COSINUS - Direct Search for Dark Matter with Cryogenic NaI Detectors

Martin Stahlberg for the COSINUS Collaboration
Positive evidence for the presence of DM particles in the galactic halo

Strong tension with other direct DM detection experiments - but different target materials used

Up to now, source of the modulation is unknown

Emergence of several NaI-based direct detection experiments in the last years
Results from ANAIS & COSINE also in strong tension with DAMA

- Physical review letters 123.3 (2019): 031302
- Physical Review D 103.10 (2021): 102005
COSINUS DETECTORS

- Idea: Operate NaI crystals as cryogenic detectors
- Well-established technique
- Two channels, read out via TES sensors + SQUIDs:
  - Heat (phonons)
  - Scintillation light
- Example: „Beaker“ design - use Si beaker to collect light
1st measurement of a NaI as cryogenic calorimeter
linear relation between light output and deposited energy
Nal threshold: 10 keV
3.7% detected in light

2nd PROTOTYPE (2016/17)
- successful test of complete COSINUS detector design
- energy resolution at zero energy: 15 eV
- Nal threshold: 8.3 keV
- 13% detected in light

3rd PROTOTYPE (2017)
- changed interface to thin layer of silicon oil
- commissioning of: in-house electronics and DAQ from MIB
- Nal threshold: 6.5 keV

4th - 20th PROTOTYPE
- tests with high-purity NaI/NaI(Tl) crystals from SICCAS
- Tests of different TES-concepts for the NaI crystal, optimization of beaker design
- Work ongoing!
- Performance goal: 1 keV
- Performance goal: 4%

- Crystals of few cubic centimeters (10-100g)
- Collaboration with SICCAS; production of high-purity NaI crystals
With TES, achievable thresholds on the order of a few keV (in recoil energy)

Additional scintillation light allows for particle discrimination

Quenched bands
Measurements of quenching factors (QF) at room temperature do not agree.

In particular, role of Tl is unclear (usually crystals are doped).

Strong influence of QF on signal interpretation.

COSINUS will provide the first cryogenic QF measurement for NaI.
**Construction site:**
Laboratory Nazionali del Gran Sasso (Italy)

**Planned facility:**
- ("Dry") cryostat with detector modules
- Cu shielding
- Water Cherenkov veto for active muon tagging
- Decoupling system to reduce vibrations
- Clean room for detector assembly

(GEANT simulation for muon veto)
COSINUS – TIME SCHEDULE

Setup
- Cryostat
- Water shield
- Buildings
- DAQ Electronics
- Comm

Detector
- Final Detector Design
- 12 dets.

Data taking
- 100 kgd
- 1000 kgd

Facility completed
Ready for data taking
First dark matter result
Picture taken from the top of XENON1T water tank
COSINUS SENSITIVITY PROJECTION

COSINUS Sensitivity Projection

- DAMA/LIBRA Na (3σ)
- DAMA/LIBRA I (3σ)
- NAIAD 2005
- COSINE-100 2018
- COSINUS Projection (1σ)
- COSINUS Threshold: 2 keV
- COSINUS Threshold: 4 keV
- COSINUS Threshold: 1 keV
- COSINUS Threshold: 6 keV

DAMA

COSINUS 100 kg days

Coherent Neutrino Scattering on NaI
COSINUS will provide:

- Cross-check of DAMA modulation using same target material (NaI) and highly radiopure crystals
- Dual-channel readout, threshold of few keV
- Model-independent check (with sufficient exposure)
- First application of NaI as cryogenic detector
- Construction of COSINUS facilities started
- Expecting first data in 2023
Thank you!
MODEL-INDEPENDENT CONSIDERATIONS

- COSINUS detectors provide background discrimination on event-by-event basis!

- Modulation amplitude cannot exceed total rate!
- No assumption on dark matter halo
- For model-independent cross-check would need $\sim 1.8$ keV nuclear recoil threshold, $\sim 300$ kgd exposure