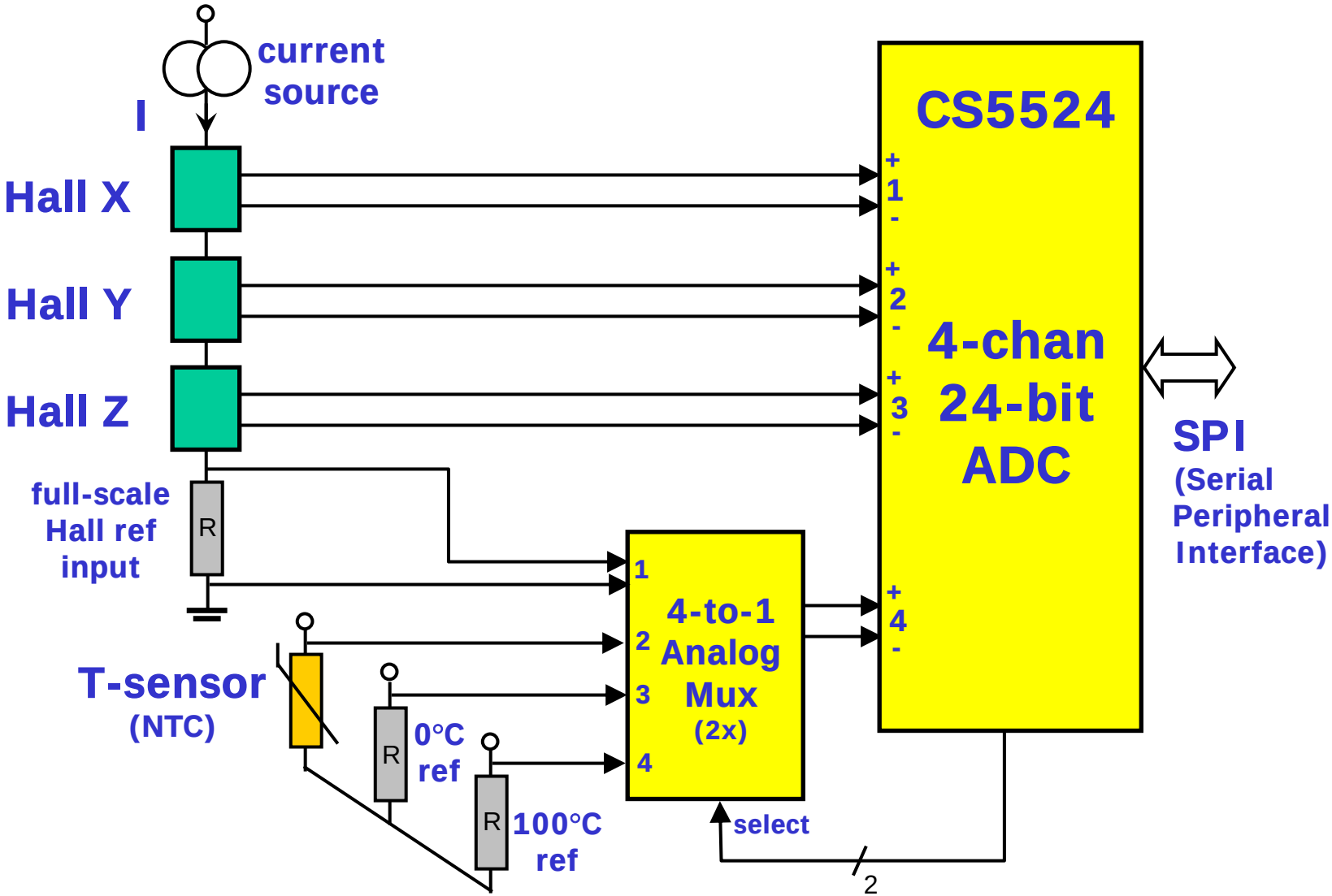
B-sensor Module operation, readout and daq

Henk Boterenbrood NIKHEF

Contents

- B-sensor module hardware
  - signal input part
  - interface for readout/control (2 types)
- Applications
  - LHCb
  - ATLAS

B-sensor: signal input part

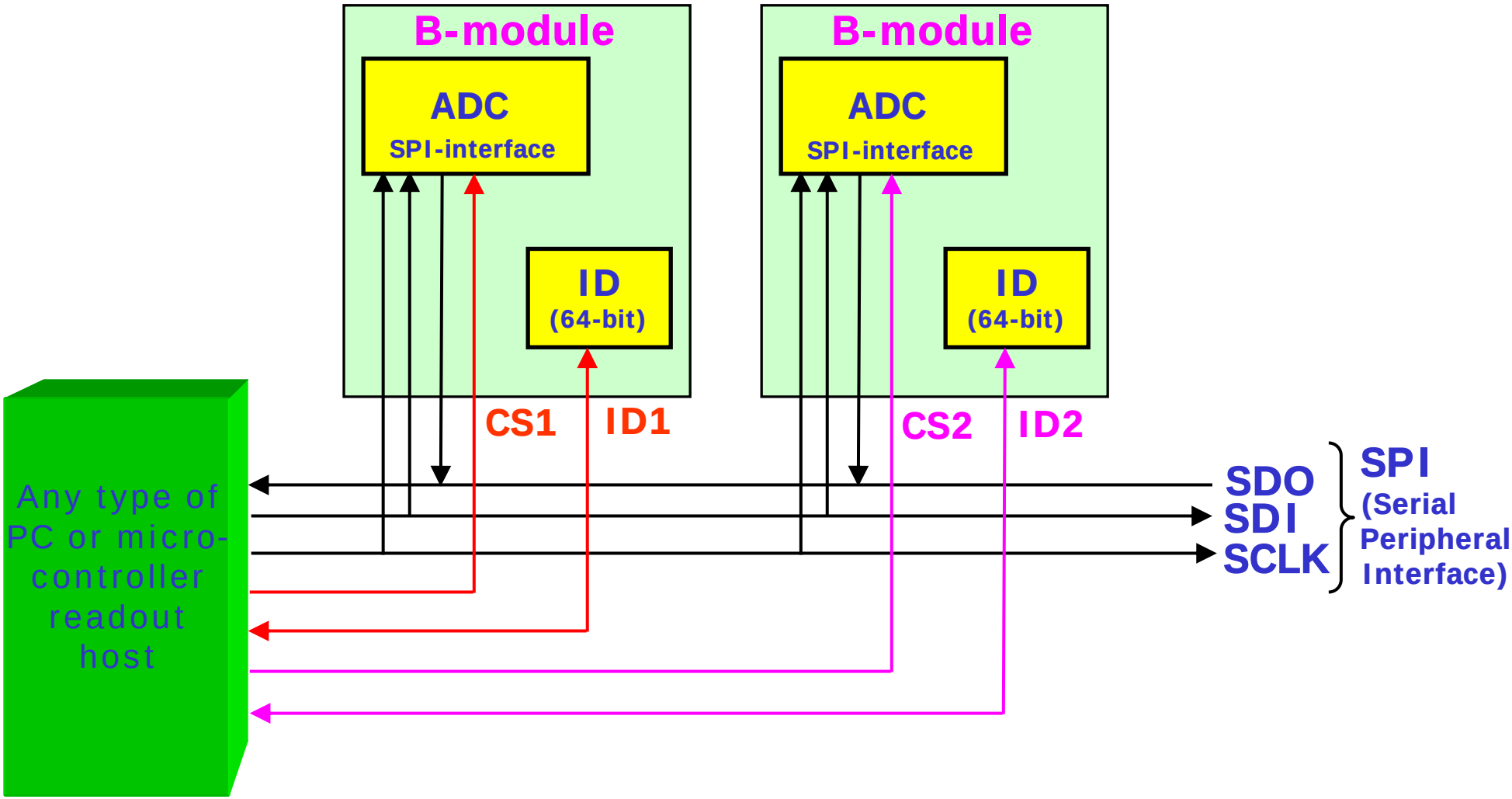


B-sensor: control/readout interface

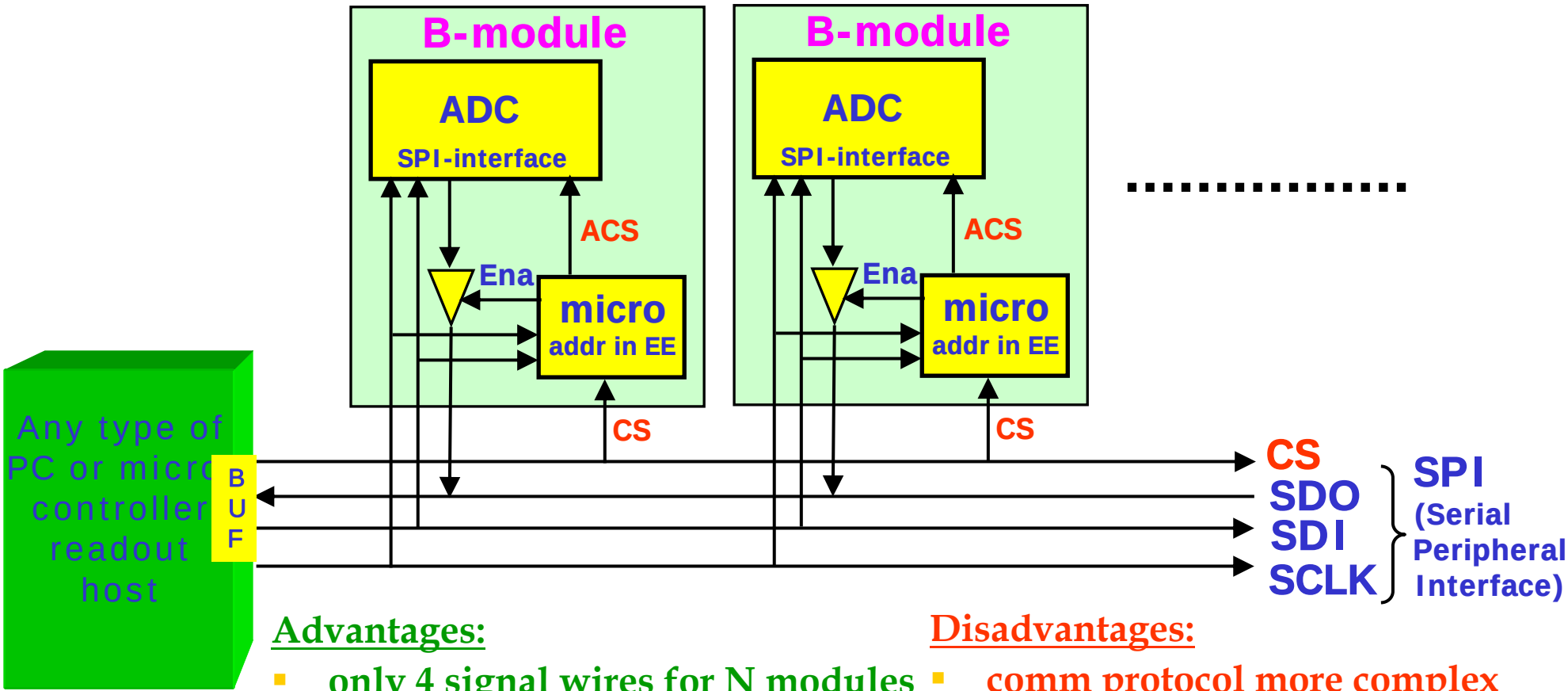
Two Types:

- **'Simple' version**
  - selection by single Chip-Select signal
  - module identification by 64-bit ID-chip
  - readout/control by SPI (*Serial Peripheral Interface*)
  - used in ATLAS
- **'Addressable' version**
  - selection by 1-byte 'address' (= module identification), using an extra protocol layer (software/firmware)
  - readout/control by SPI (*Serial Peripheral Interface*)
  - for low-cost multi-B-sensor applications in limited spatial volumes

B-sensor: simple version



B-sensor: addressable version



Advantages:

- only 4 signal wires for N modules (tested: 16 modules on 15 meter cable, using signal buffering)
- broadcast conversion command possible

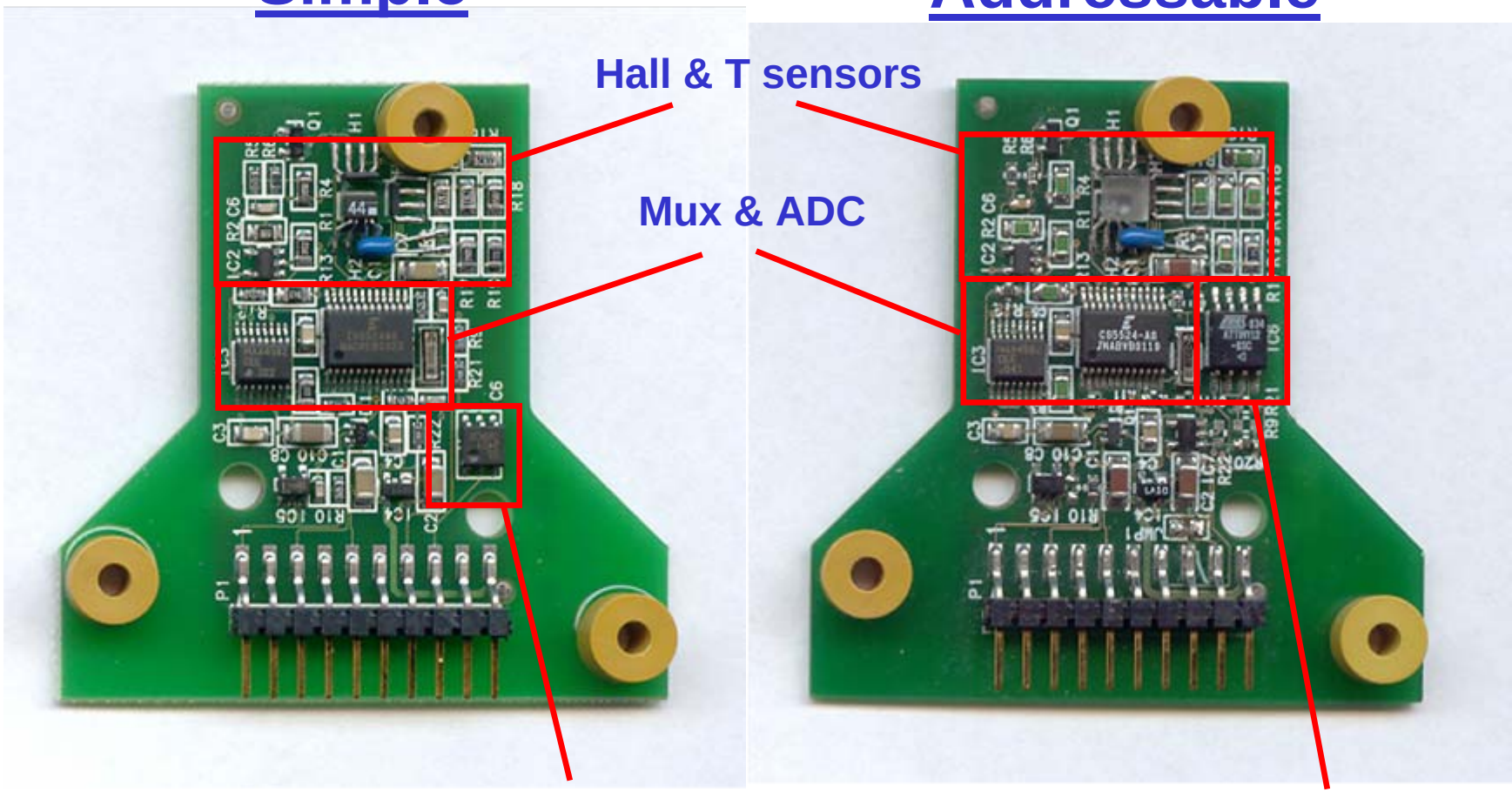
Disadvantages:

- comm protocol more complex
- production more labor-intensive (micro must be programmed)
- less radiation-tolerant (due to micro)

B-sensor Module: the 2 versions

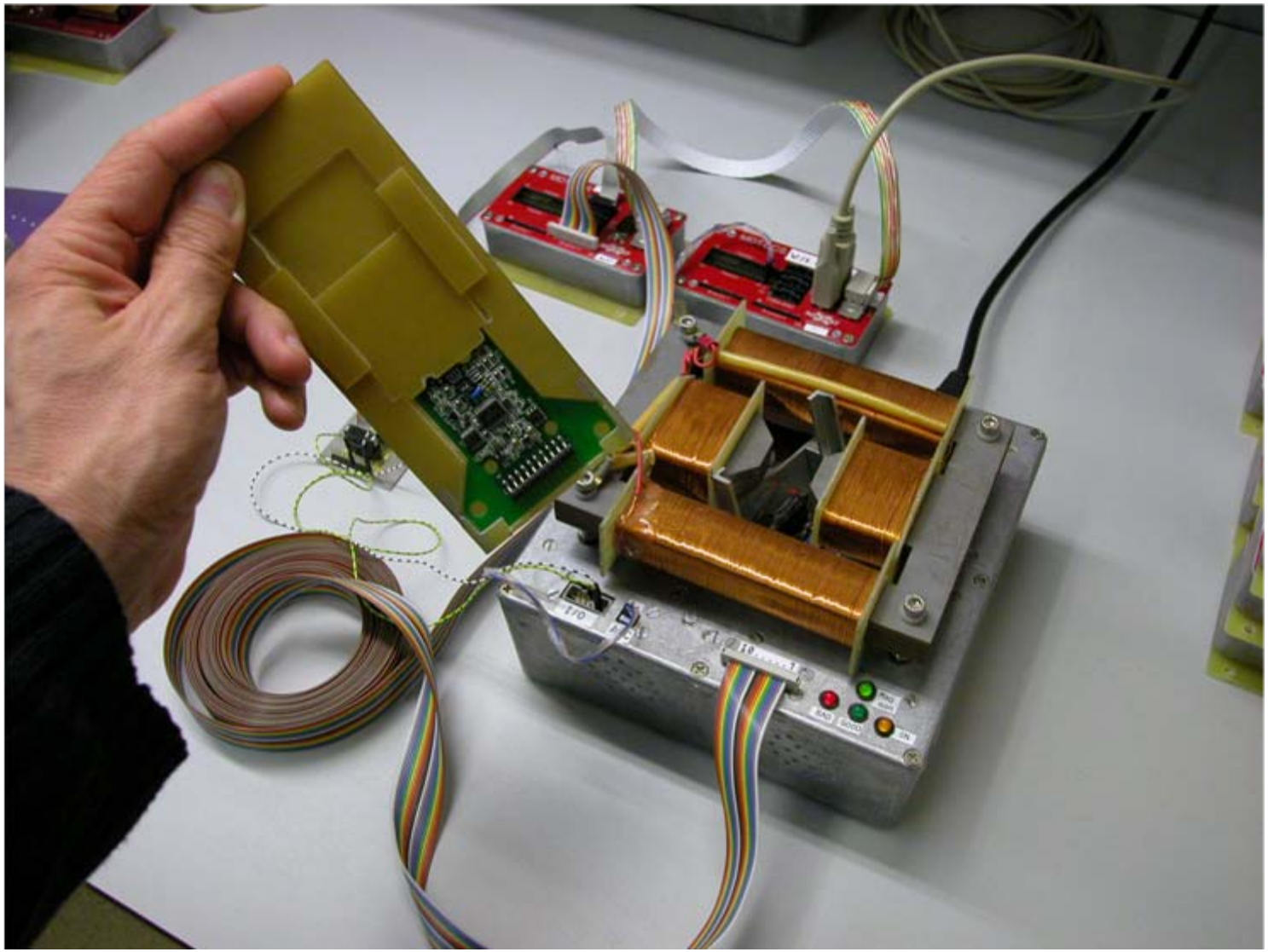
Simple

Addressable



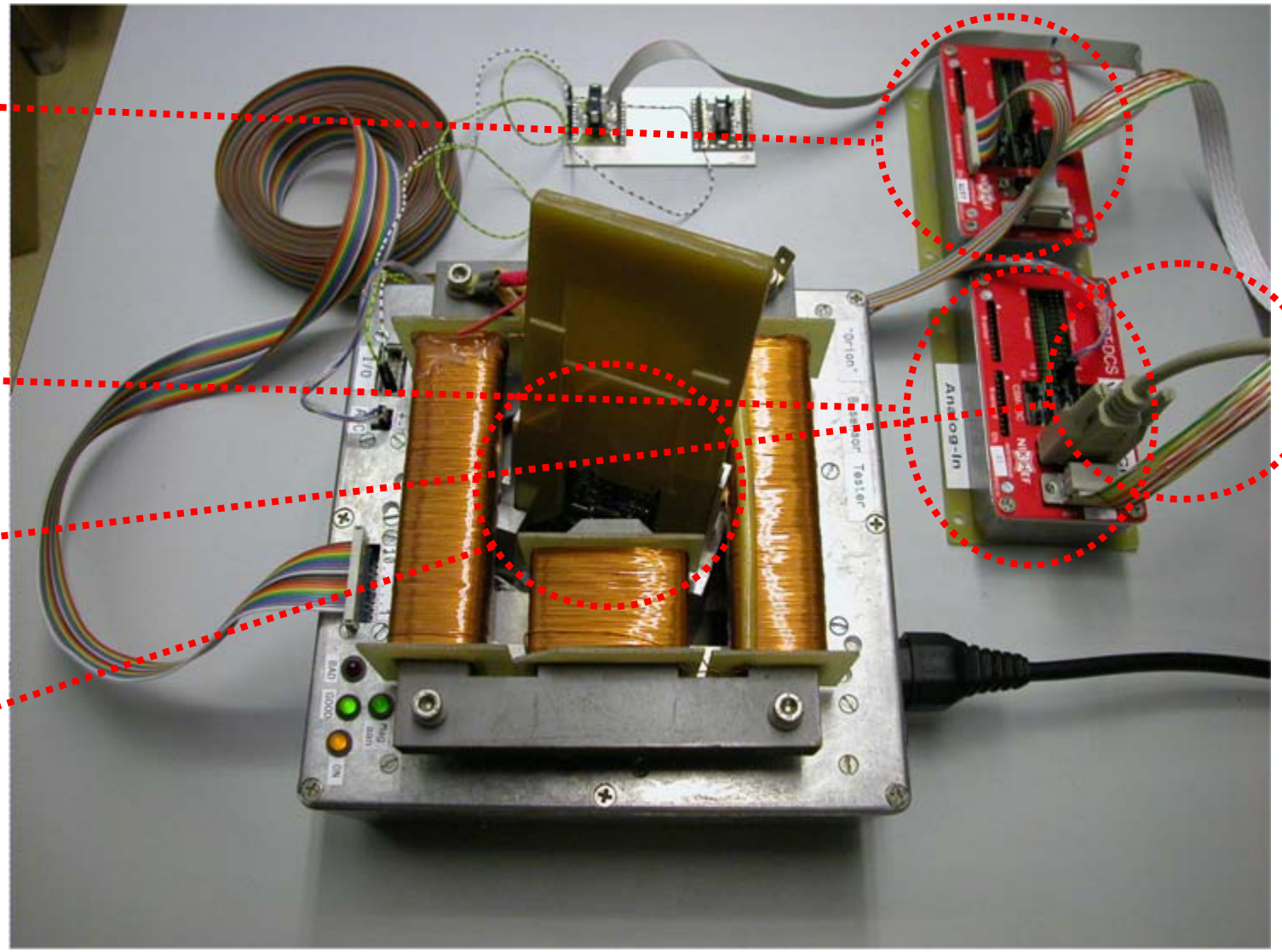
B-module Production/Acceptance Test

Quick (ca. 20s) automatic test of B-module functionality:
plug it in and wait for audible ACCEPT or REJECT signal, take it out and plug in the next



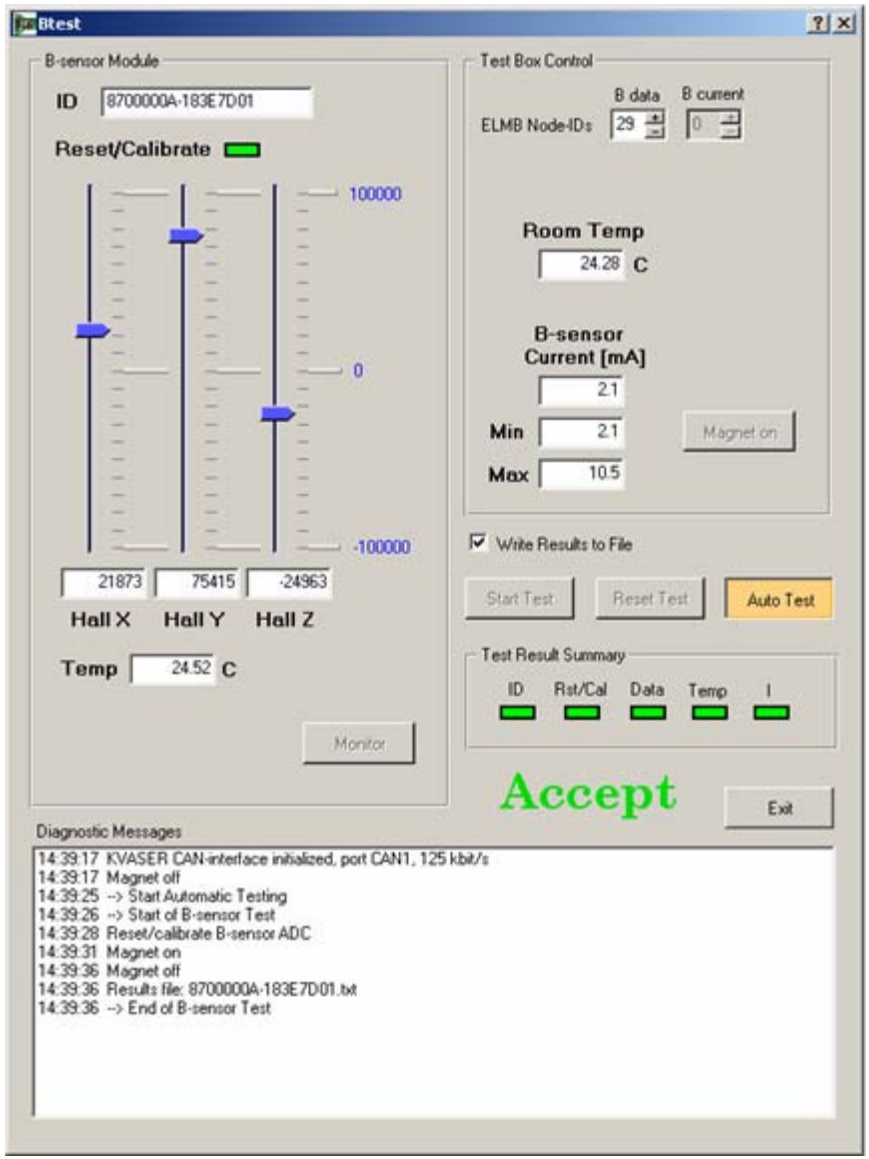
B-module Production/Acceptance Test

- B-sensor and magnet control
- B-sensor current monitor
- CAN-bus to PC host
- B-sensor module under test



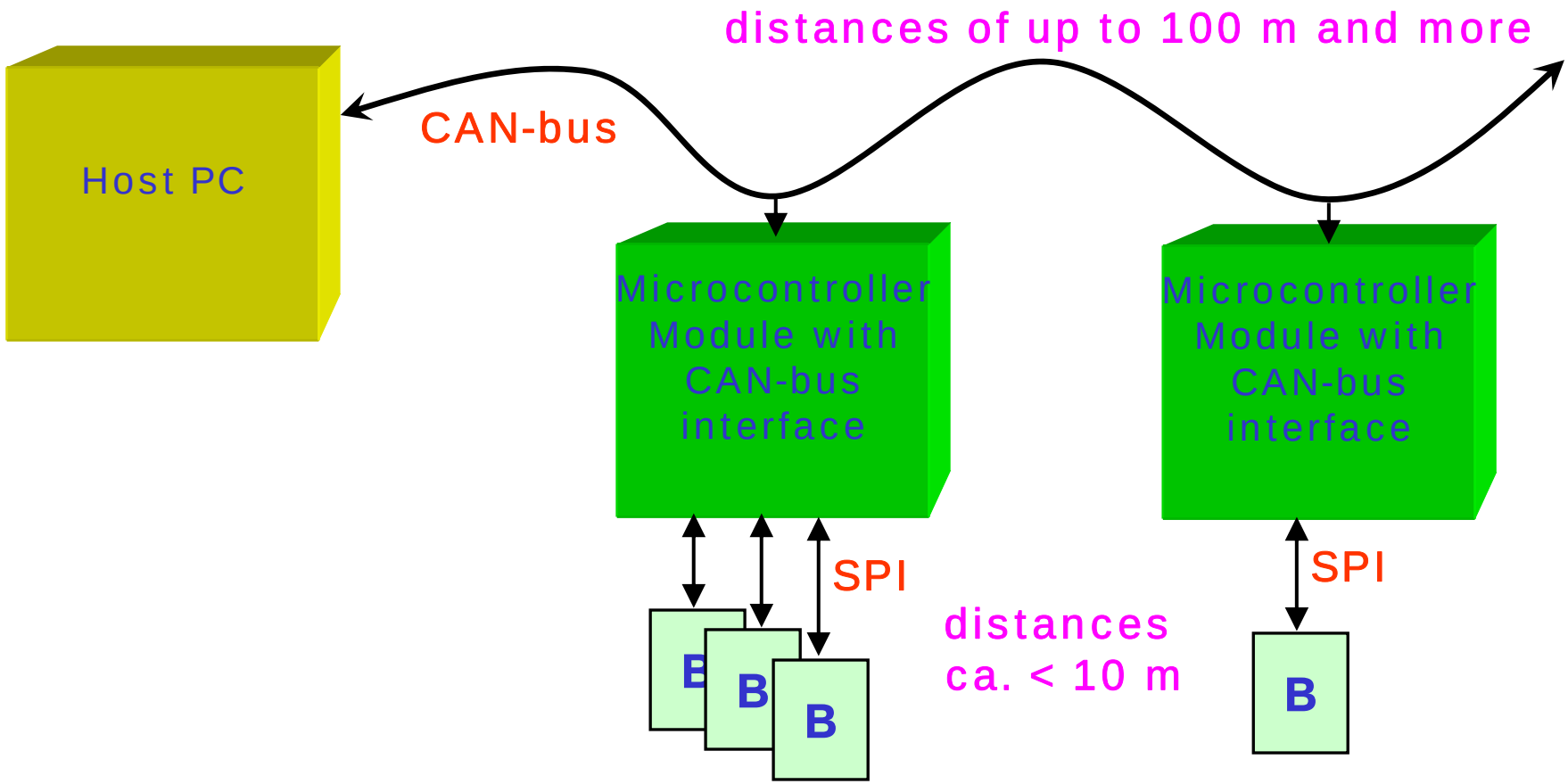
B-module Production/Acceptance Test

- User Interface

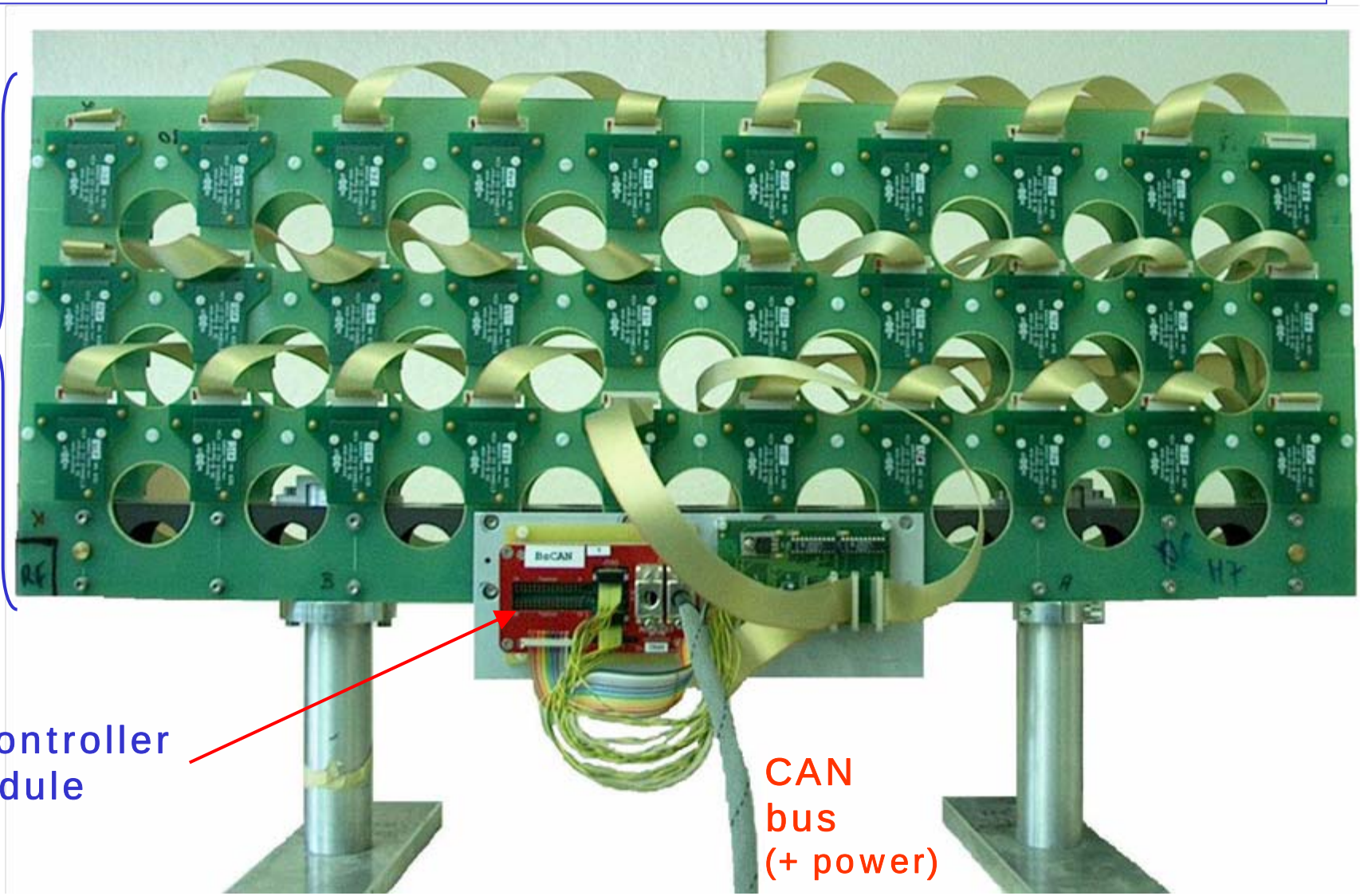


B-sensor Module: Read-out

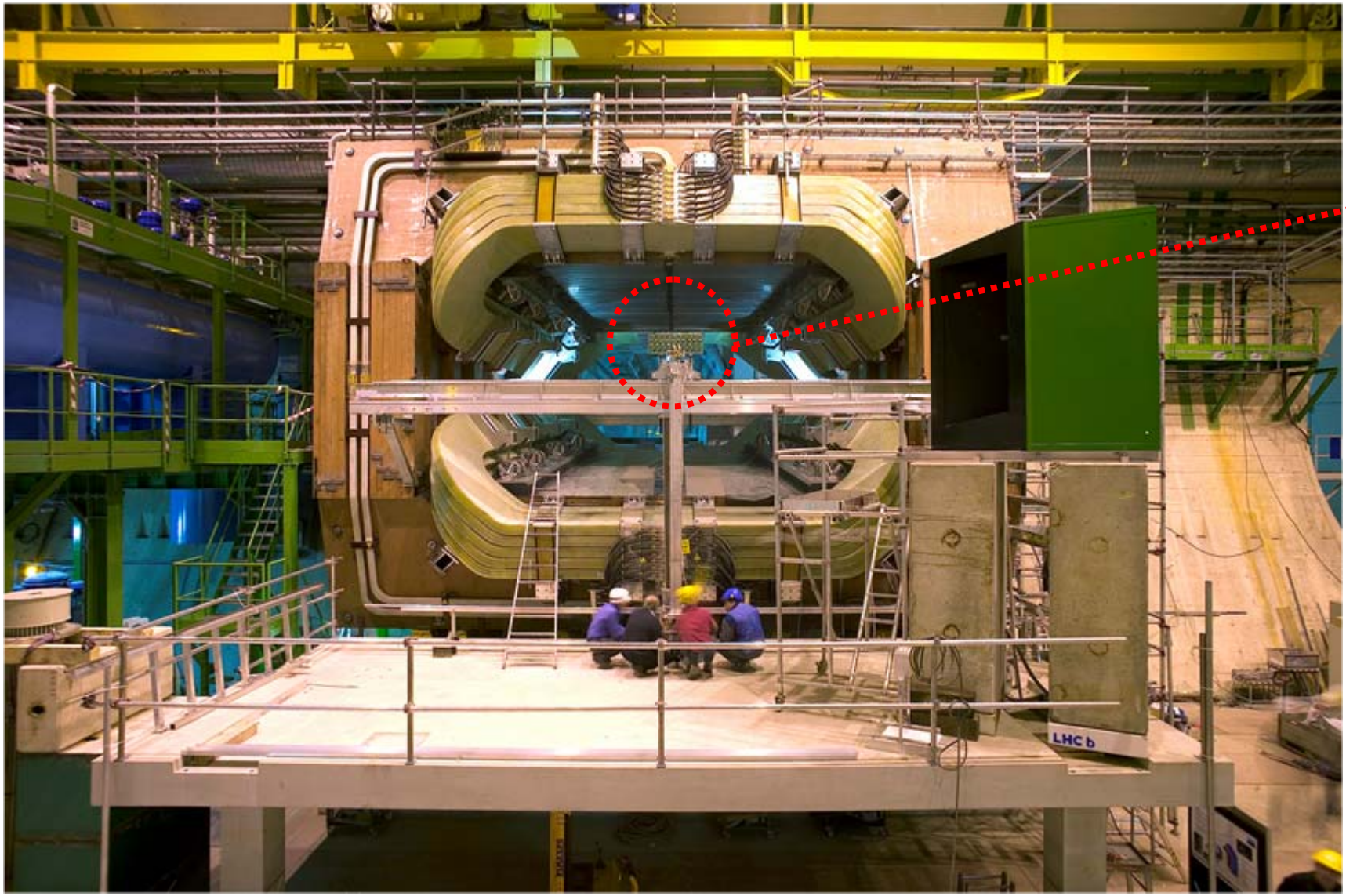
- **Any type of PC or microcontroller host, that can operate SPI, but we prefer:**



Application: LHCb Magnet Measurement (1)



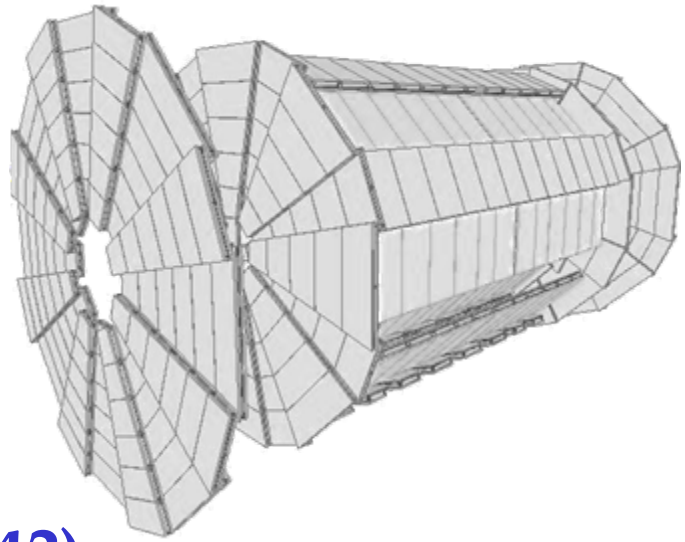
Application: LHCb Magnet Measurement (2)



frame with B-sensor modules

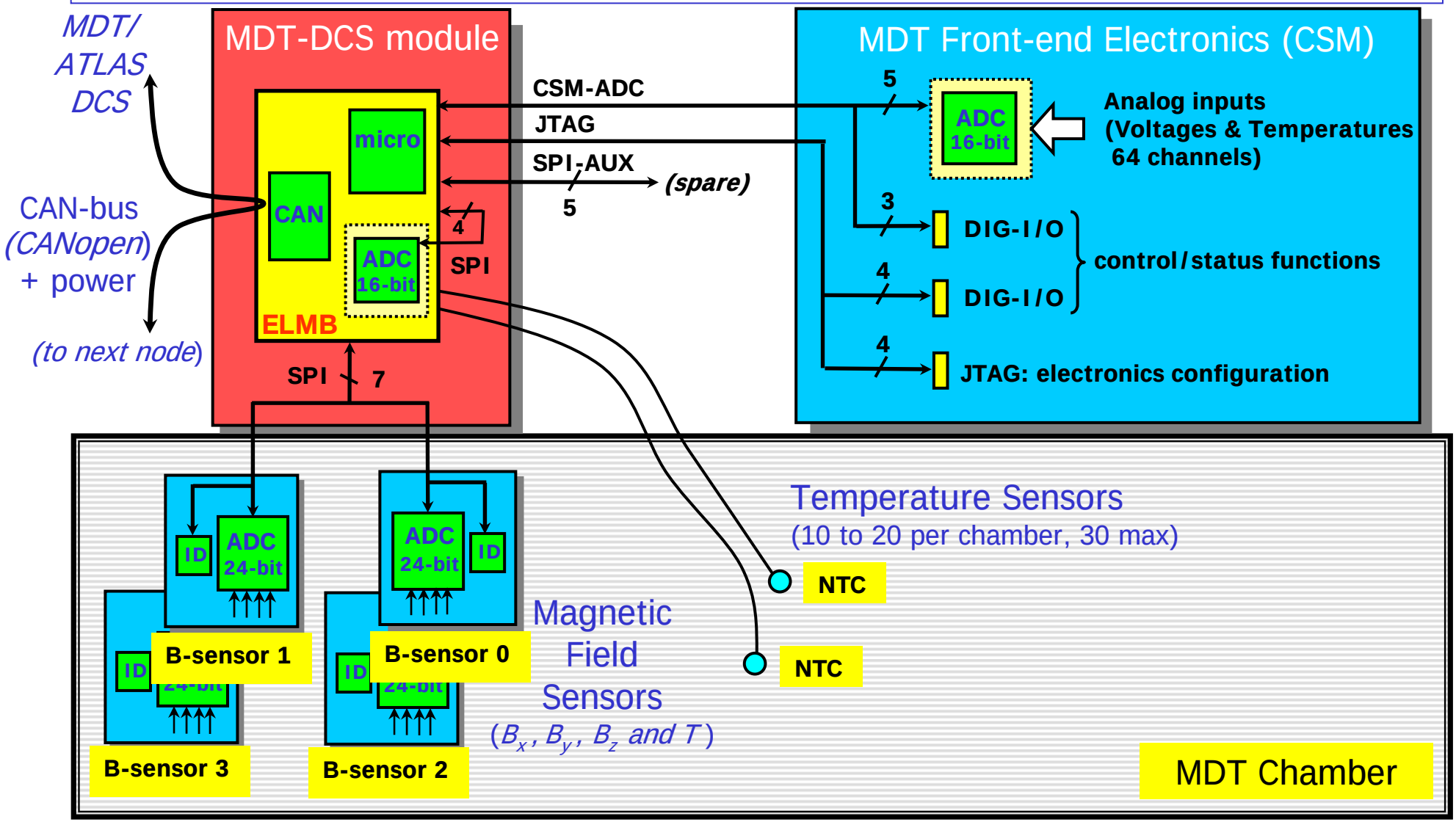
Application: ATLAS B-field Monitoring

- **B-field measurement across a large part of the Muon Detector volume**
  - **spatially distributed system**
  - **integrated in MDT chamber control system (DCS)**



- **1152 MDT chambers (1172? 1194?)**
  - **Each chamber has one controller module for DCS (*Detector Control System*) tasks**
  - **84 CAN-buses + powersupplies**
  - **Each CAN-bus services 8 to 24 *MDT-DCS* modules ('nodes')**

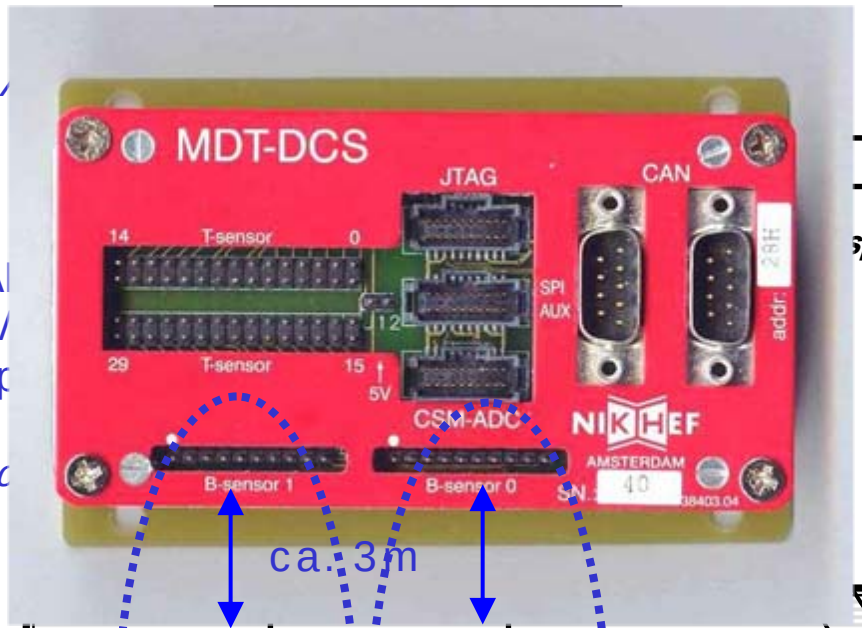
ATLAS MDT-DCS



(ca. 600 chambers with one, two or four B-sensor modules each)

(ca. 1200 chambers in total)

ATLAS MDT-DCS



MDT Front-end Electronics (CSM)

5 → ADC 16-bit ← Analog inputs (Voltages & Temperatures 64 channels)

3 → DIG-I/O

4 → DIG-I/O

} control/status functions

4 → JTAG: electronics configuration

ca. 3m

ID, ADC 24-bit, B-sensor 1

ID, ADC 24-bit, B-sensor 0

ID, 24-bit, B-sensor 3

ID, 24-bit, B-sensor 2

Magnetic Field Sensors (B_x, B_y, B_z and T)

Temperature Sensors
(10 to 20 per chamber, 30 max)

NTC

NTC

MDT Chamber

(ca. 600 chambers with one, two or four B-sensor modules each)

(ca. 1200 chambers in total)

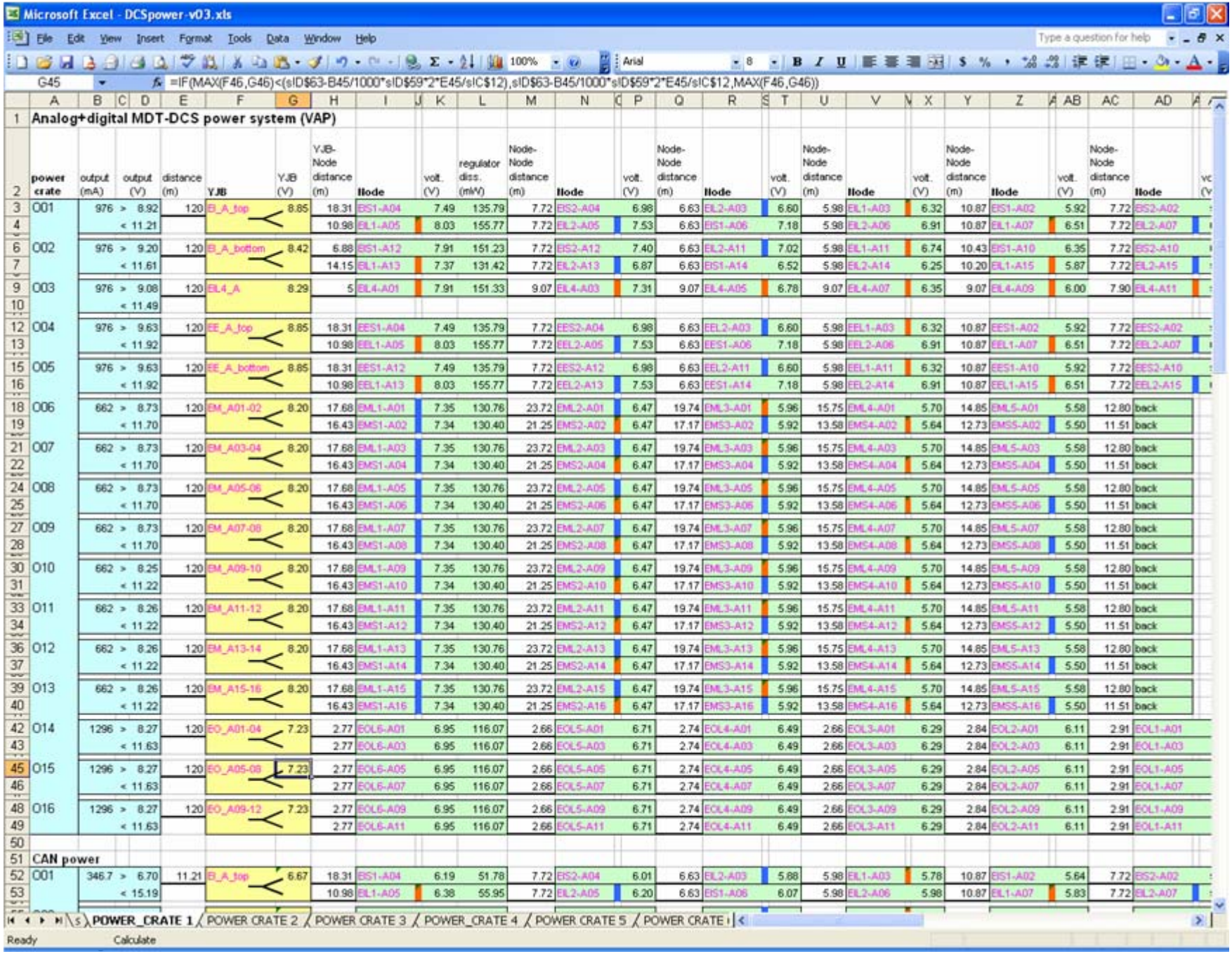
ATLAS B-field Monitoring System

- **1552 B-sensor modules (*simple* type) on 76 CAN-buses (of 84)**
  - **36 nodes with 1x B-module**
  - **502 nodes with 2x B-module**
  - **128 nodes with 4x B-module**
  - **640 B-modules located in MDT EndCap**
  - **912 B-modules located in MDT Barrel**
  - **<u>This workshop</u>**
    - **Guyot: "908 Barrel, 608 EC (with EE, without CSC)" CSC=32?**
    - **Nicolaidou: "1530 sensors"**
    - **Chevalier: "200 extra modules: 2*6*8=96 BOS, 2*6*8=96 BIS", i.e. 96 nodes with 2 B-modules to be upgraded to 4 B-modules**
- **Per measurement 1552*4 (3x Hall, 1x T) values = ca. 24 kByte raw data**

Numbers extracted from CAN-bus layout spreadsheet by Eric Heine (NIKHEF), based on topology data provided by C.Guyot and H.Wellenstein

MDT-DCS: CAN-bus layout

- **Due to number of devices/sensors to power from the (long) cable, power is an important issue**
- **Spreadsheet as tool for MDT-DCS CAN-bus(+pwr) design from a powersupply point-of-view based on device current requirements**
  - **includes cable lengths, cable resistance, voltages, currents, power dissipation in onboard regulators**
  - **verified (dynamic) current requirements in NIKHEF cosmic-ray setup, using original cables, including ca. 100m thick cable, junction box (thick→thin) and 5 fully-equipped MDT-chambers (incl. CSM, T-sensors, B-sensor modules)**
    - **by measuring current and voltage transients**
      - **at power-up**
      - **e.g. at simultaneous B-sensor and other read-out, on all chamber controllers**



Microsoft Excel - DCSpower-v03.xls

File Edit View Insert Format Tools Data Window Help

=IF(MAX(F46,G46)<($D$63-B45/1000*$D$59*2*E45/$C$12),$D$63-B45/1000*$D$59*2*E45/$C$12,MAX(F46,G46))

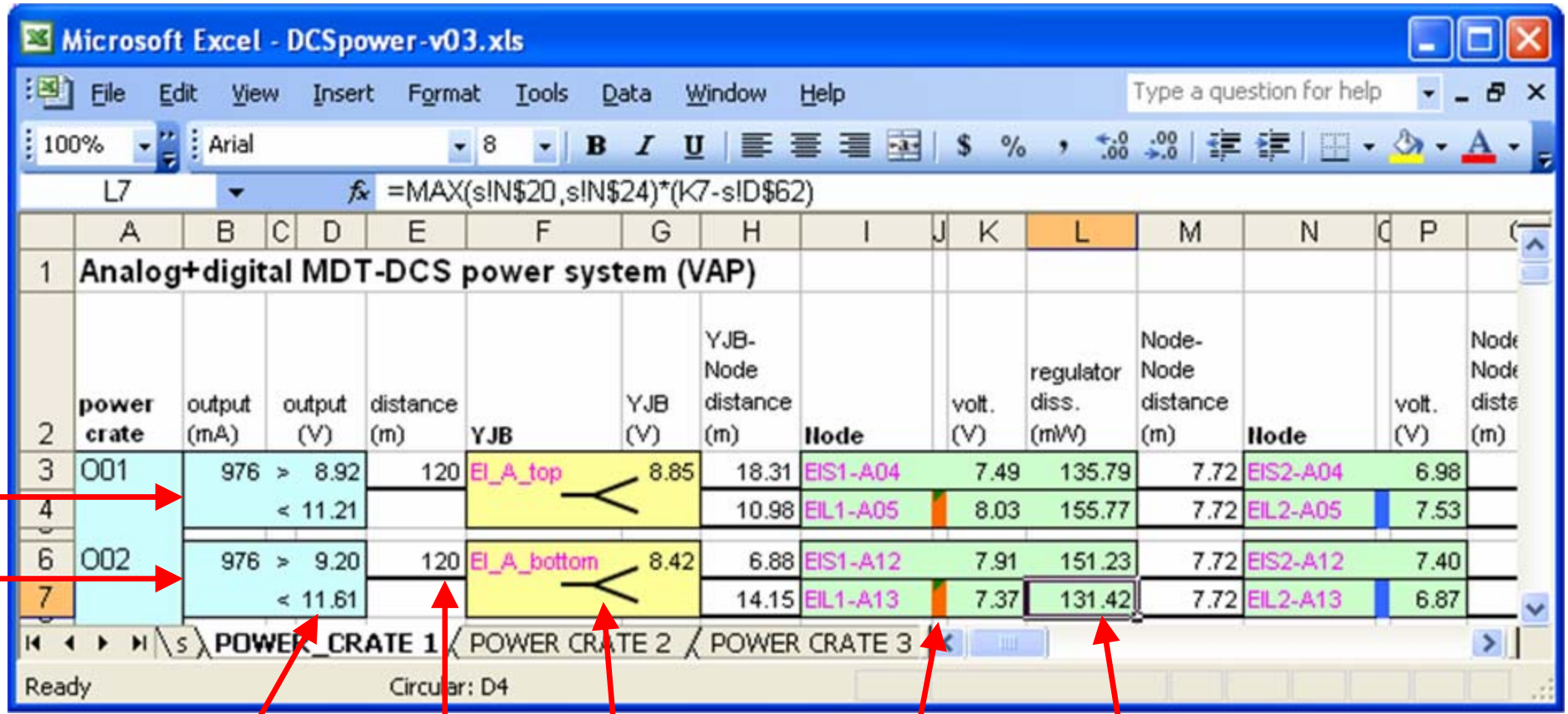
Analog+digital MDT-DCS power system (VAP)

power crate	output (mA)	output (V)	distance (m)	YJB	YJB (V)	YJB-Node distance (m)	Node	volt. (V)	regulator diss. (mW)	Node-Node distance (m)	Node	volt. (V)	Node-Node distance (m)	Node	volt. (V)	Node-Node distance (m)	Node	volt. (V)	Node-Node distance (m)	Node	volt. (V)	Node-Node distance (m)	Node
O01	976	> 8.92	120	EI_A_top	8.85	18.31	EIS1-A04	7.49	135.79	7.72	EIS2-A04	6.98	6.63	EIL2-A03	6.60	5.98	EIL1-A03	6.32	10.87	EIS1-A02	5.92	7.72	EIS2-A02
		< 11.21				10.98	EIL1-A05	8.03	155.77	7.72	EIL2-A05	7.53	6.63	EIS1-A06	7.18	5.98	EIL2-A06	6.91	10.87	EIL1-A07	6.51	7.72	EIL2-A07
O02	976	> 9.20	120	EI_A_bottom	8.42	6.88	EIS1-A12	7.91	151.23	7.72	EIS2-A12	7.40	6.63	EIL2-A11	7.02	5.98	EIL1-A11	6.74	10.43	EIS1-A10	6.35	7.72	EIS2-A10
		< 11.61				14.15	EIL1-A13	7.37	131.42	7.72	EIL2-A13	6.87	6.63	EIS1-A14	6.52	5.98	EIL2-A14	6.25	10.20	EIL1-A15	5.87	7.72	EIL2-A15
O03	976	> 9.08	120	EIL4_A	8.29	5	EIL4-A01	7.91	151.33	9.07	EIL4-A03	7.31	9.07	EIL4-A05	6.78	9.07	EIL4-A07	6.35	9.07	EIL4-A09	6.00	7.90	EIL4-A11
		< 11.49																					
O04	976	> 9.63	120	EE_A_top	8.85	18.31	EES1-A04	7.49	135.79	7.72	EES2-A04	6.98	6.63	EEL2-A03	6.60	5.98	EEL1-A03	6.32	10.87	EES1-A02	5.92	7.72	EES2-A02
		< 11.92				10.98	EEL1-A05	8.03	155.77	7.72	EEL2-A05	7.53	6.63	EES1-A06	7.18	5.98	EEL2-A06	6.91	10.87	EEL1-A07	6.51	7.72	EEL2-A07
O05	976	> 9.63	120	EE_A_bottom	8.85	18.31	EES1-A12	7.49	135.79	7.72	EES2-A12	6.98	6.63	EEL2-A11	6.60	5.98	EEL1-A11	6.32	10.87	EES1-A10	5.92	7.72	EES2-A10
		< 11.92				10.98	EEL1-A13	8.03	155.77	7.72	EEL2-A13	7.53	6.63	EES1-A14	7.18	5.98	EEL2-A14	6.91	10.87	EEL1-A15	6.51	7.72	EEL2-A15
O06	662	> 8.73	120	EM_A01-02	8.20	17.68	EML1-A01	7.35	130.76	23.72	EML2-A01	6.47	19.74	EML3-A01	5.96	15.75	EML4-A01	5.70	14.85	EML5-A01	5.58	12.80	back
		< 11.70				16.43	EMS1-A02	7.34	130.40	21.25	EMS2-A02	6.47	17.17	EMS3-A02	5.92	13.58	EMS4-A02	5.64	12.73	EMS5-A02	5.50	11.51	back
O07	662	> 8.73	120	EM_A03-04	8.20	17.68	EML1-A03	7.35	130.76	23.72	EML2-A03	6.47	19.74	EML3-A03	5.96	15.75	EML4-A03	5.70	14.85	EML5-A03	5.58	12.80	back
		< 11.70				16.43	EMS1-A04	7.34	130.40	21.25	EMS2-A04	6.47	17.17	EMS3-A04	5.92	13.58	EMS4-A04	5.64	12.73	EMS5-A04	5.50	11.51	back
O08	662	> 8.73	120	EM_A05-06	8.20	17.68	EML1-A05	7.35	130.76	23.72	EML2-A05	6.47	19.74	EML3-A05	5.96	15.75	EML4-A05	5.70	14.85	EML5-A05	5.58	12.80	back
		< 11.70				16.43	EMS1-A06	7.34	130.40	21.25	EMS2-A06	6.47	17.17	EMS3-A06	5.92	13.58	EMS4-A06	5.64	12.73	EMS5-A06	5.50	11.51	back
O09	662	> 8.73	120	EM_A07-08	8.20	17.68	EML1-A07	7.35	130.76	23.72	EML2-A07	6.47	19.74	EML3-A07	5.96	15.75	EML4-A07	5.70	14.85	EML5-A07	5.58	12.80	back
		< 11.70				16.43	EMS1-A08	7.34	130.40	21.25	EMS2-A08	6.47	17.17	EMS3-A08	5.92	13.58	EMS4-A08	5.64	12.73	EMS5-A08	5.50	11.51	back
O10	662	> 8.25	120	EM_A09-10	8.20	17.68	EML1-A09	7.35	130.76	23.72	EML2-A09	6.47	19.74	EML3-A09	5.96	15.75	EML4-A09	5.70	14.85	EML5-A09	5.58	12.80	back
		< 11.22				16.43	EMS1-A10	7.34	130.40	21.25	EMS2-A10	6.47	17.17	EMS3-A10	5.92	13.58	EMS4-A10	5.64	12.73	EMS5-A10	5.50	11.51	back
O11	662	> 8.26	120	EM_A11-12	8.20	17.68	EML1-A11	7.35	130.76	23.72	EML2-A11	6.47	19.74	EML3-A11	5.96	15.75	EML4-A11	5.70	14.85	EML5-A11	5.58	12.80	back
		< 11.22				16.43	EMS1-A12	7.34	130.40	21.25	EMS2-A12	6.47	17.17	EMS3-A12	5.92	13.58	EMS4-A12	5.64	12.73	EMS5-A12	5.50	11.51	back
O12	662	> 8.26	120	EM_A13-14	8.20	17.68	EML1-A13	7.35	130.76	23.72	EML2-A13	6.47	19.74	EML3-A13	5.96	15.75	EML4-A13	5.70	14.85	EML5-A13	5.58	12.80	back
		< 11.22				16.43	EMS1-A14	7.34	130.40	21.25	EMS2-A14	6.47	17.17	EMS3-A14	5.92	13.58	EMS4-A14	5.64	12.73	EMS5-A14	5.50	11.51	back
O13	662	> 8.26	120	EM_A15-16	8.20	17.68	EML1-A15	7.35	130.76	23.72	EML2-A15	6.47	19.74	EML3-A15	5.96	15.75	EML4-A15	5.70	14.85	EML5-A15	5.58	12.80	back
		< 11.22				16.43	EMS1-A16	7.34	130.40	21.25	EMS2-A16	6.47	17.17	EMS3-A16	5.92	13.58	EMS4-A16	5.64	12.73	EMS5-A16	5.50	11.51	back
O14	1296	> 8.27	120	EO_A01-04	7.23	2.77	EOL6-A01	6.95	116.07	2.66	EOL5-A01	6.71	2.74	EOL4-A01	6.49	2.66	EOL3-A01	6.29	2.84	EOL2-A01	6.11	2.91	EOL1-A01
		< 11.63				2.77	EOL6-A03	6.95	116.07	2.66	EOL5-A03	6.71	2.74	EOL4-A03	6.49	2.66	EOL3-A03	6.29	2.84	EOL2-A03	6.11	2.91	EOL1-A03
O15	1296	> 8.27	120	EO_A05-08	7.23	2.77	EOL6-A05	6.95	116.07	2.66	EOL5-A05	6.71	2.74	EOL4-A05	6.49	2.66	EOL3-A05	6.29	2.84	EOL2-A05	6.11	2.91	EOL1-A05
		< 11.63				2.77	EOL6-A07	6.95	116.07	2.66	EOL5-A07	6.71	2.74	EOL4-A07	6.49	2.66	EOL3-A07	6.29	2.84	EOL2-A07	6.11	2.91	EOL1-A07
O16	1296	> 8.27	120	EO_A09-12	7.23	2.77	EOL6-A09	6.95	116.07	2.66	EOL5-A09	6.71	2.74	EOL4-A09	6.49	2.66	EOL3-A09	6.29	2.84	EOL2-A09	6.11	2.91	EOL1-A09
		< 11.63				2.77	EOL6-A11	6.95	116.07	2.66	EOL5-A11	6.71	2.74	EOL4-A11	6.49	2.66	EOL3-A11	6.29	2.84	EOL2-A11	6.11	2.91	EOL1-A11
CAN power																							
O01	346.7	> 6.70	11.21	EI_A_top	6.67	18.31	EIS1-A04	6.19	51.78	7.72	EIS2-A04	6.01	6.63	EIL2-A03	5.88	5.98	EIL1-A03	5.78	10.87	EIS1-A02	5.64	7.72	EIS2-A02
		< 15.19				10.98	EIL1-A05	6.38	55.95	7.72	EIL2-A05	6.20	6.63	EIS1-A06	6.07	5.98	EIL2-A06	5.98	10.87	EIL1-A07	5.83	7.72	EIL2-A07

POWER_CRATE 1 | POWER CRATE 2 | POWER CRATE 3 | POWER_CRATE 4 | POWER CRATE 5 | POWER CRATE

Ready Calculate

MDT-DCS: CAN-bus layout



CAN buses

min/max voltage required

length thick cable from USA15

"Y" Junction Box

color code signifies number of B-modules connected

power dissipation in onboard regulator of 1st bus node !

(while sufficient voltage left at bus end!)

MDT-DCS: B-sensor DAQ