N3 Status Report

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ILIAS-N3 Dark Matter Network
- Structure - Working-Groups -

Detection Concepts

- Cryogenic Detectors and Cryostat
- Non cryogenic Detectors and liquid Xenon
- Germanium and NaI Detectors
- Advanced Detectors including directional Concepts

Common Activities

- Axion Searches
- Background Simulation, Neutron-Shield and Muon-Vetos
- High Radiopurity Materials and Materials Purification
- Common Activities

Convergence on the optimum strategy for large scale detector based on each of the alternatives

Convergence on the strategy for future large scale European Dark Matter experiments
Network on Direct Dark Matter Search – ILIAS – N3

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Common Activities

Common Activities
first 6 month:
- DMD-N3 meeting May 27 – Paris
- each working group:
  • working group meeting
  • elect coordinator
  • WG contribution to N3 Website

month 7 – month 12:
- next WG meetings
- identification of most promising cryogenic / liquid Xenon / Ge and NaI / other new detector technologies for large scale experiment
- start identification of shielding strategies
- read out schemes
- relevance of CAST data for dark matter
- identify considered Monte Carlo codes
- link to IDEA JRA2 and DBD – N4
- start collection of existing data on material purity
- link to LBT-DUSL – JRA1
- qualitative goals of a large scale dark matter search facility
- work plan together with N6 - theoretical astroparticle physics

month 12 – month 18:
- progress report / work plan for year 2 and 3
- set up subgroups on most promising detector concepts
- identification of requirements of operation: read out, cooling etc.
- identification of combined needs on purity, shielding etc. with other WGs
- start comparison of concepts
- identify advantages of each concept
- possible use EDELWEISS/CRESST data for AXION search report on how CAST can help dark matter studies
- sub-groups on different Monte Carlo codes
- implementation of Monte Carlo codes for neutron tracking
- collection of existing data on material purity
- continue working on knowledge base
- define quantitative goals and desired scale for large scale dark matter search project form theoretical considerations
# ILIAS-N3 Dark Matter Network - Participating Institutions -

## France:
- CNRS/SPM/CRTBT Grenoble
- CNRS/IN2P3/IPN Lyon
- CNRS/IN2P3/CSNSM Orsay
- ICNRS/IAS Orsay
- CNRS/INSU/IAP Paris
- CEA/DSM/DAPNIA Saclay
- CEA/DSM/DRECAM Saclay
- Modane Underground Laboratory

### Participating Institutions:
- **EDELWEISS**
  - Low background
  - Cryogenic detectors

## Germany:
- Max-Planck-Inst. Nucl. Phys., Heidelberg
- Technical University Munich
- Eberhard Karls University Tuebingen
- Max-Planck-Institute for Physics, Munich
- Institut Physik.Hochtechnologie IPHT, Jena
- Forschungszentrum Karlsruhe Institut für Kernphysik
- University Karlsruhe –Institut für exp. Kernphysik
- Max-Planck-Institute for Extraterrestrial Physics, Garching
- Technical University Darmstadt
- Frankfurt University

### Participating Institutions:
- **CRESST**
  - Low background
  - Cryogenic detectors

## United Kingdom:
- London Imperial College
- Oxford University - Department of Physics
- Rutherford-Appleton Laboratory - High Energy Physics
- Sheffield University - High Energy Physics, Sheffield
- Boulby Underground Laboratory, Boulby

### Participating Institutions:
- **ZEPLIN, DRIFT**
  - Low background
  - Liquid Xenon, gas

## Italy:
- Dipartimento di Fisica G. Occhialini dell'Università di Milano-Bicocca
- Laboratori Nazionale del Gran Sasso

## Spain:
- University of Zaragoza - Laboratory of Nuclear and High Energy Physics

## Switzerland:
- University Bern . Laboratory of High Energy Physics

### Participating Institutions:
- **CAST**
  - AXION Search

## Greece:
- Thessaloniki University

## Turkey:
- Bogazici University, Istanbul

### Participating Institutions:
- **High Purity Materials**
  - Low Background and Shielding

## Serbia:
- University of Novi Sad
Physics situation

• Three cryogenic experiments (CDMS, CRESST, EDELWEISS) have now the best sensitivity (factor 10 compared to other published results)
• Excellent background discrimination appears now mandatory for all future projects
• But we must progress by at least \( \approx \) two orders of magnitude to test more realistic models
• XMASS, XENON, ZEPLIN-n may become much stronger competitors in the future
Direct Dark Matter Search
Situation

CDMS presently best limit
European efforts very competitive

Background - Discrimination mandatory
for the future

increase sensitivity from
1/week/kg
to
few/year/100kg

very good background control

some 100kg of
low temperature detectors

⇒ EURECA, XENON,
⇒ SDMS, ZEPLIN, ...

Feb. 8th, 2005
Prague
N3 Dark Matter status report

• First N3 meeting: Paris, May 27th, 2004
• Second N3 meeting: Edinburgh, Sept. 10th, at IDM-2004
• Several recent working group meetings (Paris, Modane, AD: Prague…)
• Next N3 meeting: common N3/N6 meeting in Valencia (Spain) April 13-15, 2005
• Web site active
N3 Dark Matter status report

- Working groups in action
  (in close cooperation with JRAs and their Work Packages)
  - Muon/neutron background WG
  - Ultra-low radioactivity WG (cf. JRA1 + N2)
  - Cryogenic detector WG: EURECA Design Study proposal
  - Rare gas targets: ZEPLIN-Max Design Study proposal
  - Electronics: RTN network on cryo-electronics has been proposed to EU (H. Kraus (Oxford) coordinator)
The « 10 kg » stage(s)

- Most experiments (CRESST, EDELWEISS, ZEPLIN-II, ...) will devote a large fraction of their time during ILIAS to their « 10 kg » stages in the next few years
- But we should already look ahead and prepare for the next steps
- EURECA proposal, ZEPLIN-MAX proposal
Cryogenics WG

• Strong European groups: experience from CRESST and EDELWEISS physics groups, plus CERN and two leading nanofabrication facilities (IPhT Jena and LPN Alcatel)

• Challenges:
  - not so much the cryogenic setup required to cool down a few tons of materials at ≤ 10 mK
  - but interaction with cabling of a few thousand wires, ultra-low radioactivity, strategy for maintaining detector integrity, detector testing

• RTN network proposal on Cryo-Electronics
Cryo-electronics RTN

- SQUID-based channels: cost, size, multiplexing (?), adaptability to intermediate impedances
- GaAs electronics: promising for fast measurements, much lower dissipation, not adapted to slow signals
- Possibility to adapt VLSI-type readout to mK cryogenic setups?
- Cryogenic developments: automated dilution refrigerators without external fluids, thermal structure of tonne-scale setups
Detectors

• Optimal individual detector mass: cryogenic \( \approx 1 \) kg, liquid xenon 10-100 kg?

• Quality of rejection: active rejection of surface events, separation of nuclear recoils (O, Ca, W, Ge, Xe, radon products, ...)

• Optimize resolution (charge, light yield...)

• Reach a common standard of comparison for detector performances

• PCRD5 RTN network efficient place of exchange
Muon and neutron backgrounds

• V. Kudryavstev coordinating the WG
• Already several meetings (Paris, Garching, Edinburgh, Modane, Prague)
• Benchmarks in progress
• Compare MCNP, GEANT4, Fluka predictions
• Aim: define experimental strategy (KARMEN- or BOREXINO-like, ...) adapted to reach $10^{-9}$-$10^{-10}$ picobarn level
Ultra-low radioactivity

• How far do we need to go?
• Would we care about it if we had no problem with surface interactions?
• Surface contaminations (radon decay products!) may (will...) mimic WIMPs unless resolution and discrimination are excellent
• Relation with detector integrity
• Radon removal at $10^{-10}$ pb compatible level will be extremely challenging
• Input from JRA1/JRA2 essential (CUORE, GERDA...)
Problems to be solved

• Dispersion of efforts in Europe
  (≈ 20 experiments !)
• Common standards of performance have yet to be defined and accepted
• ApPEC Peer Review Committee role ?
• More focused DM effort in the US ?
  CDMS → SDMS, XENON, Majorana...
N3 main objective (reminder)

• reach a common strategy for Dark Matter direct detection
• reach convergence in the assessment of different detector concepts
• present dispersion of efforts in Europe: 20 direct detection experiments!
• many ideas, but effectiveness questionable
Simple example: liquid Xe quenching factor

- XENON precision determination of quenching factor ≈0.16
- DAMA quenching factor 0.44 and 0.63
- DAMA energy threshold 30 keV becomes 90 keV
- DAMA-Xe sensitivity overestimated by factor > 100

Aprile et al., in preparation
“DAMA energy resolution at low energies is better than the resolution measured for much smaller crystals and better than poissonian limit with a light yield of 10 photoelectrons per keV” (UKDMC, Robinson et al. 2002)

Note: DAMA measures ≤ 6 photoelectrons/keV (visible energy)
ZEPLIN-I: light time constants

Ionisation

Electron/nuclear recoil

Excitation

\( \text{Xe}^* \)

\( \text{Xe}_2^* \)

\( +\text{Xe} \)

\( +\text{e}^- \) (recombination)

\( \text{Xe}^* + \text{Xe} \)

175nm

175nm

Triplet 27ns

Singlet 3ns

Feb. 8th, 2005

Prague ILIAS Annual Meeting
Cryogenic Detectors

Neutrons from external source

Photons from external source

light – phonon charge – phonon

CDMS, CRESST, EDELWEISS

Feb. 8th, 2005

Praue ILIAS Annual Meetina
ZEPLIN-I neutron calibration

- Sensitivity claimed by ZEPLIN: $10^{-6}$ picobarn at $M_W = 60$ GeV requires very large background subtraction: > 99.9 %
- In presence of a neutron source, only a few low-energy nuclear recoils are observed, in strong contrast with expectations
- Instead “ambient neutrons” (when neutron source is removed) are used as calibration
- No demonstration that “ambient neutrons” are indeed neutrons
- Conservative ZEPLIN-I sensitivity: $10^{-3}$ picobarn, not $10^{-6}$ picobarn

Limit at SUF 2002 (during CDMS II)
World-best limit today
CDMS II goal 2006
SDMS Phase A with 5 kg of Ge 2008
SDMS Phase B with 25 kg of Ge 2011
SDMS Phase C with 1000 kg of Ge 2018
http://ilias-darkmatter.uni-tuebingen.de

N3/DMD
Direct Dark Matter Detection

ABOUT N3/DMD

The strong evidence for the existence of Dark Matter stands in contrast to the absence of knowledge about what this Dark Matter is. The case for non-baryonic dark matter has become compelling over the last few years. After the recent measurements of the Cosmological Microwave Background, the precision on the universal density is now a few percent and the error on Ω is approx. 3.02 ± 0.02. On the other hand, the recent appearance in the cosmological landscape of a non-zero cosmological constant or some other “quintessential” component has brought some uneasiness to an emerging concordance model: our Universe appears to be a strange mixture of approx. 70% of some cosmological repulsive component, approx. 30% of matter, with only a few percent of ordinary (baryonic) matter. 95% of the universe content is of unknown nature.

The density of ordinary matter, ρ_{baryon}, is impressively constrained by primordial nucleosynthesis and CMB constraints to be approx. 4.5%, implying that matter is composed at nearly 86% of an unknown weakly-interacting component.

Feb. 8th, 2005
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Background Simulations, Neutron-Shield and Muon-Vetoes

1. Introduction

The sensitivity of current and future dark matter detectors to WIMP-nucleus interactions depends crucially on their ability to suppress and reject all types of background. Some of these backgrounds, e.g., gammas, betas and parity alphas, can be rejected using energy deposition, event localization and intrinsic properties of the detector material. In determining electronic and nuclear-like events, in particular low-energy single nuclear recoils, being indistinguishable from those expected from WIMP-nucleus interactions, are the most important background, which remains after all other types of events are rejected by offline analysis.

The aim of this working group is to assess various backgrounds in detectors based on different technologies, and formulate requirements for passive shielding and active veto systems to reduce these backgrounds, thus helping to achieve sensitivity and to design future dark matter detectors.

2. Sources of background

We can consider three main sources of background:

- external neutron and gamma background arising from U/Th/K: traces in the rock surrounding dark matter detectors;
- internal background of neutrinos, gammas, betas and alphas from radioactive contamination of detector components and shielding;
- external and internal background from neutrons produced by cosmic-ray muons and their secondaries in the rock, shielding and detector components.

Some special cases of external and internal backgrounds should also be mentioned which are also common to practically all experiments:

- gamma, alpha and neutron backgrounds from radon, accumulated in air and detector components;
- background arising from surface contamination of the target materials and detector vessels;
- activation of detector components by cosmic rays at the surface.

The backgrounds have to be simulated with Monte Carlo codes and the rates of events in various detectors due to these backgrounds have to be calculated.

3. Plan of work

Extensive studies of various types of background for dark matter experiments have been started as parts of the national programme. The objectives of this working group are:

- To coordinate the efforts of several groups from different institutions in studying the background for dark matter experiments.
http://ilias-darkmatter.uni-tuebingen.de

Figure 1. Neutron energy spectra from rock activity behind shielding: thick red curve - spectrum at the rock/shaven boundary; thin red curve - spectrum after 30 cm of light clay, dark blue and green curves - spectra after 20, 30 and 40 g/cm² of hydrocarbon shielding.

Figure 2. Energy spectra of muon-induced neutrons at the rock/shaven boundary (red filled circles) and after the lead (20 cm) and hydrocarbon (40 g/cm²) shielding (blue open circles) from Carson et al. (Antarctic).
Addit. transparencies
N3 objectives ($f f$)

- discussion on problems common to all detector concepts
  - ultra low radioactivity issues
  - muon and neutron background
  - underground site issues
  - theoretical issues
N3 objectives (f f)

- relevance of the present and future direct and indirect dark matter searches for supersymmetry
- investigate how data from direct dark matter detection can provide information for other projects
- N3/N6 common meeting: Valencia 13-14 (or 15 ?) April 2005