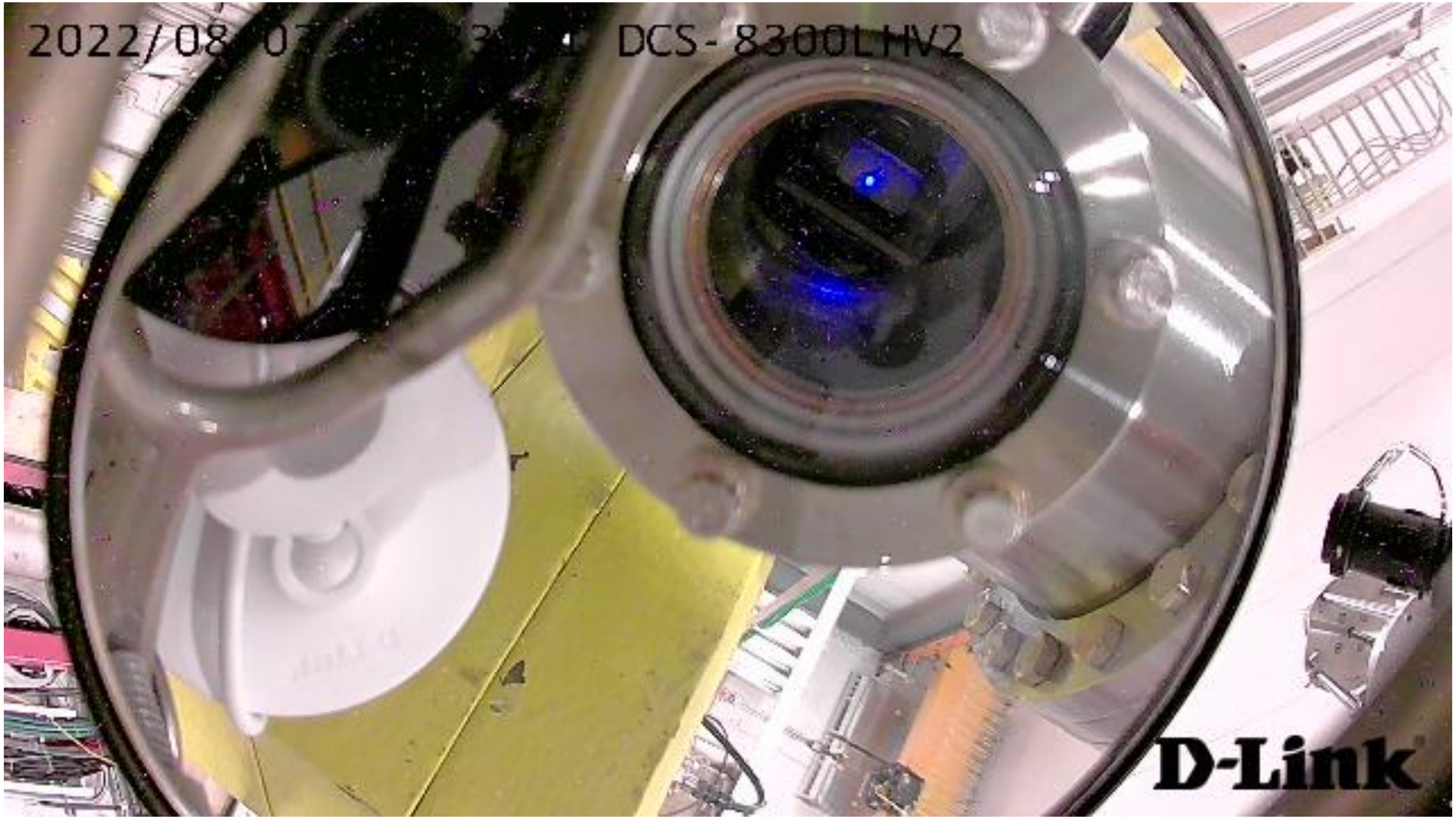
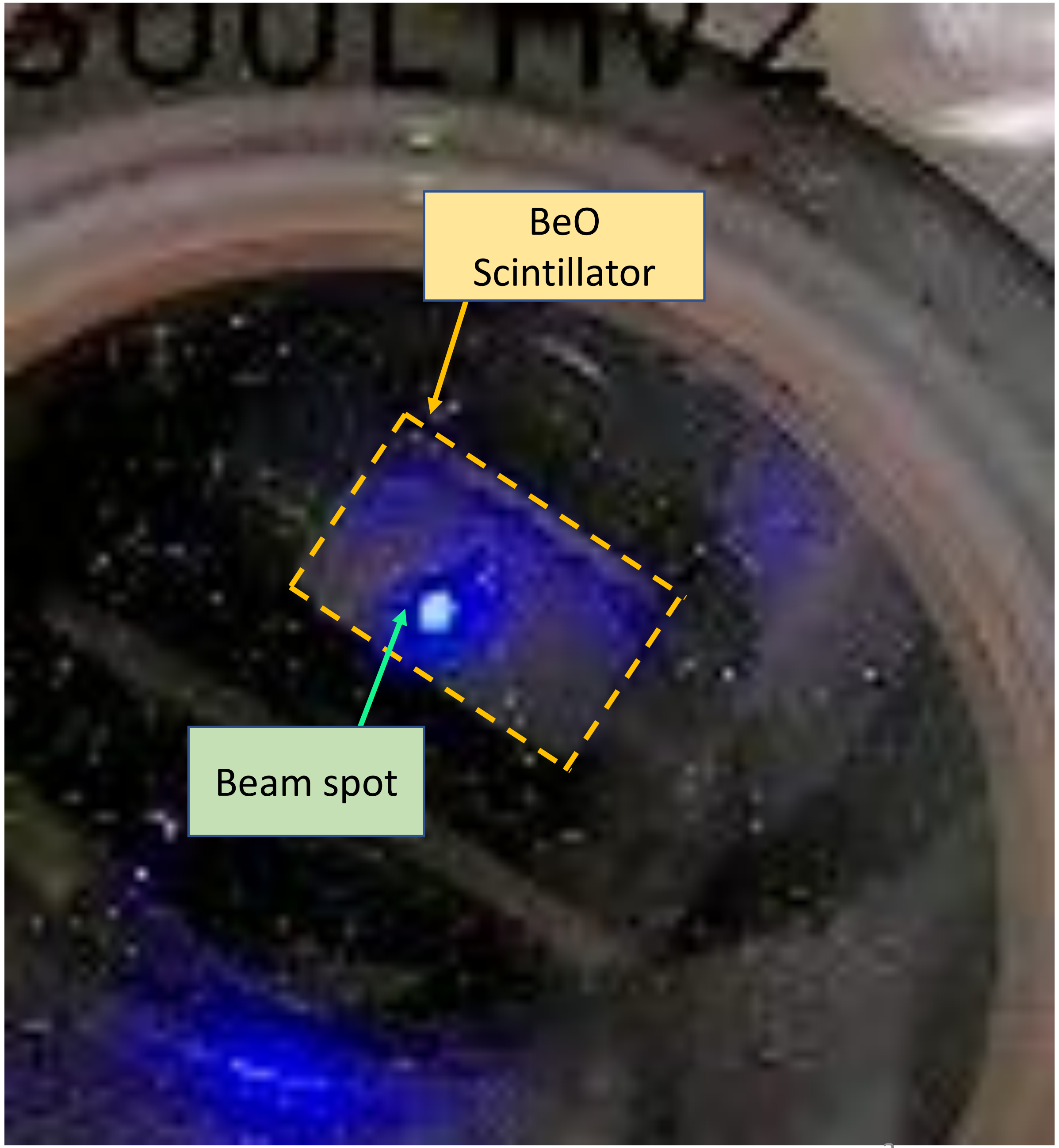
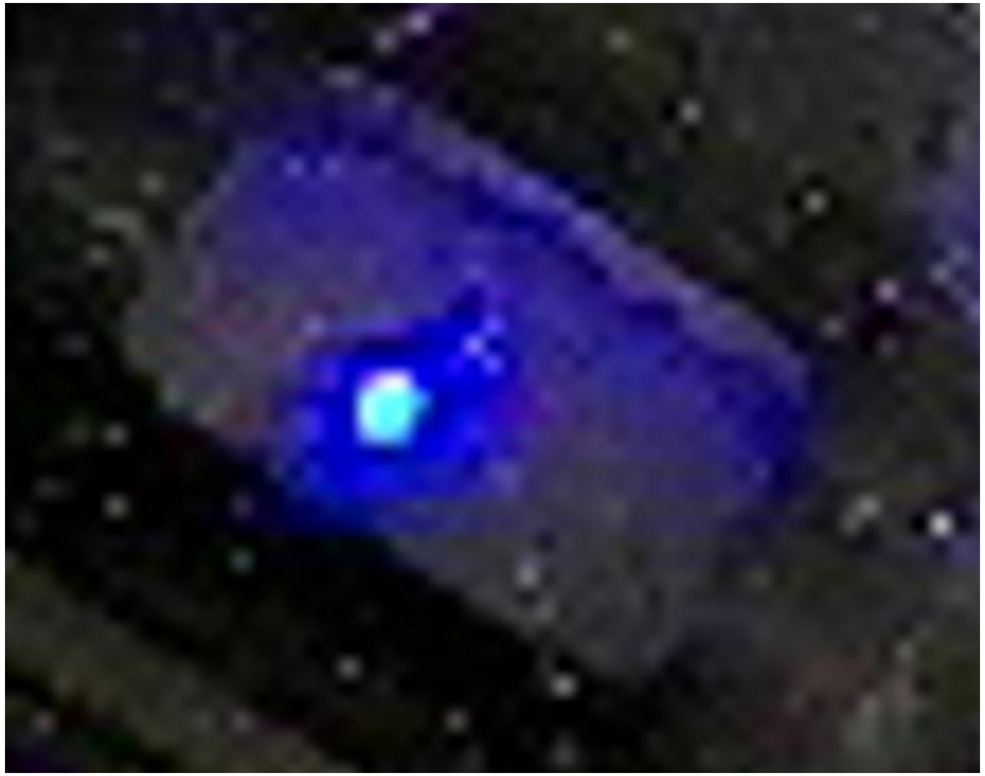
First beam on Darklight target: Examination of the beamspot

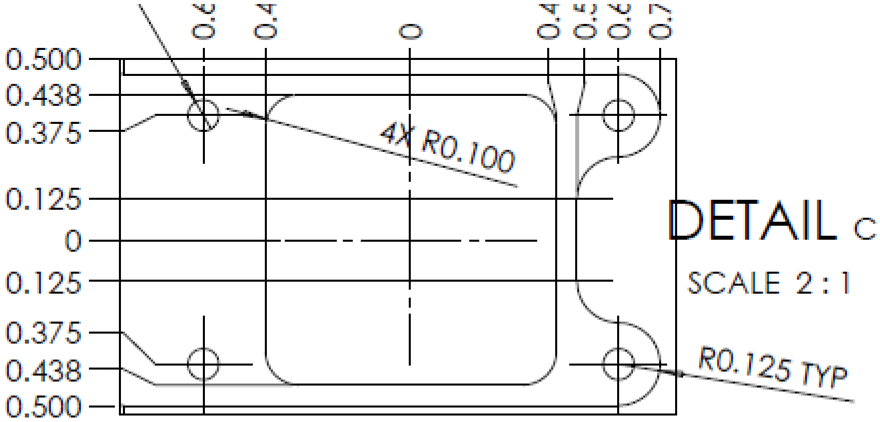
Stan Yen   08 Aug 2022



First beam on target for Darklight! 03 August 2022


BeO
Scintillator
Beam spot

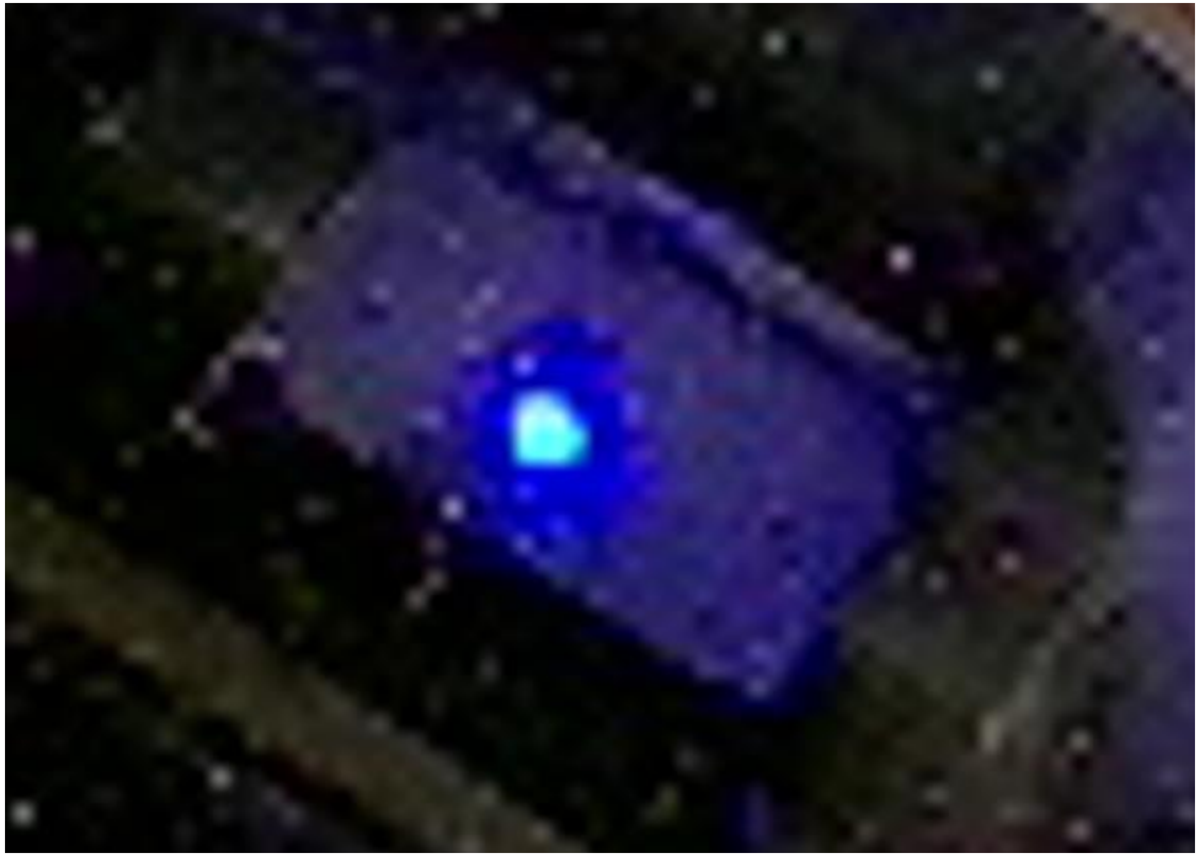




Vertical aperture in frame for
BeO scintillator screen is
± 0.438” = 0.876” full aperture
= 22.25 mm full aperture

Estimated beam spot size ≈ 3.7 mm
but scintillator saturates, so this one picture alone does not tell us
whether the illuminated region is ± 1 σ
or ± 4 σ of the beam intensity profile.
There appear to be 2 components
In the brighter zone (white and turquoise)
surrounded by a blue halo of 10.3 mm diameter.

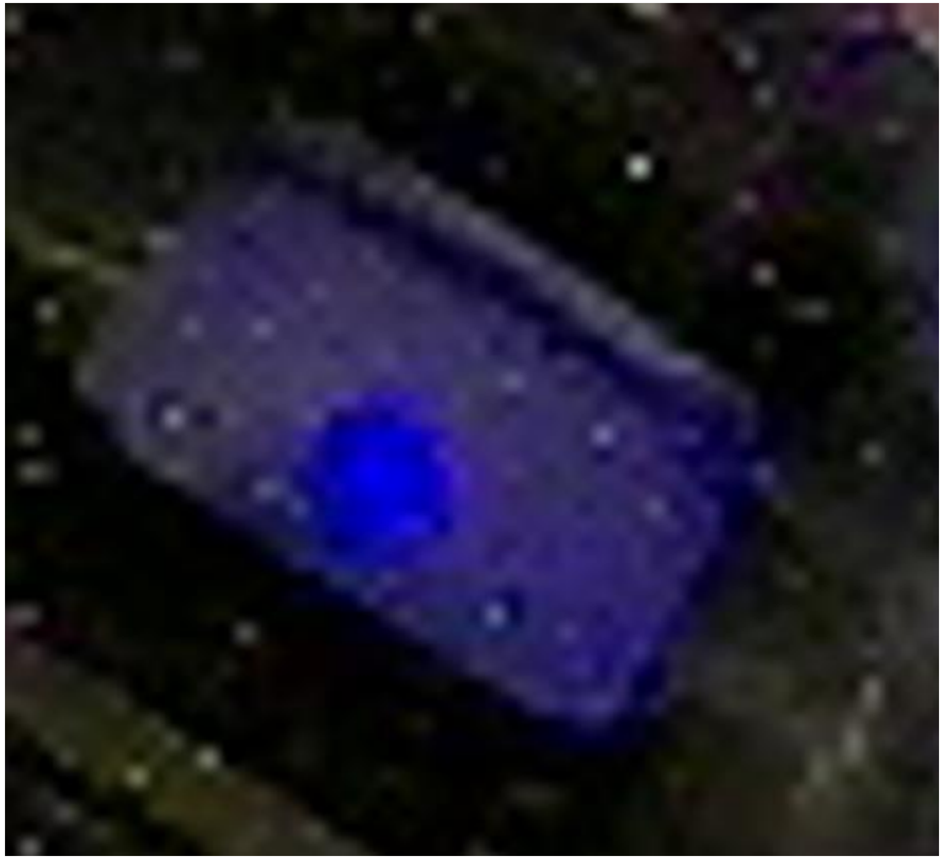
The loss of LN_2 resulted in the beam going down for 1.5 days. When beam returned, we did a series of runs with different beam intensity, controlled by the duty cycle.   The idea was that examining the beamspot size at different intensities could allow us to unfold the effect of saturation and reveal the "real" size of the beamspot.



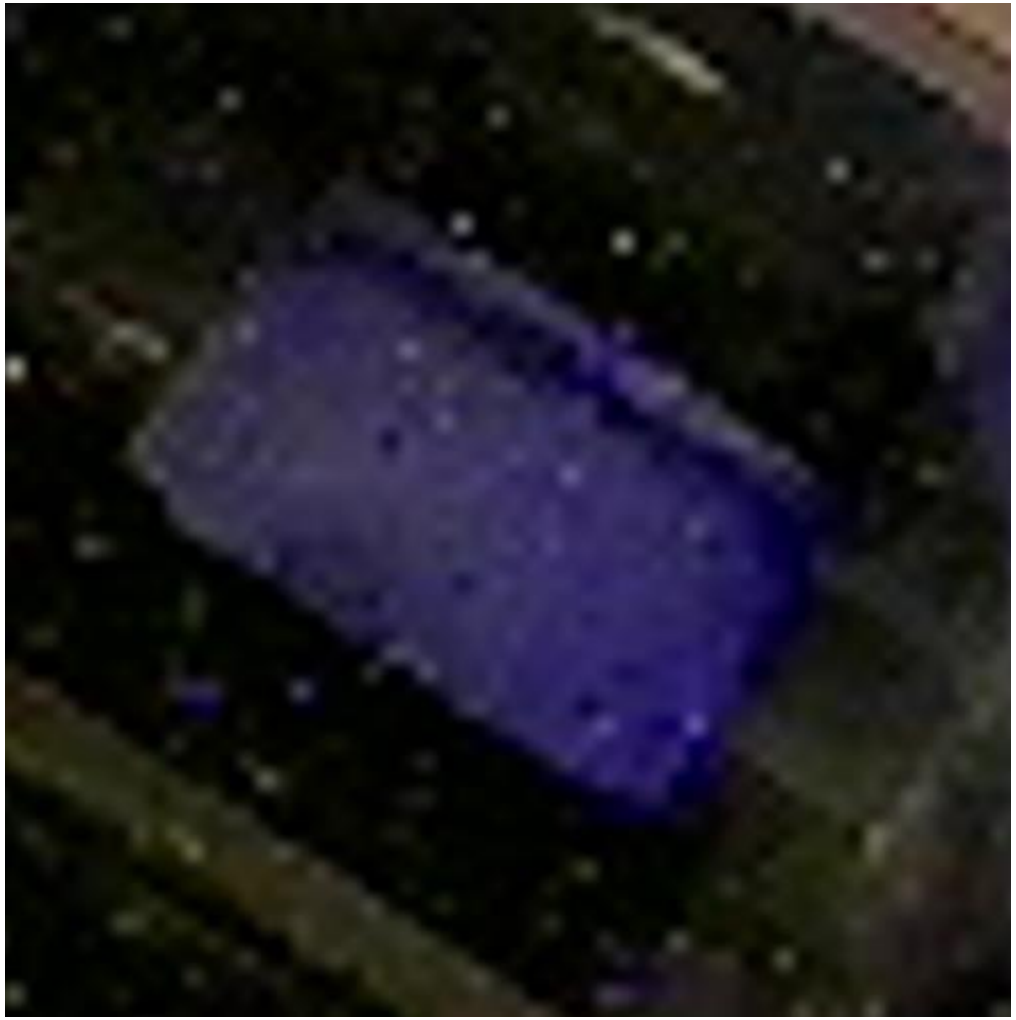
0.05% duty cycle
Estimated central spot size 3.7 mm diameter
The two components in the central beamspot (white and turquoise) are more pronounced today.

(screen shot from original picture, viewed at 895% magnification)

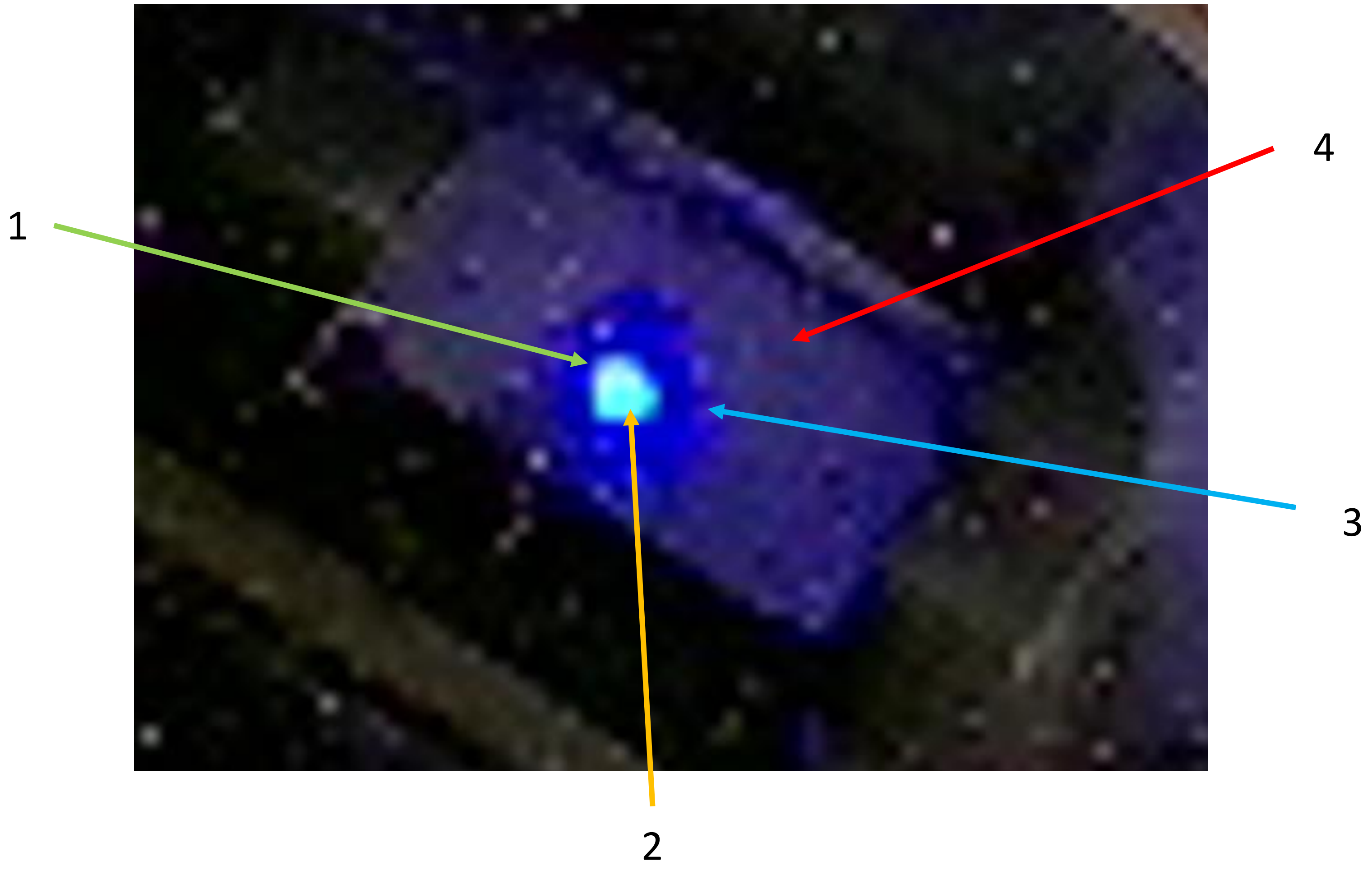
0.02% duty cycle
Estimated central bright spot is 1.3 mm diameter, surrounded by a deep blue halo



0.01% duty cycle
All that remains is the extended deep blue halo of about 8 mm diameter.

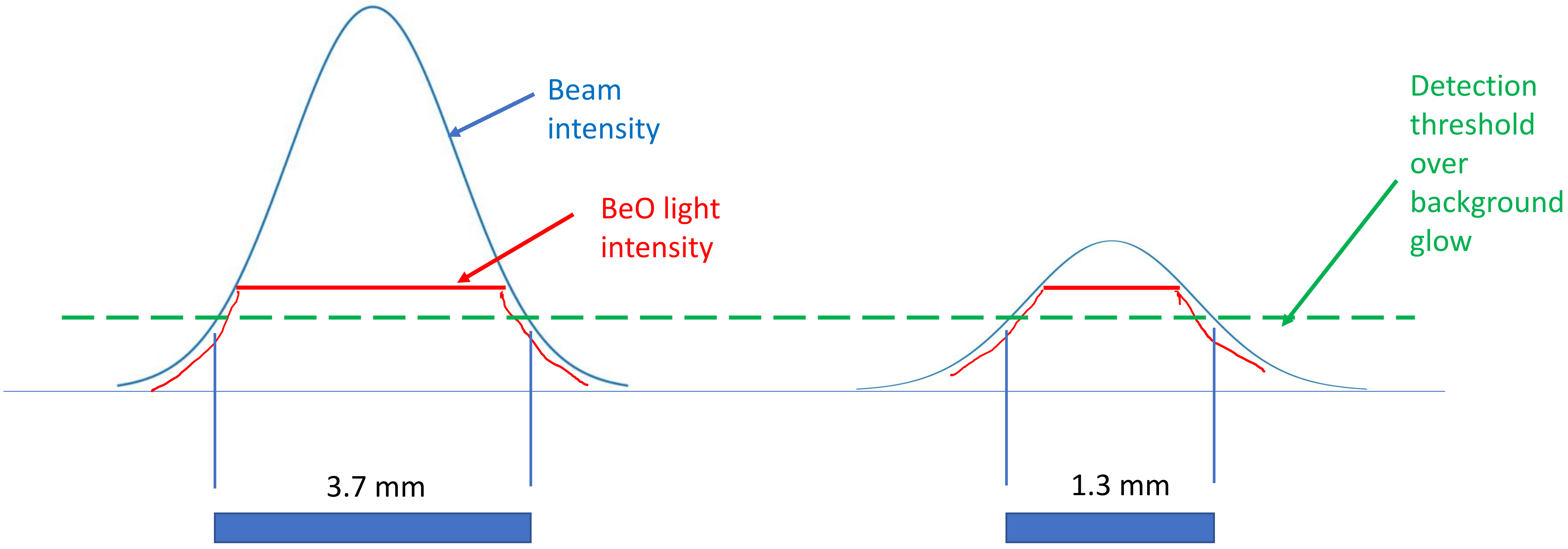


Beam off. There is still a purple glow on the scintillator.
This is probably due to low energy (~ few MeV) electrons caused by electrons that are yanked from the acceleration cavity walls by the strong electric field and accelerated. These will hopefully disappear once the beam passes through the bending magnets to the beam dump location.



There seem to be 4 components of the beam hitting the target. Not known if 1, 2, 3 have the same energy. The diffuse component 4 is presumed to be low energy electrons from cavity wall emission and persists even when beam is off. Component 3 seems to be the same regardless of duty cycle but disappears when beam is turned off. We thus presume that 1,2 are the “real” beam, which will dominate when we run the experiment at 100% duty cycle.

If we assume a Gaussian profile for the real beam:



0.05% duty cycle

0.02% duty cycle

It seems likely that the FWHM of the "real" beam (components 1+2) is ≤ 1.3 mm

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From Harald Merkel May 13, 2022 we get following optical transfer matrix parameters for the spectrometer:

- Magnification $M = -0.77$
- First order imaging of *central ray*, $(p, \theta, \phi, y)^t = J \cdot (x', \phi', y', \theta')^t$:

$$J = \begin{pmatrix} \partial_{x'} p & \partial_{\phi'} p & \partial_{\theta'} p & \partial_{y'} p \\ \partial_{x'} \phi & \partial_{\phi'} \phi & \partial_{\theta'} \phi & \partial_{y'} \phi \\ \partial_{x'} \theta & \partial_{\phi'} \theta & \partial_{\theta'} \theta & \partial_{y'} \theta \\ \partial_{x'} y & \partial_{\phi'} y & \partial_{\theta'} y & \partial_{y'} y \end{pmatrix} = \begin{pmatrix} 0.00172 & 0.00028 & 0 & 0 \\ 0.02856 & 0.50404 & 0 & 0 \\ 0 & 0 & 1.16717 & -0.06810 \\ 0 & 0 & 24.07773 & -2.21014 \end{pmatrix}$$

Thus a 1.3 mm smearing of the beamspot on target results in 1.3 x 0.77 = 1 mm smearing at the focal plane.

Since $\frac{dp}{dx'} = \partial_{x'} p = 0.00172$ (units mm^{-1}, where p=momentum fraction, x' = focal position)

The resulting smearing of the momentum fraction p is 0.00172 x 1 mm = 0.00172 = 1.72×10^{-3} in each spectrometer, due to non-zero beamspot size,
which is significantly worse than the INTRINSIC resolution of 10^{-3} in momentum for a zero-size beamspot.