Front-End Electronics of ATLAS Tile Calorimeter and its Commissioning

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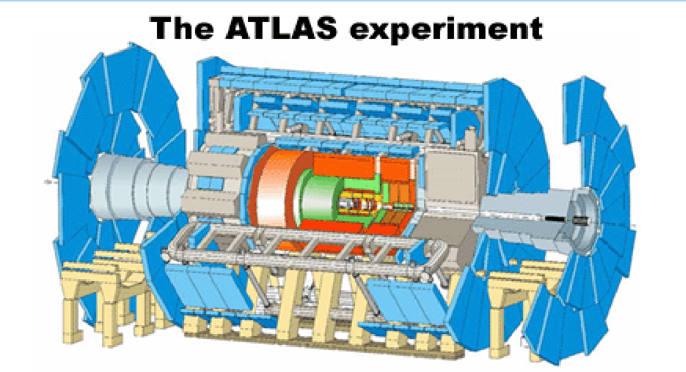
Outline

- Tile Hadron Calorimeter (TileCal) in ATLAS
  - ATLAS Imposed Requirements and Tile Calorimeter Concept
  - Status in the Experimental Cavern
- Tile Hadron Calorimeter FE read-out
  - Overview
  - Major FE Read-out Components
- Integration of the FE read-out components
  - Super-Drawer
  - Low Voltage Power Supplies
  - Quality Controls
- Commissioning of the Tile FE read-out
  - Status in the Experimental Cavern
  - Plans for the next year
- Summary

Tile Calorimeter in ATLAS Detector at LHC

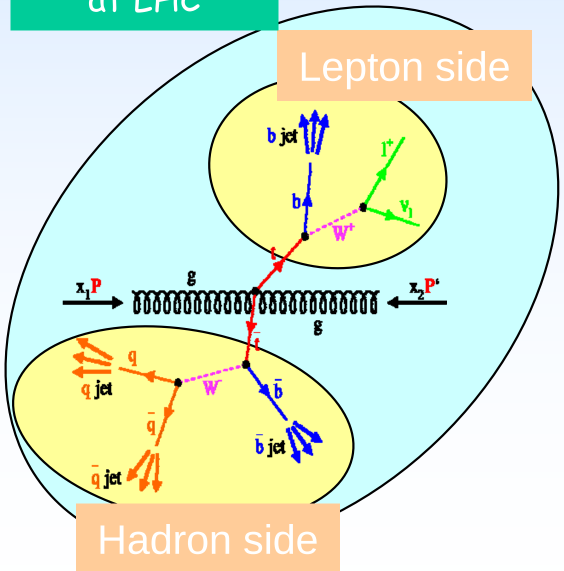


While the major goal of the LHC experiments is to find a definite answer on the mechanism of the EW symmetry breaking, the justified hope of the HEP community is also to see a hint of the physics beyond the SM.

Based on this prospective the ATLAS detector was designed as a general purpose detector sensitive to a broad range of final states resulting from different models of "new physics".

ATLAS Tile Hadronic Calorimeter plays a key role in the ATLAS physics program, specially for triggering and measuring jets and missing Et.

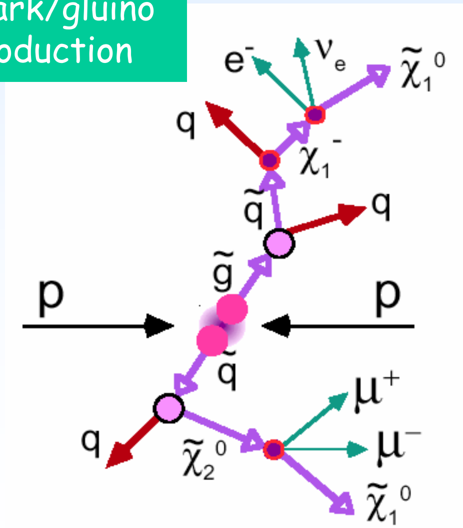
$t\bar{t}$ production at LHC



ATLAS physics with the hadron calorimeter:

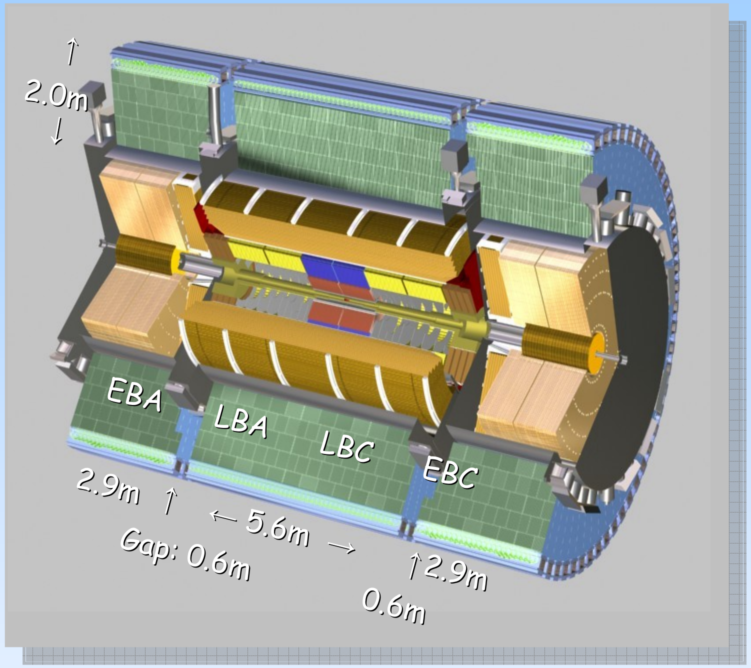
- Top physics: precise jet energy scale
- W physics: accurate ETmiss, rejection of EM-fakes
- Higgs: Jet reconstruction, rejection of muon fakes and EM-fakes, Etmiss
- SUSY: reliable ETmiss measurement, jet reconstruction
- Exotics: precise jet energy scale at large energies

SUSY at LHC: squark/gluino production



Requirements Imposed on Tile Calorimeter.

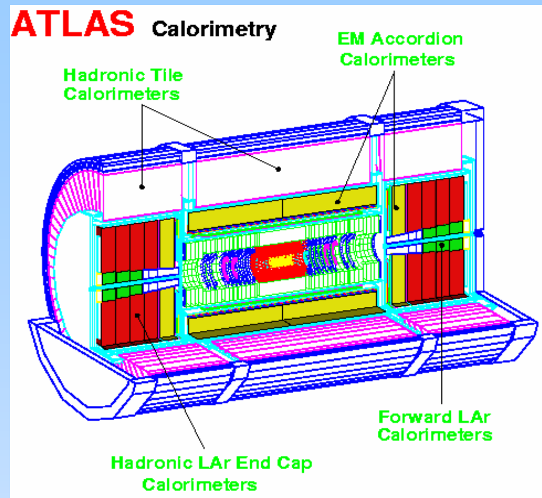
- large center-of-mass energy of 14 TeV:
  → good jet reconstruction over a large energy range for the whole η range covered :
  sE/E = 50%/√E + 3%
- large luminosity: 10^{-34}/cm2/s
  - 23 MinBias interactions/BC
    → fine granularity
  - large radiation impact
    → radiation hardness of readout
- non-compensating calorimeter
  → reasonable longitudinal segmentation in order to recover linearity of energy response
- large jet cross section → efficient hadron leakage cut for EM-ID
  → fine granularity
- avoid ETmiss faked by detector effects
  → uniformity in η,φ
  → good hermeticity
  → containment of jets



Summary of requirements:
- Precise jet energy scale
- Good jet energy resolution
- Containment
- Hermeticity
- Uniformity
- High granularity
- Radiation hardness

Detector Geometry.

The TileCal, the barrel part of the hadron calorimeter in ATLAS, is a sampling device made of steel and scintillating tiles. Due to the LAR EM-calorimeter in front mainly the hadronic response is optimized. Some sensitivity to muons might be used in the level-1 trigger.

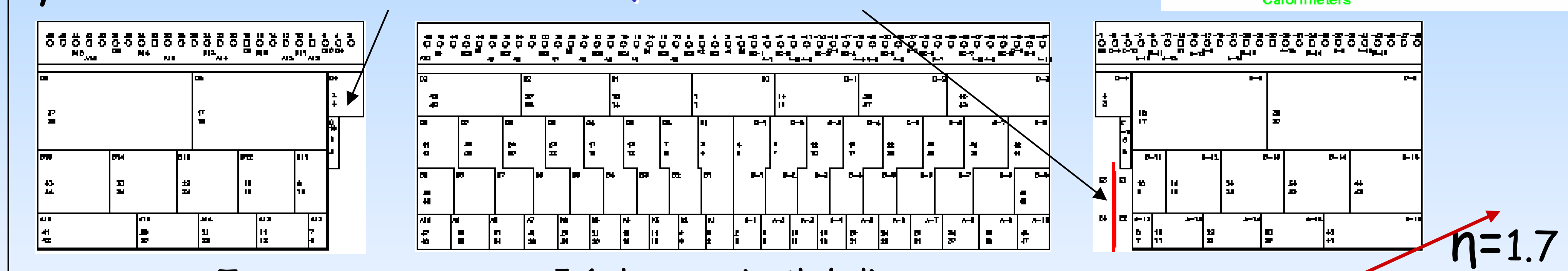


Hermeticity

η coverage ± 1.7

cracks at transition region

Y Intermediate Tile Calorimeter + Gap Scintillators



5.6 degree azimuthal slice

Segmentation

Each 0.1 azimuthal slice has 73 cells arranged into projective towers with $\Delta\eta \approx 0.1$.
Each of 64X3 modules has three depth segmentations called samples A, B, and D.

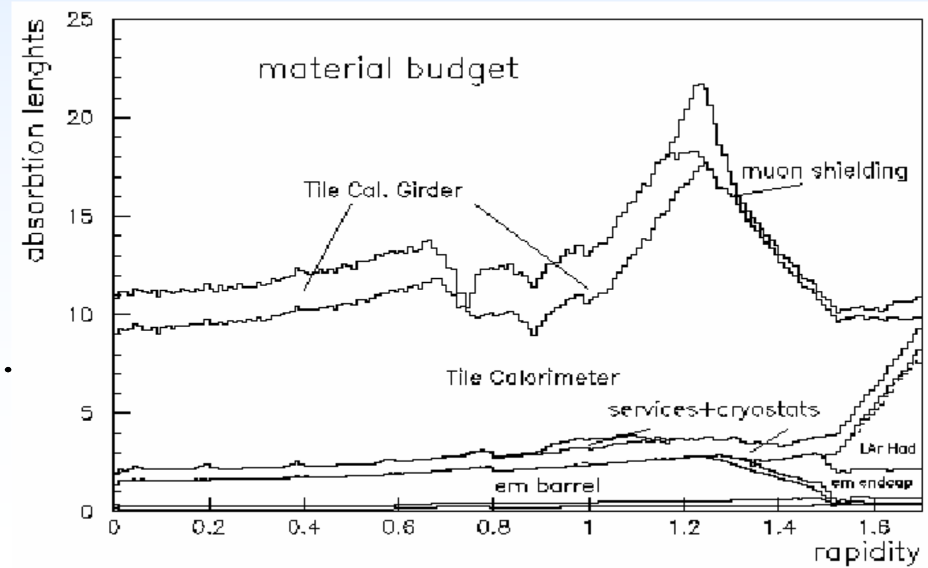
Sampling

18 mm period in z with radial tiles staggered in depth.

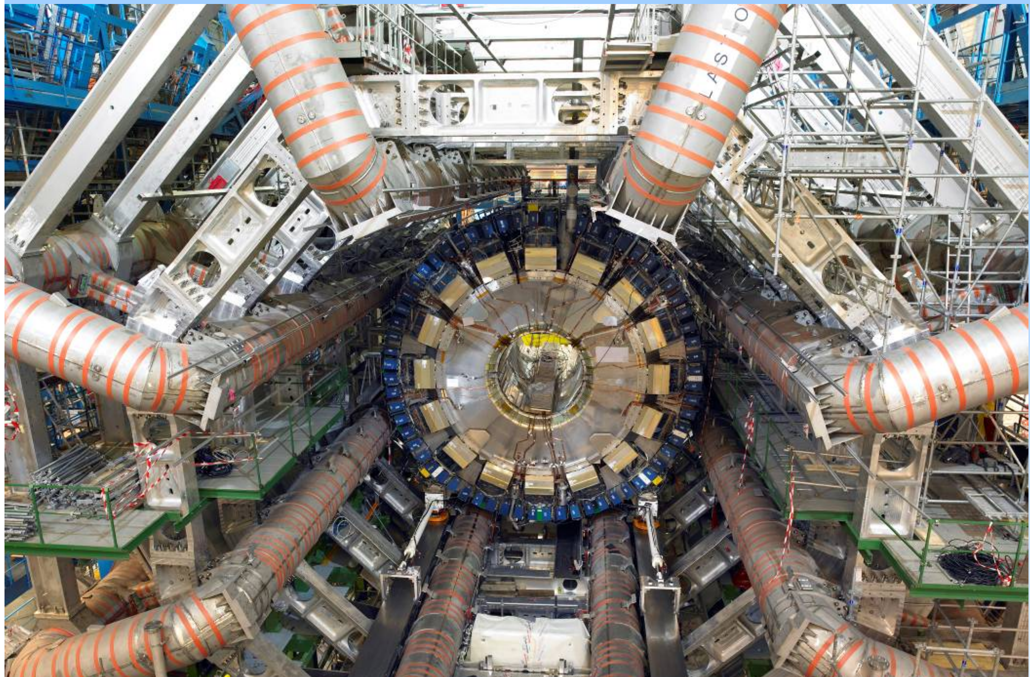
local variations in sampling fraction for $|\eta|<0.1$

Material budget

to contain jets and to shield muon system.



Mechanical Status of Tile Calorimeter in the Cavern



The Barrel

is complete and placed in its final position, with services and cabling fully installed on 5/16 part of the calorimeter and greatly advanced on the rest of the cylinder. Cooling is done on the 10/16 part of the barrel.

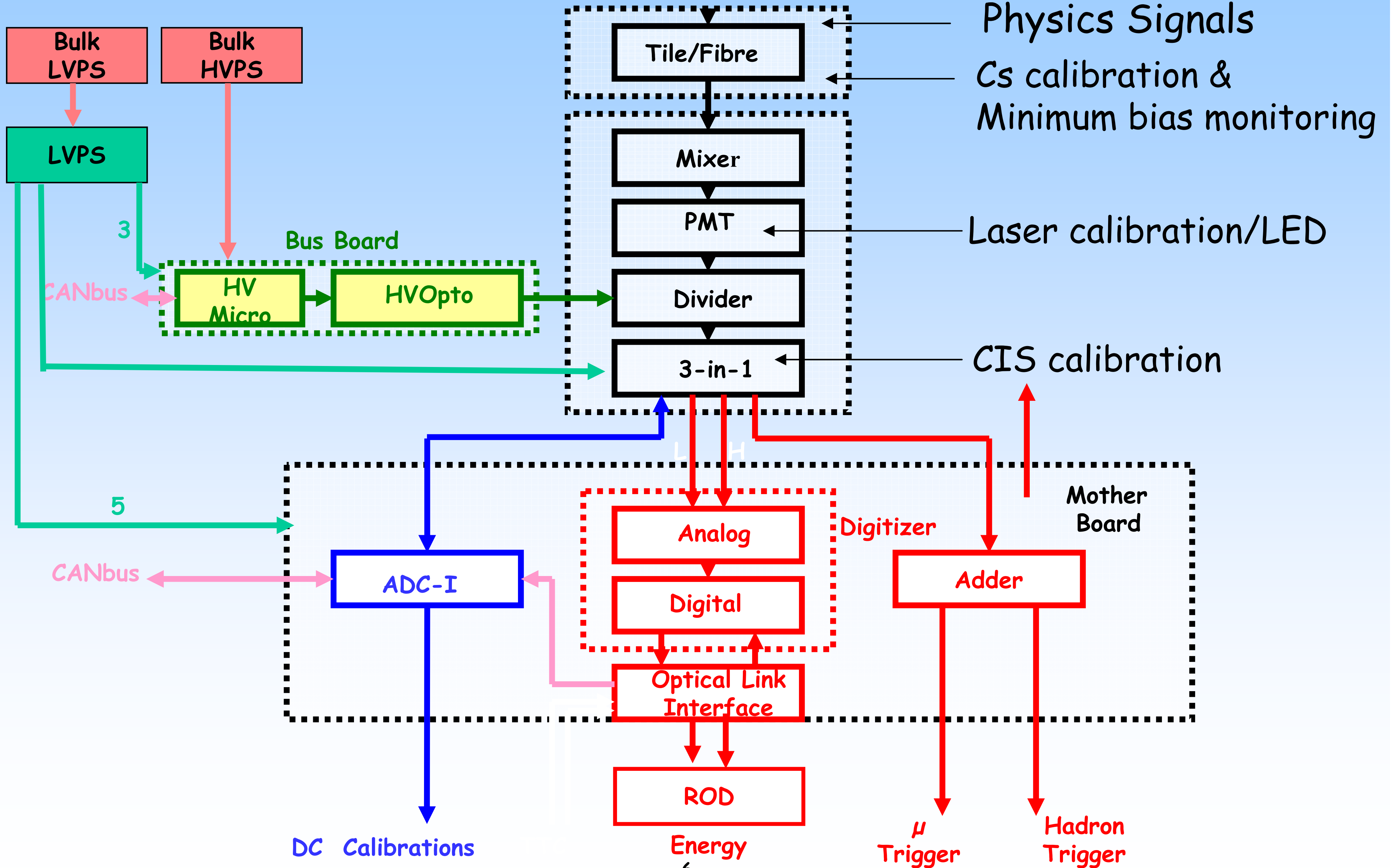
Two Extended Barrels

are complete and to be moved towards Barrel next month. Cabling preparation has started.

The installation of the **calibration system based on the movable Cs radioactive source** is mostly complete on all three cylinders.

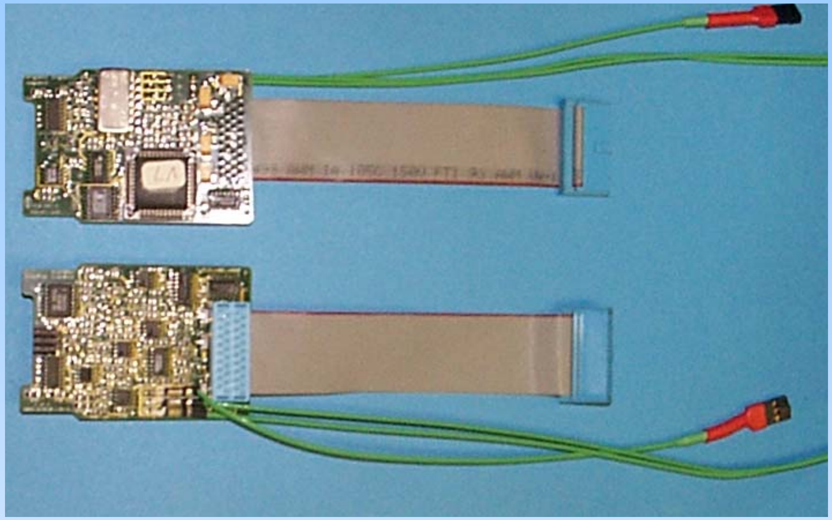
Gap and Cryostat scintillators are installed on the C side and the calibration effort is taking place.

Tile Read-Out Scheme



3in1 Card

3-in-1 card: plugged into anode of each PMT (1 channel = 1 PMT), named for its multiple functionality, ~10000 cards in TileCal



Shaping of PMT signal to digitizers

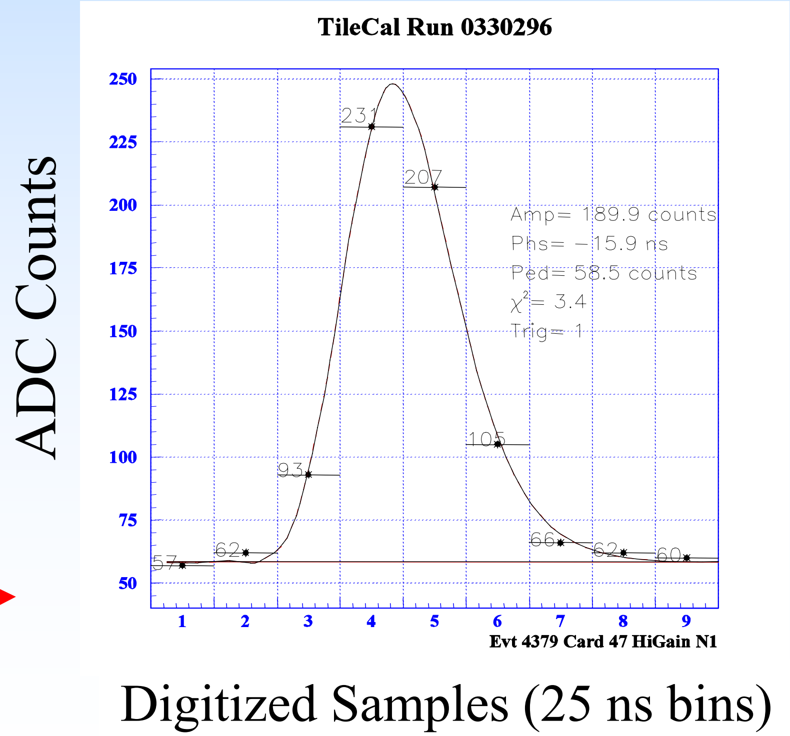
- Typically 7-9 25ns samples digitized
- Bi-Gain output (gain ratio 1:64 for dual 10-bit ADC's)
- high gain (0-10 GeV)
- low gain (10 – 1000 GeV)

Integrator for ^{137}Cs source calibration and monitoring minimum bias current.

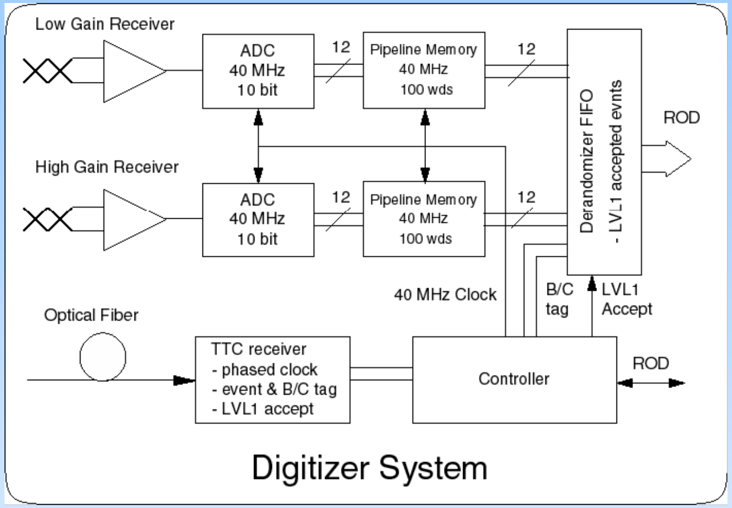
- six gains selected remotely (12pA-1.7uA)
- 10msec integration time

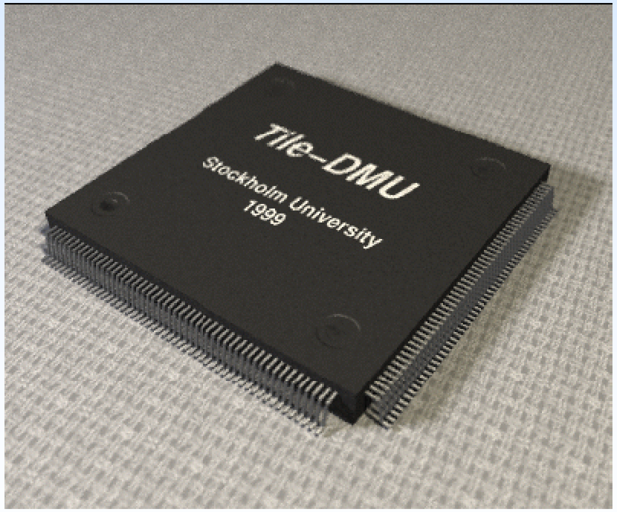
Charge injection (CIS) for electronics calibration

Example digitized 3-in-1 pulse shape from one channel responding to CIS



Digitizer Card





Six 3in1 channels per digitizer board
- ~1600 cards in the TileCal

Two 10-bit 40 MSPS ADC's per channel
- Digitizes pulses from both gains of 3-in-1 card every 25 ns

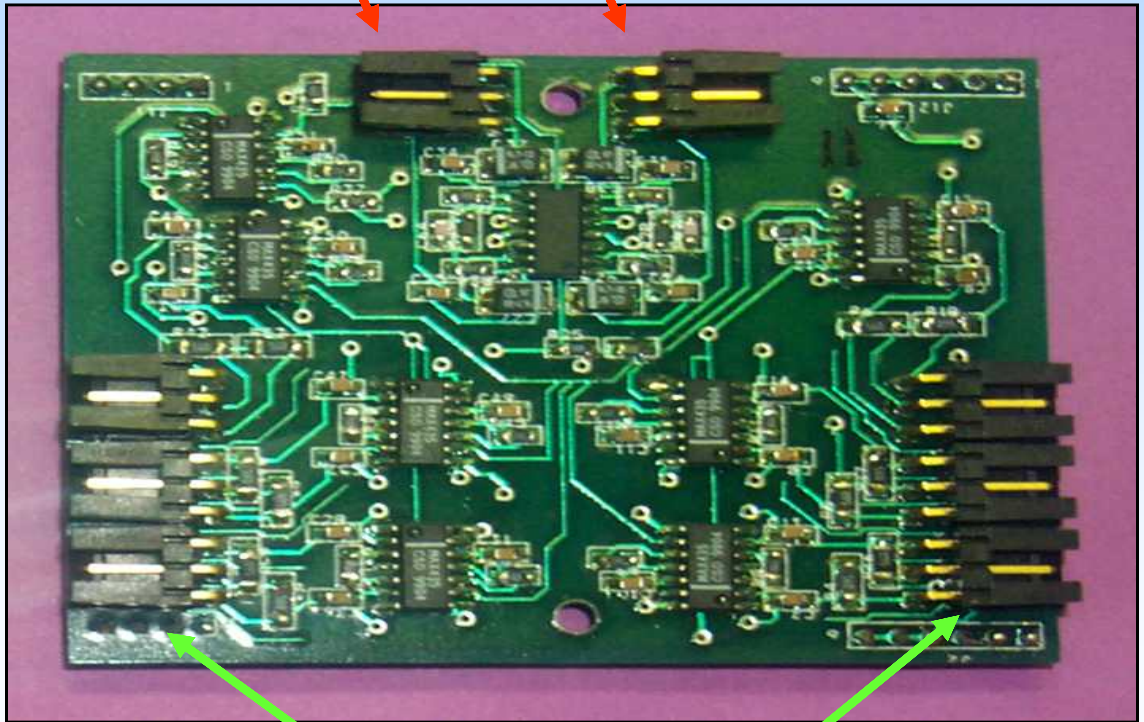
LVL1 trigger latency <2.5μs
- Digital pipeline
- Readout 7 or 9 samples of 25ns

Control via custom chip (TileDMU) from Chip express, 20K gates, coded in VHDL

Adder Card

Analog outputs to LVL1

Hadron μ



6 inputs from 3in1s

TileCal LVL-1 signal consists of

- **adder tower sum** (calorimeter trigger) – analog sum of PMT signals in the given η,φ direction
- **muon output** – amplified analog signal from 1 PMT of D-sampling

adder tower sum: 10 mV/pC ± 3%

noise: 3.7 ± 0.9 mVrms (5 inputs)

adder muon output: 280 mV/pC ± 5%

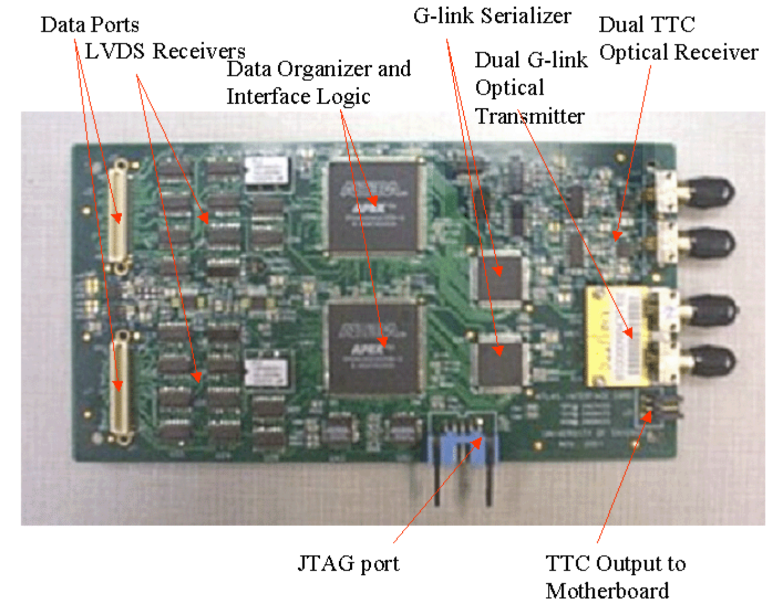
noise: 45 ± 5 mVrms (1 input from D cell)

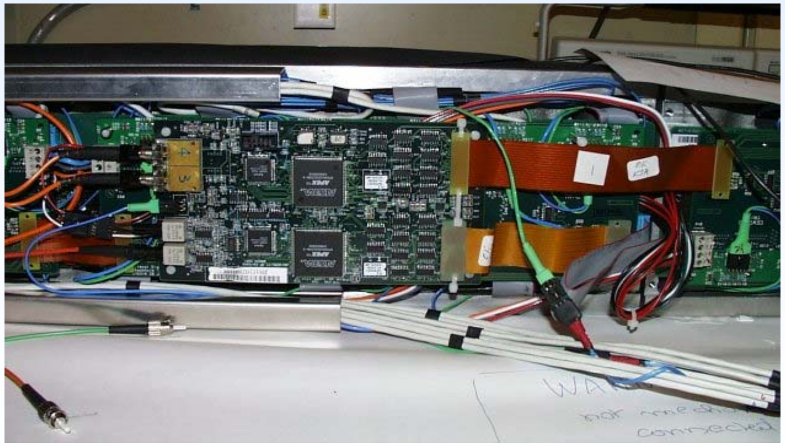
Timing for physics (alignment of the trigger tower inputs): < 2 ns

checked in the testbeams

calibration is part of the commissioning program

Interface Card





Interface card receives data from digitizers

2 PLD's format data

2 GLINKS transmit over optical fiber to ROD

Input TTC 40 MHz LHC clock

Repack 32-bit data words
- From scrambled data transferred over 2-bit LVDS data lines (40Mpbs)
- Insensitive to timing differences related to digitizer board geometry

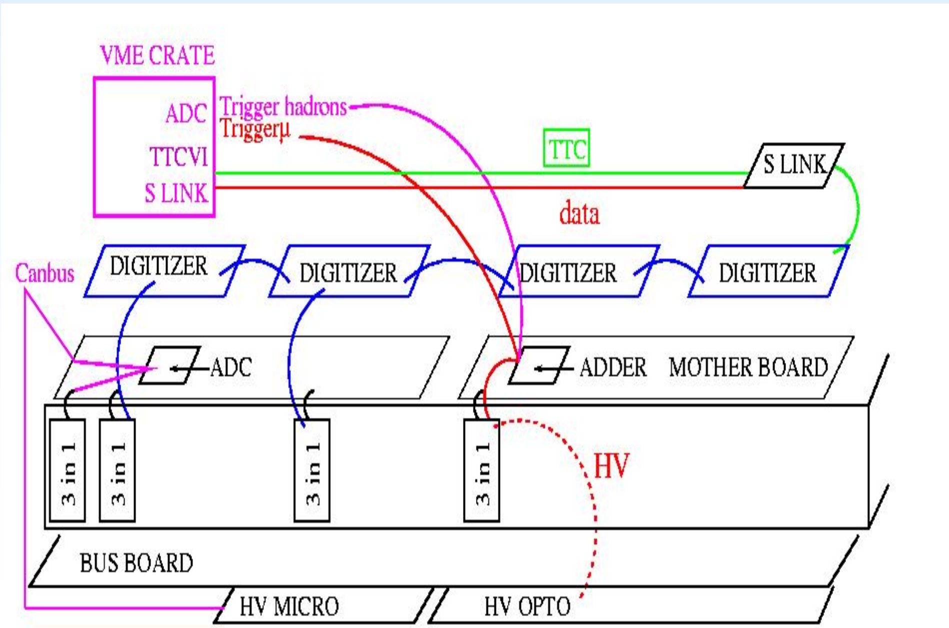
Generates CRC-16 and Global CRC
- Check transmission errors over input and output segments

Redundant design
- Dual optical inputs
  - Interface automatically selects other TTC input if 1 fails
- Dual optical GLINK output
  - In case a fiber breaks
- Dual logic
  - Robust against transient SEE events

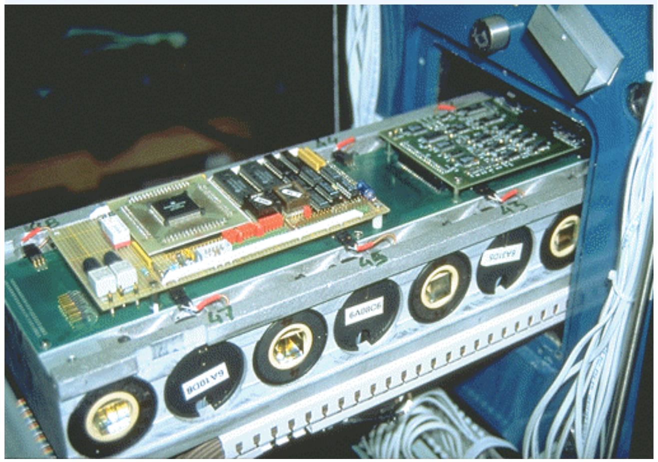
Altera EPC2 programmable in-situ via JTAG port

Motherboards, Integration of the Tile FE Components in the Drawer

- Mother Boards
  - Set of four chained motherboards per drawer
    - Up to 12 channels per motherboard
    - ~1000 Motherboards in TileCal
  - Services and control signals to 3-in-1
- Digitizer Boards, set of 8 per drawer, 6 channels per digitizer
- Interface Cards, One per drawer
- Connections to drawer   D.C. Power & CANbus



Drawer

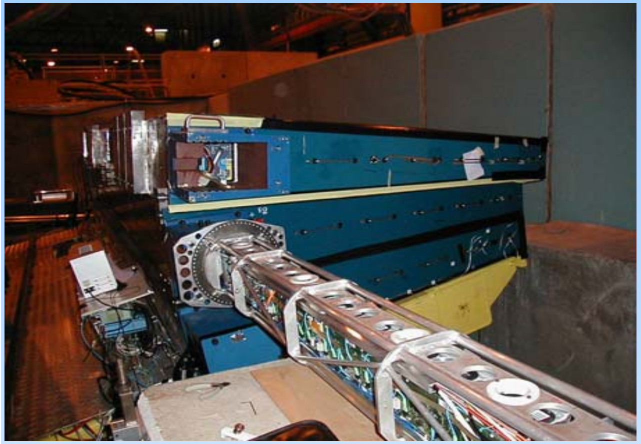


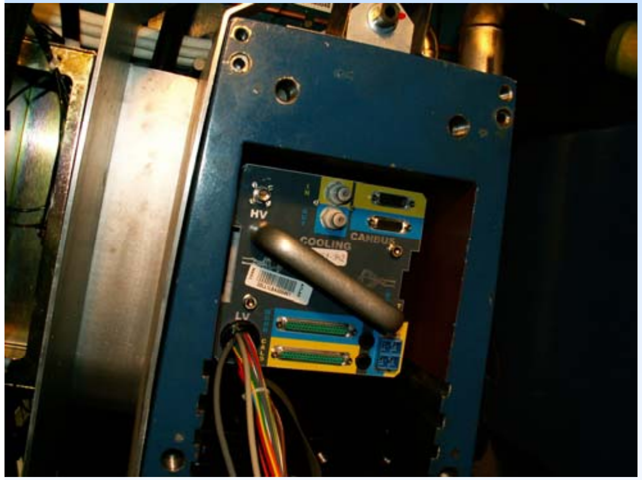
LV PS system (power branch)

- Main Power supply (Bulk PS)
  - 3x200 V DC, 1kW/channel (max. 1.7kW)
  - 22/64 pieces are in the cavern
- 200 V & AUX Star boxes
  - all are produced, installed for the Barrel
- LV Box
  - Integrates **8 bricks** in the **metallic boxes with heat sinks** – all are produced
  - **fuse boards** – all are produced
  - **internal cable sets** ~70% done
  - all small items to Build LV Boxes are in hands
  - **21 "final" LV boxes are in the cavern, to be 40 by the end of June, to be used to commission services on entire Barrel**
- Bricks
  - DC DC converters to 3,5,15V, 2048 pieces, 8pc per LV-BOX, home made transformer

Later comer,
working prototypes were given to users at the cavern in Aug'05.
Many improvements since then, based on the user experience.
Goal is to finalize the performance tuning and go into full speed assembly in few months. Big fraction of bricks (>90%) is in stock awaiting final tuning.

Drawer Insertion, Cabling, LVPS Insertion





1)
Drawer is inserted in the module
All drawers are already inserted

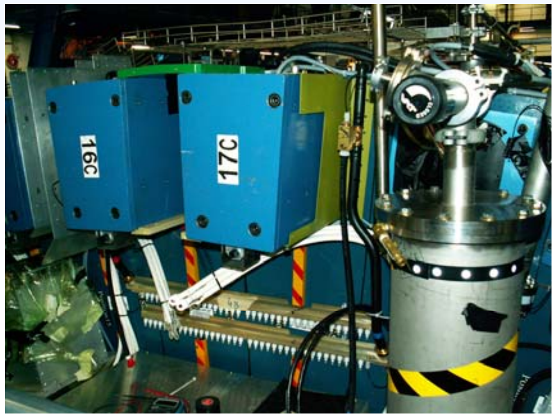
4)
LV PS to be connected to the drawer
40 LVPS to be in the cavern by July

2)
Drawer is ready for cabling

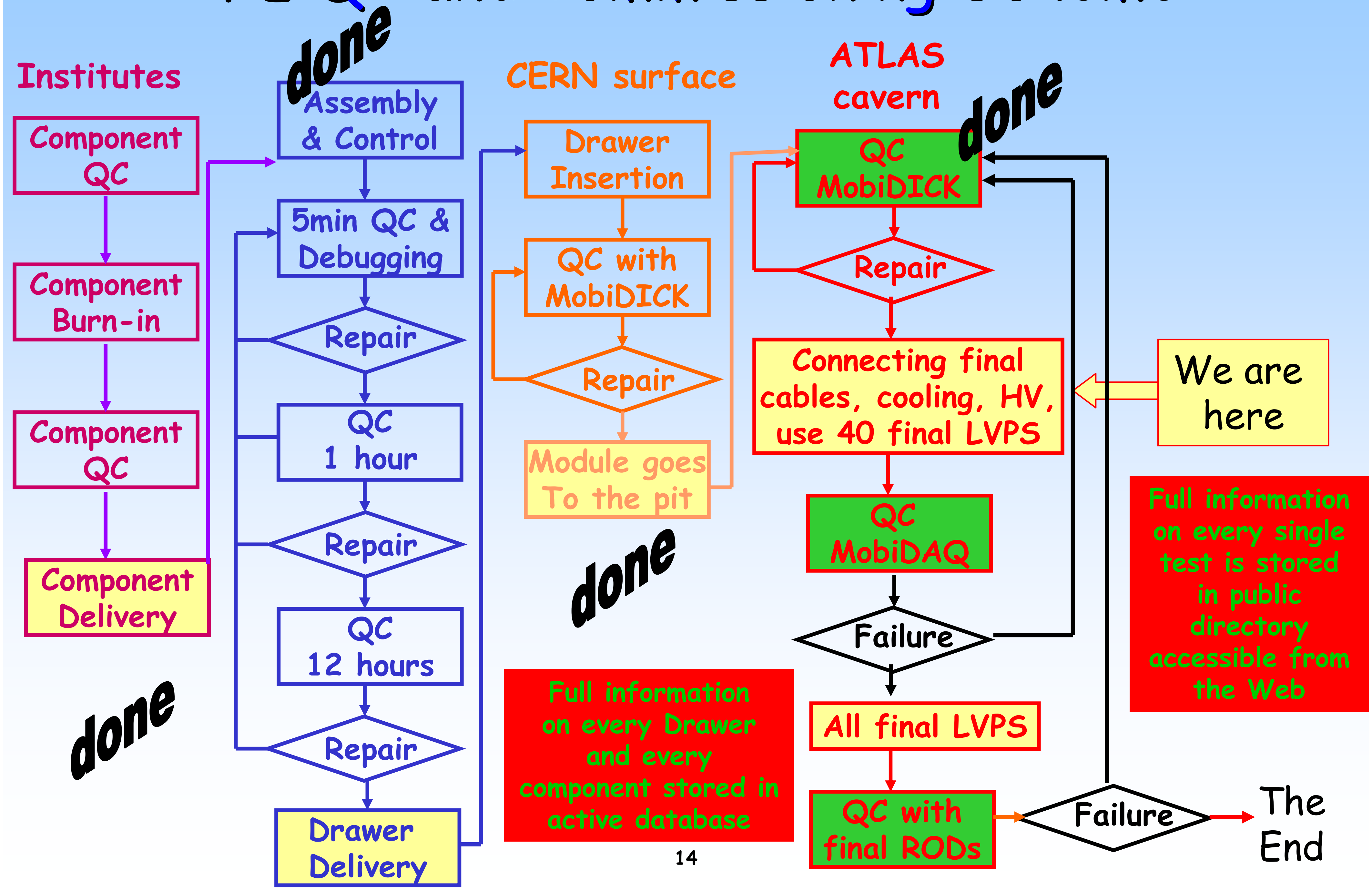
5)
LV PS connected to the drawer
21 Barrel modules are currently powered

3)
Drawer Cabling started
~3/16 of the TileCal is fully cabled

6)
modules are closed and light sealed



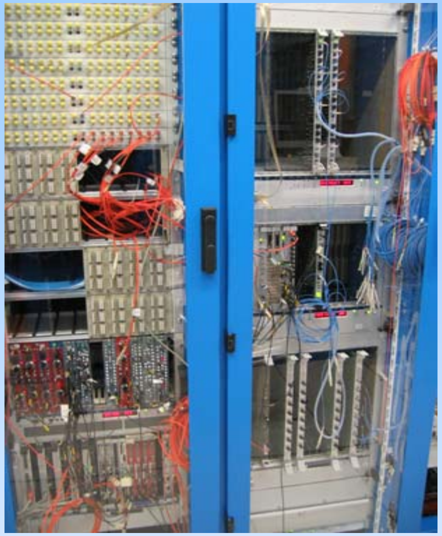
FE QC and Commissioning Scheme



QC Stations: MobiDick, MobiDAQ, RODs

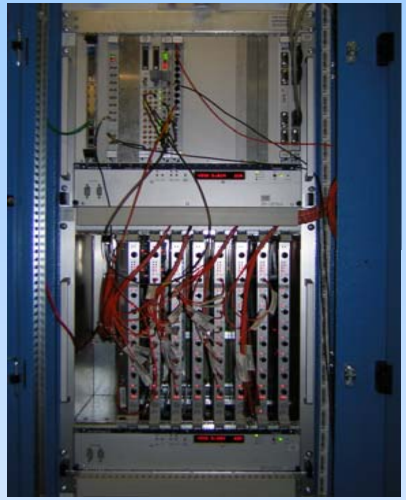
MobiDick

Detailed tests of all FE electronic components of a single drawer.
Used both before and after the installation in the pit
Used to verify any additional failure caused during commissioning and to certify the repairs



MobiDAQ

Mobile DAQ station that mimics all functions of the final read-out. It allows data taking with a set of 8 drawers at once. Besides electronic checks, it was used to develop commissioning software tools.

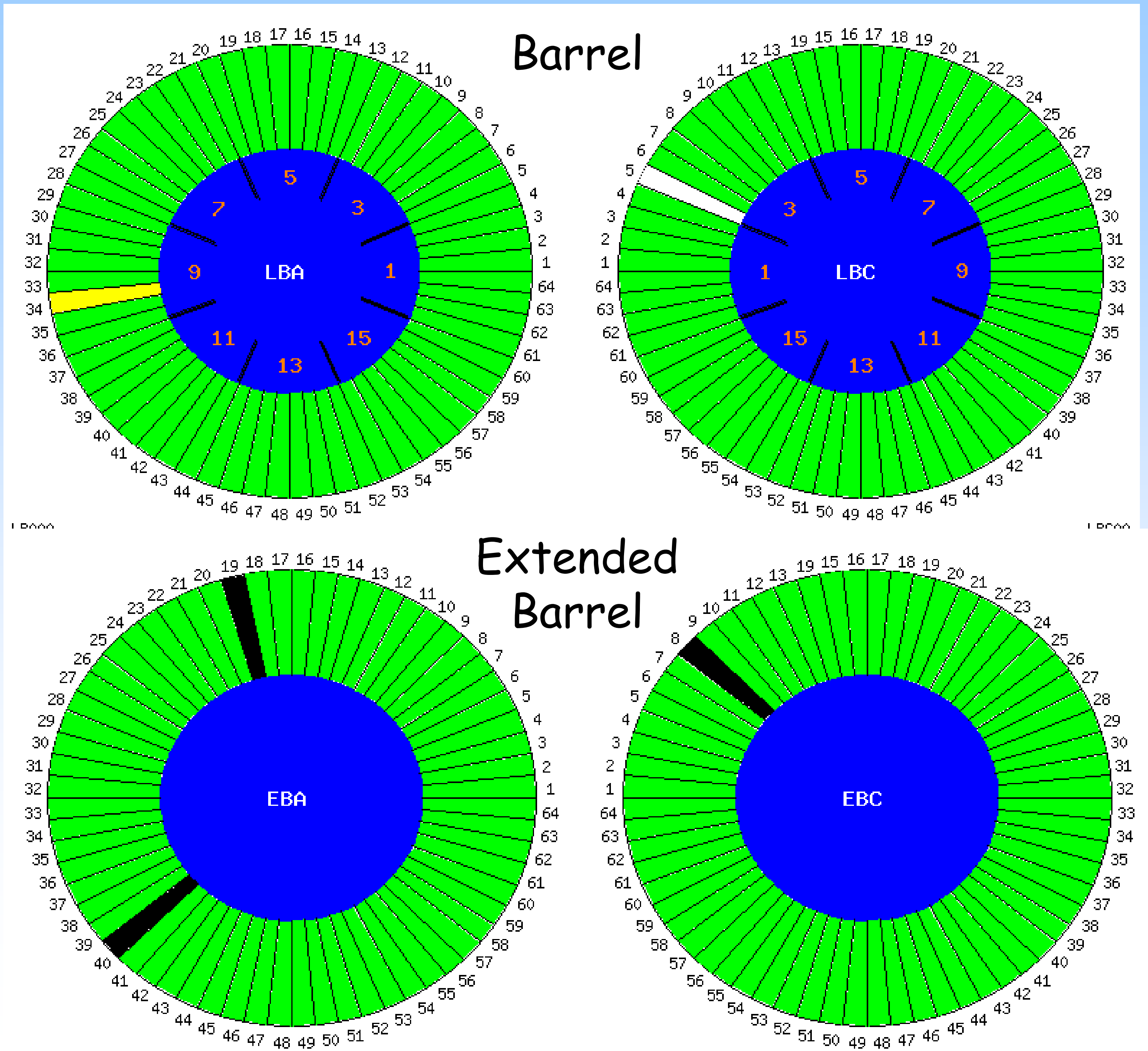


Final BE read-out, RODs

Capable of reading all Tile Calorimeter channels at once. All commissioning tools developed with moviDAQ were duplicated in RODs. Undergoes final debugging. Can take over the commissioning load or be used for dedicated studies in parallel.

Status of the Tile Calorimeter FE Electronics.

(as on June 07)



- To be tested
- OK
- Almost OK
- To be repaired
- Extracted

Summary.

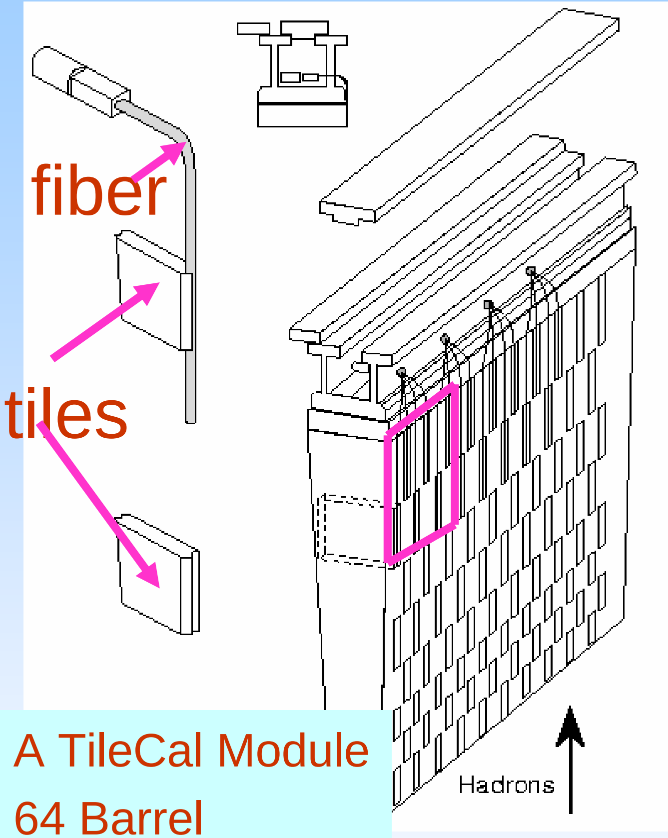
The Tile Calorimeter was designed with powerful capabilities of triggering and measuring jets and missing Et. It is essential element of ATLAS physics program. The calorimeter geometry and principles were optimized for the best hadronic performance in a combined operation with other ATLAS calorimeters.

Barrel cylinder is assembled and placed in its final position. The routing of the cables and connection to FE patch panels is completed in 5 out of 16 barrel sectors. Big fraction of the Barrel cooling is available. Both extended barrel cylinders are fully assembled and soon will be moved towards the central part. Manufacturing and routing of the cables is starting. GAP and cryostat scintillators are installed on the C side.

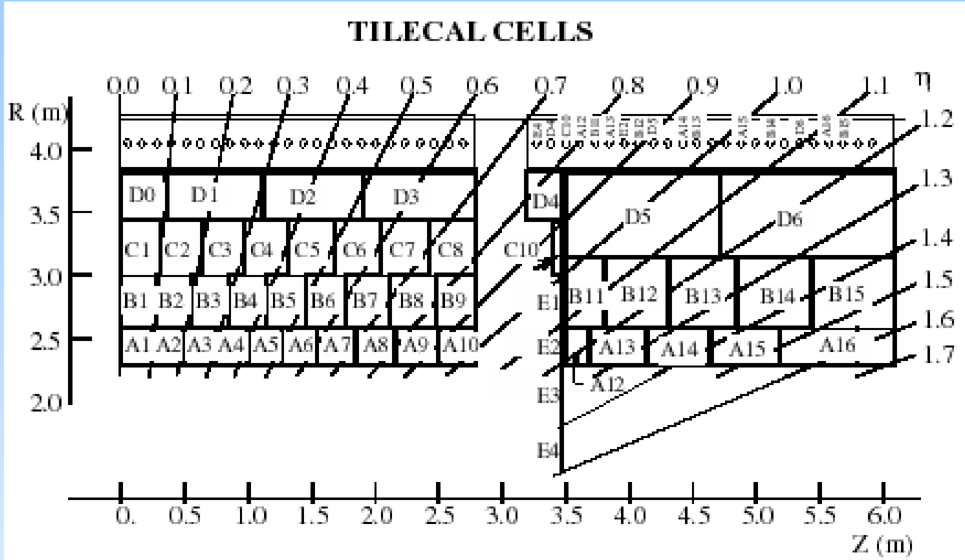
Practically all the Tile Calorimeter modules are equipped with FE electronic components those functionality is systematically checked with several dedicated test stations. The FE electronics of the Tile Calorimeter is mostly commissioned in the stand-alone mode. Commissioning with final services and LV power supplies will follow.

Back-up Slides:

The TileCal detector



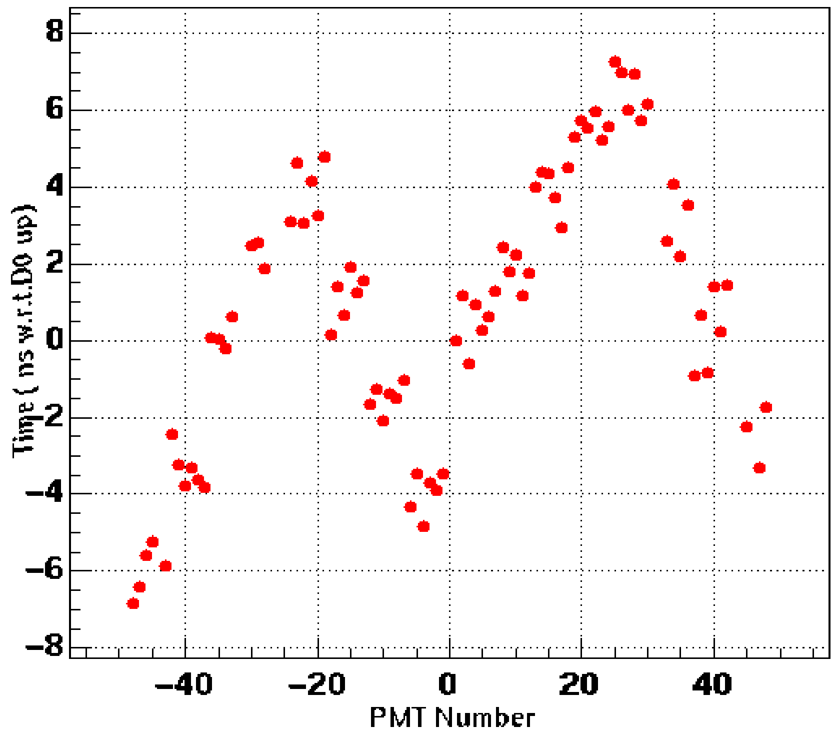
A TileCal Module
64 Barrel
2x64 Ext. Barrel

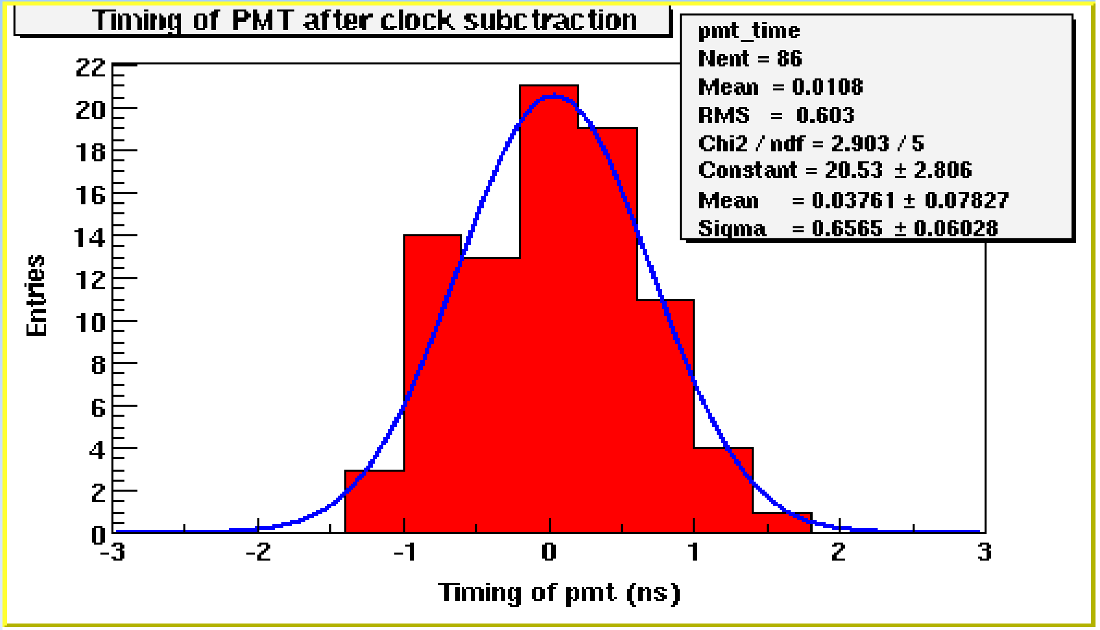


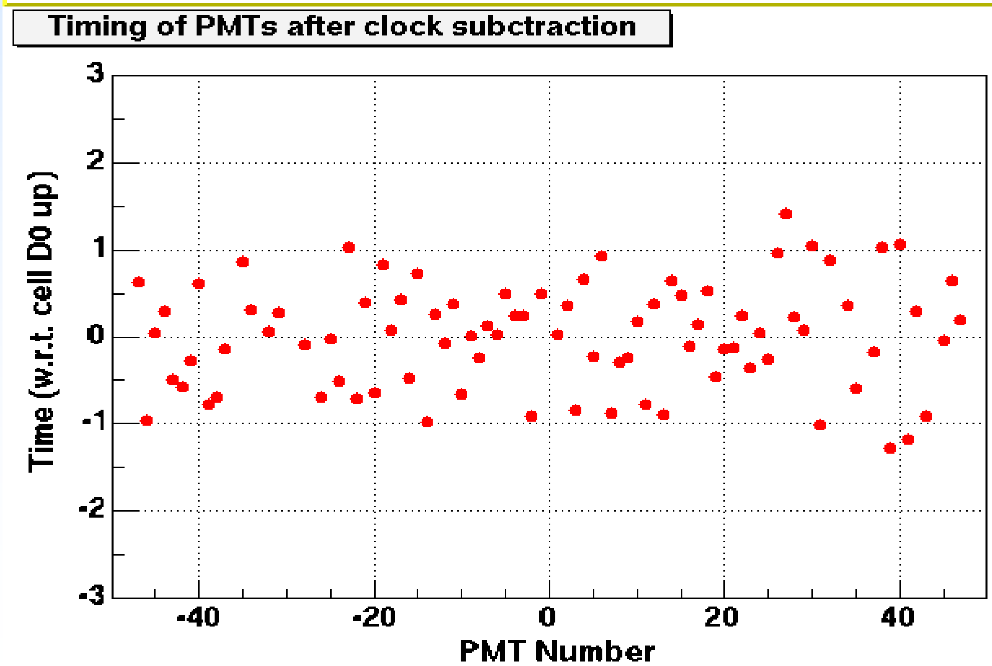
8.5 m outer diameter
12.2 m long
2900 tons
10000 channels

- Sampling calorimeter:
  - absorber: steel tiles
  - active material: scintillating tiles
  - laminated structure withtiles perpendicular to beam axis,
- The two outside faces are read out bywave lenght shifting (WLS) fibres into seperate PMTs → increase light yield, provide redundancy
- Tiles grouped to cells of Dh=0.1(0.2)
  Cells arranged into projective towers
- PMTs and FE electronics on removable drawer in the back-beam

Aug-2001 Laser Data







Using a simple and very fast timing algorithm, the distribution of the timing of PMTs has a spread of 0.7 ns once that the TTC clock modulation effect is removed.

Dynamic Range.

Npe/GeV improves over the years due to the instrumentation experience.

Current plan is to set PMT gains to 1.2pC/GeV of em energy at 90 degrees.

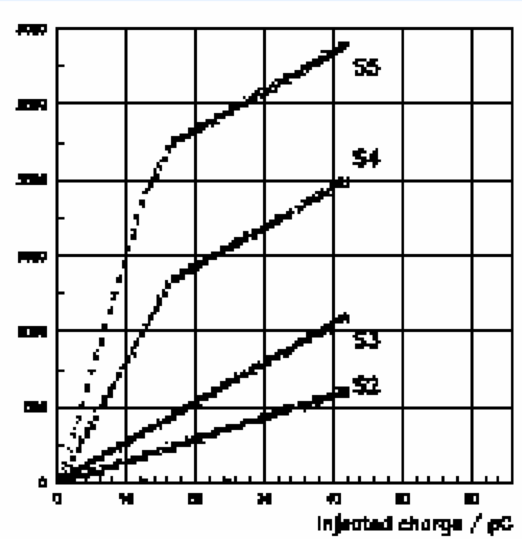
This will require setting HVs down by (10-40)V from the nominal values -> non-linearity from PMTs rises up to 2%.

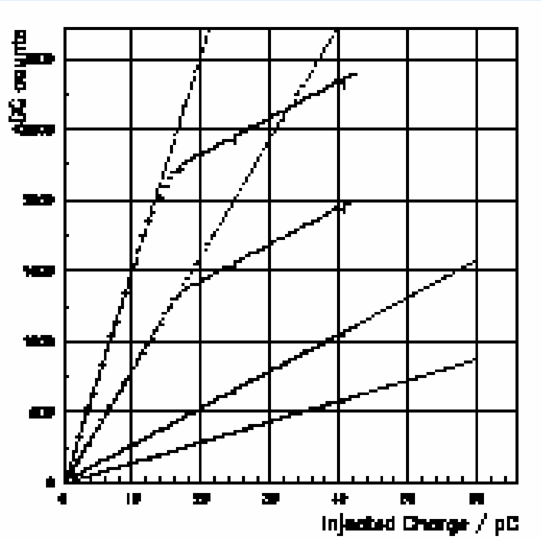
Non-linearity can be recovered by LAS calibration or by weighting technique (less likely)

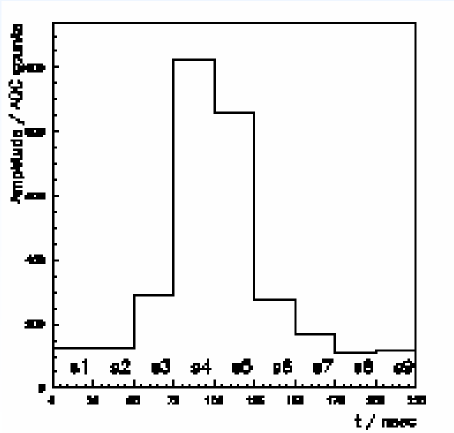
	Module type	Tile material	Average Npe/GeV
'98	Barrel prototype	PSM	48
'00	Production barrel	PSM	61
'01	Two production extended barrels	PSM BASF	63 70
'06	Re-thinking all the TB data		75

Dynamic Range = 1.52GeV/cell (had scale)

Proposal to enhance the dynamic range by recovering saturation.







Calibration Strategy.

Jets in-situ calibration

To correct for detector effects
- non-linearity from non-compensation, longitudinal leakage, pmts,
- energy lost in the dead material, (3-13)% depending on η,
- noise from min bias and electronics, magnetic field effects, finite granularity

depending on physics goals may go deeper into fragmentation, IRS, FRS …

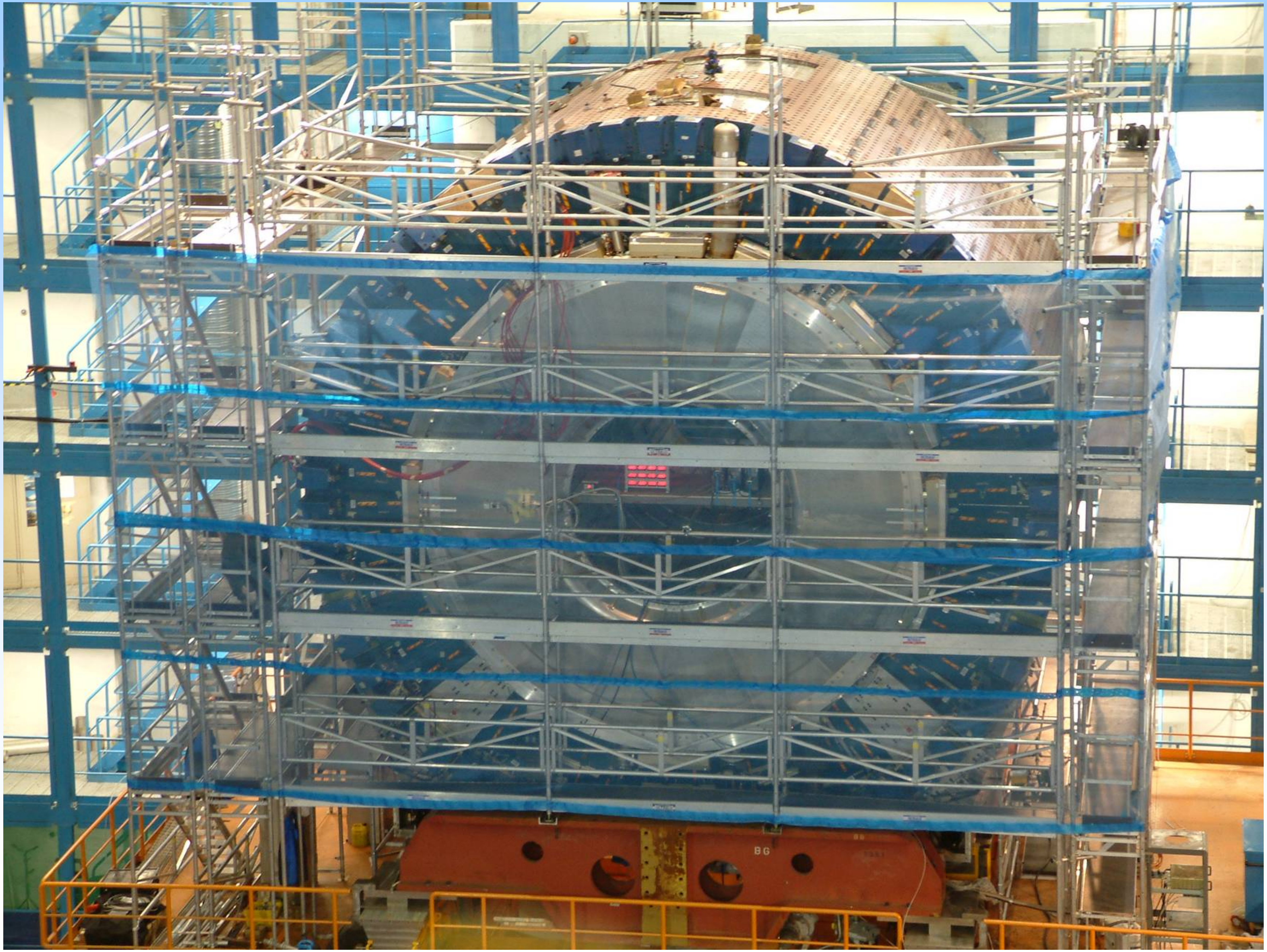
Recovery methods:
- Weighting Techniques (H1), Energy flow method (using tracker information)

Golden channels:
- Z/γ+jet Pt balance
  - with 10fb of data may reach 1% level in jet E calibration and 1% linearity.
- t->W->jj
  - with 10fb of data may reach 2% level in jet E calibration and 2% linearity.
- E/Pt for a single hadron (usually coming from τ)
  - with 10fb of data (320k signal evts) may reach few% level in jet E calibration.

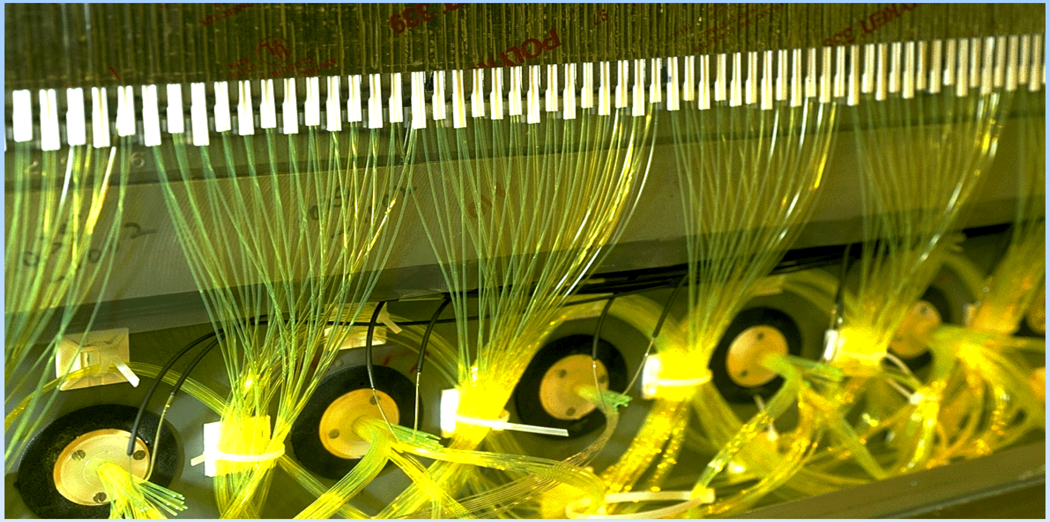
Concerns
- limited statistics and HUGE number of weights (usually both Energy and η dependent)
- analysis usually assumes no tails in Energy measurements.

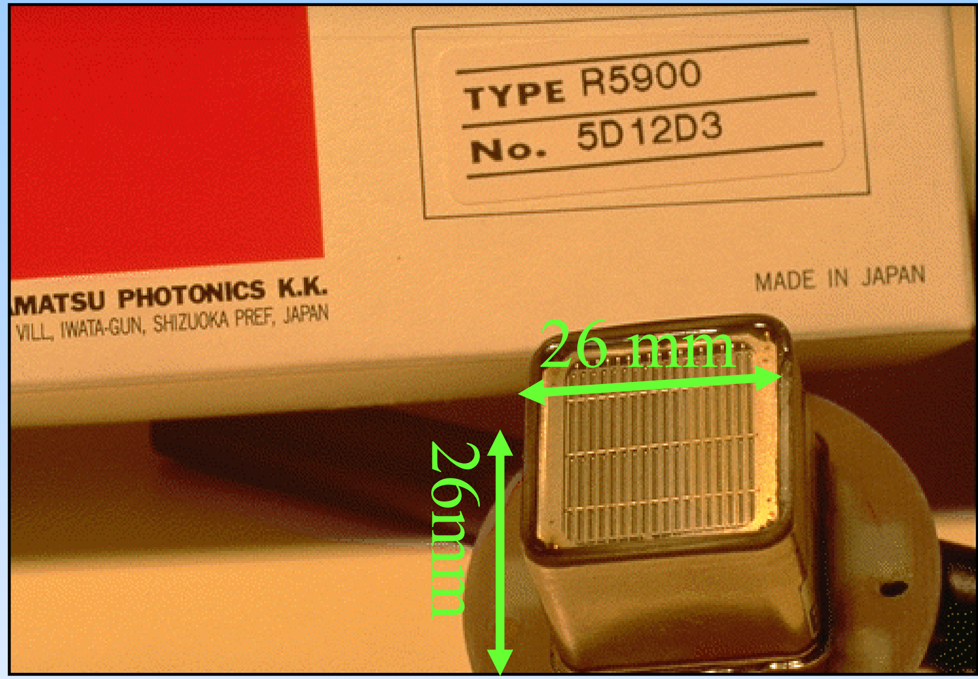
Requirements from the detector:
- (5-10)% accuracy on EM scale after transporting TB calibration to the ATLAS, stability.

Extended Barrel, Side C



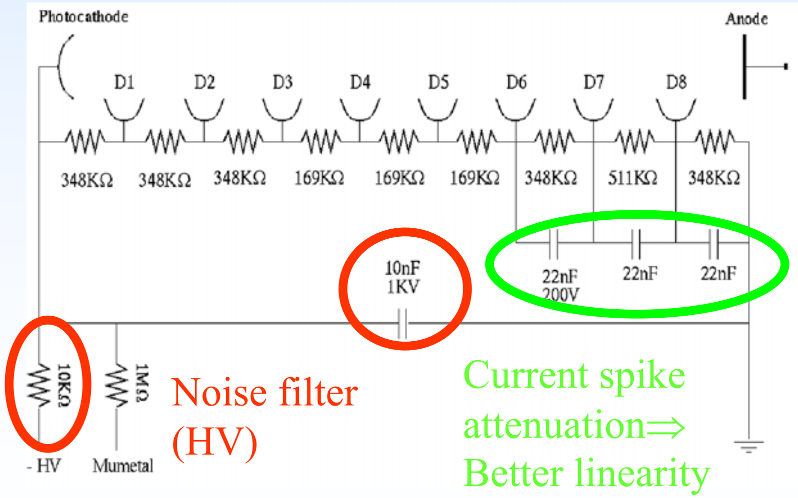
PMT



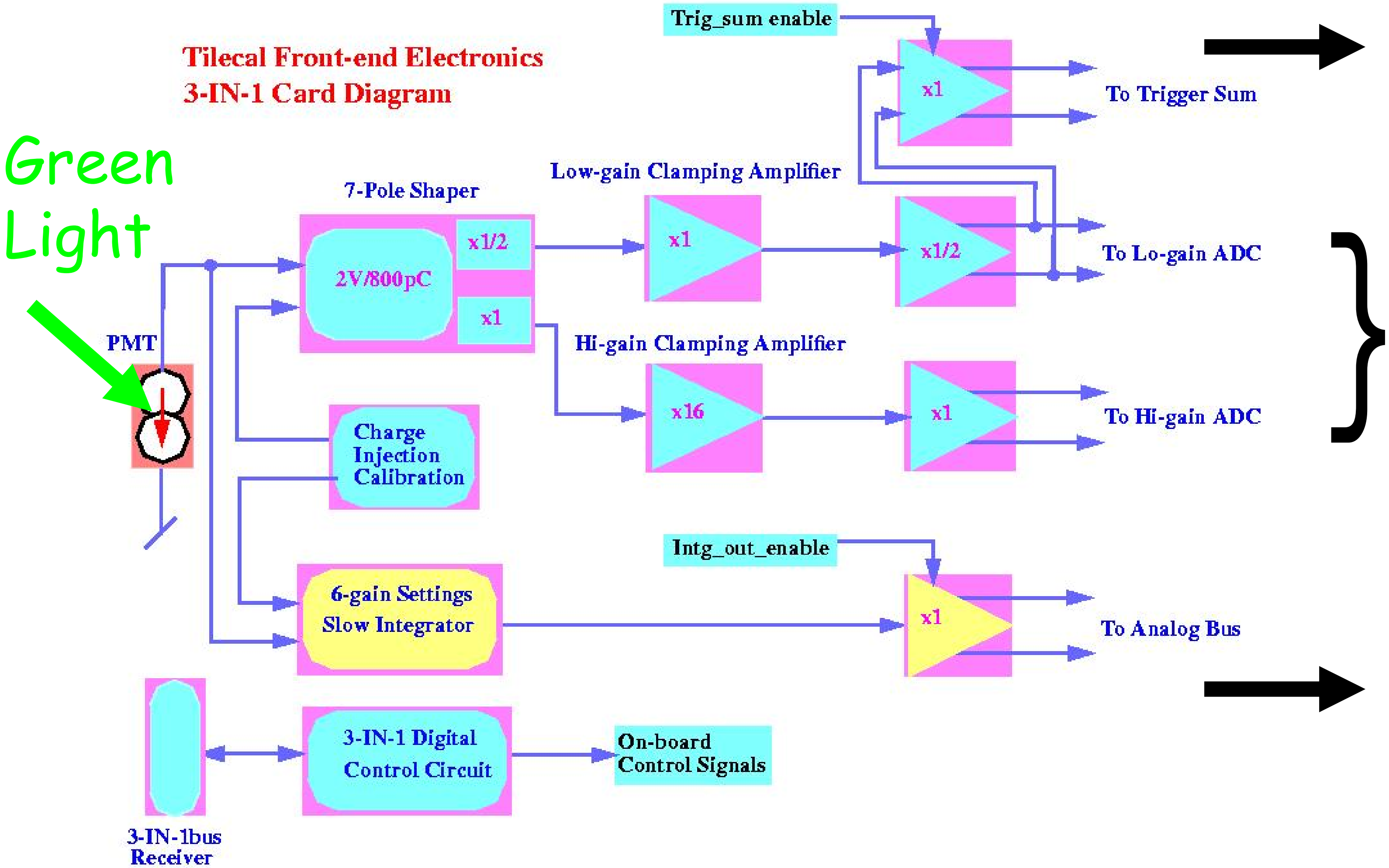


Tile+PMT ~ 75 pe/GeV (mu scale)
Photocathode 18×18 mm² (bialkali)
300 to 650 nm, max @ 420nm
8 dynodes
Dark current ~ 100pA@680V
$\tau_{\uparrow}$ 1.4 ns, width 3.4ns, $\tau_{\downarrow}$ 3.3ns (Rms 0.3ns)
Small sensitivity to B & T (0.25%/°C)

3 steps of tests:
PMT 'alone', PMT+divider, PMT+divider+3in1



3-in-1 Card Schematic



To Analogue Trigger Sums For Lvl1 trigger

To Digitizers e.g. CIS cal

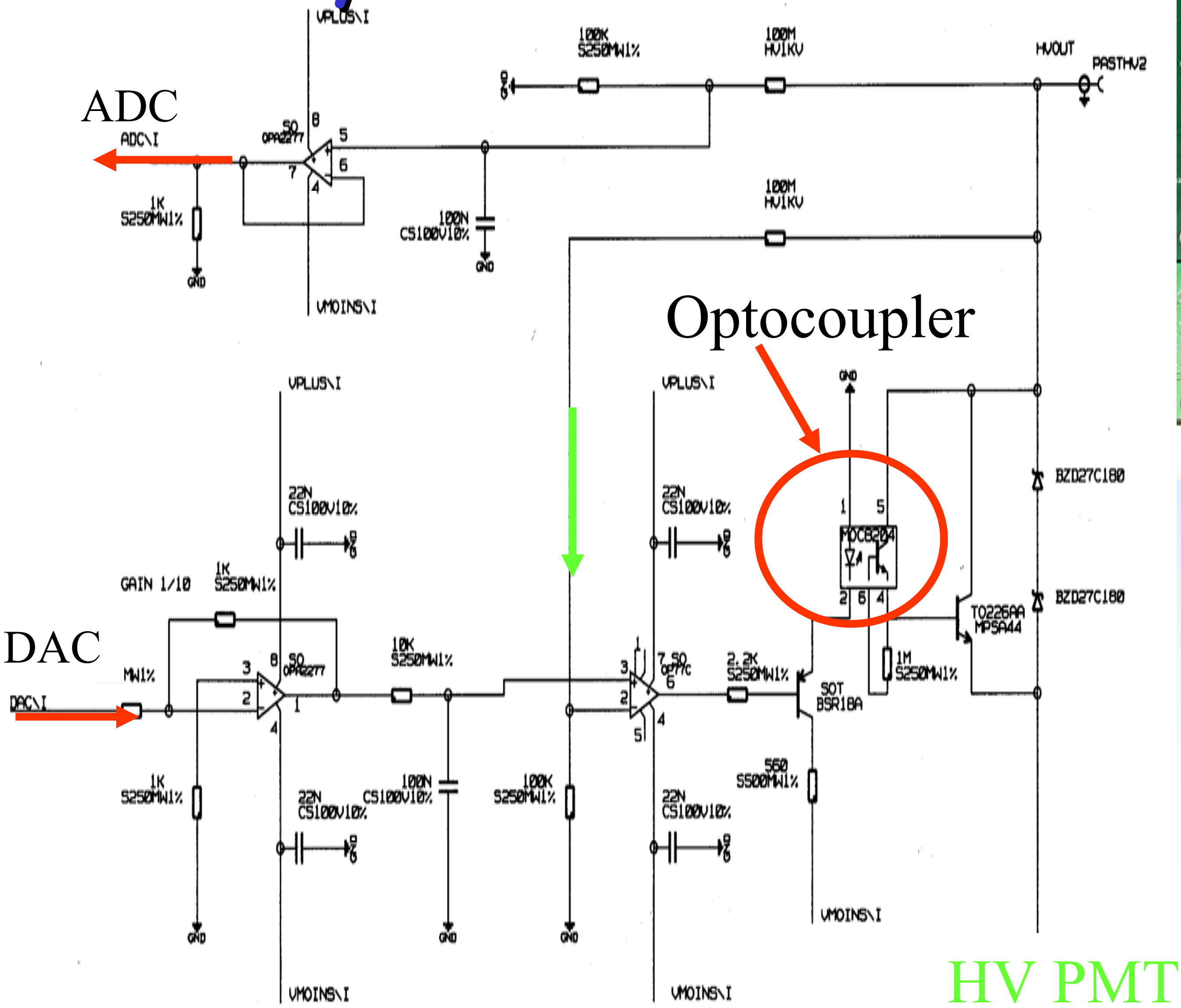
To ADC for Cs calibration and min bias Monitoring

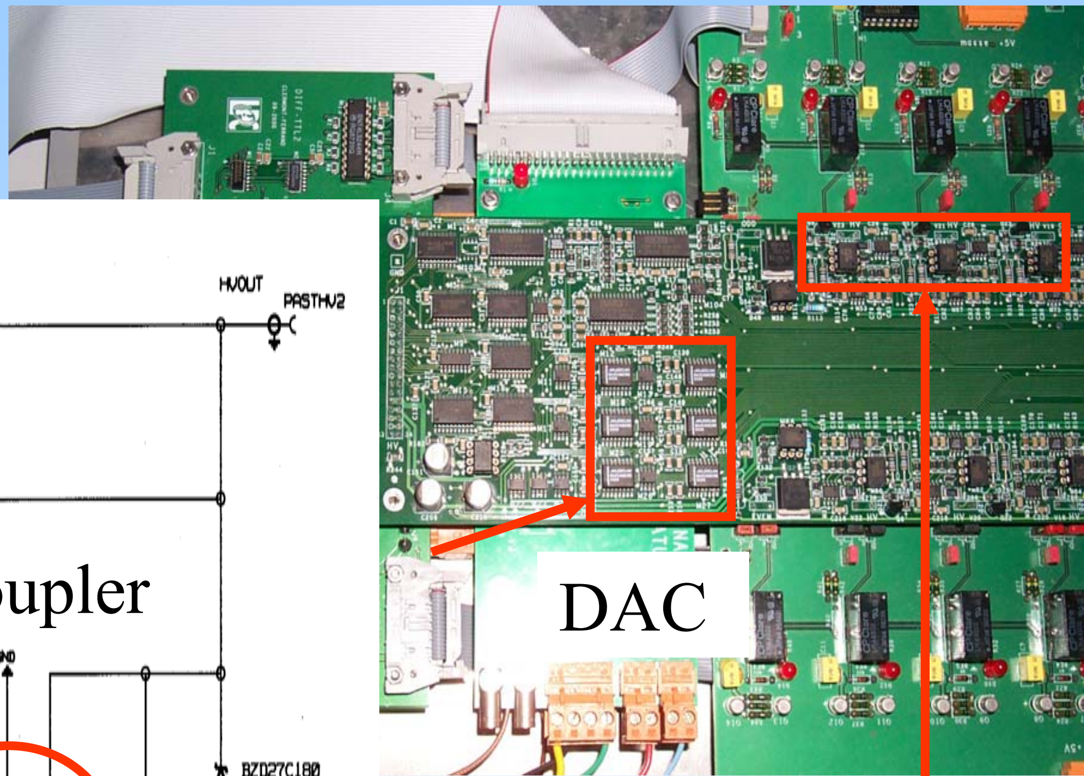
12 bits ADC

Cs current ~50nA

$\sigma(I)$~2.5%

HV Distribution System





Regulation loops:
HV @0.4V
$\equiv G_{PMT}$ @0.5%

Power diss. ~35W

All components certified in the Institutes, then

	Mechanical assembly	**Cooling** tests: over pressure (2.5 bars), under pressure (0.5 bar)
	Electronics assembly	**Electrical** tests (Grounding, Temp. Probe) **Full cross-check of 2 operators** (in 3 steps)
Step1: Fixed Test Bench (Clermont-Fd)	Debugging Willy (5 min)	**Everything** including Cooling, except HV on Including reprogramming of Interface **Repeated** up to zero default
Step1: Fixed Test Bench (Clermont-Fd)	Short term test (1 hour)	**Everything**, including HV_{Nom} loading **Back to Willy** if failure
Step1: Fixed Test Bench (Clermont-Fd)	Long term test (> 12 hours)	**Pulsed LED** with HV on (Stability test) **Back to Willy** if failure
CERN	Insertion	**Control** of all LVs **Now** use of sense lines
Step 2: Portable Test Bench	MobiDICK (5 min)	**Everything** including Cooling and including HV on (24/12 V) **Repeated** up to zero default
Step 3	New tests: Stand-Alone/ MobiDick	**Additional tests later** ... new **repairs** can be required!