Measurements of DCDC converters in detector systems

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Outline

- DCDC converter prototype used for system test.
- System tests:
    1. Hcal CMS
    2. Silicon Strip Tracker (U. Liverpool) ATLAS
    3. Silicon Strip Tracker (UNIGE) ATLAS
- System test conclusions.
- Shielding.

Converters for system tests

- 2 different converters based on the commercial chip LT3605 from Linear Technology

- PCB design based on guidelines given at TWEPP10.

(C.Fuentes: Study and methodology for decreasing noise emissions of DC-DC converters through PCB layout)

- a) SM01: Designed specially for Super Module specifications.
- b) STV10: Designed specially for Stavelet specifications.

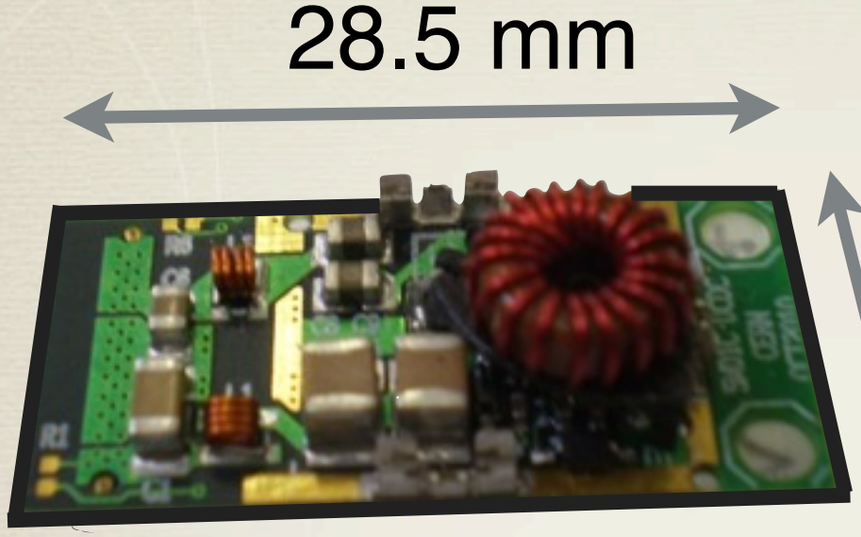
Electrical Properties:

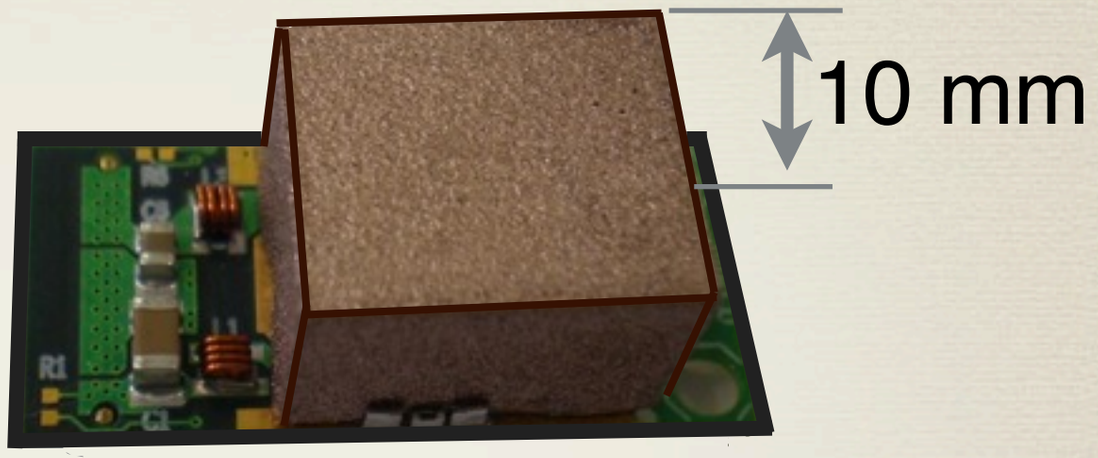
Nominal Input Voltage: 10V (stands up to 15V)

Power rated for ABCN25 hybrids: 5A at 2.5V.

The output voltage can be adjusted to the experiment needs.

a) SM01c for Super Module





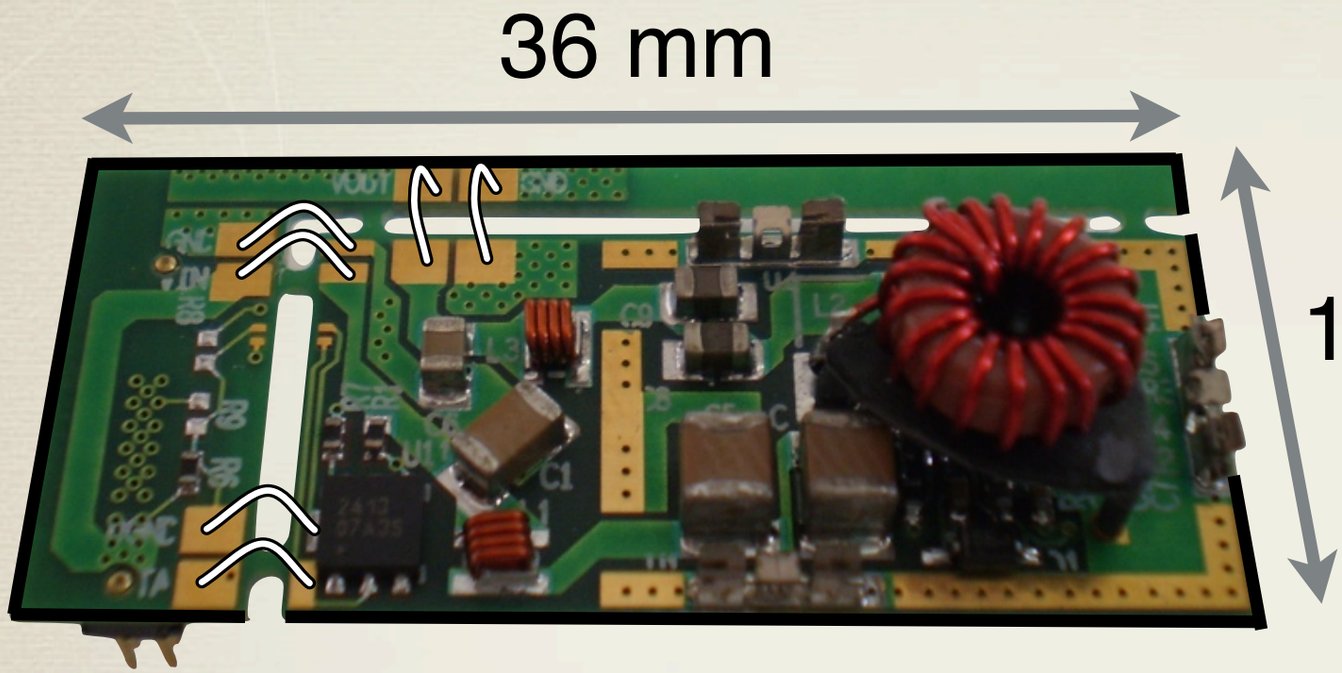
Designed for: Super Module (UNIGE)

34 SM01 converters have been produced, tested and given to UNIGE collaborators

It has been used for:

- FEE Board HCal CMS
- Frame Module ATLAS (Liverpool)
- Module ATLAS (UNIGE)

b) STV10 for Stavelet



DCDC for
test on LAB

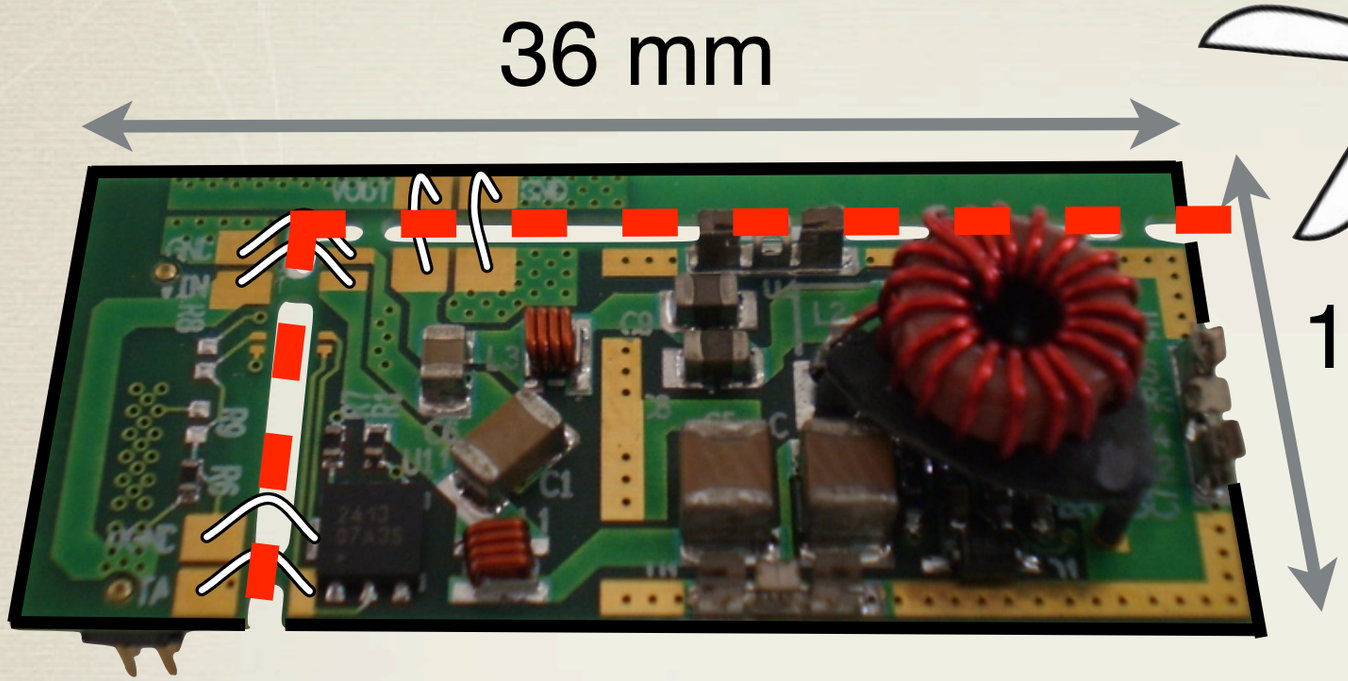
Designed for:
Stavelet ATLAS (Liverpool)

40 STV10 converters are being
produced for Liverpool collaborators

It has been used for:

- Frame Module ATLAS
  (Liverpool)

b) STV10 for Stavelet



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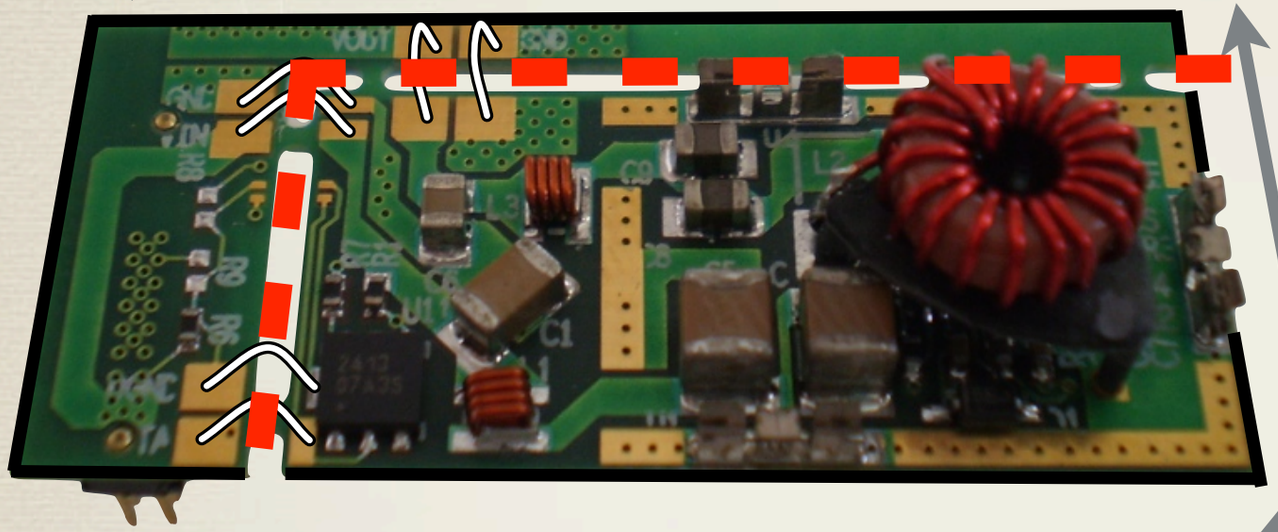
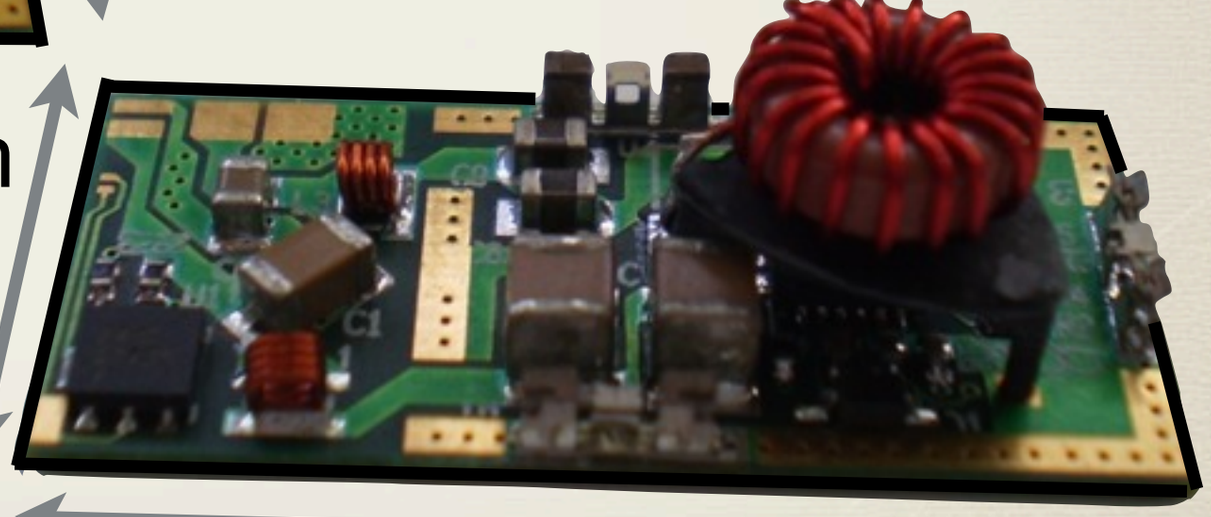


DCDC for test on LAB



DCDC for Stavelet (bonded)

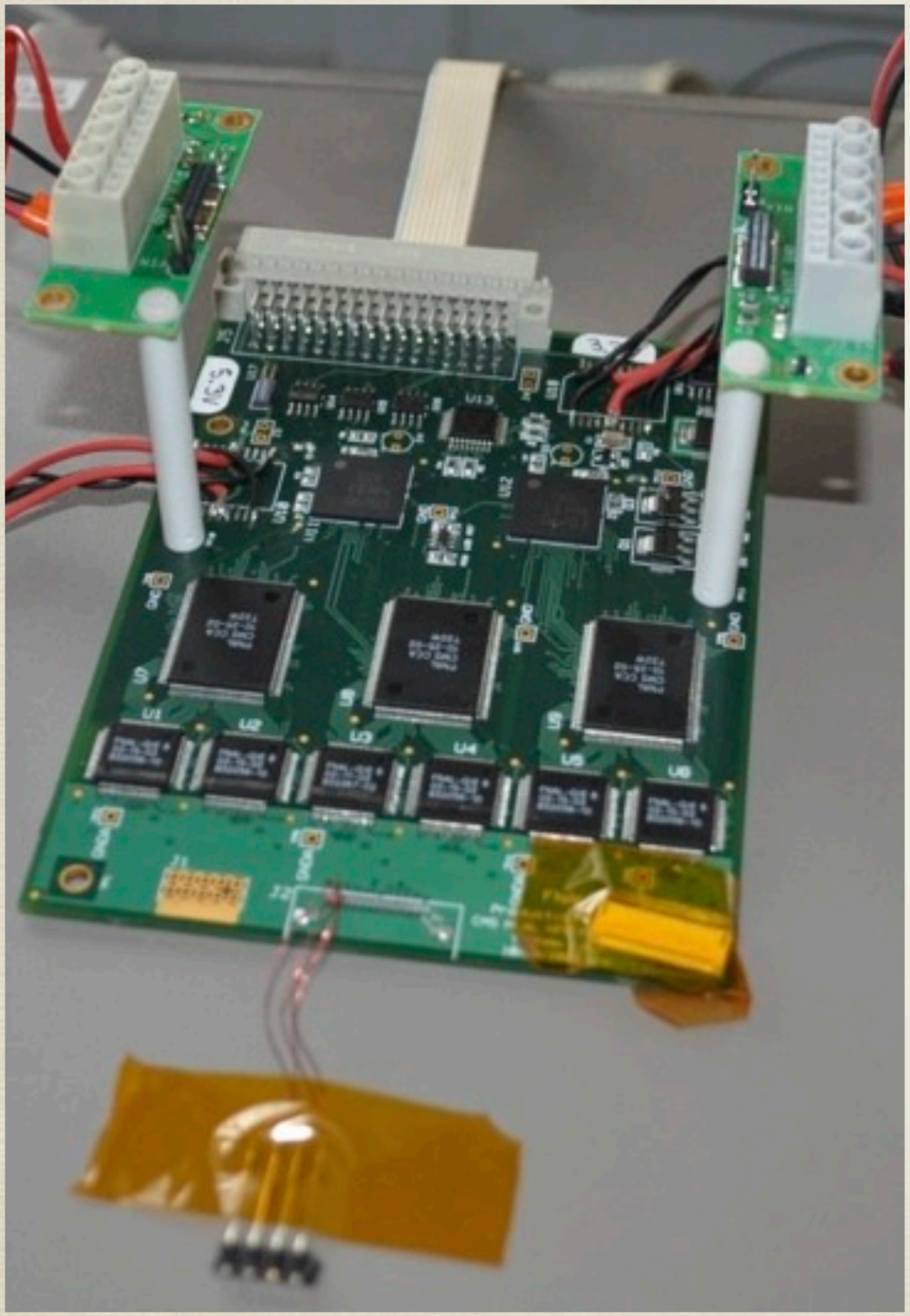
Designed for:
Stavelet ATLAS (Liverpool)

40 STV10 converters are being produced for Liverpool collaborators

It has been used for:

- Frame Module ATLAS (Liverpool)

1) Test with FEE Hcal CMS

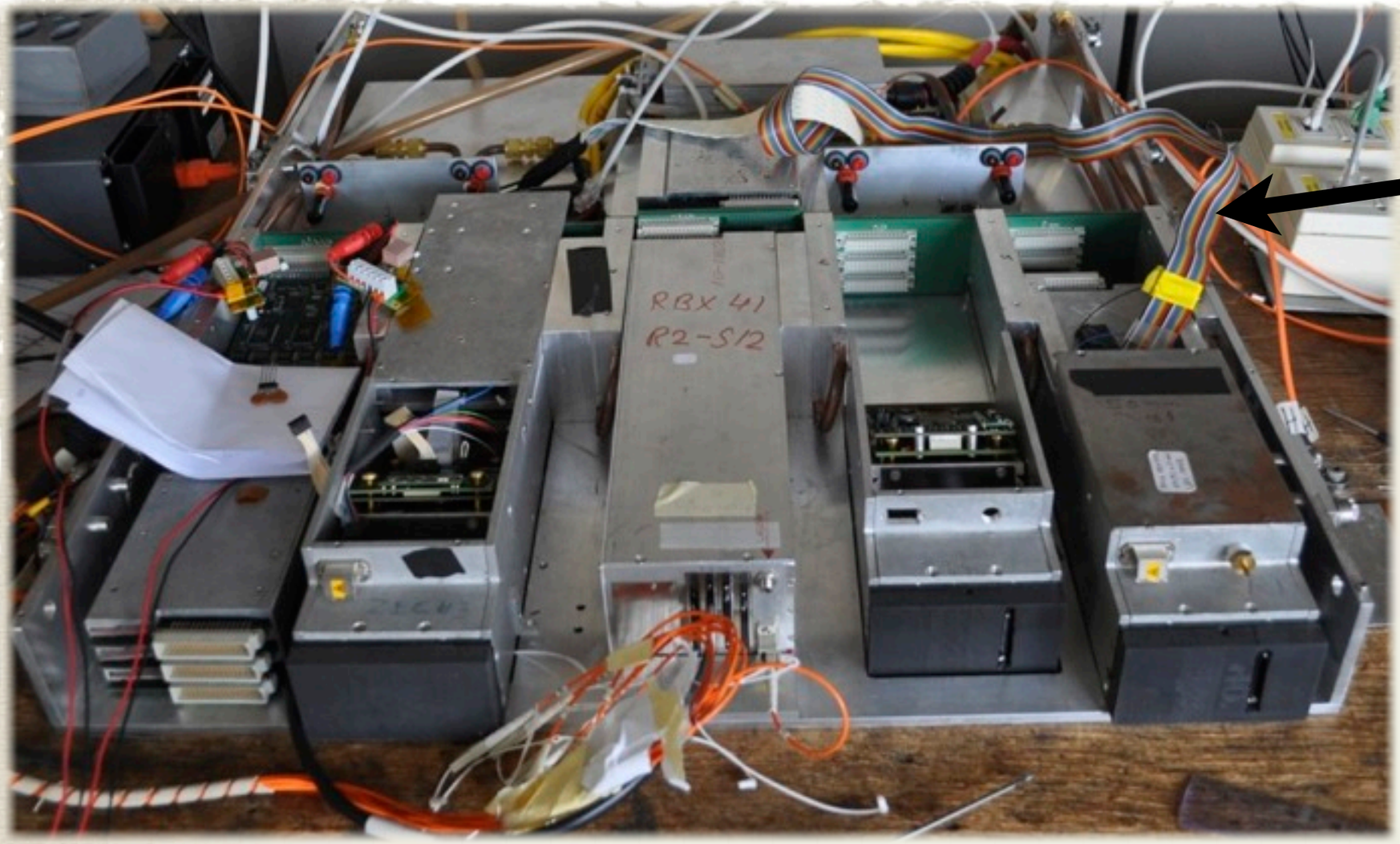


A front end board was powered using two SM01c dcdc converters.

The converters were modified to fit the application needs. One converter providing 5.3V and the other 3.3V.

The system noise was compared with the one obtained while powering the FE board with the nominal Linear Regulator.

Thanks to: Tullio Grassi



Readout box

72 channels

↓

4x Readout module

18 channels

↓

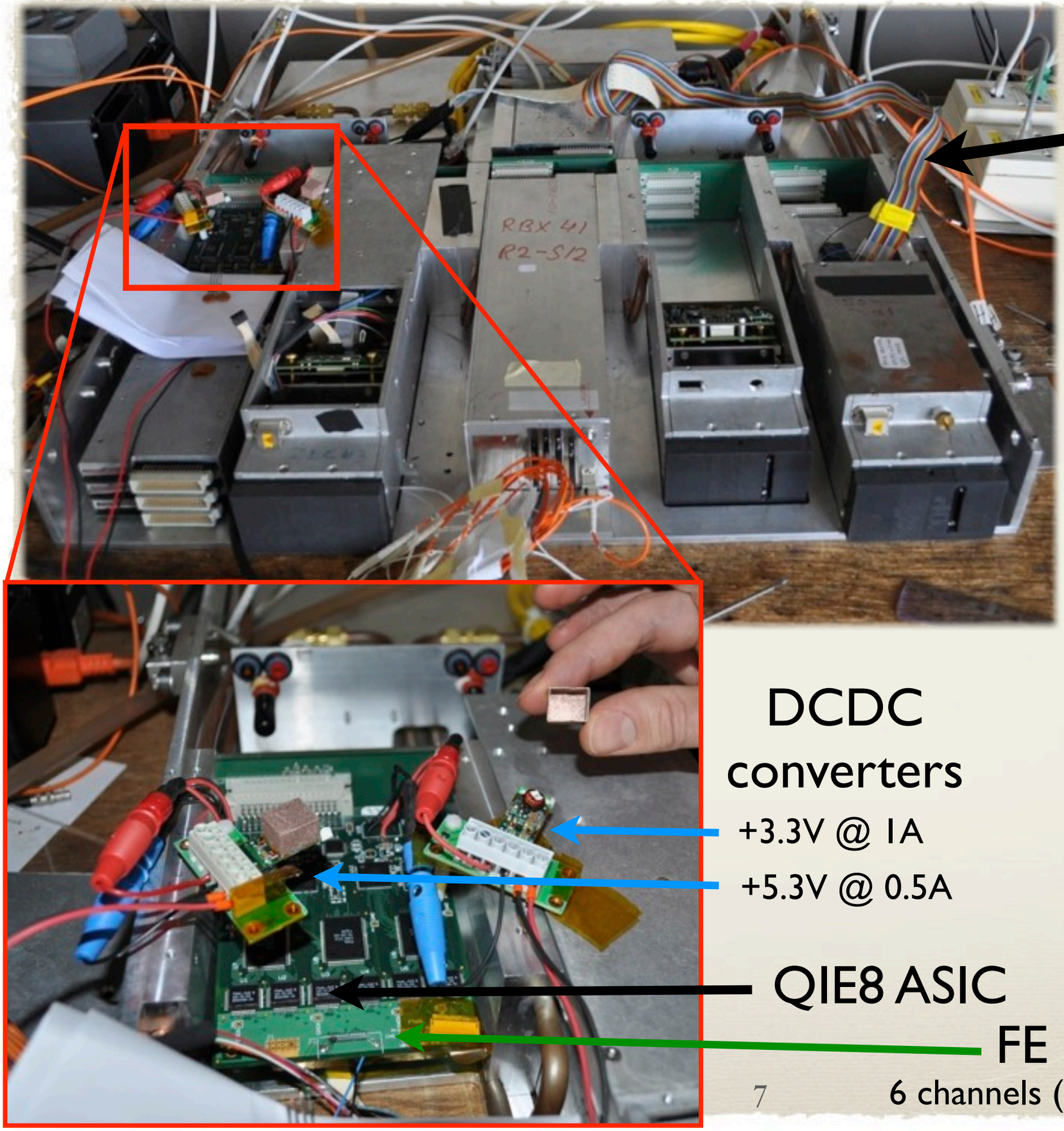
3x FE board

6 channels

↓

6x QIE8 ASIC

1 channel



Readout box

72 channels

4x Readout module

18 channels

3x FE board

6 channels

6x QIE8 ASIC

1 channel

DCDC converters

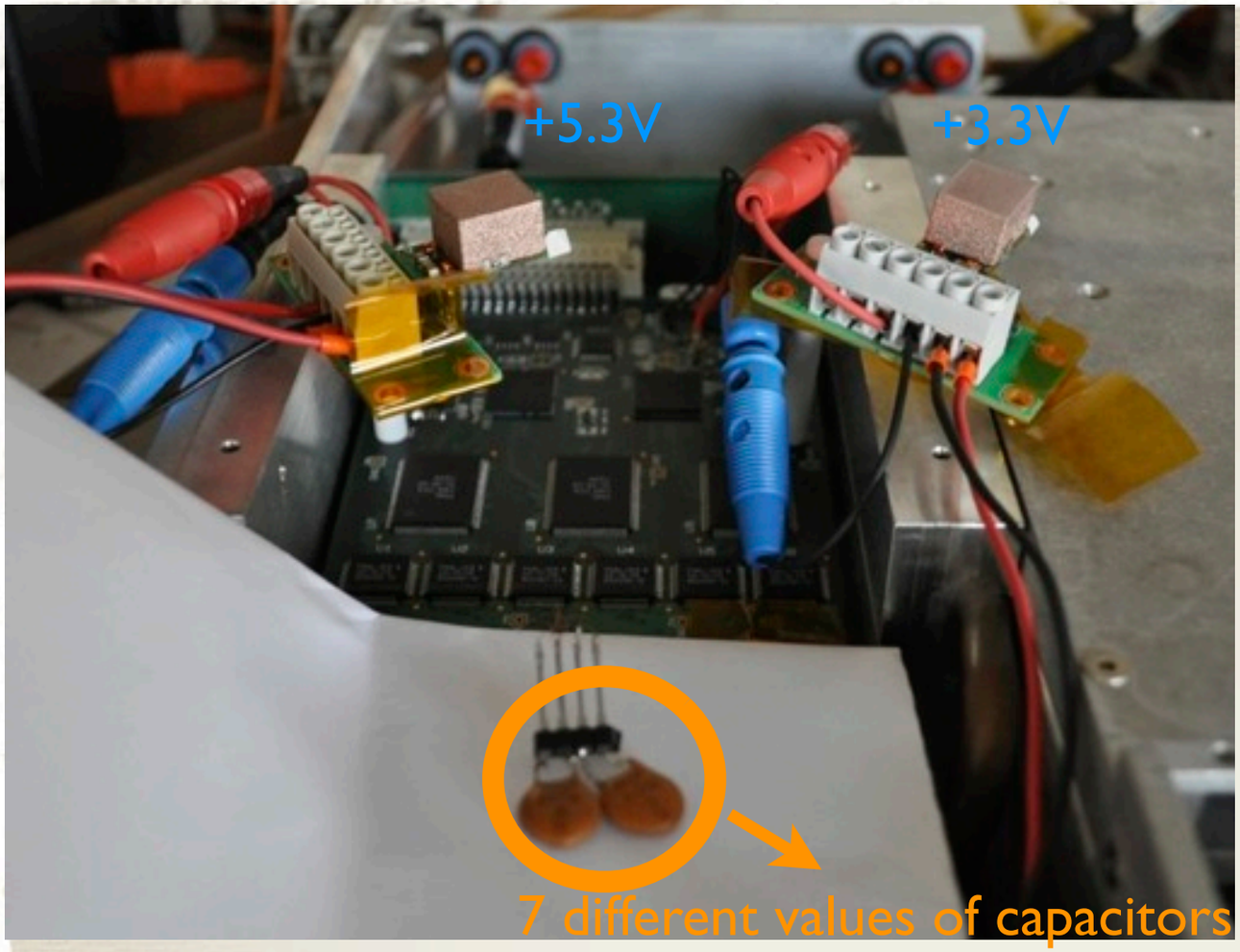
+3.3V @ 1A

+5.3V @ 0.5A

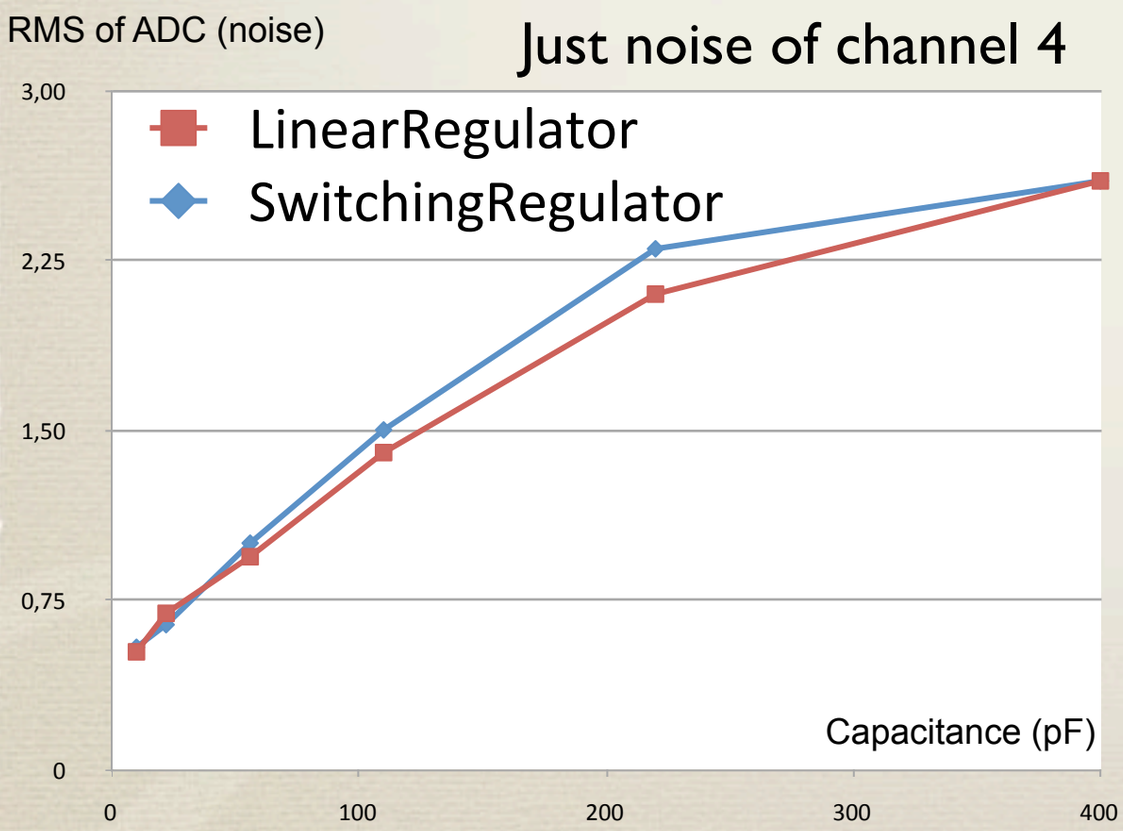
QIE8 ASIC

FE board

6 channels (one per QIE8 ASIC)



- The photodiode is emulated using different values of capacitors.
- A representation of the channel noise is obtained for each capacitor value.
- No significant difference of noise using DCDC converters instead of linear regulators.



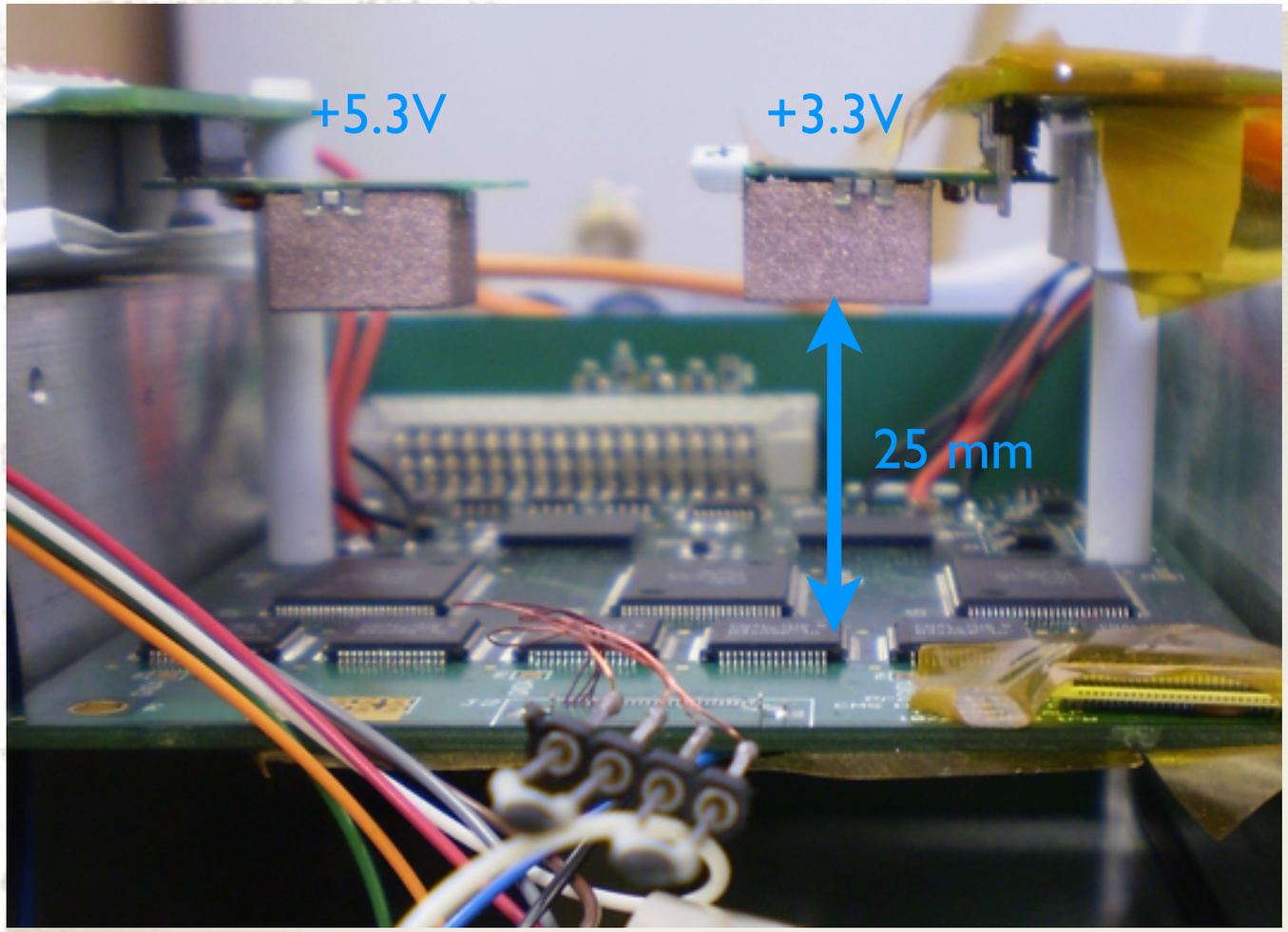
ORIGINAL REGULATOR

Capacitance (pF)	RMS of ADC
*10000	4,1
400	2,6
220	2,1
110	1,4
56	0,94
22	0,69
10	0,52

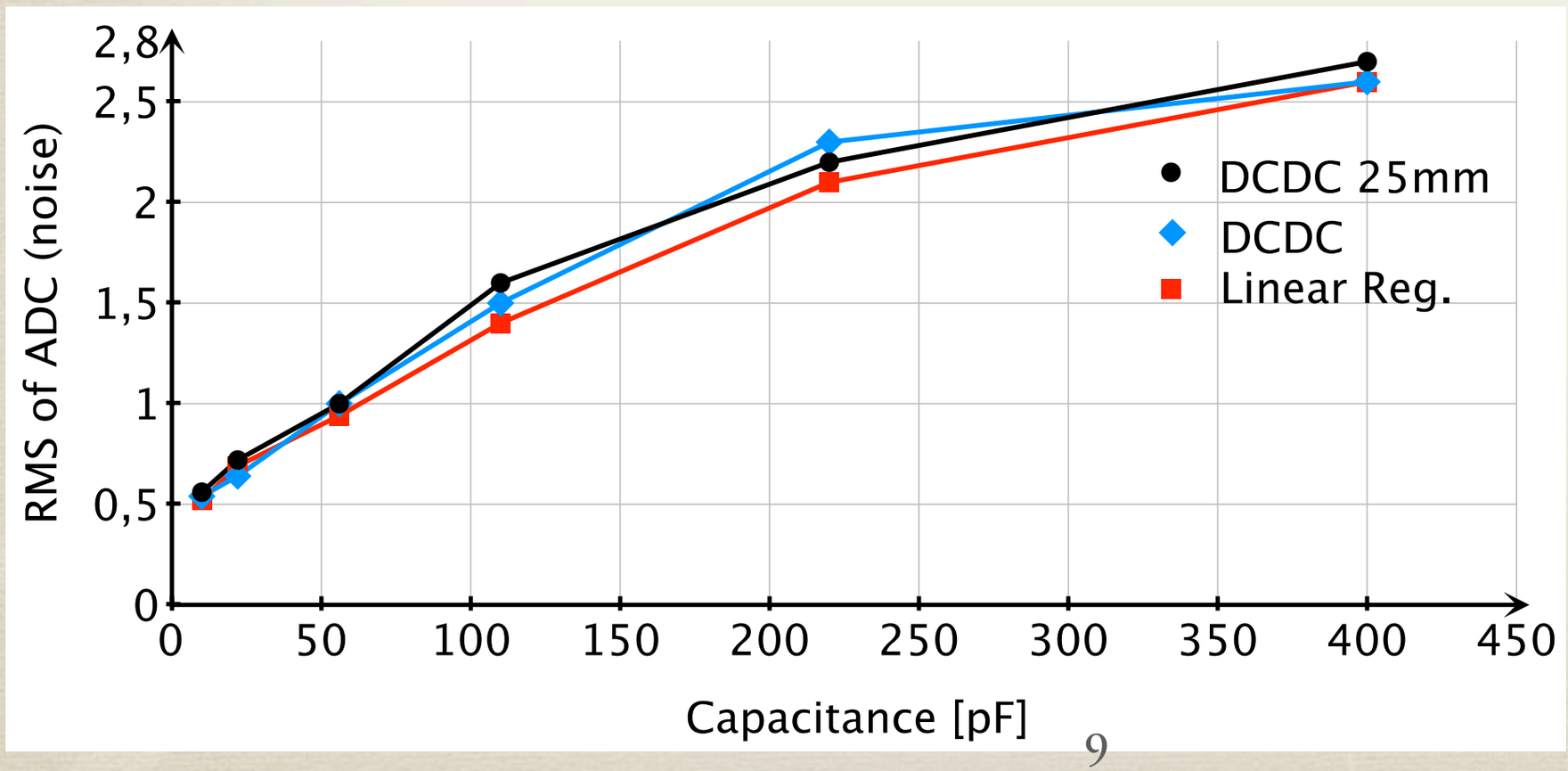
SWITCHING REGULATOR

Capacitance (pF)	RMS of ADC
*10000	4,5
400	2,6
220	2,3
110	1,5
56	1
22	0,64
10	0,54

*10nF does not represent a feasible capacitance value for the photodiode



- The same measurement was repeated for the converters upside down at 25mm from the QIE ASICs
- The use of DCDC converters at close proximity do not degrade the system performance.



SWITCHING REGULATOR
(25 mm from QIE ASIC)

Capacitance (pF)	RMS of ADC
*10000	--
400	2,7
220	2,2
110	1,6
56	1
22	0,72
10	0,56

*10nF does not represent a feasible capacitance value for the photodiode

Conclusion

- The noise performance of the switching regulators is comparable with the one of linear regulators, even when placed at close proximity (25mm) from the QIE8 ASICs.

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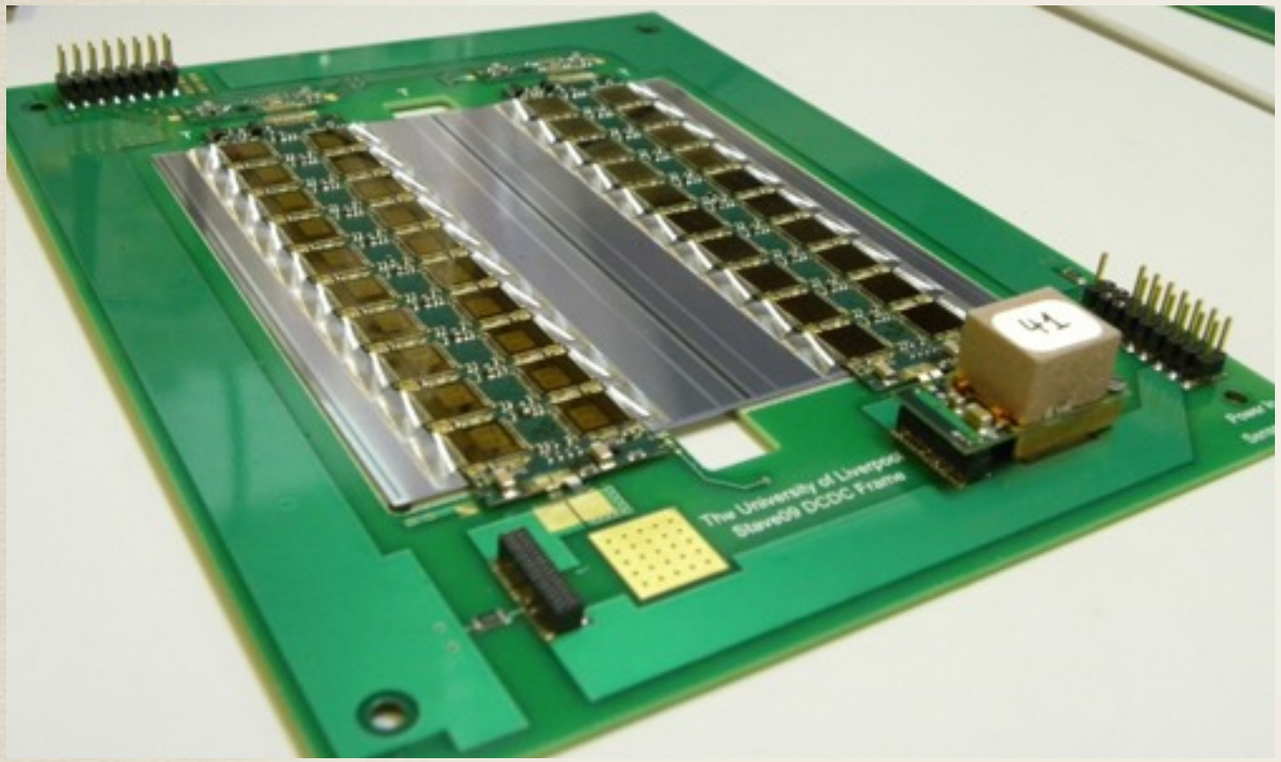
What's next

- Close collaboration to customize a converter for their particular needs, based on requirements for the upgraded QIE10 FE board.

2)Test with Frame Module (Liverpool)

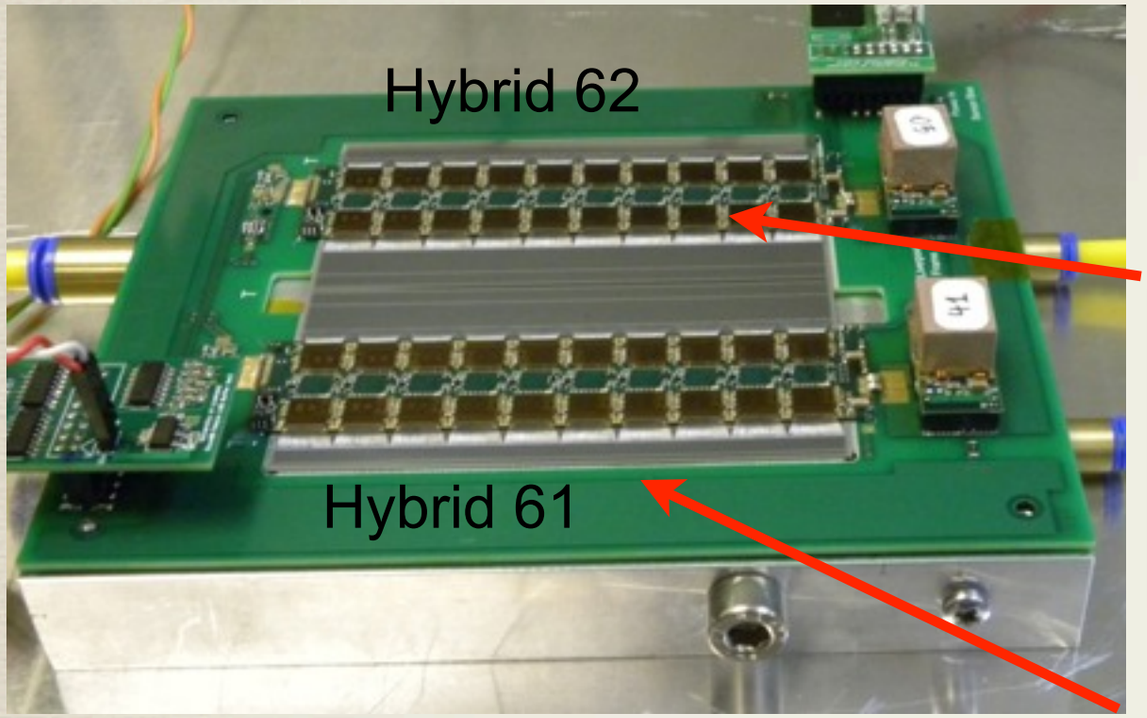


A Frame Module dedicated for DCDC converters have being tested using the two available converters.

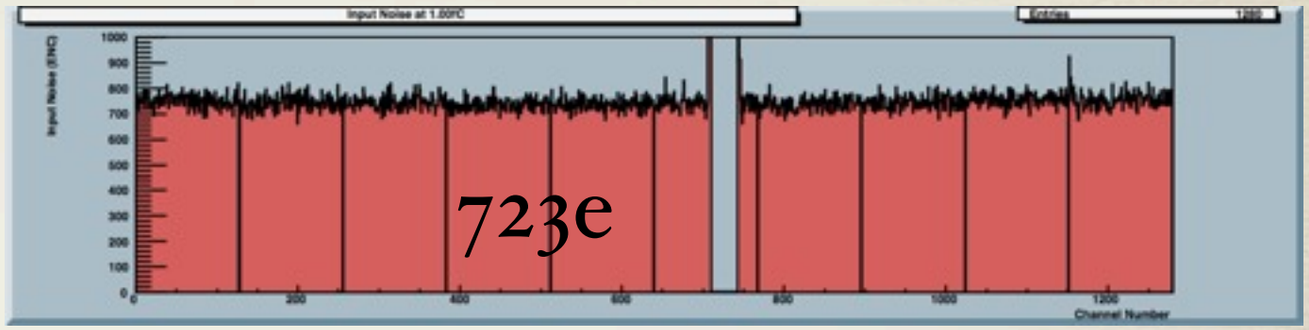
Different shield were tried, in order to undestand compatibility issues.

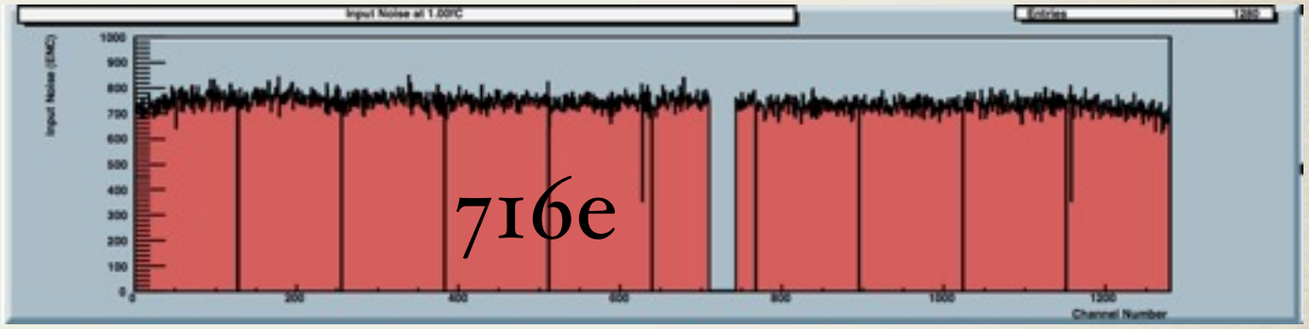
Thanks to: Ashley Greenall & Tony Affolder

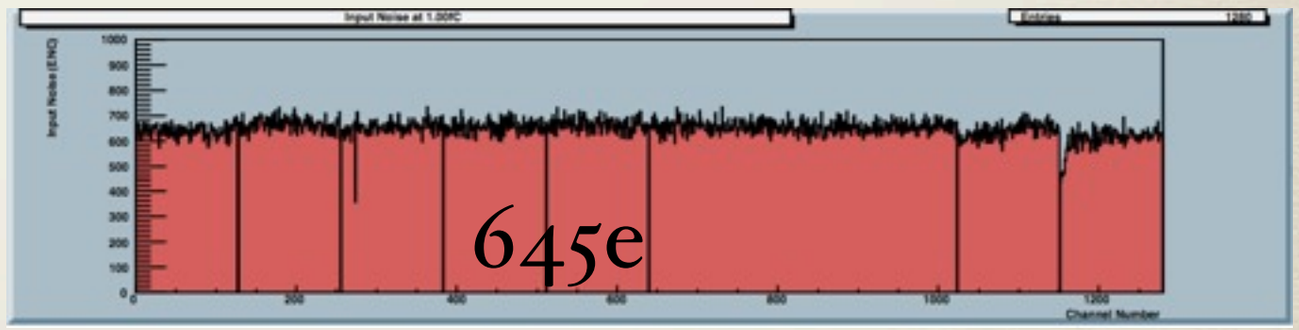
First results (Painted Shields)

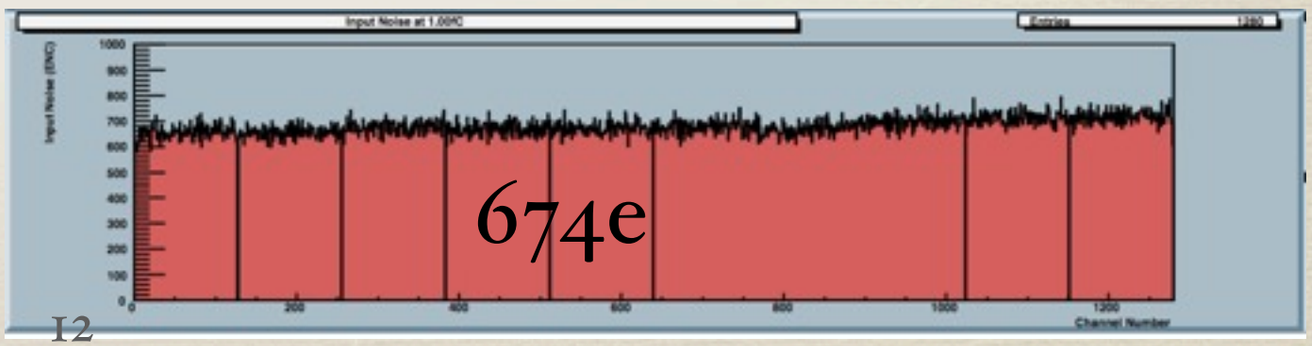


Hybrid	Linear regulator [ENC]	DCDC Painted Shield [ENC]
62	570	723
	596	716
61	585	645
	591	674

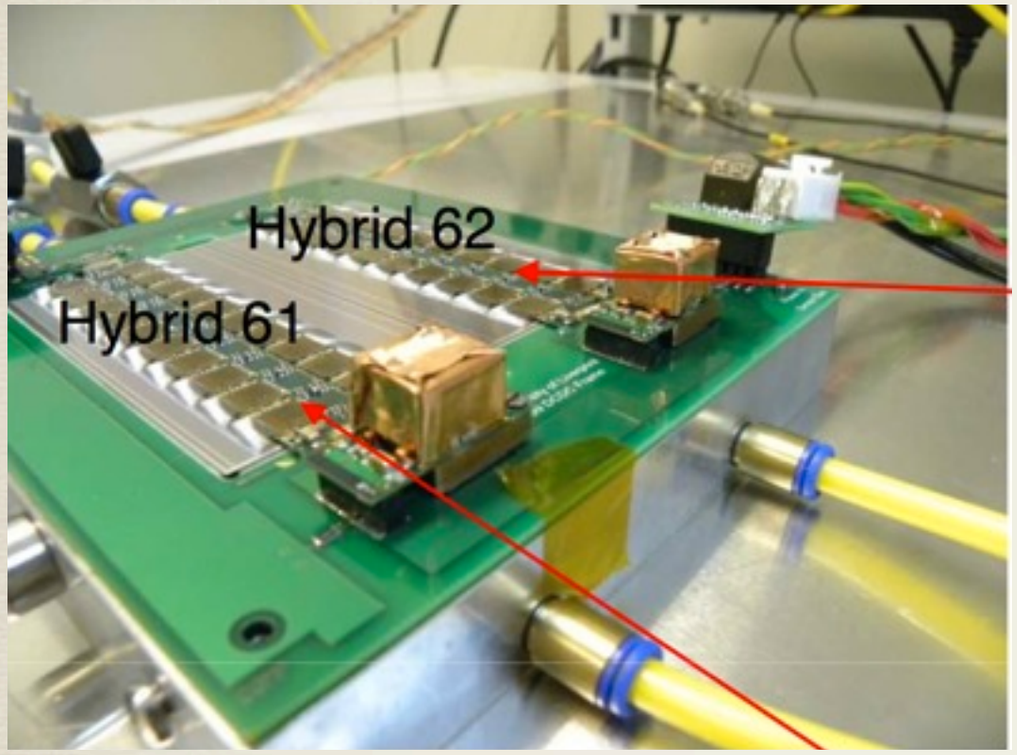




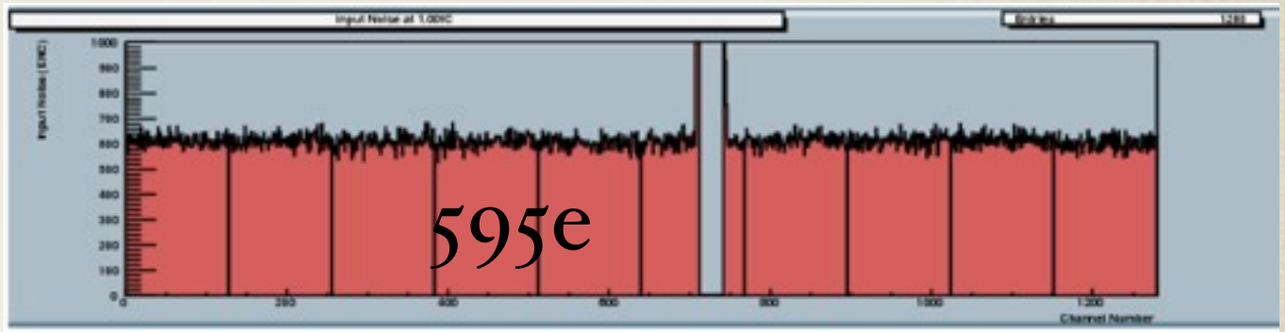


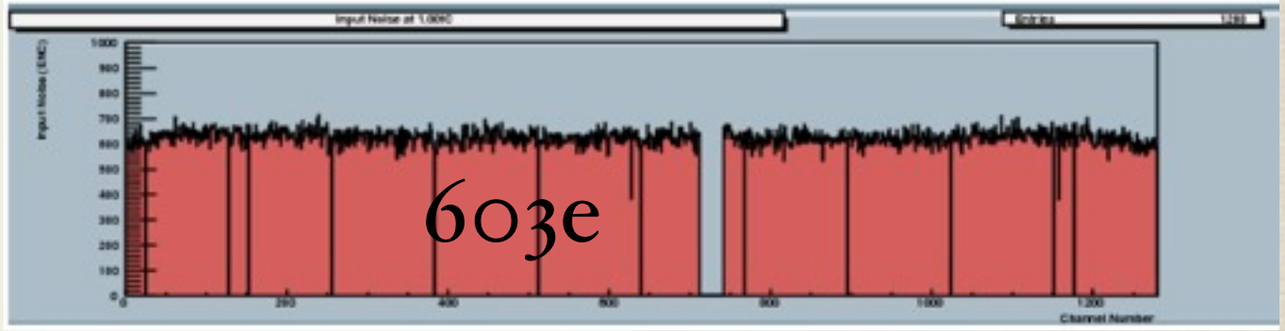


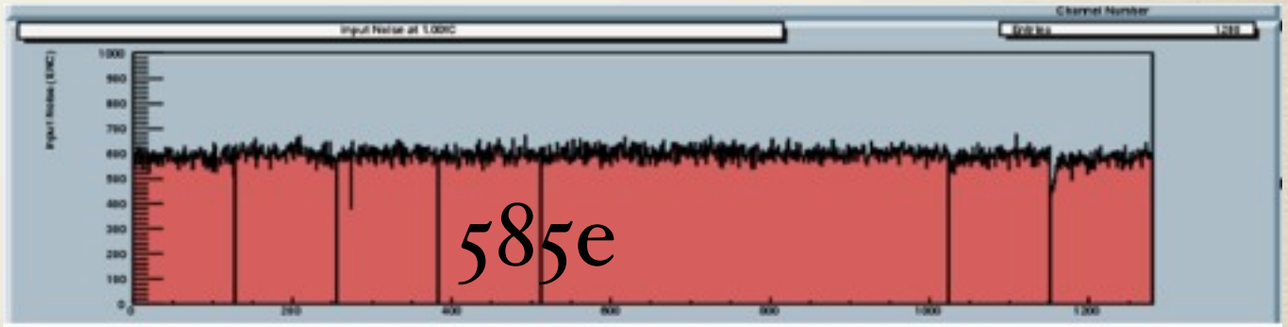
Shields wrapped with cu tape

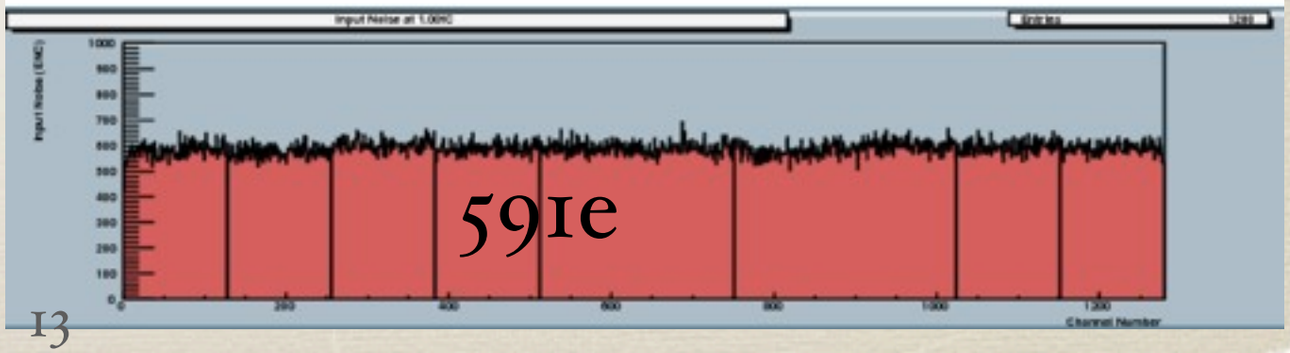


Hybrid	Linear regulator [ENC]	DCDC Shield Tape [ENC]
62	570	595
	596	603
61	585	585
	591	591









Conclusion

Hybrids are sensitive to magnetic field.

35um of cu tape is sufficient to shield the magnetic field emissions of the converters, becoming fully compatible with the modules.

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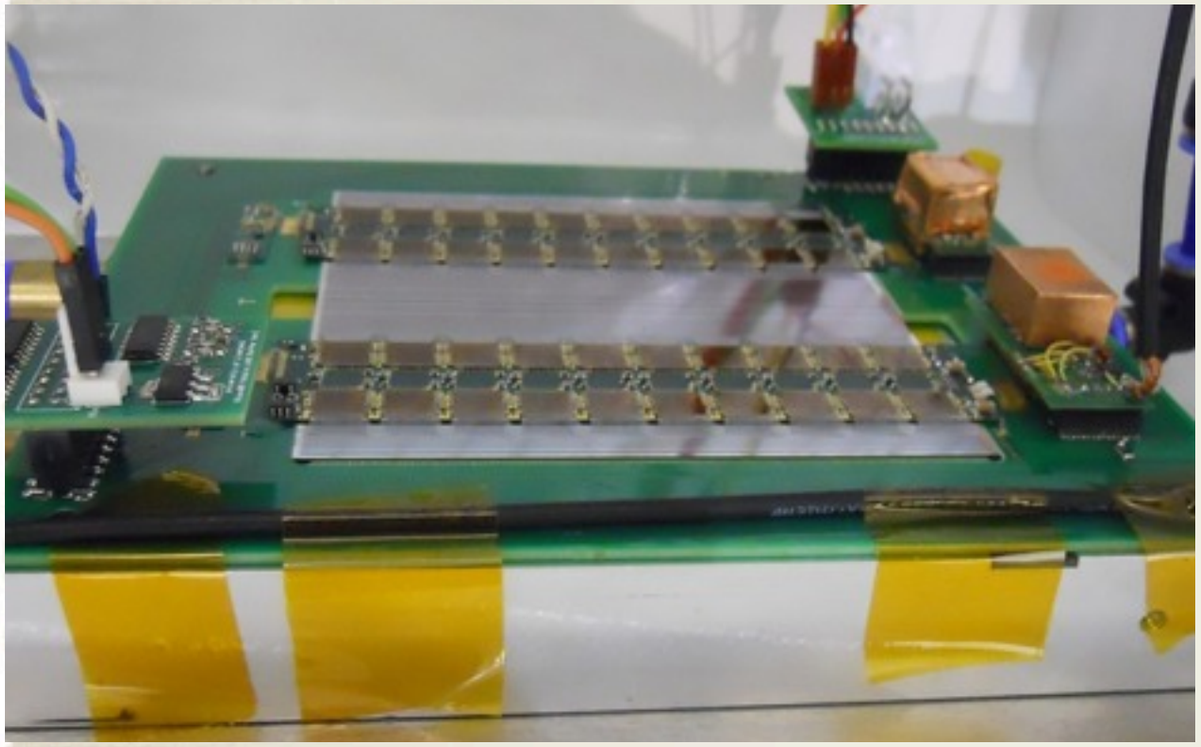
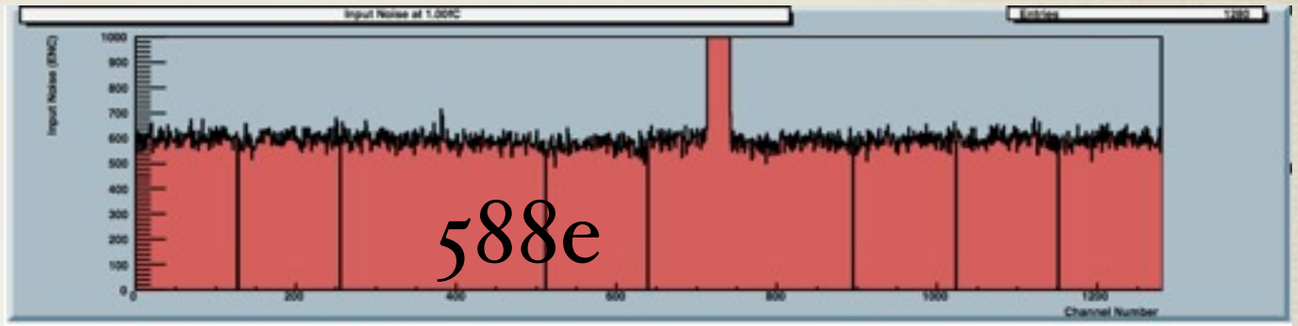
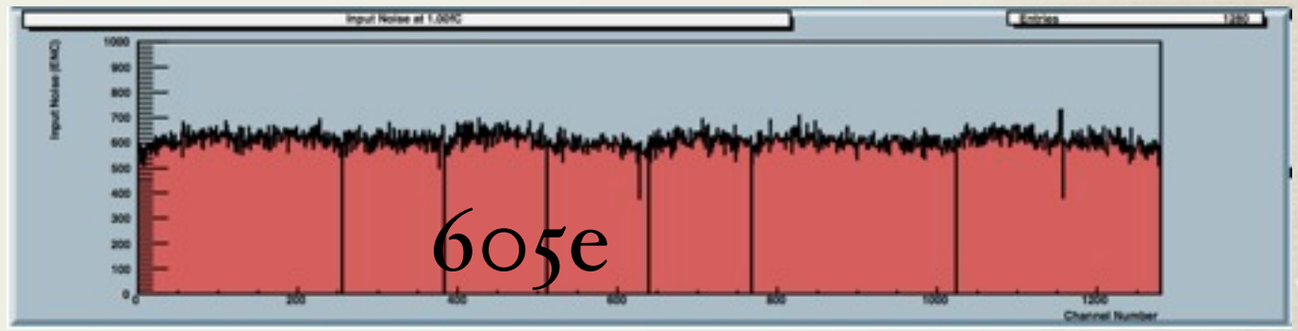
What's next

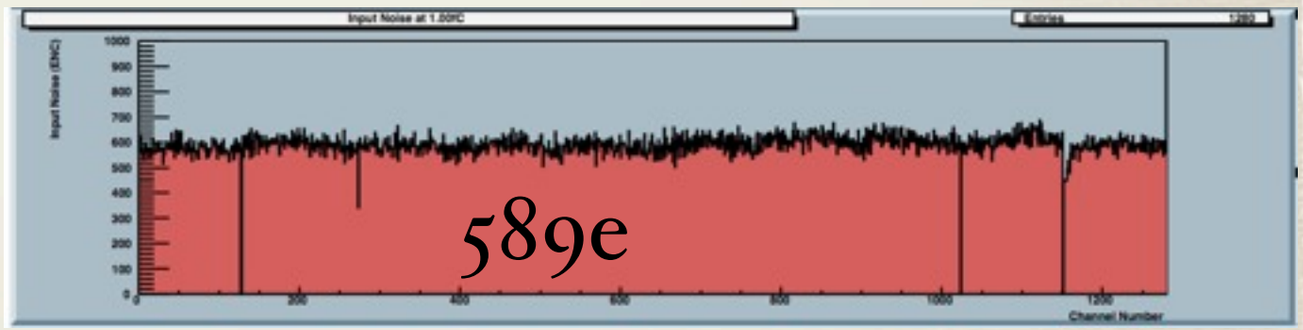
* Find the thinnest (manufacturable) shield for compatibility with the systems.
* Try more modules together: Stavelet.

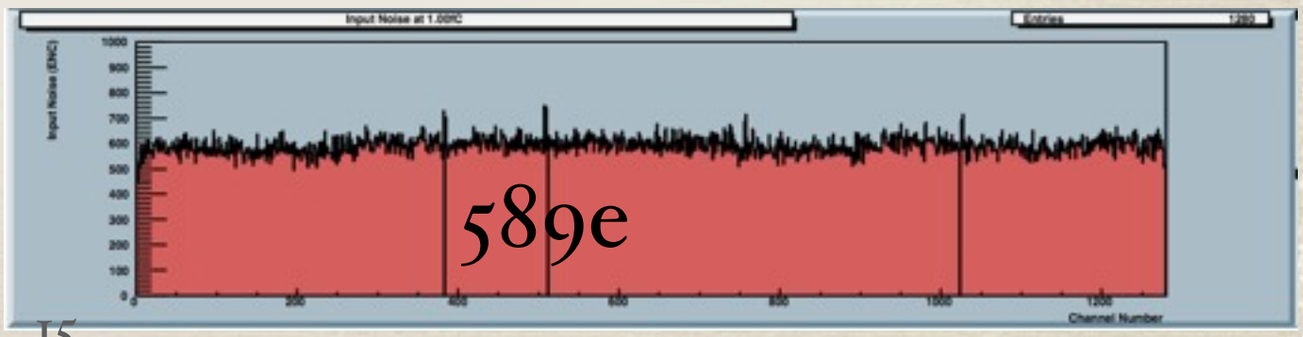
2)Test Frame Module with STV10 converter (@ bdg 180)











Hybrid	Linear regulator [ENC]	DCDC STV10 [ENC]
62	570	588
	596	605
61	585	589
	591	599

3)Test with UNIGE Module

Thanks to: Didier Ferrere & Sergio Gonzalez-Sevilla

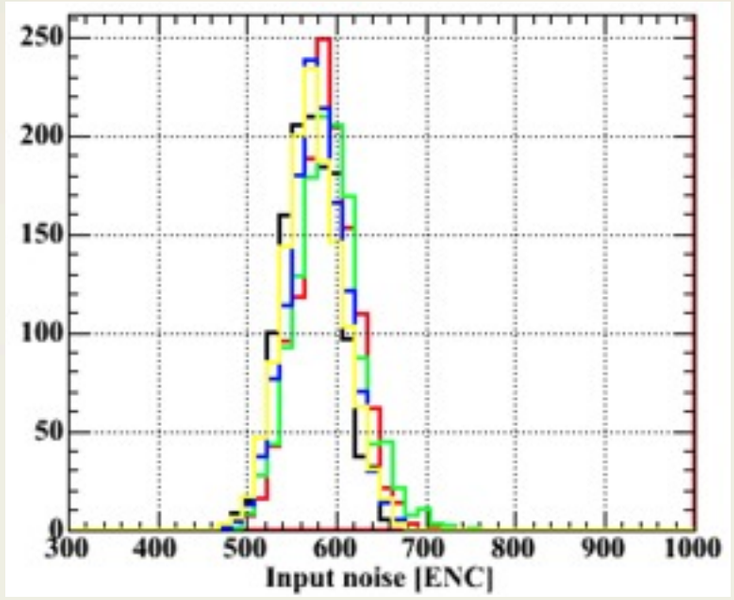
Input noise

Linear Regulator

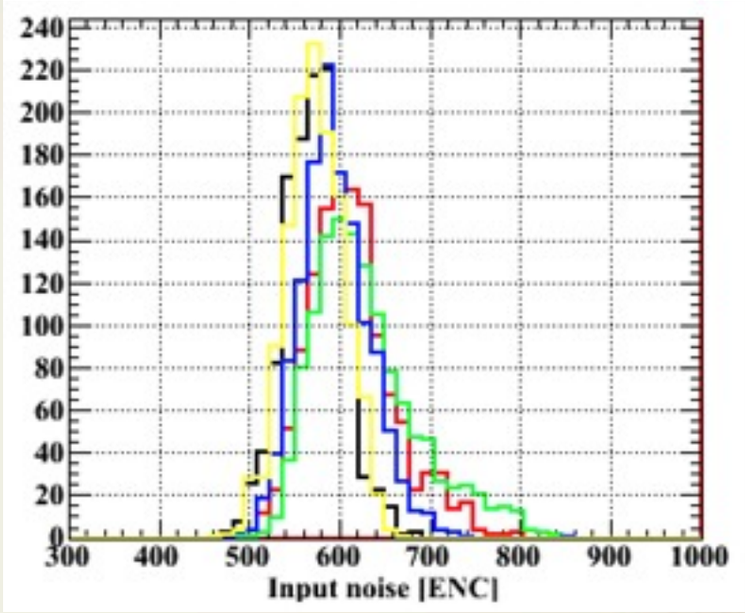
Painted Shield

Tape Shield

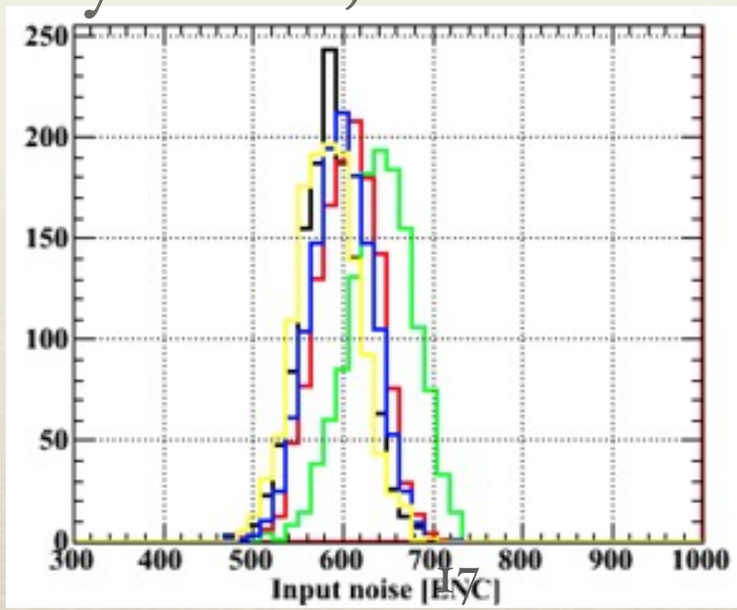
hybrid 0, stream 0



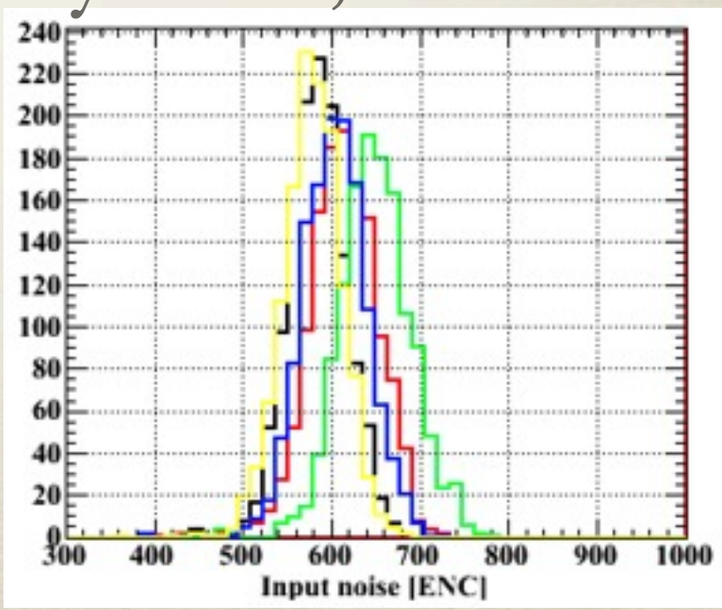
hybrid 0, stream 1



hybrid 1, stream 0



hybrid 1, stream 1



Input noise

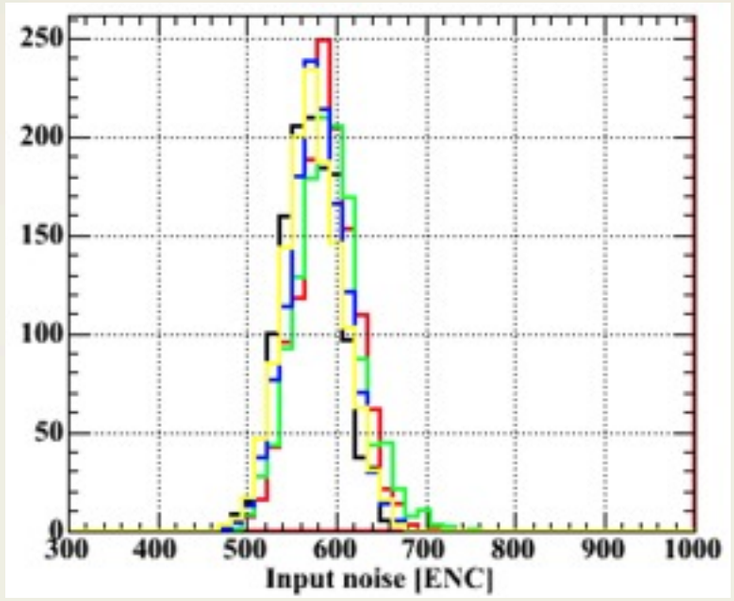
Linear Regulator

Painted Shield

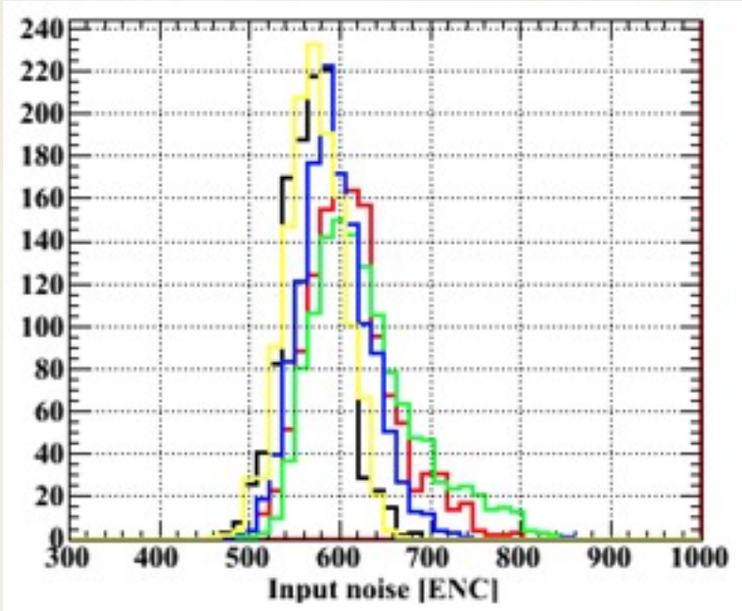
Tape Shield

Noise increases with DCDC converters with Painted Shield

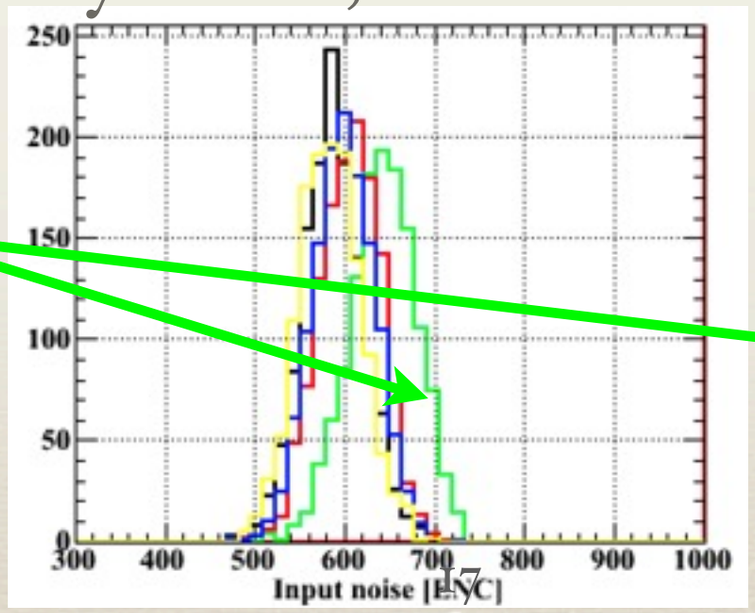
hybrid 0, stream 0



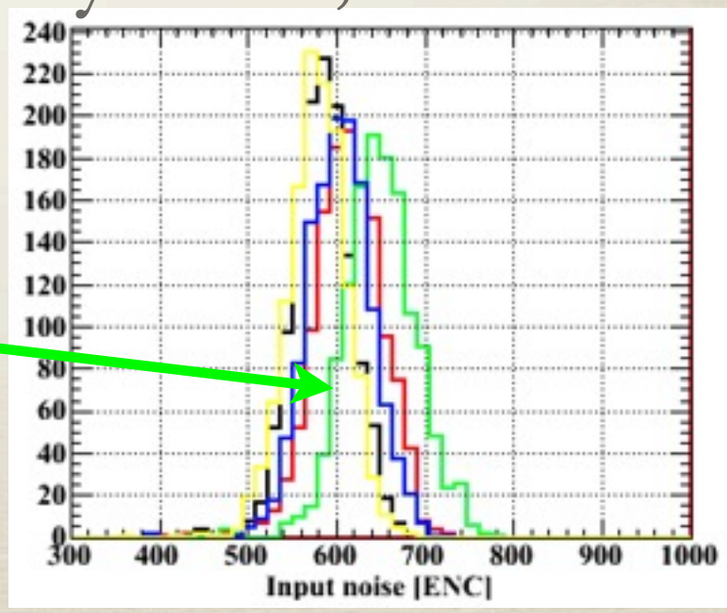
hybrid 0, stream 1



hybrid 1, stream 0



hybrid 1, stream 1



Input noise

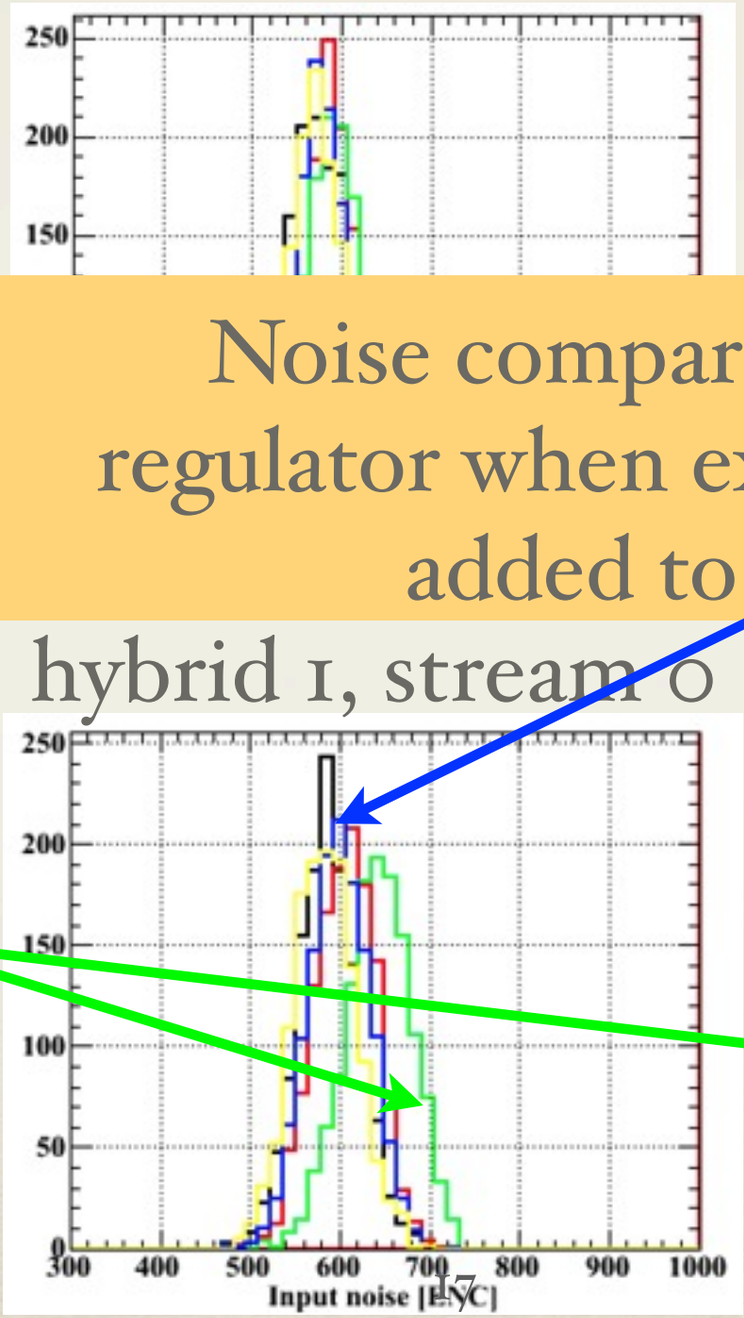
Linear Regulator

Painted Shield

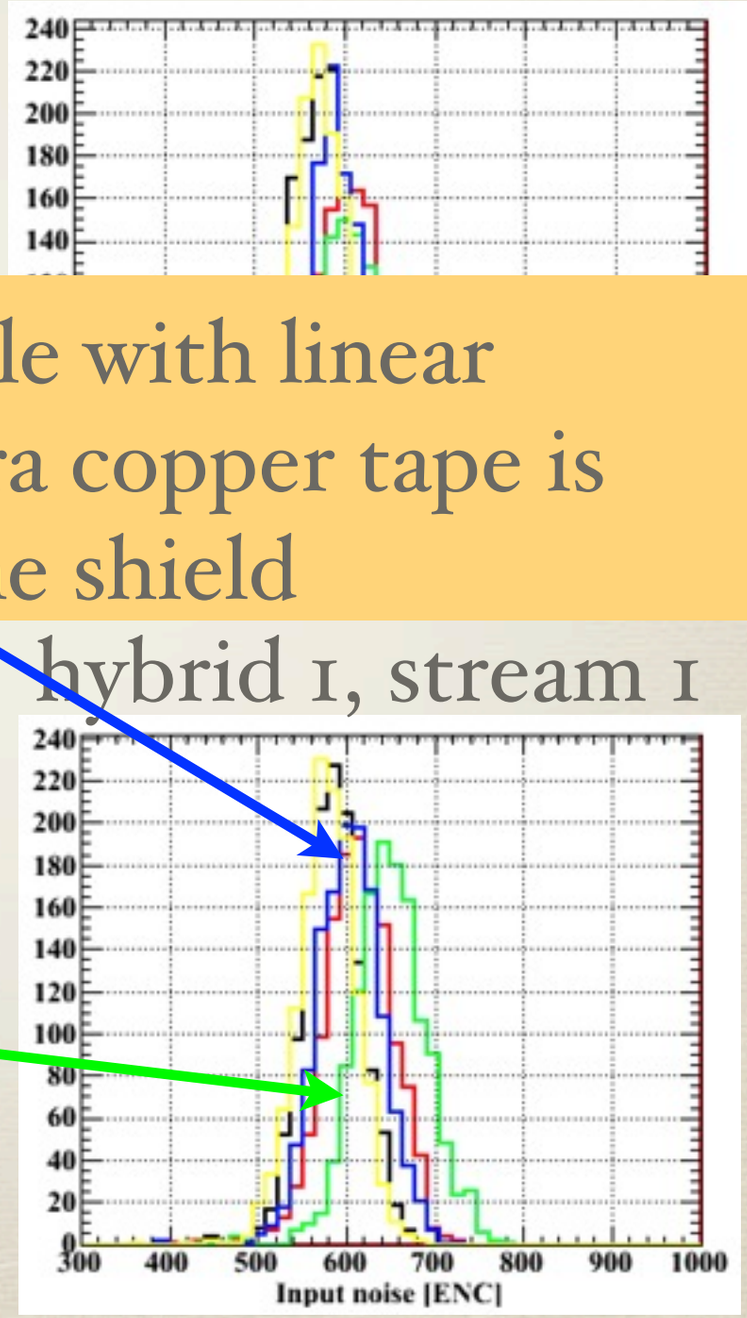
Tape Shield

Noise increases with DCDC converters with Painted Shield

hybrid 0, stream 0



hybrid 0, stream 1



Noise comparable with linear regulator when extra copper tape is added to the shield

hybrid 1, stream 0

hybrid 1, stream 1

Conclusion

This test confirms the sensitivity of the Hybrids to magnetic field emissions. Noise levels differ from those measured in Liverpool due to the difference in distance between DCDC converters and hybrids.

Similarly, 35um of cu tape is sufficient for providing fully compatible with the modules.

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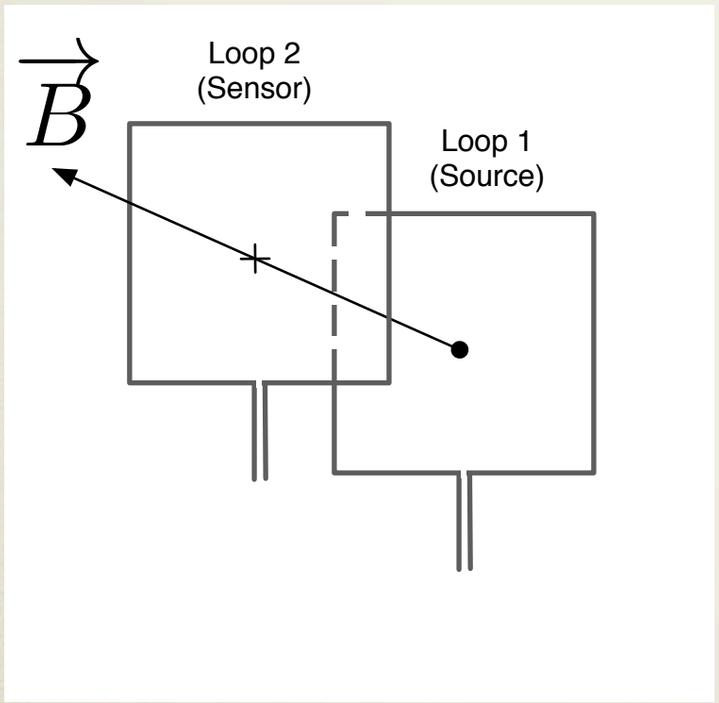
What's next

* Try more modules together: Super Module

Shielding effectiveness

The sensitivity of FE systems to magnetic field yields to studies of how to improve B-field shield effectiveness. As well, a way to measure their effectiveness for comparison purpose must be defined.

Top Side View



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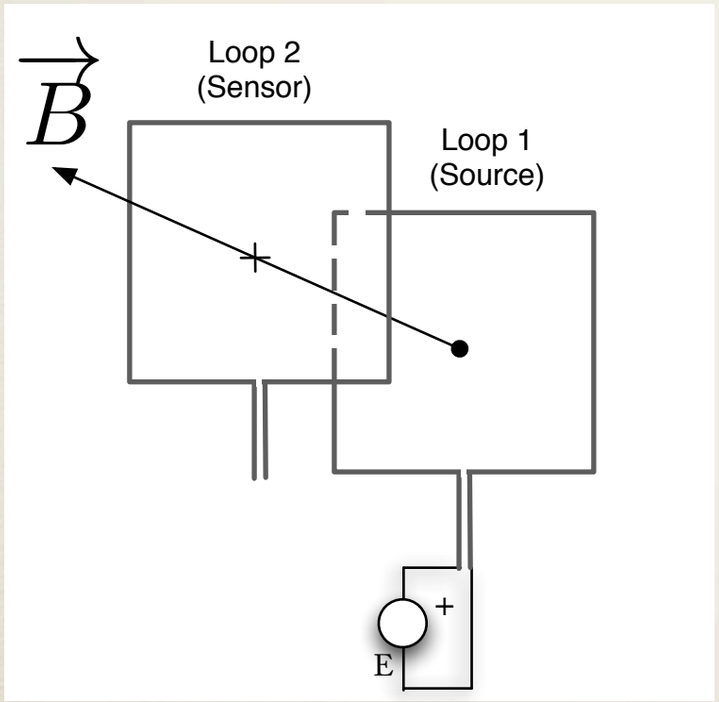

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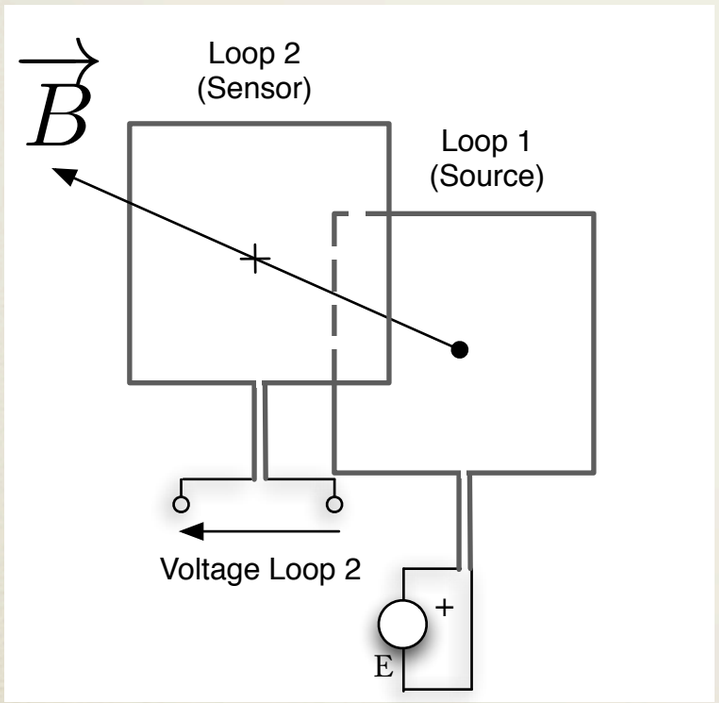

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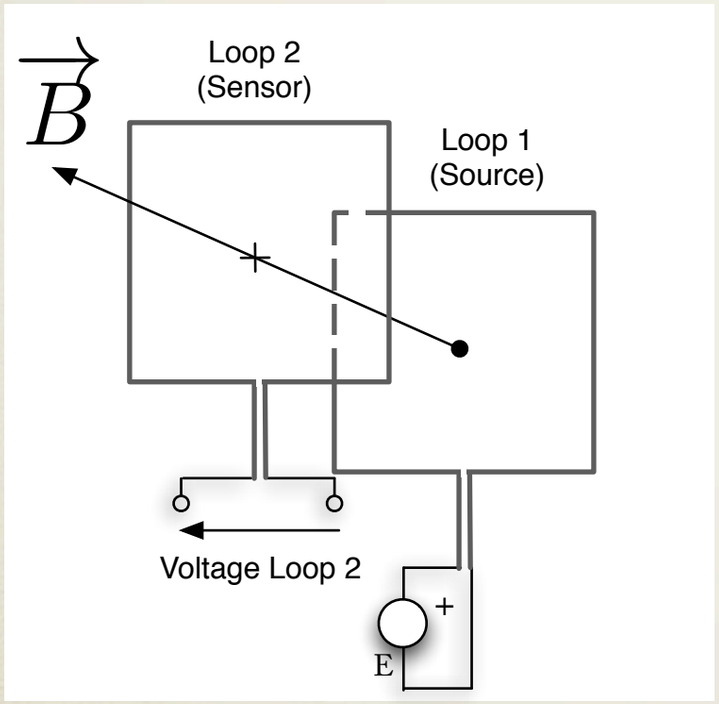
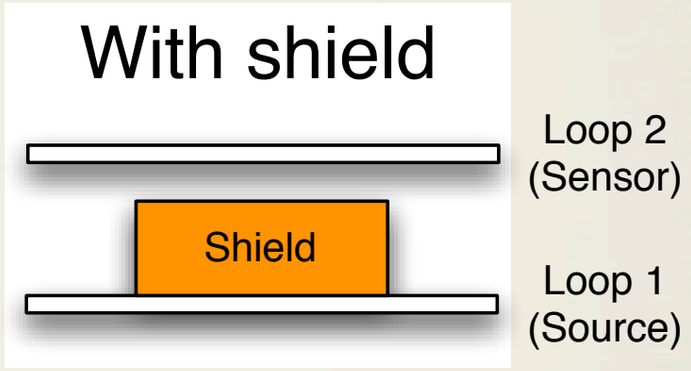


Front View



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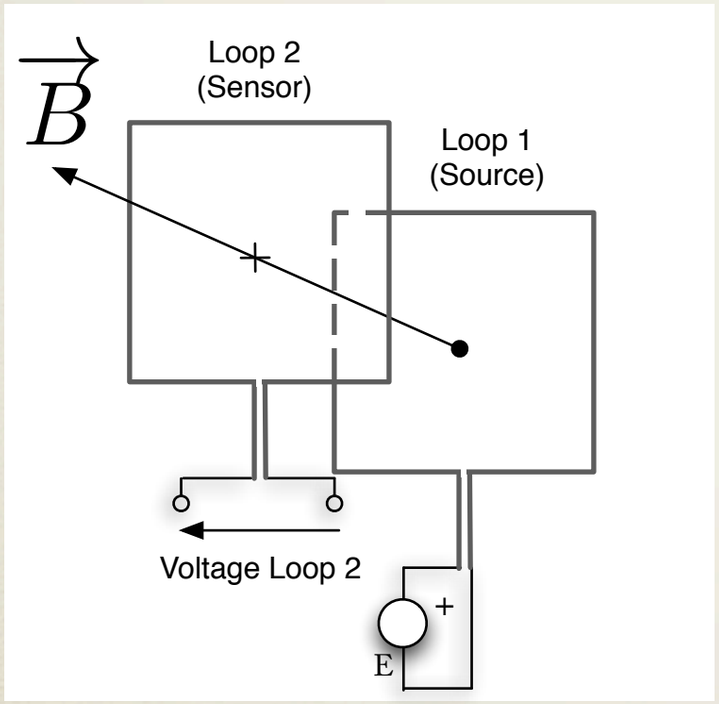
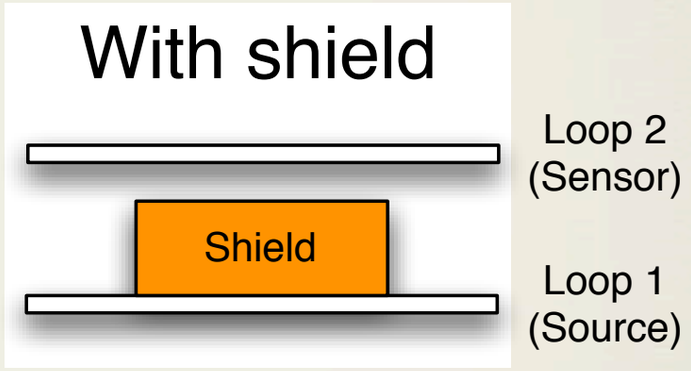
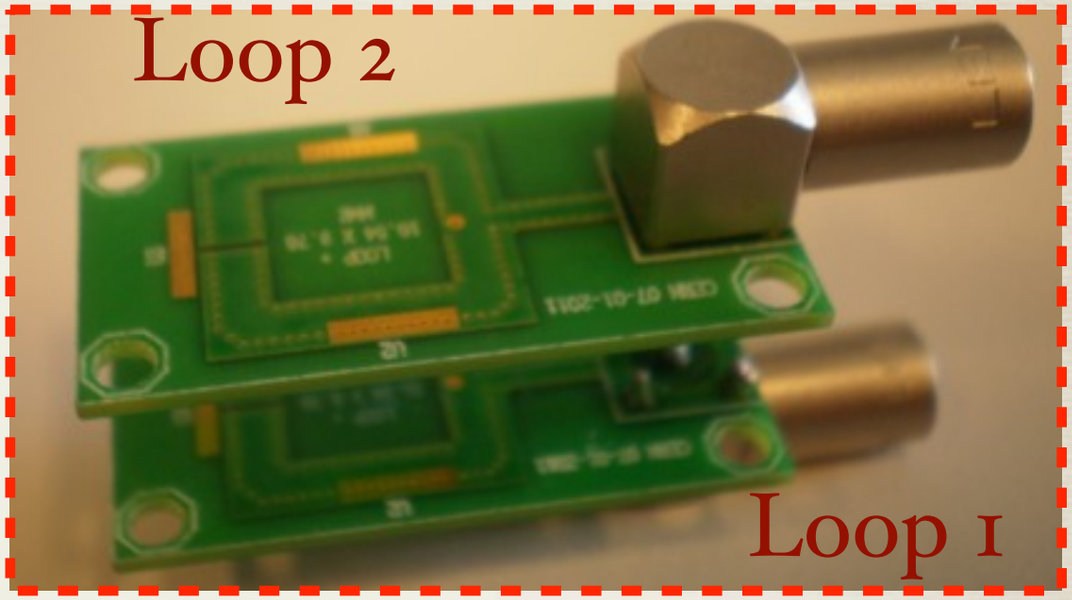


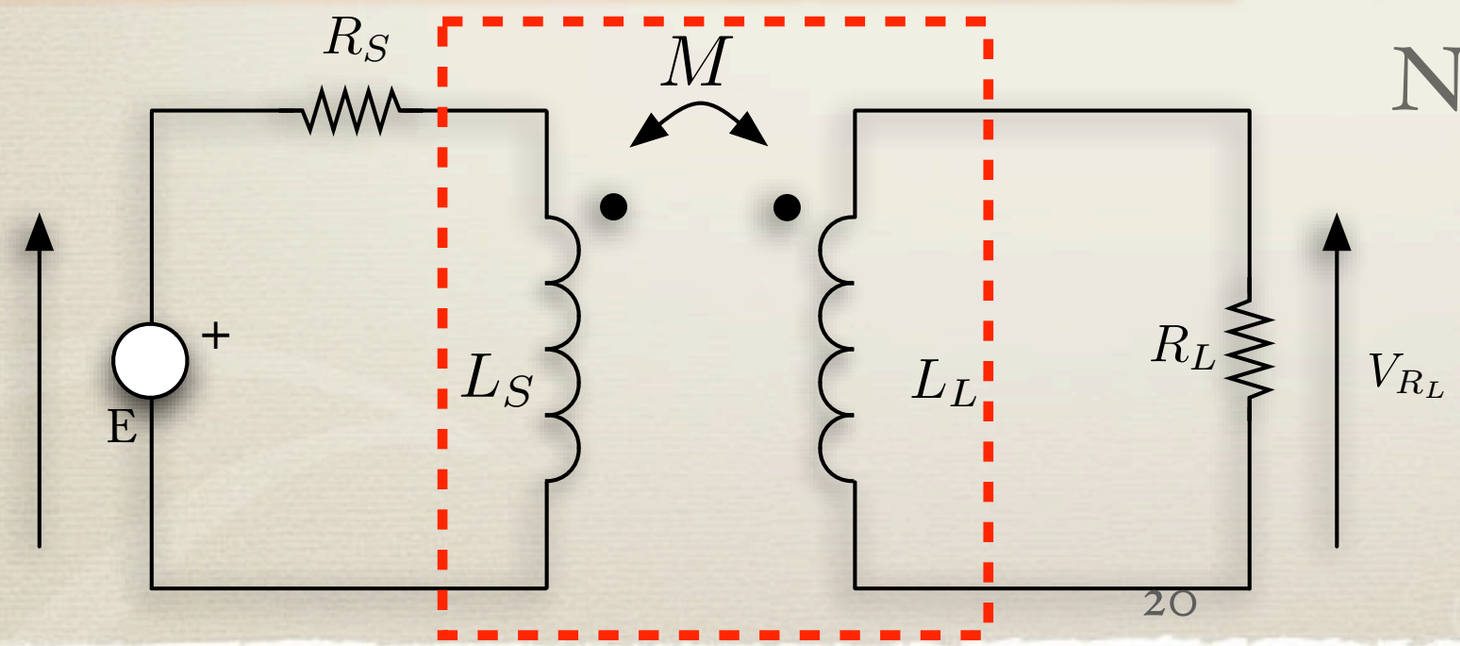
Front View



$$\text{Shielding Effectiveness} = \frac{\text{Voltage Loop 2 without shield}}{\text{Voltage Loop 2 with shield}}$$

Shielding effectiveness

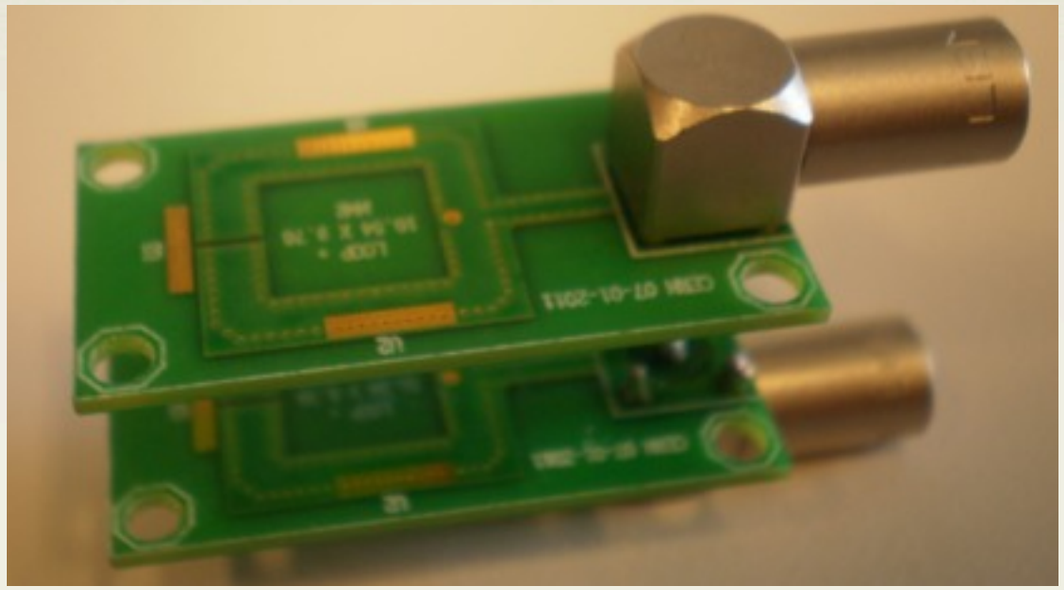




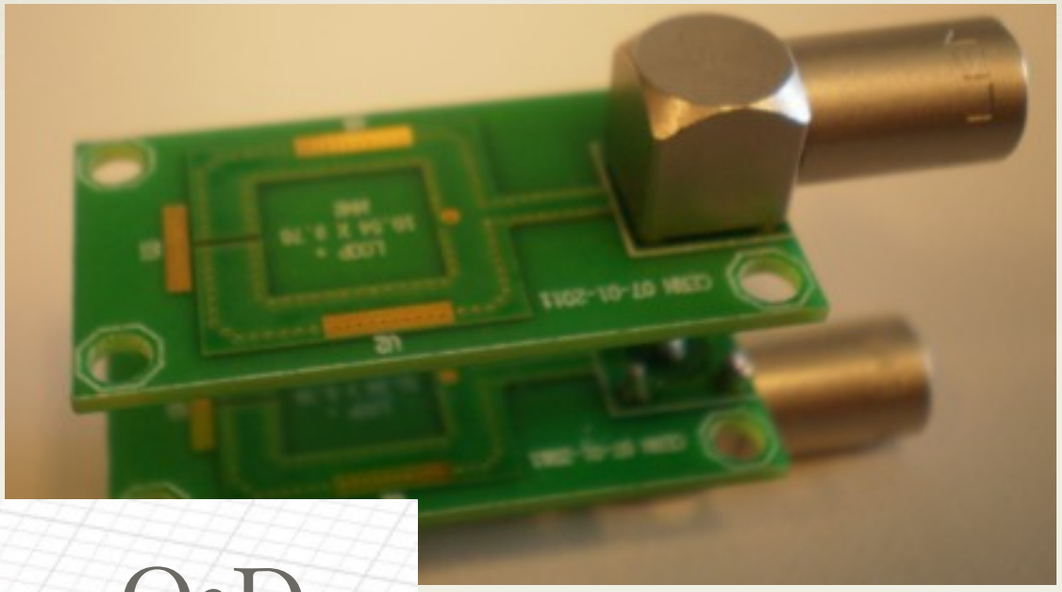
Network Analyzer output

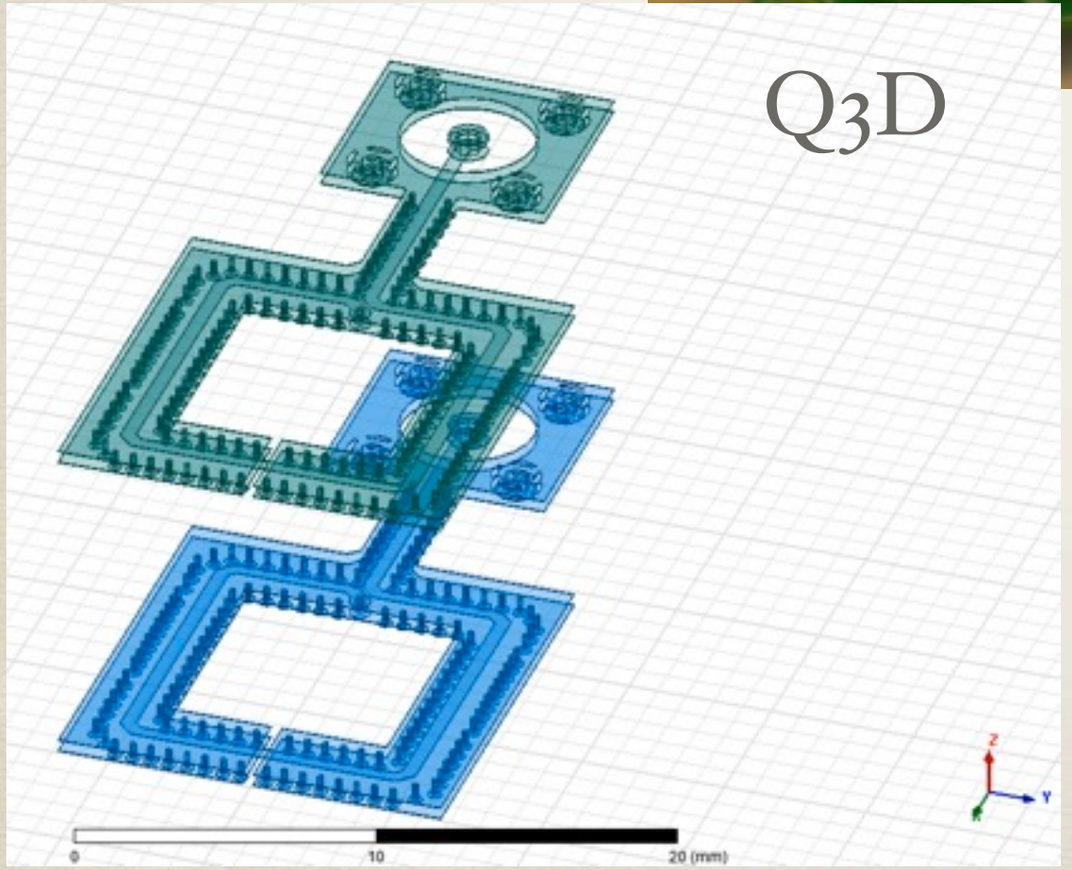
$$S_{21} = 20 \log \frac{2V_{R_L}}{E}$$

Simulation & validation

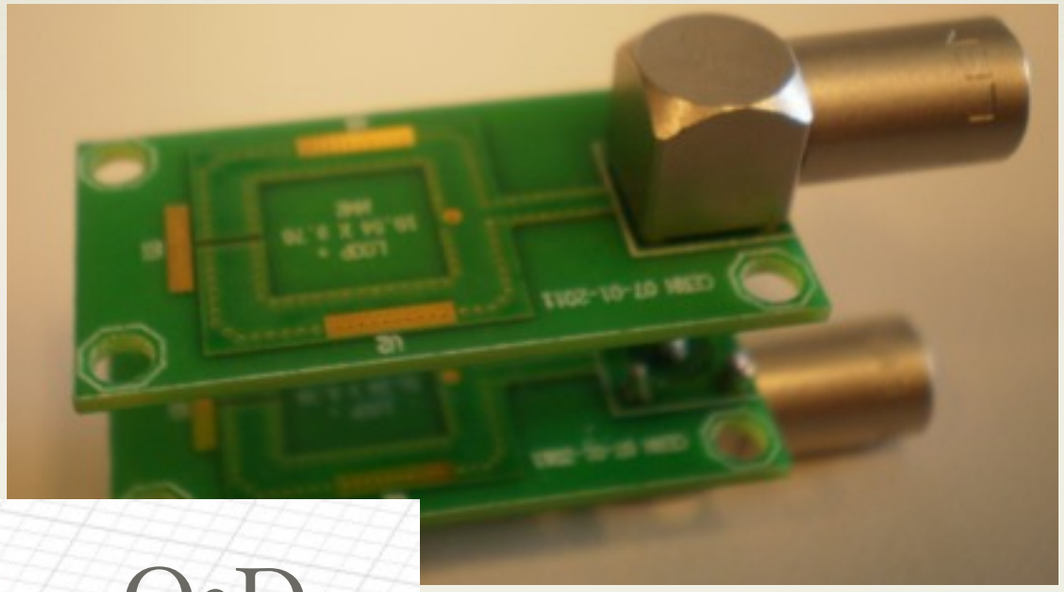


Simulation & validation

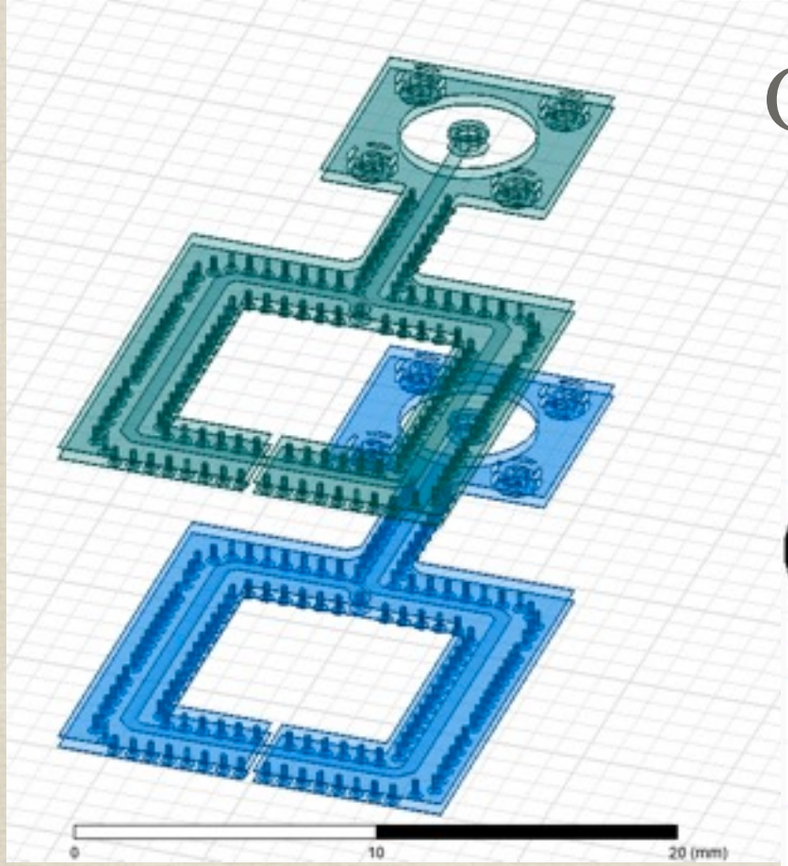




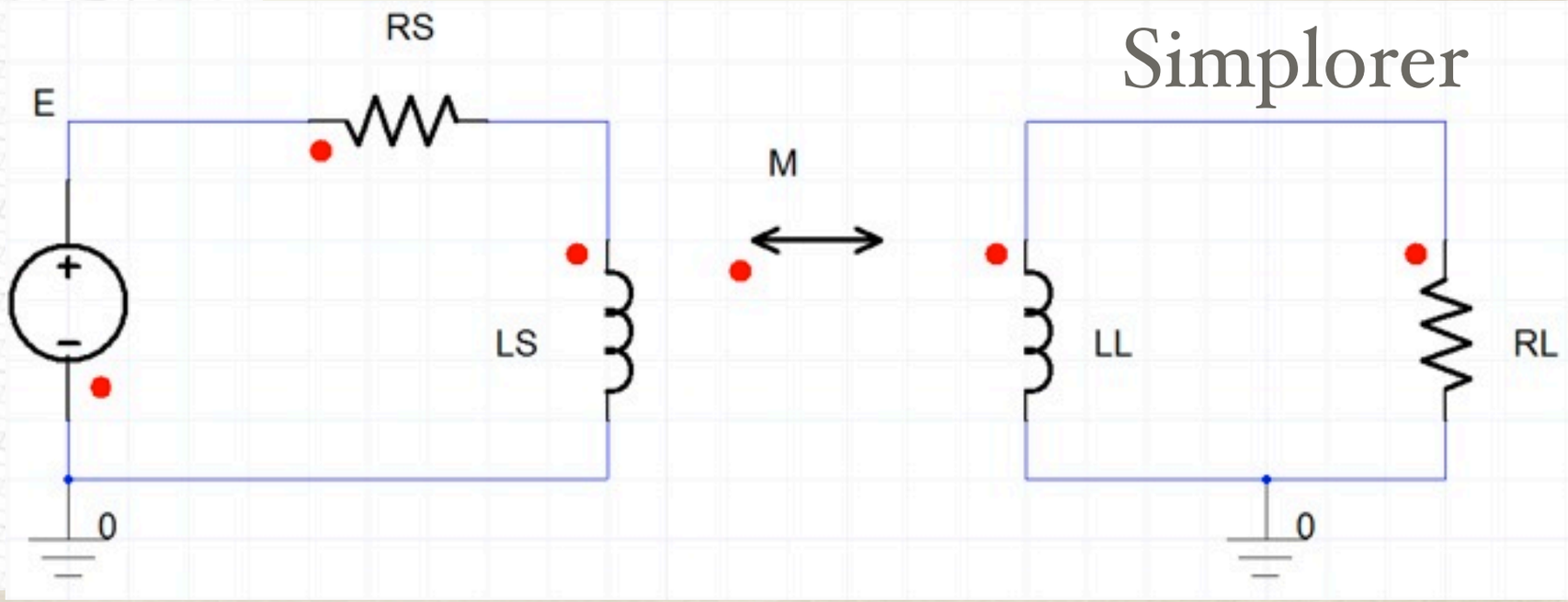
Simulation & validation



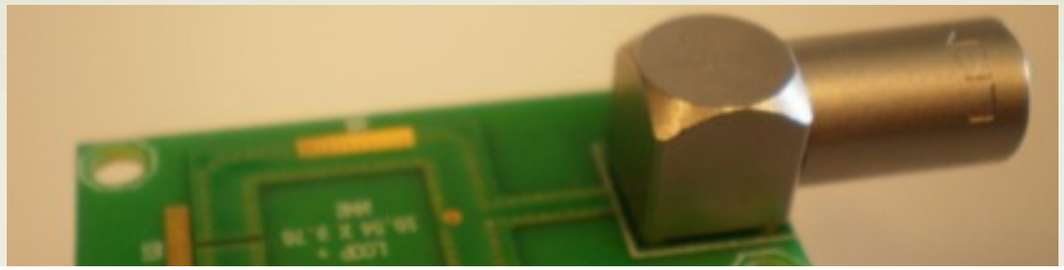
Q3D

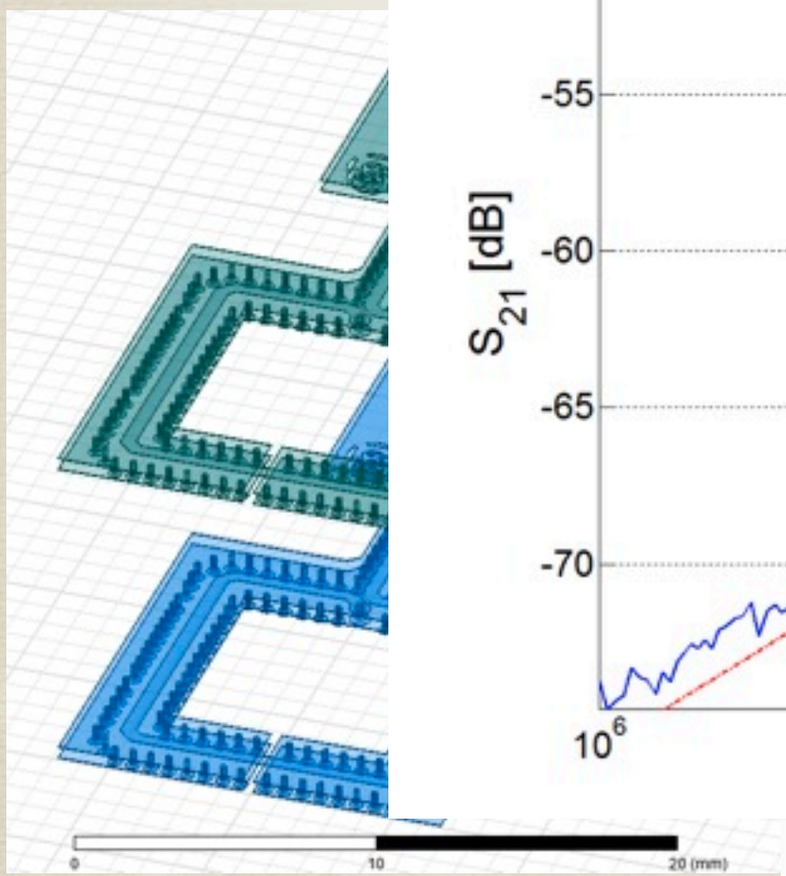


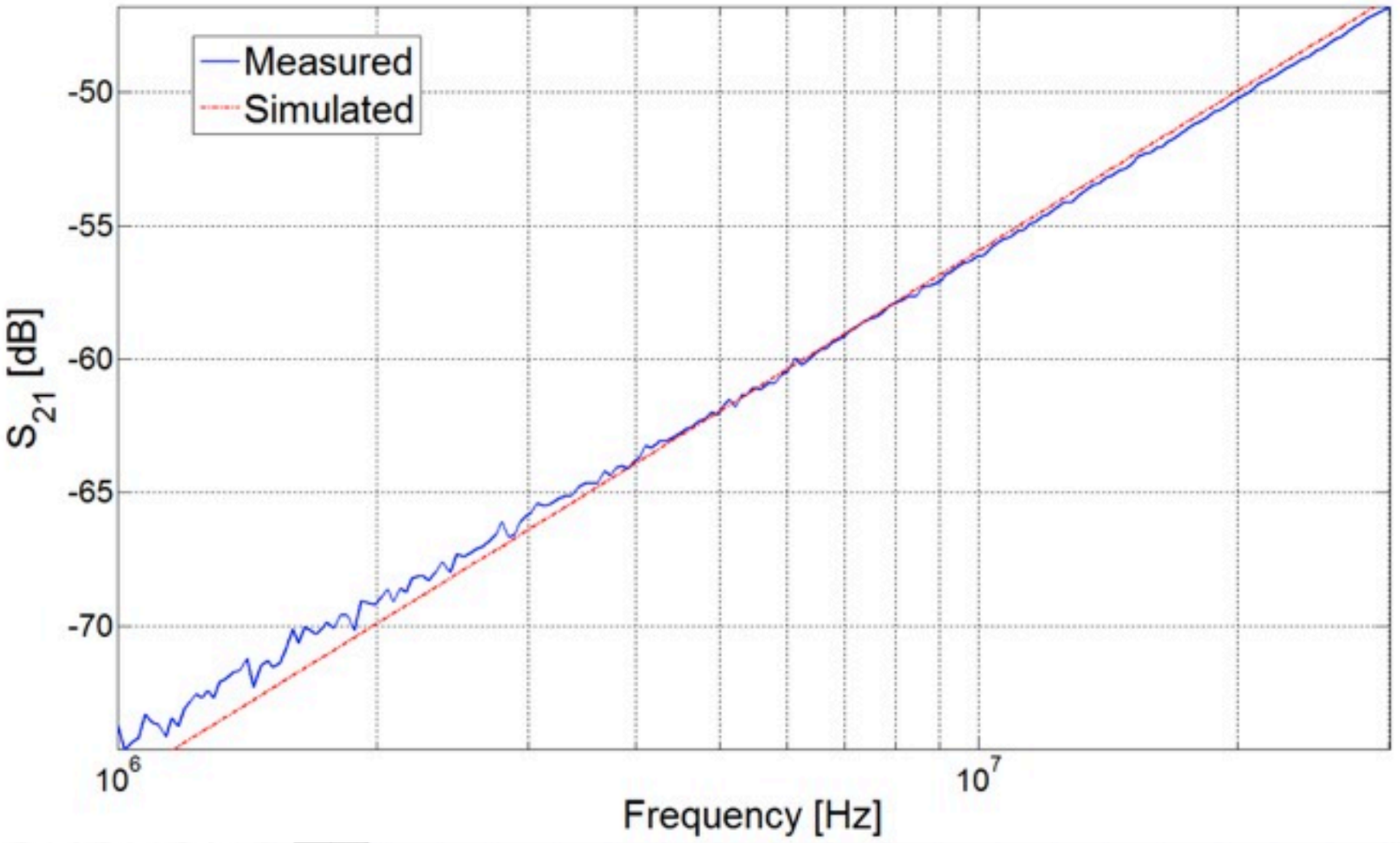
Simplorer



Simulation & validation

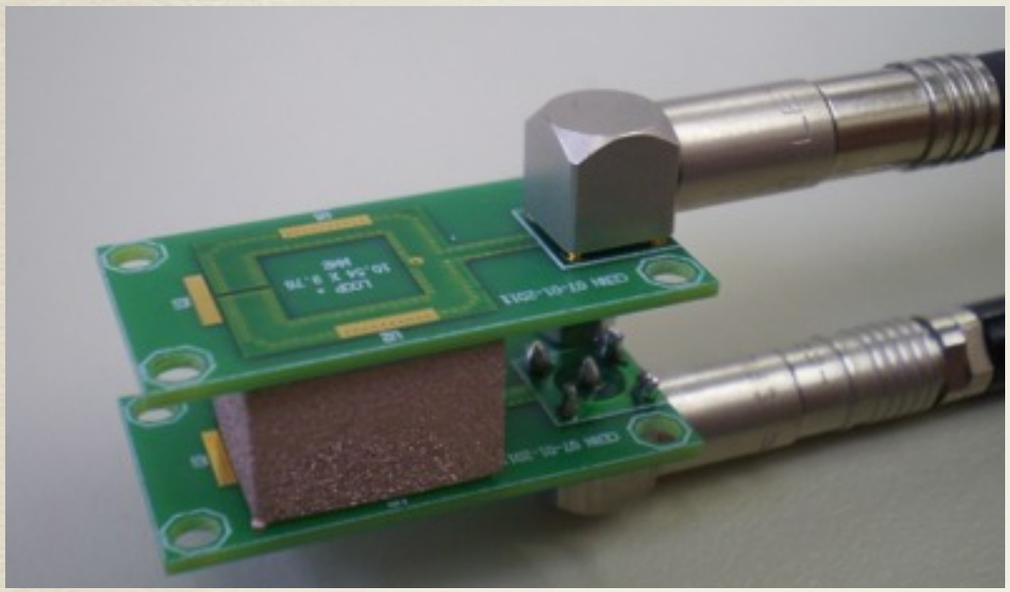




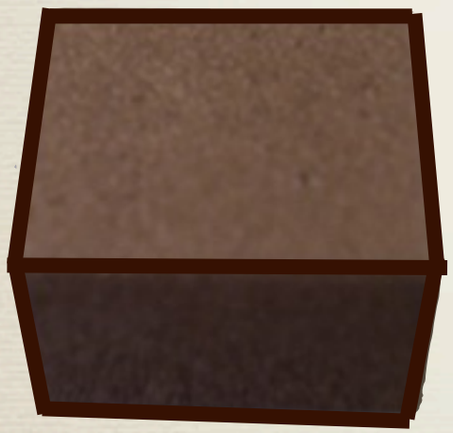


olorer

SE of some shields



Different constructions and thickness (t)



Painted Shield

$t =???$

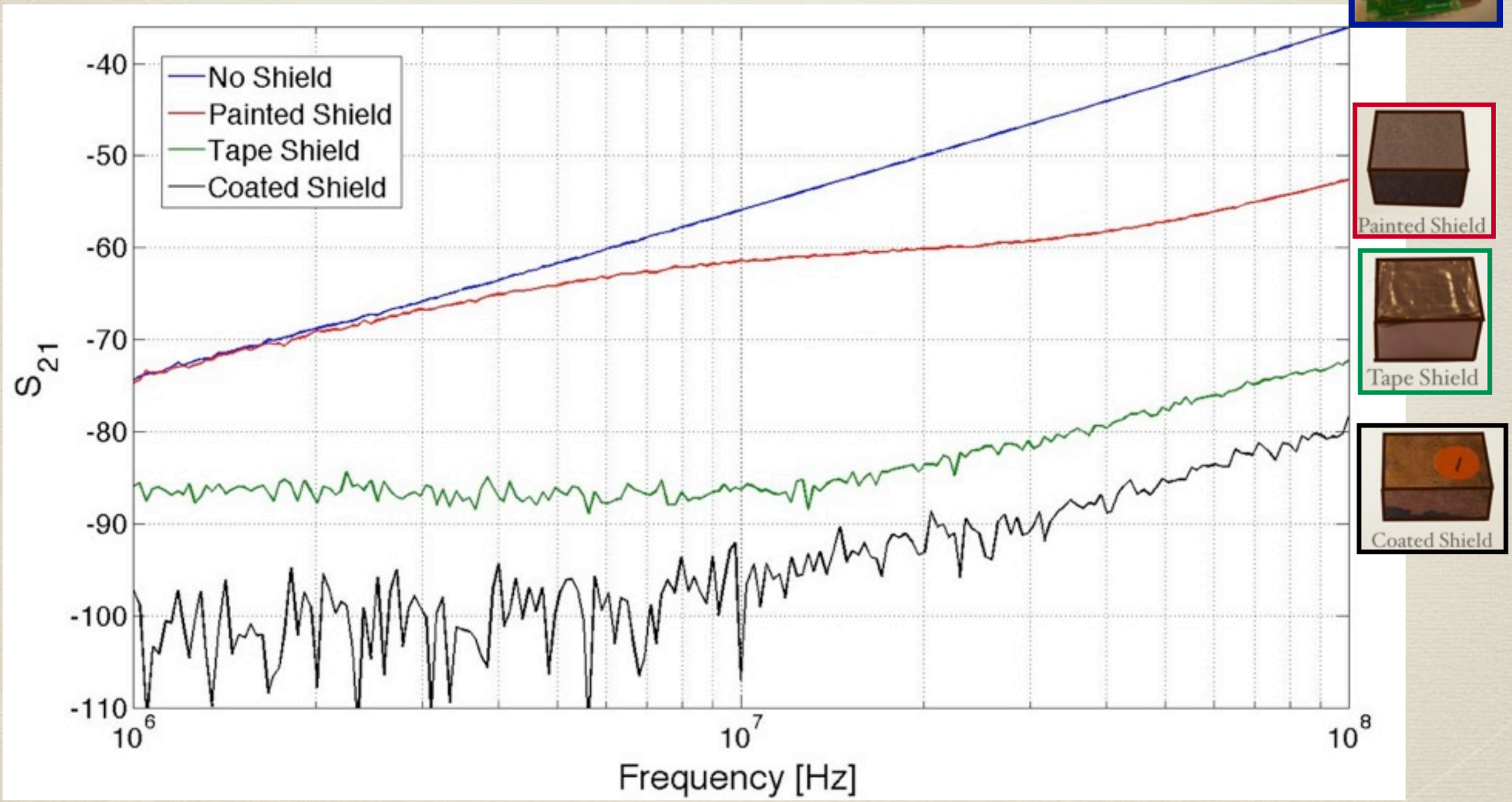
Tape Shield

$t = 35[\mu m]$

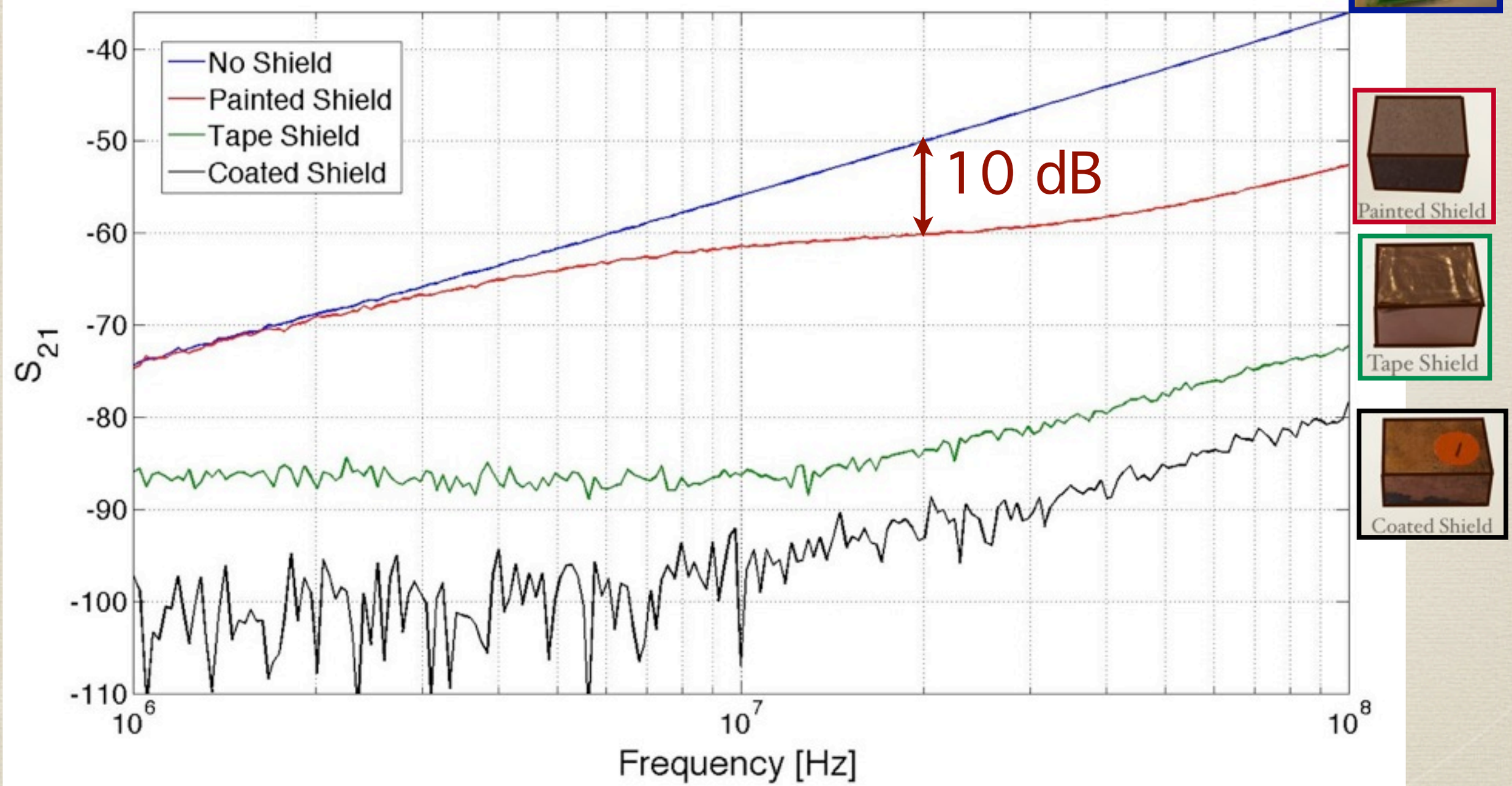
Coated Shield

$10 < t < 100[\mu m]$

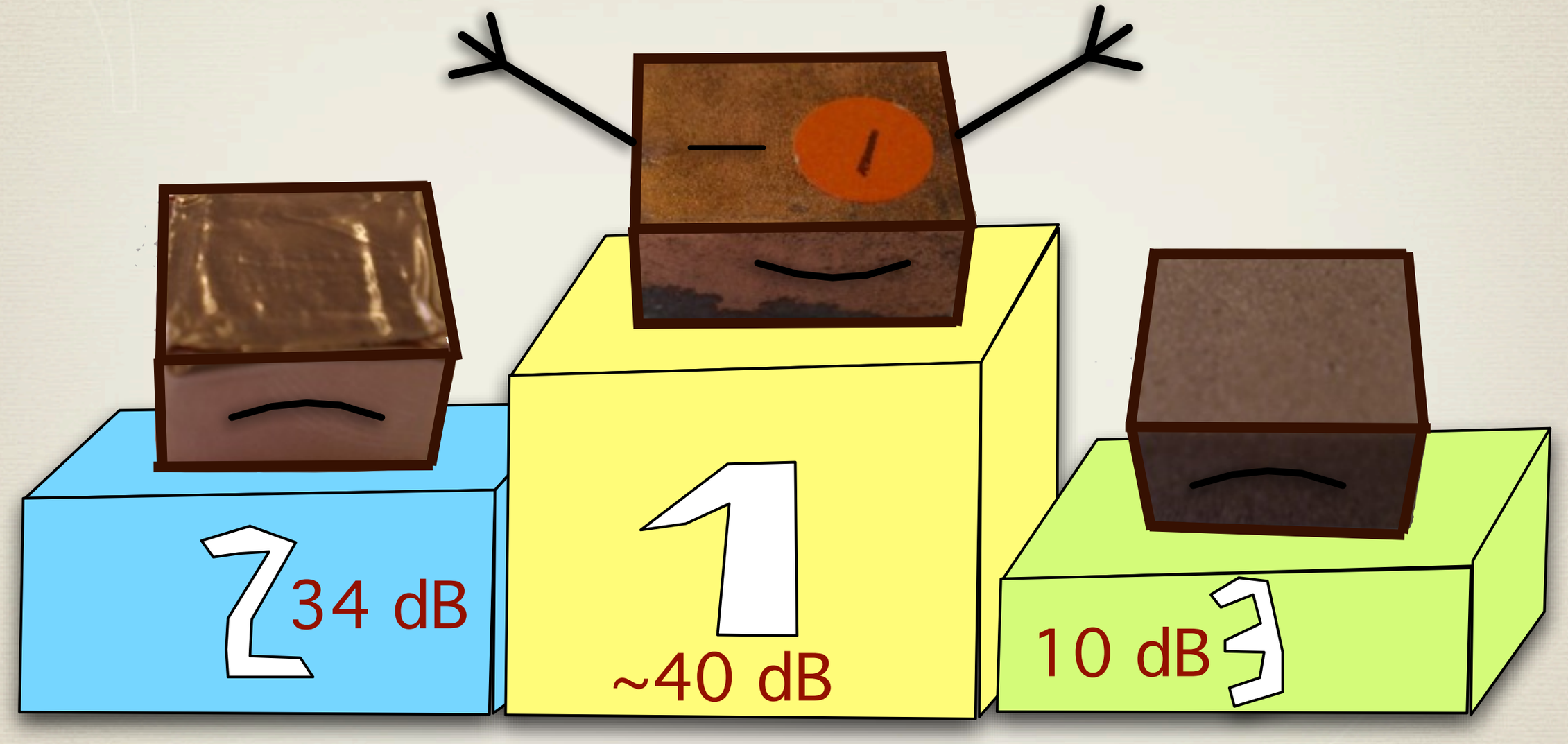
SE of some shields



SE of some shields



SE @ 20MHz



Tape Shield Coated Shield Painted Shield

Conclusion

- A test stand for evaluating the shield effectiveness of several shield prototypes is available.
- Painted copper shields are not a good solution. Other shielding strategies must be explored.

Conclusion

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What's next

- Copper coating of plastic shield will be explored.