Activities of Uni. Autónoma Madrid

⇩

radio-purity measurements @ LSC

⇩

request to participate in next

Luis Labarga, University Autonoma Madrid
next *CM meeting, 2011103 Valencia*

experimental neutrino physics in the UAM

Present:

Super-Kamiokande (SK) ⇦ **main activity**

- learn about experimental ν physics
- carry out R&D to improve dramatically water-cherenkov techniques for SK and successors
- perform top-class ν measurements

[FPA Coordinated Project with IFIC et al.]

Laguna

- R&D on next generation ν experiments *[EU FP7 Project]*

Medium term:

- next generation 2β0ν experiments ? ⇦ **why I am here today**
- incorporate T2K to the scientific program ?

Long term:

- next generation ν experiments Laguna / HyperKamiokande
- next-to- next generation 2β0ν (and / or DM) experiments ?

UAM UNIVERSIDAD AUTONOMA DE MADRID — FACULTAD DE CIENCIAS — Universidad Autónoma de Madrid Departamento de Física Teórica

Luis Labarga,
Dept. Física Teórica,
Facultad Ciencias, Mod. 15
Universidad Autónoma de Madrid
28049 Madrid, Spain
Ph.: +34-914978589
e-mail: luis.labarga@uam.es

Dear Gloria, Juanjo,

with this letter I would like to request to the NEXT Collaboration to participate in the experiment as an official member, both myself and my group, the latter as it evolves with time. The main reasons for this interest are two very correlated ones: 1) the superb scientific interest of NEXT, and 2) the close relation that one of the relevant works in its preparation, study of radioactivity contaminations, has with my corresponding effort (named SuperkGd) within the neutron tagging R&D program of my main experiment Super-Kamiokande. This relation, I believe, will make rather easy for me to contribute to NEXT.

Given my full commitment to Super-Kamiokande, my participation in NEXT has to be necessarily modest in dedicated time. However the above synergy will translate, hopefully, into a rather productive, most efficient, work effort.

To be precise: I propose to participate in the main program of "screening" and Radio-purity carried out at the LSC. Because of my close relationship with the LSC and with its physicist in charge of the VLB Ge-detector farm, I think I could take the lead in:
1) the scheduling of the measurements in coordination with the LSC and SuperkGd),
2) the works of preparation, start and finish,
3) the regular analysis of the data.

It is my intention to hire one physicist/engineer to help me in the above. However, if I do not succeed in finding the right person, I think that with the help of the Collaboration (mainly shifts for item 2), I can still undertake the proposed task.

I thank you for the interest you may pay to this request, and I look forward to a positive reply from the Collaboration.

Madrid, October 19th 2011

UAM works

1. LAGUNA
2. SK
3. radio-purity measurements for SK in the LSC

What is (was ?) LAGUNA ?

- The current European approach to the next generation, liquid [Mt-like], p-decay and neutrino detectors

- It considers seven candidate sites:

CUPP @ Pyhäsalmi mine, Finland
IUS @ Boulby mine, UK
SUNLAB @ Sieroszowice mine, Poland
IFIN-HH @ Unirea mine, Romania
LSM @ Frejus tunnel, France
New-Italian-Site @ CNGS beam halo, Italy
LSC @ Canfranc RW tunnel, Spain

- It considers three different detector technologies:
  - Water-Cherenkov: ~ 1 Mt
  - Liquid-Argon TPC: ~ 0.1 Mt
  - Liquid-Scintillator: ~ 0.05 Mt

LNGS is not there (i!)

Feasibility Study for LAGUNA at the LSC

- The coordinator of the Feasibility Study (FS) for the LSC was L. Labarga (UAM); he had the help of LSC staff

- For the FS, LAGUNA-EU assigned ~145 K€ to the LSC, and 31 K€ to the the UAM, the LSC and UAM contributed with ~100 K€ and 7 K€ respectively (the later from the AC FPA2008-03002-E)

- The LSC has not Geotechnic Dept.; technical part had to be subcontracted

- July 2008 --> March 2009
  - Contact, discussions and (private) pre-selection of Geotechnic Companies candidate to carry out the FS for the LSC
  - Administrative and legal procedure to select the Company.
  - Select Company (got a *"dream team"*, see next slide), sign contract, Company starts working

- June 2010: the main document basis of WP2's *"Interim Report for the LSC"* is delivered
  [final version is at http://www.lsc-canfranc.es/ links *activity → LAGUNA*]

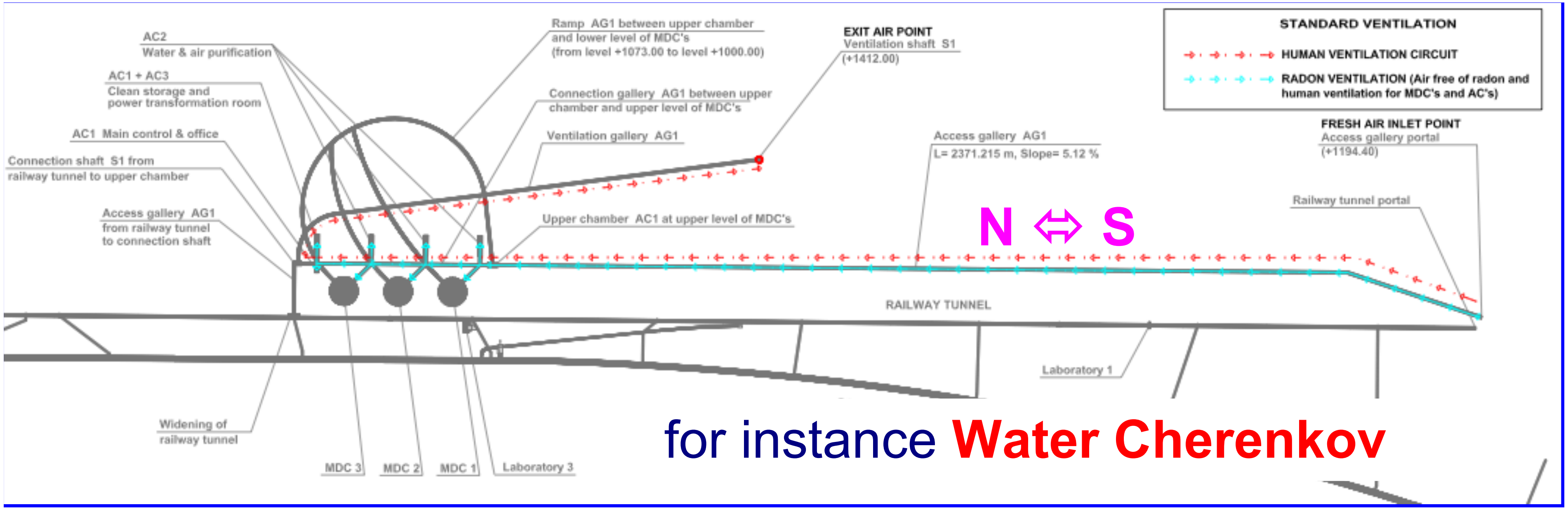
PROJECT TEAM

leader: *Manuel Romana* (STMR)
co-leader: *Clemente Saenz* (Iberinsa-ACCIONA)
Companies involved:

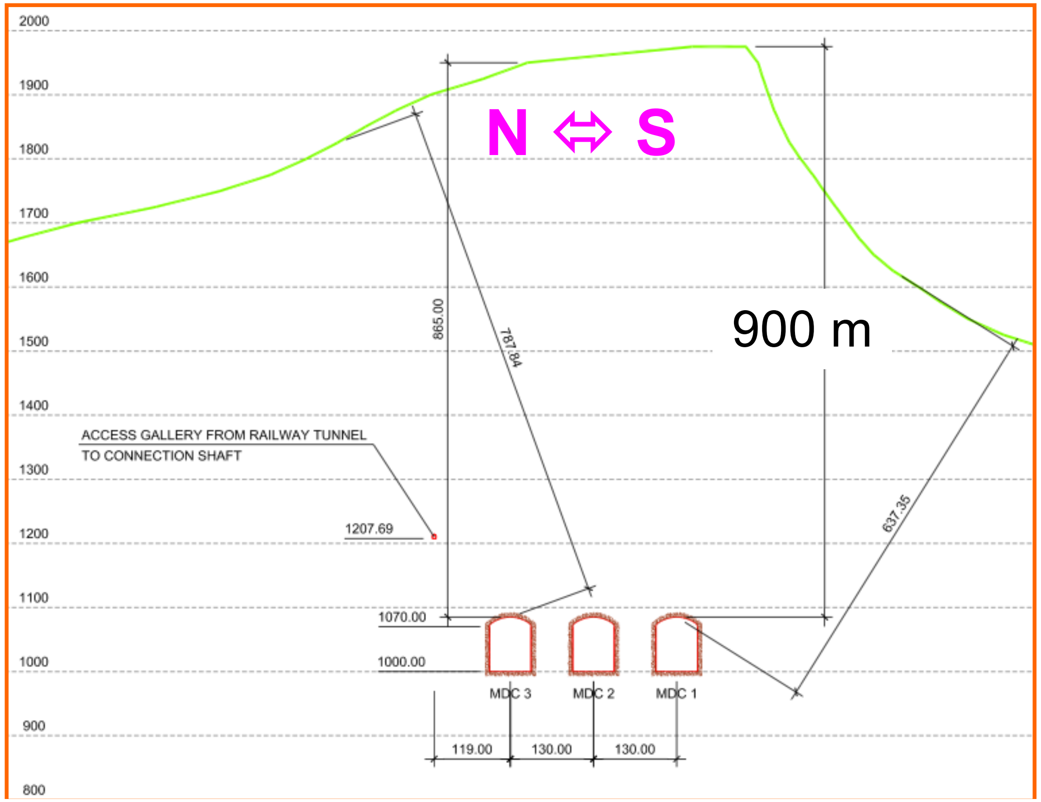
Main work
Help work

LAGUNA Canfranc feasibility study

- **Iberinsa: big Spanish consulting firm**
  - Geological-geotechnical work (General)
  - Numerical modelling
  - Environmental questions
  - Auxiliary installations. Buildings
  - Cost estimates
- **STMR: small Spanish geotechnical and tunnelling firm**
  - Project managing and coordination
  - Geologic-geotechnical work (Rock Mechanics problems)
  - Construction processes and work methods
- Obras Subterraneas (OSSA): Biggest Spanish firm for underground works contruction
  - Construction processes and work methods
  - Cost estimates
- Itasca Spain: Local branch of Itasca network of firms
  - Numerical modelling
- Individual consultants
  - Site knowledge (project and construction Manager for Somport Tunnel)
  - Tectonic stresses and seismicity (Madrid Geology Faculty Professor)



AC2
Water & air purification
AC1 + AC3
Clean storage and power transformation room
AC1 Main control & office
Connection shaft S1 from railway tunnel to upper chamber
Access gallery AG1 from railway tunnel to connection shaft
Ramp AG1 between upper chamber and lower level of MDC's (from level +1073.00 to level +1000.00)
Connection gallery AG1 between upper chamber and upper level of MDC's
Ventilation gallery AG1
Upper chamber AC1 at upper level of MDC's
EXIT AIR POINT
Ventilation shaft S1
(+1412.00)
Access gallery AG1
L= 2371.215 m, Slope= 5.12 %
STANDARD VENTILATION
HUMAN VENTILATION CIRCUIT
RADON VENTILATION (Air free of radon and human ventilation for MDC's and AC's)
FRESH AIR INLET POINT
Access gallery portal
(+1194.40)
Railway tunnel portal
N ⇔ S
RAILWAY TUNNEL
Laboratory 1
Widening of railway tunnel
MDC 3
MDC 2
MDC 1
Laboratory 3
for instance Water Cherenkov



2000
1900
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900 m
865.00
787.84
637.35
ACCESS GALLERY FROM RAILWAY TUNNEL
TO CONNECTION SHAFT
1207.69
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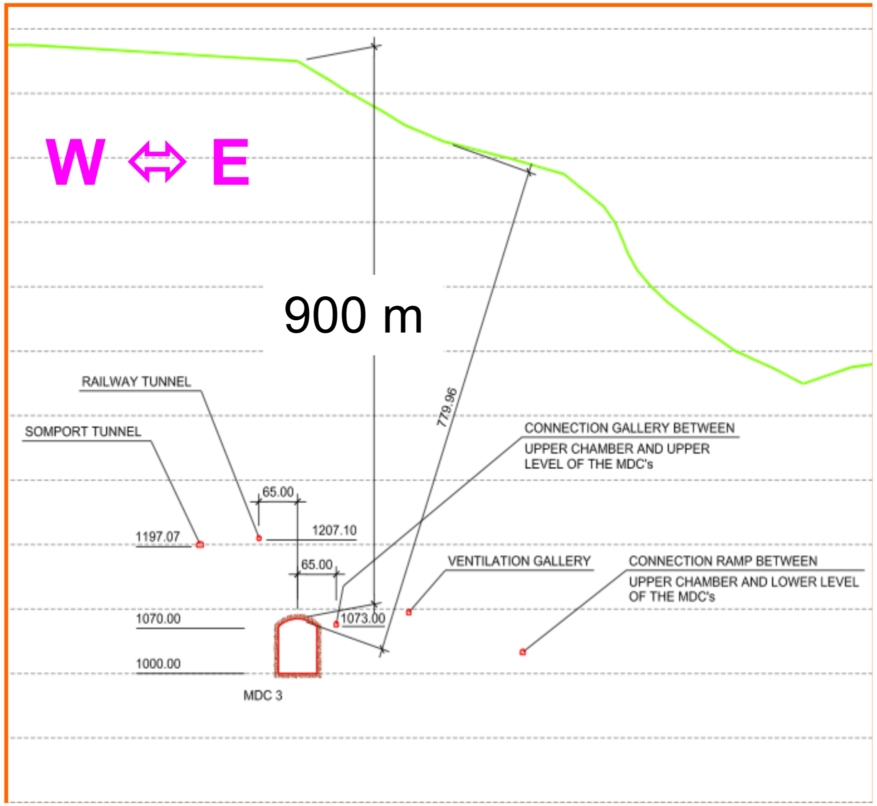
MDC 2
MDC 1
119.00
130.00
130.00



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RAILWAY TUNNEL
SOMPORT TUNNEL
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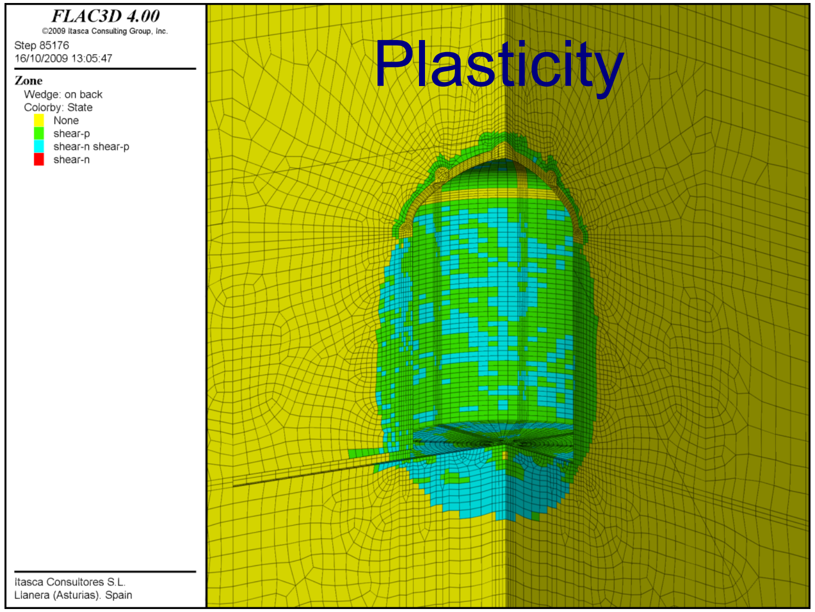
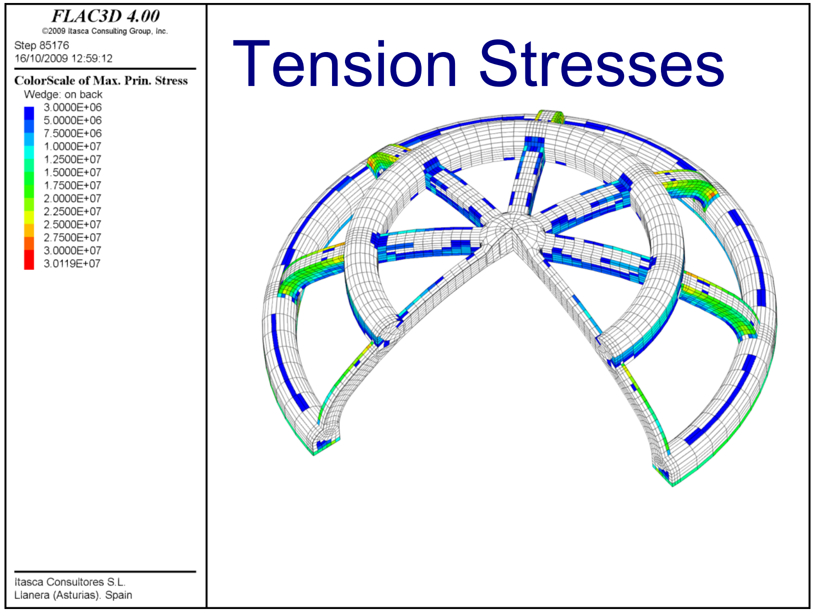
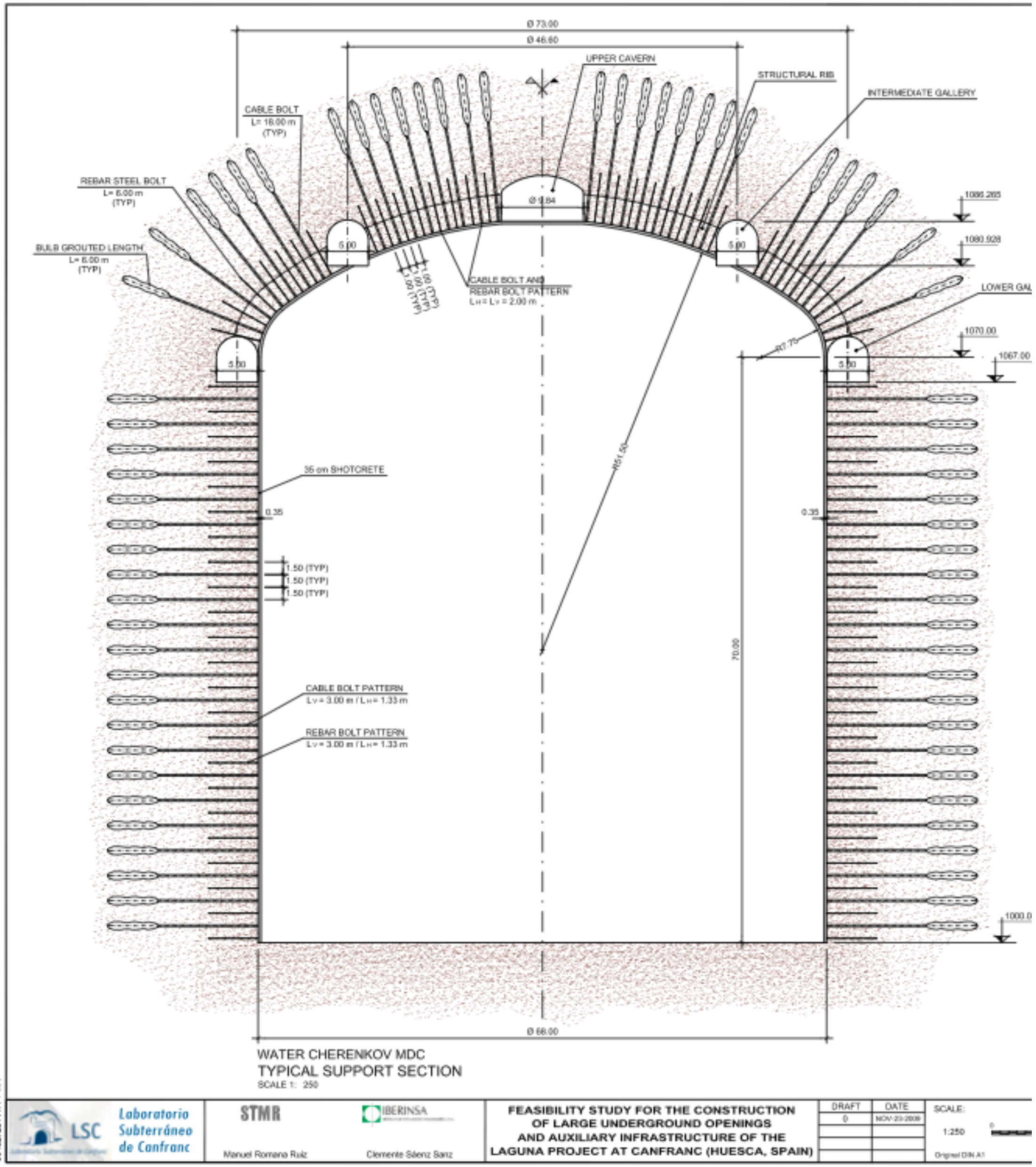
1207.10
65.00
1070.00
1073.00
1000.00
MDC 3
CONNECTION GALLERY BETWEEN
UPPER CHAMBER AND UPPER
LEVEL OF THE MDC's
VENTILATION GALLERY
CONNECTION RAMP BETWEEN
UPPER CHAMBER AND LOWER LEVEL
OF THE MDC's

Pre-design after elasto-plastic structural calculations of one of the three MENPHYS detector' caverns



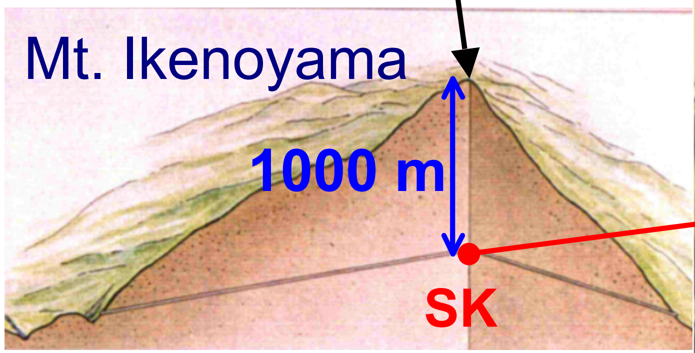




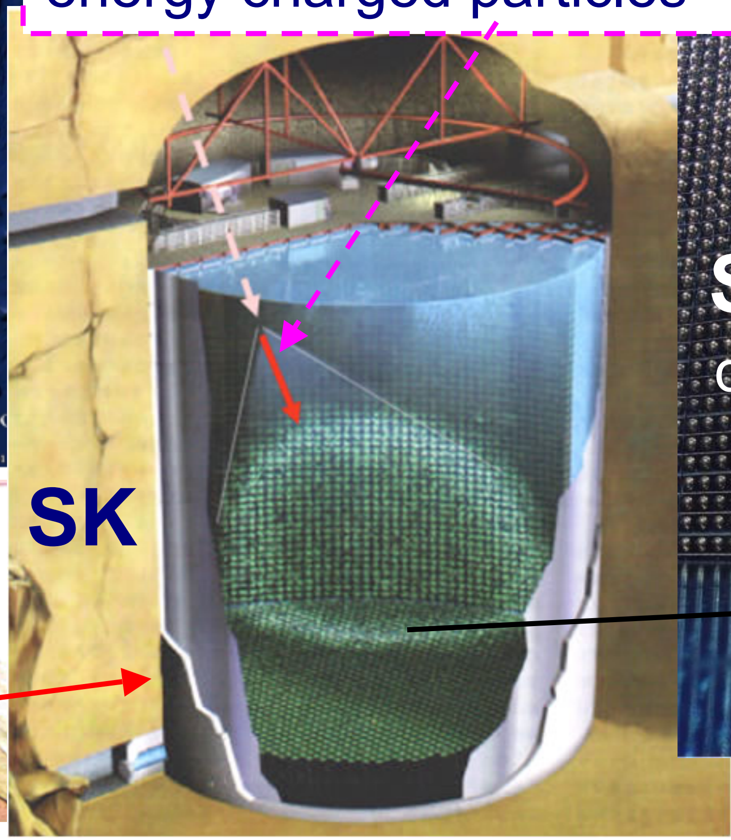
***S**uper-**K**amiokande* (SK) paradigm of Water-Cherenkov detector

Kamioka Observatory
(Gifu Prefecture, Japan)

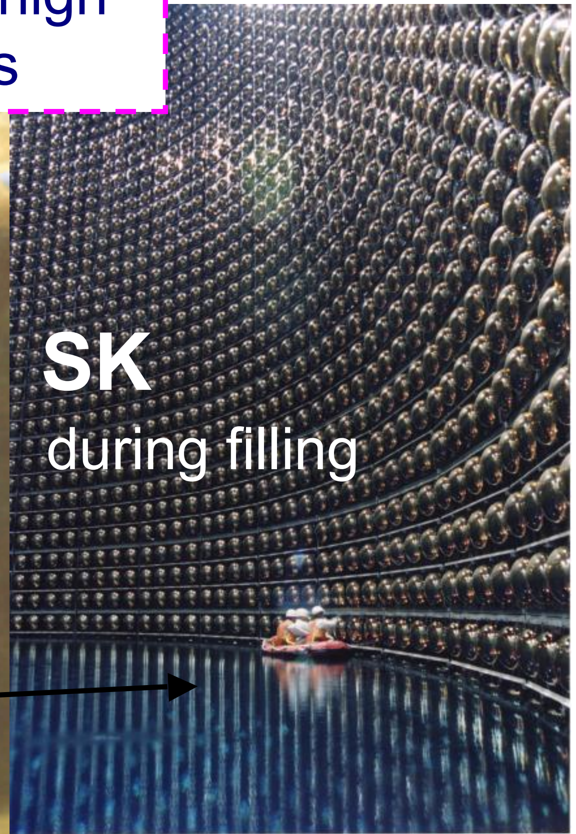
SK measures the Cherenkov radiation generated by "high" energy charged particles



2700 m.w.e
overburden



50.000 m^3 of water
tank: 40m ∅ x 40m H



no. of PMTs:
11148 de 50 cm ∅
1885 de 20 cm ∅

4. We are in charge of two of SK calibration systems: 1) The Auto-Xenon system. We are developing the alysis tools and the necessary hardware modifications to be able to measure the attenuation length of the water at different regions of the detector as a function of time; if successful, such knowledge would allow SK to reduce significantly the systematic errors of the measurements within the "Solar Neutrino" analysis. 2) Most related to it, we are also in charge of the so-called Ni calibration that uses the ~9 MeV γs from the capture by a Ni ball of the thermalised neutrons emitted in the spontaneous fission of a ^{252}Cf source inside the Ni ball to absolute-calibrate the PMTs.

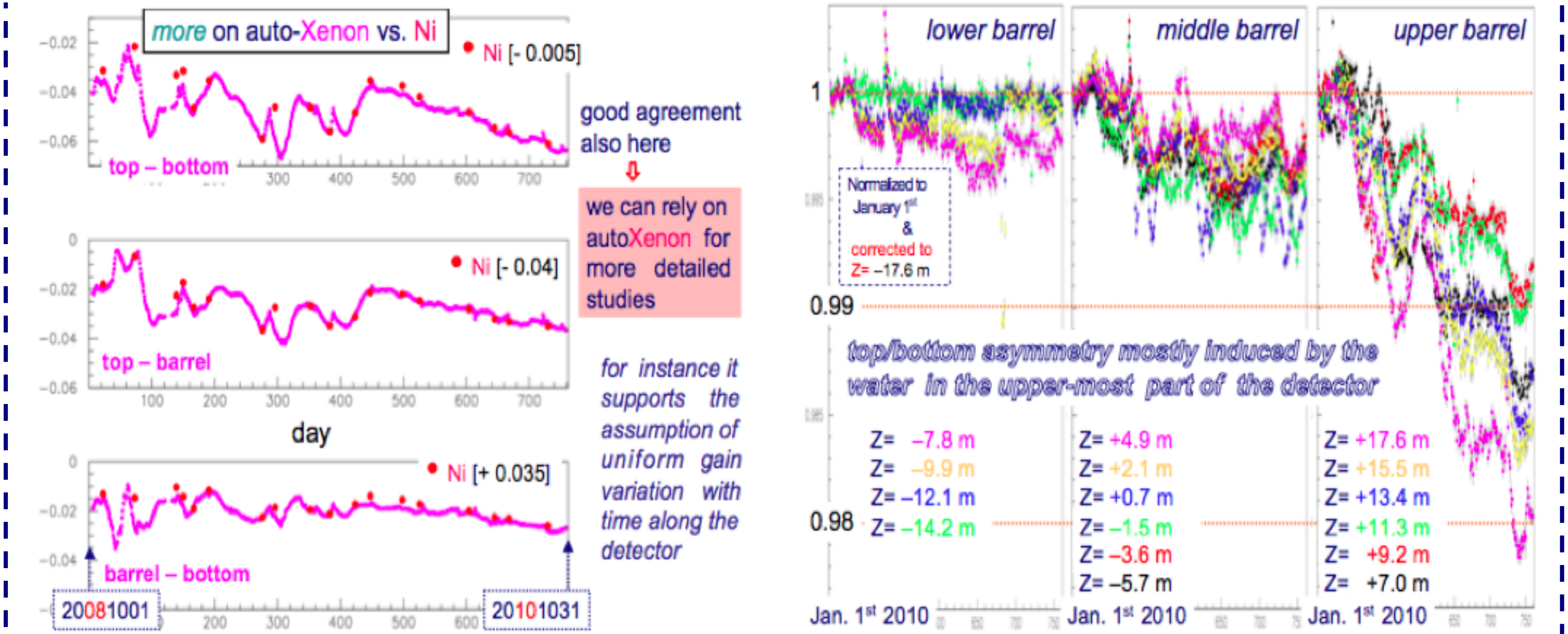


Fig. 9 left (a) comparison Ni autoXenon for the evolution with time of the differences in light transmission to different detector parts, right (B) rather detailed measurement with the autoXenon of the variation with time of the light transmission along the height of the detector.

matter-flavor tagging in Water Cherenkov detectors

Super-Kamiokande is currently the most powerful scientific apparatus for *p*-decay and ν physics

- ⇨ discovery of *Atmospheric*-ν oscillations
- ⇨ help solving *Solar*-ν problem
- ⇨ world's best limit on *p* lifetime
- ⇨ first long base ν experiment (K2K), and now T2K !

- ⇨ precise measurement of leptonic mixing matrix parameters
- ⇨ discovery of SN1987a ν burst (Kamiokande)
- ⇨ world's best limit on relic Supernova ν,s

WC detectors; the Gd

- SK success largely due to detection technique: Water Cherenkov
- Caveat: no *n*eutron tagging
  - ⇨ no inverse β^- decay reaction (CCQE) measurement
  - ⇨ no anti-ν tagging at all
    - → *marginal sensitivity to "relic" Supernova-ν*
    - → *no sensitivity to reactor-ν*
    - → *no "others" ...*

- Solution: dissolve 0.2% (by mass) Gd compound in SK water

VOLUME 93, NUMBER 17 PHYSICAL REVIEW LETTERS week ending 22 OCTOBER 2004

Antineutrino Spectroscopy with Large Water Čerenkov Detectors

John F. Beacom[1] and Mark R. Vagins[2]

[1]*NASA/Fermilab Astrophysics Center, Fermi National Accelerator Laboratory, Batavia, Illinois 60510-0500, USA*

[2]*Department of Physics and Astronomy, 4129 Reines Hall, University of California, Irvine, California 92697, USA*

(Received 25 September 2003; published 20 October 2004)

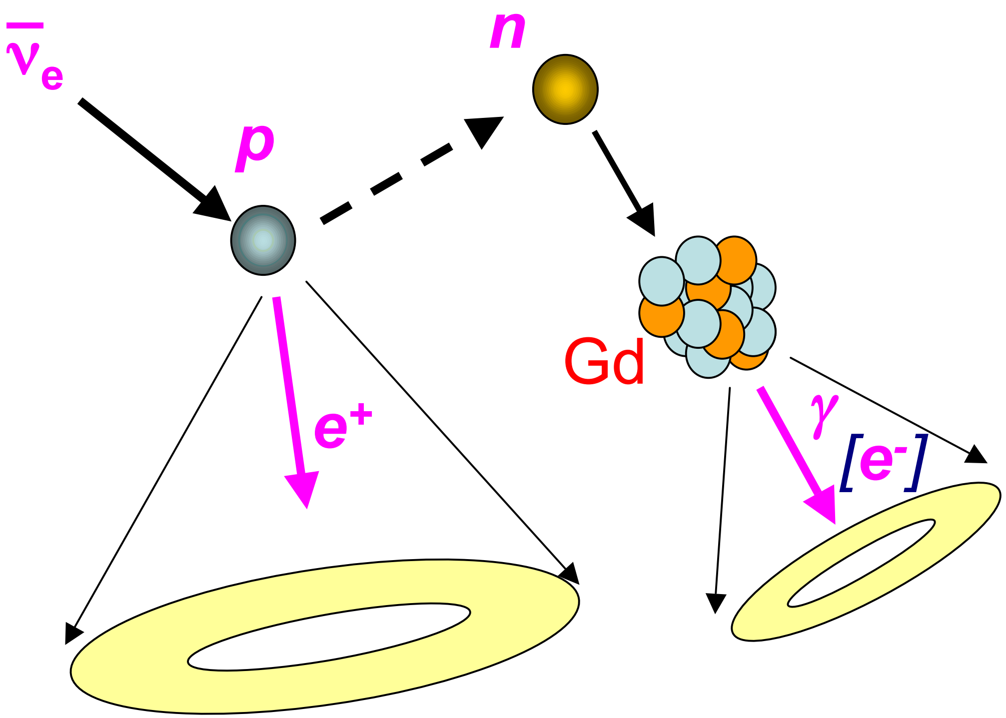
key:

→ Gd has a very large cross-section for *n* capture,

→ in the process it emits a few γ,s with total energy 8 MeV

***n*eutron tagging** in Gd-enriched Water-Cherenkov detectors

basic reaction is inverse β process



→ e^+ is detected

→ *n* wanders around for ~12μs until thermalises

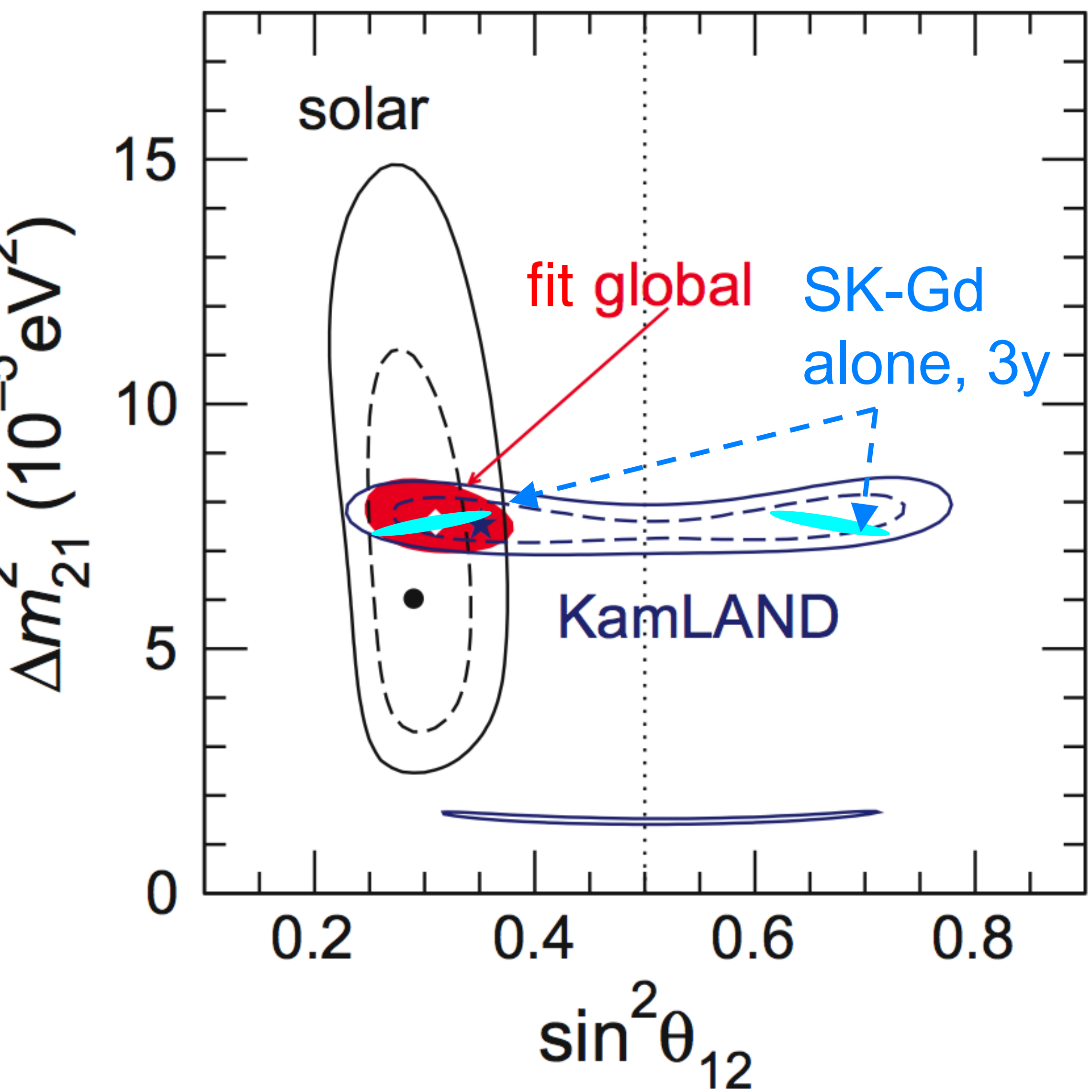
→ ~ 20μs [*50cm*] until Gd-capture → 8MeV γs

→ an e^- is Compton-scat. off the* γ and detected

⇨ $\bar{\nu}_e$ is identified by the coincidence between the e^+ and the *delayed* e^-, with high efficiency (> 80%)

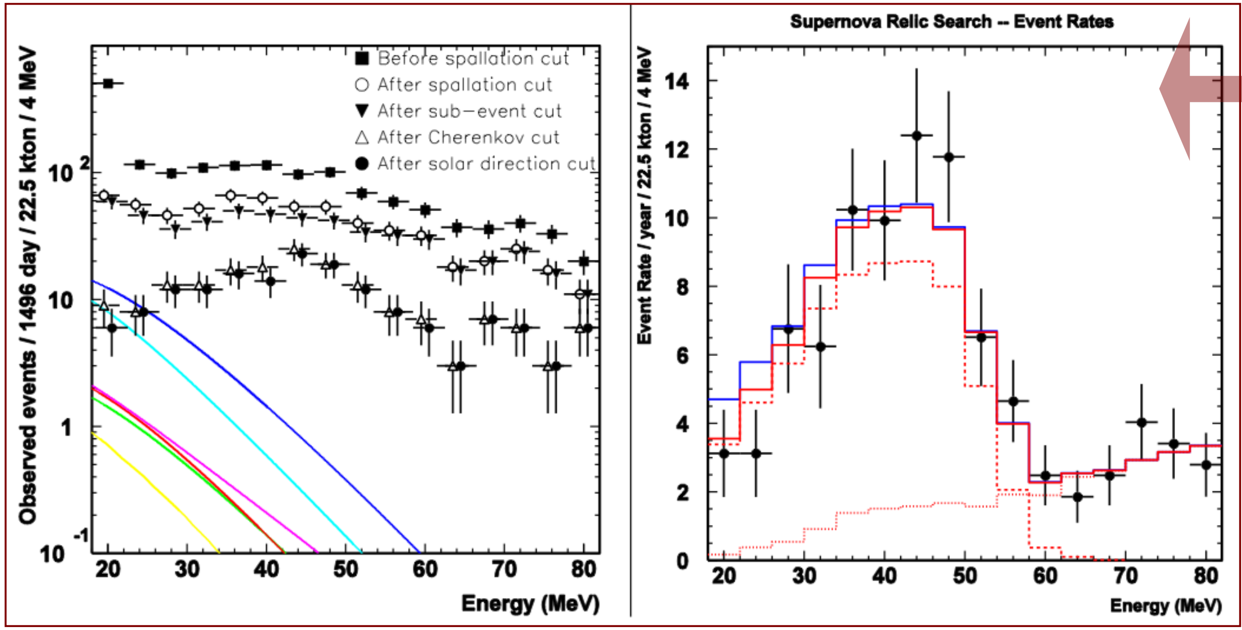
N.P. reactor ν's

⇨ SK may improve significantly the measurement of Δm^2_{21}



[Global/Solar/KamLAND plot from Schwetz,Tortola,Valle; New J, of Phys.10 (2008)113011]
[SK-Gd estimate translated from Choubey,Petcov; Phys. Lett. B594(2004)333]

"relic" ν's or Diffuse SN Neutrino Background (DSNB)



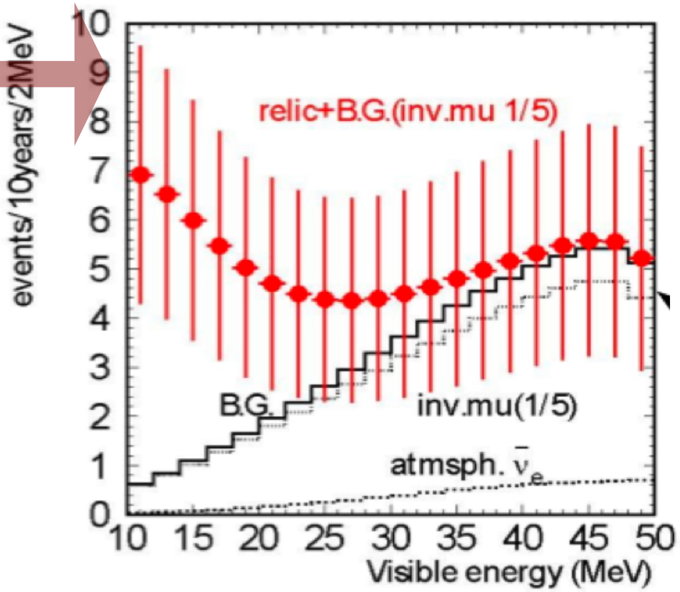
without delayed *n*-tag

world's best limit (SK)

SK, M.Malek et al. PRL90(2003)061101

overwhelmed by the background

with delayed *n*-tag

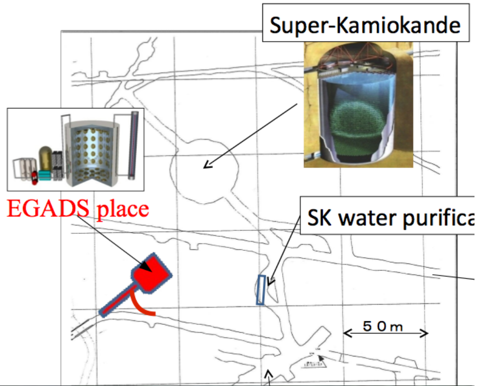


Relic model:
AstropartPhys18(2003)307
with flux revised in NNN05

Assumptions:
- 67% detection efficiency
- Invisible μ can be reduced by a factor of 5

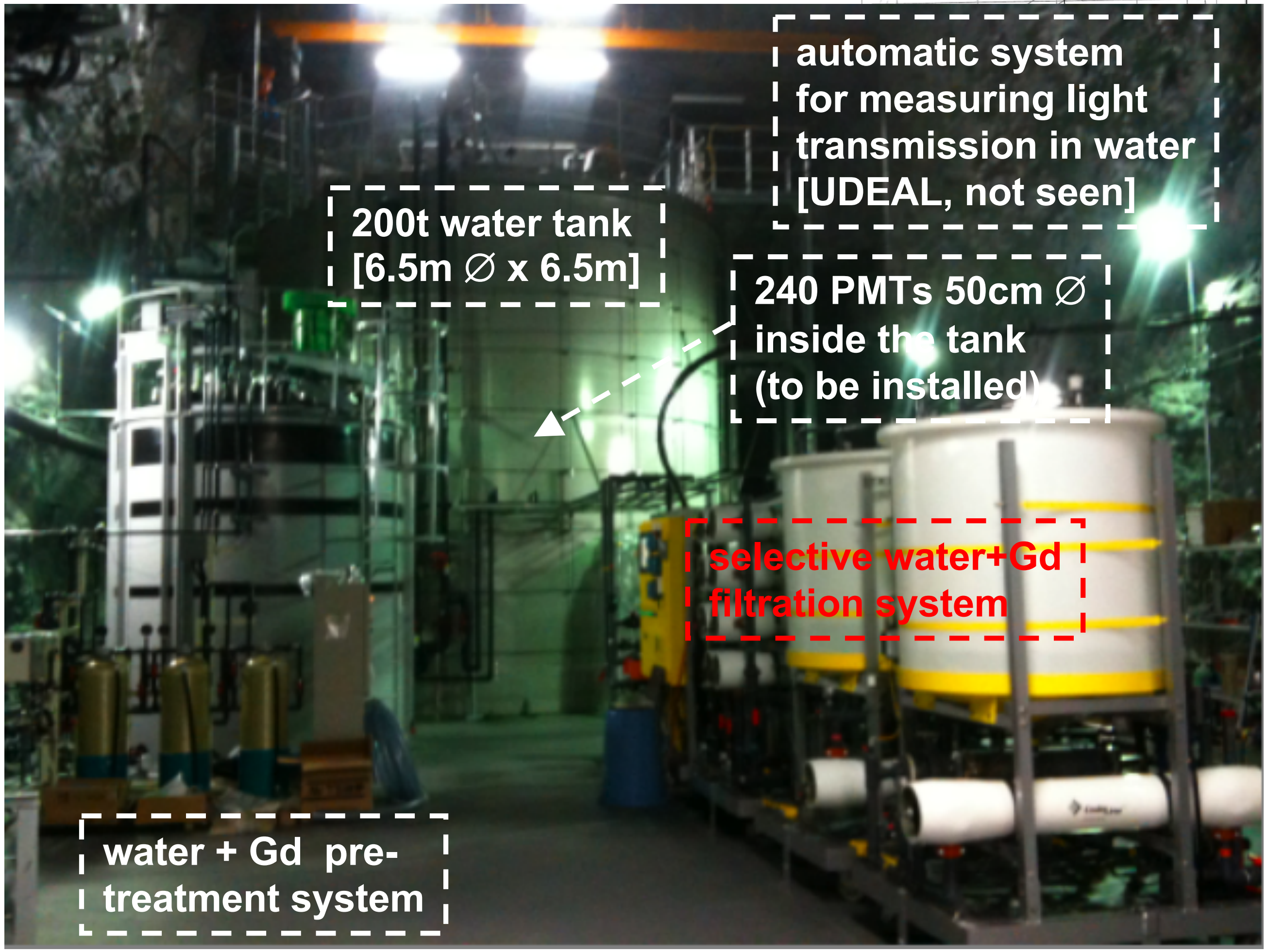
SK, 10y, 10-30 MeV
33 signal events
27 bkg. events
⇩ ⇩ ⇩
SK will *discover DSNB*

The GADZOOKS! / EGADS program



evaluating neutron identification with Gadolinium for anti-*neutrino* tagging in SK (… and NNN)

- Tokyo-ICRR
  Kishimoto, Nakahata, Sekiya, Ueno, Yokozawa
- Tokyo-IPMU: Vagins
- Kobe: Y.Takeuchi
- Madrid: Labarga, Marti (now ICRR)
- Okayama: Ishino, Kibayashi, Mori, J.Takeuchi, Sakuda, Yamaguchi
- Tsinghua: Zhang
- UCI: Arenshaw, Bays, Smy, Giada



Lluis M. has been pivotal in its setup

Fundamental tool: monitoring Gd concentration

[developed a procedure based on Atomic Absorption Spectrometry]

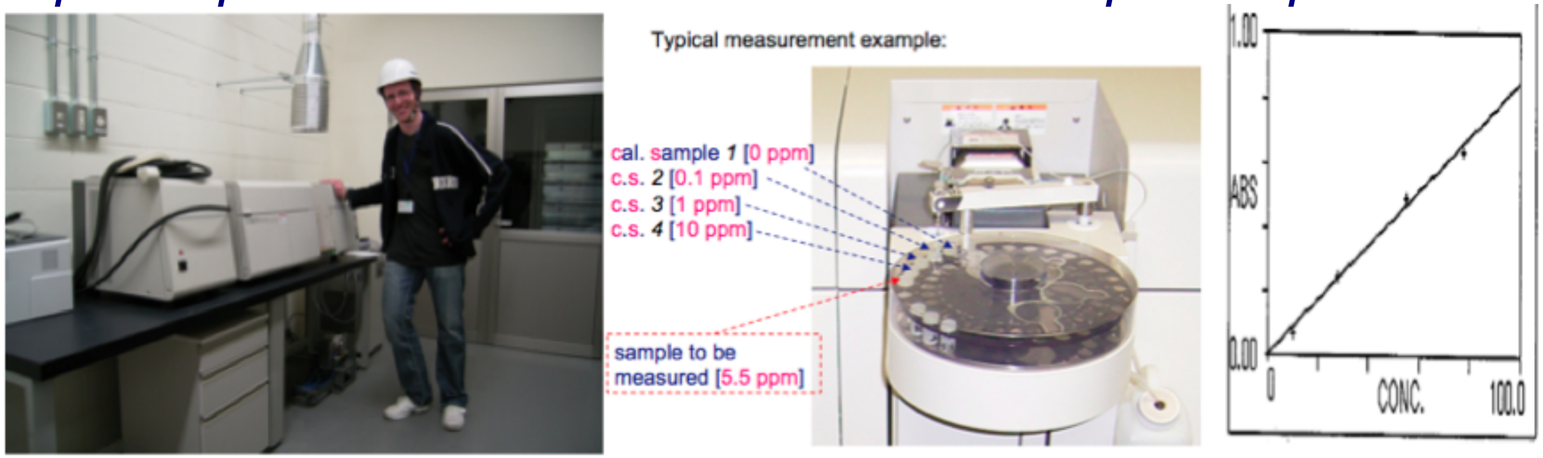


Fig. 4: left (a) Lluis Marti showing the AAS at the EGADS experimental area, middle (b) a typical AAS measurement scheme, right (c) typical AAS calibration curve: abscissa is Gd concentration in ppm, ordinate is absorption in arbitrary units.

Fundamental task: minimize and quantify radioactive contaminations

[below: measuring U/Th contaminations using ICP-MS]

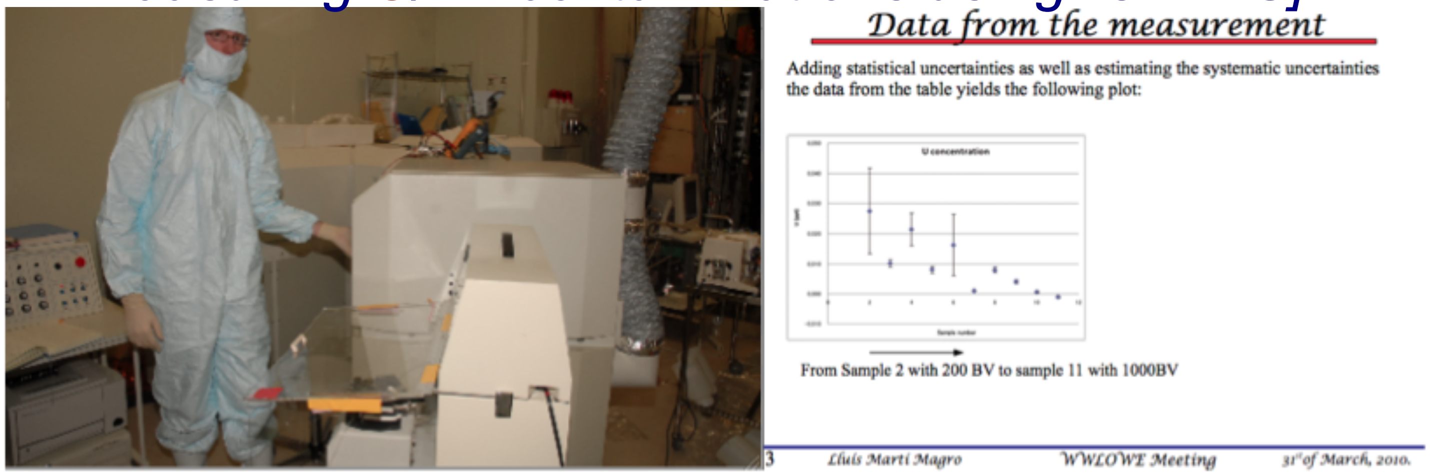
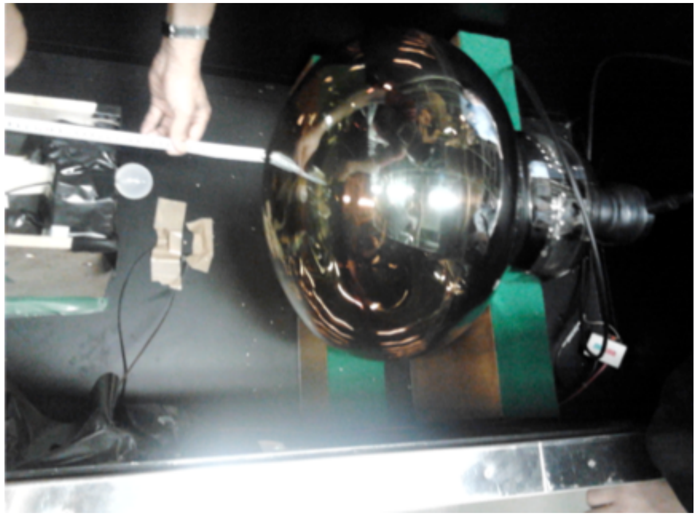


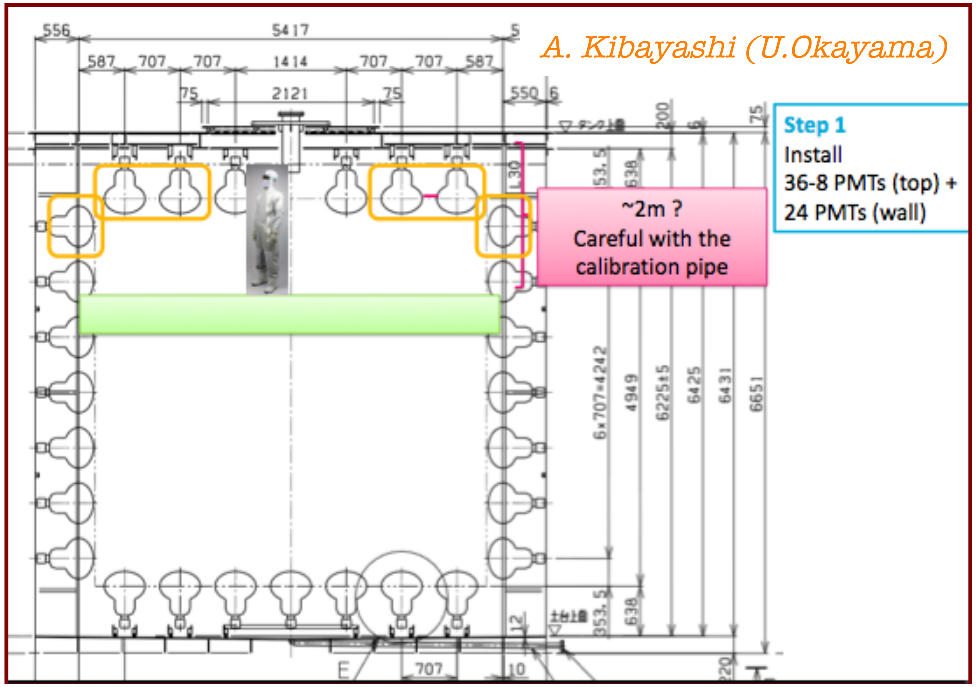
Fig. 5: left (a) ICP-MS at the Kamioka Observatory, right (b) regular working result presented to the Group by Ll. Martí (UAM).

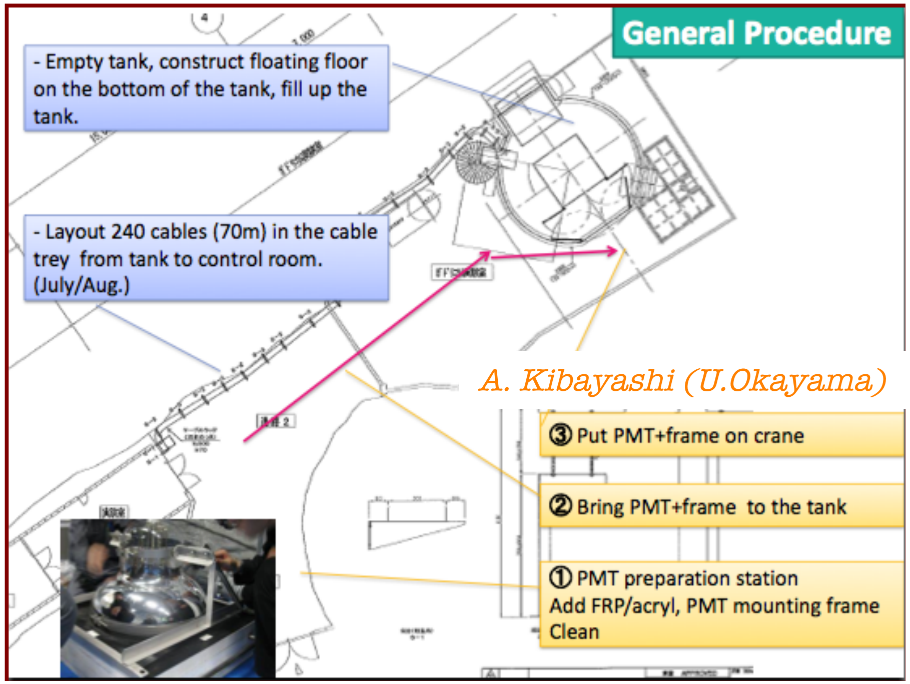
⇨ pre-calibration of the 250 PMT for the 200 ton Tank EGADS: ✓
determining experimentally the operating HV that equalize their response

in collaboration with ***U.O***kayama

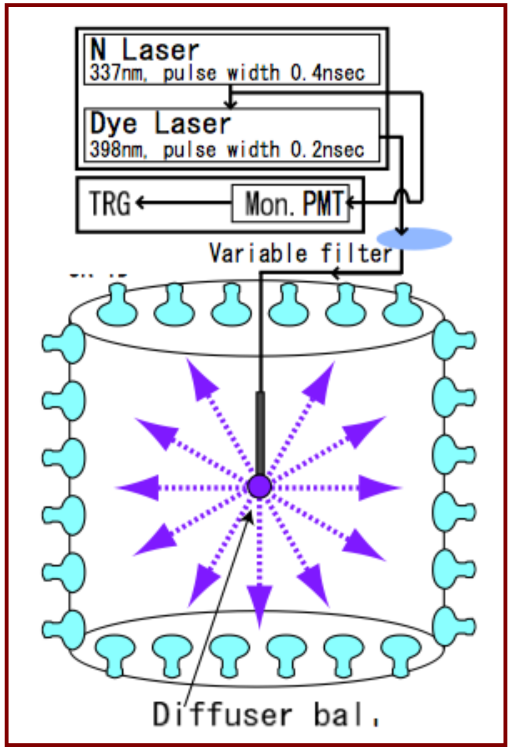


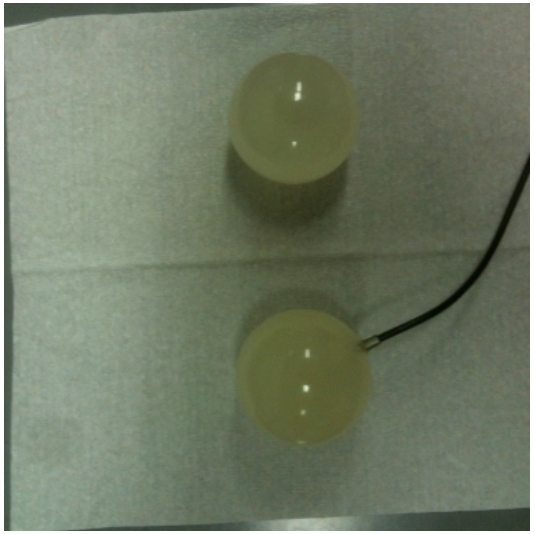
⇨ Mounting the PMTs inside the EGADS tank, cabling, testing, etc.





⇨ mounting and commissioning the EGADS calibration system





⇨ .....

⇨ **radio-purity** measurement and control

The SK-Gd project has the unavoidable problem that, in addition to inverse β-decay reactions from SN and Nuclear Reactor ν, SK will see almost ALL the thermal-n inside the SK tank; they come mainly from (α,n) reactions and Spontaneous Fission from ^{238}U, ^{232}Th contaminations in the various materials

A) they must neither saturate SK nor deteriorating data taking

B) work out their contributions to other SK measurements, particularly solar ν analysis ⇨ *implement in SK detector simulation*

C) carefully control *^{238}U* contamination: [prompt-γ + n] events from its Spontaneous Fission are irreducible background to the inverse inverse β^- decay reaction

For SK-materials and the Gd-compound:

1. *estimate n-yield vs. E_n per ppt of ^{238}U and ^{232}Th*
3. *Input total n-yield vs. E_n to SK MC and work out the n background in SK analyses*
2. measure ^{238}U, ^{232}Th contaminations of the materials (they may be many, f.i. the many batches of Gd) + …

Measurements of radioactive contaminations at the LSC

We did submit to the LSC Directorate the LoI *"SuperkGd: Very low background measurements for the Super-Kamiokande R&D program on neutron tagging by dissolving Gadolinium in its water"* that was officially approved as LSC experiment (EXP-06-2009) in December 2009. Some details can be found at http://www.lsc-canfranc.es/pagina-227/ link EXP 06-2009–SUPERKGD.

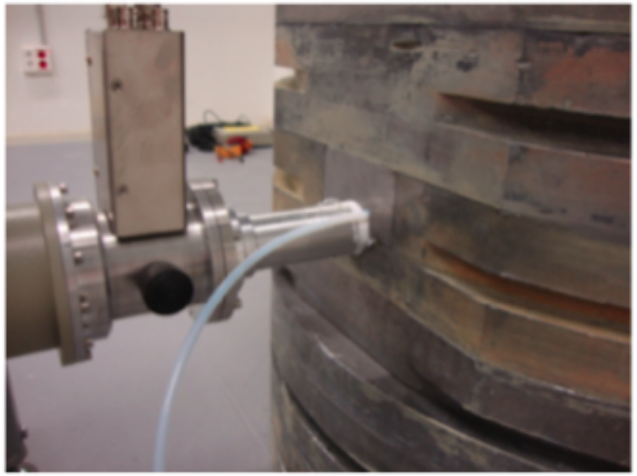
Hall for *HpGe detector farm*
now it is not empty anymore …

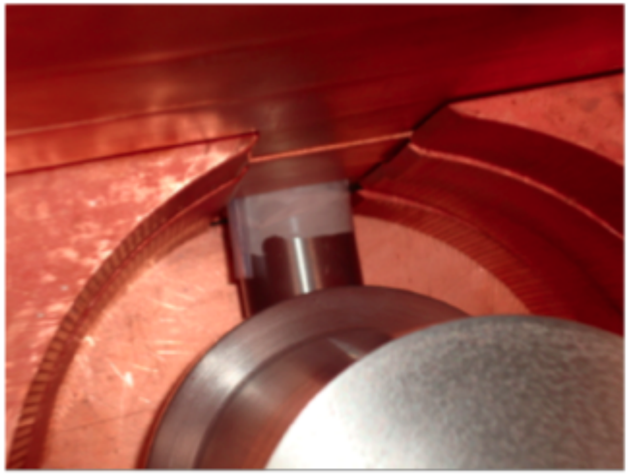
Main Hall: next, ...

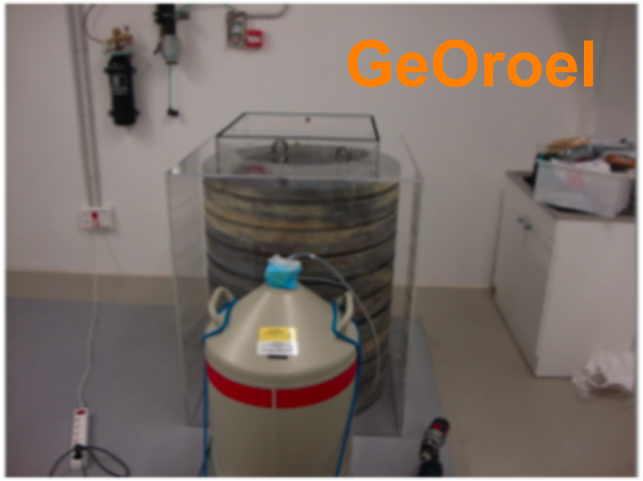
in day-to-day collaboration with ***I.C. Bandac*** *(LSC)*

a program rather synergic to next

we battled our particular war against Radon …







that payed off a rather low background that allowed the start of SuperkGd

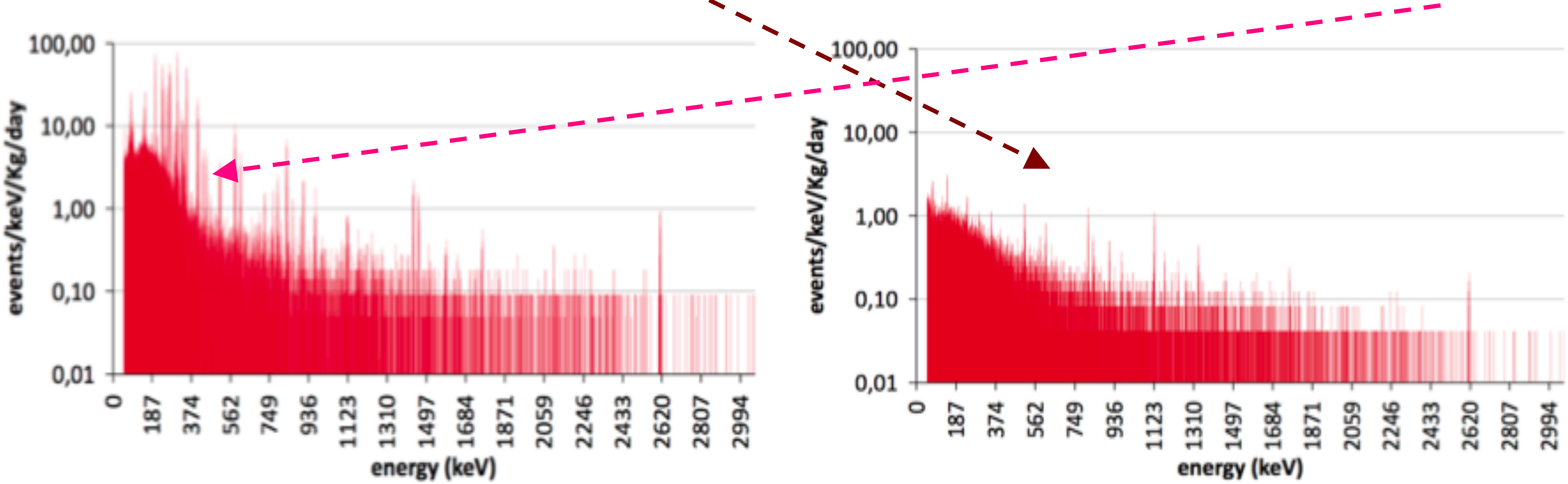


Fig. 7: [left] 2 weeks measurement, background corrected, of 1.3 Kg of $Gd_2(SO_4)_3$ from the 200904 batch. [right] background spectrum showed again here to ease the comparison.

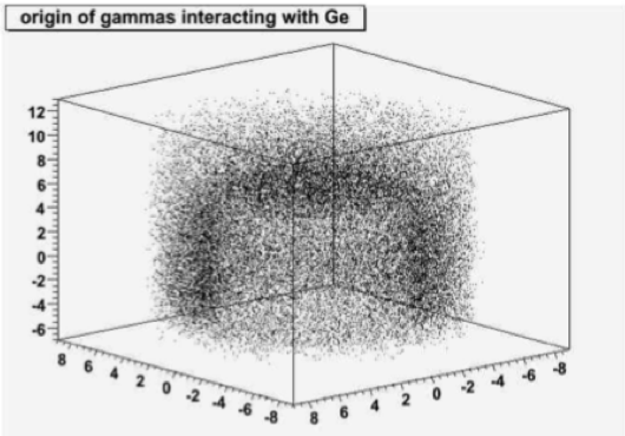
and also the start of the next radio-purity measurements program

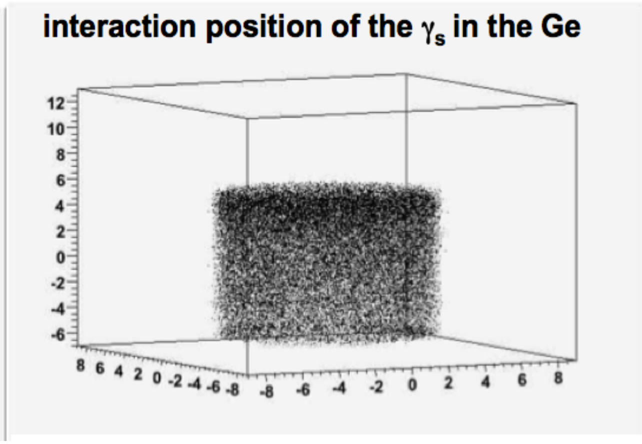
Currently there are 3 *HpGe*'s commissioned

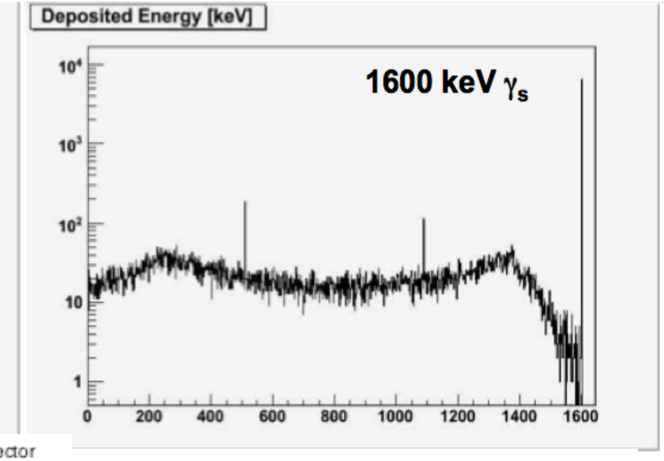
With these 3 detectors, the short-near future needs of SuperkGd and next are covered, but more will be needed soon

2 other detectors are coming …

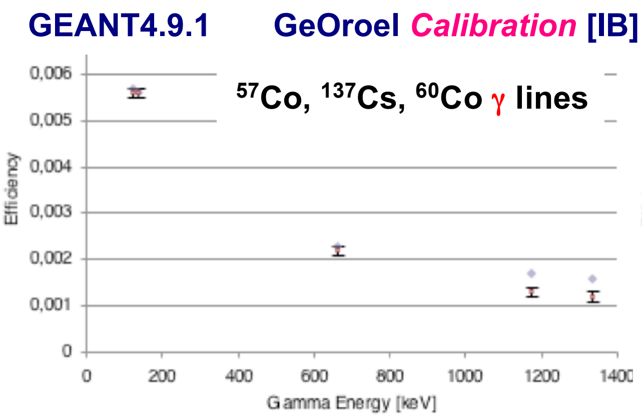
we are fine-tuning our GEANT4 simulation *[Lluis Marti, Iulian Bandac]*

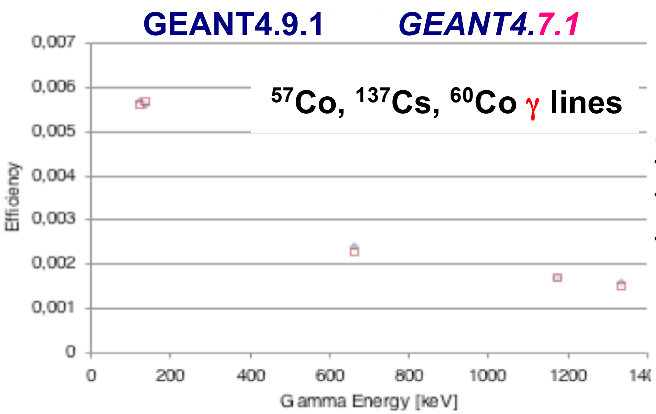


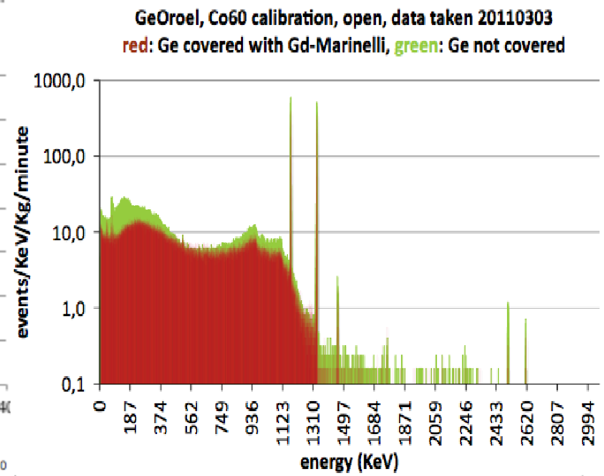


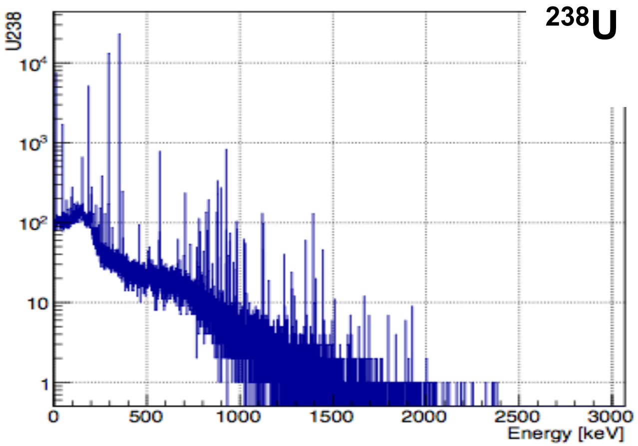


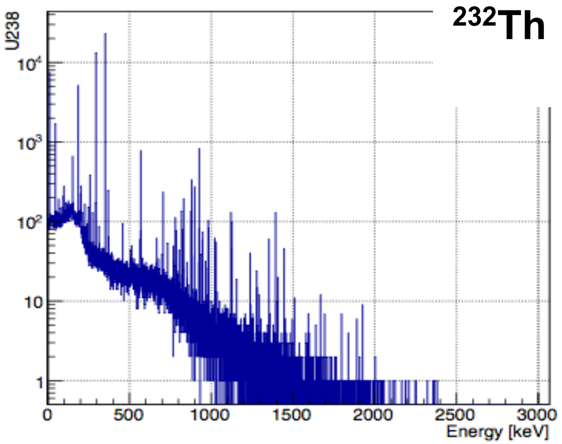
full γ energy absorption by the Ge detector

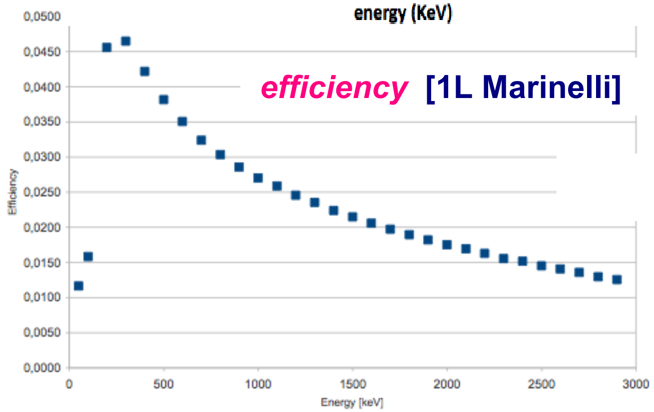




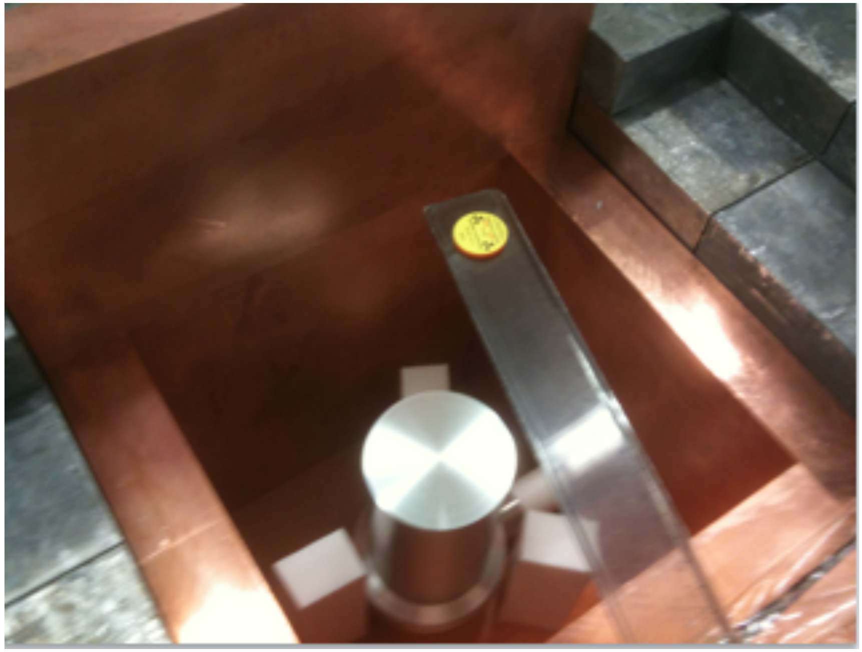


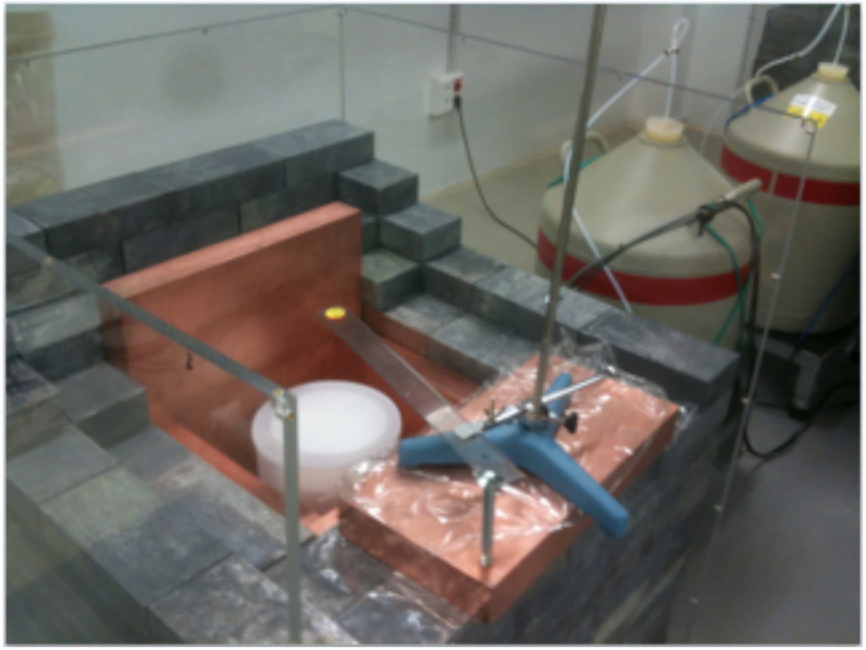




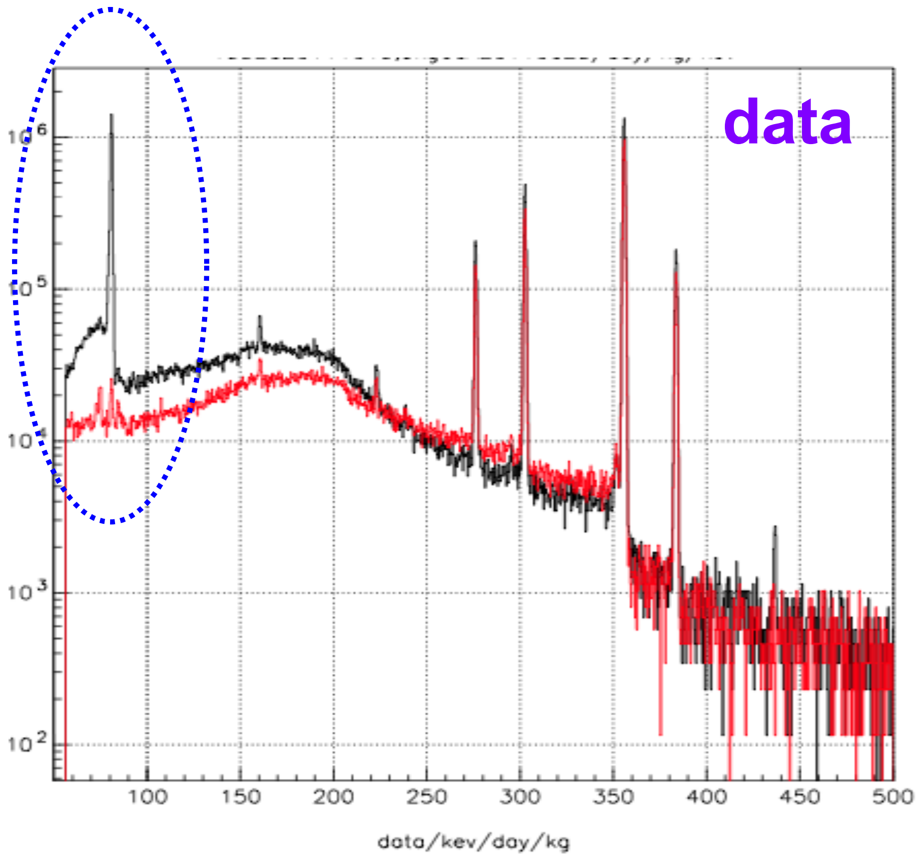


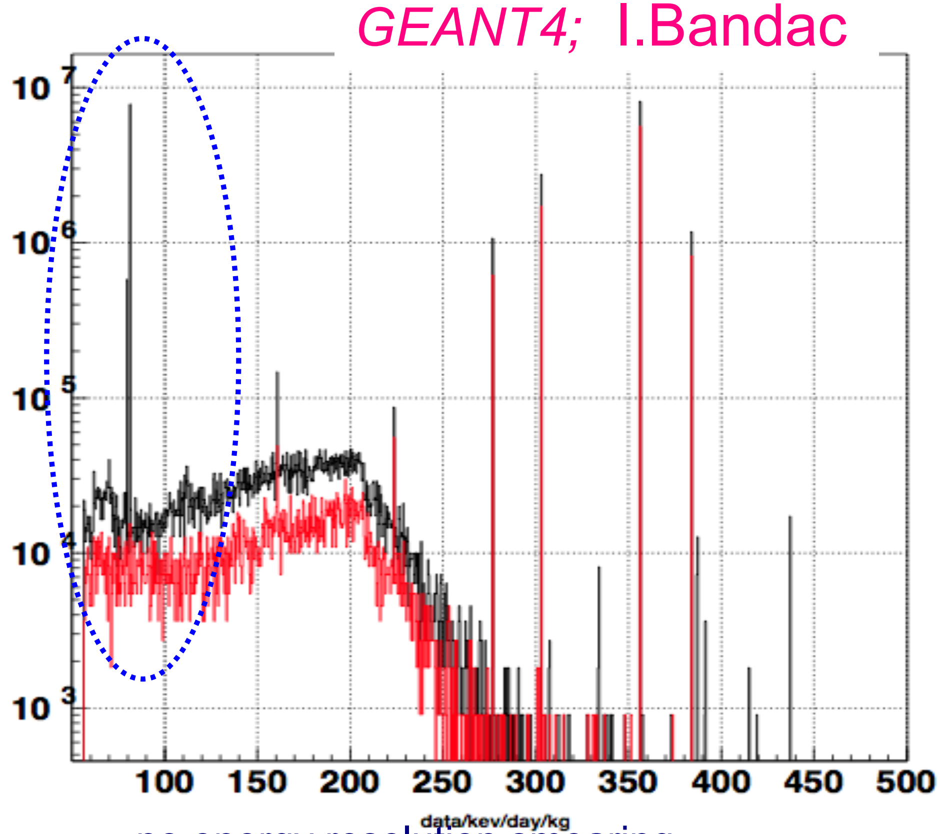
analyzing performance: response to ^{133}Ba





radioactive source ^{133}Ba





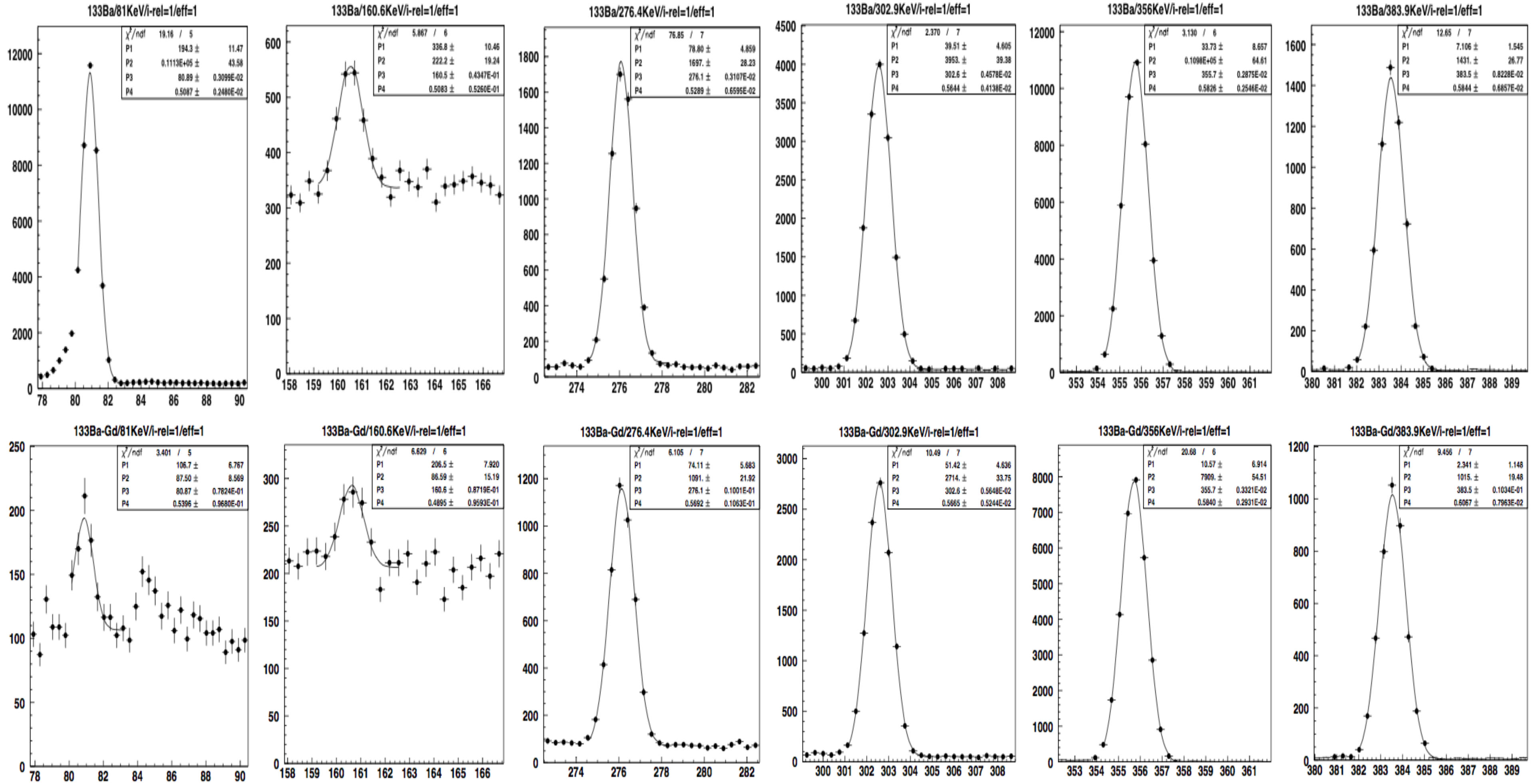
- no energy resolution smearing
- no background (detector is open) subtracted

black: Ge crystal ***not*** covered by Marinelly with $Gd_3(SO_4)_2$

red: Ge crystal ***covered*** by Marinelly with $Gd_3(SO_4)_2$

⇨ at low energies, < 200 keV say, the γ absorption by the $Gd_3(SO_4)_2$ reduces rather strongly the detection efficiency

source: ^{133}Ba duration: 900 s date: *20111013* without & with Gd

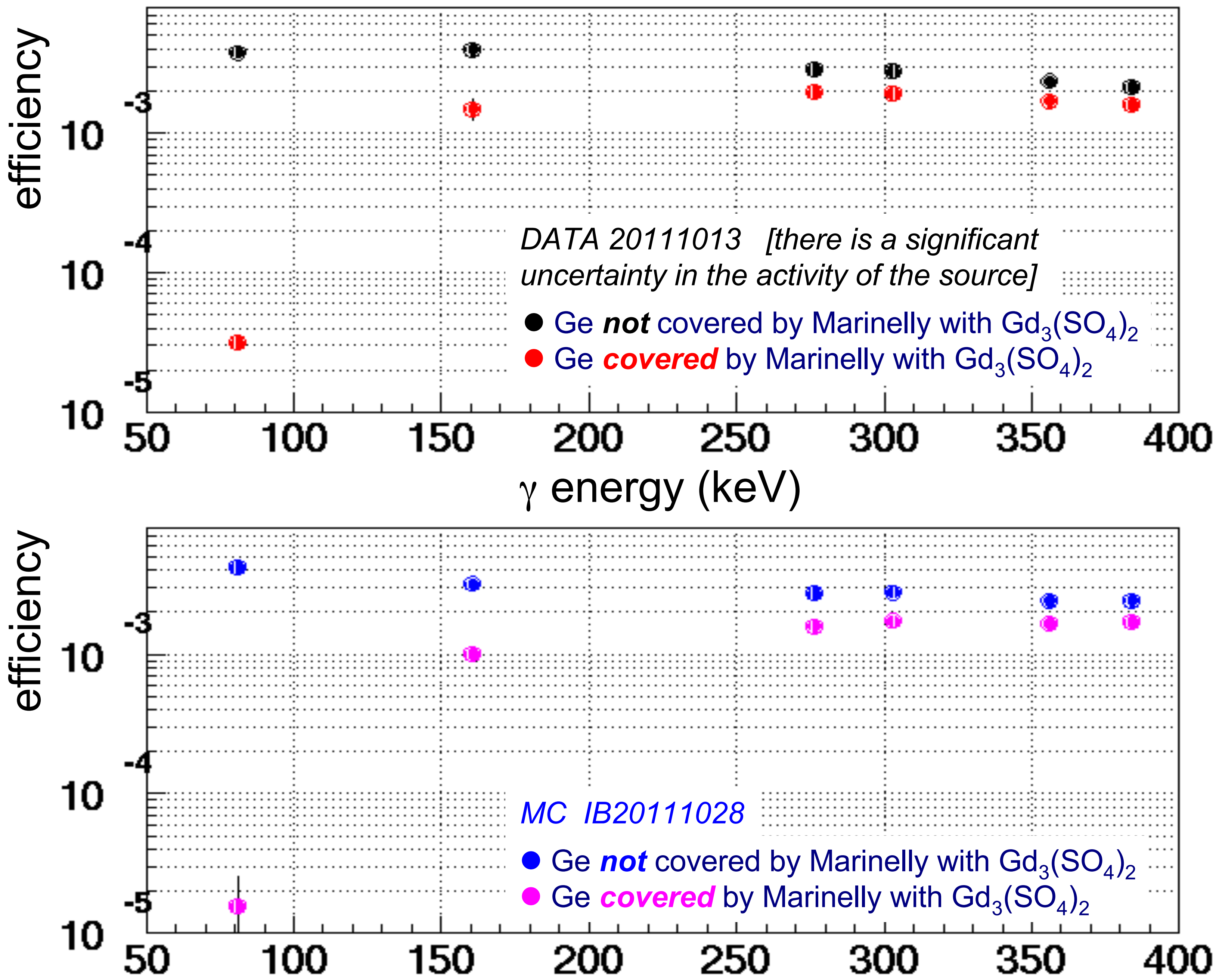


energy:	***81,0** KeV*	***160,6** KeV*	***276,4** KeV*	***302,9** KeV*	***356,0** KeV*	***383,9** KeV*
no. detected γ_s:	*(5,65 ± 0,04)* x 10^3	*(1,13 ± 0,10)* x 10^2	*(8,98 ± 0,15)* x 10^2	*(2,23 ± 0,02)* x 10^3	*(6,40± 0,04)* x 10^3	*(8,36 ± 0,16)* x 10^2
	(4,72 ± 0,46) x 10^1	*(4,24 ± 0,74)* x 10^1	*(6,21 ± 0,13)* x 10^2	*(1,54 ± 0,02)* x 10^3	*(4,62 ± 0,03)* x 10^3	*(6,19 ± 0,12)* x 10^2

JANIS SEARCH RESULTS FOR:
[Photons], Z=56 A=133, Library=ENDF/B-VI.8, 75000.0 <= E, 0.0050 <= I

Search	Evaluation	E	E error	Intensity	Intensity error	Type	Material	Half Life
Local	ENDF/B-VI.8	7.9623e4	10	0.0262	6e-4	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	8.0997e4	3	0.3406	0.0027	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	1.60613e5	8	0.00645	8e-5	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	2.76398e5	2	0.07164	2.2e-4	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	3.02853e5	1	0.1833	6e-4	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	3.56017e5	2	0.6205	0.0019	Gamma	Ba133	10.52 years
Local	ENDF/B-VI.8	3.83851e5	3	0.0894	3e-4	Gamma	Ba133	10.52 years

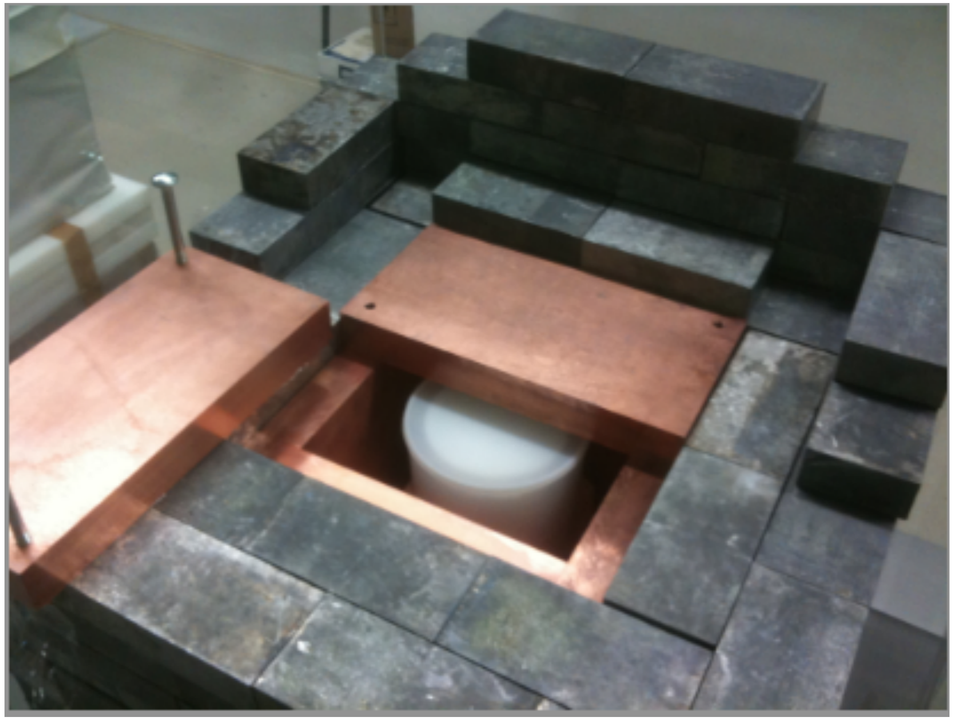
efficiency estimate with radioactive source ^{133}Ba

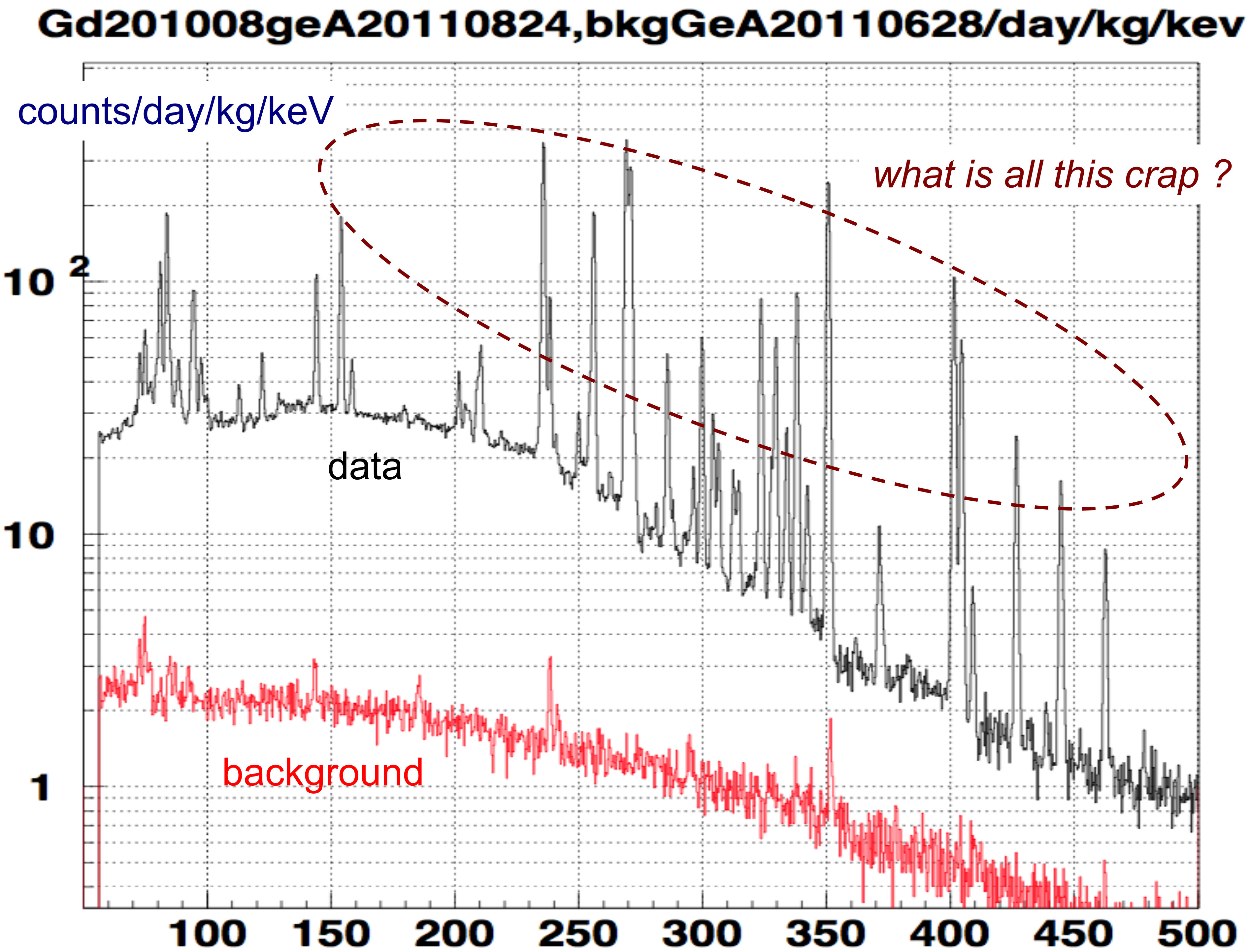


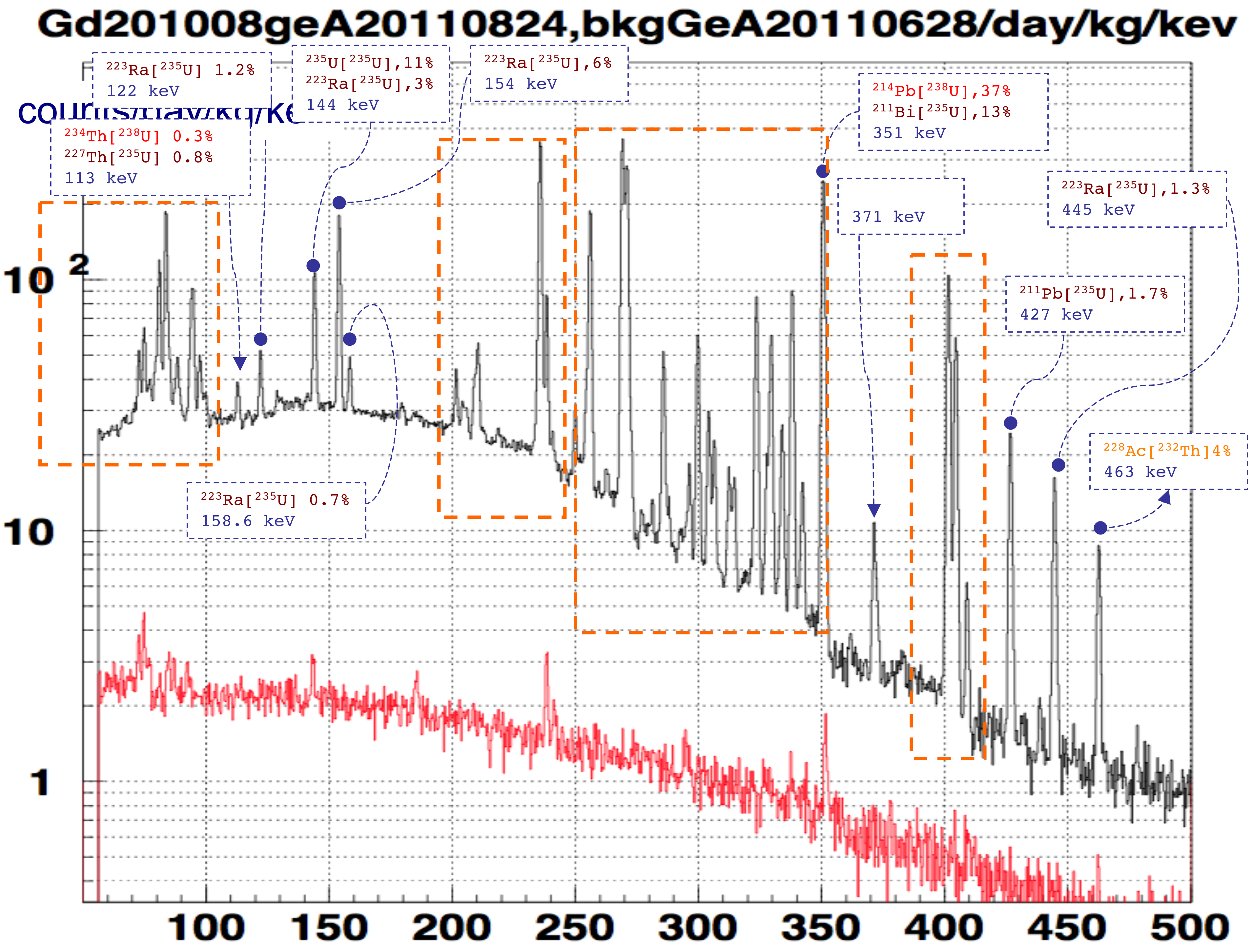
measuring with geAnayet

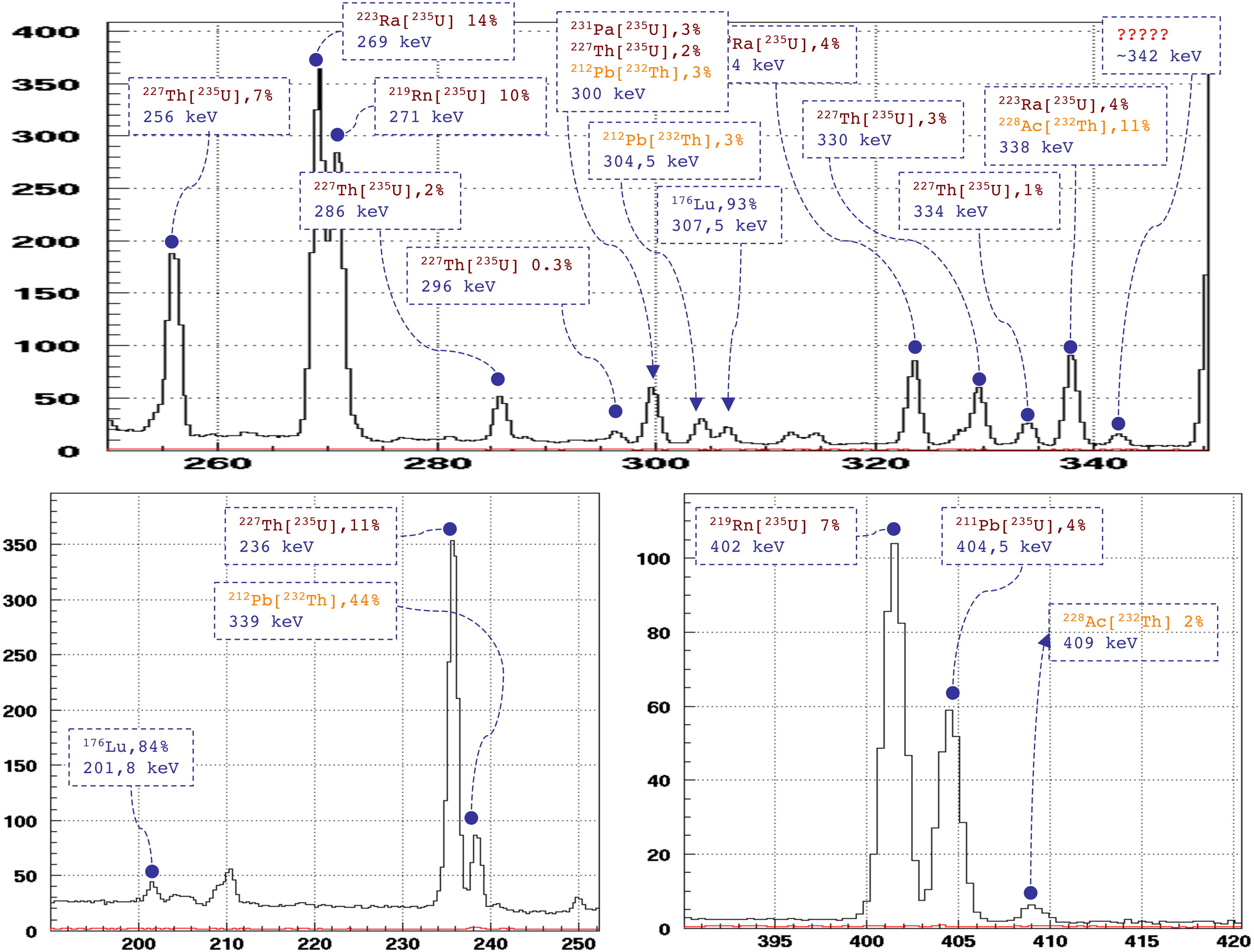
- sample of $Gd_2(SO_4)_3$ arrived to Canfranc on May 27th

- measurement time background: 65 days, April 24th to June 28th
- measurement time $Gd_2(SO_4)_3$: 47 days, July 13th to August 24th

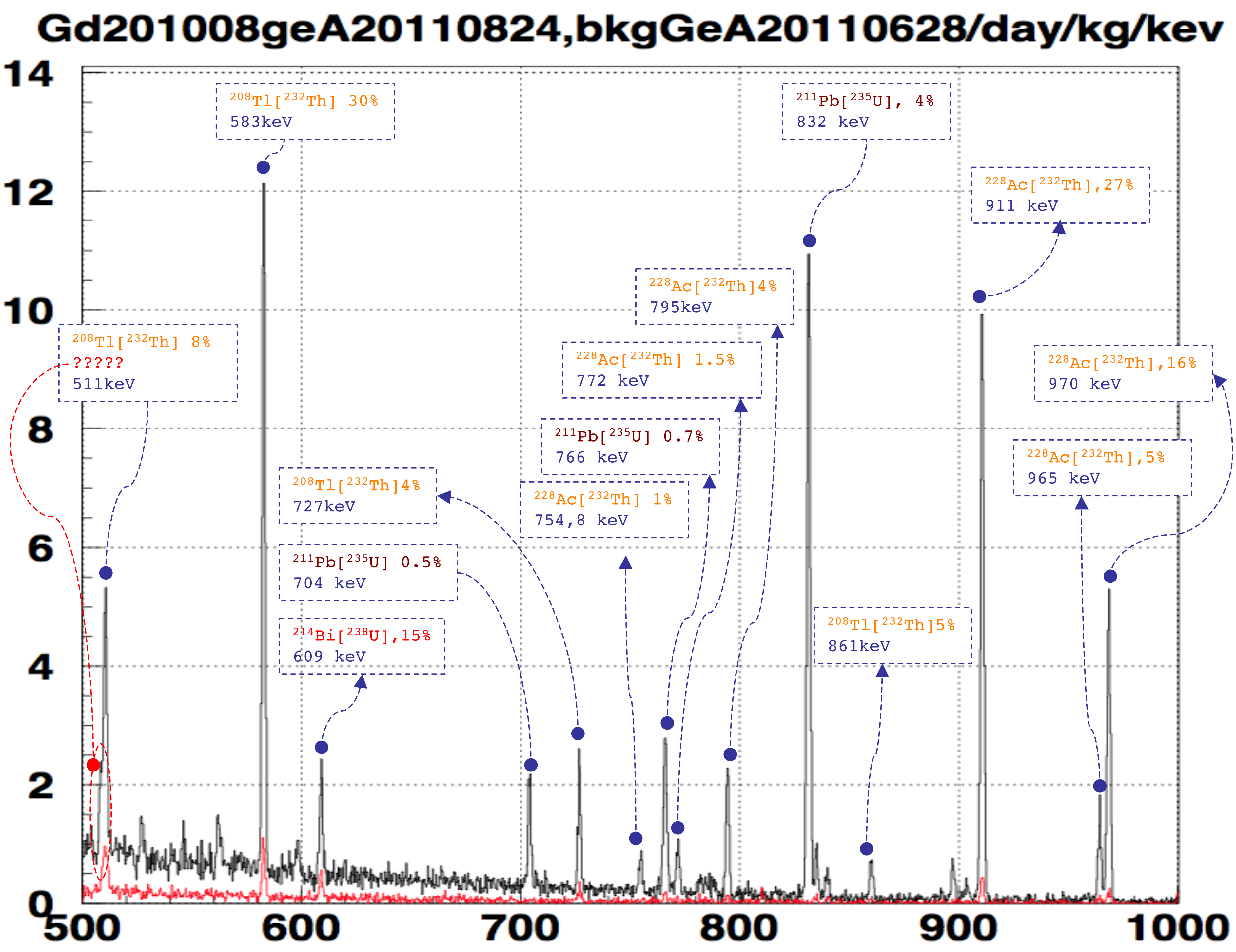



Gd201008geA20110824,bkgGeA20110628/day/kg/kev
counts/day/kg/keV
what is all this crap ?
data
background
10 2
10
1
100
150
200
250
300
350
400
450
500


Gd201008geA20110824,bkgGeA20110628/day/kg/kev
counts/day/kg/keV
^{223}Ra[^{235}U] 1.2%
122 keV
^{235}U[^{235}U],11%
^{223}Ra[^{235}U],3%
144 keV
^{223}Ra[^{235}U],6%
154 keV
^{214}Pb[^{238}U],37%
^{211}Bi[^{235}U],13%
351 keV
^{234}Th[^{238}U] 0.3%
^{227}Th[^{235}U] 0.8%
113 keV
371 keV
^{223}Ra[^{235}U],1.3%
445 keV
^{211}Pb[^{235}U],1.7%
427 keV
^{228}Ac[^{232}Th]4%
463 keV
^{223}Ra[^{235}U] 0.7%
158.6 keV
10^2
10
1
100
150
200
250
300
350
400
450
500

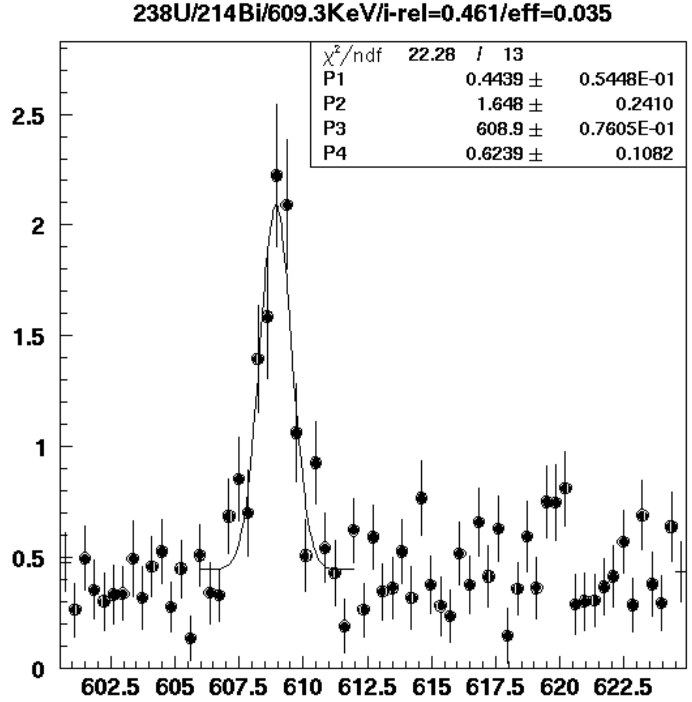


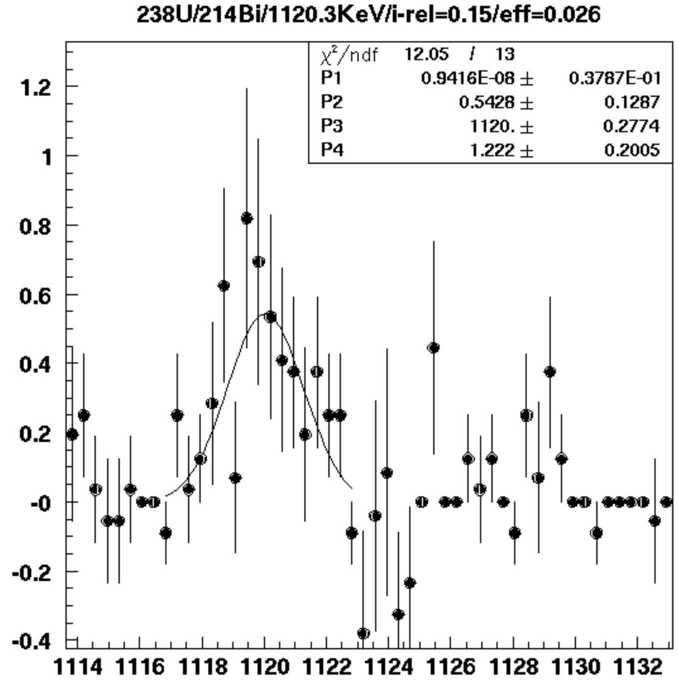
227Th[235U],7%
256 keV
223Ra[235U] 14%
269 keV
219Rn[235U] 10%
271 keV
227Th[235U],2%
286 keV
227Th[235U] 0.3%
296 keV
231Pa[235U],3%
227Th[235U],2%
212Pb[232Th],3%
300 keV
212Pb[232Th],3%
304,5 keV
176Lu,93%
307,5 keV
Ra[235U],4%
4 keV
227Th[235U],3%
330 keV
227Th[235U],1%
334 keV
223Ra[235U],4%
228Ac[232Th],11%
338 keV
?????
~342 keV
0
50
100
150
200
250
300
350
400
260
280
300
320
340
227Th[235U],11%
236 keV
212Pb[232Th],44%
339 keV
176Lu,84%
201,8 keV
0
50
100
150
200
250
300
350
200
210
220
230
240
250
219Rn[235U] 7%
402 keV
211Pb[235U],4%
404,5 keV
228Ac[232Th] 2%
409 keV
0
20
40
60
80
100
395
400
405
410
415
420



Gd201008geA20110824,bkgGeA20110628/day/kg/kev
208Tl[232Th] 30%
583keV
211Pb[235U], 4%
832 keV
228Ac[232Th],27%
911 keV
228Ac[232Th]4%
795keV
228Ac[232Th] 1.5%
772 keV
208Tl[232Th] 8%
?????
511keV
228Ac[232Th],16%
970 keV
211Pb[235U] 0.7%
766 keV
228Ac[232Th],5%
965 keV
208Tl[232Th]4%
727keV
228Ac[232Th] 1%
754,8 keV
211Pb[235U] 0.5%
704 keV
208Tl[232Th]5%
861keV
214Bi[238U],15%
609 keV
0
2
4
6
8
10
12
14
500
600
700
800
900
1000

^{238}U - ^{214}Bi





^{214}Bi[609kev]= 1.0±0.2 *mBq/kg*

^{214}Bi[1123kev]= 0.7±0.2 *mBq/kg*

JANIS SEARCH RESULTS FOR:
Z=83 A=214, Library=ENDF/B-VI.8, 100000.0 <= E, 0.07 <= I

Search	Evaluation	E	E error	Intensity	Intensity error	Type	Material	Half Life
NEA	ENDF/B-VI.8	6.09318e5	20	0.460933	8.442e-4	Gamma	Bi214	19.9 minutes
NEA	ENDF/B-VI.8	1.120276e6	22	0.150368	0.002961	Gamma	Bi214	19.9 minutes
NEA	ENDF/B-VI.8	1.76451e6	50	0.159214	0.002963	Gamma	Bi214	19.9 minutes

radioactivity contamination of one sample of the 500 kg of $Gd_2(SO_4)_3$ for EGADS phase 1 as measured with the geAnayet detector at Canfranc:

Summary Table

^{238}U chain ~1 mBq/kg ==> ~0.3 ppb
^{235}U chain n/a
^{232}Th chain ~15 mBq/kg ==> ~13 ppb

others
^{227}Th[^{235}U chain] ~400 mBq/kg ==> ~20 ppb ⇦?⇦?⇦

^{40}K 1.5 ± 0.3 mBq/kg
^{176}Lu 6.5 ± 0.5 mBq/kg

Luis Labarga,
Dept. Física Teórica,
Facultad Ciencias, Mod. 15
Universidad Autónoma de Madrid
28049 Madrid, Spain
Ph.: +34-914978589
e-mail: luis.labarga@uam.es

Dear Gloria, Juanjo,

with this letter I would like to request to the NEXT Collaboration to participate in the experiment as an official member, both myself and my group, the latter as it evolves with time. The main reasons for this interest are two very correlated ones: 1) the superb scientific interest of NEXT, and 2) the close relation that one of the relevant works in its preparation, study of radioactivity contaminations, has with my corresponding effort (named SuperkGd) within the neutron tagging R&D program of my main experiment Super-Kamiokande. This relation, I believe, will make rather easy for me to contribute to NEXT.

Given my full commitment to Super-Kamiokande, my participation in NEXT has to be necessarily modest in dedicated time. However the above synergy will translate, hopefully, into a rather productive, most efficient, work effort.

To be precise: I propose to participate in the main program of "screening" and Radio-purity carried out at the LSC. Because of my close relationship with the LSC and with its physicist in charge of the VLB Ge-detector farm, I think I could take the lead in:
1) the scheduling of the measurements in coordination with the LSC and SuperkGd),
2) the works of preparation, start and finish,
3) the regular analysis of the data.

It is my intention to hire one physicist/engineer to help me in the above. However, if I do not succeed in finding the right person, I think that with the help of the Collaboration (mainly shifts for item 2), I can still undertake the proposed task.

I thank you for the interest you may pay to this request, and I look forward to a positive reply from the Collaboration.

Madrid, October 19th 2011

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