CERN alignment sensors

checks, calibrations and infrastructure

Andreas HERTY

April 02, 2009

sensors

field of application at CERN

· LHC **low-beta magnet monitoring** and alignment system
· **CLIC** studies

field of application at CERN

- Monitoring of the **ATLAS** feet (**Bedplates HLS**)
- Monitoring of **CMS YB0-HLS** with direct link to low-beta magnets
- vibration measurements **CNGS neutrino horn**

sensors

monitoring sensors in the LHC

- 112 hydrostatic levelling sensor (HLS)
- 64 wire position sensor (WPS)
- 24 distance offset measurement sensor (DOMS)

HLS

WPS

DOMS

characteristics

- FOGALE nanotech
- capacitive sensors
- no stand alone
- different generations
- integrated / remote electronics

- range of up to 10 mm
- resolution of 0.1 micron
- signal output 0 - 10 V
- power input 15 VDC

sensor choice for the LHC

- all sensors already **used at CERN before** (LEP, CTF2, calibration laboratory, vibration measurements)
- sensors already tested for **long-term** and **radiation** in accelerator environment
- only tested **off-the-shelf** sensors available

nevertheless

- development of remote electronics for HLS
- cable lengths of up to 30 m

off-the-shelf with major modifications

checks and calibrations

Nuclear Base Installation

CERN is declared a Nuclear Base Installation

- Installation Nucléaire de Base (INB)
- convention with French government (1984 & 2000)

all material exposed to radiation has to be traced

makes it difficult to ship material back to manufacturer

- for check and calibration
- for repair

calibration methods, knowledge and infrastructure have to be created at CERN

checks and calibrations

sensors
checks and calibrations
problems
future
summary

checks: at reception

- validate manufacturer's parameters before installation in the LHC
- same checks as manufacturer carries out during calibration
- **warm-up, stability** and **linearity**

additional checks: investigate sensor performance

- **radiation**: total ionisation dose (TID), dose rate dependence (DRD)
- **magnetic field**: influence to the exposure to magnetic fields
- on-site check with **capacitive references**

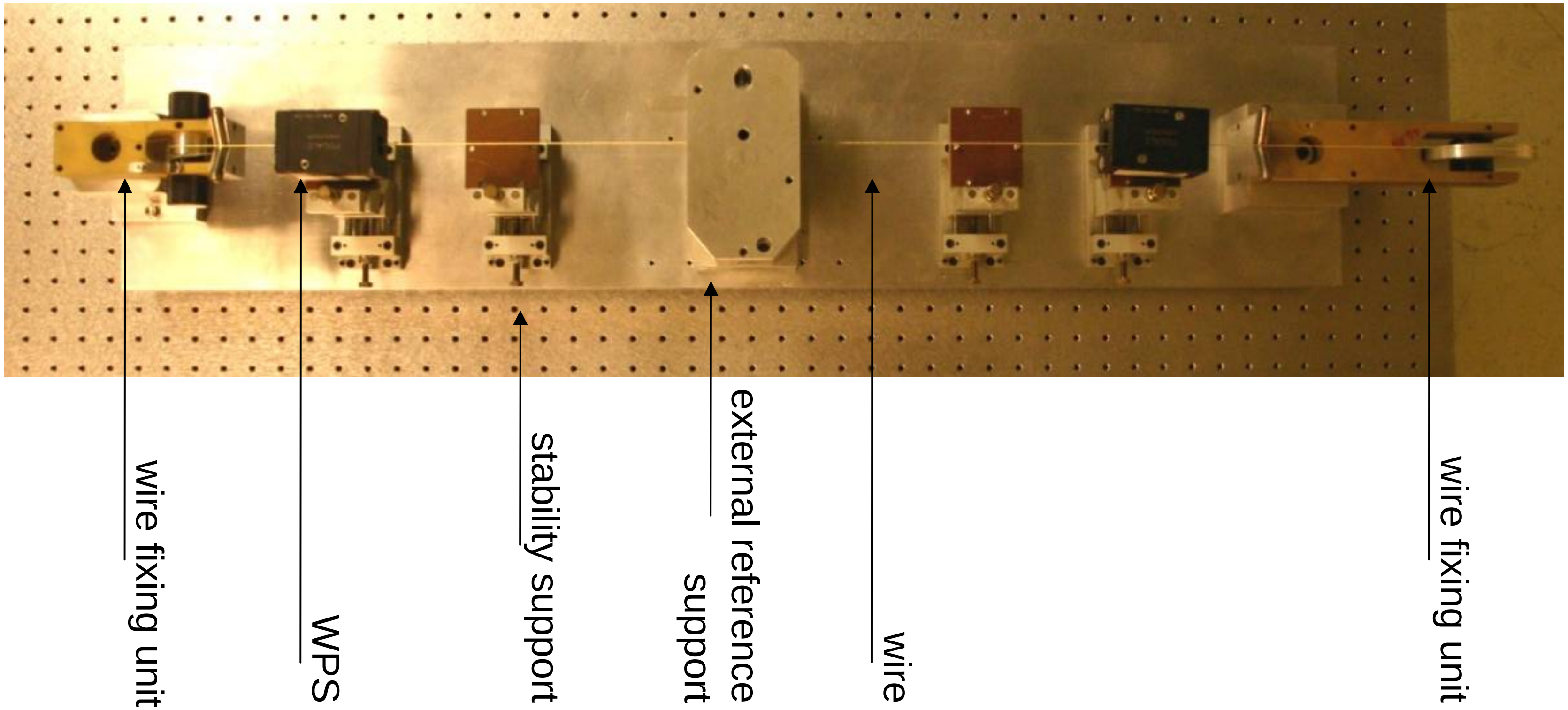
calibrations

- additional parameters for the low-beta monitoring system
- **interchangeability** and **absolute reference**
- **geodetic interface calibration**

warm-up

warm-up times given by manufacturer

- WPS and DOMS after 5 min
- HLS after 48 hrs → electrode heated



warm-up

sensors

checks and calibrations

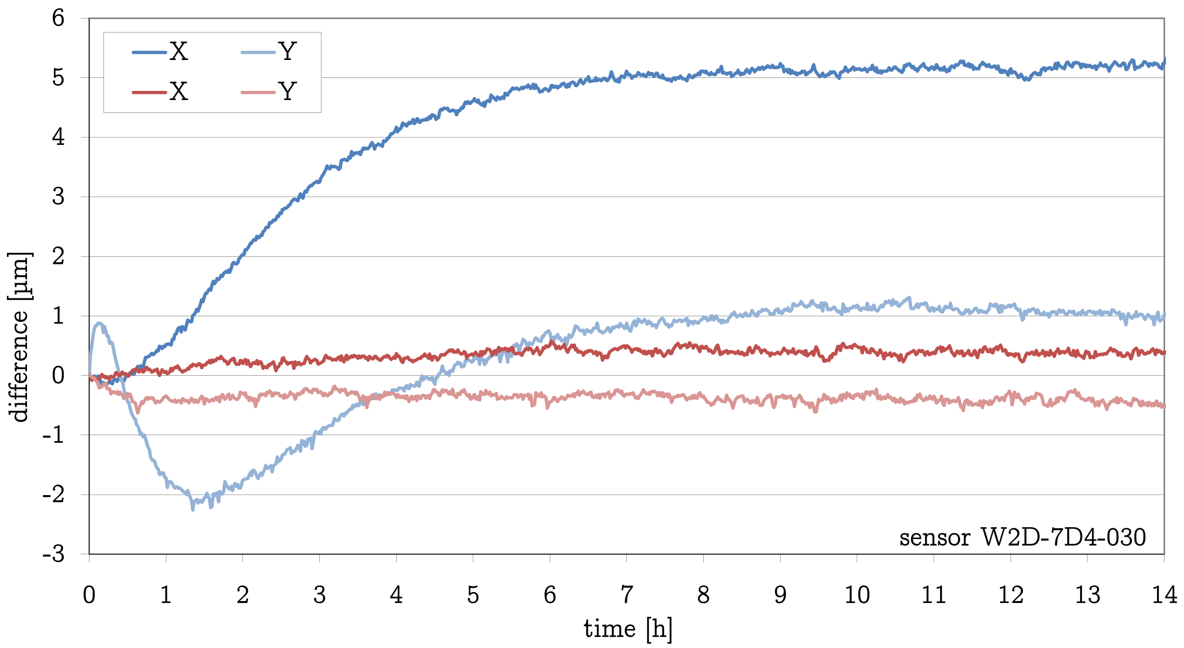
problems

future

summary

example: WPS warm-up test

warm-up effect shown for WPS on both axes (blue curve)
no warm-up after short power cut of 10 min (red curve)



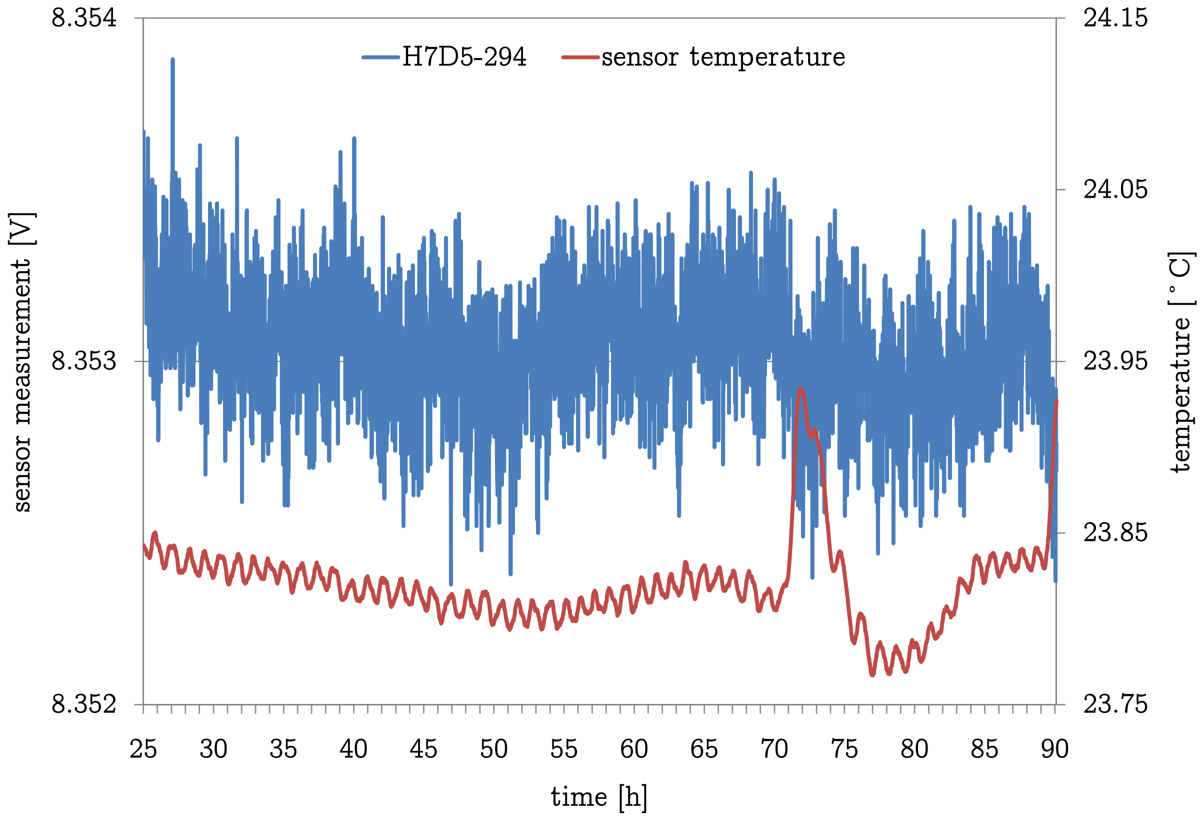
all sensors need 3 hrs to be within ± 2 micron of final value

maximum warm-up effect observed ± 6 micron

stability

measurements show

- all sensors are within manufacturer's drift limits ($\leq$ 3 micron / month)
- DOMS prototypes with problems, method changed manufacturer



stability

stability bench allows

· measurements at fixed distances
· reference measurements with respect to calibrated distances
· offset and interchangeability determination

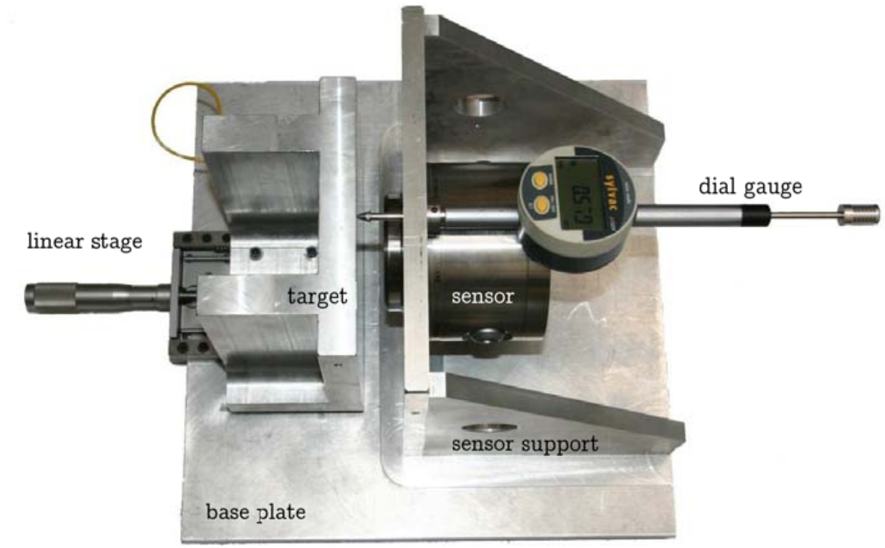
concept also used for

· warm-up measurements
· zero and gain point determination of the sensor

linearity

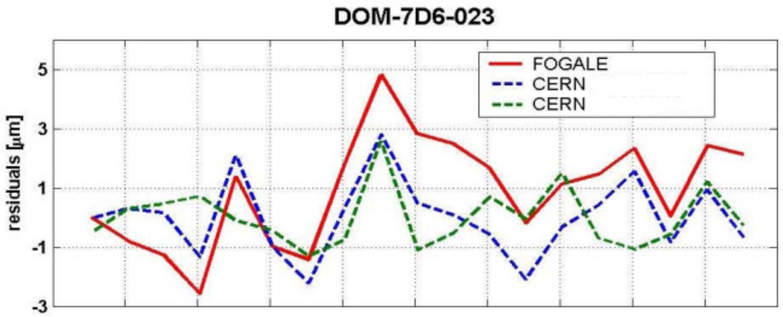
FOGALE nanotech provides calibration functions to better than

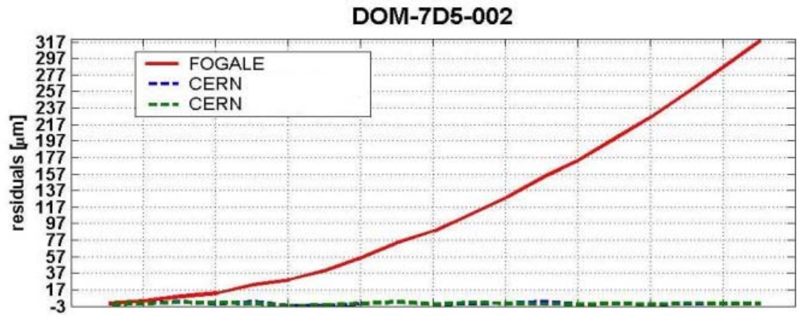
$\pm$ 0.4 micron for HLS (3rd order polynomial)
$\pm$ 0.8 micron for DOMS (4th order polynomial)
$\pm$ 3.0 micron for WPS (6 x 6 matrix for each axis)



linearity check bench designed to validate calibration within 10 micron

linearity





results

· non conform sensors detected
· manufacturer’s linearity calibration validated
→ within 10 micron for HLS and DOMS
→ WPS linearity check bench with concept problem

radiation tests

sensors

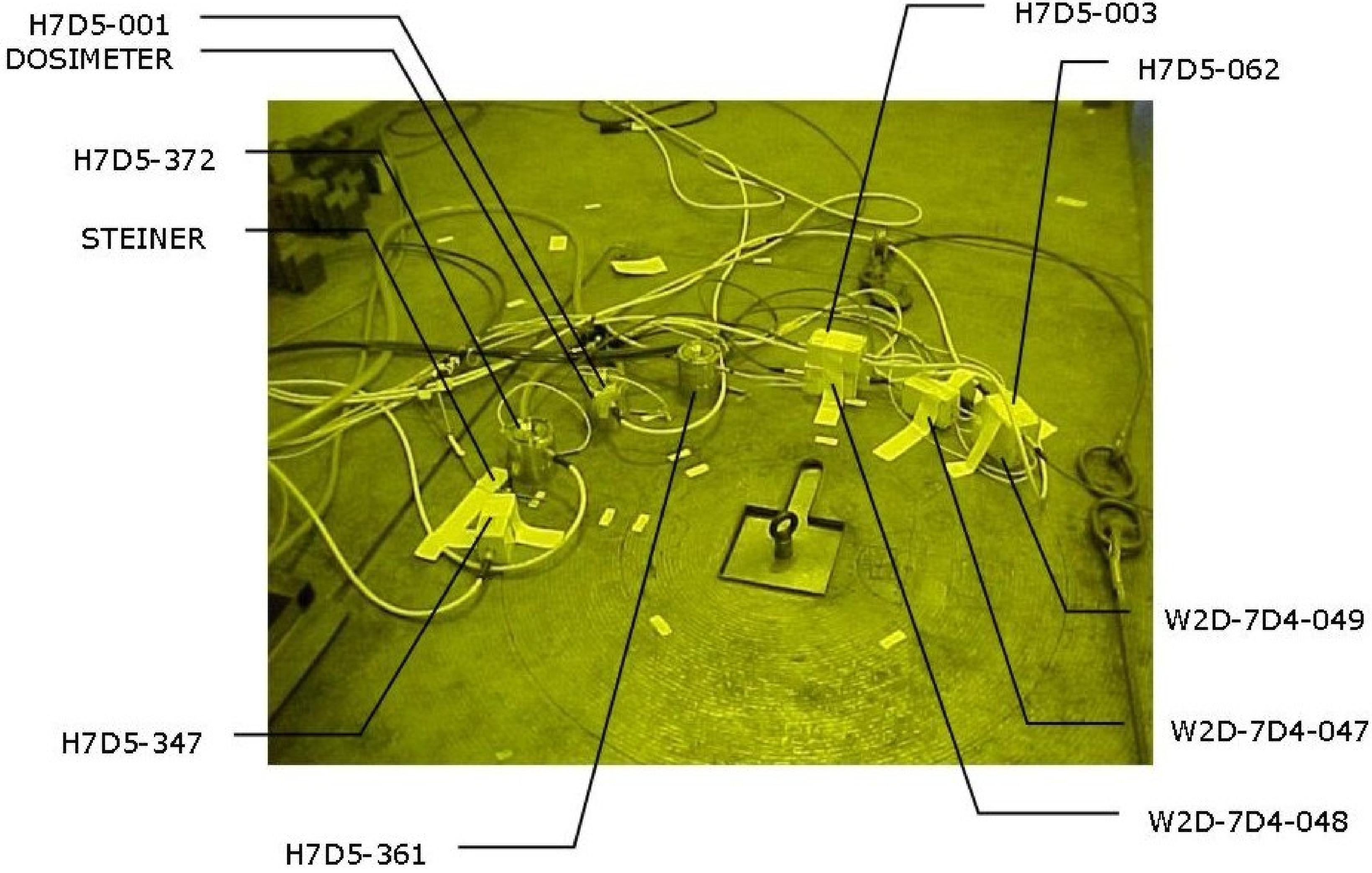
checks and calibrations

problems

future

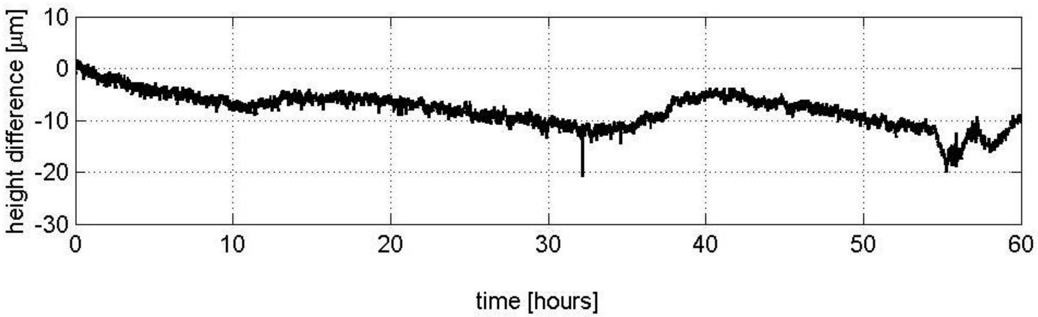
summary

for TID and DRD tests a ^{60}Co source is used



radiation tests

Total Ionisation Dose: sensor



tested HLS and WPS withstand 160 kGy

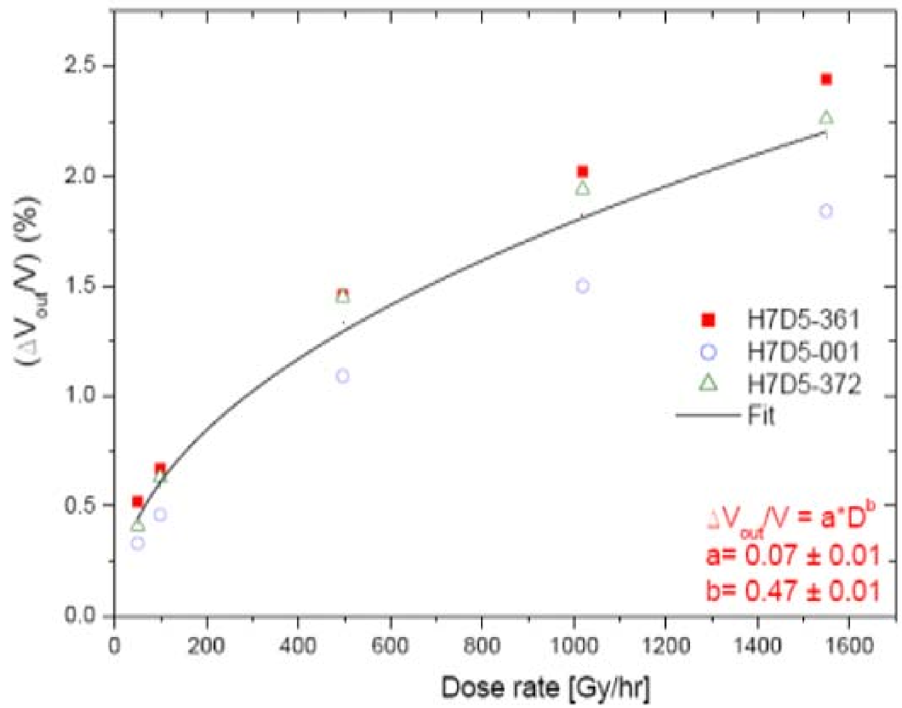
Total Ionisation Dose: electronics

electronics withstand 500 Gy

this means for the LHC

- electronics are placed in protected areas
- long cables between sensor and electronics needed
- electronics can recover from radiation damage

Dose Rate Dependence on HLS sensors

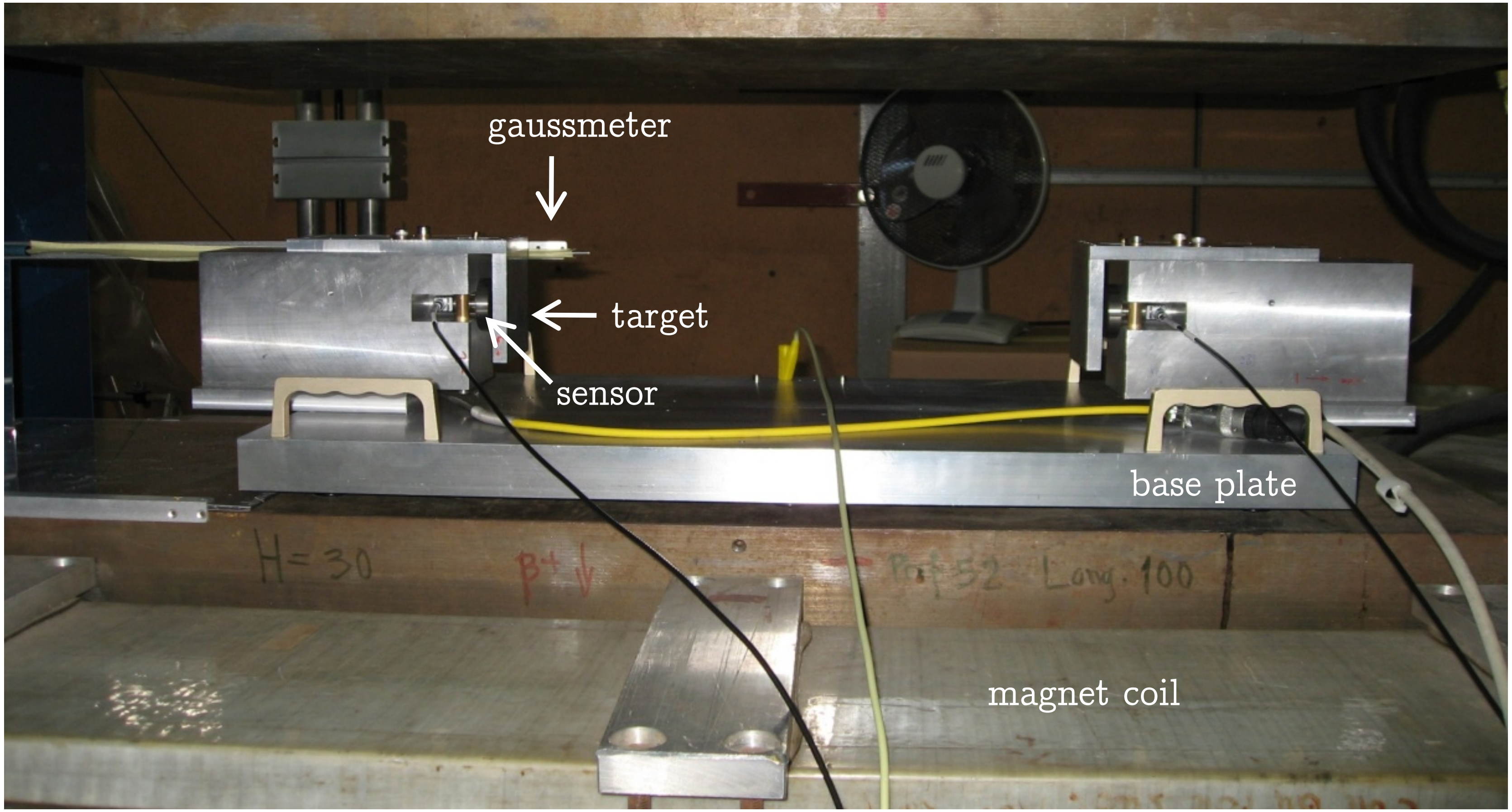


influence

- quantified by an experimental formula
- can be deducted from measurements
- investigation for WPS and DOMS pending

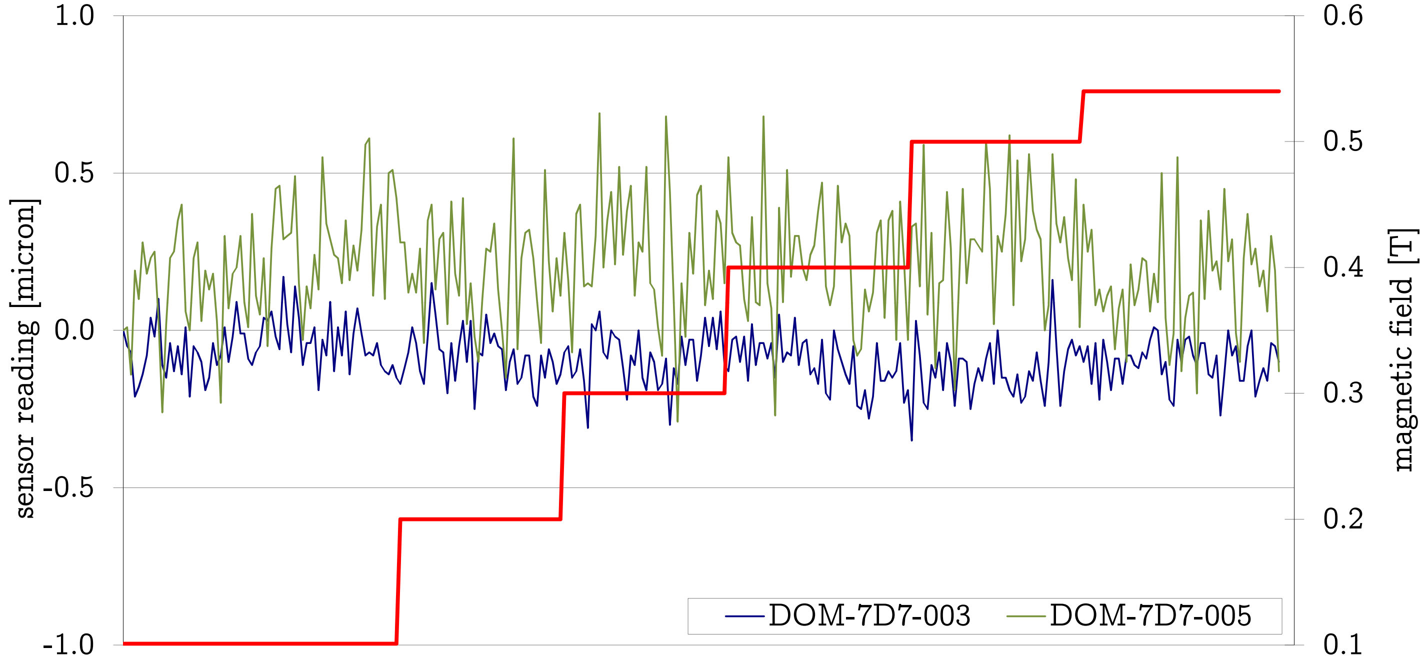
magnetic field

electronics supposed to withstand 0.03 T (FOGALE nanotech)



magnetic field

DOMS sensor in field of up to 0.54 T



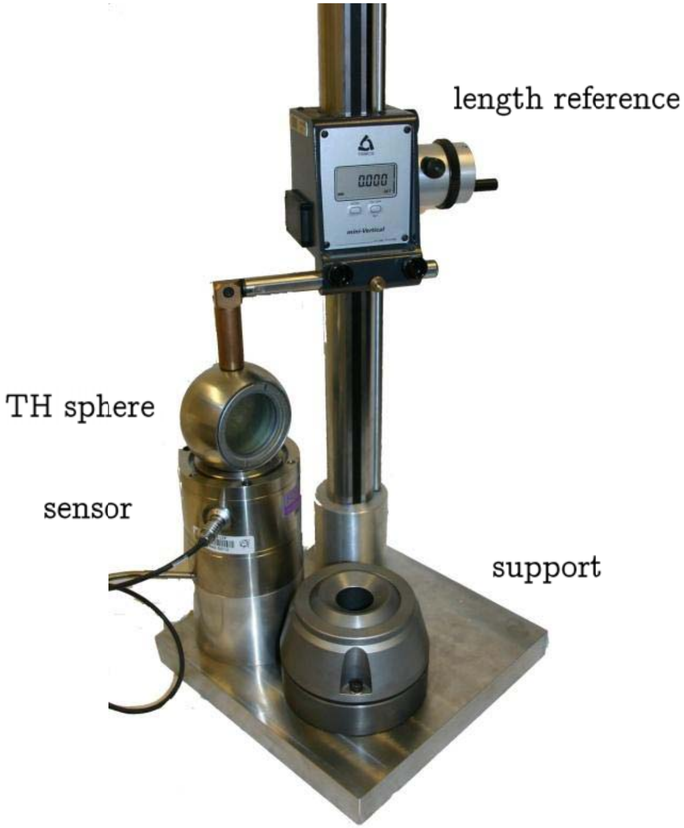
no infuence on sensor

- neither cable, nor electronics tested
- HLS and WPS have to be tested

checks and calibrations

interfaces and references

- additional parameters for the low-beta monitoring system
- interchangeability, external reference



checks and calibrations

absolute reference

- external, absolute reference provided to $\pm$ 50 micron
- not sufficient for LHC . . . and particularly not for CLIC studies

solution

- investigate calibration methods
  - $\longrightarrow$ aim: absolute calibration to better than $\pm$ 5 micron
  - $\longrightarrow$ HLS concept, validated on manual and automated bench (absolute and geodetic interface)
  - $\longrightarrow$ DOMS concept, validation on linearity calibration bench pending
  - $\longrightarrow$ WPS concept, bench ready, validation pending (Thomas Touzé)

coordinate-measuring machine available since 2008

capacitive references

mobile on-site testing device for stability of electronics

- capacitive references
- suitable for zero and gain measurements
- allows check of sensor's stability

follow-up of sensors without dismounting

- short interruption in data acquisition
- no complicated radiation protection checks of equipment

problems

problems

sensors

- mechnically broken cables (HLS/DOMS)
- electronics components broken (WPS)
- dust problem (WPS)
- stability drifts (DOMS)
- sensor frequency drifts (WPS)
- noise and electro-magnetic interference with other equipment

concept

- sensors ascociated with cable and electronics
- absolute calibration

broken cables

problem

- fragile wires in the cable
- several layers of shielding for primary, capacitive sensor signal

solution

- cable can be fixed in our workshop
- calibration will be checked

electronics components broken

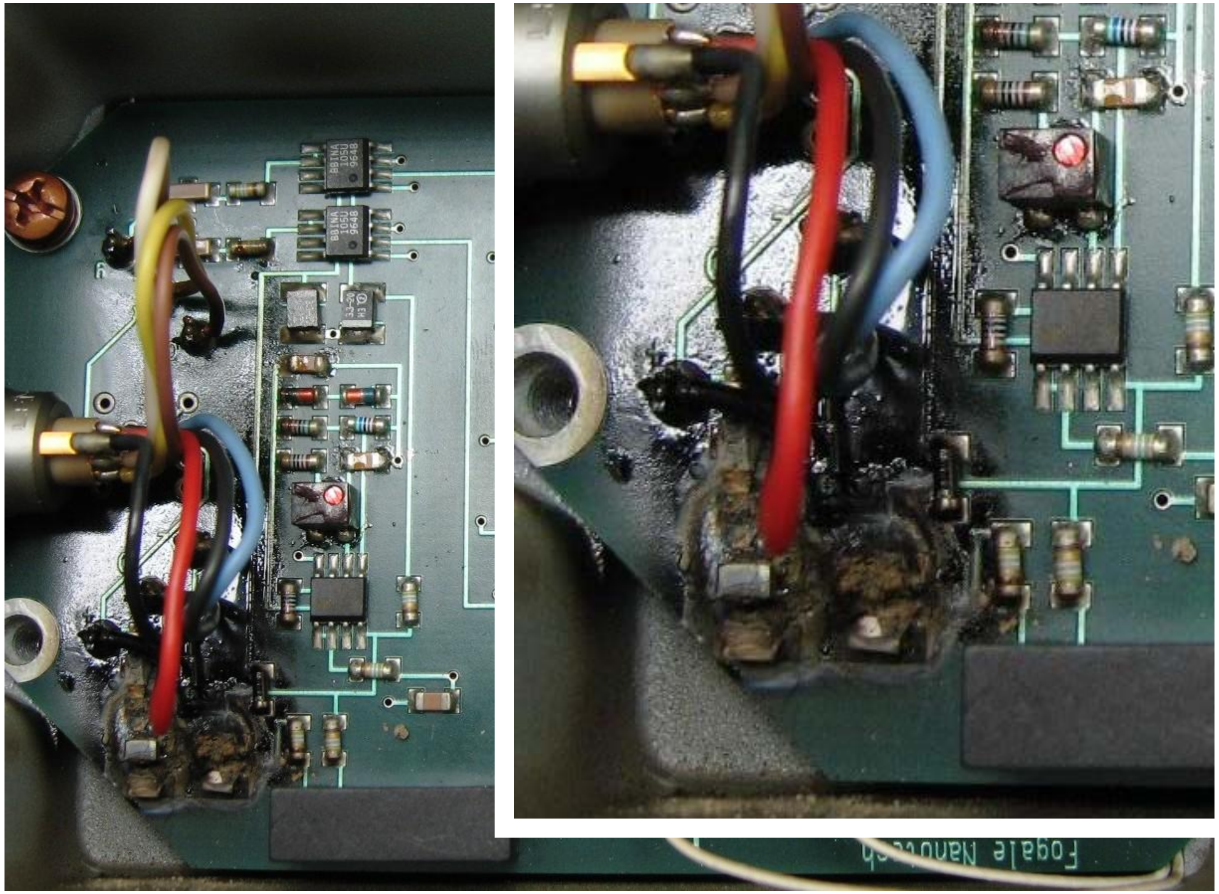
sensors

checks and calibrations

problems

future

summary



problem identified

- always same components brake
- can not be reprocuded
- source of the problem to be found

WPS frequency drifts

WPS has a frequency modulated on the wire for each sensor

- frequencies range from 3 kHz to 8 kHz
- sensors adjusted to 100 Hz gap
- frequency gaps have to be more than 20 Hz
- same frequencies on the same wire create an oscillating signal of one or both sensors involved

observations

- frequencies drifted with up to 980 Hz
- range of the drifts 1480 Hz

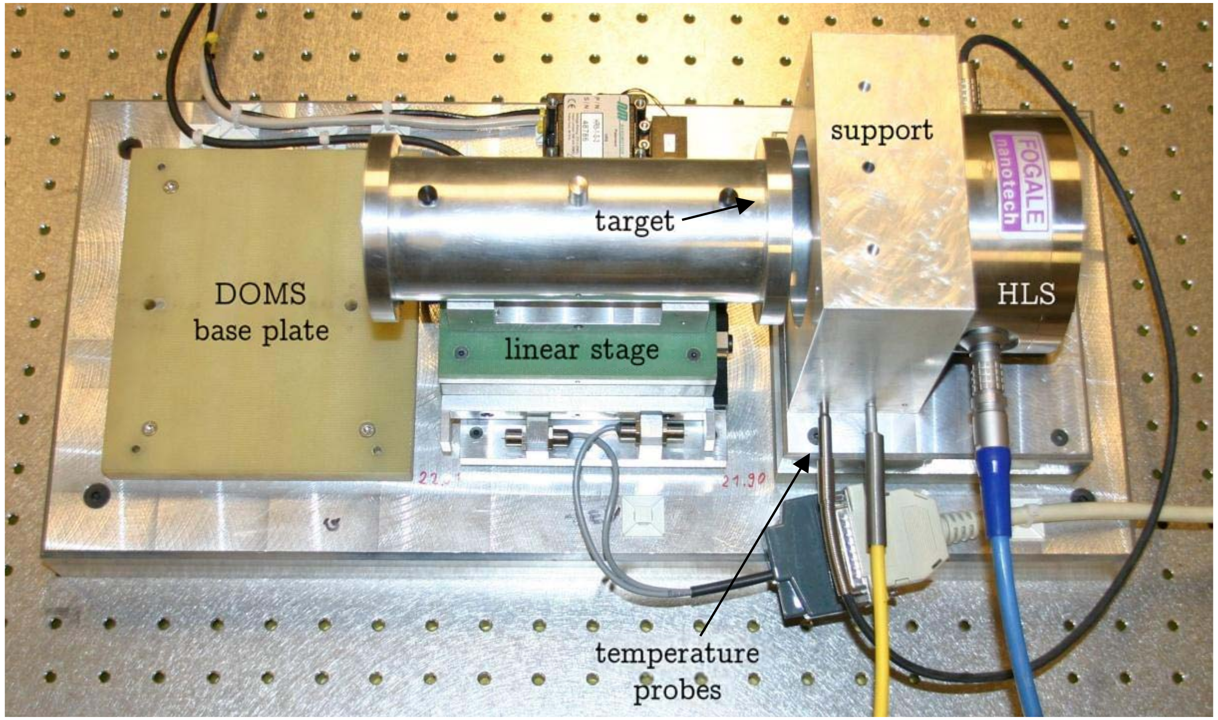
solution

- adjustment of frequencies
- increasing of the gap

future

automated linearity calibration

- HLS: in operation since 11/2008
- DOMS: bench validation phase
- WPS: concept and installation



future

radiation tests

- Single Event-Upset (SEU) tests for sensors and DAQ rack
- Total Ionisation Dose (TID) tests for DAQ rack

absolute calibration

- validated for DOMS on automated linearity bench
- concept and design for WPS (Thomas Touzé)

long-term

- sensor long-term stability in LHC with radiation
- in TT1 test facility
- test benches in the laboratory

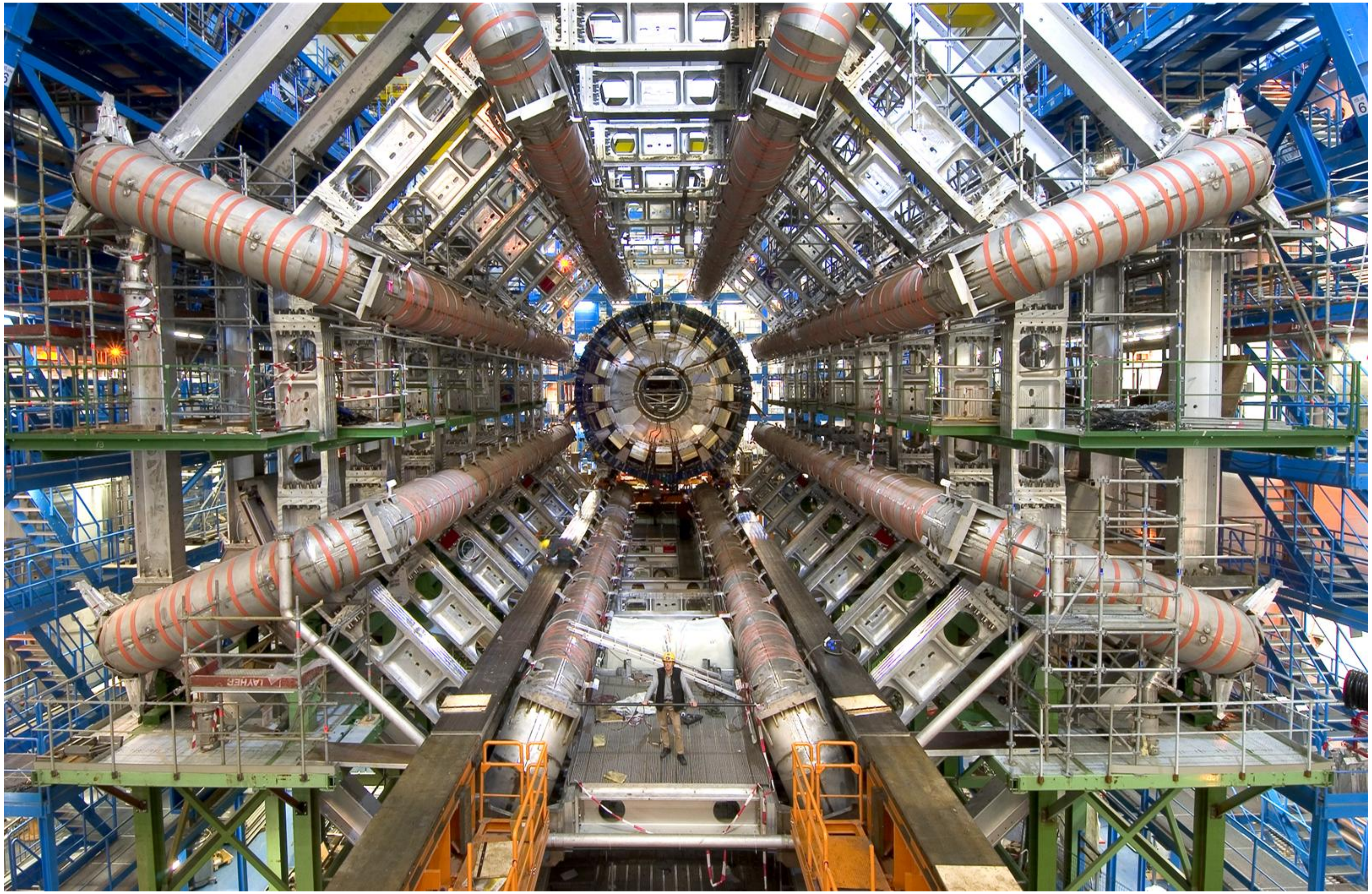
compare

- started for HLS with Fermilab, since beginning 2009

summary

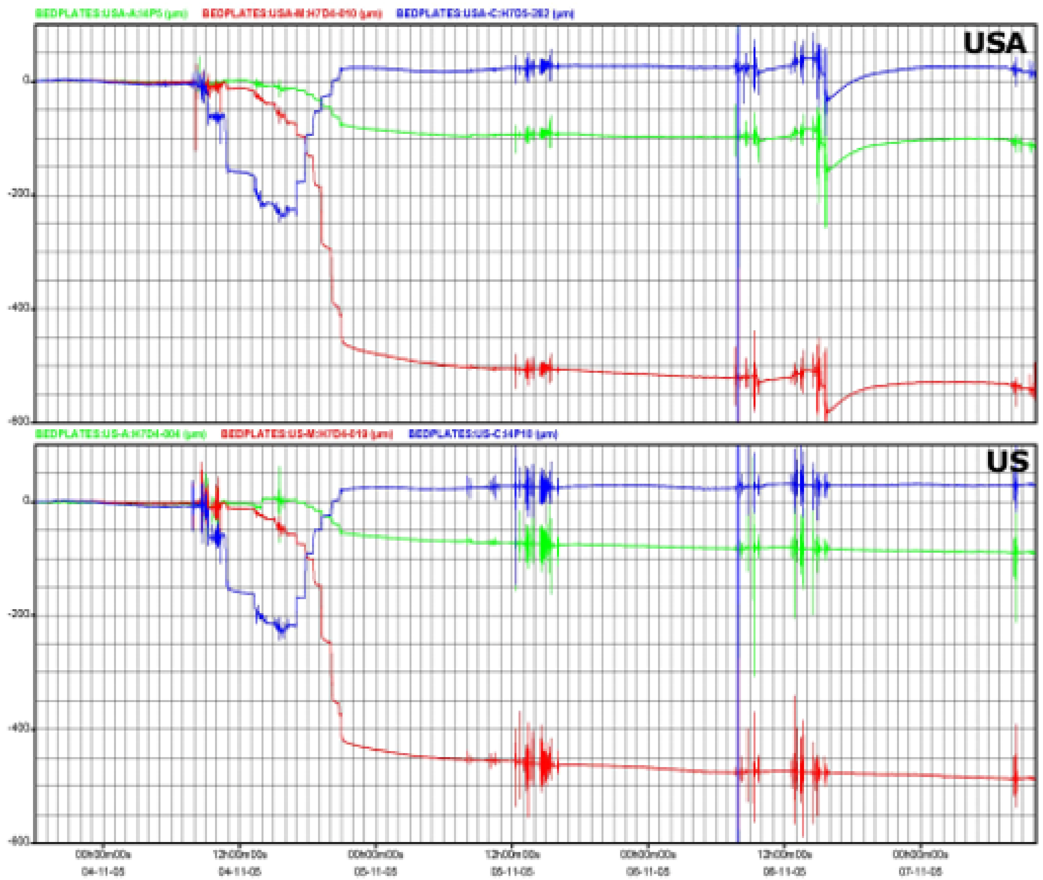
sensor results: ATLAS

installation of the calorimeter



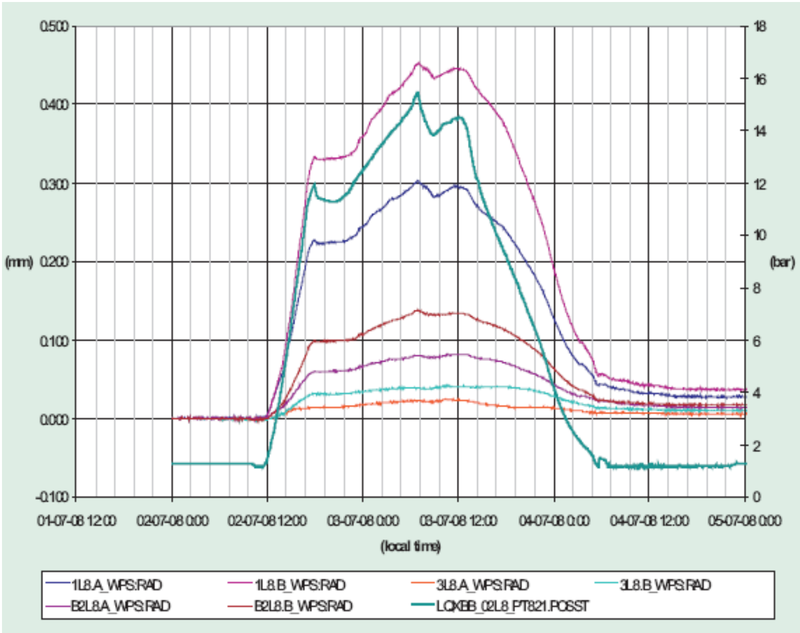
sensor results: ATLAS

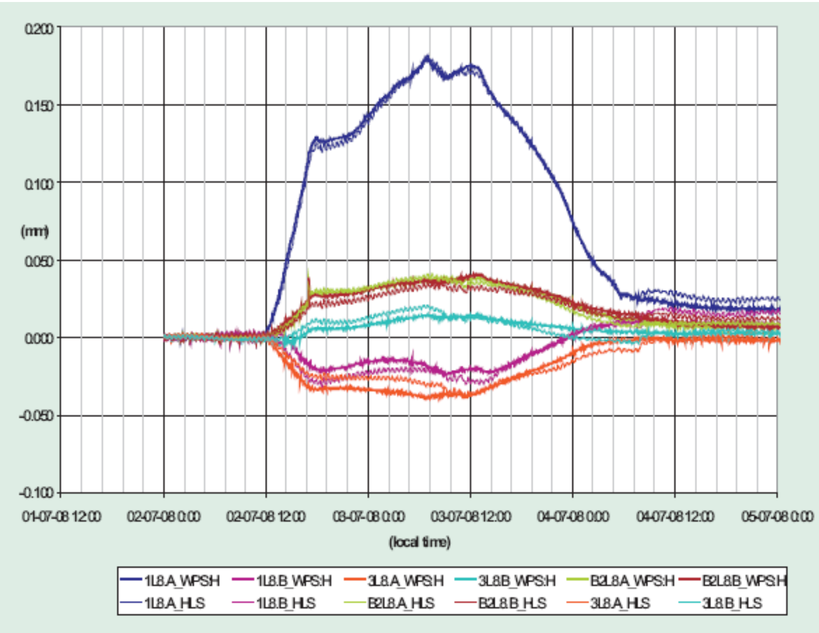
deformation monitored during calorimeter displacement



sensor results: LHC

pressure change in cryostat causes magnet displacement





observations

- same displacement monitored by HLS and WPS
- coherent results of both sensor types

summary

sensors passed the LHC validation tests

- linearity and stability
- total ionisation dose
- interchangeability and external references
- additional calibration parameters introduced
- on site test methods designed

further investigation in

- long-term behaviour in the LHC
- radiation influence with TID, test for SEU influence
- absolute calibration of the sensors
- magnetic field influences

important for CERN

- to be able to check / repair sensors due to INB
- to have check and calibration methods to be confident in measurements

CERN alignment sensors

checks, calibrations and infrastructure

Andreas HERTY

April 02, 2009