IMMW12

Magnetic measurements of LHC dipoles and quadrupoles at room temperature at the factories

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Introduction - Aims

- The magnetic field is proportional to the current in the search coils

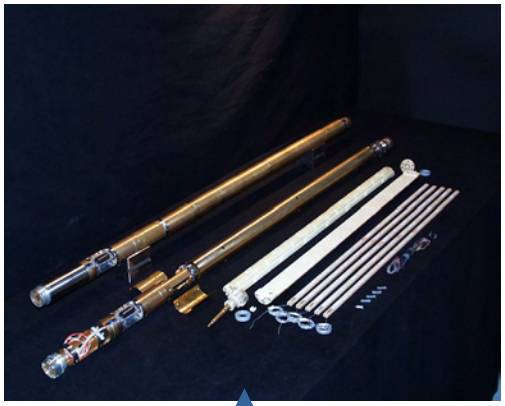
- Quality Control of collared coils and cold masses at the factories
- Early detection of defects and acceptance tests
- Study of the evolution of characteristics of single magnets over time to observe the trend
- Collection of data of general interest for several studies, e.g. beam optics

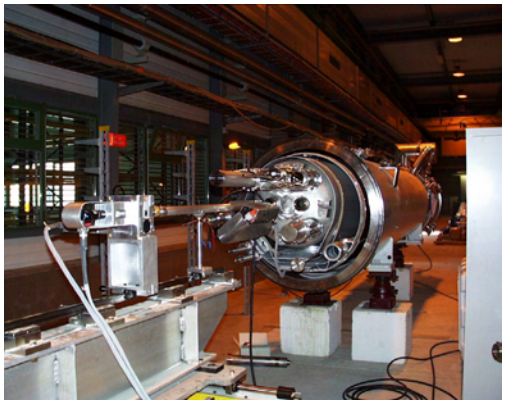
- A correlation exists between measurements at room temperature and at cold in spite of some limitations

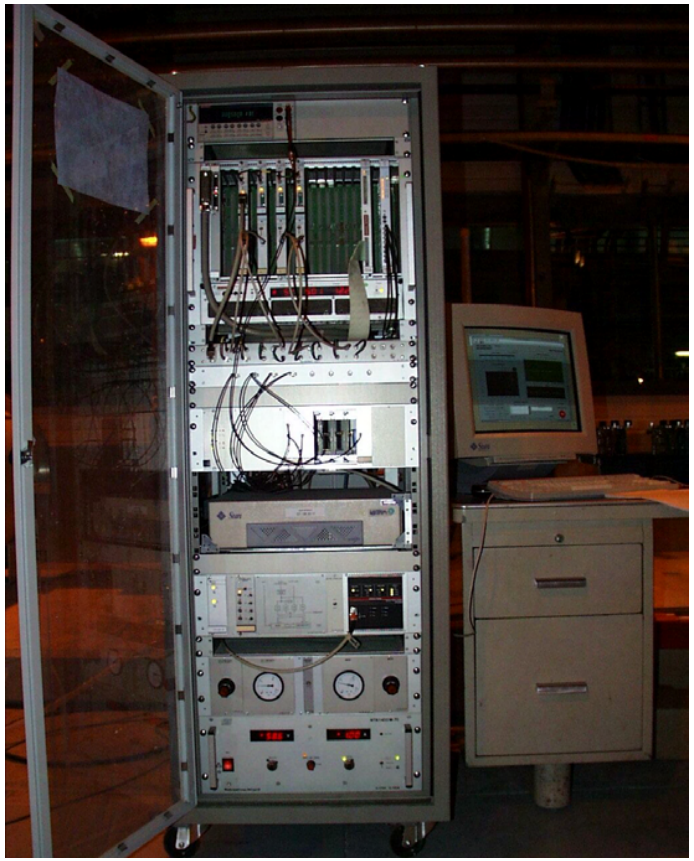
People involved

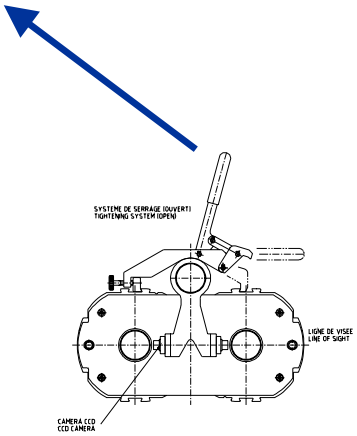
- Search coils manufacture (LHC/MMS-IF)
- Mole manufacture (LHC/MMS-IF & EST/ME)
- Software (LHC/IAS)
- Bench for the mole translation inside quadrupoles (CEA/ Saclay)

Global view

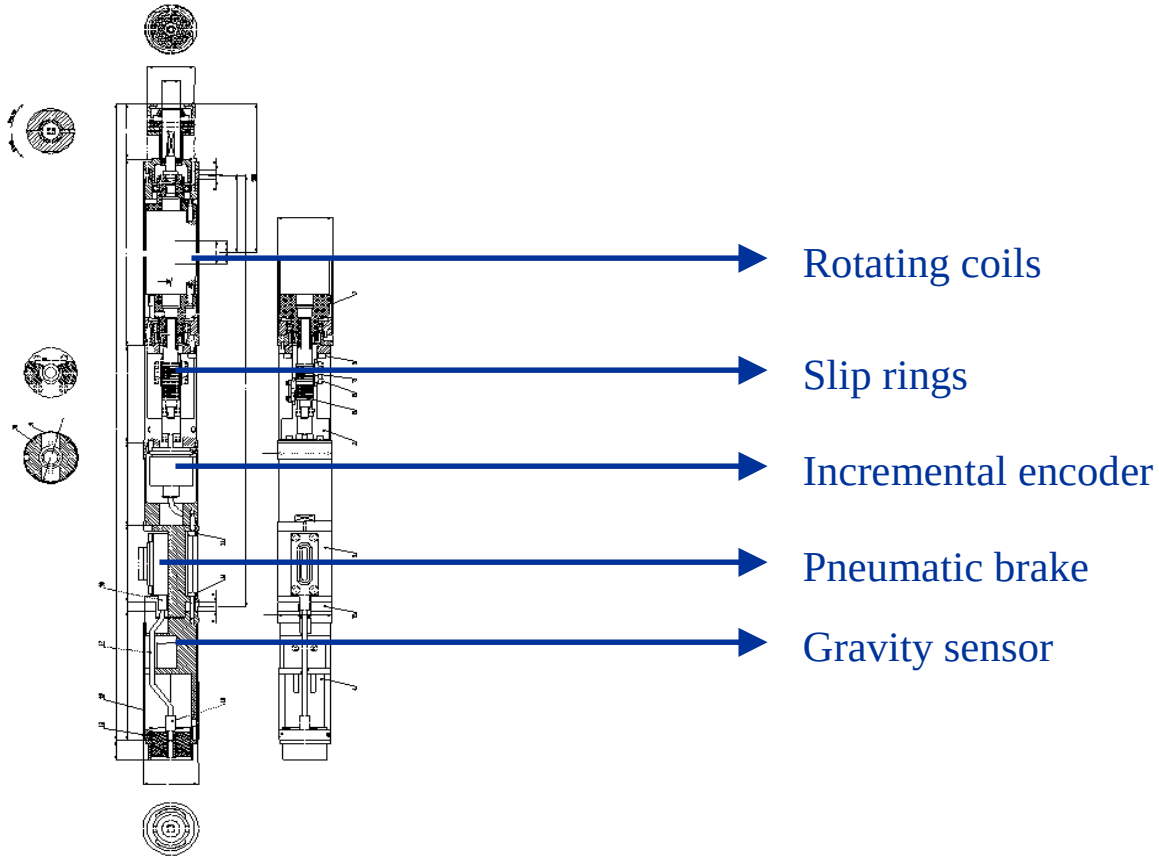




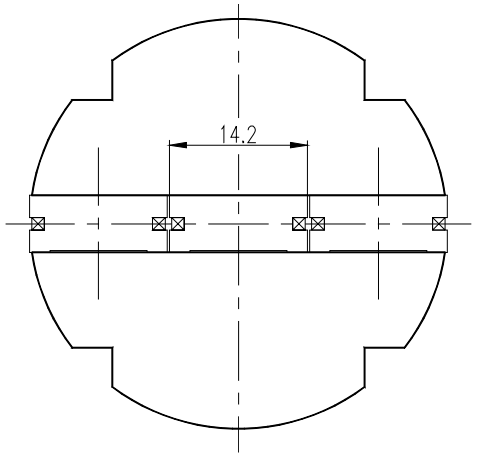



SYSTEME DE SERRAGE (OUVERT)
TIGHTENING SYSTEM (OPEN)
LIGNE DE VISEE
LINE OF SIGHT
CAMERA CCD
CCD CAMERA

The mole


Rotating coils
Slip rings
Incremental encoder
Pneumatic brake
Gravity sensor

The coils set



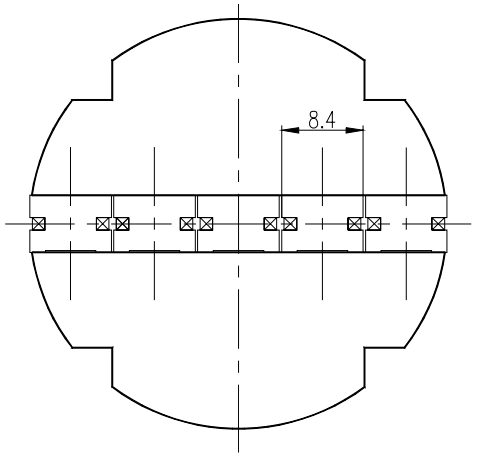
Dipoles & correctors

Coils are 14.2 mm wide

3 coils per mole

25 moles required

5 ready, 4 in the final phase



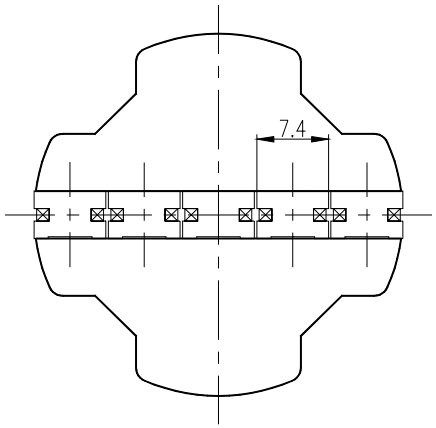
MQ, MQM, MQY & correctors

Coils are 8.4 mm wide

5 coils per mole

12 moles required

4 ready



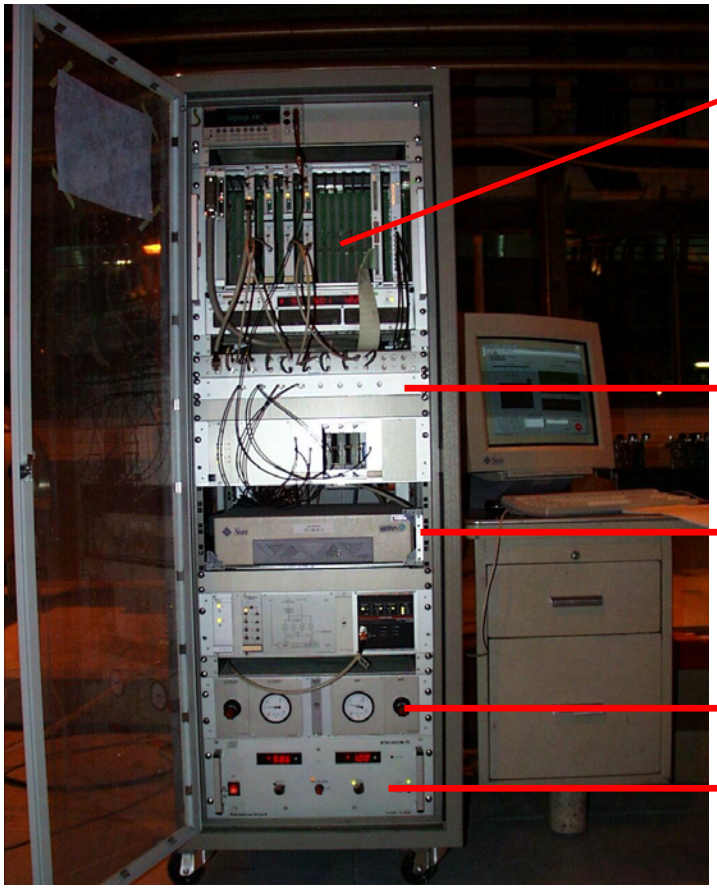
MQW (resistive)

Coils are 7.4 mm wide

5 coils per mole

1 mole to be produced

Measurement rack



VME crate (integrators, ADC, IO, MXI, CPU)

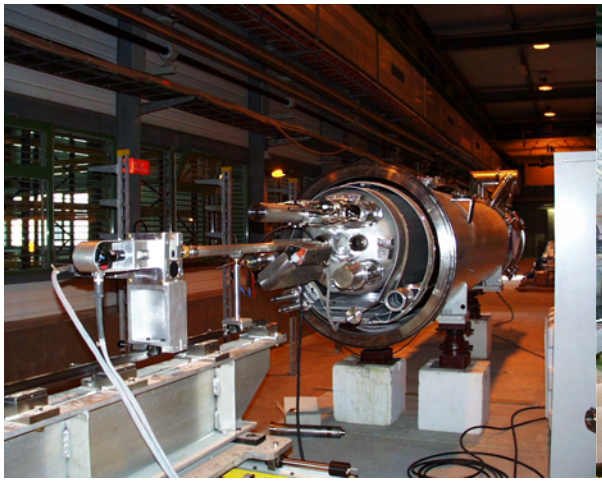
Coils bucking

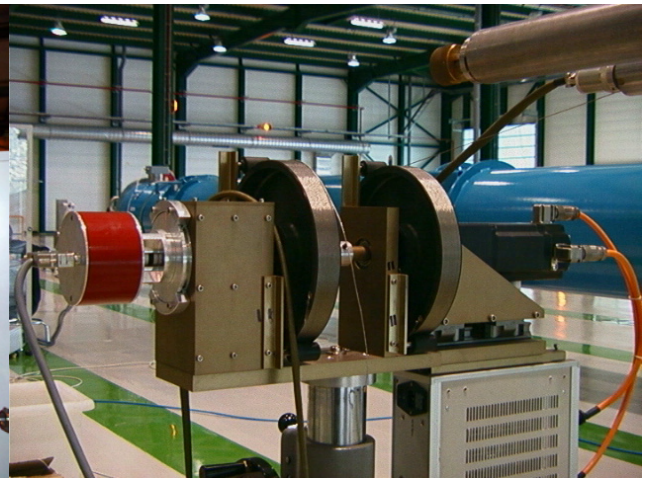
Sun workstation

Brake

Power supply

Mole translation devices





Extensions - Manual

Used for MQM, MQW, MQY and for MB until April 2002.

Measuring a magnet takes about 6 hours (MB)

Cable – Automatic

Used for MB starting in April 2002

2 moles in parallel.

About 4 hours per magnet.

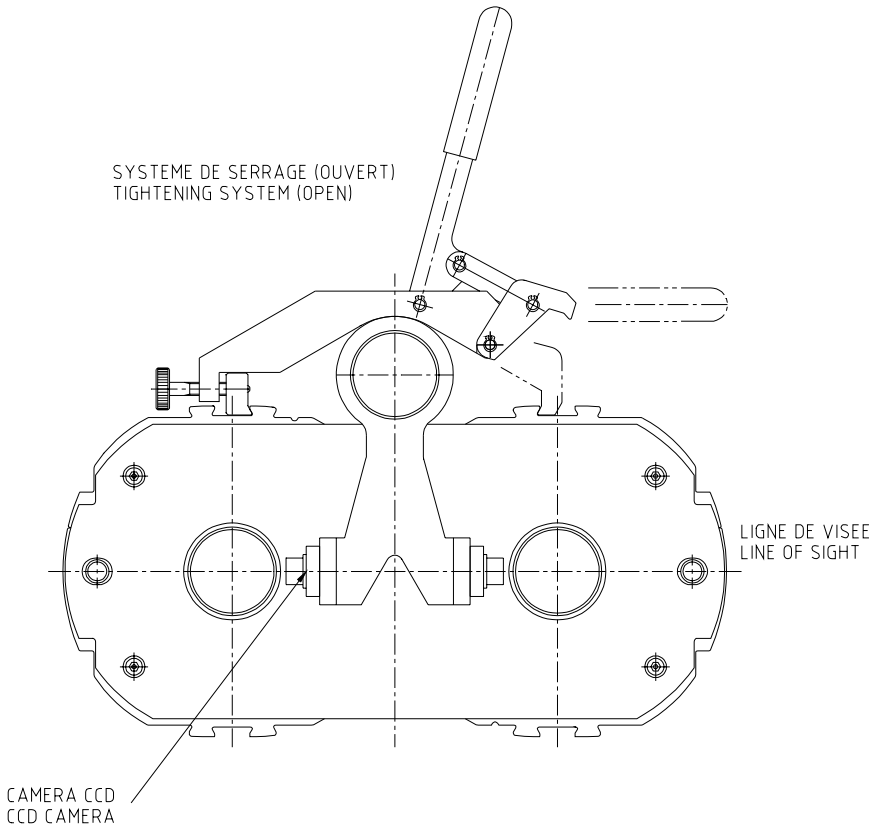
Extensions – Automatic

Used for MQ.

System developed by CEA/SACLAY.

First measurement at ACCEL, November 2001.

Measuring the magnetic length



Precision required: ± 0.3 mm

Stainless steel tube carefully measured and calibrated at 20°C

LED or camera at the extremities to measure the first and last position of the mole

Software

- Program developed in Labview by the LHC/IAS group
- Modules shared with the LHC/MTA group:
  - Coil position encoder interface
  - Harmonic analysis performed at a given mole position
- Dedicated modules for:
  - Control of the coil rotation
  - Longitudinal mole translation
  - Mole orientation with respect to the gravity
  - Control of power supply
  - Complete harmonic analysis, including the integral and magnetic length

Output files

- « Internal files » for historical analysis and comparison within LabView. Files are stored on a Sun at CERN
- Integrator output «raw data » for off-line analysis on demand. Files are stored on a PC at CERN
- Summary of harmonic analysis are imported in Excel files and stored on the Web server:

  URL: http://cern.ch/lhc-div-mms

  Measurements -> ITP 21 and 34

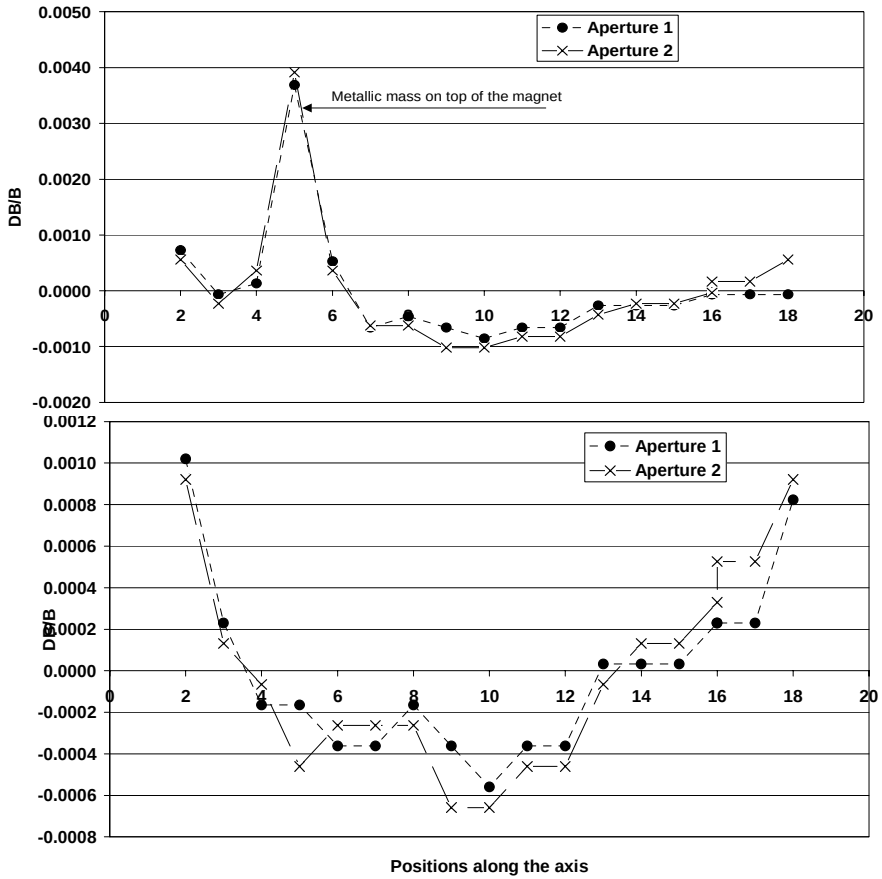
Summary of harmonic analysis

File	Aperture 1 - Collared coils																				Integrals
C1 (mT)	0.003	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.003	0.073
Angle (mrad)	-6.589	-0.835	-0.241	0.231	-0.282	-0.435	-0.368	-0.123	0.029	0.053	-0.237	-0.110	0.483	0.269	1.598	1.223	-0.434	-0.721	1.580	2.424	12.267
Multipoles	Position 1	Position 2	Position 3	Position 4	Position 5	Position 6	Position 7	Position 8	Position 9	Position 10	Position 11	Position 12	Position 13	Position 14	Position 15	Position 16	Position 17	Position 18	Position 19	Position 20	
b1	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
b2	-6.499	1.855	0.409	-0.622	-1.897	-0.079	0.878	0.326	0.047	-0.462	-0.424	-0.732	-1.090	0.165	-2.460	-0.173	-1.215	-2.772	-5.697	-4.423	-1.081
b3	44.810	3.539	1.167	0.461	0.707	-1.289	2.953	3.896	3.017	3.512	2.310	3.017	1.841	-0.242	-4.734	-5.426	-7.140	-5.705	0.797	-7.268	1.279
b4	-1.039	0.004	-0.013	-0.594	0.059	0.358	-0.041	-0.009	-0.180	-0.275	-0.378	-0.281	-0.936	0.131	-0.318	0.233	0.165	-0.015	0.015	0.538	-0.121
b5	-1.256	1.922	1.495	1.911	2.464	2.813	2.424	1.934	1.834	2.241	2.254	2.202	1.502	1.682	2.911	3.365	4.045	2.519	1.674	-1.999	2.028
b6	-1.740	-0.081	0.007	0.443	0.149	-0.181	-0.045	0.017	-0.010	0.133	-0.059	0.002	0.502	0.058	0.622	-0.123	0.290	0.262	-0.256	-0.331	0.024
b7	2.708	0.544	1.082	0.849	0.577	0.627	0.628	0.825	0.951	0.764	0.634	0.768	0.905	1.016	0.938	0.974	1.087	1.671	0.541	0.318	0.893
b8	-0.083	0.100	-0.022	-0.005	-0.013	-0.04	0.044	0.008	0.051	0.002	0.092	0.119	-0.032	-0.072	-0.114	-0.081	-0.047	-0.117	0.072	0.095	-0.002
b9	0.379	0.374	0.242	0.257	0.331	0.39	0.393	0.394	0.386	0.369	0.379	0.383	0.353	0.286	0.225	0.218	0.172	0.058	0.376	0.348	0.311
b10	-0.343	0.041	-0.050	0.053	0.047	0.043	0.017	0.031	0.010	-0.011	-0.051	0.029	-0.055	-0.035	0.054	-0.108	0.048	0.023	0.030	0.133	0.000
b11	0.620	0.740	0.690	0.720	0.740	0.727	0.753	0.741	0.729	0.746	0.751	0.752	0.728	0.715	0.734	0.716	0.693	0.648	0.729	0.652	0.719
b12	-0.036	0.014	-0.017	0.008	-0.009	-0.004	0.008	0.007	-0.003	0.001	-0.001	0.010	-0.001	-0.012	-0.017	-0.027	-0.012	-0.020	0.005	0.014	-0.004
b13	0.110	0.088	0.114	0.096	0.082	0.082	0.084	0.094	0.092	0.093	0.089	0.091	0.100	0.110	0.099	0.095	0.088	0.130	0.109	0.076	0.096
b14	-0.018	-0.004	-0.008	0.005	-0.009	-0.011	-0.006	-0.003	-0.002	-0.005	-0.004	0.002	0.003	-0.005	0.000	-0.015	-0.007	-0.004	-0.003	0.001	-0.004
b15	0.011	0.032	0.031	0.036	0.033	0.038	0.031	0.026	0.027	0.028	0.030	0.029	0.026	0.025	0.038	0.033	0.046	0.035	0.020	0.002	0.030
b16																					
b17																					
a1	-55.893	-8.354	-2.408	2.911	-2.817	-4.952	-3.68	-1.226	0.294	0.535	-2.370	-1.103	4.889	2.692	15.977	12.235	-4.339	-7.211	15.798	24.242	0.000
a2	-4.062	-2.133	-0.521	0.757	-6.277	-7.900	-2.896	-0.677	-1.983	-1.186	-0.741	-1.267	1.242	3.364	3.299	-3.186	-11.573	-6.824	6.127	4.277	-1.656
a3	1.205	-0.288	-0.011	0.514	0.292	1.047	-0.027	0.224	0.302	0.022	0.720	-0.464	0.629	0.100	-0.761	0.100	0.724	1.088	-0.793	-1.603	0.159
a4	1.758	-0.294	0.076	-0.398	-1.139	1.165	0.175	0.027	-0.361	-0.323	-0.126	0.229	0.164	-0.491	-0.254	2.003	4.491	2.649	-0.343	-0.874	0.519
a5	-3.179	0.373	0.110	-1.091	0.159	-0.348	-0.084	-0.009	-0.219	-0.239	-0.141	-0.357	-0.755	-0.229	-0.686	-0.218	0.195	-0.177	0.366	0.519	-0.266
a6	-0.180	-0.283	-0.342	-0.462	-0.005	-0.401	-0.419	0.021	0.071	-0.064	-0.215	-0.221	-0.332	-0.551	-0.245	-0.747	-0.714	0.041	0.378	0.341	-0.251
a7	-2.193	0.057	0.051	0.165	-0.118	-0.057	-0.008	0.025	0.035	0.107	0.0	0.139	0.101	0.060	0.324	0.052	-0.217	-0.116	-0.022	-0.021	-0.037
a8	0.008	0.004	0.055	0.114	-0.119	-0.104	0.046	-0.020	-0.065	0.014	0.021	0.060	0.116	0.277	0.141	0.115	-0.310	-0.324	-0.178	-0.137	-0.013
a9	0.142	-0.097	-0.009	0.021	0.011	0.063	-0.024	-0.008	0.010	-0.023	-0.002	-0.021	0.107	0.013	-0.096	0.020	0.031	0.096	0.013	0.051	0.012
a10	-0.167	-0.001	-0.023	0.001	-0.004	0.023	0.000	0.021	0.005	0.016	0.020	0.037	0.020	0.007	-0.007	-0.004	-0.042	-0.047	0.055	0.029	0.000
a11	-0.221	0.011	-0.007	-0.014	-0.026	-0.061	-0.027	-0.013	-0.015	0.002	-0.010	-0.007	-0.042	-0.015	0.036	0.014	-0.025	-0.045	0.023	0.022	-0.017
a12	-0.052	-0.002	-0.006	-0.011	0.005	0.003	-0.014	0.004	0.007	0.004	-0.006	-0.008	-0.021	-0.038	-0.019	-0.036	0.005	0.016	0.012	0.008	-0.007
a13	-0.006	-0.005	0.000	-0.001	-0.001	-0.003	-0.003	-0.003	0.000	-0.004	0.000	-0.003	-0.006	-0.002	-0.006	-0.004	0.006	-0.003	0.002	0.001	-0.002
a14	0.032	-0.006	-0.002	-0.006	-0.007	-0.003	-0.004	-0.005	-0.008	-0.007	-0.008	-0.002	-0.004	0.002	-0.008	0.005	0.001	-0.011	0.000	0.009	-0.002
a15	-0.052	0.000	-0.009	0.003	-0.002	-0.003	-0.005	-0.002	-0.002	-0.005	-0.005	-0.001	-0.003	-0.007	-0.008	-0.009	-0.003	-0.003	-0.001	0.005	-0.005
a16																					
a17																					
Dx (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dy (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magnetic length (m)	14.4548																				
C1 centre (mT)	0.005064																				

L_m c_1 α b a Δ x,y

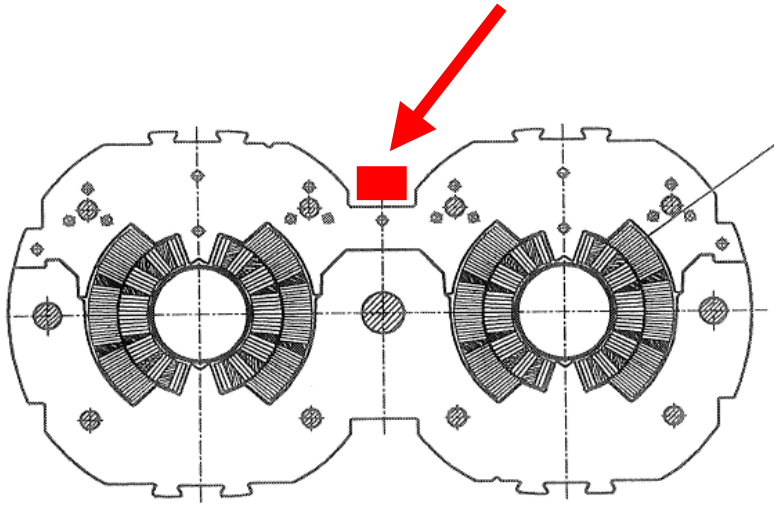
Measuring at the factories

Main field relative module:

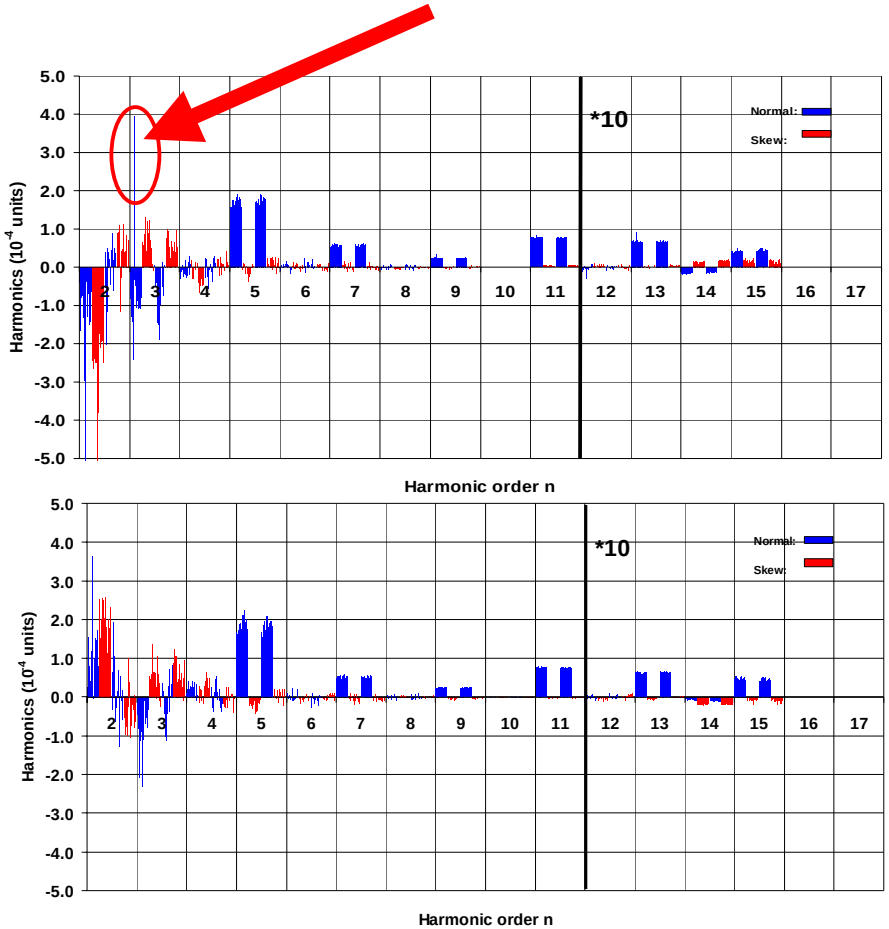


A logistic problem

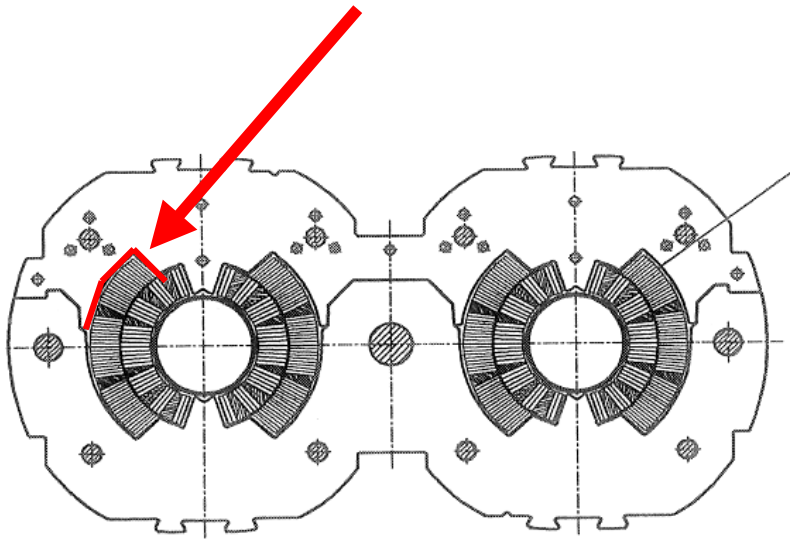
A training problem



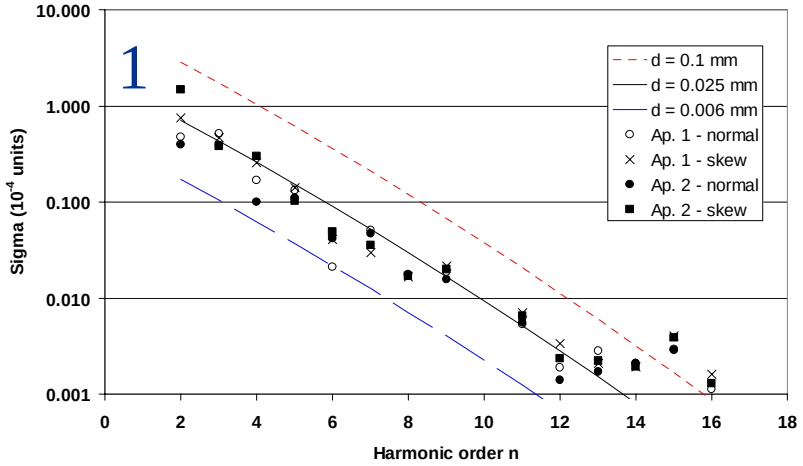
Detecting defects – an example

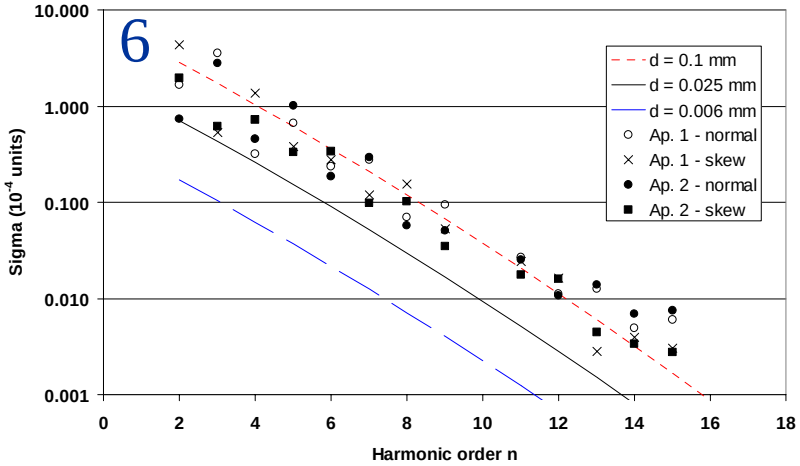


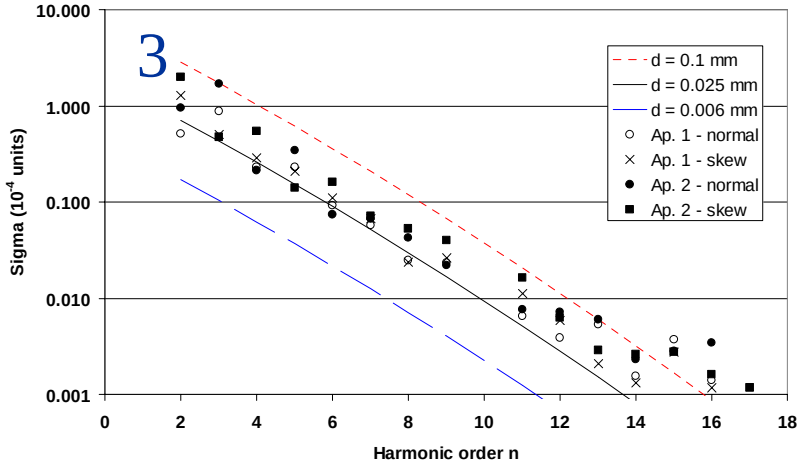
Harmonics along the collared coils



Example of trend







Situation & Planning

- Quadrupoles and dipoles: one system at CERN.
- Quadrupoles:
  - MQ: 1 system operational at Saclay, 1 system to Accel
  - MQW: 1 system to SL
  - MQM : 1 system to Accel (end of the year)
  - MQY: 1 system to Tesla (end of the year).
- Dipoles:
  - A provisional system delivered to Ansaldo, Alstom and Noell.

    Final systems: 1st in April 2002, 2nd by end of 2002.
- An extra system at CERN for final acceptance tests (end of 2001).

Conclusions

- Last May the magnetic measurement system, originally designed for quadrupoles, had to be adapted to dipoles.
- Installed and already being used at the manufacturers' premises.
- Robust, easy maintenance, rapid measurement, self-sufficient.
- Hardware commonly available on the market.
- Software developed using industrial control system standards.
- The system proved to be flexible, adaptable and able to measure any LHC magnet.