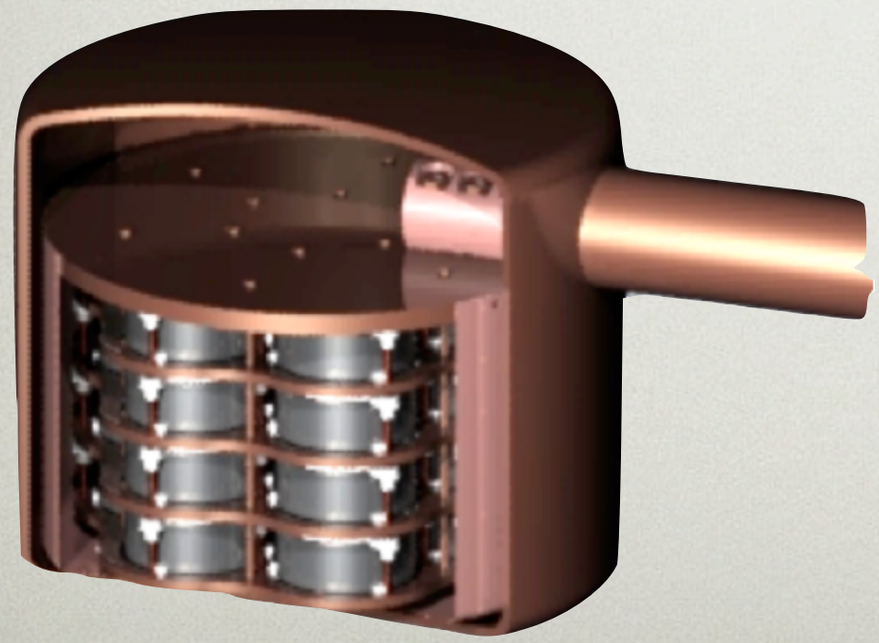
Electronics & Cables
for the
Majorana Demonstrator

James Loach

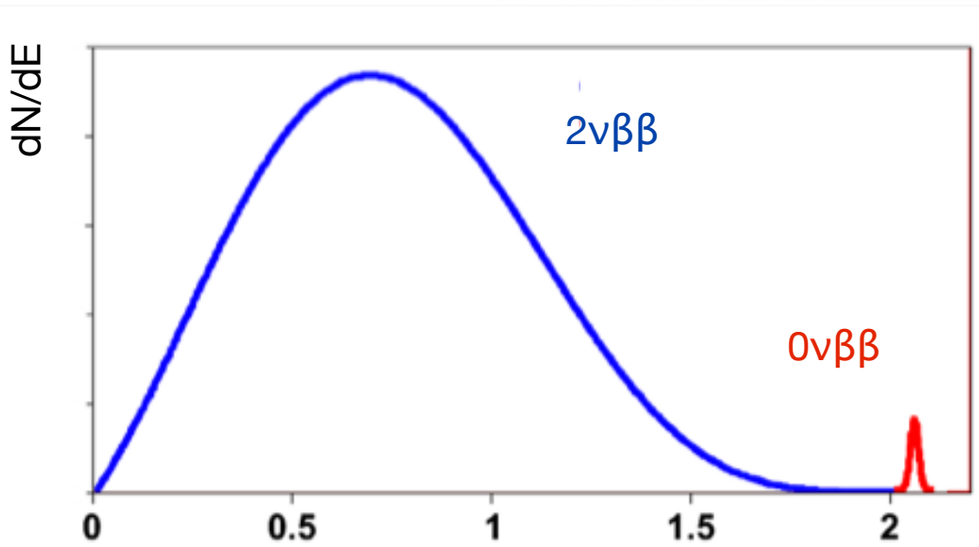
for LBNL & the Majorana collaboration

The MAJORANA experiment

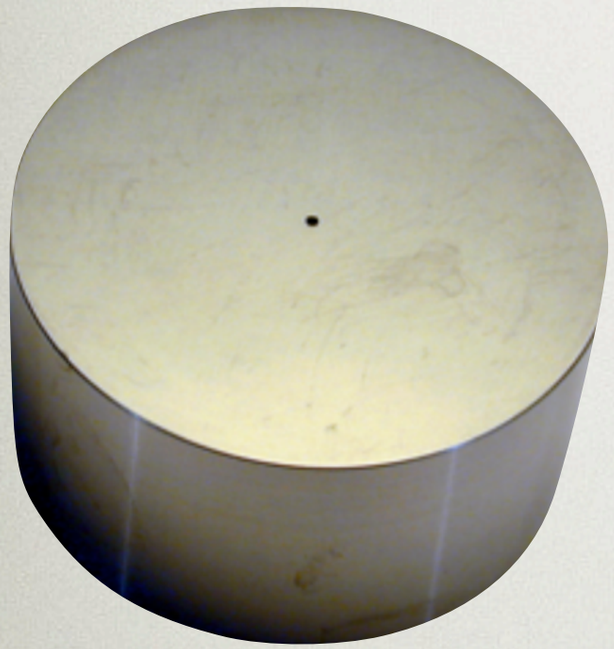


Search for $0\nu\beta\beta$ in ^{76}Ge with an array of point contact Ge detectors

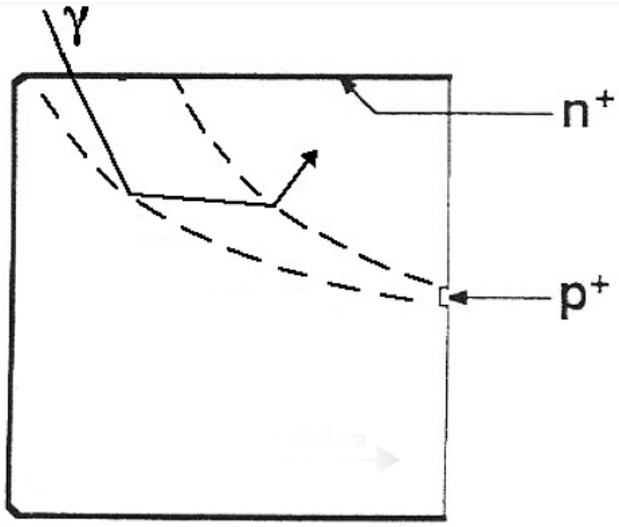
$T_{1/2} > 10^{24}$ years



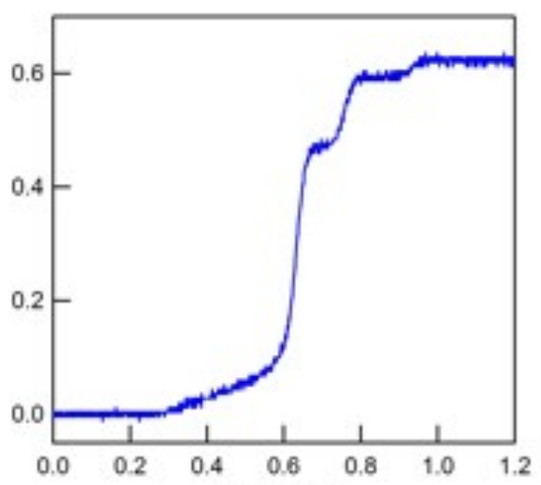
Point contact Ge detectors



Charge trajectories



Multiple-site event



Electronics chain must be
low noise and low background

[see Luke et al. (1989)]

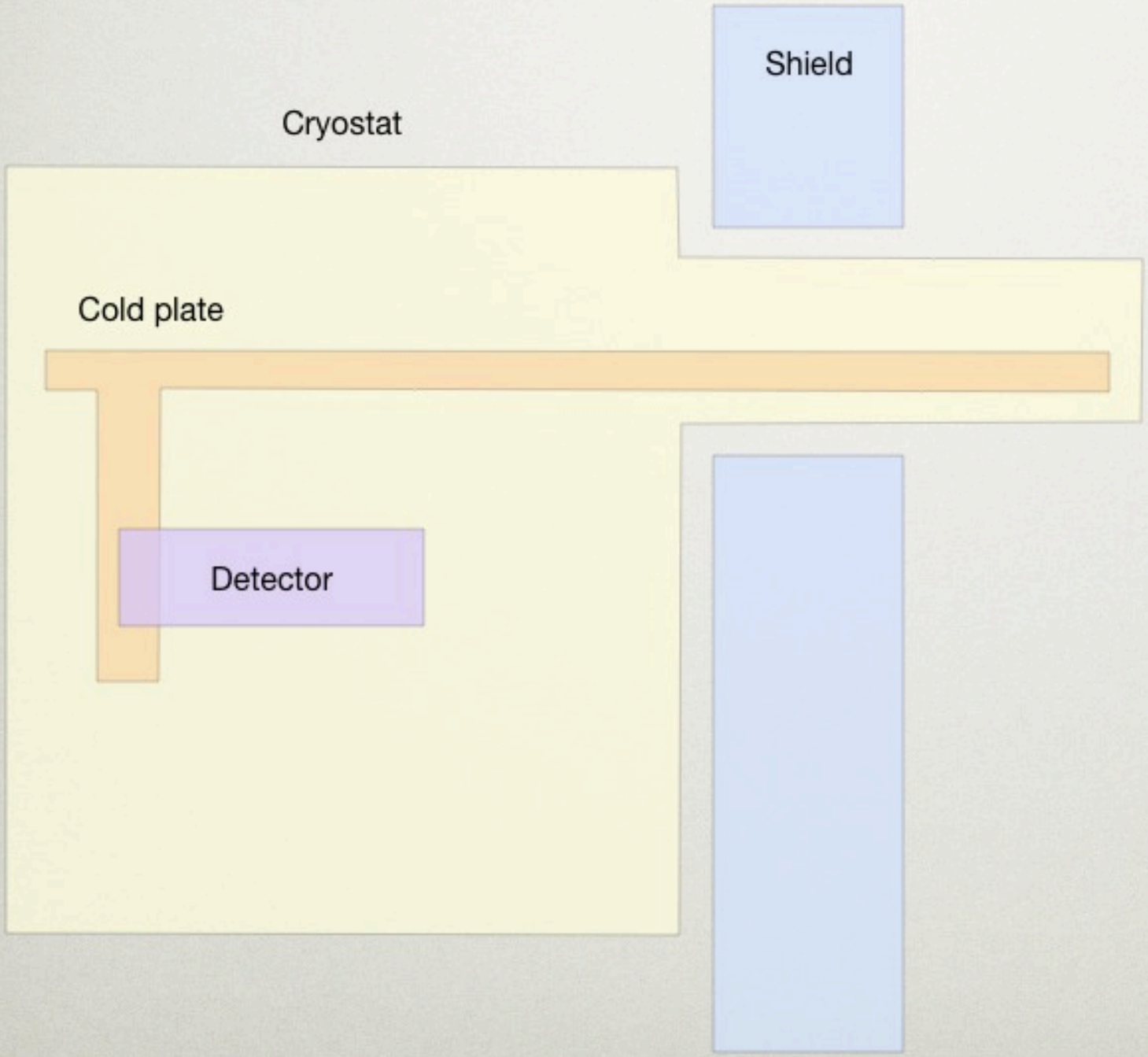
Just how low in background?

MAJORANA DEMONSTRATOR goal is 4 cts / ROI / t / y

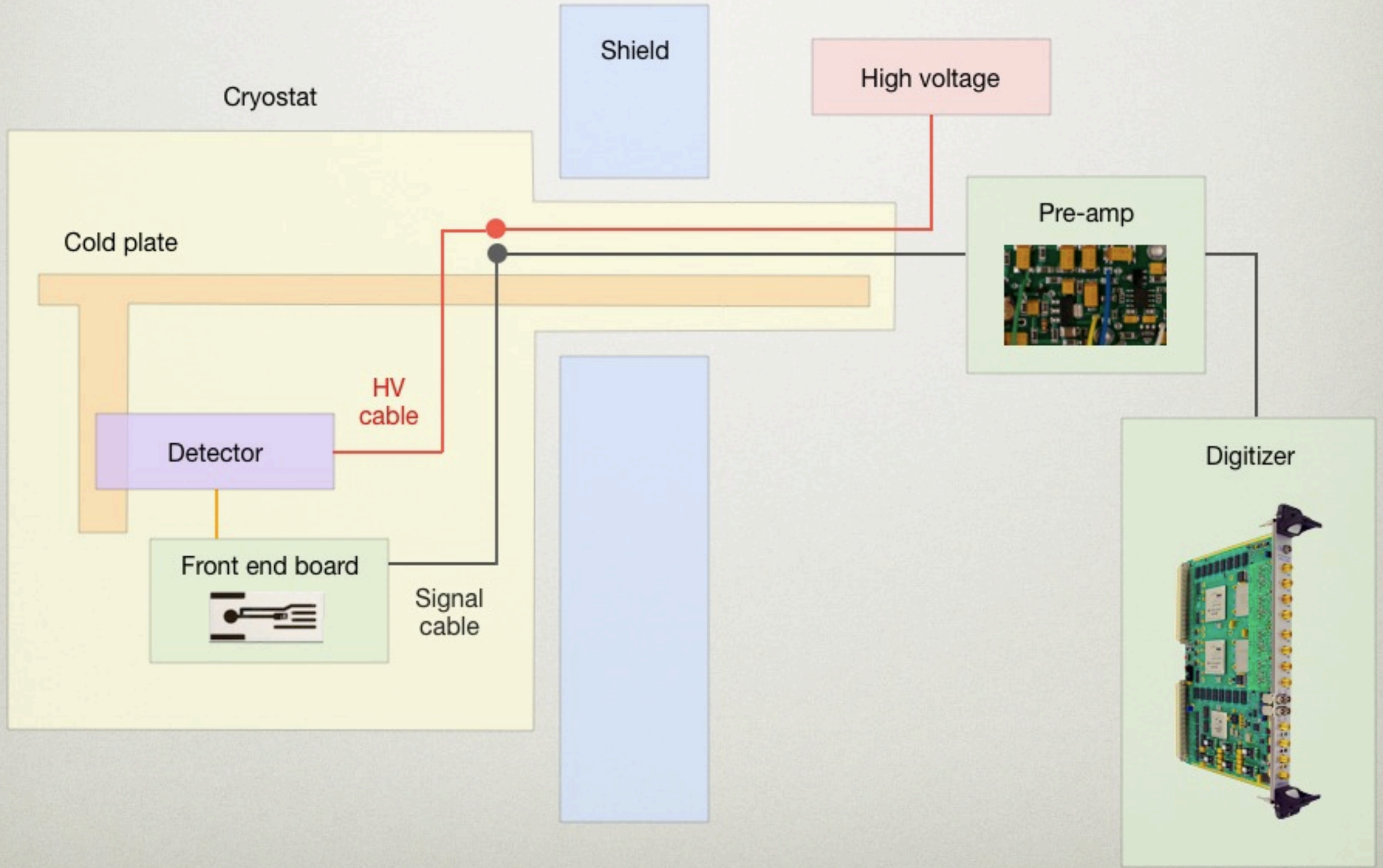
[scales to ~ 1 cts in the 1-tonne experiment]

Electro-formed copper	Detector mounts, cryostat, inner shield	< 0.1 μBq / kg ^{208}Tl < 0.3 μBq / kg ^{214}Bi
Commercial copper	Outer copper shield	< 0.3 μBq / kg ^{208}Tl < 3 μBq / kg ^{214}Bi
Lead	Lead shield	< 1 μBq / kg ^{208}Tl < 10 μBq / kg ^{214}Bi
Plastic	Detector mounts, insulation	< 0.4 μBq / kg ^{208}Tl < 10 μBq / kg ^{214}Bi
Small components	Front-end electronics, contacts	< 6 nBq / channel ^{208}Tl < 24 nBq / channel ^{214}Bi
Cables	Signal, high voltage	< 40 μBq / kg ^{208}Tl < 500 μBq / kg ^{214}Bi

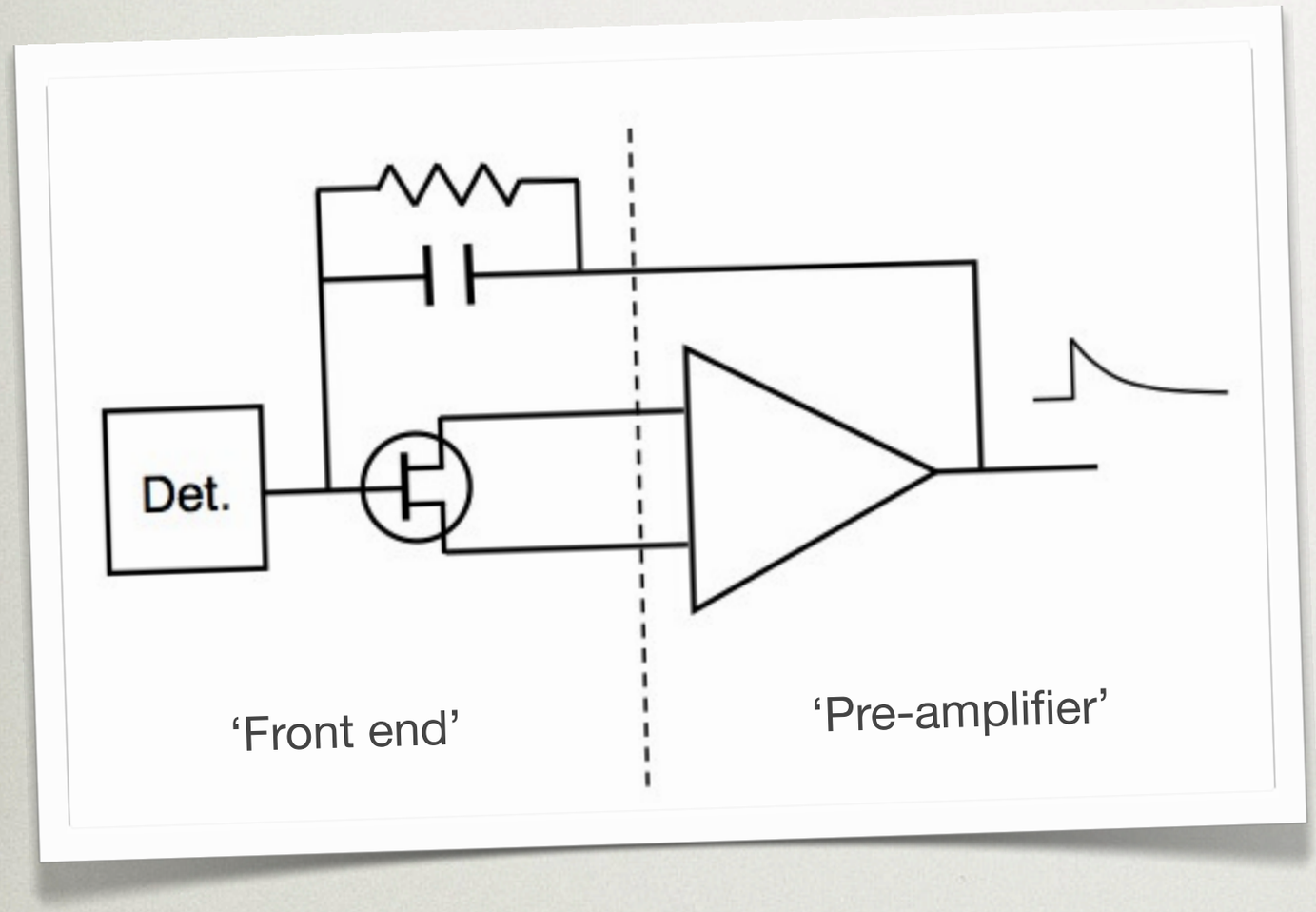
The MAJORANA electronics



The MAJORANA electronics



Divide and conquer



Simple

Resistor radioactivity

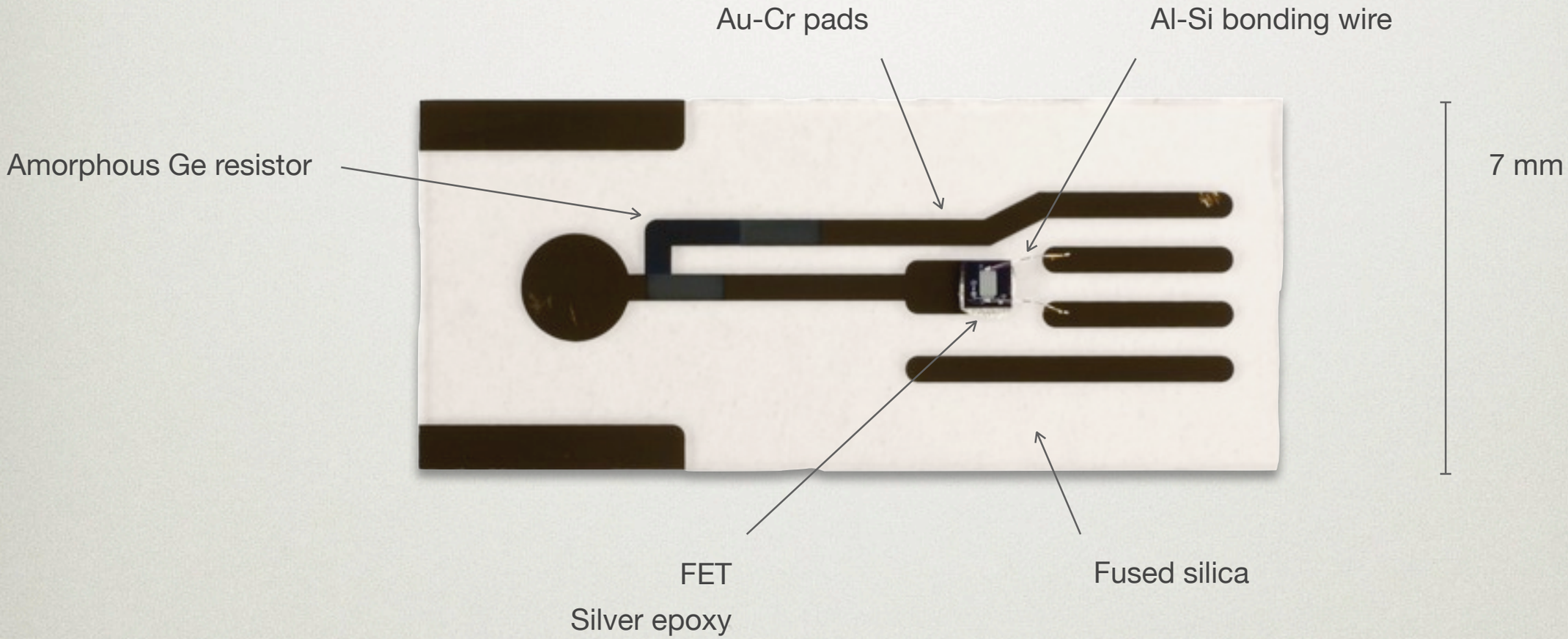
Thermal noise

Rate limitations

Pole-zero difficulties

Resistive feedback design

Be small



Weighs 63 mg

Be pure

Assay strategy

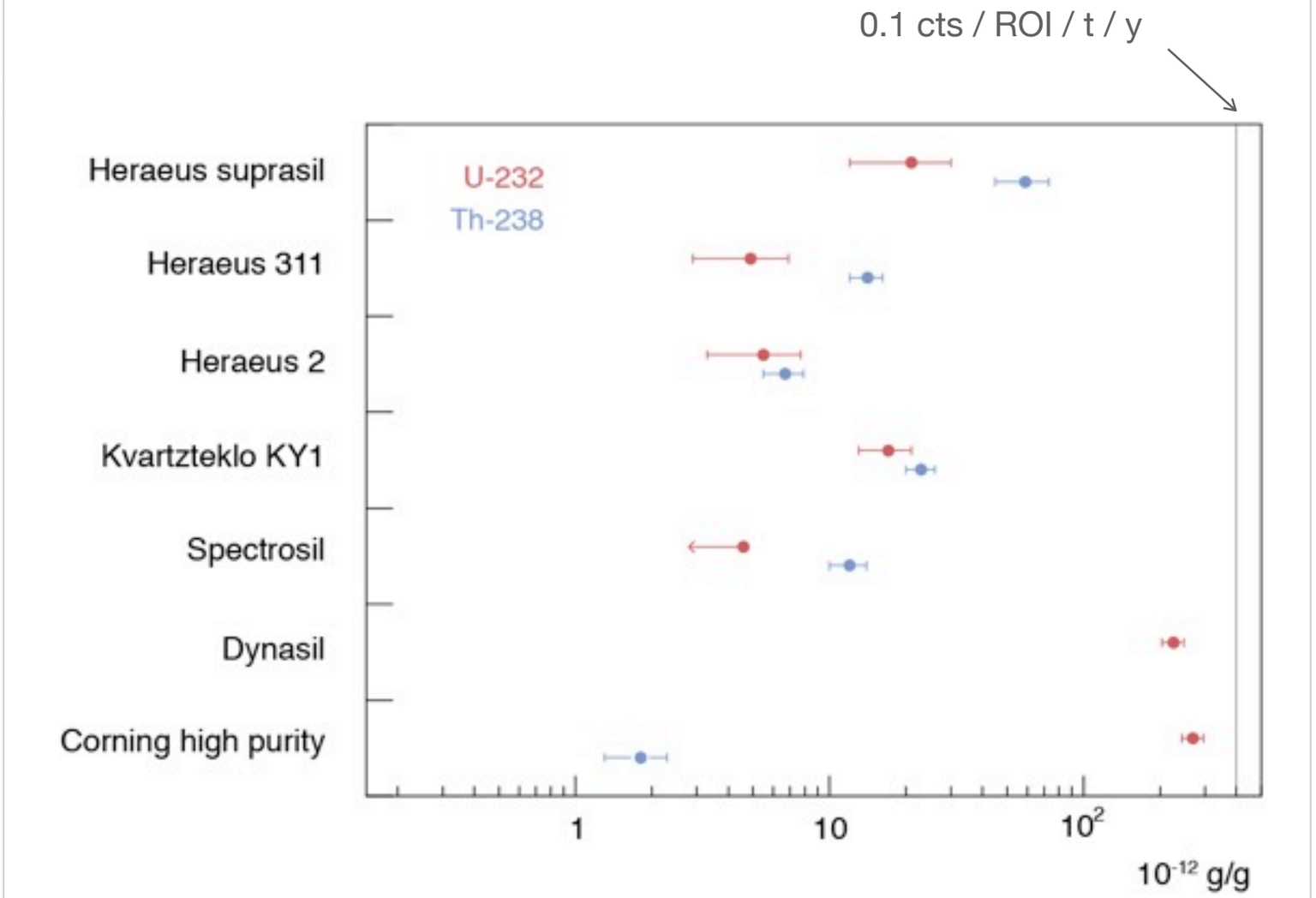
(1) Gamma count sample

(2) NNA or ICP-MS sample
& gamma count raw material

(3) ICP-MS or NNA sample

And spot checks using ICP-MS

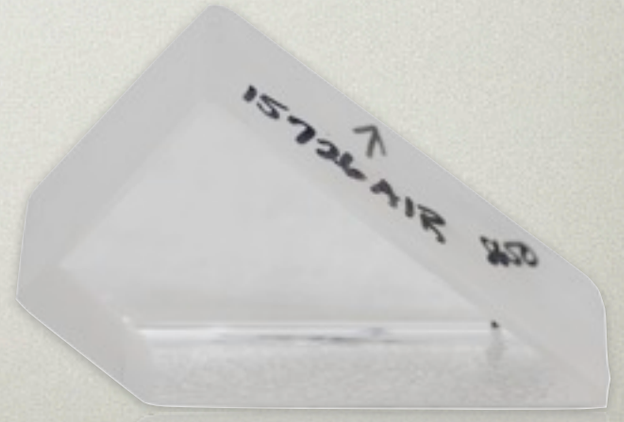
Be pure



[Leonard et al. (2008)]

Fused silica

- Candidates from literature
- ICP-MS of samples
- NNA of candidate



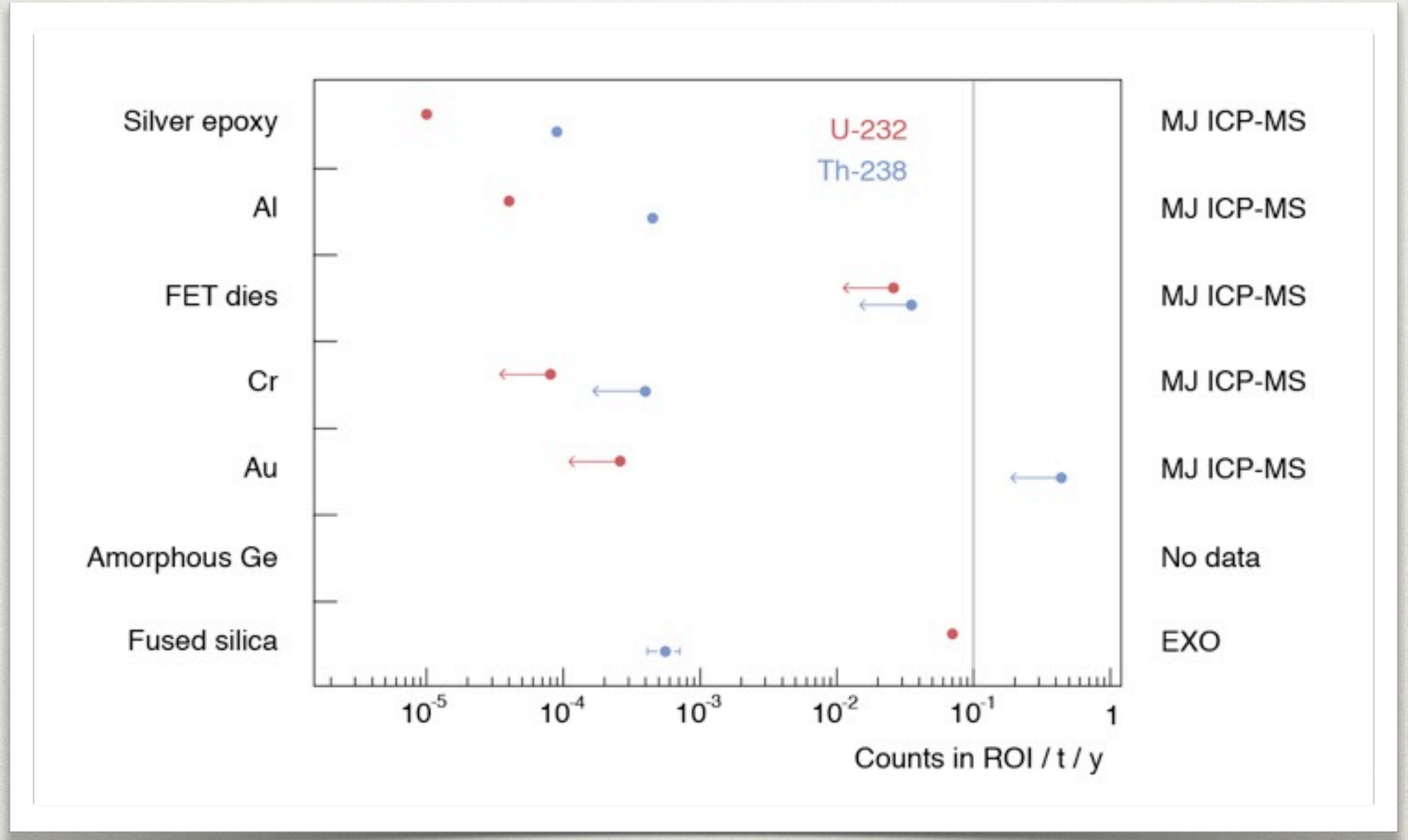
Be pure

Gamma		ICP-MS		
LBF	WIPP	PNNL	LBNL	Chernogolovka
1-2 ppb (LBNL) < 100 ppt (Oroville)	~ 1 ppb	< 1 ppt	~ 10 ppt	~ 1 ppt

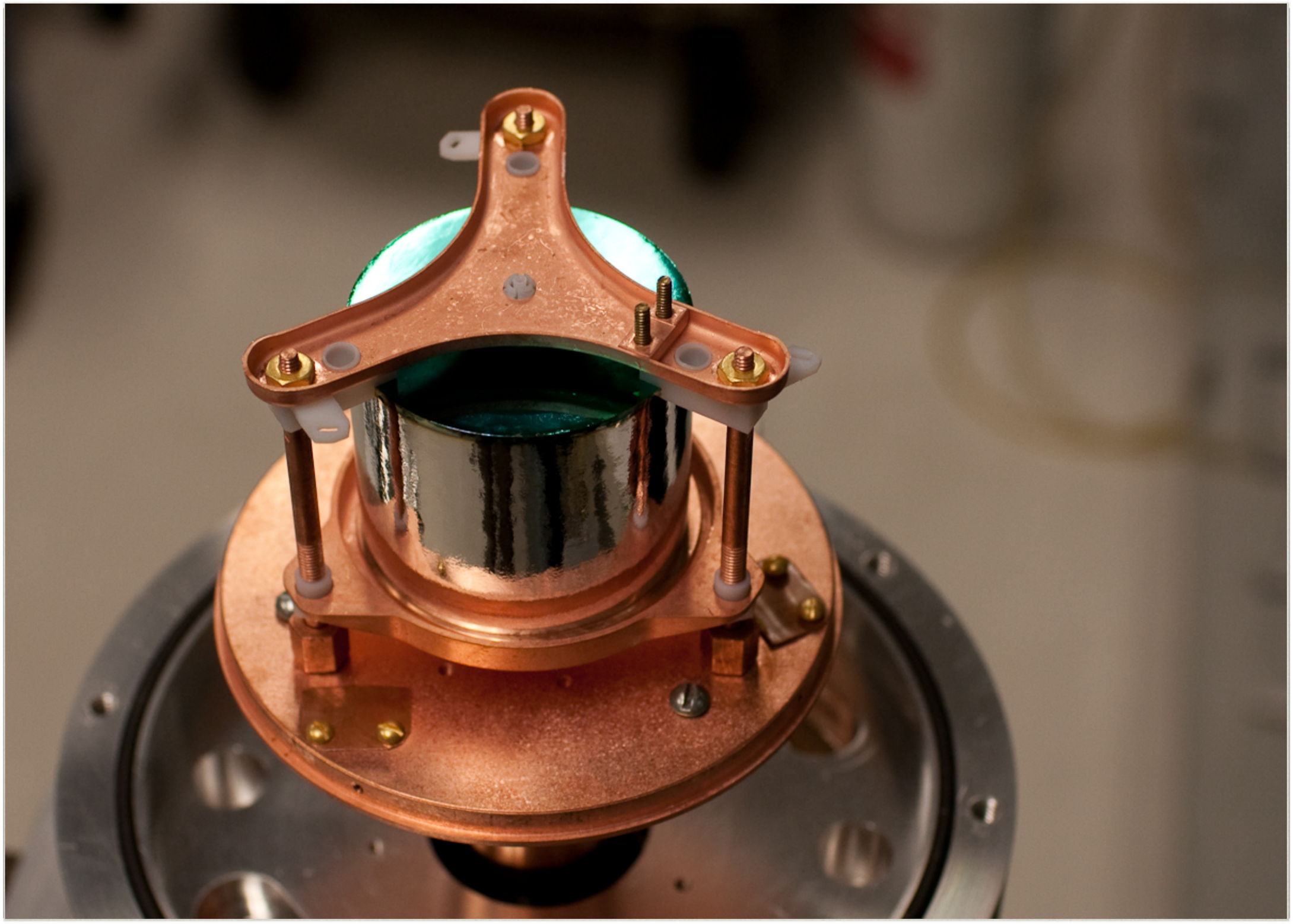
[Talk by Henning] [Talk by Hoppe]

[all values for ^{238}U and ^{232}Th]

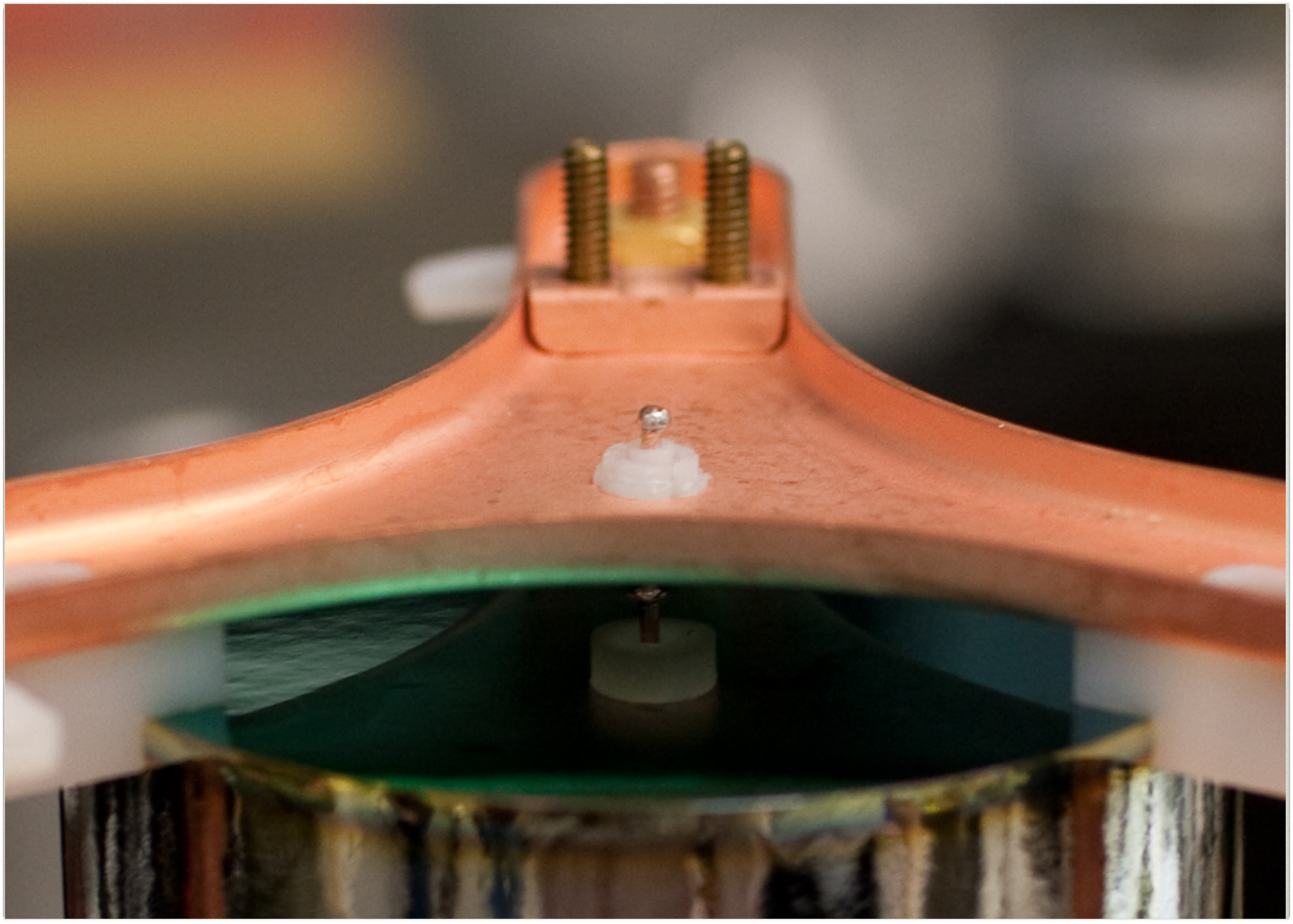
Be pure



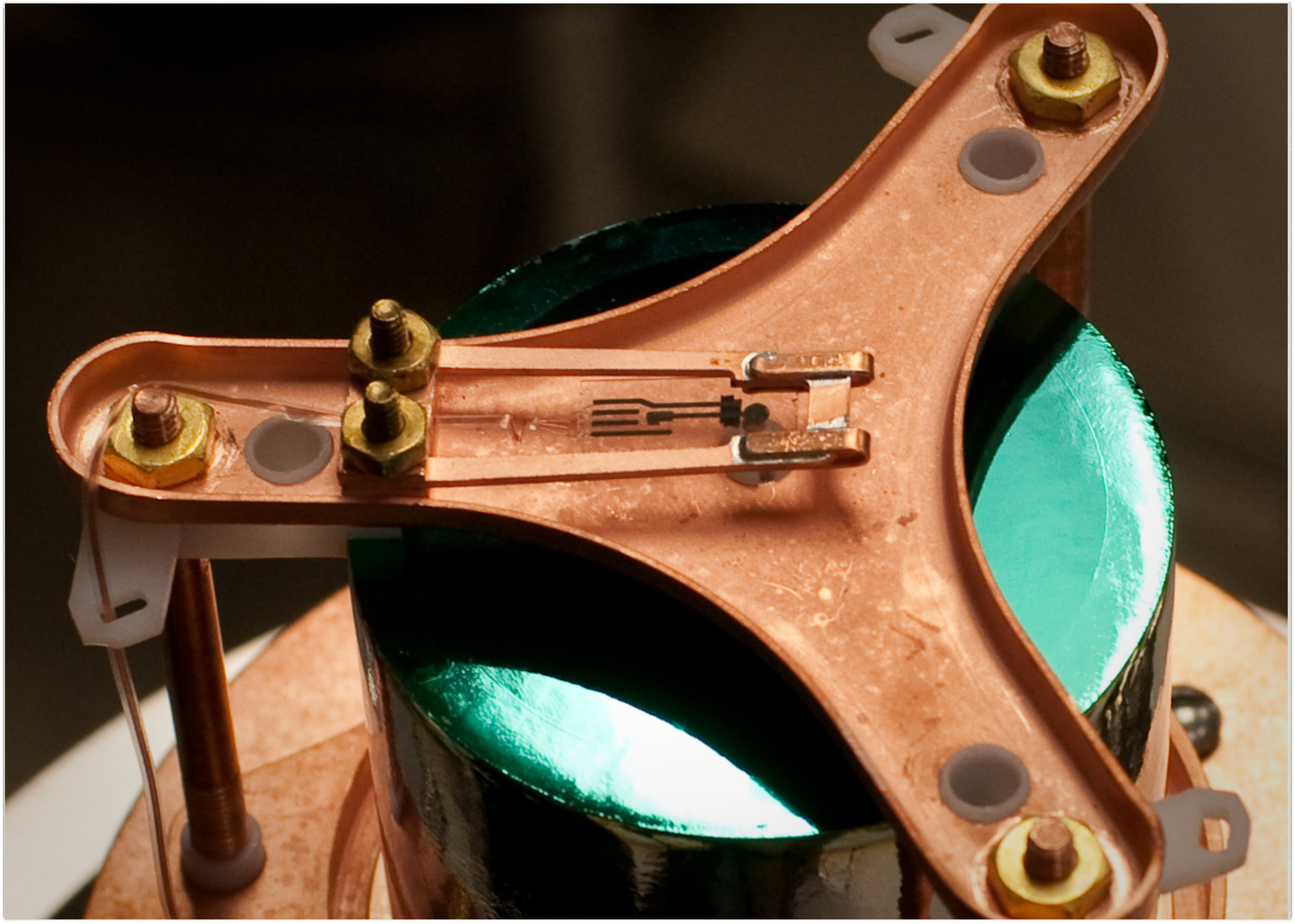
Many measurements in progress



[prototype design]



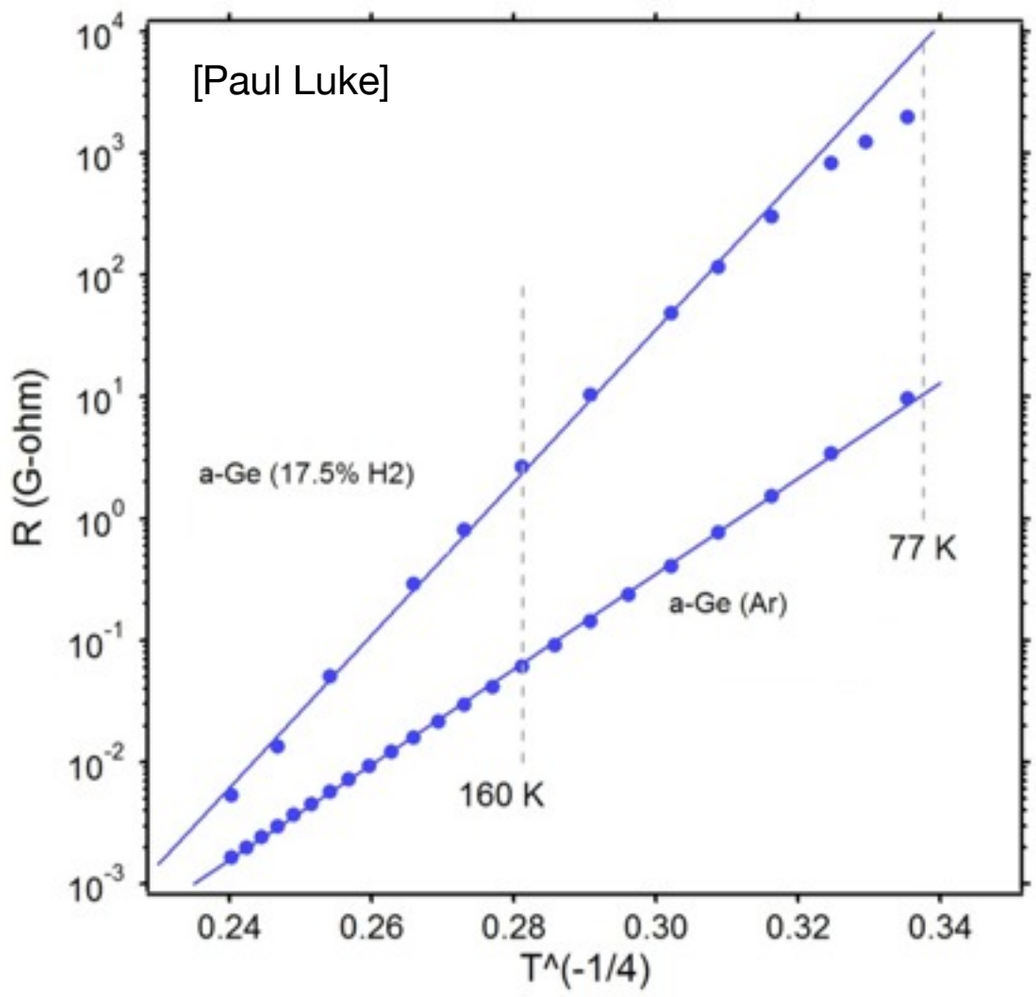
[prototype design]



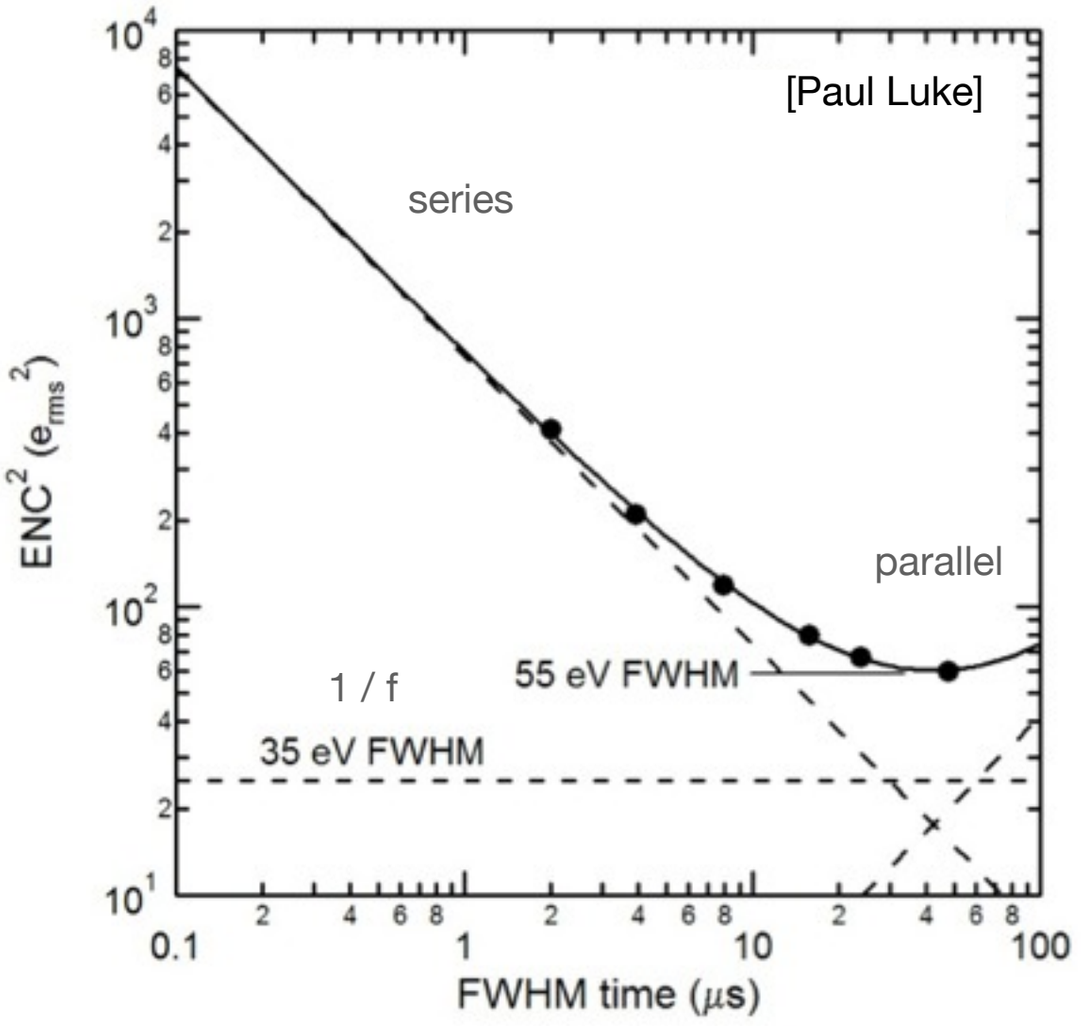
[prototype design]

Performance

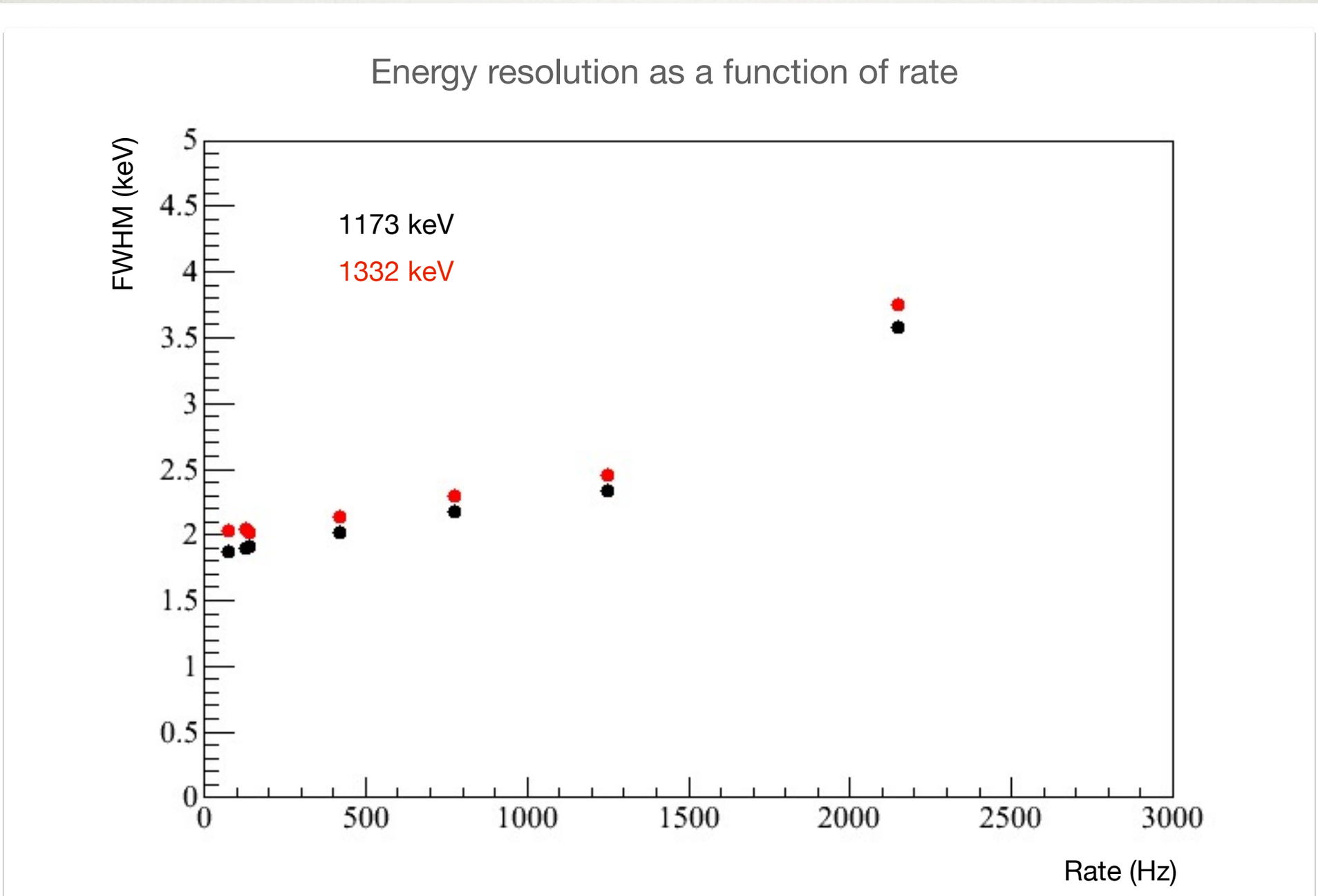
Amorphous Ge resistor



Noise



Performance



A novel alternative

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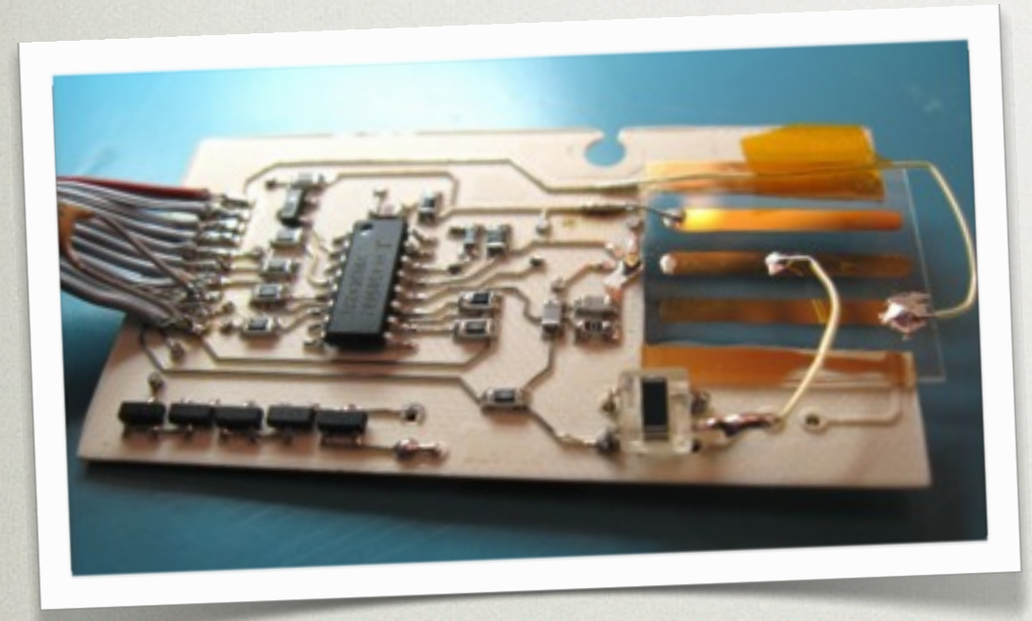
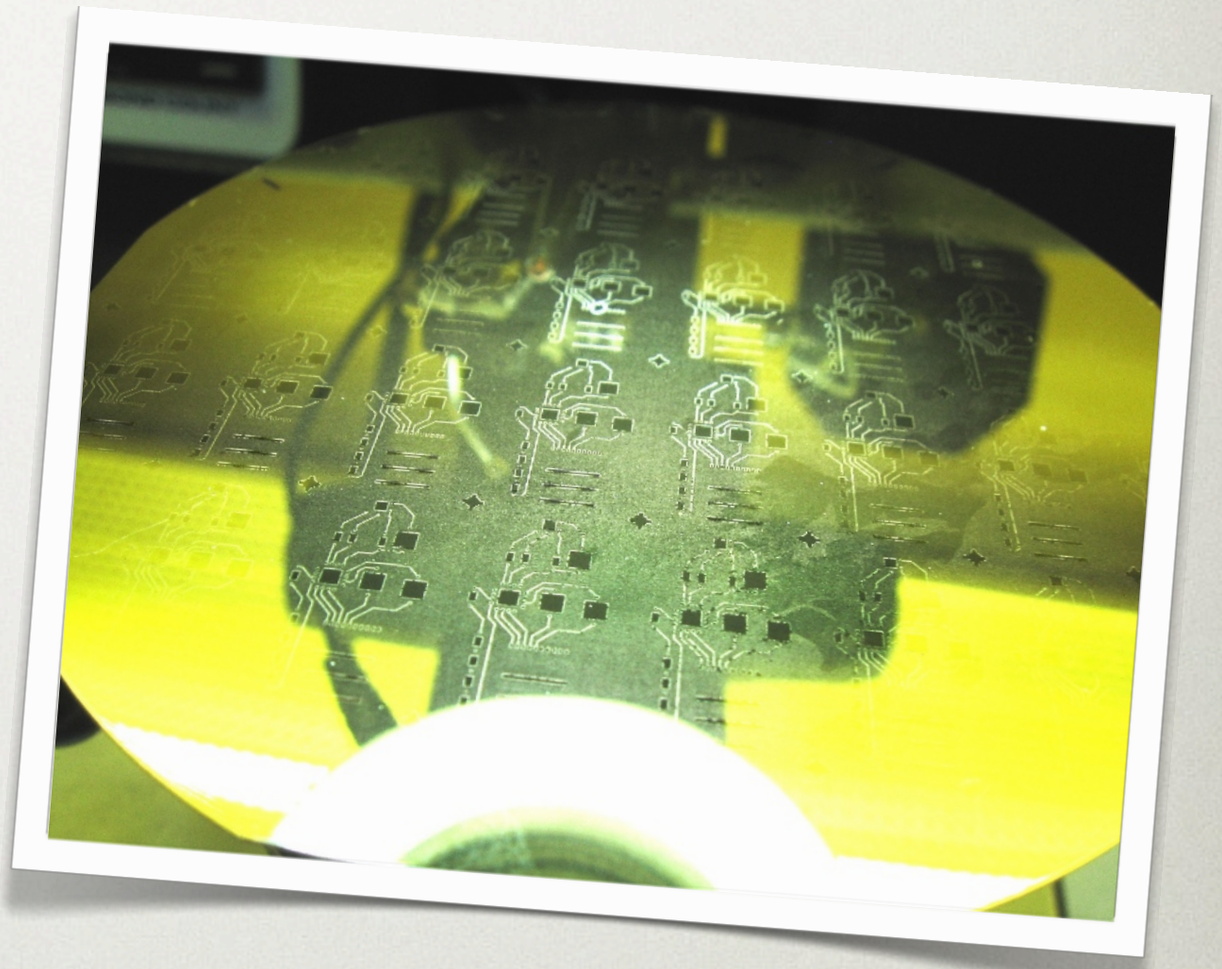
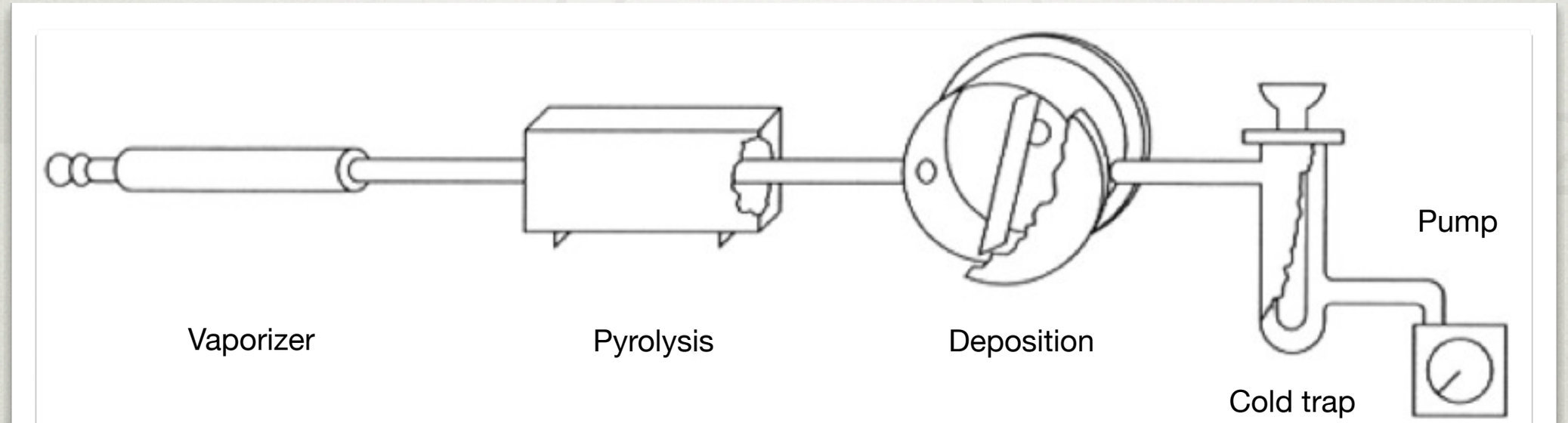




Unique design with forward-biased JFET
Entirely on the front end

The wonders of parylene

Excellent electrical properties and low background



	Parylene C	Parylene N
Dissipation factor (at 1 kHz)	0.019	0.0002
Dielectric strength (short time)	5600 V / mil	7000 V / mil
Dielectric constant (at 1 kHz)	3.10	2.65

Slender threads

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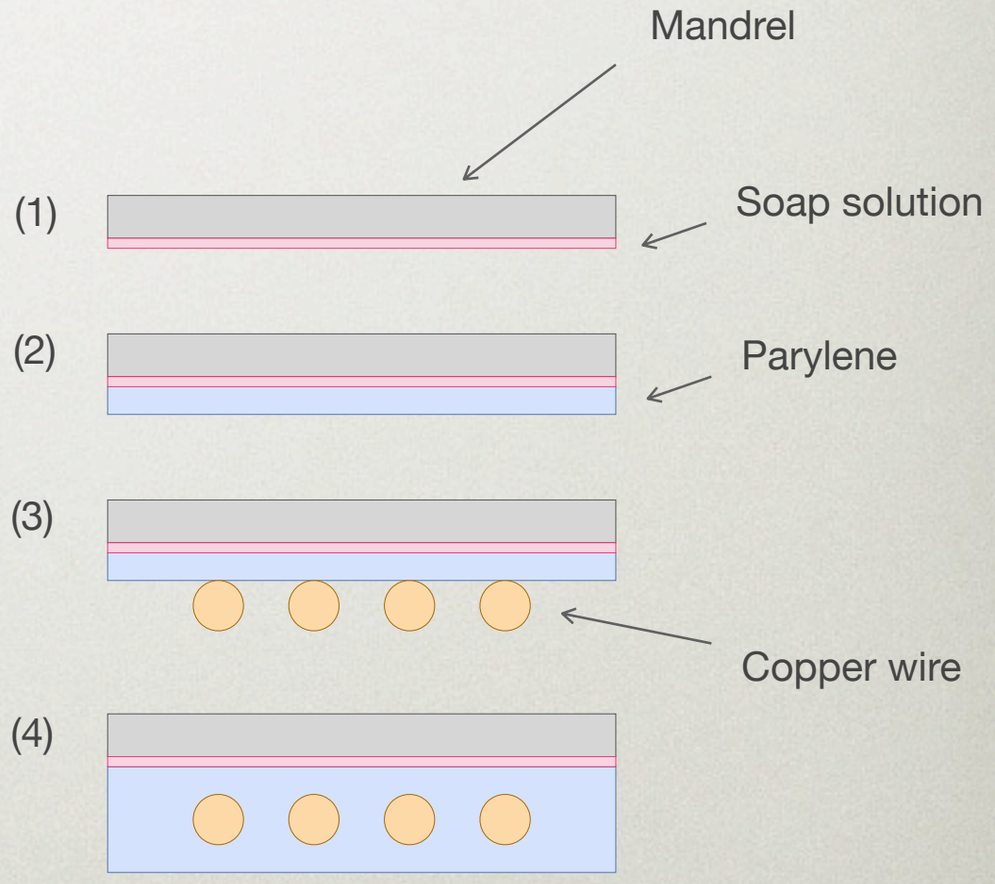
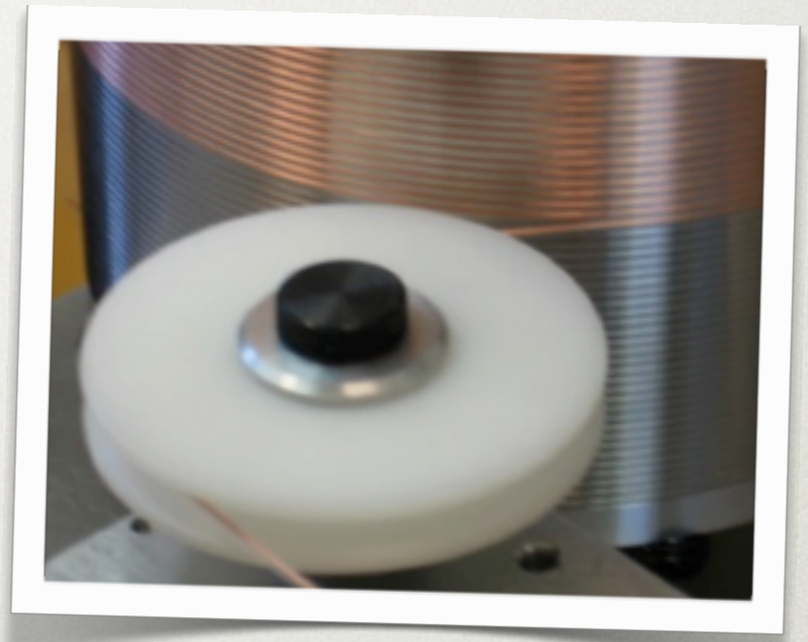


	^{238}U	^{232}Th
Parylene N	< 1 ppb	< 49 ppt
Copper wire	< 86 ppt	< 40 ppt
Soap solution	< 1.5 ppb	< 0.6 ppb

[Miller, Robertson et al.]

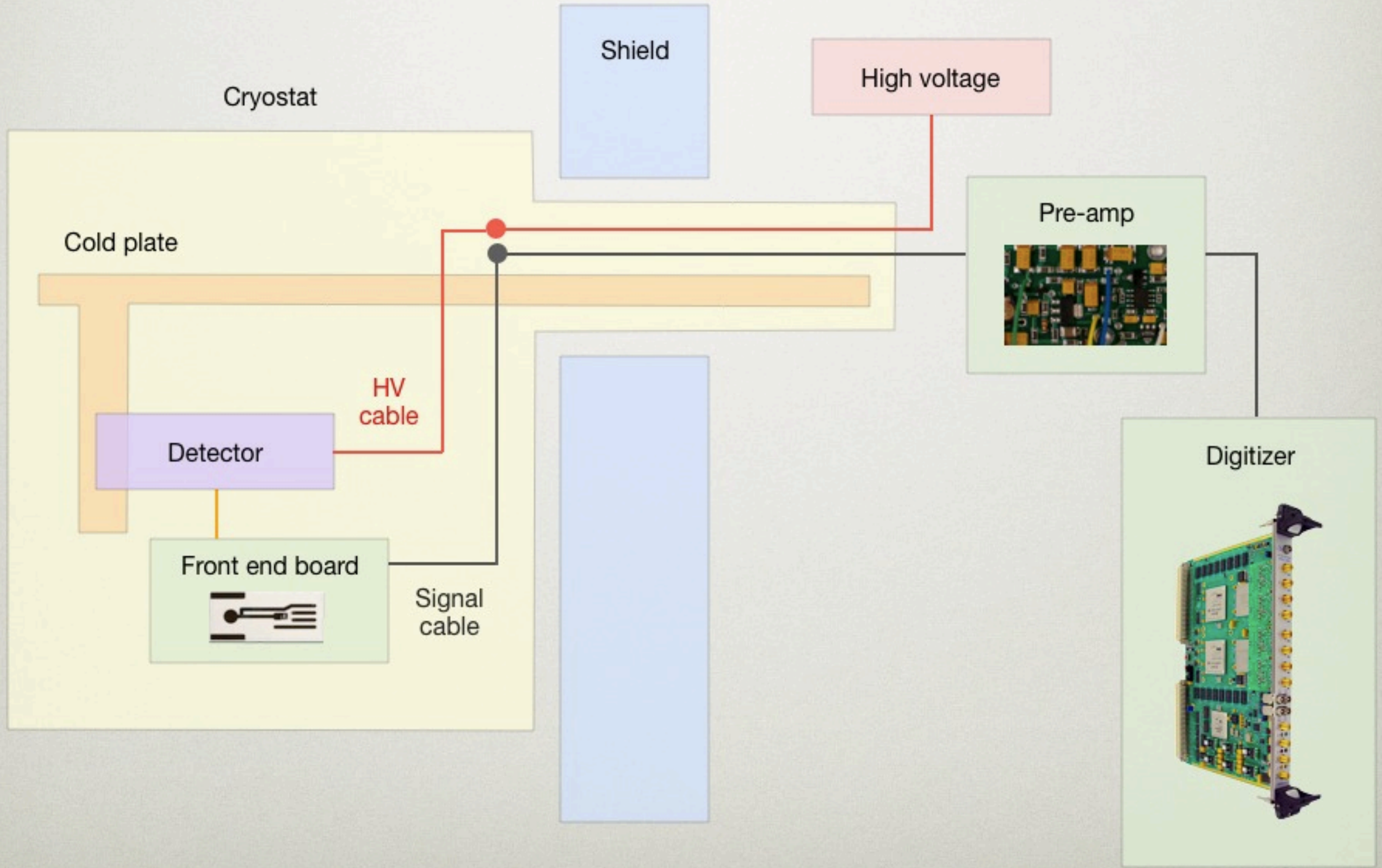
Slender threads

Cable winding

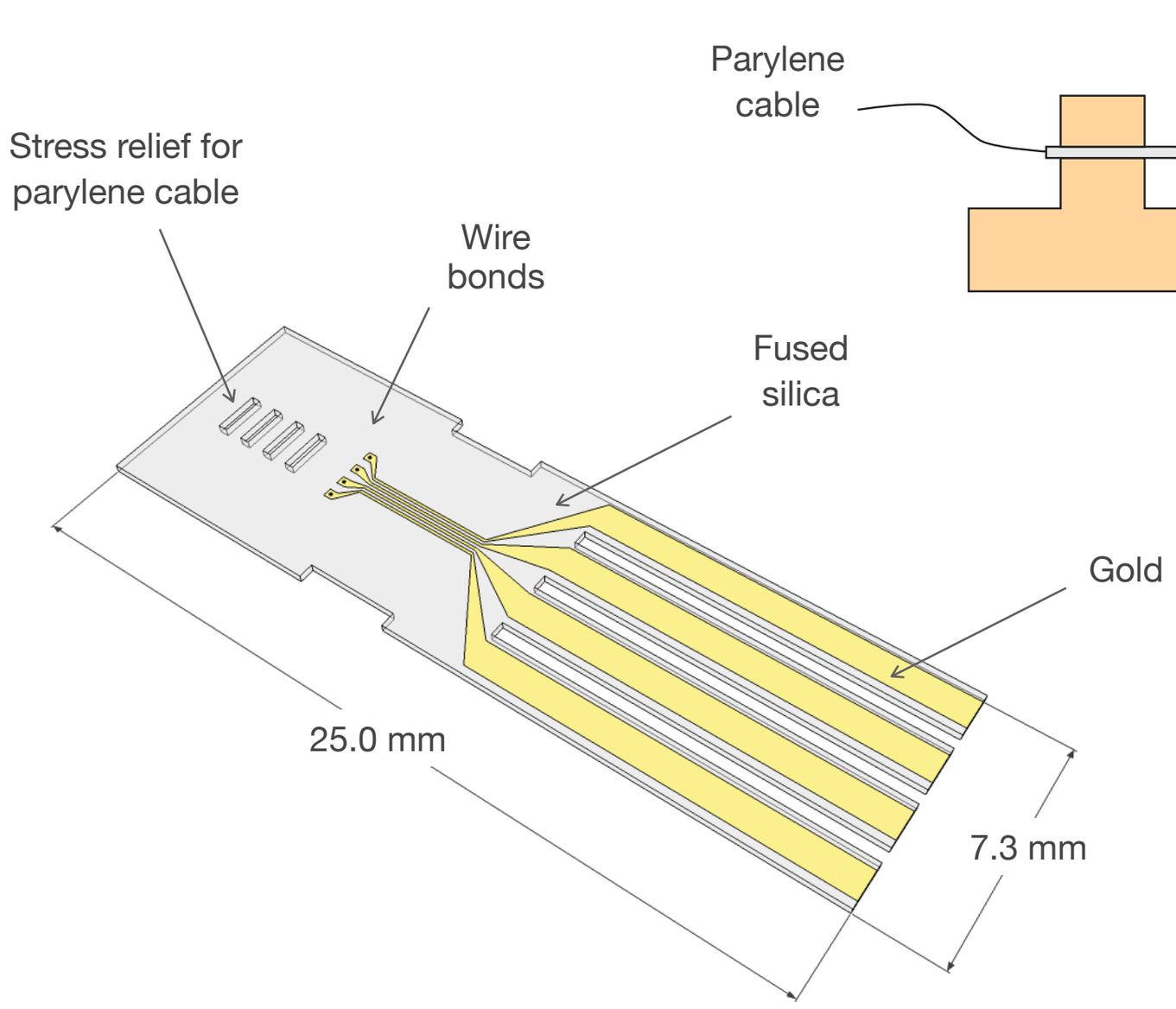


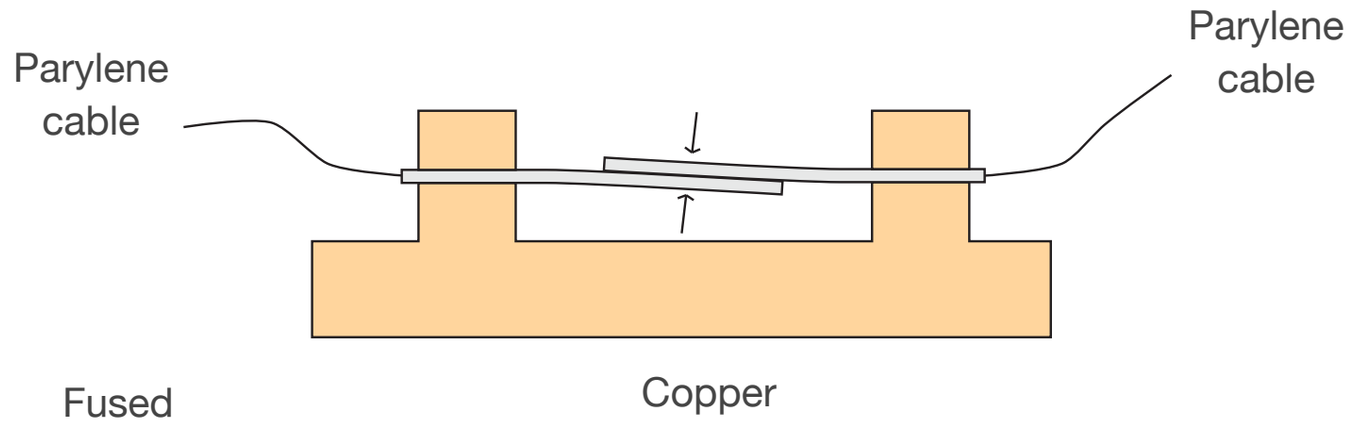
	Predicted	Measured
Impedance	97 Ω	110(10) Ω
Capacitance	16.6 pF/m	16.8(0.2) pF/m

Connections



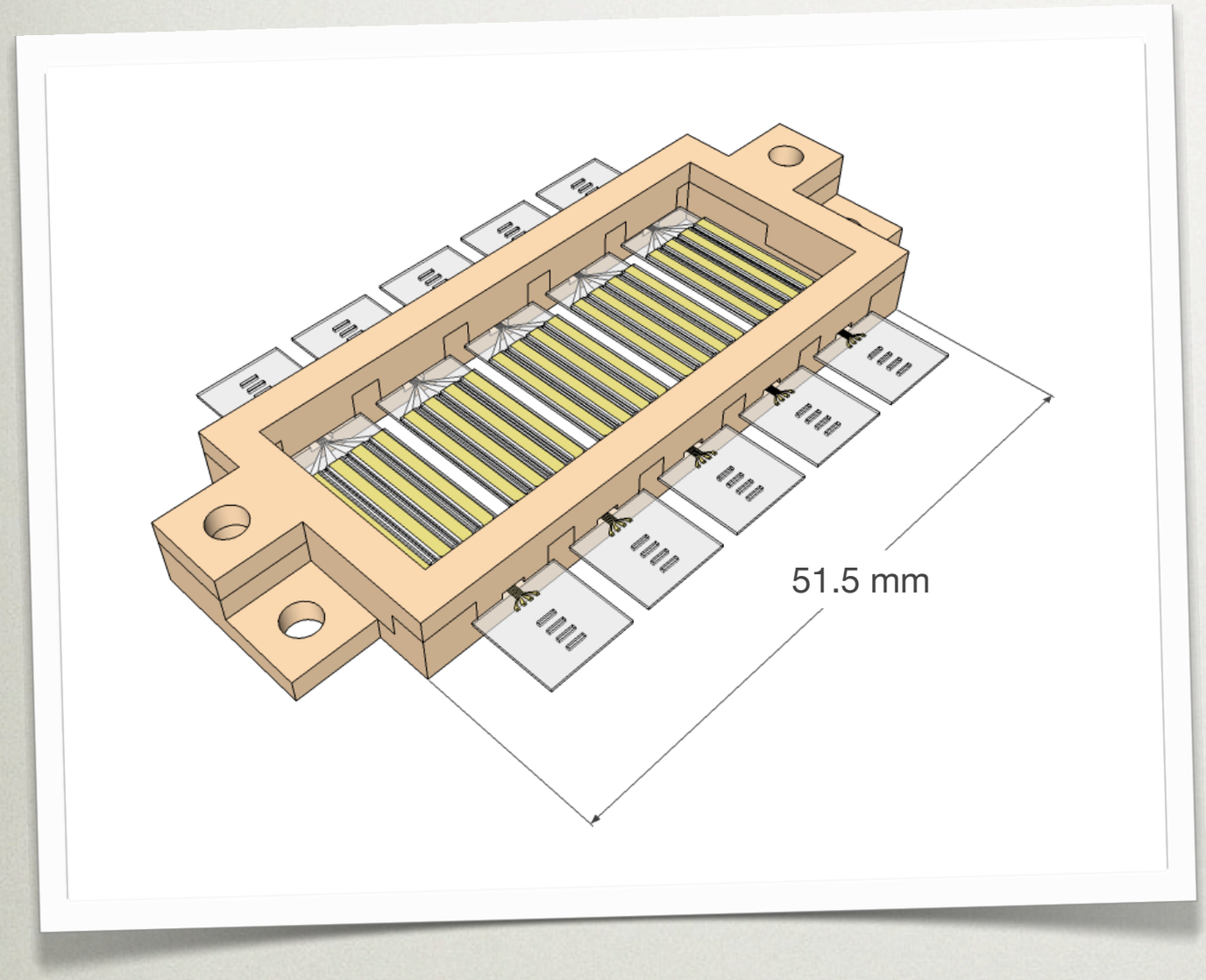
Connections



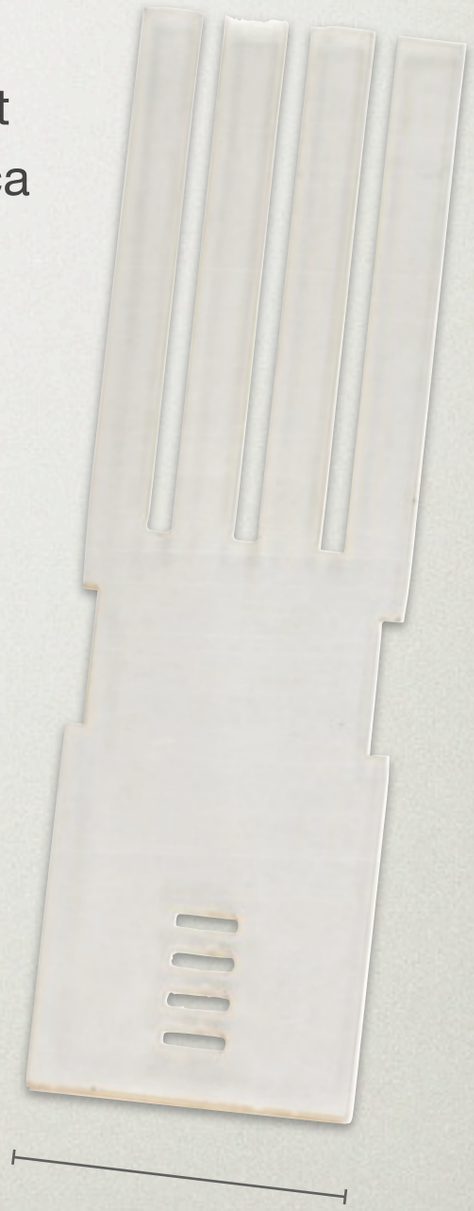


To join cables below the cold plate to those above

Connections



Laser-cut
fused silica
paddle



At the prototype stage

Connections

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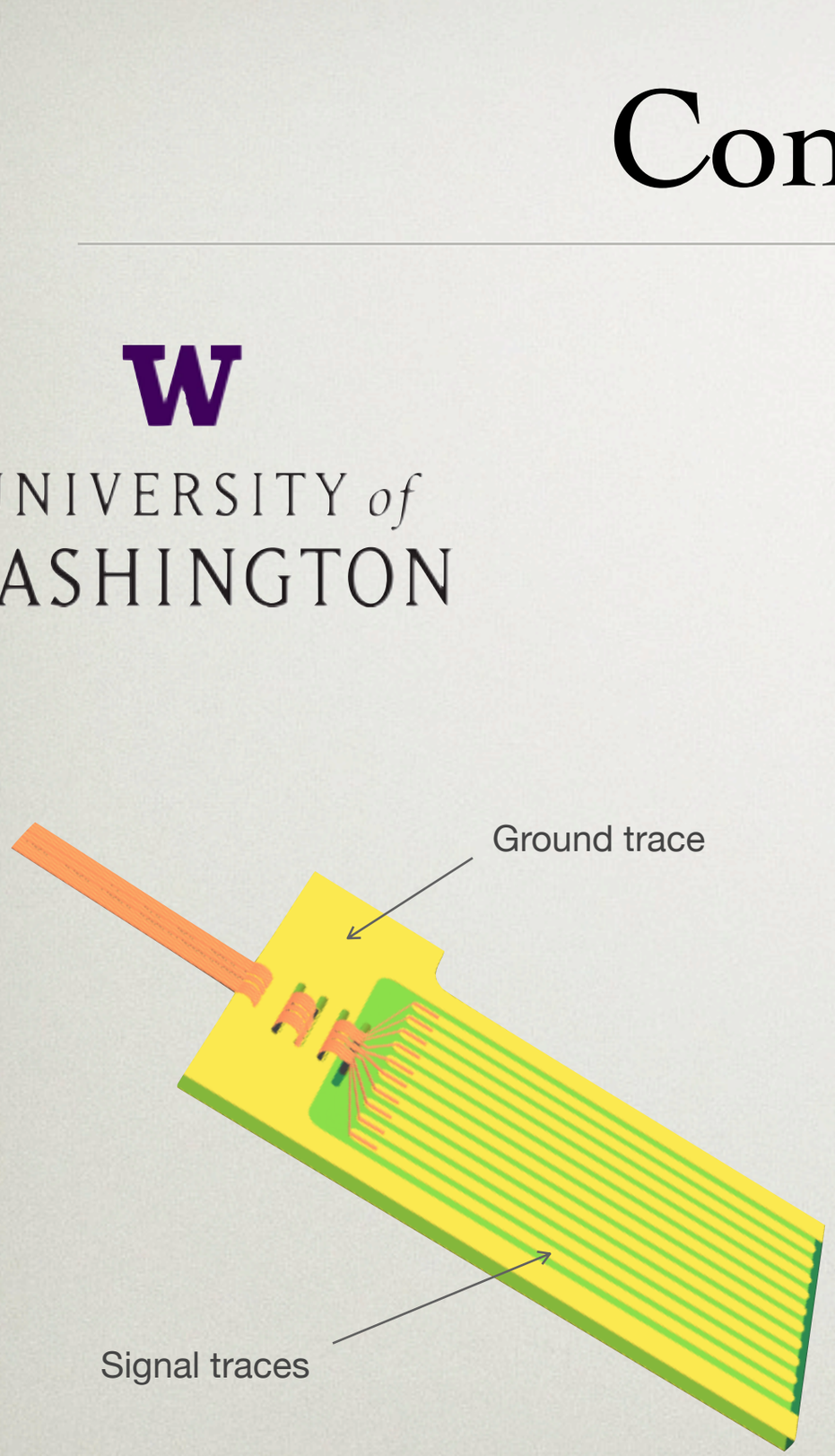
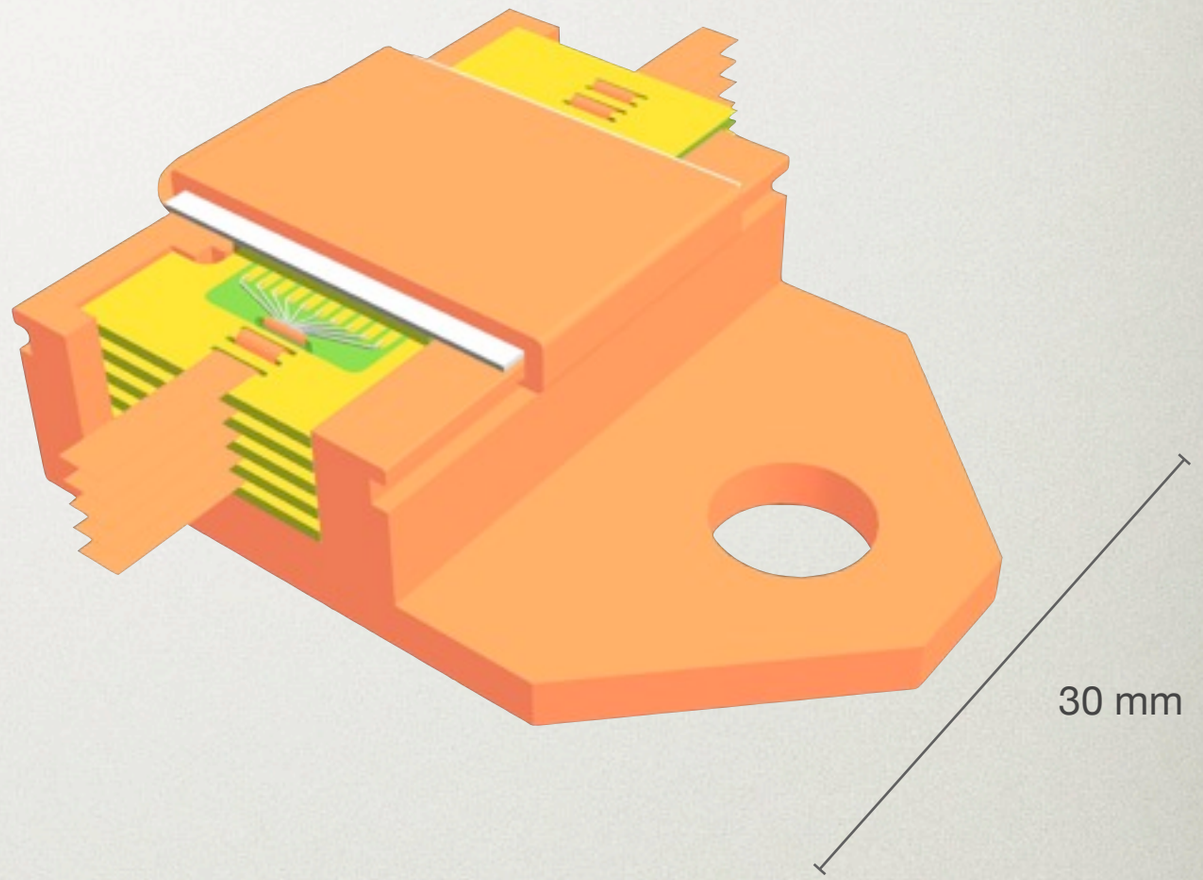




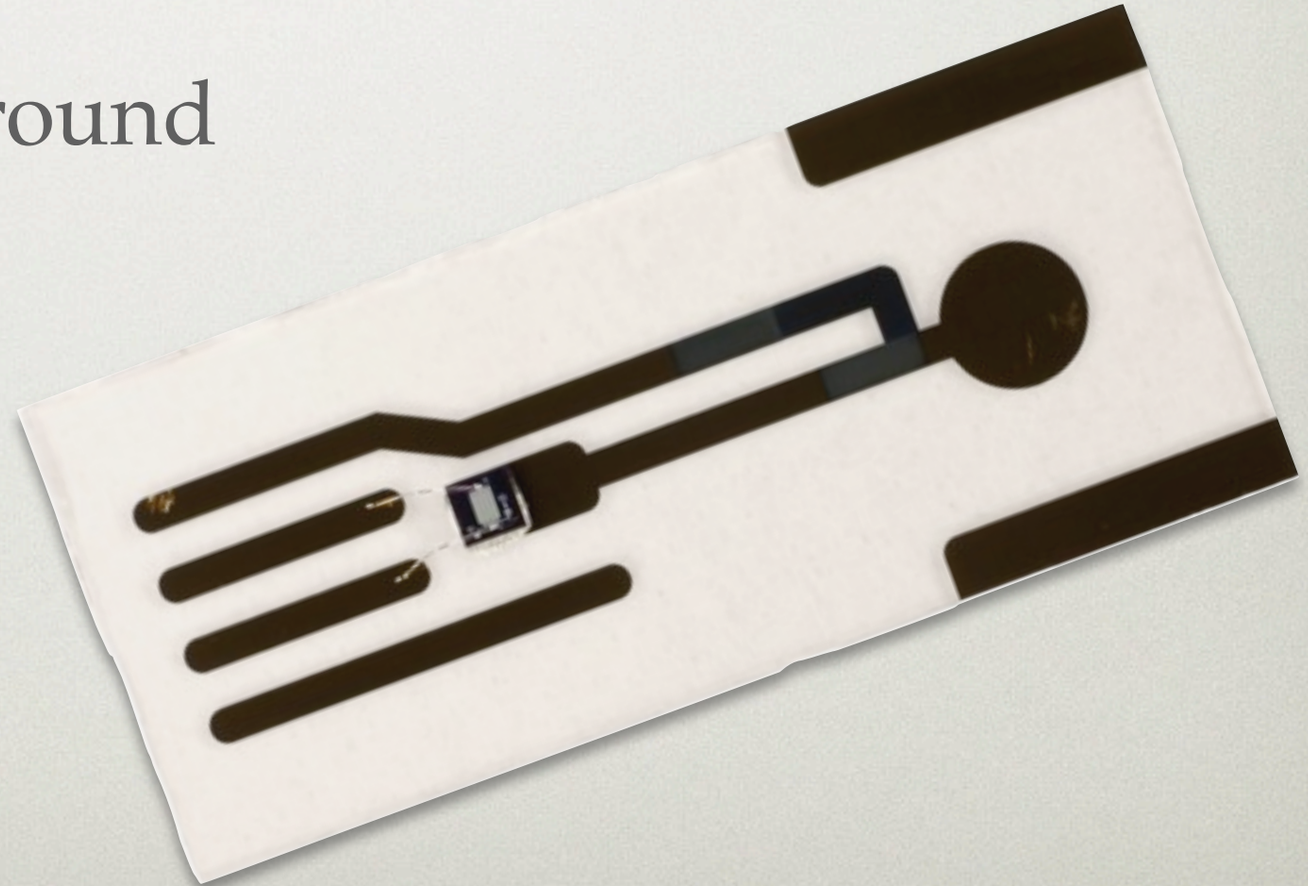
Boards stacked inside a copper clamp

[Knecht et al.]

Summary

The MAJORANA collaboration is developing Ge detector electronics, cables and connectors with excellent properties

- Ultra-low background
- Ultra-low noise




Thank you