The distributed Hall measuring system

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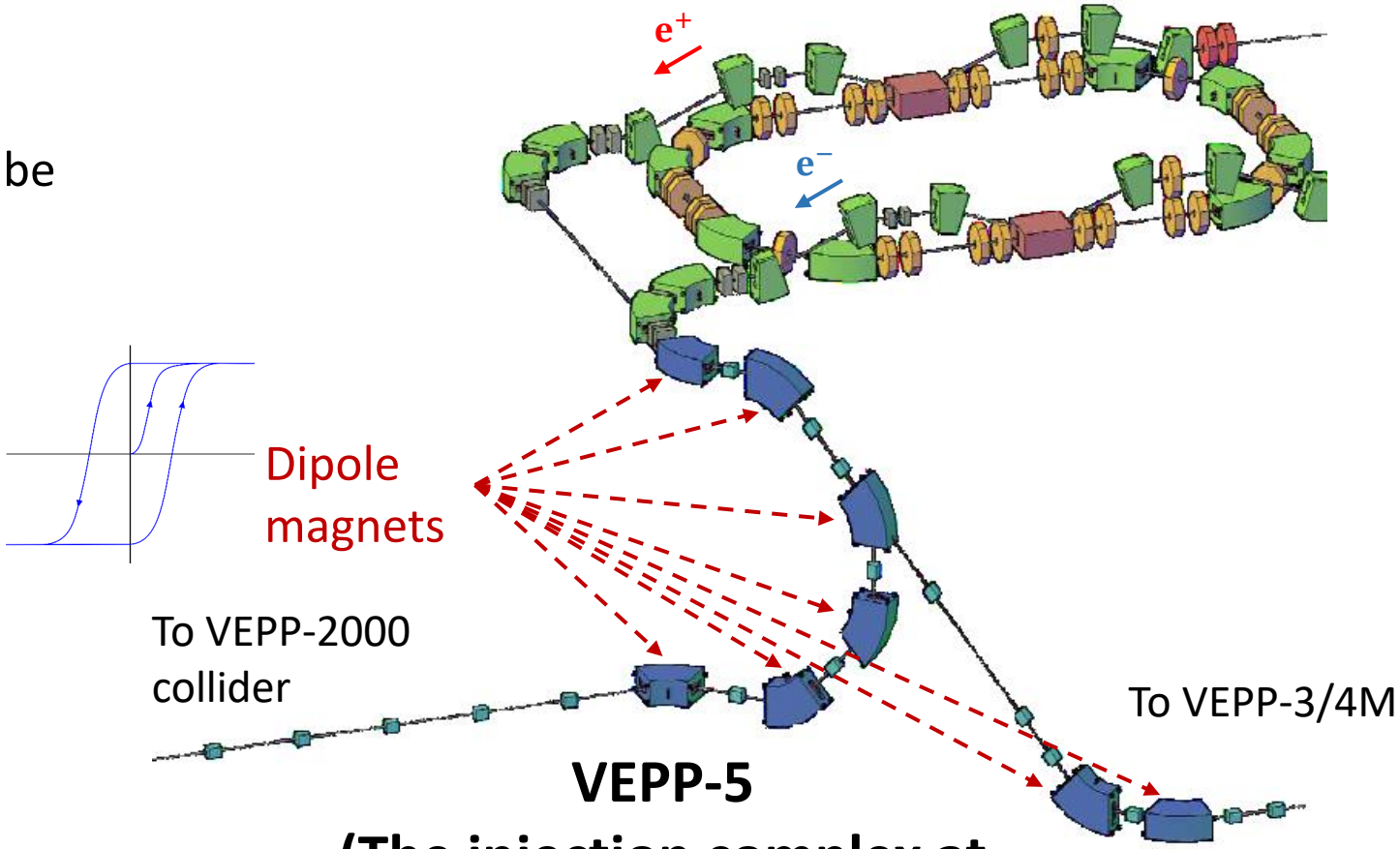
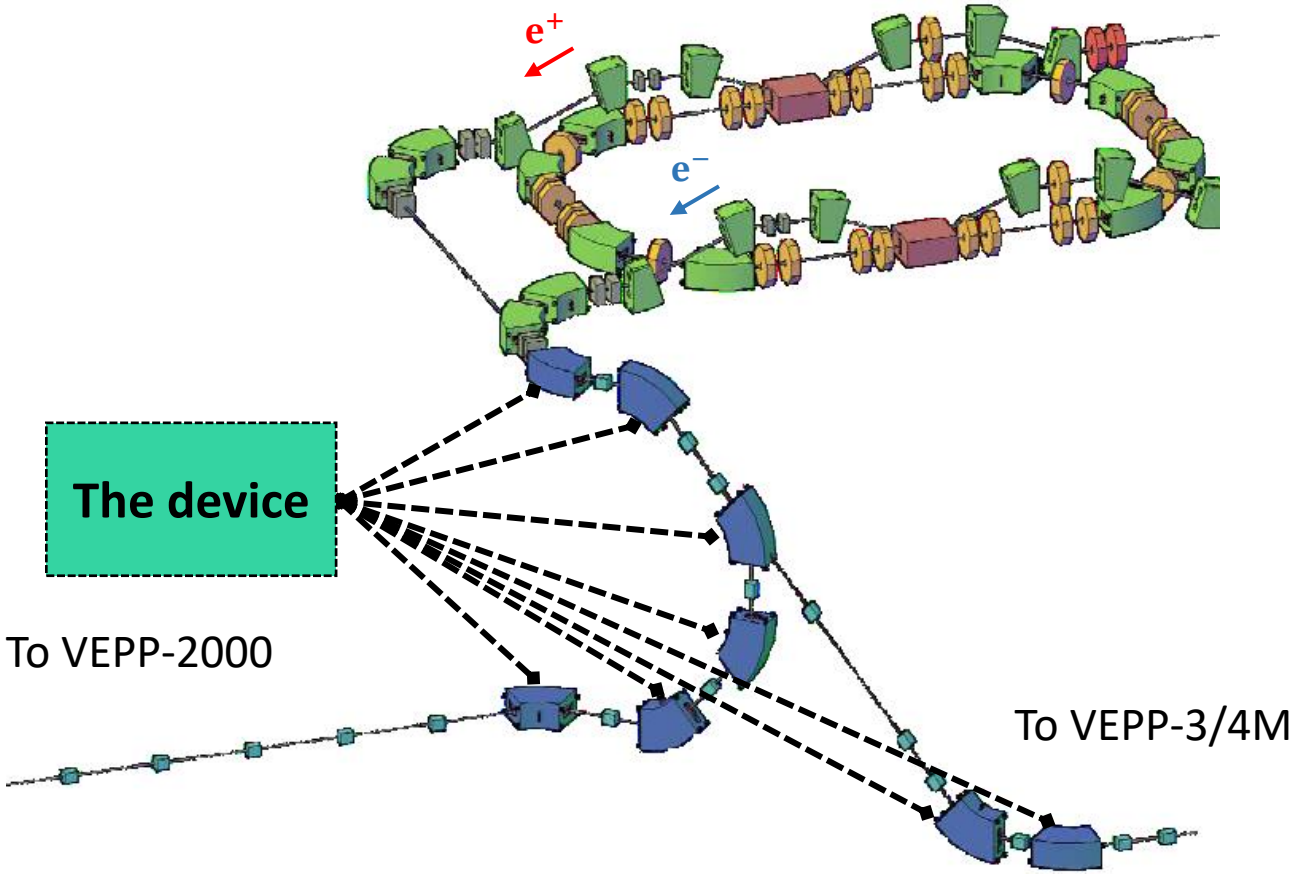
Magnetic field measurement

The dipole magnets magnetic field must be measured



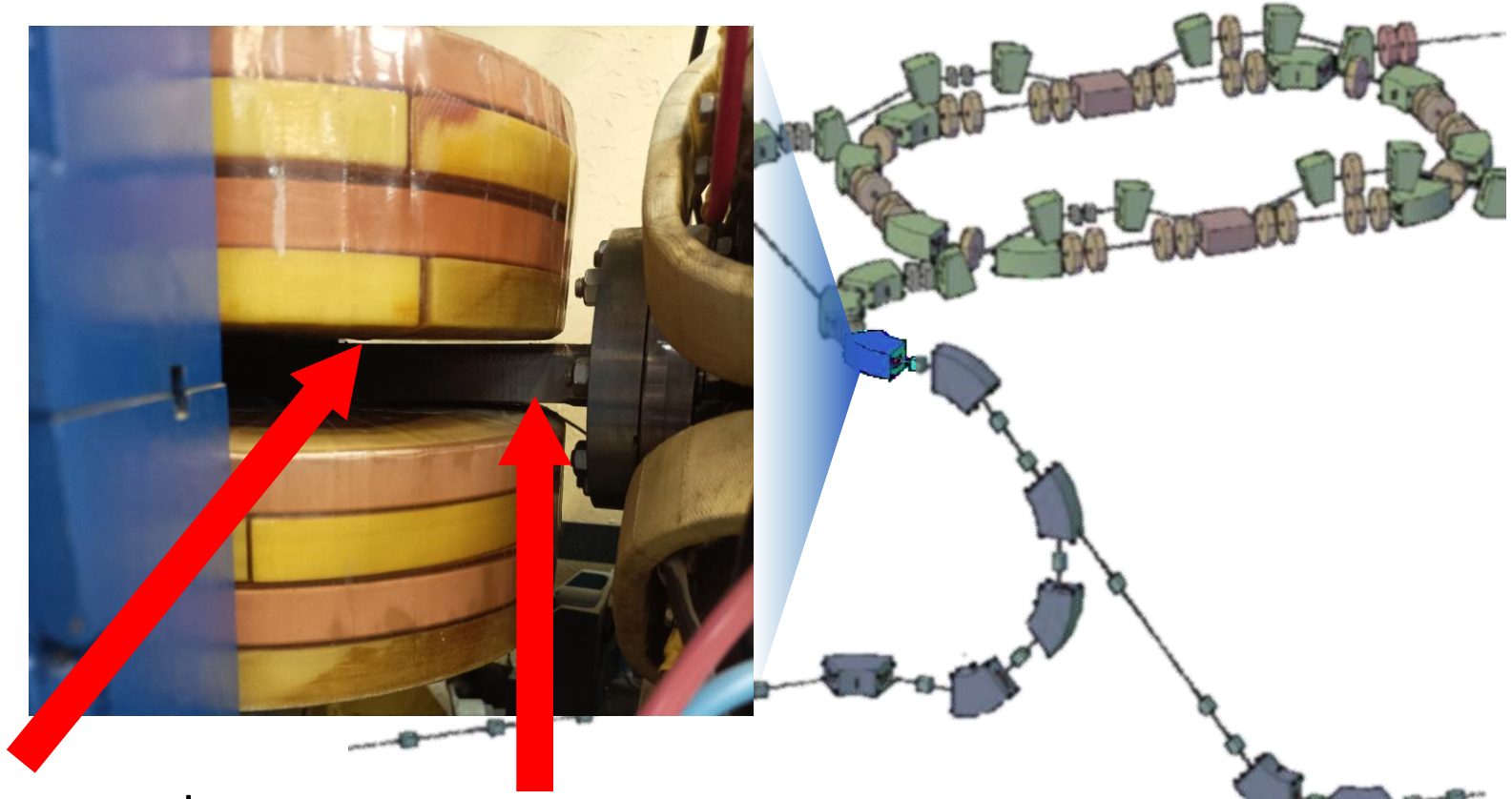
The device requirements

1. Magnetic field in the 8 injection complex magnets must be **remotely** measured by the device
2. The total accuracy must be better than 10^{-3}
3. The device must be designed to register the field which is around 1 T
4. The device sensors have to be thin and small



The device requirements

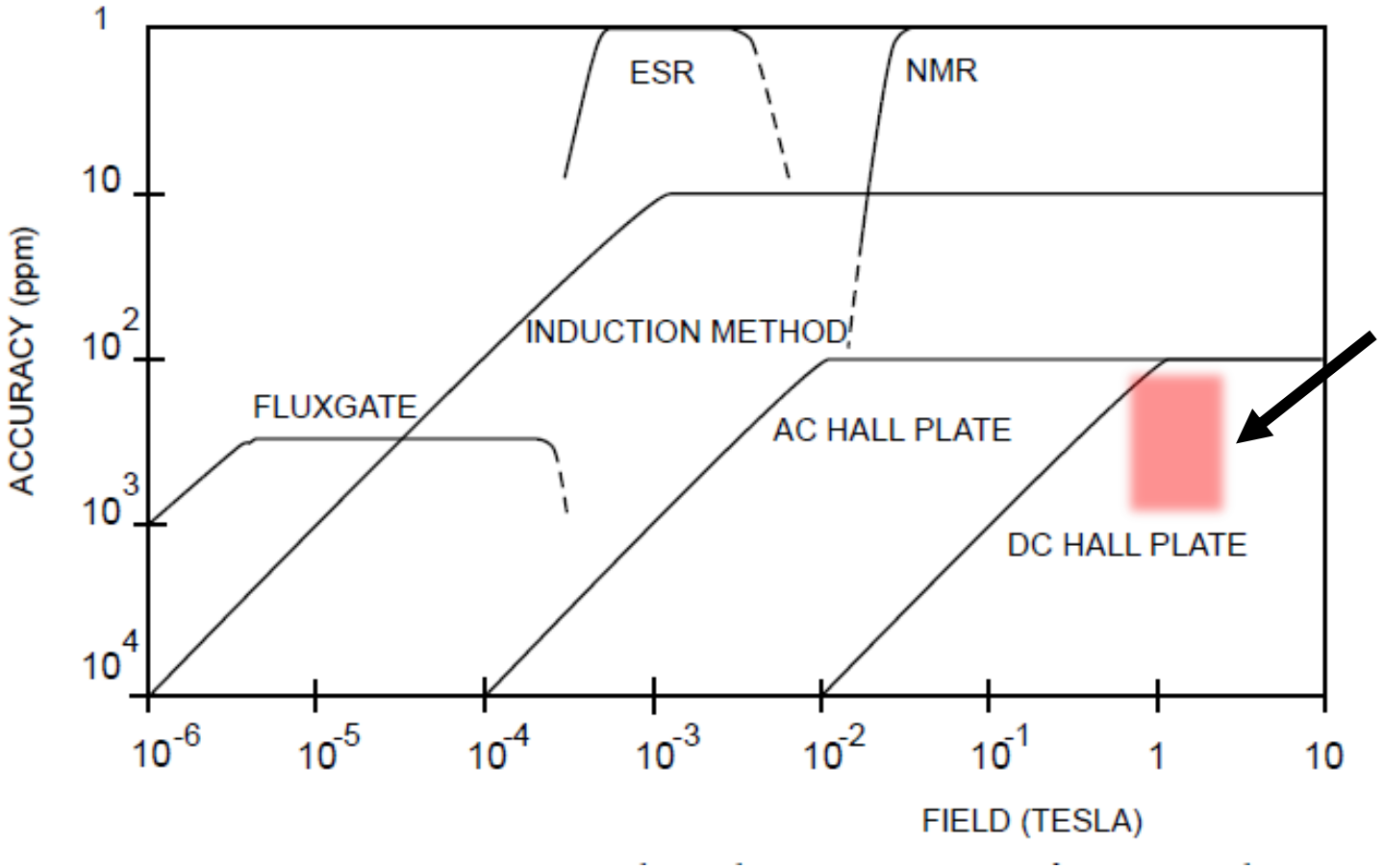
4. The device sensors have to be thin and small



The gap between the tube and the magnet pole is about 1.5 mm

Transportation channel vacuum tube

Magnetic field measurers review



The work area

Hall effect sensors

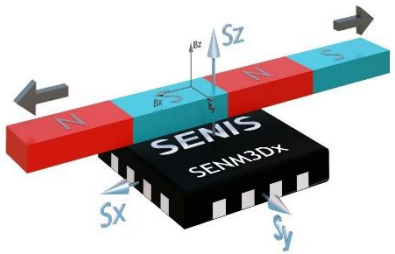
- ✓ Possibility to make measurements remotely
- ✓ 10^{-3}
- ✓ 1 T
- ✓ Thin
- ✓ Hall plate is small

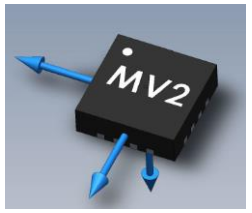
3-dimensional sensors:

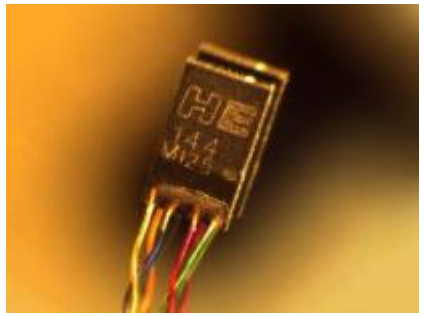
- SENM3Dx (FSV 100 x 100 x 10 μm^3)
- MV2 (FSV 200 x 200 x 5 μm^3)

1-dimensional sensors:

- ИМ10 3А1-1
- НЕ144

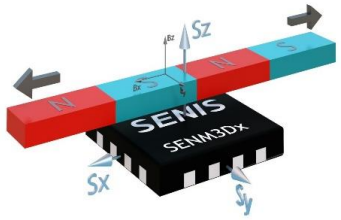


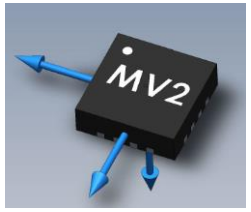


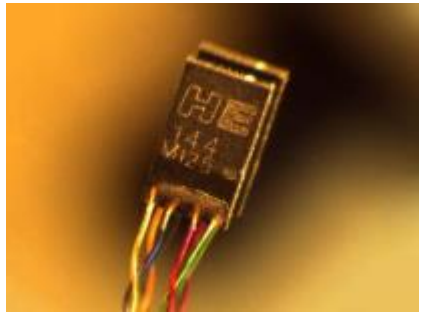


Hall effect sensors parameters

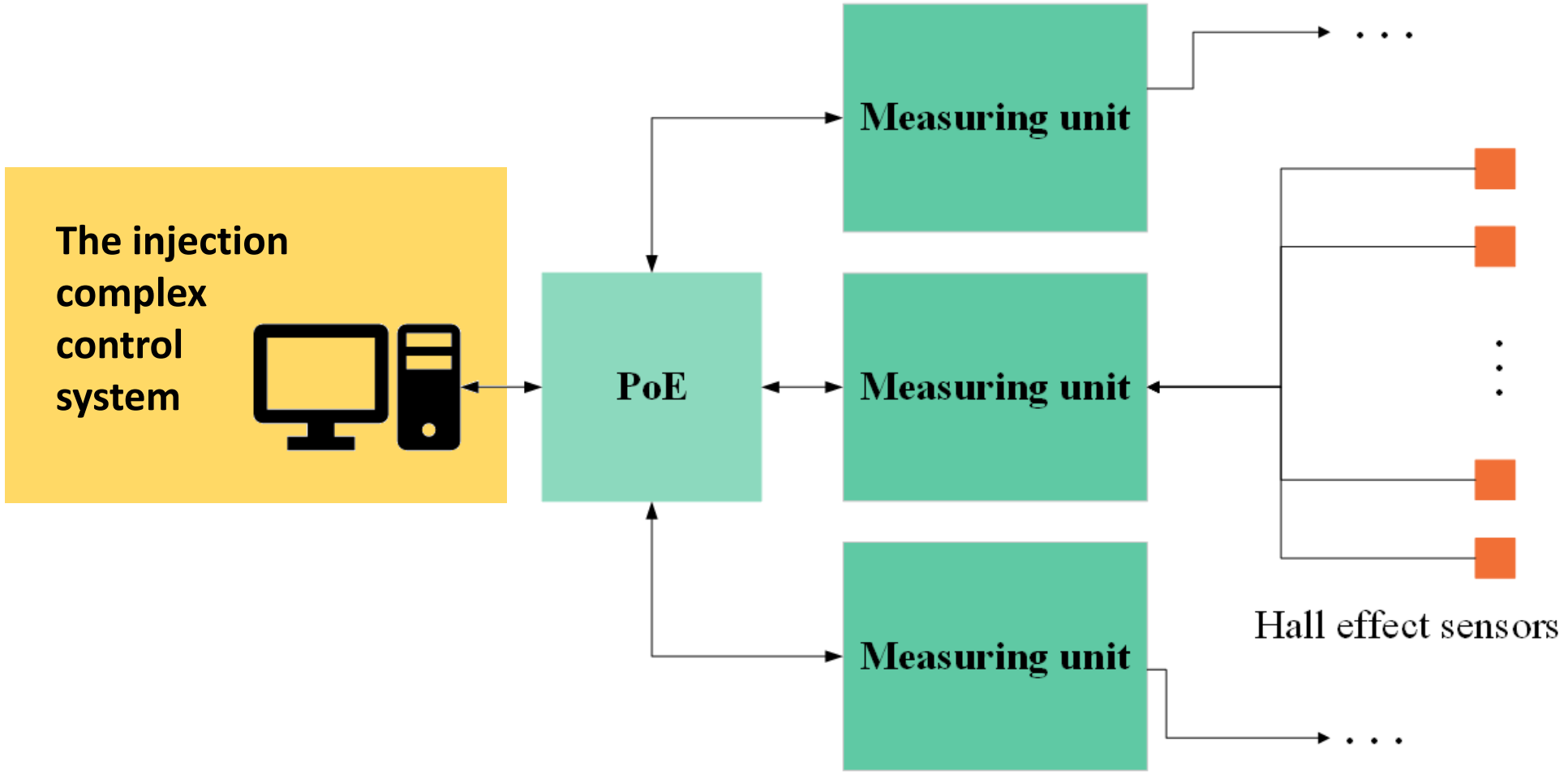
	SenM3Dx	MV2	ИМ10 3А1-1	НЕ144
Signal at 1T, V	**0.7**	**1.77**	**0.13**	**0.17**
Offset, mV	-11	49	-0.07	8.9
Offset drift, mV/^{o}C	-0.003	<2	0,25	-0,015
Gain, V/T	0.7	1.72	0,1237	0,2
Gain drift, ppm/^{o}C	<100	238	-24	200



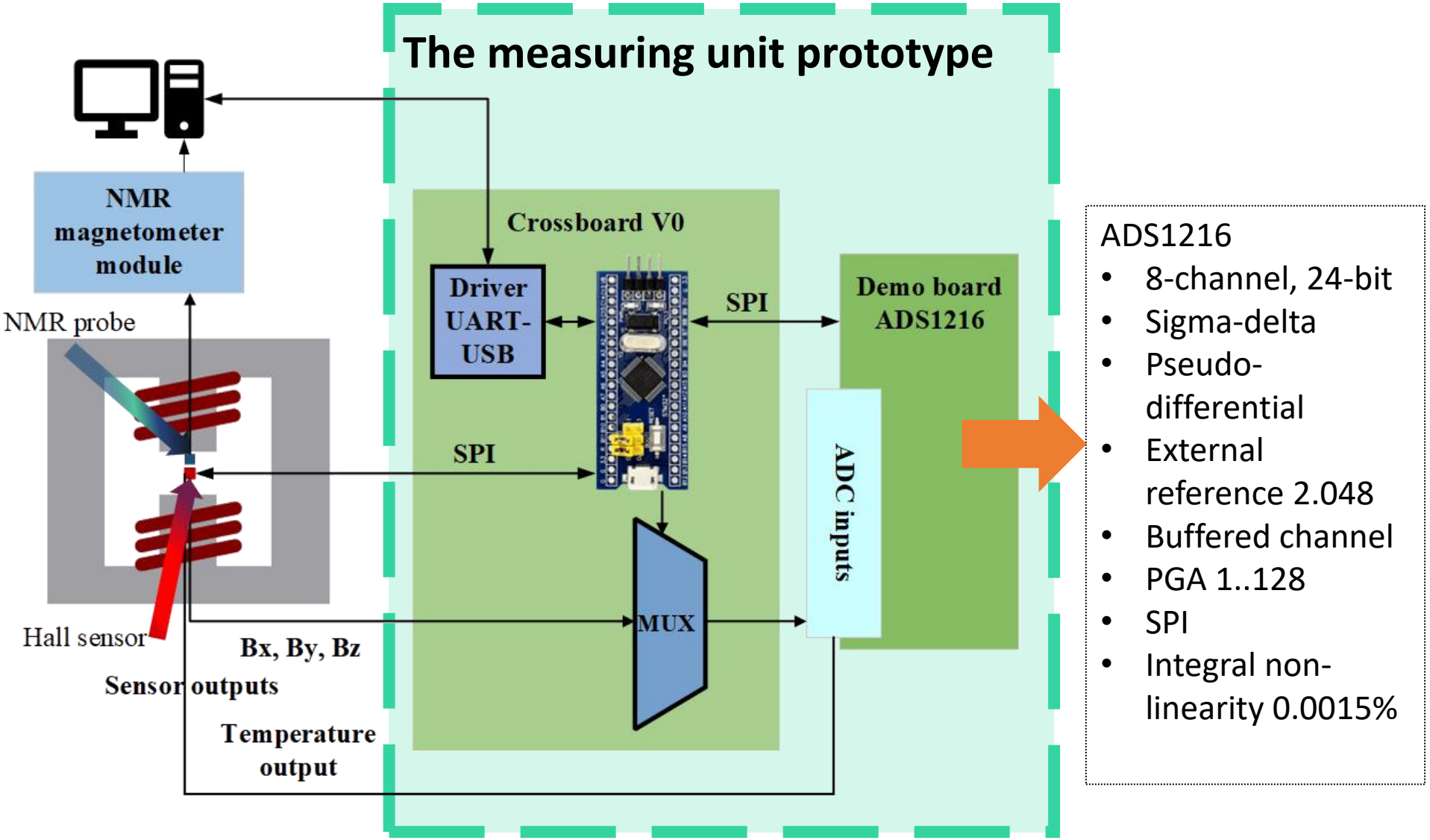




The distributed magnetic field measuring system



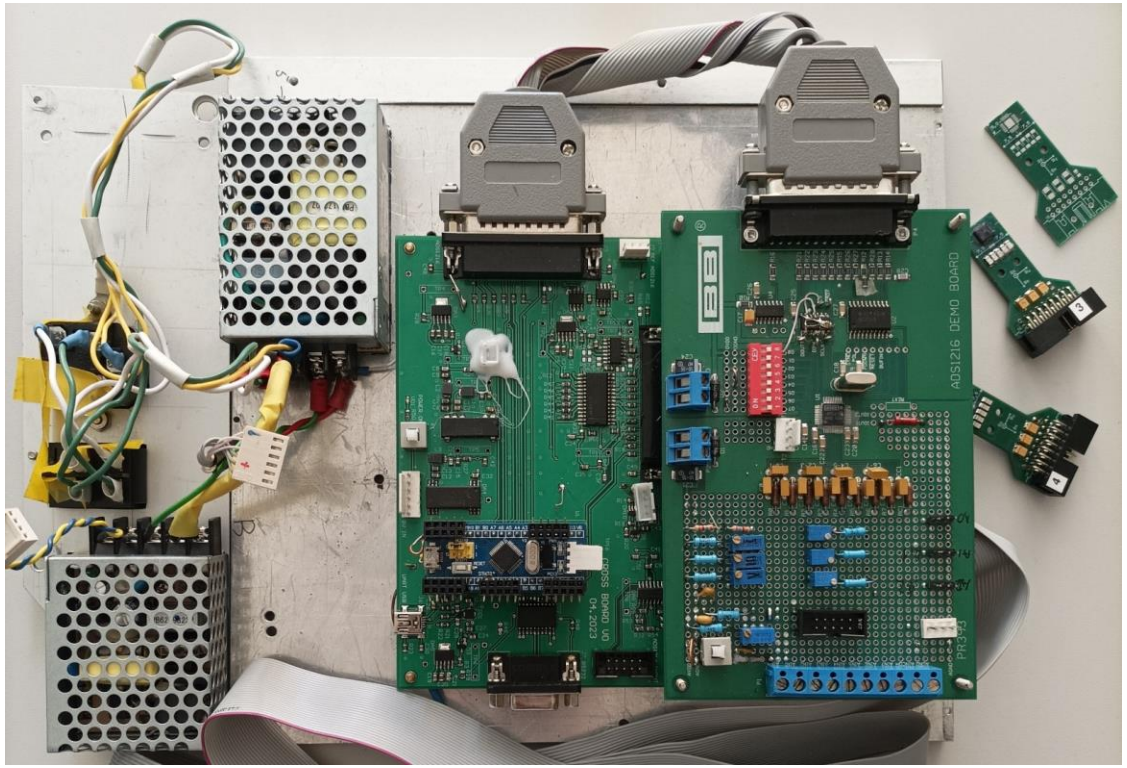
The measuring unit prototype



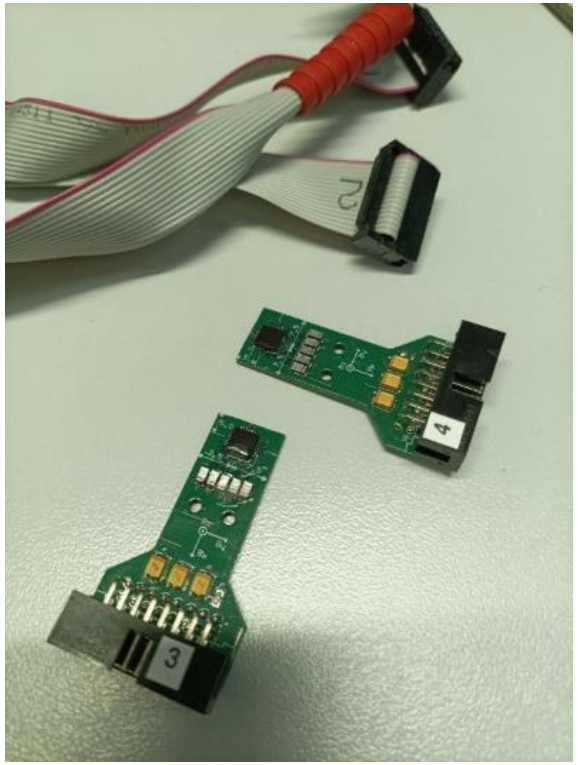
ADS1216

- 8-channel, 24-bit
- Sigma-delta
- Pseudo-differential
- External reference 2.048
- Buffered channel
- PGA 1..128
- SPI
- Integral non-linearity 0.0015%

The measuring unit prototype



Source, Cross board V0 and ADS1216 Demo board



Hall board probes (SENM3Dx)

Measured prototype parameters

	Average	Peak-to-peak
Offset	$25\ \mu V$	$0.6\ \mu V$
Gain	$0.244\ \cdot 10^{-7}\ V/bit$	

Signal	Estimated accuracy	
$1.72\ V$	$\leq \frac{U_{gain}}{U_{signal}} + \delta U_{offst} = 5.52\ \mu V$	

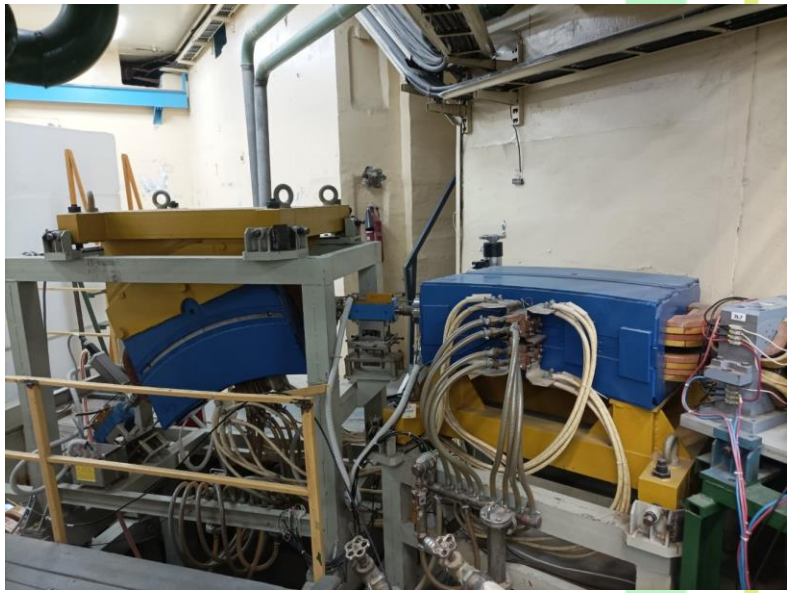
Sensors test

The calibration magnet

The sensors measurement is verified by NMR.

Measurements repeatability is registered
(< 10^{-3} for 3D and ИМ10 3А1-1
10^{-4} for HE144)

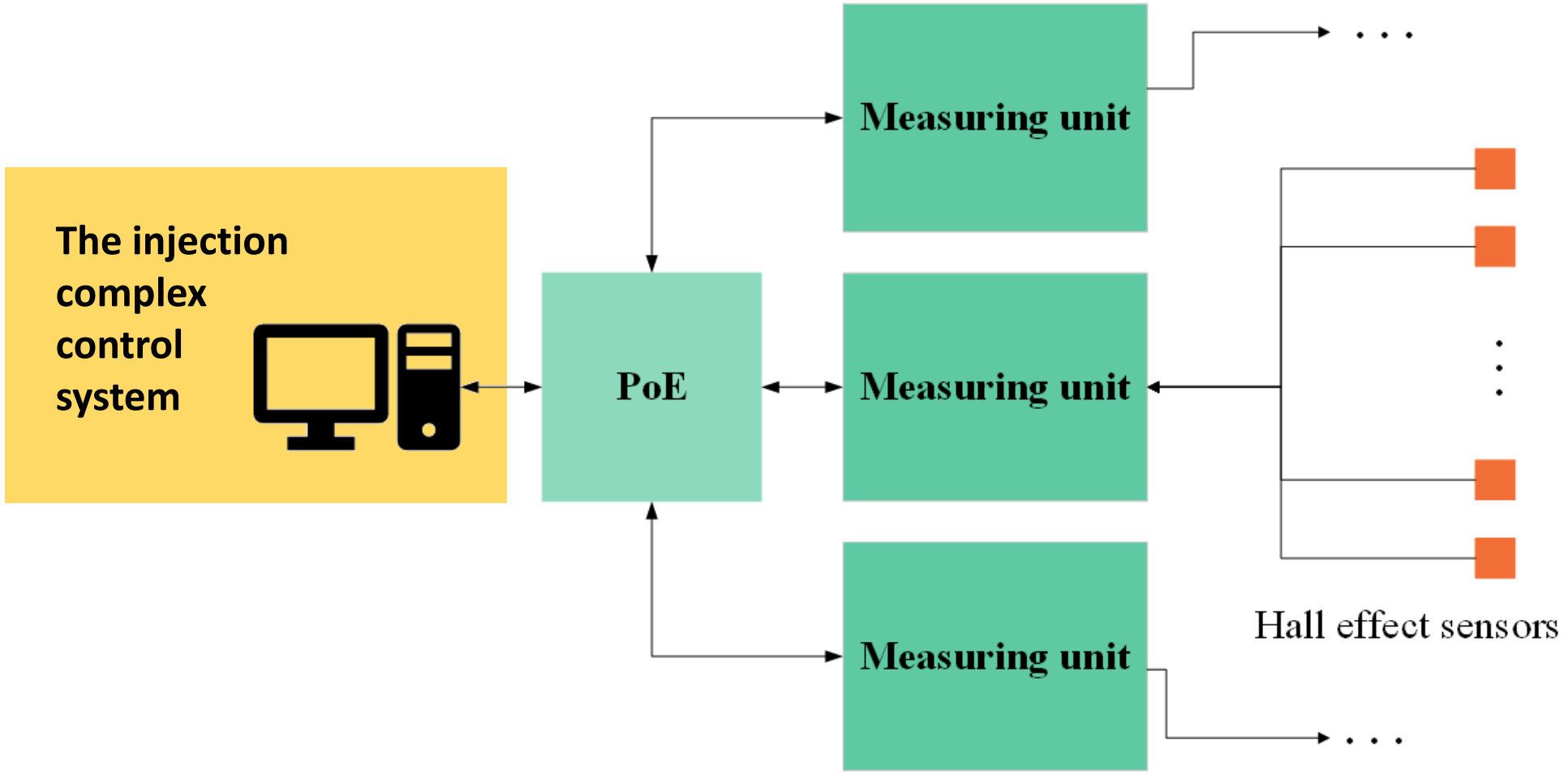
The injection complex magnets



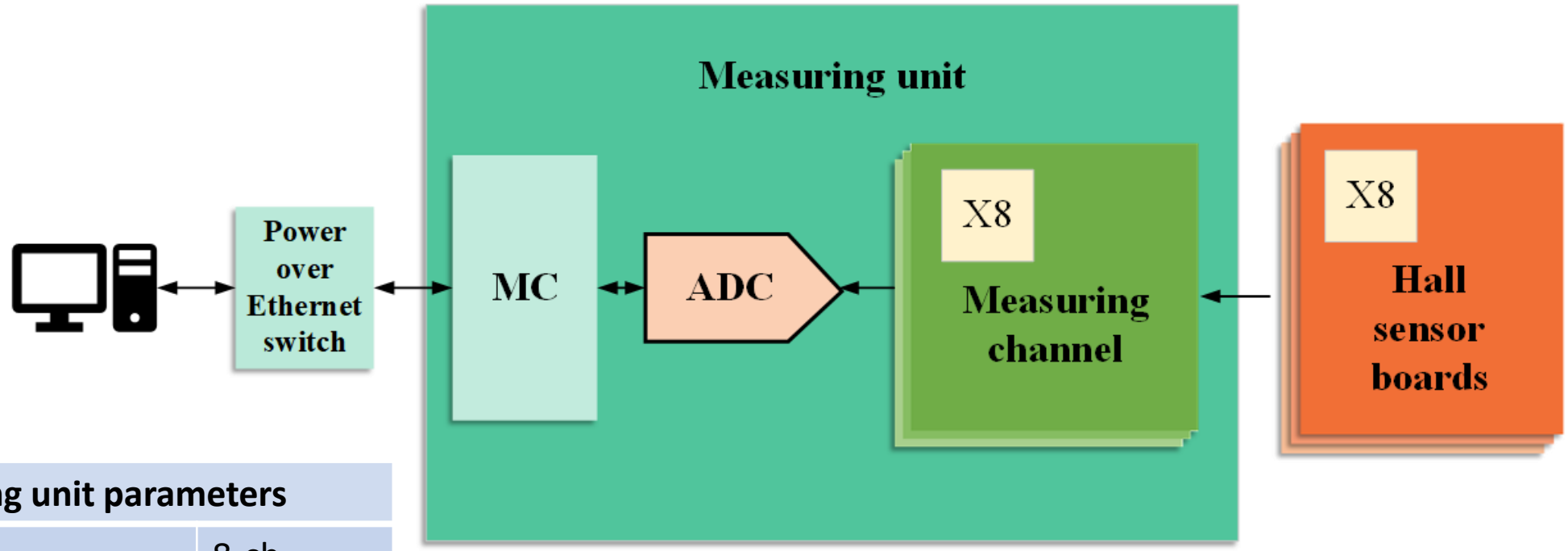
Three-dimensional sensors have been exposed to radiation for 2 weeks.

One-dimensional sensors have been exposed to radiation for 2 weeks and than for 4 weeks.

The distributed magnetic field measuring system

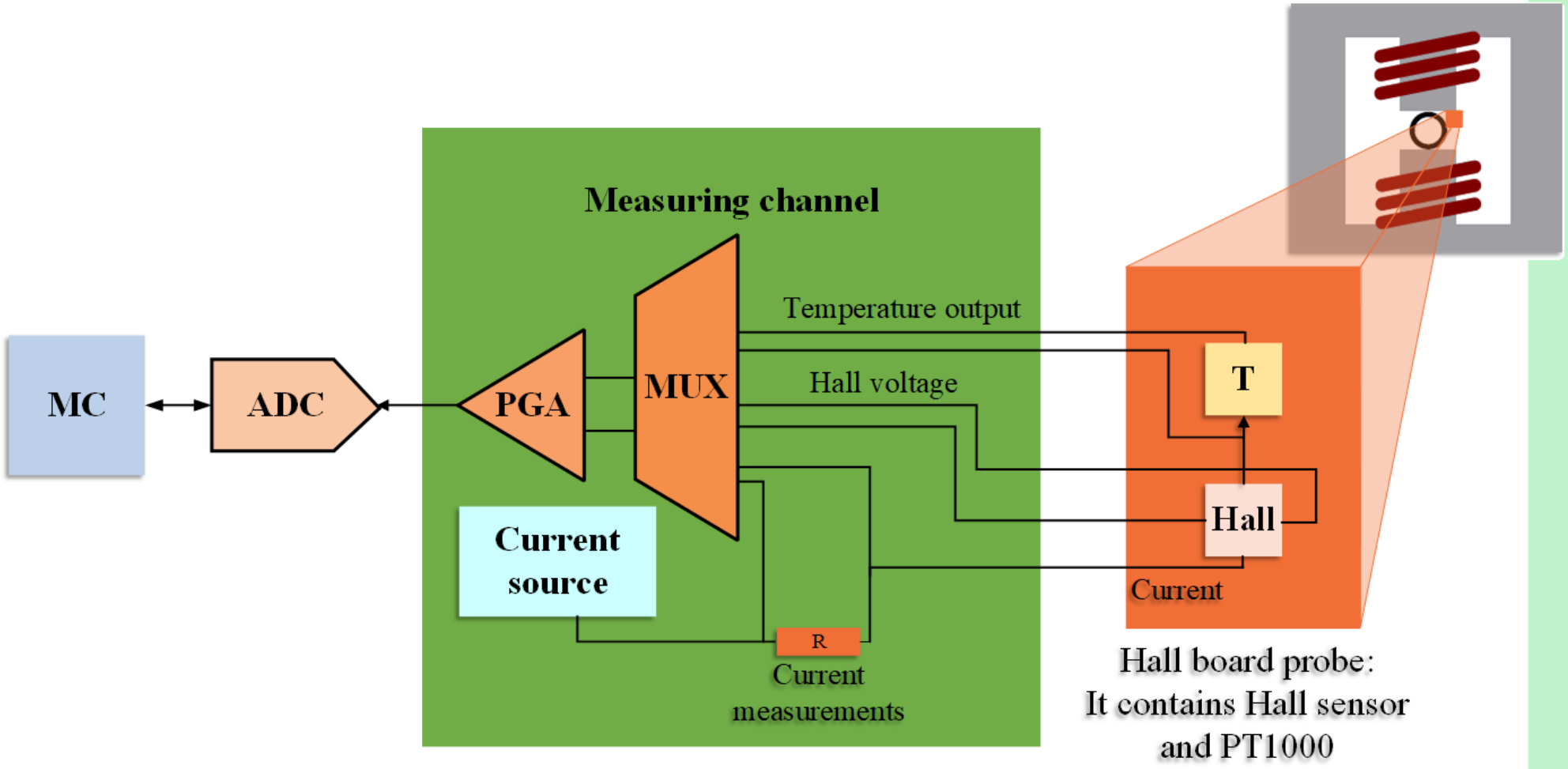


The device architecture



Measuring unit parameters	
Channels	8-ch
Field	1T
Sample rate	1-5 sec
Unit-probe distance	20 m
Estimated noise	1.6 µV
Hall current	1..100 mA

A measuring channel



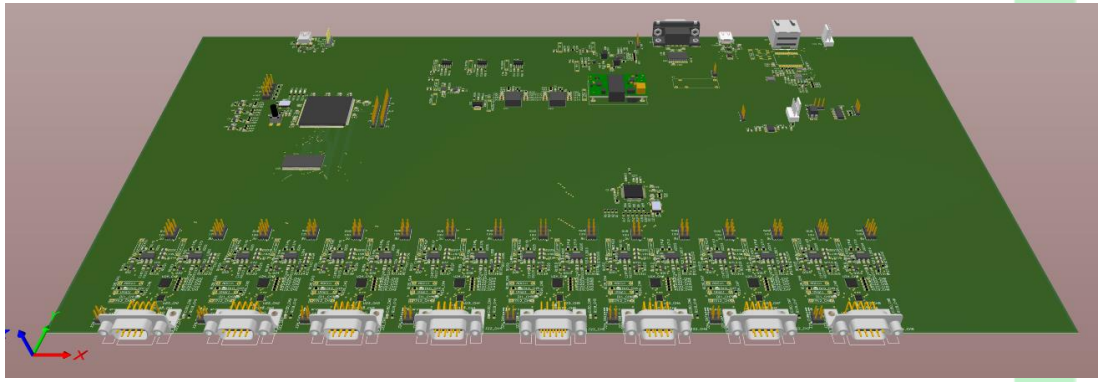
Conclusion

What is done/achieved:

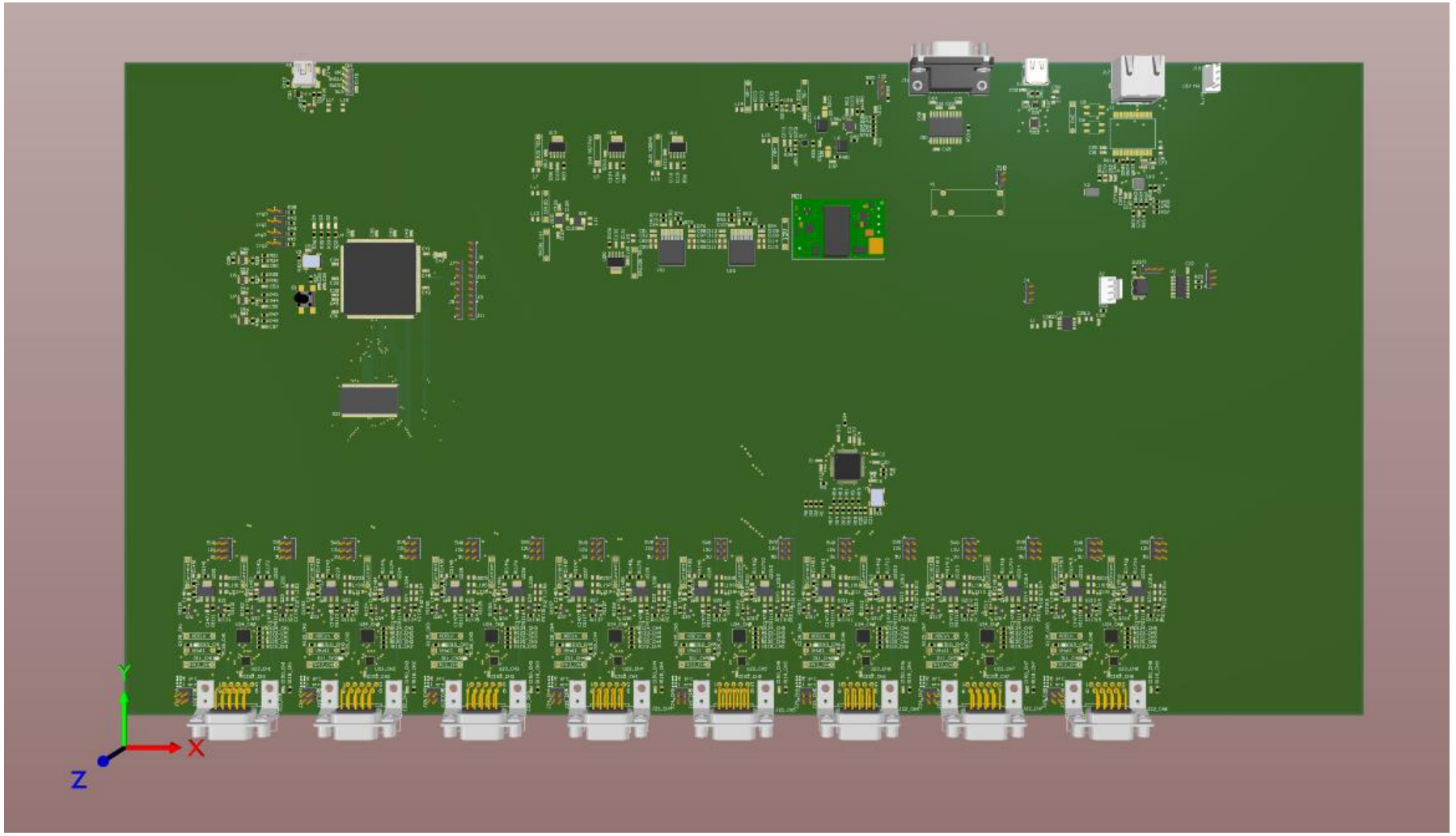
- The measuring system structure;
- The measuring unit prototype;
- Measuring control and obtaining software;
- Measurement repeatability with an accuracy better than 10^{-3};
- The measuring module circuitry.

What remains to be done:

- Device board project developing, building, programming, debugging;
- Test and implementation radioactivity-resistant sensors.

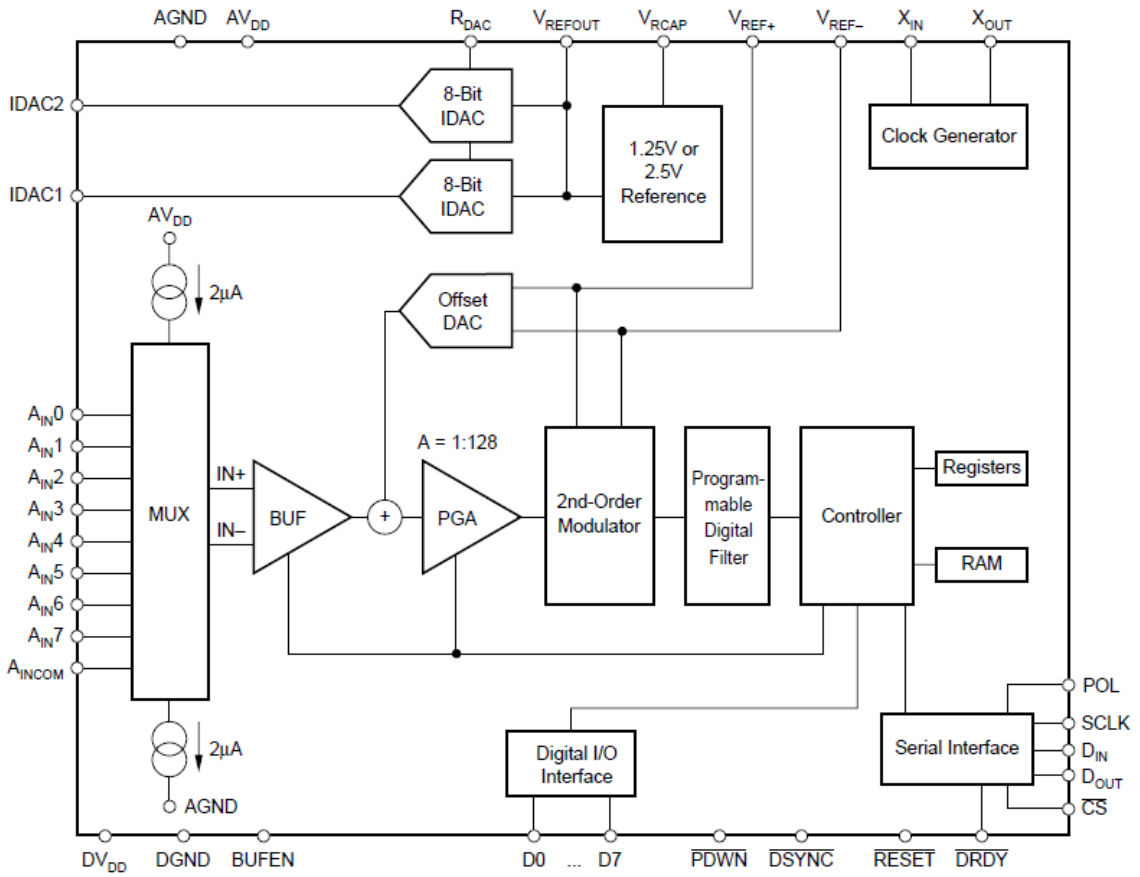


Application

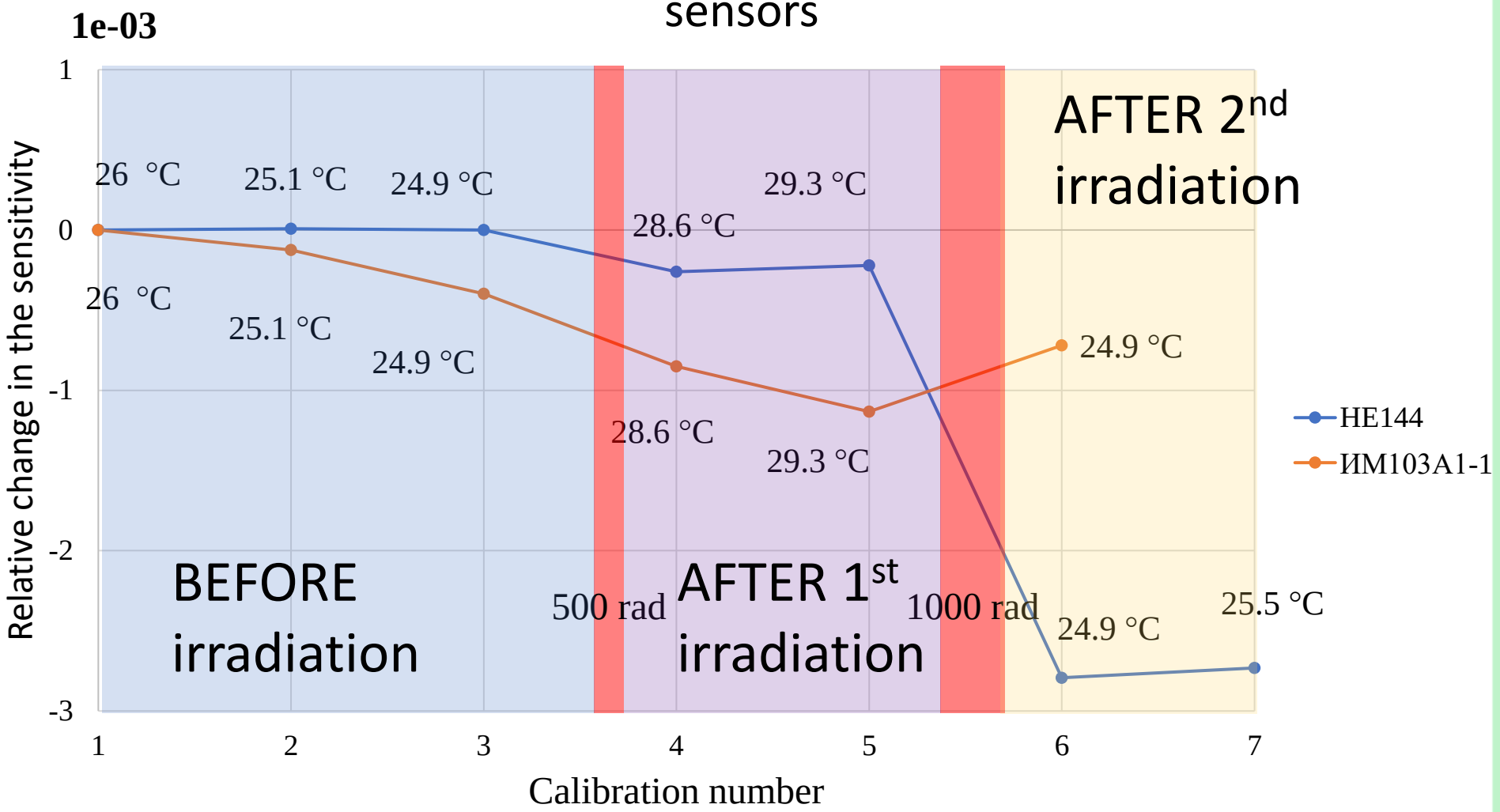


ADS1216

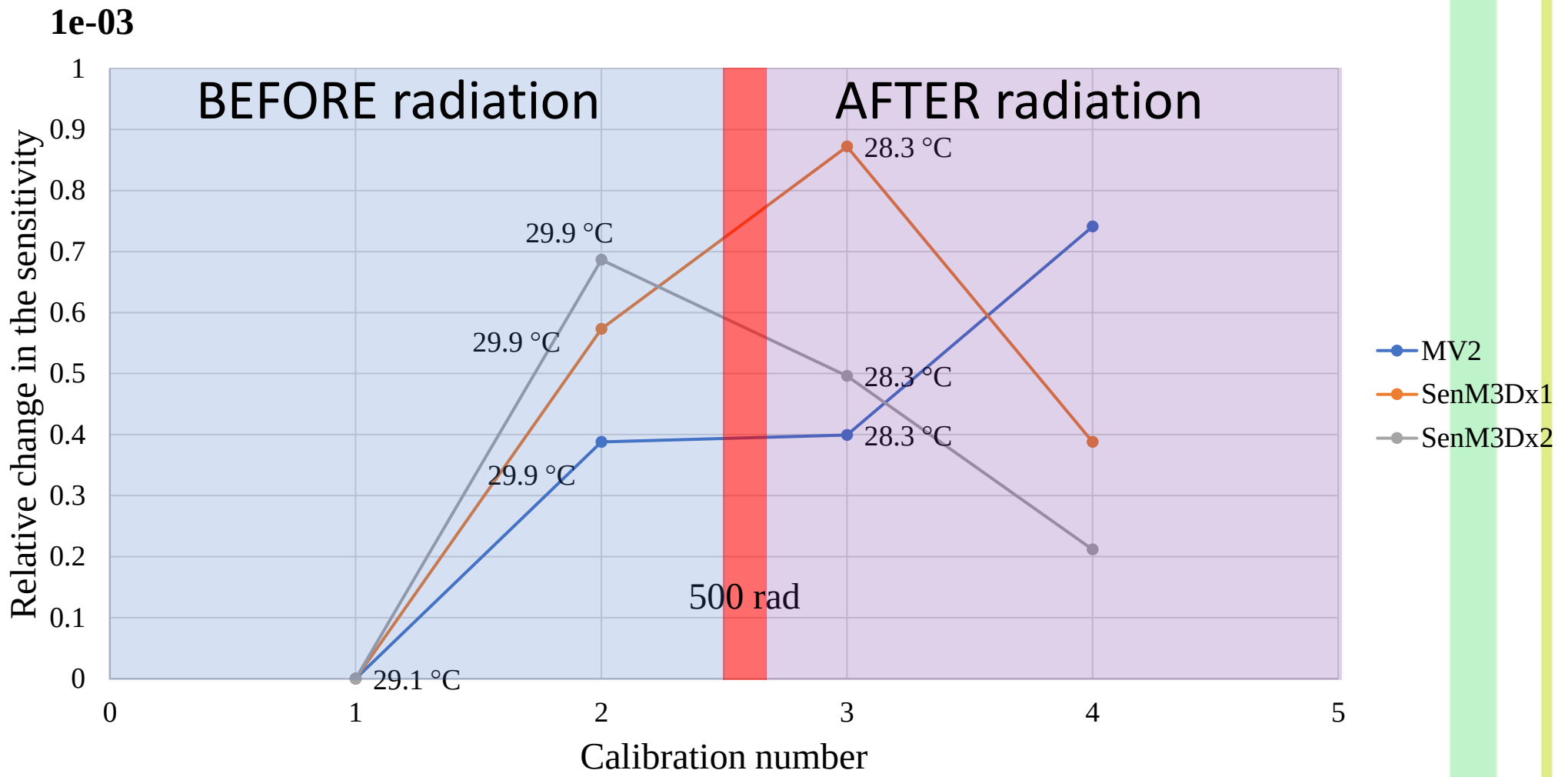
- 8-channel, 24-bit
- Sigma-delta
- Pseudo-differential
- External reference 2.048
- Buffered channel
- PGA 1..128
- SPI
- Integral non-linearity 0.0015%
- External reference temperature drift is about 2ppm/°C
- Precision reference output resistance has temperature drift about 2 ppm/°C



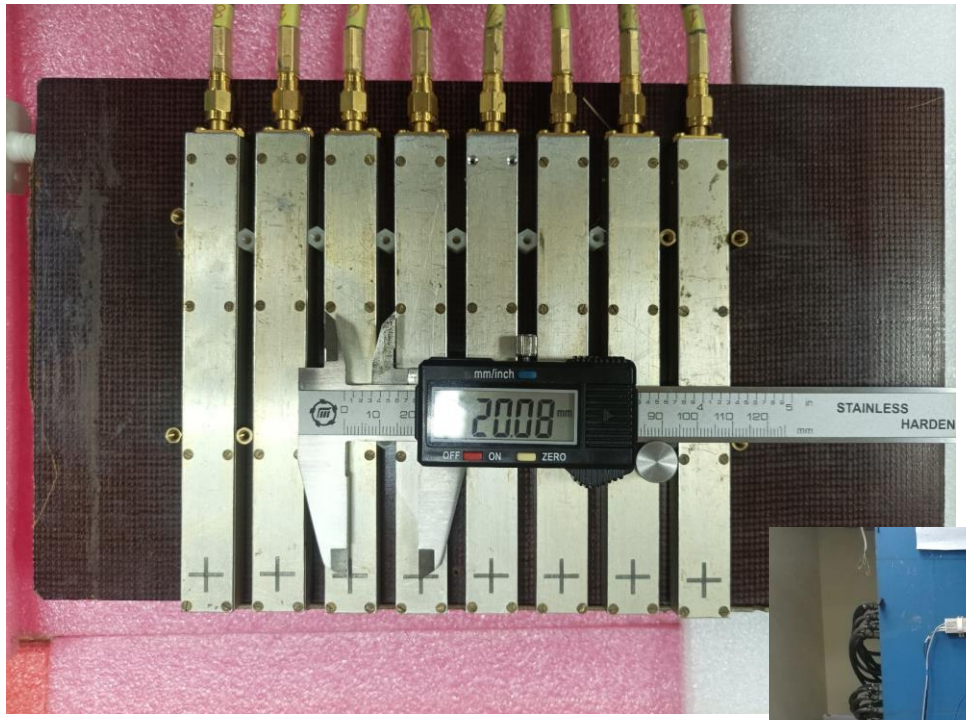
Relative change in the sensitivity of one-dimensional sensors



Relative change in the sensitivity of three-dimensional sensors

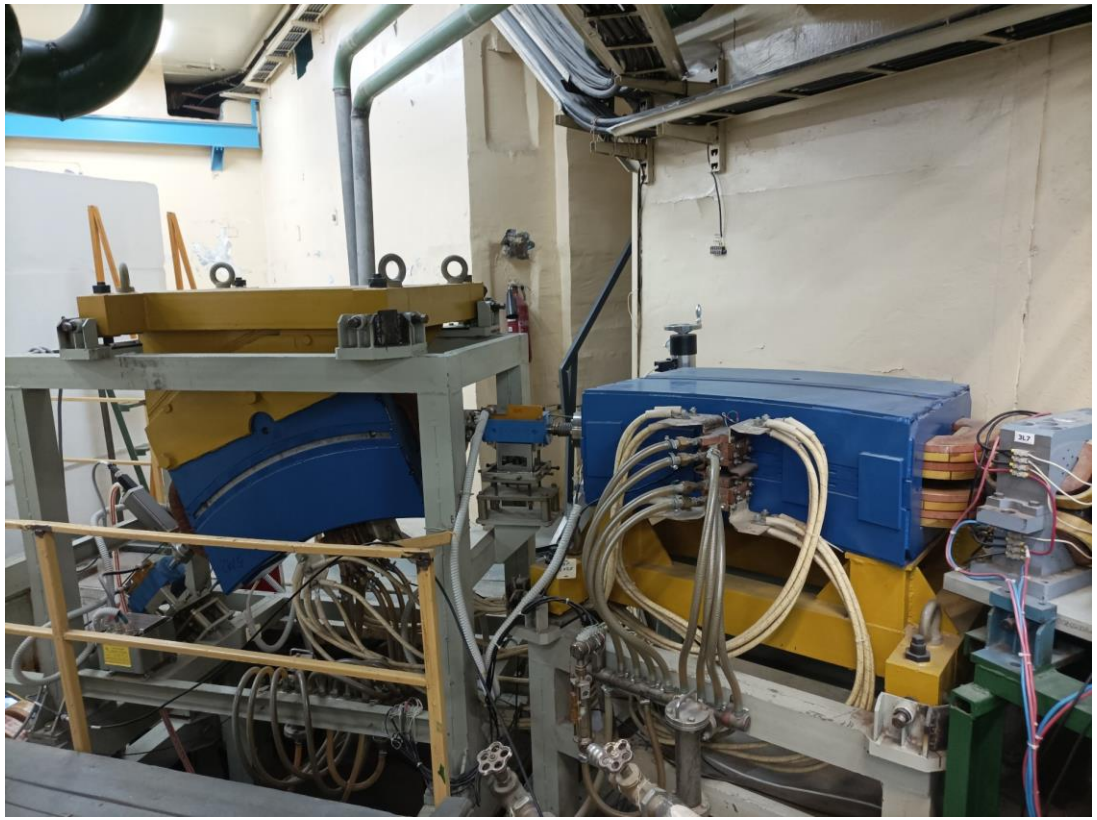


The radioactivity resistance experiment



1. A number of calibrations were conducted to *validate* measurements repeatability;
2. The sensors were placed to the injection complex magnet;
3. Several calibrations were made to register radioactivity *impact*.

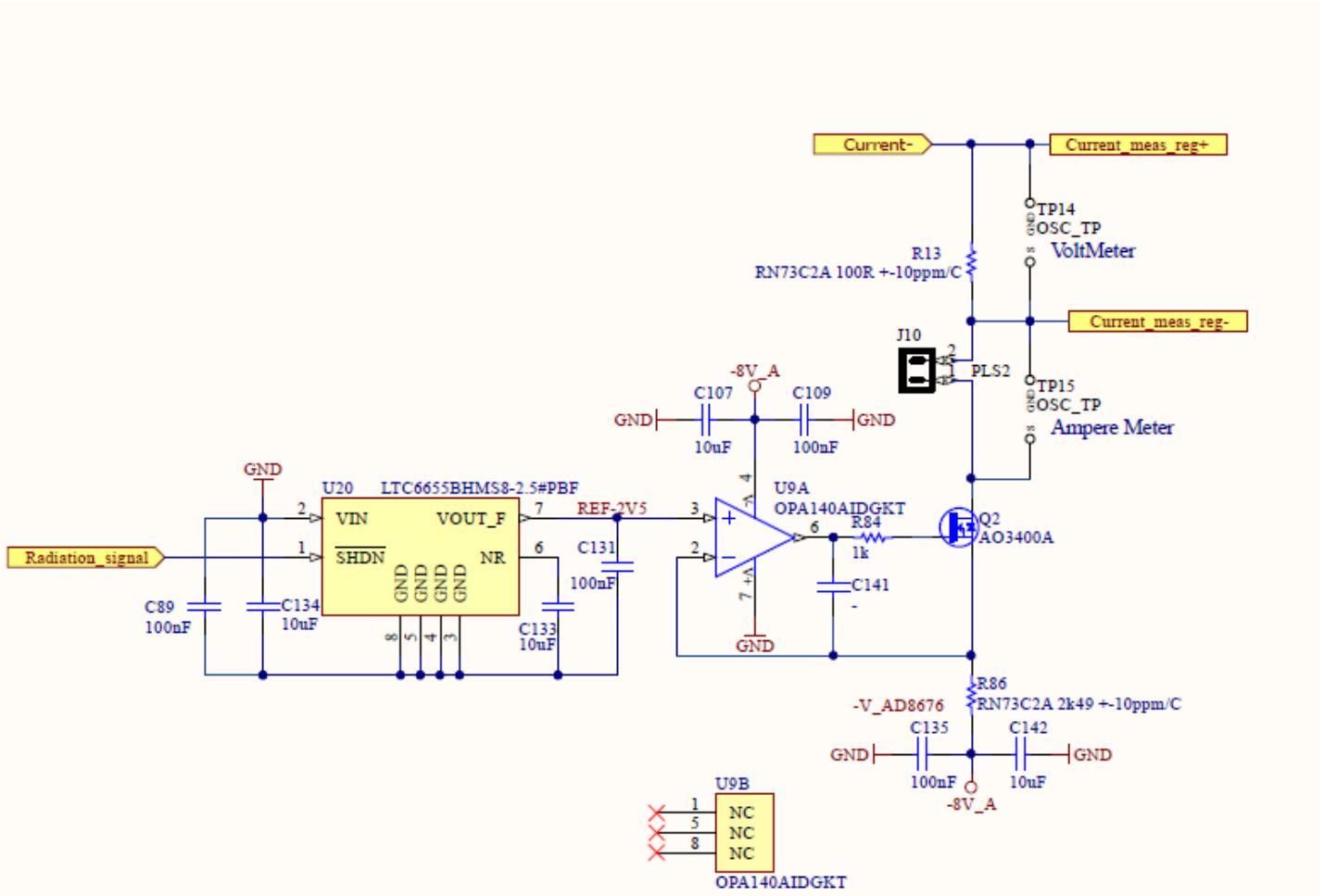
The radioactivity resistance experiment



The target magnet (on the right)

Three-dimensional sensors have been exposed to radiation for 2 weeks.
One-dimensional sensors were exposed to radiation twice: the first time is for 2 weeks and the second time for 4 weeks.

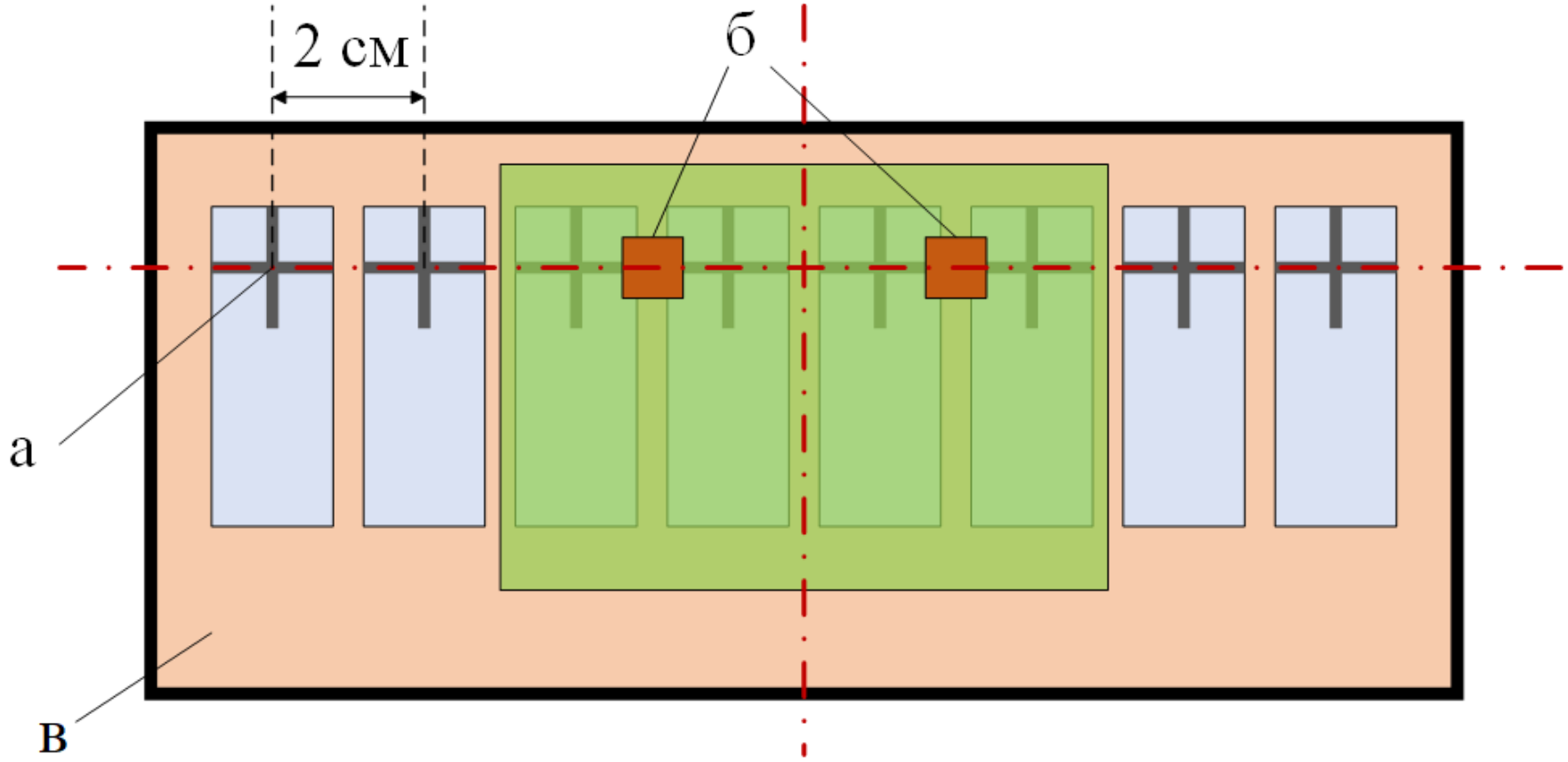
Application



Application

Device	Accuracy
Measuring stand intended for **three-dimensional** sensors, signal value is about 1.7 V	5.52 uV/6 days
Measuring stand intended for **one-dimensional** sensors, signal value is about 0.2 V	22 uV/90 days
NMR magnetometers	10^{-7} при однородности поля $2 \div 3 \cdot 10^{-4}/cm$

Application



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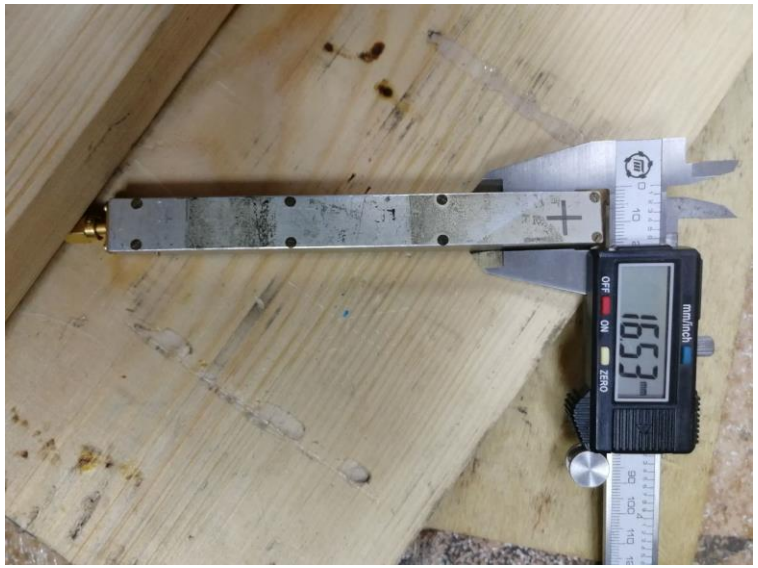
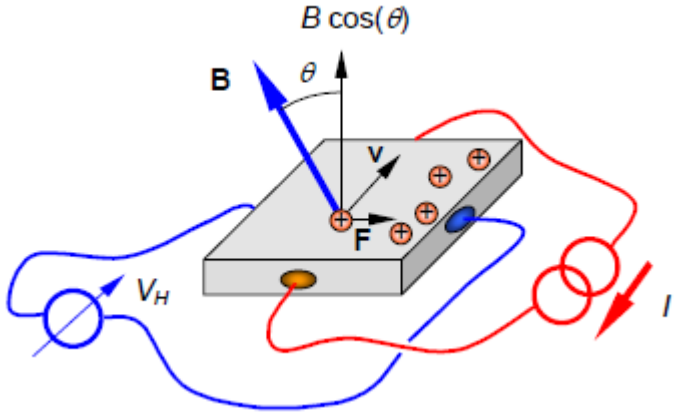


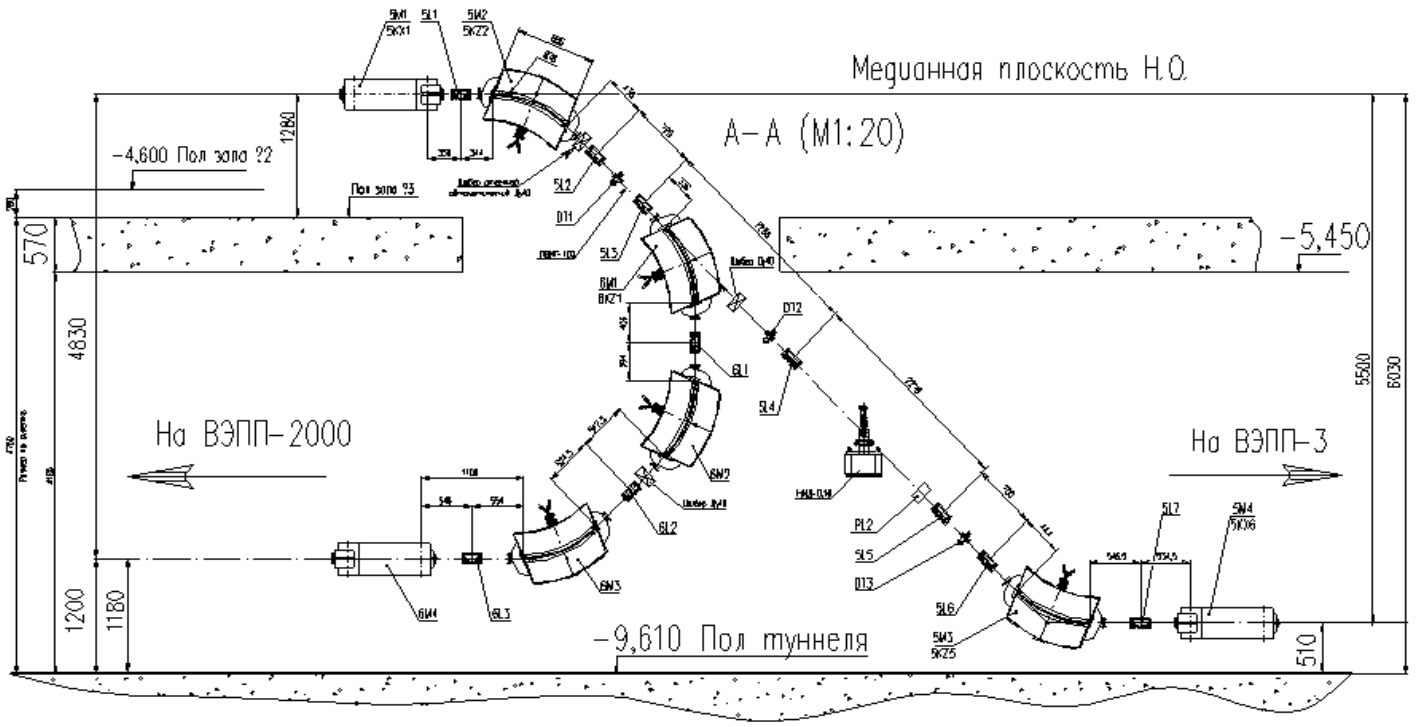
ЯМР датчик

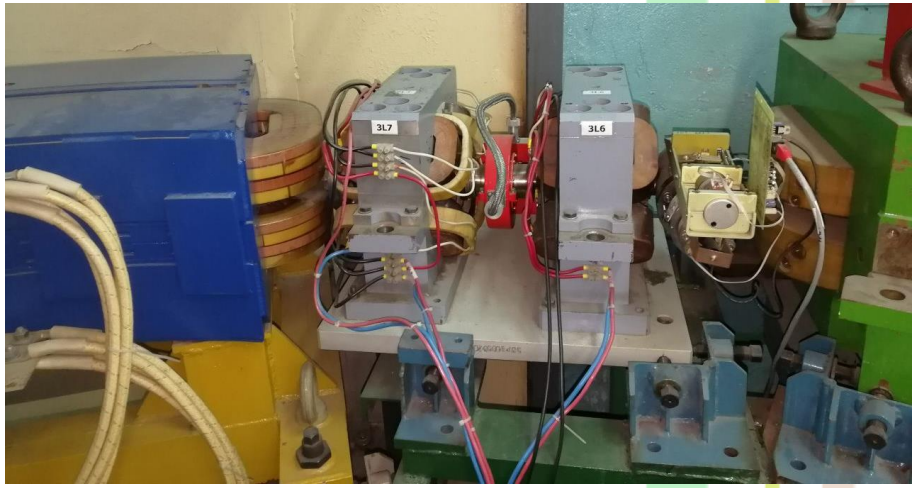
Катушки индуктивности

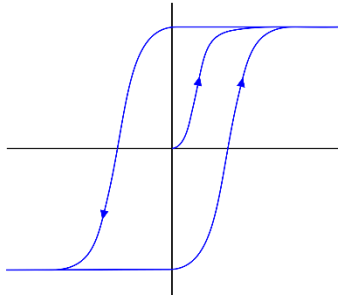


Датчик Холла

Application







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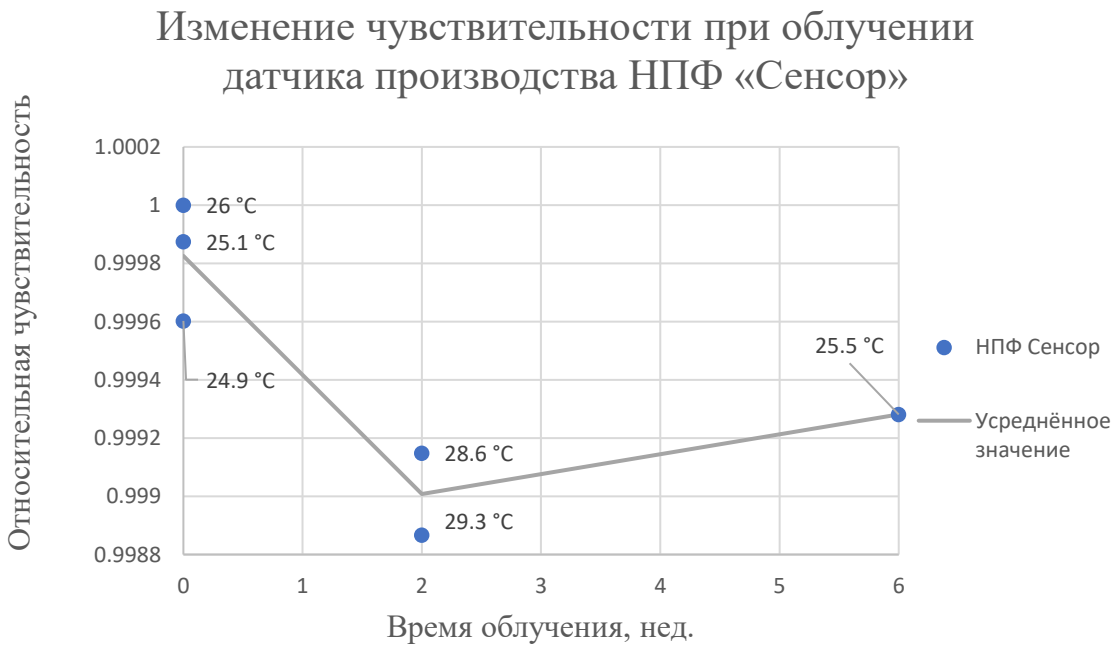

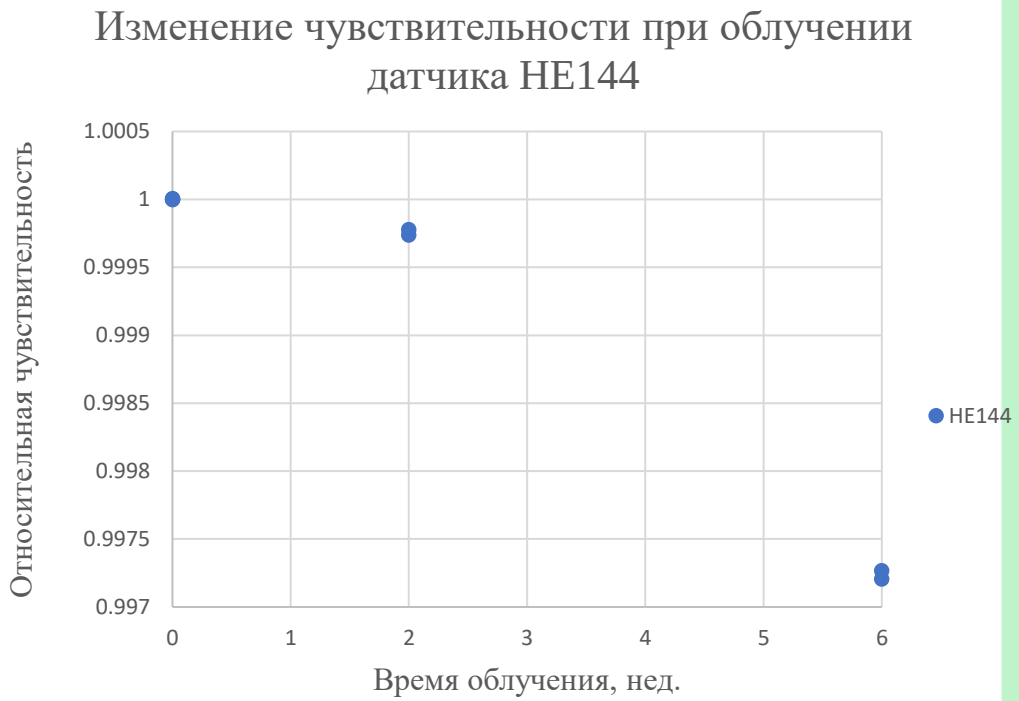

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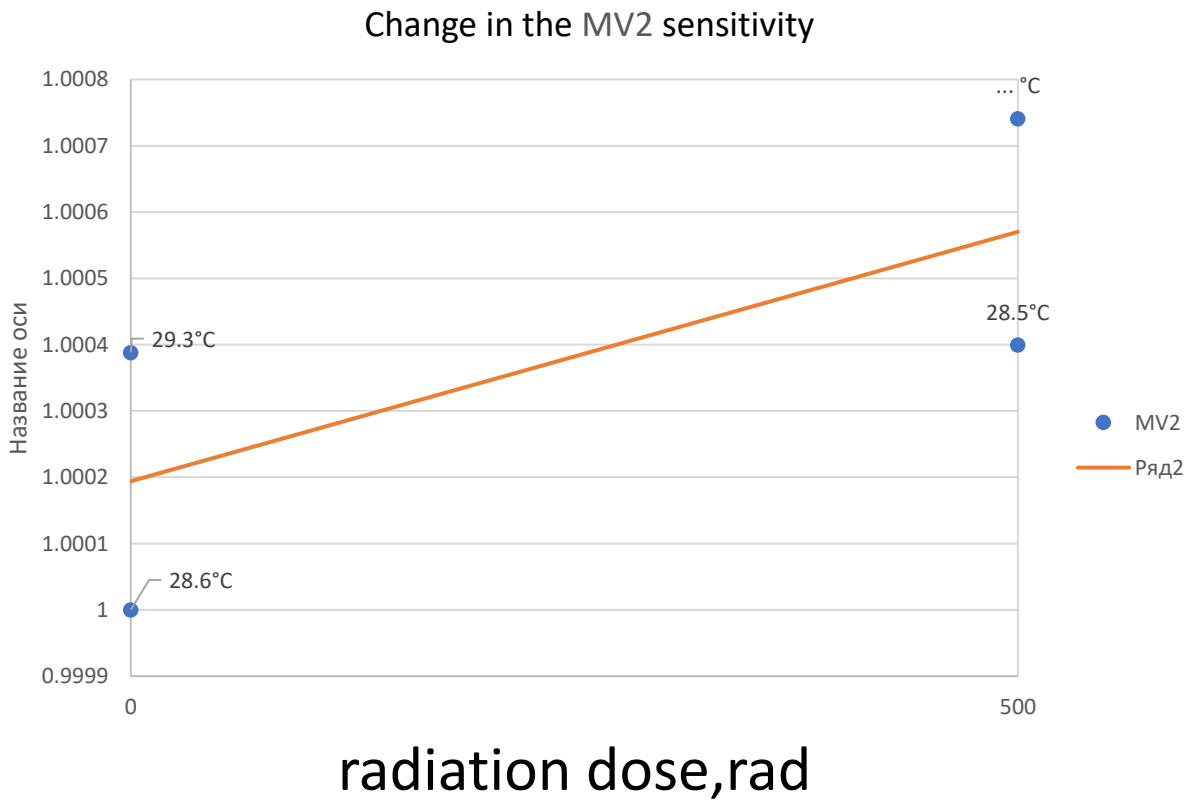
Application



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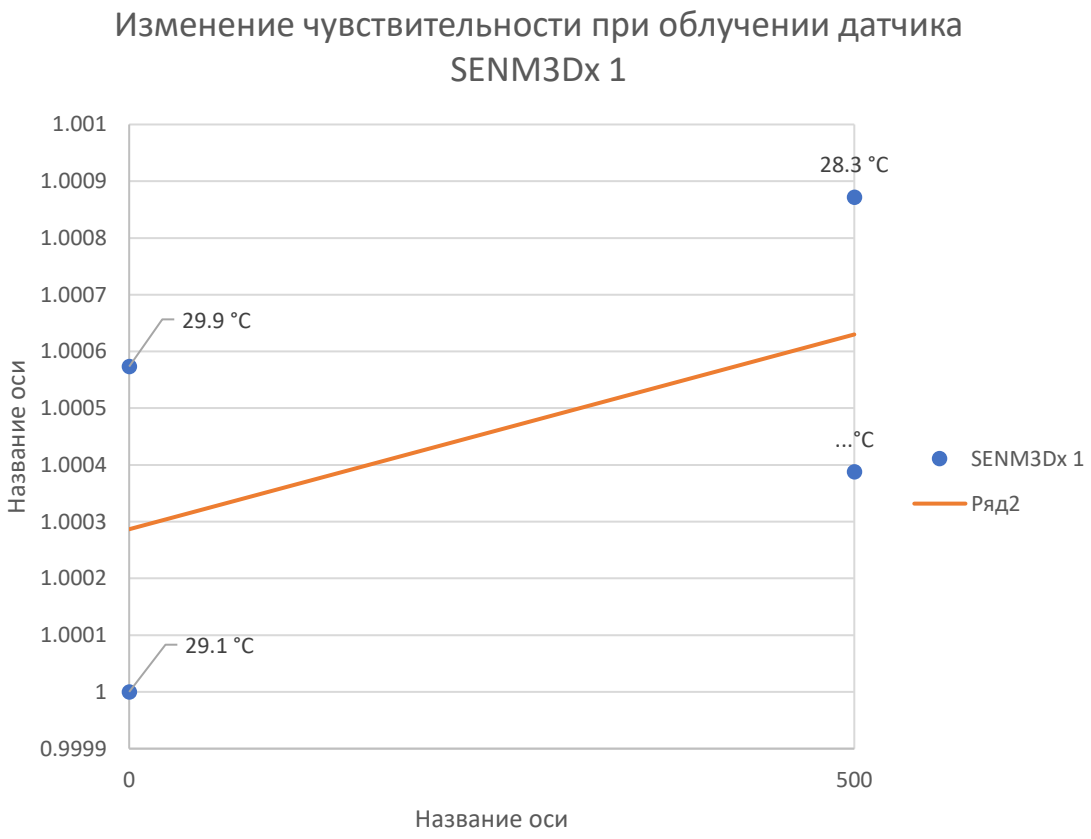

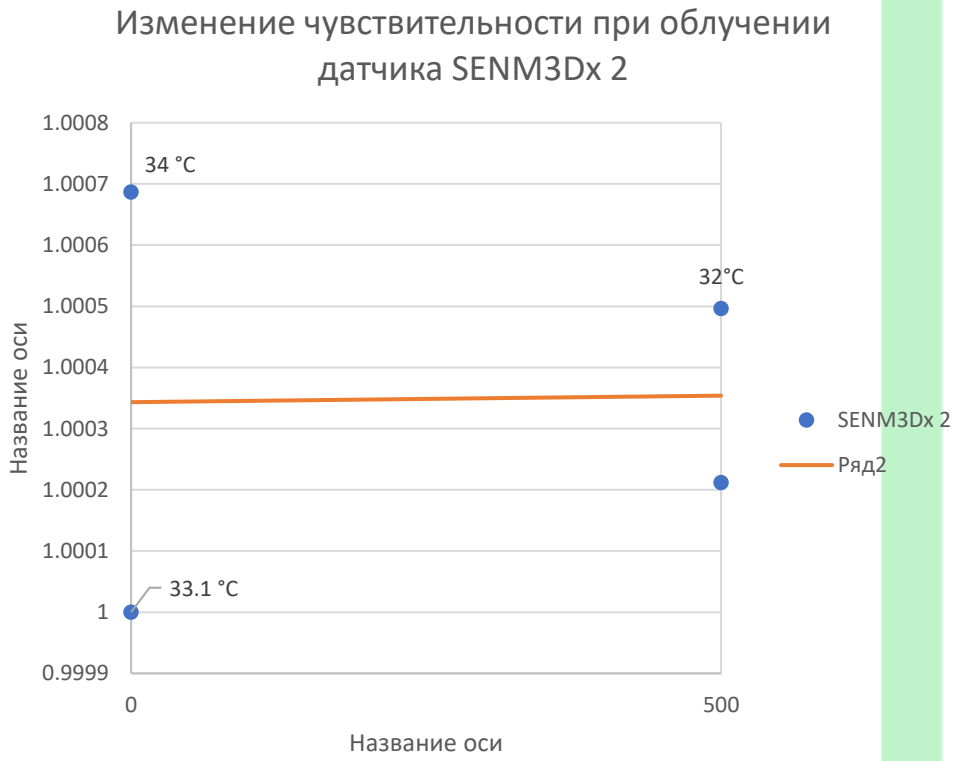

The measuring stand intended for **one-dimensional** sensors