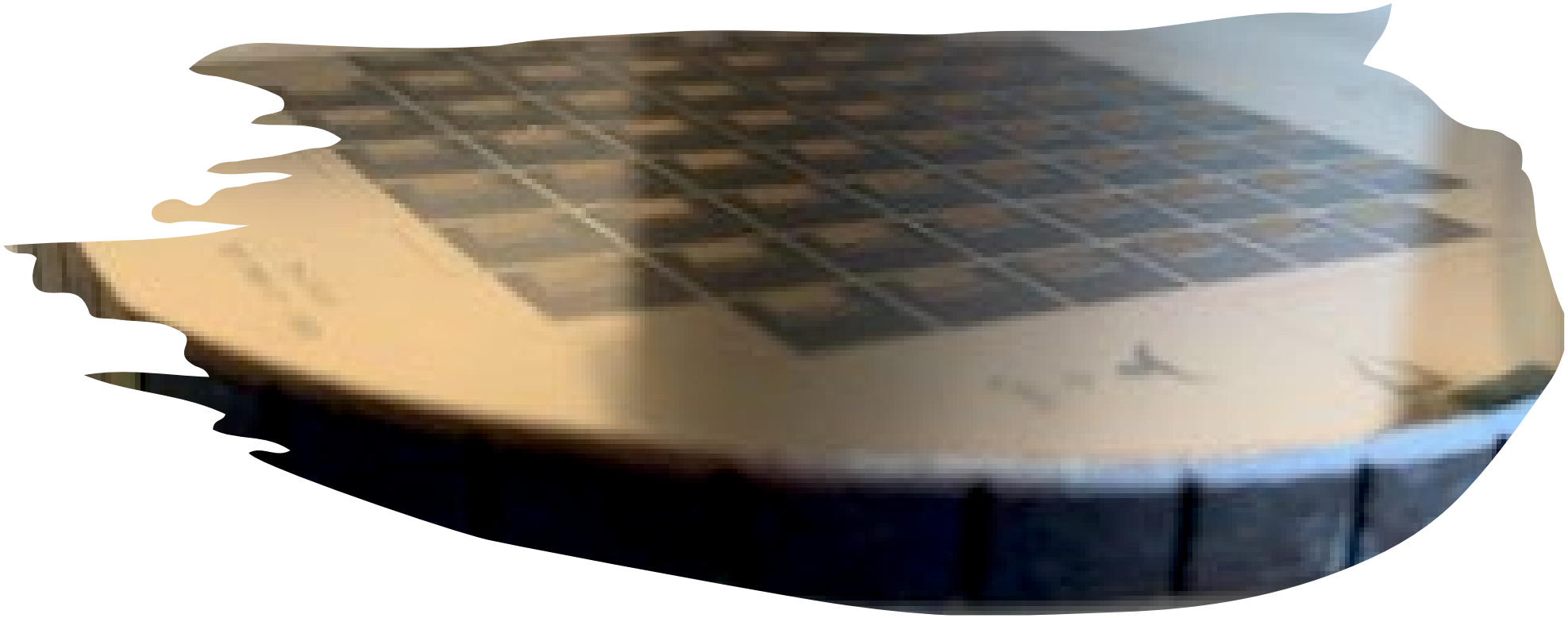


BULLKID-DM

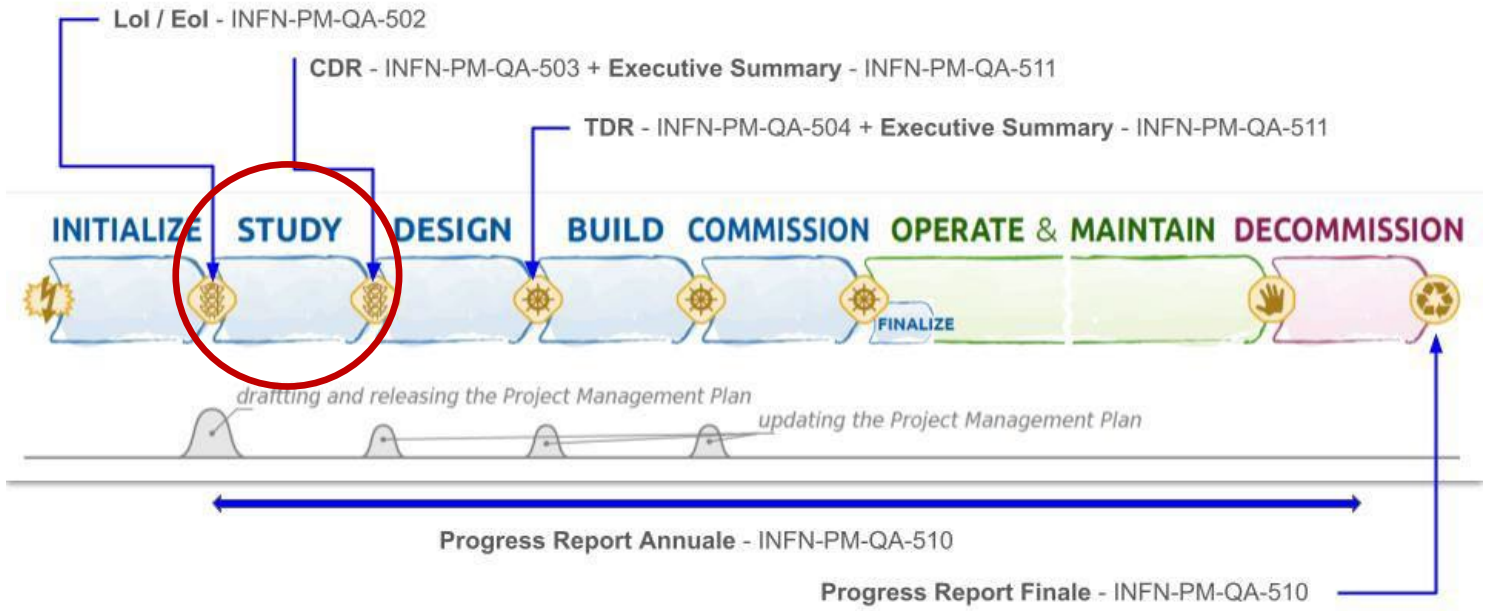
Conceptual Desgin Report

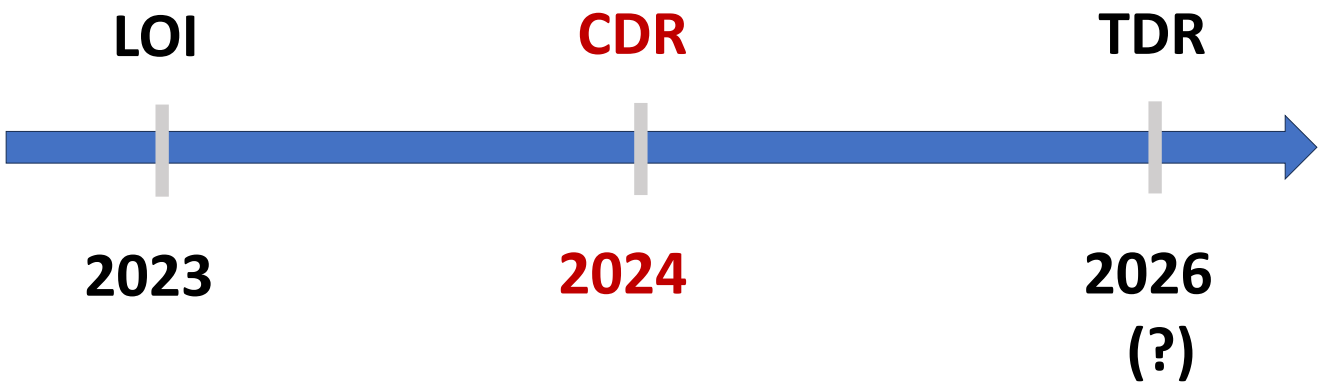
BULLKID-DM KOM

Angelo Cruciani

INFN PAQ (quality plan)

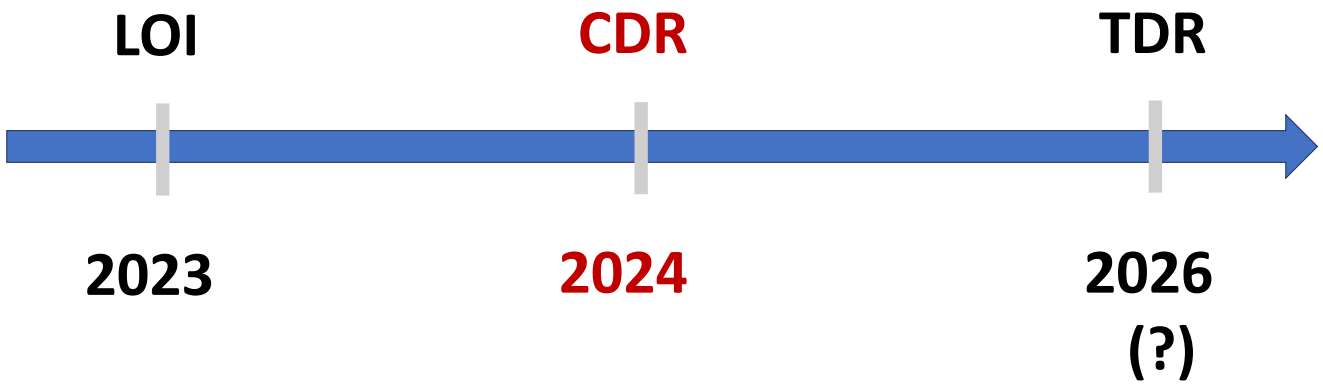
Since 2021, INFN CSN2 has introduced a new project management approach for new projects.



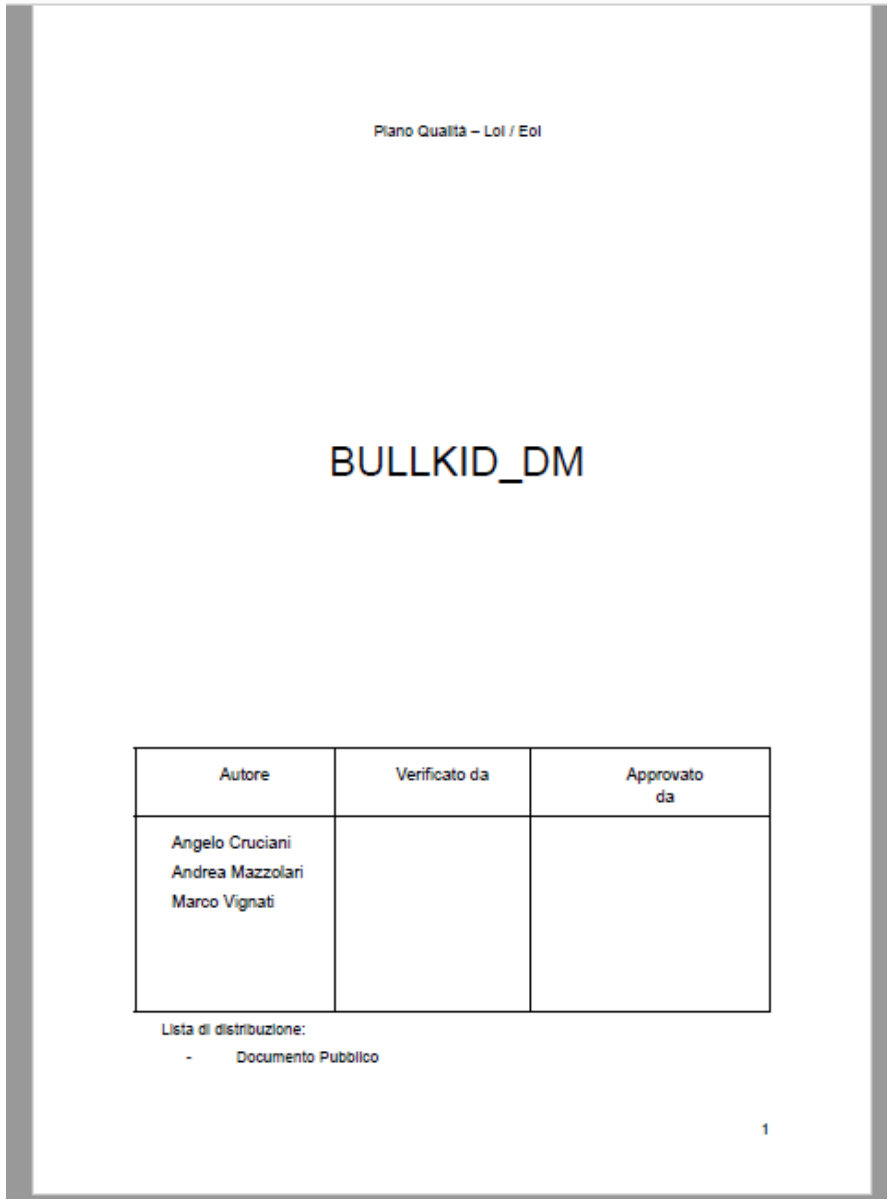


- We need urgenly to organize a working group for the drafting of the CDR and PMP

- What follows are preliminary thoughts, but (almost) nothing is frozen and need to be discussed toether



BULLKID_DM LOI



Piano Qualità – LoI / EoI

BULLKID_DM

Autore	Verificato da	Approvato da
Angelo Cruciani Andrea Mazzolari Marco Vignati		

Lista di distribuzione:

- Documento Pubblico

1

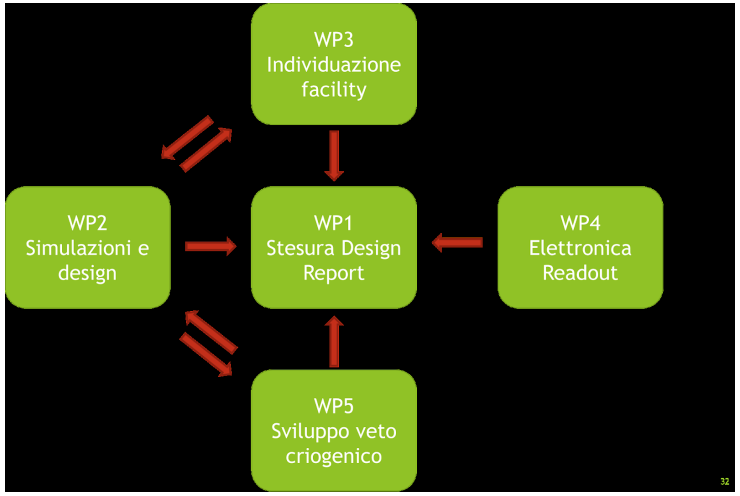
- Sent to CSN 2 in July 2023
- Signed by INFN-RM, INFN-PI, INFN-FE and INFN-LNGS
- Time schedule:

  2024-2025 TDR

  2026-2028 Construction of the instrument

  2029 Commissioning and data taking

SISTEMA	COSTO PRESUNTO [k€]	OSSERVAZIONI
Rivelatore	250	
Criostato	700	Da considerare solo in piccola parte se esperimento ospitato in facility
Shielding	300	Costo da diminuire se in facility
Muon Veto	300	Se le simulazioni ne evidenziano la necessità
Veto Criogenico	100	Se le simulazioni ne evidenziano la necessità
Elettronica	500	Include elettronica fredda, calda e il DAQ.
Calibrazione	?	Definita da Design Report
TOTALE	250+1000+900=2150	



LNGS scientific committee LOI

- Presented in October 2023
- Signed by INFN, KIT and Neel
- Follow up of our request in Oct. 2024

Letter of interest for BULLKID-DM: Search for Dark Matter with arrays of Kinetic Inductance Detectors a

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(Dated: September 29, 2023)

BULLKID-DM aims to conduct an experiment for the search of WIMP-like Dark Matter particles with GeV / sub-GeV mass and cross section down to 10^{-42} cm^2. The detector consists of a highly segmented array of thousands silicon targets sensed by Kinetic Inductance Detectors, with total target mass exceeding 0.5 kg and energy threshold below 200 eV. The proposed array structure avoids the use of inert material between the single sensitive units and enables fiducialization techniques for background reduction, not yet exploited in solid-state detectors searching for WIMPs. With this Letter We manifest our interest in operating the experiment at LNGS, possibly exploiting one of the planned cryogenic facilities.

I. SCIENTIFIC CONTEXT

WIMP-like particles with GeV mass or less are highly intriguing candidates for Dark Matter [1]. The search for these particles needs detectors sensitive to nuclear recoils with energy thresholds of hundreds or tens of eV [2–4]. A thorough exploration of interactions with cross-sections lower than 10^{-40} cm^2, approaching the neutrino floor (10^{-44} cm^2), demands the development of an experiment with a few kilograms of active mass and zero background, a prospect that is challenging for existing experiments and their planned upgrades.

BULLKID-DM aims to establish an experiment based on silicon targets sensed by cryogenic Kinetic Inductance Detectors (KIDs), capable of achieving energy thresholds between 50 and 200 eV, with an exposed mass exceeding 0.5 kg. The potential of an experiment with these characteristics is illustrated in Fig. 1, where the blue regions represent sensitivity to the spin-independent cross-section of WIMP-like particles as a function of their hypothetical mass, assuming a threshold of 200 eV (dark) or 50 eV (light). The experiment's background cannot be predicted at this time, thus the areas extend vertically from the sensitivity achievable in the case of a background matching that measured in the CRESST experiment [3] to the case of zero background.

The experiment will be based on the technology developed within the BULLKID project, which was funded by INFN-CSN5 and by Sapienza U. from 2019 to its conclusion in 2023. The current BULLKID prototype consists of a 3-inch diameter, 5 mm thick monocrystalline silicon wafer [6]. The wafer is grooved on one side with deep grooves measuring 4.5 mm, which create cubes capable of effectively containing phonon propagation generated by an interaction. Simultaneously, this approach maintains a thin common disk shared among all the cubes, defining a modular system in which a single crystal constitutes a matrix of 60 cubes with a total active mass of approximately 20 g. Phonons are detected by an array of Kinetic Inductance Detectors (KIDs) on the opposite side of the grooves, with one KID for each cube. The KIDs are read in parallel (multiplexed) and are coupled to a single transmission line (Fig. 2 top). This design allows for easy scalability to masses of the order of kilograms by producing and stacking several identical wafers.

The average energy resolution of the prototype is 2 eV [6], and recent measurements [7] have demonstr *d* an energy threshold of 160 eV (equivalent to 6 σ). *It* worth noting that, unlike other experiments [8], the *m* sured background is flat and does not show the p*r sy* of excess events near the threshold, which is a sig *if*

CDR structure

- Physics case
- Conceptual design
- (Main) parameters
- TRL of the subsystems
- Safety
- Needed R&D
- Stakeholders

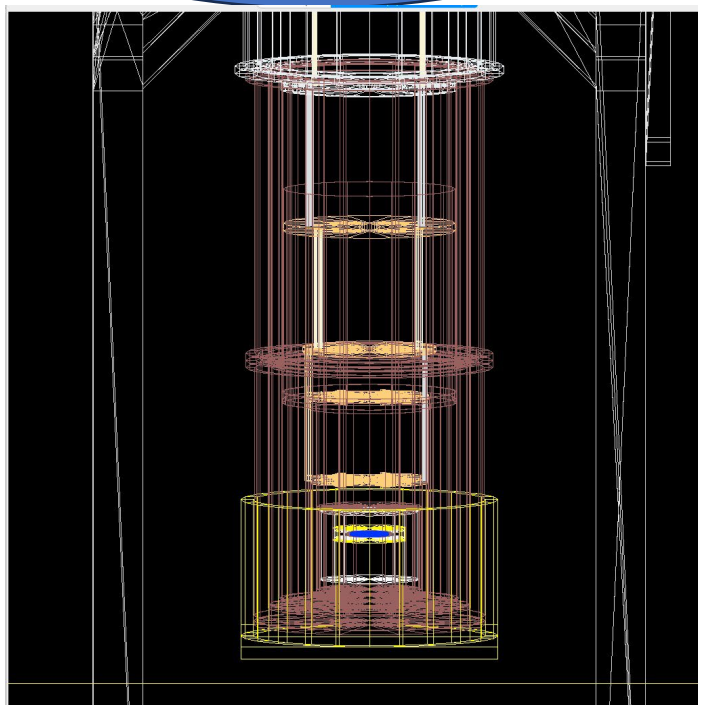
BULLKID_DM CDR: Physics case

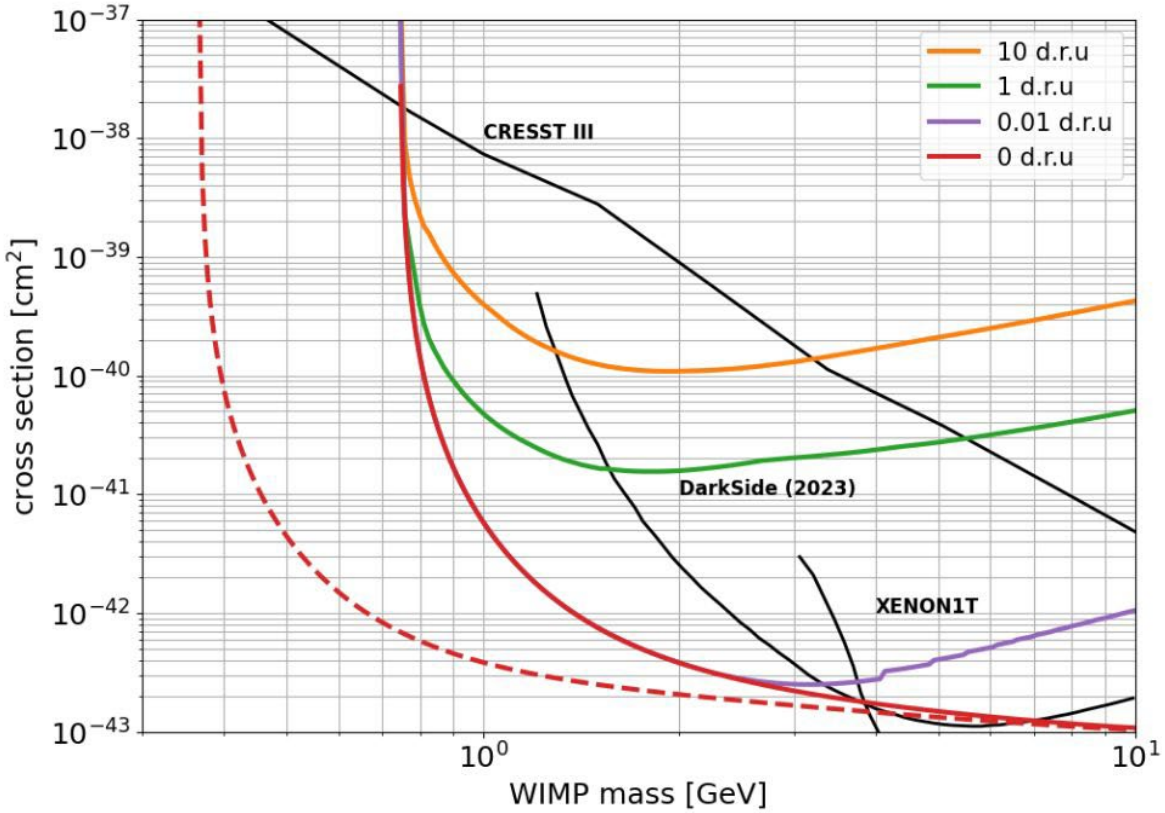
Input:

- **Ethr [eV] baseline/upgrade**
- **Exposure [kg year]**
- **BG [dru]**

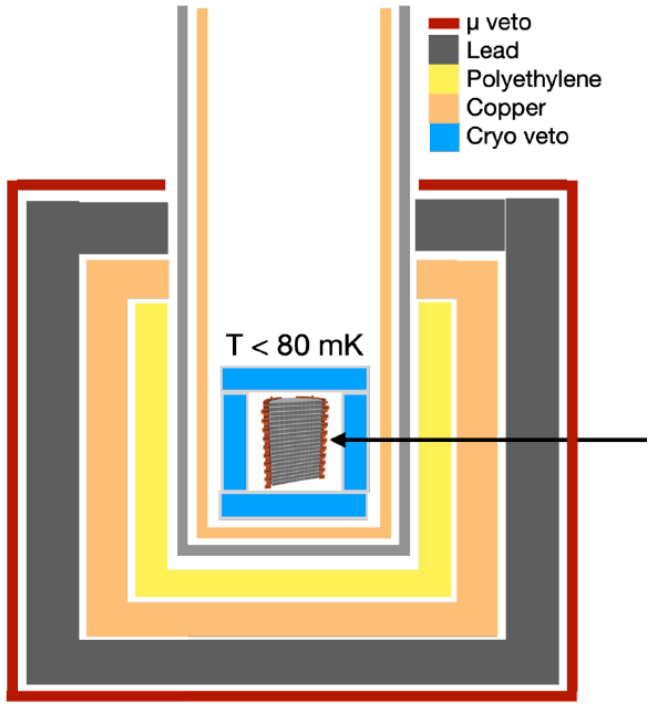
Output:

Sensitivity curves





CDR Conceptual design: baseline and possible upgrades



	Baseline	upgrade
Cryo-facility	Cryoplatform @ LNGS	
Detectors	16 * 4 inch wafers (2320 detectors, 1744 fiducialized) Total fiducialized mass: 600 g Threshold energy: 200 eV	down to 50 eV
Cryo-veto	BGO Thr. Energy of X0 keV	GSO? Other? Down to XX keV
Passive shielidng	Lead + Polyethylene TBD	
Calibration system	Optical fibers? External sources?	
Electronics + DAQ	TBD	

High-level PBS & TRL

Consolidated systems

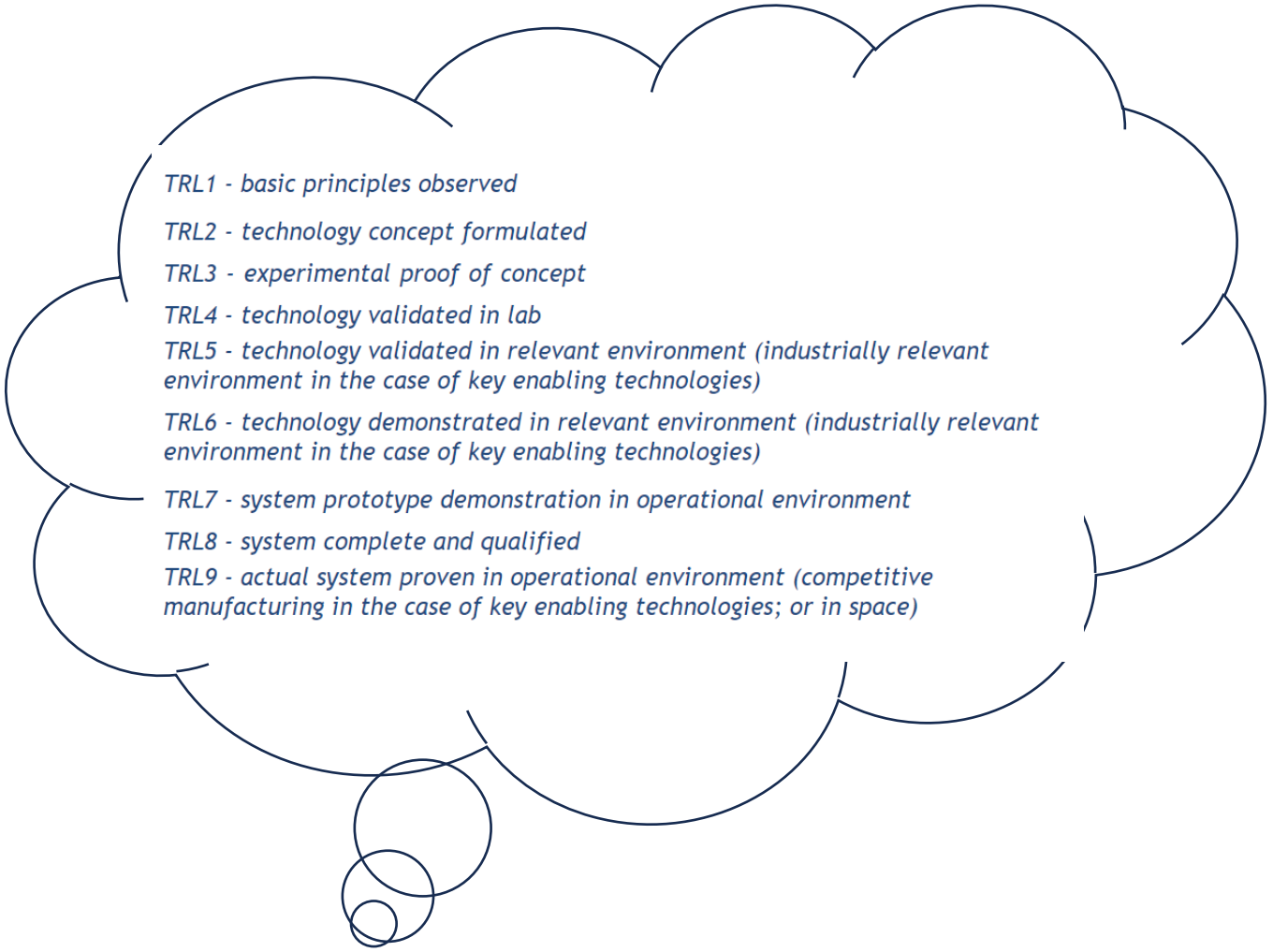
- Cryoogenic infrastructure
- Cryoelectronics
- Passive Shielding

Develoment needed

- Electronics
- DAQ
- Muon veto (?)
- Analysis

R&D needed

- Detectors (TRL 6->8)
- Cryogenic veto (TRL 3->8)
- Calibration system



BKG Simulations

Validation:

Test in progress in Roma, but a larger scale strategy has to be defined.

Role/need of a (underground) demonstrator (10^3 – 10^4 DRU)

Experiment design:

Passive shielding design <-> cryogenic infrastructure

Impact of active veto energy threshold

natural radioactivity of the materials <-> dedicated measurements, check on the material of all the inner subsystems

R&D map & development needed

- Detector stack development -> DANAE
- Cryogenic Veto -> PISA (+ Roma)
- Calibration system (?)

Develoment needed

- Electronics
- DAQ
- Muon veto (?)
- Analysis

BULLKID_DM PMP: Project Managment Plan

- A first draft of this document is required with the CDR
- Definition of roles: Project leader, Technical coordinator and PM, WP coordinators
- Budget and expected fundings
- Baseline description: schedule, costs
- Management / Monitoring and Control Tools
- Risk analysis

Risk Analysis – Preliminary thoughts

- Detectors R&D failure: LOW
- Excess: TBA before TDR
- Commisioning of the cryo-platform (including shielding): LOW
- Availability of the cryo-platform: TBA before TDR
- Performances of the cryogenic veto: MEDIUM
- Calibration: MEDIUM
- Competitors: TBA

Comments:

- It is worth to simulate a configuration without cryogenic veto?

WP list

#	WP	$	Unit	Resp	2024		2025	
					I	II	I	II
1	Collaboration	-	All		Meeting	CDR		TDR
2	Stack	ERC	Rm-Fe-Neel		Prototype assembly	4" test	Final assembly	Stack start
3	Demonstrator	ERC	Rm-Fe-Neel		Lead RM1 10^4 DRU		< 10^4 DRU ? at LNGS?	
4	Simulations	?	MX		Surface Sci. Impact	Under-ground		
5	Material tests and validation							
6	Electronics	?	KIT-Pi		60 px	150 px		
7	RM1 Cryo	ERC	Rm		Tender		Delivery/ Shielding	
8	LNGS Cryo	LNGS	LNGS			Delivery?	Shielding	
9	Cryo veto	CSN2	Pi-Fe-Rm		PoC	Project	Delivery	Tests
10	Calibration	CSN2	?				PoC	
11	KID R&D	ERC	Rm-Neel					
12	DAQ	CSN2	Pi?			Project	Delivery	Tests
13	Computing	CSN2	Pi?					