PANDA X

Microbulk Micromegas for the search of DBD of 136Xe in the PandaX-III experiment

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SJTU university (China) - University of Zaragoza (Spain)

The nature of neutrinos

One of the big questions *still open* in particle physics.

Do Majorana particles exist?

In Quantum Field Theory there are 2 possible mathematical approaches to describe the behaviour of fermions.

Dirac and **Majorana**

The Majorana description for fermions entails that **a particle and its antiparticle are the same**.

The only particle we know where we can probe this theory is **the neutrino.**

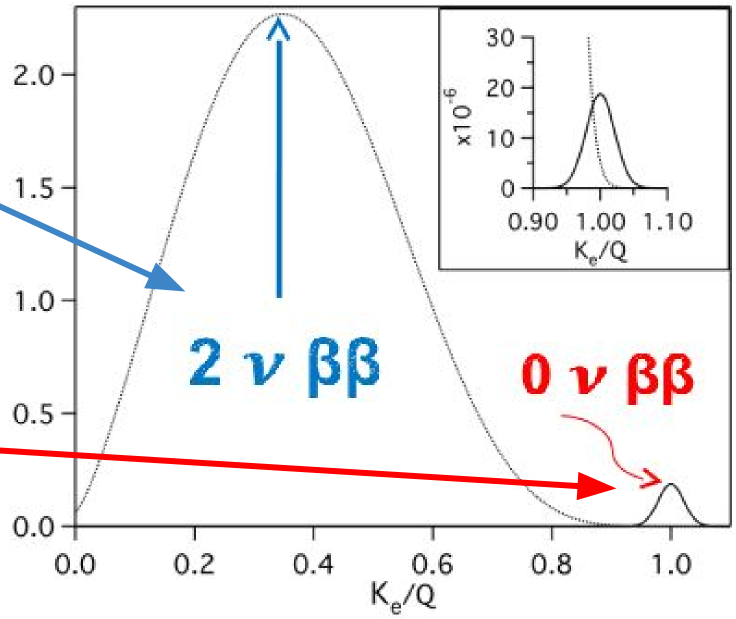
A neutrinoless ββ decay

A typical process involving neutrinos is a nuclear beta or double beta decay.

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

If the neutrino it is its own antiparticle (Majorana) then a **double beta decay** without neutrino emission is possible.

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

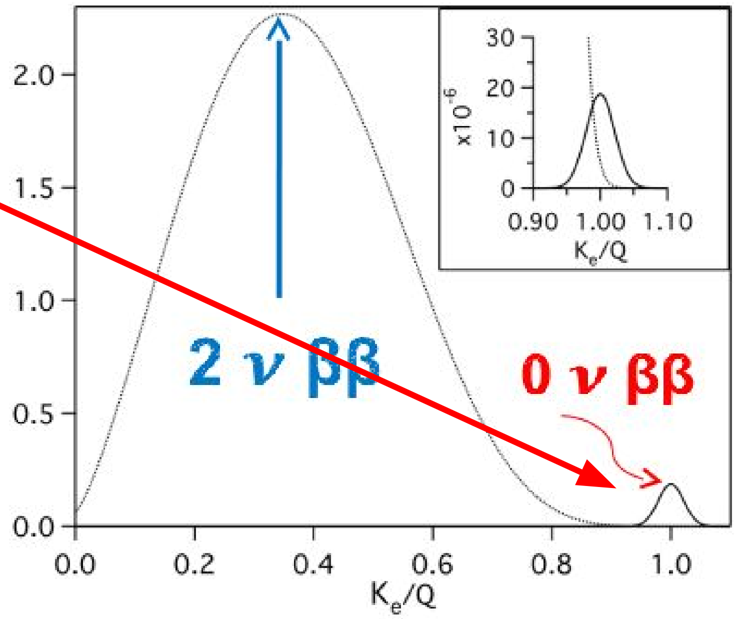


A neutrinoless ββ decay

Any experiment willing to measure this phenomenology needs to be able to resolve this peak.

Mainly to separate 2νββ process from 0νββ and any other backgrounds.

Good energy resolution required



A neutrinoless ββ decay

This process occurs with very low probability.

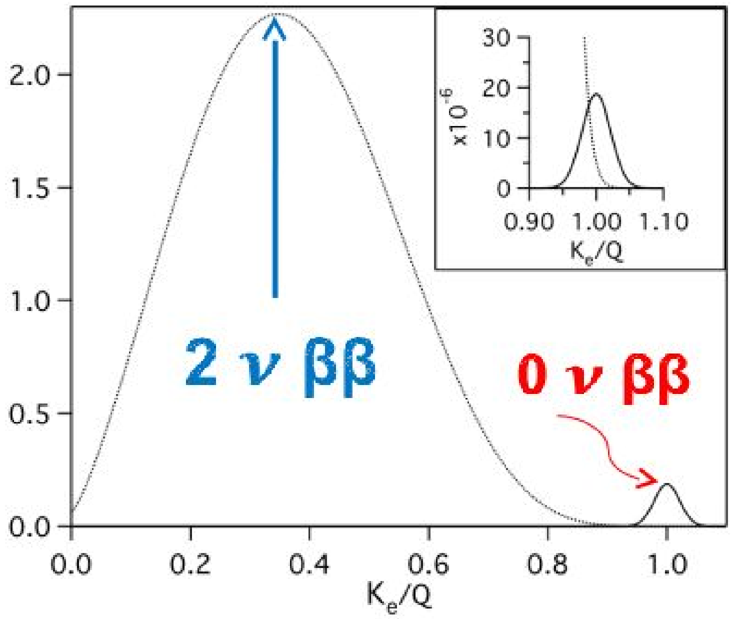
In practice, what we measure is the lifetime of the decay

isotopic abundance

mass exposure

$$T^{\frac{1}{2}}_{0\nu\beta\beta} \sim \frac{a}{A}\sqrt{\frac{Mt}{B\Delta E}}$$

background



Status of ββ0ν searches

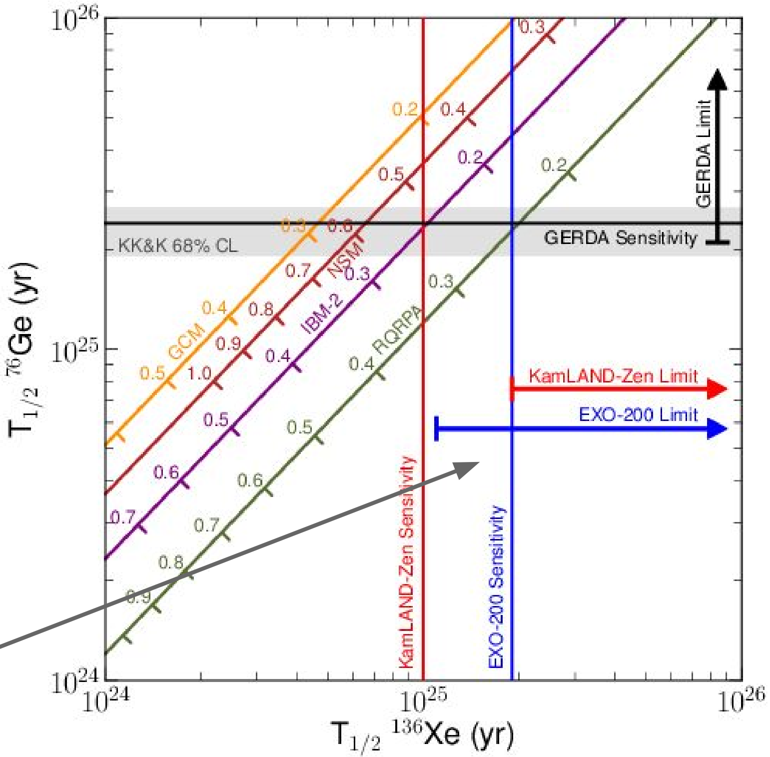
Few isotopes can have 0νββ decay channel:

^{48}Ca, ^{76}Ge, ^{82}Se, …, ^{136}Xe, ^{150}Nd

Many experiments have been searching and search for 0νββ.

The best sensitivity limit have been obtained with liquid ^{136}Xe (EXO200)

$$T_{\frac{1}{2}} \gtrsim 1.1 \cdot 10^{25}\ \text{yr at 90\% C.L.}$$



Choosing the right isotope

What matters on isotope selection is the mass

The **ββ0ν** physics frontier depends on the experiment scalability. We need to go towards ton scale experiments.

Isotopic abundance of ^{136}Xe in natural Xenon is about 8%.

Enrichment method is well stablished and **cost effective**.

Advantage of gas/liquid based detectors.

In case we observe a signal candidate we can replace the 136Xe enriched gas by depleted Xenon and compare!

Unique feature

Could you do that with a solid detector?

The case of a HPXe TPC for a DBD

Xenon for DBD

well known advantages (shared with liquid Xe)

- cost
- enrichment
- detector granularity
- scaling-up

Gaseous Xenon

- Improved energy resolution
- Lower diffusion (Xe+TMA): Topological discrimination
- Complexity

However, recent progress and **consolidation of mMs readouts** mitigates this drawback

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PANDA X

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PANDA X

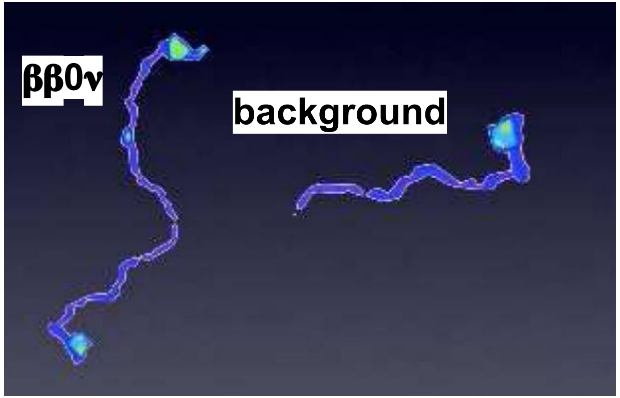
Improving sensitivity

Once the mass has been fixed the only way to improve sensitivity is to reduce the background level of the detector at the Xenon ROI.

$$Q_{\beta\beta} = 2457.83\ keV$$

$$T^{\frac{1}{2}}_{0\nu\beta\beta} \sim \frac{a}{A}\sqrt{\frac{Mt}{B\Delta E}}$$

background (B) — energy resolution (ΔE)



We require ...

- Underground laboratory.
- Detector materials radiopurity.
- Energy resolution.
- Topological event discrimination.

We need to optimize ...

Good radiopurity, low background, materials

Improved energy resolution

Enhanced tracking for topological background discrimination

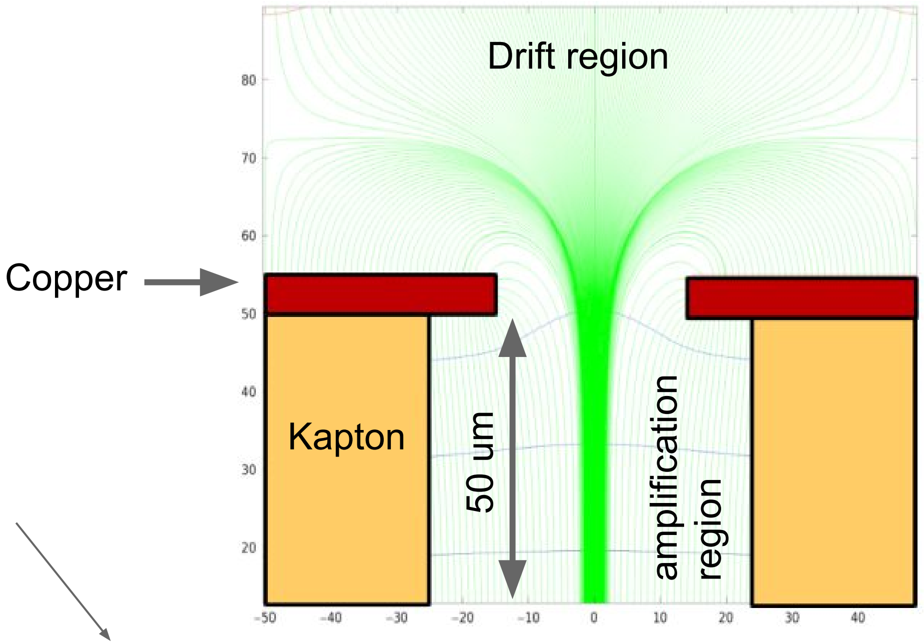
Radiopurity of Microbulk micromegas technology

Microbulk technology allows for detector readout with little mass budget, and potentially very radiopure materials (Copper and Kapton).

Microbulk radioactivity measured at Canfranc Underground Laboratory Germanium detector.

Th^{232} < 9.3 µBq/cm^2 and U^{238} < 26.3 µBq/cm^2

New measurements (not yet published) provide a **factor 100 better limits**.



See details in
Astropart. Phys. (2011) 34, 354

Energy resolution (Xe gas)

Xenon **gas has better intrinsic energy resolution** than liquid Xenon.

Constant up to 50bar

A. Bolotnikov, B. Ramsey / Nucl. Instr. and Meth. in Phys. Res. A 396 (1997) 360–370

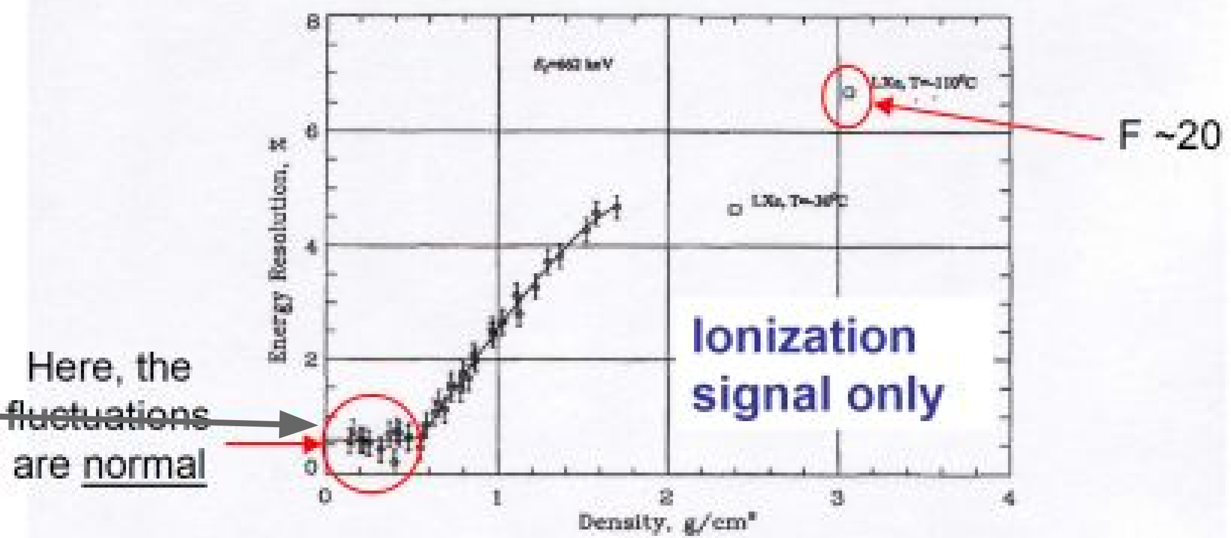


Fig. 5. Density dependencies of the intrinsic energy resolution (%FWHM) measured for 662 keV gamma-rays.

For ρ <0.55 g/cm³, ionization energy resolution is "intrinsic"

Energy resolution (Quencher)

A Xenon-TMA mixture reduces the negative effect of pressure on energy resolution.

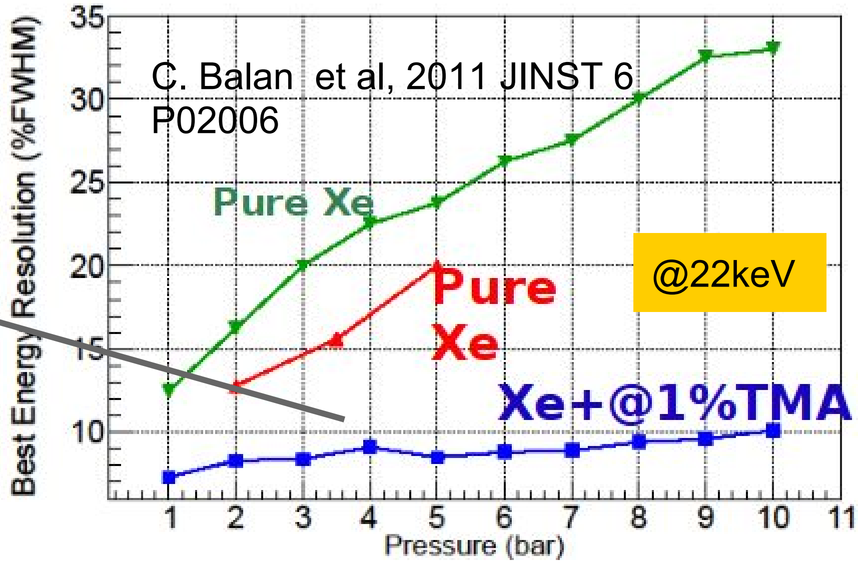
Required energy resolutions for 0νββ can be achieved using Micromegas microbulk technology.

0.9% FWHM @ Qββ for 10bar

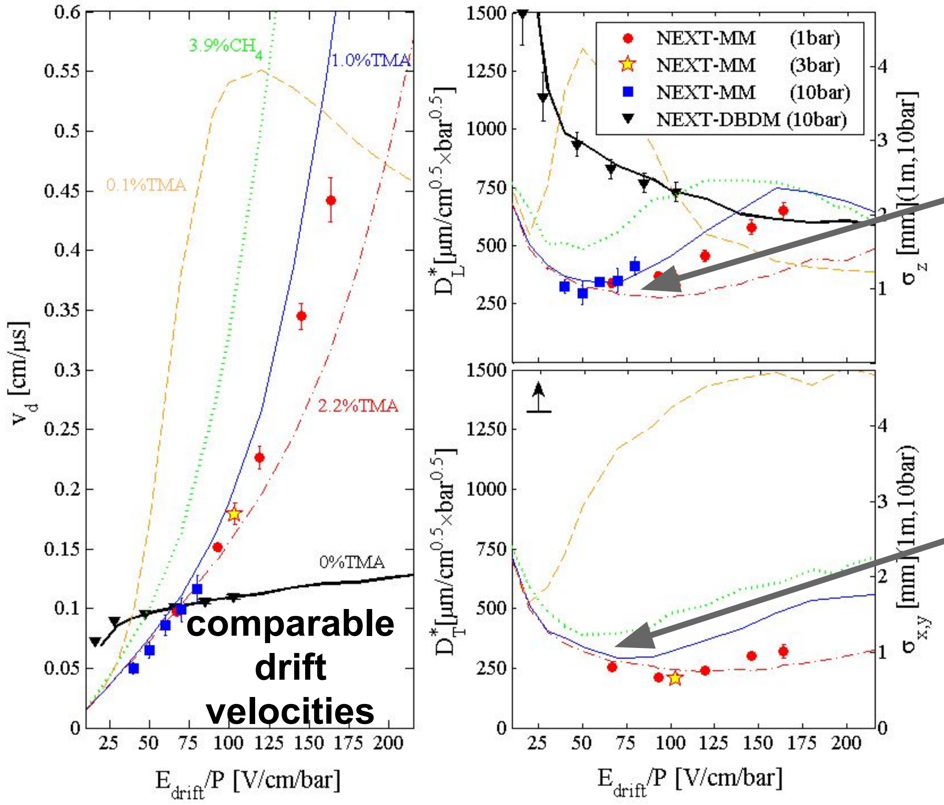
For extended tracks (^{22}Na 1.2MeV)

3% FWHM @ Qββ (not intrinsic limitation, room for improvement)

Studies carried out in the framework of an ERC funded project (T-REX) for rare event searches using MPGD at University of Zaragoza (Spain).



Additional benefits of quencher

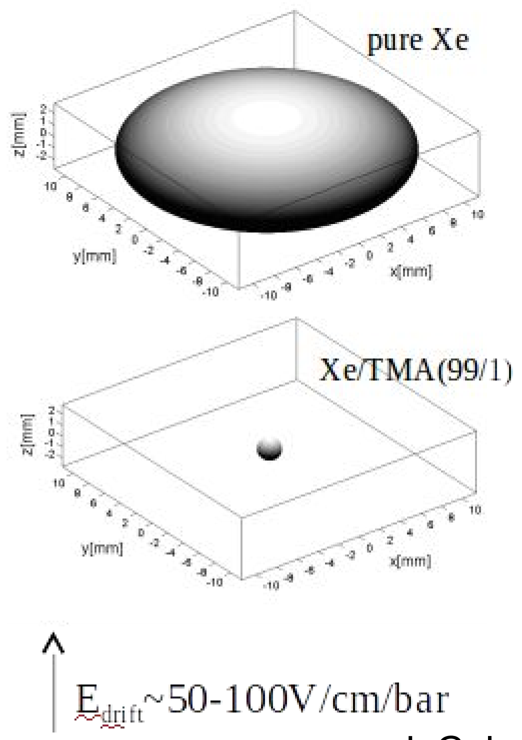


comparable drift velocities

x3 lower longitudinal diffusion

x10 lower transversal diffusion

A pointlike deposit after 100cm drift



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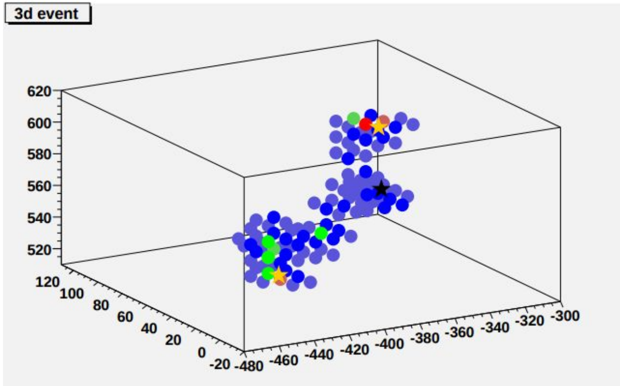
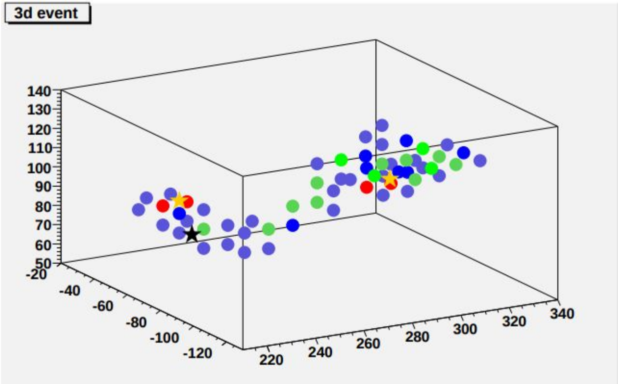
Topological discrimination



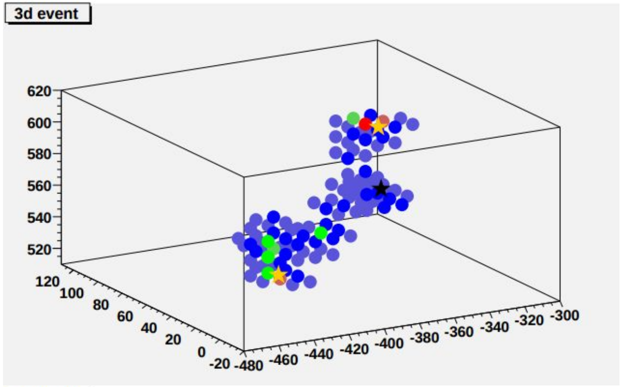


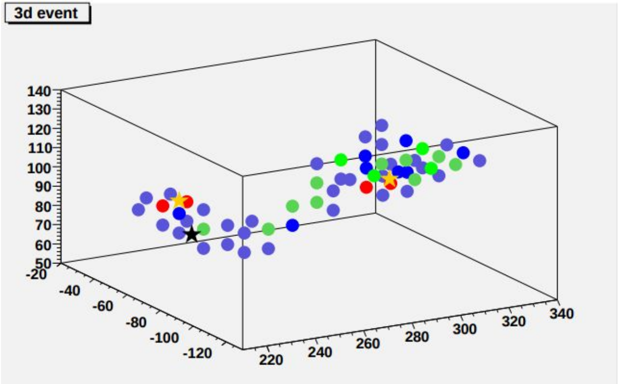
A neutrinoless double beta decay has a very particular topology that can be exploited in gaseous detectors.

Discrimination analysis can exploit

- event shape and volume
- track connection
- 2-blob identification

Topological discrimination





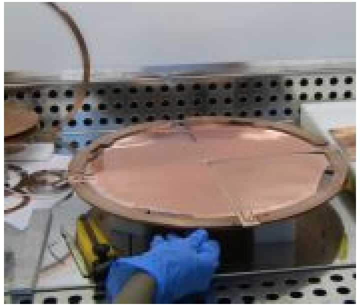
Montecarlo studies show that the background rejection allows to reduce backgrounds by a factor 100.

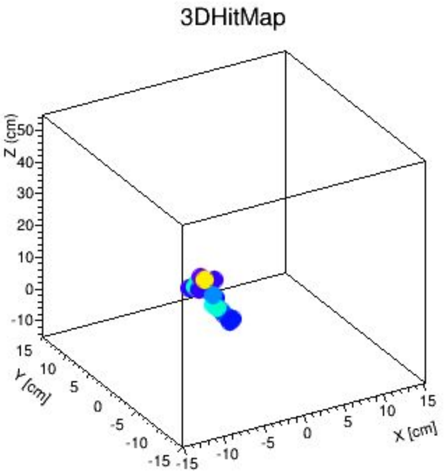
These studies show also that lower diffusion increases rejection at least by a factor 3 (respect to higher diffusion, Pure Xenon).

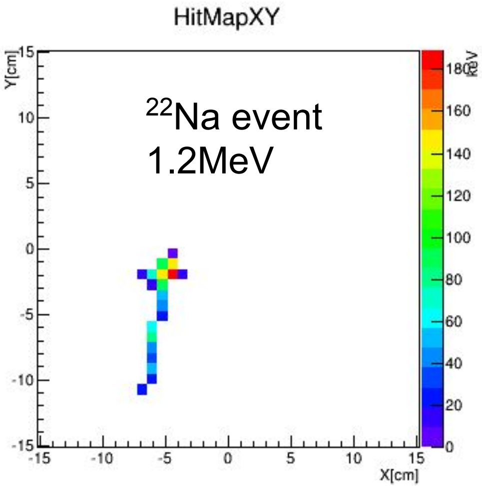
J. Phys. G40 (2013) (arXiv:1306.3067)

Last years R&D Progress in the framework of T-REX project

During the last years progress on Micromegas for rare event searches was possible thanks to the T-REX ERC funded project, by the group of I.G. Irastorza at the University of Zaragoza







Relevant references for 0NDBD developed in the T-REX project.

Radiopurity of MM

- Radiopurity of Micromegas readout planes, Astropart.Phys. 34 (2011) 354-359 (arXiv:1005.2022)
- New results to be published soon (x100 better limits for U and Th)

NEXT-MM:

- Description and commissioning of NEXT-MM prototype: first results from operation in a Xenon-Trimethylamine gas mixture. JINST 9 (2014) P03010(arXiv:1311.3242)
- Characterization of a medium size Xe/TMA TPC instrumented with microbulk Micromegas, using low-energy γ-rays. JINST 9 (2014) C04015 (arXiv:1311.3535)

Pattern recognition:

- Pattern recognition of 136Xe double beta decay events and background discrimination in a high pressure Xenon TPC, J. Phys. G40 (2013) (arXiv:1306.3067)

Xe+TMA, energy resolution,...

- Micromegas-TPC operation at high pressure in xenon-trimethylamine mixtures. JINST 8 (2013) P01012 (arXiv:1210.3287)
- Micromegas readouts for double beta decay searches, JCAP 1010 (2010) 010 (arXiv:1009.1827)
- See also Nucl Instrum Meth Nucl.Instrum.Meth. A608 (2009) 259-266

PANDA X-III collaboration was born

- Panda X-III built based on the experience on Panda X-II (dark matter rare event search).
- Panda X-III community building up, since early 2015.
- Different working groups established in different areas

prototypes, gas system, water tank purification, readout, top-metal and shared between different institutions

Aggressive program, 200Kg detector to be installed by the end of 2017. Towards 1-tonn experiment by 2022.

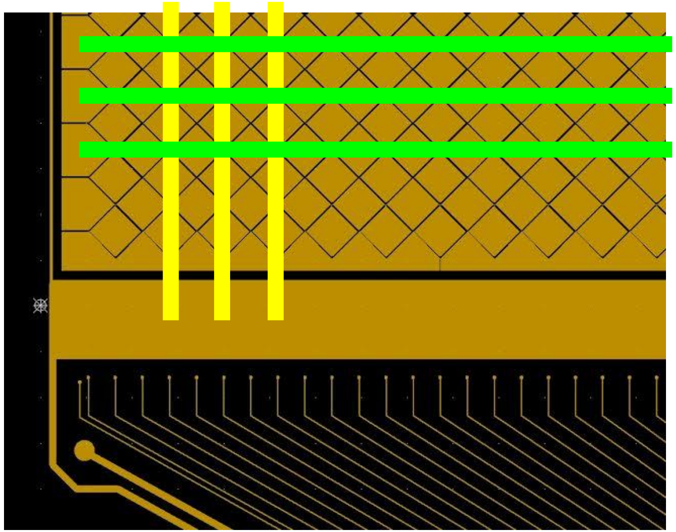
Different prototypes and testing units being developed in parallel.

Zaragoza (UZ), Berkeley (LBNL), Shanghai (SJTU)

A **10Kg prototype** under development at SJTU

Micromegas readout tests for PANDA X-III

A stripped readout with interconnected pixels



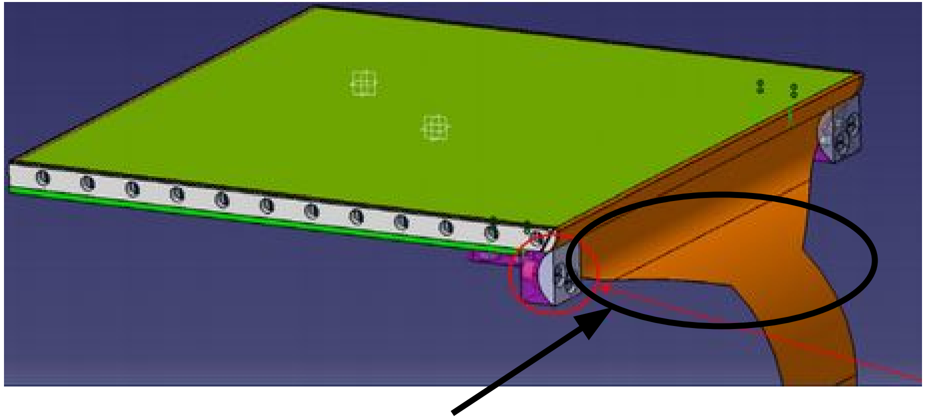
Microbulk's production at PCB Workshop (Rui de Oliveira)

Several AGET cards, provided by CEA Saclay, ready to be used in micromegas testing benches.

Several micromegas prototypes with different readout topologies will be tested during the next months.

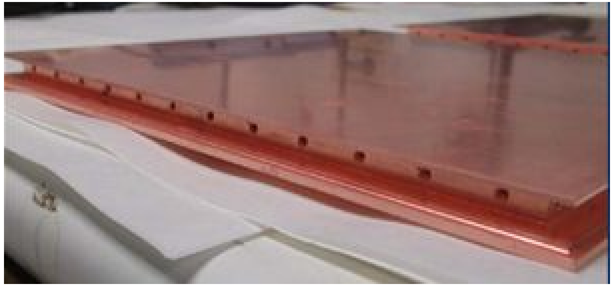
Micromegas module preparation

Micromegas module concept design



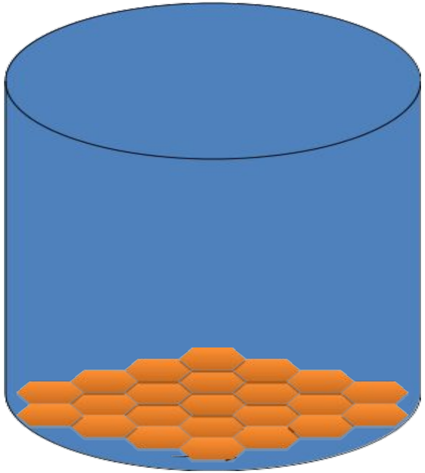
We avoid use of non-radiopure connector here. Just extension of kapton-copper foil with readout lines.

Copper pieces preparation

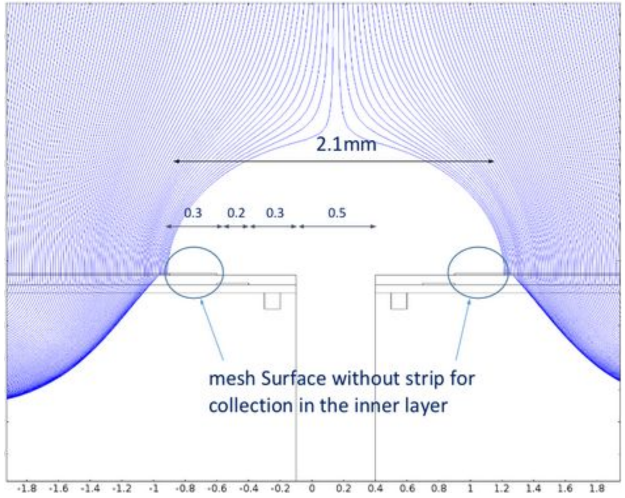


Micromegas-read TPC implementation

The total active area will be covered by a mosaic of 20cm x 20 cm Micromegas modules.



To avoid charge losses in the interfaces a correcting field will be used.



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Background Montecarlo and topological event selection for PANDA X-III

Panda X-III Montecarlo activities running in parallel

for experimental set-up optimization and physics preparation.

Identify sensitive detector components to **background contributions**

Vessel design

Material requirements

Radiopurity levels : electronics

Optimize gas and readout topology to enhance **background discrimination**

Comparison between prototype experimental

data and simulation

Background model

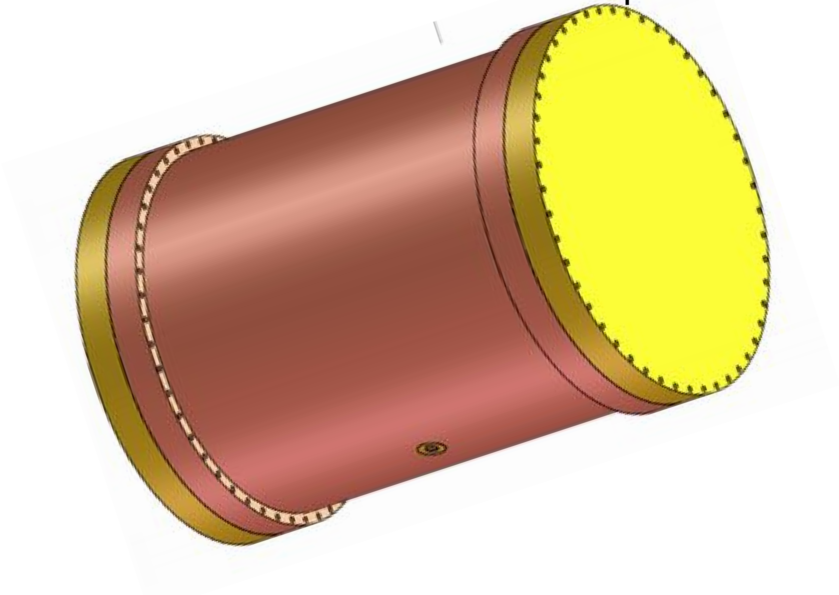
Be ready

for physics run!

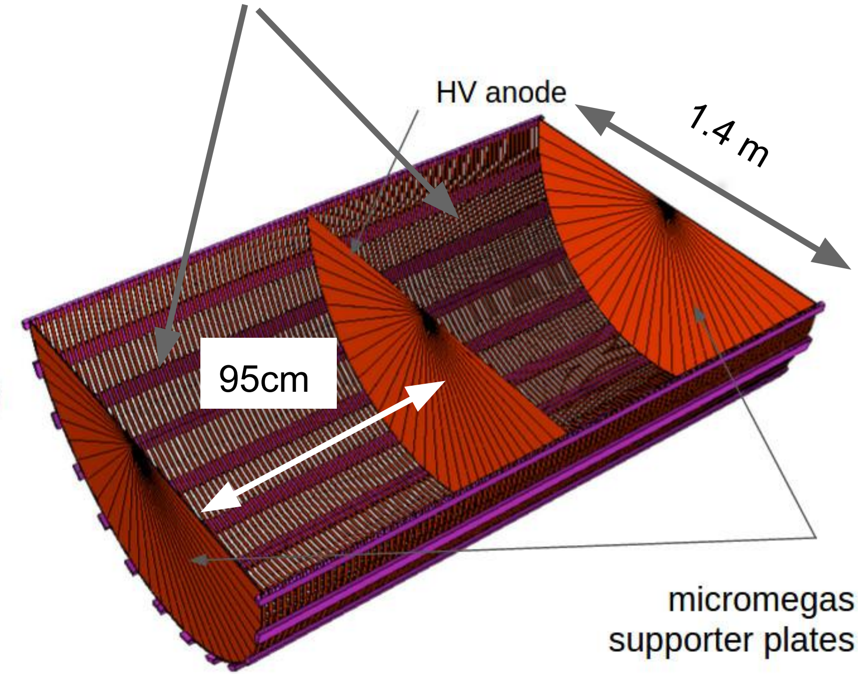
Preliminar PANDA X-III vessel design

$4m^3$ volume, 8-tons radiopure copper

3cm thickness + 15cm endcap

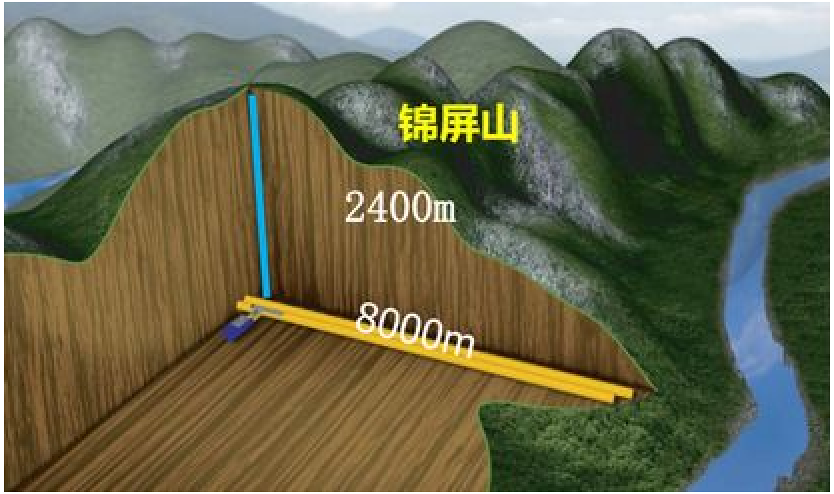


Splitted in 2-TPC sides



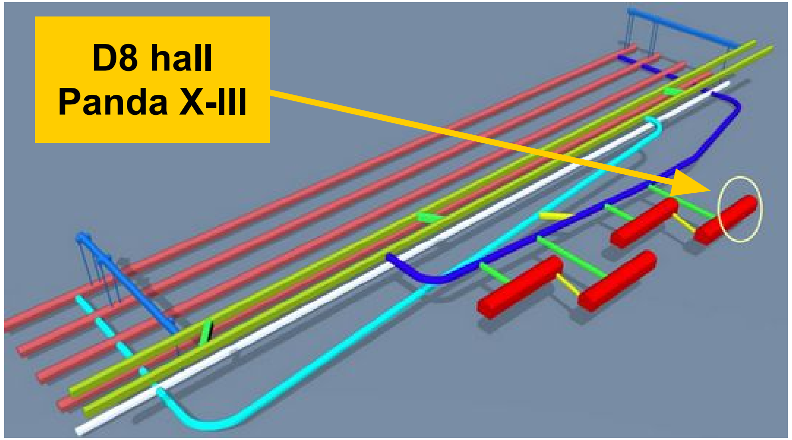
The PANDA X-III underground laboratory

Panda X-III will be installed at the Jinping Underground Lab (deepest in the world – 1μ/week/m^2)



Upgrade : CJPL-II under construction

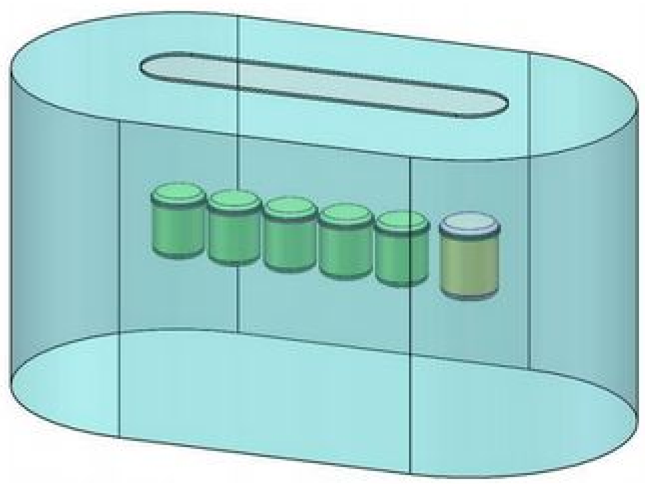
8 experimental halls 65m long



The PANDA X-III underground hall

CAD representation of D8 Hall where Panda X-III will be installed

A water tank with purification system. ^{238}U and ^{232}Th at the level of 10^{-15} g/g_{H2O}



Conclusions

MPGD developments during the last years provide good expectation on Rare Event Searches (T-REX).

Panda X-III prepares for a next generation, tonn-scale, neutrinoless double beta decay experiment.

Background levels achievable of 10^{-4} - 10^{-5} keV^{-1} Kg^{-1} yr^{-1} would allow to reach increased sensitivities on the neutrino mass.

$$T_{\frac{1}{2}} > 10^{26}\ \mathrm{yr}$$

The measurement of a neutrinoless decay.

1. would discover elementary Majorana particles
2. demonstrate lepton number violation
3. and provide a direct measurement of the neutrino mass.