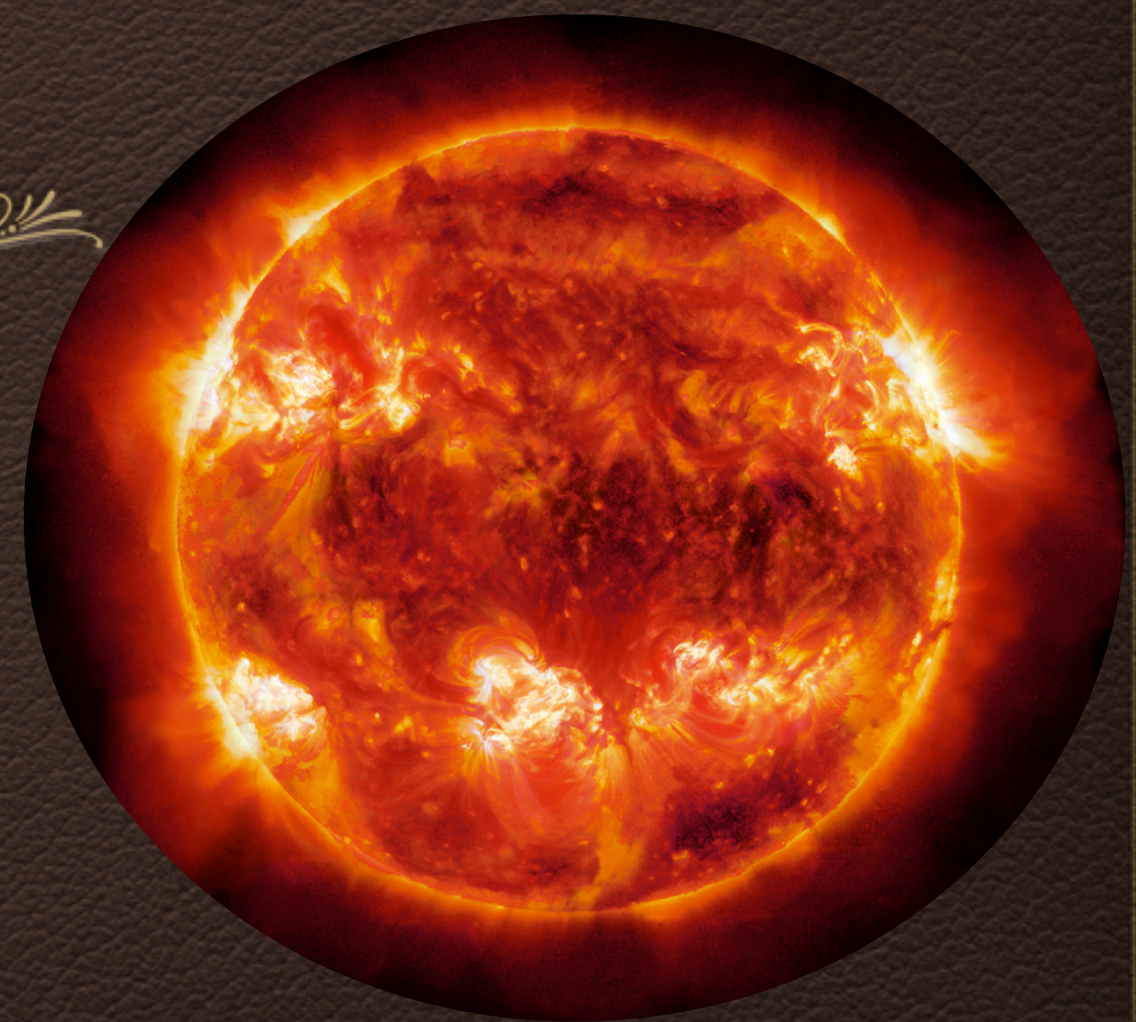
Requirements for Large Neutrino/Astrophysics Faclities



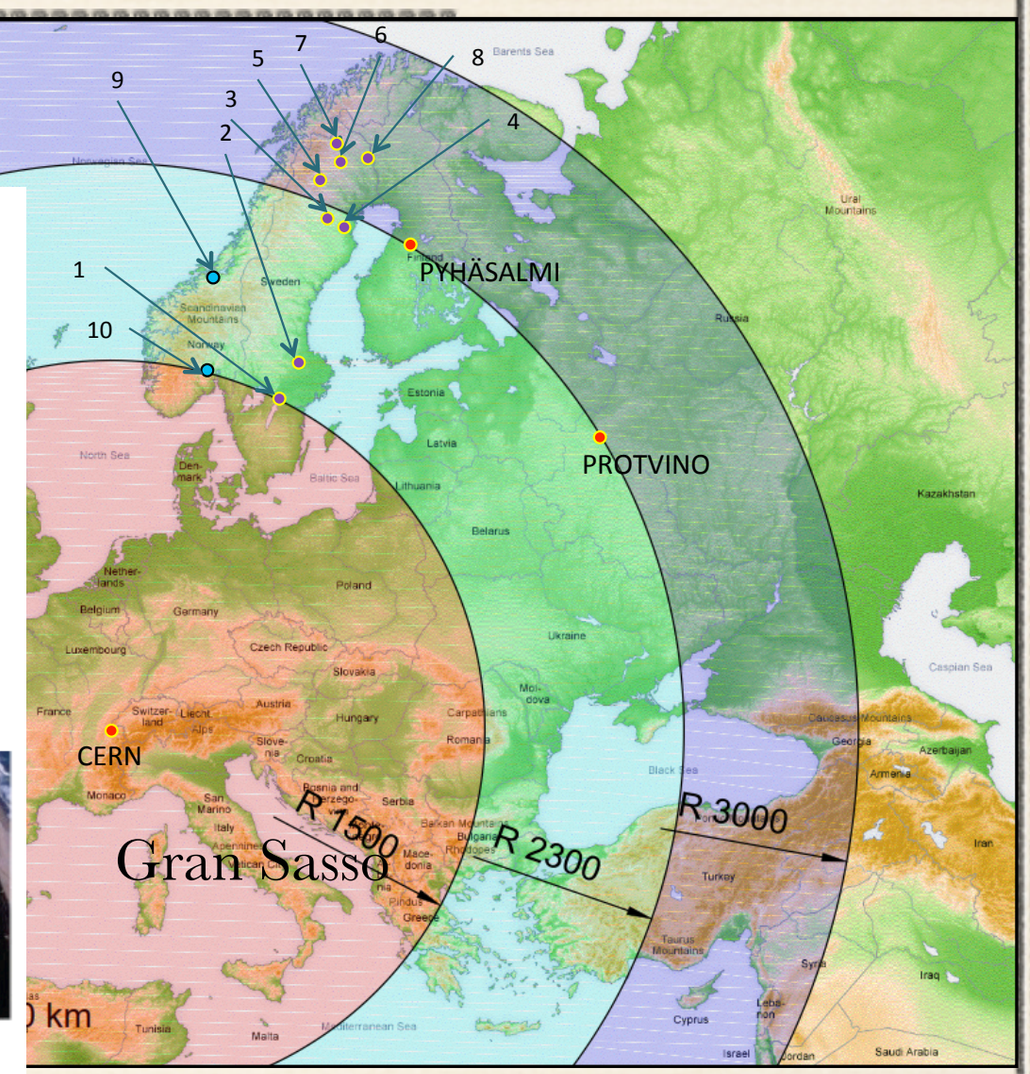
"Snowmass" Cosmic Frontier Meeting
SLAC, March 8th 2013

Michael Smy, UC Irvine

Disclaimer

- I'm no real expert in underground facilities (I've visited SNOLAB, SURF, and Gran Sasso; and work at Kamioka)
- impossible to follow <u>all</u> relevant discussions since many were in parallel (although I tried hard by racing madly from session to session)
- this talk therefore is colored by my personal taste

Overseas Facilities



INO: ~1.2km underground

South Pole!!

Courtesy Yokoyama/Wark

Overseas Facility Physics Goals

- address ν mass hierarchy with giant detectors at
  - South Pole (PINGU) using atmospheric neutrino interactions in ice
  - ICAL@INO using atmospheric neutrino interactions in a magnetized iron calorimeter
  - Kamioka using atmospheric neutrino interactions in water
  - Daya-Bay II/Reno 50 using reactor anti-neutrino interactions in liquid scintillators
  - Pyhäsalmi using CERN beam neutrino interactions in liquid argon

Overseas Facility Physics Goals

- search for CP violation in neutrino oscillation at
  - Kamioka using the J-PARC beam
  - Pyhäsalmi using the CERN beam neutrino
- precision oscillation parameter measurements and non-standard oscillation physics at
  - Daya-Bay II/RENO-50 using reactor neutrinos
  - Kamioka using the J-PARC beam
  - Pyhäsalmi using the CERN beam neutrino

Overseas Facility Physics Goals

- search for nucleon decay at
  - Kamioka (water)
  - Pyhäsalmi (liquid argon/scintillator)
  - ICAL@INO (iron)?
  - Daya-Bay-II/RENO-50 (liquid scintillator)
- observe galactic supernova neutrino burst everywhere
- study solar neutrinos at
  - Kamioka
  - Pyhäsalmi (scintillator)
  - Daya-Bay-II/RENO-50??

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Overseas Facility Physics Goals

- observe geo-antineutrinos at
  - Pyhäsalmi (liquid scintillator)
  - Daya-Bay-II (liquid scintillator)
  - RENO (liquid scintillator)
- search for neutrino-less double beta decay at
  - Pyhäsalmi (liquid scintillator)
  - Kamioka (liquid scintillator, CaF_2)
  - Gran Sasso (multiple projects)

North American Facilities

- SNO-LAB
- SURF
- Soudan
- WIPP
- KURF

North American Facility Physics Goals

- on top of SURF (liquid argon) using a Fermilab beam:
  - address ν mass hierarchy
  - search for CP violation in neutrino oscillation
  - precision oscillation parameter measurements
  - non-standard oscillation physics
- observe galactic supernova neutrino burst everywhere
- study solar neutrinos at
  - SNO-Lab (Nd loaded scintillator)
  - KURF (In loaded scintillator)

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North American Facility Physics Goals

- oscillation parameter measurements at Soudan using Fermilab beam
- search for neutrino-less double beta decay at
  - WIPP (Xe)
  - SNOLAB (Nd, Xe)
  - SURF (Ge)
  - KURF (Ge)
- Reactor monitoring feasibility at KURF

Facility Merits

What do Neutrino Measurements Require?

- Depends on the measurement! Requirements differ widely.
- example: large liquid Argon TPC (Kate Scholberg)

Signal	Energy range	Expected Signal Rate per kton of LAr (s^{-1} $kton^{-1}$)
Beam neutrinos (CP violation/ mass hierarchy)	~ GeV	5×10^{-4} osc ν_e in beam window
Proton decay	~ GeV	$< 2 \times 10^{-9}$
Atmospheric neutrinos	0.1-10 GeV	$\sim 10^{-5}$
Supernova burst neutrinos	few-50 MeV	~3 @ 10 kpc over ~30 secs
Solar neutrinos	few-15 MeV	$\sim 4 \times 10^{-5}$
Supernova relic neutrinos	20-50 MeV	$< 2 \times 10^{-9}$

Easy to pick from bg due to beam time & direction

Easy to pick from bg, but highly intolerant of bg

Easy to pick, somewhat more tolerant of bg

Potentially harder to select (esp. low energy end) *but arrive in a burst* (and bg can be well known)

Very hard to select *and* intolerant of bg

Hard to select *and* intolerant of bg

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What do Neutrino Measurements Require?

- neutrino-less double beta decay search
  - depth
  - low radioactivity environment
  - underground infrastructure: clean room facilities, crystal-growing, “cool” materials, isotope enrichment??
- solar neutrino studies
  - depth
  - low radioactivity environment
  - large, stable cavities
  - underground infrastructure

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What do Neutrino Measurements Require?

- atmospheric neutrino studies & nucleon decay search
  - modest depth
  - large, stable cavities
- reactor and geo anti-neutrino studies
  - modest depth/nominal depth
  - large, stable cavities
- galactic supernova neutrino burst
  - modest depth

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What do Neutrino Measurements Require?

- beam neutrino physics
  - nominal depth (or surface)
  - large, stable cavities (or buildings)
- other issues:
  - access (drive in, shaft size, elevator speeds, rock removal)
  - surface infrastructure (e.g. access)
  - underground infrastructure (e.g. cryogenics)

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Intensity Frontier Discussions of Facilities

My impression:

- just starting this kind of discussion; so far we mostly discuss experiments rather than facilities
- often, each experiment seems to finds its own solutions using already existing facilities and infrastructure or creating their own

Conclusion

from Alan Poon:

Underground Laboratory

Who needs an underground lab?

We do!

- The recommendation on underground laboratory from LRP 2007 has been realized (although not exactly as originally envisioned). Its importance was reaffirmed in the recent LRP 2007 implementation review

- Sanford Underground Research Facility (SURF) is a new asset for the scientific community:
  - Deepest underground laboratory in the US
  - Attracted $75M in private funding
  - Hosting MAJORANA DEMONSTRATOR (NP), LUX (HEP), and experiments from other fields

- Other facilities are also playing important roles in the field.