GEODM Interest in the SNOLAB Cryopit

2011/08/15 S. Golwala (Caltech) for GEODM Collaboration

From CDMS II to SuperCDMS and GEODM

CDMS II

⌀7.5cm x 1cm ZIP
0.25 kg/detector

16 detectors = 4 kg
2 yr, 1700 kg-d

SuperCDMS Soudan

⌀7.5cm x 2.5cm iZIP
0.64 kg/detector

15 detectors = 10 kg*
2 yr, 4000 kg-d

*iZIP has 2x larger fiducial efficiency than CDMS II ZIP

SuperCDMS SNOLAB

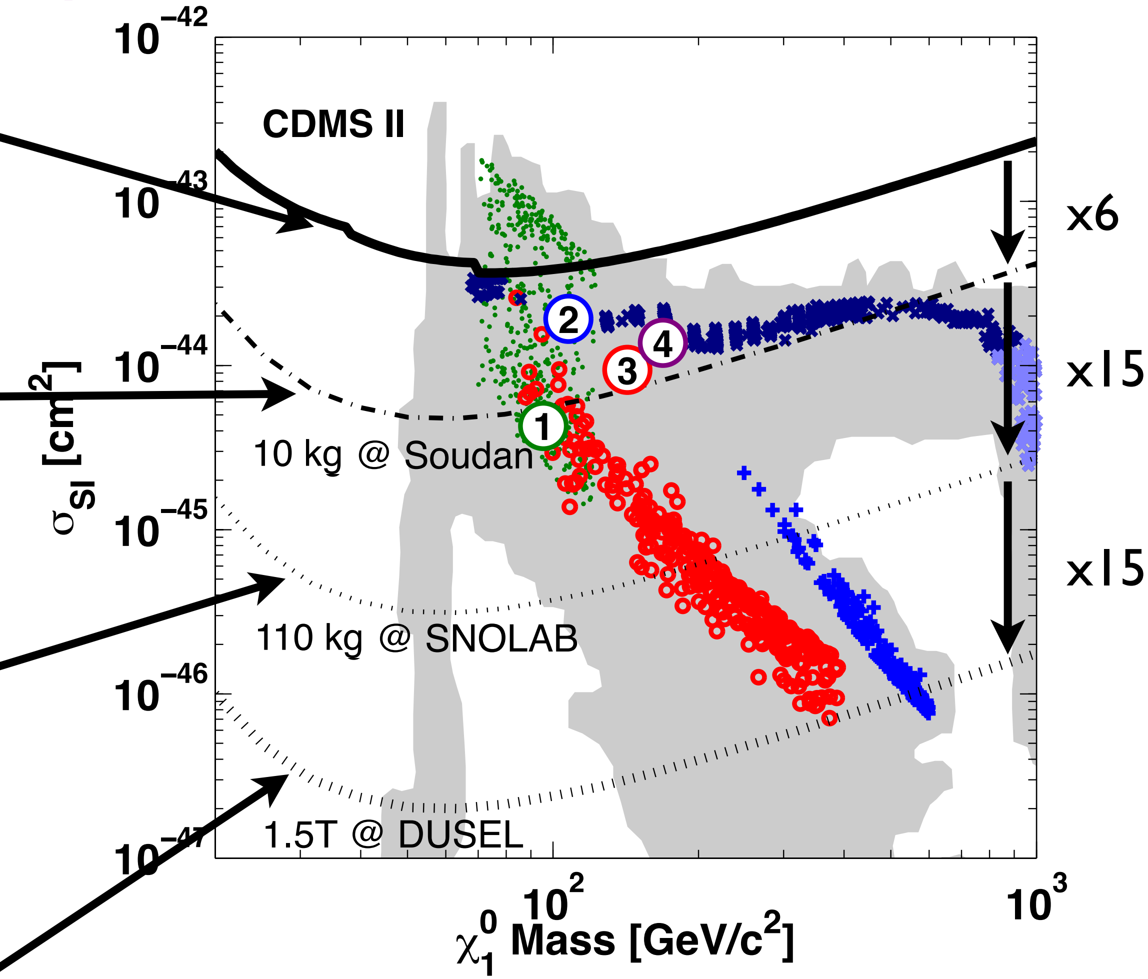
⌀10cm x 3.3cm iZIP
1.5 kg/detector

72 detectors = 110 kg
3 yr = 100,000 kg-d

GEODM

⌀15cm x 5cm iZIP
5.1 kg/detector

300 detectors = 1.5 T
3 yr, 1.5 M kg-d



Staged three-prong program to explore MSSM or study a signal:

- decreased backgrounds
- improved background rejection
- increase in mass/detector and decrease in cost/detector

< 1 event misid'd bgnd at each stage

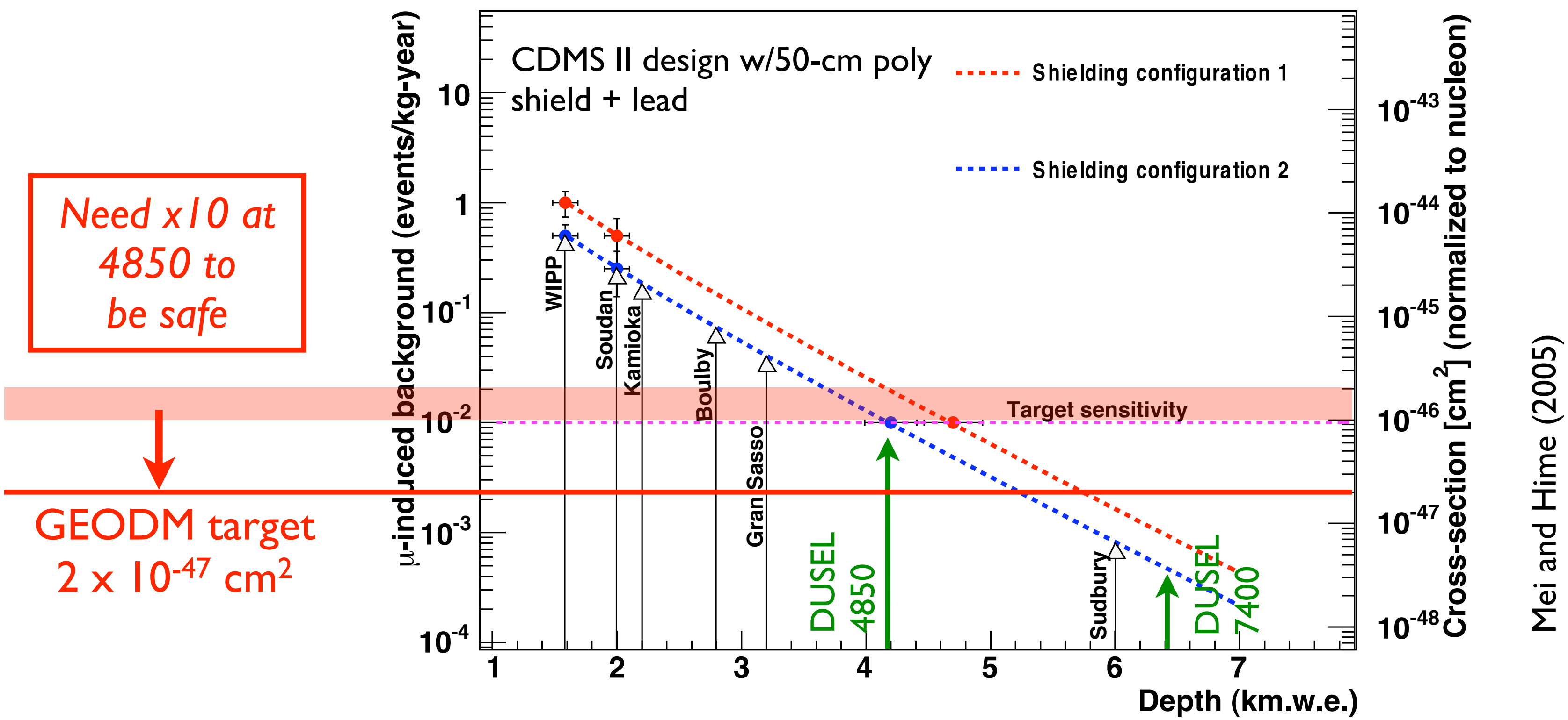
Physics Requirements and Approach

- GEODM: Germanium Observatory for Dark Matter
- Physics requirement: WIMP search with reach of 2 x 10^{-47} cm^2 at 60 GeV/c^2 from 1.5 M kg-d exposure
- Approach to meet this requirement
  - 1.5 tons of cryogenic Ge detectors of SuperCDMS iZIP type; 3 yrs run
    - each detector measures athermal phonons and ionization produced by nuclear and electron recoils in a semiconducting Ge subtrate cooled to 40 mK
    - discrimination between nuclear recoils (WIMPs) and electron recoils (background) by:
      - ionization yield: number of e-hole pairs per keV deposited energy (energy deposition density)
      - fiducial volume cut to remove surface backgrounds and detector reconstruction nonidealities
        - ionization signal radial partition
        - ionization signal top-bottom asymmetry
        - phonon signal top-bottom asymmetry
        - phonon signal timing
    - segmented into 5-kg 15-cm x 5-cm individual substrates assembled in towers
  - Employs shielding to reduce backgrounds to acceptable level
    - low U/Th Cu cryostat and 50-cm thick Cu shield for photons
    - 150-cm thick polyethylene or water shield for radiogenic neutrons
    - deep site provides sufficiently low cosmogenic neutron flux

Physics Approach: Cosmogenic Neutron Backgrounds

- cosmic-ray muon spallation of nuclei in rock walls
- SNOLAB or DUSEL 7400 level reduce background below necessary levels
  - CDMS-II-like shield: cryostat, high-Z gamma shield, low-Z neutron moderator

Need x10 at 4850 to be safe

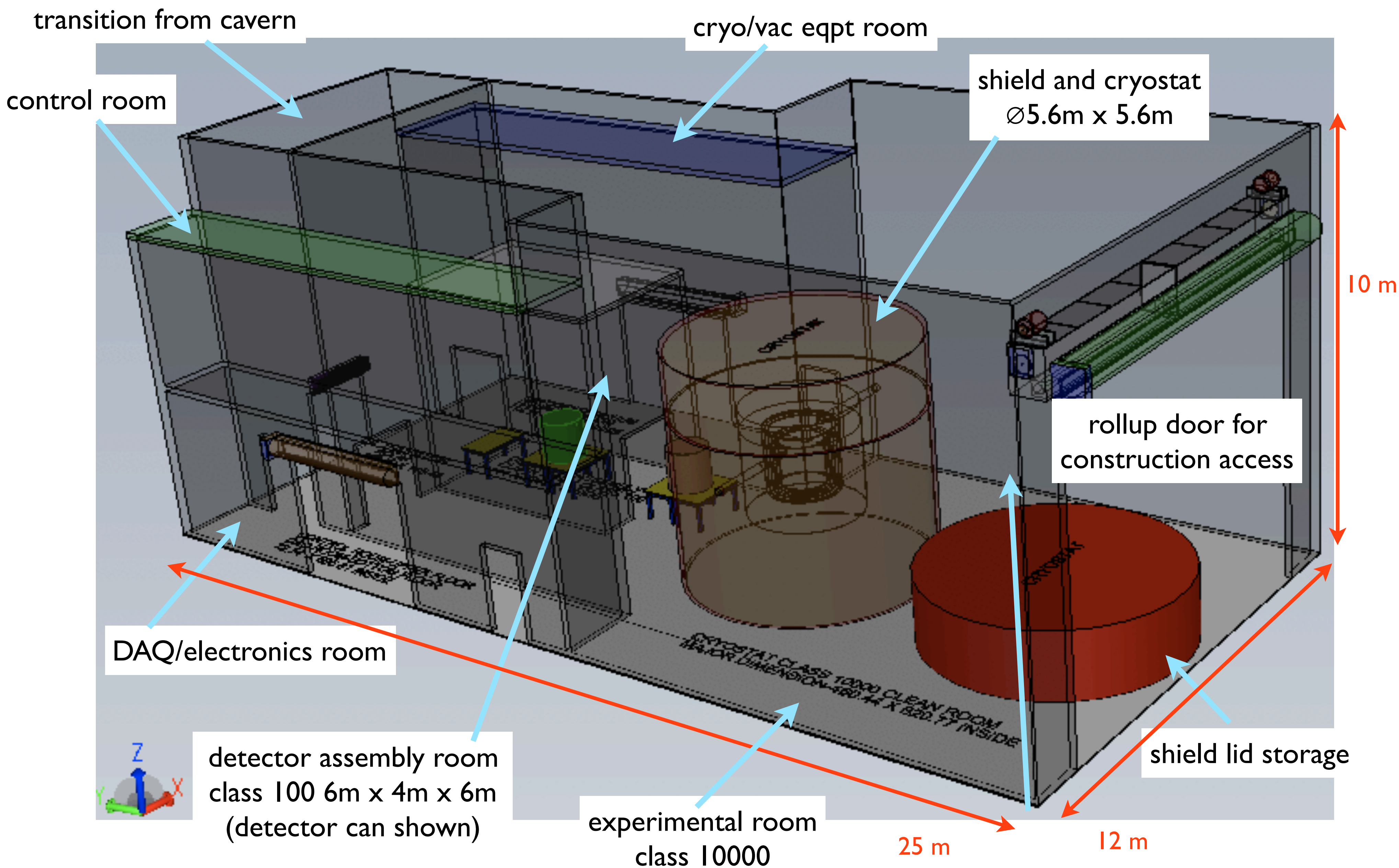


GEODM target
2×10^{-47} cm^2

CDMS II Experience for Lab Requirements

- Cleanroom: 6.8m L x 4.9m W x 5.8m H = 200 m^3
  - Class 1000 unoccupied, class 10000 when people working
- Anteroom (transition from dirty lab, storage):
  4.4m L x 5.2m W x 3.8m H = 90 m^3
- Crane: 5-ton bridge crane, free-standing, enclosed in RF/cleanroom
  - Not clear the RF room works very well...
- Cleanroom sits on following:
  - 30-cm Soudan cavern floor, sloped for drainage
  - 10-cm level slab
  - 1/2-cm polyethylene layer
  - 1-cm steel plate floor of cleanroom
- Cleanroom has mezzanine for shield storage;
  5 tons lead shield + 2 tons polyethylene
- No radon abatement aside from
  - purging of shield volume and cryostat inside when open
  - purged storage of innermost components

GEODM/Homestake 7400 Design

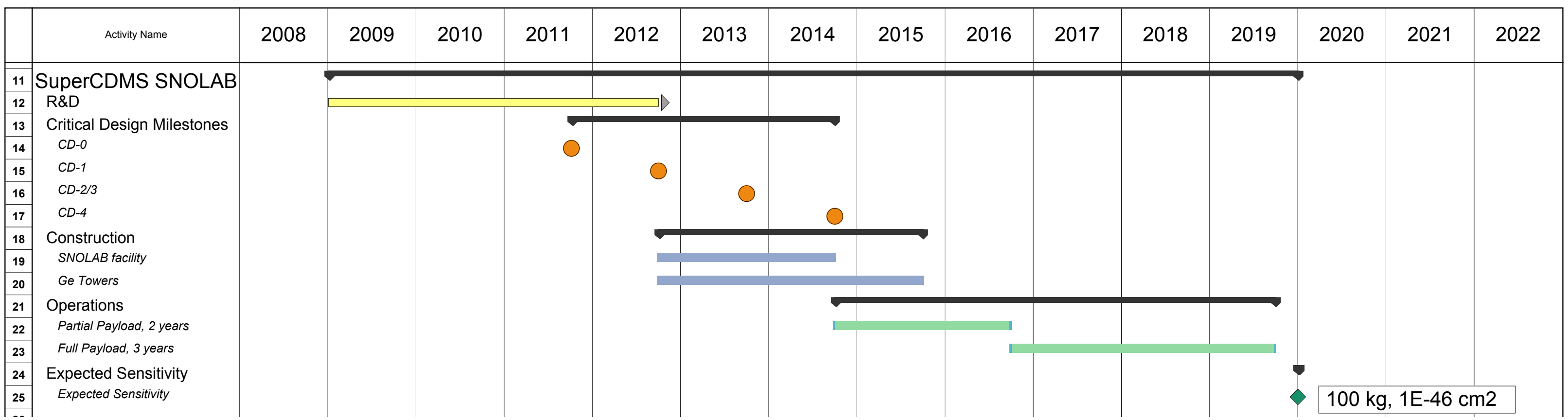


Modifications for GEODM @ SNOLAB

- Cleanliness:
  - SNOLAB = class 2000 cleanroom. Obviates GEODM class 10000 cleanroom.
  - RF barrier to minimize pickup of noise from rest of lab
    - Full enclosure or barrier at entrance to hall? Experience suggests unnecessary?
  - Still need internal class 100 radon-abated cleanroom and temporary structure over experiment during detector payload installation.
- Space
  - Cube hall: 18m x 15m x 15m
  - Cryopit: ∅15m x 15m
  - Shortened 25m dimension compensated by greater overhead space at SNOLAB, in-hall crane, use of drifts for noncritical utilities.
    - DUSEL required experiments to be self-contained inside predefined lab modules; not a requirement at SNOLAB
    - e.g., cryo/vac, DAQ/control could go into drifts or mezzanine level
- No other major issues; likely cost-neutral or less expensive thanks to excellent SNOLAB infrastructure.

Timescale

- SuperCDMS SNOLAB currently expecting start of science operations at start of FY15
  - Getting project-specific R&D funds in FY11
  - Begin construction of facility, long-lead-time purchases in FY12
  - Must do experiment-specific R&D, pass CD milestones, and keep cost reasonable



- GEODM desired timeline *for SNOLAB siting*
  - Start project-specific R&D phase of GEODM in ~2015
  - Construction start ~2017/2018
  - Science operations start ~2020
  - Takeaway: need a hall of size similar to cryopit or cube hall in latter years of decade.

Lab Interface Requirements

- Following are lab interface requirements developed for DUSEL design, quickly adapted for SNOLAB.
- More careful and SNOLAB-specific assessment needs to be done.
- Esp. need to consider hoist trip requirements: very lab specific.

Power/Cooling

- 173 kW for experiment
- Cooling
  - 100 kW directly by chilled water
  - 73 kW by cavern ventilation; need additional chilling capacity?
- Emergency power
  - 80-100 kW UPS to enable carryover to generator
  - Generator-supplied 80-100 kW to keep system cold during outage
    - Avoids cryogenic cycle time

Item	Power Draw	Cooling Method
4 pulse tube coolers	60 kW	chilled water
DR circulation pumps	40 kW	chilled water
class 100 cleanroom air handler	5 kW	cavern vent.
front end electronics	30 kW	cavern vent.
back end electronics	20 kW	cavern vent.
control room	5 kW	cavern vent.
back end/control room air handler	13 kW	cavern vent.
Total expt	**173 kW**	

Ventilation/Radon Requirements

- Modest amounts of cryogenic liquids
  - few x 100L LN, LHe
  - Need more during cooldown to assist cooling
- Radon mitigation required during opening of cryostat/detector installation
  - LN boiloff purges radon from between high-Z shield and poly and inside poly during normal operation
- Implementation of radon abatement:
  - Need ~ 30 m^3 radon-abated volume around inner can for detector insertion
  - Need similar sized volume over cryostat during inner can insertion
  - Existing radon abatement systems (Ateko) provide 150 m^3/hr at 1 mBq/m^3 using 15 Bq/m^3 input air for ~$200k and ~50 kW. Achieved 150 mBq/m^3 at 1 air change/hr for NEMO-3, probably limited by leaks.
  - Even with ~ 500 Bq/m^3 and higher output radon level due to higher change rate (10-60 changes/hr) seems likely could achieve < 1 Bq/m^3 in 30 m^3
  - Need to detail power requirements, hazards; but low duty-cycle for use, anti-phased with experiment cryo/electronics power needs, so doesn't increase total power draw.

Floor Loading and Hoisting Needs

- Dominant weights:
  - Copper shield: 100 tons, segmented
  - Polyethylene or water or liquid scintillator shield: 125 tons, segmented
- Floor loading:
  - Close-in shield: ~250 tons spread over ~6 m diameter circle = 10 tons/m^2
- Crane
  - Need a 20-ton crane to hoist shield parts for opening of cryostat.

Dimensions

- What dimensions set our needs for hoist trips?
  - Detectors? no, 1.5T Ge only ~ 1m^3, will come down in multiple trips
  - Cryostat? yes, 77K can ~1.6m diameter & height. Can make cryostat aspect ratio flat to accommodate. Vacuum shell will need a split flange and its diameter will be limited. Dogleg parts long and thin.
  - Dilution fridge? no, long and thin.
  - Dilution fridge plumbing? no, can be disassembled into parts that can be joined underground
  - Shielding material?
    - High-Z: will need to segment into blocks anyways, hoist capacity will set limit
    - Scintillator panels? Long thin, light transport sets natural limits anyways.
  - Pumps and chillers? They will fit. Could always be disassembled and reassembled.
  - Air handlers: may need to disassemble
  - Structural elements: clean room walls, long structural pieces
  - Electronics? Can be disassembled.
  - Purge cabinets: can be assembled underground

Major Hazards

- Major hazards
  - Lifting
  - Cryogenic hazards during cooldown
  - HV for PMTs
  - Vacuum loss
  - Fire hazard due to plastic scintillator veto (~6 m^3 of plastic scintillator)
  - Water tank if water moderator shield
  - Fire, chemical hazard due to liquid scintillator neutron veto if implemented
  - Electrical/water interaction if instrumented water moderator shield

IT Requirements

- IT: 50 TB/day data rate, rather demanding
  - because # sensors/mass is not being reduced. Details:
    - 16 bit digitization → 2 bytes/sample, 5000 samples at 1 MHz, 64 channels/detector = 640 kB/event/detector.
    - Assume 10 detectors on average in each event → 6.4 MB/event.
    - Event rate ~ 0.3 Hz in CDMS II, x 300 in mass, so 100 Hz → 640 MB/sec, 50 TB/day
    - Probably a substantial overestimate:
      EM bgnd will be reduced because of U/Th reductions needed to reach desired radiogenic n bgnd, self-shielding of inner detectors will reduce rate
  - Need 10 Gb/s ethernet, few days local storage needed ($100/TB today).
  - Calibration mode is greater challenge: ~100x faster for 10% of the time , but don't need to keep up with rate in real time. Still, would increase needs by x10. Need to select energy region of interest online to cut down rate.
  - Send all data to surface ~immediately for local backup, fast analysis
  - Transfer data off-site immediately, need to buffer in case of network outage.
  - Few days local storage, CPU to do quick offline diagnostics
  - Need 10 Gbits/sec out of SNOLAB to off-site storage
- Need routine remote control access (on- and off-lab)

Other Space Needs

- Underground materials manufacture, storage
  - No: cosmogenic activation not an issue
- Surface needs
  - Storage of materials between arrival and transport underground;
    Largest parts: cleanroom walls, water tank raw materials
  - Office space for up to 5-6 people, facilities for collaboration meetings
  - Machine and electronics shops for utility work, but no substantial machining or electronics design or manufacture on-site.

Staging 1: Dirty

- Preparation and sealing of main experimental hall, but not final clean
- Bring in construction materials for RF barrier and inner class 100 cleanroom, cryostat vacuum can, refrigerator, cryocoolers before room becomes clean.
- Cryo/vac, DAQ/electronics, control room can be constructed in parallel or afterward.
  - Once cryo/vac and DAQ/electronics rooms are ready, this equipment can be brought down and installed in parallel with inside-clean-room operations.
    - Not as complicated, no cleanliness requirements except in making feedthroughs.
    - Includes radon abatement system up to feedthrough ducts to clean room
- Construct class 100 cleanroom, do all mechanical infrastructure work for cryostat, shield, refrigerator, cryocoolers (i.e., frame to hold fridge, mechanical structure to hold cryostat and shield materials, etc., but not the cryostat itself yet)

Staging 2: Clean

- Go class 2000 in experimental hall, class 100 in inner cleanroom
- Reclean all items inside cleanroom.
- Begin construction of shield, cryostat, and refrigerator/cryocooler.
- Bring in cryostat cans. Maintain in radon-free storage.
  - Could bring them in earlier if transported in and stored in airtight, purgeable containers
  - Radon abatement by purge from gas canisters, not radon-abated air.
- Plumb radon-abatement system into class 100 cleanroom and cryostat cover tent (through HEPA filters)
- Install cryostat cans
- Bring in detectors in batches through transition and store in class 100 cleanroom in radon-free storage (purge cabinet)