SuperCDMS Development Project

Fermilab Program Advisory Committee

April 7-9, 2005

Blas Cabrera

Spokesperson SuperCDMS Collaboration

PAC Charge on CDMS II (E-891) and SuperCDMS (P-947)

The CDMS group has received assurances from Fermilab that we will support:

a) ongoing operations of the CDMS II detectors at Soudan; and

b) cryogenic support for the R&D phase of the Development Proposal and, in particular, their current NSF MRI proposal.

Thus far the PAC has not discussed the complete program dubbed Super-CDMS. The collaboration is requesting Laboratory endorsement of this program, or by June, in order to provide a (necessary) laboratory anchor for the full project.

Please comment as appropriate.

SuperCDMS - P947

- SuperCDMS is bold program to extend the sensitivity for dark matter search by a factor of one thousand in three phases
  - using demonstrated CDMS technology base
  - using technical and management expertise at national lab
- SuperCDMS Development Project proposal
  - Towers 1-5 continued running to increase Ge x4 beyond CDMS-II
  - Development Project - 5 kg Ge new detectors run at Soudan
  - Provide CDRs and TDRs for Phase A (25 kg) & Phase B (150 kg)
- Design and fabricate new cryogenic installation in SNOLab
- SuperCDMS Phase A will operate 25 kg of Ge
- SuperCDMS Phase B will operate 150 kg of Ge
- SuperCDMS Phase C will operate 1000 kg of Ge

- **Major Fermilab role includes cryosystems, electronics, DAQ, computing and analysis (and possibly detector characterization & testing)**

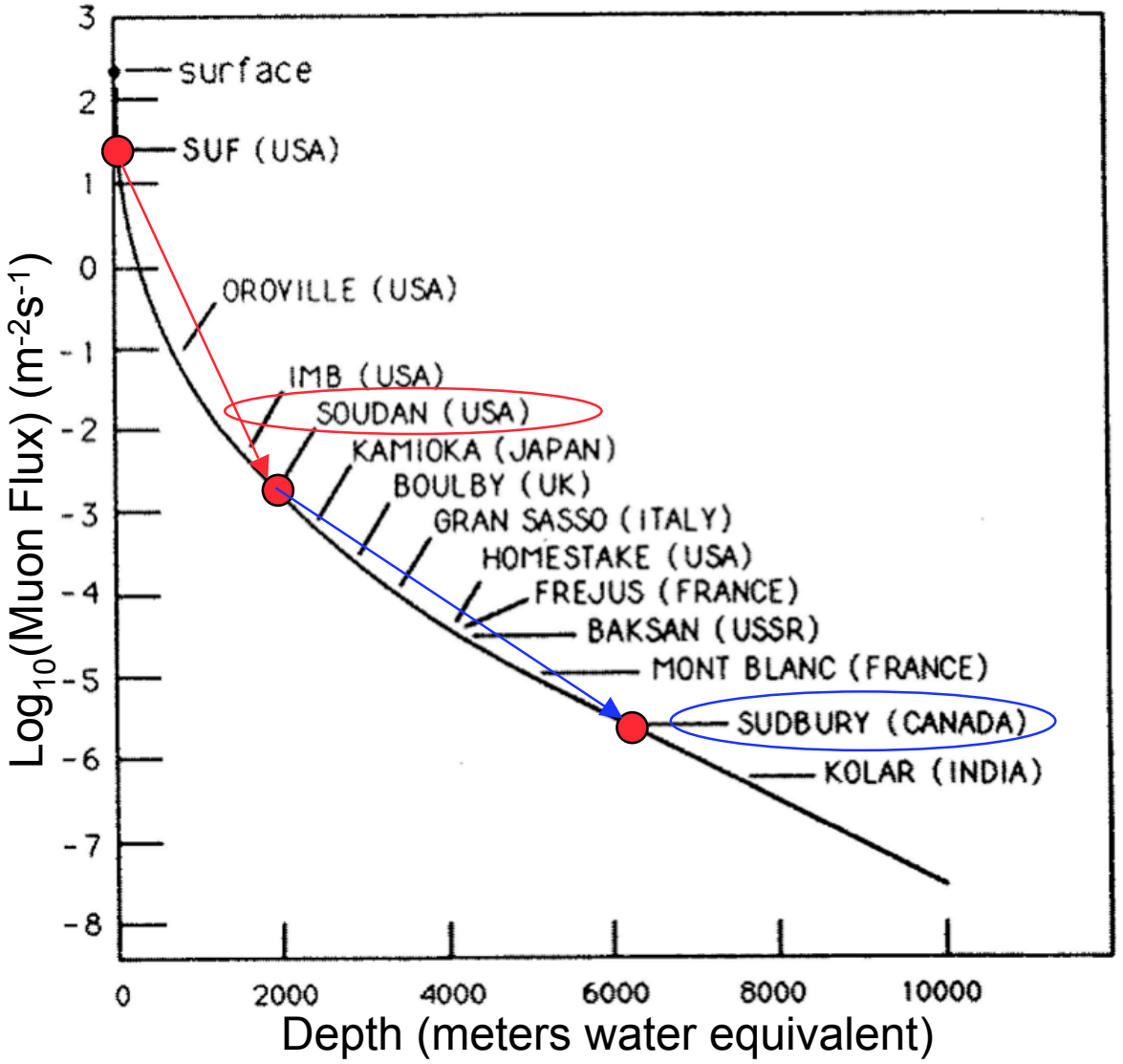
CDMS-II Project

- CDMS-II Project over at end of calendar 2005
  - Towers 1-5 Run 120 will have about six months operation and is expected to increase Ge exposure x4
  - DOE continues base support and operations support
  - NSF completes CDMS-II Project funding
  - **Fermilab continues support of operations**

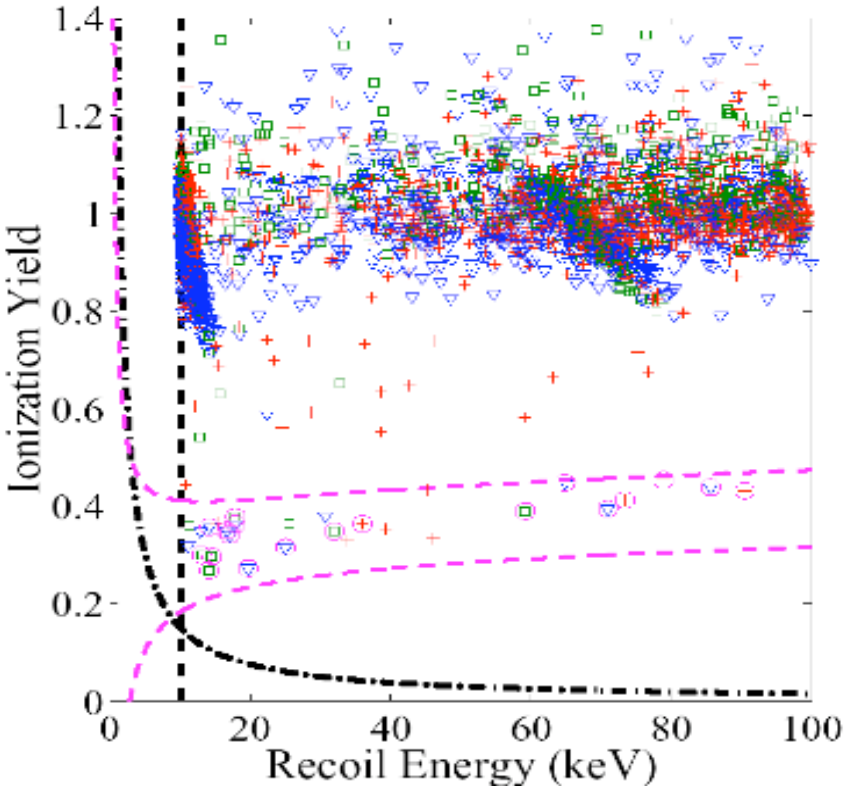
- Continue CDMS Soudan operations through 2006
  - Towers 1-5 continued running is expected to increase Ge x4
  - DOE continues base support and operations support
  - NSF has approved new base funding for FY2006-7
  - **Fermilab Director/PAC committed to continue support**
- Should continue world's best dark matter search experiment
  - Requested as part of SuperCDMS Development Project

SUF (17 mwe), Soudan (2090 mwe), & SNOLab (6060 mwe)

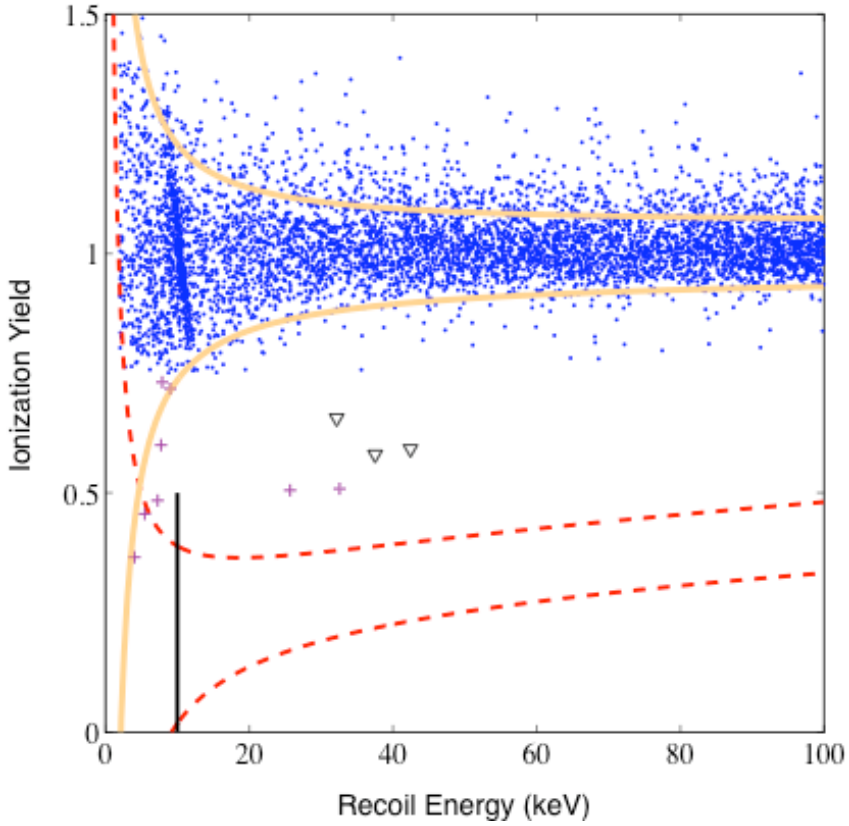
- At SUF
  - 17 mwe
  - 0.5 n/d/kg
- At Soudan
  - 2090 mwe
  - 0.8 n/y/kg
- At SNOLab
  - 6060 mwe
  - 1 n/y/ton



Tower 1 (4 Ge & 2 Si) at SUF then at Soudan



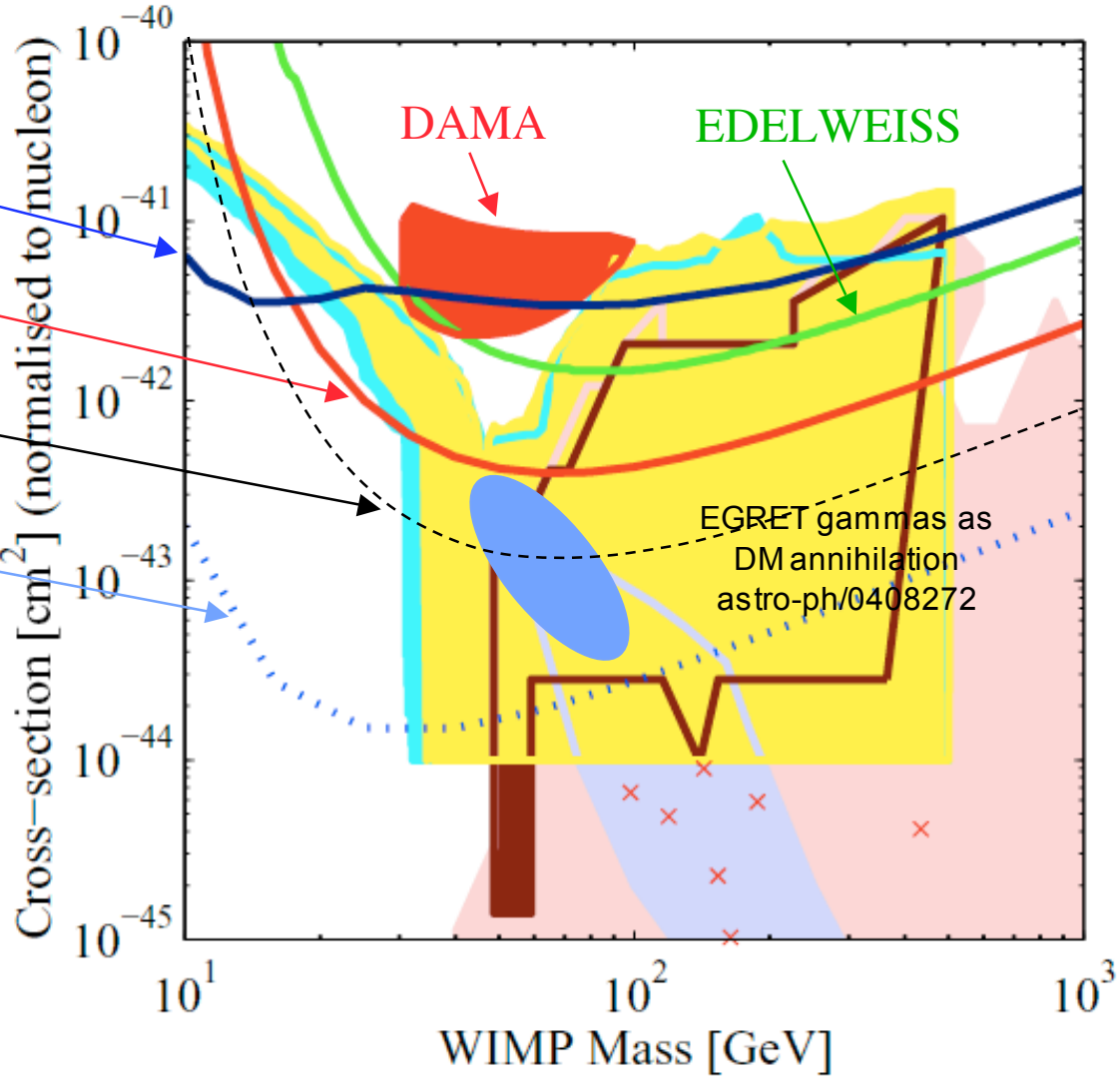
19 neutron events at SUF



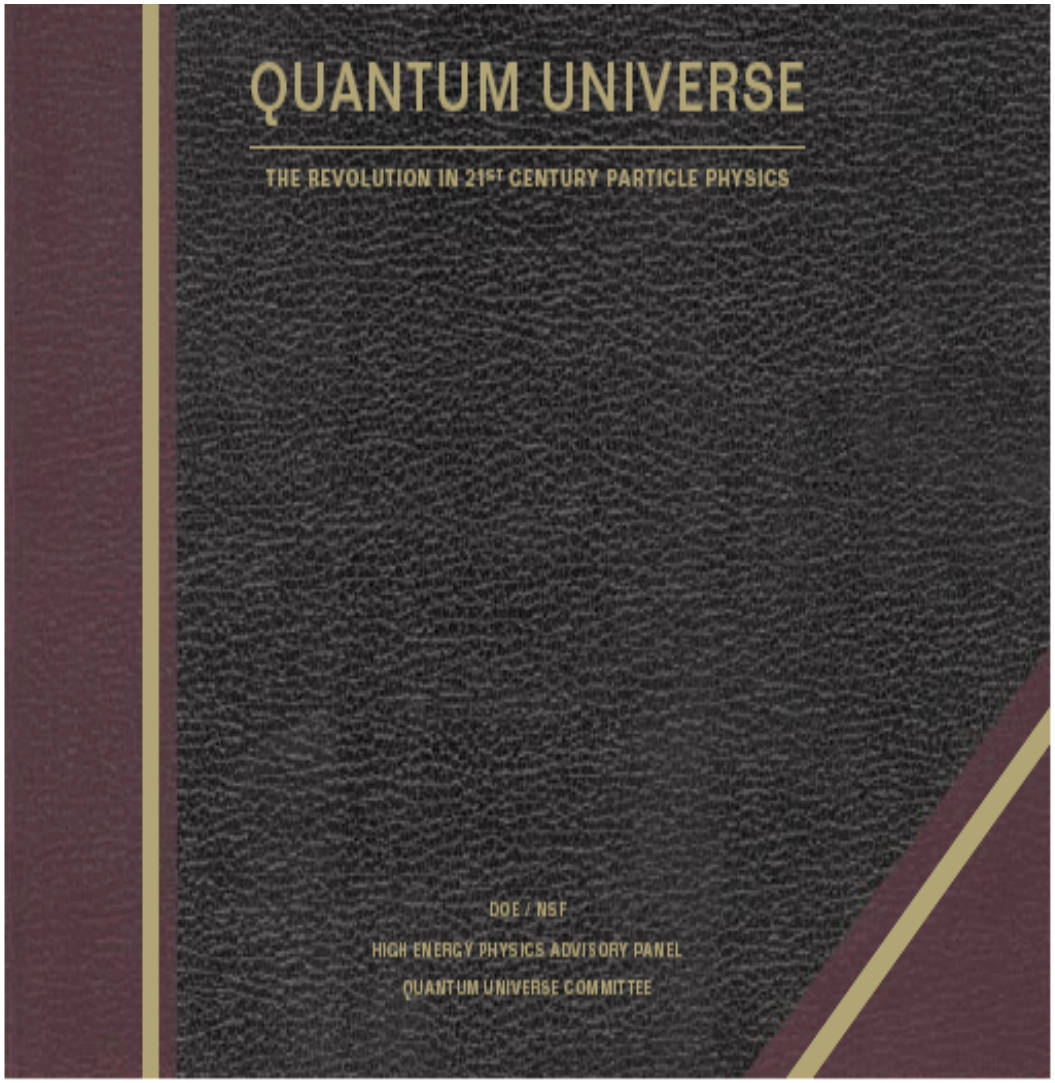
0 events at Soudan

CDMS-II Scientific Reach

- CDMS-II explores MSSMs in series of runs
- SUF Tower 1 in 2002
- Soudan Tower 1 in 2003
- Soudan Tower 1-2 in 2004
- Soudan Towers 1-5 2006
- Another factor of 3-5 improvement at Soudan past CDMS-II (neutrons)
- THEN MUST GO DEEPER - Planning SuperCDMS at SNOLab in Canada



Quantum Universe



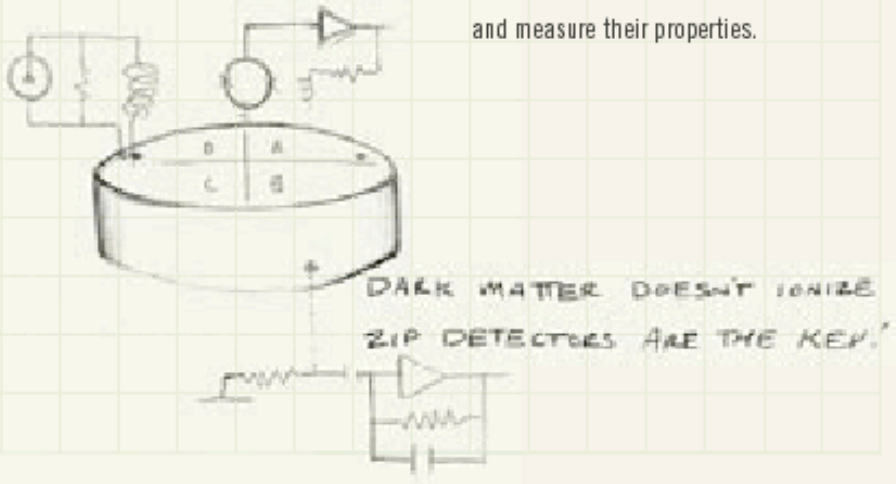
- Question 6:
  - WHAT IS DARK MATTER?
  - HOW CAN WE MAKE IT IN THE LABORATORY?

- "…We need to study dark matter directly by detecting relic dark matter particles in an underground detector and by creating dark matter particles at accelerators, where we can measure their properties and understand how they fit into the cosmic picture."

Quantum Universe - CDMS!

From a vantage point a half-mile below ground, physicists of the Cryogenic Dark Matter Search have launched a quest to detect the dark matter that pervades the universe. Scientists of CDMS II, an experiment in the Soudan Iron Mine in northeastern Minnesota, hope to discover the weakly interacting massive particles that are leading candidates for the constituents of dark matter. The WIMPs are thought to be particles more massive than protons but interacting so rarely that thousands would pass through us undetected each second. Only occasionally would a WIMP hit a terrestrial atom, leaving a signal in the CDMS II detector.

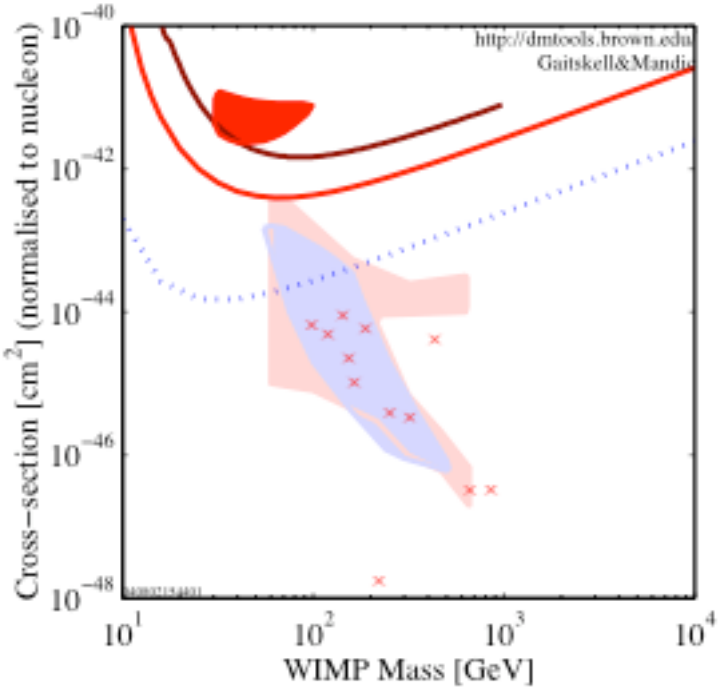
In the kind of convergence that gets physicists' attention, the characteristics of WIMPs appear to match those of a particle predicted by supersymmetry, the neutralino. While CDMS II watches for WIMPs, accelerator experiments seek to create neutralinos in particle collisions and measure their properties.

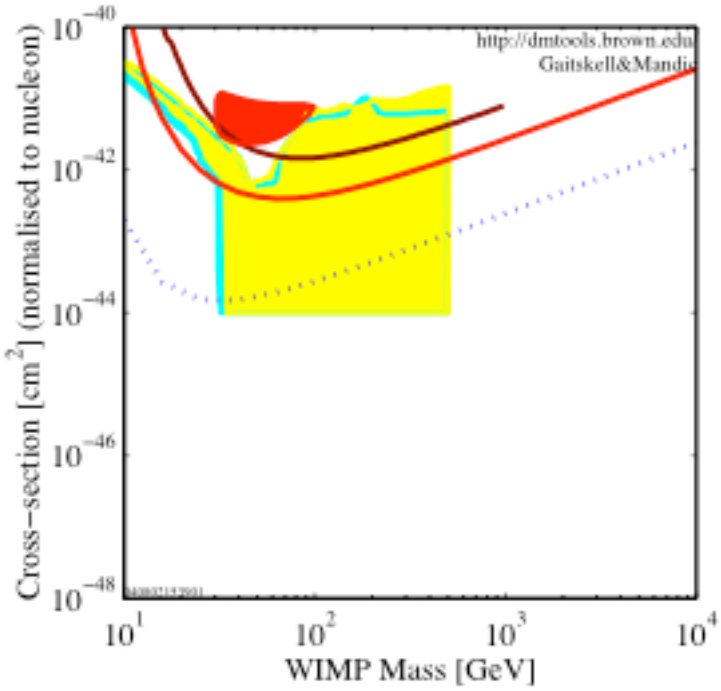


Strong Cosmology and Particle Physics Case

- WMAP has strengthened case for non-baryonic dark matter at 23+/-2% of universe
- Local dark matter density 0.3 GeV/cm^3 within a factor of two from halo shape and lumpiness
- Supersymmetry models continue to be favorite extension of Standard model of particle physics with LSP an excellent candidate for dark matter
- Error bars for cross section are now within a factor of 2-3, so even negative limits are significant
- Direct detection signal would measure a mass through the spectrum and cross section of WIMP

mSUGRA and relax GUTs





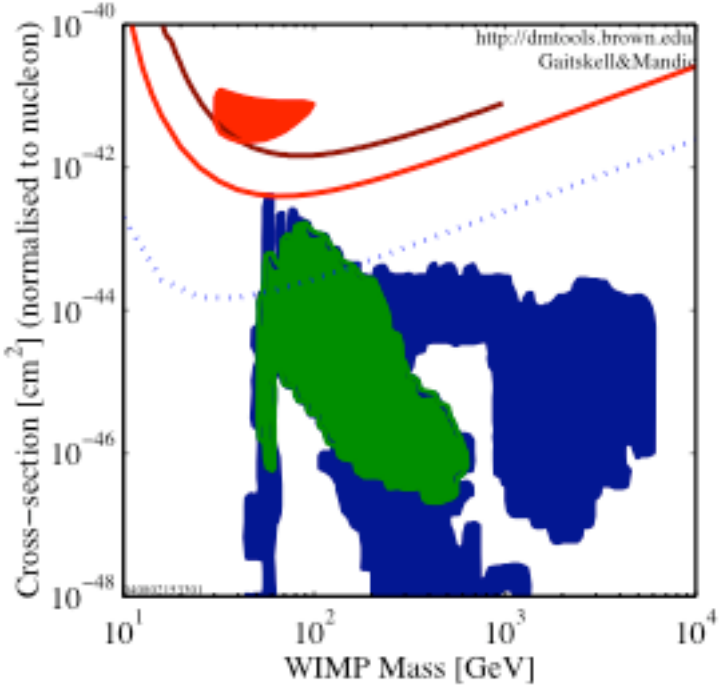
Baer et al, hep-ph/0305191

Chattopadhyay et. al, hep-ph/0407039

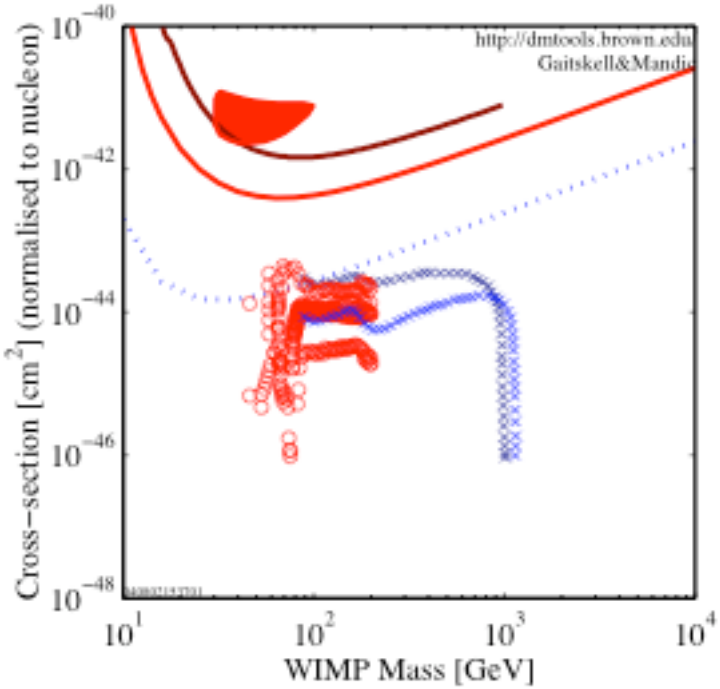
Ellis et al, hep-ph/0306219

Bottino, et al hep-ph/0307303

mSUGRA and Split Supersymmetry

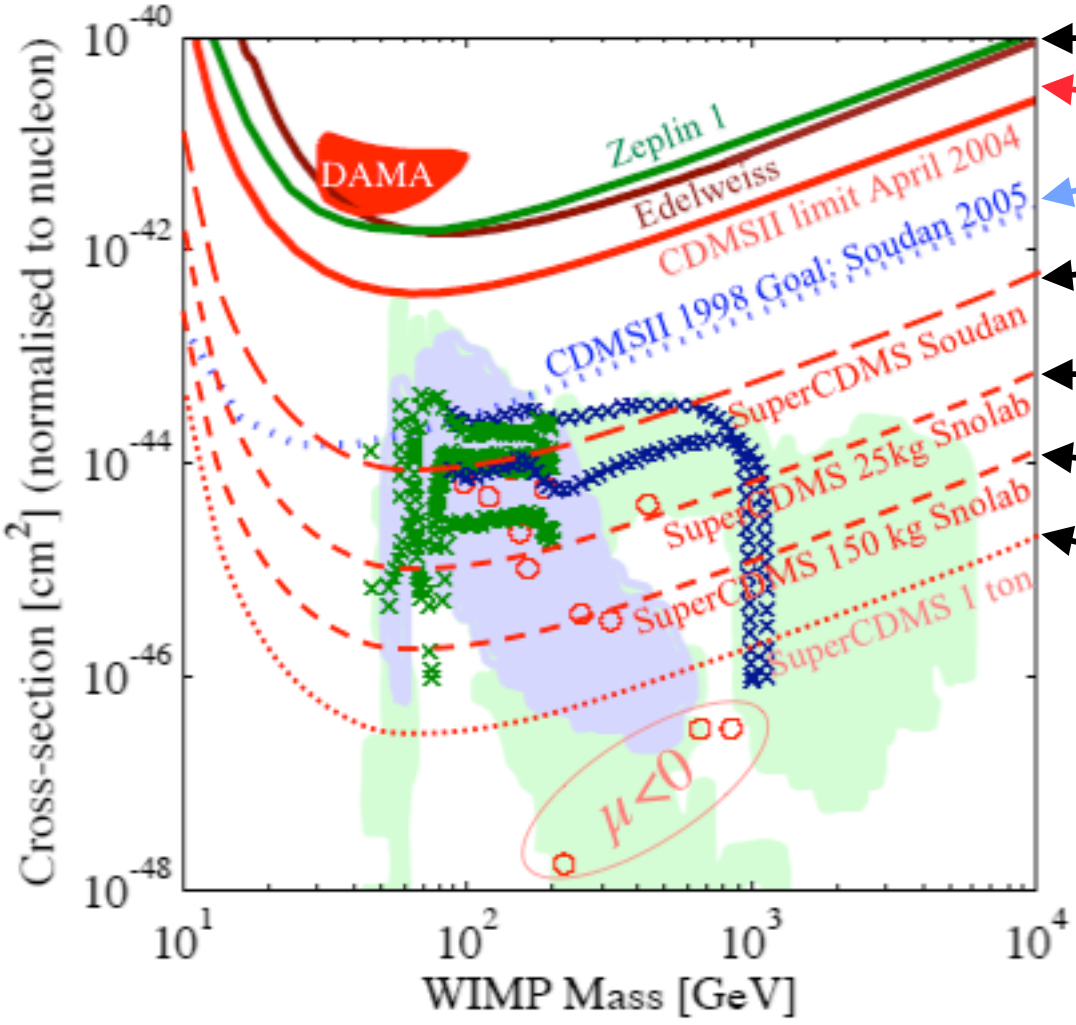


Baltz & Gondolo hep-ph/0407039



A. Pierce, hep-ph/0406144 &
G. F. Giudice and A. Romanino
hep-ph/0406088

Summary and bold future vision



Limit at SUF 2002
(during CDMS II)

World-best limit today

CDMS II goal 2006

Development Project
5 kg of Ge 2008

SuperCDMS Phase A
25 kg of Ge 2011

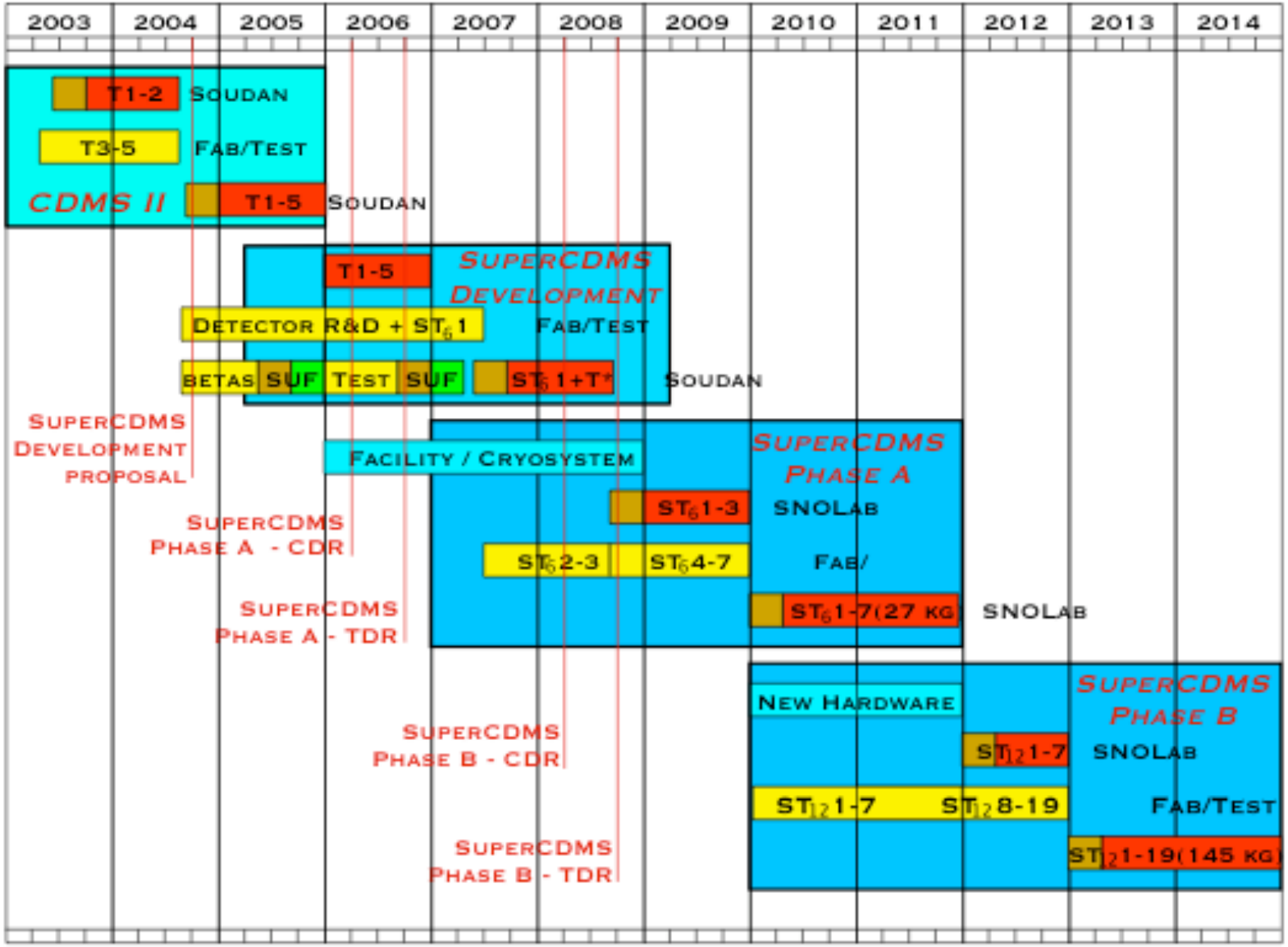
SuperCDMS Phase B
150 kg of Ge 2014

SuperCDMS Phase C
1000 kg of Ge

SuperCDMS Development Project proposals

- NSF MRI Proposal for SuperCDMS cryogenic system
  - Design and purchase cryogenic system
  - Submitted to NSF Jan 2005 to start fall 2005
  - **Fermilab Director commits cryo-engineering support**
- SuperCDMS Development Project (request start FY2006)
  - Submitted to NSF Oct 2004 and DOE University Dec 2004
  - **Submitted to Fermilab PAC Apr 2005**
  - Towers 1-5 continued running is expected to increase Ge x4
  - Development Project - 5 kg Ge new detectors run at Soudan
  - CDRs & TDRs for Phase A (25 kg) & for Phase B (150 kg)
- Agency plans
  - NSF and DOE plan Dark Matter Task Force early 2006
  - **Need Fermilab endorsement and R&D backing in 2005**
  - Seed funding Stanford/KIPAC and requests to DOE & NSF

SuperCDMS Roadmap to SNOLAB



Detector development (increase mass)

- Existing ZIPs
  3" dia x 1 cm thick

CDMS II ZIPs: 3" dia x 1 cm => 0.25 kg of Ge

- Thicker ZIPs
  3" dia x 1" thick
  (base detector)

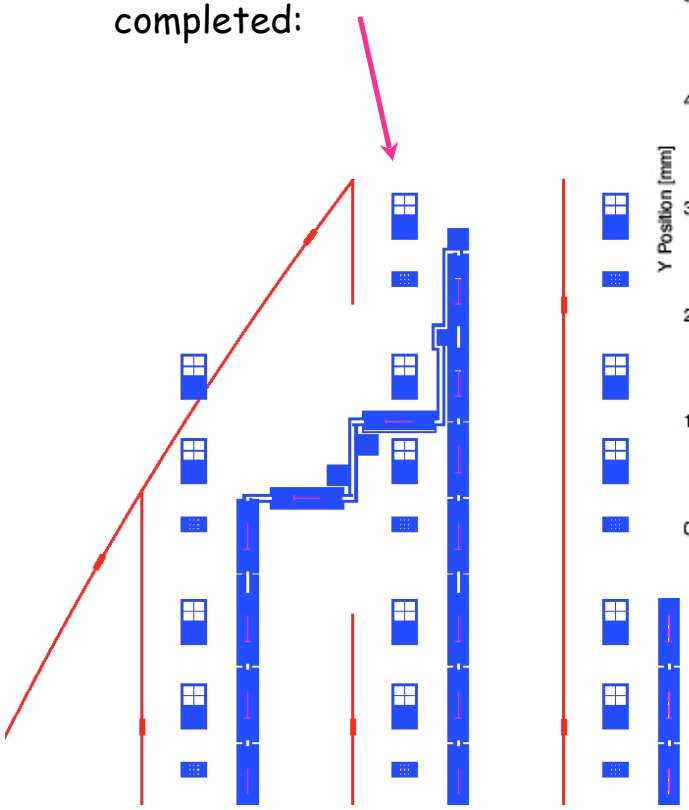
CDMS III tZIPs: 3" dia x 1" => 0.64 kg of Ge

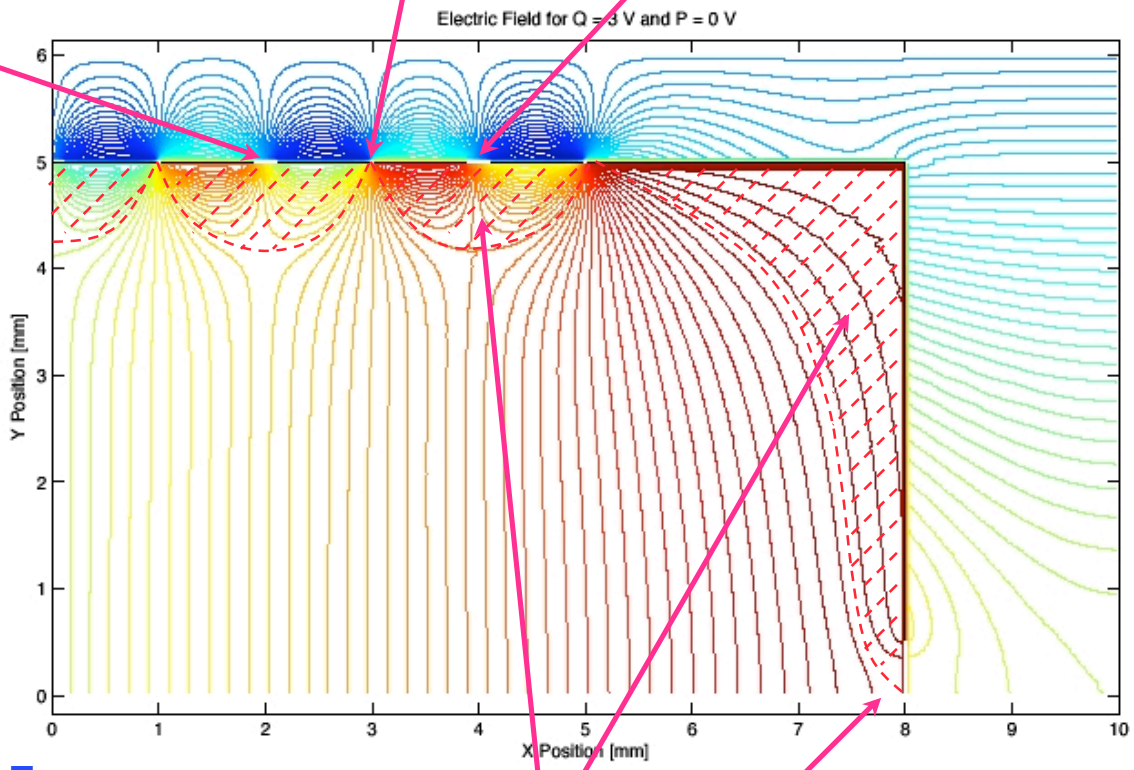
- Explore larger ZIPs to 4" dia and up to 4 cm thick

CDMS SNOLAB sZIPs: 4" dia x 1" => 1.13 kg of Ge

Interleaved electrode improves beta rejection

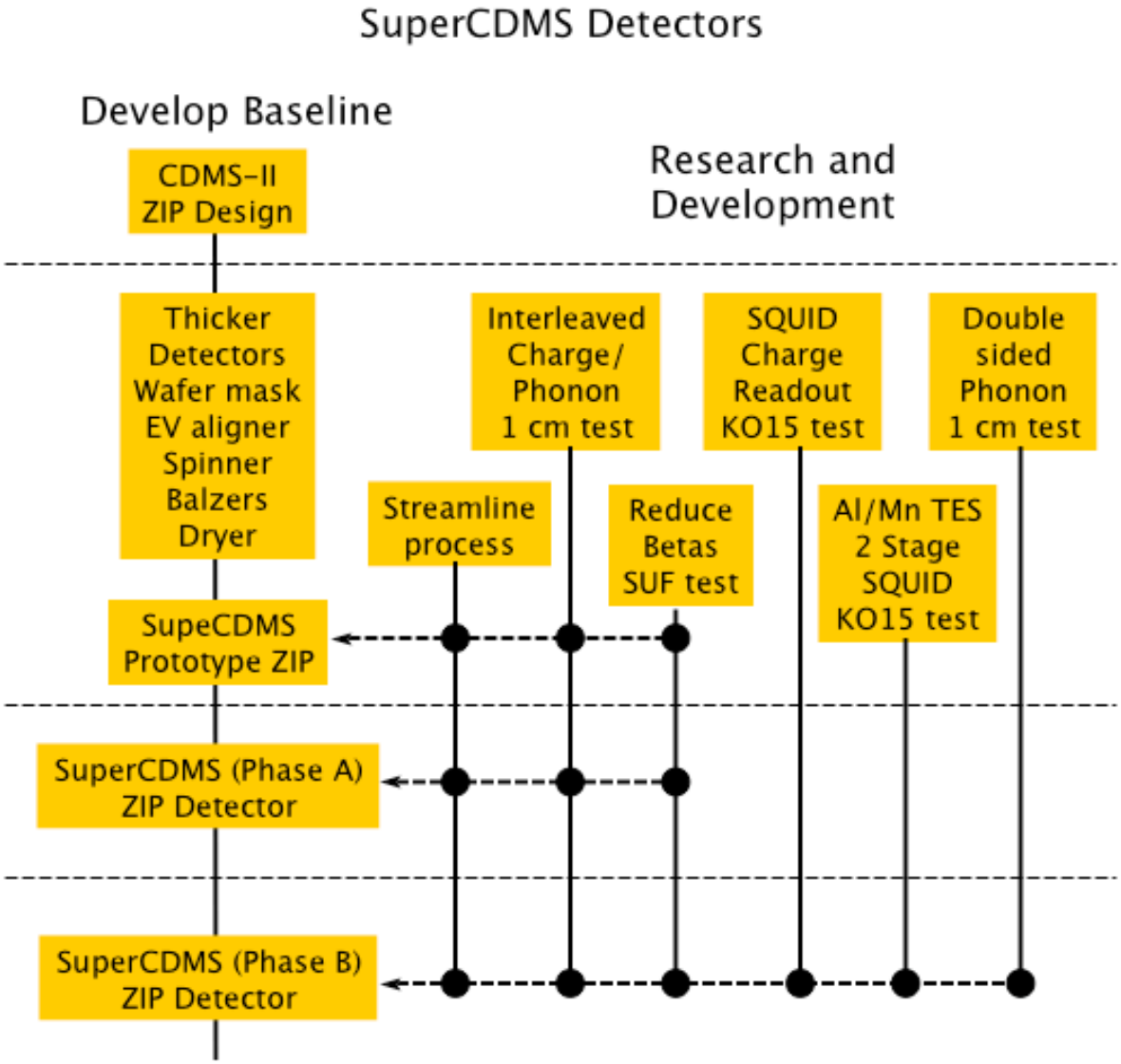
- Design details
  - To maintain ~60 pF of capacitance requires keeping bias and ground rails ~ 1 mm apart.
  - Phonon sensors 'contained' within the (200 μm wide) ground rails.
  - First mask-layout recently completed:





Ground ring around side to define the 'Qouter' volume containing all surfaces

Detector development strategy



How to build a 1000 kg experiment in stages

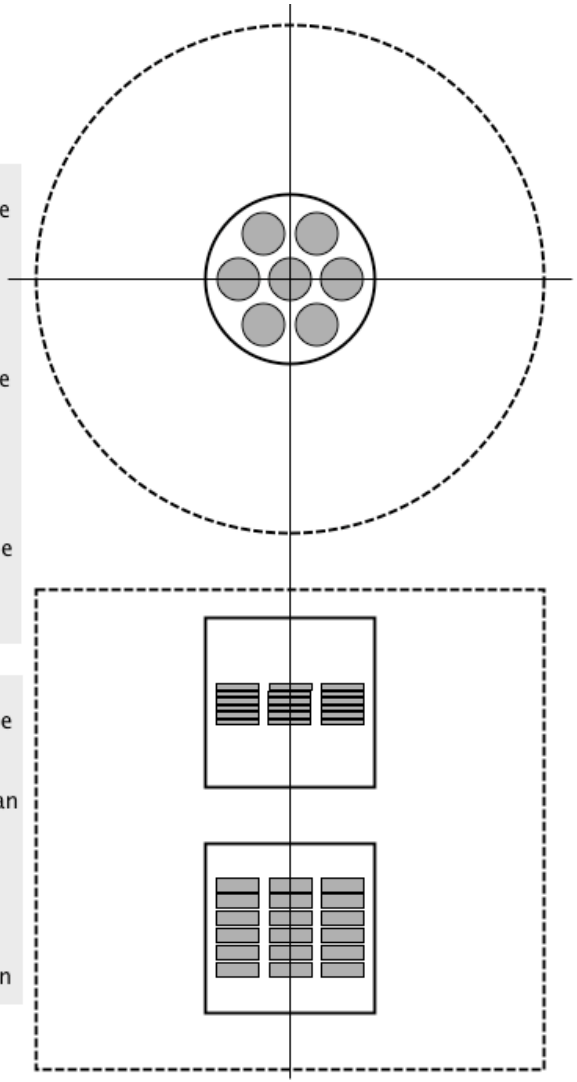
CDMS II – Phase A:
3"x1 cm => .25 kg Ge
1 x 6 Det Towers =>
1 kg Ge + 0.2 kg Si
SUF -> Soudan

CDMS II – Phase B:
3"x1 cm => .25 kg Ge
2 x 6 Det Towers =>
1.5 kg Ge + 0.6 kg Si
Soudan

CDMS II – Phase C:
3"x1 cm => .25 kg Ge
5 x 6 Det Towers =>
4.5 kg Ge + 1.2 kg Si
Soudan

CDMS III – Phase A:
3"x1 cm => .25 kg Ge
5 x 6 Det Towers =>
4.5 kg Ge + 1.2 kg Si
x3 exposure at Soudan

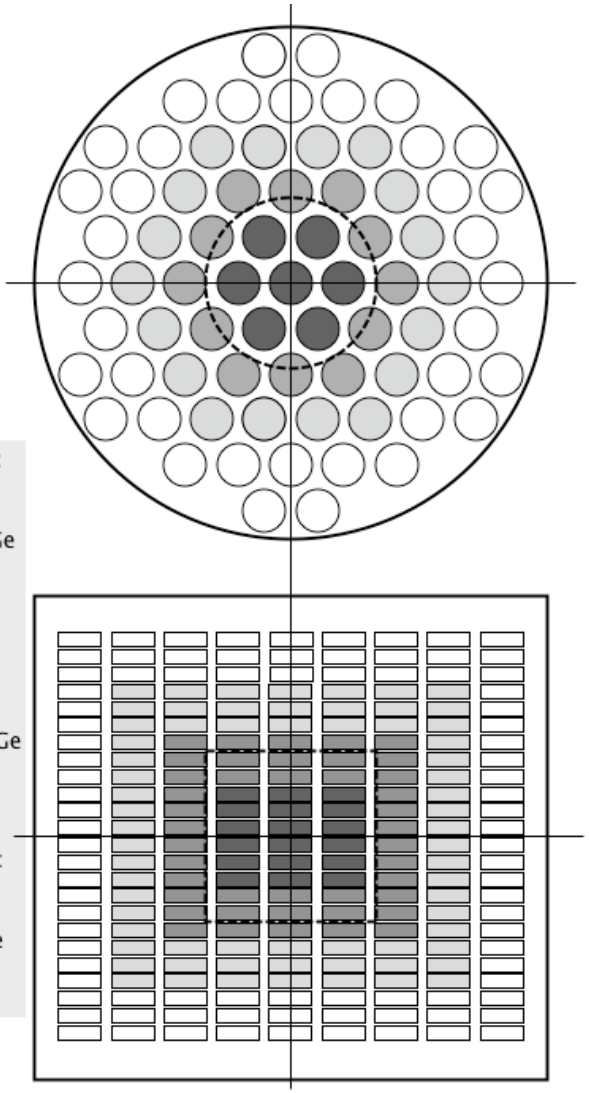
CDMS III – Phase B:
3"x1" => .64 kg Ge
2 x 6 Det Towers =>
up to 7.6 kg Ge
x10 less n's at Soudan



CDMS SNOLAB – Phase A:
3"x1" => 0.64 kg Ge
7 x 6-Det Towers =
42 Dets =>to 26.7 kg Ge
Soudan -> SNOLAB
SUF testing (2 batches)

CDMS SNOLAB – Phase B:
3"x1" => 0.64 kg Ge
19 x 12-Det Towers =
228 Dets =>to 145 kg Ge
Soudan/SUF testing
(6 batches)

CDMS SNOLAB – Phase C:
3"x1" => 0.64 kg Ge
73 x 24 Det Towers =
1752 =>to 1,113 kg Ge
Soudan/SUF testing
(45 batches)

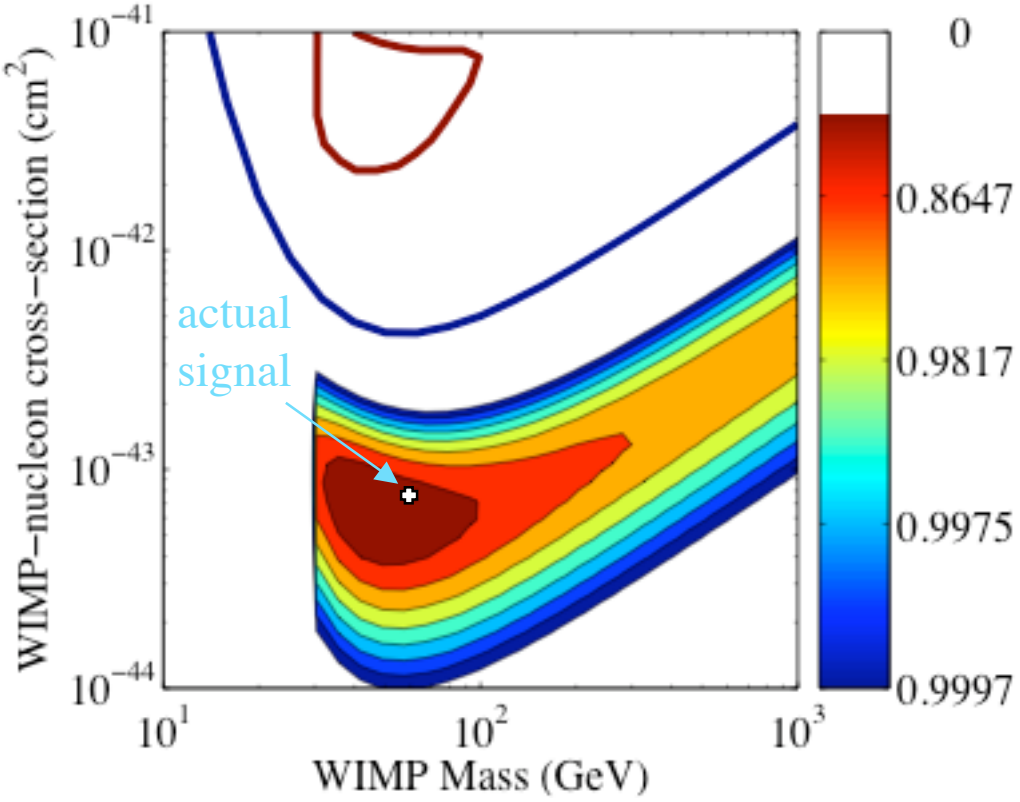


Conclusion

- Soudan Run 118 (Tower 1) sensitivity leads the field of WIMP direct detection by x4, demonstrating that CDMS-II has best discovery potential.
- Soudan Run 119 (Towers 1&2) completed and analysis nearly completed ~x3 - announce results at Apr APS
- Soudan Run 120 (Towers 1-5) will run for half of 2005 and we expect an additional ~x4 improved sensitivity.
- **REQUEST APPROVAL FROM FERMILAB PAC** for SuperCDMS Development Project to continue running Towers 1-5, to develop larger ZIP detectors, to operate one SNOLAB Tower at Soudan, and deliver the CDRs and TDRs for Phase A (25 kg) & Phase B (150 kg)

What do we learn if we see a signal?

- Best 90% C. L. corresponds to < 1 evt per 8 kg-d for Ge
- Suppose we see 8 events at rate of 1 evt per 50 kg-d
- Then mass & cross section determined as shown and SI vs SD determined from different targets
- Suggest properties to look for at LHC and future LC



A convincing signal would motivate large TPC such as DRIFT for velocity distribution

If SUSY seen first at LHC would still want to determine if LSP is the dark matter, SO NEED TO PUSH DIRECT DETECTION EITHER WAY

Compare with Competition

- NaI - annual modulation with no discrimination (<6 pe/keV)
  - DAMA signal is suspect because near threshold (systematics)
  - LIBRA - 250 kg new installation (still no discrimination)
- Cryogenic technologies - lowest intrinsic threshold (10^6 phon/keV)
  - (Super)CDMS Ge & Si ionization + phonon + timing (now best)
  - EDELWEISS Ge thermal + ionization (no timing)
  - CRESST $CaWO_3$ thermal + scintillation (no light for W)
- Liquid Xenon - intrinsically high threshold (~1 pe/keV)
  - ZEPLIN I & XMASS scintillation (uncalibrated result)
  - XENON scintillation + ionization (need demo of threshold & stability)
- Superheated liquids - no energy resolution (counting)
  - COUPP CF_3Br & CF_3I (need demo of stability)
- Liquid He (HERON) and Ne (NEON) detectors good for SD only
- TPC DRIFT - good for directionality (near term not enough mass)

Schematic of new 'SNObox'

Exploring cryocooler system with little or no cryogen servicing