Dark Matter Search With The PICASSO Experiment

New Limit and Plans for the Next Phase

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On behalf of the PICASSO Collaboration

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PICASSO

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Project In Canada to Search for Supersymmetric Objects.
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- Measuring nuclear recoils of spin-dependent interactions with Dark Matter.
- Results from last years data taking
- Plans for next phase
- Forming of an international collaboration
Collaboration

- Indiana University at South Bend
  I. Levine, W. Feighery, J. Nuerenberg, E. Behnke, C. Muthusi

- Prague Technical University
  S. Pospisil, I. Stekl, J. Sodomka, J. Bocan

- Queen’s University (Kingston)

- Universite de Montreal

- University of Pisa
  S. Shore

- Yale University
  F. d’Errico

- Universita di Lisboa

- Paris VI, VII
  G. Waysand, D. Limagne
Dark Matter

- Strongest bounds on Dark Matter properties currently from cosmology
- Supersymmetric models by and large predict the existence of a stable heavy particle.
- This particle (if abundant) can be associated with the dark matter required by recent cosmological models.
- **PICASSO** trying to find **Cold Dark Matter** (CDM)
Cosmological Evidence for CDM

- WMAP - satellite image of the cosmic microwave background
Cosmological Evidence for CDM

- WMAP
- Supernova relics intensity data
- Visible mass distribution and gravitational profile of spiral galaxies
Nuclear Recoil

- Whatever SUSY model the WIMP is made according to - it is only interacting weakly.
- Observation is only possible in nuclear recoils.
- Nuclear recoils are heavily ionizing particles that travel very short distances
Superheated Droplet Detection

- Following the principle of the bubble chamber with a superheated liquid as active mass.
- Suspending 10-100μm superheated droplets in a matrix of gel.
- Has been in use commercially as neutron detector for many years (BTI, Chalk River, Ontario)
- Threshold detectors that are insensitive to MIPS and gamma radiation under normal WIMP -detection operation conditions.
- Only nuclear fissions, alpha particles and nuclear recoils from fast neutrons have enough stopping power to be detected.
Active Mass is $C_4F_{10}$

One detector (1l volume) carries $\approx 7.5g$ of active mass

The Fluorine nucleus interacts with the spin of the WIMP - PICASSO is therefore sensitive to spin carrying Dark Matter particles

Operation between $15^\circ$ and $50^\circ$C
Acoustic Sensing of Radiation

- Expanding bubbles create shockwave that is picked up by acoustic detectors
- Waveforms of 4096 samples within 4ms are recorded
Waveform is split and Fourier transforms of sub-samples are calculated.

Characteristic time-frequency patterns identify bubble events over acoustic noise.
Setup at SNO

- 6 1l detectors were operated in a corner of the SNO facility in the Creighton Mine, Sudbury Ontario.
- Data taken remotely without shift crew in Sudbury.
- The muon flux at this facility is less than $0.27 \mu/m^2/day$
  → Unprecedented low background from cosmic radiation.
Data Sample

- Data is taken in $\approx 30\text{h}$ runs - each followed by a recompression period.
- 79 runs at temperatures between 20-47°C.
- Data taken between April and August 2004
- A total of 1.98kgd of data were analyzed.
Interpretation of Data

- Alpha spectrum of $^{128}\text{U}$ and $^{142}\text{Am}$ doped detectors.
- Both alpha spectrum and detector response understood well.
Three detectors have significantly lower internal activity and therefore dominate in the determination of the exclusion limits.

Combined alpha and WIMP response curves are fit to these spectra.
Results
\[ \sigma_p = 1.31 \text{pb and } \sigma_n = 21.5 \text{pb for a WIMP mass of 29 GeV.} \]
Effective coupling strength $a_n$ for neutrons and $a_p$ for protons for a WIMP mass of 50GeV.
Next phase with a total active mass of 2kg Fluorine.
Final phase of planning and testing is going on right now.
Production of major components has started or is about to start.
Setup with 32 Detectors

- 8 Groups of four to be installed this year at the location that we were kindly given by the SNO collaboration for the previous data taking.
- First detector modules have been build.
- Data taking is scheduled to start this summer.
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New Detectors

- 4.5l Acrylic and stainless steel containers.
- A higher loading than in previous detectors seems feasible with a new fabrication technique.
- Each to be loaded with 33.5-66 g active mass.
- Bubble size to be uniformly distributed around 80μm.
- Improved design based on previous experience.
Challenges

- The new detectors will not only be larger in size, there will also be improvements in
  - Radio-purity
  - Mechanical Design
  - Piezo mounting and response
  - Readout
  - Temperature control (more accurate definition of threshold)
- Subject of a separate talk by Ubi Wichoski
- Position reconstruction of expanding bubble will be used to identify hotspots and external backgrounds.
Plan

- Install **PICASSO** 32 in 2005
- Take data in 2006 to be ready for publication by the end of 2006.
- Limit will be in the order of 0.11pb.
Plans for SNOLAB Experiment

- 100kg active mass detector to be ready by 2007.
- The PICASSO 32 phase will show by the end of this year if this is feasible
- Phased approach by first developing 30kg detector system and deploying it underground
- To be located in → SNOLAB .
- within 6 month of data-taking 14,000kgd of exposure can be accumulated
  → This will be equivalent to a limit of $6 \times 10^{-5}$ pb in cross section.
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Summary

- PICASSO now has competitive sensitivity in the spin-dependent sector (hep-ex 0502028).
- The next phase of the experiment is set to increase the active mass at least 50-fold with respect to the presented data.
- This setup will push the exclusion limits for the spin dependent interaction to new levels.
- There are collaborators from 6 countries planning to take part in the PICASSO 32 experiment or the large scale PICASSO scheduled to start operation in SNOLAB 2007.