CLAS12 RICH Review

H8500 Characterisation

Matthias Hoek
on behalf of the CLAS12 RICH Collaboration

26. June 2013 | JLAB

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Introduction

- Requirements
- Position-sensitive photon detectors
- Test procedure
  - Laser Test Facility
- Results
  - Spatial Response
  - Crosstalk
  - Signal Characteristics
- Selection Criteria
- Conclusions

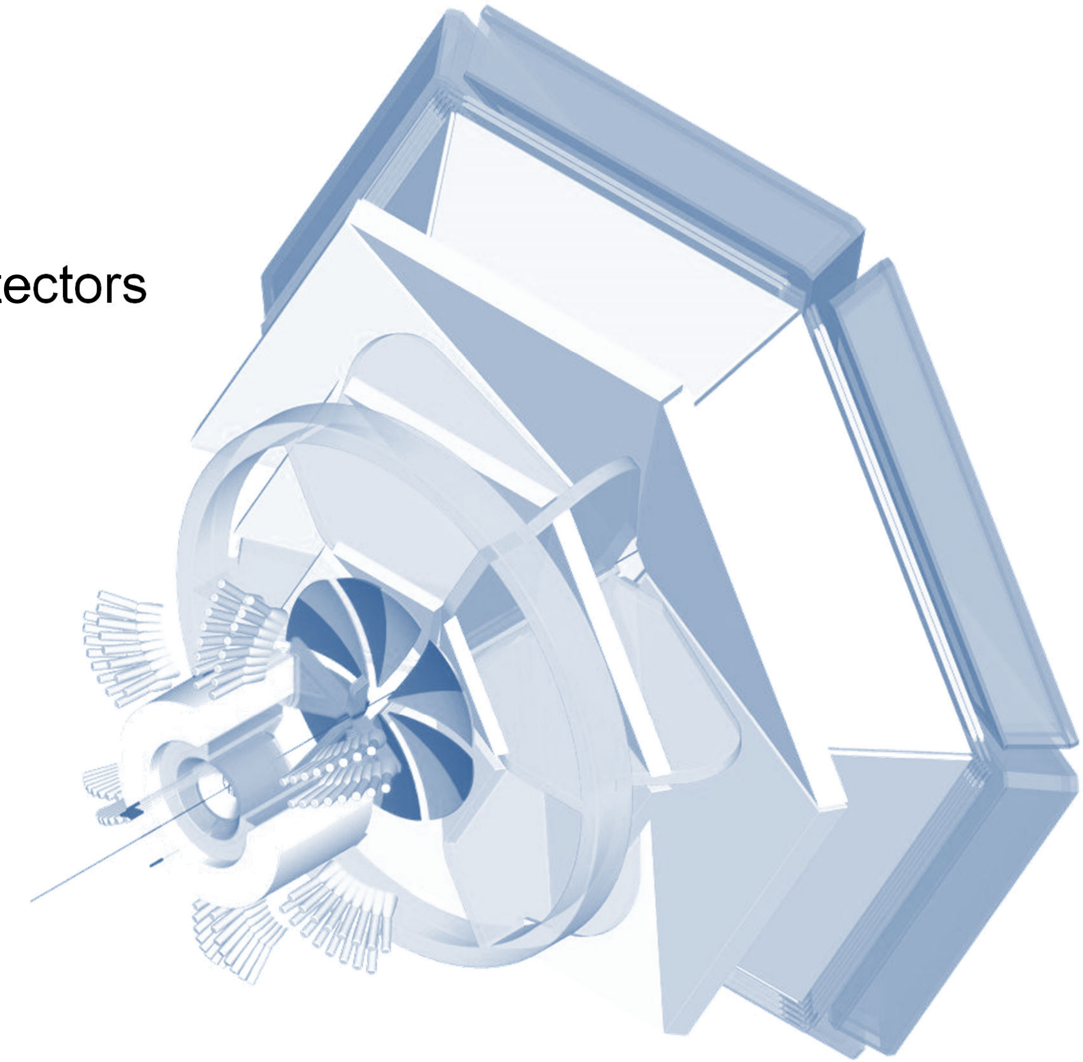
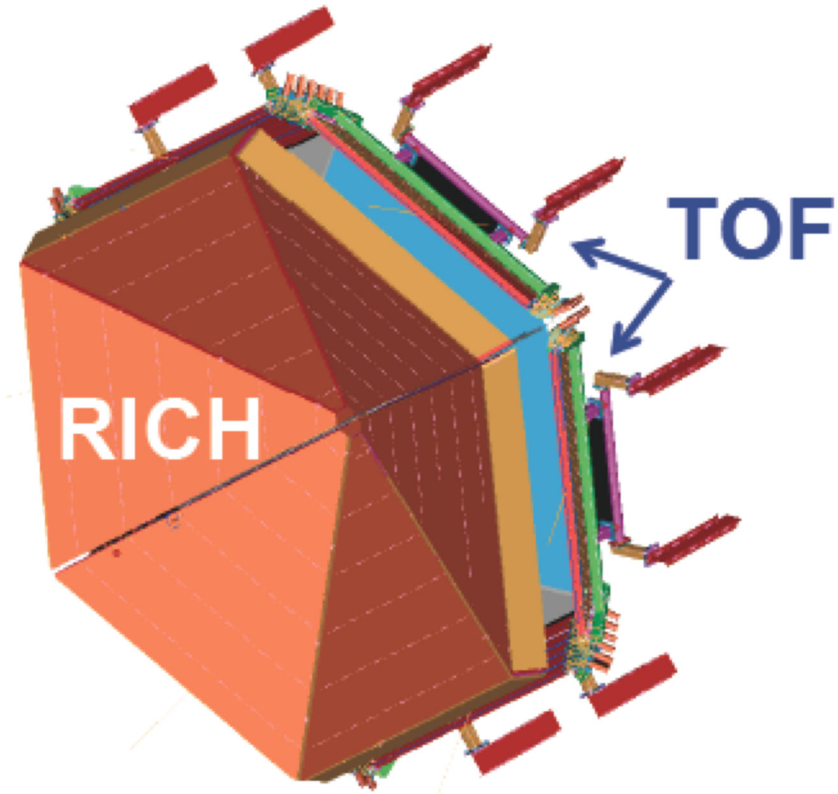


Photo-Detector Brief

Particle identification between 3-8GeV/c with aerogel radiator

- Spatial resolution
  - Pixel size <1cm^2
- Single photon detection
  - Gain ~ 10^6
  - Visible range (300-700nm)
- Magnetic field <10 Gauss
- Image Plane ~1m^2 per sector
  - Multi-anode Photon Detectors
  - Tile photon detectors
  - Large active area
- Compact size
- Mature Technology
  - Readily available



Position Sensitive Photon Detectors

Silicon PM

- High gain
- Excellent SPE resolution
- Radiation hardness
- Dark noise

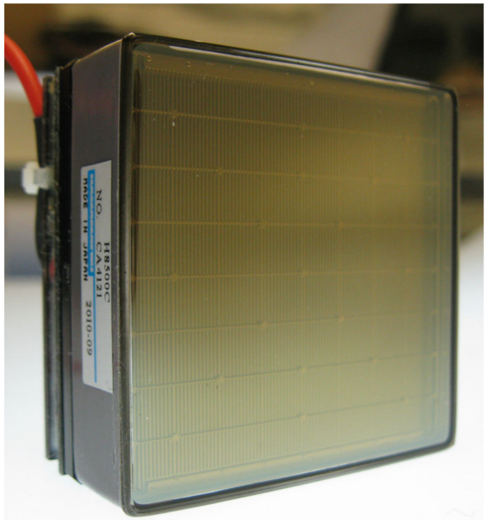
MCP-PMTs

- Fast timing
- Works in strong magnetic fields
- Gain limited
- Lifetime
- Cost

Multi-anode PMTs

- Mature technology
- High gain
- Low Dark Noise
- Susceptible to magnetic fields

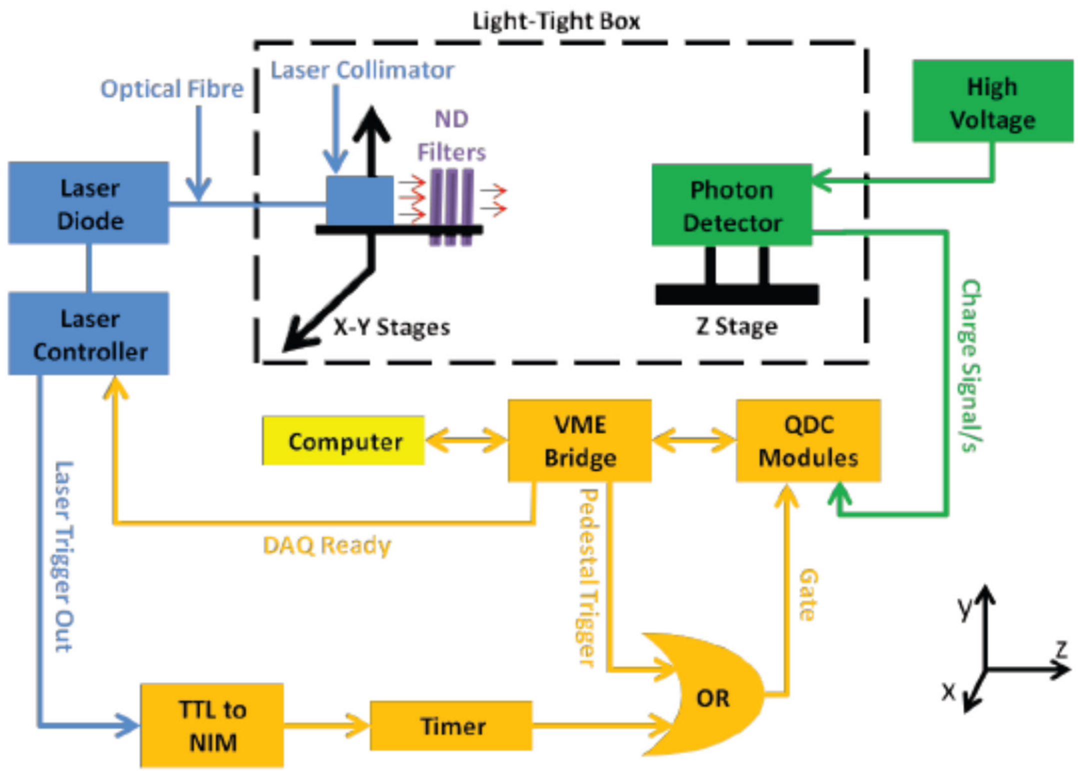
Multi-anode PMTs



Hamamatsu H8500		Hamamatsu H7546
64	Number of Pixels	64
5.8×5.8	Pixel Size [mm^2]	2.0×2.0
52.0×52.0	Dimensional Outline [mm^2]	30.0×30.0
49.0×49.0	Effective Area [mm^2]	18.1×18.1
-1100	Max Supply Voltage [V]	-1000
0.8	Rise Time [ns]	1.0

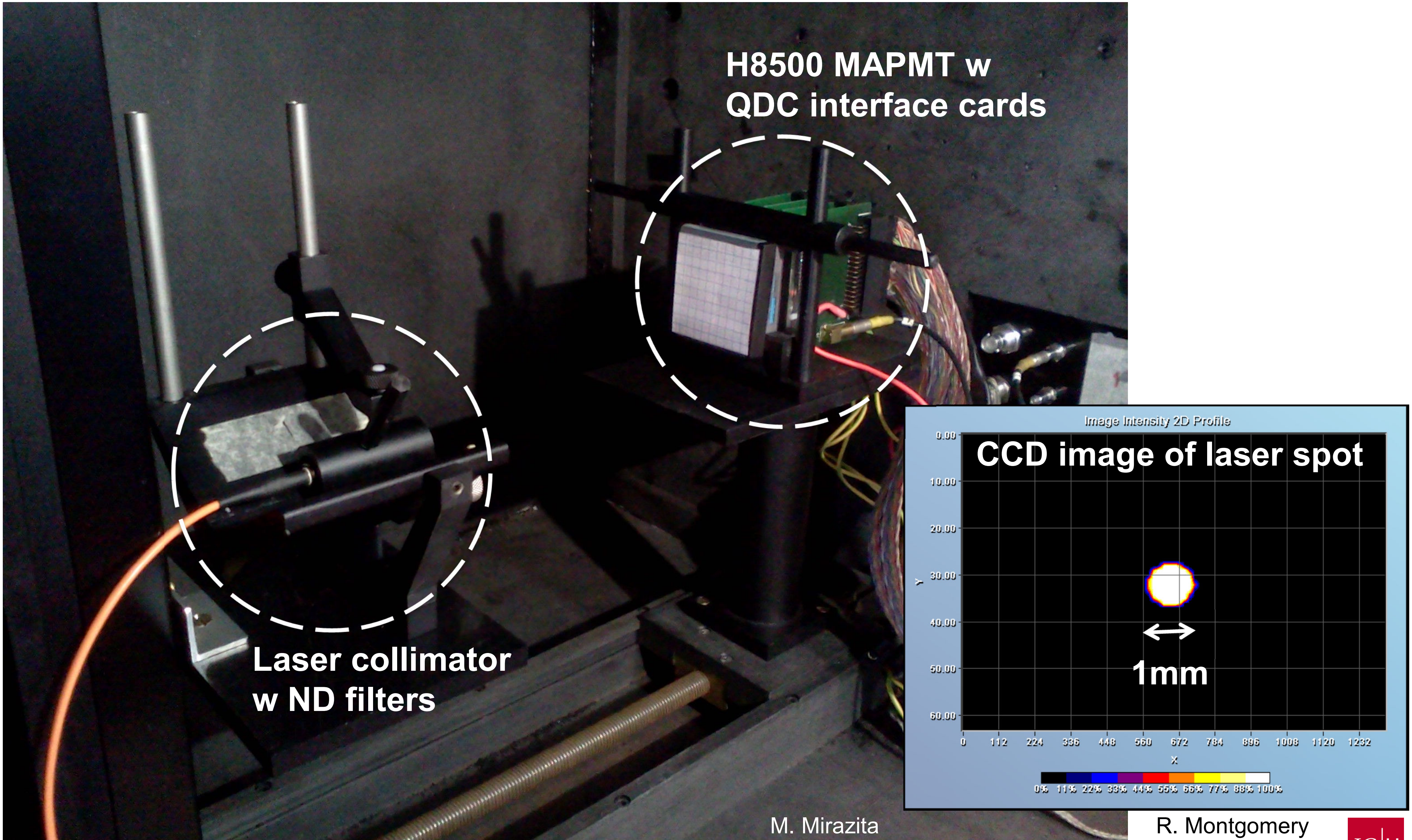
PMT Test Facility

- Pulsed laser source
  - 405nm and 633nm heads
  - pulse FWHM <50ps
  - laser spot diameter ~1mm
  - with micro-focus <0.1mm
  - intensity adjusted with ND filters
- X-Y table
  - 150mm range
  - 5micron accuracy
- VME-based DAQ
  - gated QDC
  - readout rate up to 8kHz
- Fully automated scanning procedure



R. Montgomery

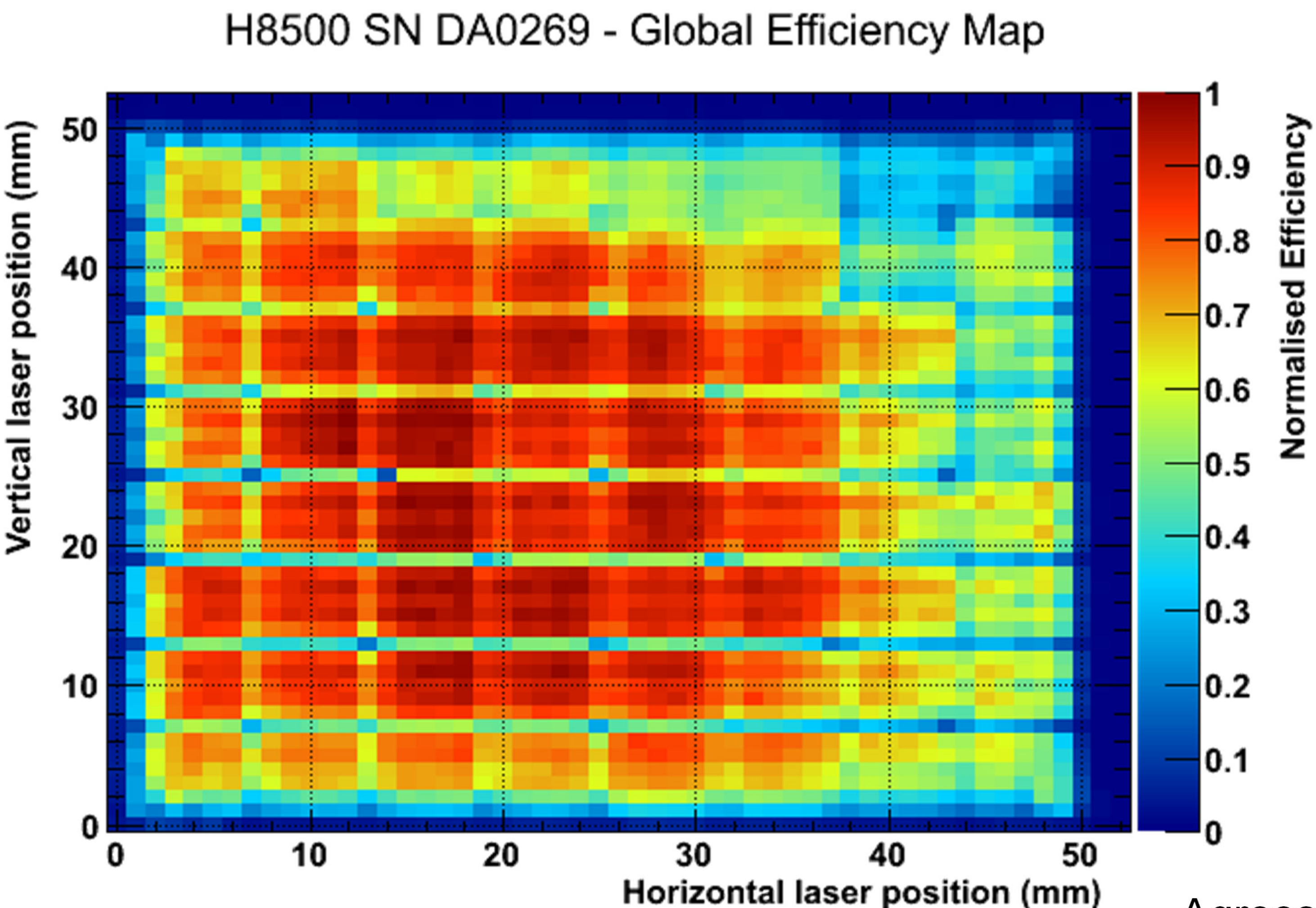
PMT Test Facility (Frascati)



M. Mirazita

R. Montgomery

Spatial Response – Full Scan

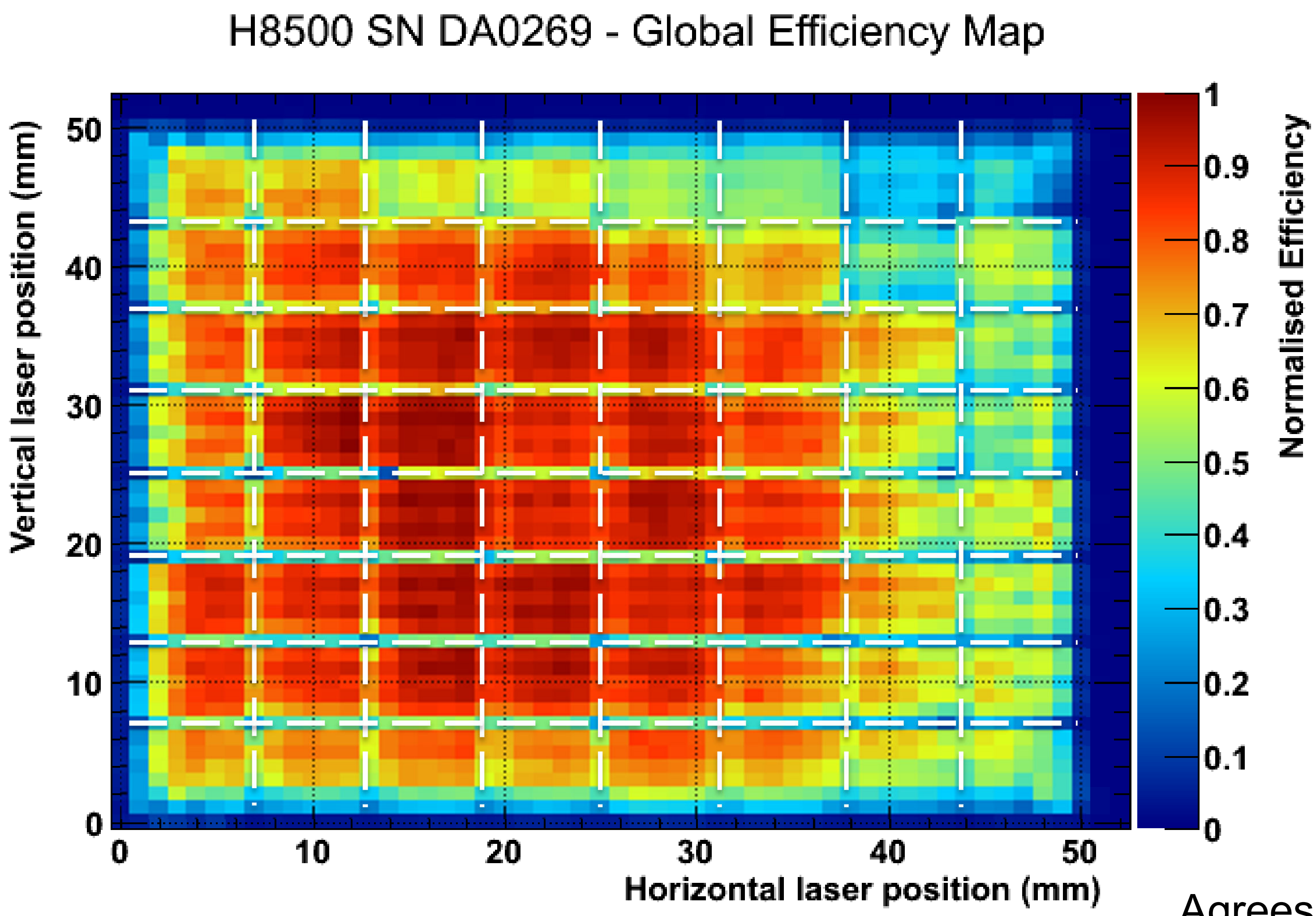


- 1mm-step size scan
- Pixel boundaries visible
- High & low gain regions visible
- Pixel non-uniformity seen

Agrees with information furnished by Hamamatsu

- Only average pixel gain

Spatial Response – Full Scan



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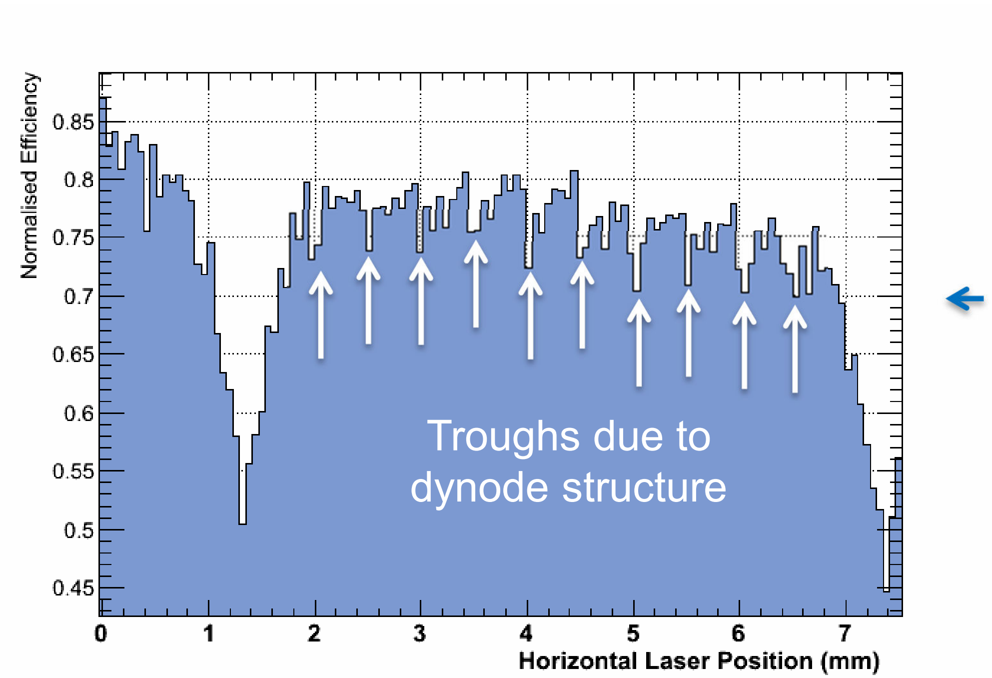
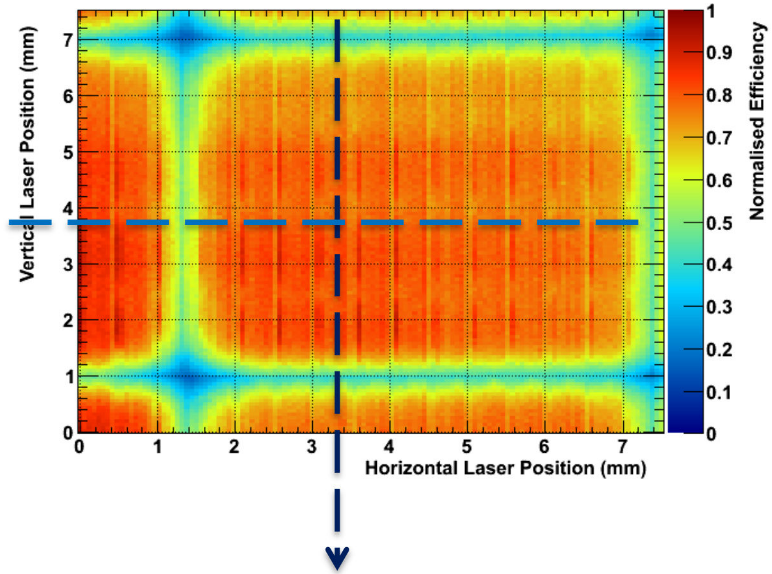
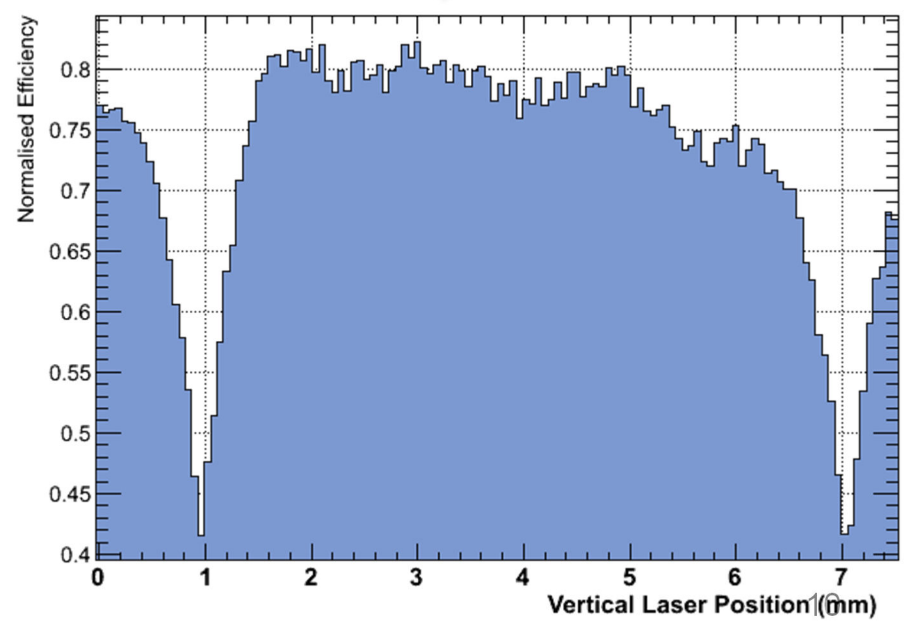
Spatial Response – Pixel Boundaries

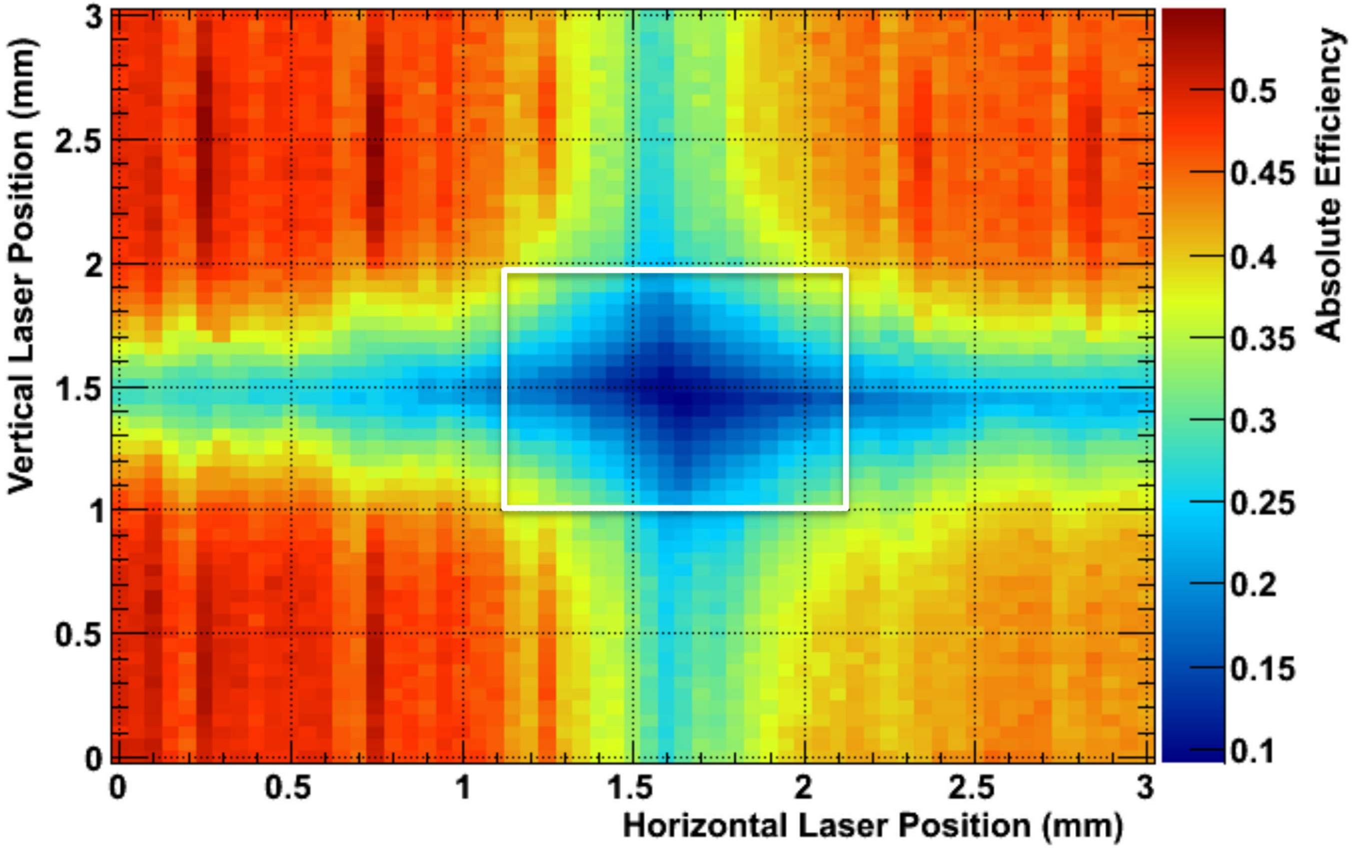


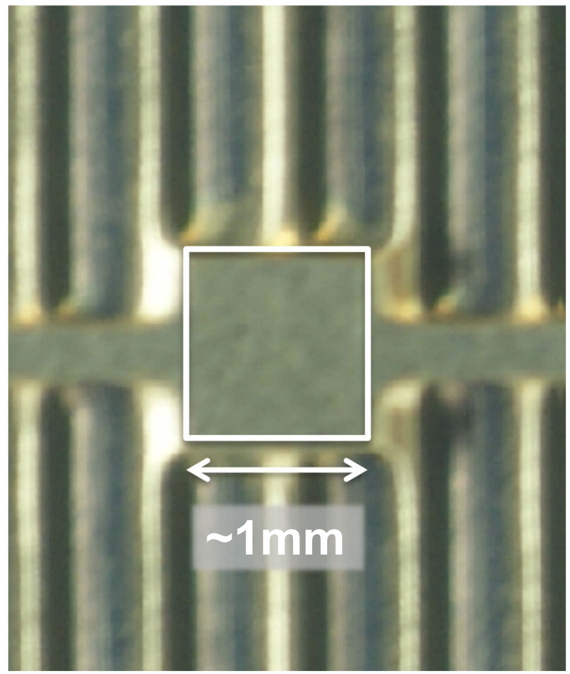




- 280 micron nominal gap
- Well defined edge
  - ~400 micron transition region
- 87% of pixel area in plateau
- Gap efficiency ~50% of plateau
- Dynode edge ~5% reduction

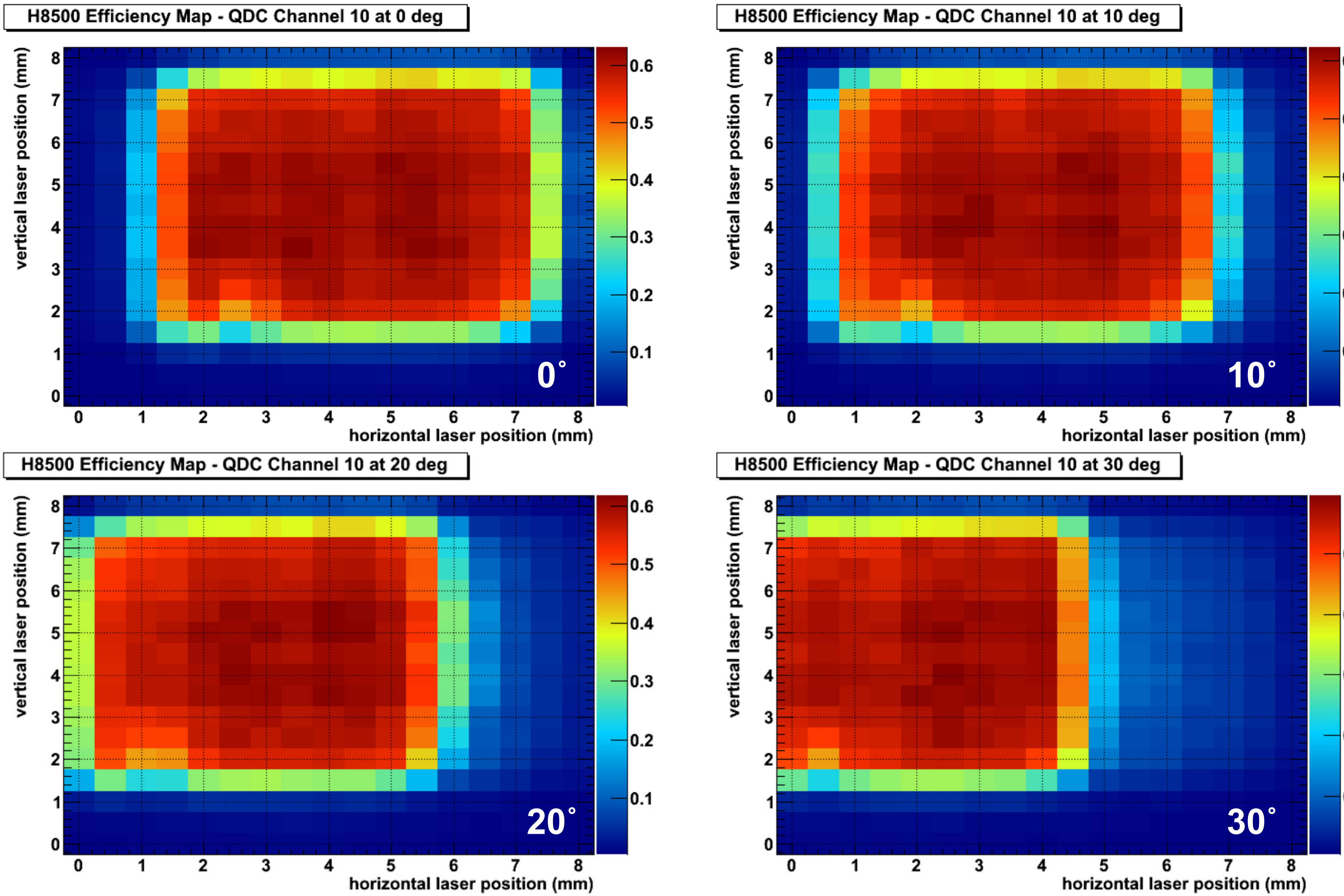
Spatial Response - Corners





- Mechanical support structure clearly visible
  - 19 per H8500
- Efficiency drops to 20% of pixel peak value
- Affected area ~0.5mm^2

Spatial Response - Incidence Angle

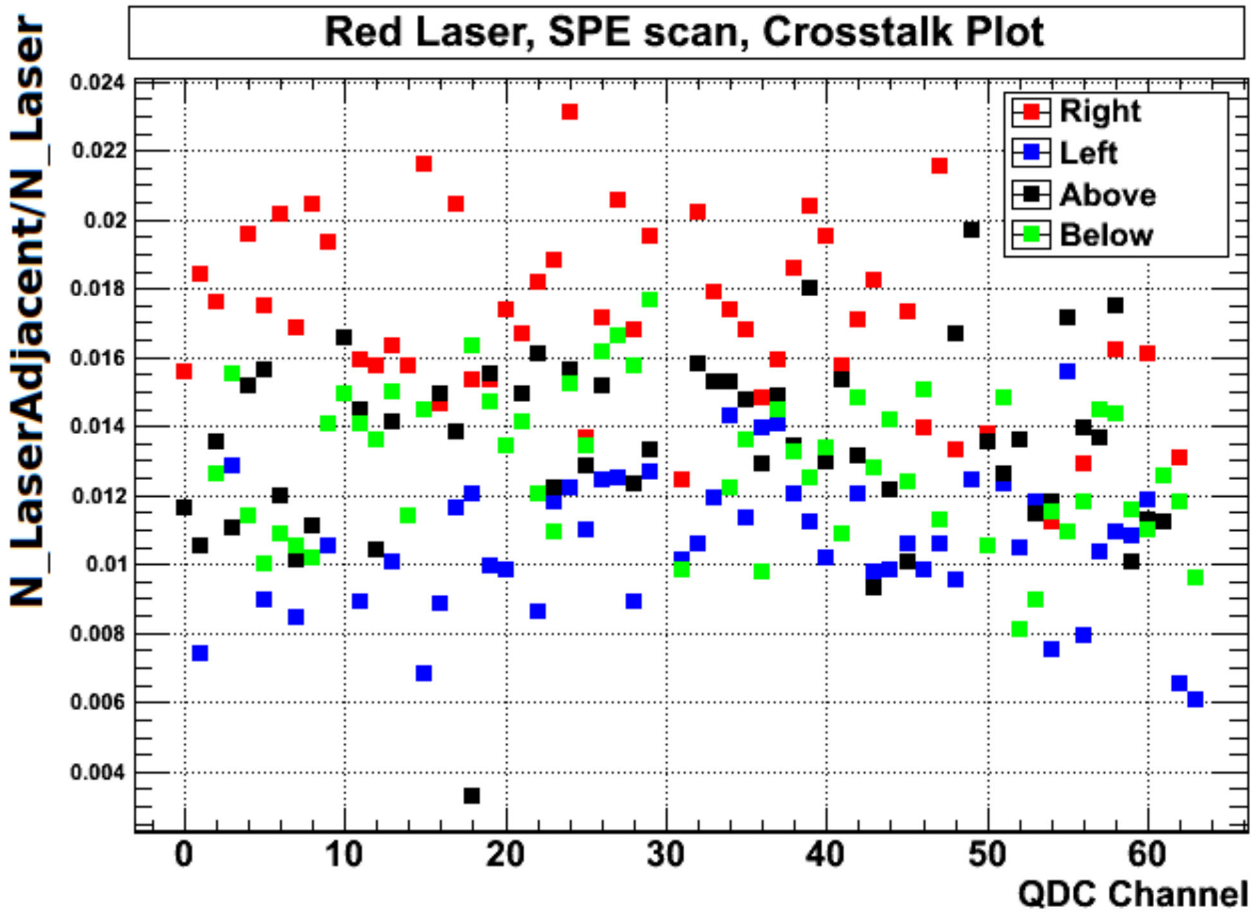


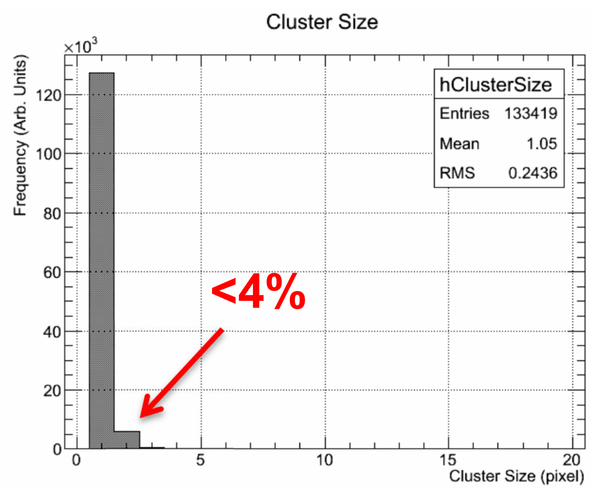
Crosstalk Effects – Next Neighbours

- Crosstalk magnitude crucial
  - Degrades position information
- Illuminate pixel centre and extract crosstalk in adjacent pixels

$$C_i = \frac{N_{adj}}{N_{laser}}$$

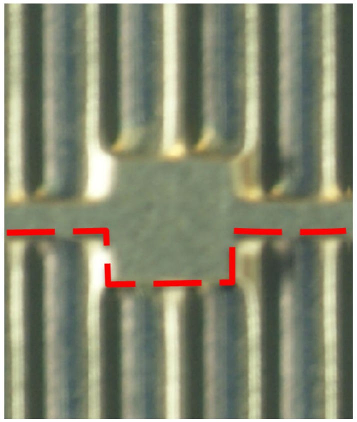
- Less than 3% crosstalk
  - Small horizontal asymmetry seen



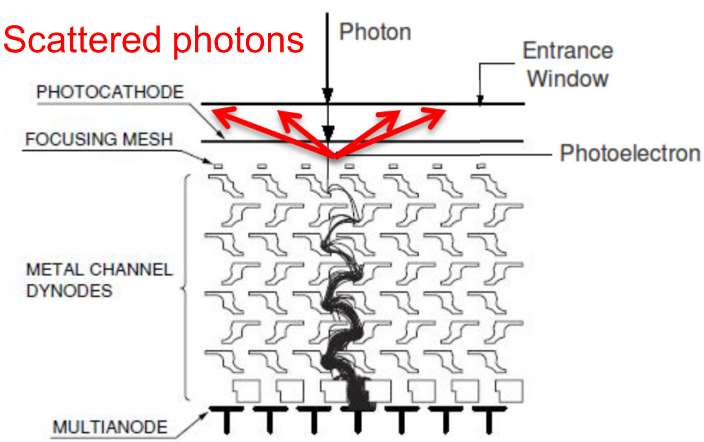


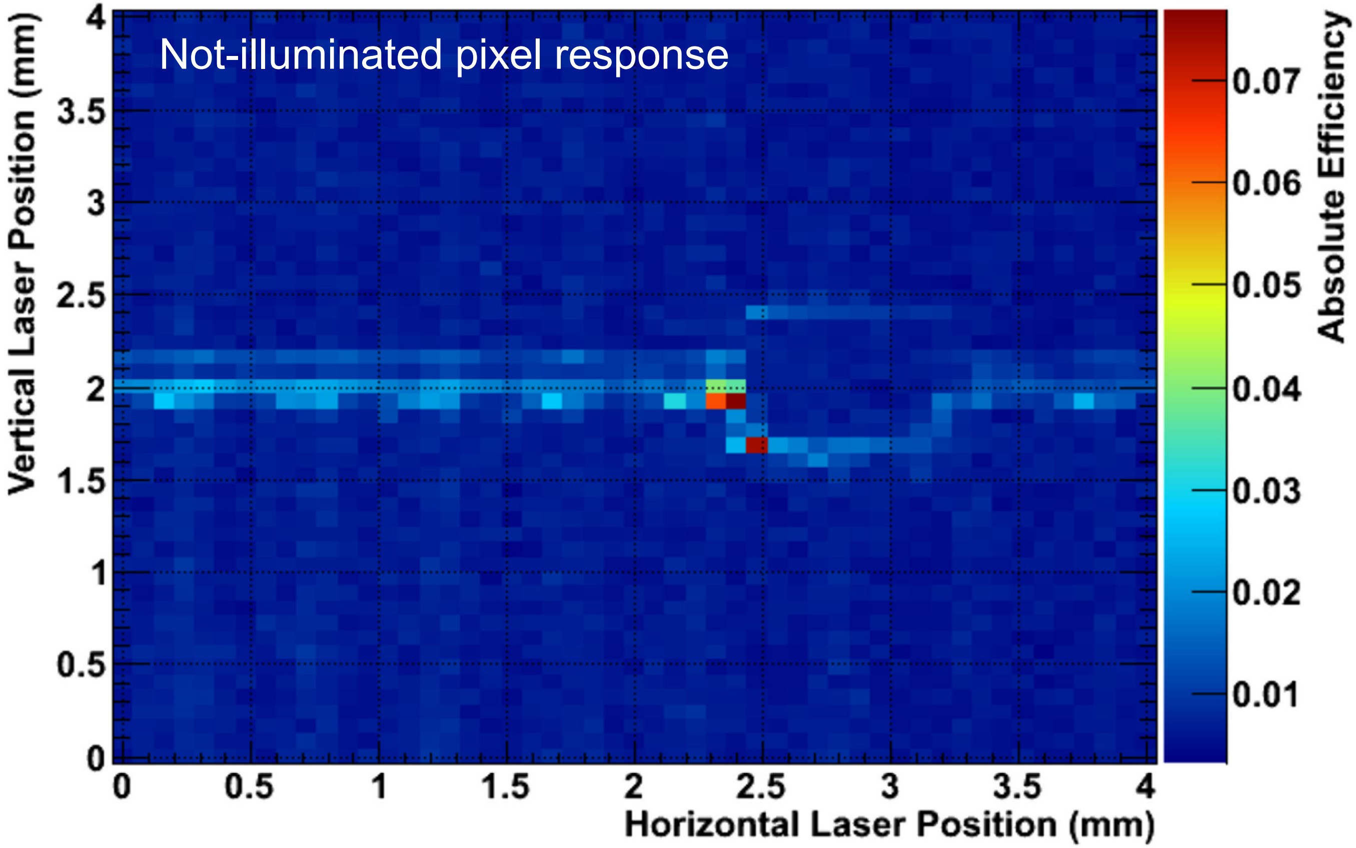
Similar crosstalk magnitude found in data from CERN test experiment (Dec 2012)

Crosstalk Effects – Beyond the Neighbours



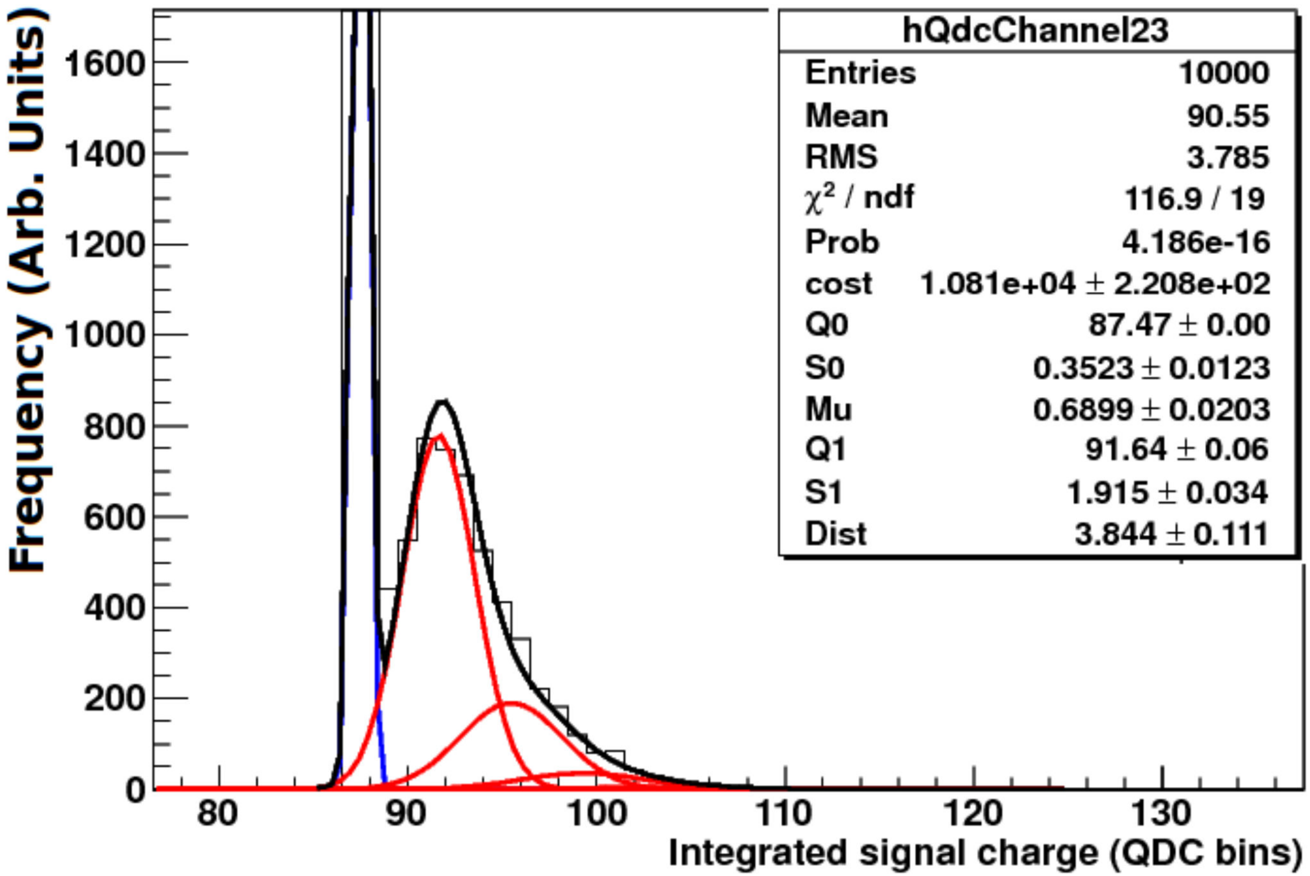
H8500 dynode support structure





- Light scattering on dynode structure
  - mostly horizontal
  - (dynode structure is vertical)
- Negligible compared to direct neighbours
  - <1%

Single Photo-Electron (SPE) Response



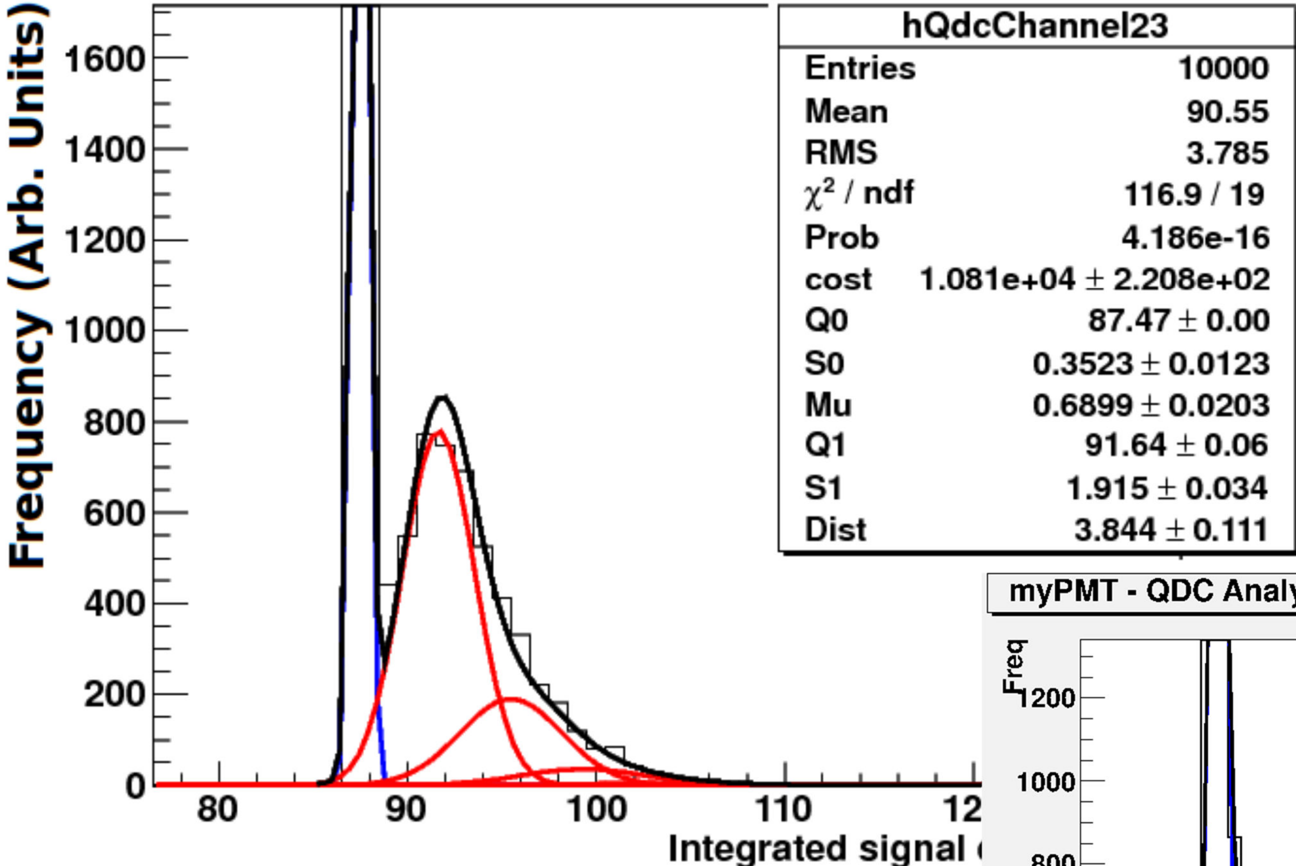
$$F(q) = A\left\{e^{-\mu}PED(q) + \sum_{k=1}^{N}\frac{e^{-\mu}\mu^k}{k!}SIG_k\,(q)\right\}$$

No photo electron

Up to 5 PE included

- Attenuate light level
  - <1PE on average
- Contributions to charge spectrum according to Poisson distribution
- Individual PE contribution $SIG_k\,(q)$ modelled as Gaussian distribution
- Fit spectrum to extract
  - Average light level
  - Absolute Gain
  - SPE resolution
- Study SPE loss
  - Depends on threshold

Single Photo-Electron (SPE) Response



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No photo electron

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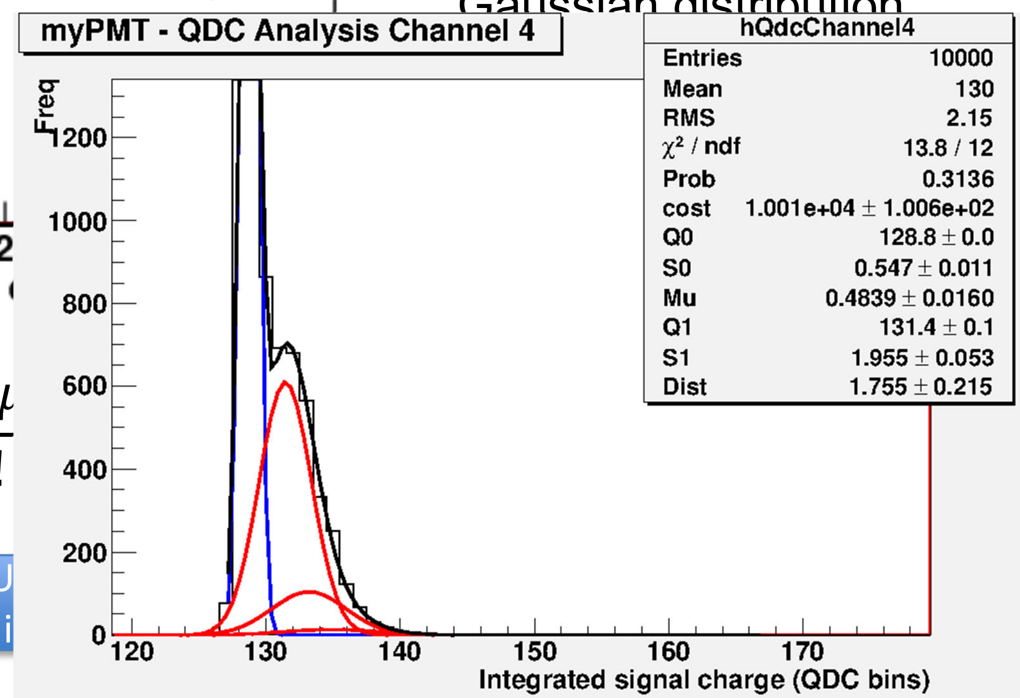
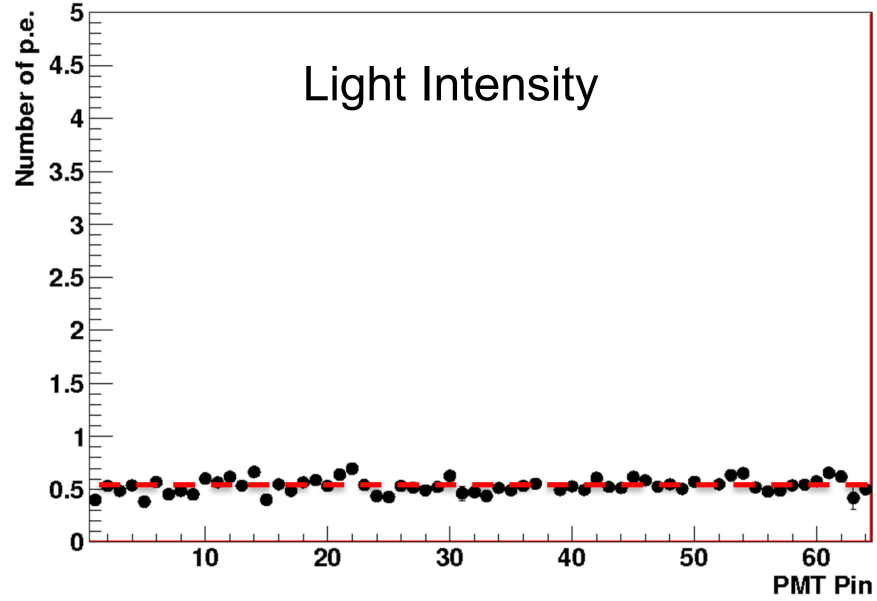
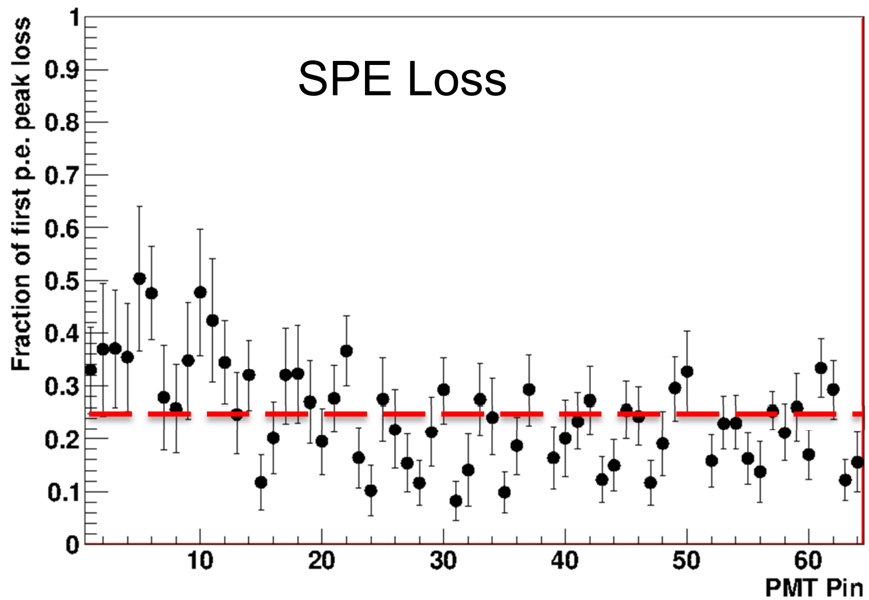
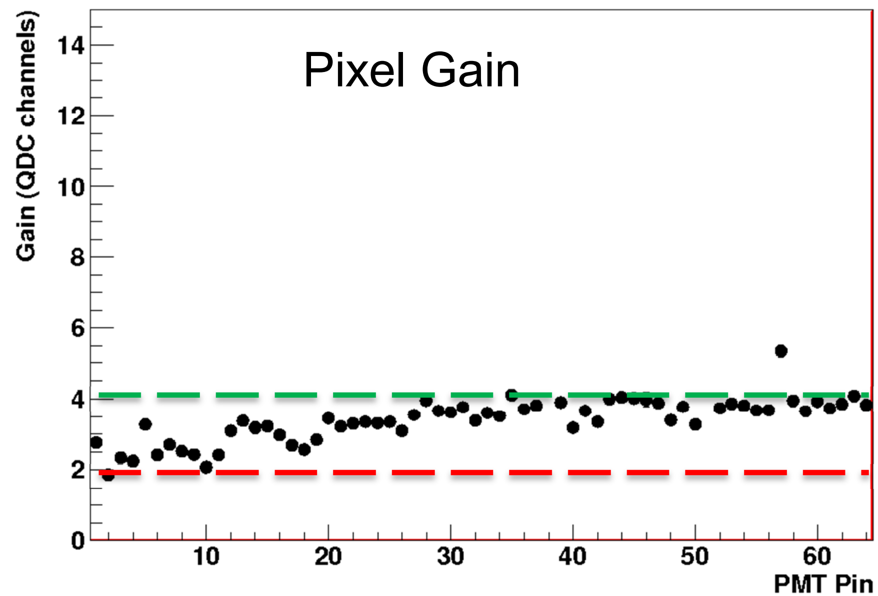


Pixel Response Variations (1000V)

- Illuminate each pixel centre
- Threshold set to 3σ of pedestal width
- Light intensity stable
- Gain variation ~ 1:2
- SPE loss ~25%
  - Low gain pixels show increased loss

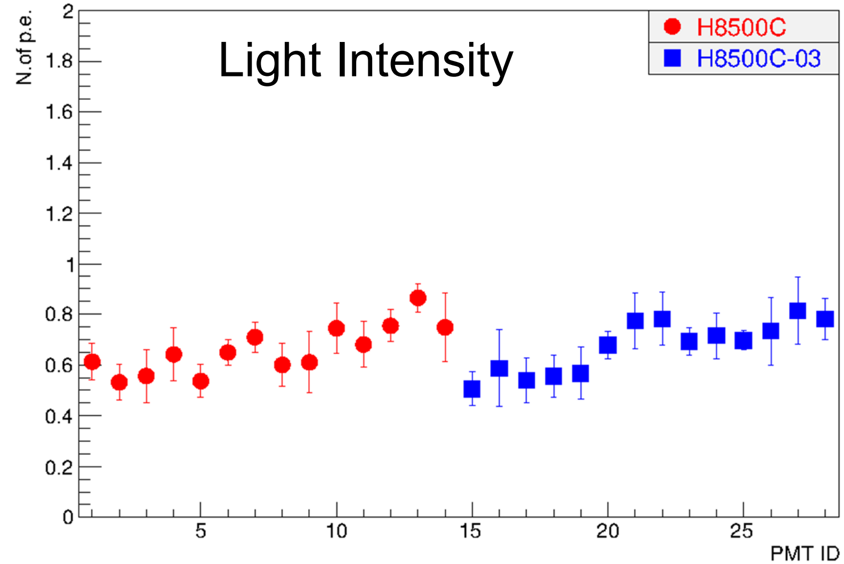


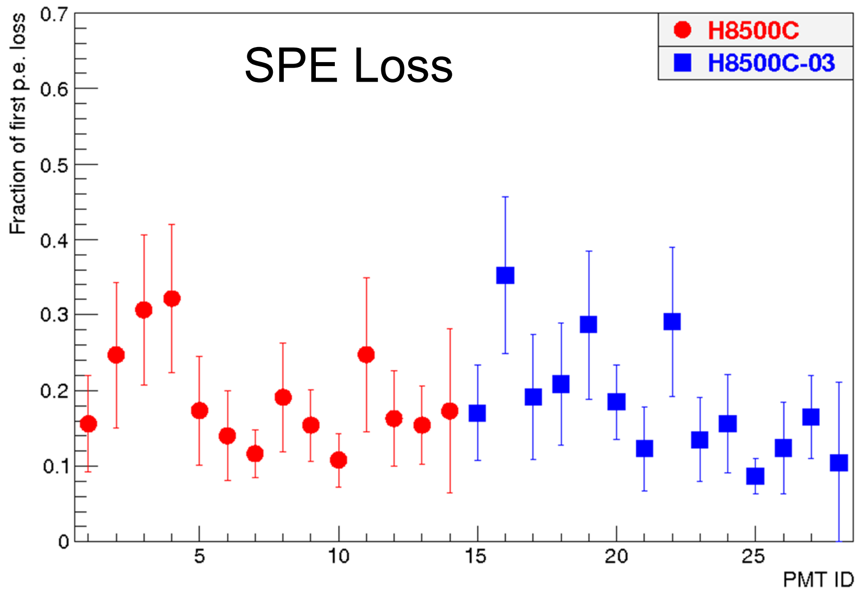


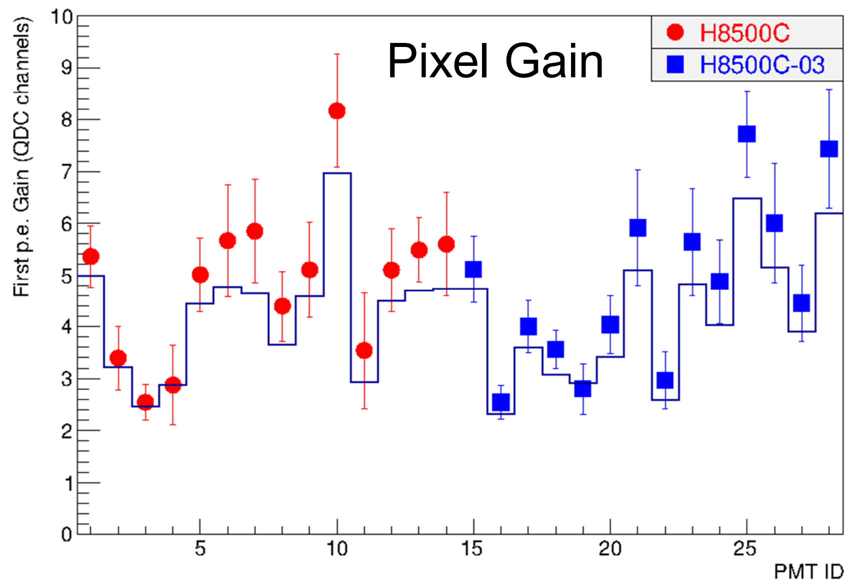


H8500 Average Response Variations (1000V)

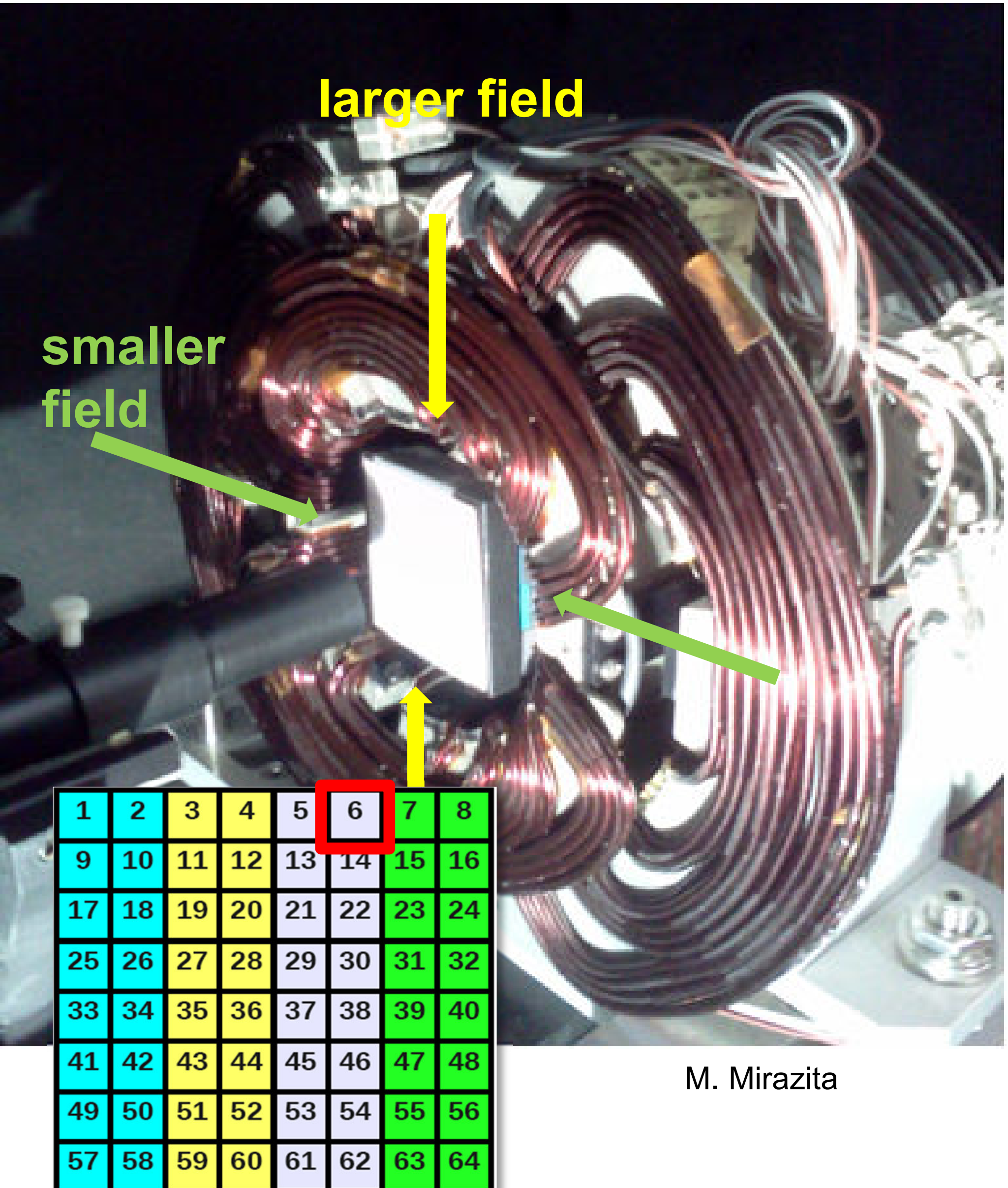
- 28 H8500 MAPMTs
  - 14 with standard window (H8500C)
  - 14 with UV window (H8500C-03)
- Gain matches Hamamatsu data
- Both types show comparable
  - Gain
  - SPE loss





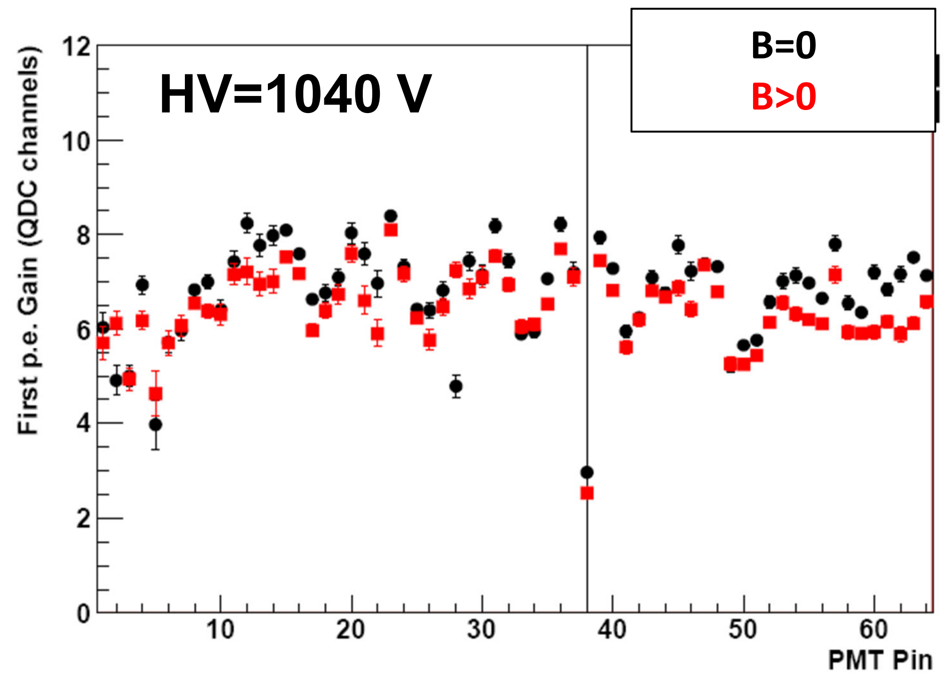


SPE Response in Magnetic Field

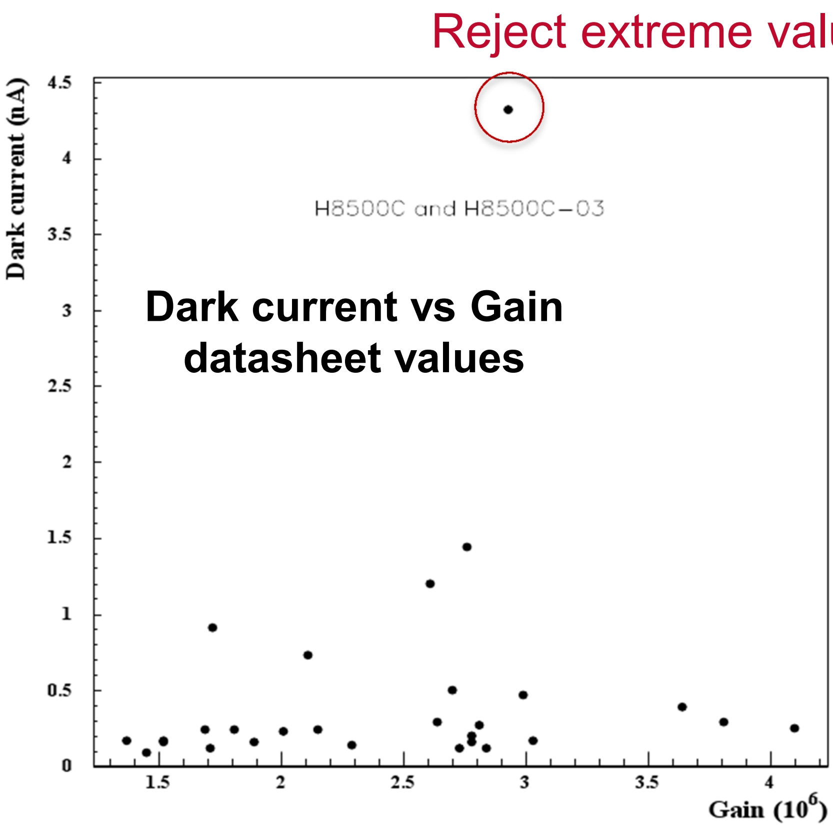


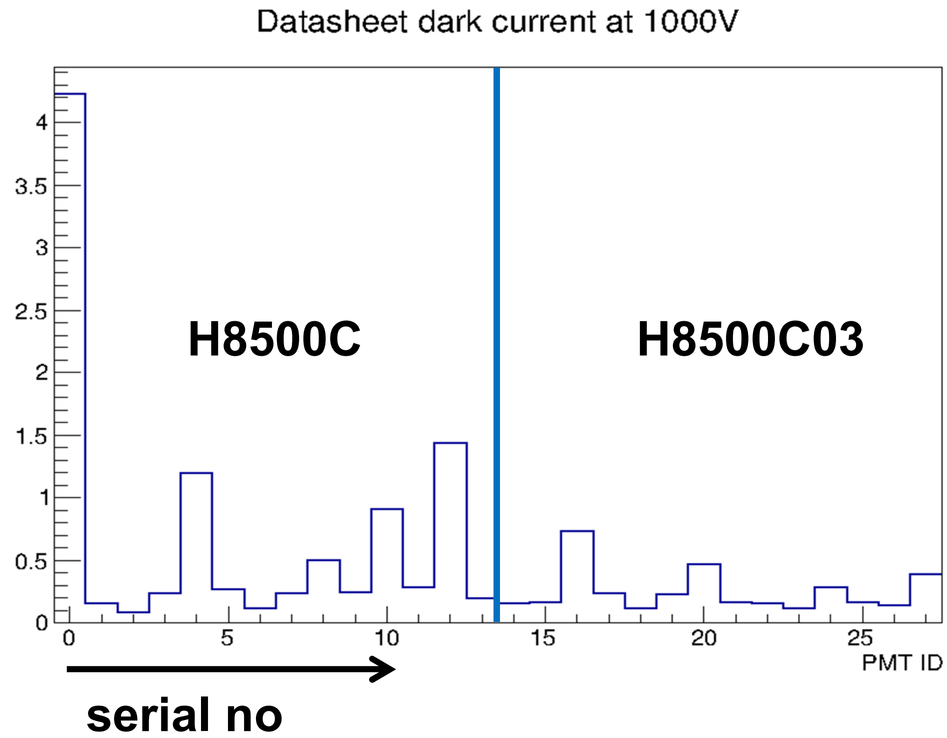
M. Mirazita

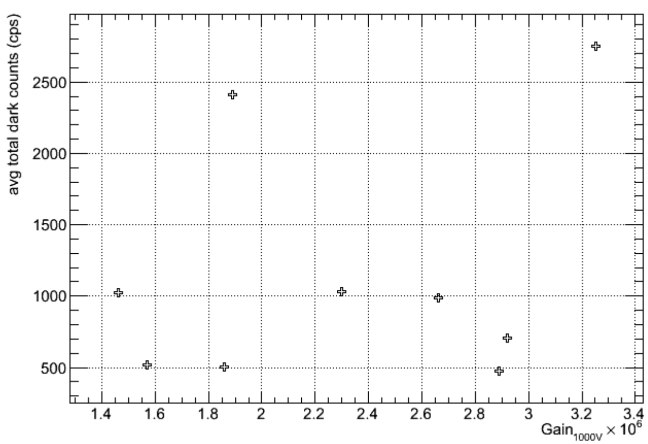
- Compensating sextupole magnet
  - No field at the center
  - Up ≈ 5mT toward the border
  - Perpendicular to the electron motion in the MAPMT
- Small gain loss observed



Dark Current & Noise

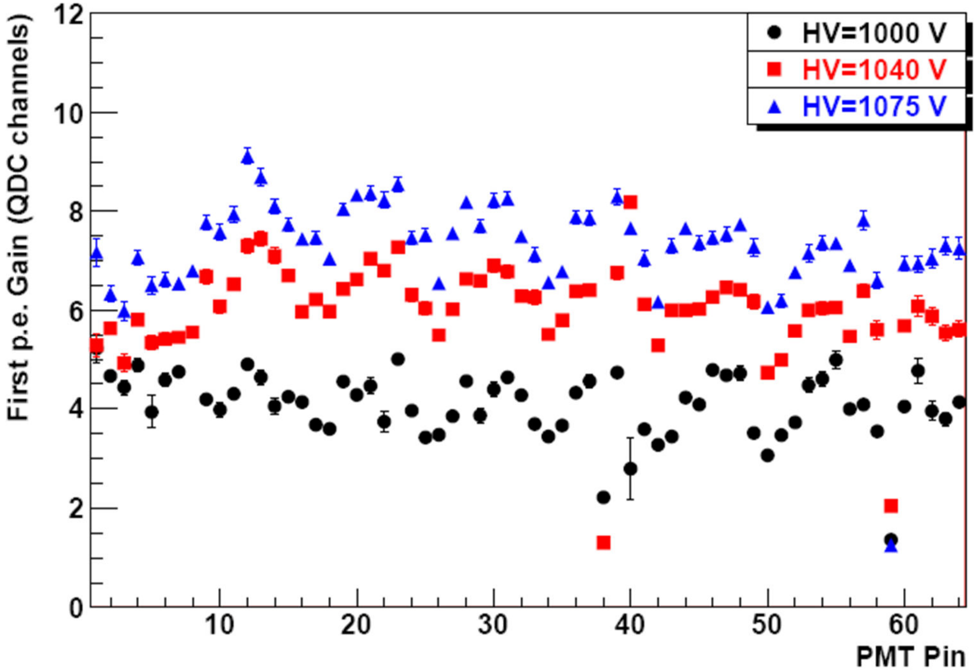




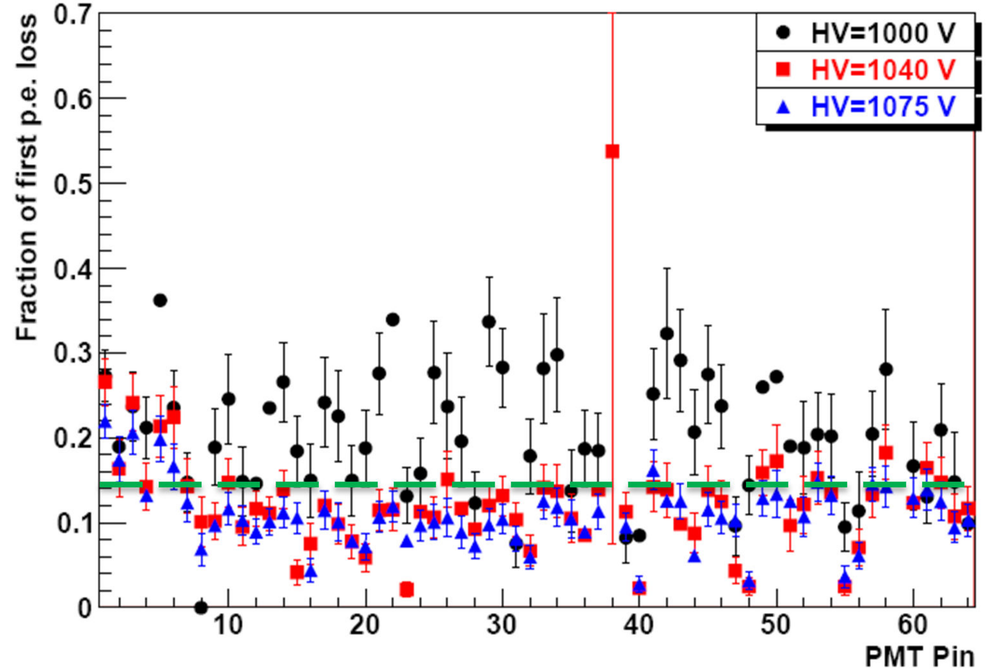


- Based on Hamamatsu test ticket data
- No correlation between dark current and gain observed
- No correlation with production time
- <1500cps estimated

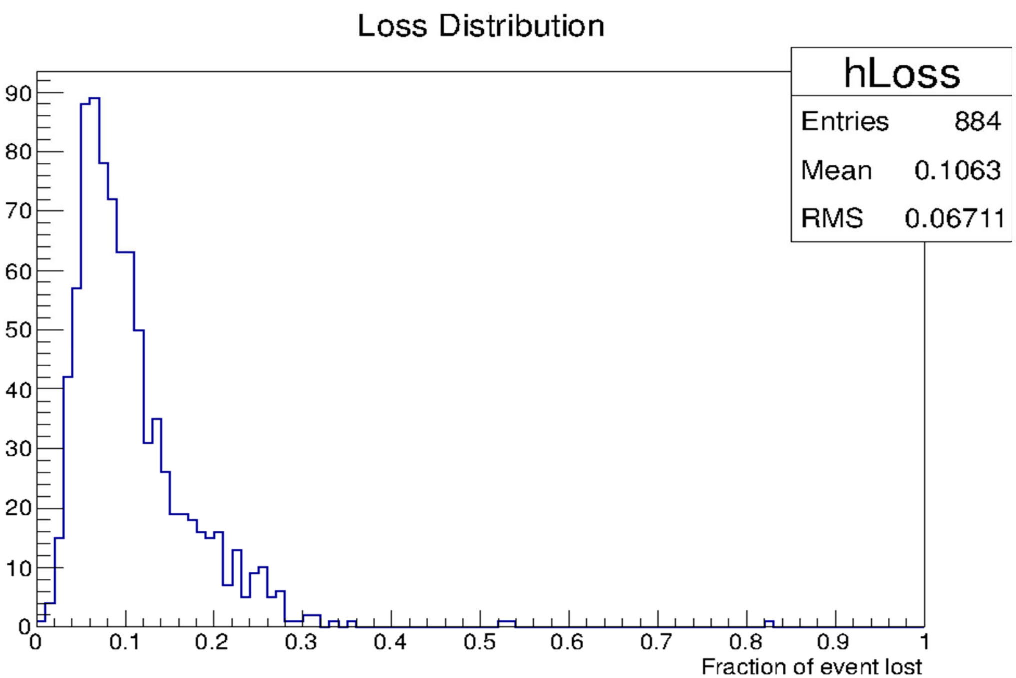
Tuning Operating Parameters

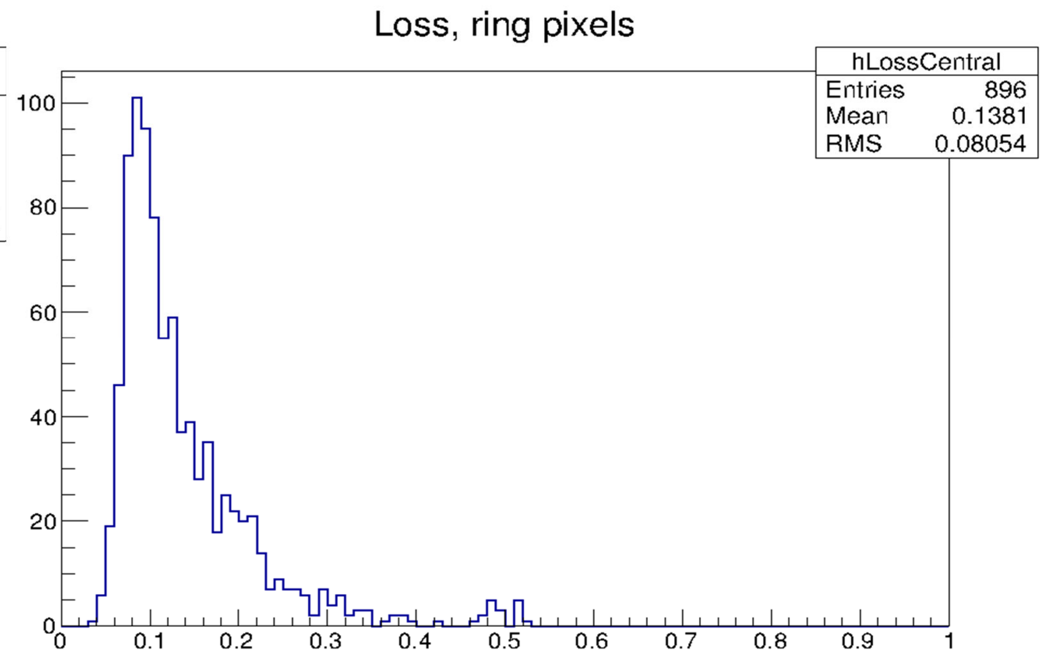


- Primary parameter is SPE loss
  - reduces Cherenkov photon yield
  - On average 15% achievable
- Increase supply voltage
  - >1040V



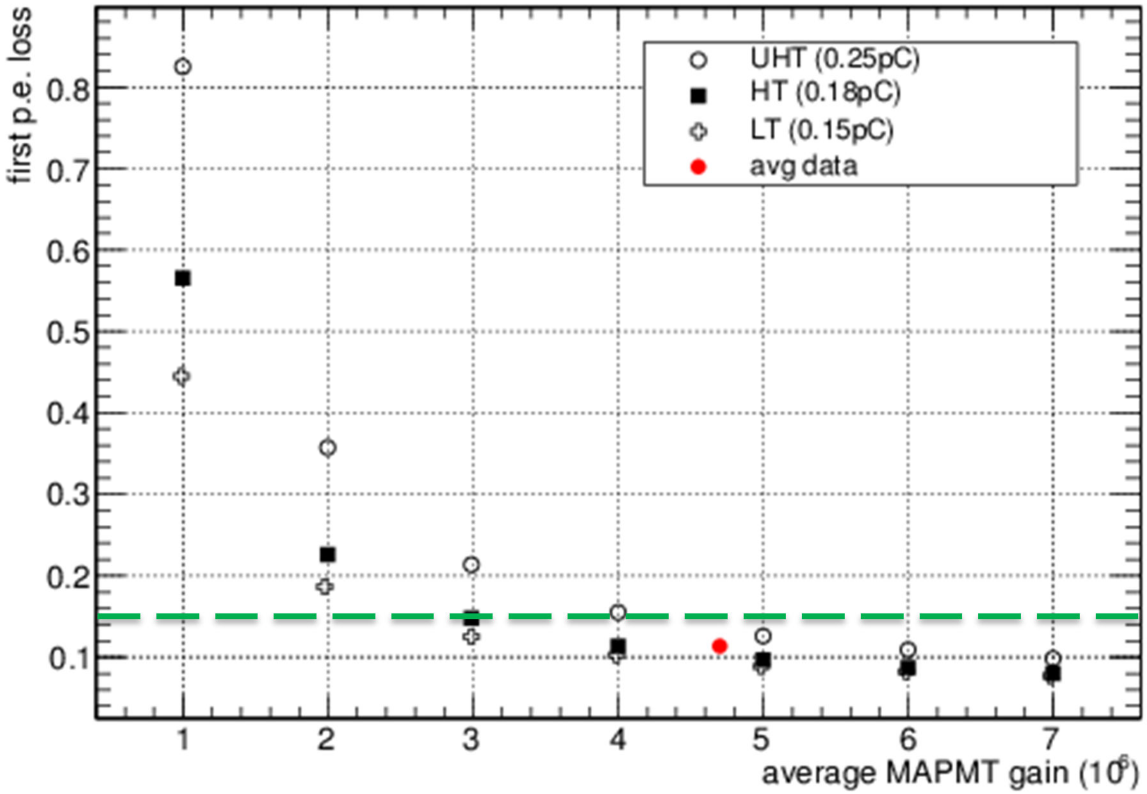
Comparison of SPE Loss Fractions (1075V)





Laser Test Facility	CERN T9 Test Experiment
VME electronics	MAROC electronics
No amplification	Amplification x4
Pedestal cut 3σ	Pedestal cut 5σ

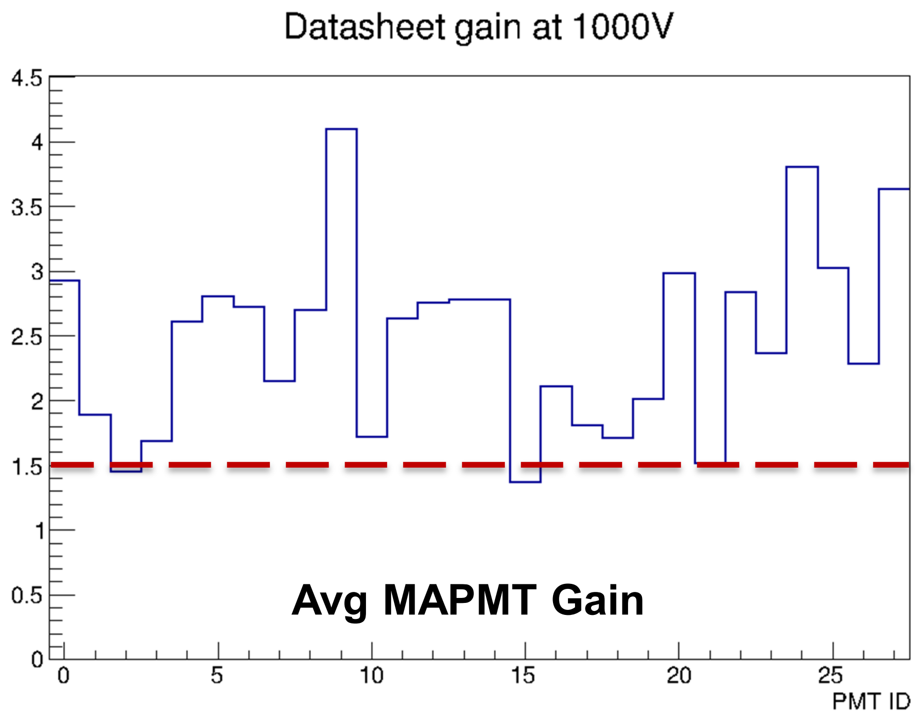
Threshold & Minimum Gain



- SPE loss depends not only on gain but also threshold
  - Depends on readout electronics
  - ~0.18pC for QDC readout
  - MAROC readout similar
- SPE charge distribution
  - Gaussian shape
  - Resolution ~0.6
- Extract loss fraction for different
  - Gain values
  - Threshold values

→ **Minimum gain of 3·10^6 at 1075V needed**

MAPMT Selection Criteria - Gain



- 28 H8500 MAPMTs
  - 14 with standard window (H8500C)
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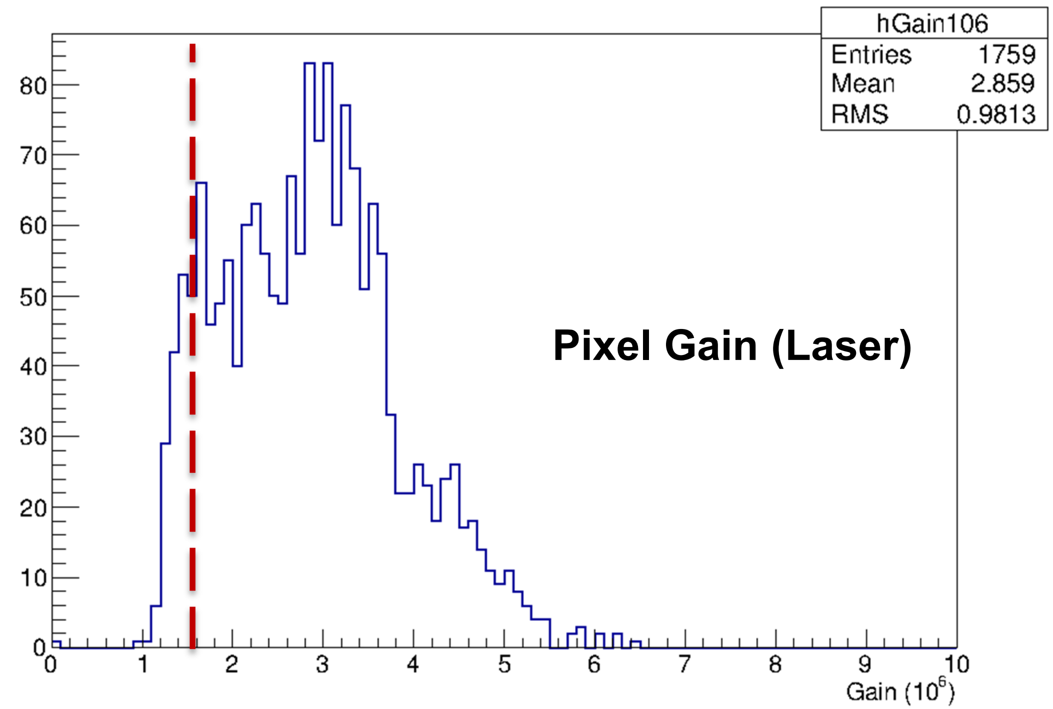
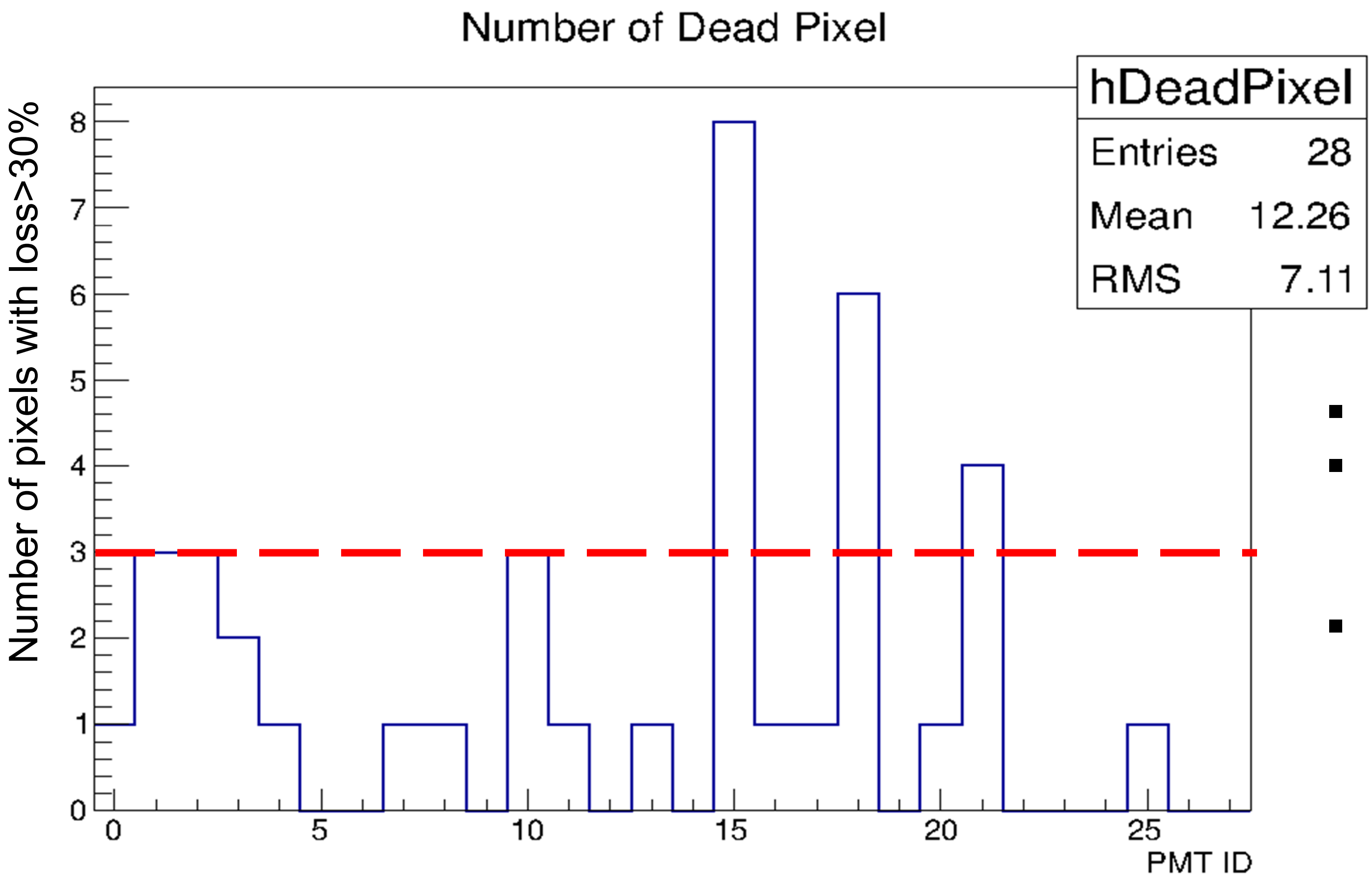


- Minimum gain of $1.5 \cdot 10^6$ at 1000V
- 3 MAPMTs close or below limit
- ~10% of pixels below limit

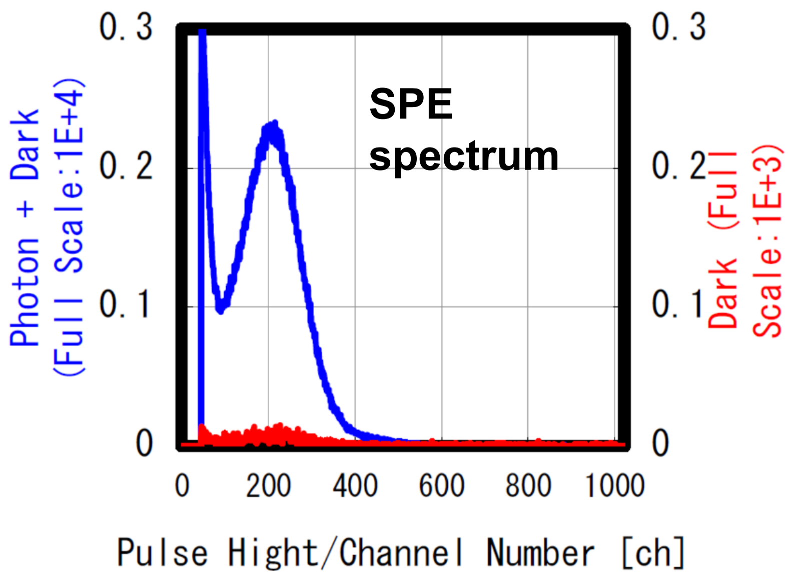
MAPMT Selection Criteria - SPE Loss

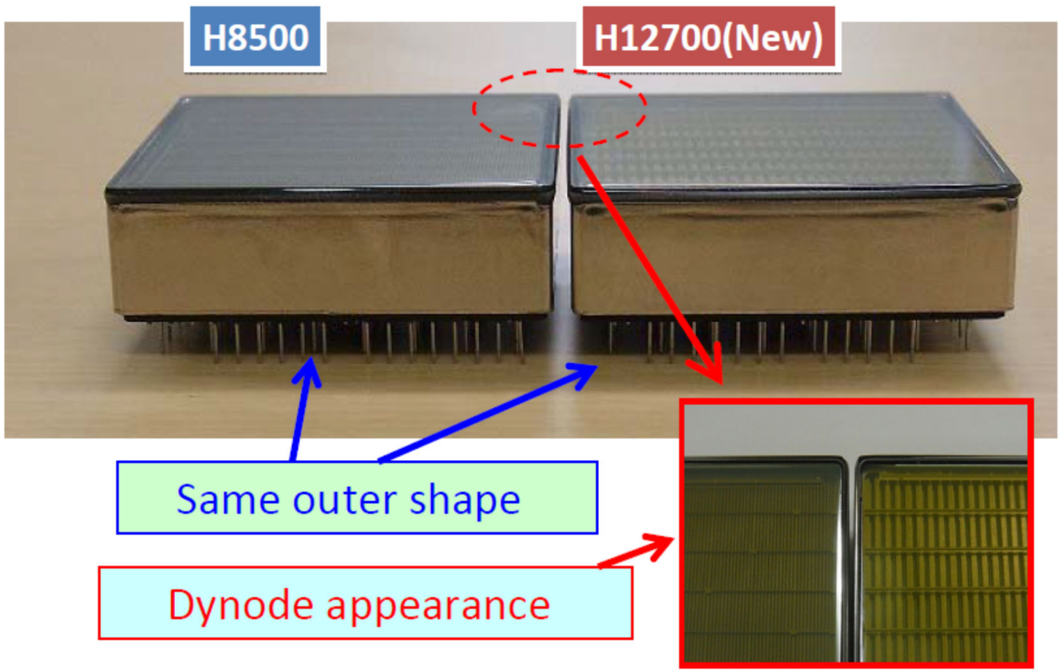


- Optimal HV (1075V)
- Allow 3 pixels with large SPE loss (>30%) per MAPMT
- 3 MAPMTs above limit

New Developments (H12700)

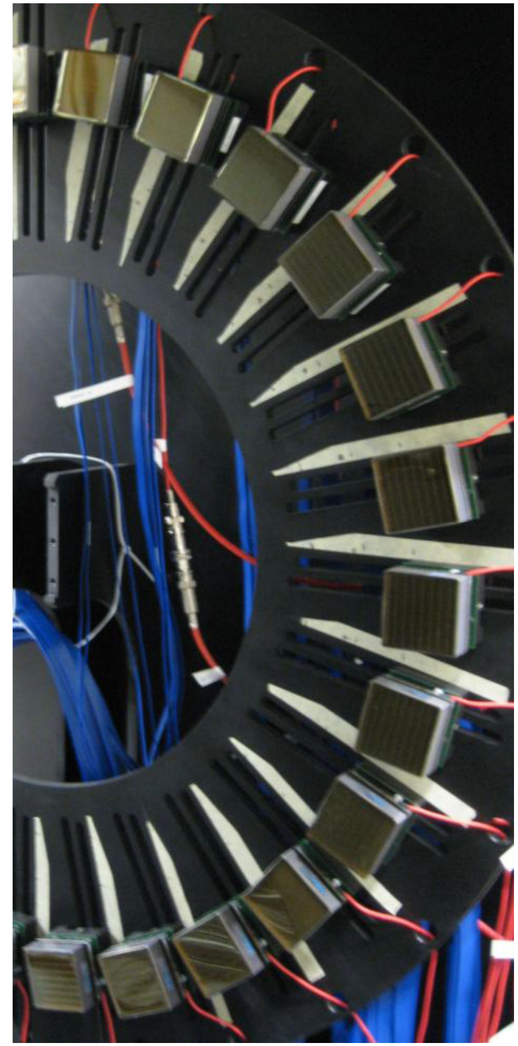
- New flat-panel MAPMT announced by Hamamatsu
  - Improved dynode chain design for better SPE detection
  - Similar gain & dark current characteristics
  - Same footprint & active area
  - Official release date January 2014
    - Samples available from August 2013
  - Same price tag



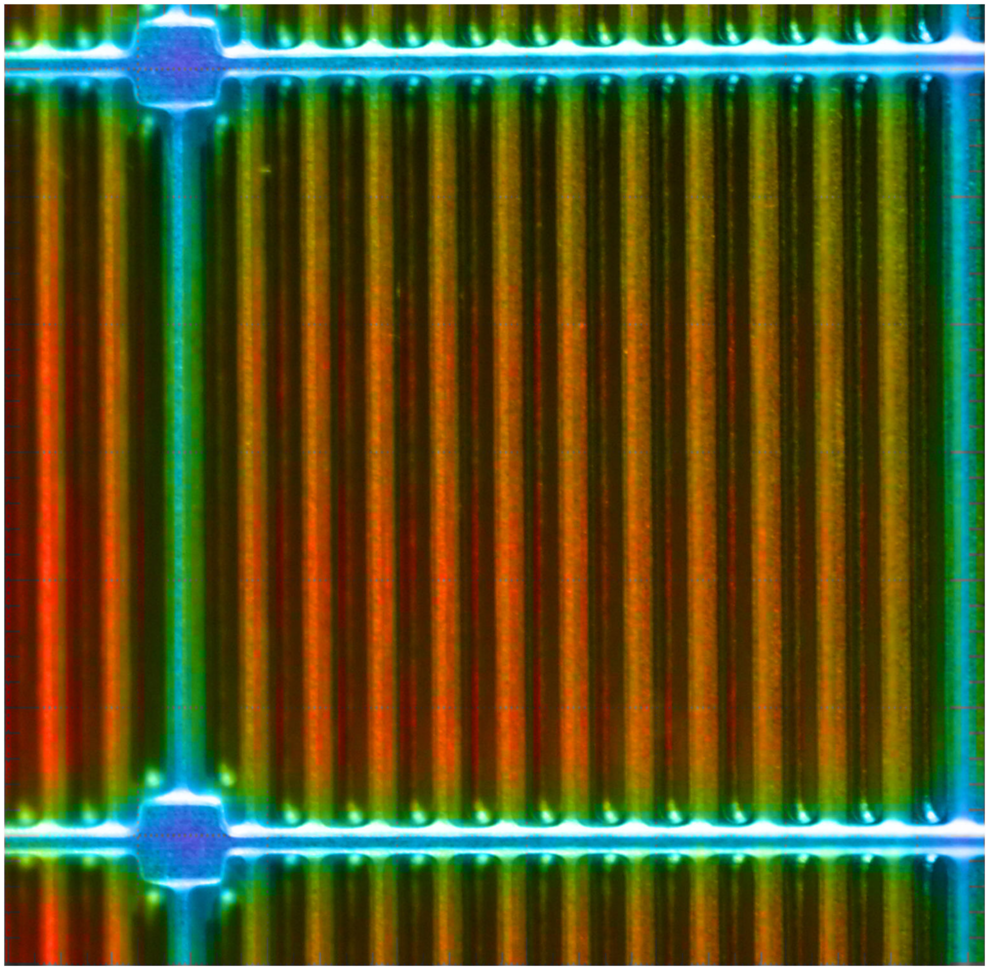


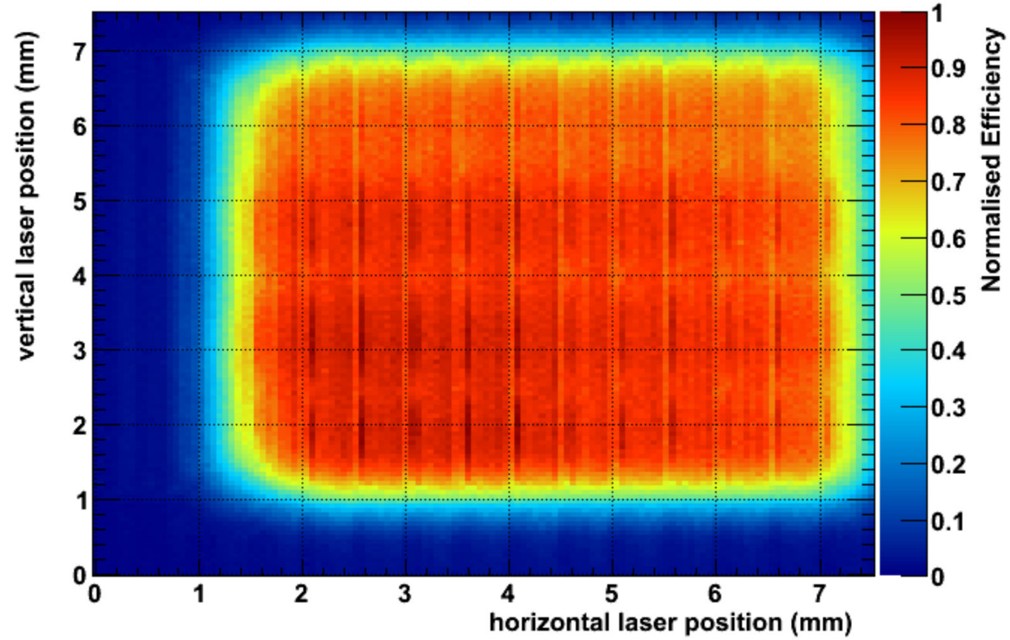
Conclusions

- Laser test facility provides excellent environment to study MAPMT response
  - gain distributions
  - crosstalk effects
  - results confirmed during CERN test experiments
- Multi-anode PMTs preferred choice
  - Hamamatsu H8500 preferred candidate
    - 400 H8500 per sector
  - mature technology readily available
  - pixel size and gain match requirements
  - Cost-efficient solution
  - 85-90% of MAPMTs match selection criteria
  - Further improvements in near future



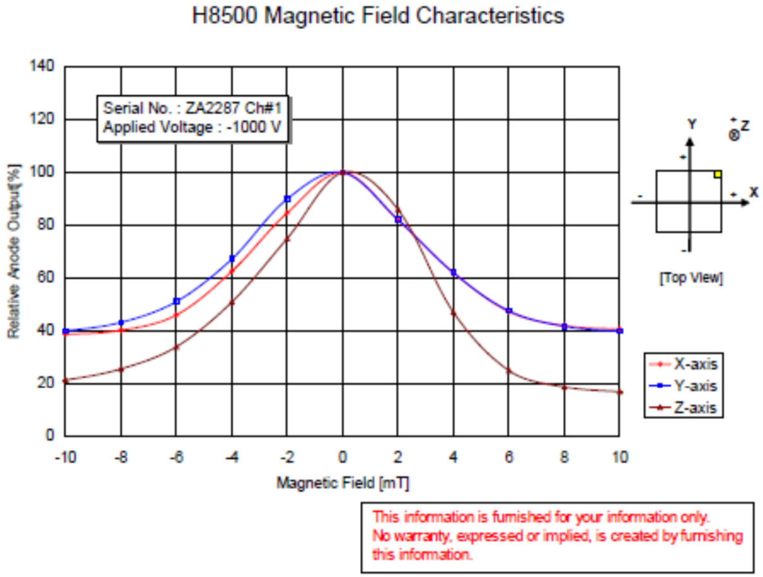
Spatial Response – A Closer Look

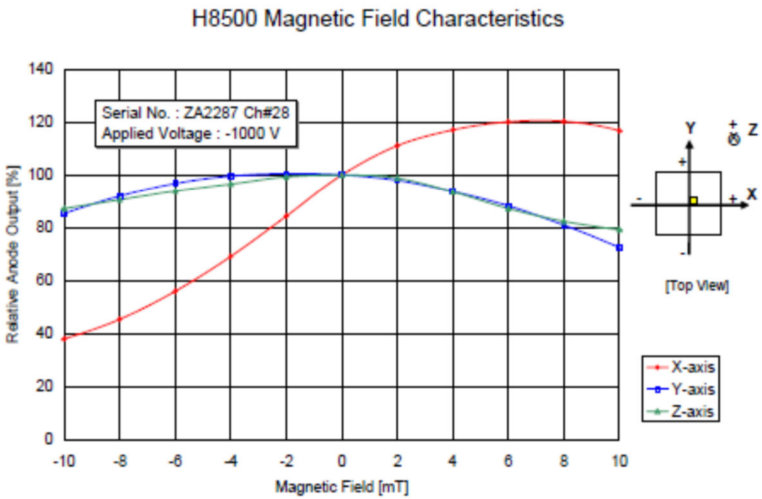




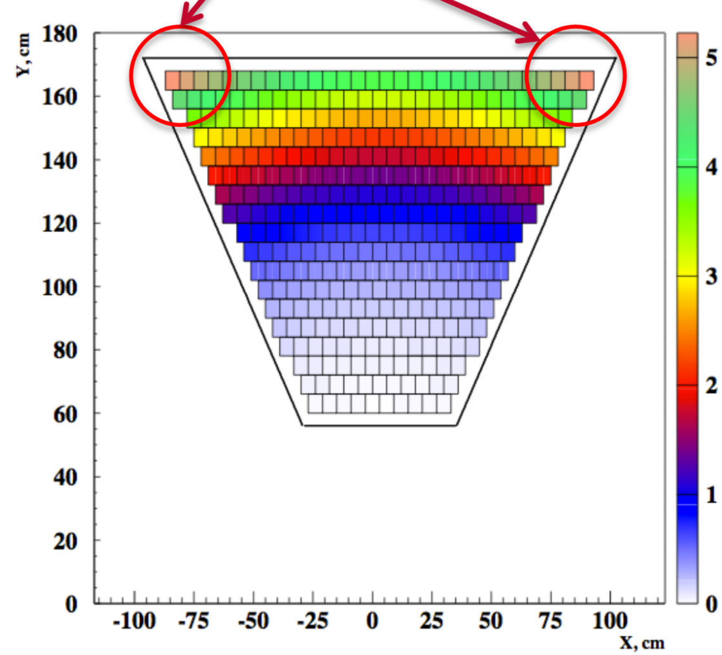
- High resolution scan of a H8500 pixel
  - step size ~40micron
- Reveal pixel substructure
- Boundary & corner effects
- Substructure matched to physical dynode structure

Magnetic Field Susceptibility





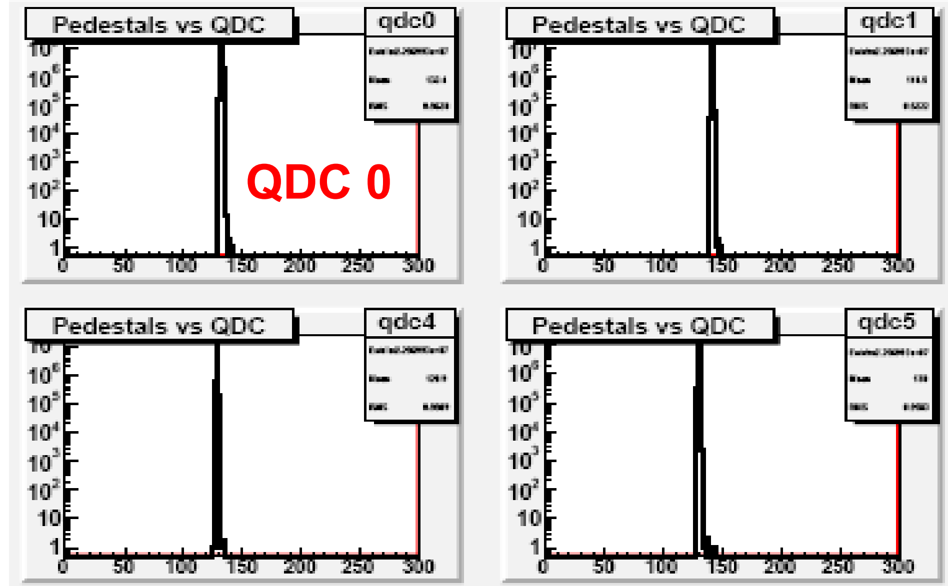
- Magnetic fields affect gain
  - Z-direction slightly worse
- Expected field strength for CLAS12 RICH
  - Perpendicular to Z-axis
  - Max 0.5mT

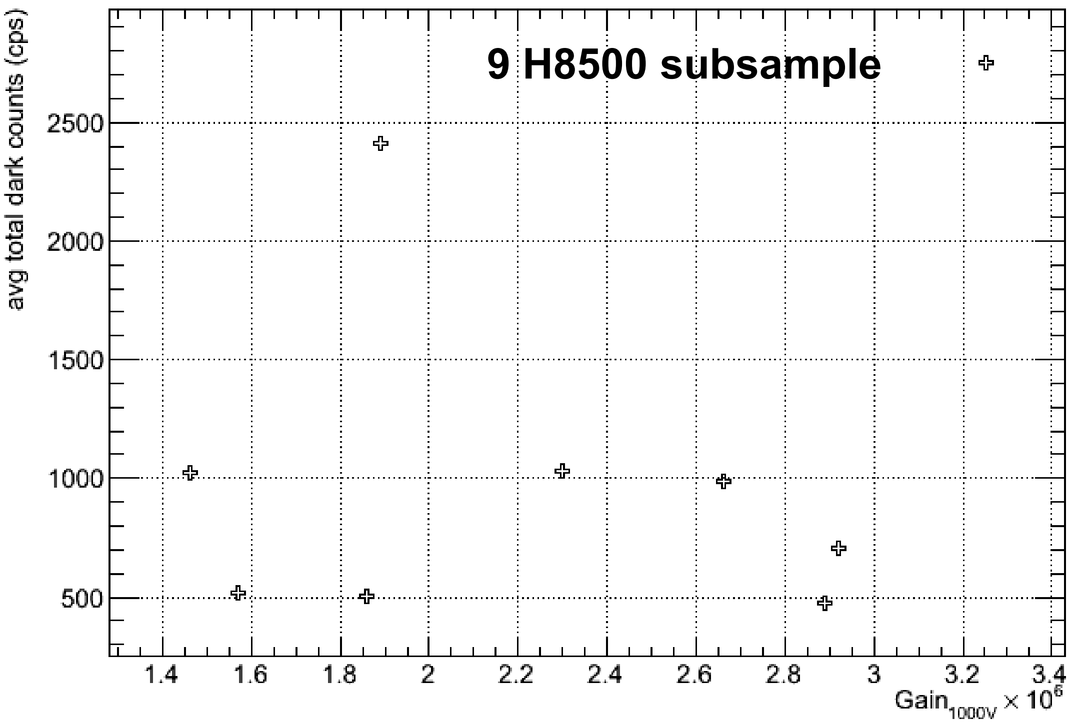


HAMAMATSU

Dark Noise

- Direct measurement of dark count charge spectrum
  - HV -1125V
  - PMT covered by its cap





- Estimate dark count rate using dark current data
- On average <1500cps per MAPMT
- Independent of gain

H8500 SPE Signals