MAD-X vs. LSA magnet polarities

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Conventions

- Reference beam is beam 1 - observer looks in direction of beam 1
- Field and gradients positive **if** current enters A terminal
- Left aperture from connection end is aperture 1 (V1)
- For single aperture magnets covering both beams:
  - beam 1 is used to describe the polarity.

REFERENCE

LHC Magnet Polarities

Stephan Russenschuck

Orbit Correctors

- A positive horizontal **kick** on beam 1 deflects beam outwards.
  - This implies a negative B field.
- A positive vertical **kick** on beam 1 deflects beam upwards.
  - This implies negative skew dipole - field point outwards

- The agreement is that a positive current from the power converter should give a positive kick. This mean connecting positive to the B terminal for B1.

Orbit Correctors – B2

- A positive horizontal **kick** on beam 2 deflects beam outwards. This implies a positive B field.
- A positive vertical **kick** on beam 2 deflects beam upwards. This implies positive skew dipole - field point inwards
- The agreement is that a positive current from the power converter should give a positive kick. This mean connecting positive to the A terminal for B2

For correctors acting on both beams, B1 is the reference but we have to very careful in the software: a positive kick is negative for B2.

Correctors

Beam	Kick [LSA]	Deflection	Field
B1	+θ H	OUT	V NEG
B1	+θ V	UP	NEG (OUT)*
B2	+θ H	OUT	V POS
B2	+θ V	UP	POS (IN)
B1/B2	+θ H	B1 OUT B2 IN	V NEG
B1/B2	+θ V	B1 UP B2 DOWN	NEG (OUT)*

Quadrupoles

- A positive quadrupole field gradient or polarity is one where the vertical B-field increases as one moves in a positive x direction (away from the centre of the machine). This is focusing for beam 1
- MAD: a positive value corresponds to horizontal focusing of a positively charged particle.
- Beam 1
  - +K horizontally focusing $\longrightarrow$ positive A
- Beam 2
  - +K horizontally focusing $\longrightarrow$ positive B

MAD

- kqd := -0.008600955656 ;
- kqf := 0.008990100753 ;

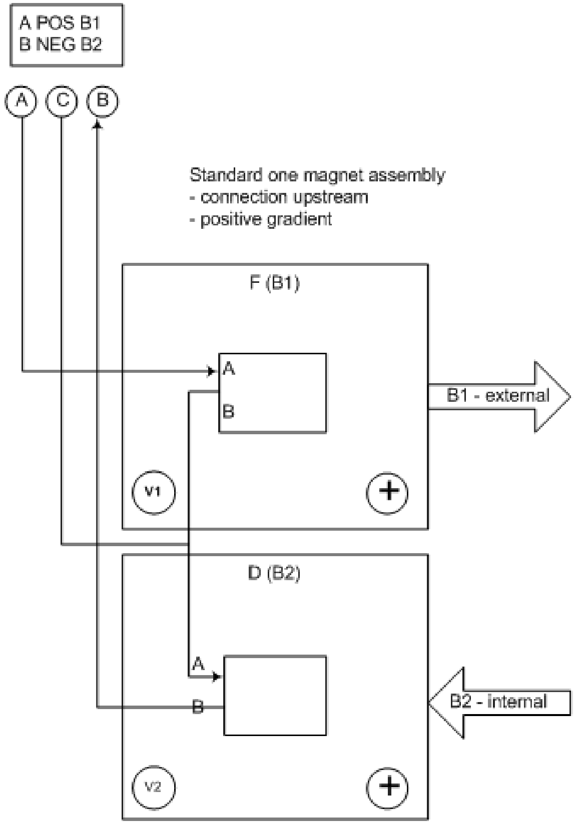
- kqf.a12 := kqf ;
- kqd.a12 := kqd ;

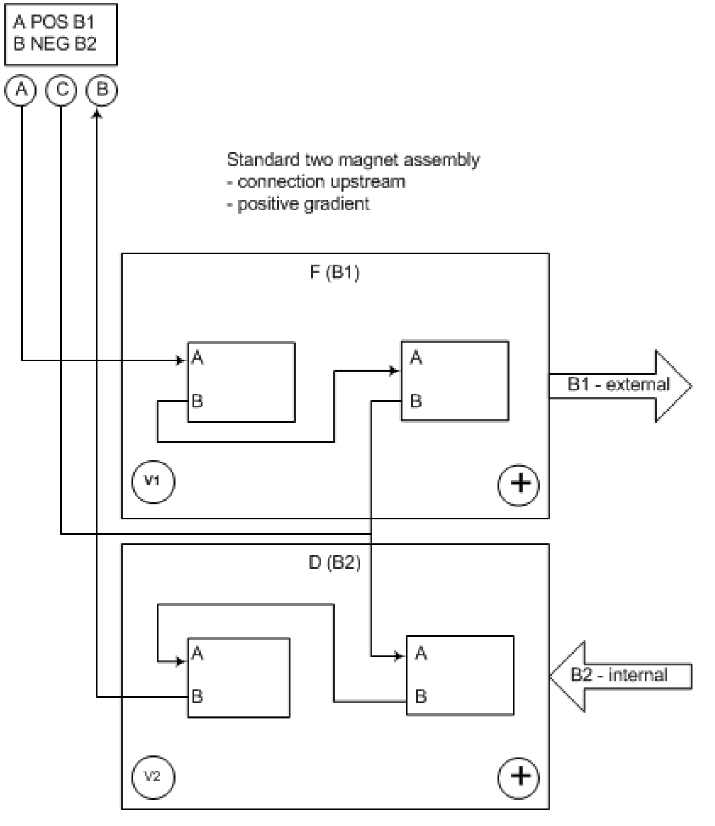
- RQF.A12B1 : MQ, K1 := KQF.A12;
- RQF.A12B2 : MQ, K1 := -KQF.A12;

- MQ.23R5.B1:RQF.A56B1
- MQ.23R5.B2:RQD.A56B2

Quads etc.

- Except for bipolar supplies we give power converters positive references
- Rely on cabling to get things right





LSA

- In LSA parlance:
  - Magnet is an element
  - Magnet string is a logical hardware
    - i.e stuff we can not directly address
    - A piece of logical hardware consists of one or more elements
  - Power converters are actual hardware
    - i.e. stuff we can actually talk to, load functions etc.
    - not always a one to one mapping
  - We get twiss outputs from optics for elements
    - Then we populate them as strengths of logical hardware
      - In case one logical hardware contains elements covering B1 and B2 we take the sign of B1 elements' twiss (see: Conventions)
  - We map calibration curves (B versus I) to logical hardware
    - i.e. we calculate currents for magnets strings and worry about the power converters later

LSA

- In LSA we keep strengths (K) and current (I) for magnet strings (logical hardware).
  - NB We keep the strength sign: + is F, - is D for both beams

- The magnet strings are mapped on to power converters for which we calculate currents (IREF).

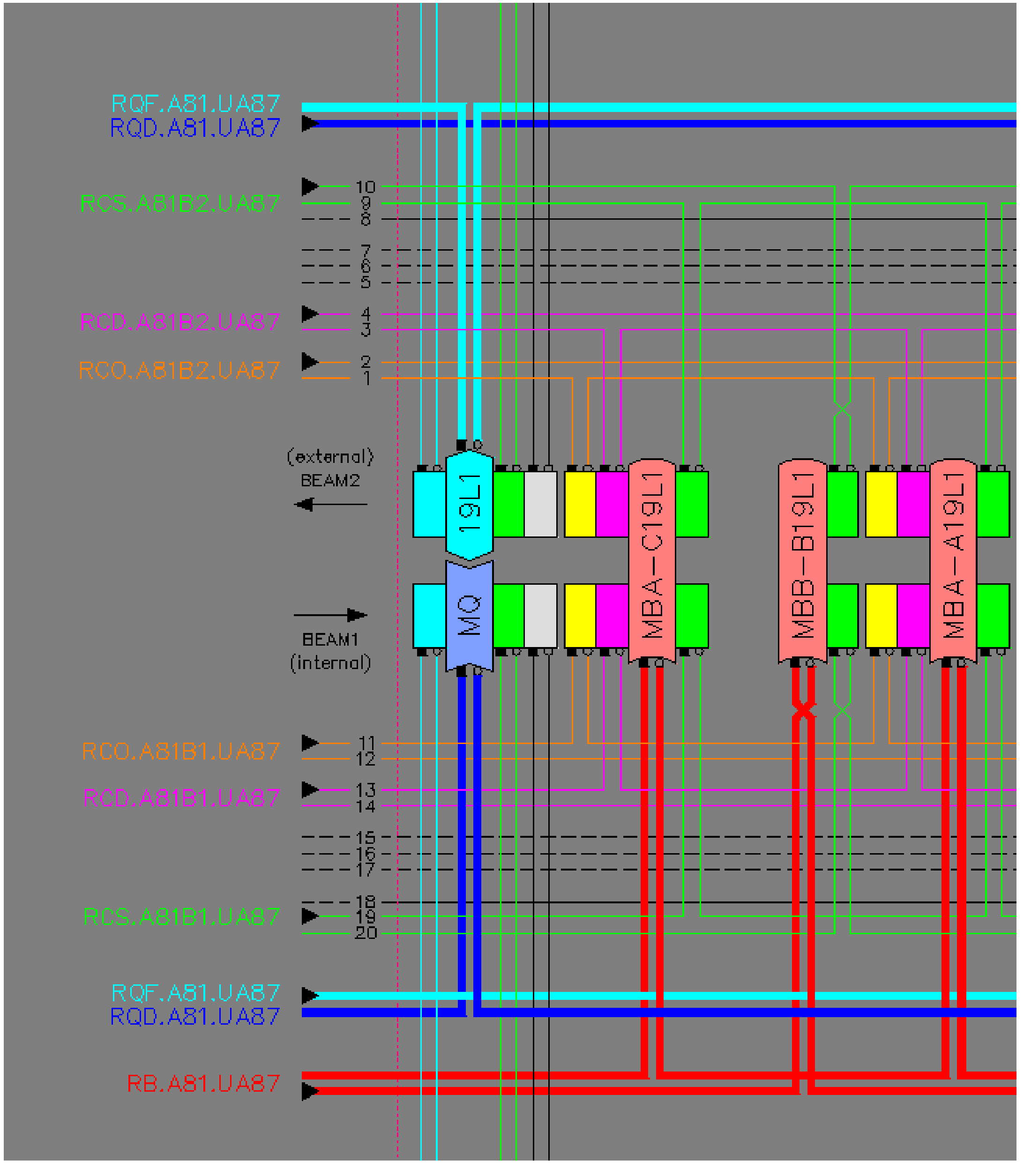
- To take care of the cases where negative strengths have to give positive reference we have a "calibration sign" for each logical hardware in the database which is set to give the correct current when we go through the calibration.

- For non-bipolar quads we only keep the positive signed calibration.

Logical Hardware

	LOGICAL_HARDWARE_NAME	NB_OF_ELEMENTS	ACTIVE_CAL_NAME	CAL_SIGN	MAGNET_TYPE
1	RQTF.A23B1	8	MQT_F	1	MQT
2	RQSX3.L2	1	MQSX_F	1	MQSX
3	RQTD.A78B1	8	MQT_F	-1	MQT
4	RQTD.A81B1	8	MQT_F	-1	MQT
5	RQS.R2B2	2	MQS_F	1	MQS
6	RQTF.A23B2	8	MQT_F	1	MQT
7	RQTF.A34B2	8	MQT_F	1	MQT
8	RQTD.A67B1	8	MQT_F	-1	MQT
9	RQS.R5B1	2	MQS_F	1	MQS
10	RQTF.A78B1	8	MQT_F	1	MQT
11	RQS.R7B1	2	MQS_F	1	MQS
12	RQTD.A67B2	8	MQT_F	-1	MQT
13	RQS.A78B2	4	MQS_F	1	MQS
14	RQS.L2B1	2	MQS_F	1	MQS
15	RQTD.A12B1	8	MQT_F	-1	MQT
16	RQSX3.R2	1	MQSX_F	1	MQSX
17	RQSX3.R8	1	MQSX_F	1	MQSX

And then hope the cabling is right



Bipolar supplies

- Pretty natural
- Standard signs for strengths
  - e.g. positive sextupole compensates negative b3
- Keep both positive and negative branches of the calibration curve
  - so in general positive strength will demand positive current…

#	CALIBRATION_NAME	B_FIELD	I	SLOPE
1	MCS	-3646.429694	-600	0
2	MCS	3646.429694	600	0

MAD-X polarity flag

- The polarity flag is defined (proposal by S. Fartoukh) as:

  $\text{Sign} [K_{twiss} * bv * \text{polarity\_flag}] = \text{Sign} [\text{current in LHC}]$

  - K_{twiss} stands for the element strength as reported in a Twiss output.

- It can be computed from:
  - The way the circuit under consideration is cabled
  - The magnet orientation
  - The machine convention for the sign of magnetic field gradient
  - The change of coordinate system between machine and MAD-X (x-axis positive pointing towards the outside of the machine) should be taken into account.

MAD-X polarity flag (2)

- More formally:
  - Normal element:
    - polarity_flag = Sign[I * $d^n B_y/d x^n$]
    - The opposite should be taken for elements represented as H-kickers in the MAD-X sequence
  - Skew element:
    - polarity_flag = Sign[I * $d^n B_x/d x^n$]

- For details refer to Massimo's talk at LHC Beam Commissioning from 19/05/2009

- MAD-X polarity flag is claimed to be fully implemented and debugged since 2009

Compliance LSA vs. MAD-X

- Method
  - Take standard LHC sequence
  - Take standard LHC optic (e.g. Injection optic)
  - Assign non-zero strengths for multipoles (incl. skew)
  - Generate twiss and import optic to LSA
    - Use of the same tools as for standard optic import
  - Generate a beamprocess based on prepared optic
  - Generate settings for the beamprocess
  - Dump all LSA currents
  - Compare LSA current sign with MAD-X polarity flag definition formula
    - Take care about logical hardware covering both beams
    - Take into account cabling

Compliance MAD-X vs. LSA – Outcome (B1)

NAME	BV	POLARITY	MAD K sign	MAD Curr sign	ELEMENT_NAME	DEVICE_NAME	BEAM	LSA_K	LSA_I	CURR SIGN AGREE	
MQXA.1L1	0	-1	-1	1	MQXA.1L1	MQXA1.L1	B1	-0.008577	408.077	TRUE	
MQXB.A2L1	0	1	1	1	MQXB.A2L1	MQXB2.L1	B1	0.01	697.674	TRUE	
MCO.10L2.B1	0	1	1	1	MCO.10L2.B1	RCO.A12B1	B1	0.010000	0.028	TRUE	
MCO.10L3.B1	0	1	1	1	MCO.10L3.B1	RCO.A23B1	B1	0.010000	0.028	TRUE	
MCOX.3L1	0	1	1	1	MCOX.3L1	RCOX3.L1	B1	0.010000	0.027	TRUE	
MCS.A10L2.B1	0	1	1	1	MCS.A10L2.B1	RCS.A12B1	B1	0.166809	40.920	TRUE	
MCS.A10L3.B1	0	1	1	1	MCS.A10L3.B1	RCS.A23B1	B1	0.165841	40.683	TRUE	
MCSSX.3L1	0	1	1	1	MCSSX.3L1	RCSSX3.L1	B1	0.001000	0.200	TRUE	
MCSX.3L1	0	1	1	1	MCSX.3L1	RCSX3.L1	B1	0.001000	0.743	TRUE	
MBX.4L2	0	-1	-1	1	MBX.4L2	RD1.L2	B1	-0.000162	345.504	TRUE	
MBXW.A4L1	0	1	1	1	MBXW.A4L1	RD1.LR1	B1	0.000055	43.115	TRUE	
MBRC.4L1.B1	0	-1	-1	1	MBRC.4L1.B1	RD2.L1	B1	-0.000119	283.570	TRUE	
MBW.A6L3.B1	0	-1	-1	1	MBW.A6L3.B1	RD34.LR3	B1	0.000056	40.927	TRUE	
MBRB.5L4.B1	0	1	1	1	MBRB.5L4.B1	RD4.L4	B1	0.000166	394.693	TRUE	
MO.22L2.B1	0	-1	1	-1	MO.22L2.B1	ROD.A12B1	B1	0.010000	-0.022	TRUE	
MO.25L2.B1	0	1	1	1	MO.25L2.B1	ROF.A12B1	B1	0.010000	0.022	TRUE	
MQML.10L1.B1	0	1	1	1	MQML.10L1.B1	RQ10.L1B1	B1	0.007324	296.597	TRUE	
MQY.4L1.B1	0	1	1	1	MQY.4L1.B1	RQ4.L1B1	B1	0.005011	167.413	TRUE	
MQWA.A4L3.B1	0	1	1	1	MQWA.A4L3.B1	RQ4.LR3	B1	0.001241	34.841	TRUE	
MQWA.A5L3.B1	0	-1	-1	1	MQWA.A5L3.B1	RQ5.LR3	B1	-0.001304	36.726	TRUE	
MQ.12L2.B1	0	-1	-1	1	MQ.12L2.B1	RQD.A12	B1	-0.008601	685.805	TRUE	
MQ.11L2.B1	0	1	1	1	MQ.11L2.B1	RQF.A12	B1	0.008990	716.997	TRUE	
MQS.23L3.B1	0	1	1	1	MQS.23L3.B1	RQS.A23B1	B1	0.000100	0.625	TRUE	
MQS.23L2.B1	0	1	1	1	MQS.23L2.B1	RQS.L2B1	B1	0.000100	0.625	TRUE	
MQS.27L2.B1	0	1	1	1	MQS.27L2.B1	RQS.L2B1	B1	0.000100	0.625	TRUE	
MQS.23R3.B1	0	1	1	1	MQS.23R3.B1	RQS.R3B1	B1	0.000000	0.000	FALSE	I_PNO = 0
MQS.27R3.B1	0	1	1	1	MQS.27R3.B1	RQS.R3B1	B1	0.000000	0.000	FALSE	I_PNO = 0
MQSX.3L1	0	1	1	1	MQSX.3L1	RQSX3.L1	B1	0.000100	1.021	TRUE	
MQT.12L1.B1	0	1	-1	-1	MQT.12L1.B1	RQT12.L1B1	B1	-0.000423	-2.647	TRUE	
MQWB.4L3.B1	0	1	1	1	MQWB.4L3.B1	RQT4.L3	B1	0.000689	22.044	TRUE	
MQT.14L2.B1	0	-1	1	-1	MQT.14L2.B1	RQTD.A12B1	B1	0.000010	-0.063	TRUE	
MQT.15L2.B1	0	1	1	1	MQT.15L2.B1	RQTF.A12B1	B1	0.000010	0.063	TRUE	
MS.12L2.B1	0	-1	-1	1	MS.12L2.B1	RSD1.A12B1	B1	-0.108181	9.612	TRUE	
MS.11R1.B1	0	1	1	1	MS.11R1.B1	RSF1.A12B1	B1	0.064897	5.766	TRUE	
MSS.29L2.B1	0	1	1	1	MSS.29L2.B1	RSS.A12B1	B1	0.001000	0.089	TRUE	
MSS.34L1.B1	0	1	1	1	MSS.34L1.B1	RSS.A81B1	B1	0.001000	0.089	TRUE	

Compliance MAD-X vs. LSA – Outcome (B2)

NAME	BV	POLARITY	MAD K sign	MAD Curr sign	ELEMENT_NAME	DEVICE_NAME	BEAM	LSA_K	LSA_I	CURR SIGN AGREE	
MQXA.1L1	-1	-1	1	1	MQXA.1L1	MQXA1.L1	B2	-0.008577	408.077	TRUE	
MQXB.A2L1	-1	1	-1	1	MQXB.A2L1	MQXB2.L1	B2	0.008577	697.674	TRUE	
MCO.10L2.B2	-1	1	1	-1	MCO.10L2.B2	RCO.A12B2	B2	0.010000	0.028	FALSE	cabling
MCOX.3L1	-1	1	-1	1	MCOX.3L1	RCOX3.L1	B2	0.010000	0.027	TRUE	
MCS.A10L2.B2	-1	1	1	-1	MCS.A10L2.B2	RCS.A12B2	B2	0.001000	0.245	FALSE	cabling
MCSSX.3L1	-1	1	-1	1	MCSSX.3L1	RCSSX3.L1	B2	0.001000	0.200	TRUE	
MCSX.3L1	-1	1	-1	1	MCSX.3L1	RCSX3.L1	B2	0.001000	0.743	TRUE	
MBX.4L2	-1	-1	1	1	MBX.4L2	RD1.L2	B2	-0.000162	345.504	TRUE	
MBXW.A4L1	-1	1	-1	1	MBXW.A4L1	RD1.LR1	B2	0.000055	43.115	TRUE	
MBRC.4L1.B2	-1	1	1	-1	MBRC.4L1.B2	RD2.L1	B2	-0.000119	283.570	FALSE	common for B1 & B2
MO.25L2.B2	-1	-1	1	1	MO.25L2.B2	ROD.A12B2	B2	0.010000	-0.022	FALSE	cabling
MQML.10L1.B2	-1	-1	-1	-1	MQML.10L1.B2	RQ10.L1B2	B2	-0.007192	291.392	FALSE	cabling
MQY.4L1.B2	-1	-1	-1	-1	MQY.4L1.B2	RQ4.L1B2	B2	-0.004979	166.258	FALSE	cabling
MQWA.A4L3.B2	-1	-1	-1	-1	MQWA.A4L3.B2	RQ4.LR3	B2	0.001241	34.841	FALSE	cabling
MQ.11L2.B2	-1	-1	-1	-1	MQ.11L2.B2	RQD.A12	B2	-0.008601	685.805	FALSE	common for B1 & B2
MQ.12L2.B2	-1	1	1	-1	MQ.12L2.B2	RQF.A12	B2	0.008990	716.997	FALSE	common for B1 & B2
MQS.23L2.B2	-1	1	1	-1	MQS.23L2.B2	RQS.A12B2	B2	0.000100	0.625	FALSE	cabling
MQS.23L1.B2	-1	1	1	-1	MQS.23L1.B2	RQS.L1B2	B2	0.000100	0.625	FALSE	cabling
MQS.27L1.B2	-1	1	1	-1	MQS.27L1.B2	RQS.L1B2	B2	0.000100	0.625	FALSE	cabling
MQS.27R8.B2	-1	1	1	-1	MQS.27R8.B2	RQS.R8B2	B2	0.000100	0.625	FALSE	cabling
MQSX.3L1	-1	1	-1	1	MQSX.3L1	RQSX3.L1	B2	0.000100	1.021	TRUE	
MQT.12L1.B2	-1	-1	1	1	MQT.12L1.B2	RQT12.L1B2	B2	0.001244	-7.778	FALSE	cabling
MQWB.4L3.B2	-1	1	1	-1	MQWB.4L3.B2	RQT4.L3	B2	0.000689	22.044	FALSE	common for B1 & B2
MQT.15L2.B2	-1	-1	1	1	MQT.15L2.B2	RQTD.A12B2	B2	0.000010	-0.063	FALSE	cabling
MQT.14L2.B2	-1	1	1	-1	MQT.14L2.B2	RQTF.A12B2	B2	0.000010	0.063	FALSE	cabling
MS.11R1.B2	-1	-1	-1	-1	MS.11R1.B2	RSD1.A12B2	B2	-0.108851	9.671	FALSE	cabling
MS.12L2.B2	-1	1	1	-1	MS.12L2.B2	RSF1.A12B2	B2	0.065437	5.814	FALSE	cabling
MSS.28L2.B2	-1	1	1	-1	MSS.28L2.B2	RSS.A12B2	B2	0.001000	0.089	FALSE	cabling
MSS.33R8.B2	-1	1	1	-1	MSS.33R8.B2	RSS.A81B2	B2	0.001000	0.089	FALSE	cabling

Conclusions

- Unipolar power converters take positive references
  - LSA uses calibration sign in one place to take care of this
  - Cabling should give correct magnet polarity
- For bi-polar circuits
  - Stick with natural strengths, calculate positive or negative currents as required
  - Again rely on correct cabling
- MAD-X polarity takes into account machine conventions and cabling
- Polarity might been accidentally flipped (e.g. in optic import procedure or by setting wrong LSA calibration sign)
  - But it is now proved **this has not happened**