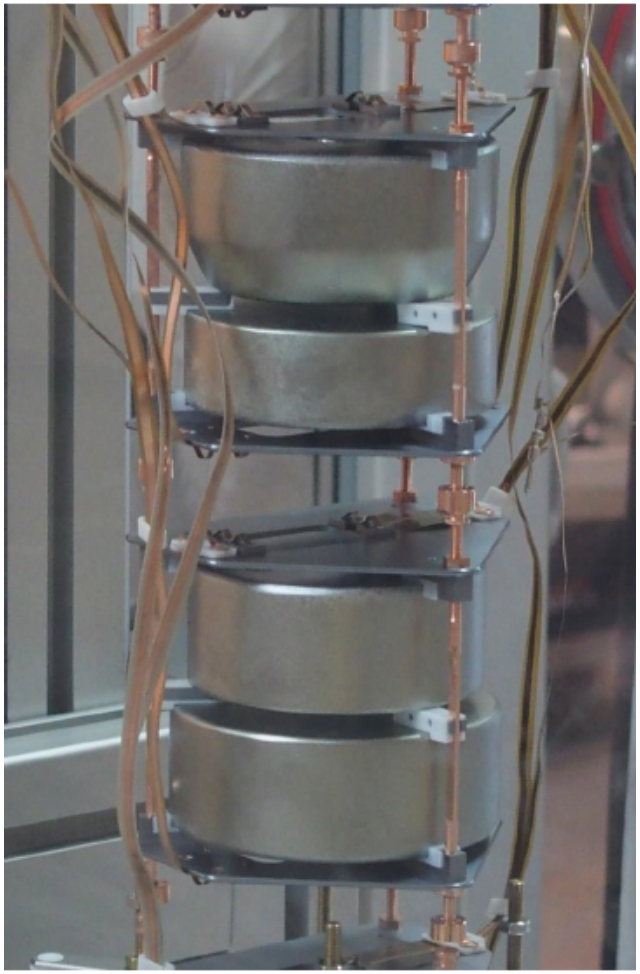
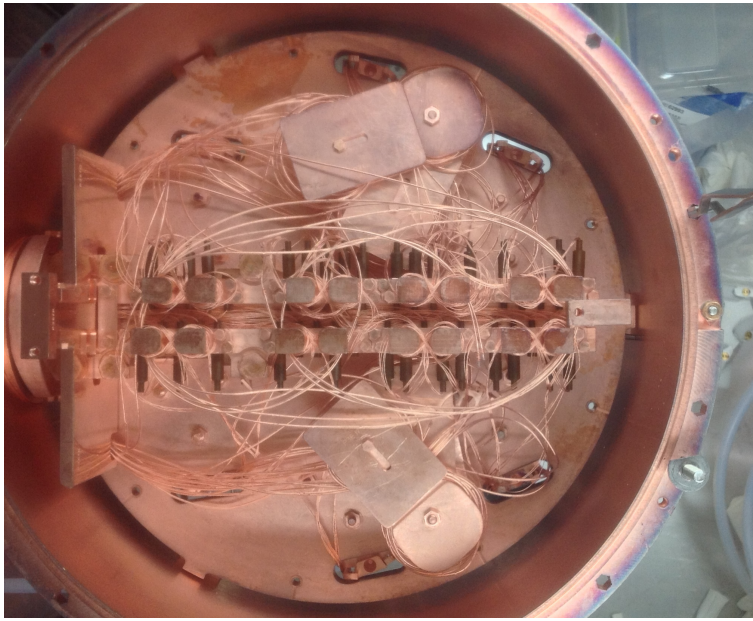
Cable R&D

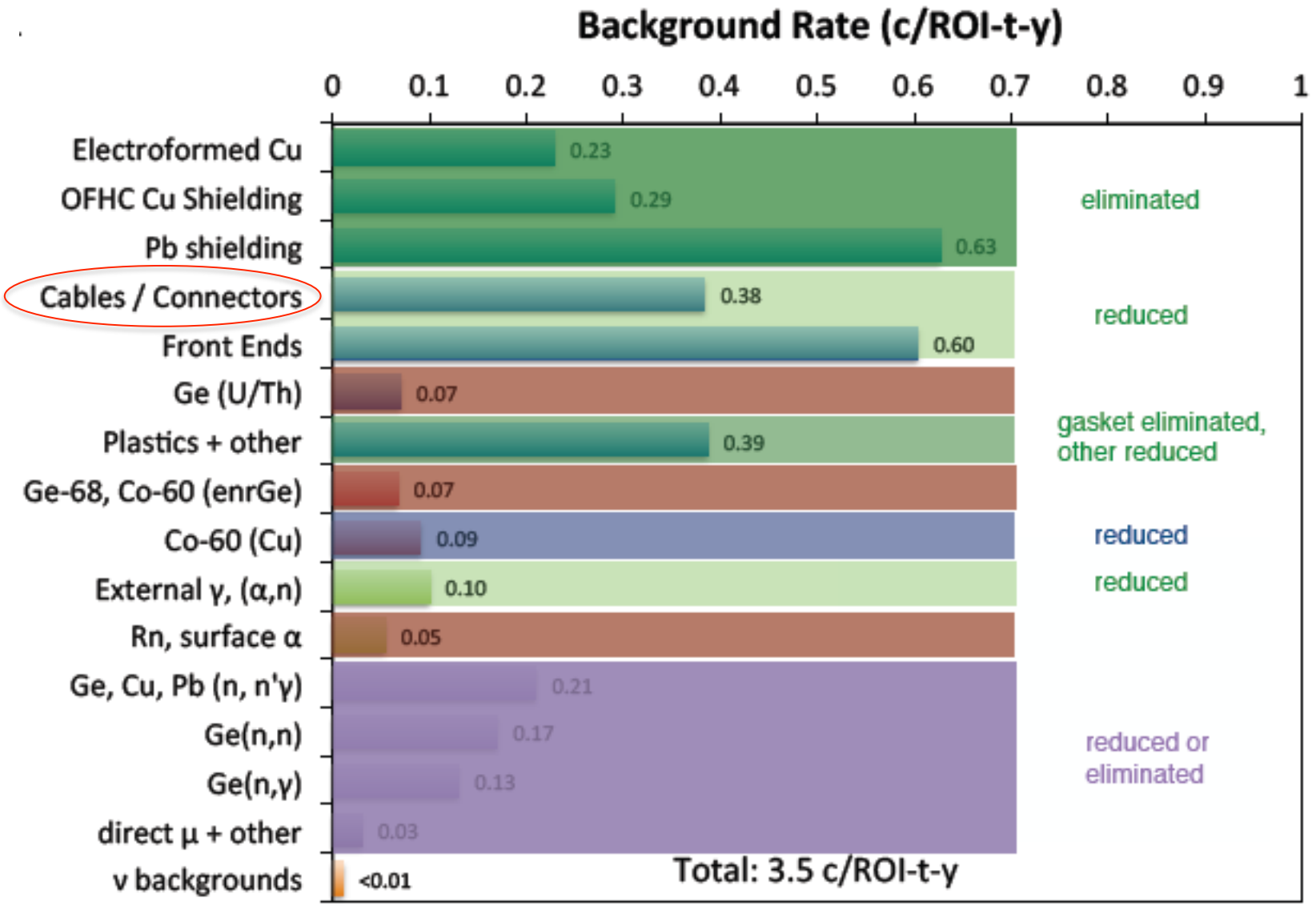




NG-Ge76 meeting, 25-27.4.2016
Stefan Schönert, TUM

MJD material provided by
Matthew Busch TUNL/Duke University

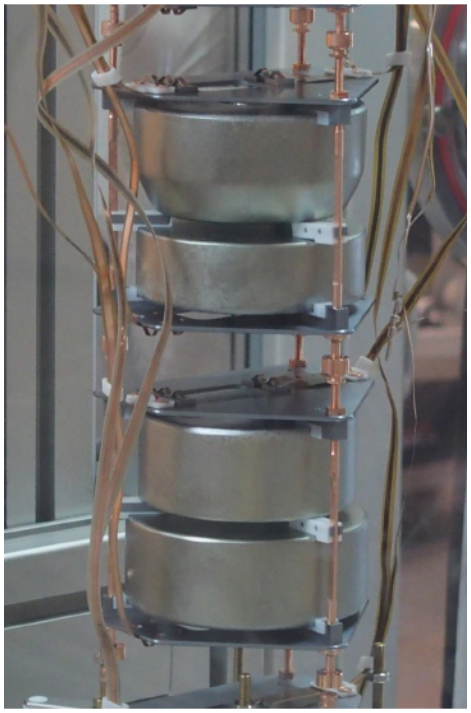
MJD background budget break down



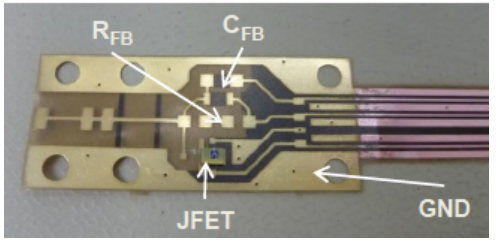
GERDA

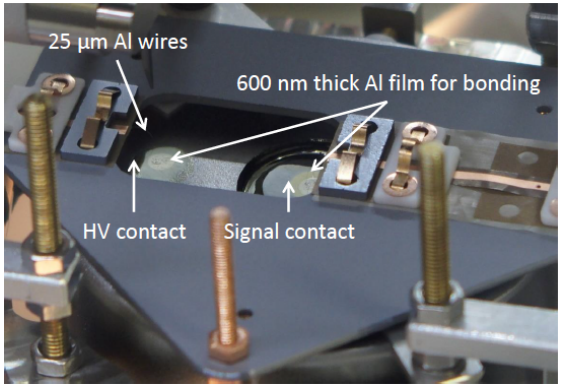
Phase I

Phase II



Wire bonding cable--detector

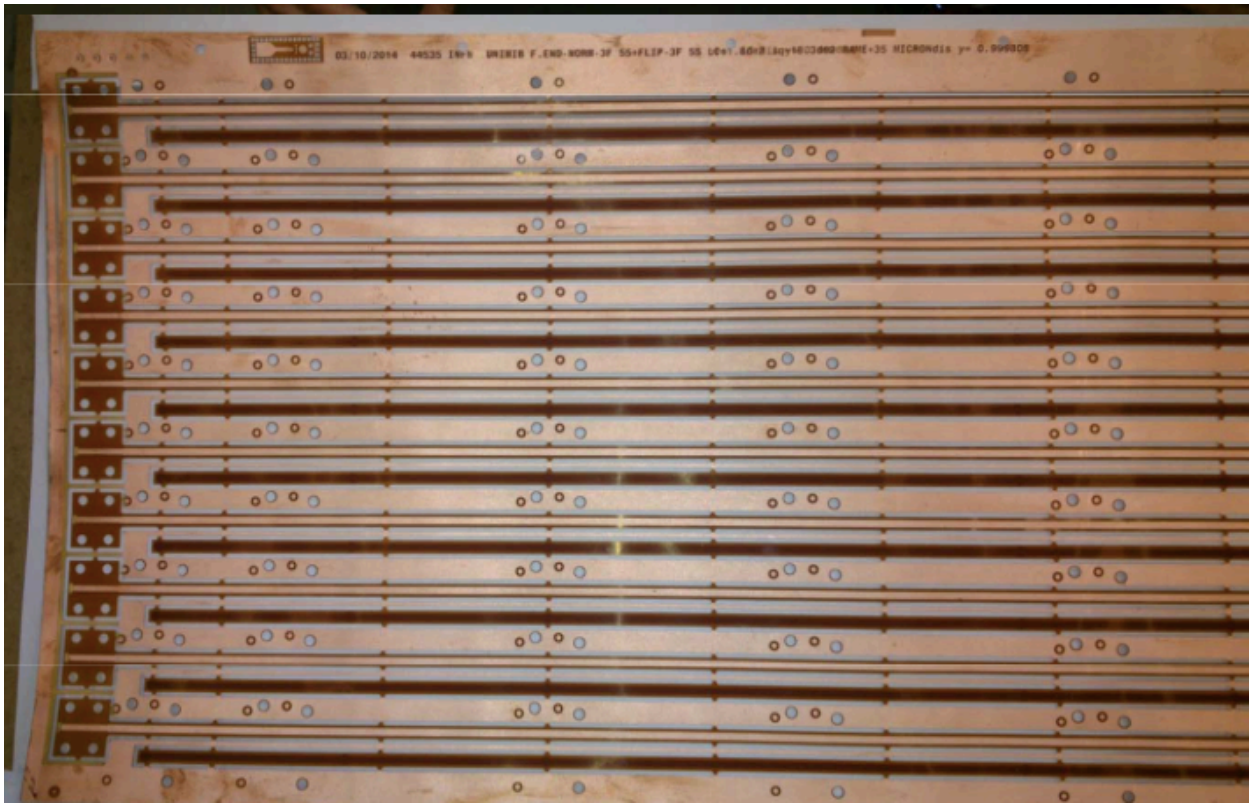




- Copper stripes machined from screened massive copper blocks
- Insulator: PTFE tube

Coplanar wave guide
made from Cuflon (PTFE laminate)/
Pyralux (Kapton laminate)

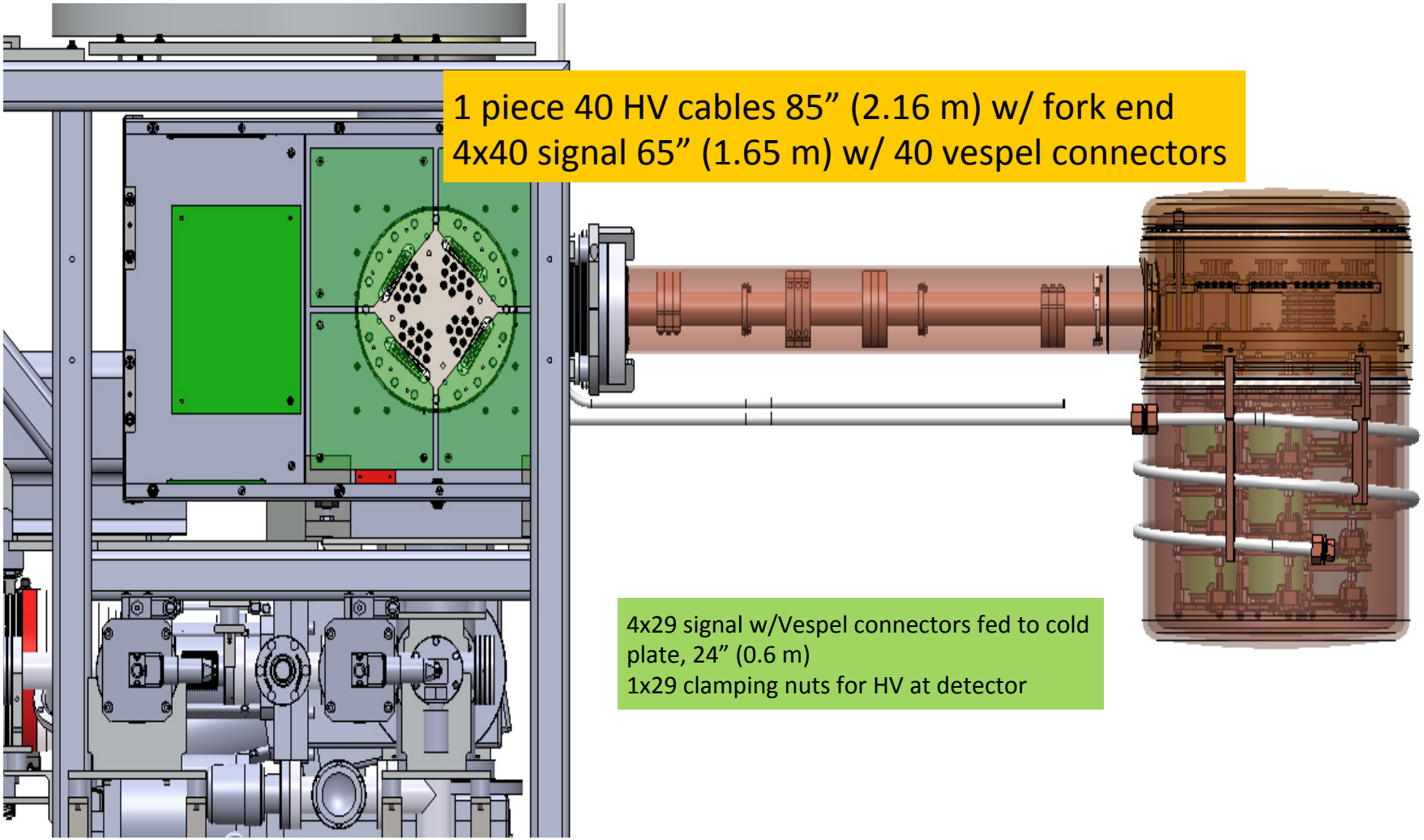
HV-Flex strip produced in Kapton



C. Cattadori, V. D'Andrea, A. Di Vacri, E. Ferri, S. Riboldi, F. Salamida
M.L. Di Vacri, M.Laubenstein, S. Nisi

manufacturer	type	impedance	capacitance	outer diam.	mass / length		U/Ra-226		Th		measured by	comment
		ohm	pF/m	mm	g / m		µBq/kg	µBq/m	µBq/kg	µBq/m		
Pyralux Tecnomec							6000		3300		ML	HPGe
Pyralux Tecnomec	3 mil (single trace)				0,63		3800	2,38	5500	3,44	ML	HPGE
Pyralux Tecnomec	2 mil (multi trace)				5,63		**6000**	**33,75**	5400	30,38	ML	HPGe

MAJORANA DEMONSTRATOR cables and connections

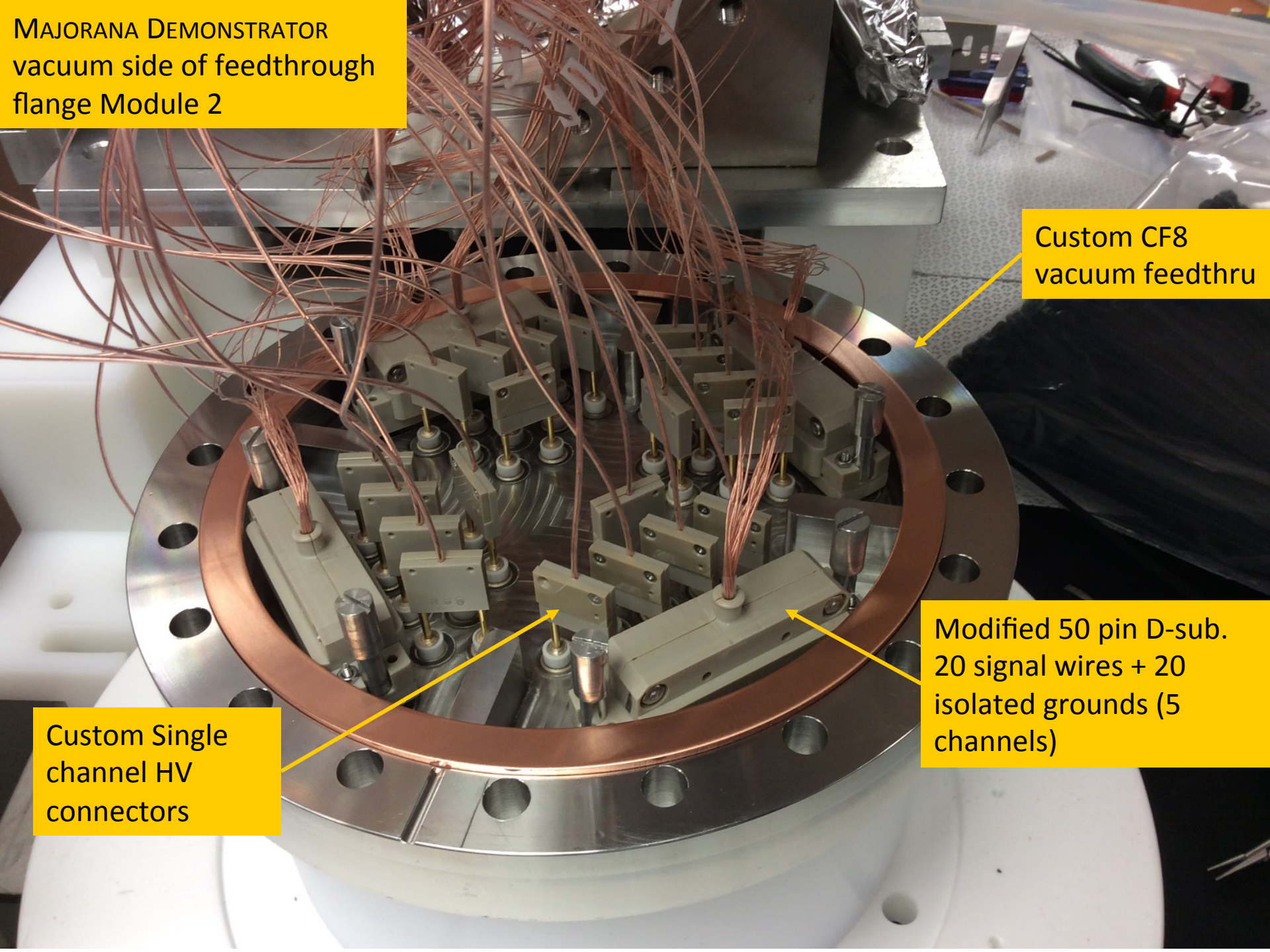


1 piece 40 HV cables 85” (2.16 m) w/ fork end
4x40 signal 65” (1.65 m) w/ 40 vespel connectors

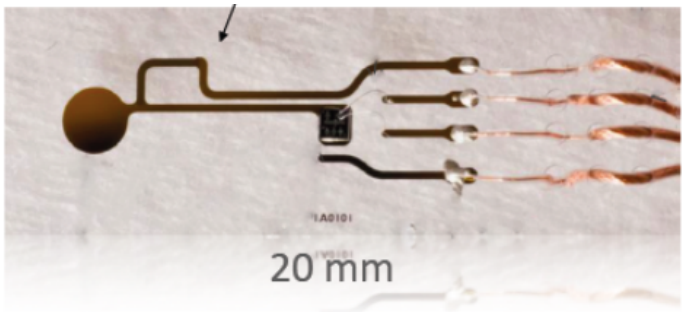
4x29 signal w/Vespel connectors fed to cold plate, 24” (0.6 m)
1x29 clamping nuts for HV at detector

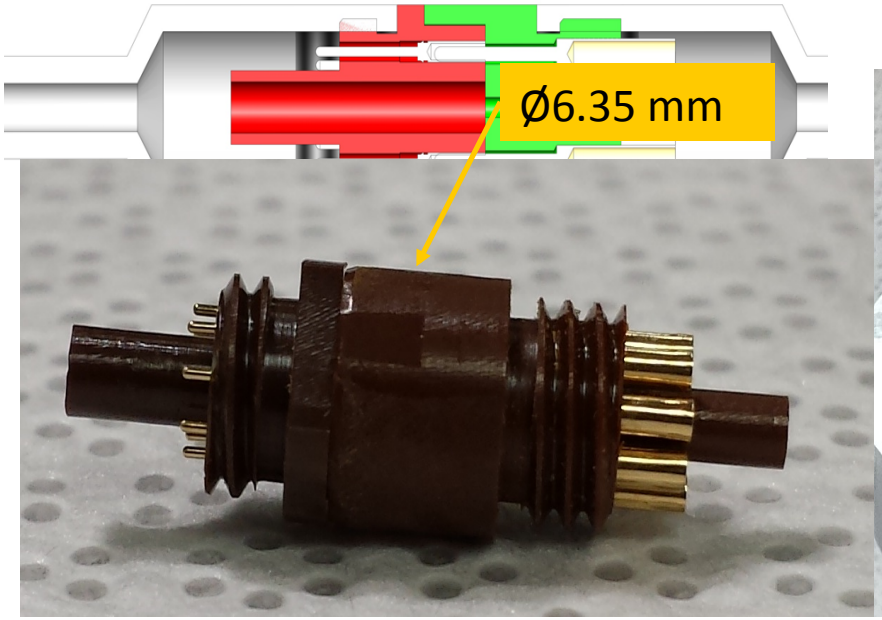
MAJORANA DEMONSTRATOR cables and connections

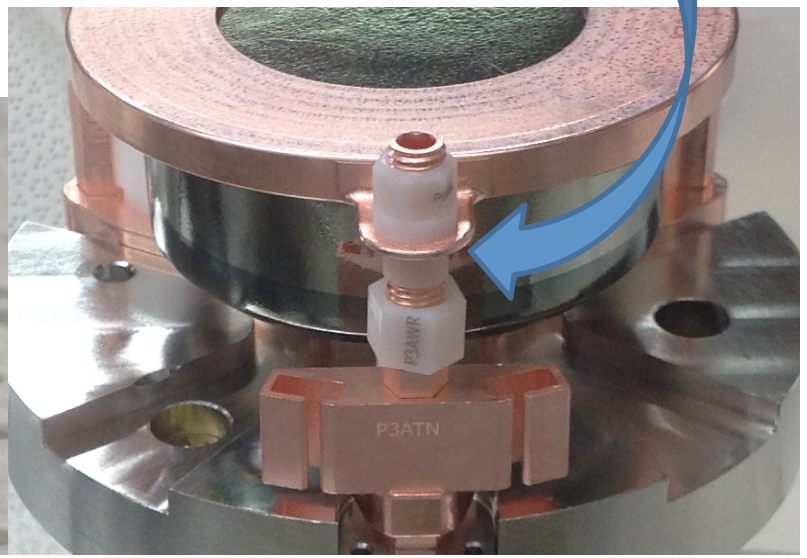
- "pico-coax" cables from Axon' per detector
  - 4 signal Ø0.4 mm, AWG 40 inner conductor
  - 1 HV Ø1.2 mm, AWG 34 inner conductor
  - Total mass per channel: 4.6 g/m
- In-house made connectors and terminations at cold plate end made from ultra pure assayed Vespel SP-1 and UGEFCu.
- In-house assembled connectors at feedthrough end to accommodate wire gauge and custom hi density feedthrough.
- Cables and connectors went through several revisions during development to improve performance and reliability. As a result, cable management and ergonomics were constrained by existing parts.
- For coldplate connections, assay results for Cu-Be were all unacceptable, eliminating the possibility of a commercial solution


MAJORANA DEMONSTRATOR
vacuum side of feedthrough flange Module 2
Custom CF8 vacuum feedthru
Modified 50 pin D-sub. 20 signal wires + 20 isolated grounds (5 channels)
Custom Single channel HV connectors

MAJORANA DEMONSTRATOR FE & HV







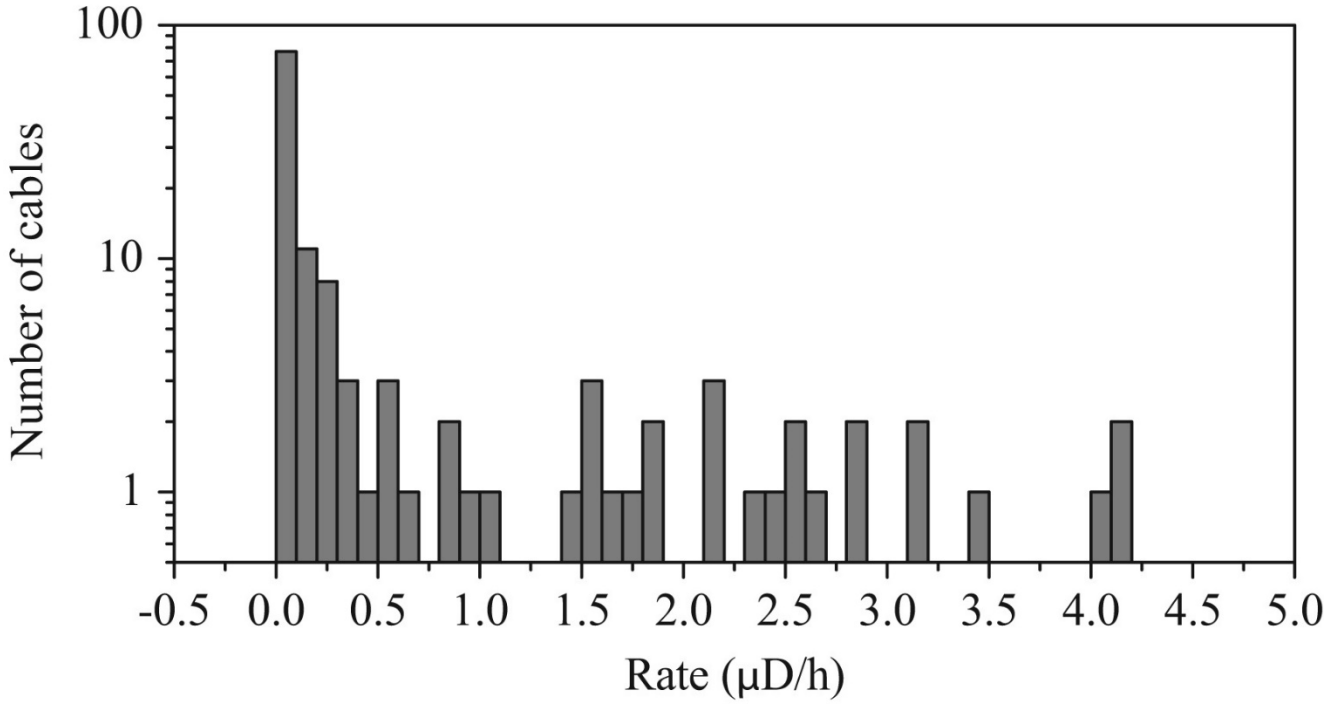
Vespel signal connectors assay

- With Cu-Be spring elements removed, connectors meet our goals using ICMPS of a complete connector bulk assay

Material	Mass (g)	Post-Ash Mass (g)	Undigested Mass (g)	Isotope	Specific Activity (µBq/kg)	Background (c/ROI t y)
Female plug assembly	0.453	0.068	0.004	^{238}U	1160±17	0.052
				^{232}Th	365±6	0.083
Male plug assembly	0.600	0.183	0.035	^{238}U	281±24	0.017
				^{232}Th	27±2	0.008
Connector totals	1.05			^{238}U	1160±17	0.052
				^{232}Th	365±6	0.083

- See paper for details **arXiv:1601.03779**

MJD HV cable testing results

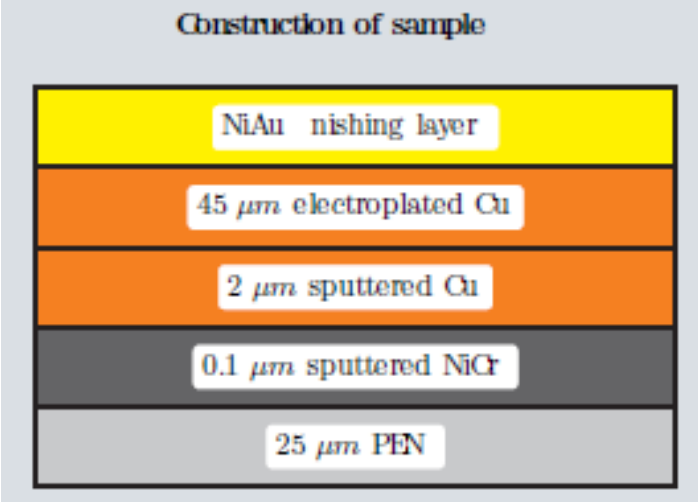


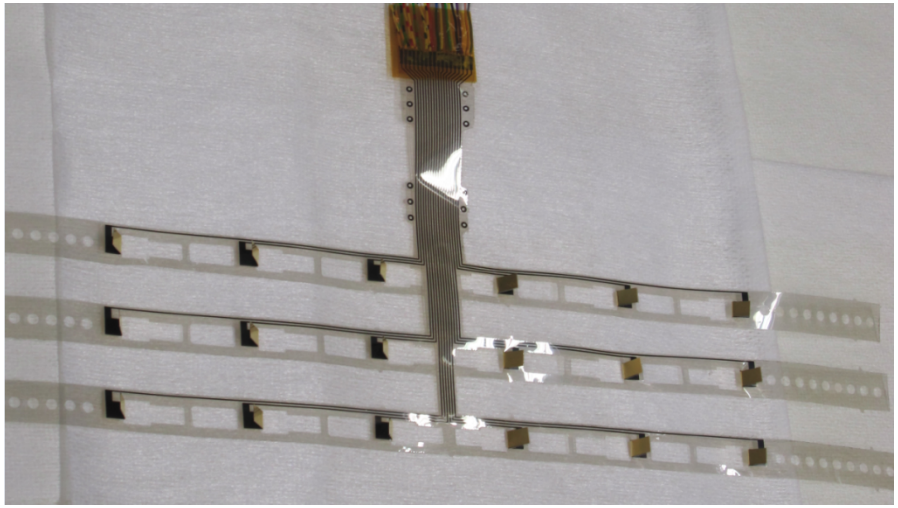
- 100% testing of assembled cables was completed, all cables passed.
- See paper for details **arXiv:1603.08483**

Cable R&D at MPI für Physik

- PEN: R&D on lamination
- PEN: Snap contact for SegHPGe
- PEN: Capacitor
- CUFLON: Tests
- PFA signal & HV: Medikabel, Cable weaving

R&D on lamination



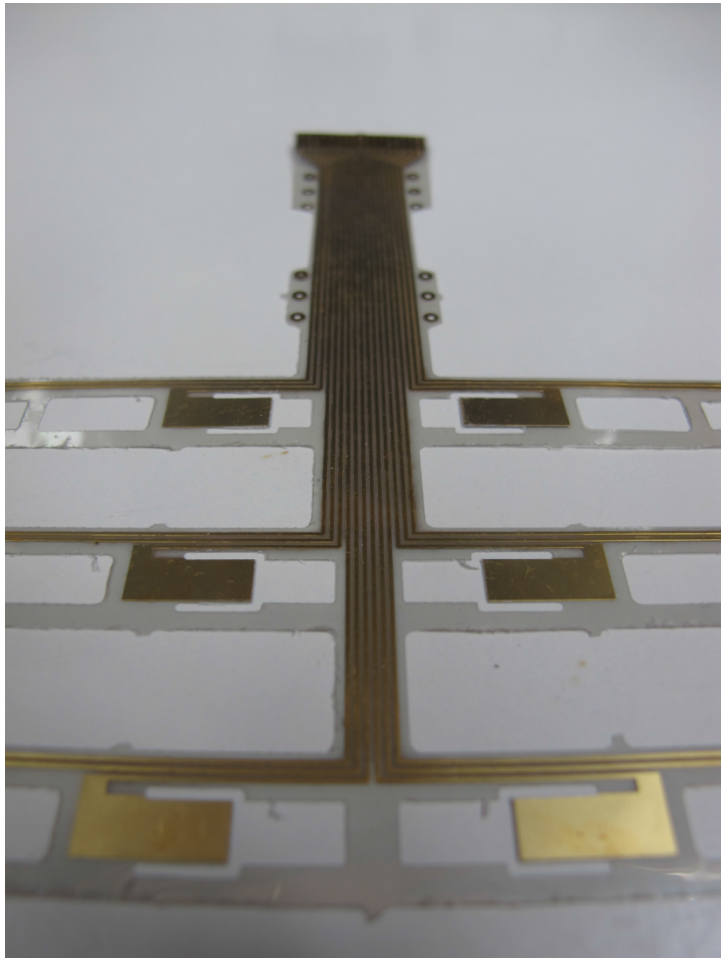


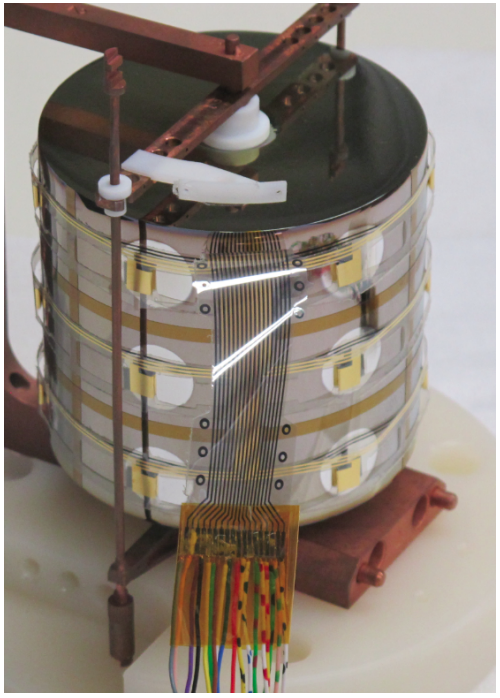
PEN lamination process for GERDA proved to work:

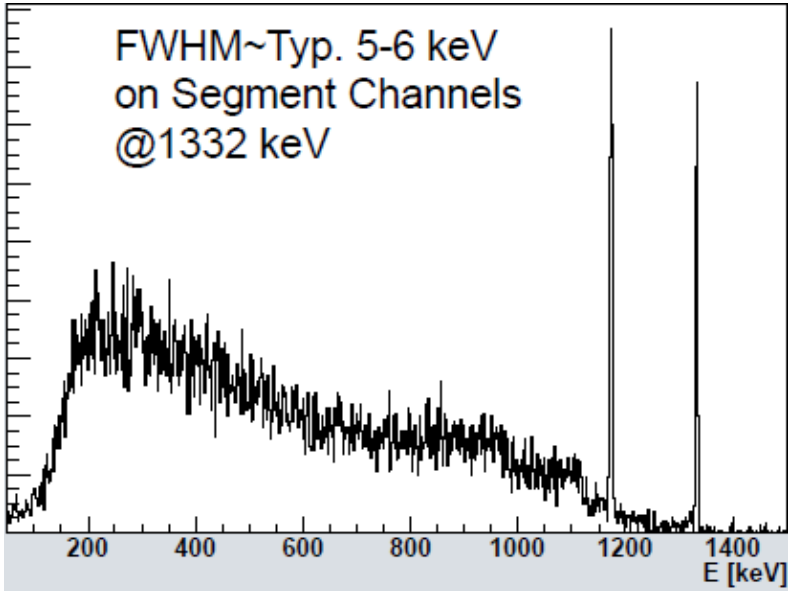
1) **Procure TEONEX Q51 (DuPon Teijin)**
2) **Sputter 150nm NiCr tie coat (GFO)**
3) **Sputter 2μm Cu (GFO)**
4) **Electroplate 45μm of Cu and NiAu finishing (Lüberg)**
5) **Processing into FPC boards (Lüberg) NiCr tie coat problematic!**

R&D time: 2008-2010

R&D on lamination @ MPP







Contacts require bending.
All 18 contacts good!

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DOI 10.1140/epjc/s10052-013-2445-3

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

High voltage capacitors for low background experiments

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[6]Max-Planck Institut für Kernphysik, Heidelberg, Germany
[7]Joint Institute for Nuclear Research, Dubna, Russia

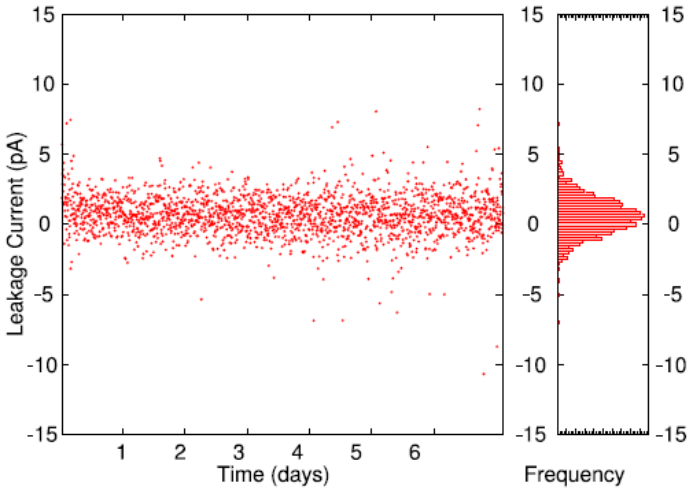


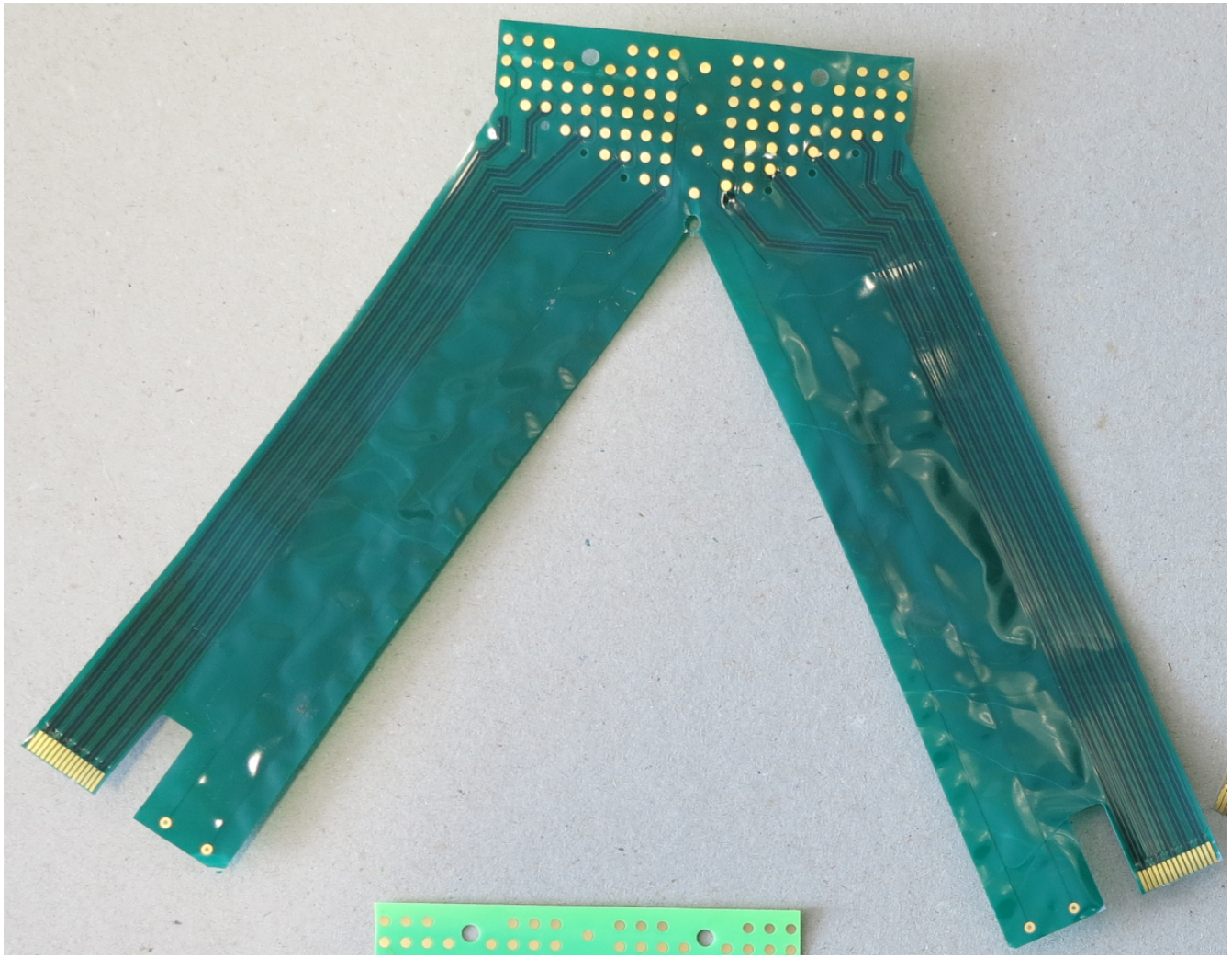
Fig. 4 Long-term measurement of the leakage current with the capacitor biased to 5 kV at 77 K. The right hand projection is a binned frequency distribution showing the Gaussian profile

HV capacitor tested in LAr for several days: No (micro-)discharges observed

→ Can be used for HV cables!

CuFlon processed by Polyflon for Pogopin matrix:

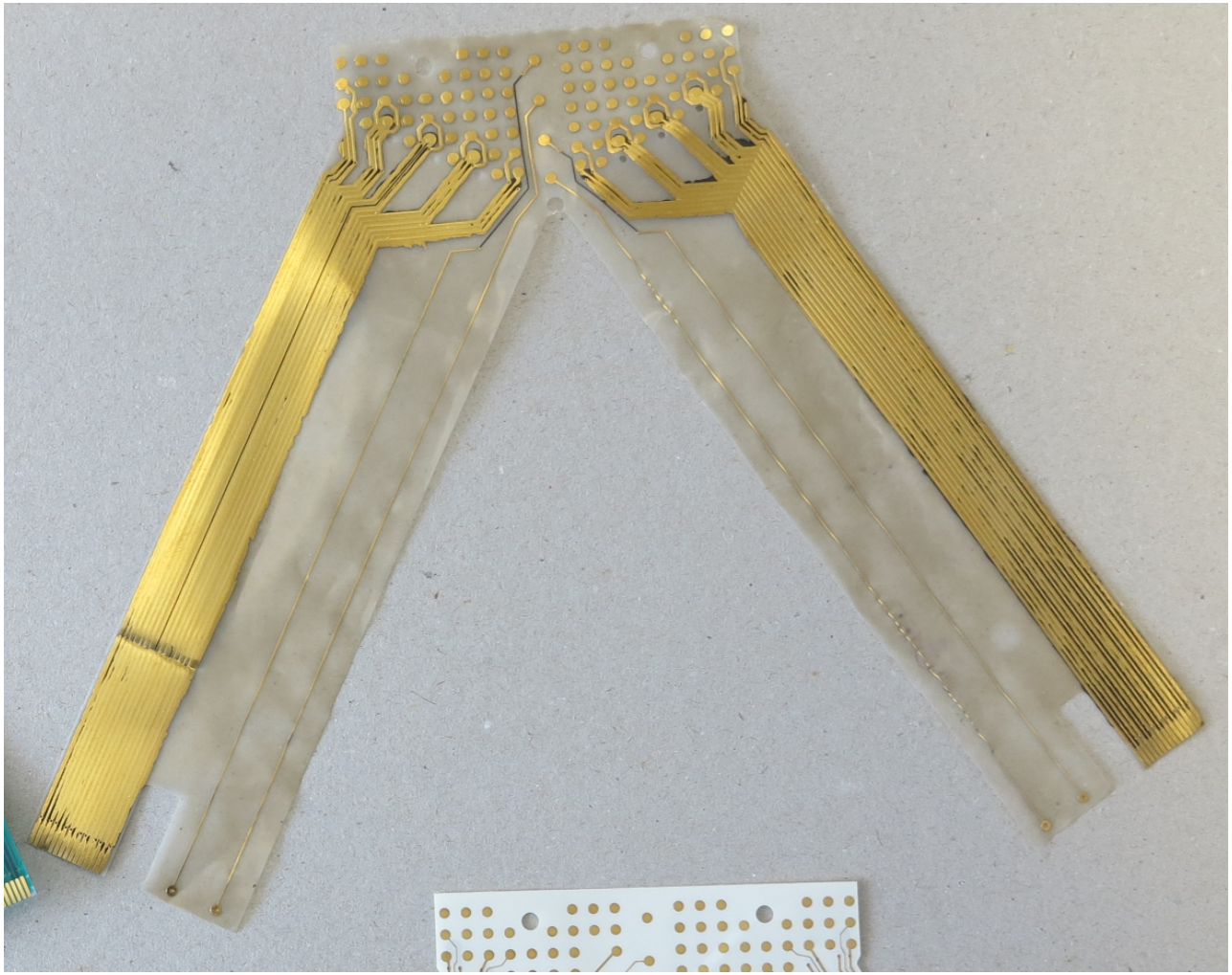
Standard production with cover layer



June 2008

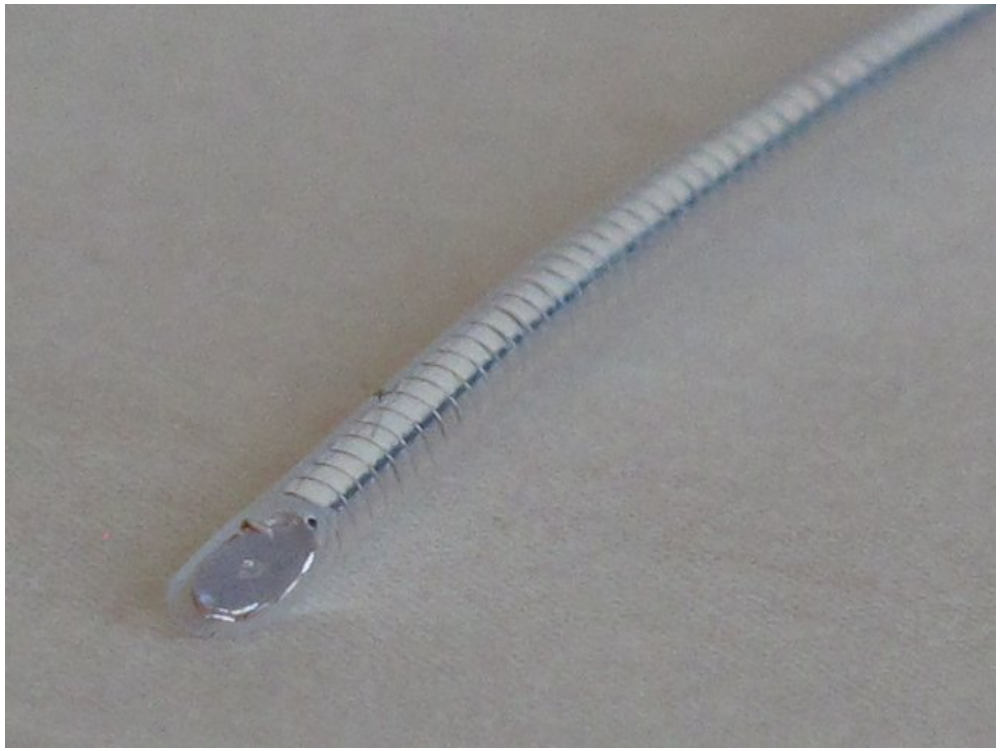
CuFlon processed by Polyflon for Pogopin matrix :

Production without cover layer



Sept. 2008

Medikabel: PFA coaxial cable for signal and HV up to ~2kV



Procured special batch of PFA
Used silver coated copper foil
as outer shield
Special production by company
Medikabel

Gamma screening results:

Th-228:	(0.4 +- 0.2) mBq/kg	<==>(1.0 +- 0.4) E-10 g/g
Ra-226	(0.5 +- 0.2) mBq/kg	<==>(4 +- 2) E-11 g/g
K-40:	(26 +- 4) mBq/kg	<==>(8 +- 1) E-7 g/g
Cs-137:	(0.8 +- 0.2) mBq/kg	
Co-60:	< 0.10 mBq/kg	
Ag-108m:	(0.32 +- 0.08) mBq/kg	

- CuFlon R&D was abandoned as no technology for processing without cover layer was available (in 2008)
- PEN satisfies low background requirements
- PEN is most likely also suitable for HV

→ PEN is promising material for flexible cables

- Lead times were/are considerable!

Considerations from B. Majorovits

Overview radio purity of cable candidates

manufacturer	type	impedance	capacitance	outer diam.	mass / length		U/Ra-226		Th		measured by	comment
		ohm	pF/m	mm	g / m		µBq/kg	µBq/m	µBq/kg	µBq/m		
axon coax MJD	signal	50	87	0,4	0,45	axon data sheet	145	0,07	2,2	0,00	MJD	ICPMS
							9880	4,45	4070	1,83	MJD	HPGE
axon coax MJD	HV			1,2	3,00	axon data sheet	145	0,44	2,2	0,01	MJD	ICPMS
							2470	7,41	2850	8,55	MJD	HPGE
axon GERDA	FEP 9494						74	0,03	16	0,01	SN	ICPMS
	FEP 9494						400	0,18	140	0,06	ML	HPGE
	FEP NP 2020						37	0,02	33	0,01	SN	ICPMS
	FEP NP 2020						290	0,13	110	0,05	ML	HPGE
	Cu shield											
	Cu wire (signal)											
	Cu wire (HV)											
Sami coax		75		1,4	5,25	meas. B&St	1000	5,25	1000	5,25	ML	HPGe
Sami coax	RG178			1,8	8,94	sami data sheet	400	3,57	330	2,95	ML	HPGe
Sami coax	RG179	75	64	2,6	14,69	sami data: 17 g/m	370	5,44	400	5,88	ML	
Cuflon Milano	3+7 sheet						1400		1200		ML	HPGe
Cuflon Häfele (HV)	10 mil				2,63		8000	21,00	5500	15,00	ML	HPGe
Cuflon Häfele (Signal)								27,00		13,00	ML	HPGe
Pyralux							2600		500		ML	HPGe
Pyralux Tecnomec							6000		3300		ML	HPGe
Pyralux Tecnomec	3 mil (single trace)				0,63		3800	2,38	5500	3,44	ML	HPGE
Pyralux Tecnomec	2 mil (multi trace)				5,63		**6000**	**33,75**	5400	30,38	ML	HPGe
Koax24, 196A/U	Xe/signal	50	97	1,8	9,2	data sheet	400	3,68	560	5,15	Xe/UZH	HPGe
Medikabel		95			3,18	Bela	500	1,59	400	1,27	ML	HPGE
Elring Klinger	PTFE tube	-	-		4,28		1100	4,71	620	2,65	ML	HPGe

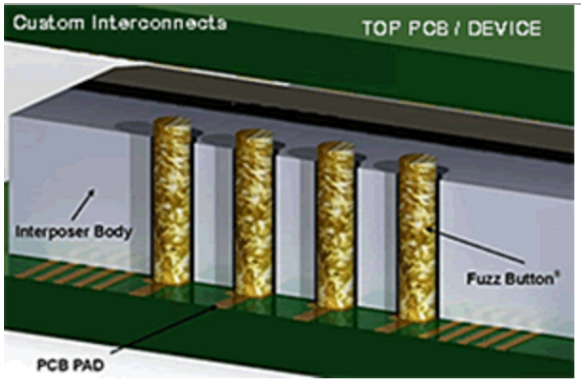
Challenges for future cables and connectors

- Signal pico-coax are somewhat delicate and prone to damage during handling.
- 40 AWG wire is too small to reliably crimp. This limits commercial aerospace grade options.
- High density reliable vacuum feedthrus will increase in complexity / cost for next generation.
- Vespel connectors and MIL-MAX gold plated brass pins in coldplate connector may not meet radiopurity requirements for next generation, and at least would require significant reliability improvements

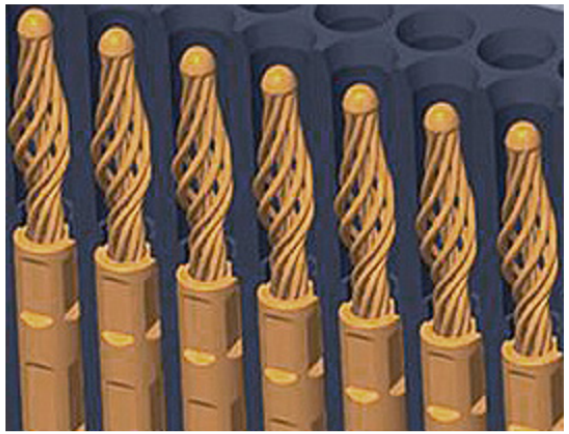
Future considerations for cables
(from Matthew Busch)

- Sharing grounds can reduce total cable count per channel
- In vacuum digitization can reduce complexity of vacuum feedthrough and mitigate cable length limit issues.
- Low background low mass connectors will be useful even in active shield to increase flexibility of string assembly and rework.
- Some commercial solutions show promise for adaptation to low background materials
- Recent assay work with Phosphor Bronze shows promise as a low background spring element

Commercial small connectors with no Cu-Be



Fuzz buttons: Gold plated Molybdenum “wool”
~0.6mm pitch, used in IC testing



Nano twist pins: Gold – Silver alloy, 0.32-0.64 mm pitch
Used in aerospace