The Camera Alignment System
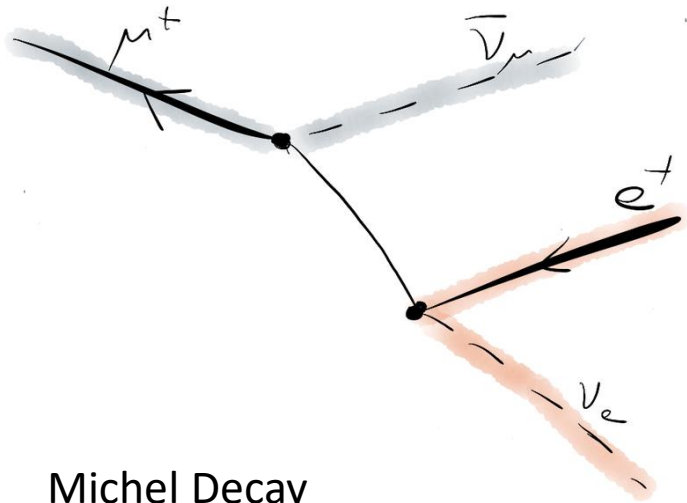
FOR THE MU3E EXPERIMENT

DPG FRÜHJAHRSTAGUNG, KARLSRUHE 2024

SOPHIE GAGNEUR

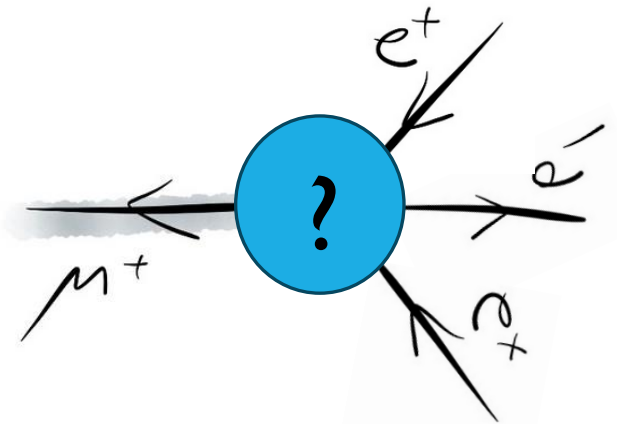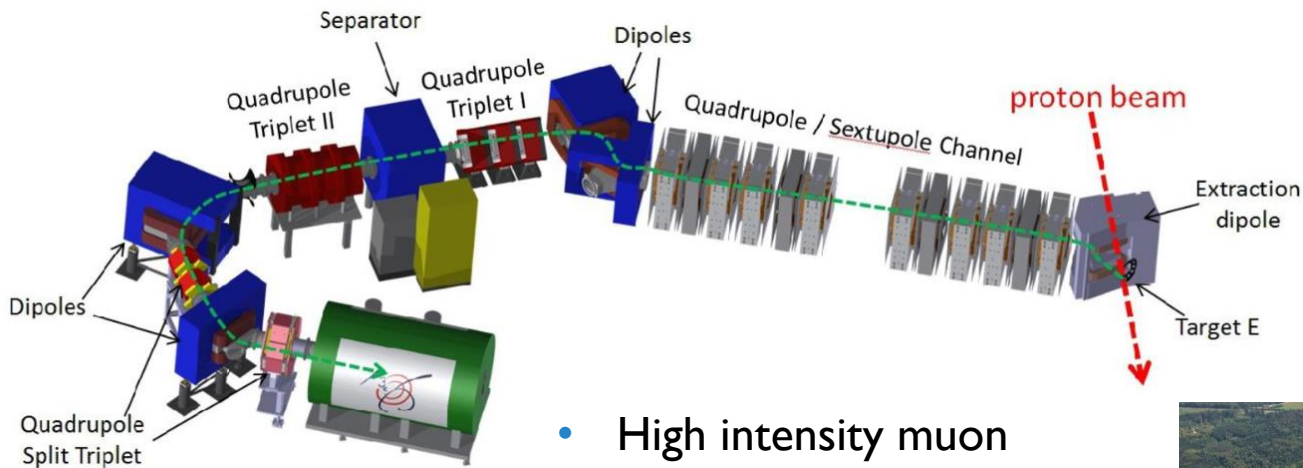# Motivation

Michel Decay
- Branching ratio nearly ~100%
- μ → eee suppressed in the standard model
    lepton flavour violation

Theories of physics beyond the standard model

The Experiment

Paul Scherrer Institute, Villigen, Switzerland

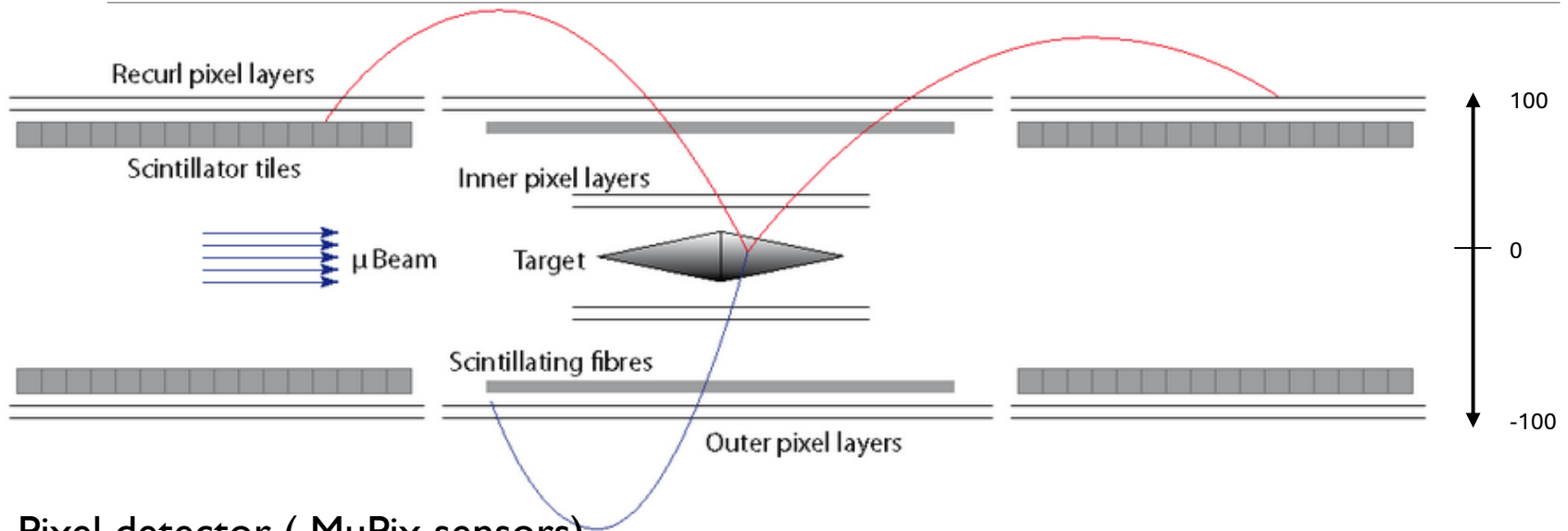- High intensity muon beam
  - $10^7 - 10^8$ muons/seconds
- Sensitivity goal:
- $B(\mu \rightarrow eee) \leq 2 \cdot 10^{-15}$

The Detector

Recurl pixel layers

Scintillator tiles

Inner pixel layers

µ Beam

Target

Scintillating fibres

Outer pixel layers

100

0

-100

➢ Pixel detector (MuPix sensors)
  ➢ Accurate track and vertex reconstruction

➢ Scintillating fibres ⎤
                       ⎬ Exact timing measurements
➢ Scintillating tiles ⎦

- Supported by a cage with infrastructure

- Placed inside a 1T strong magnetic field

- Cooled with gaseous helium

- Very little material budget

Alignment

- Very high momentum resolution is needed to reach the precision goals

- Influenced by the misalignment of the detector

- Caused by
  - Environmental factors such as thermal expansions and gravitational effects
  - Limited mechanical assembly precision
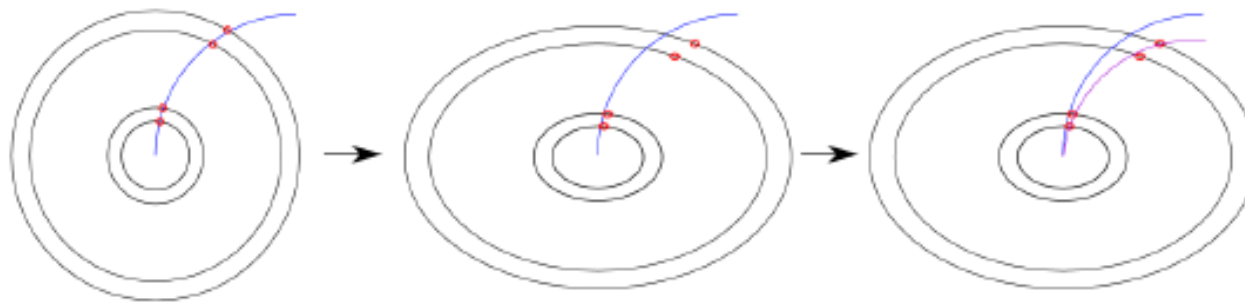 - Construction, magnet ramping, helium flow

Track Based Alignment:
- We check if the hits are on the track
- Looking for minimal χ^2 function

$$\chi^2(q_j, p) = \sum_j^{tracks} \sum_i^{hits} \left(\frac{r_{ij}}{\sigma_{ij}}\right)^2$$
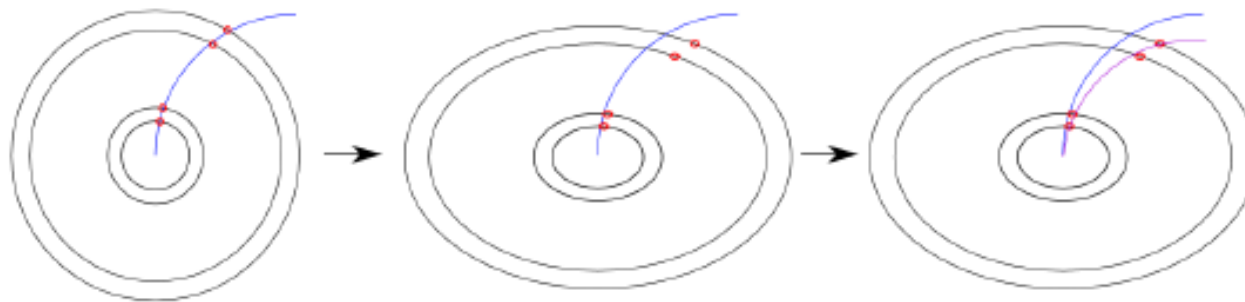
Alignment

New track with the same χ^2 as the original one

- Specific track deformations do not influence the χ^2 function
    ⟹ weak modes

    - Bowing, shearing, torsion, stretching etc.

- Track based alignment can't detect weak modes

Alignment

New track with the same χ^2 as the original one

- Specific track deformations do not influence the χ^2 function
    →   weak modes

  - Bowing, shearing, torsion, stretching etc.

- Track based alignment can't detect weak modes

→ Optical alignment system with cameras

The Basic Principle

- We want to determine the distance from a fixed point (cage) to the detector
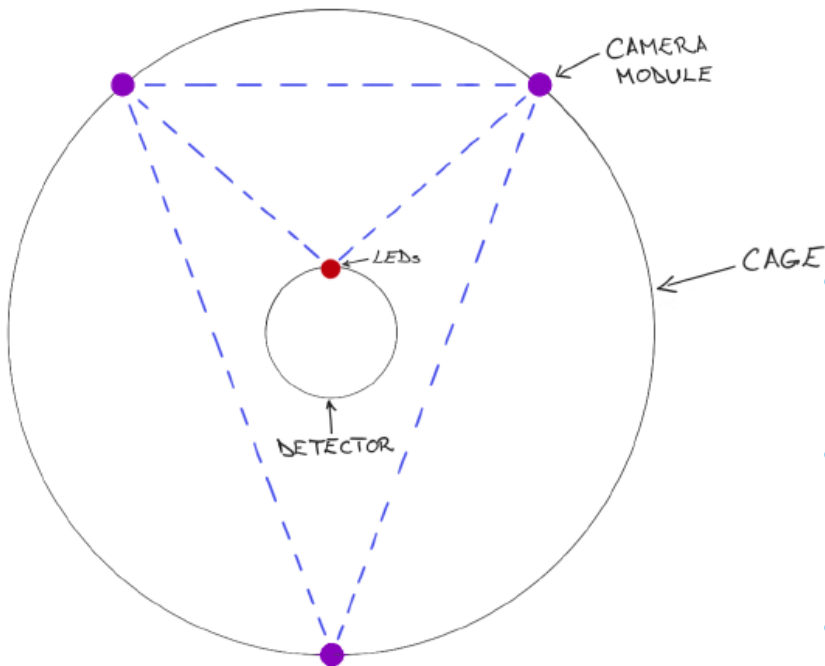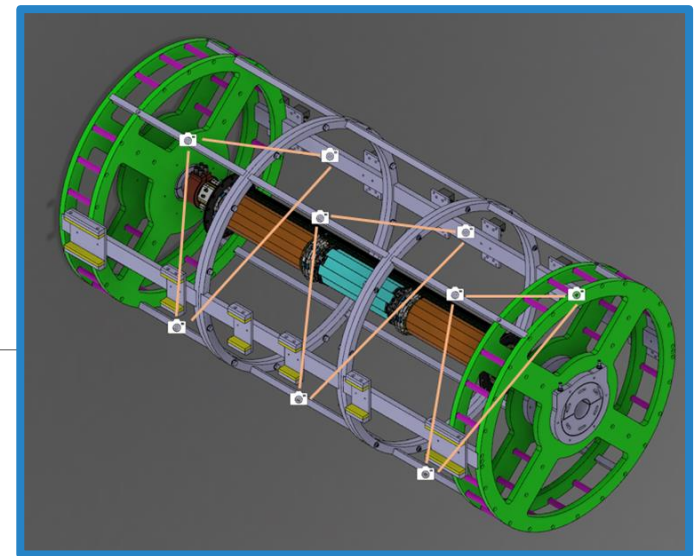
- Basic geometric optics:
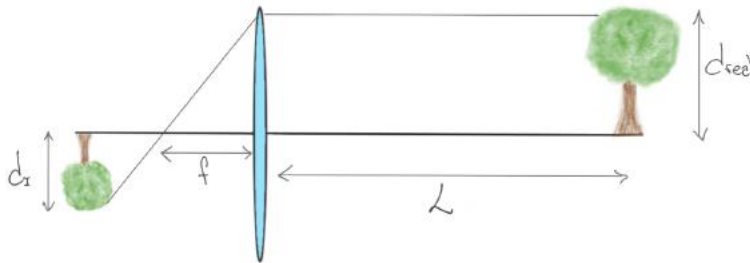
$$\frac{d_I}{d_{real}} = M = \frac{f}{f - L}$$

- What is best suited as an object?

- No space for big cameras with auto-focus

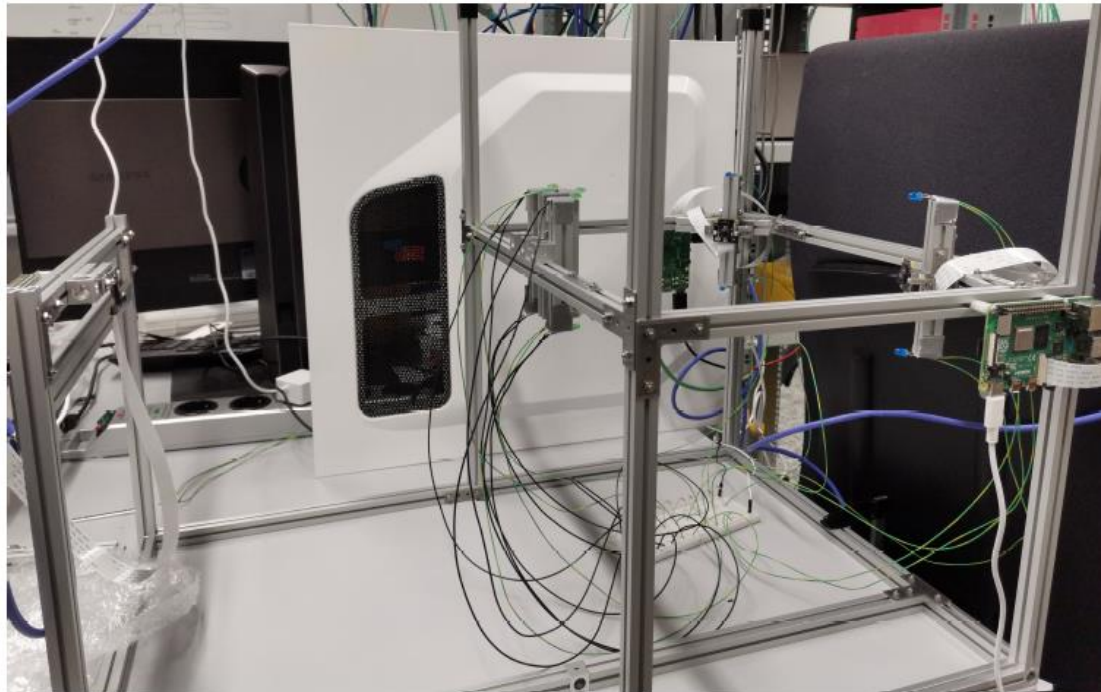 ⟹ a system consisting of 2 LEDs , distance of the LEDs as d_{reel}

The Basic Principle

CAMERA MODULE

LEDs

CAGE

DETECTOR

- 3 cameras are mounted on the cage
  - 1 main camera
  - 2 cameras also with LEDs
- Like that we can determine the distances between the cameras and the cage movement
- LEDs are placed at the end of every detector segment
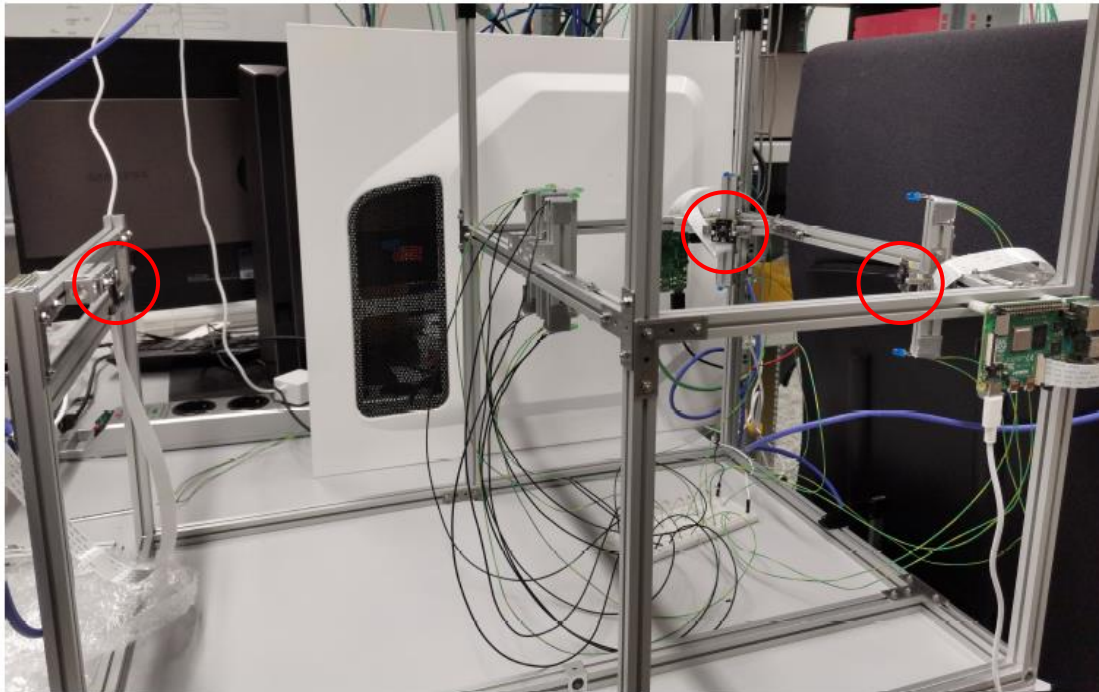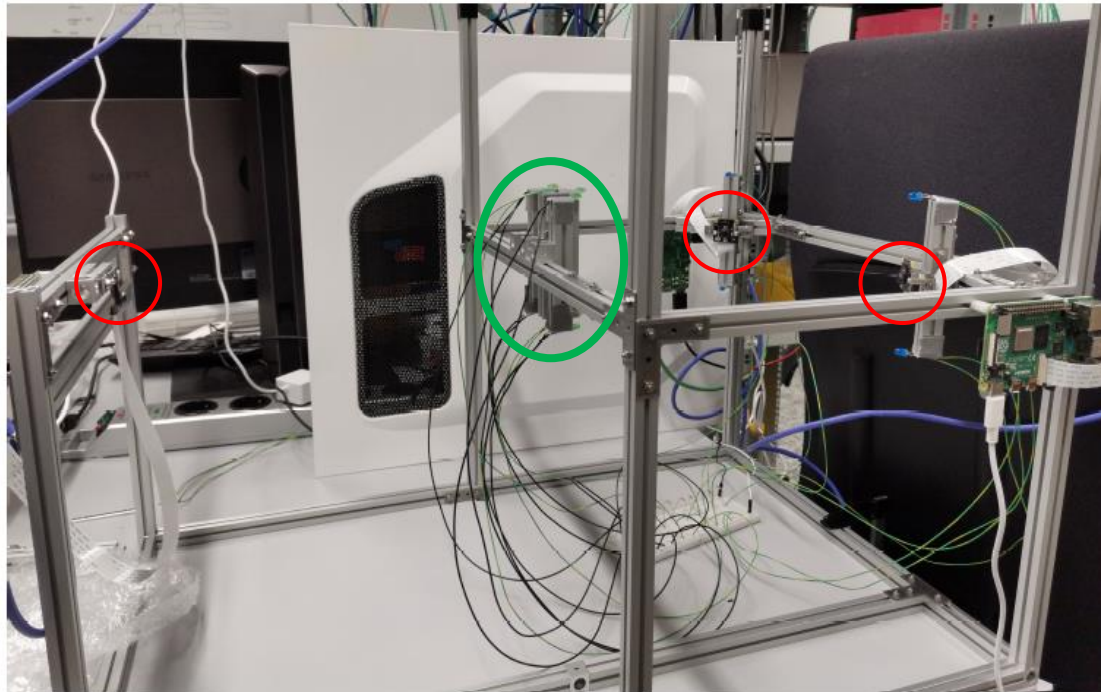
The Setup

The Setup

Main camera

2 cameras
with LEDs

The Setup

2 cameras with LEDs
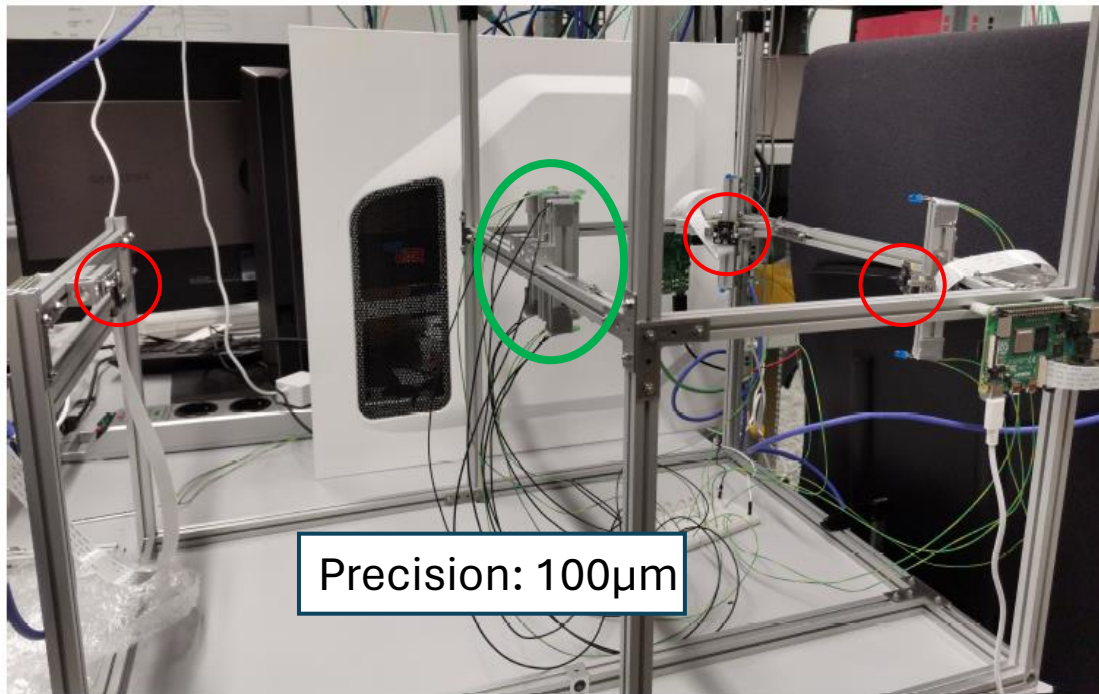
Main camera

LEDs on the detector

The Setup

2 cameras with LEDs

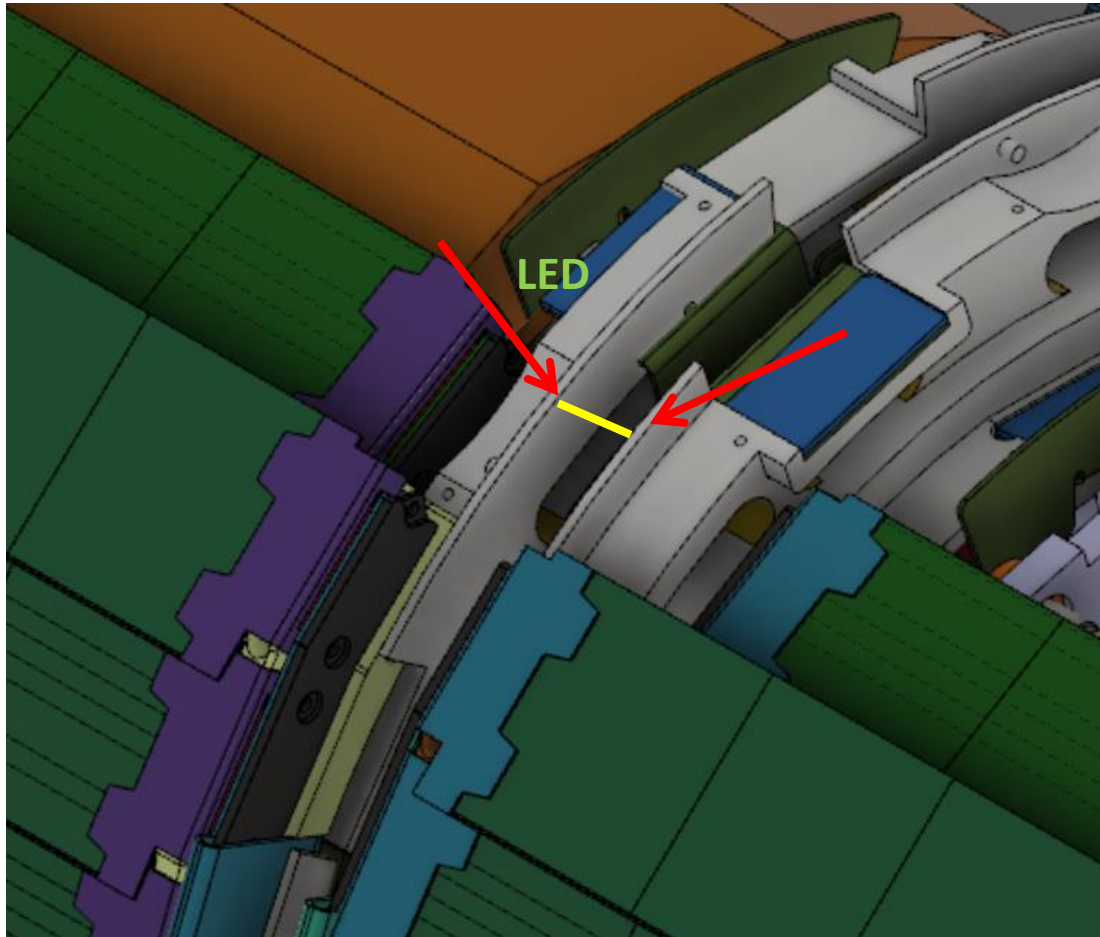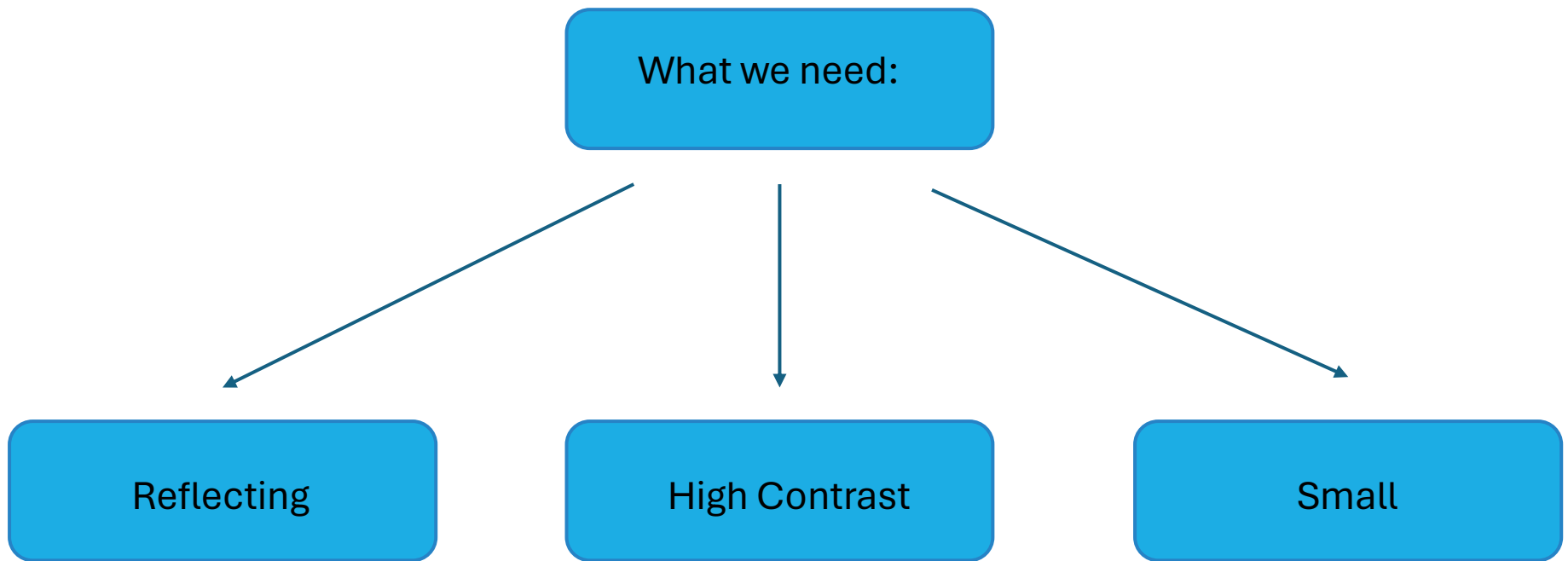Main camera

LEDs on the detector

Precision: 100μm

Problems with the Integration

- Just a 9mm gap for the LEDs an
- Mounting very difficult
- Les space for the cables inside the detector

Alternatives for LEDs

What we need:

Reflecting

High Contrast

Small

Tooling Balls
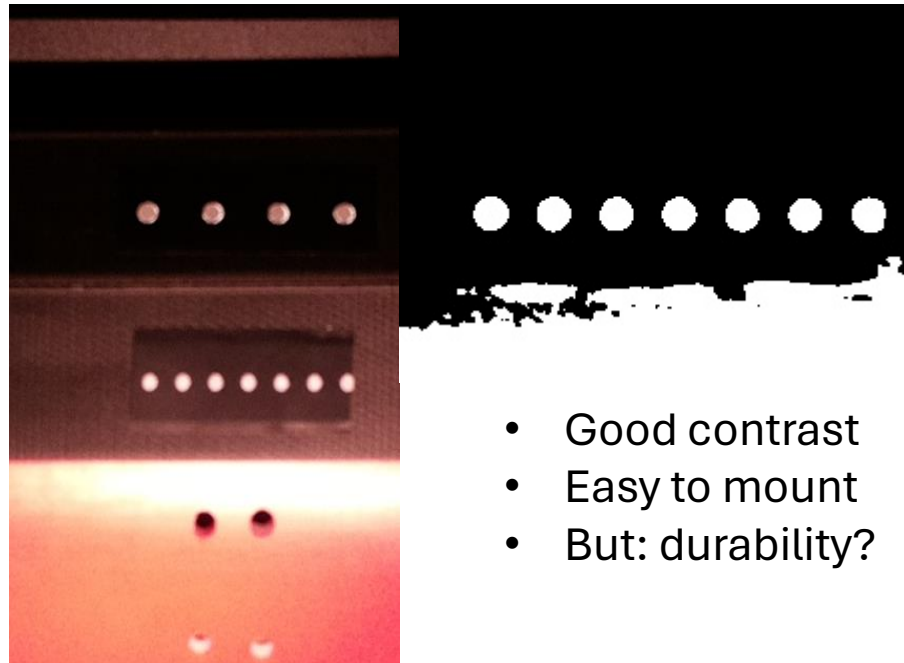

- Pins with thread
- Available in different sizes
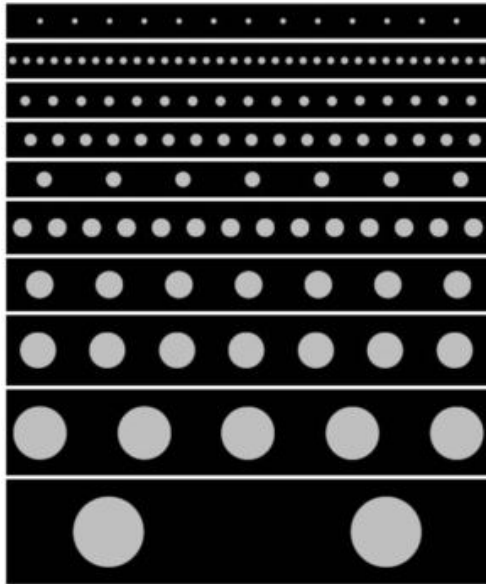

Problems:
- Double reflections depending on the lighting
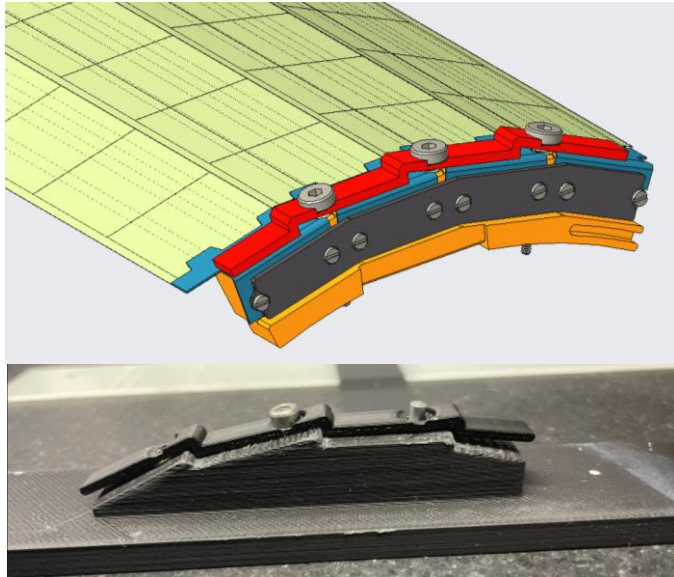- Very bulky
- Difficult to assemble
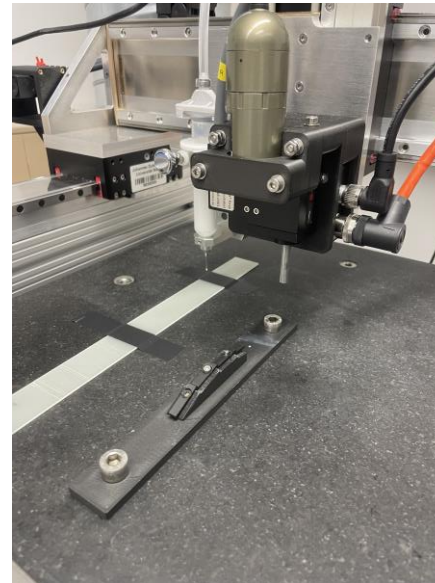
Retro-reflective Tape

- Good contrast
- Easy to mount
- But: durability?

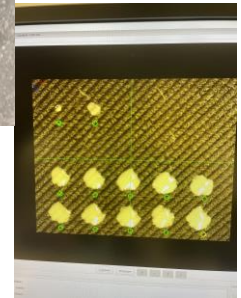# Creating Dots with a Glue-Bot

Available area:
0.5 x 1.5 cm

Retro reflective paint is used to dispense small dots on the rings

First results are promising

Paint is too liquid

→ Next tests with glue

Conclusion & Outlook

Different fiducials are tested

Glue-Bot results are the most promising

Precision test are still pending

Integration of the system