Institut
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Ljubljana, Slovenija

TPA-TCT measurements status

F9 Weekly, 06. 08. 2021

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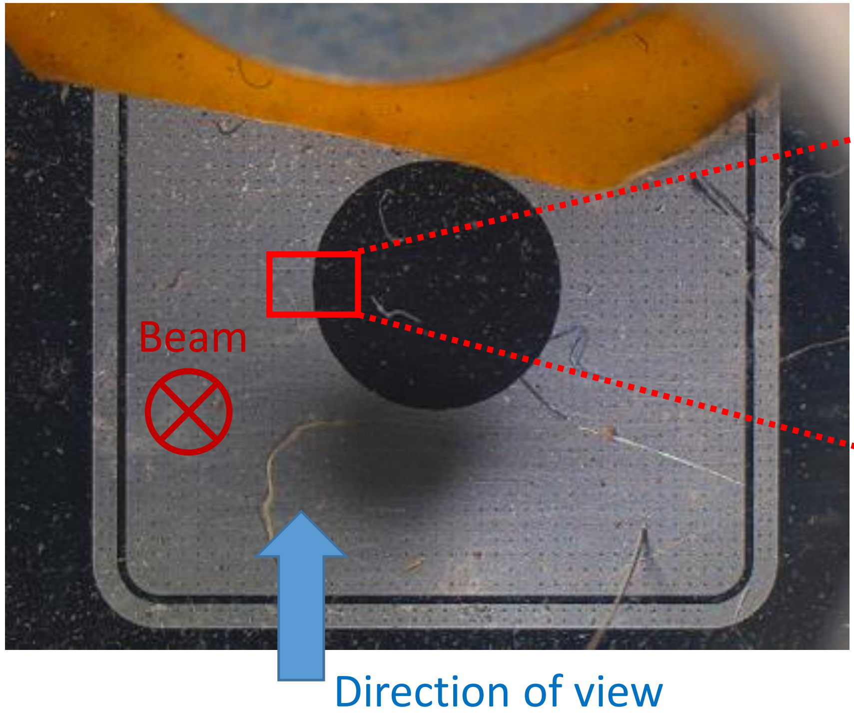
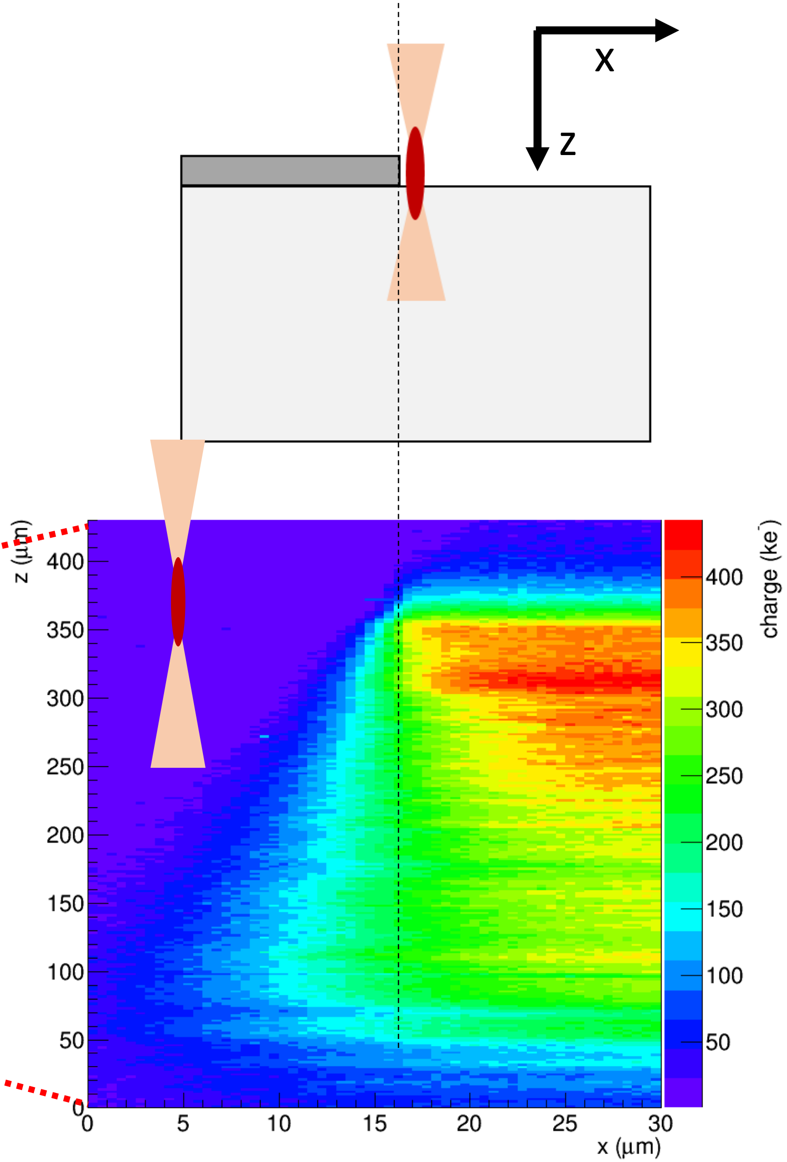
Ljubljana TPA-TCT setup

- Based on FYLA LFC 1500X fs laser (λ=1550 nm)
- Readout electronics and DAQ based on standard Particulars TCT

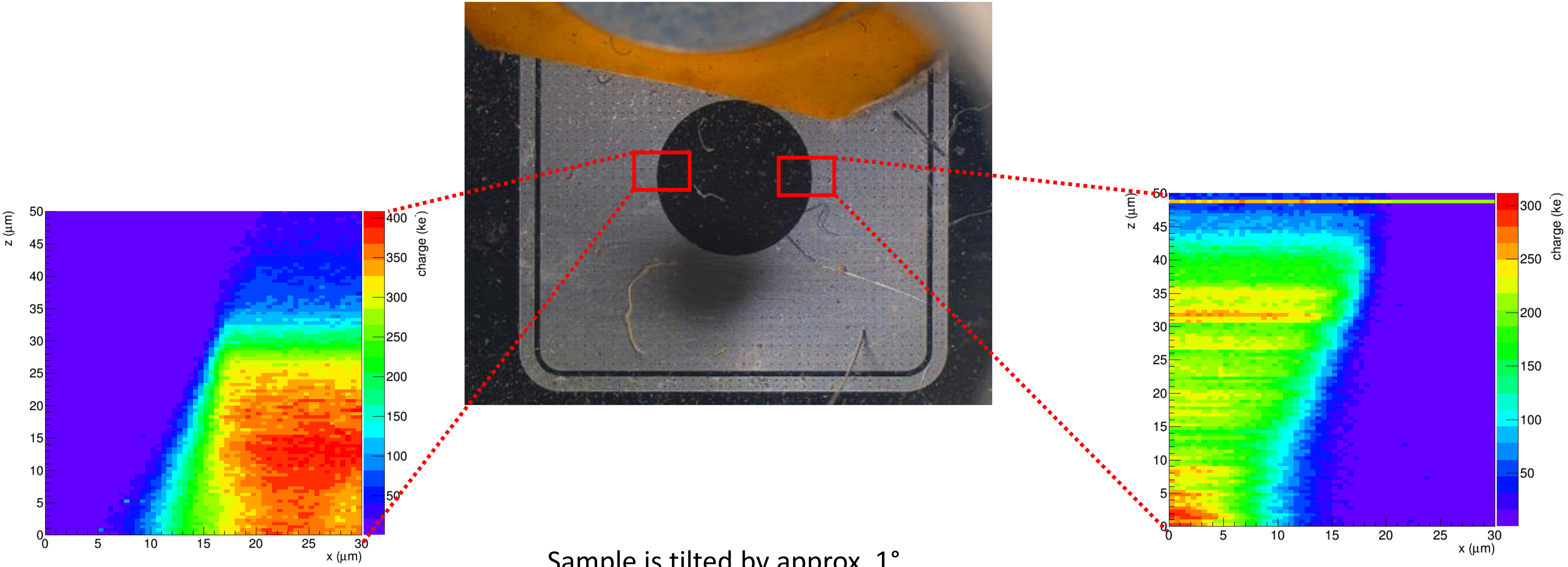
Sample and measurement

- Sample:
  - 6 x 6 mm p-in-n pad diode, metalization opening 2 mm
  - Thickness 300 µm, Vfd=20 V, 10 kΩ·cm, unirradiated
- Charge = time integral (25 ns) of TCT-pulse
- Amplifier output calibrated with Am^{241} alpha source (5.4 MeV)





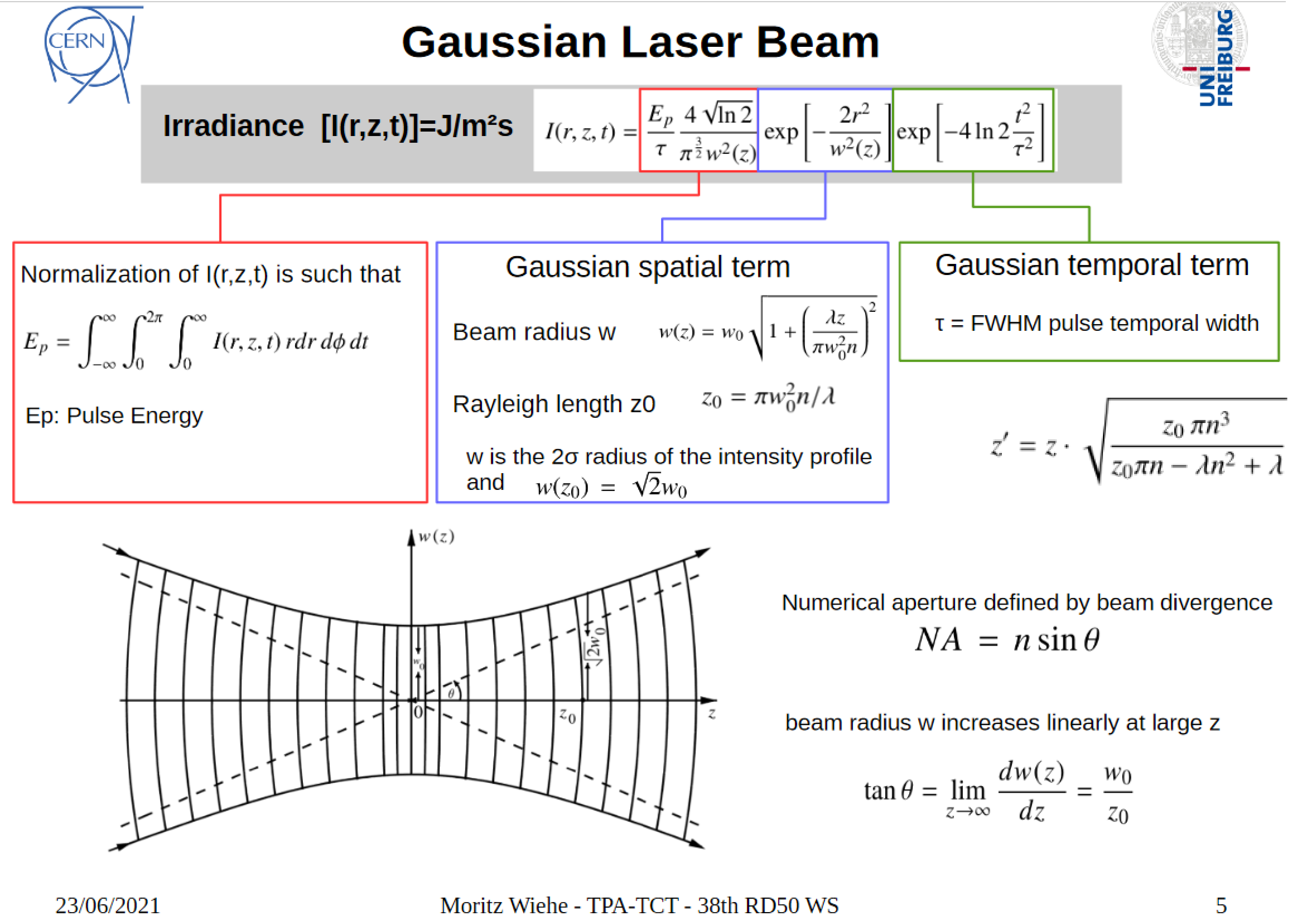
Sample tilt



Sample is tilted by approx. 1°

Ordered a manual tilt stage to compensate

Beam characterization



Gaussian Laser Beam

Irradiance [I(r,z,t)]=J/m²s

$$I(r,z,t) = \boxed{\frac{E_p}{\tau}\,\frac{4\sqrt{\ln 2}}{\pi^{\frac{3}{2}}\,w^2(z)}}\,\boxed{\exp\left[-\frac{2r^2}{w^2(z)}\right]}\,\boxed{\exp\left[-4\ln 2\,\frac{t^2}{\tau^2}\right]}$$

Normalization of I(r,z,t) is such that

$$E_p = \int_{-\infty}^{\infty}\int_0^{2\pi}\int_0^{\infty} I(r,z,t)\, r dr\, d\phi\, dt$$

Ep: Pulse Energy

Gaussian spatial term

Beam radius w $w(z) = w_0\sqrt{1+\left(\frac{\lambda z}{\pi w_0^2 n}\right)^2}$

Rayleigh length z0 $z_0 = \pi w_0^2 n/\lambda$

w is the 2σ radius of the intensity profile and $w(z_0) = \sqrt{2}w_0$

Gaussian temporal term

τ = FWHM pulse temporal width

$$z' = z\cdot\sqrt{\frac{z_0\,\pi n^3}{z_0\pi n - \lambda n^2 + \lambda}}$$

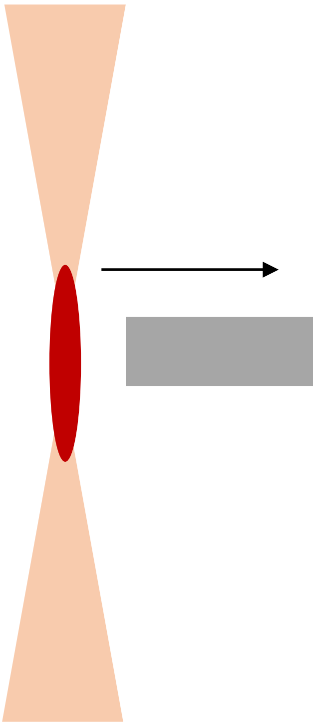
Numerical aperture defined by beam divergence

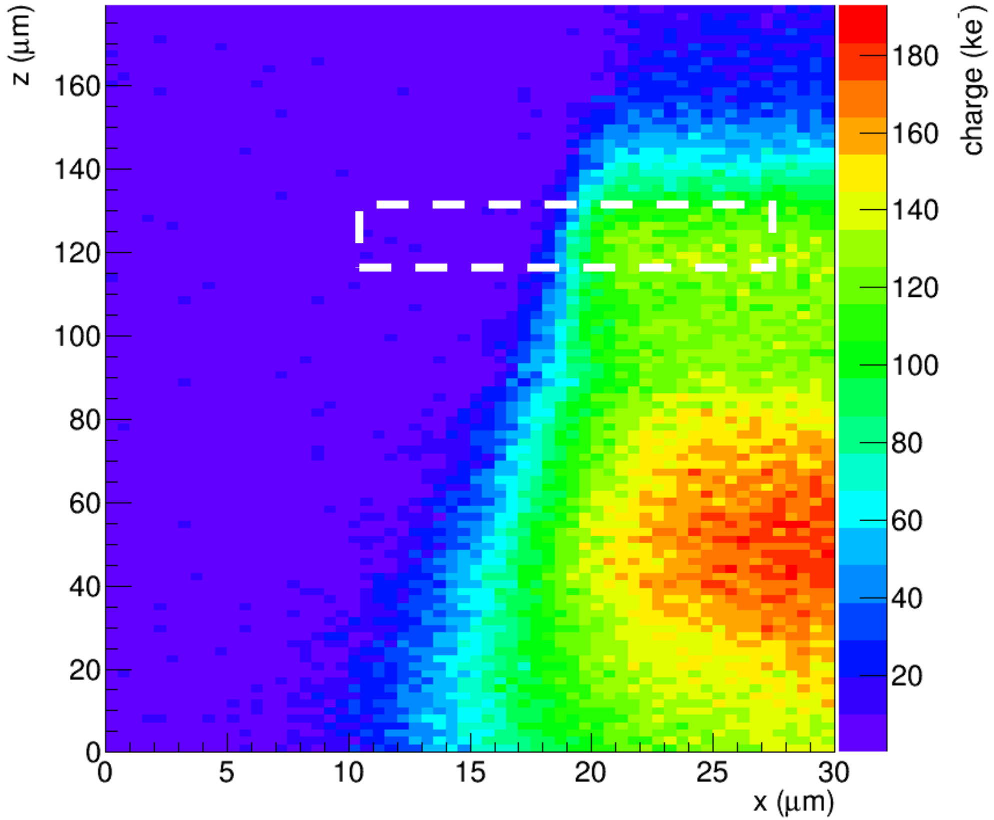
$$NA = n\sin\theta$$

beam radius w increases linearly at large z

$$\tan\theta = \lim_{z\to\infty}\frac{dw(z)}{dz} = \frac{w_0}{z_0}$$

Beam characterization





$$I(r,z,t) = \boxed{\frac{E_p}{\tau}\frac{4\sqrt{\ln 2}}{\pi^{\frac{3}{2}} w^2(z)}}\boxed{\exp\left[-\frac{2r^2}{w^2(z)}\right]}\boxed{\exp\left[-4\ln 2\frac{t^2}{\tau^2}\right]}$$

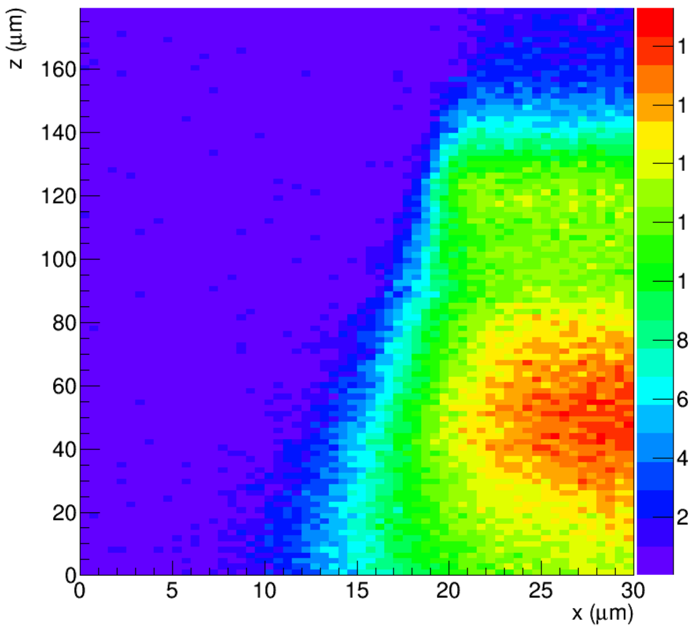
Beam radius w $w(z) = w_0\sqrt{1+\left(\frac{\lambda z}{\pi w_0^2 n}\right)^2}$

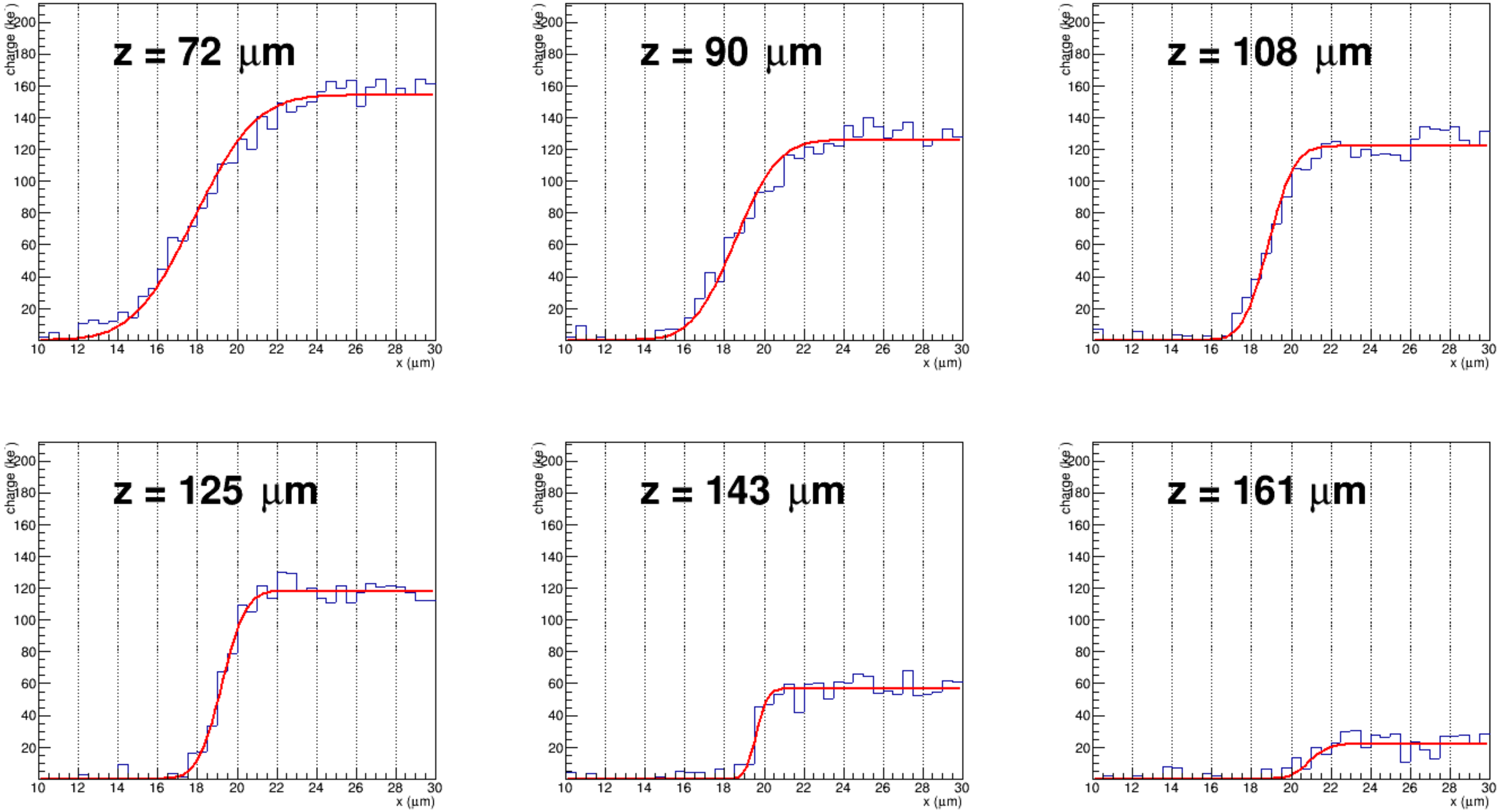
Rayleigh length z0 $z_0 = \pi w_0^2 n/\lambda$

w is the 2σ radius of the intensity profile
and $w(z_0) = \sqrt{2}w_0$

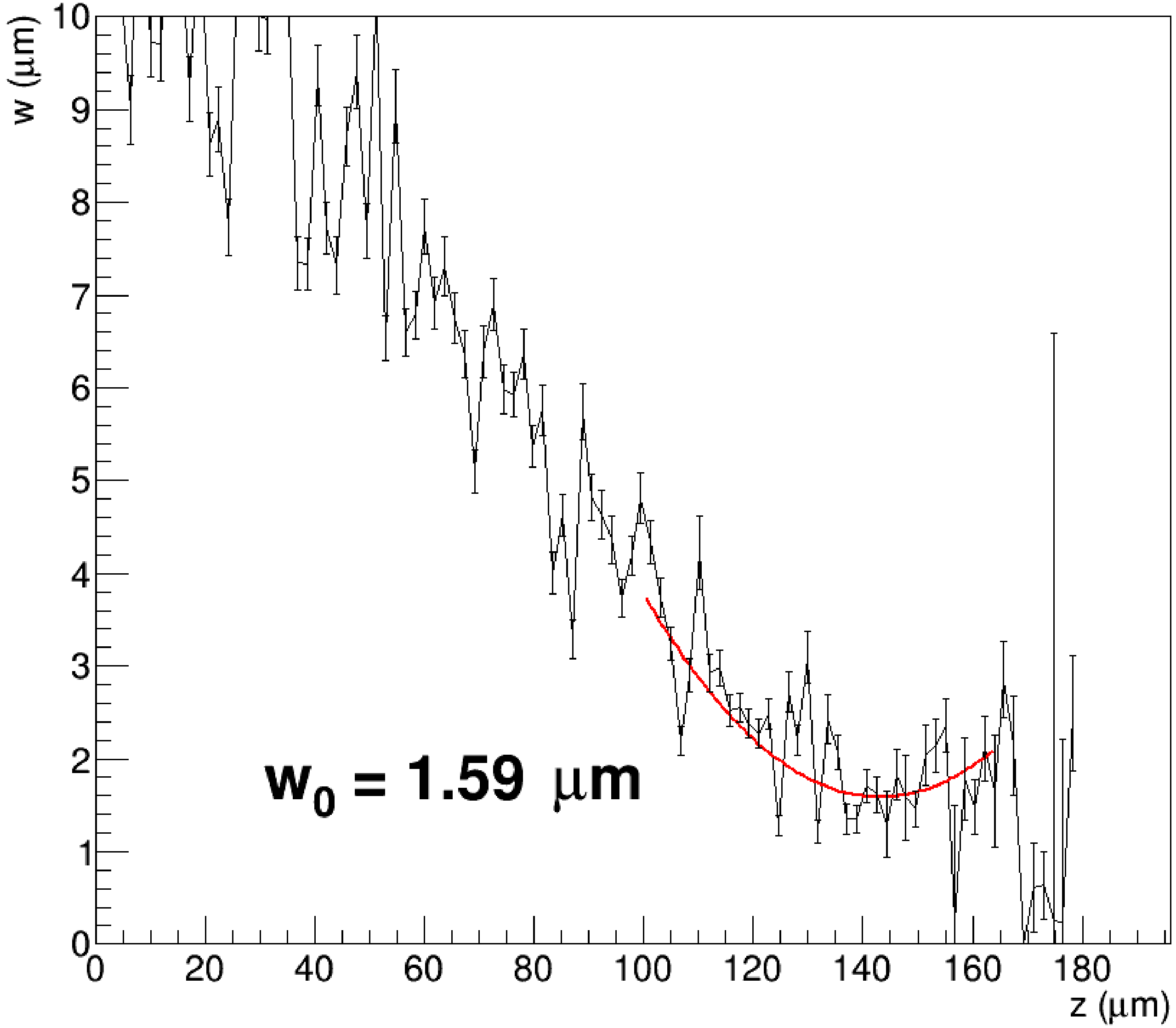
Fit Error function at different z
→ extract w(z)
→ extract w0

Beam characterization





Beam characterization

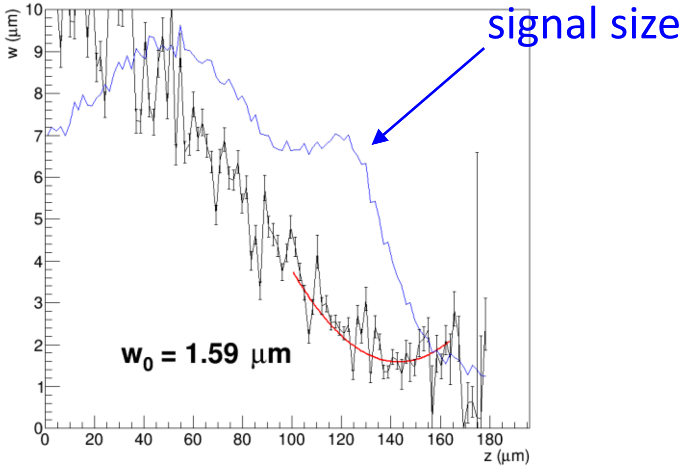


Beam radius w $$w(z) = w_0\sqrt{1+\left(\frac{\lambda z}{\pi w_0^2 n}\right)^2}$$

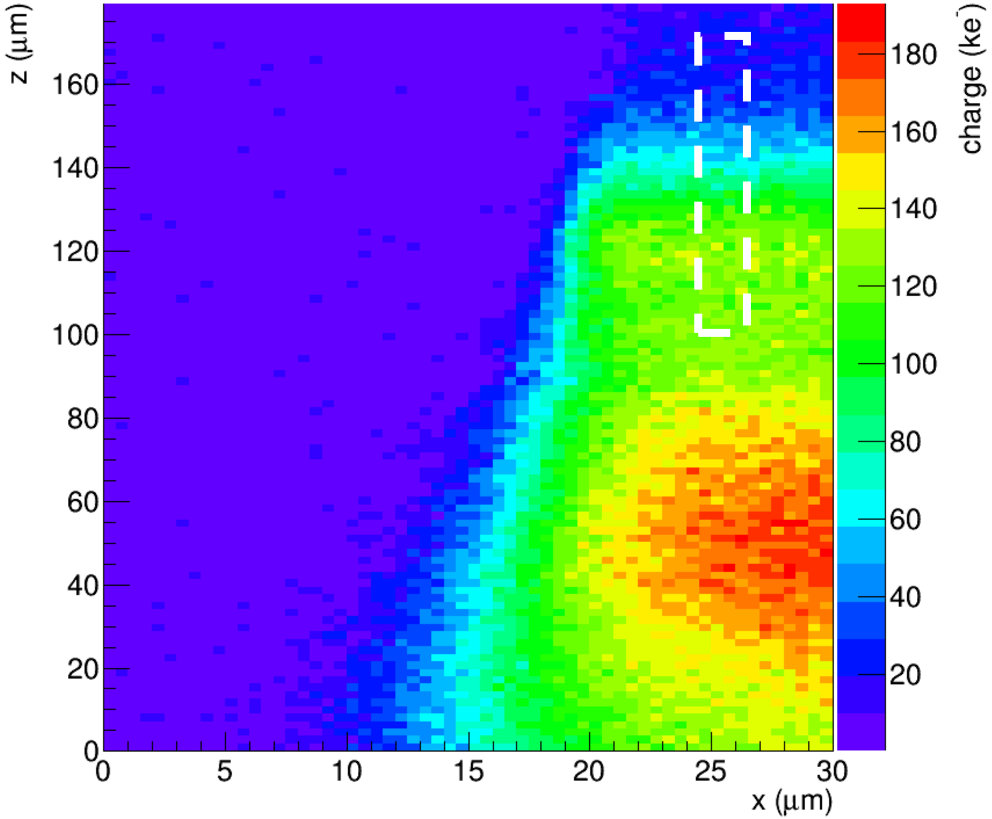
Rayleigh length z0 $$z_0 = \pi w_0^2 n/\lambda$$

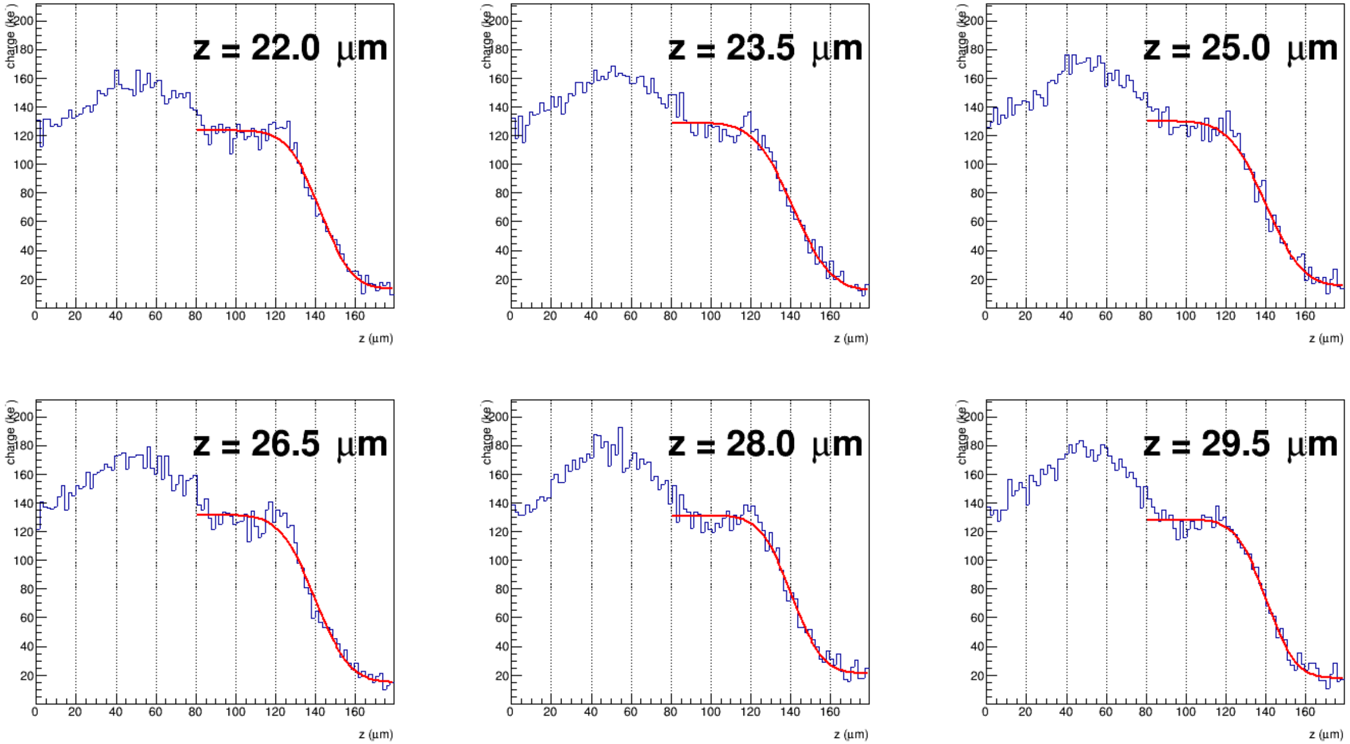
w is the 2σ radius of the intensity profile and $w(z_0) = \sqrt{2}w_0$

z0 = 18 um
charge generated in approx.
± 2 z0 → 72 um



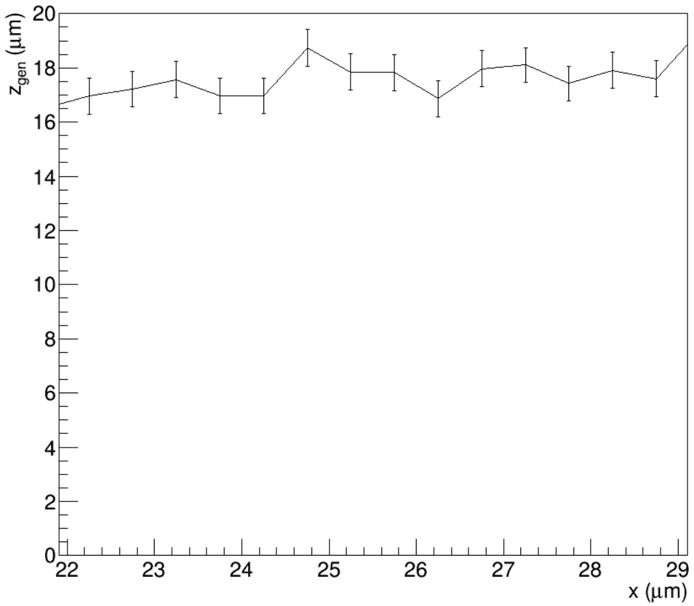
Longitudinal spot size

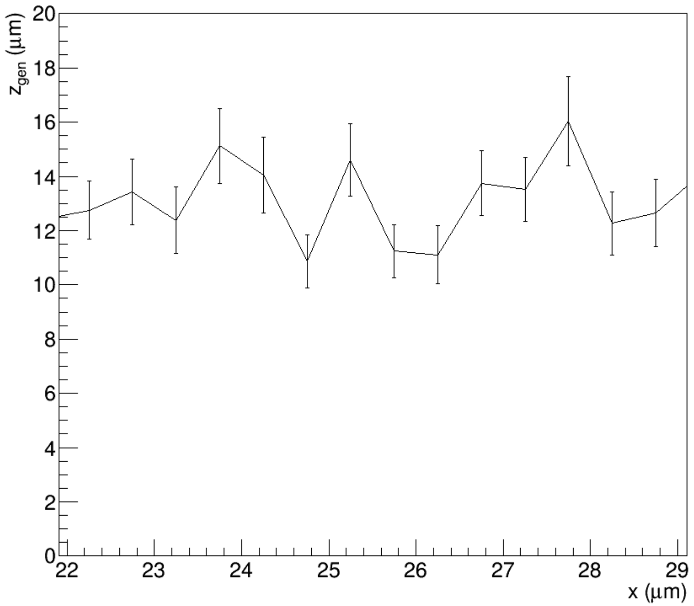


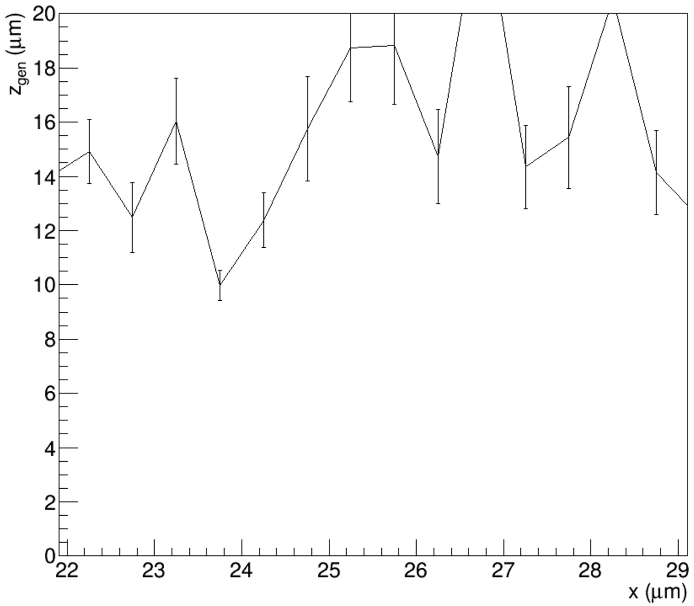


Errata z->x

Longitudinal spot size







$$z' = z \cdot \sqrt{\frac{z_0\,\pi n^3}{z_0 \pi n - \lambda n^2 + \lambda}}$$

Reducing beam intensity (approx. factor 2 in charge)

Cigar half-length cca 15 um in air

for z0 = 18um:

z' = 15um * 3.6 = 54 um

SEU potential

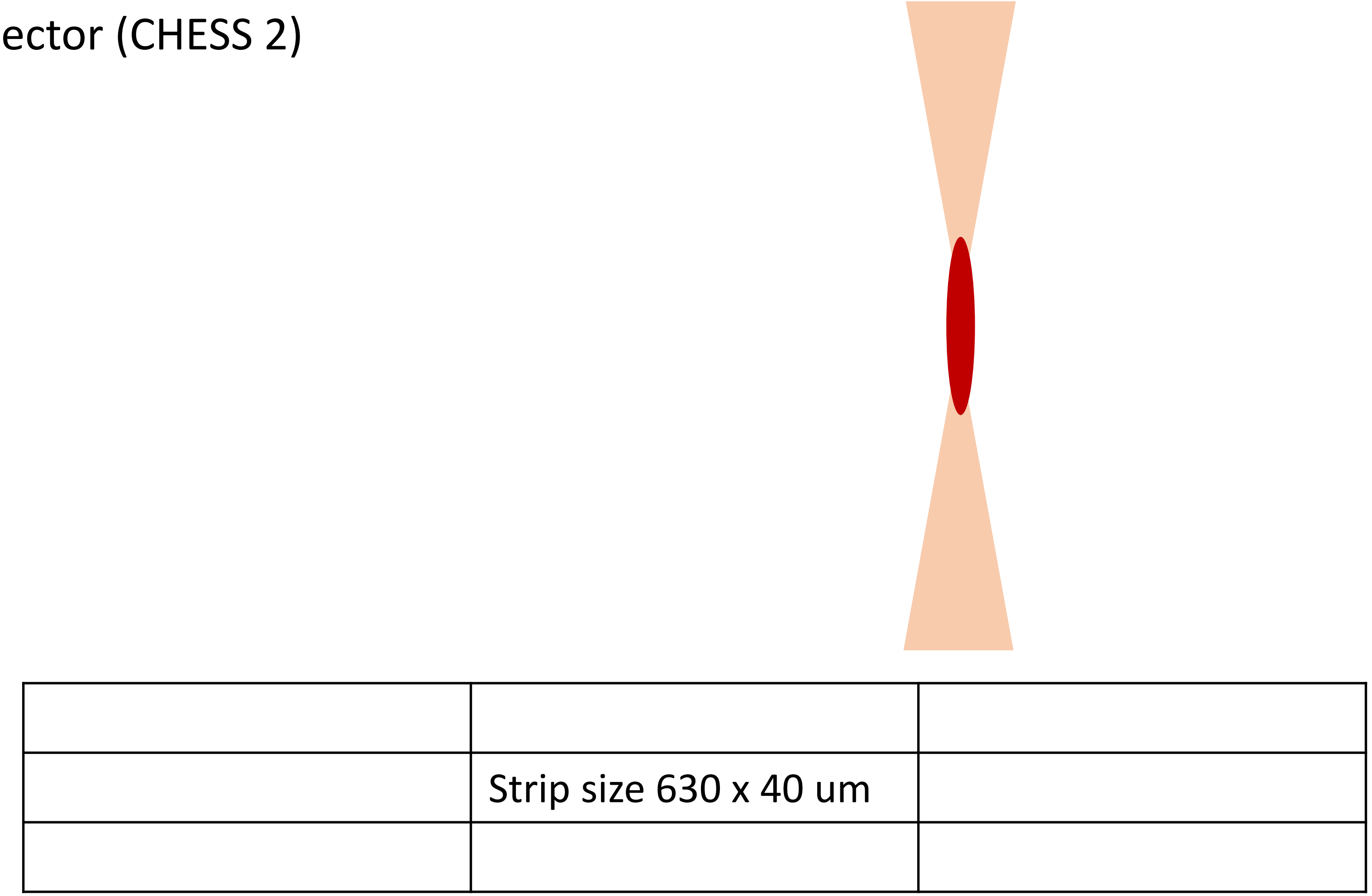
- LGAD mortality studies require charge of the order of 30M e-h pairs
    - Can it be done with TPA?

- Maximized laser signal
- HPK LGAD 2.5e15 biased to 700 V → failed in DESY test beam
- No defects observed with TPA

- There is still potential to increase pulse energy, but setup overhaul
    - Reduce losses on optical bench
    - Pin = 100 mW, Pout = 15 mW

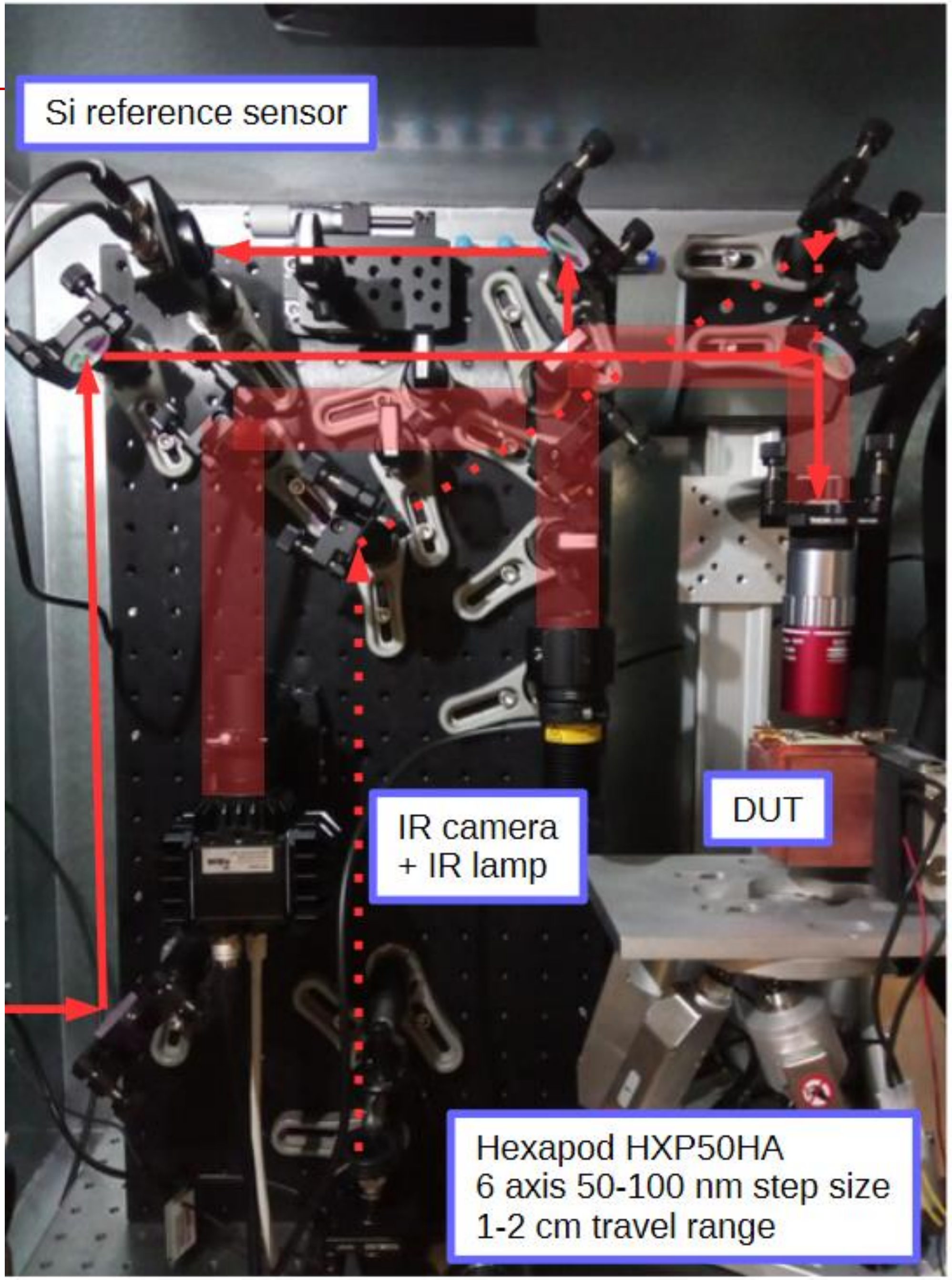
Edge TPA-TCT

- Try Edge-TCT configuration using strip detector (CHESS 2)
- So far no signals yet observed



Beam locating with IR camera

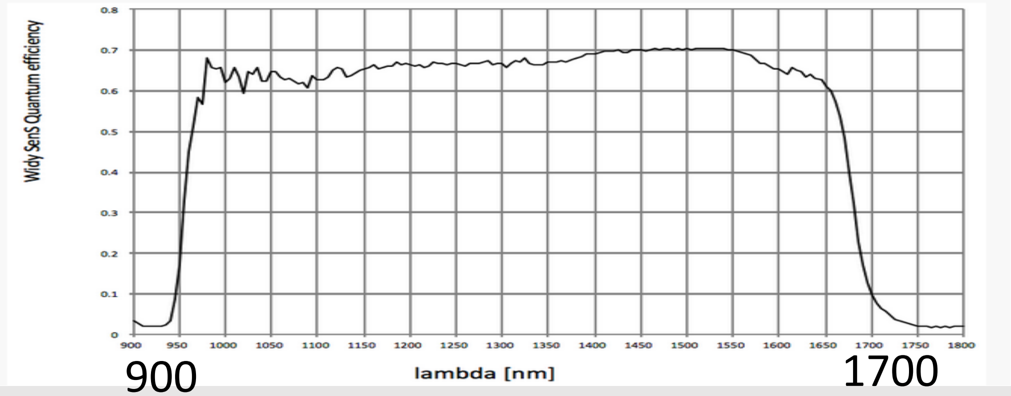
- CERN uses an IR camera to see the location of the beam on the sample
- Huge simplification for structure searching
- Can see through silicon → for example backside injection → see structures on the front side + beam spot
- Beam intensity loss due to semi transparent mirrors



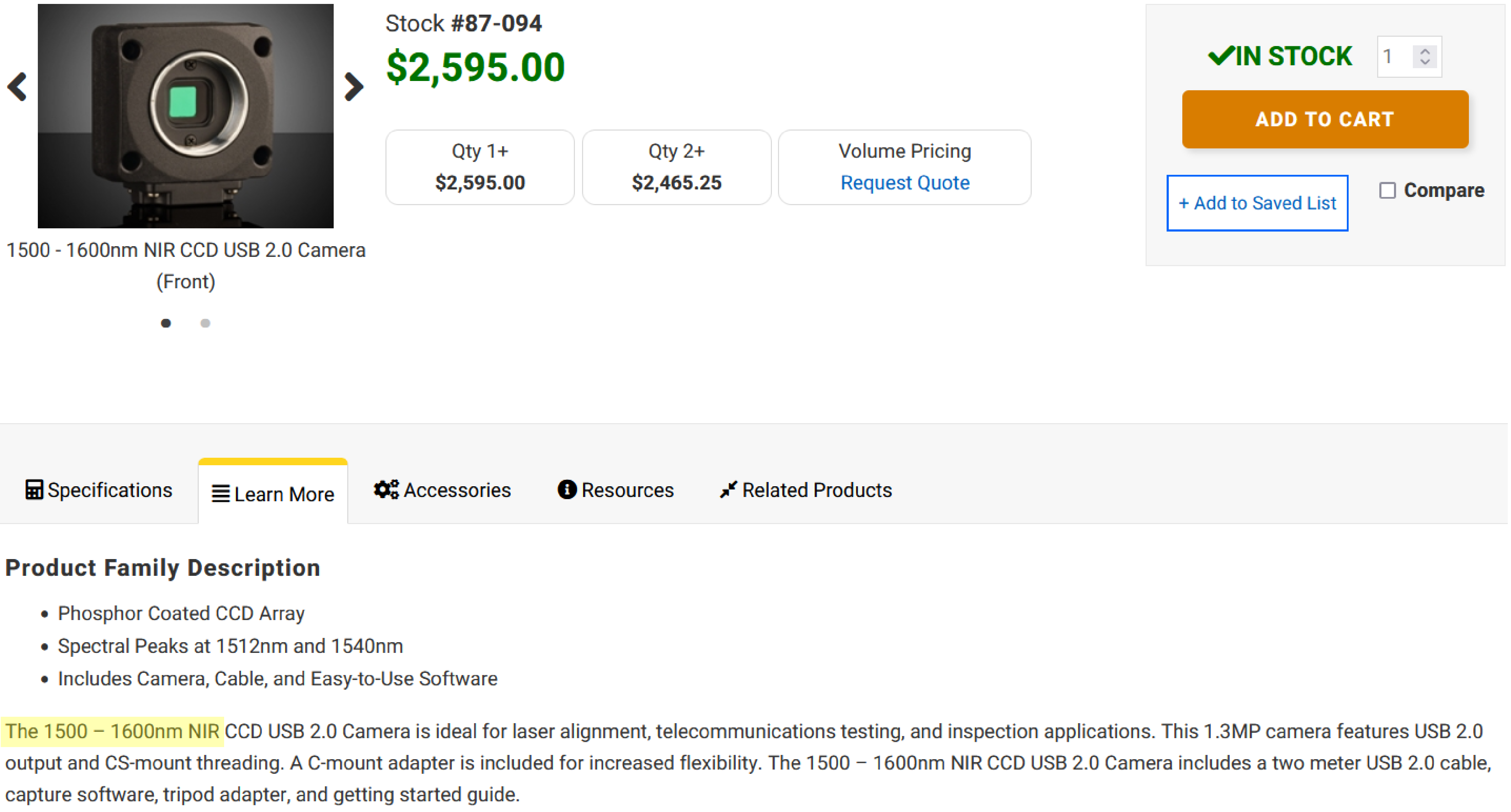
NIT WiDy SenS 640G-STE

CERN solution:

- VGA 640×512, Pitch : 15µm
- Dual-mode InGaAs sensor (Lin&Log)
- Near-Infrared Imaging up to 1700nm
- Dynamic Range 120dB typical in Log, 63dB typical in CTIA (Low Gain), 49dB typical in CTIA (High Gain)
- TEC on/off
- Up to 225fps full frame
- GigE output
- NUC, BPR & AGC On-board
- Power Over Ethernet (PoE) option



1500-1600nm NIR CCD USB 2.0 Camera



1500 - 1600nm NIR CCD USB 2.0 Camera (Front)

Stock #87-094

$2,595.00

Qty 1+	Qty 2+	Volume Pricing
$2,595.00	$2,465.25	Request Quote

Product Family Description

- Phosphor Coated CCD Array
- Spectral Peaks at 1512nm and 1540nm
- Includes Camera, Cable, and Easy-to-Use Software

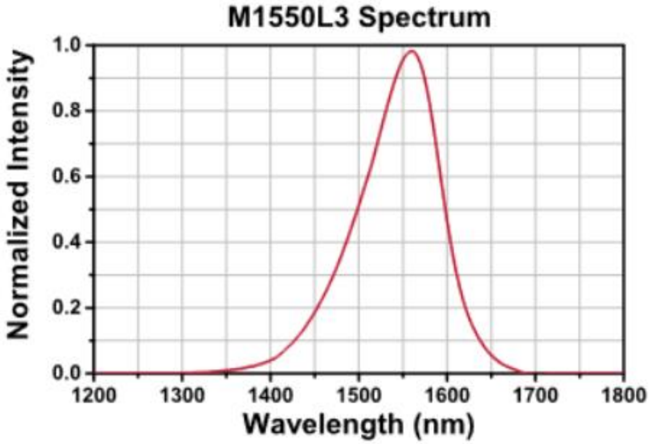
The 1500 – 1600nm NIR CCD USB 2.0 Camera is ideal for laser alignment, telecommunications testing, and inspection applications. This 1.3MP camera features USB 2.0 output and CS-mount threading. A C-mount adapter is included for increased flexibility. The 1500 – 1600nm NIR CCD USB 2.0 Camera includes a two meter USB 2.0 cable, capture software, tripod adapter, and getting started guide.

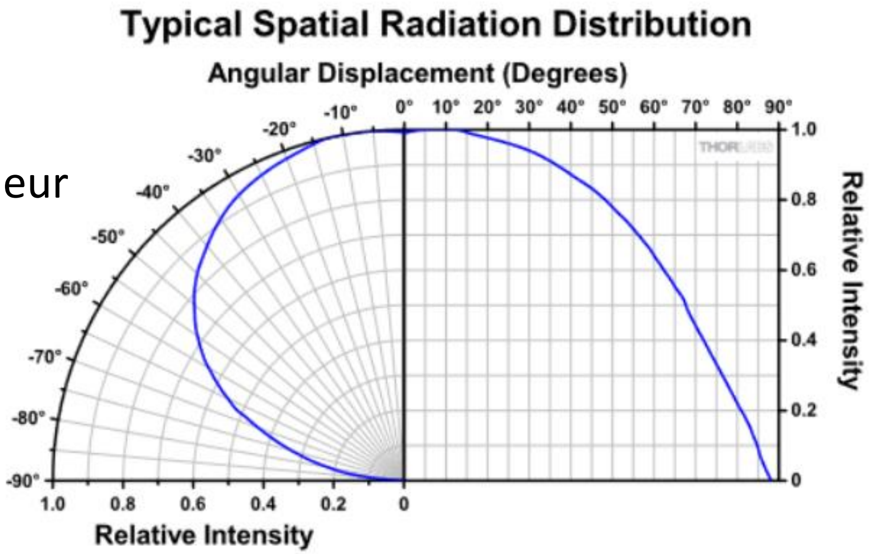
IR illumination

IR Mounted LEDs (780 - 1650 nm)

Item #	Info[a]	Nominal Wavelength[b]	Housing Type[c]	LED Output Power (Min / Typ.)[b,d]	Bandwidth (FWHM)	Irradian (Typ.)[e]			iewing Angle ngle at Half Max)
M780L3	ⓘ	780 nm	■	200 mW / 300 mW	28 nm	47.3 µW/m			20°
M780LP1	ⓘ	780 nm	🟥■	800 mW / 950 mW	30 nm	13.3 µW/m			120°
M810L3	ⓘ	810 nm	■	325 mW / 375 mW	25 nm	61.8 µW/mm^2	500 mA	3.6 V	20°
M810L4	ⓘ	810 nm	■	363 mW / 542 mW	32 nm	23.7 µW/mm^2	1000 mA	3.55 V	80°
M850L3	ⓘ	850 nm	■	900 mW / 1100 mW	30 nm	22.9 µW/mm^2	1200 mA	2.95 V	90°
M850LP1	ⓘ	850 nm	🟥■	1400 mW / 1600 mW	30 nm	19.4 µW/mm^2	1500 mA	3.85 V	150°
M880L3	ⓘ	880 nm	■	300 mW / 350 mW	50 nm	5.6 µW/mm^2	1000 mA	1.7 V	132°
M940L3	ⓘ	940 nm	■	800 mW / 1000 mW	37 nm	19.1 µW/mm^2	1000 mA	2.75 V	90°
M970L4	ⓘ	970 nm	■	600 mW / 720 mW	60 nm	7.4 µW/mm^2	1000 mA	1.9 V	130°
M1050L2	ⓘ	1050 nm	■	50 mW / 70 mW	60 nm	1.9 µW/mm^2	700 mA	1.5 V	120°
M1050L4	ⓘ	1050 nm	■	160 mW / 210 mW	37 nm	3.7 µW/mm^2	600 mA	1.4 V	128°
M1100L1	ⓘ	1100 nm	■	168 mW / 252 mW[g]	50 nm[g]	18.1 µWmm^2[d,g]	1000 mA[g]	1.4 V[d,g]	18°[g,h]
M1200L3	ⓘ	1200 nm	■	30 mW / 35 mW	80 nm	0.7 µW/mm^2	700 mA	1.4 V	134°
M1300L3	ⓘ	1300 nm	■	25 mW / 30 mW	80 nm	0.6 µW/mm^2	500 mA	1.4 V	134°
M1450L3	ⓘ	1450 nm	■	31 mW / 36 mW	80 nm	0.4 µW/mm^2	700 mA	1.15 V	136°
M1550L3	ⓘ	1550 nm	■	31 mW / 36 mW	102 nm	0.5 µW/mm^2	1000 mA	1.35 V	136°
M1650L4	ⓘ	1650 nm	■	13 mW / 16 mW	120 nm	1.2 µW/mm^2	600 mA	1.1 V	20°

600 eur





- Is 35 mW sufficient?