



The Soudan Underground Laboratory

5 March 2013

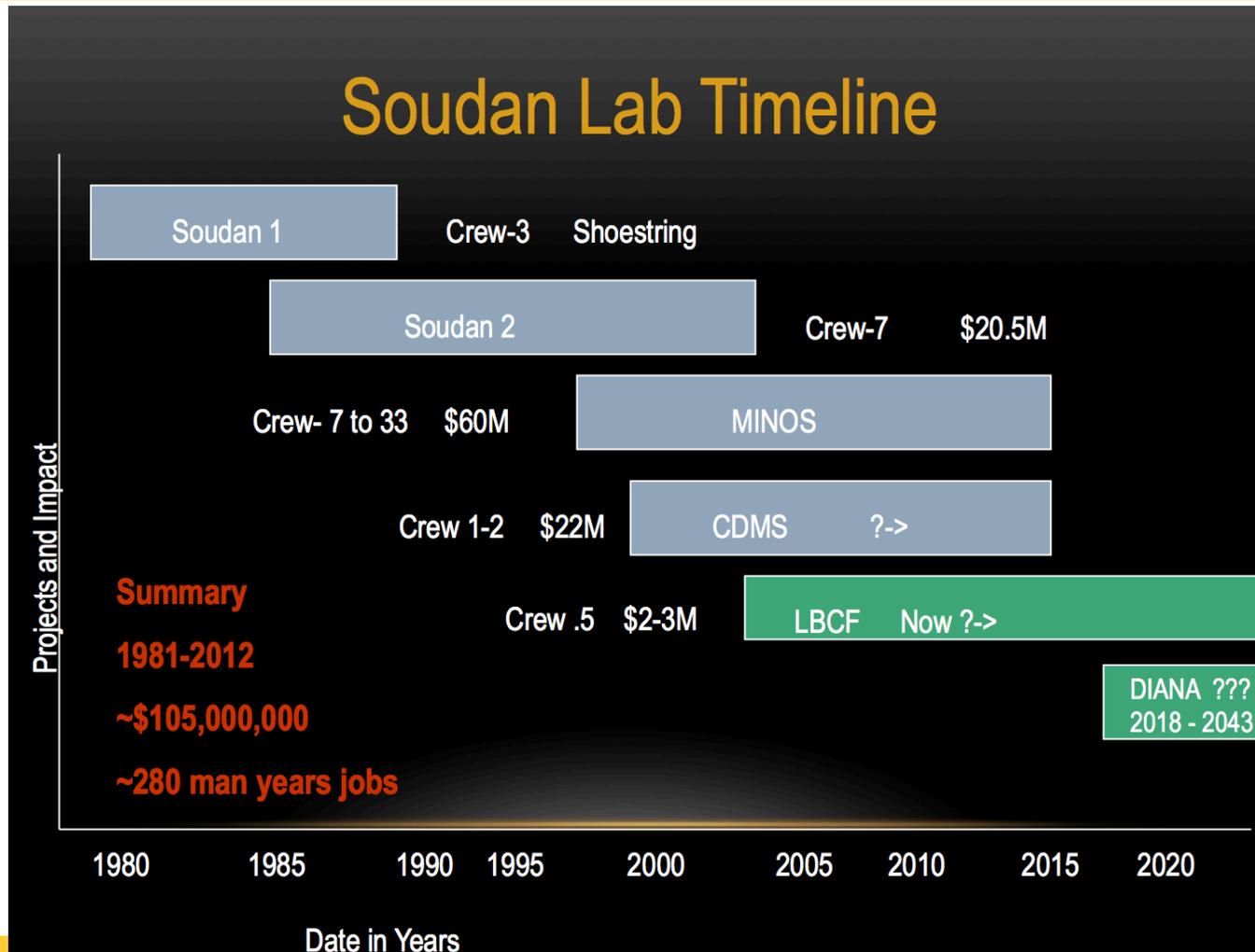


MINOS neutrino detector, Soudan Underground Laboratory

The Soudan Underground Laboratory

- The Soudan Underground Laboratory has unique attributes, including:
 - History of producing important scientific results
 - Highly competent staff to install and maintain equipment
 - Existing infrastructure to facilitate experiments, such as power, internet, clean room, cryo facilities, low background facility
 - World's longest and most intense neutrino beam
 - Efficient, low cost operation with minimal water pumping
 - Outstanding outreach and visitor program, operated in cooperation with State Park tourism professionals
 - Ongoing, diverse experimental program
 - University lab with minimal bureaucracy and no access limits

Soudan Lab Timeline



Important Scientific Results (Physics)

- Soudan 2 Collaboration: 84 publications, 5 “top cites”,
 - 1 Ph.D. thesis
- MINOS Collaboration: 150 publications, 14 “top cites”
 - 33 Ph.D. theses
- CDMS Collaboration: 140 publications, 12 “top cites”,
 - 7 Ph.D. theses
- COGeNT Collaboration: 4 publications, 2 “top cites”

FERMILAB-PUB-06-243, BNL-76806-2006-JA, hep-ex 0607088

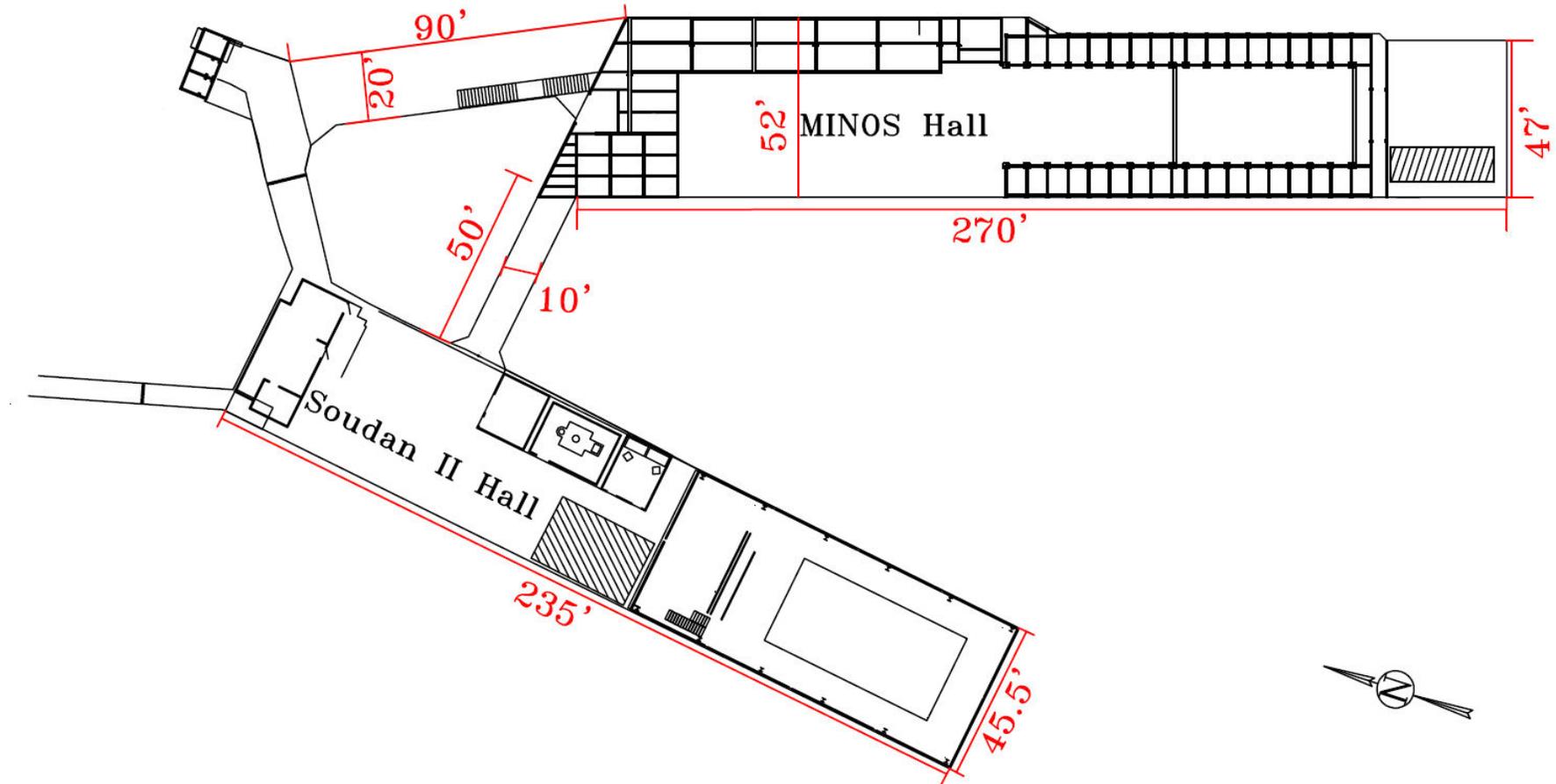
Observation of muon neutrino disappearance with the MINOS detectors in the NuMI neutrino beam

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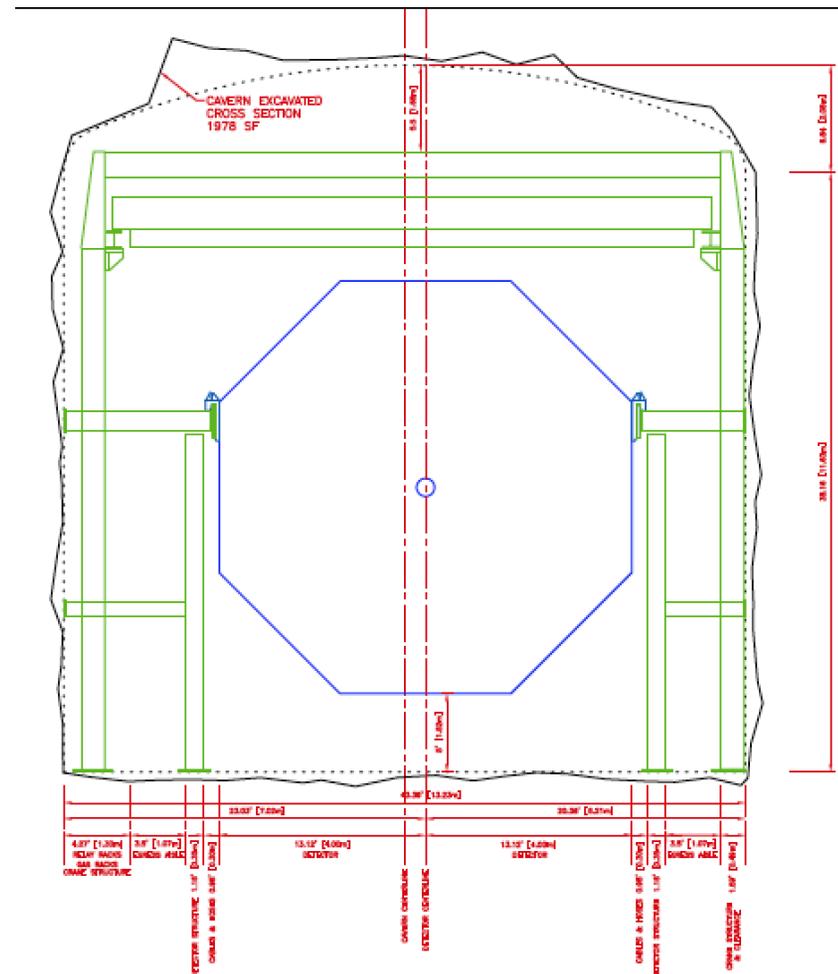
Highly Competent Staff

- Lab Manager: Jerry Meier (24 years experience)
- Assistant Manager and Safety Officer: Denise Osterholm (1 year at Soudan; 14 years at UM-Duluth)
- Assistant Scientist: Hiring new person
- Senior Lab Tech: Dan DeVaney (1.5 years)
- Data and Network Tech: Dave Saranen (13 years)
- Lab Machinist: Jack Zorman (14 years)
- Administrator: Eileen Amos (12 years)

Soudan Lab Plan View



MINOS Hall Cross-Section View



13.68 m

15.85 m

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Detector Installation and Materials Handling

Putting
On
Cables



Placing a module



Plane 0!

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Jan. 2007

William Miller

Low Background Counting Facility



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Low Background Counting Facility (LBCF)

- The LBCF is a response to the following urgent and immediate needs in the underground science community
 - Screening of low-background materials and shielding for approved and proposed experiments
 - Testing of prototypes by 2nd generation experiments and proposed new experiments
 - Facilities and infrastructure in which to perform these tasks in a flexible, defined, and cost-effective manner (economy of scale)



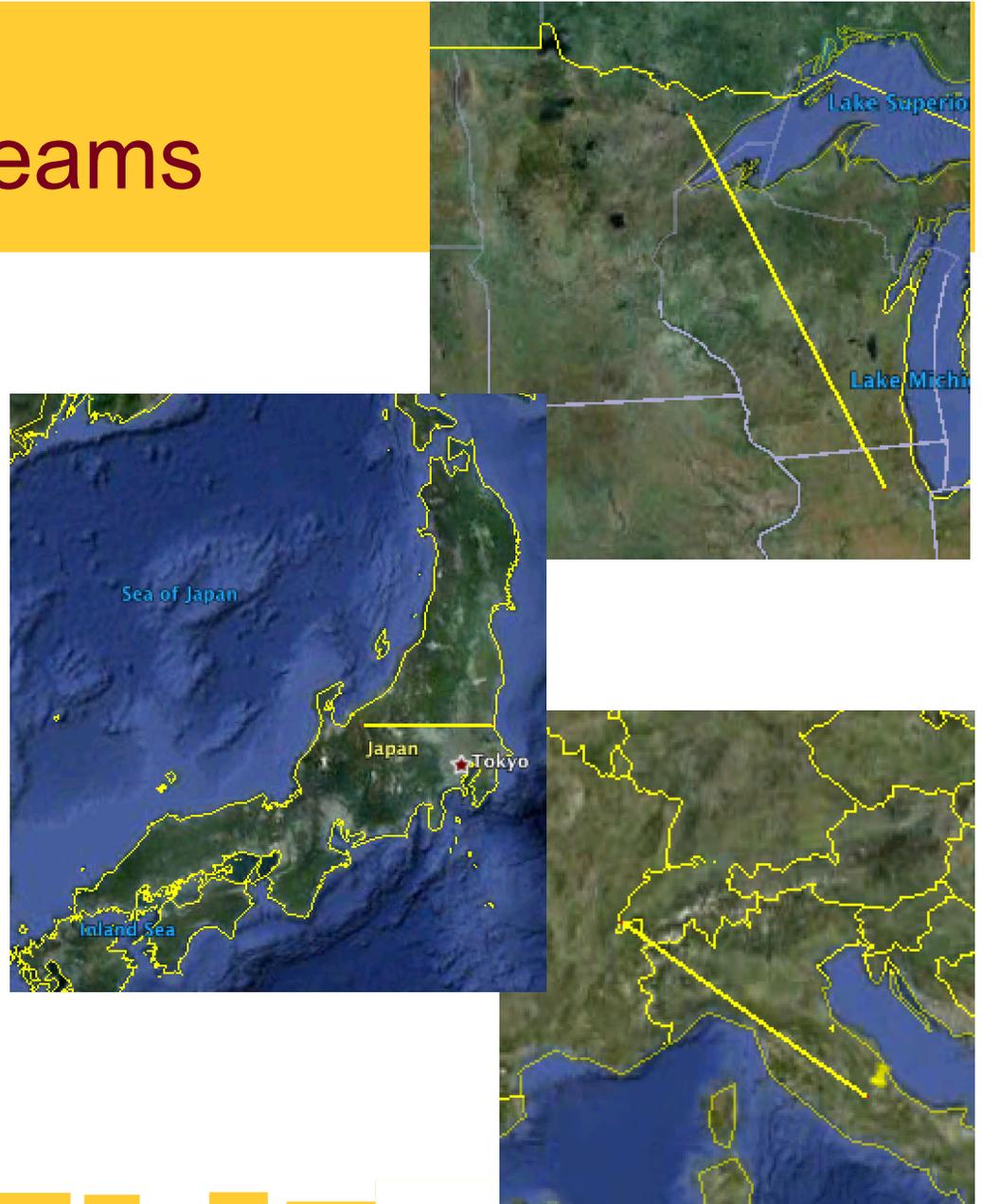
Low Background Counting Facility (LBCF)

- A 35 ft x 40 ft x 100 ft underground experimental hall at a depth of 2090 mwe (existing water, power, lighting, office space, network infrastructure)
- Total cavern coverage by active muon veto shield and a unified DAQ system, with user configurable trigger and remotely-accessible time-stamped muon database collecting in real time.
- A multipurpose clean room under multiple-coincident muon veto panels.
- Two HP Ge detectors for gamma screening and two novel beta screening devices: a neon gas drift chamber with multi-wire proportional readout and a resistive parallel plate chamber.
- Surface facilities for receiving, storage, assembly, remote computer access.

Soudan Lab Budget (FY2012)

World's Neutrino Beams

- NuMI:
 - Length: 735 km to Soudan, 810 km to NOvA Ash River
 - Power: Now upgrading to 700 kW
- T2K
 - Length: 295 km
 - Power: 200 kW (ICHEP 2012)
- LNGS Beam
 - Length: 732 km
 - Power: 510 kW



Education and Outreach



- Soudan is a State Historic Park;
listed on National Register of Historic Sites
- ~25,000 visitors each year tour underground historic site
- ~5,000 visitors each year participate in physics tours
 - Regularly scheduled summer visits to the public
 - Arranged tours for K-12 students and other groups year round
 - Tours led cooperatively by Lab and Park Staff
- Outreach coordinator visits schools, meetings, conventions, etc.
- Educational materials for various ages
- Outreach program supported by NSF

Soudan Scientific Program—1

- Long Baseline Neutrino Physics
 - MINOS, MINOS+
- Dark Matter Search
 - CDMS: Cryogenic Dark Matter Search
 - CoGeNt
- Low Background Counting Facility
 - Gopher
 - SOLO
 - University of South Dakota Neutron Counter
 - Neutron Multiplicity Counter
- Earth Sciences (Geology, Geochemistry and Geomicrobiology)

Soudan Scientific Program—2

- Completed Experiments
 - Proton Decay: Soudan 1 and Soudan 2
 - High Purity Copper Electroforming: Reeves and Sons, Inc.
 - Semiconductor Error Rate: Cypress Semiconductors
 - Medtronic Semiconductor Testing
- Possible Future Experiments
 - DIANA (Dakota Ion Accelerators for Nuclear Astrophysics)

Snowmass 2013 White Papers

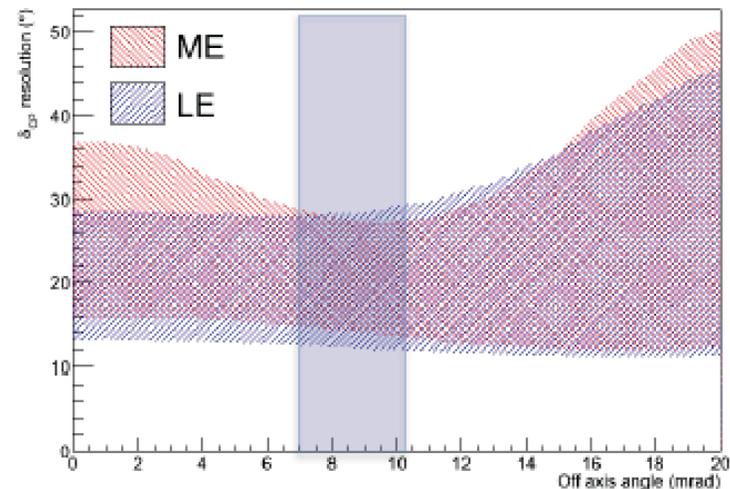
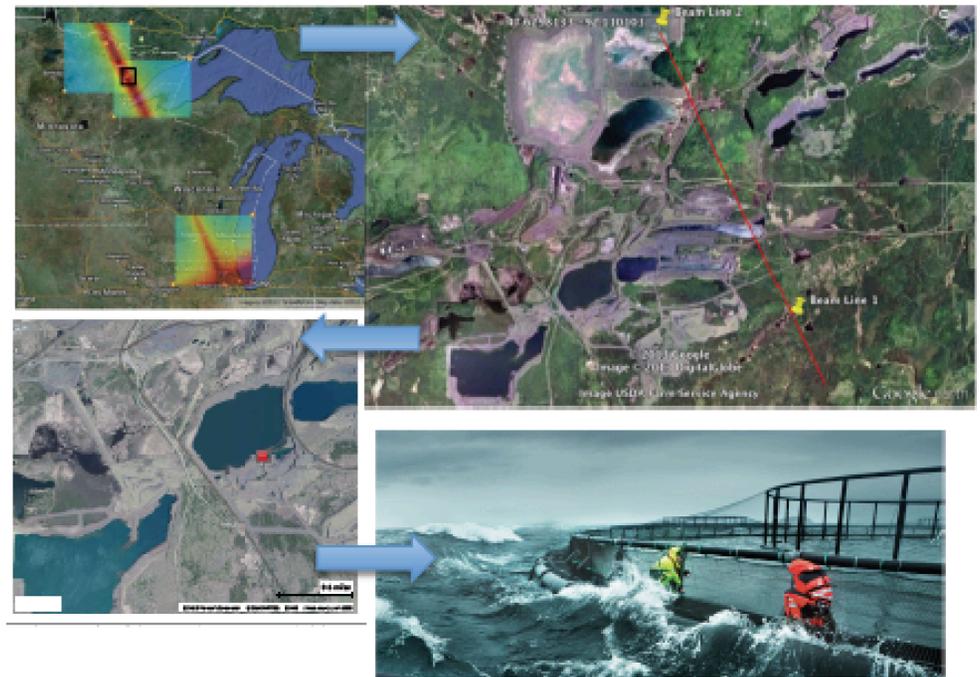
- Key questions are Mass Hierarchy (MH) and CP Violation (CPV) parameter Delta
- Long baseline is particularly useful for MH. If MH is known from other experiments, the shorter baseline ambiguity for delta is removed and the resolution for CPV Delta is not so dependent on baseline

Snowmass 2013 White Papers

- What happens before substantial LBNE data (15? years from now)
 - NOvA and T2K
 - Atmospheric neutrinos in SuperK and PINGU(?)
 - New reactor experiments (?)
 - Upgraded or new detectors for NuMI Beam?
 - Complete NOvA to 18 kT
 - LAr at Ash River or Soudan (GLADE)
 - Water Cerenkov Detector in Mesabi Range (CHIPS)
 - Add scintillator to MINOS

CHIPS

- The water Cherenkov detector In mine PitS, has 100kt target volume
- It will sit in the Wentworth mine pit, 7mr off axis (optimal position for both ME and LE) of the NuMI beam and search for evidence of CP violation, providing complementary information to NOVA
- Wentworth pit is ~50m deep
- CHIPS will be based on technology already developed for Ice Cube and floating deployment originating from an LBNE study.
- It can run in ME or LE beam (LE preferred)



Soudan is a University Laboratory

- No access restrictions for foreign nationals
- University of Minnesota has constitutional autonomy and sovereign immunity
 - University issues building permits, certificates of occupancy, does code inspections, does environmental reviews
- University administrative infrastructure supports research goals at Soudan
- University monitors environmental health and safety, in cooperation with Fermilab, Minnesota State Parks, OSHA, MPCA; semi-annual inspections; joint safety training with State Parks staff

Question About DURA?

- Question asked by Gilchriese Panel
- Is DURA a Users' Organization solely for Sanford Lab or do its interests extend to other U.S. underground labs (Kimballton, WIPP, Soudan, etc.)?

Soudan Laboratory Future

- Near Term
 - Continue ongoing and approved experiments
 - Consider new experiments expeditiously
- Intermediate Term
 - Be open to new opportunities such as DIANA or NuMI Beam Upgrades
 - Seek funding for infrastructure improvement
 - Additional access
 - Increased underground electric power capacity

Acknowledgements

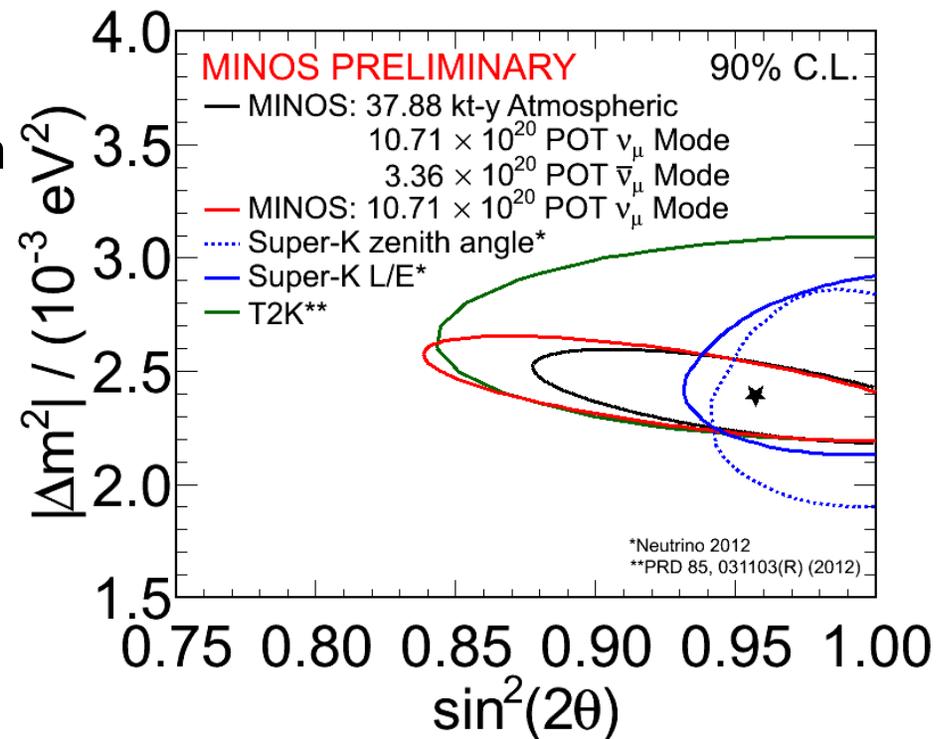
- Thanks to Calvin Alexander, Dan Bauer, Lindsey Briscoe, Priscilla Cushman, Alec Habig, Bill Miller and Jerry Meier for slides.
- Thanks to the Office of Science, U.S. Department of Energy and the National Science Foundation for support of research and outreach programs at the Soudan Laboratory.
- Thanks to the Minnesota Department of Natural Resources for cooperation in the facilitating the research and outreach programs at Soudan.
- Thanks to the University of Minnesota for financial and administrative support.
- Thanks to the People and State of Minnesota for their continued support of education and research to better people's lives.

Information About Soudan Lab Program

- The following slides include more information about the Soudan Laboratory Scientific Program.

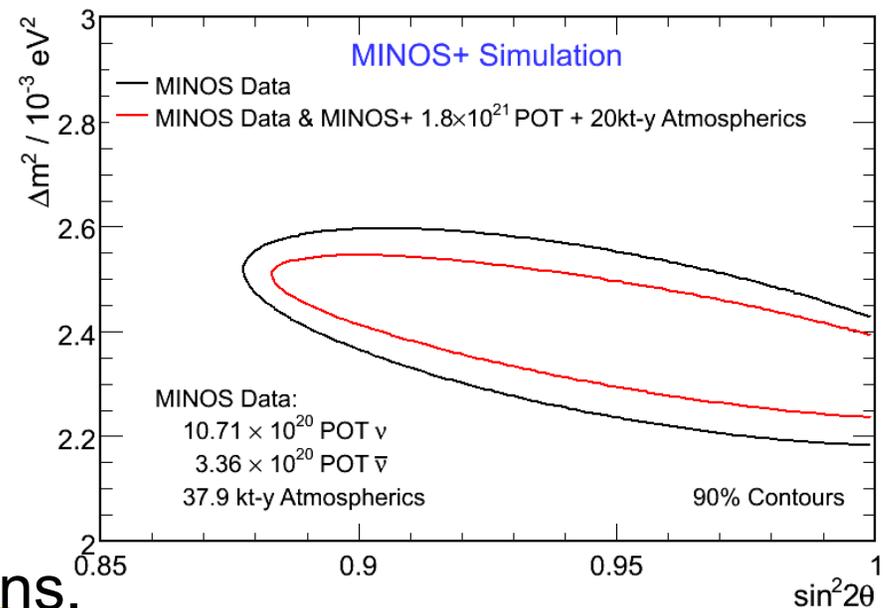
MINOS

- Long baseline neutrino oscillation experiment
 - Measurement of 2-3 oscillation parameters for both neutrinos and antineutrinos
 - Observation of 1-3 oscillations
 - Limits on sterile neutrinos, neutrino decay and non-standard interactions
 - Measurement of neutrino velocity
 - Cosmic ray studies including atmospheric correlations



MINOS+

- Exposure of MINOS Detector to Medium Energy Beam for NOvA Experiment
- ~3,000 events per year ≥ 4 GeV
- Improved 2-3 oscillation parameter measurements
- Extended sensitivity to sterile neutrinos, standard and non-standard neutrino oscillations, extra dimensions and non-standard interactions and atmospheric neutrino oscillations.



SuperCDMS Soudan Experiment

Science Goal

Direct detection of dark matter as Weakly Interacting Massive Particles

Detectors

Pure germanium crystals with interleaved charge and phonon sensors on both sides to provide excellent background rejection

Cryogenics

Cool to near absolute zero in order to see single particle interactions

Shielding and Veto

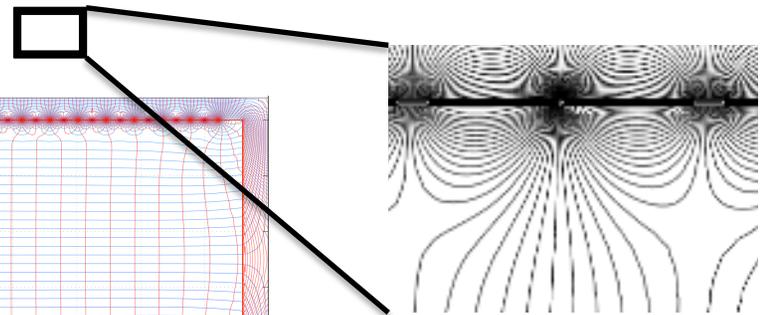
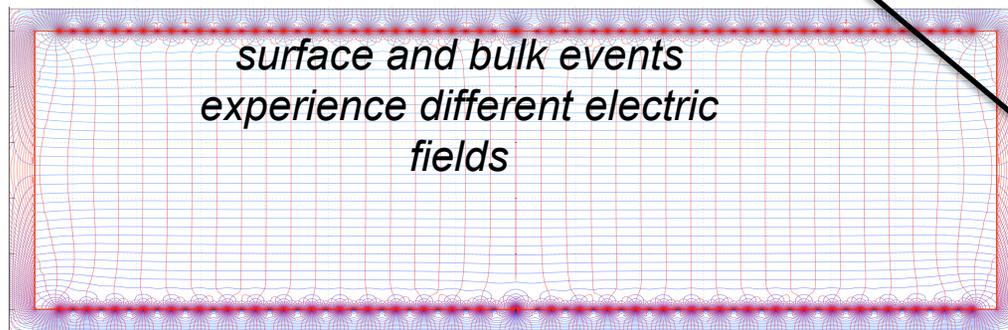
*Reduce flux of radioactive decay particles near the detectors
Actively tag any interactions associated with cosmic rays*

Electronics and Data Acquisition

Custom cold and warm electronics with commercial readout electronics and trigger DAQ software with custom fast event builder and Java-based run control and monitoring

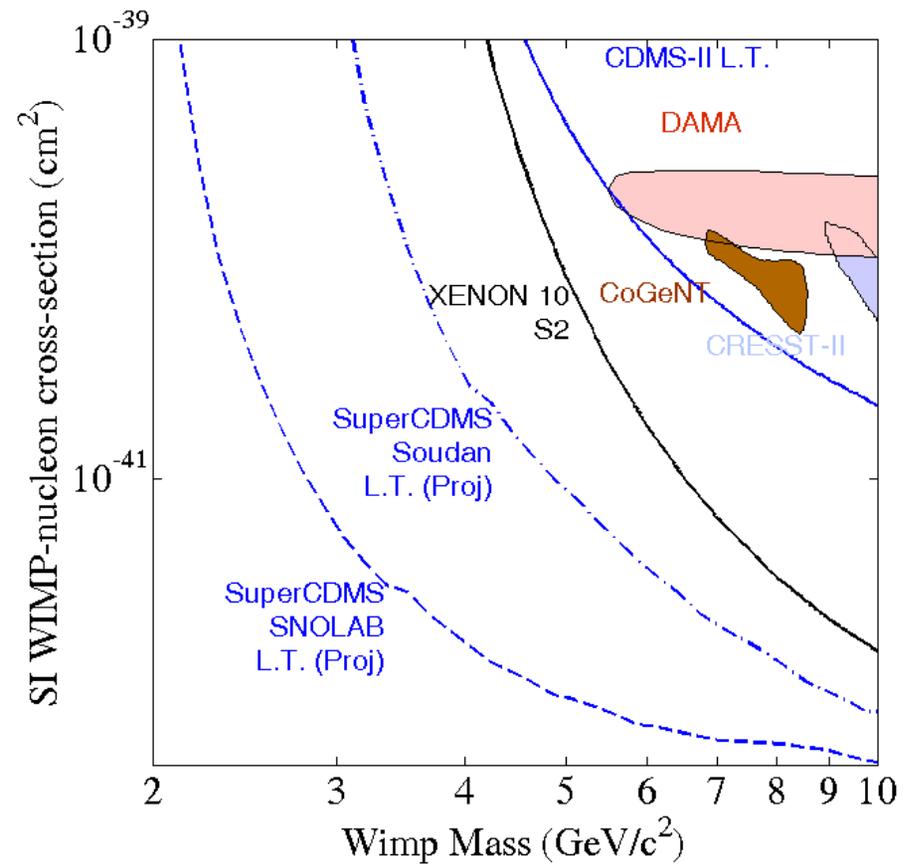
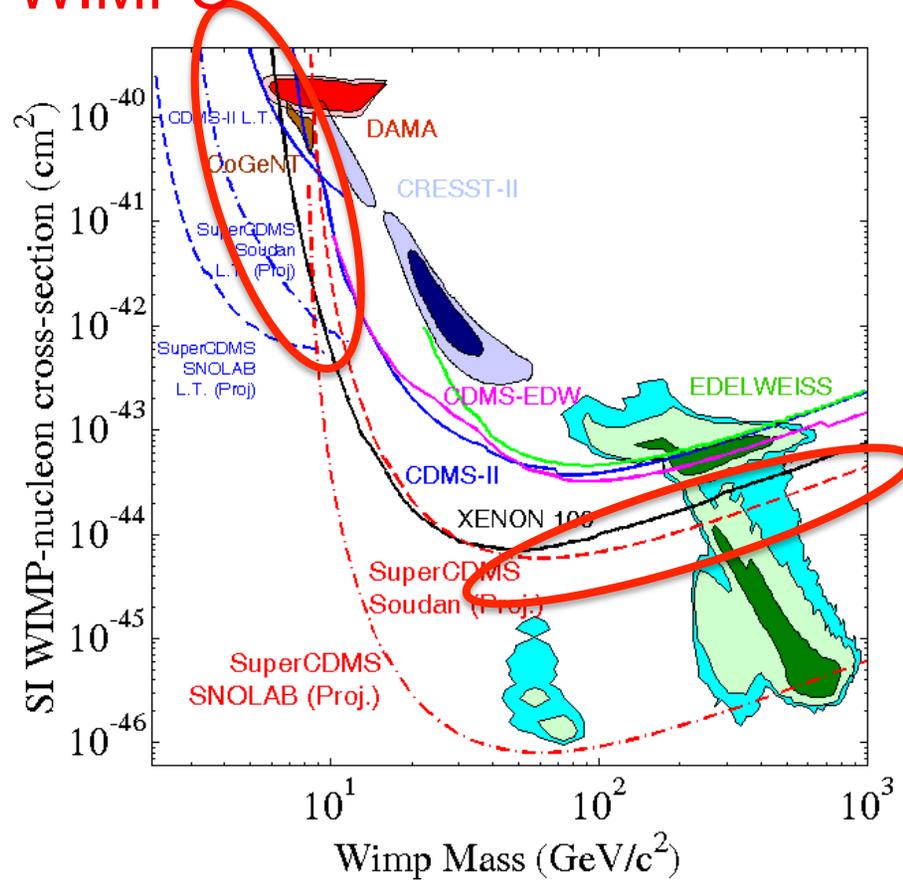
SuperCDMS Uses New iZip Detectors

- Measure both phonons and ionization for each particle interaction; ratio used to identify nuclear recoils
- Interleaved phonon and charge sensors on both sides of the Ge crystal
- Charge asymmetry between surfaces used to reject surface events (x100 better than in CDMS II!)
- Phonon asymmetry and timing provides additional discrimination against electron recoils



SuperCDMS Soudan Physics Reach

Best sensitivity for low (<10 GeV) and high (> 1 TeV) mass WIMPS



Requirements to meet science goals

- Stable data taking for at least 3 years is the requirement for achieving high-mass (>100 GeV) WIMP sensitivity and studying annual modulation. Would need to run until March 2015.
- Much shorter exposures (<200 kg-days) are needed to achieve world leading sensitivity to low-mass (<10 GeV) WIMPS. Will have sufficient exposure by fall 2013.
- Control of backgrounds at the level of <1 event in 27 kg-years of exposure. iZIP detectors have already demonstrated the required surface event discrimination.

Background Expectations

- SuperCDMS Soudan may be limited by neutron backgrounds after ~3 years.
- This is the main rationale for proposing the next phase at SNOLAB

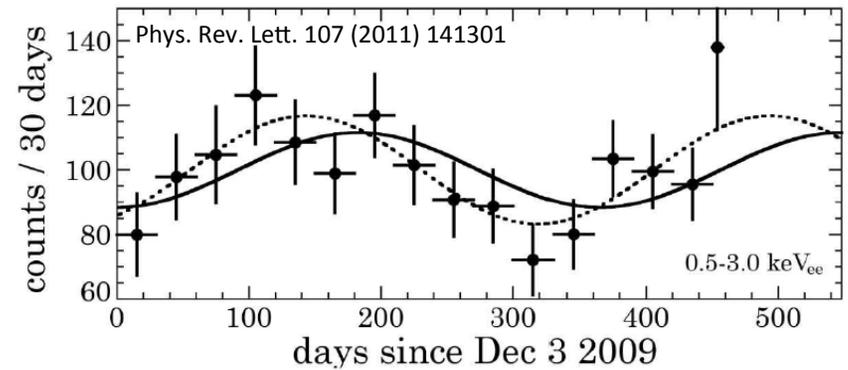
Background Type	Raw rate/kg-y	Background rate in region of interest / kg-y	Number of background events expected in 3 years
Bulk gammas	100,000	0.003	0.08
Surface events	318	0.00087	0.02
Radiogenic neutrons	0.07	0.04	1
Cosmogenic neutrons	5.4	0.013	0.35

Recent History of SuperCDMS Soudan

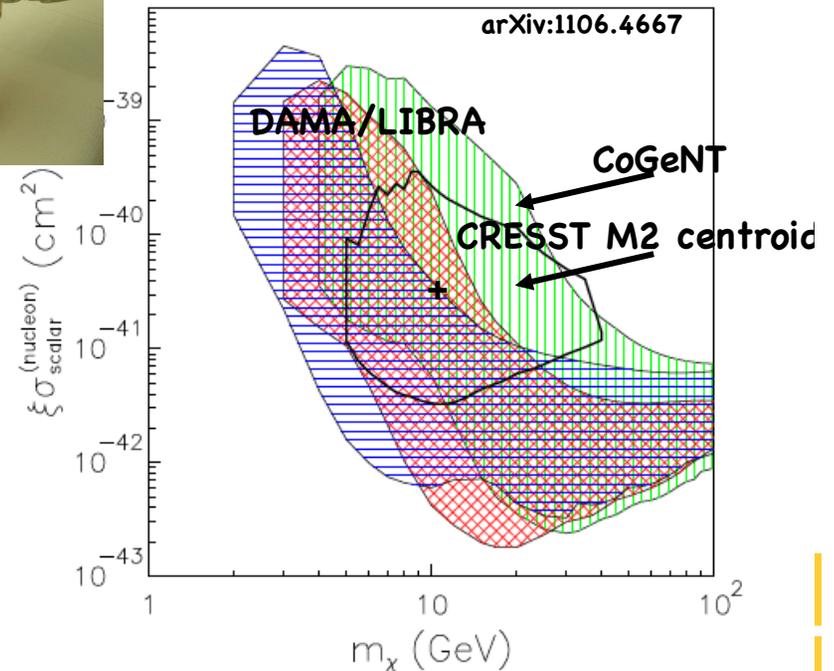
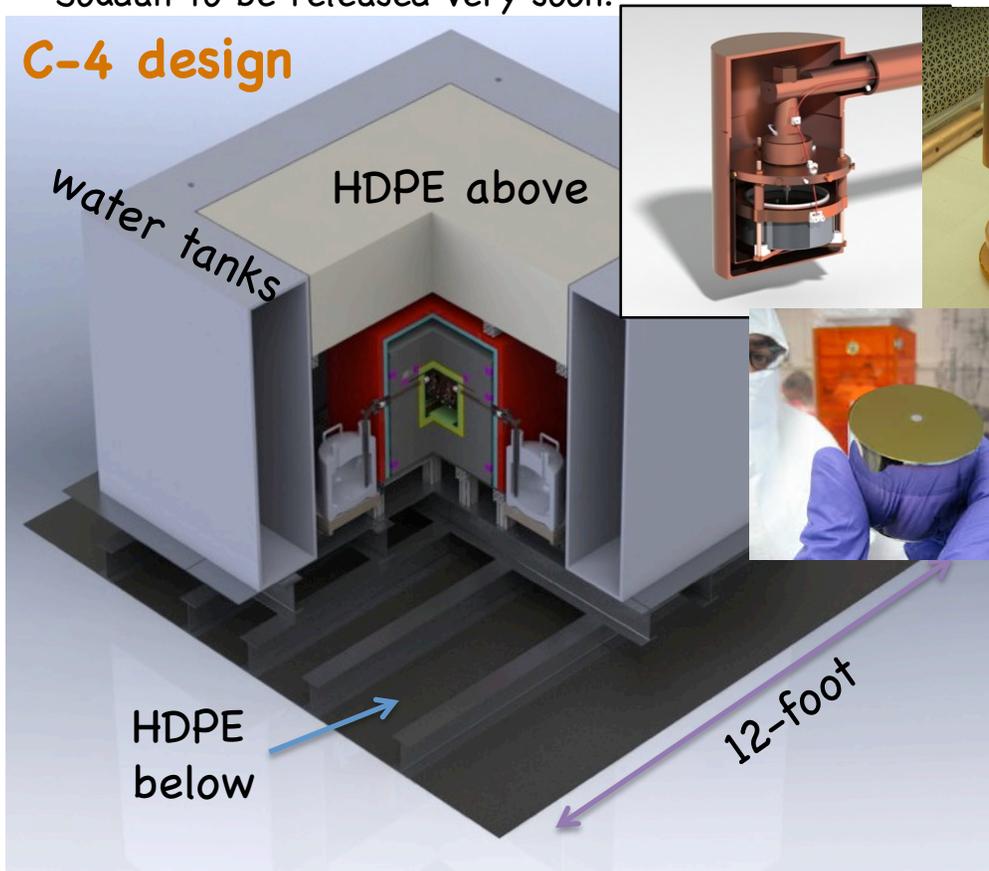
Event	Date
Install iZIP detectors	Oct 25, 2011
Cool to 50 mK	Nov 29, 2011
Start of operations	Mar 1, 2012
Stable data taking	Apr 9, 2012
Data set with very low energy threshold	Aug/Sep 2012
One year continuously at 50 mK!	Nov 29, 2012
Reliquefiers operational	Jan 21, 2013

CoGeNT: dedicated search for light-mass WIMPs

- Annual modulation of unknown origin, measured with 0.4 kg PPC germanium crystal at Soudan, in possible agreement with DAMA/LIBRA & (now) CRESST. Compatible with a light WIMP interpretation.
- C-4 expansion to start 2013 in Soudan (x12 present target mass, significant reduction in bckg and threshold expected). First detector arriving Jan 2013.
- C-4 detectors to feature measures against parallel-f electronic noise (i.e., lower threshold).
- Three years of continuous data-taking from detector at Soudan to be released very soon.



C-4 design



Low Background Counting facility

- Inside Soudan-II muon veto shield
- Clean room ready
 - Large water tank for neutron shielding planned
- Related projects:
 - Two HPGe counting facilities
 - Solo, Gator
 - Neutron counting unit
 - Copper electroforming facility



Earth Sciences

- Extreme Microbiology
 - Plus large bat population
- Geology
 - Precambrian Research Center active in mine as well as surrounding area
- Small experiments:
 - Seismology



"The rocks are the final court of appeal" Francis Pettijohn

Methane Production in Deep Salines



Gas

methane ~ 90%

nitrogen ~ 9%

ethane ~ 1%

propane - tr

butane - tr

Phil Bennett (2007)

unknown iron phase

Goethite + ferrihydrite +
magnetite

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Geomicrobiology and Geochemistry

- Old volcanic and sedimentary rocks
- Isolated from surface environment
- Salinity primary geochemical variable
- Deep sequencing – low diversity
- Suboxic brines dominated by Gallionella
- Communities fall along salinity-redox gradient