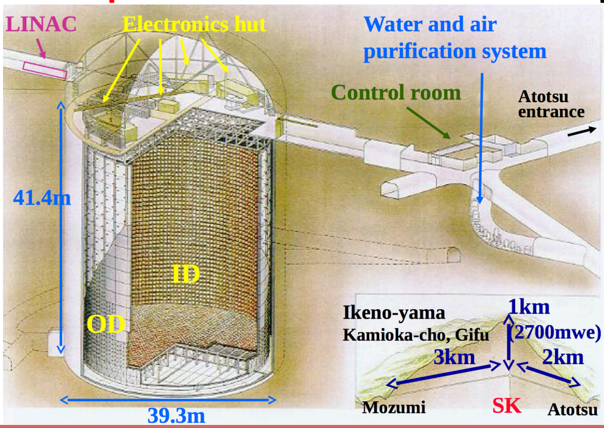
Very low background measurements of Radioactive Contaminations for SuperK-Gd

Javier Pérez Pérez (LSC, now at Jagiellonian University), Iulian C. Bandac (LSC), Luis Labarga (UAM)

H2020-MSCA-RISE-2014-GA641540, SKPLUS

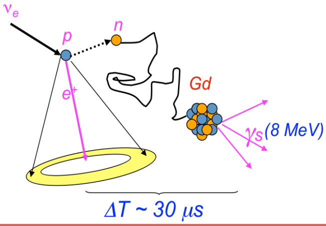
The Super-Kamiokande Evolution: SuperK-Gd



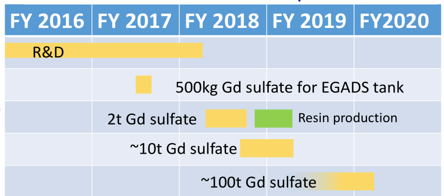
Go further with **high efficiency neutron tagging: SuperK-Gd**

Beacom and Vagins PRL93,171101 (2004)

Adding a 0.2 % by mass of a Gd compound, $Gd_2(SO_4)_3$, **to SK** water, the majority of final state **neutrons** produced in the interactions (90% captured × 90% reconstructed) will, after thermalized, be **captured by Gd** after ~30 µs and detected through the **8 MeV γ ray cascade** from its de-excitation.



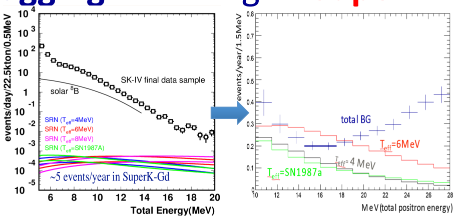
Tentative time-line for Gd procurement



What neutron tagging will bring to SuperK

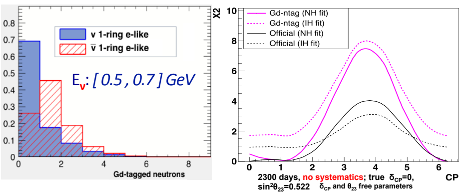
- Anti-neutrino tagging at inverse β reaction:

Be in the position of discovering **S**upernova **R**elic **N**eutrino thanks to the very much reduced background



- Neutrino/anti-neutrino discrimination by neutron counting

very significant increase of sensitivity to **CP** **v**iolation in the leptonic sector



Also: Supernova early warning from Si burning ν_S , precision solar- ν_S elements from reactor ν_S , Improvement of E_ν reconstruction with the tagged neutrons, neutron veto in nucleon decay searches… more to come along the learning curve

Radioactive Contaminations

RC, principally in the Gd salt, induce severe backgrounds to the measured processes. The typical activities are orders of magnitude larger than we need.

Decay Chain	Part of the Chain	Typical Activities	Required for SRN	Required for Solar ν
^{238}U	^{238}U	50	< 5	-
	^{226}Ra	5	-	< 0.5
^{232}Th	^{228}Ra	10	-	< 0.05
	^{228}Th	100	-	< 0.05
^{235}U	^{235}U	30	-	< 3
	^{227}Ac / ^{227}Th	300	-	< 3

(Units are mBq/Kg)

Their impact on relevant measurements is large:

Supernova **R**elic **N**eutrino

- expected signal: ~5 events/year/fiducial volume
- background from ^{238}U Spontaneous Fission: ~5.5 [γ (Eγ >10.5 MeV) + 1 **n**] / year/ f.v. x10 reduction desirable

Solar neutrino measurements

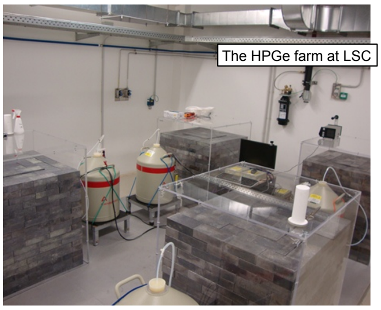
- current baseline: ~200 events/day/f.v.
- from neutrons from U: ~320 events/day/f.v. x10 reduction desirable
- from β, γ from Th/Ra: ~3 x 10^5 events/day/f.v. x10^3 reduction needed

Radioactive Contamination:

a) as low as feasible
b) all the Gd salt used should be screened ➡ SuperKGd-LSC
c) must be known with high precision

Radioactive Measurements at LSC: SuperKGd-LSC

SuperKGd-LSC is a program of complete series of measurements of the **R**adioactivity **C**ontamination of the different samples of **Gd** salts and relevant materials of SuperKGd in the **LSC**'s superb Radiopurity Facility. After the first batches measured by **SuperKGd-LSC**, it was clear that the **RC** is a serious issue; we obtained **RC**s not acceptable for the experiment. After a thorough worldwide search of providers and a dedicated R&D program with some of them lead by **ICRR (U. Tokyo)**, they succeed in producing high purity salt in a reproducible manner. They are three Japanese companies: Nippon Yttrium Co. Ltd., Shinetsu Chemicals and Kanto Chemicals. In order to keep the confidentiality necessary at this stage of the Program, we will refer those as companies A, B, and C (notice that the ordering is different). D is used for measurements for other companies. The measurements by SuperKGd-LSC keep increasing their precisions, in particular to cope with the nowadays very high purities of some of the salts. The instruments used up to know are the High Purity Ge Detectors of the LSC radio-purity service. Starting from some time next in this year, those particular very long-lived radio active isotopes will be also measured with an even better precision by a new ICP-MS, now under commissioning in the LSC.



(Units are mBq/Kg; limits are at 95% CL)

CHAIN	MAIN SUBCHAIN ISOTOPE	GOX-1510-D-001	GSF-1701-D-003	GSF-1705-D-001	GSF-1711-D-171111B	GSF-1711-D-171111A	GSF-1703-A-702142	GSF-1703 B- (RGD-OSF-005)	GOX-1603-B-237	GOX-1603-B-239	GOX-1603-B-236	GSF-1604-B-1	GSF-1611-B-003	GSF-1703-B-(RGD-OSF-005)	GSF-1703-B-(RGD-OSF-005)-b	GSF-1707-B-007	GSF-1604-C-160303	GSF-1707-B-007	GSF-1710-C-170901	GSF-1710-C-170902	GSF-1710-C-170903
^{238}U	^{238}U	1672 ± 122	< 45	< 11	< 52	< 168	< 13	< 13	< 68	< 130	< 36	< 25	< 13	< 10	< 19	< 10	< 20	< 10	< 9.7	< 12	< 11
	^{226}Ra	< 2.8	0.4 ± 0.2	4.3 ± 0.6	< 1.1	2.0 ± 1.4	0.7 ± 0.4	< 0.34	< 0.9	< 1.0	< 1.4	< 0.6	< 0.3	< 0.31	< 0.54	< 0.18	< 0.64	< 0.18	< 0.19	< 0.21	< 0.21
^{232}Th	^{228}Ra	259 ± 6	28.5 ± 1.1	12.2 ± 1.0	300 ± 7	778 ± 39	< 0.39	< 0.39	< 2.7	< 2.3	< 1.4	< 0.7	< 0.3	< 0.30	< 0.74	< 0.21	< 0.67	< 0.21	< 0.24	< 0.26	< 0.30
	^{228}Th	124 ± 3	6.3 ± 0.5	2.5 ± 0.4	31 ± 2	70 ± 3	1.7 ± 0.4	< 0.28	< 2.5	< 1.4	< 0.8	0.9±0.3	< 0.4	< 0.33	< 0.43	< 0.26	0.5 ± 0.2	< 0.26	< 0.28	< 0.31	< 0.30
^{235}U	^{235}U	28.7 ± 1.5	< 1.5	< 1.0	< 3	< 4	< 1.3	< 0.77	< 1.6	< 0.8	< 1.0	< 3.1	< 0.6	< 0.69	< 0.82	< 0.3	< 0.7	< 0.3	< 0.35	< 0.41	< 0.42
	^{227}Ac / ^{227}Th	< 14	< 5.5	3.4 ± 1.4	31 ± 5	46 ± 9	< 3.1	< 2.3	< 4.3	-	-	< 6.1	< 1.9	< 1.8	< 2.0	< 1.2	< 2.3	< 1.2	< 1.7	< 1.4	< 1.6
	^{40}K	21 ± 6	< 1.0	< 1.8	27 ± 3	57 ± 4	< 8.2	< 3.2	< 4.6	< 5.3	< 3.4	< 2.1	< 1.8	< 1.5	< 2.5	< 0.9	< 1.6	< 0.9	< 0.8	< 1.0	< 0.7
	^{138}La	< 3.2	< 0.25	< 0.36	< 2.4	< 2.4	< 0.29	< 0.29	< 0.6	< 0.7	< 0.7	< 0.5	< 0.3	< 0.29	< 0.31	< 0.20	< 0.3	< 0.20	< 0.09	< 0.05	< 0.14
	^{176}Lu	5.9 ± 0.4	26.5 ± 0.8	6.1 ± 0.4	< 1.2	4.3 ± 0.6	2.6 ± 0.3	< 0.29	< 0.8	< 0.7	< 1.6	0.4±0.3	0.4±0.1	< 0.46	< 0.41	0.4±0.1	< 0.4	0.8 ± 0.1	0.13± 0.03	0.11± 0.04	< 0.14
	^{134}Cs	-	-	-	-	-	-	-	< 0.24	< 0.4	< 0.23	< 0.24	< 0.09	< 0.09	-	< 0.06	< 0.1	< 0.06	< 0.08	< 0.06	< 0.07
	^{137}Cs	-	-	-	-	-	-	-	< 0.3	< 0.34	< 0.30	< 0.24	< 0.16	< 0.12	-	< 0.12	< 0.1	< 0.12	< 0.13	< 0.10	< 0.11

Name of Samples analyzed
[MATerial*-date-**C**ompany-lot]

***GSF:** $Gd_2(SO_4)_3$ **GOX:** Gd_2O_3

Excellent $Gd_2(SO_4)_3$ achieved, within specifications within experimental limits; Now preparing for mass production screening.