Characterisation of LAPPD

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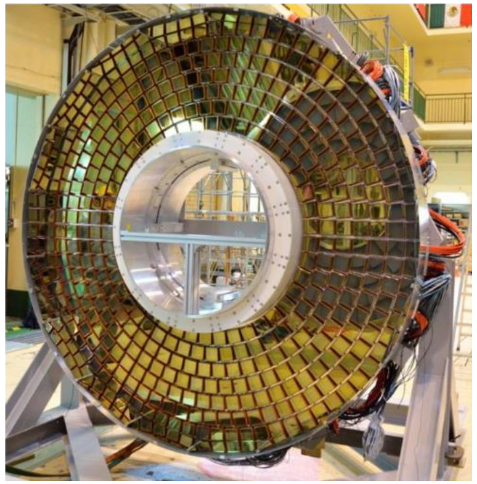
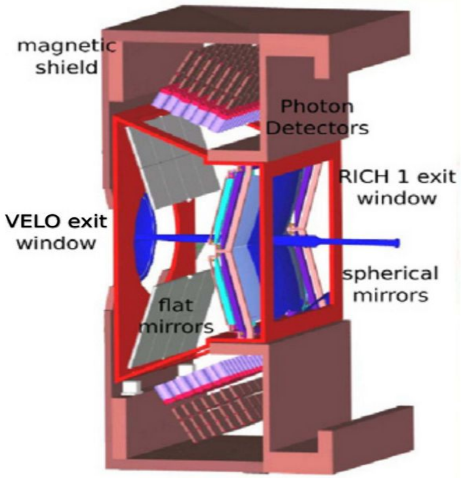
University of Maribor

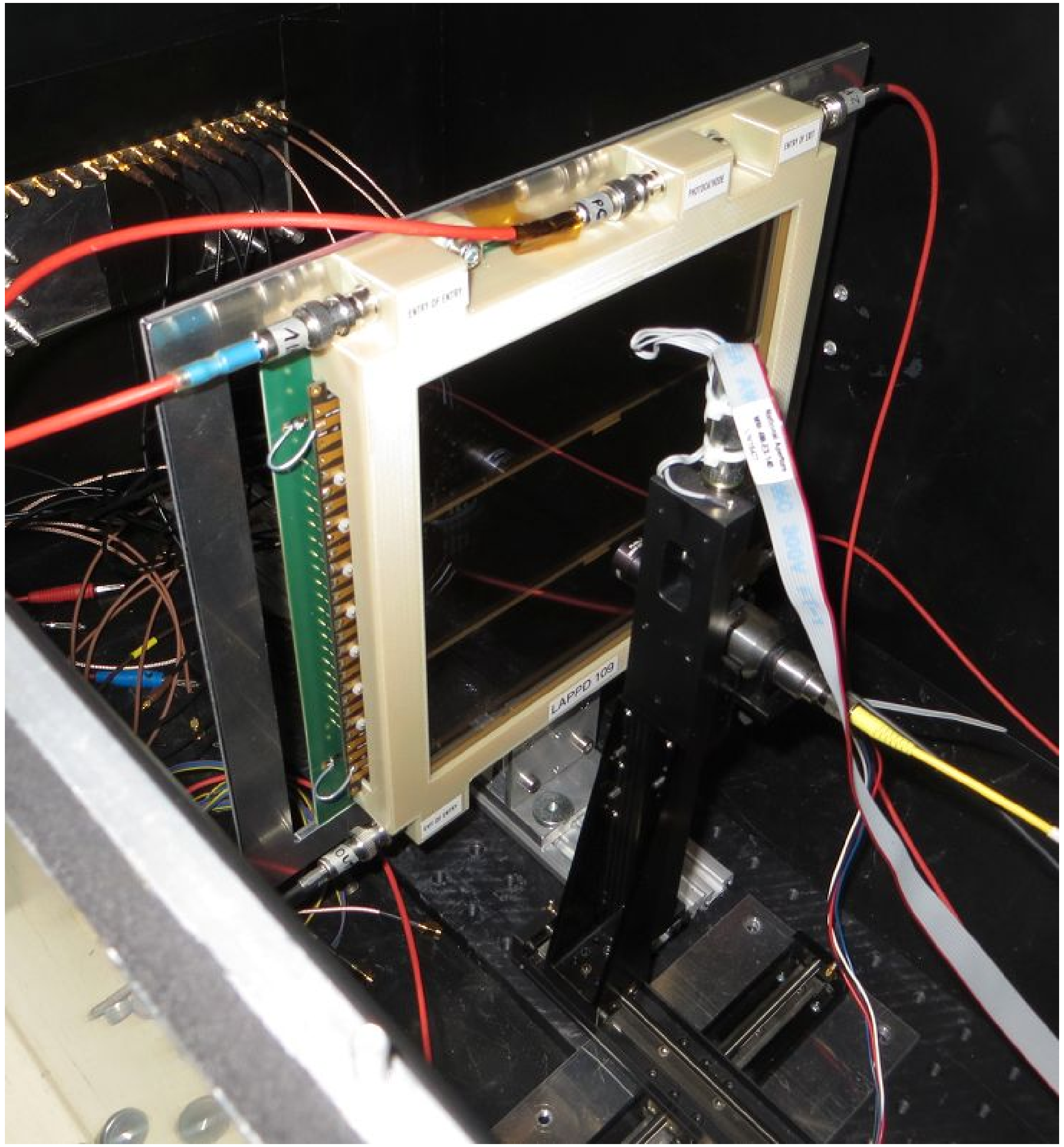
- Large area picosecond photodetector (LAPPD)
- Candidate for future RICH detectors
- Experimental setup
  - timing resolution
  - charge sharing
- Model
- Comparison of model and experiment
- Multichannel readout - PETsys, FastIC
- Conclusions

Belle II ARICH

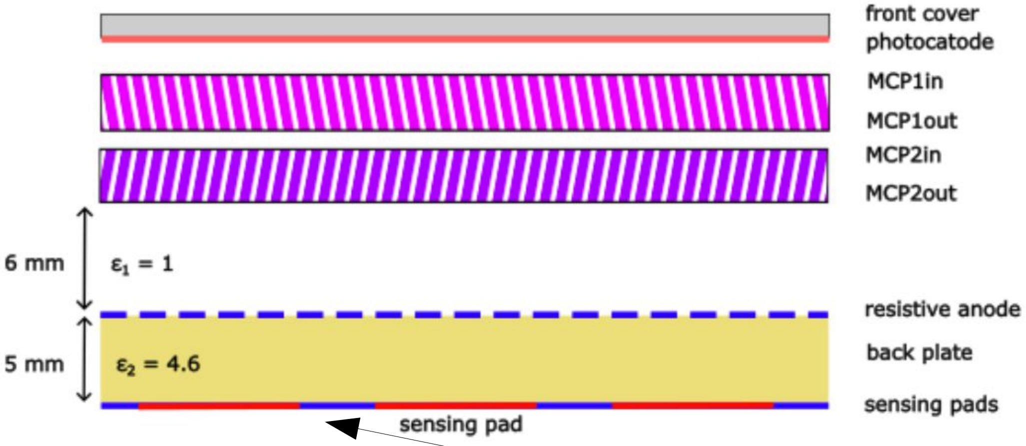


LHCb RICH

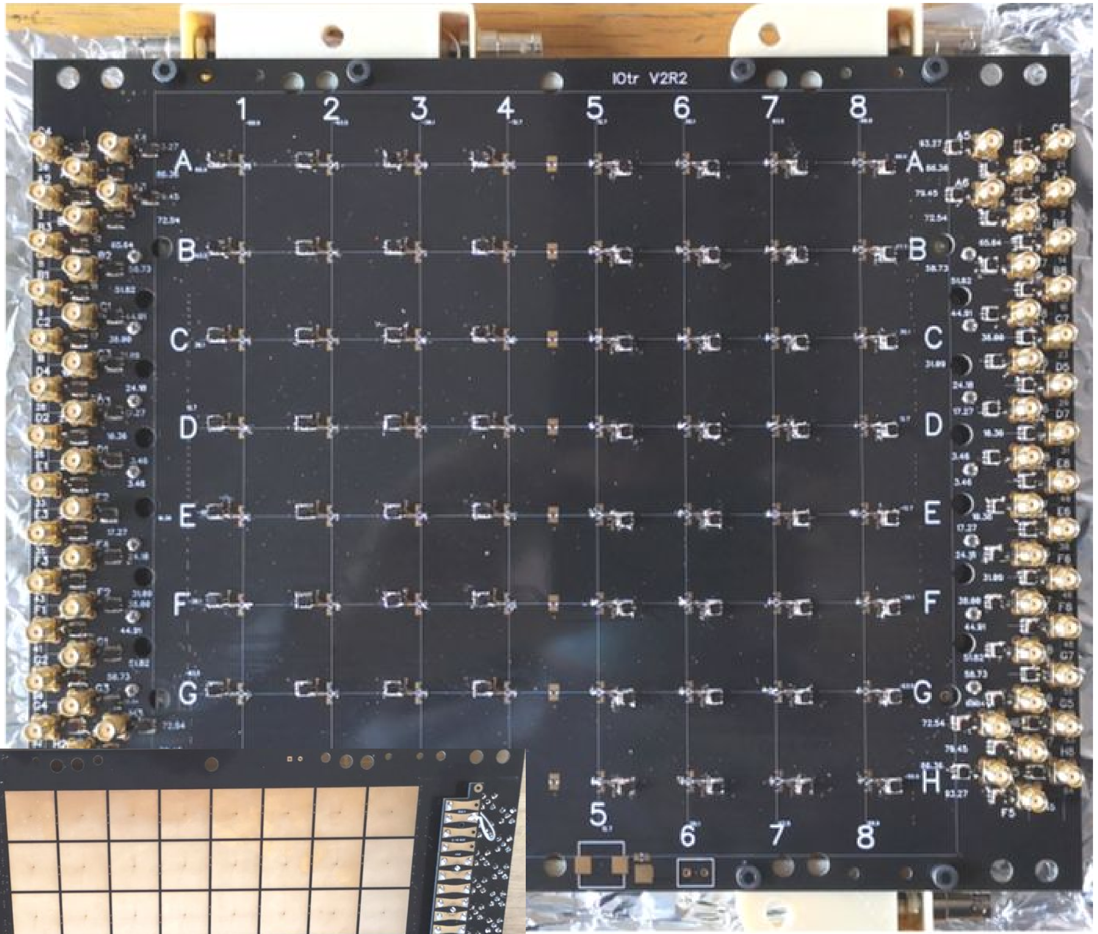


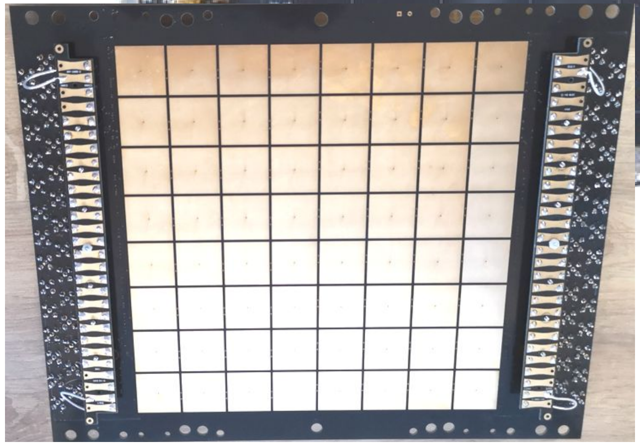


- Samples #109 and #162
- Monolithic ground plane anode, capacitively coupled to the readout electronics on the external side
- Different photocathode-MCPs-anode distances, resistive anode dielectric constants

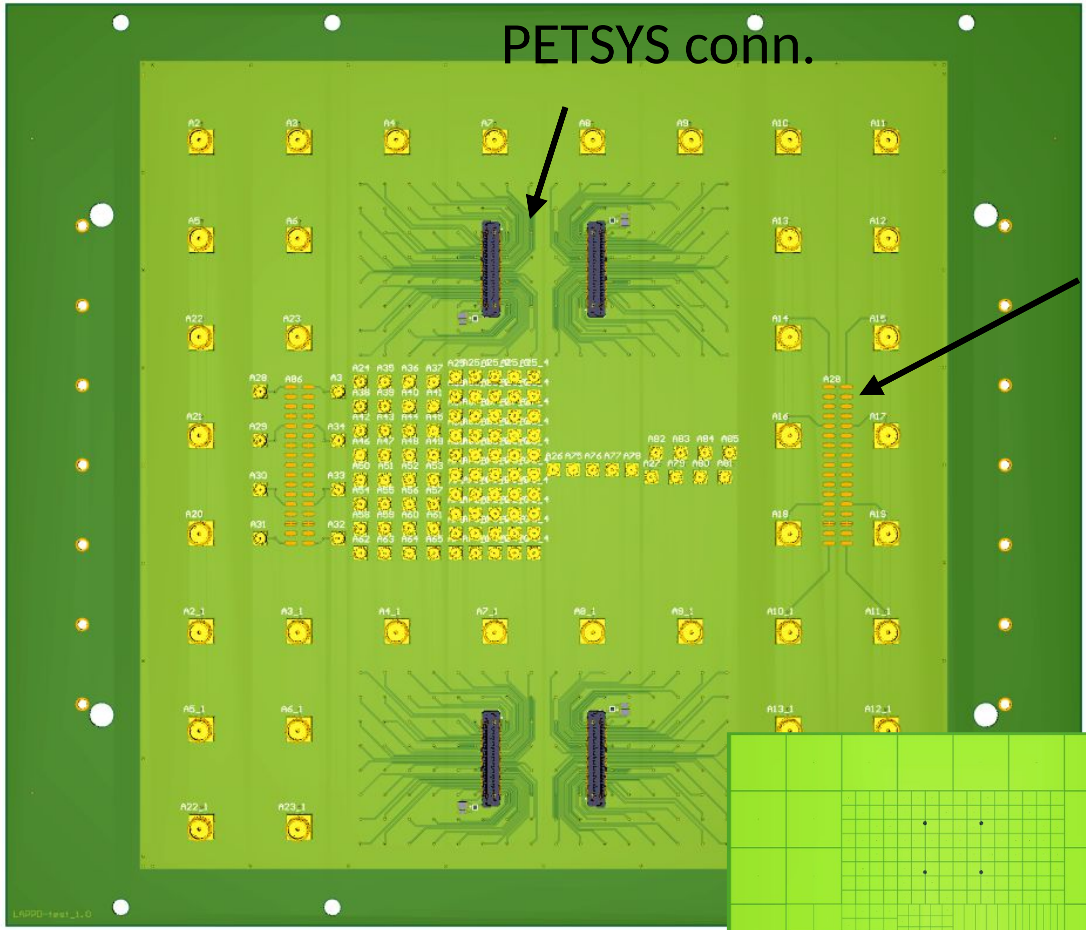


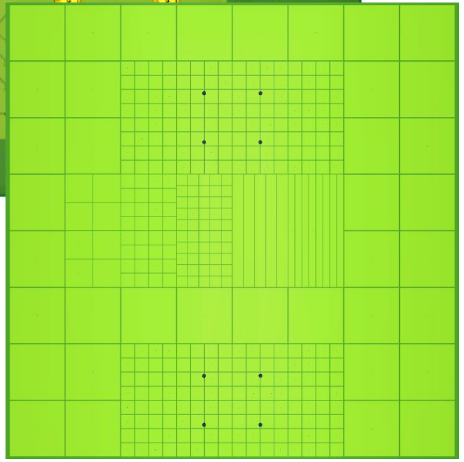
	LAPPD #109	LAPPD #162
Type	ALD-GCA	
Size	230 mm x 220 mm x 22 mm	
Window	silica glass (5 mm)	
Photocathode	Na_2KSb	
Peak QE @ 365 nm	27 %	33 %
Pore size	20 µm	10 µm
Pore pitch	25 µm	13 µm
Bias angle	13 °	
Gain @ recommended voltage	$5 \cdot 10^6$	$4 \cdot 10^6$
Photocathode-to-MCP1 distance	2.8 mm	1.19 mm
MCP2-to-anode distance (g)	6.7 mm	3 mm
Back plate thickness (d)	5 mm	2 mm
Back plate material	glass	ceramic
Back plate dielectric constant ε	4.6	10





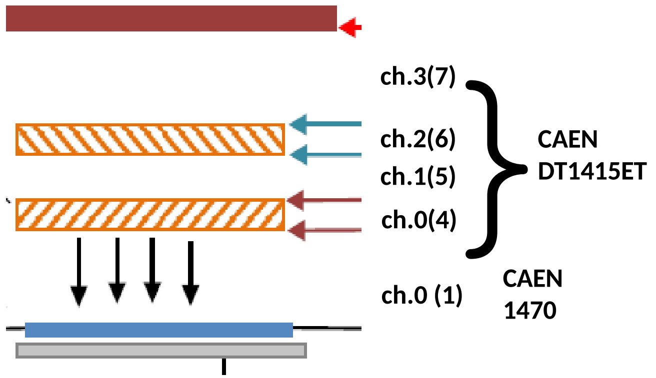
INCOM
(1” pads)

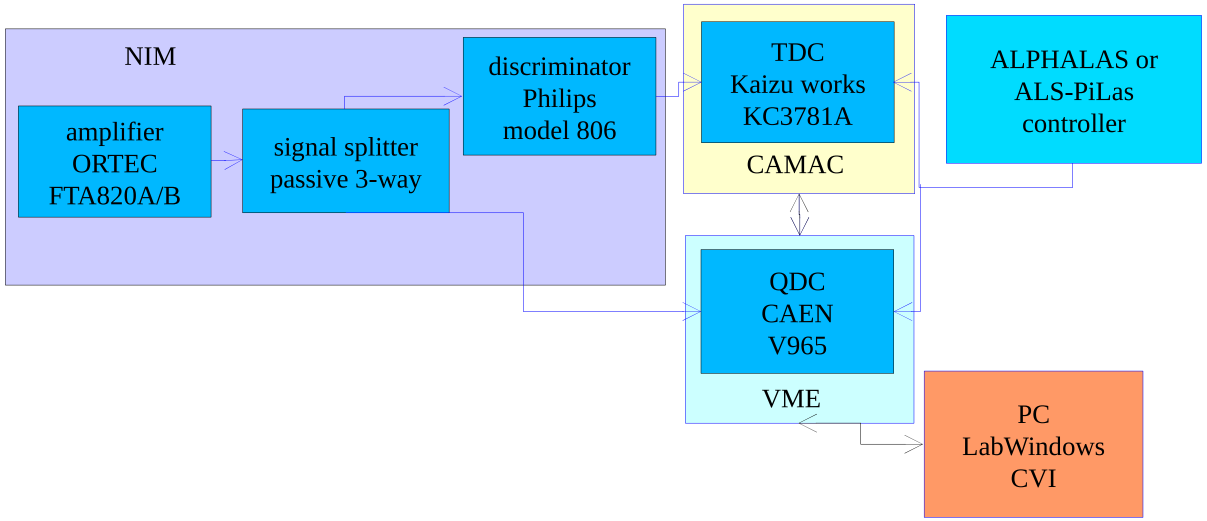


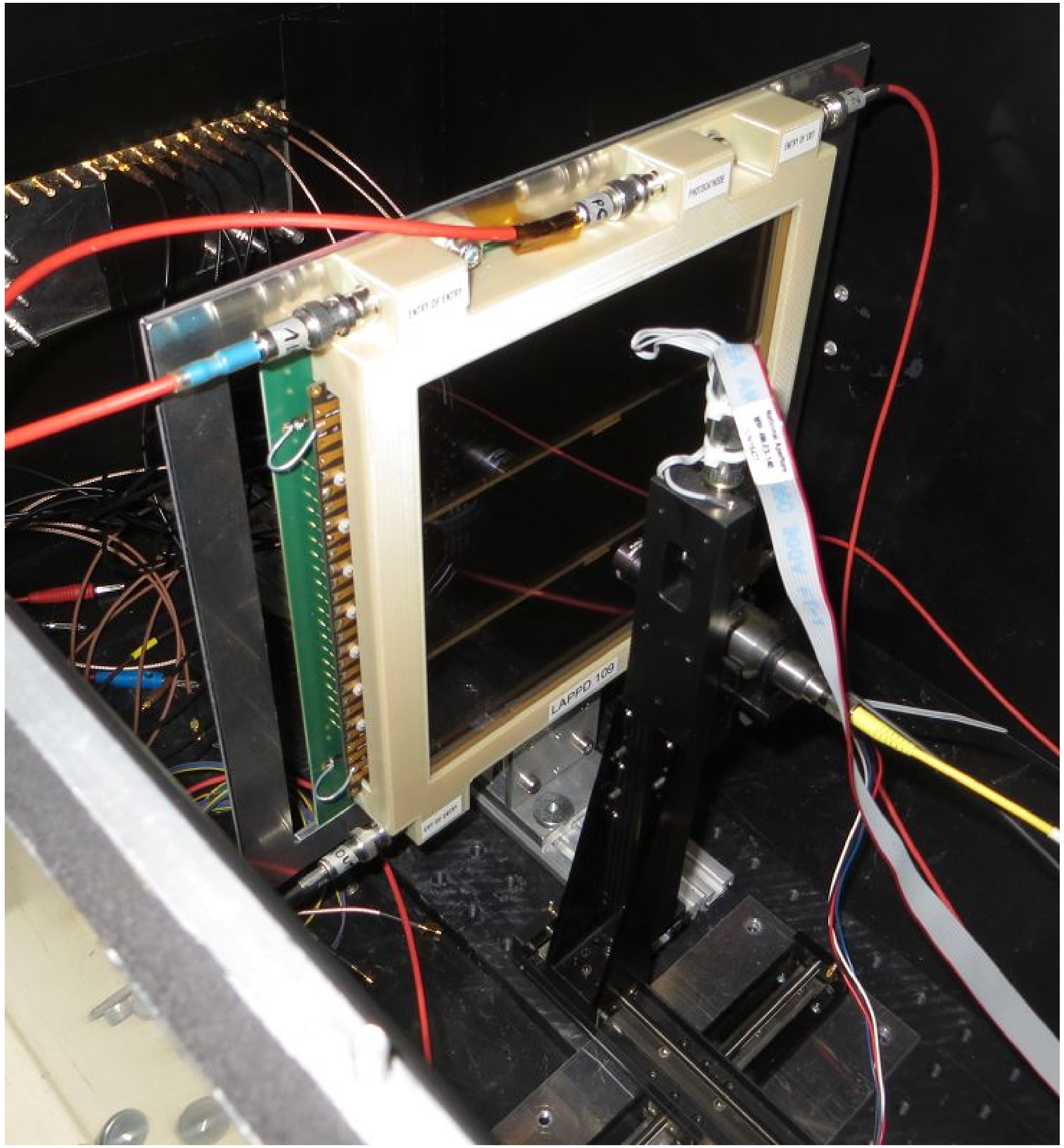


IJS
(1”, 1/2”, 1/4”, 1/5” pixels;
1/5” x 1” strips)

- ALPHALAS PICOPOWERTM-LD Picosecond Diode Laser (405 nm, FWHM ≈ 20 ps, spot size < 100 μm)
- Laser focusing optics on 3D motion stage
- independent control of voltages to LAPPD stages

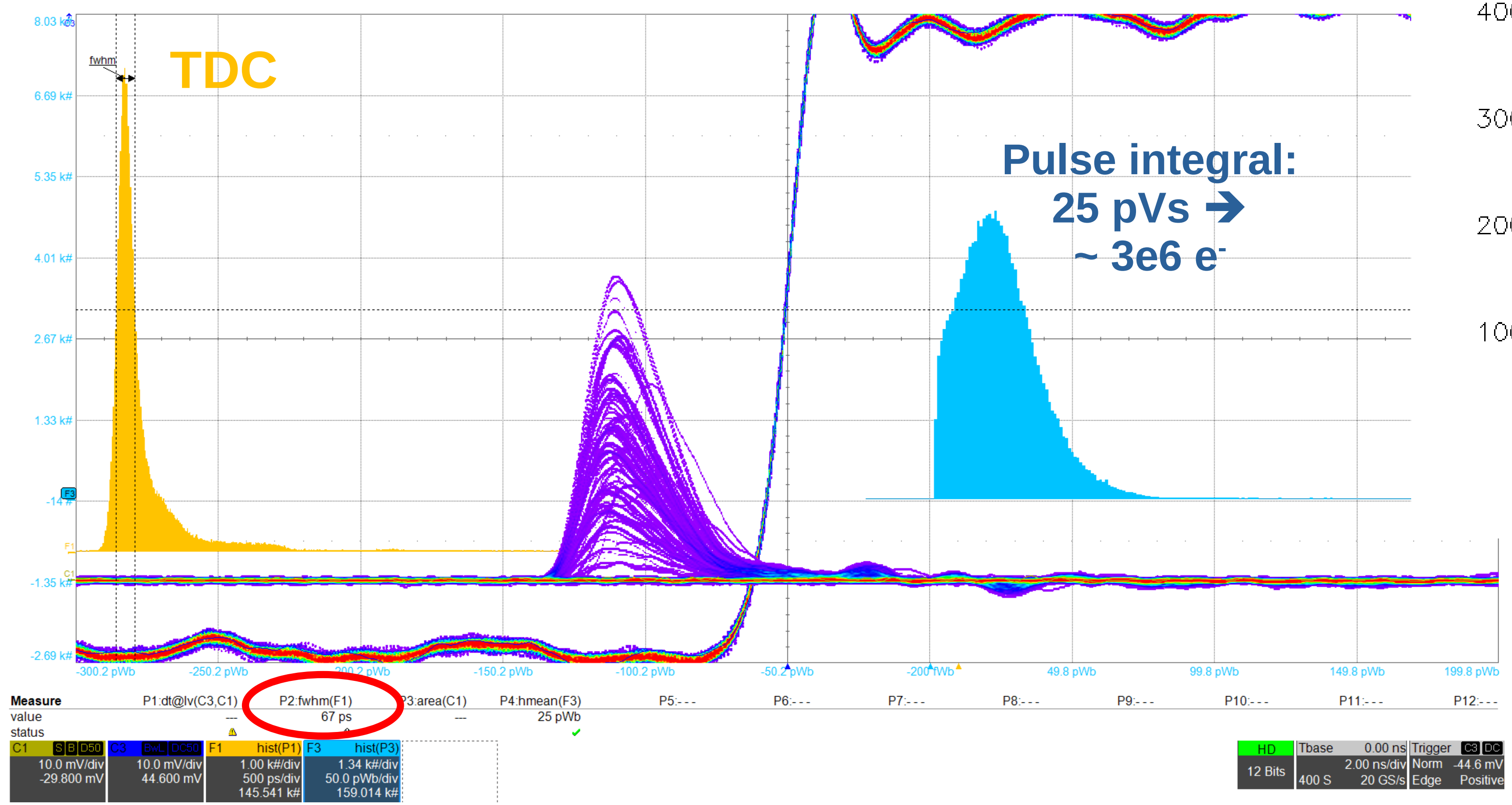


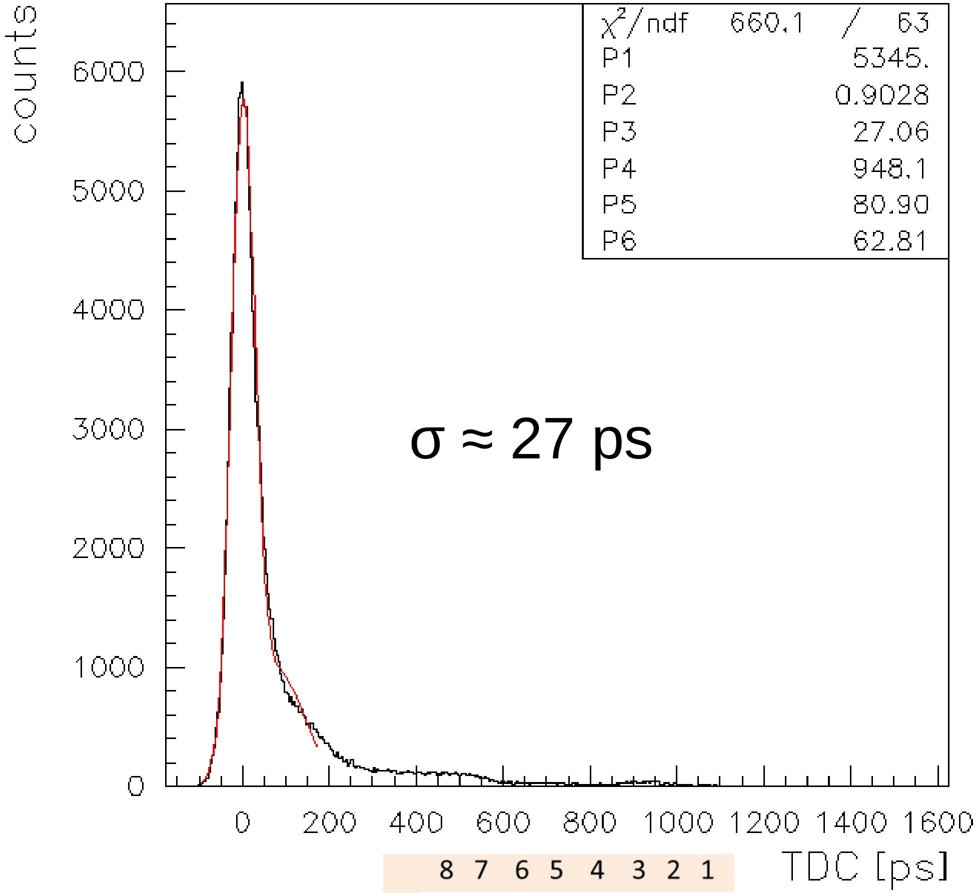


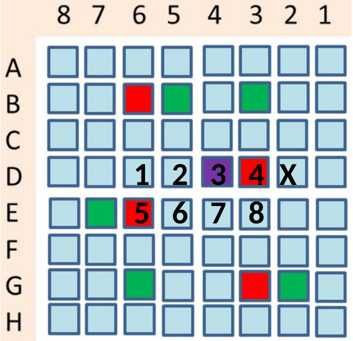


Results: timing resolution

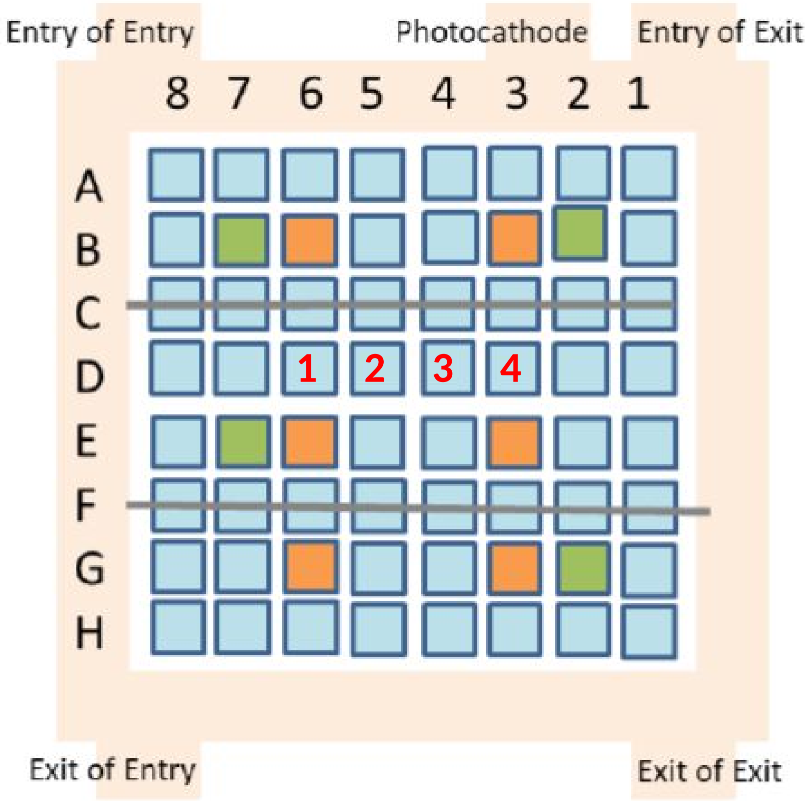
- LAPPD #162
- TDC main peak sigma 27 ps (67 ps FWHM)
- Average pulse integral ~3e6 electrons

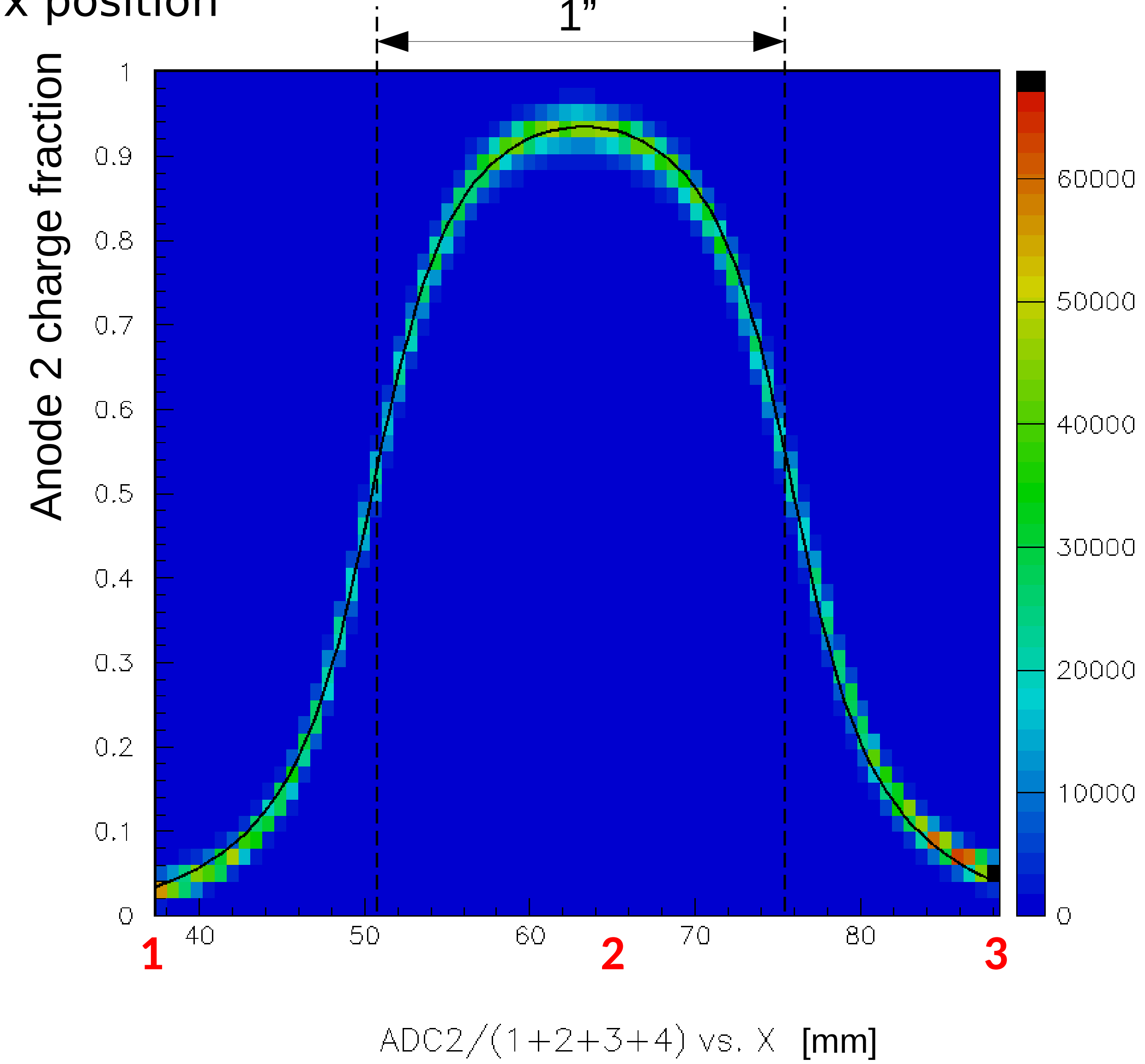






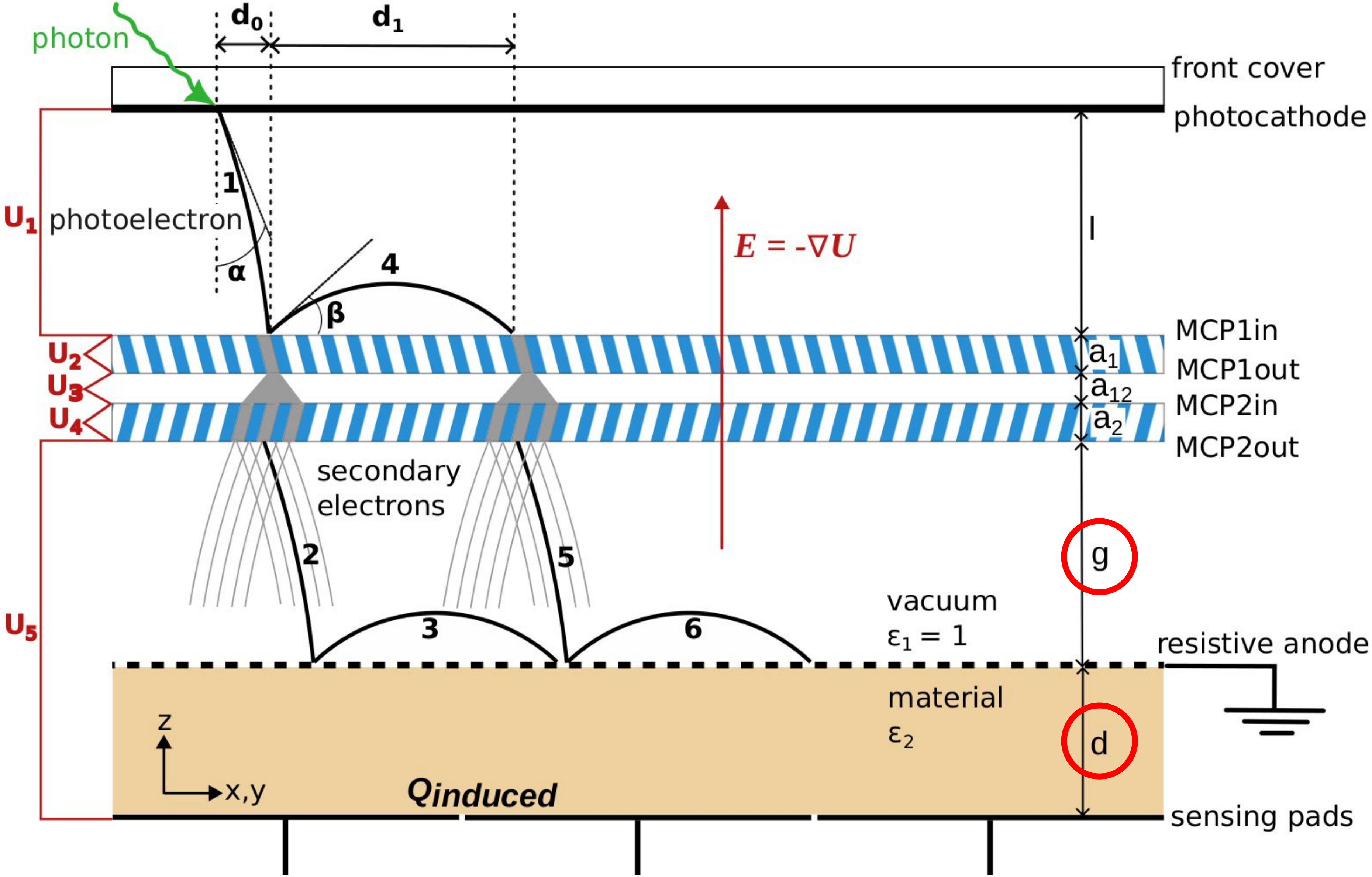
- Fraction of the signal on anode 2 vs laser spot x position





- How to model the charge sharing?

Modeling of the response of the detector



$d_{0\ max}$ ~ 0.4 mm
$d_{1\ max}$ ~ 2.4 mm
(LAPPD #162)

← secondary electrons after 2^{nd} MCP modeled as **point like charge**

← fraction **η** of charge is absorbed

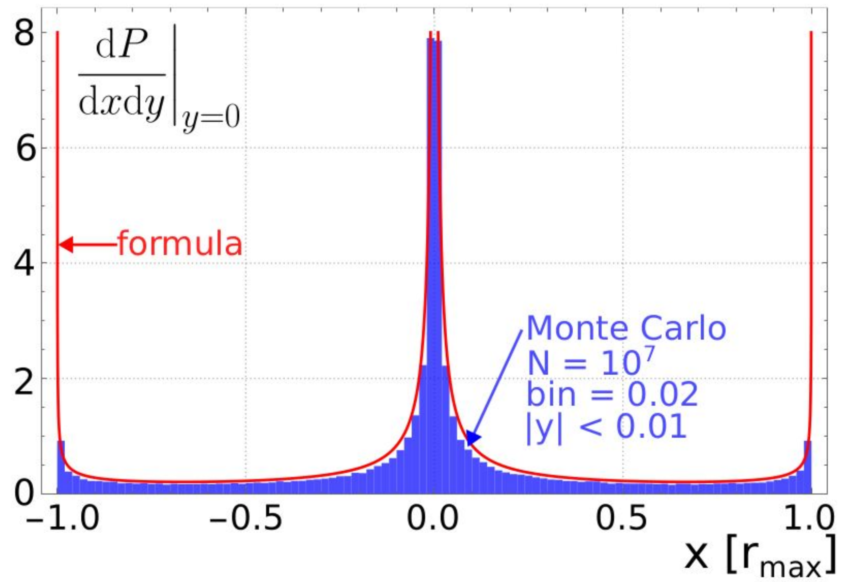
fraction **(1-η)** of charge scatters

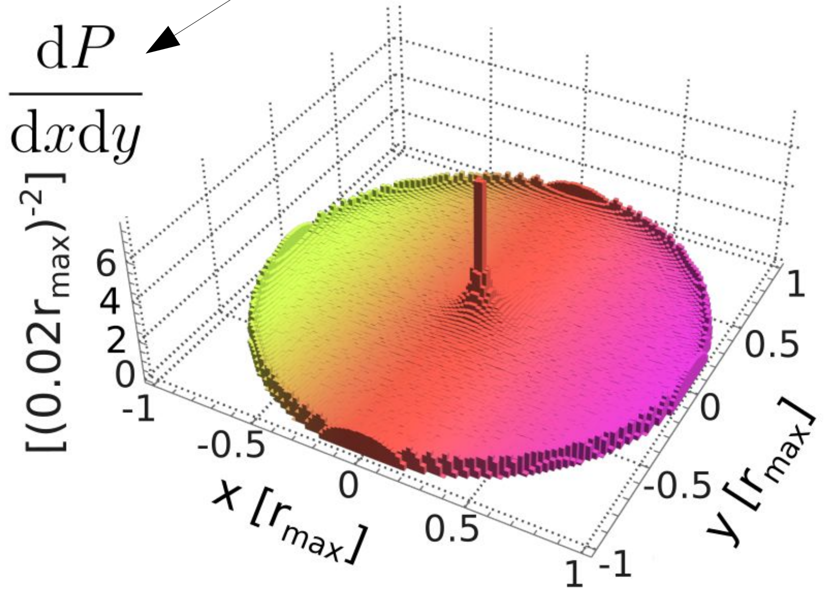
Calculation of induced charge on anode

- Shockley–Ramo theorem
- Induced charge at the electrode j: $Q_j(t) = -\sum_{i=1}^{N} q_i u_j(r_i(t))$
- Weighting field u_j: $\nabla\left[\epsilon(r)\nabla u_j(r)\right] = 0$
- Fraction of the signal collected at the anode: $Q_{anode}/Q_{signal} = \left(1 + \frac{\epsilon_1}{\epsilon_2}\frac{d}{g}\right)^{-1} = \begin{cases} 0.9 \text{ (g=2 mm, d=2 mm)} \\ 0.8 \text{ (g=5 mm, d=2 mm)} \end{cases}$
- Charge collected at a pixel of the read-out anode:

$$Q_{pixel}(x,y,d) = -Q_{signal}\left[\underbrace{\eta\, u(x,y,d)}_{\text{absorbed}} + \underbrace{(1-\eta)\left(\frac{d^2P}{dxdy} * u(z=d)\right)(x,y)}_{\text{scattered}}\right]$$

- Photoelectron backscatter distribution:



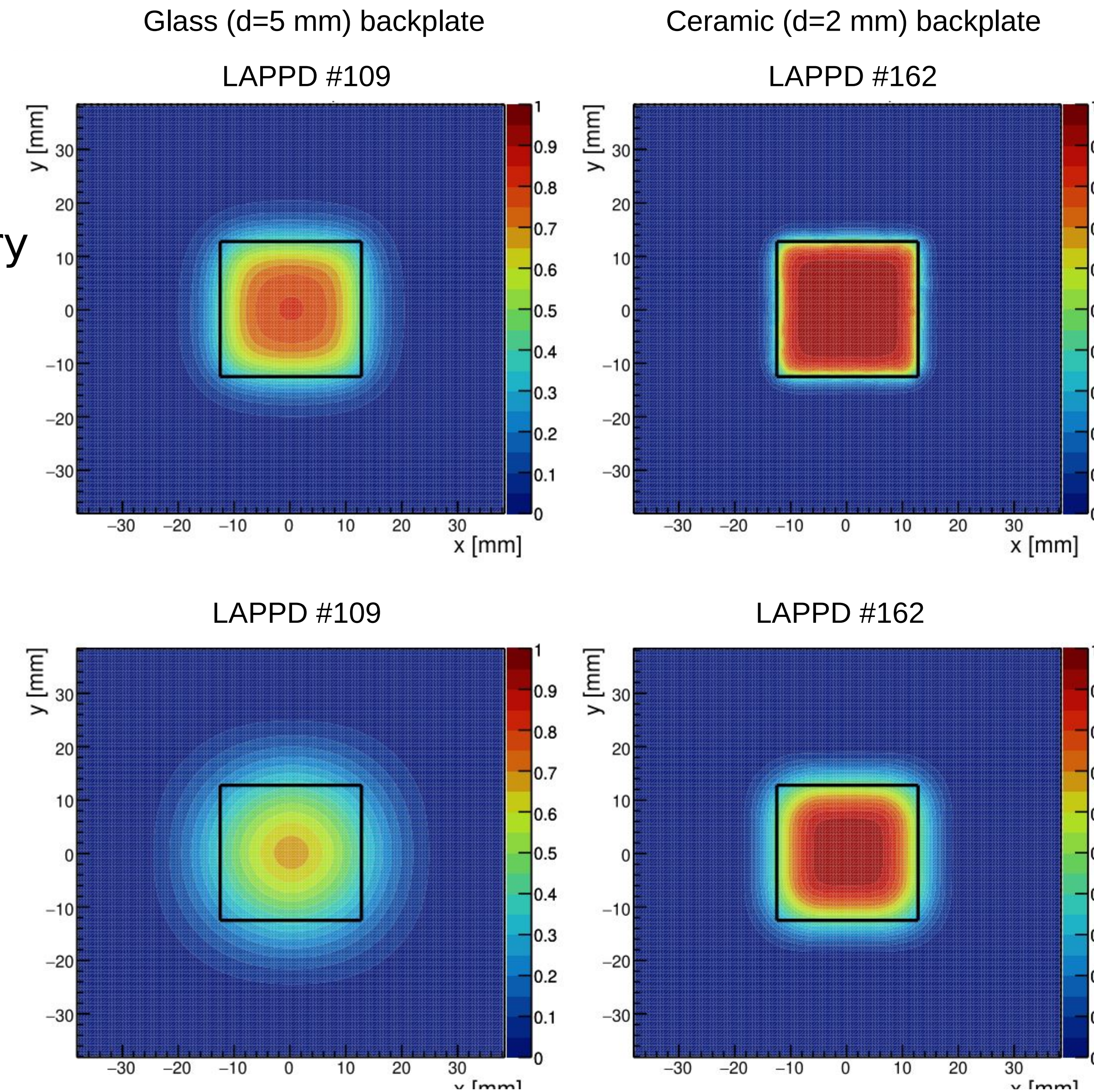


Modeling results: induced charge

- Fraction of the charge detected on a given sensing pad for different photon hit positions
- 25.4 mm pad readout

Without secondary electron back-scattering

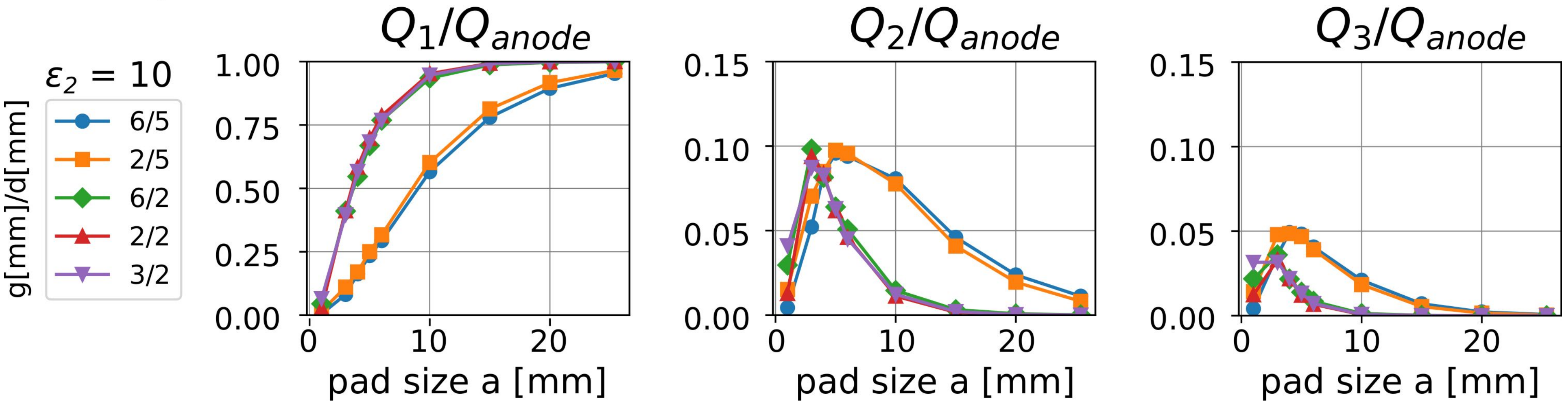
With secondary electron back-scattering



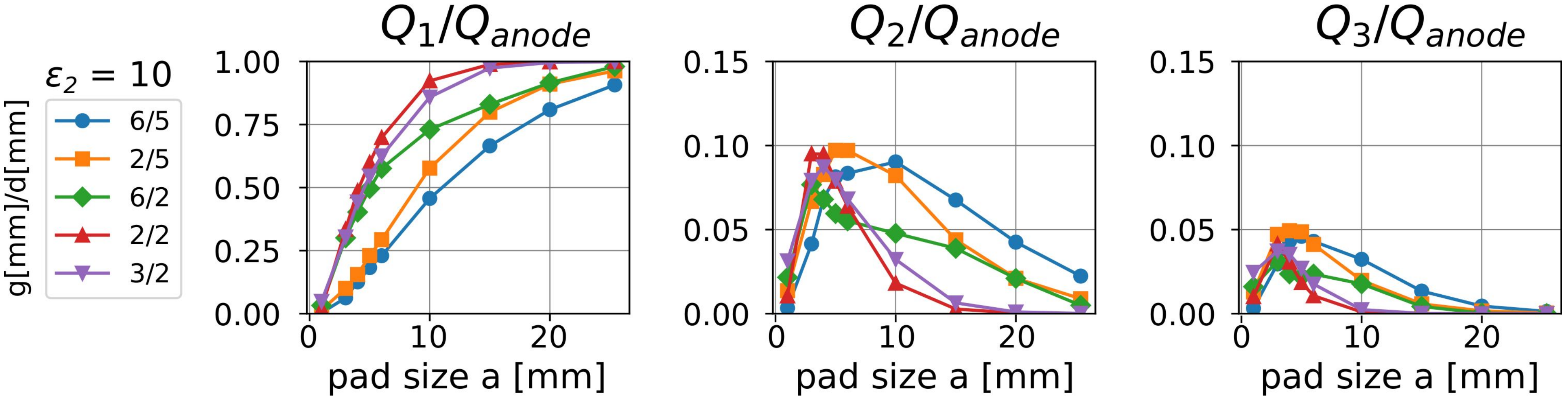
Modeling results: induced charge vs. pad size

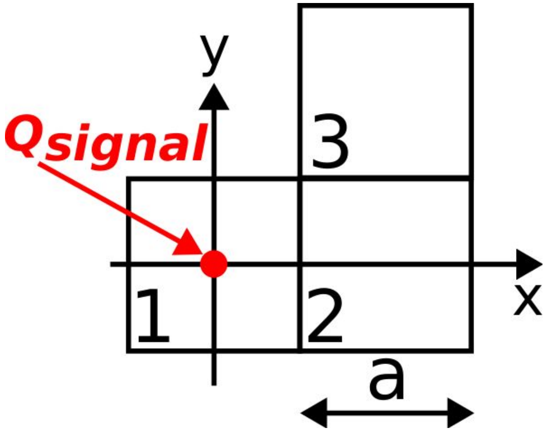
g: MCP2-anode
d: anode thickness

0% of Q_{signal} scattered



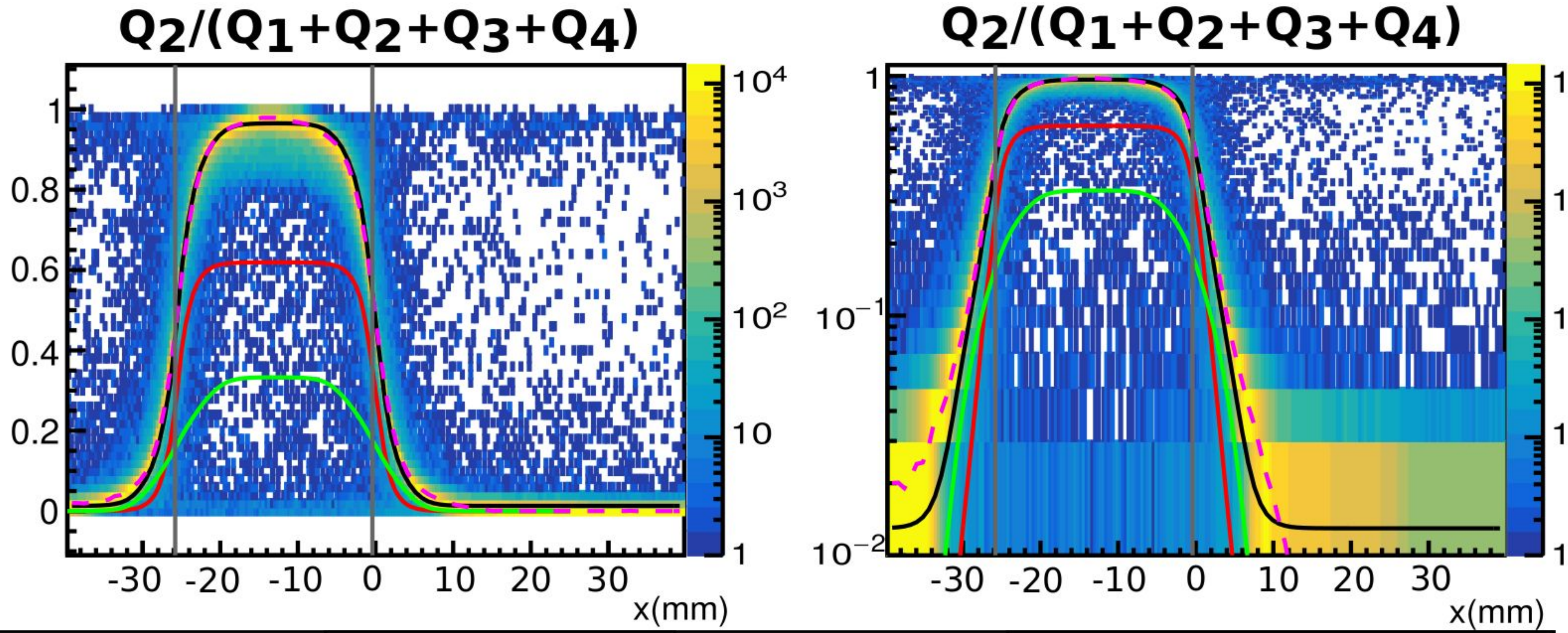
30% of Q_{signal} scattered





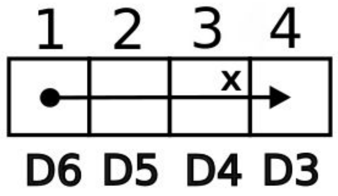
Comparing the model to experimental data

- LAPPD #162

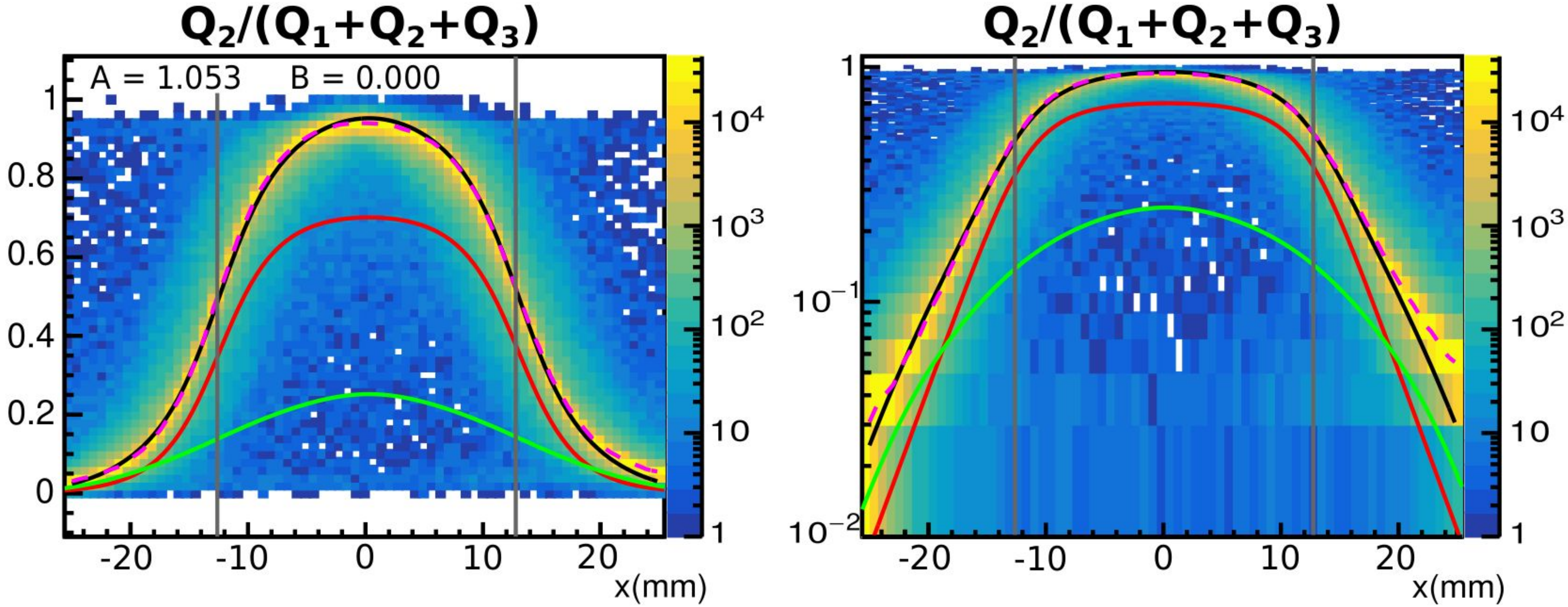


1 - η = 0.35	A = 0.953	B = 0.013	$1 + \epsilon_1 d/g\epsilon_2 = 1.07$

- Red: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot \eta \cdot u(x, 0, d)$
- Green: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot (1-\eta) \cdot \left(\frac{\mathrm{d}P}{\mathrm{d}x\,\mathrm{d}y} * u\big|_{z=d}\right)(x, 0)$
- Black: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot \left[\eta \cdot u(x, 0, d) + (1-\eta) \cdot \left(\frac{\mathrm{d}P}{\mathrm{d}x\,\mathrm{d}y} * u\big|_{z=d}\right)(x, 0)\right] + B$
- Magenta: spline fit



- LAPPD #109



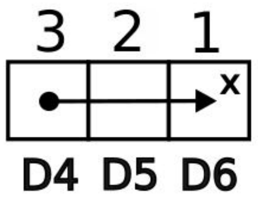
$1 - \eta = 0.30$	$1 + \epsilon_1 d / g \epsilon_2 = 1.18$

Red: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot \eta \cdot u(x,0,d)$

Green: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot (1-\eta) \cdot \left(\frac{\mathrm{d}P}{\mathrm{d}x\,\mathrm{d}y} * u\big|_{z=d}\right)(x,0)$

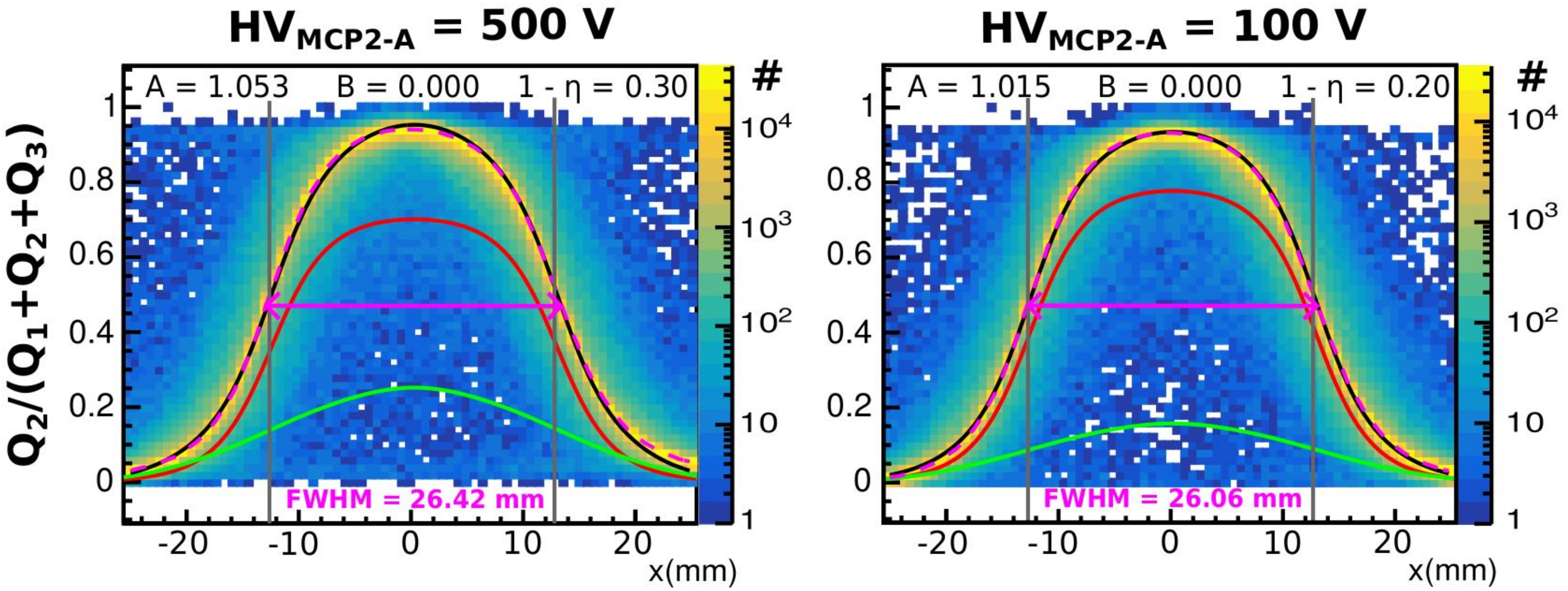
Black: $A \cdot \left[1 + \frac{\epsilon_1}{\epsilon_2} \cdot \frac{d}{g}\right] \cdot \left[\eta \cdot u(x,0,d) + (1-\eta) \cdot \left(\frac{\mathrm{d}P}{\mathrm{d}x\,\mathrm{d}y} * u\big|_{z=d}\right)(x,0)\right] + B$

Magenta: spline fit

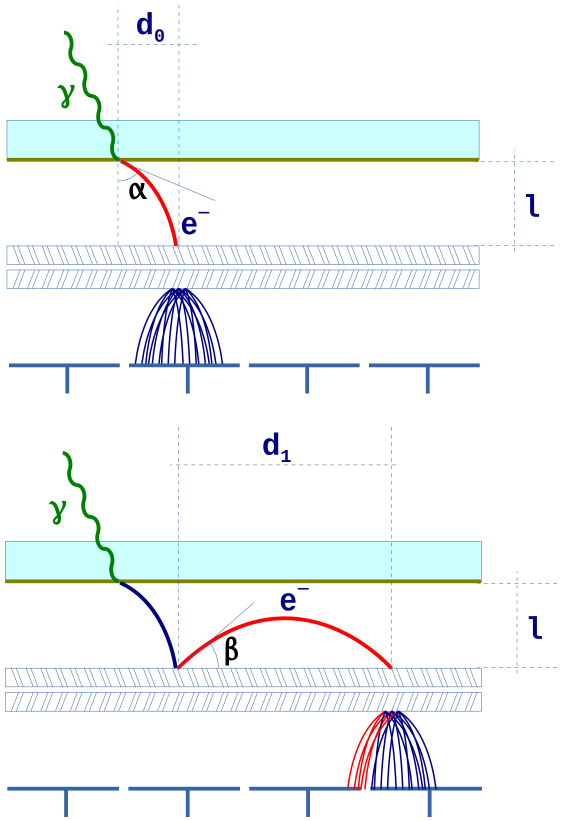


Laser scan at different MCP2-anode voltages

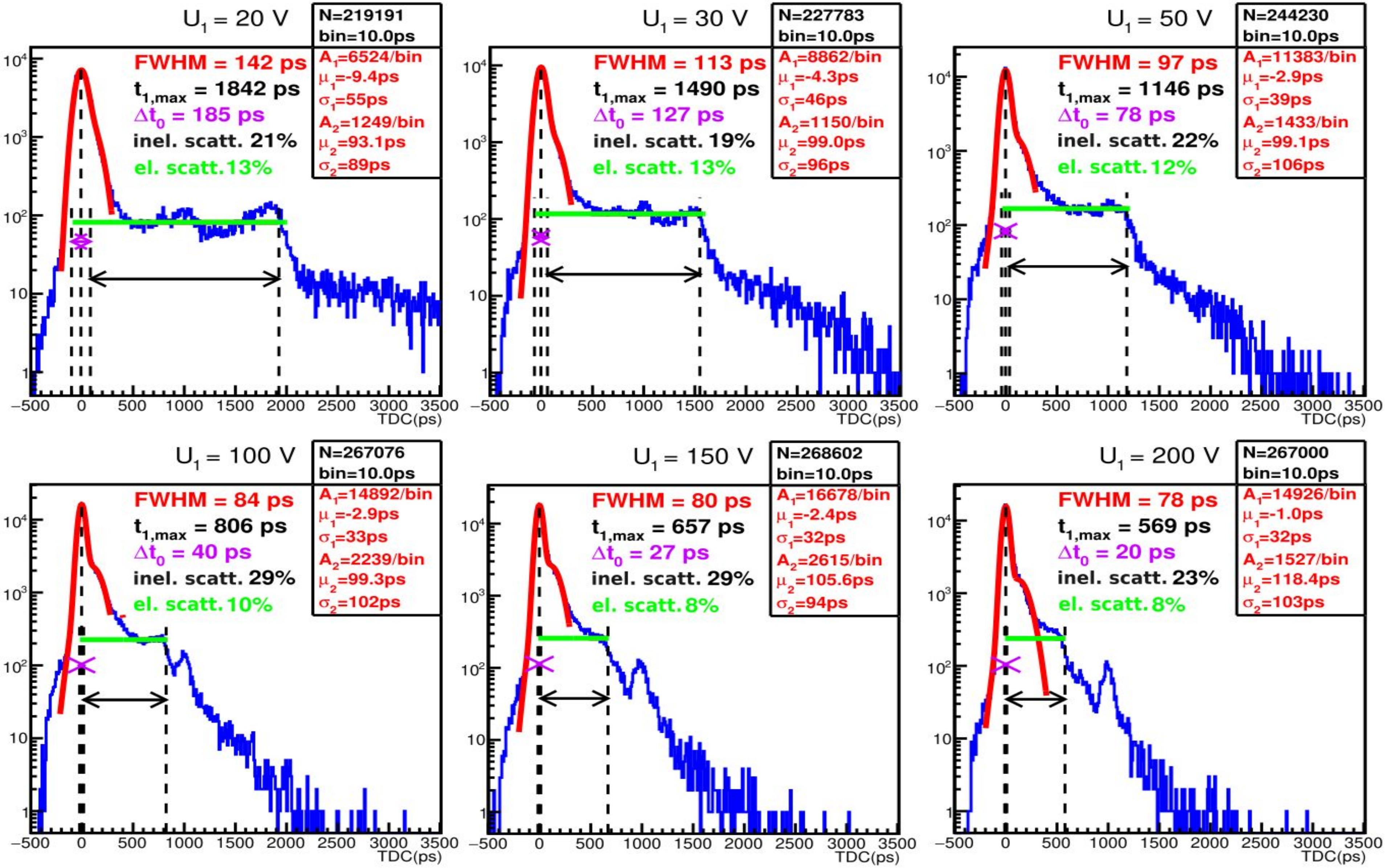
- No difference observed on charge sharing at different MCP2-anode voltages - secondary electron cloud spread has negligible contribution to anode charge distribution
- LAPPD #109



- LAPPD #162

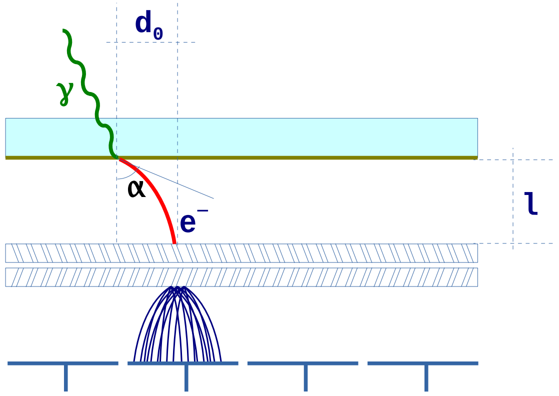


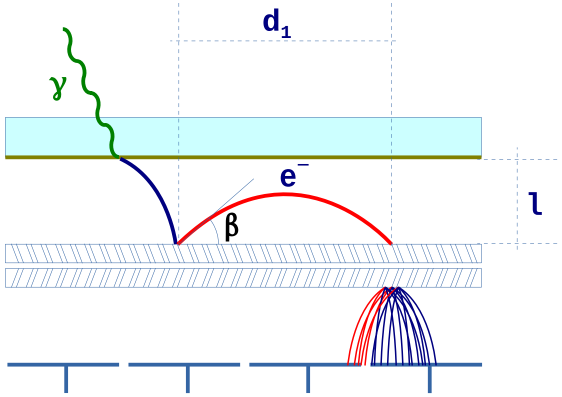
S. Korpar, PD07



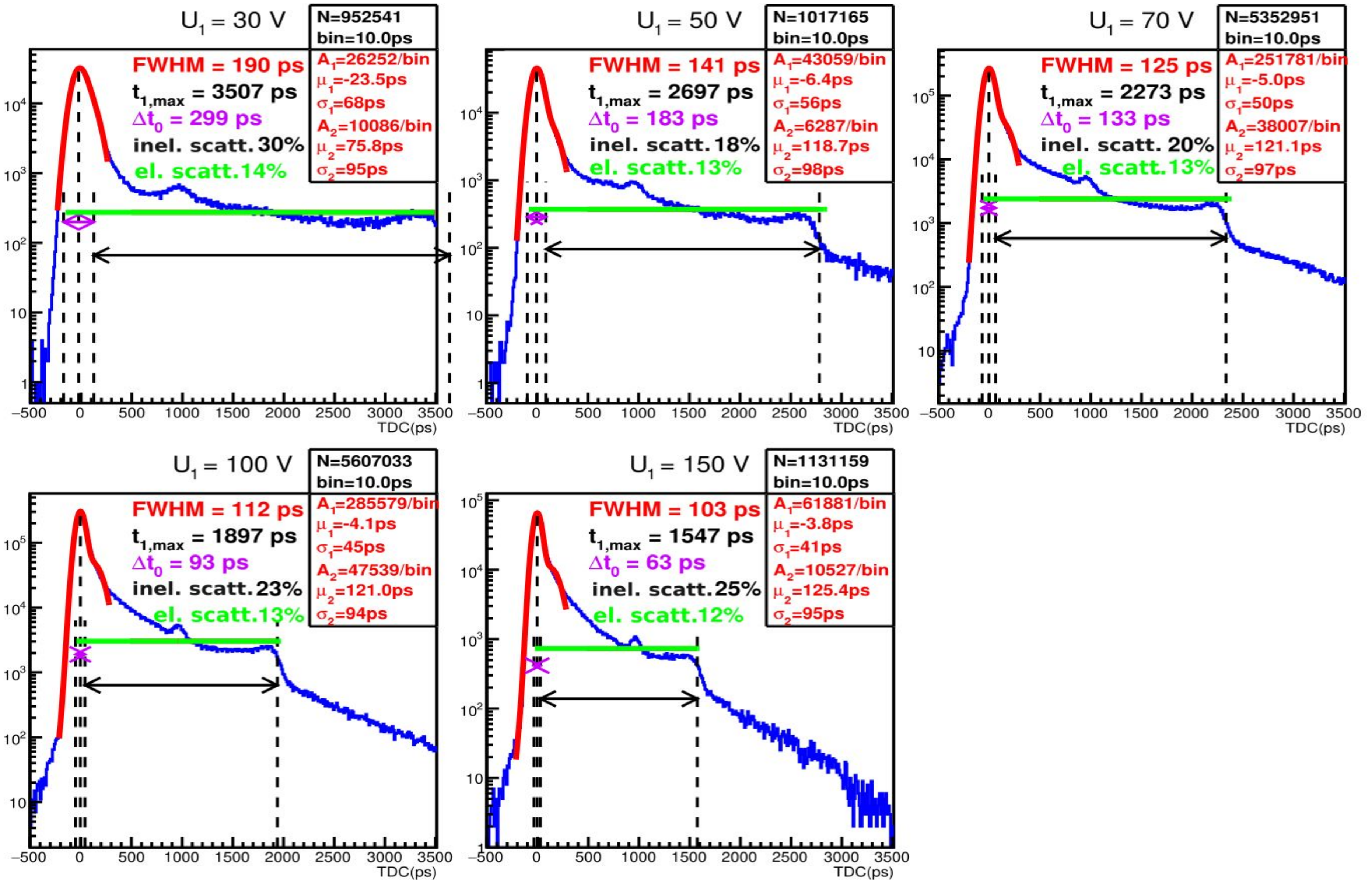
Experimental LAPPD timing distributions

- LAPPD #109

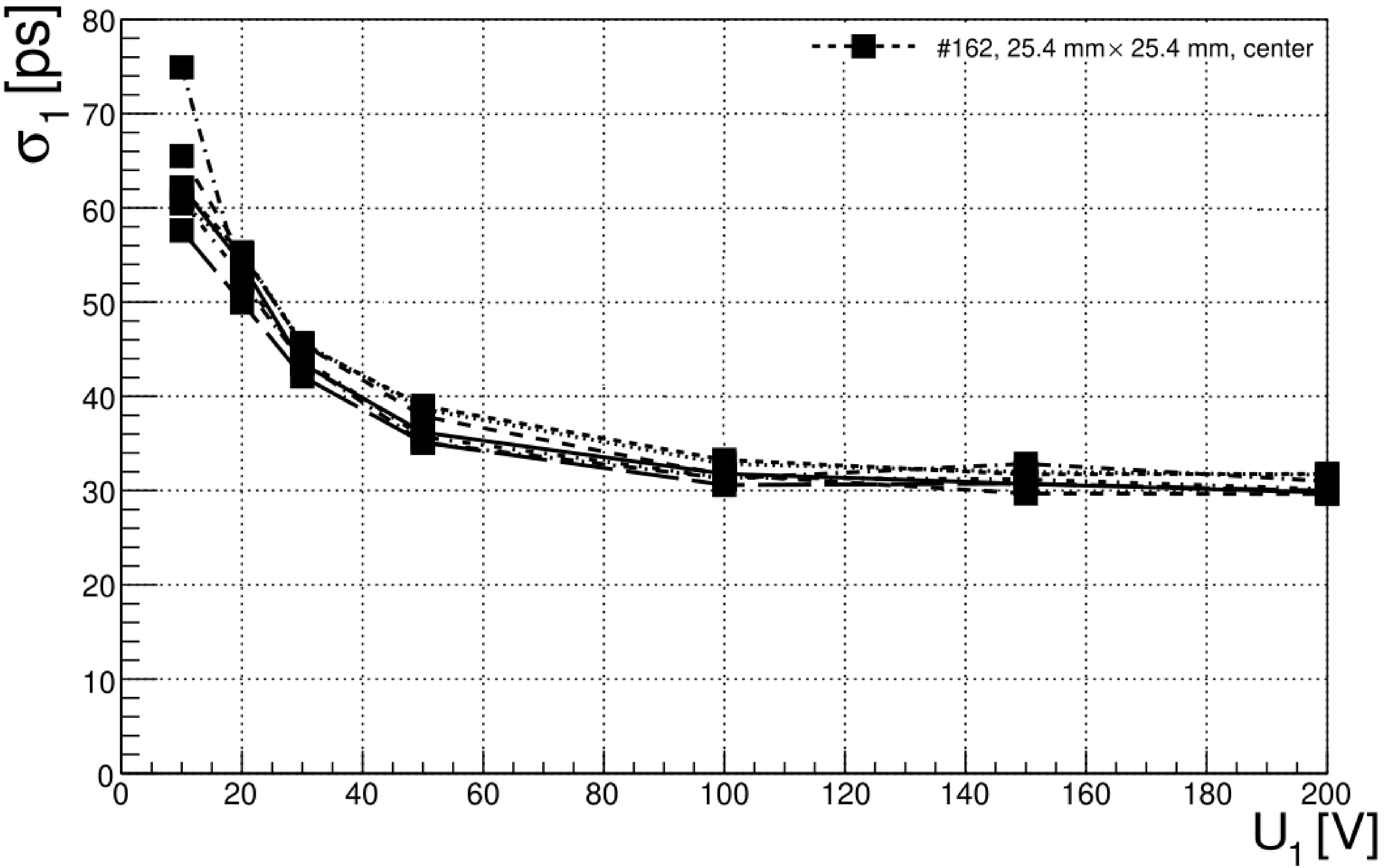




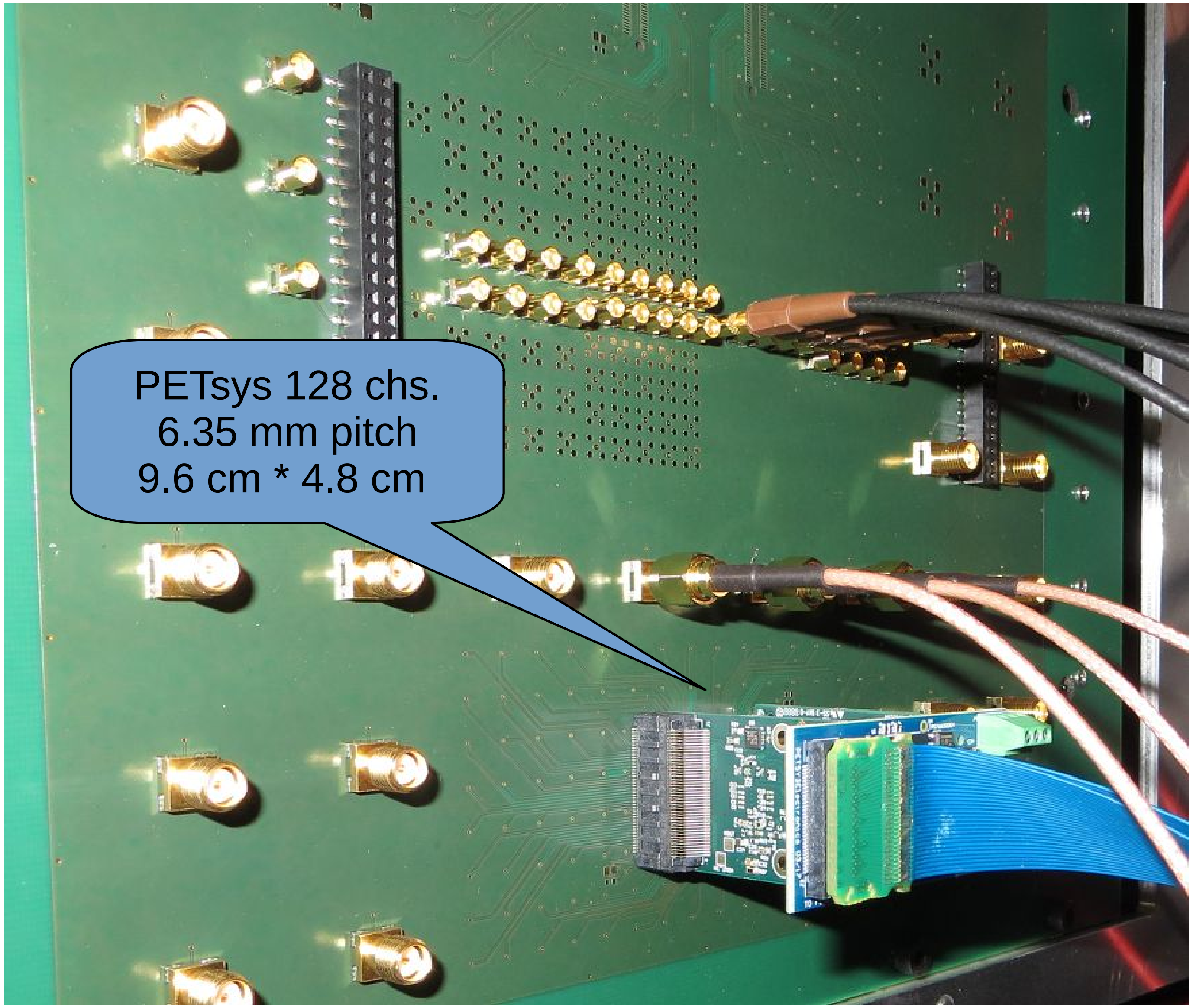
S. Korpar, PD07



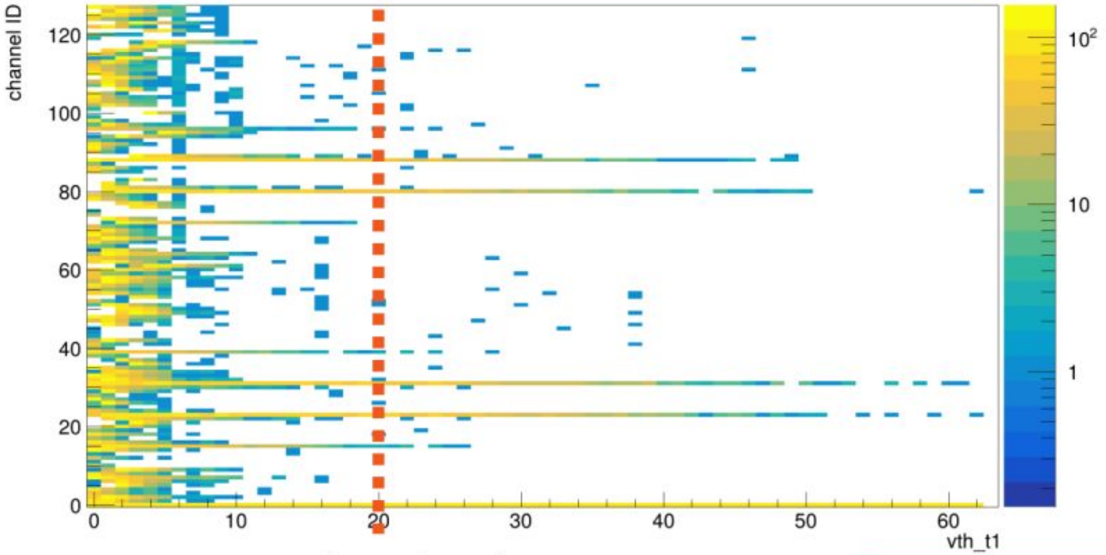
Timing vs. photocathode-MCP1 voltage



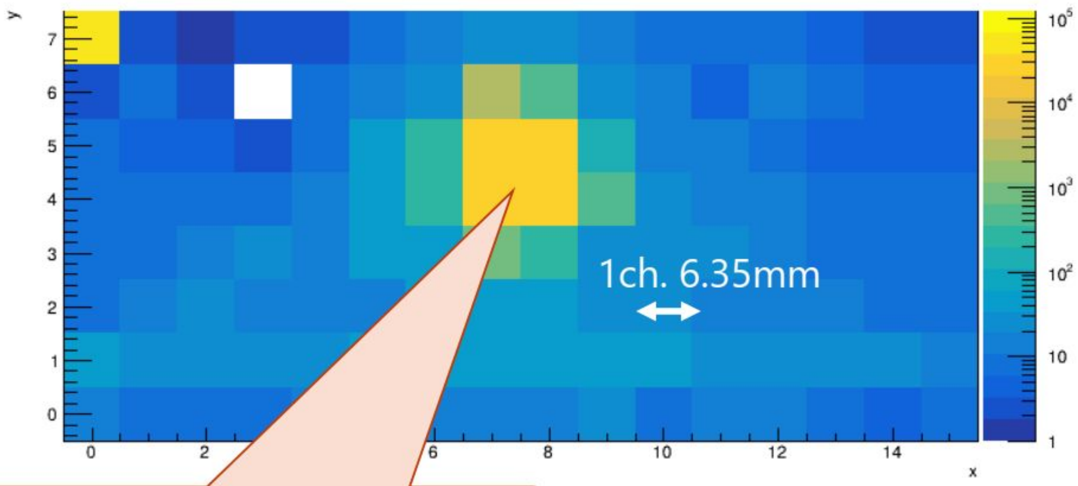
Results: LAPPD + PETsys



Threshold scan

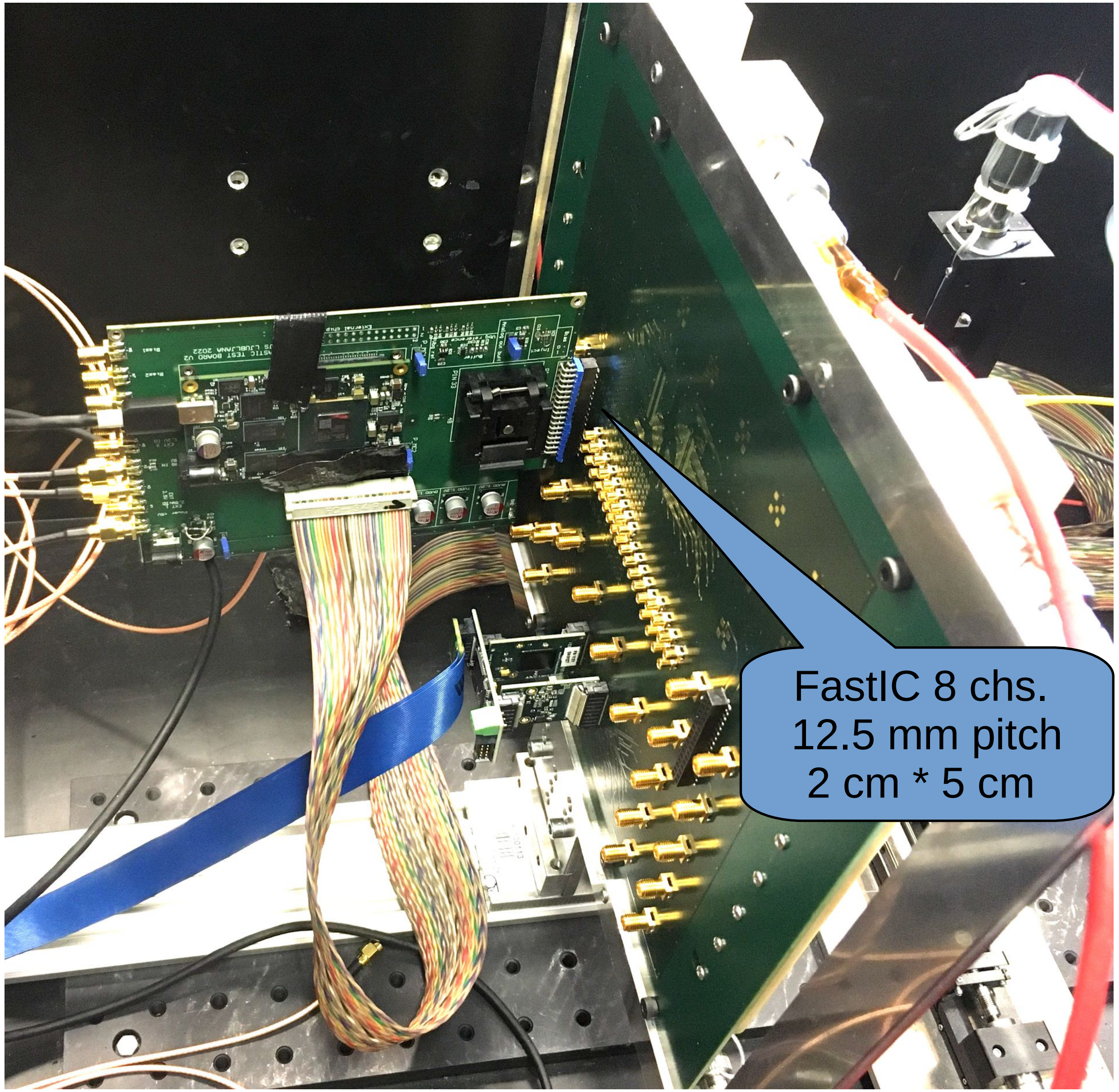


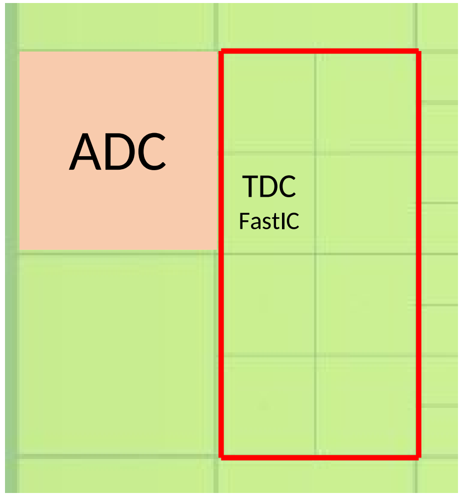
V_{th} for single photon signal

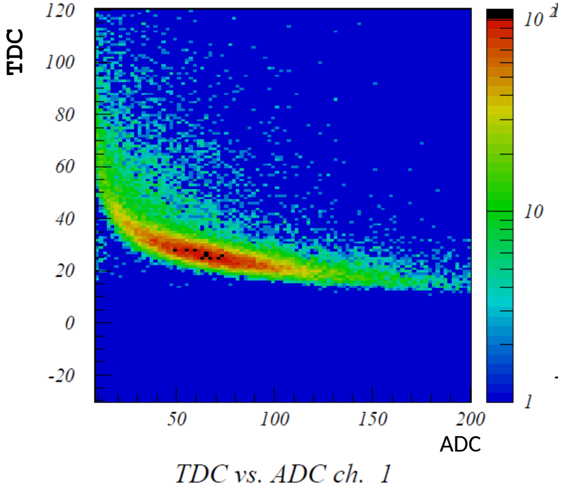


Confirmed light spot by pulse laser

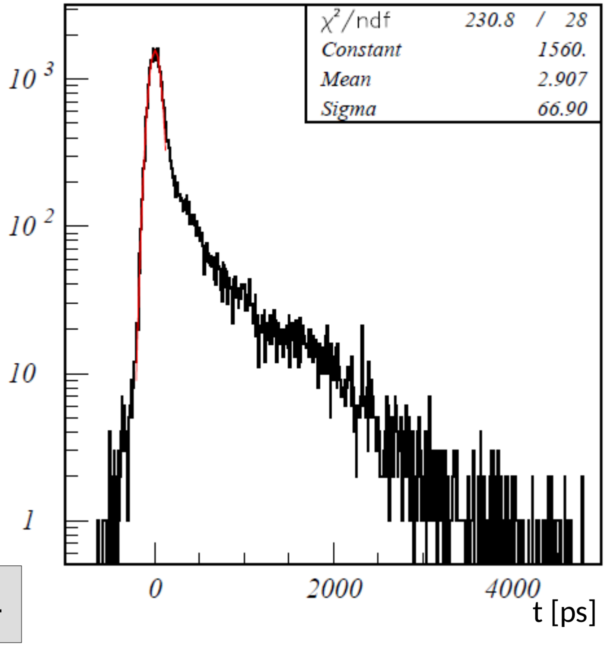
Poster: S. Kurokawa







- Time-walk correction based on shared signal from neighboring pad, read out using modular electronics
- timing σ ≈ 67 ps



DOI: 10.1016/j.nima.2024.169864

Conclusions

- Two Incom LAPPD Generation II with different geometries characterized
  - timing resolution
  - charge sharing
  - PETsys and FastIC ASIC readouts
- Response of the detector modeled
  - primary electron propagation and scattering from MCP
  - multiplied charge propagation after MCP, scattering from anode, charge induced on external sensing pads
- Electron scattering from MCP and anode has important impact on anode charge distribution
- Timing sigma ~ 30 ps with tails explained by elastic/inelastic electron scattering

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Photocathode-to-MCP1 distance	2.8 mm	1.19 mm
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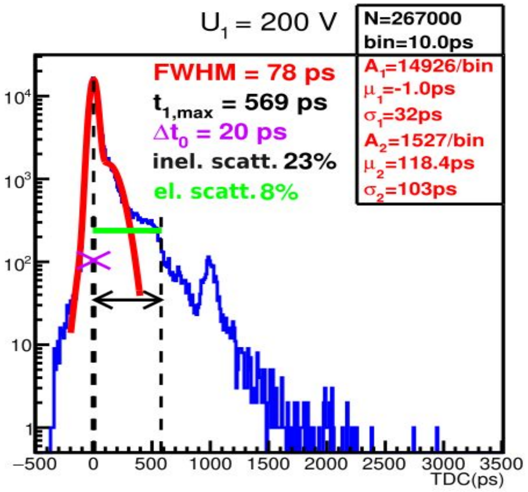
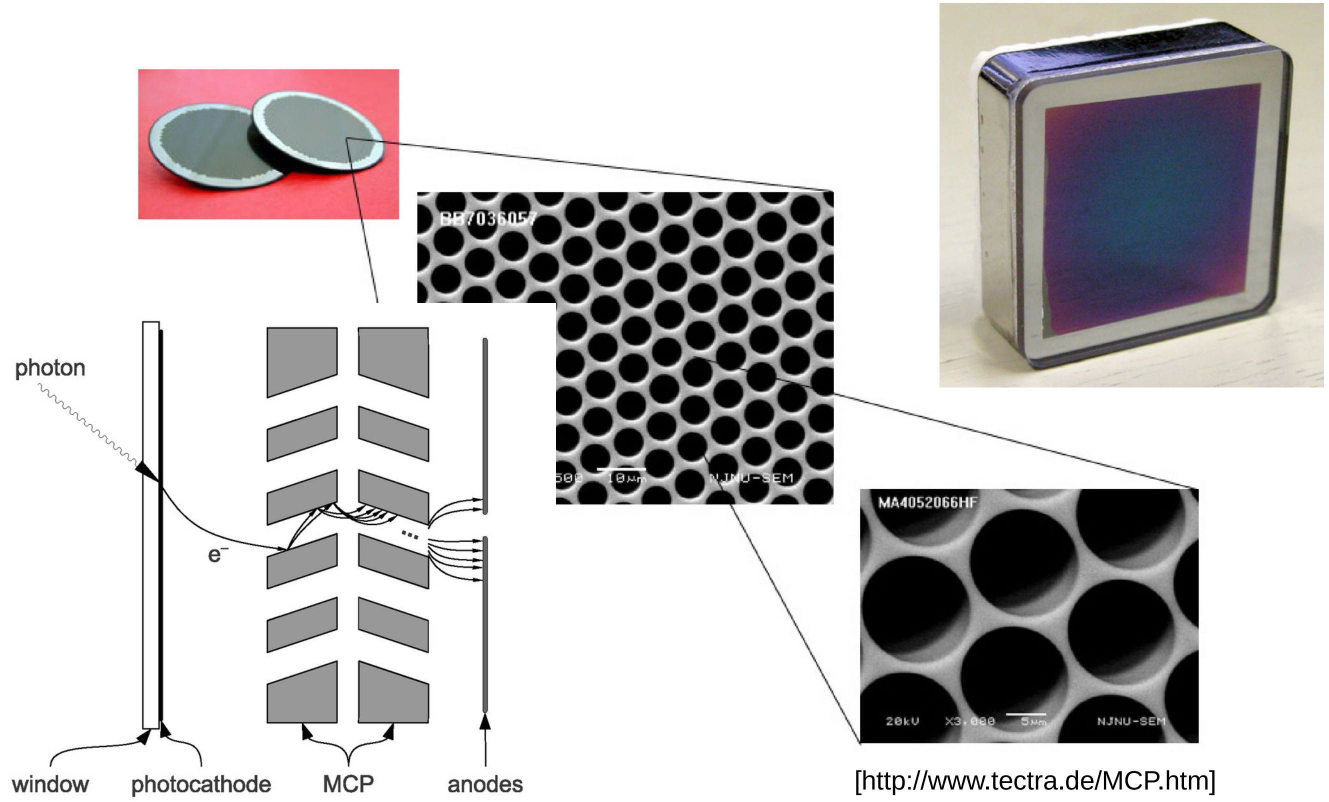
Back plate thickness (d)	5 mm	2 mm
Back plate material	glass	ceramic
Back plate dielectric constant ε	4.6	10



Backup

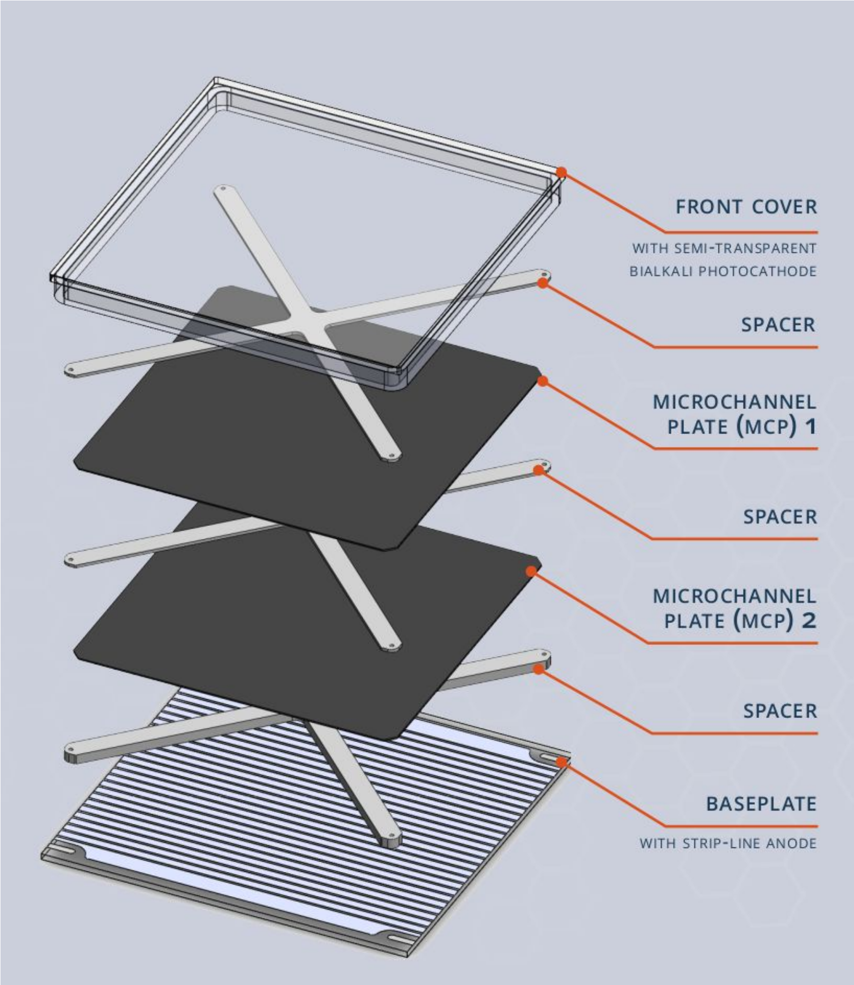
LAPPD

- Microchannel plate photomultiplier tube (MCP-PMT)
  - fast timing
  - low dark counts
  - some resistance to magnetic fields
  - spatial resolution (anode segmentation)



[http://www.tectra.de/MCP.htm]

- Large area picosecond photodetector (LAPPD)
  - large area (20 cm x 20 cm)



[Incom LAPPD Product Datashhet]

- Timing distributions were corrected for time-walk effect due to the use of leading edge discriminator

$$f(ADC) = -24.472\,\mathrm{ps} + \frac{326.625\,\mathrm{ps}}{\sqrt{ADC[\mathrm{channels}] + 13.970}}$$