

Is or is not DAMA/LIBRA's a Dark Matter signal? No PANIC, the COSINUS experiment is coming!

DIRECT DARK MATTER SEARCH

- Cosmology and astrophysics suggest the existence of dark matter
- The Earth is expected to be constantly hit by a wind of dark matter particles
- Low background detectors on the Earth aim at detecting tiny energy depositions (O(keV)) released in the target material by scatterings of dark matter off nuclei or electrons

EVENT RATE

$$\frac{dR}{dE_R} = \frac{\rho_\chi}{m_\chi} \frac{1}{v} \int_{v_{min}}^{v_{max}} d^3v f(\mathbf{v}) \frac{d\sigma}{dE_R}(\mathbf{v}, E_R)$$

Local DM density over DM mass

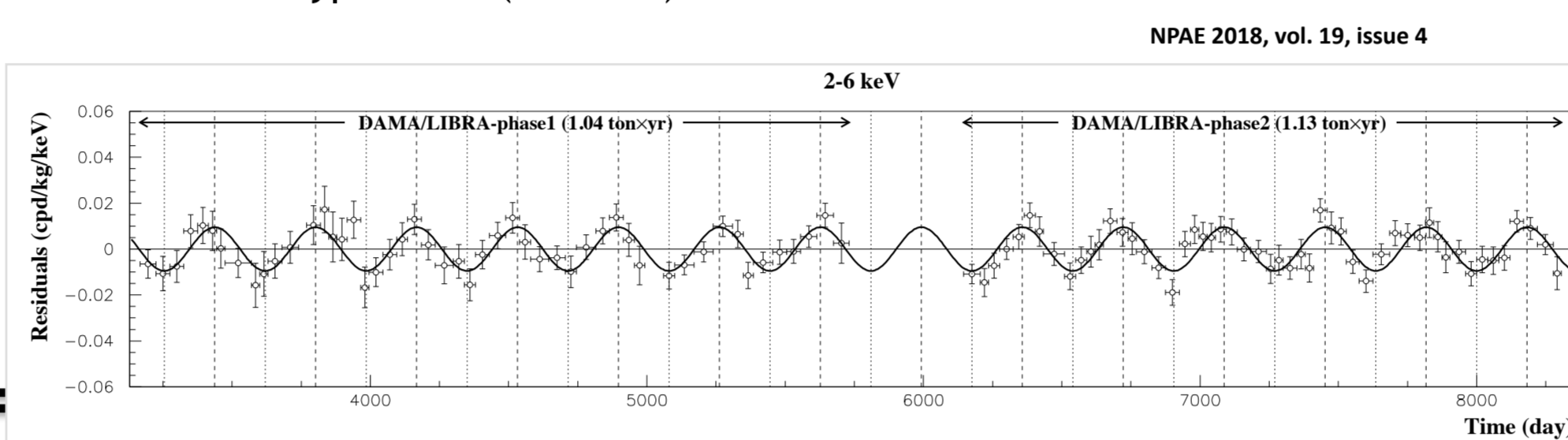
v_{min} : minimum velocity which can produce a recoil energy E_R

Maxwell-Boltzmann velocity distribution

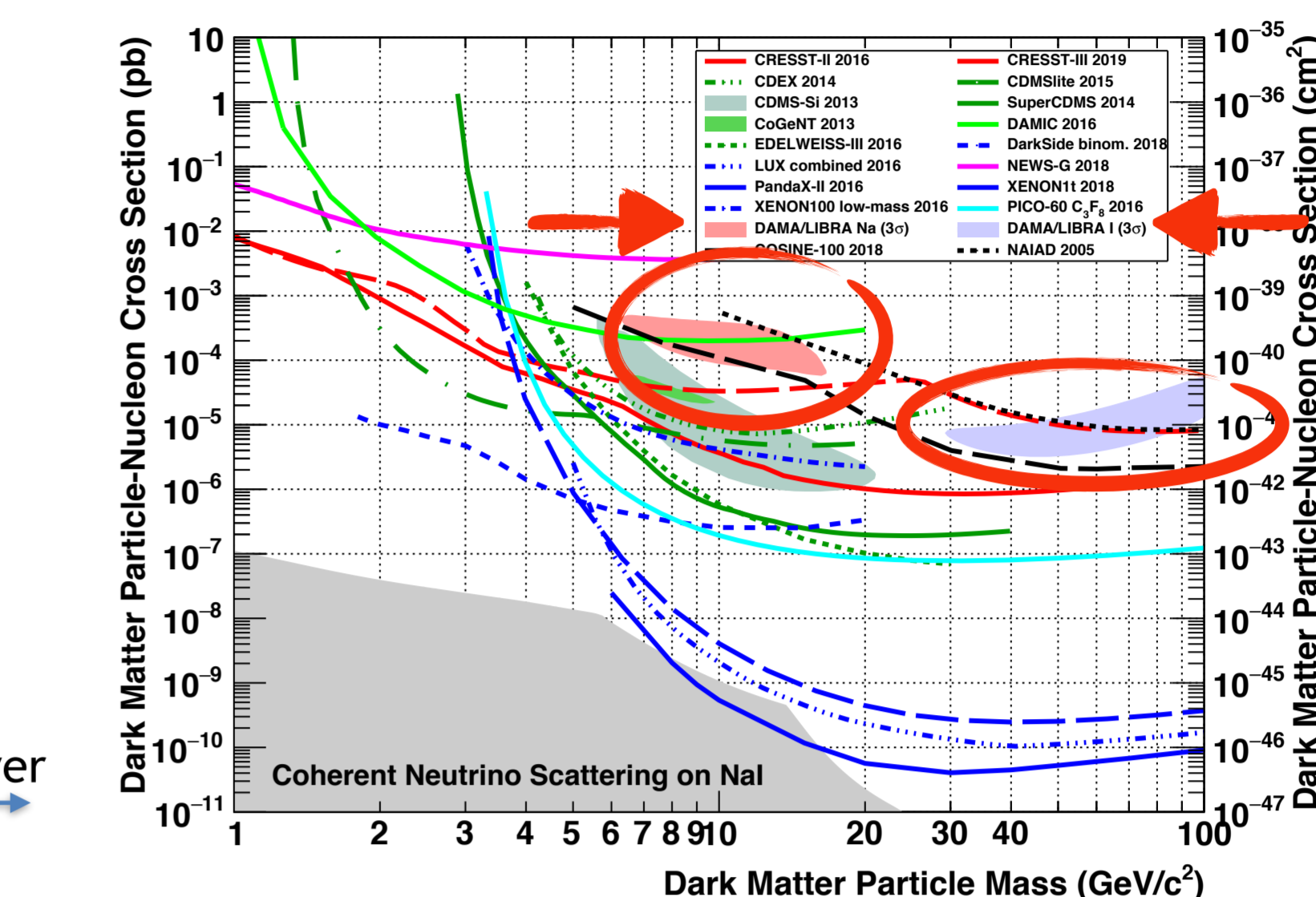
Differential dark matter-nuclei cross-section

ANNUAL MODULATION

- The composition of the Earth-velocity around the galactic center and the Earth-velocity around the Sun introduces an annually periodic time-dependence in the event rate
- The DAMA/LIBRA collaboration is detecting since 20 years a signal compatible with the DM hypothesis (12.9 σ !!)



EXPERIMENTAL PANORAMA



Despite of the extreme efforts, results are still not consistent in the standard scenario

NaI-CRYOGENIC CALORIMETERS

- Material-independent cross-check of the DAMA/LIBRA result [JINST 12 \(2017\) no.11, P11007](#)
- NaI crystal: hygroscopic, low Debye temperature, ^{40}K contamination
- NaI crystals for the first time operated at mK-temperature as scintillating calorimeters
- ^{40}K radio-purity: 5-9 ppb at crystals' nose and 22-35 ppb at crystals' tail **Goal achieved!**

DUAL-CHANNEL READOUT: PHONON and LIGHT

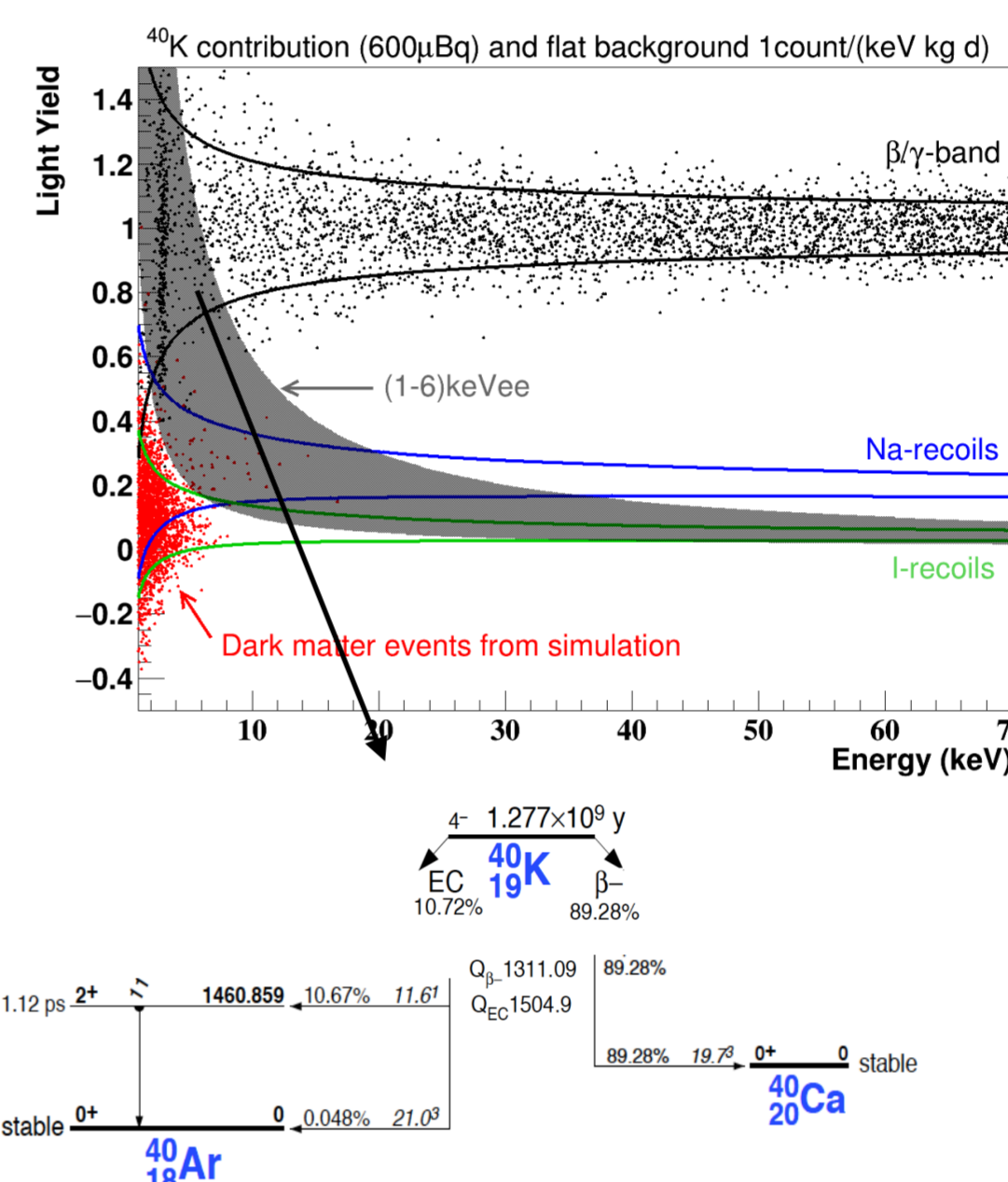
Si-beaker + TES is the light-channel

Scintillation light (few %) amount of emitted light depends on particle type \rightarrow LIGHT QUENCHING

NaI crystal + TES is the phonon-channel

Phonon signal (~90%) (almost) independent of particle type

PARTICLE-DISCRIMINATION



- SIMULATED DATA (100 kg day gross exposure):
- 20 ppb of ^{40}K
 - flat background: 1 cpd/(keV kg)
 - threshold (NaI): 1 keV
 - $\epsilon=50\%$ ($>2\text{keV}$), 20% (1-2 keV)
 - light energy conversion: 4%
 - QF(Na) ~ 0.3
 - QF(I) ~ 0.09
 - $\sigma^{\text{SI}} = 2 \times 10^{-4} \text{ pb}$ ($m_{\text{DM}}=10 \text{ GeV}/c^2$)

The dark-grey-area indicates the electron-equivalent energy range of 1-6 keVee, where the DAMA experiment observes a positive modulation amplitude

DETECTOR DESIGN OPTIMIZATION: NEW RESULTS

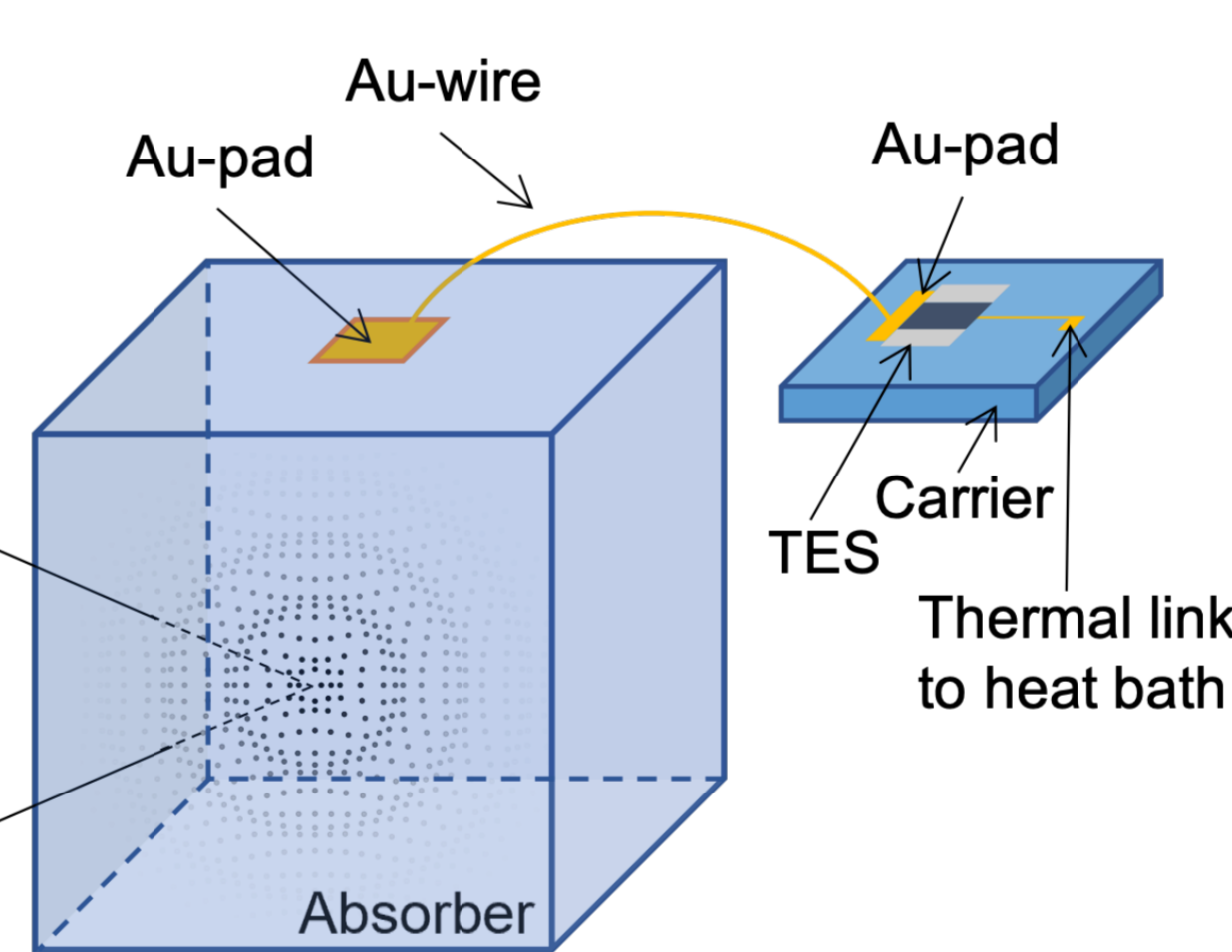
Baseline design

Blue = A - part "phonon NaI part"

Green = B - part "light part"

$$\Delta T_e(t) = \sum_{i=1}^3 A_i [e^{\lambda_i t} - e^{-t/\tau_i}] + \sum_{i=1}^3 B_i [e^{\lambda_i t} - e^{-t/\tau_i}]$$

remoTES design



| R&D best results | | |
|------------------|------------------------------|----------------|
| Absorber | Dimension (mm ³) | Threshold (eV) |
| Si | 20x10x5 | 323 |
| TeO ₂ | 20x10x2 | 1100 |

GOAL: lower NaI phonon channel threshold!

- remoTES idea first suggested by M. Pyle et al. in 2015 arXiv:1503.01200
- COSINUS successfully operated the first remoTES detector design
- COSINUS successfully operated the first NaI remoTES detector design

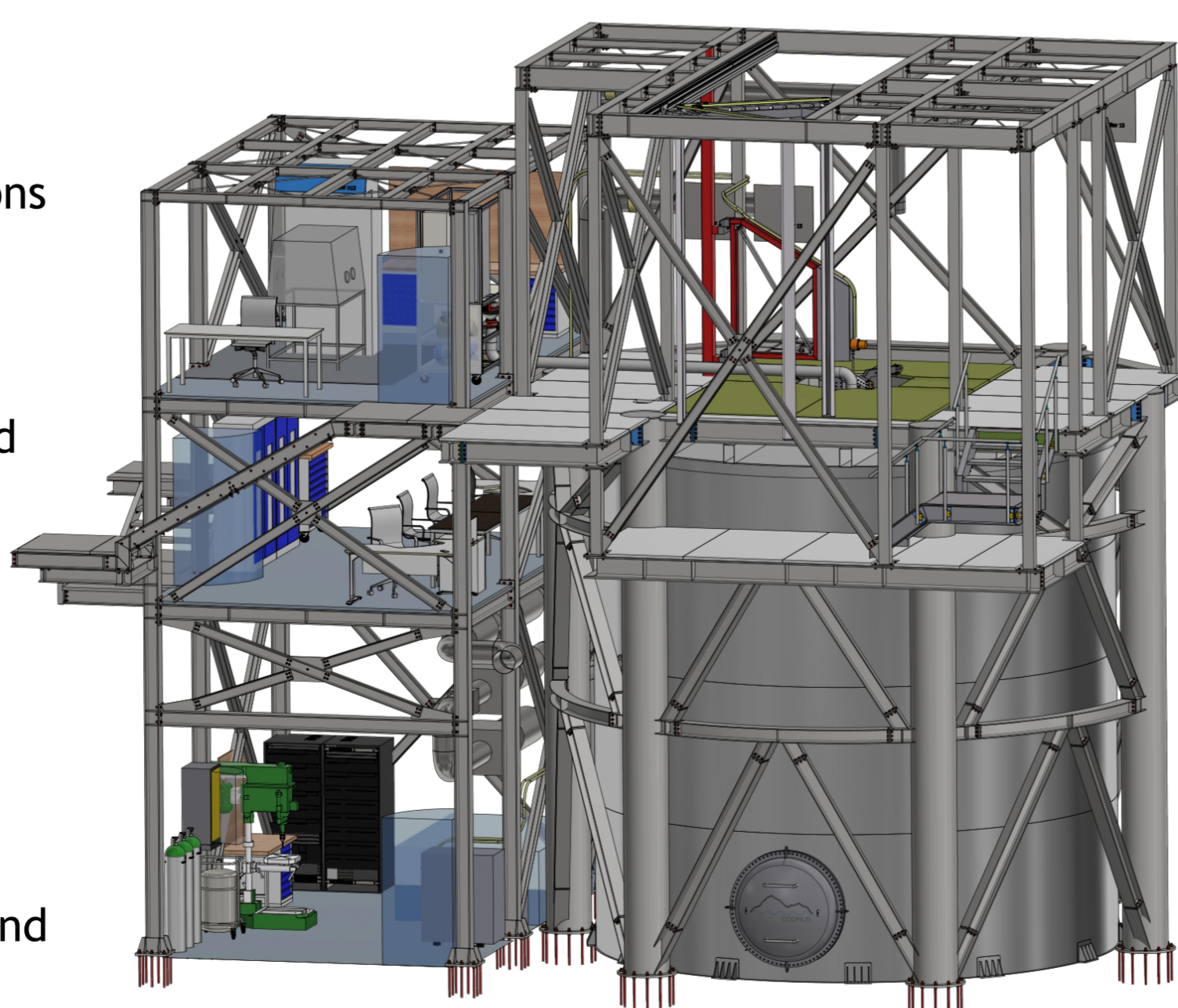
BUILDING CONSTRUCTION at LNGS (Italy)

Background budget evaluation and shielding concept investigated using GEANT4 simulations (e-Print: [2106.07390](#))

7 x 7m water tank, as neutron moderator and active Cherenkov veto

Clean room for detector assembling and mounting

Three level control room will host the DAQ and the electronics, the cryostat-related infrastructure and a working area



QUENCHING FACTOR MEASUREMENT



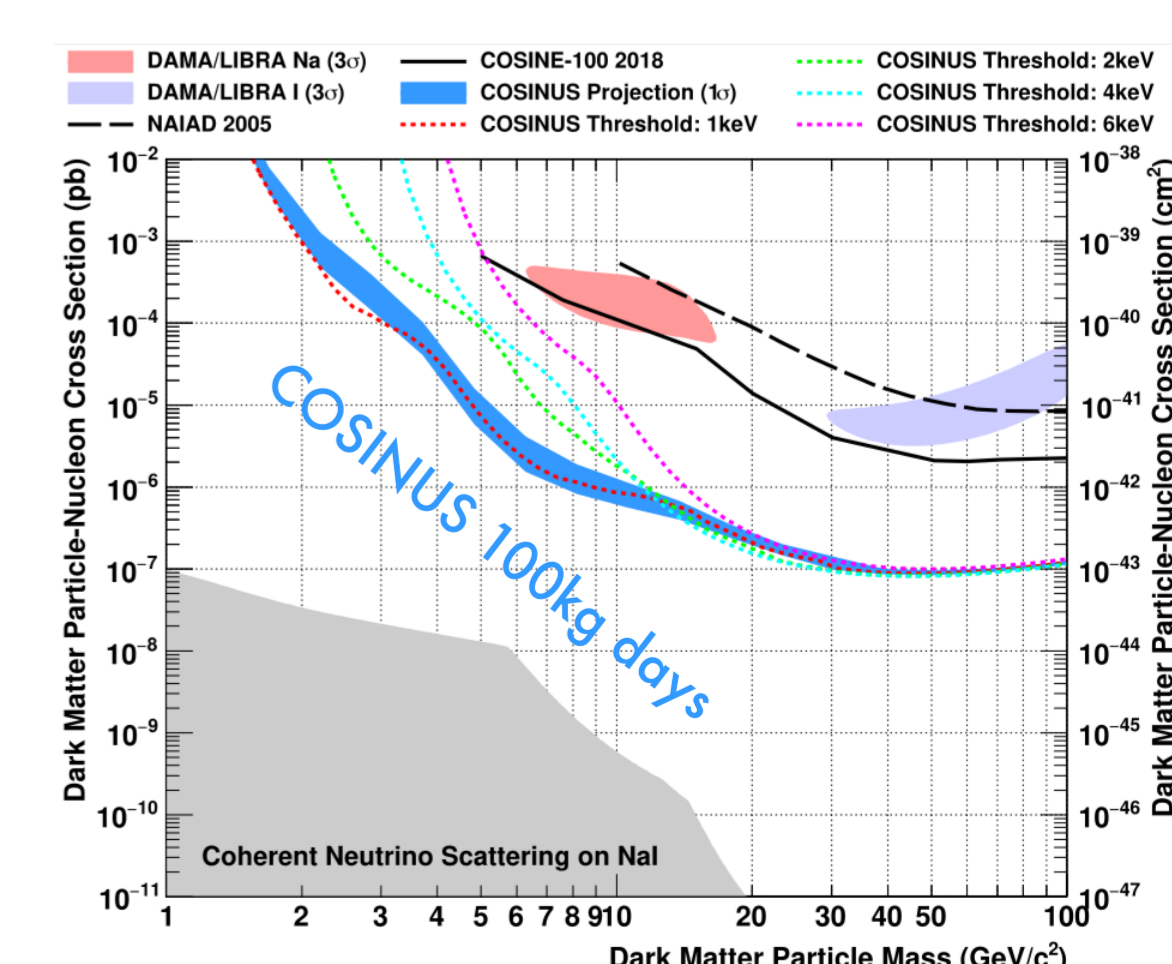
Room-temperature measurements planned in August 2021 at TUNL in U.S., for different concentrations of TI-dopant

Low-temperature measurements done with AmBe source and with the beam of 11MeV neutrons at the Meier-Leibnitz Laboratories - Tandem accelerator

PHYSICS REACH

COSINUS 1 π goal: clarify if the DAMA signal consists of events of dark matter scattering off nuclei

Two-data taking runs are planned:
 1st: collect an exposure of 100 kg day in 2023 and 2024
 2nd: collect an exposure of 1000 kg day in 2024-2027



PUBLICATIONS

News: <https://arxiv.org/abs/2106.07390>
 Low Temp Phys 200, 428-436 (2020). <https://doi.org/10.1007/s10909-020-02464-9>
 Detector. J Low Temp Phys 193, 1174-1181 (2018). <https://doi.org/10.1007/s10909-018-1967-3>
 JCAP05(2018)074 <https://doi.org/10.1088/1475-7516/2018/05/074>
 J. Phys.: Conf. Ser. 1342 012099 <https://doi.org/10.1088/1742-6596/1342/1/012099>
 JINST 12 P11007 <https://doi.org/10.1088/1748-0221/12/11/P11007>

