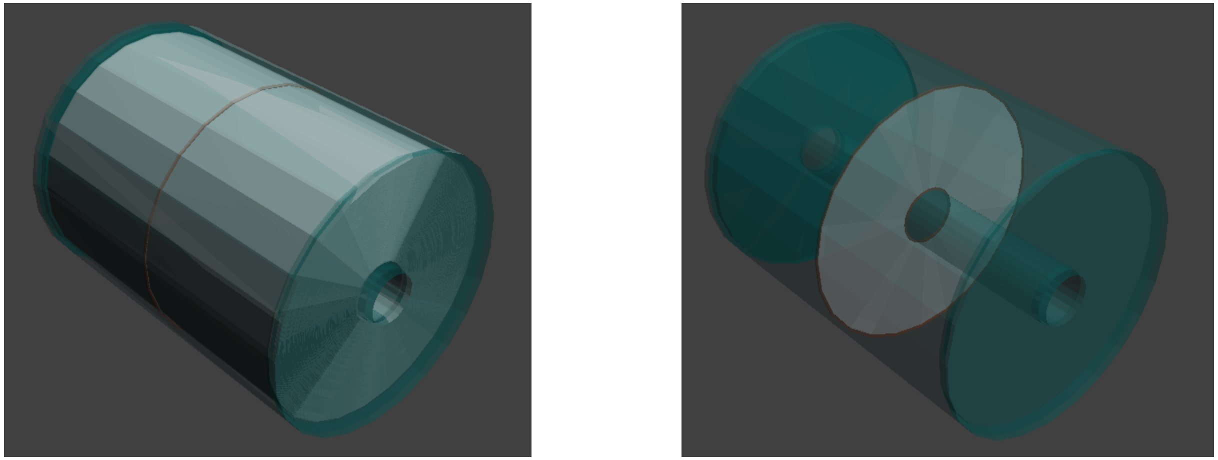
TPC development status in preparation of DBD (and further)

Jan Timmermans

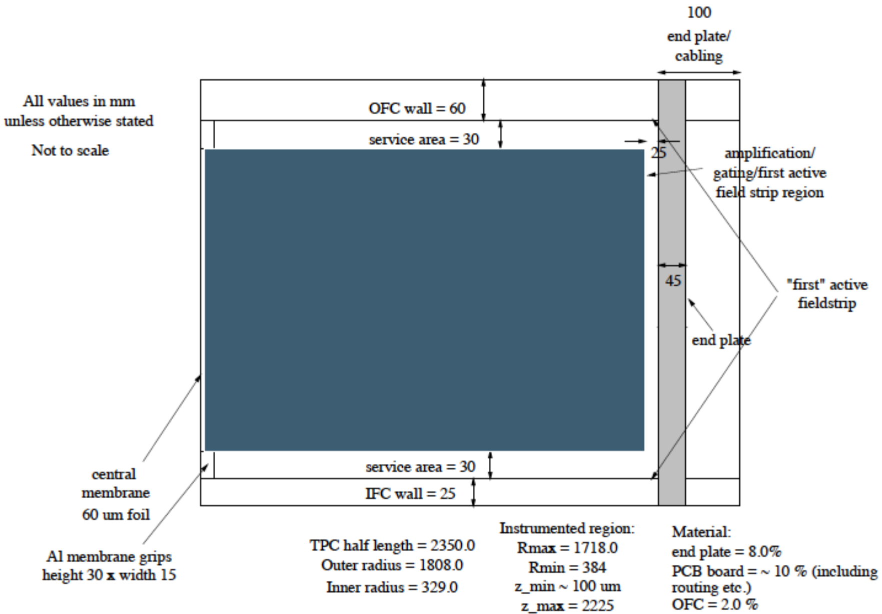
outline

- TPC Mokka detector model
- MarlinTPC developments

- Testbeam activities and plans
- Advanced endplate studies
  - Mechanics
  - Electronics
  - Cooling
- Ion backflow and gating studies



S. Aplin



TPC half length = 2350.0
Outer radius = 1808.0
Inner radius = 329.0

Instrumented region:
Rmax = 1718.0
Rmin = 384
z_min ~ 100 um
z_max = 2225

Material:
end plate = 8.0%
PCB board = ~ 10 % (including routing etc.)
OFC = 2.0 %
IFC = 1.0 %
membrane = 0.1%
membrane holder = 33.8% (*)
gas = 1%

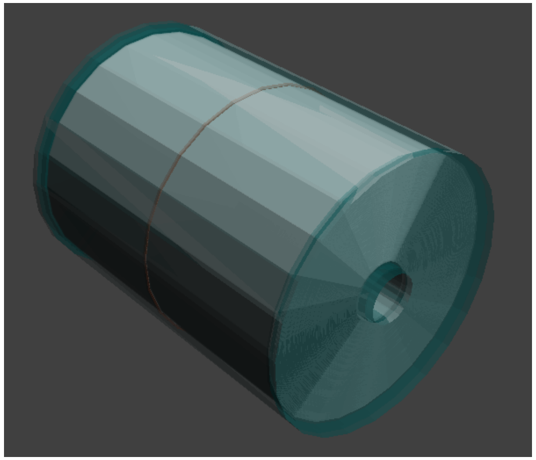
(*) The membrane support is made out of Al and gives X_0 within a width of 30 mm (in total)

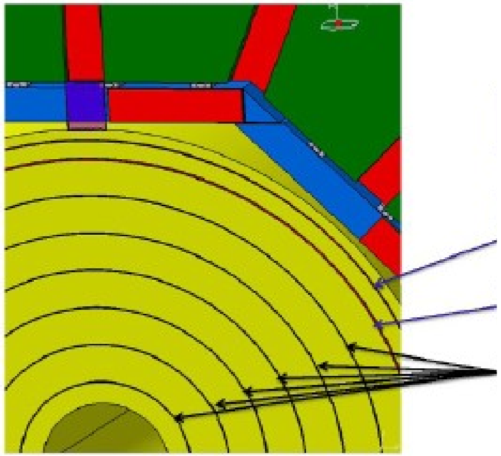
TPC Driver established in ILD_01 Mokka detector model as TPC10_01.
(figures above left taken from Geant4).

Model derived from the working design shown to the left.

Inner and Outer field cage modeled using appropriate sandwich structure:
Copper, G10, Air, Kapton and Aluminum.

Cathode constructed from two thin discs, insulator and conductor, held by membrane grip.



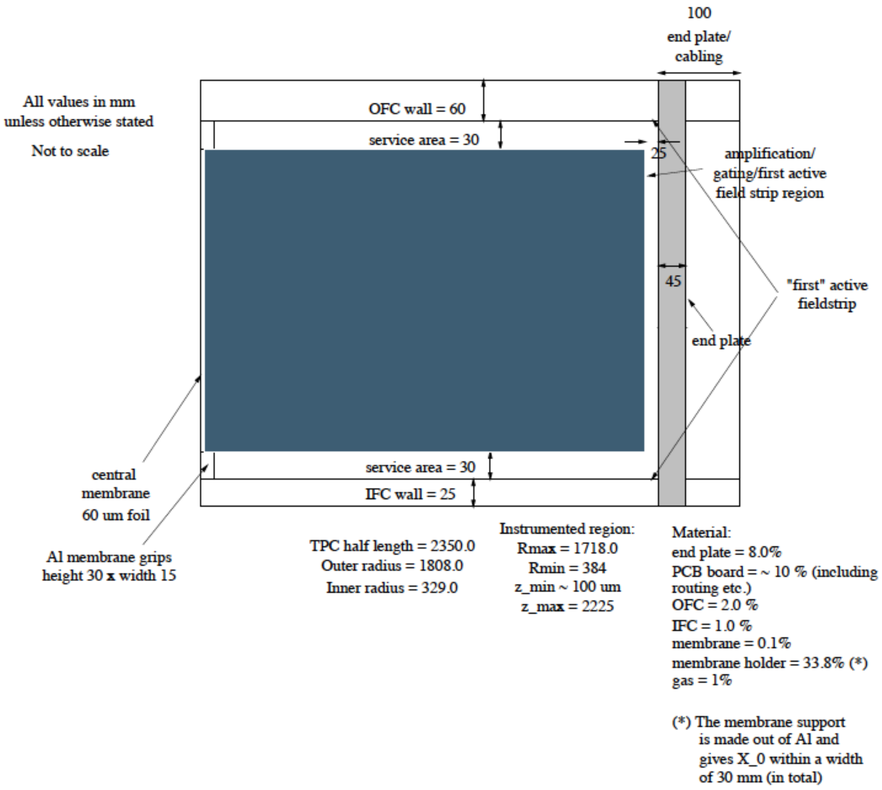


rings of equivalent thickness
in copper

Liquid supply ring 7x2.7 mm^2

Vapor return ring 10x2.8 mm^2

6 Cooling tubes 4x1.9 mm^2



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End-Plate modeled as discs of material representing components of the readout: GEM structure, Readout, and Support frame.

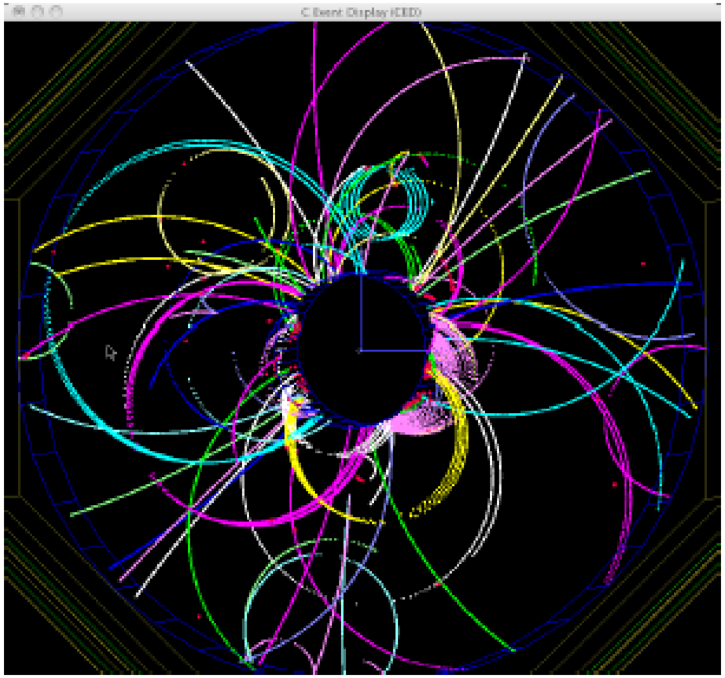
Cathode constructed from two thin discs, insulator and conductor, held by membrane grip.

Cooling modeled using rings attached to the outside of the end-plate.

Parameterised digitisation well established in the main reconstruction chain.

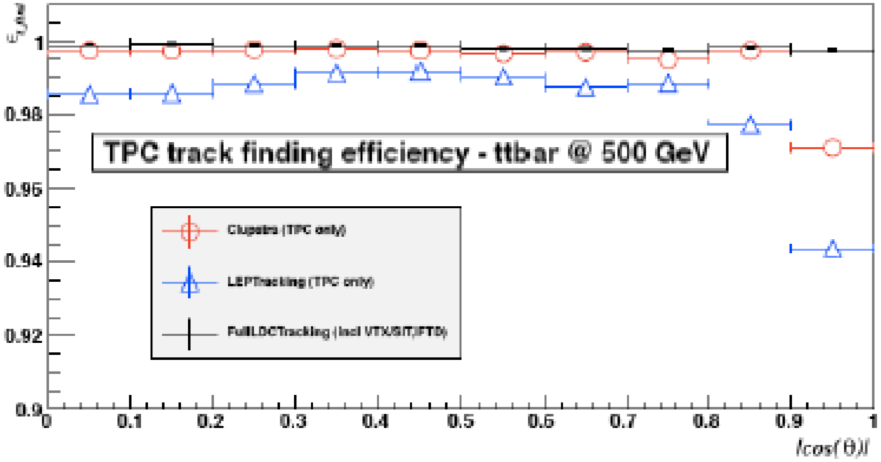
F. Gaede

Clupatra: topological TPC pat-rec



- use **NN-clustering in full TPC**
  - merge hits that have dist<3cm
- in merged clusters (duplicate pad rows) cluster in **pad row ranges** (15 rows) – **outside inwards** to find clean track stubs
- ***extend clean stubs with Kalman fitter***
  - pick up matching hits fwd & bwd if delta(chi2) < 35.
  - update track state
- ***force leftover clusters into one, two or three tracks*** (depending on pad row multiplicity)
- **merge curler segments:**
  - delta(R), delta(xc,yc) and delta(tanL) < 10%

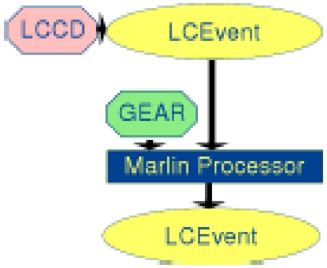
- track finding efficiency better than previous algorithm (based on LEP tracking code)
- NB: no fully reconstructed tracks yet -> might loose a bit due to quality cuts
- next steps:
  - fully reconstruct tracks
  - merge with Si-Tracks (hits)

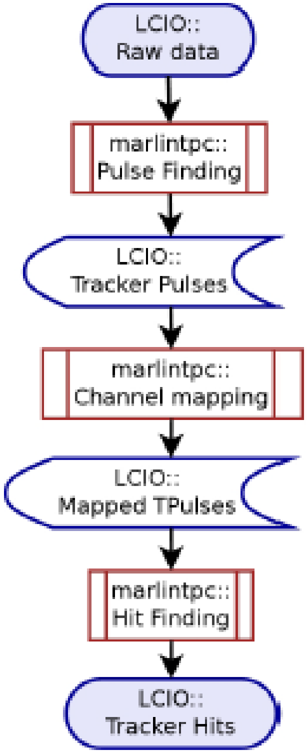


Software: MarlinTPC

C. Rosemann

- Working reconstruction chain from raw data (LCIO input) to track finding
- For pad based data:
  - Pulse Finding (single channel data)
  - Hit Building (space point reco)
- Pixel data:
  - Cluster Finding (from TOT/time measurement)
  - Hit Building (space points)
- Pattern recognition works, three options
- Within/Uses Marlin framework:
  - Geometry description (GEAR)
  - Data format/Persistency (LCIO)
  - Conditions Data (LCCD)
- In use (at least started) for all types of modules that were tested



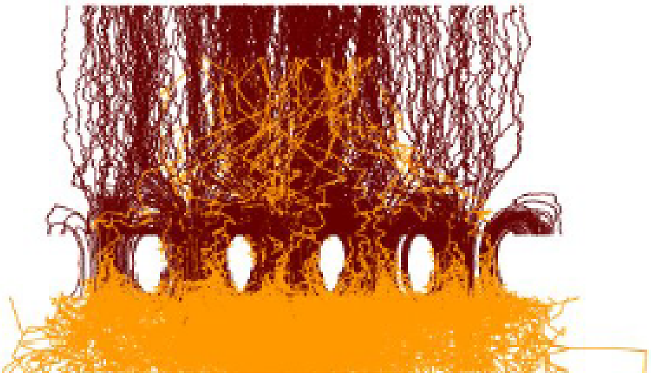


Software: Current workplan and Needs

- Information management improvement
  - Data location on grid
  - Converter programs for ALTRO, AFTER electronics (and pixel?)
  - Geometry and pad mapping info
- Conditions data access and usage (almost done)
- Reconstruction – Fitting:
  - Currently no fitter **truly** works in MarlinTPC
  - KalTest is a good option, but extra effort is needed (e.g. geometry description)
  - Other option is still work in progress (possibly with direct connection to alignment)
- Reconstruction – Alignment and Calibration
  - Very important but no common tools so far
  - Makes little sense without a working fitter

Simulation status

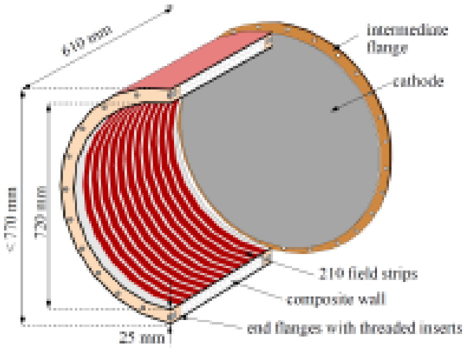
- Several different approaches existing in MarlinTPC
  - Simple Geant Hit smearing (used e.g. for ILD simulation)
  - Charge cloud approximation (used e.g. for the Likelihood fitter technique)
  - Detailled ionisation and drifting & (fixed) parametrised amplification
- None that fit exactly our needs:
  - Possible single electron level from ionisation to readout plane
  - Different amplification structures
  - Ion backdrift studies
- (Possible) Solution: Garfield++ by Rob Veenhof and Heinrich Schindler in collaboration with RD51
  - Some experience already there
  - PhD candidate + C.R. will start to work on/with it
- Other parts also there
  - Ion Backdrift studies (Torsten Krautscheid)
  - Photo dots for calibration (Jason Abernathy)

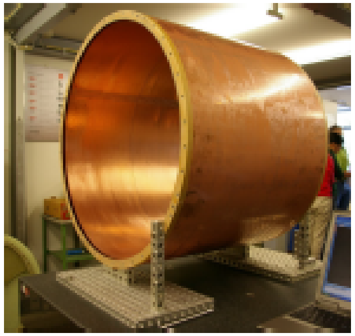


Testbeam Setup

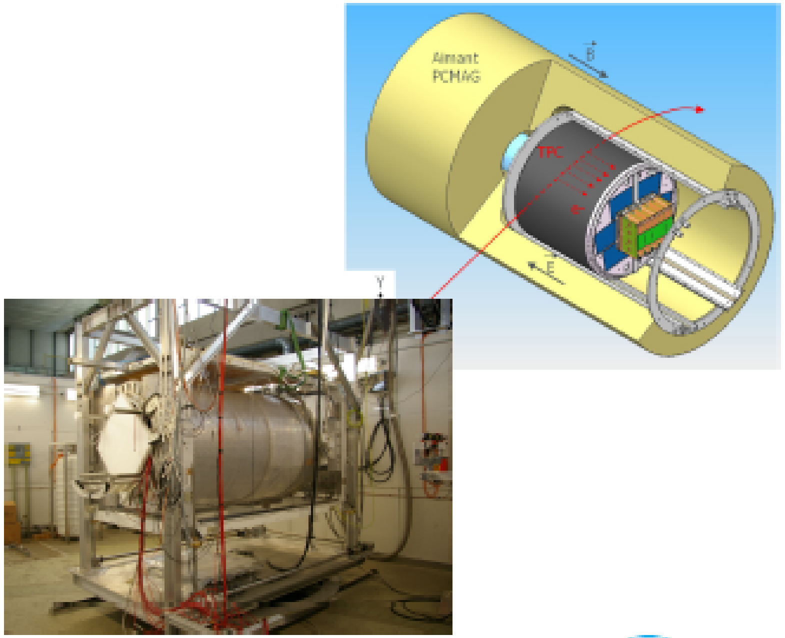
C. Rosemann/R. Diener

- Field cage:
  - Due to fabrication imperfection: 2nd field cage planned
  - Status: Mandrel worked over and measured



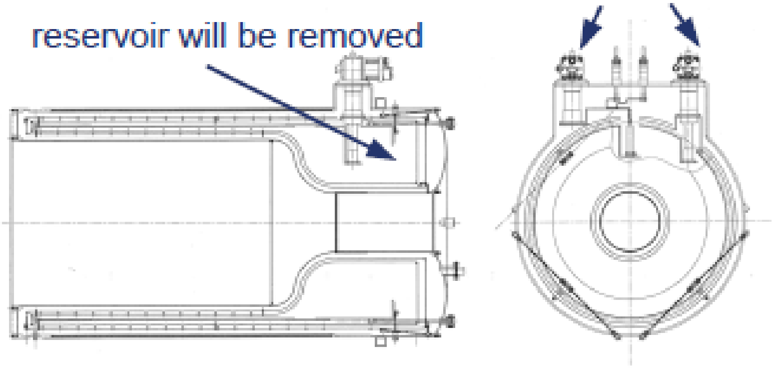


- Setup at T24/1:
  - PCMAG magnet mounted on movable lifting stage (3 axis): Control and saftey systems currently being completed
  - Cosmics trigger logic just updated
  - HV and gas system including slow control
  - Laser calibration system
  - Outer silicon reference detector in progress, some problems due to missing parts



PCMAG Modification

- Up to now: filling manually with liquid He
  - Expert work, many steps to be taken carefully → error-prone
- Magnet modification:
  - Inside AIDA (+ contrib. by KEK, DESY)
  - No filling, but using closed Helium circuit with cryo modules
  - Safe, easy and efficient operation + Portability
- Schedule:
  - Test beam end: 10.July 2011 → warm up of magnet
  - End of July: shipping to Japan
  - Ready in the beginning of 2012
- Status: Preparations ongoing
  - Details of installation being planned: cable/tube lengths, packaging, cooling water, etc.



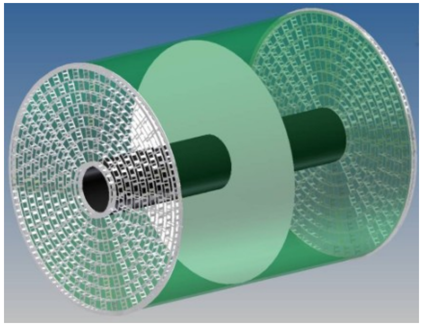
cryo modules will be installed

reservoir will be removed

Test Beam Planning

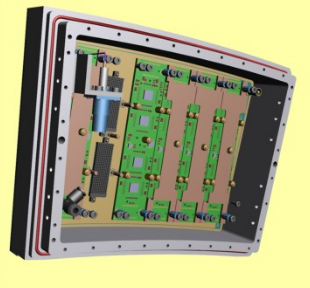
- Near future (2011)
  - June: DESY GridGEM module with ALTRO electronics
  - June/July: Asian GEM modules with ALTRO electronics
  - From mid July to beginning 2012: PCMAG modification
- Farer Future
  - Late 2011/early 2012:
    - 7 Micromegas modules w. AFTER electronics (without magnetic field)
    - Tests with S-Altro 16 electronics
  - 2012:
    - Continuation of LP1 tests (with magnetic field)
    - LP2 (advanced endplate) tests at test beam
  - Late 2012/2013: Move to hadron test beam for some months

Goals of the ILD TPC endplate



D. Peterson

Detector module design:
Endplate must be designed to
implement Micro Pattern Gas Detector (MPGD) readout modules.
Modules must provide near-full coverage of the endplate.
Modules must be replaceable without removing the endplate.

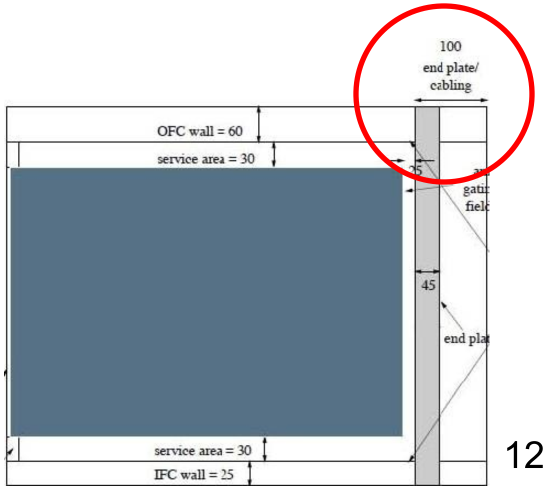


Low material - limit is set by ILD endcap calorimetry and PFA:

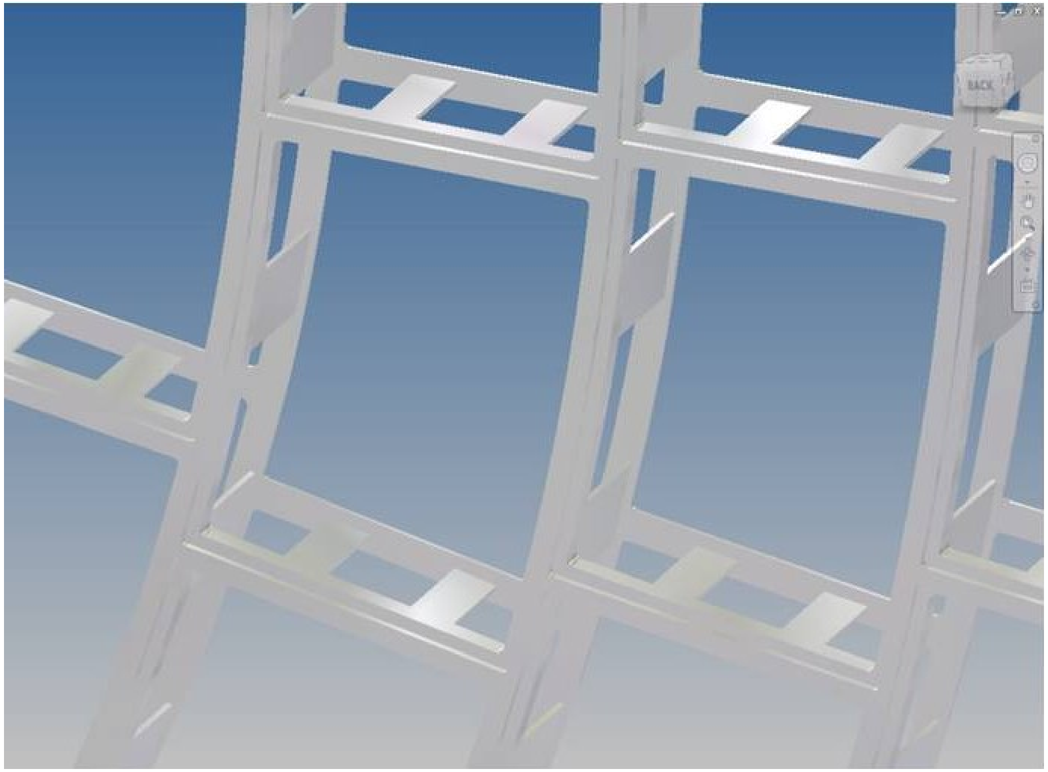
25% X_0 including	readout plane, front-end-electronics, gate	5%
	cooling	2%
	power cables	10%
	mechanical structure	**8%**

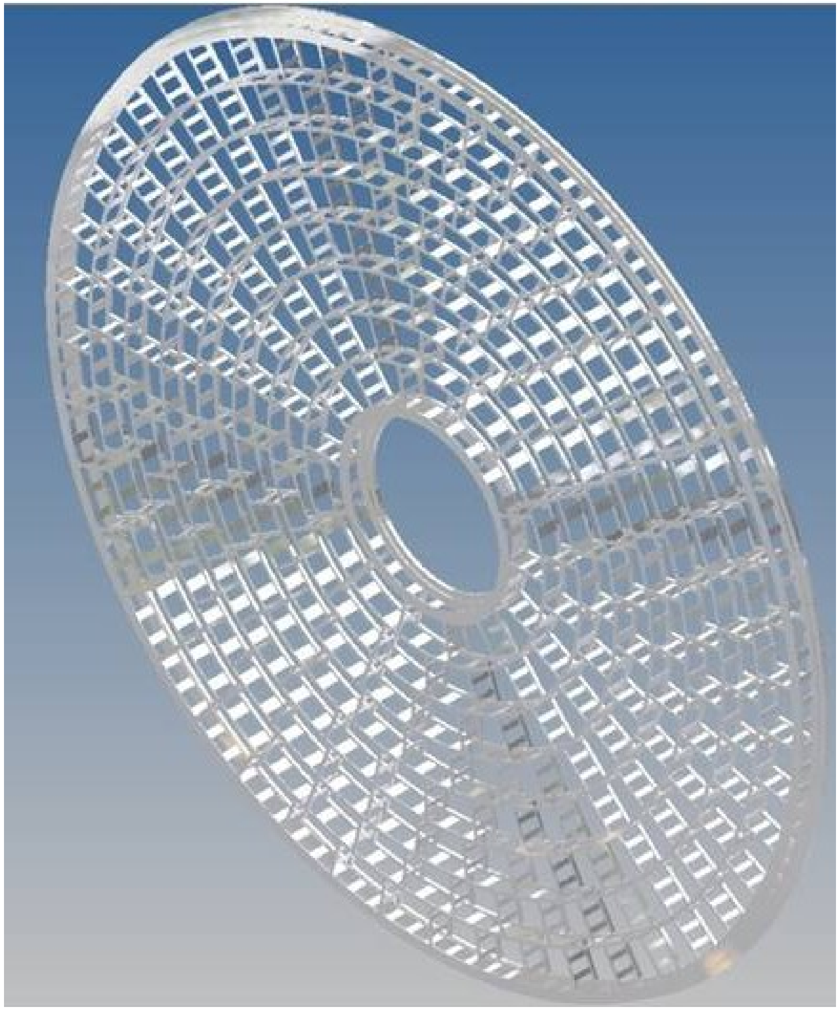
Rigid - limit is set to facilitate the de-coupled alignment of
magnetic field and
module positions.
Precision and stability of x,y positions **< 50μm**

Thin - ILD will give us **100mm** of longitudinal space
between the gas volume and the endcap calorimeter.



The **ILD endplate design is a space-frame** and shown here as the solid model used for the Finite-Element-Analysis (FEA).



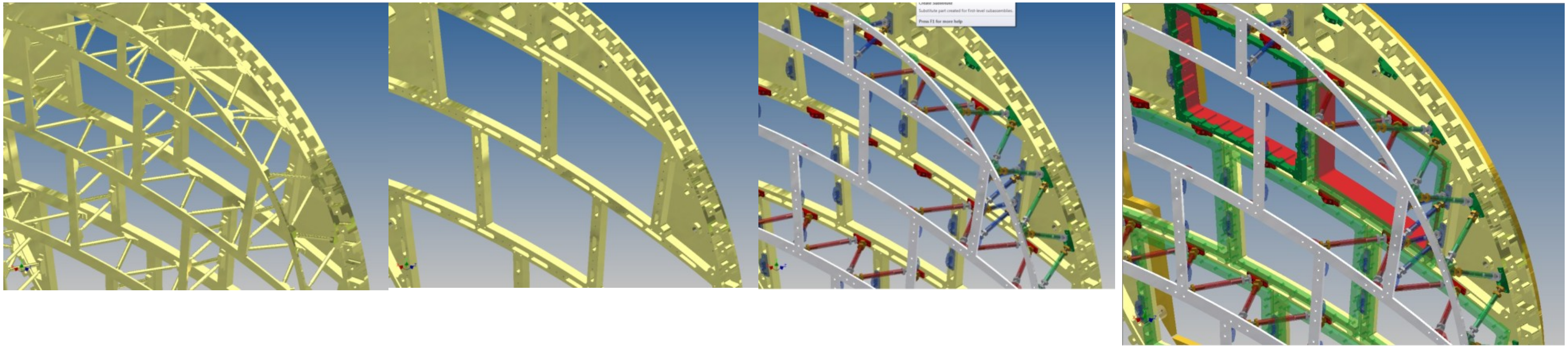


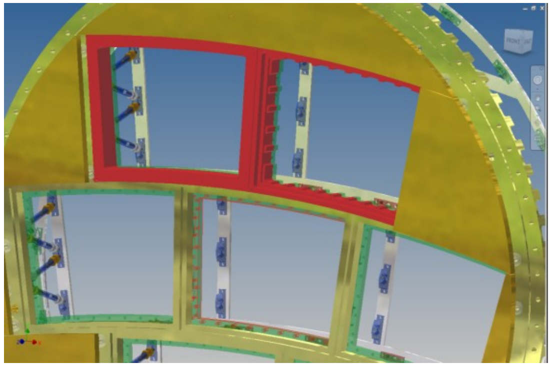
This model has a full thickness of 100mm, radius 1.8m, and a mass of 136kg.
The material thickness is then 1.34g/cm^2, **6% X_0**.

This is the "equivalent-plate" design space-frame; the separating members are thin plates.
This design has rigidity and material equivalent to a strut design, which will be used for a new LP1 endplate.

(inside view)

The next phase of prototyping/validation in the ILD endplate study:
construction and measurement of a fully functional LP1 endplate in a space-frame design.





FEA shows that an LP1 endplate in the space-frame design
with material 7.5% X_0, deflects by 33 μm.
when center loaded with the force due to 2.1millibar overpressure.

Also, FEA shows that the current LP1 endplate (2008)
with material 16.9% X_0, deflects by 23 μm.
This is confirmed with measurements of the LP1 endplate.

Measurements of small test beams also validate the
FEA predictions of the space-frame properties.

The new LP1 space-frame endplate will be used to
further validate the FEA, understand complexities of the construction, and study lateral rigidity and stability.
It is compatible with LP1 field cage, modules, field cage termination, alignment devices.

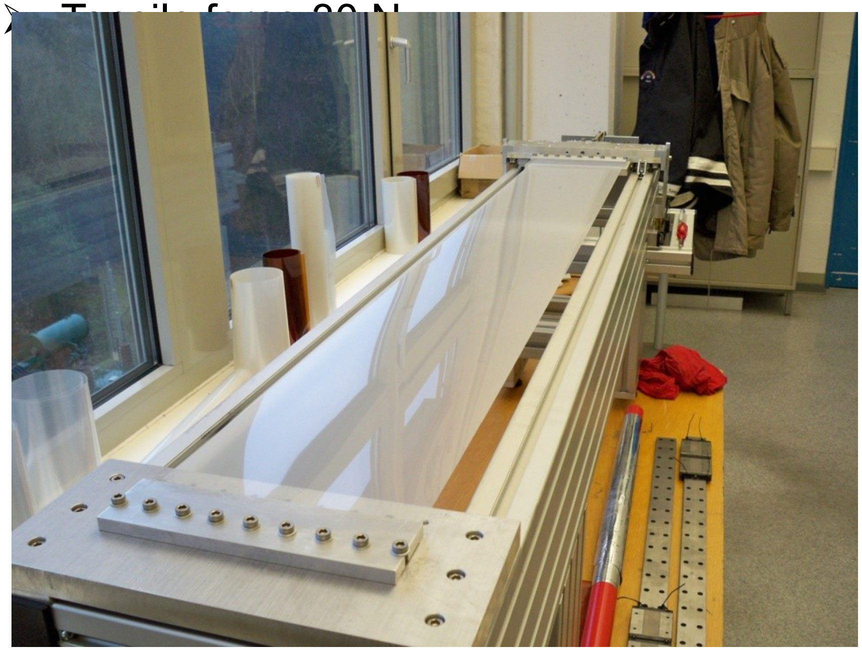
Mass: 6.56 kg in main plate, 0.81kg in back plate, 1.72kg in struts, =9.2 kg total (LP1 2008 = 18.9 kg)

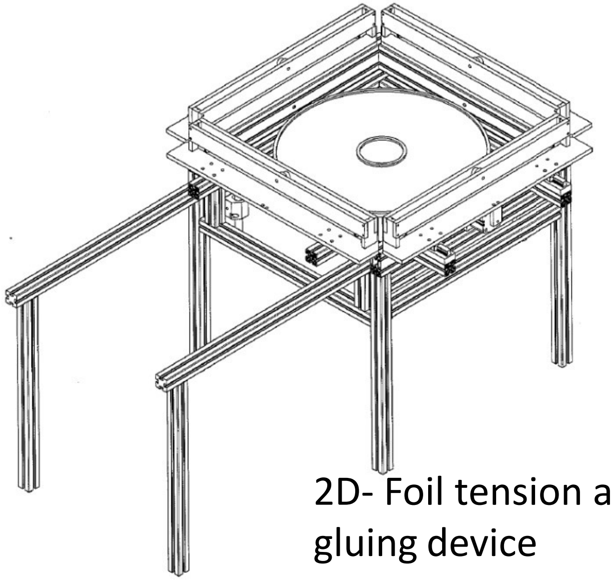
ILD TPC Cathode Status

V. Prahl

Now in progress:

- Several cathode designs in discussion (Foil, Honeycomb… ideas are welcome)
- Foil tests with different kind of foils without copper coating
- First tensile tests for one direction only(see picture below on the left)
- Dimensions of the strips 1600 mm x 200 mm
- Tensile force [illegible] N





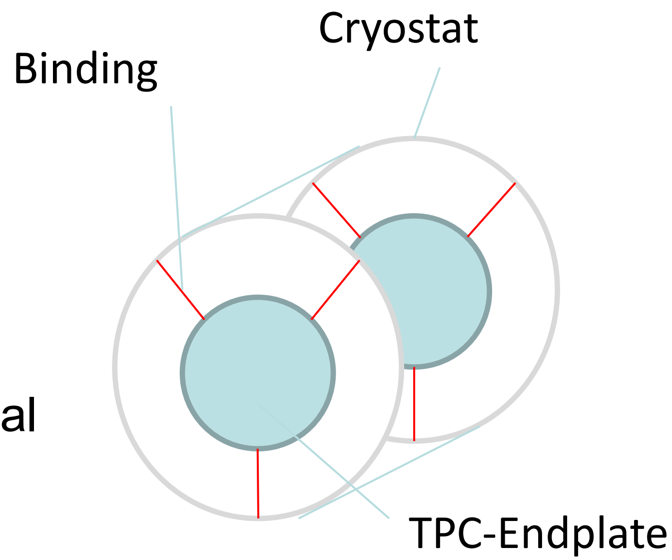
2D- Foil tension and gluing device

Planned or ongoing:

- Build a tensile device for two axes
- A gluing tool for a carbonfiber support ring to build a cathode with foil has finally been designed and will be build soon
- Help would be needed to find suitable foils

ILD support structure preferred design

- Binding structure, 120 degree each using a cobweb“ design
- Fixing points on the Cryostat and preferrably on the Endplate
- Adjustable bracket at the cryostat
- Material: CFK, GFK, small parts made out of metal or non magnetical material



Sketch of the cobweb

Required items

- Min free space required is about 10 x 100 mm
- Gap to neighbouring Detectors and other Components about 10 mm (this may be very optimistic)
- Straight line between Endplate and cryostat is necessary

Planned tasks

Build test parts for the field cage vessel for mechanical and electrical tests

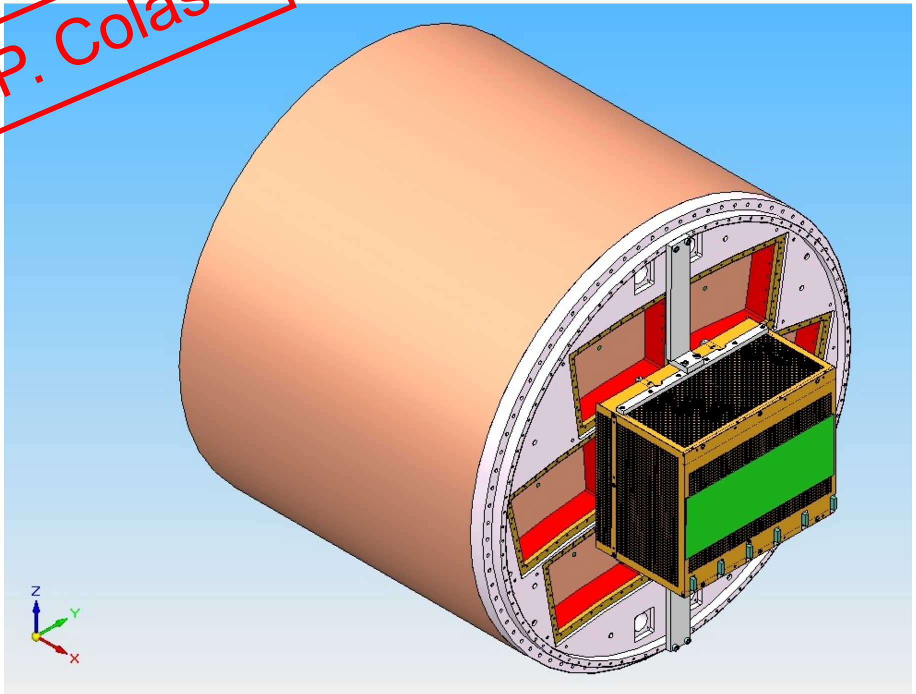
Design of a alignment system for the cathode

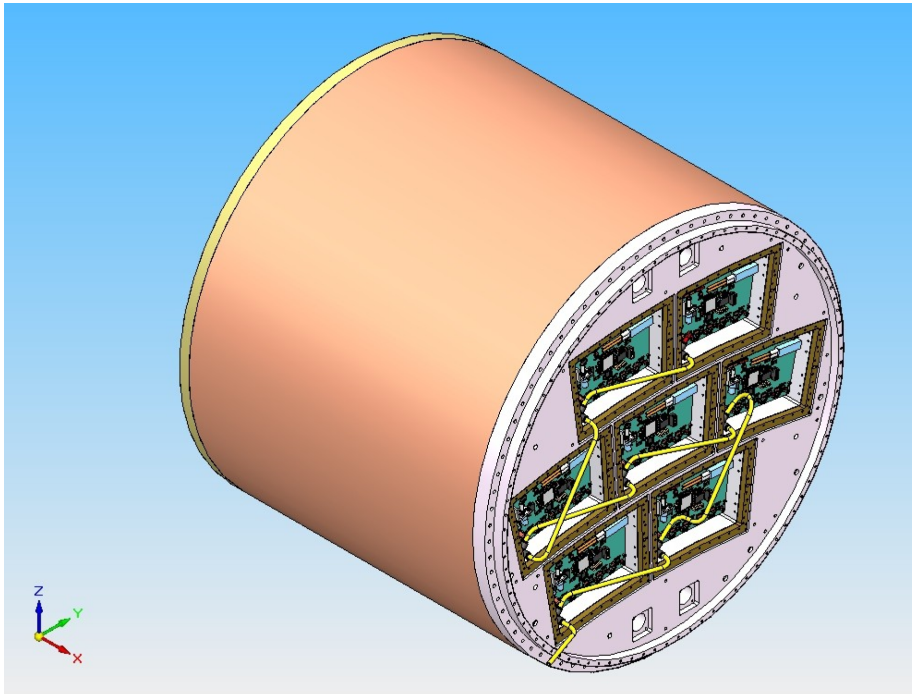
HV feed-through to the Cathode

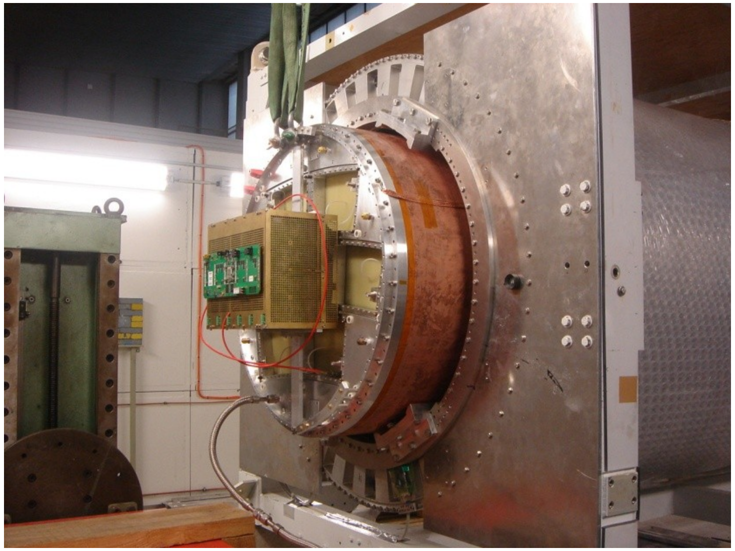
V. Prahl

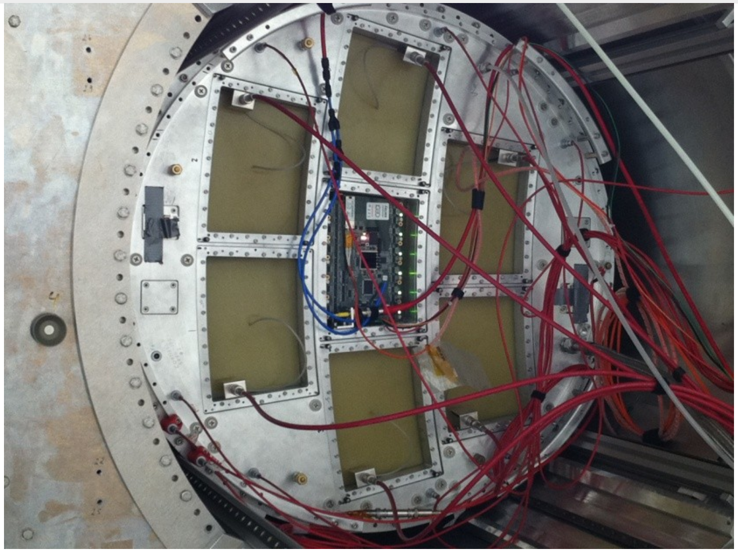
Integrated electronics for 7 module project

P. Colas

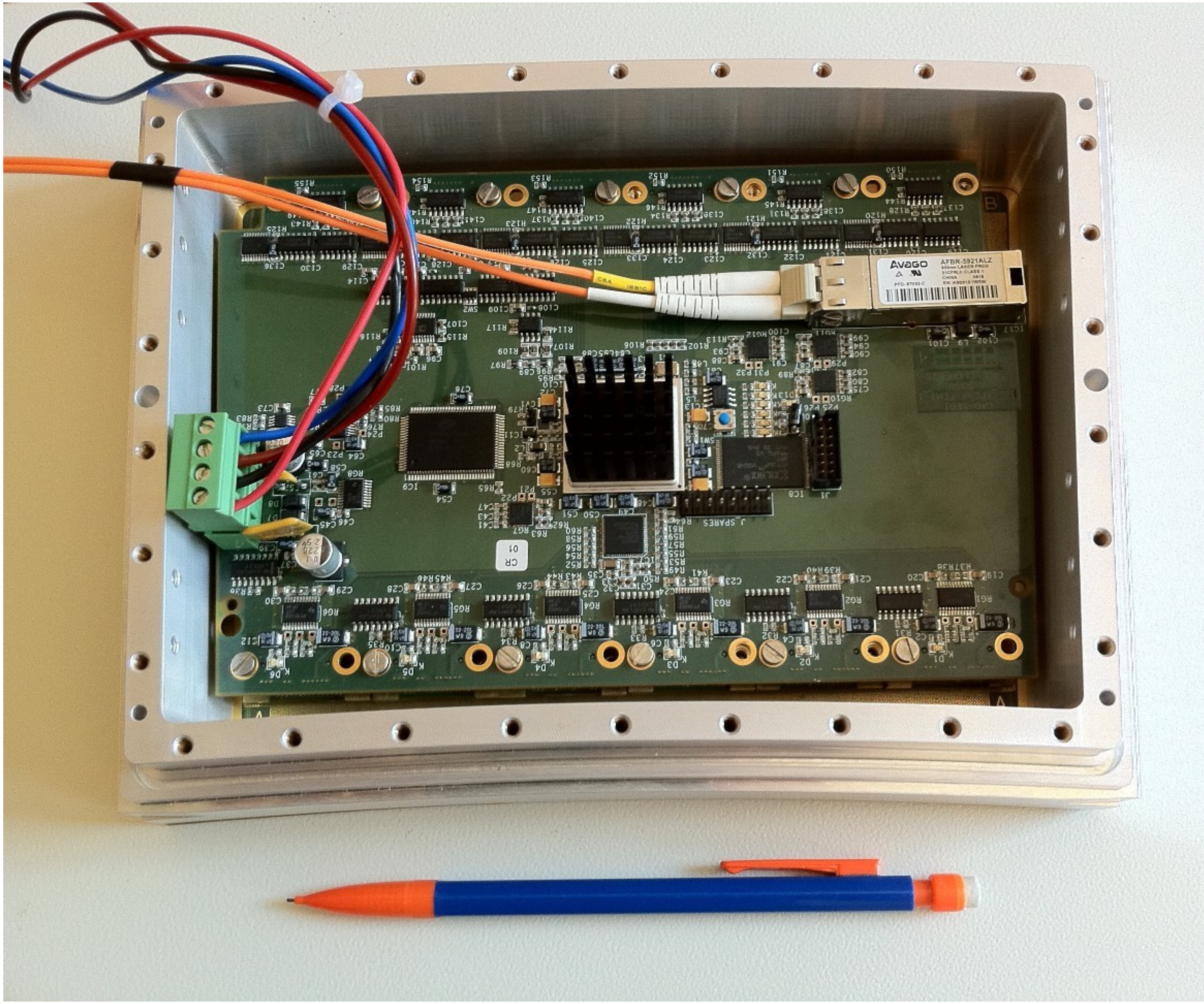




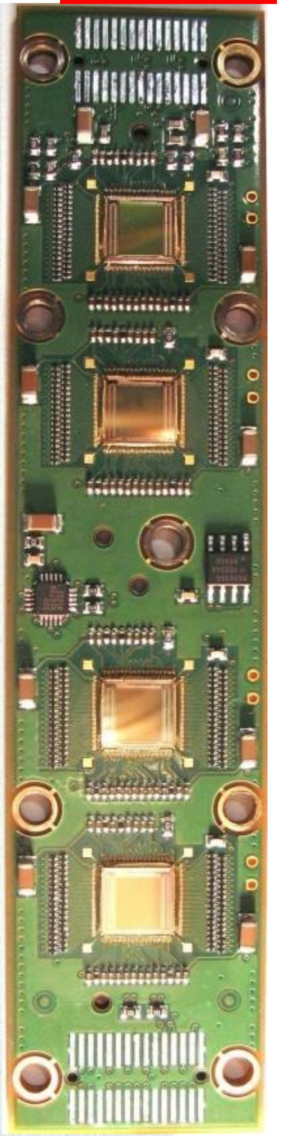




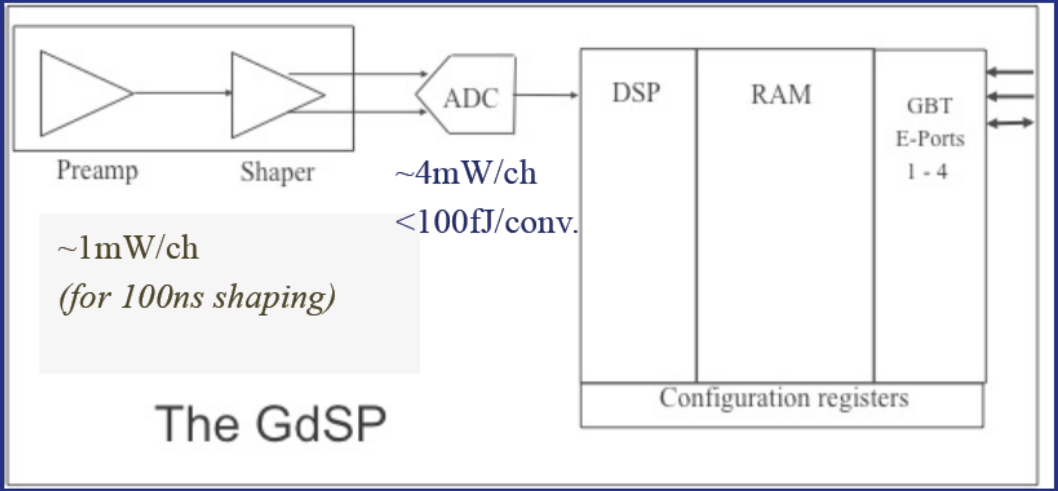
First prototype of the electronics



FEC



The GDSP (Gas Detector Signal Processor)



Estimate for optimal future power (static)

64 channels = Analog power ~ 320mW + Digital power ~ a few hundred mW.
Approx. ~500mW / chip.

128 channels = Analog power 640mW + Digital power ~ some hundreds mW.
Approx. ~900mW / chip.

Should be possible to get 7-8 mW/ch for everything on a 128 ch chip.

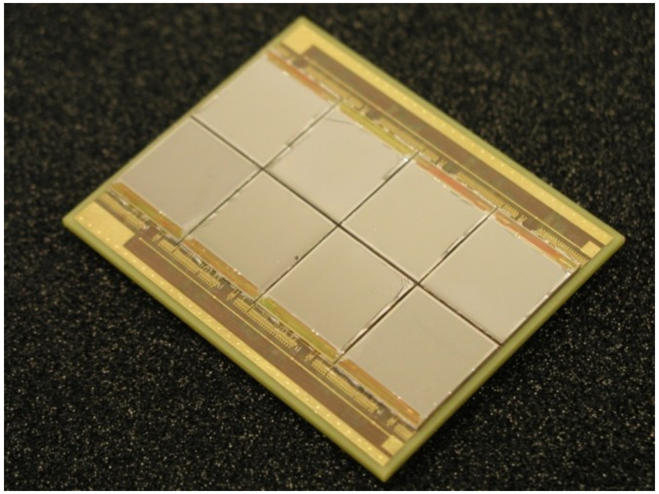
Power management & pulsing may then be applied to reduce power further.

P. Colas

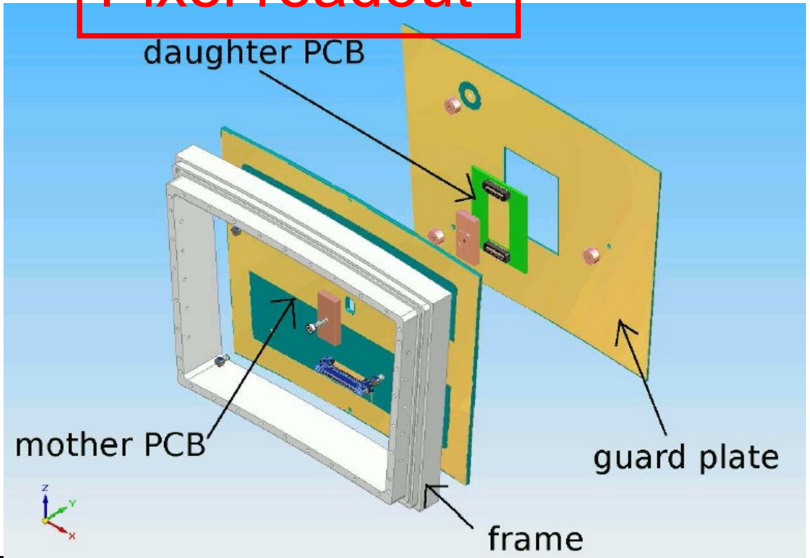
New Conclusions

- Continue integration work with PCA16+ALTRO and SALTRO16 or AFTER with help from AIDA (Lund, Saclay,…). None of these is the final LD electronics (insufficient packing, protection, too much consumption, memory depth,…)
- Start design work on a future GdSP chip using synergy between LD-TPC and SLHC muon chambers. Paul Aspell is putting together a design team. Saclay volunteer to participate. Directly going to full Si chip is too expensive and premature.

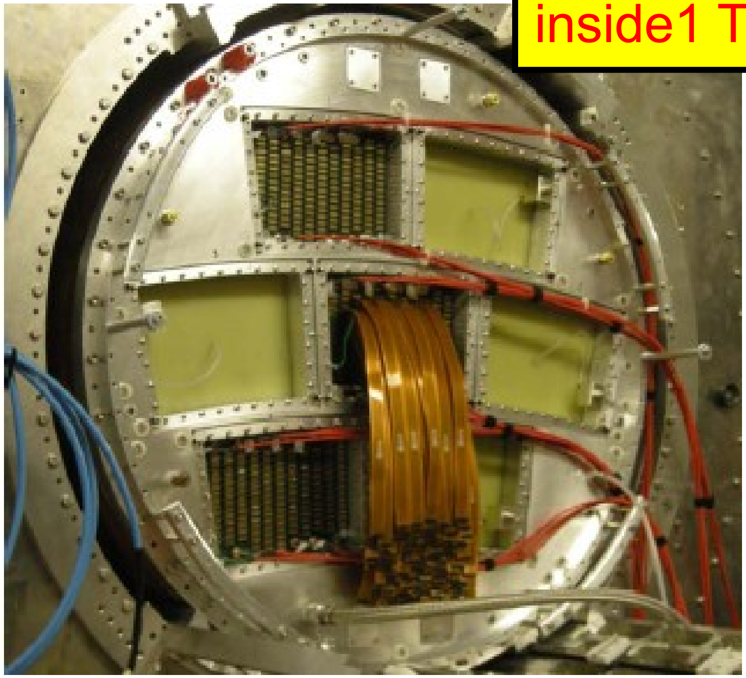
8 Ingrids on daughter board

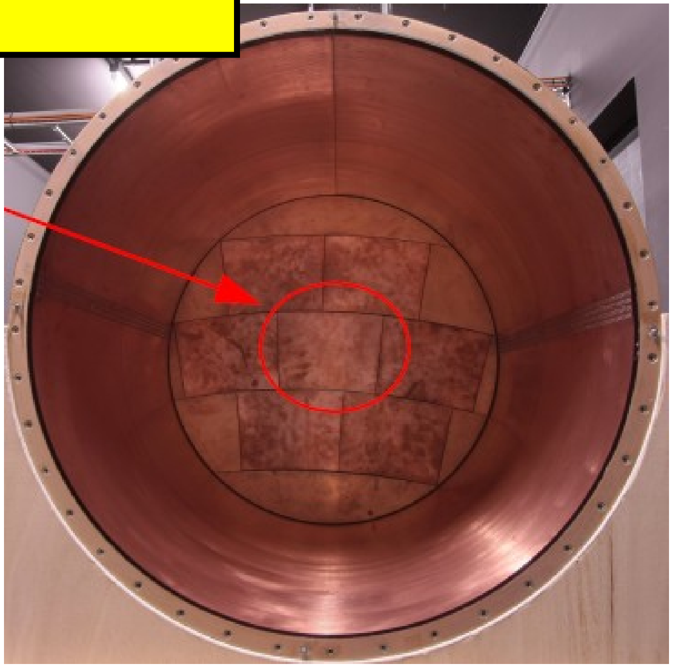


Pixel readout



LPTPC with 7 detector slots inside1 T solenoid

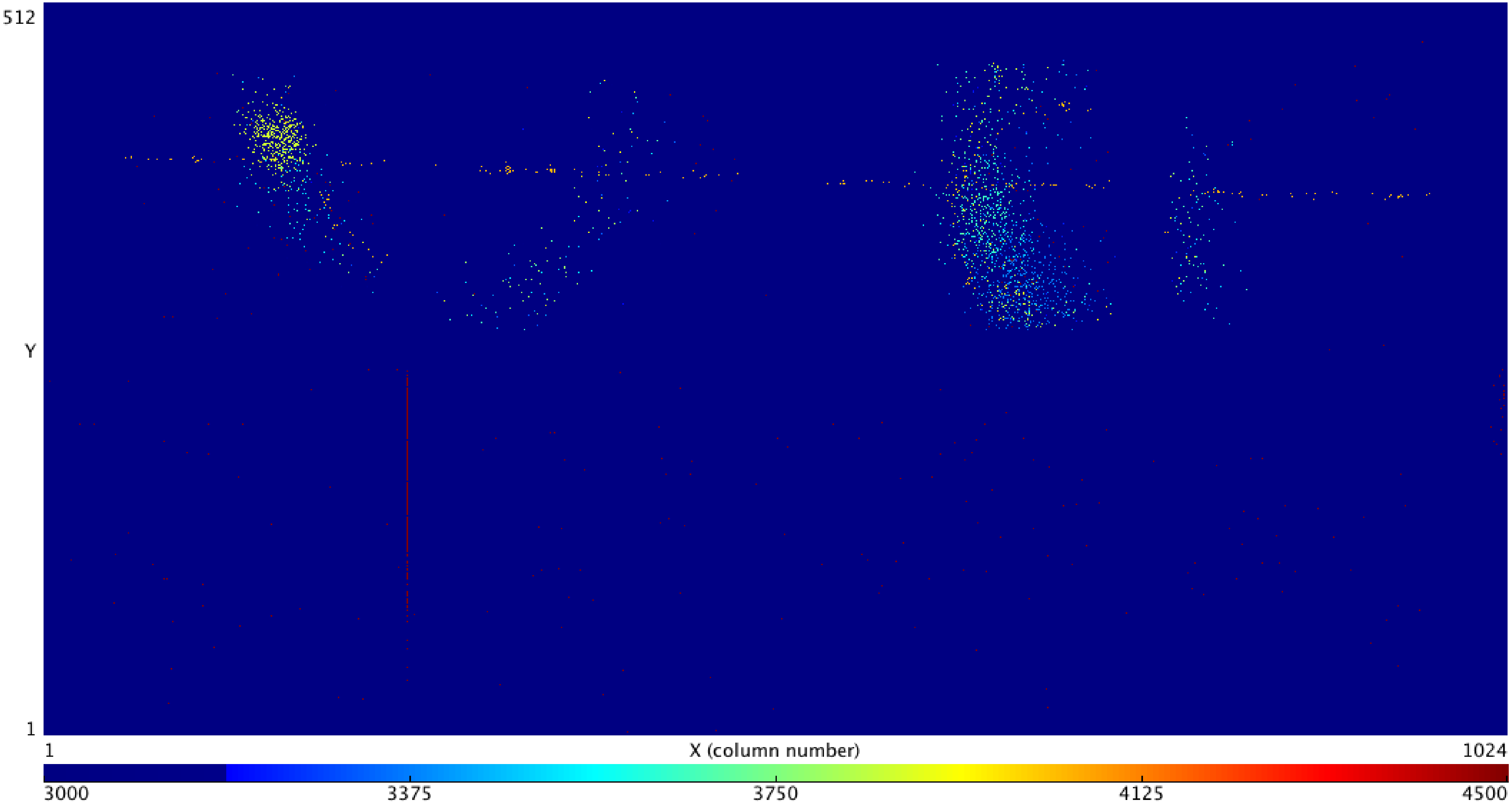




The last trigger taken: 4 Dec 2010, 11:06

He/iC_4H_{10} 80/20 V_{grid} = -400 V B = 1 T

(5 GeV beam electron with two delta curlers)



Power pulsing and Cooling test with the AEP Test Board

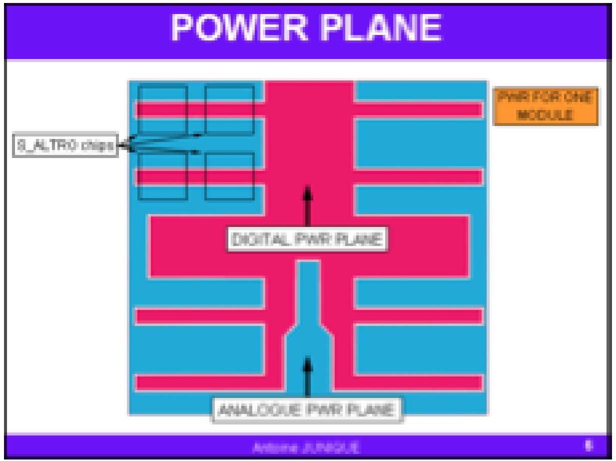
T. Fusayasu

AEP power consumption (w/o power pulsing)

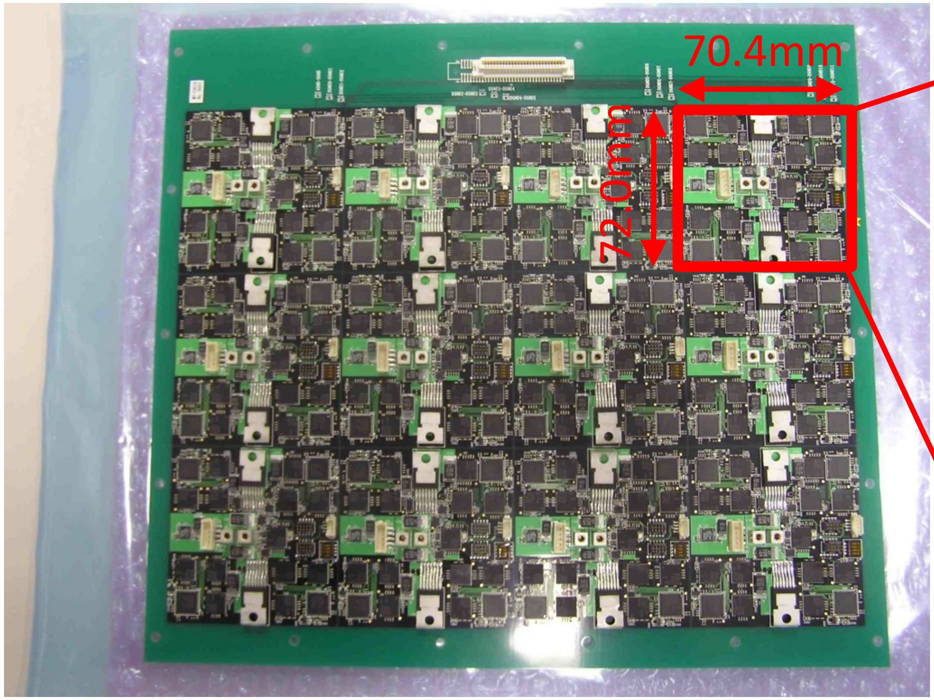
11(20)kW/m^2 @ 10(40) Msps

Purpose of the test board

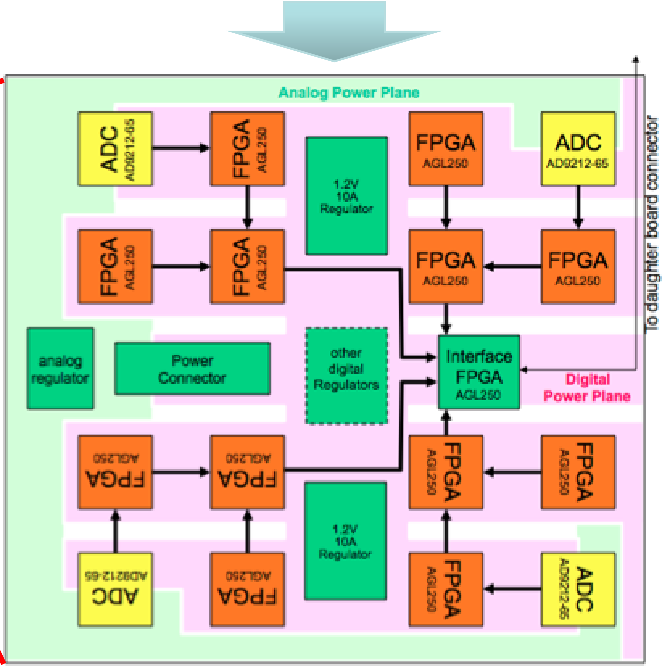
- Fabricationability
- Thermal test (CO$_2$ cooling)
- Power pulsing test
- Power pulsing test in magnetic field
- Noise condition



Advanced Endplate layout plan



Maximum power: 600W (10kW/m^2)



Advanced Endplate Test Board
(FPGAs and ADCs instead of SALTRO64)

Setup for first power pulsing and cooling test w. the test Bd.

Plan

May - Jun /2011:

start up of the board

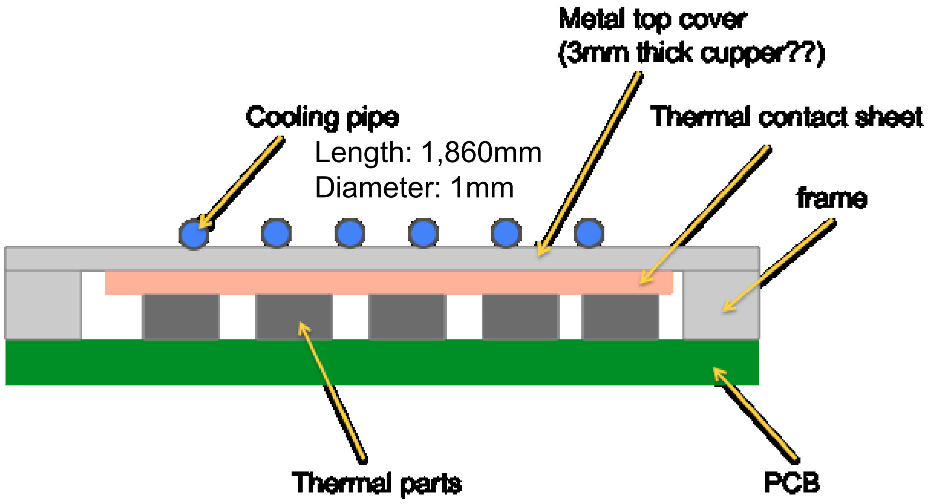
(programming, function check, cooling device)

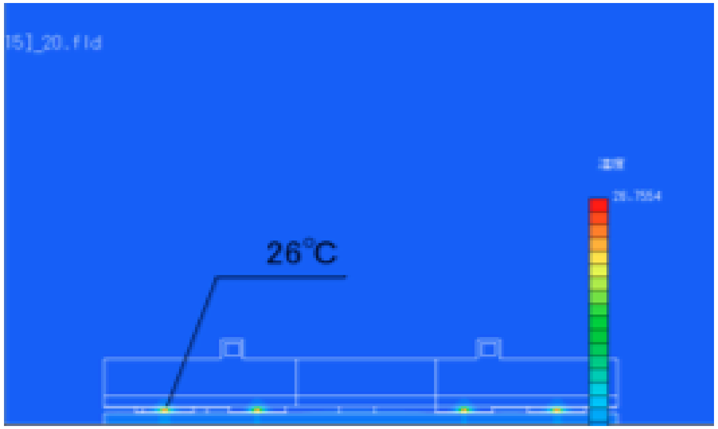
Jul - Aug / 2011:

test at KEK CO_2 cooling bench

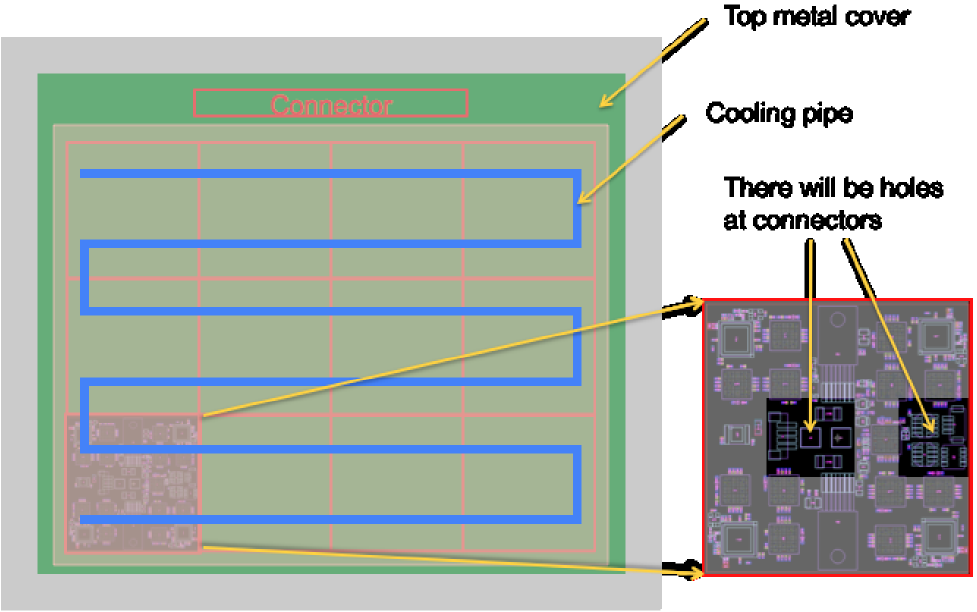
Sep - Oct / 2011:

test at NIKHEF CO_2 cooling bench.





Thermal simulation ongoing



Takeshi Matsuda

TPC Cooling by 2 Phase CO$_2$

Goal : Uniform gas temperature in the whole volume of the filed cage down to $\Delta T_{gas} <$ O(0.1°C) (*) to achieve Δz = 0.5mm and the uniform gain.

(*) 0.1°C @ALICE TPC(TDR)

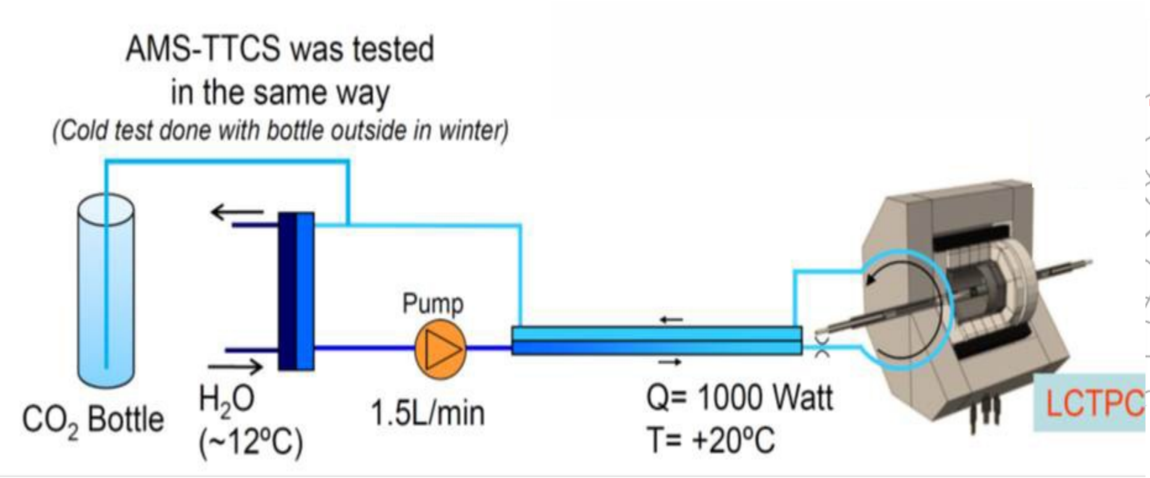
Advantages of 2 Phase CO2 cooling:

Large latent heat of liquid CO2 (300J/g), and

High Pressure operation (5MPa @+15°C)

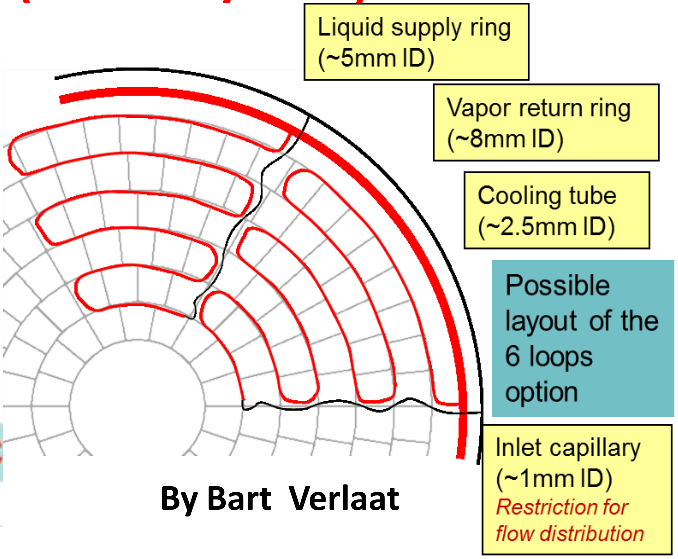
→ Minimum amount of coolant and thin pipes

→ No temperature gradient of coolant (until "dry out")



AMS-TTCS was tested in the same way

(Cold test done with bottle outside in winter)



By Bart Verlaat

TPC Cooling by 2 Phase CO_2

A Proposal to demonstration at LP Beam Test

(A) **Exercises and preliminary cooling tests using a simple 2PCO2 blow system @KEK (later at NIKHEF)**

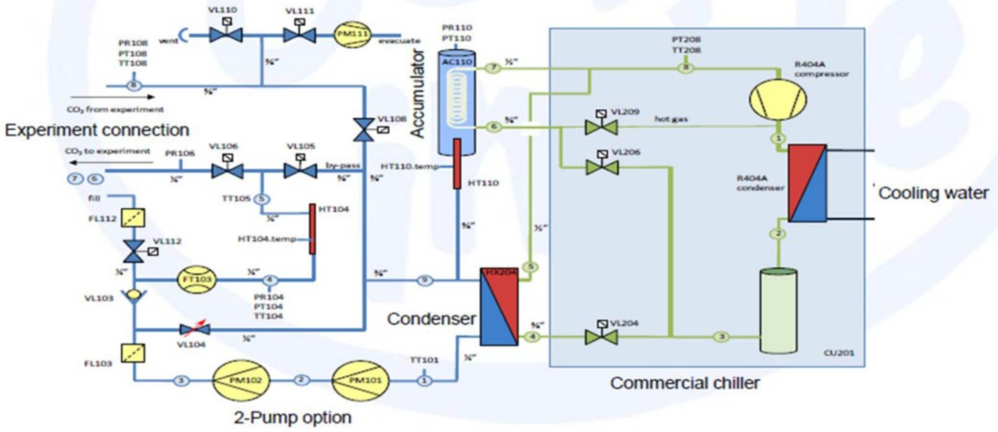
Heroic effort by Kasami-san who built the whole system all alone!

2PCO2 blow system (KEK)

(B) **Obtain a 2PCO2 Circulation System now available**

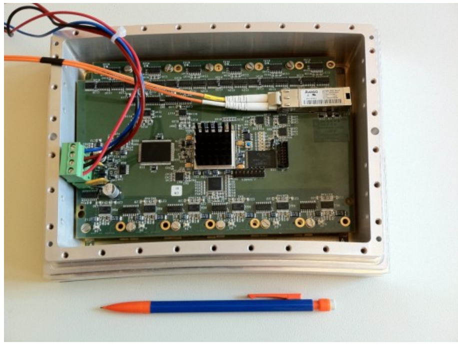
CERN / Nikhef 1kW Unit Schematics.

- Base design for future cooling plants (IBL, XFEL, Belle-2)



CERN Test System (2KW)

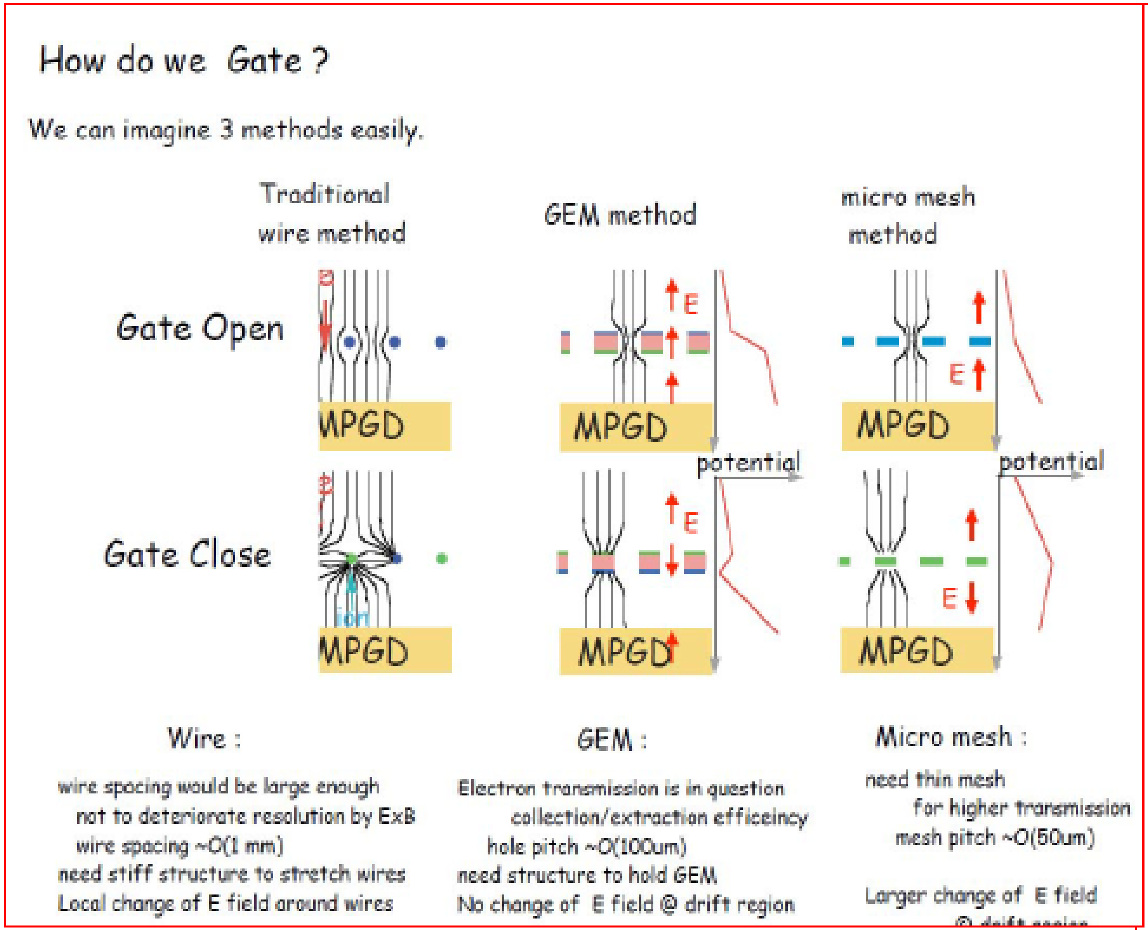
(C) **Demonstrate with new LP TPC detector modules with compact readout electronics (S-ALTRO16/T2K) in 2012-2013:**



From Akria's talk at lctpc 2009

Gating:

R. Settles



How do we Gate ?

We can imagine 3 methods easily.

Traditional wire method

GEM method

micro mesh method

Gate Open

Gate Close

Wire :

wire spacing would be large enough
not to deteriorate resolution by ExB
wire spacing ~O(1 mm)
need stiff structure to stretch wires
Local change of E field around wires

GEM :

Electron transmission is in question
collection/extraction efficeincy
hole pitch ~O(100um)
need structure to hold GEM
No change of E field @ drift region

Micro mesh :

need thin mesh
for higher transmission
mesh pitch ~O(50um)

Larger change of E field

Another idea…

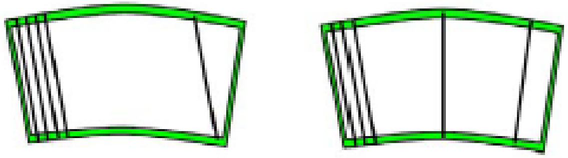
We don't need to use the traditional method of a crossed E-field between neighbouring wires for "gate closed"; all we have to do is to flip the E-field polarity.

Here is a rough example: if the gate is 0.5cm above the MPGD surface and T2K gas (Vdrift ~ 220V/cm)

-Gate open: Vgate = ~ +100V

-Gate closed: Vgate = ~ -100V

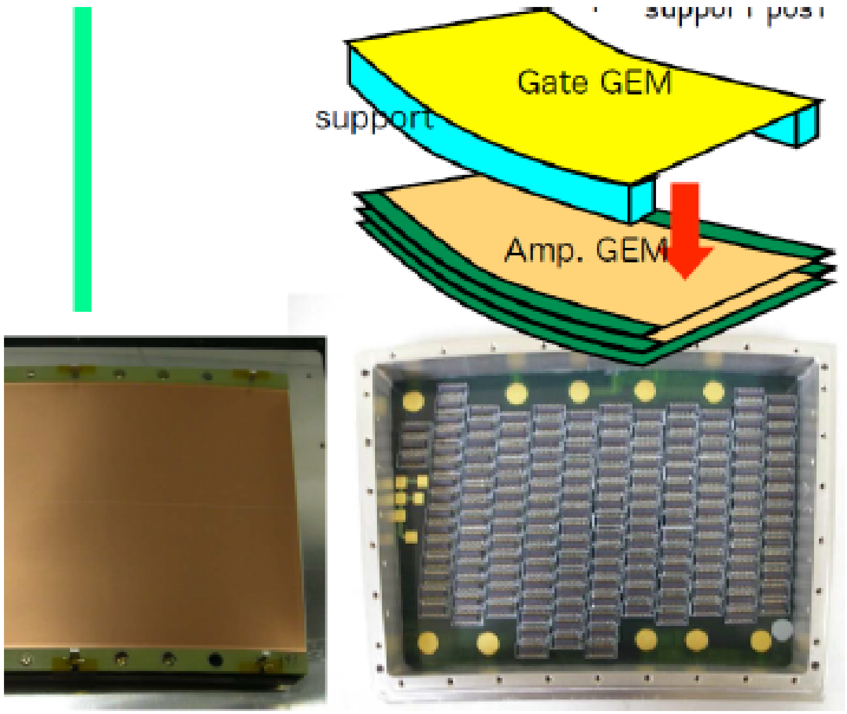
How to strech the wires?
From Akria's talks:



Does this work ?

how to treat insulator

If we choose wire gate
better to reconsider the concept of LP1 (small module) again ??

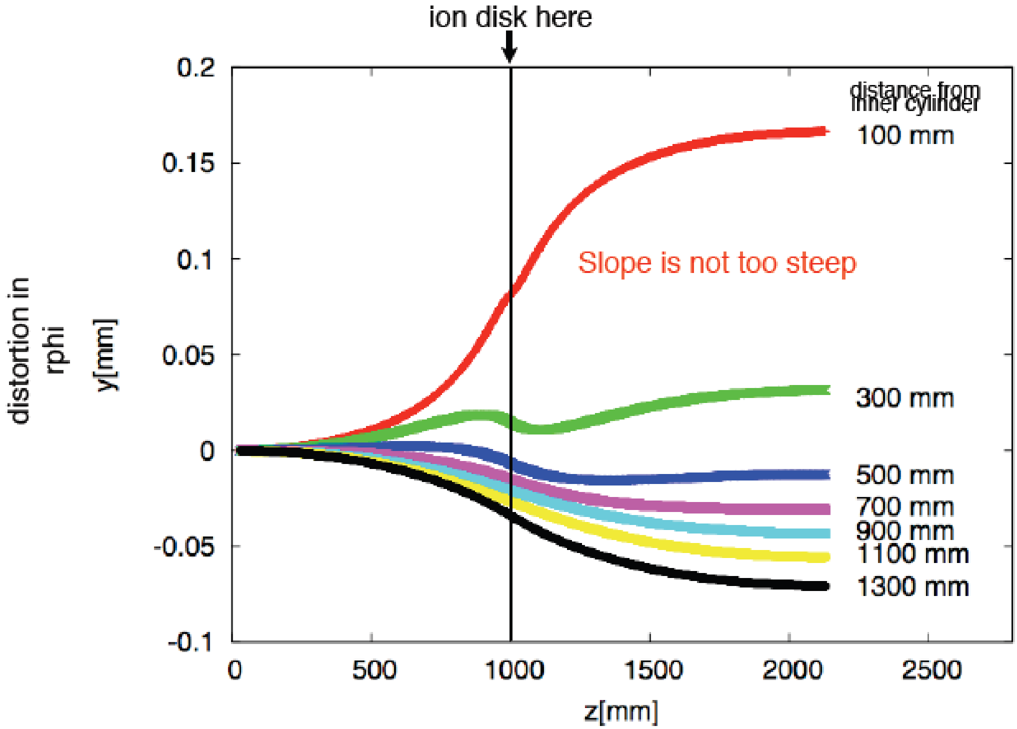


Ion backflow simulations

- Work restarted by Thorsten Krautscheid (Bonn)
- Also at KEK by Keisuke Fujii + student

  (ion disk between gate and MPGD plane)
- Distortion results for tracks beyond the ion disk (Peter Schade)

O(0.1)mm distortion for tracks beyond the ion disk



Slope is not too steep

Summary

- Realistic Mokka simulation model
- Progress in software devlopments (but less than hoped for; personpower limited)
- Lots of R&D activities on mechanics, electronics, cooling and their integration (also here reduced manpower)
- Several open questions (backgrounds, ion backflow, gating, …)

Backup slides

TPC Occupancy

The TPC has 1.6 billion voxels

- 1.6 million pads (Pad size 1×6 mm^2)
- 1000 time samples (40 MHz ADC)

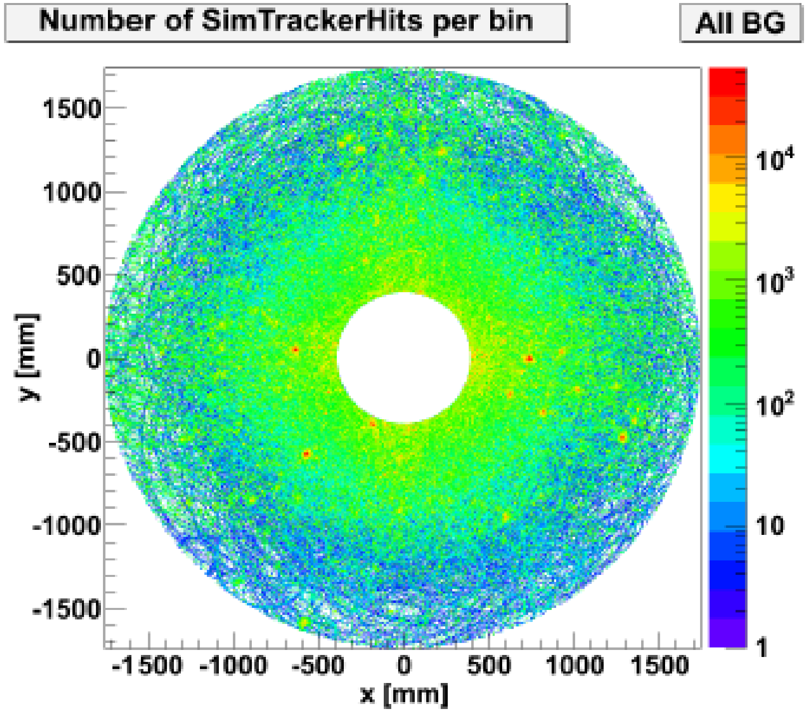
How many are occupied after integrating a full bunch train of beam induced background (CLIC bunch train length: 156 ns)?

Simulation takes into account

- Realistic primary charges (Mokka driver in lowPT mode)
- Diffusion (T2K gas)
- Gas gain fluctuations (3 GEMs, total gas gain ≈ 3000)
- Electronics shaping (rising and falling edge 60 ns)

Occupancy is calculated from "raw data" (ADC signal like a real TPC)

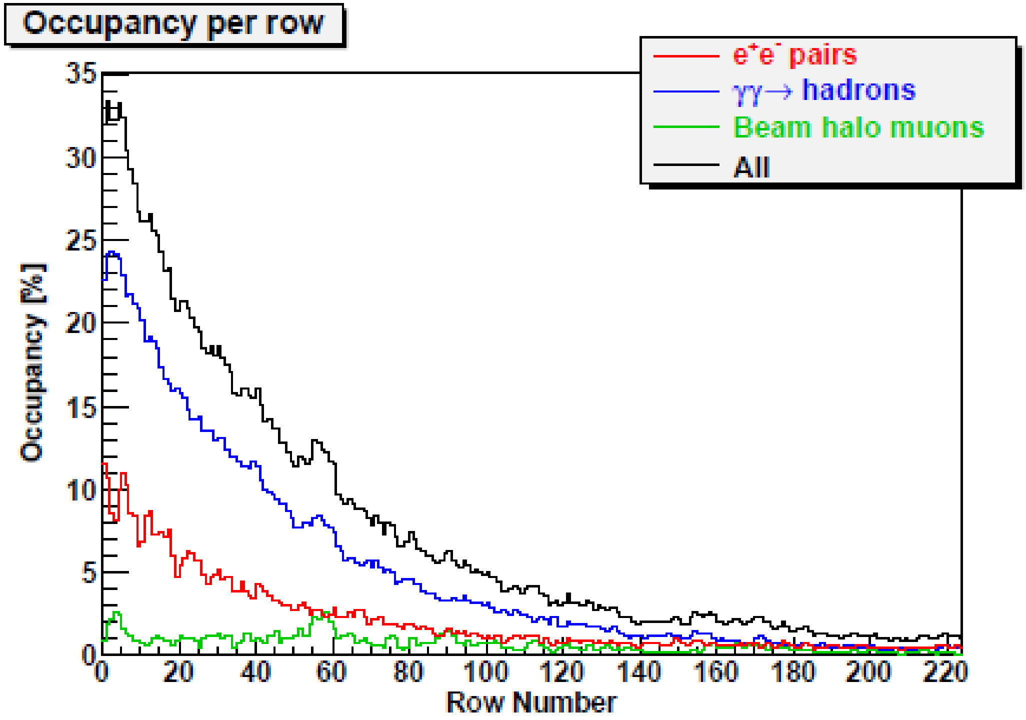
Mokka with lowPT driver, digi in MarlinTPC



TPC Occupancy (Results)

Beam induced backgrounds

- $\gamma\gamma \rightarrow$hadrons: 3.2 per BX
- Incoherent pairs: $\approx$ 300k per BX
- Beam halo muons: 5 per BX (with muon spoilers)[1]



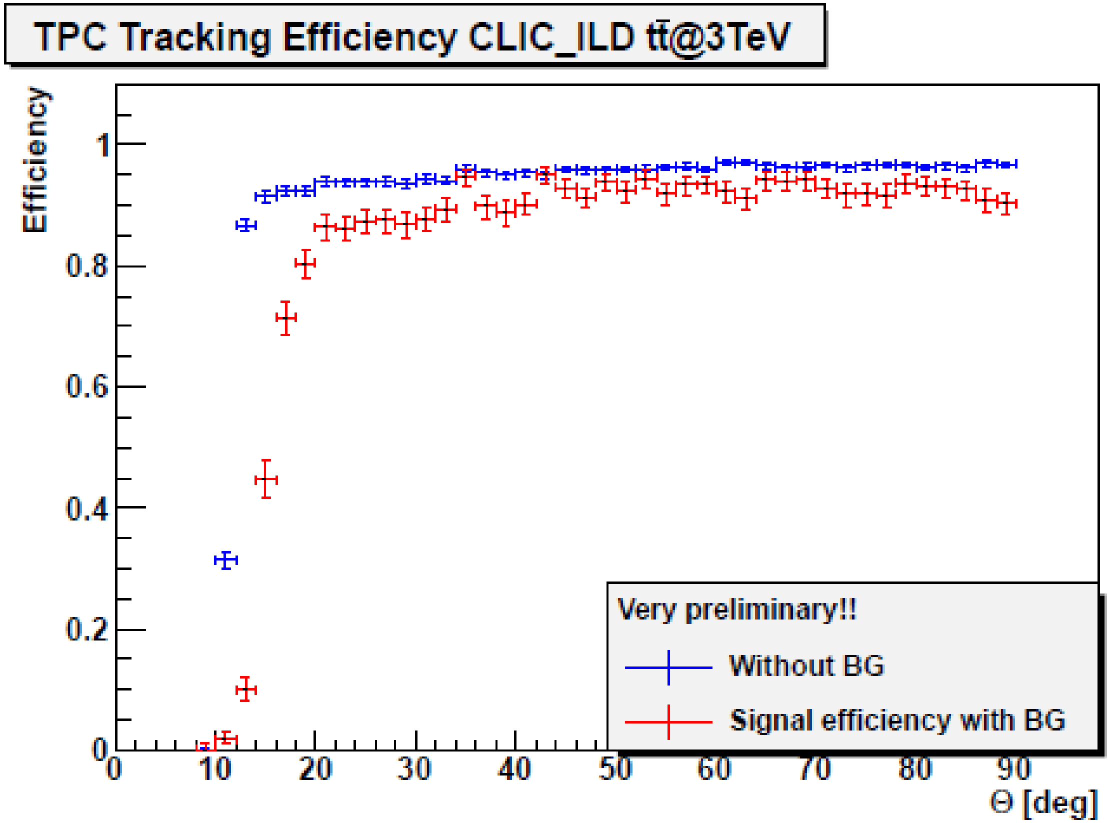
Background	Average Occupancy	Average Inner 10 Pad Rows
$\gamma\gamma \rightarrow$hadrons	3.1 %	20.3 %
Incoherent pairs	1.4 %	9.0 %
Beam halo muons	0.55 %	1.6 %
Total	5.1 %	31.0 %

---

[1] Spatial and momentum distribution without spoilers, scaled to the rate with spoilers

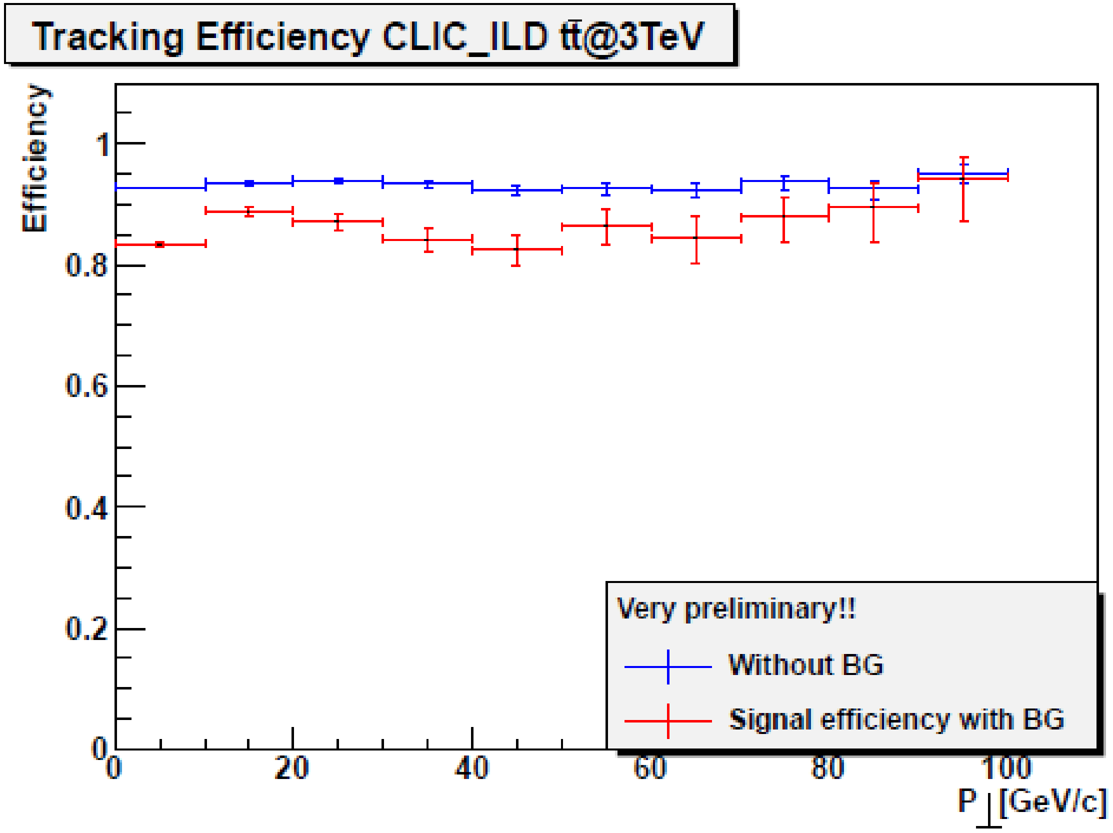
Tracking Efficiency for Signal vs. θ

- Signal $t\bar{t}$@3TeV
- Background 60 BX $\gamma\gamma\rightarrow$hadrons
- Mokka with default driver
- Digitisation and reconstruction with MarlinReco



Tracking Efficiency for Signal vs. PT

- Full θ range, incl. the inefficient regions

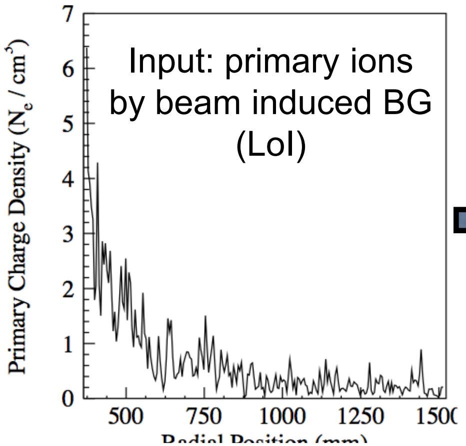


Ion Disk Back Flow

To gate or not to gate?

Two problems:
- Ion disk in the drift region if not gated
- Ion disk in-between the gate and the amplification device even if gated

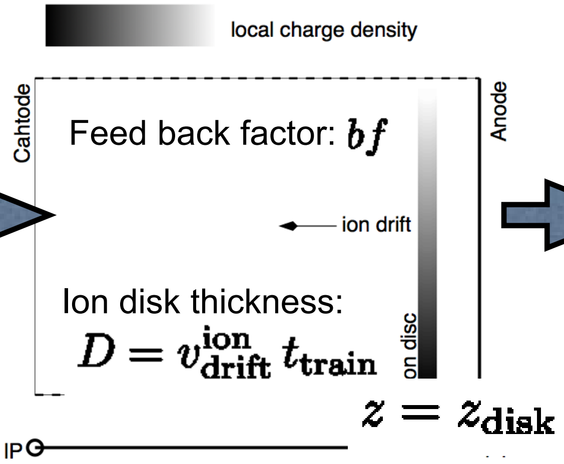
Simulation:



Input: primary ions by beam induced BG (LoI)

$$\rho_{\mathrm{TPC}}(\boldsymbol{x}) = \rho_{\mathrm{TPC}}(r, \cancel{\phi, z})$$

Assume primary ions uniformly distributed in both z and phi

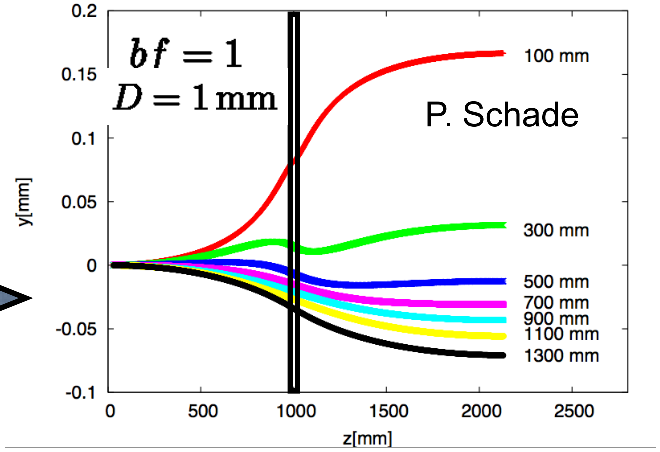


Feed back factor: bf

Ion disk thickness:

$$D = v_{\mathrm{drift}}^{\mathrm{ion}} t_{\mathrm{train}}$$

$$\rho_{\mathrm{disk}}(\boldsymbol{x}) = -\frac{bf}{D} \int_0^{L_{\mathrm{drift}}} \rho_{\mathrm{TPC}}(\boldsymbol{x}') dz' \times \Theta(z - z_{\mathrm{disk}} + D/2) \times \Theta(z_{\mathrm{disk}} + D/2 - z)$$



$$z_{\mathrm{disk}} = 1000\,\mathrm{mm}$$

O(0.1)mm distortion for a single ion disk in the middle of the drift region!

Slope should be gentler behind the gate

The electric field distortion should be smaller behind the gate since the gating plane and the MPGD plane constrain the electric field to be perpendicular to their surfaces, thereby making the radial component smaller.
The distortion behind the gate is probably small because of this and the short drift under the influence of the disk.
-> To be confirmed by simulation