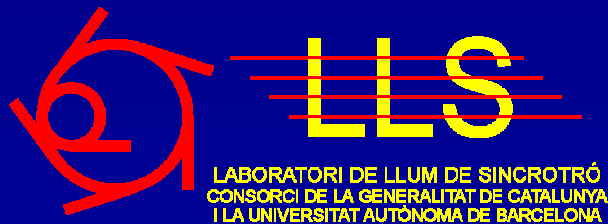

An instrument for precision magnetic measurements of large magnetic structures

D. Beltrán, J. Campmany, J. Bordas
A. Molins, J. Perlas, J. Rosich, M. Traveria



1 st-October-2001

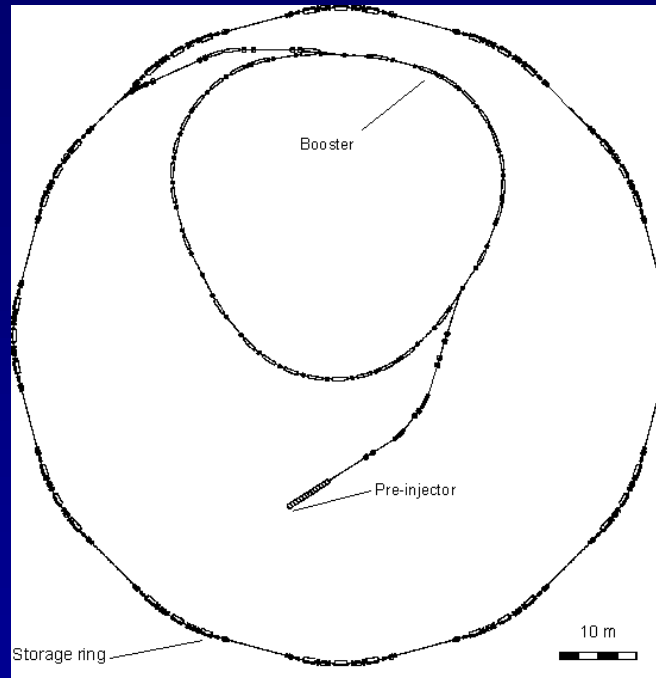
Outline

- **Introduction**

- Design requirements
- System description
- Performance
- Real examples
- Conclusions

Introduction

LLS (Spanish synchrotron light source)
at Barcelona

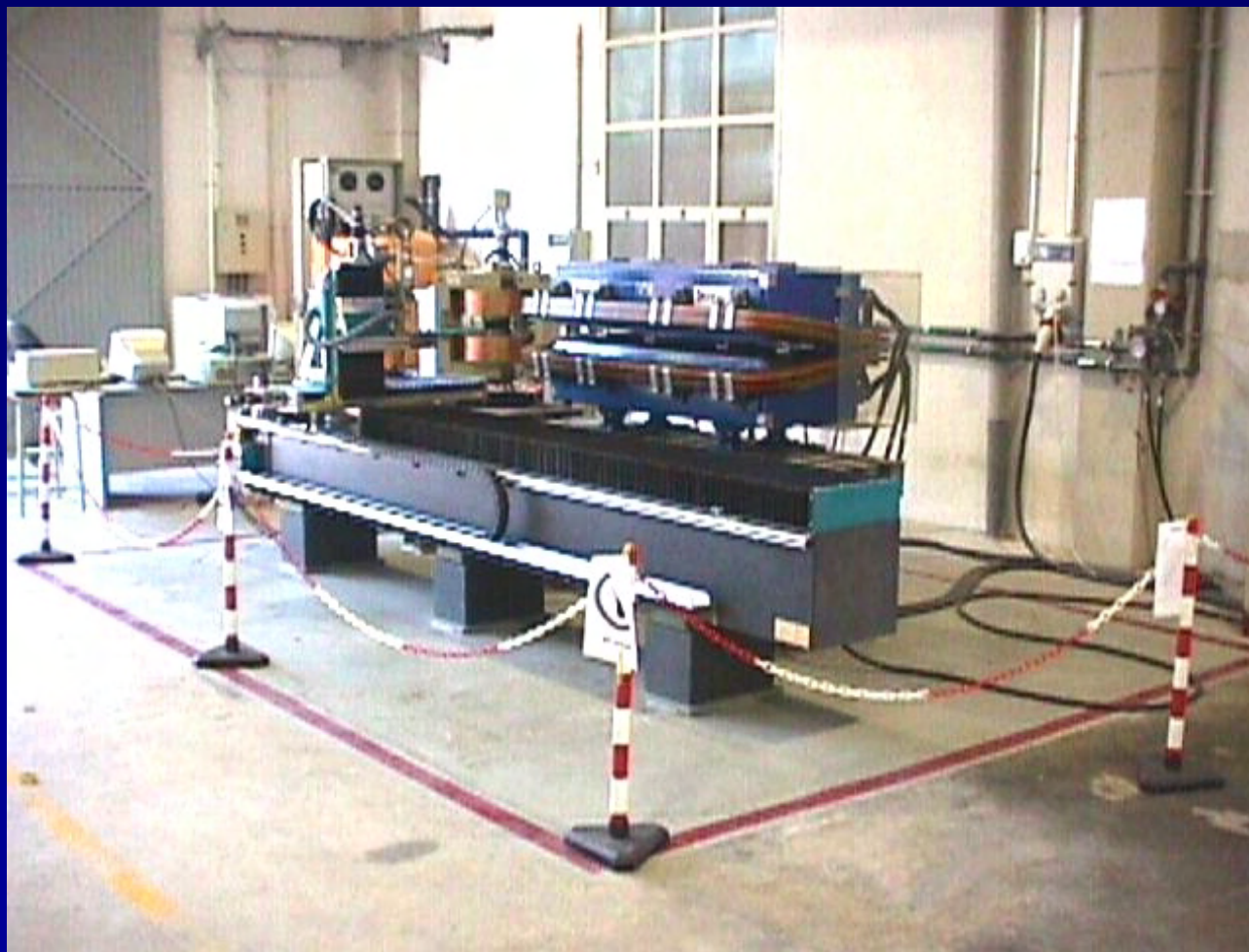


Characterize B in Bending, Quadrupolar and higher order magnets

Design requirements

- $\Delta B < \pm 2$ Gauss ($B < 1.4$ T)
- Scan a Volume $500 \times 250 \times 3000$ mm³
- Position confusion $< \pm 50$ μ m
- Hall probe motion re-programmable

System overview

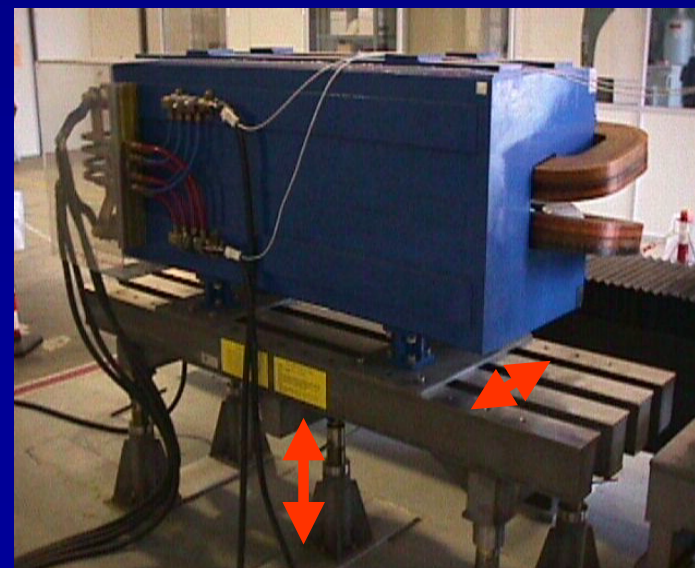


System mechanics (I)

- Anti-vibration floor (50 μ m)

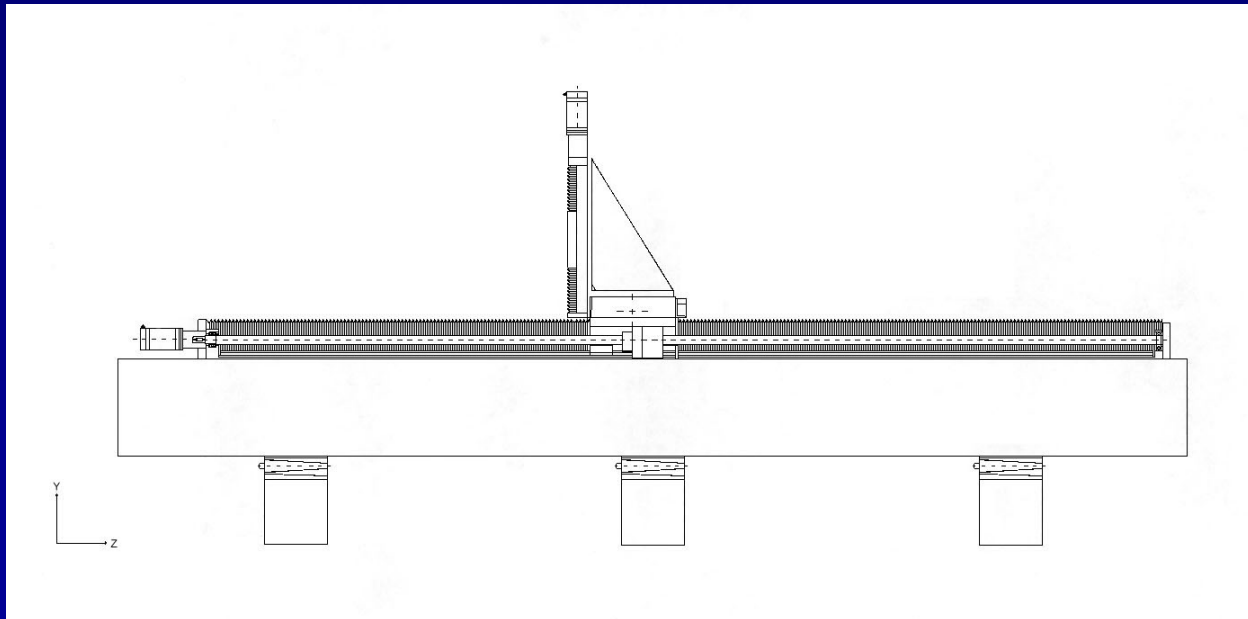


- Magnet support (6000 Kg)



System mechanics (II)

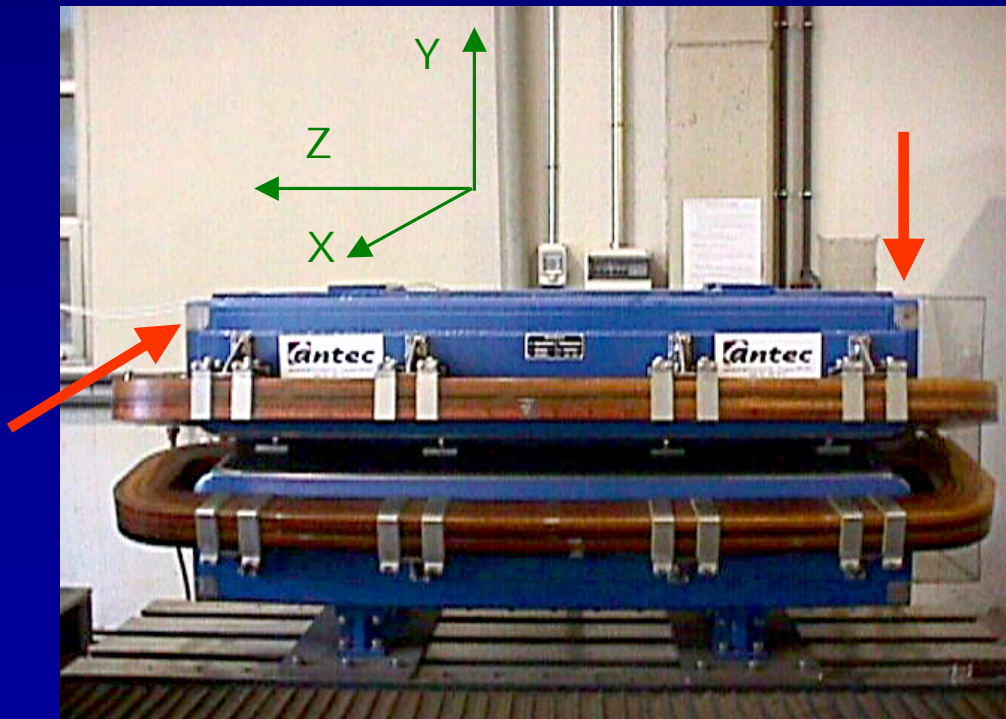
- Hall probe bench (500x250x3000 mm³)



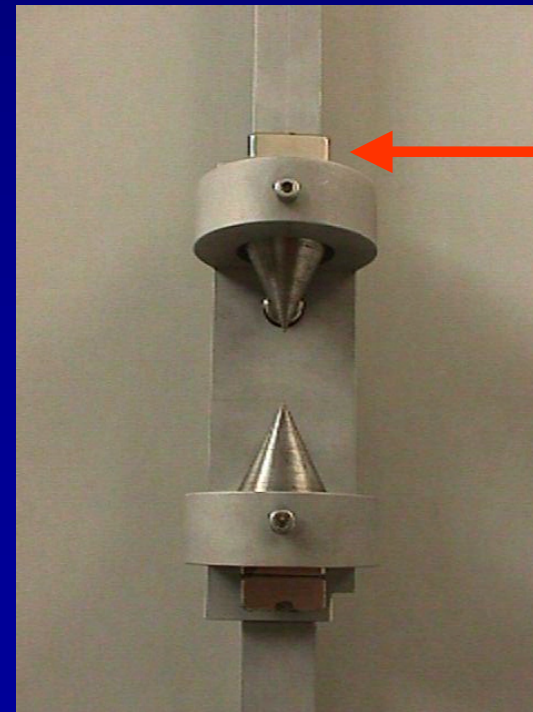
Mechanical alignment

Reference magnet mechanical center to arm coordinate system

1. Parallelism magnet-bench

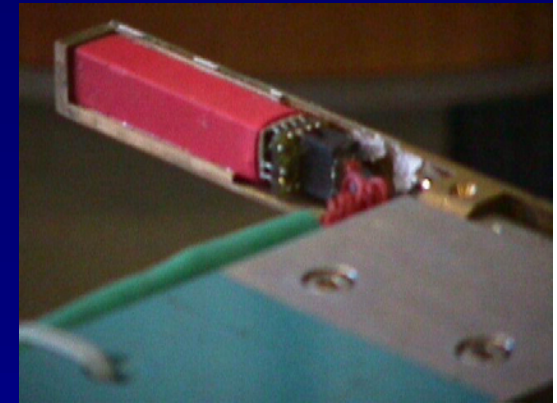


2. Translation vector magnetic struc.-bench



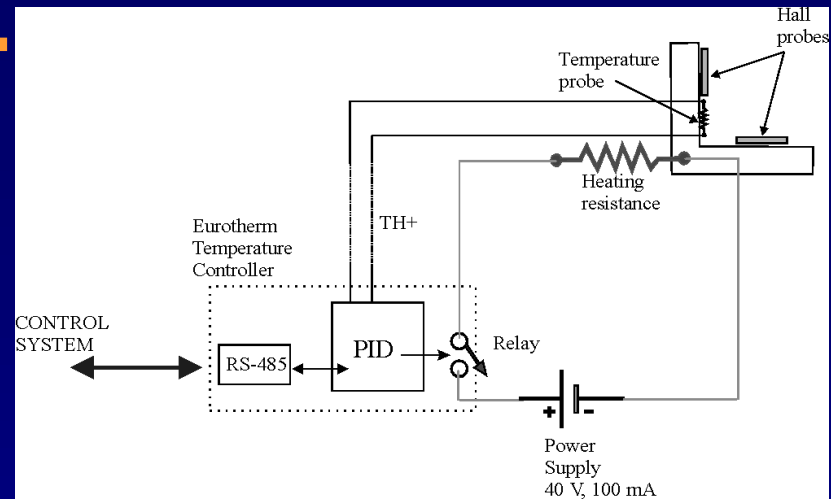
Electronics and controls (I)

- Hall probe \longrightarrow Manufactured by Sentron
450 mV/T $\pm 10\%$
- Hall probe power supply
- Voltmeter
- Calibration system \searrow
 - Reference Magnet $\Delta B/B < 15$ ppm
 - DC Power converter $\Delta I/I < 2$ ppm
 - Magnetometer $\Delta B < 0.02$ G



Electronics and controls (II)

- Temperature controller



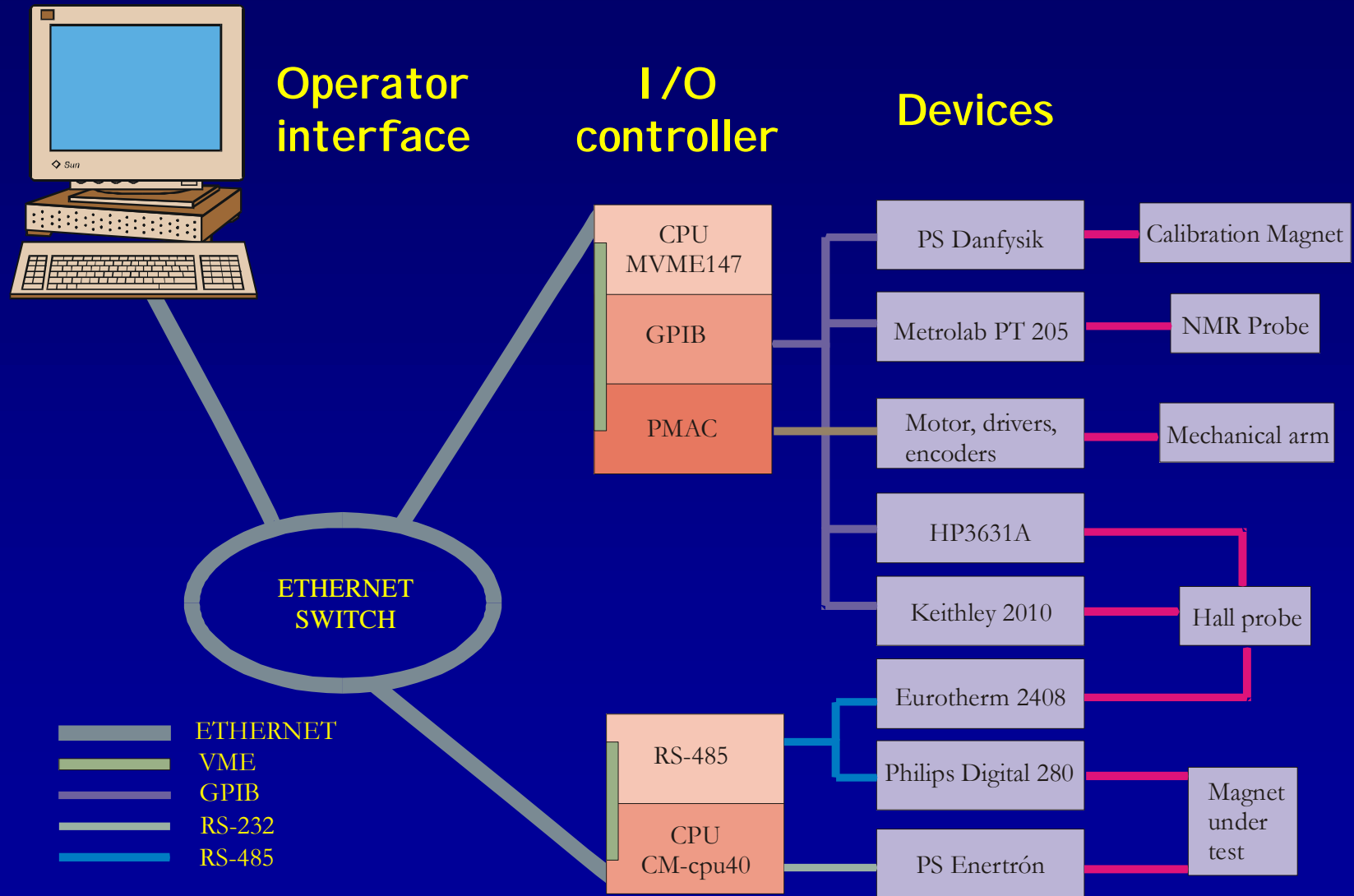
- Magnet power converter



- Cooling system

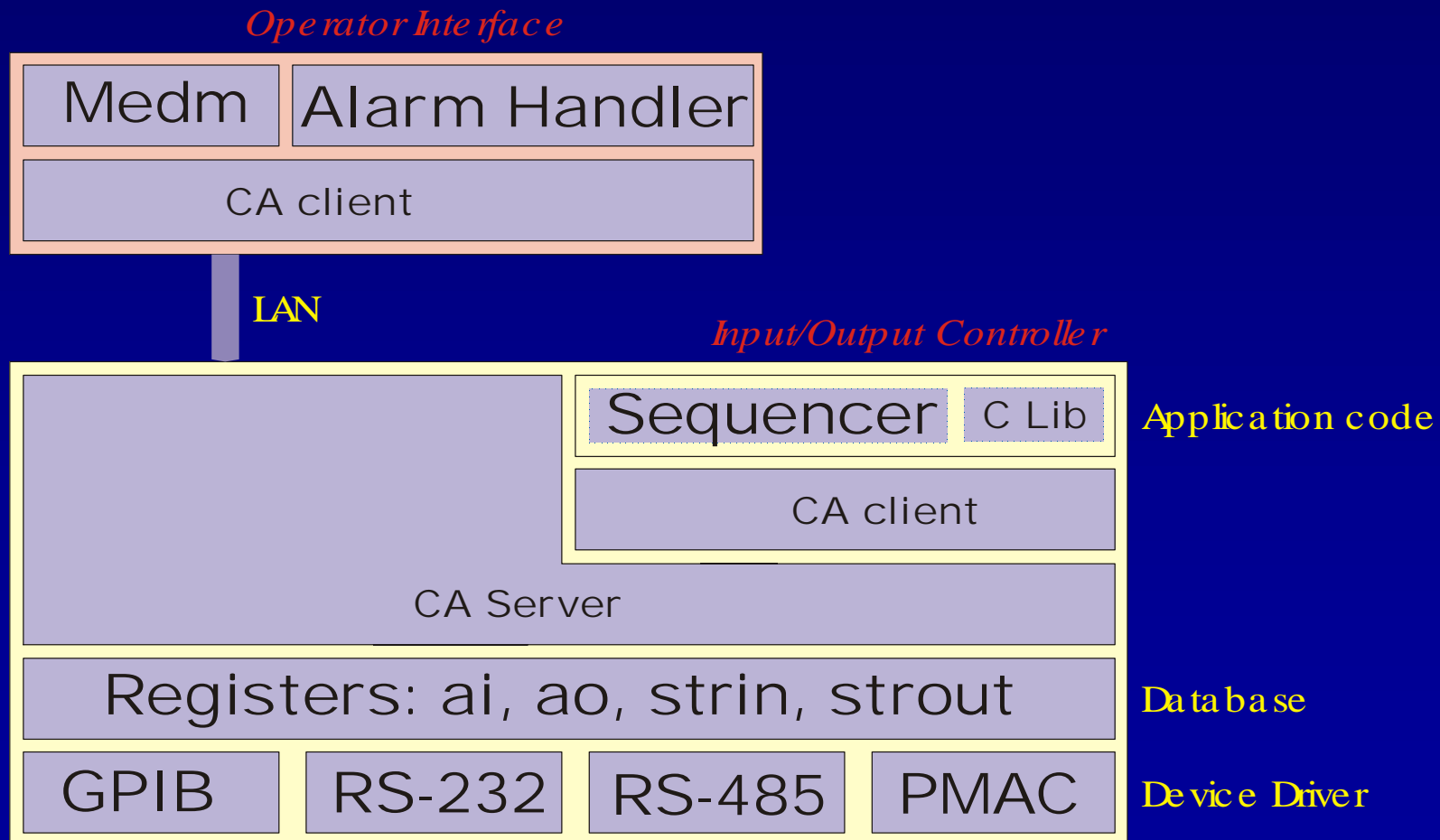


DAQ (HW architecture)



DAQ (SW architecture)

Toolkit EPICS



DAQ (User interface) I

The screenshot shows a software window titled "Antec.adl" with a green background. At the top, it says "MAGNETIC MEASUREMENT". Below that, a blue bar displays "Measurement 136". Underneath, another blue bar says "PRESENT STATUS" followed by "Go to next point to measure".

There are two main colored panels:

- A green panel on the left for "FOR NORMAL OPERATION" containing a "START" button, and "CONTINUE" and "END" buttons below it.
- A red panel on the right for "FOR ABNORMAL OPERATION (Please use with care)" containing a "SAVE AND QUIT" button and an "ABORT" button below it.

At the bottom left, there are two buttons: "CONFIGURE" (with a small icon) and "VIEW GRAPHS" (with a small icon).

On the right side, there is a progress indicator: "Percentage of program execution" with a slider set to "6 %".

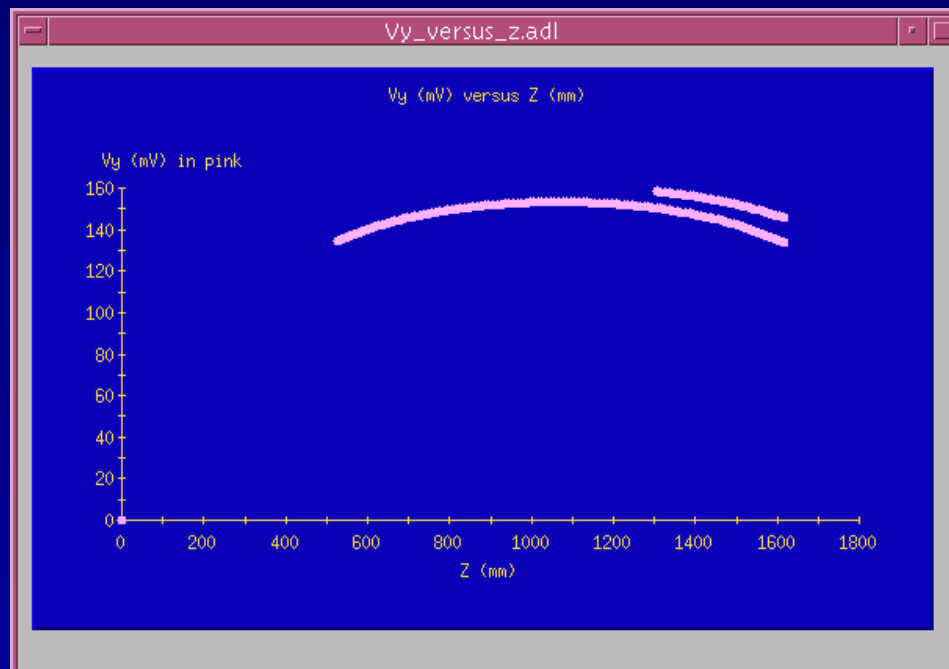
Below the progress indicator, several sensor readings are shown with colored backgrounds:

- HALL TEMPERATURE: 22.7 °C (pink background)
- MAGNET TEMP.(OUTLET): 18.3 °C (pink background)
- MAGNET TEMP.(INLET): 17.7 °C (pink background)
- ENERTRON CURRENT: 349.98 A (orange background)

At the bottom, "DAQ POSITION" is displayed with three coordinates:

- X: 205.070 mm (yellow background)
- Y: 1.225 mm (yellow background)
- Z: 1375.850 mm (yellow background)

DAQ (User interface) II



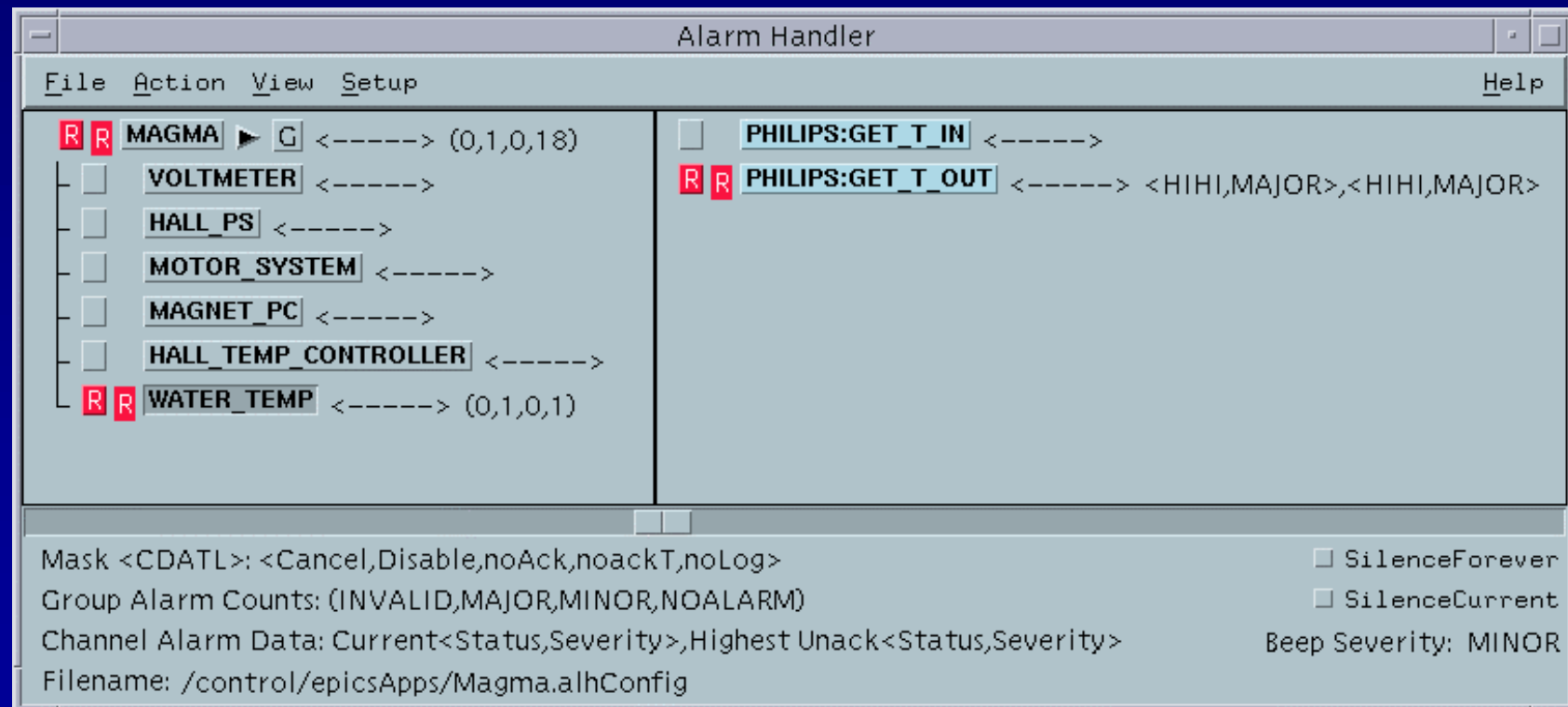
Magma configuration.adl

I Meas (A)

SET HALL TEMP. (C)

Choose scanning mode

DAQ (User interface) III



DAQ (User interface) IV

29/7/99

17:45

magma990729-1745.bin

Normal

Measurement

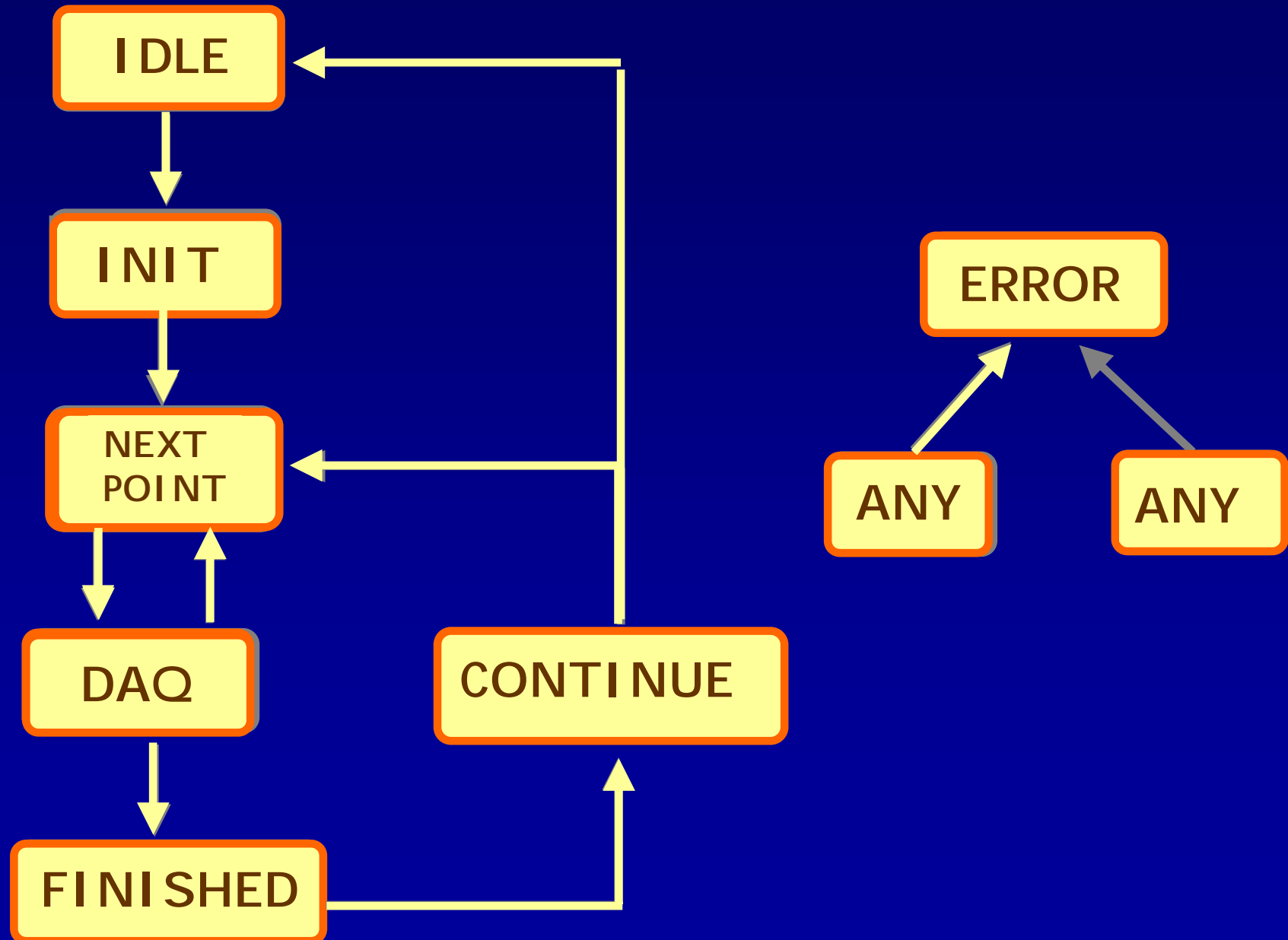
2000

Magnet #9

Hour	minute	second	TH	Tin	Tout	X (mm)	Y (mm)	Z (mm)	Vx (mV)	Vy (mV)	I (A)
16	9	20	0.0	0.0	0.0	200.000	0.000	1000.000	4.567	352.848	0.00
16	9	22	0.0	0.0	0.0	200.000	0.000	1010.001	4.581	353.016	0.00
16	9	25	0.0	0.0	0.0	200.000	0.000	1020.000	4.234	352.826	0.00
16	9	28	0.0	0.0	0.0	200.000	0.000	1030.000	4.590	353.002	0.00
16	9	30	24.0	18.0	32.9	200.000	0.000	1040.000	4.621	352.832	849.96
16	9	33	0.0	0.0	0.0	200.000	0.000	1049.999	4.432	352.999	0.00

...

DAQ (FSM)



Data analysis

Labview

CLS-TESLA MAGNET MEASUREMENT CALCULATOR

Comments

Position X centre: 232.870 Position Y centre: 9.090 Position Z centre: 1268.887

Alpha: 0.230 Beta: 1.436 Gamma: -24.22

X probe measured tension at centre (mV): 8.39

Correction because of non-orthogonality (mV): 7.34

Polynomial Fit Coefficients for X Hall probe:

2.29335E-3	-2.18986E-3	8.07054E-10	-2.39455E-11	-1.08908E-15	2.07411E-18
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Polynomial Fit Coefficients for Y Hall probe:

-7.47922E-4	2.19720E-3	5.40092E-11	2.72069E-11	-7.51645E-16	-5.38151E-18
-------------	------------	-------------	-------------	--------------	--------------

By (Integral and error (T·m))

2.7110	0.0018
2.6237	0.0018
2.5355	0.0018
2.4464	0.0018
2.3572	0.0018

MNIE By: 6.1E-5

VFB edge +

Phi (deg)	-1.37	3.5
d (mm)	-0.971	±2

VFB edge -

Phi (deg)	1.82	3.5
d (mm)	2.610	±2

B'y Integral and error (T)

7.3818	0.1009
7.4408	0.1010
7.4689	0.1011

MNIE B'y: 1.8E-4

Gradient integral (T): 7.0802 7.2358

By0 (Gauss) **Quality criteria By** **Left (mm)**

14498.317	0.99986	1869.88
14025.441	0.99988	1870.69
13546.754	1.00000	1871.65
13066.376	0.99996	1872.29
12588.503		1872.47

13543 0.99988 < 1.002

max Bx: 44.31 min Bx: -20.32

By (Gauss) **B'y (T/m)** **Quality criteria Bx**

14505	14031	13552	13071	12593	3.81	3.84	3.83	0.328	0.343	0.000
14504	14029	13551	13072	12592	3.81	3.83	3.83	0.335	0.350	0.000
14501	14027	13550	13069	12591	3.80	3.83	3.84	0.339	0.356	0.000
14501	14028	13551	13068	12591	3.80	3.84	3.84	0.344	0.361	0.000
14500	14027	13549	13068	12590	3.81	3.83	3.83	0.347	0.365	0.001
14498	14025	13547	13066	12589	3.81	3.84	3.83			
14498	14024	13546	13065	12588	3.81	3.84	3.83			
14499	14025	13547	13065	12587	3.81	3.84	3.84			
14497	14024	13545	13064	12586	3.81	3.84	3.84			
14495	14021	13543	13063	12585	3.81	3.83	3.83			
14495	14020	13542	13061	12584	3.81	3.83	3.83			

0.3 to 0.7 0.002

Performance

<u>Error source</u>	<u>Rnd/Syst</u>	<u>Relation with B</u>	<u>Worst case</u>
Magnet power supply (ΔI_1)	Syst	$\frac{\Delta B}{B} = \frac{\Delta I_1}{I}$	± 0.28 Gauss
Hall probe power supply (ΔV_1)	Syst	$\Delta B = \frac{B}{V} \times \Delta V_1$	± 0.25 Gauss
Multimeter (ΔV_2)	Syst	$\Delta B = \text{Gain} \times \Delta V_2$	± 0.12 Gauss
Calibration Error (ΔB_1)	Syst	$\Delta B = \Delta B_1$	± 0.9 Gauss
Total systematic			± 1.6 Gauss
Temperature (ΔT_1)	Rnd	$\Delta B = (0.5 + 10^{-4} B) \times \Delta T_1$	± 0.15 Gauss
Hall probe power supply (ΔV_3)	Rnd	$\Delta B = \frac{B}{V} \times \Delta V_3$	± 0.02 Gauss
Multimeter (ΔV_4)	Rnd	$\Delta B = \text{Gain} \times \Delta V_4$	± 0.03 Gauss
Hall probe noise (ΔV_5)	Rnd	$\Delta B = \text{Gain} \times \Delta V_5$	± 0.4 Gauss
Cable noise (ΔV_6)	Rnd	$\Delta B = \text{Gain} \times \Delta V_6$	± 0.04 Gauss
Total random			± 0.4 Gauss

Real examples

- ✓ LLS Bending magnet prototype
- ✓ ANKA storage ring bending magnets
- ✓ CLS combined magnets



Conclusions

- High precision measurement system (± 2 Gauss)
- Large volume ($250 \times 20 \times 300$ mm³) with high precision (± 50 μ m)
- Easily adapted of a wide range of magnets
- Movement + acquisition: 2.5 s per point
- In situ data analysis
- Proved: LLS prot., Anka bending, CLS prototype