Background simulations for the BULLKID-DM experiment

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Outline

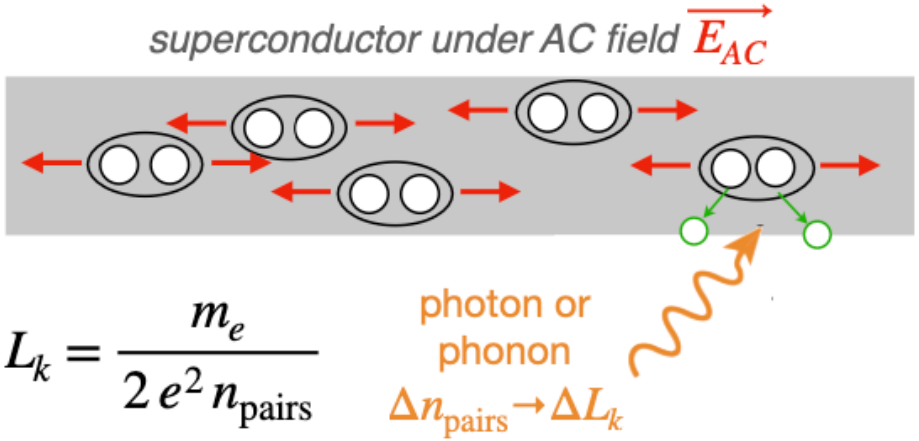
- Experiment overview
- DANAE setup at Sapienza
- Monte Carlo simulations for BULLKID-DM with GEANT4
- BULLKID-DM experiment underground
- Final remarks

BULLKID: BULky and Low-threshold Kinetic Inductance Detectors

Physics with kinetic inductance detectors

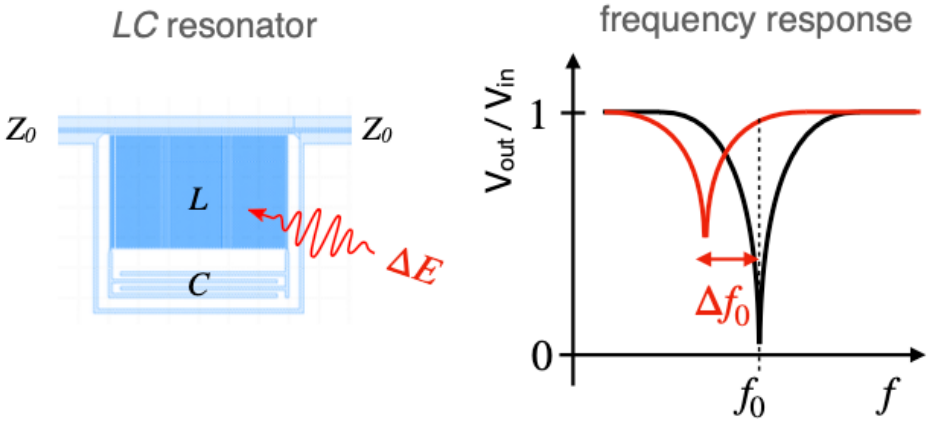
AC superconductivity

- Electrons bound into Cooper pairs
- Kinetic inductance from physical inertia of mass pairs dependent on Cooper pair density
- High quality factors ($Q \sim 10^4 - 10^6$)



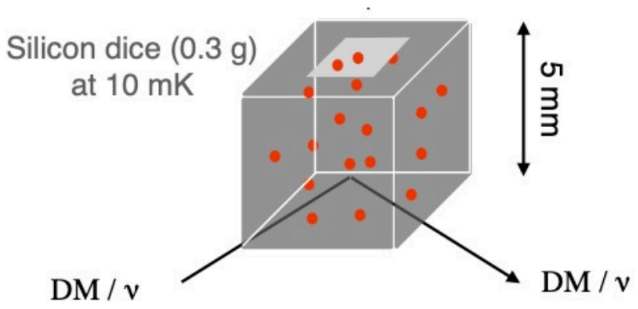
Kinetic Inductance Detectors

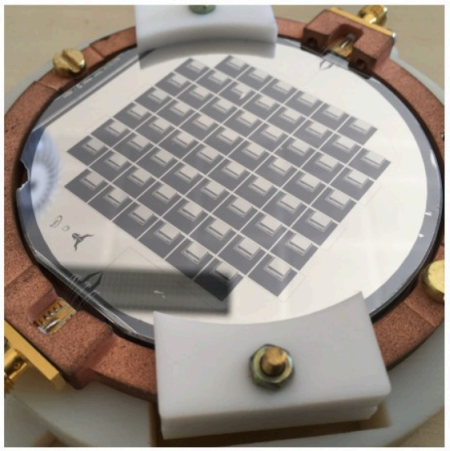
- Superconductor at T $<$ 200 mK (Aluminium)
- Resonant circuit
- Energy deposition breaks Cooper pairs

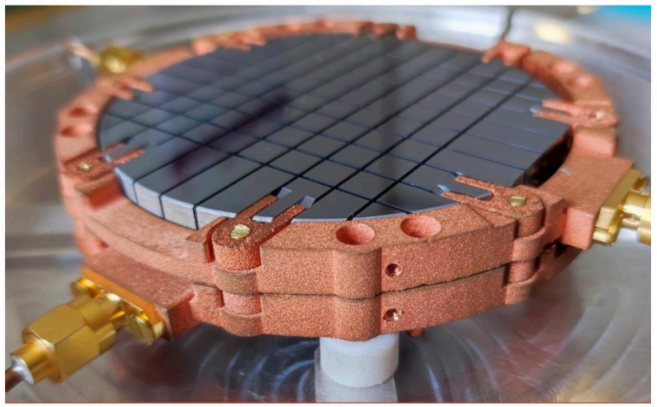


A scalable detector for rare event searches

- Detection of phonons created by nuclear recoils in a silicon dice (0.3 g)
- Multiplexed readout: several KIDs coupled to the same feedline at different frequencies
- KID: $\sim 2 \times 2$ mm$^2 \times 50$ nm, 0.5 μg
- Dices carved in a thick silicon wafer: 60 detectors in 1
- Calibration using optical photons of known energy







First demonstration of BULLKID-DM

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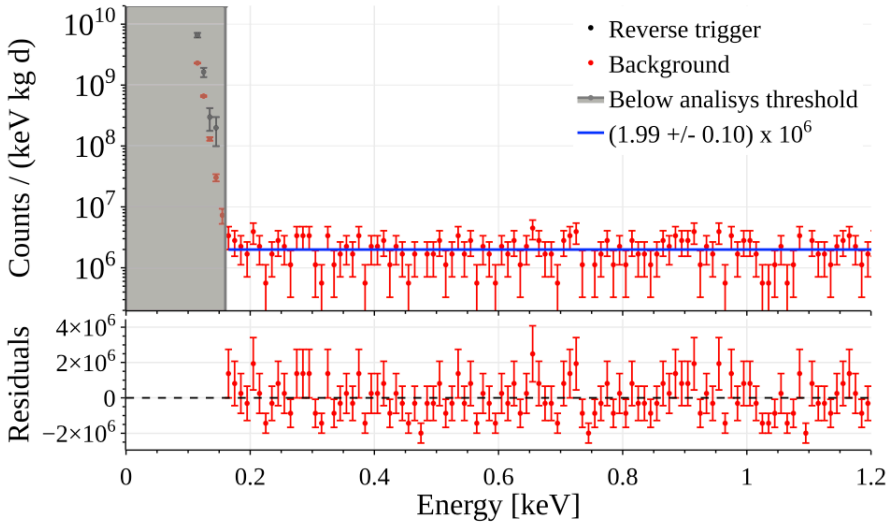
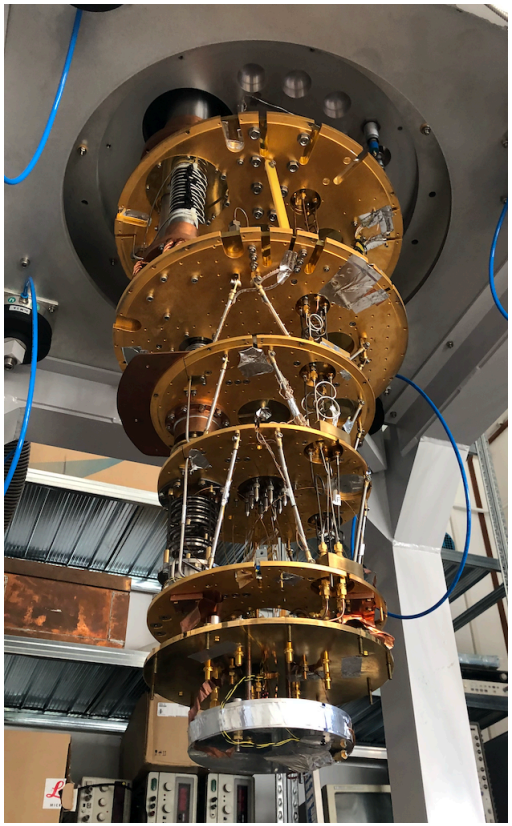


- Exposure of 39 hrs. (environmental backgrounds)
- Flat spectrum observed: $(2.0 \pm 0.1$ stat. $\pm$ 0.2 syst.$) \times 10^6$ counts/keV kg days
- Energy threshold of 160 ± 13 eV
- Energy resolution: 27 ± 2 eV

Experiment at Sapienza:

- Array of 60 cubic silicon particle absorbers (0.3 g each)
- Analysis on one of the central elements of the array using surrounding elements as veto



BULLKID Collaboration

25 people
6 institutions
4 countries

BULLKID: Monte Carlo simulations for BULLKID-DM with GEANT4

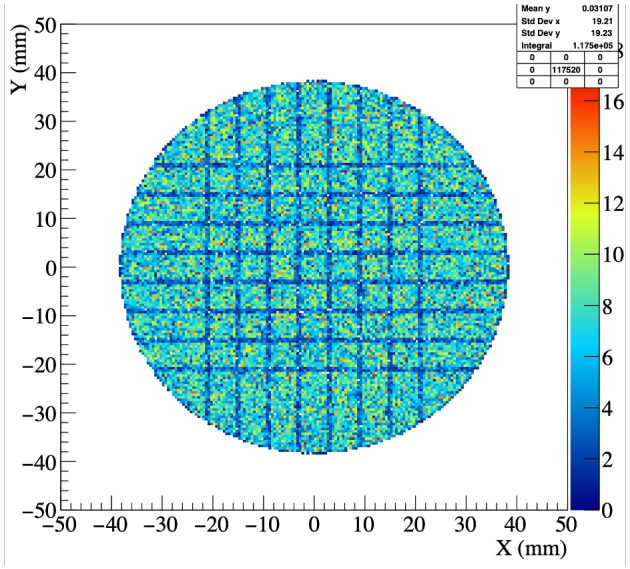
Experiment at Sapienza

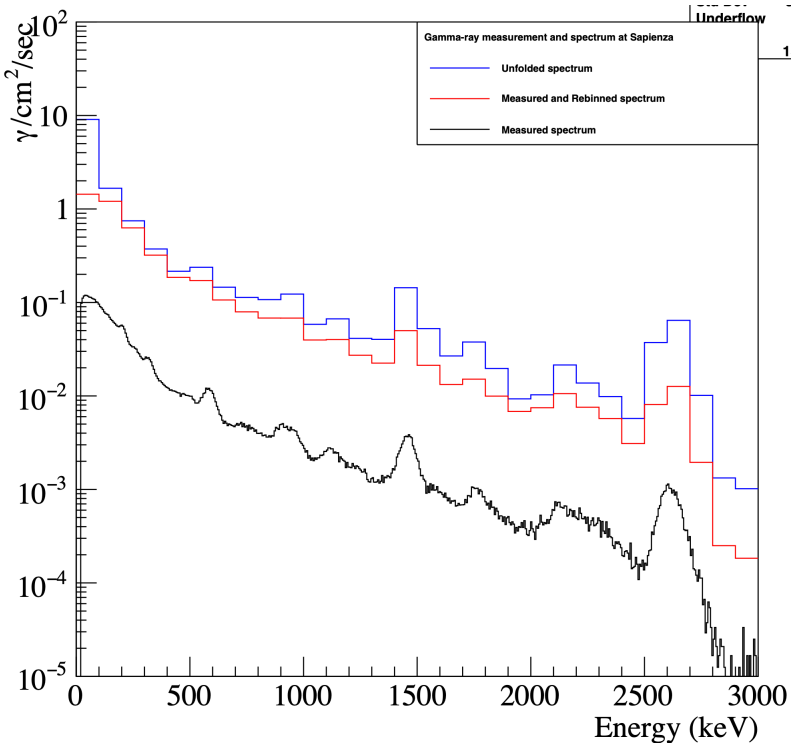
GEANT4 model:

- GEANT4 v11.1.3 using Shielding Physics List

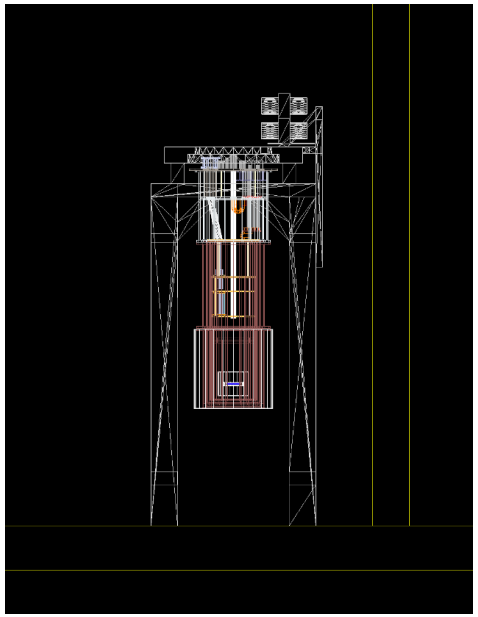
Simulation of backgrounds on surface:

- Gamma-rays and neutrons measured in laboratory
- CRY generator for cosmic rays



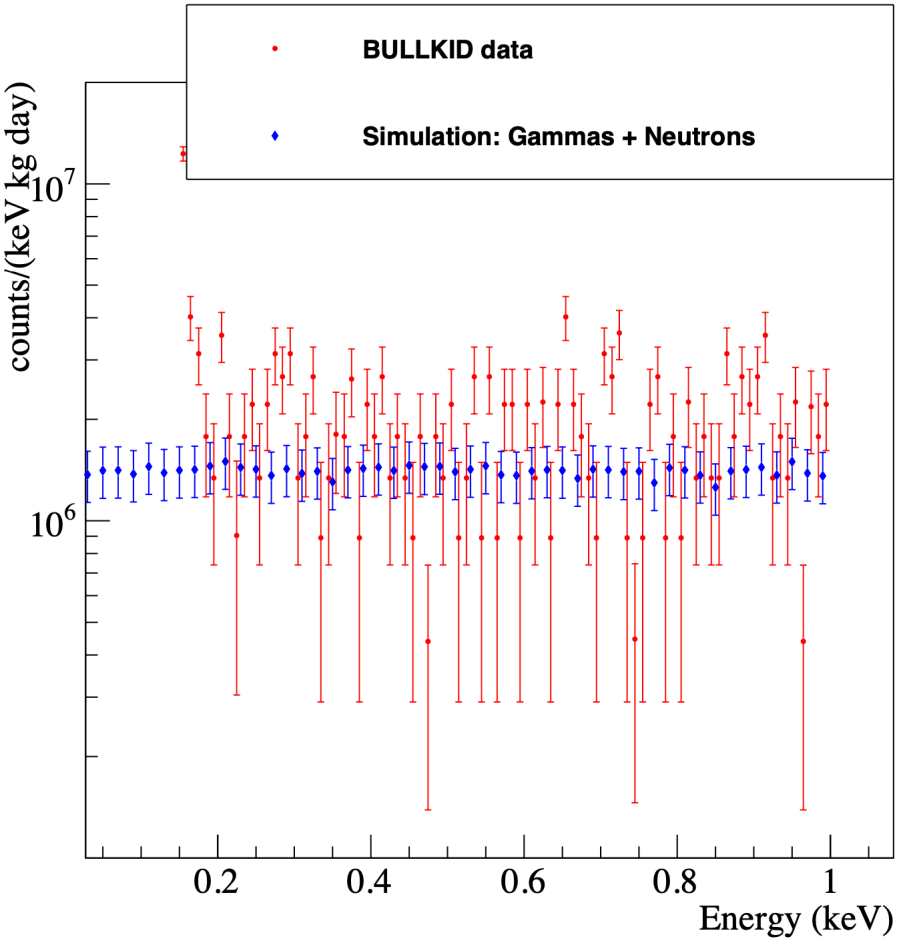


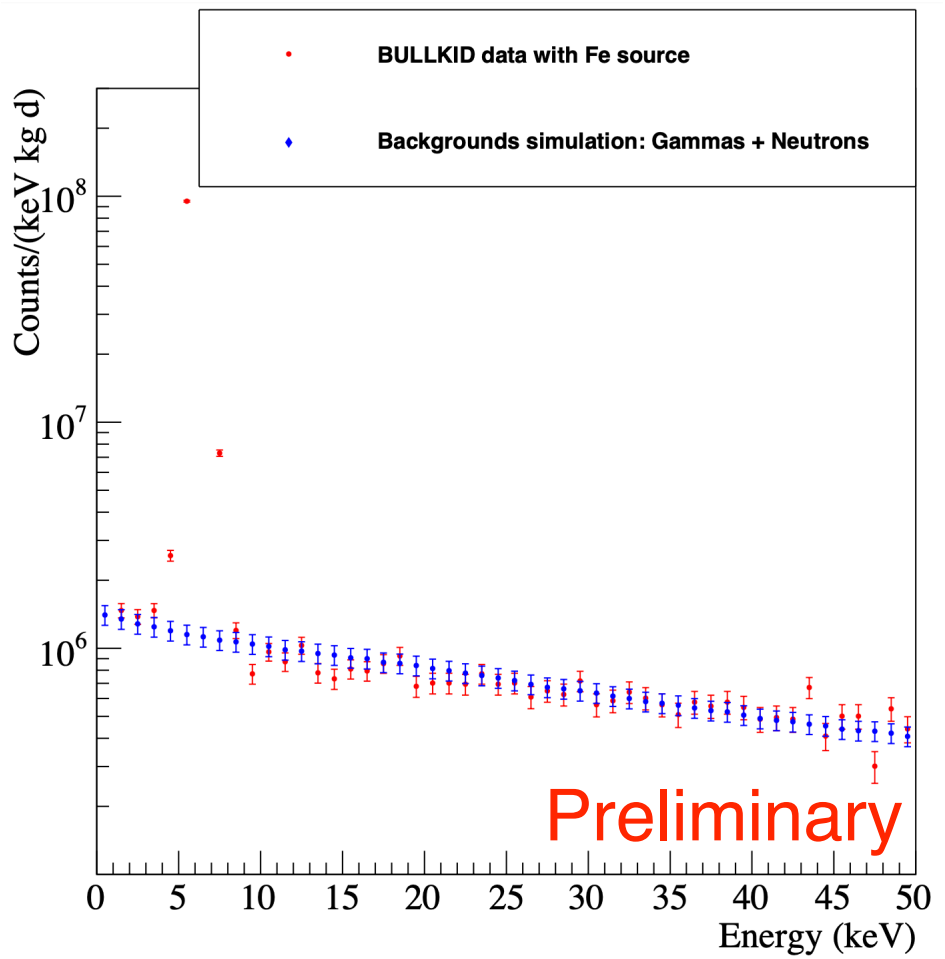
Detailed implementation of cryostat and inner detector



Data vs Simulations

- Backgrounds dominated by environmental γ-rays
- Agreement between data and simulations

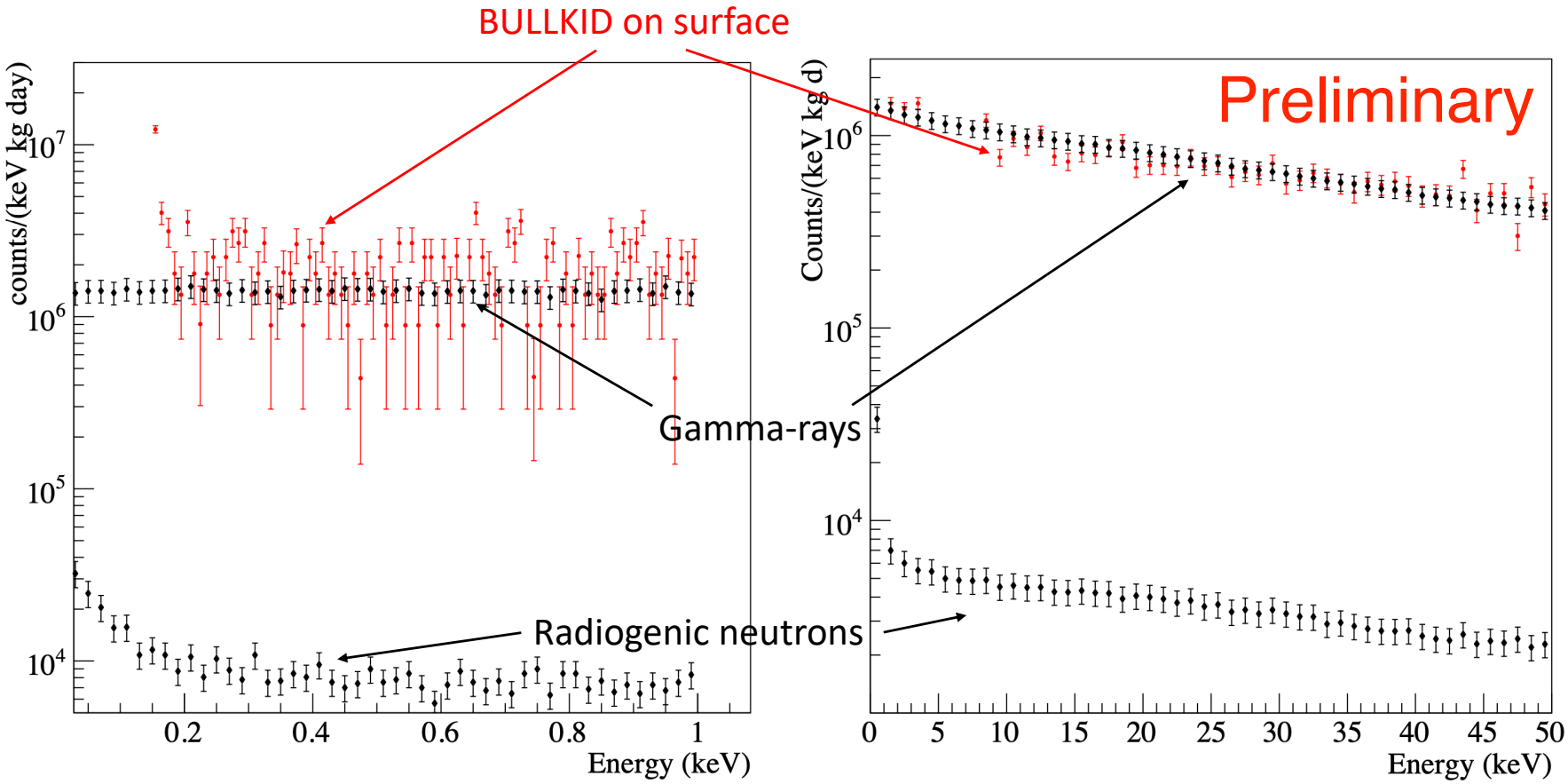




- Simulations: 1.41×10^6 d.r.u. between 0 and 1 keV
- Very good agreement up to 50 keV

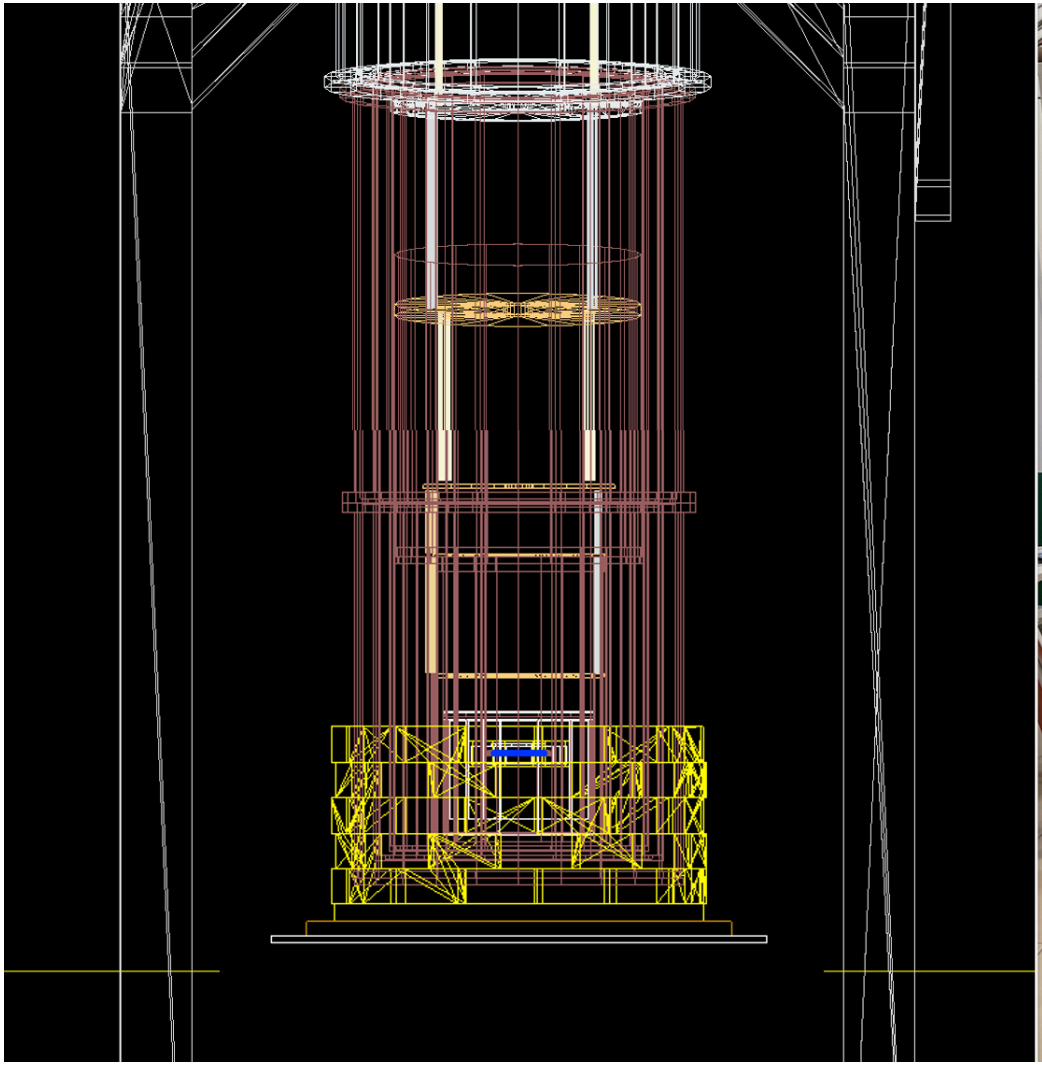
Subleading backgrounds on surface

- **13.47 γ/cm^2/sec from the environment are the main background source**
- **Neutrons have a contribution two orders of magnitude lower, while cosmogenic backgrounds (muons and neutrons) are below 10^4 d.r.u.**



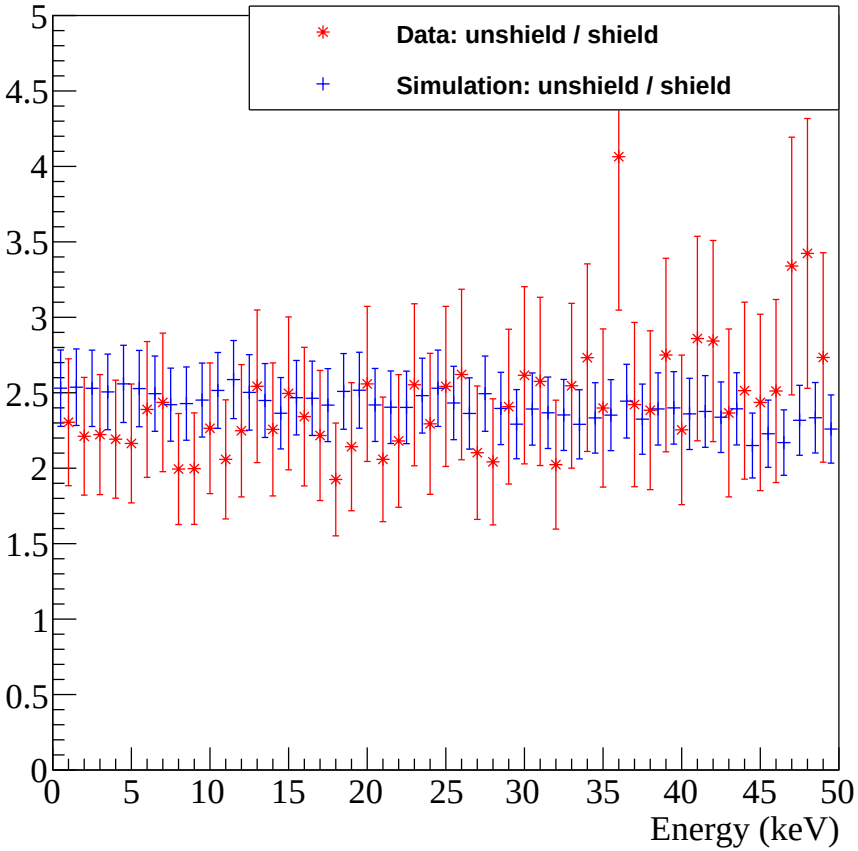
Shielding on surface

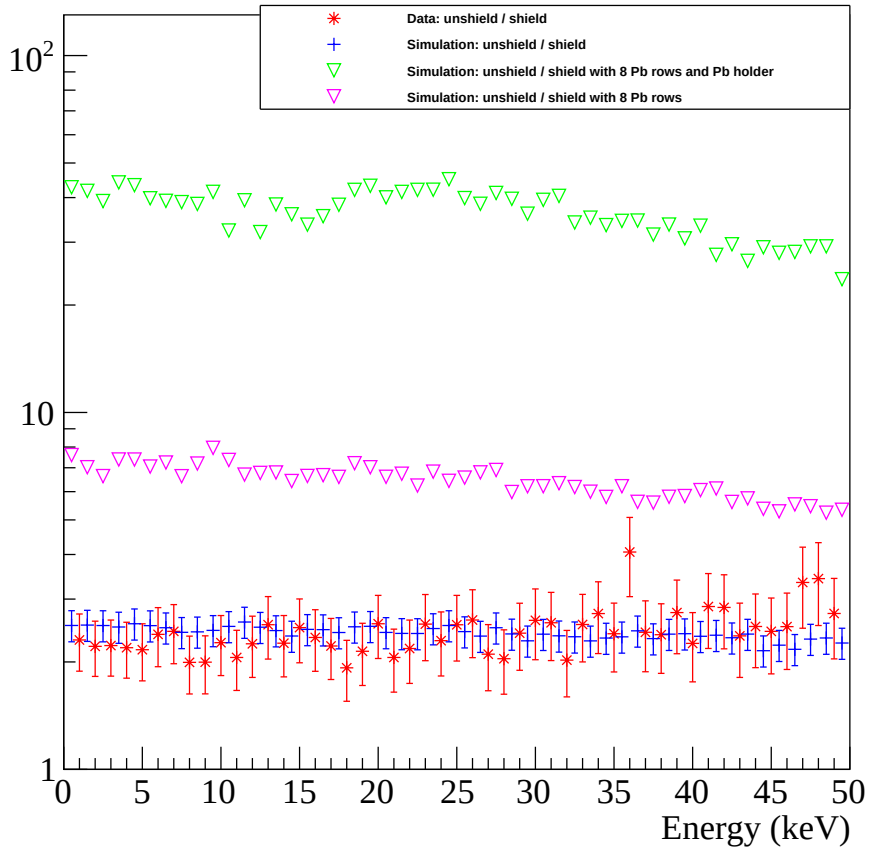
- Moderate γ-rays with Pb to reduce backgrounds by at least a factor of two
- Continue validating the GEANT4 model on surface



Data vs Simulations with shielding

- Unshielded/shielded ratio in very good agreement
- Further reduction by adding additional rows of Pb





- Replacement of the waffer holder and 8 rows of Pb would reduce gamma contribution by nearly two orders of magnitude

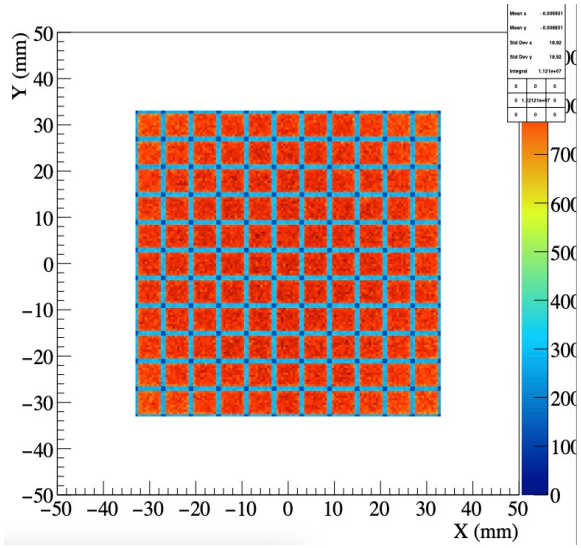
Monte Carlo simulations for the underground experiment at Gran Sasso

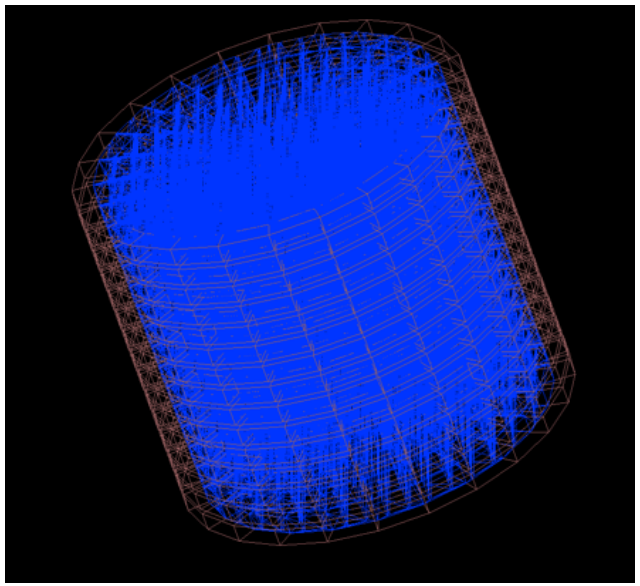
Underground experiment at Gran Sasso

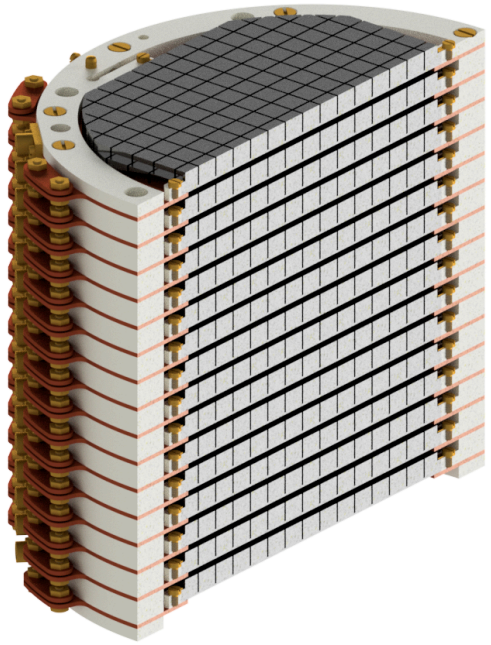
- Active silicon target: ~ 600 gr.
- 16 waffers each 5 cm radius and 5 mm thick

Initial simulation of most relevant backgrounds underground to define shielding configuration:

- Gamma-rays: $0.729\ \gamma/\mathrm{cm}^2/\mathrm{sec}$
- Neutrons in several energy ranges: thermal, radiogenic, cosmogenic
- Muon flux: $3.2 \times 10^{-8}\ \mu/\mathrm{cm}^2/\mathrm{sec}$

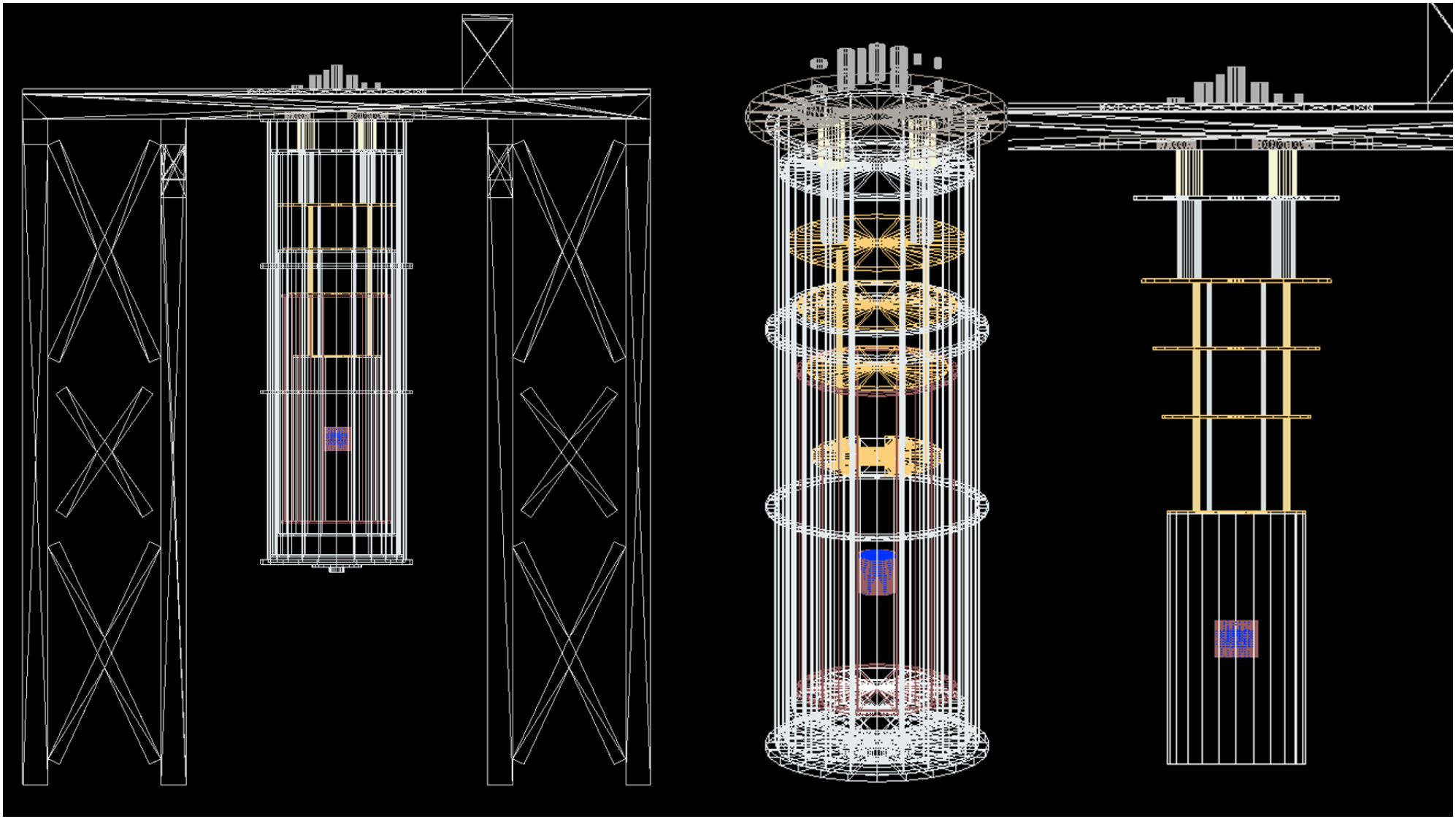






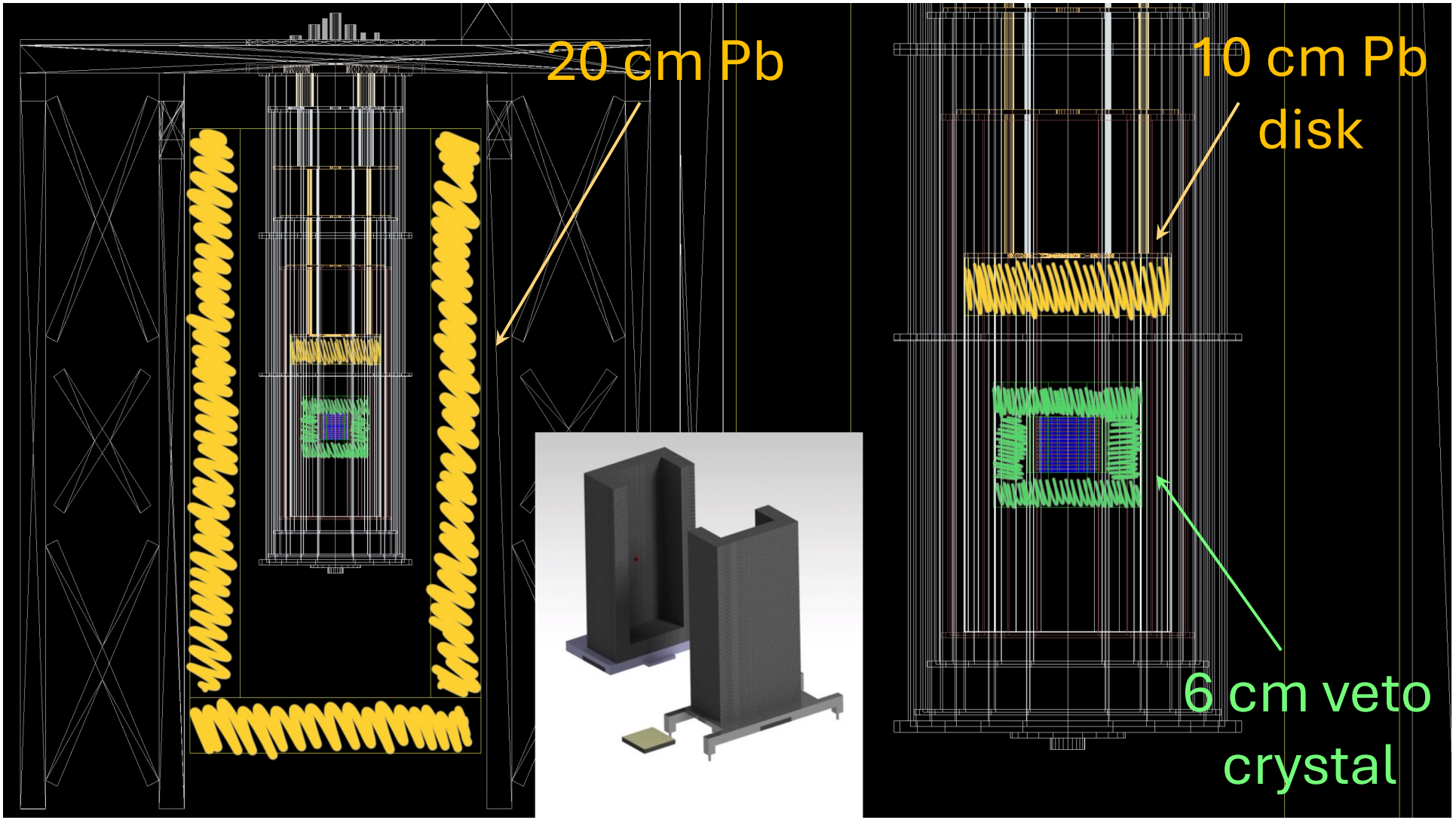
Model for underground experiment

- Installation planned in the cryo facility at Gran Sasso (Hall B)
- Large volume available inside cryostat for additional shielding and veto



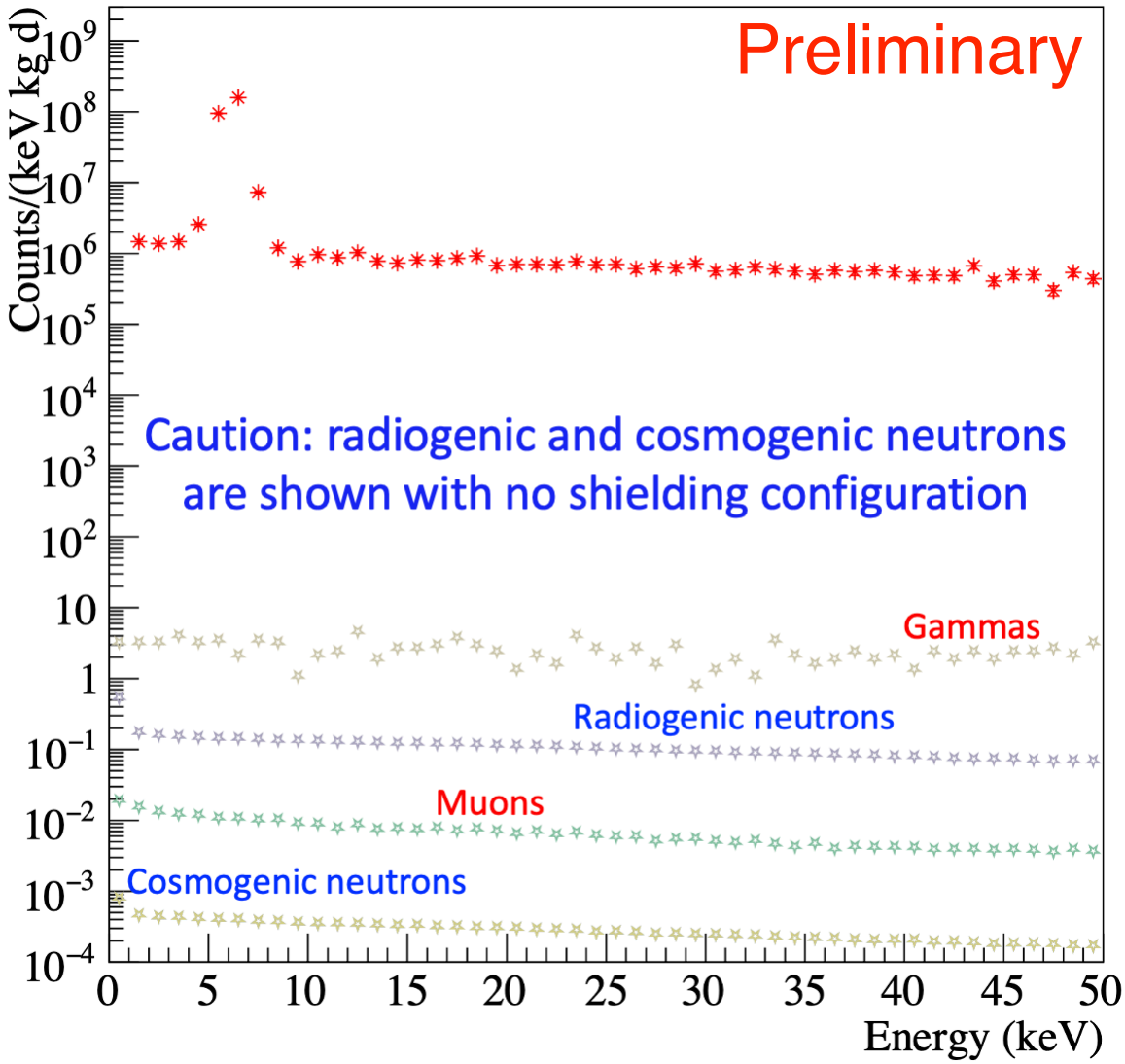
Shielding for underground experiment: preliminary

- Baseline shielding to reduce external backgrounds: optimization in progress
- Addition of inner veto with high Z material (BGO, GSO)



Baseline shielding: preliminary

- External gammas reduced at the level of a few d.r.u.
- Radiopurity level required for internal components in progress, including requirement for veto crystal purity
- Neutron moderator to reduce contribution from internals: (α,n) reactions, spontaneous fission, n captures



Final remarks

- BULLKID-DM proved as a promising technology for low-mass dark matter searches
- Possible to reduce backgrounds on surface by two orders of magnitude to explore background excess in phonon experiments
- Underground detector has the potential to be a leading experiment
- Monte Carlo simulations are in good shape with excellent agreement and validation