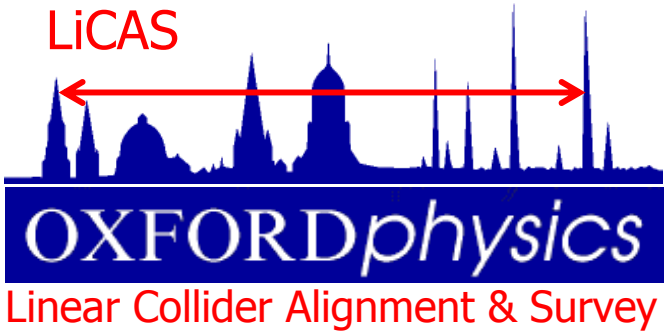
LiCAS

(Linear Collider Alignment and Survey)

Status "Highlights"

Armin Reichold

Warsaw University



Overview

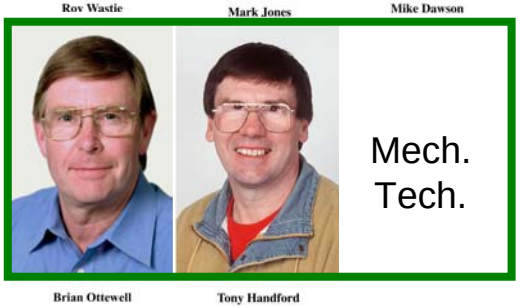
- Aims and measurement principle (reminder)
- Status:
  - Reference Interferometers
  - FSI measurement technique
  - FSI measurement results
  - Electronics and DAQ
  - Service Cars and Drive Tests
  - DESY tunnel
  - Measurement Units
  - Measurement Cars
  - LSM
  - Software and Simulations
- Future Plans
  - Short term
  - Long term

LiCAS People

JAI @ Oxford

Academic & post doc

electronic & DAQ



mechanic

student*ic* (PhD)

Project & Masters Students

Robert Apsimon
Peter Baker
Ken Chuang
Thomas Zlosnik
Simon Wilshin
Chris Glassman
James Robinson
Pauline Sliwa
Anna Lewis

DESY

- Johannes Prenting
- Markus Schloesser
- Ernst-Otto Saemann
- Daniel Kaemtner

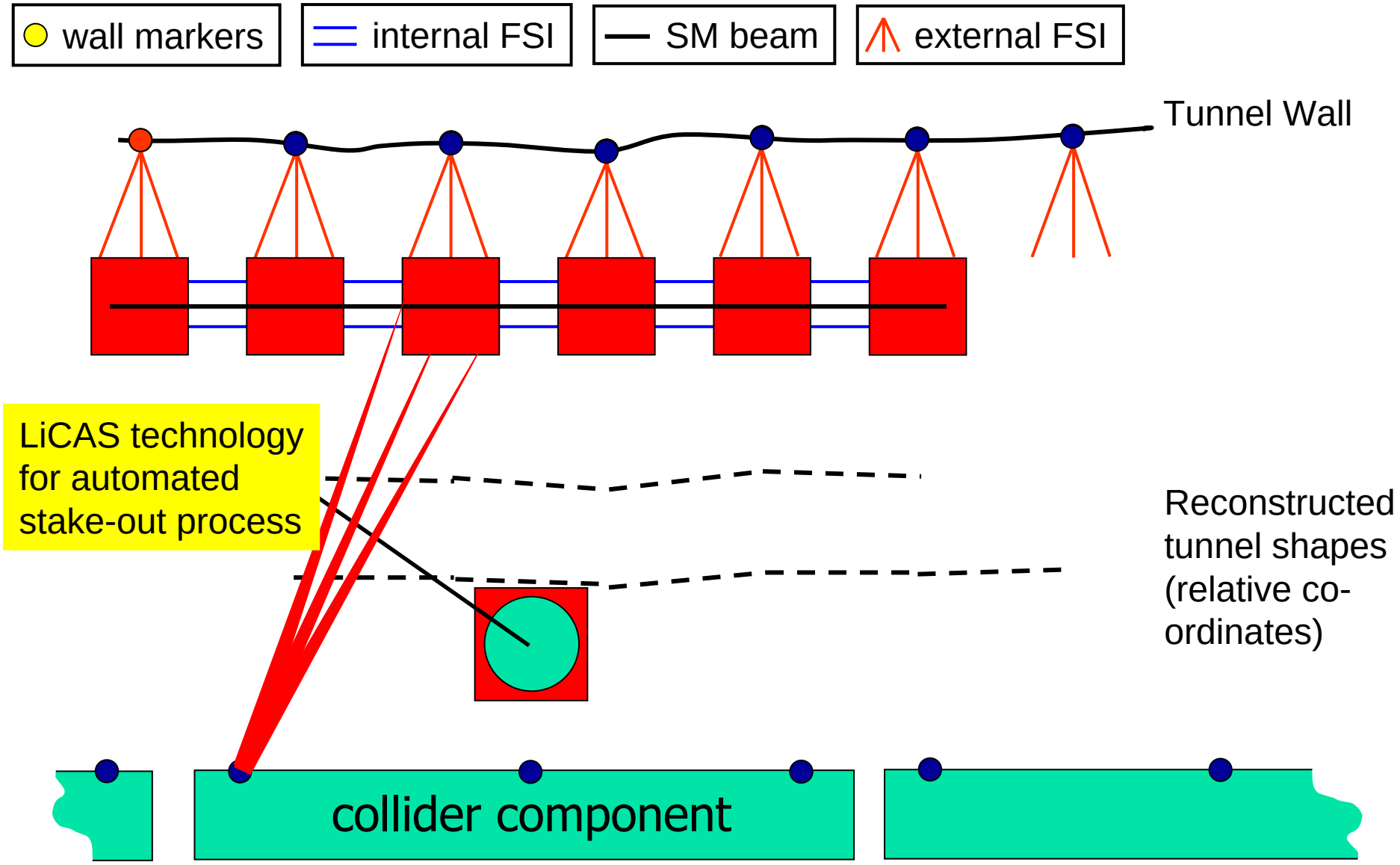
Warsaw

Bartek Szczygiel student

Problem & Aim

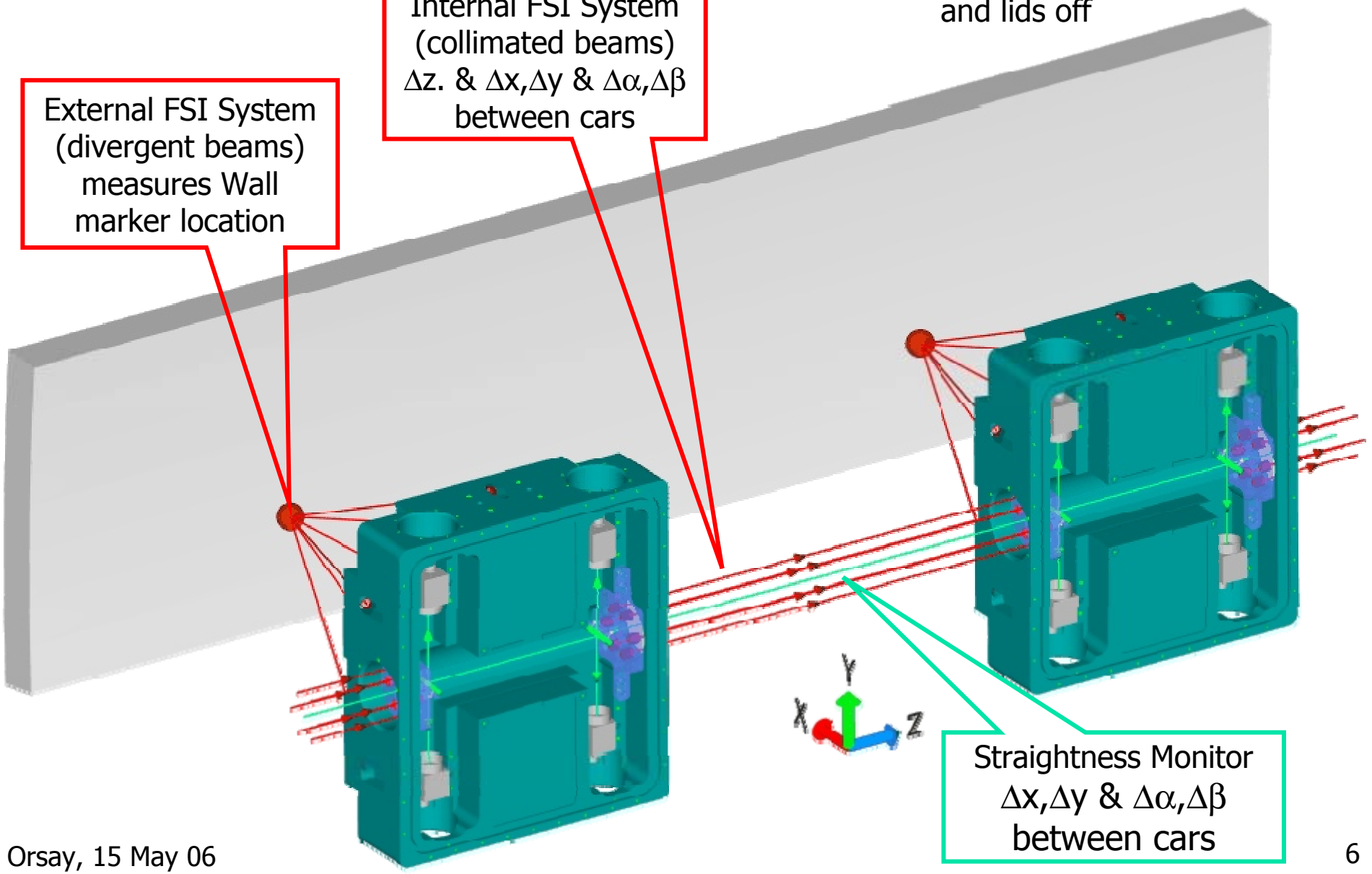
- Problem (in a *peanut* shell):
  - ILC linac requires survey of components to 200 μm over distances of 600 m (vertical)
  - The survey should be "sufficiently fast"
  - Existing technology can not do this
- Aim
  - Develop a Rapid Tunnel Reference Surveyor (RTRS) to demonstrate feasibility of "LiCAS style" ILC survey
  - Build RTRS prototype and operate in a test tunnel at DESY as demonstrator and R&D platform
  - Current RTRS is aimed at the straight sections of the ILC

RTRS concept



Measurement Principle

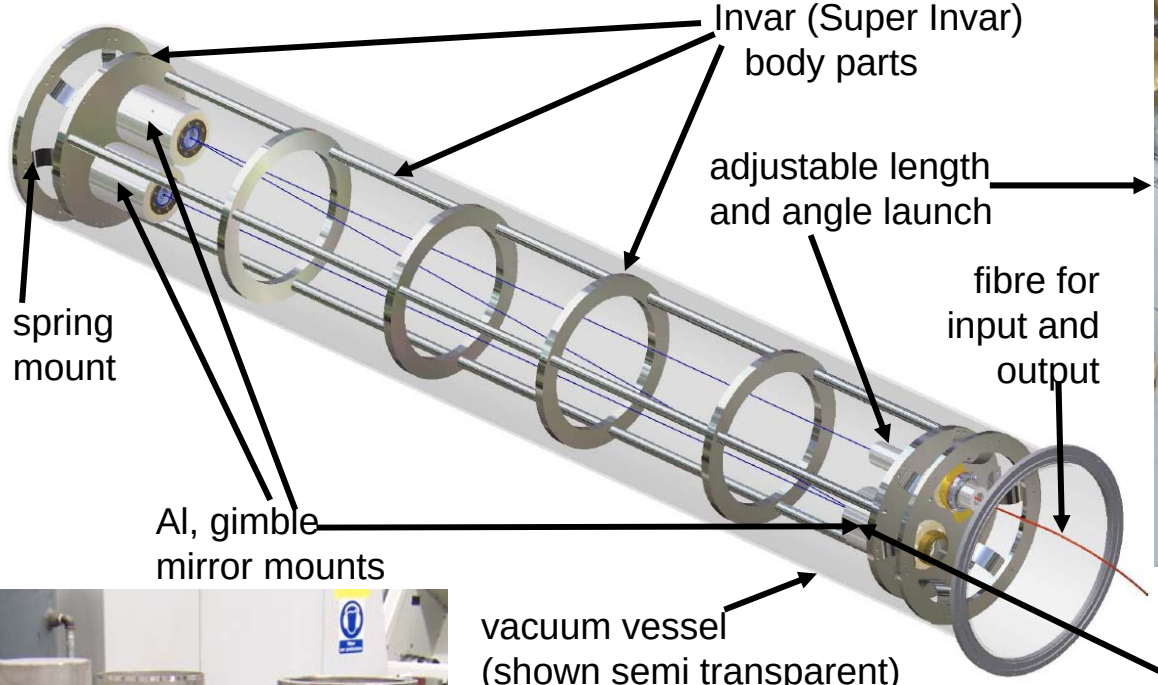
Two measurement units without vacuum connections and lids off



Status of LiCAS

- All parts of the project (Electronics, Mechanics, LSM, FSI) are involved in end of series production or sub-system assembly, calibration.
- Shipment of service cars to DESY in 14 days
- Shipment of measurement units in 2 months
- I can only show “highlights” of electronics and mechanics status.

Reference Interferometers

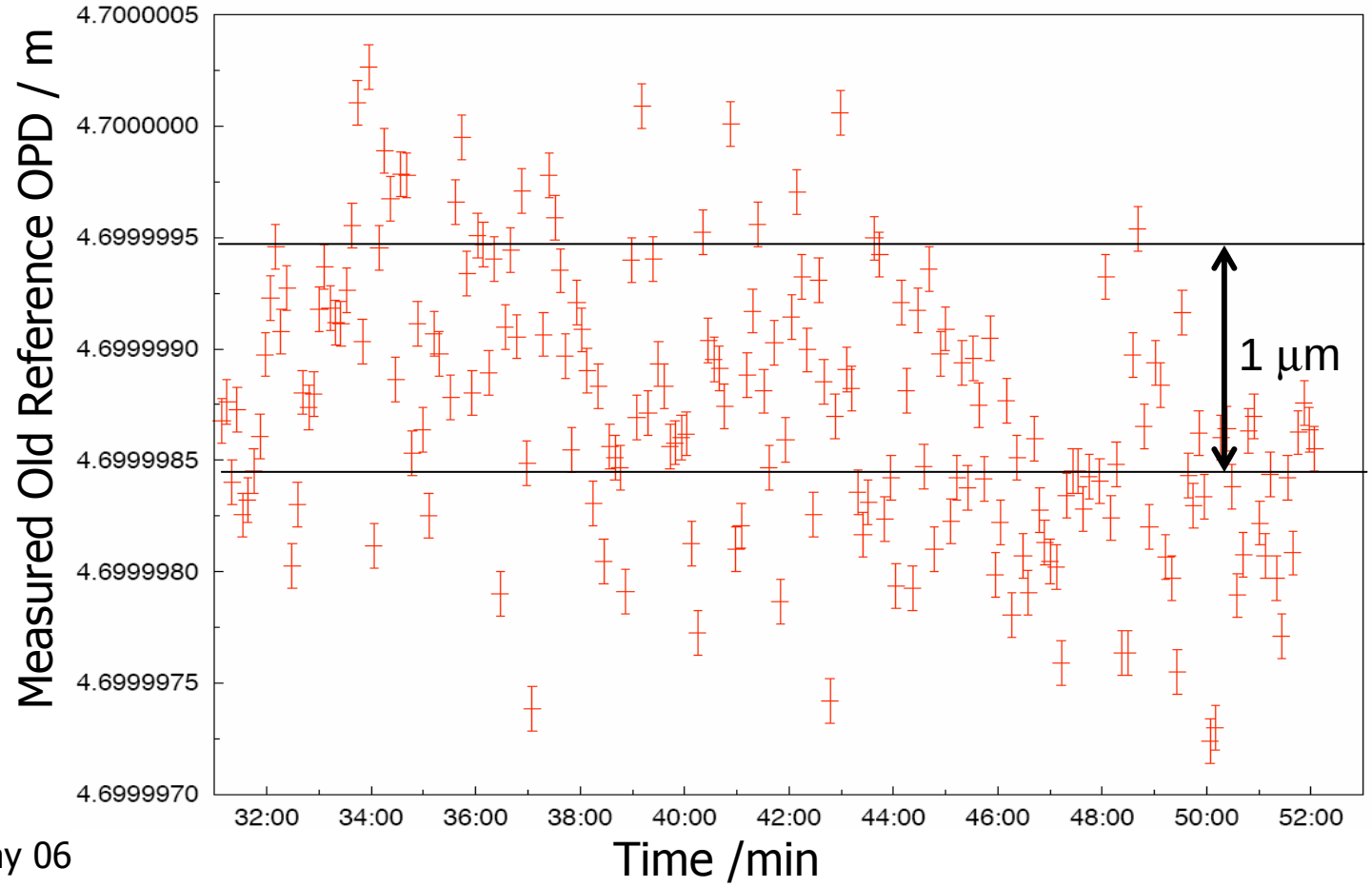


- Passive thermal shield around vac. chamber
- Thermal expansion tuning using temperature swing from +70 to -70 C
- Vibration damped mounts
- Aged through thermal cycles
- 16 accurately calibrated and aged temperature sensors
- Lots of tools for optimising mirror alignment
- Build 4 interferometers to study systematics

FSI results (John Green)

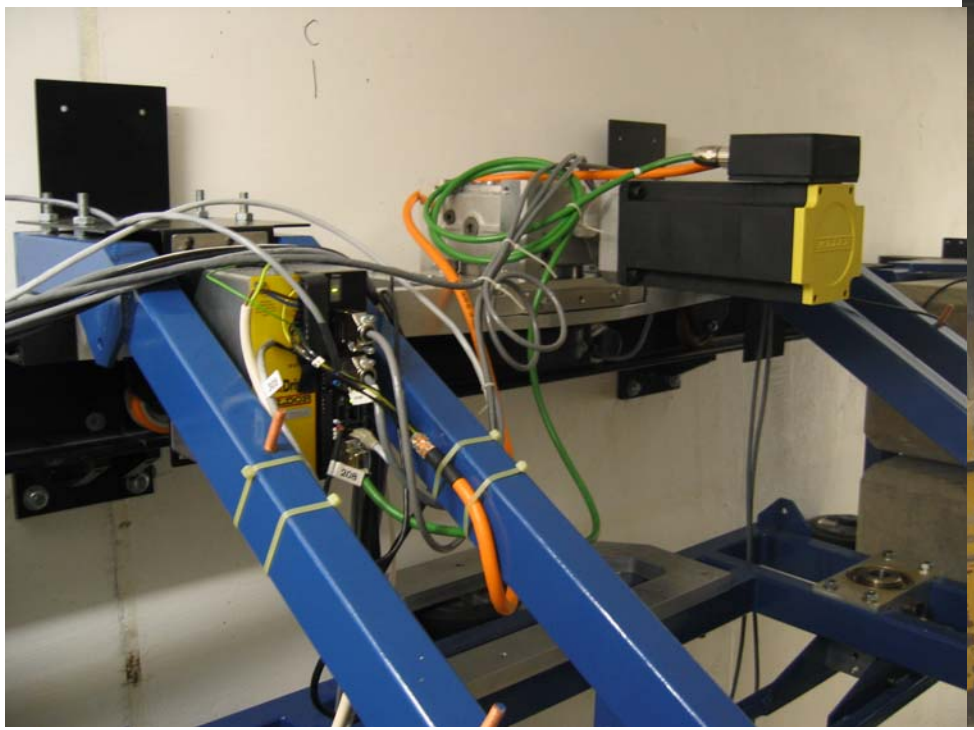
- Using old Michelson style Ref. Interferometer
- Passive thermal shield, operates in air, no expansion compensation, steel table
- OPD measured over 25 min

- No offline corrections for thermal expansion
- OPD = 4.6999989 ± 5.94×10^{-7} m
- This is sufficiently sensitive
- Expect big improvements from new reference interferometers



Service Cars

- Oxford drive tests on 25m rail
- 3 service + 1 master car + 3 "dummy" measurement cars as pay load
- Developed torque synchronisation software
- Three schemes tested
- A week to complete

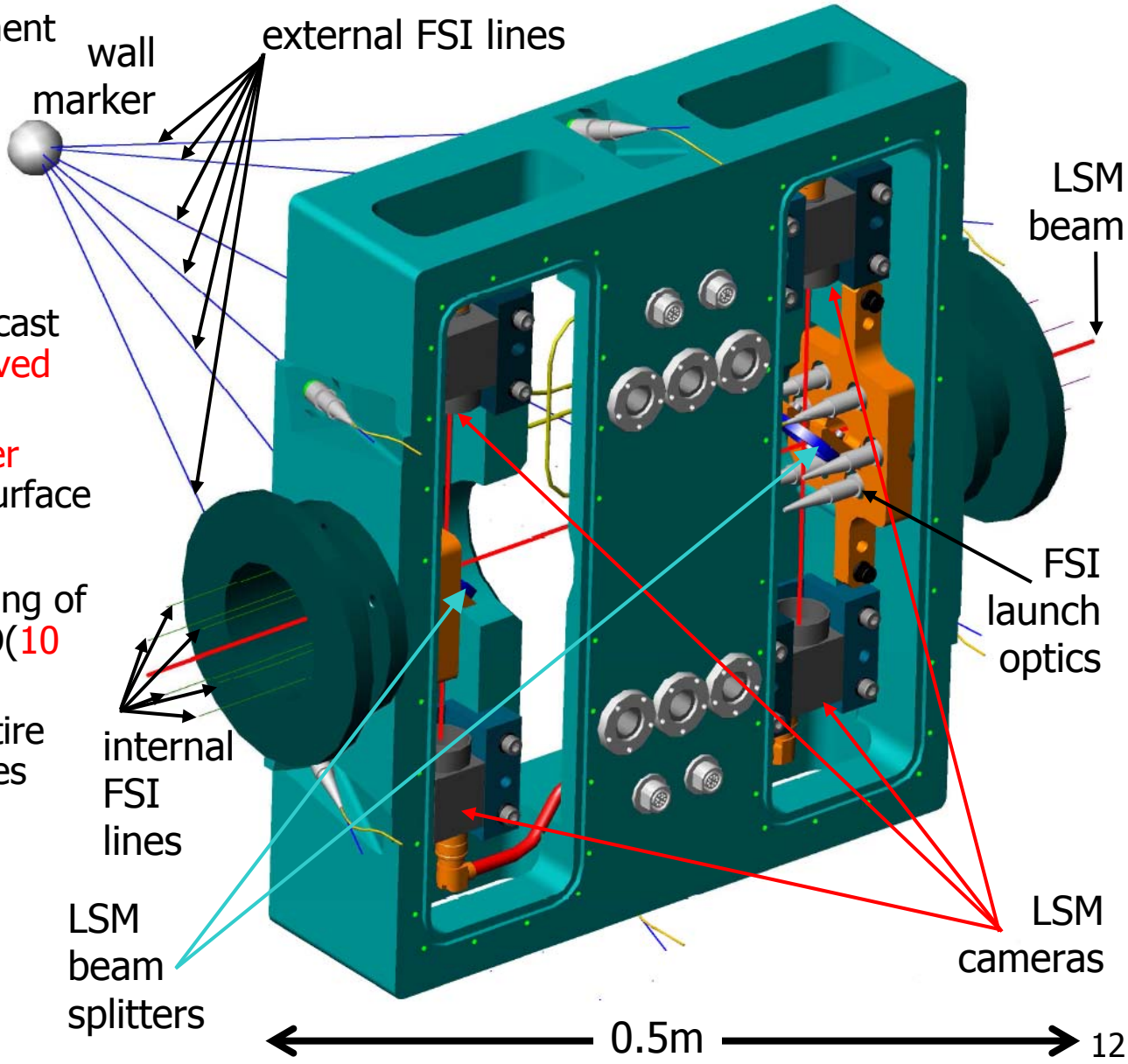


DESY tunnel

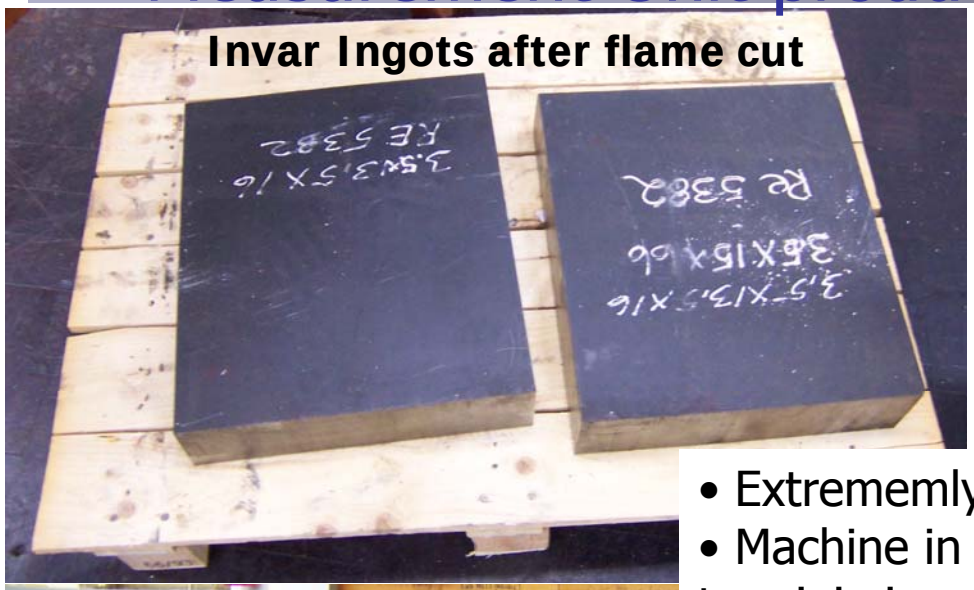
- 55m long
- stable walls
- air conditioning
- WLAN & LAN
- safety systems
  - air lock access
  - End stops
  - Laser interlocks
- Rail installed
- Power chain installed

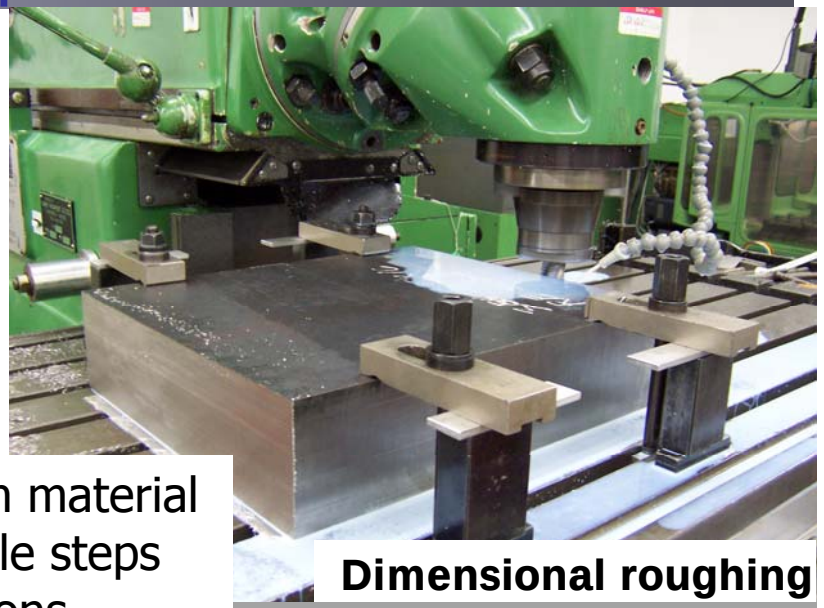
Measurement Unit

- Design maxime:
  - Stability of active element positions and OPDs
  - Calibratability
  - Machinabiliy
- Stability:
  - Unit under vacuum
  - Machined from single cast of multiply stress relieved Invar
  - Optimised heat transfer paths from CCD's to surface
- Calibratabiliy
  - High precision machining of active element seats O(10 μm)
  - CMM survey of the entire unit and sub-assemblies

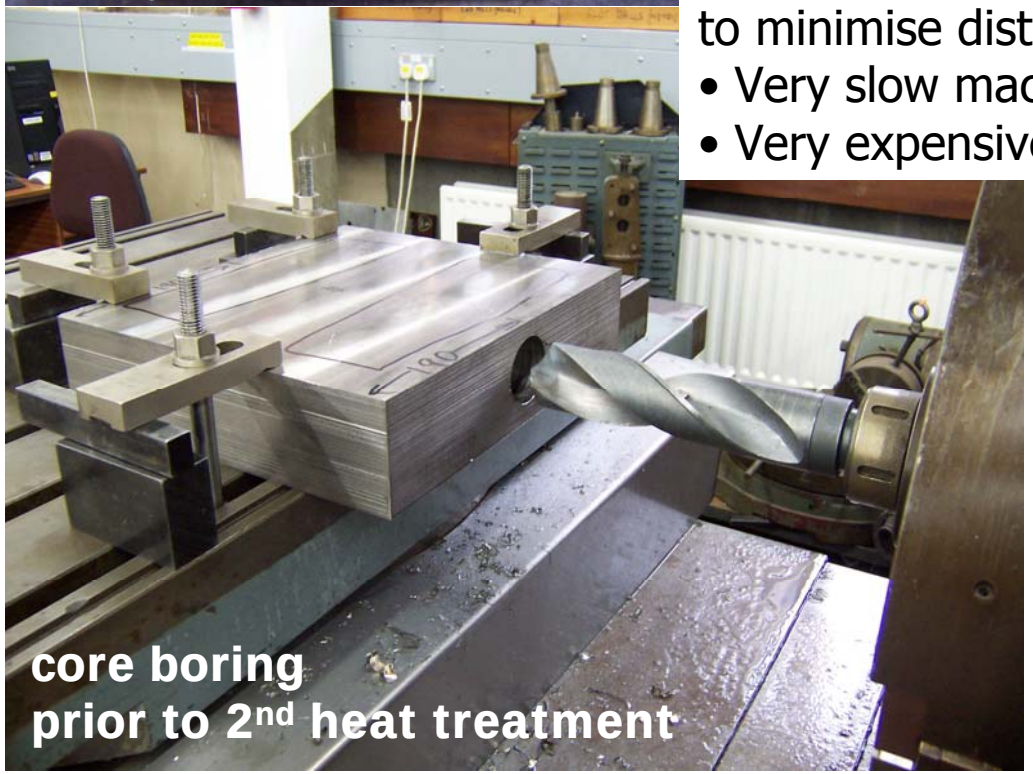


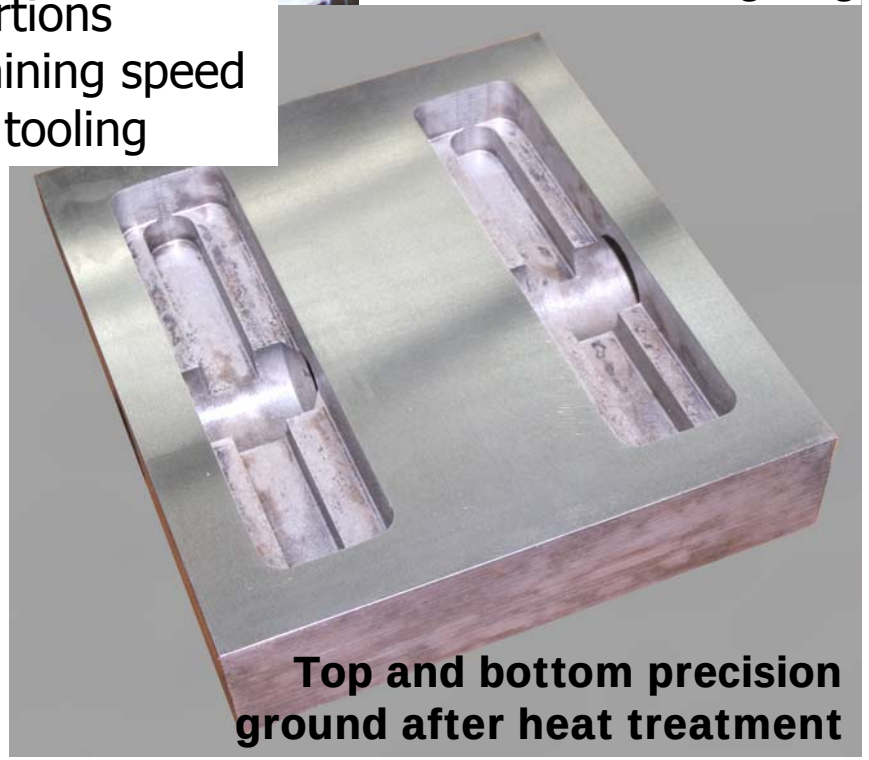
Measurement Unit production



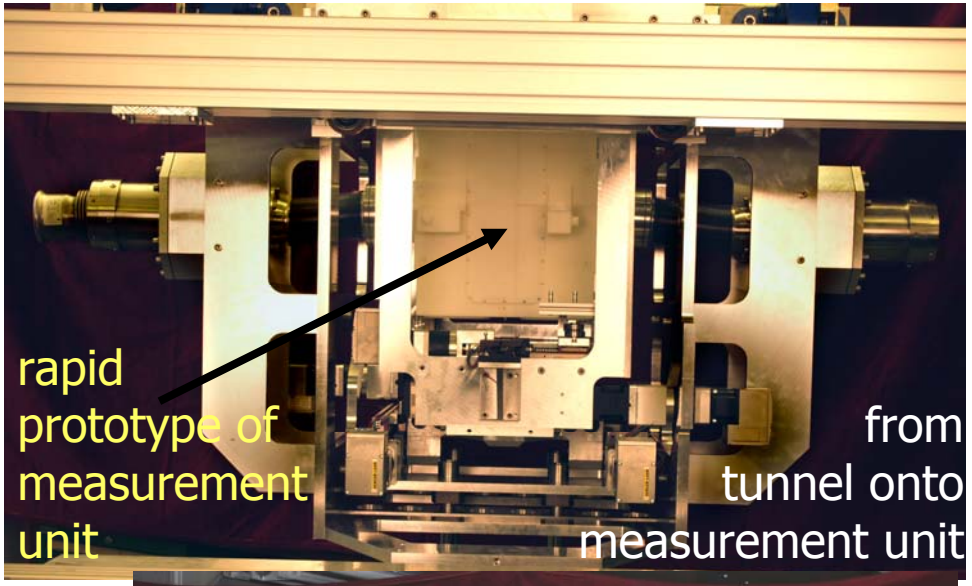


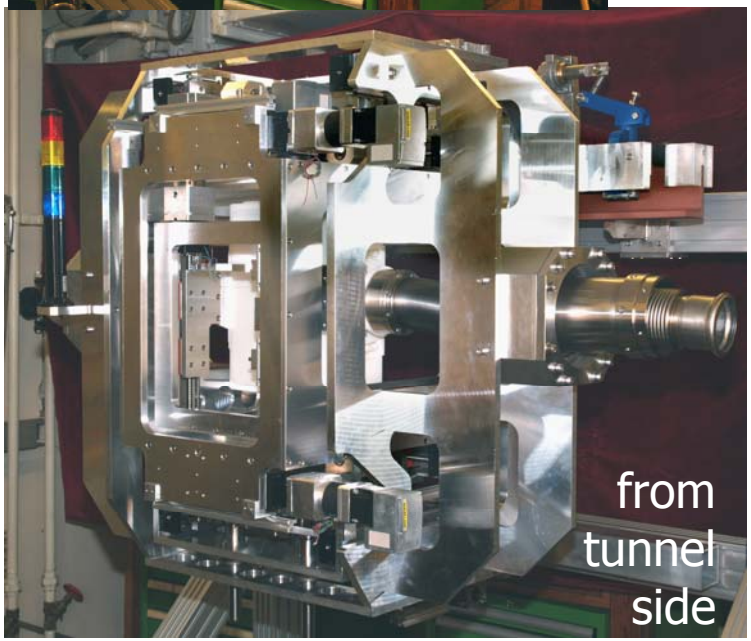
- Extrememly tough material
- Machine in multiple steps to minimise distortions
- Very slow machining speed
- Very expensive tooling

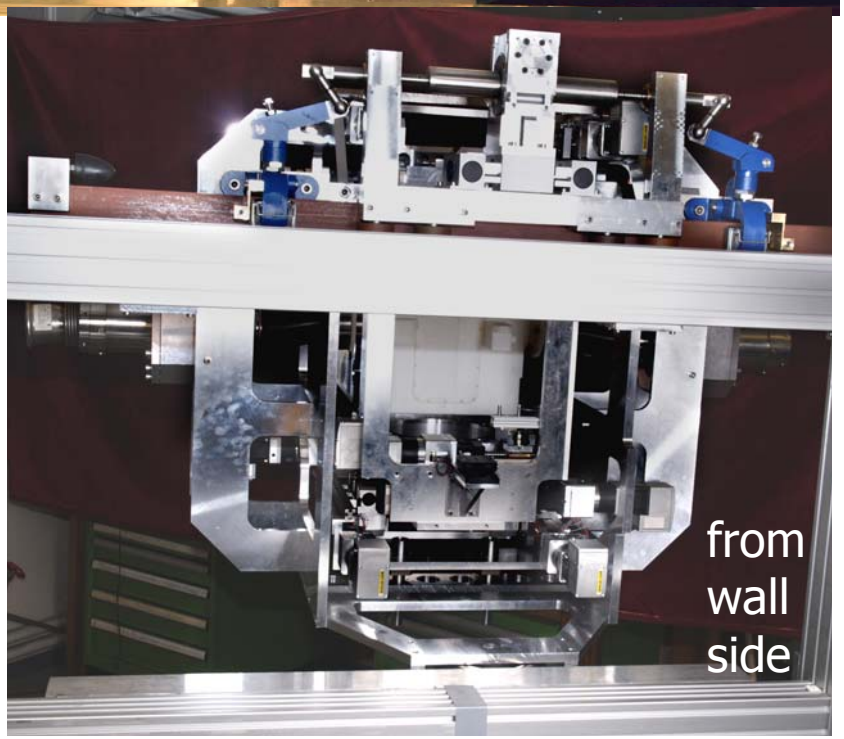




Measurement Cars*



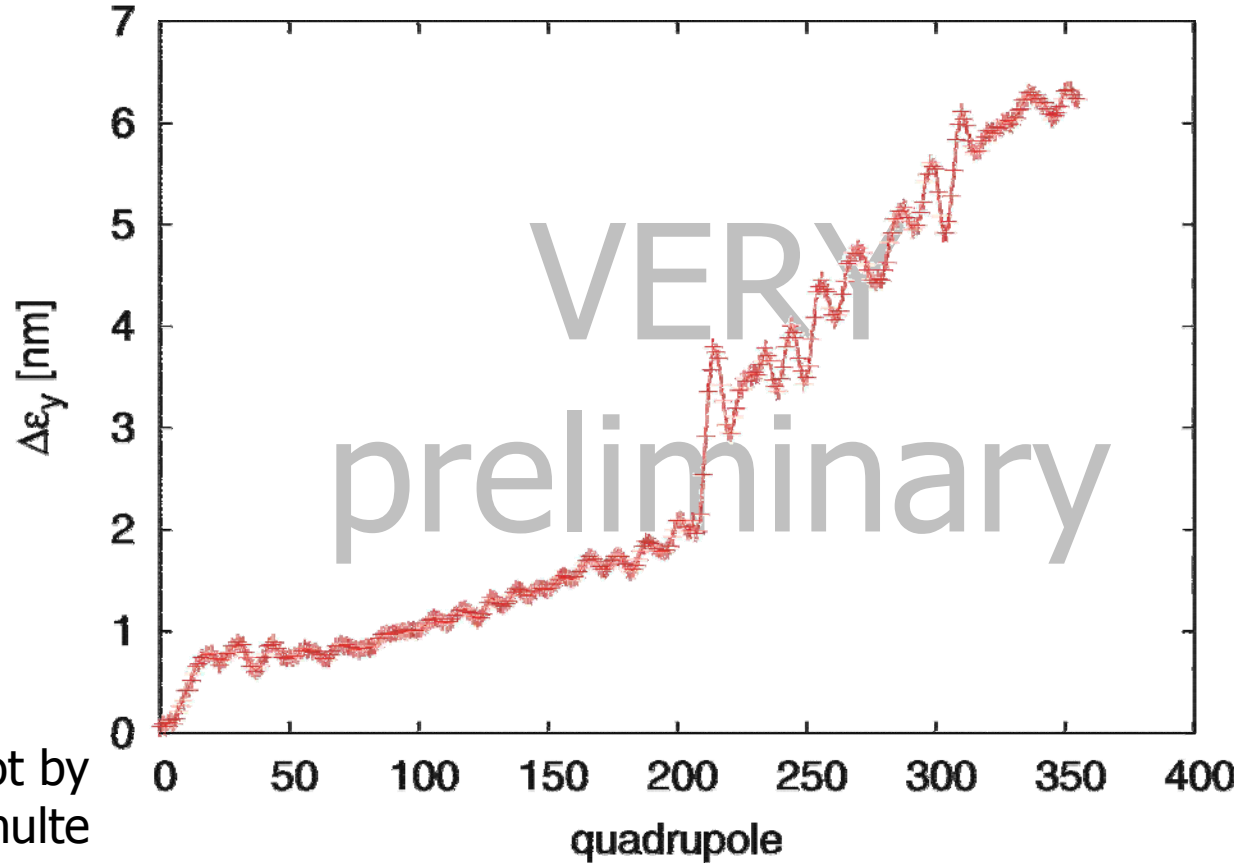




Accelerator Simulations

- Currently dormant due to prototype production
- To be continued by current first year graduate student
- Interface from performance simulations to PLACET
- Preliminary beam based alignment study using LiCAS-aligned linac (this slide)

- Emittance growth vs. Quadrupole number
- Long range Licas survey errors only
- ongoing study



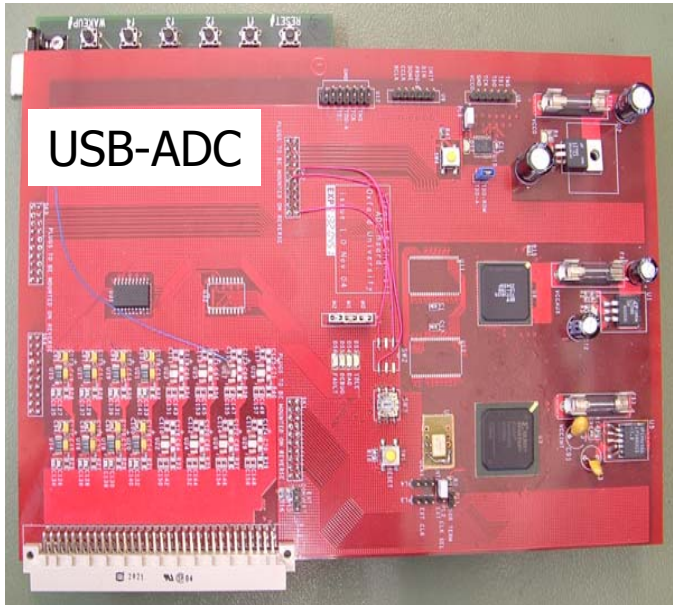
plot by D. Schulte

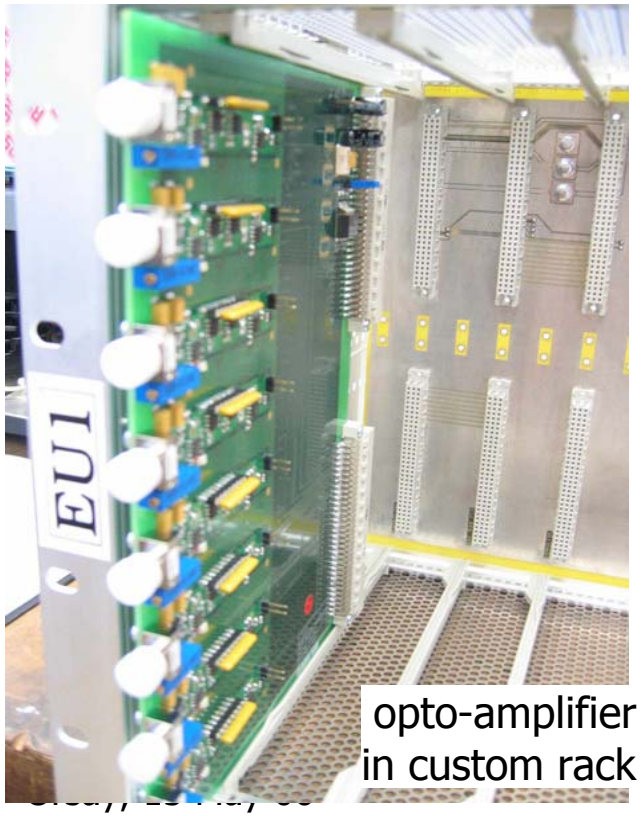
The End

Backup Slides

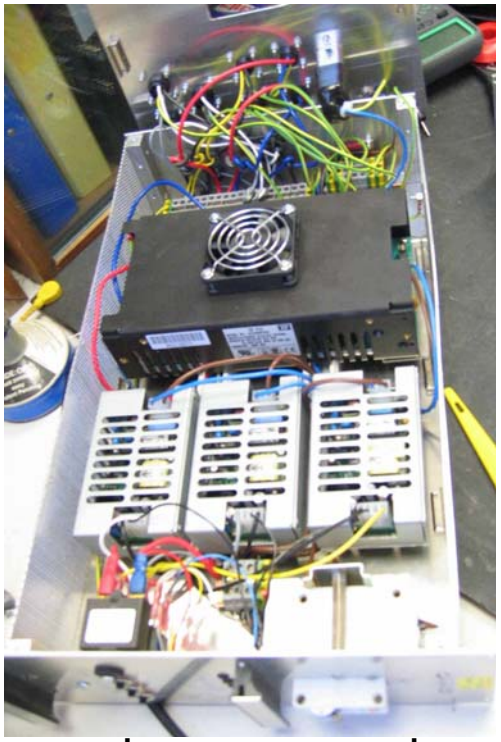
Electronics Status

- Custom Opto-detection & amplification, ADC & USB-DAQ for FSI (50 chan.) in final tests, some firmware still improving
- Readout for 12 LSM CCD cameras finished
- Trigger & clock distribution system finished
- RTRS propulsion control finished
  some software tuning remaining

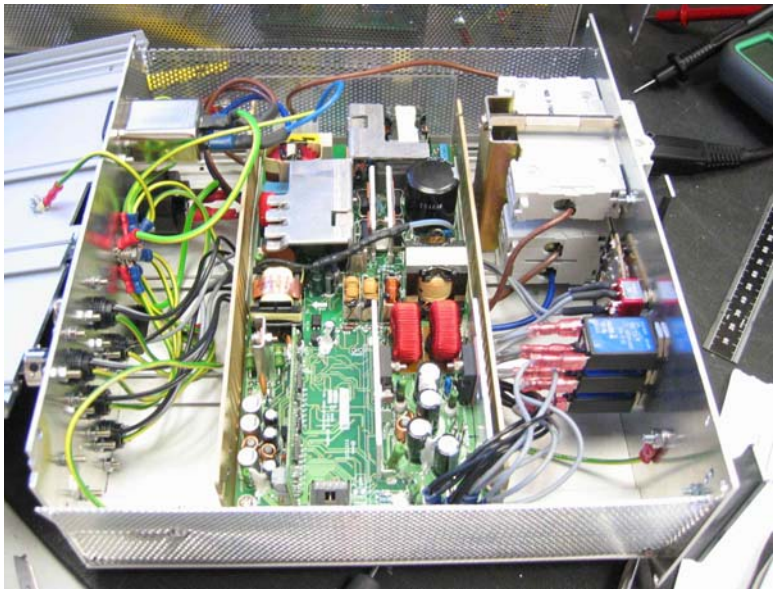




opto-amplifier in custom rack



rack power supply



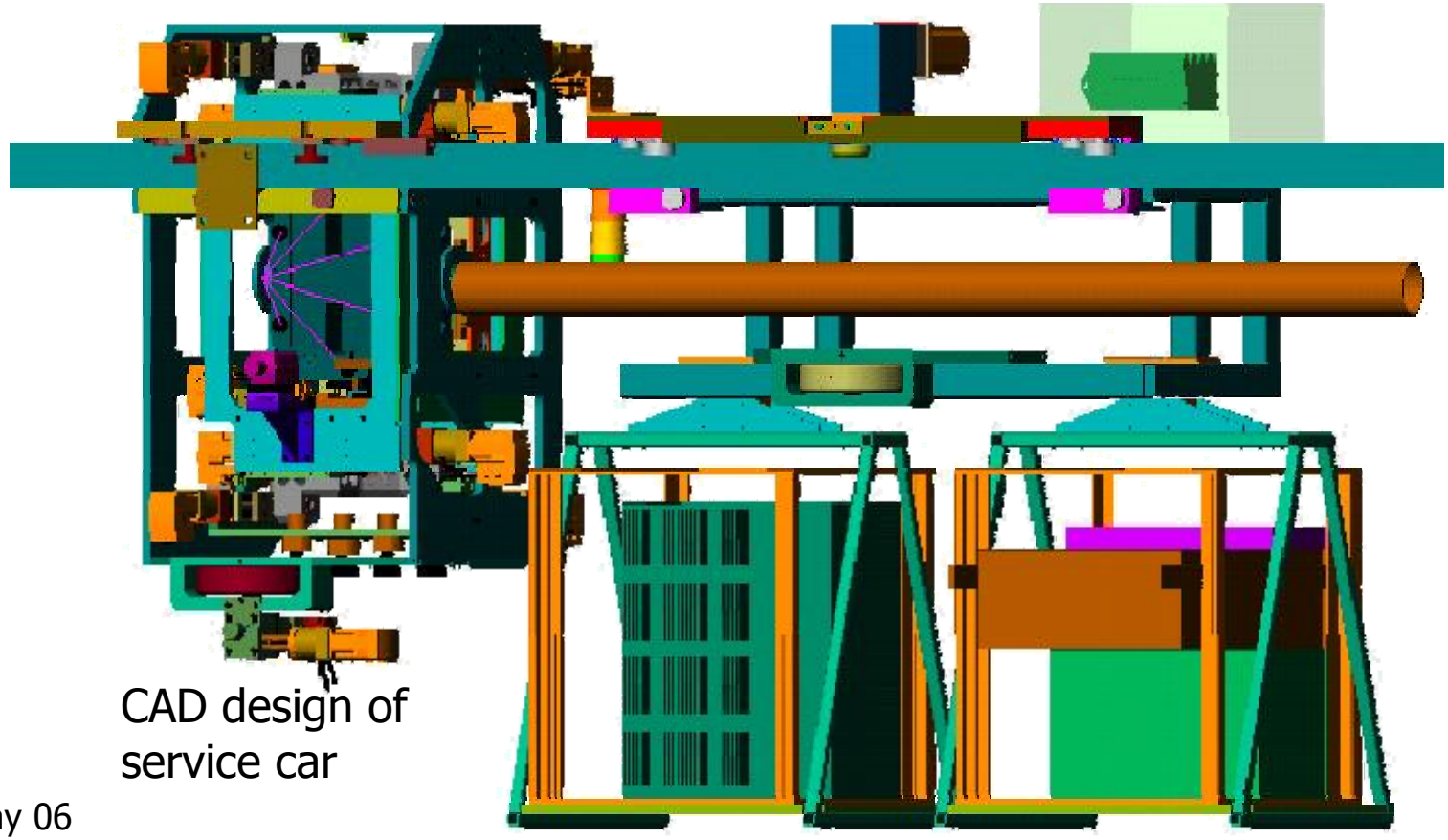
interlock and security switch unit

Reference Interferometers

- Provide length reference for FSI (OPD=10m bit longer then longest measurement)
  - Folded path to keep external dimension low
  - Absolute length calibration by measurement of frequency range of FSI scan through high accuracy, pre-calibrated acetylene absorption cell
- Must have long term stable length to O(10^{-7})
  - Extremely rigid design for optical mounts
  - Fully stress relieved parts
  - Age the interferometer through many temperature cycles
- Must have temperature invariant length to O(10^{-8}/K)
  - Evacuated optical cavity with Invar (SuperInvar) spacers
  - Expansion tuned using counter expanding AL parts of finely adjustable length
  - Good thermal contacts between all parts
  - Tuning of counter expansion length:
    - Stabilise temperature of one interferometer to O(0.3K)
    - Sweep temperature of the other from +70C to -70C
    - Measure length changes of the swinging interferometer wrt to the stabilised one and adjust length accordingly
- Must be verifiable
  - Use 4 Interferometers (2*Invar, 2*Super Invar) to get differrent systematics
  - Slightly differrent OPDS (8m and 10m)
  - One is on the train the other is off in a stabilised room
  - Frequently compare on-train with off train and Invar with Super Invar
  - Highly accurate calibrated temperature measurement system to keep monitoring length vs. temperature

Service Cars

- Each measurement car has one service car
- Service car carries:
  - DAQ-electronics rack with PS, FSI readout, stepper motor control, temperature and pressure readout
  - DAQ-server with LSM framegrabber
  - propulsion units with slave controller
- One additional master car for central train control & lasers



CAD design of service car

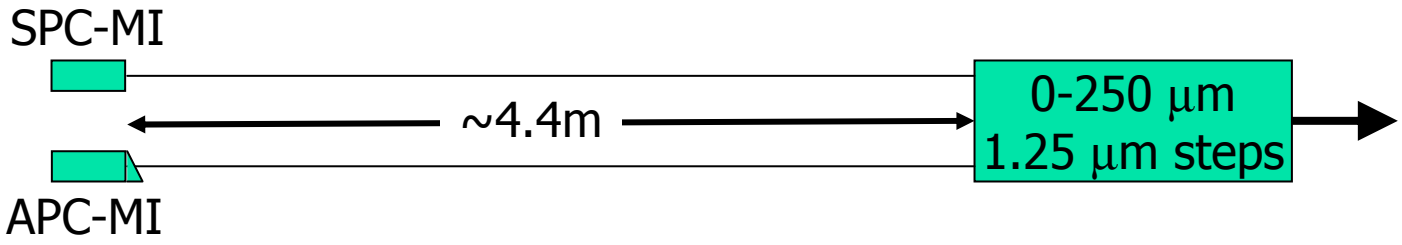
Measurement Cars

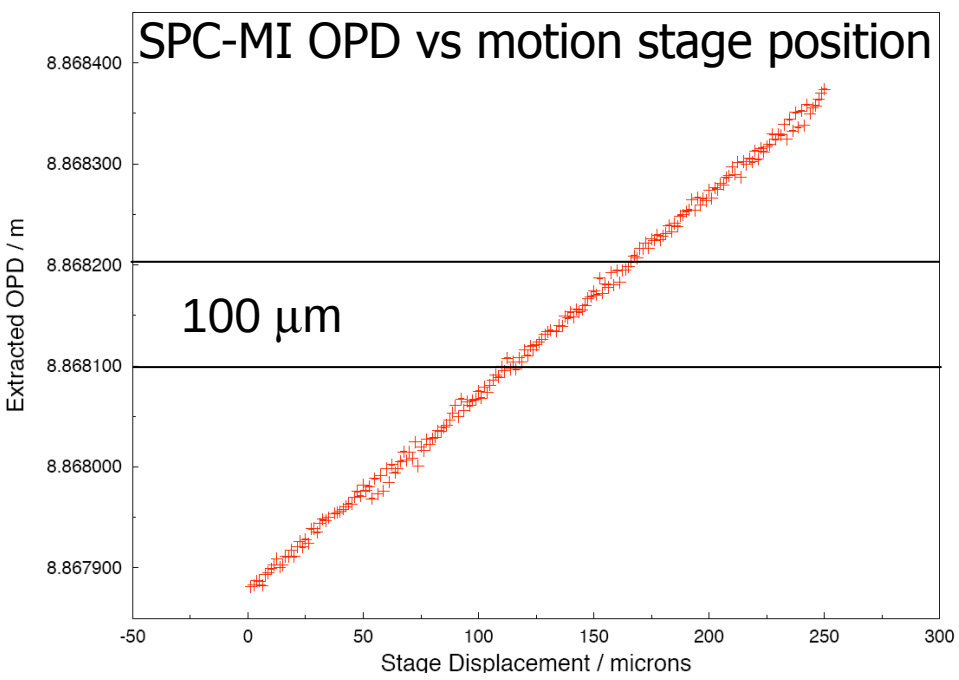
- 3 Units built at DESY (finished)
- 6 DOF for position of measurement unit to:
  - Adjust to wall marker
  - Adjust to neighbouring cars
- Total of 12 stepper motors and stages controlled via CAN-bus
- Extremely rigid frame for:
  - Position repeatability
  - Vibration stability
- Mechanical decoupling from noise in service car
- Clamps to rail while measuring

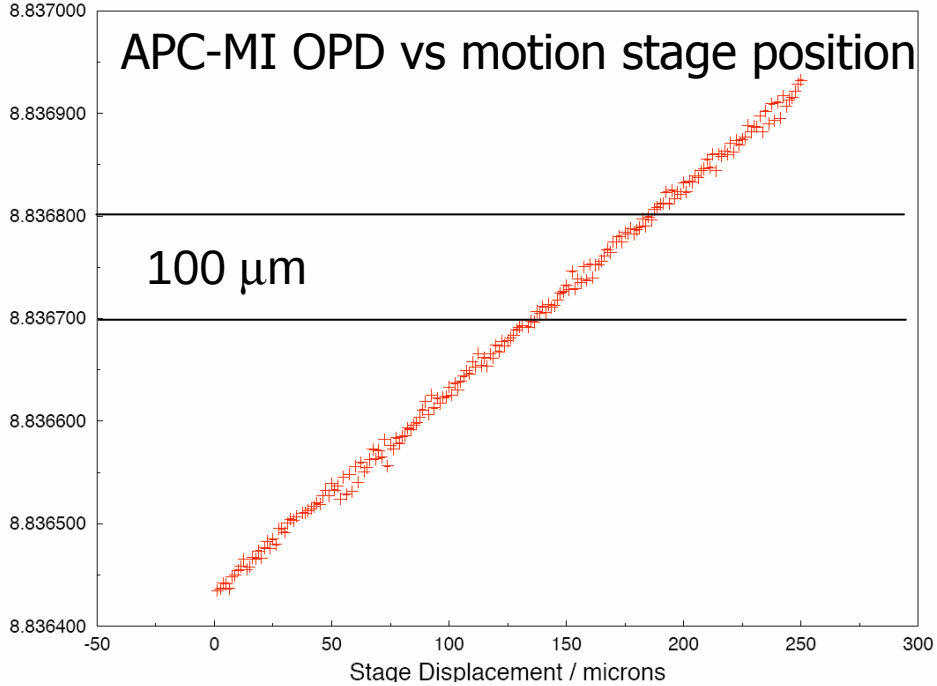
FSI results (John Green)

	SPC-MI	APC-MI
Gradient	1.96474 ± 0.005161	1.97536 ± 0.005546
Intercept	$8.86788 \pm 7.5 \times 10^{-7}$	$8.83643 \pm 8.1 \times 10^{-7}$
RMS of residuals	5.24735×10^{-6}	5.63799×10^{-6}

Collimated FSI lines in open air





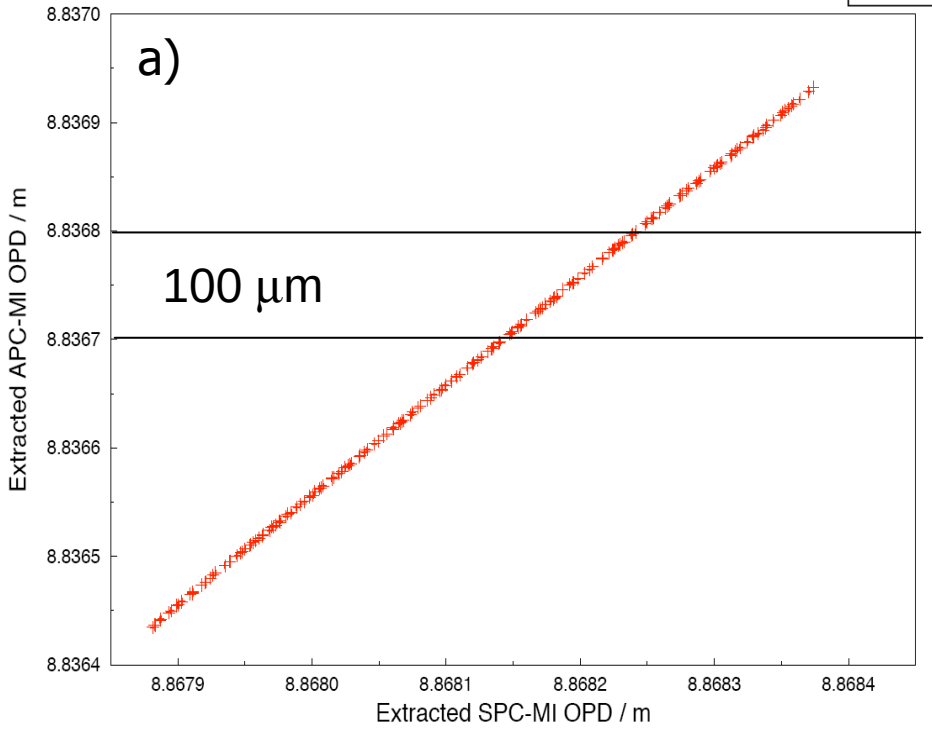


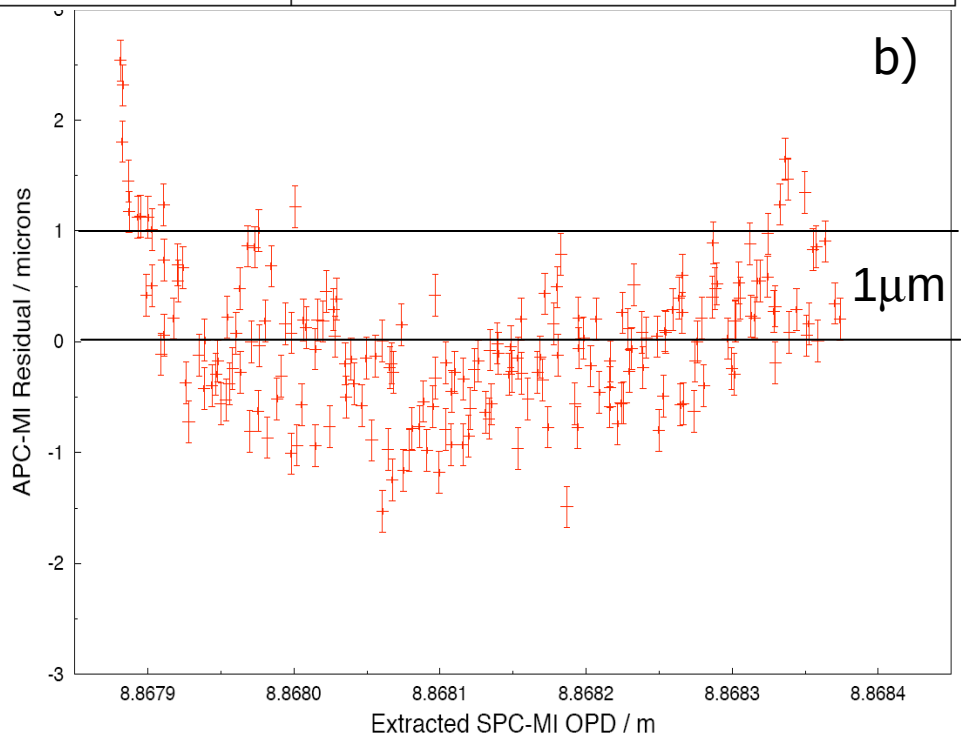
APC = Angle polished connect; SPC = Flat polished connector

FSI results (John Green)

- (a) OPD correlation between SPC-MI and APC-MI, 0.25mm stage displacement
- (b) Residuals of the linear fit to the correlation.
- Clear that we see common mode fluctuations in both interferometers
  - Reference length variations
  - OPD changes from
    - Temperature
    - pressure

	Value
Gradient	1.00549 ± 0.0003328
Intercept	-0.0801344 ± 0.002951
RMS of residuals	$6.65152 \times 10^{-7} \pm 4.42 \times 10^{-13}$



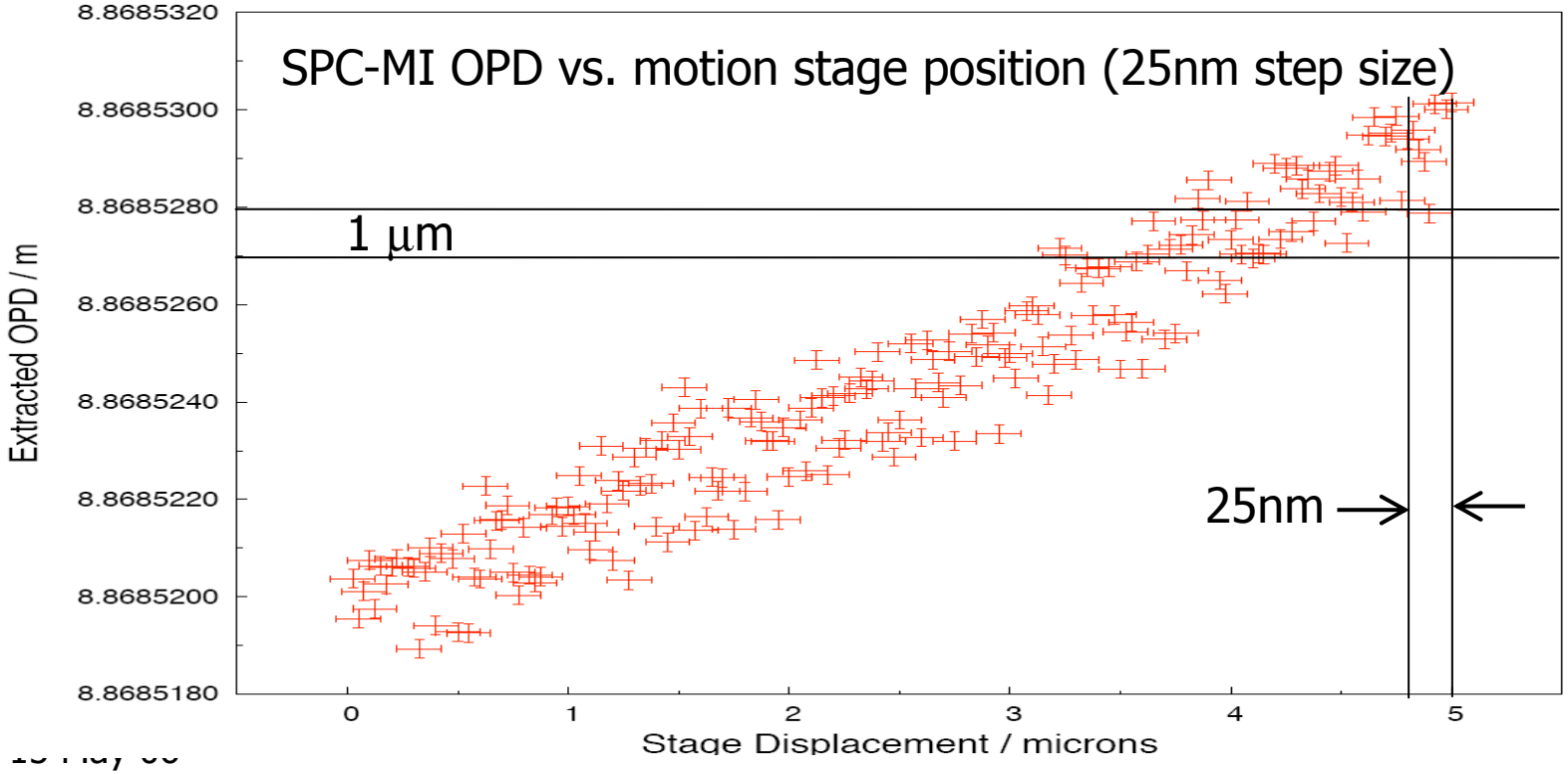


FSI results (John Green)

	SPC-MI	APC-MI
Gradient	1.94716 ± 0.004202	1.87703 ± 0.009822
Intercept	$8.86852 \pm 1.2 \times 10^{-7}$	$8.83708 \pm 2.8 \times 10^{-7}$
RMS of residuals	8.21495×10^{-7}	1.92007×10^{-6}
Spectral SNR	42292 ± 599	29425 ± 523

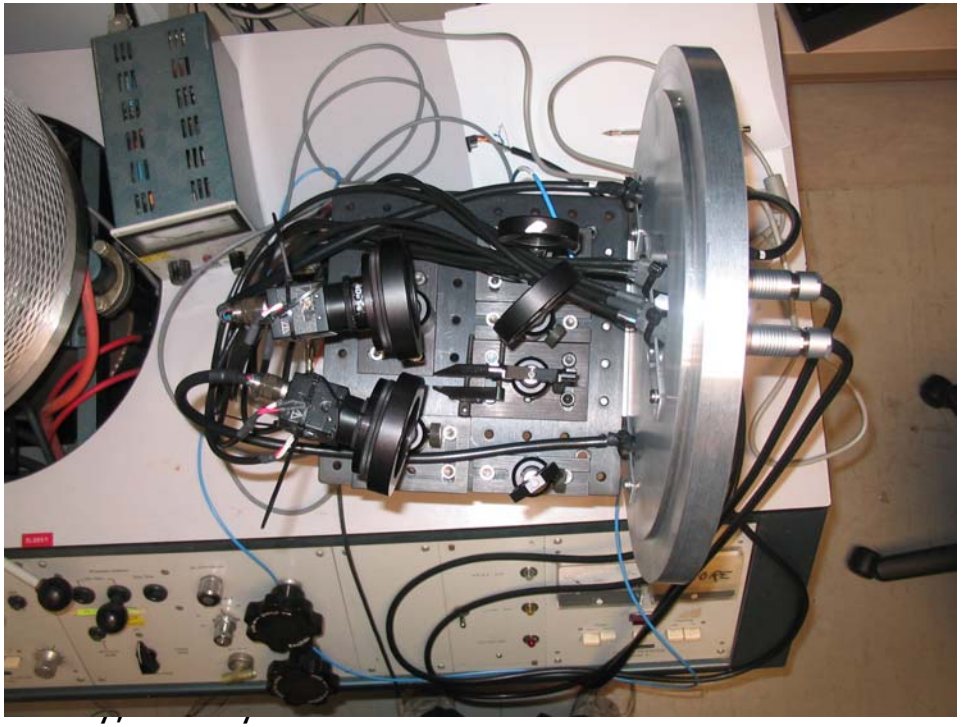
Summary:
- Sub micron repeatability
- Now air refraction limited
- Absolute calibration to come shortly

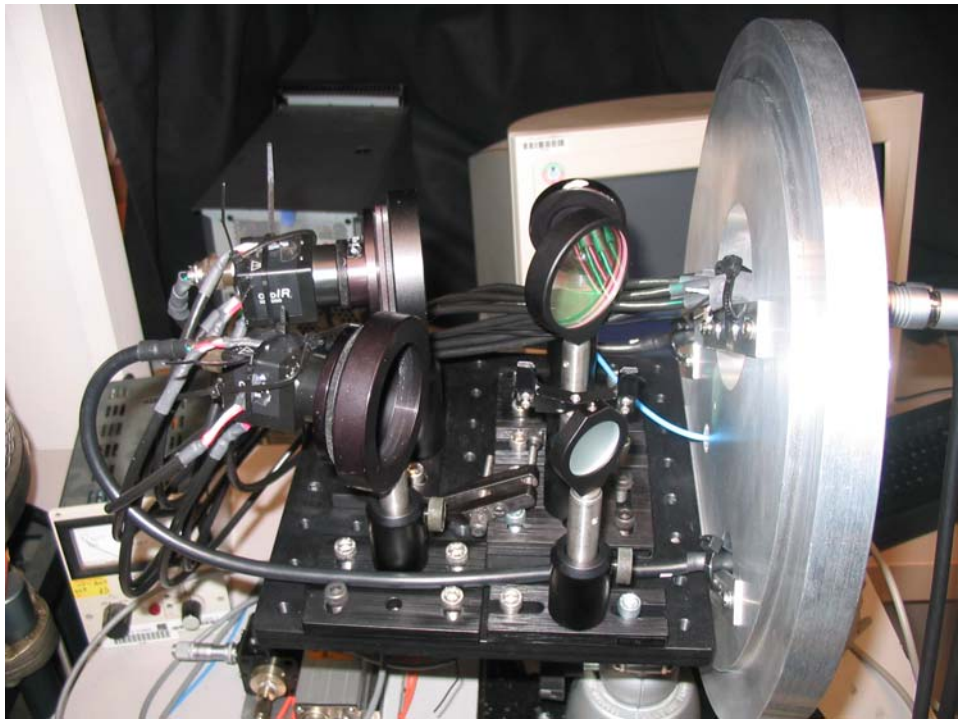
- performance with evacuated reference & measurement interferometer should be much better.
- More potential if we start using phase information in spectral analysis as M-Phys thesis has shown in simulation



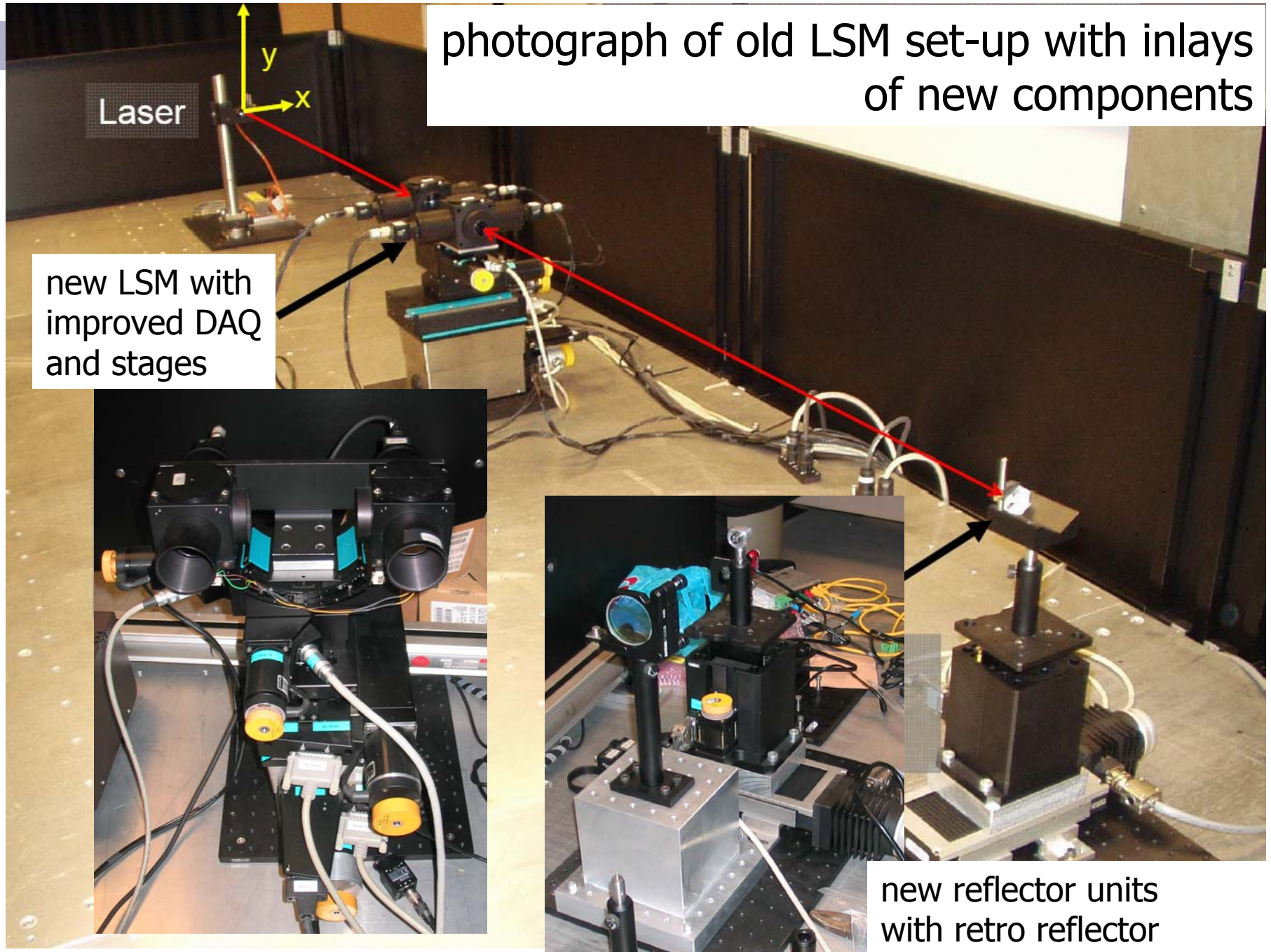
LSM camera vacuum test stand

- measure temperature distribution on cameras in vacuum
- measure image distortions in vacuum by viewing 2D grating interference pattern
- result: camera works very well in vacuum due to very low power consumption and good mechanical structure
- Distortions below detection level (0.1 micron)



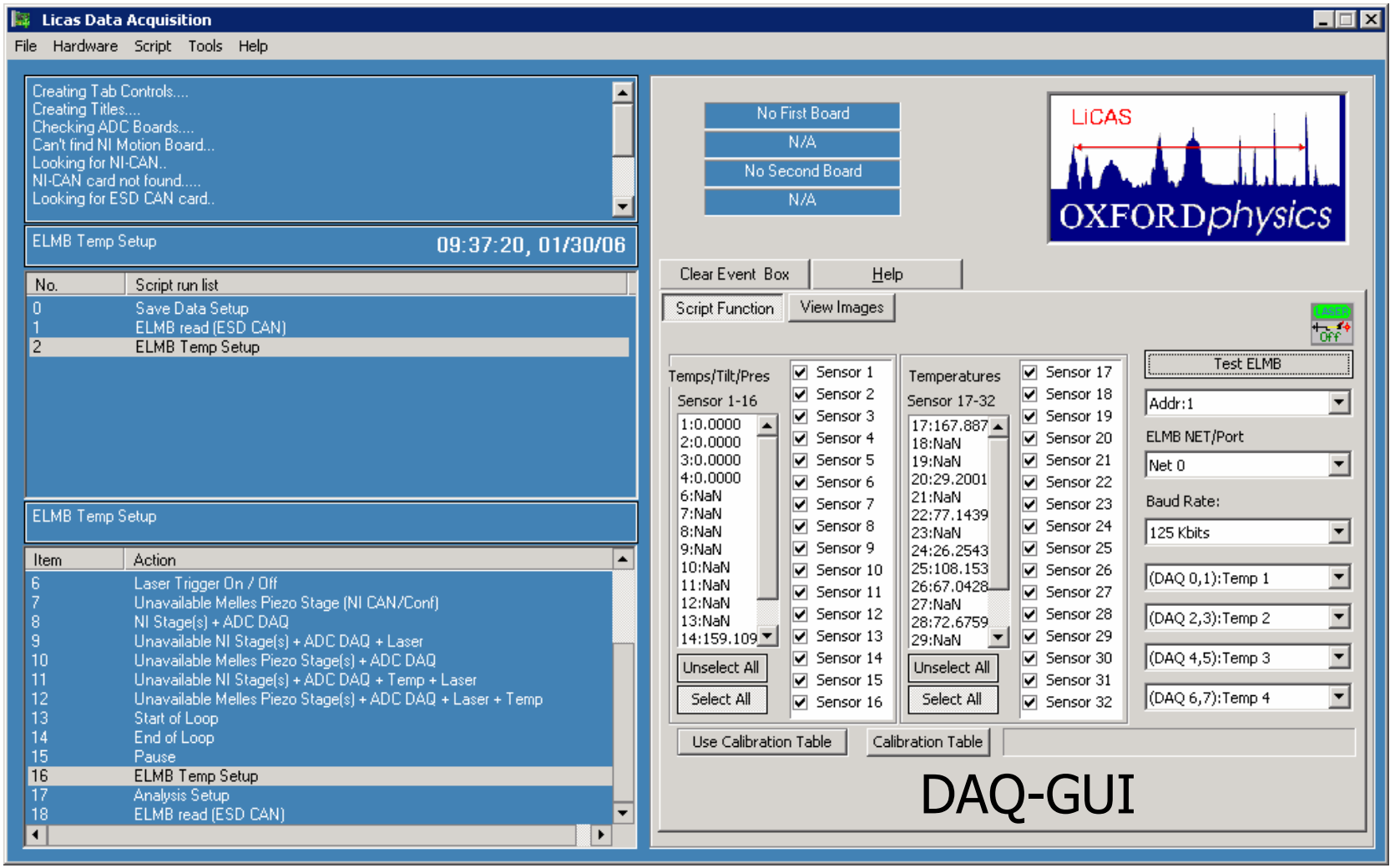


photograph of old LSM set-up with inlays of new components



Software Status

- C++ DAQ software (90% tested)
- Spectral FSI analysis (works to sub micron levels but not yet automatic)
- LSM-Analysis (spectral filters, fits and noise suppression) completed
- LiCAS performance simulation complete



Short Term Future Plans

- LiCAS-I (funded from current LC-ABD program and embedded in EuroTeV)
  - = current 3-car prototype RTRS
  - complete production & assembly
  - install @ DESY May 06
  - operate @ DESY until end 06 (potential end 07)
  - data analysis
  - final results/publications by summer 07

LiCAS Medium Term Future Plans

(LiCAS-I uprade)

- Design < Apr.07 (current grant)
- Construction < Jul. 08 (needs new funds)
- Small upgrade of sensing unit
  - Carbon Fibre → reduce weight → faster alignment
  - compact (potential for X-FEL)
- Reuses existing RTRS
- Electronics
  - dynamical train alignment during motion

LiCAS Long Term Future Plans

(LiCAS-II)

- Aims:
  - Add Damping Ring survey capability (CESR-TF)
  - Demonstrate LiCAS in real application (X-FEL)
- CESR-TF ←→ ILC-DR (time scale: early 2009? to start of ILC)
- DESY X-FEL ←→ ILC-Linac & BDS (time scale for survey: summer 2009 to end 2010)
- One RTRS (mech., DAQ, sensors, lasers) ←→ two configurations (straight, circular)
- Unclear how many units: 4(current+1) <N< 6(ILC specs)
- potential for some fixed installations (HLS, LSM) at CESR-TF