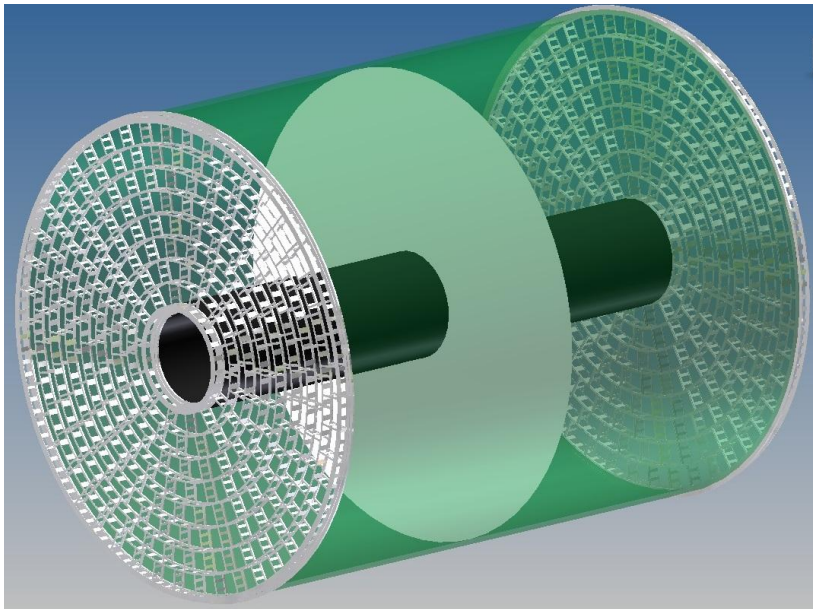
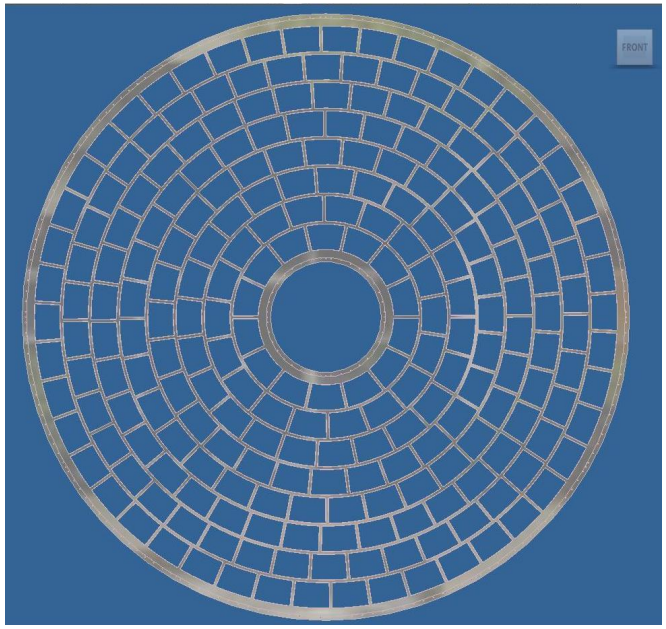
(Pixel) modules for ILD TPC

- LCTPC module development
- TimePix1 modules
- Concept proposal for engineered TimePix3 module

TPC design





- Endcaps made with spaceframes
- Allows stable positioning of detector modules to <50 μm
- Deflection under 2.1 mbar over-pressure is 0.22 mm
- Mass is 136 kg/endplate

- 10 m^2 per endcap
- 8 rows of MPGD detector modules; module size ~ 17 x 22 cm^2
- 240 modules per endcap
- Endplate is 8% X_0
- Readout modules+electronics 7% X_0
- Power cables 10% X_0

Some numbers on resolution (1)

- $p \cos \lambda = 0.3\ B\ R$ B [Tesla], R [m], p [GeV]
- Sagitta $s \approx L^2 / 8R$ L ≈ pathlength

- B=4T, p=100GeV, L=1.2m => R=83.3m
- => s=2.16 mm

Some numbers on resolution (2)

- B=4T, p=100GeV, L=1.2m => R=83.3m
- => s=2.16 mm

- TPC alone (pad readout ~200 points):
  $\Delta\, 1/p = \Delta p/p^2 \sim 10^{-4}\ \mathrm{GeV}^{-1} \Rightarrow \Delta p/p = 10^{-4}\ p$

- P = 100 GeV: $\Delta p/p = 10^{-2} = \Delta s/s$

- $\Delta s = 10^{-2}$ s => $\Delta s = 22\ \mu$m !!!

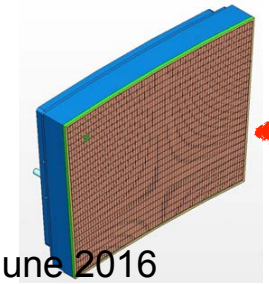
Some history (not complete)

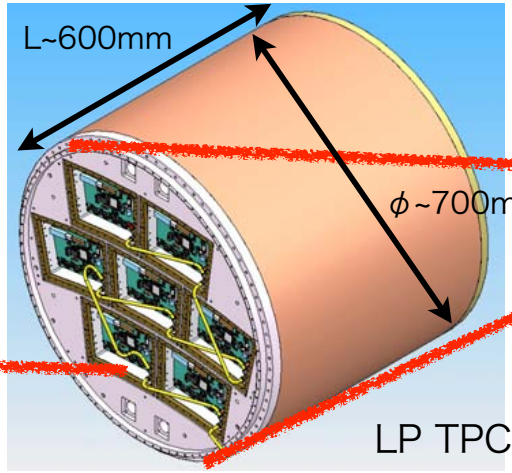
- 2008: 1T magnet + Large Prototype TPC; first Micromegas module test (Saclay)
- 2009 ++: double-GEM (Japanese) and triple-GEM (DESY) modules tests
- End-2010: first (single) Octopuce TimePix1 module test (Nikhef+Saclay)
- 2012 ++: 7-module Micromegas (with integrated electronics)
- 2014: 2 (single) Octopuce (16 TimePix1) + 5 Micromegas (Nikhef+Saclay) modules; synchronised readout
- 2015: 3 multi-Oktoboard modules (Bonn); 160 TimePix1 GridPix

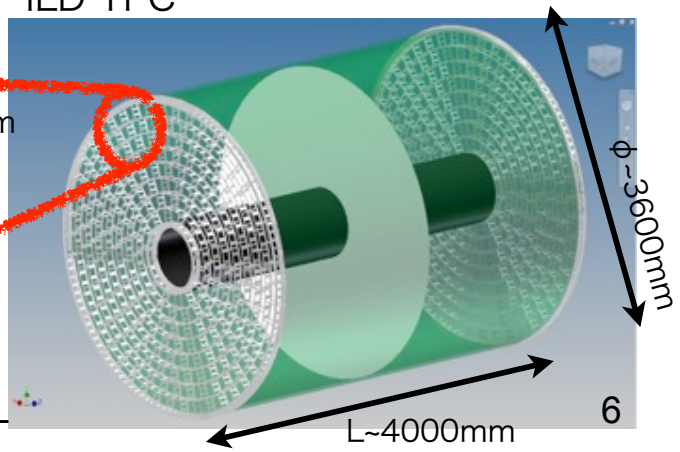
Beam Tests of the Large Prototype TPC

- Large Prototype (LP) TPC is setup in DESY test beam, area T24/1. e^+/e^- from 1 to 6 GeV/c.
- PCMAG magnet: 1T magnet. ~~This year~~ modified to run with cryo coolers and closed cooling cycle.
- Mounted on 3-axis movable table.

7 readout modules
with the size of ~230 x 170mm^2
can be installed.

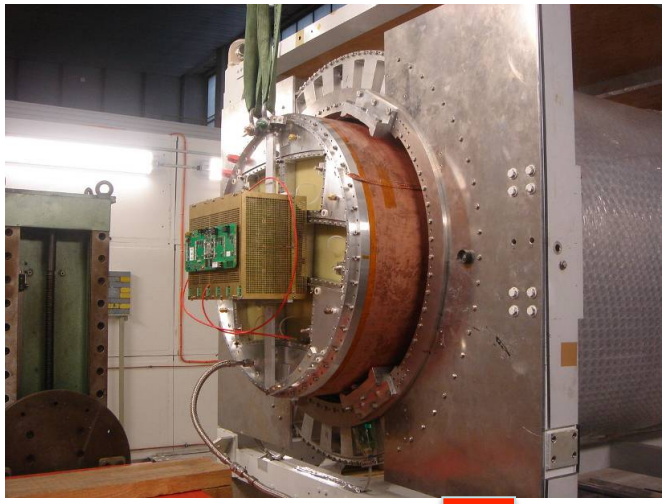




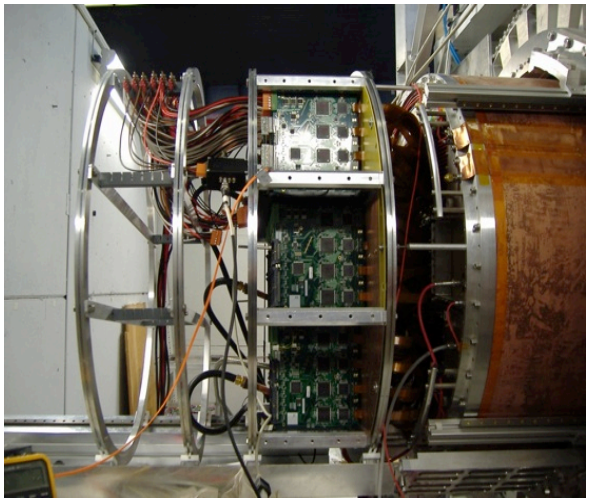


Several beam tests at DESY with LP (2008-2013) by LCTPC collaboration

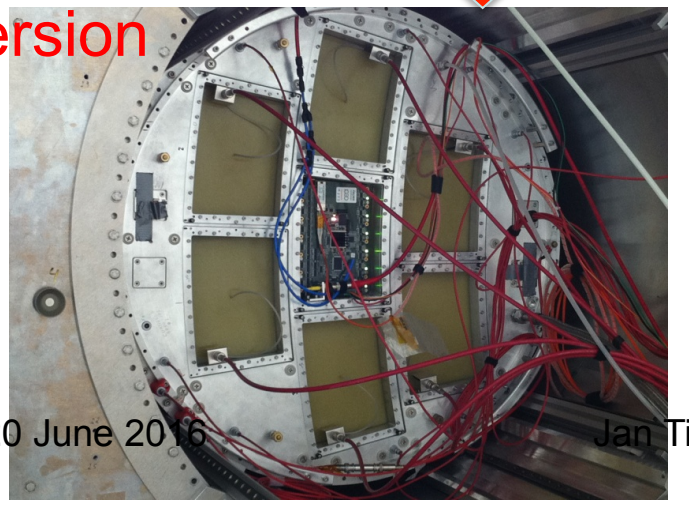
Micromegas (T2K readout)



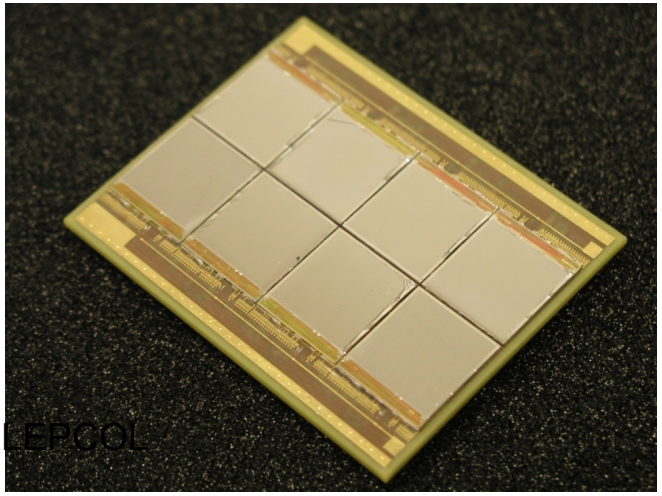
GEMs (Altro readout)



Integrated version



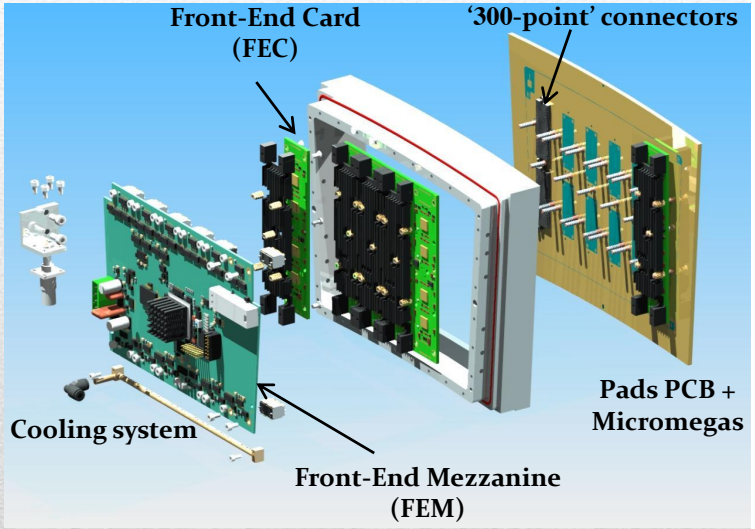
8-chip Ingrid module



Micromegas module

Material budget of a module

		M (g)	Radiation Length (g/cm²)
Module frame + Back-frame + Radiator (×6)	Al	714	24.01
Detector + FEC PCB (×6) + FEM	Si	712	21.82
12 '300-point' connectors	Carbon	30	42.70
screws for FEC + Stud screws+	Fe	294	13.84
Air cooling	brass	12	12.73
	Plexiglas	128	40.54
Average of a module		1890	21.38



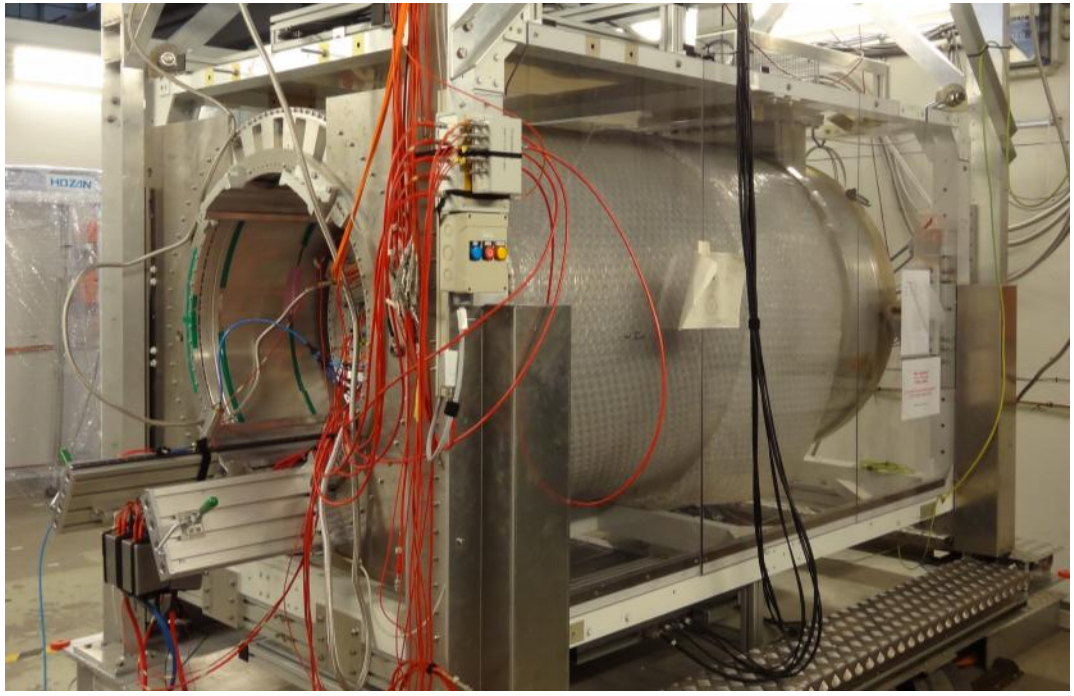
Low material budget requirement for ILD-TPC:

- **Endplates: ~25% X_0**
  (X_0: radiation length in cm)

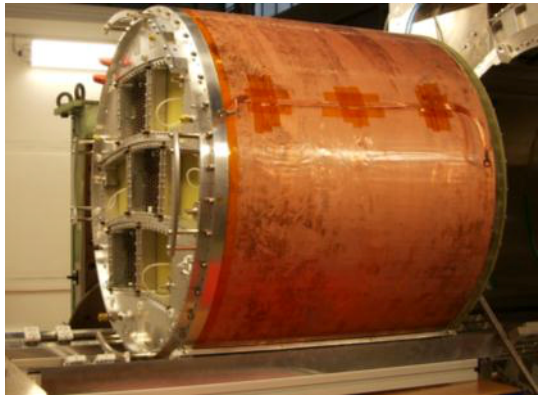
$$\frac{d}{X_0} = 0.236 < 0.25$$

Large Prototype TPC for ILC

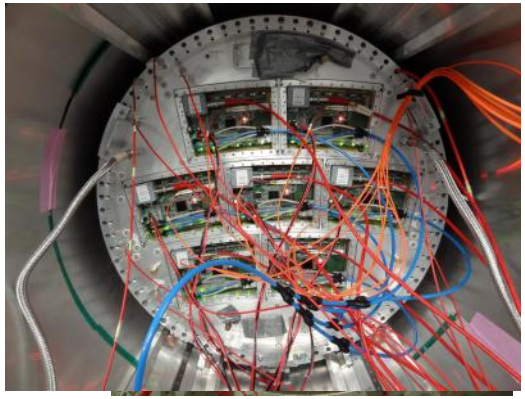
1T PCMagnet on lifting stage



Large Prototype TPC

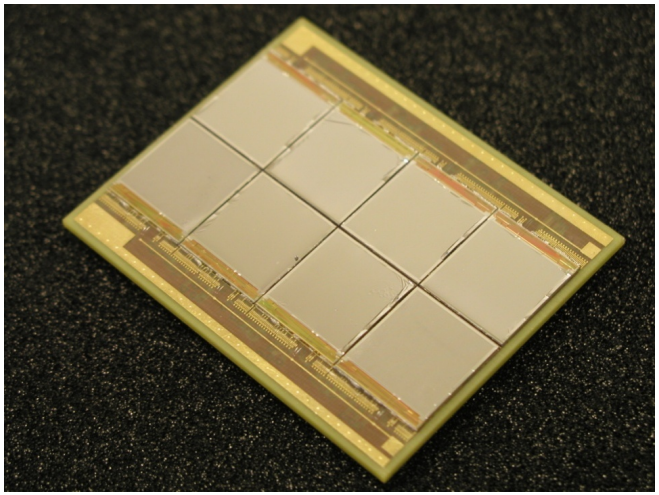


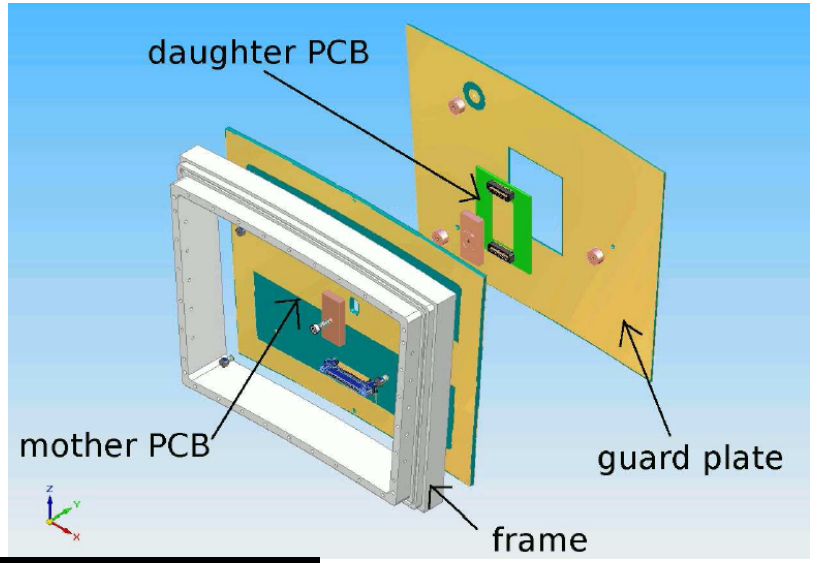
Enplate + 7 Micromegas modules



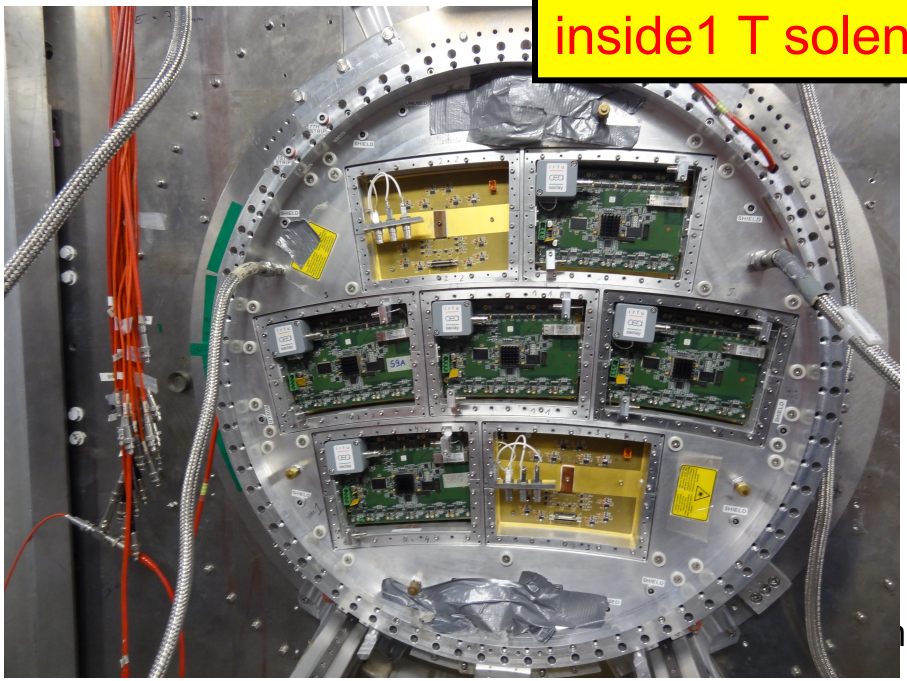
- Built by the collaboration LC-TPC
- Financed by EUDET & AIDA
- Located at DESY: 6 GeV e- beam
- Sharing out :
  - magnet: KEK, Japan
  - field cage: DESY, Germany
  - lifting stage: DESY, Germany
  - cosmic trigger: Saclay, France
  - beam trigger: Nikhef, Netherlands
  - endplate: Cornell, USA
  - Micromegas: Saclay, France, Carleton U., Canada
  - GEM: Saga, Japan, Desy, Bonn, Germany
  - TimePix pixel: F, G, NL

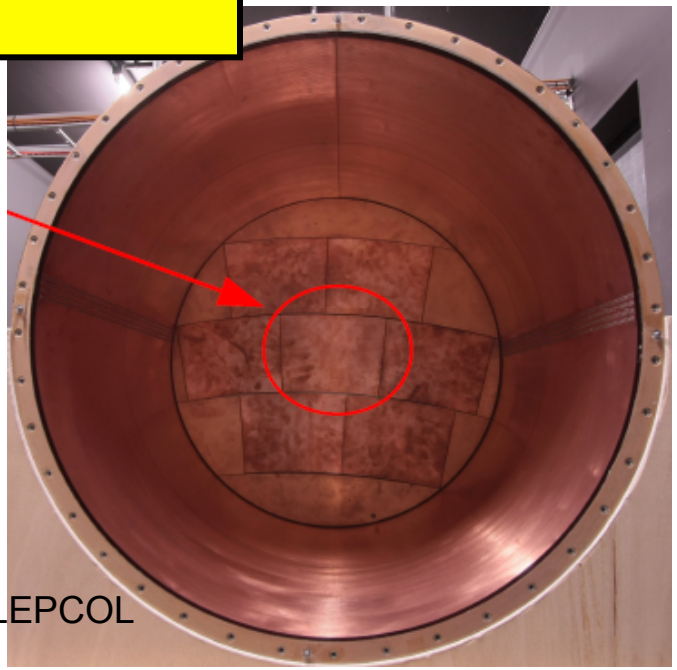
8 Ingrids on daughter board





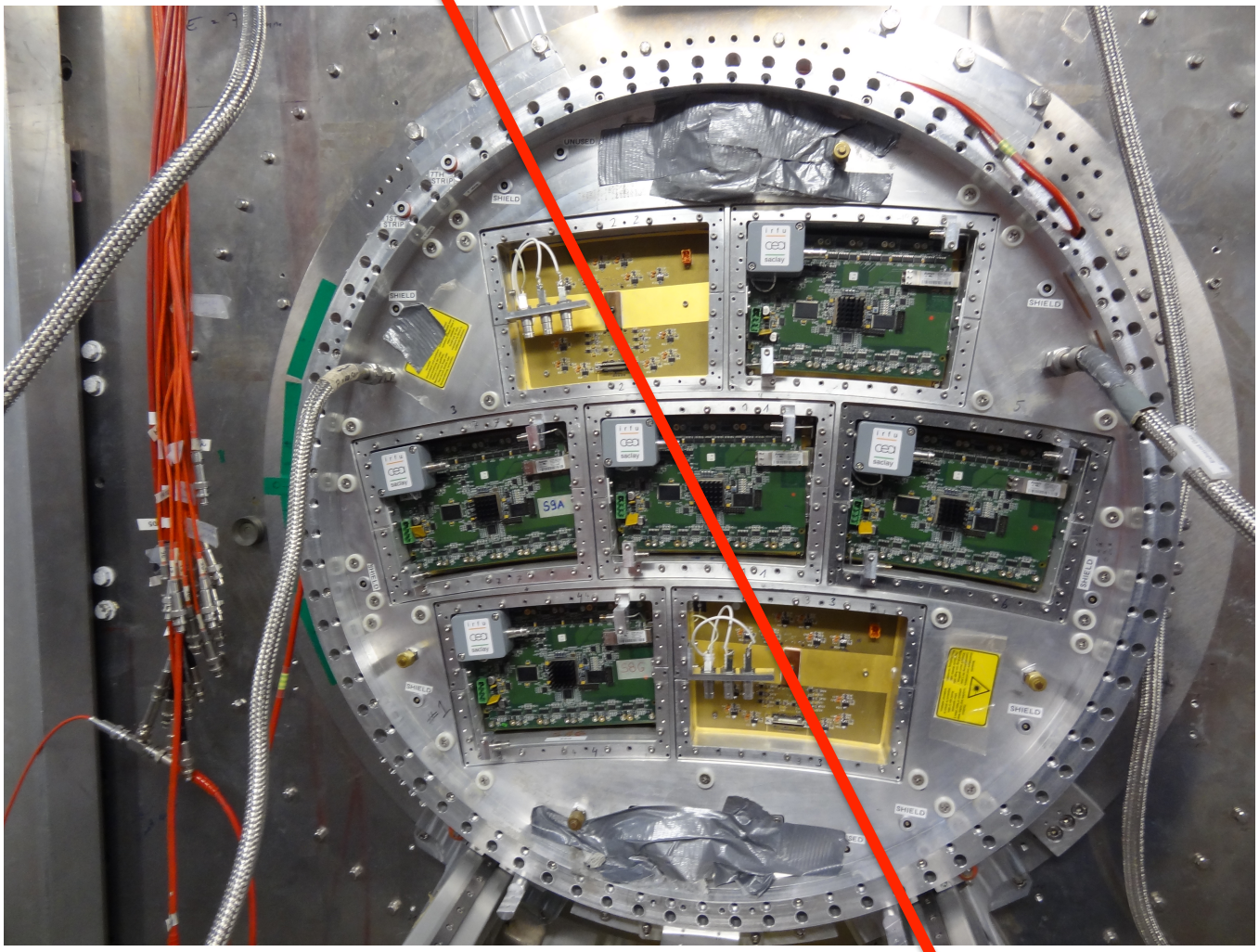
LPTPC with 7 detector slots inside1 T solenoid





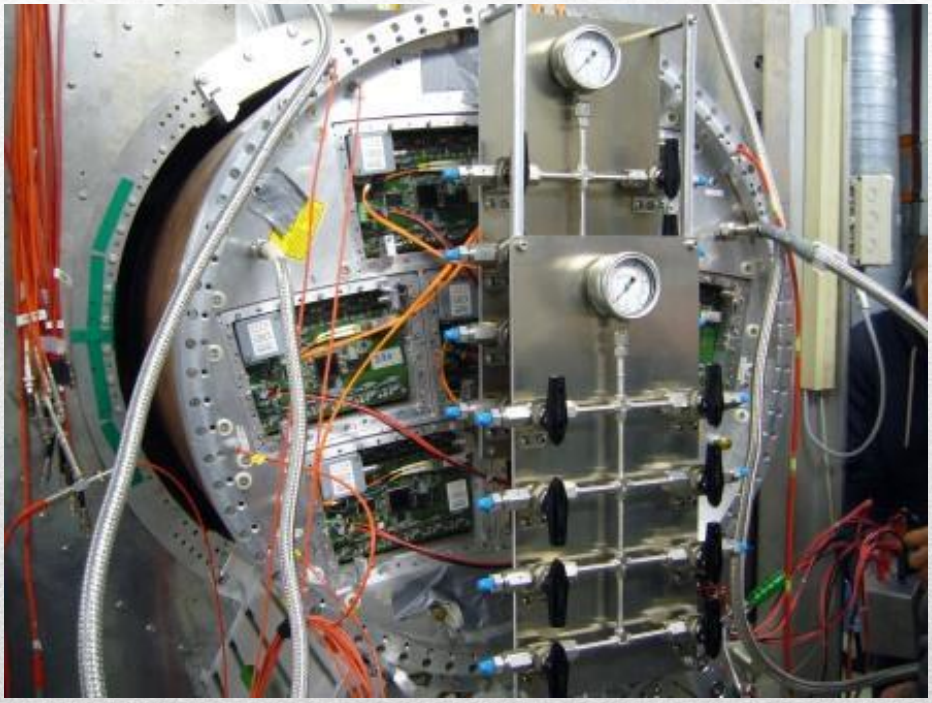
Beam

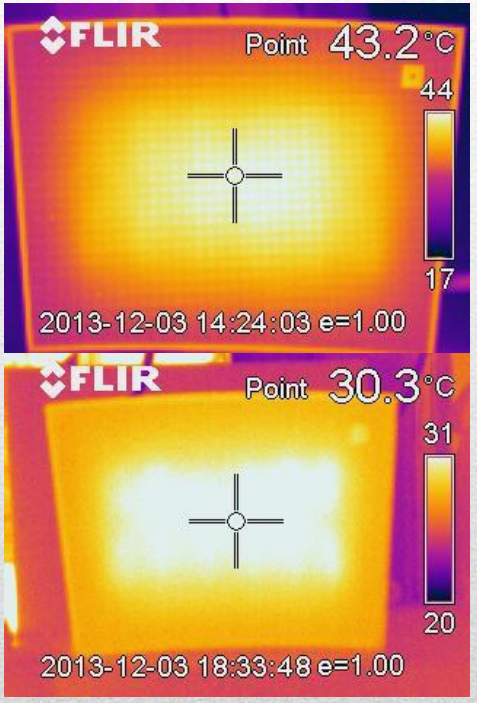
Diameter ~70 cm
Max. Drift ~58 cm



Tests with 1 module were performed at Nikhef in December

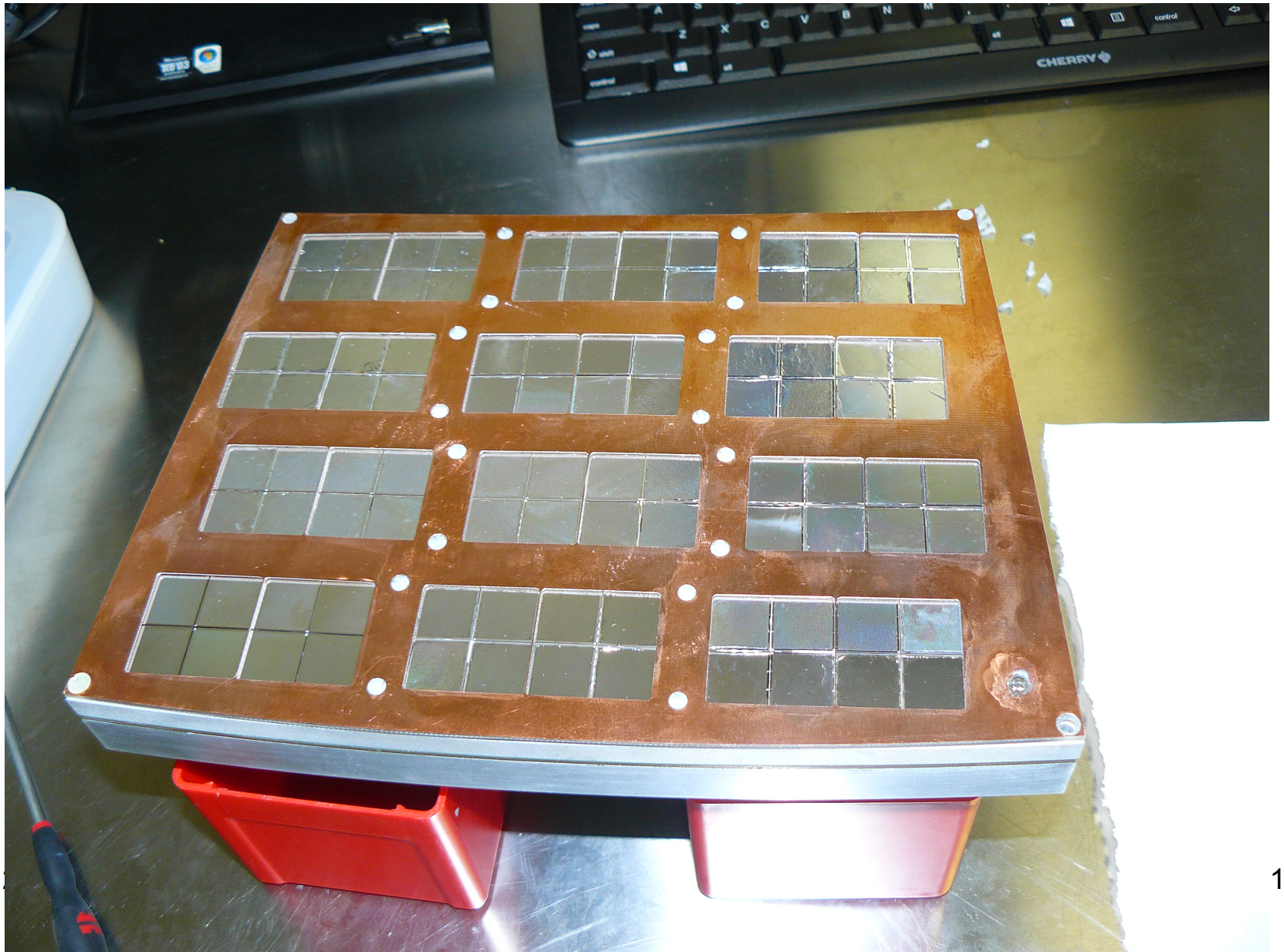
Tests with 7 modules are ongoing at DESY





2-phase CO_2 cooling

Bonn 96-TimePix1 GridPix module

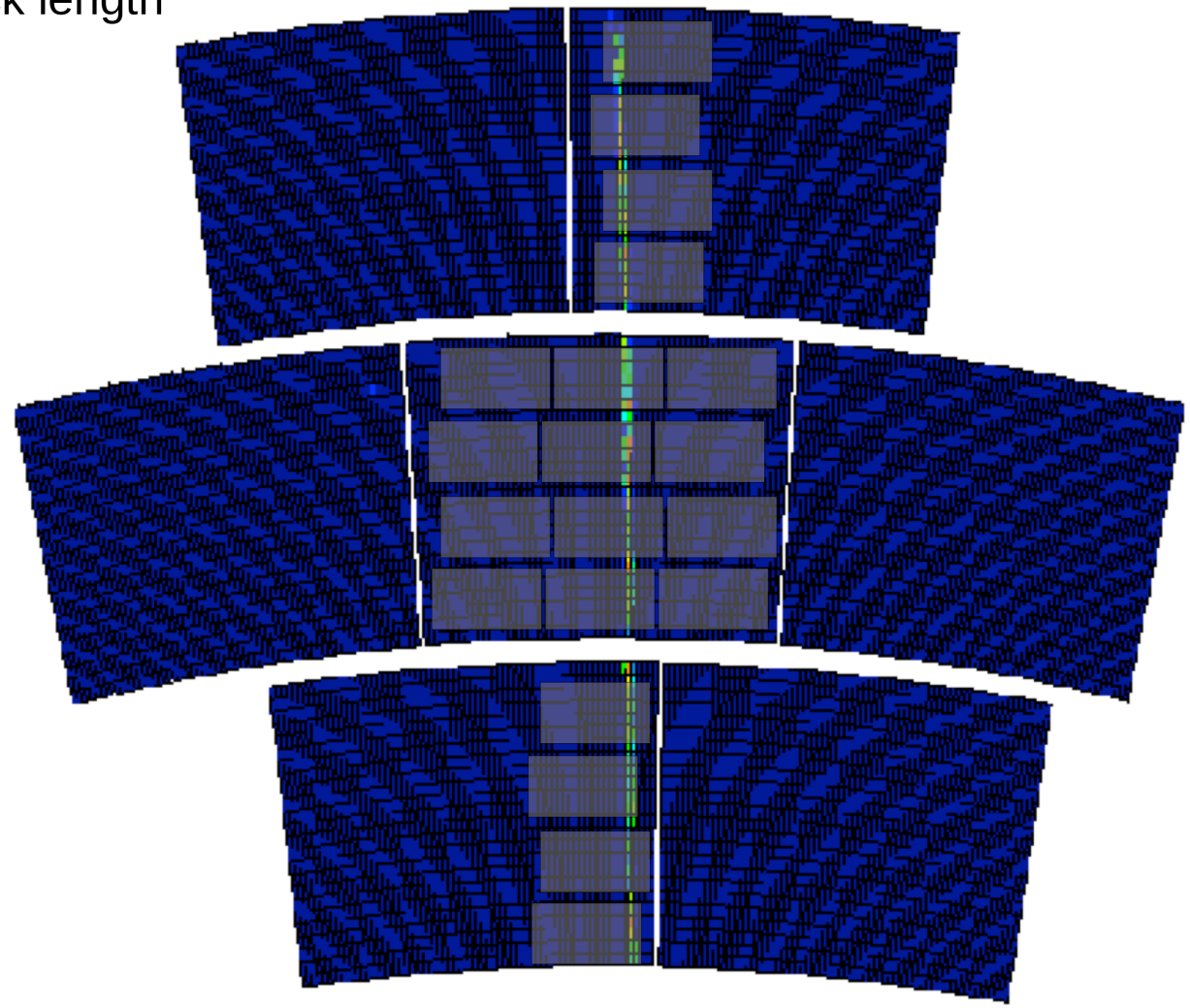


Bonn test beam with 160 TimePix1 Ingrids Mar/Apr 2015

Setup

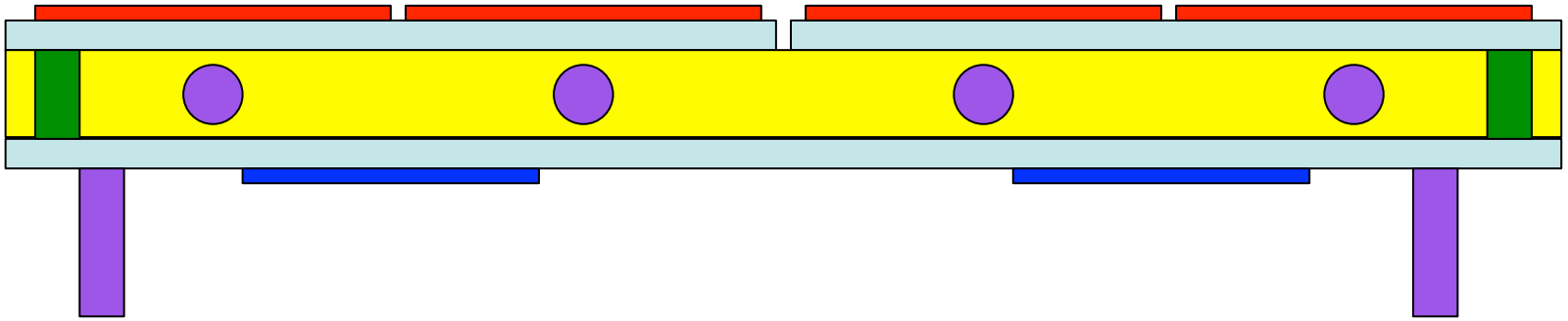
3 modules (one with 12 octoboards, 2 with 4 octoboards)

Full track length



Sketch of a layout

Guard field grid, possibly serving also as wire ion gate



PCB

TPG (2.5 mm thick)

Ingrid

(FPGA)/ + Voltage regs. + Data concentrator + LV/HV connect.

Connectors

CO2 cooling tube 1.5 mm Ø

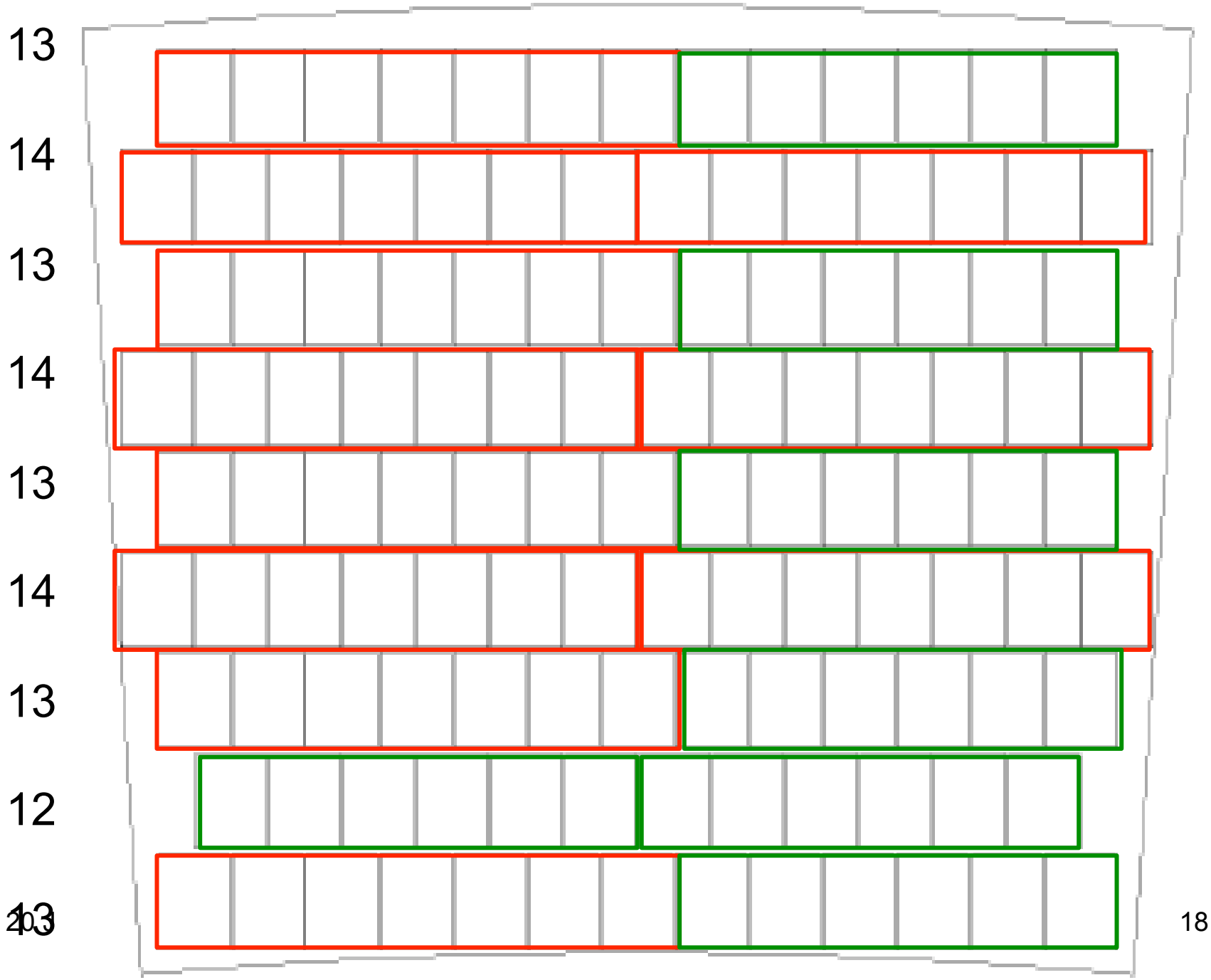
“Nikhef” plan/proposal

- Full engineering study of LP TPC module with maximum coverage Timepix3-Ingrids
- Optimisation of:
  - Geometric coverage
  - Mechanical precision
  - Readout (SPIDR)
  - (roomtemperature) CO2 cooling
  - Minimum amount of material (< 0.25 X0)
  - If possible, compatible with future Through-Silicon-Vias connectivity and Ion gate

First questions/wishes….

- Basic unit: N Ingrids on daughter-PCBs, sectors on base-PCB or full-module PCB?
- “flipped-chip” mounting of FPGA for N Ingrids
- What is minimum and/or optimal value of N?
- CO2 cooling capacity for 100% duty cycle possible? At ILC power pulsing ~1-2% duty c. (Japanese groups in LCTPC bought Nikhef cooling plant)
- LV power distribution? Compatible with power pulsing
- HV supply & sectoring? + HV for gating GEM
- Temperature monitoring

#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Planning/staging questions….

- Should be realised within coming 1.5-2 years
- Pre-study full-scale cooling (6 months?)
- Pre-module for full-scale (bare-chip) uitlezing (6 months?)
- Full-module with Timepix3-Ingrids (month<18?)

- Engineering personpower?
- Who wants to participate of R&D group and other Nikhef staff?
- Possible collaboration with Saclay/Bonn?
- Costs? (I believe limited)

- Possibility insertion of “data serialiser” between TimePix3 chips and SPIDR FPGA, allowing 1 SPIDR to read 96 TimePix3 (possibility of SPIDR at ‘large’ distance?)
- Rough estimates of costs:
  - 3 kEur per TimePix3 wafer (w. 50% yield is 50-60 good chips)
  - ~ 3 kEur /wafer for IZM Ingrid production
  - ~ 3 kEur /module for SPIDR readout
  - ~ few kEur /module for base PCB + mechanics module frame
  - X number of modules = 3
  - Contingency x2 for 2 years = total of ~ < 100 kEur
  - Some items to be shared with Bonn (possibly Saclay?)