NEWS from
SNO+

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Jornadas do LIP 2014
SNO+ and SNOLAB

780 tons of liquid scintillator viewed by 9000 PMTs (55% cover.)

for low energy neutrino physics:
- $0\nu\beta\beta$
- Oscillations
- SuperNovae
- Geo $\nu$
- Solar $\nu$
- ...

Other $\nu$/DM experiments:
- HALO
- PICO
- COUPP
- DEAP-3600
- MiniCLEAN
...
Fiber calibration system

92 (+spares) mounting points:
36 installed from cavity floor,
others with boating and climbing
Commissioning Runs 2014

3 short Air Runs in 2013/2014:
- characterize LED/Fiber system
- first paper of SNO+ hardware
- first test of PMT calibrations

Long Water Run in 2014:
- measure all PMT & optical properties
- cross-check with SNO last data
- test continuous running @ 10 Hz

3000 PMT calibrated w/ 18 Fibers

Water Run Physics
- nucleon decay
- solar/reactor \( \nu \)
SNO+ last pieces...

Umbilical Retrieval Mechanism for Calibration Sources
- to insert / move radioactive sources inside the scintillator
- being made at LIP workshops; needed at SNOLAB in 2015
- general design approval from SNO+ & SNOLAB experts
- stringent requirements; material radio-purity tests on-going

Scintillator Processing Systems also being done at SNOLAB
DAQ & Data Quality

DAQ based on ORCA (as in Majorana/Katrin)
- monitoring / slow control
- operator / level experts

Low level DQ tests
- check hardware vs run-log info
- data recording & building
- monitoring info – needing detector action
& logging info – set bit mask on run quality

Gersende Prior

Nasci em Paris e estudei física na Suíça, no EPFL. Durante a minha tese de diploma, trabalhei na experiência NOMAD no CERN. Descobri assim o mundo dos neutrinos. Isso convenceu-me a fazer o doutoramento na experiência HARP, que mediu secções eficazes hadrônicas importantes para as experiências dos neutrinos. Ajudei a construir a TPC, a renovar detetores de feixe e a instalar o DAQ.

Quando SNO publicou o artigo que contribuiu para provar as oscilações dos neutrinos, sonhei visitar um dia essa experiência. Aconteceu em 2005, quando fui para Berkeley para trabalhar em SNO. Era a ultima fase da experiência, em que uma rede de contadores proporcionais foi construída para melhorar as medidas. Trabalhei na calibração dos contadores e colaborei no R&D de um detetor de Germânio para a experiência MAJORANA.

Em 2009, voltei para o CERN e trabalhei no estudo do design de uma fábrica de neutrinos. Nos departamentos de aceleradores e engenharia, aprendi sobre a ótica dos feixes (radiofrequência, imanes) e participei em simulações da performance da captura do feixe.

Foi com grande prazer que, no início deste ano, integrei o grupo do José Maneira para trabalhar na experiência SNO+, a sucessora de SNO. Apesar de esta mudança implicar que a nossa família tem agora que se distribuir entre França e Portugal, como o meu filho de dois anos diz, há coisas que vem aos pares, como “pão beurre”.

(Boletim do LIP – nb 7, Março 2014)
Optical Calibration

Group coordination at LIP (expertise since SNO)

Based on uniform Laser Ball with continuous monitoring by LED / Fiber

Light absorption, re-emission and scattering in Scintillator + Water (+ AV) and PMT angular response

Processing, reconstruction and selection of large sets of calibration data:

- central LaserBall @ 6 wavelengths
- 30 x 6 positions & wavelengths
- Each LED / Fiber (1Hz + calib runs)

Large MC production in Pt GRID
$\textit{0νββ}$

lower energy resolution than other $\beta\beta$ detectors

**BUT** very high quantity of the isotope dissolved in low background medium

**NEED** not to degrade energy resolution tested $^{150}\text{Nd}$ (high Q) and $^{130}\text{Te}$ (high NA)

(136$\text{Xe}$ tested and used in KamLAND–Zen)

\[
Q(2\nu) \sim \Delta M - E_e = 2M_\nu = 2 \sum U_{ei} m_i
\]

\[
\Gamma(0\nu) \propto |M_{\beta\beta}|^2 = | \sum (U_{ei})^2 m_i |^2
\]

<table>
<thead>
<tr>
<th>2$\nu\beta\beta$ [years] measured by NEMO-3:</th>
<th>0$\nu\beta\beta$ [years] calculated by IBM-2:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nd</strong></td>
<td>$9 \times 10^{18}$ (g.s.)</td>
</tr>
<tr>
<td></td>
<td>$1 \times 10^{20}$ (e.s.)</td>
</tr>
<tr>
<td><strong>Te</strong></td>
<td>$7 \times 10^{20}$ (g.s.)</td>
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$\beta\beta$ with $^{130}$Te

High natural abundance, expected high $0\nu\beta\beta / 2\nu\beta\beta$ can be loaded in scintillator (0.3% ok, tests up to 3%)

Expected sensitivity in 5 years ("simple" counting experiment):
$T_{1/2} > 7.3 \times 10^{25}$ yr (90%CL)
$T_{1/2} = 2.4 \times 10^{25}$ yr (5 $\sigma$)
Backgrounds & $\alpha/\beta$ tags

PMT/H$_2$O/AV backgrounds reduced by Fiducial cuts

Loaded scintillator backgrounds reduced by 2 stage purification (can be tested in-situ with loading)

On-peak $^{214}$Bi and $^{208}$Tl reduced by $\alpha-\beta$ coincidence tagging (including pulse-shape discrimination)

Irreducible $2\nu\beta\beta$ energy resolution (& pile-up rejection)

Solar $^8$B neutrinos irreducible but known and visible
Anti-neutrinos \( \bar{\nu}_e + p \rightarrow e^+ + n \)

Group coordination at LIP (new 1-year “exploratory project”)

Positron annihilation gives anti-neutrino energy and interaction point
Delayed neutron capture gives clear tagging and “smeared” direction

Almost background free
& very high efficiency

Contributions from:
- distant nuclear reactors
- 3 Canadian reactors
- geo-neutrinos from U/Th decay chains inside crust & mantle

Mainly energy, but reactor variations and directions to be explored
Neutrino oscillations

In 2012 last mixing angle was measured with close-by reactors, from now on $3\nu$ matrix must be used in analysis of all experiments

$$
\begin{pmatrix}
0.82 & 0.55 & -0.15 \\
-0.35 & 0.70 & 0.61 \\
0.44 & -0.45 & 0.77
\end{pmatrix}
$$

SNO+ will see 12 oscillations

Solar $\nu$ for $\theta_{12}$ and $\theta_{13}$ and
Only LBL Reactor $\nu$ for $\Delta M_{12}^2$ ("directly" from L/E pattern)

Same precision as KamLAND
Geo-neutrinos

New field, measurements with impact on geo-physics!

Only two experiments up to now (KL – Japan, BX – Italy)

In SNO+, less background, larger area, well known crust fraction

We will try to use directionality (e⁺ / n vector) to improve selection

- will be tested for SNO+ and future improved detectors with:
  - enhanced neutron capture
  - enhanced position resolution
Summary and outlook

SNO+ almost ready for (water) data in the end of 2014
- new PMT calibration system installation being finalized
- new URM being built at LIP workshops in Coimbra

LIP's group has grown in people and tasks
- DAQ & DQ
- Optical and PMT Calibration
- External Backgrounds
- $\alpha/\beta$ discrimination
- Reactor anti–neutrino Oscillations
- Geo–anti–neutrino Physics

Scintillator data now expected in 2015
- $0\nu\beta\beta$ in $^{130}$Te (0.3% loading, can be later increased to 3%)
- Anti–neutrinos, SuperNovae, Solar Neutrinos, ...
Solar ν

B-8, measured at high energy
total rate measured by SNO!
CC / NC fixes oscillation

pep, measured @20%,
model prediction, @1%

Be-7, 1st line @5%,
model prediction, @7%,
ratio of 2 lines fixed

CNO, upper limits only,
direct test of metalicity

pp, only radio–chemical exps.
oscillation fit + luminosity

hep, unmeasured but small
SNO+ last pieces...

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MOTOR BOX & ROPE MECHANISM

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