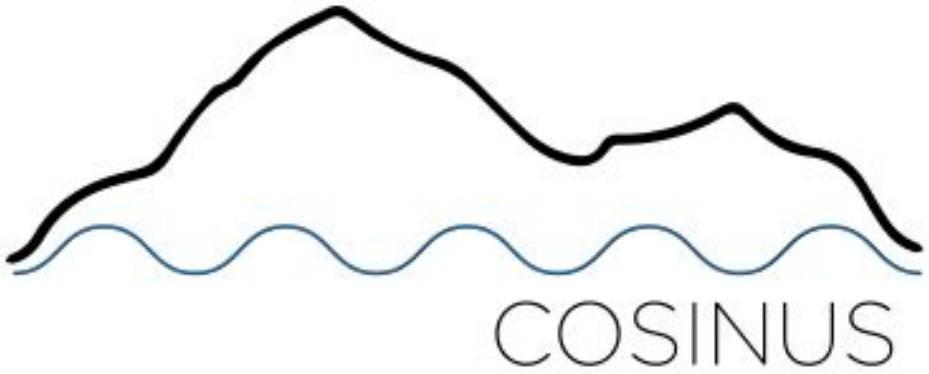


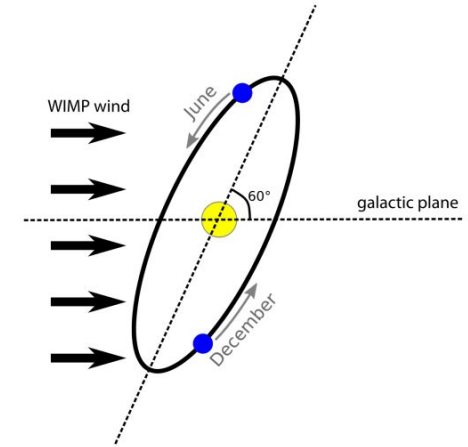
2021 Scientific Fair GSSI

Andrei Puiu

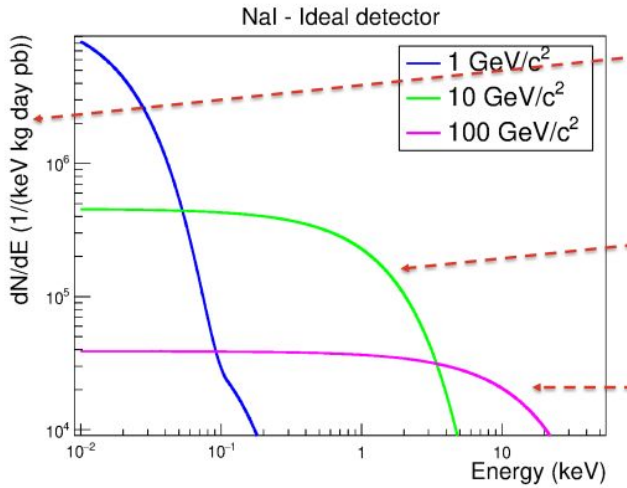
COSINUS collaboration

cosinus.lngs.infn.it

Direct Dark Matter Detection



Period: 1 year
Phase: cosine peaking June 2nd



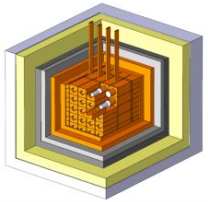
Very rare
current limit*
$\mathcal{O}(0.01)$ counts/tonne/day

Featureless spectrum

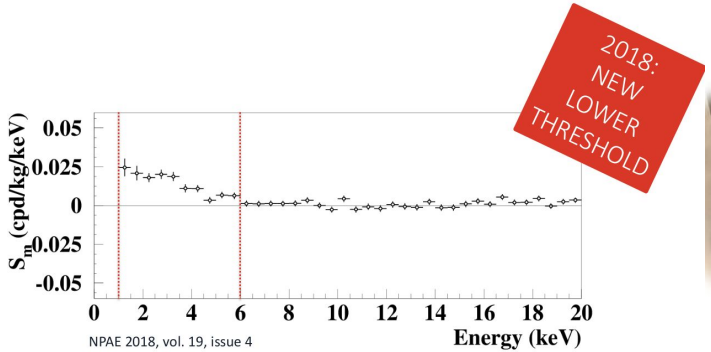
Small recoil energies
~keV range

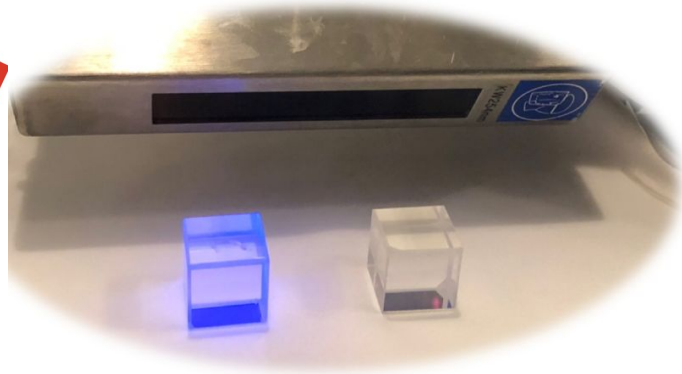
COSINUS – the target: NaI

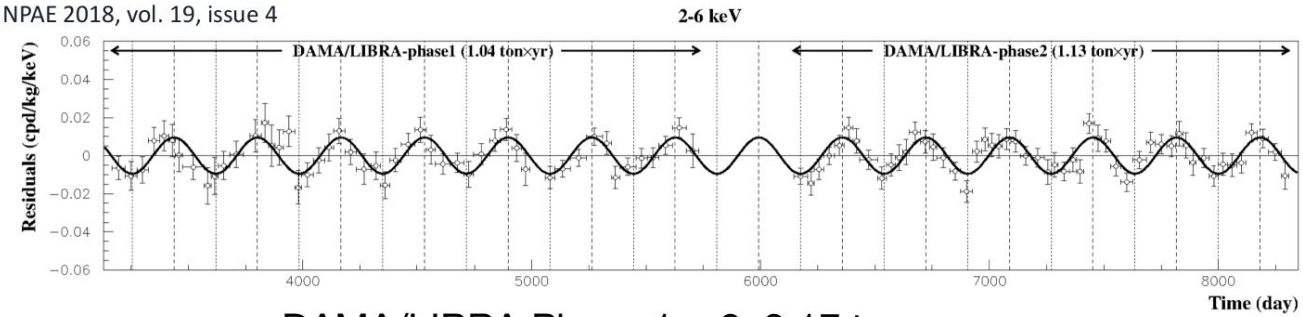
DAMA/LIBRA



Material	250kg of NaI (Tl)
Signal(s)	Light (PMTs)
Location	LNGS
β/γ-discrimination	no
Taking data	since 1996
Threshold	1keVee

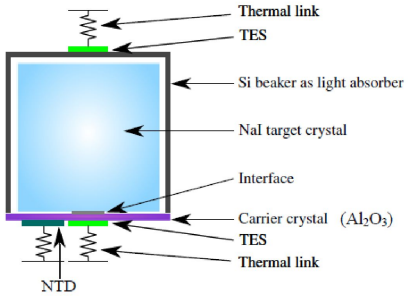


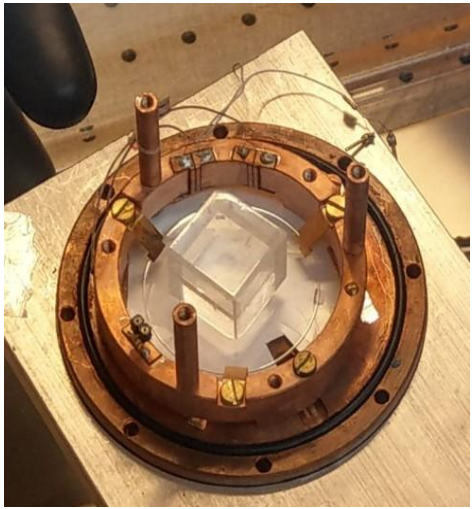


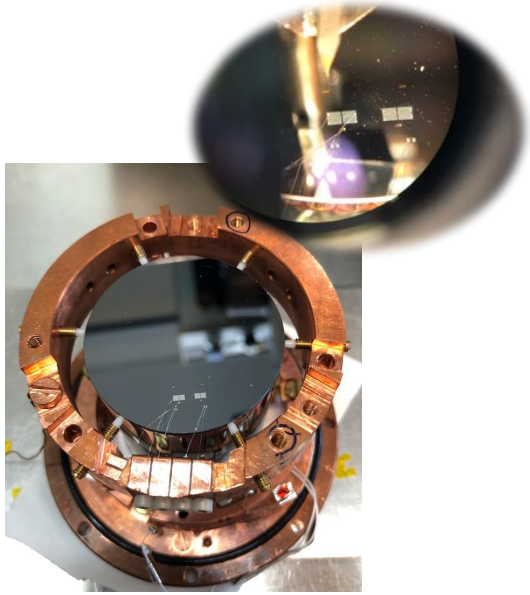


DAMA/LIBRA Phase 1 + 2: 2.17 tonne years
Statistical significance: 11.9σ

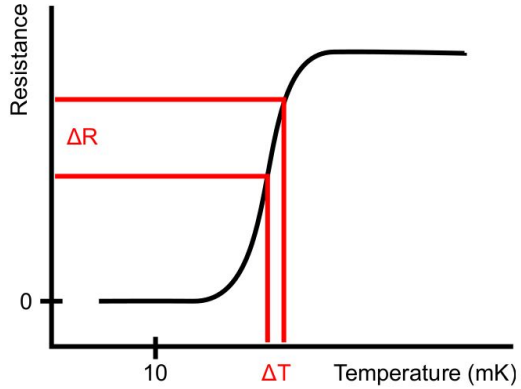
COSINUS – detection technique





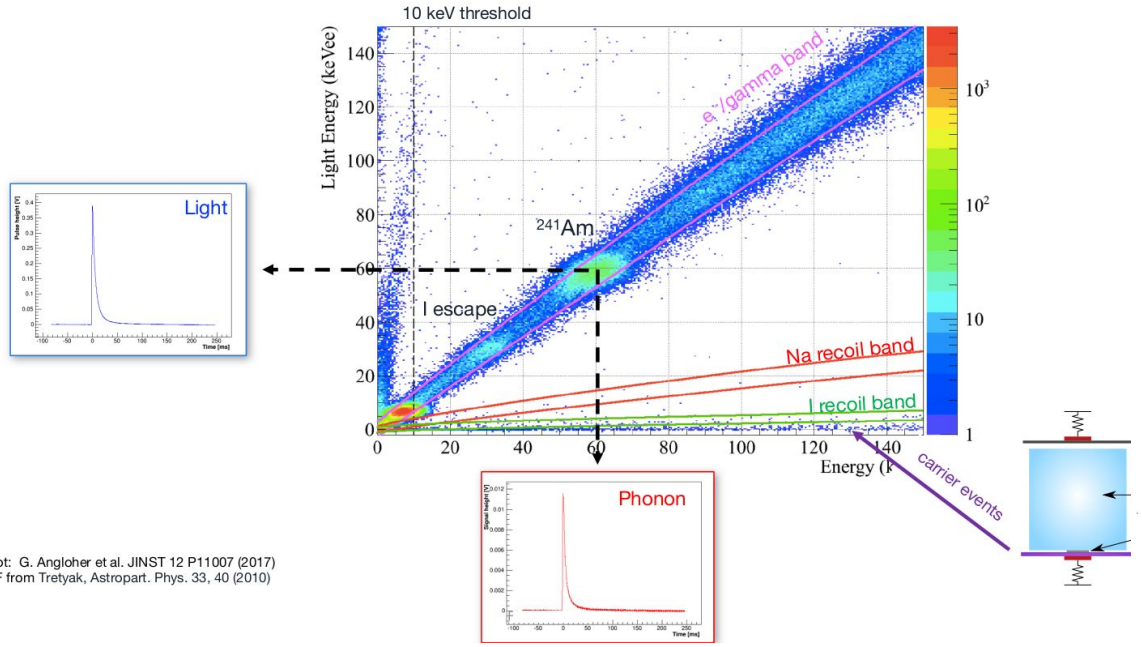


- Low temperature calorimeters: unquenched signal
- Phonon/light signal: double readout for particle identification → background reduction
- NaI crystal coupled to carrier
- Light detector for a 4-pi active coverage
- W-based Transition Edge Sensors

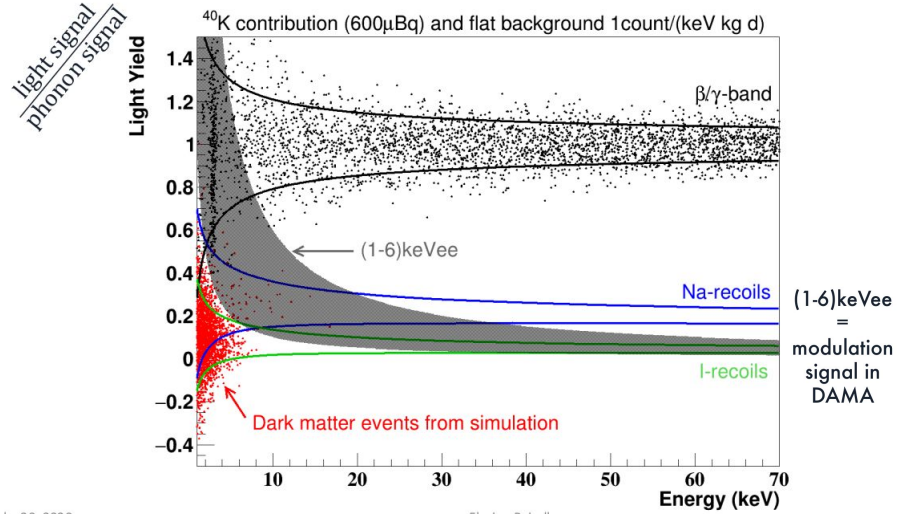


Energy deposition
~keV
↓
Temperature rise
~μK
↓
Resistance change
~mΩ

COSINUS – Signal extraction



plot: G. Angloher et al. JINST 12 P11007 (2017)
QF from Tretyak, Astropart. Phys. 33, 40 (2010)



Combining the information from the phonon channel and the light channel event-by-event particle identification is achieved. DM interactions are expected in the nuclear recoil bands of Na and I atoms.

The Physics goal

To reach the target sensitivity for COSINUS:

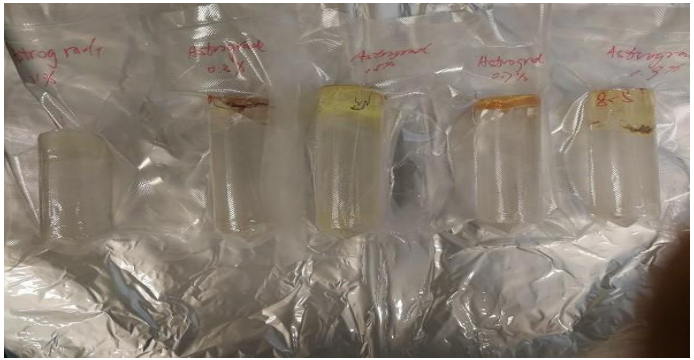
- Exposure:
  - 100 kg×days (i.e. 10 crystals, 50 gr each, 1 year of data taking)

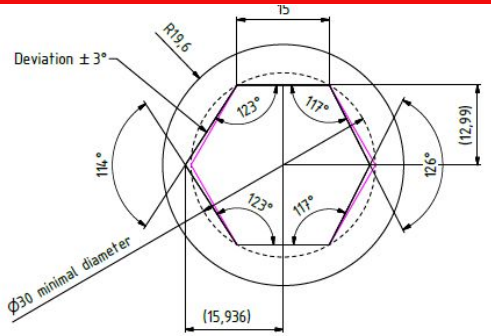
    → exclusion of the DAMA region by about two orders of magnitude in cross section
  - 1000 kg×days (COSINUS-1π, i.e. 20 crystals, 50/150 gr each, 3/1 year of data taking)

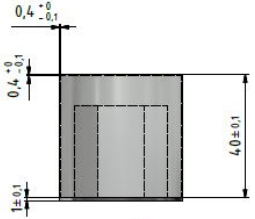
    → **Cross-check of the DAMA modulation signal independent of the dark matter halo (astrophysics) and the interaction mechanism (particle physics) apart from demanding that dark matter interacts with the nuclei and not the electrons in the target.**
- Detection threshold: 1 keV → TES Signal-to-noise ratio
- Particle identification: Quenching factor and light and phonon collection

NaI crystals R&D

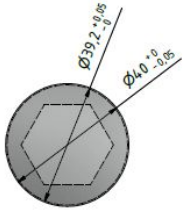
- Crystal production at Shanghai: pure NaI vs Tl-doped
- 13 K cryo at LNGS: light yield, scintillation measurements for different dopant concentrations and for pure crystals
- Coating for crystal handling and improved detector mounting GSSI/LNGS and INFN-Legnaro:
  SiO_2, **TiO_2**, **Al_2O_3** coating for protection
  Superconductive Nb coating for light collection
  (CUPID-shared activity)





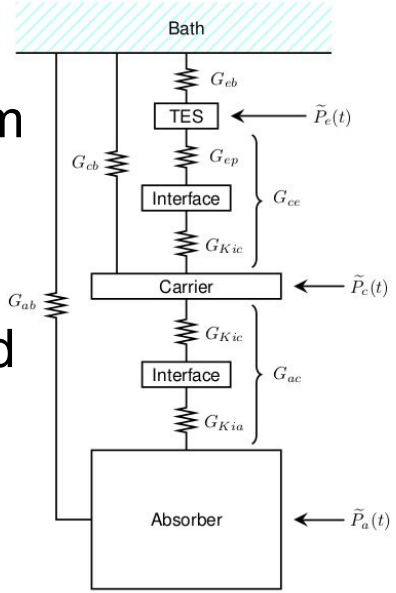


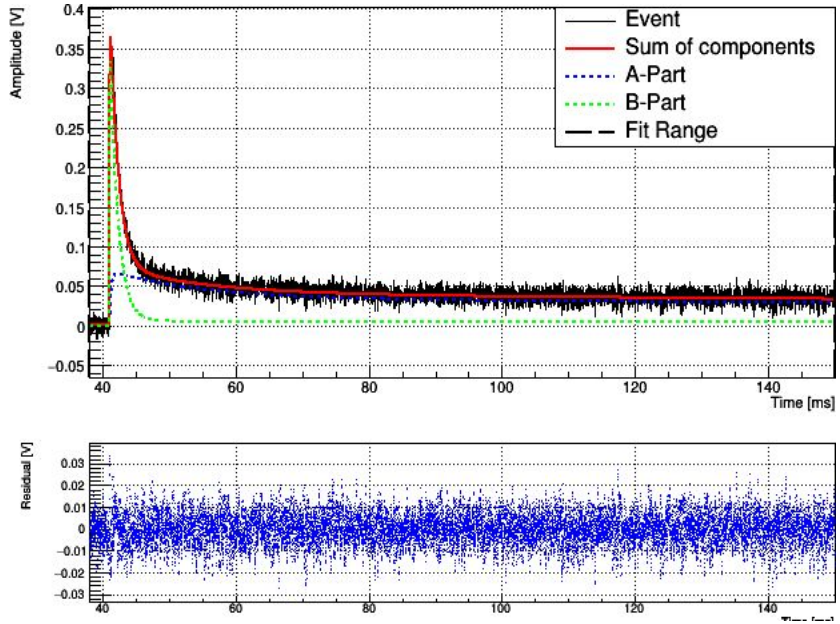
H: 40mm
Φ: 30mm
volume: 17.537cm3
mass: 64.36g



Pulse shape analysis R&D

- The crystal+carrier+TES system is not trivial to model
- The light emitted in the crystal gets absorbed in the carrier and produces an extra non-thermal component in the pulse
- **A new model has to be developed**

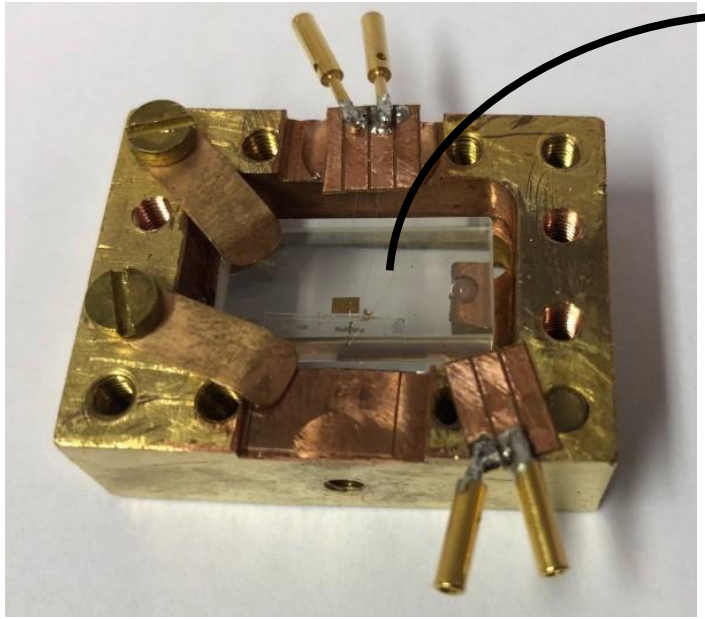




$$\Delta T_e(t) = \sum_{i=1}^{3} A_i \left[e^{\lambda_i t} - e^{-t/\tau_n'}\right] + \sum_{i=1}^{3} B_i \left[e^{\lambda_i t} - e^{-t/\tau_\ell}\right]$$

No Carrier: coating and Remo-TES

- A very promising R&D activity is ongoing: Tests at MPIK/LNGS
- Mounting the TES aside of the crystal and connecting them with a strong thermal link (RemoTES)

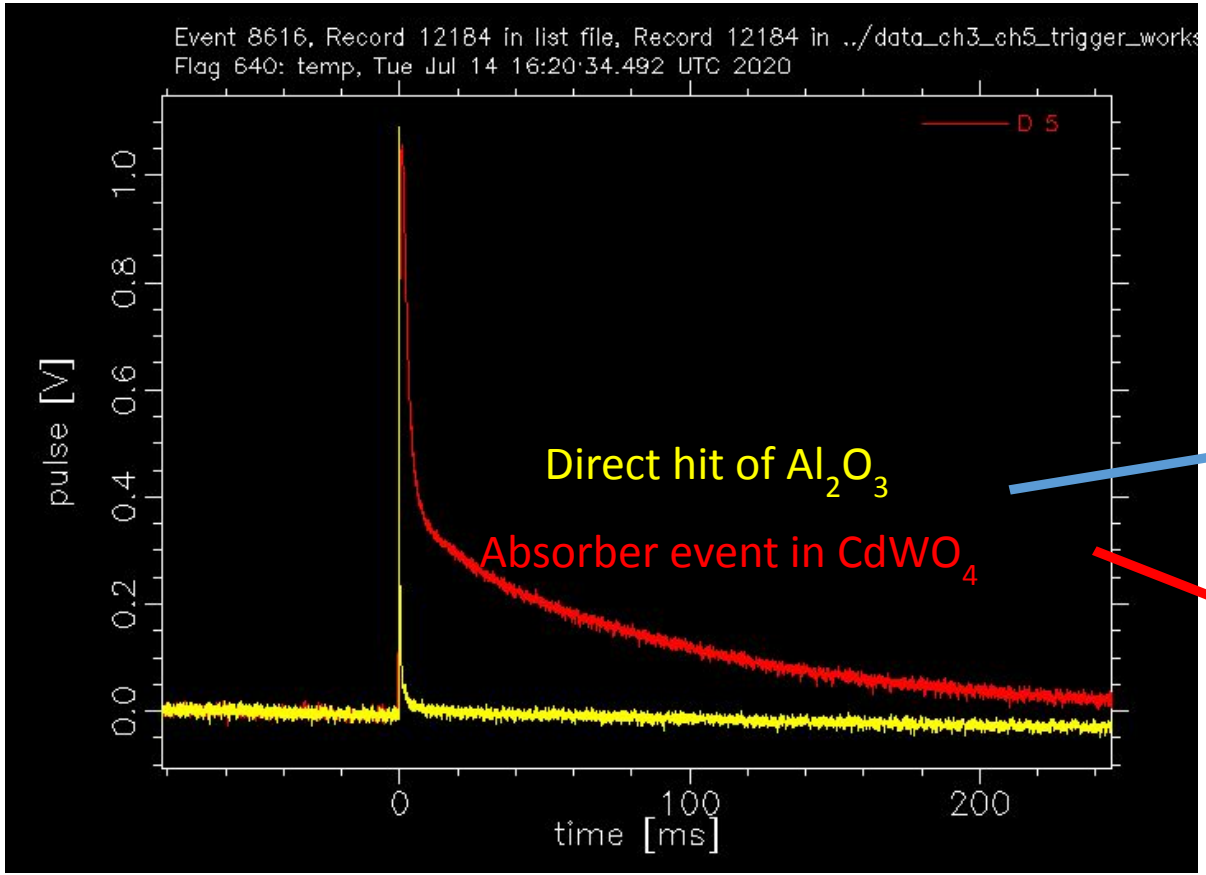


20x10x5 mm^3 $CdWO_4$ with Gold pad for phonon collection

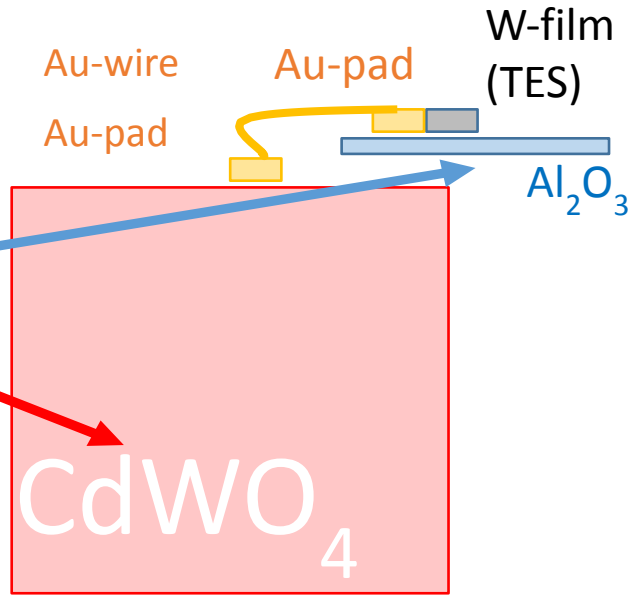
Bonded Gold wire for thermal link to

TES on small Al_2O_3 wafer ($10x10mm^2$)

Detector R&D: Remo-TES



Preliminary test



Detector development activities

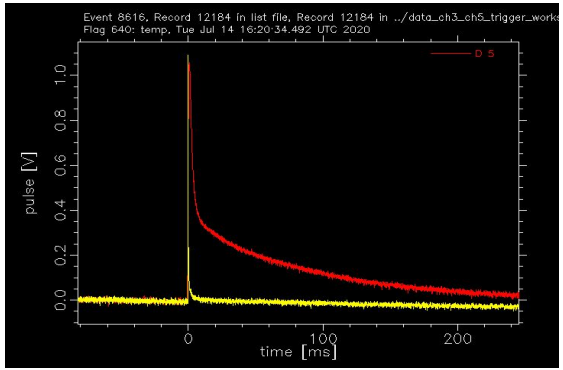
- Remo-TES tests with NaI absorber:
  - TES design optimisation to match the long time constants of NaI crystals
  - Thermal link between Crystal-TES-Thermal bath to maximise the signal
- Coating for NaI:
  - protective layer for hygroscopicity
  - reflective layer for light collection
- Light collection:
  - Position dependency in beaker LD vs standard LD

OpticalCryo@LNGS (also for LE-5 lab)

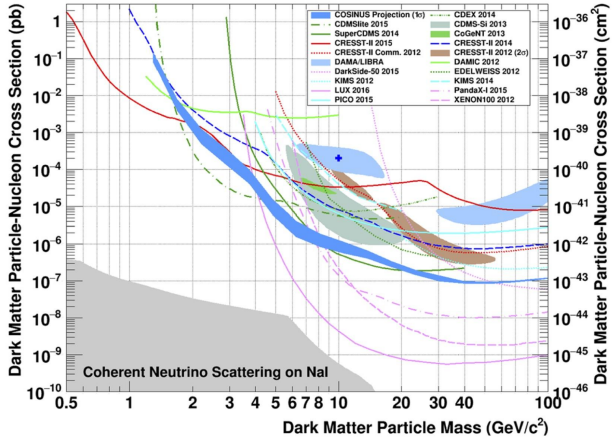
Data analysis

- Cryogenic calorimeters data acquisition and processing
  - development/optimization of the software for pulse analysis and fitting
  - rejection of non-physical/spurious/pile-up events etc..
  - development/optimization of sw for calibration and study of the energy scale
  - pulse shape studies
- Develop the tools for rare events data analysis for limit setting

From



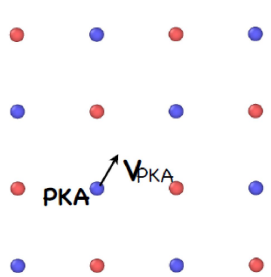
to

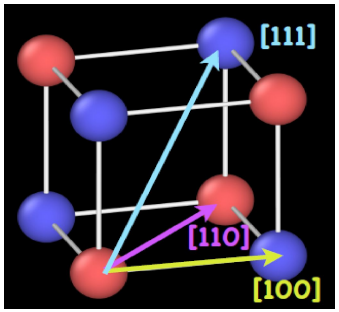


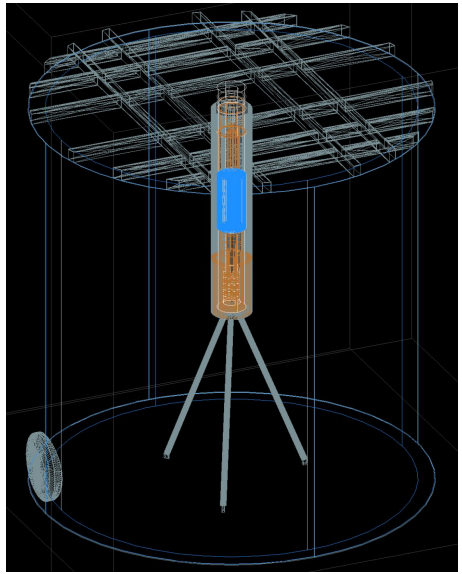
Simulation and Analysis

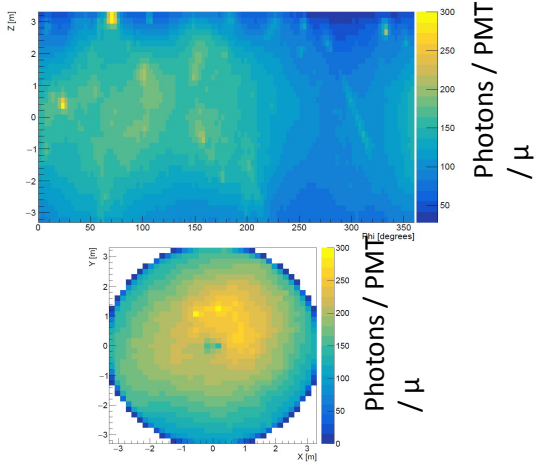
UNIVERSITÀ DEGLI STUDI DELL'AQUILA

- Thermal model for detectors:
  - Energy estimation in TES-based COSINUS modules
  - Phonon generation and propagation in NaI crystals (in collaboration with UnivAQ, prof. Filipponi, prof. Profeta)
  - EXAFS measurements
- Water Cherenkov veto design:
  - Best PMT geometry
  - PMT calibration
  - Reflective layer and buffer layer
- Material screening
- Background modeling









2021: the year the journey starts...

HallB

Mar 2021- Feb2022

Construction:
-water tank
-cryostat
-control building

Feb 2022 – May 2022

Commissioning

June 2022 →

Start data taking
100 kg d → June 2023
Goal exposure -> 1000 kg days

Collaboration

\+ 1 Post Doc

N.DM.: Analisi/tecniche di PSD
Material Screening and Assay

A.P./L.P.: Misure
Criostati (HallC, IETI, HdM)
Cristalli
Muon Veto

S.P.: Misure
Criostati
(HallC, IETI, HdM)

M.B.: Water recirculation

P.M.: opere civili

A.F.: Misure EXAFS

G.P.: Simulazioni di dinamica molecolare

I.D.: Cristalli

\+ MPP (Germany)
\+ HEPHY/TU (Vienna)
\+ HIP (Finland)
\+ SICCAS (China)

Questions and curiosity

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