The ATLAS pneumatic solenoid mapper

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F. Bergsma, P.A. Giudici, A. Kehrli, X. Pons   CERN/PH-DT1

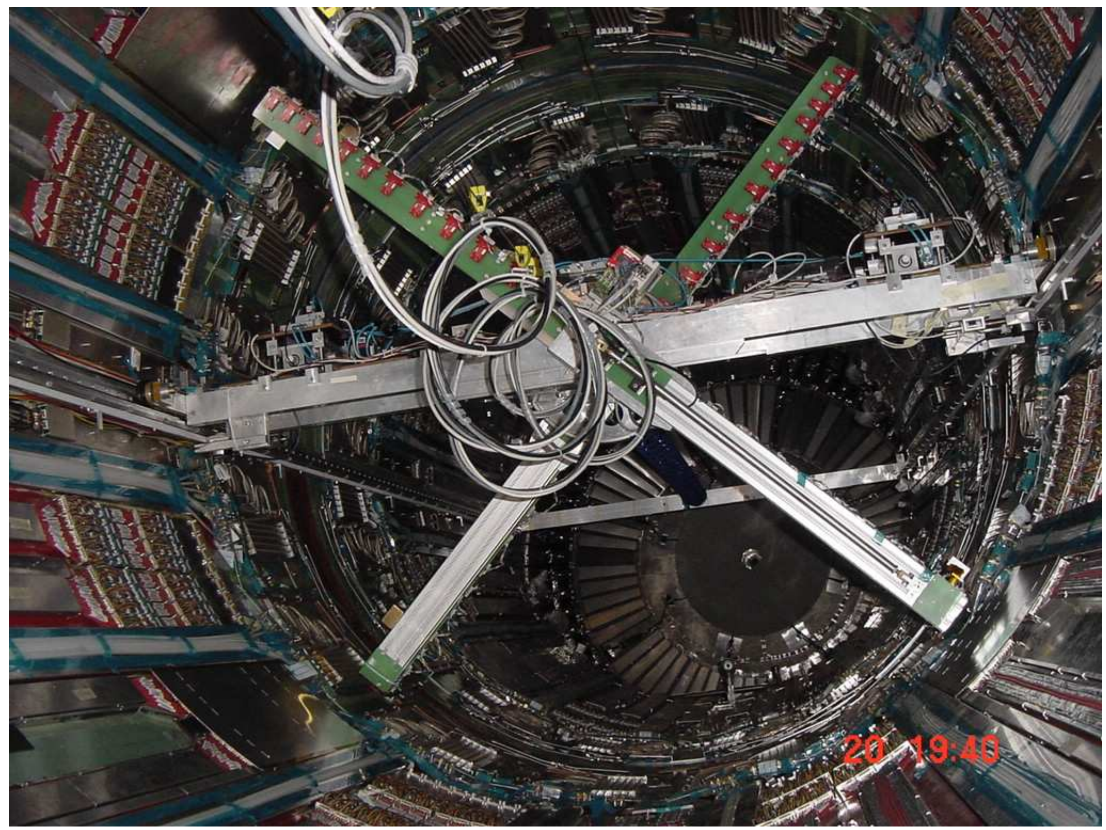
Pneumatic motor

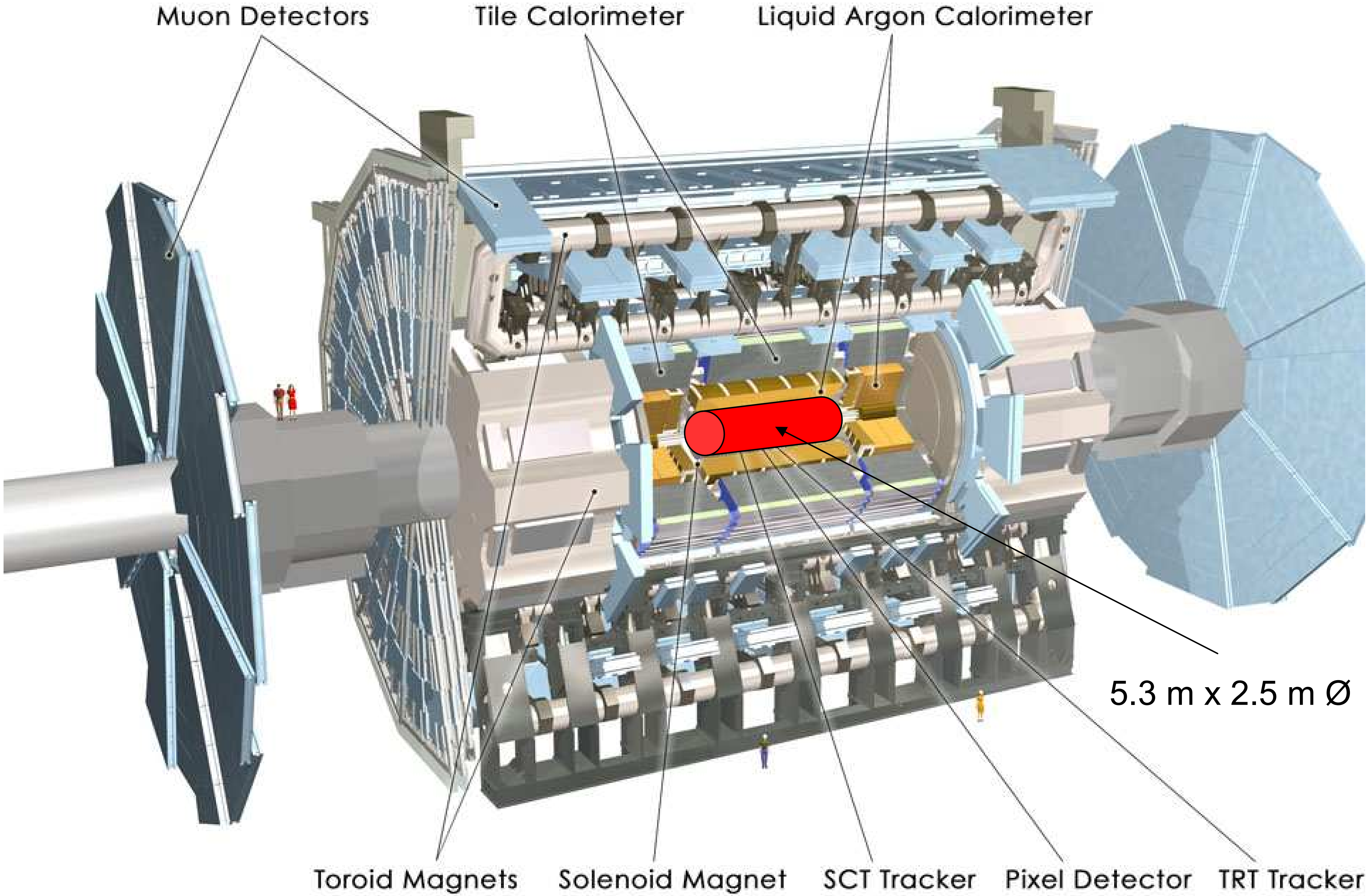
Gear system

Operation in magnetic field

Control

Performance




Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
5.3 m x 2.5 m Ø
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

Why pneumatic propulsion?

Old system: electric engines kept outside field region by long axes
and cables + counterweights

For ATLAS difficult to realize:
- cables too long => elasticity, keeps on moving
- only access via hole for beam pipe
- axes too long => sag
- huge scaffolds to support engines, cables and axes
- no access during mapping

Pneumatic engines:
- more difficult to control
- have to be made non-magnetic
- eddy currents
- valves inside field => no electro valves

First make test set-up with standard (magnetic) components
If useful system is found, try to demagnetize

Main components and dimensions:

Vane engine Atlas Copco LZB 22R , housing stainless steel, inner parts magnetic

Piezo proportional pressure control type = Hoerbiger Airfit tecno

Piezo valve for direction control type = Hoerbiger serie S9

Baldor NextMoveESB motion controller, P (ID) control loop

Tooth belt with weights to simulate mass and friction of bench

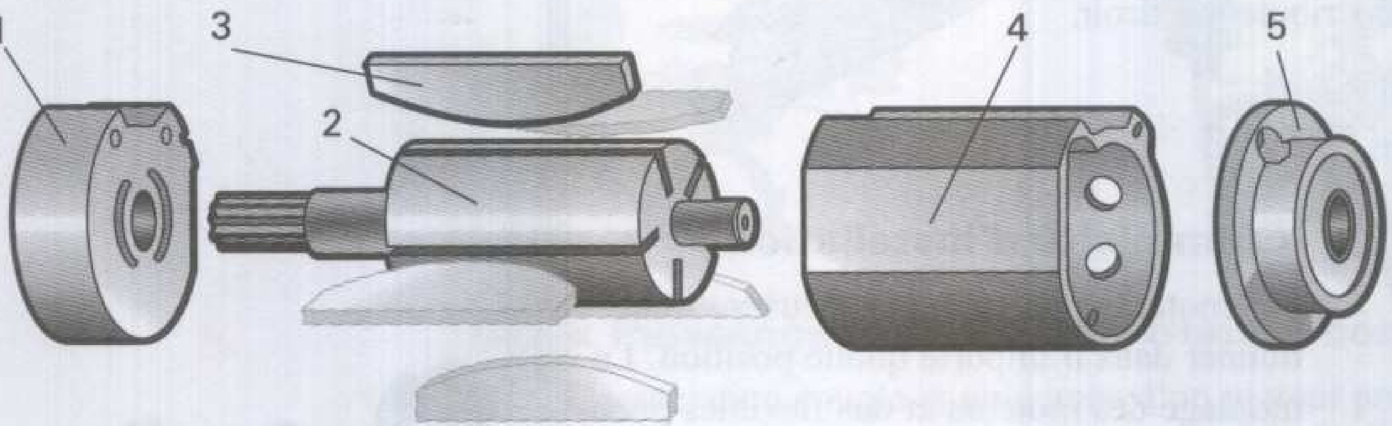
Encoder 40000 cts/rev

300 mm displacement/rev for main wheel

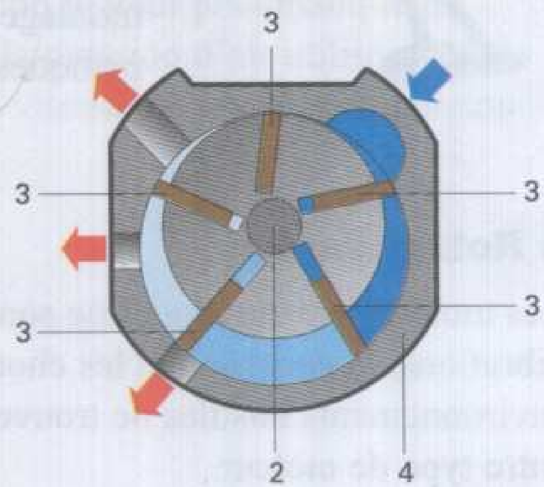
Reduction $4.46^4 \times 6 = 2374$

Max speed 9740 rev/min => 20.5 mm/sec

Approach speed 1.5 mm/sec



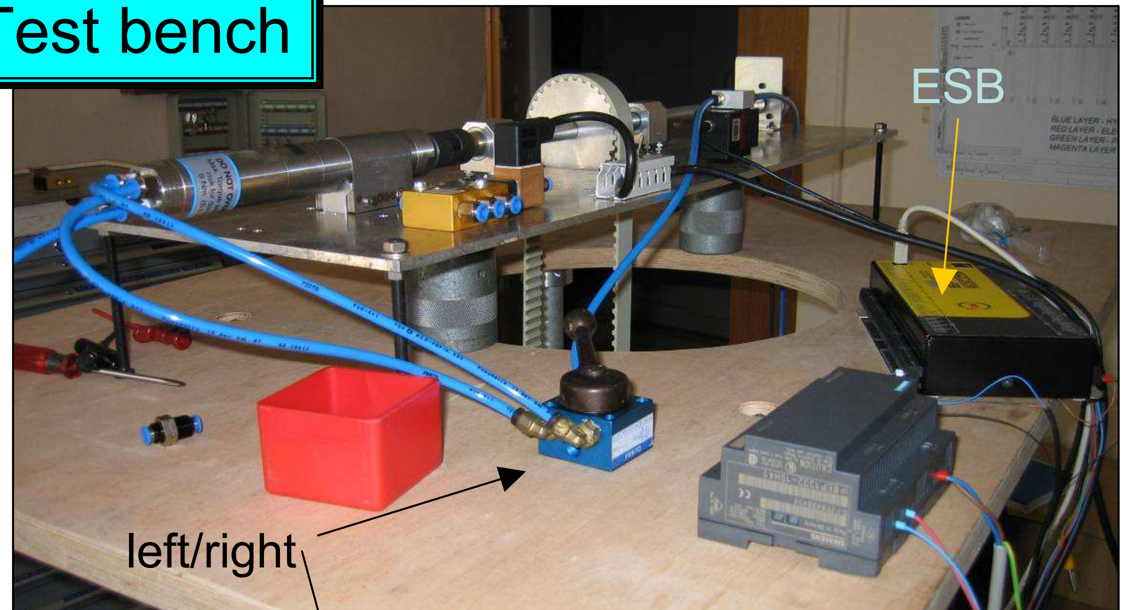
1. Flasque d'extré-
mité avant
2. Rotor
3. Palettes
4. Cylindre
5. Flasque d'extré-
mité arrière



Le moteur à palettes de conception basique nécessite peu de composants

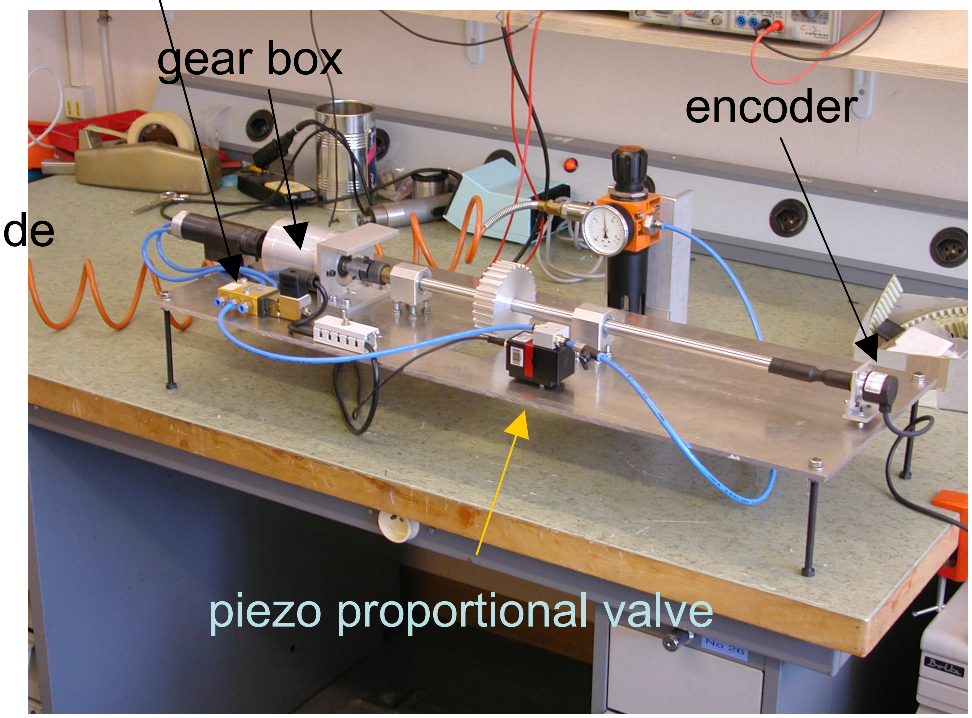
Atlas Copco

Test bench

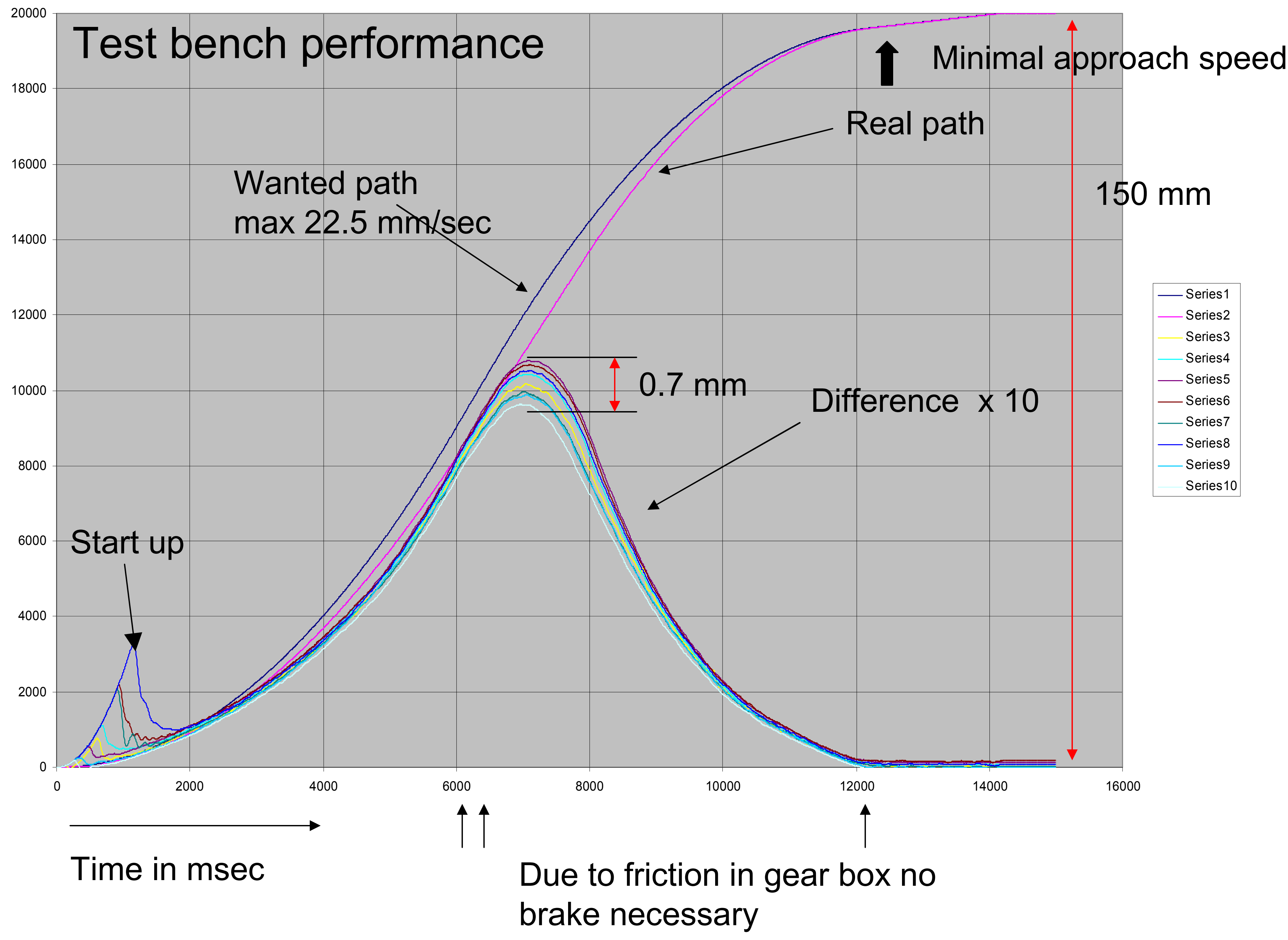


Max. 4 x
= 16 kg
on one side

Total ≤ 5 x
= 20 kg



Combinations used: 4-4, 4-8, 4-12, 4-16,
8-4, 8-8, 8-12, 12-8, 16-4 [kg]



Test bench performance
Minimal approach speed
Real path
Wanted path
max 22.5 mm/sec
150 mm
0.7 mm
Difference x 10
Start up
Series1
Series2
Series3
Series4
Series5
Series6
Series7
Series8
Series9
Series10
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Time in msec
Due to friction in gear box no
brake necessary

Make it work at 2.5 Tesla

Most magnetic parts had to be replaced and also some fast moving conductive parts because of eddy currents

motor: motor housing made already of stainless steel
rotor, cylinder and ball bearings made out of magnetic steel

rotor, fast rotating => stainless steel, peek, (Macor); eddy currents
cylinder => stainless steel, (Macor)
ball bearings => stainless steel

NextMoveESB: dc-dc converter with transformer, relays
Baldor gave information on voltages used
replaced by voltage stabilizer and charge pump

Piezo valves: screws

Pressure regulator: adjustment screw

Some small magnetic parts left in: connectors (fixed)
springs of piezo valves
encoder housing (forgotten)

Problem: no possibility to test entire bench, no access after closing tile cal

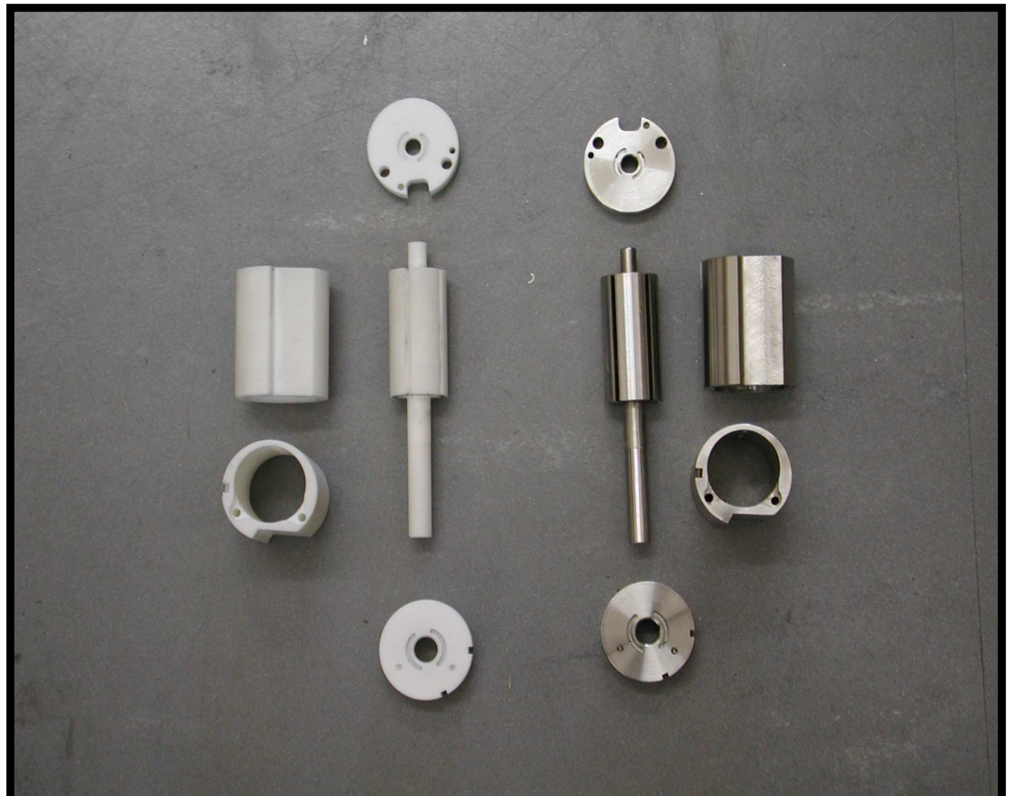
PNEUMATIC MOTOR DESIGN

Motor inner pieces made of 316 stainless steel, planetary reductor removed (too difficult to copy)

Ball bearings of 440 stainless steel, slightly magnetic.

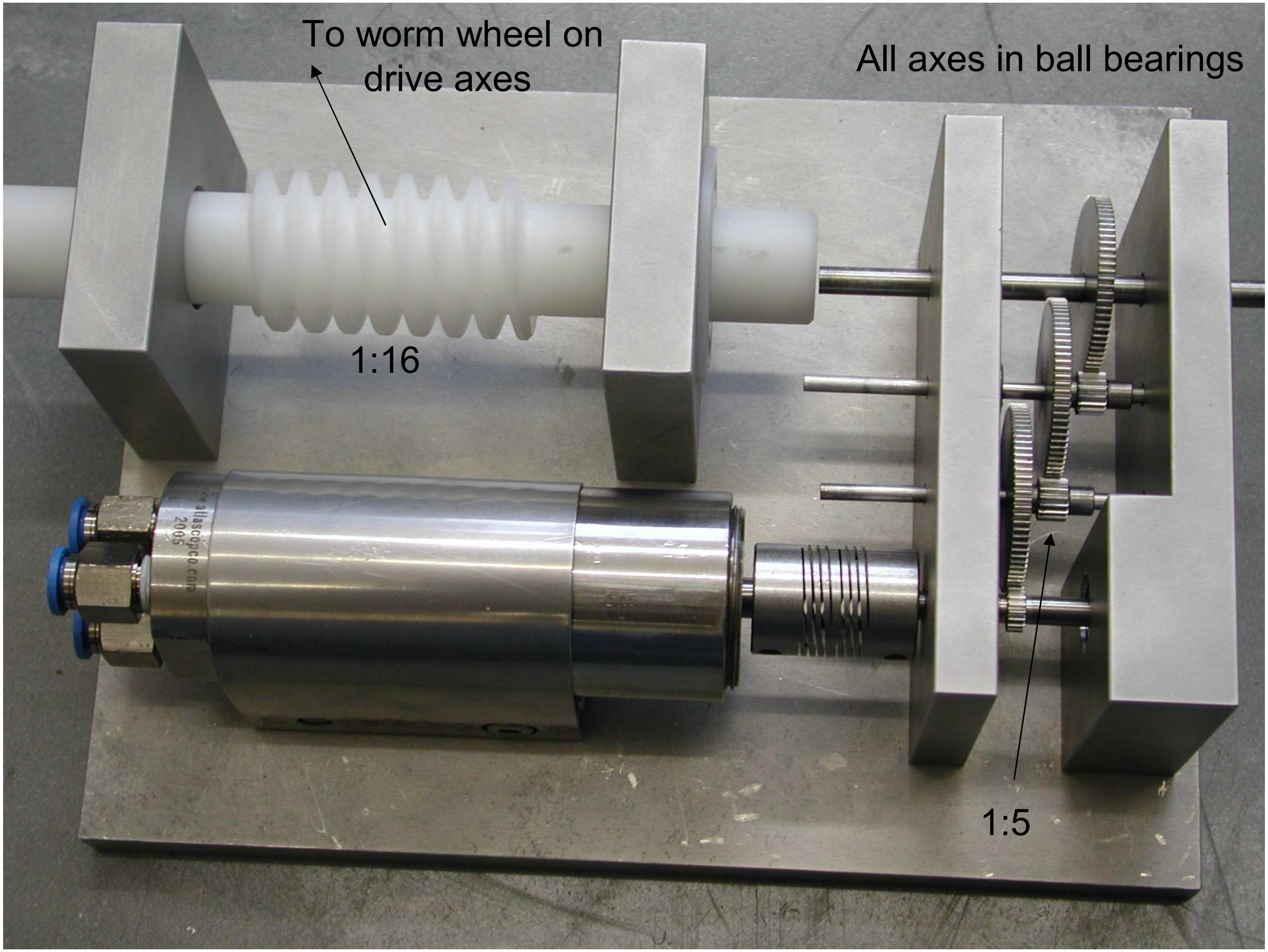
It has been tried to make a prototype of this motor out of Macor® machinable glass ceramics (Corning), but it was too difficult and expensive. Macor is very brittle .

A rotor was also made out of PEEK 1000 , a thermo plastic.



Place motor axes in beam direction => field mainly in direction of rotation axes

Gear box



Test in transverse field of 0.7 Tesla

Stainless steel rotor:

Max 0.7 Tesla at R = 1.0 m

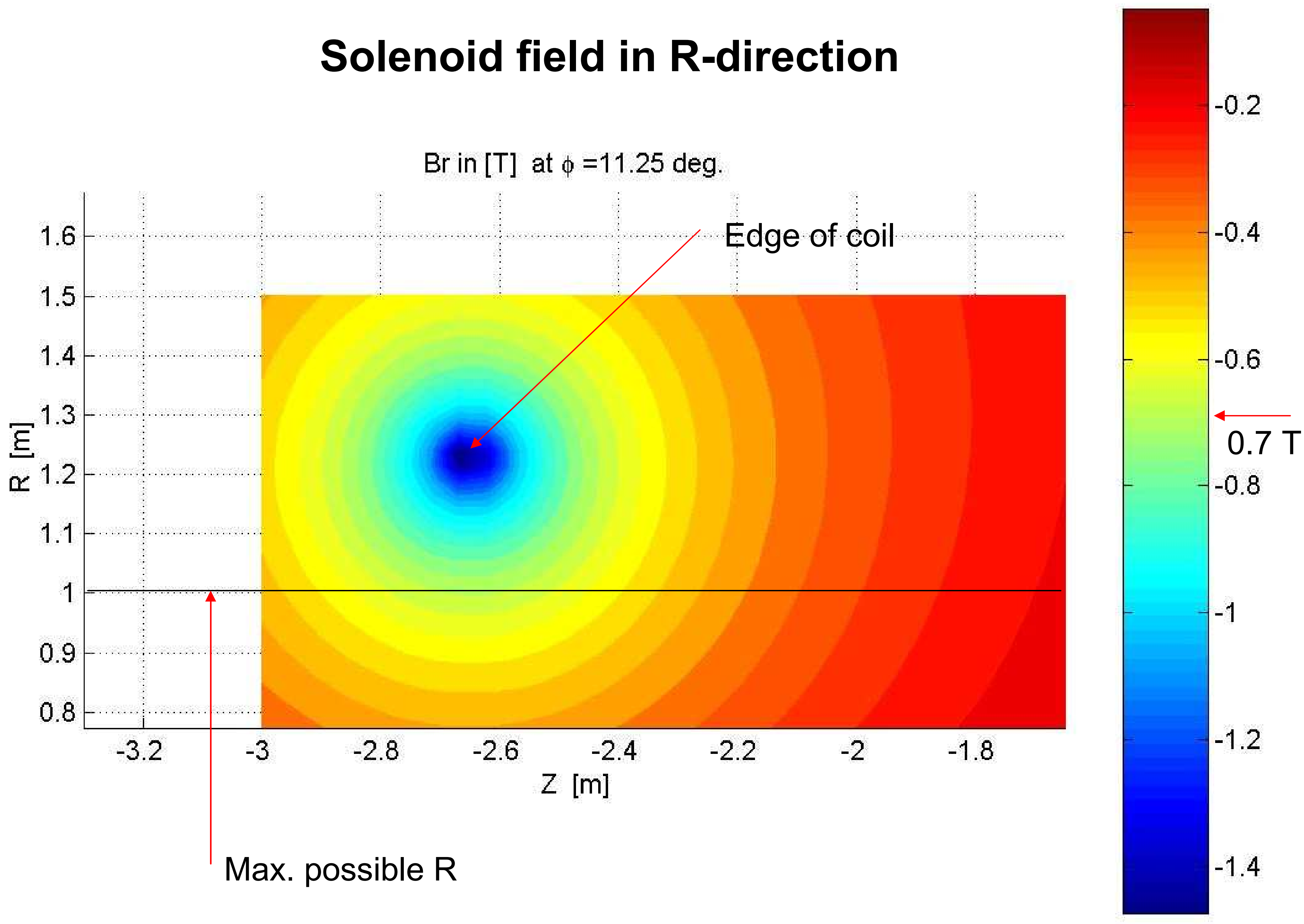
12500 rev/min @ 0 Tesla

10500 rev/min @ 0.7 Tesla => ok

> 5 Gauss @ 5 cm => ok

Peek rotor:
No significant effect at 12500 rev/min, mechanically strong enough
Peek rotor was adopted.

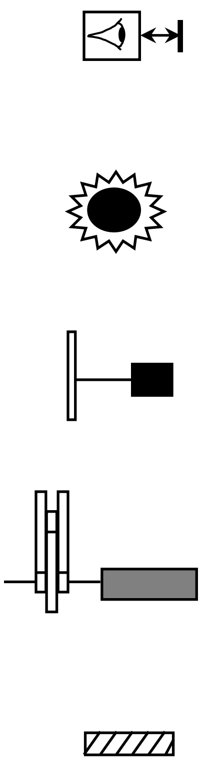
Solenoid field in R-direction



Bench layout

Two arms with 4 x 12 B-sensors

Homing on optical targets



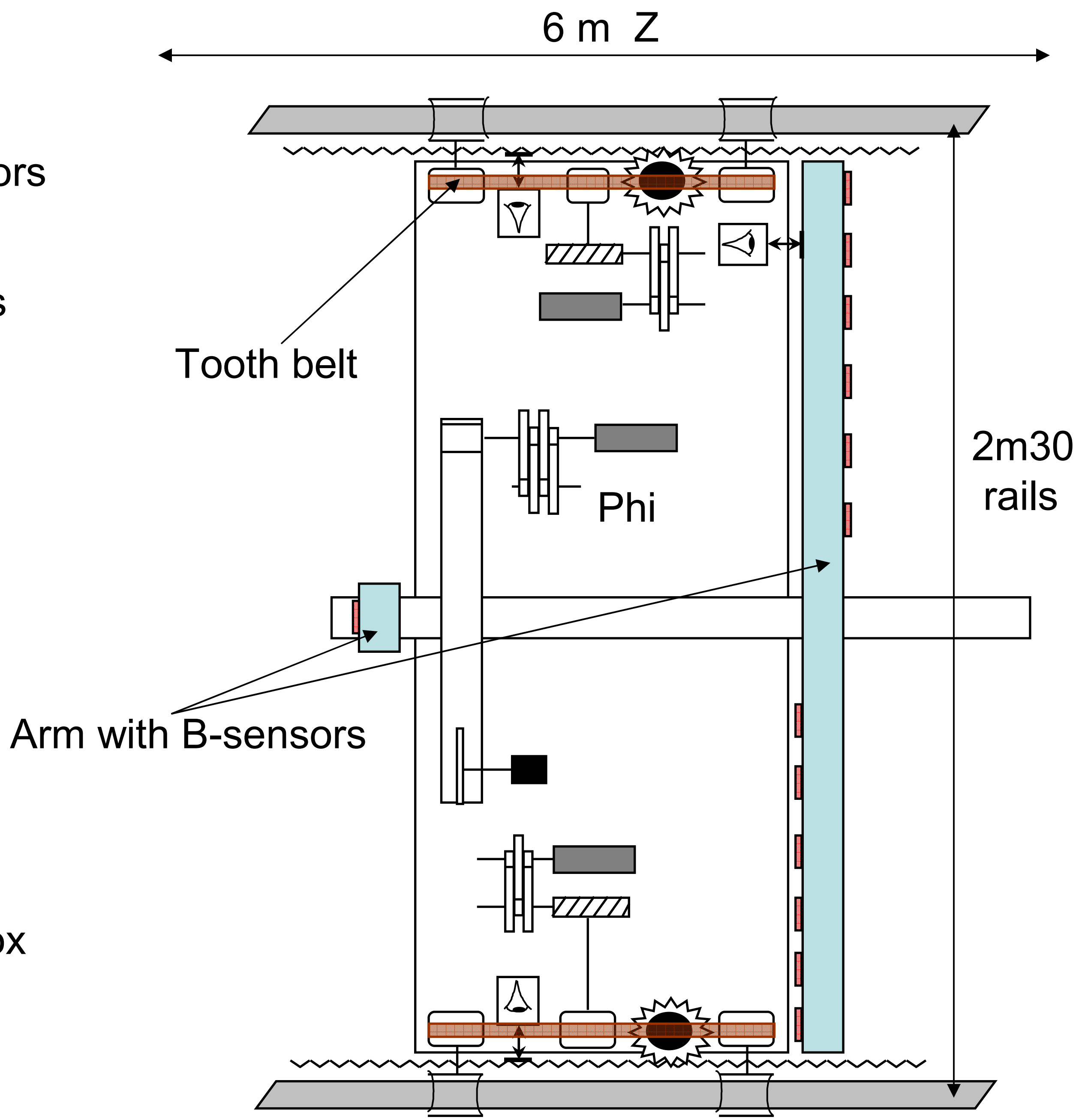
= Optical sensor

= Z-encoder

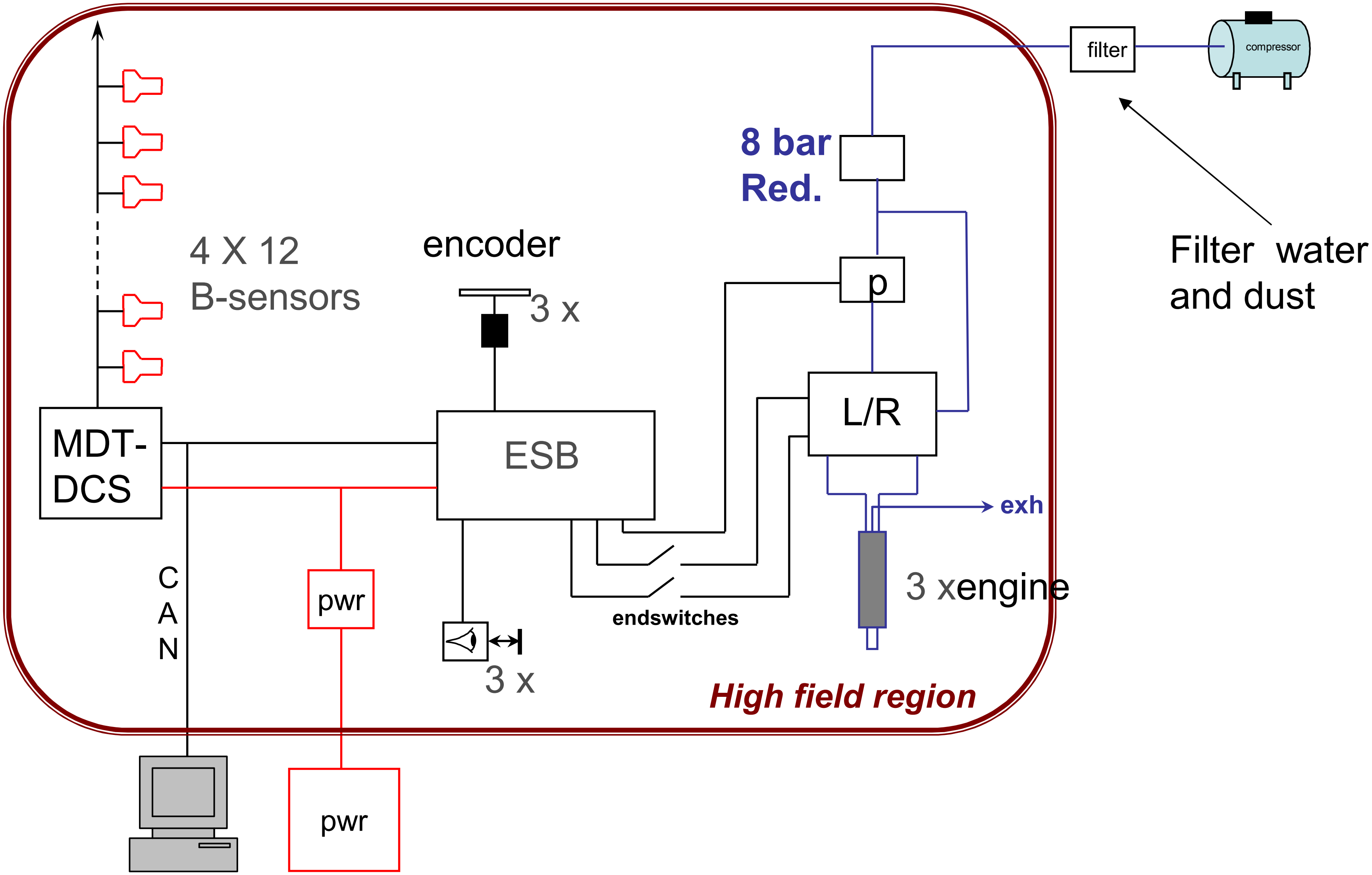
= Phi-encoder

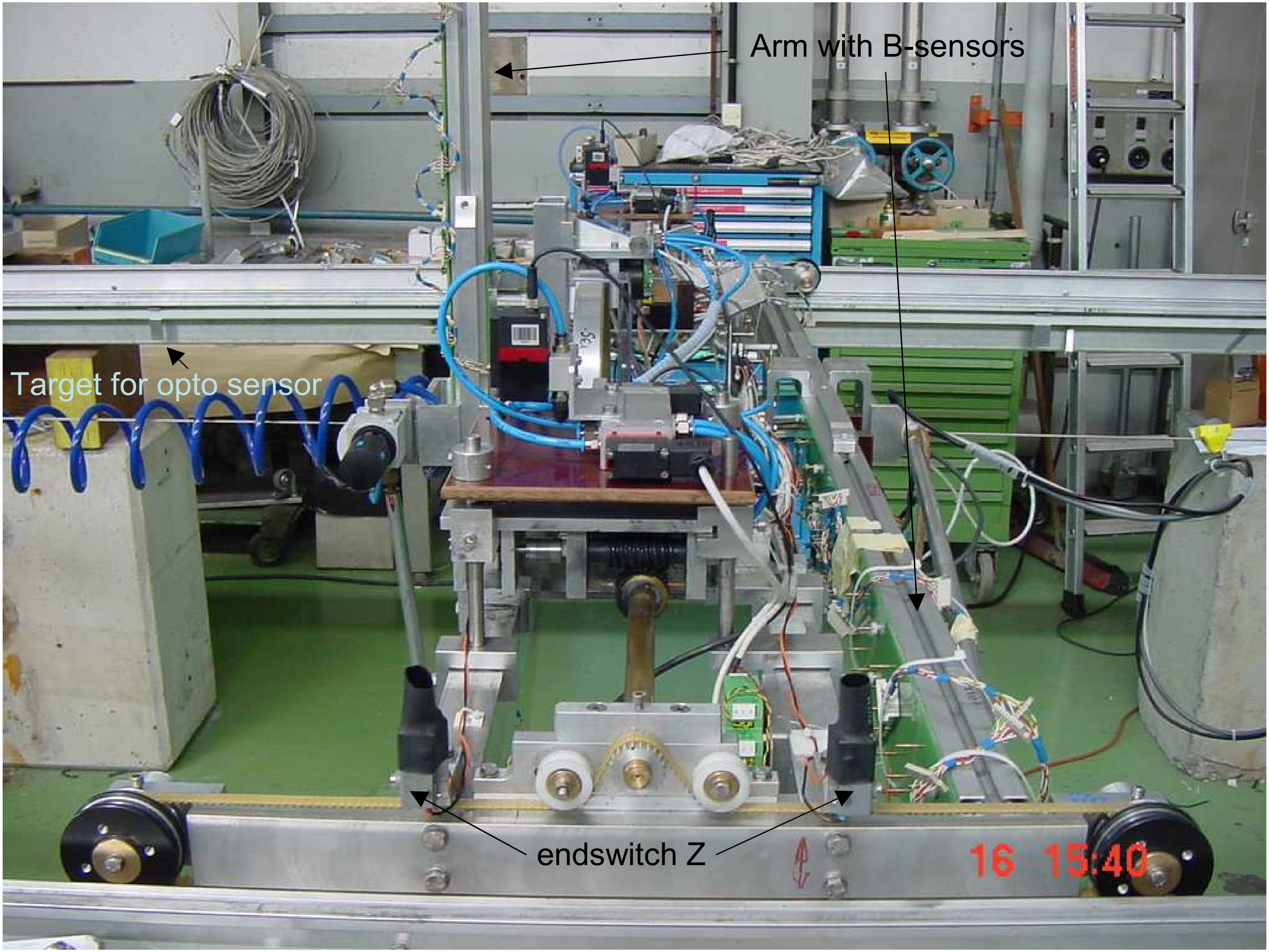
= Engine + gearbox

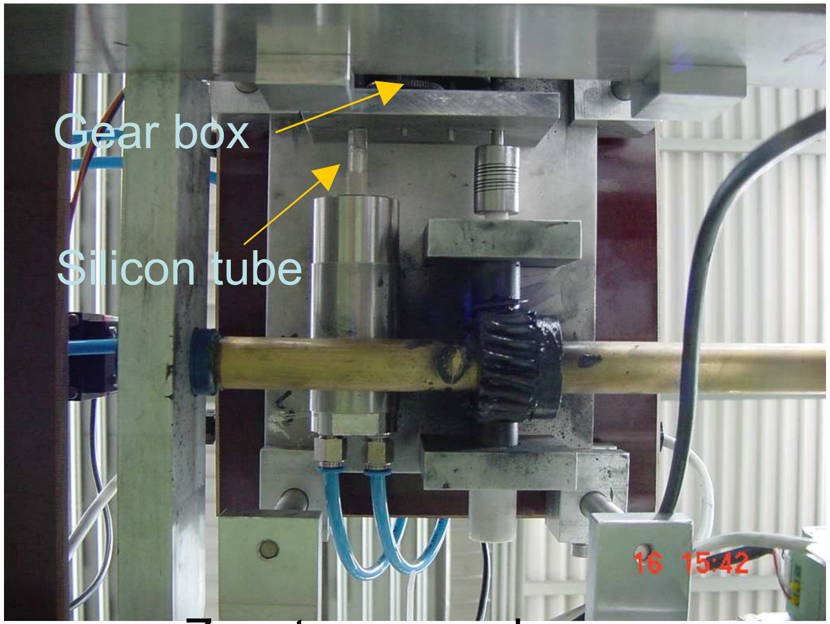
= Worm wheel



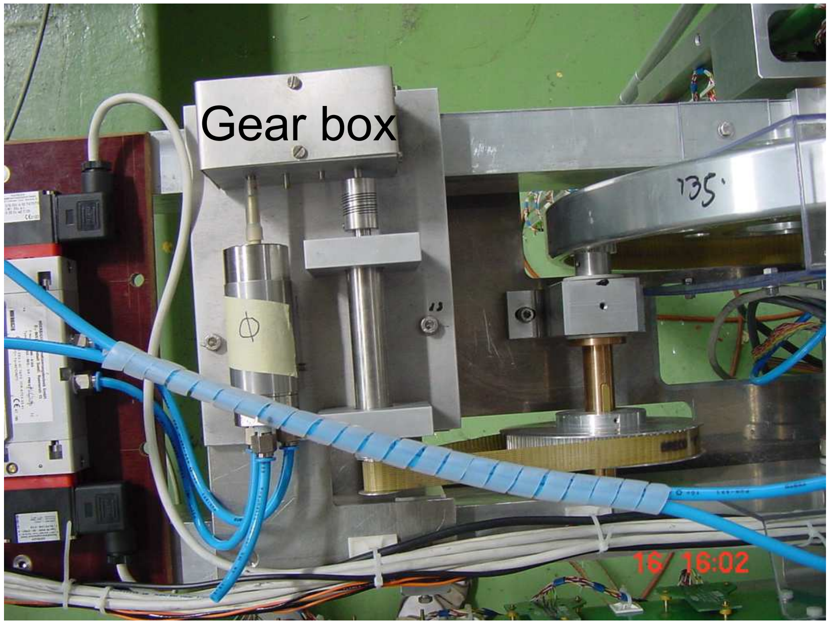
Schematic of pneumatic mapper



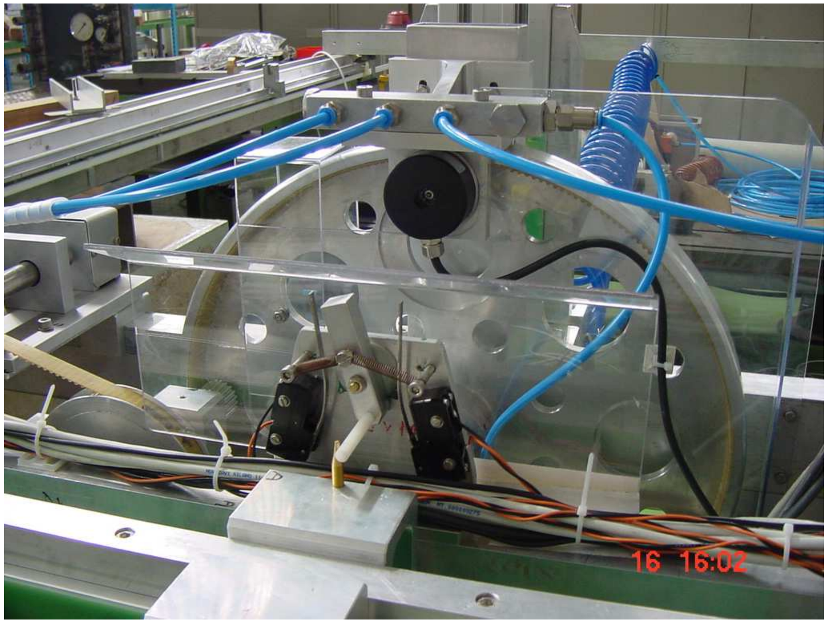

Arm with B-sensors
Target for opto sensor
endswitch Z
16 15:40



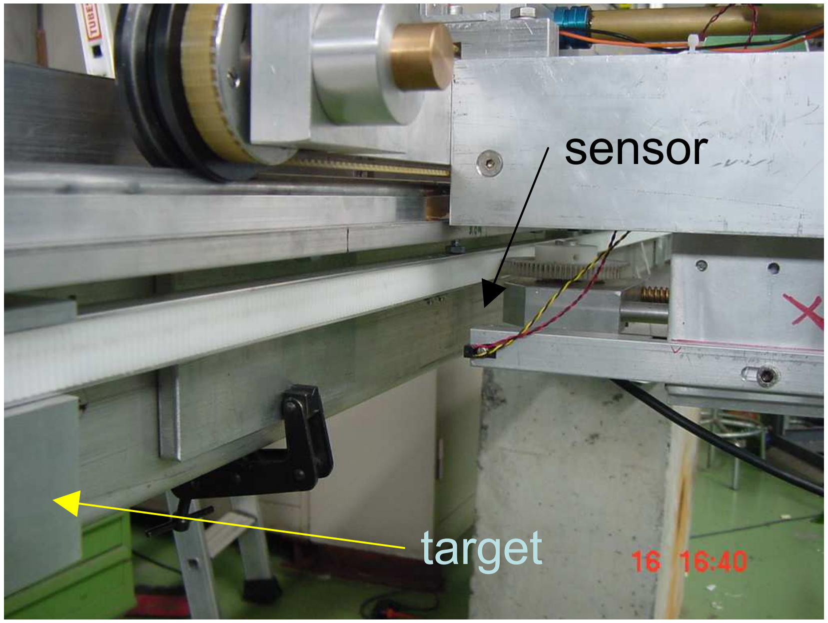
Z motor + gear box



Phi motor +gear box



Phi encoder + endswitches



Optical sensor

control

Simple P servo loop , calculate ideal path with acceleration, deceleration and minimal approach speed, regulate pressure on engines proportional to difference of real position and wanted position as function of time

Difference of left and right Z-encoder in error signal

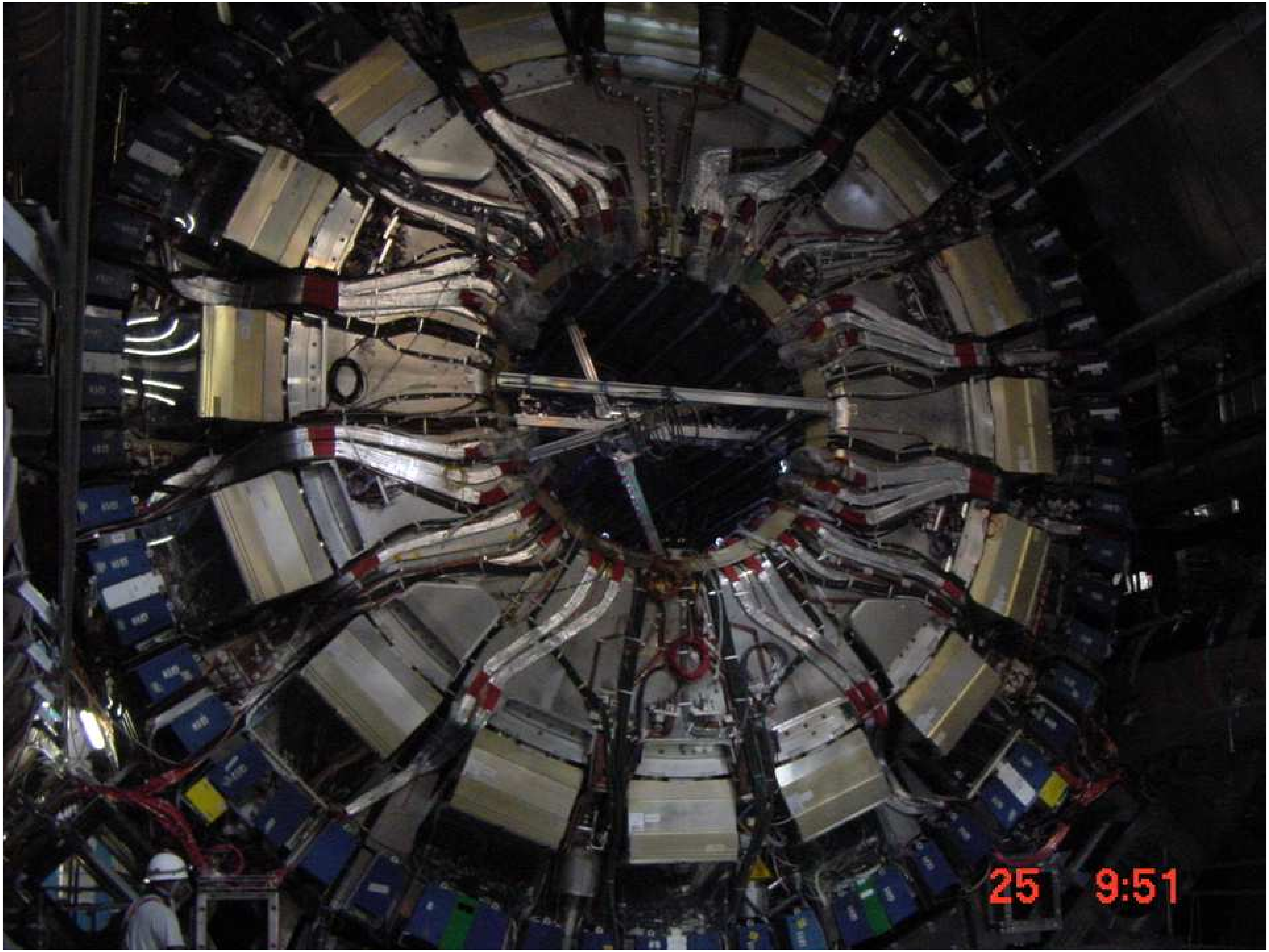
Safety:
- stop if difference between wanted and real position is too big (obstacle, air leak)
- stop if difference in left and right Z-position is too big
- end switches in Z and phi blocked the piezo valves when touched, only movement in the unblocked position possible

Homing with opto sensors on 6 targets in Z and 2 in phi, max. 1.2 m to target

Communication to PC via CAN   (USB,RS232)

DAQ program records B-sensor data and sends new position to ESB, wait for ready signal from ESB

ESB takes care of start, acceleration, deceleration and approach, sends ready signal to DAQ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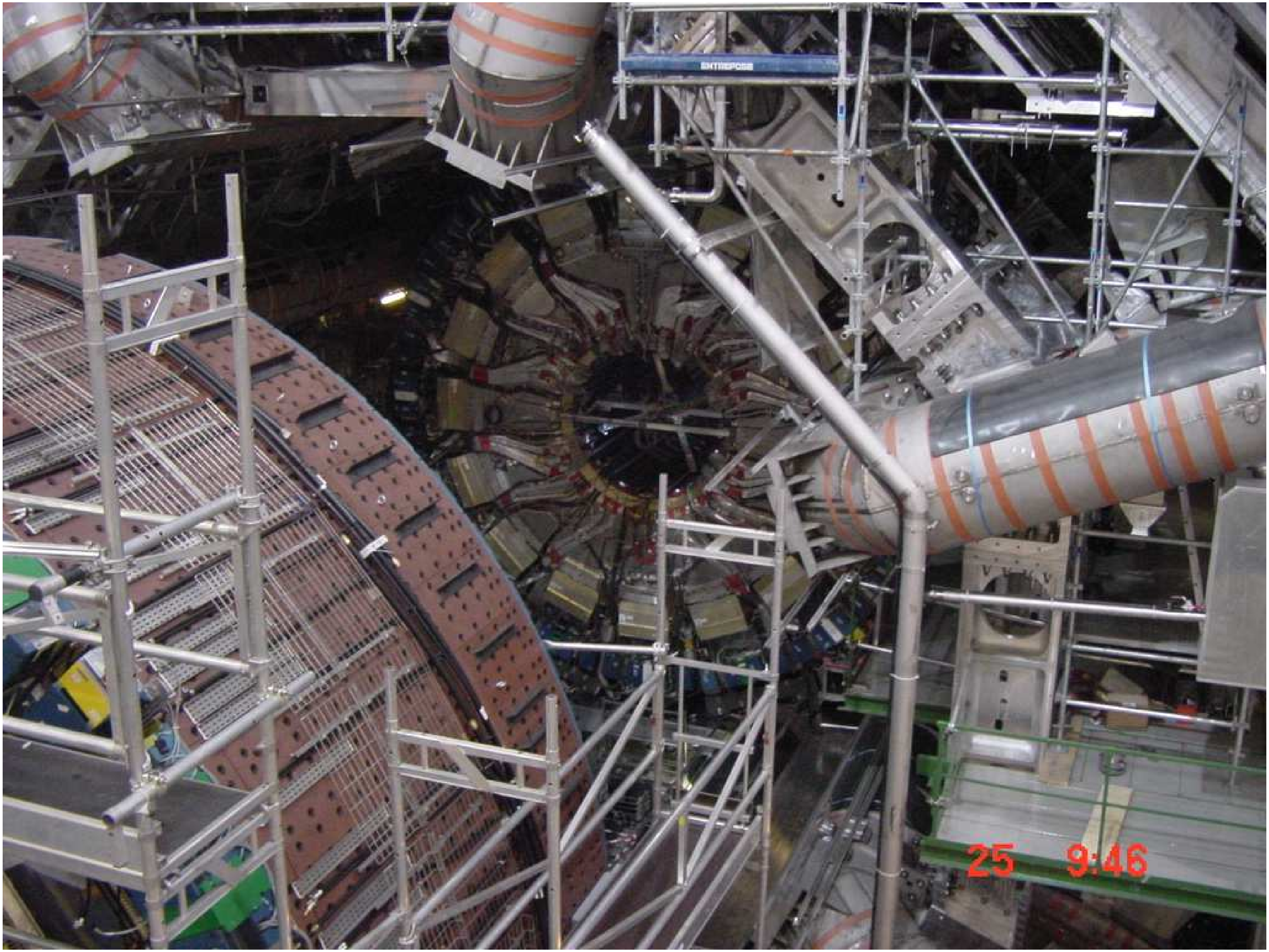
ENTREPOSE
25 9:46

performance

No failures, mapping program finished on schedule

Precision	beam direction:	0.1 mm
	angle of arms:	1 mrad

Result analysis: 4 Gauss rms on all directions at 2 Tesla in centre
to be published soon

Underestimation of eddy currents: at edge of coil the forces became significant for the z movement. Too much aluminum and too many current loops. No influence on precision

Lateral force on Z worm wheel not enough absorbed

Future:

Improve engine = gear box absorb lateral force with pressure bearing

smaller gearbox

better machining of cylinder, polishing of surface

Use less aluminium, more composites, avoid current loops
lighter construction

Try other techniques:

Piston engines evt. with piezo control => lower revs, pneumatic servo engine
e.g. 3 piston engine on excentric

Piezo engines


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