Beam-Induced Fluorescence Monitors

Semesterproject

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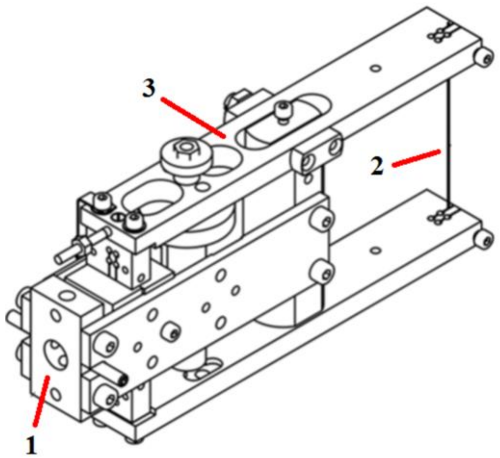
Introduction & Definitions

- Beam diagnostics (beam shape, position, intensity, emittance, …) is indisensable
- There are two kinds of measurements to distinguish

Intrusive measurements



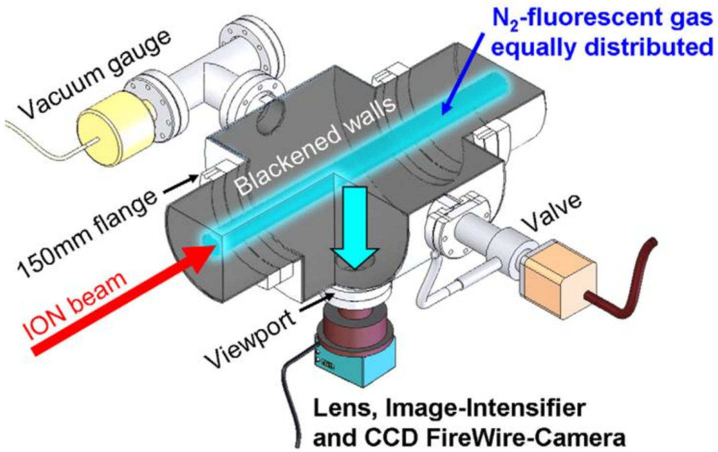
[1]

- Direct measurement

Good resolution, strong signal, but:

- Difficult/impossible for high brightness beams
- May introduce secondary particles disturbing the beam and other devices

Non- Intrusive measurements

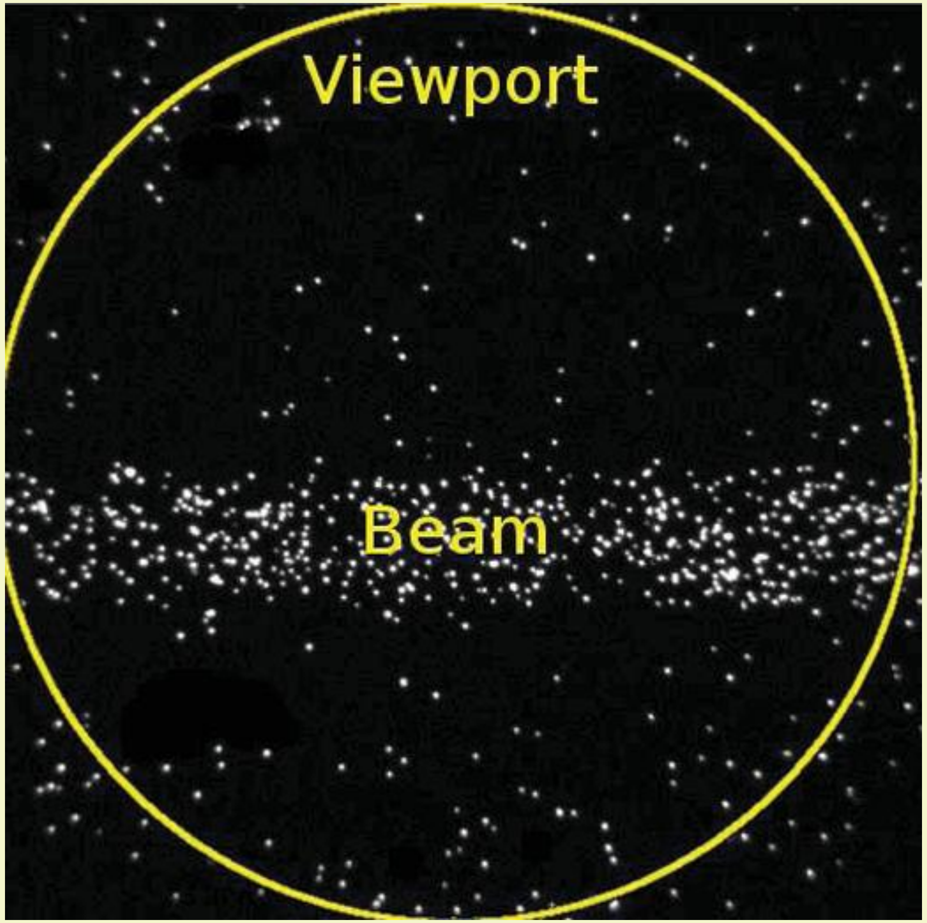


[2]

- LPM
- RGM
- BIF
- MWL
- …
- RGI

Beam Induced Fluorescence Monitoring

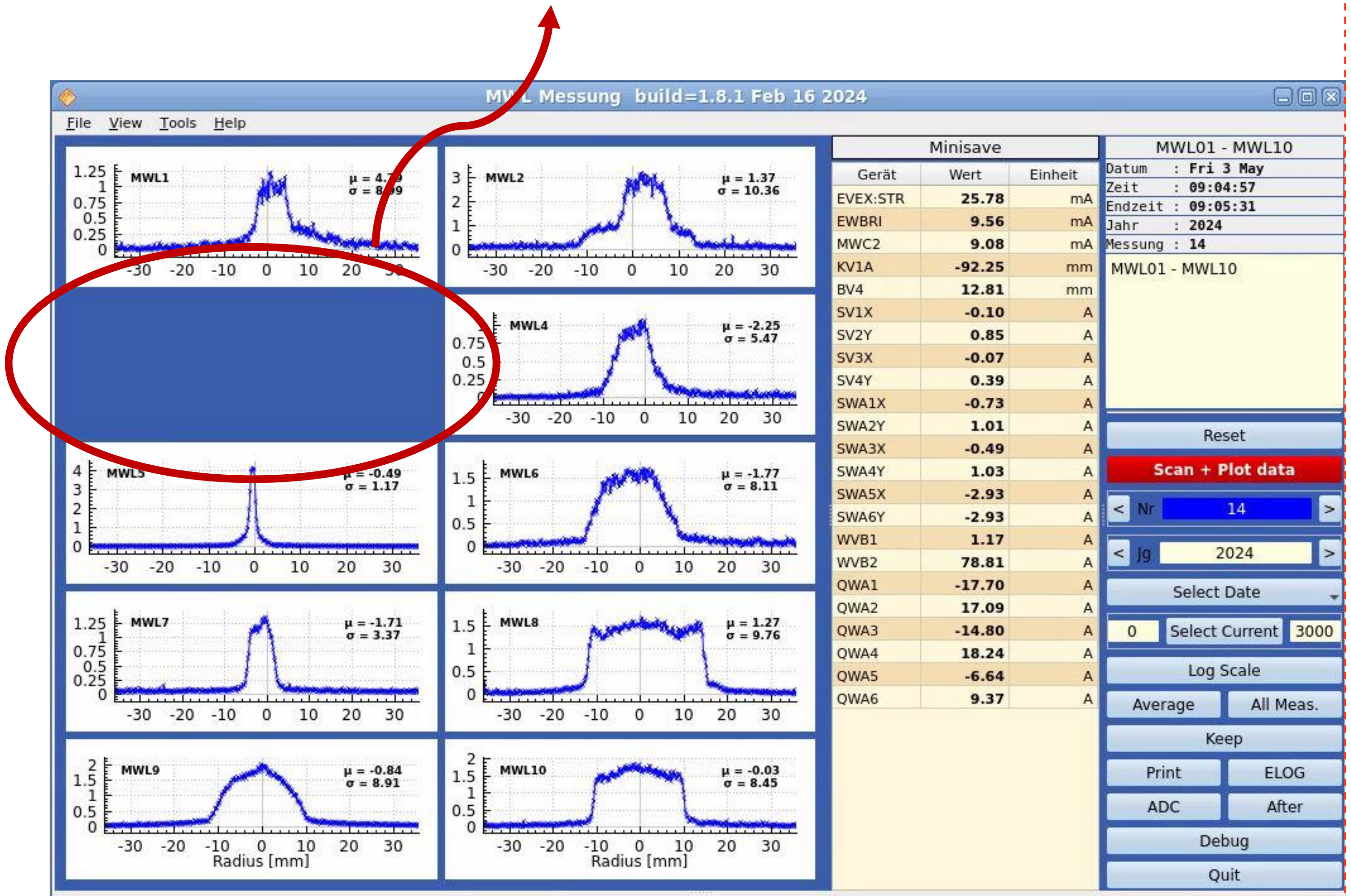
- Particles (in our case protons) travel through vacuum tube
- Vacuum is never perfect. So residual gas is present
- Protons excite gas atoms through interaction
- During de-excitation, gas atoms may release photons
- Reveals the beam position:



[3]

Context and Motivation

My Measurement



- Obsolete CAMAC electronics

So replacement is necessary in any case

- Currently there are not a lot BIF monitors in operation

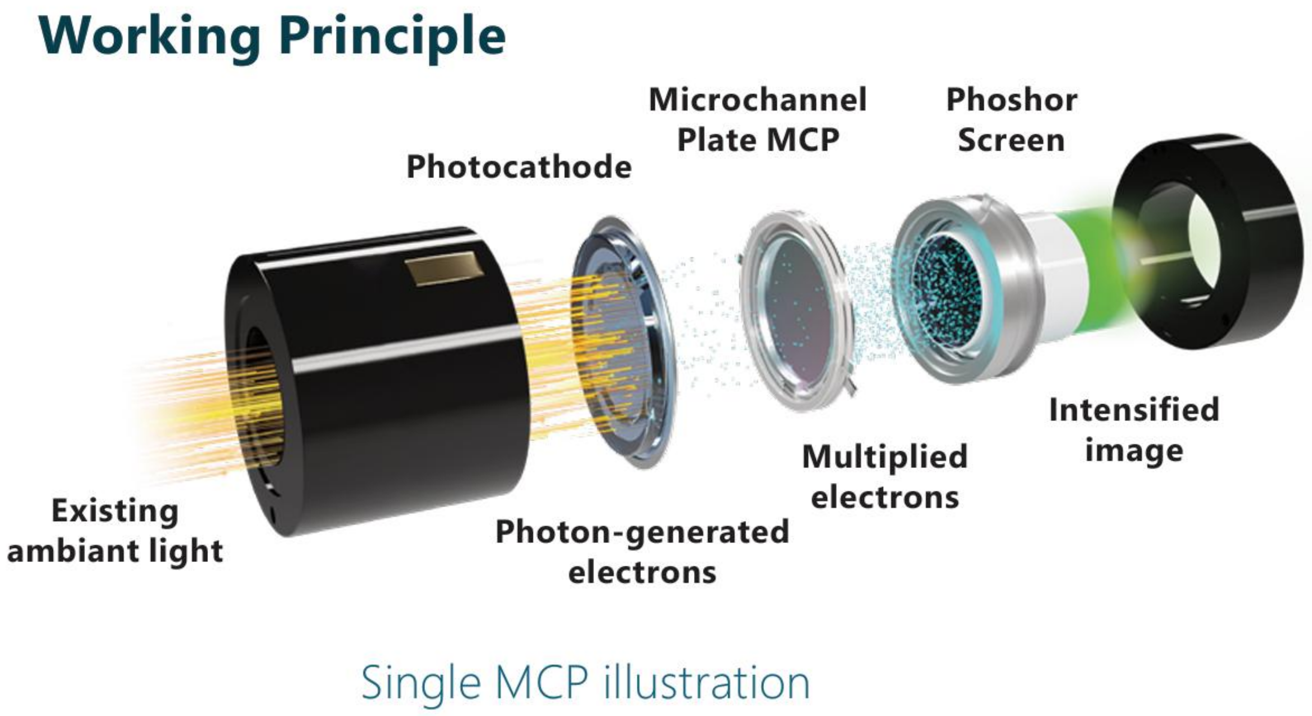
New monitors will be built. Stay with old technology?

- Use opportunity and suggest a simple solution

Choice of Technology – Image Intensifier

- By Exosens (used to be called photonics)

1) Incoming photon is converted into a photoelectron
2) Electron accelerates through internal electrical field towards the micro-channel plate (MCP)
3) There it multiplies several thousand times by impingin on the inner walls (like an avalanche)
4) Phosphor screen converts the electrons back into an optical image



[4]

- Maximum gain: 2 Million times
- Gain control by adjusting internal electrical field through external voltage (0V – 5V)
- Same technology was used in GSI (Darmstadt) and proofed itself helpful

Choice of Technology – Raspberry Pi

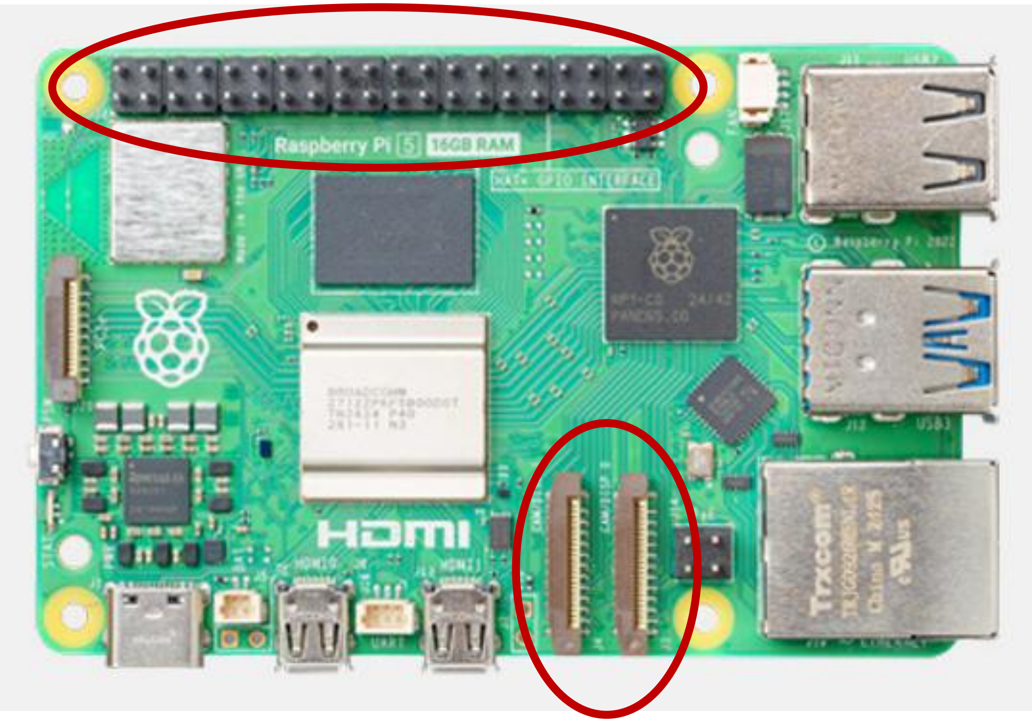
- Core of the installation as it enables control of

1) Camera for data acquisition

2) Gain adjustement for the image intensifier

3) Through remote access via the wifi

General Purpose Input/Output (GPIO) Pins



[5]

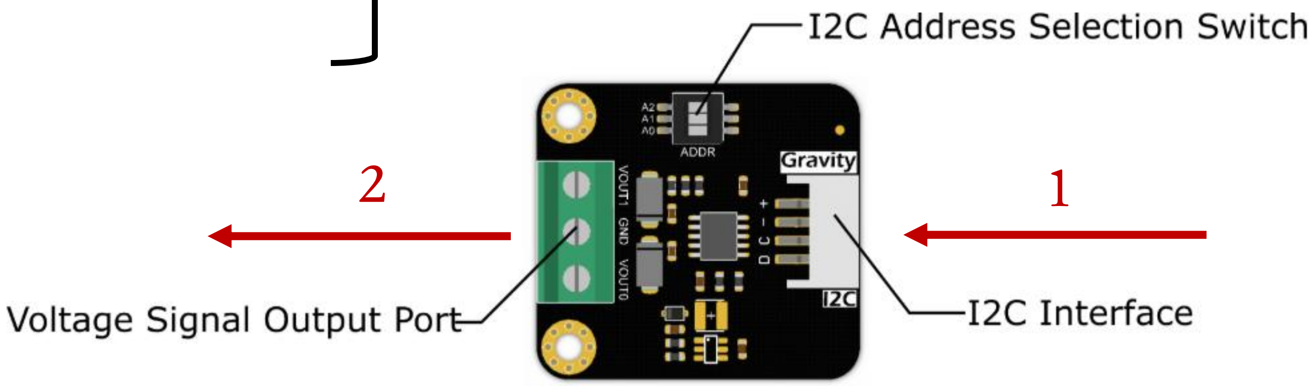
Camera Serial Interface (CSI) connector

Choice of Technology – DAC Unit

- Issue: GPIO Pin output is either
  - LOW = 0V
  - High = 3.3V
- Requirement: Continuous control voltage
  - 0-5V analog signal

1: digital control value from raspberry pi

2: corresponding analog voltage level



[6]

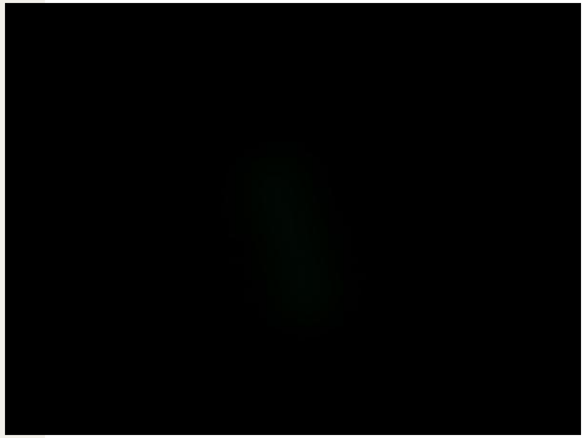
Choice of Technology – Camera and lens

- Camera by raspberry pi
- Several lenses available with different focal distances and aperture settings
    - Distance to beam
    - Close aperture to increase focus in depth. But decrease amount of light entering the lens
    - Aperture of the vacuum tube suggests a narrow field of view (next slide)
    - Pixel to milimeter conversion

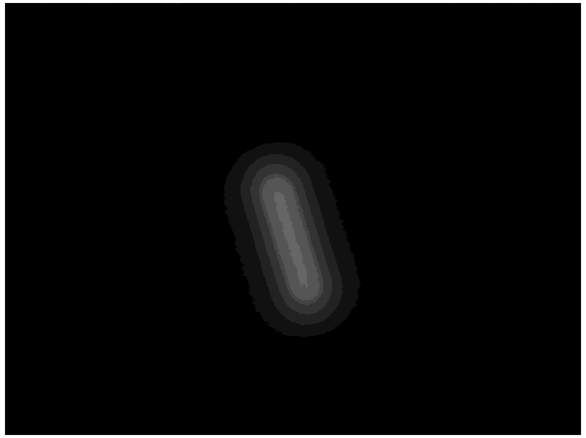
Mounting

- Thanks to
  - Martin
  - Simon

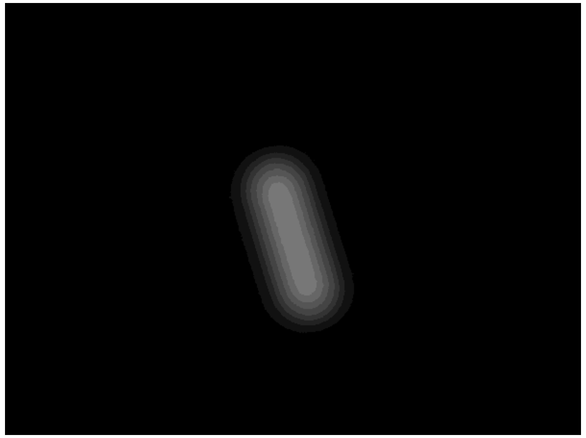
Results



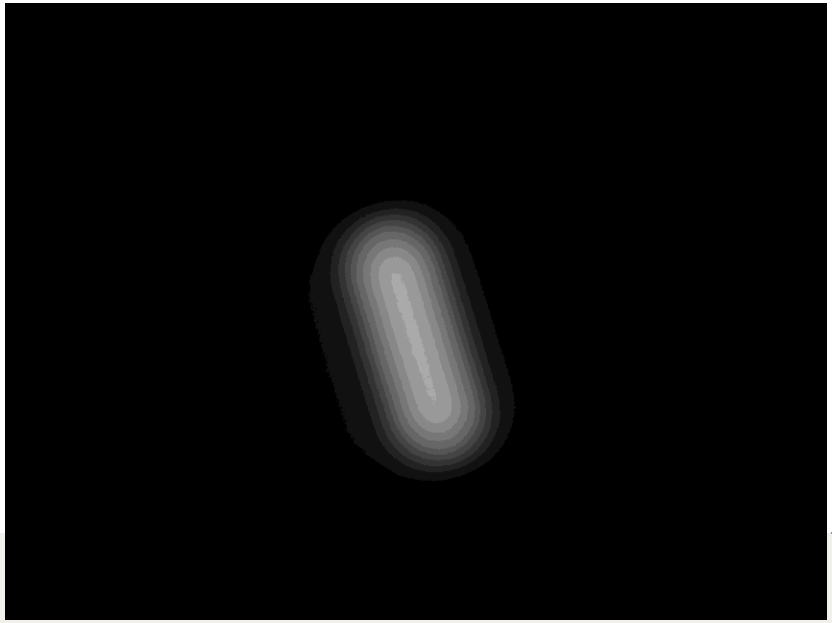
Gain: 0.0V



Gain: 0.0V
Overlay: 20 pictures

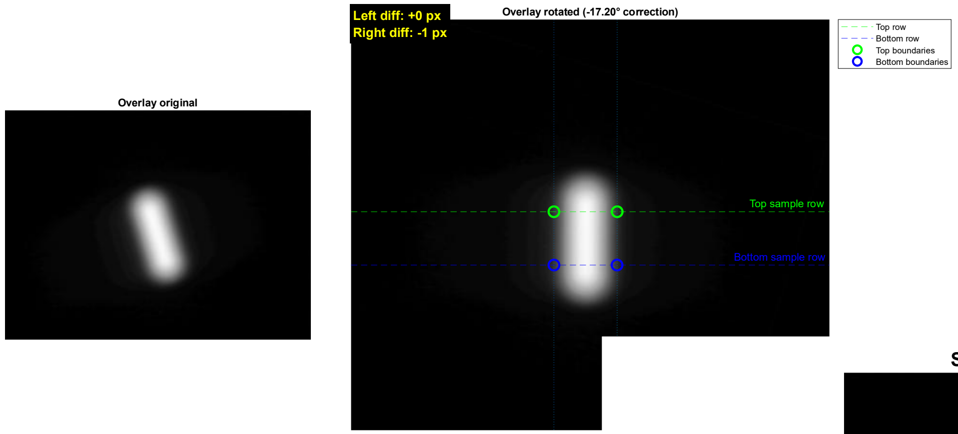


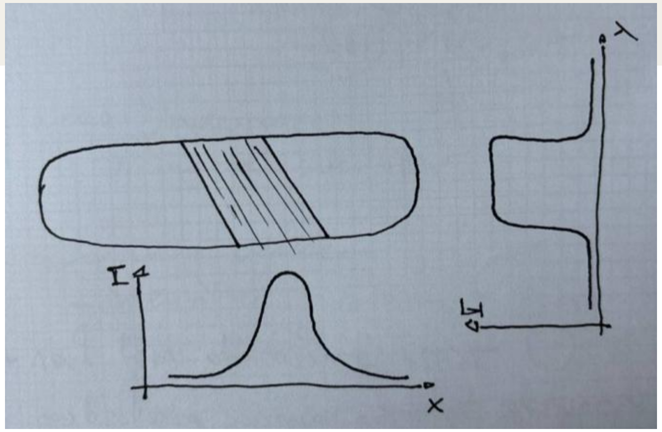
Gain: 0.0V
Overlay: 5 pictures
Shutter time: 500 ms



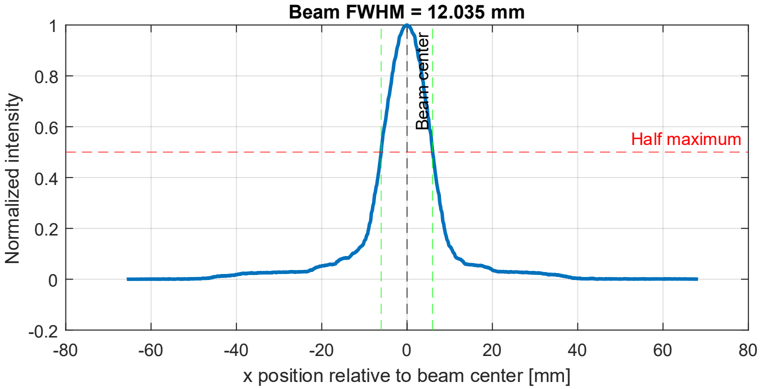
Gain: 0.0V
Overlay: 4 pictures
Shutter time: 1000 ms

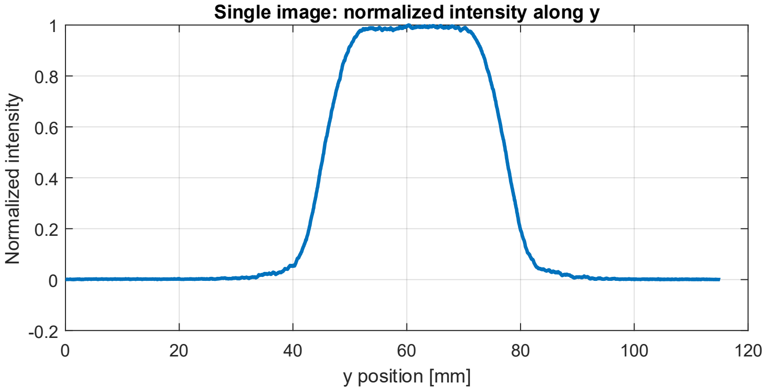
Results





1. Identifies object and it`s main axis
2. Calculates the rotation w.r.t. the horizontal axis (negative means clockwise)
3. Applies 90° - rotation correction
4. Checks how many pixel difference the top and bottom sample row have for validation





Perspective

- Radiation shielding
  - New mount including a box covering the electronics
- Upgrading the mounting from PLA to tungsten incorporated materials for robustness
- Replacing the very simple raspberry pi with a more suitable solution

- Sources of Error:
  - Lens Calibration
  - Picture settings (e.g. shutter time)
  - Code (rotation & result extraction)
  - DAC Unit output has an error of plus minus 0.02%

- Improvements:
  - Simplify user interface

  E.g. changing gain and overlaying pictures…replace with one single alias

References

- [1]: SG Arutunian, AV Margaryan, GS Harutyunyan, EG Lazareva, Moses Chung, D Kwak,and DS Gyulamiryan. Vibrating wire monitor: Versatile instrumentation for particle andphoton beam measurements with wide dynamic range. Journal of Instrumentation, 16(01):R01001–R01001, 2021.
- [2]: P Forck, C Andre, F Becker, R Haseitl, and B Walasek-Höhne. Beam induced fluorescenceprofile monitor developments. HB2010, Morschach, Switzerland, page 497, 2010.
- [3]: F Becker et al. Beam induced fluorescence monitors. WEOD01, Proceedings of DIPAC, 2011.doi: 10.18429/JACoW-DIPAC2011-WEOD01.
- [4]:Exosens. Image intensifiers for scientific applications, 2024. URLhttps://www.exosens.com/products/detection-analytical-science/image-intensifiers-scientific-applications.

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- [5]: Raspberry, 2012. URL https://www.raspberrypi.com/
- [6]: DFRobot. URL https://www.dfrobot.com/product-2756.html