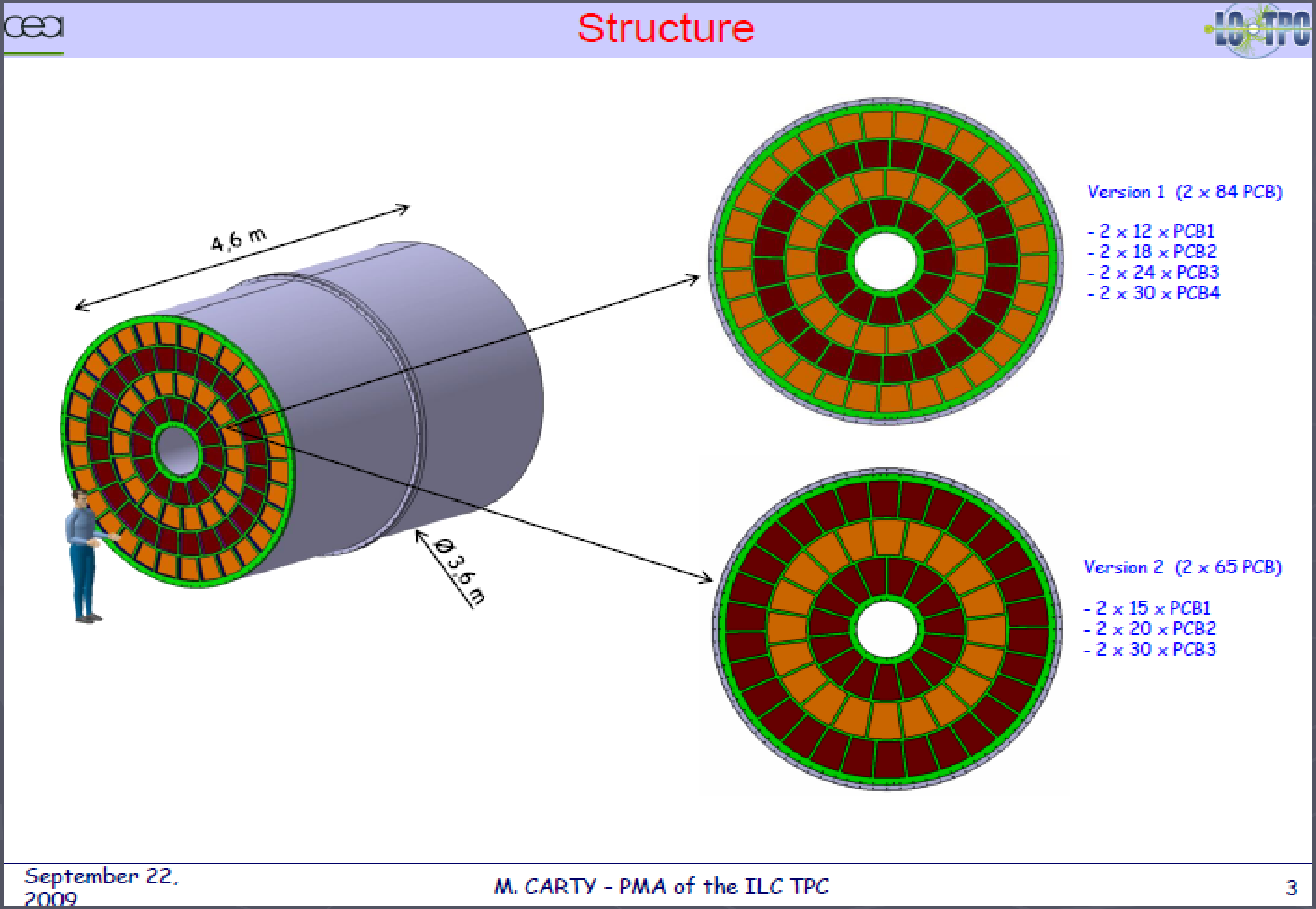
ILC (ILD) TPC: Design Issues

M. CARTY
(R. Volkenborn)

Design of TPC (Field Cage)
Size of MPGD module



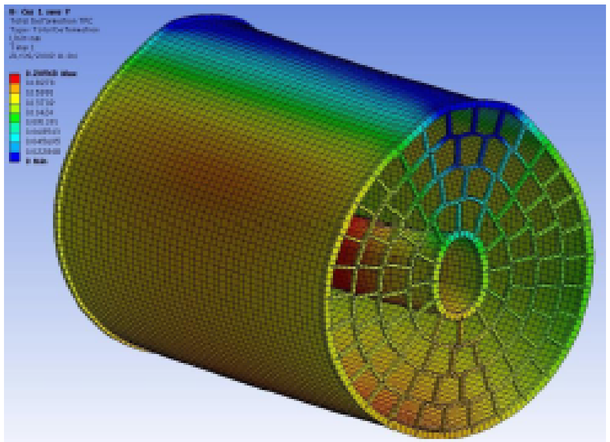
M. CARTY
(R. Volkenborn)

cea

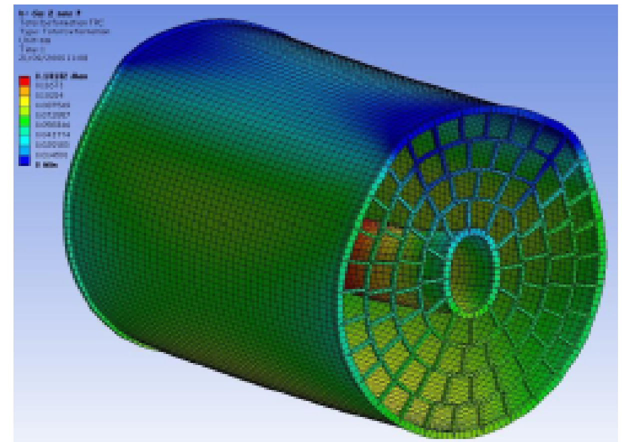
TPC V1 - ΔP= 0 – Results

LC-TPC

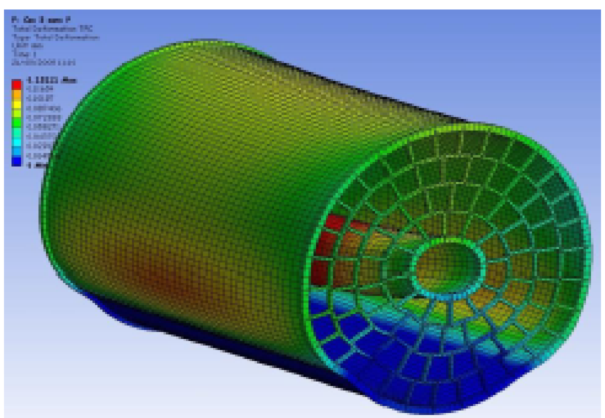
Case 1



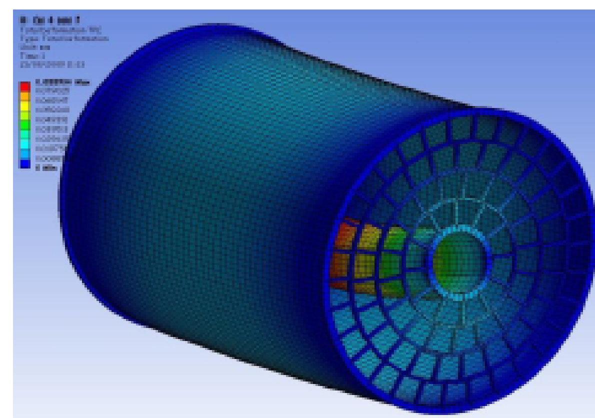
Case 2



Case 3

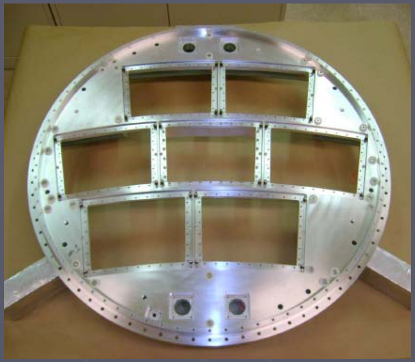


Case 4



D. Peterson/Cornell

Advanced Endplate
Thinning Endplate Structure

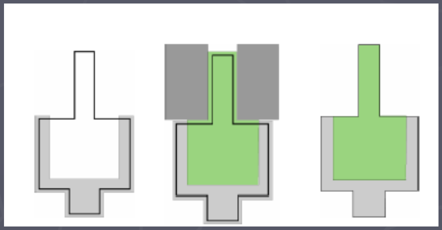


Current LP endplate: Al

Effective thickness:
Bare endplate: 1.4cmt Al (average)
Loaded with modules: 2.6cmt Al equiv.
(29% Xo)

Next LP endplate:

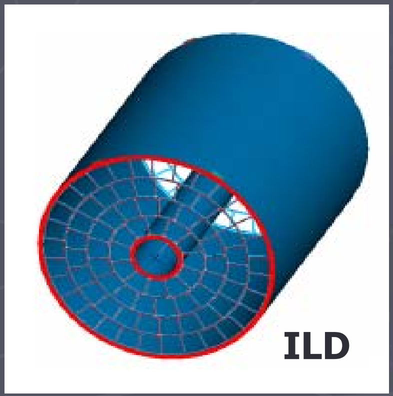
Thinning the outer support area
Hybrid composite/aluminum on the mullions
→ already 15% Xo from 29% Xo



Next LP endplate:
Gray: AL & Green: fiber glass

Study more advanced designs for ILC:

Composite (JWST primary mirrors)
A rigid bonded structure attached to a relatively thin gas-seal and module support structure
Space-frame of adjustable struts, etc



Advanced Endplate
Thinning Endplate Structure

D. Peterson

TPC Endplate Development at Cornell

Research toward the development of a TPC endplate for the ILD detector with the goals:

consistent with the implementation of Micro Pattern Gas Detector (MPGD) readout modules

scattering material < 0.15 X_o to minimize influence on PFA

mechanical alignment and stability of detector elements ~50 µm to facilitate calibration of the electric and magnetic distortions.

Research Activities (not all 1st year deliverables)

computer modeling of possible designs of the full-sized ILD endplate

construction of small prototypes to examine detailed properties of constructions methods proposed for the full-sized endplate

compare **Finite Element Analysis** (FEA) predictions with **measured properties** of the **small prototypes** used to understand the properties and provide input to FEA studies of more complex models

construct a **functional low material endplate for the LCTPC LP1** large prototype (The low material prototype for the LCTPC LP1 large prototype is a complimentary activity that allows detailed study of the properties of one construction technique within a system. It provides information on the stability beyond that which can be gained from the small prototypes, above)

FEA studies of the complex designs of the **full size endplate**

design and construct **test pieces** for the purpose of identifying **construction problems in the full-sized endplate design**

D. Peterson

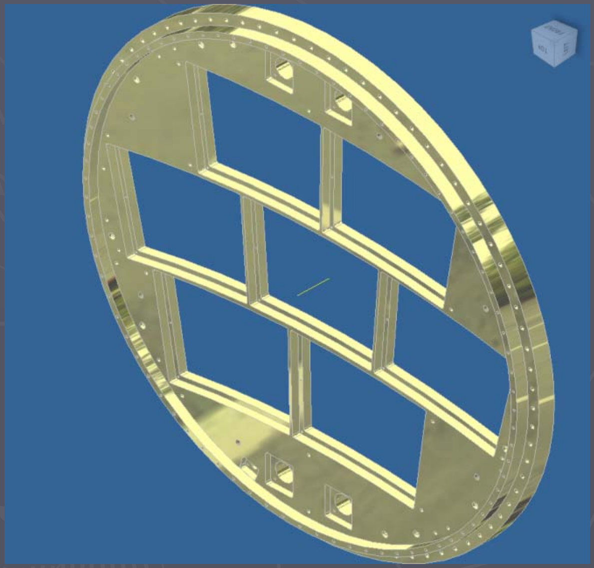
Advanced Endplate
Thinning Endplate Structure

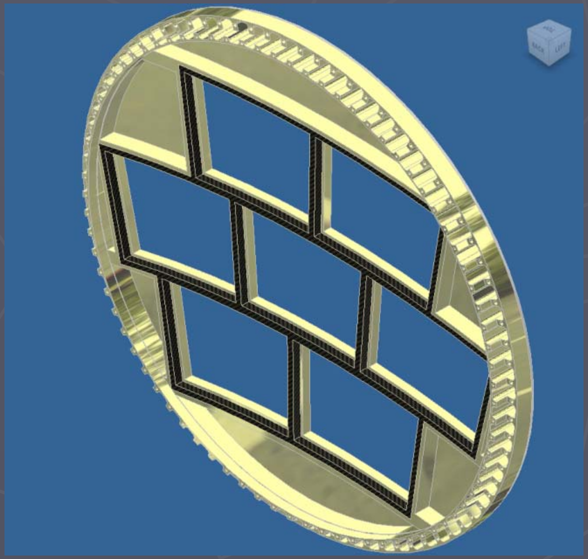
Demonstration at Large Prototype (LP)

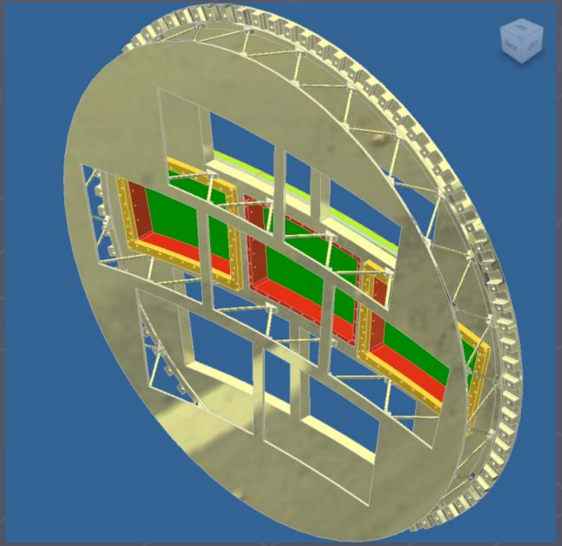
Compares to **18.87 kg** aluminum for the current LP1 endplate.

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.







Ions Feedback and Ion Disks

The ion feedback ratios

0.2-0.3% for MicroMEGAS and for a certain triple GEM configuration.

When MPGD gas gain < 1,000, the average density of feed back ions in the drift region is same to that of primary ions.

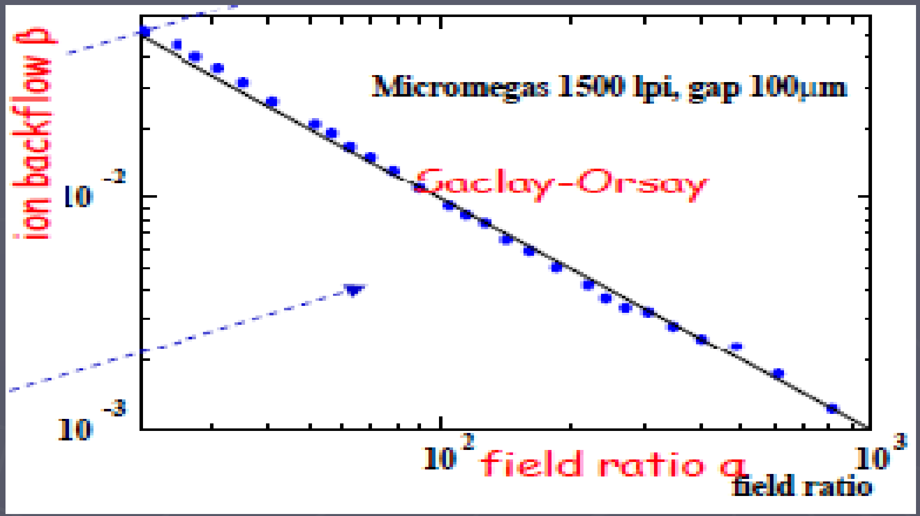
Ion disks:

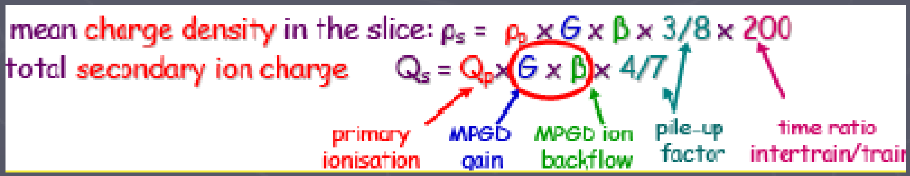
Note that the density in ion disks higher by a factor of ～ 200.

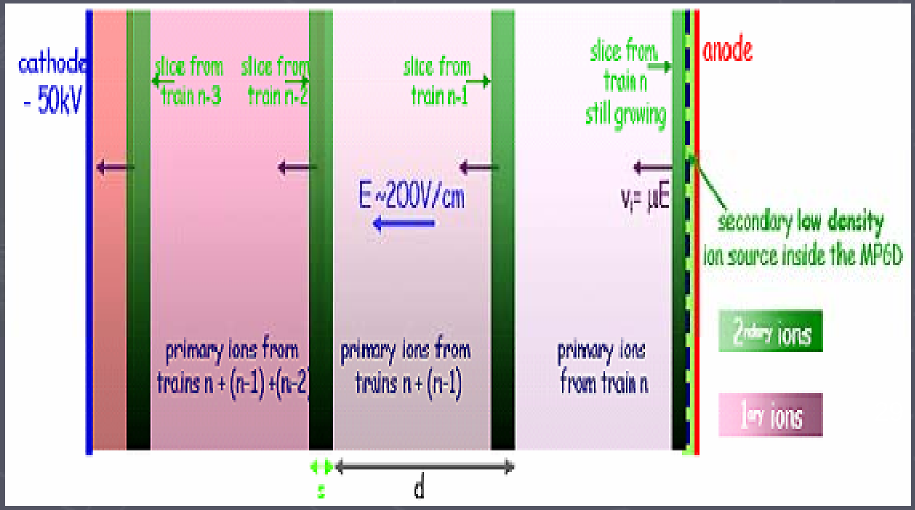
Urgently need to estimate the level of track distortion due to the disks by a full simulation for different background consitions

(Thorsten Krautscheid/Bonn)

Still to complete Marlin TPC!







Ion Feedback: Gating Device

Gating GEM (By Asian LC TPC group)

Stop ions at the level of 10-4 only by the gating GEM.

Transmission of primary electrons by special thin (14μmt) gating GEM:
50% or less by simulation and measurements.
Neff then becomes one half (20 → 10 for GEM, 30 → 15 for MicroMEGAS)
deteriorating position resolution at large drift distances.

Gating wire plane

Well established method.
100% ion stopping and closed to 100% electron transmission.

Introduce mechanical complication MPGD detector modules.
Need design study, in particular, on the impact to material budget/dead space.

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.

There are important engineering issues to realize MPGD TPC for ILC (ILD): R&D for the advanced endplate and R&Ds for ion feed back/gating devices.

We are also starting to work for DBD (Detector Basic Design) of ILD TPC.