The SNO+ neutrino experiment – thesis opportunities @ LIP

the SNO+ LIP group

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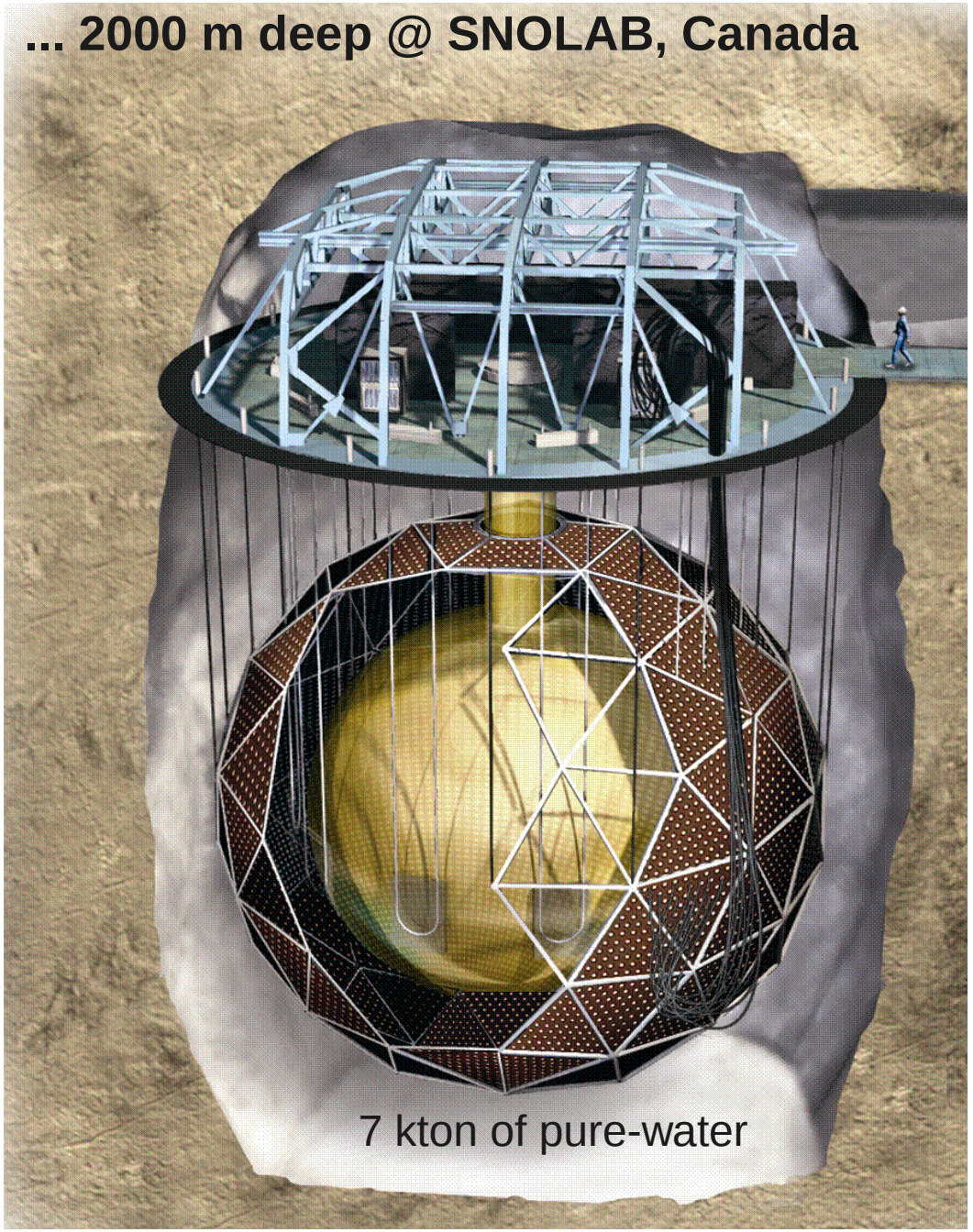
The SNO+ neutrino experiment



Follows / reuses hardware from **Sudbury Neutrino Observatory** (2015 Nobel prize for solar neutrino oscillations)

9300 PMTs, 8.5 m away from centre

12 m diameter transparent sphere holding 750 ton of active medium:

heavy water -> liquid scintillator

make lower energy events visible

loaded with 1.3 tons of ^{130}Te

Still an observatory but now focusing on neutrino mass!

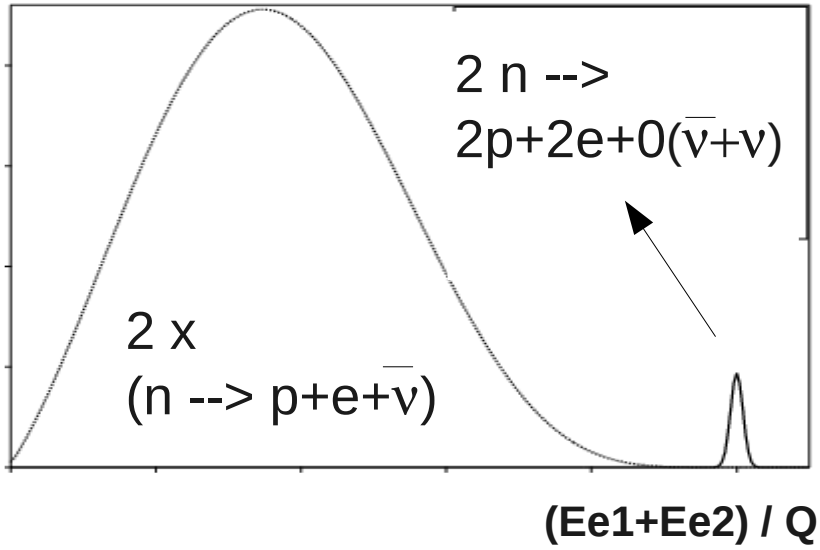
The main question: what is the origin of neutrino mass?

Oscillations => neutrinos have mass / Beta decays => it is very, very small

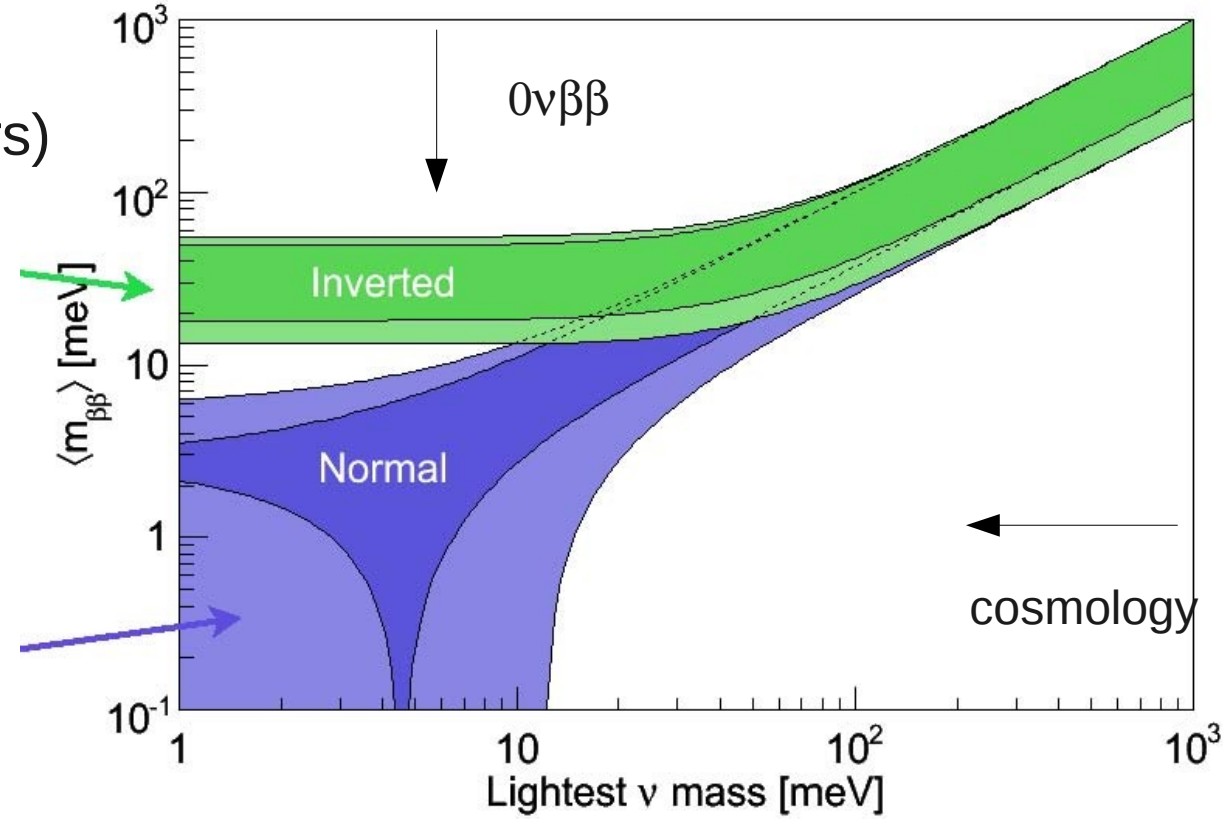
A different mechanism for mass? Are neutrinos Majorana particles?

A few isotopes have $2\nu\beta\beta$, if $\nu=\bar{\nu}$ also $0\nu\beta\beta$

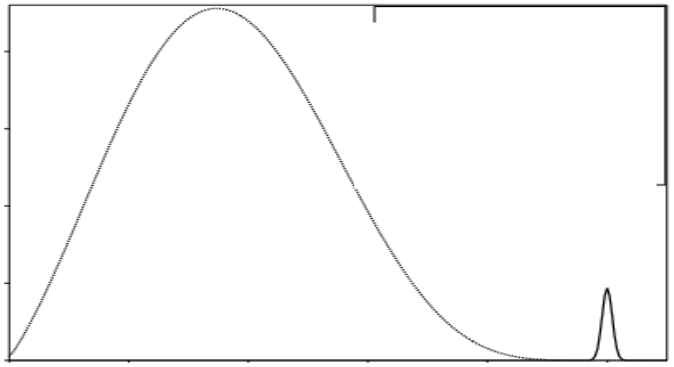
Very rare process ($T_{1/2} \sim 10^{20}$ yrs)



mass bands from neutrino oscillation parameters



$0\nu\beta\beta$ experimental signature

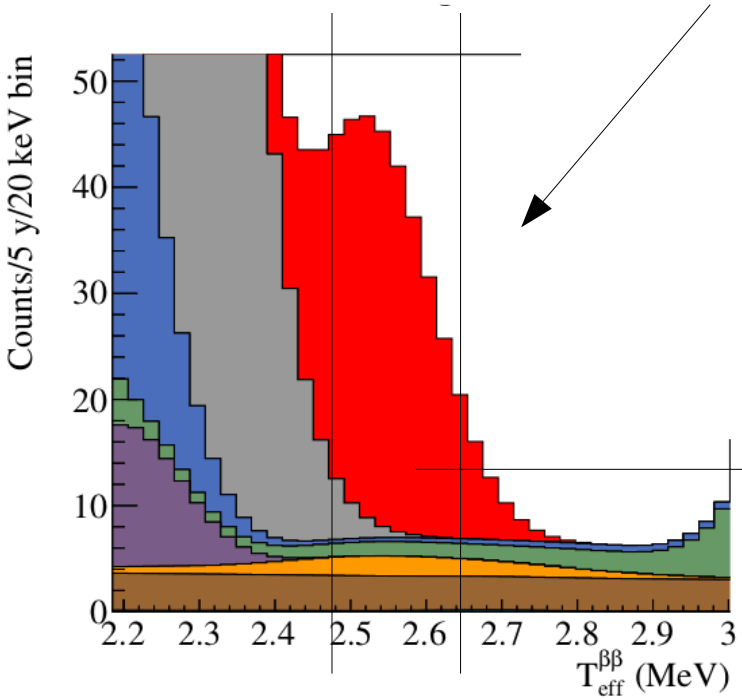


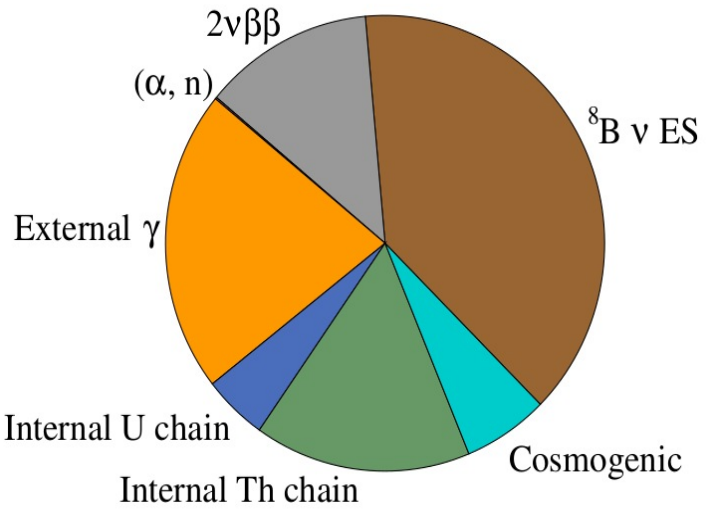
Peak scales with $\langle m_{\beta\beta} \rangle$ (and Tellurium mass!)

Window depends on energy resolution

~ 14 non $0\nu\beta\beta$ events / year (reducible?)

5 year sensitivity: $T_{1/2} \sim 10^{26}$ y $\langle m_{\beta\beta} \rangle \sim 50$ meV

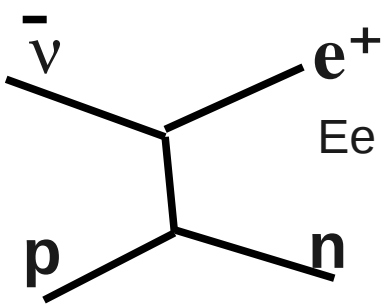




Optimizing detection and background reduction for $0\nu\beta\beta$ peak (~2.5 MeV)

Extending the detection range to search also for other new physics
High energy boosted Dark Matter particles produced/annihilated in the Sun

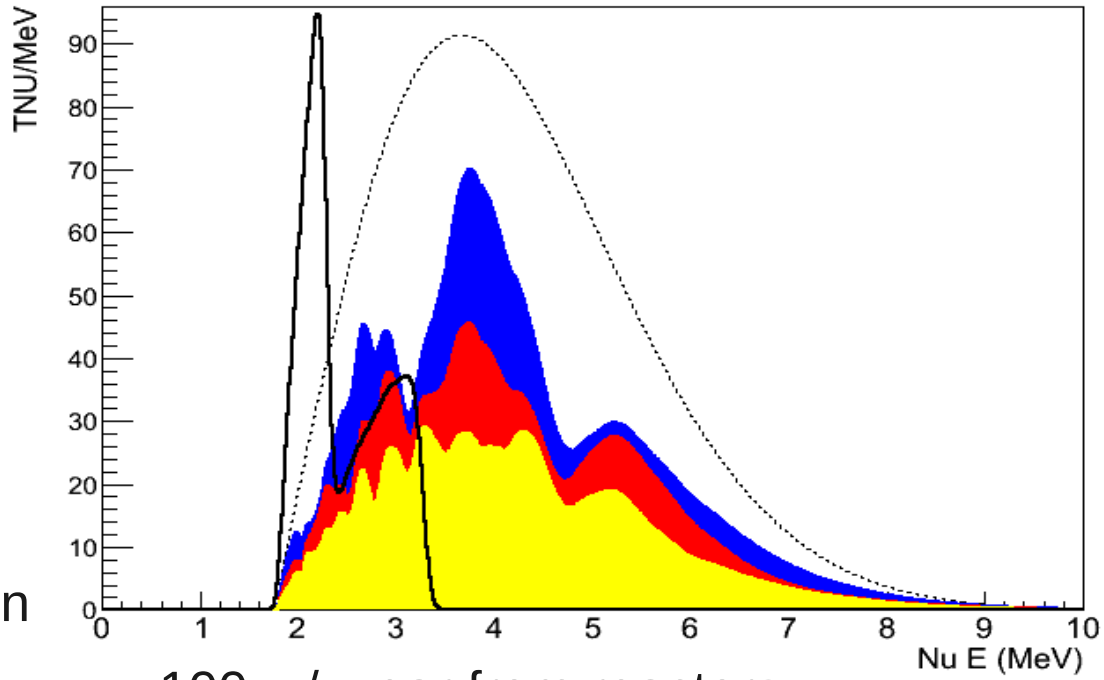
Particle, geophysics and astrophysics with anti-neutrinos



Ee = Eν + 0.8 MeV

200 μs delay, 2.2 MeV γ

* tagging of a delayed coincidence
* identification of gamma and positron
* reduction of neutron backgrounds
* and again the energy resolution



~ 100 ν / year from reactors
Oscillation signals @ 250 km, 350 km

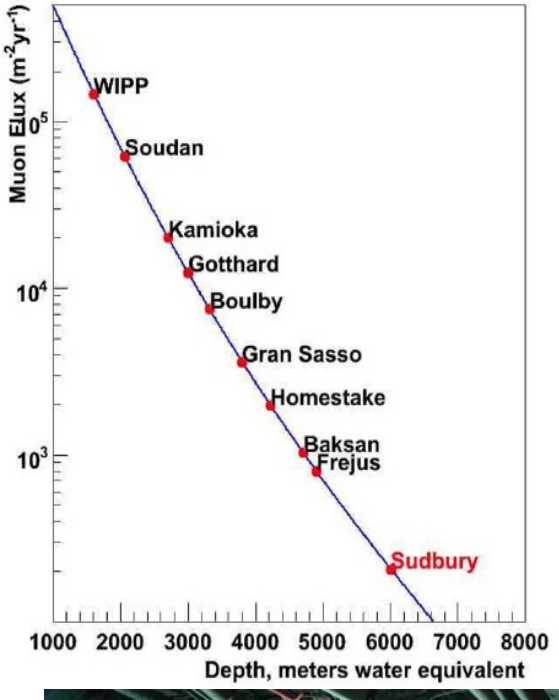
In addition to the $0\nu\beta\beta$ search SNO+ is also an Observatory!

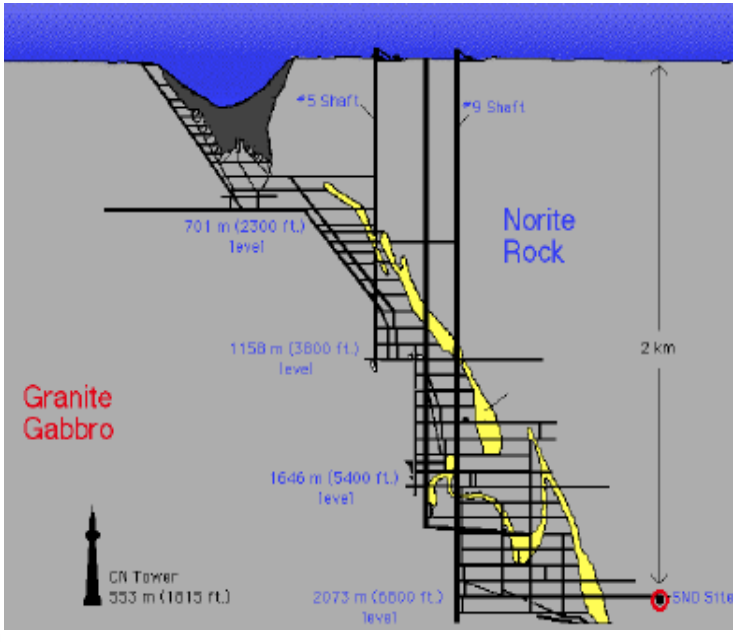
~ 20 / year from U/Th in the Earth
measured only in Japan and Italy,
disentangle crust / mantle in global analysis

~ several / day in pre-supernova phases
monitor rate changes in an automated way

~ many ν / minute in a supernova explosion
neutrinos arrive 3 hours before light: SNEWS!

SNOLAB: a deep and clean underground laboratory

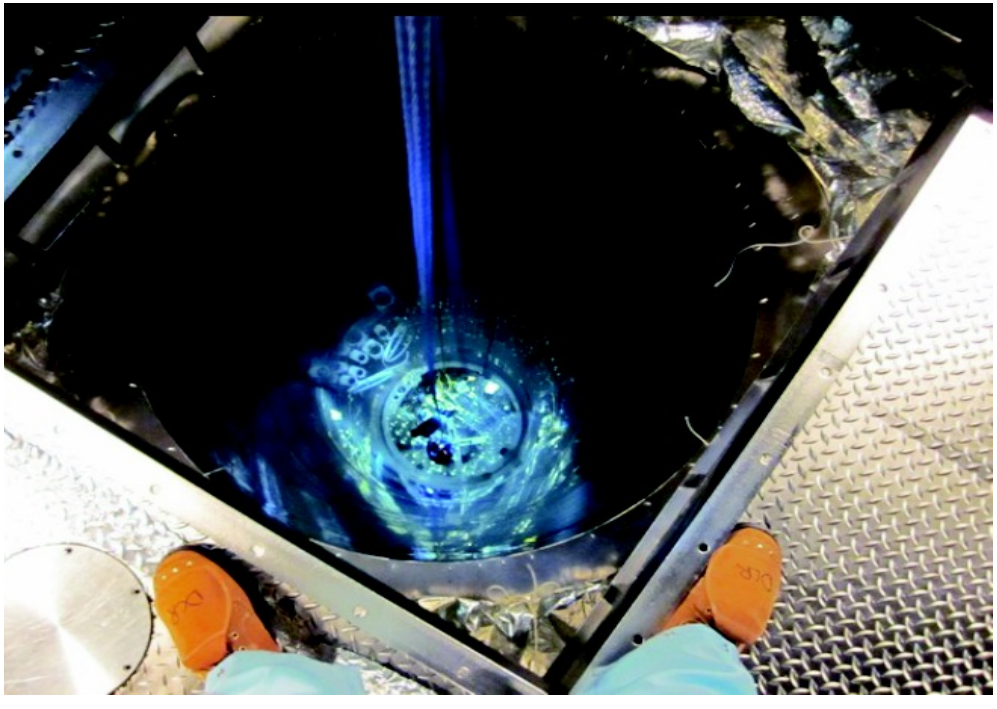




50x10⁶ less muons at -2000 m!
100 / day in 20m x 20m hall

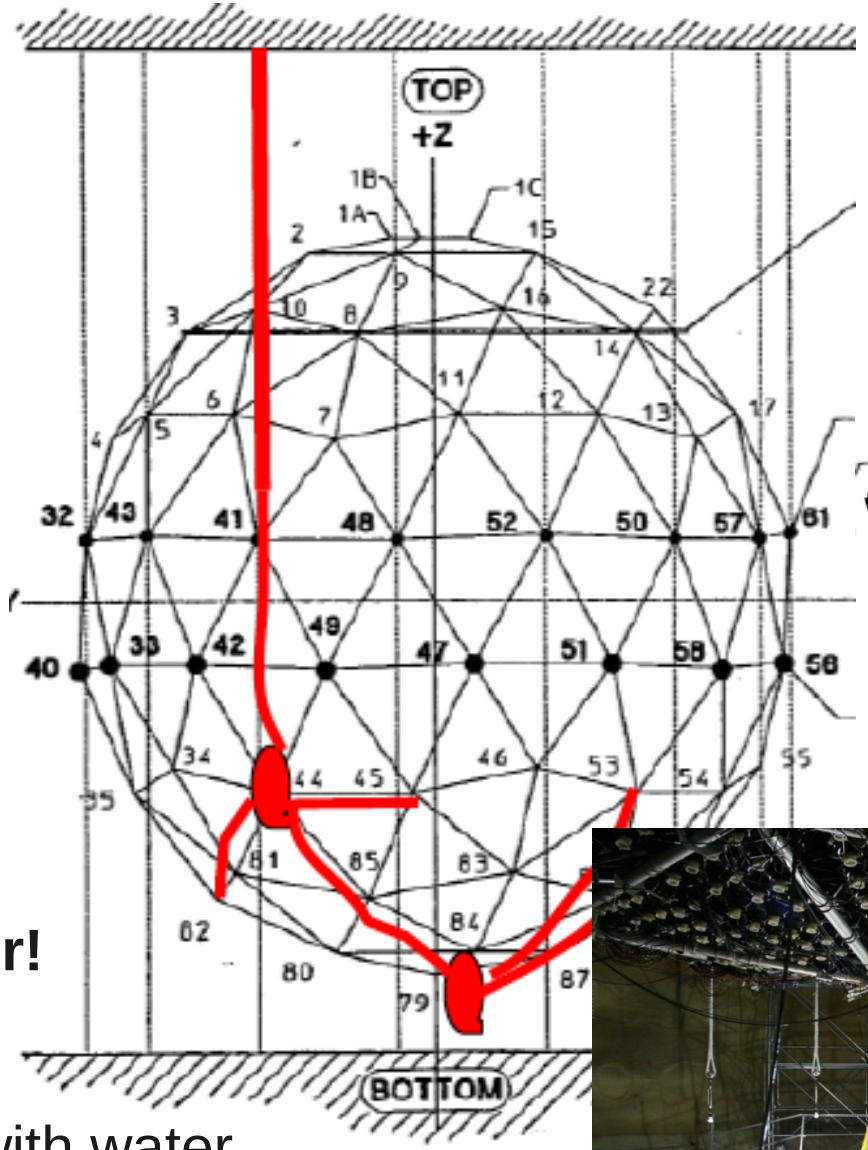
Scintillator and tellurium are stored in the clean lab underground for a few years

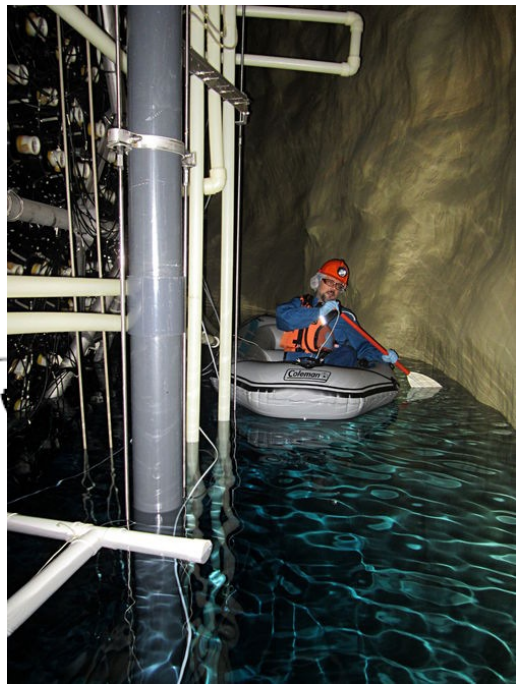
<u>Measuring and constraining cosmogenic backgrounds</u>



Inside SNO+: installation of calibration / monitoring systems

(optical fibre system – already used to test PMTs in air and half-water runs)



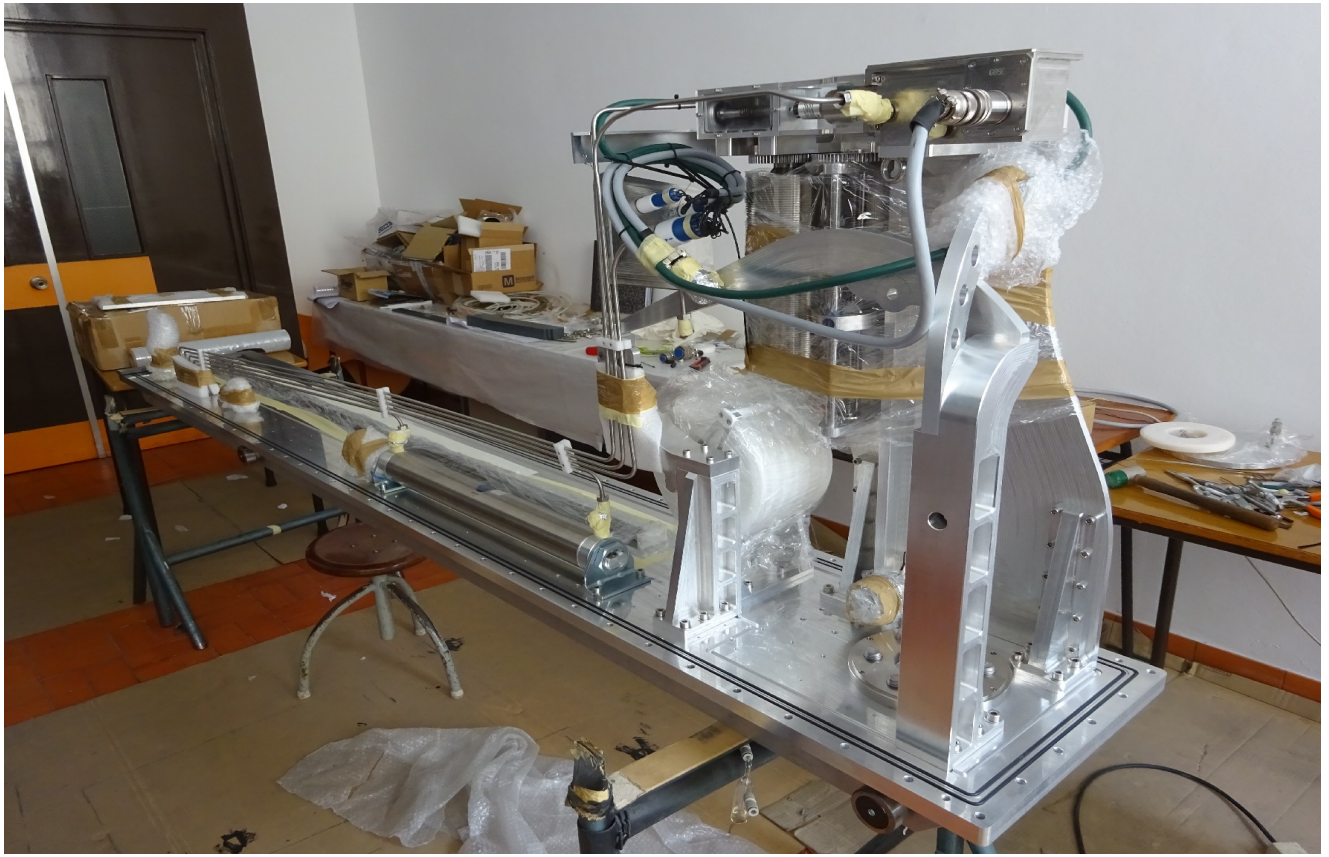


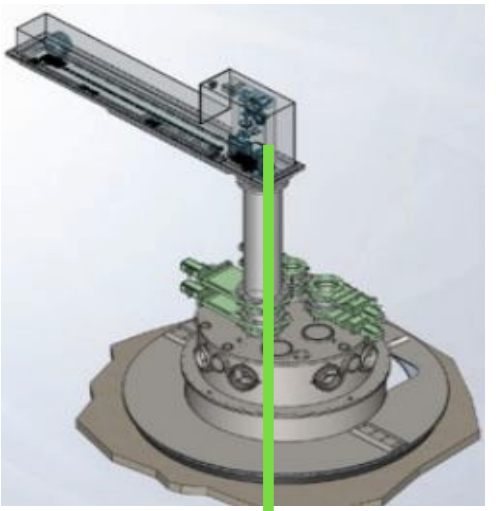
Now all filled with water!
Data taking is starting!

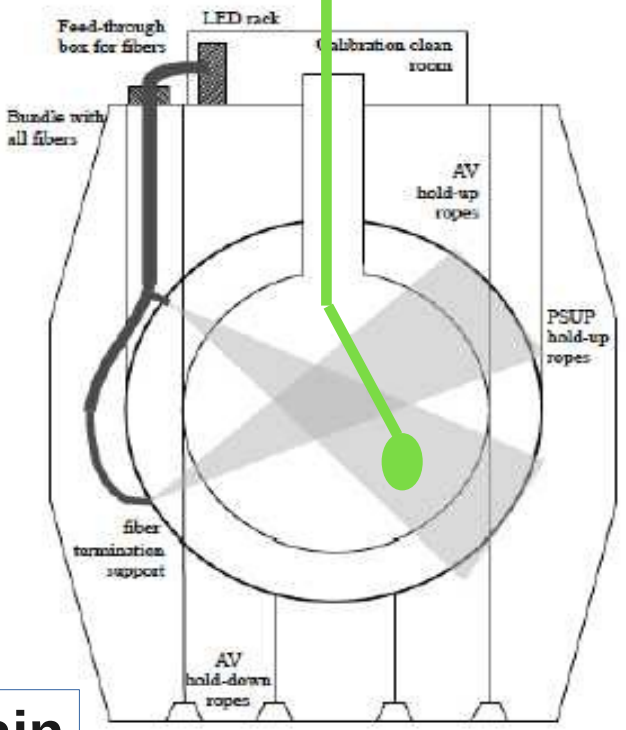
- first detector filled with water
- still this year with scintillator
- later with the tellurium load

Internal sources for detector calibration

Source insertion mechanism
made at LIP-Coimbra, now at SNOLAB!







Optical calibration is one of our main tasks

Particle sources check all the reconstruction chain

Scale and resolution for gamma energy

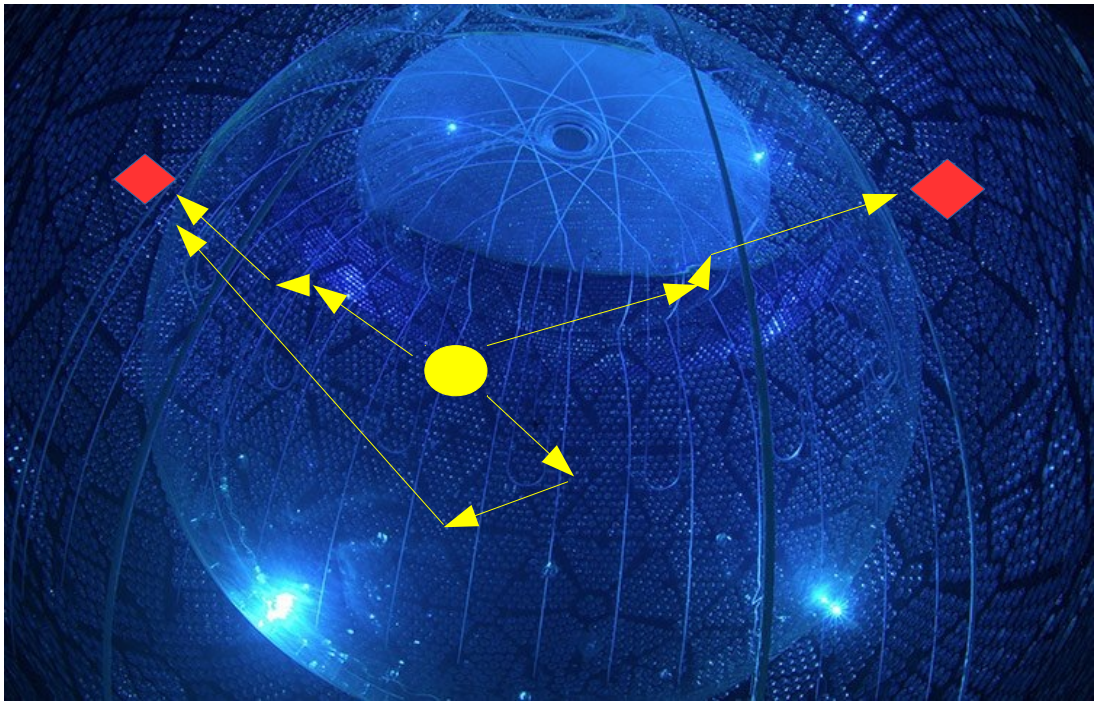
from the lower threshold to the $0\nu\beta\beta$ end-point

SNO+, a optical detector

Single photons in 9300 PMTs

PMT hit scale with emitted light
=> reconstruct the event energy

PMT hit time and pattern
=> reconstruct the event position



Emulate signals with a light diffuser at different wavelengths and positions

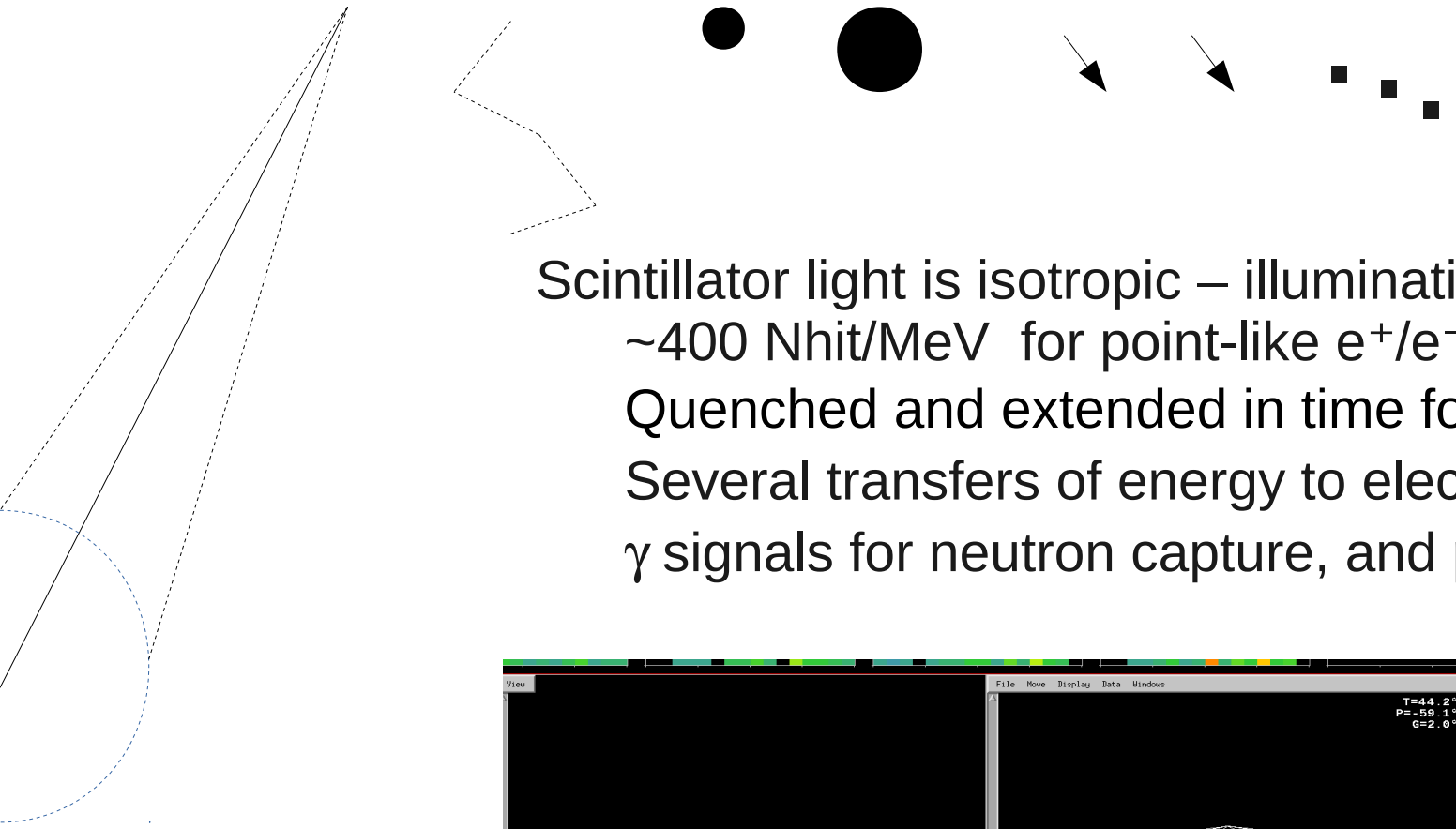
In water, to characterize the acrylic vessel and PMT properties
In scintillator, to characterize its much more complex properties

Crucial to improve detector response uniformity

Numerical tool for an easy transfer of this information to event analyses

Trying to separate different signals and improve particle identification

ν / $\bar{\nu}$ / μ / n / p / α / β^- / β^+ / γ ?



Scintillator light is isotropic – illuminating all the detector

~400 Nhit/MeV for point-like e^+/e^- (+ Cherenkov light)

Quenched and extended in time for p/α

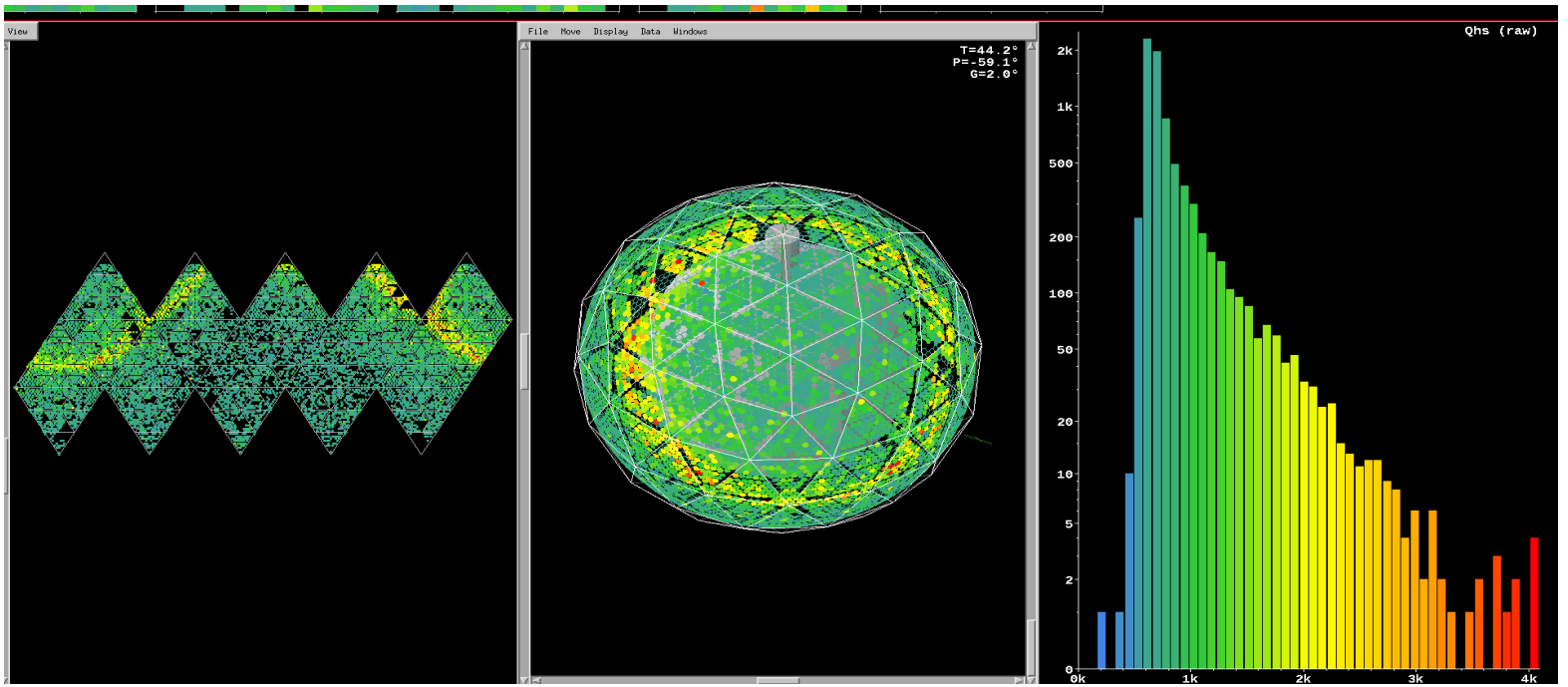
Several transfers of energy to electrons signal a γ

γ signals for neutron capture, and positron annihilation

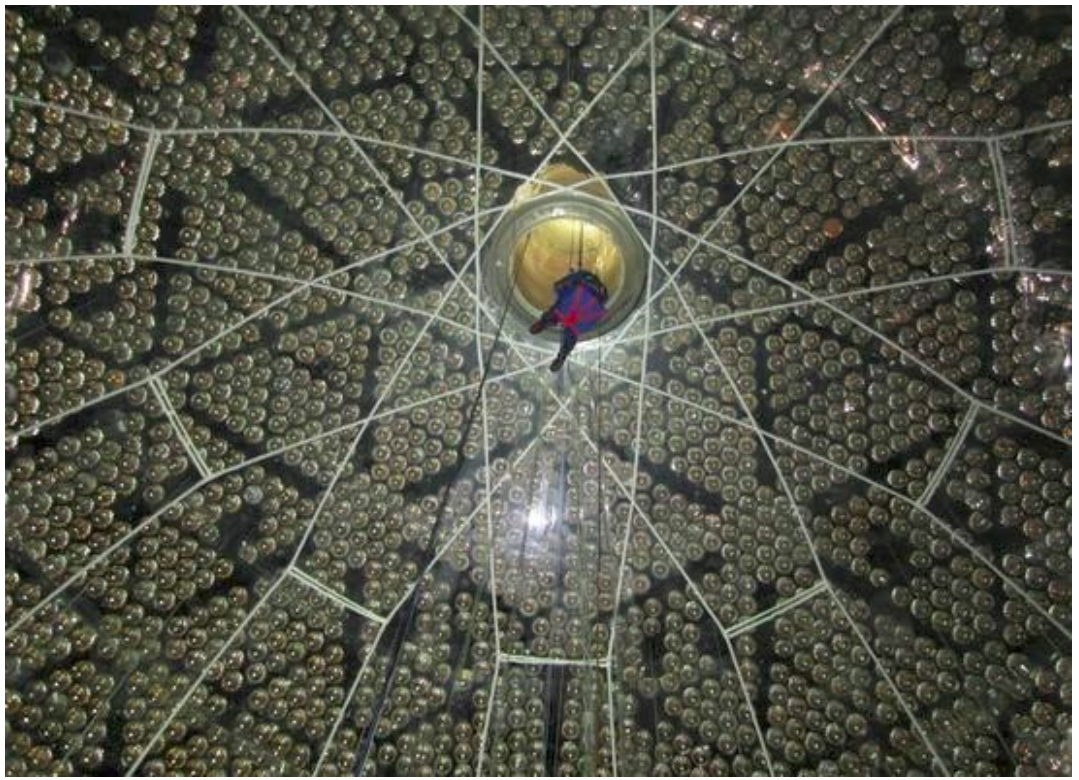
neutrino-like event

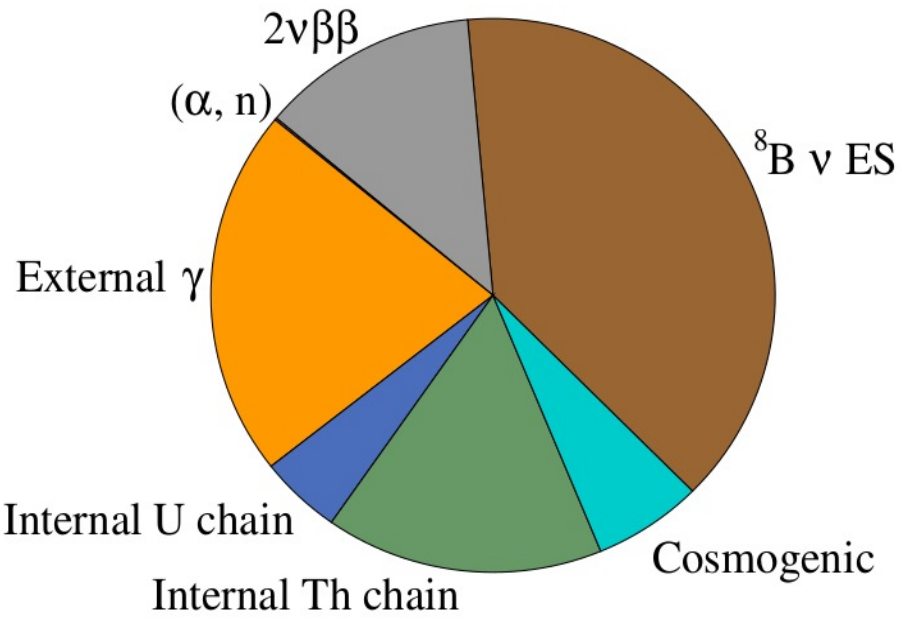
in water data (on 5/2/2017)

Cherenkov cone



backgrounds to SNO+ physics





<u>Backgrounds from the PMTs</u>
measuring directly during the water phase

<u>Backgrounds from the acrylic vessel</u>
modelling their diffusion in time and space

<u>Backgrounds in scintillator cocktails</u>
developing new identification techniques

Example: internal U/Th chains

-> scintillator purified before filling

-> tag separately alphas / betas
-> tag their delayed coincidence

* can achieve O(99%) reductions

The SNO+ neutrino experiment

neutrino-like event

in water data
(on 5/2/2017)

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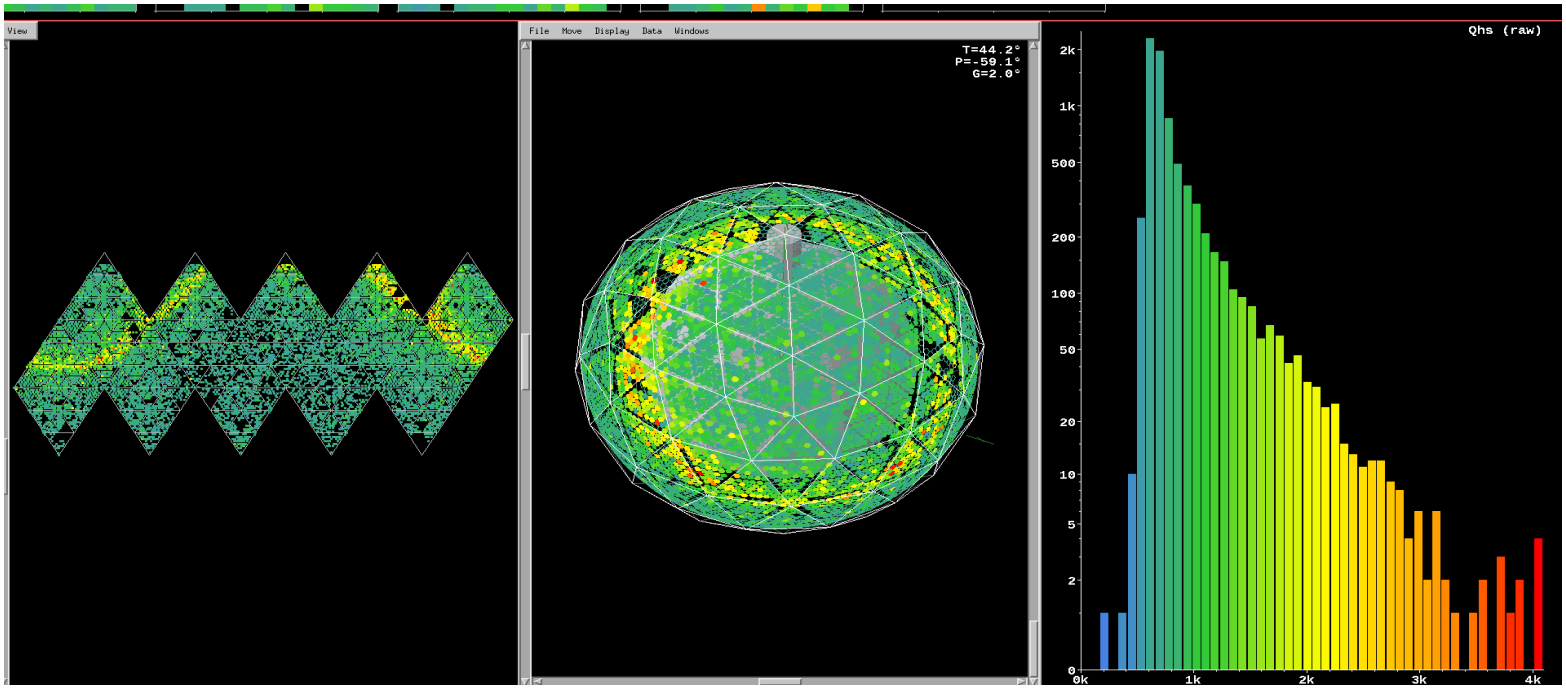

Data taking is just starting, lots of data to analyse in the next years!

Particle and nuclear physics, astrophysics and geophysics goals
Measurements of the different backgrounds are faster and crucial
Modelling and calibrating the detector fundamental in all analyses

Thank you for you attention
don't hesitate to contact us for more information