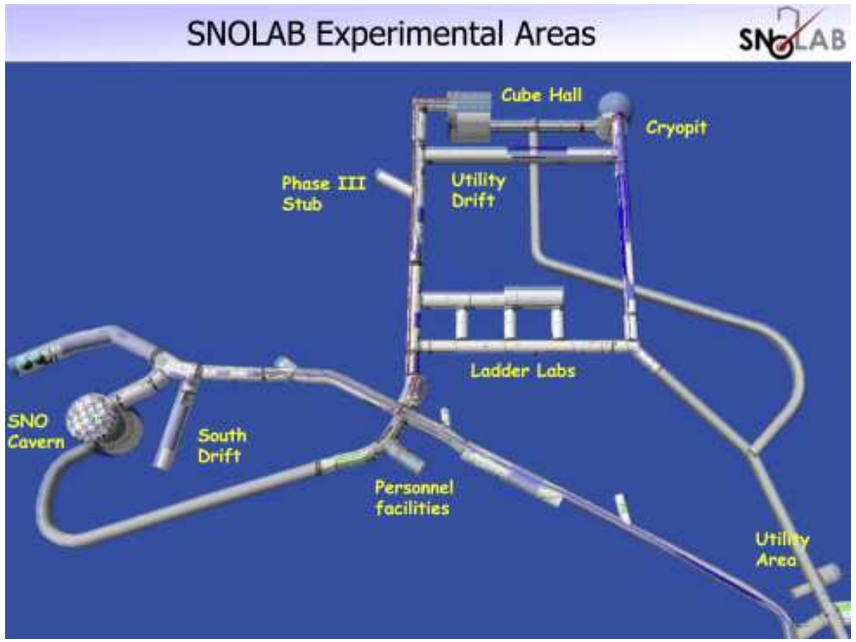
Neutron Backgrounds at SNOLAB



SNOLAB

AARM S4 Collaboration Meeting
SLAC; March 4, 2013

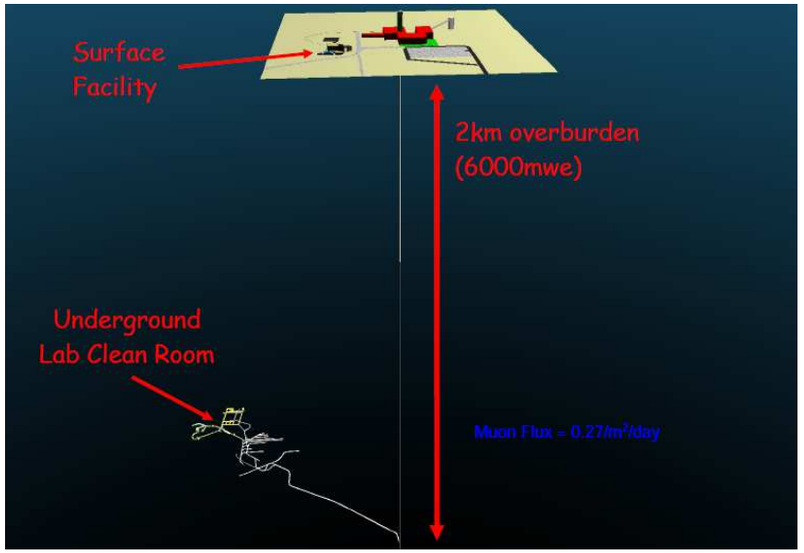
Neutron Backgrounds

- **Rock neutrons: (α,n), spontaneous fission, (γ,n)**
- **Muon induced neutrons**
- **Measurements and simulations**
- **Radio assay of materials**
- **Examples: SNO, PICASSO, COUPP**

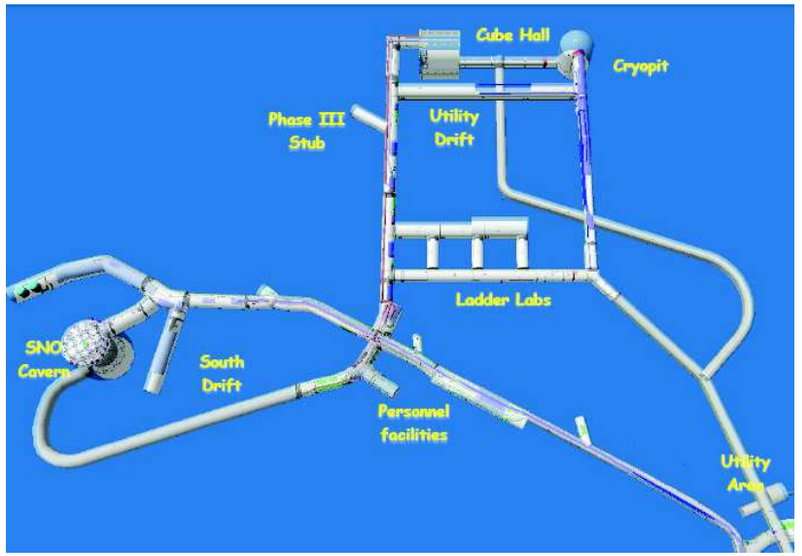
SNOLAB

- Fast neutron flux:
  ~ 4000 neutrons/m^2/day
- Thermal neutron flux:
  $4144.9 \pm 49.8 \pm 105.3$
  neutrons/m^2/day

muons: 0.27 m^2/day
radon: 130 Bq/m^3



- 2 km underground
  near Sudbury, Ontario
- ultra-low radioactivity
  background environment
  Class 2000
- Physics programme focused
  on neutrino physics
  and dark matter searches

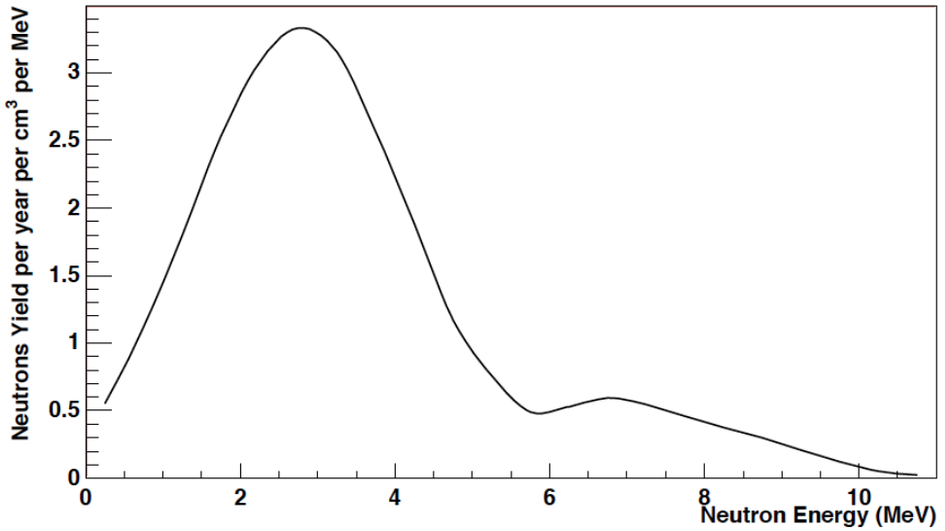


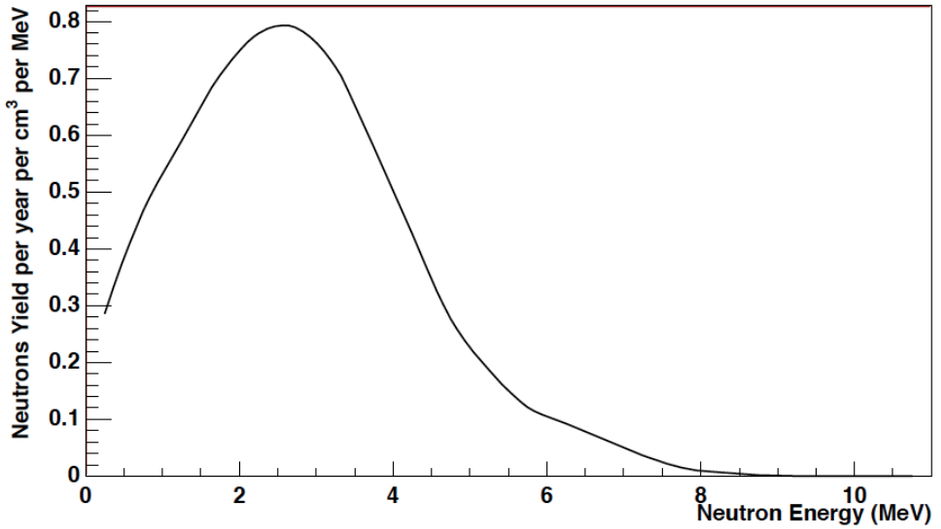
Rock neutrons

- **Norite: O, Si, Al, Fe, Ca, Mg, Na, K**
- **Shotcrete: O, Si, Ca, H**

Isotope	Norite	
	Concentration (ppm)	Neutron production (n/y/cm^3)
Th	5.10	8.13
U	1.10	3.51
U-fission		1.19
Total		12.83

Shotcrete	
Concentration (ppm)	Neutron production (n/y/cm^3)
2.4	0.99
1.2	1.05
	1.03
	3.07



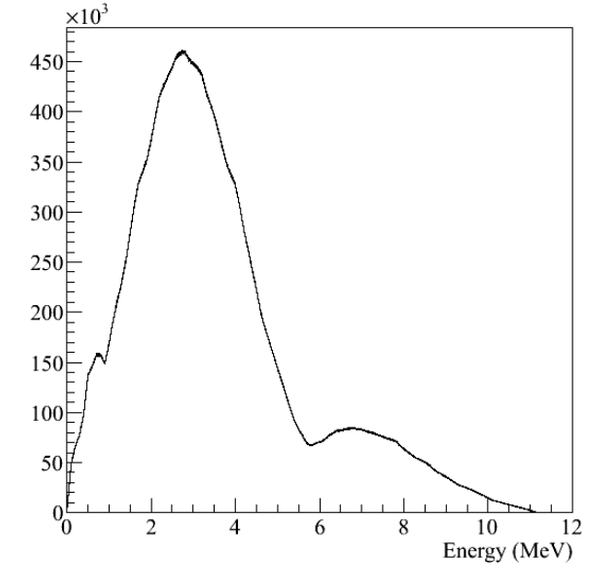


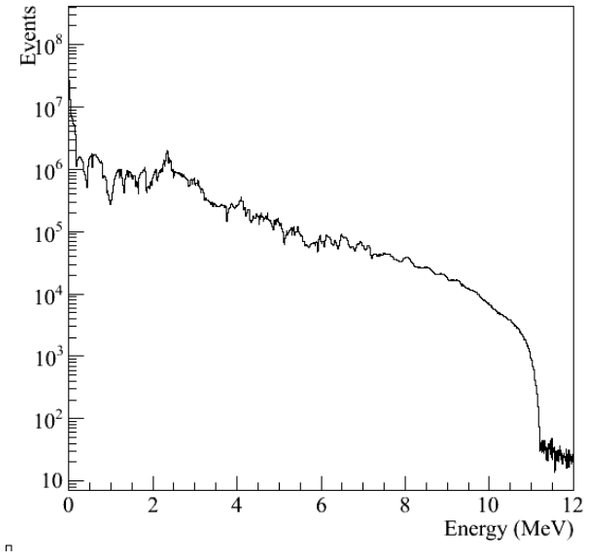
Rock neutrons

Rock samples analyzed:

- **Norite: new lab areas agree with SNO samples**
- **Shotcrete: new areas slightly higher for Uranium and more than 2x for Thorium**

- **90%: (α,n) on light elements**
- **10%: ^{238}U spontaneous fission**



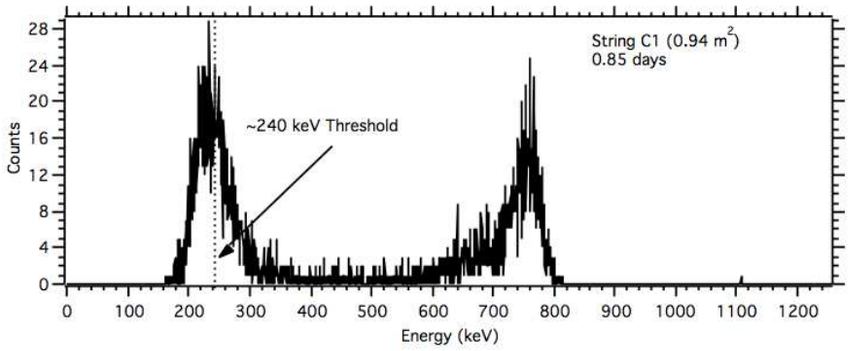


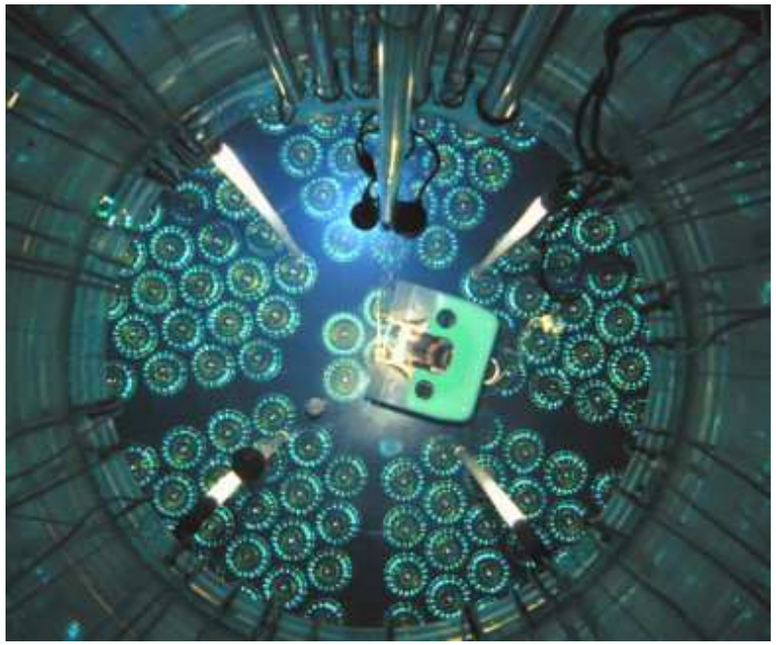
Measurements at SNOLAB

Neutral Current Detectors (NCDs):

- cylinder composed of a thin layer of Nickel (^{58}Ni)
- filled with a mixture of gas (mixture by pressure is 85%:15% ^{3}He:CF_4)
- used by the SNO experiment

Most of them being used by HALO for supernova detection





Measurements at SNOLAB

Neutral Current Detectors (NCDs):

- **4 2m-long proportional counters used**
- **sensitivity: 0.00003 mRem/hr**

Counters can be deployed inside shielding structures to determine how effective the shielding is at stopping neutrons

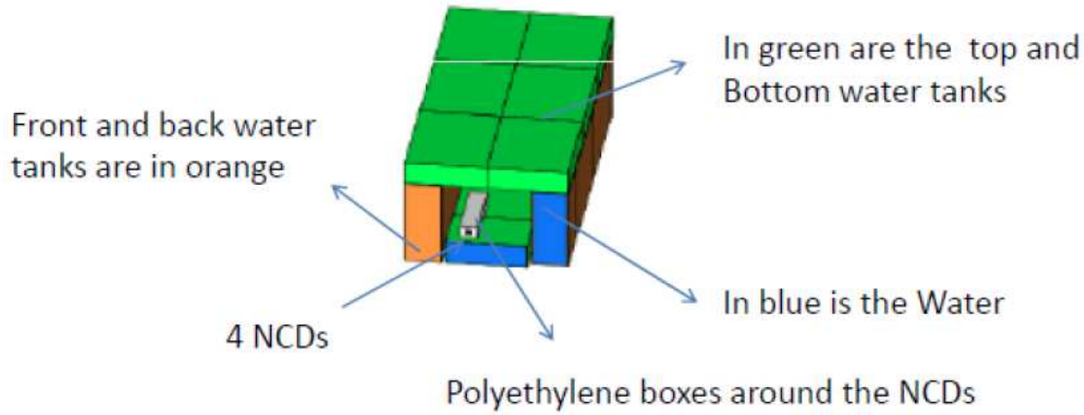
Measurements at SNOLAB

PICASSO water shielding:

- Input: (α,n) in norite
- Propagate through 0.5 m of rock
- Different shielding layers (water)

Good agreement between data and simulation

Efficiency=99.8%



Measurements at SNOLAB

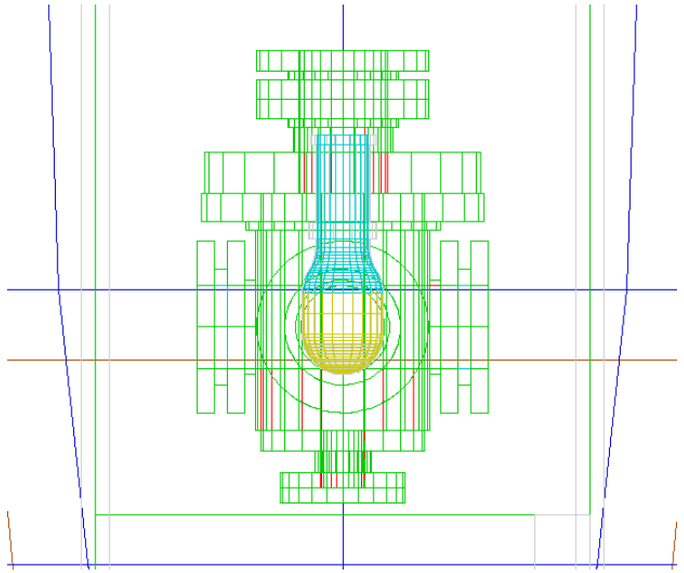
	5 regions combined(Simulation)	Measurement (Data)
0/1	0.766±0.021	1.430 ± 0.018
1/2	1.161±0.031	1.443± 0.047
2/3	1.437 ±0.045	1.432 ±0.147
0/WT	52.114 ± 8.362	50.287±4.066
WT/(WT+1)	1.913 ± 0.515	2.071 ±0.0.615
(WT+1)/(WT+2)	1.438 ± 0.476	2.270 ± 0.746
(WT+2)/(WT+3)	2.280 ± 0.868	1.298 ± 0.275
1- WT/0	0.981±0.003	0.980 ± 0.002
1-((WT+1)/1)	0.992±0.002	0.986 ± 0.004
1- ((WT+2)/2)	0.994±0.002	0.991 ± 0.001
1- ((WT+3)/3)	0.996±0.001	0.990 ±0.002

Several MC inputs and combinations of NCD shielding with/without water tanks for PICASSO

Measurements at SNOLAB

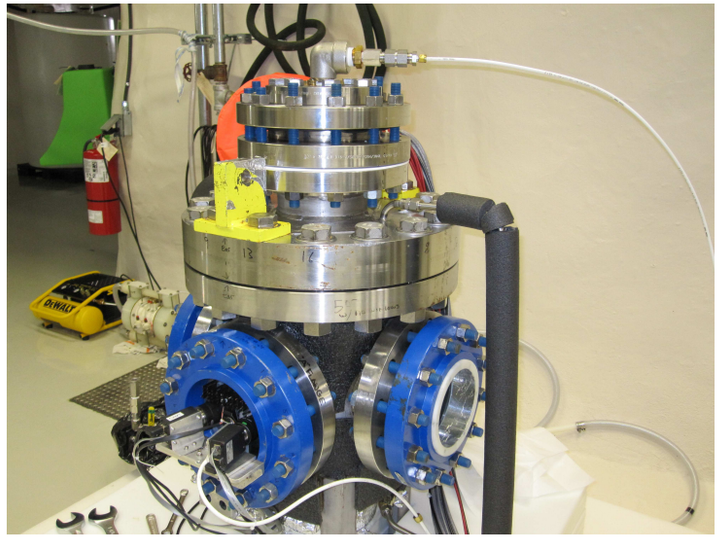
COUPP4 bubble chamber:

- **Dark matter detection with CF_3I**
- **4kg detector operating**
- **60kg being installed (propose to measure neutron rate without shielding)**



0.3 cts/kg/day (data)
0.6 cts/kg/day (GEANT4)

statistics limited,
not a concern as background
(20" of water as shielding)

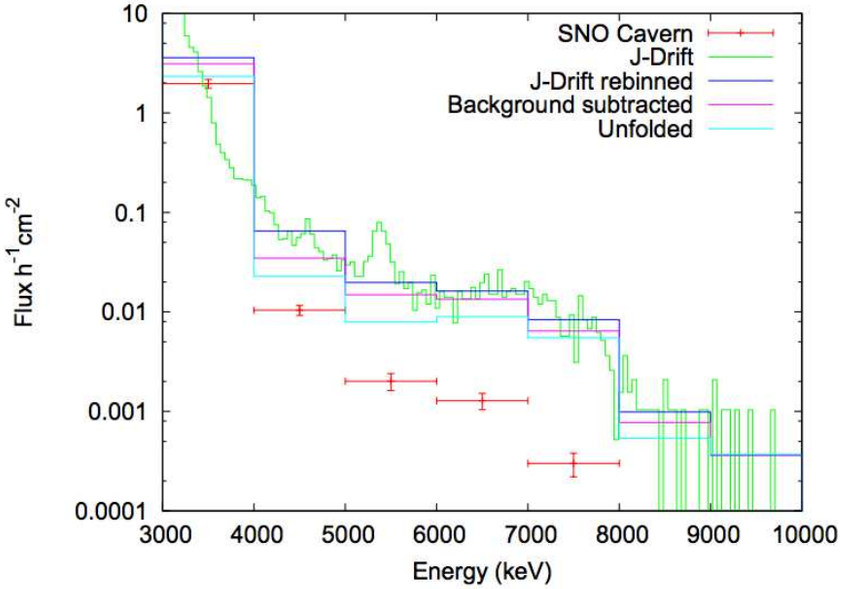


Measurements at SNOLAB

COUPP4 bubble chamber:

- Measurement of gamma spectrum in J-drift
- 1.78 kg low-background NaI(Tl) crystal
- Photonuclear background from ^{127}I(γ,n)^{126}I and photodissociation of deuterium in the water and glycol

Detector	Events/year
COUPP4	0.14
COUPP60	0.28
COUPP500	1.2
	(1 m water shielding)

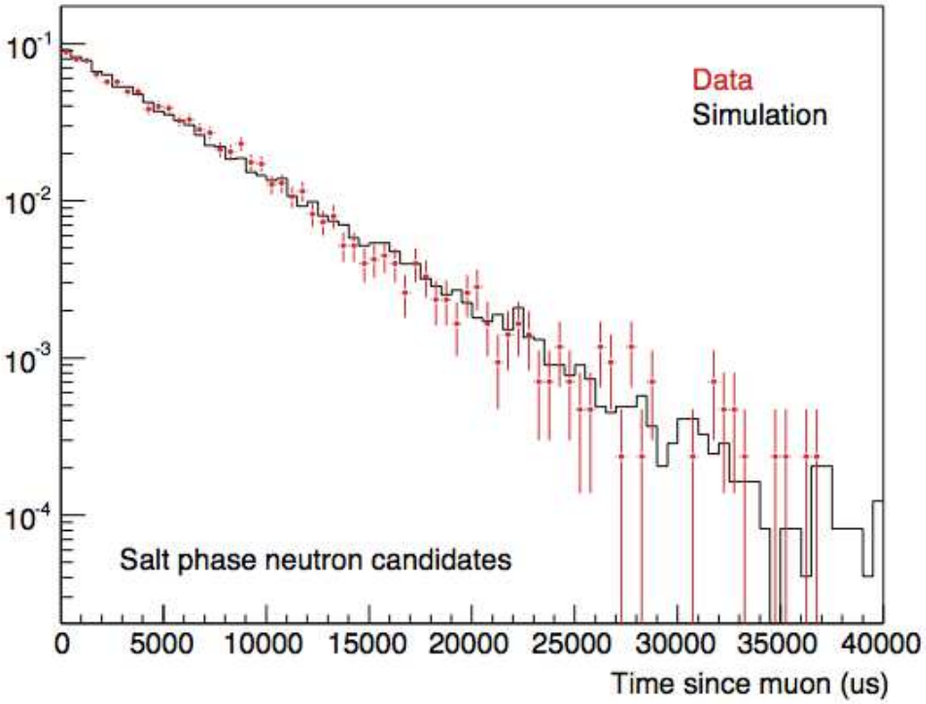


Reaction	Unshielded Rate ((kg-yr)$^{-1}$)	Shielded Rate ((kg-yr)$^{-1}$) COUPP-4	COUPP-60	COUPP-500 1m shield	COUPP-500 3m shield
		$E_\gamma < 10$MeV			
^{12}C($\gamma, 3\alpha$)	4.4e-4	3.2e-5	5.8e-6	6.2e-6	3.8e-8
^{13}C(γ, n)^{12}C	2.4e-3	1.6e-4	2.6e-5	2.8e-5	1.1e-7
^{19}F(γ, α)^{15}N	5.4e-4	3.4e-5	5.3e-6	5.8e-6	1.9e-8
^{19}F(γ, p)^{18}O	1.4e-5	1.1e-6	2.1e-7	2.2e-7	1.5e-9
^{127}I(γ, n)^{126}I	0.19	0.015	2.8e-3	3.1e-3	2.4e-5
Subtotal	0.20	0.015	2.9e-3	3.1e-3	2.4e-5
		1.0γ/cm^2/yr at 12MeV			
^{12}C(γ, x)	9.3e-5	8.0e-6	1.6e-6	1.7e-6	1.5e-8
^{13}C(γ, x)	5.6e-5	4.8e-6	9.8e-7	1.0e-6	8.8e-9
^{19}F(γ, n)^{18}F	0.016	1.4e-3	2.8e-4	2.9e-4	2.6e-6
^{127}I(γ, n)^{126}I	0.16	0.013	2.8e-3	2.9e-3	2.5e-5
Total	0.37	0.030	5.9e-3	6.2e-3	4.7e-5
Events/yr	n/a	0.087	0.21	0.89	6.9e-3

Measurements at SNOLAB

SNO: muon induced neutrons

- Muon rate= $3.31 \pm 0.01 \pm 0.09 \times 10^{-10}$ $\mu/s/cm^2$
- 38.4 neutrons/day in SNO from cosmic rays

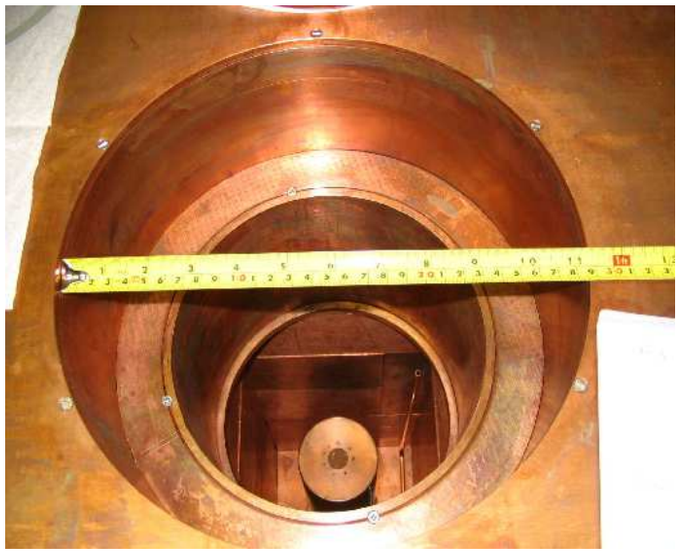


Quantity	Night value	Day value	Asymmetry ratio (%)
Event rate (day^{-1})	3.50 ± 0.09	3.56 ± 0.10	-1.83 ± 3.81
Mean energy (MeV)	5.78 ± 0.06	5.67 ± 0.06	1.96 ± 1.49
Energy width (MeV)	1.47 ± 0.06	1.47 ± 0.06	0.00 ± 4.69
Mean isotropy (β_{14})	0.311 ± 0.004	0.312 ± 0.005	-0.24 ± 2.03
Capture time (ms)	4.9 ± 0.3	4.6 ± 0.3	7.27 ± 8.36

Measurements at SNOLAB

HPGe detectors:

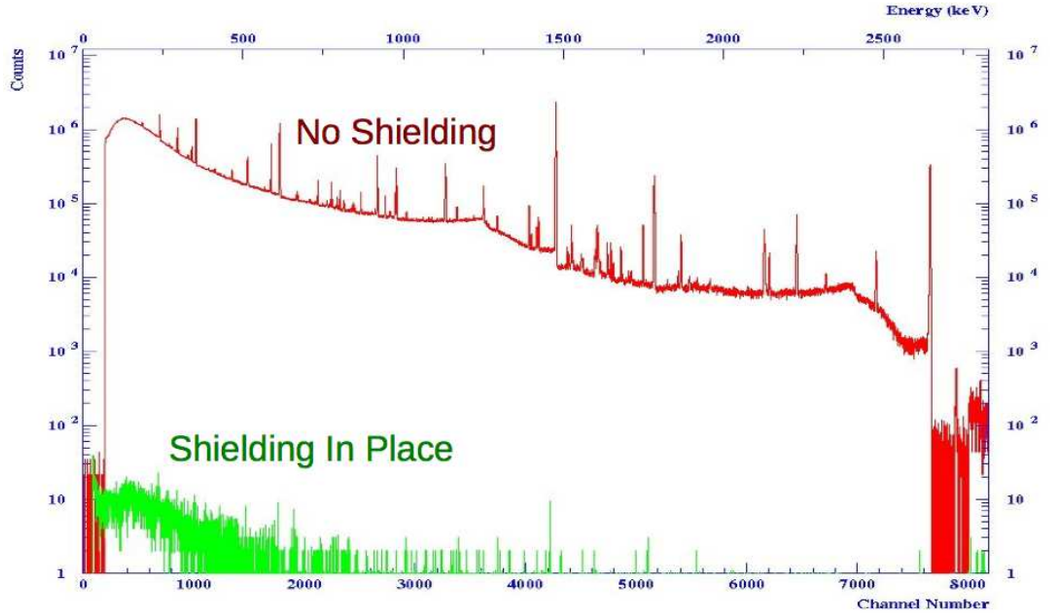
- **63 mm × 67 mm crystal**
- **Efficiency: 55%, relative to 7.62 cm dia × 7.62 cm NaI(Tl) detector for 1332 keV γ-rays from a ^{60}Co source 25cm from the crystal**
- **Resolution: 1.8 keV FWHM**
- **Shielding: 2" Cu + 8" Pb**
- **Nitrogen purge at ∼ 2L/min**



Measurements at SNOLAB

HPGe detector:

- Measure activity in materials
- Data used as input to calculate (α,n), (γ,n)



- Two new low-background high purity Ge counters: p-type coaxial and well
- 3 crystal detector moved from 4600 to 6800 level

Isotope	1 Bq/kg	1 ppb	Sensitivity for Standard Size Samples	Typical for Earth's Crust
^{238}U	81 ppb	12 mBq/kg	~ 1 mBq/kg ~ 0.1 ppb	37 Bq/kg 3 ppm
^{232}Th	246 ppb	4.1 mBq/kg	~ 1.5 mBq/kg ~ 0.3 ppb	45 Bq/kg 11 ppm
^{40}K	32 ppm	0.031 mBq/kg	~ 21 mBq/kg ~ 0.7 ppm	800 Bq/kg 2.5 %

Conclusions

- **Several measurements for neutron backgrounds during the SNO experiment**
- **Measurements being performed in the new areas of the lab**
- **Input from data used for simulations in dark matter experiments**
- **Low background counting lab under construction**