Updates on hardware installation, optics and measurements HRPPD #25

Ageing studies - Global Meet
9 July 2025

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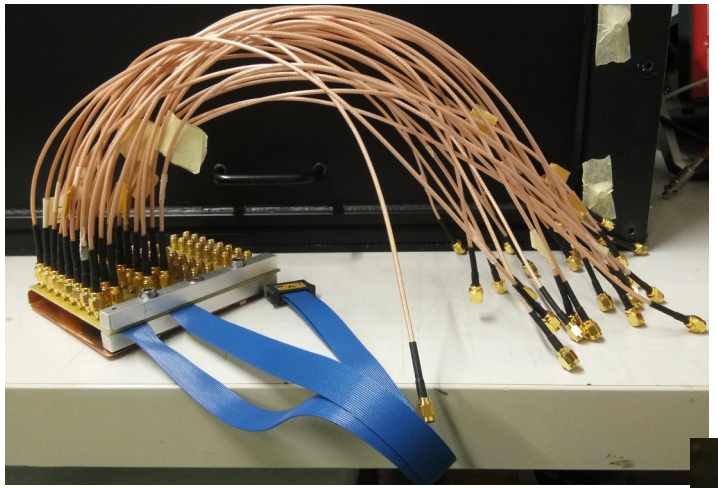
Istituto Nazionale di Fisica Nucleare

Outline

- Hardware Installation (Readout PCBs)
- Optics (RECAP + updated tuning)
  - Splitting Ratio (SR) and PD Cross-Calibration (CC)
  - Intensity scan of the ageing spot
- Measurement Protocol
- Few measurements
  - PDE horizontal scan
  - QE measurements

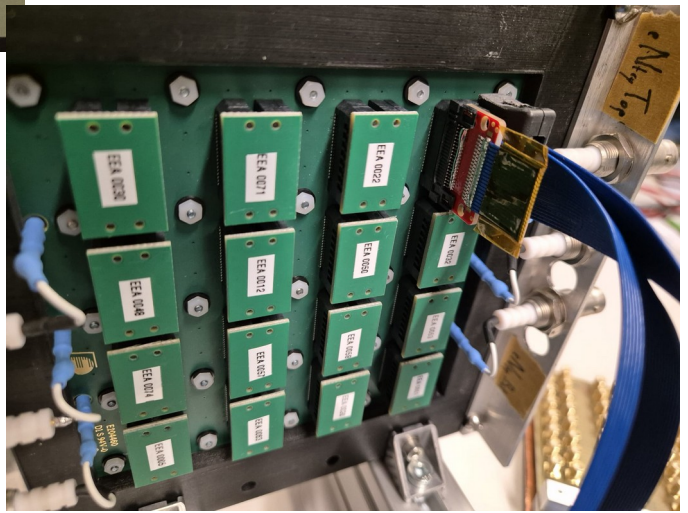
Previously used breadboard

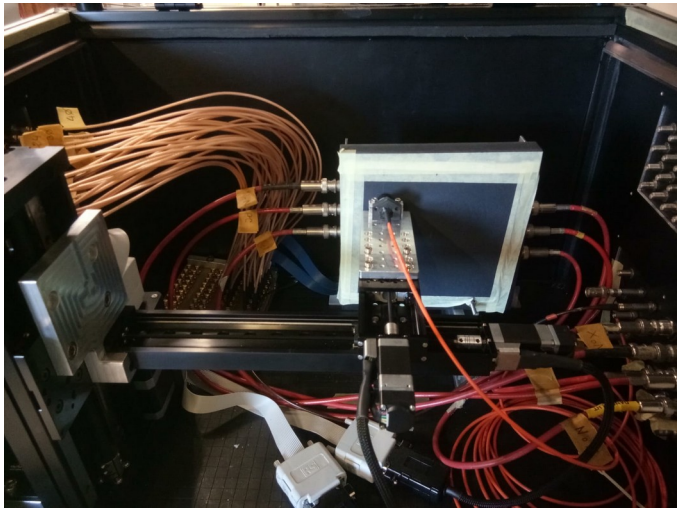


The breadboard was in use until June 2025

It could read 32 channels from one 4x8 sector

We need to read 16+16 from two different region



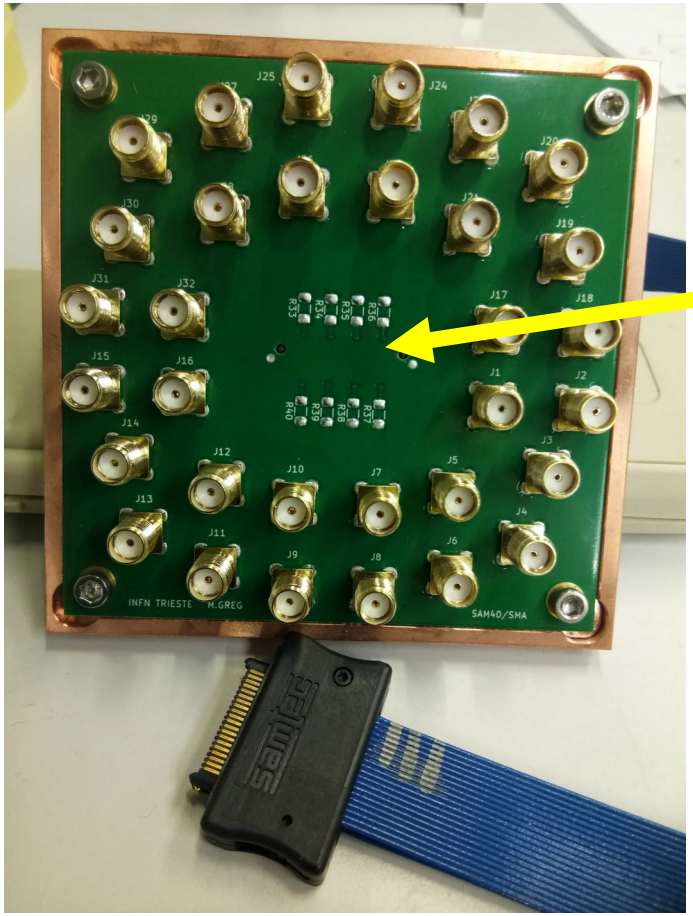


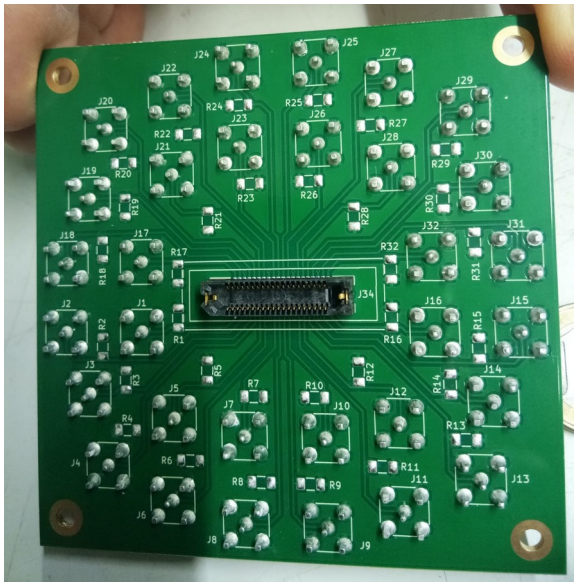
RO PCBs installed

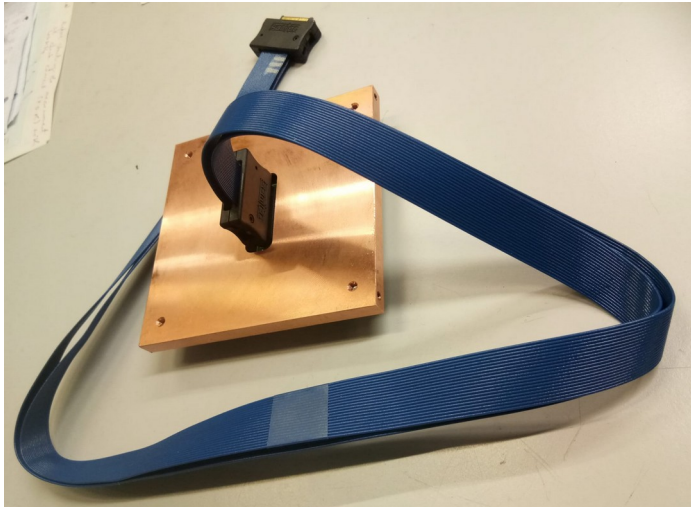
SCEN PCB: 8.4 cm x 8.4 cm x 1.7 mm
Holder: 9 cm x 9 cm x 7 mm

32 channels can be fed

Pins to HRPPD ground







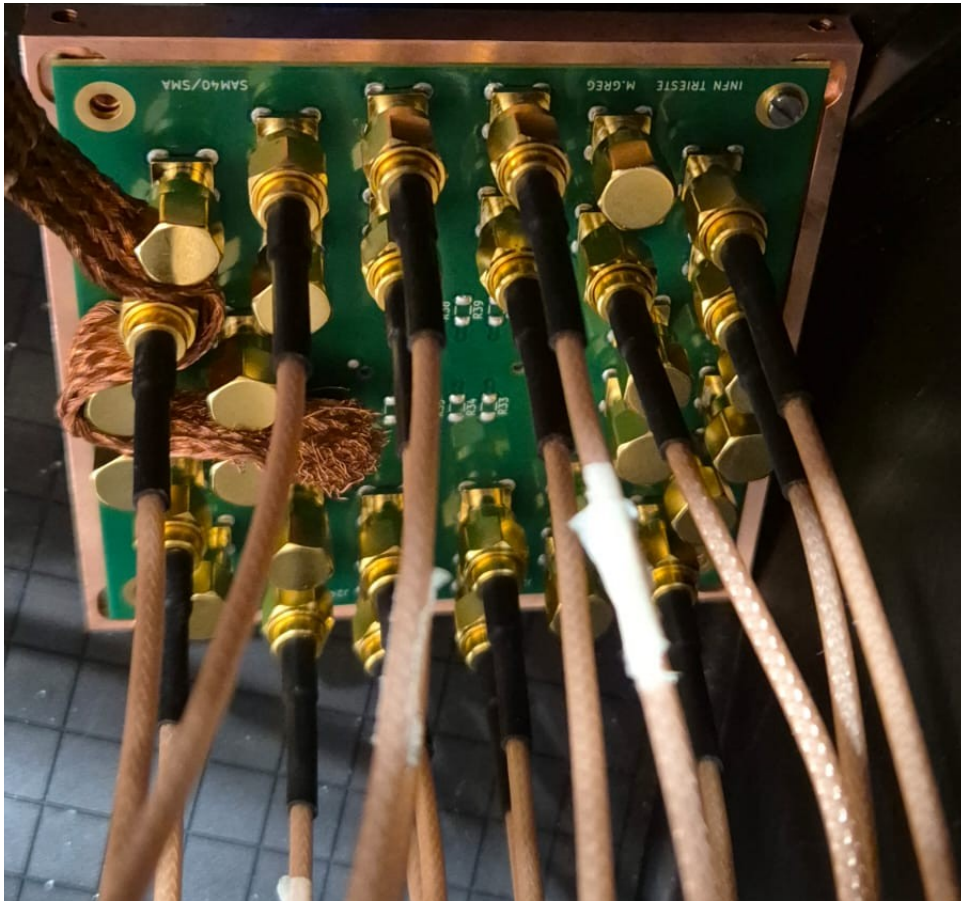
RO PCBs installed

SCEN PCB: 84 mm x 84 mm x 1.7 mm
Holder: 90 mm x 90 mm x 7 mm

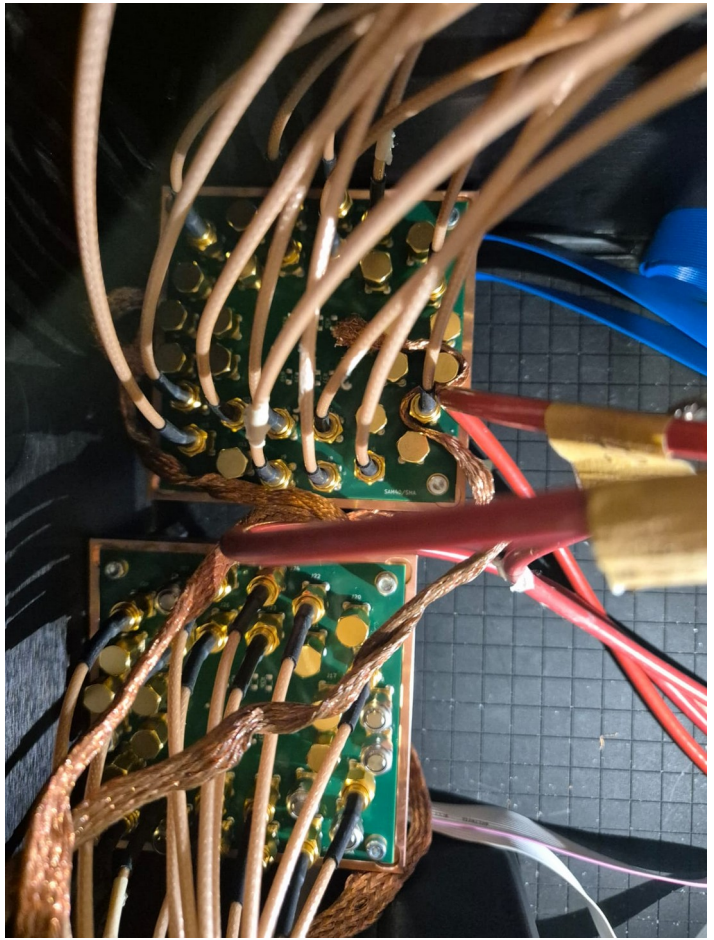
32 channels can be fed

16 channels are connected
Central 16 of 4x8 sector of RO Anode pads

Other 16 channels are terminated

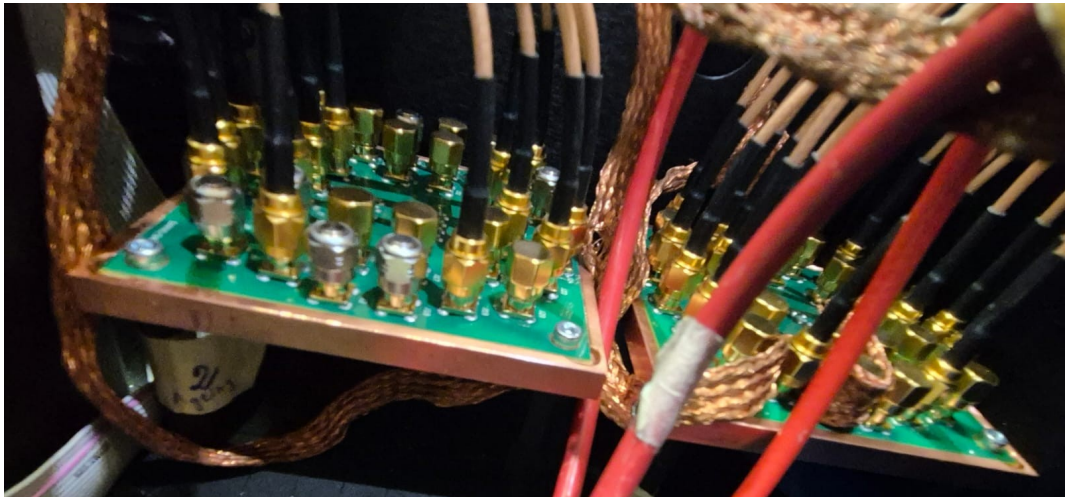


RO PCBs installed

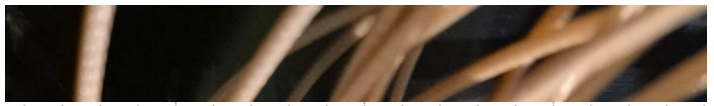


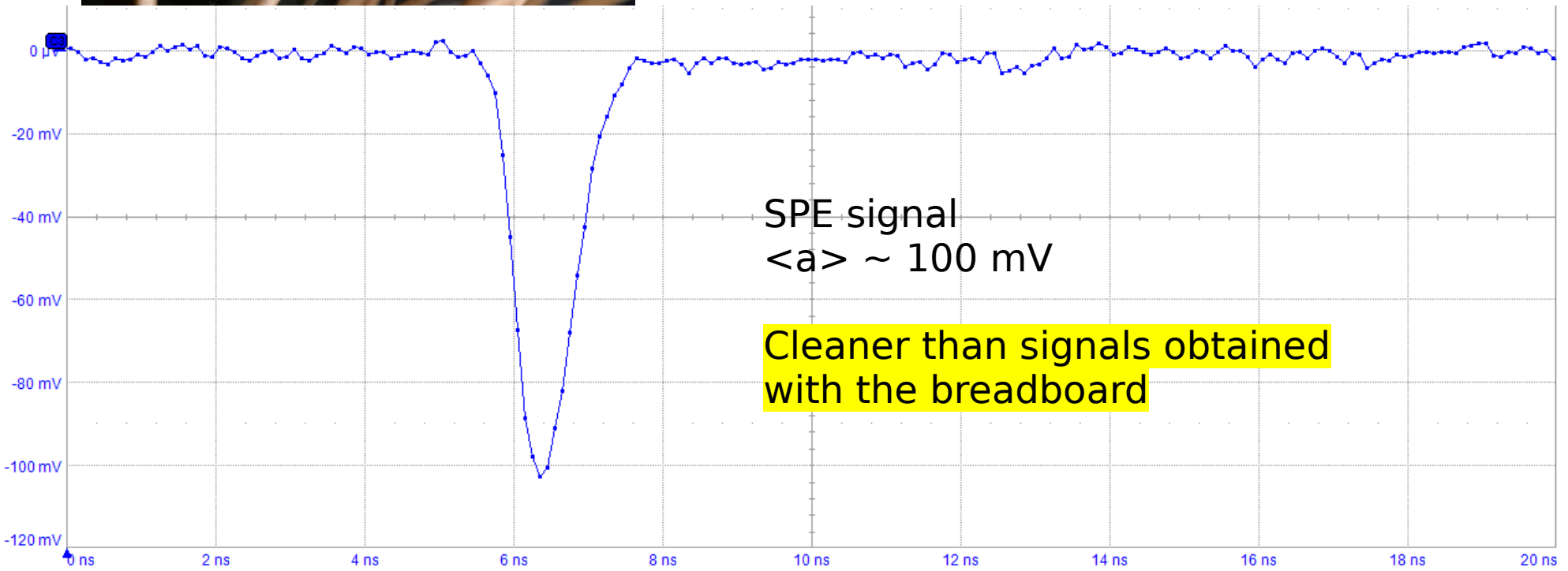
Two SCEN PCBs installed inside the darkbox

PCB 1: Reference region – 16 pads
PCB 2: Ageing region– 16 pads



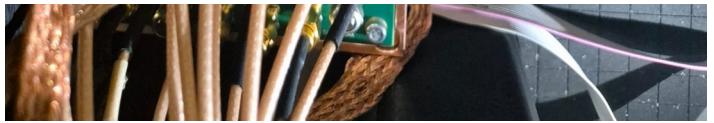
RO PCBs installed

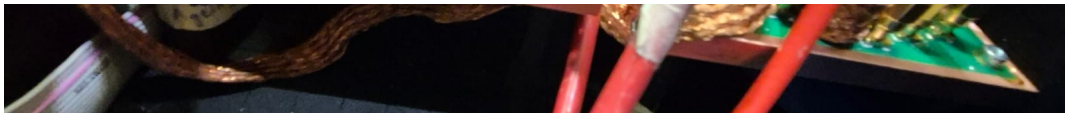




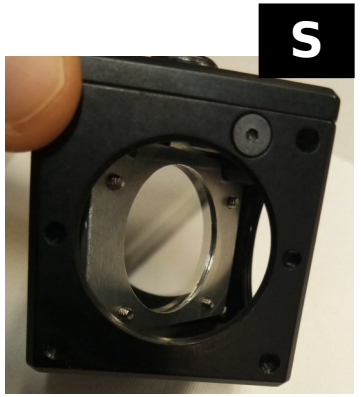
SPE signal
<a> ~ 100 mV

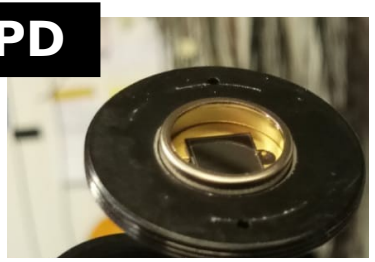
Cleaner than signals obtained with the breadboard

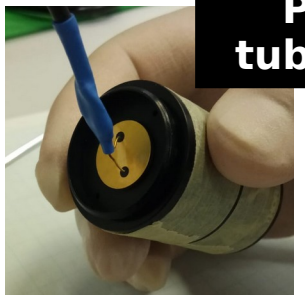


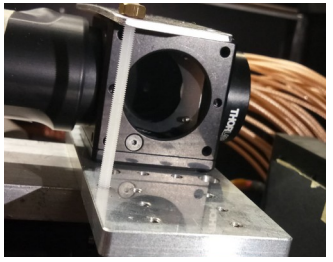


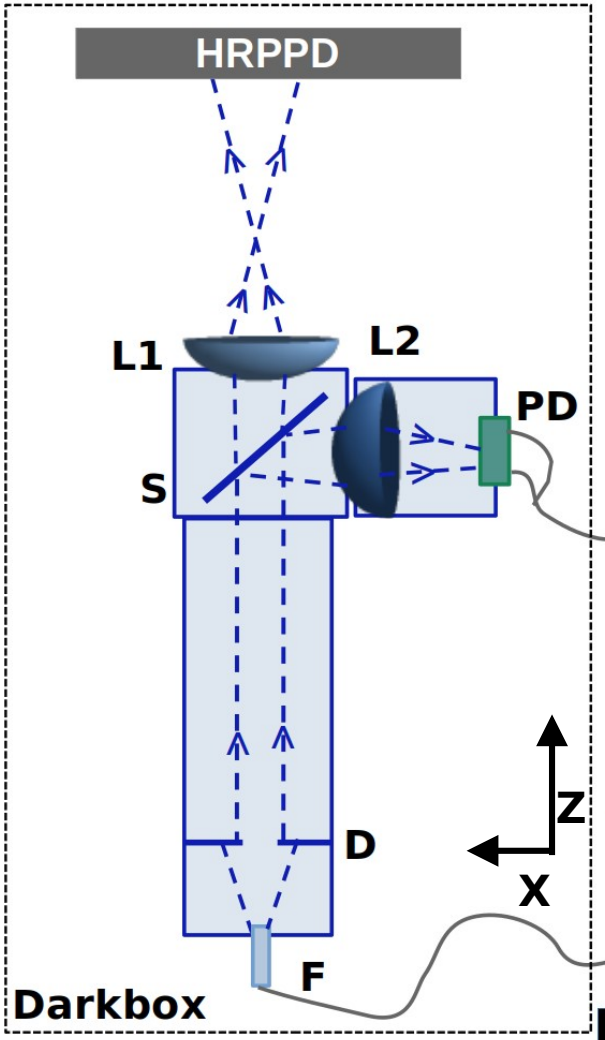
Optics











L1 Lens (20 mm)
L2 Lens (50 mm)
S splitter
PD Photo-Diode
K Keithley
D Diaphragm
F Fibre
W motorised wheel

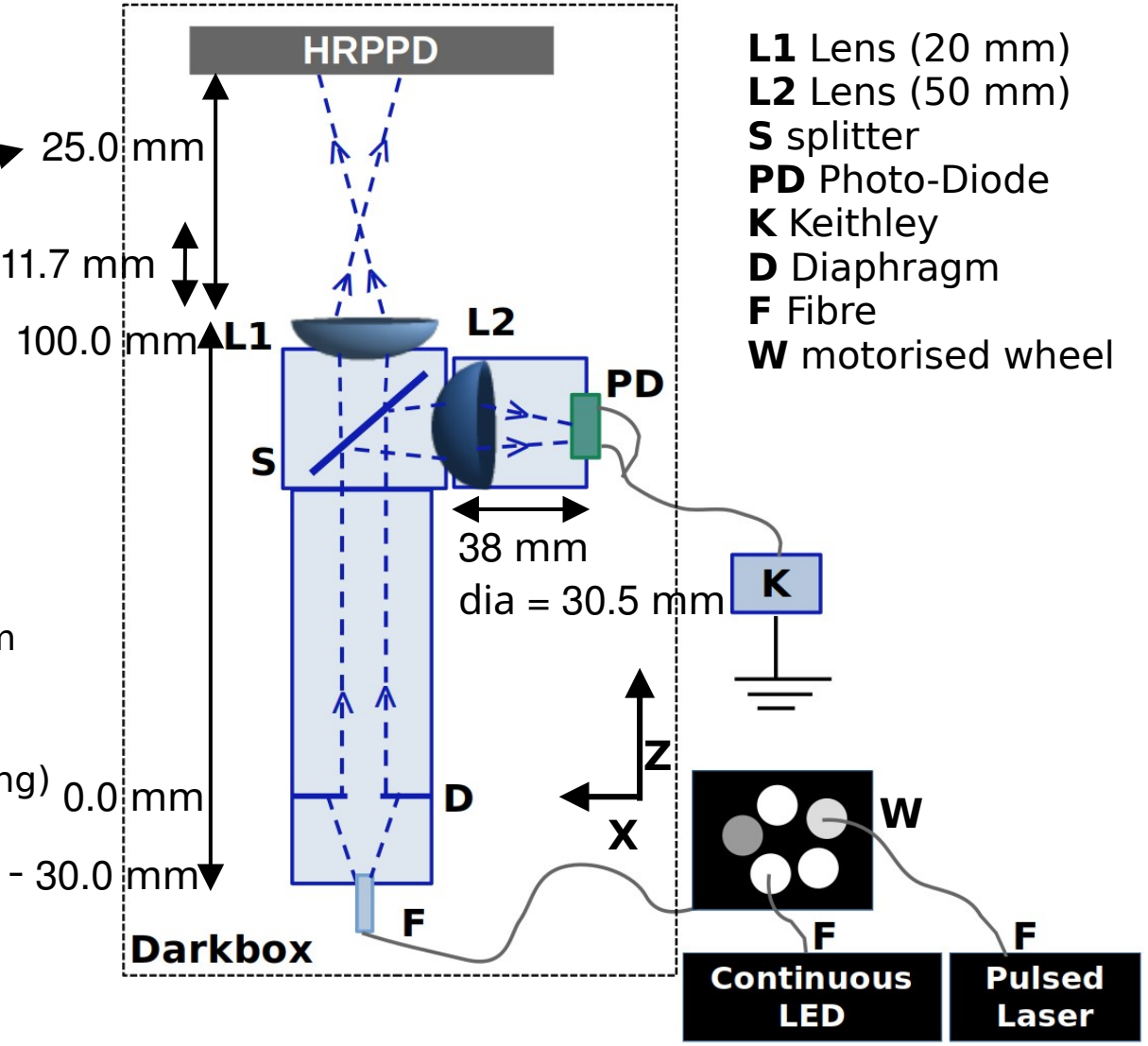
Optics

From the PC surface
NOT HRPPD window

Refractive index of Quartz taken into account to calculate the distance (Detailed in Backup Slides)

$r_{focused}$: < 1 mm
r_{ageing}: 5.32 mm

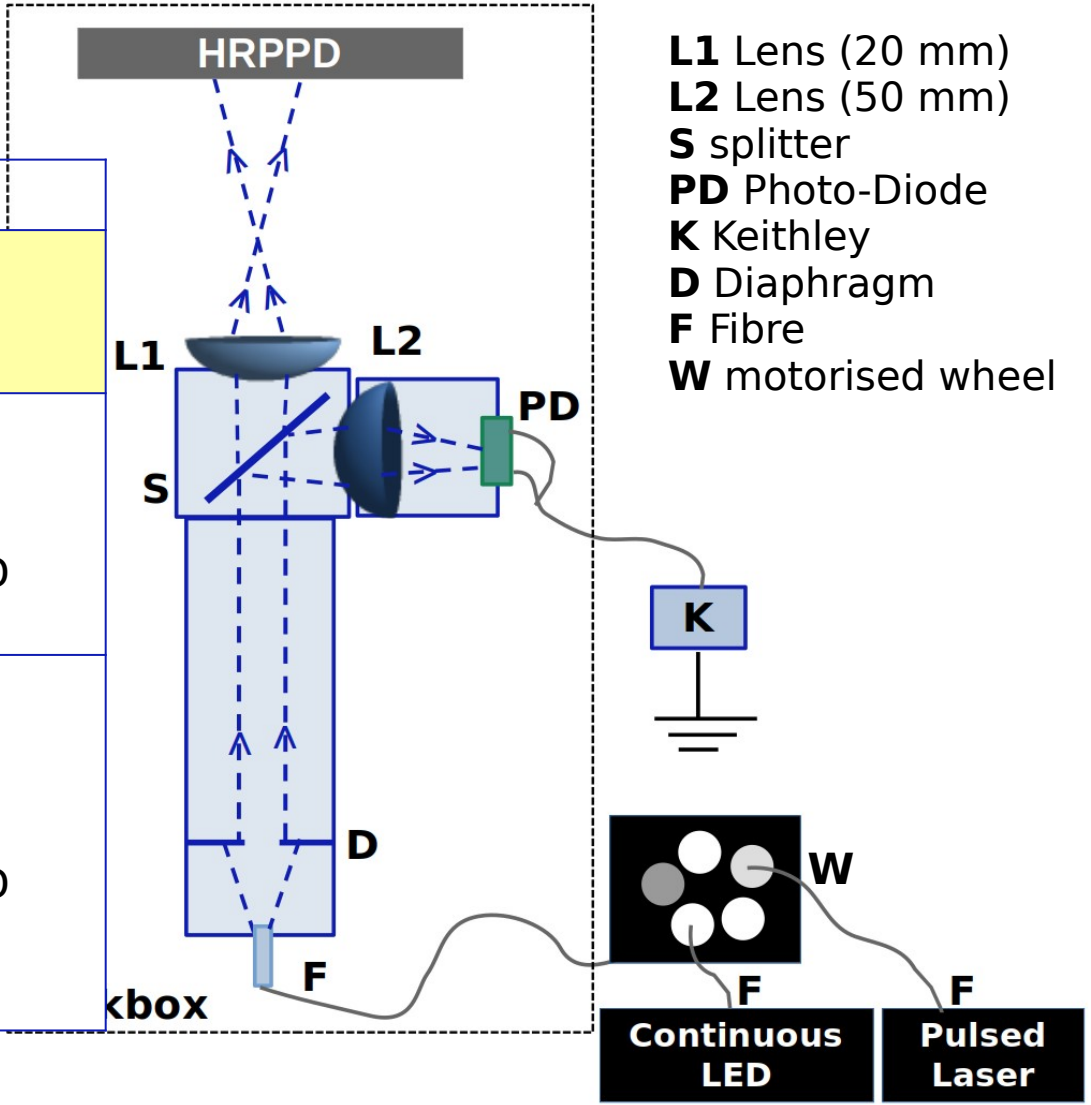
- Optics installed on a movable (XYZ) system
- Same optics at two different Z positions – focused (measurements)/ defocused (ageing) spots
- Same optics at two different X positions – ageing/reference region



L1 Lens (20 mm)
L2 Lens (50 mm)
S splitter
PD Photo-Diode
K Keithley
D Diaphragm
F Fibre
W motorised wheel

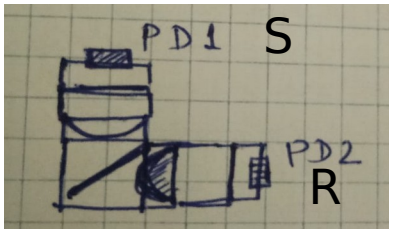
Five optics configuration

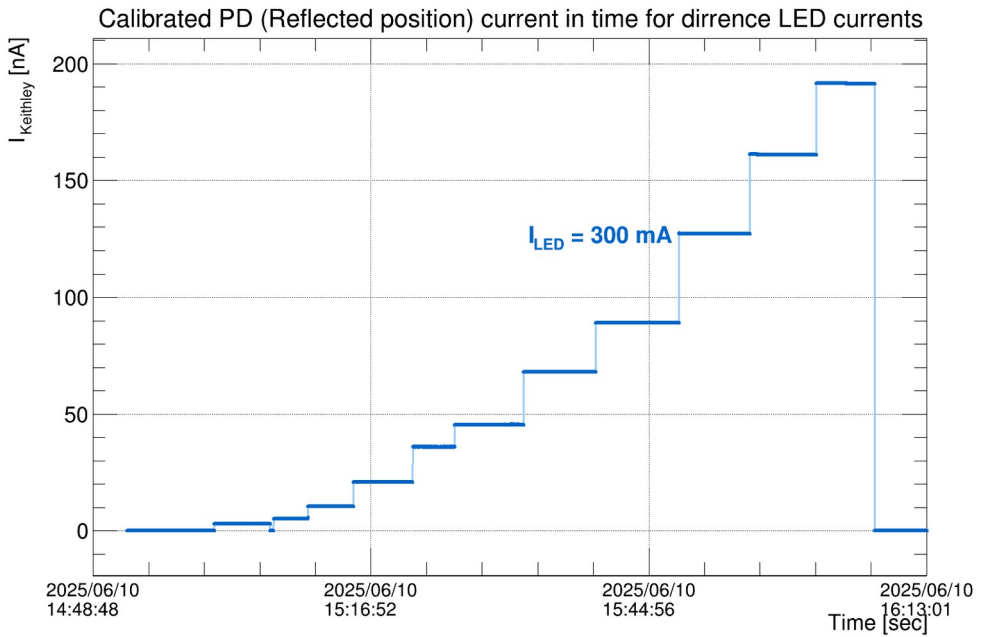
Five configurations	
Pulsed Laser **(Int.9.0,40MHz)** + ND filters in wheel	Continuous LED
~1% Pure SPE (λ=0.01), OD3 **measurements** PD(R) = 0.15 pA	Direct for **QE** PD(R)=3 nA @ LED I_{SET} = 16 mA (min) PD(R)=191 nA @ LED I_{SET} = 500 mA (max)
~15% SPE (λ=0.15), OD2 **measurements** PD(R) = 2.3 pA	Via wheel (empty) **Ageing** PD(R)=2 pA @ LED I_{SET} = 16 mA (min) PD(R)=116 pA @ LED I_{SET} = 500 mA (max)
~3 PE (λ=3), OD1 **measurements** PD(R) = 60 pA	

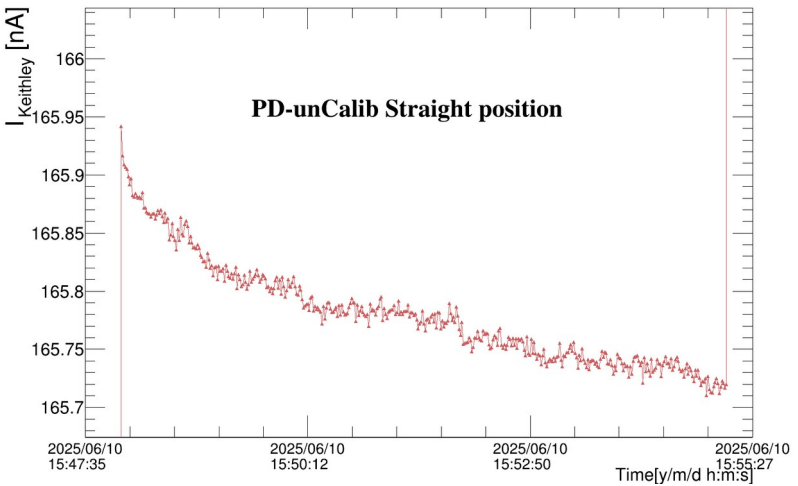


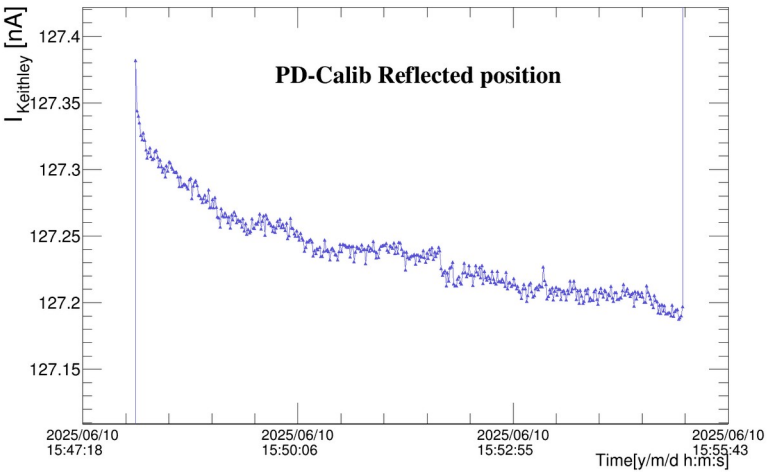
L1 Lens (20 mm)
L2 Lens (50 mm)
S splitter
PD Photo-Diode
K Keithley
D Diaphragm
F Fibre
W motorised wheel

SR and CC – Photodiode currents









30% more flux received by the Photo-diode mounted on the Straight position

SR and CC - formula

$$\phi_S = I_S / QE_S \,, \quad \phi_R = I_R / QE_R$$

$$SR = \frac{\phi_S}{\phi_R}$$

$$CC = QE_{uncalib} / QE_{calib}$$

Measurement 1 : $PD_{uncalib}$ (S) , PD_{calib} (R)

$$I_1 = \phi_S \cdot QE_{uncalib}$$

$$I_2 = \phi_R \cdot QE_{calib}$$

Measurement 2 : PD_{calib} (S) , $PD_{uncalib}$ (R)

$$I_3 = \phi_S \cdot QE_{calib}$$

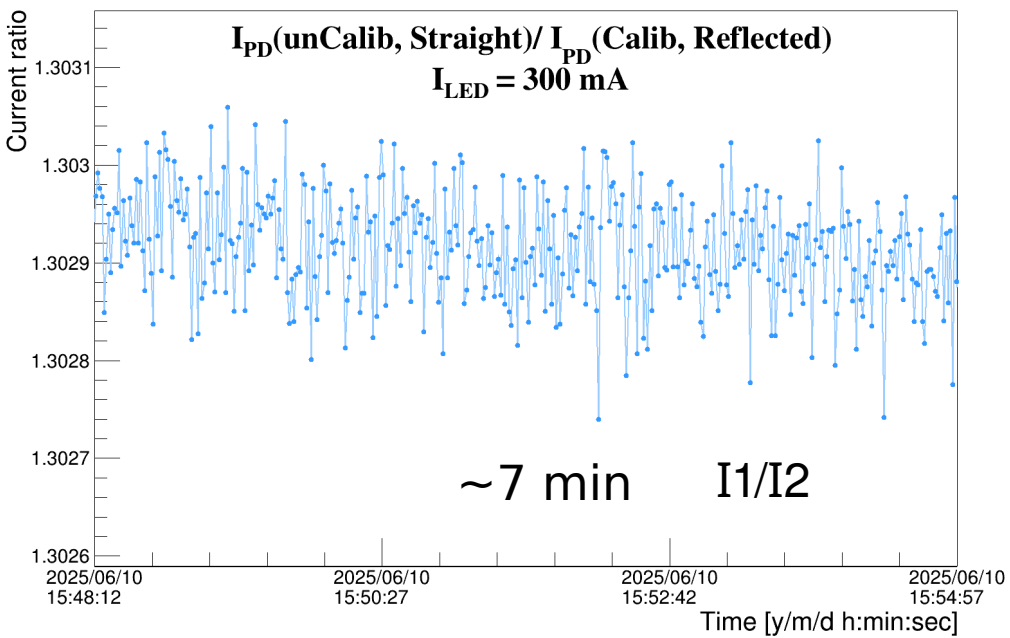
$$I_4 = \phi_R \cdot QE_{uncalib}$$

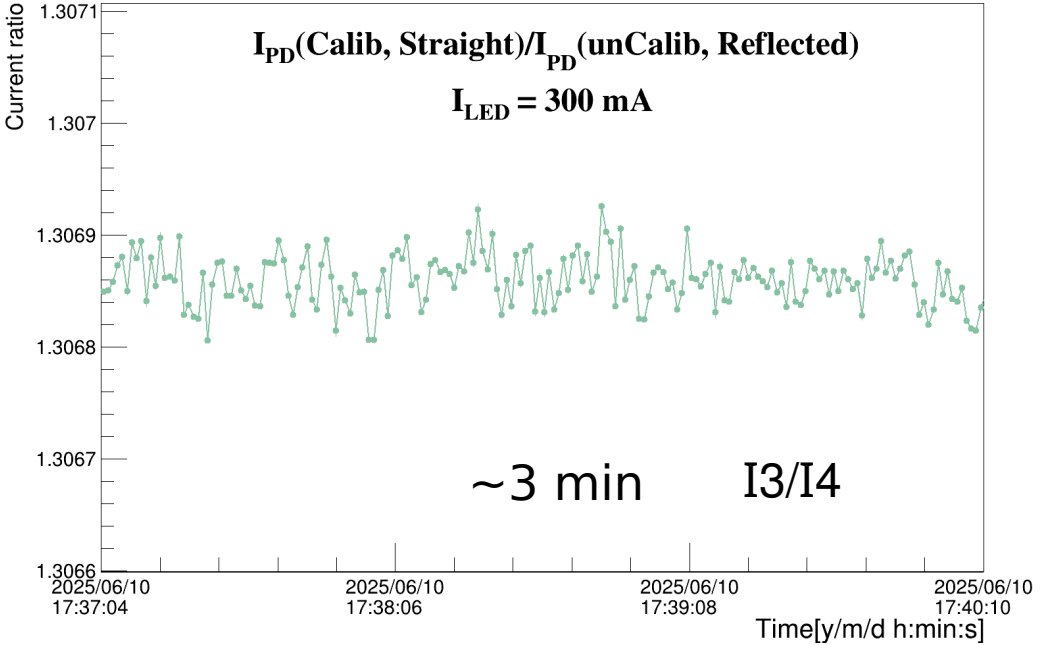
$$\left\langle \frac{I_1}{I_2} \right\rangle \cdot \left\langle \frac{I_3}{I_4} \right\rangle = \frac{\phi_S^2}{\phi_R^2} = SR^2$$

$$\left\langle \frac{I_1}{I_2} \right\rangle / \left\langle \frac{I_3}{I_4} \right\rangle = CC^2$$

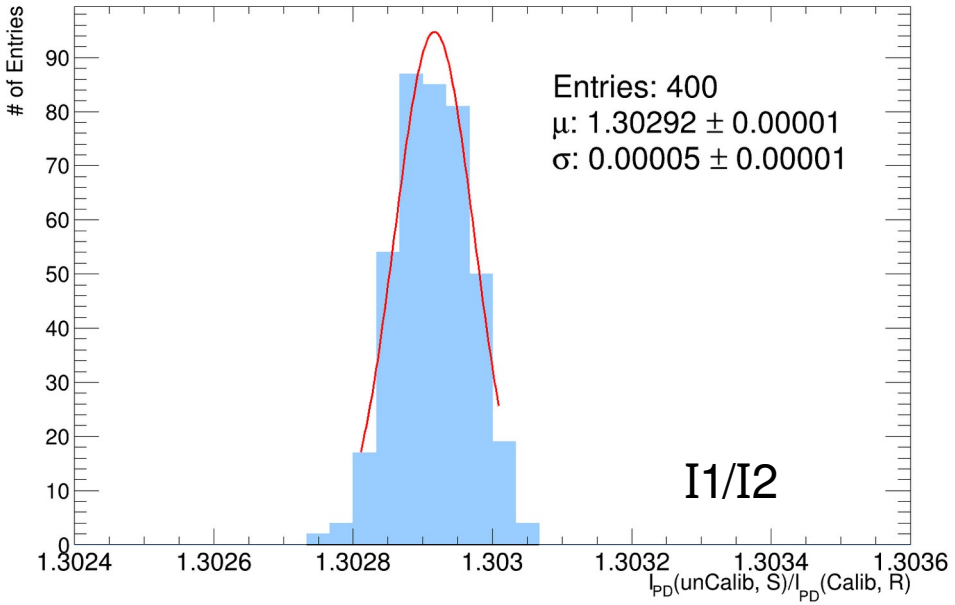
SR and CC – ratio of PD currents

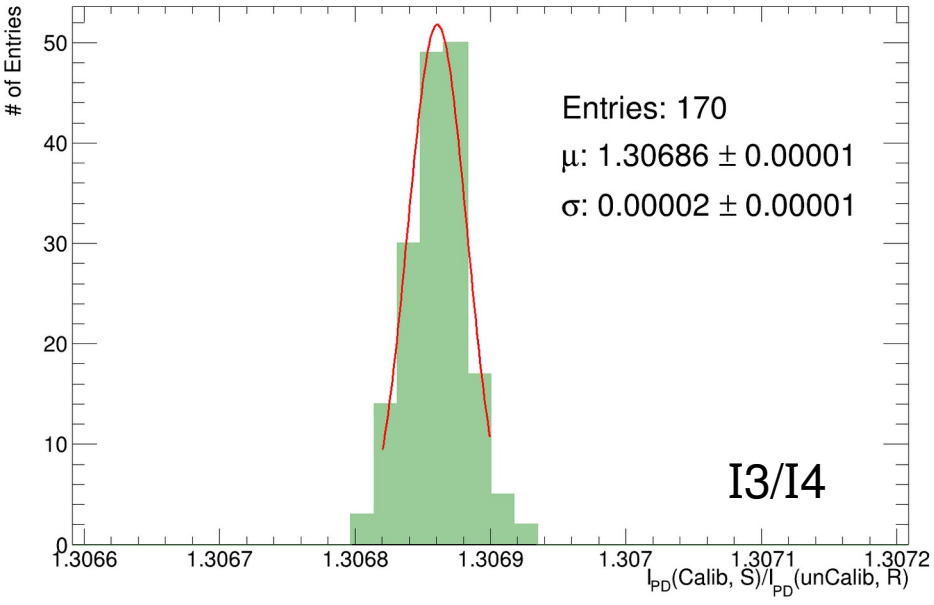
Two photo-diodes' positions swapped for the two plots





SR and CC





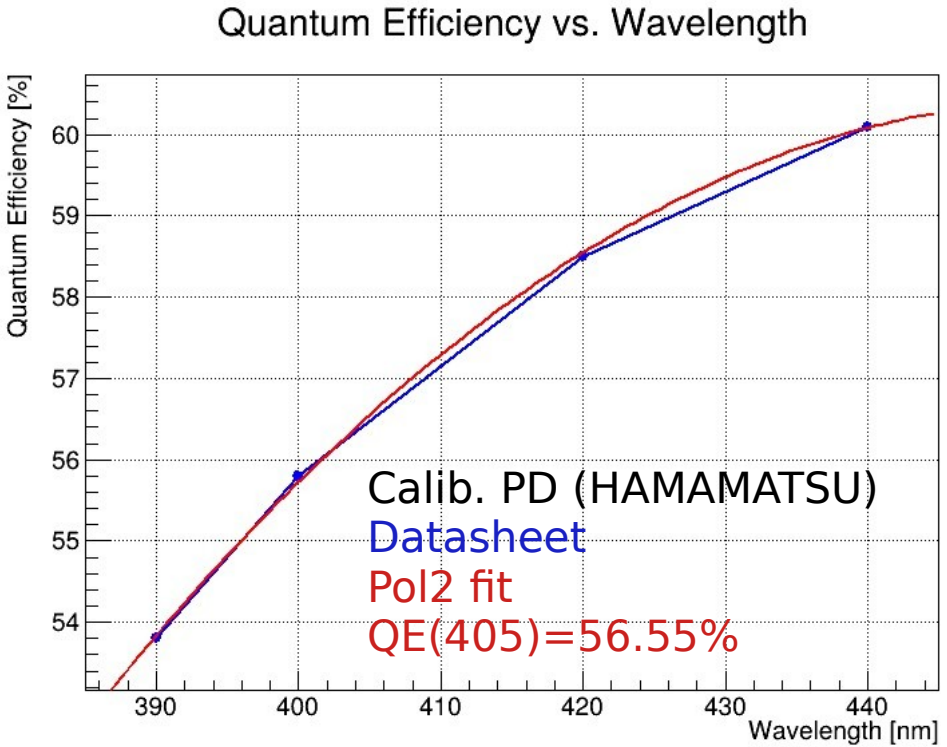
SR = sqrt(I1/I2 x I3/I4)

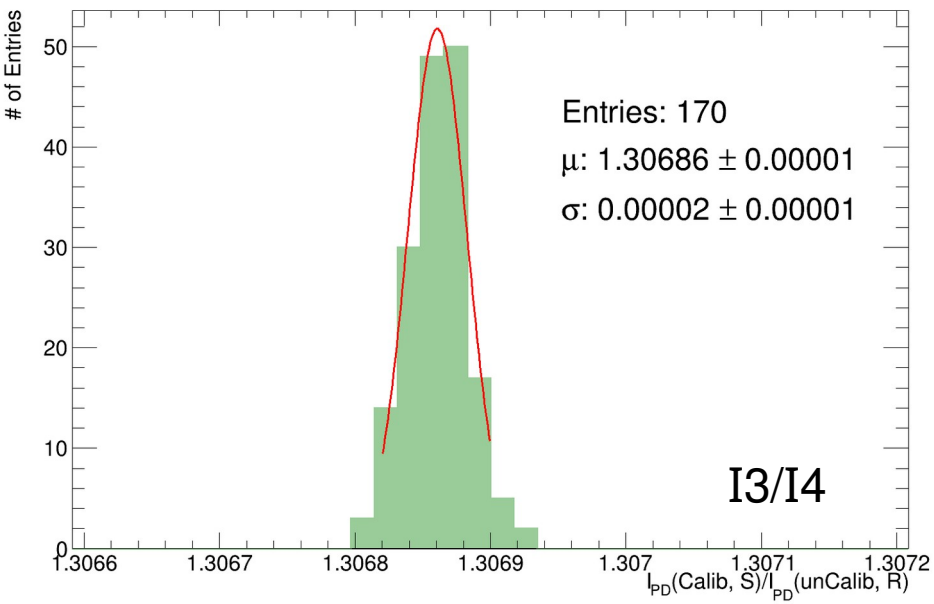
= **1.30489 ± 0.00001**

CC = sqrt((I1/I2) / (I3/I4))

= **0.99849 ± 0.00001**

SR and CC





CC = sqrt((I1/I2) / (I3/I4))

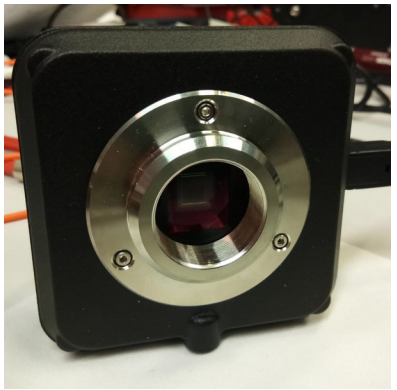
= **0.99849 ± 0.00001**

QE of unCalib PD = 0.99849 x 56.55%

= **56.46%**

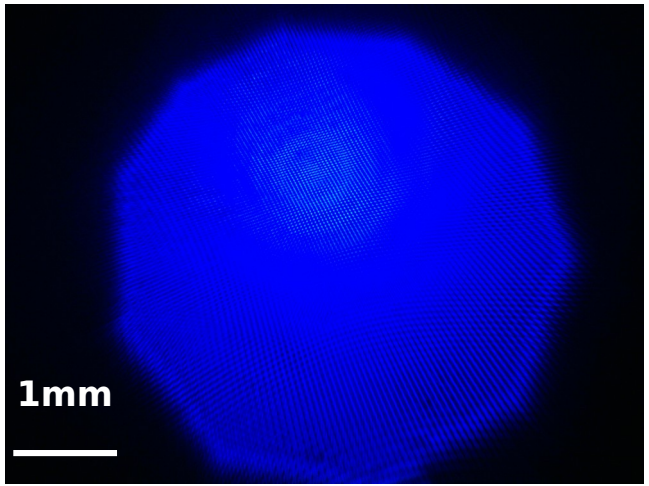
Optics – LED light spots

Numbers are NOT precise
Camera sensor is ~ 1 cm after the glass window



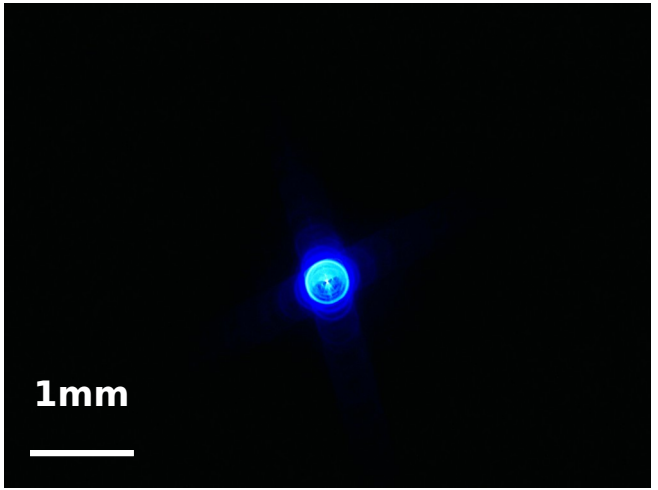
Interface	
Interfaces	USB 2.0

Camera	
Cameratype	USB2 Microscope camera - C-Mount
Camera - Resolution	5,1 MP
Camera - Sensor type	Aptina CMOS
Camera - Sensor size	1/2,5"
Camera - Colour depth	Colour
Camera- Mounting types	C-mount
Camera - Exposure method	Rolling Shutter
Camera - Sensor dimensions	5,7×4,28 mm
Camera - Pixel size	2,2×2,2 µm
Camera - FPS range 1	7 FPS



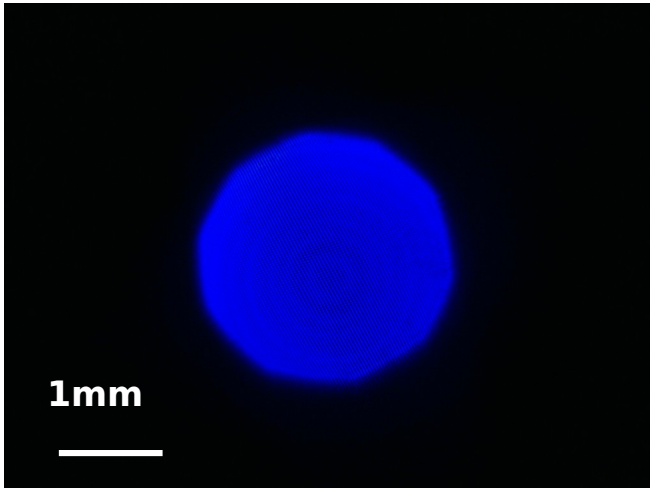
Farthest

At 9 mm away from contact, r ~2.0 mm
Ageing spot at further 9.5 mm away



Focused

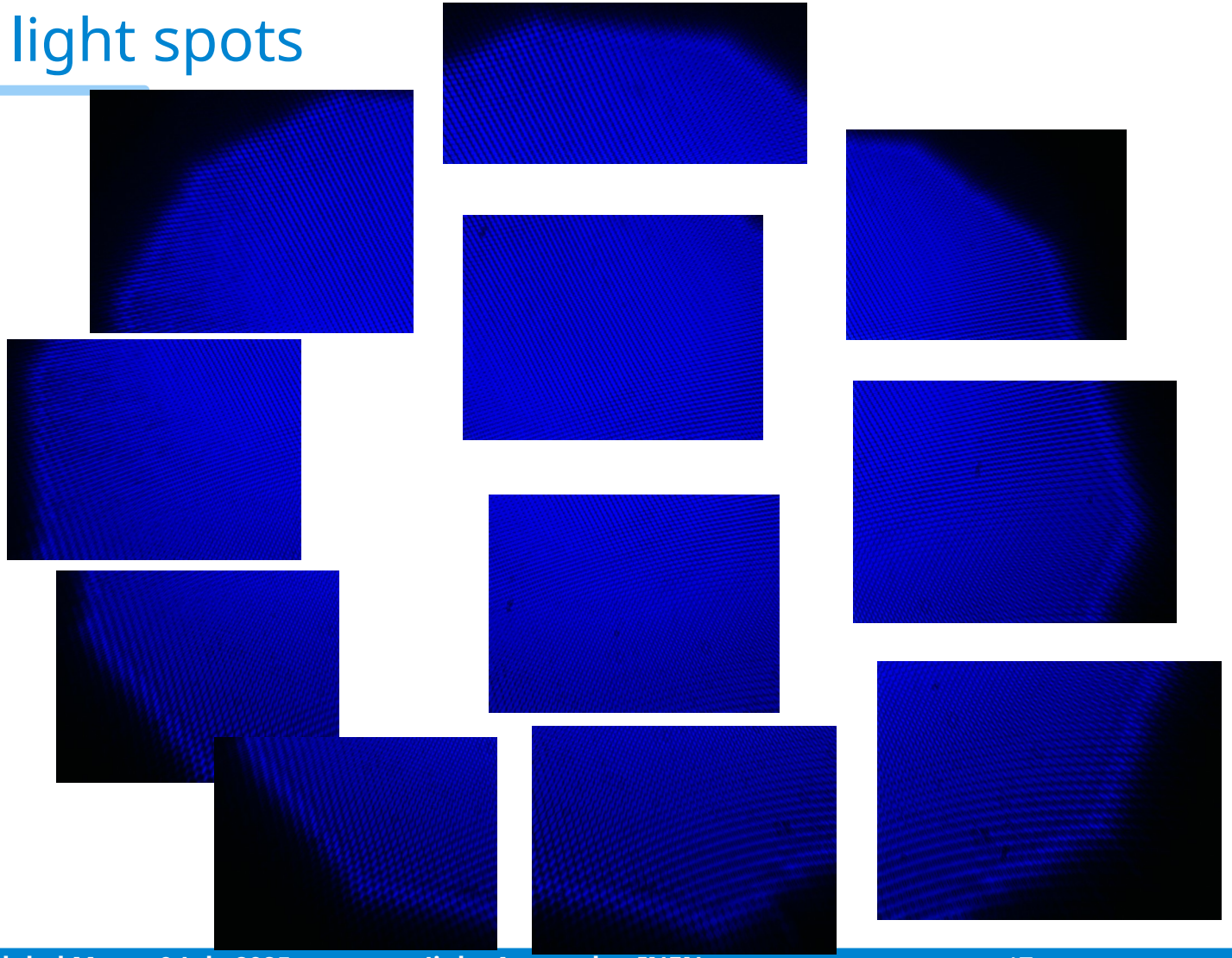
At 2 mm away from Contact, r ~0.2 mm



Nearest to Camera Sensor

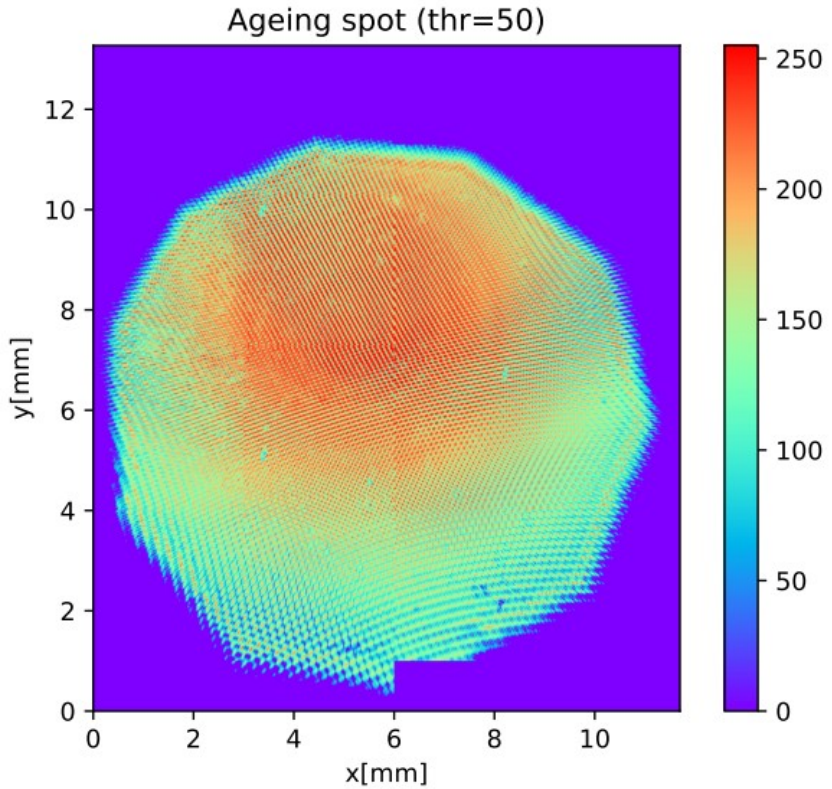
At Contact, r ~1.2 mm

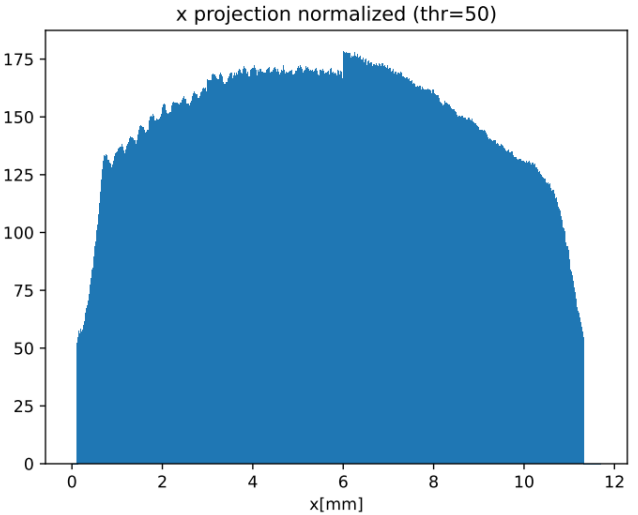
Optics – LED light spots

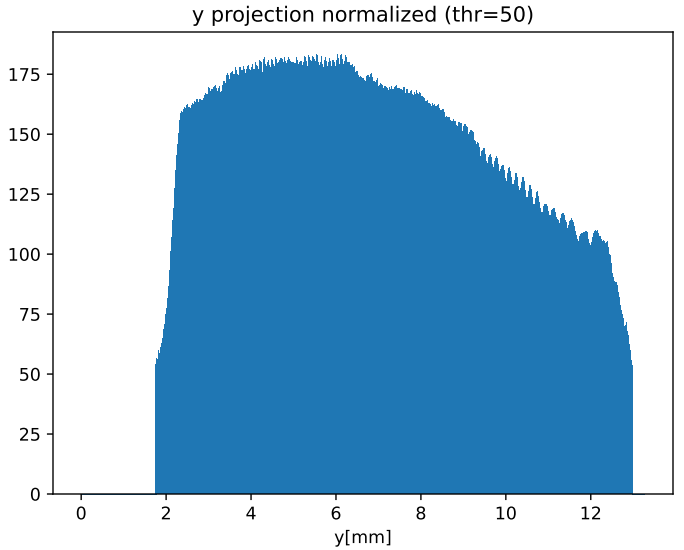


Optics – LED light spots

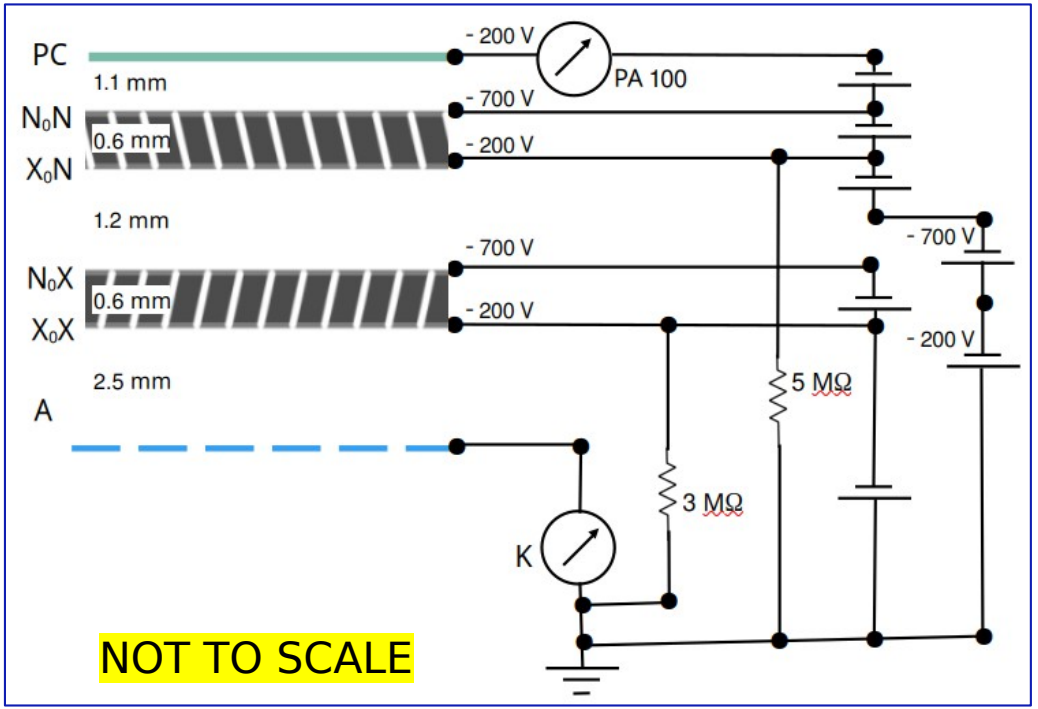
Intensity Scan



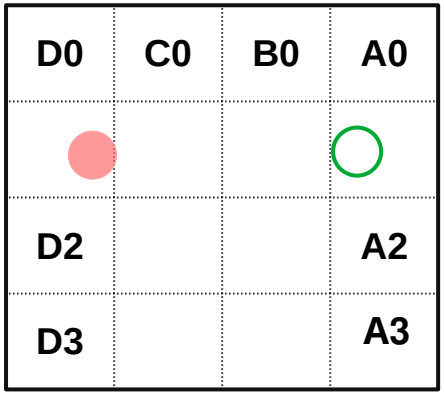




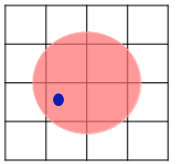
Strategy – ageing studies



Circuit for measurements/characterisation

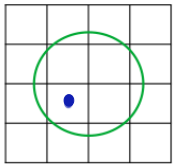


Window Frontview



Ageing spot Characterisation + irradiation

- Defocalised spot (d ~ 10 mm)
- Central 2 x 2 pads irradiated
- 4 x 4 pads under study



Reference spot Characterisation

- Focalised spot (d < 1 mm)
- 4 x 4 pads under study

Protocol - Measurements

A) Measurements at Ageing Region and Reference Region
(Before, Intermediate, After)

Measurement	HV bias	Light source	Light spot	Details	Instrument
PDE SCAN	ROP	pulsed Laser λ=0.15 W.P.4, OD2	focused	2 horizontal+2 vertical scans 10 mm with 0.5 mm steps (20 points x 4 scans)	Digitizer
QE SCAN	-50 V at PC EntryMCP at G	Continuous LED Direct I_{SET}=300 mA	focused	4x4 pads 0.3 mm steps (100 points/ pad)	i) Keithley EntryMCP, ii) PA120 Iii) Keithley PD
Average QE	-50 V at PC EntryMCP at G	Continuous LED Direct I_{SET}=300 mA	defocused	1.5 hours (??) 5 OFF - 4 ON states(??)	i) Keithley EntryMCP, ii) PA120 Iii) Keithley PD
Gain	ROP	pulsed Laser λ=0.01 W.P.5, OD3	focused	16 charge spectra for 16 pads Central 4 + adjacents	Digitizer
DCR	ROP	X	X	16 pads; 3 Th (-6/-10/-15 mV)	elX modules
APR	ROP	pulsed Laser λ=3 W.P.3, OD1	focused	200 ns time window Logic: Enea	Digi/scope?

Protocol - Ageing

→ 10^{14} γ / cm² in 10 days

→ 10 hours per day

Φ (per cm²) = $\frac{10^{13}}{10 \times 3600}$ per sec.

≃ 2.77×10^{8} per sec.

r_{spot} ≃ 5.32 mm

Area ≃ 0.89 cm²

$\Phi_{equivalent}$ ≃ 2.47×10^{8} /sec.

= Φ_T (Ageing)

Photon Flux at HRPPD and PD current

$\Phi_R = \frac{\Phi_T}{1.30}$ (on Photo-Diode)

e^- PD (R) = $\Phi_R \times QE_{PD}$

= $\Phi_R \times 0.565$

= $\frac{2.47 \times 10^{8}\ \gamma/sec \times 0.565}{1.30}$

$N_{e^-} \simeq 1.07 \times 10^{8}$ /sec.

$I_{PD(R)} = N_{e^-} \times 1.6 \times 10^{-19}$ C/sec

= 1.71×10^{-11} A.

$I_{PD(R)} \simeq 17$ pA

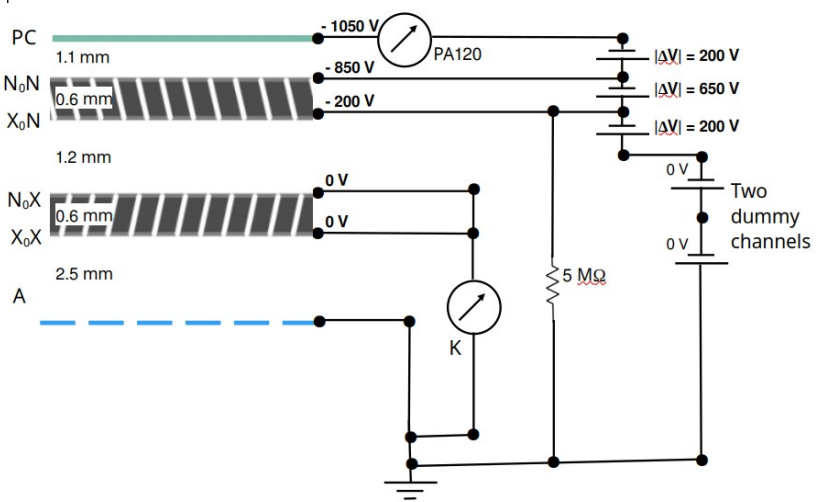
Via wheel (empty) **Ageing**
PD(R)=**2 pA** @ LED
I_{SET} = 16 mA **(min)**

PD(R)=**116 pA** @ LED
I_{SET} = 500 mA **(max)**

PD(offset): -0.1 pA

Protocol - Ageing

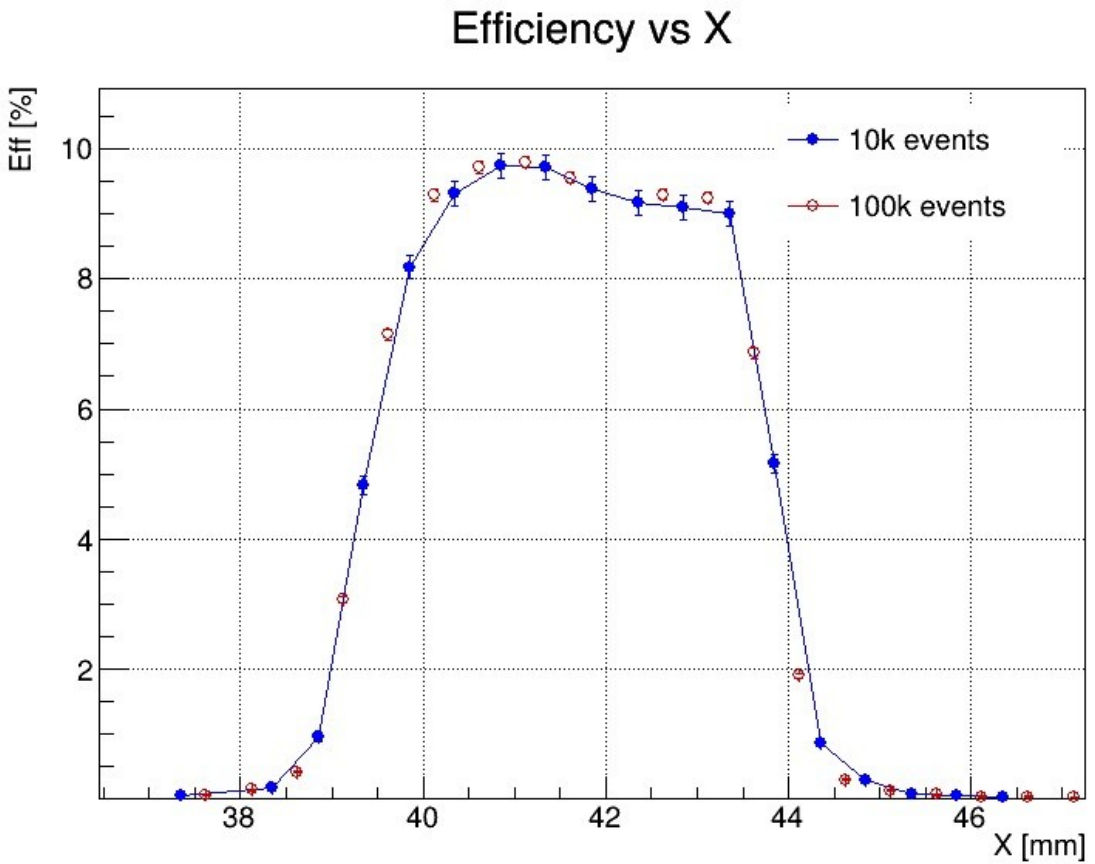
B) Ageing

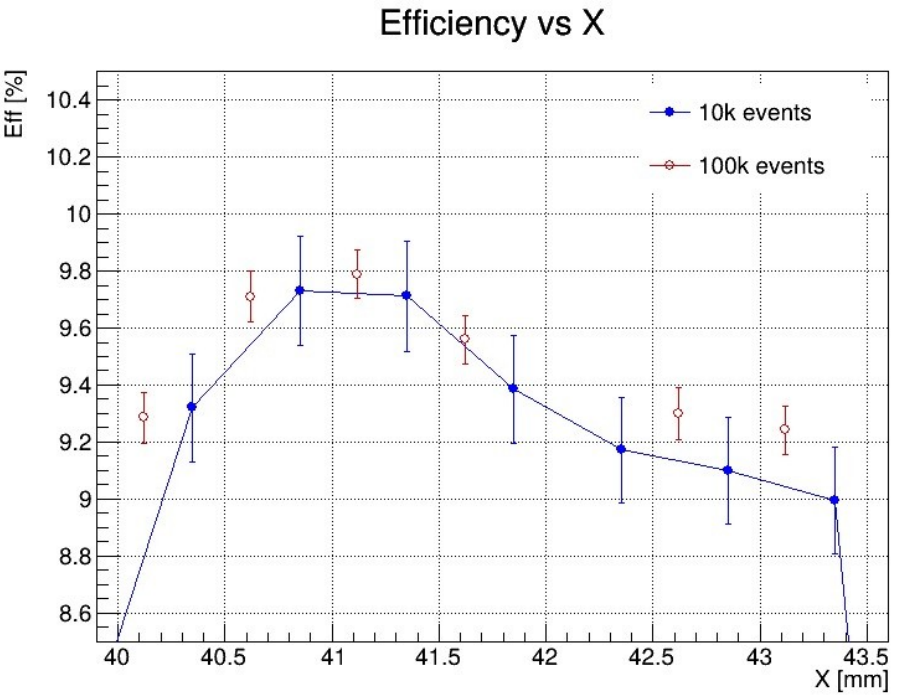
elX Circuit	Monitor Currents	HV bias	Light source	Light spot
	CAEN	200_650_200 V Exit MCP at G	Continuous LED I_{SET}=300 mA Wheel Position 1 (Empty)	defocused
	Keithley Exit MCP			
	Keithley Photo-Diode			
	PA120			

Temperatute inside the darkbox will be monitored all the time (work in progress)

PDE – horizontal scan

Digitizer
Pulsed laser (λ~0.10), W.P.4, OD2
10% non-empty events pulsed Laser
PDE: # of coincidence events/# of TR events
In steps of 0.5 mm





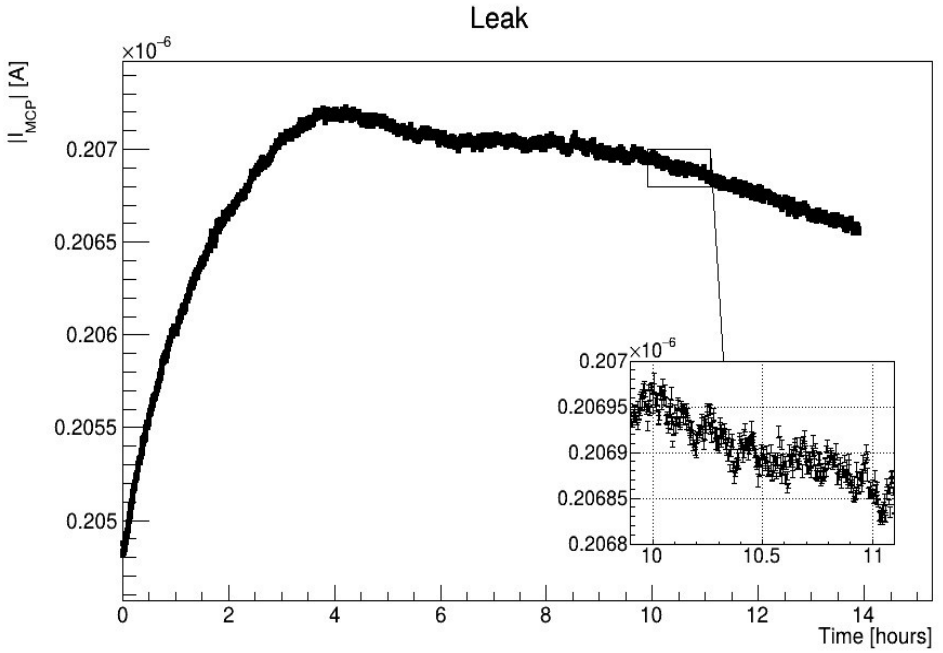
Good reproducibility

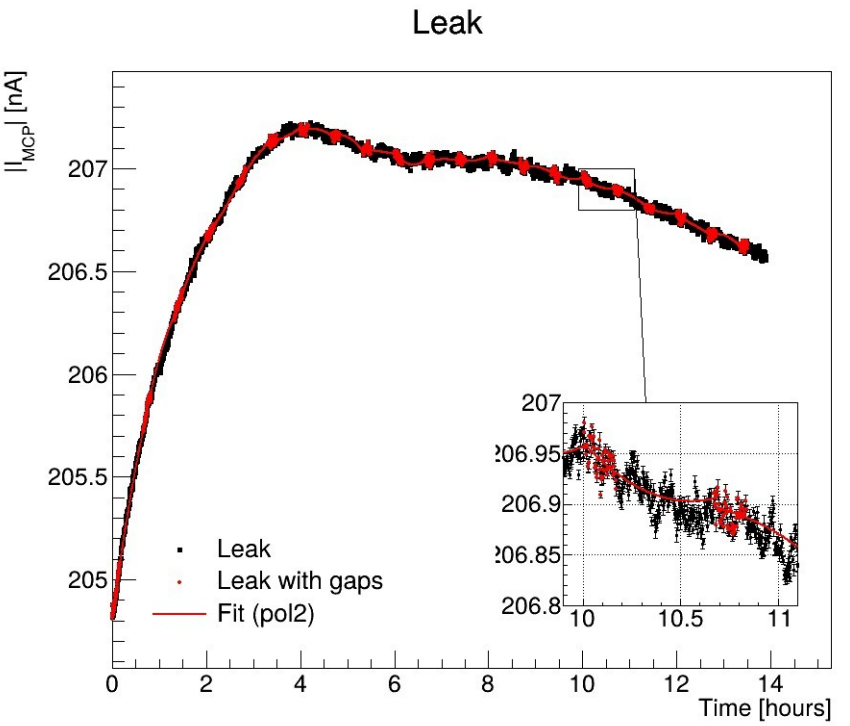
QE – leak estimate

$$QE_{HRPPD} = (I_K - L)/\varphi_S$$

$$\varphi_S = SR \cdot \varphi_R = SR \cdot I_{PD}/QE_{HC} = \frac{SR \cdot I_{PD}}{CC\,QE_C}$$

$$QE = \frac{(I_K - L)}{I_{PD}} \cdot \frac{CC\,QE_C}{SR}$$





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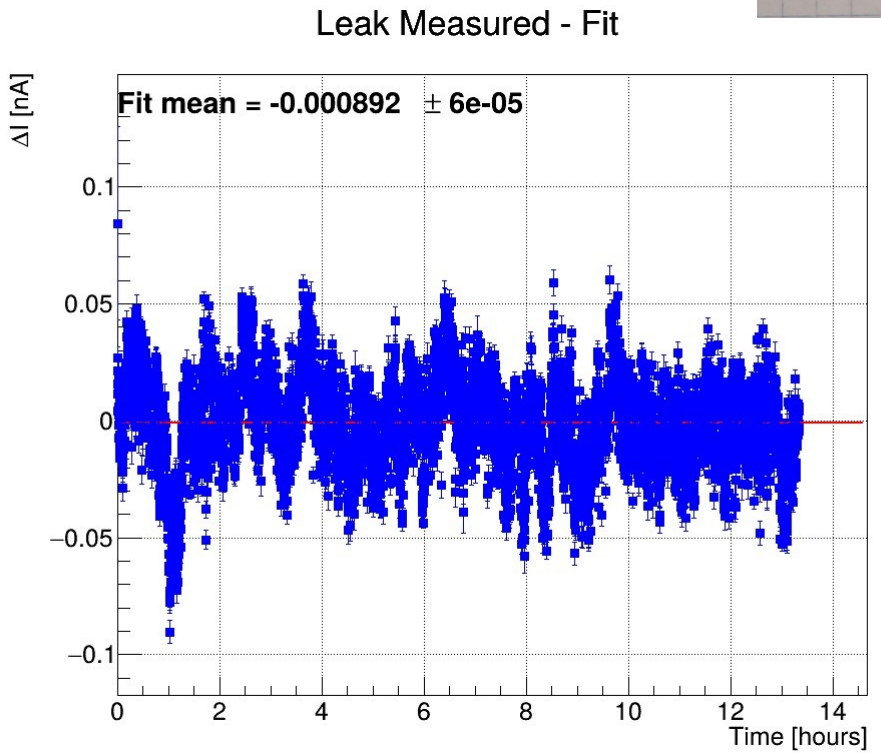
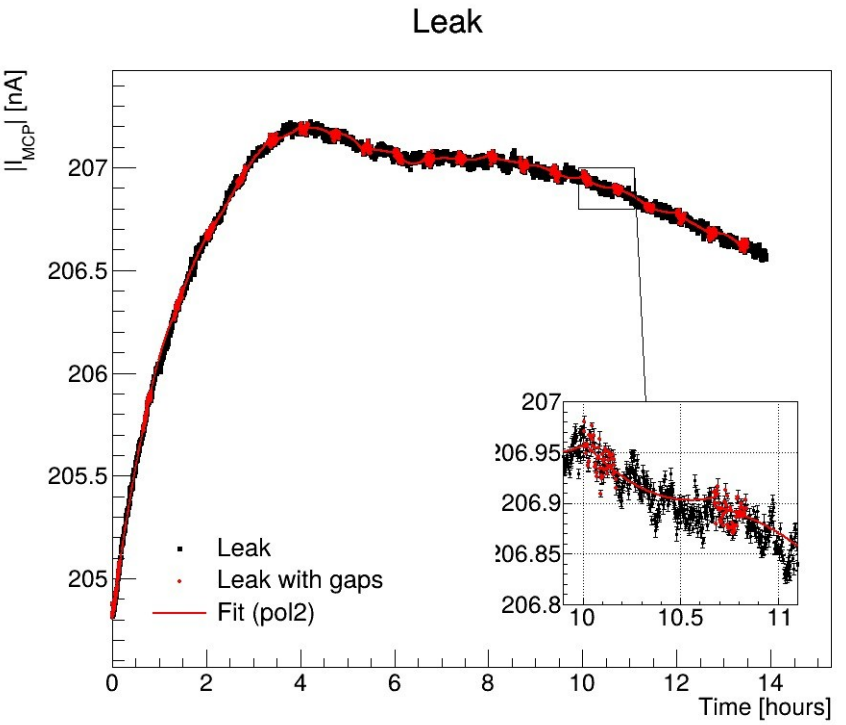
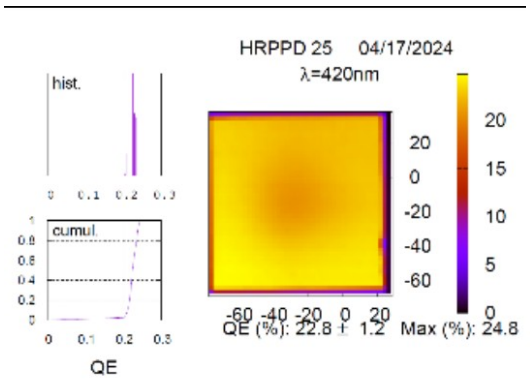
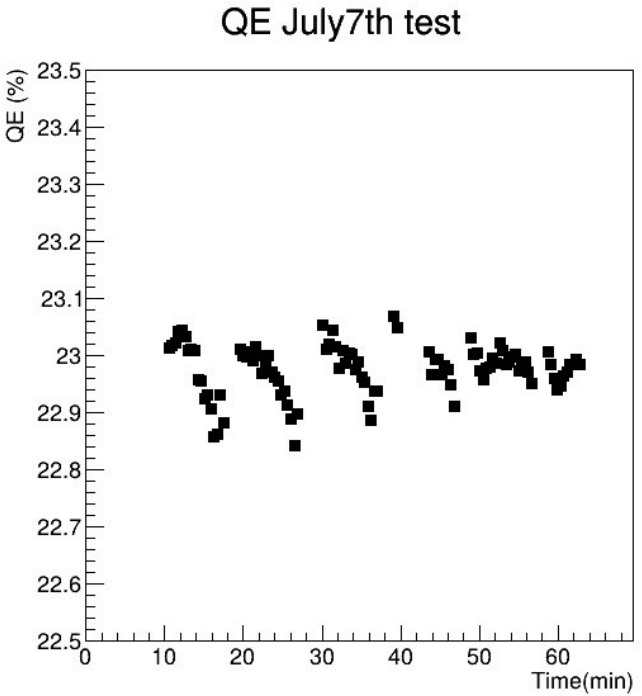
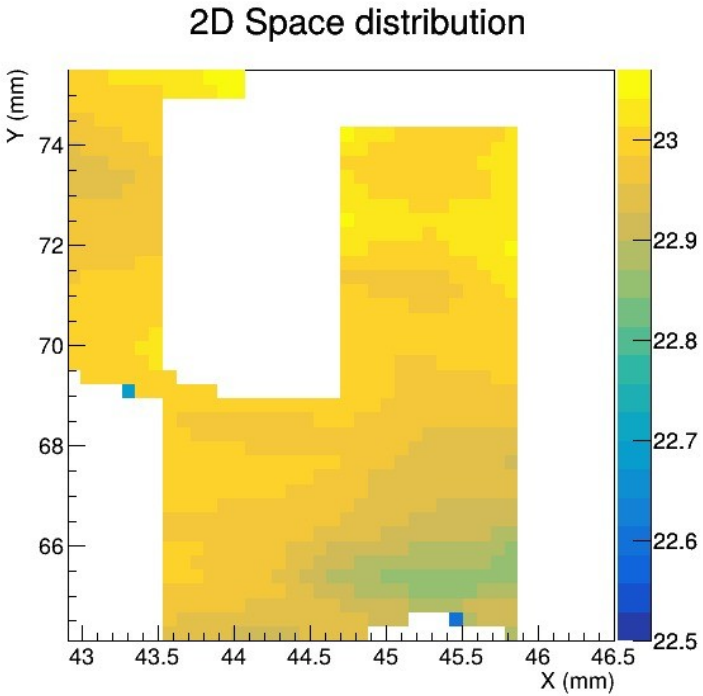




QE – measurement



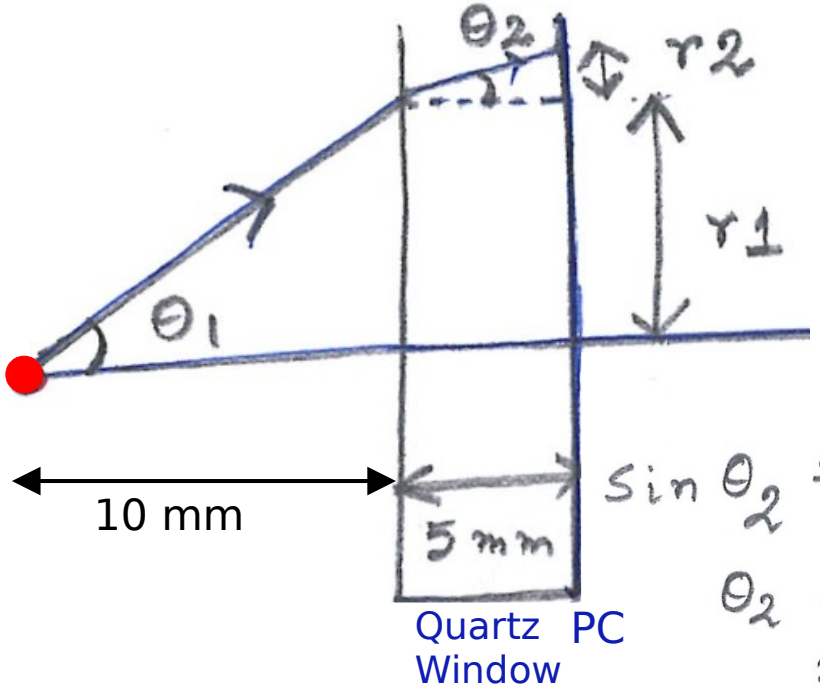




Backup

Positions of spots from the Photocathode

Focused spot here
(optics edge is 10 mm before)



$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1$$

$$\theta_2 = \arcsin(0.254)$$

$$\simeq 14.7$$

n1 (air)~ 1
n2 (quartz) ~ 1.46

θ1 = arctan(0.4) ~ 21.8°
r1 = 10 x tanθ1 = 4.0 mm

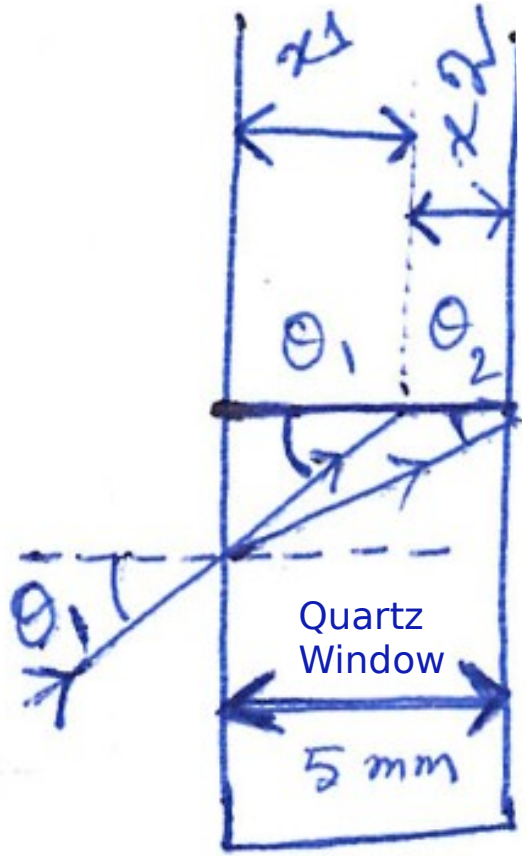
θ2 = arcsin(0.254) ~ 14.7°
r2 = 5 x tanθ2 = 1.3 mm

r_total = r1+r2 = **5.3 mm**

$A = \pi r^2 =$ **0.89 cm²**

NOT TO SCALE

Positions of spots from the Photocathode



NOT TO SCALE

$$5 \times \tan\theta_2 = x_1 \times \tan\theta_1$$

$$\Rightarrow x_1 \simeq 3.3$$

$$x_2 = (5 - 3.3)\ mm$$

$$= 1.7\ mm$$

Spot	Zaber Z [mm]	d'_c [mm]
Focused	38.3	11.7
Defocused	23.7	25