CASPAR Status
provided by F. Strieder
and
Neutron Background in Underground Labs

2nd CUNA workshop on Nuclear Astrophysics

Andreas Best

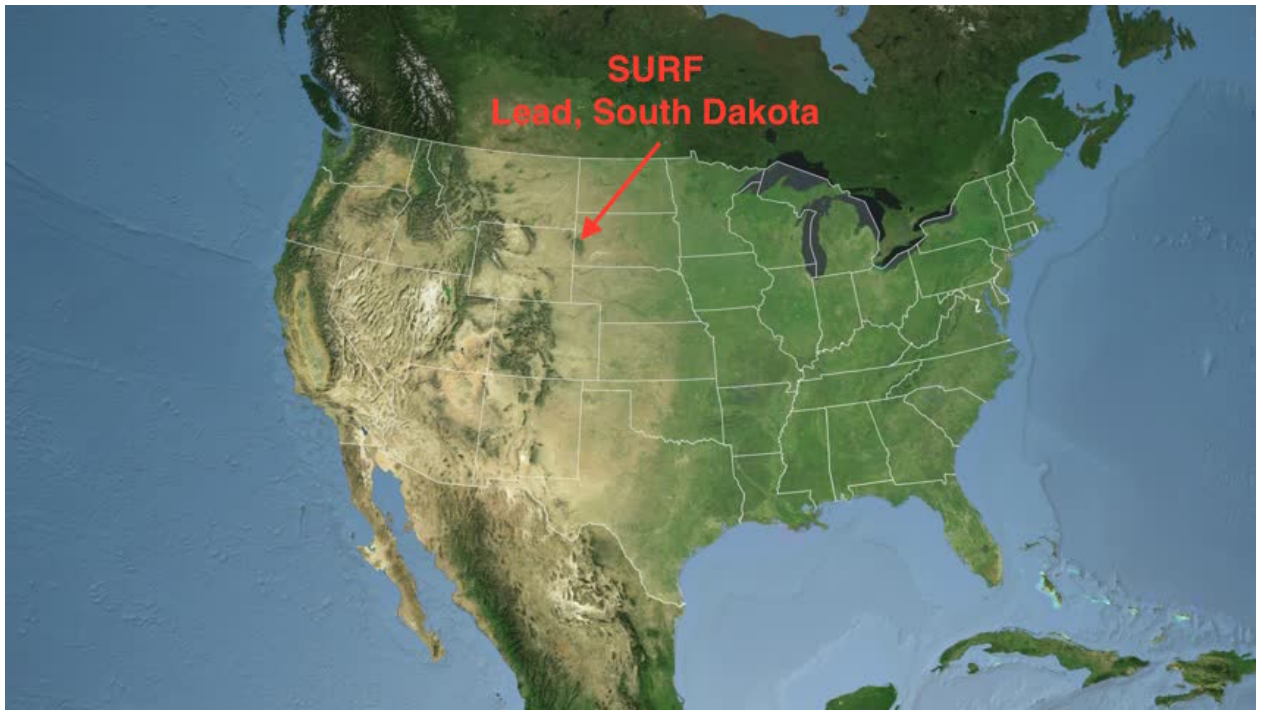
INFN and University of Naples

March 1, 2016

Sanford Underground Research Facility

- Homestake gold mine in the Black Hills in South Dakota
- Historic Davis neutrino experiment at the 4850L

Sanford Underground Research Facility



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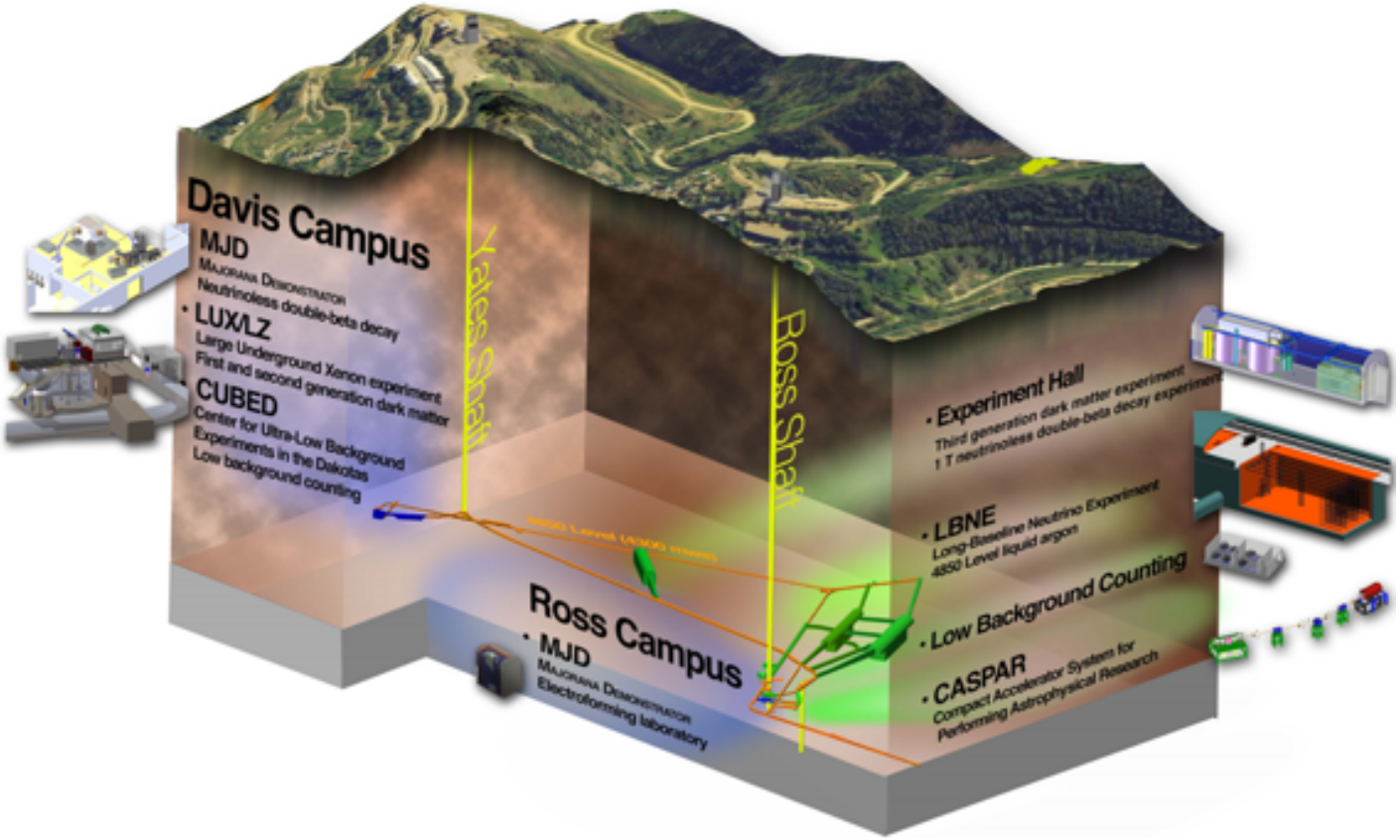
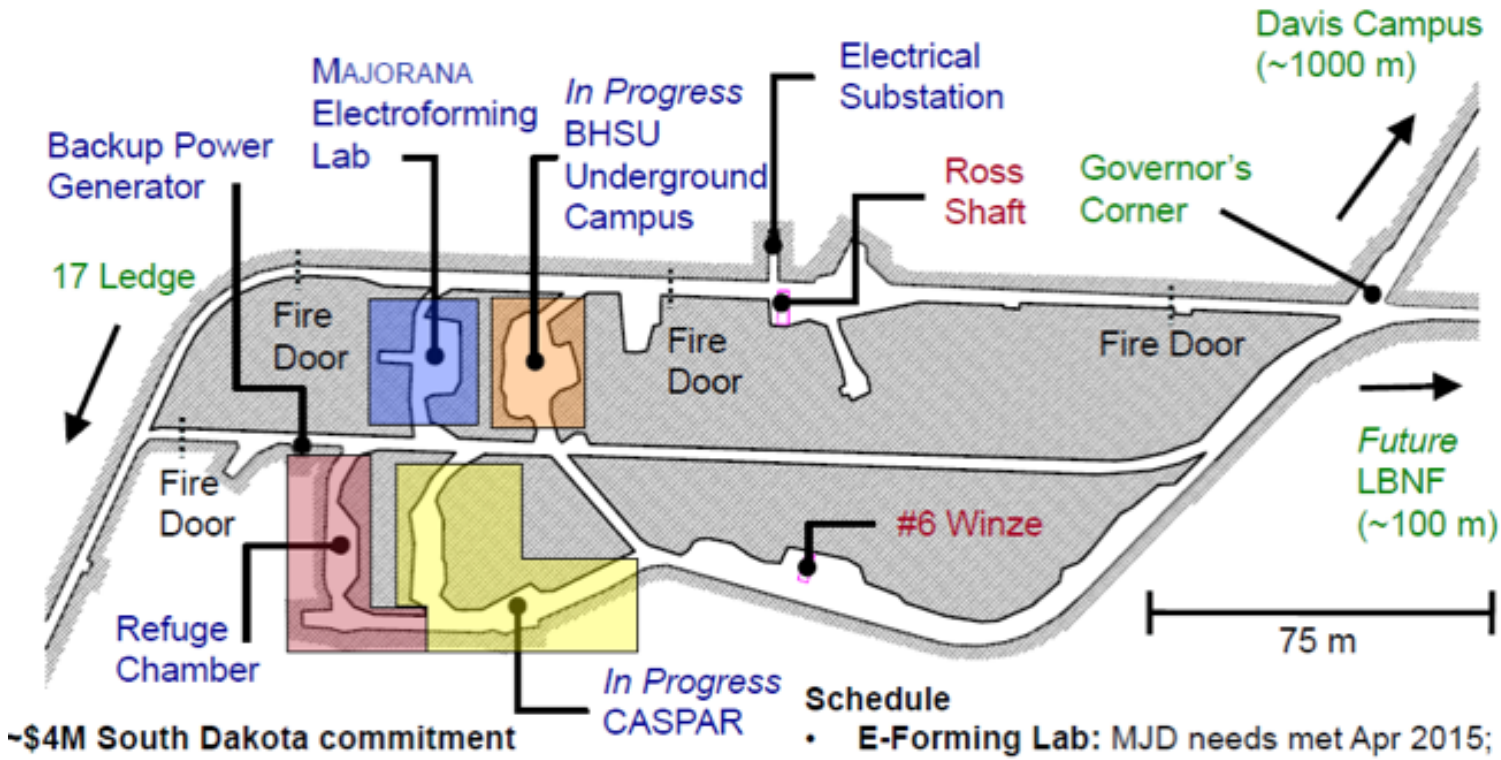
- Historic Davis neutrino experiment at the 4850L

SURF



- Envisioned as very large, multi-level science and engineering laboratory
- Scaled down to one level at 4850 ft (1500m, 4300 m.w.e.)
- Low-background counting, Majorana, LUX/LZ, DUNE (ex LBNE), CASPAR

Ross campus


Davis Campus
(~1000 m)
MAJORANA
Electroforming
Lab
In Progress
BHSU
Underground
Campus
Electrical
Substation
Backup Power
Generator
Ross
Shaft
Governor's
Corner
17 Ledge
Fire
Door
Fire
Door
Fire Door
Future
LBNF
(~100 m)
Fire
Door
#6 Winze
75 m
Refuge
Chamber
In Progress
CASPAR
~$4M South Dakota commitment
Schedule
• E-Forming Lab: MJD needs met Apr 2015;

CASPAR

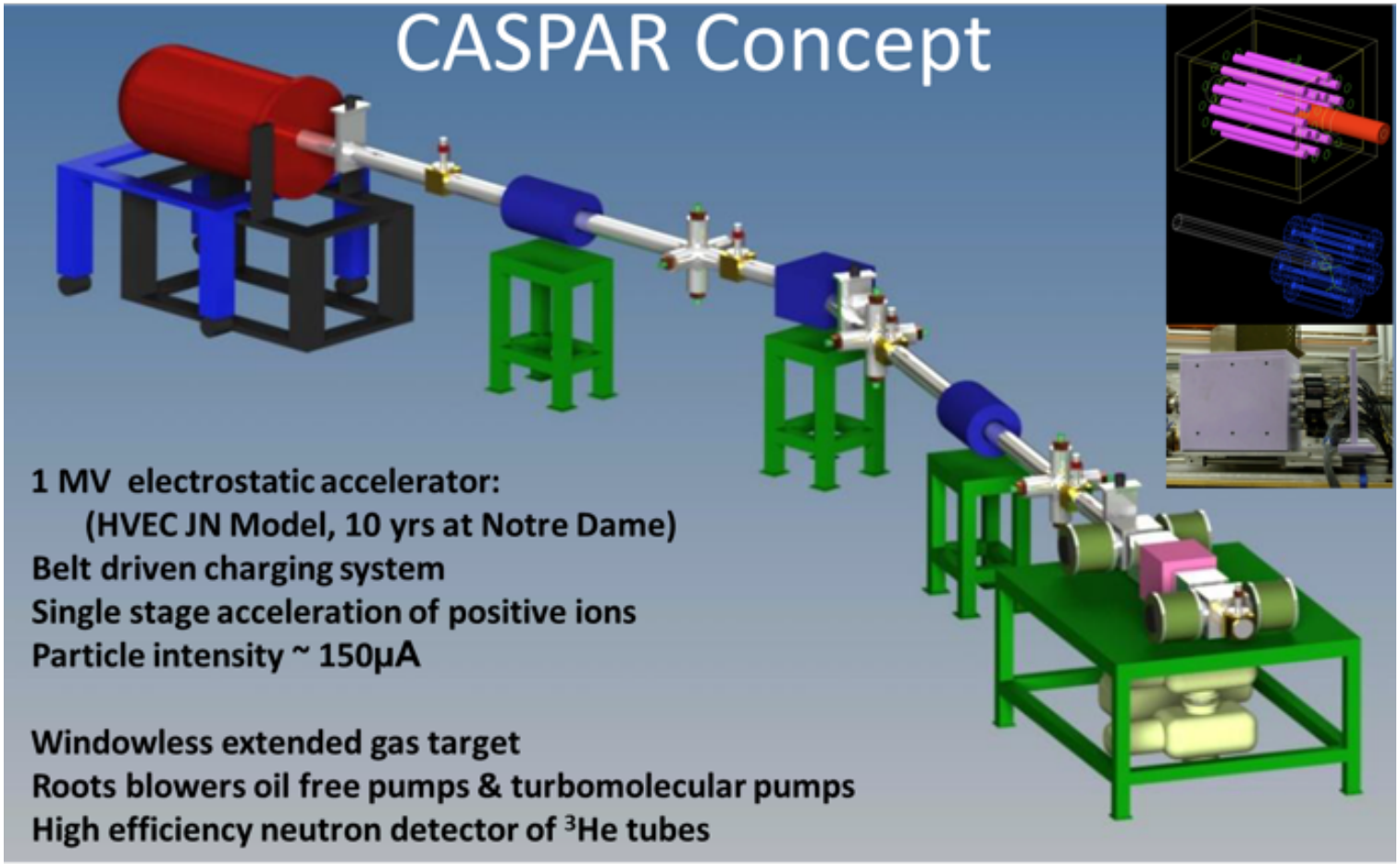
Compact **A**ccelerator **S**ystem for **P**erforming **A**strophysical **R**esearch

Frank Strieder (PI)
Doug Wells
Tyler Borgwardt
Mark Hanhardt
Thomas Kadleczek
David Molash
Joe VanDriel
John Harrison
Lucas Lindholm

Dan Robertson (TC)
Manoel Couder
Michael Wiescher
Rory Hamilton
Zach Meisel
Bryant Vande Kolk

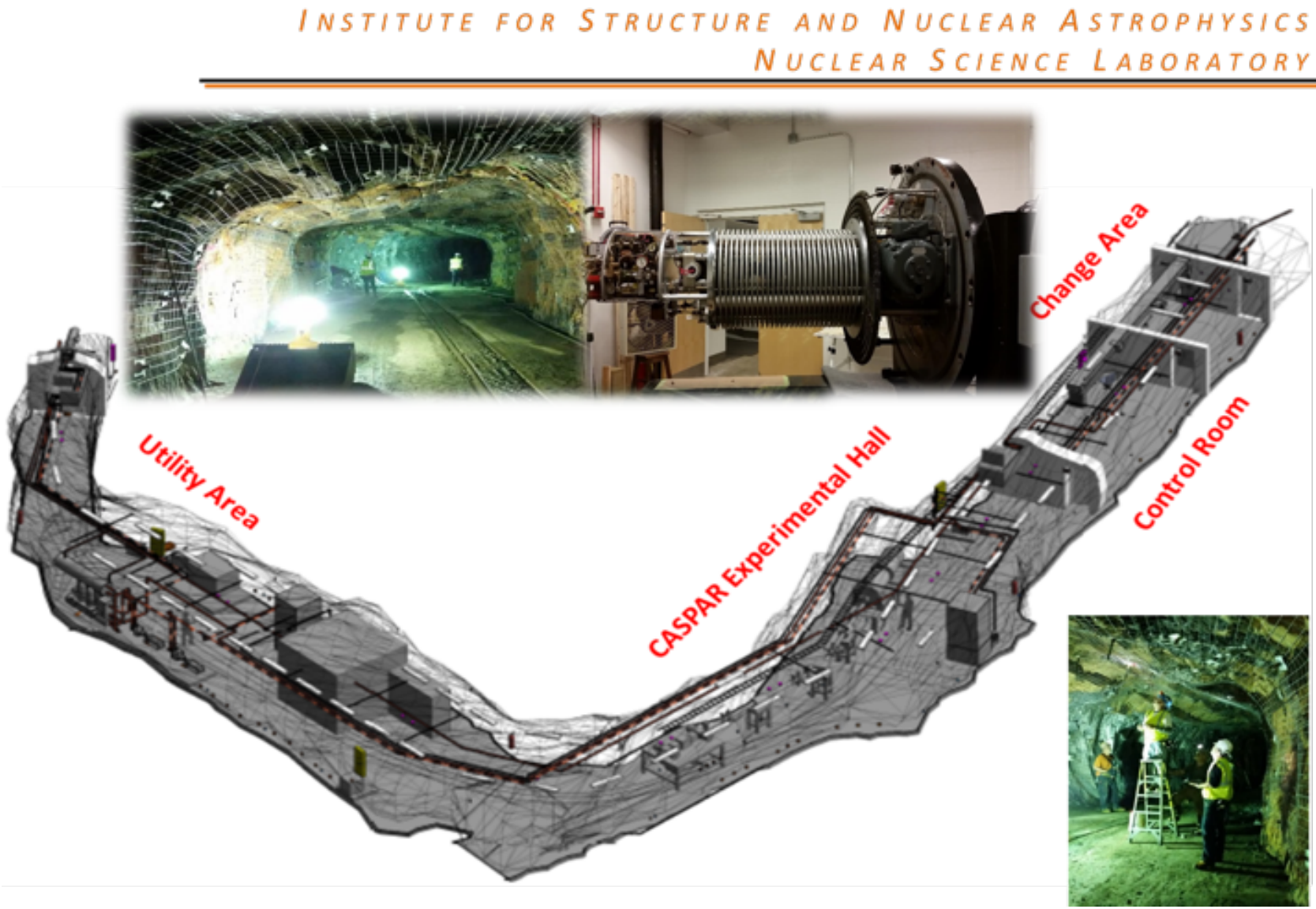
Uwe Greife

Hardware



- 1MV JN accelerator provides $\sim 150\mu$A protons, alphas
- 10 years at Notre Dame, refurbished and moved to South Dakota

Caspar site layout



Before

Caspar makes the news

Sanford Underground Research Facility

Subscribe at: Sanfordlab.org/newsletters

Deep Thoughts

Notes from the underground by Communications Director Constance Walter — **Monday, August 17, 2015**

CASPAR moves in

The mood was almost festive in the CASPAR cavern. After a nearly one-year delay, collaborators began putting together the backbone of the accelerator in which researchers will attempt to mimic nuclear fusion in stars. By January 2016, the collaboration hopes to begin calibrations and other tests on the accelerator.

Equipment for the Compact Accelerator System for Performing Astrophysical Research experiment arrived at Sanford Lab early last week. Within 24 hours and with the help of a stellar Sanford Lab team, the equipment had been moved from the surface to the cavern. "That's pretty amazing," said Dan Robertson, Assistant Research Professor at Notre Dame.

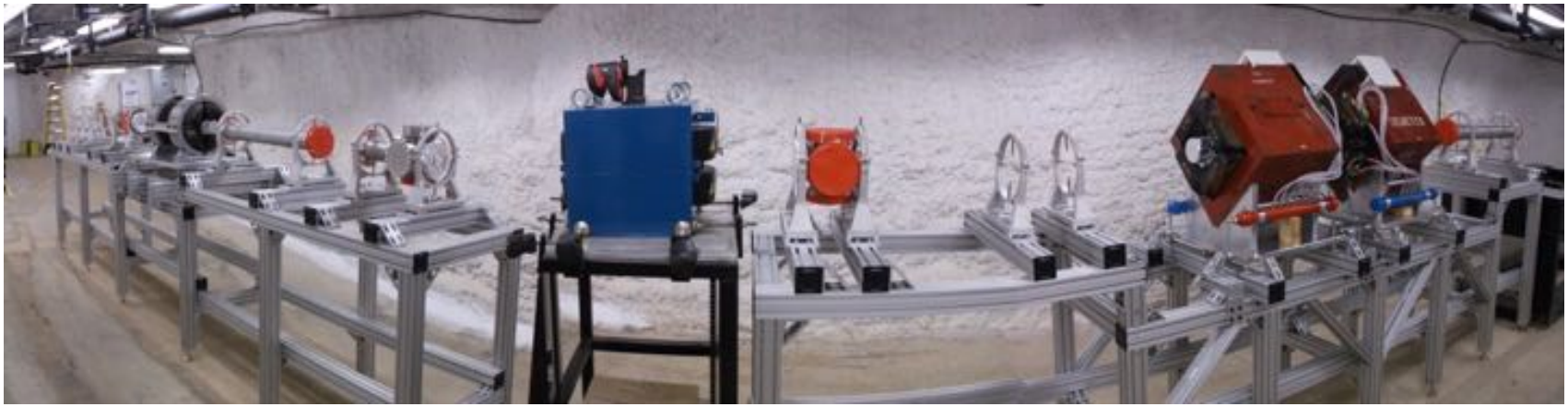
"Our goal is to create the same reactions that happen in stars that are a bit 'older'

Members of the CASPAR collaboration began setting up the accelerator last week. From left: Dan Robertson, Rory Hamilton, Frank Strieder, Manoel Coulder, Tyler Borgwardt, Zach Meisel, Mark Hanhardt and Bryant Vande Kolk.

Move-in after site preparation

August 19

The nagging feeling of having forgotten something

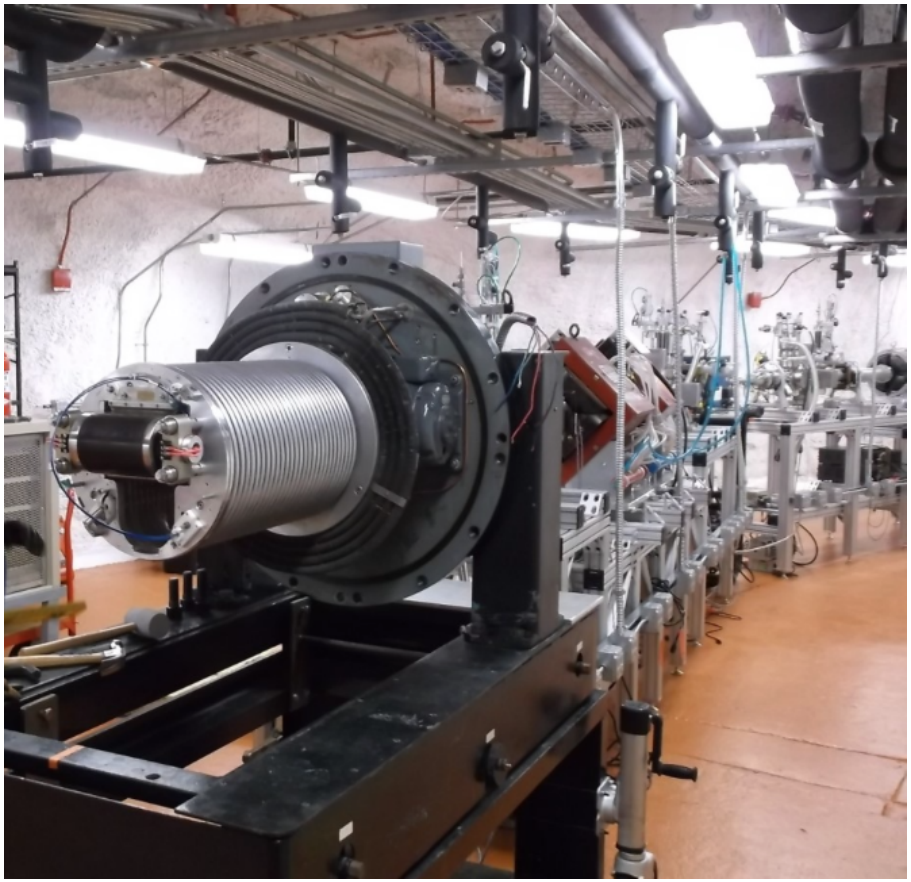


August 26

New floor

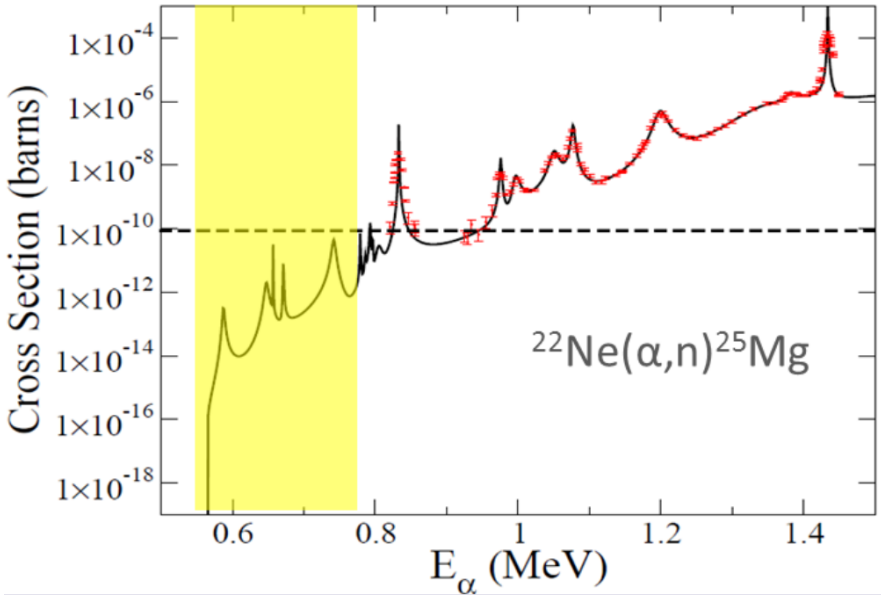
- October 6: Beamlines and components installed

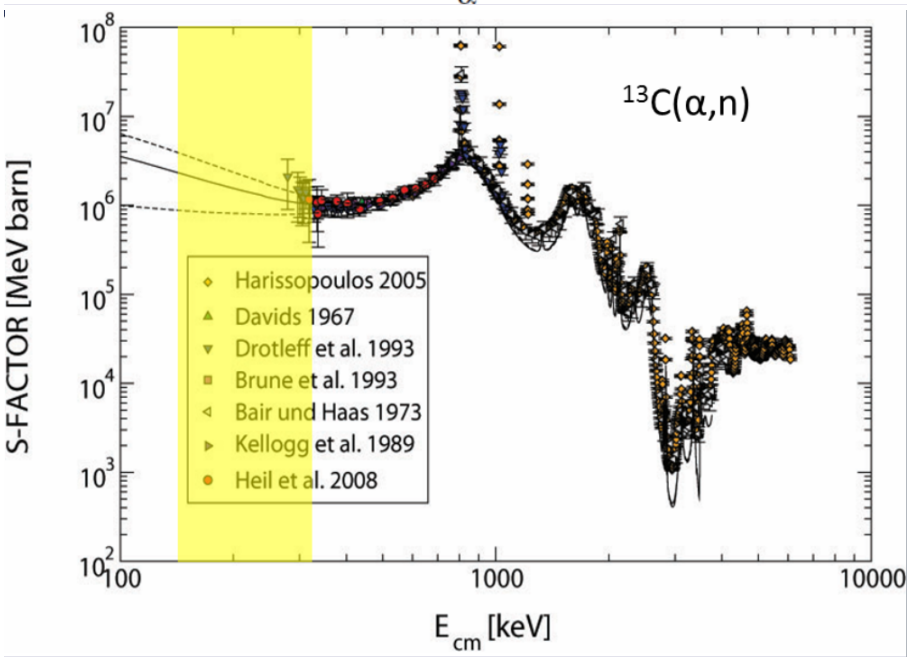
Current status and schedule



- Accelerator connected underground
- First beam expected April
- First science results early 2017

Experimental program (5-8 years)

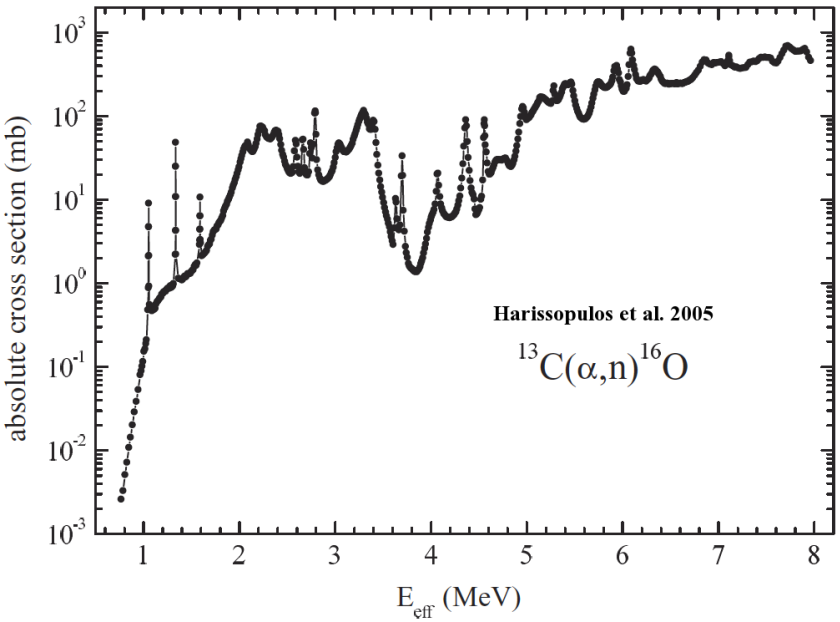


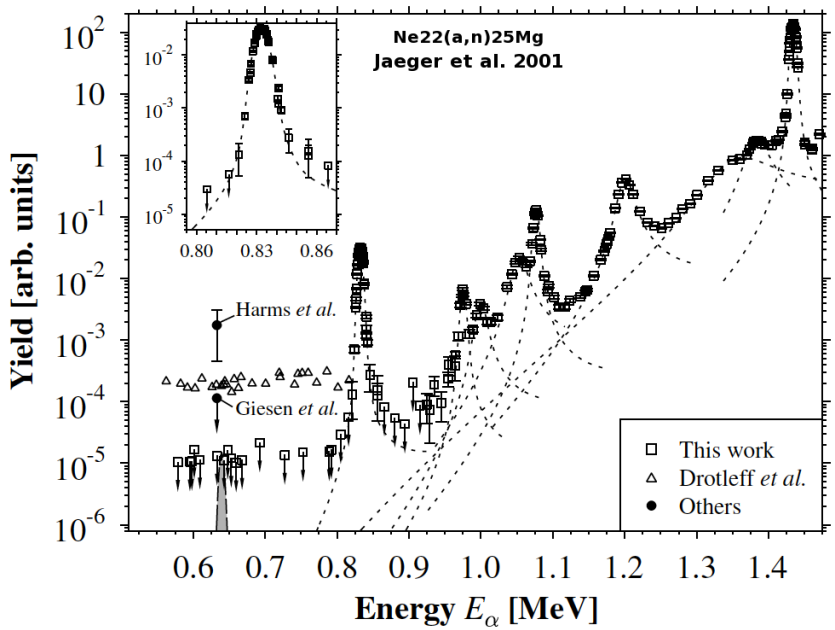


- Priority: s process neutron sources
  - $^{22}\mathrm{Ne}(\alpha,\mathrm{n})^{25}\mathrm{Mg}$
  - $^{13}\mathrm{C}(\alpha,\mathrm{n})^{16}\mathrm{O}$
- γ-ray spectroscopy
  - $^{14}\mathrm{N}(\mathrm{p},\gamma)^{15}\mathrm{O}$
  - $^{22}\mathrm{Ne}(\alpha,\gamma)^{26}\mathrm{Mg}$
  - $^{3}\mathrm{He}(\alpha,\gamma)^{7}\mathrm{Be}$
- Future challenge
  - $^{26}\mathrm{Al}(\mathrm{p},\gamma)^{27}\mathrm{Si}$

Part II - Neutrons

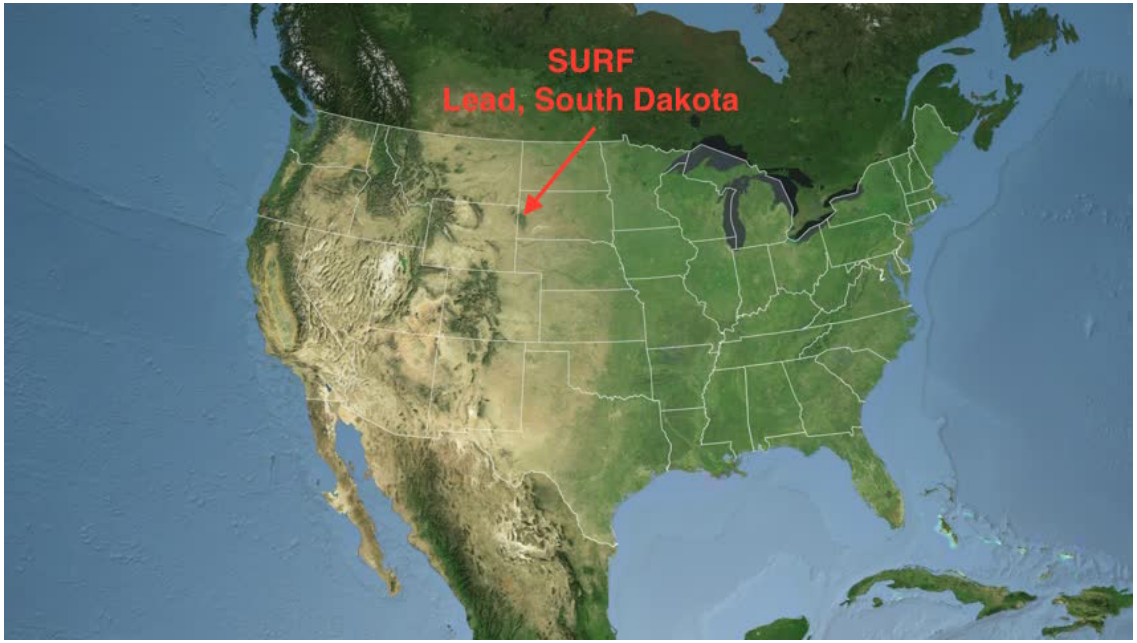
Motivation





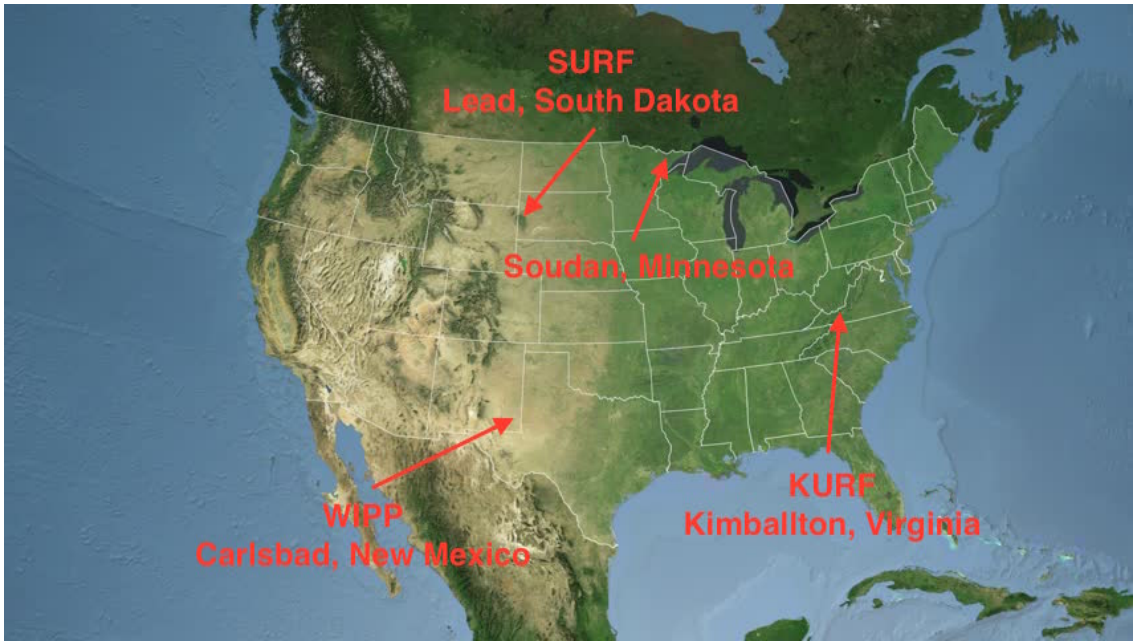
- Astrophysical neutron sources $^{13}C(\alpha,n)^{16}O$, $^{22}Ne(\alpha,n)^{25}Mg$
- Very low cross sections: background-free environment
- Underground n flux $> 10^3$ suppression over surface
- Site characterisation for DIANA project in USA

Program



- Neutrons not easy to measure
- Large systematic differences between different groups
- Use single portable setup:
  - relative flux comparison
  - absolute values with same systematics
- Visited SURF

Program



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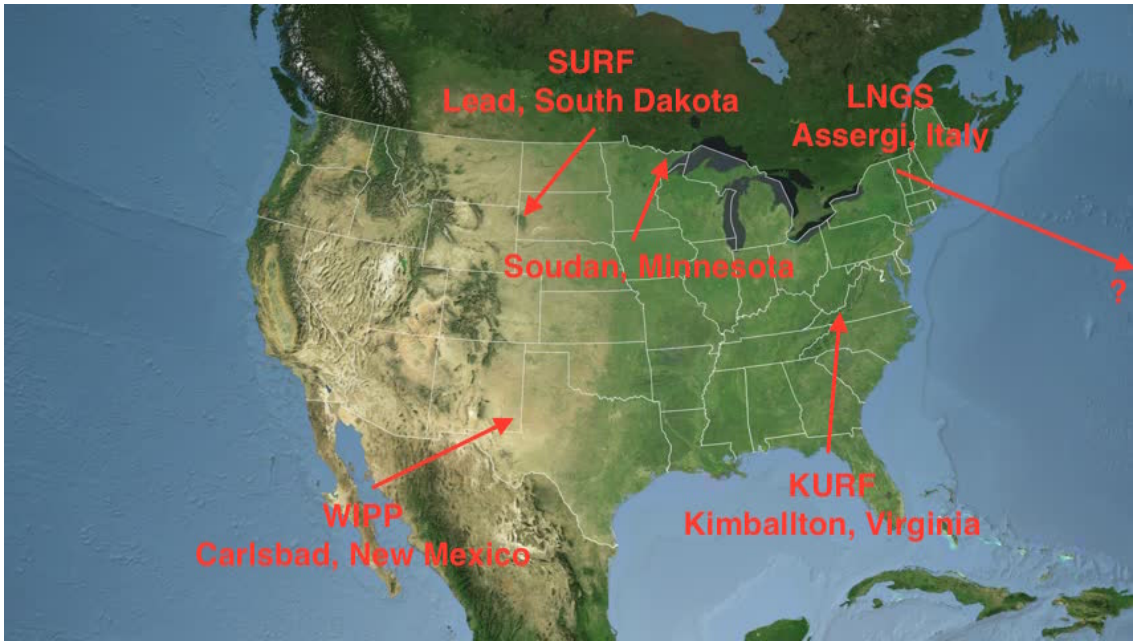

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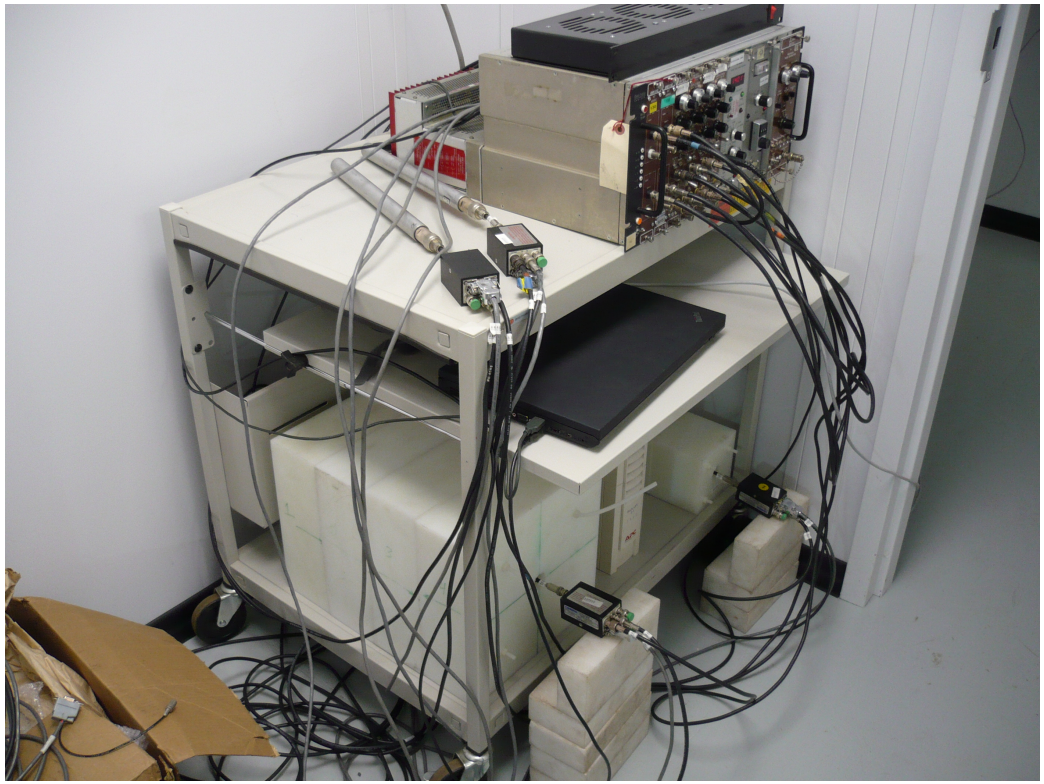
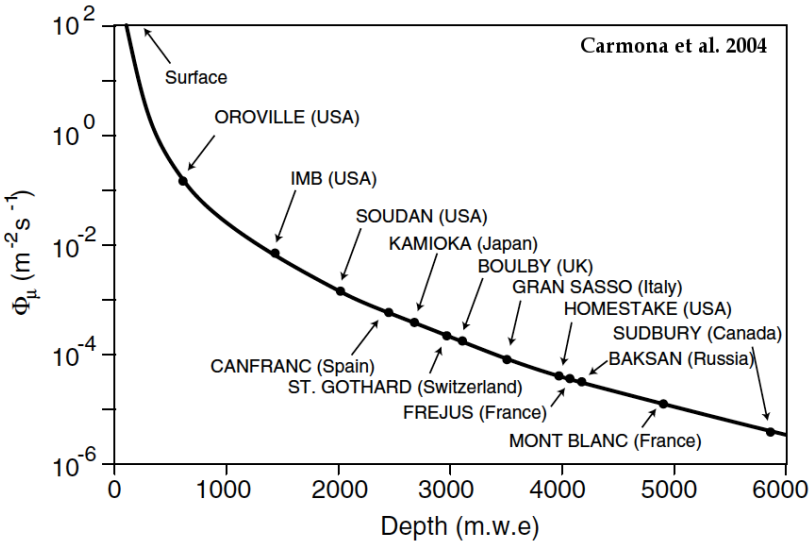
- Visited SURF, KURF, Soudan, WIPP
- New job $\rightarrow$ new site! (LNGS)

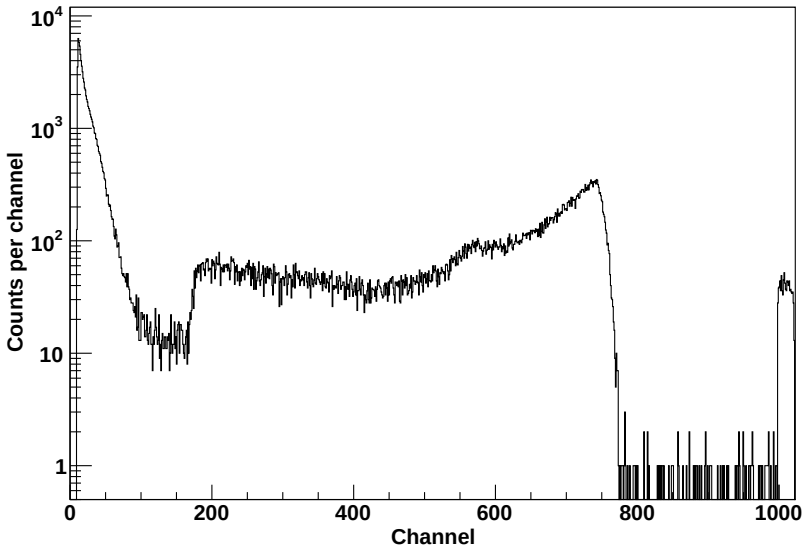
Setup



- ^{3}He counters, 10 bar pressure in Al housing
- Analog electronics, laptop for DAQ
- Small footprint
- Supervisionless data taking ($>$ 5 months)

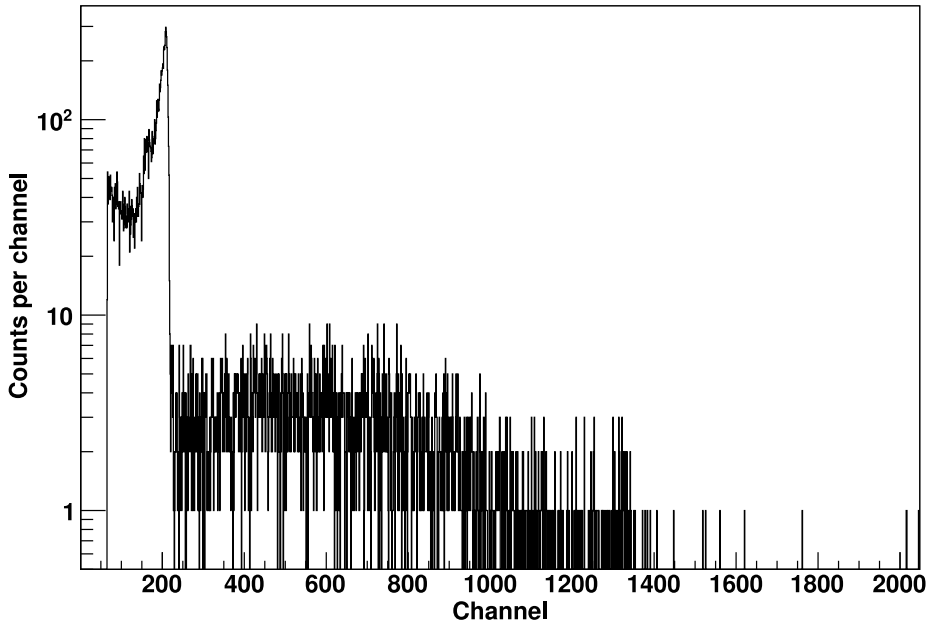
Background conditions & detector response





- Neutrons on surface: cosmic-ray muon induced, $\approx 10^{-3}$ cm^{-2} s^{-1}
- "No" muons underground $\rightarrow 10^{-6}$ cm^{-2} s^{-1} from (α, n) and ^{238}U
- ^{3}He is a counter, no energy info
- Underground neutrons $\approx 70\%$ thermal

Internal counter background



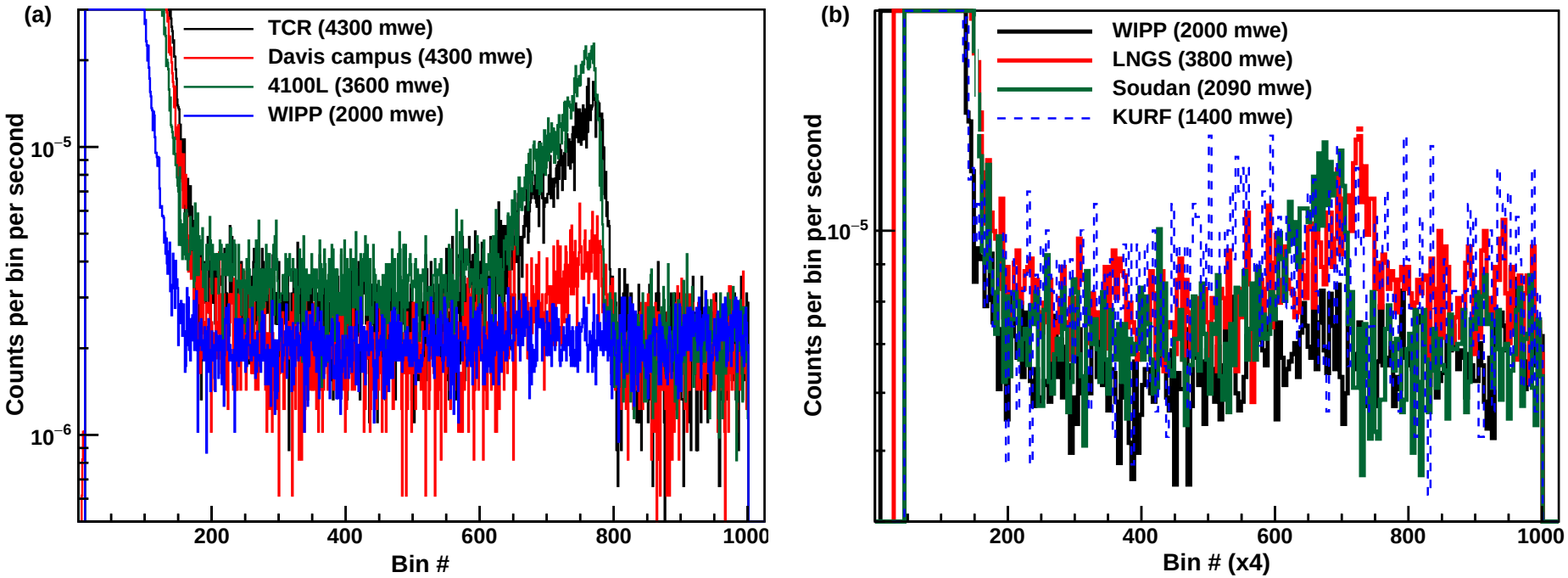
- Residual neutron flux 3-4 o.o.m. lower than surface
- Internal counter background major contribution ($\approx$3 /hour)
- alphas from U, Th contaminants in housing (Hashemi-Nezhad 1996)
- Energy spectrum up to 9 MeV, but covering entire neutron region

Site properties

Location	WIPP [14]	Soudan [12,15]	KURF [16]	SURF [11,12]	LNGS [9,17]
Environment	Salt	"Ely Greenstone"	Limestone	Poorman foundation	Limestone
Depth (m)	655	780	500	1500	1400
Equivalent depth (m.w.e.)	2000	2090	1450	4300	3800
Muon flux (10^{-7} s^{-1} cm^{-2})	4.77 ± 0.09	2.0 ± 0.2	≈ 20	0.044 ± 0.001	0.32 ± 0.01
^{238}U (ppm)	$(0.5-1.5) \cdot 10^{-3}$	0.2		3.4	6.8 (Hall A)
^{232}Th (ppm)	$(1.0-1.9) \cdot 10^{-3}$	0.9		7.1	2.2 (Hall A)

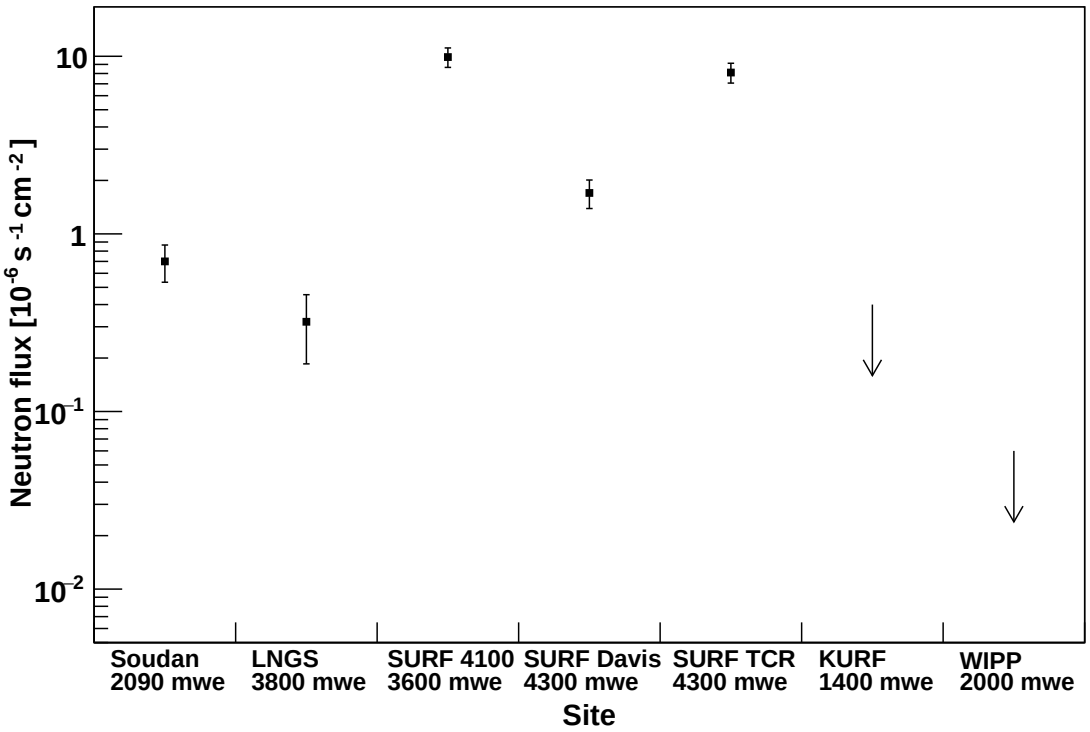
- Iron-, gold-, limestone-, and salt mines
- No shallow sites, no competition with muon-induced n measureable
- Air-circulation (radon) appears to have effect
- Spoiler: salt is good

Spectra



- KURF first test site, only 1 month */to* bad statistics
- WIPP: after 5 months still no discernible signal

Spectra



- KURF first test site, only 1 month */to* bad statistics
- WIPP: after 5 months still no discernible signal
- Three times at SURF, but Michael still not happy with the flux

Thanks!