SNOLAB:

AstroParticle-Physics Research in Canada

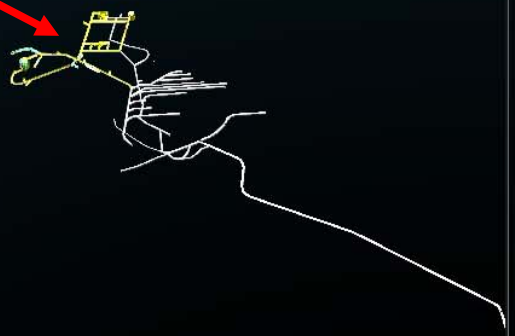
- Overview and Status of the facility
- Current Scientific programme
- Schedule

T. Noble Queen's University

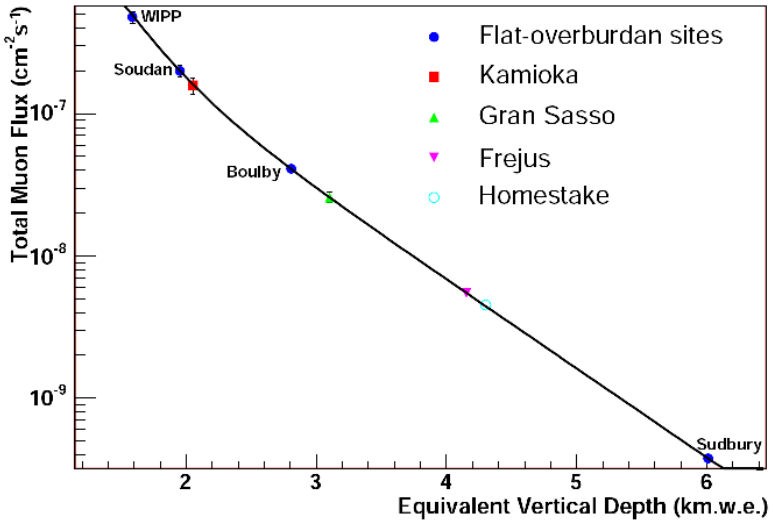
Surface Facility

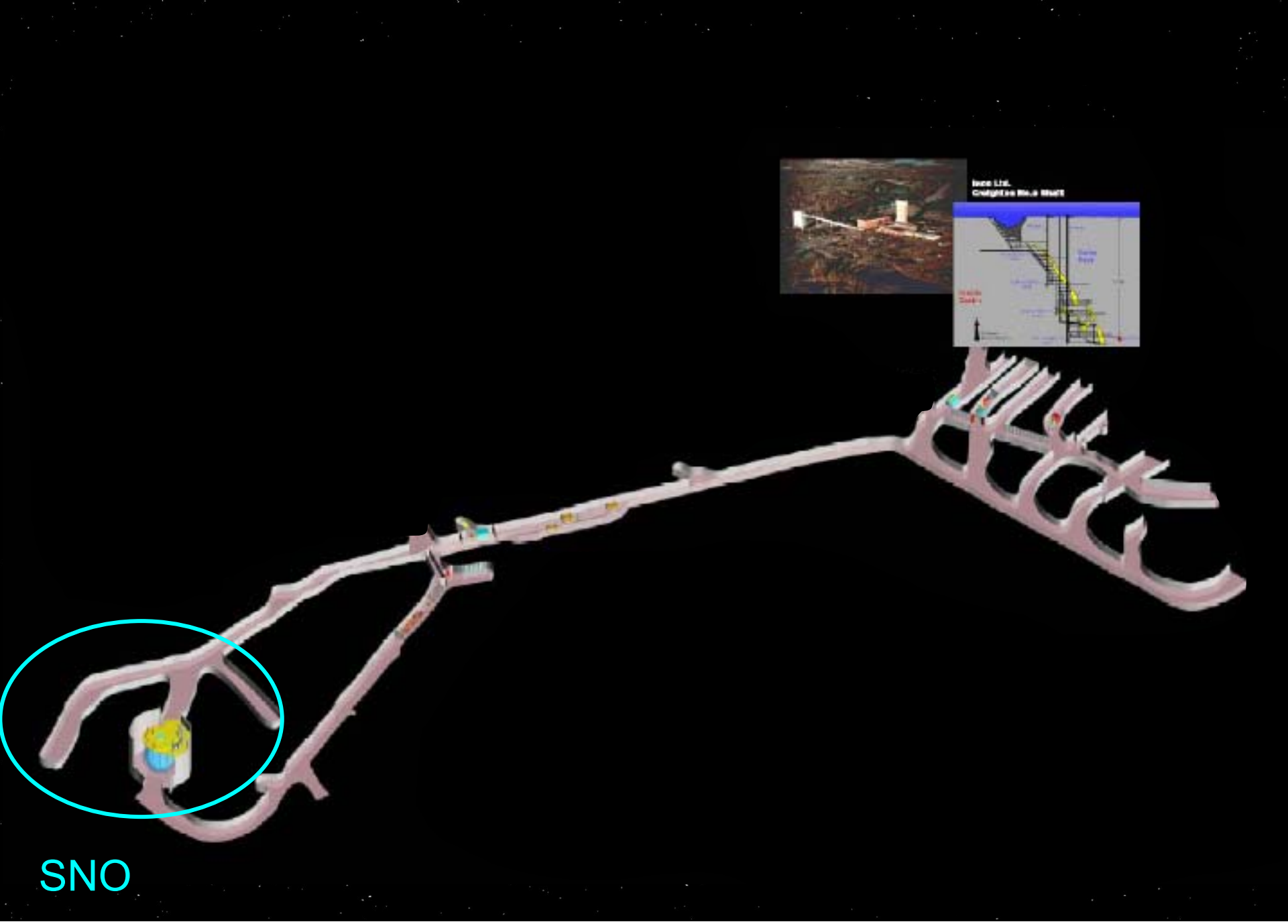
2km overburden (6000mwe)

Underground Lab Clean Room



Muon Flux = 0.27/m^2/day




SNO

Laboratory Space

	Excavation Area	Excavation Volume	Clean Rm Area	Clean Rm Volume	Laboratory Area	Laboratory Volume
Existing	20,049 ft^2 1,863 m^2	582,993 ft^3 16,511 m^3	12,196 ft^2 1,133 m^2	470,360 ft^3 13,321 m^3	8,095 ft^2 752 m^2	412,390 ft^3 11,679 m^3
Existing + Phase I	65,340 ft^2 6,072 m^2	1,367,488 ft^3 38,728 m^3	41,955 ft^2 3,899 m^2	1,049,393 ft^3 29,719 m^3	26,117 ft^2 2,427 m^2	837,604 ft^3 23,721 m^3
Existing	77,636 ft^2	1,647,134 ft^3	53,180 ft^2	1,314,973 ft^3	32,877 ft^2	1,043,579 ft^3
+ Phase I&II	7,215 m^2	46,648 m^3	4,942 m^2	37,241 m^3	3,055 m^2	29,555 m^3

SNO: 752 m^2 lab space single experiment

4 x the space

SNOLAB: 3,055 m^2 lab space ~4 large experiments, several medium/small

SNOLAB

Construction Status

Surface Facilities

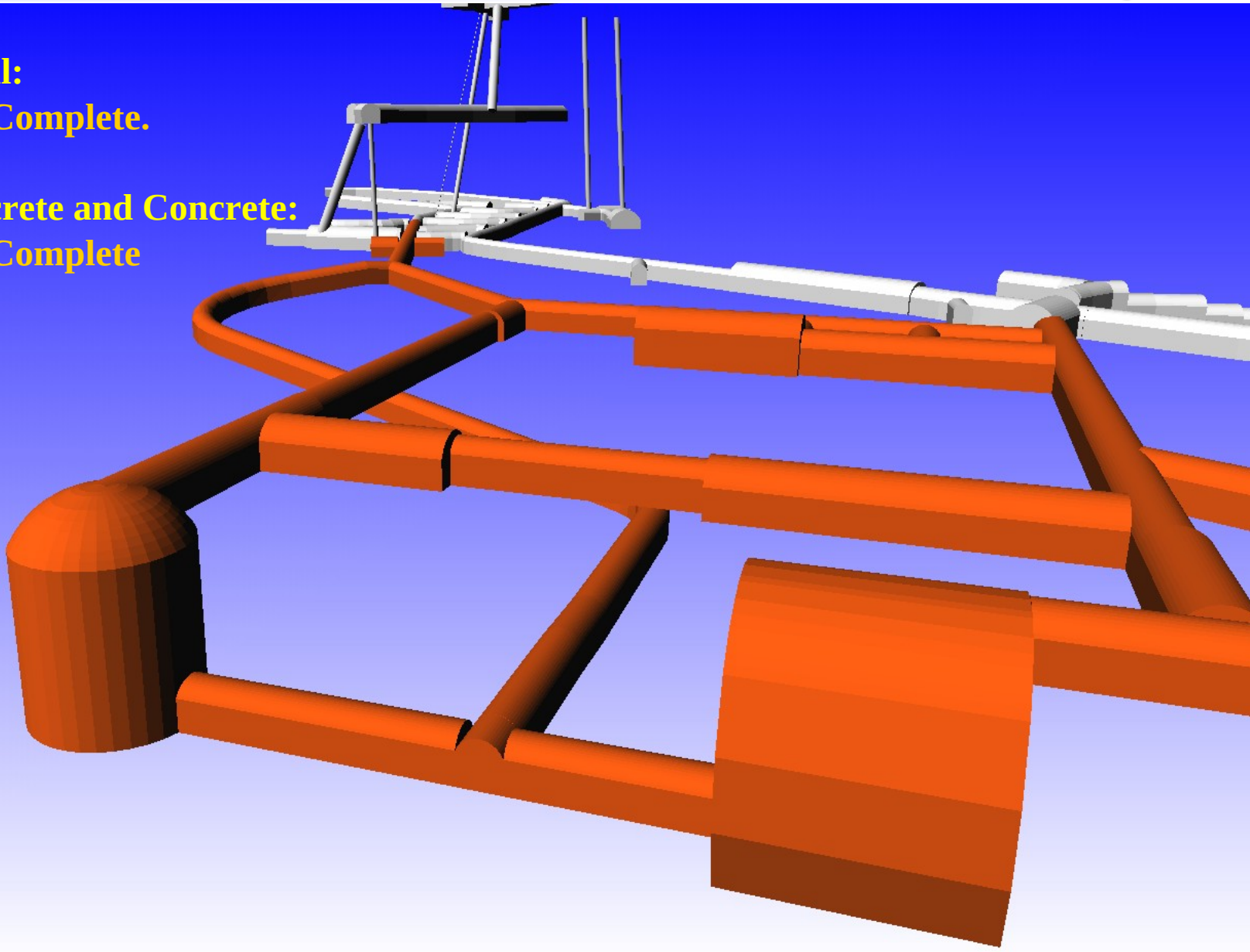
Excavation Status

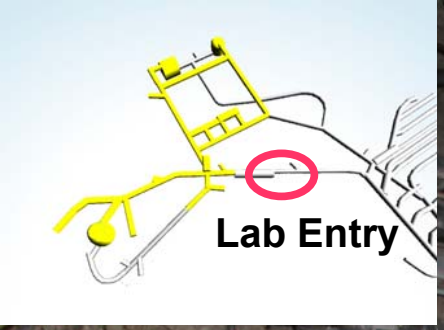
Rock Removal:

100% Complete.

Bolting, Shotcrete and Concrete:

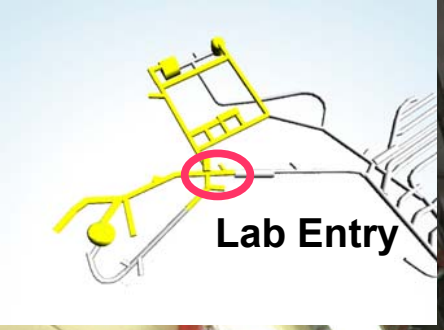
100% Complete



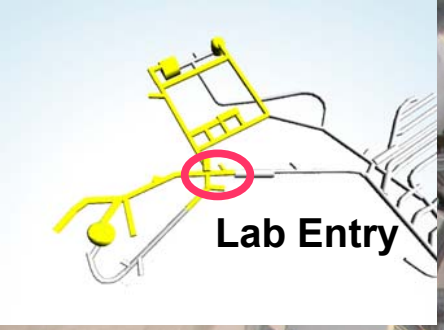

Lab Entry


Lab Entry
CAUTION

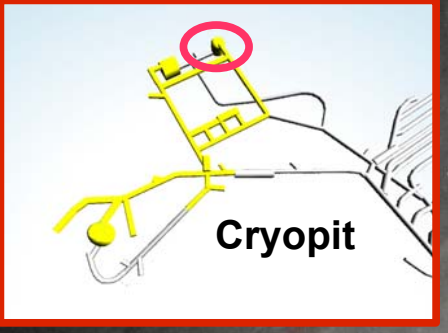

Personnel
Facility


Lab Entry


Personnel
Facility


Lab Entry


Cube Hall


Cryopit


Ladder
Labs


Personnel
Area

SNOLAB Status Summary

- Underground Construction (Cube Hall, Cryopit, Ladder Labs, Lab Entrance)
  - Excavation 100% complete.
  - Outfitting (elctrical, lighting, water, HVAC, infrastructure…) ~100% Complete.
  - Commissioning and final cleaning ongoing. Junction area, refuge station, now part of new clean area. Clean boundary extended to new entrance.
  - Spaces available now for experimental infrastructure installation.
- Surface Facility
  - Operational since 2005.
- Experimental Program
  - Assignments of space underground on an ongoing basis. Review by international Experimental Advisory Committee
  - Currently Operational: PICASSO, DEAP I, PUPS
  - Approved experiments: SNO+, DEAP/CLEAN, MiniCLEAN, SuperCDMS.
  - Under Review HALO
  - Anticipated (awaiting formal application to SNOLAB) EXOgas 200, COUPP?

SNOLAB

Scientific Program

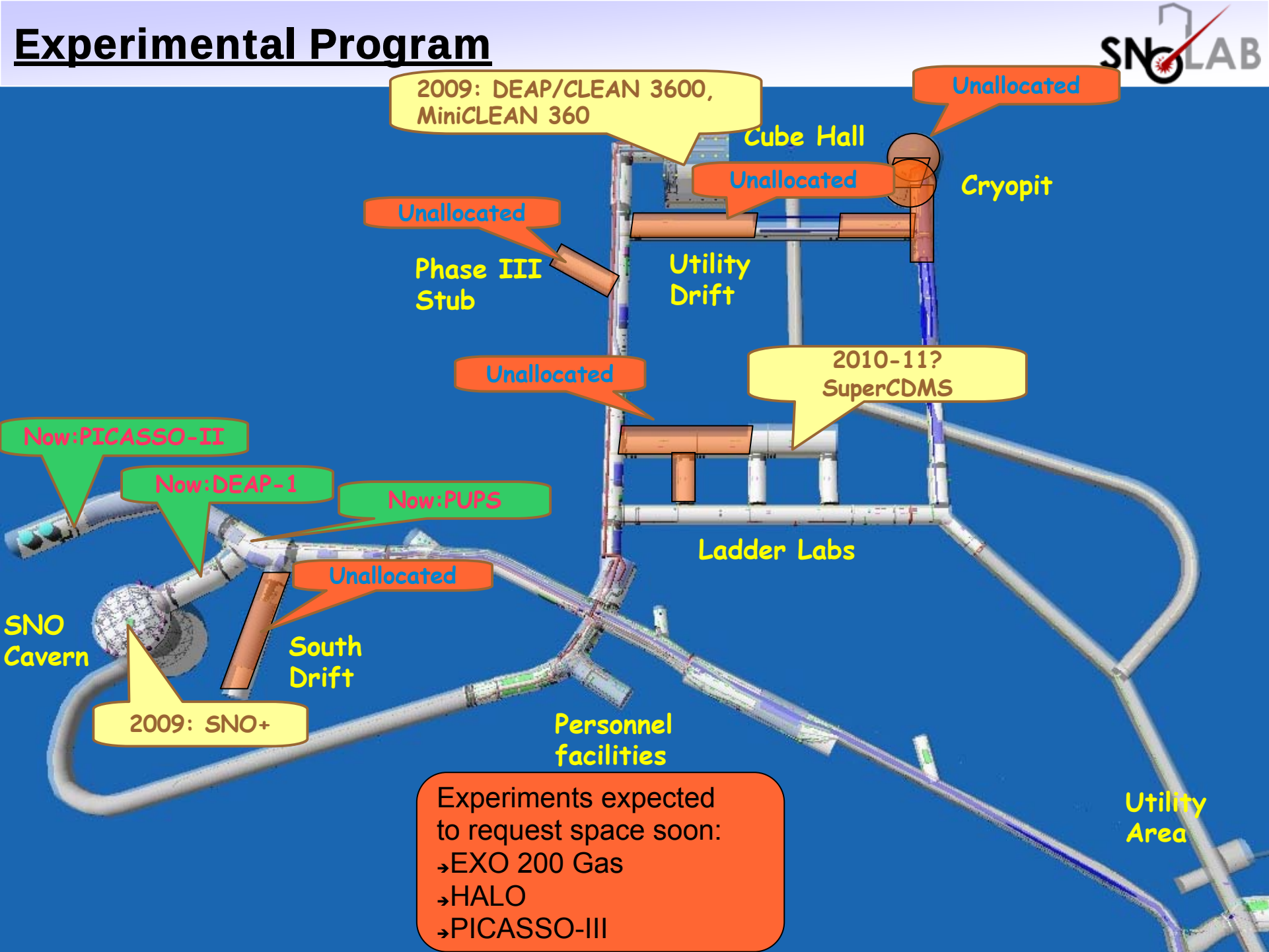
The Niche for SNOLAB:

- Focus on dark matter, double beta decay, solar & SN
- Large scale expt's = ktonne, not Mtonne
- Ready for occupancy now.
- A unique clean and very deep resource: A new facility with space available now and for the next few years.

Experimental Program

Experiment	Solar Nu	0nuBB	Dark Matter	Super nova	GeoNu	Other	Space Allocated	Status
SNO+	X	X		X	X		SNO Cavern	Install 2009
PICASSO			X				SNO Utility Room	Running
DEAP-1			X				SNO Control Room	Running
MiniCLEAN 360			X				Cube Hall	Install 2009
DEAP/CLEAN 3600			X				Cube Hall	Install 2009
EXO		X						Install 2010?
SuperCDMS			X				Ladder Labs	Install 2010?
HALO				X				Install 2009
PUPS						Seismic	Various Locations	Running

Experimental Program



Status of Experiments

Dark Matter at SNOLAB

Noble Liquids: Deap I, DEAP/Clean, & MiniClean :

- Single Phase Liquid Argon.
- Uses pulse shape discrimination
- Prototype DEAP I Installed in SNOLAB now. Very successful demonstration of PSD.
- Will measure Spin Independent cross-section.

Superheated Liquids: PICASSO: COUPP ?

- Superheated droplet detector. Insensitive to MIPS radioactive background at operating temperature.
- PICASSO Currently Operational in existing SNO lab. Next phase will need SNOLAB space.
- Will measure Spin Dependent cross-section.

Solid State: SuperCDMS :

- State of the art Ge crystals with ionization and phonon readout.
- Has led the field for many years. Currently operational in Soudan. Next phase will need SNOLAB depth to reach desired sensitivity.
- Most sensitivity to Spin Independent cross-section.

DEAP/CLEAN Program
At SNOLAB

DEAP-1:

- 7 kg prototype experiment
- run at Queen's for demonstration of PSD
- installed underground at SNOLAB in 2007 for continued PSD and background studies, DM search

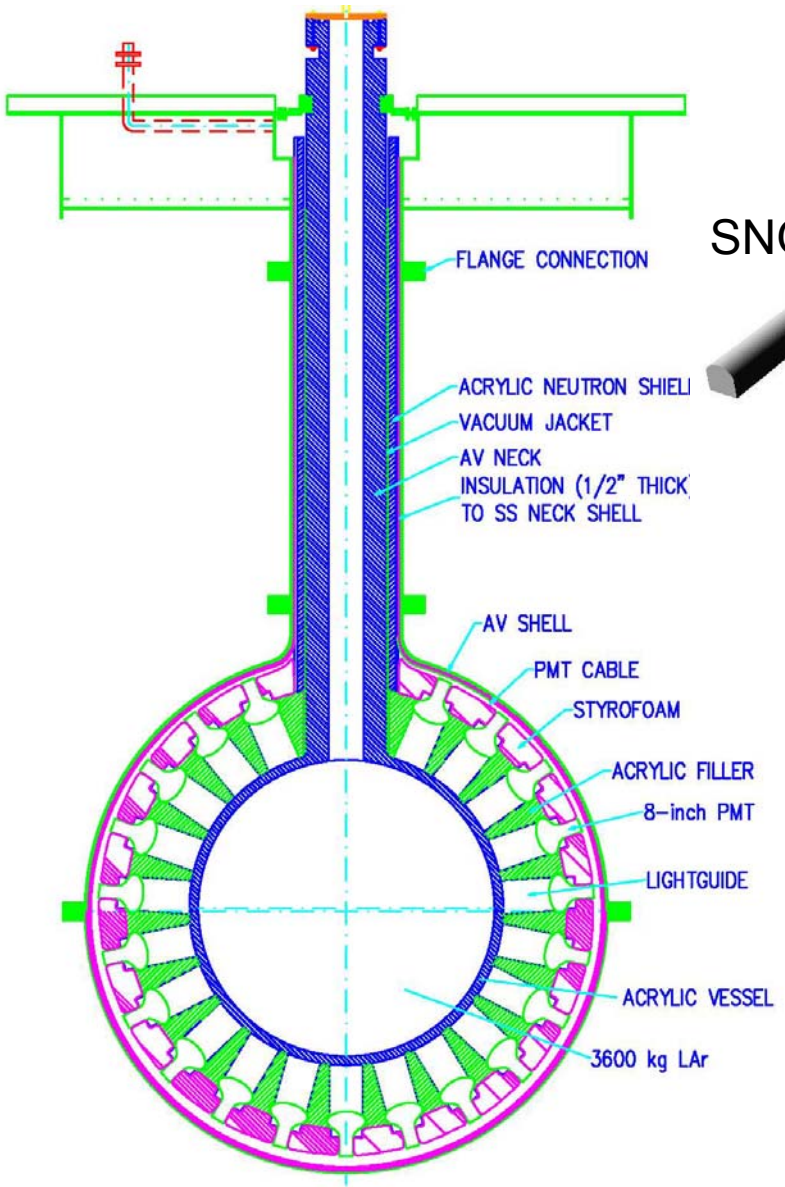
DEAP/CLEAN-3600:

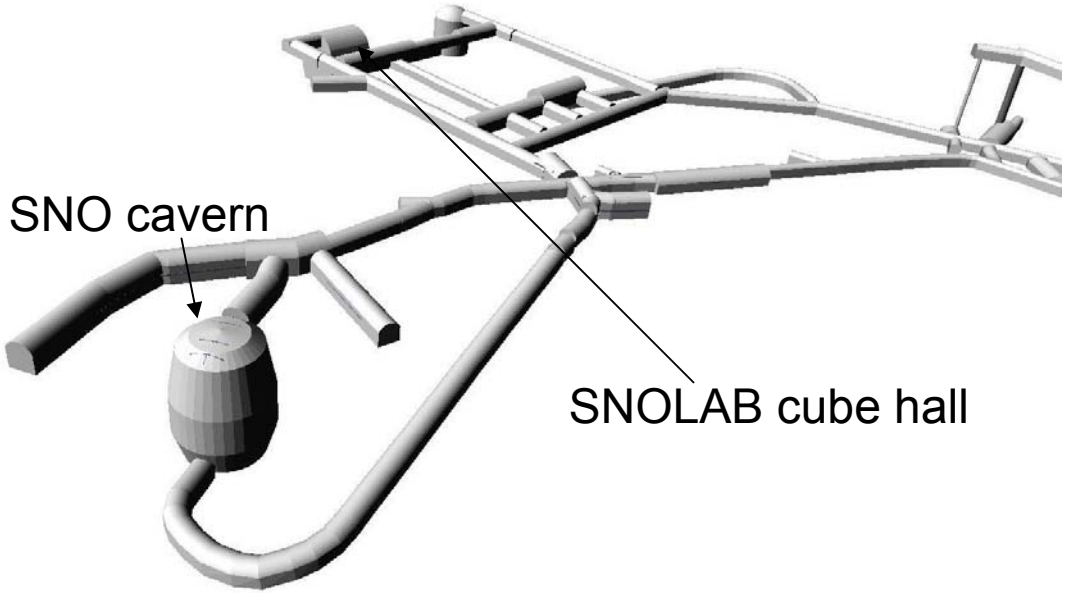
- 3600 kg experiment targeting DM with LAr
- Cyogenic Acrylic Vessel (AV) for radon mitigation
- Primary emphasis of Canadian collaborators in short term

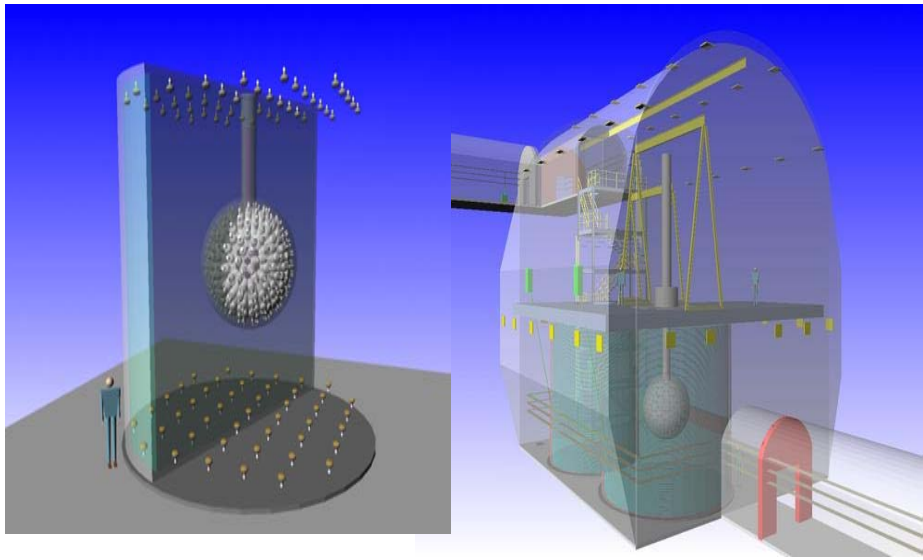
miniCLEAN:

- 360 kg experiment targeting DM with LAr and prototyping neon for DM/solar neutrinos
- Modular design, assembly in glove box for radon mitigation
- primary emphasis of US collaborators in short term

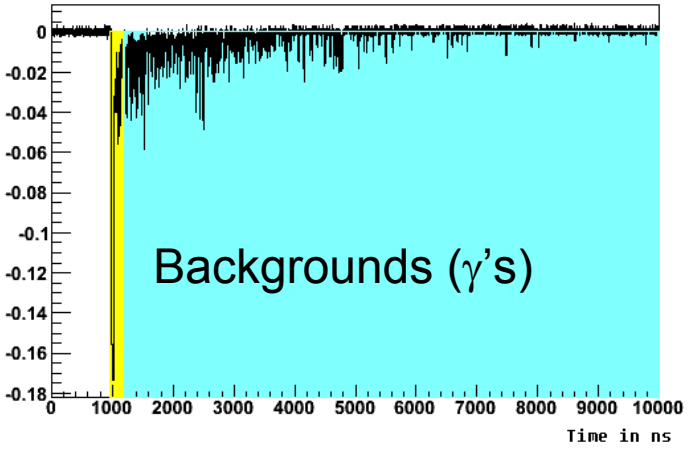
DEAP/CLEAN 3600 construction will begin at SNOLAB 2009,



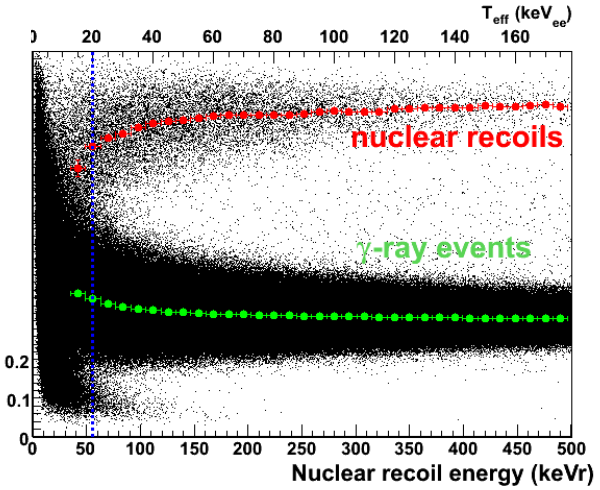


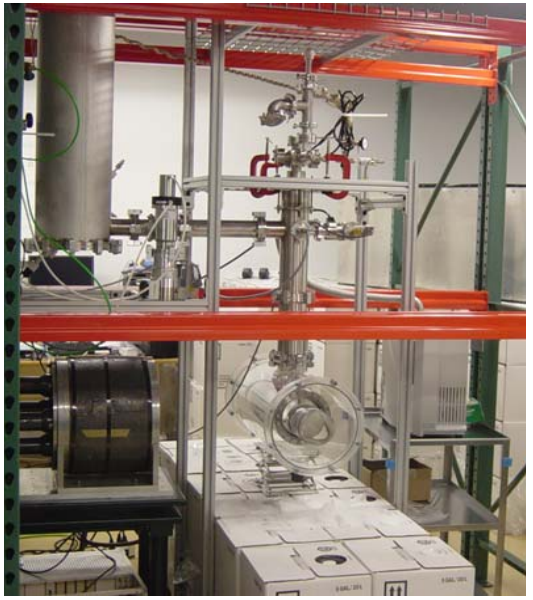


Background suppression with PSD in DEAP-1

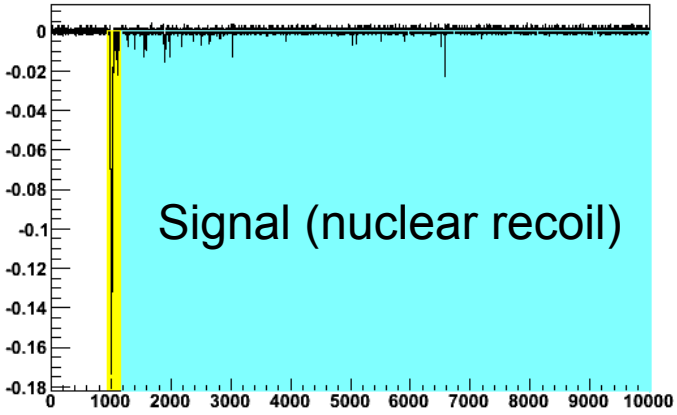


Yellow: Prompt light region
Blue: Late light region

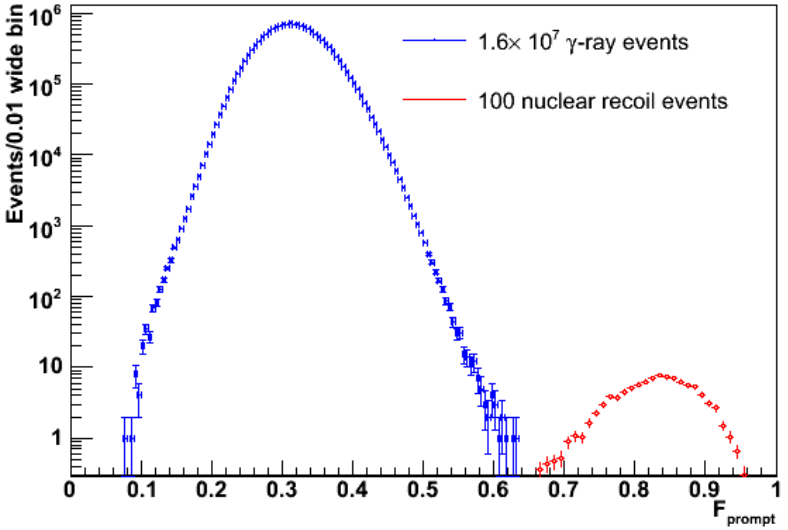




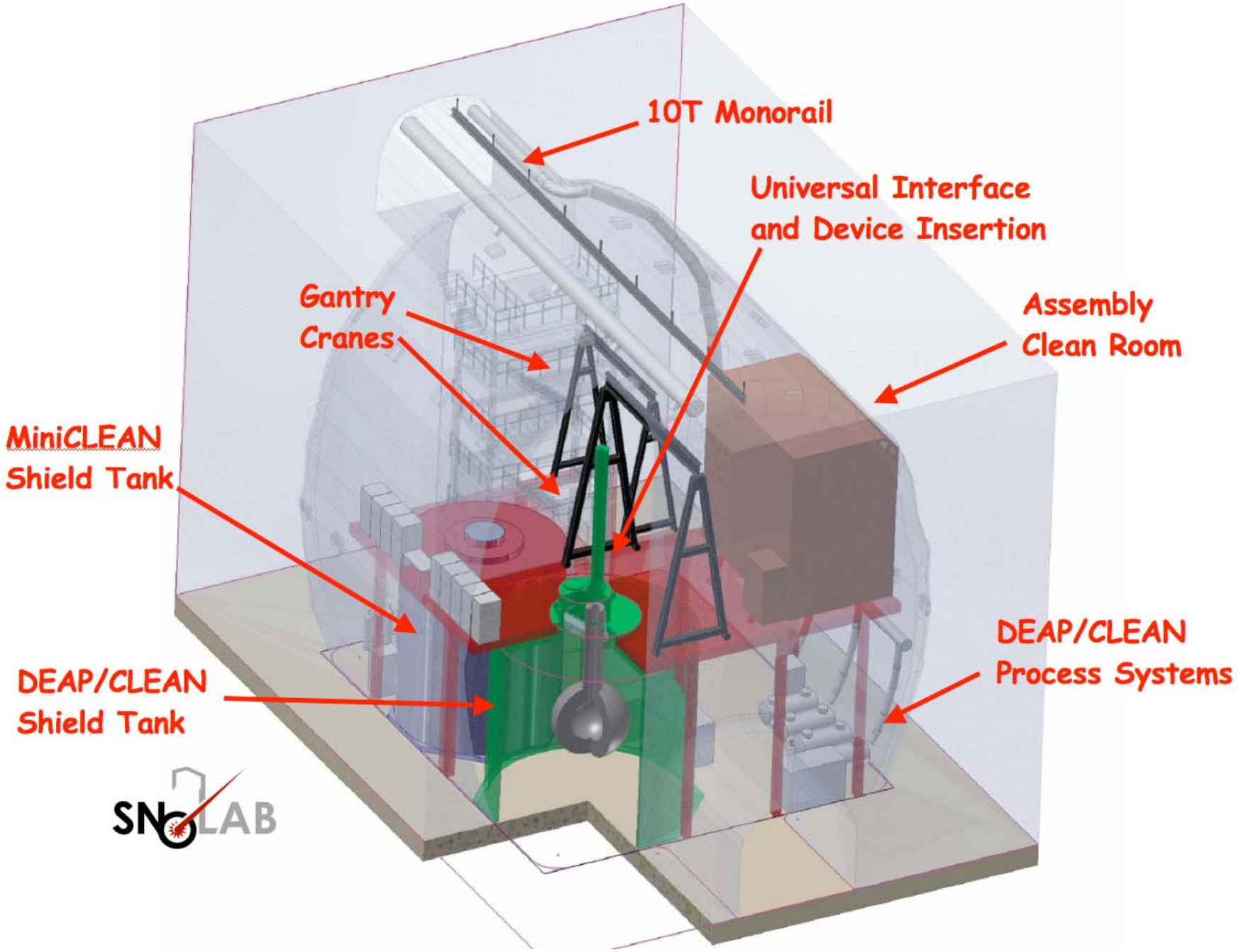
DEAP-1 at SNOLAB

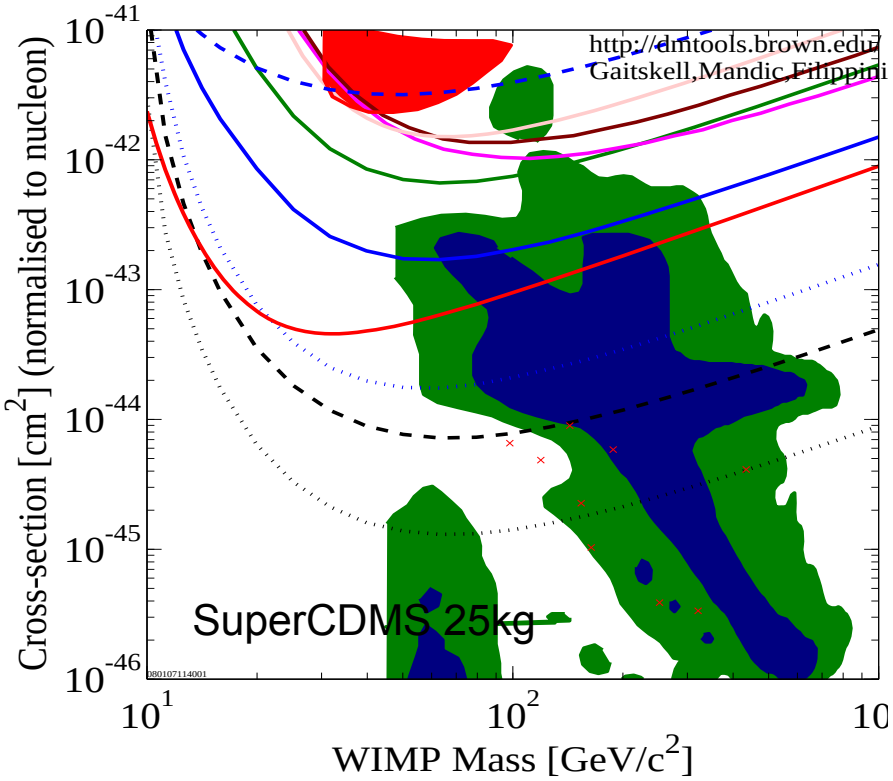


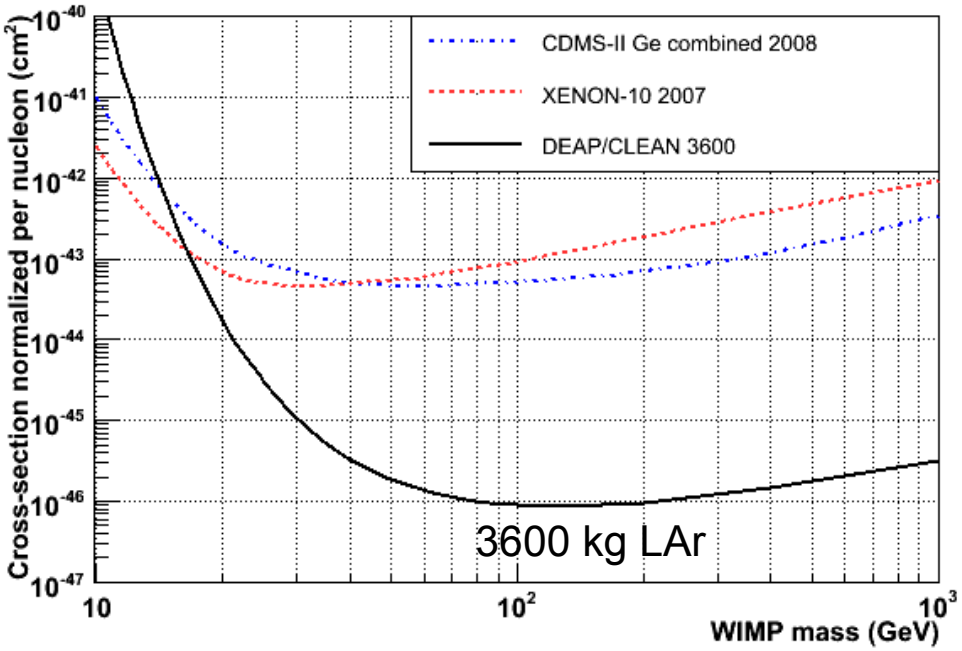
$$F_{prompt} = \frac{PromptPE(150ns)}{TotalPE(9\mu s)}$$



Background suppression DEAP I better than 2E-8 !


10T Monorail
Universal Interface
and Device Insertion
Gantry
Cranes
Assembly
Clean Room
MiniCLEAN
Shield Tank
DEAP/CLEAN
Process Systems
DEAP/CLEAN
Shield Tank
SNOLAB





DATA listed top to bottom on plot
CDMS (Soudan) 2005 Si (7 keV threshold)
DAMA 2000 58k kg-days NaI Ann.Mod. 3sigma,w/o DAMA 1996 limit
CRESST 2004 10.7 kg-day CaWO4
Edelweiss I final limit, 62 kg-days Ge 2000+2002+2003 limit
WARP 2.3L, 96.5 kg-days 55 keV threshold
ZEPLIN II (Jan 2007) result
CDMS (Soudan) 2004 + 2005 Ge (7 keV threshold)
XENON10 2007 (Net 136 kg-d)
CDMS Soudan 2007 projected
SuperCDMS (Projected) 2-ST@Soudan
SuperCDMS (Projected) 25kg (7-ST@Snolab)
Ruiz de Austri/Trotta/Roszkowski 2007, CMSSM Markov Chain Monte Carlos (1
Ruiz de Austri/Trotta/Roszkowski 2007, CMSSM Markov Chain Monte Carlos (1
X X X Ellis et. al Theory region post-LEP benchmark points
080107114001

CDMS-II: ~50 kg-days (Ge)
XENON-10: ~300 kg-days (Xe)
DEAP/CLEAN: 1,000,000 kg-days (Ar)

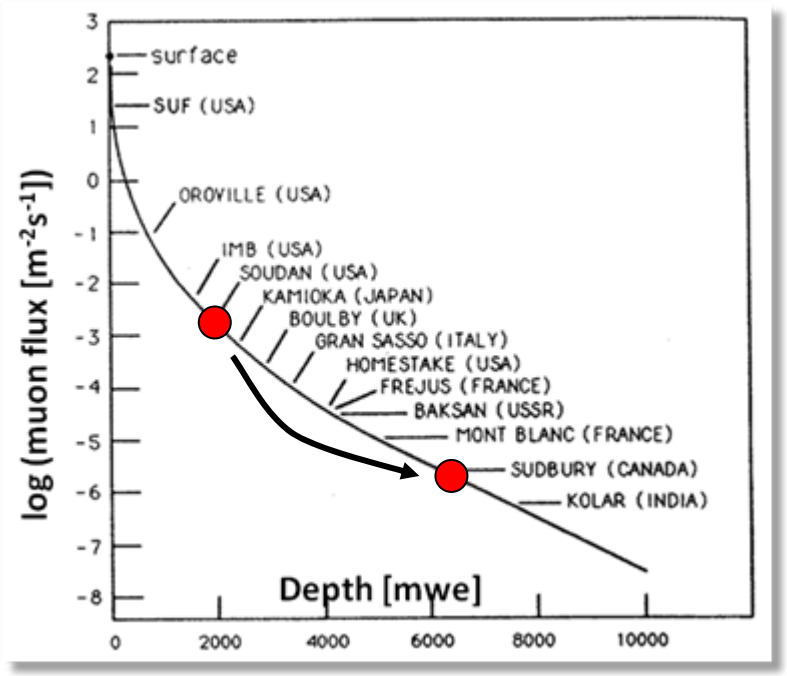
20 keV threshold, without depletion of argon-39.

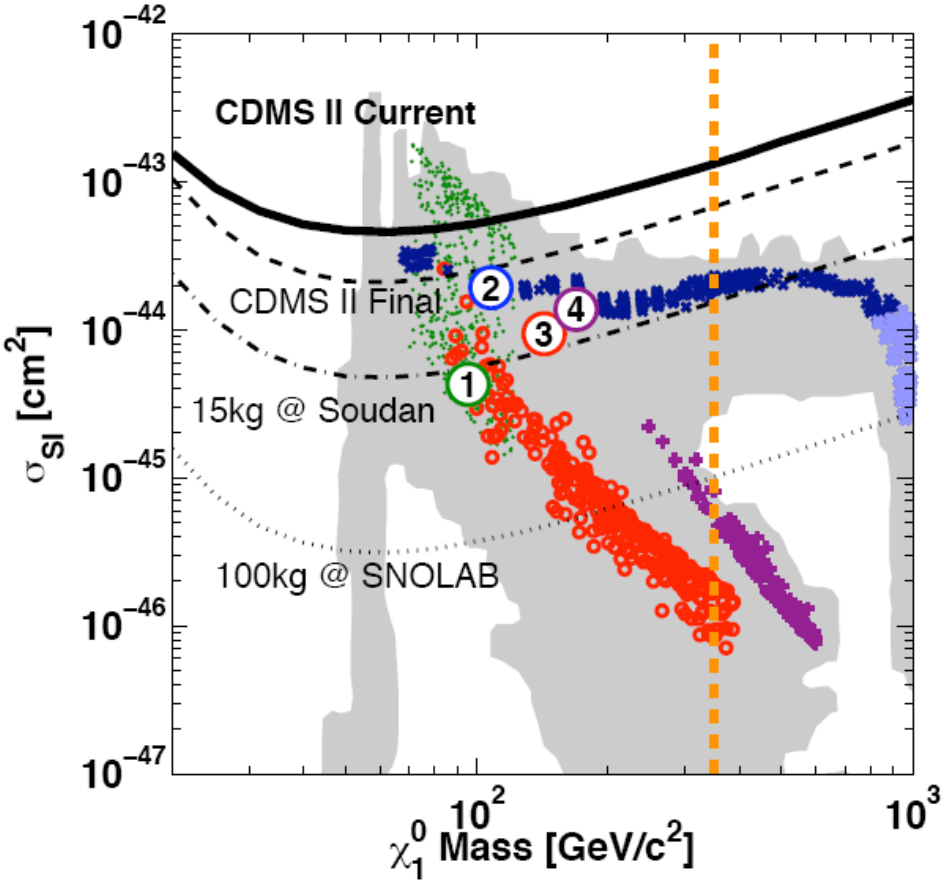
SuperCDMS Detector Development

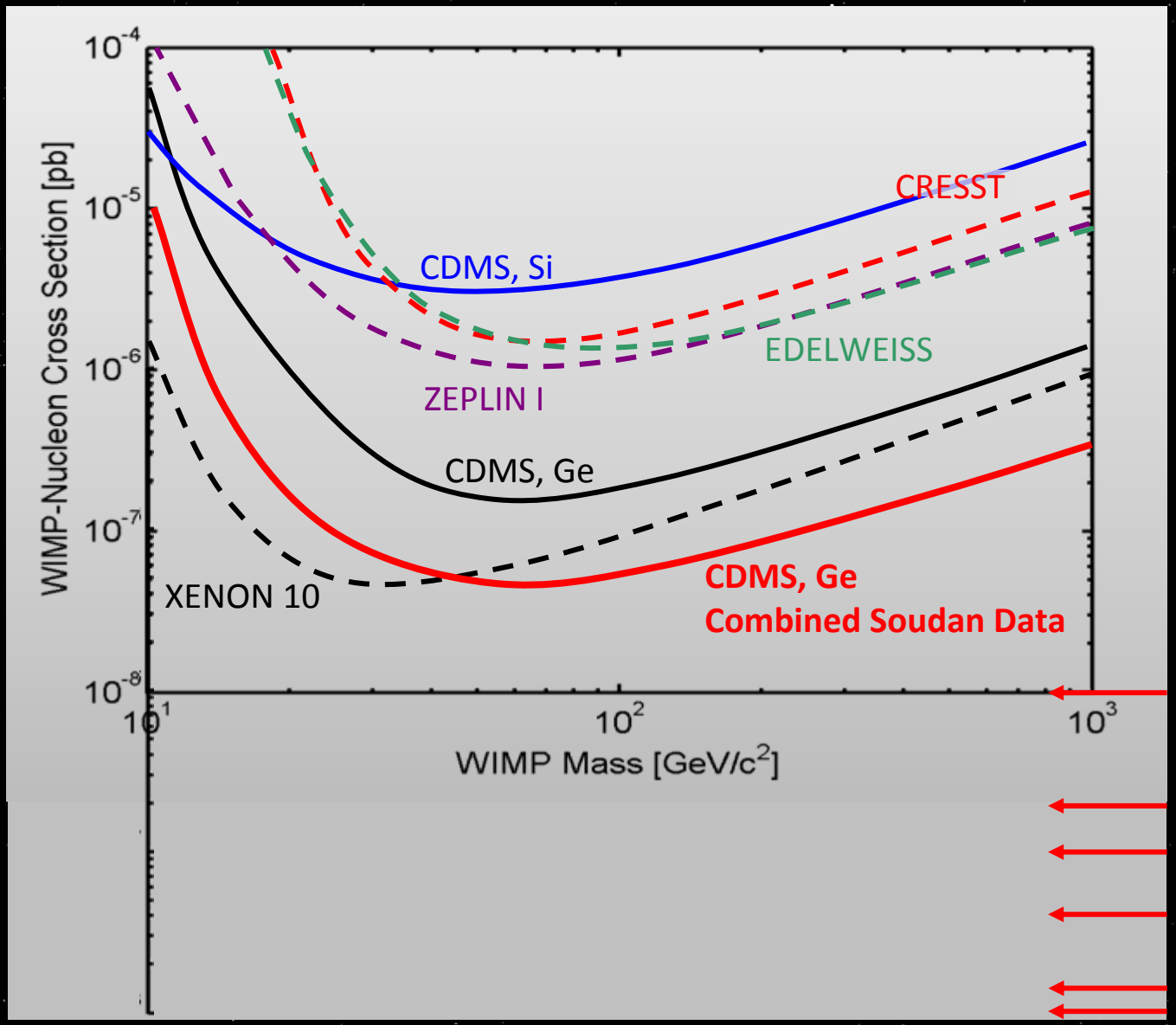
- Increase mass of single module (~ 650 g exists, up to several kg under investigation)
  - Reduce number of readout channels per mass
  - Increase volume-to-surface ratio (surface events)
- Change sensor design
  - Electrode: improved diffusion barrier for surface events
  - Thermal sensor: increased surface coverage (better timing)

SuperCDMS at SNOLAB

- Considerably larger total mass
- Lower background
  - improved shielding, discrimination, analysis
  - cleaner setup







Edelwiess'

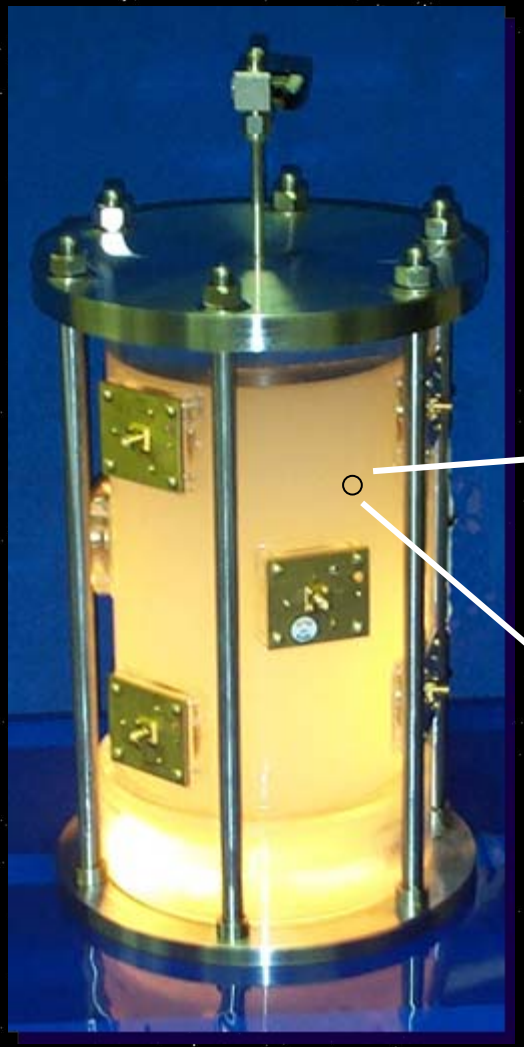
Xenon 100, **MiniCLEAN**
SuperCDMS 25 Xmass

LUX, EUREKA

SuperCDMS 100
DEAP/CLEAN

Spin-Independent Limits.
Current & Projected

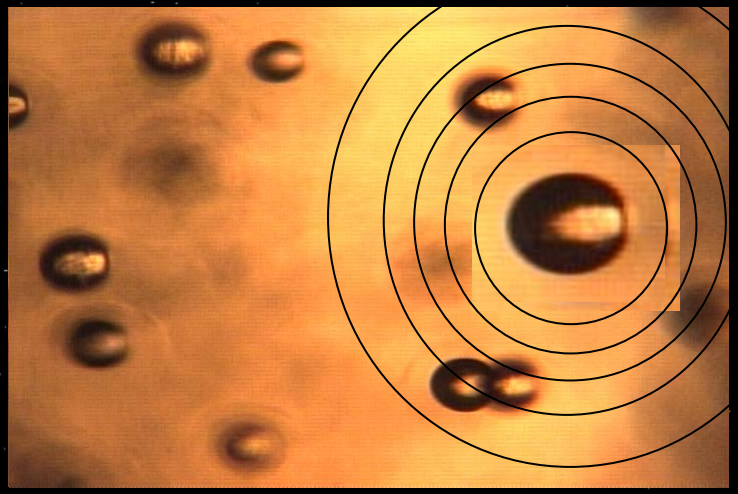
The Picasso Dark Matter Search Experiment

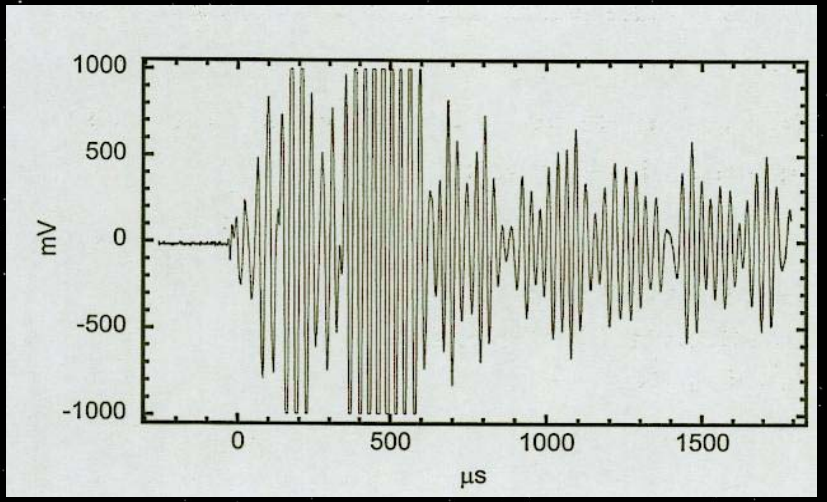


- Detector consists of tiny (5 to 100 μm) halocarbon liquid droplets (C_4F_{10}) embedded in a gel.
- The droplets are superheated - maintained at a temperature higher than their boiling point.

Detector Operation

- When a nuclear recoil (from WIMP, or neutron interaction, or alpha) deposits a spike of heat into droplet, it rapidly evaporates.
- The evaporating bubble creates a sound shock wave, which can be recorded by a sensitive microphone.

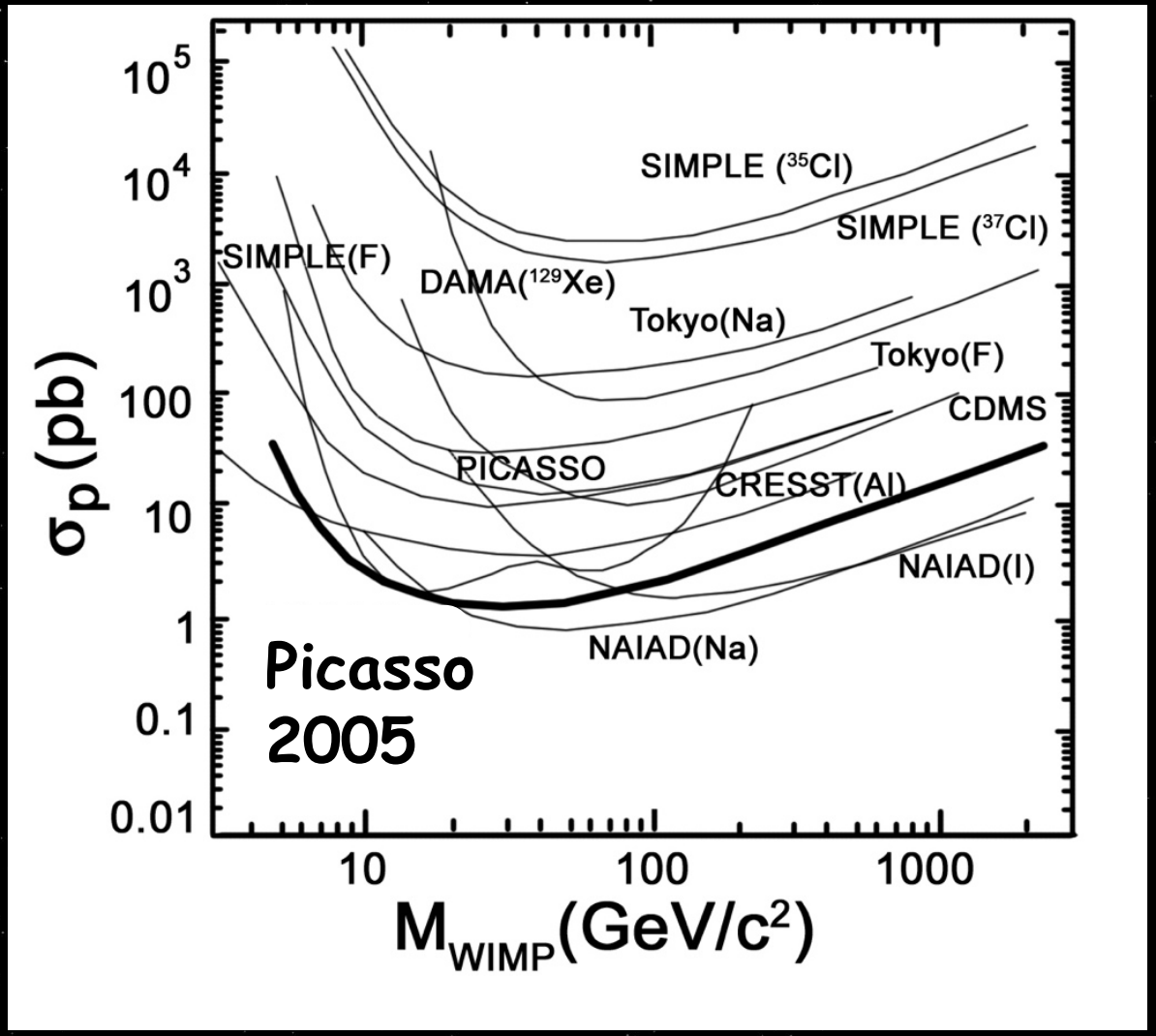




A bubble forms iff the particle creates a heat spike

- with enough energy E_{min}
- deposited within R_{min}

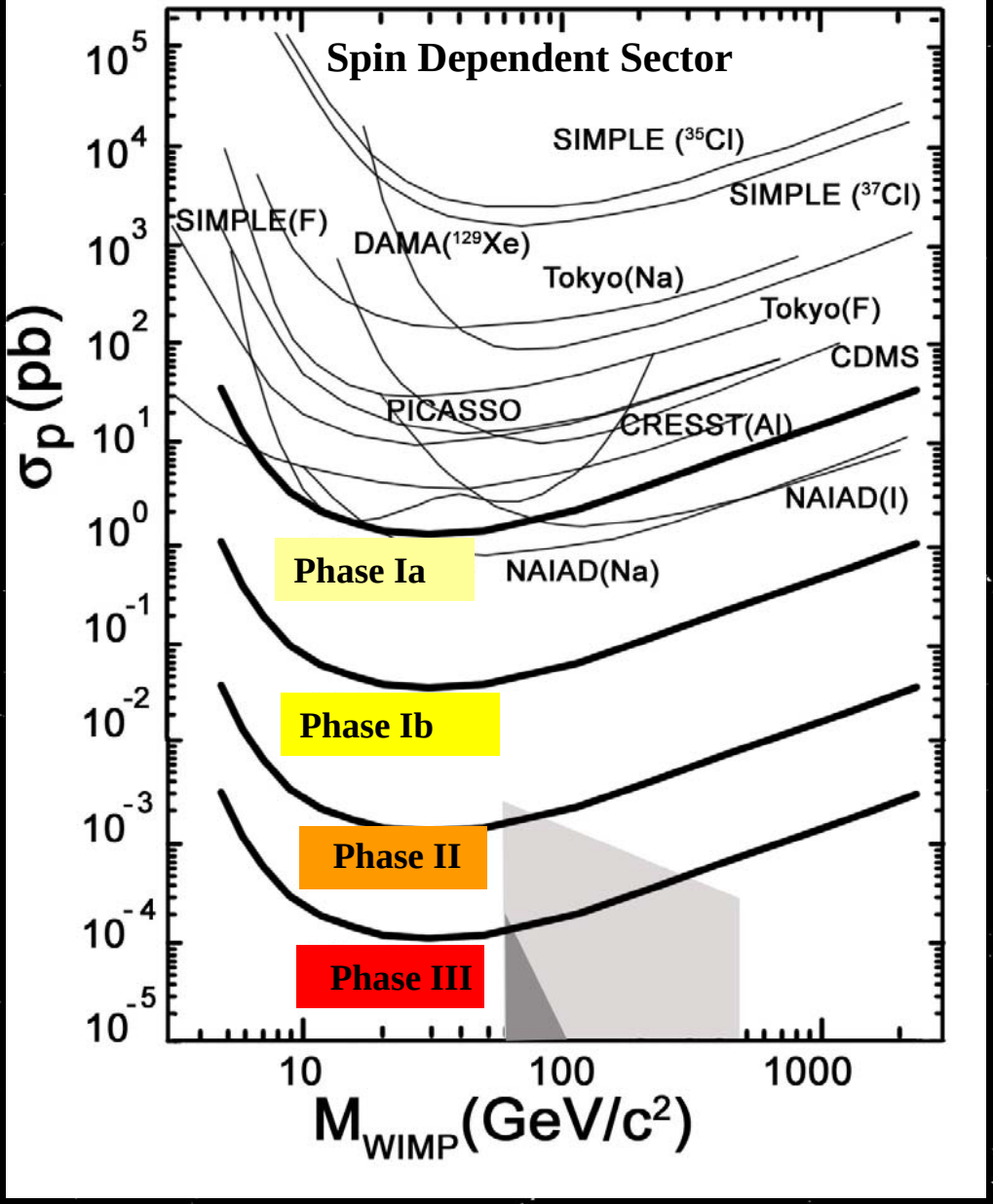
} Mainly sensitive to heavily ionizing particles



- Exclusion plot for spin-dependent neutralinos (90% C.L.) on unpaired proton in ^{19}F
- lowest point in parameter space σp=1.31pb for a WIMP with 29 GeV mass

Phys. Lett. B **624** 186 (2005)

Spin-Dependent



← Xenon 10 Published
← Kims Published

← PICASSO Phase II Projected

Example Program: $0\upsilon\beta\beta$ at SNOLAB

SNO+ : $^{150}Nd \rightarrow {}^{150}Sm + e^- + e^-$

- Uses existing SNO detector. Heavy water replaced by scintillator loaded with ^{150}Nd. Modest resolution compensated by high statistical accuracy.
- Requires engineering for AV hold down and purification plant. Technologies already developed. ~Ready to go.
- Easily obtain best limits or confirm claim within first year of running.

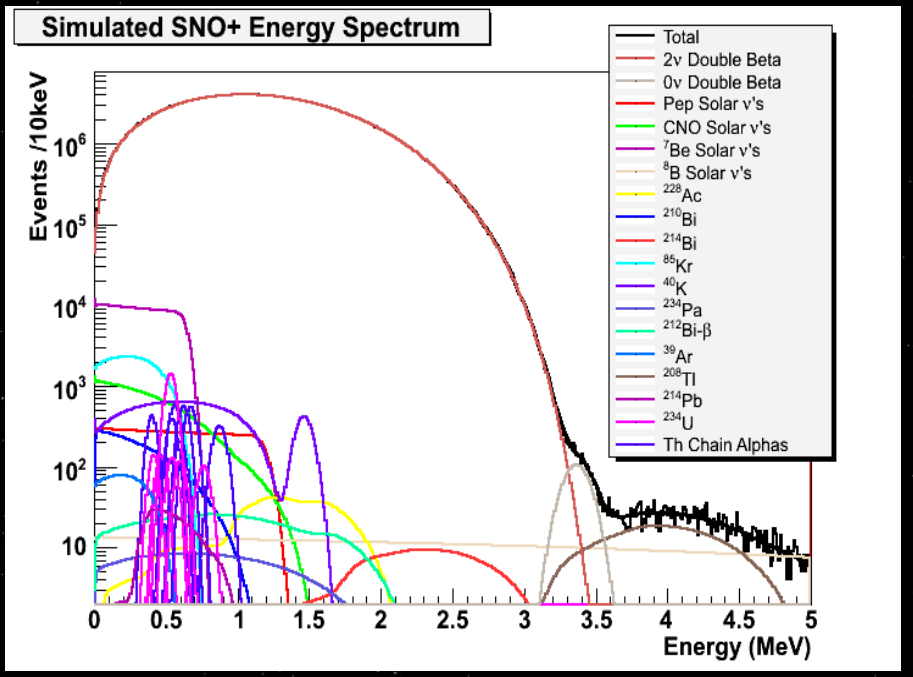
EXO_{gas} : $^{136}Xe \rightarrow {}^{136}Ba^{++} + e^- + e^-$

- Ultimate detector = large volume Xe Gas TPC
- Developing technique to tag Ba daughter. Electron tracking capability.
- Prototype soon.
- Future large scale detector with Ba tagging likely to have best sensitivity.

SNO+ $0\nu\beta\beta$:

Double beta decay with Nd-loaded scintillator

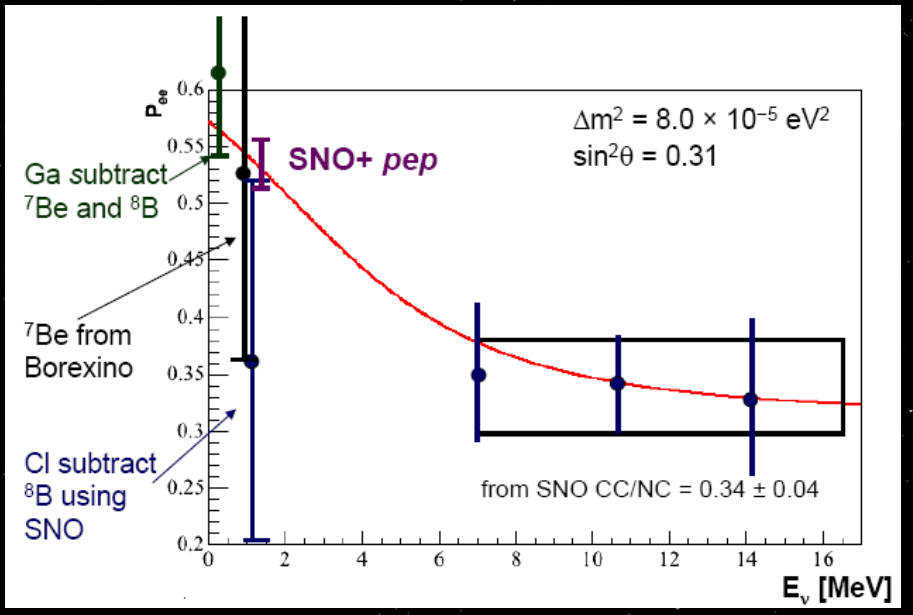
- statistical reach down to 30 meV with 500 kg ^{150}Nd (enriched)
- statistical reach below 100 meV with 0.1% Nd (natural)

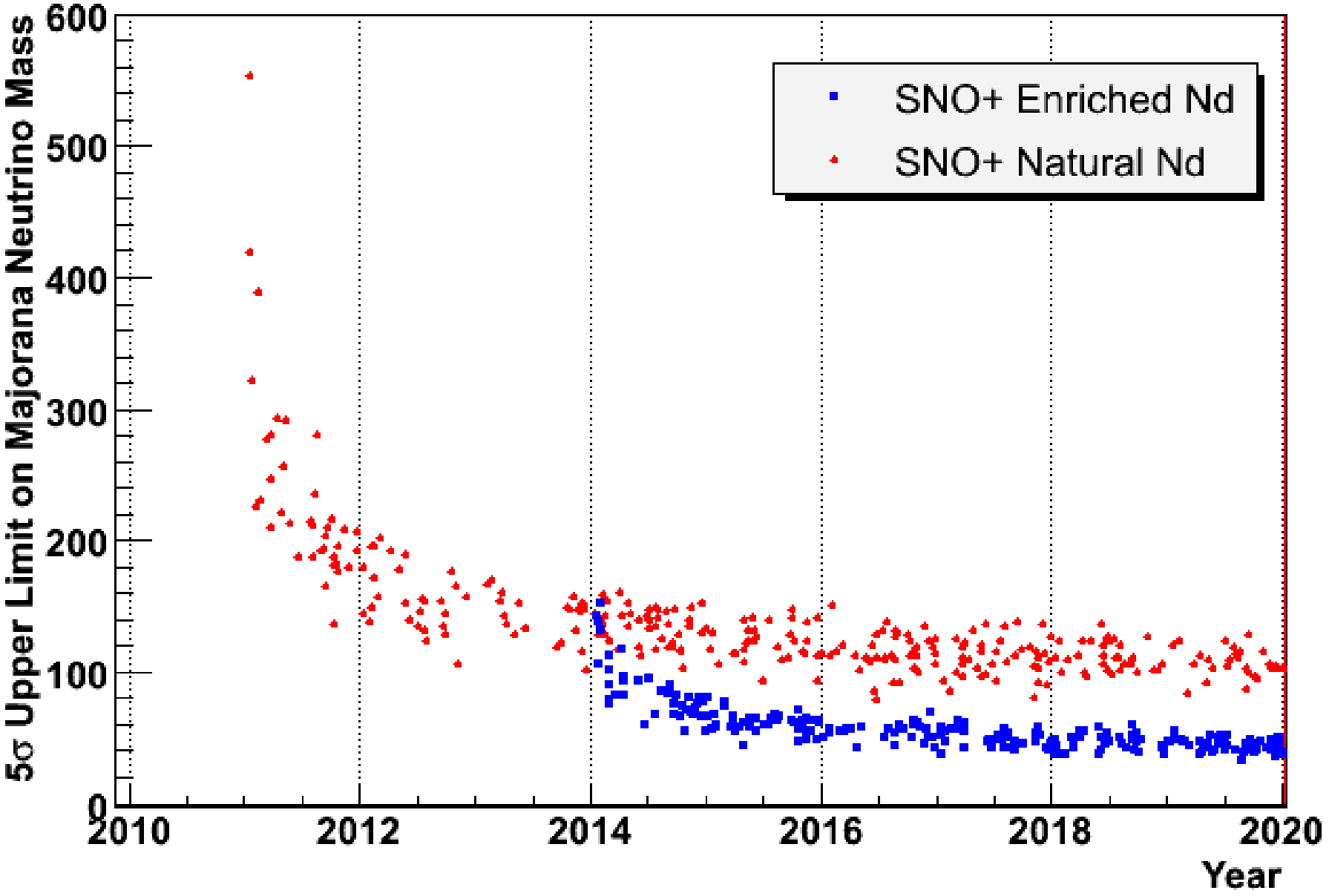


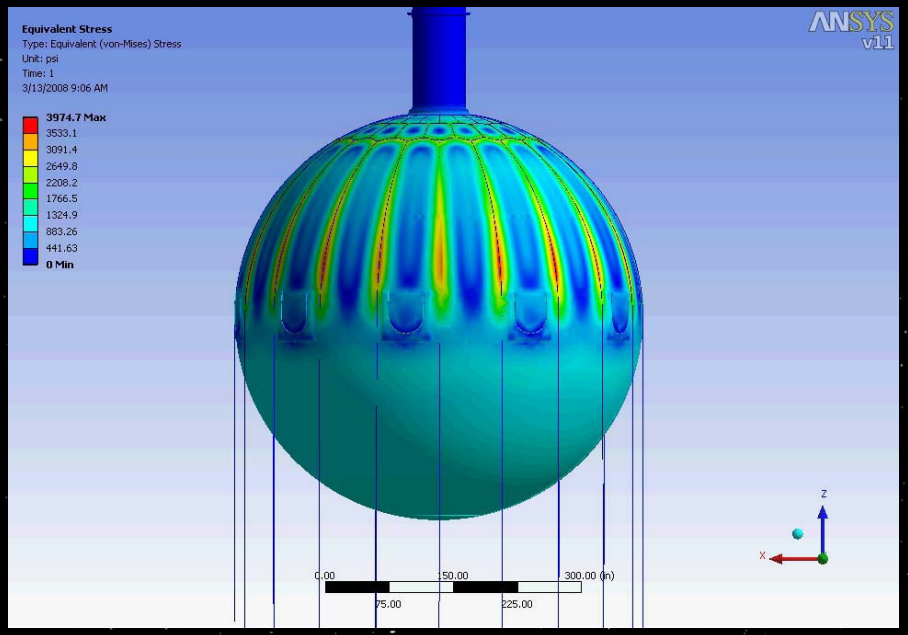
SNO+ Solar:

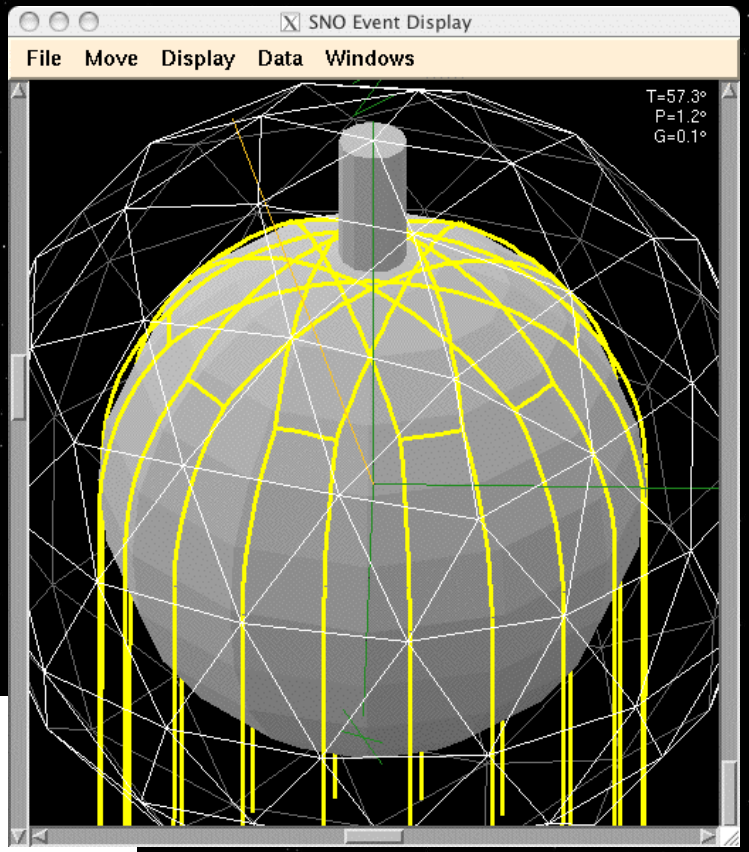
Exploit pep solar neutrinos for precision studies of neutrino-matter couplings

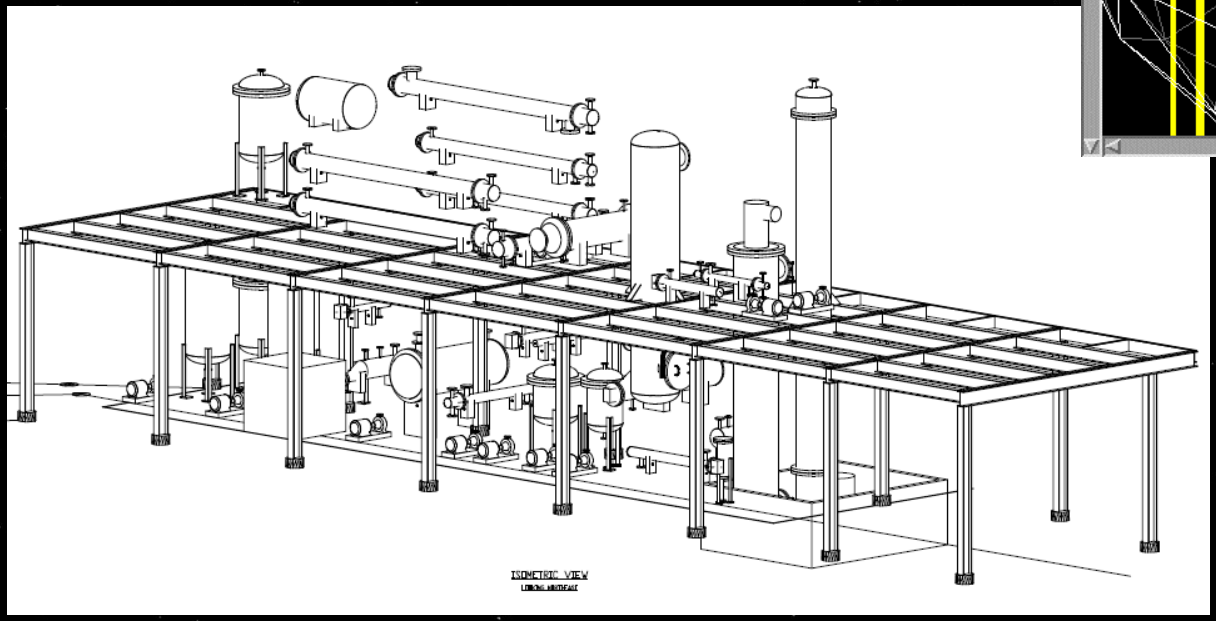
- pep allows for it to be precision
- SNOLAB depths allows it to be done
- Sensitive probe of neutrino-matter couplings (e.g. non-standard interactions) and could reveal new physics




SNO+ Enriched Nd
SNO+ Natural Nd
5σ Upper Limit on Majorana Neutrino Mass
Year
0
100
200
300
400
500
600
2010
2012
2014
2016
2018
2020

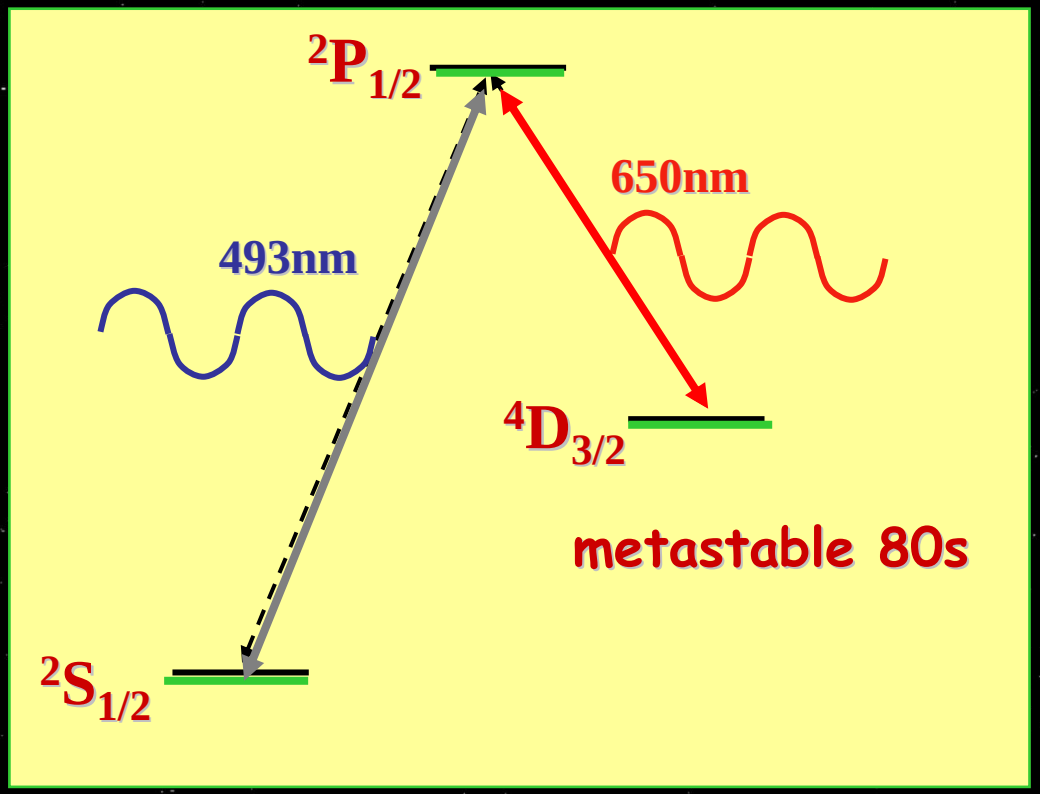






- R&D largely complete
- Detector exists
- Final engineering for purification and hold-down well advanced

EXO_{gas} and Ba tagging:



Original concept to tag Ba production using lasers

New Concept being explored:

- Identify the barium production by extracting the ion into vacuum and using conventional techniques to identify a mass 136, ++ ion.
- Expect this to be unique to Ba
- Operate the detector in pure noble gas (Xe or Xe+Ne)
- Use electroluminescence in place of gas electron gain

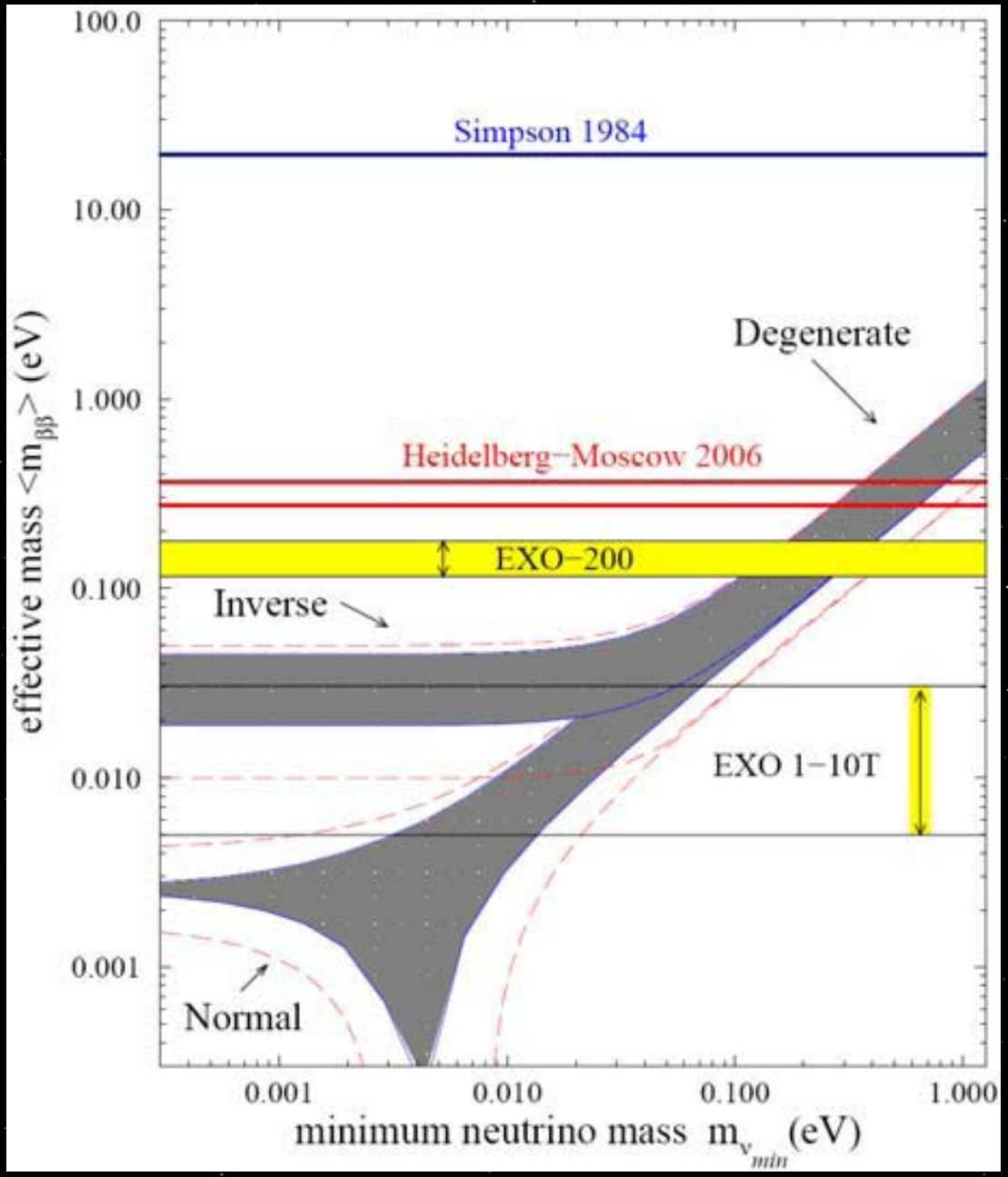
Projections

Xmass

Majorana

Gerda

SuperNemo



SNO+ natural Nd

SNO+ enriched Nd

Schedule & Milestones @ SNOLAB

Construction

2002 Idea of SNOLAB conceived.

2002 Funding awarded by CFI 38.9 M$ for underground facility.

2003 Funding awarded (OIT, FedNor, NOHFC, CFI) 10.4 M$ for surface facility.

2004 June. Construction of building begins….after the ground thaws enough.

2004 June. Excavation of Phase I begins underground.

2005 July. Surface building complete and occupied.

2007 June. Excavation of Phase II begins

2007 August. Funding for Phase II approved

2008 May-June Excavation of Phase II complete

2008 December. Entire Facility construction complete

Schedule & Milestones @ SNOLAB

Experiments:

Experiment	Physics	Space Allocated	Current Status	Expected Construction Period	Expected Operations Period
SNO+	0νββ, solar, geo, reactor	SNO Cavern	Preparing to install	2009 through 2010.	2011-2016
Construction Funding:		Primarily CFI/NIF and FEDNOR ($380 k) CFI Grant for Capital ($ 14 M) requested. Decision June 2009 NSERC Capital: $300k 07/08. $ 500k 08/09 conditional on CFI approval			
Operations Funding:		NSERC ($1 M 07/08 and $800k 08/09)			
PICASSO	DM	Utility Room	Running through 2010	Constructed, although improved modules being swapped in	2008 –2010
Construction Funding:		Received from NSERC.			
Operations Funding:		NSERC, 07/08 and 08/09			
Other Support		Support from CFI via Ladd, and personal CFI awards.			
DEAP- I	DM	SNO Counting Room	Running. Requested space through 2010	Constructed, some upgrades in 2009 (CFI and NSERC)	through 2010
Construction Funding:		Operational 2007			
Operations Funding:		Joint with Deap/Clean 3600, NSERC			
Other Support		CFI-LOF, NSERC, Ontario			

Schedule & Milestones @ SNOLAB

Experiments:

Experiment	Physics	Space Allocated	Current Status	Expected Construction Period	Expected Operations Period
MiniCLEAN 360	DM	Cube Hall	Final design procurement. Preparing to install 2009	Spring 2009 (infrastructure) to Spring 2010	2010 to 2014
Construction Funding:		Non agency funding at LANL and Yale.			
Operations Funding:		DOE and NSF operating support being sought.			
DEAP/CLEAN 3600	DM	Cube Hall	Final design and R&D. Preparing to install in 2009	Spring 2009 (infrastructure) to Summer 2011	2011 to 2016
Construction Funding:		CFI – LOF/ MRI $800,000 received. Requested $10,000,000 from CFI (Decision June 2009) $350,000 from NSERC (2009) Requested $450,000 support from SNOLAB for infrastructure.			
Operations Funding:		$550K in 2008, request $1,300,000 NSERC 2009, will request future operations funding (approx. 1M$/year total) from NSERC			
EXO-GAS	0νββ	Not allocated yet	R&D for gas phase detector with tagging concurrent with liquid detector running at WIPP.	Earliest possible installation at SNOLAB would be 2013 with 2 yrs construction.	Begin 5 yr run starting 2015.
Construction Funding:		NSERC RTI equipment grant requested for 09/10			
Operations Funding:					
Other support		R&D funding from NSERC Project Grant for EXO-gas Canada Some US groups have support for R&D work on EXO-gas.			

Schedule & Milestones @ SNOLAB

Experiments:

Experiment	Physics	Space Allocated	Current Status	Expected Construction Period	Expected Operations Period
SUPERCDMS	DM	Ladder Lab C	Running at Sudan. Possible install in 2010	Earliest possible start 2010 running through 2011	2011-2012 15kg, 2013-2016 150 kg
Construction Funding:		DOE and NSF with some fraction from CFI/NIF			
Operations Funding:		Approximately equally split between DOE, NSF and Canadian sources.			
HALO	Supernova	Phase 3 stub anticipated	Design. Preparing to install mid 2009	Largely complete in 2009	Indefinitely. Plans to upgrade to larger mass
Construction Funding:		Partial NSERC funding, some SNOLAB assistance			
Operations Funding:		Through NSERC, not yet requested			
Other support		Groupe Technologique, UoM			
PUPS	Seismic	Various locations.	Running indefinitely		
Construction Funding:		NSERC not sub-atomic			
Operations Funding:		NSERC			

Summary

- SNOLAB has great potential to address many of the most fundamental questions in subatomic physics today.

- Lab is ready now to begin installation of experiment specific infrastructure.
  - Construction schedule finished a few months ahead of schedule…→ more infrastructure
  - Skilled technical staff, engineering and scientific support.

- Several smaller sized programs (PICASSO, DEAP-1, PUPS) already operational

- Dark Matter programme: Diverse targets and sensitivities.

– DEAP/CLEAN	Spin Indep	Ar	10^{-46}
– SuperCDMS	Spin Indep	Ge	10^{-45}
	Spin Dep	Ge	neutron
– Picasso	Spin Dep F	proton	

- Neutrinoless double beta decay programme:

– SNO+	Nd	High statistics and clean
– EXO	Xe	Gas TPC with tagging

SNOLAB is open for business!
Highest priority now is to get experiments fully funded. designed, reviewed and installed.

We welcome new proposals !!

We are looking for new Students and Postdocs

There are several faculty positions still open in Canada

We welcome sabbatical visits

End