Magnet Test Stand and Cold Magnet Tests

WP 11

H. Brueck, DESY

DESY March 25, 2009

Topics

- Operation of XMTS at DESY
- Tests of magnets and leads
- Status and future plans

Abbreviations used:

XMP	XFEL Magnet Package
XCLA	XFEL Current Lead Assembly
XMTS	XFEL Magnet Test Stand

Involved people so far are:

F. Toral, P. Abramian,J. Calero, L. García-Tabarés, J.L. Gutierrez,
E. Rodriguez, I. Rodríguez, S. Sanz, C. Vazquez, CIEMAT-CEDEX, Spain
J. Lucas, Elytt-Energy, Madrid, Spain

A. Ballarino, P. Denis, CERN

R. Bandelmann, Y. Bozhko, A. Zhirnov, M. Stolper, J. Fischer, W. Maschmann, B. Henschel, C. Hagedorn, D. Weitbrecht, H. Brueck, DESY MKS

N. Mildner, DESY MVS

XMTS XFEL Magnet Test Stand for SC Magnets

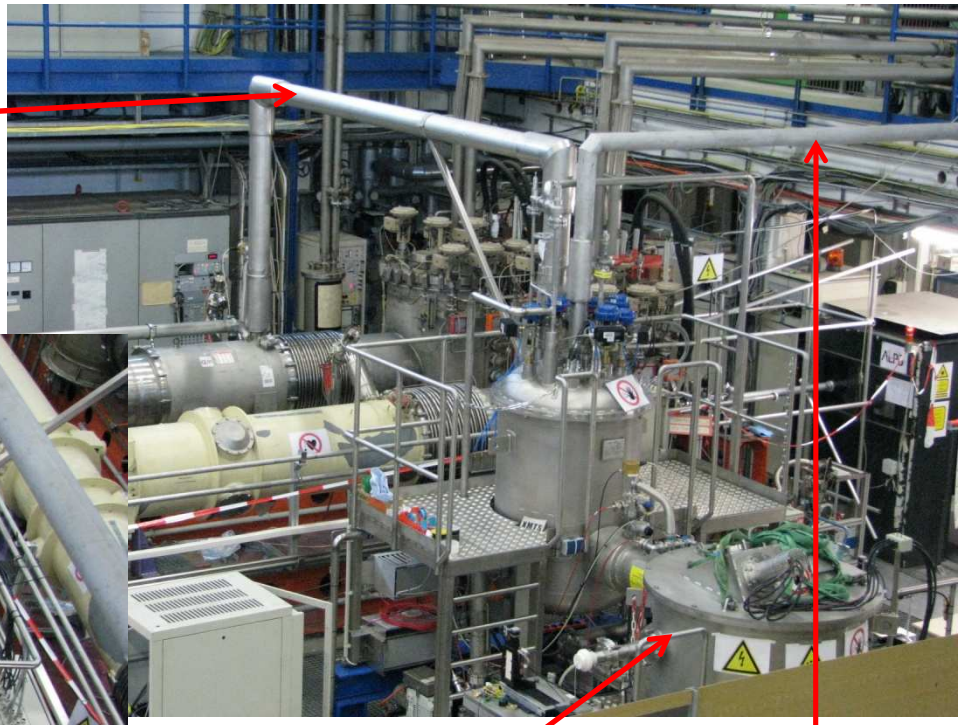
- **Designed by DESY (Y. Bozhko, A. Zhirnov)**
  - **Cold tests of magnets and leads down to 2K**
  - **Access of the magnet bore at room temperature using an anti-cryostat with a large diameter of about 65mm**
  - **Option: separate “beam vacuum” for testing copper plated magnets**
- **Built in industry (Netherlands)**
- **Delivered and installed by the manufacturer and the help of many colleagues of MKS late Summer 2008**
- **Installed in H55, cryogenically connected to old HERA quadrupole test stand**
- **XMTS successfully operating for magnet test at 2K since October 2008 by MKS-1**

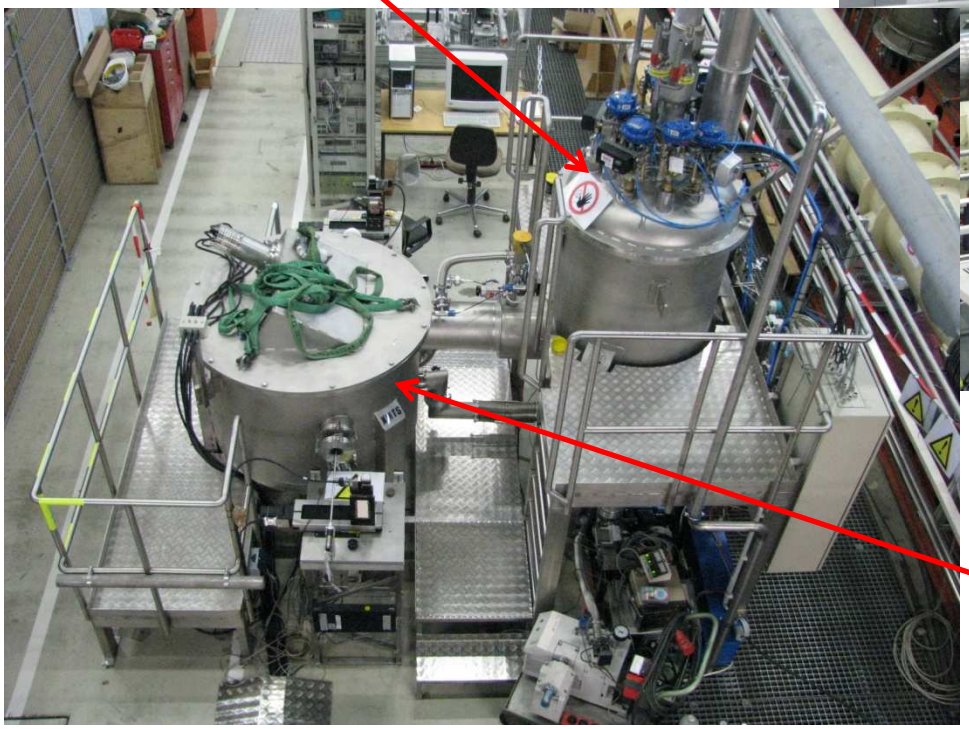
Delivery of XMTS mid August 2008

XMTS in H55 at DESY

Cryo connection to HERA test stand

Valve Box





Magnet Box
For cold tests

Pumping line to H54 for 2K operation

XMTS in H55 at DESY

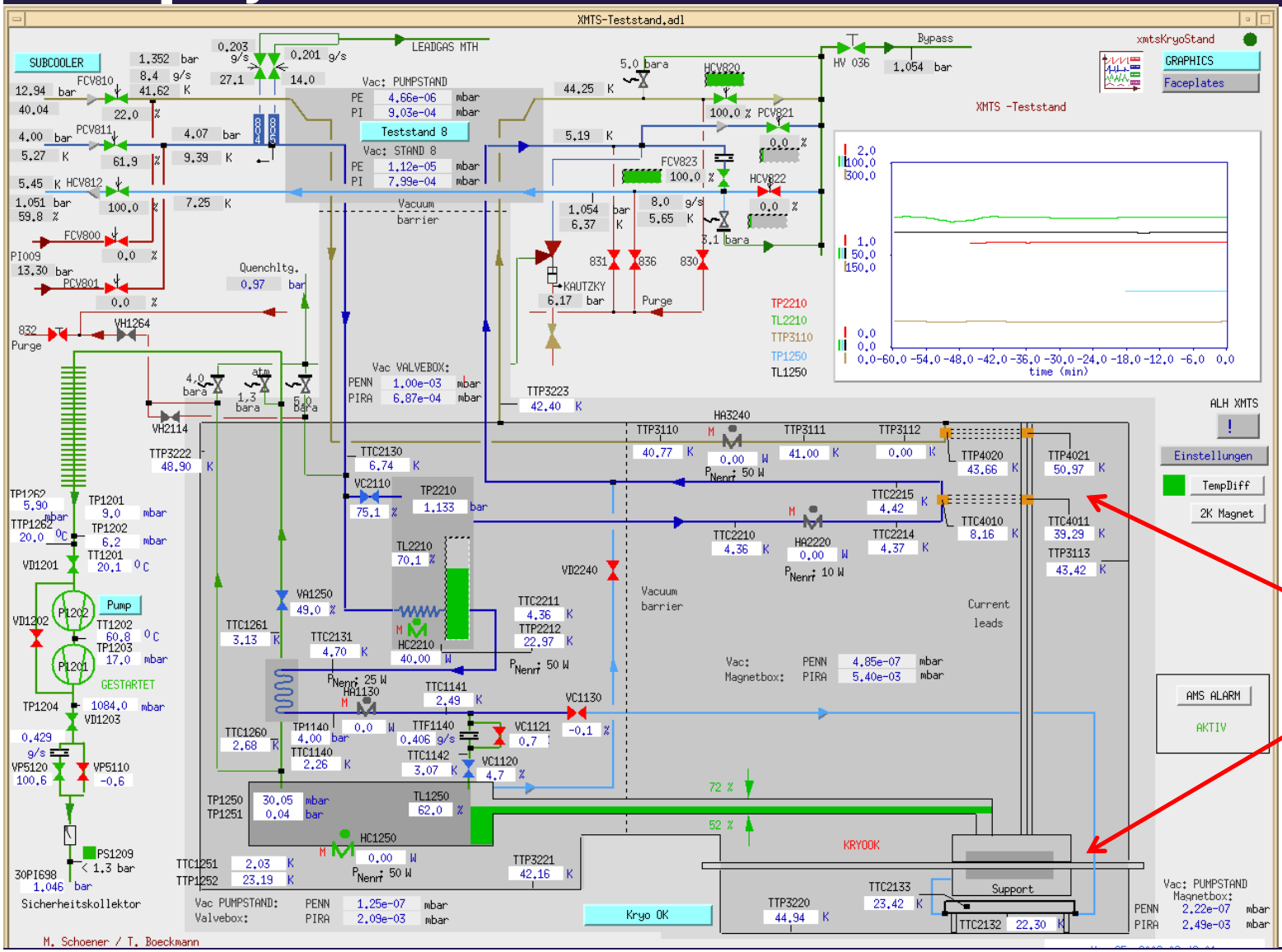
Cryo connection to HERA test stand

Valve Box

Pumping line to H54 for 2K operation

Magnet Box
For cold tests

Cryo Control Panel

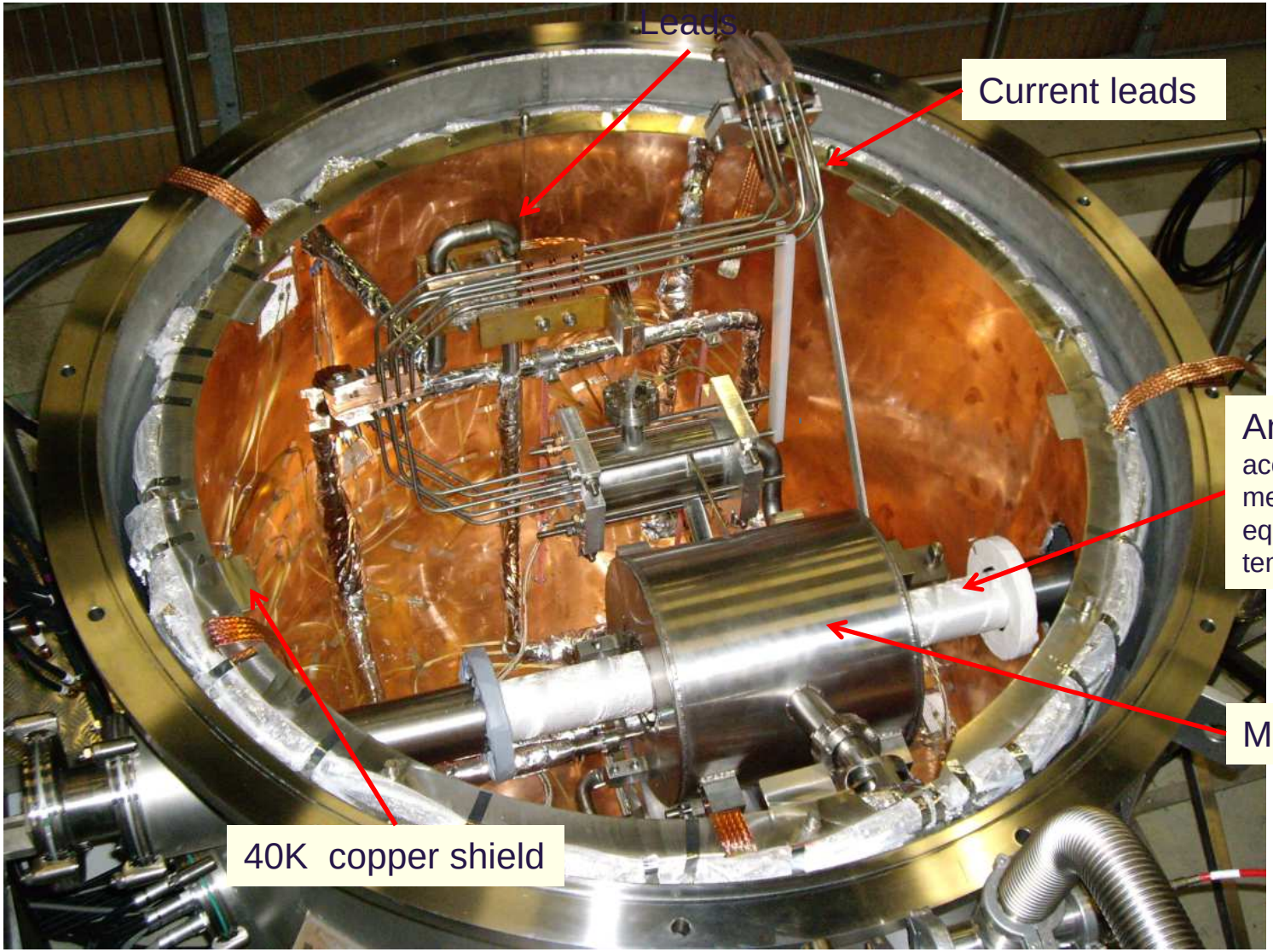


Current lead heat sinks

Magnet

European XFEL

Magnet and Leads mounted in XMTS



Anti cryostat,
access for measurement equipment at room temperature

Magnet

DESY HELMHOLTZ ASSOCIATION

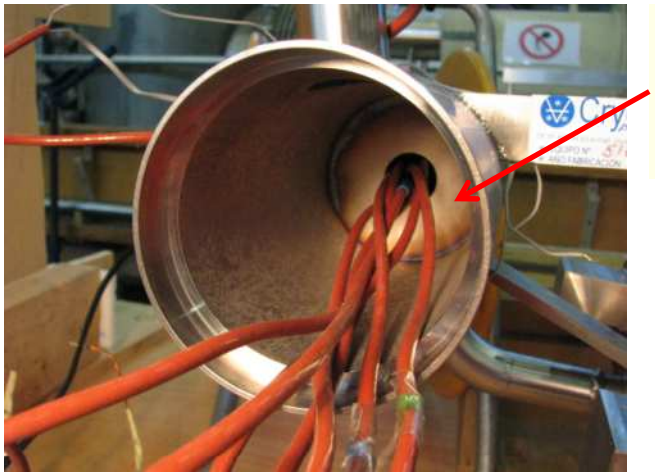
European XFEL

Current Leads in XMTS

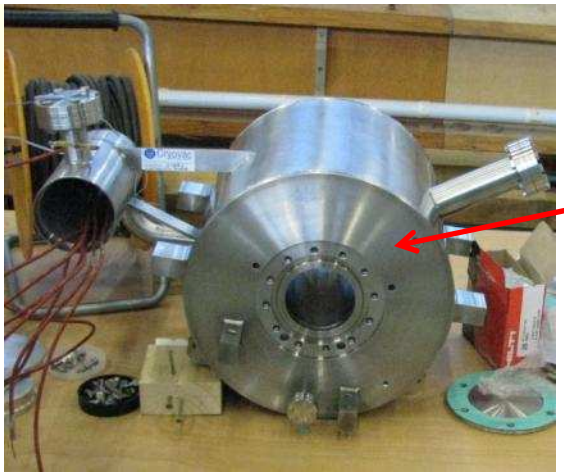
Magnet and leads with super-insulation

DESY HELMHOLTZ ASSOCIATION

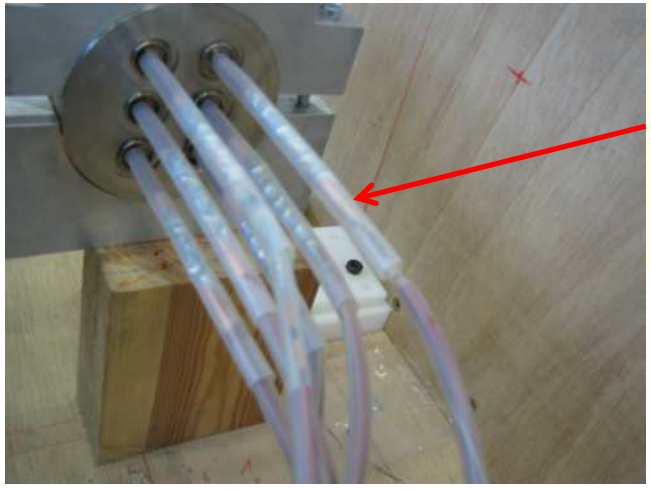
Magnet Preparation for Cold Test



SL cables in wiring box



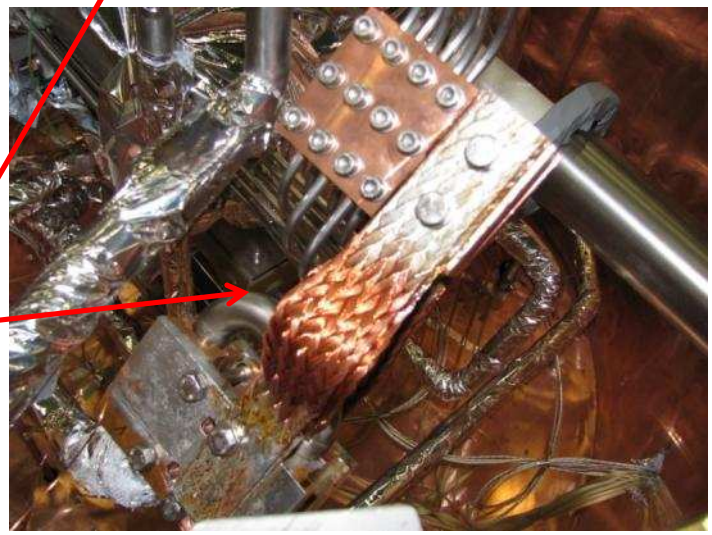
Magnet as it comes from Spain



SL cables soldered to lead ends and isolated

Lead assembly flanged to wiring box, ready for mounting in XMTS

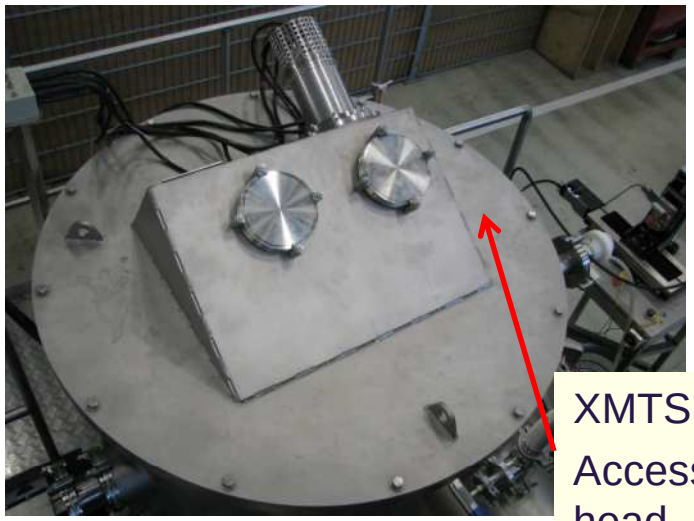
Leads and Heat Sinks



- Lead assembly flanged to wiring box, ready for mounting in XMTS
- heat sink connections with copper braid
  - 40-80K
  - 4-8K

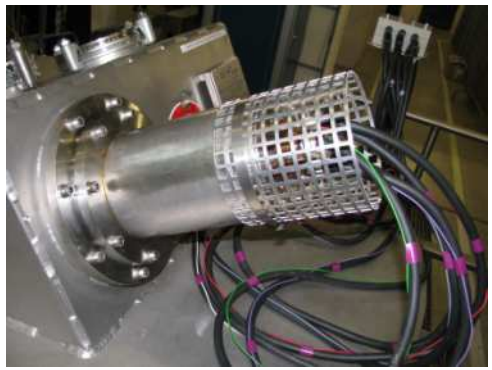
XMTS Closing and Lead Head Assembly

XMTS covered by super-insulation



XMTS closed by cover

Access ports and lead head

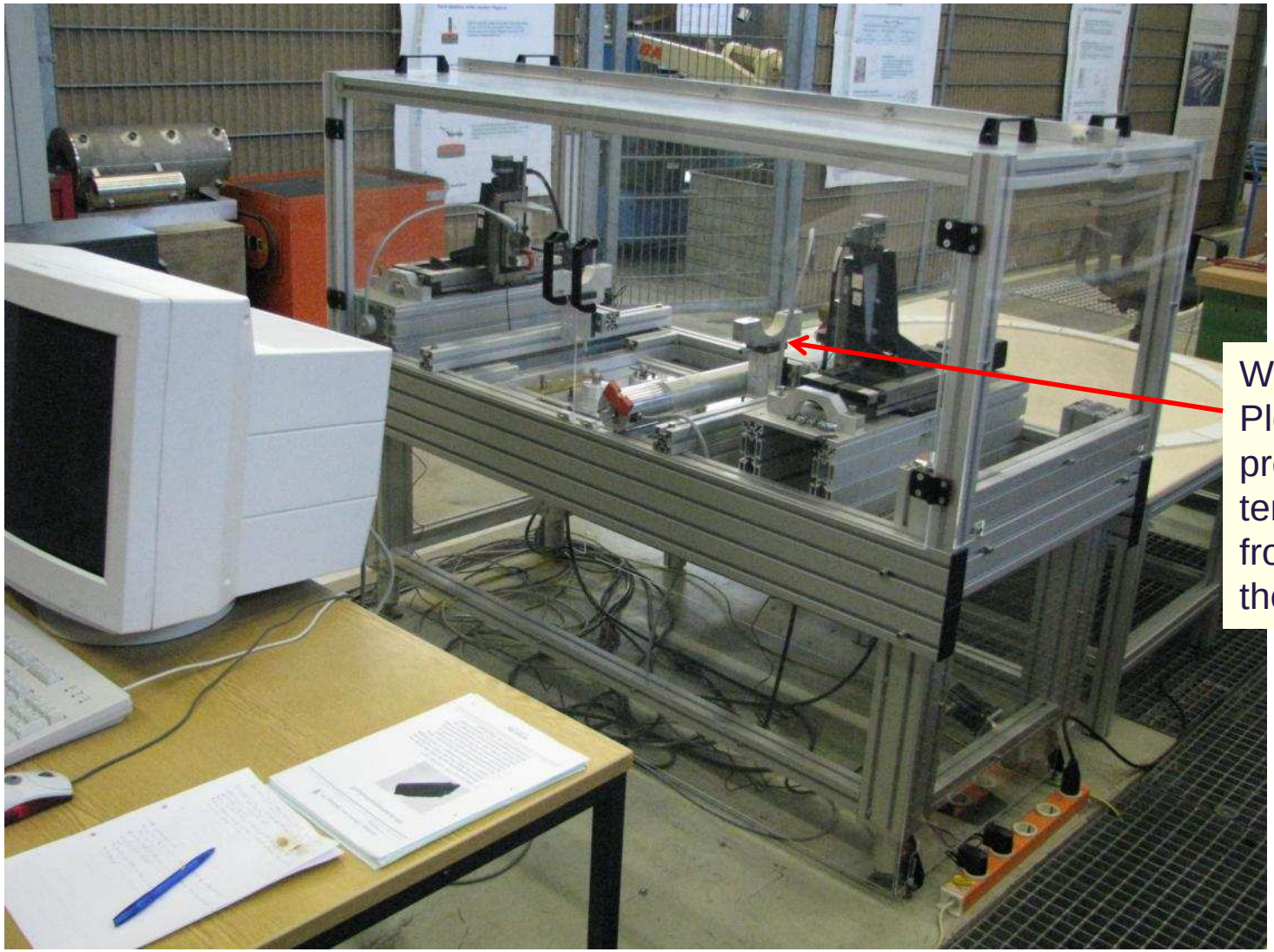


Lead head assembly and connection of power cables

Status Measurement Equipment

- Warm and cold test stand in operation
- Harmonic coils from IHEP, Beijing
- Stretched wire systems improved
  - AC at room temperature
    - ➔ axis and angle measurements for alignment
  - DC for cold tests
- The new measurement equipment is in operation
  - very good signals
  - high quality results

Warm Test Stand

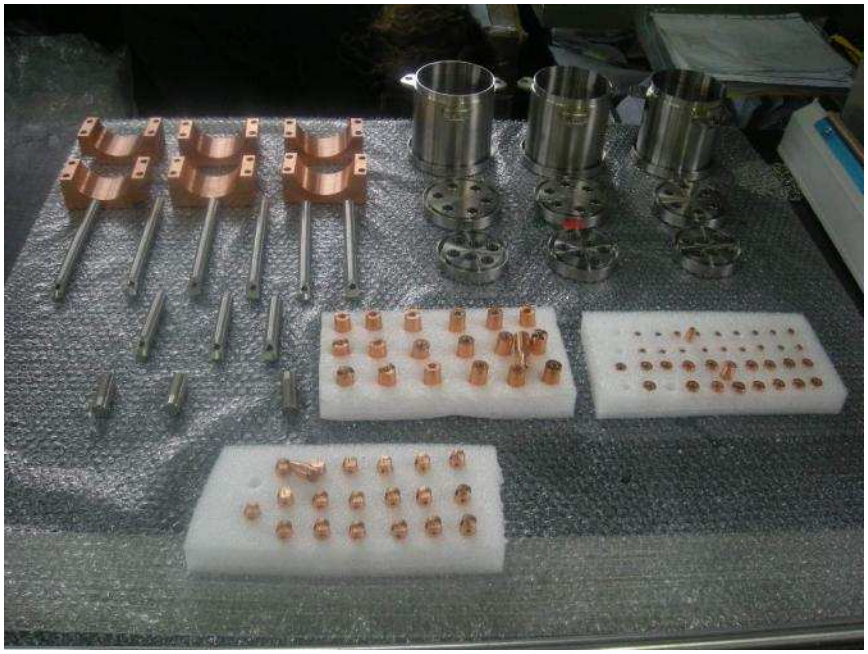


Warm tests stand with Plexiglas cover to protect against temperature effects from air circulations in the hall

Status of Magnet and Leads

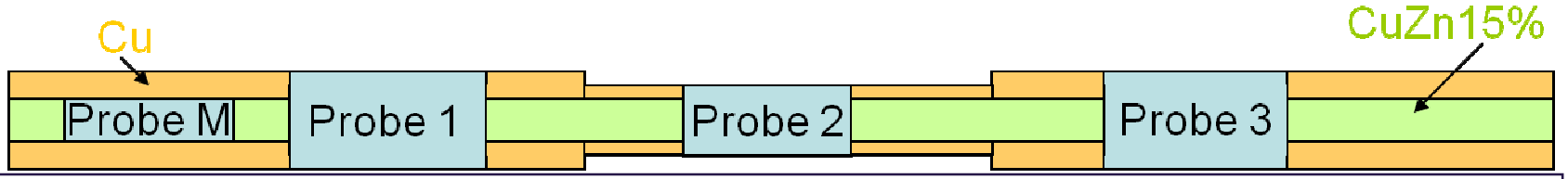
- Magnets:
  - 3 prototype magnets tested
    - ➔ 2 magnets copper plated beam pipe
      - Waiting for cleaning and assembly
    - ➔ 1 magnet for further tests until needed
- Leads
  - 1 lead assembly available (made at CERN)
  - 3 lead assemblies ordered quite some time ago
  - They are delayed due to difficulties with the copper deposition
  - Now ok, we got probes for inspection and RRR measurement
  - RRR is ok, surface still has some “smooth” spikes
- Expect leads within 6 weeks

Parts at Manufacturer and Copper Plated Brass Bars



Some remaining problems with the copper surface will be solved

Measurement by Xenia Singer



	diameter, µm	Cu-layer, µm	RRR±3% of total probe	RRR ±10% of the Cu layer only
Probe 1	4232,4	624	190	378
Probe 2	3225,9	108,7	43	360
Probe 3	4250,4	623	193	409
Probe M	3009		1,8	

The surface of Probe 2 looks more rough then for 1 und 3. The deviation in the thickness of the copper layer for probe 1 is < 1%, for probe 2 is about ± 8% and for probe 3 is ±3%

Picture under microscope ot the cross section of the 3 probes

Measurement Program

- Warm tests
  - → Multipoles
  - → Axis
  - → Angle
- Cold tests
  - Current lead performance
  - Magnet performance
    - → Multipoles as function of the current
    - → Axis variation with current
    - → Cross talk between magnets
- Continuing work on summarizing the Results

Stretched Wire Results XMP-P1 to P3

Warm Stretched Wire Files

Prototype 1

stretchedwire11.txt

File Name	Accu	Rep	Move	Q-current[A]	Dip1-current[A]	Dip2-current[A]	alpha[mrad]	sdev[mrad]	BL[Tm/A]	sdev[Tm/A]	GL[T/A]	sdev[T/A]	xo[mm]	sdev[mm]	yo[mm]	sdev[mm]	I[A]	sdev[mA]	Remarks
SQ_26092008_1436.txt	10	5	12	0.1	0	0	0.004	6.60E-02			0.128050	2.3E-05	-0.077	3.0E-03	0.045	0.004	0.095235	0.0532	
SQ_29092008_0824.txt	1	1	4	0.1	0	0					0.128077	2.9E-05	-0.078	5.0E-03	0.048	0.003	0.095106	0.0322	
SD_29092008_0838.txt	10	5	12	0	1	0	6.325	2.39E-01	0.000157716	5.0E-08							1.013359	0.8914	
SD_29092008_1010.txt	10	5	4	0	1	0	6.25	2.20E-01	0.000157692	3.0E-08							1.014177	0.9226	
SD_29092008_1022.txt	3	5	12	0	0	1	8.467	3.03E-01	0.000159836	3.0E-08							1.012697	0.8116	

Prototype 2

stretchedwire11.txt

File Name	Accu	Rep	Move	Q-current[A]	Dip1-current[A]	Dip2-current[A]	alpha[mrad]	sdev[mrad]	^BL[Tm/A]	sdev[Tm/A]	GL[T/A]	sdev[T/A]	xo[mm]	sdev[mm]	yo[mm]	sdev[mm]	I[A]	sdev[mA]	Remarks
SQ_30012009_1343.txt	10	5	12	0.1	0	0	0.022	5.70E-02			0.12528	5.0E-05	-0.073	5.0E-03	0.064	3.0E-03	0.088422	0.036	
SQ_30012009_1424.txt	1	1	12	0.1	0	0	0.026				0.125271		-1.069		-0.94		0.088466	0.029	all origins with +1mm
SD_30012009_1558.txt	10	5	12	0	1	0	-47.973	3.33E-01	0.00015503	5.0E-08							0.963389	1.590	
SD_30012009_1634.txt	10	5	12	0	0	1	-47.22	2.61E-01	0.00015581	4.0E-08							0.963913	1.046	

Prototype 3

stretchedwire11.txt

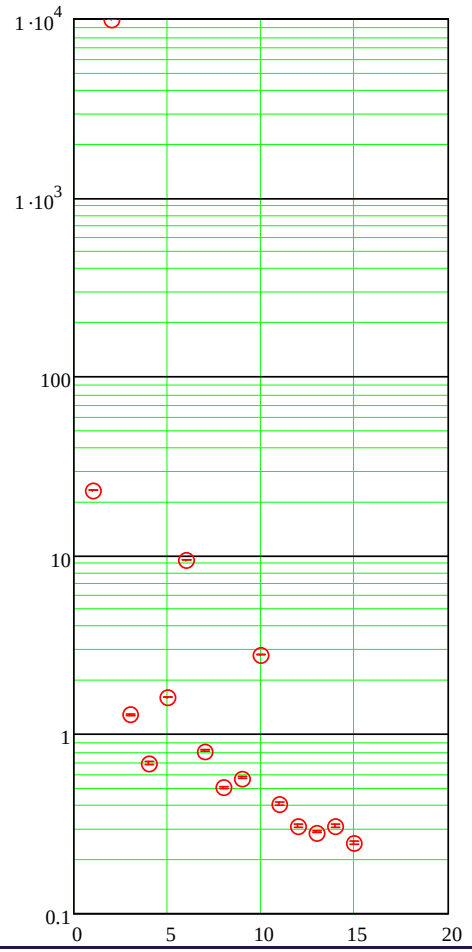
File Name	Accu	Rep	Move	Q-current[A]	Dip1-current[A]	Dip2-current[A]	alpha[mrad]	sdev[mrad]	^BL[Tm/A]	sdev[Tm/A]	GL[T/A]	sdev[T/A]	xo[mm]	sdev[mm]	yo[mm]	sdev[mm]	I[A]	sdev[mA]	Remarks
SQ_06022009_0740.txt	10	5	12	0.1	0	0	0.014	5.60E-02			0.126521	2.5E-05	0.1	3.0E-03	0.079	4.0E-03	0.088050	0.1339	
SQ_06022009_0825.txt	1	1	12	0.1	0	0	-0.011				0.126555		-0.896		-0.922		0.088054	0.025	all origins with +1mm
SD_06022009_1042.txt	10	5	12	0	1	0	-4.653	3.18E-01	0.00015528	3.0E-08							0.968672	1.077	
SD_06022009_1117.txt	10	5	12	0	0	1	-13.594	3.44E-01	0.00015685	5.0E-08							0.968478	1.085	

The magnetic axis is measured with respect to the mechanical axis defined by reference plates

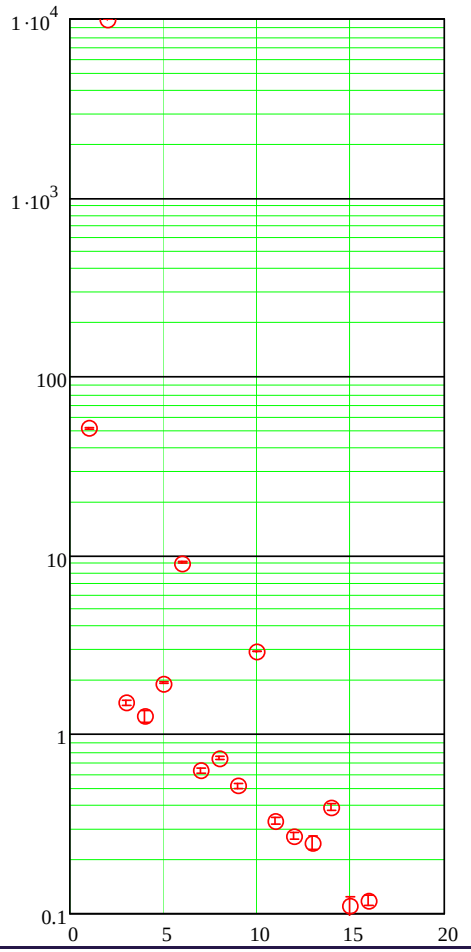
The roll angle is adjusted to ZERO with respect to the wire coordinate system (which was adjusted by a precise water level). Then ZERO is transferred by a tool to the magnet.

Quadrupoles Multipoles Warm

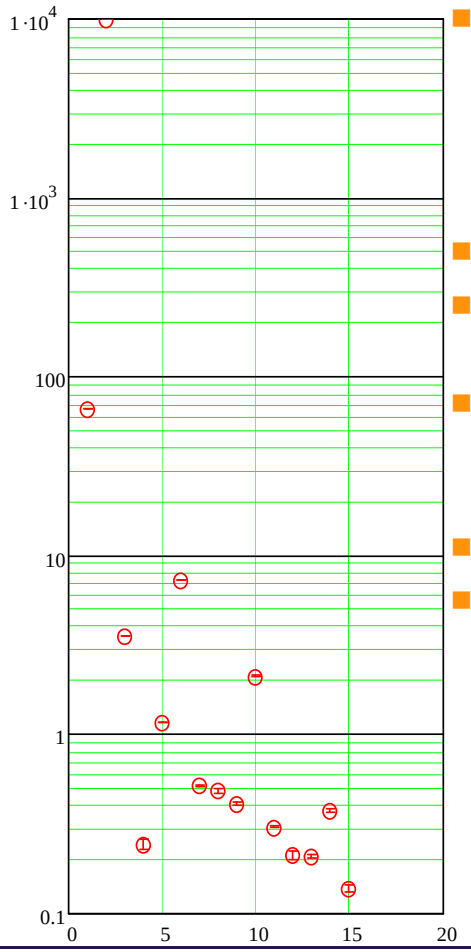
$x_{ave} = -0.00362$ $y_{ave} = 0.12852$
fname = "HA0_01102008_1105.dat"
magnet = "XMP-P1"
Multipoles at: r0 = 30 $I_0 = 0.29998$



$x_{ave} = 0.02831$ $y_{ave} = 0.12187$
fname = "HA0_02022009_1000.dat"
magnet = "XMP-P2"
Multipoles at: r0 = 30 $I_0 = 0.29999$



$x_{ave} = 0.11217$ $y_{ave} = 0.0519$
fname = "HA0_03022009_1508.dat"
magnet = "XMP-P3"
Multipoles at: r0 = 30 $I_0 = 0.29999$



- 0.3A
- Combine I^+ and I^- to correct for non current depending fields like earth field
- P1 and P3 virgin
- P2 after cold tests
- multipoles at 30mm reference radius
- In units of 10-4
- Super ferric quadrupole very good, only allowed n=6, 10, 14

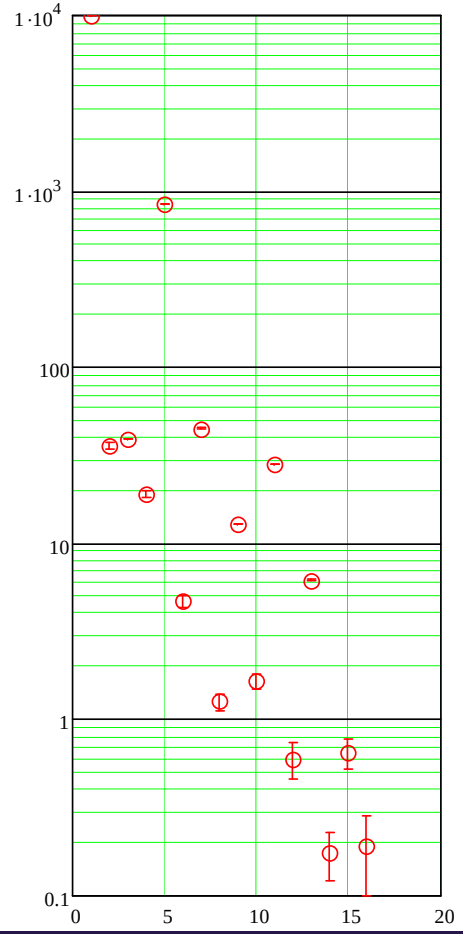
Dipole 1 Multipoles Warm

$x_{ave} = -0.4162$ $y_{ave} = 0.2135$

fname = "HA0_01102008_0930.dat"

magnet = "XMP-P1"

Multipoles at: r0 = 30 $I_0 = 0.49998$

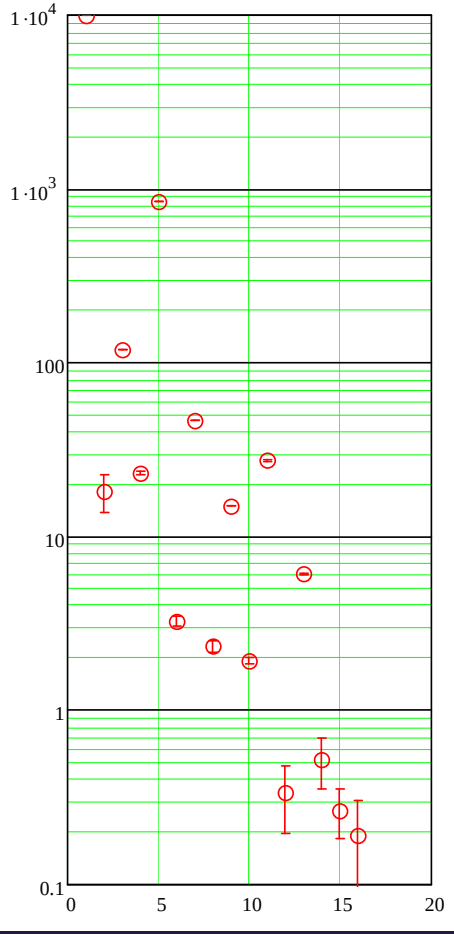


$x_{ave} = 4.57607$ $y_{ave} = -0.27298$

fname = "HA0_02022009_1147.dat"

magnet = "XMP-P2"

Multipoles at: r0 = 30 $I_0 = 0.49999$

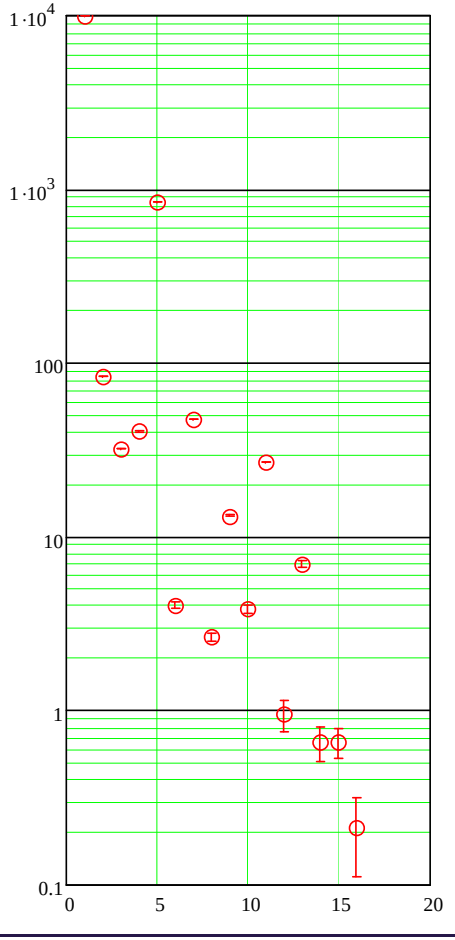


$x_{ave} = 0.64444$ $y_{ave} = 0.10769$

fname = "HA0_04022009_1315.dat"

magnet = "XMP-P3"

Multipoles at: r0 = 30 $I_0 = 0.5$



- 0.5A
- Combine I^+ and I^- to correct for non current depending fields like earth field
- P1 and P3 virgin
- P2 after cold tests
- multipoles at 30mm reference radius
- In units of 10-4
- Cos(θ) correction dipoles
- multipoles n= 5,7,9…
  - Sextupole component minimized by design
  - Decapole large about 8%

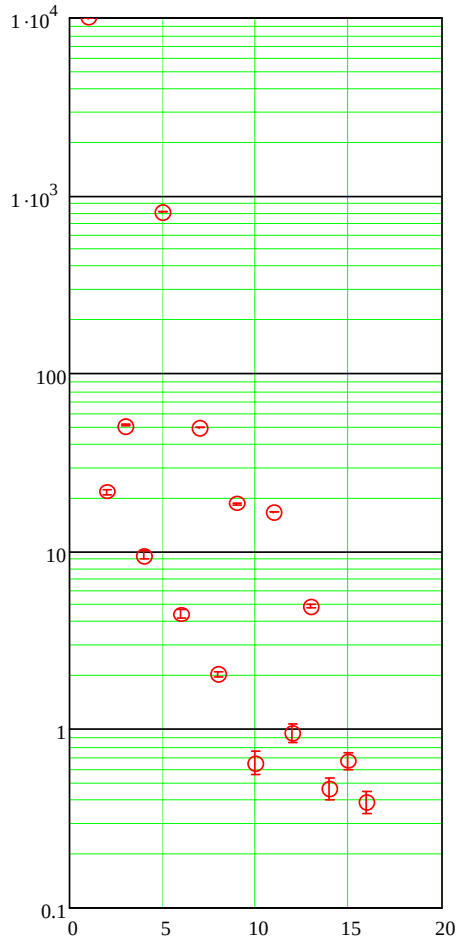
Dipole 2 Multipoles Warm

$x_{ave} = 0.38997$ $y_{ave} = -0.22173$

fname = "HA0_01102008_0856.dat"

magnet = "XMP-P1"

Multipoles at: r0 = 30 $I_0 = 0.49998$

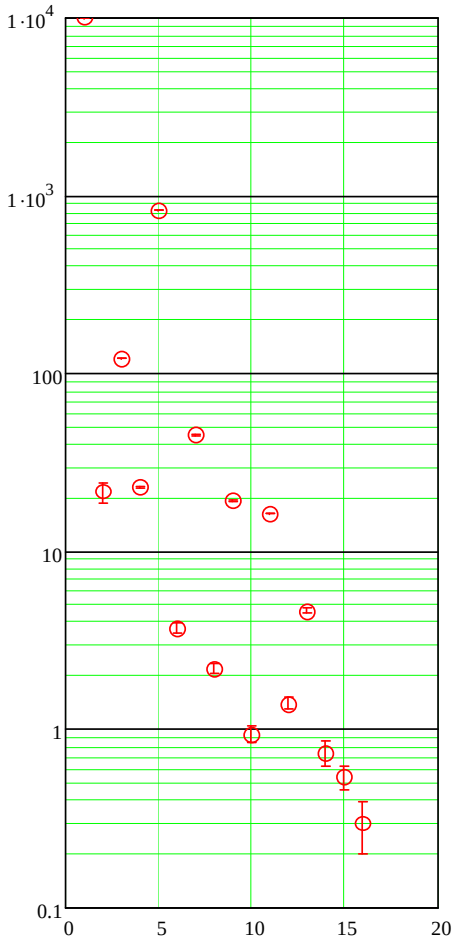


$x_{ave} = -4.37707$ $y_{ave} = 0.24319$

fname = "HA0_02022009_1218.dat"

magnet = "XMP-P2"

Multipoles at: r0 = 30 $I_0 = 0.49998$

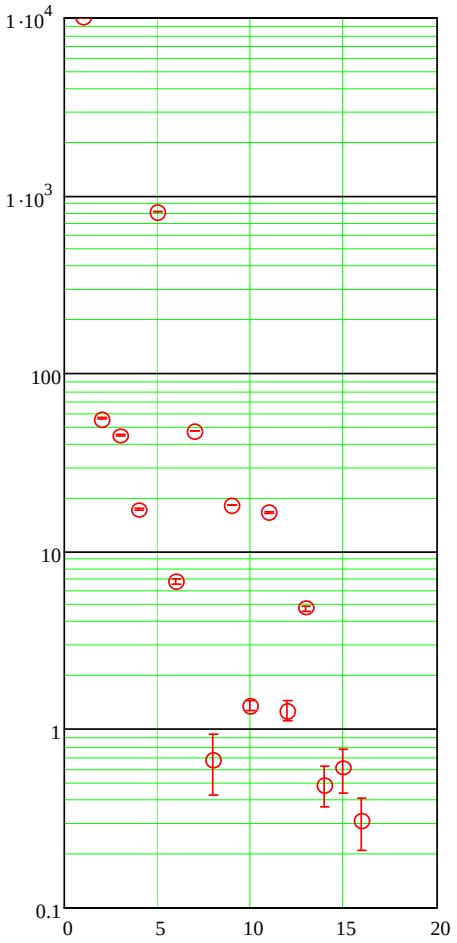


$x_{ave} = -0.65951$ $y_{ave} = -0.09609$

fname = "HA0_03022009_1753.dat"

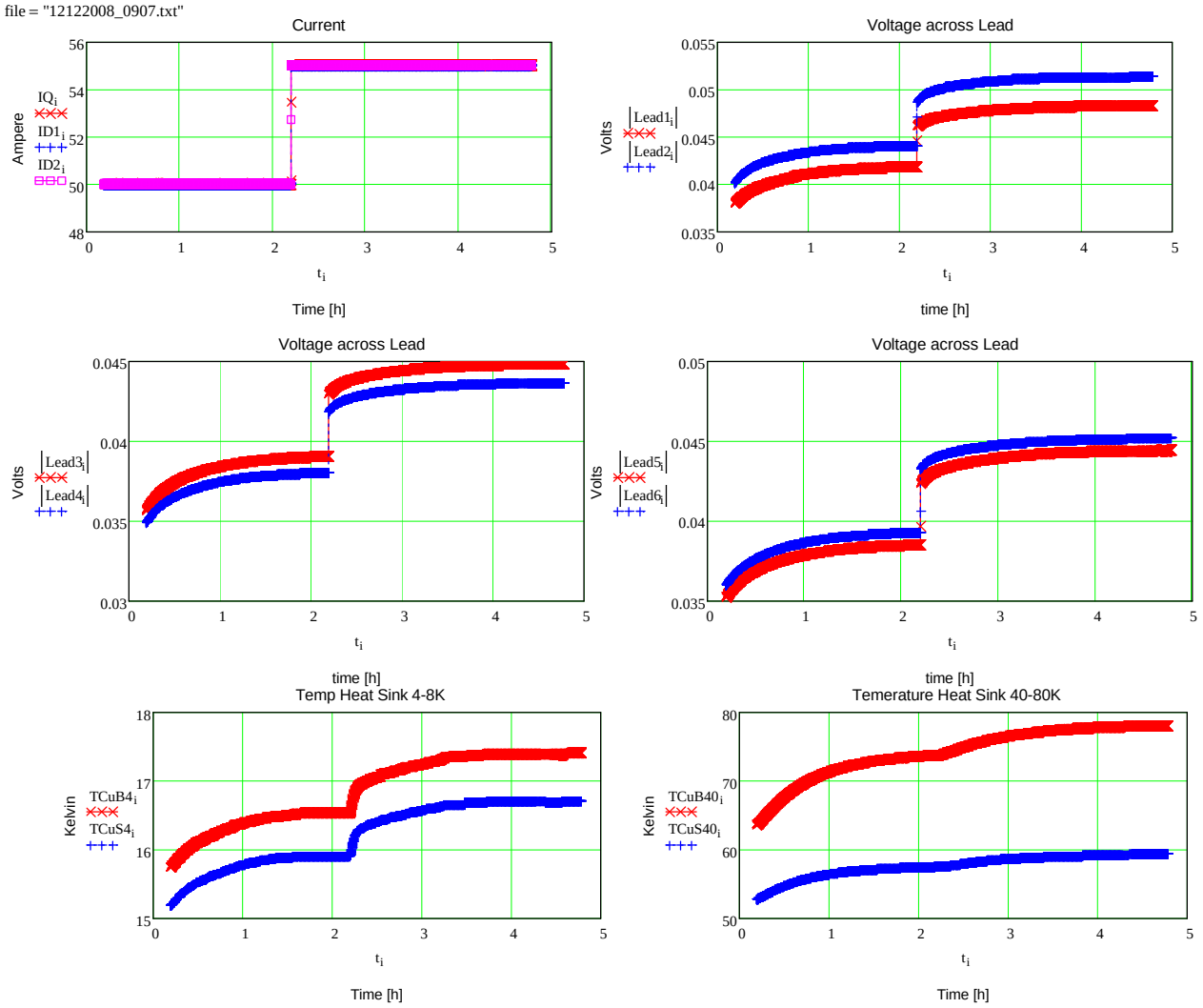
magnet = "XMP-P3"

Multipoles at: r0 = 30 $I_0 = 0.49998$

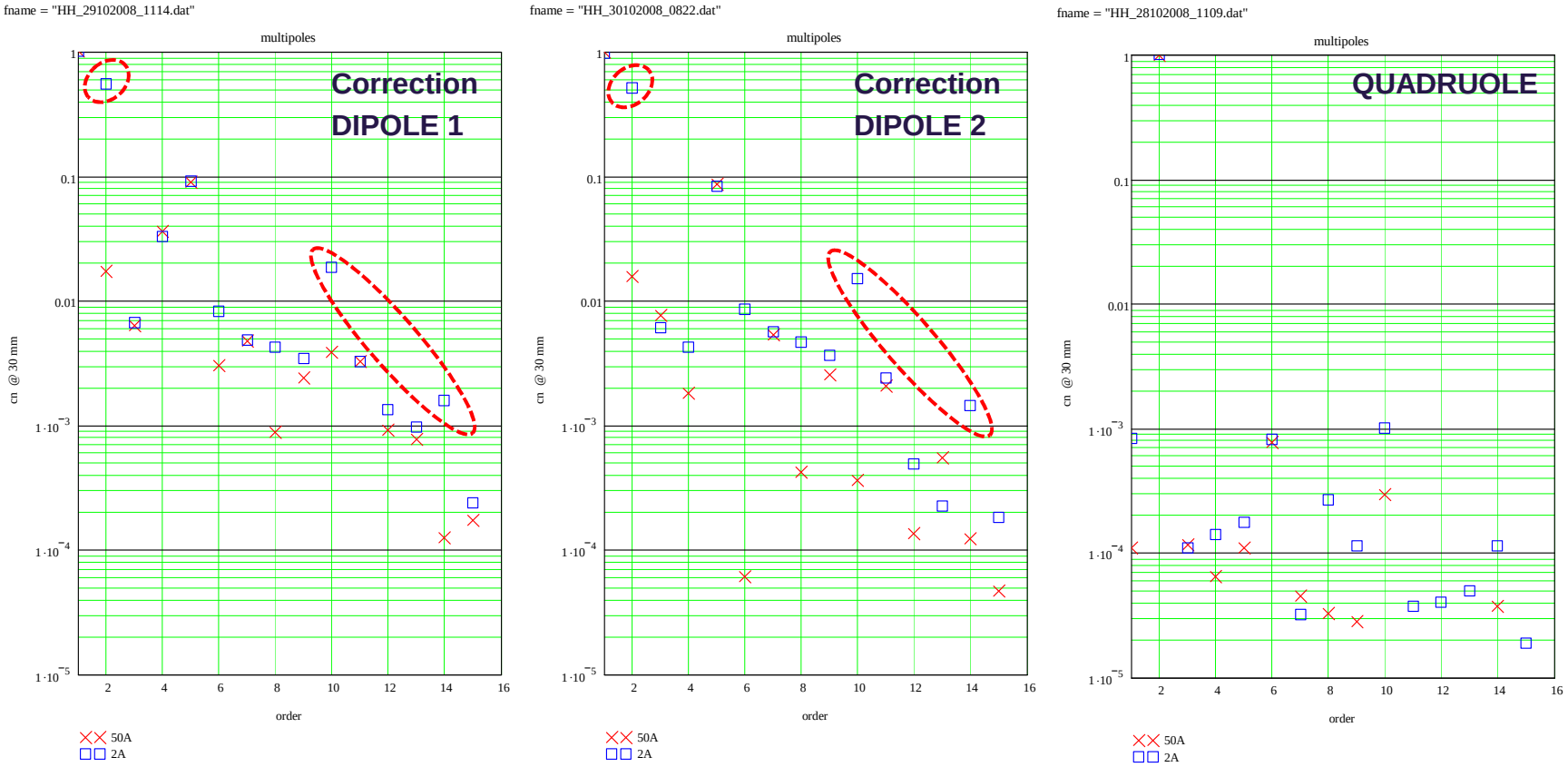


Current Lead Performance XCL CERN 1 and 2

- 1st lead assembly tested twice in Module 8
  - Up to a nominal current of 50A and even at 55A
- 2nd lead assembly tested in XMTS
- Voltage drop for both leads is similar (about 40 to 45mV)
- Temperatures at the heat sinks
  - differ at CMTB and XMTS
  - are higher then expected
  - Still improving setup at XMTS
- Heat loads must be checked by cryo experts at CMTB test of M8*



Normalized Multipoles Cold (XMP-P1) at 2 and 50A

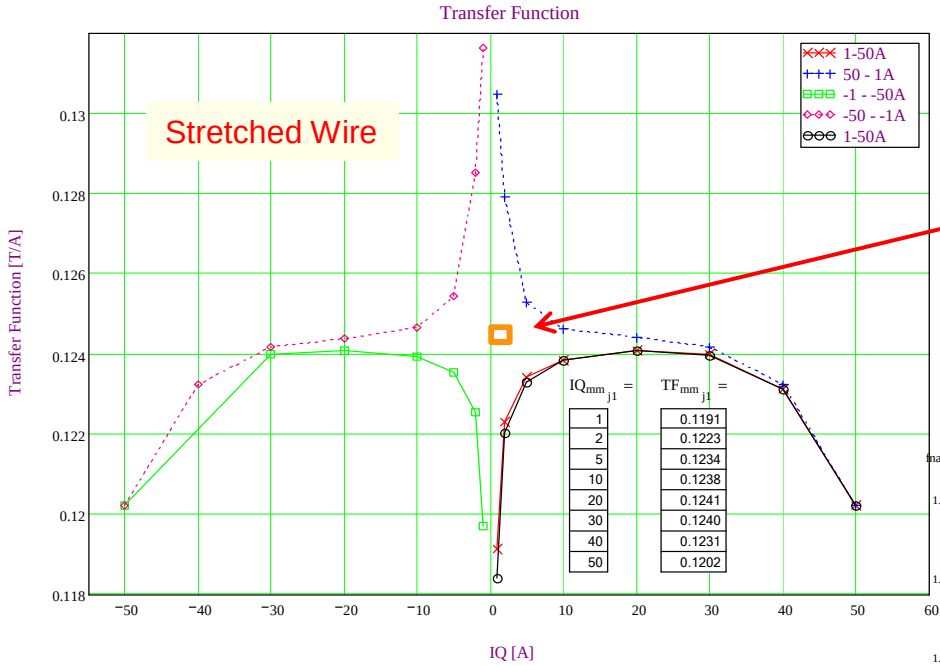


- Precycled
- Multipoles at 30mm reference radius
- In units of 10-4

- Large quadrupole, c10 and c14 at low current in dipole coils due to persistent current effects after pre-cycle

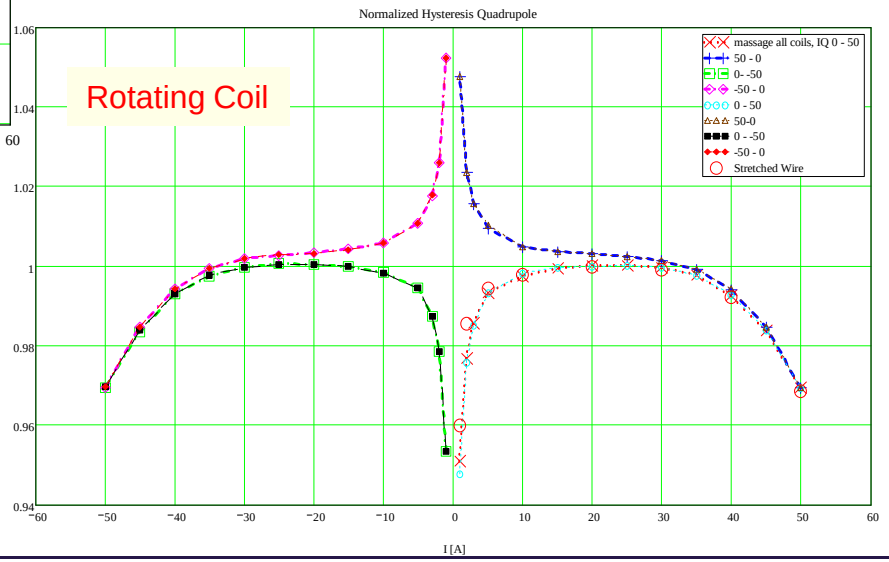
Quadrupole Hysteresis (XMP-P1) Dipoles at zero Current

fname1 = "O:\Brueck\DATA\XFEL\MAGNETS\ST\COLD_DC\XFEL2\SH_24112008_1125.dat"



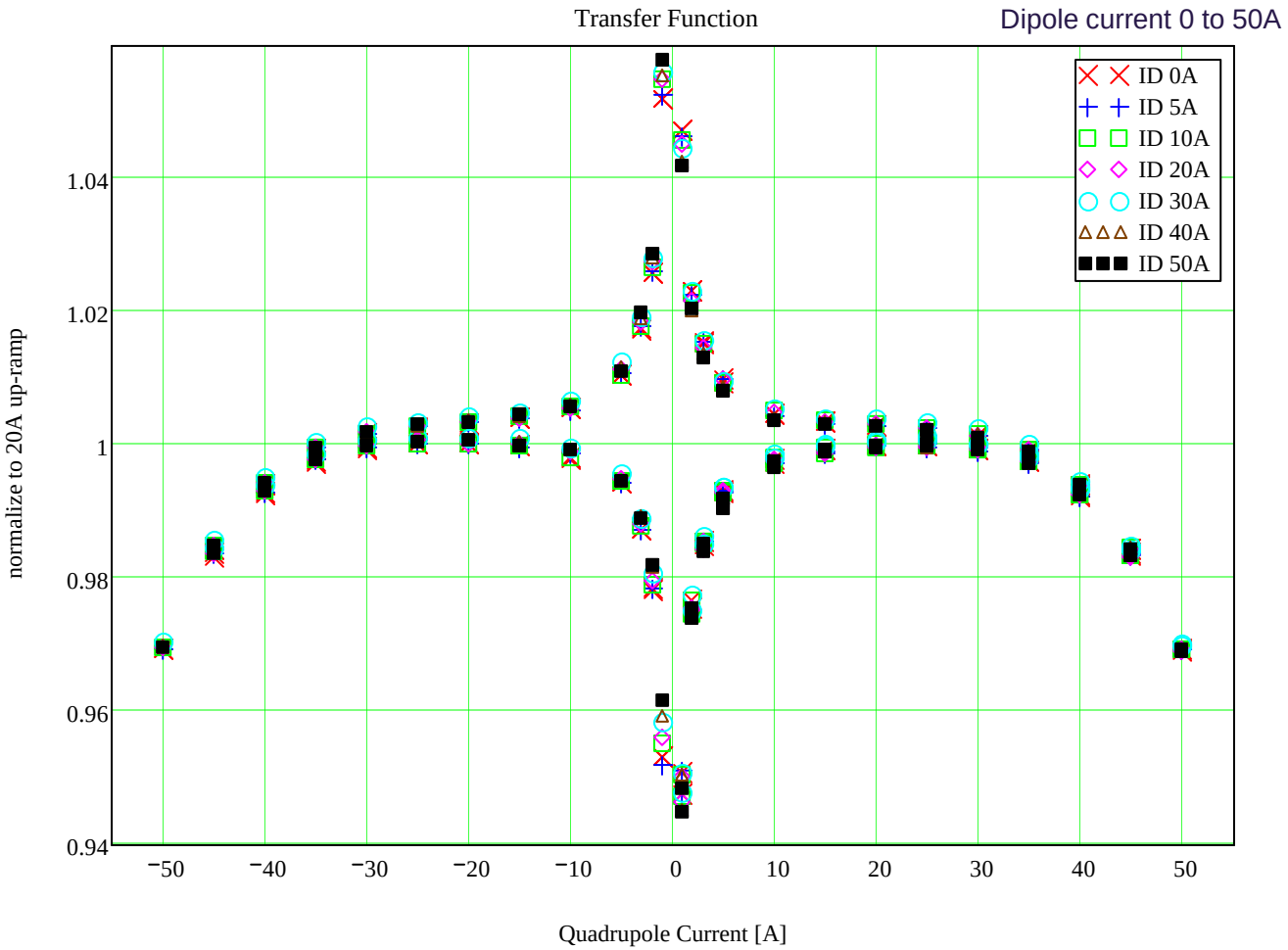
- Stretched Wire data (absolute numbers)
- Harmonic coil data (normalized to the value of the transfer function at 20A up-ramp
- The calculated and measured values agree very well
- Warm at 2A measured 0.125T/A
  - Contributions at low current are persistent current effects and not magnetization
- Saturation starts above 30A, about 3.5% at 50A

fname = "HH_28102008_1109.dat"



Quadrupole Hysteresis at some Dipole Currents

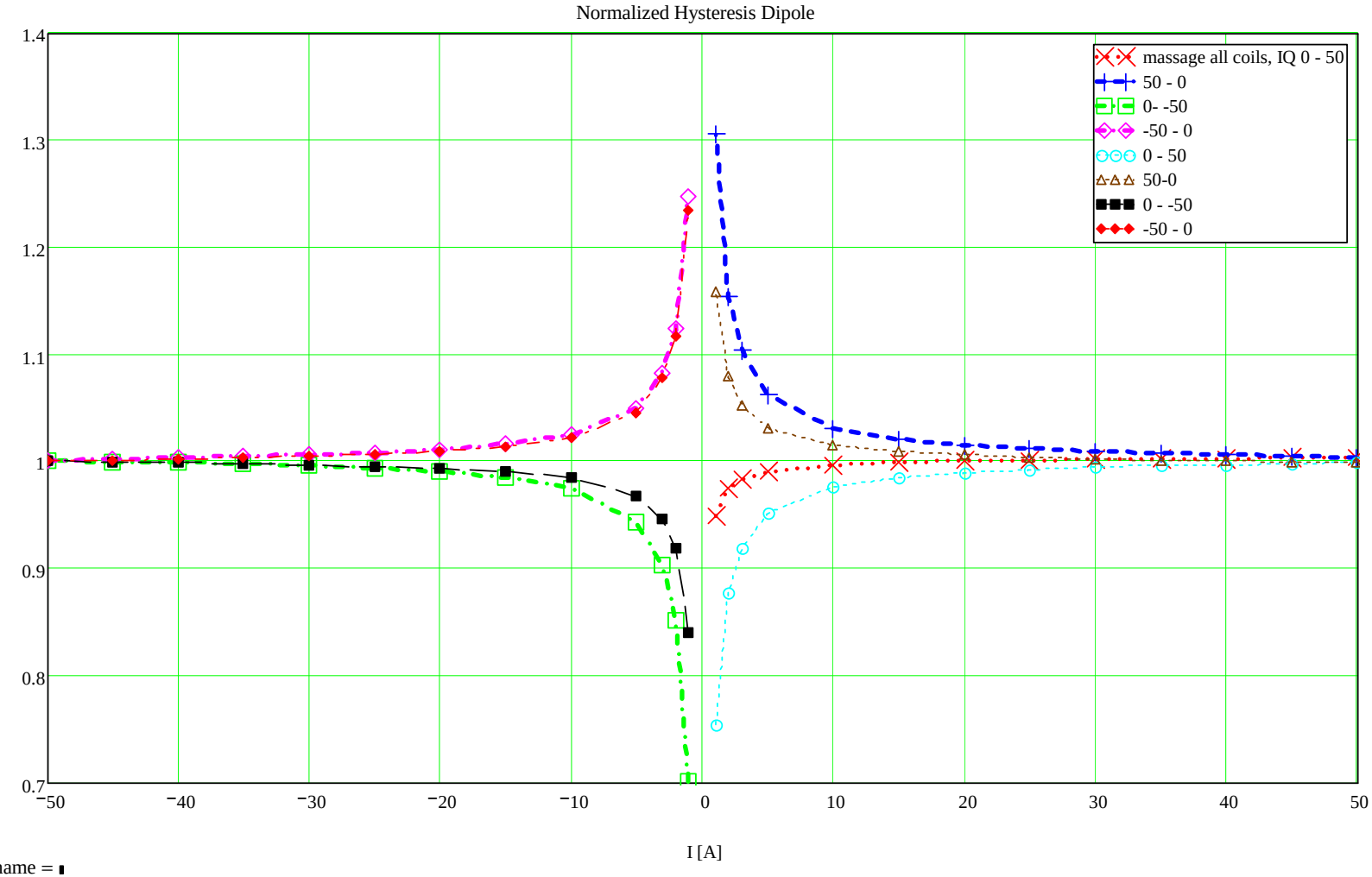
Normalized transfer function



- No big effects due to powering of one correction dipole

Dipole Hysteresis normalized at 20A (XMP-P1)

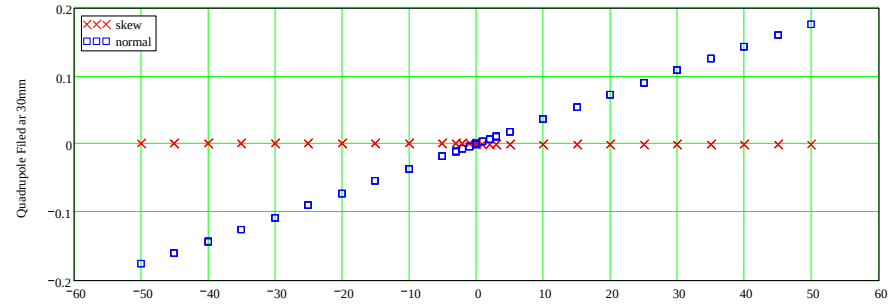
fname = "HH_29102008_1114.dat"

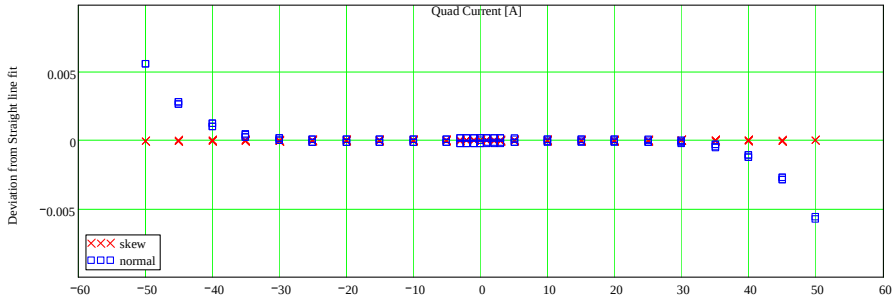


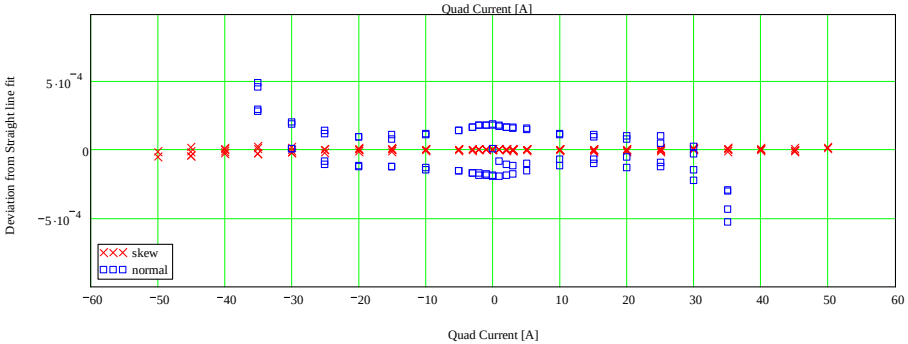
fname =

Quad and Dipole (XMP-P3)

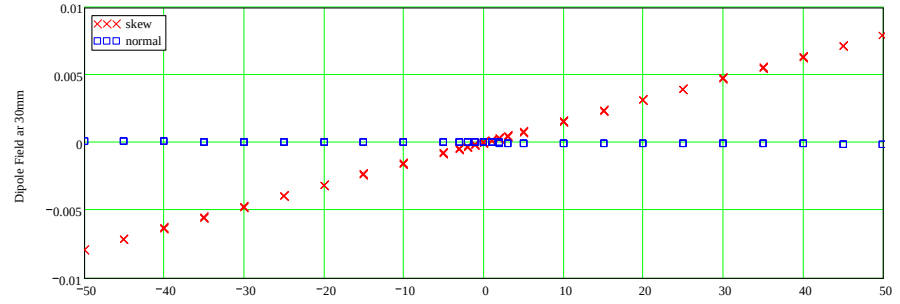
magnet = "XMP-P3" fname = "HH_05032009_0835.dat"

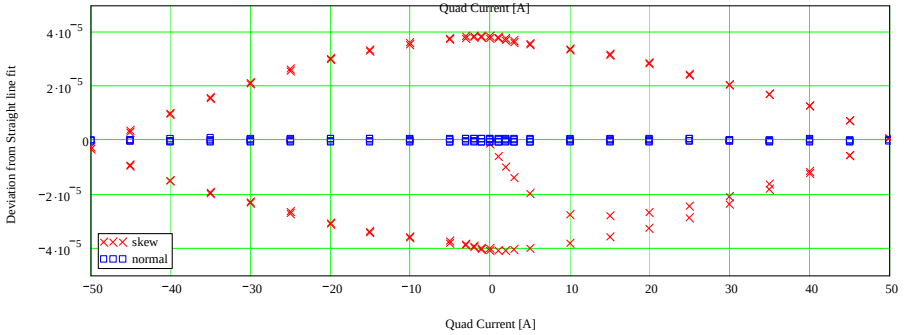






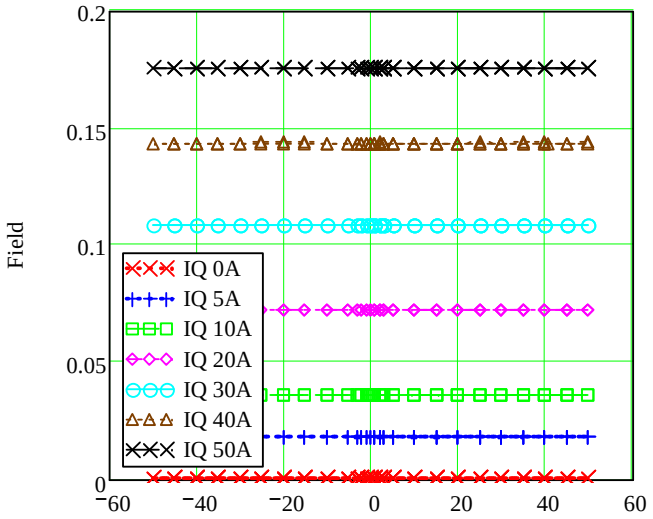
magnet = "XMP-P3" fname = "HH_04032009_0847.dat"

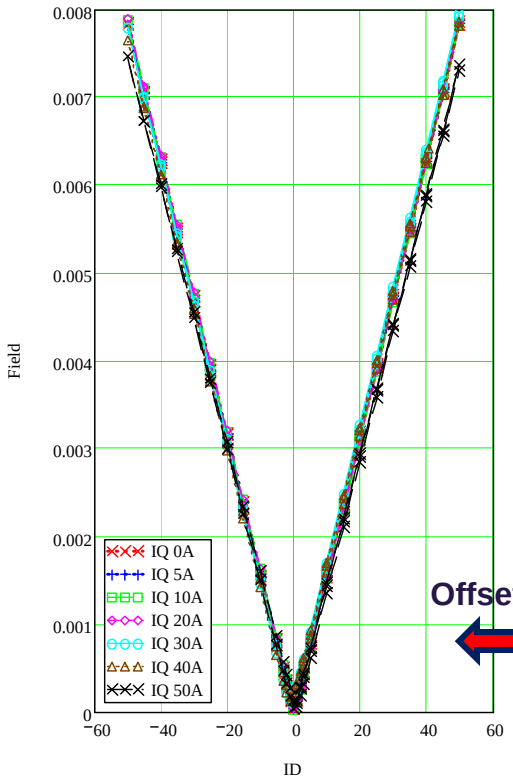




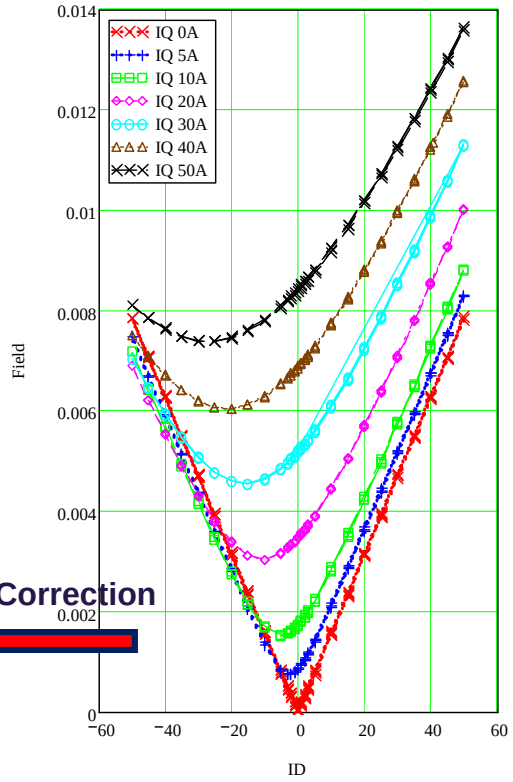
Field Variation with Dipole Current at different Quadrupole Currents

- Coil rotates not in the centre of the quad
- This leads to a fake dipole in the presence of a quadrupole field
- This can be corrected offline
  - Measure the multipoles at ±50A quadrupole current and zero dipole currents
  - Assume the measured dipole component is only due to the off-centered measurement coil
  - Calculate the offset x_{off} and y_{off}





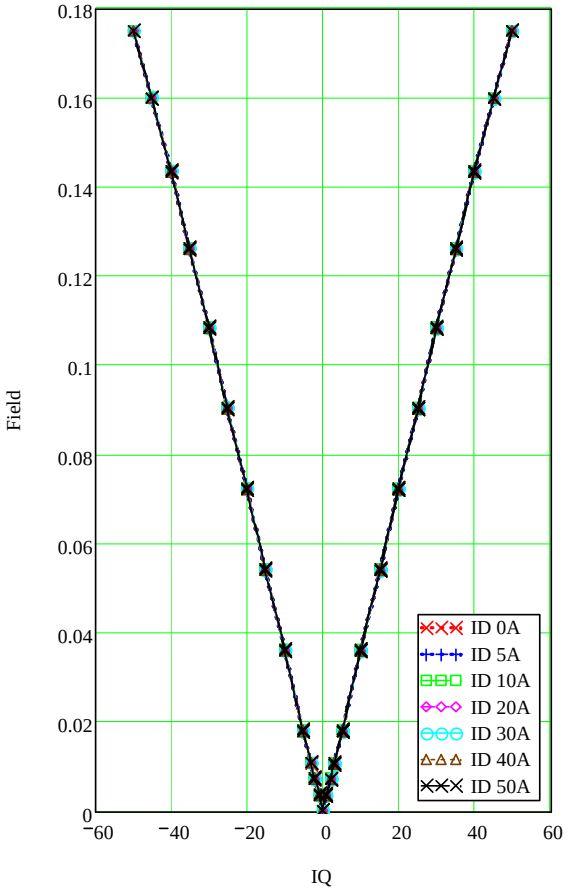
Offset Correction



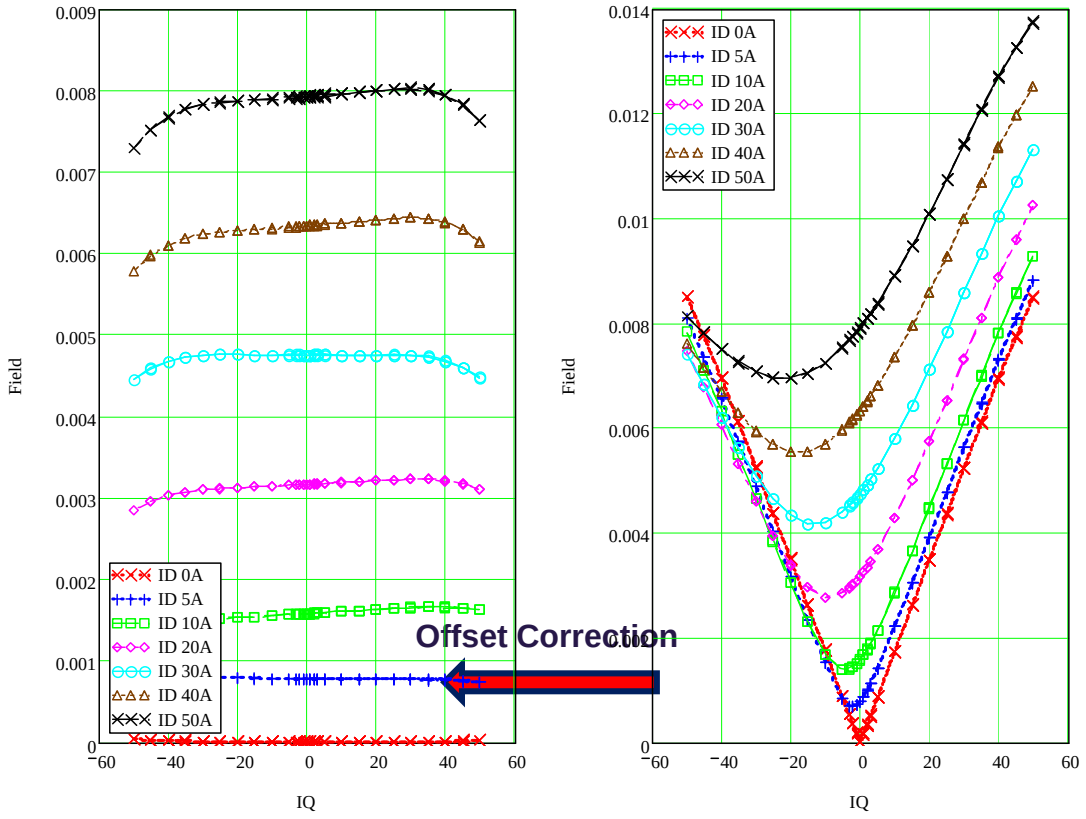
Quadrupole field not depending on dipole current

Field Variation with Quadrupole Current at different Dipole Currents

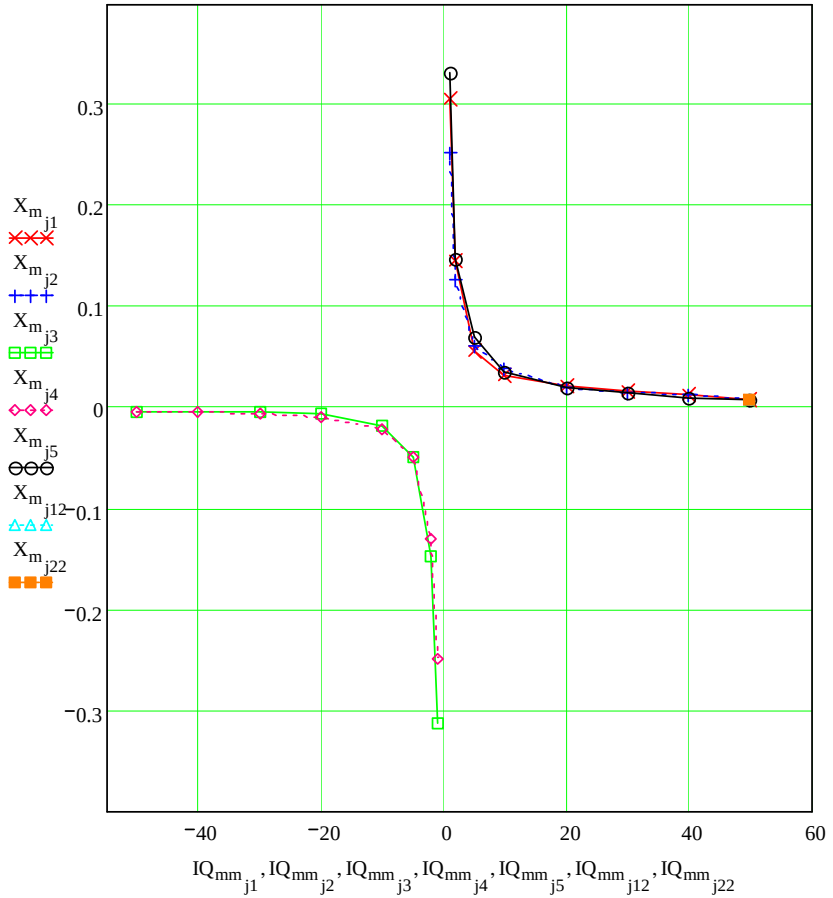
Quadrupole field not depending on dipole current

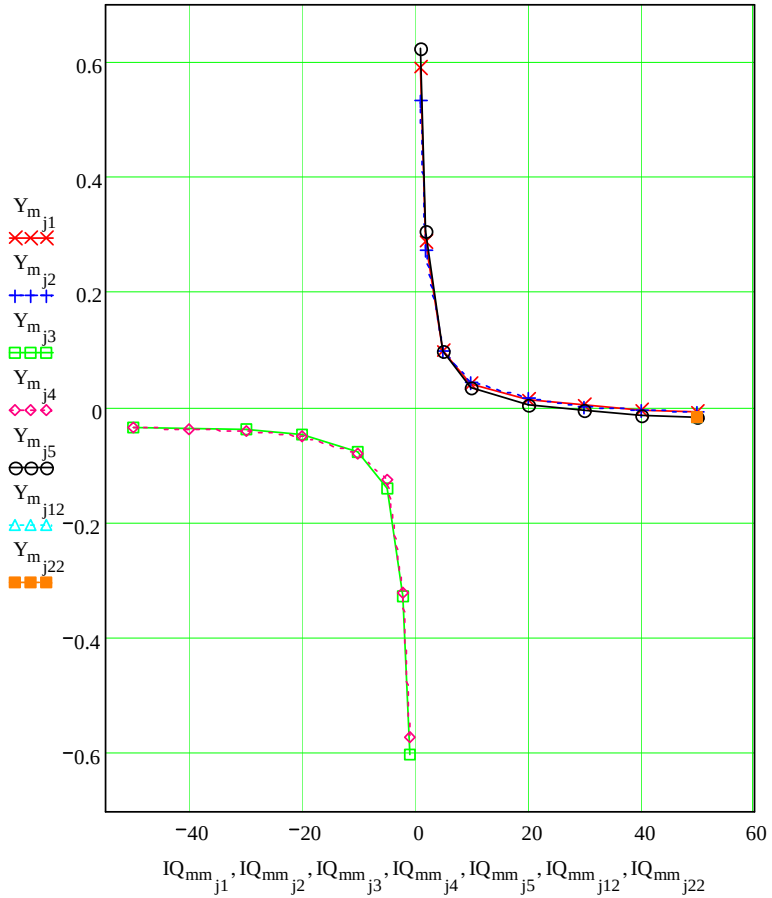


Dipole field some dependence on quadrupole current (iron saturation)



Quad Axis Dependence on Current

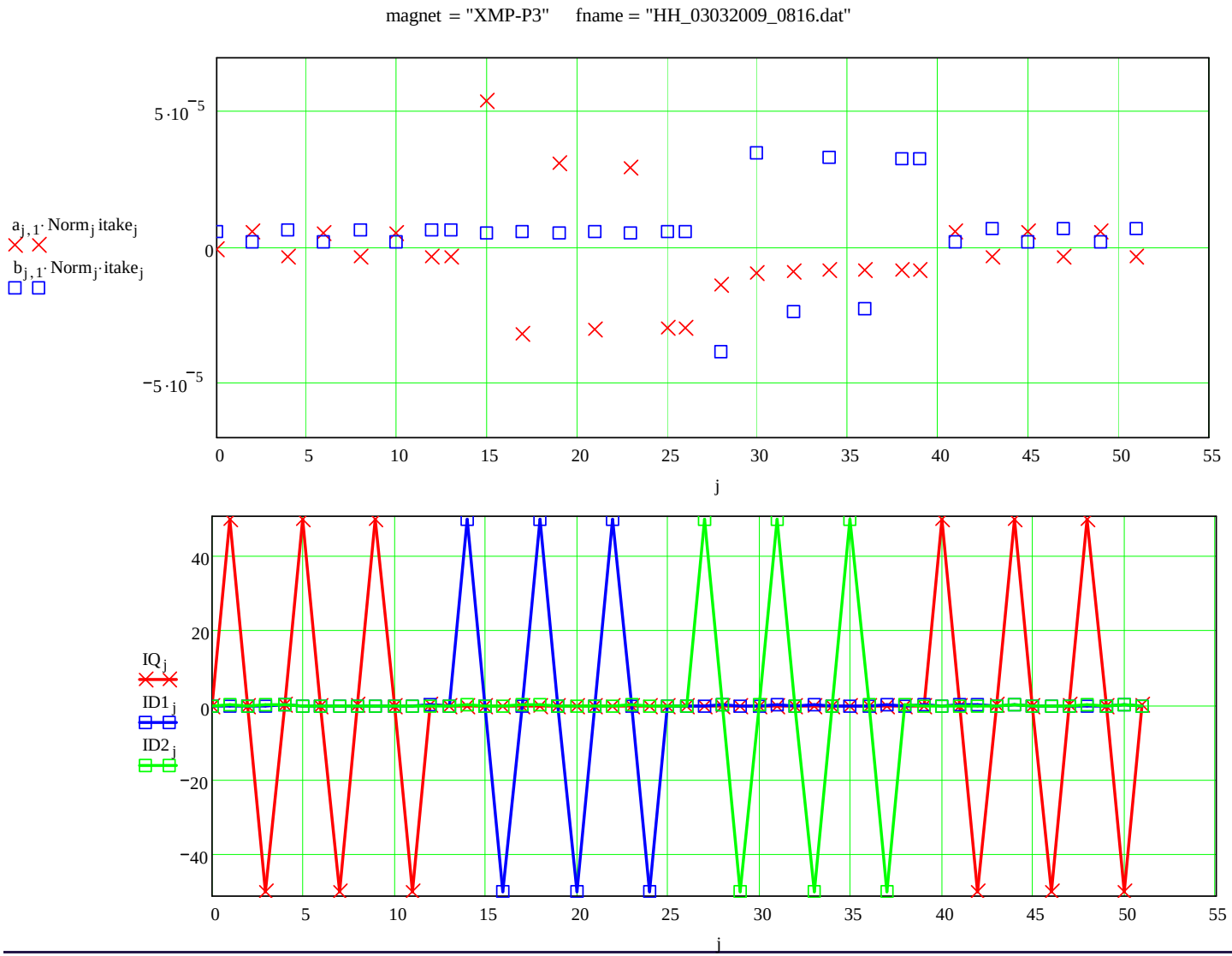




The large change of the quad axis is due to the persistent dipole after the massage cycle.

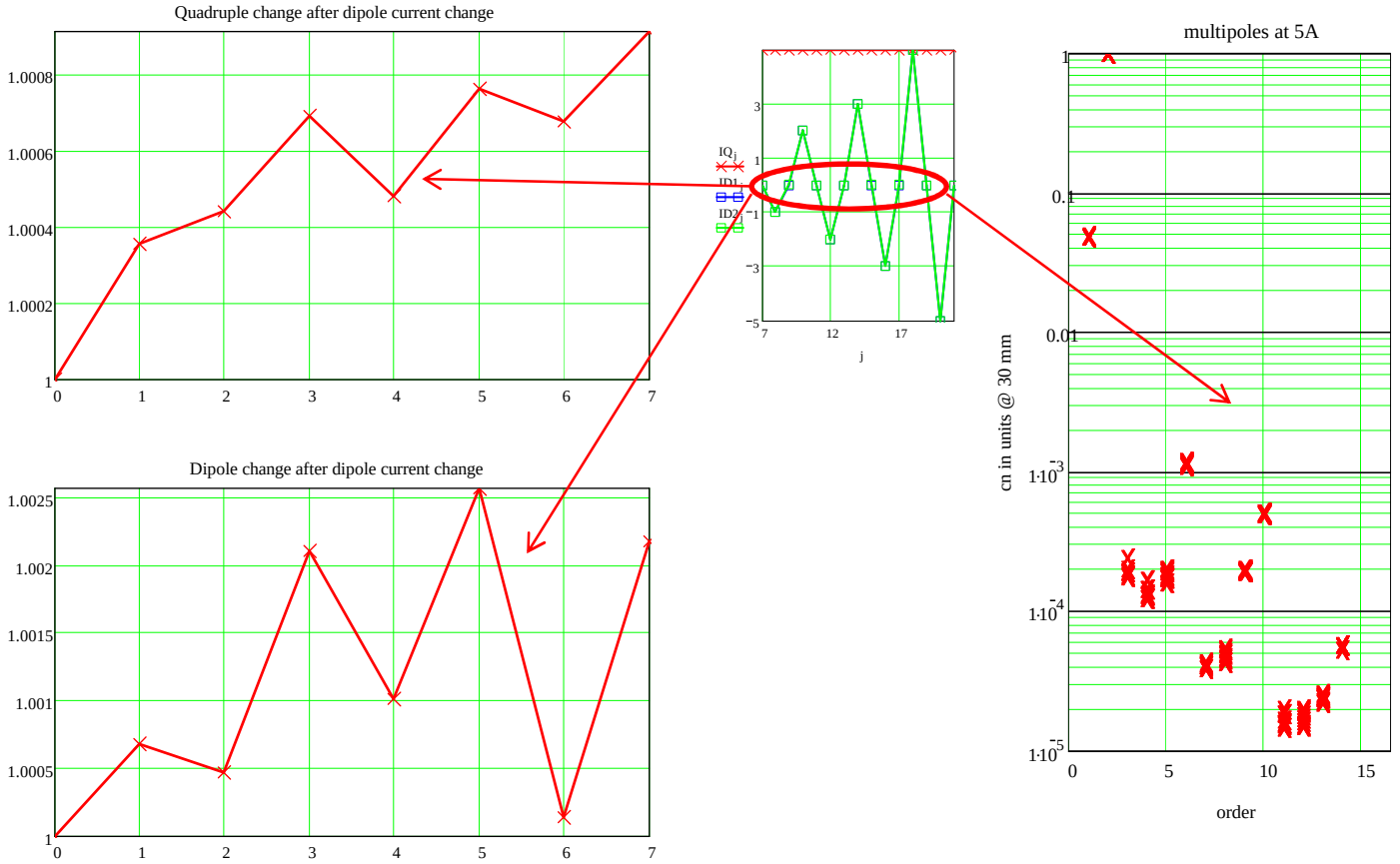
The magnetic axis in a quadrupole is defined as the axis where the dipole filed is zero.

Influence of Current Cycles



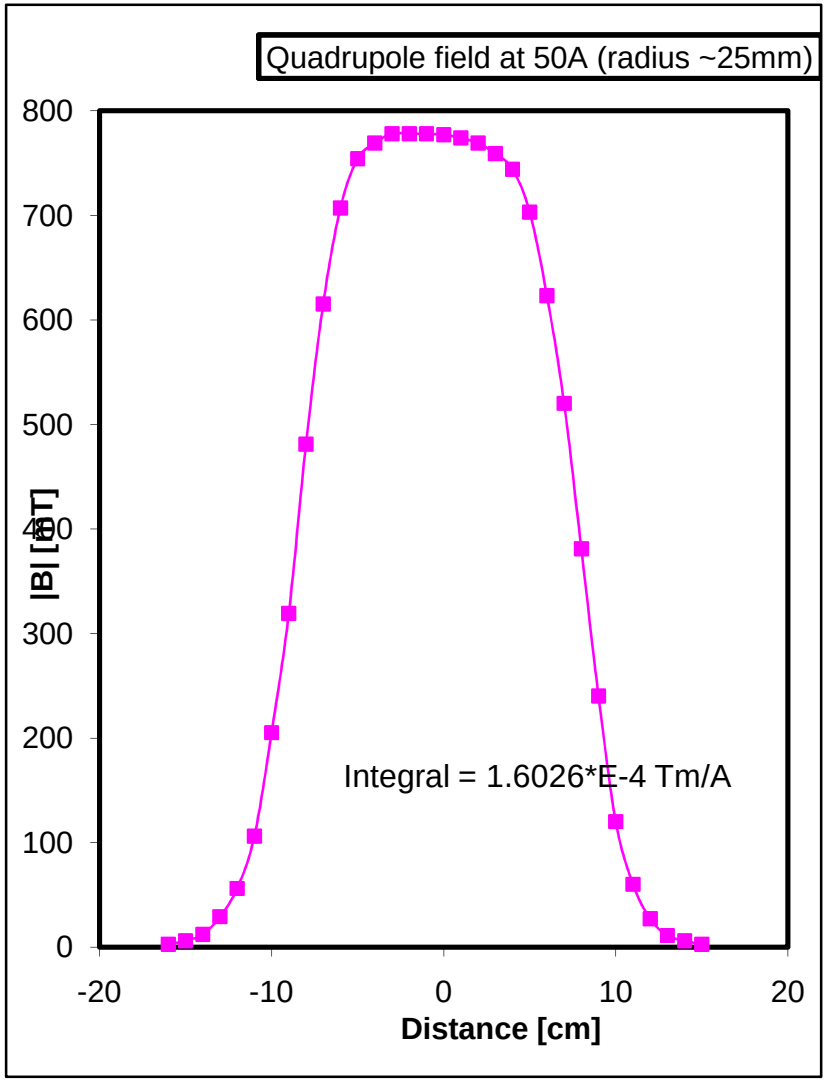
- Quadrupole current clears most of the dipole persistent current field

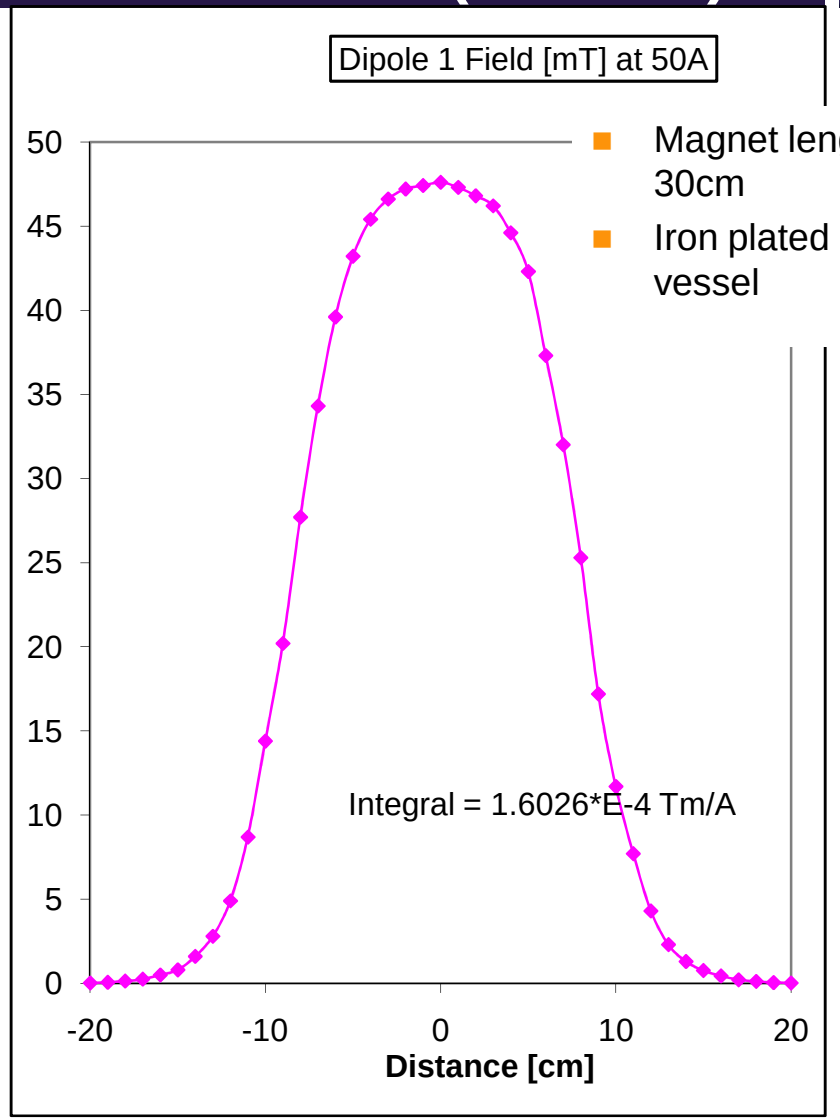
Influence of Current Cycles (cont.)



- Quad at 5A
- Dipole current changed ID1 and ID2: ±0, ±1, ±2, ±3, ±5A
- Measurements at zero dipole current
- No effects on Field strength and multipoles

Axial Field measured with Hall Probe (XMP-P3)



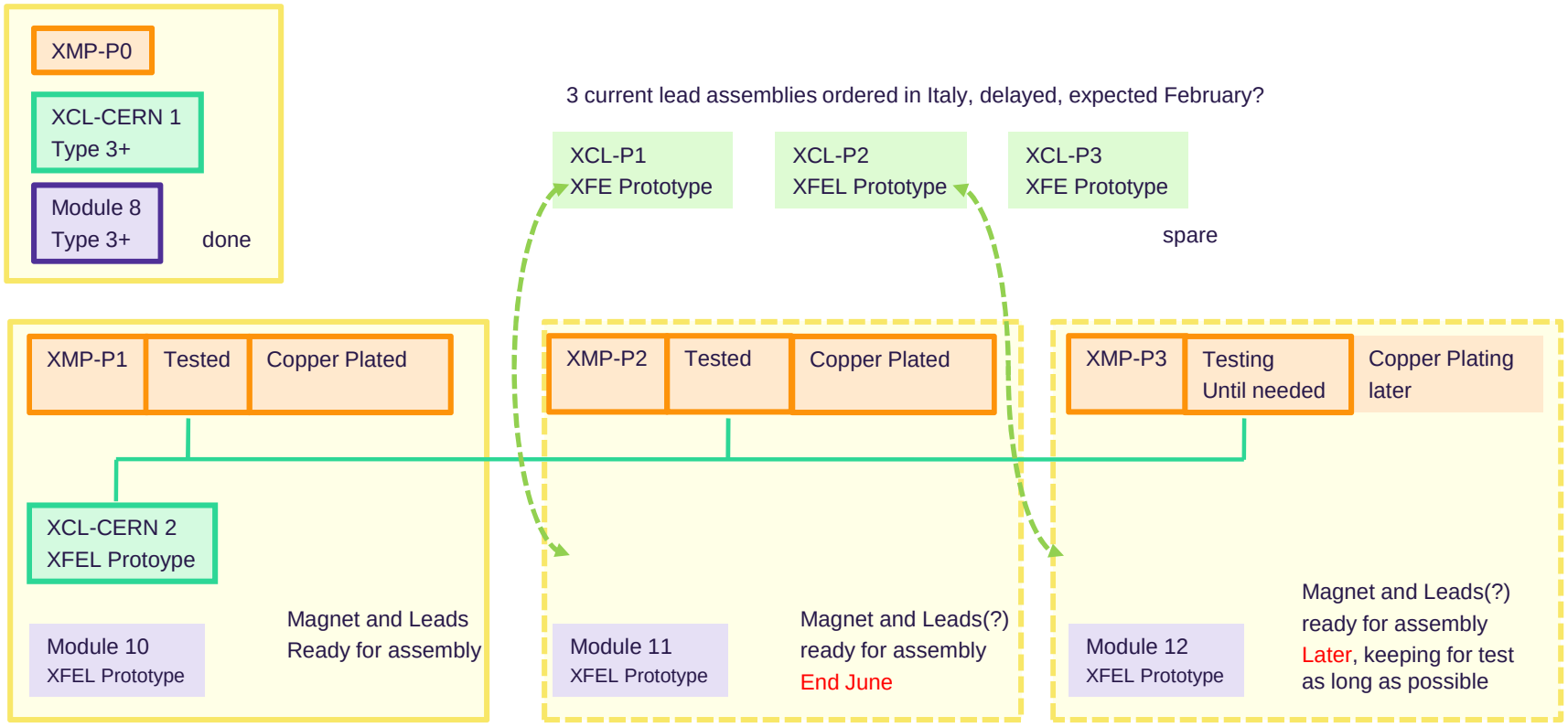


- Magnet length 30cm
- Iron plated inside vessel

Summary on Magnet Performance

- Heat loads of the current leads into 2K helium still unclear, wait for conclusions after the module 8* test at CMTB
- Magnetic field deviations at low currents are too large
  - CIEMAT tries to find a dipole cable with less superconductor and smaller filament size to reduce the persistent current contributions
  - An alternative option is to use only copper wire (no SC) for the first (10) modules, this removes the PC contribution in the dipole coils
- We plan to have 3 types of magnets now:
  - Low energy (10 modules) with:
    - ➔ Quad, both vertical and horizontal Dipoles
  - 45 modules with Quad and only vertical Dipole
  - 45 modules with Quad and only horizontal Dipole
- One more prototype necessary (1st of the 3 pre-series magnets)
  - Test in autumn 2009 before cryo shutdown

Status Summary next 3 Modules



- 4 magnets made in Spain are at DESY
- 2 lead assemblies from CERN are at DESY
- 3 lead assemblies from industry expected soon
- 2 magnets are ready for cleaning and assembly
- 1 magnet remaining for copper plating

Plans for Pre-Series and Series Production

- Preparation for the pre-series production started
- Pre-series of 3 magnets and series of 100 magnets and leads
- Coils for PS 1-3 at CIEMAT, vessels in industry
- Start Call for Tender planed for December 2009