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A Measurement Level Module for the Pellet Tracking System

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Outline

- Pellets
- The UPTS (Uppsala Pellet Test Station)
- The PTR (Pellet Tracking) System
- The DM (Detection Module)
- Stability and Functionality of the DM
- Outlook
- Summary



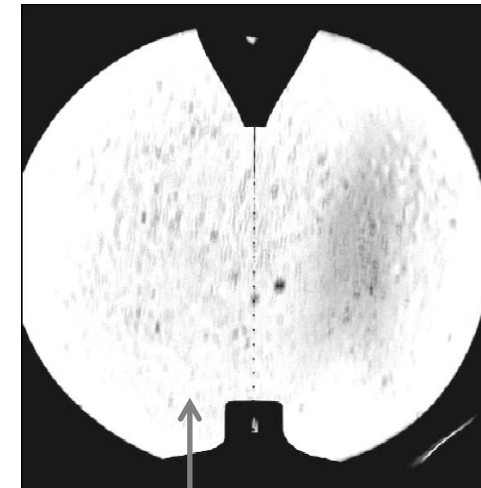
Pellets

- Spheres of frozen hydrogen, $\Phi \sim 25 \mu\text{m}$
- Internal targets in hadron physics experiments
- Density well above 10^{15} atoms/cm² ($2 \cdot 10^{15}$ - $6 \cdot 10^{15}$ atoms/cm² at WASA)
- Created some distance away from the accelerator, roughly 2 m due to the space needed for detectors closest to the accelerator
- Travel to the interaction region
- The position of a single pellet in the interaction region can be determined using a PTR system

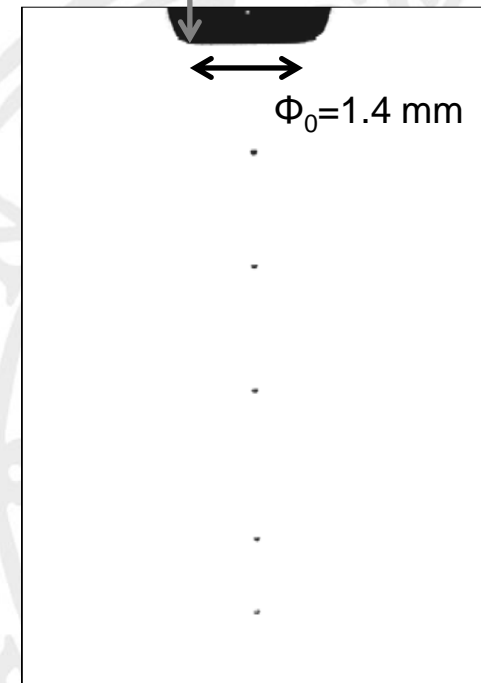
Pellets

1. Hydrogen gas cooled to 14.1 K
2. Gas liquefies
3. A vibrating nozzle ($\Phi = 11 \mu\text{m}$) breaks up the liquid into droplets
4. Droplets enter a droplet chamber
5. Droplets reach a VIC (Vacuum Injection Capillary)
6. Droplets freeze due to high pressure gradient
 - pressure before VIC $\sim 20 \text{ mb}$
 - pressure after VIC $\sim 10^{-4} \text{ mb}$

Pellets have been formed!



70 mm

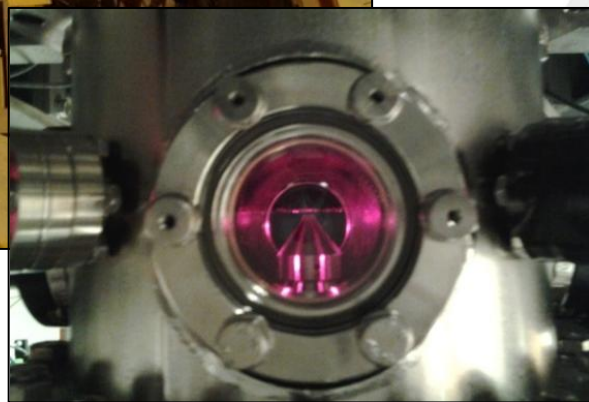
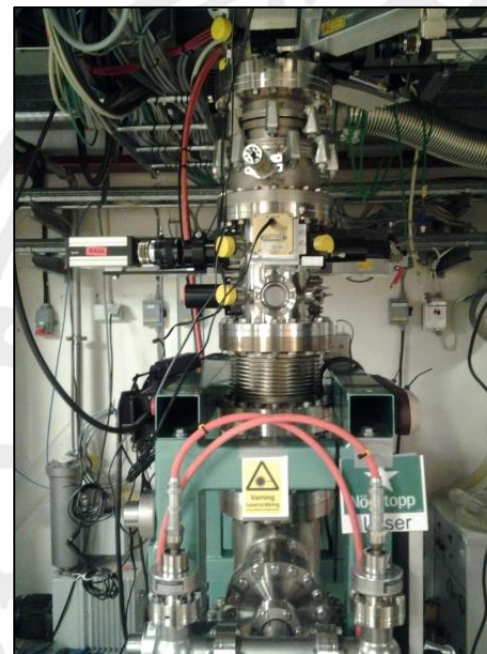


$\Phi_0 = 1.4 \text{ mm}$



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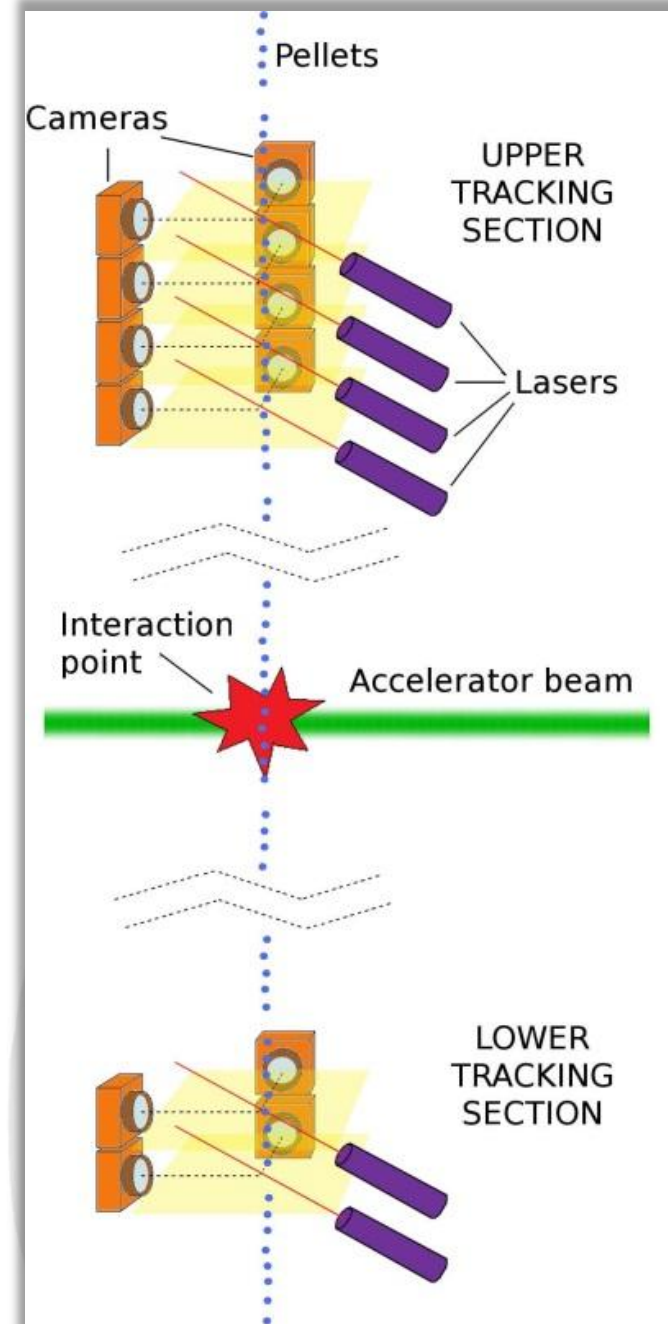
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Tracking Pellets

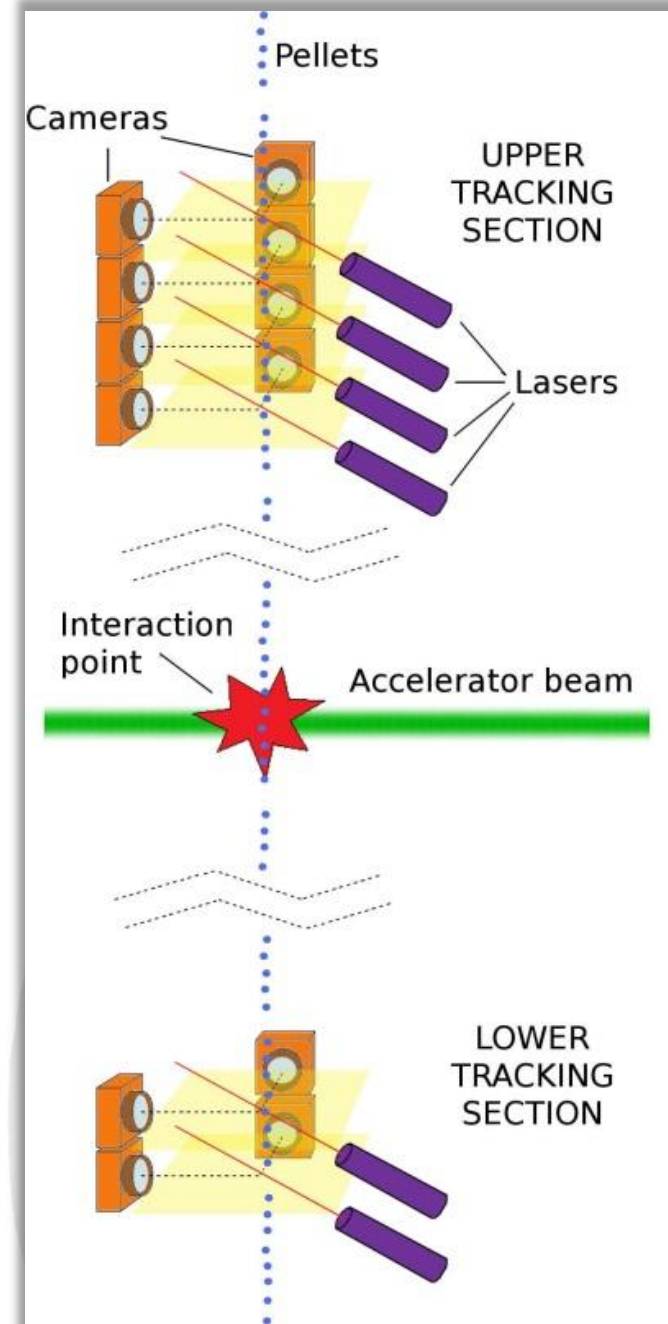
- STR (Structured-light-pattern diode) lasers, can be set to have a horizontal beam line profile of 3 mm width and 50 μm height at the central position corresponding to the pellet stream region
- LS (Line-Scan) cameras, detect one line of pixels at the time, size of one camera pixel at the working distance is 35x35 μm^2
- The camera line of sight and the beam line profile of the laser must coincide in a plane within 10 μm
- A pellet measurement accuracy of 20 μm at the detection levels is required

Position of a pellet in the interaction region can be reconstructed with a precision of 0.1 mm

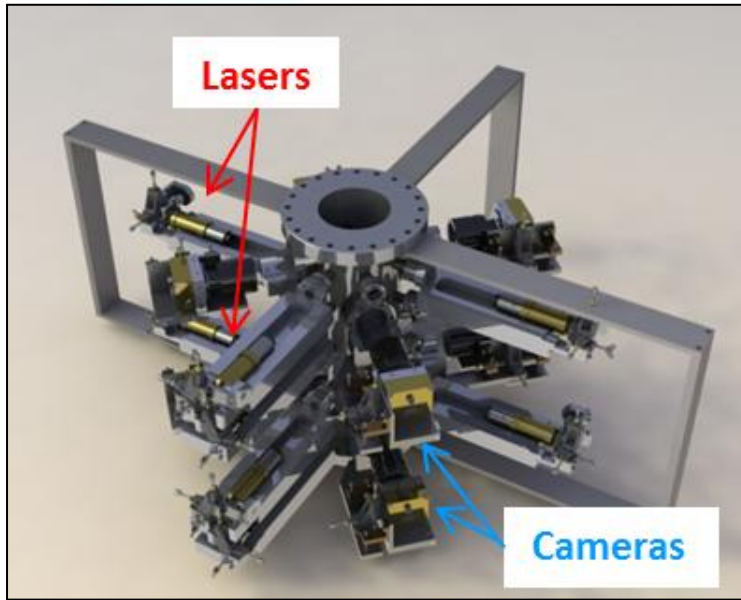


Tracking Pellets

- Alignment of the lasers and cameras in one level is done mechanically
- Alignment of different levels with each other is done in the track reconstruction procedure
- Alignment relative to the accelerator beam is done by including the frequency of reactions as a function of the pellet position in the data analysis



Why do we Need the DM?



Old conceptual design in the TDR for a tracking section

- Separate laser and camera holders
- 60 mm spacing between the two levels
- Difficult to align lasers and cameras!

The Detection Module

1. Provides a possibility to align cameras and lasers away from the pellet beam pipe (at the PTS and at PANDA)
2. The cameras and lasers can be aligned with a target which is simpler to set up and to control than a pellet stream
3. Can be used to optimize camera effects

Detection Module

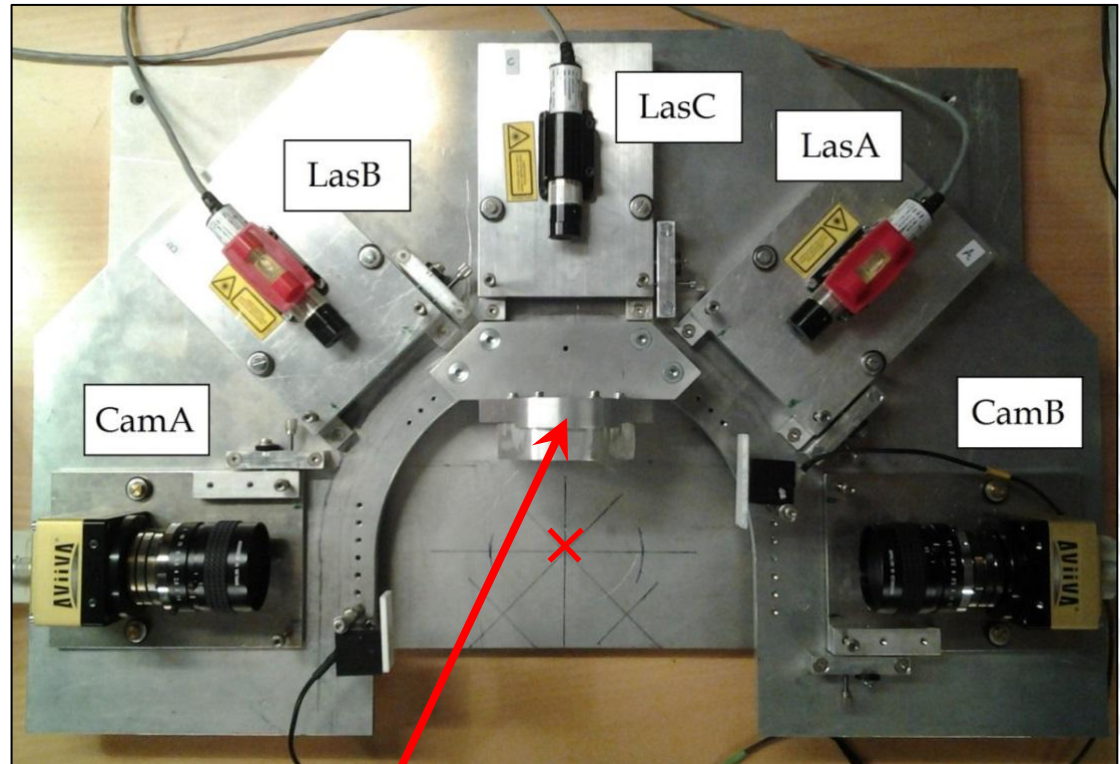
-At the Alignment Bench

Cameras

- CamA and CamB are facing each other for optimal pellet detection

Lasers

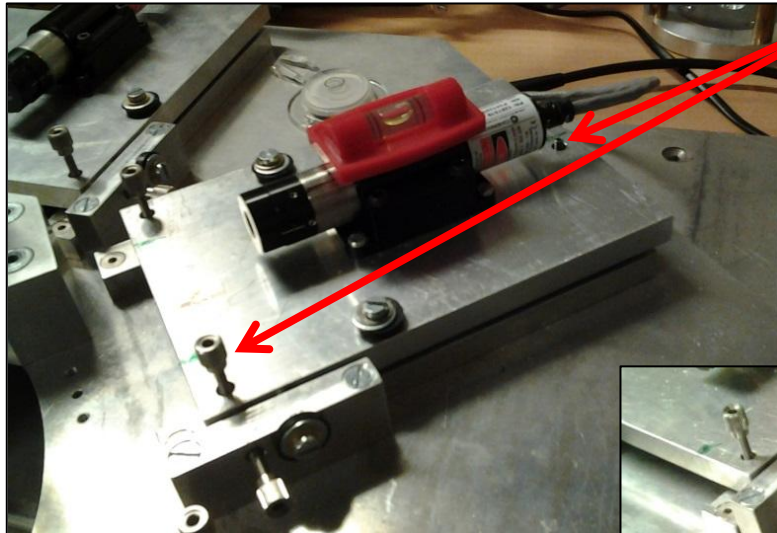
- LasA and LasB with 135° (refracted light) and 45° (reflected light) with respect to the cameras are optimized for pellet measurements
- LasC, 90° with respect to both cameras, is mainly used for alignment



The DM plate is fastened to a base plate via a dummy window-flange

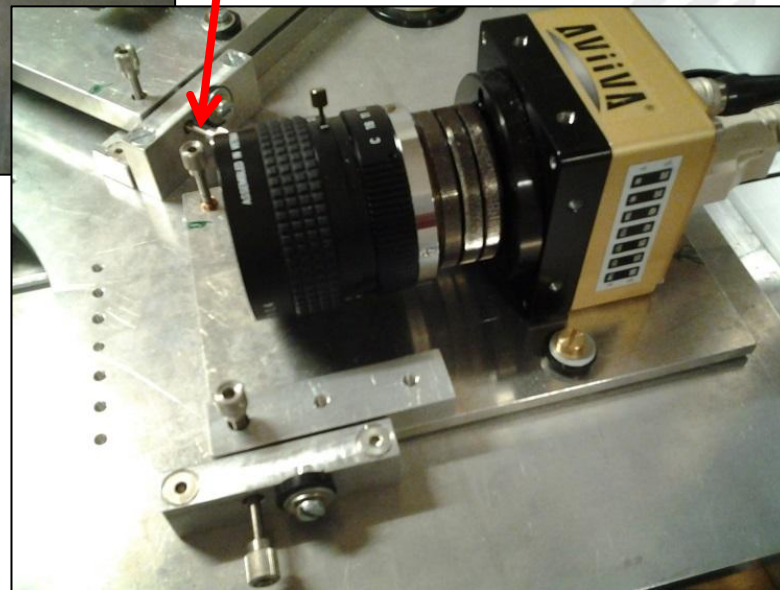


Cameras and Lasers



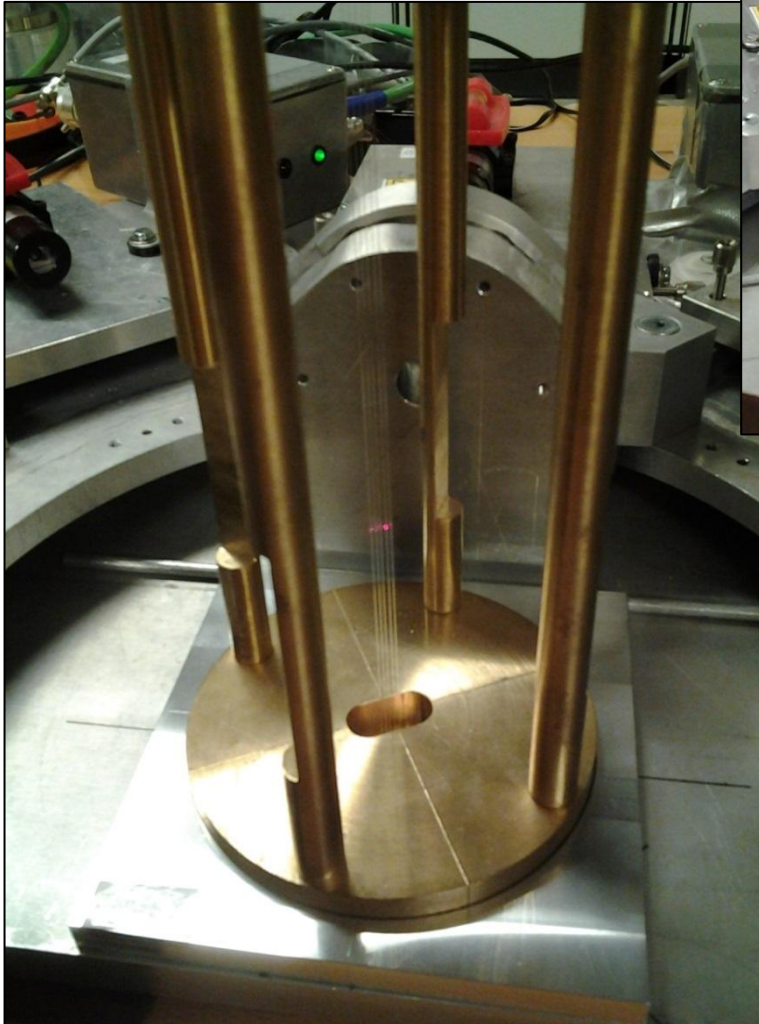
μm screws

-for precision height adjustment and rotation



Alignment Bench Targets

- Fishing Lines

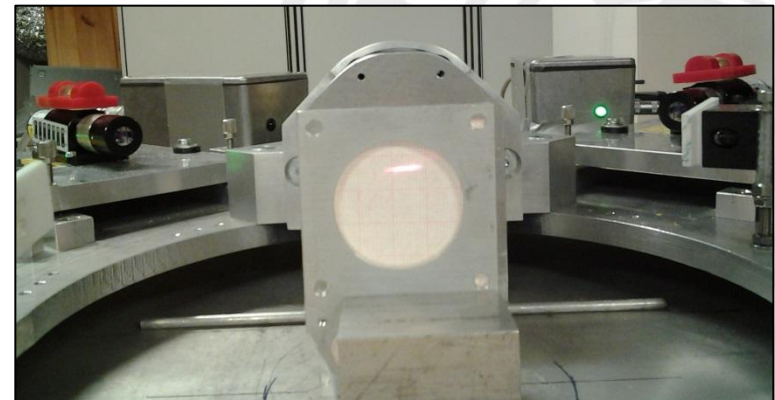
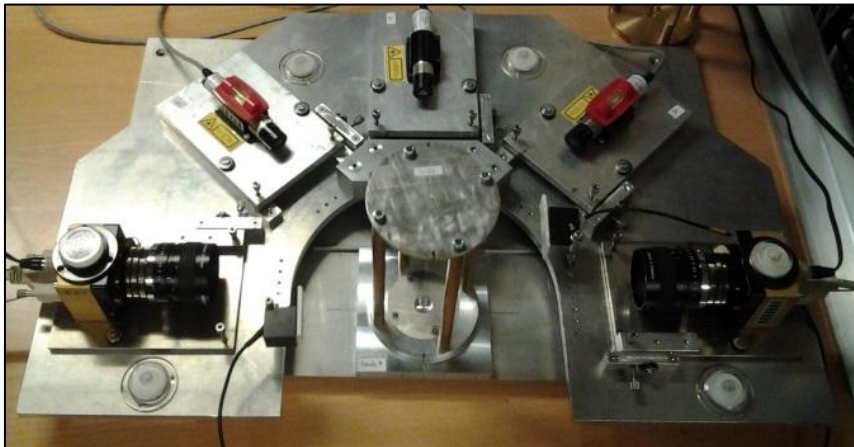




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Alignment Procedure

1. Rough alignment of the support structure is performed
2. All cameras and lasers are placed at nominal heights above the DM plate
3. The lasers are roughly focused and rotated using a mm-paper
4. CamA and CamB are aligned (the heights are set and the camera plates rotated) with respect to LasC
5. LasA and LasB are aligned (the heights are set and the laser plates are rotated) with respect to CamA and CamB using refracted light
6. Camera focus and apertures can be set
7. The alignment can be checked using reflected light

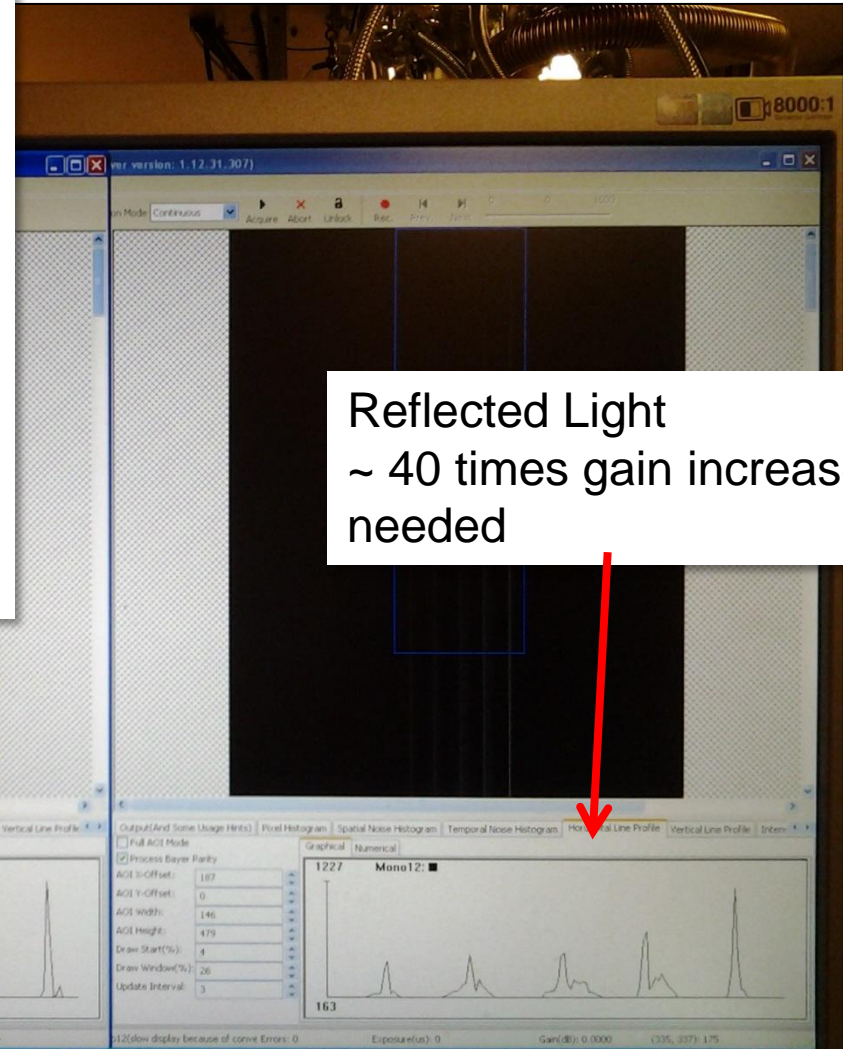




Alignment

-Using the Data Monitoring Program

- By changing the height of the camera line of sight or the laser beam, the overlap region can be determined from the distribution from the program
- Optimal vertical position of the distribution can be determined with an accuracy of $\sim 10 \mu\text{m}$
- By using more than one fishing line, relative rotations between the camera and laser can be detected



Reflected Light
 ~ 40 times gain increase is needed

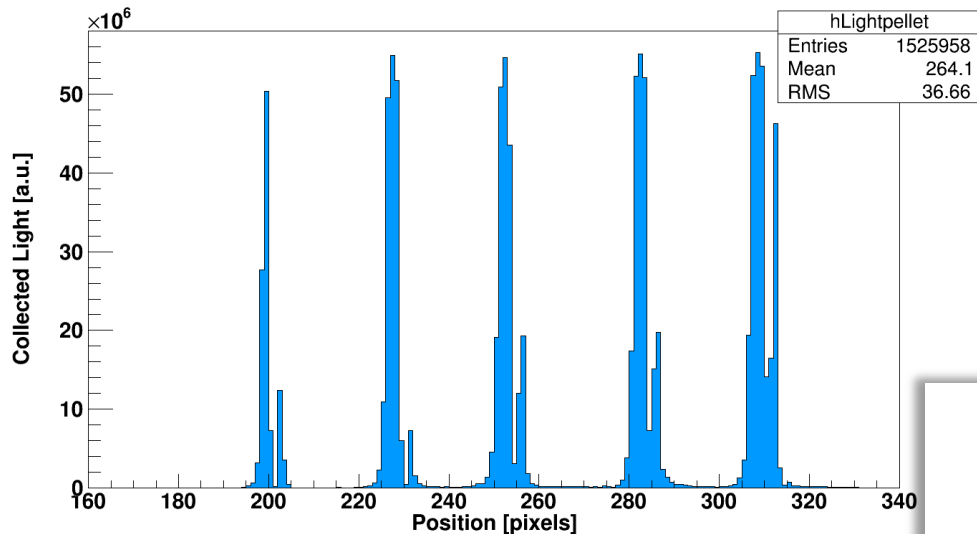
Refracted Light



Data Analysis

- Light and Position Distribution

The region of the camera image of the fishing lines covers the region of the pellet distribution



Fishing Lines

Distance between peaks in distribution

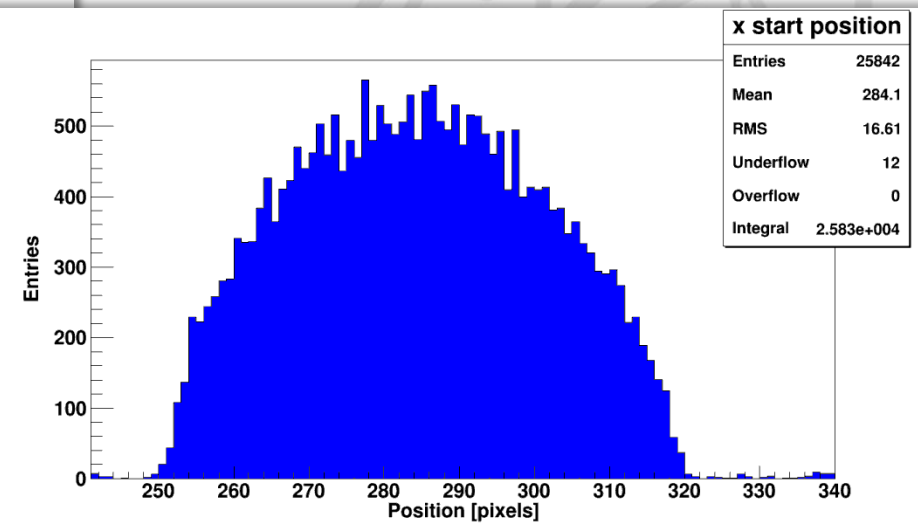
~ 30 pixels $\rightarrow 1.05$ mm

Expected distance ≈ 1 mm

Distance between outermost peaks ≈ 5 mm

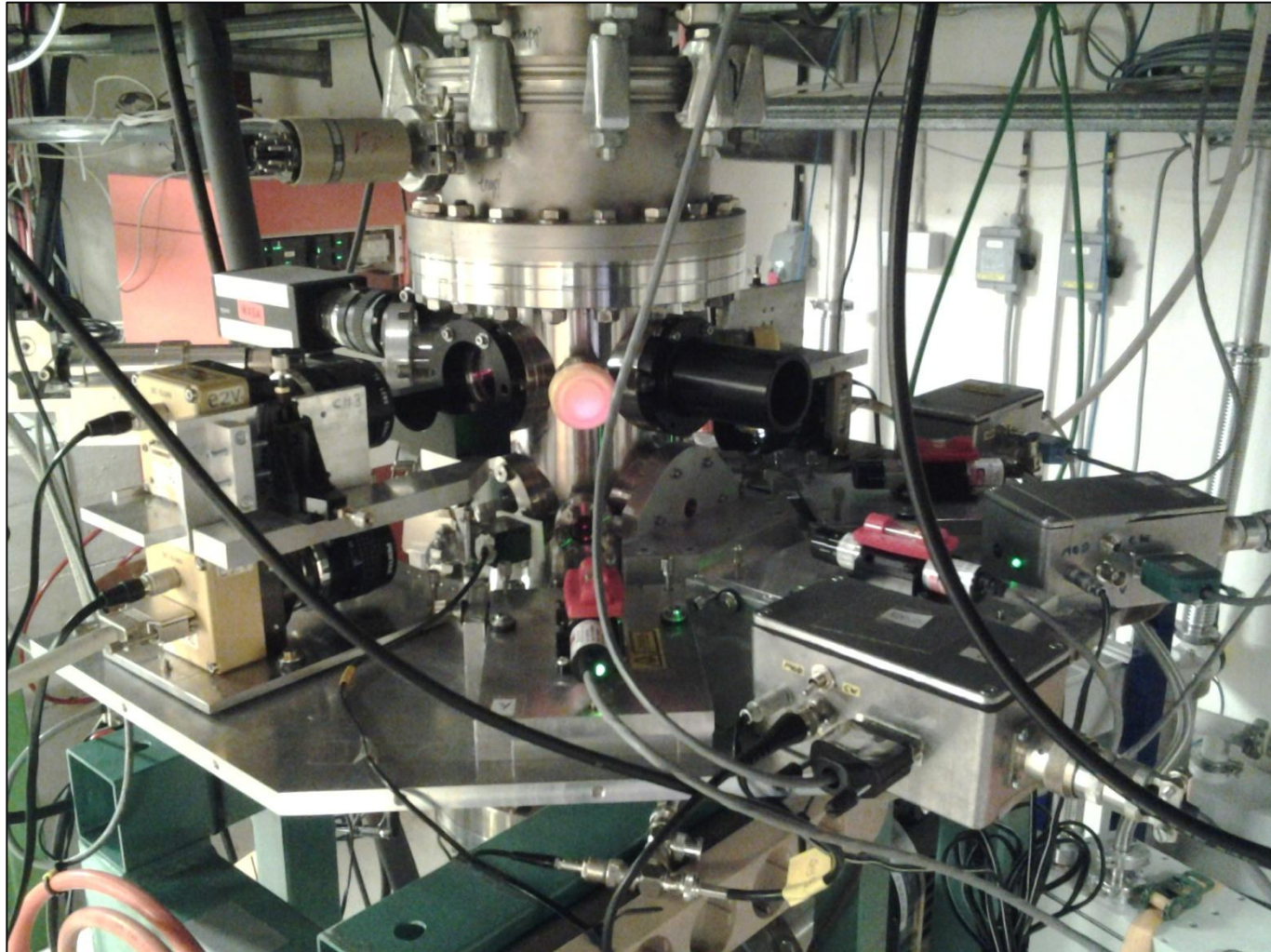
Pellets

Width of the distribution
 ~ 70 pixels $\rightarrow 2.5$ mm



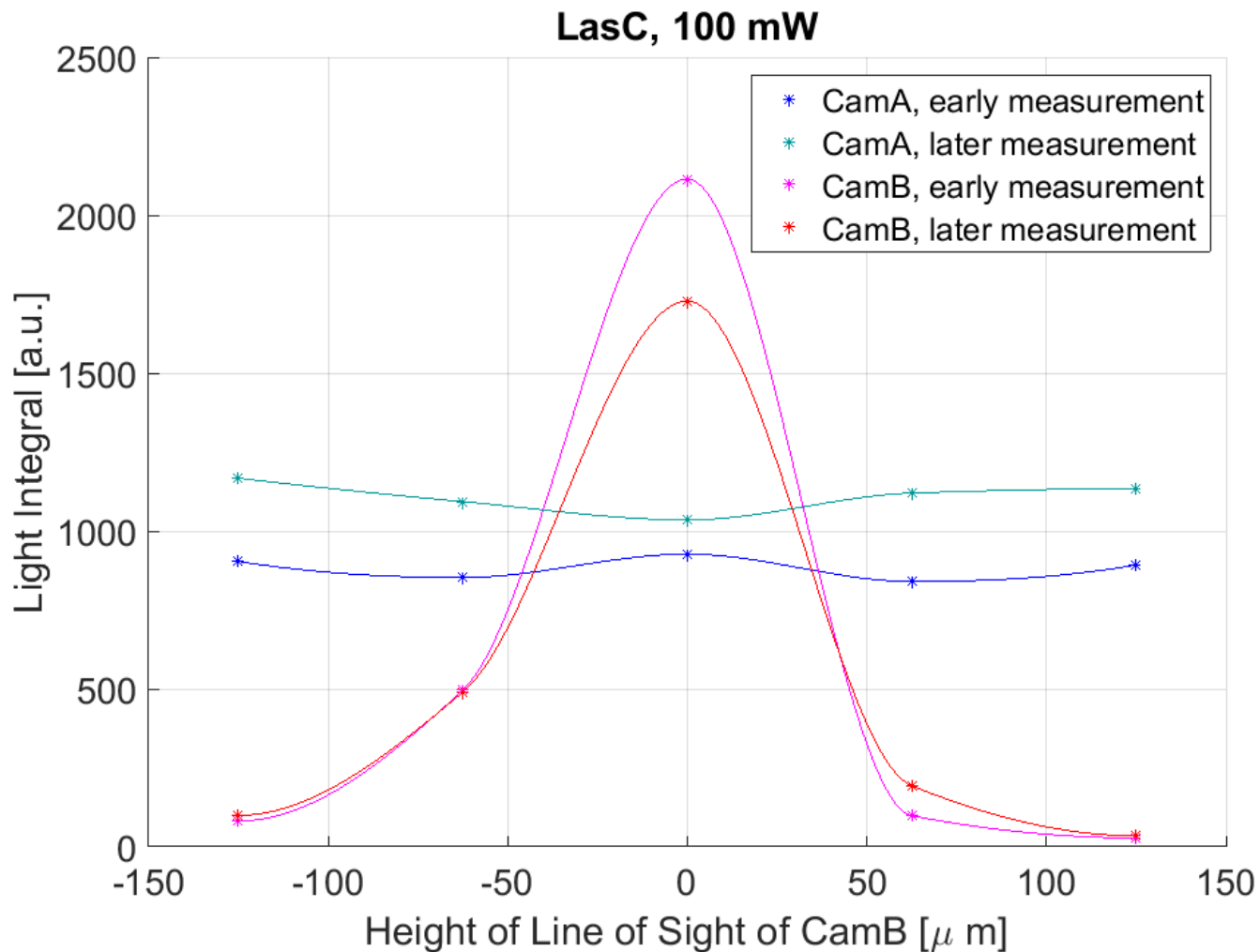
Detection Module

-At the Pellet Tracking Chamber





Alignment Checks with Pellets

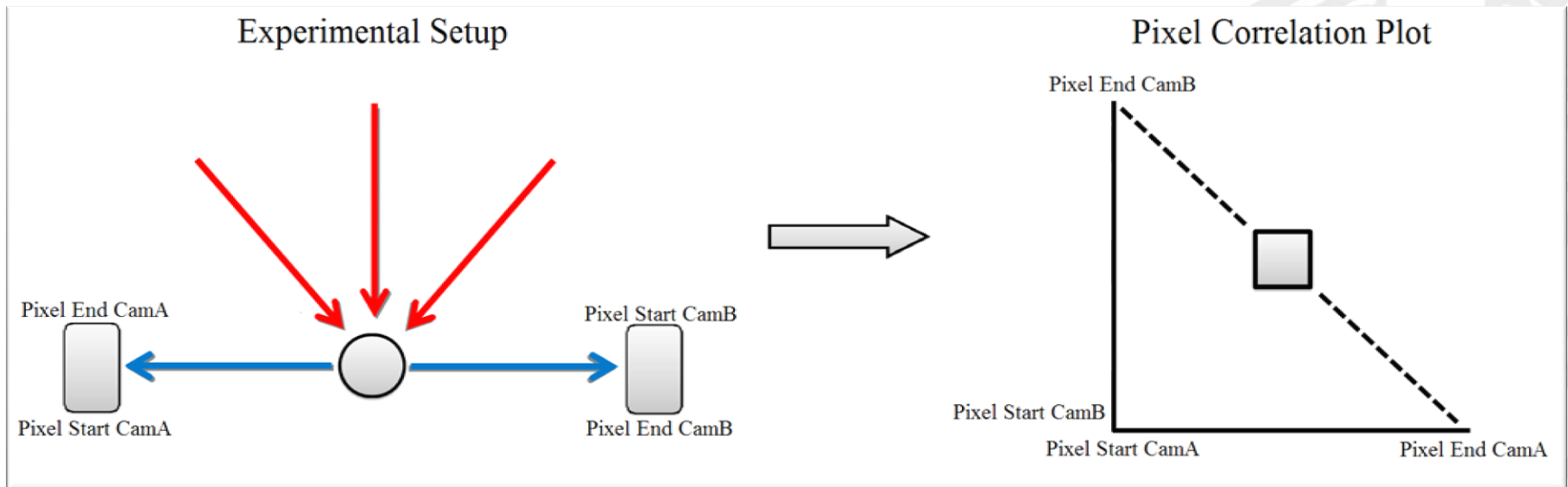




Data Analysis

Pixel correlation plot

- Relative changes in the positions of the cameras can be detected
- Comparing pixel correlation plots from two different measurements is the only way to check if the horizontal alignment have changed in between two measurements on the pixel level

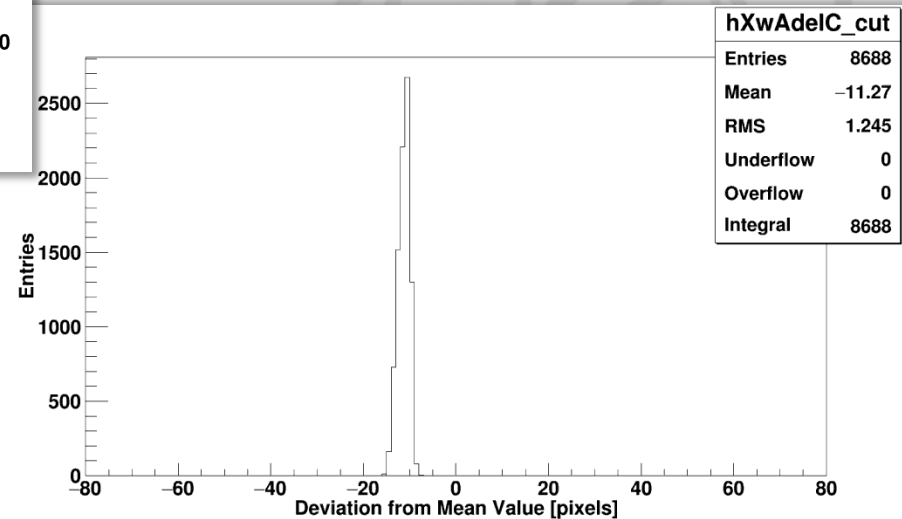
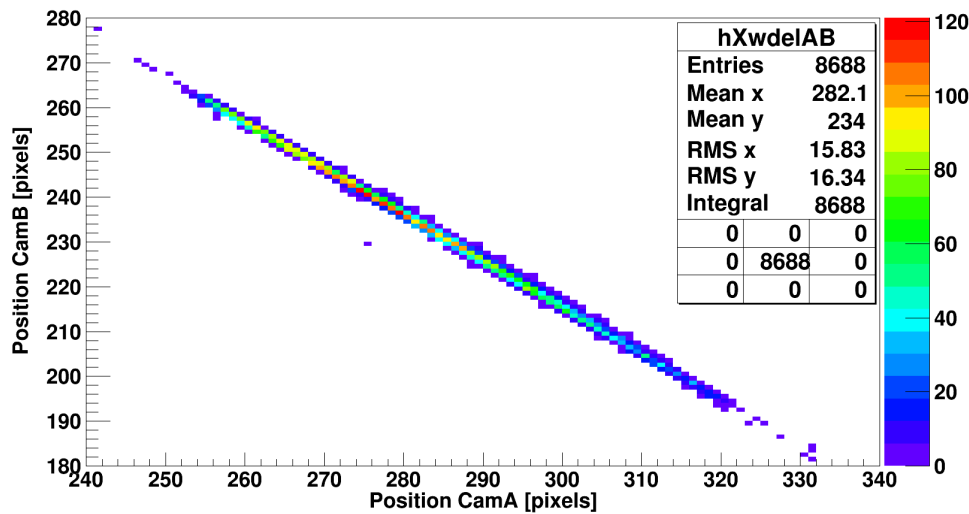




Data Analysis

Pixel correlation plot

-Measurement with pellets

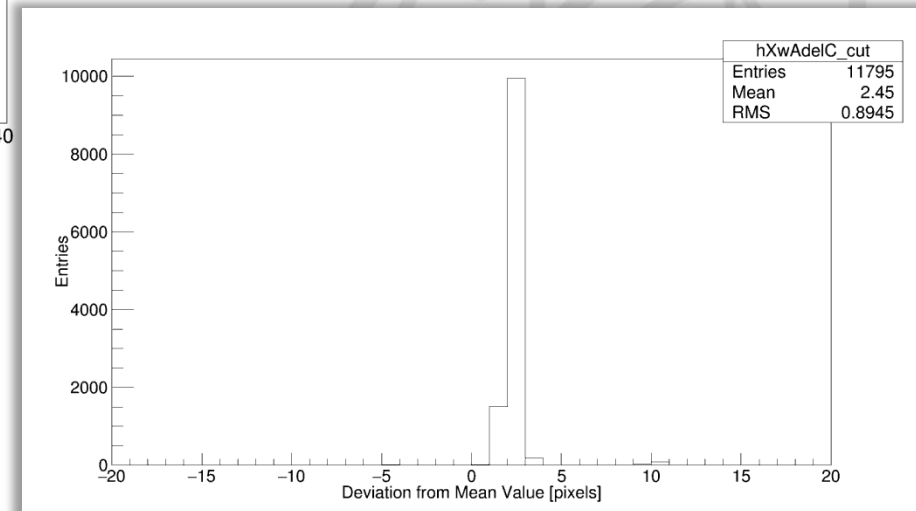
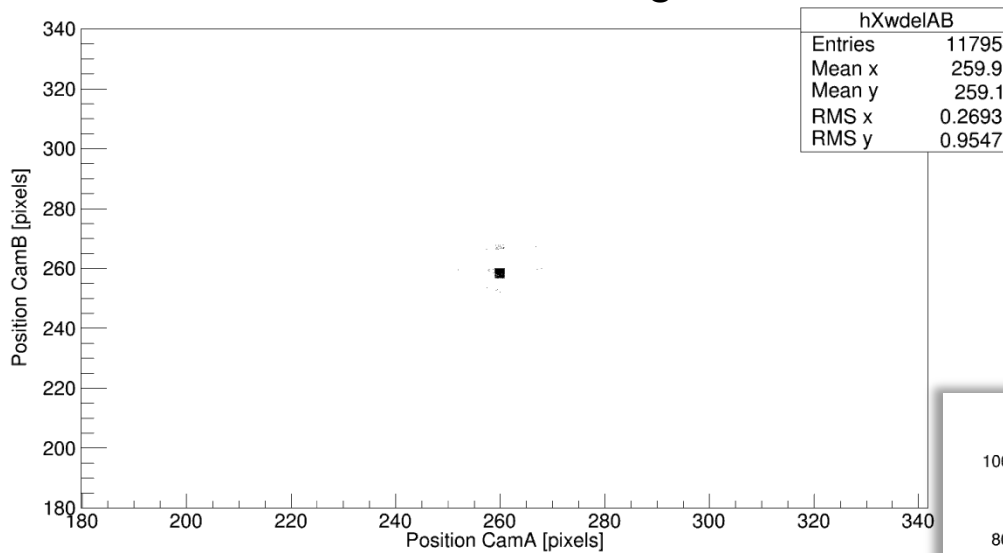




Data Analysis

Pixel correlation plot

-Measurement with fishing lines



Stability of the Alignment

1. Temperature Changes ($\sim 5^{\circ}\text{C}$)
2. Transportation (from the desktop setup to the pellet beam pipe)
3. Exposure to Vibrations (due to pumps during pellet runs)
4. Exposure to magnetic fields (~ 50 Gauss))

Method used for investigation

1. Alignment checks using the camera monitoring program
2. Alignment checks by plotting the mean value of the light integral (measure of the collected light in one pixel) for different heights of the camera line of sight
3. Investigations of the pixel correlation plot

Results

Estimated limits on the stability of the alignment taking into account the method of investigation:

1. Temperature Changes

- No significant difference detected so the vertical alignment of all cameras and lasers differ $\ll 20 \mu\text{m}$ for measurements at temperature differences of $\sim 5^\circ\text{C}$
- Relative horizontal position of CamA and CamB differ less than $35 \mu\text{m}$ (one pixel)

2. Transportation

- No significant difference detected so the vertical alignment of CamA, CamB, LasA and LasB differ $\ll 20 \mu\text{m}$ after a transportation
- Relative horizontal position of CamA and CamB differ less than $35 \mu\text{m}$ (one pixel)

3. Exposure to Vibrations

- No significant difference detected and the vertical alignment of all cameras and lasers differ $\ll 30 \mu\text{m}$ after a 7 h exposure to vibrations
- Relative horizontal position of CamA and CamB differ less than $35 \mu\text{m}$ (one pixel) after approximately 12 h exposure to vibrations

Summary

The Detection Module

- Consists of a DM plate with cameras and lasers for pellet detection and alignment
- Can be aligned in a desktop setup using a relatively simple alignment procedure and a good alignment target before transportation to the tracking section of a pellet beam pipe
- Is needed in order to optimize the optics of the lasers and cameras

Results

The alignment of the cameras and lasers on the DM was found to be stable against transportation, vibrations and temperature variations which are the main sources of distortions anticipated



Outlook

- More precise initial determination of the height of the camera- and laser-plates above the DM-plate
- Further investigations of the optical effects connected to both the cameras and lasers
- Optimizing time resolution by tuning the camera exposure cycle
- Preparation of a 4 level pellet tracking section for tests at the UPTS
- Reduction of the weight of the DM by drilling holes in the DM-plate making it easier to handle and easier to inspect visually when more levels are added
- Work on our new readout systems that will handle all detection levels needed finally



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Thank You!



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24 (24)