ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

A Laser Based Alignment System for the CLIC project

Guillaume Stern

CLIC workshop at CERN

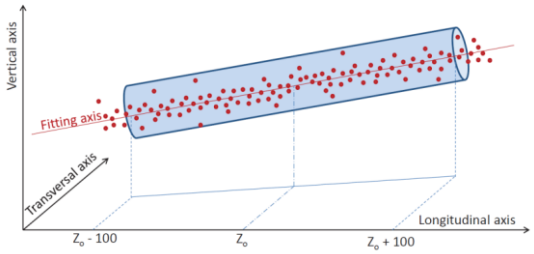
January 28, 2015

Outline

- Introduction
- Description of the laser alignment system
- Challenge of the PhD thesis
- Experiment results
- Conclusion

CLIC alignment

- Components need to be pre-aligned before beam based alignment



Component	*Pre-alignment requirements*
Main linac component	14-17 µm
Main linac reference points	10 µm
Beam Delivery System (BDS)	10 µm

- Pre-alignment strategy
  - Fiducialisation of components and girders
  - Initial alignment of the components on the girders
  - Active alignment system using sensors and actuators

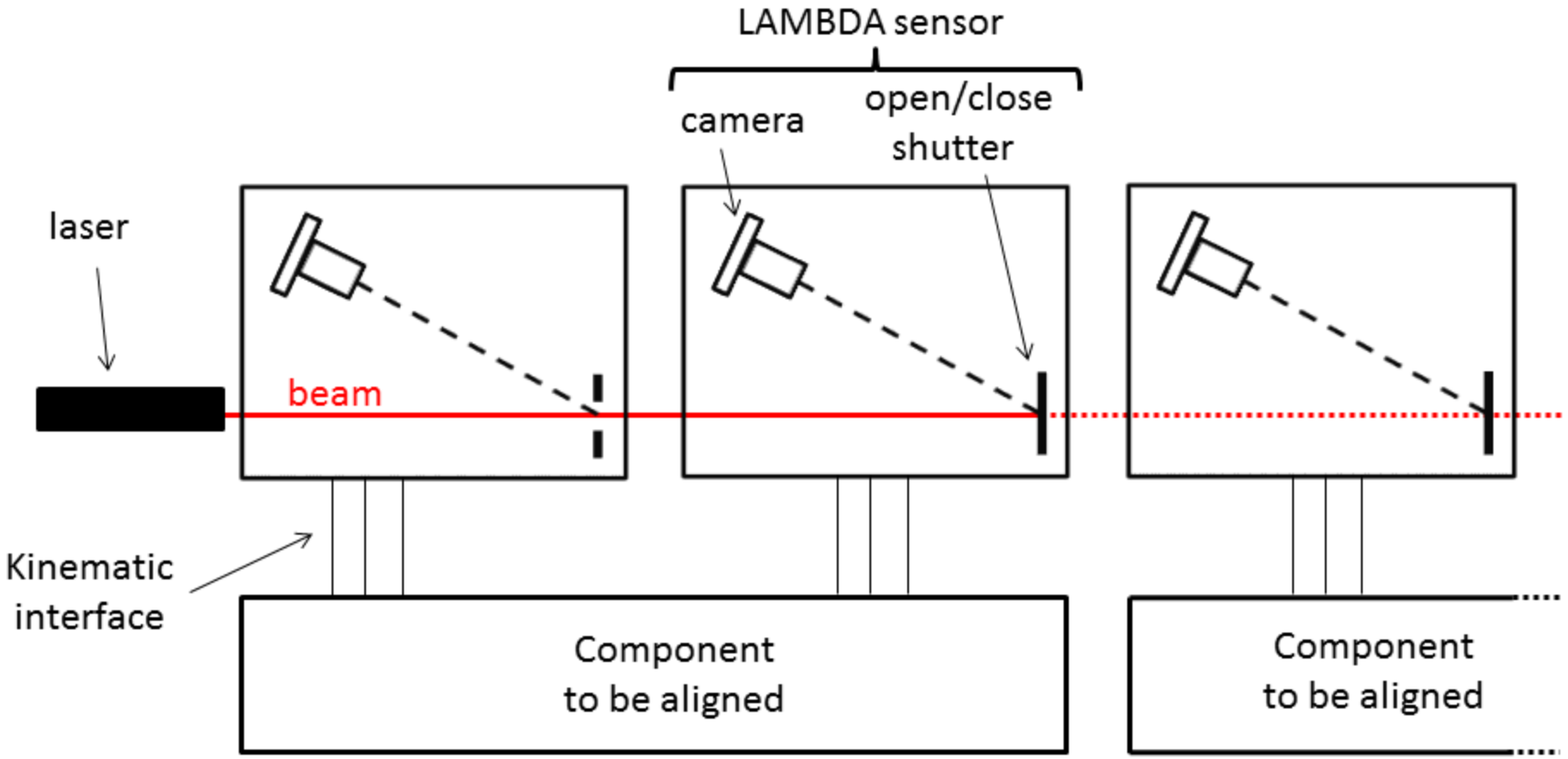
Problem

- Existing systems (e.g. based on stretched wire) not fully satisfying because of cost, difficult implementation
- Existing systems to be compared with a system based on different principle

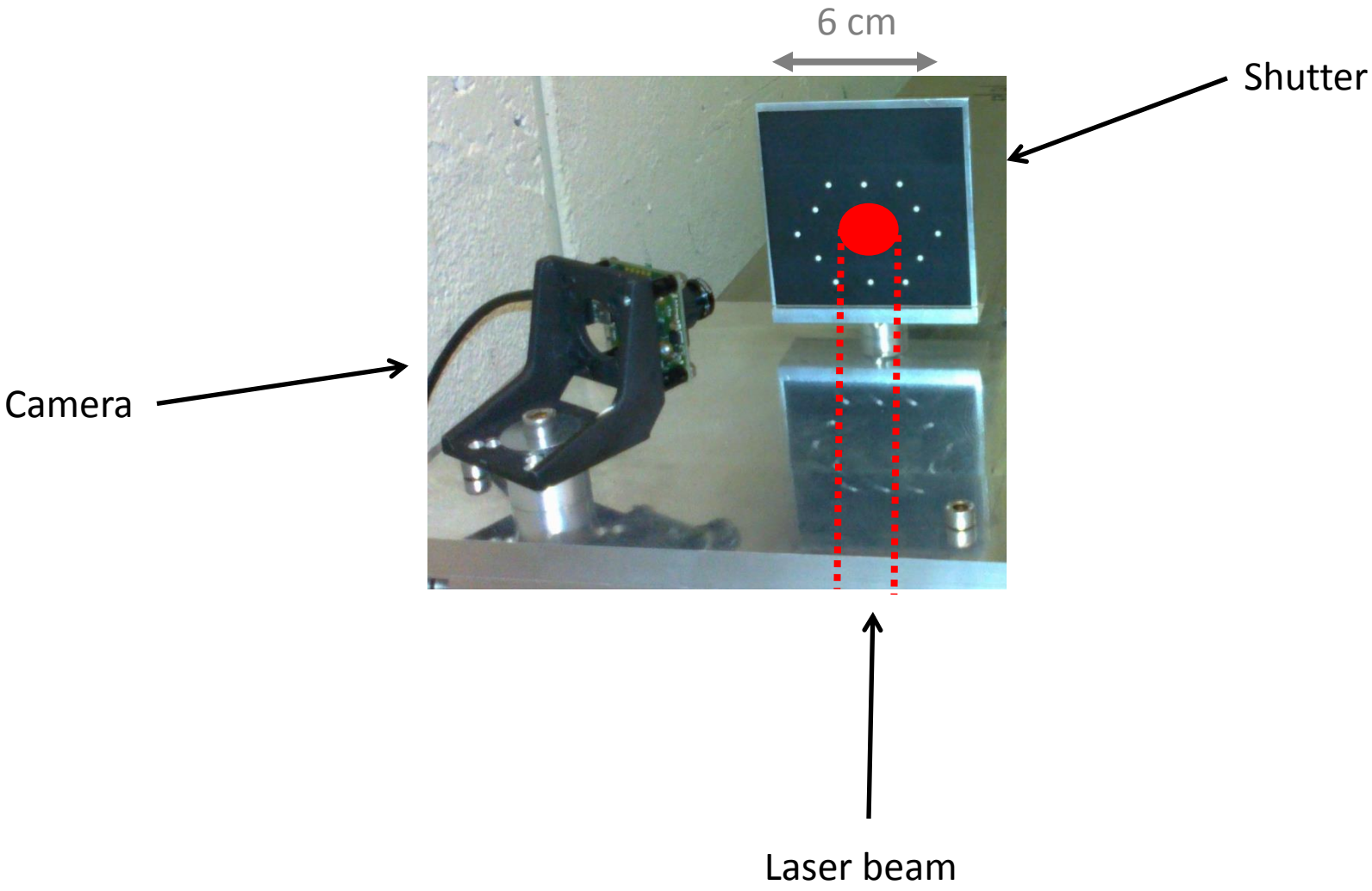
Proposal of solution

- Laser beam as straight line reference
- Camera combined with open/close shutter to measure distance between laser beam and components to be aligned
- Project name: LAMBDA project (Laser Alignment Multipoint Based Design Approach)

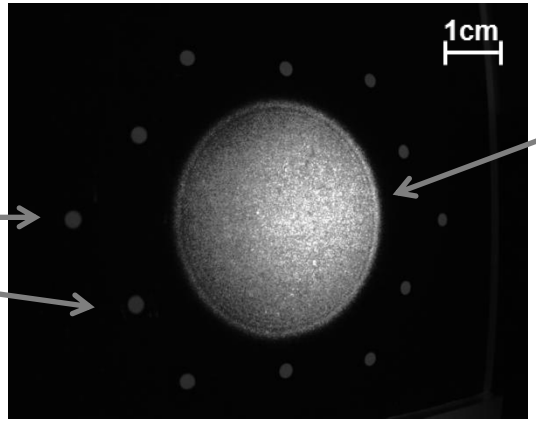
Alignment principle



LAMBDA sensor



Laser spot centre coordinates computed by image processing

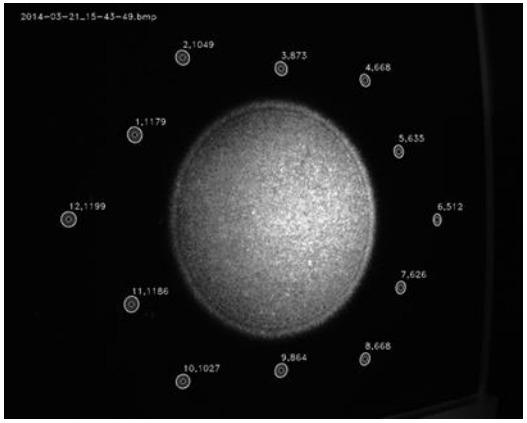


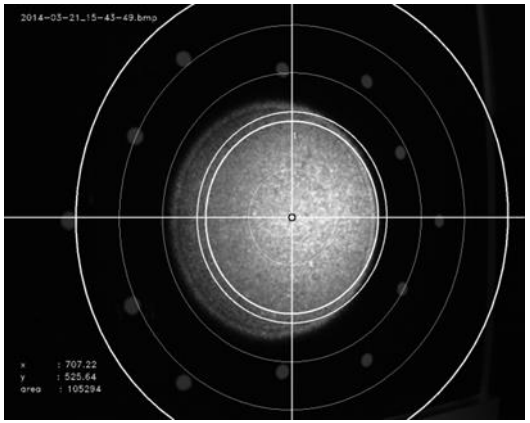
Laser spot

Reference targets

Ellipse fitting

2D Gaussian fitting





Bias to the right because laser beam not centred in the middle of beam expander

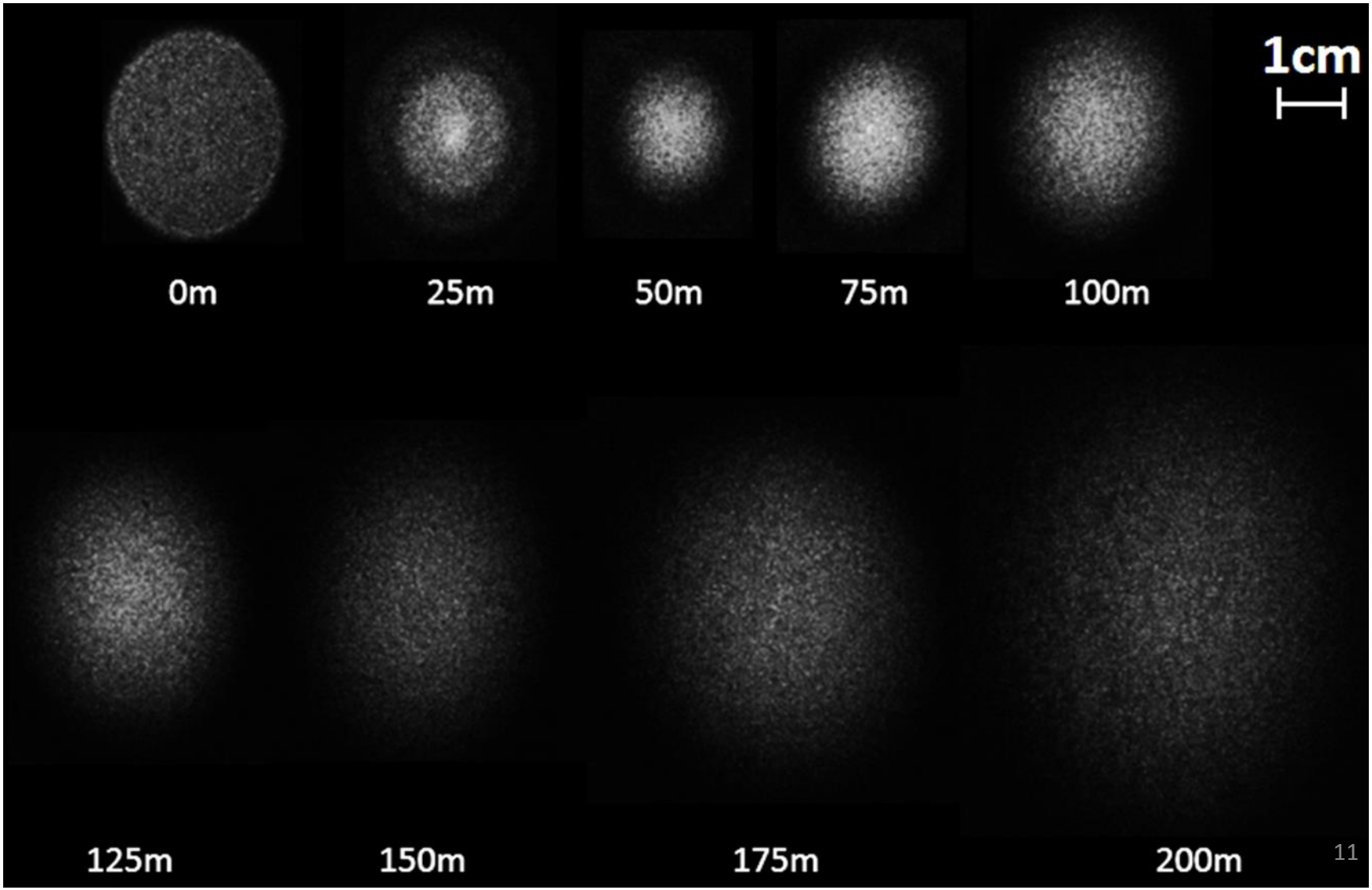
LAMBDA sensor requirements

- Compact
- Compatible with its environment
- Low cost
- Measurement repeatability 1 µm
- Measurement accuracy 5 µm

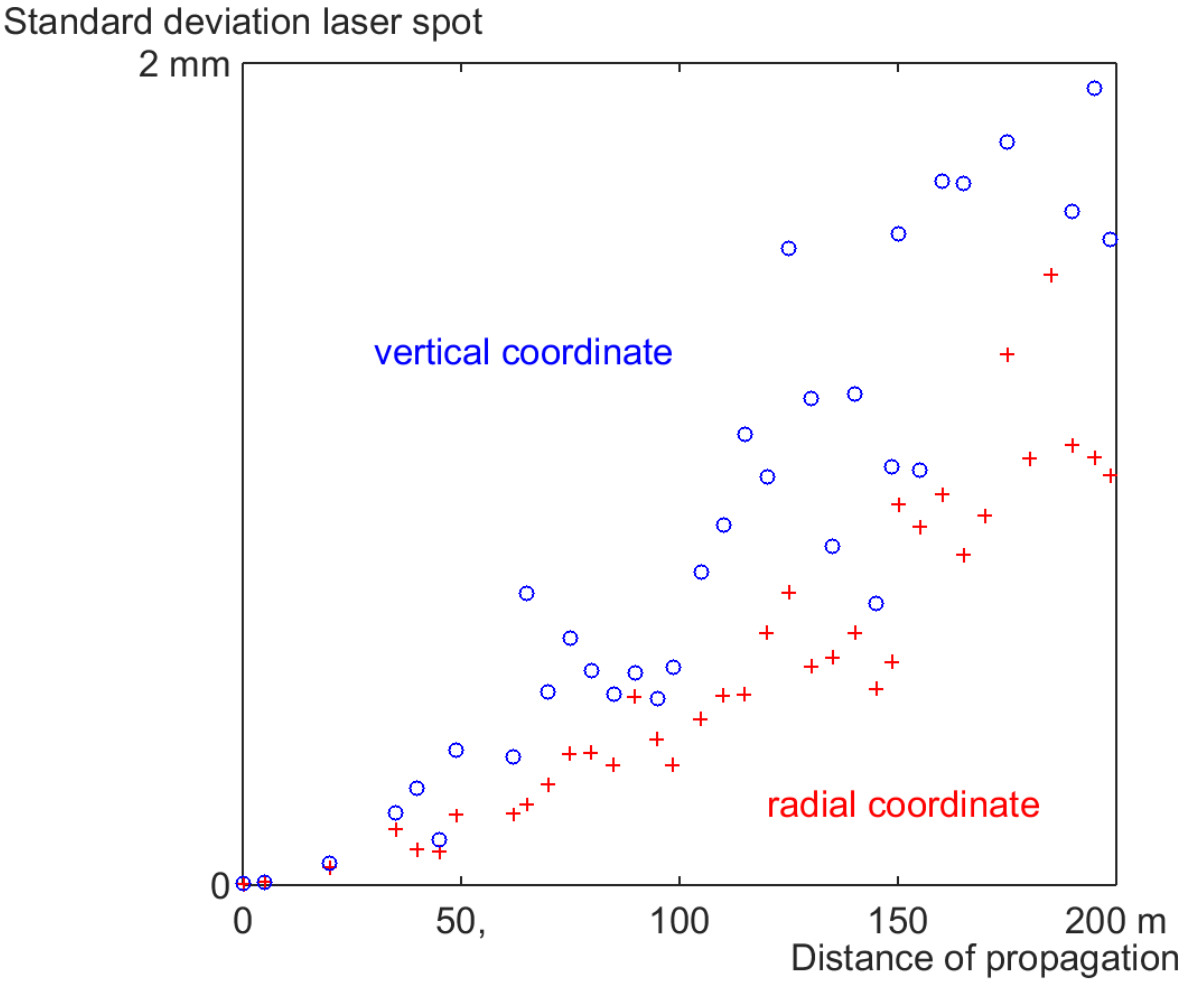
Challenge

- Determine sources of uncertainty
  - Laser beam as straight line reference?
  - Measurement of laser spot on shutter?
  - Sensor in its environment?
- Estimate and minimise uncertainty by experiments and simulations

Beam expander is needed to minimise laser beam diameter

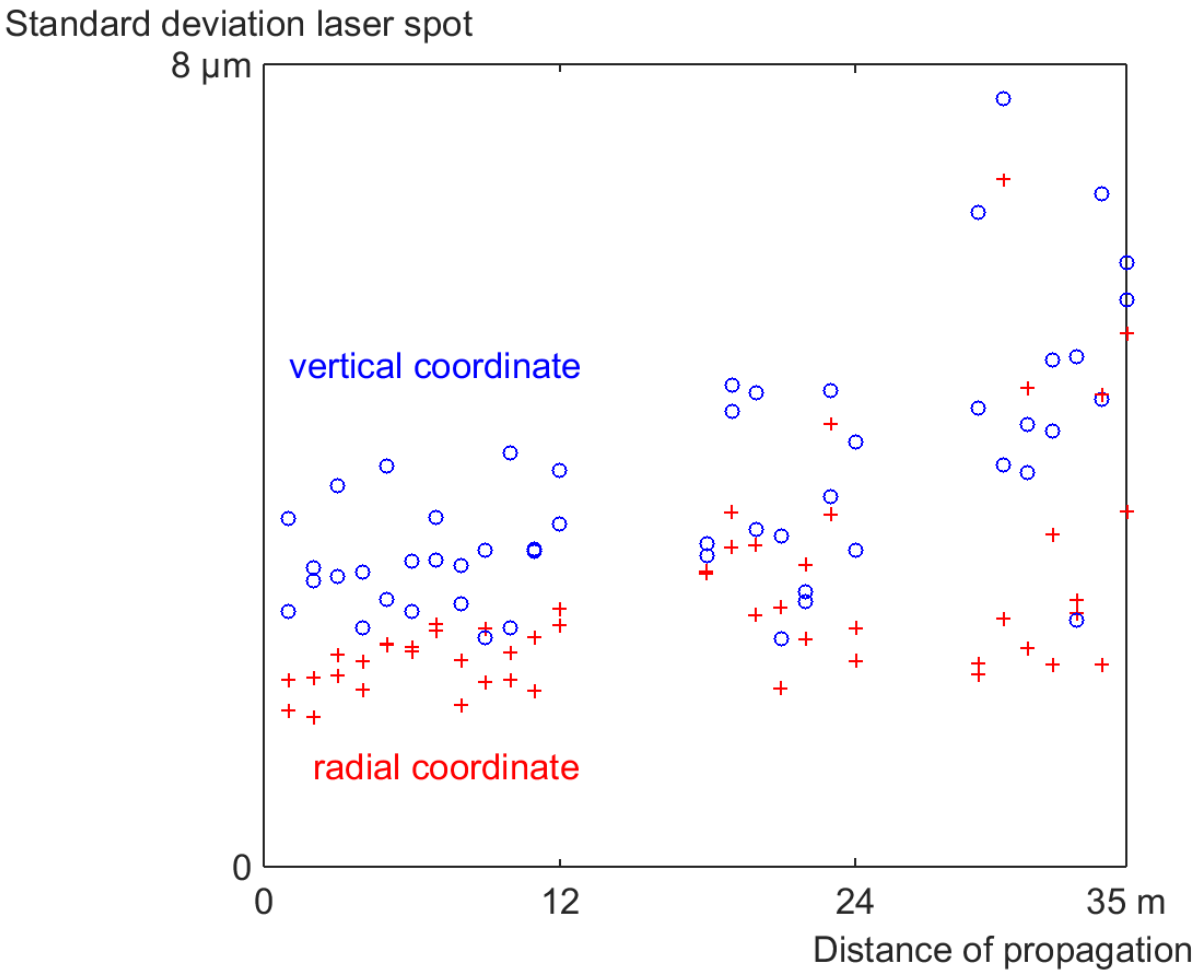


Laser pointing stability decreases with distance of propagation



Laser beam propagates
4 times over 50 m
by means of 3 mirrors

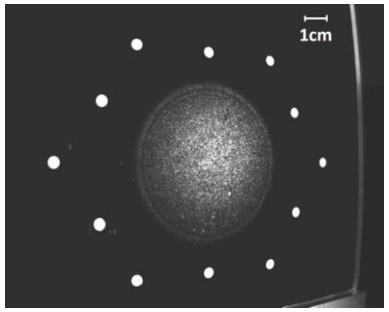
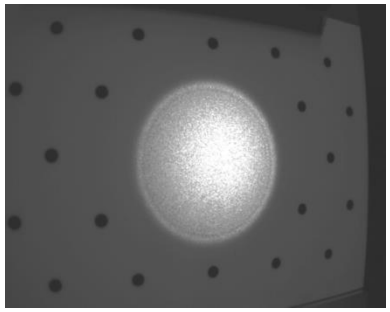
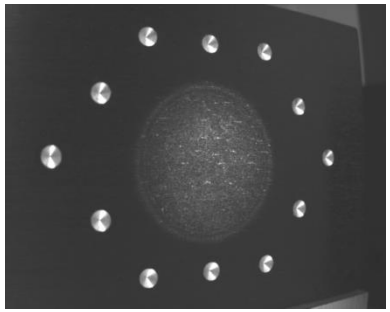
Vacuum pipe is needed to increase laser pointing stability



Laser beam propagates
3 times over 12 m
by means of 2 mirrors

Comparison at 35 m:
Air: st. dev. < 200 µm
Vacuum: st. dev. < 8 µm

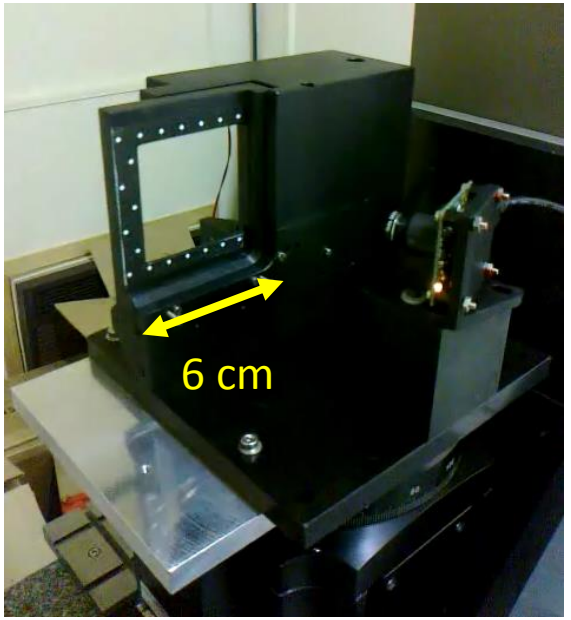
Ceramic shows a good compromise between paper and metal

Shutter type	*Picture*	*Flatness*	*Standard deviation laser spot (distance of propagation: 3m)*
Paper		30..110 µm	< 5 µm
Ceramic		36-37 µm	< 6 µm
Metal		15..16 µm	< 12 µm

Ongoing experiment: laser pointing stability w.r.t. shutter repositioning

Shutter closed

Shutter half way



Shutter open

Conclusion

- Laser based alignment system studied to align magnets with 10 µm accuracy over 200 m
- Sensor = camera + open/close shutter
- Lessons learnt from experiments
  - Beam expander and vacuum pipe needed
  - Ceramic shutter good compromise
- Next steps
  - Experiments on shutter repositioning
  - Simulations to complete the experiments
  - Calibration protocol for sensor
  - Thesis report