WP7: Metrology and Stabilisation LiCAS and MONALISA progress

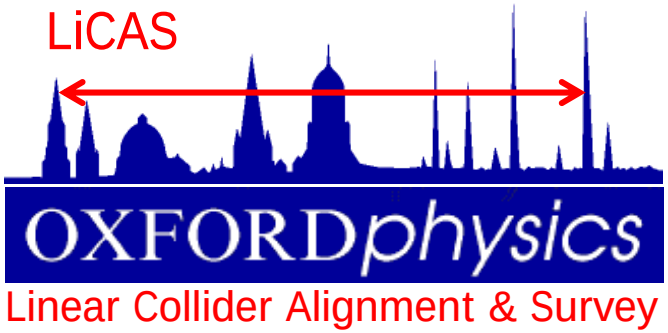
LiCAS = Linear Collider Alignment and Survey

MONALISA = Monitoring Alignment & Stabilisation with high Accuracy

WP6: Stabilisation and Alignment

LiCAS = Linear Collider Alignment and Survey,

Warsaw University



Who are we now

academic

Armin Reichold

student*ic* (PhD)

Gregory Moss

John Green
Robert Apsimon*2
Peter Baker
John Nixon
Edward Botcherby
Ken Chuang
Thomas Zlosnik
Simon Wilshin*4
Chris Glassman*3
James Robinson
Pauline Sliwa
Anna Lewis
Richard Ollerhead
Total: 12

Rov Wastie | Mark Jones | Mike Dawson | Sigal Cohen | Ron Morton

electronic & DAQ

Mech. Designer

Tony Handford

Mech. Tech.

mechanic

Gregorz Grzelak

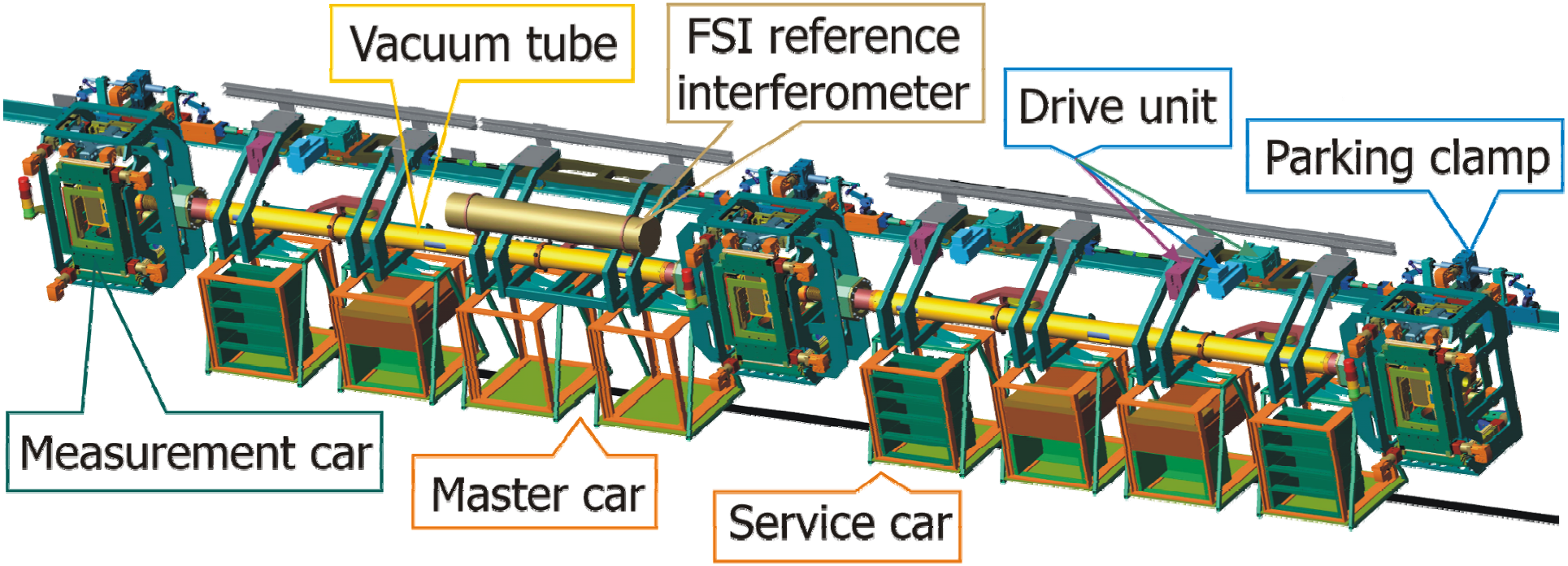
Project & Masters & ex. PhD Students

- Johannes Prenting
- Markus Schloesser

What is our Mission

- All ILC elements need to be accurately aligned to produce ultra high luminosity
- We do the reference network **S**urvey (LiCA**S**):
  - 200μm vertical = our slice of tolerance budget
  - over 600m = O(betatron) wavelength
- Open air survey too inaccurate due to instrument resolution and refraction (3mm) and ...
- ... "somewhat" slow and ...
- ... "a touch" expensive ➔
- Need new techniques & instruments
- We develop these based on experience with ATLAS and ZEUS alignment systems

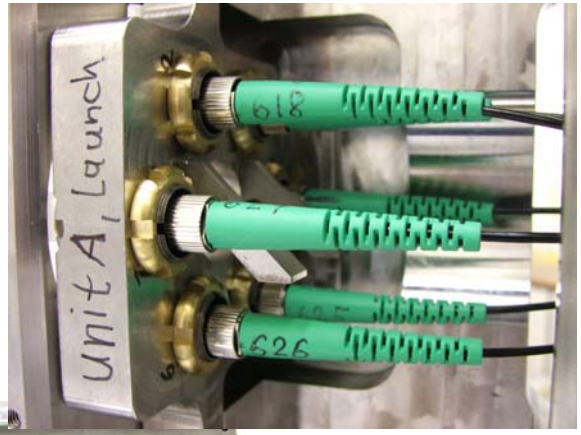
RTRS Concept (design overview)

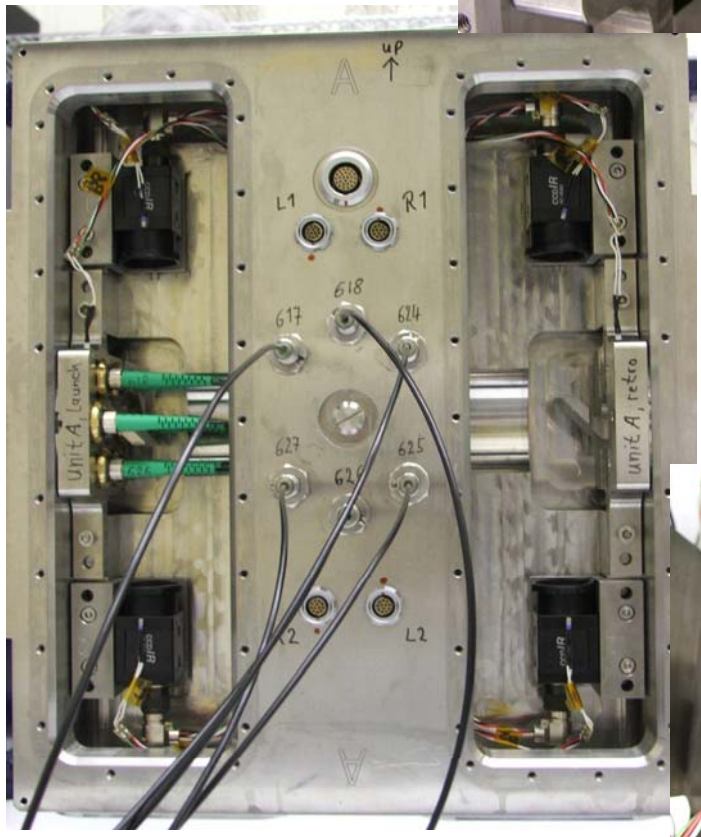


- Robotic survey instrument
- designed to autonomously survey reference network in the linac tunnel
- uses novel survey technology (FSI, LSM)
- needs very advanced data analysis techniques
- now located in a test tunnel at DESY

LiCAS Measurement Unit Assembly

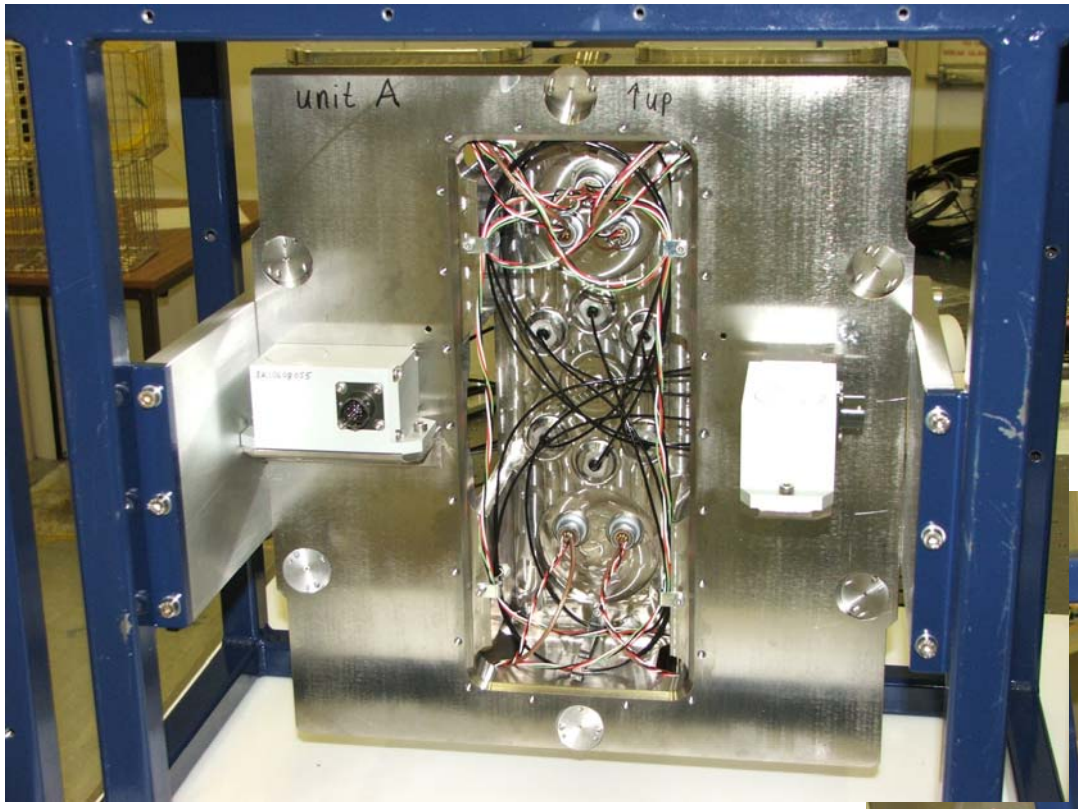
- Assembly was VERY hard work over a very long time under clean room conditions
- The Oxford workshop was essential in making this happen (lots of overtime, weekends, long hours, fast turnaround)
- John did 30 days straight in the clean room!!



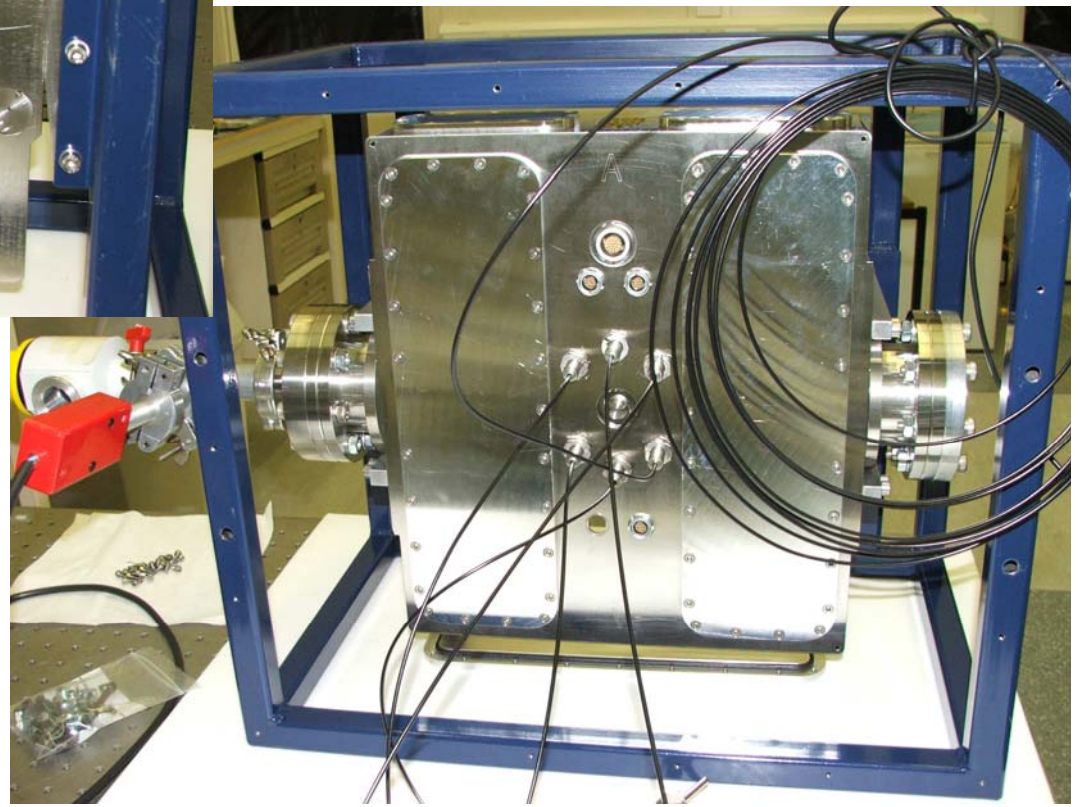


we now have three of these at DESY

LiCAS Measurement Unit Assembly

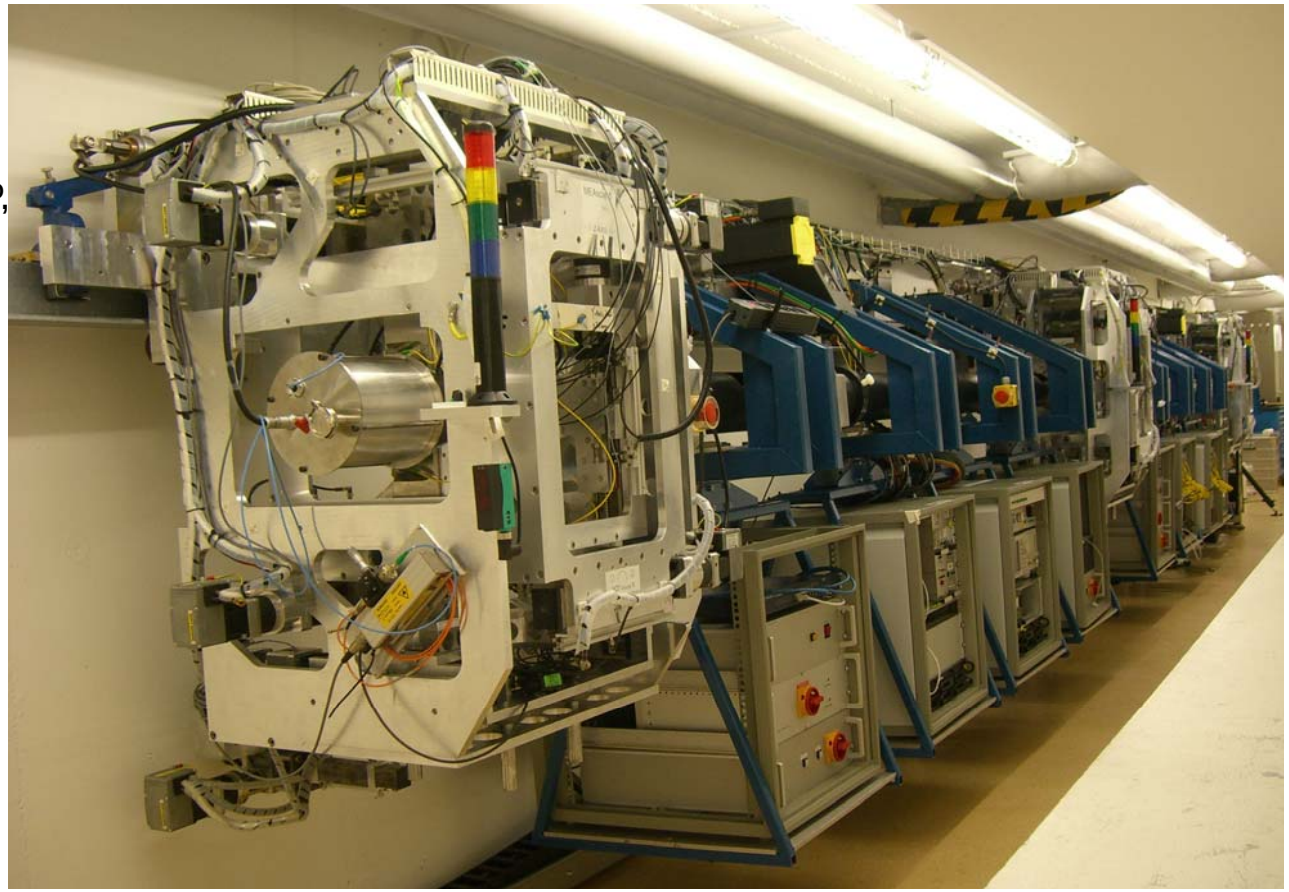


- They are nice, shiny and jolly heavy when completed!



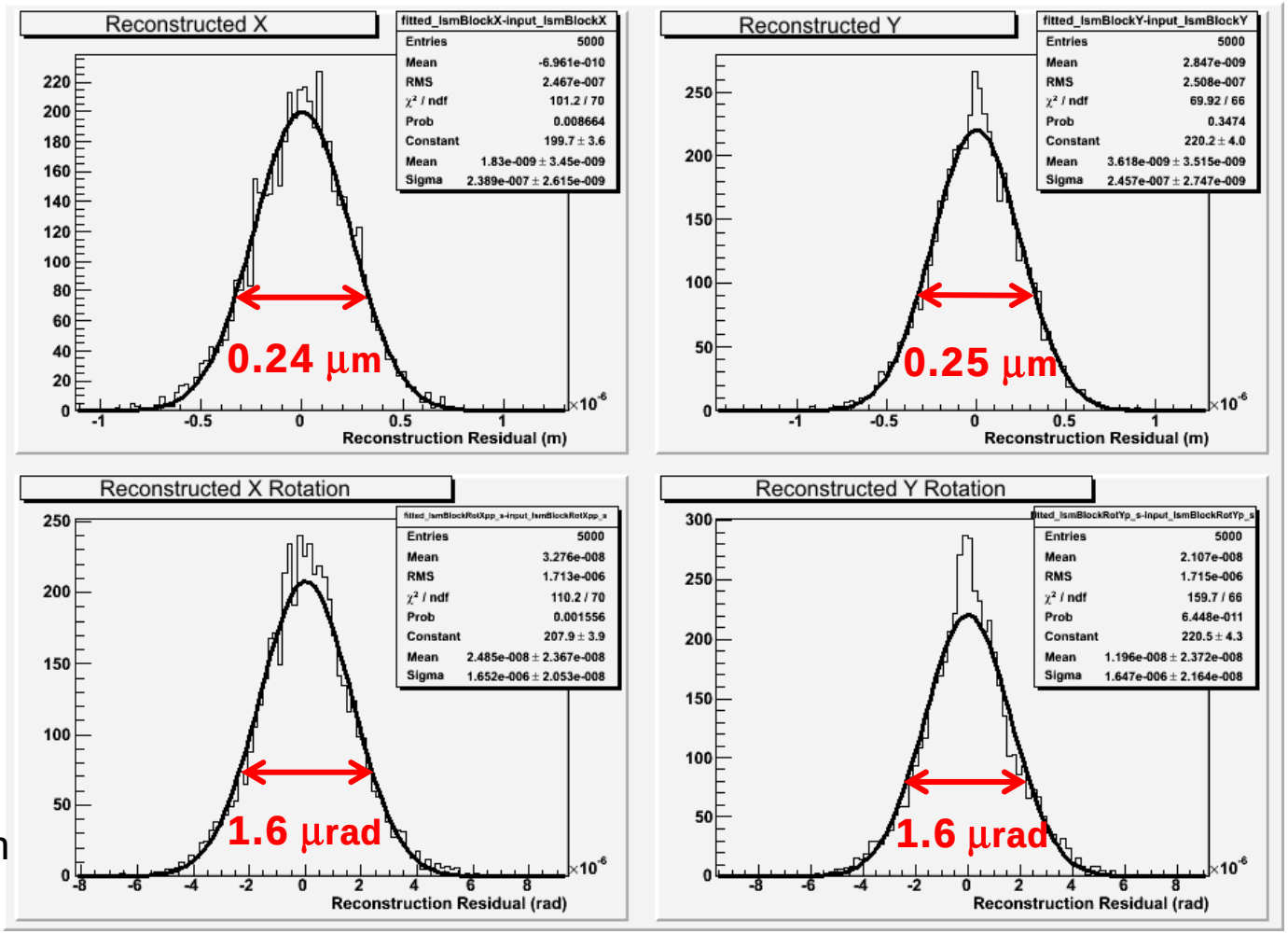
LiCAS Achievements to date

- RTRS = Large scale robotic sensing system
  - Robotics:
    - 1 ton moving mass
    - each measurement unit moves in 6D
    - 25 axis of motion
    - 39 CAN bus controlled stepper motors
    - 6 network controlled picco motors
    - 3 drive motors with 6 kW total power
    - 82 limit and proximity switches
- DAQ
  - 102 MB data per stop
  - 4 servers with 1.2 TB storage take data via:
  - CAN, USB-II, RS485, TCP-IP, PCI
- Mechanics
  - vacuum system with > 100 accesses, joints and feedthroughs, many custom
- Calibration
  - all sensing elements measured with CMM and smart scope
  - in-situ calibration procedure for entire RTRS
  - FSI length scale will be separately calibrated
- Sensing systems (data source rate):
  - 38 FSI interferometers (210 MB/sec)
  - 12 LSM cameras (298 MB/sec)
  - 3 wall marker cameras (78 MB/sec)
  - 96 calibrated temperature sensors
  - 3 computer controlled lasers
  - 12 axis of gravity reference tilt sensors



LiCAS Achievements to date

- Straightness Monitors
  - sub micron accuracy spot fitting (0.2 μm in air, should improve in vacuum)
  - reconstruction of 4-DOF confirms system performance (see below)
  - method for in-situ calibration works in simulation
  - thesis by G. Moss expected Sep. 08



Residuals of LSM reconstruction

- Frequency Scanning Interferometry
  - interferometers for long and short lines exceed specification of 1 μm in lab experiments
  - Technology for serial production of low cost interferometers works
  - long line reference interferometers show world leading resolution (see below)
  - Methods for auto-calibration of external FSI network without any need for witness observation close to completion
  - Thesis from J. Dale expected Sep. 09

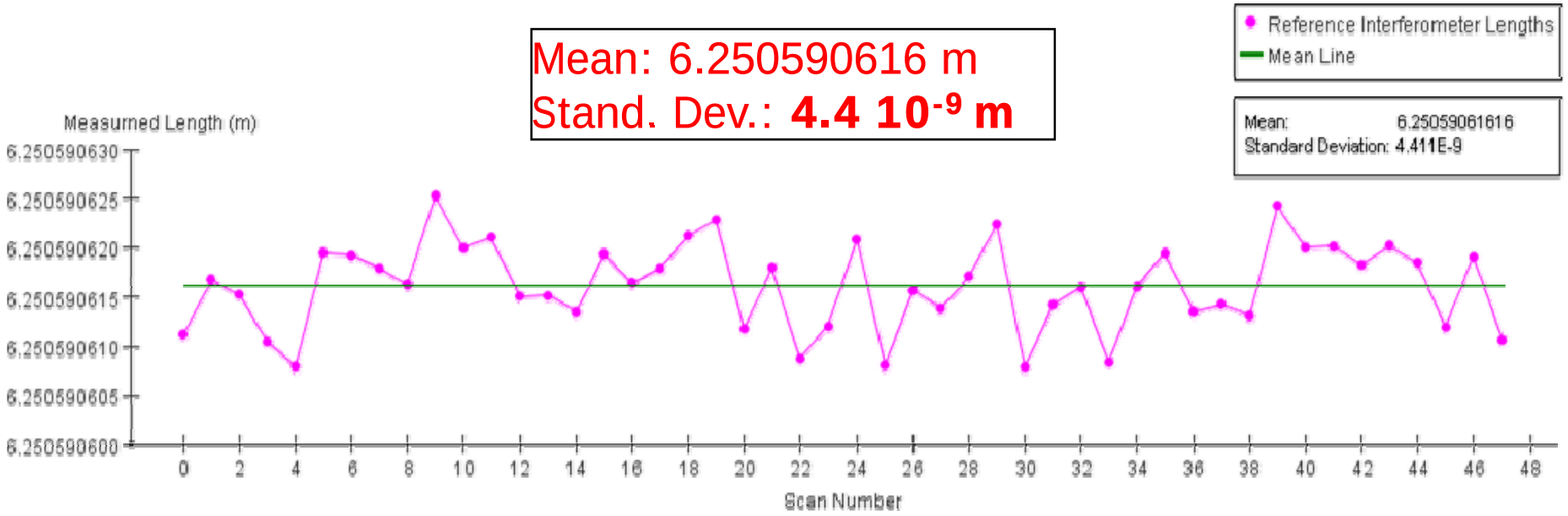


Fig. 2 Repeatability of FSI Ref. Interf. measurements

LiCAS-I project status summary

- RTRS fully constructed and installed at DESY (70m tunnel)
- Majority of subsystems commissioned and integrated into the DAQ software
- All measurement techniques proved principle and resolution in laboratory experiments
- Techniques for in-situ calibration have been developed
- Simulation and reconstruction software has been written and works
- Small team at DESY now on LTA (Greg, John, Armin)

- Remaining goals for the first prototype:
  - complete commissioning
  - calibration and operation in test tunnel at DESY
  - analysis of data with multiple methods
  - conclusions for the next generation instrument

MONALISA

Monitoring Alignment & Stabilisation with high Accuracy

Armin Reichold

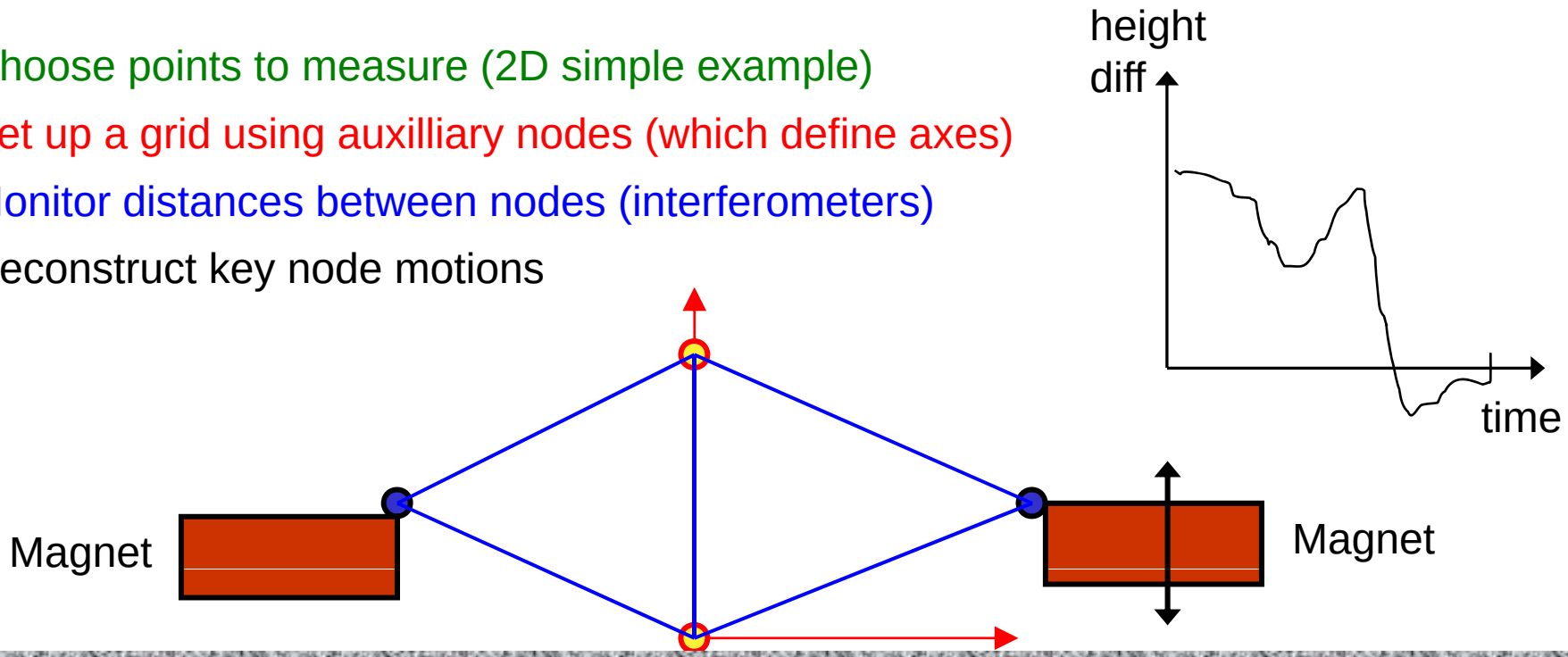
David Urner

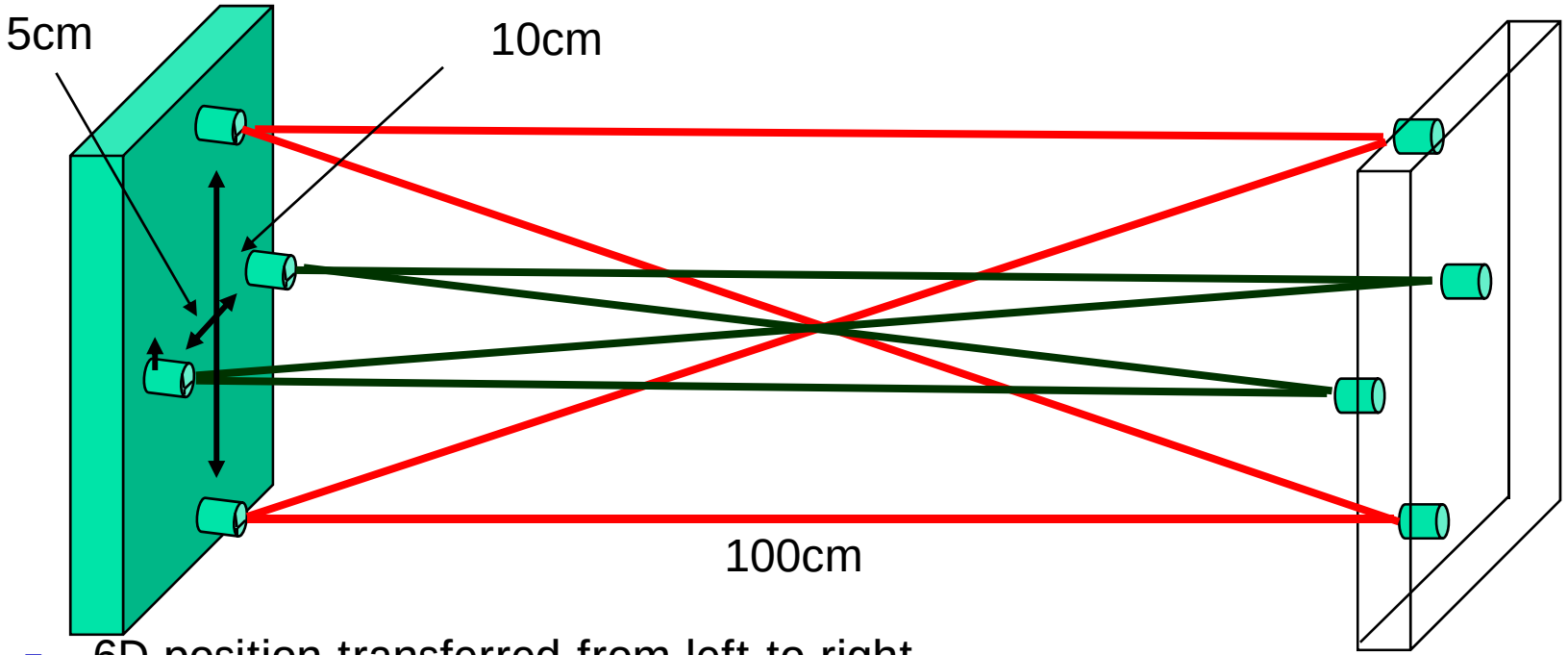
Paul Coe

Matthew Warden

- ILC luminosity goal : Focus 639 nm x 5.7 nm (1σ)
- BDS must provide sufficient
  - instrumentation
  - diagnostics
  - feedback systems
- Principal challenges include :
  - tight tolerances on magnets (Order nanometres)
  - "may well" require mechanical stabilization of critical components

- Choose points to measure (2D simple example)
- Set up a grid using auxilliary nodes (which define axes)
- Monitor distances between nodes (interferometers)
- Reconstruct key node motions

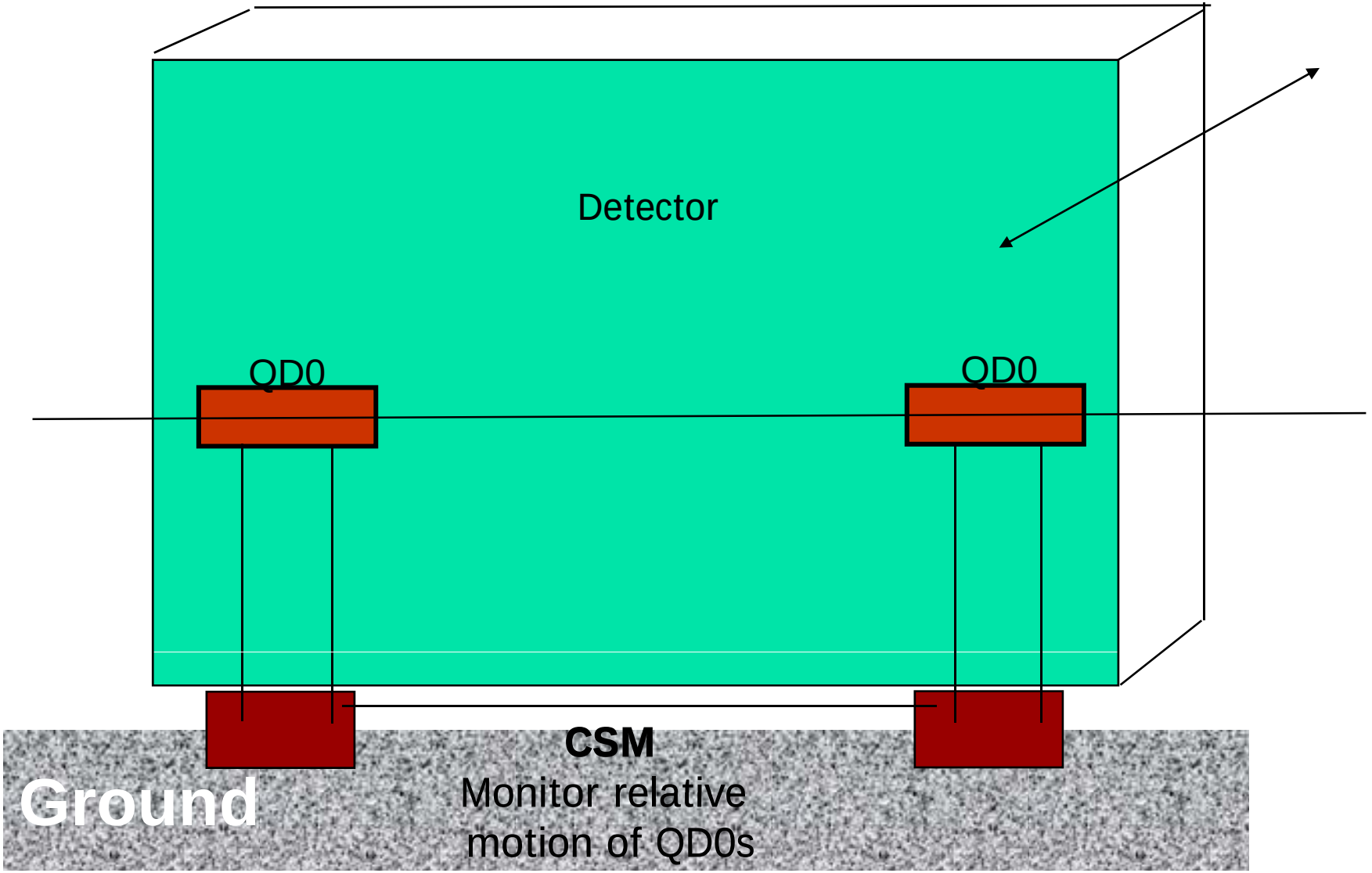


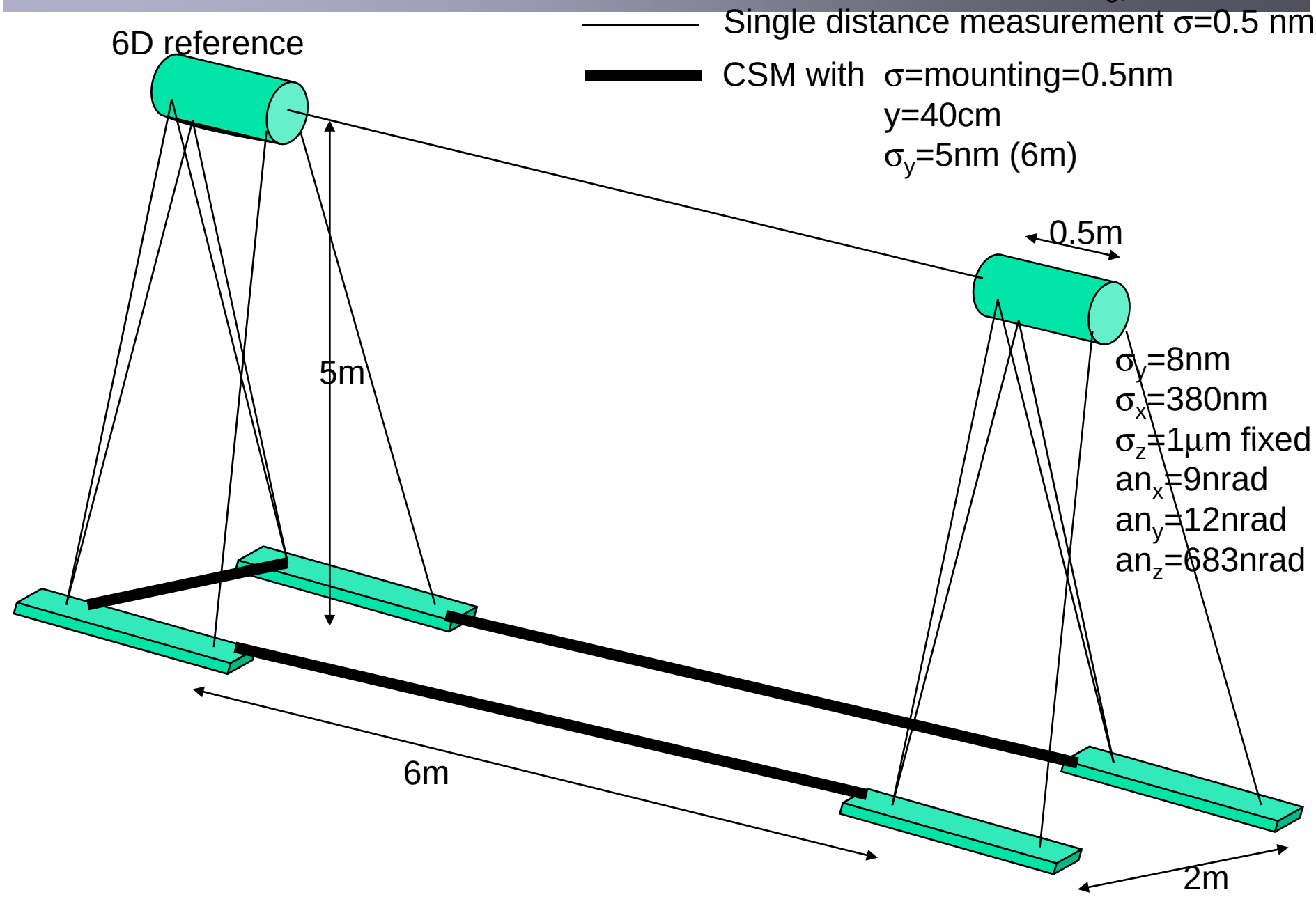


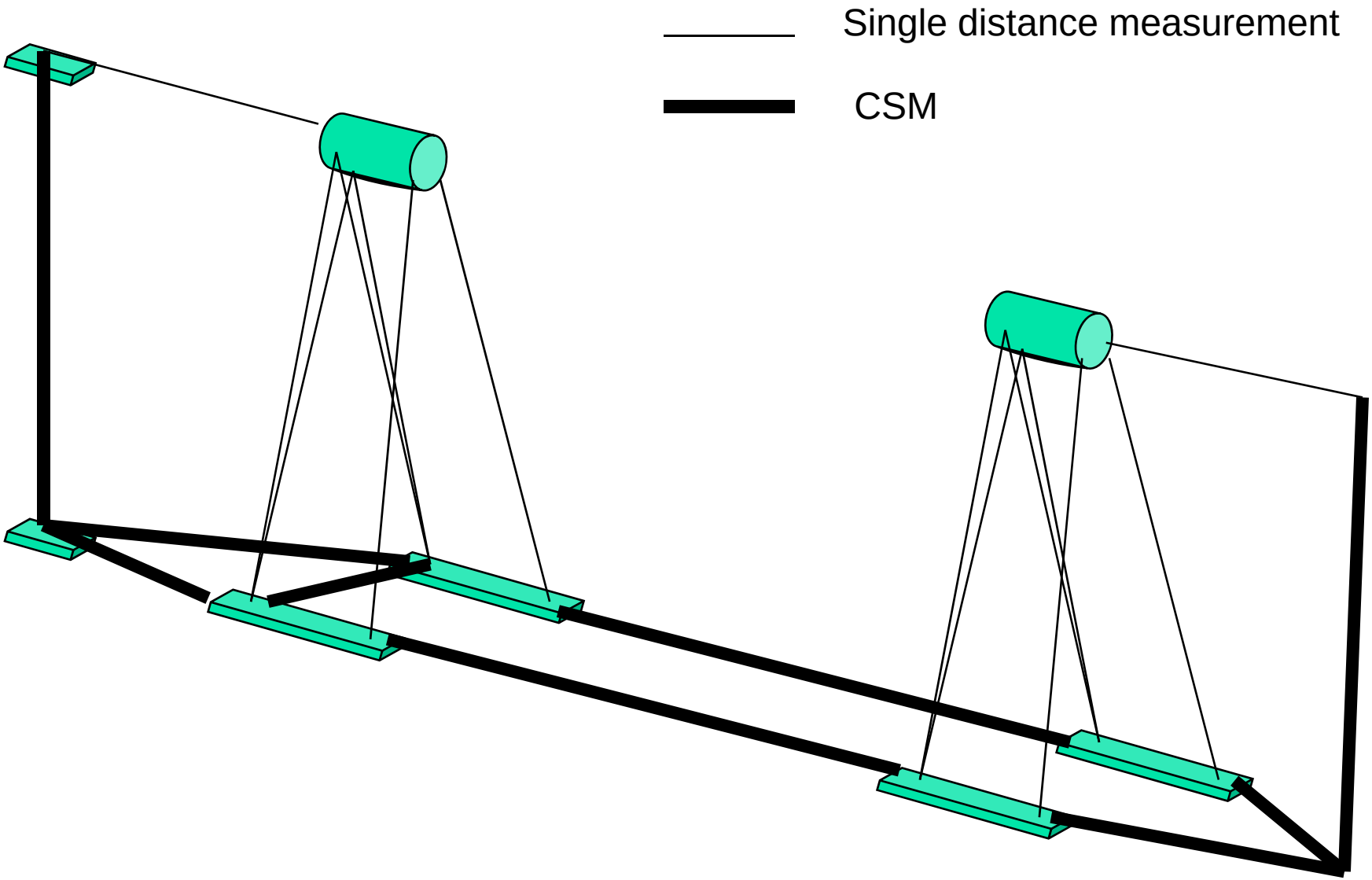
- 6D position transferred from left to right
  - breaking of symmetries is important
  - Use mechanical stability of small platforms A&B.
  - Use multiple lines to cancel systematic effects
  - Resolution scales aproximately with H/L
- Preliminary simulation results of CSM Resolution:
  - σ_y:10nm
  - distance meter resolution: 1nm
  - Positional change of optics components with respect to each other: 1nm

  That's the challenge.

After reposition of detector MONALISA can measure position of QD0s to 1μm
Likely realignments of vertical lateral and pitch axis of QD0s are required

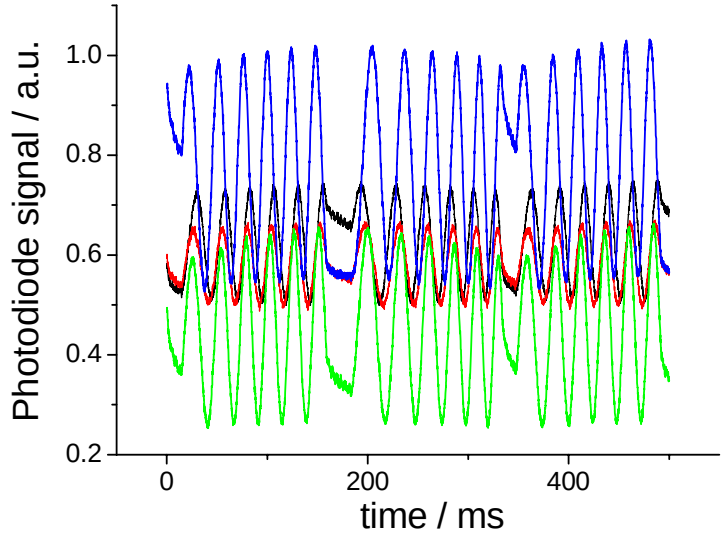


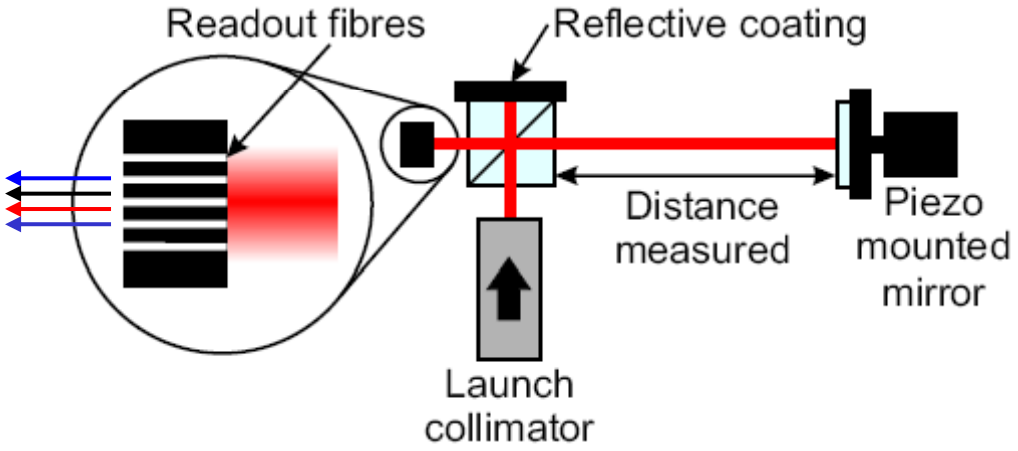

Single distance measurement σ=0.5 nm
CSM with σ=mounting=0.5nm
y=40cm
σy=5nm (6m)
6D reference
0.5m
5m
σy=8nm
σx=380nm
σz=1µm fixed
anx=9nrad
any=12nrad
anz=683nrad
6m
2m

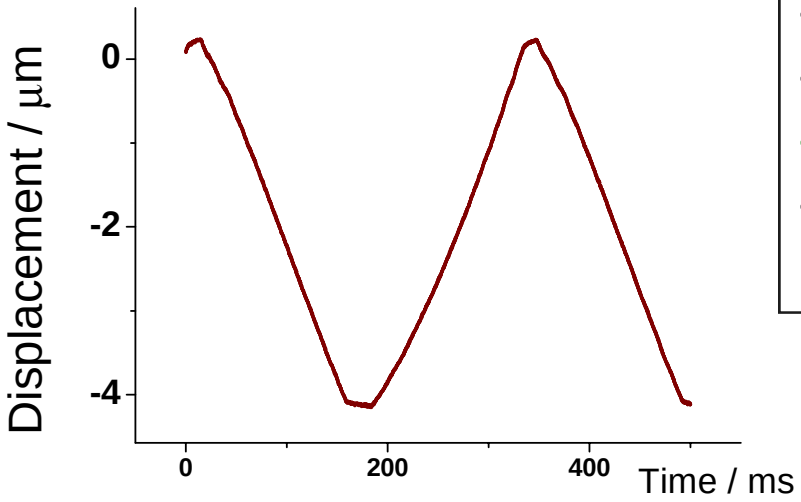

Single distance measurement
CSM

- Hardware
  - Built novel Interferometer designs
  - Pioneered new phase measurement techniques
  - vacuum vessel to demonstrate nm precision being currently commissioned.
  - Tested compact launch optics
- Software
  - Developed novel phase analysis technique
  - Collaborated with LiCAS on OO analysis package
  - Developed binary file format for data handling
    - users MonAliSA, LiCAS and ATLAS (FSI)...
    - Available in Java, C and LabVIEW

FFI: Fixed Frequency Interferometry (OPD 400mm)

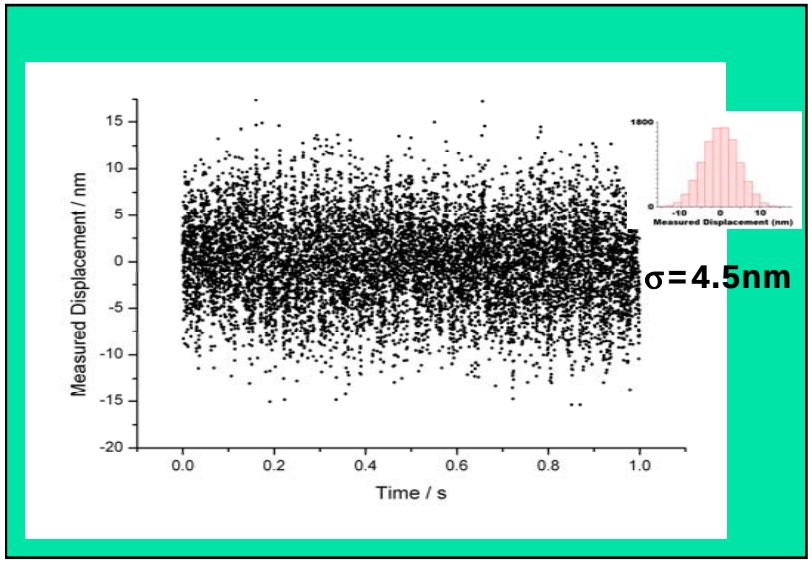


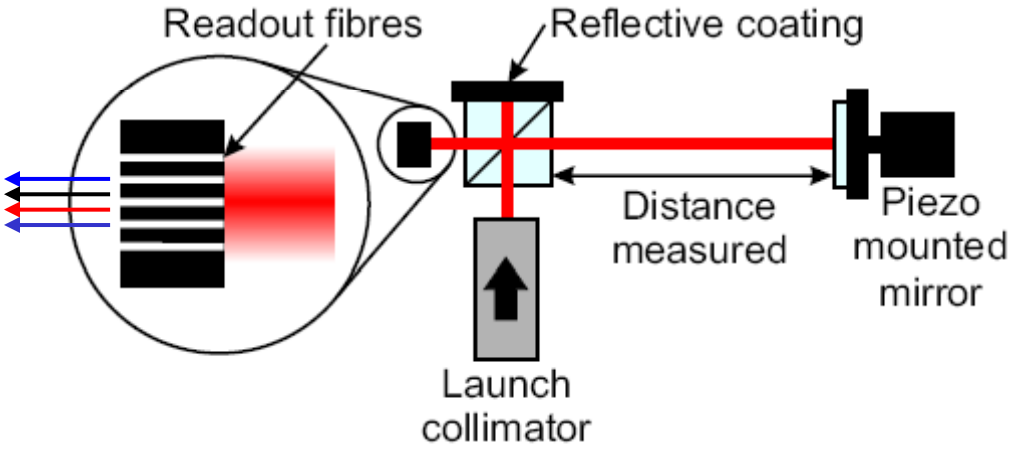


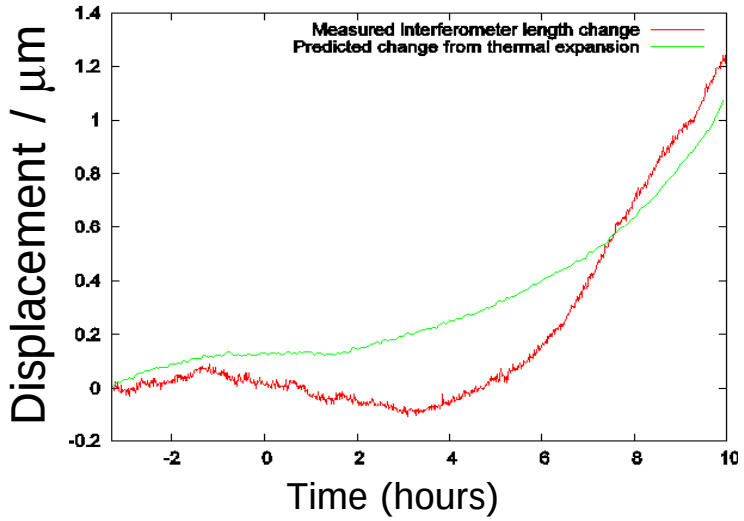


- Fixed frequency laser (FFI)
- Compact Launch: 25x25x15mm
- Test *shown here* with moving mirror
- The “real” setup will use retro-reflector
  - easier for setup!

FFI: Fixed Frequency Interferometry (OPD 400mm)

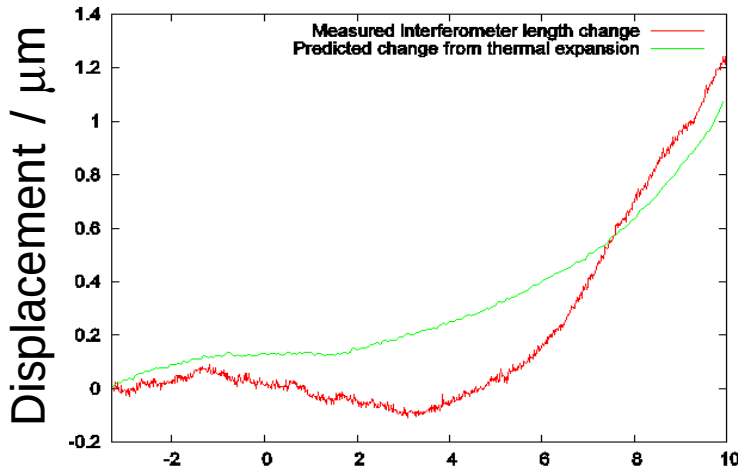


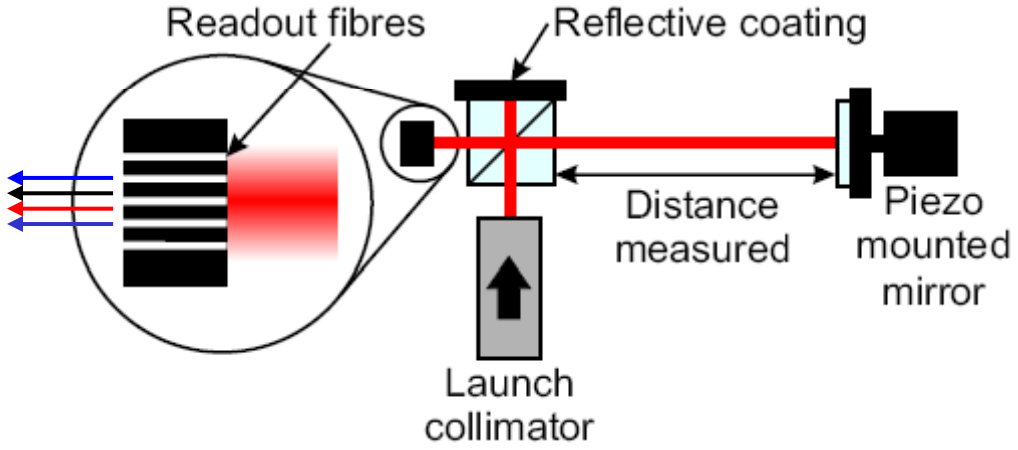


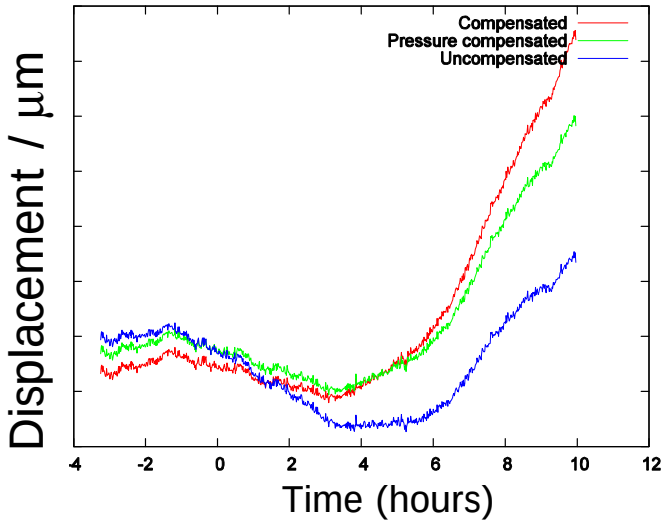


- Fixed frequency laser (FFI)
- Compact Launch: 25x25x15mm
- Test *shown here* with moving mirror
- First stationary mirror test :
  - resolution 5 nm demonstrated
  - to be improved with vaccuum
  - and laser frequency stabilisation

FFI: Fixed Frequency Interferometry (OPD 400mm)







- Fixed frequency laser (FFI)
- **Compact Launch: 25x25x15mm**
- Test *shown here* with moving mirror
- First stationary mirror test :
  - resolution 5 nm demonstrated
  - to be improved with vaccuum
  - and laser frequency stabilisation
  - temperature and pressure dependence look reasonable

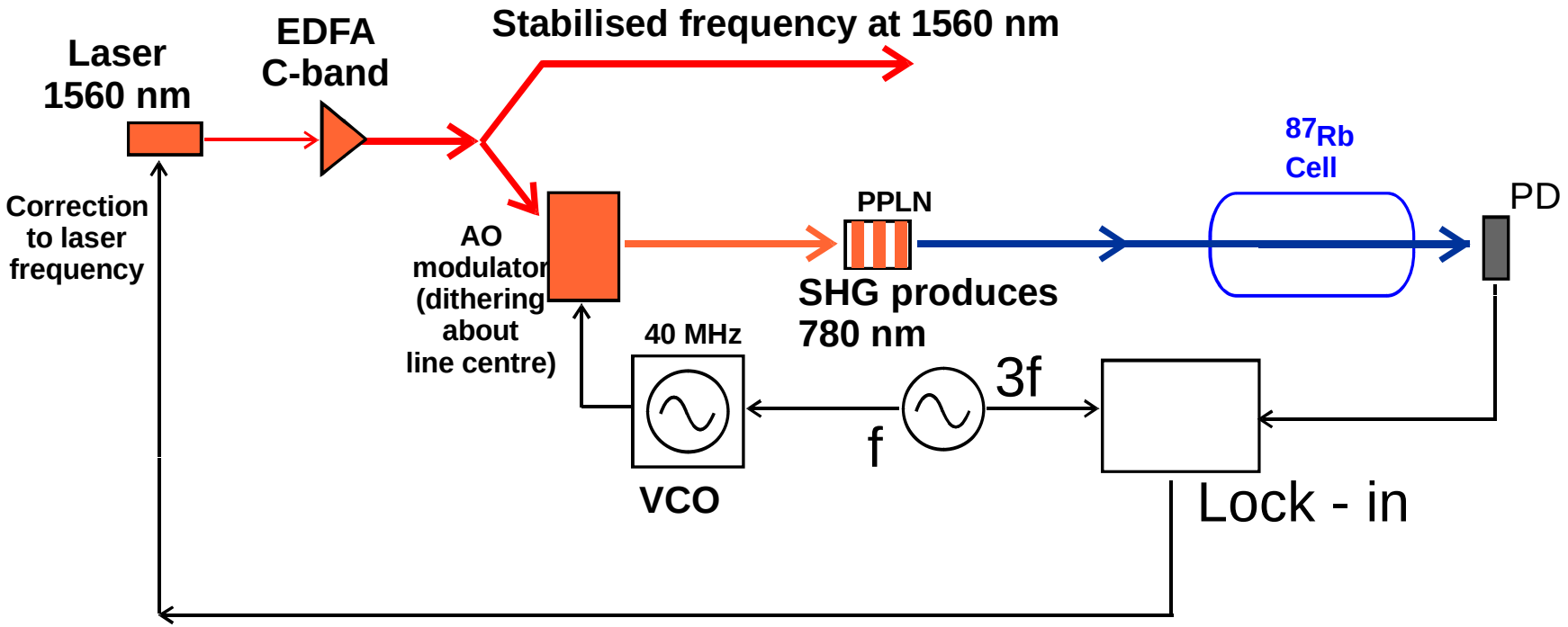
Frequency standard : ^{87}Rb D_2 line at 780 nm

- Take ultra – narrow line-width laser at 1560 nm
- Amplify with EDFA (erbium doped fibre)
- Frequency double in PPLN to produce 780 nm
- Use saturated absorption spectroscopy ^{87}Rb to pick out hyperfine structure
- Lock source laser to peak providing stability of a few kHz (compared to 1 MHz without Rb)
- At 10 m range, 1 MHz limits resolution to 5 nm
  - locked laser (theoretically 20 pm)
  - other errors will take over

Frequency stabilisation

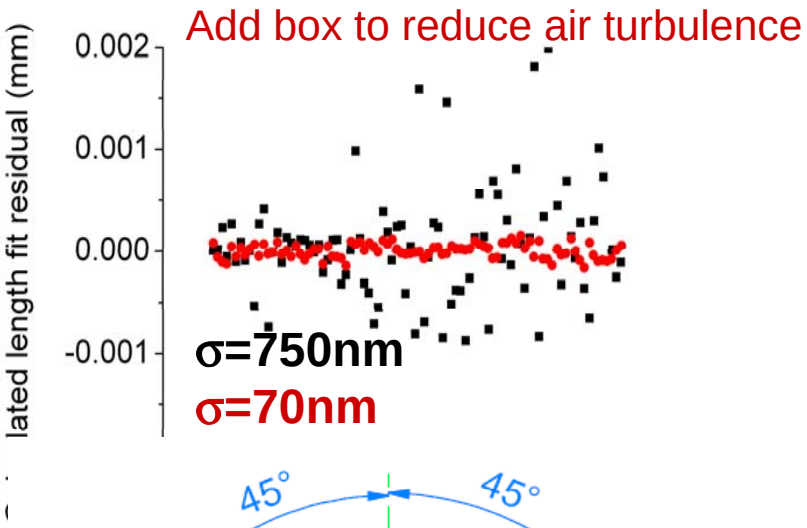
Frequency standard: ^{87}Rb D_2 line at 780 nm

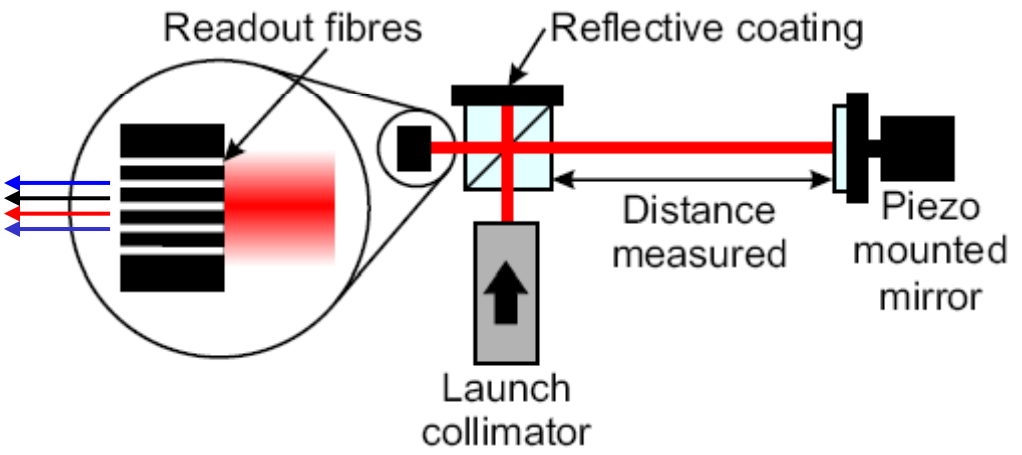
Simplified Schematic:

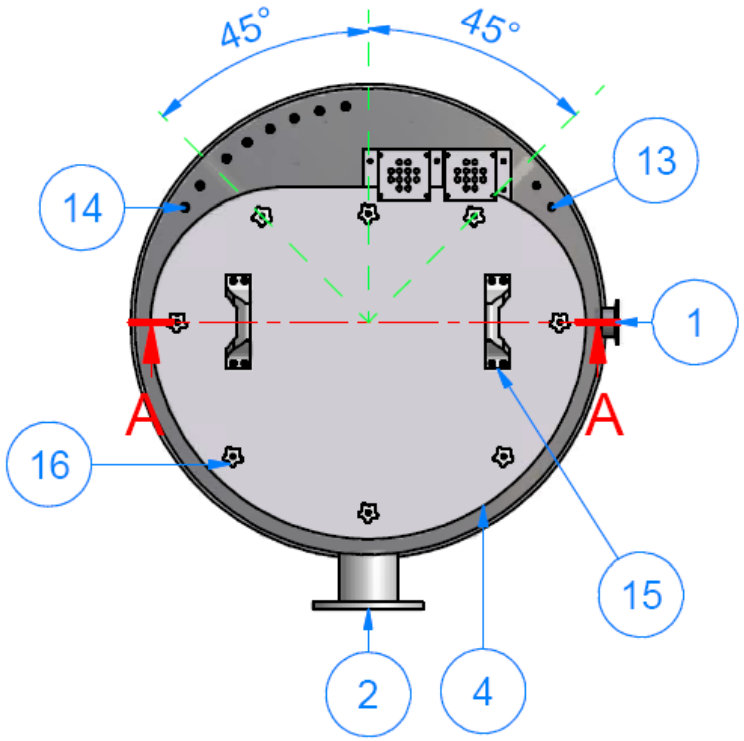


- Need 20 kHz stability for 1nm over distances of 10m.
- NPL done ~kHz.

FSI:Frequency Scanning Interferometry (OPD 400mm)

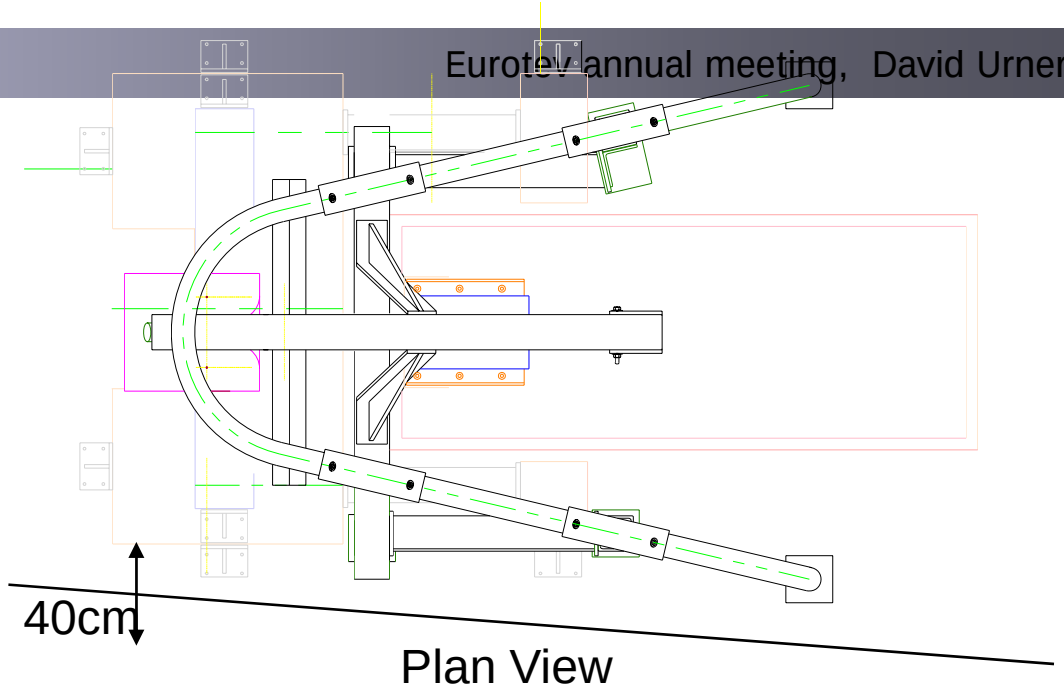




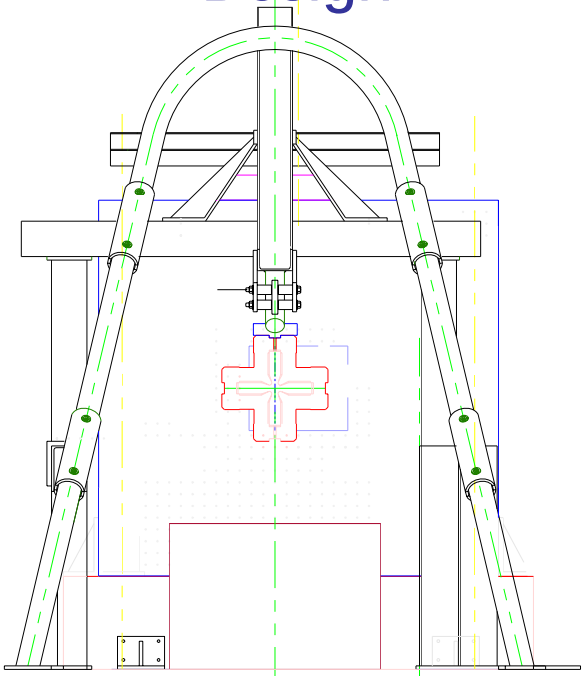


- Same interferometer can be used for FSI
- Better resolution by just covering interferometer with box
  - expect to do even better in vacuum!

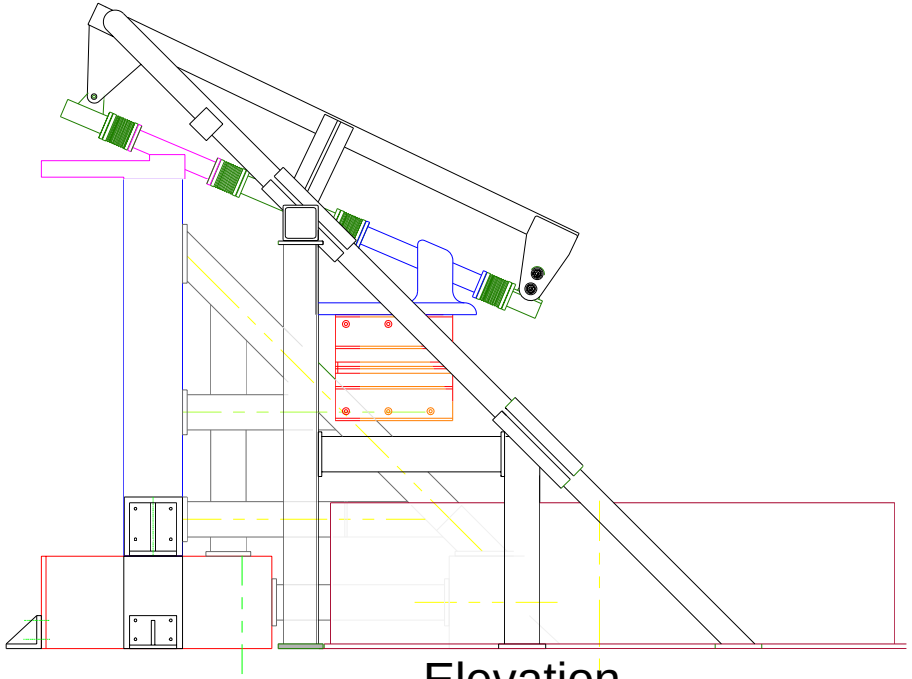
Deployment of MONALISA at ATF2 Goal: measure mechanical motion of QD0 and IP instumentation Overview of Current Design



Plan View



End View



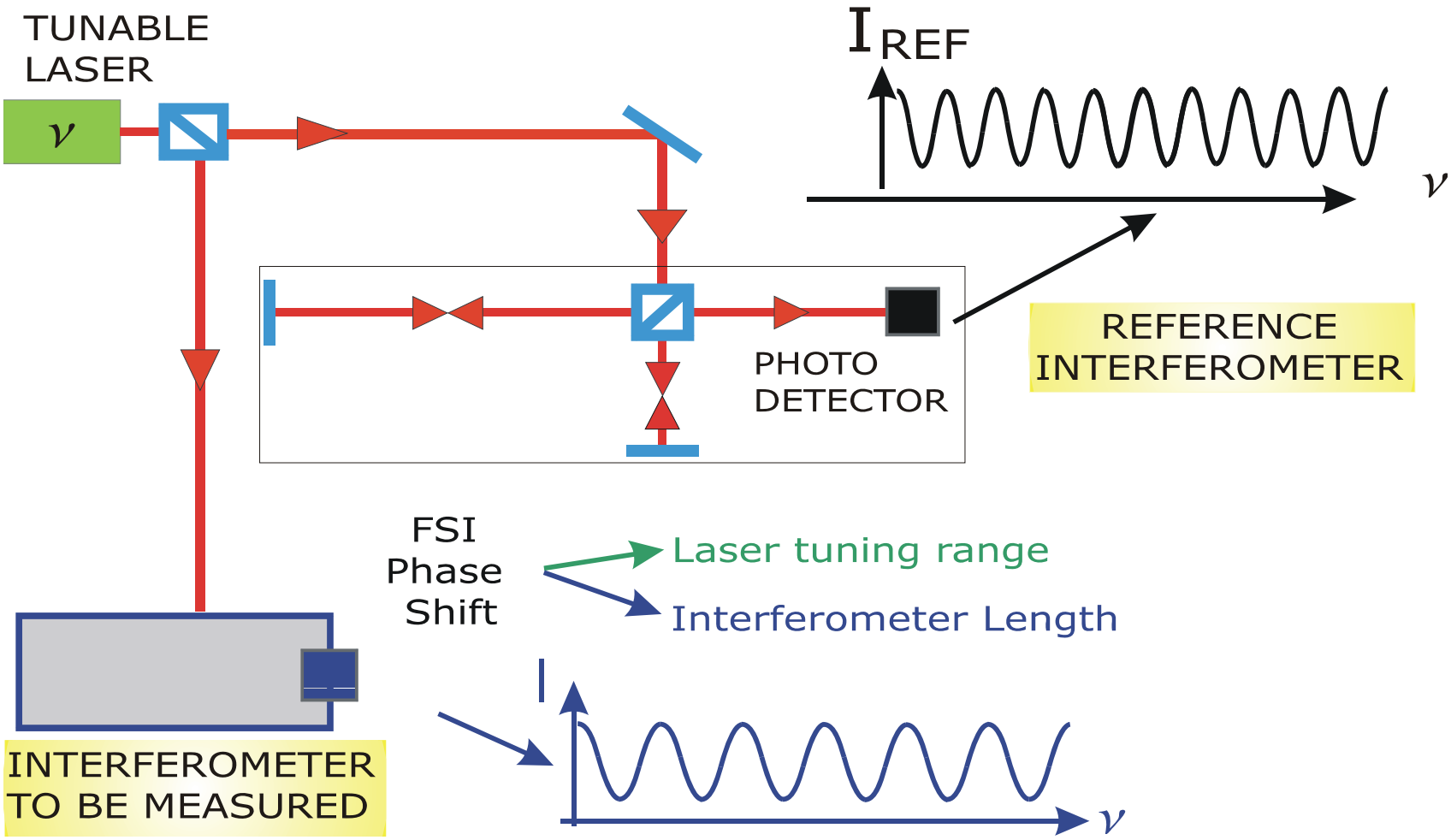
Elevation

Plans

- Combine FSI and FFI in same measurement
  - Should achieve nm resolution
- Laser frequency stabilisation with ^{87}Rb standard
  - Required for stable FFI
- Demonstrate nm resolution in vacuo
  - Install interferometers into vacuum drum
- Continue analysis software collaboration with LiCAS
  - Analysis framework
  - Adapt LiCAS readout hardware / software
- Develop CSM
- Monitor ATF2 IP

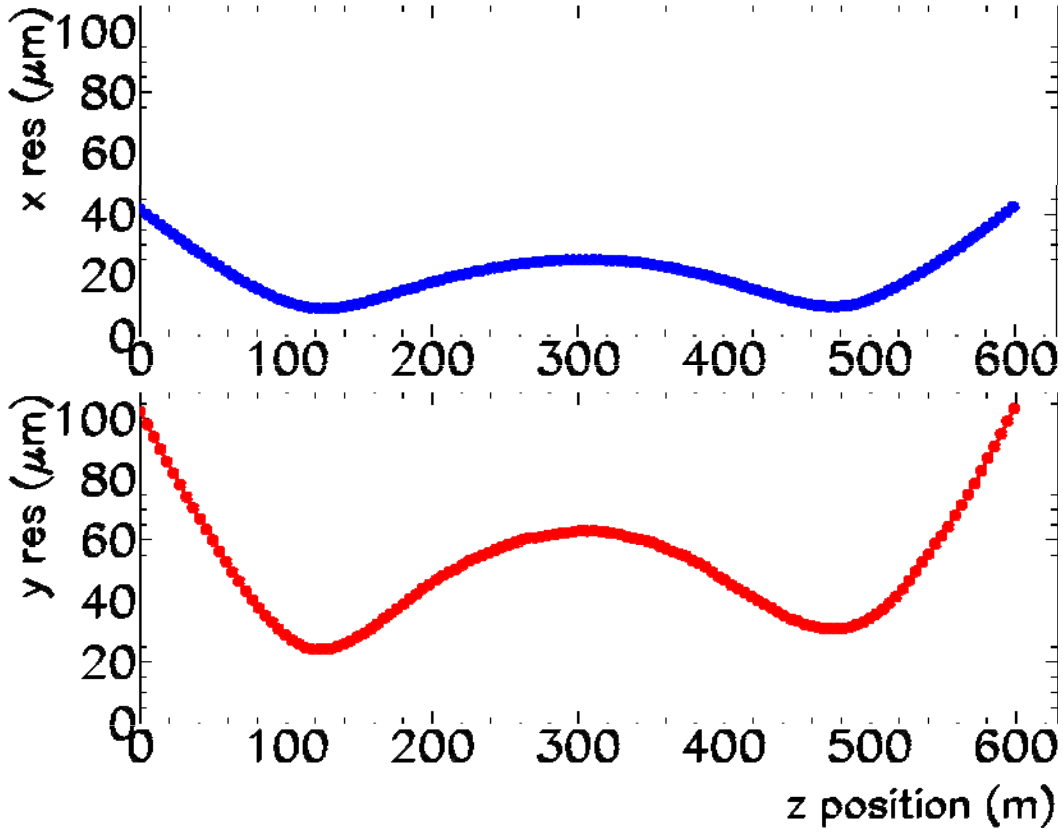
END

FSI: Frequency Scanning Interferometry



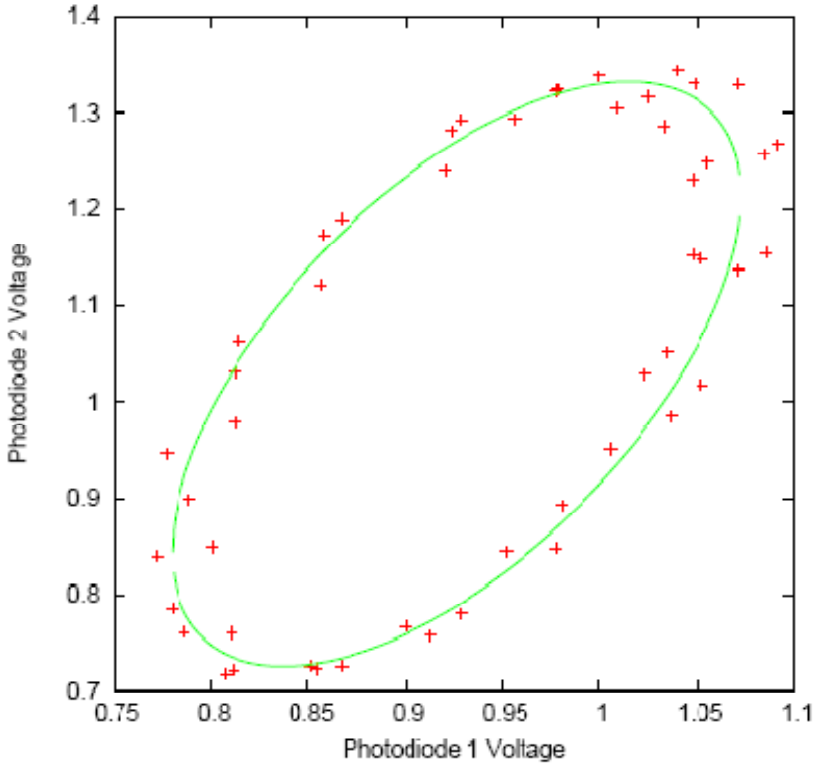
LiCAS Achievements to date

- Performance Simulations
  - Survey simulations over full linac length have been performed and exceed requirements (see below)
  - linac alignment simulations interfaced to accelerator simulations (PLACET)
  - alternative methods for large scale simulations and reconstruction of tunnel co-ordinates are in the making

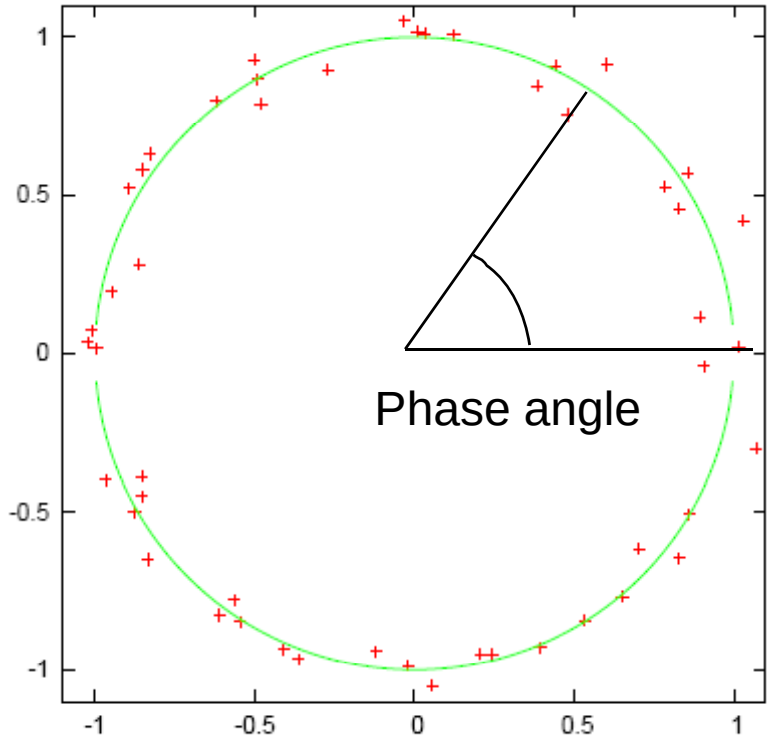


Simulated accuracy of main linac survey over 600m

- Novel technique for multi-fibre phase



Signals from 2 fibres



Normalise onto unit circle