TPC R&D, status and plans

Jan Timmermans

Performance goals and design parameters for a TPC with standard electronics at the ILC detector

Size	$\phi = 3.6$m, L $= 4.3$m 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)
σ_{point} in $r\phi$	$< 100\mu$m (average over $L_{sensitive}$, modulo track ϕ angle)
σ_{point} in rz	~ 0.5 mm (modulo track θ angle)
2-hit resolution in $r\phi$	~ 2 mm (modulo track angles)
2-hit resolution in rz	~ 6 mm (modulo track angles)
dE/dx resolution	~ 5 %
Performance	$>$ 97% efficiency for TPC only ($p_t >$ 1GeV/c), and
	$>$ 99% all tracking ($p_t >$ 1GeV/c) [82]
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

with MPGD

Technology options considered

- Pad readout (‘analog’ TPC, ADC digit.):
  - Double-GEM, triple-GEM
  - Micromegas (with resistive pad plane)

(TDC readout likely being discontinued)

- Pixel readout (‘digital’ TPC, Timepix):
  - Triple-GEM
  - Ingrid (integrated ‘Micromegas-like’ grid)
- Gating studies w. GEM or wire plane

Current status: LCTPC/EUDET infrastructure at DESY electron testbeam (5 GeV)

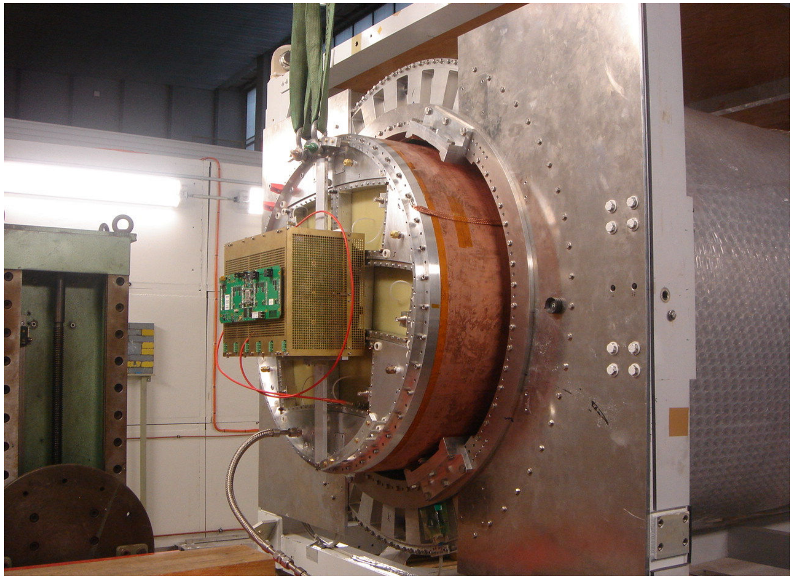
- 1T solenoid PCMAG
- LP (fieldcage, endplate, cathode) + services
- Endplate modules tested sofar;
  - Micromegas (3 different modules); T2K electronics
  - 3 (Asian) dual-GEMs; ALTRO electronics
  - Triple-GEM with Timepix readout (8 chips)
  - Triple-GEM with ALTRO pad readout
  - Micromegas (2x) together with Si-envelope (at B=0)
  - (soon: Ingrid+Timepix readout (8 chips))
- Software development (MarlinTPC) ongoing; more work than anticipated

MarlinTPC: status and plans

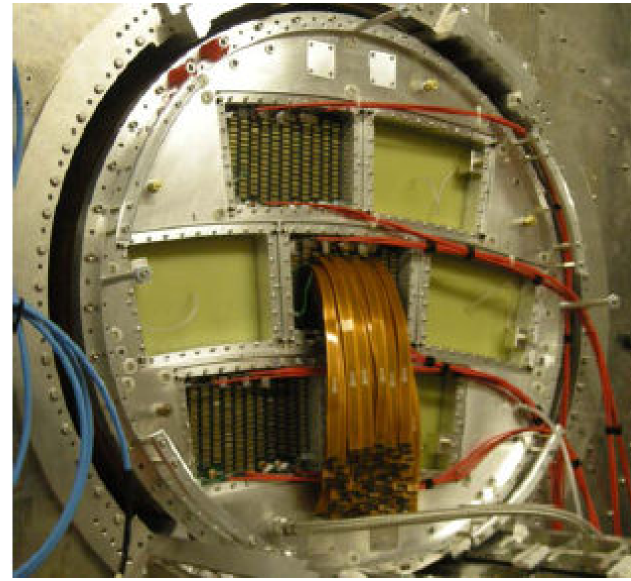
- MarlinTPC is a TPC simulation and reconstruction project within MARLIN framework; some simulation outside GEANT4 also available
- Basic reconstruction chain is set up and in validation phase for some of the hardware implementations; higher level track finding and fitting in rudimentary shape
- Geometry description in GEANT4 and signal digitisation needs to be verified/validated with testbeam data
- Plans: setup of reliable reconstruction chain up to track level, including errors; development conditions data objects and their usage; incorporation of all readout concepts.

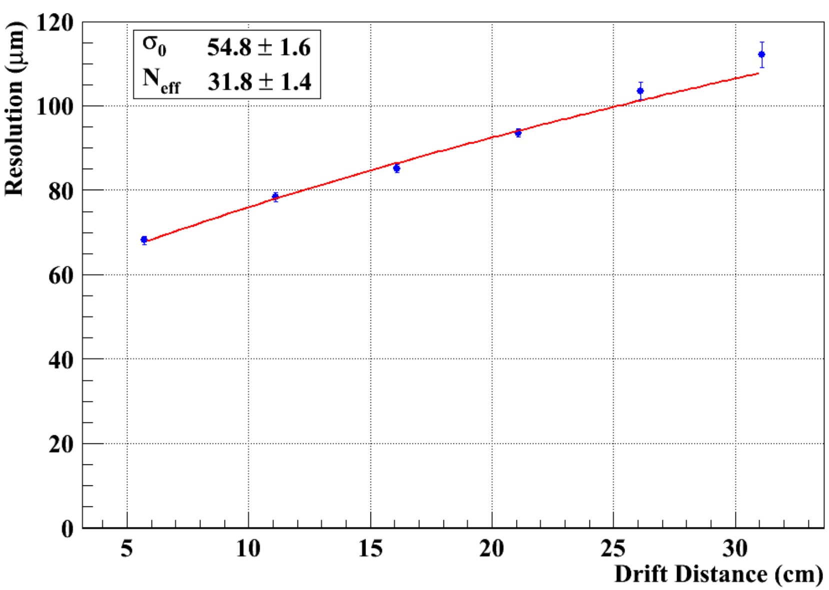
  Also implementation of “alternative” Kalman filter tracking/fitting into MarlinTPC (see Katsumasa Ikematsu talk in Software pre-meeting)
- Limited person power!

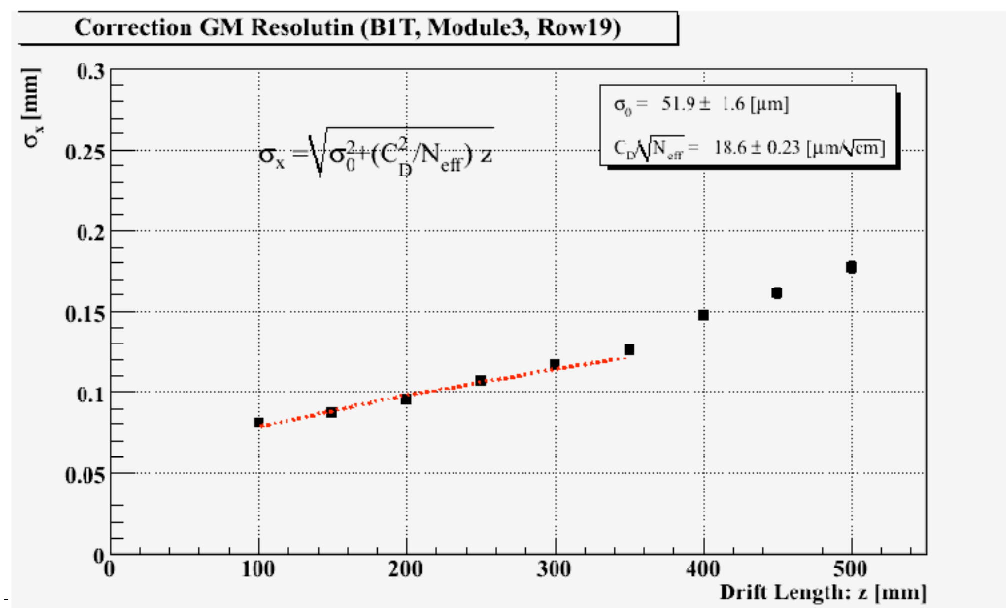
Micromegas (1 module 1700 ch.)



3 double-GEM modules (3300 ch.)

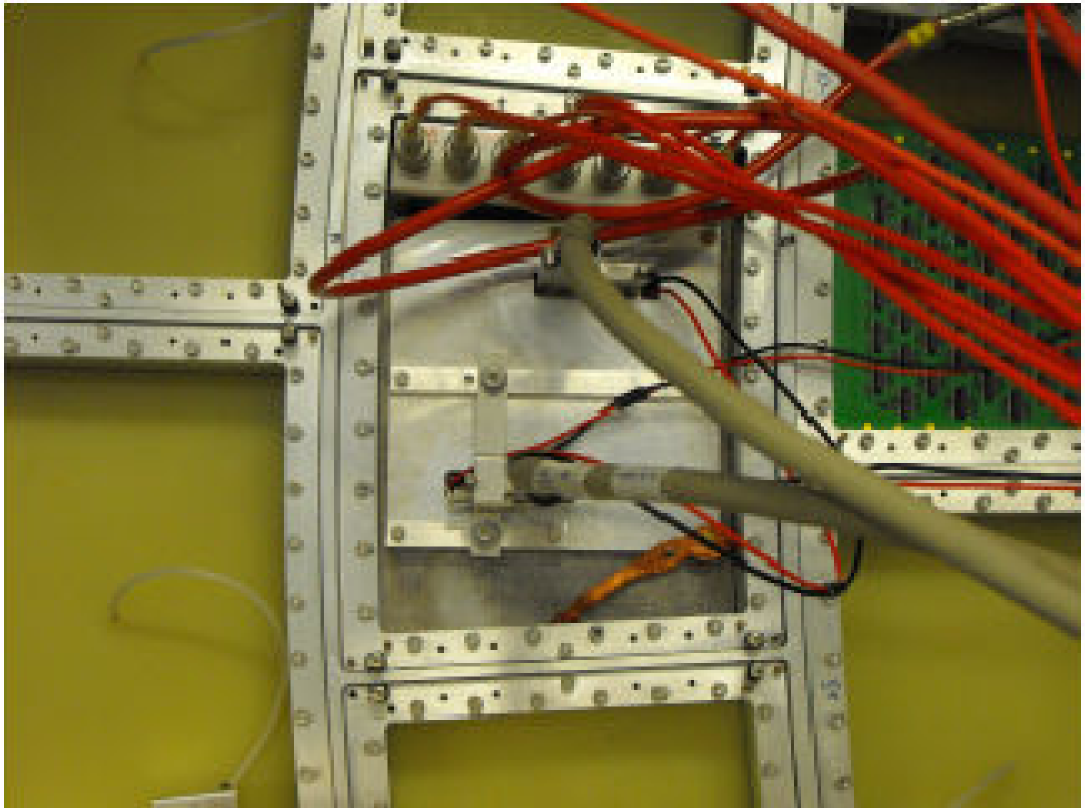


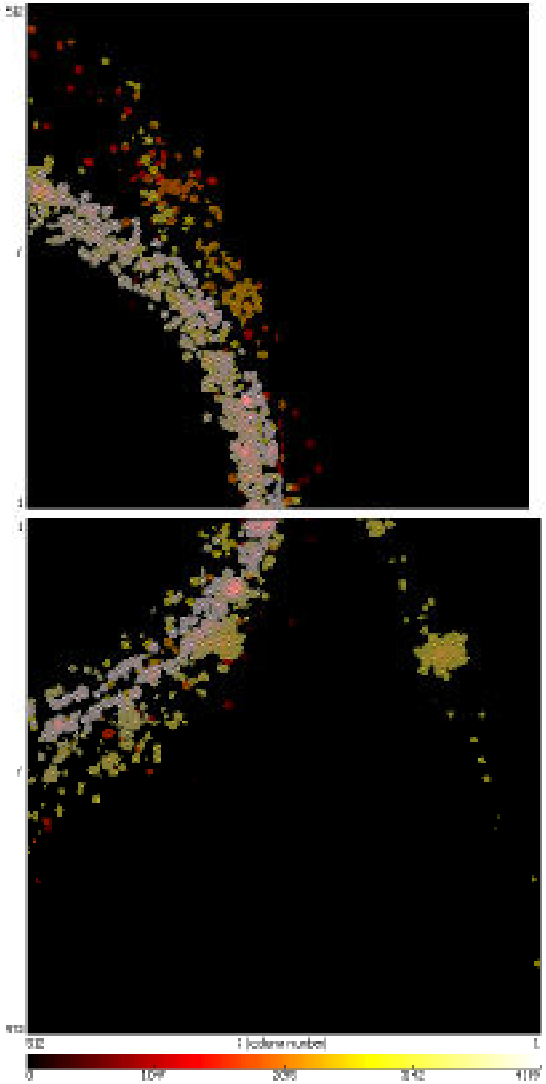




Triple-GEM module with readout by 8 Timepix chips: 16 cm2 active area, 0.5M channels

Bonn/Freiburg





Near future plans (~2010)

- 7 modules Micromegas w. T2K electr. in ‘flip-chip’ mounting (7x1700 ch.)
- Up to 4 modules of (Asian) double-GEM + gating-GEM w. 10,000 ch. ALTRO electr.
- Development of new ‘stiffer’ GEM module/mounting
- Development S-ALTRO 0.13um chip; 16ch prototype Spring 2010; final 64ch version needs funding
- New endplate (some funding available):
  - Thinning of present design: could reach close to .15 X_0 (2 yrs)
  - New technology (e.g. C) or spaceframe design study (~3 yrs)
- Development “full” endplate module w. Timepix (64/119 chips)
- Development new fieldcage including improved HV cathode connection

Further studies up to 2012+

- Power pulsing and cooling tests:
  - Start in 2010 with (Japanese) dummy modules
  - Using both LP and smaller prototype detectors
  - These studies can be done without beam in e.g. 5T solenoid at DESY
- Ion backflow studies; include in order of priority:
  - Simulation studies
  - Development of gating device
  - Development of device for producing ILC-like ion sheet

TPC R&D priorities

1a) development endplate (max. 15% X_0 including cooling) (2010-2011+)

1b) continue tests with electron beam for correction procedures (2010)

2a) future tests in hadron beam (2011):
- for momentum resolution
- for two-track separation in a ‘jet’ environment

2b) powerpulsing/cooling tests both on LP and SP (2010+)

3) ion backflow studies (2010++):
- simulations of ion sheets for GEM, Micromegas
- development gating device
- development device for producing ILC-like ion sheet

Resources

- LCTPC collaboration has no (common) funding; groups have more or less funding. Inventory has to be (re)made
- EUDET funding has ~ finished
- New EU proposal in preparation; however (if accepted) will be less €€€ than EUDET

- Some funding available for:
  - Endplate studies
  - Powerpulsing
  - Cooling
  - If Timepix2 development, large contribution from Medipix Coll. and RD51 groups

RD's Work Plan after Validation

1. Demonstrate proof of principle on critical components
   When there are options, at least one option for each subsystem will reach a level of maturity which verifies feasibility
2. Define a feasible baseline design
   While a baseline will be specified, options may also be considered
3. Complete basic mechanical integration of the baseline design accounting for insensitive zones such as the beam holes, support structure, cables, gaps, or inner detector material
4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations
5. Develop a push pull mechanism, working out the movement procedure, time scale, alignment and calibration schemes in corporation with relevant groups
6. Develop a realistic concept of integration with the accelerator including the IR design
7. Simulate and analyze updated benchmark reactions with the realistic detector model, including the impact of detector dead zones and updated background conditions
8. Simulate and study some reactions at 1TeV, including realistic higher energy backgrounds, demonstrating the detector performance
9. Develop an improved cost estimate

Some requests from Henri V.

- a full simulation with the right level of details: dead zones, inefficiencies, inhomogeneity of response, distortions...

-a full reconstruction where the input is proper (for example strips have to be handled as strips and not points)

Likely not possible for MC mass production, “too heavy”; try to do on limited simulations of e.g. single muons and single jets

-a full integration, the detector has to fit into the envelope defined in the integration model and to have adequate services, power, cooling, hanging, ..

Work has started, see talk Paul Colas in MDI pre-meeting

-a description of the calibration and of the alignment in particular at the time of push-pull.

See LOI; need 1 pb^{-1} Z-peak data @ $L=10^{32}$ $cm^{-2}s^{-1}$

Next steps, from the LOI

- 2009-12 Continue R&D on technologies at LP, SP, pursue simulations, verify performance goals
- 2009-11 Plan and do R&D on advanced endcap; power-pulsing, electronics and mechanics are critical issues.
- 2011-12 Test advanced-endcap prototype at high energy and power-pulsing in high B-field.
- 2013-18 Design and build the LCTPC.

At the beginning of the period 2012-18, the selection must be made from the different technological options – GEM, MicroMegas, resistive anode, pixel, electronics, endcap structure – to establish a working model for the design of the LCTPC. This design will be used for the ILD proposal in 2012 and include pad segmentation, electronics, mechanics, cooling and integration, so that performance, timeline and cost can be estimated reliably. [2] For the technology selection, a scenario could be that questions must be answered as to which options give the best performance based on R&D results from LP, SP, electronics and endcap studies. Main performance criteria could be endcap thickness and σ_{point}, double-hit and momentum resolution for single tracks and for tracks in a jet environment. Choice of criteria to use will be decided over the next two years.

See also updates in yearly Addendum to LCTPC MoA

Executive summary

- All aspects covered in TPC chapter of the LOI
- Adequate performances wrt point-, 2-hit-, and momentum-resolution in Table 5 of Addendum2009 have been already demonstrated by SP studies.
- "To do" list of critical R&D for 2010 to mid-2012, in a nutshell:
  - Develop correction techniques, confirm resolution at LP at Desy
  - Develop advanced endcap (15%X_0, S-Altro, cooling, mechanics, power pulsing, gating) and fieldcage
  - Develop detector-integration engineering
  - Improve software model
  - Confirm alignment, calibration procedures

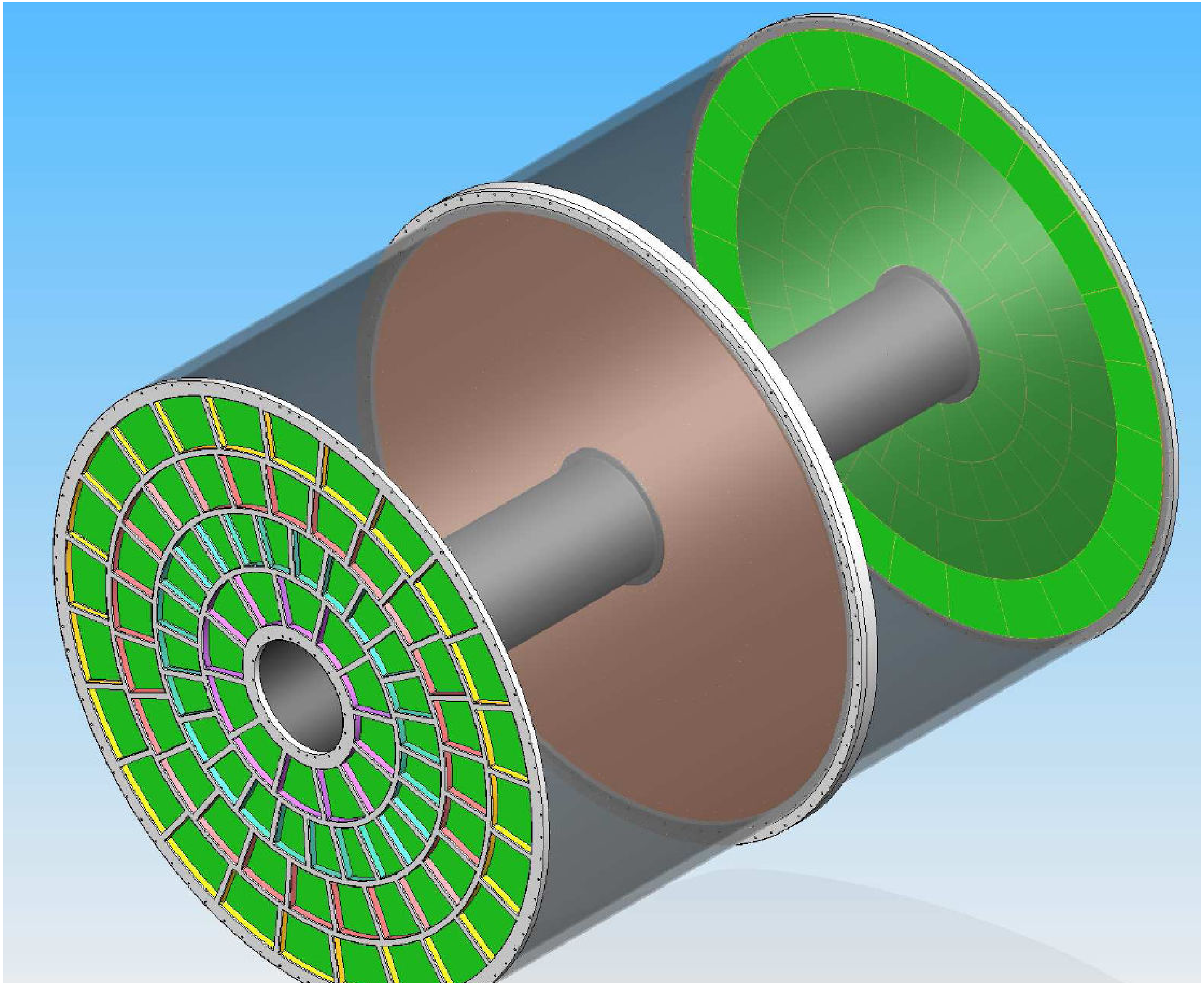
Table 2

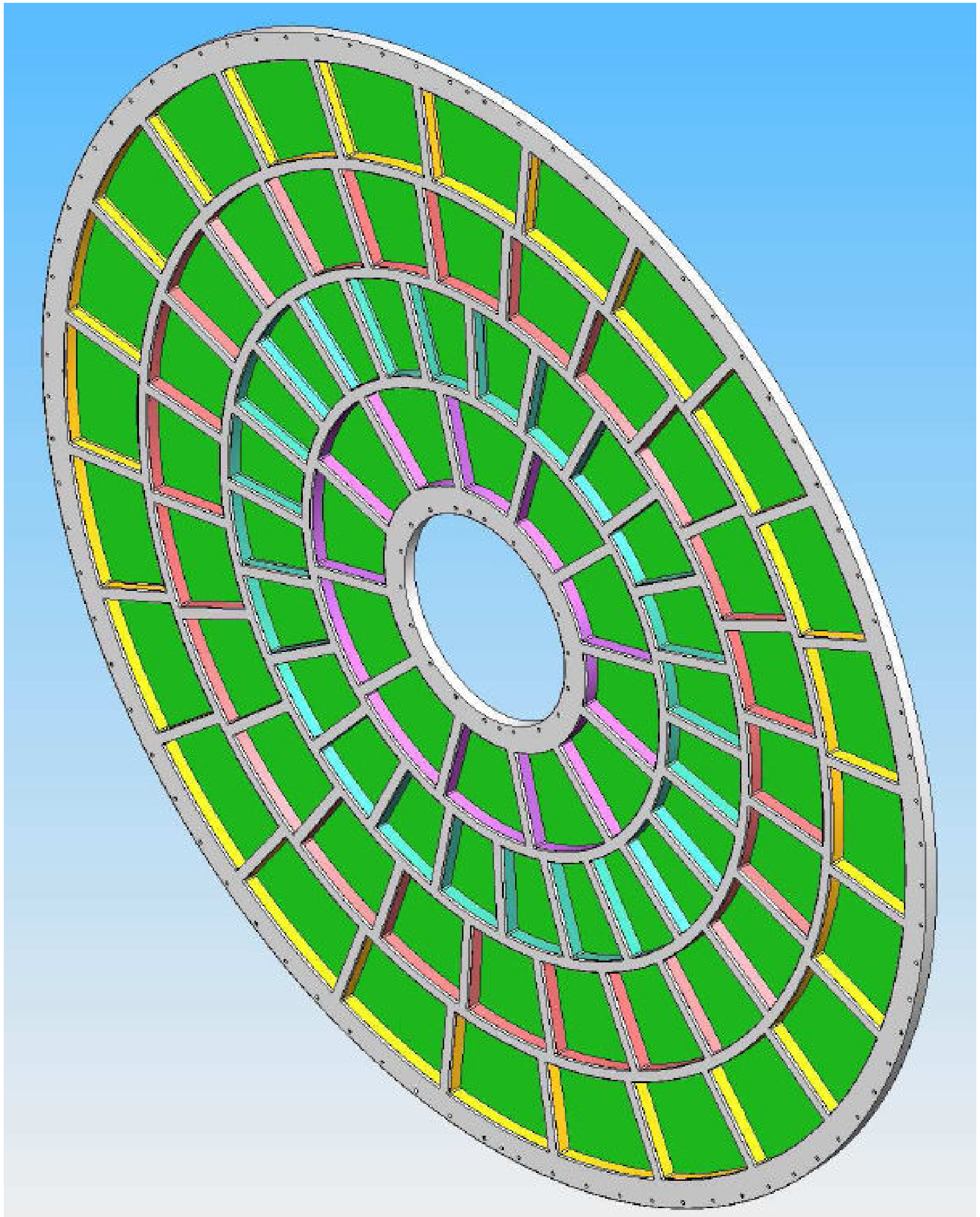
Workpackage	Convener
Workpackage (0) TPC R&D Program	LCTPC collaboratioı
Workpackage (1) Mechanics	
a) LP endplate structure, design	**Dan Peterson**
b) Fieldcage, laser, gas	**Ties Behnke**
c) GEM panels for endplate	**Akira Sugiyama**
d) Micromegas panels for endplate	**Paul Colas**
e) Pixel panels for endplate	**Jan Timmermans**
f) Resistive anode for endplate	**Madhu Dixit**
Workpackage (2) Electronics	
a) Standard RO/DAQ sytem for the Large Prototype	**Leif Joensson**
b) CMOS RO electronics	**Harry van der Graaı**
c) Standard electronics for LCTPC	**Luciano Musa**
Workpackage (3) Software	
a) LP software + simulation/reconstruction framework	**Christoph Rosemann**
b) LP DAQ	**Gilles De Lentdecker**
c) LCTPC simulation/performance/backgrounds	**Keisuke Fujii**
Workpackage (4) Calibration	
a) Field map for the LP	**Lucie Linsen**
b) Alignment	**Takeshi Matsuda**
c) Distortion correction	**Dean Karlen**
d) Outgassing properties of materials	**Anatoliy Krivchitch**
e) Gas/HV/Infrastructure for the LP	**Klaus Dehmelt**

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

Workpackage (5) LCTPC preparations for TDR	**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 TDR preparations; more explanation is presented in Section 3.3.2.



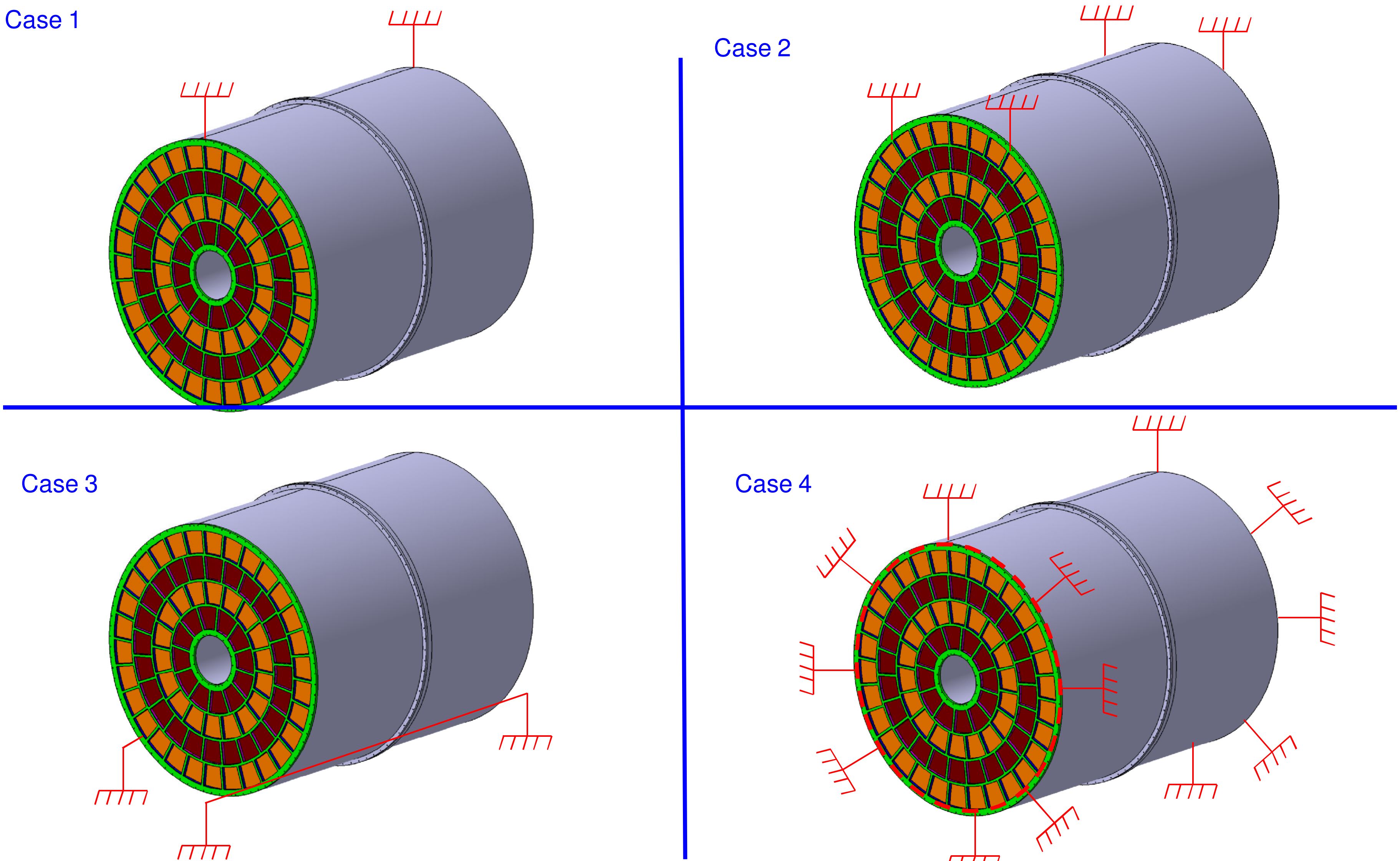


Total weight 400kg per side (with Al)

A design with 3 wheels also exists

TPC Support

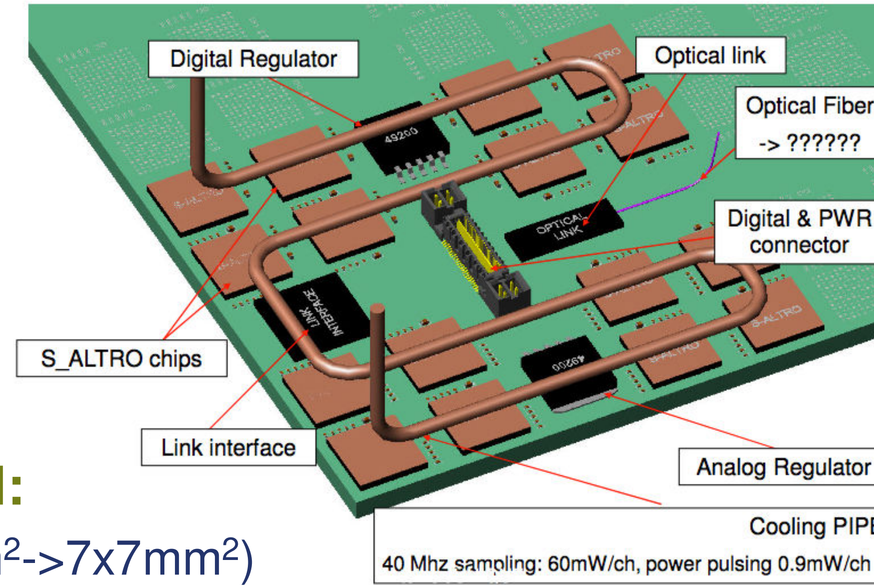
4 configurations



27/01/2010

Advanced endplate

- For ILD, space for the electronics will be very limited (~10cm) => developments are ongoing to reduce the size of the FE elec.
  - **S-ALTRO (L. Musa, CERN):**
    - New 64ch chip integrating PCA16 and ALTRO
    - Flip-chip bounded on PCB
    - Designed for power-pulsing
      - For 0,5% duty cycle beam 0,5mW/ch at 10MHz sampling



  - **AFTER FE also being redesigned:**
    - Remove chip packaging (20x20mm^2->7x7mm^2)
    - Remove most of the protection (the resistive layer protects)
    - No change to AFTER chip itself: analog memory (SCA) suitable for ILD ?
- Other issues (to be discussed with other subsystems):
  - **Trigger on train ? (TPC is integrating ~100 BX)**
  - **Power-pulsing: need signal to wake-up electronics**
  - **Cooling,…**

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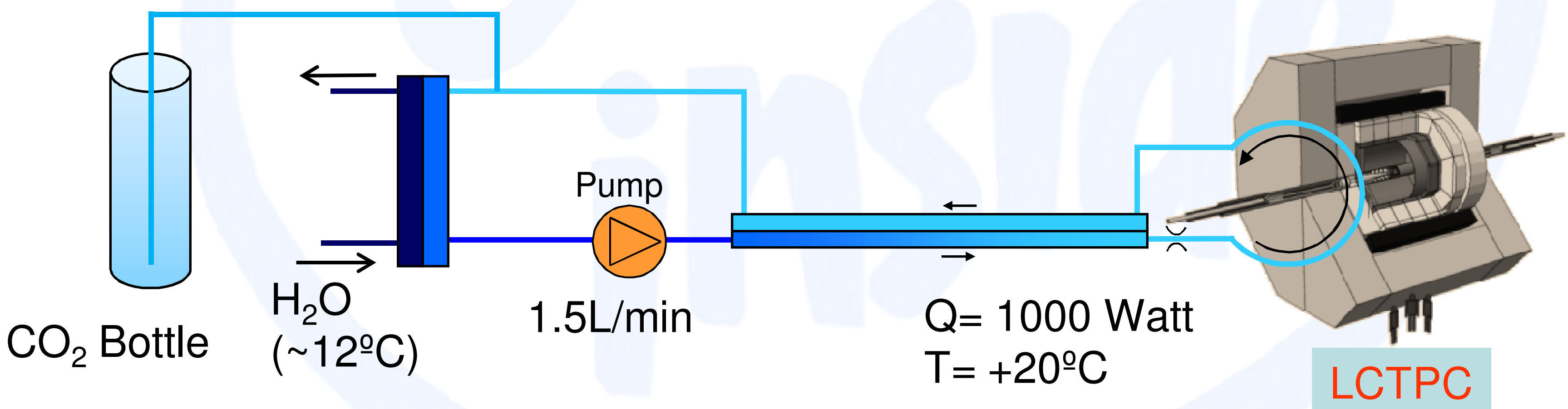
2PACL for LCTPC

Warm 2PACL very simple

- Accumulator is CO_2 bottle @ room temperature
- Cold source is cold water

Bottle temperature = Detector temperature



AMS-TTCS was tested in the same way

(Cold test done with bottle outside in winter)

Current TPC DAQ

- Each electronics (ALTRO, AFTER, Timepix and Si envelope) has its own DAQ system :
  - **Each system is working stand alone**
  - **Each system has local online monitoring tools**
  - **Most systems have local reconstruction and analysis**
  - **All have a converter to LCIO**
  - **Analysis in Marlin has started on all systems**
- For TPC alone tests, each system is working fine

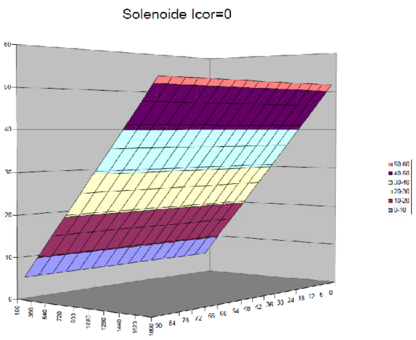
  + already one successful combined test MICROMEGAS+Si envelope
- However :
  - **Except Timepix, other systems are not using EUDAQ**
  - **So far, only ALTRO can use TLU (with an extra distributor board)**
    - One of the problem : TLU uses LVDS signal while ALTRO/AFTER use LVTTL

For future combined test beams, both items have to be improved

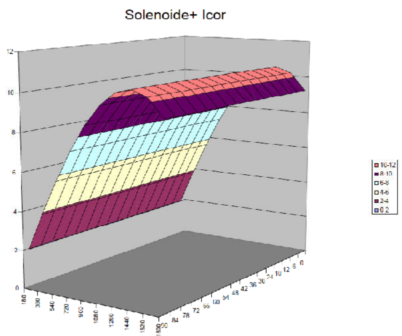
Further questions of Henri V. yesterday

- TPC endplate thickness (and X0)
  - Now 10 cm; could become less, but is premature to reduce it now
  - Can one see the difference between 10%, 15%, 20%X0?
- Endplate to ECAL (ETD) distance
  - If just for cables, could become less; in 10 years there will be just a few bundles of fibers
- TPC length:
  - see PFA optimisation results
- TPC field cage thickness (and shape)
  - Cylinder seems a lot simpler/cheaper
  - Outer fieldcage thickness probably ~50 mm sufficient
  - Inner fieldcage thickness: mechanically could be 25 mm, for HV maybe a bit more (has been tested to 30 kV)
- TPC requirements on homogeneity B-field
  - See following slides Ron Settles
- TPC to ECAL “play”; cables?
  - If just for cables, could become less

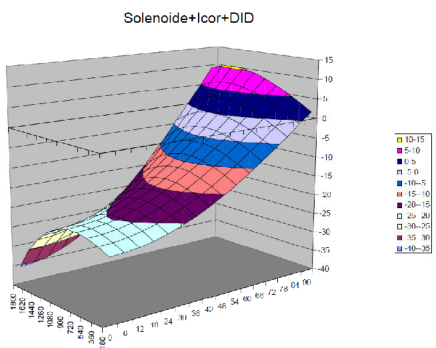
From the ILDMDI meeting: options for the ILD solenoid…



Bare magnet, ∫Br/Bz dz ≤ ~ 54mm

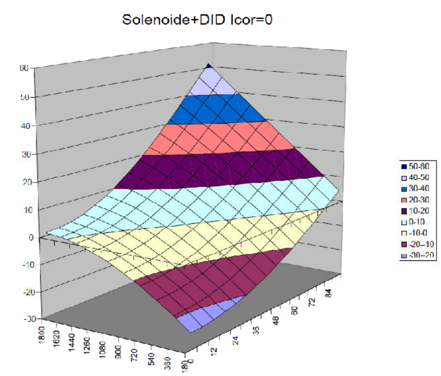


Correction coils, ∫ ≤ ~ 10mm



Add antiDID, ∫ ≤ ~ 35mm

With antiDID but no correction, ∫ ≤ ~ 50mm



Since 35mm with the antiDID and 50mm without corrector windings is only a factor 1.5 larger, ergo the BIG question: “Do we need the corrector windings?” LCTPC no longer has any requirement on B-homogeneity, since the requirement now specifies the accuracy with which the B-field must be mapped and since the to-do list of critical R&D for 2010 to mid-2012 contains:

“develop correction techniques, confirm resolution at LP at Desy”

(my) Summary/conclusion

- Well under way for detector hardware and services
- Need more person power for software development