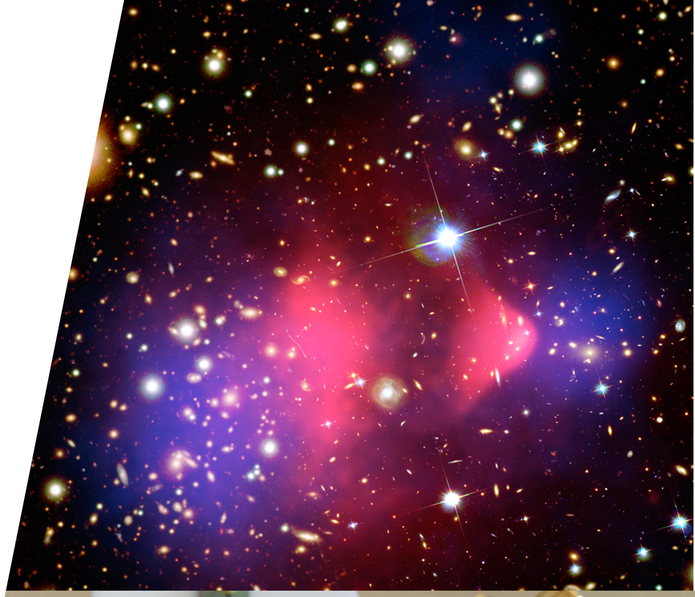
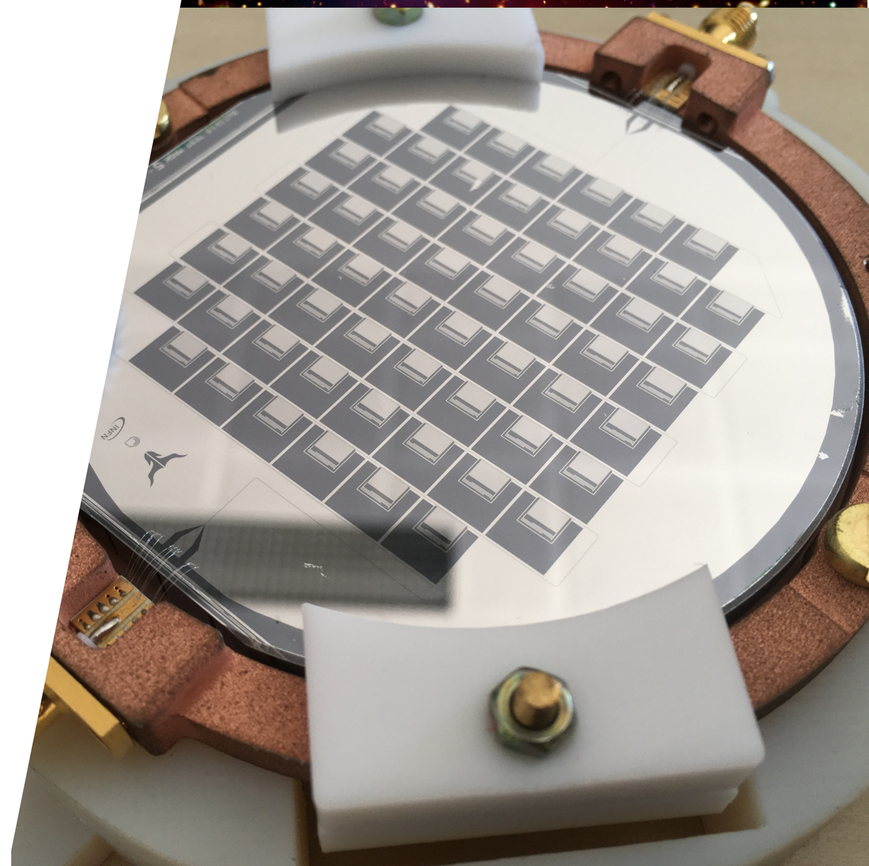
SAPIENZA
UNIVERSITÀ DI ROMA

INFN
Istituto Nazionale di Fisica Nucleare



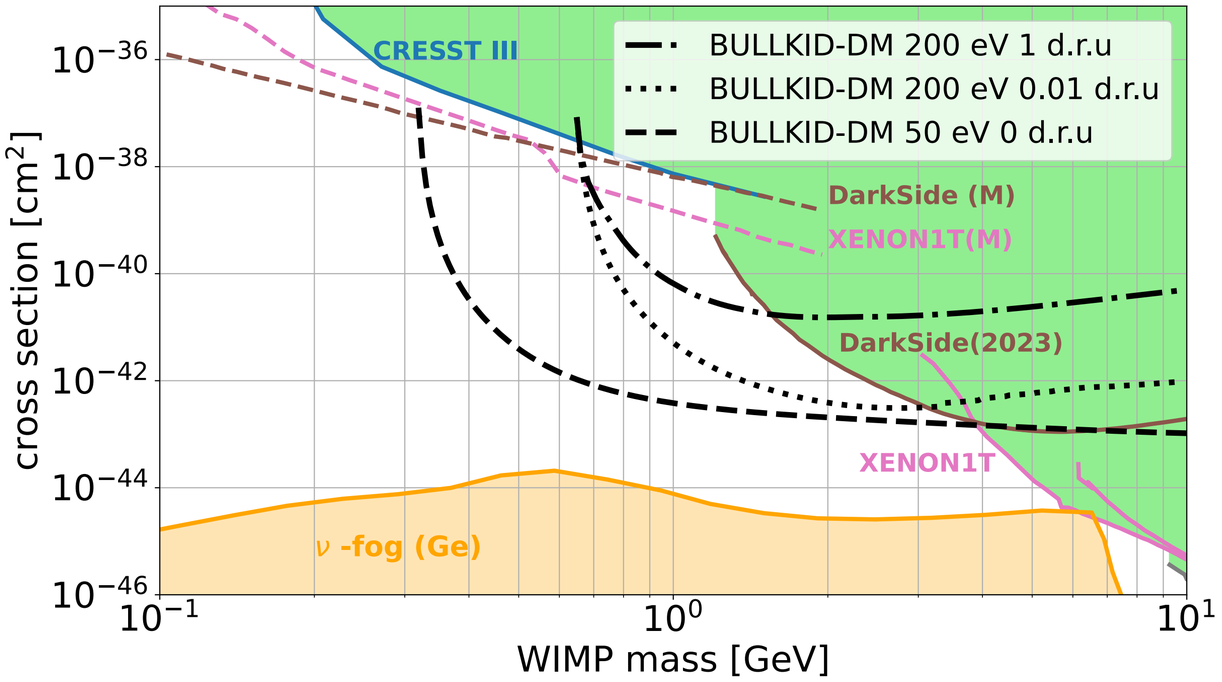


General status

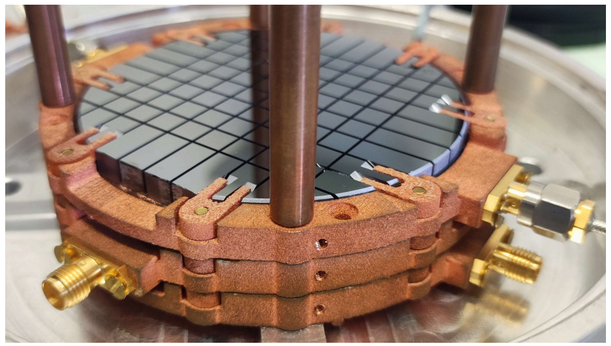
Marco Vignati, BULLKID-DM Coll. meeting, Ferrara - July 2025

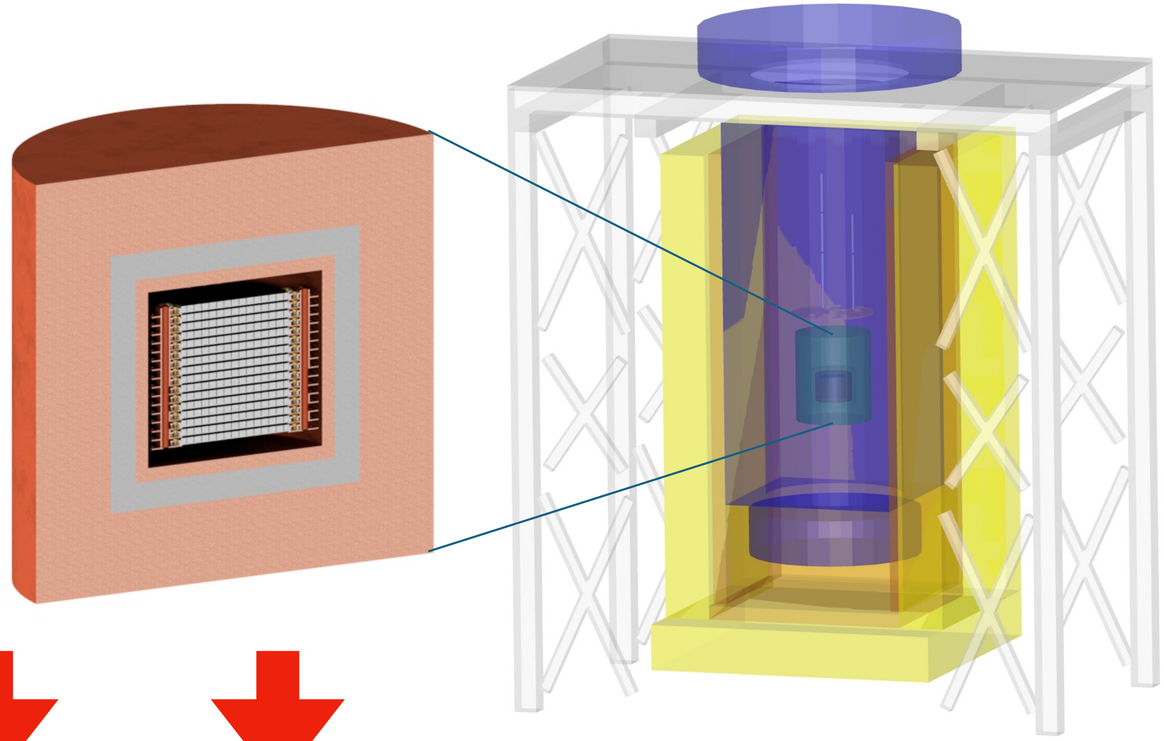
Dark Matter - direct search with BULLKID-DM

	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**
laboratory	Sapienza U.	Sapienza	LNGS	**LNGS**
installation	2023	2024	2026	**2027**
bkg (c/keV kg d)	2x10^6	*< 10^5*		**1 - 0.01**



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 approved by INFN
Demonstrator approved by LNGS

TDR
Decision on veto

Plan

BULLKID-DM
Conceptual Design Report (CDR)

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June 28, 2024

Required for TDR Required for experiment		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		

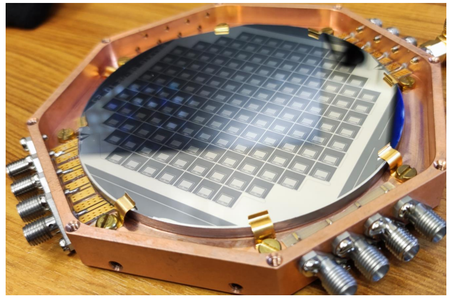
Stack

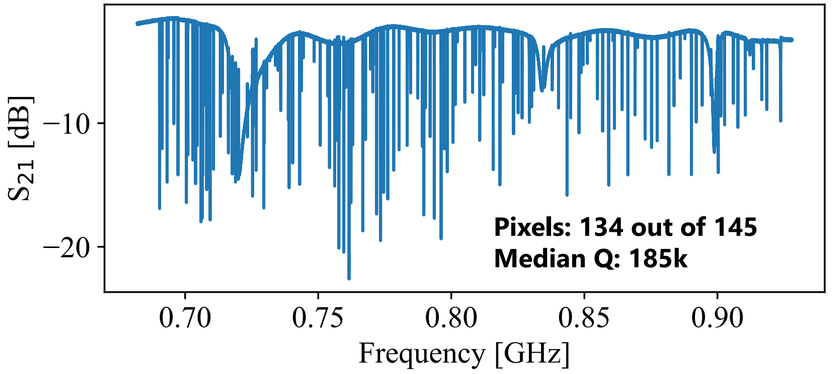
	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

3-6 months delay, but 6 m. buffer

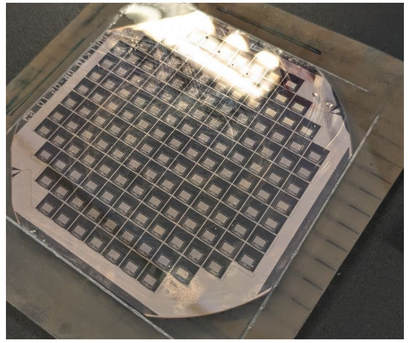
145 KID array test on thin (0.3 mm) 100mm wafer successful (new matrix designs ongoing)

M. Cappelli



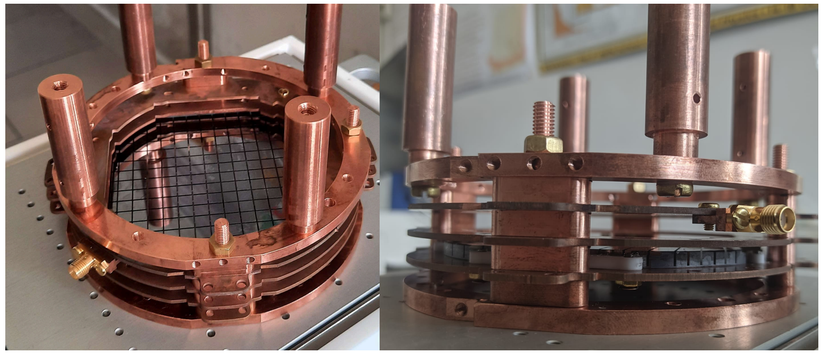


Wafers started production



Assembly produced

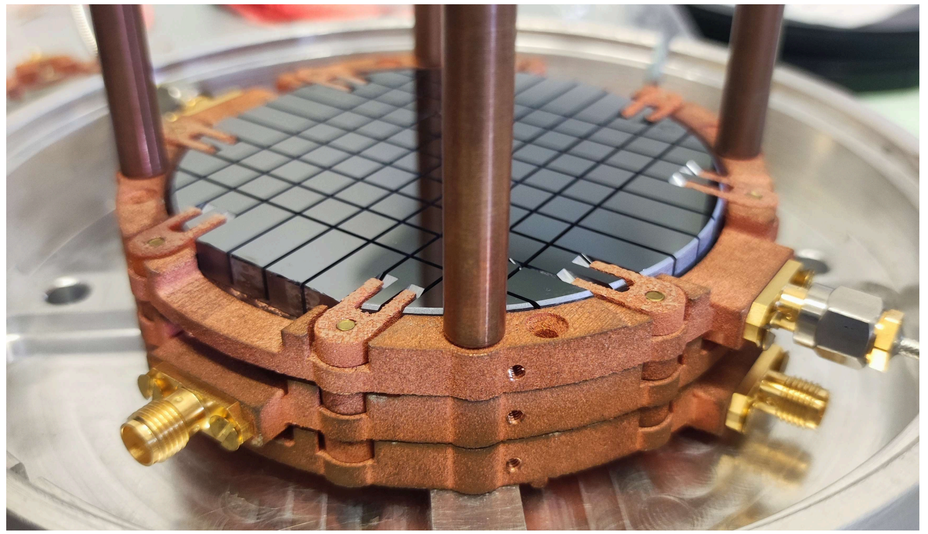
D. Pasciuto



Demonstrator

slowed but on schedule

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			



1st version built: issue in wafer/KID uniformity

2nd version in production:

1 wafer done 3 ready for lithography

L. Malagutti

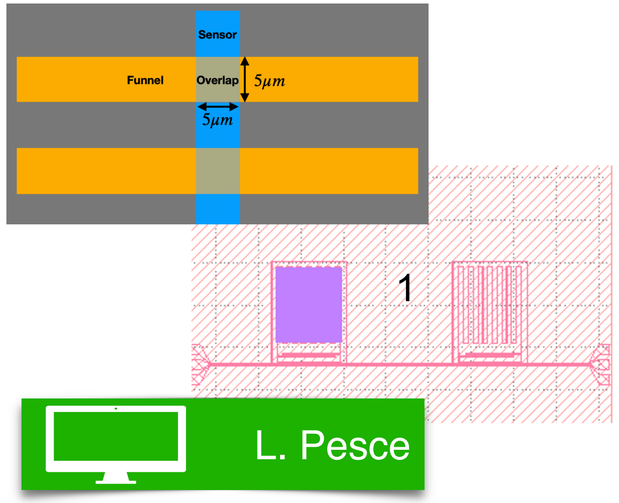
Results with lead case and shield presented at conferences

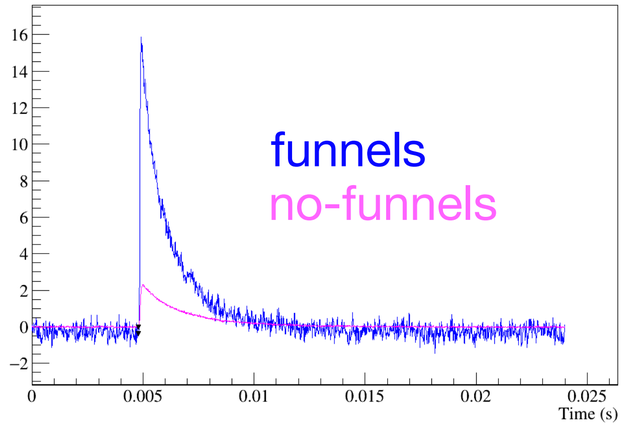
D. Delicato

KID threshold R&D (optional)

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

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)

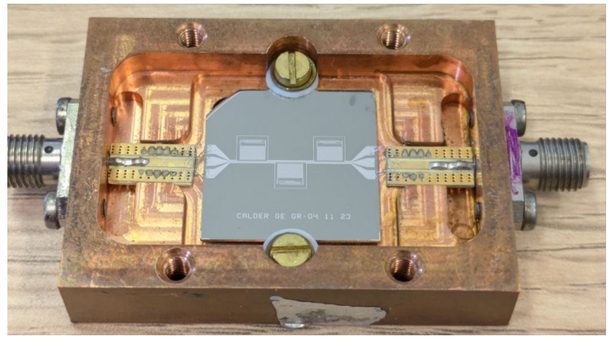
	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

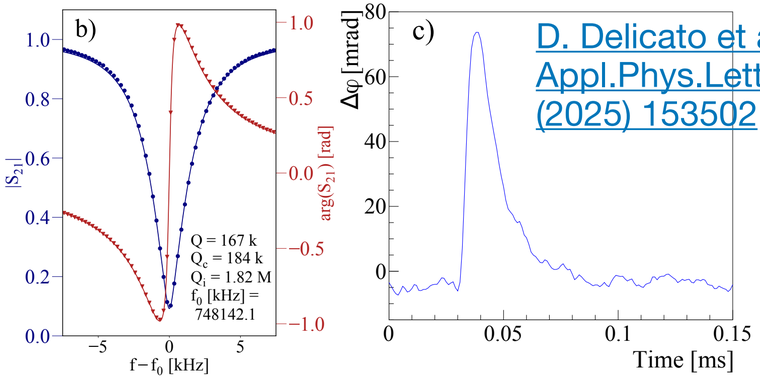
Alternate target for DM, better target for neutrinos than Silicon

✓ First working detectors.

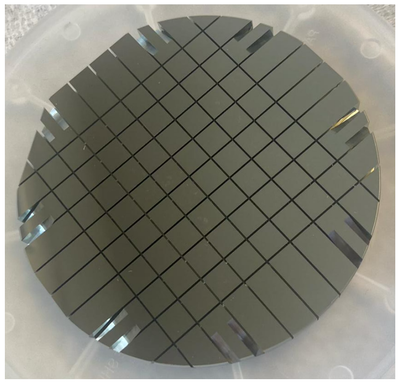
✓ Same electrical and phonon properties of Si.

➡ Ready to move to thick substrates





D. Delicato et al, Appl.Phys.Lett. 126 (2025) 153502



- 9 wafers 3”x 5 mm available in Ferrara: 2 have being diced.
- TBD: Baking in an oven (Quartz, T > 1000 °C, Diameter > 3”, Ultra High Vacuum) -> at MPP?
- TBD: Lithography and test in the standard BULLKID setup.

Simulations and Materials

on schedule

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield design		M2.2 Final shield design
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

Simulations:

- ✓ preliminary design of the experiment in the CDR
- ✓ defined a configuration for the shield and proposed to LNGS
- ✓ Ongoing comparison with low-bkg demonstrator at Sapienza

A. Acevedo

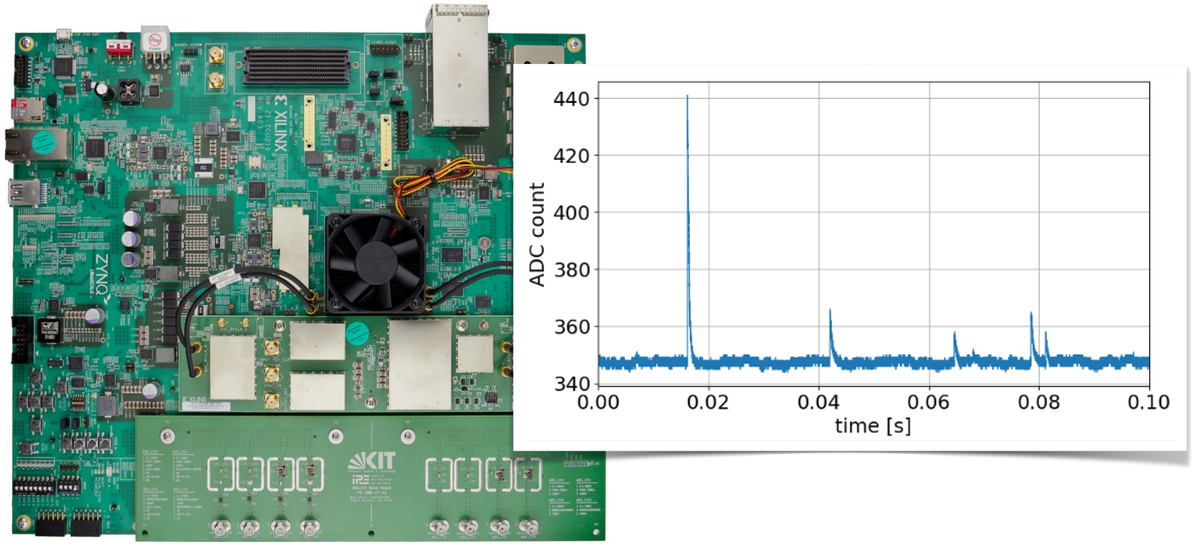
Bill of materials and plan:
Copper/lead assay at LNGS

Electronics

3-6 months delay, but 6 m. buffer

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1		M3.2
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of demo
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

Board + 1st BULLKID customised interface tested in April 2024



Board + 2nd BULLKID customised interface + firmware upgrade tested in Rome in Spring.

Noise to be understood, trigger to be implemented

T. Muscheid

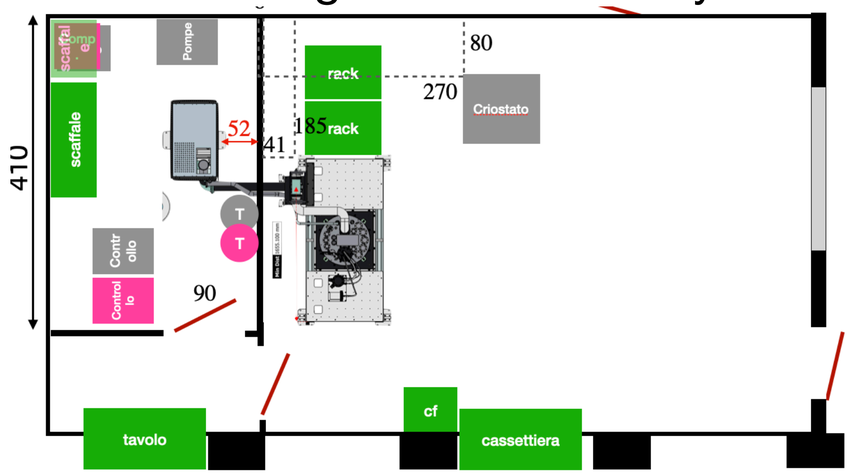
Cryostat at Sapienza

on schedule (almost)

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

✓ Delivery in September

- Lab starting renovation today

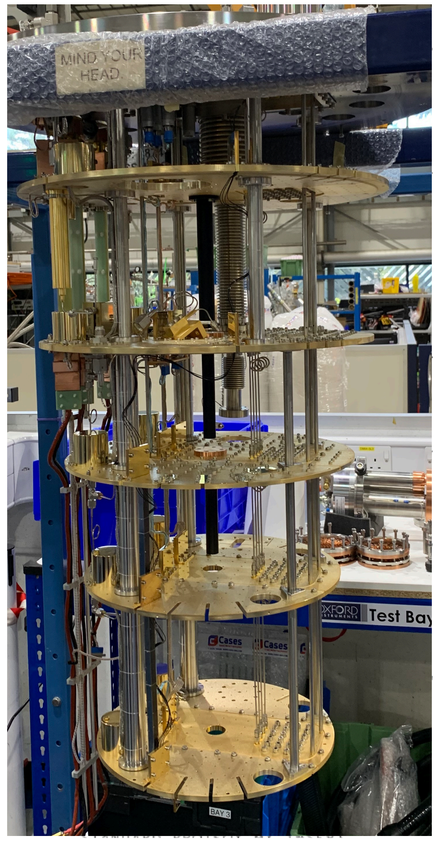


Cryostat at Gran Sasso

Cryostat on schedule

Drawings of ext. shield delayed

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			



Cryostat installation this month

Design of shield ongoing.

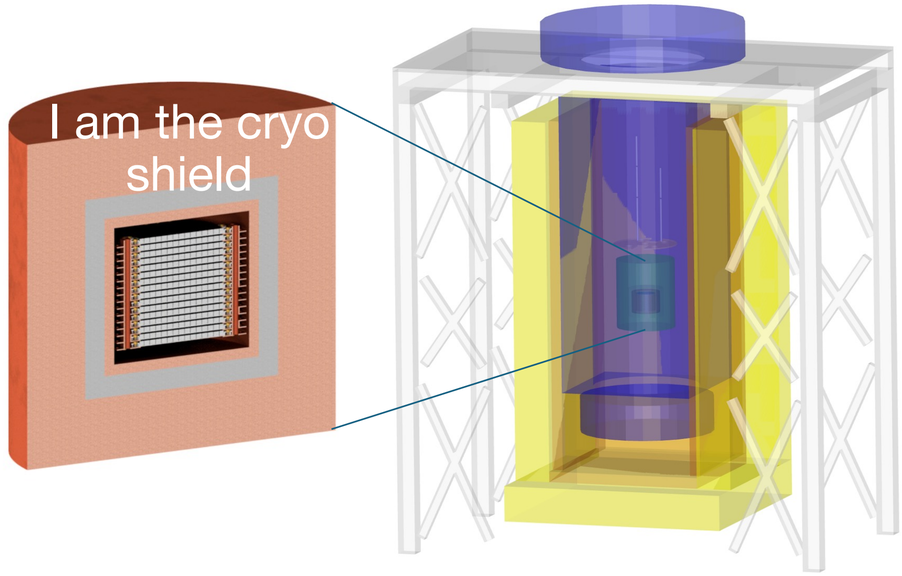
Funds for shielding secured?

A. D’Addabbo

Cryogenic shield

on schedule

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			



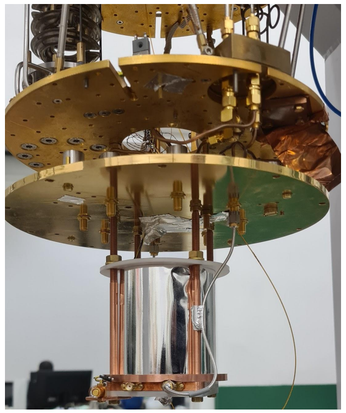
- ✓ Actual project related to the outcome of simulations
- ✓ First design produced
- ✓ Possible Copper suppliers identified.
- ✓ Sample testing at LNGS ongoing

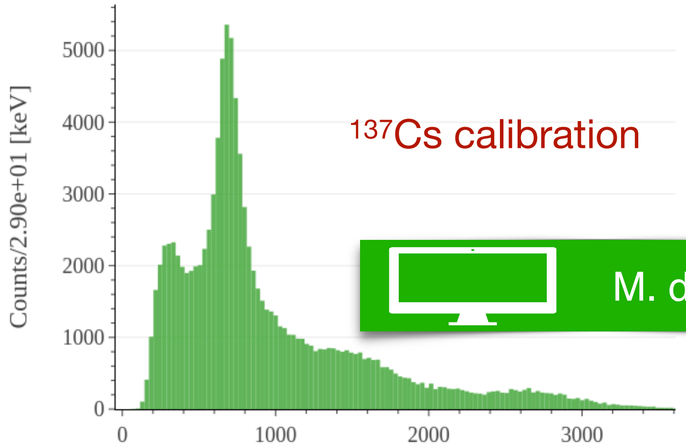
Cryogenic veto R&D

Milestone approaching

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary	M7.2 Cu shield
R&D Cryo veto			M7.3 single module demonstration
Calibration		M8.1 PoC	
Computing			
Data analysis			

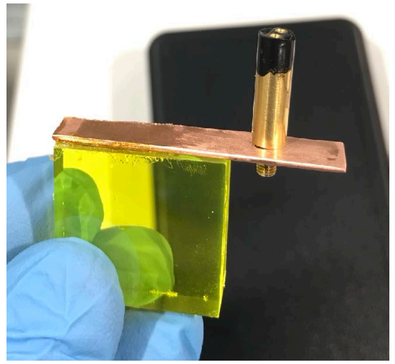
1st test in Rome completed with BGO, 100 keV threshold





M. del Gallo

R&D continues in Pisa with GAGG / GSO



M. de Lucia

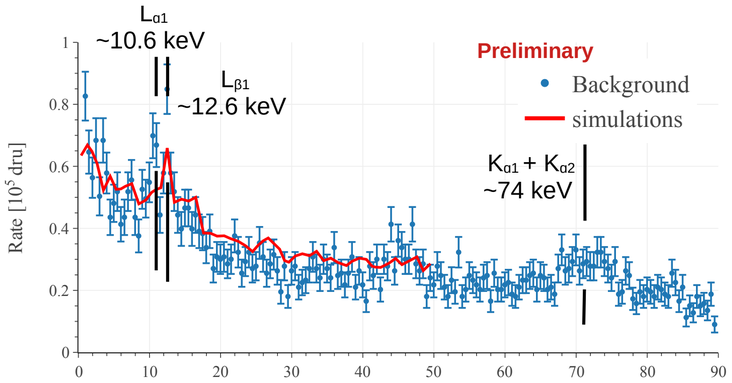
T. Lari

Calibration

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

Milestone will not be met?

60 keV γ-ray from ^{241}Am proved
X-rays from Lead case observed
X-rays from Cu shield and Si stack?



M. Folcarelli

Autocalibration with response function

$$\frac{d\phi}{dE} = \frac{\eta\alpha S_2(\omega_0, T)}{N_0 V \Delta^2} \cdot \frac{Q}{1+4y^2}$$

D. Quaranta

Not clear yet how we will proceed
^{192}Ir wires?

D. Nicoló

Comupting and analysis

	2024	2025	
WP	**II**	**I**	**II**
Stack	M1.1 4” test	M1.2 final assembly	
Demonstrator	M1.4 < 10^5 DRU @ RM1		
Thr. R&D		M1.6 New sensors	
R&D Germanium		M1.7 Diced wafer	
Simulations	M2.1 Preliminary shield		M2.2 Final shield
Materials	M3.1 BOM and plan		M3.2 Validated
Ele/DAQ	M4.1 Readout of 60 KIDs		M4.2 Full readout of
RM1 Cryo		M5.1 Delivery	D5.1 Ready
LNGS Cryo	M6.1 Drawings of ext. lead shields	M6.2 Comm. without shields	M6.3 Delivery of ext. shielding
Cryo shield		M7.1 Preliminary project	M7.2 Cu shield ready
R&D Cryo veto			M7.3 single module
Calibration		M8.1 PoC	
Computing			
Data analysis			

No hurry, but we need to start putting our mind on it

Misc

- WP regular meetings to be started
- Collaboration paper derived from CDR (experimental setup, simulations and sensitivity)
- Website and wiki
- Next meeting in January 2026? Grenoble-KIT-LNGS?