

A Test Bench for the Warm Magnetic Measurement of the LHC-Corrector Magnets in Industry

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Summary

- Introduction
- Corrector magnets to measure
- Standard measurement and objectives

- 1st generation (positioning)
- Calibration of the bench

- 2nd generation (positioning)

Introduction

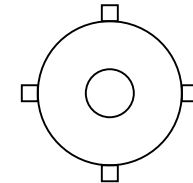
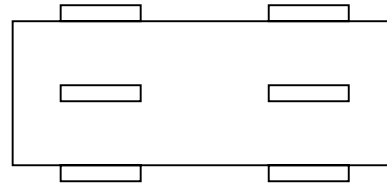
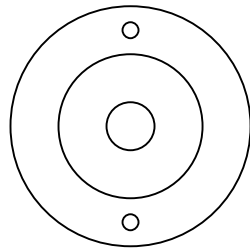
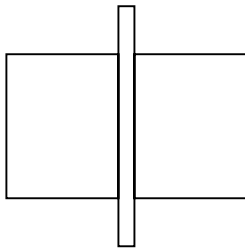
- LHC : more than 3500 corrector magnets
- Series production in industry
- Testing in industry and at CERN
- Control of the magnetic field quality
- Control of the magnetic axes position for alignment (< 0.1 mm)

Corrector magnets to measure

- **Lattice :**
 - MQTL
 - MQT
 - MQS
 - MQSX
 - MQSXA
 - MS
 - MSS
 - MO
- **Orbit (H&V) :**
 - MCB
 - MCBC
 - MCBR
 - MCBY
 - MSCB
 - MCBX
 - MCBXA
- **Multipol :**
 - MCD
 - MCO
 - MCS
 - MCOX
 - MCSX
 - MCTX
 - MCOSX
 - MCSSX

Corrector magnets to measure

Magnets	MCS	MCDO	MO	MSCB		MCBC	MCBY	MQT	MQTL	MCBX	MCBXA	MQSXA
						MCBR		MQS				
Nested windings		MCD MCO		MCB	MS(S)						MCBX MCTX MCSX	MQSX MCOSX MCOX MCSSX
Main harmonics	B3	B5, B4	B4	B1	B3	B1	B1	B2	B2	B1	B1,B6,B3	B2,B4,B4,B3
N magnets	2464	1232	176	752	752	172	80	448	120	27	9	9
Lengh [mm]	160	110	366	785.2	455	1099	1100	365	1391	700	700	530
Diameter[mm]	120	115	104	185.6	185.6	187.6	187.4	135	135	350	350	180
Weight [Kg]			8	135	75	200	200	25	95			
positioning	holes	holes	keys	keys	keys	keys	keys	keys	keys	holes	holes	holes



Standard measurements

- In the industry (all magnets) :
 - Warm measurements
 - Quench tests at 4.2 K
 - Warm measurements
- At Cern (2 to 10 % of the magnets) :
 - Warm measurements
 - Quench and magnetic measurements at 1.9 K
 - Warm measurements

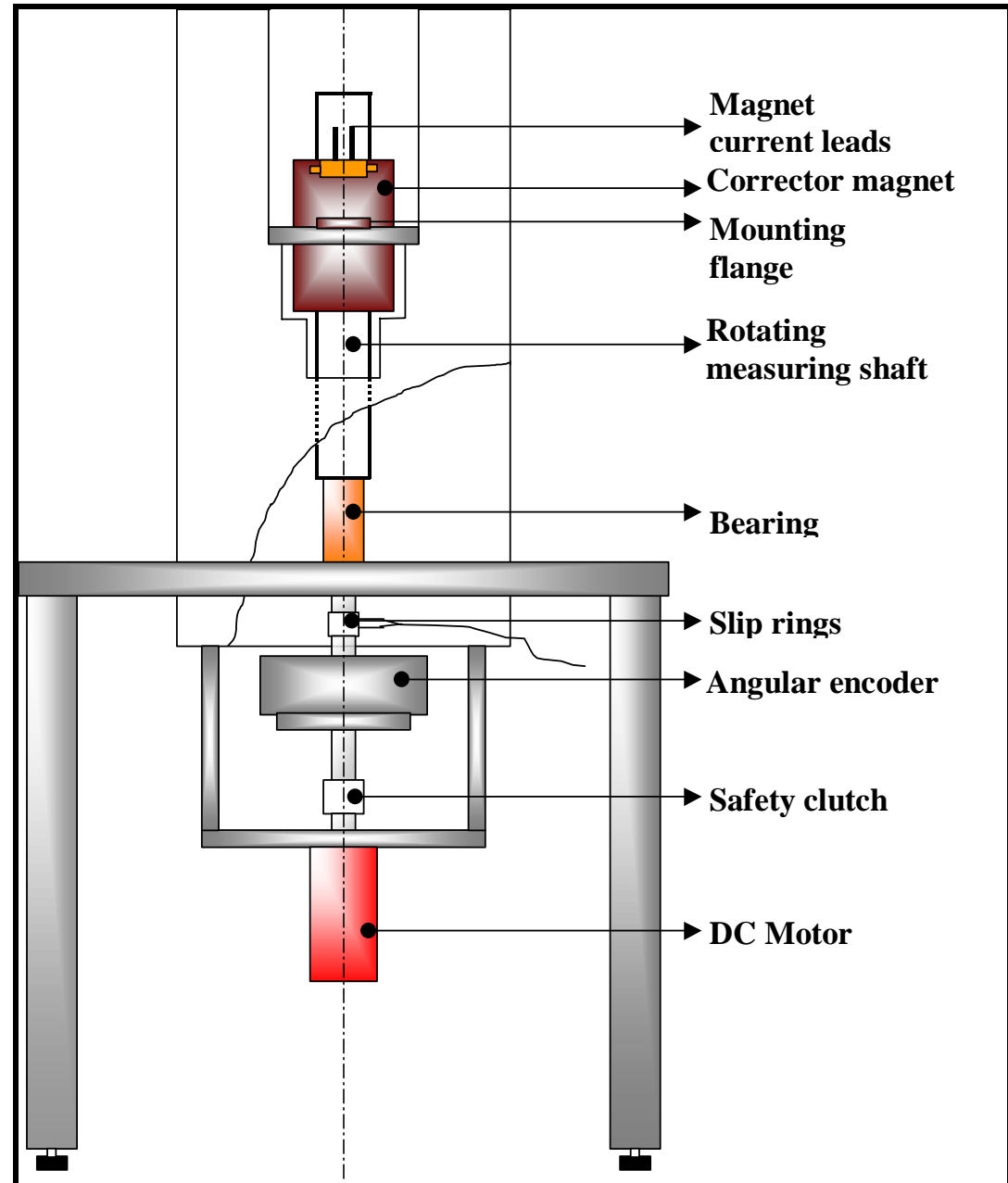
Objectives

- Check field quality at room temperature
- Quick measurement : around 5 minutes
- Simple for use in industry

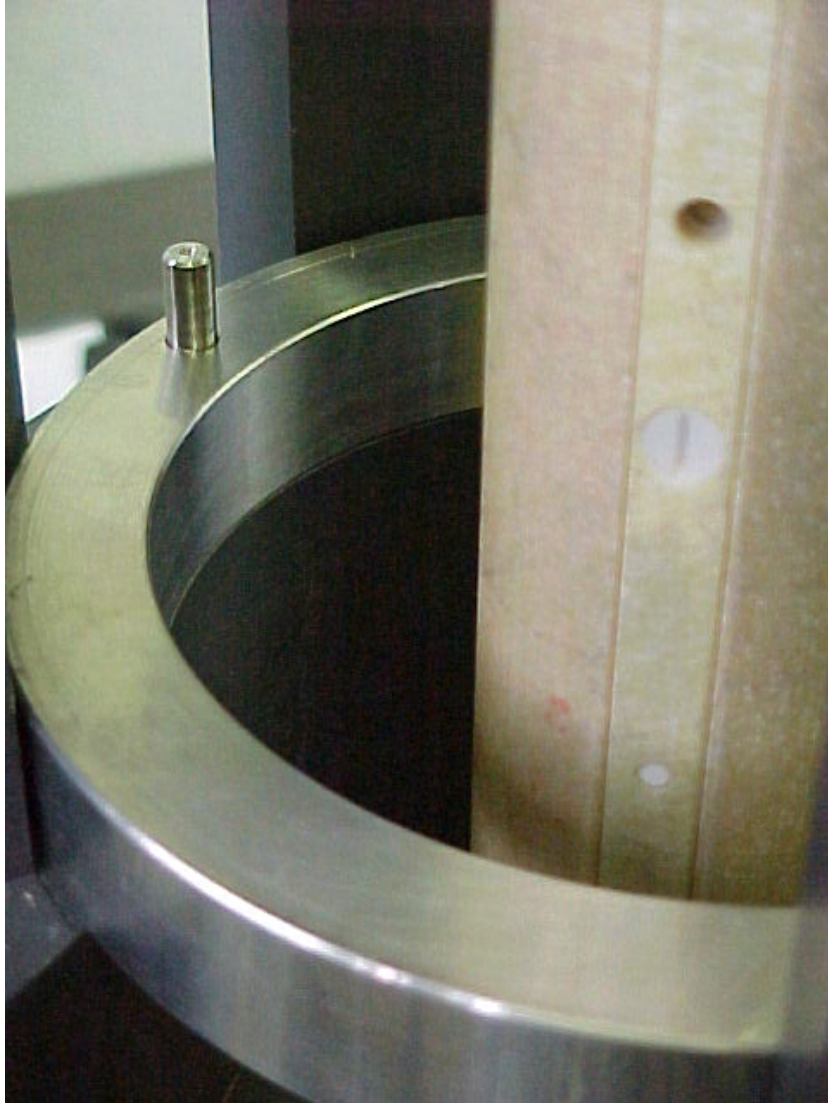
The bench measures :

- the strength of the main field
- the level of harmonics up to order 15
- the axis position and orientation of the main field with respect to the mechanical references
(Specification for magnets : 0.1 mm)

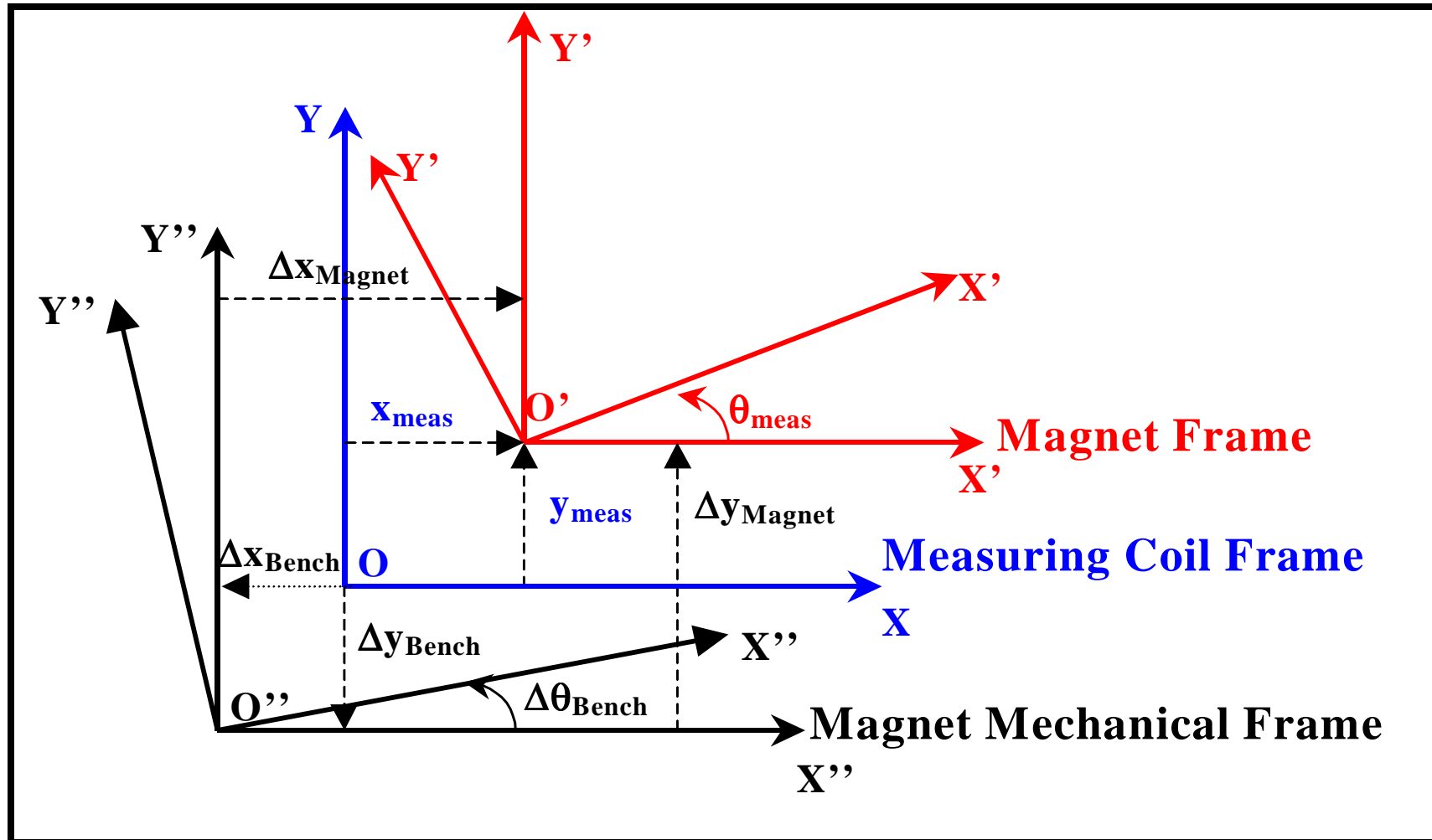
1st generation



1st generation : positioning

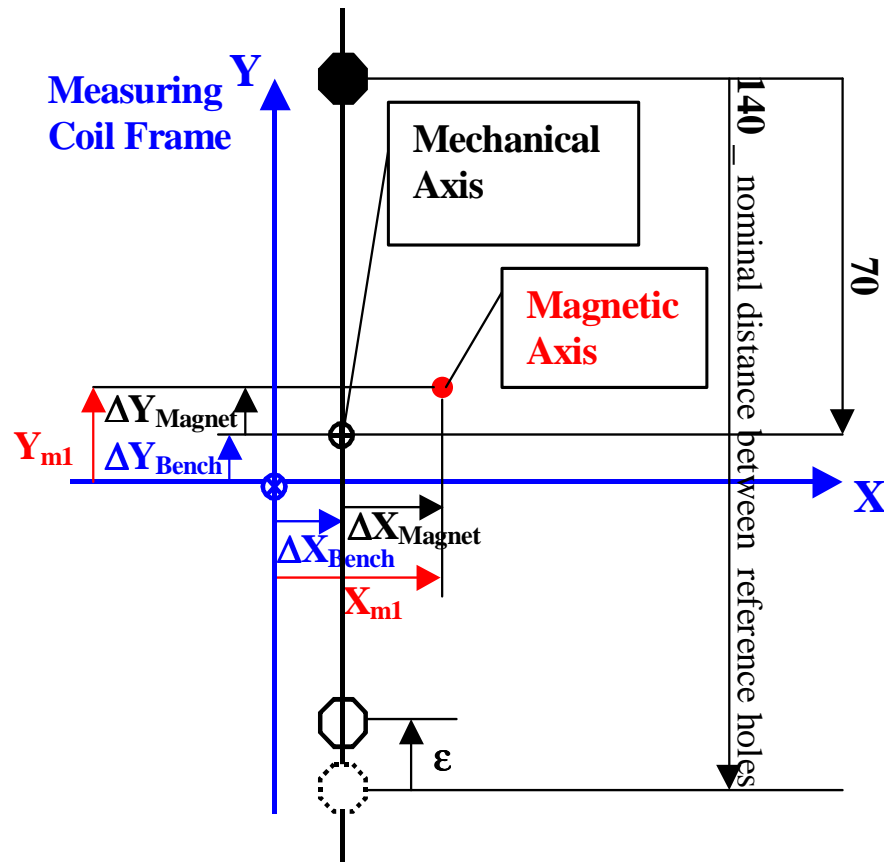


Calibration of the bench

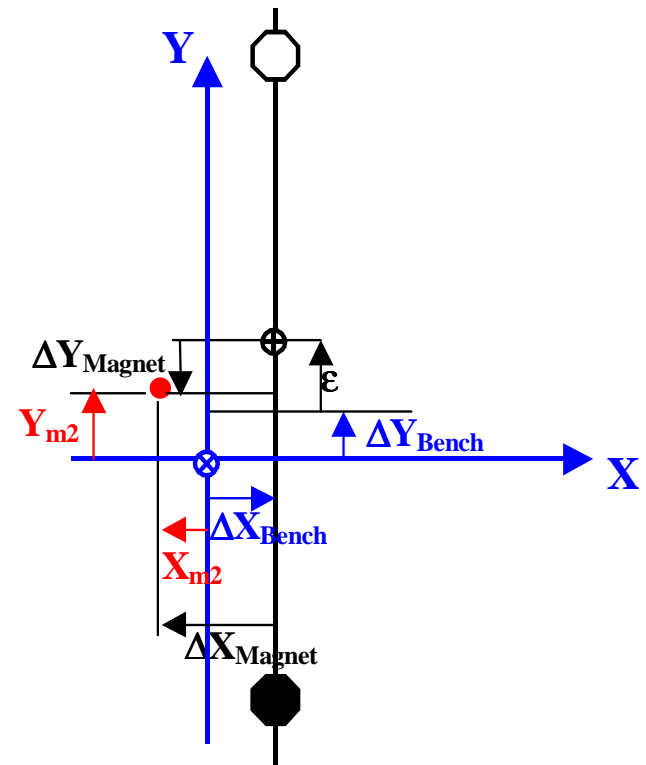


Calibration of the bench

Position 1 : Normal Position

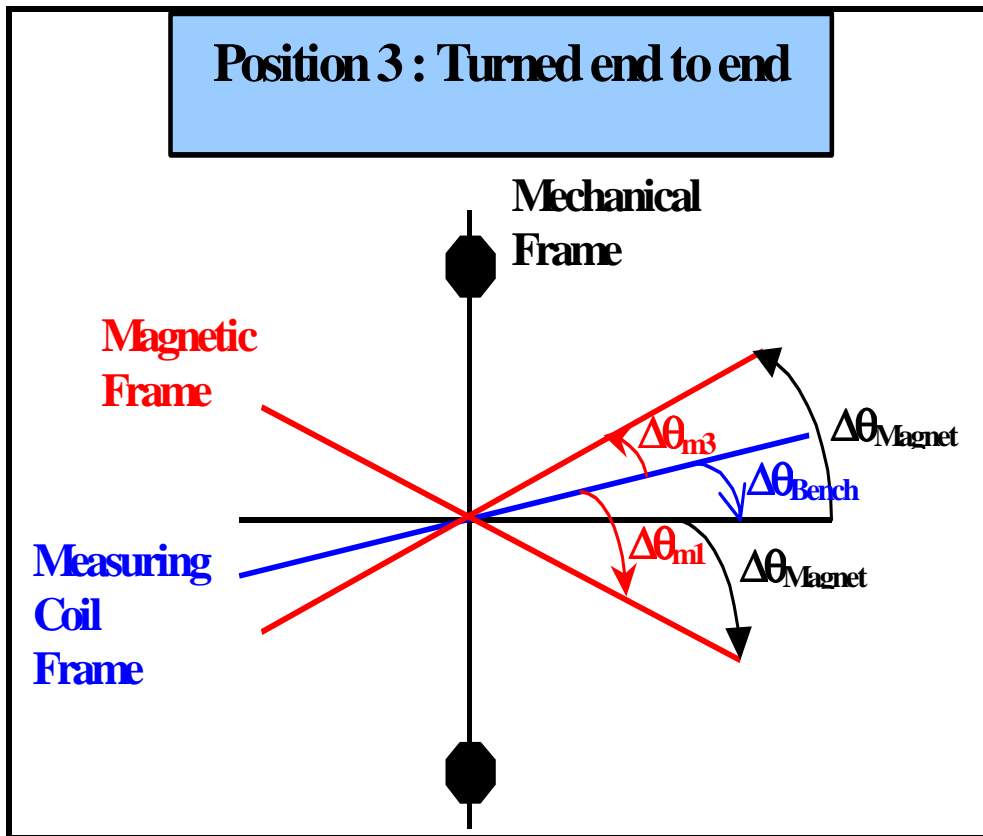


Position 2 : Rotation by 180° / normal position



Calibration of the bench

Position 3 : Turned end to end



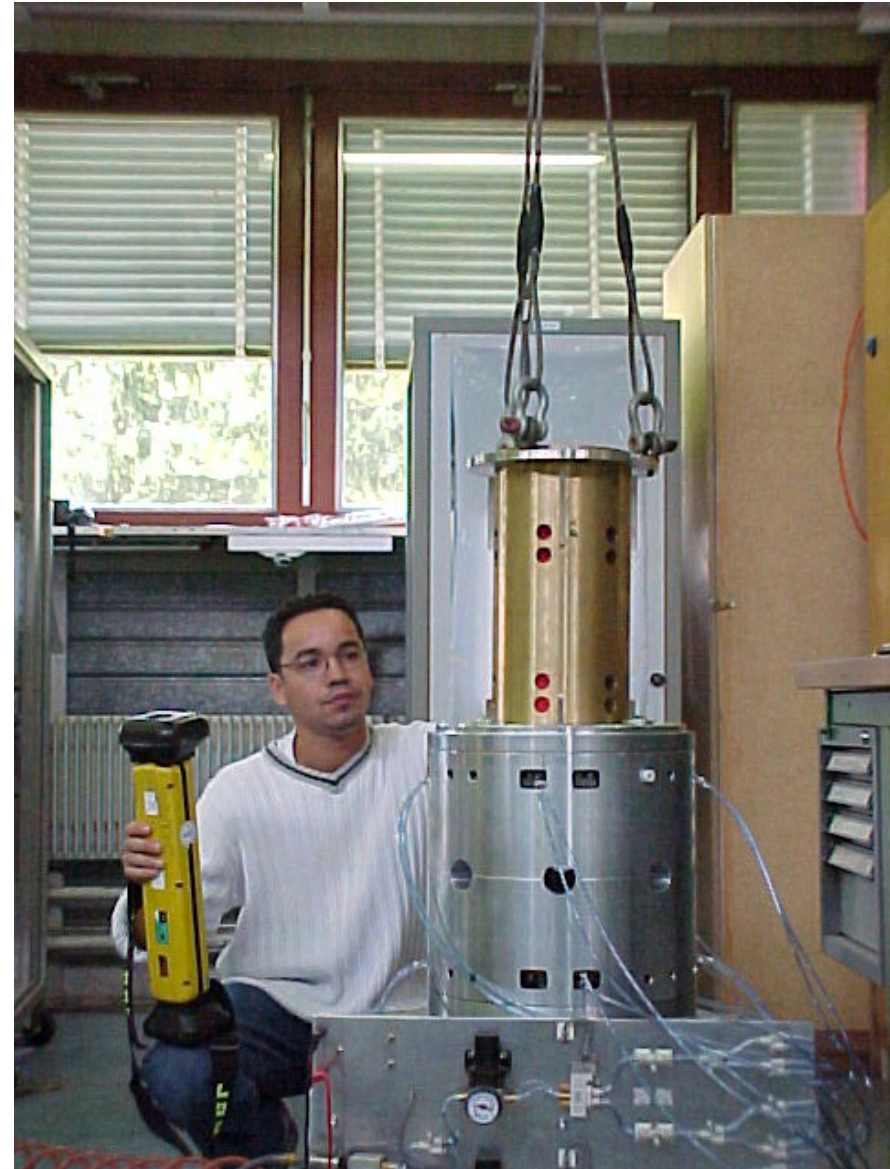
Calculation

- $\Delta X_{\text{Bench}} = (X_{m1} + X_{m2} - \epsilon)/2$
- $\Delta Y_{\text{Bench}} = (Y_{m1} + Y_{m2} - \epsilon)/2$
- $\Delta \theta_{\text{Bench}} = (\theta_{m1} + \theta_{m2})/2$
- $\Delta X_{\text{Magnet}} = X_{\text{meas}} - \Delta X_{\text{Bench}}$
- $\Delta Y_{\text{Magnet}} = Y_{\text{meas}} - \Delta Y_{\text{Bench}}$
- $\Delta \theta_{\text{Magnet}} = \theta_{\text{meas}} - \Delta \theta_{\text{Bench}}$

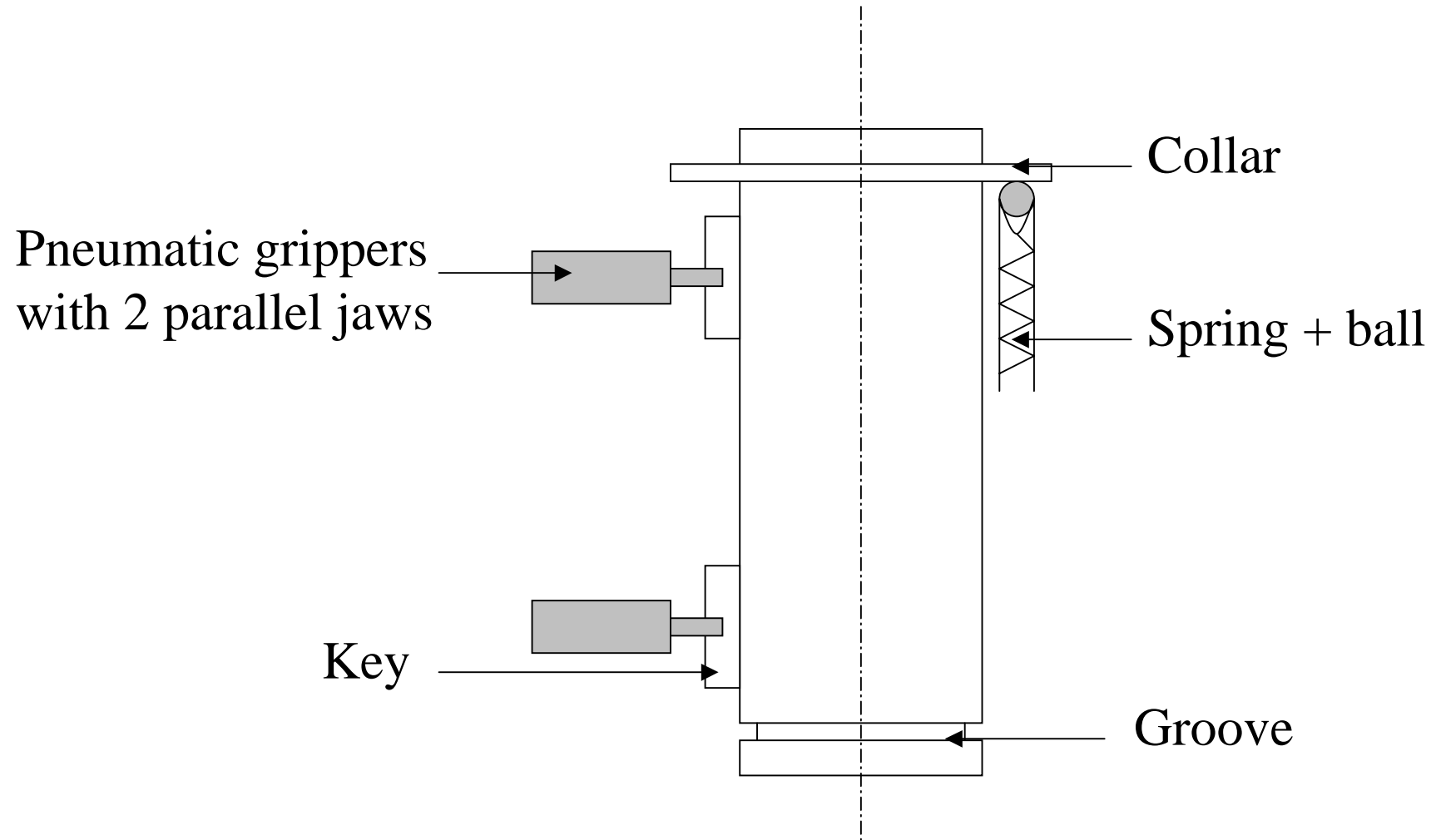
Results of 1st generation benches

	St. dev. on a Bench	Max. dev. between benches over pre- series magnets	Specification
dx axis offset	5 μm	30 μm	0.1 mm
dy axis offset	5 μm	21 μm	0.1 mm
dθ B_n orienta- tion	0.05 mrad	0.2 mrad	1.5 mrad
B_n (main field)	10⁻⁹ Tm/A	2 10⁻⁷ Tm/A	9.7 10⁻⁵ Tm/A
B_m , A_n (n\neqm)	10⁻¹⁰ Tm/A	10⁻⁹ Tm/A	< 10⁻⁶ Tm/A

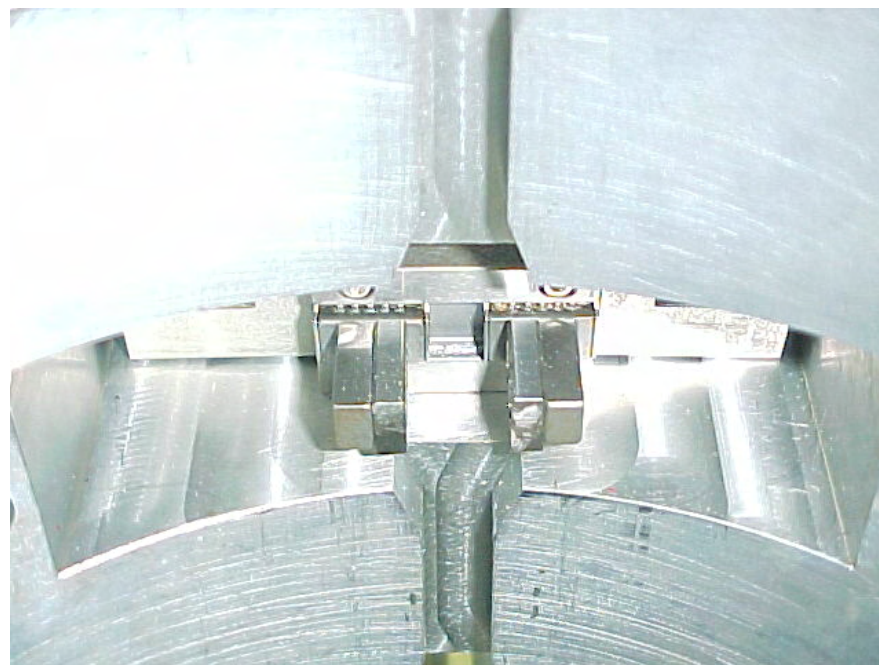
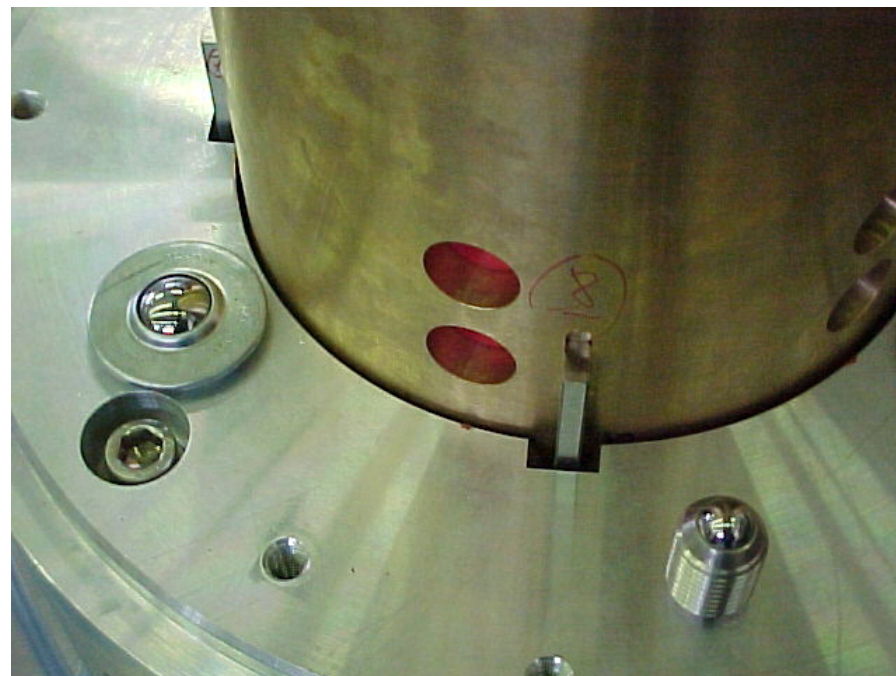
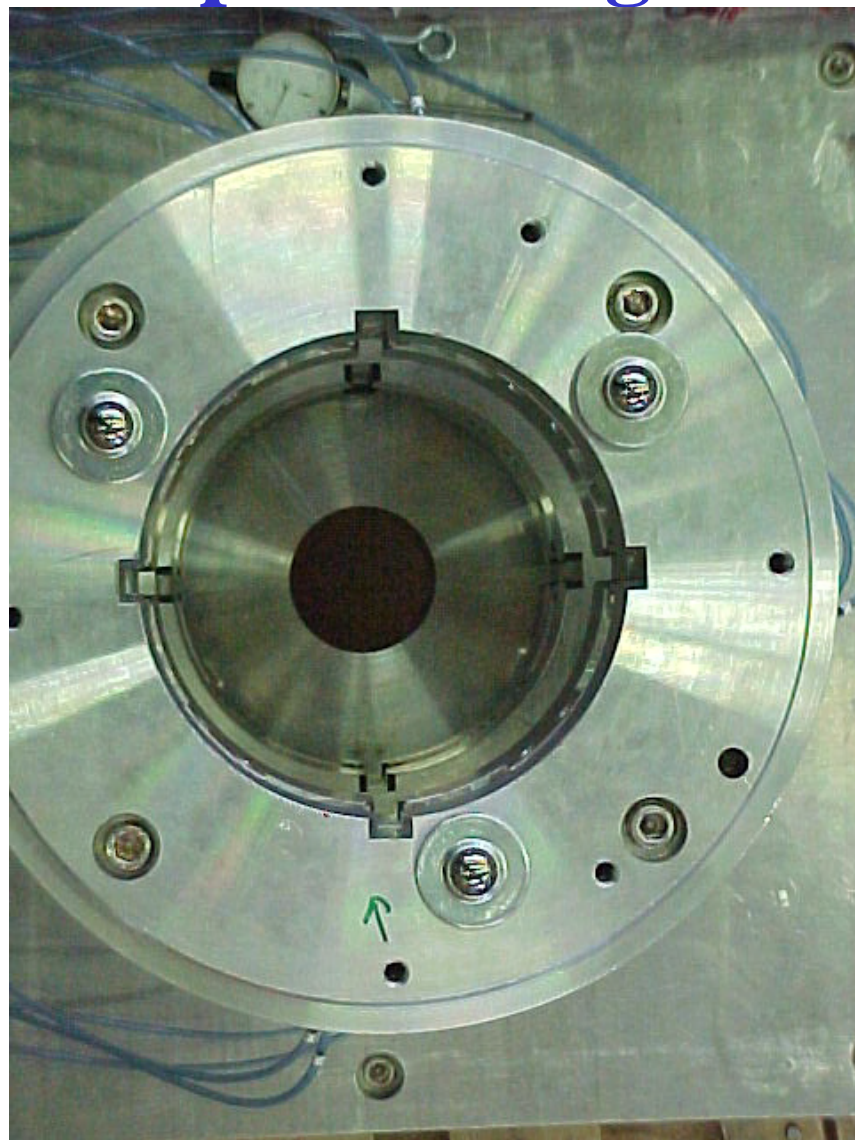
2nd generation



2nd generation : positioning



2nd generation : positioning



2nd generation : first results

- Testing with mechanical comparator :
 - open & close grippers : dispersion $< 10 \mu\text{m}$
 - default of 1 mm on the collar : dispersion $< 50 \mu\text{m}$
- Testing with permanent magnets and measuring coils :
open & close grippers : dispersion $< 10 \mu\text{m}$

⇒ 15 other benches to do