Calorimetry and the DÆ Experiment

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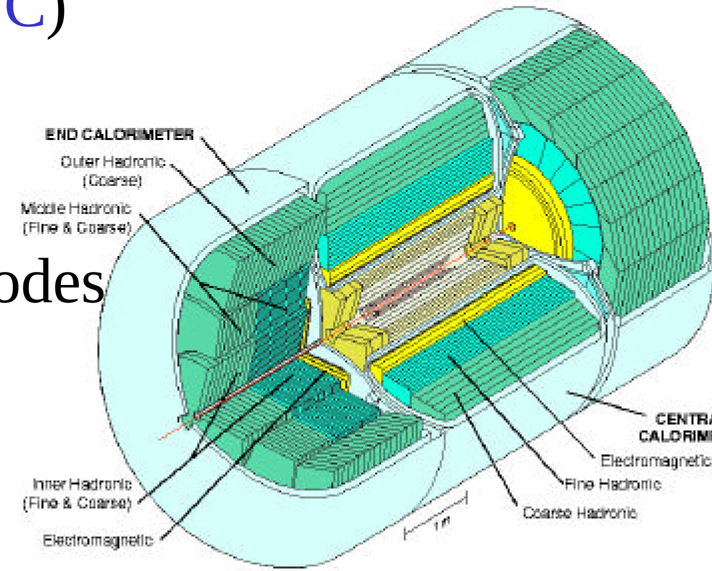
Calorimeter Description

Liquid Argon Calorimeter

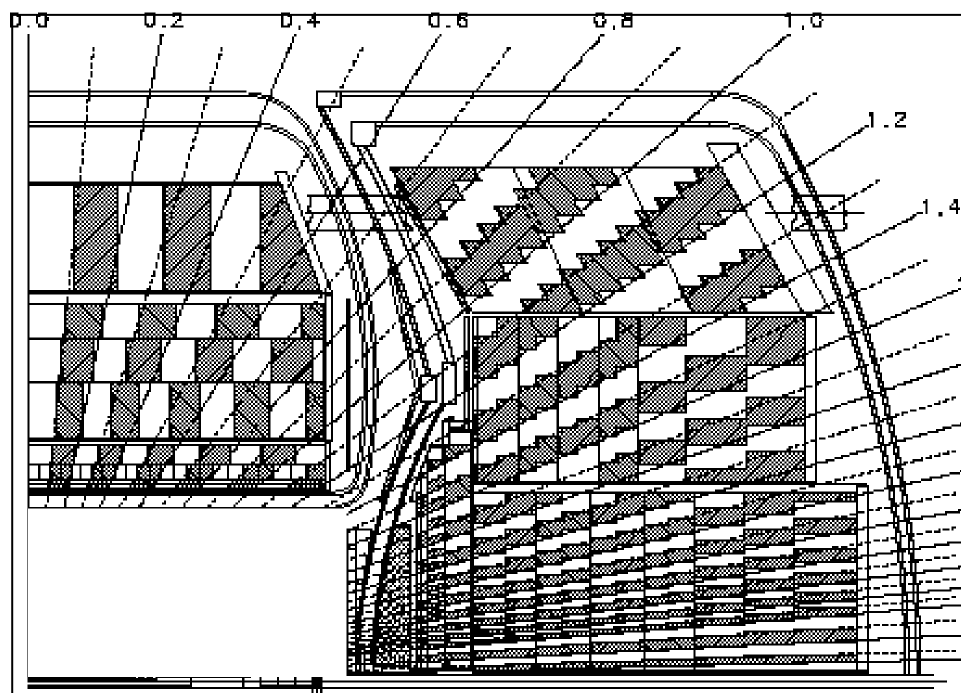
- 3 cryostats: central (CC) + 2 end caps (EC)
- 3 sections: EM + HAD + CH
- Plate geometry

  2.3 mm LAr gaps + 4.6 mm G10 electrodes
- 1.6 kV; ~ 450 ns drift time
- Coverage: |η|<4.2
- Granularity: $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$

  0.05×0.05 at shower max



	# of X_0/λ_0	Absorber
CC EM	2 + 2 + 7 + 10	U 3mm
CC FH	1.3 + 1 + 0.9	U 6 mm
CC CH	3	Cu 46.5 mm
EC EM	0.3 + 3 + 8 + 9	Fe 1.4 mm + U 4 mm
EC FH	1.3 + 1.2 + 1.2 + 1.2	U 6 mm
EC CH	3 + 3 + 3	Fe 46.5 mm



Results from Run I – Upgrade for Run II

Run I: very successful operation

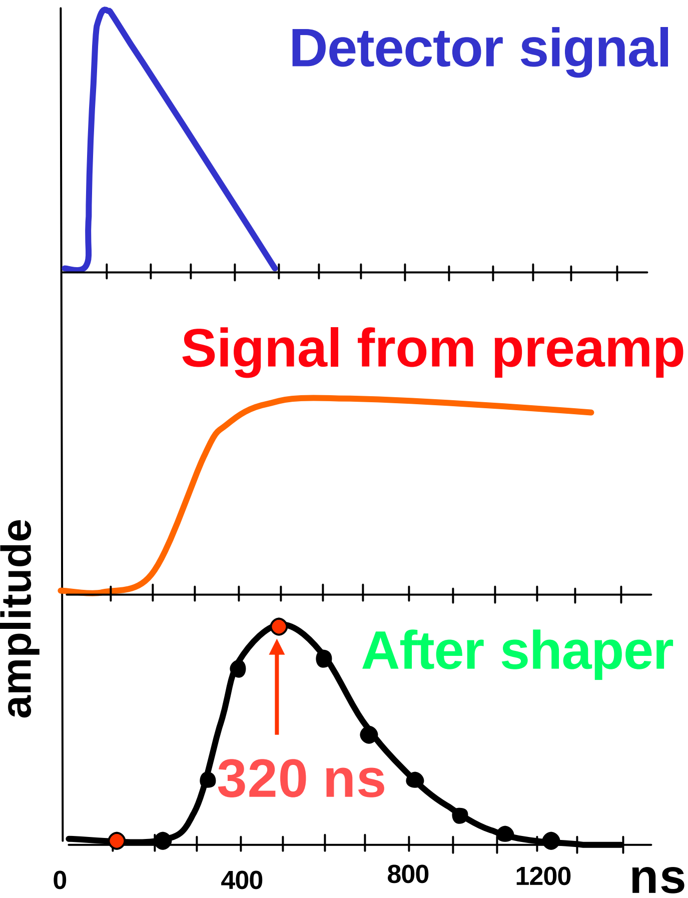
- Energy resolution (W mass paper)
- e: central $\sigma_E / E = 13\% / \sqrt{E} + 1.5\% + 0.4\ \text{GeV}/E$
  end caps $\sigma_E / E = 16\% / \sqrt{E}$
  had: $\sigma_E / E = 80\% / \sqrt{E} + 4\% + 1.5\ \text{GeV}/E$
- Less than 50 dead channels out of 55000

Run II upgrade: 3.5 µs between crossings ? 396 ns

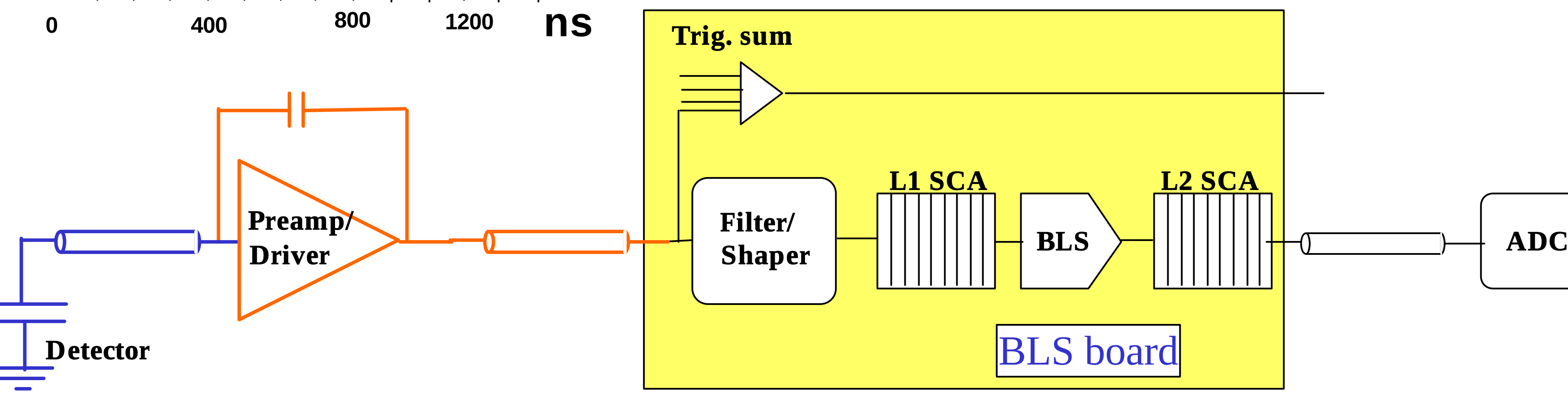
- Replace front end electronics and cables
- Keep cabling, crates (power supplies) and ADC cards
- Replace calibration system, timing and control system

Electronics Description

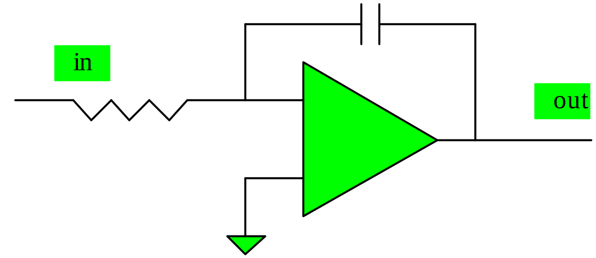
Basics of Readout



- Detector signal ~ 450 ns long
- Charge preamplifiers
- BLS boards
  - Short shaping ~2/3 of signal integrated
  - Signal sampled and stored every 132 ns in analog buffers waiting for L1
  - Samples retrieved on L1 accept and baseline subtraction (BLS) to remove pile up and low frequency noise
  - Signal retrieved after L2
- Digitized



Preamplifiers



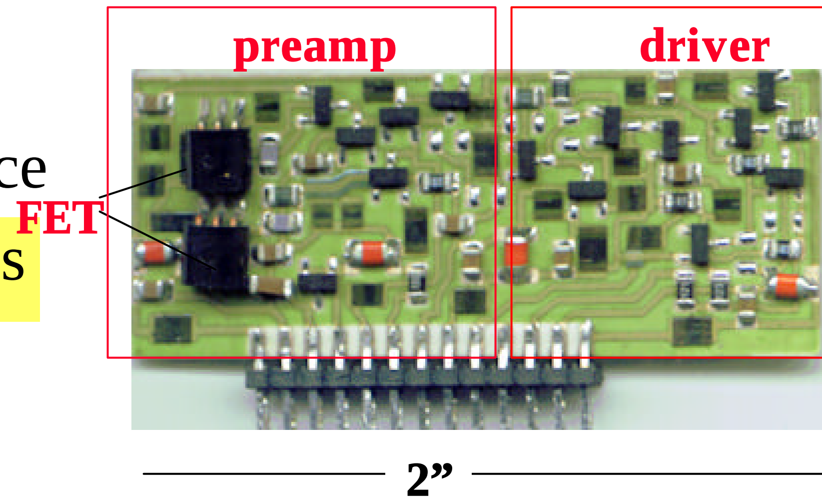
Charge preamplifier similar to Run I

Hybrid on ceramic

Dual front end FET (noise/√2)

Compensation for detector capacitance

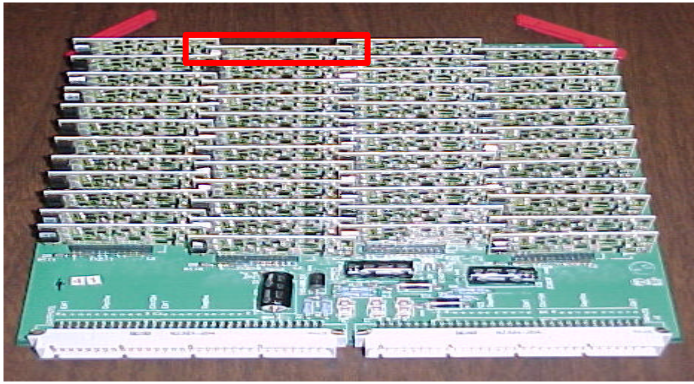
- 0.25 – 4 nF ? 14 different species



up to 48 channels per board

i.e. 4 towers ($\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$)

1152 boards

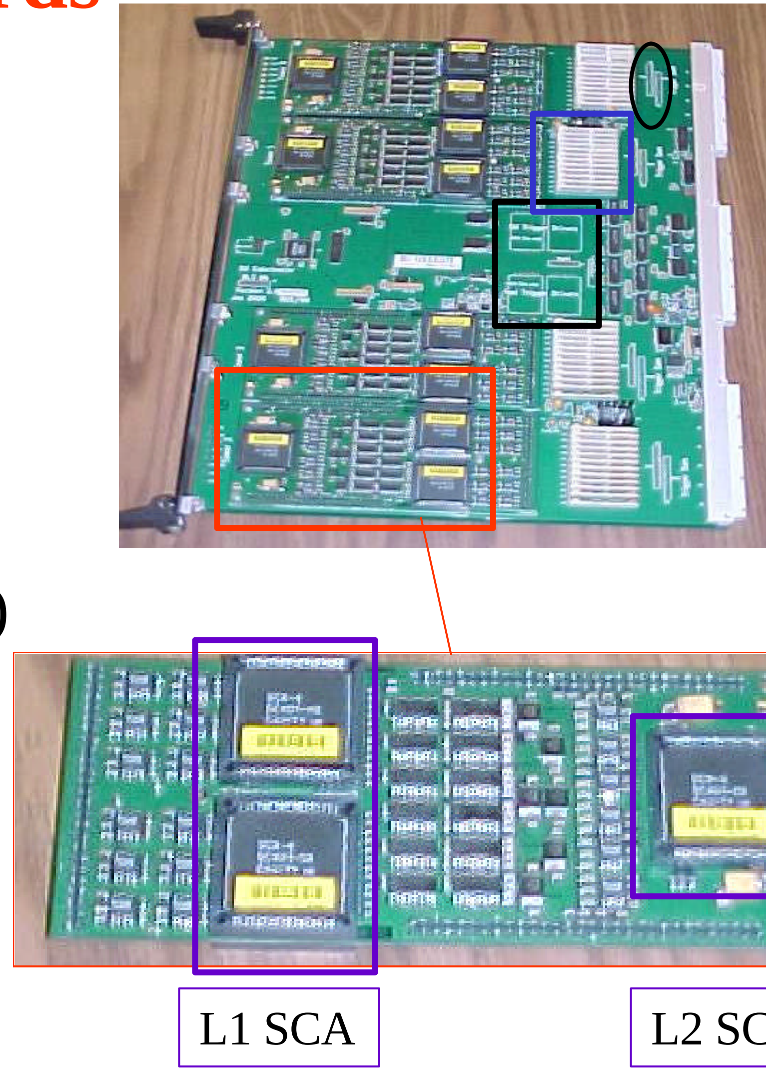


Very reliable system (inside iron, ~ 1 day access time!)

BLS Boards

48 channels from $\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$
i.e. 1 trigger tower

- Trigger summers + drivers
- Shapers
- L1 and L2 analog memories (SCA)
- Baseline subtraction

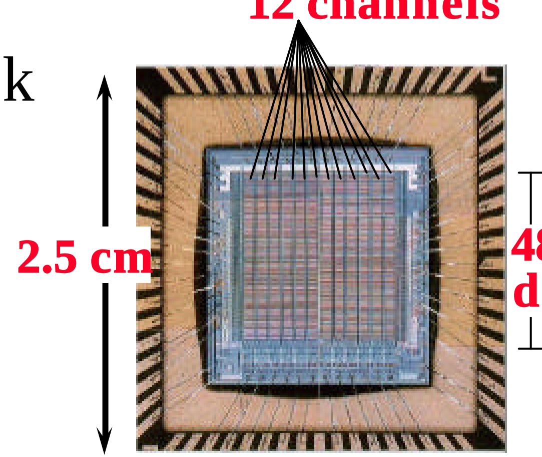


4 daughter cards ($\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$)

- 2 gains ×8 and ×1 (12–bit ADC, 15–bit dynamic range)
- Analog memories not simultaneously read–write

In the collision hall, short access time (~ 1 hour)

SCAs



Designed by LNBL, FNAL, SUNY Stony Brook

12 channels × 48 cells deep memories

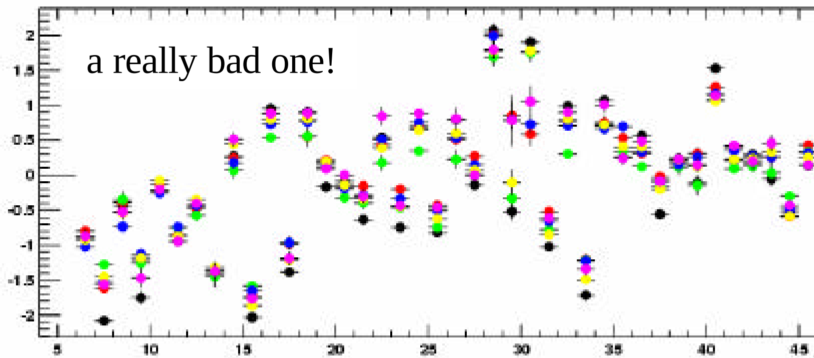
Allow ~ 6 µs for L1 decision time (4.2 µs)

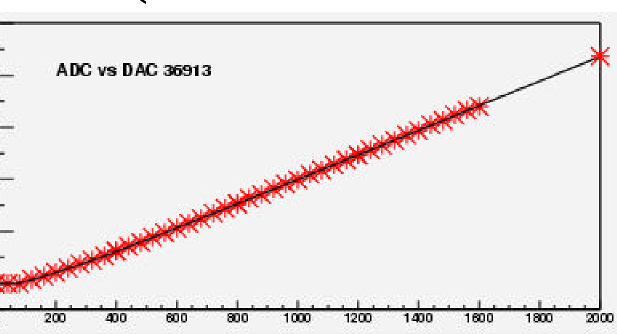
Read time 2.5 µs

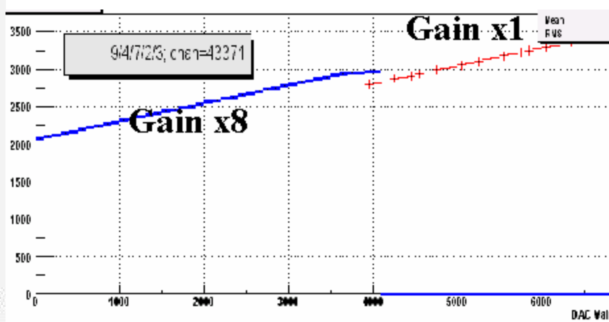
No dead time @ 10 kHz L1 trigger rate

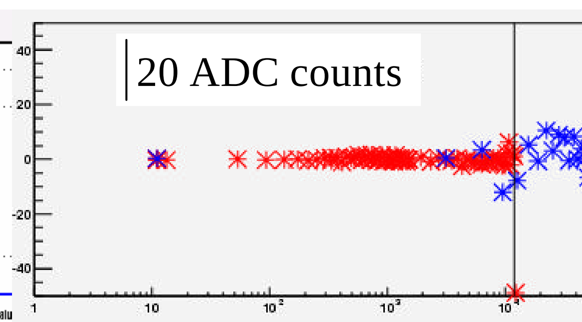
On–board properties

- pedestal dispersion 0.6 ADC count rms; acts as coherent noise
- non linearity at low ADC values (software corrected)









ADC Cards

144 ADC cards (12 crates x 12 cards) from Run I

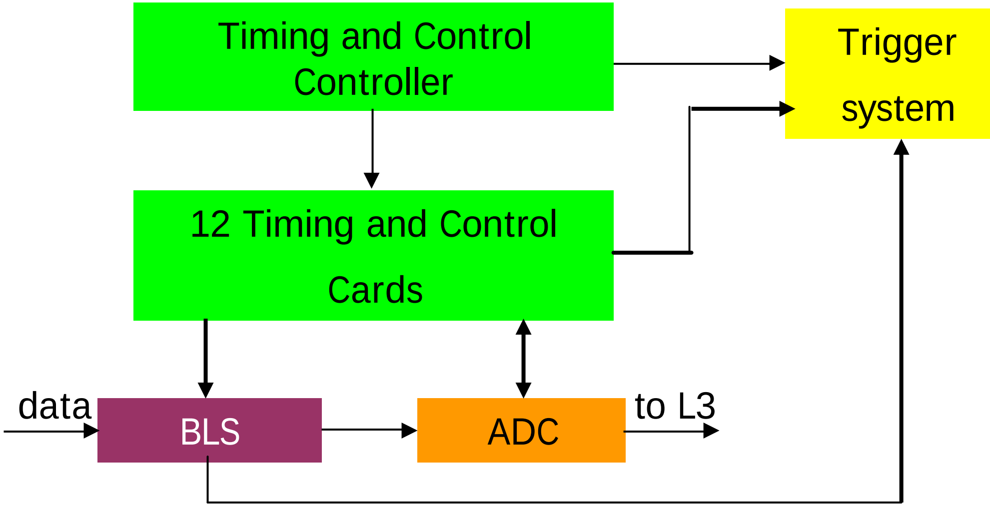
Each card houses 24 successive approximation digitizers (2.5 μs)

Each digitizer services 16 sequential frames

- pedestal subtraction (optional)
- settable zero suppression ? only ~ 5000 cells read out @ 1.5 σ

Timing and Control Cards

- Receives accelerator, clock and trigger signals
- Distributes those to BLS and ADC boards
- Keeps track of where relevant data are sitting in SCAs
- Generates busy signals
- Driven by code in FPGAs

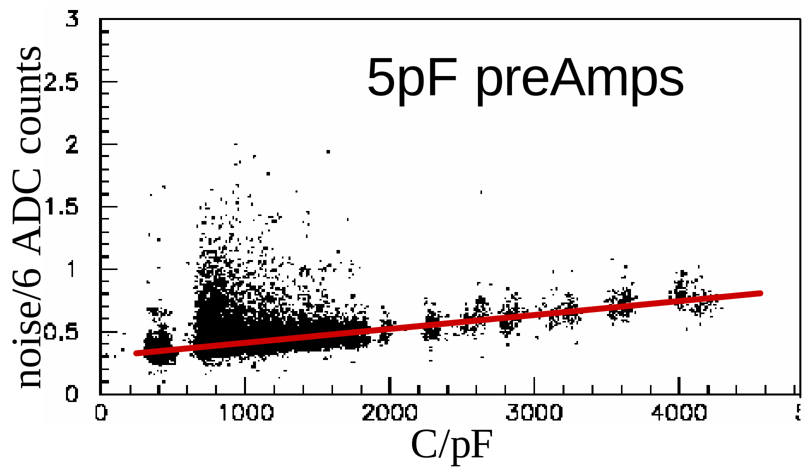


Pedestals – Noise

Noise

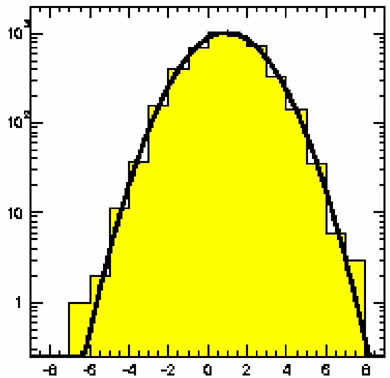
Electronics contribution (except preAmps) < 1 ADC count

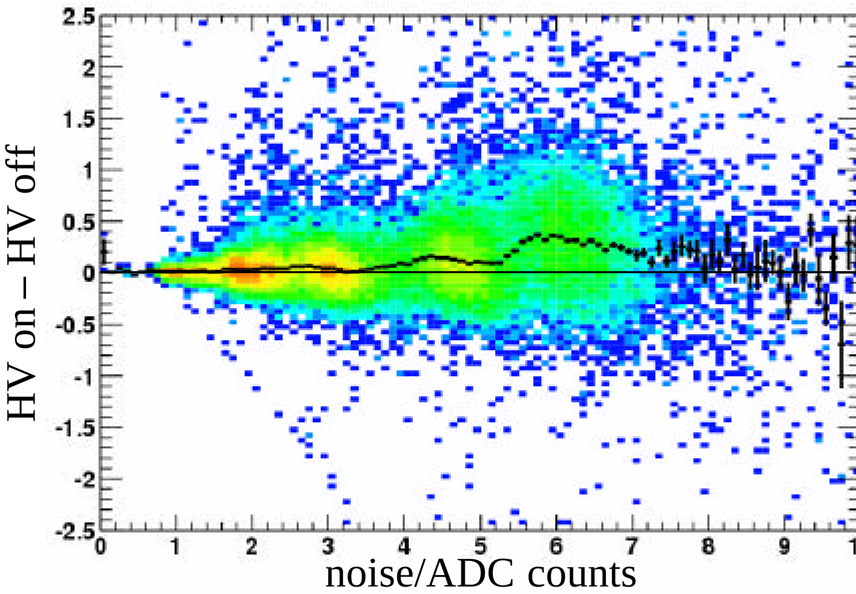
Noise increases with capacitance



Uranium noise (HV on/off)

- sensitive only for large area channels (high capacitance)
- Gaussian!





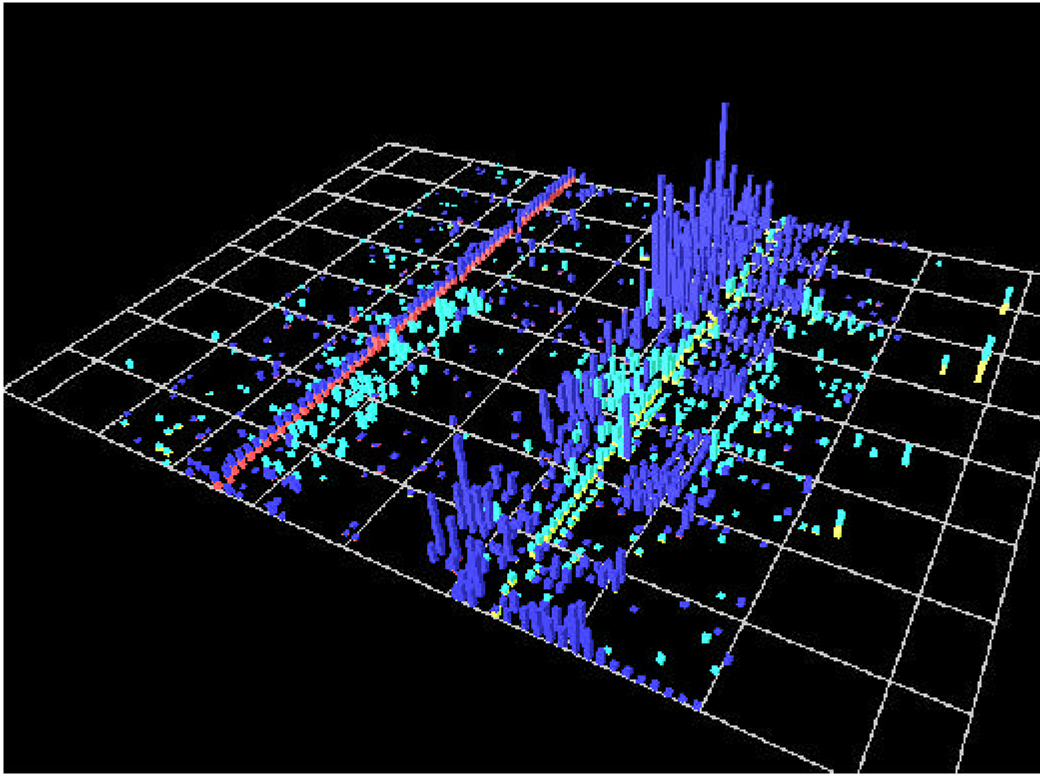
Coherent Noise

from SCAs below 1 ADC count

DØ had to be grounded for safety reasons

- designed to have a single point grounding
- was OK for Run I and then forgotten by many of the community

and some day, …



Dozen of contacts of DØ and with "ground"

Ground repaired + some temperature monitoring cables disconnected

Gone (for ever?)

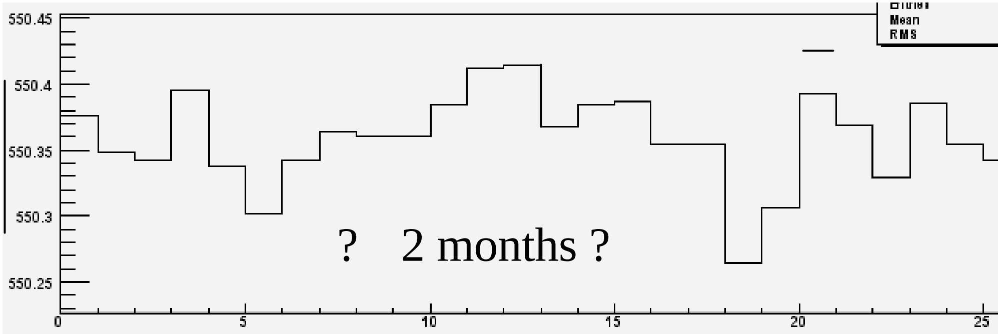
Pedestal Stability

Pedestal run taken in between stores (every ~ 30 hours)

Mean values and rms computed in L3 filters (data not written to tape)

10^4 events @ 20 Hz, altogether ~ 15'

0.1 ADC count

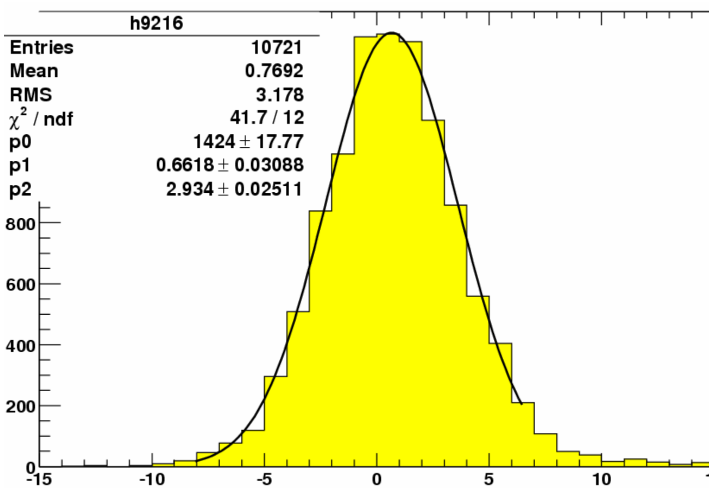


Excellent long term stability

Tool able to find channels drifting by <1 ADC count/month

No pedestal shift in physics

No change in noise



Calibration

Pulser System

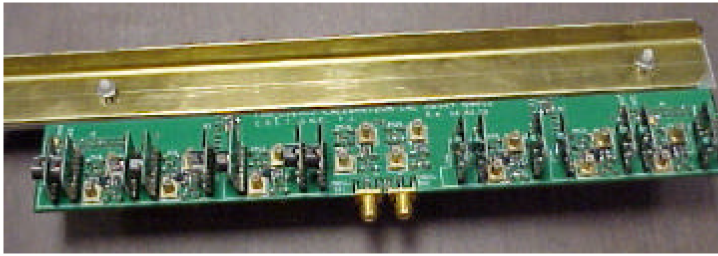
Similar to ATLAS system

- 1 mH inductance loaded by a DC current
- opening a switch diverts current to ground
- inductance produces exponential calibration current through precision injection resistors
- but charge injected at preamp input

12 pulsers

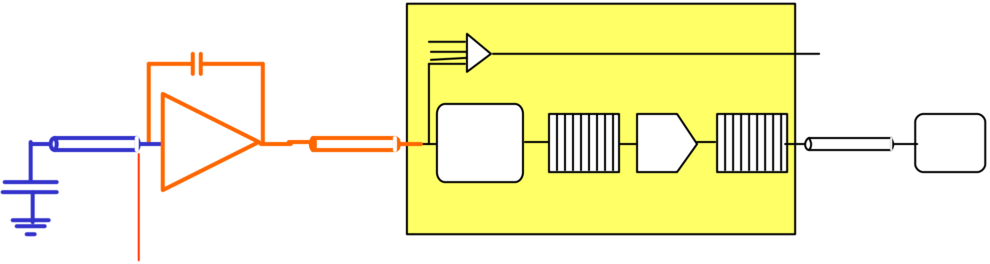
- 6×16 DC currents; a single 18-bit DAC controls intensities (∝ pulse height); individually enable; better than 0.2% linearity
- 6 command lines each with a programmable 8-bit delay (0–400 ns (∝ pulse start)

12×6×16 switches close to preamplifiers



Calibration Pulses

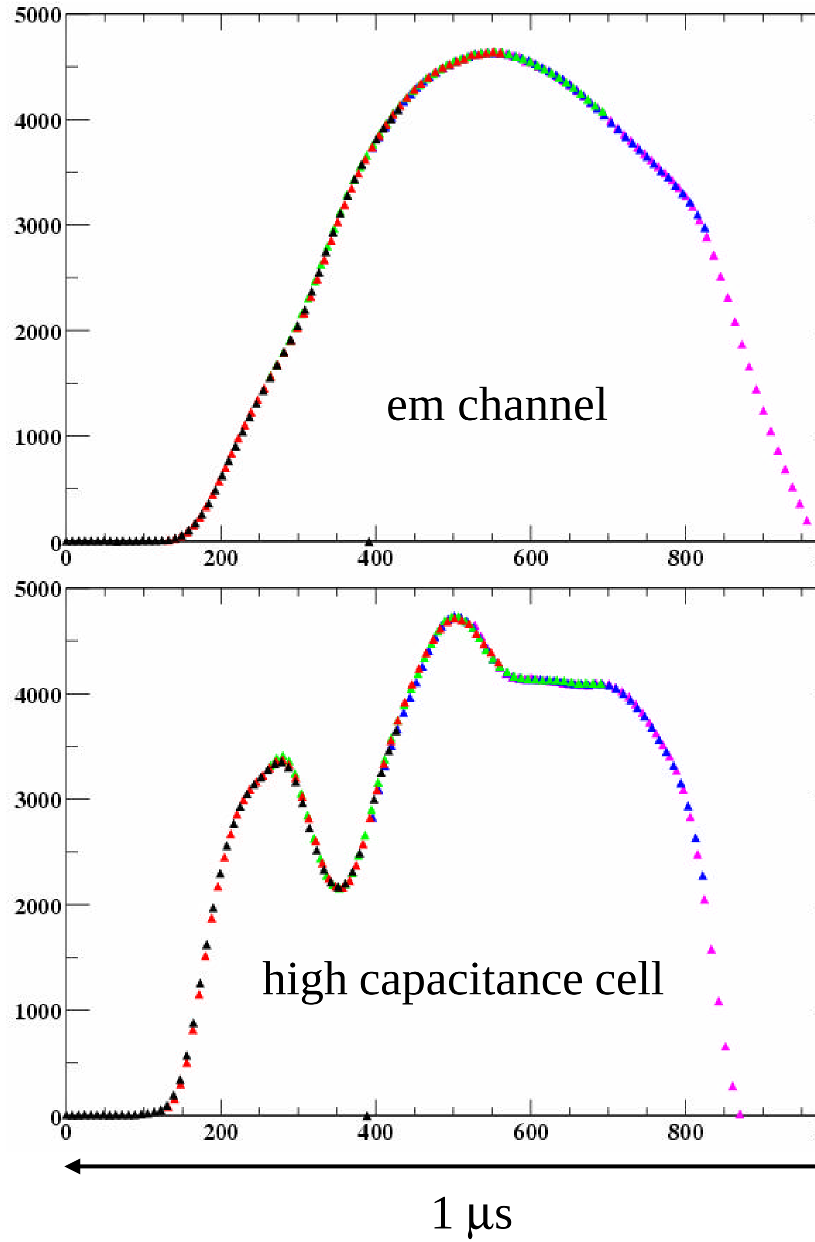
Measured by varying the delay



Reflection on detector capacitance due to injection close to preAmps

- most pronounced for high capacitance cells (HAD)
- still visible in EM channels

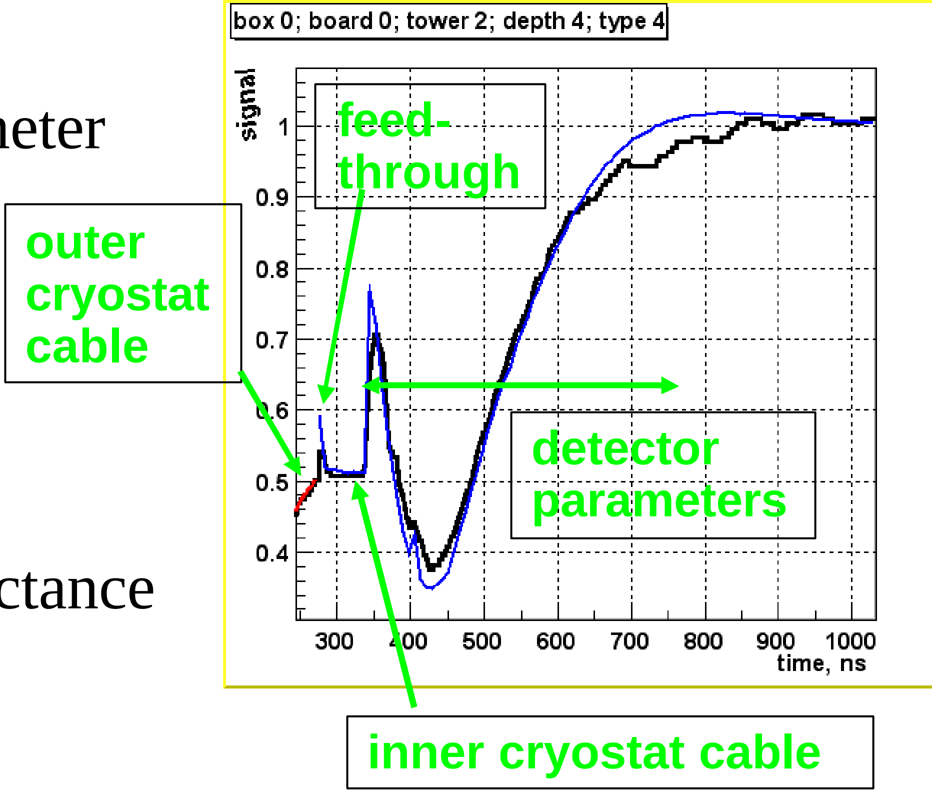
Needs to be taken into account



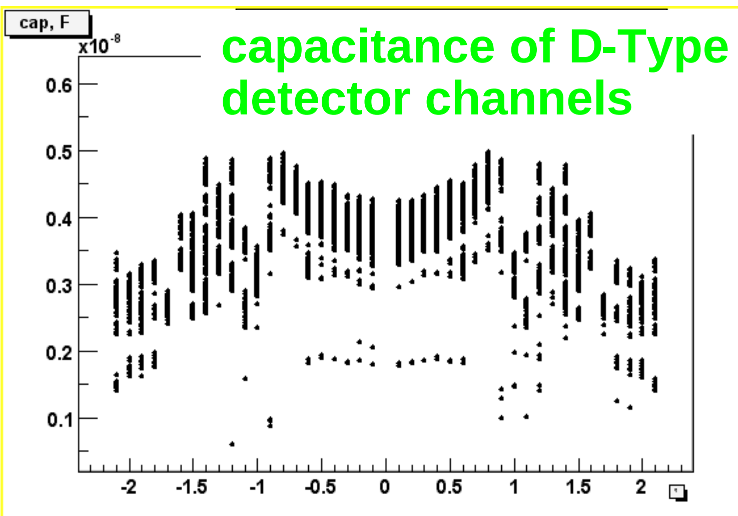
Reflection Measurements

Using a Time Domain Reflectometer

- send a square pulse
- measure reflected signal
- complicated fit yields
  - detector capacitance
  - strip capacitance and inductance
  - various cable lengths
  - skin effect parameter



55,000 channels measured and parameters extracted

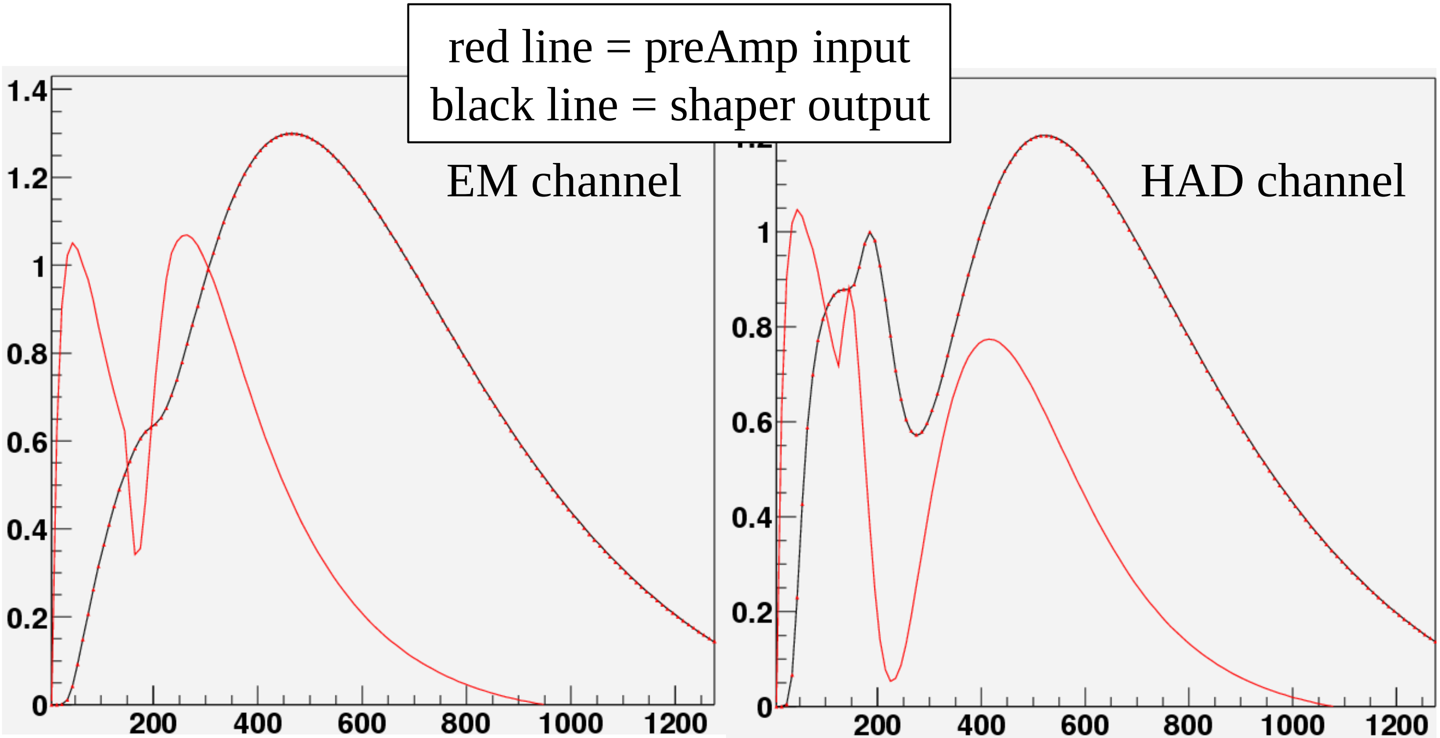


Electronics Simulation

Individual channel properties before preAmp known

Cables, detector capacitance, etc. known

? Predicted input pulse to preamps



Generic description of each preamp type

Generic description of one shaper

Plans for Full Calibration

In calibration mode, from

- predicted input signal to preamp (channel per channel)
- measured output signal from BLS

? compute numerically transfer function H (preamp + shaper)

In physics mode, from

- predicted physics input signal to preamp
- transfer function H

? predict channel to channel variation in pulse height

Calibration = correction for those variations

Long way to go!

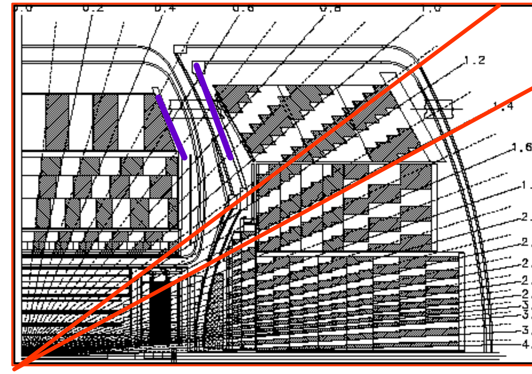
Other Pieces

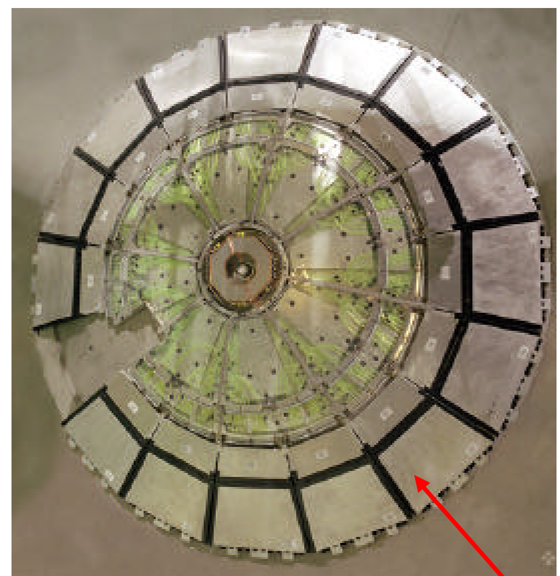
Inter Cryostat Region

Limited coverage of region 1.1<|η|<1.4

ICD detector similar to Run I

- Scintillator + WLS fiber + clear fibers
- Reuse of R647 Hamamatsu PMT's (low B)
- 2×16 modules (384 channels)
- Electronics adapted from calorimeter
- Same RO
- Same electronics calibration system as
- calorimeter
- PMT calibration with cosmics on test stand + LED pulsers for monitoring





Massless gaps in CC and EC

Preshower

2 teslas Solenoid in Run II (60 cm radius)

Energy loss backed by a 2 X_0 preshower

Scintillating fibers + lead

WLS readout + ~10 m clear fibers

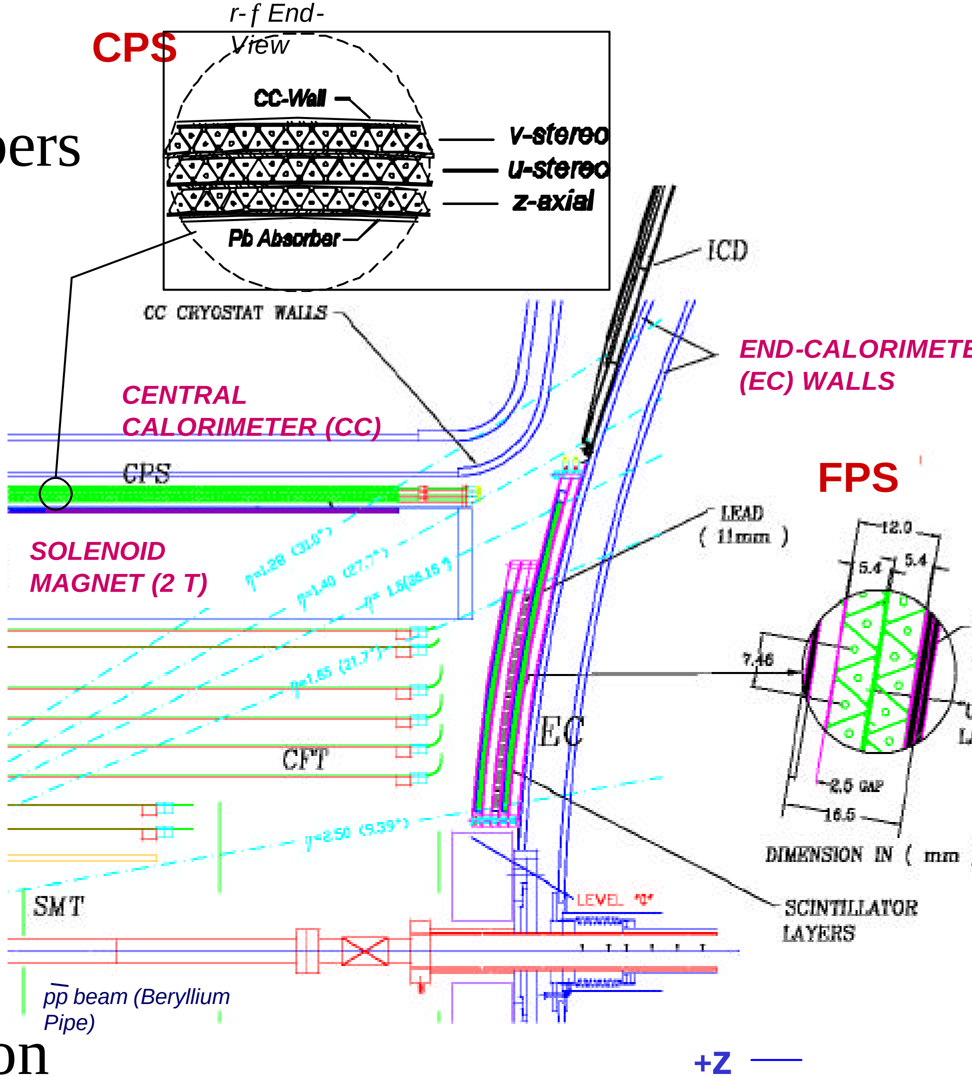
VLPCs + 8–bit ADC

Central (|η|<1.3, CPS)

- 7680 channels
- 3 layers (axial, u, v)

End caps (1.5<|η|<2.5, FPS)

- 4 layers (u, v) + lead
- 15000 channels



Effort yet concentrated on track matching and γ/π^0 rejection

Trigger

Granularity 0.2×0.2 down to $|\eta| = 3.2$

Analog signal pickup in BLS boards

Sums of em and had sections separately

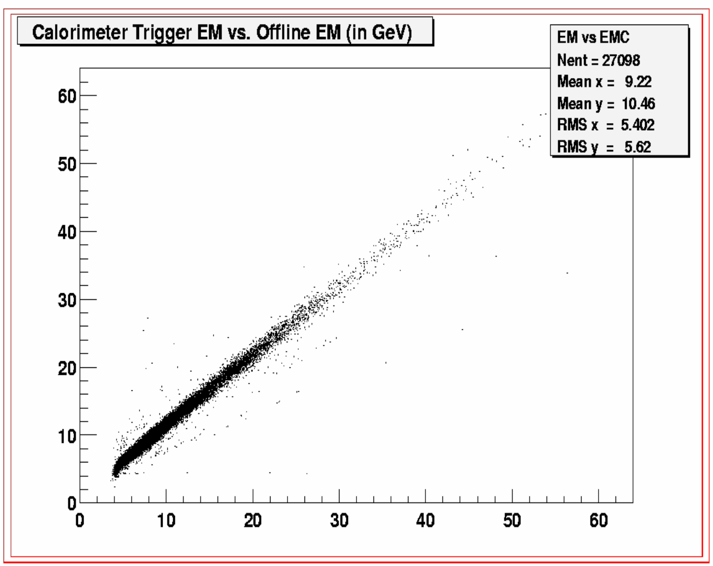
Converted to E_T

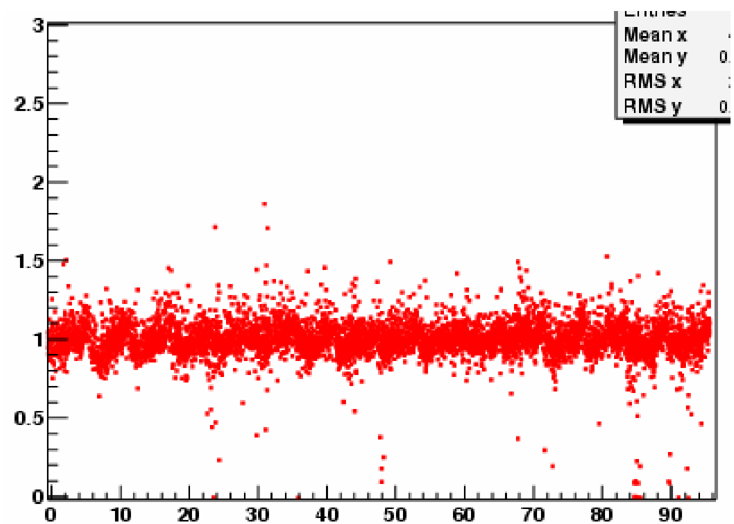
Flash digitized @132 ns; 8 bit precision.

Pedestal and gain compensation

Excellent comparison with “precision” readout

- Alternative route to check data

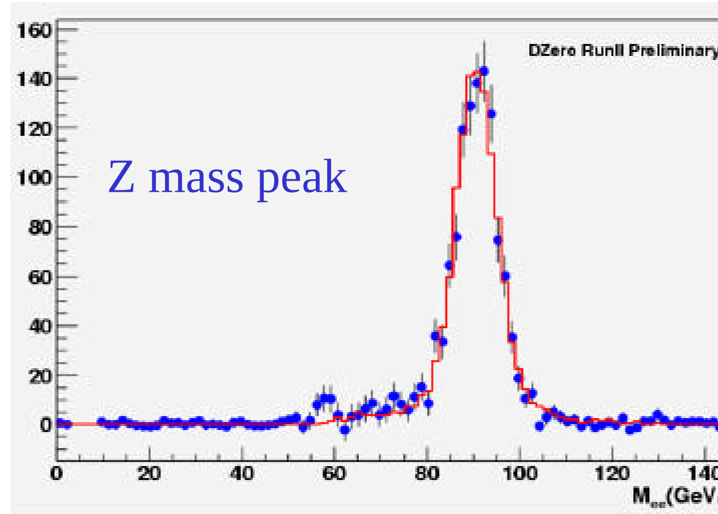




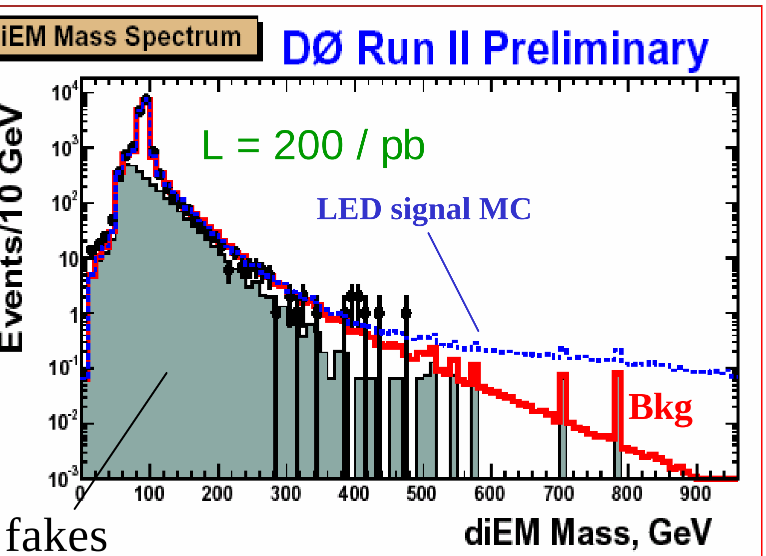
Some Results

EM Performance

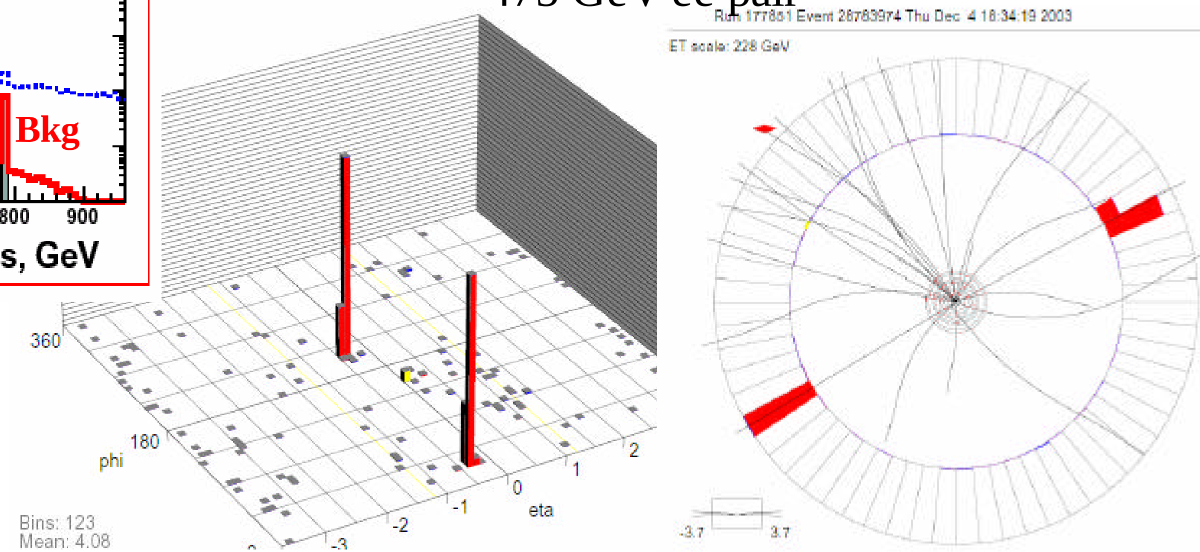
Benchmark is Z peak. Also J/Ψ and Υ available to compute in beam resolution (see Sophie Trincaz – Duvois's talk)



High mass pairs



475 GeV ee pair



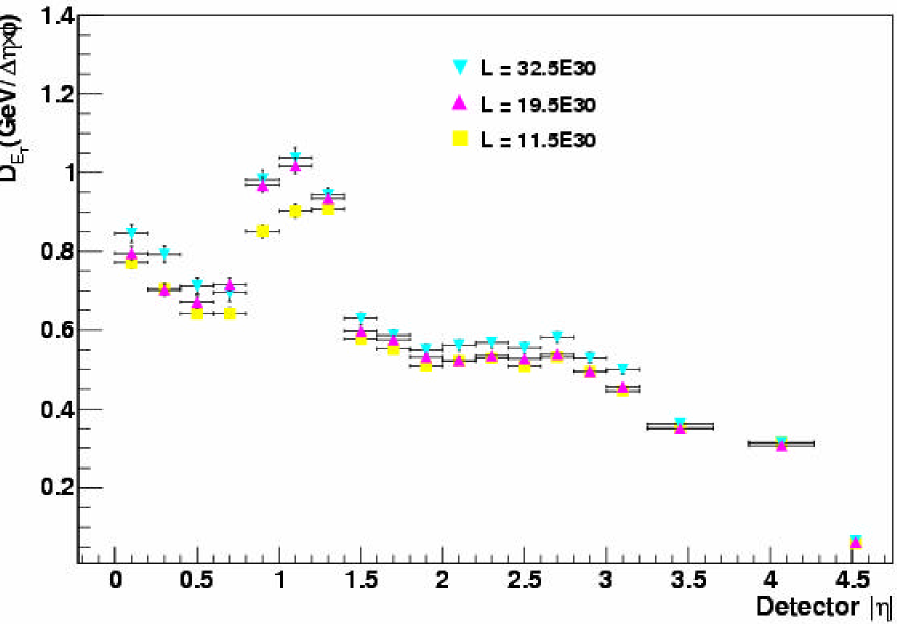
MET

Missing E_T quality very sensitive to any calorimeter problem (“hot cells”)

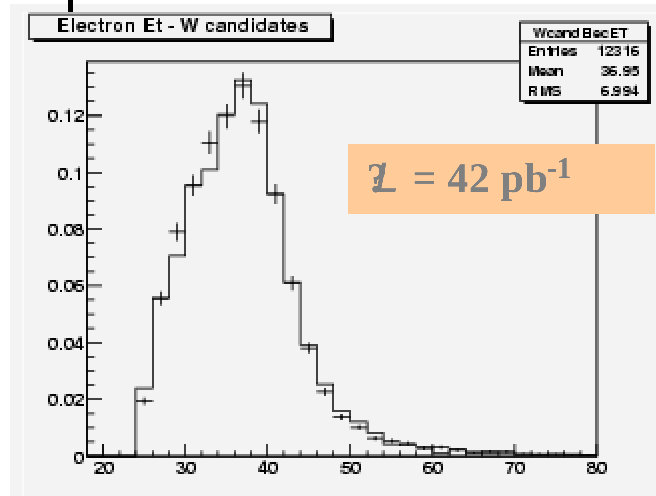
Resolution dominated by jet resolution

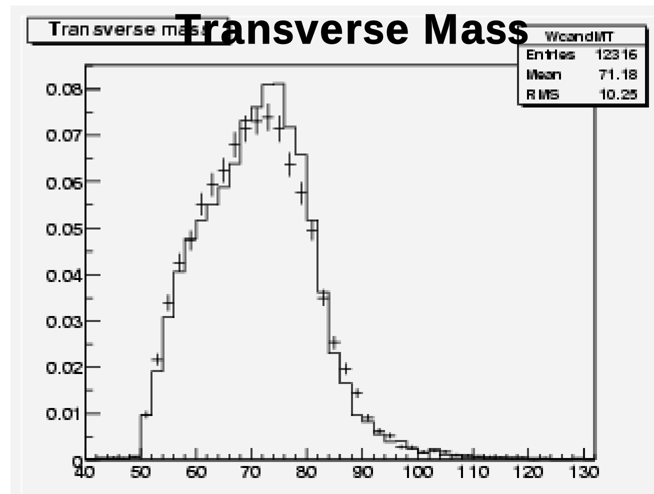
Bench mark: W mass ?

Underlying event ?



E_T Distribution of Electrons



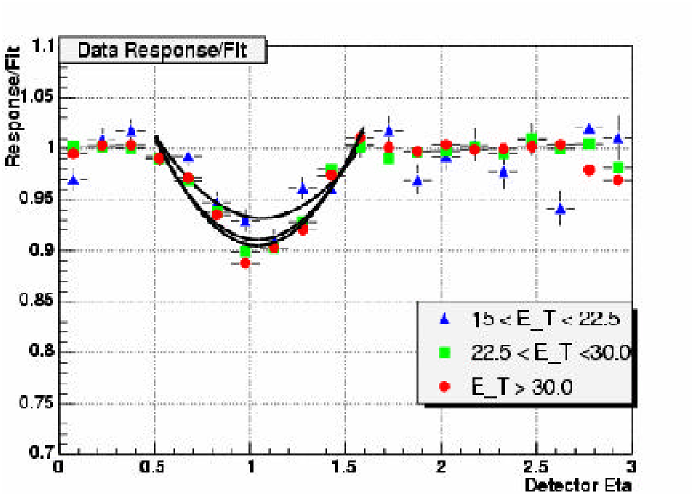


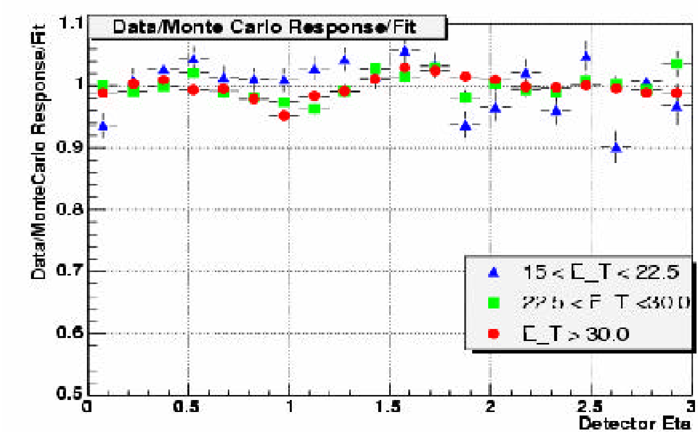
Jets

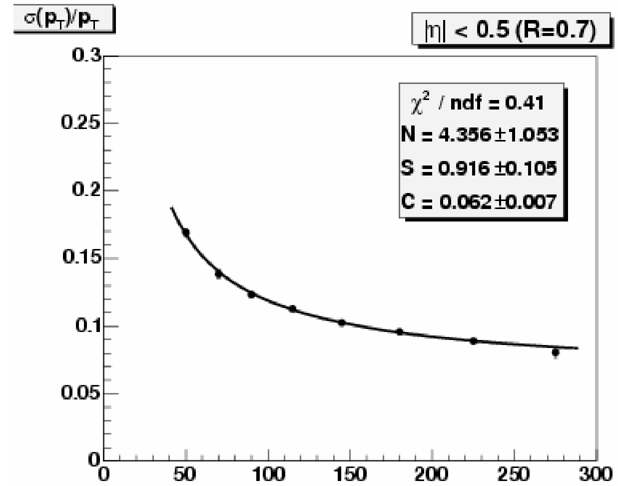
Resolution measured from γ/π^0–jet events

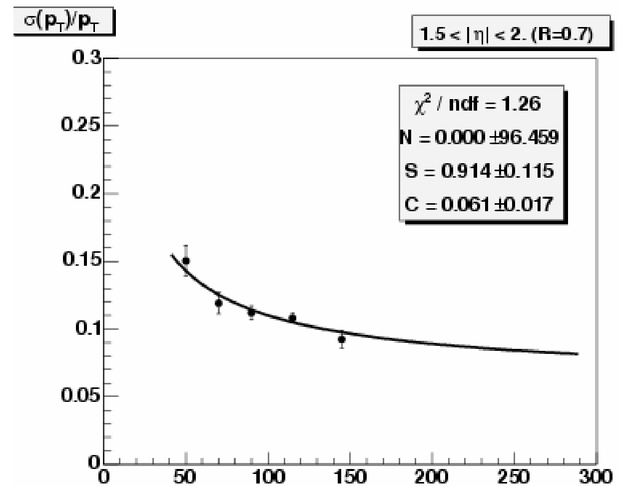
(see Sacha Kupco's talk)

Response uniformity









Summary

Mechanical design and building of 1980's

But almost entirely new electronics build for high luminosity

- no test beam debugging

Commissioning not ended by the time good beam was delivered

- no long time of cosmic run debugging as in Run I

Debugging with beam is very difficult!

Still many detector studies in progress to get ultimate information out of the data

Data quality (see next talk, Slava Shary, LAL, Orsay)