SuperCDMS-SNOLAB: an active neutron veto shield design

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SuperCDMS collaboration

SuperCDMS

Dark Matter Search

Goal: direct detection of WIMP elastic scattering off nuclei few WIMPS/year/ton

Signature: nuclear recoil with E<100 KeV

Shielding (Pb, polyethylene, Cu)

Reduce backgrounds from radioactivity

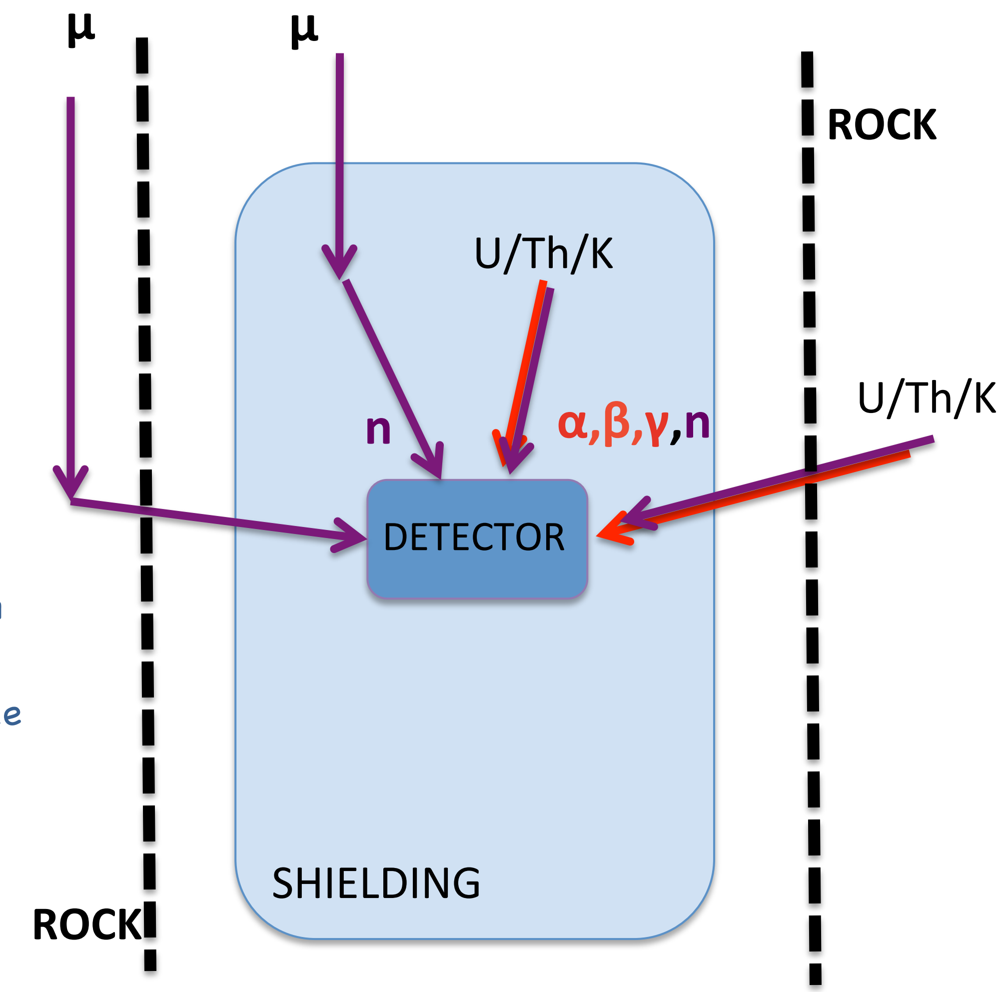
Active Background Rejection

Distinguish between nuclear recoils (WIMPS, neutrons) and electron recoils (backgrounds) -> by recording both ionization and heat (phonon) signals

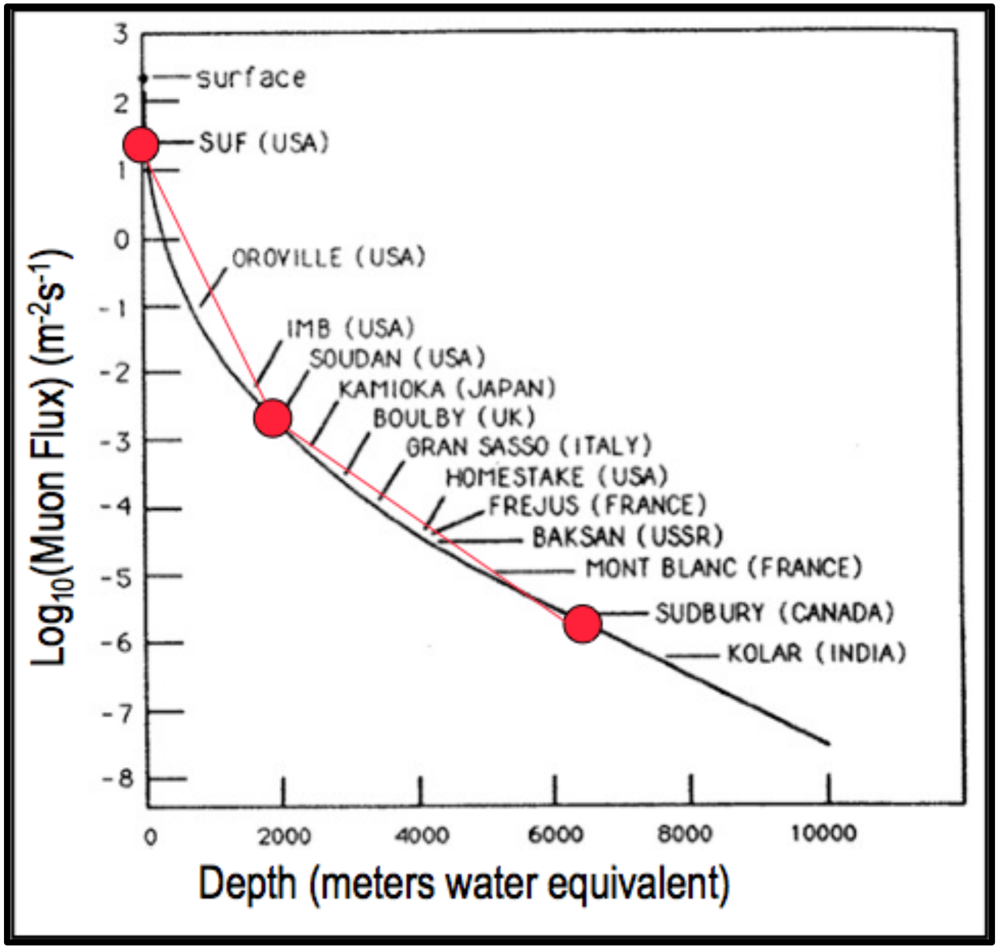
Surface events tag -> interdigitized electrode scheme – phonon sensor

Deep Underground (SNOLAB)

Fewer cosmic rays to produce neutrons
Neutrons produce nuclear recoils



Depth is Important !



SUF

17 mwe

0.5 n/d/kg

(182.5 n/y/kg)

Soudan

2090 mwe

0.05 n/y/kg

SNOLab

6060 mwe

0.2 n/y/ton

(0.0002 n/y/kg)

Moving from Soudan to SNOLab:

Reduce muon flux by **500x**

Reduce high-energy neutron flux by **100x**

Worry about neutrons from **residual radioactivity only**

Which Neutrons?

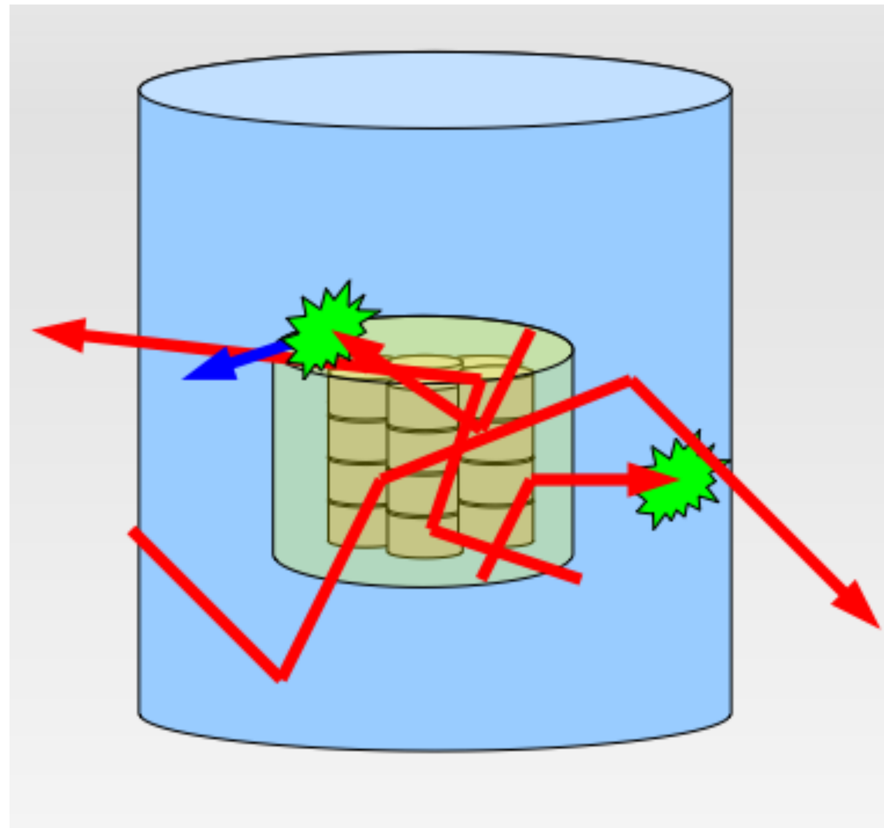
- ***Cosmogenic*** muon-induced: expect <0.1 in 100kg- years @SNOLab
- ***External radiogenics*** (Fission and (α, n) from U,Th in cavern rock): expected to be negligible with passive shielding
- ***Internal radiogenics*** (Fission and (α, n) from U,Th in Cu cans and supports): expect order of 1 in 100 kg - depending on screening and material cleanliness

Active Neutron Veto

- Identification background events especially neutrons that can produce nuclear recoils similar to WIMPS.
- The veto will indirectly act as a diagnostic device.

Neutron veto - how to

- n capture in the veto
- fast scatters in the veto
- gamma from captures outside the veto



WIMP search strategy

Any WIMP candidate in coincidence with a veto energy deposited of the n-capture process will be rejected

Physics Requirements

- Total unvetoed background in Ge <<1 counts in 100kg SNOlab phase

- Total background rate (neutron & gamma) must be the same: neutron veto must not generate excessive backgrounds in the zips

  -> Implies radioclean construction

- Negligible contribution to dead-time
  -> Implies low (<kHz) non-coincident trigger rate

- High (~90% or better) efficiency

(a modest efficiency of ~80% would reduce neutron background to <1 event)

Neutron Flux Monitor

Additional requirement:

good ability to discriminate neutrons from the gamma background

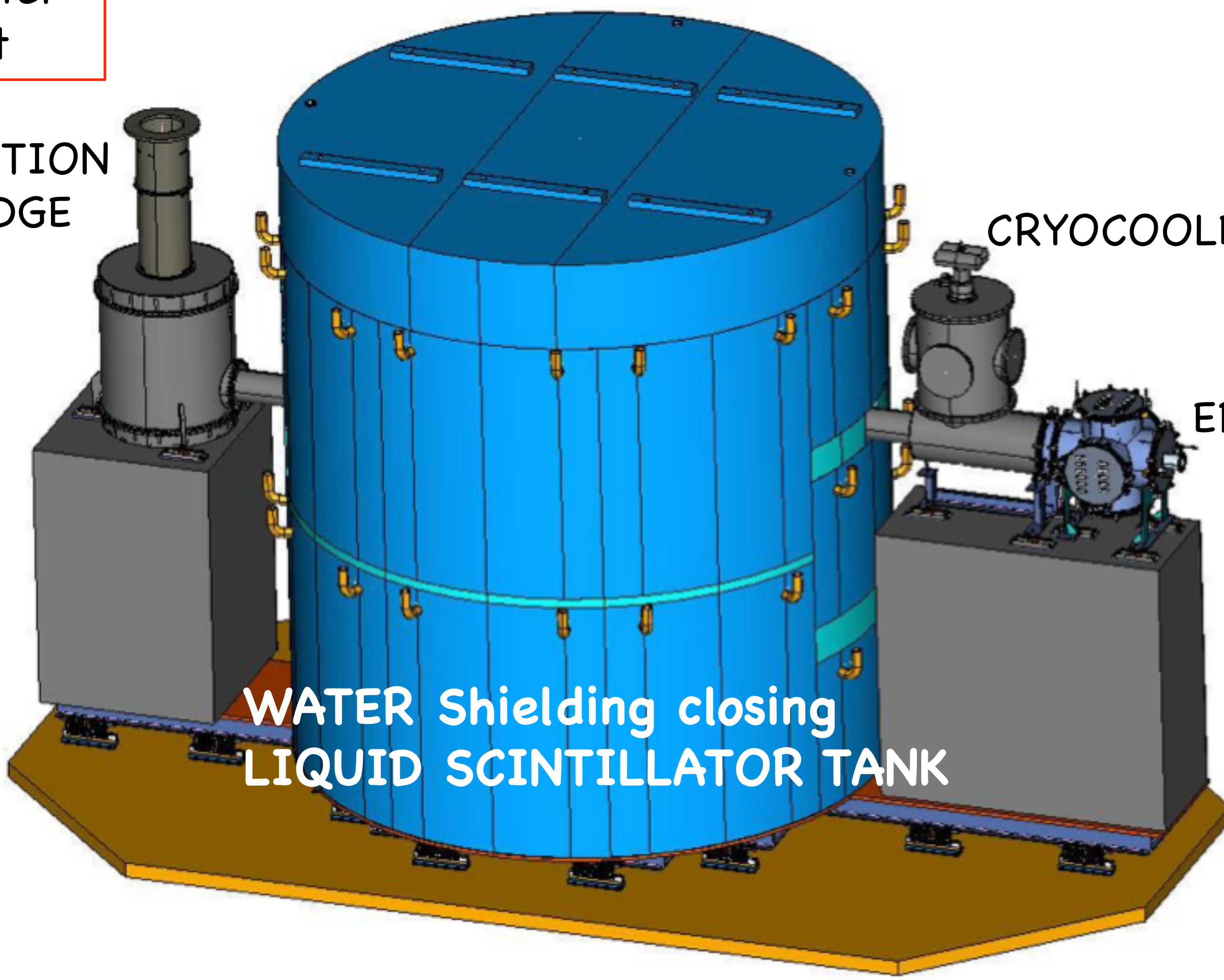
- *In situ* measurement of radiogenic neutron rates – better precision than the multiple scattering measurement

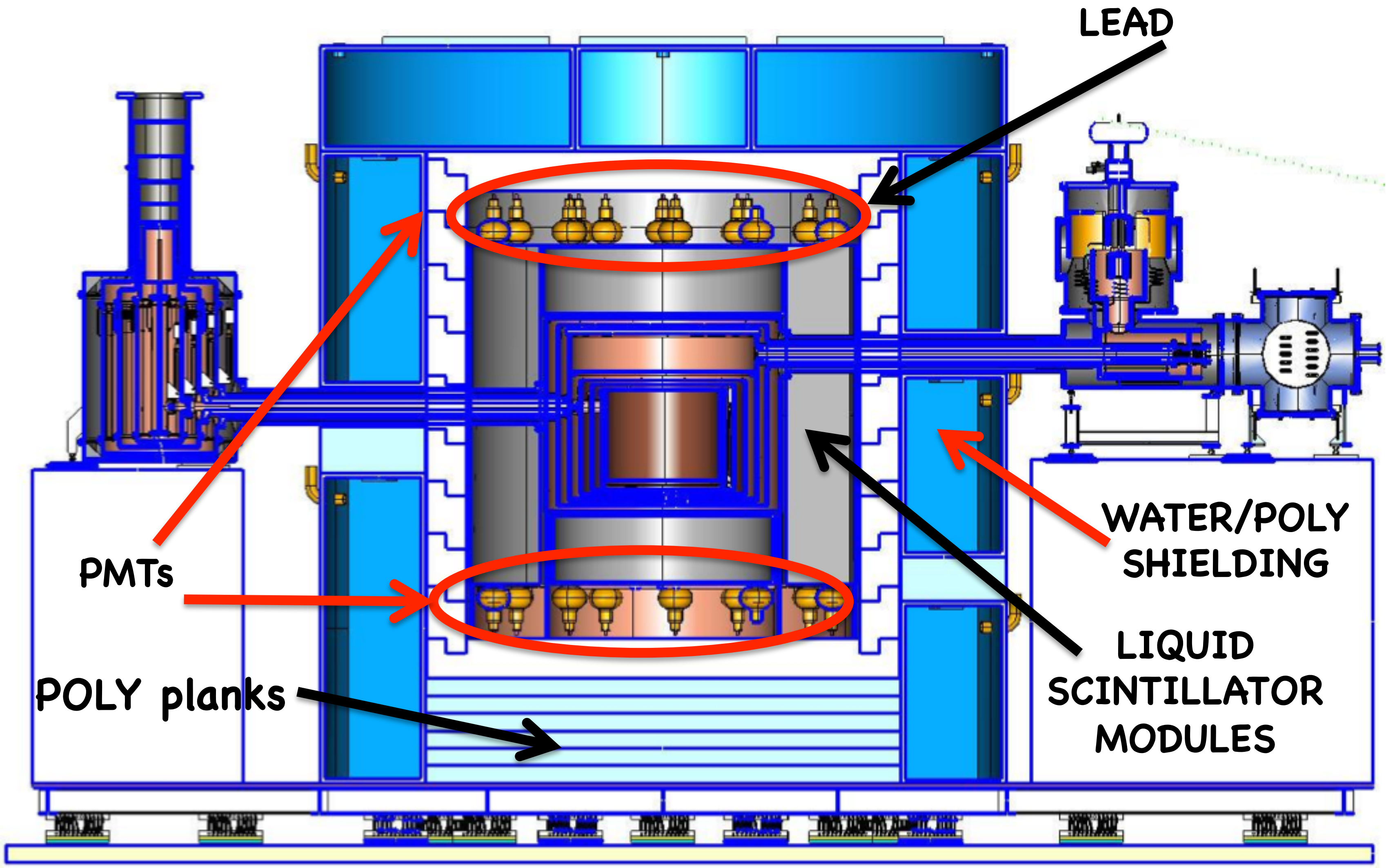
- Evaluation of Monte Carlo systematics

- Monitoring/tuning of Ge nuclear recoil acceptance using tagged neutrons

Current Design

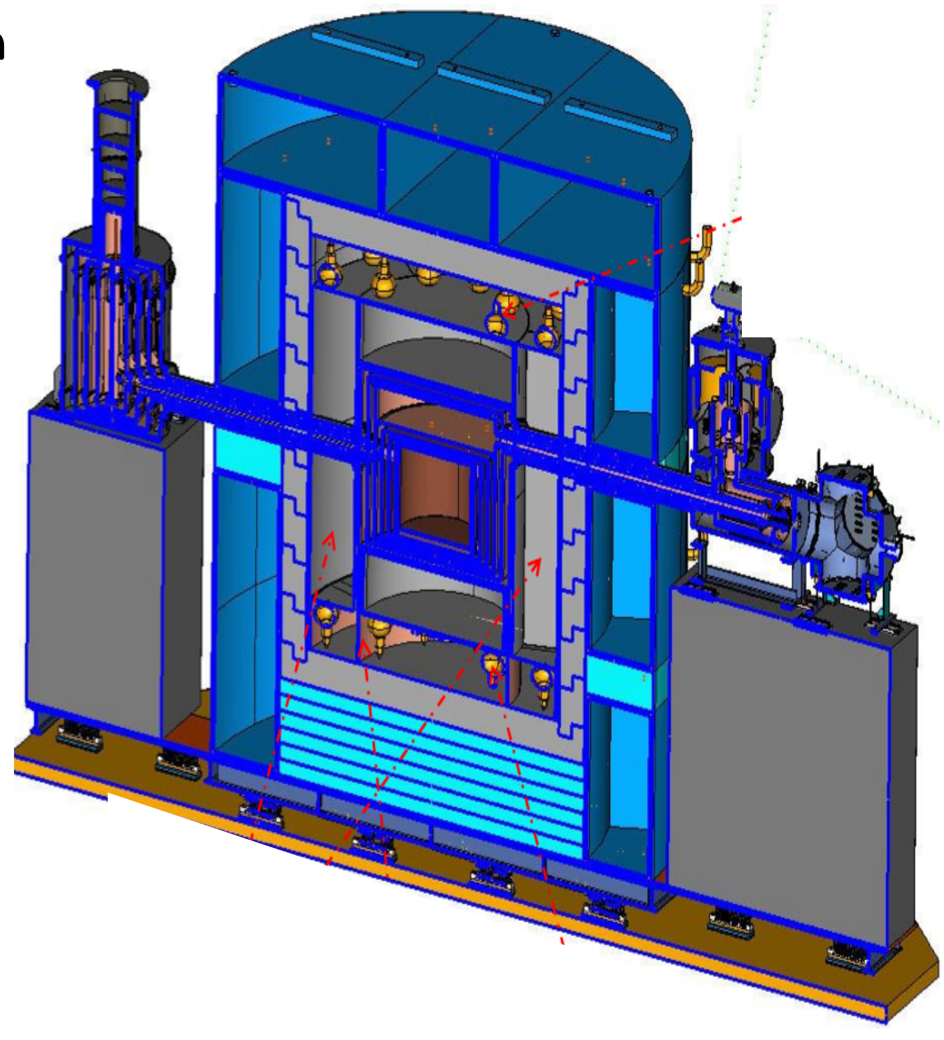
Dimensions:
13 feet diameter
14 feet height




LEAD
PMTs
WATER/POLY
SHIELDING
POLY planks
LIQUID
SCINTILLATOR
MODULES

Neutron veto modules filled with Linear Alkylbenzene (LAB), read out by PMTs

Doped with high cross-section isotopes (B, Gd, Li)
- decreases capture time/distance (ex. 5% Boron doping reduces capture time from 250 μs to 3μs)
- affects design due to need to contain+detect capture products



LAB Doping

Boron

-> ALPHA (~3 MeV) + GAMMA (500keV)

-> observed light may be as low as 50keVee

Challenges:

- ✓ minimize environmental radioactivity by
  - constructing the detector out of radiopure materials,
  - developing a clean boron-loaded scintillator,
  - utilizing adequate shielding for the neutron veto.
- ✓ energy threshold

Gadolinium

-> GAMMA cascade 8MeV

(> ^{208}Tl line ~2.7MeV)

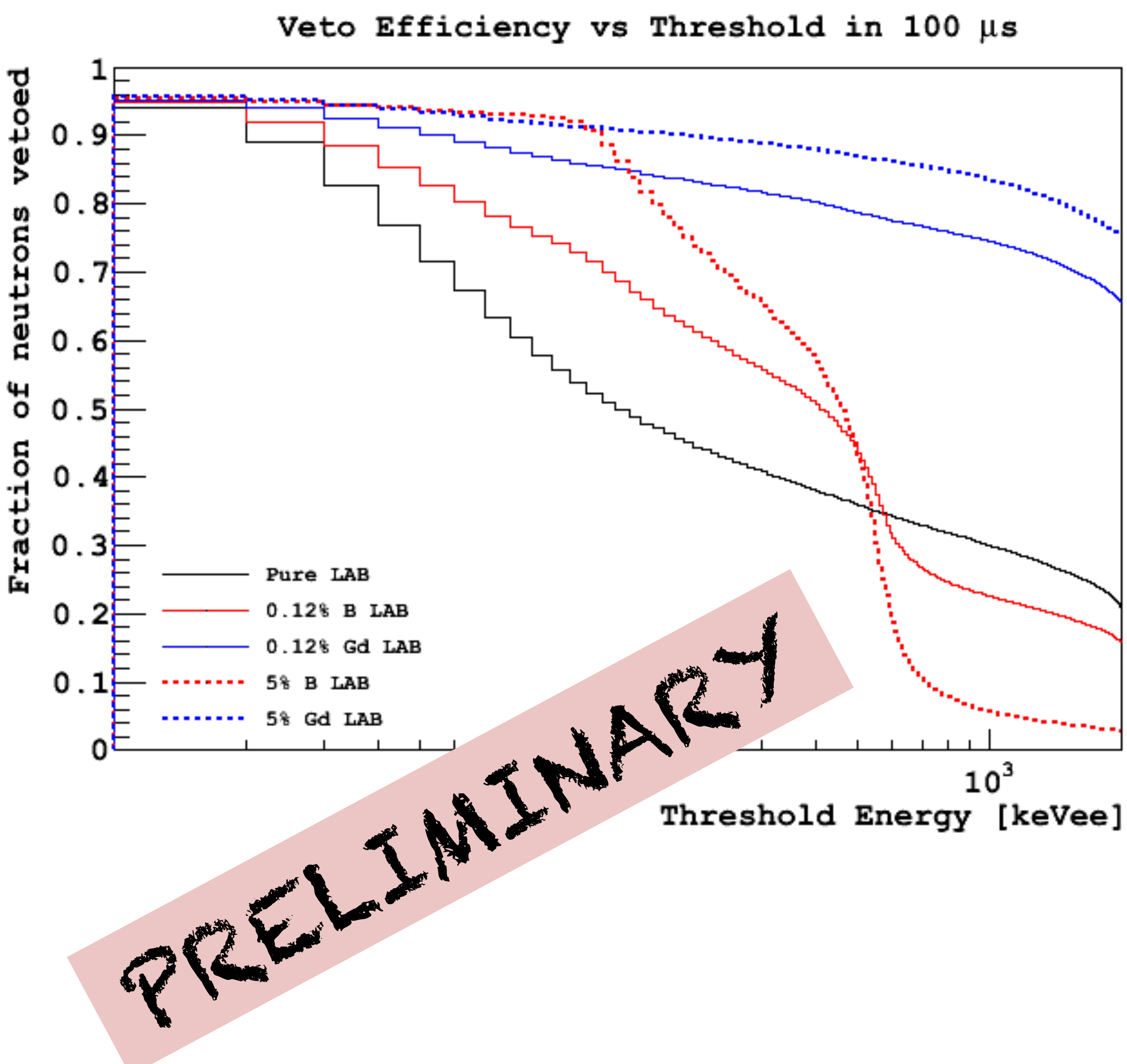
- Reduction outer shielding

- It has been demonstrated by Daya Bay experiment

BUT

- decreased efficiency for detecting internal neutrons
- possible introduction of radio contaminant (Gd is less pure than B)

Efficiency



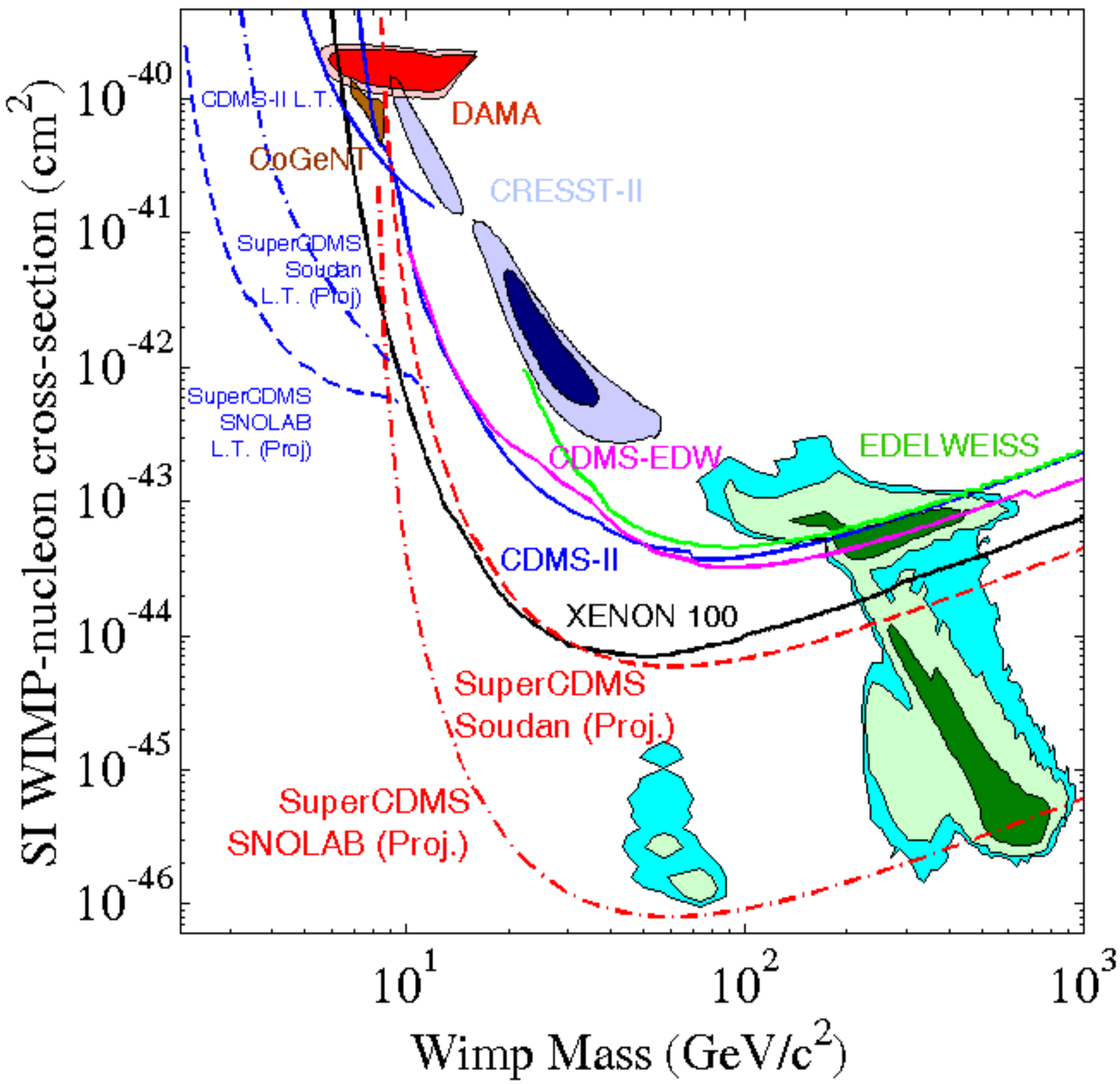
Veto efficiency vs threshold for 100mus veto times for recoil events.

Recoil events: passing the energy deposition criteria (10 -100keV) and >10% of the deposited energy must have come via recoils

LAB Gd doped shows higher efficiency than LAB B doped

Sensitivity and Timeline

- Scintillator and optical test starting soon
- Final design by 2014
- SuperCDMS SNOLab construction 2014



CDMS/SuperCDMS Collaborations

Caltech

Instituto de Fisica Teorica, Universidad Autonoma de Madrid Fermilab

MIT

NIST

Queens University

Santa Clara University

SLAC/KIPAC

Southern Methodist University

Stanford University

Syracuse University

University of British Columbia

University of California , Berkeley

University of California , Santa Barbara

University of Colorodo, Denver

University of Florida

University of Minnesota

University of Texas A&M

THANKS