Neutrinoless double beta decay search using $^{136}$Xe: The NEXT experiment.

Héctor Gómez Maluenda

gomez@lal.in2p3.fr
OUTLINE

✓ Neutrino and double beta decay.

✓ The Experiment.
  ✓ Why HP Xe TPC?
  ✓ The SOFT concept.

✓ Present Status.
  ✓ Prototypes.
    ✓ NEXT-$\mu$M.
    ✓ NEXT-100.

✓ Outlook.

✓ Summary.
Neutrino oscillation experiments have shown that neutrino is a non-zero mass particle, implying the existence of Physics beyond the Standard Model of Particles.
Neutrino oscillation experiments have shown that neutrino is a non-zero mass particle, implying the existence of Physics beyond the Standard Model of Particles.

It is also known that neutrino mass could have two different mass hierarchies: normal and inverse.

Normal hierarchy: $m_1 \sim m_2 << m_3 \rightarrow (\Delta m_{23}^2) > 0$

Inverted hierarchy: $m_1 \sim m_2 >> m_3 \rightarrow (\Delta m_{23}^2) < 0$
Neutrino oscillation experiments have shown that neutrino is a non-zero mass particle, implying the existence of Physics beyond the Standard Model of Particles.

It is also known that neutrino mass could have two different mass hierarchies: normal and inverse.

Unfortunately, neutrino oscillation experiments can only measure $(\Delta m_{ij})^2$.

**HOW TO MEASURE THE ABSOLUTE MASS VALUE OF THE NEUTRINO?**

- End point study of the $^3$H decay energy spectrum *(KATRIN)*
- Upper limits from Astrophysical Observations *(SN 1987-A)*
- Neutrinoless Double Beta Decay Detection *(0$\nu$ββ)*
**NEUTRINO AND DOUBLE BETA DECAY**

- Double beta decay processes:

  \[ 2\nu^-\beta^-:(A,Z)\rightarrow(A,Z+2)+2e^-+2\bar{\nu}_e; \quad (\Delta L = 0) \]
  \[ 0\nu^-\beta^-:(A,Z)\rightarrow(A,Z+2)+2e^-; \quad (\Delta L = 2) \]

- \(0\nu\beta\beta\) process detection:

  \[
  T_{1/2}^{0\nu}(0^+ \rightarrow 0^+)^{-1} = G_{0\nu} \left| M_{GT}^{0\nu} - \frac{g_V^2}{g_A^2} M_{F}^{0\nu} \right|^2 \left\langle m_\nu \right\rangle^2 \frac{m_e^2}{m_\nu^2} \\
  \left\langle m_\nu \right\rangle = m_e \left(F_N T_{1/2}^{0\nu}\right)^{-1/2}
  \]

  \[
  \left\langle m_\nu \right\rangle = \sum_j U_{ej}^2 m_j
  \]
Study of the $0\nu\beta\beta$ decay for almost 20 years. Some experiments already finished:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Isotope</th>
<th>Technique</th>
<th>Laboratory</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGEX</td>
<td>$^{76}$Ge</td>
<td>Ge Diodes</td>
<td>Canfranc</td>
<td>$T_{1/2}^{0\nu} (y) \geq 1.57 \times 10^{25}$, $&lt;m_\nu&gt; (eV) \leq 0.33-1.35$</td>
</tr>
<tr>
<td>HEIDELBERG-MOSCOW</td>
<td>$^{76}$Ge</td>
<td>Ge Diodes</td>
<td>Gran Sasso</td>
<td>$T_{1/2}^{0\nu} (y) \geq 1.55 \times 10^{25}$, $&lt;m_\nu&gt; (eV) \leq 0.35$</td>
</tr>
<tr>
<td>HEIDELBERG-MOSCOW*</td>
<td>$^{76}$Ge</td>
<td>Ge Diodes</td>
<td>Gran Sasso</td>
<td>$T_{1/2}^{0\nu} (y) = 1.20 \times 10^{25}$, $&lt;m_\nu&gt; (eV) = 0.44$</td>
</tr>
<tr>
<td>MIBETA</td>
<td>$^{128}$Te</td>
<td>Bolometers</td>
<td>Gran Sasso</td>
<td>$T_{1/2}^{0\nu} (y) \geq 8.60 \times 10^{22}$, $&lt;m_\nu&gt; (eV) \leq 1-2$</td>
</tr>
<tr>
<td></td>
<td>$^{130}$Te</td>
<td>Bolometers</td>
<td>Gran Sasso</td>
<td>$T_{1/2}^{0\nu} (y) \geq 1.44 \times 10^{23}$, $&lt;m_\nu&gt; (eV) \leq 1-2$</td>
</tr>
<tr>
<td>CUORICINO</td>
<td>$^{130}$Te</td>
<td>Bolometers</td>
<td>Gran Sasso</td>
<td>$T_{1/2}^{0\nu} (y) \geq 3.00 \times 10^{24}$, $&lt;m_\nu&gt; (eV) \leq 0.19-0.68$</td>
</tr>
<tr>
<td>NEMO 3</td>
<td>$^{100}$Mo $^{82}$Se</td>
<td>Track + Calorimetry</td>
<td>Modane</td>
<td>$T_{1/2}^{0\nu} (y) \geq 1.00 \times 10^{24}$, $&lt;m_\nu&gt; (eV) \leq 0.31-0.96$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$T_{1/2}^{0\nu} (y) \geq 3.2 \times 10^{23}$, $&lt;m_\nu&gt; (eV) \leq 0.94-2.60$</td>
</tr>
</tbody>
</table>

Where are we going now? *New generation* experiments.

- Trying to reach sensitivities to explore $<m_\nu> \sim 50 \text{ meV}$.
- Some requirements are mandatory:
  - Big amount of $\beta\beta$ emitter mass.
  - Radiopure materials.
  - Placement underground.
  - Background events discrimination.
  - ...
- Klapdor's claim could be checked.
NEUTRINO AND DOUBLE BETA DECAY

✓ If no signal is found:

\[ \langle m_v \rangle = m_e (F_N T^{0v}_{1/2})^{-1/2} \]

\[ \langle m_v \rangle < m_e (F_N F_D)^{-1/2} \]

- Isotopic abundance ↑↑
- Atomic weight ↓↓
- Detection efficiency ↑↑
- Exposure ↑↑
- Background level ↓↓
- Energy resolution ↓↓

Several techniques, isotopes and detectors proposed trying to optimize \( F_D \).
Some new generation $0\nu\beta\beta$ experiments:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Isotope</th>
<th>Technique</th>
<th>Main Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANDLES</td>
<td>$^{48}\text{Ca}$</td>
<td>CaF$_2$ Scintillation</td>
<td>Background, Efficiency</td>
</tr>
<tr>
<td>CARVEL</td>
<td>$^{48}\text{Ca}$</td>
<td>CaWO$_4$ Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>COBRA</td>
<td>$^{130}\text{Te},^{116}\text{Cd}$</td>
<td>ZnCdTe Semiconductors</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>CUORE</td>
<td>$^{130}\text{Te}$</td>
<td>Bolometers</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>CUORICICINO</td>
<td>$^{130}\text{Te}$</td>
<td>Bolometers</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>DCBA</td>
<td>$^{150}\text{Nd}$</td>
<td>Gaseous TPC</td>
<td>Bkg Rejection, Efficiency</td>
</tr>
<tr>
<td>EXO</td>
<td>$^{136}\text{Xe}$</td>
<td>TPC Ionization + Scintillation</td>
<td>Mass, Efficiency, Final State Signal</td>
</tr>
<tr>
<td>GERDA</td>
<td>$^{76}\text{Ge}$</td>
<td>Ge Diodes</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>MAJORANA</td>
<td>$^{76}\text{Ge}$</td>
<td>Ge Diodes</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>MOON</td>
<td>$^{100}\text{Mo}$</td>
<td>Tracking + Calorimetry</td>
<td>Compactness, Bkg Rejection</td>
</tr>
<tr>
<td>NEXT</td>
<td>$^{136}\text{Xe}$</td>
<td>Tracking + Calorimetry</td>
<td>Bkg Rejection, Efficiency</td>
</tr>
<tr>
<td>SNO++</td>
<td>$^{150}\text{Nd}$</td>
<td>Nd Liquid Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>SUPERNEMO</td>
<td>$^{82}\text{Se},^{150}\text{Nd}$</td>
<td>Tracking + Calorimetry</td>
<td>Bkg Rejection, Isotope Selection</td>
</tr>
<tr>
<td>XMASS</td>
<td>$^{136}\text{Xe}$</td>
<td>Liquid Xe</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>YANGYANG</td>
<td>$^{124}\text{Sn}$</td>
<td>Sn Liquid Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
</tbody>
</table>
### NEUTRINO AND DOUBLE BETA DECAY

- Some new generation $0\nu\beta\beta$ experiments:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Isotope</th>
<th>Technique</th>
<th>Main Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>CANDLES</td>
<td>$^{48}\text{Ca}$</td>
<td>$\text{CaF}_2$ Scintillation</td>
<td>Background, Efficiency</td>
</tr>
<tr>
<td>CARVEL</td>
<td>$^{48}\text{Ca}$</td>
<td>$\text{CaWO}_4$ Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>COBRA</td>
<td>$^{130}\text{Te}, ^{116}\text{Cd}$</td>
<td>$\text{ZnCdTe Semiconductors}$</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>CUORE</td>
<td>$^{130}\text{Te}$</td>
<td>Bolometers</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>CUORICINO</td>
<td>$^{130}\text{Te}$</td>
<td>Bolometers</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>DCBA</td>
<td>$^{150}\text{Nd}$</td>
<td>Gaseous TPC</td>
<td>Bkg Rejection, Efficiency</td>
</tr>
<tr>
<td>EXO</td>
<td>$^{136}\text{Xe}$</td>
<td>TPC Ionization + Scintillation</td>
<td>Mass, Efficiency, Final State Signal</td>
</tr>
<tr>
<td>GERDA</td>
<td>$^{76}\text{Ge}$</td>
<td>Ge Diodes</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>MAJORANA</td>
<td>$^{76}\text{Ge}$</td>
<td>Ge Diodes</td>
<td>Resolution, Efficiency</td>
</tr>
<tr>
<td>MOON</td>
<td>$^{100}\text{Mo}$</td>
<td>Tracking + Calorimetry</td>
<td>Compactness, Bkg Rejection</td>
</tr>
<tr>
<td>NEXT</td>
<td>$^{136}\text{Xe}$</td>
<td>Tracking + Calorimetry</td>
<td>Bkg Rejection, Efficiency</td>
</tr>
<tr>
<td>SNO++</td>
<td>$^{150}\text{Nd}$</td>
<td>Nd Liquid Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>SUPERNEMO</td>
<td>$^{82}\text{Se}, ^{150}\text{Nd}$</td>
<td>Tracking + Calorimetry</td>
<td>Bkg Rejection, Isotope Selection</td>
</tr>
<tr>
<td>XMASS</td>
<td>$^{136}\text{Xe}$</td>
<td>Liquid Xe</td>
<td>Mass, Efficiency</td>
</tr>
<tr>
<td>YANGYANG</td>
<td>$^{124}\text{Sn}$</td>
<td>Sn Liquid Scintillation</td>
<td>Mass, Efficiency</td>
</tr>
</tbody>
</table>
The NEXT (Neutrino Experiment with a Xenon TPC) experiment expects to measure the $0\nu\beta\beta$ decay of $^{136}\text{Xe}$ using a high pressure Xenon TPC.
THE EXPERIMENT

✓ The NEXT (Neutrino Experiment with a Xenon TPC) experiment expects to measure the 0νββ decay of ¹³⁶Xe using a high pressure Xenon TPC.

WHY A HP XENON TPC?

✓ Let’s try to find the answer in these equations:

\[ \langle m_\nu \rangle < m_e (F_N F_D)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{b\Gamma}} \]
THE EXPERIMENT

\[ \langle m_v \rangle < m_e (F_N F_D)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \sqrt{\frac{MT}{b \Gamma}} \]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
THE EXPERIMENT

\[ \langle m_\nu \rangle < m_e (F_N F_D)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \sqrt{\frac{MT}{b \Gamma}} \]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
- \(^{136}\text{Xe}\) has higher \(W_{at}\) compared with other isotopes considered.
THE EXPERIMENT

\[ \langle m_v \rangle < m_e \left( F_N F_D \right)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \epsilon \sqrt{\frac{MT}{b\Gamma}} \]

✓ Xe is not difficult to enrich.
✓ Ability of purification and reuse of the enriched Xe.
✓ \(^{136}\text{Xe}\) has higher \(W_{at}\) compared with other isotopes considered.
✓ Source = detector experiment.
THE EXPERIMENT

\[
\langle m_\nu \rangle < m_e \left( F_N F_D \right)^{-1/2}
\]

\[
F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{b\Gamma}}
\]

✓ Xe is not difficult to enrich.
✓ Ability of purification and reuse of the enriched Xe.
✓ \(^{136}\)Xe has higher \(W_{at}\) compared with other isotopes considered.
✓ Source = detector experiment.
✓ High pressure \(\rightarrow\) Bigger amount of emitter.
✓ Scalable to higher masses.
THE EXPERIMENT

\[
\langle m_v \rangle < m_e (F_N F_D)^{-1/2}
\]

\[
F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{b \Gamma}}
\]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
- $^{136}$Xe has higher $W_{at}$ compared with other isotopes considered.
- Source = detector experiment.
- High pressure $\rightarrow$ Bigger amount of emitter.
- Scalable to higher masses.
- High $Q_{\beta\beta}$ value (2457.83 keV).

$Q_{\beta\beta} (^{136}\text{Xe}) = 2457.83 \text{ keV}$

M. Redshaw et al, PRL 98 (2007) 053003
THE EXPERIMENT

\[ \langle m_\nu \rangle < m_e (F_N F_D)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{b}} \]

✓ Xe is not difficult to enrich.
✓ Ability of purification and reuse of the enriched Xe.
✓ \(^{136}\text{Xe}\) has higher \(W_{at}\) compared with other isotopes considered.
✓ Source = detector experiment.
✓ High pressure \(\rightarrow\) Bigger amount of emitter.
✓ Scalable to higher masses.
✓ High \(Q_{\beta\beta}\) value (2457.83 keV).
✓ Long \(T_{1/2}^{2\nu\beta\beta}\) (2.11 ± 0.048(stat.) ± 0.21(sys.) \(\times 10^{21}\) y).

Observation of Two-Neutrino Double-Beta Decay in \(^{136}\text{Xe}\) with EXO-200

We report the observation of two-neutrino double-beta decay in \(^{136}\text{Xe}\) with \(T_{1/2}^{2\nu\beta\beta} = 2.11 \pm 0.048\) (stat.) \(\pm 0.21\) (sys.) \(\times 10^{21}\) yr. This second order process, predicted by the Standard Model, has been observed for several nuclei but not for \(^{136}\text{Xe}\). The observed decay rate provides new input to matrix element calculations and to the search for the more interesting neutrino-less double-beta decay, the most sensitive probe for the existence of Majorana particles and the measurement of the neutrino mass scale.

arXiv: 1108.4193v2 [nucl-ex]
THE EXPERIMENT

\[ \langle m_\nu \rangle < m_e \left( F_N F_D \right)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \epsilon \sqrt{\frac{MT}{b \Gamma}} \]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
- \(^{136}\text{Xe}\) has higher \( W_{at} \) compared with other isotopes considered.
- Source = detector experiment.
- High pressure \( \rightarrow \) Bigger amount of emitter.
- Scalable to higher masses.
- High \( Q^{\beta\beta} \) value (2457.83 keV).
- Long \( T_{1/2}^{2\nu\beta\beta} \) (2.11 ± 0.048(stat.) ± 0.21(sys.) x 10\(^{21}\) y).
- Possibility to detect Ionization/Scintillation and to study Tracking.
THE EXPERIMENT

\[ \langle m_\nu \rangle < m_e \left( F_N F_D \right)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{\beta\Gamma}} \]

✓ Xe is not difficult to enrich.
✓ Ability of purification and reuse of the enriched Xe.
✓ \(^{136}\)Xe has higher \( W_{at} \) compared with other isotopes considered.
✓ Source = detector experiment.
✓ High pressure \( \rightarrow \) Bigger amount of emitter.
✓ Scalable to higher masses.
✓ High \( Q_{\beta\beta} \) value (2457.83 keV).
✓ Long \( T_{1/2}^{2\nu\beta\beta} \) (2.11 ± 0.048(stat.) ± 0.21(sys.) x 10\(^{21}\) y).
✓ Possibility to detect Ionization/Scintillation and to study Tracking.
✓ Good energy resolution.
THE EXPERIMENT

\[ \langle m_v \rangle < m_e \left( F_N F_D \right)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{MT/b\Gamma} \]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
- \(^{136}\)Xe has higher \(W_{at}\) compared with other isotopes considered.
- Source = detector experiment.
- High pressure \(\rightarrow\) Bigger amount of emitter.
- Scalable to higher masses.
- High \(Q_{\beta\beta}\) value (2457.83 keV).
- Long \(T_{1/2}^{2\nu\beta\beta}\) (2.11 ± 0.048(stat.) ± 0.21(sys.) \(\times 10^{21}\) y).
- Possibility to detect Ionization/Scintillation and to study Tracking.
- Good energy resolution.
- \(F_N\) is worse if compared with other isotopes.
THE EXPERIMENT

\[ \langle m_\nu \rangle < m_e (F_N F_D)^{-1/2} \]

\[ F_D = 4.17 \times 10^{26} \frac{f}{W_{at}} \varepsilon \sqrt{\frac{MT}{b\Gamma}} \]

- Xe is not difficult to enrich.
- Ability of purification and reuse of the enriched Xe.
- \(^{136}\text{Xe}\) has higher \(W_{at}\) compared with other isotopes considered.
- Source = detector experiment.
- High pressure \(\rightarrow\) Bigger amount of emitter.
- Scalable to higher masses.
- High \(Q_{\beta\beta}\) value (2457.83 keV).
- Long \(T_{1/2}^{2\nu\beta}\) (2.11 ± 0.048(stat.) ± 0.21(sys.) x 10\(^{21}\) y).
- Possibility to detect Ionization/Scintillation and to study Tracking.
- Good energy resolution.
- \(F_N\) is worse if compared with other isotopes.

- Difficulty to design a compact experiment.
- Typical problems coming from working at High Pressure (~10 bars).
The NEXT (Neutrino Experiment with a Xenon TPC) experiment expects to measure the $0\nu\beta\beta$ decay of $^{136}\text{Xe}$ using a high pressure Xenon TPC.

Events detection is based on the SOFT TPC concept.

- Separated-Optimized Energy Function from Tracking
THE EXPERIMENT

✓ **SOFT** TPC: Separate-Optimized Energy Function from Tracking.

✓ The experiment will have a *better sensitivity* if we are capable to obtain as accurate as possible:

  ✓ *Energy* of the event (with good resolution).
  ✓ Time of the event ($t_0$, related to z position).
  ✓ *Track* of all the particles of the event.

✓ These characteristics will allow not only to determine the energy of the event, but also to reconstruct it in order to apply *pattern recognition* to *discriminate* background events from $0\nu\beta\beta$ ones.
✓ **SOFT** TPC: Separate-Optimized Energy Function from Tracking.
✓ **SOFT** TPC: Separate-Optimized Energy Function from Tracking.

**THE EXPERIMENT**

- **PMT** plane:
  - Primary scintillation $\rightarrow t_0$
  - Electroluminescence Light $\rightarrow$ Energy

- **SiPM** plane:
  - Electroluminescence Light $\rightarrow$ Tracking
PRESENT STATUS: PROTOTYPES

- Different small and medium size TPCs to test and improve elements that will be used in the final setup.
  - Detectors: Energy Resolution, Time Stability…
  - Vessel and internal components: Outgassing, Leak rates…
  - DAQ
- There are still decisions to be taken about some features of NEXT-100.
PRESENT STATUS: PROTOTYPES

✓ NEXT DBDM:

✓ Test PMTs energy resolution in HP Xe (up to 15 bar).
PRESENT STATUS: PROTOTYPES

✓ **NEXT DBDM:**

✓ Test PMTs energy resolution in HP Xe (up to 15 bar).
✓ Promising results.

✓ 1% FWHM @ 662 keV
  ▪ Drift Field: 0.05 kV/cm/bar
  ▪ EL Field: 2 kV/cm/bar

✓ Primary Scint. also observed
  ▪ Work with higher Drift Fields.
  ▪ Radial dependence and other points to clarify.
PRESENT STATUS: PROTOTYPES

✓ NEXT DEMO:

✓ Analog to the NEXT-100 baseline detector concept.

Ø = 16 cm  →  SV ~ 6 l

$m_{Xe} \sim 0.34$ kg @ 10 bar
PRESENT STATUS: PROTOTYPES

✓ NEXT DEMO:
  ✓ Analog to the NEXT-100 baseline detector concept.

PMT Plane ($t_0$ and Energy)  SiPM Plane (Tracking)
PRESENT STATUS: PROTOTYPES

✓ **NEXT DEMO:**

✓ Analog to the NEXT-100 baseline detector concept.
✓ Prototype just commissioned (only preliminary calibrations done).
PRESENT STATUS: PROTOTYPES

✓ NEXT µM:
  ✓ Testing of different Xe-base mixtures (effects on the energy resolution).
  ✓ Outgassing and Leak Rates for Feedthroughs and internal components.

✓ But Also…
PRESENT STATUS: PROTOTYPES

✓ **NEXT \(\mu M\):**
  ✓ Testing of different Xe-base mixtures (effects on the energy resolution).
  ✓ Outgassing and Leak Rates for Feedthorughs and internal components.

✓ **But Also…**
  ✓ Study of Micromegas detector as alternative to the baseline.

✓ No operational problems in HP
✓ Long term stability
✓ Radiopure solution
✓ Capable to register energy and tracking
✓ Ongoing studies to see EL
✓ …
**PRESENT STATUS: PROTOTYPES**

- **NEXT $\mu$M:**
  - Testing of different Xe-base mixtures (effects on the energy resolution).
  - Outgassing and Leak Rates for Feedthroughs and internal components.
- **But Also…**
  - Study of Micromegas detector as alternative to the baseline.
  - No operational problems in HP
  - Long term stability
  - **Radiopure solution**

---

*S. Cebrián et al, Astrop Phys 34 (2011) 354-359*

<table>
<thead>
<tr>
<th>Sample</th>
<th>$^{232}$Th</th>
<th>$^{235}$U</th>
<th>$^{238}$U</th>
<th>$^{40}$K</th>
<th>$^{60}$Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micromegas without mesh</td>
<td>$4.6 \pm 1.6$</td>
<td>&lt;6.2</td>
<td>&lt;40.3</td>
<td>&lt;46.5</td>
<td>&lt;3.1</td>
</tr>
<tr>
<td>Microbulk-Micromegas</td>
<td>&lt;9.3</td>
<td>&lt;13.9</td>
<td>26.3 ± 13.9</td>
<td>57.3 ± 24.8</td>
<td>&lt;3.1</td>
</tr>
<tr>
<td>Kapton–copper foil</td>
<td>&lt;4.6</td>
<td>&lt;3.1</td>
<td>&lt;10.8</td>
<td>&lt;7.7</td>
<td>&lt;1.6</td>
</tr>
<tr>
<td>Copper–kapton–copper foil</td>
<td>&lt;4.6</td>
<td>&lt;3.1</td>
<td>&lt;10.8</td>
<td>&lt;7.7</td>
<td>&lt;1.6</td>
</tr>
<tr>
<td>Hamamatsu R8520-06 PMT [30]</td>
<td>27.9 ± 9.3</td>
<td>–</td>
<td>37.2</td>
<td>1705.0 ± 310.0</td>
<td>93.0 ± 15.5</td>
</tr>
</tbody>
</table>

* Level obtained from the minimum detectable activity (MDA) of the detector [31].
PRESENT STATUS: PROTOTYPES

✓ **NEXT μM:**
  ✓ Testing of different Xe-base mixtures (effects on the energy resolution).
  ✓ Outgassing and Leak Rates for Feedthorughs and internal components.

✓ **But Also…**
  ✓ Study of Micromegas detector as alternative to the baseline.

✓ No operational problems in HP
✓ Long term stability
✓ Radiopure solution
✓ Capable to register energy and tracking
✓ Ongoing studies to see EL
✓ …
PRESENT STATUS: PROTOTYPES

✓ *NEXT* $\mu M$:

✓ ~ 79 l Stainless Steel Chamber.

✓ $\varnothing = 28$ cm and 35 cm Drift Length for 21.5 l of sensitive volume.

→ Up to ~1.2 kg of Xe @ 10 bar in the sensitive volume.
PRESENT STATUS: PROTOTYPES

✓ NEXT μM:
  ✓ ~79 l Stainless Steel Chamber.
  ✓ Ø = 28 cm and 35 cm Drift Length for 21.5 l of sensitive volume.
  ➔ Up to ~1.2 kg of Xe @ 10 bar in the sensitive volume.

✓ In a first step the prototype was fully equipped with:
  ✓ Bulk mM detector Ø ~ 30 cm.
  ✓ Copper + Peek + Cirlex Field Cage.
  ✓ Teflon + Copper HV Feedthrough.
  ✓ Readout Feedthrough.
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu M$:

✓ ~ 79 l Stainless Steel Chamber.
✓ $\varnothing = 28$ cm and 35 cm Drift Length for 21.5 l of sensitive volume.

→ Up to $\sim 1.2$ kg of Xe @ 10 bar in the sensitive volume.

✓ In a first step the prototype was fully equipped with:

✓ Bulk mM detector $\varnothing \sim 30$ cm.
✓ Copper + Peek + Cirlex Field Cage.
✓ Teflon + Copper HV Feedthrough.
✓ Readout Feedthrough.
PRESENT STATUS: PROTOTYPES

✓ **NEXT μM:**
  ✓ ~ 79 l Stainless Steel Chamber.
  ✓ Ø = 28 cm and 35 cm Drift Length for 21.5 l of sensitive volume.
    → Up to ~1.2 kg of Xe @ 10 bar in the sensitive volume.

✓ In a first step the prototype was fully equipped with:
  ✓ Bulk mM detector Ø ~ 30 cm.
  ✓ Copper + Peek + Cirlex Field Cage.
  ✓ Teflon + Copper HV Feedthrough.
  ✓ Readout Feedthrough.
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu$M:

✓ ~ 79 l Stainless Steel Chamber.
✓ Ø = 28 cm and 35 cm Drift Length for 21.5 l of sensitive volume.
   ⇒ Up to ~1.2 kg of Xe @ 10 bar in the sensitive volume.

✓ In a first step the prototype was fully equipped with:

✓ Bulk mM detector Ø ~ 30 cm.
✓ Copper + Peek + Cirlex Field Cage.
✓ Teflon + Copper HV Feedthrough.
✓ Readout Feedthrough.
**PRESENT STATUS: PROTOTYPES**

- **NEXT μM:**
  - ~ 79 l Stainless Steel Chamber.
  - Ø = 28 cm and 35 cm Drift Length for 21.5 l of sensitive volume.
  - → Up to ~1.2 kg of Xe @ 10 bar in the sensitive volume.

- In a first step the prototype was fully equipped with:
  - Bulk mM detector Ø ~ 30 cm.
  - Copper + Peek + Cirlex Field Cage.
  - Teflon + Copper HV Feedthrough.
  - Readout Feedthrough.

- Before to measure:
  - Pressure Tests
  - Vacuum and Outgassing measurements
  - HV and many others…
PRESENT STATUS: PROTOTYPES

✓ **NEXT \( \mu M \): Pressure Tests.**

✓ Useful to test the vessel but also the Gas System to put the gas inside the vessel (valves, flowmeters, ...)

- **11** bar of \( Ar \)
- Monitoring of \( P \) and \( T \)
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu M$: Pressure Tests.

✓ Useful to test the vessel but also the Gas System to put the gas inside the vessel (valves, flowmeters, …)

- 11 bar of Ar
- Monitoring of $P$ and $T$

11 bars constant during more than 10 days
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu M$: Vacuum and outgassing measurements.

✓ To keep the purity of gas, elements in contact must not emanate any contaminant.

✓ In principle the inner materials were chosen with this purpose.

✓ Bake-out cycles $\rightarrow$ To “clean” possible impurities.

Outgassing \[
\frac{mbar \times l}{s} = \frac{(P(t) - P_0) \times \text{Volume}}{t - t_0}
\]

P < 10^{-6} mbar

Og < 10^{-6} mbar l/s
PRESENT STATUS: PROTOTYPES

✓ **NEXT μM**: Other tests.
✓ HV tests to check that Electric Field needed for the Drift is reachable.
✓ Installation of the electronics close to the vessel.

✓ DAQ based on **AFTER** chip.
✓ Possibility to read mesh (E) and pixels (track) of the μM **simultaneously**.
PRESENT STATUS: PROTOTYPES

✓ **NEXT $\mu M$**: First measurements.

✓ $^{222}$Rn source diffused in the gas (Ar-$iC_4H_{10}$ 5%)

✓ ~ 6 MeV $\alpha$ inside the sensitive volume.
PRESENT STATUS: PROTOTYPES

✓ **NEXT μM**: First measurements.

✓ $^{222}$Rn source diffused in the gas (Ar-iC$_4$H$_{10}$ 5%)

✓ $\sim$ 6 MeV $\alpha$ inside the sensitive volume.

\[ R = R_0 e^{-\lambda t} \]

- $R_0 = 17.5 \pm 0.05$
- $\lambda = 140.55 \pm 1.66 \text{ h}^{-1}$
- $T_{1/2} = 4.05 \pm 0.05 \text{ days}$
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu$M: First measurements.
  ✓ $^{222}$Rn source diffused in the gas (Ar-iC$_4$H$_{10}$ 5%)
  ✓ $\sim$ 6 MeV $\alpha$ inside the sensitive volume.

3-D Energy Distribution

2-D Event Reconstruction
PRESENT STATUS: PROTOTYPES

✓ NEXT $\mu M$: Presents Status.
  ✓ Prototype fully operative with Bulk $\mu M$.
  ✓ Possible to register Energy and 2-D tracks.

✓ Next steps:
  ✓ Installation of microbulk mM → LARGEST SURFACE COVERED
  ✓ Complete the system to register $t_0$ → 3-D tracks
PRESENT STATUS: NEXT 100

✓ **NEXT 100** will be placed at Canfranc Underground Laboratory (**LSC**), in the Spanish Pyrenees (**2450 m.w.e.**).
PRESENT STATUS: NEXT 100

✓ NEXT 100 time schedule:
  ✓ Commissioning of the detector along 2013.
  ✓ Start data taking in 2014.

✓ Technical Detector Report (TDR) finished:
  ✓ Pressure Vessel (SS + internal Cu shielding)
PRESENT STATUS: NEXT 100

✓ **NEXT 100** time schedule:
  ✓ Commissioning of the detector along **2013**.
  ✓ Start data taking in **2014**.

✓ Technical Detector Report (TDR) finished:
  ✓ Pressure Vessel (SS + internal Cu shielding)
  ✓ Field Cage
PRESENT STATUS: NEXT 100

✓ **NEXT 100** time schedule:
  ✓ Commissioning of the detector along **2013**.
  ✓ Start data taking in **2014**.

✓ Technical Detector Report (TDR) finished:
  ✓ Pressure Vessel (SS + internal Cu shielding)
  ✓ Field Cage
  ✓ PMTs and MPPCs
PRESENT STATUS: NEXT 100

✓ **NEXT 100** time schedule:
  ✓ Commissioning of the detector along **2013**.
  ✓ Start data taking in **2014**.

✓ Technical Detector Report (TDR) finished:
  ✓ Pressure Vessel (SS + internal Cu shielding)
  ✓ Field Cage
  ✓ PMTs and MPPCs
  ✓ Shielding
PRESENT STATUS: NEXT 100

✓ **NEXT 100** time schedule:
  ✓ Commissioning of the detector along **2013**.
  ✓ Start data taking in **2014**.

✓ Technical Detector Report (TDR) finished:
  ✓ Pressure Vessel (SS + internal Cu shielding)
  ✓ Field Cage
  ✓ PMTs and MPPCs
  ✓ Shielding

✓ Radiopurity measurements → Bkg Model

✓ Simulations

✓ …

**EXPECTED TO REACH THE**

\[ \langle m_\nu \rangle \approx 50 \text{ meV SENSITIVITY} \]
OUTLOOK

✓ **PROTOTYPES:**

✓ Data taking and test of different element and techniques that will be used in NEXT 100.

✓ **NEXT 100:**

✓ Construction and Commissioning of Shielding and Gas System (2012).


✓ Construction of Field Cage and HV Feedthroughs (2012).

✓ Commissioning of NEXT 100 at LSC (from ~ June 2013).

✓ Start Data Taking (2014).
SUMMARY

✓ $0_{\nu}\beta\beta$ is a hot topic in Particle Physics.

✓ New generation experiments aim to explore new regions for the neutrino effective mass around 50 meV.

✓ NEXT experiment expects to reach this sensitivity using a HP Xe TPC.

✓ NEXT prototypes are showing that the technology chosen could be suitable for this objective.

✓ NEXT 100 design is already finished and works to construct the setup will start in 2012.

✓ The goal is to start the data taking in 2014.

IS A REALLY AMBICIOUS TIME LINE… BUT LET’S TRY IT
Neutrinoless double beta decay search using $^{136}$Xe: The *NEXT* experiment.

Héctor Gómez Maluenda

gomez@lal.in2p3.fr