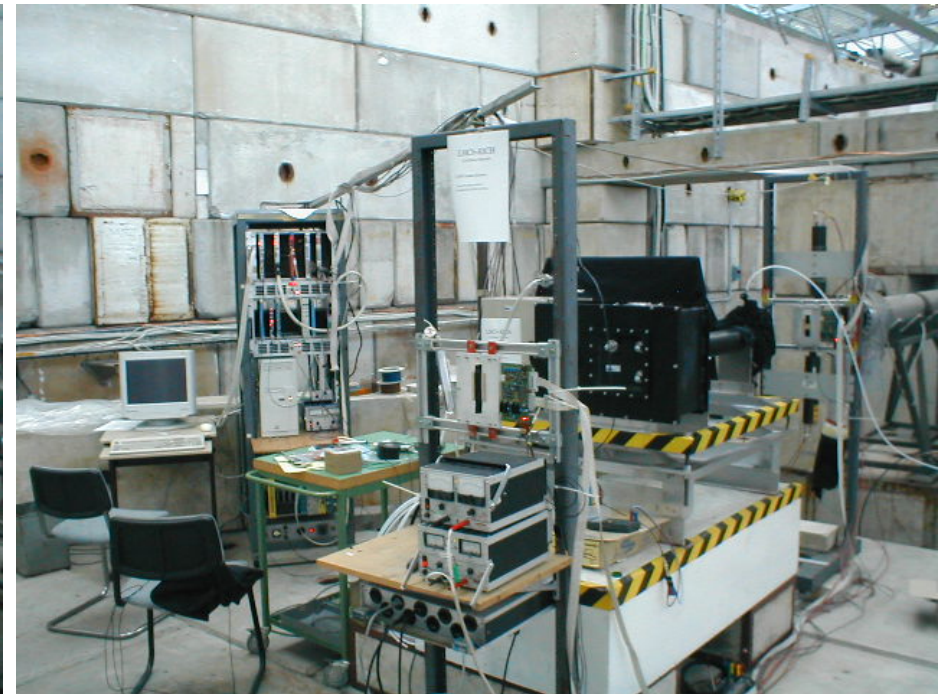
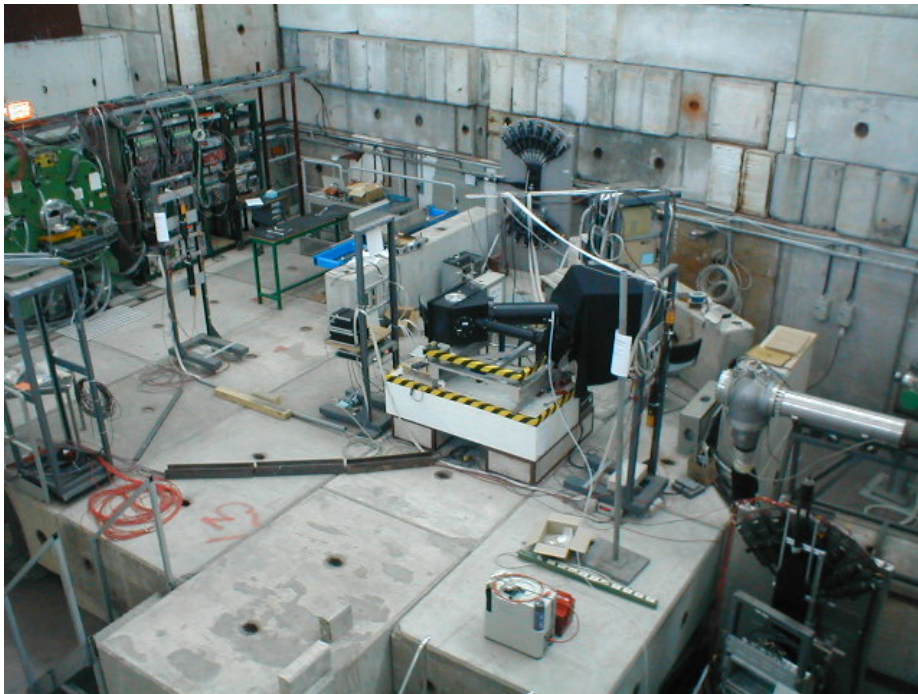


Beetle Readout for the MaPMTs: First Results from the Testbeam

LHCb
ITCP



- history of events
 - documentation of setup
- RICH meeting, Zürich, 16.09.2003

- measurements & data
 - preliminary results
- Stephan Eisenhardt
University of Edinburgh



History of Events I: pre-testbeam

- Thu 14.08.: first ever boardBeetle 1.2 finished and shipped to Edinburgh
- Fri 15.08.: lorry of carrier crashed in road accident
- Mon 18.08.: shipment of first boardBeetle 1.2 arrived at Edinburgh
visual inspection: board OK
- Wed 20.08.: first data frames after sorting out problems in the I2C level adaptation and the temporary cabling
- Wed 20.08.: first boardBeetle 1.2MA0 finished and shipped to Edinburgh
- Thu 21.08.: adaptation of FED to differential read-out and
first ever LED light signals via DAQ chain (boardBeetle 1.2)
→ success!
(although a limitation of the dynamic range was observed – amplifier saturates?!?)
- Fri 22.08.: test of boardBeetle 1.2MA0
→ success!
- Sat 23.08.: pack and go

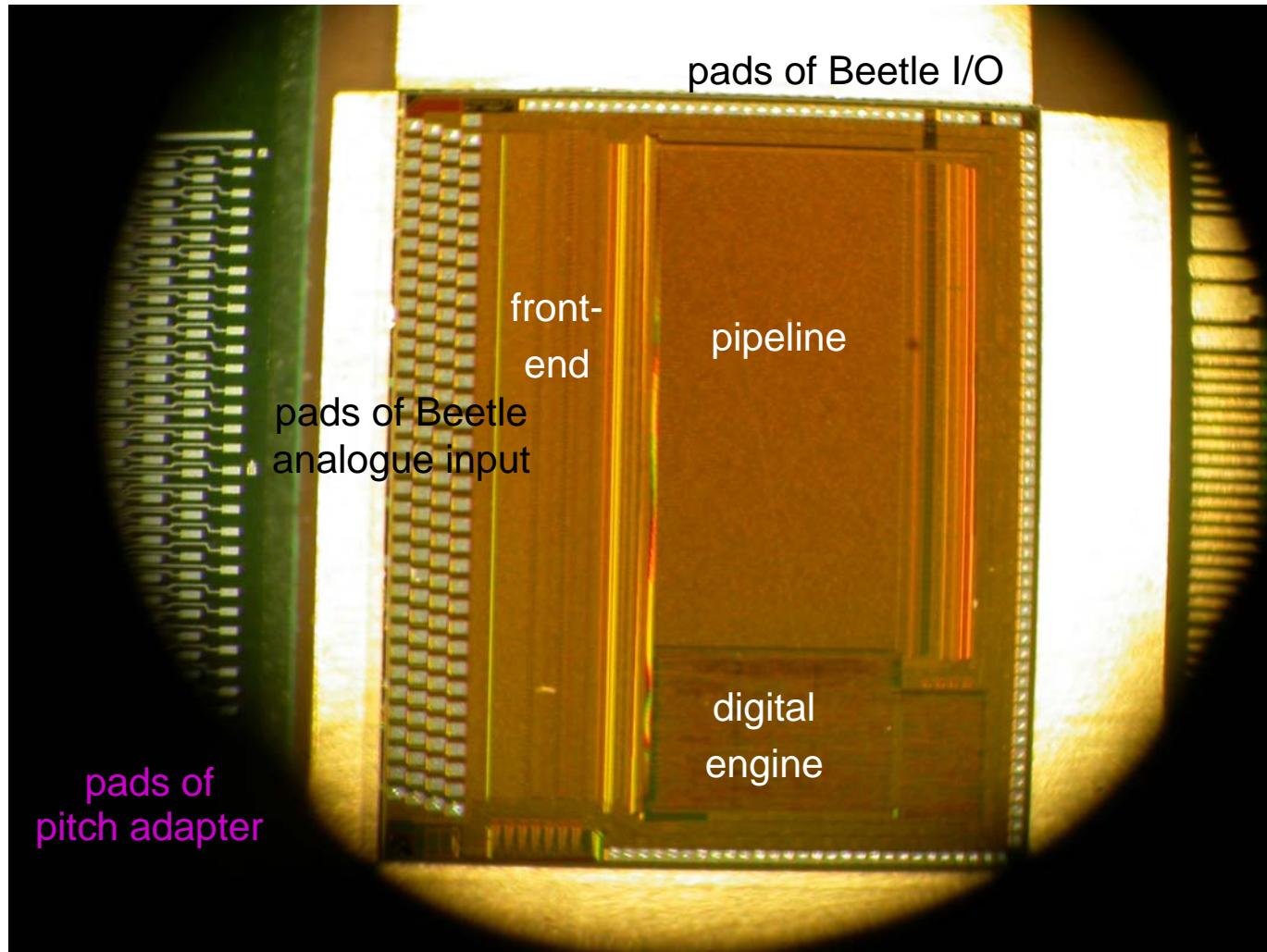
History of Events II: pre 05.09.

- Sun 24.08.-Wed 27.08.: troubleshooting of interference between WinXP, NI-interface and Labview on DAQ PC
- Mon 25.08.: 4 more boardBeetle 1.2 delivered to CERN
- Wed 27.08.: move into beam area
- Thu 28.08.-Fri 29.08.: infrastructure & cabling for missing interface board
- Sat 30.08.: tuning of timing &
first data frames with LED light and one boardBeetle 1.2
- Sun 31.08.: tuning of setup for Cherenkov light &
first Cherenkov photons with one boardBeetle 1.2
- Mon 01.09.: cabling for the MaPMT cluster due to missing interface board
- Tue 02.09.: I2C problems with cluster → work around found
- Wed 03.09.: mounting & tuning of cluster of 8 8-dynode stage MaPMT
- Thu 04.09.: tuning of read-out map for right geometry match &
first ring of Cherenkov photons → success!!

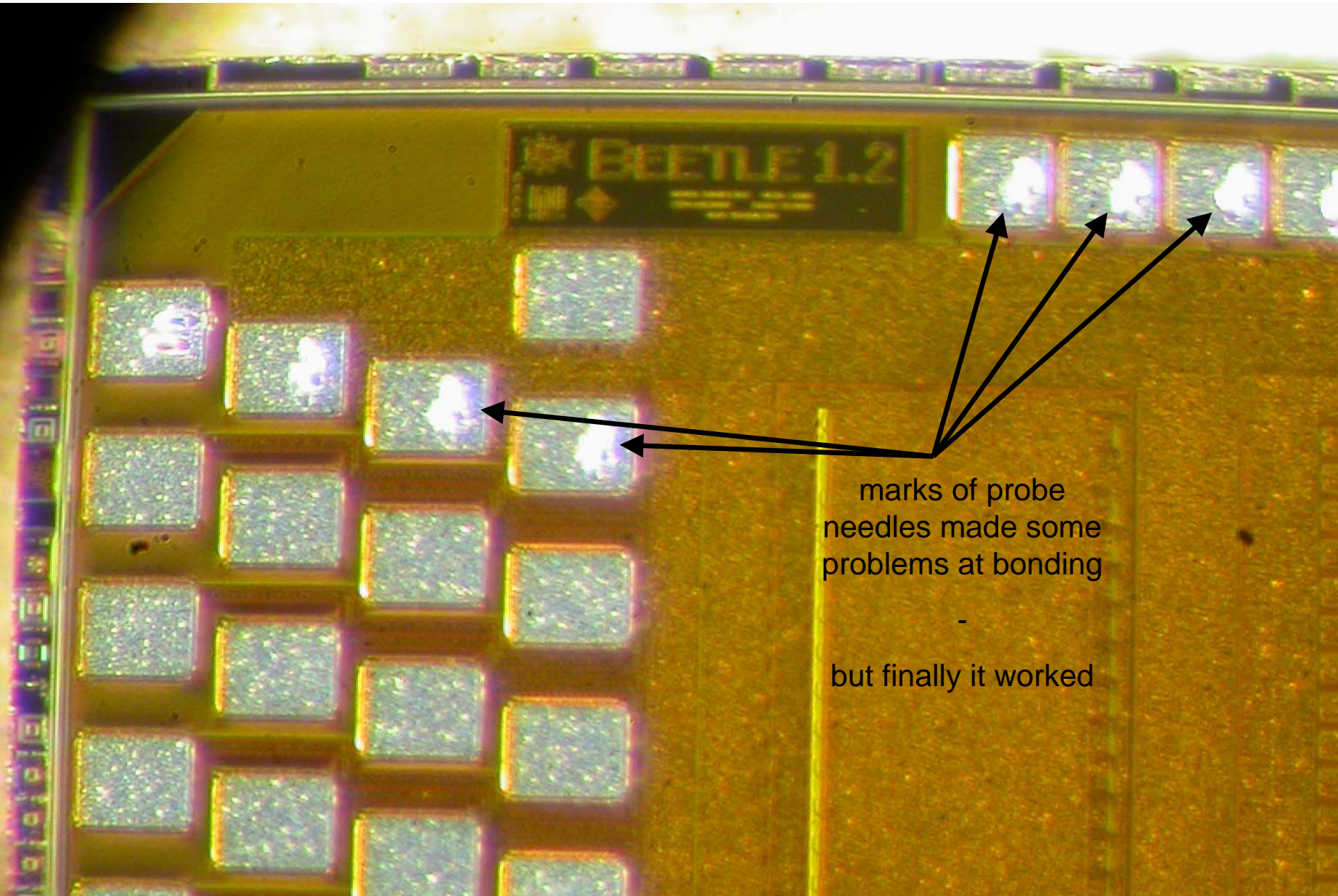
History of Events III: post 05.09.

- Fri 05.09.: 1 spare differential FED delivered to CERN to fix saturation (but of no use as with new CMS firmware)
- Fri 05.09.: lenses mounted on cluster
- Sat 06.09.: Silicon Telescope & Cherenkov counter in DAQ
- Sun 07.09.: TDC in DAQ & timing & DC-offset adjustment
- Mon 08.09.: first attempt on binary readout
- Tue 09.09.: data taking for: CF_4 for cluster of 8 MaPMT (Beetle 1.2)
- Wed 10.09.: end of testbeam... continuing with parasitic use of beam
- Thu 11.09.: data taking for: N_2 for cluster of 8 MaPMT (Beetle 1.2) & completion of cluster
- Fri 12.09.-Sat 13.09.: attempt to measure S-curves in binary readout
data taking for: Air, CF_4 for cluster of 9 MaPMT (Beetle 1.2)
- Sun 14.09.: mount of cluster with 6 MaPMT (Beetle 1.2MA0)
lenses, DC-offsets, ...
→ ring fragments

Beetle 1.2 chip: pre-bonding



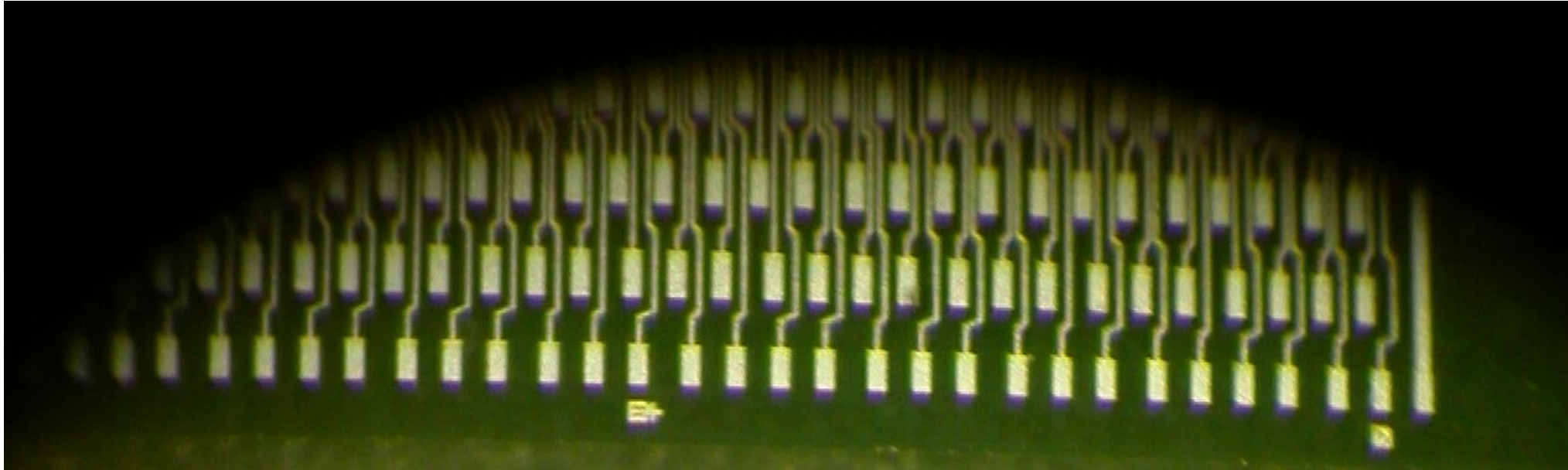
Zoom for probe-tested Chip



marks of probe
needles made some
problems at bonding

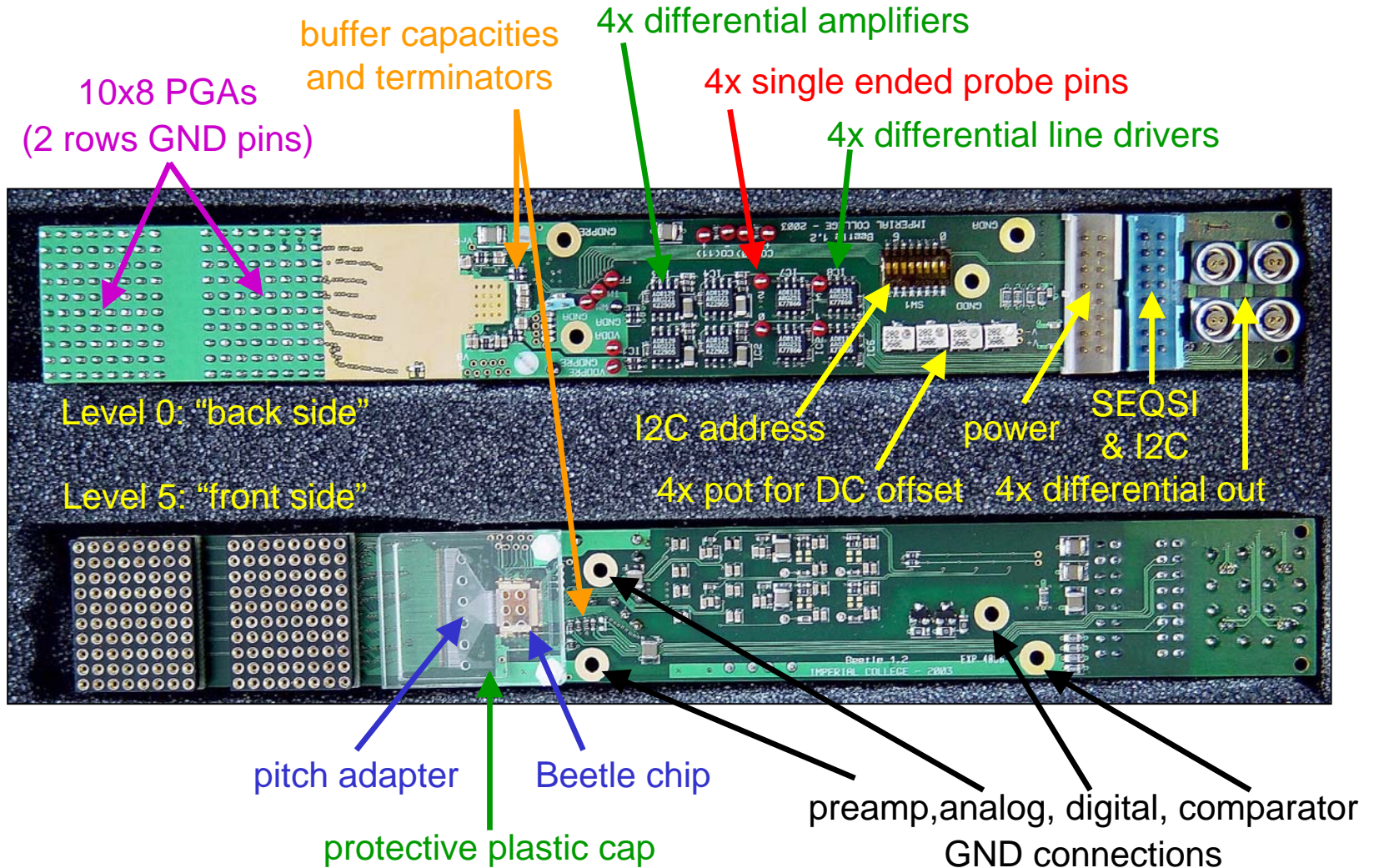
-
but finally it worked

Pitch adapter

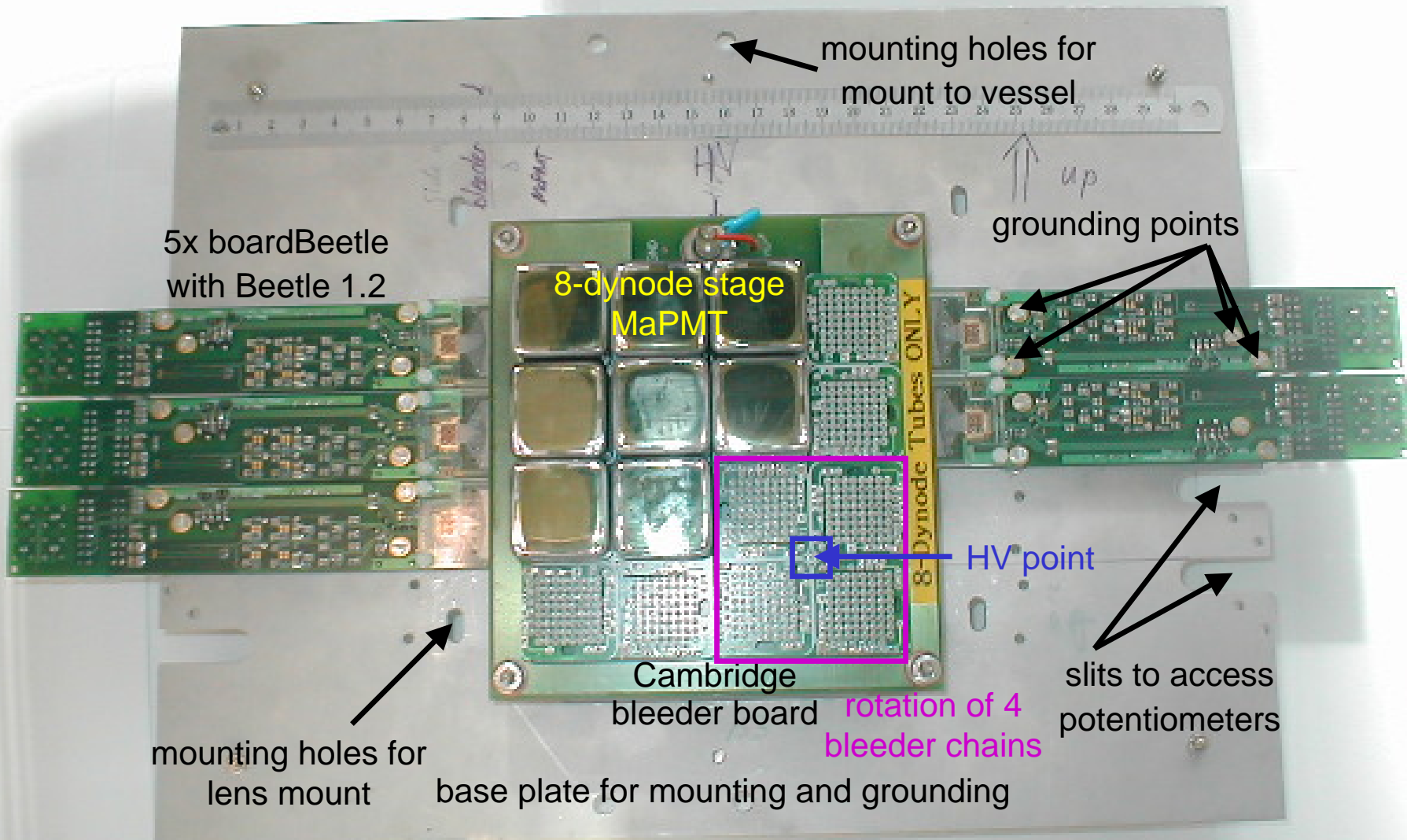


- Pitch adapter is irregular: due to accident in submission
 - design was sent in **low accuracy** → **rounding errors & shorts**
 - layout altered at CERN to fix shorts (but not the rounding errors...)
 - **not communication back to IC**
 - so this structure only was found at bonding...
- Cause of cross-talk??

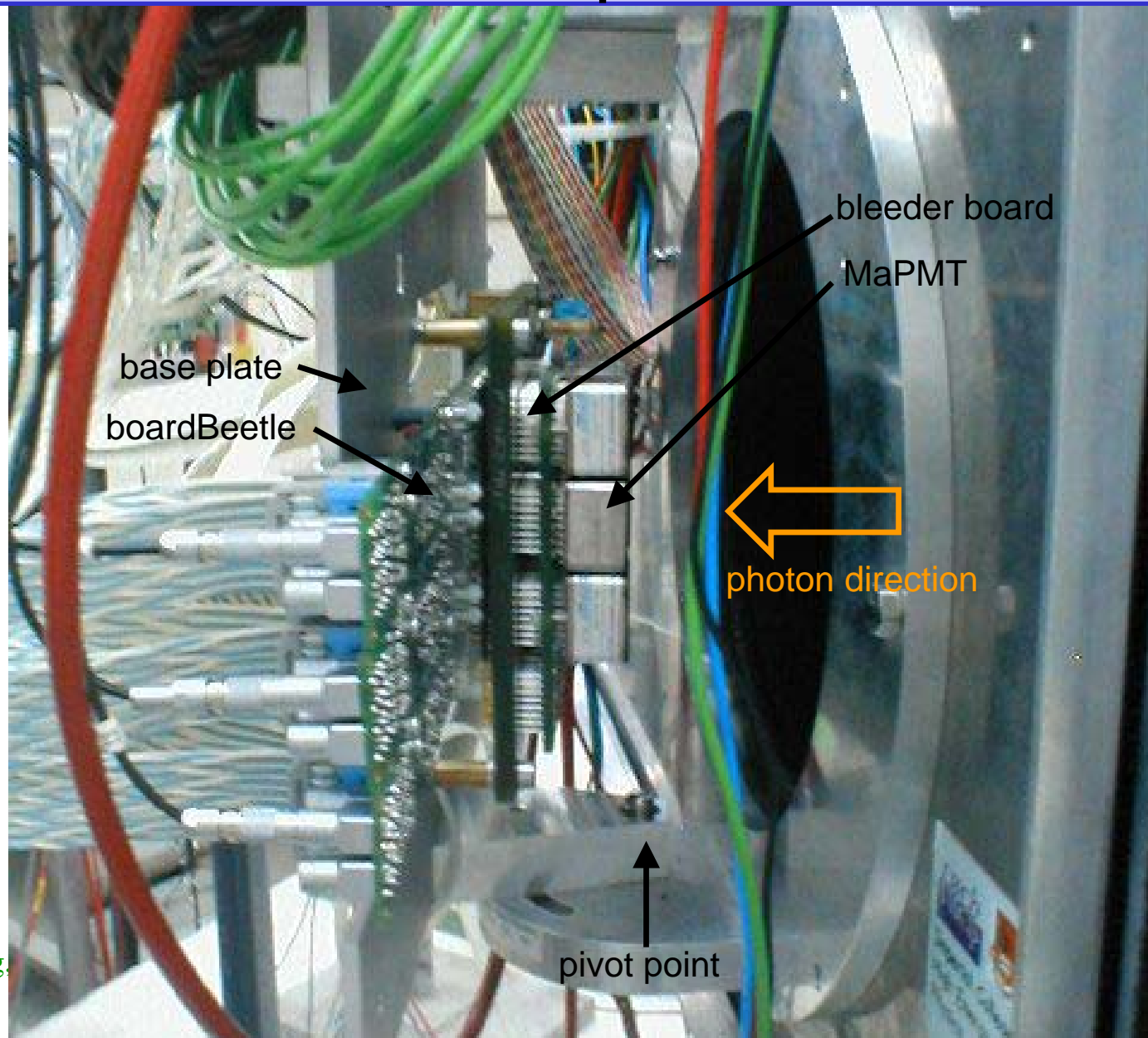
Equipped boardBeetle



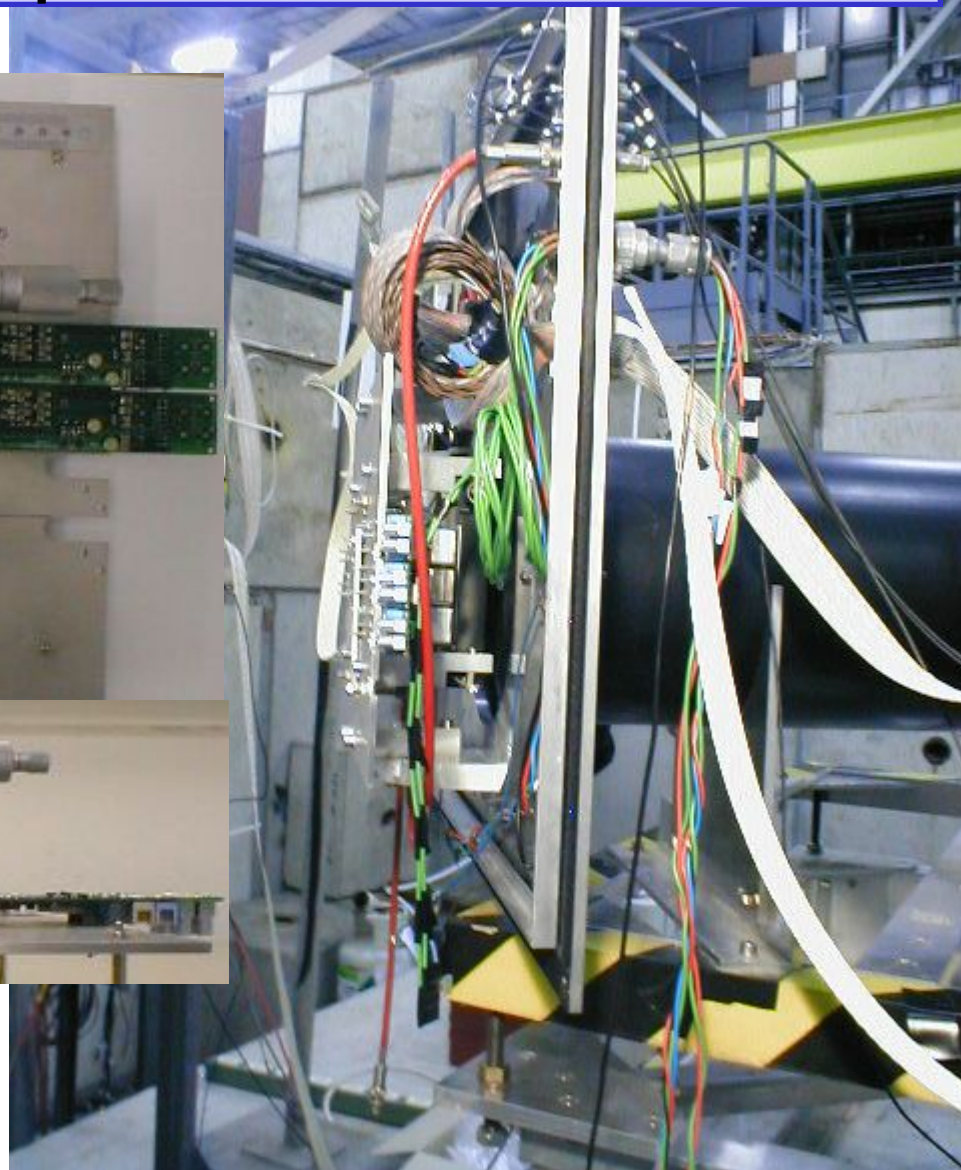
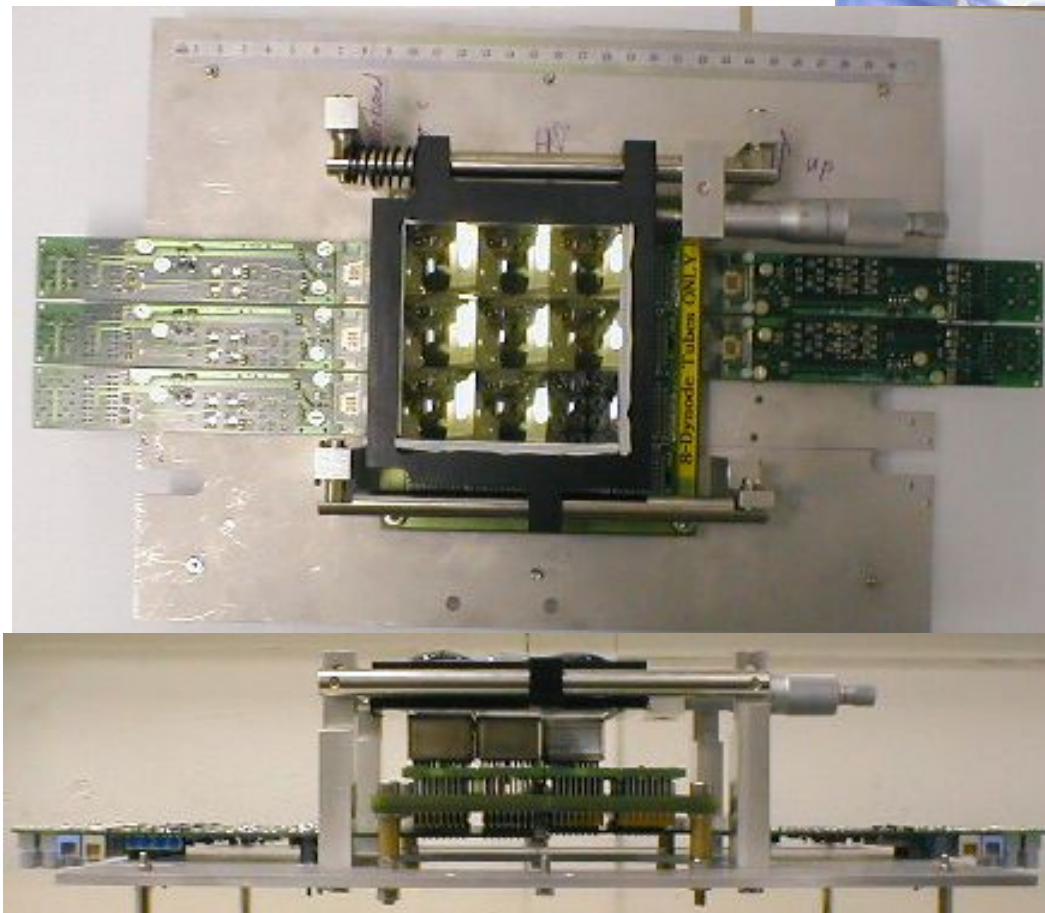
Cluster Setup



Cluster Setup: vessel

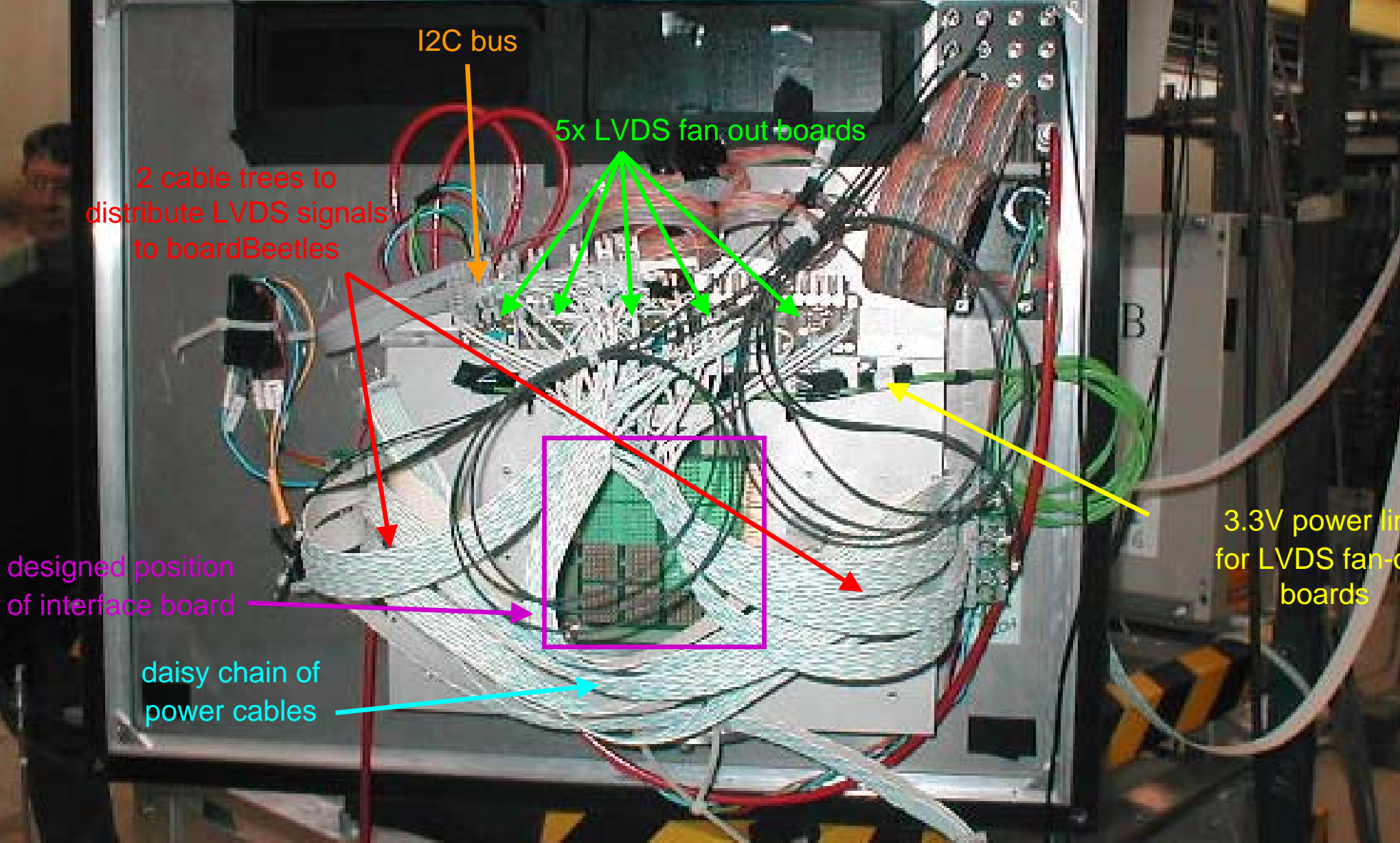


Cluster Setup: with lenses



RICH meeting, Zürich, 16.09.2003

Interface Board is missing...



I2C bus

5x LVDS fan out boards

2 cable trees to distribute LVDS signals to boardBeetles

designed position of interface board

daisy chain of power cables

3.3V power line for LVDS fan-out boards

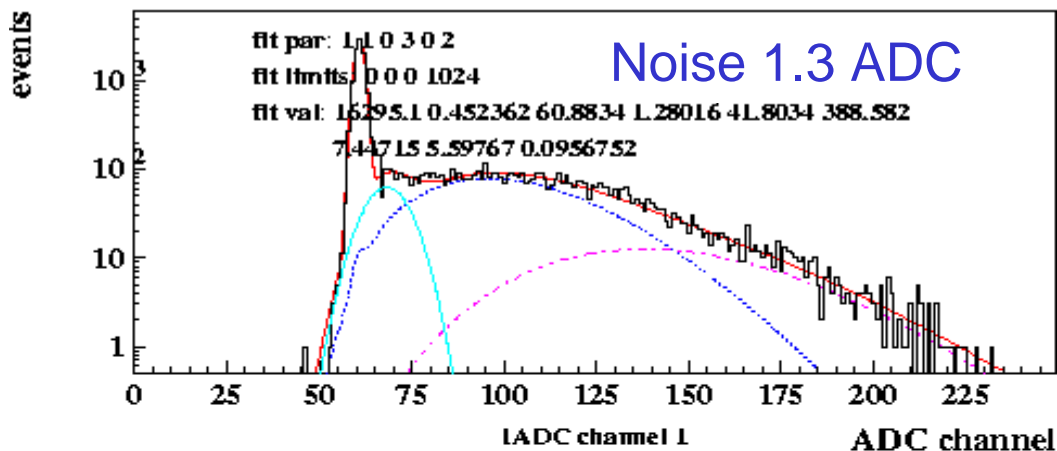
Pre-Testbeam Results

- using Heidelberg board at Edinburgh
 - noise
 - signal loss
 - comparison Beetle 1.2 / Beetle 1.2 MA0
- using boardBeetle at Edinburgh
 - first spectra
 - comparison Beetle 1.2 / Beetle 1.2 MA0
 - Saturation
 - cross-talk

Comparison using Heidelberg Board

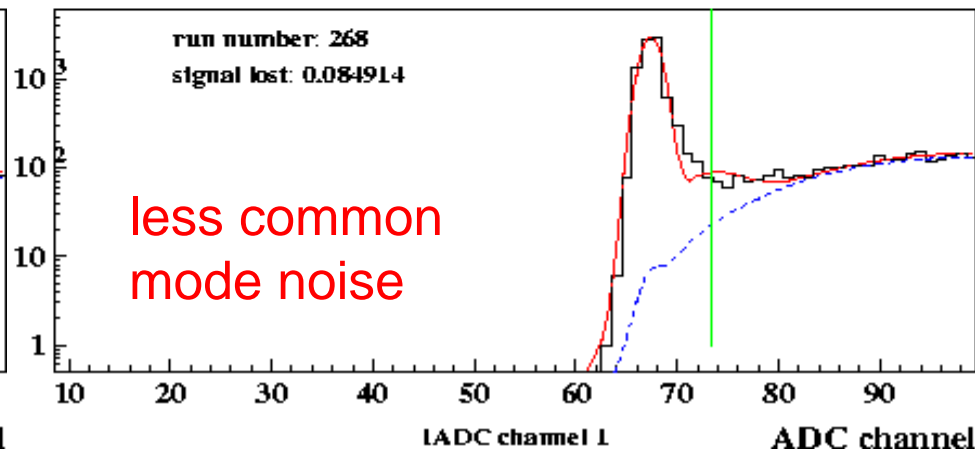
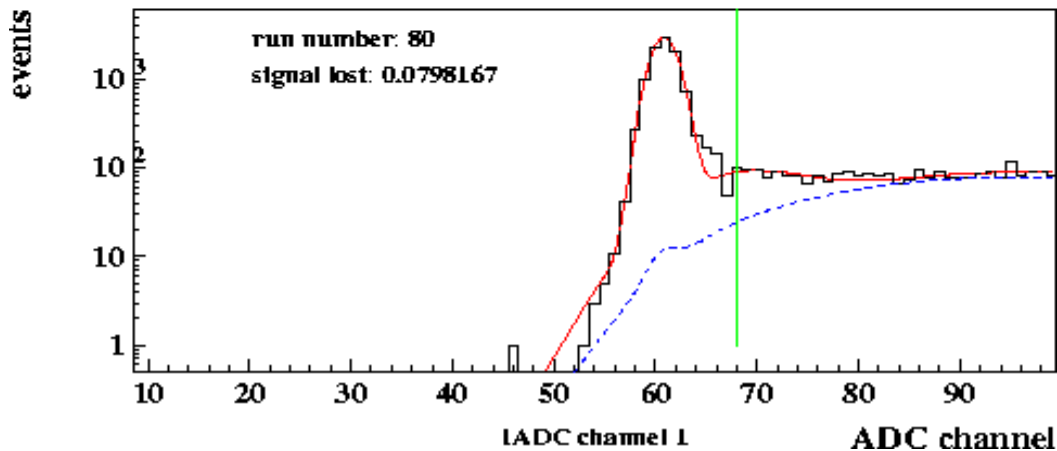
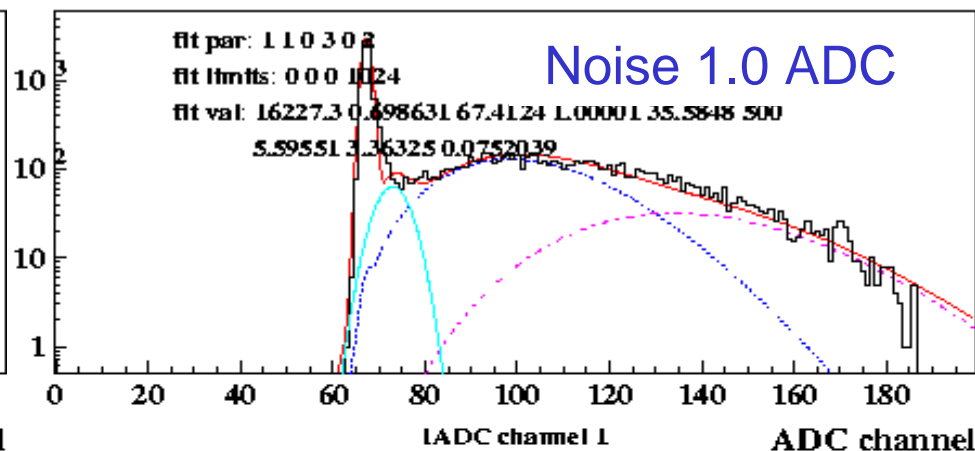
8-dynode/Beetle1.2

MaPMT Spectrum Fit with Poisson and 1st Dynode Effects

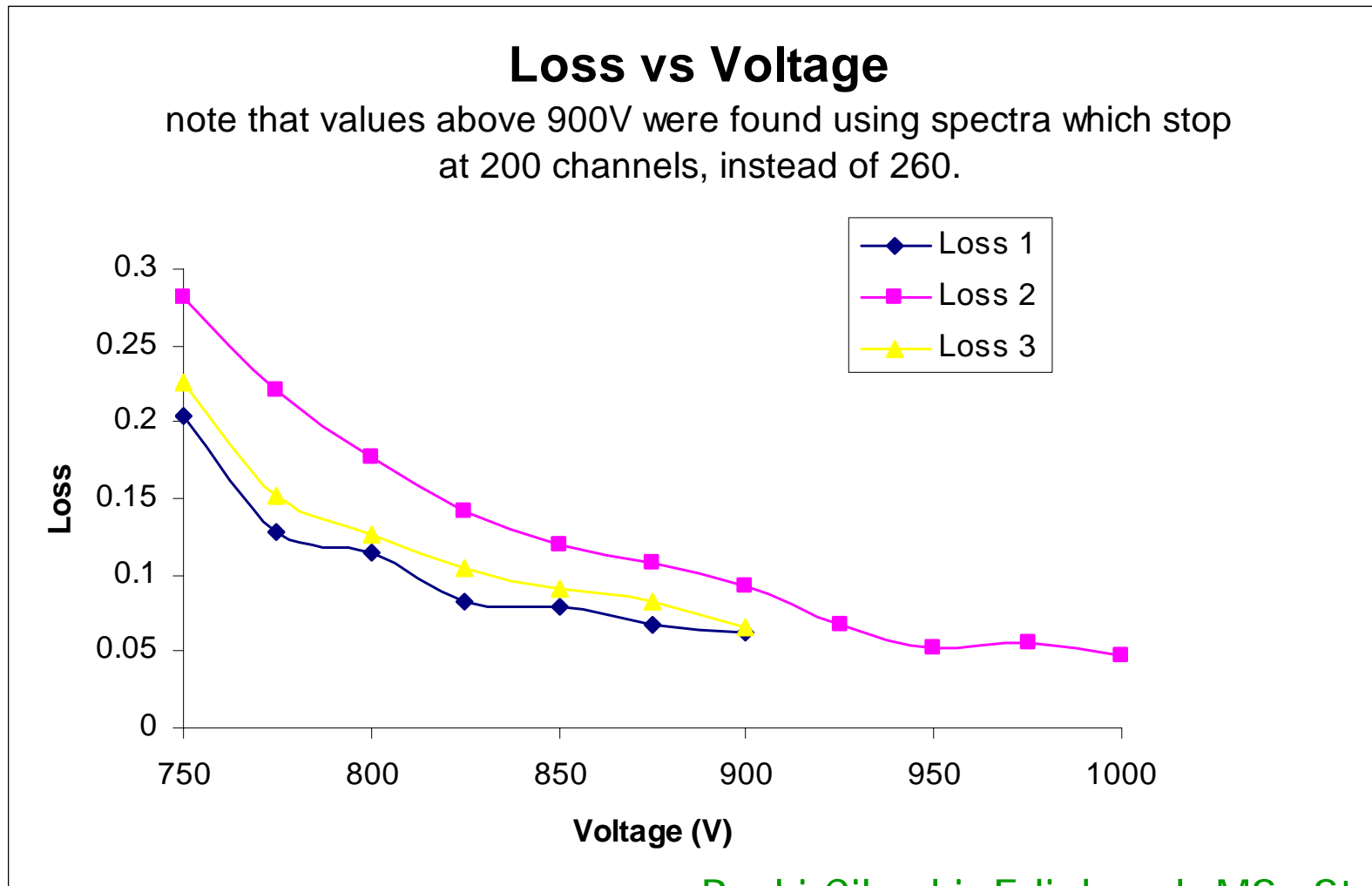


12-dynode/BeetleMA0

MaPMT Spectrum Fit with Poisson and 1st Dynode Effects



Signal Loss Study

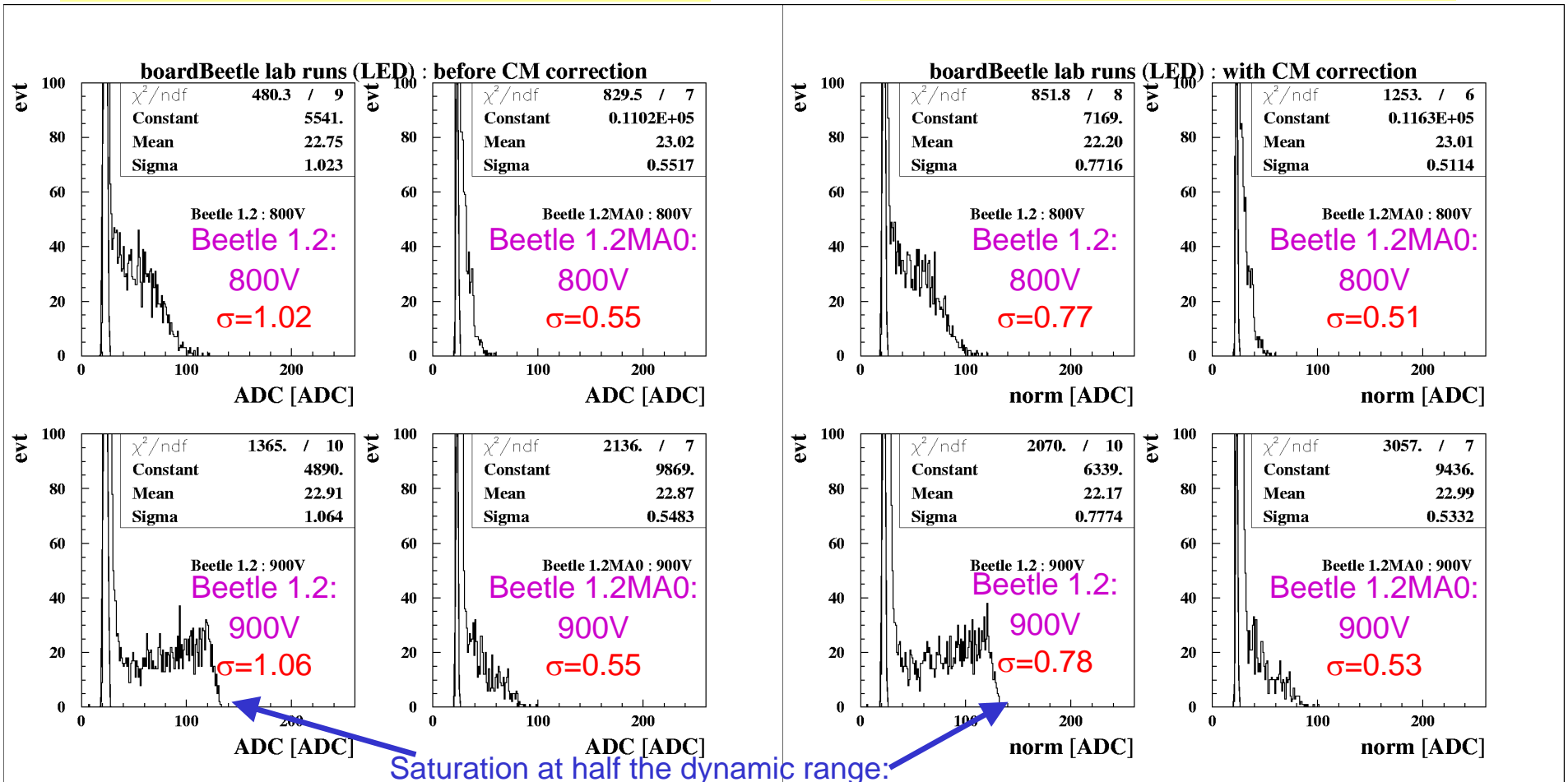


Becki Cikoski, Edinburgh MSc Student

First Spectra with boardBeetle

before CM correction

after CM correction



Saturation

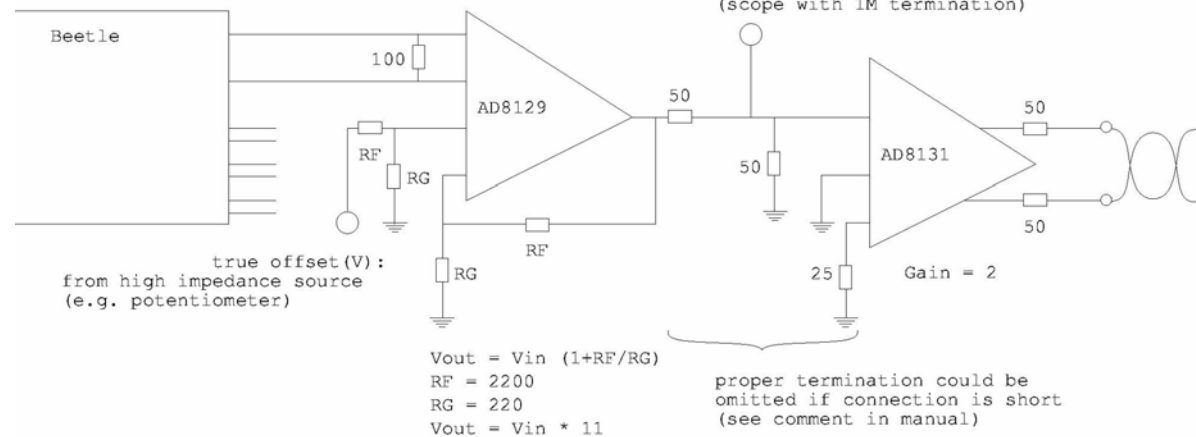
□ A) differential amplifier

– gain 10 seems too much for our signals

– easy fix:

- gain 5
- remove serial 50Ω
- total gain maintained
- dynamic range doubled

Board Beetle (4 channels):
+-5V supplies with 100nF, 10uF
buffering are omitted in the drawing



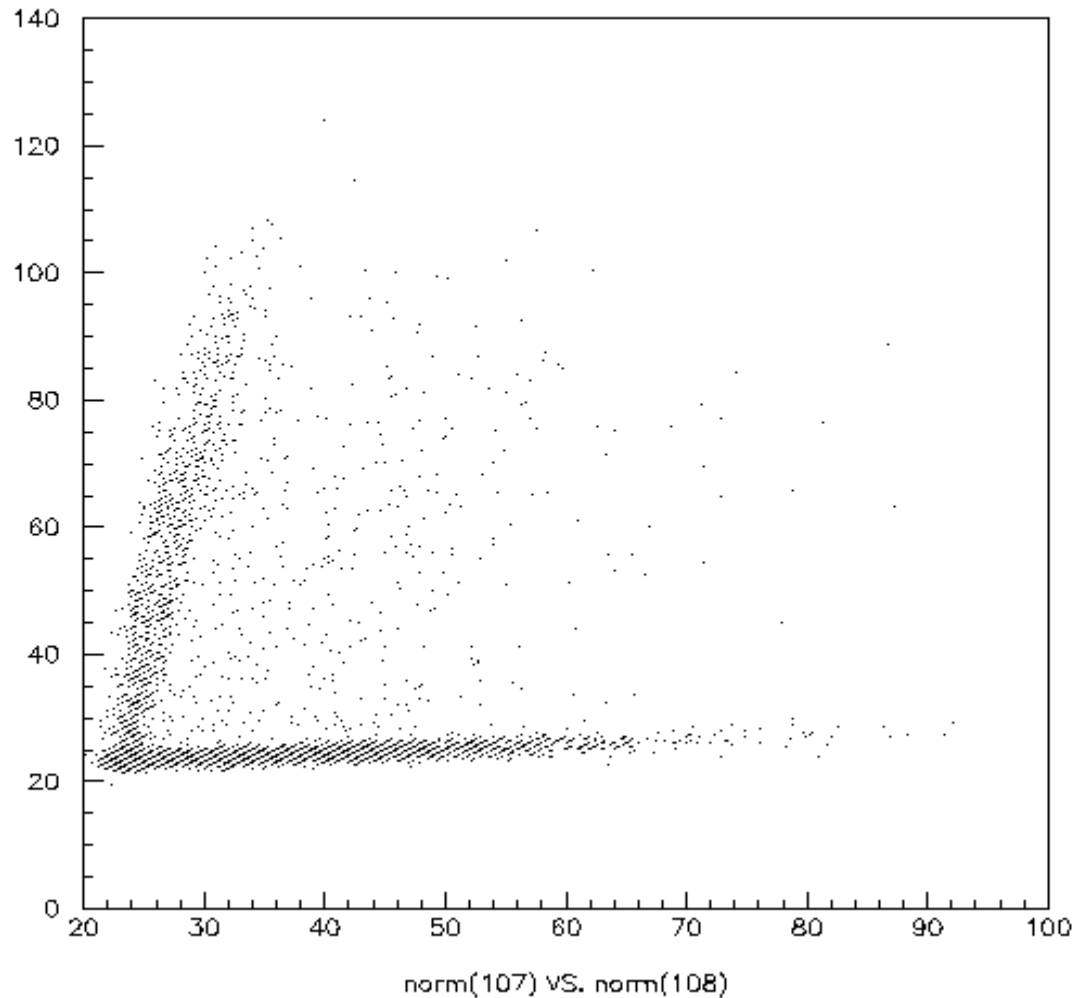
□ B) FED

– Edinburgh FED was configured **single-ended, unipolar**

– conversion to **differential OK**, but still **unipolar (no level shifters)**,
i.e. **0...0.75V** instead of **-0.75...0.75V** → 8-bit → 7-bit reduction

□ ... at least the two devices match...

Cross-talk in LED Study

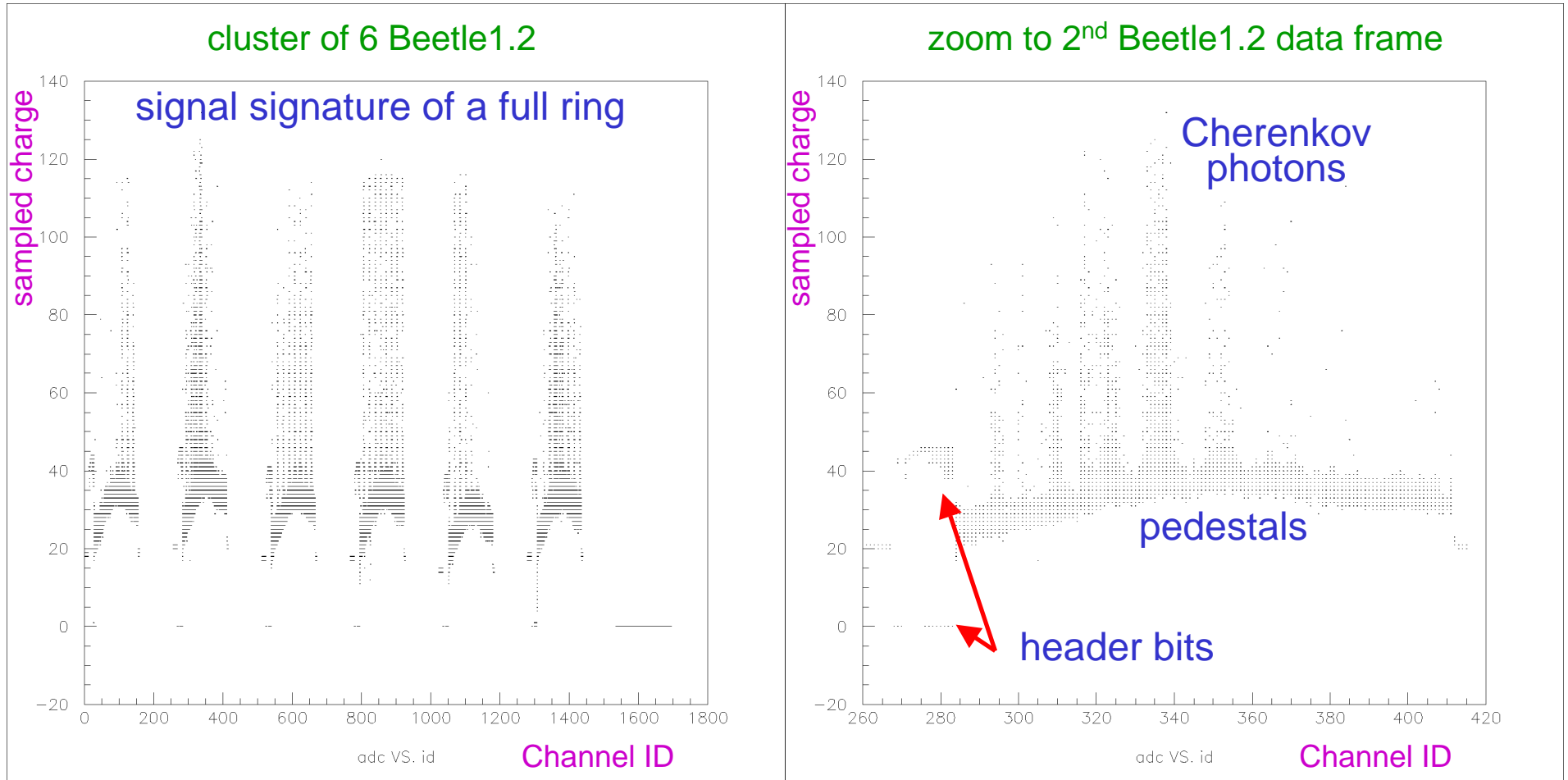


- Crosstalk
 - two adjacent channels
 - ~8 %
 - worst found case
 - actual worst case?

Preliminary Testbeam Results

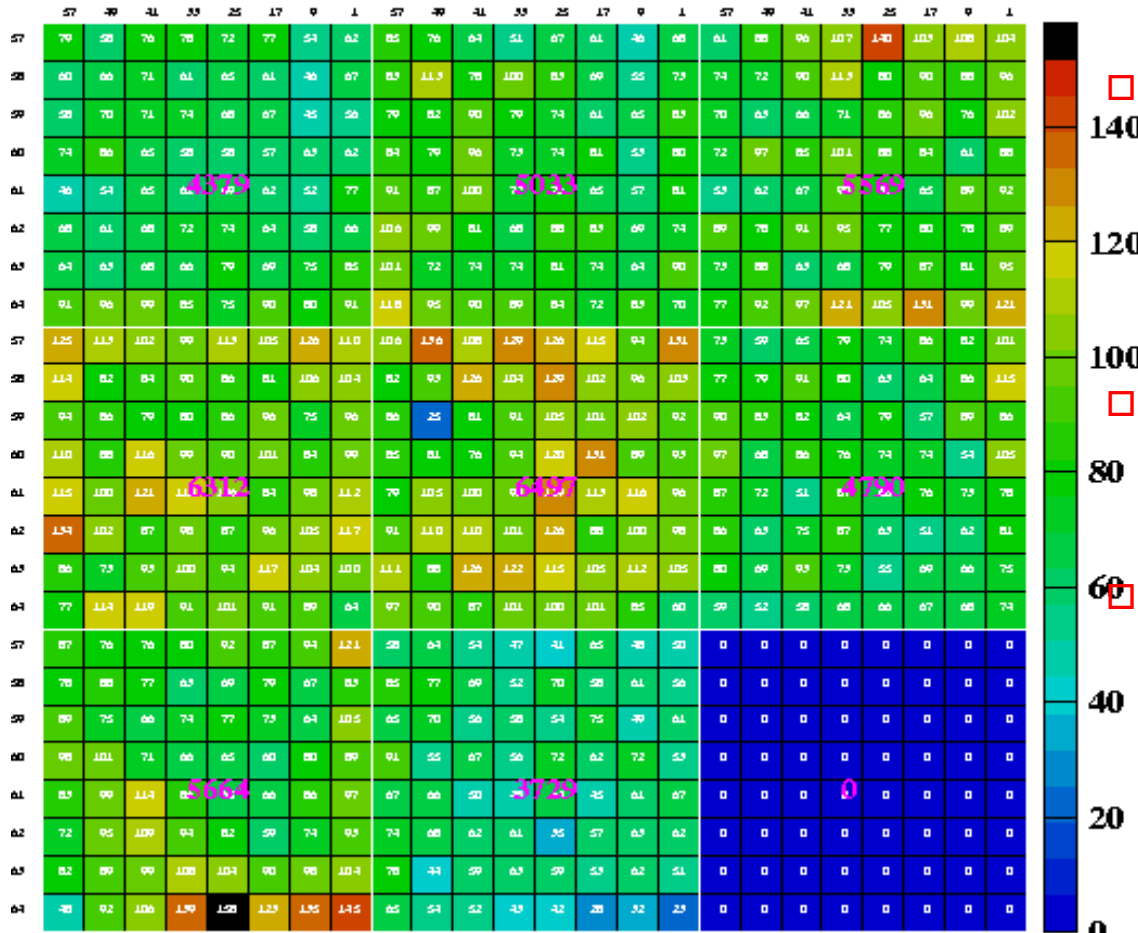
- first measurements with cluster: 8 8-dynode MaPMT & 5 Beetle1.2
 - data frames, LED light, adjustment of pixel map, first Cherenkov ring
- timing optimisation
- noise level and CM suppression
 - cluster of 8-dynode MaPMT & Beetle1.2
 - half cluster of 12-dynode MaPMT & Beetle1.2MA0
- cross-talk study
 - first approach to correct
- photon yields:
 - Air: 960 mbar
 - N₂: 960 mbar
 - CF₄: 80 mbar , 800 mbar

Data Frames



LED Light

2003/09/05 00.05

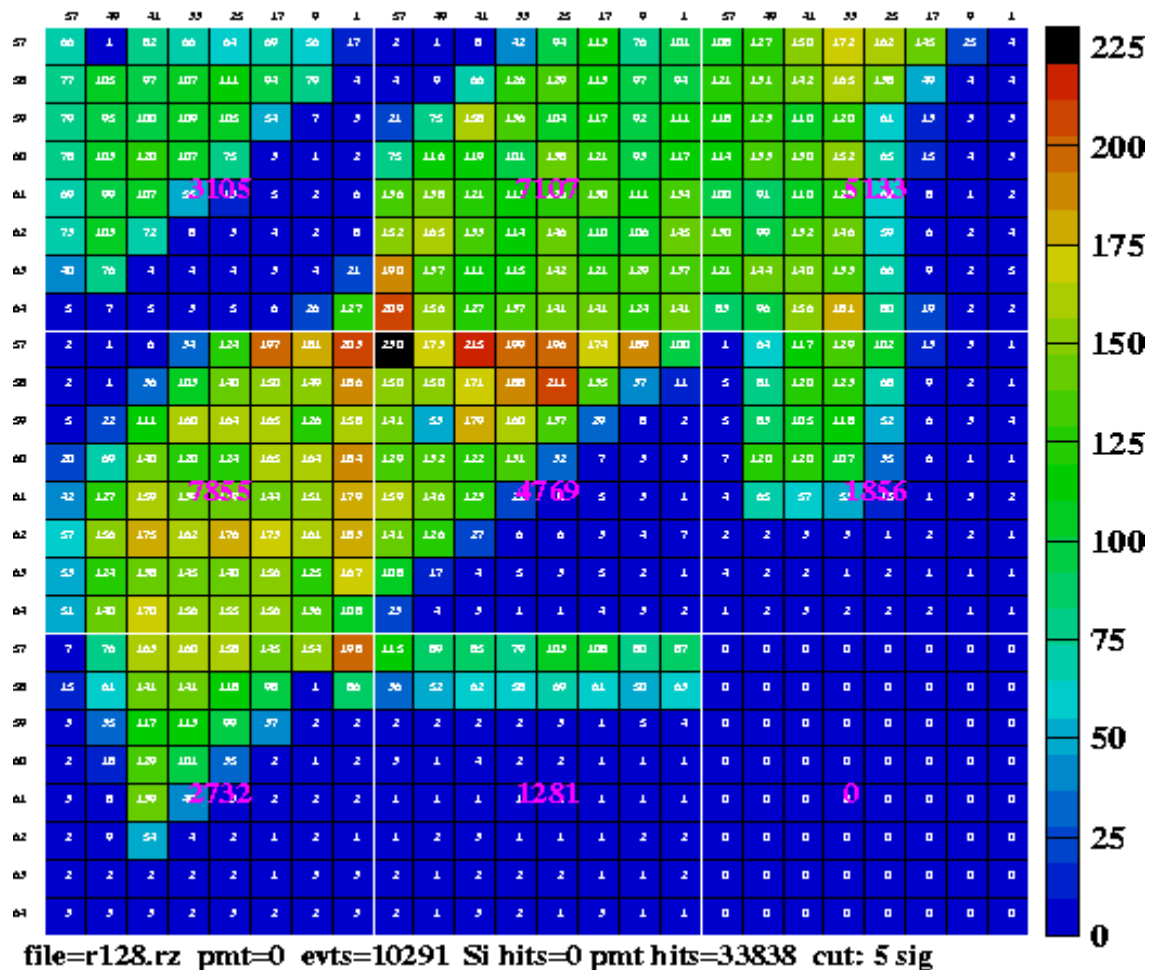


file=r12Lrz pmt=0 evts=6754 Si hits=0 pmt hits=41973 cut: 5 sig

- 8 8-dynode MaPMTs
 - 6 new + 2 existing
 - all working
 - HV = 800 V
- 5 boardBeetle 1.2
 - all working
- Analysis
 - in progress
 - gain variation look okay

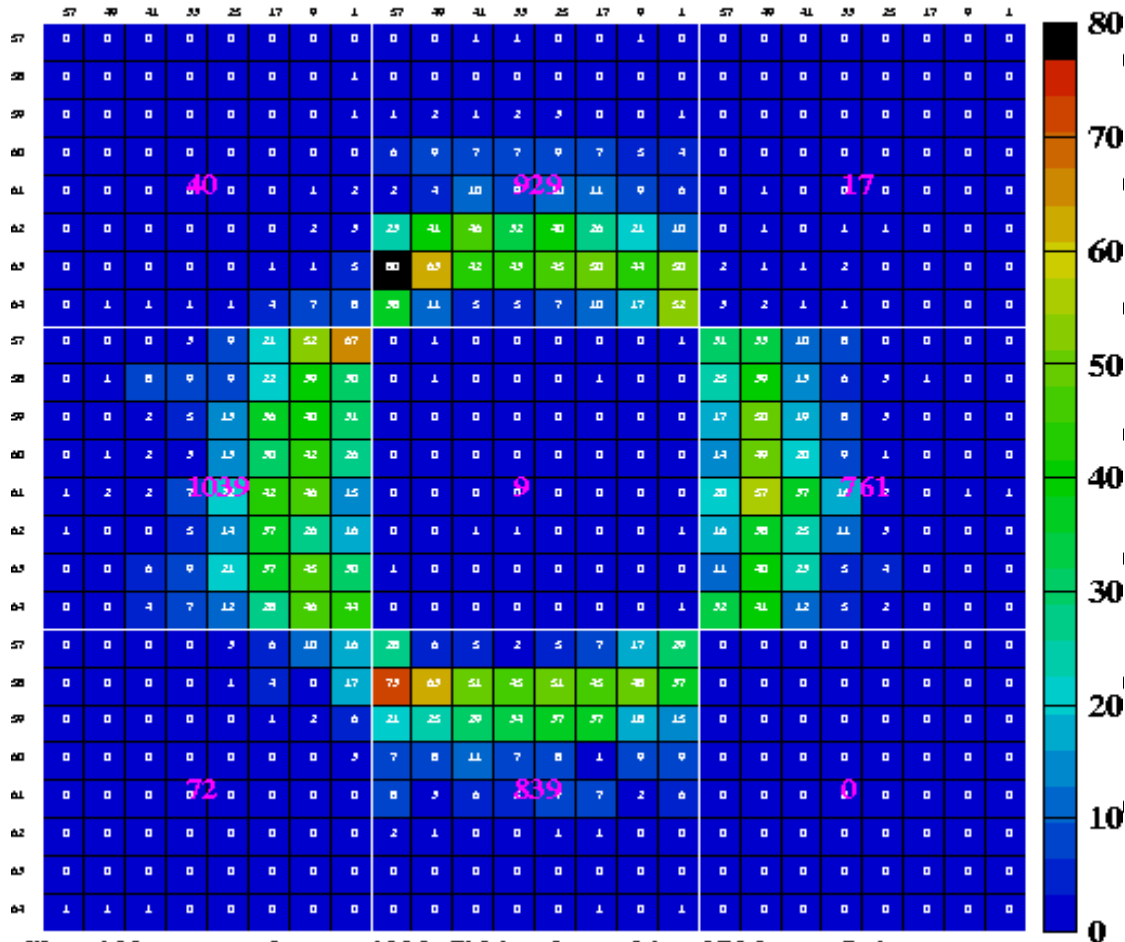
Pixel Map

2003/09/05 01.16



First Cherenkov Light

2003/09/04 19.28

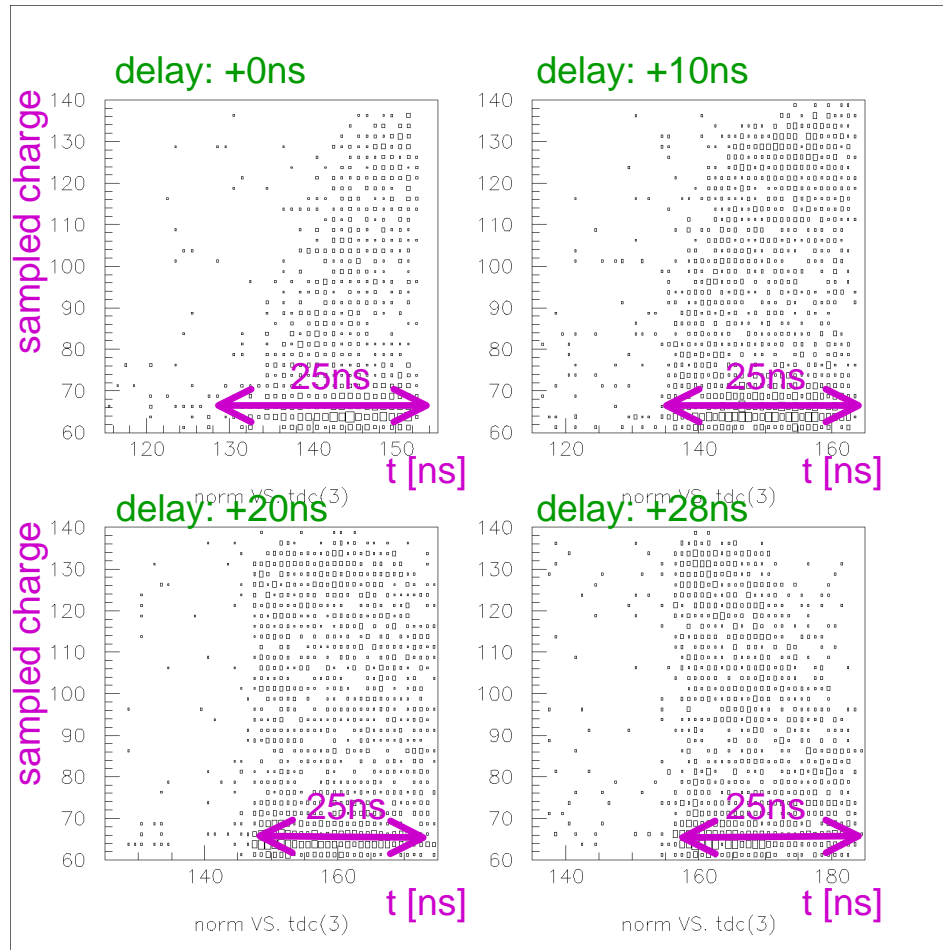


file=r133.rz pmt=0 evts=1223 Si hits=0 pmt hits=3706 cut: 5 sig

- 8 MaPMTs
 - no lenses
 - HV = 800 V

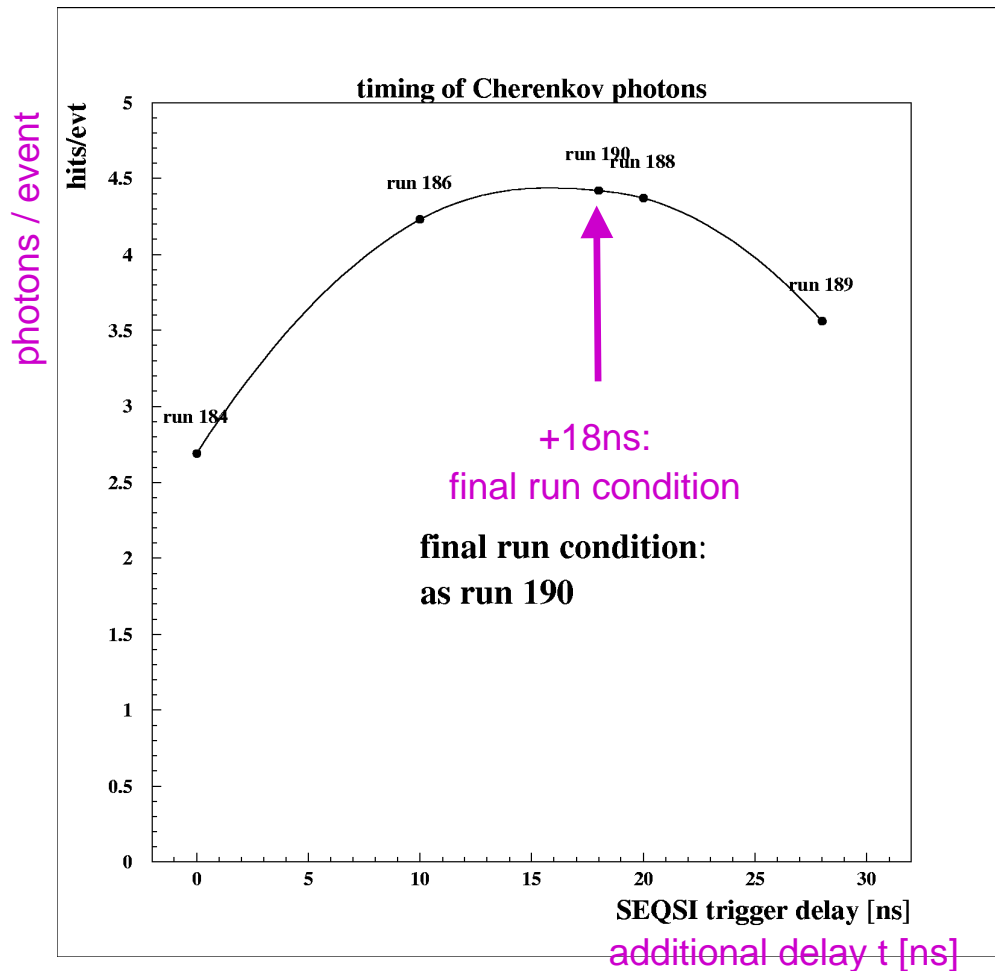
- Cherenkov Ring
 - Air 960 mbar
 - 3.6 pixels / event with 5 sigma cut
 - from raw data

Timing of Beam Photons



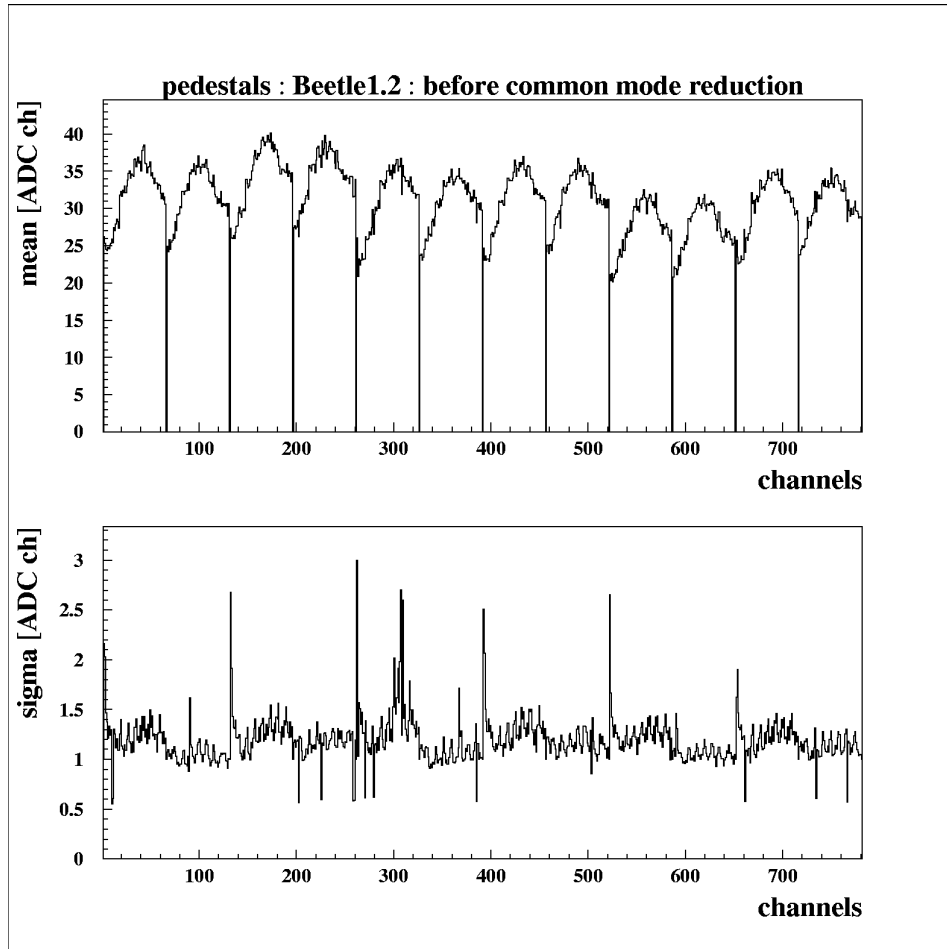
- adjusted average timing between beam photons and Beetle clock
 - 25ns jitter
 - measured by TDC
- aim to sample at peak of signal
 - adjustment for average by cable delay

Result of Timing Optimisation



- made from Cherenkov Ring
 - Air 960 mbar
 - no lenses
 - HV = 800 V
 - 8 8-stage MaPMTs
 - 5 Beetle 1.2
- narrow distribution
 - as one expects
 - indicates shape of analog pulse signals at sampler in the Beetle

Noise in Beetle1.2



- final noise level
 - after DC-offset tuning
 - after tuning of timing

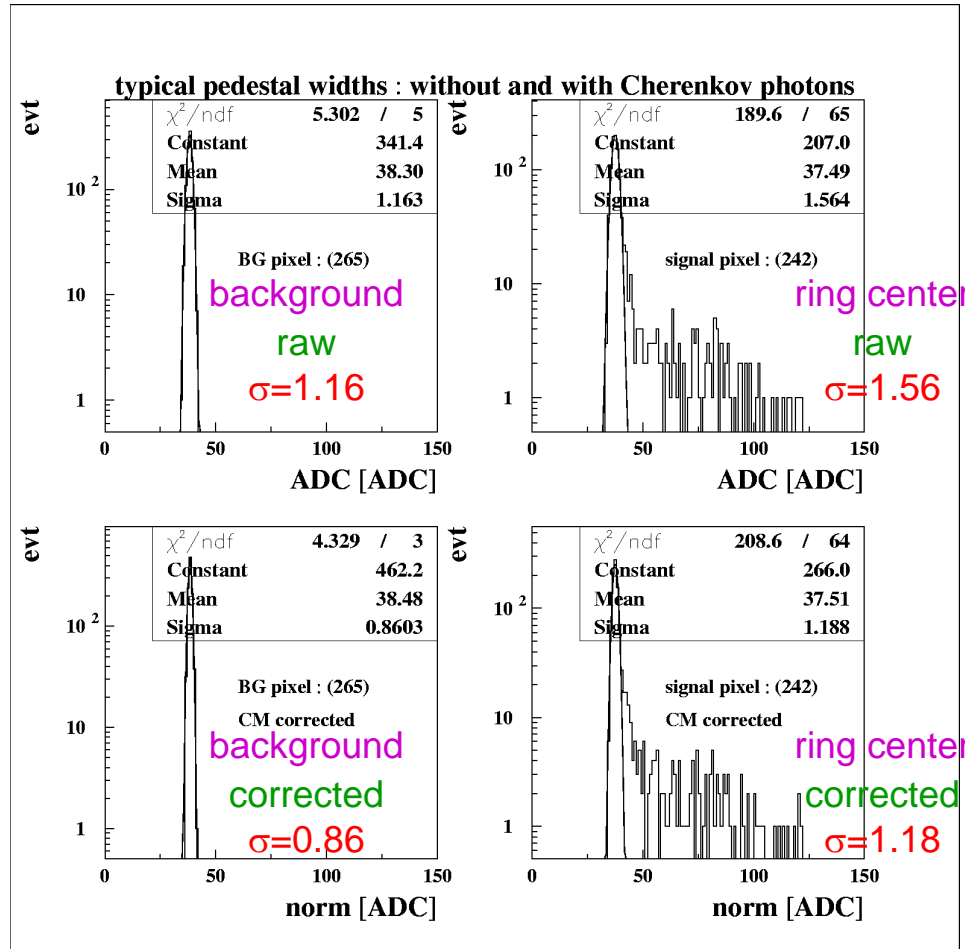
- full cluster
 - 6 boardBeetle1.2
 - 9 8-stage MaPMT

- from pedestal run
 - before CM correction

- low σ (1.0...1.5 ADC)
 - no CM problem

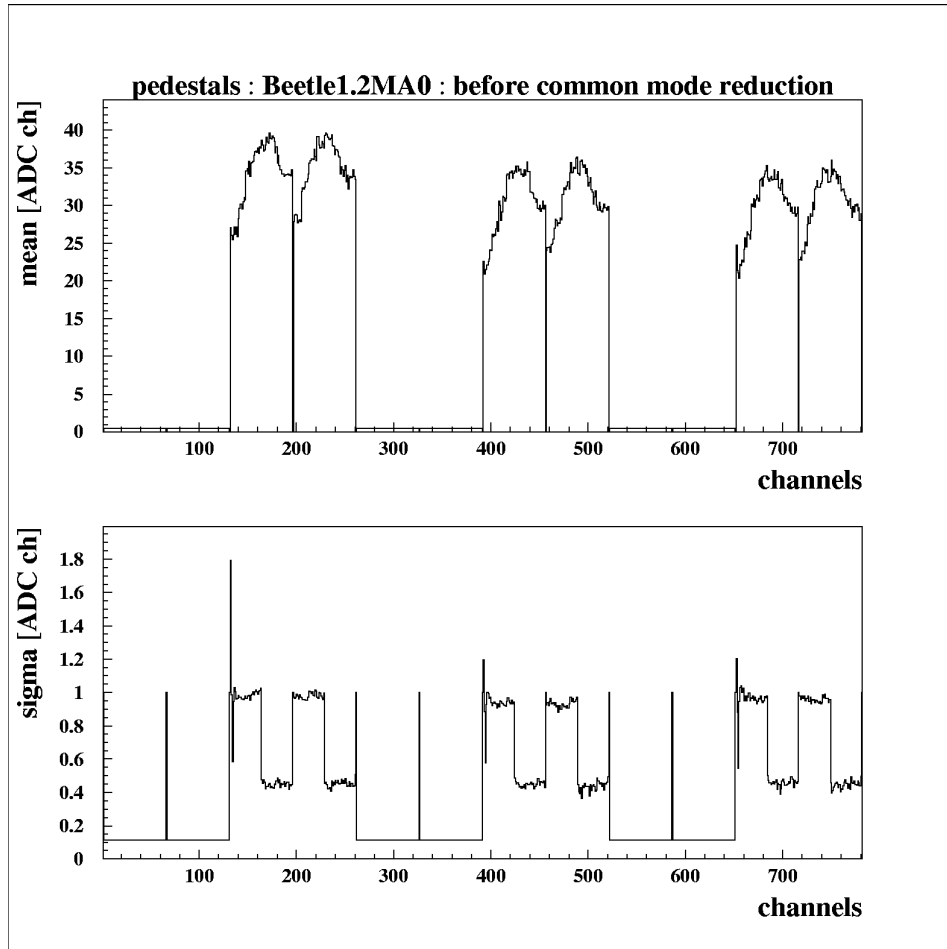
- uniform offsets

CM Suppression in Beam Run



- from CF_4 beam run
 - HV= 800V
 - cluster of 8-stage MaPMT with Beetle1.2
- without cross-talk suppression
 - pedestals of ring pixels broadened

Noise in Beetle1.2MA0



- final noise level
 - after DC-offset tuning
 - after tuning of timing

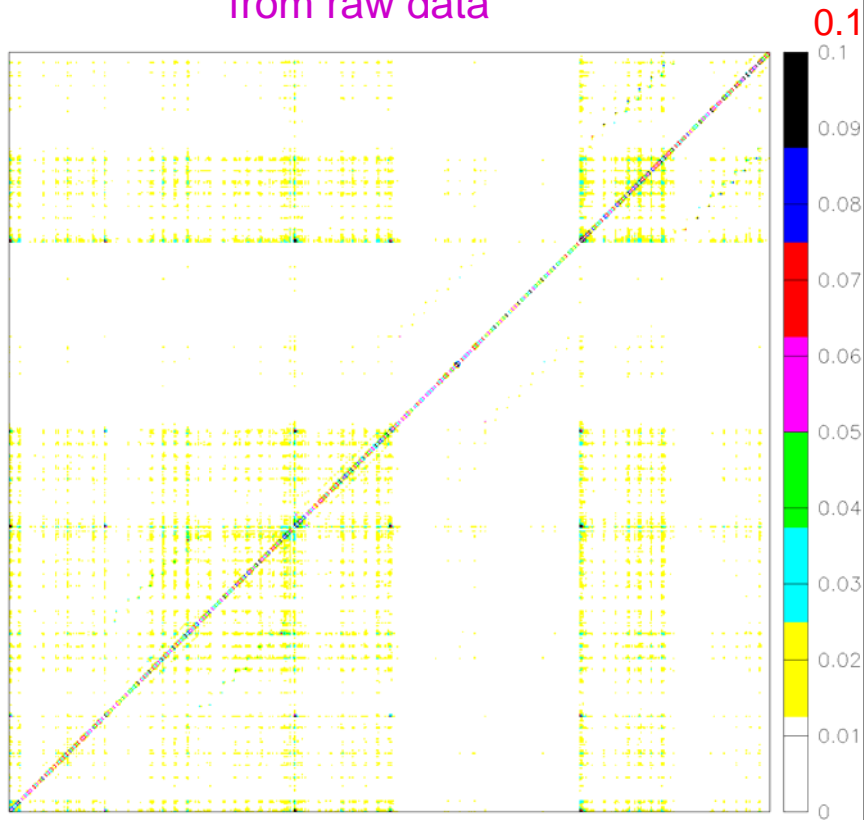
- half cluster
 - 3 boardBeetle1.2MA0
 - 6 12-stage MaPMT

- from pedestal run
 - before CM correction

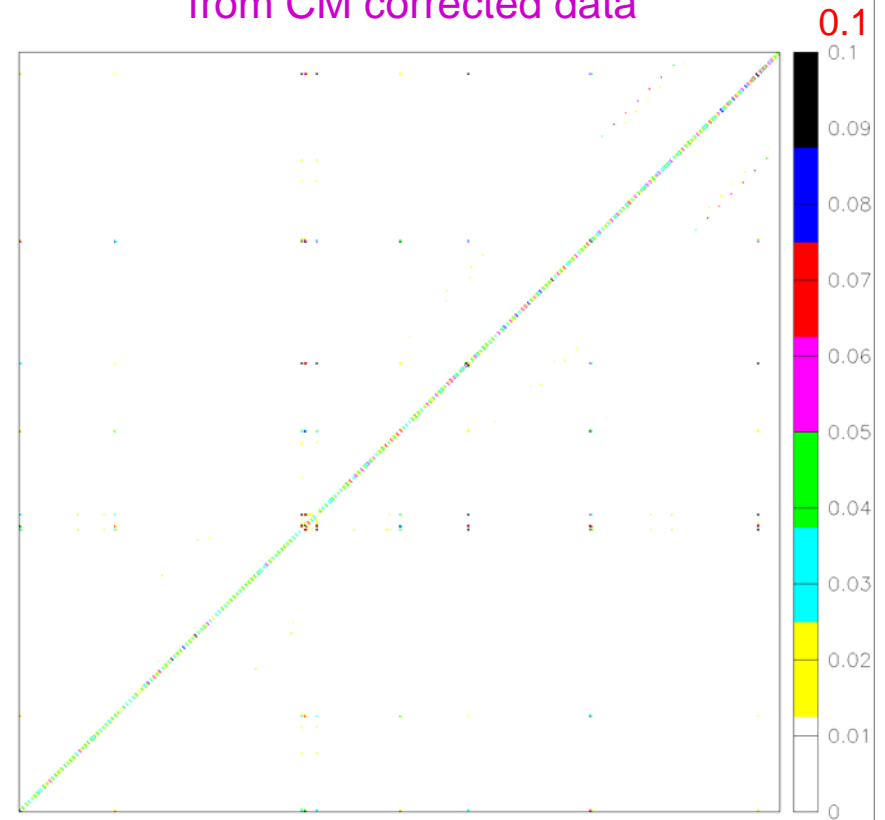
- lower σ for charge divider (1.0 ADC)
- even lower σ for attenuator (0.5 ADC)
- uniform offsets

Cross-talk I: Correlation Coeff.

from raw data

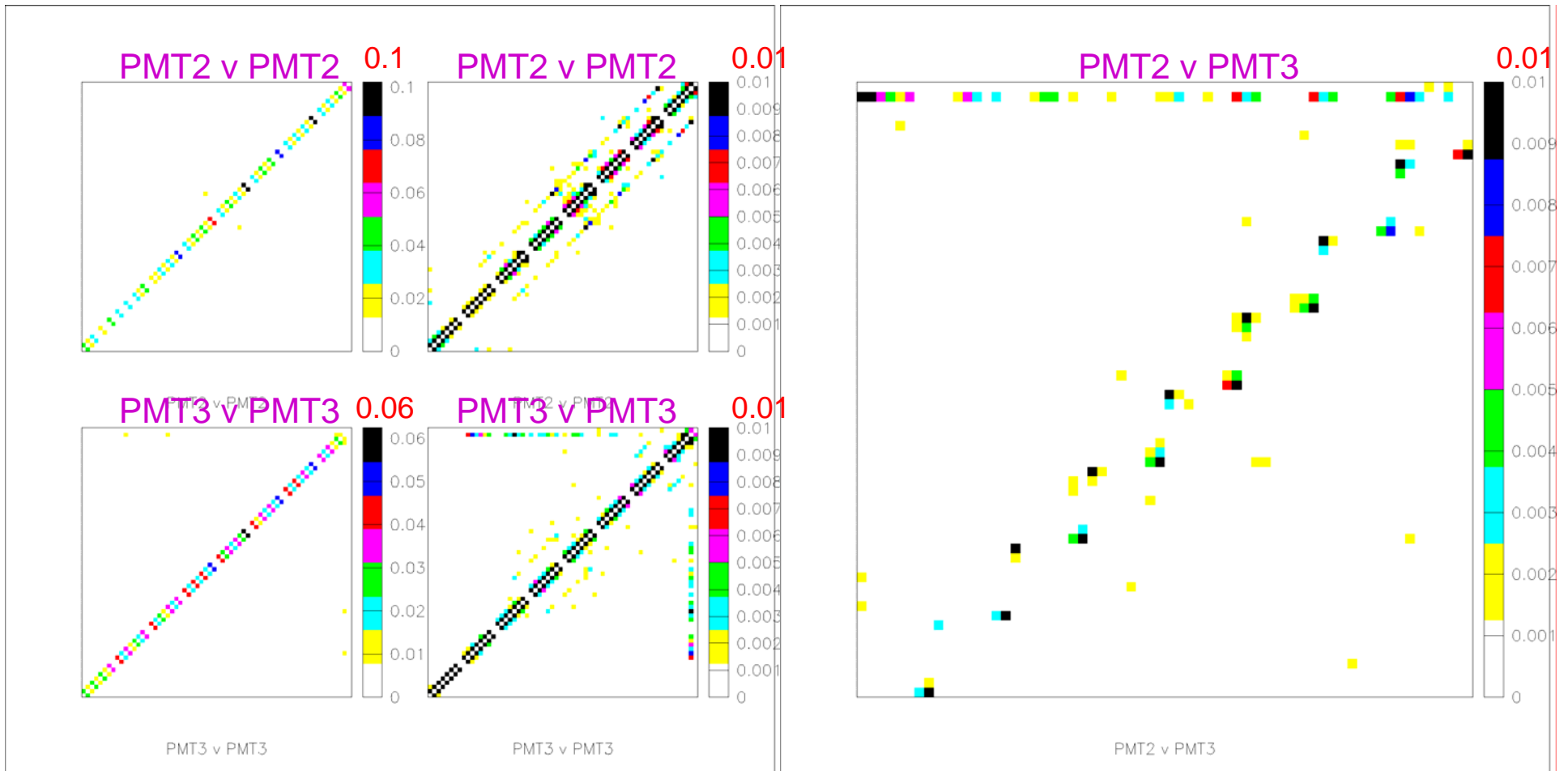


from CM corrected data



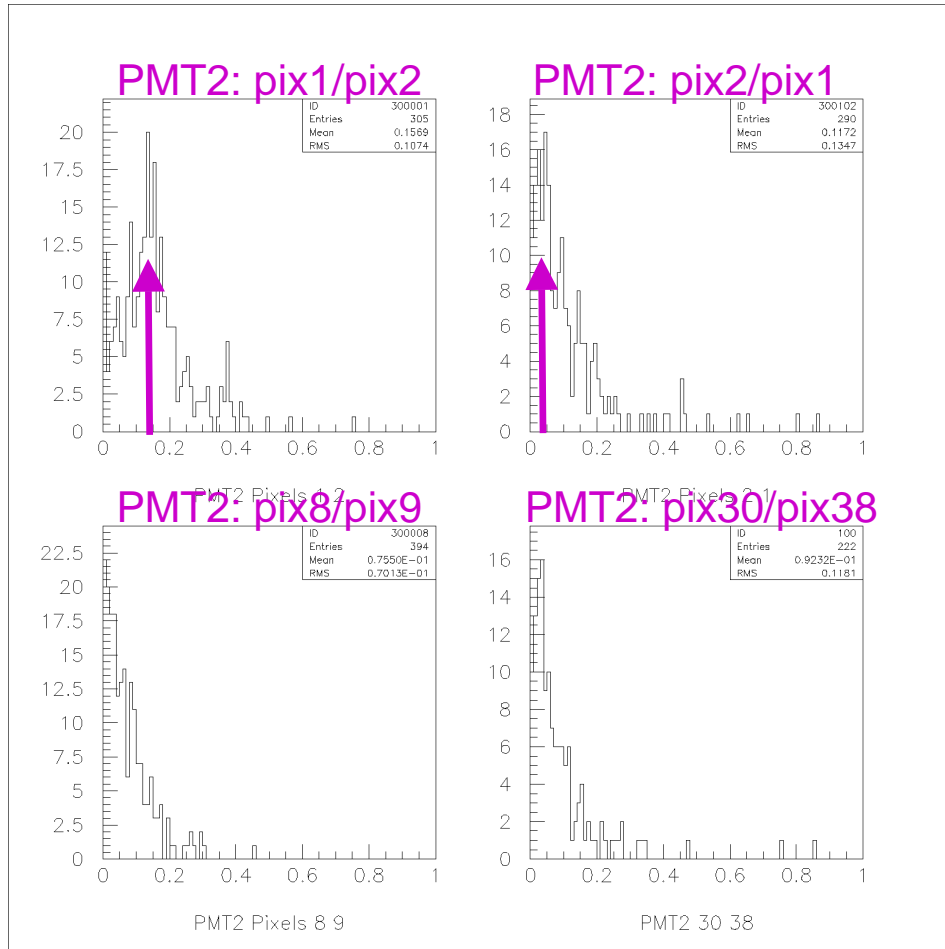
Study by Andrew Pickford

Cross-talk II: tubes on one board



Study by Andrew Pickford

Cross-talk III: charge ratios



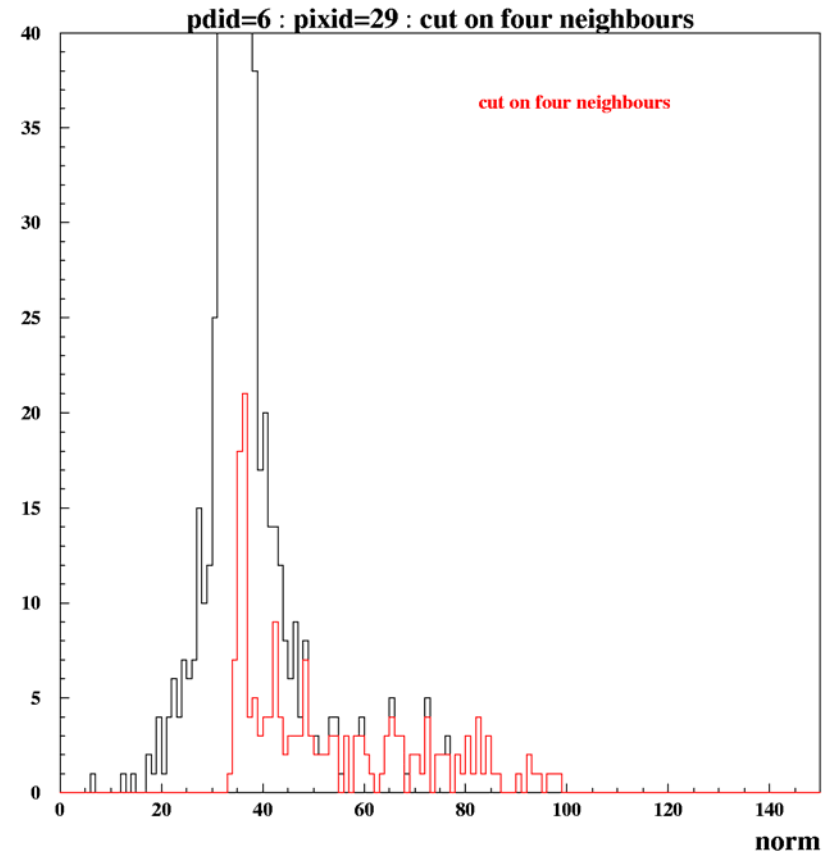
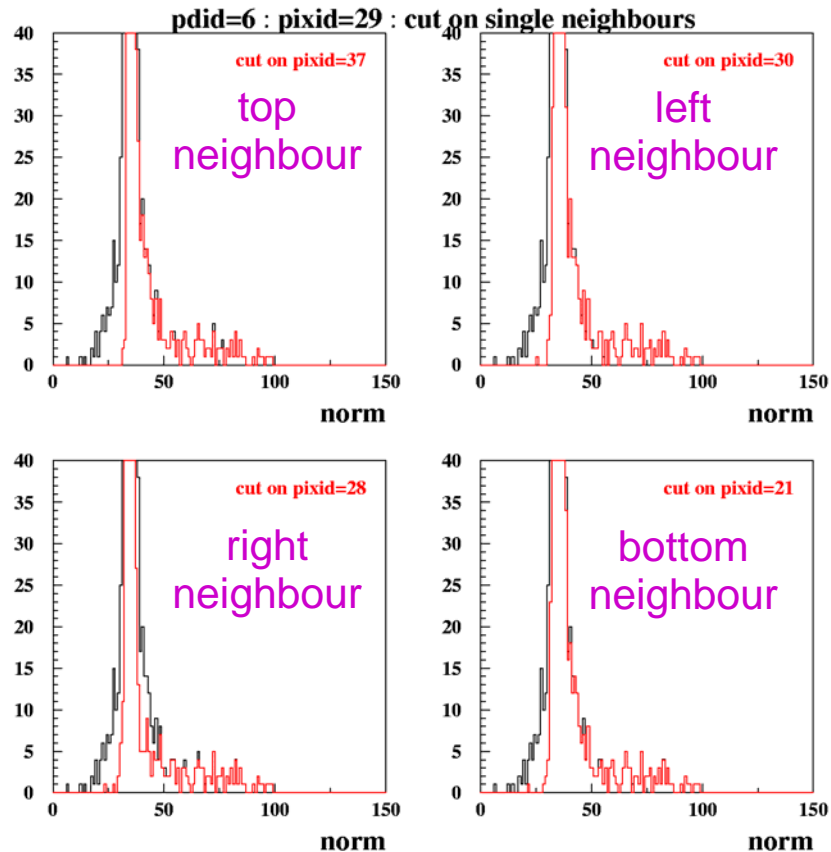
- Cross-talk is:
 - horizontal
 - asymmetric
 - ~13% right → left
 - ~4% left → right
 - not vertical
- Suspects:
 - tracks in or on boardBeetle
 - pitch adaptor

Study by Andrew Pickford

Cross-talk reduction: first approach

cut on one neighbour

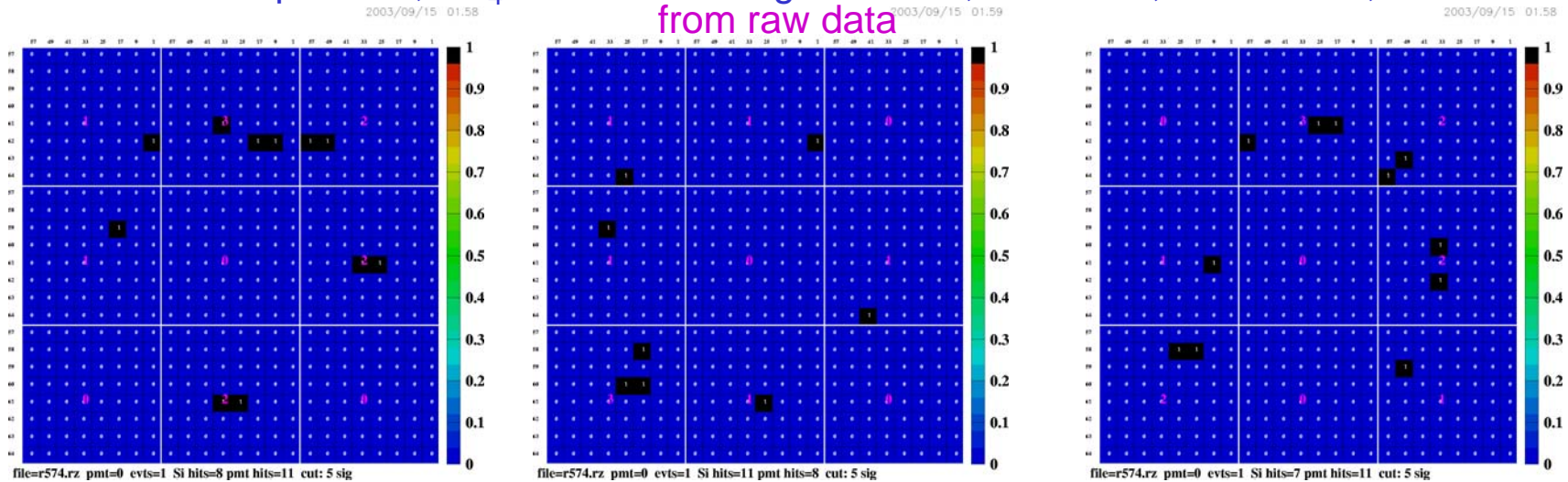
cut on four neighbours



□ LED photons: 8-stage MaPMT, Beetle1.2; with lenses, -800V

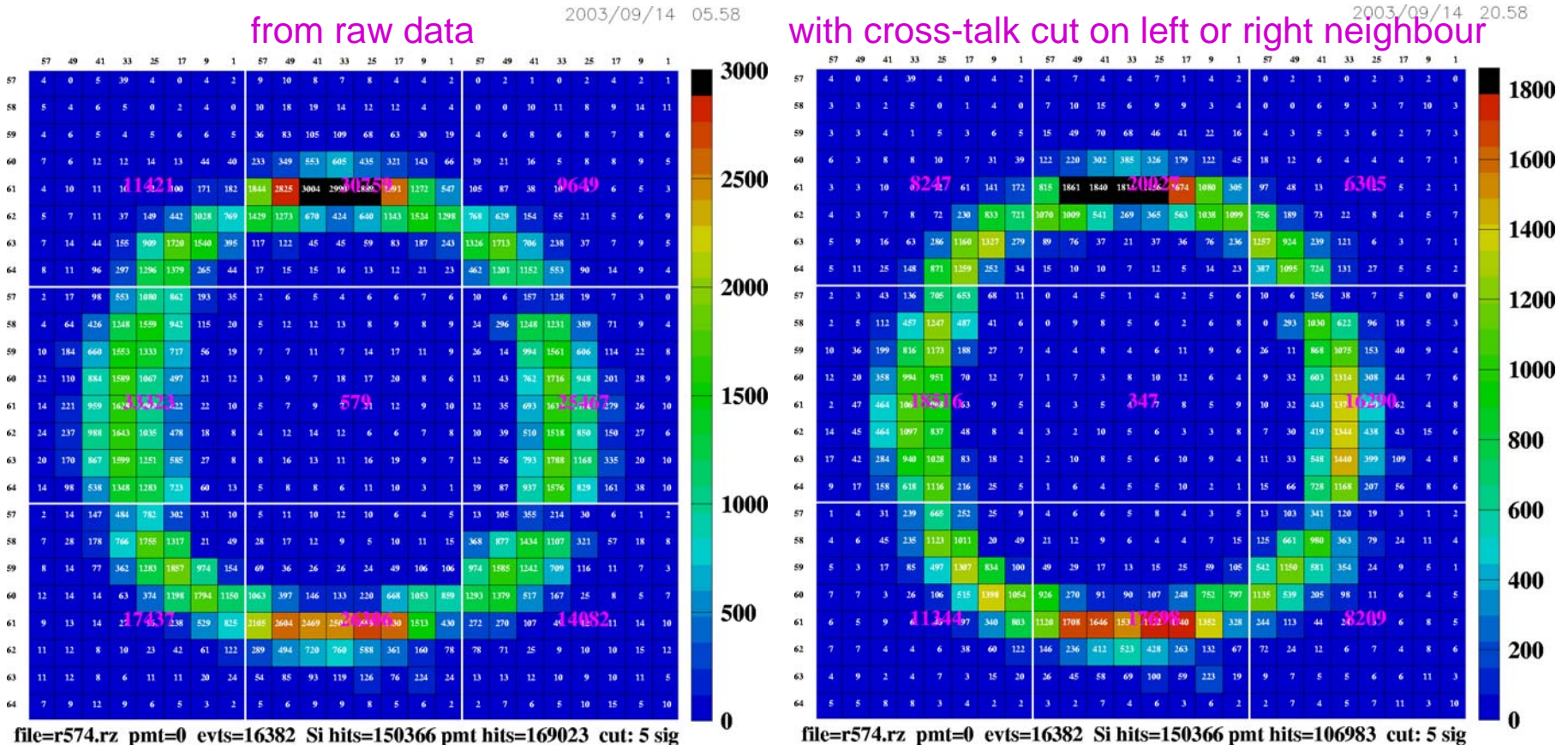
Single Events

- Cherenkov photons, CF₄ 800mbar: 8-stage MaPMT, Beetle1.2; with lenses, -900V



Cherenkov Rings I

- Cherenkov photons, CF₄ 800mbar: 8-stage MaPMT, Beetle1.2; with lenses, -900V

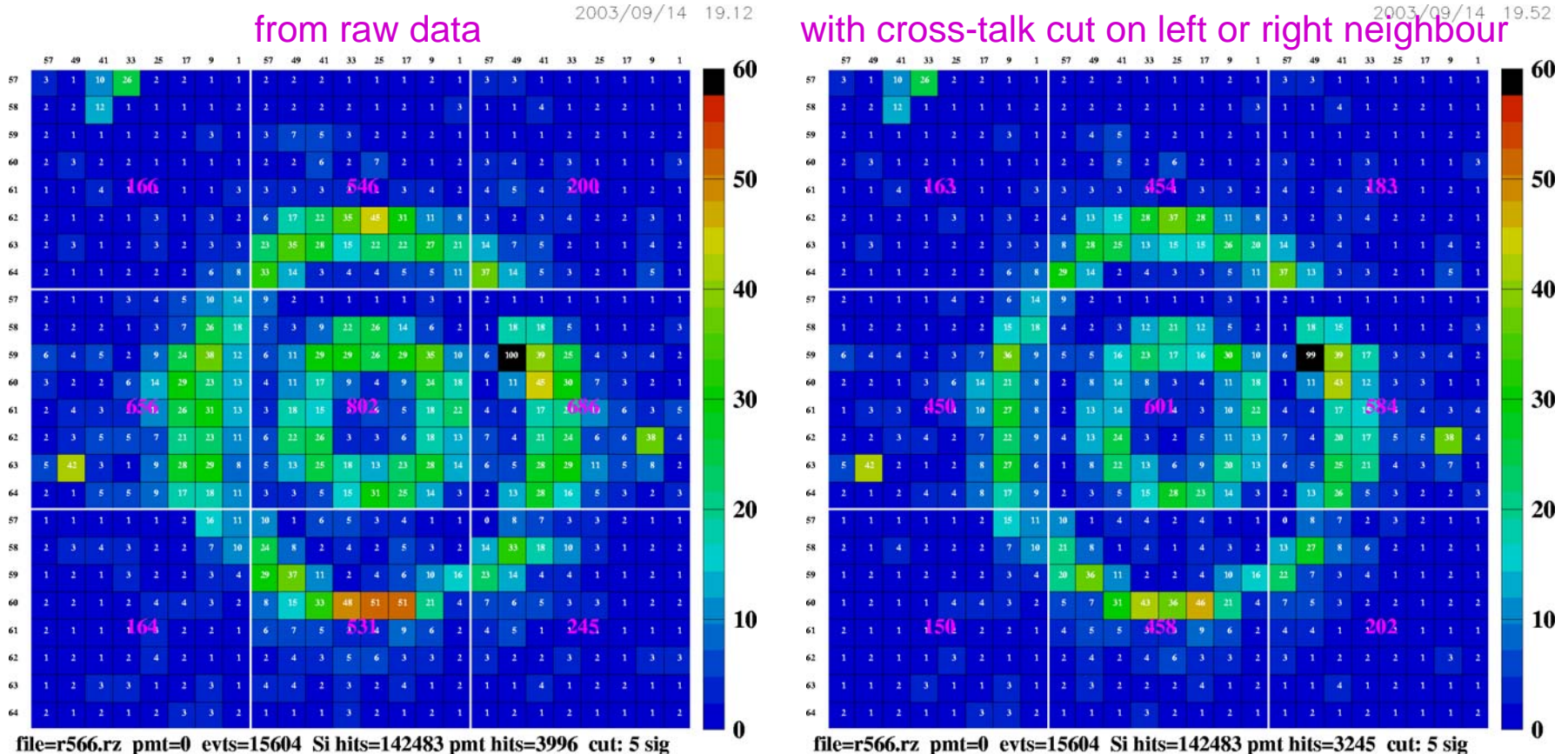


10.3 photons/evt

beam: -10 GeV → mostly π^- 6.5 photons/evt

Cherenkov Rings II

- Cherenkov photons, CF₄ 80mbar: 8-stage MaPMT, Beetle1.2; with lenses, -900V

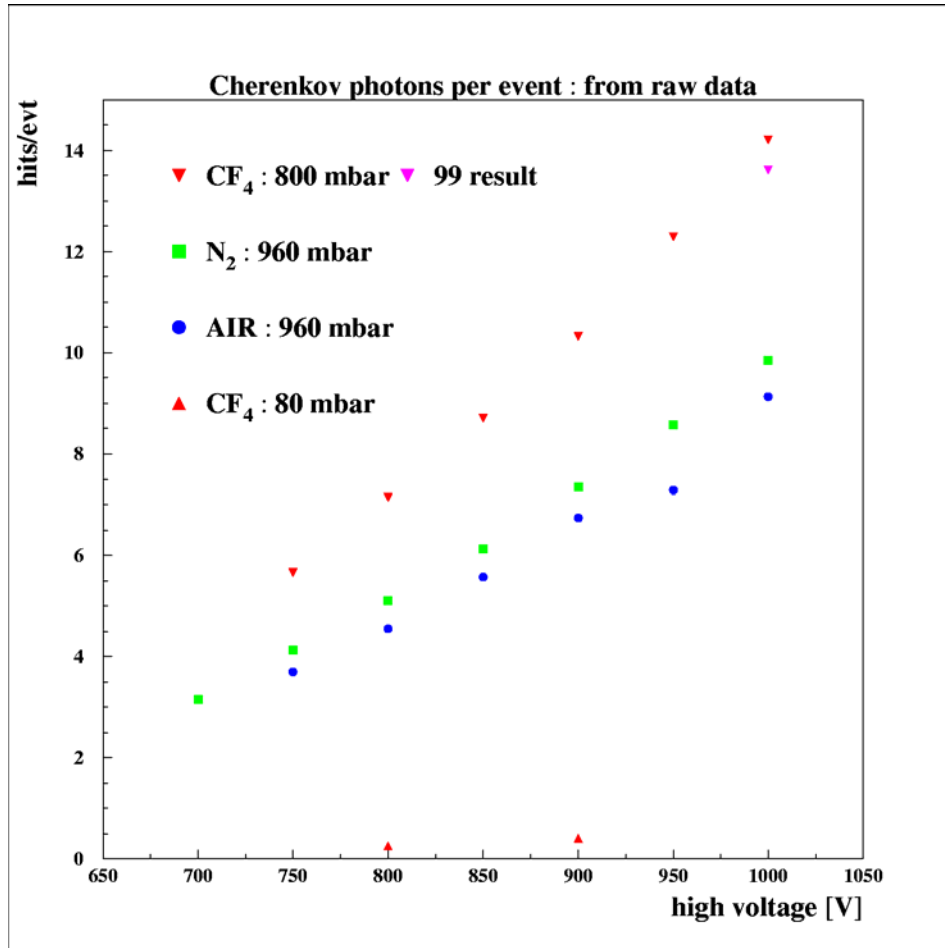


0.26 photons/evt

beam: -10 GeV $\rightarrow \pi^-$ and e^-

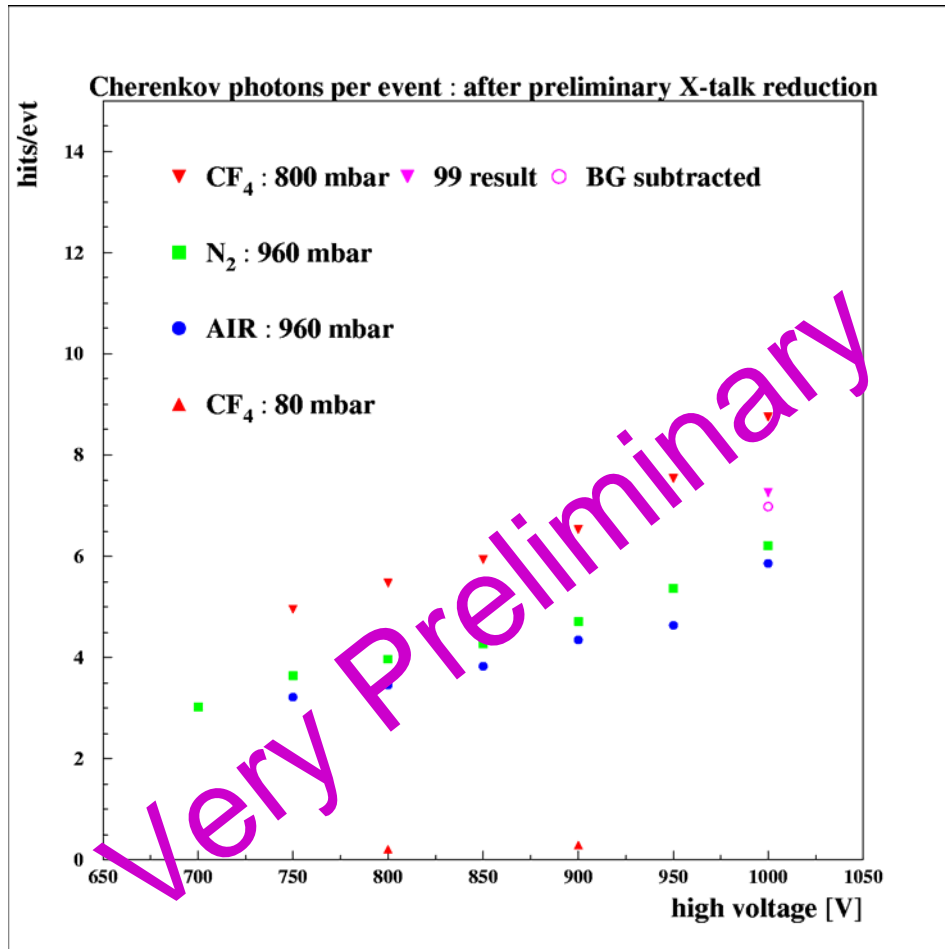
0.21 photons/evt

Preliminary Photon Yield



- photon yields from raw data:
 - no CM correction
 - no cross-talk correction
 - 9 8-stage MaPMT – full ring (N₂: only 8 tubes)
 - Beetle1.2
 - with lenses
 - '99 result CM corrected

Preliminary Photon Yield



- photon yields from data with simple minded algorithm for cross-talk reduction:
 - no CM correction
 - cross-talk correction over-corrects
 - algorithm still questionable
 - 9 8-stage MaPMT – full ring (N₂: only 8 tubes)
 - Beetle1.2
 - with lenses

- further increase expected due to:
 - CM correction
 - better cross-talk correction

Unfinished Business I

2003/09/14 21.16

□ cluster of 6 12-stage MaPMT & 3 boardBeetle1.2MA0:

- time too short to get it to run properly
- only ring fragments

□ measure with single base

- to exclude cross-talk from bleeder board

□ measure with Hamamatsu bleeder board

- check for load effects

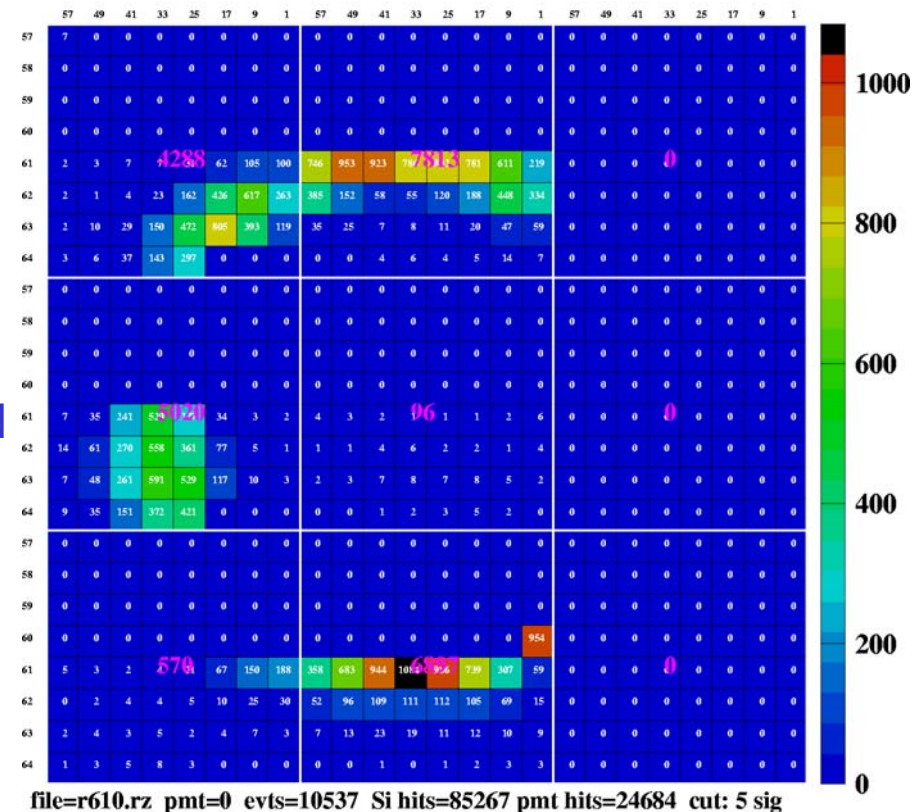
□ test of interface board:

- production only almost finished

□ fix saturation of amplifier

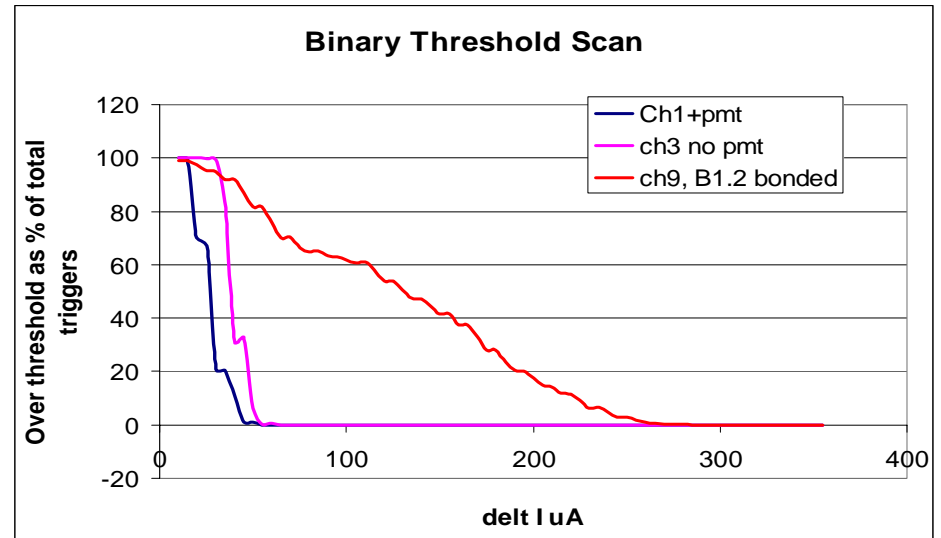
□ regain dynamic range in FED

□ fix I2C problem with cluster



Unfinished Business II

- binary readout:
 - in Oxford lab: threshold scan of single channel of Beetle1.2MA0



Study by Nigel Smale

- at testbeam: threshold scan of cluster of Beetle1.2
 - but results not yet understood

Unfinished Business III



Conclusions

□ the testbeam was a success:

- Beetle1.2 & 8-stage MaPMT work
- noise excellent, almost no CM
- preliminary photon yields look OK
- further analysis is ongoing

□ issues:

- Beetle1.2MA0 not fully tested
- binary readout only started
- source of cross-talk
- no new data till review

□ Thanks to all the people who made this result possible!!!

2003/09/14 06.25

