5th Lisbon miniSchool
on Particle and Astroparticle Physics
Costa da Caparica, 5-7 February 2020

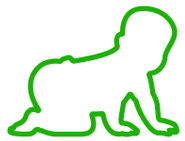
SNO+ and DUNE: Deep underground neutrino physics

Valentina Lozza

FCT Fundação para a Ciência e a Tecnologia

LIP Lisbon

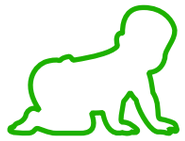
The world of NEUTRINOS



Neutrinos have been postulated for the first time in 1930

They are practically babies in the particle zoo

The world of NEUTRINOS



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They are basic ingredients in nuclear and particle physics, cosmology and astrophysics

Play a key role in the early Universe

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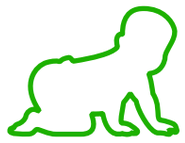

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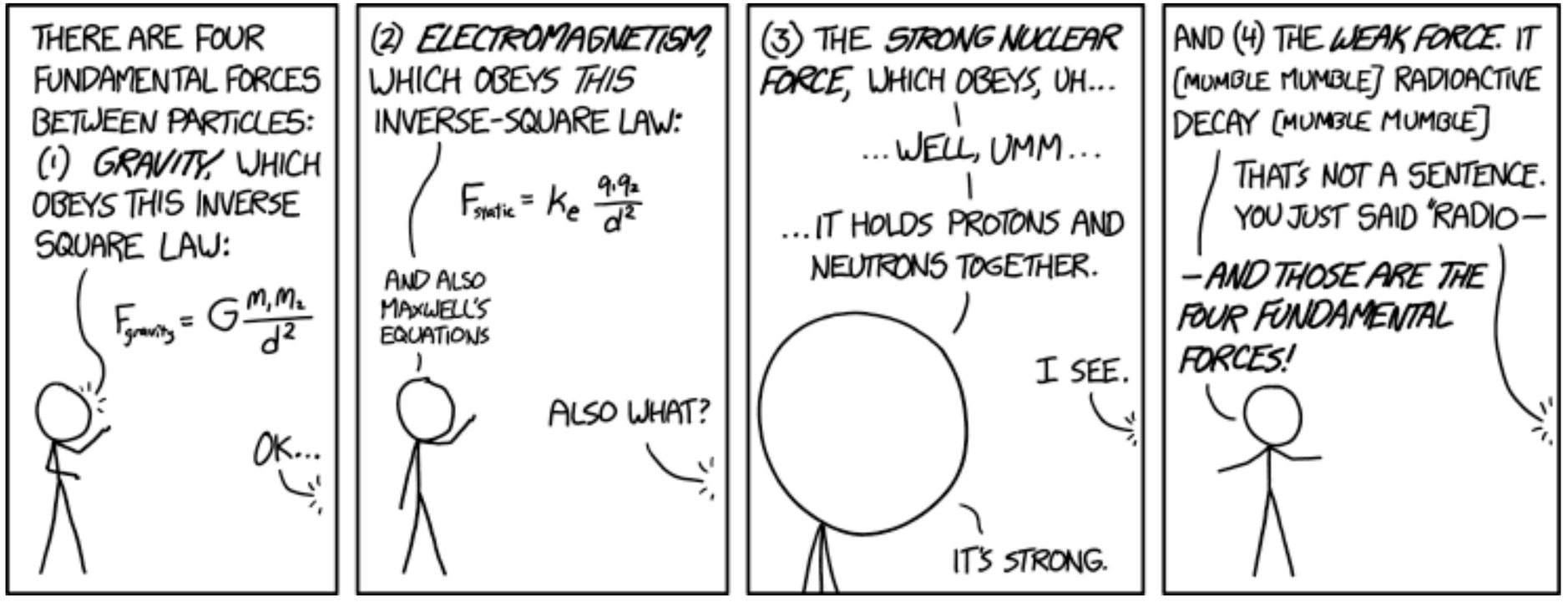
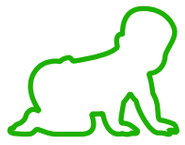


The world of NEUTRINOS



Neutrinos have been postulated for the first time in 1930

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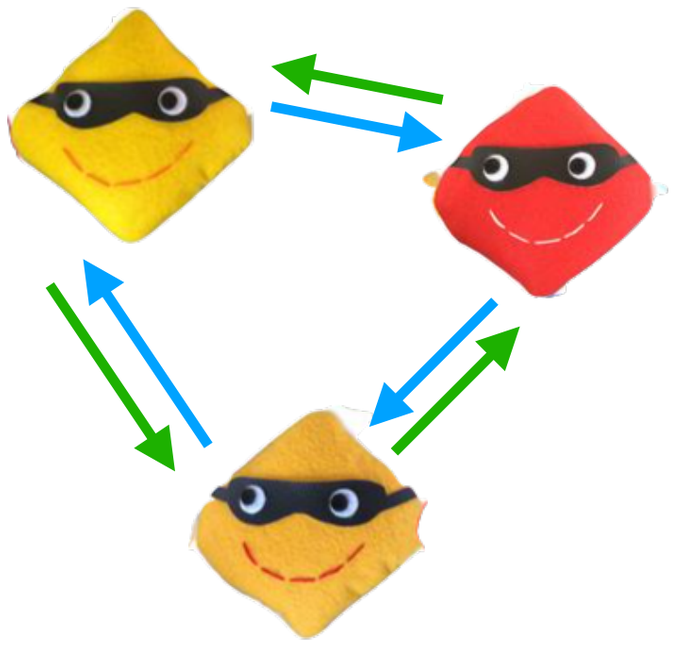
They obey to the weakly interaction

We know that they oscillate, which indicates they **have a mass**



But there are still many open questions

Are neutrinos Dirac or Majorana?

Dirac neutrino

ν^D

4 ν states

lepton number conservation ΔL = 0

neutrino ≠ antineutrino

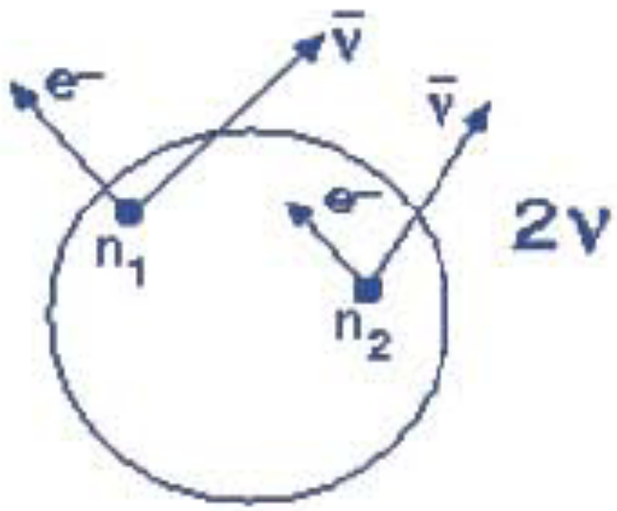
Majorana neutrino

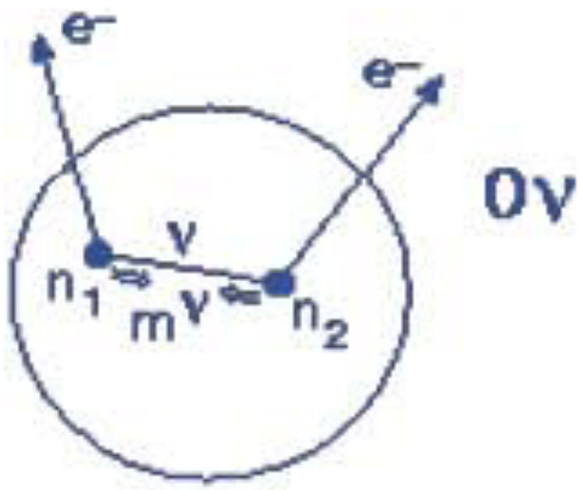
ν^M

2 ν states

lepton number violation ΔL = 2

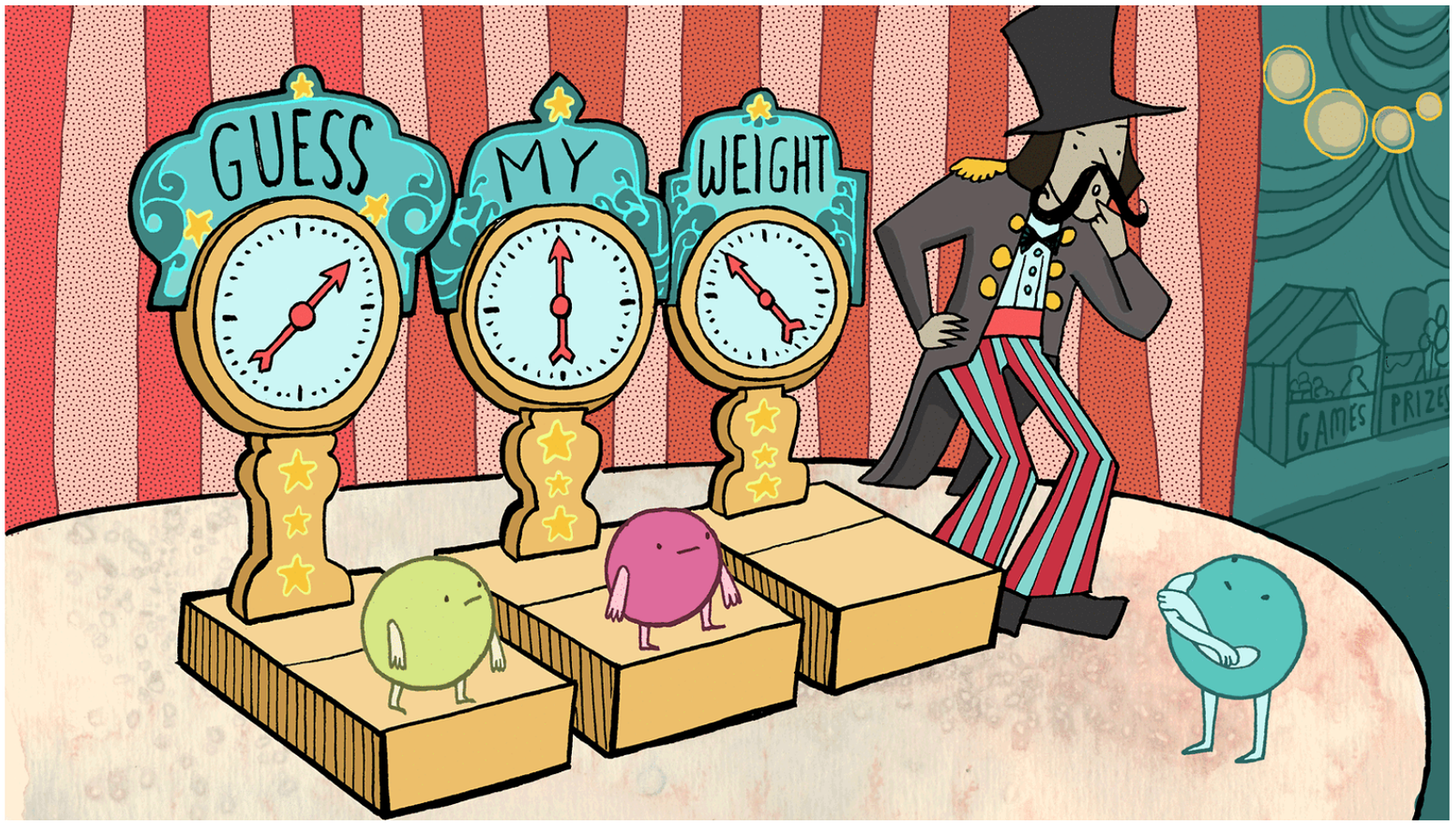
We need to look at the rarest decays: The double-beta decay with 0 neutrinos





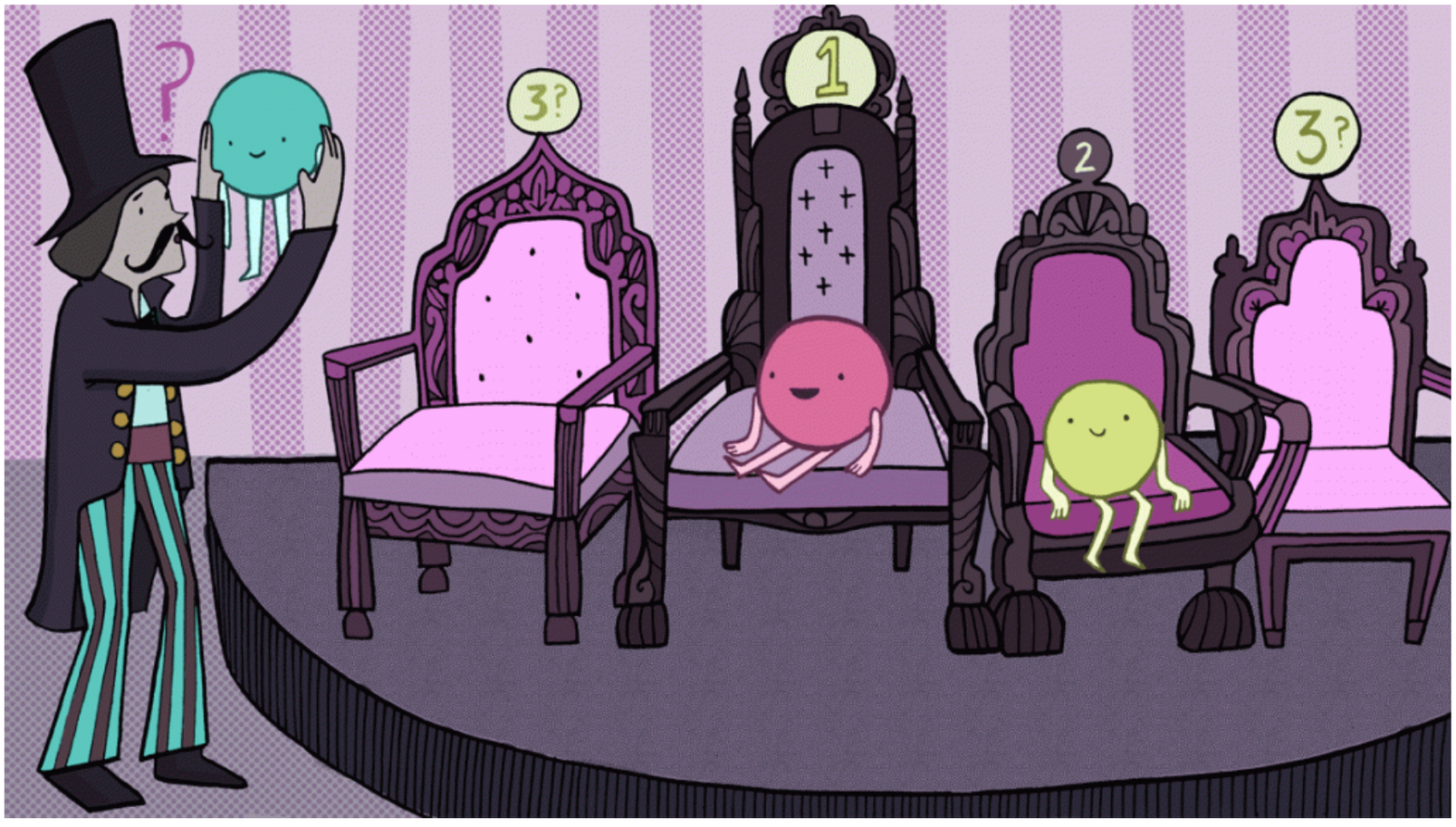
- not observed …. yet
- If observed it will tell us that neutrinos are MAJORANA!!!!
- The $T_{1/2}$ is > 10^{26} yr requires huge detectors

What is the absolute value of their masses?



- We know that neutrinos do have a mass (SNO/SK Nobel prize)
- We know mass^2 differences!
- We don't know the absolute value of it

Or their ordering?



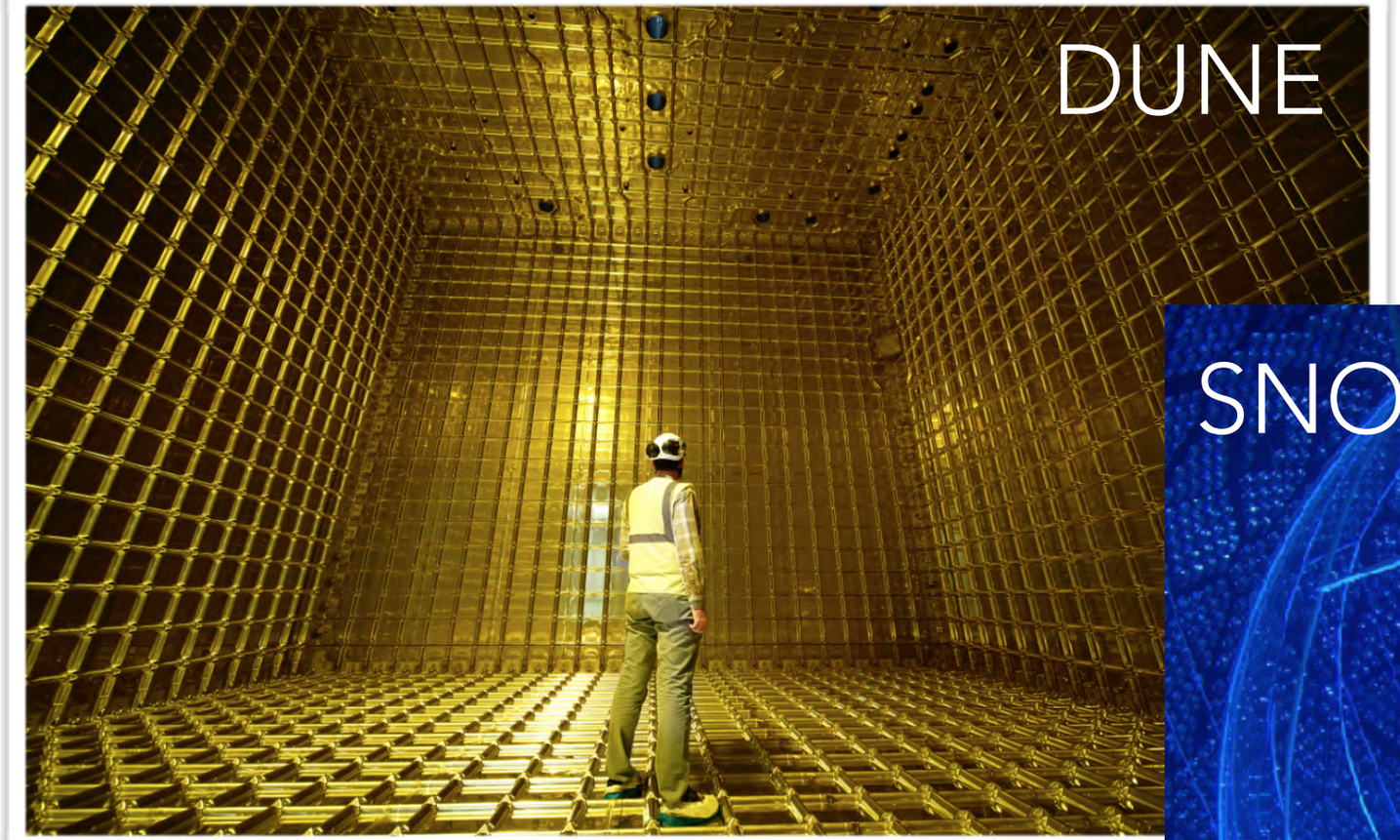
- We know mass^2 differences!
- We know that m_2 is heavier than m_1
- We don't know if m_1 or m_3 is the lightest

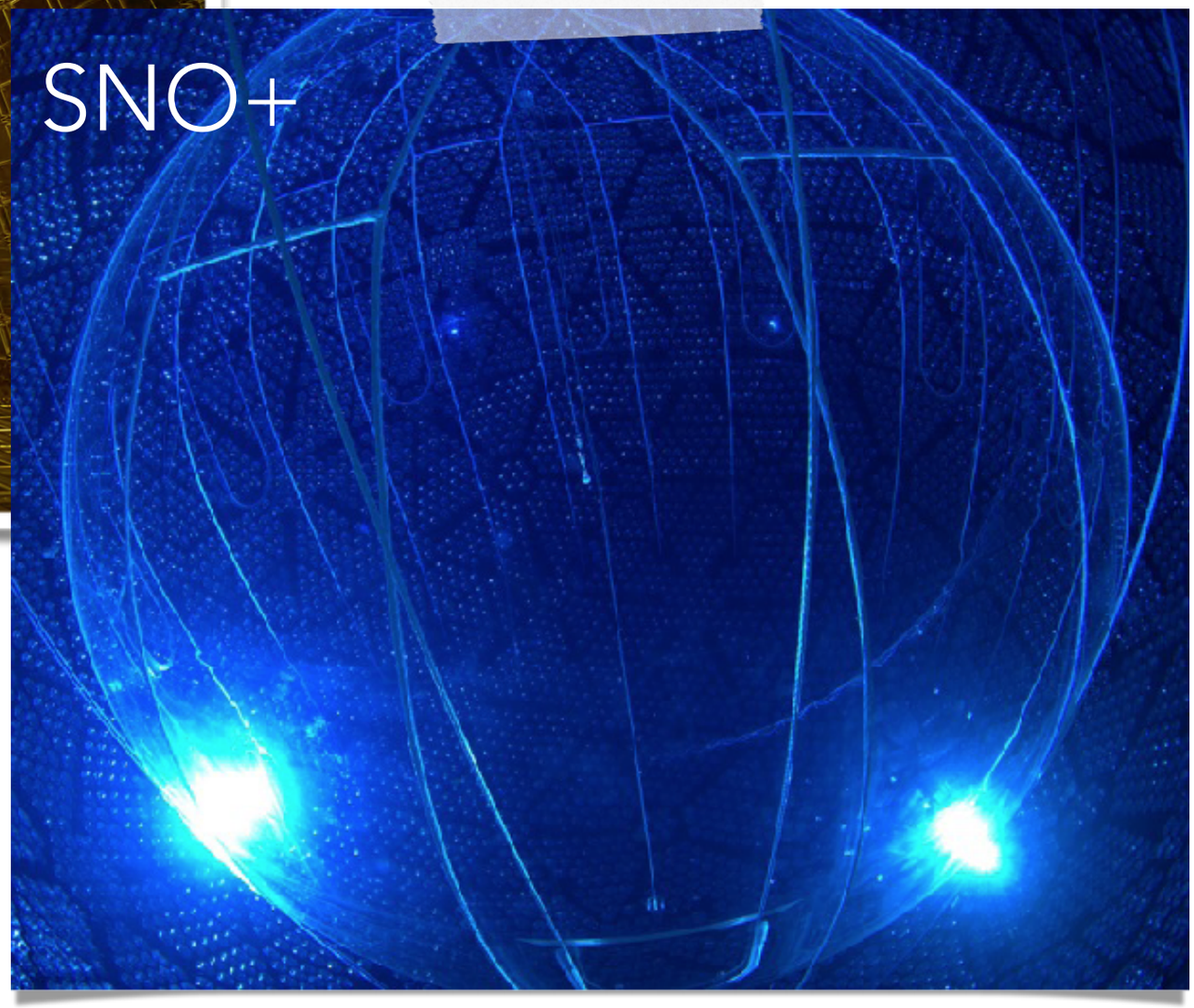
Can they explain the matter excess?

- Physics laws need to be slightly different for particle and anti-particles
- We know that the current asymmetry in the quark sector cannot explain the difference
- An asymmetry in the lepton sector could solve the mystery
  - ✳ Really heavy neutrinos are produced in the Big Bang (Majorana-like particles)
  - ✳ They decay into light particles, but more to particles than to anti-particles (violation of CP-symmetry)

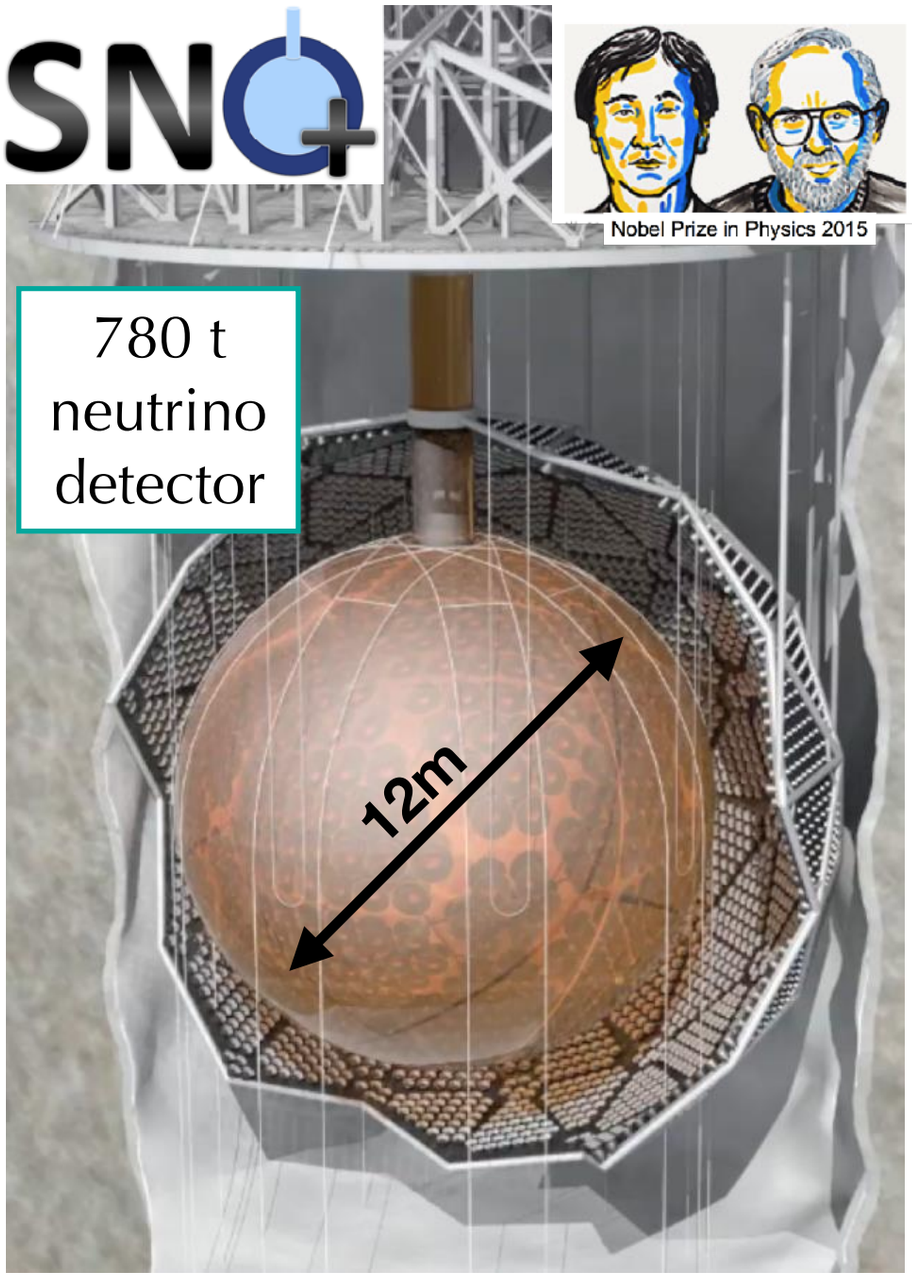
Neutrinos at LIP

At LIP we try to answer these questions using the data from two main experiments:





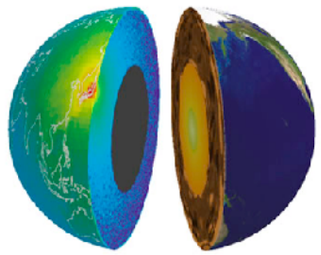
SNO+: 0νDBD search and much more!

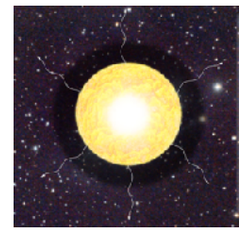


Nobel Prize in Physics 2015

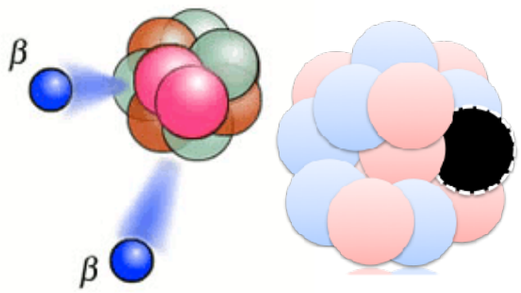
- 10^4 less muons than at sea level
  - Second deepest laboratory in the world

Geo anti-neutrinos





Supernovae neutrino



Rare decays

Reactor anti-neutrinos

Solar neutrinos

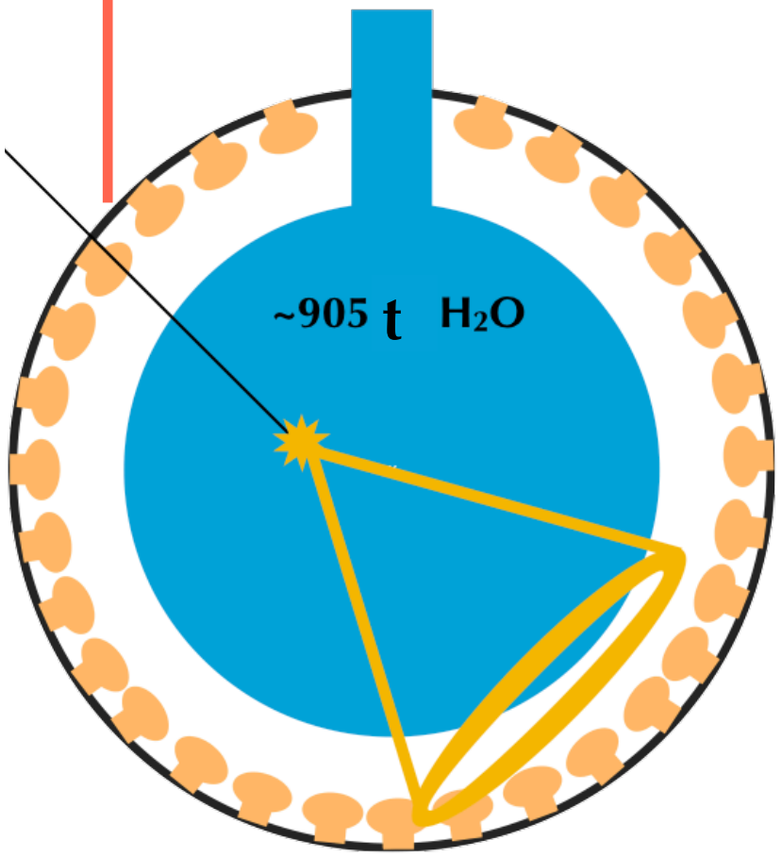
Data taking: Water phase

2017 2018 2019 2020 2021

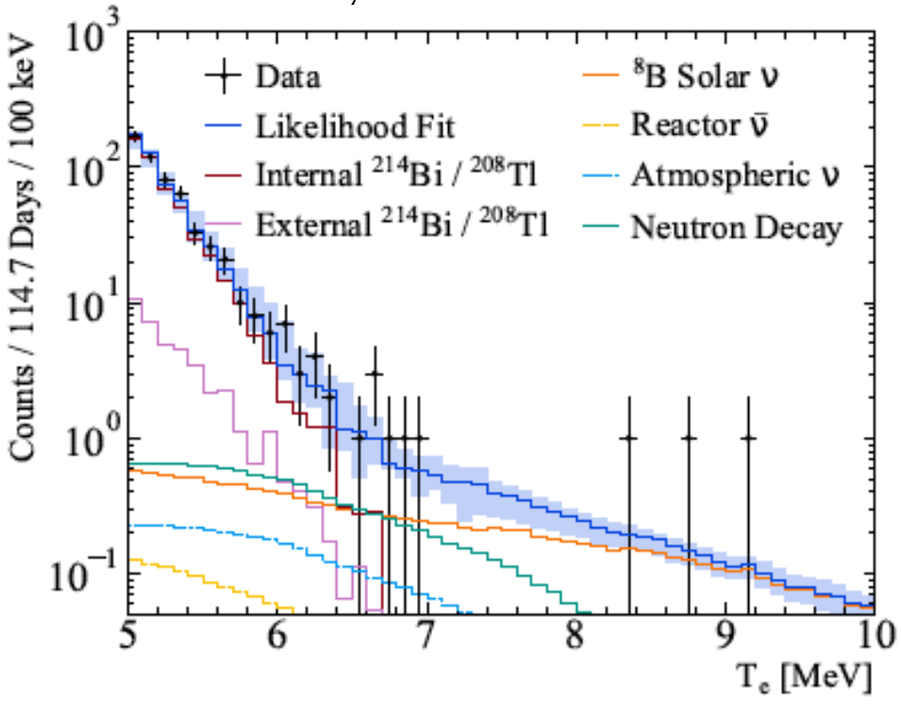
May
Start of official data taking in water

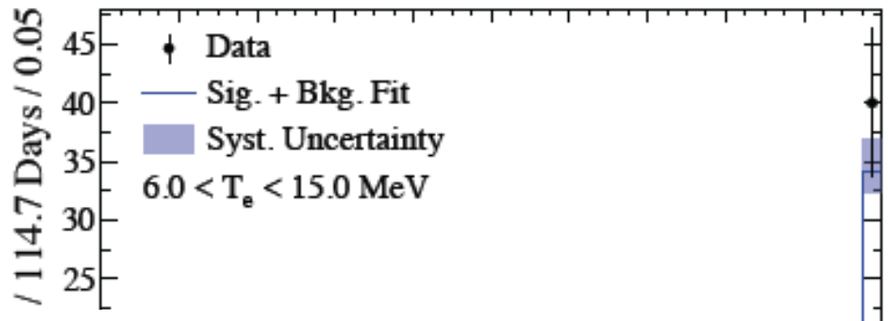
July
End of water phase

July
Start of scintillator filling



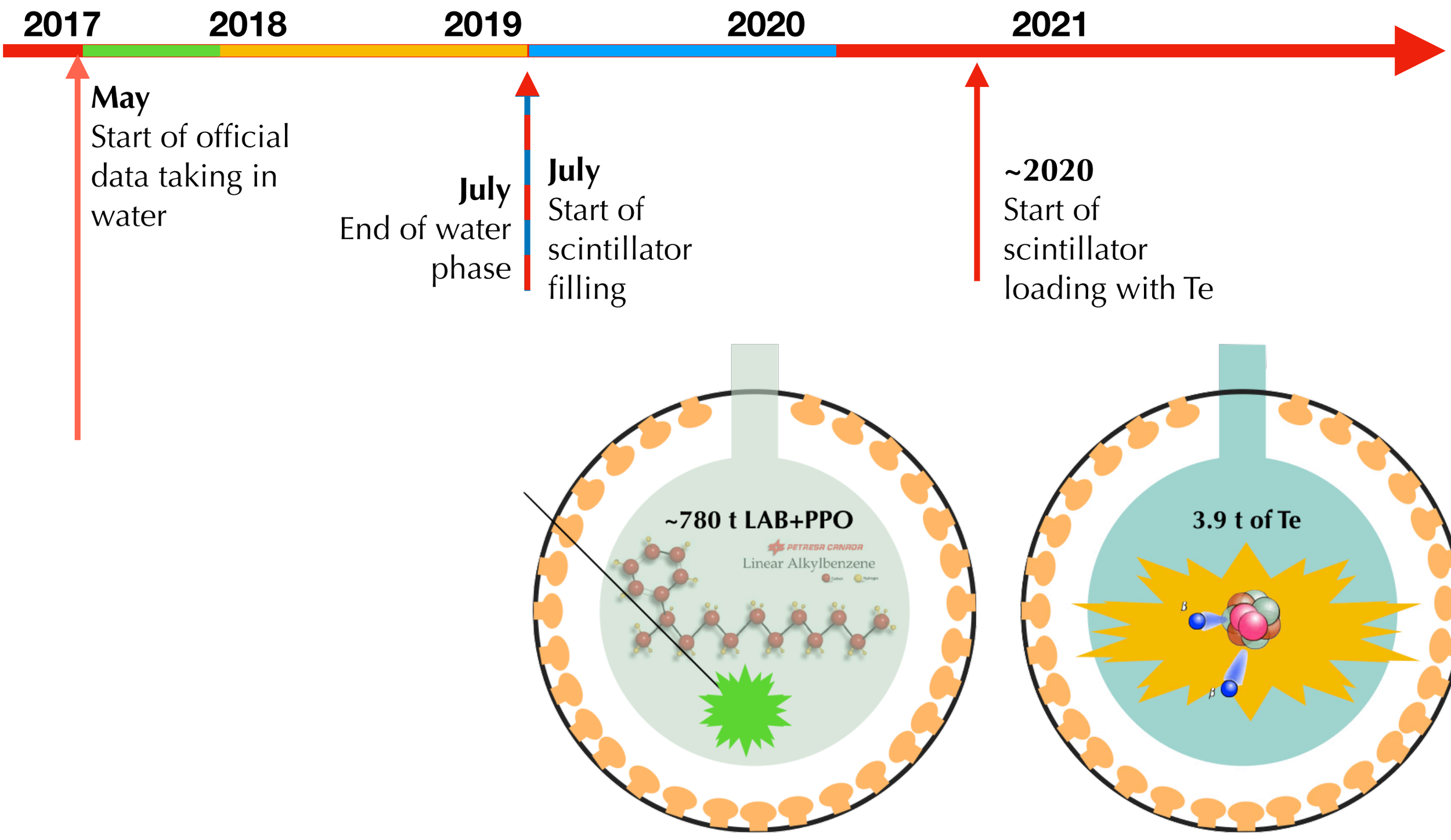
Improved the limits on the half-life of nucleon decay into invisible channels





Solar neutrino flux measurement

Data taking: Present and Future

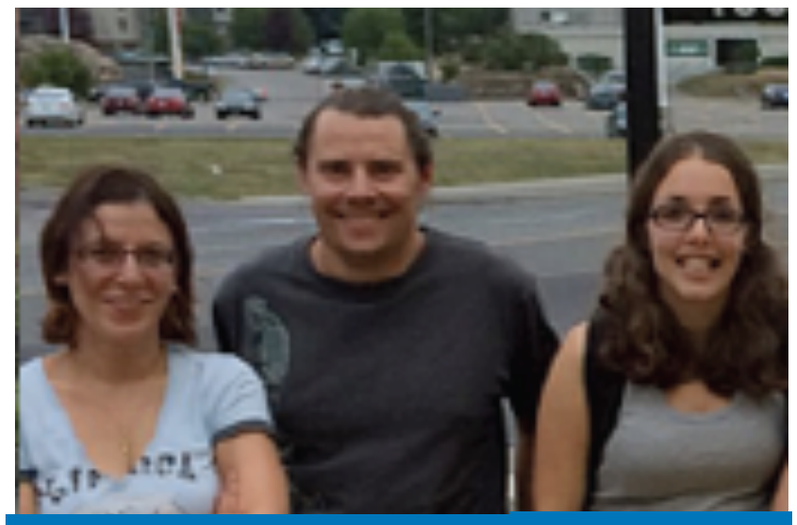


Our group @ Lip Lisboa

Jose Maneira (PI)

Sofia Andringa

Amelia Maio



Valentina Lozza

Nuno Barros

Ana Sofia Inacio (PhD)

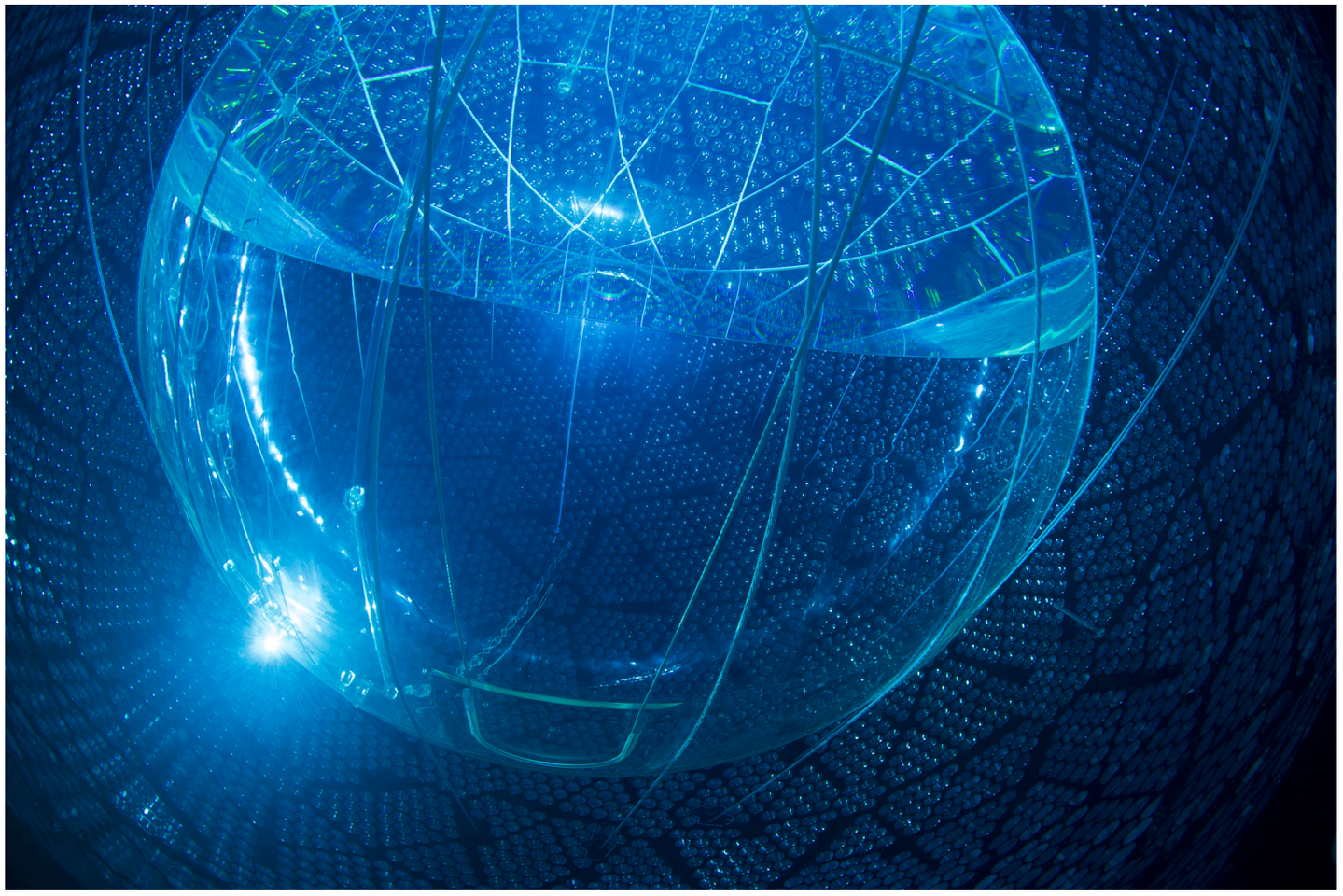
Fernando Barão

Matt Cox (PhD)

Our areas of expertise:

1. **Anti-neutrino analysis**
2. **Solar and double-beta decay analysis**
3. **Background characterisation** (cosmic muons, intrinsic radioactivity, cosmic induced activity)
4. **Detector calibration** (optical & with gamma sources)

Opportunities: Data analysis with SNO+



- **Antineutrinos in water**
  - Analysis of coincidence events in 2018-2019 water data
  - Background and signal discrimination
- **Calibration of the liquid scintillator**
  - Use gamma and optical sources to characterise the energy and position resolution of the detector
- **Background events during filling**
  - Identification of radioactive decays (backgrounds) during filling to characterise the liquid scintillator
- **Pre-Supernova identification**
  - Preparation of algorithms that can promptly identify a pre-supernova event
- **Muons in SNO+**
  - Analysis of cosmic muon events and the induced background in SNO+

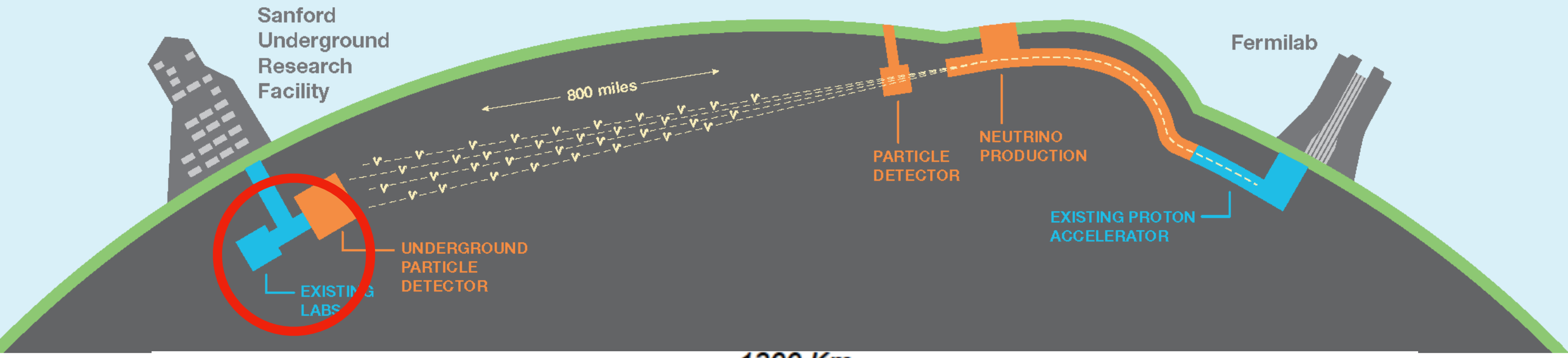
Contact us:
- Sofia Andringa (LIP)
– Fernando Barão (LIP, IST)
– Nuno Barros (LIP, FCUL)
– Valentina Lozza (LIP, FCUL)
– José Maneira (LIP, FCUL)

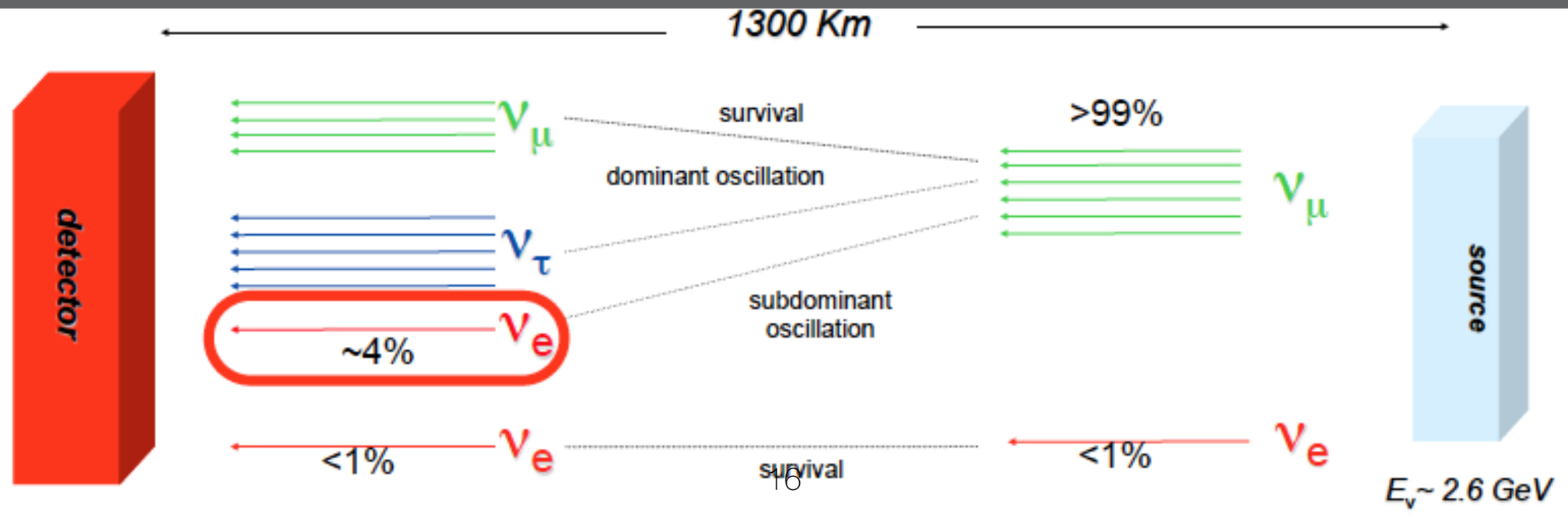
DUNE: CP violation and mass ordering

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Target = 4 x 10 kton (fid.) detectors

Beam experiment:
** Wide band, high purity νμ beam
** Peak flux at **2.5 GeV**

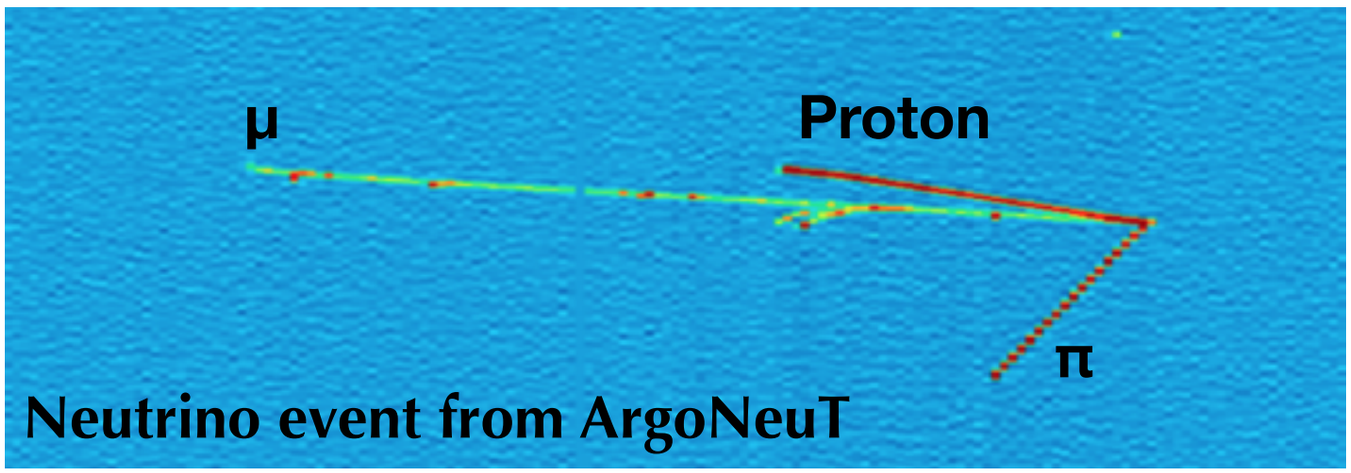


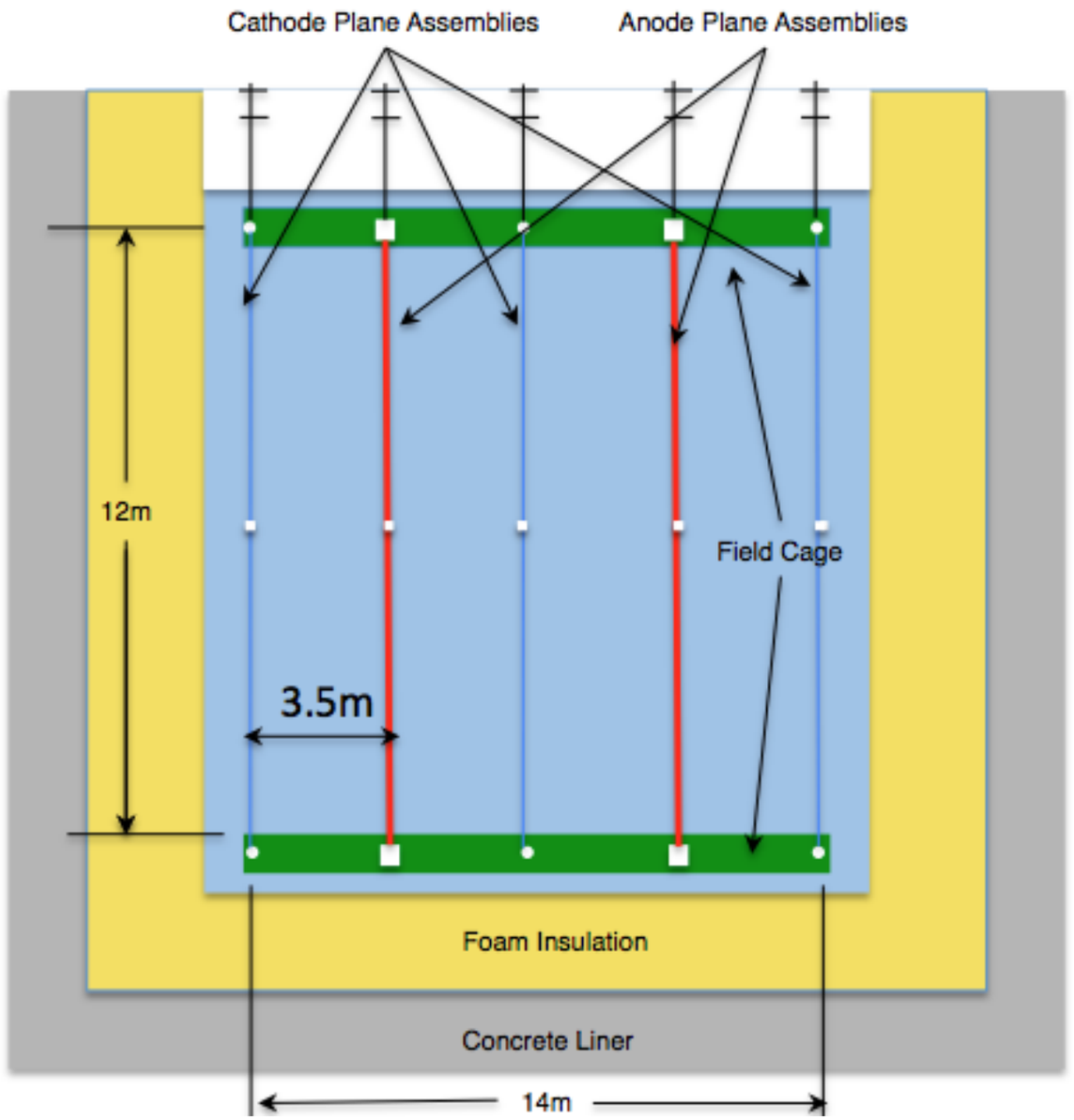


Huge detector & lots of physics!!!

** Liquid Argon Time Projection Chambers

** Full measurement of all particle tracks —> more information than in water Cherenkov detector





CP violation in lepton sector

Proton decay

Atmospheric neutrinos

SN detection

Hierarchy order

Precise osc.

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Amélia Maio

Nuno Barros

Fernando Barão

Our areas of expertise:

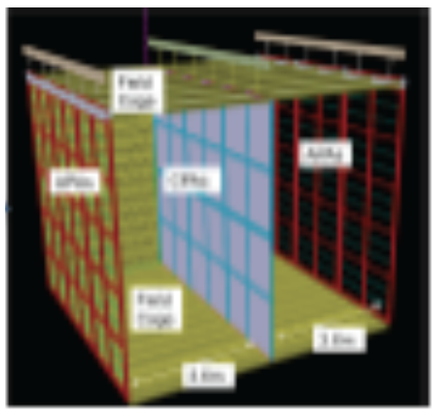
1. **Neutron analysis and calibration**
2. **Detector Calibration with Laser**
3. **Trigger & DAQ**
4. **Data analysis**

Exciting times

2017 2018 2019 2020 2021

June
ProtoDUNE -SP detector completed

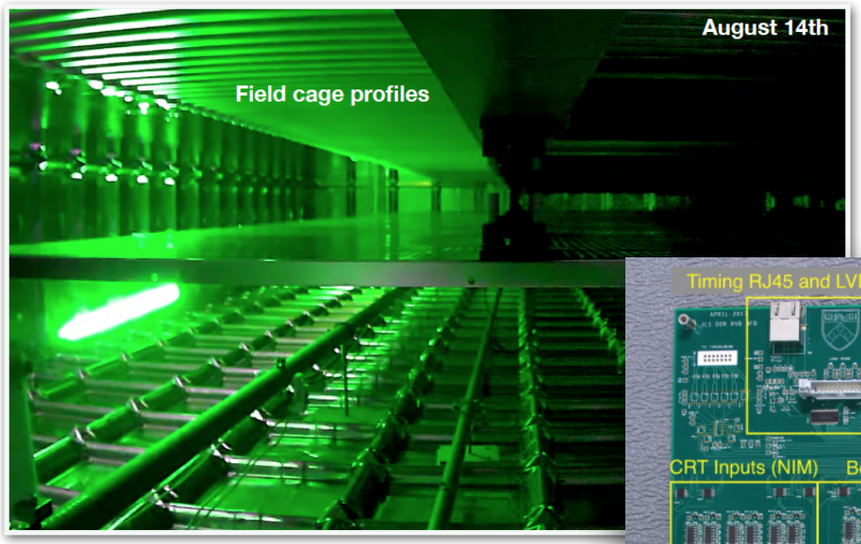
September - November
Filling the cryostat completed
TPC activated
Beam ON

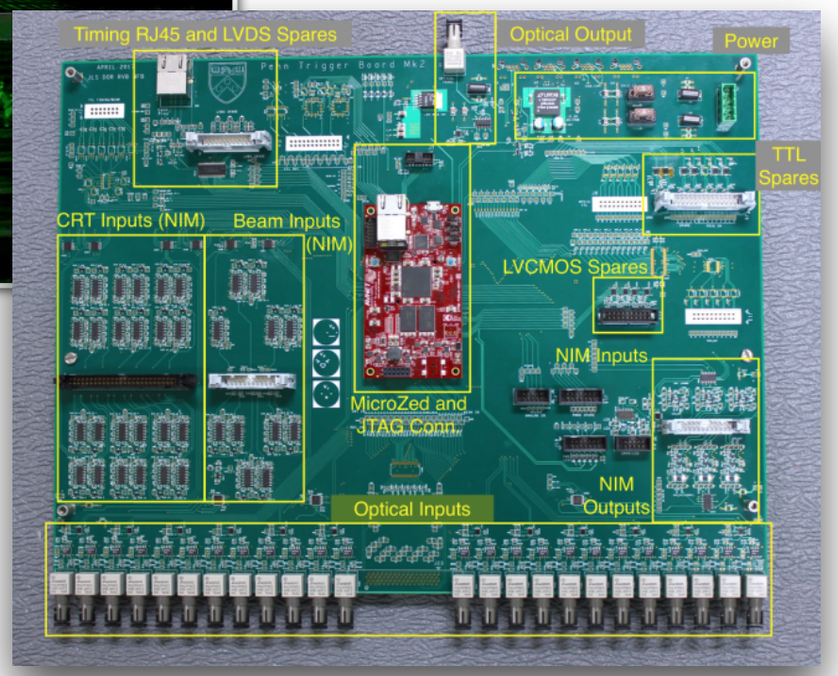


June
Building of ProtoDUNE DP

~2021-2022
Test calibration sources developed at LIP!

Opportunities: Develop the DUNE detector





- **Analysis of proto-DUNE data**
  - Data similar to the one tested with calibration sources (muons, neutrons, kaons)
- **Calibration system**
  - Develop the neutrons and optical (laser) calibration system of the single phase/double phase experiment
- **Neutron cross section**
  - Analyse the data of 'table-top' neutron experiment to understand their interaction in Liquid Argon
- **Trigger and DAQ**
  - Develop the electronics for DUNE data acquisition system
- **DUNE sensitivity**
  - Determine the sensitivity to the various physics topics

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– Francisco Neves (LIP Coimbra)
– Vladimir Solovov (LIP Coimbra)