http://moriond.in2p3.fr

Résumé des Rencontres de Moriond 2022

23-30/01 : Cosmology

30/01-06/02 : Gravitation

12-19/03 : Electroweak Interactions & Unified Theories

19-26/03 : QCD and High Energy Interactions

19-26/03 : Very High Energy Phenomena in the Universe

S. Loucatos
DPhP-Irfu et APC

16/5/22

56th **Rencontres de Moriond** session devoted to **ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES March 12-19, 2022**.

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La Thuile is a pleasant winter sport resort located in the Italian Alps, at 1450 m alt., about 120 km from Geneva. Conference founded in 1966 by Jean Tran Thanh Van.

Meribel 1974

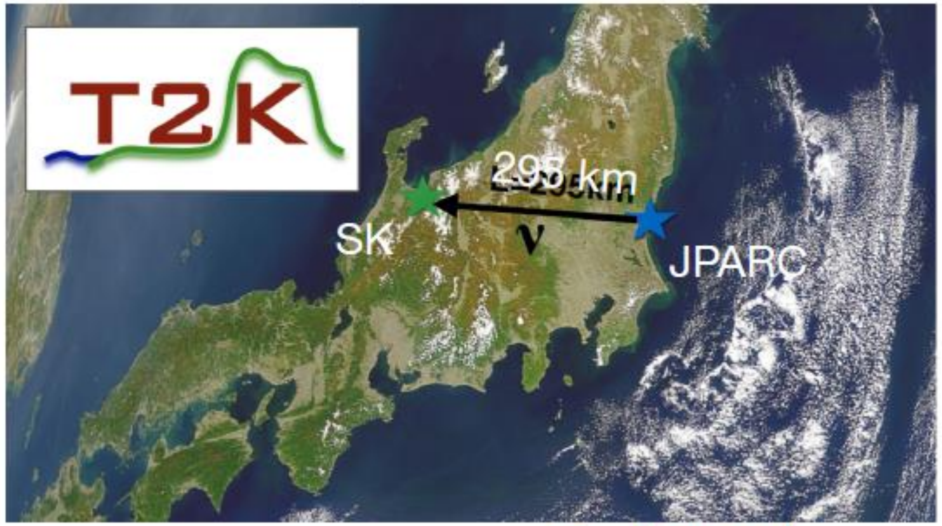
Subventionnée par l'Irfu

Organisateurs CEA:
E. Armengaud
S. Loucatos
E. Moulin
D. Denegri
L. Schoeffel
JM. Le Goff
F. Vernizzi

Neutrinos

Long-baseline Neutrino Experiments

- An intense ν beam, shot through a near detector (ND) near the beam target, to a larger massive far detector (FD)
- Measure $P(\nu_\mu \rightarrow \nu_\mu)$ and $P(\nu_\mu \rightarrow \nu_e)$, combine to extract oscillation parameters



E. ATKIN

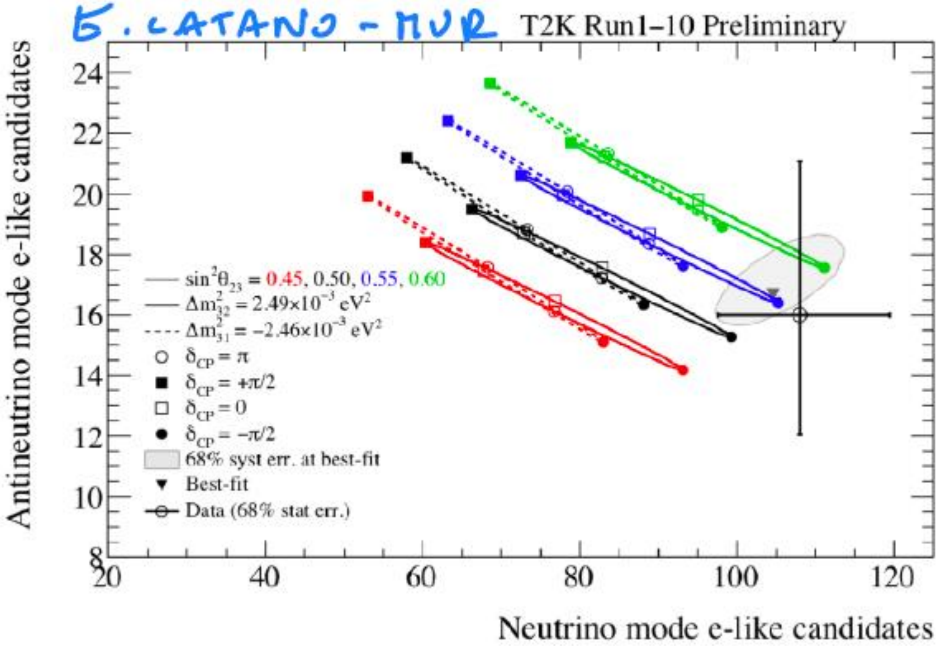
Baseline: 295 km
Peak E_ν: ~0.6 GeV (off axis)
ND: ND280, π^0 detector, 2T target, TPC, magnetic field
FD: Super-K, 50kT, Water-Cherenkov

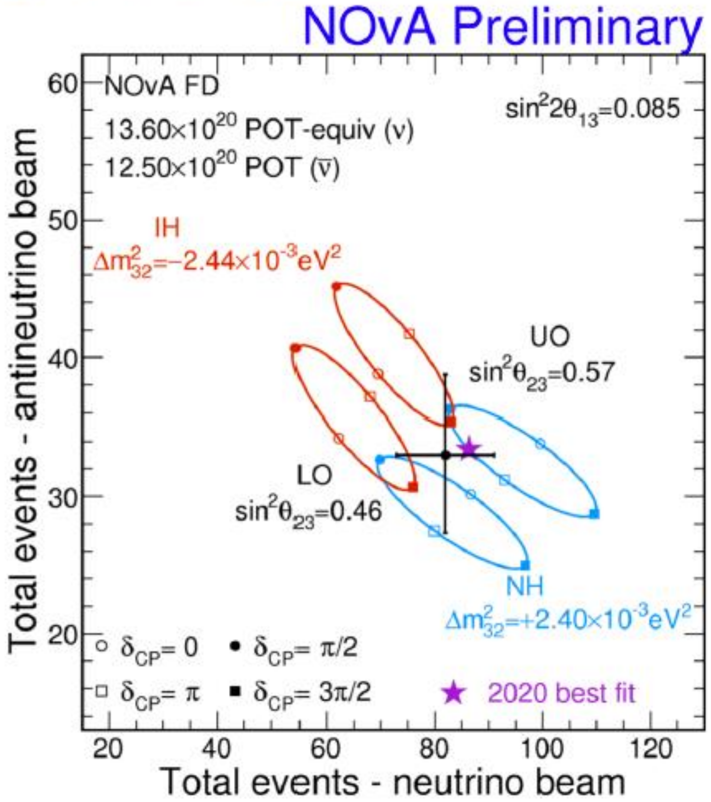
E.CATANO-MUR

Baseline: 810 km
Peak E_ν: ~2GeV (off axis)
ND: Scintillator tracker (0.3kT)
FD: Scintillator tracker (14kT)

Comparison of NOvA & T2K

E. ATKIN
S. CATANO-MUR

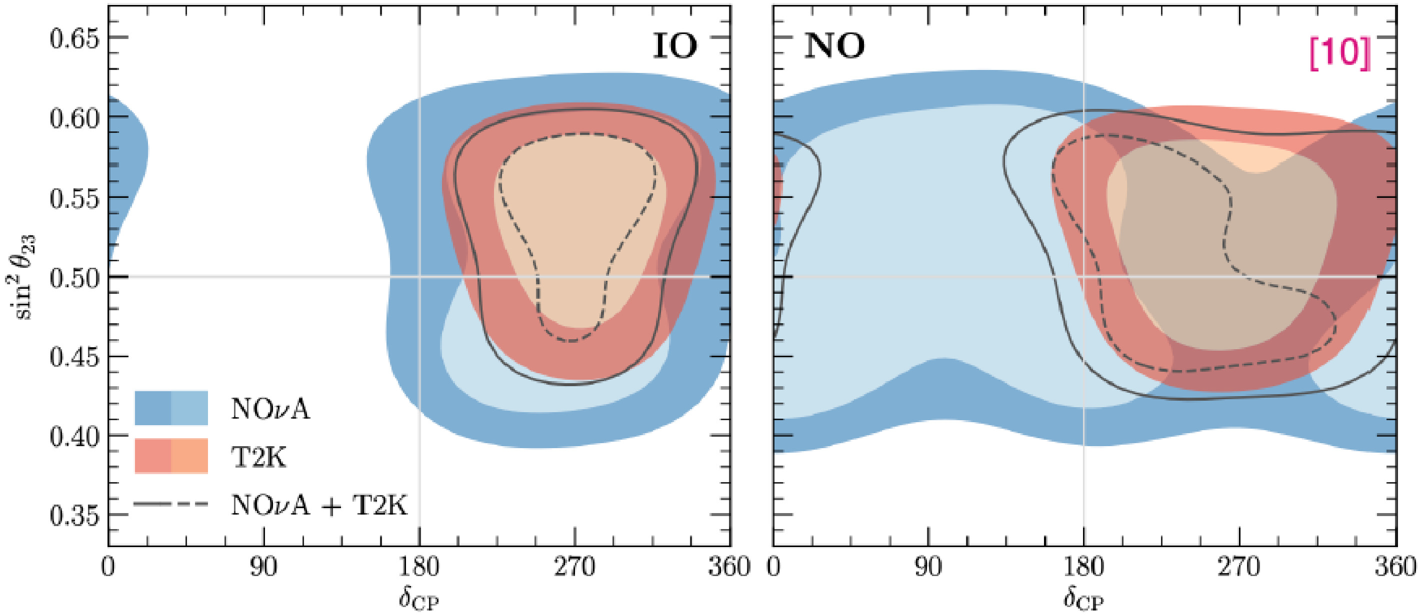




- T2K data show a clear preference for maximal CPV ($\delta_{\rm CP} \simeq -\pi/2$), irrespective of the mass ordering;
- NOvA data also favour maximal CPV for IH, but it disfavours for NH, preferring instead $\delta_{\rm CP} \simeq \pm\pi$ (CP conserving)

Comparison of NOvA & T2K II

- In Normal Ordering (NO) slight disagreement. Inverted Ordering (IO) agrees well.
- δ_{CP} tension implies that combined LBL experiments prefer IO
- Further combination with reactor data restores NO



M. MALTONI

Reminder: both experiments have different sensitivities and both experiments still statistics limited.

Absolute mass observables: (m_β, $m_{\beta\beta}$, Σ)

1) **β decay**: $m^2_i \neq 0$ can affect spectrum endpoint. Sensitive to the "effective electron neutrino mass":

$$m_\beta = \left[c_{13}^2 c_{12}^2 m_1^2 + c_{13}^2 s_{12}^2 m_2^2 + s_{13}^2 m_3^2\right]^{\frac{1}{2}}$$

2) **$0\nu\beta\beta$ decay**: Can occur if $m^2_i \neq 0$ and $\nu=\bar{\nu}$ (**Majorana**, not Dirac) Sensitive to the "effective Majorana mass" (and phases):

$$m_{\beta\beta} = \left|c_{13}^2 c_{12}^2 m_1 + c_{13}^2 s_{12}^2 m_2 e^{i\phi_2} + s_{13}^2 m_3 e^{i\phi_3}\right|$$

3) **Cosmology**: $m^2_i \neq 0$ can affect large scale structures in (standard) cosmology constrained by CMB + other data. Sensitive to:

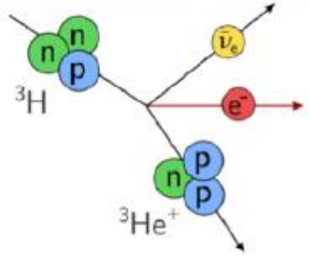
$$\Sigma = m_1 + m_2 + m_3$$

Cours d'E. Lisi à Nikhef
https://indico.nikhef.nl/event/1828/

How light is a neutrino?

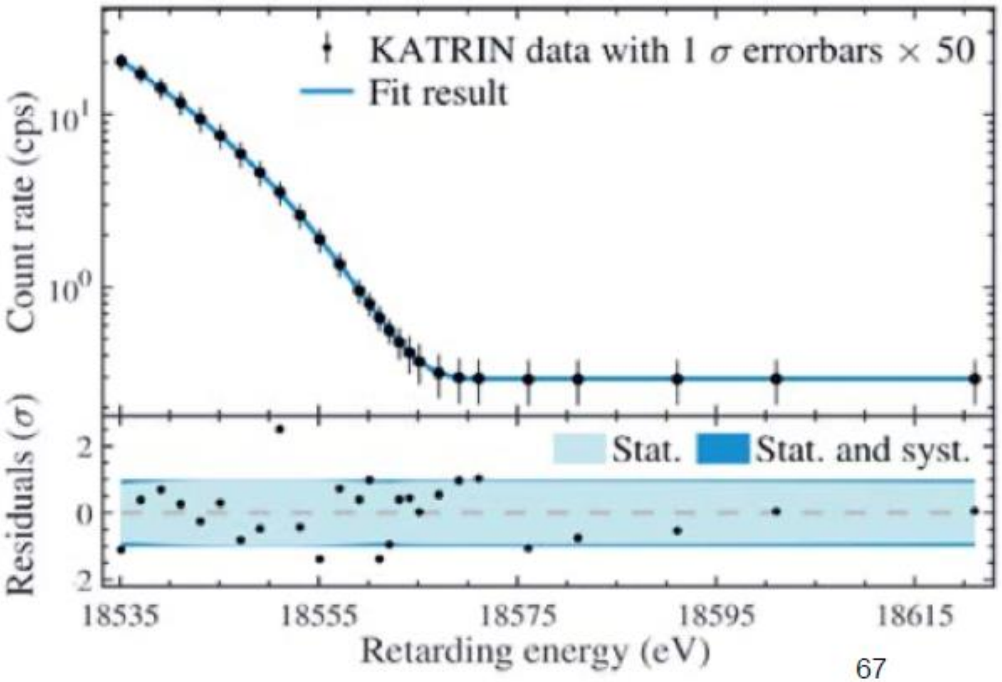
The KATRIN experiment : endpoint measurement of tritium β decay

- Kinematic measurement→most direct test of ν mass regardless of its nature



$$^3H \rightarrow ^3He^+ + e^- + \overline{\nu_e}$$

What is really measured is $m_\nu^2 = \sum_i |U_{ei}|^2 m_i^2$



First push into the range below 1 eV!

$$m_\nu < 0.8\,\mathrm{eV}\ \ (90\,\%\,\mathrm{CL})$$

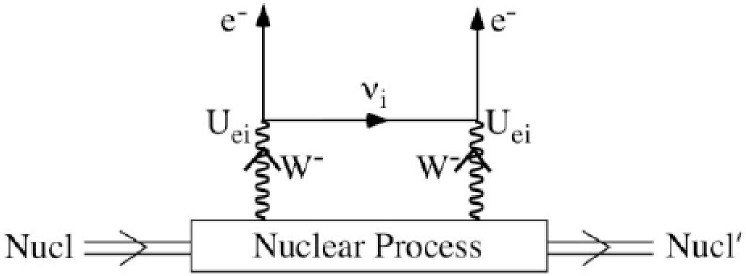
[Nature Physics 18, 160 (2022)]

Target sensitivity of 0.2 eV (90% CL)

Are neutrinos their own antiparticles?

- The experimental test is the observation of neutrinoless double beta decay $(0\nu\beta\beta)$

- $(Z, A) \rightarrow (Z+2, A) + 2e^-$



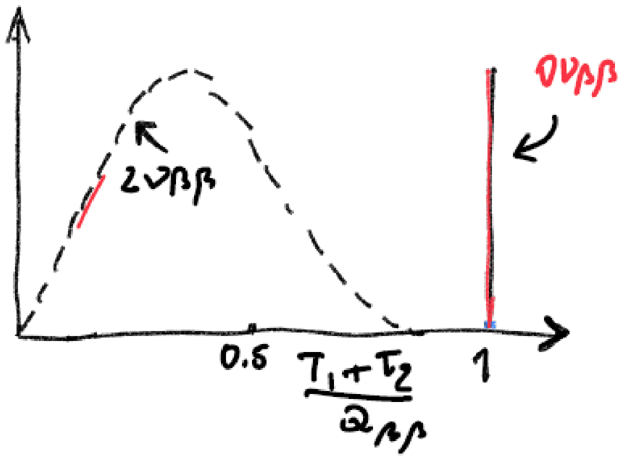
- $\Delta L = 2$, forbidden in SM

- Rate $(0\nu\beta\beta)$ << Rate $(2\nu\beta\beta)$

$(0\nu\beta\beta$ can only occur in isotopes that undergo $2\nu\beta\beta)$

Effective Majorana neutrino mass:

$$m_{\beta\beta} \equiv \left| \sum_i m_i U_{ei}^2 \right|$$



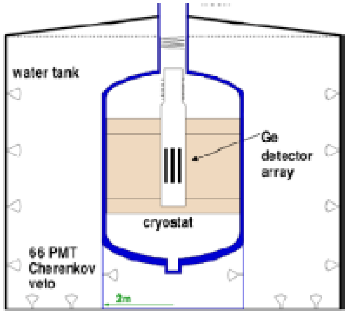
L. PERTOLDI

Neutrinoless Double Beta Decay

- A worldwide search for $0\nu\beta\beta$ is ongoing in several isotopes

GERmanium Detector Array @ LNGS, IT

L. PERTOLDI



- High-purity Ge detectors in LAr

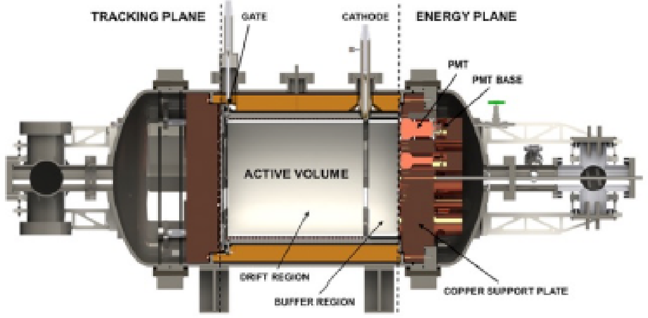
- No signal after 127.2 kg yr of total exposure between 2011-2019

Final result and best limit: $T_{1/2} > 1.8 \times 10^{26}\,\mathrm{yr}\ 90\,\%\,\mathrm{CL}$
PRL 125,252502 $m_{\beta\beta} < 79 - 180\,\mathrm{meV}$

Next step LEGEND

J.A. HERNANDO

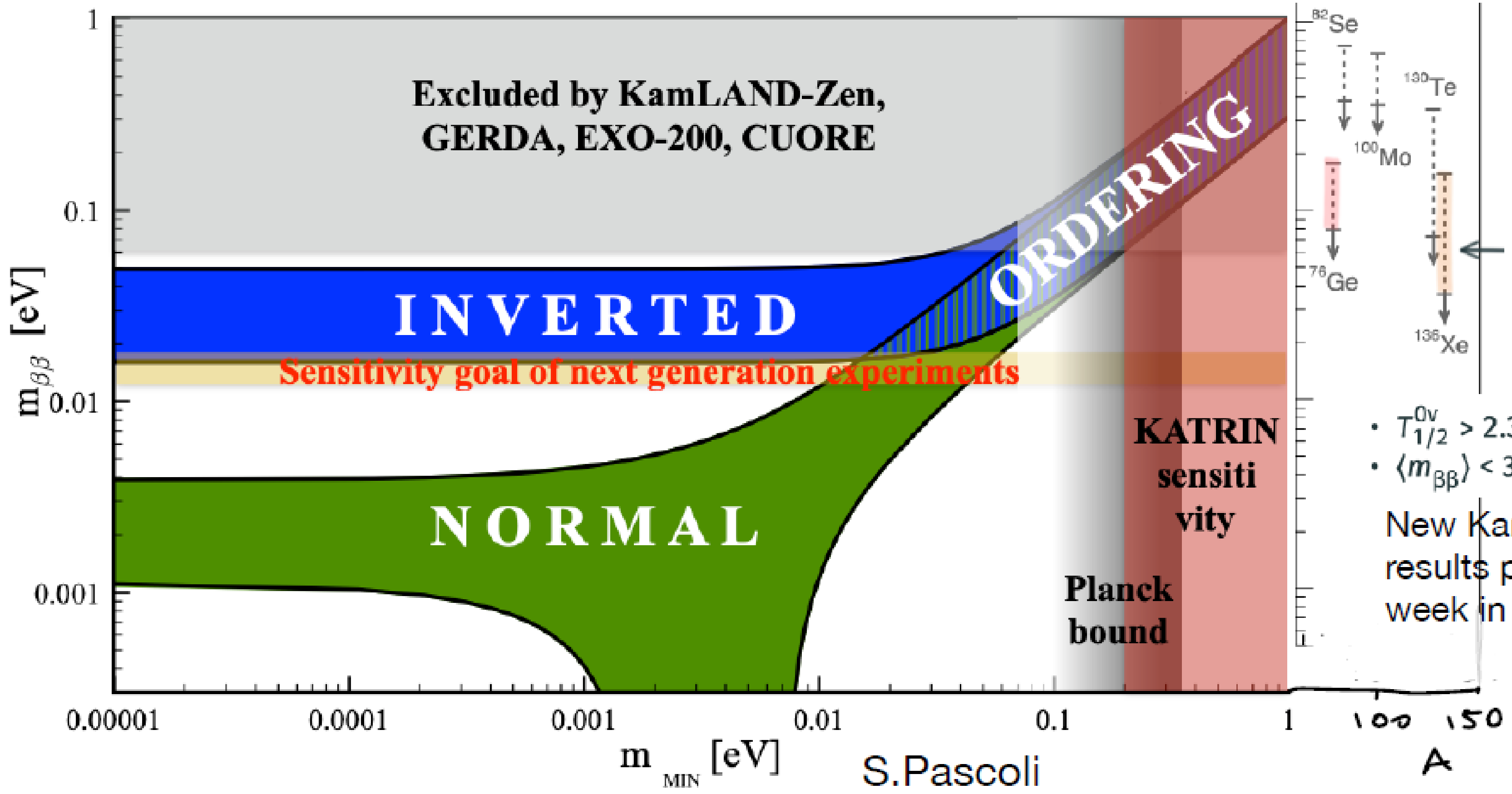
next Neutrino Experiment with a Xenon TPC @Laboratorio Subterráneo de Canfranc, SP



- Measured $2\nu\beta\beta$ half-life of ^{136}Xe with a fiducial mass of only 3.5 Kg
- Proof of principle for future $0\nu\beta\beta$ (NEXT-100 under construction)

Neutrino mass: complementarity of approaches

$m_{\beta\beta}$ as a function of the lightest neutrino mass



L.PERTOLDI

- $T_{1/2}^{0\nu} > 2.3 \cdot 10^{26}$ yr (90% C.L.)
- $\langle m_{\beta\beta} \rangle$ < 36–156 meV

New KamLAND-ZEN800 results presented last week in La Thuile

NEW

CUPID arXiv:2202.08716

^{100}Mo $0\nu\beta\beta$ decay half-life of $T_{1/2}^{0\nu} > 1.8 \times 10^{24}$ year

$\langle m_{\beta\beta} \rangle < (0.28–0.49)$ eV

The search for the sterile neutrino

- They do not couple directly with gauge bosons, can only participate in weak interactions through mixing with active neutrinos

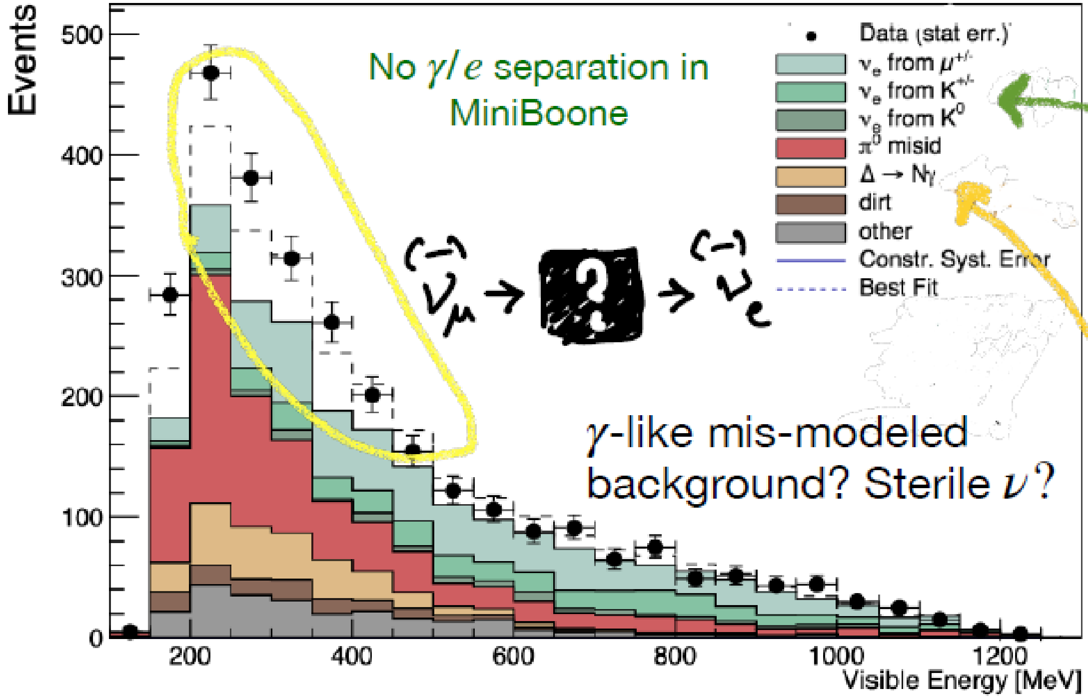
- Search motivated by a series of anomalies in SBL experiments with neutrinos from accelerator (LSND, MiniBooNE), nuclear reactors (reactor antineutrino anomaly) and radioactive sources (gallium anomaly, GA). These anomalies cannot be accounted for by the standard three-neutrino framework

- All above results can be understood via SBL ν oscillations driven by $\Delta m^2 \sim 1\mathrm{eV}^2$, substantially higher than solar $(\Delta m_{12}^2 \approx 7.5 \times 10^{-5}\mathrm{eV}^2)$ and atmospheric $(|\Delta m_{23}^2| \approx 2.5 \times 10^{-3}\mathrm{eV}^2)$

The MicroBooNE Experiment

- Same beam, baseline, L/E as MiniBoone, but LAr TPC (85 T), much improved detector (eg, O(mm) spatial resolution, γ/e discrimination)
- First results covering ~1/2 of data set

MiniBoone electron-like low energy excess ($\sim 4.5\sigma$)



Three independent, e-like analyses to test whether excess is due to enhancement of ν_e interactions

A photon-like search for NC $\Delta \to N\gamma$

- Results consistent with nominal ν_e rate expectations
- No excess of ν_e events observed
- No excess NC $\Delta \to N\gamma$

Minireview on sterile neutrinos (Conclusions)

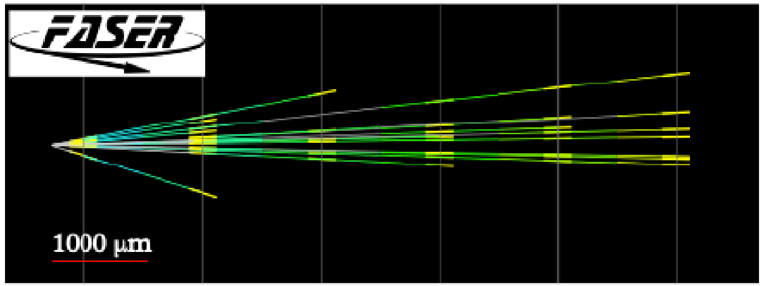
M. DANILOV

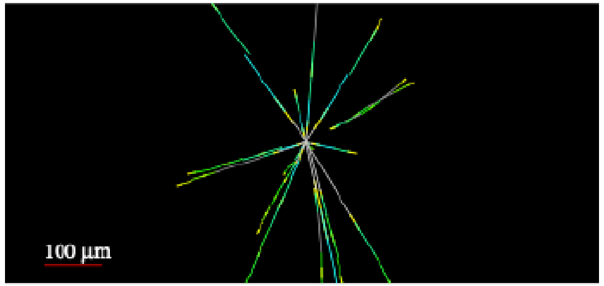
- More than 10 experiments are searching for sterile neutrinos N. SKROBOVA (DANSS) R. ROGLY (STEREO)
- MicroBooNE has not confirmed electron-like low energy excess but has not excluded it completely (yet)
- BEST confirmed the GA with high (>5σ) significance but almost all allowed region is already excluded by other experiments. DANSS, Neutrino-4, PROSPECT and KATRIN will scrutinize the remaining part. (All allowed region really excluded?) P. COLOMA
- The absolute reactor flux anomaly is almost all explained by a smaller ^{235}U cross section but our understanding of nuclear reactor fluxes is still incomplete (note however that modern experiments searching for ν_s do not use an absolute flux) C. TERNES
- There is no significant indication of ν_s in reactor experiments except for Neutrino-4
- The Upgraded DANSS, Neutrino-4, and PROSPECT experiments will give an answer in ~3 years

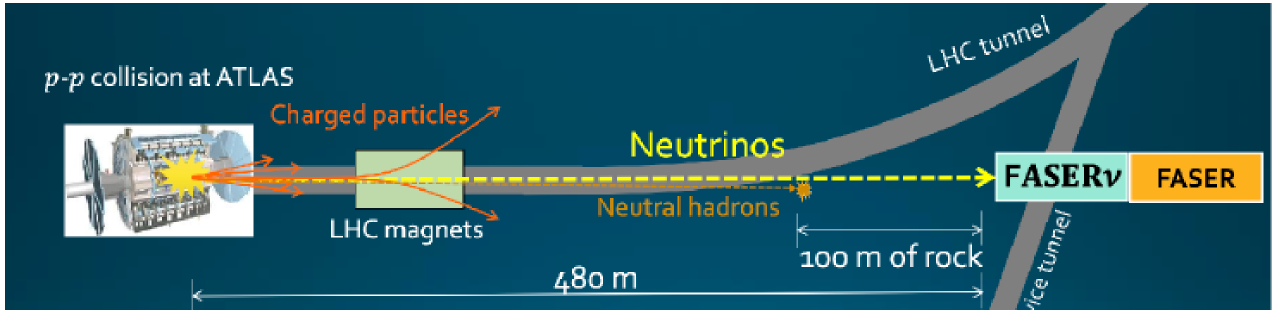
First observed neutrinos in FASER-ν

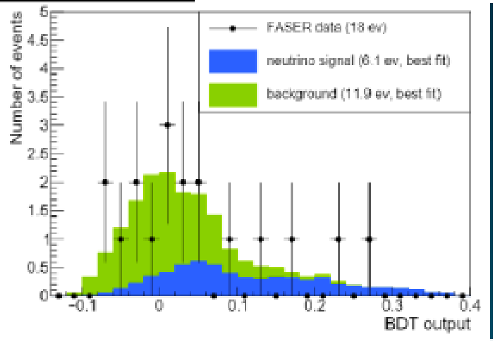
- These are the first ever directly observed neutrinos @ the LHC!! A. ARIGA

Neutrino interaction candidates from pilot run with small emulsion detector

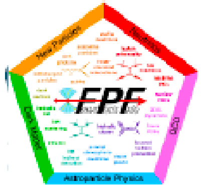








- Experiment designed to profit from the large neutrino flux in the forward direction@LHC and study neutrino cross sections at TeV energies, where no such measurements exist
- Also proposing Forward Physics Facility (FPF) at the HL-LHC



- SND@LHC is another approved experiment that will complement FASER-ν covering a different pseudoηrapidity range

Matière noire

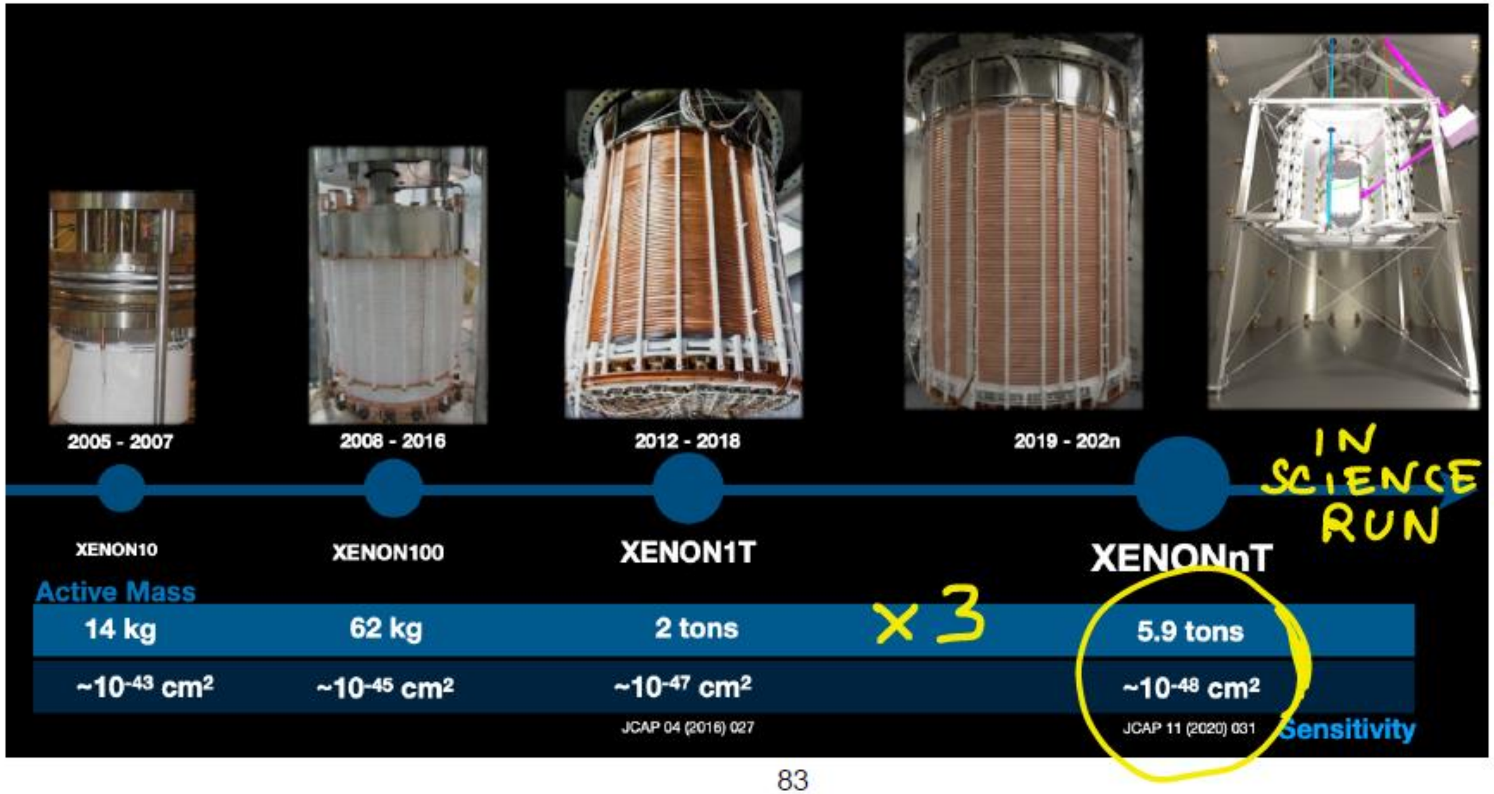
Several Possibilities

- Observations favour cold DM (non-relativistic at decoupling), non-baryonic
- Particle physics candidates, motivated by SM problems:
  - Weakly Interacting Massive Particle (WIMPs) such as neutralinos in SUSY models
  - Axions (QCD axion and Axion-Like Particles, ALPs)
  - Sterile ~keV neutrinos ("warm DM") (light neutrinos would be hot DM, i.e., highly relativistic at decoupling, disfavoured by observation as the only DM constituent)
- Alternatives to Particle DM (Primordial Black Holes, MACHOs, modifications of gravity,…)

XENON Dark Matter Project

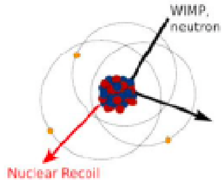
- Liquid Xe target operated as a dual-phase (liquid/gas) TPC @LNGS
- Detect both prompt scintillation (S1) and delayed ionization (S2) light → Energy deposited and 3D event reconstruction; S2/S1 → discriminate electron recoils from nuclear recoils

E. ANGELINO

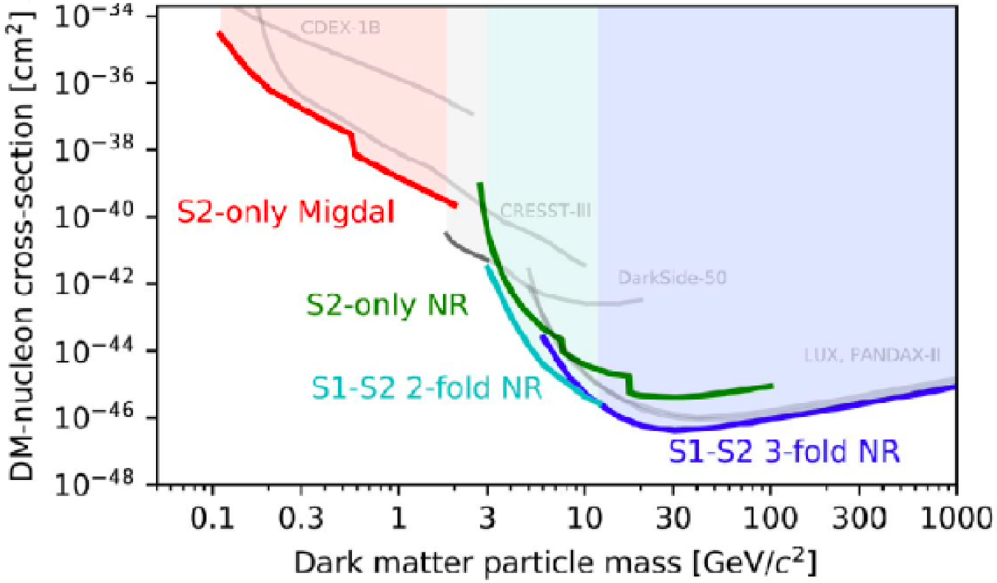


XENON1T: main results

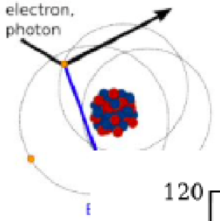
E. ANGELINO



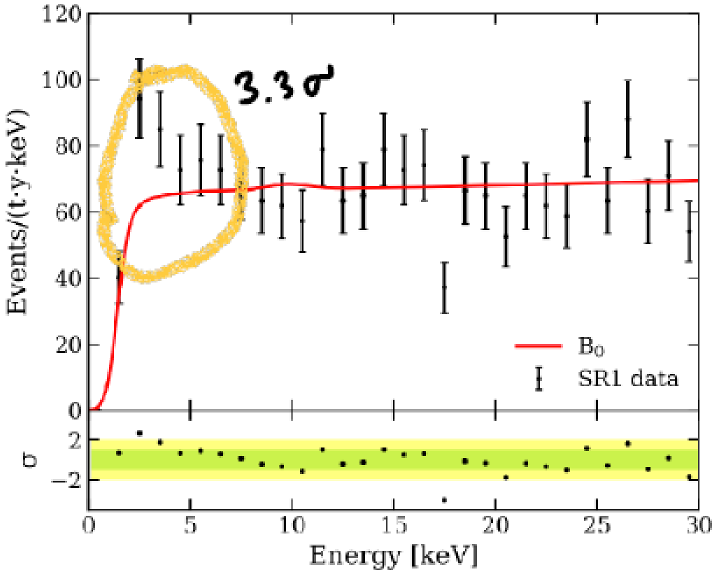
Nuclear Recoil searches



Best limit spin-indep. WIMP nucleon cross-section (mass> 6 GeV)



Low-energy Electron Recoil events



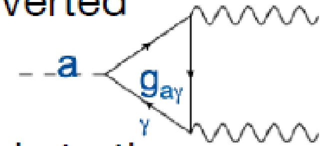
Observed low-energy excess between 1-7 KeV (stat. fluctuation or unexplained background, e.g., β-decay of Tritium or a cocktail?)

- Science run of XENONnT is ongoing - a few months should clarify the nature of electron recoil excess

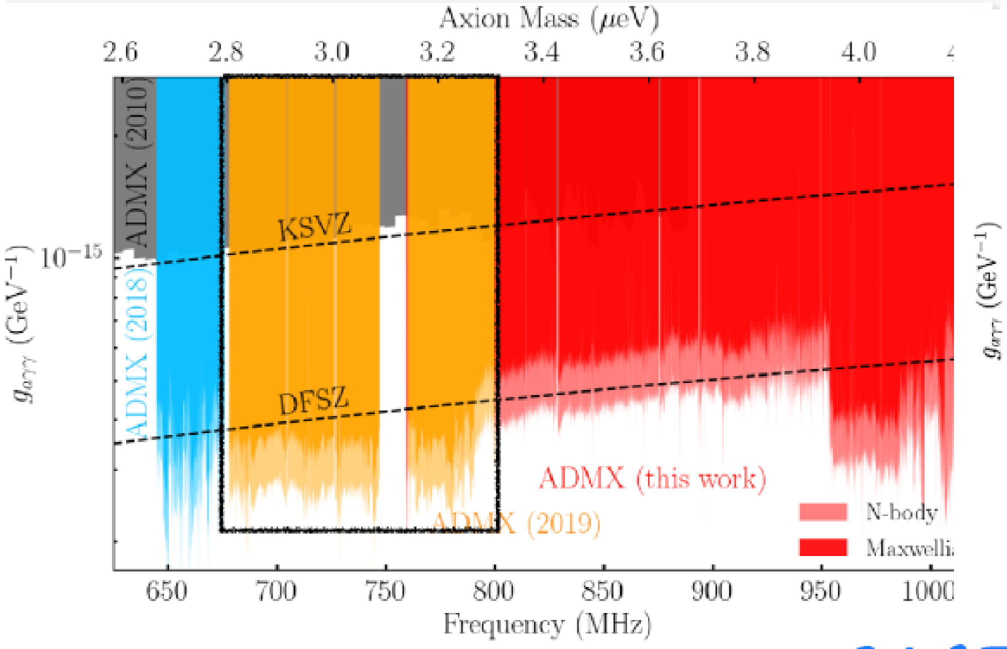
An excess is observed at low energies that is consistent with a solar axion signal, a bosonic dark matter signal with a mass of 2.3 keV/c^2, a solar neutrino signal with enhanced magnetic moment, or a possible tritium background. We are unable to confirm nor exclude the presence of tritium at this time.

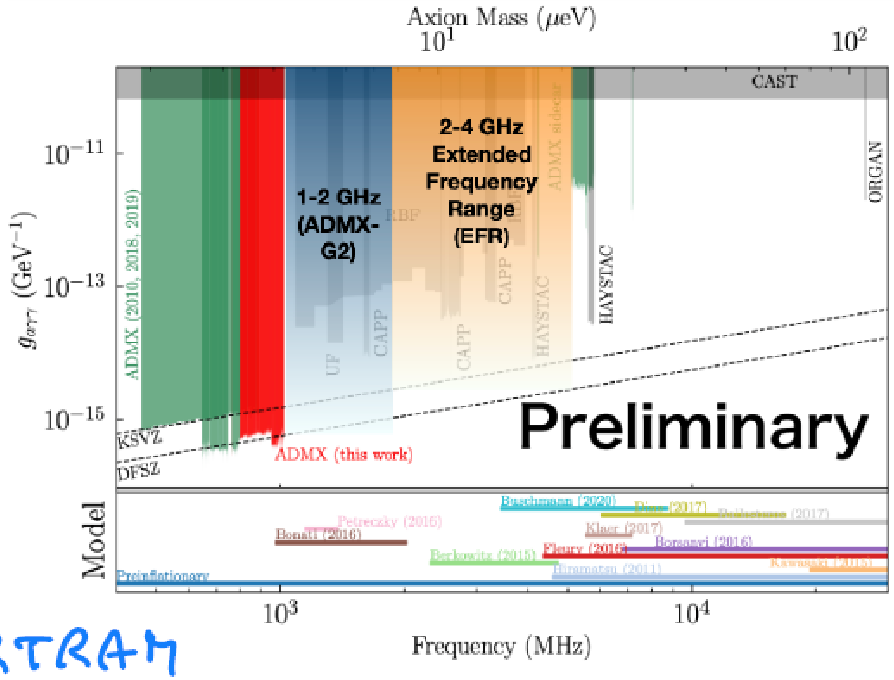
The Axion Dark Matter eXperiment

- ADMX is based on a resonant cavity approach, where axions are converted into photons via a 7T magnetic field inside a radio-frequency cavity.



- The conversion rate is enhanced if the photon's frequency corresponds to the cavity's resonance frequency. The detection requires a very cold experiment and an ultra-low noise receiver chain.





C. BARTRAM

arXiv:2110.06096

"Discovery could happen at any moment; parameter space is wide and axion dark matter is very much a possibility"

of interest, we set 90% confidence level (C.L.) upper limits on the axion-photon couplings across the explored mass ranges with the assumption that axions make up 100% of the local dark matter density as shown in

Quelques exposés théoriques:

- Decoherence effects in reactors in nu oscillation; Valentina De Romeri
- Global fit steriles; Pilar Coloma: bad fit
- Unstable nus relax cosmo mass bounds; Stefan Sandner:

  Generic Neutrino Decay with tau<age of the universe via light bosons can relax the bound to up to 1eV