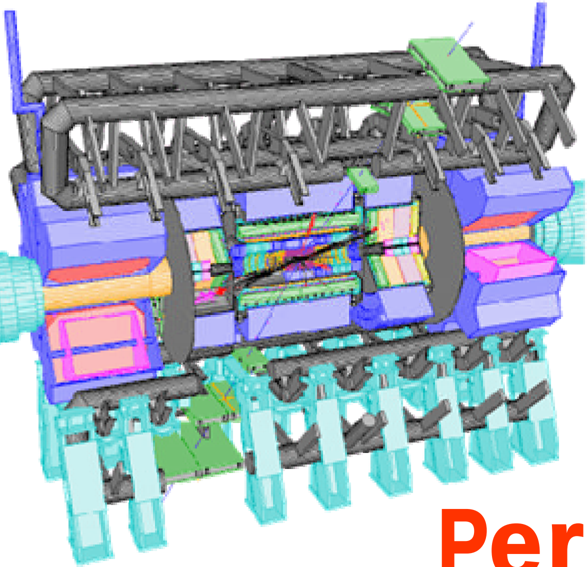
Performance of the liquid argon final calibration board

C. De La Taille, N. Seguin-Moreau, L. Serin, N. Dumont-Dayot, I. Wingerter-Seez



ATLAS

Performance of Calib128 LArG final calibration board

N. Dumont-Dayot, G. Ionescu, N. Massol, I Wingerter-Seez

LAPP Annecy

P. Imbert, C. de La Taille, N. Seguin-Moreau, L. Serin

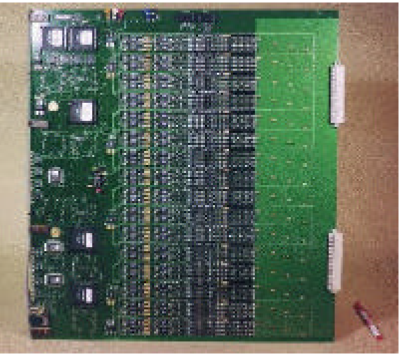
LAL Orsay

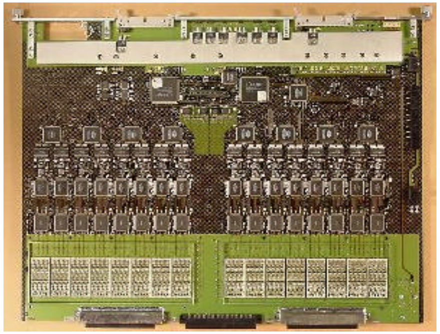
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

ATLAS Lar em calorimeter readout overview

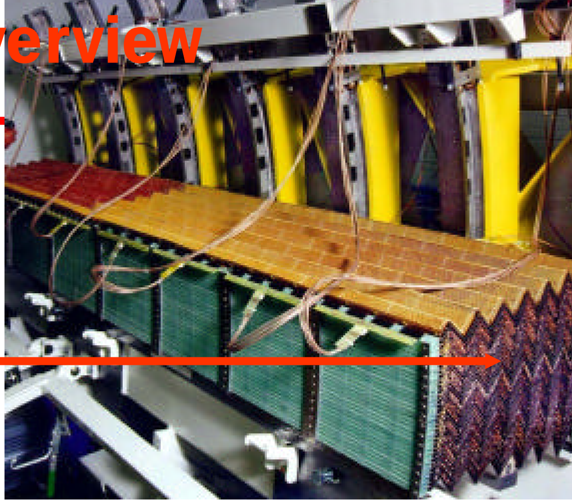
Calibration :
116 boards @ 128 ch

Front End Board (FEB) :
1524 boards @ 128 ch





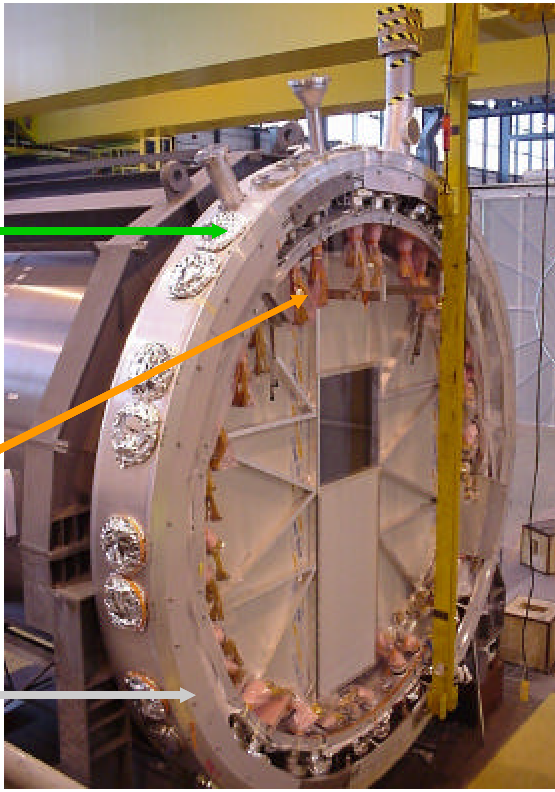
Electrodes



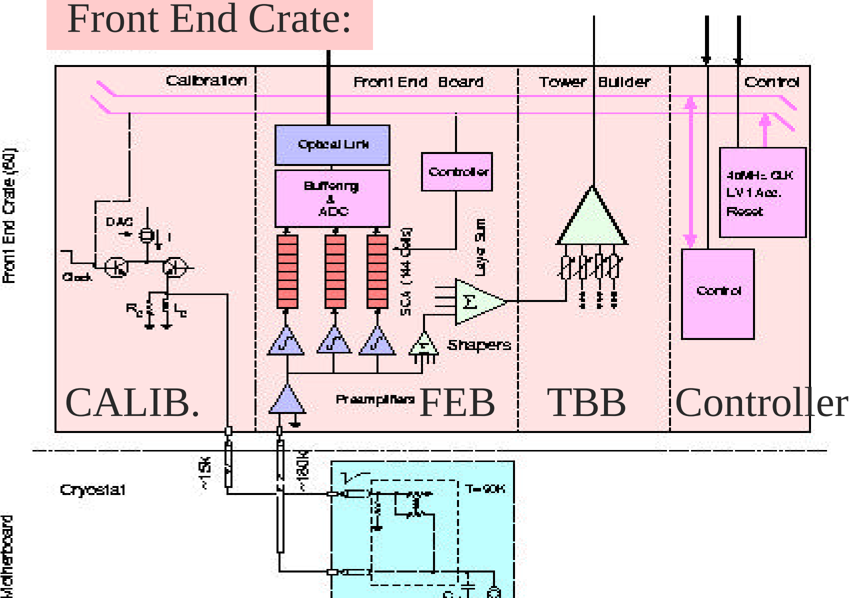
Cold to warm Feedthrough

Readout and Calib. signals

Cryostat

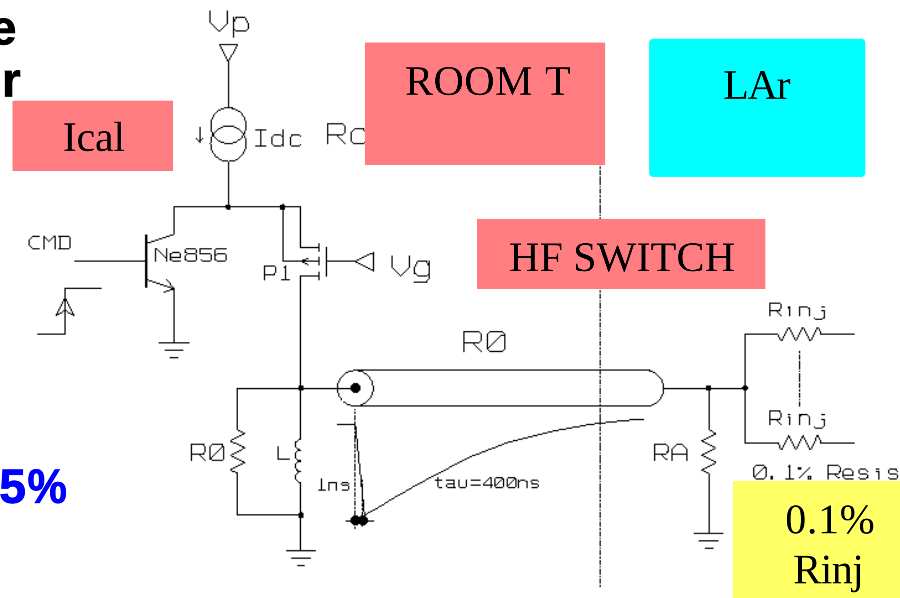


Front End Crate:

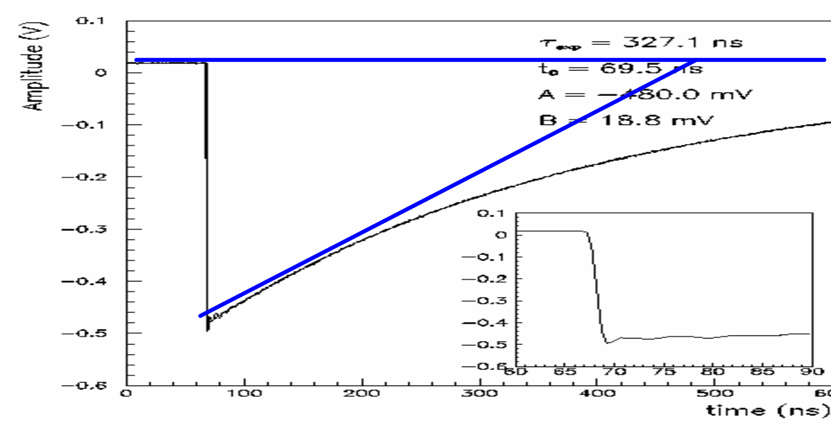


CALIBRATION: Requirements and Principle

- **Goal: Inject a precise current pulse as close as possible as the detector pulse**
  - Injection with precision resistors
  - Rise time < 1ns, Decay time ~ 450 ns .
- **Dynamic range : 16 bits**
  - Output pulse : 100 µV to 5V in 50O
  - Integral non linearity < 0.1% .
- **Uniformity between channels < 0.25%**
  - To keep calorimeter constant term below 0.7%)
- **Timing between physics and calibration pulse ±1ns**
- **Operation in around 100 Gauss field**
- **Radiation hardness:**
  - 50 Gy, 1.6 10^{12} Neutrons/cm^2 in 10 years
  - Qualification at 500 Gy, 1.6 10^{13} Neutrons/cm^2 to include safety factors
- **Run at a few kHz**

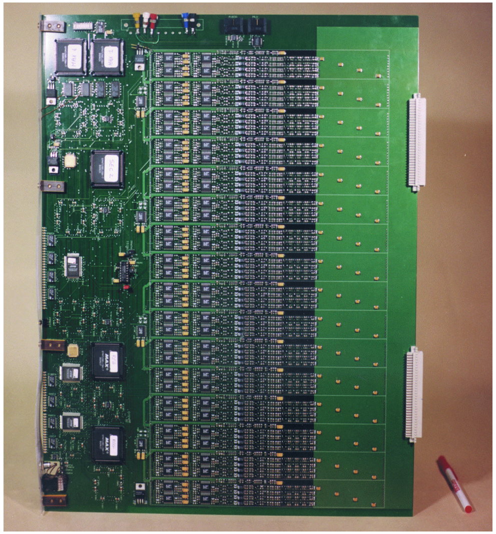


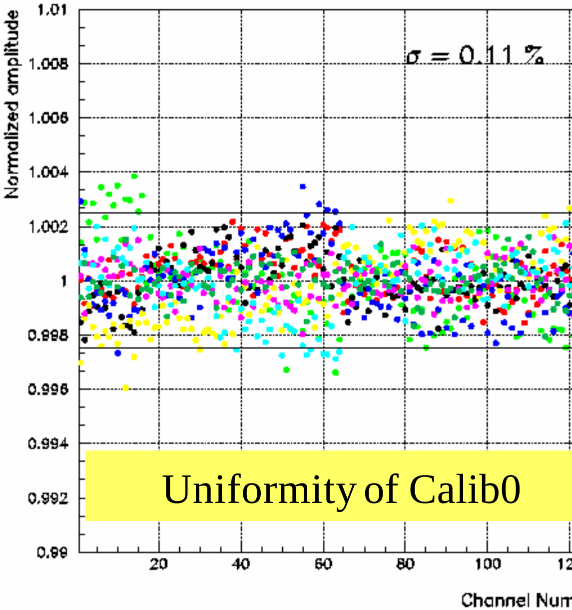
$$Ical = Idc \frac{R0/2}{Rinj} e^{-2R0t/L}$$



HISTORY

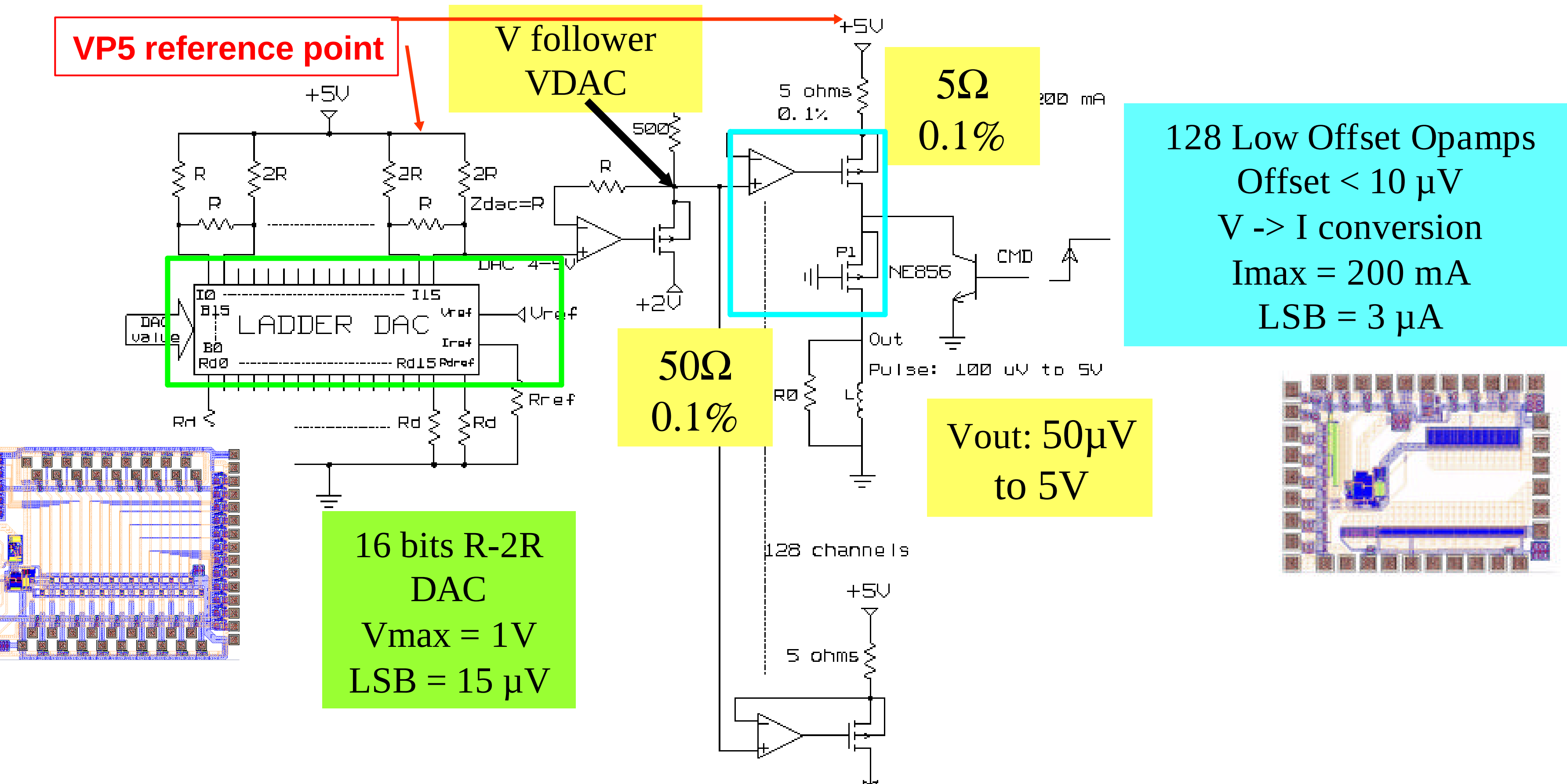
- **12 boards produced in 1998 with COTS for module 0**
  - 5 years successful operation in beam tests.
  - Excellent uniformity : 0.11% rms on 1300 channels
  - But radiation soft : COTS failed at 20 Gy
- **Active elements designed in DMILL in 1999-2001**
  - DAC, Pulser, Control logic, delay chip
  - Radiation qualified at 5 kGy
  - Improved performance (DAC stability, parasitic signal at DAC=0, DAC stability and offset)
  - Simplified logic, 10 Alteras replaced by 6 identical ASICs (DMILL Calogic)
  - All ASICs produced in 2003, currently under test
- **3 radiation hard boards produced in 2002-2003**
  - Final design review in 2002
  - Production readiness review passed in march 2004
  - Production of 140 boards in 2004-2005



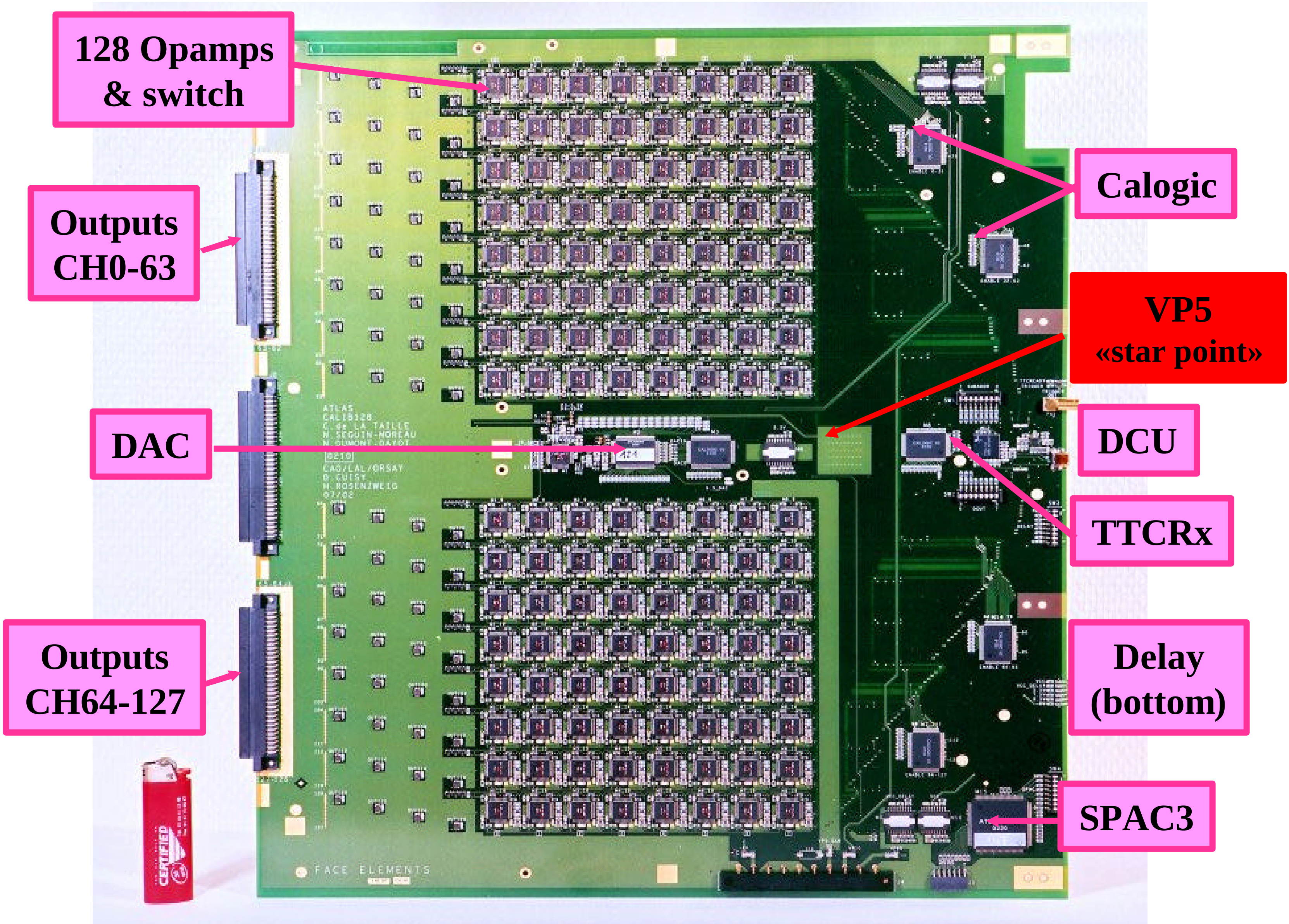


CALIBRATION BOARD : ANALOG PART

- A **16 bit DAC** voltage is distributed to the 128 channels.
- One **low offset op.amp**. per channel generates the calibration current I_{CAL} through a 5O [0.1%] external precision resistor.
- The **pulse** is made by interrupting I_{CAL} with a high frequency switch

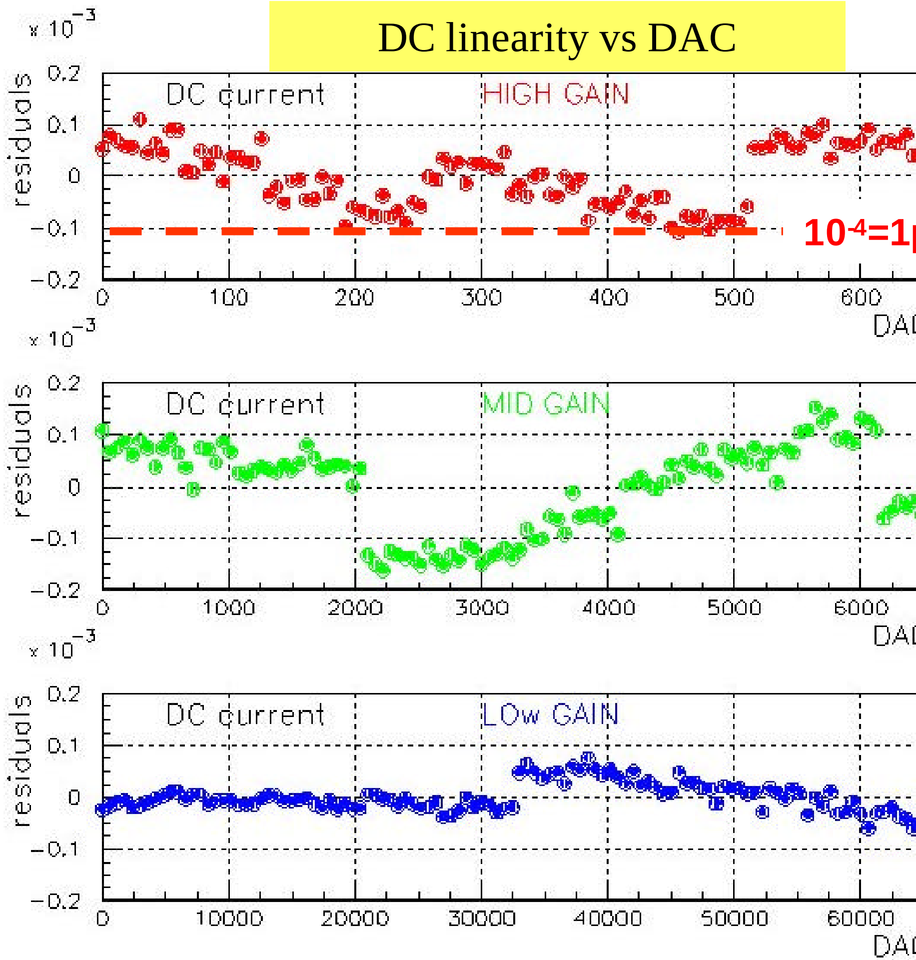


Final calibration board layout



DC linearity

- **DC output current : I_{CAL}**
- **Linearity on the 3 shaper ranges**
  - High gain HG = G100 :
    DAC = 0 – 655   (0-10 mV)
  - Medium gain MG = G10 :
    DAC = 0 – 6535   (0-100 mV)
  - Low gain : LG = G1 :
    DAC = 0 – 65535   (0-1 V)
- **Linearity < 100 ppm (0.01%)**
  - HG : < ± 1 µV (0.07 LSB) rms 58ppm
  - MG < ± 10 µV (0.7 LSB) rms 85 ppm
  - LG < ± 50 µV (3 LSB) rms 28 ppm
  - Dominated by DAC linearity



IDC/DAC	P0	P1	RMS
High Gain	2.5 µA	3.0080 µA/DAC	58 ppm
Mid Gain	7.1 µA	3.0056 µA/DAC	85 ppm
Low Gain	6.7 µA	3.0056 µA/DAC	28 ppm

DC uniformity

DAC=0 : offset dominated

- AVG = 4.5µA = 1.5 LSB
- RMS = 2.2 µA = 0.7 LSB

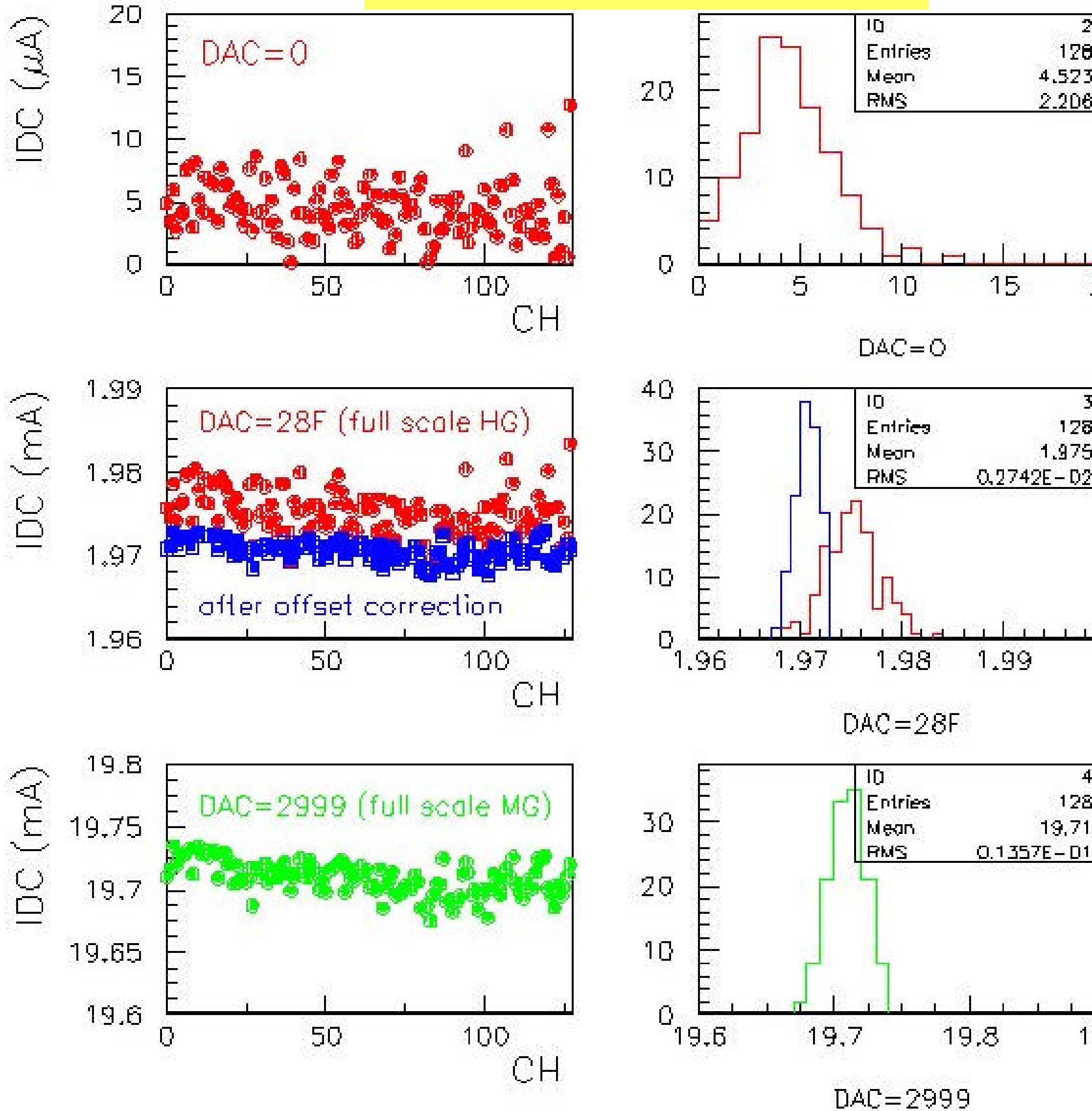
DAC=655 (full scale HG)

- Without offset correction
  - AVG = 1975 µA
  - RMS = 2.7 µA = 0.9 LSB
- With offset correction
  - AVG = 1971 µA
  - RMS = 1.21 µA = 0.06 %

DAC = 6553 (full scale MG)

- AVG = 19.71 mA
- RMS = 13.6 µA = 0.06%
- Dominated by dispersion on 5O 0.1% resistor

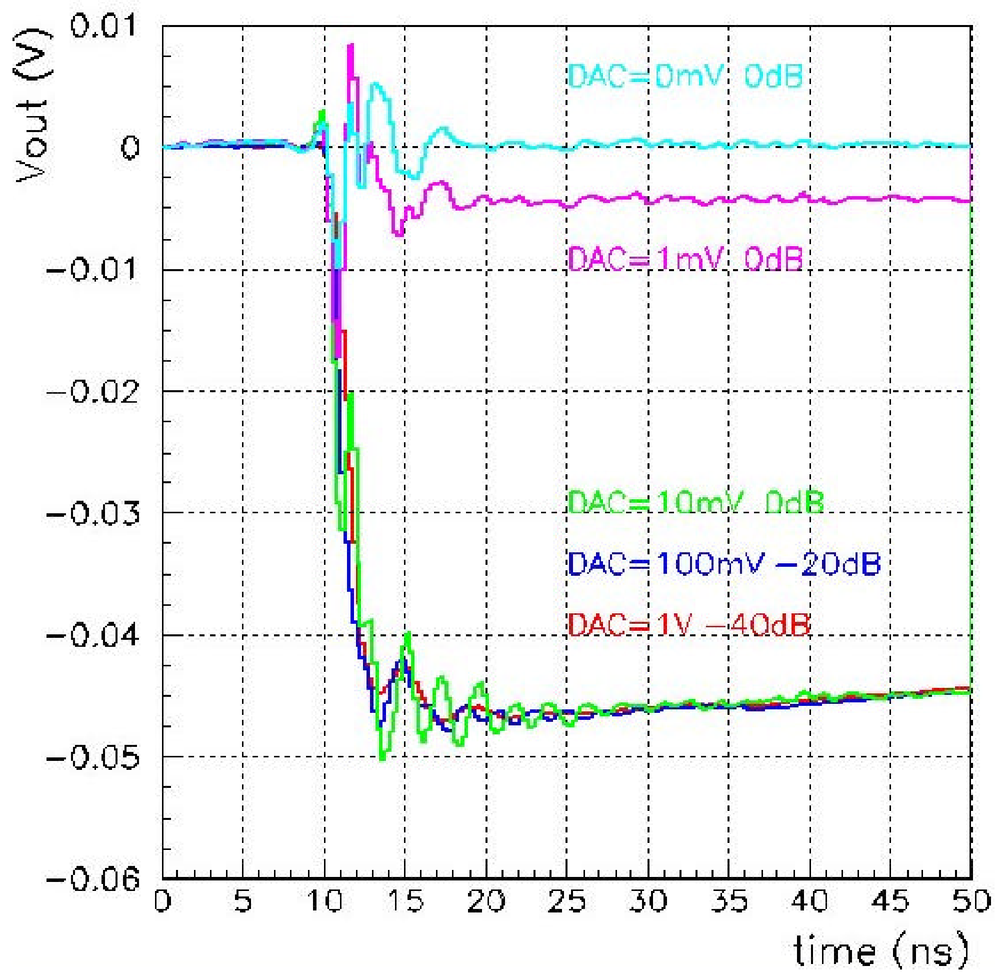
DC uniformity 128ch



Pulse shape before shaping

- **Full DAC range**
  - 100 µV → 1V
  - Up to 5V pulses in 50Ω
- **Rise time < 2 ns**
  - Small increase at large DAC
- **Decay time ~ 450 ns**
  - Matched to Argon drift time
  - Accuracy : ± 2%
- **HF Ringings :**
  - At small DAC values, due to parasitic package inductance in HF switch
  - « Parasitic injected charge »
  - 20 mV pk-pk
  - Very small area

Pulse output without shaping



Pulse shape after shaping

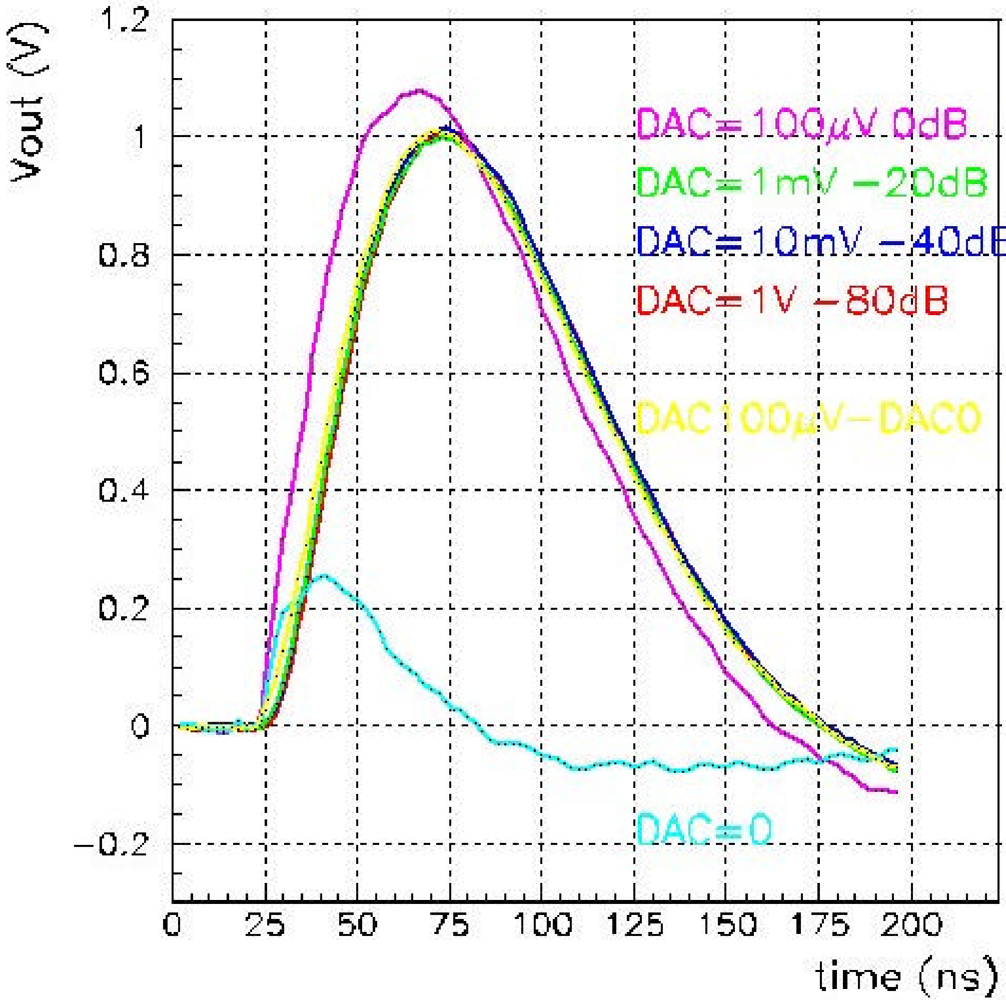
Parasitic injected charge (PIC)

- Peak of Qinj : equivalent to DAC=30 µV (2LSB)
- At signal peak :
  PIC < DAC = 15 µV = 1 LSB
  (~30 MeV in Barrel Middle < noise)
- Improvement by >10 compared to module 0

CMD feedthrough

- Parasitic pulse on disabled channels
- Equivalent to DAC=3 µV =0.2 LSB : ~negligible

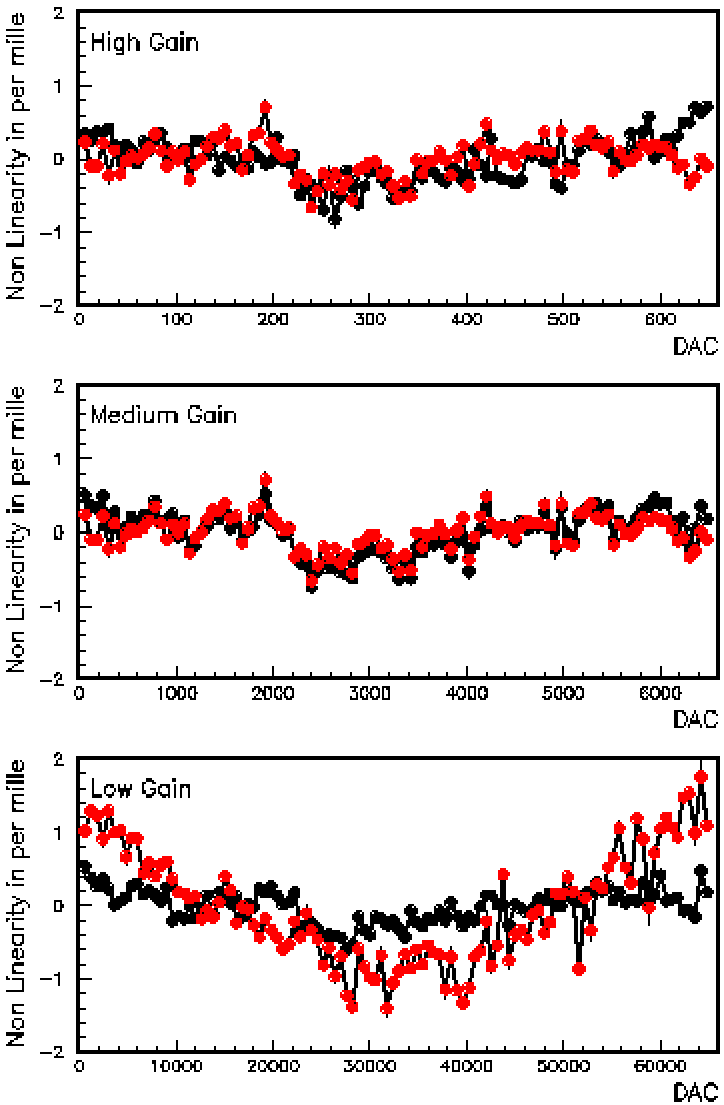
Pulse output after 50 ns shaping

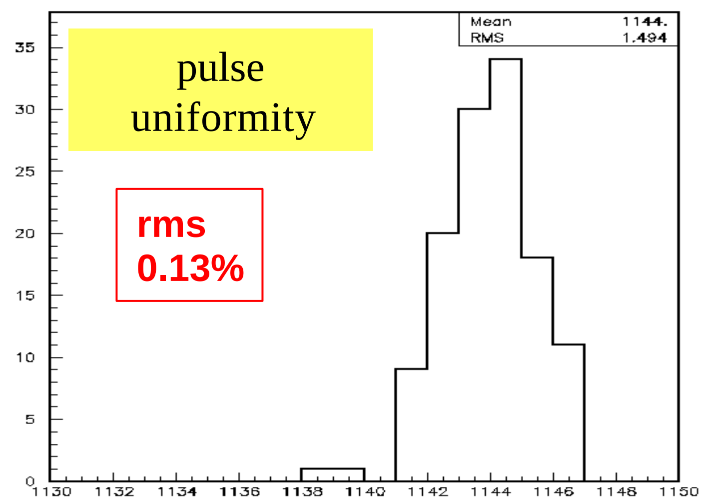


pulse uniformity and linearity

- **Linearity : < 0.1%**
  - Red : at signal peak
  - Black : peak of signal
  - Dominated by readout non-linearity
- **Uniformity at DAC=5000**
  - Rms : 0.13% (DC was 0.07%)
  - Additionnal contribution from output resistors, output lines, inductors and scanner board

pulse linearity vs DAC

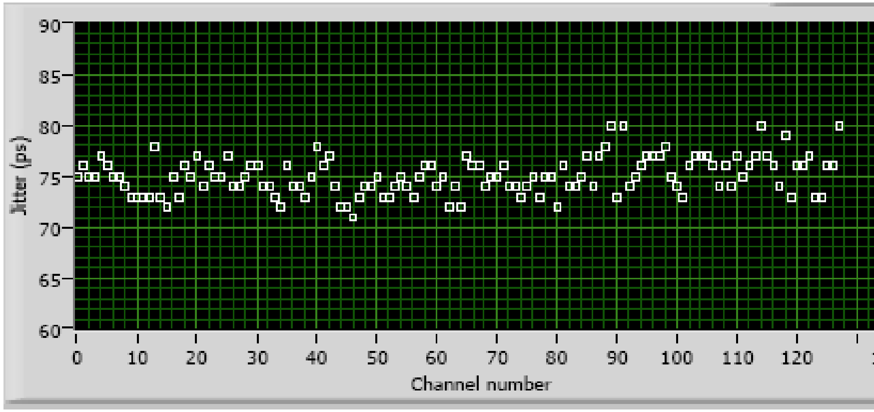




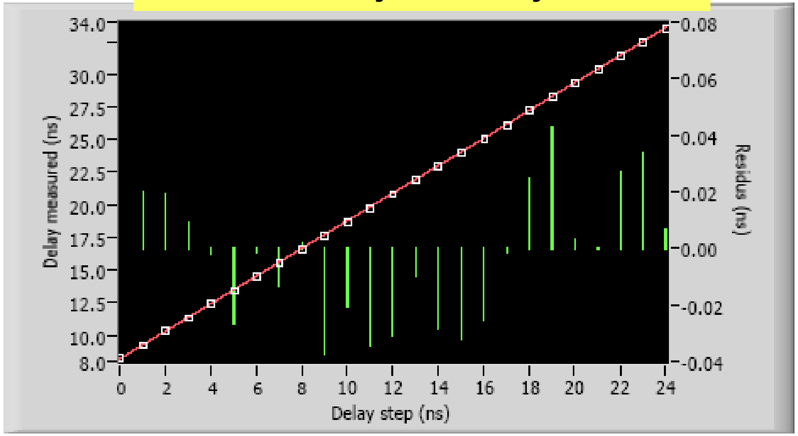
Timing performance

- **Jitter of output pulse < 75 ps**
  - Diminated by TTCRx chip
- **Delay chip (PHOS4)**
  - Used to adjust timing between calibration pulses and particles with 25 steps of ~1 ns
  - Linearity : residuals within 50ps
  - Slope : varies with channel inside chip (by up to ± 10%)

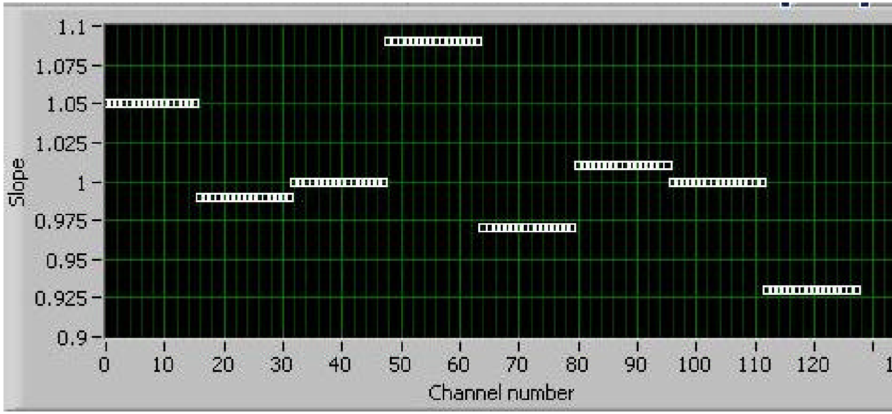
Output pulse jitter vs channel#



Delay linearity

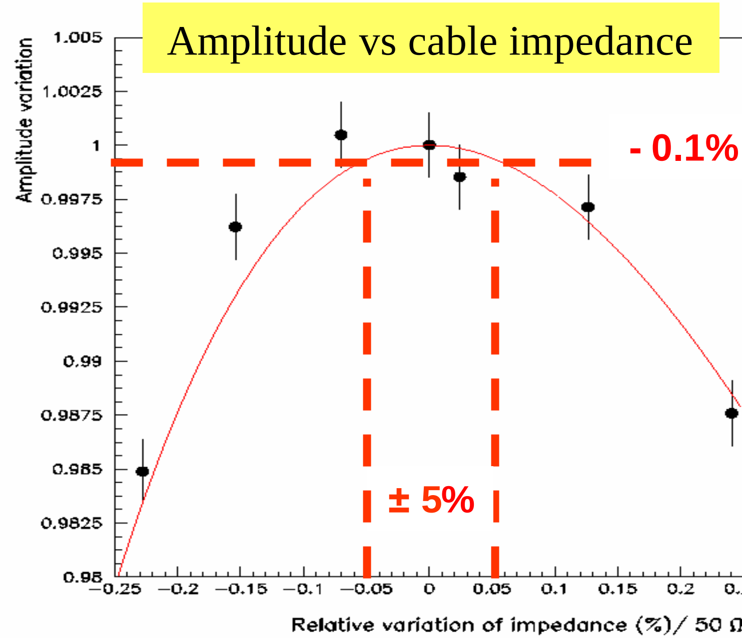


Delay step vs channel#

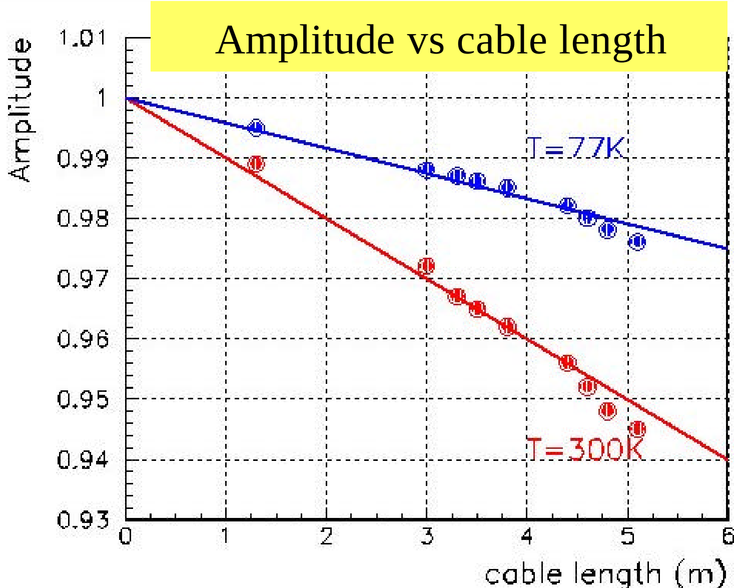


Calibration sensitivity to cables

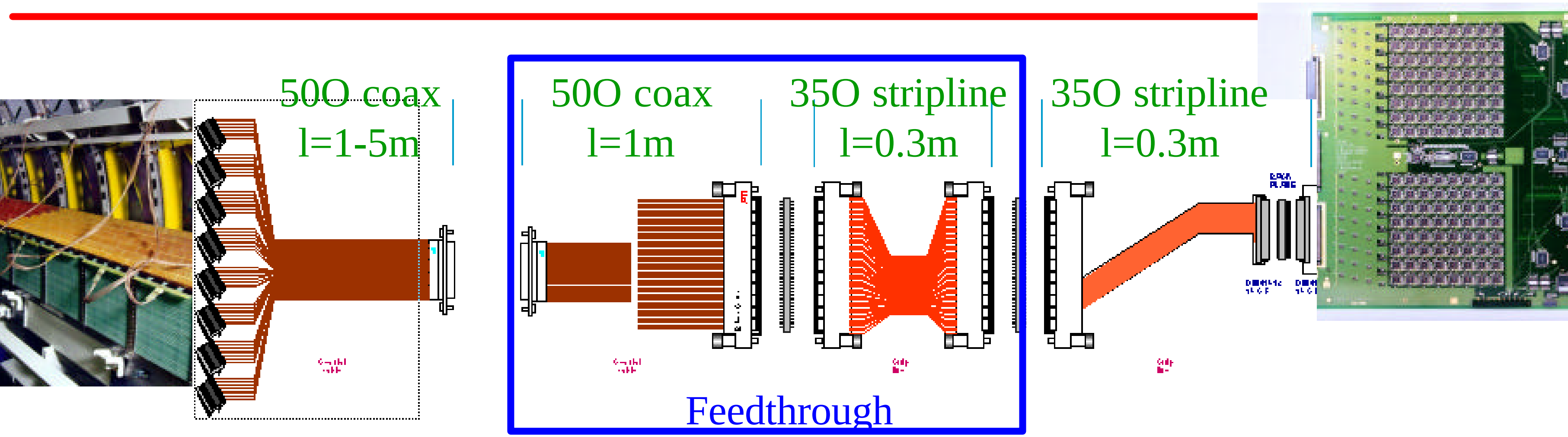
- **Sensitivity to cable characteristic impedance Zc**
  - Second order effect (if terminated both ends) : $dV/V = 1 - (dZc/2Zc)^2$
  - ± 2.5O tolerance on cable gives ± 0.1%



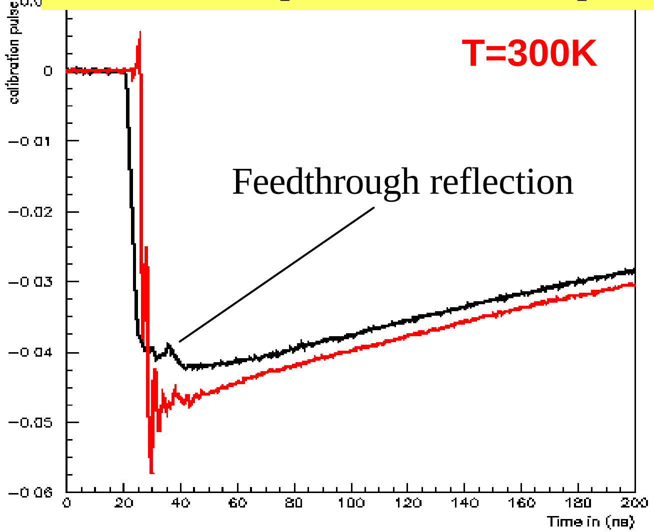
- **Sensitivity to skin effect**
  - First order effect :
    - - 1.2 %/m @ 300 K,
    - - 0.5 %/m @ 77 K
  - Correction necessary for cable length
  - Calibration cable length : 3-6 m : expect ~ 0.2% contribution at cold (~0.4% at warm)



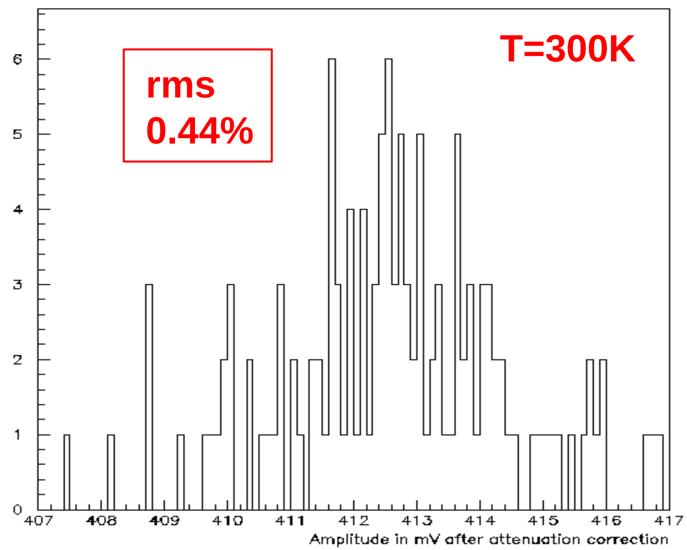
Calibration at cable output



Calibration pulse at cable output

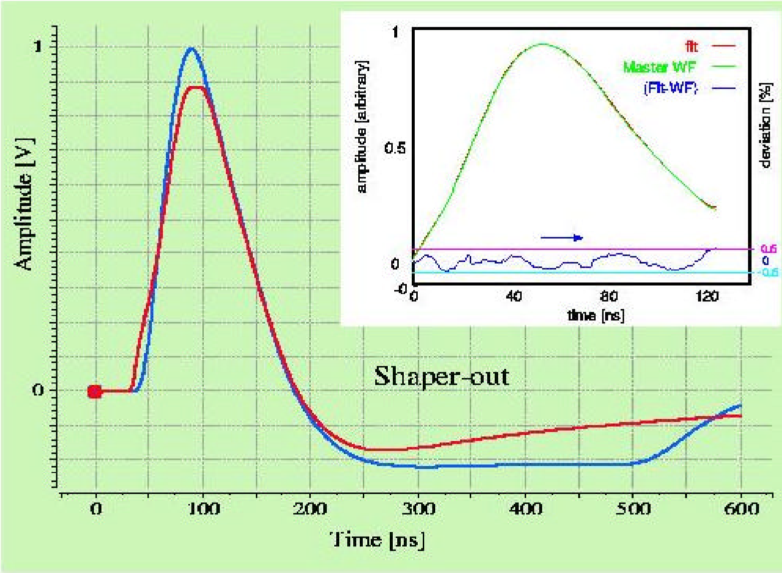


pulse uniformity at cable output

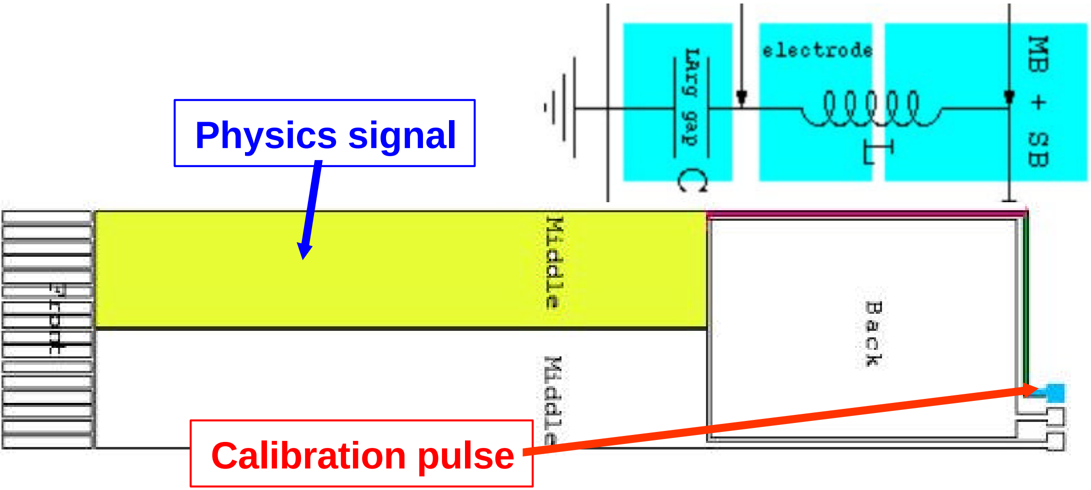


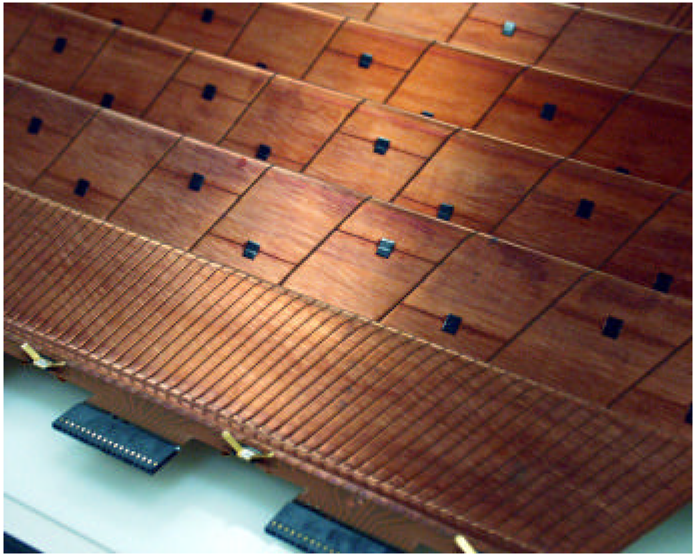
Difference between calibration and physics

- **Calibration pulse shape**
  - Exponential shape vs triangle
  - Systematic effect in t_{SHAPER}/t_{CAL}
  - Accuracy in calib decay time t_{CAL}: ± 2%



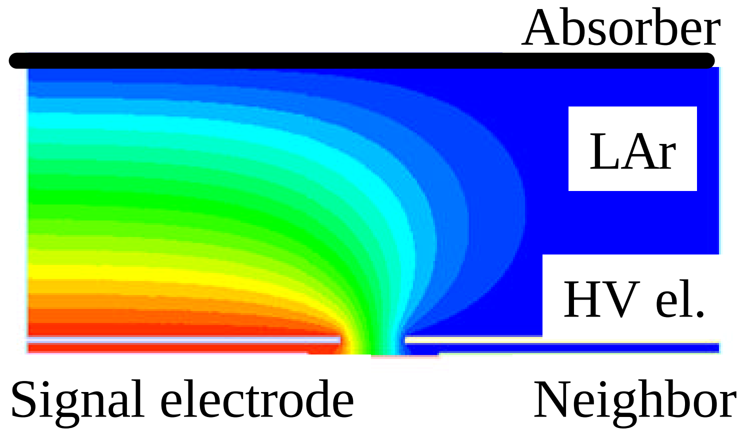
- **Detector inductance**
  - Physics signal at shower max in the middle of the accordion : non negligible output line : inductive effect
  - Sizeable effect : - 0.2%/nH on physics/calibration ratio
  - Inductance measurement necessary

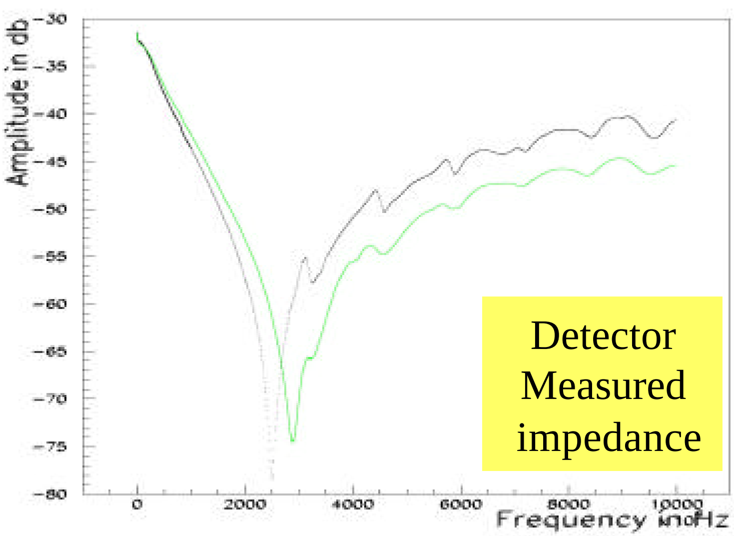


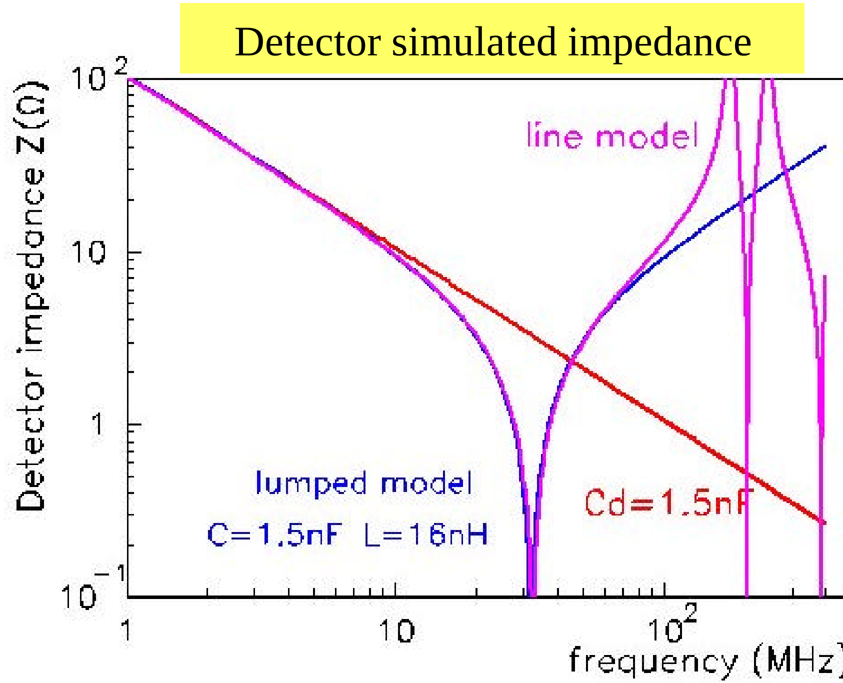


ATLAS Lar : detector modelization

- **Line model**
  - “stripline” Absorber-LAr-HV-Kapton-Signal. Propagation t_d = 4.12 ns/m
  - Solving Poisson to calculate capacitances Cd, Cx and impedance : Zc = t_d/Ct
- **Good lumped model**
  - Detector (Zc = 1.5-2O) = capacitance (1 - 1.5nF)
  - Connection (Zc = 15-20O) = inductance (20-30 nH)
  - (Difficult) measurement of f_0 = 1/2pvLC

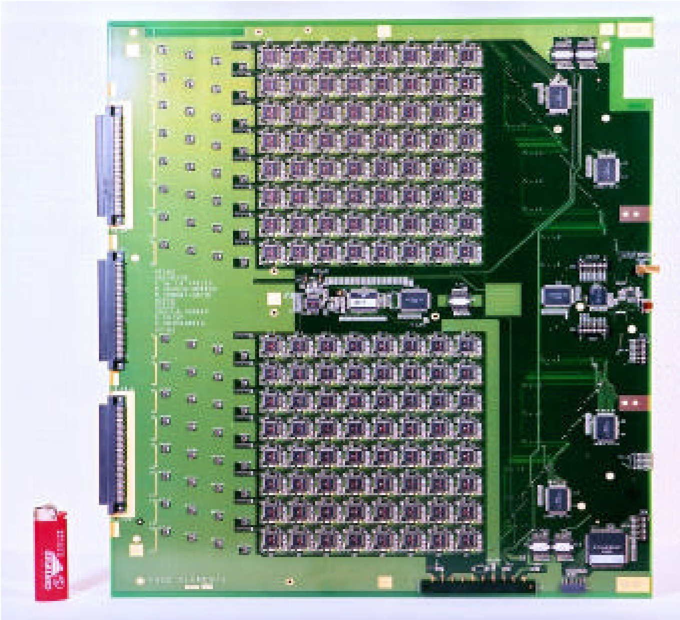






Conclusion

- **Calibration board for ATLAS Lar calorimeter final**
  - 16 bits dynamic range : 100 µV – 5 V pulses
  - Linearity better than 100 ppm
  - Board uniformity < 0.2%
  - Overall uniformity < 0.3%
  - Jitter < 100 ps
  - Radiation hard



- **Production of 140 boards in 2004**
  - DMILL ASICS all produced
  - Final prototype validated
  - Installation beginning of 2005
- **Calibration of calorimeter needs additionnal inputs**
  - Fine effects due to detector parasitic inductance need to be corrected for
  - A major activity in 2002-2003
  - See talks by L. Serin and O. Gaumer