Progress and prospects on large volume TPCs for rare event searches and its application to axion and neutrino searches

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Outline

- Micromegas as a radiopure readout to construct TPCs for rare event physics searches.

- Physic cases : Axions, WIMPS and neutrino physics.

  - Axion searches using TPCs : CAST, IAXO and AMELIE

  - Neutrino-less double beta decay searches : R&D developments, PandaX-III.

  - R&D using a spherical TPC for rare event searches.

- REST (Rare Event Software for TPCs) : A software development framework for gaseous micropatterned readouts.

Particle physics processes occurring with very low probability can be investigated in very low background conditions.

To achieve the best signal to background ratio we need to optimize

Good radiopurity, low background, materials.
+
Shielding against external radiation
+
Underground lab

Improved energy resolution

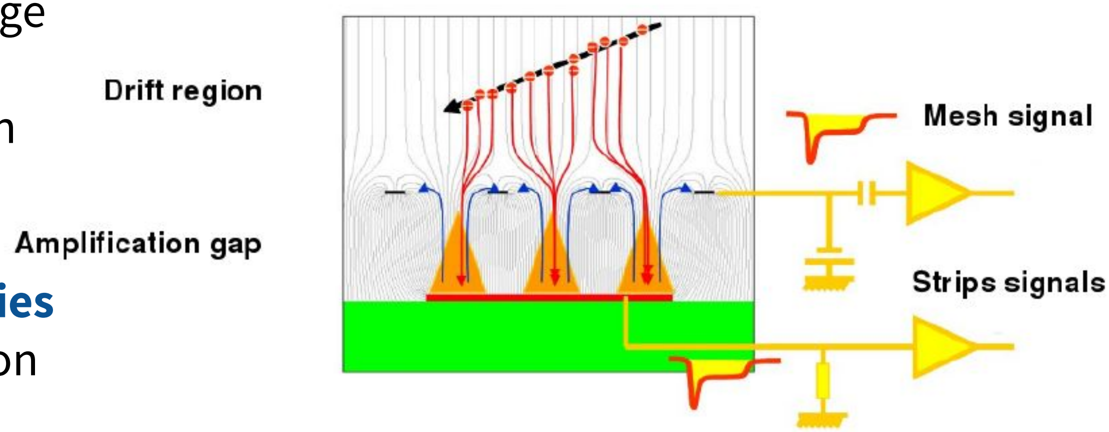
To reduce the size of ROI

Exploit tracking for topological background discrimination

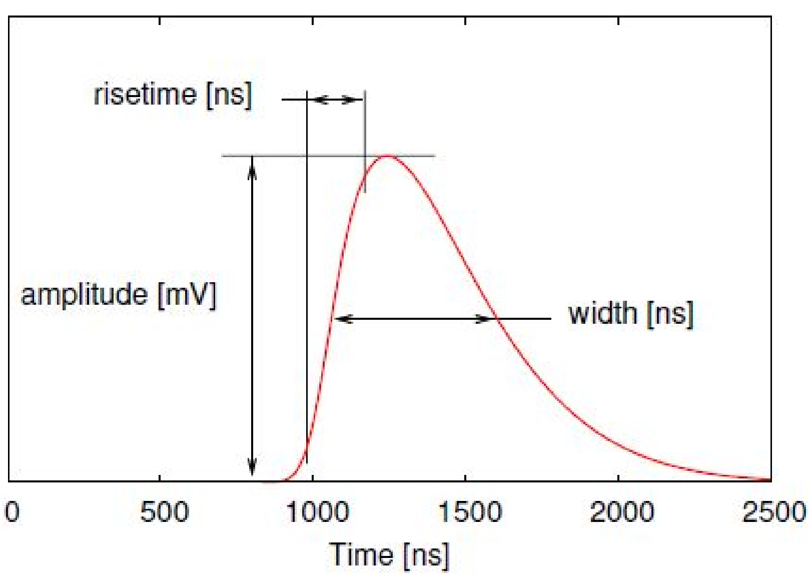
Micromegas detectors detection principle

Micromegas readout provides charge amplification for TPCs, with **record energy resolution** on micropatterned readouts

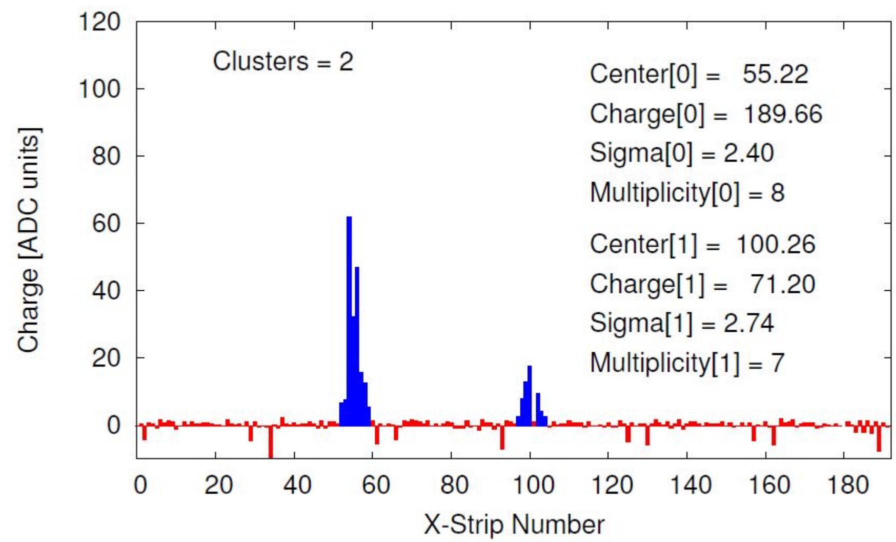
The **temporal and spatial properties** of events allow event reconstruction and event recognition



Time signal



Spatial signal



Different micromegas technology for TPC readout

In first Micromegas detectors (conventional technology) mesh and read-out strips were two independent entities. **New technologies were developed to keep mesh and strips in a single entity** providing a fixed amplification gap.

Foreseen R&D to achieve radiopure readout and improved energy resolution

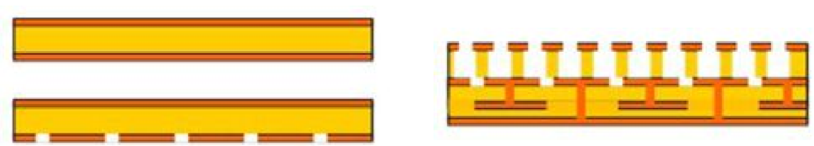
Made of low radiactive materials

Bulk

30 um inox mesh
128 um pillars
Reachable energy resolution 18% FWHM @ 6 keV
Spatial uniformity and very robust
Limit on energy resolution due to thickness of the mesh

Microbulk

5 um copper mesh
30 um mesh holes
Pillars are replaced by attached Kapton substrate.
Reachable energy resolution (<13% FWHM @ 6keV)
Good behaviour against sparks



Application to **large area** detectors

Application to **rare event searches** and low Energy resolution requirements

Radiopurity of microbulk micromegas technology

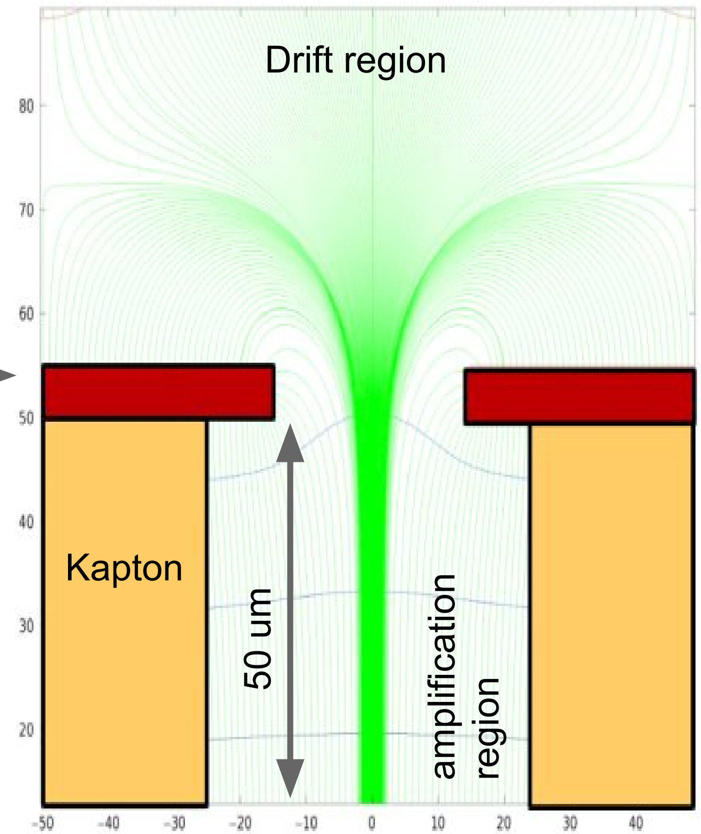
Microbulk technology allows to construct a charge amplification readout with little mass budget, and potentially very radiopure materials (Copper and Kapton).

Microbulk radioactivity measured at Canfranc Underground Laboratory Germanium detector.

$Th^{232} < 9.3\ \mu Bq/cm^2$ and $U^{238} < 26.3\ \mu Bq/cm^2$

New measurements (not yet published) provide a **factor 100 better limits (<0. 1μ**Bq/cm^2).

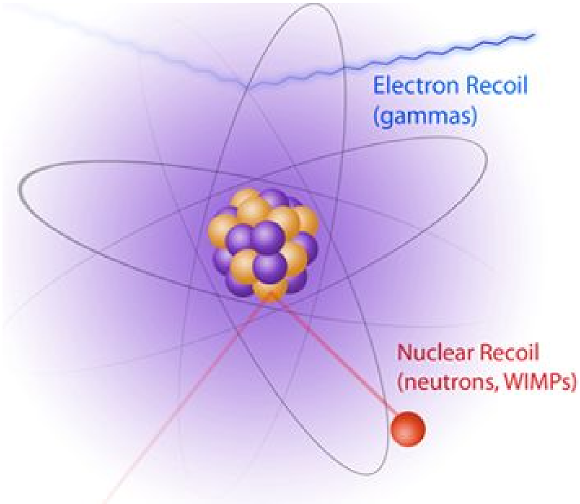
Copper



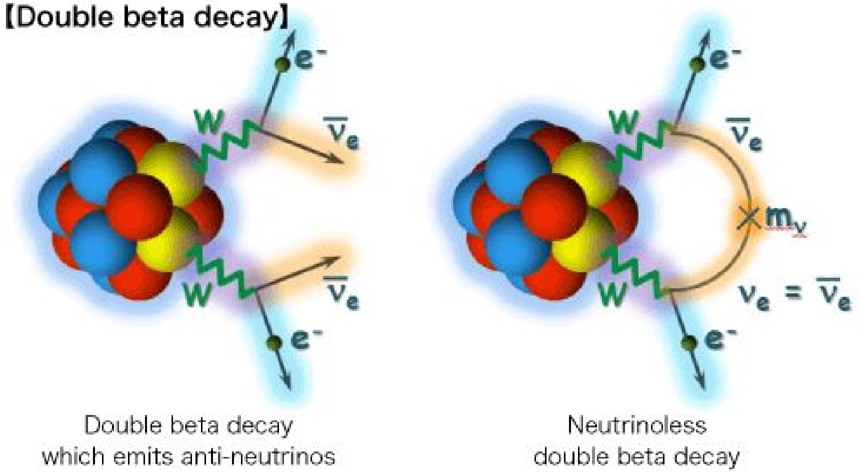
See details in
Astropart. Phys. (2011) 34, 354

Physics motivation to develop TPCs for rare event searches

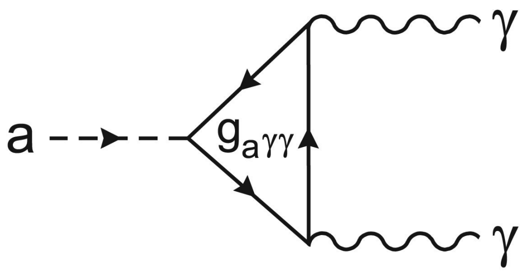
WIMPS



neutrinos



Axions



Physics case : The axion

QCD predicts violation of CP in strong interactions

$$\mathcal{L}_\theta = \frac{g^2\bar{\theta}}{32\pi^2} G^{\alpha}_{\mu\nu}\tilde{G}^{\alpha\mu\nu}$$

Bad agreement between theoretical and experimental values for the electric dipole moment of neutron

$$\Rightarrow \bar{\theta} < 10^{-9}\, e\cdot cm$$

Why is $\bar{\theta}$ so small ?

$$d_n(theory) \approx 10^{-16}\, e\cdot cm$$
$$d_n(\exp.) < 6.3\times 10^{-26}\, e\cdot cm$$

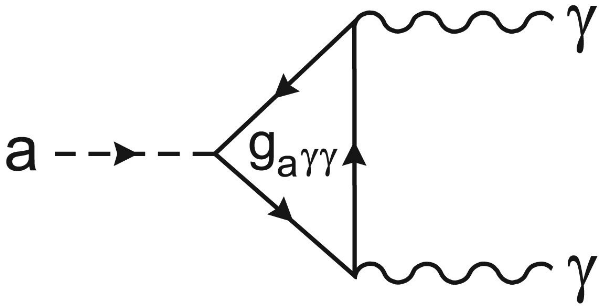
$$\bar{\theta} = \theta + Arg(\det M)$$

Peccei-Quinn introduced a field to solve this problem that could be later attributed to a new particle, the axion.

$$\mathcal{L}_a = \left(\bar{\theta} - \frac{a(x)}{f_a}\right)\frac{1}{f_a}\frac{g}{8\pi} G^{\mu\nu}_a \tilde{G}_{a\mu\nu}$$

Axion detection principle

The axion has an interaction vertex with two photons.



This enables its experimental search by using intense magnetic fields.

The magnetic field provides one of the photons in the interaction, and under the right conditions we can convert axions to photons.

We can search for
* galactic axions (haloscope searches - ADMX),
* purely laboratory generated axions (ALPS-II)
* **solar axions** (CAST, IAXO, AMELIE)

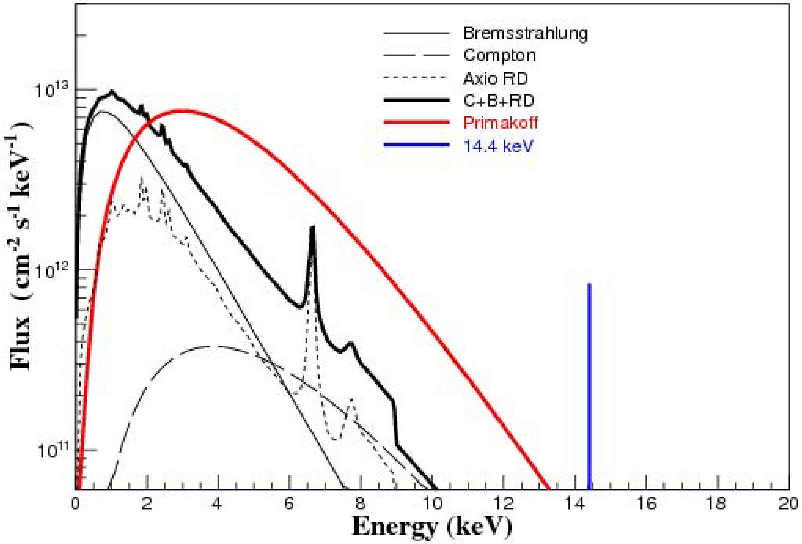
The **axion coupling to two photons** makes them really attractive from an experimental point of view.
Many detection ideas using a **magnetic field for axion-photon conversion**

The axion must have a very small mass (<eV) since otherwise we would have already observed.
Astrophysical and cosmological models place the axion mass in the ueV-meV range.

The CAST Experiment

Micromegas detectors have taken data at the CAST experiment

Earth solar axion spectrum produced in the Sun core

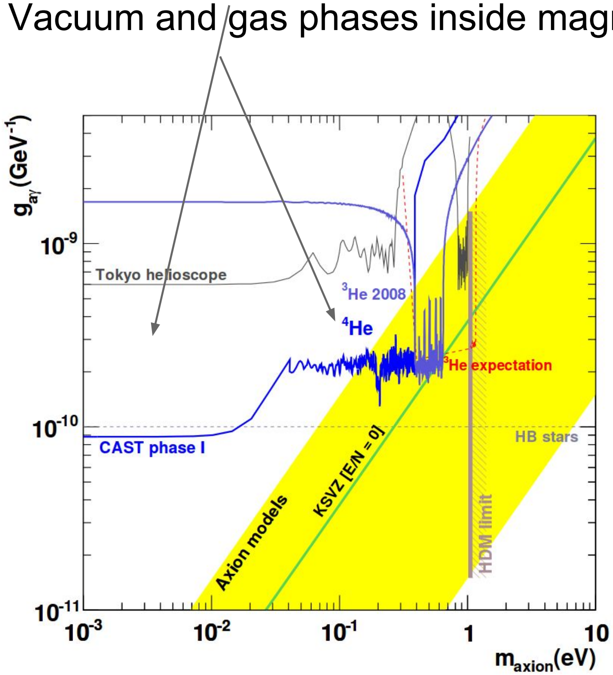


CAST magnet points to the Sun during 2x1.5h during Sunrise and Sunset.

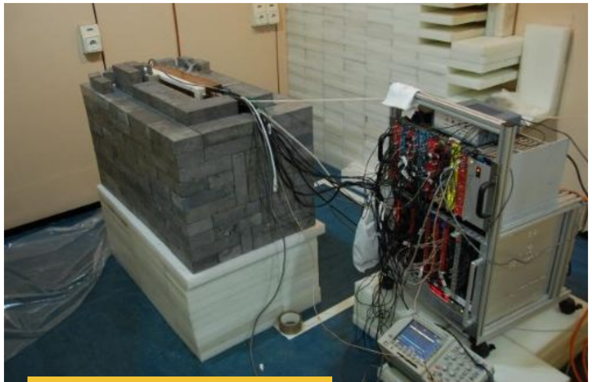
Axions are converted to X-rays and travel all the way towards the detectors at the more ends.

Several **upgrades on micromegas** detectors showed capability to reach low background levels enhancing the sensitivity of the experiment.

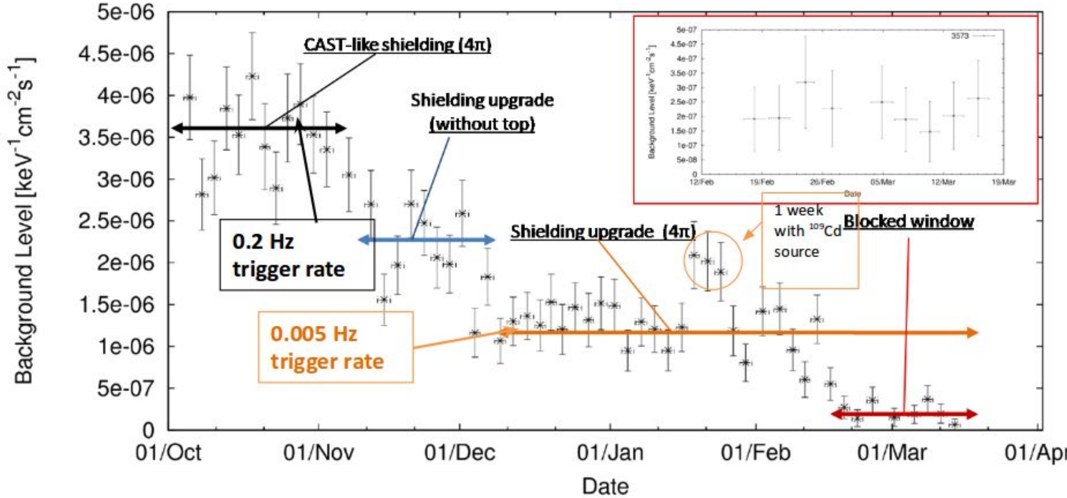
Vacuum and gas phases inside magnet



First micromegas studies for rare event searches in the framework of CAST experiment (2010-2011)



Canfranc Underground Lab



Zaragoza Lab set-up preparation

Lowest background level ever achieved by a CAST Micromegas detector.

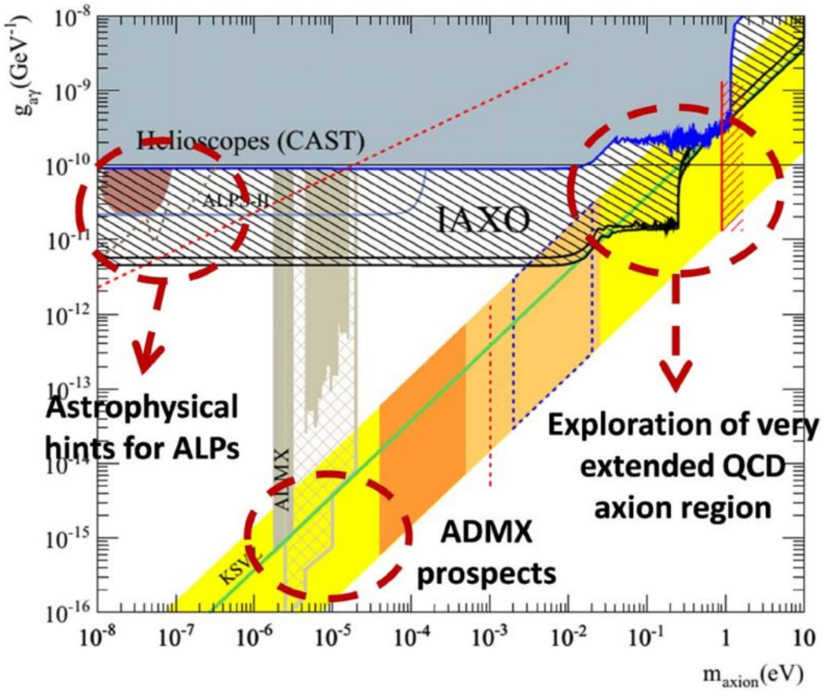
$2 \cdot 10^{-7}$ counts keV^{-1} cm^{-2} s^{-1} [2-7 keV] (~1 count/day in ROI)

Motivation of Micromegas detectors for rare event searches. IAXO, WIMPS, Double beta

J. Galan et al., Low X-ray background measurements at the Underground Canfranc Laboratory, EAS Publications Series / Volume 53 / January 2012, pp 155-163.
F. J. Iguaz et al., The discrimination capabilities of Micromegas detectors at low energy, Physics Procedia Volume 37, 2012, Pages 1079–1086.
A.Tomas et al., CAST microbulk micromegas in the Canfranc Underground Laboratory, Physics Procedia, Volume 37, 2012, Pages 478–482.

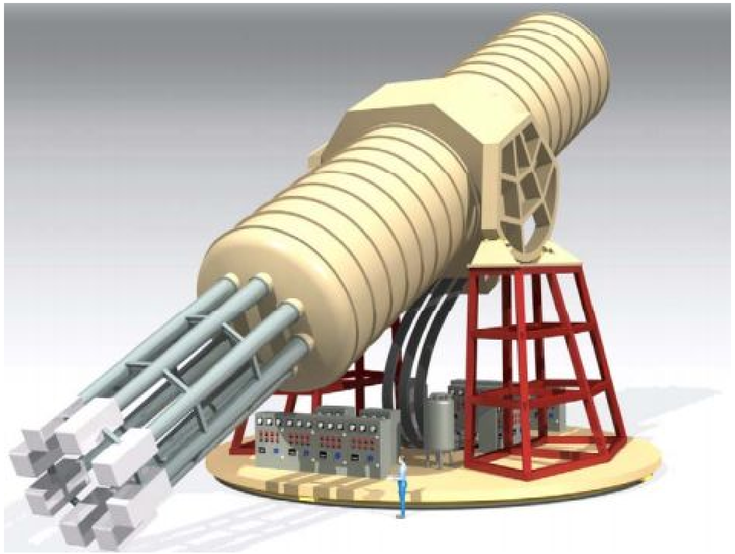
The International AXion Observatory

Prospects for a new axion helioscope based on the experience gained in the CAST Collaboration.



IAXO will use a dedicated **8-bore large area magnets**, using focusing optics and proper shielded detectors. And capable of taking data using longer exposure times.

Improving CAST signal sensitivity by 10^5-10^6



E. Armengaud [IAXO Collaboration], Conceptual design of the International Axion Observatory (IAXO), 2014 JINST 9 T05002
I.Irastorza et al., Towards a new generation axion helioscope, JCAP06(2011)013.

Vacuum versus buffer gas axion conversion

CAST was composed of two phases : vacuum and buffer gas.

For higher axion masses the coherent axion-photon conversion is lost, and we need to introduce an effective mass to the virtual photon participating in the interaction.

Axion-photon conversion probability in a transversal magnetic field

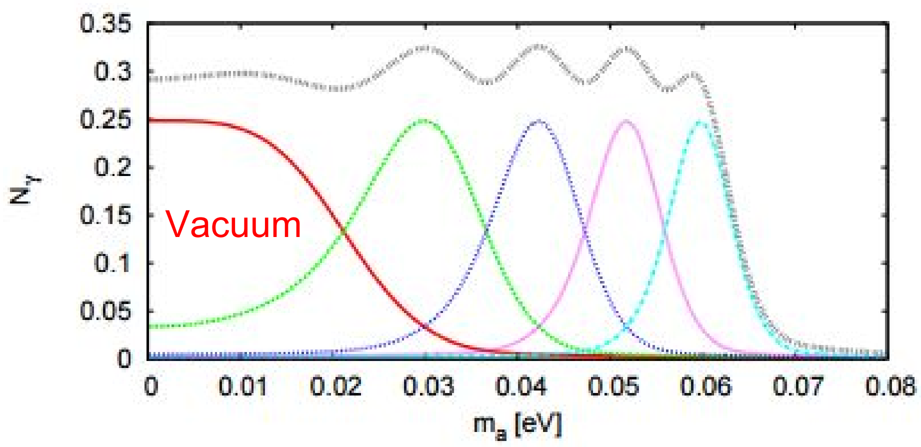
$$P_{a\to\gamma} = 1.6278 \cdot 10^{-17} \left(\frac{BL}{B_{cb}L_{cb}}\right)^2 \left(\frac{g_{a\gamma}}{10^{-10}\,\mathrm{GeV}^{-1}}\right)^2 \mathcal{M}(q,L)$$

Vacuum :

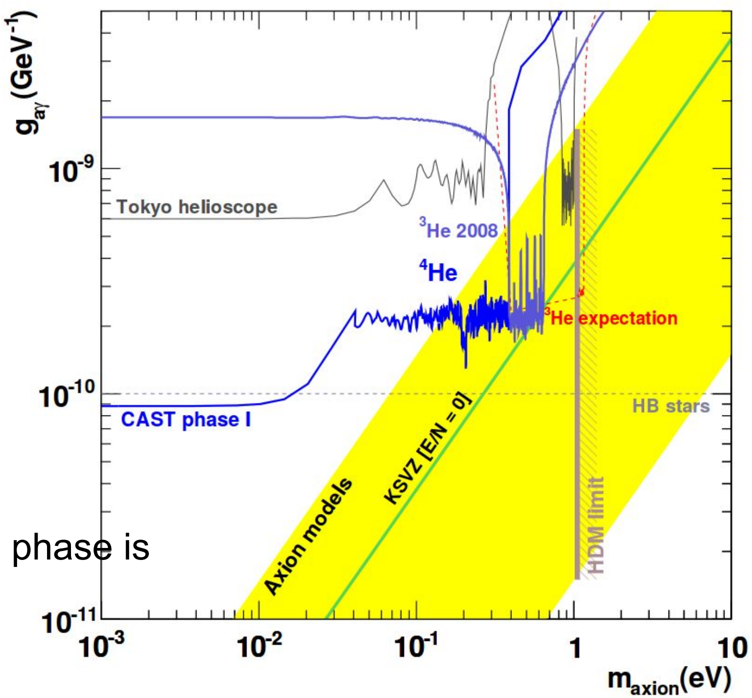
$$\mathcal{M}(q,L) = \frac{2}{(qL)^2}\left[1-\cos(qL)\right].$$

Gas buffer :

$$\mathcal{M}(q,L) = \frac{1}{L^2(q^2+\Gamma^2/4)}\left[1+e^{-\Gamma L}-2e^{-\Gamma L/2}\cos(qL)\right]$$



Vacuum and gas phases inside magnet

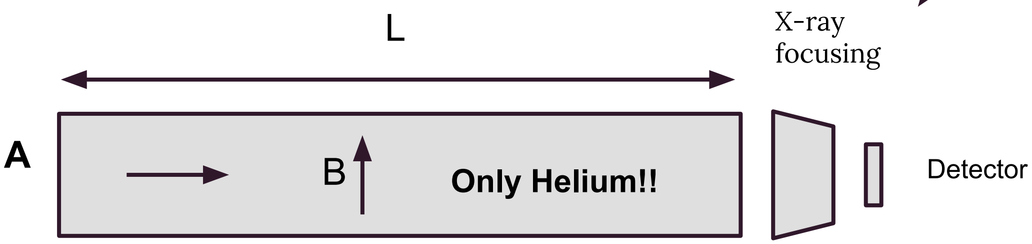


4He phase is

A new helioscope concept based on large volume TPCs

Photons detected **at the end** of magnet bore

Tracking Helioscope method (CAST,IAXO, Sikivie)

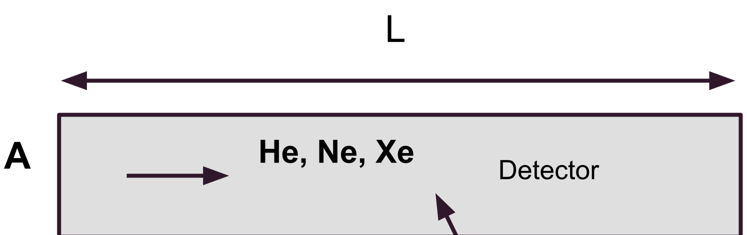


Number of photons found at a distance L

$$P_\gamma = \frac{(B/2M)^2}{q^2 + \Gamma^2/4}\left[1 + e^{-\Gamma L} - 2e^{-\Gamma L/2}\cos(qL)\right]$$

Starts to be competitive for higher masses ~ 100meV

Absorption Helioscope Method (AMELIE, Galan)



Photons detected **inside** the magnet bore

Number of photons absorbed along a distance L

$$P_\gamma = \frac{(B/2M)^2}{q^2 + \Gamma^2/4}\Gamma L$$

Seminal papers on axion helioscopes were proposing something similar already in 1989

VOLUME 51, NUMBER 16 PHYSICAL REVIEW LETTERS 17 OCTOBER 1983

Experimental Tests of the "Invisible" Axion

P. Sikivie
Physics Department, University of Florida, Gainesville, Florida 32611
(Received 13 July 1983)

1983

THIRD SERIES, VOLUME 39, NUMBER 8 15 APRIL 1989

Design for a practical laboratory detector for solar axions

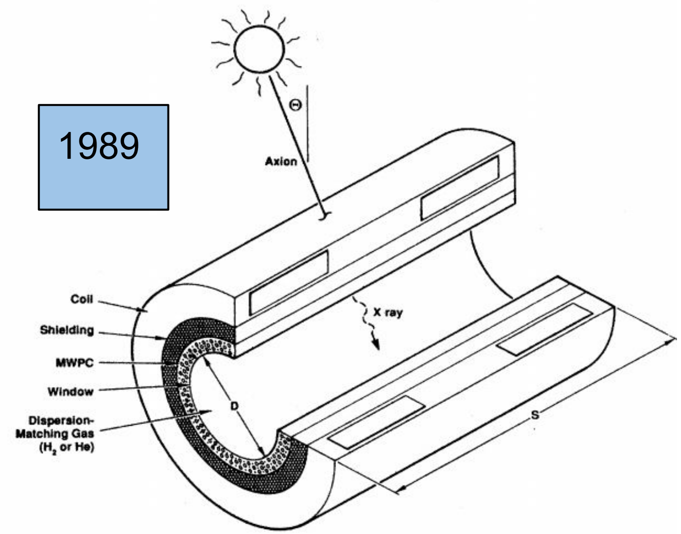
K. van Bibber
Physics Department, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550

P. M. McIntyre
Physics Department, Texas A&M University, College Station, Texas 77843

D. E. Morris
Physics Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720

G. G. Raffelt
Institute for Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, University of California, Livermore, California 94550
and Astronomy Department, University of California, Berkeley, California 94720
(Received 19 September 1988)

1989



A new helioscope idea based on large volume low background TPC developments.

Exploring 0.1-10 eV axions with a new helioscope concept.

J. Galán[a], T. Dafni[a], E. Ferrer-Ribas[b], I. Giomataris[b], F.J. Iguaz[a], I.G. Irastorza[a], J.A. García[a], J. Gracia[a], G. Luzon[a], T. Papaevangelou[b], J. Redondo[a], A. Tomás[a] [1]

The main difference in the new idea is that TPC and conversion volume are exactly the same entity.

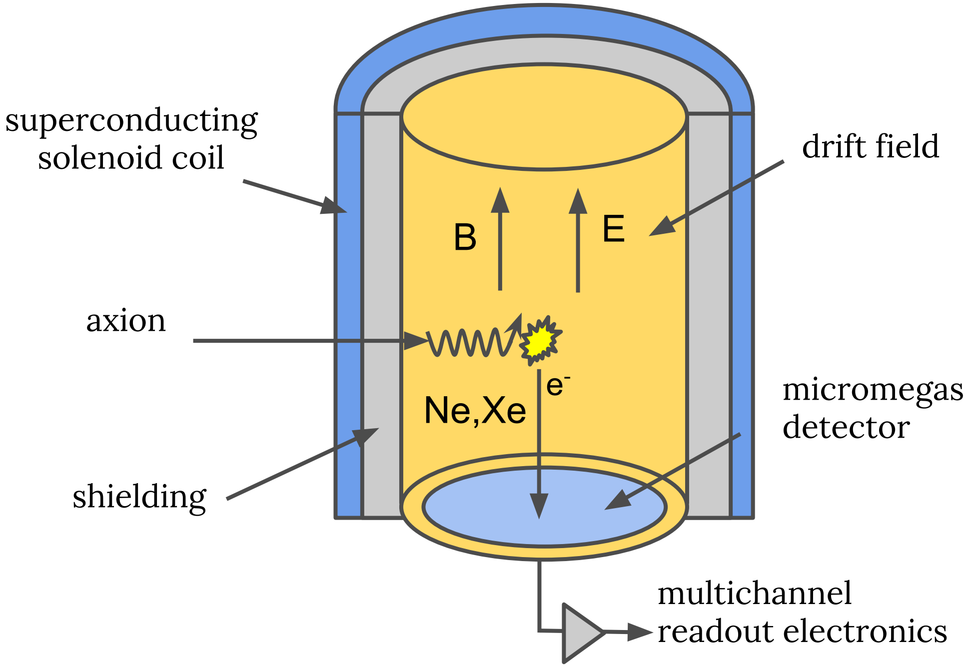
This allows to increase efficiency to the higher axion mass accessible with a buffer gas, since **higher Z gases are possible**.

This **helioscope is stationary** gaining on experimental setup stability.

Always there is a transversal field component present, 24 hours tracking with full angular efficiency, meaning that **we can place it underground**.

An Axion Modulation hELIoscope Experiment (AMELIE)

Idea : A stationary underground TPC immersed in a magnetic field (Galan, 2015) [arXiv:1508.03006]



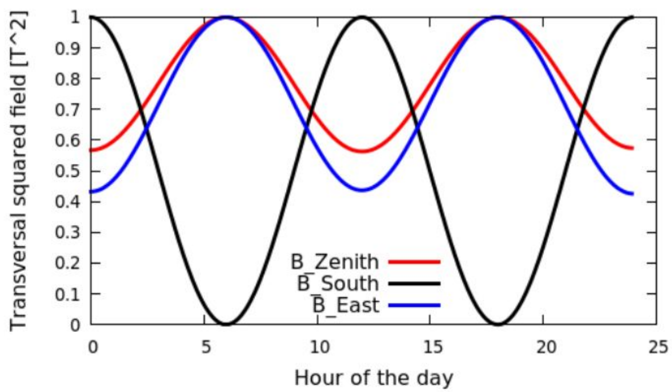
Main difference with proposed 1989 axion helioscope resides on the fact that buffer gas and detection volume are the same.

Possibility to use higher Z gases.

75% Efficiency 24 hours tracking!

Transversal magnetic field component along the day.

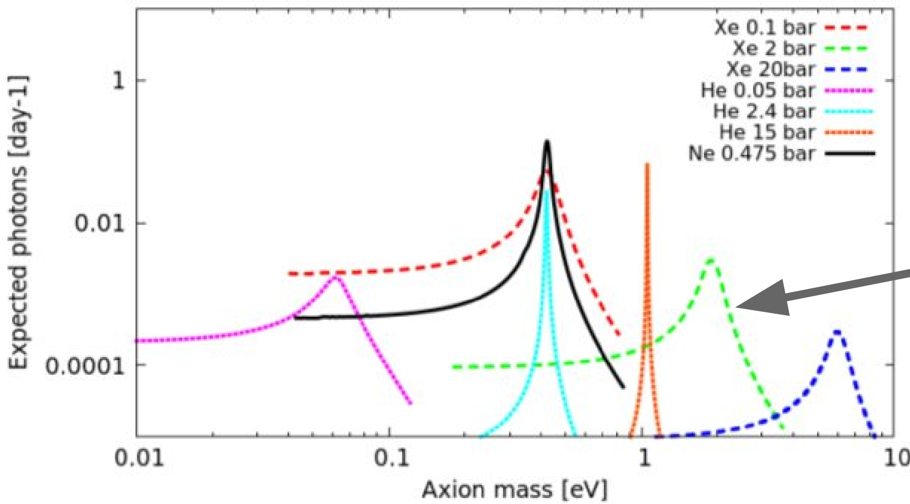
DAILY SIGNAL MODULATION



Axion mass and wide angular range coverage

Pressure versus axion mass for different gases

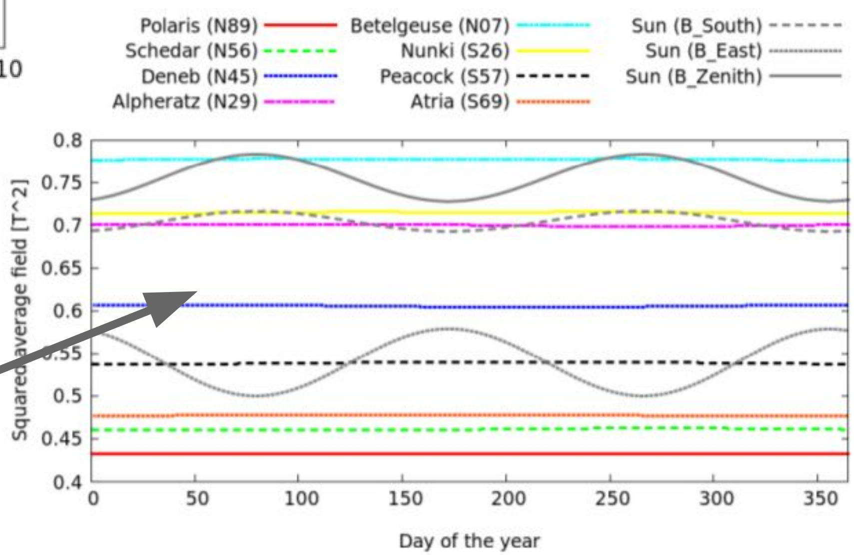
Helium	Neon	Argon	Xenon
100 mbar - 10 bar	20 mbar - 10 bar	4 mbar - 10 bar	4 mbar - 10 bar
86 meV - 0.86 eV	137 meV - 1.94 eV	51 meV - 2.57 eV	79 meV - 4.05 eV



The sensitivity to a particular axion mass depends on the TPC gas density.

Higher Z-gases have wider axion mass resonances. Wider mass scan.

AVERAGED YEAR SIGNAL MODULATION



Is not a directional helioscope. But we have full angular coverage.

Efficiency depends on the position in the sky.

Axion mass and wide angular range coverage

Pressure versus axion mass for different gases

Helium	Neon	Argon	Xenon
100 mbar - 10 bar	20 mbar - 10 bar	4 mbar - 10 bar	4 mbar - 10 bar
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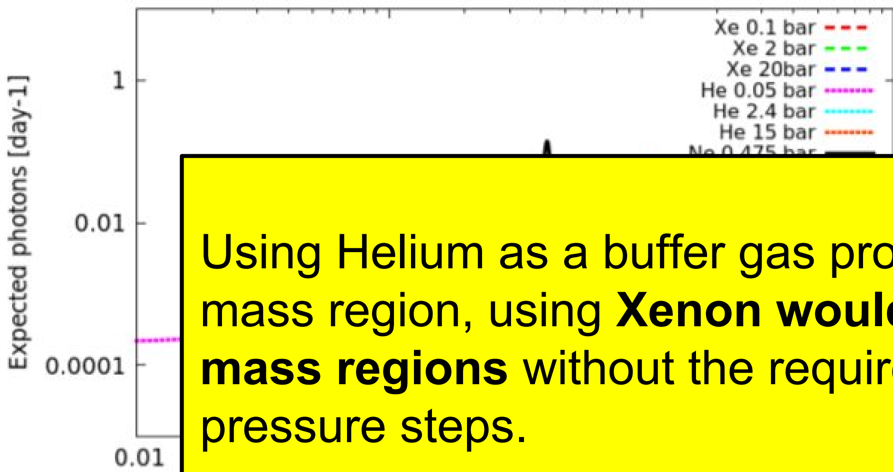


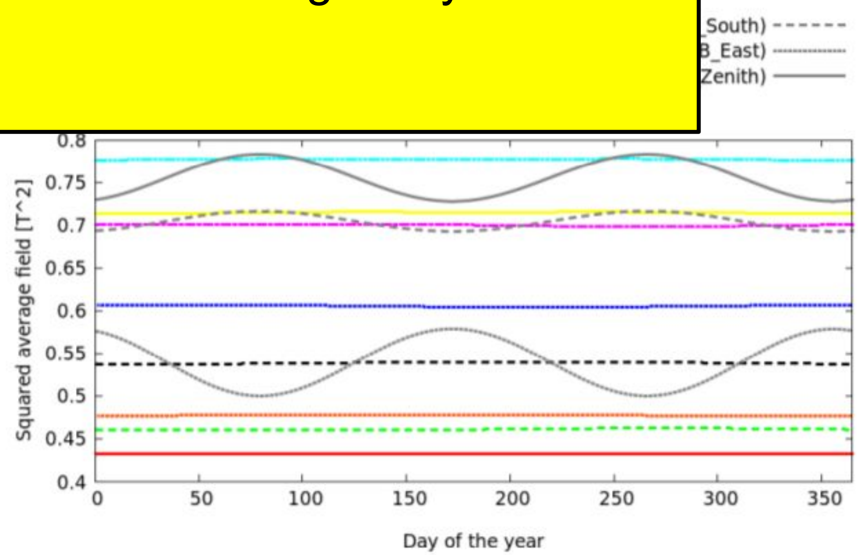
The sensitivity to a particular axion mass depends on the TPC gas density.

on mass

Using Helium as a buffer gas provides sensitivity to a thin axion mass region, using **Xenon would allow to scan wider axion mass regions** without the requirement of taking many different pressure steps.

Is not a directional helioscope. But we have full angular coverage.

Efficiency depends on the position in the sky.



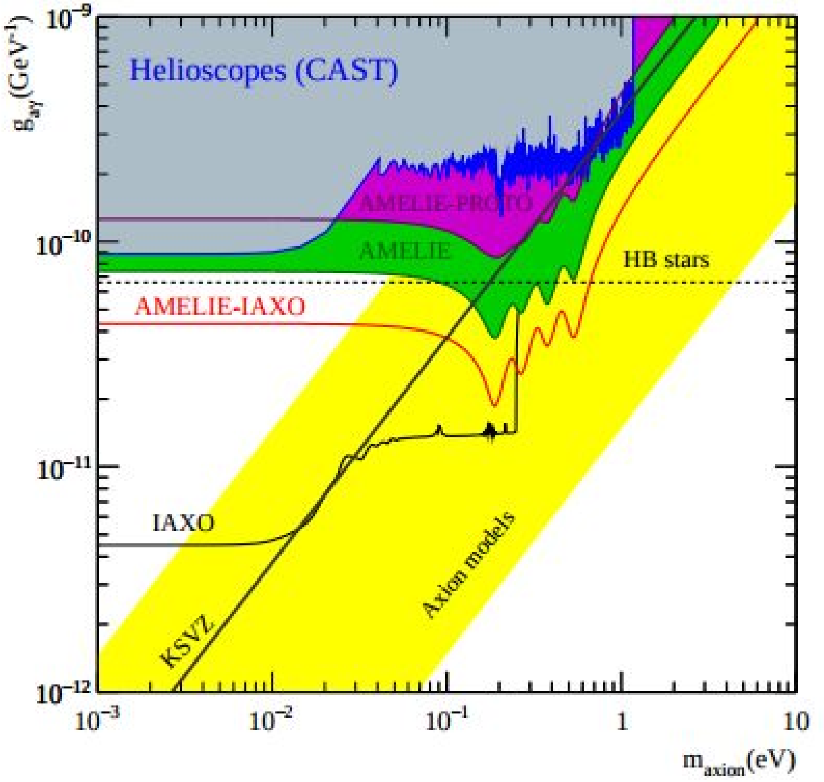
Sensitivity prospects for AMELIE

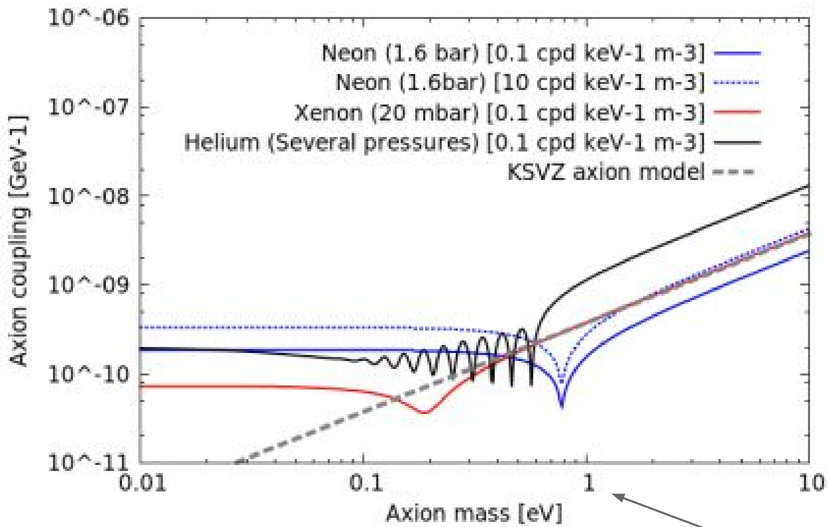
J.Galan et al. JCAP12(2015)012

Xenon at 20mbar, 40 mbar, 80 mbar and 160mbar

AMELIE-PROTO : 5 years. Volume = 21dm^3. Bck : 1cpd/m^3/keV

AMELIE : 5 years. Volume = 0.8m^3. Bck : 0.1cpd/m^3/keV





Sensitivities reachable operating at different buffer gases, and background levels.

Each curve has been calculated for a 5 years data taking program. For a 1m3 scale 5T TPC.

Physics case : Neutrino nature

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.**

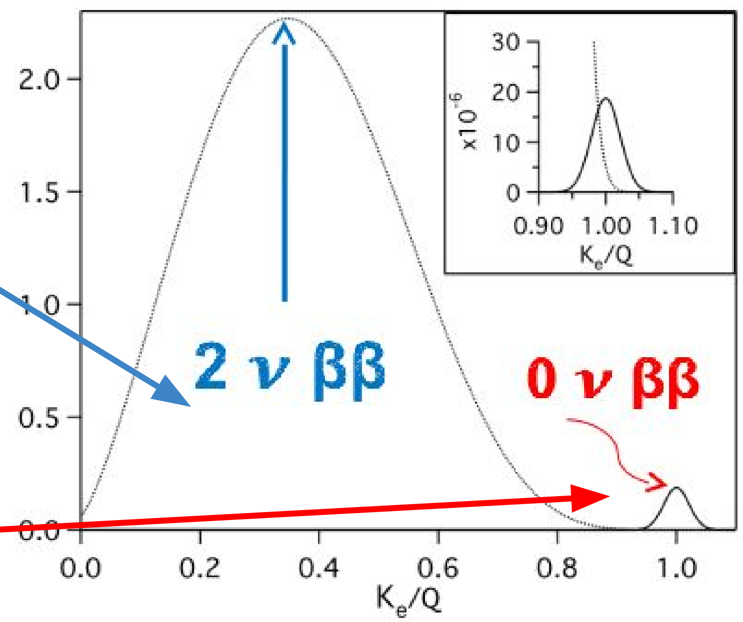
Neutrinoless double beta decay

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

(A, Z) → (A, Z + 2) + 2e⁻ + 2ve

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

(A, Z) → (A, Z + 2) + 2e⁻

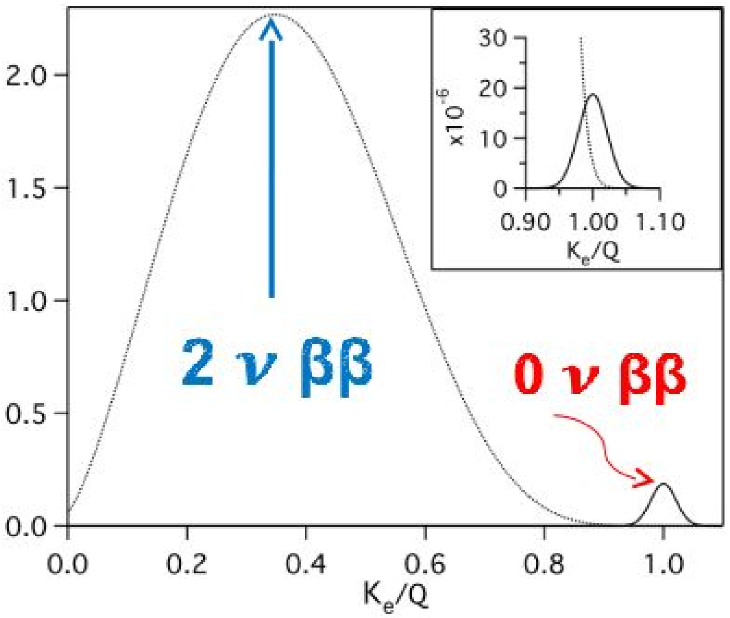


Neutrinoless double beta decay

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

Mainly to separate 2ν**ββ** process from 0ν**ββ** and any <u>other backgrounds</u>.

Good energy resolution required



Neutrinoless double beta decay

This process occurs with very low probability.

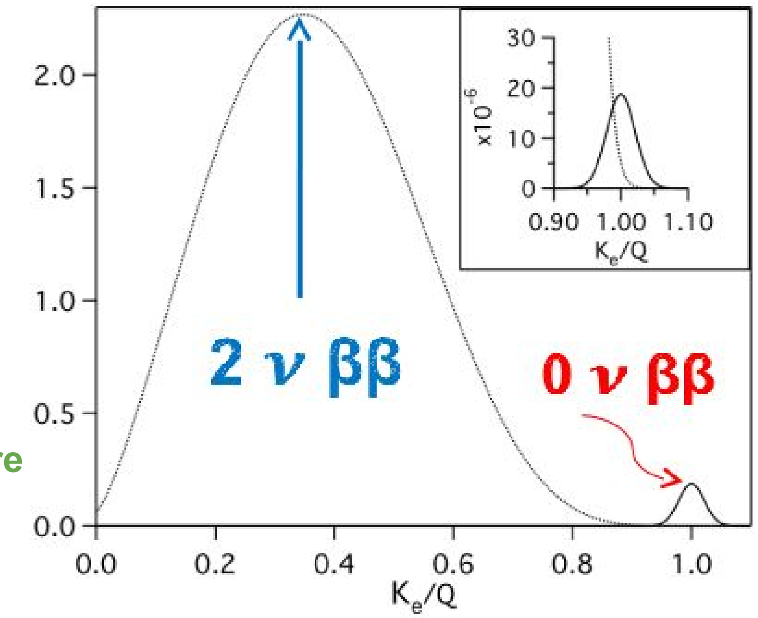
In practice, what we measure is the lifetime of the decay

isotopic abundance

mass exposure

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

background



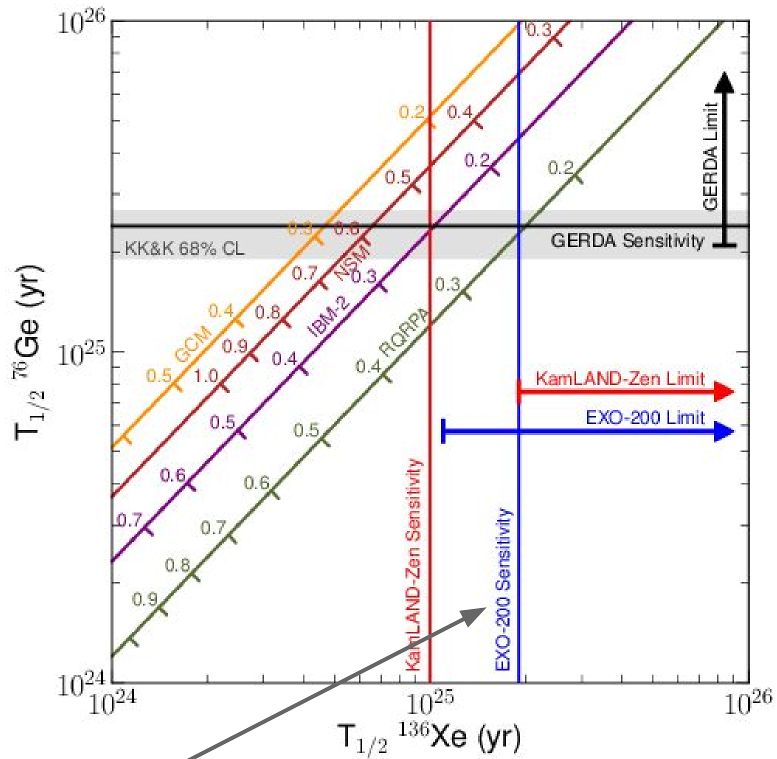
Status of $\beta\beta0\nu$ searches

Few isotopes can have 0vββ decay channel:

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

Many experiments have been searching and search for 0vββ (CUORE, Gerda, KamLand, etc).

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 $\beta\beta0\nu$ isotope

What matters on isotope selection is just the mass

Using Xenon

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**.

Additional advantage of Xenon

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

A gaseous Xenon TPC for $\beta\beta 0\nu$ searches

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

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

Constant up to 50bar

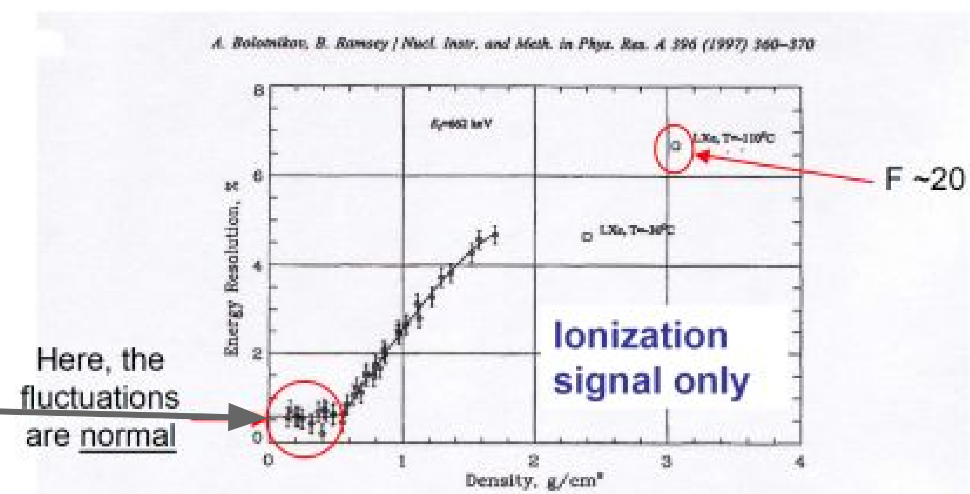
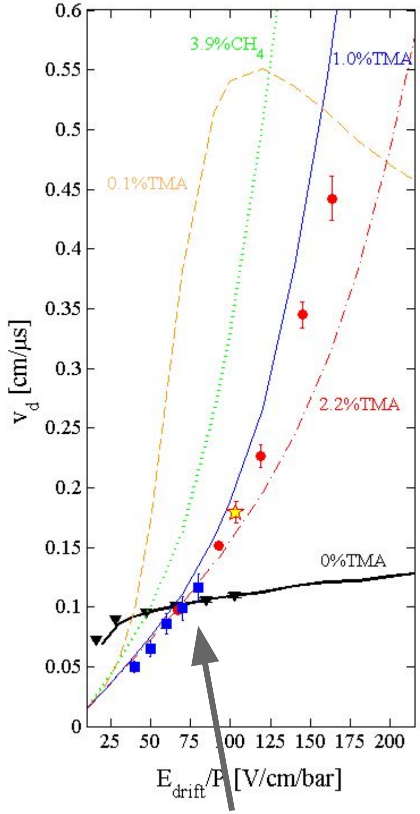


Fig. 5. Density dependencies of the intrinsic energy resolution (%FWHM) measured for 662 keV gamma-rays.

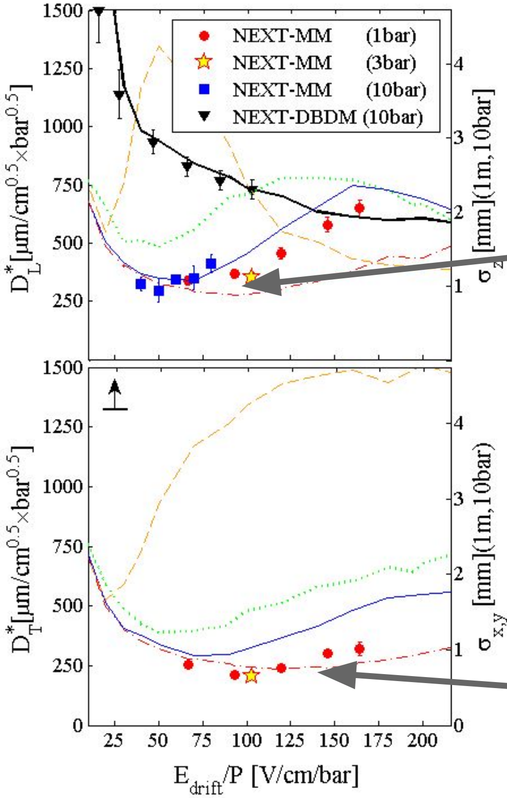
For ρ <0.55 g/cm^3, ionization energy resolution is "intrinsic"

Additional benefits of using a Xenon+TMA mixture

A very important feature when we want to do pattern recognition. Specially in large chambers.



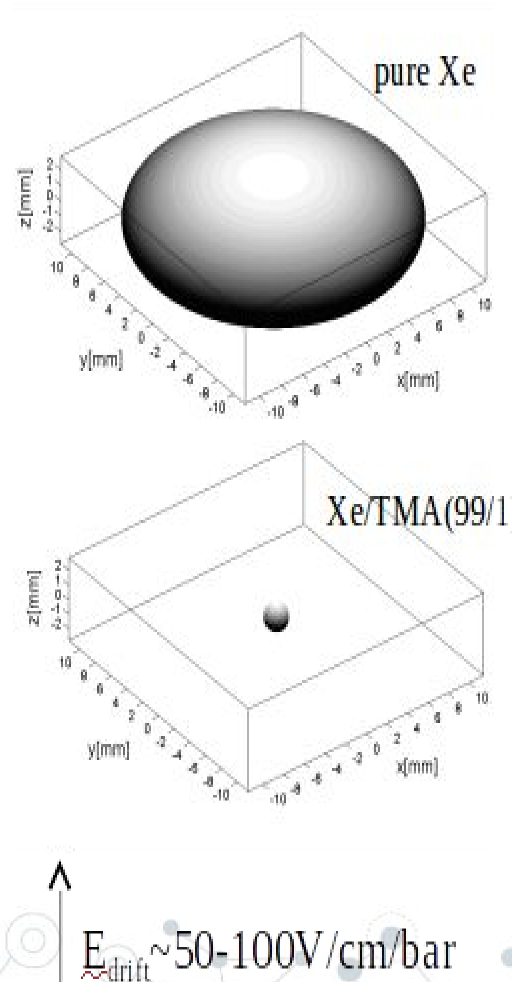
comparable drift velocities



x3 lower longitudinal diffusion

x10 lower transversal diffusion

A pointlike deposit after 100cm drift



Additional benefits of using a Xenon+TMA mixture

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

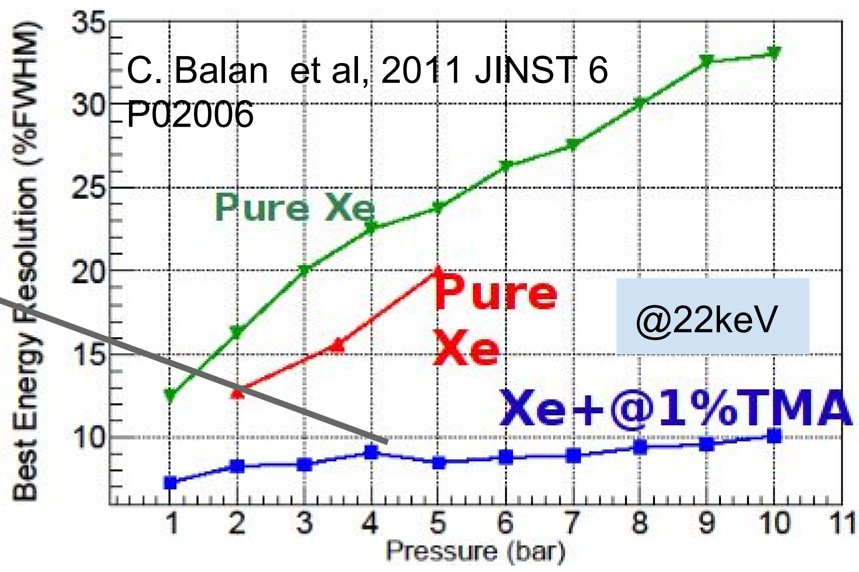
Required energy resolutions for **0νββ** can be achieved using Micromegas microbulk technology.

0.9% FWHM @ Q**ββ** for 10bar

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

3% FWHM @ Q**ββ** (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).



Improving sensitivity

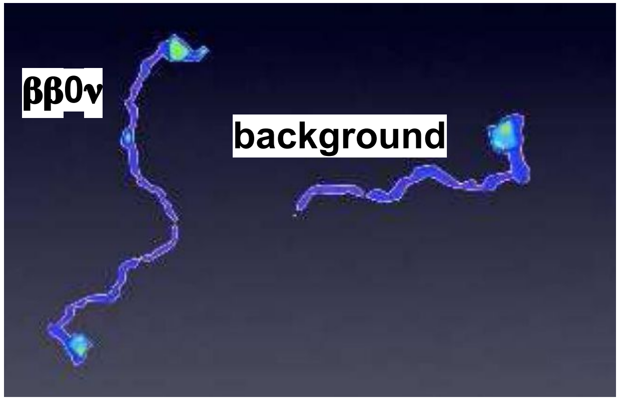
Once the mass has been fixed the only way to improve sensitivity is to reduce the background level of the detector at the Xenon ROI.

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

background

energy resolution

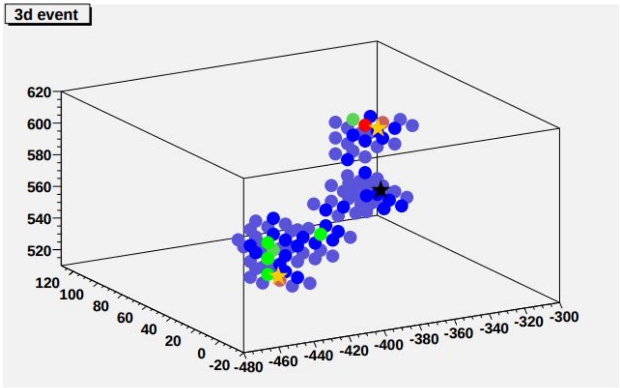
$$Q_{\beta\beta} = 2457.83\ keV$$

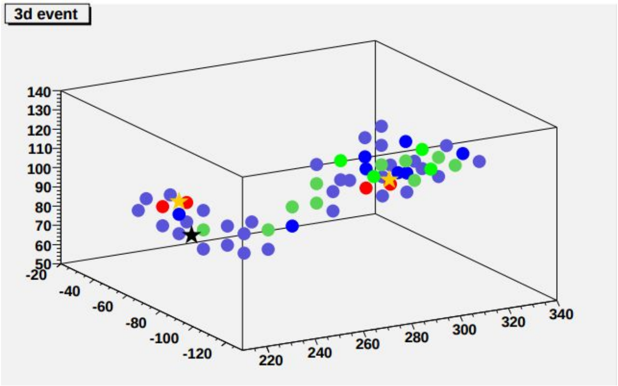


We require ...

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

Topological discrimination



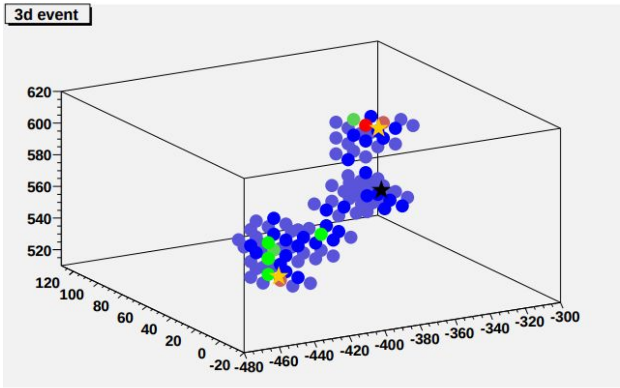


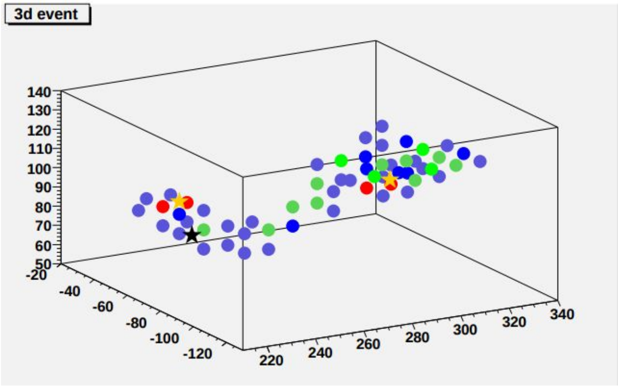
A neutrinoless double beta decay has a very particular topology that can be exploited in gaseous detectors.

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.

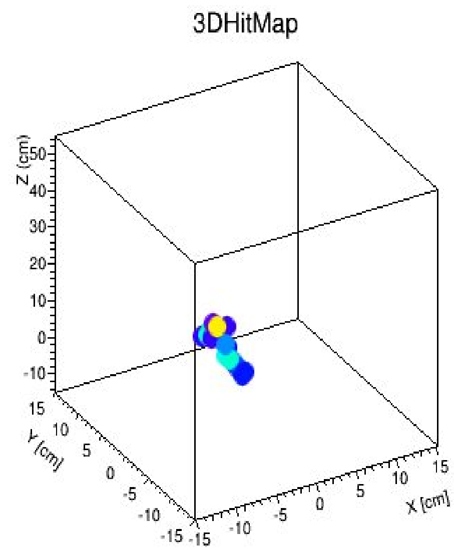
Importance of diffusion

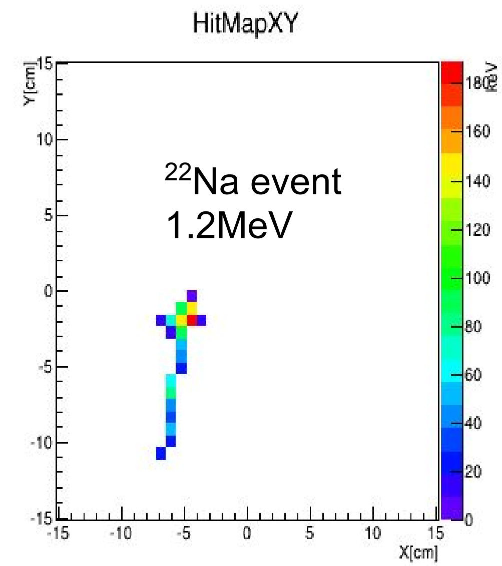
These studies show also that lower diffusion increases rejection at least by a factor 3 (respect to higher diffusion, Pure Xenon).

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**



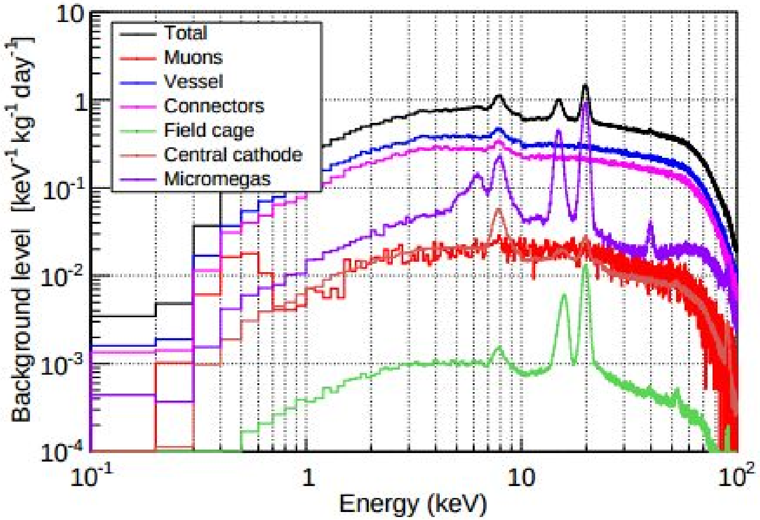


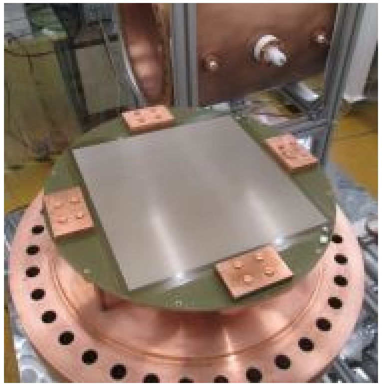
T-REX DM

T-REX Prototype

T-REX is an ERC funded project for development of micromegas for rare event searches at the University of Zaragoza.

TREX-DM chamber shown here will be installed at Canfranc Underground Laboratory (2016)





Extracted from reference : arXiv:1503.07085

Background model: Higher contributions coming from vessel, connectors and micromegas.

Publications on the framework of T-REX

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

Several review papers on T-REX for rare event searches will be soon published

The PandaX-III experiment

The group at the University of Zaragoza got involved in the PandaX-III proto-collaboration for 0nuDBD. The experiment is willing to use micromegas technology for the construction of a large volume TPC.

- 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.

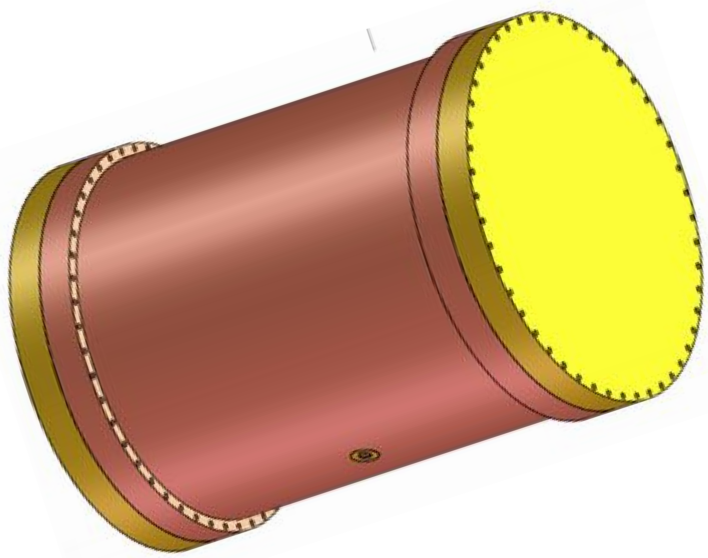
Zaragoza (UZ), Berkeley (LBNL), Shanghai (SJTU)

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

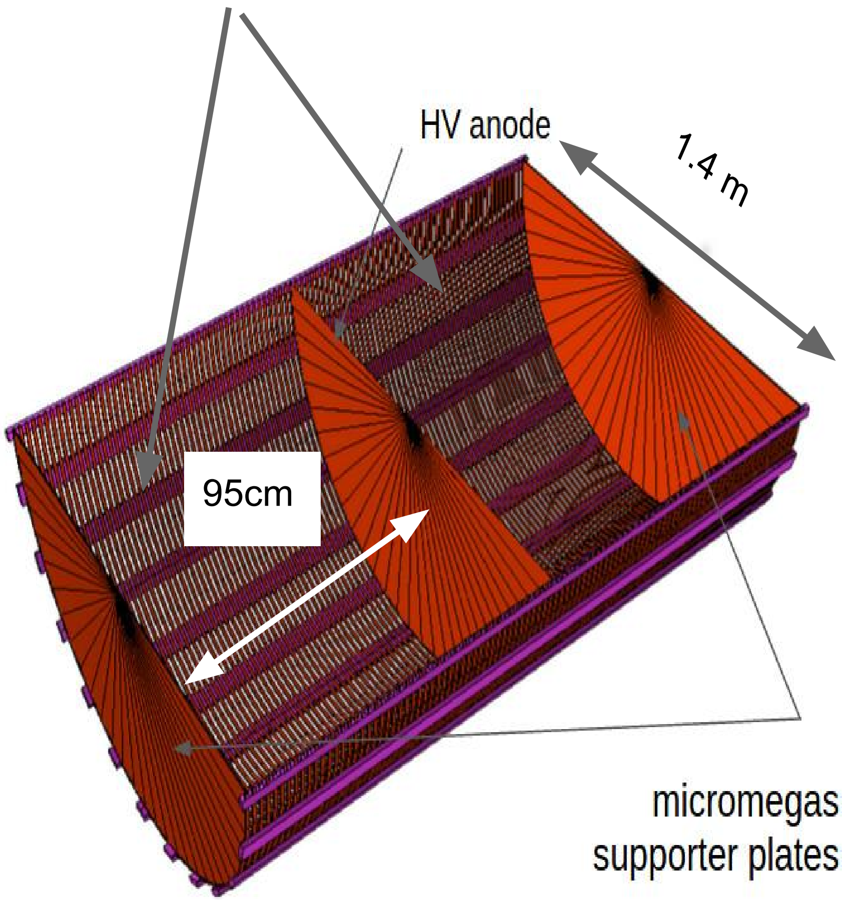
Preliminar PandaX-III vessel design

4m^3 volume, 8-tons radiopure copper

3cm thickness + 15cm endcap



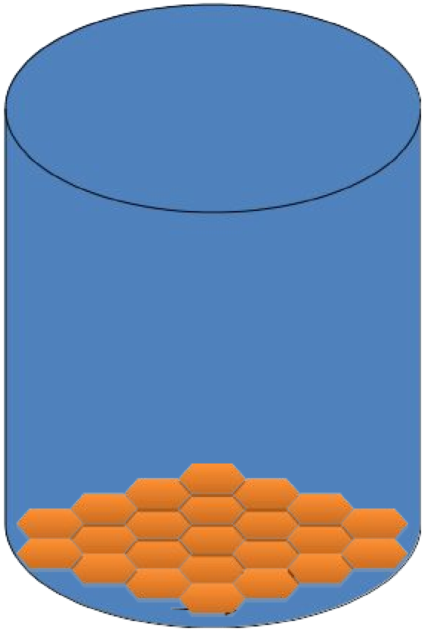
Splitted in 2-TPC sides



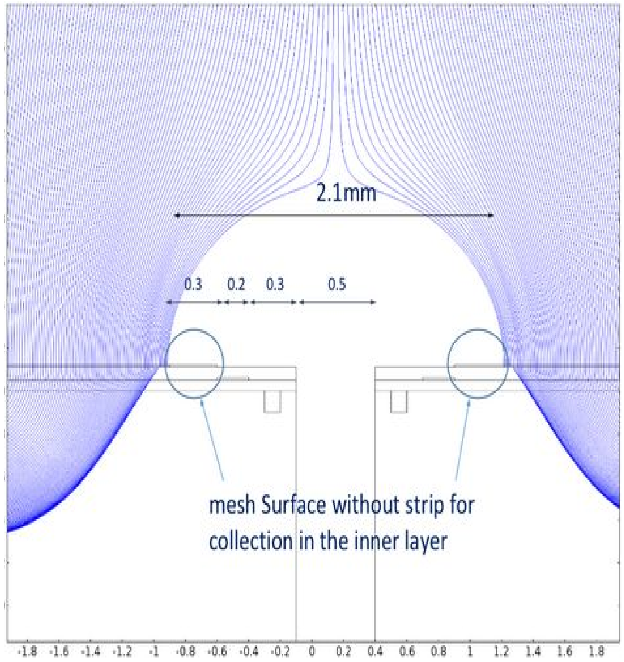
Micromegas-read TPC implementation

Microbulk micromegas cannot be produced yet in large areas

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

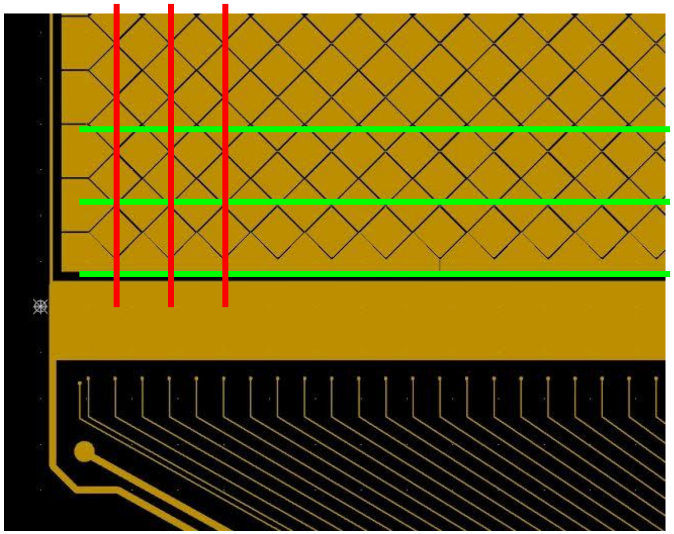


To avoid charge losses in the interfaces a correcting field will be used.



Micromegas readout test for PandaX-III

A stripped readout with interconnected pixels



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

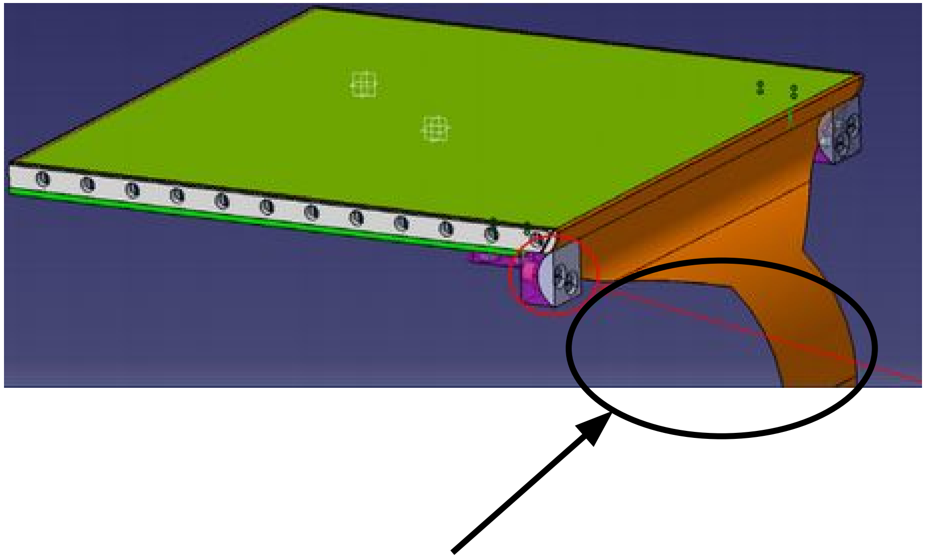
Several **AGET** cards, provided by CEA Saclay, ready to be used in micromegas testing benches.

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

AGET provides self trigger **time signal for every channel**

Micromegas module preparation

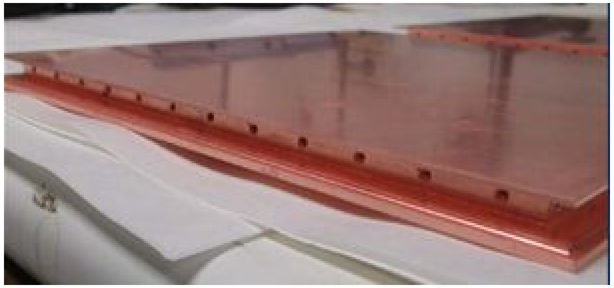
Micromegas module concept design



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

Copper pieces preparation

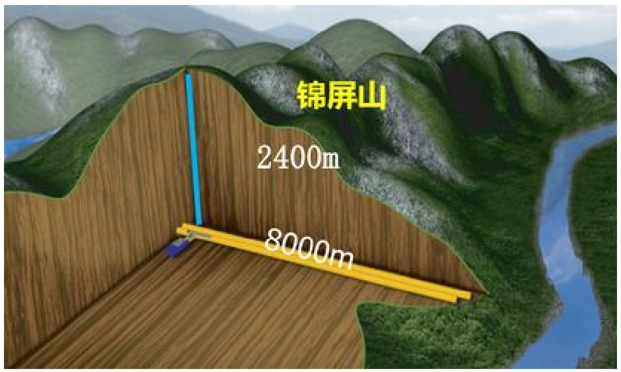
gluing tool



PandaX-III Underground dedicated space

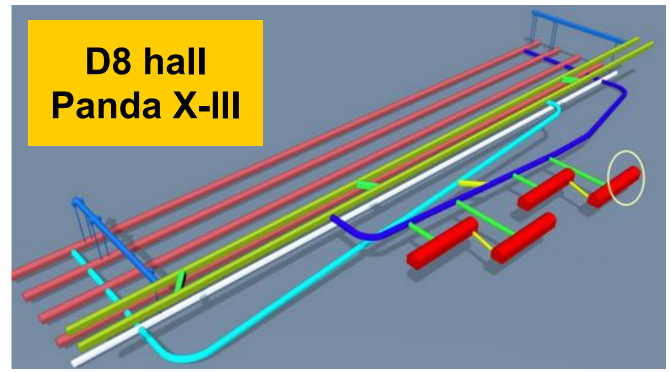
Panda X-III will be installed at the Jinping Underground Lab

(deepest in the world - 1μ/week/m^2)



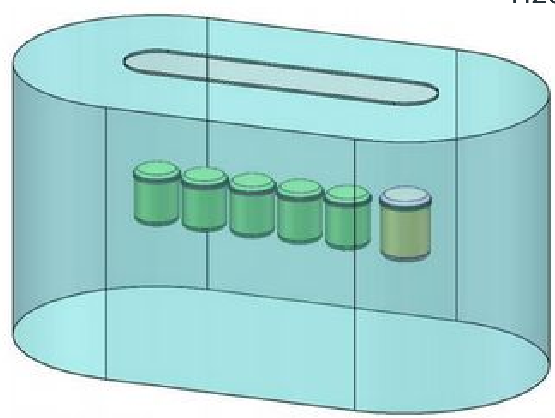
Upgrade : CJPL-II under construction

8 experimental halls 65m long



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$_{H20}$



Background contribution of the different detector components of PandaX-III

Assumed
Most of th

Detector component	Mass, surface or volume	Isotope	Activity	$b_{ROI}^{\sigma 1\%}$ ($keV^{-1}\,Kg^{-1}\,y^{-1}$)
Vessel	7721.74 Kg	Th^{232}	1 μBq/Kg	1.71×10^{-4}
		U^{238}	1 μBq/Kg	3.81×10^{-4}
		Co^{60}	100 μBq/Kg	7.67×10^{-3}
Electronics	Not used	Th^{232}	1 Bq	2.22×10^{-3}
		U^{238}	1 Bq	4.98×10^{-4}
		Co^{60}	1 Bq	-
μMs readout	$130.69\,dm^2$	Th^{232}	$0.1\,\mu Bq/cm^2$	1.59×10^{-3}
		U^{238}	$0.1\,\mu Bq/cm^2$	3.01×10^{-4}
Gas	$3.5\,m^3$	Rn^{222}	$10\,\mu Bq/m^3$	2.15×10^{-4}
Field cage rings	176.79 Kg	Th^{232}	1 μBq/Kg	2.9×10^{-5}
		U^{238}	1 μBq/Kg	7.7×10^{-4}
Field cage supporters	79.2 Kg	Th^{232}	1.1 μBq/Kg	1.32×10^{-4}
		U^{238}	9.6 μBq/Kg	2.66×10^{-3}
Water	1.18×10^5 kg	^{238}U	1 μBq/kg	1.480×10^{-4}
		^{232}Th	1 μBq/kg	4.000×10^{-4}

The goal of PandaX-III is to keep the background level at **10^{-2} - 10^{-3} cpy keV^{-1} Kg^{-1}**

The spherical TPC concept

An original idea of I. Giomataris

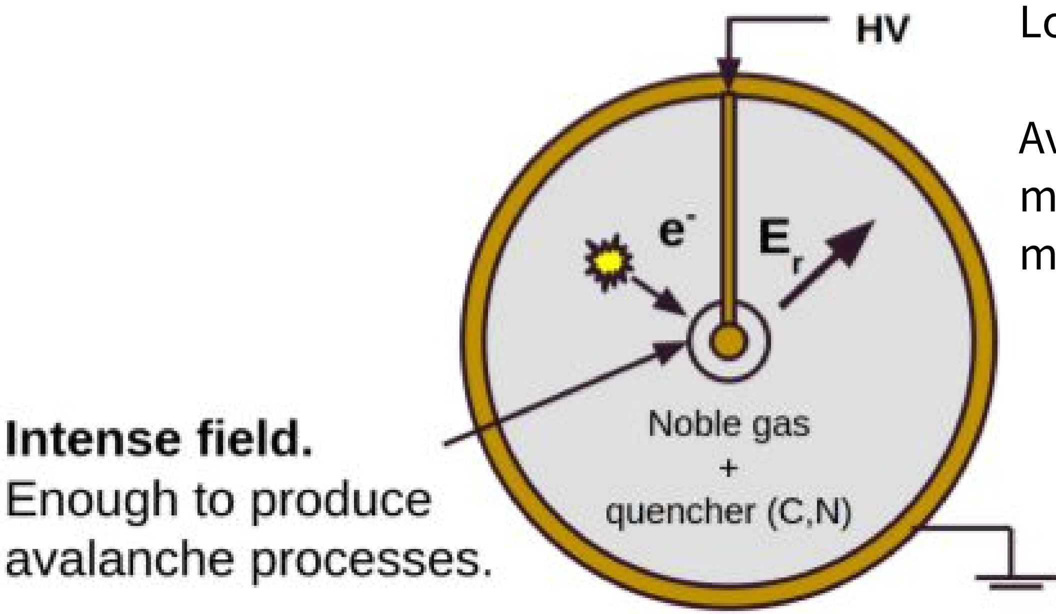
Development at CEA Saclay
using an old LEP cavity.

Vessel and field cage are the same entity

Single channel

Low energy threshold

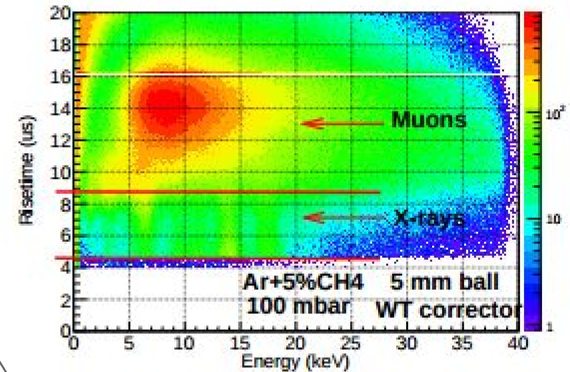
Avalanche produced within a few microns from the sensor. Reducing macroscopic fluctuations on avalanche.

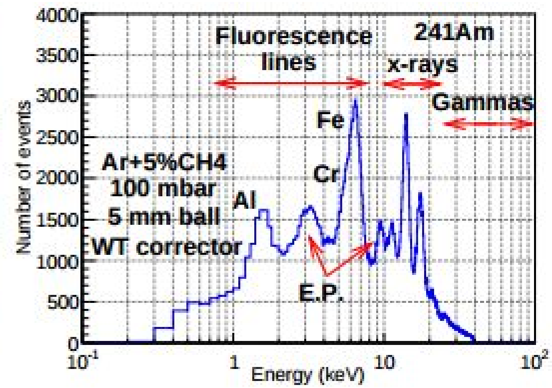


A spherical TPC for rare event searches

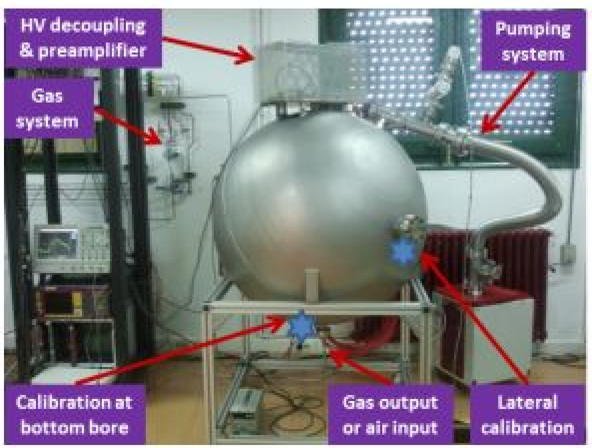
Good discrimination capabilities exploiting time signal of a **single channel.** Pulse shape dependence.

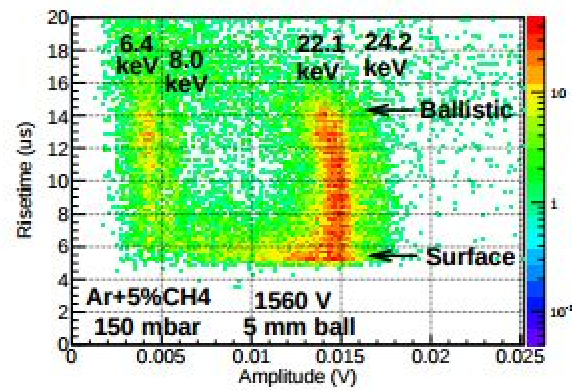
Spatial origin. Fidutialization cuts.

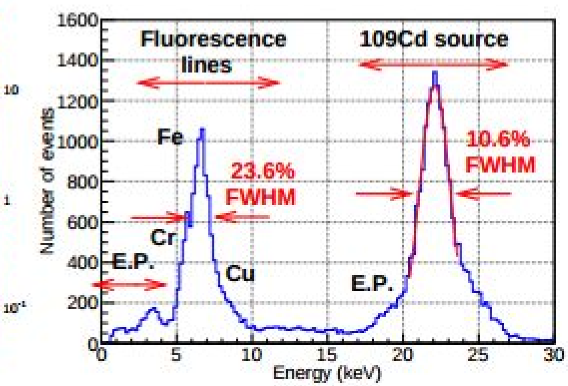




Spherical TPC installed
at U. Zaragoza (Spain)



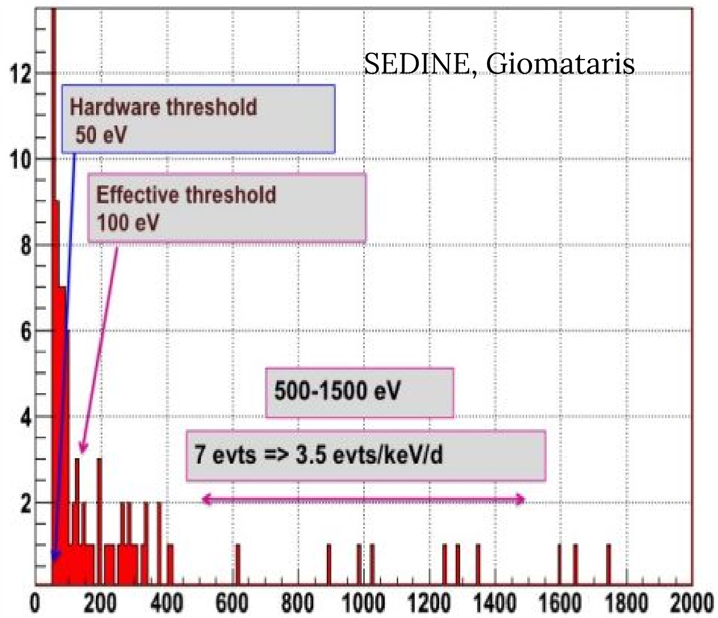




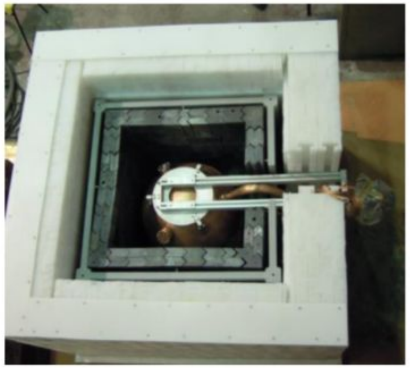
A spherical TPC taking data at Modane Underground Lab

SEDINE Spherical TPC [arXiv:1412.0161] (2014)
Background about **30 counts/day/keV/m³** is still limited by external gamma (factor 3 reduction expected)

Background level, **low energy region** bellow 2keV!



SEDINE Installation inside shielding



SEDINE Spherical vessel

Low energy threshold only limited by the ionization potential of the gas.

Good energy threshold

Excellent for low mass WIMP searches

A spherical TPC for neutrinoless double beta decay searches?

Idea (Giomataris) : Use a single spherical TPC hosting 1 tonne Xenon at 50 bar.

Advantages

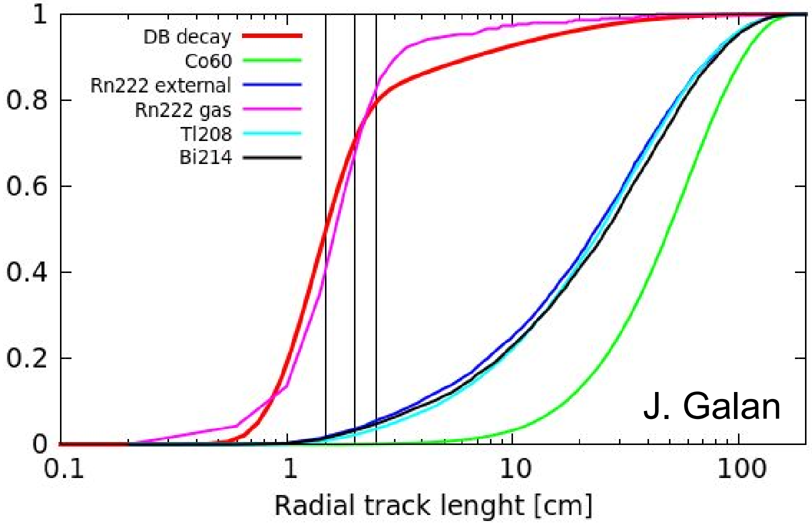
Volume maximization. Field cage and vessel are the same entity.

Simplified design. One single channel required. **Non-radiopure electronics minimization.**

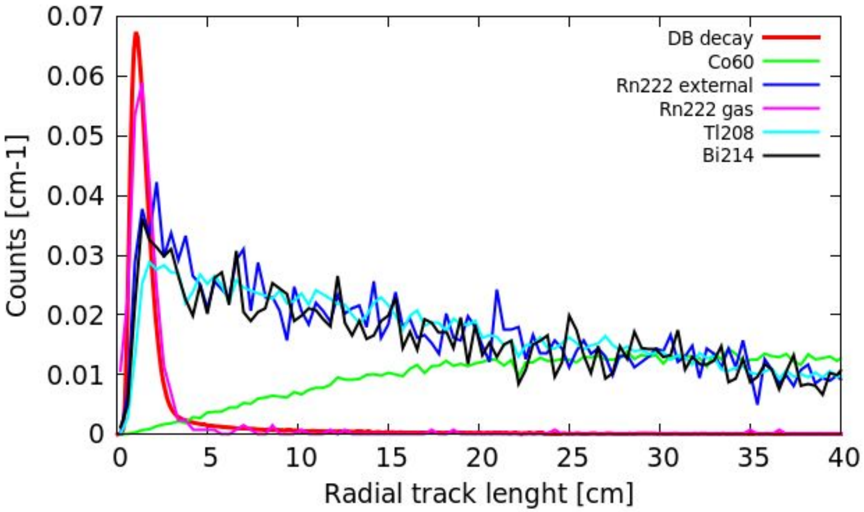
Excellent energy resolution. Noise from a single channel, and **low capacitance given by spherical geometry.**

Reduced number of components. Better intrinsic radiopurity.

A preliminar study shows that background levels of the order
10^{-4} - 10^{-5} cpy kg^{-1} keV^{-1}
could be achievable



Still room for background rejection using a single channel!



REST: Rare Events Software for TPCs

Based on the knowledge, experience and existing code developed for micromegas detectors at University of Zaragoza.

Now developing REST v2.0 as standarization and unification of code

User oriented framework. Motivation to produce a wide application software to be public. Research and also academic.

Based on ROOT libraries and philosophy. Framework with general pourpose (Data acquisition, simulation, data analysis)

The framework defines:

Common event data structures (TRestSignalEvent, TRestHitsEvent, TRestG4Event, …)
Config/Metadata storage. Information relative to run description (Readout, Acquisition parameters, Simulation description)
Defines processes development and management (TRestSignalDeconvolution, TRestElectronDrift, …)
Takes care of **file input/output** and **event/metadata storage** through a common class TRestRun

Main abstract class structures

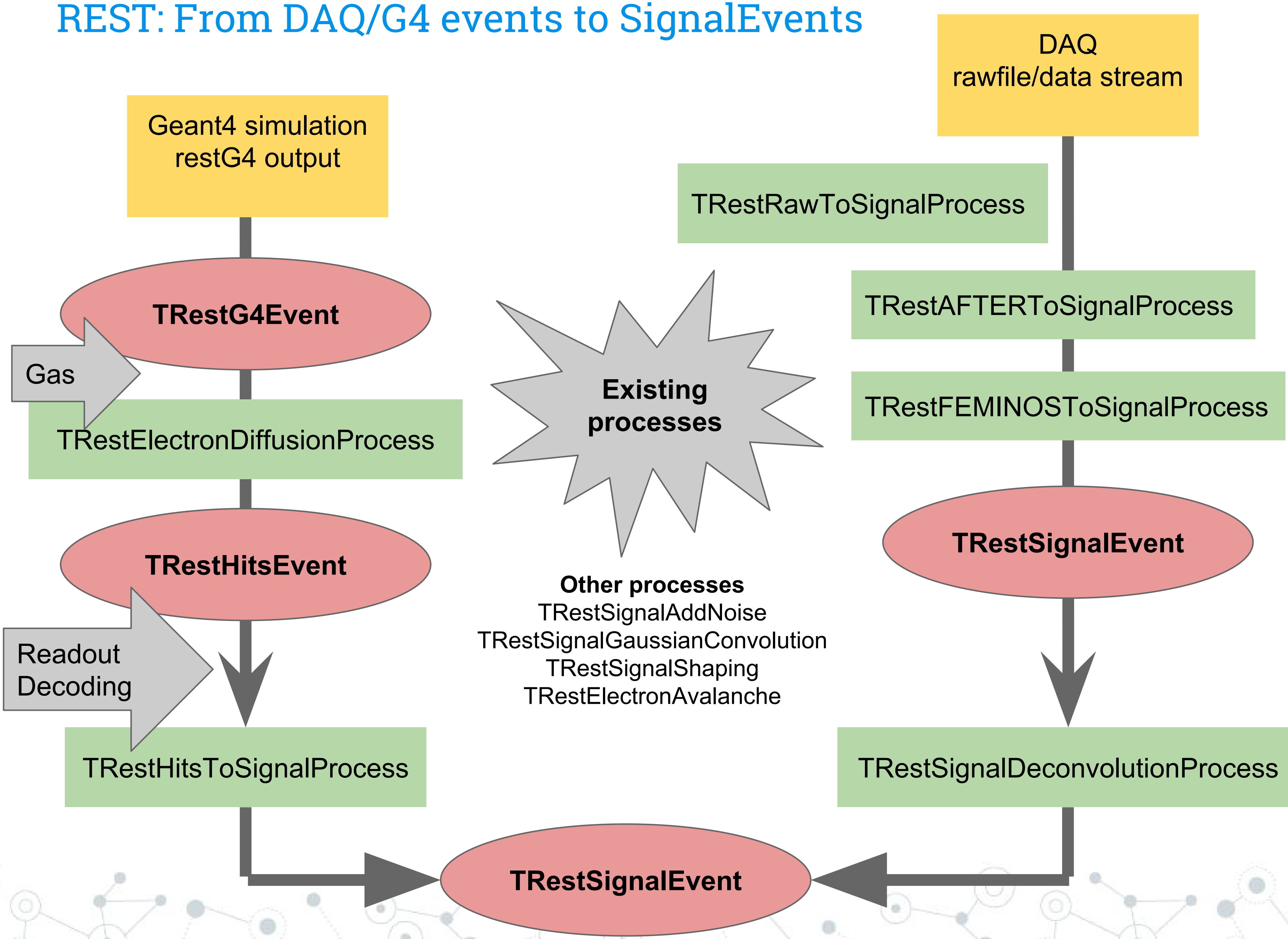
TRestRun (File I/O and metadata storage)

TRestEvent

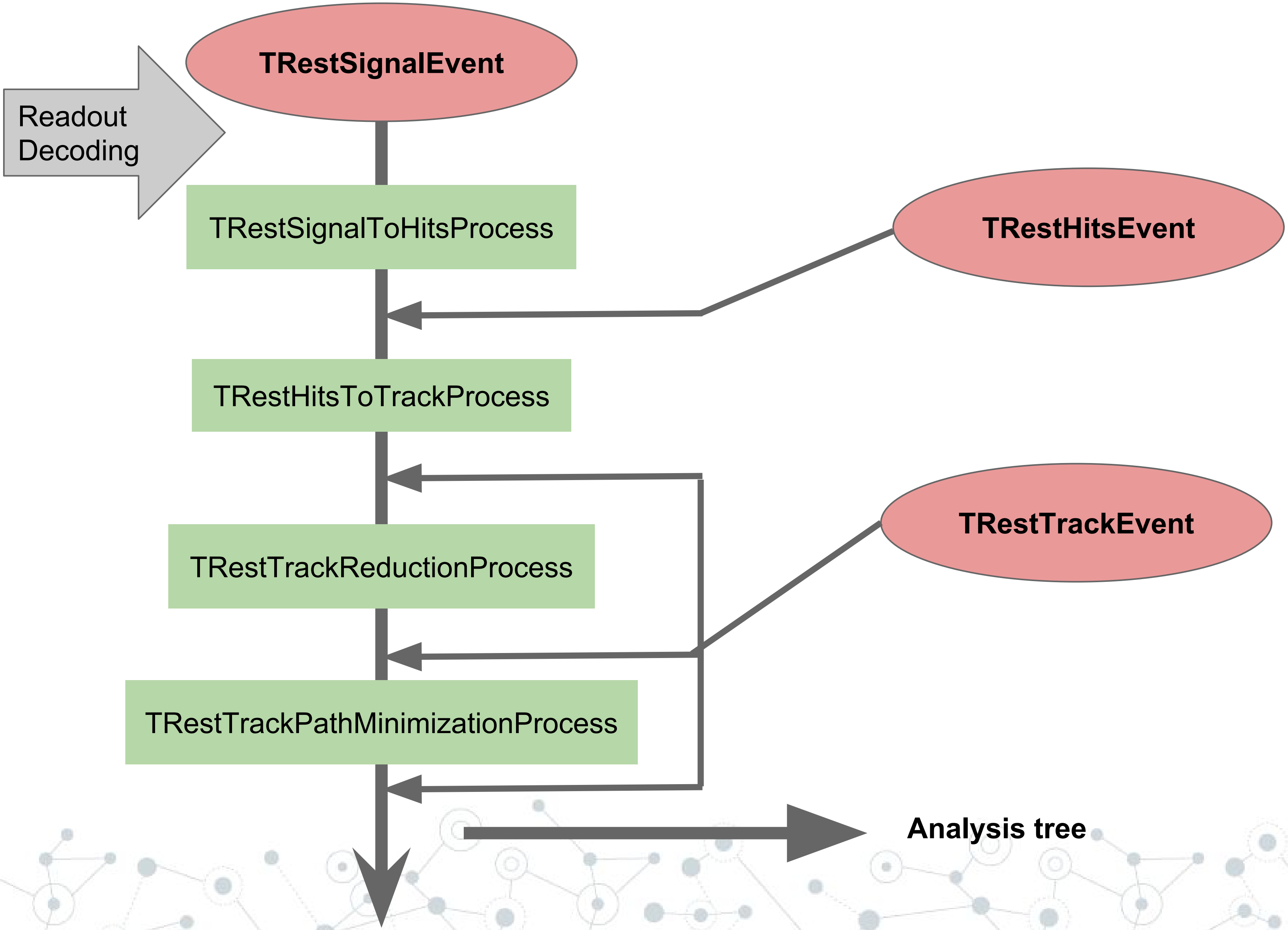
TRestMetadata

TRestEventProcess

REST: From DAQ/G4 events to SignalEvents



From TRestSignalEvent to event reconstruction and track analysis



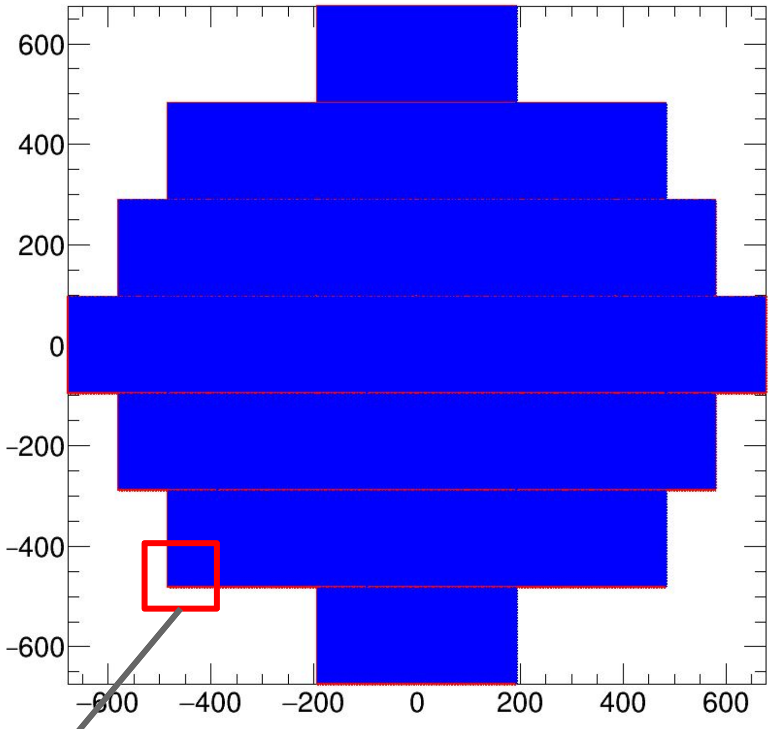
The readout definition

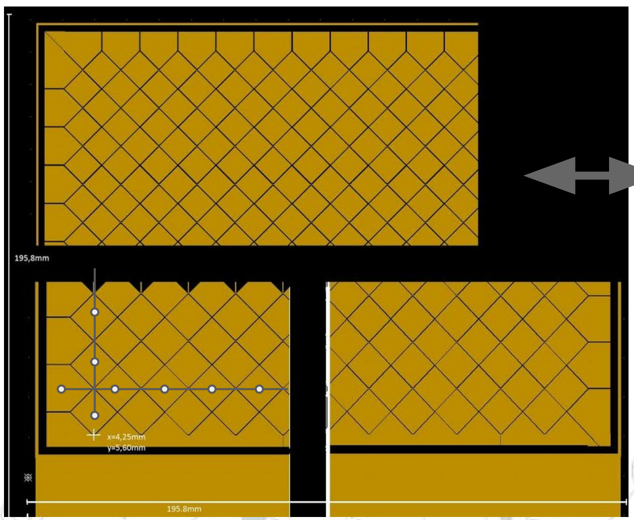
A metadata class
used for readout descriptio.
PandaX-III example

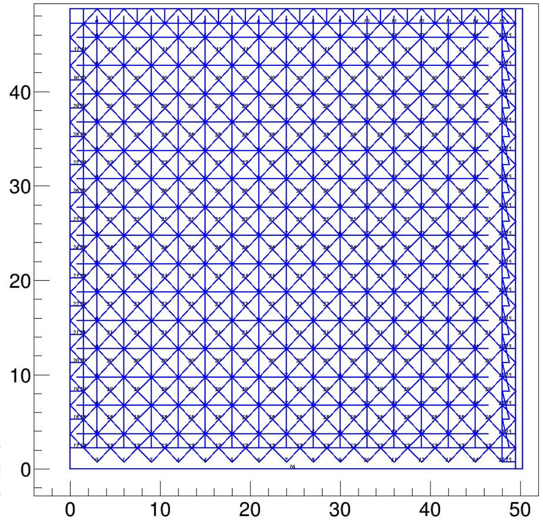
Full readout plane of PandaX-III

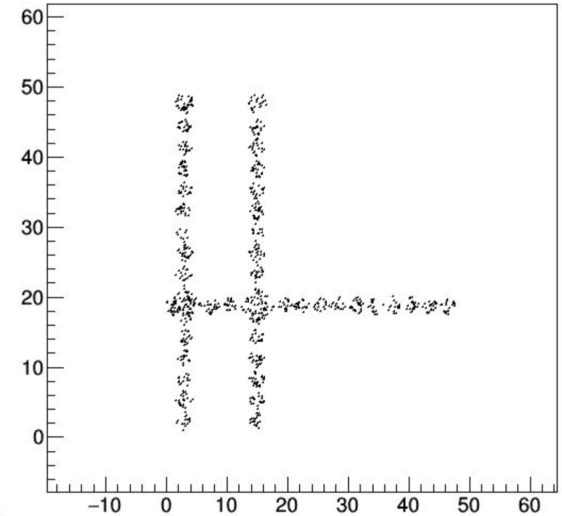
Stripped readout - Pixels are interconnected

Real design and micromegas module already produced.

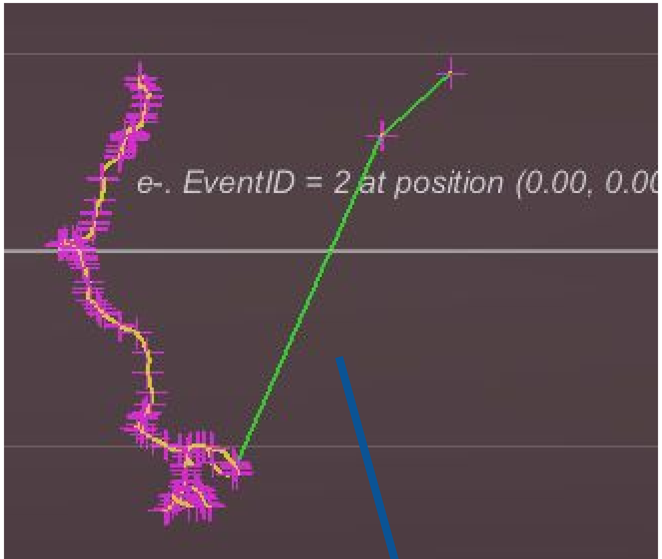






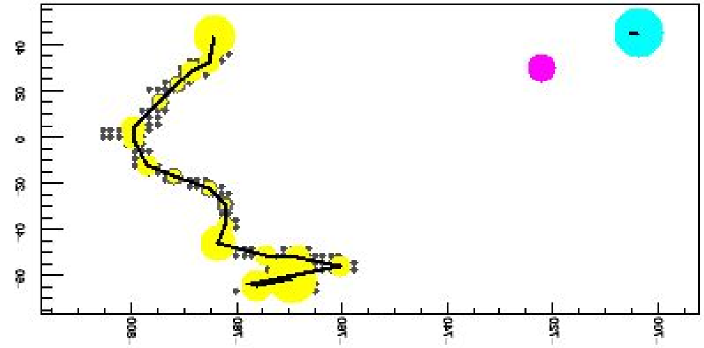


REST : Event processing at different steps

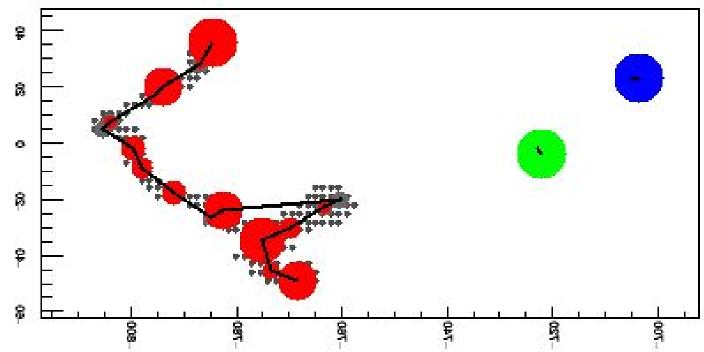


Geant4 Event

Reconstructed track event

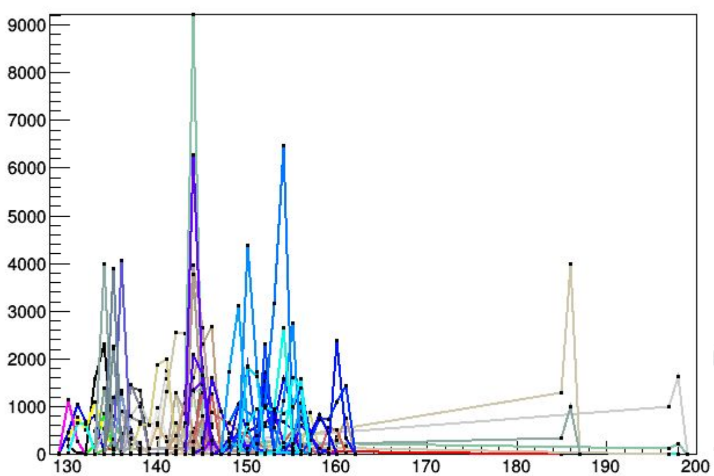


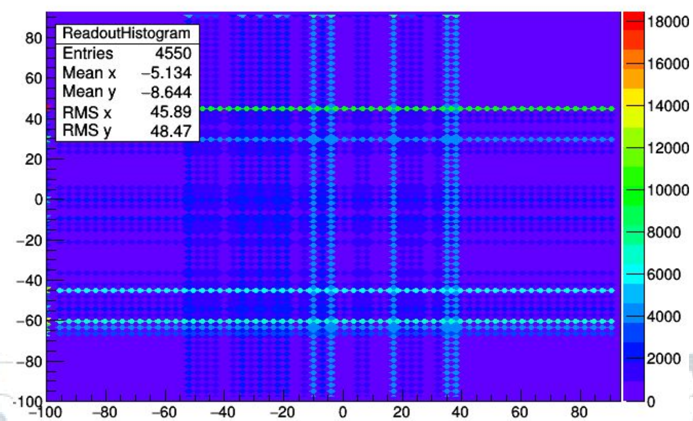
X-axis



Y-axis

DAQ Event Signal





Stripped readout signal event viewer

Conclusions

Recent progress on **TPCs** places this technology to be as **competitive for Rare Event Searches** as other solid and liquid state detectors.

We believe discrimination capabilities provided by gaseous TPCs will allow to increase **discovery potential in several physics cases**. Neutrinos, low mass WIMPS, axions.

We believe there is still **room for improvement** on background rejection and detector optimization.

Interesting **new R&D line with magnetic TPC** for the development of an **Underground Axion Helioscope.** Perhaps also for neutrinoless double beta decay (discrimination enhancement in the presence of a magnetic field to be studied)