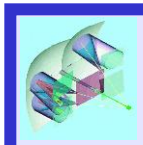


Qualifying the R11265 MaPMT for use in RICH Upgrade

- Qualification Parameters
- Available Data from Tests at Edinburgh
- Edinburgh Plans
- Conclusions

RICH upgrade meeting, 08.05.2013

Stephan Eisenhardt
University of Edinburgh

Qualification Parameters I

Extract all parameters (apart from QE) from single photon spectra

- Absolute Gain:
  - measure: gain dependence on HV
    - determine: the dynamic range of signals
    - conclude: the margin available to adjust gain by increase of HV (e.g. to counter ageing)
- Gain uniformity:
  - measure: gain variation within single MaPMT
    - determine: gain variation distribution, range & patterns
    - conclude: needs to adjust gain in readout (with the aim to equalise the signal loss)
  - measure: gain variation between MaPMTs
    - determine: gain variation distribution
    - conclude: need for gain matching in final setup
- Signal loss (Signal-over-Noise):
  - use: gain measurement data & well defined loss
    - determine: typical & maximal loss of single photon signal below 5σ noise threshold
    - conclude: acceptability of losses (depending on whole system!)

Qualification Parameters II

- Cross-talk:
  - measure: probability & signal size of cross-talk signals in all pixels
    - determine: cross-talk integrated over 8 neighbours
    - determine: cross-talk matrix, i.e. (a-)symmetries of cross-talk patterns
    - conclude: acceptability of cross-talk (depending on whole system)
- Effective active area:
  - measure: relative photon detection efficiency & signal gain across surface
    - determine: effective pixel boundaries & efficiency patters
    - conclude: effective active area & non-recoverable gaps between pixels
- Quantum Efficiency of SBA Photocathode:
  - measure: absolute photon induced current in dependence on wavelength
    - determine: photon detection efficiency, integrated over surface
    - conclude: match to manufactures specs & gain in figure-or-merit wrt. standard PC

Qualification Parameters III

- Dependence on magnetic fields:
  - test for effects on signal gain & single photon detection efficiency
  - measure: single photon spectra for field directions x, y, z
    - determine: shape and threshold of relative signal gain & photon detection efficiency
    - determine: increase in signal & photoelectron loss
- Dependence on ageing:
  - test for effects on signal gain & Quantum Efficiency
  - measure: gain & signal loss dependence on temperature
    - determine: drift of key parameters on operation conditions
  - measure: gain & signal loss in accelerated heat-cycles (low illumination)
    - determine: robustness (of tube and SBA PC) against operational cycles
  - measure: QE, gain & signal loss for 10yr equivalent accelerated illumination
    - determine: shape and rate of change of QE (wavelength dependent?) & signal loss
  - measure: rate of delayed ‘after-pulses’ with lever arm of months
    - determine: increase of rate of Ion Feedback
  - measure: charge collection dependency on bias in QE measurement
    - determine: onset of secondary electron production from ionisation

Qualification Parameters IV

- Dependence on irradiation:
  - test for effects on signal gain & Quantum Efficiency
  - measure: QE, gain & signal loss for 10yr equivalent accelerated irradiation
    - determine: shape and rate of change of QE (wavelength dependent?) & signal loss
- Dependence on readout:
  - test for effects on signal loss & cross-talk
  - compare readout options for: VME-based QDC, MAROC, CLARO
    - determine: significance of differences between systems

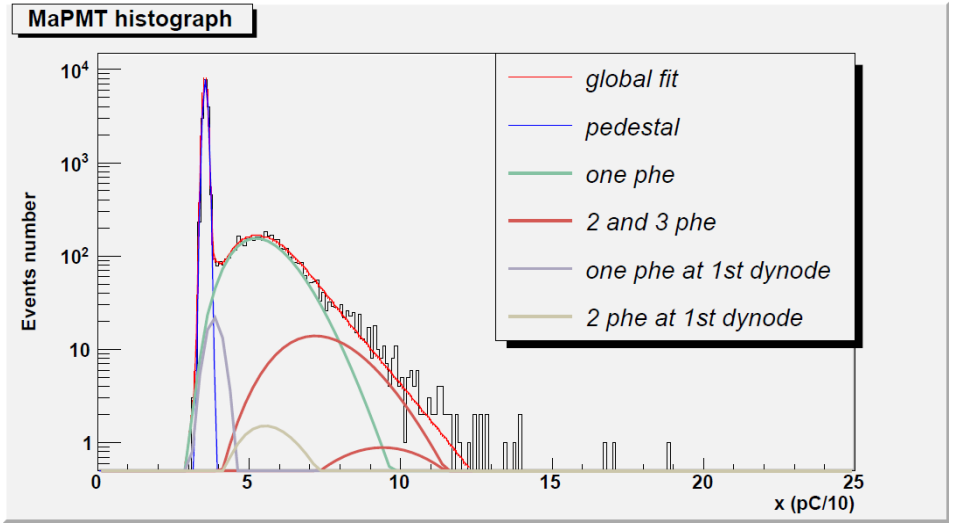
Available Edinburgh Data

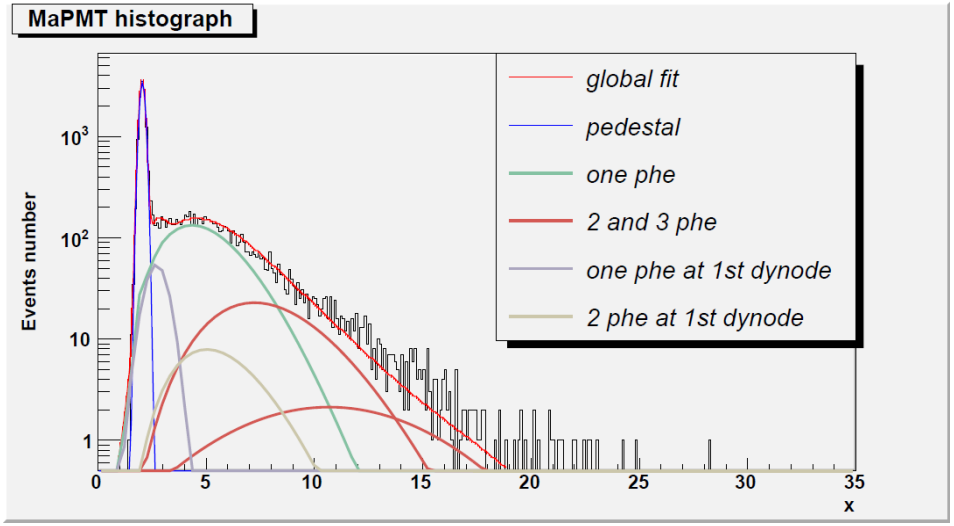
- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Single photon spectra:

all data by Haofei Luo
see his presentation
26.11.2012

MaPMT: R11265
nominal/max HV: 1000V/1100V
used HV: 800V
pixel (medium gain): 6
illumination: μ ~0.26

MaPMT: R7600
nominal/max HV: 900V/1000V
used HV: 900V
pixel (medium gain): 11
illumination: μ ~ 0.45





- Fit to data (Poisson) gives: pedestal, #photoelectrons, signal gains & widths
- R11265 shows much better separation of single photon signal than R7600

Available Edinburgh Data

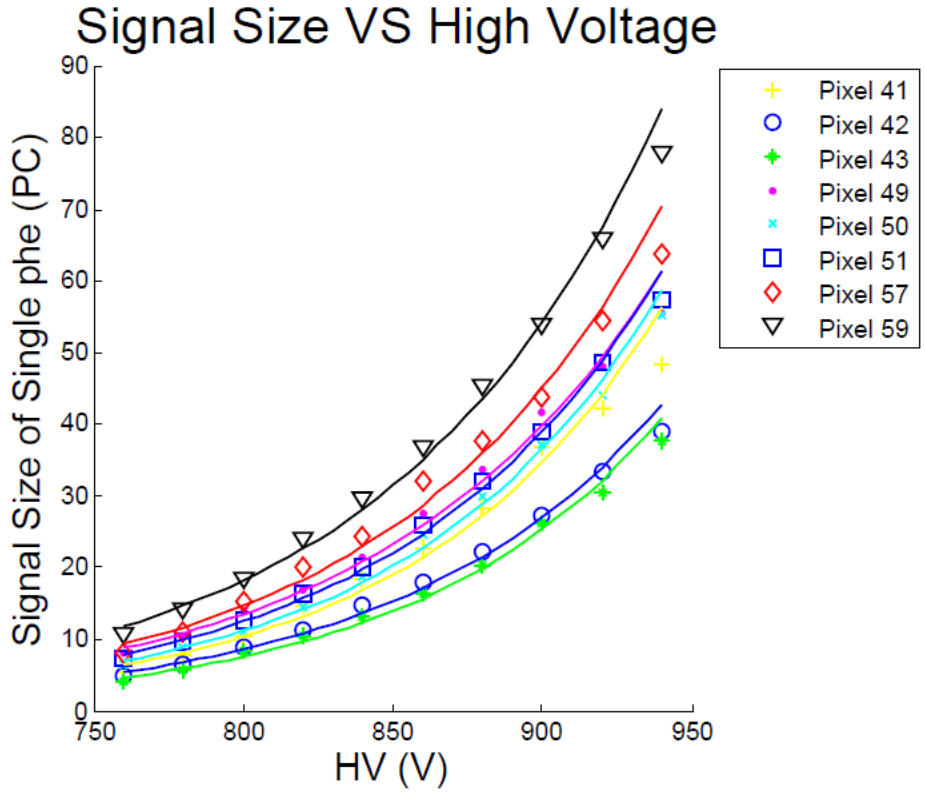
- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Absolute gain:

all data by Haofei Luo
see his presentation
26.11.2012

MaPMT: R11265

y = exp(a + bx)

typical a: -6.7
typical b: 0.0015



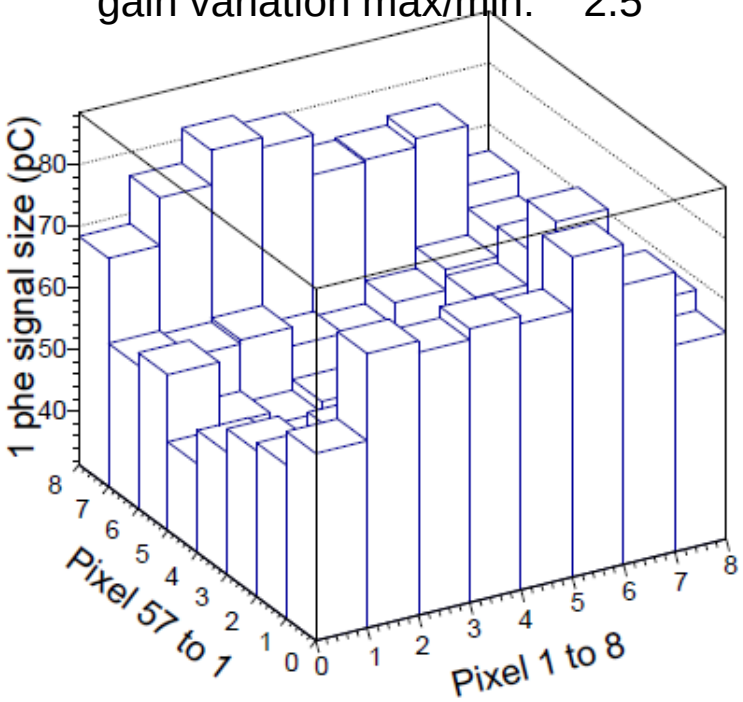
- exponential rise of gain: doubles every ~60V → plenty of margin to raise gain
- R7600 data from 2003 available

Available Edinburgh Data

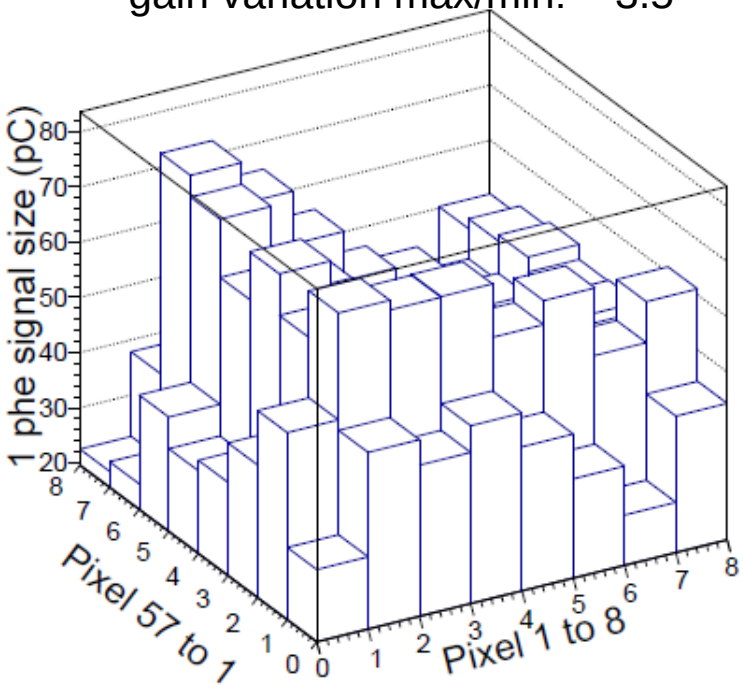
- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Gain uniformity:

all data by Haofei Luo see his presentation 26.11.2012

MaPMT: R11265
used HV: 950V
gain variation max/min: 2.5



MaPMT: R7600
used HV: 950V
gain variation max/min: 3.5

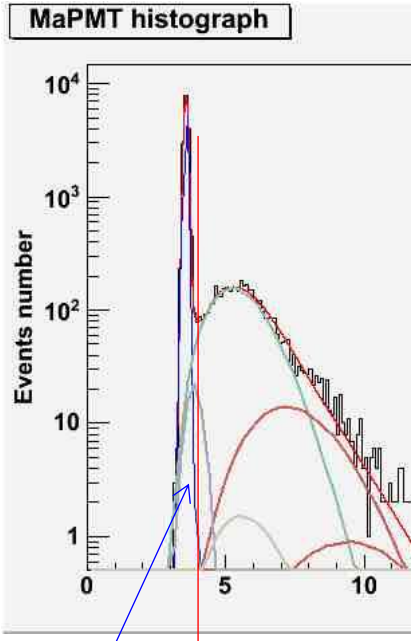


- very different pattern of large/small gain pixels (re-visit 1d histograms!)
- R11265 has weaker central pixels, R7600 has weaker edge and corner pixels

Available Edinburgh Data

- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Signal loss:
  - three methods to calculate signal loss from fitted spectra:

all data by Haofei Luo
see his presentation
26.11.2012



1) from fitted photoelectron spectra
   using Poisson statistics (preferred method)

2) from integrals over total signal spectrum
   (includes higher orders)

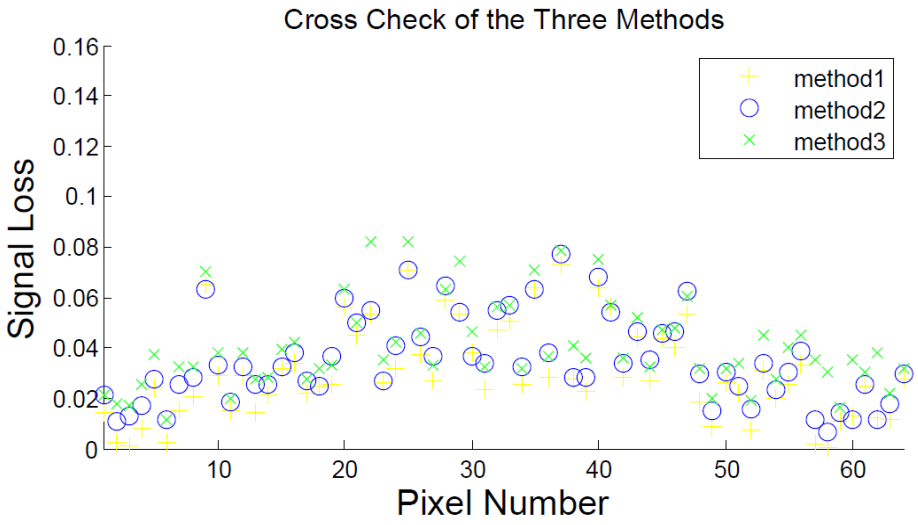
3) from fit to pedestal
   (gives upper estimate and may include noise contributions)

Available Edinburgh Data

- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Signal loss:

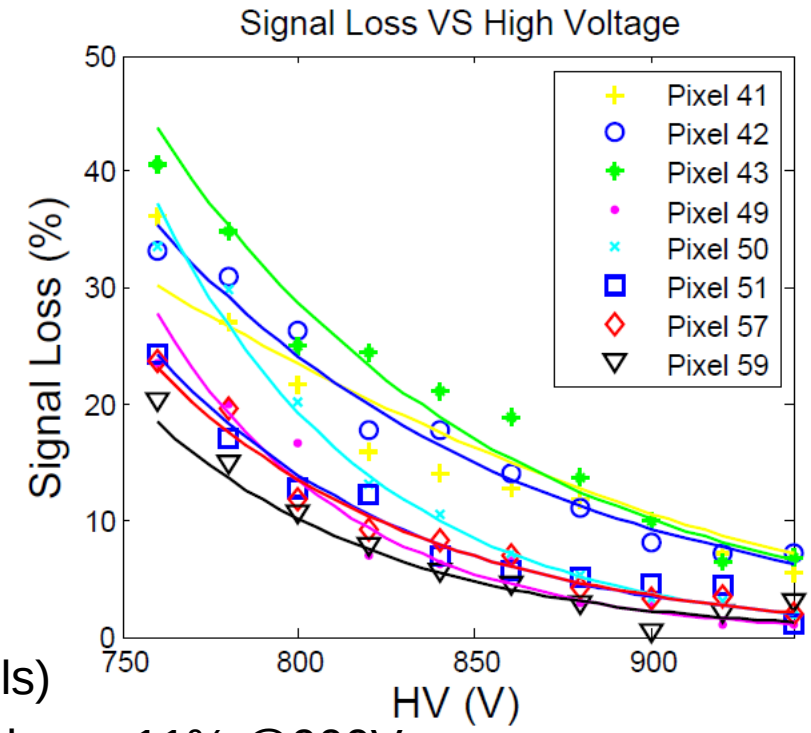
MaPMT: R11265

used HV: 950V



all data by Haofei Luo see his presentation 26.11.2012

MaPMT: R11265

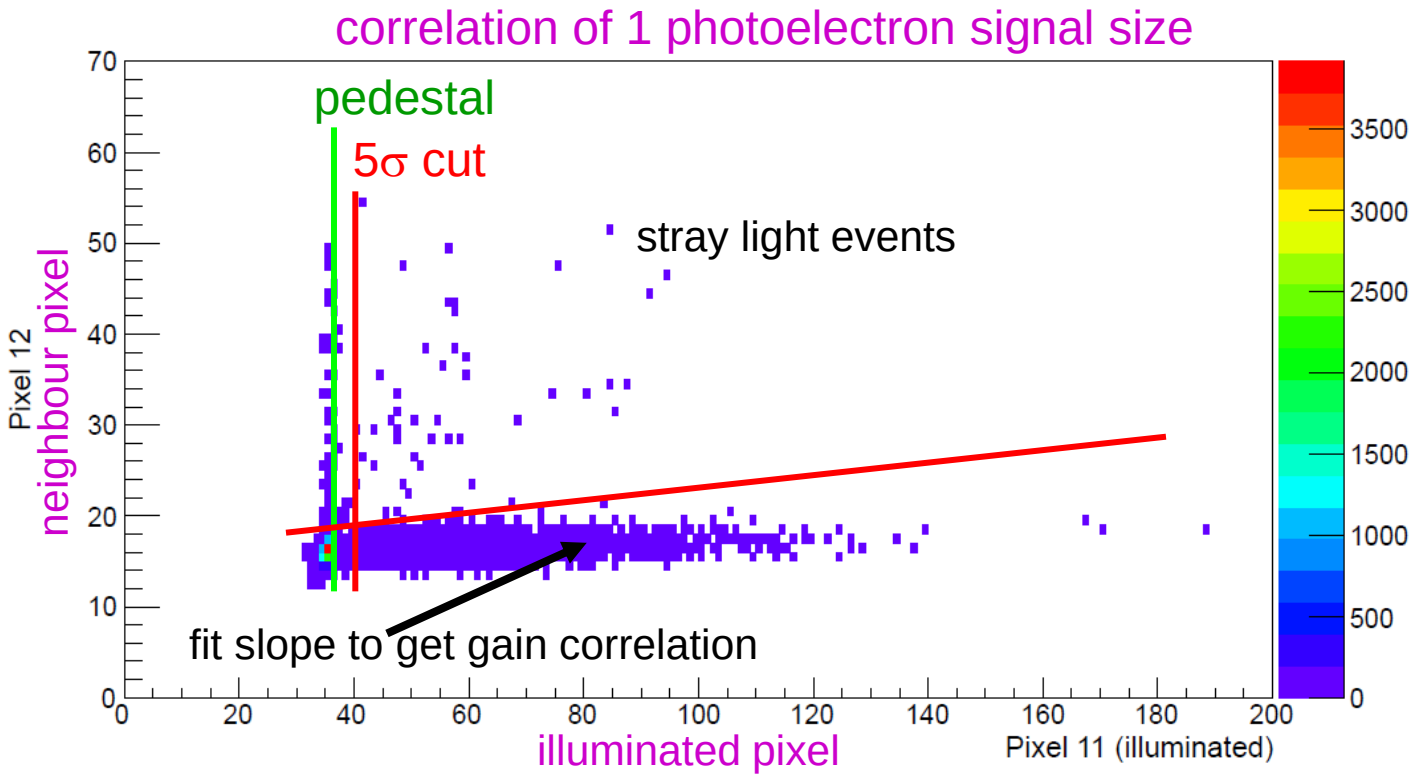


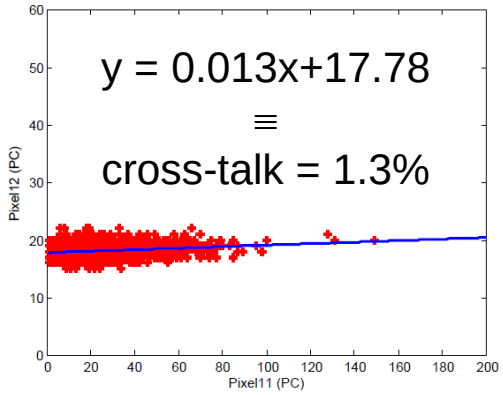
- loss correlates with gain / HV:
  halves with every ~60V
- @ 940V: loss <5% (<8%: low gain pixels)
- 2003 data: R7600 with AVPm readout: loss ~11% @900V

Available Edinburgh Data

- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Cross-talk:

all data by Haofei Luo
see his presentation
26.11.2012





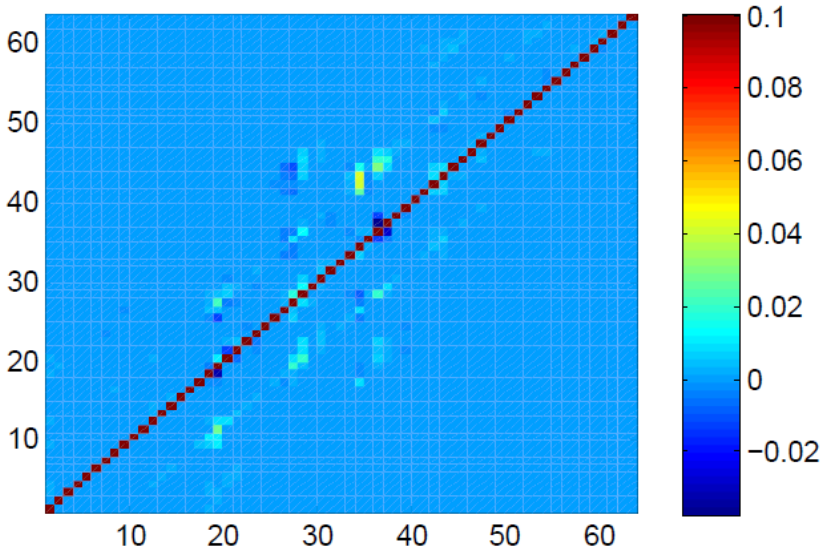
  - measured for all neighbours of all 64 pixels

Available Edinburgh Data

- All data using VME-based QDC, x100 amp, 8 channels at a time (amp-limited)
- Cross-talk:

all data by Haofei Luo
see his presentation
26.11.2012

MaPMT: R11265
used HV: 950V



MaPMT:	R11265	R7600
used HV:	950V	950V
cross-talk		
adjacent pixels	<2%	2-4%
diagonal pixels	<0.5%	<1%
sum of 8 neighbours	<5%	

- R11265: cross-talk between pixels is symmetric
- non-uniform patters visible: probably due to gain variations (to be re-checked)

Edinburgh Plans I

- Available MaPMT:
  - 1x R11265 @ Edi lab, ~5x R7600 @ Edi lab (+ x4 R11265 @Cam/CERN)
  - 4x R11265 ordered from Edinburgh money (expected to arrive in June)
  - 4x R11265 ordered from LHCb money (expected to arrive at RAL in August)
- Available Infrastructure:
  - pulsed single photon light source (focussed) & dark box with xy-stages
  - VME-based QDC readout for 64 channels:
    - x100 linear amplification from commercial amplifiers: currently only for 8 channels
    - 64-ch x100 amplifier under development in-house
  - MAROC readout:
    - will get 2 MAROC readout boards (Cambridge development) over summer
  - Magnet and dark chamber for MaPMT fitting into gap (unfocussed pulsed LEDs)
  - QE measurement:
    - established method from HPD measurements
    - automation to be finished over summer
  - Climate chamber:
    - to be commissioned (when? – man power limited)

Edinburgh Plans II

- Test programme – personnel assigned:
  - absolute gain, gain variations, signal loss
    - on up to 9 MaPMT R11265
    - compare to available R7600
  - cross-talk
    - on ~2 MaPMT R11265
    - compare to R7600
  - magnetic field measurements
    - on ~2 MaPMT R11265
    - compare to R7600
- Test programme – discussing personnel:
  - comparison of VME based QDC to MAROC readout (& comparison to CLARO?)
  - Quantum Efficiency measurement for SBA photocathode
  - effective active area scans on xy-stage
  - ageing tests:
    - temperature dependency, operation cycles, high integrated illumination

Conclusions

- Comprehensive evaluation of R11265 needs further systematic studies:
  - magnetic field measurements
  - ageing due to temperature, operating cycles & illumination
  - Quantum Efficiency of SBA photocathode & its stability
  - scan of effective active area
  - gain statistics on multiple MaPMT for gain, variation, signal loss, cross-talk
- Edinburgh data available on:
  - absolute gain, gain variations, signal loss, cross-talk
  - for single R11265 and R7600 so far
- Edinburgh will contribute significantly to that:
  - established methods and standards of signal loss and cross-talk
  - infrastructure available or provided shortly
  - still discussing personnel for some tasks