TPC Power Consumption and Power Pulsing

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On behalf of LCTPC Collaboration

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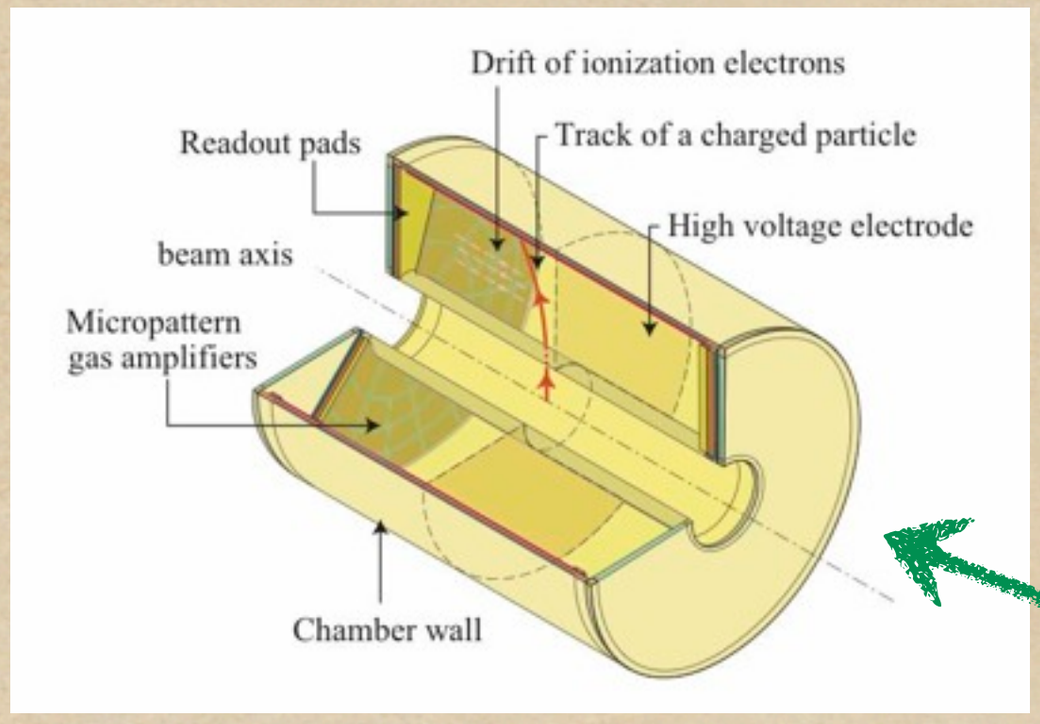
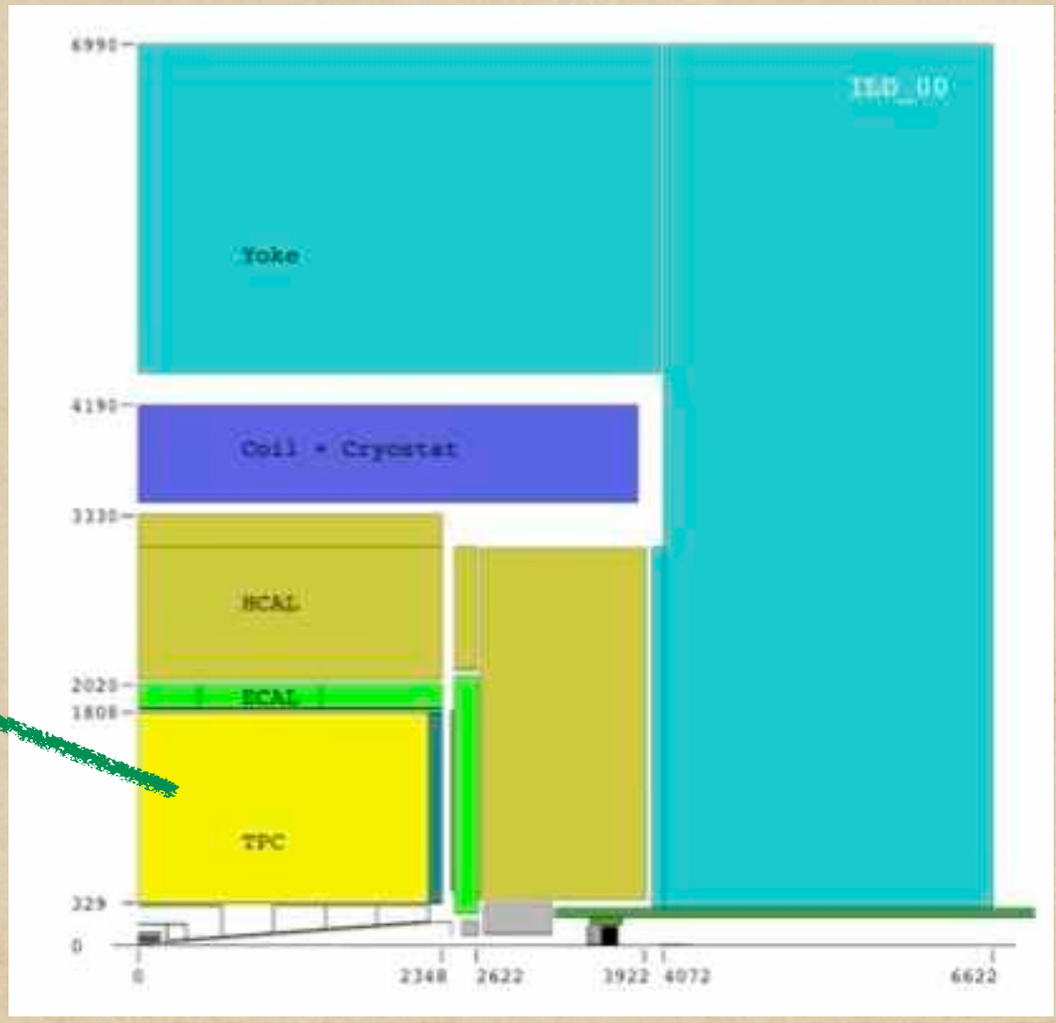
Linear Collider Power Distribution and Pulsing WS

Gas Tracking Detector for ILD Detector Design Concept

The ILD detector concept uses Time Projection Chamber (TPC) as tracking.



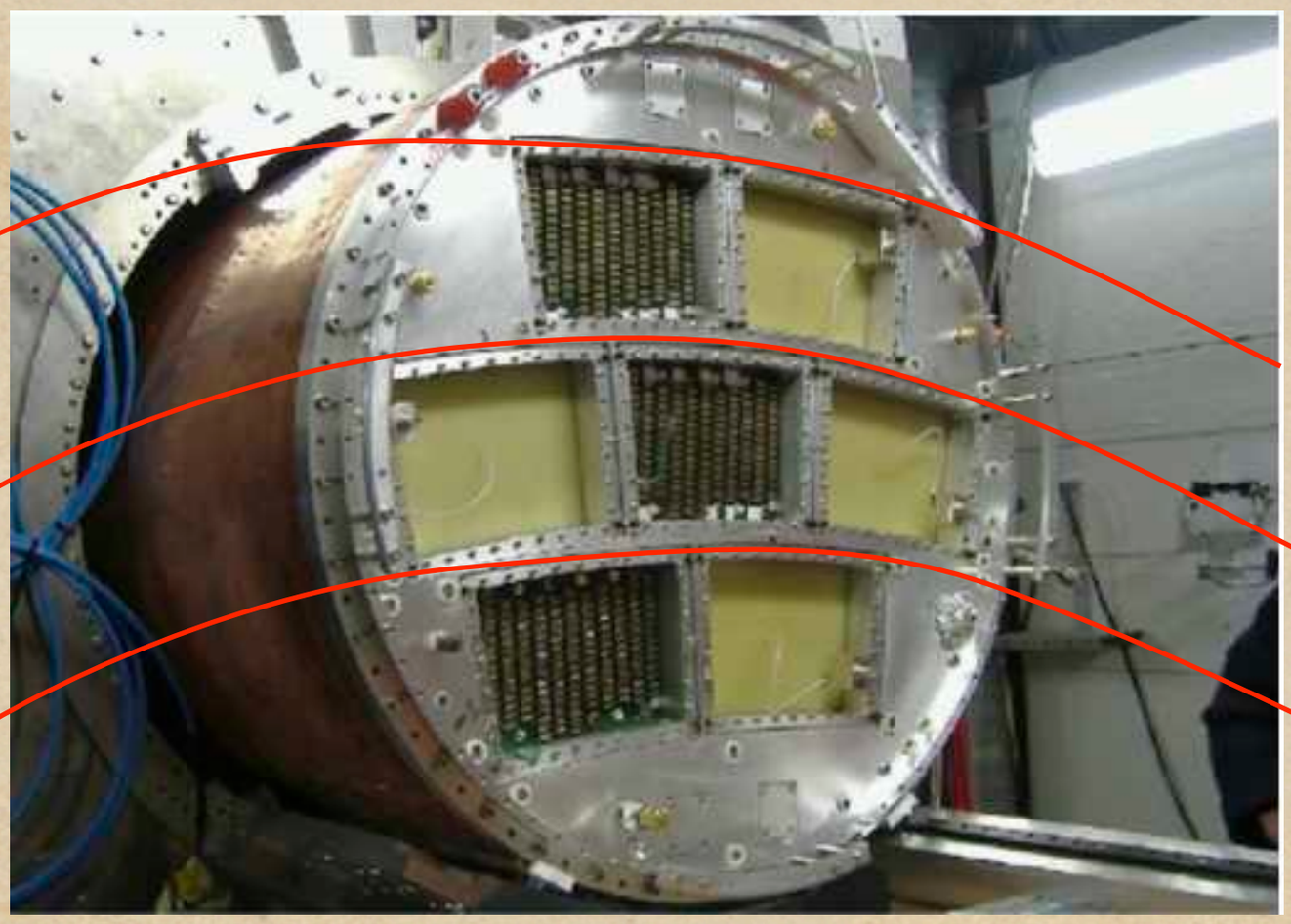
TPC for the ILD detector design concept

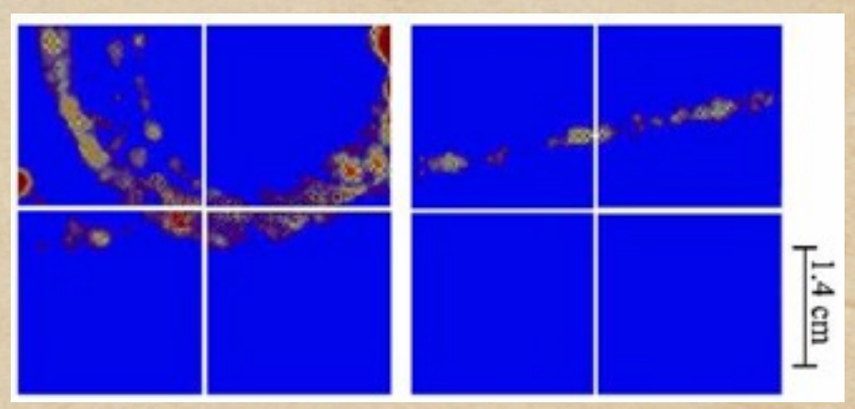


1/4 view of the ILD detector concept

Large Prototype 1 of the LCTPC

Large Prototype 1: current prototyping of LCTPC.
It can contain 7 modules.
Both Micromegas modules and GEM modules are being tested.





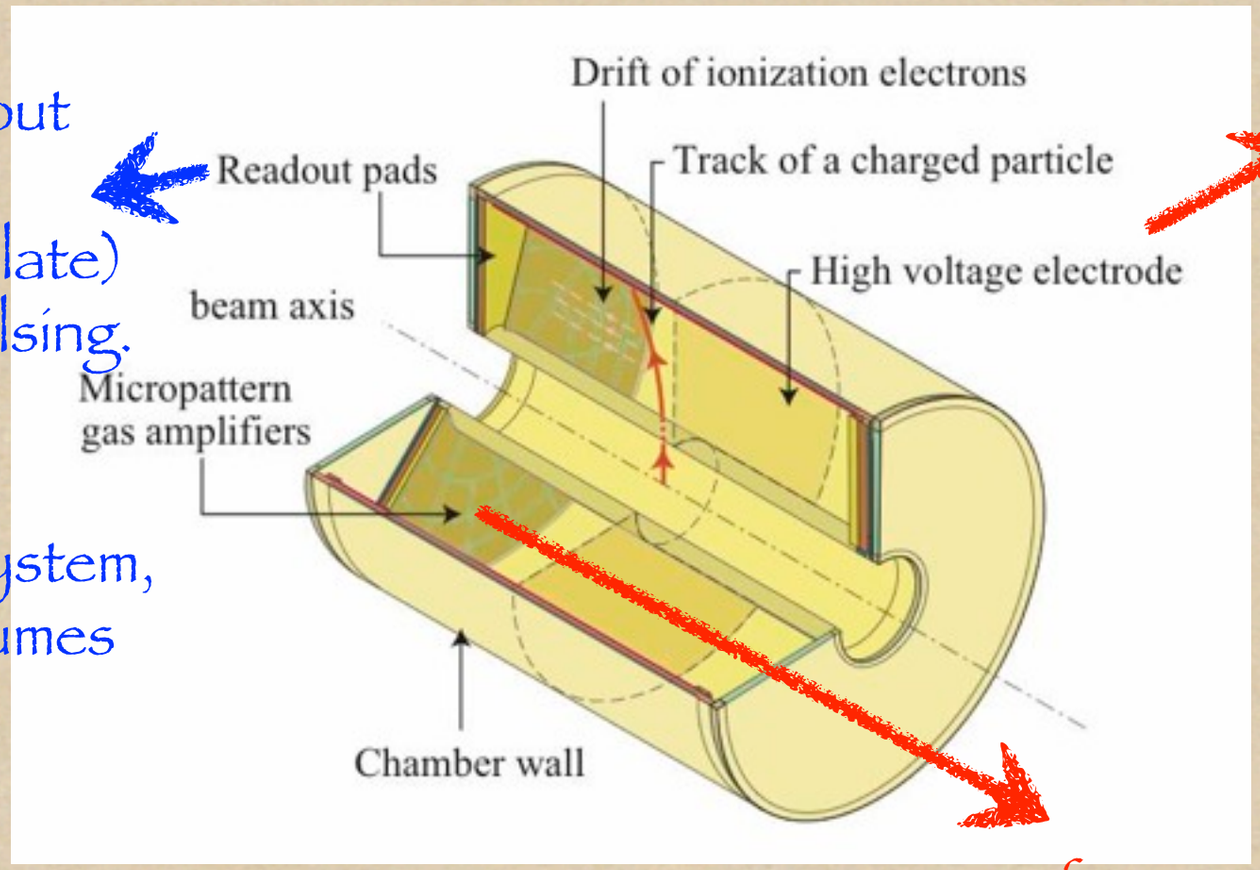
Tracks obtained by pixel ASIC (TimePix) and GEMs.

Power Consumed by Gas Tracking Detector (TPC)

The ILD detector concept uses Time Projection Chamber (TPC) as tracking.
Power consumed is categorized as follows.

LV for pad readout electronics (advanced endplate) Needs power pulsing.

Needs cooling system, which also consumes power.



HV ~70kV for electric field

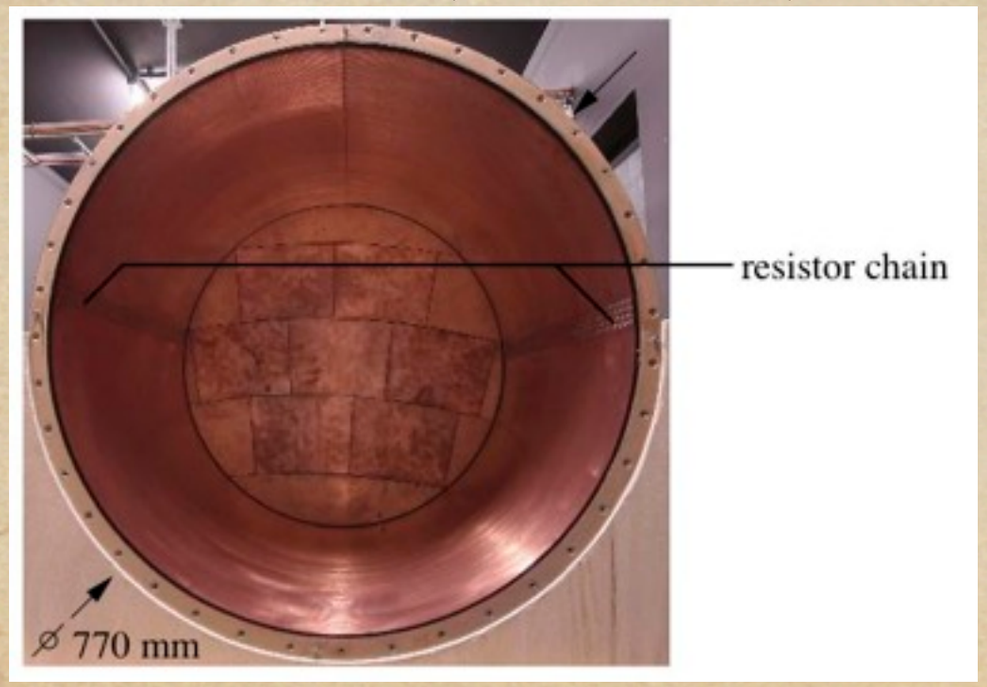
HV for gas amplification ~kV.
Either Micromeas or GEM.
Both are under study.

High Voltage: TPC Field Shaper

20kV on 210MΩ chain resistor,
so it's just about 2W power consumption.
Roughly saying, it could be scaled by
3.5 to the ILD TPC design goal.

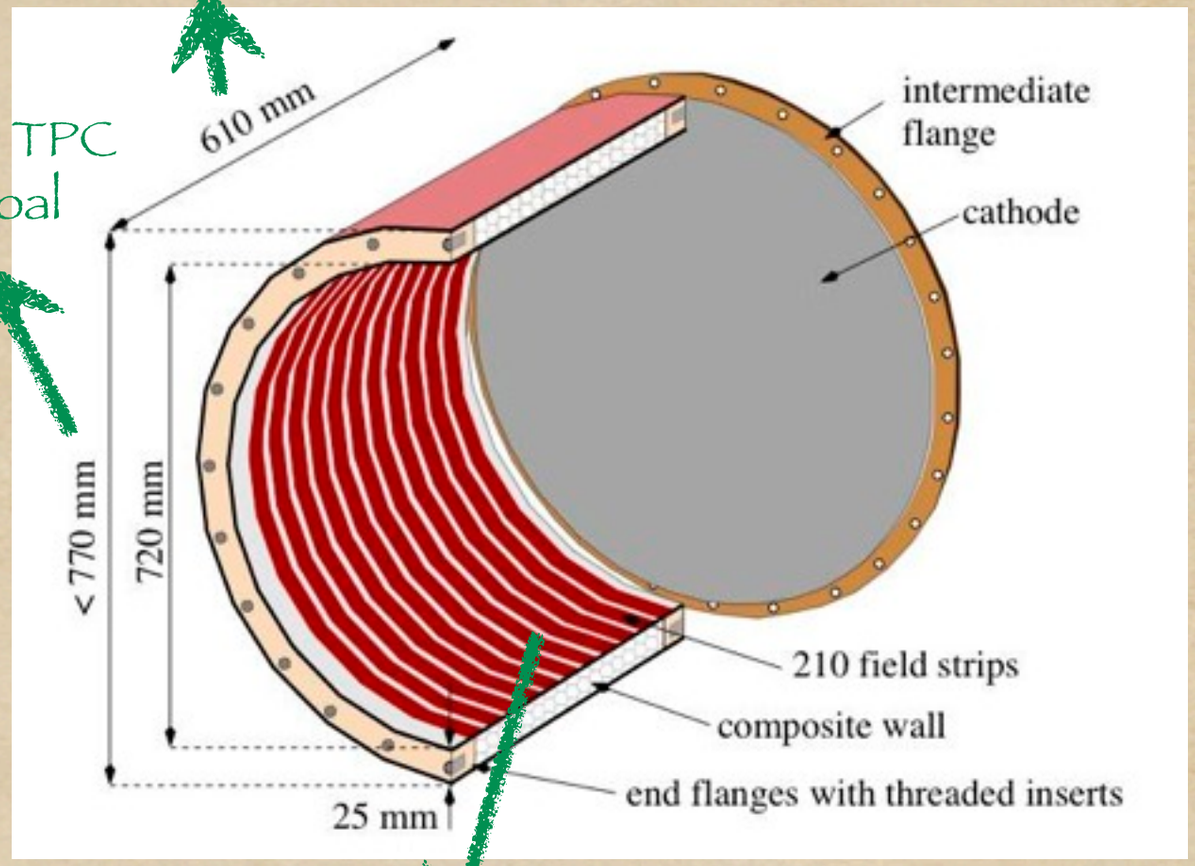
In addition, there are
- inner field cage with Φ=0.65m
- ion charge absorbed in cathode,
  which generate some current.

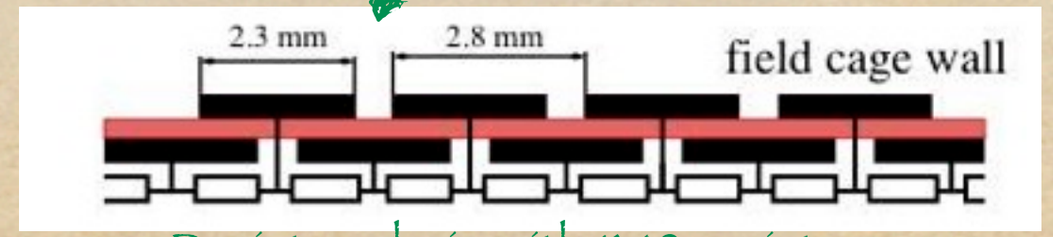
LP1 "Prototype" field shaper



2.15m in ILD TPC design goal

3.6m in ILD TPC design goal



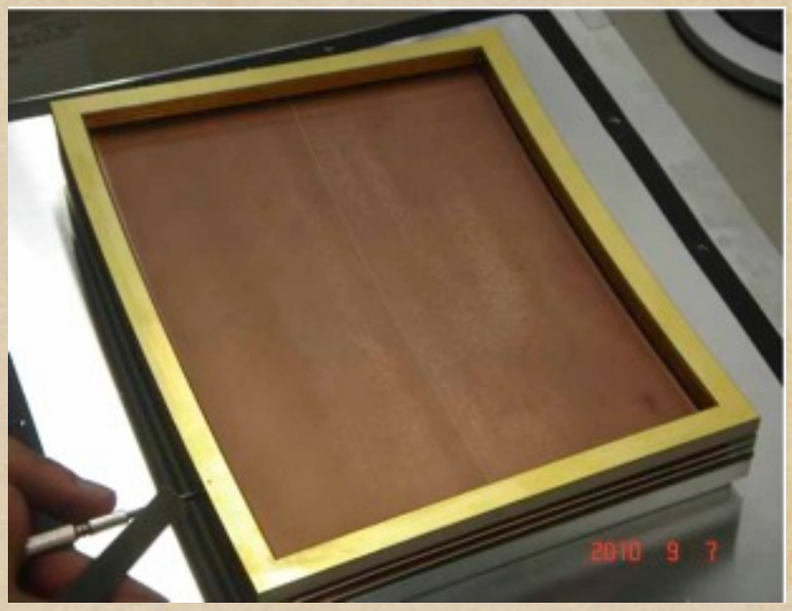


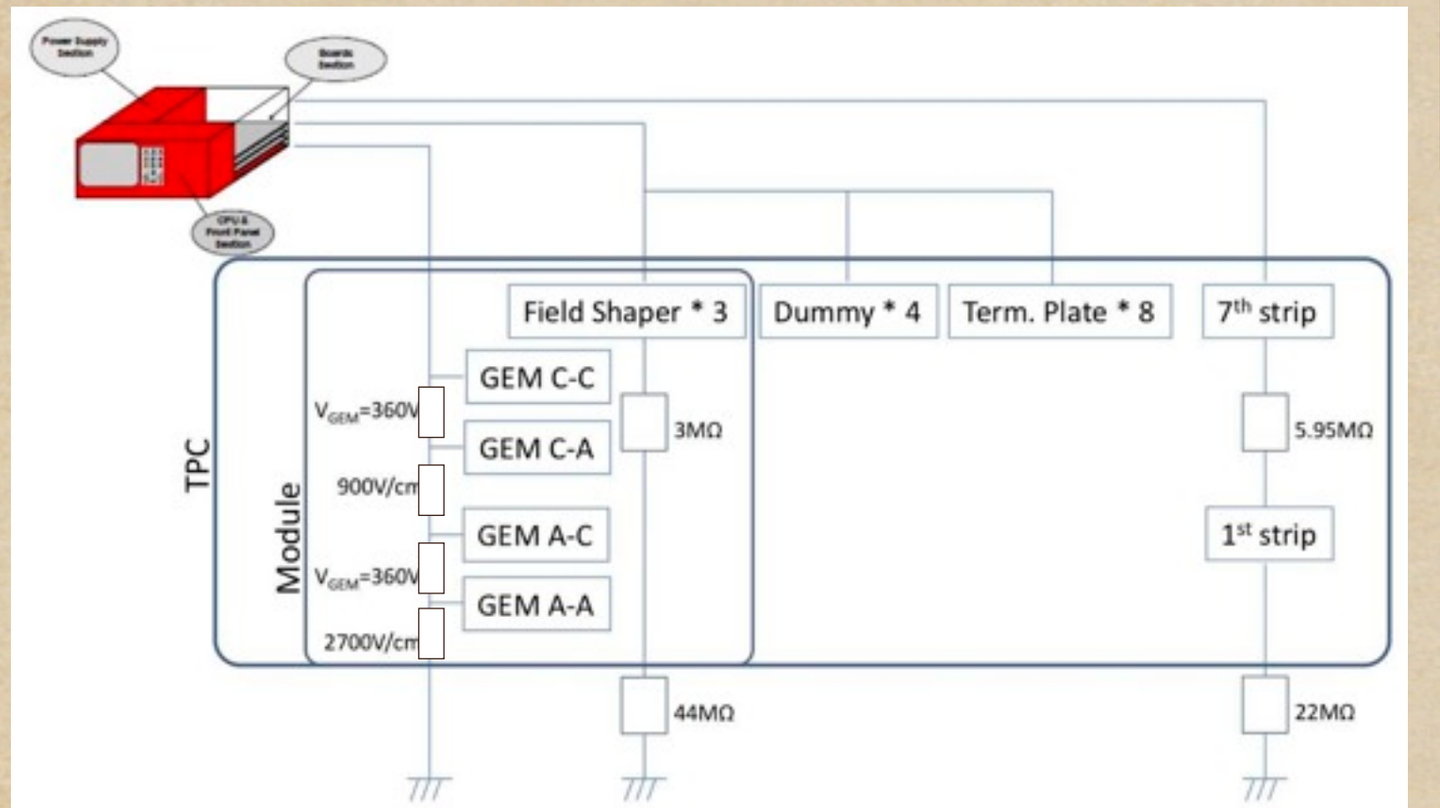
Resistor chain with 1MΩ resistors

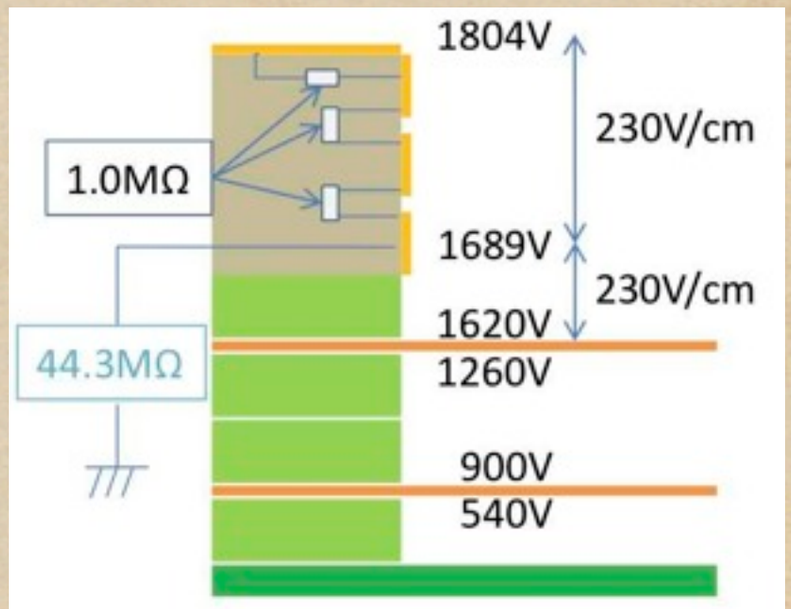
High Voltage: Gas Amplification (case of GEM)

Here, let me just mention that HV with order of about 2kV is used for gas amplification in the case of GEM. (The situation is somewhat different for Micromegas module)

One module current is small, but should be multiplied by a few hundreds for the whole detector of the ILD design goal. Cabling will be also issue.







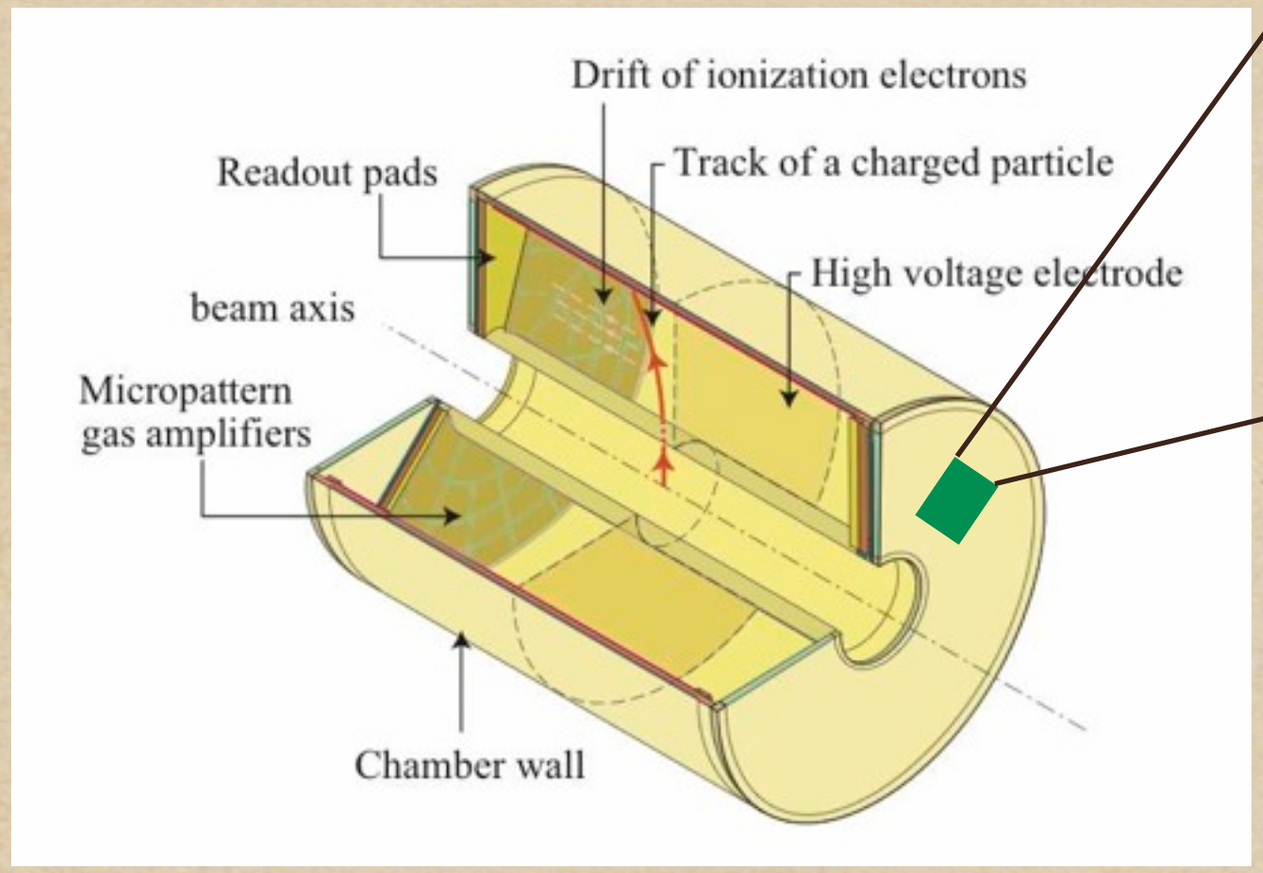
HV for GEM in the current prototype (LP1) testing

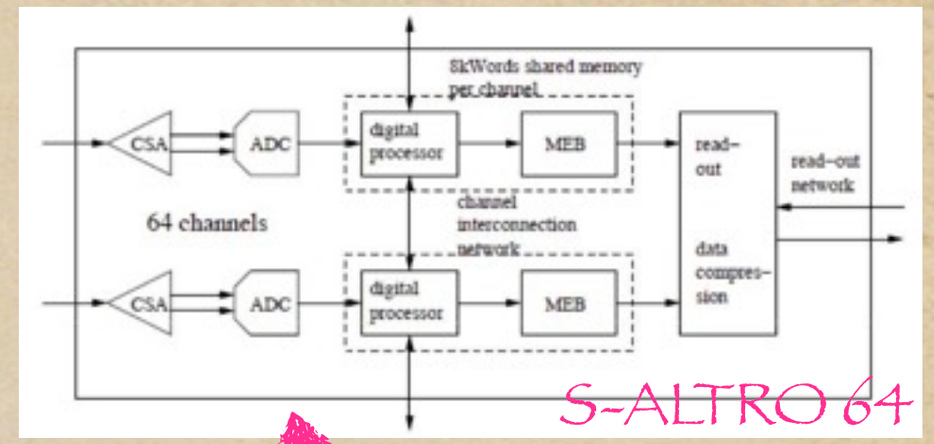
TPC Pad Readout
- Advanced Endplate -

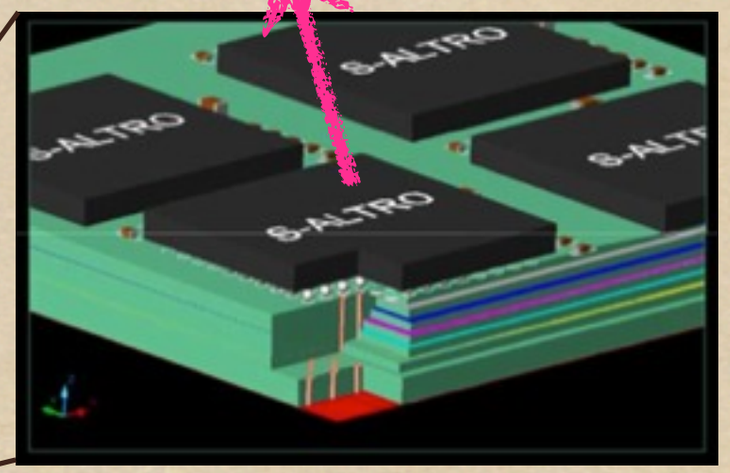
The TPC advanced endplate will have surface-mounted frontend chips on its backside.

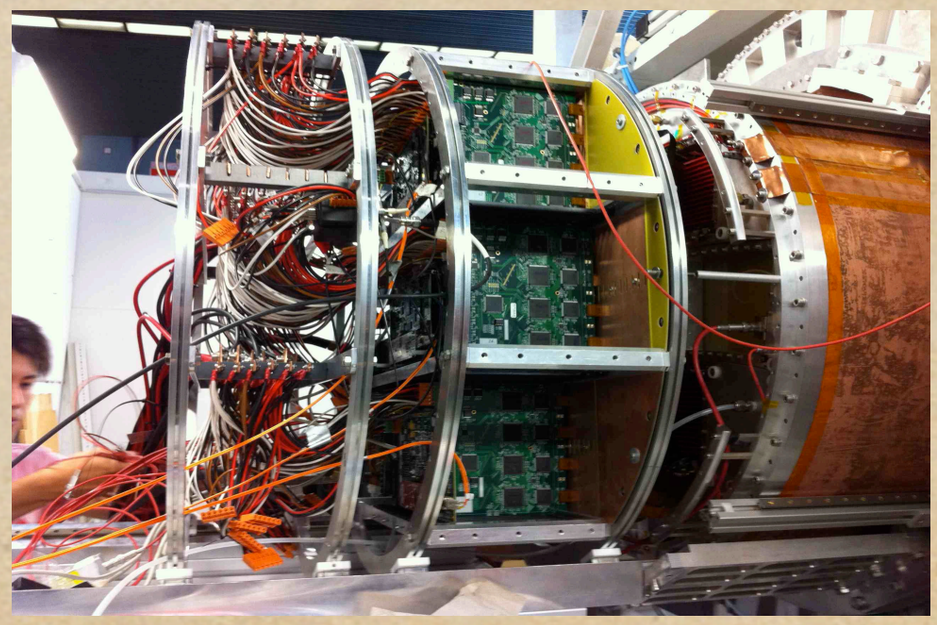
→ Dense electronics. Dense thermally.

→ Needs power pulsing.





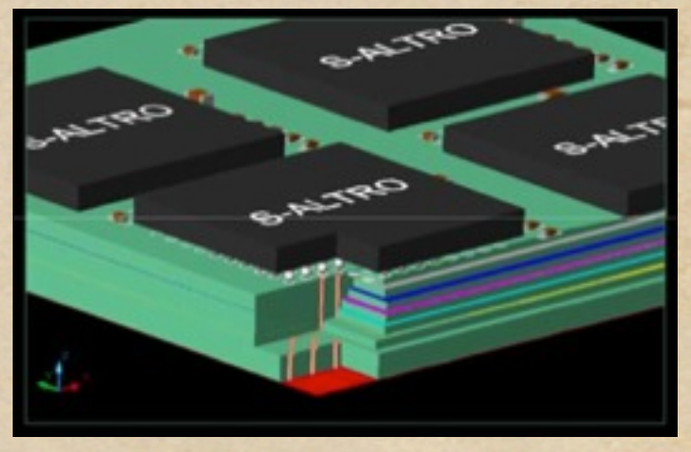




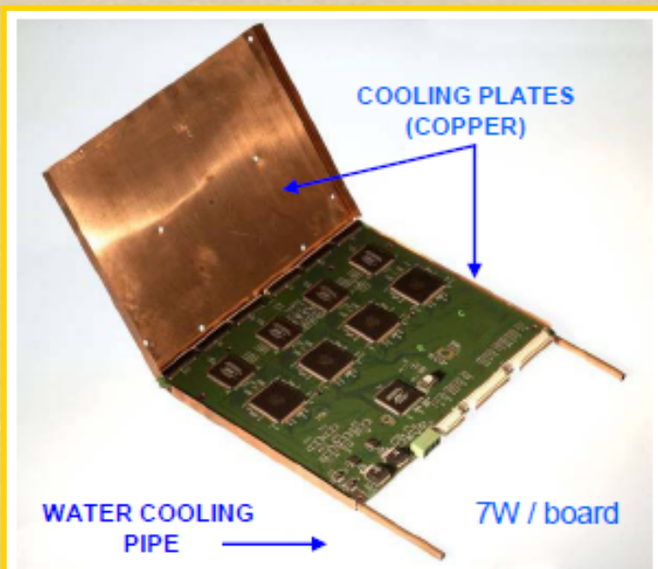
Current prototype (LP1: Large Prototype 1) is module type.
At this stage, air cooling still works well.

Power Consumption of S-ALTRO and TPC Advanced Endplate

- At 10 (20) [40] Ms/s operation,
  PASA (PreAmp&ShapeAmp) : 8 (8) [8] mW/ch
  ADC : 20 (26) [34] mW/ch
  Digital Processor : 2 (4) [8] mW/ch
  Digital Links : 2 (4) [8] mW/ch
  Power Regulators and Aux. : 11 (14) [20] mW/ch
- In total, one channel consumes : 43 (56) [79] mW/ch
- When the pad pitch is 1mm x 4mm, power density will be : 11 (14) [20] kW/m^2
- With power pulsing of 1.5% duty cycle : 160 (210) [300] W/m^2
- This number is comparable with ALICE TPC frontend. But in our case, X_0 is required to be <0.15.
- These numbers can be decreased by sophisticating the S-ALTRO design in the future.
- Half Cylinder of ILD TPC with inner Φ=0.65m and outer Φ=3.6m : 1.5 (2.1) [3.0] kW of which 88 (81) [72] % is analog.



↑ LCTPC / ALICE TPC ↓

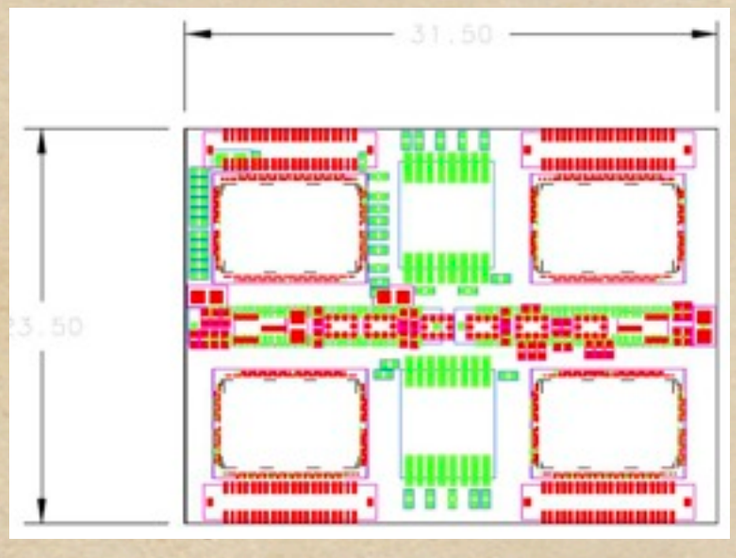


ALICE TPC Electronics

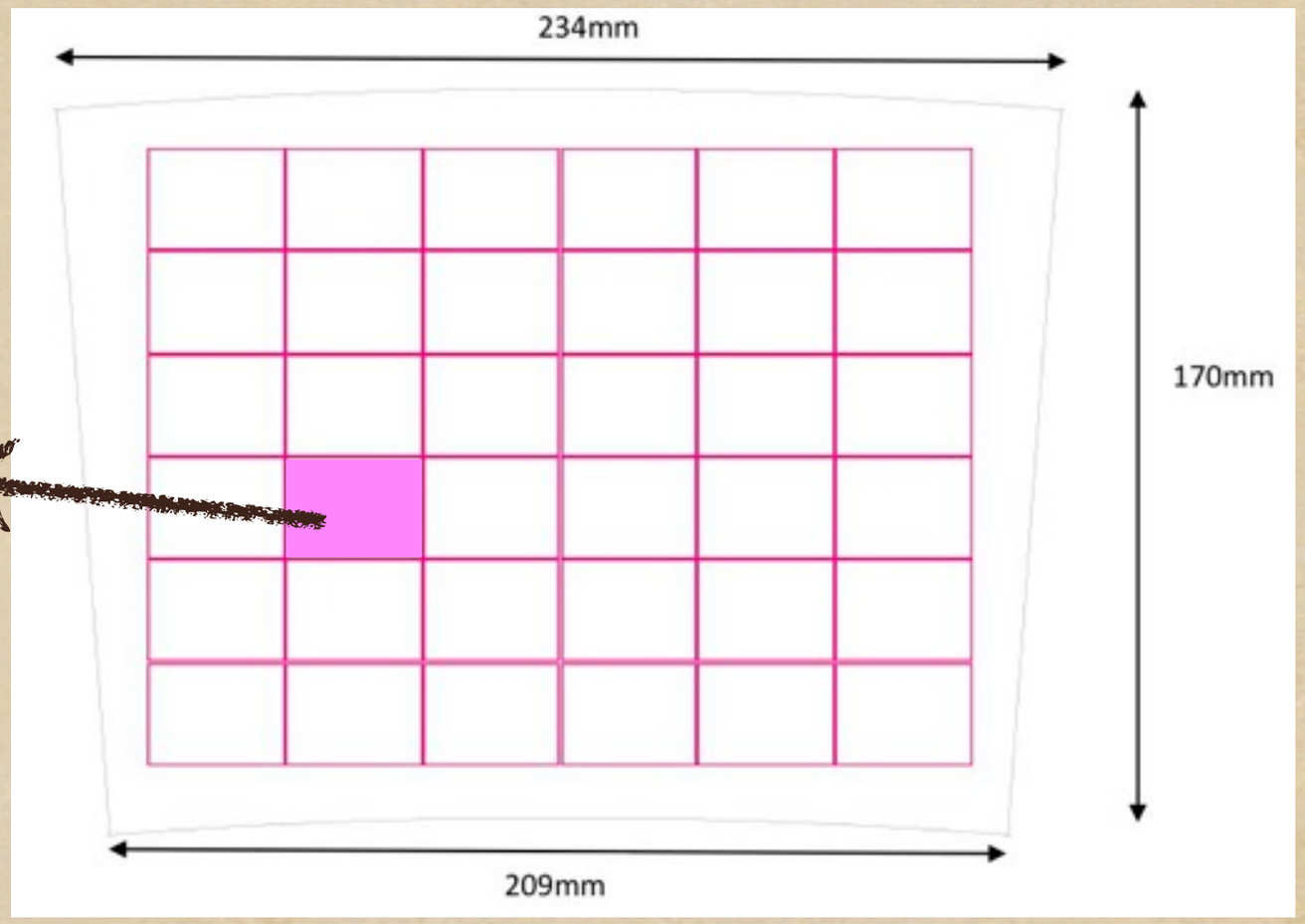
- PC board ~150μm Cu (0.1 X_0)
- 22mW / cm^2 ➡ 220W / m^2
- 0.3mm copper plate (0.2 X_0)

Daughter-board option for TPC readout

(Temporary option before S-ALTRO64 comes)



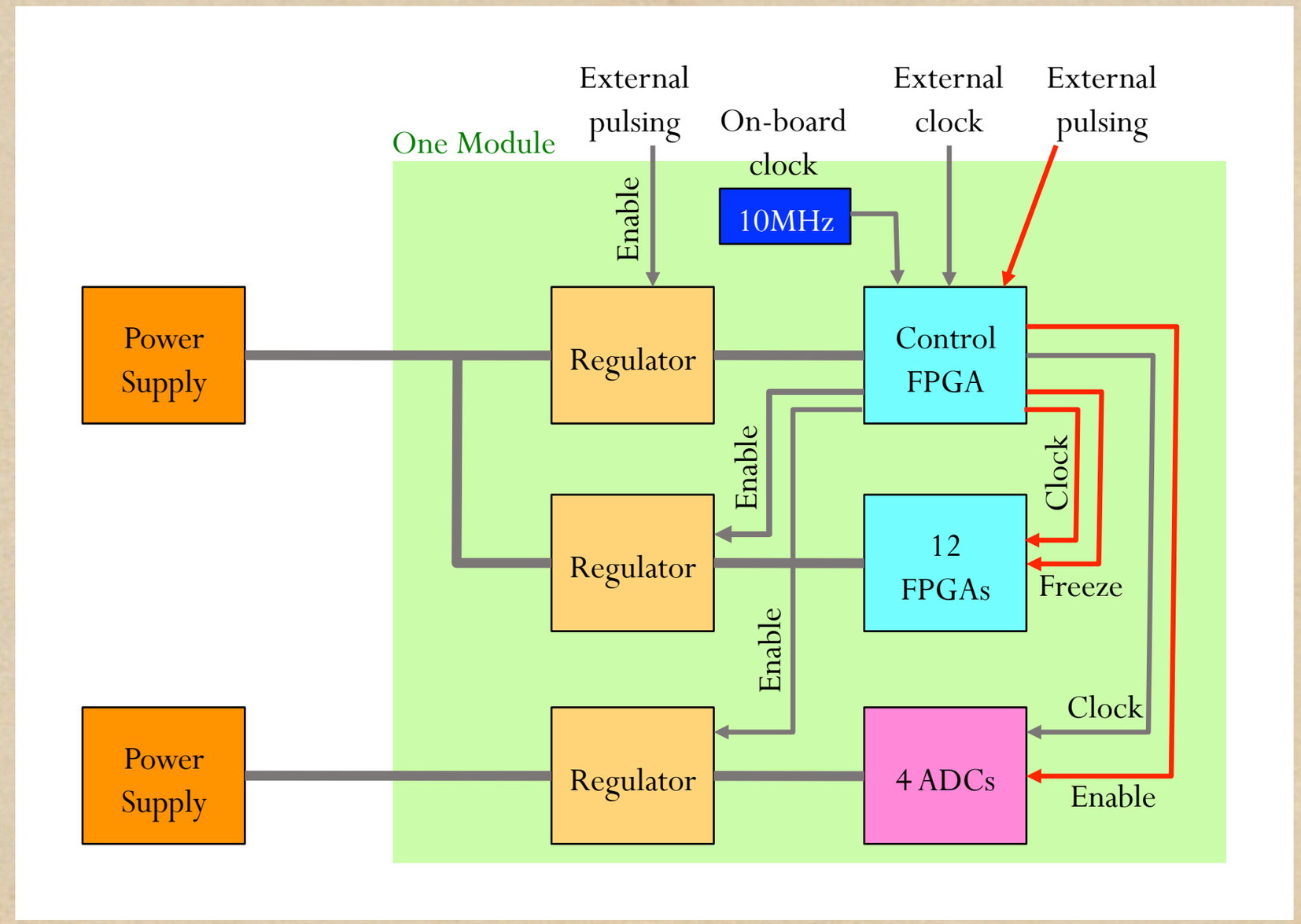
Daughter boards are mounted onto backplane by connectors



A Backplane Module

We don't have 64ch version of S-ALTRO (S-ALTRO 64) yet,
while 16 ch version (S-ALTRO 16) has been fabricated and is ready to be characterized.
The Daughter Bd. scheme is now under consideration for the next prototype endplate with S-ALTRO 16.
Essentially, total power condition is not different much from the advanced-endplate,
while cabling, cooling and material estimation could be additional issue.

Power Pulsing Upstream or Downstream
Most Downstream case (will be tested with a test board)



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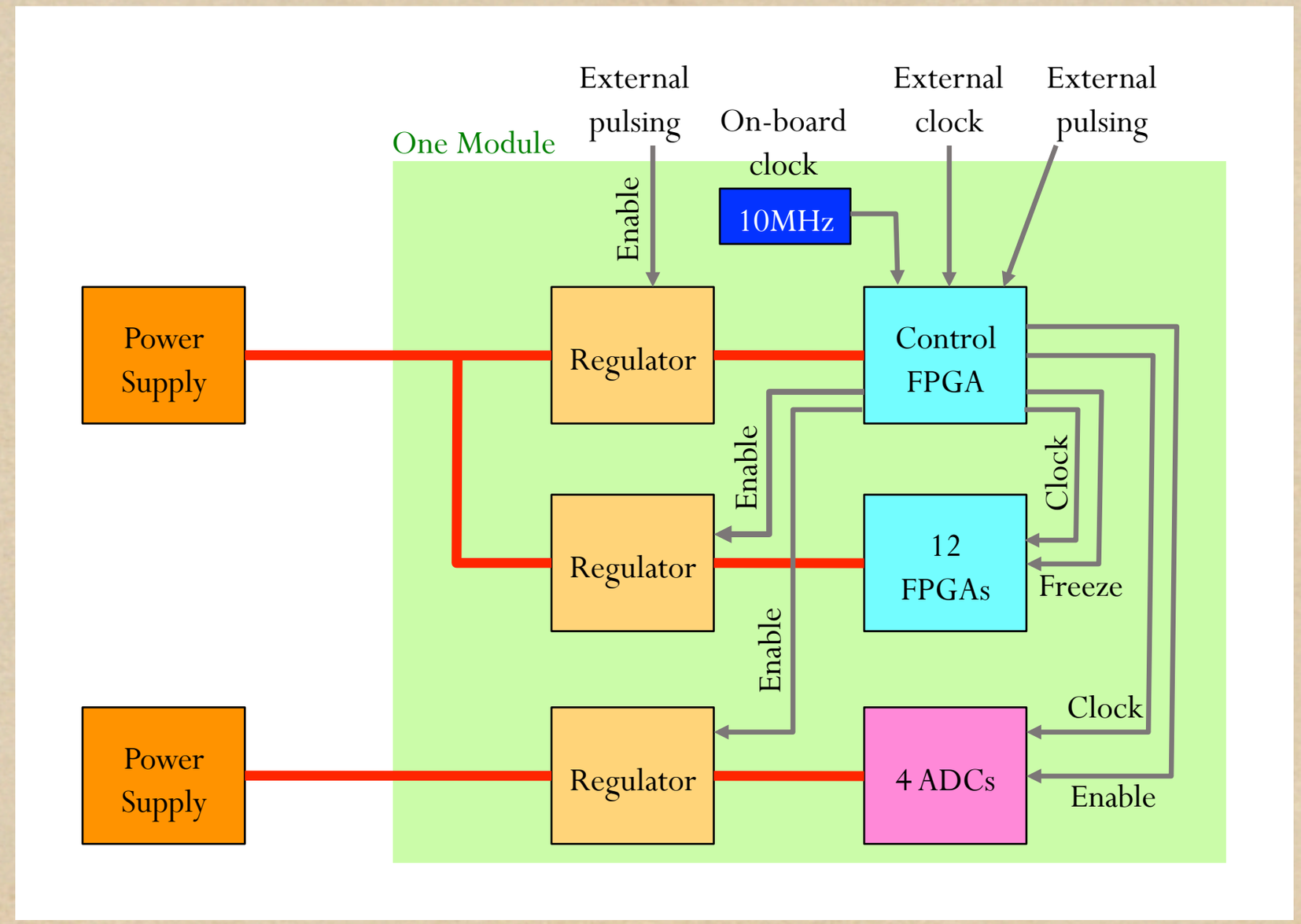
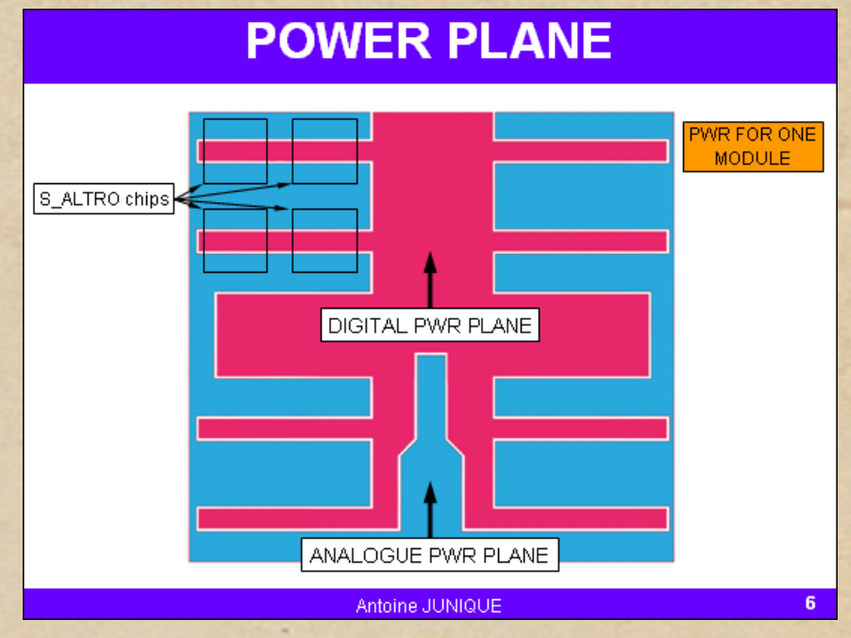


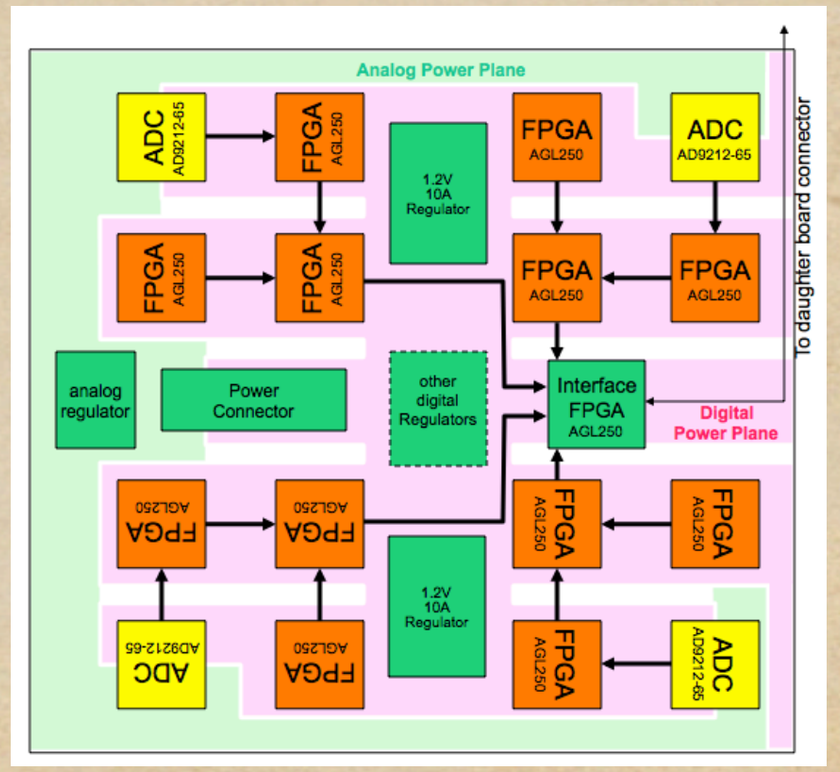
Advanced Endplate Test Board

We have constructed "Advanced-Endplate test boards" to test:

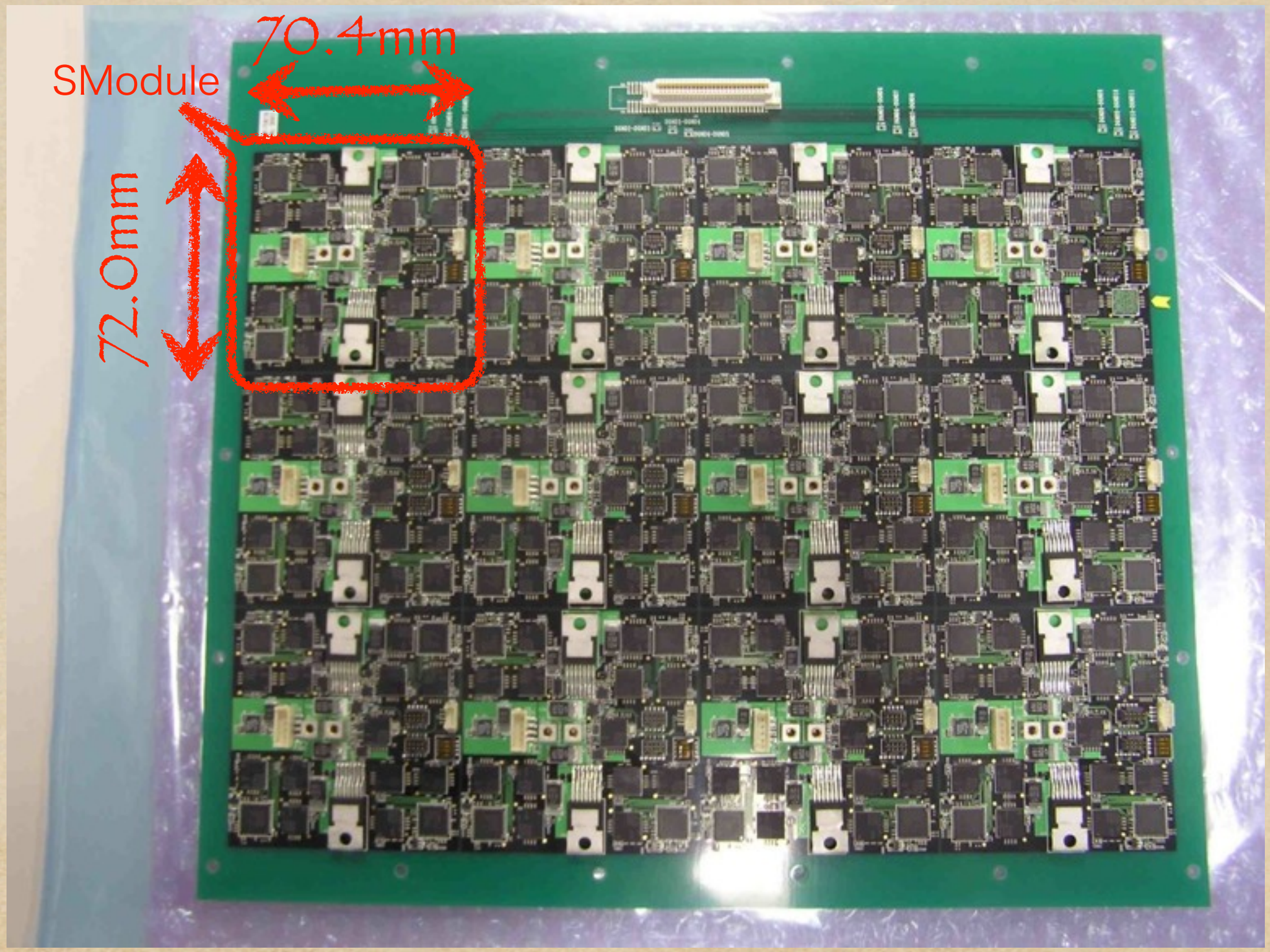
- Power pulsing condition
  - Power line stability
    - Noise effect to analog signals
- Liquid CO_2 cooling
  - Temperature of ASICs and pads.

For these studies, surface-mounted FPGAs and ADCs are mounted instead of S-ALTRO





Advanced Endplate Test Board (Parts-side view)



Power feeding options for the readout electronics

We haven't decided strategy.....

- Linear regulators:
  - AEP Test Board uses this option.
  - Large current required
    if bypass capacitors flatten: 1000A for half cylinder @ 20Ms/s
    if not: peak can be 67,000A → massive copper cables!?
- DC-DC converters (switching regulators)
  - Switching noise consideration (probably acceptable)
  - Needs test under magnetic field and radiation
  - Needs new development? (depends on spec.)
- Serial cabling between SModules

Liquid CO_2 cooling for LCTPC

- Problems with water cooling
  - We would like to avoid thick Cu plate.
    In the case of ALICE TPC,
    PCB ($0.1\,X_0$) + Cu Plate ($0.2\,X_0$) = $0.3X_0$,
    while requirement to LCTPC is $0.15\,X_0$.
  - Even if ASICs are cooled effectively for them to work,
    thermal leak to detector gas volume is an additional problem.
- Solution: Liquid CO_2 cooling, with which
  - We can use thinner cooling pipes compared to water cooling
  - We can keep ΔT along cooling path small,
    which is nice to keep detector temperature flat.
- Studies on CO_2 cooling for LCTPC is just started and power consumption estimation for cooling is not yet clear.
  Most of the system will be outside of the detector and liquid CO_2 will be delivered by dedicated pipes.

Summary

- High voltage categories of LCTPC were shown.
- Pad readout electronics (LV) consume most of power. Estimation of their total power was shown. Power pulsing is necessary.
- Voltage/Current specifications of power sources for readout electronics depend on how to feed the power to modules, which is not yet decided.
- Studies of power pulsing condition and CO_2 cooling method have just started using dedicated test boards.