
CALICE ECAL Readout Status

Paul Dauncey

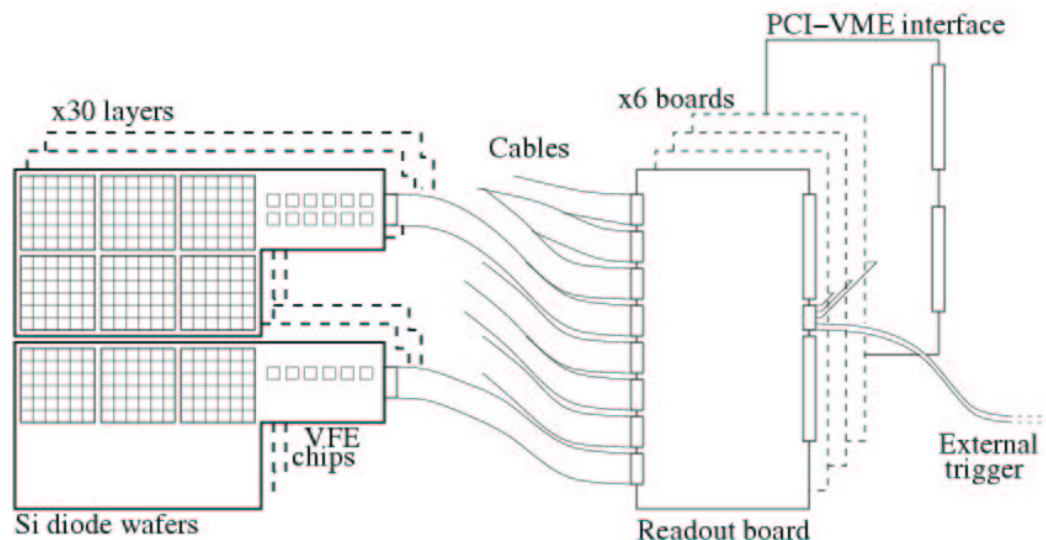
For the CALICE-UK electronics group:

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Readout electronics overview

CALICE ECAL has 30 layers, 18×18 channels/layer, **9720** total

- Each gives analogue signal, 14-bit dynamic range required
- Very-front-end (**VFE**) ASIC (FLC_PHY from LAL-Orsay) multiplexes 18 channels to one output line
- VFE-PCB handles up to 12 VFEs (216 channels)
- Cables from VFE-PCBs go directly to **UK** VME readout boards, called Calice Ecal Readout Cards (**CERCs**)

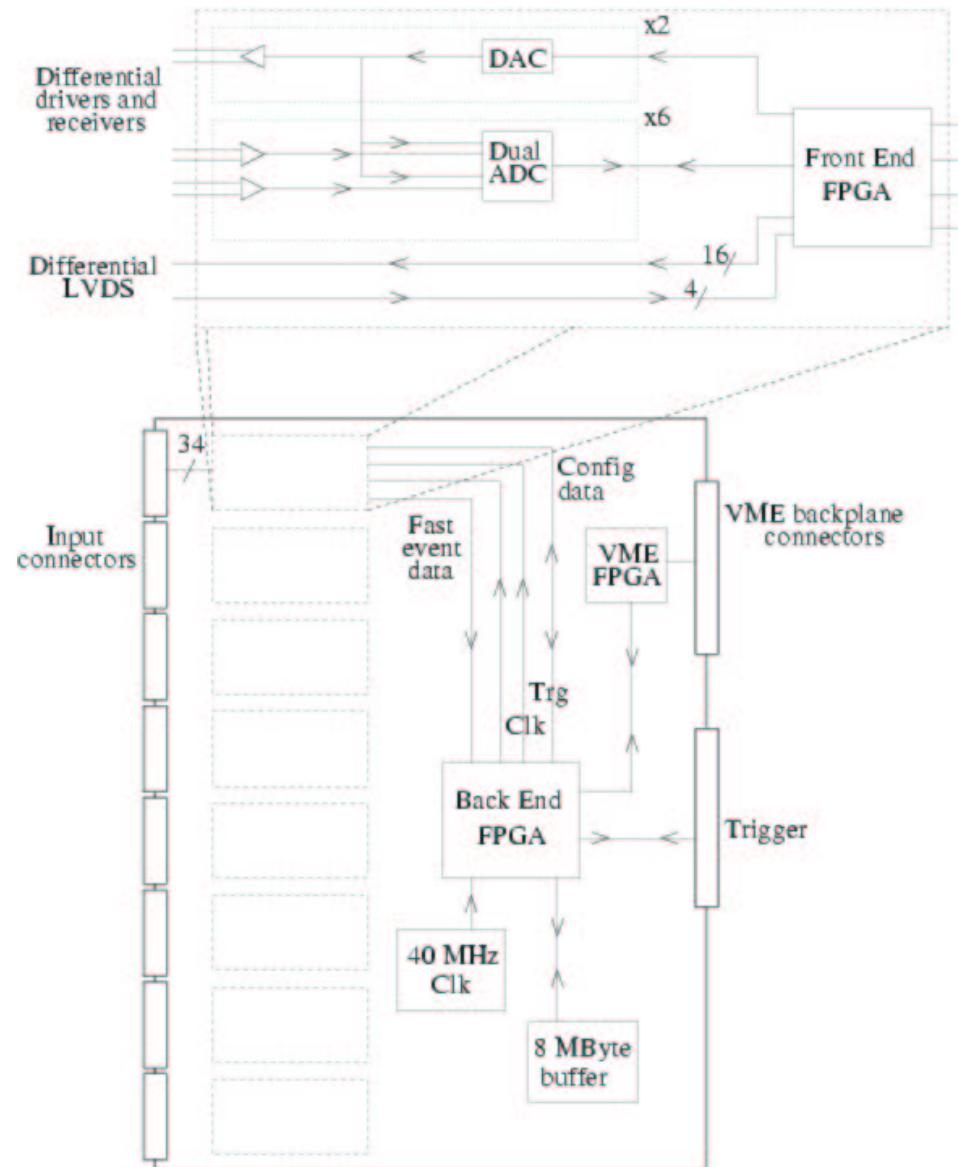


CERC features

- Based on CMS silicon tracker readout (**FED**) board
 - Reuse some firmware from this board
- Dual 16-bit **ADCs** and 16-bit **DAC**
 - DAC able to be fed back for internal as well as front end calibration
 - ADC 500kHz; takes **~80 μ s** to read and digitise event data from VFE-PCB
- No data reduction in readout board
 - ECAL event size: 5 kBytes per board, **30 kBytes** total per event
- On-board buffer memory; **8 MBytes**
 - No buffering available in ECAL front end; receive data for every trigger
 - Memory allows up to **~1.6k** event buffer on readout board during beam spill
- Large **jumper array** behind input connectors
 - Can select **different signal I/O** to and from connectors
 - Reroute signals to ADCs; one full or two half-full VFE-PCBs for each input
 - Bypass ADCs; purely digital I/O

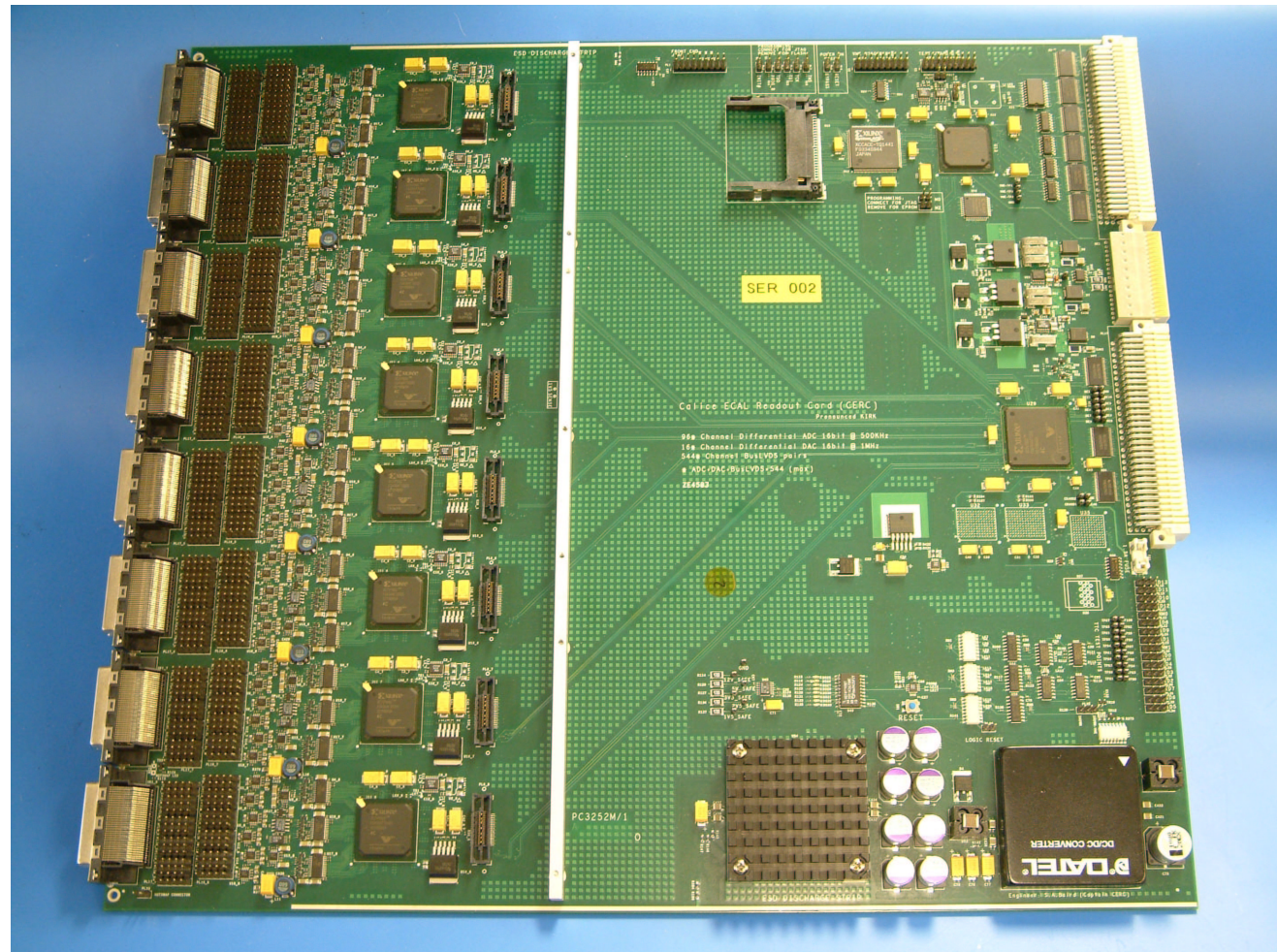
CERC overview

- Eight Front End (**FE**) FPGAs control all signals to front end electronics via front panel input connectors
- Back End (**BE**) FPGA gathers and buffers all event data from FE and provides interface to VME
- **Trigger** logic in BE for timing and backplane distribution; only active in one board
- Each input is one full or two half-full VFE-PCBs; need 45 inputs = **6 CERCs**



CERC status

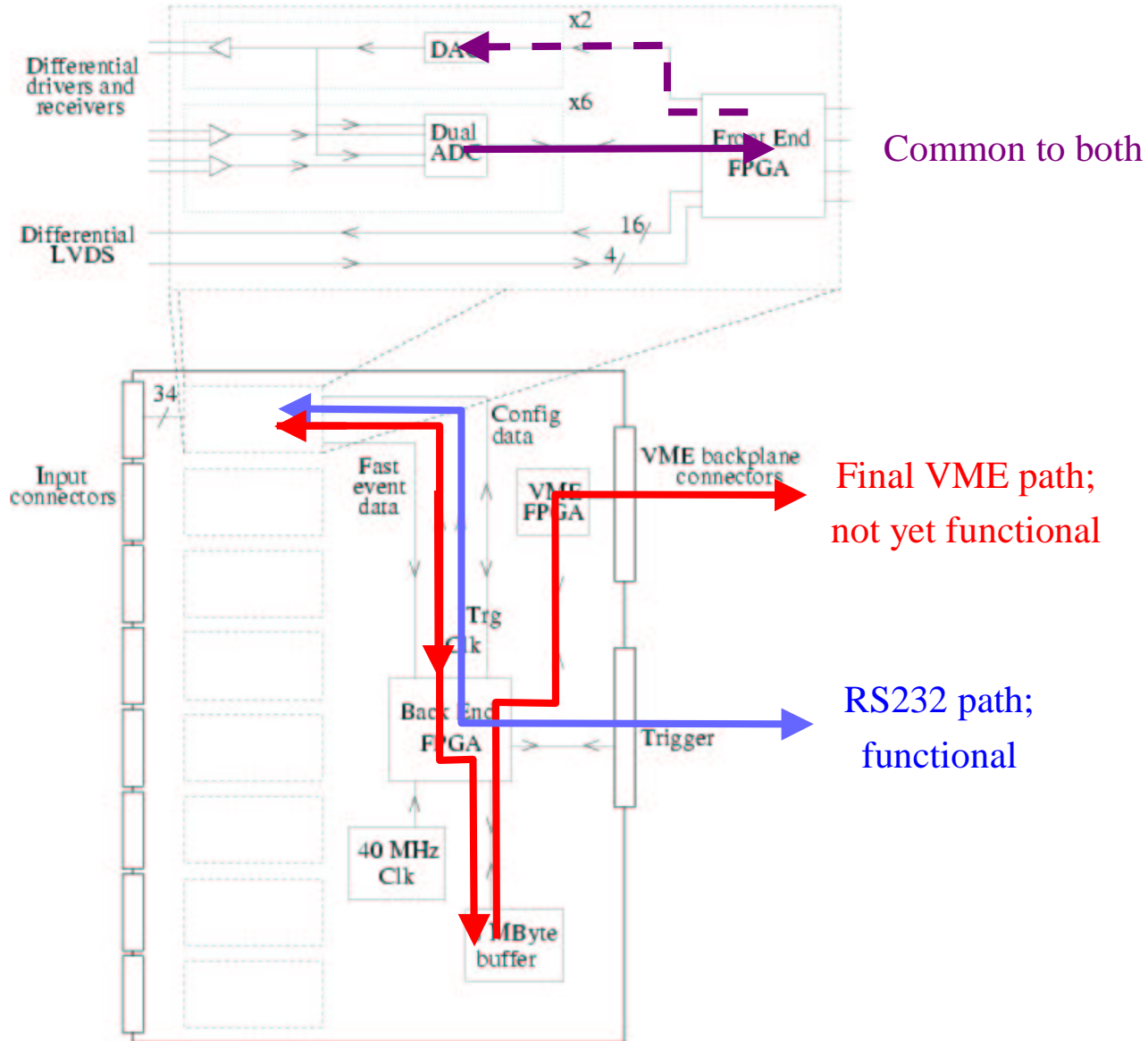
- Prototype design **completed** last summer
- Two prototype boards fabricated in **November**
- Currently under tests with a prototype **VFE-PCB** in Ecole Polytechnique
- Further tests with final version of VFE-PCB in **May**
- CERC final production in **July**



Test setup

- **Final path** for data has several complex steps
 - FE digitises ADC data for each trigger and stores in FIFO in FE
 - Automatically transferred to 8MByte memory
 - Memory read from VME when bandwidth available
- Needs data transfer, memory control and VME interface
 - BE FPGA firmware **not yet functional**
 - 8MByte memory components delayed in delivery; not yet mounted
 - Aiming for **end of June** for all this to be working
- Backup for current tests
 - Implement simple **RS232** interface from PC to BE and hence to FEs
 - RS232 reads FE FIFO one word at a time directly to PC
 - 8MByte memories **bypassed**, must read each event before next trigger
 - Rate is slow; **~1Hz** of events, but sufficient for cosmics **~0.1Hz**
- **Analogue parts** (ADC, DAC) operated as for final system
 - Noise, dynamic range, etc, measurements reliable

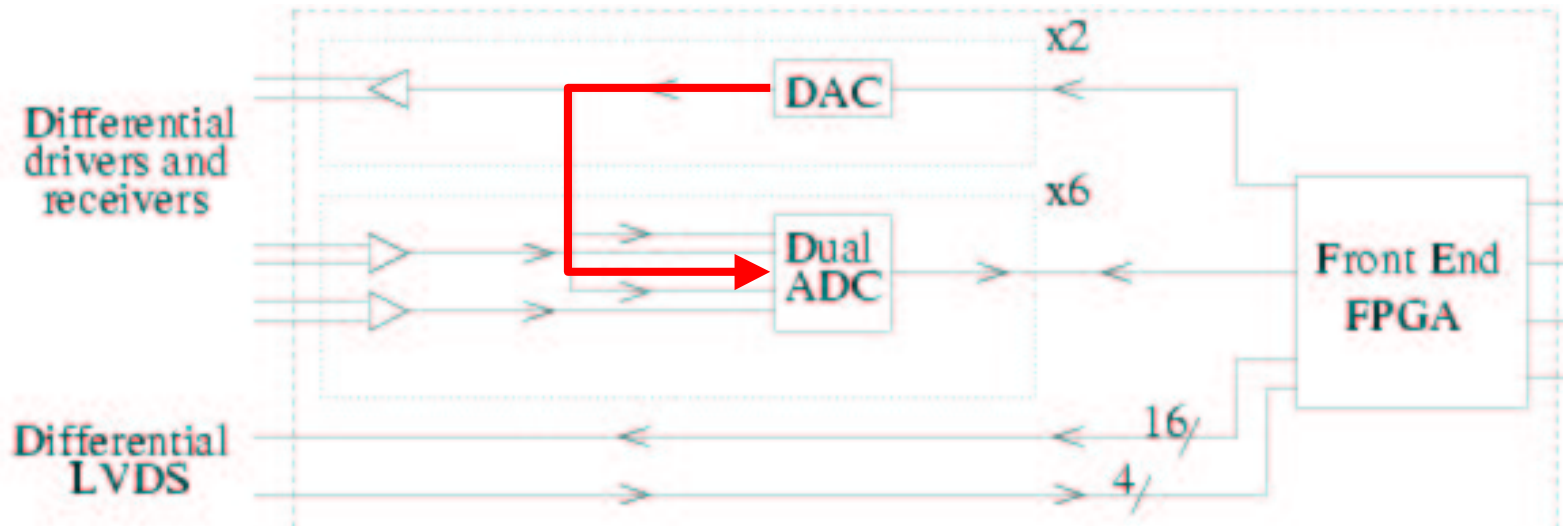
Test setup data paths



Firmware functional status

- RS232 path **working**
 - Read and write configuration data to RAMs in FEs
 - Read and write fake event to RAMs in FEs
 - Read back fake event via FIFO on trigger
- Trigger input **working**
 - Can fire trigger from BE with RS232 command
 - Can send trigger as LVDS signal on spare backplane pins to BE
 - Latter acts as **external cosmic trigger** path for VFE tests
- ADC readout and DAC control **working**
 - ADC can be read, DAC can be set
 - DAC can be looped back to ADC internally and through front panel
 - All VFE-PCB and ADC timing control **software configurable**
 - ADC data stored in FIFO and read through RS232

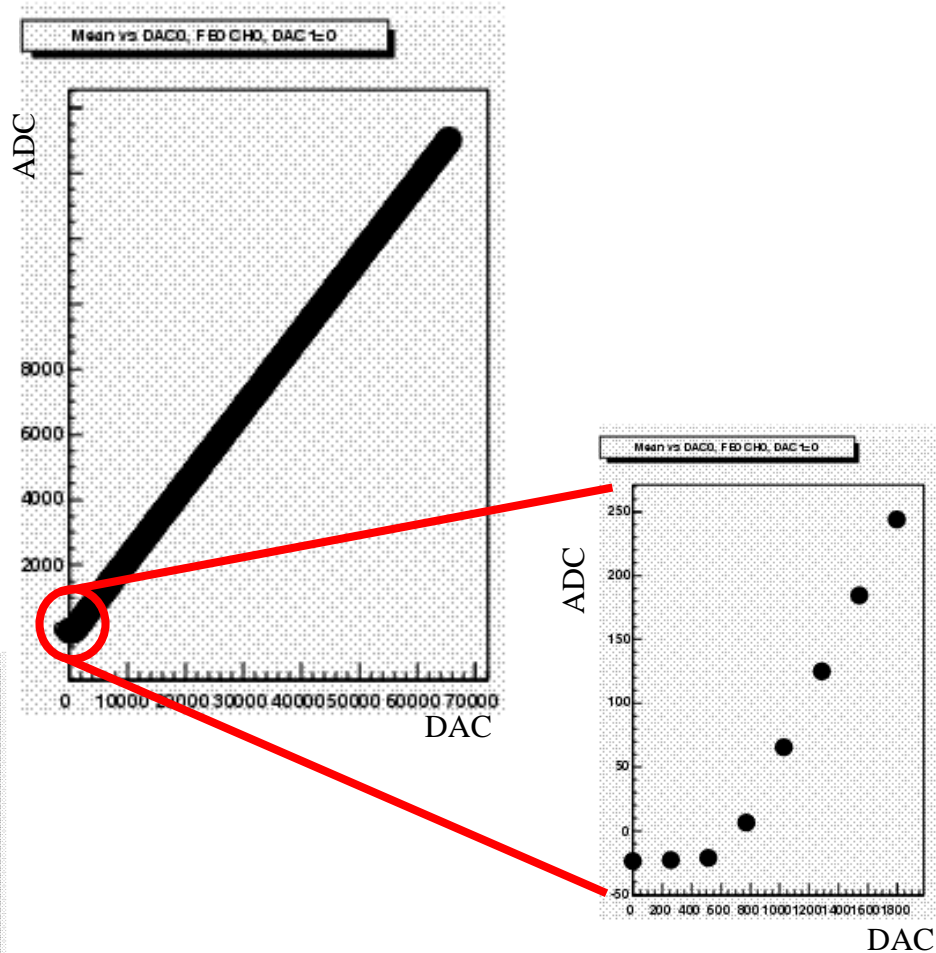
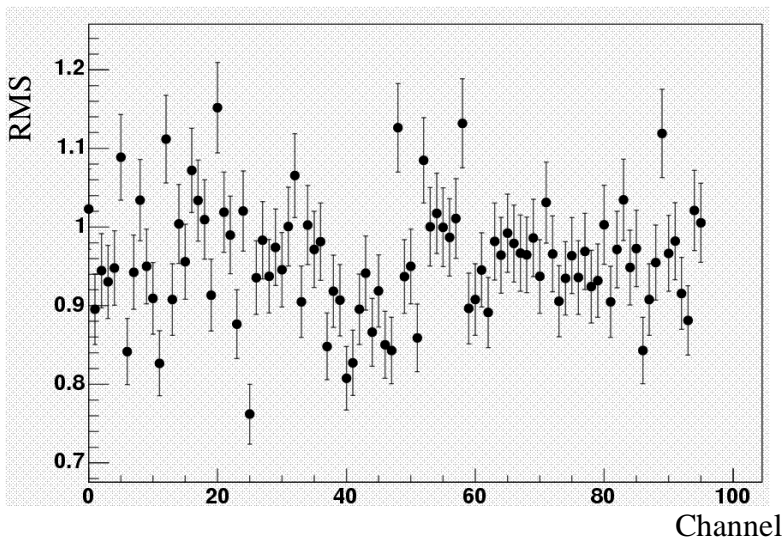
DAC internal loopback path



- ADC has **two inputs** per channel; selected in configuration
 - DAC feeds directly into one; “**internal**” loopback
- Differential analogue path only **~1cm** and entirely tracked on PCB
 - Expect **minimal noise**
- Scan DAC and check **linearity** of ADC response
 - **Intrinsic** CERC performance, not due to external electronics, etc.

DAC internal loopback tests

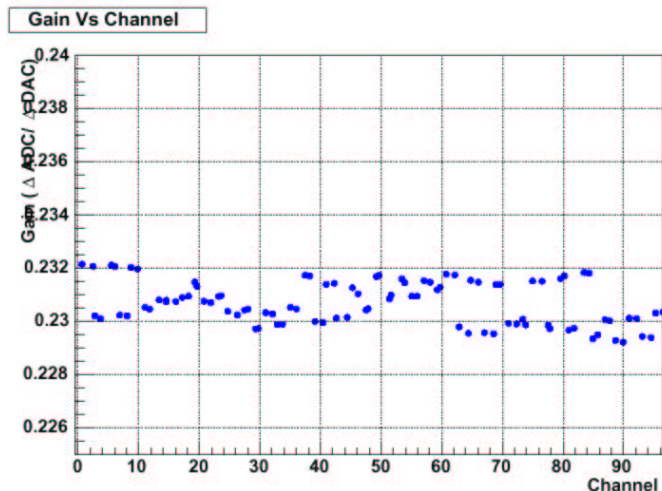
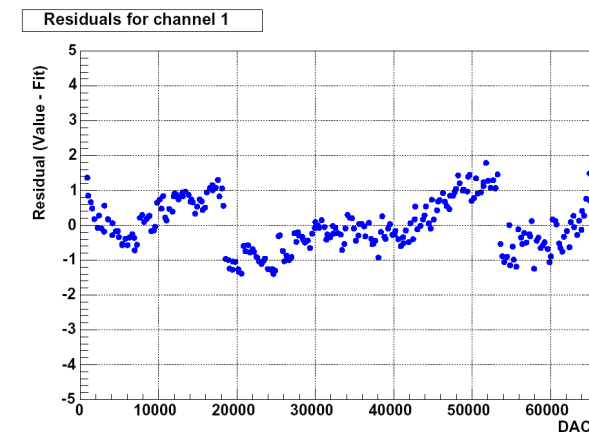
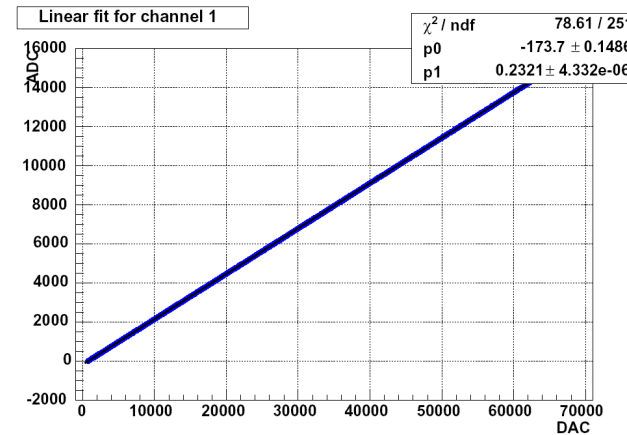
- Plot **ADC vs DAC** setting
 - **Good linearity** over most of the range
 - DAC saturation seen in lowest **1%** of range (**not** due to ADC!)
 - Mismatch of DAC range to ADC; only covers $\frac{1}{4}$ of ADC range (0 to $\sim 15k$ for ADC range of $\pm 32k$)



- Intrinsic noise around **1 ADC count** for all 96 channels

DAC internal loopback tests (cont)

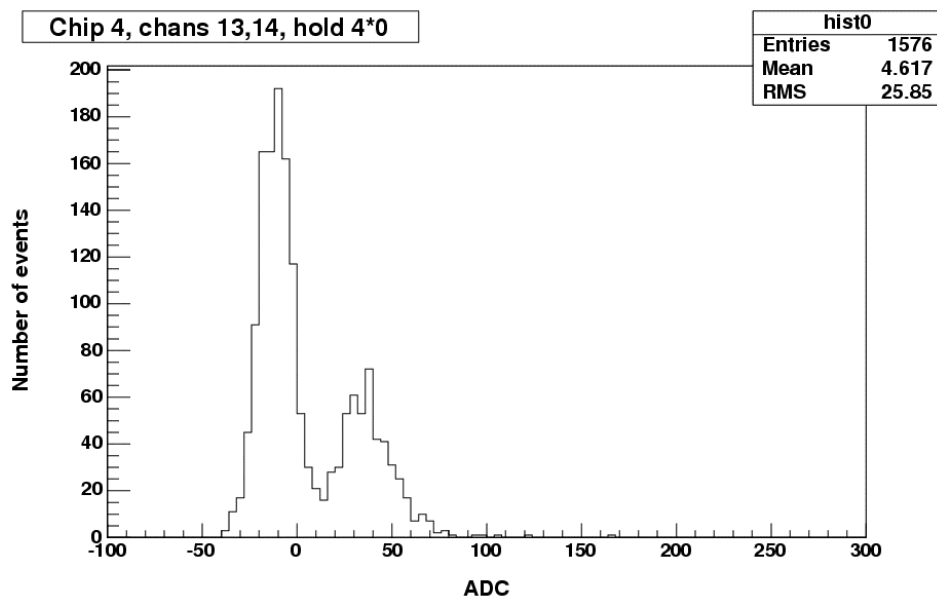
- **Fit** over range above non-linear region
 - Simple **straight line** fit; no higher terms included
- **Residuals** from fit show various structures
 - Example channels shown
 - Typically **under 2 ADC counts**



- Intrinsic board performance **very good**
 - **Linear to 0.01%** over ADC range testable
 - Gains **uniform to 1%** over this range

Strontium source tests

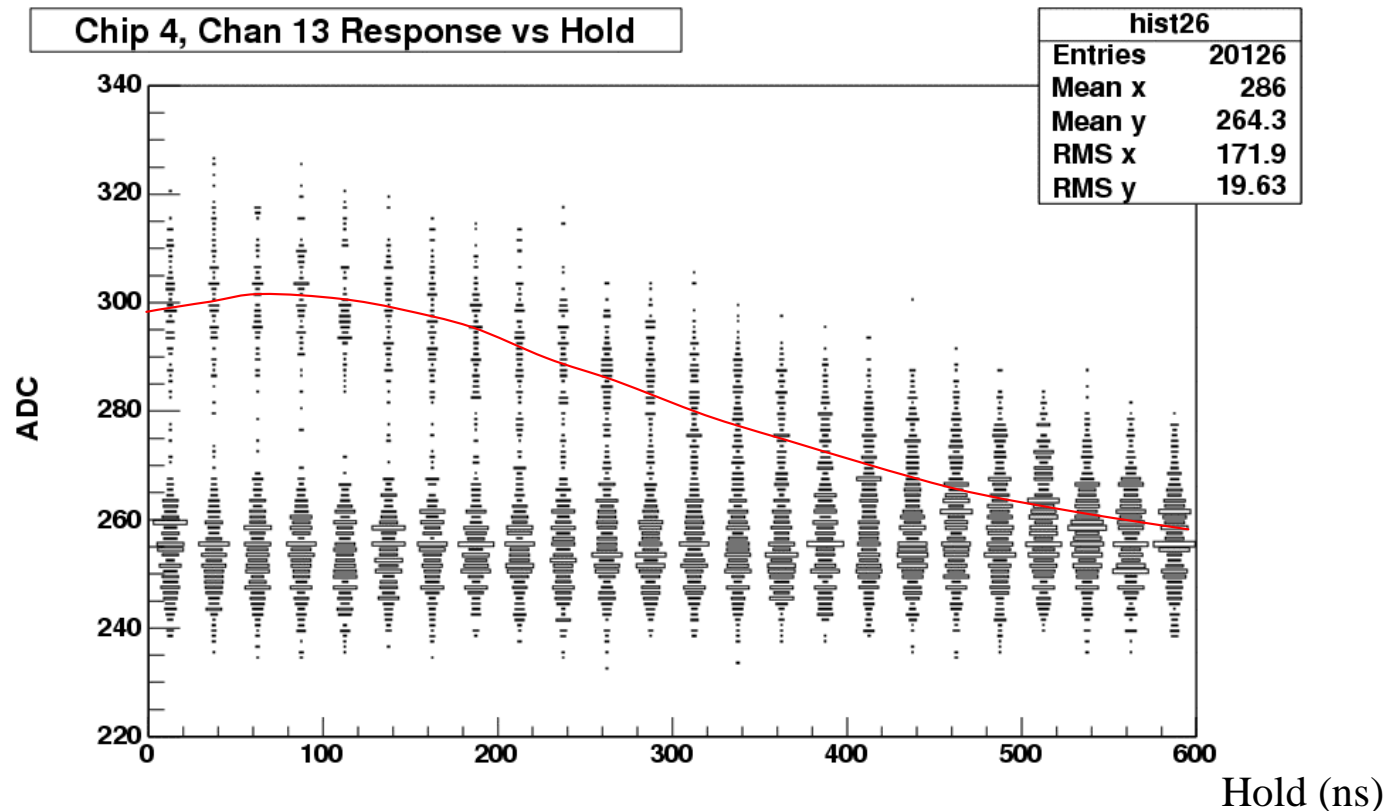
- Need to determine timing of **sample-and-hold signal** to VFE-PCB
 - Must hold signal at **shaping peak** to maximum signal and minimise noise
- Hold delay **configurable** in software on CERC
 - Counts of 160MHz clock; **6.25ns** steps
 - Some latency due to trigger logic, cables, etc; **~160ns**
 - Need to measure hold delay using physical signal
- **Strontium** beta source; high rate so can **scan** hold timing



- Example of strontium signal with **minimum** hold delay

Strontium source results

- FLC_PHY chip **CR-RC** shaper gives xe^{-x} shape, $x=t/\tau$
 - Peaking time $\tau \sim 210\text{ns}$
- Scan over sample-and-hold time relative to trigger to **find peak**
 - Close to **maximum** allowable latency; will try to shorten trigger logic path!

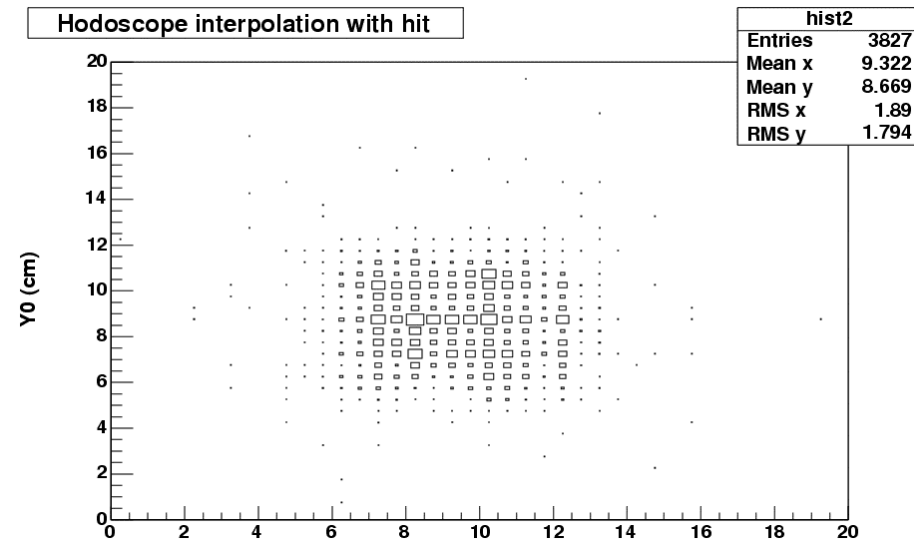
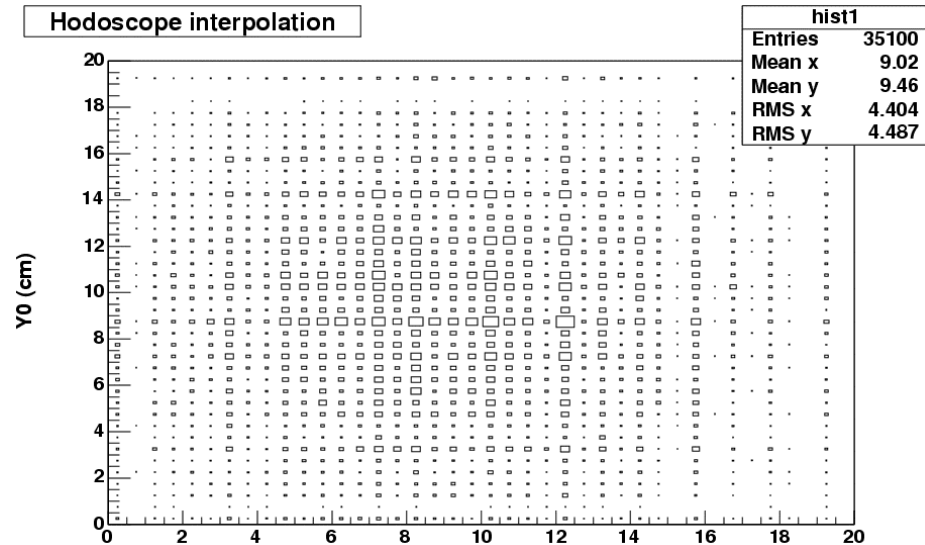


Cosmic tests

- Aim to provide **absolute calibration** using MIP peak
 - Check of full system dynamic range
- Ecole Polytechnique teststand has XY **hodoscope scintillator** array above and below VFE-PCB
 - No significant thickness of material between; cosmics of all energies
 - Covers **20×20 cm²** area, angles up to 10° from vertical
 - Provides rudimentary **tracking**; interpolation accurate to ~1cm in X,Y
 - Thanks to Jean-Charles Vanel for setting this up!
- Prototype VFE-PCB has only **one silicon wafer** mounted
 - **6×6 pad** array, each 1×1 cm² area
 - 36 channels, read by two FLC_PHY chips
 - Another two FLC_PHY chips mounted provide control comparison
- Active area is only **~10%** of total teststand
 - Each silicon pad only hit once every **~360 triggers**
 - Use hodoscope tracking to select events with cosmic close to wafer

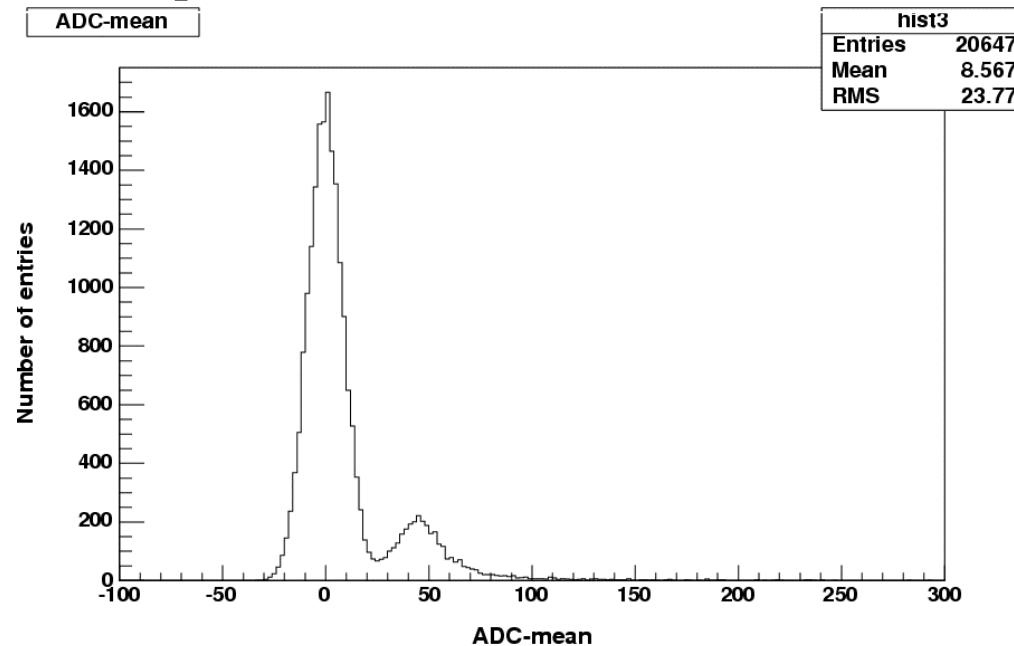
Cosmic test results

- Hodoscope track **interpolation** over whole 20×20 cm² area
 - Interpolation reasonably **smooth** over this area
- Select events with at least one silicon pad **>40 ADC counts** above pedestal
 - More than 4 sigma cut
- Clear **outline** of 6×6 cm² silicon wafer observed
 - Allows **survey** of position of wafer
 - Pad-by-pad readout order check also possible



Cosmic test results (cont)

- Select pads consistent with hodoscope track interpolation
 - Improves pad occupancy per event from $\sim 1/360$ to $\sim 1/6$
- Clear **cosmic MIP** peak seen, ~ 45 ADC counts above pedestal
 - MIP = 200 keV; calibrates ADC so 1 count = 4.4 keV
 - 32k **full range** ~ 700 MIPs; requirement > 600 MIPs \mathcal{J}
- **Noise** per channel ~ 9 ADC counts = 40 keV
 - **MIP:noise** $\sim 5:1$; requirement $> 4:1$ \mathcal{J}



Known CERC problems

- FPGAs do not always **load correctly** on CERC power-up
 - Thought to be due to power-up boot timing sequence
- **Mismatch** of DAC output op-amp differential range and ADC input op-amp differential range
 - DAC differential output only single polarity
 - Can only cover top half of ADC range
 - Incorrect resistor values used to set range; only half of the above range
- **Common mode** noise when coupled with VFE-PCB
 - Approximately half observed noise contribution
- Not yet clear if these can be fixed or require redesign
 - Risk in changing layout for production

BUT...

- Prototype board has already demonstrated it meets requirements for dynamic range, linearity and digital resolution

Use for CALICE HCAL readout

- CALICE also includes **analogue** and **digital HCAL** prototypes
 - AHCAL based on tile scintillator
 - **Less stringent requirements** (dynamic range, noise) than ECAL
- Potential to **use CERC** as readout board
 - AHCAL may also use ECAL FLC_PHY chip
 - Very similar readout so CERC directly usable in this case
- Large **jumper array** between input and FE FPGA
 - Firmware change allows large variety of I/O signals
 - Can **mix analogue and digital** as needed
 - Could even read out all-digital DHCAL
- Possibilities still **under study**
 - AHCAL would need ~6 more CERCs; still only one VME crate
 - DHCAL less clear, but could need ~20 CERCs; need two crates

Future plans

- VFE-PCB tests in Paris continuing in **May**
 - Essential test of final VFE-PCB before moving to full production
- Possible AHCAL test at DESY in **May/June**
 - Prototype of AHCAL front end electronics fabricated by this time
- Finalise CERC redesign by **end June**
 - Decide if modifying prototype or not
- Relayout and fabricated nine production CERCs in **July/August**
 - Simple bricolage fix for known problems may be possible
 - If so, may not relayout; save a month
- ECAL system tests from **September onwards**
 - Initially at least 10 layers in cosmic teststand at Ecole Polytechnique
 - DESY ECAL electron beam test in **Oct/Nov**
- Beam tests with HCALs in hadron beams during **2005**