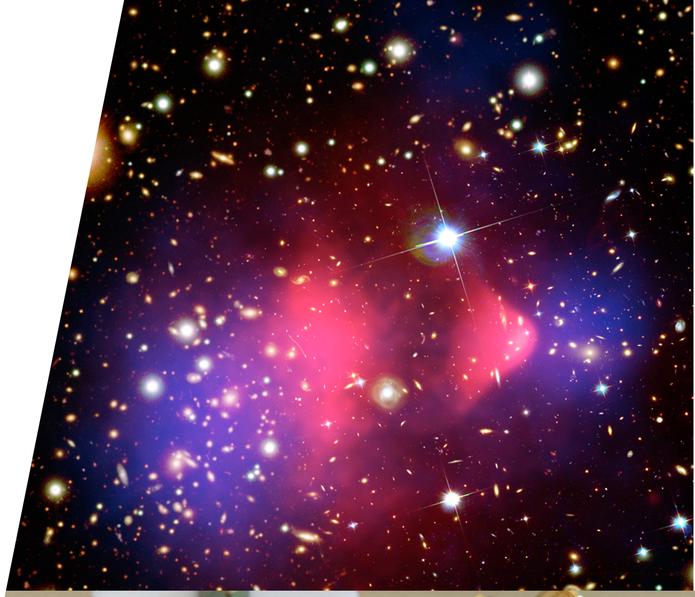
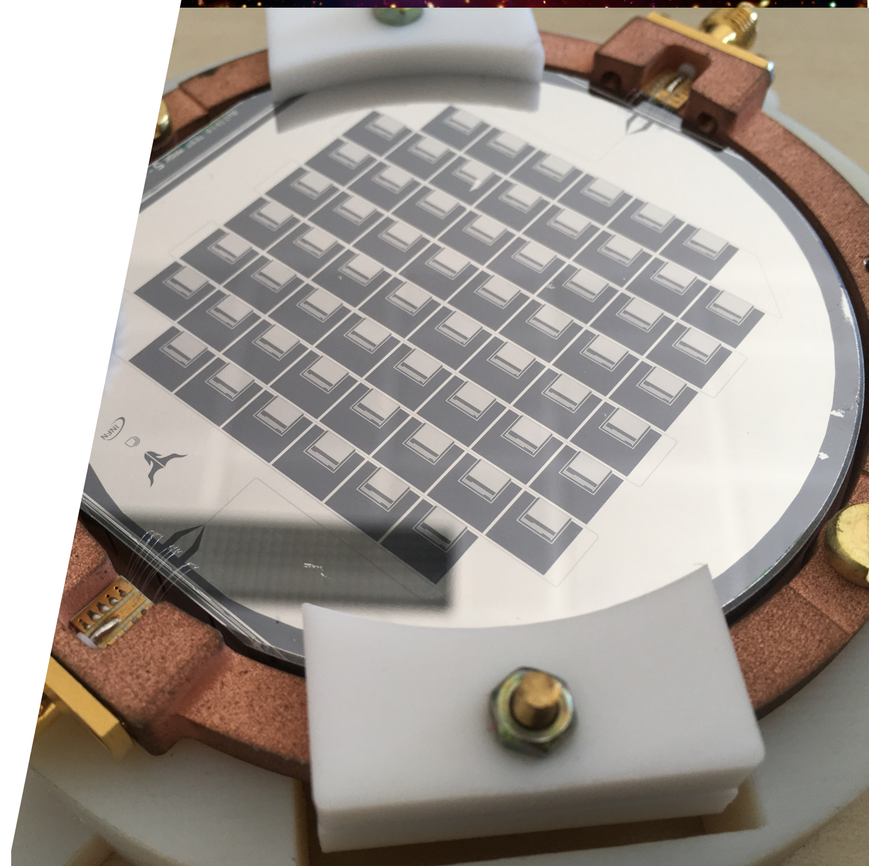
SAPIENZA
UNIVERSITÀ DI ROMA

INFN
Istituto Nazionale di Fisica Nucleare



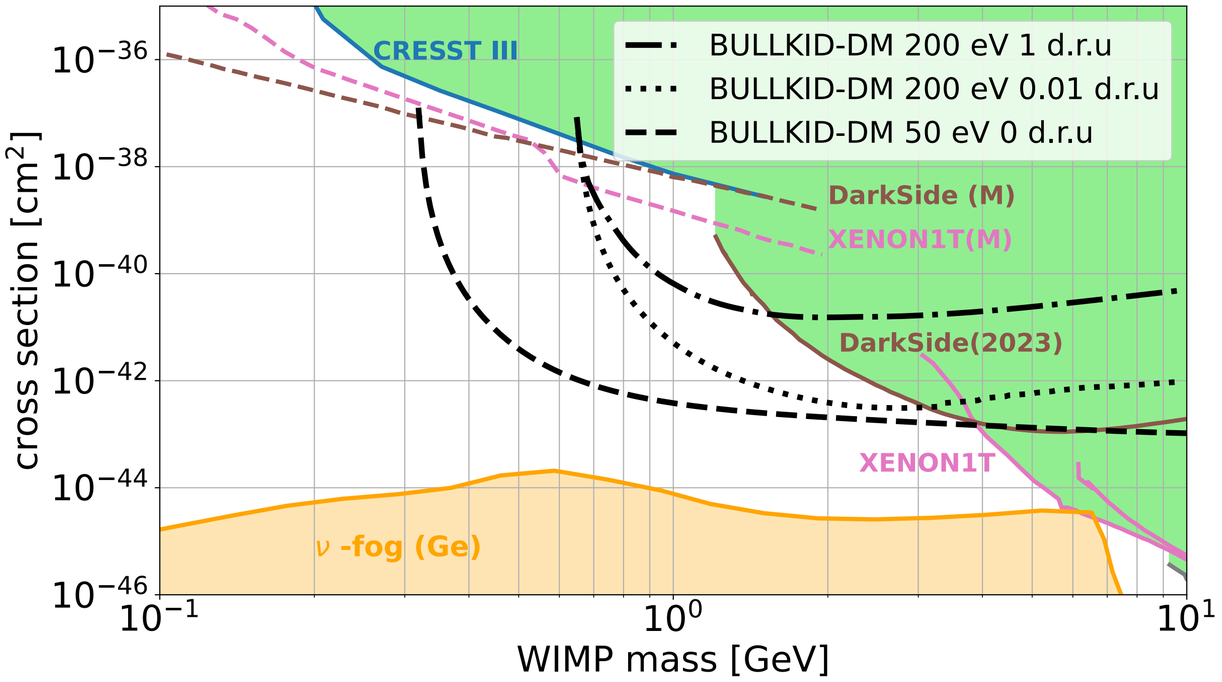


General status

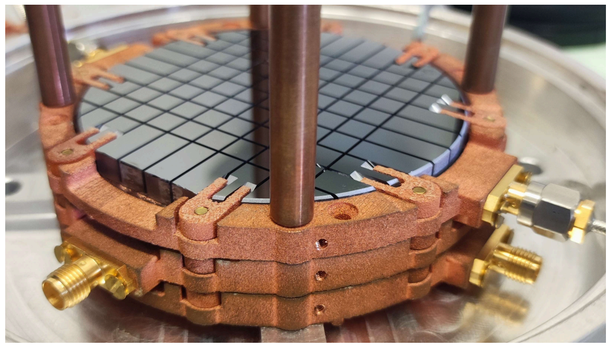
Marco Vignati, BULLKID-DM Digest, October 2024

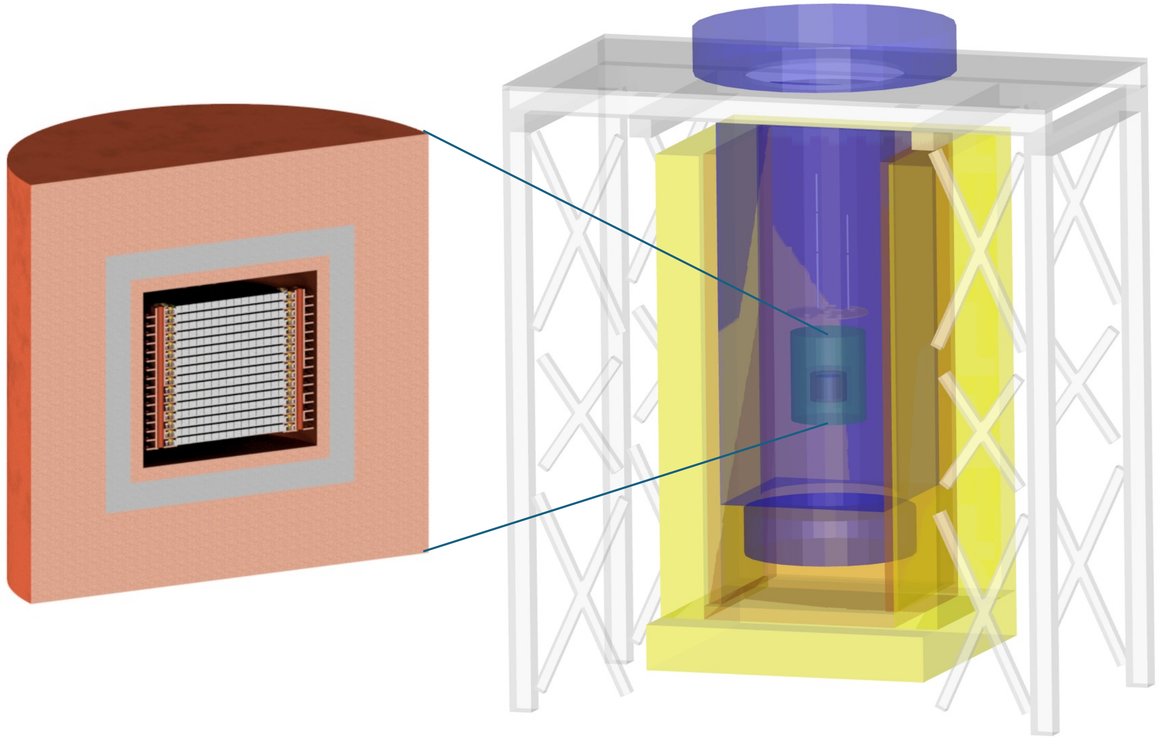
Dark Matter - direct search with BULLKID-DM

	BULLKID prototype	BULLKID-DM demonstrator		BULLKID-DM
mass	20 g	60 g		**800 g**
# of sensors	60	180		**2300**
threshold	160 eV	200 eV		**≤ 200 eV**
bkg (c/keV kg d)	$2x10^6$	$< 10^5$		**1 - 0.01**
laboratory	Sapienza U.	Sapienza	LNGS	**LNGS**
installation	2023	2024	2026	**2027**



Path





Prototype works

demonstrator (3 wafer)

demonstrator at Sapienza

Cryostat at LNGS

demonstrator at LNGS

full detector at Sapienza

installation at LNGS

2023

2024

2025

2026

2027

LoI to INFN and LNGS

CDR submitted
Approved by INFN
Approved Demonstrator by LNGS

TDR
Decision on veto

Plan

BULLKID-DM
Conceptual Design Report (CDR)

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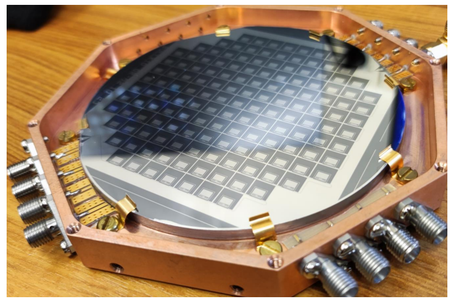
June 28, 2024

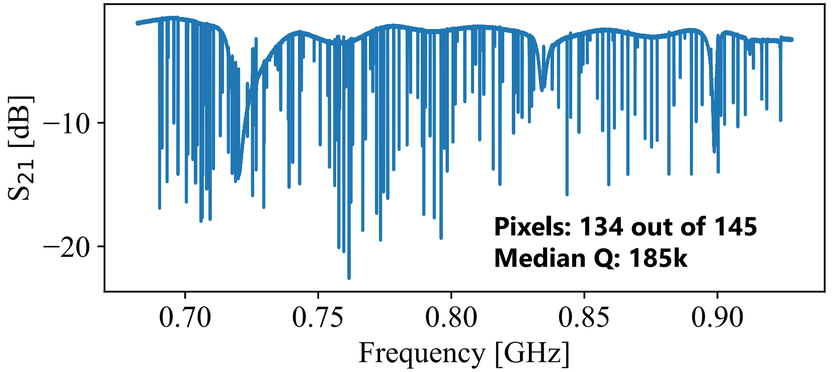
		2024	2025		2026		2027	
#	WP	II	I	II	I	II	I	II
1.1	Stack	M1.1 4" test	M1.2 final assembly		M1.3 baseline ready	D1.1 comm at RM1	Payload (stack + cryogenic shield or veto) installation and commissioning	
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1			M1.5 Tech. run @LNGS			
1.3	Thr. R&D		M1.6 New sensors					
1.4	R&D Germanium		M1.7 Diced wafer					
2	Simulations	M2.1 Preliminary shield design		M2.2 Final shield design	Bkg model			
3	Materials	M3.1 BOM and plan		M3.2 Validated				
4	Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of demo	M4.3 Readout of 145 KIDs	D4.1 Full stack 16x145		
5	RM1 Cryo		M5.1 Delivery	D5.1 Ready				
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding	D6.1 Comm. with ext. shields			
7	Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready	M7.4 shield / veto selection	D7.1 Cryo shield ready		
7.1	R&D Cryo veto			M7.3 single module demonstration				
8	Calibration		M8.1 PoC		D8.1 Ready			
9	Computing				D9.1 Ready			
10	Data analysis					D10.1 Ready		

Stack

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

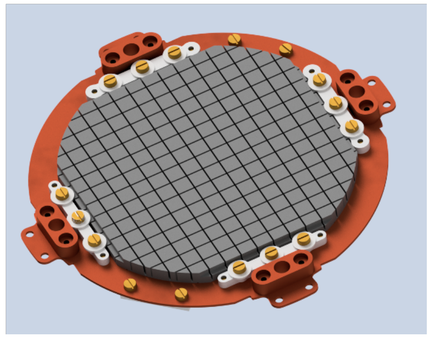
145 KID array test on thin (0.3 mm) 4” wafer successful
(further matrix improvements ongoing)

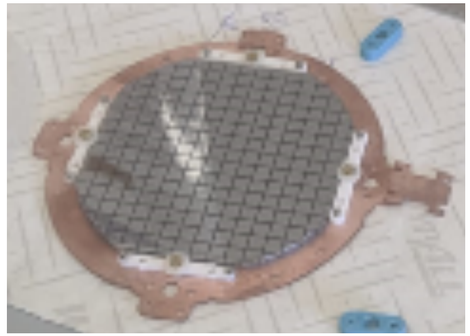




4” x 4mm wafer grooving successful

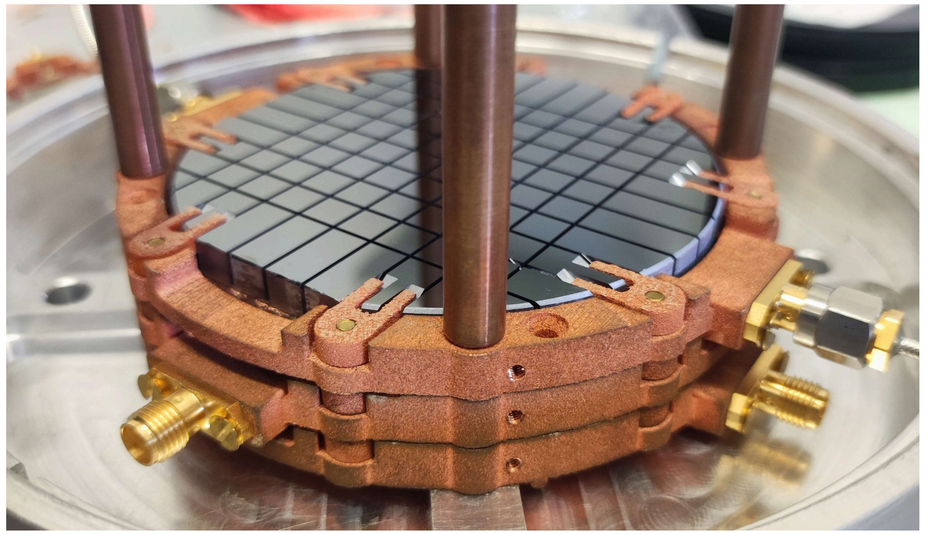
Assembly project ongoing





Demonstrator

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC



1st version built: issue in wafer/KID uniformity
2nd version in production

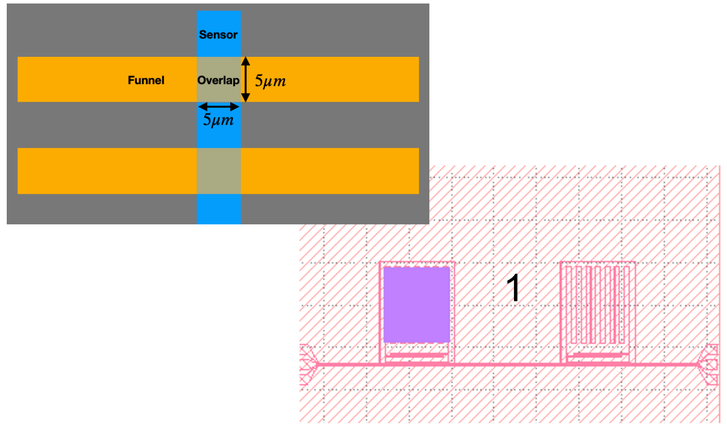
Lead case for 10^5 DRU in delivery

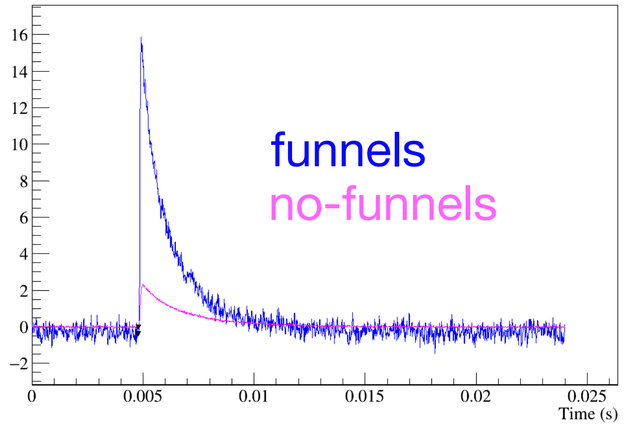
see talk by Matteo F.

KID threshold R&D (optional)

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

1. Quasiparticle funnels: increase qp density in inductor





2. Replace Aluminum with Al-Ti-Al (5x inductance)

In KID light detectors lowers threshold by 2x (CALDER experience)

Application in BULLKID delayed: priority to demonstrator

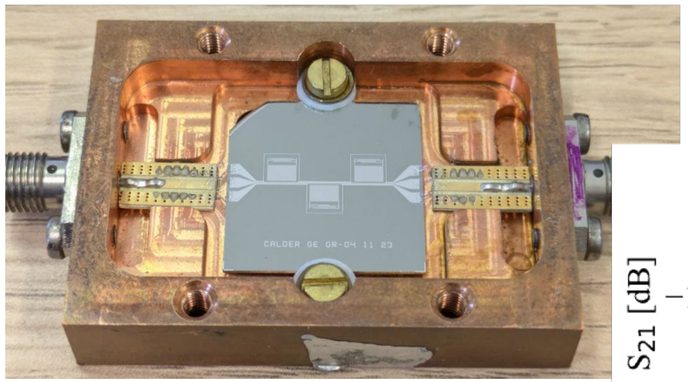
Germanium R&D (optional)

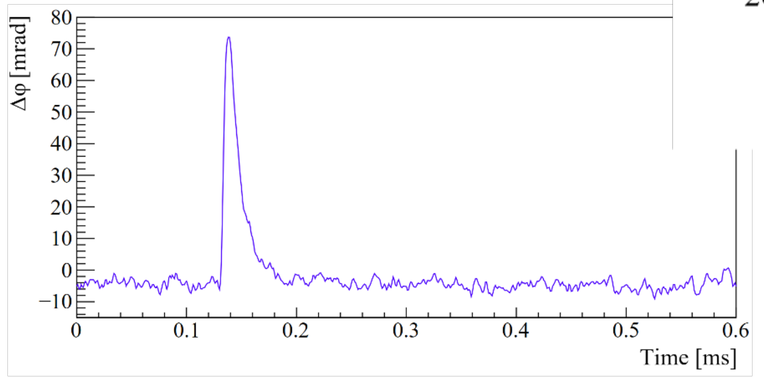
		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

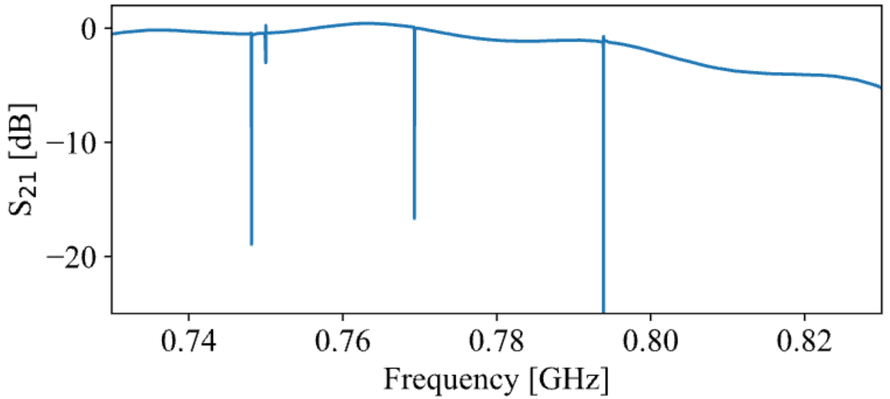
Alternate target for DM, better target for neutrinos than Silicon

✓ First working detectors!

✓ Same electrical properties of Si. Energy resolution to be assessed







Simulations and Materials

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

Simulations (FWPW - fastest WP of the west):

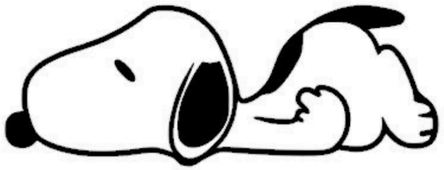
✓ preliminary design of the experiment in the CDR

- Now working on a configuration for the demonstrator to be proposed to LNGS

see talk by UNAM group

Bill of materials and plan:

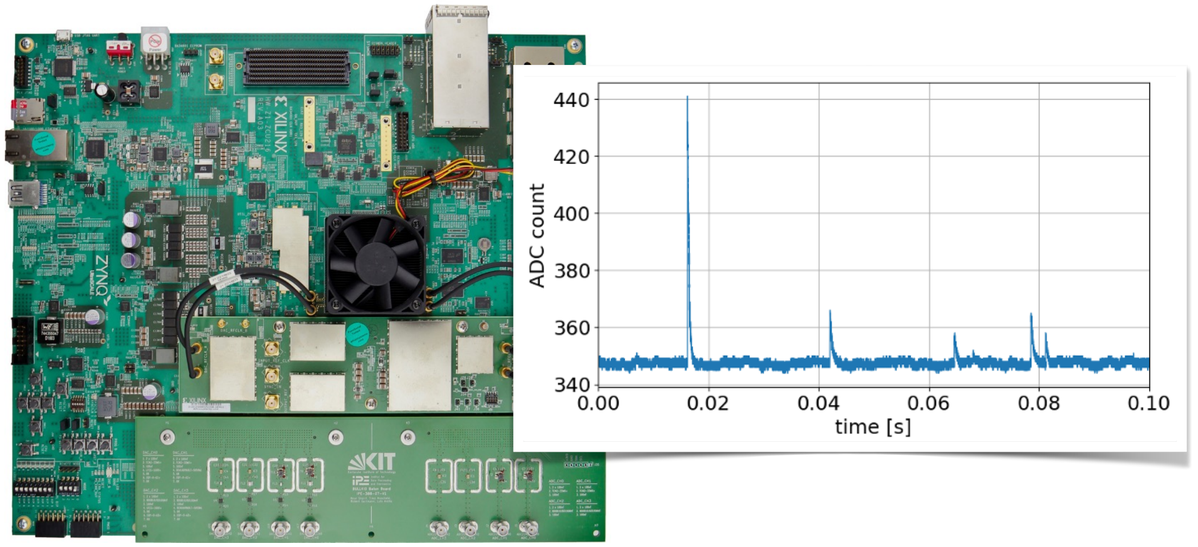
WP needs to be vitalised



Electronics

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

Board + 1st BULLKID customised interface tested in April 2024



Board + 2nd BULLKID customised interface + firmware upgrade to be tested in Rome end of October

see talk by Timo

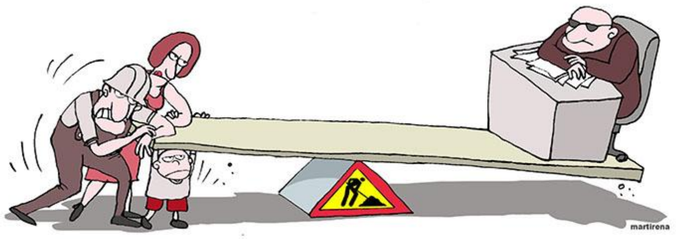
Cryostat at Sapienza

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

7+ months delay due to University bureaucracy

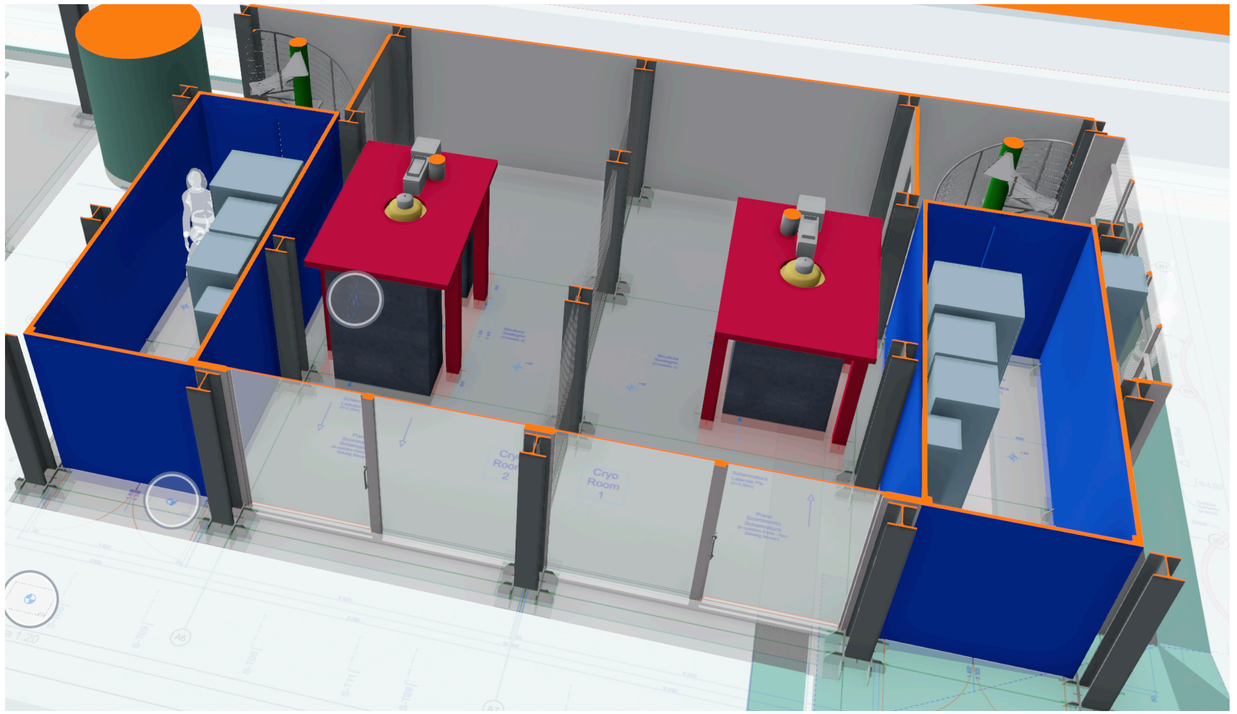
✓ Tender closed: Oxford and Leiden participated

- Evaluation of the offers ongoing
- Delivery possibly shifted to 2025 II
- Not affecting the schedule (yet)



Cryostat at Gran Sasso

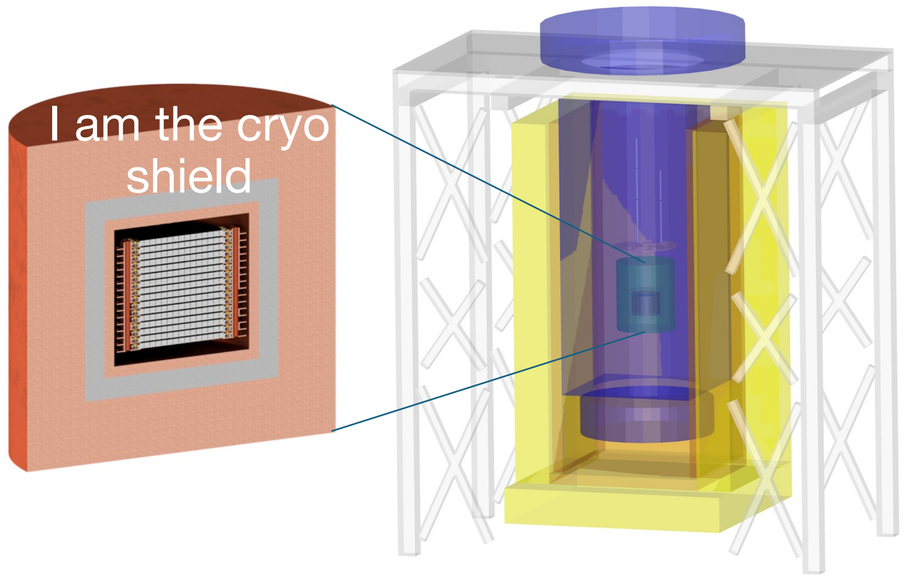
		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC



On schedule! *see talk by Nello*

Cryogenic shield

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC



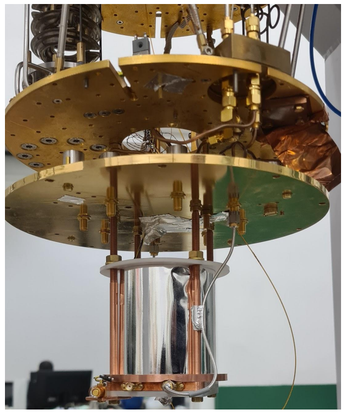
Copper shield funded by INFN-CSN2 in September 2024

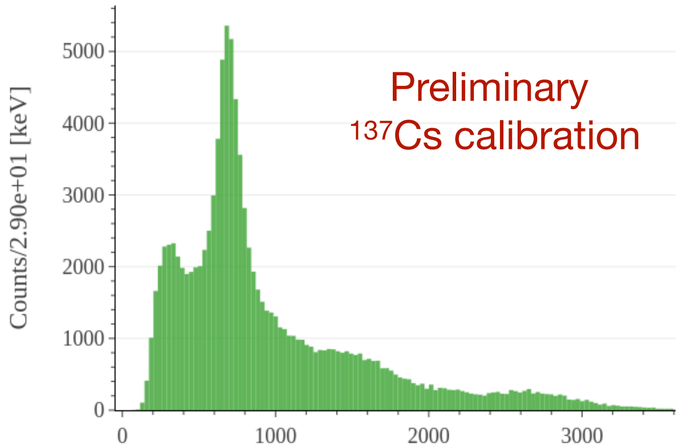
✓ Actual project related to the outcome of simulations

Cryogenic veto R&D

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

1st test in Rome completed with BGO





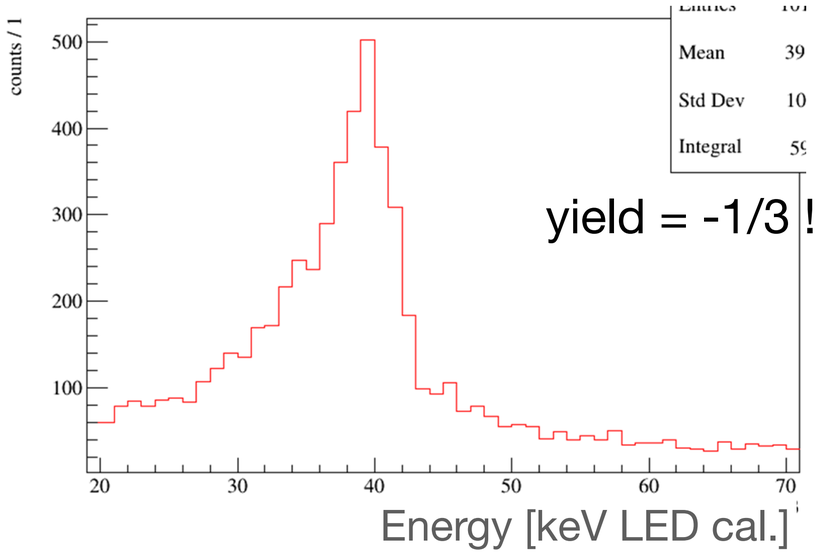
R&D continues in Pisa on different crystals

see talk by Pisa group

Calibration

		2024	2025
#	WP	II	I
1.1	Stack	M1.1 4” test	M1.2 final assembly
1.2	Demonstrator	M1.4 < 10^5 DRU @ RM1	
1.3	Thr. R&D		M1.6 New sensors
1.4	R&D Germanium		M1.7 Diced wafer
2	Simulations	M2.1 Preliminary shield design	
3	Materials	M3.1 BOM and plan	
4	Ele/DAQ	M4.1 Readout of 60 KIDs	
5	RM1 Cryo		M5.1 Delivery
6	LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields
7	Cryo shield		M7.1 Preliminary project
7.1	R&D Cryo veto		
8	Calibration		M8.1 PoC

Test with 60 keV x-ray from ^{241}Am - external to the cryostat
(bulk events in silicon w.r.t surface events from LED)



yield = -1/3 !, to be confirmed

We need new ideas a and momentum on this WP!

Misc

- Collaboration paper derived from CDR (experimental setup, simulations and sensitivity)
- Indico: https://agenda.infn.it/category/2125/
- Wiki ? At the INFN we can offer dokuwiki https://wiki.infn.it/
- Website (tedious but must be done).
- Meeting in January in Pisa, fill the poll https://strawpoll.com/polls/YVyPvOGW2gN