Dark Matter Search With The PICASSO Experiment

New Limit and Plans for the Next Phase

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Queen's University
On behalf of the PICASSO Collaboration

CAP Meeting Vancouver, June 8 2005

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)

  A. J. Noble, C. B. Krauss, X. X. Dai, K. Clark, C. Storey, C. Hearns
- Universite de Montreal

  V. Zacek, L. Lessard, C. Leroy, G. Azuelos, J.-P. Martin, U. Wichoski, P. Doane, R. Gornea, M. Bernabe-Heider, M. H. Genest, R. Guenette, F. Aubin, Y. Landry, N. Starinski, G. Richard
- University of Pisa

  S. Shore
- Yale University

  F. d’Errico
- Universita di Lisboa

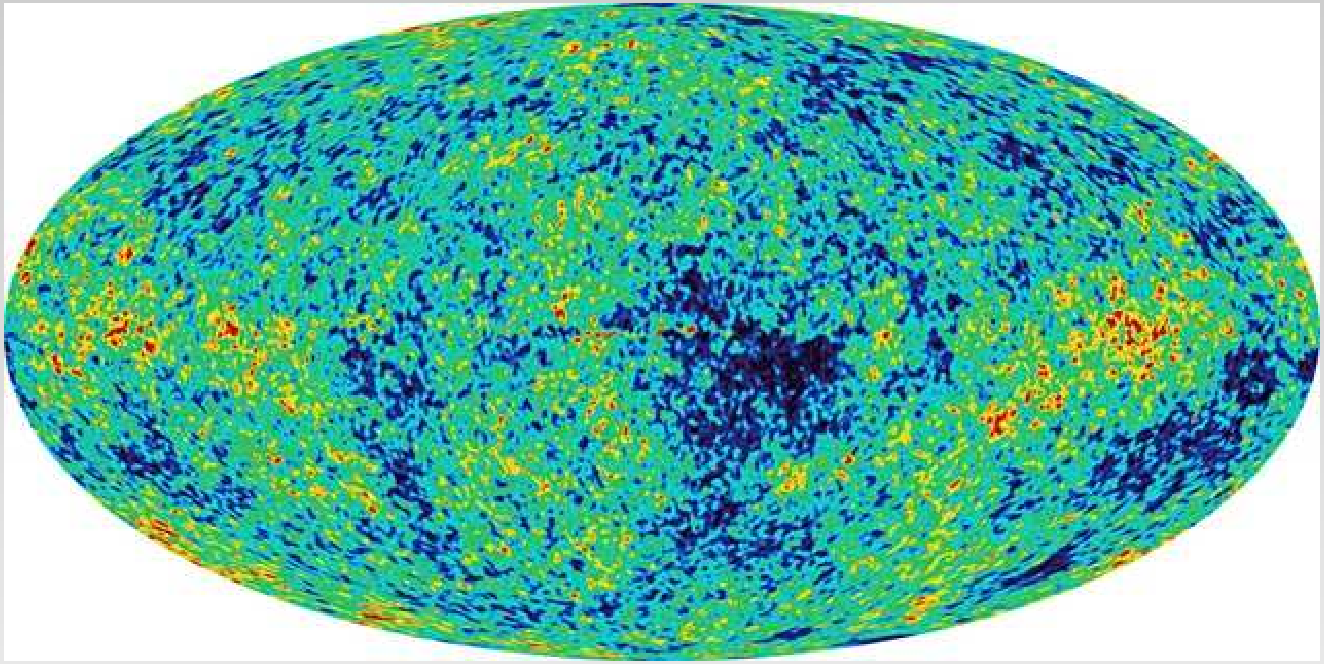
  T. Girard, F. Giuliani, T. Morlat, J. G. Marques, A. Fernandes, R. Martins, M. Da Costa
- Paris VI, VII

  G. Waysand, D. Limagne

Dark Matter

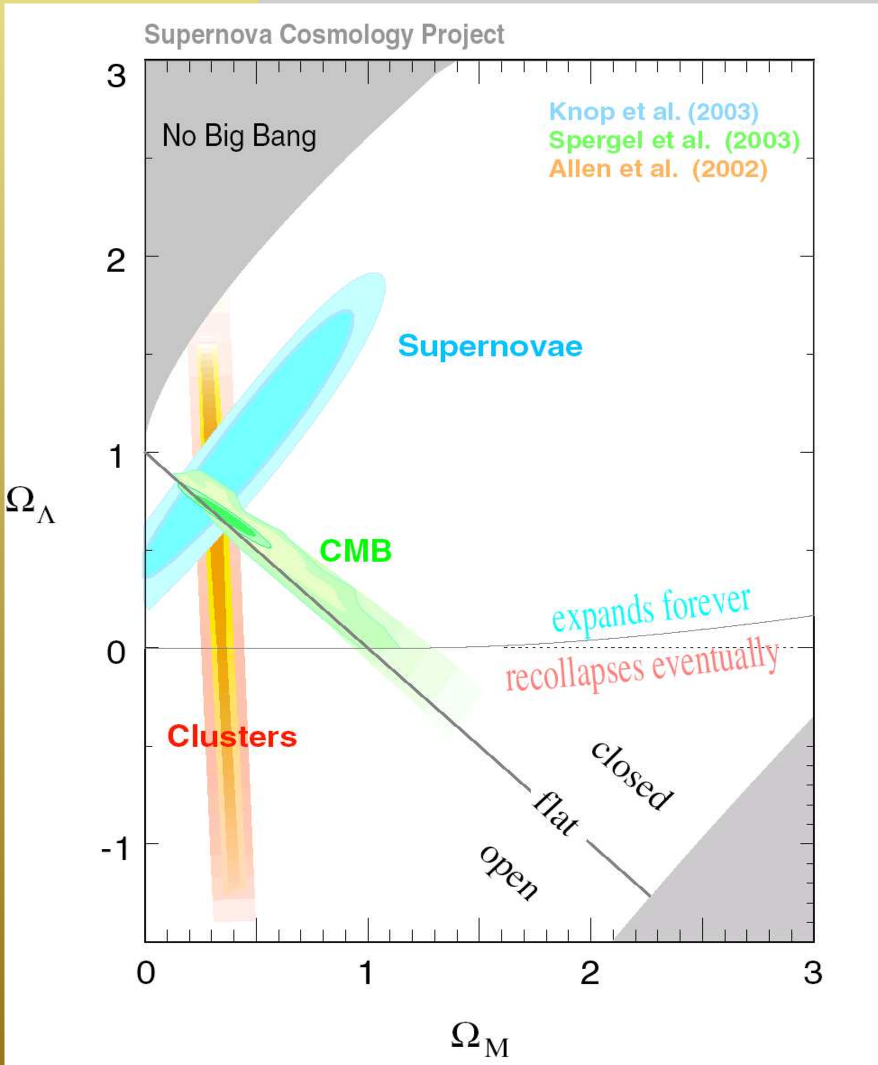
- Strongest bounds on Dark Matter properties currently from cosmology
- Supersymmetric models by and large predict the existence of a stable heavy particle.
- This particle (if abundant) can be associated with the dark matter required by recent cosmological models.
- PICASSO trying to find Cold Dark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

Cosmological Evidence for CDM



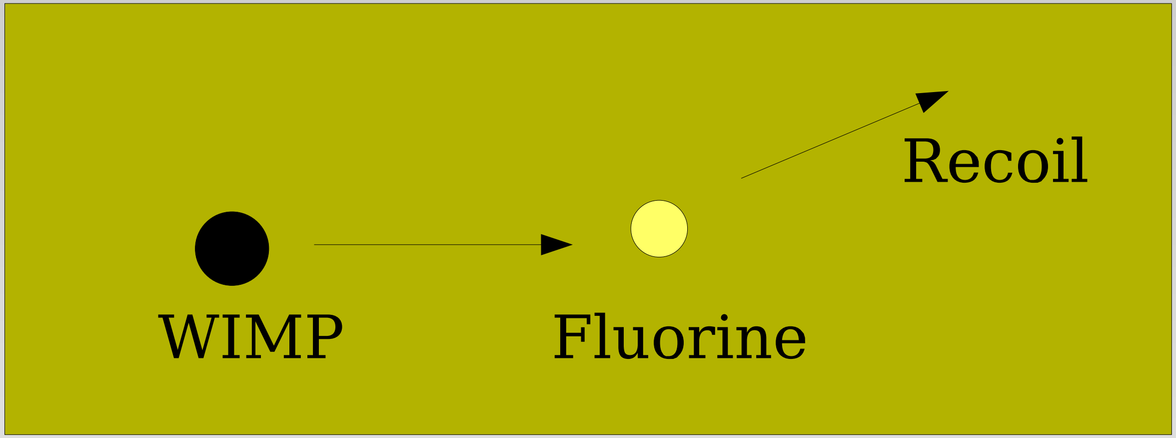
- WMAP - satellite image of the cosmic microwave background

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

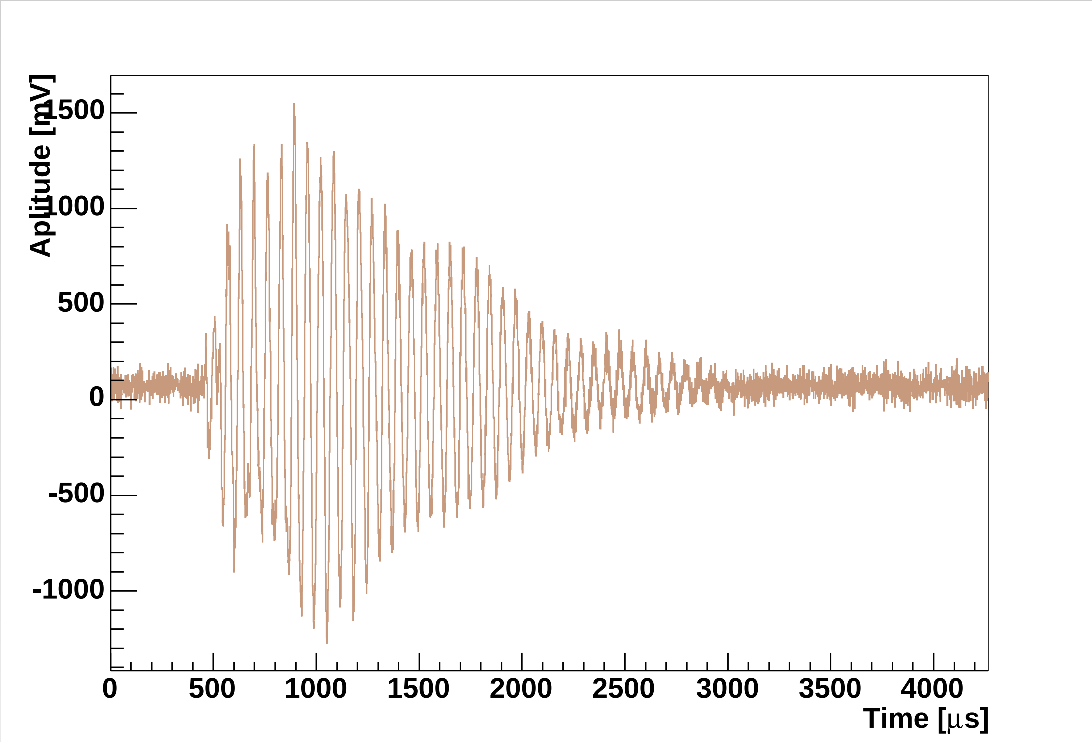
Superheated Droplet Detection

- 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.

PICASSO SDD

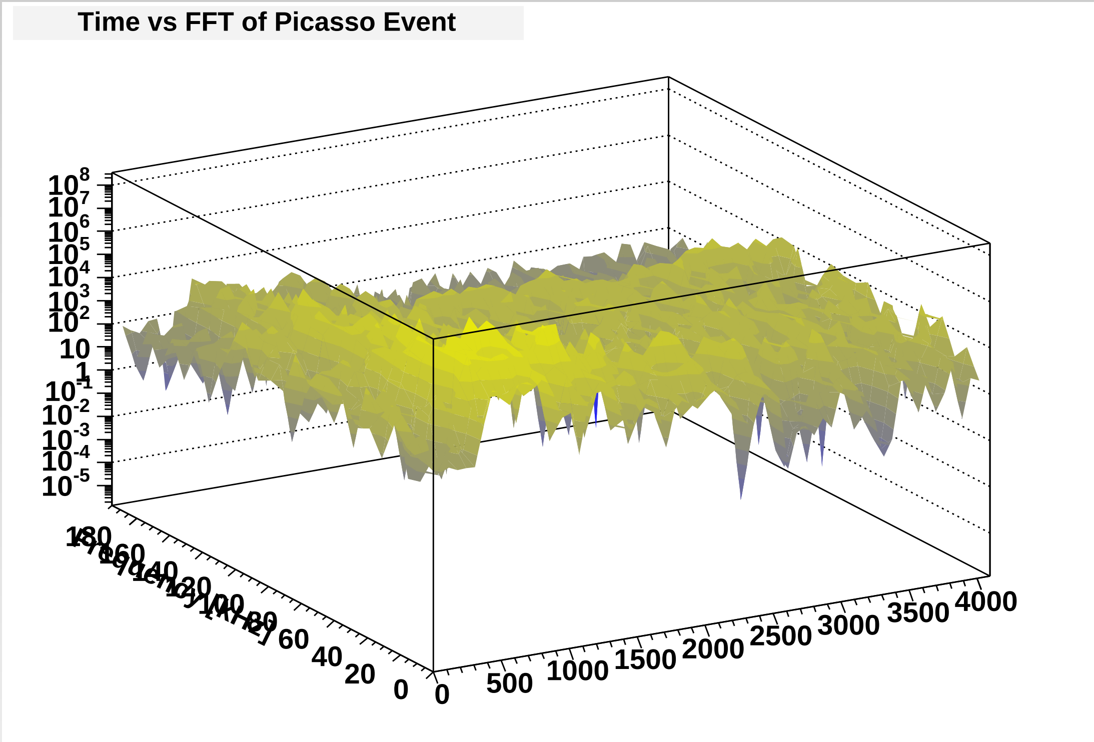
- Active Mass is C_4F_{10}
- One detector (1l volume) carries $\approx$ 7.5g of active mass
- The Fluorine nucleus interacts with the spin of the WIMP - PICASSO is therefore sensitive to spin carrying Dark Matter particles
- Operation between 15° and 50°C

Acoustic Sensing of Radiation



- Expanding bubbles create shockwave that is picked up by acoustic detectors
- Waveforms of 4096 samples within 4ms are recorded

Bubble Filtering



- Waveform is split and Fourier transforms of sub-samples are calculated.
- Characteristic time-frequency patterns identify bubble events over acoustic noise.

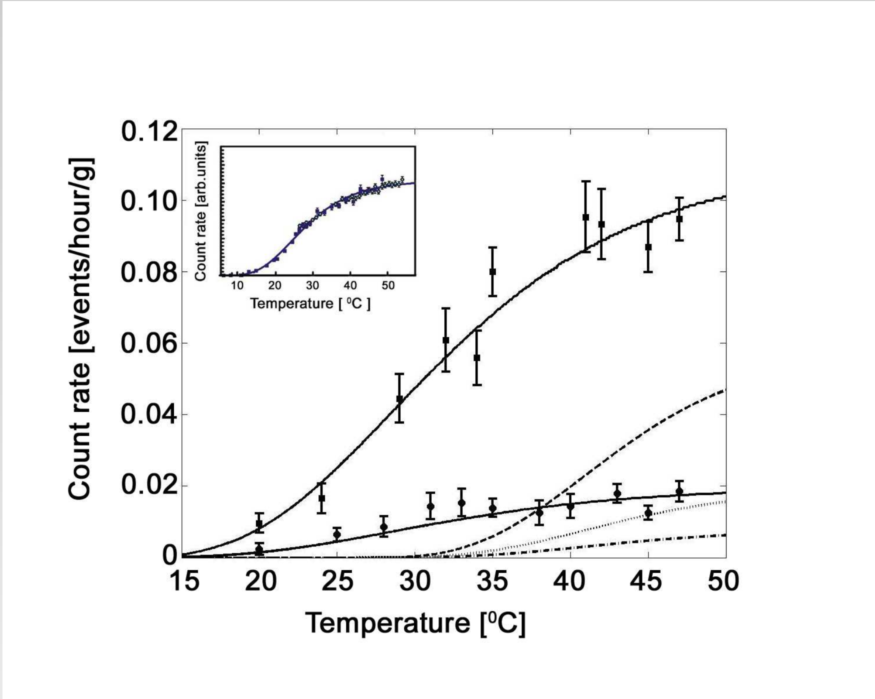
Setup at SNO

- 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 $0.27\mu/\mathrm{m}^2/\mathrm{day}$
  $\rightarrow$ Unprecedented low background from cosmic radiation

Data Sample

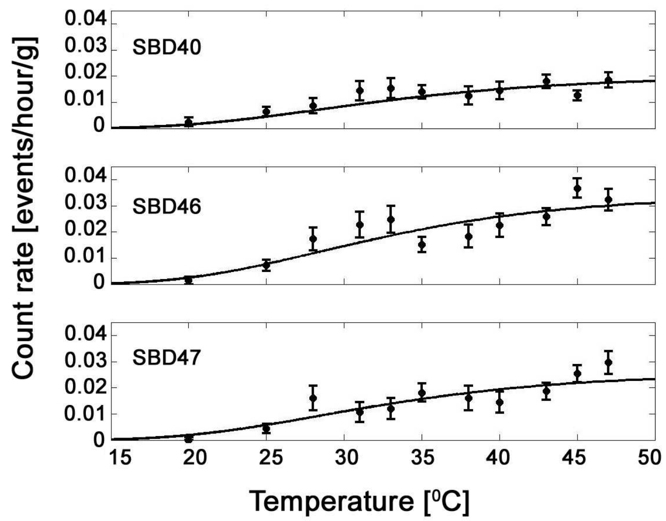
- Data is taken in $\approx$ 30h runs - each followed by a recompression period.
- 79 runs at temperatures between 20-47°C.
- Data taken between April and August 2004
- A total of 1.98kgd of data were analyzed.

Interpretation of Data



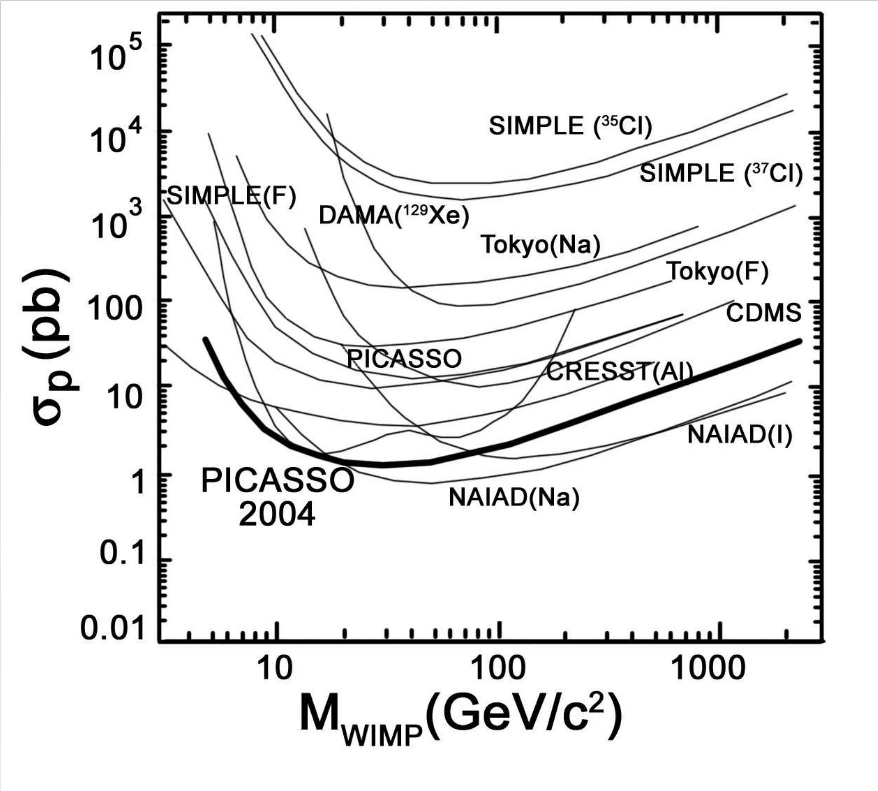
- Alpha spectrum of ^{128}U and ^{142}Am doped detectors.
- Both alpha spectrum and detector response understood well.

Detector Data



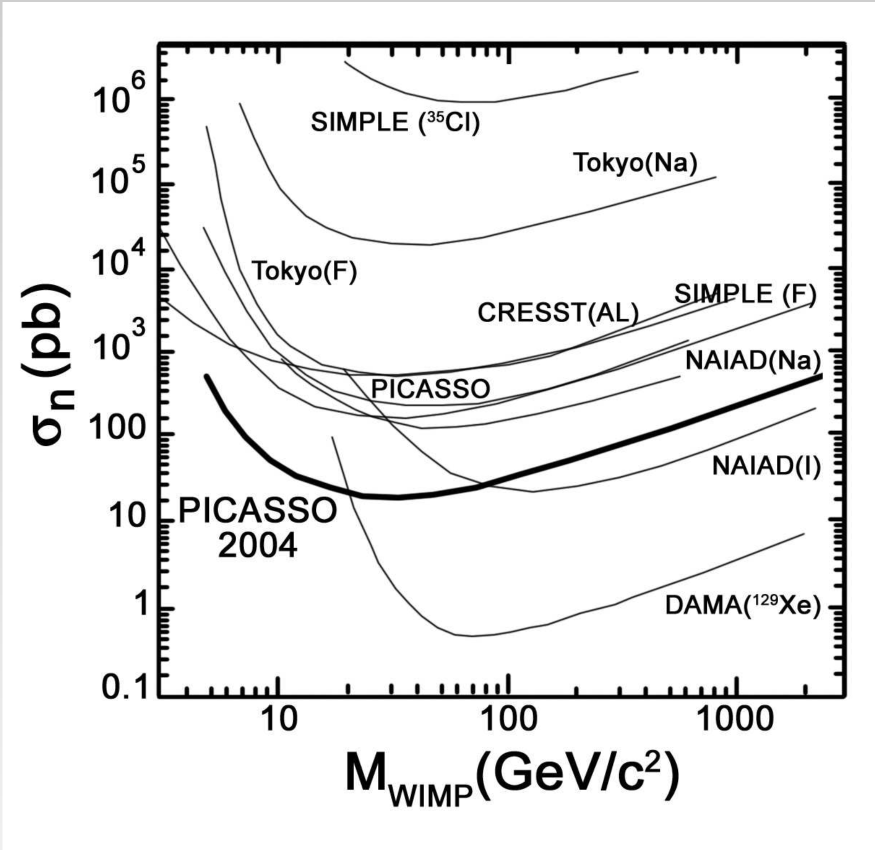
- Three detectors have significantly lower internal activity and therefore dominate in the determination of the exclusion limits.
- Combined alpha and WIMP response curves are fit to these spectra.

Results



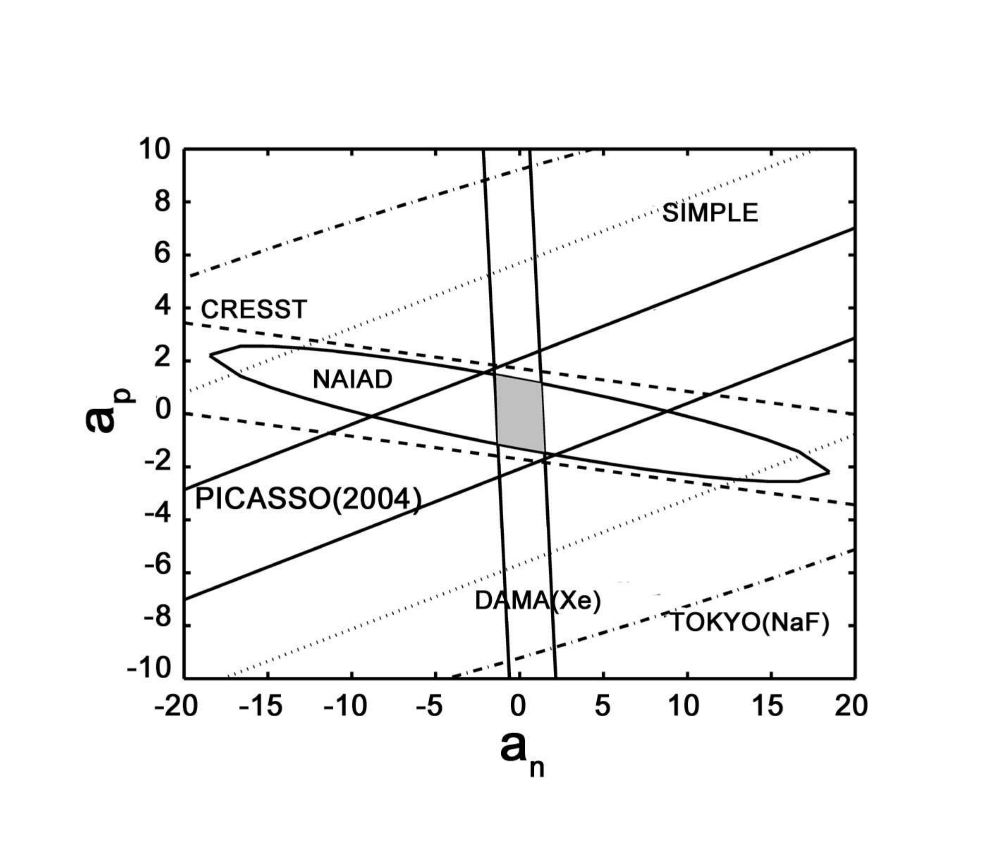
SIMPLE (^{35}Cl)
SIMPLE (^{37}Cl)
SIMPLE(F)
DAMA(^{129}Xe)
Tokyo(Na)
Tokyo(F)
CDMS
PICASSO
CRESST(Al)
NAIAD(I)
PICASSO 2004
NAIAD(Na)
σ_p (pb)
M_{WIMP}(GeV/c^2)

Results



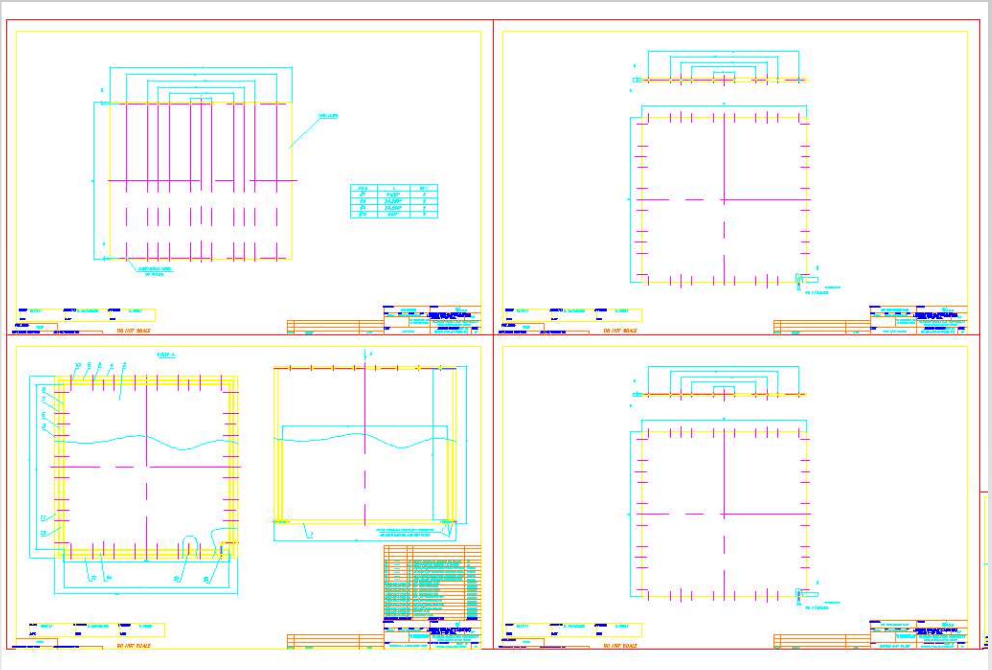
- $\sigma_p = 1.31$pb and $\sigma_n = 21.5$pb for a WIMP mass of 29 GeV.

Results



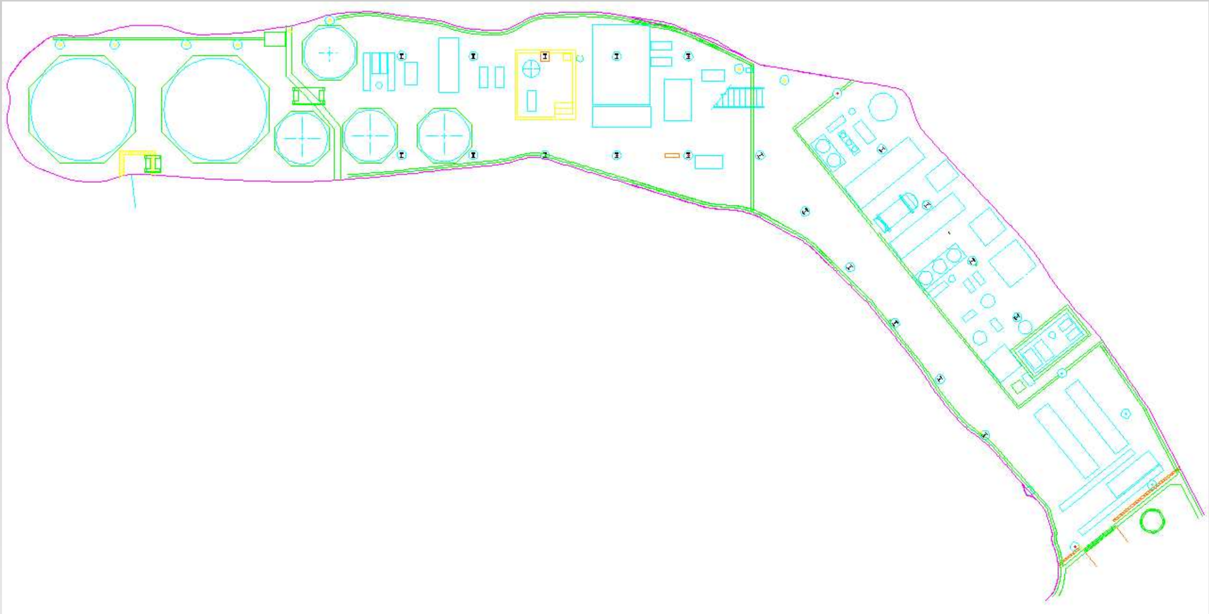
- Effective coupling strength a_n for neutrons and a_p for protons for a WIMP mass of 50GeV.

PICASSO 32



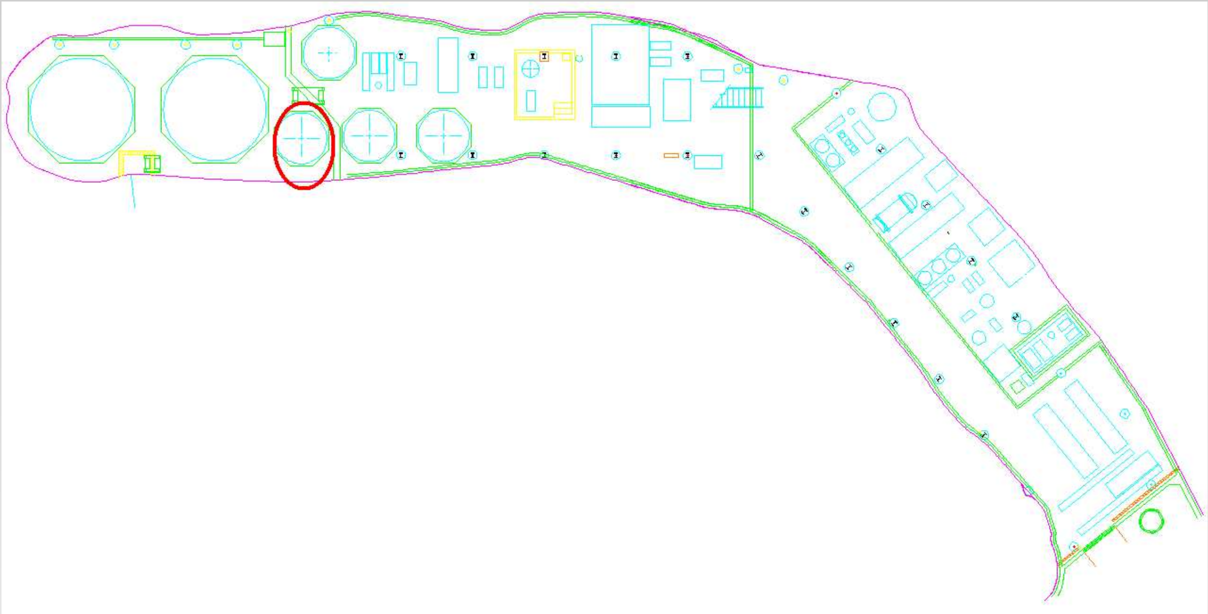
- Next phase with a total active mass of 2kg Fluorine.
- Final phase of planning and testing is going on right now.
- Production of major components has started or is about to start.

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.

Setup with 32 Detectors



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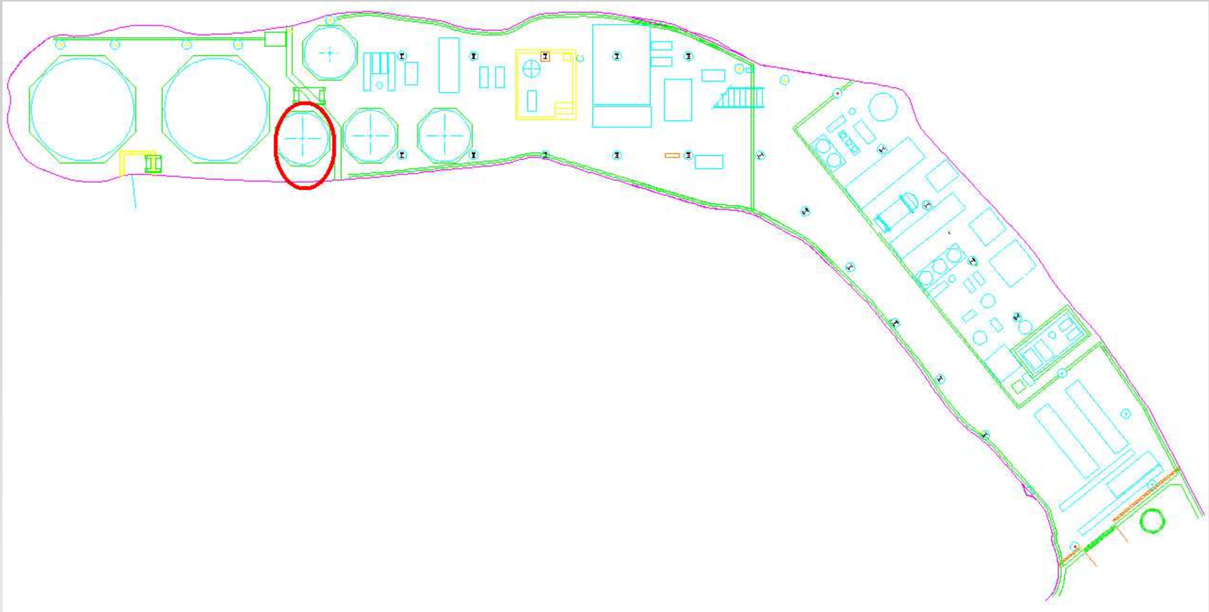

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New Detectors

- 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 $\rightarrow$ SNOLAB .
- within 6 month of data-taking 14,000kgd of exposure can be accumulated
  $\rightarrow$ This will be equivalent to a limit of 6×10^{-5}pb in cross section.

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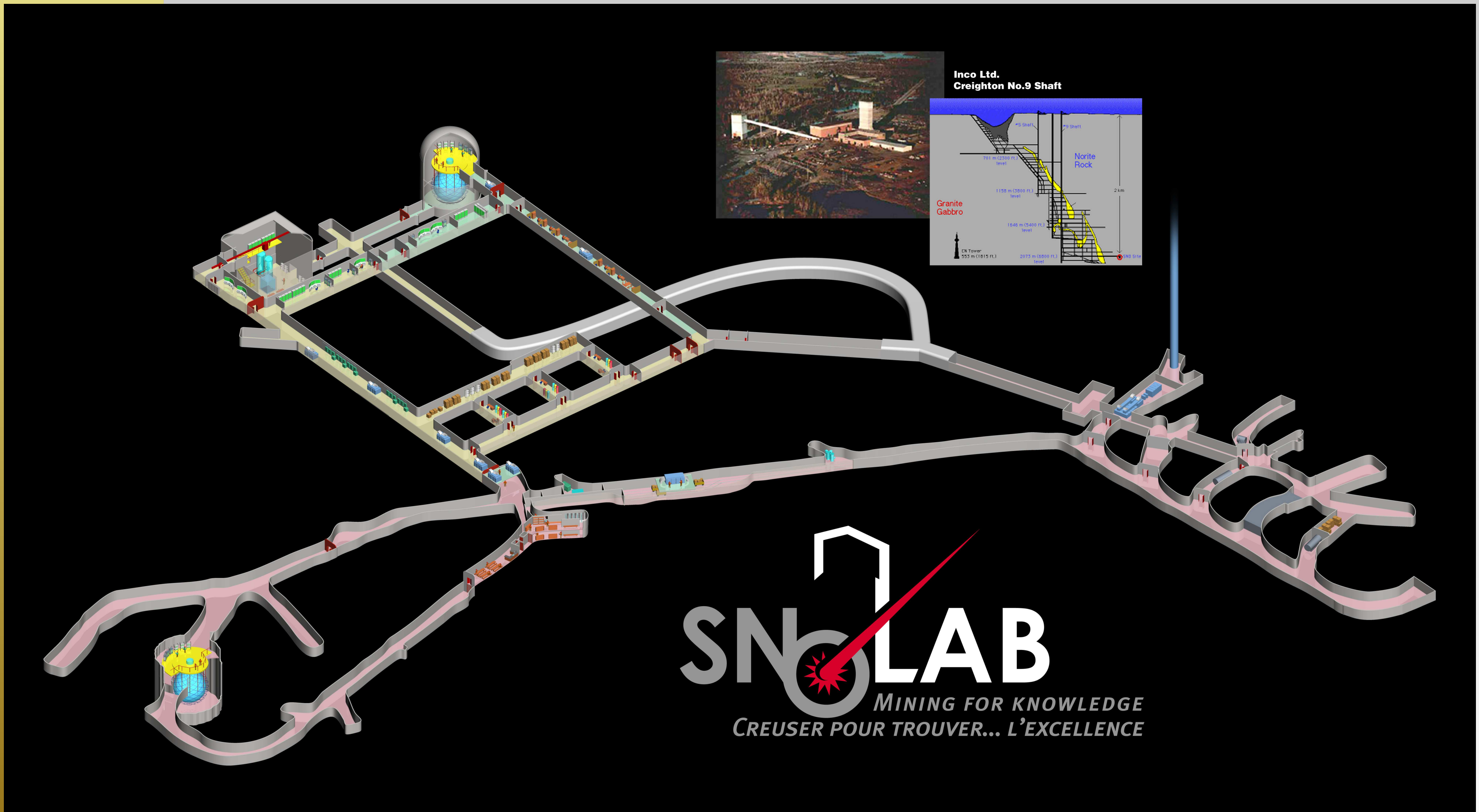

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Summary

- 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.