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saclay

The PandaX-III experiment

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Motivations and constraints

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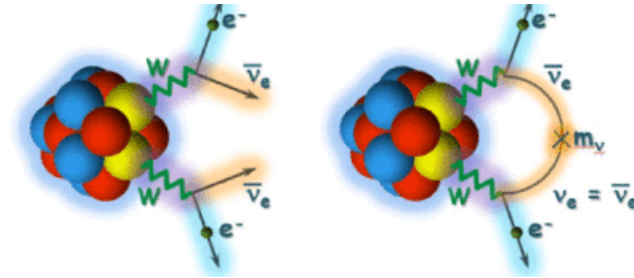
saclay

Search for neutrinoless double-beta decays

Neutrino = antineutrino \rightarrow Majorana neutrino

Violation of the leptonic number

Physics beyond standard model



PandaX-III experiment

Double-beta decay in **Xenon 136**

Gaseous TPC at 10 bar, 200kg (\rightarrow 1t) of ^{136}Xe

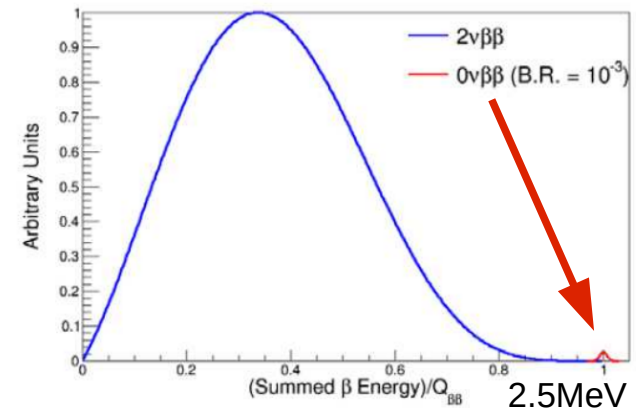
Charge readout with gaseous detectors

Experimental constraints

Excellent **energy resolution** (goal 1% at $Q_{\beta\beta}=2.458$ MeV)

Excellent **radiopurity**

Background rejection by factor 100 using **event topology**



The PandaX-III collaboration

International collaboration

China → 7 institutes (lead by SJTU)

France → CEA Saclay

Espagne → Zaragoza

USA → BNL + Maryland University

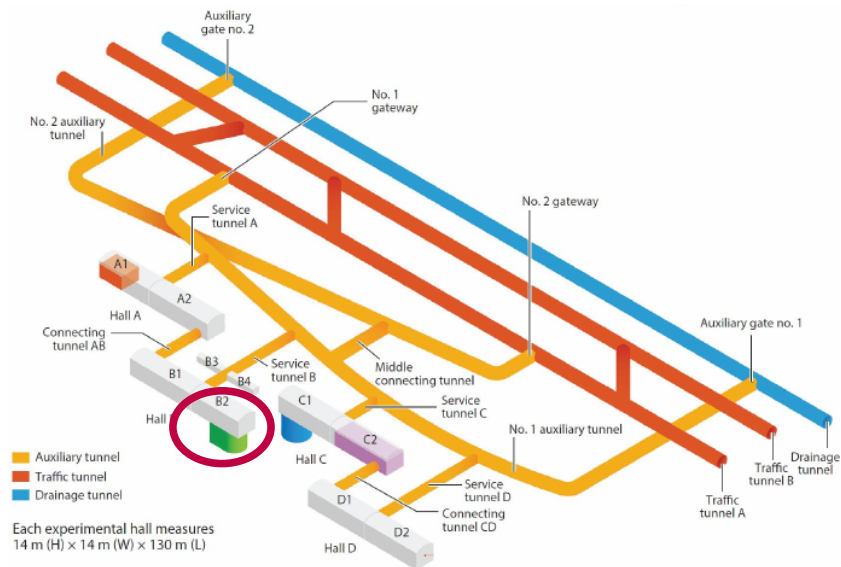
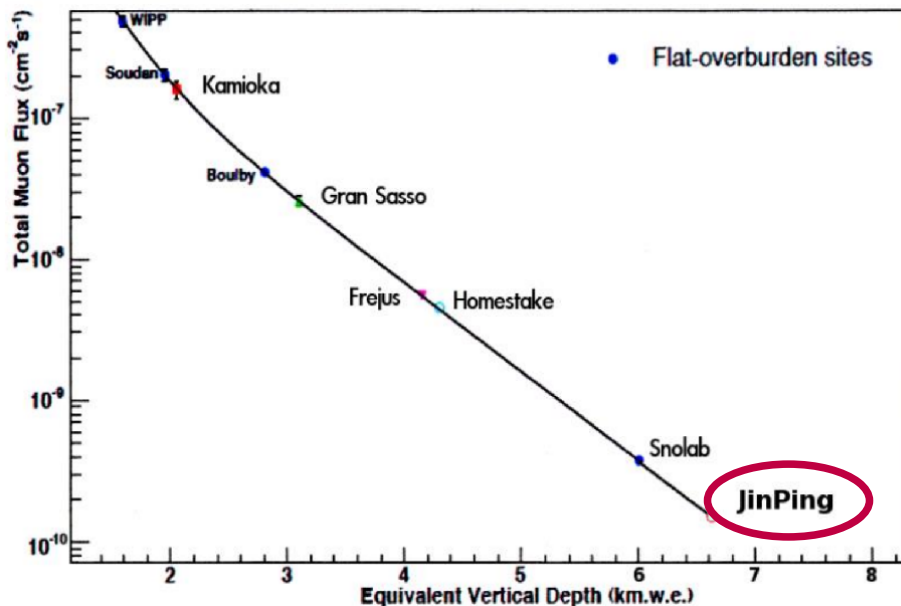
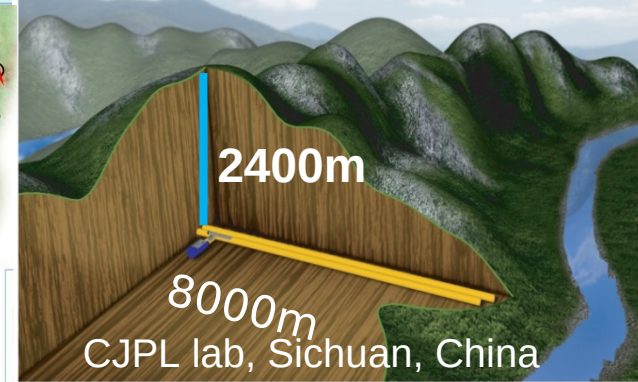
Thailand → Nakhon Ratchasima

Laboratory

Jinping CJPL underground laboratory (Sichuan, China)

One of the worldwide lowest muon flux

Large caverns, easy access to trucks



The PandaX-III experiment

Detection principle

10 bar ^{136}Xe (90% enriched) time projection chamber (TPC)

Ionization electron readout by Microbulk Micromegas

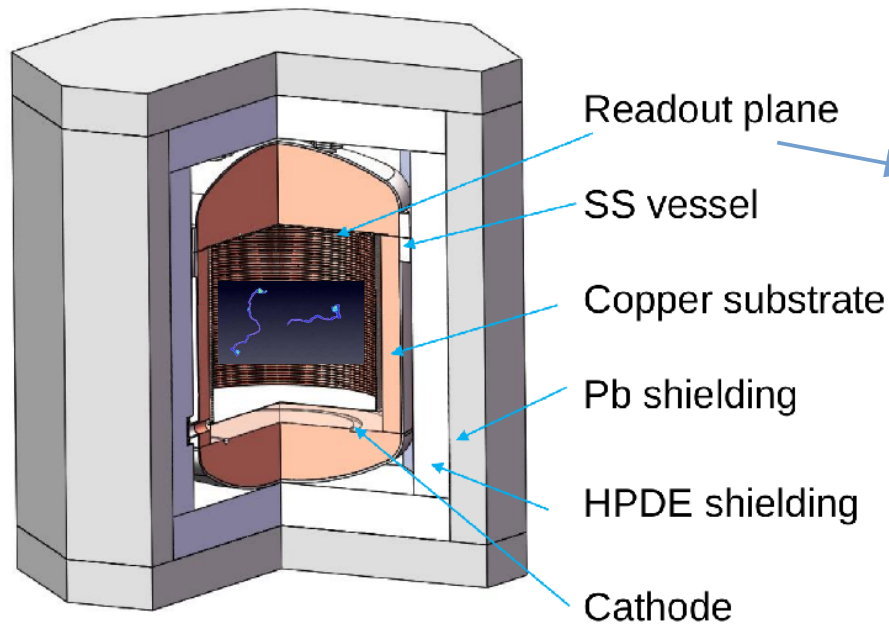
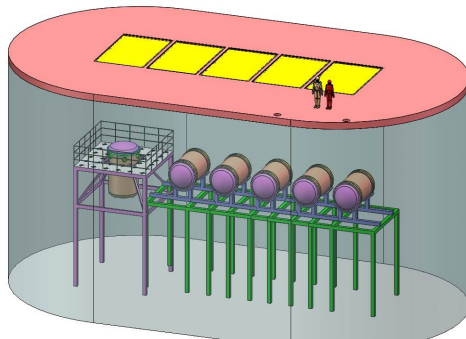
Double-beta vs gamma discrimination using event topology

Experimental setup

5 TPC modules with Xenon + 1% TMA at 10 bar foreseen in total
200kg in each module, but 1st module 145kg only

1st module: stainless steel vessel + internal copper shielding + external shielding

A lot of efforts to reduce U and Th contamination



X-III experiment

Read-out with Micromegas Microbulk detectors

Principle and advantages

Micromegas based on a copper clad 50 μ m-thick kapton foil

40 μ m diameter holes

Top face \rightarrow mesh

Bottom face \rightarrow read-out plane

Studied by Zaragoza, IRFU and SJTU

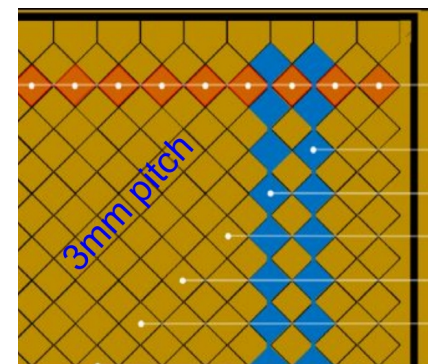
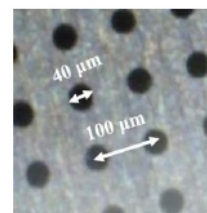
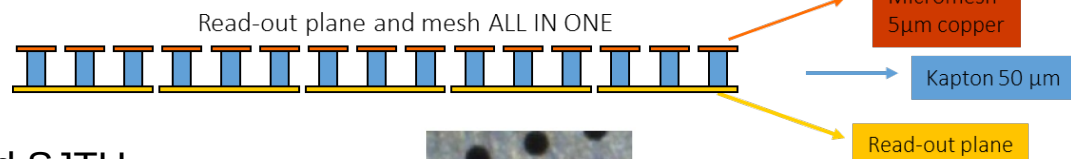
Built at CERN, used at CAST, n_TOF

Constant kapton foil thickness

\rightarrow very good gain homogeneity

\rightarrow best energy resolution for MPGDs

Excellent radiopurity $\sim 0.1 \mu\text{Bq}/\text{cm}^2$ for ^{214}Bi and ^{208}Tl



Characteristics

SR2M design from Zaragoza (v1 \rightarrow v2)

52 large Microbulks (20x20cm), 3mm pitch

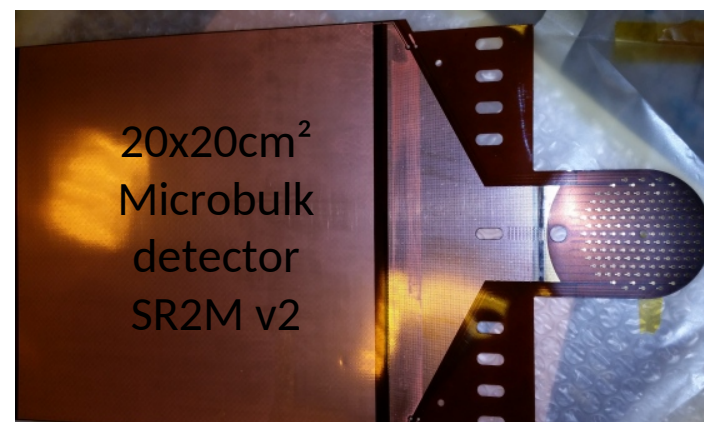
X and Y readout on same board, 64 channels each

But not 3D, XZ and YZ read independently

Status

2 productions of prototypes

Study still ongoing



Read-out electronics of 1st module

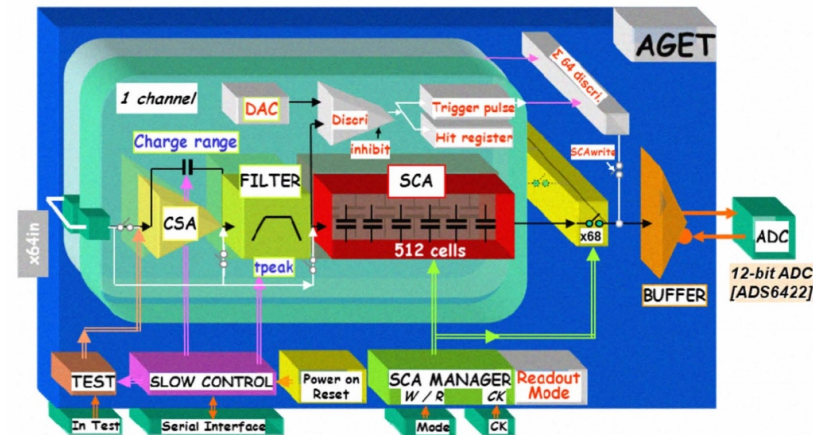
AGET read-out ASIC

Charge sensitive preamplifier 120fC to 10pC
dynamic range

Analog filter 50ns to 1μs peaking time

64 channels sampled at 1 to 100MHz

Multiplicity signal available

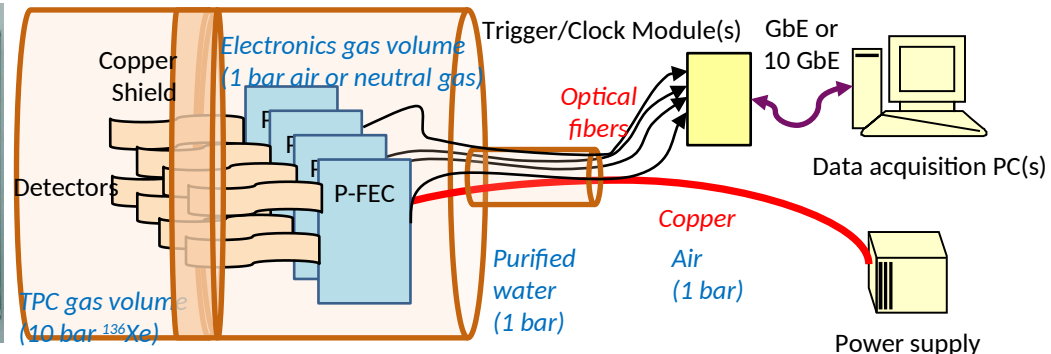
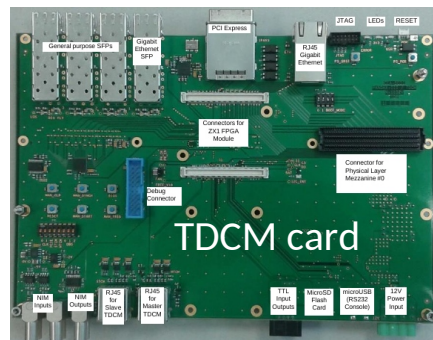
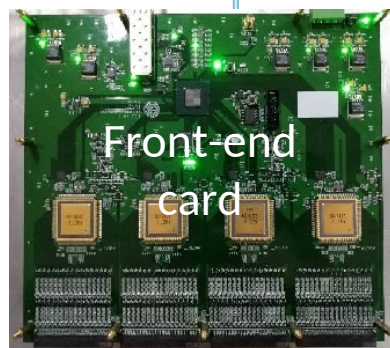


Read-out electronics

Front-end cards (USTC) close to detectors, 1 card for 2 Microbulks (4 AGET chips),
special radio-pure design with polyimide PCB material (<990 mBq/card)

Back-end TDCM cards (Saclay) out of the TPC, optical fiber connection

Specific trigger and clock card



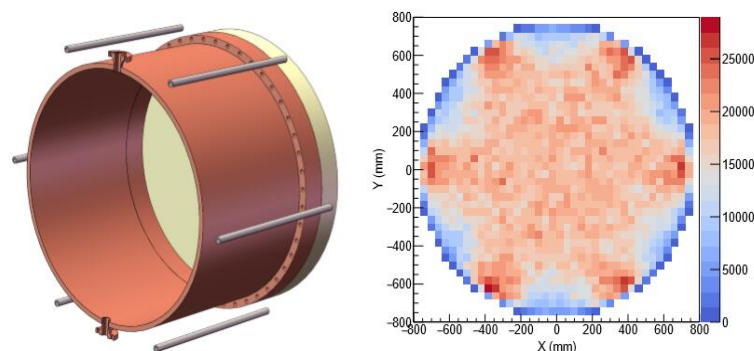
Calibration system

External system

Non-linearity of the detector energy response

Absolute calibration at $Q_{\beta\beta}$ value

Calibration sources outside the vessel (^{232}Th , ^{60}Co)

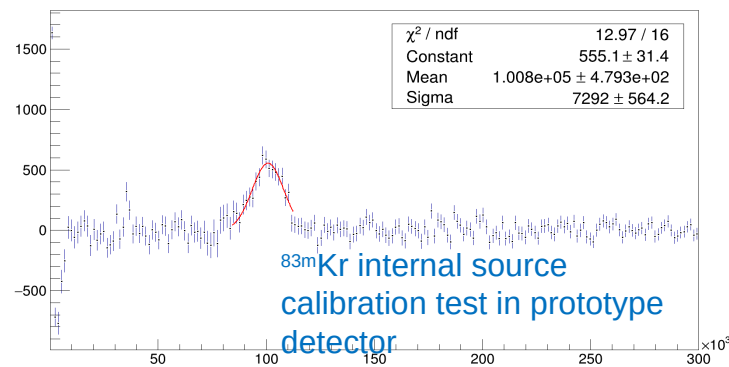
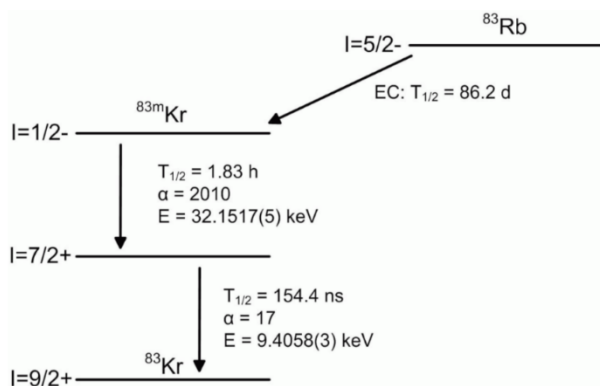
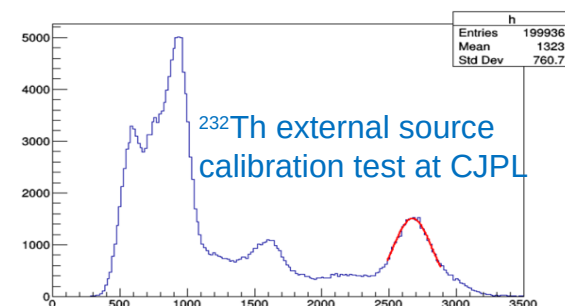


Internal system

Event generation inside the gas volume

Calibration at $Q_{\beta\beta}$ using ^{220}Rn

Micromegas uniformity and geometrical correction using $^{83\text{m}}\text{Kr}$ generated from ^{83}Rb



Studies on a TPC prototype

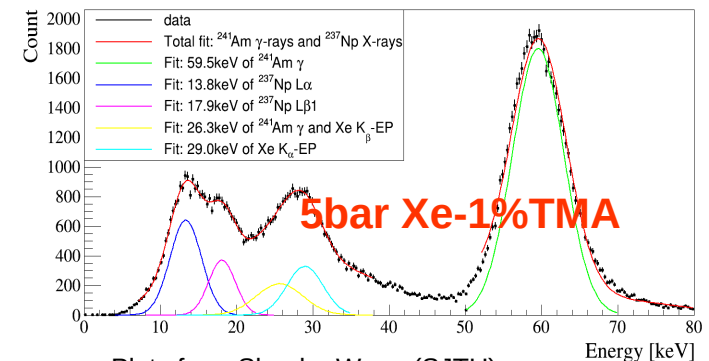
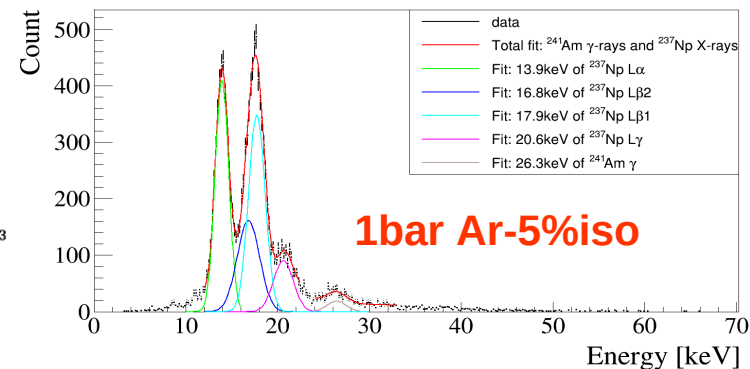
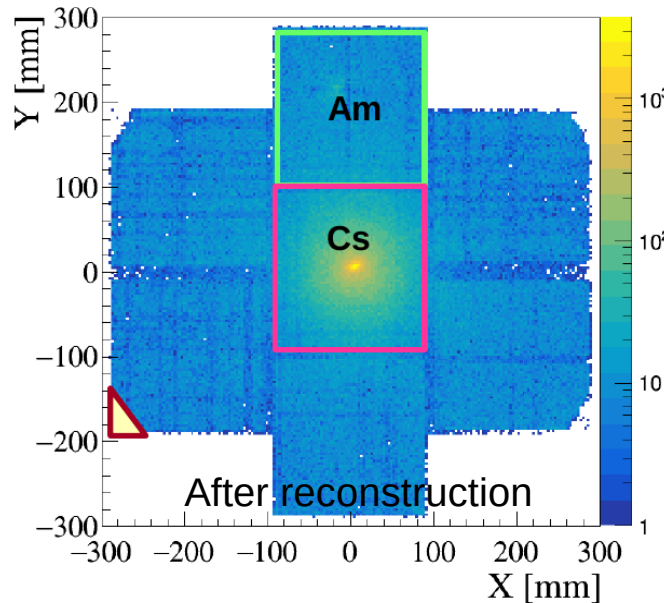
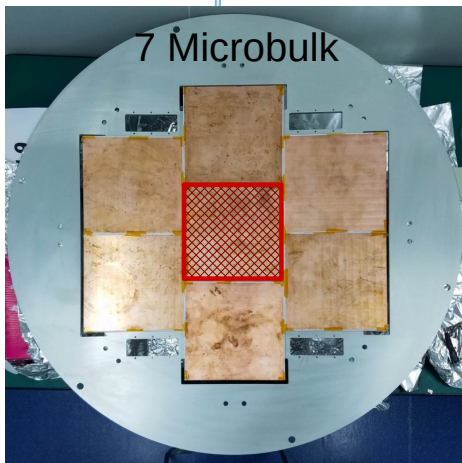
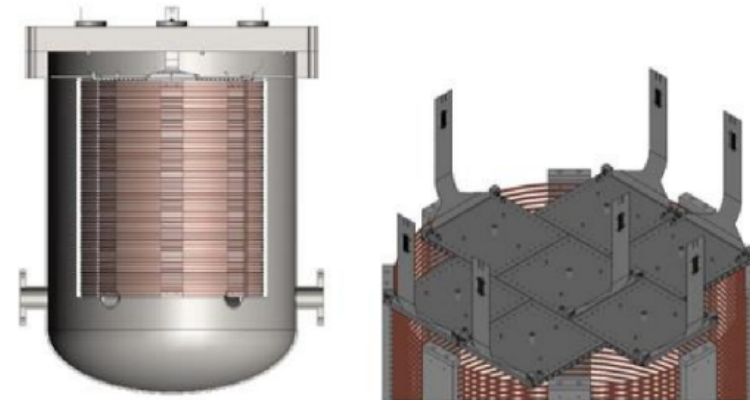
First results from TPC prototype in 2018-19

7 mounted v1 Microbulks

Tested at SJTU with different pressures and gas mixtures (Ar, Xe)

Several problems: cut channels, high current between mesh and some channels, unstable behaviors

Gain and energy resolution measurements with different sources



Plots from Shaobo Wang (SJTU)

Microbulk studies at Saclay

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Tests with v1 prototype

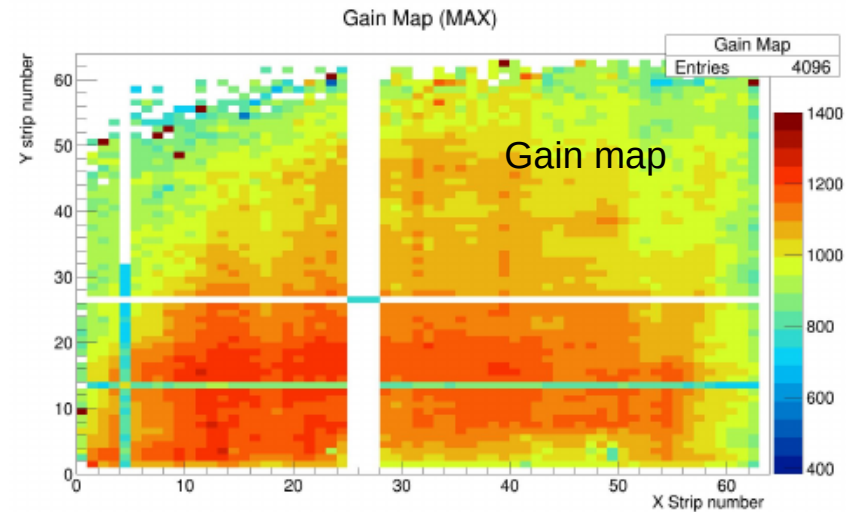
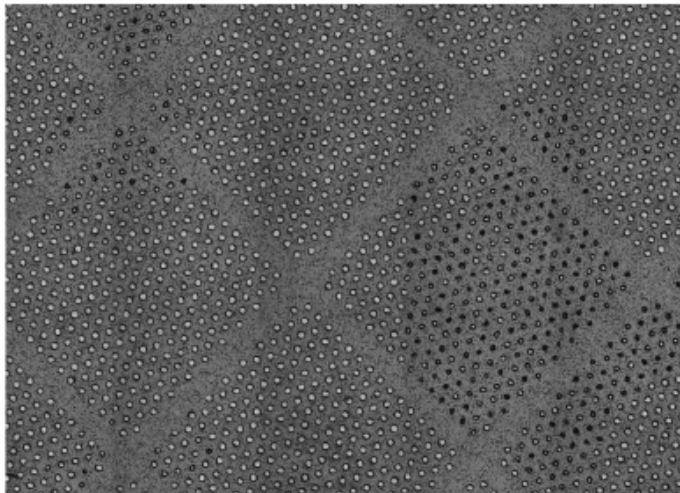
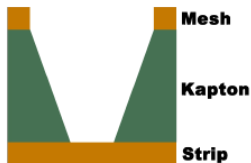
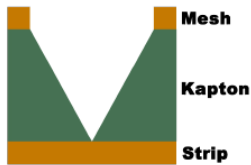
Ar+5%isobutane gas mixture, 1 bar

^{59}Fe 5.9keV photon source

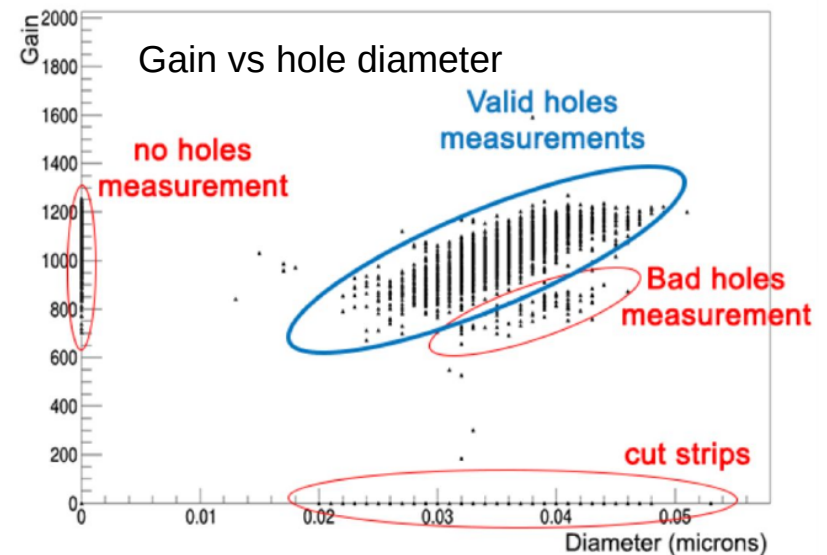
Also a few deactivated channels due to leak current

Gain measured on whole surface using AGET data → important inhomogeneity due to production problems

Better situation with v2 prototypes (15% variation)



Correlation between gain and the diameter of the bottom of the holes



Plots from Benjamin Manier (Saclay)

R&D on charge detection for next modules

Microbulk detectors

MPGD best energy resolution so far, mainly due to homogeneous amplification gap

Possible improvement: segmented mesh

- 2 parallel energy read-out
- Promising tests on a small old n_TOF segmented mesh prototype
- 10x10cm² prototype ready to be tested

Bulk detectors

More robust than Microbulks, easier to produce in large surface

But energy resolutions not as good as Microbulk ones (~18% at 6 keV)

Radioactive contamination (stainless steel mesh)

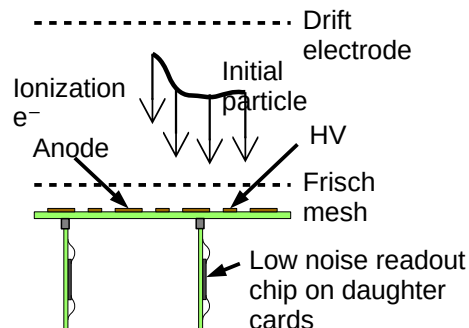
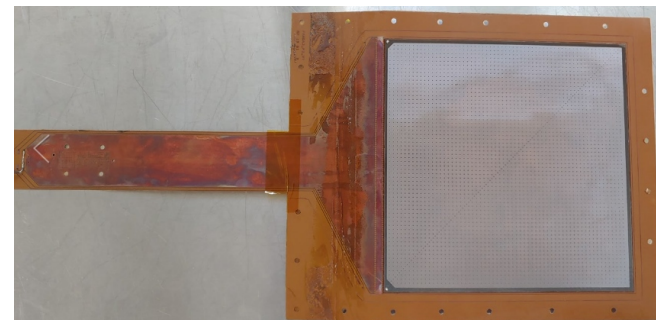
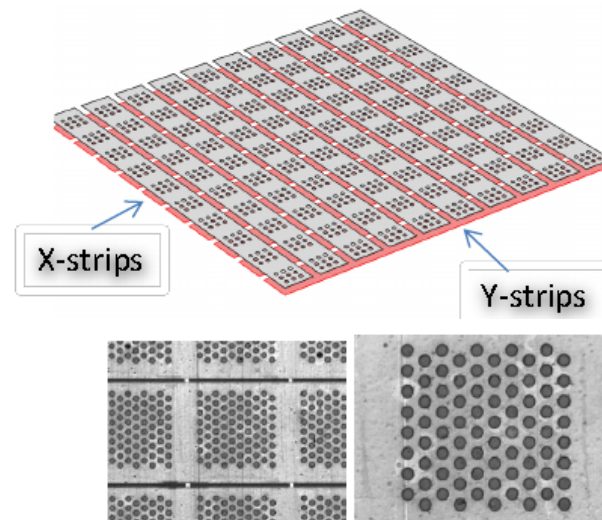
Can be a backup for 1st module if too many problems with Microbulks

No amplification: NoAmpTPC

Direct readout of ionization electron

Very low noise electronics: IDeF-X chips

Tests ongoing on a prototype



PandaX-III event reconstruction

Event topologies

Db-beta: 2 electrons \rightarrow 2 Bragg peaks

Background gamma events: 1 electron \rightarrow 1 Bragg peak

But very scattered tracks, recognition not obvious

Also need to reconstruct precisely the deposited energy

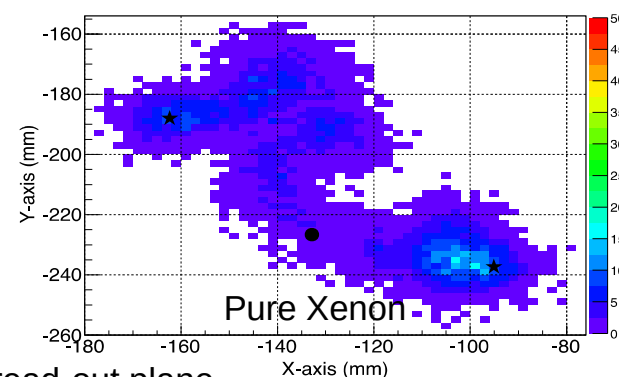
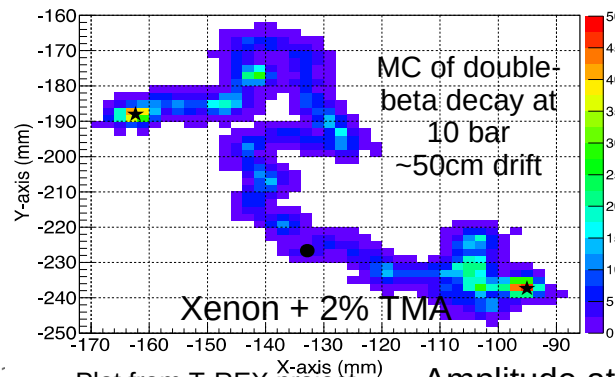
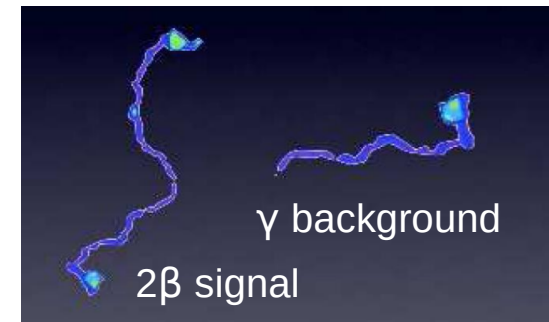
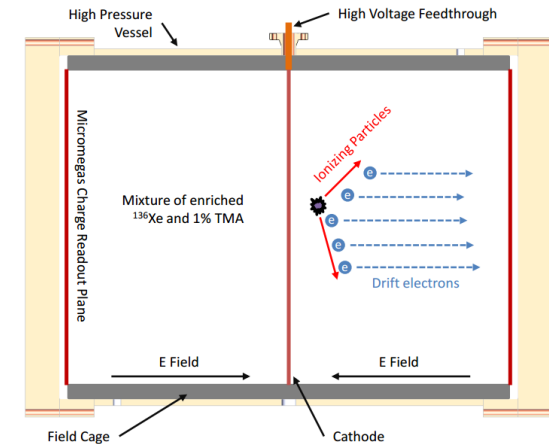
1% tri-methyl amine in gas mixture helps a lot:

- Lower diffusion
- Suppress scintillation
- Better energy resolution
- Quencher for the amplification

Reconstruction software

Based on REST package initiated by Zaragoza for T-REX

Under development to refine reconstruction of deposited energy and background rejection



PandaX-III event reconstruction

Studies on background rejection

Based on track topology

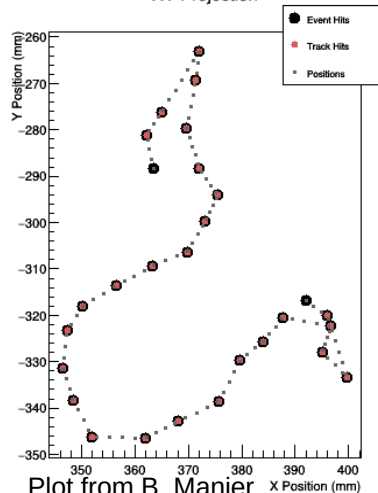
MC studies, include electron diffusion and raw signal formation, 2 x 2D readout (XZ and YZ)

Main criterion: two energy blobs (2 Bragg peaks)

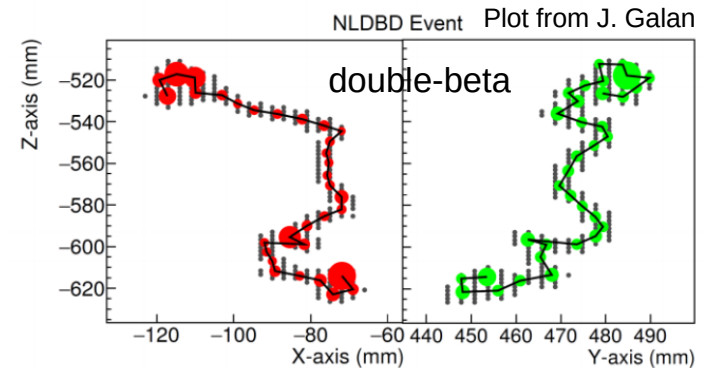
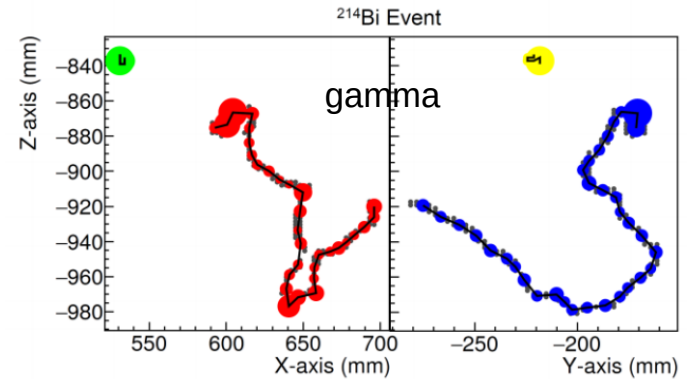
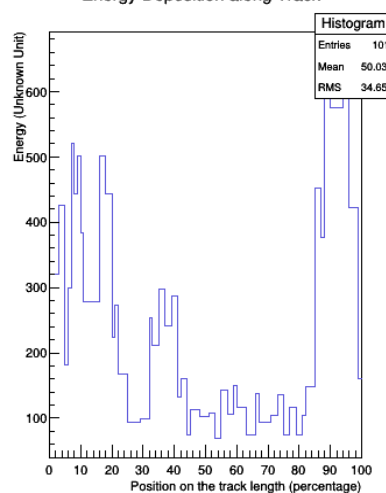
Other criterions: secondary tracks, track length, blob energies, twist at end of track, also study on Fisher discriminant on energy along the track

Performance to be improved (~43% efficiency with ~1% background surviving cuts in ROI)

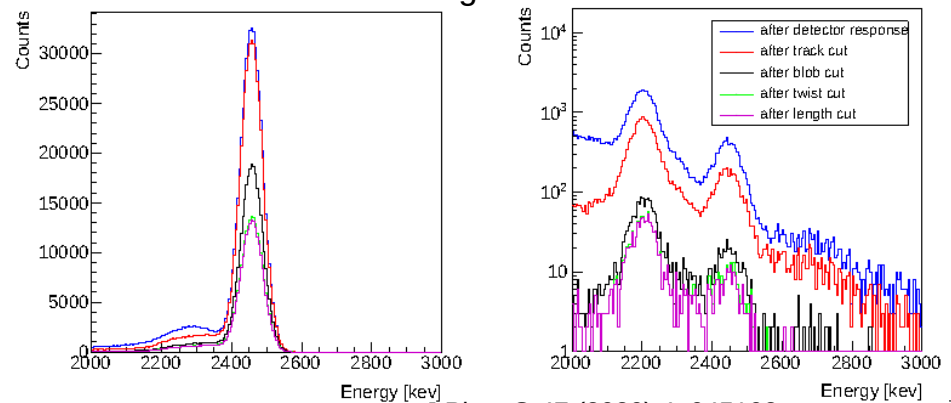
XY Projection



Energy Deposition along Track



Double-beta and background before and after cuts



PandaX-III event reconstruction

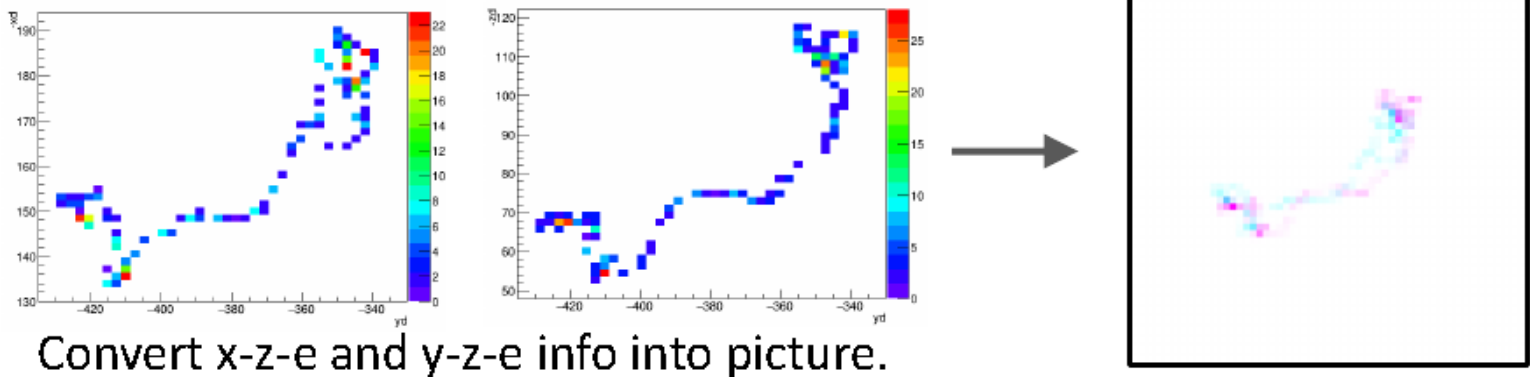
Selection with neural networks

Recent studies in China and at Saclay

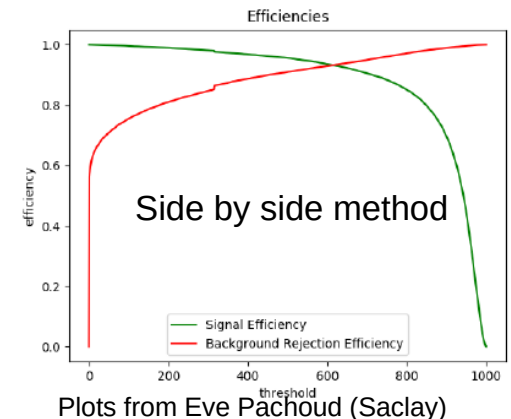
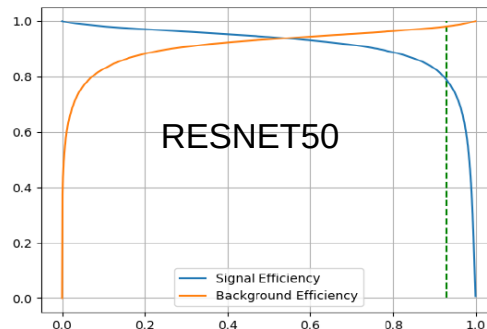
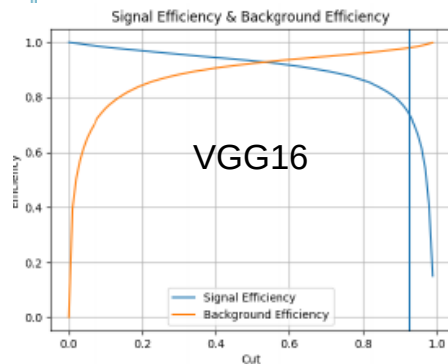
Based on pictures built from XY and YZ projections, given to image recognition neural network tools

Network training with MC double-beta decay and gamma background events

Looks promising with ~80% efficiency, 2% background surviving

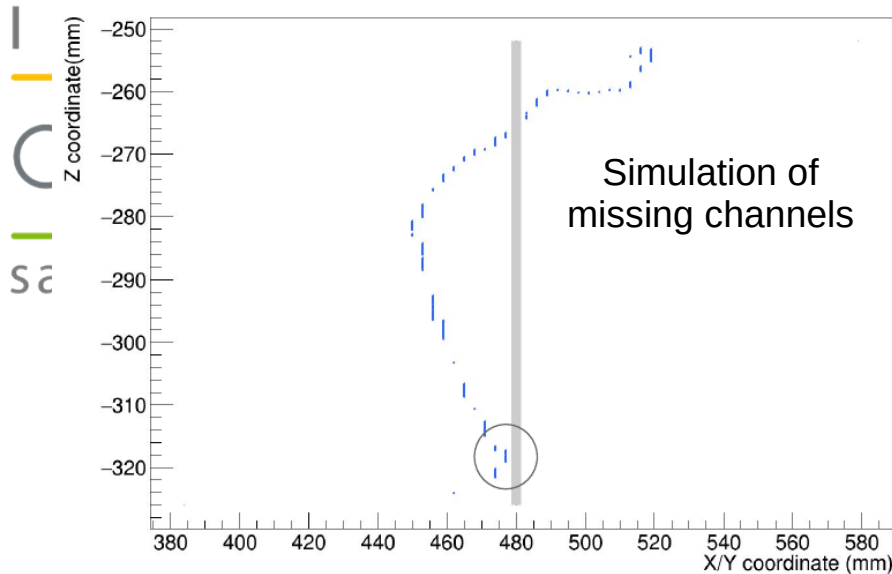


Convert x-z-e and y-z-e info into picture.

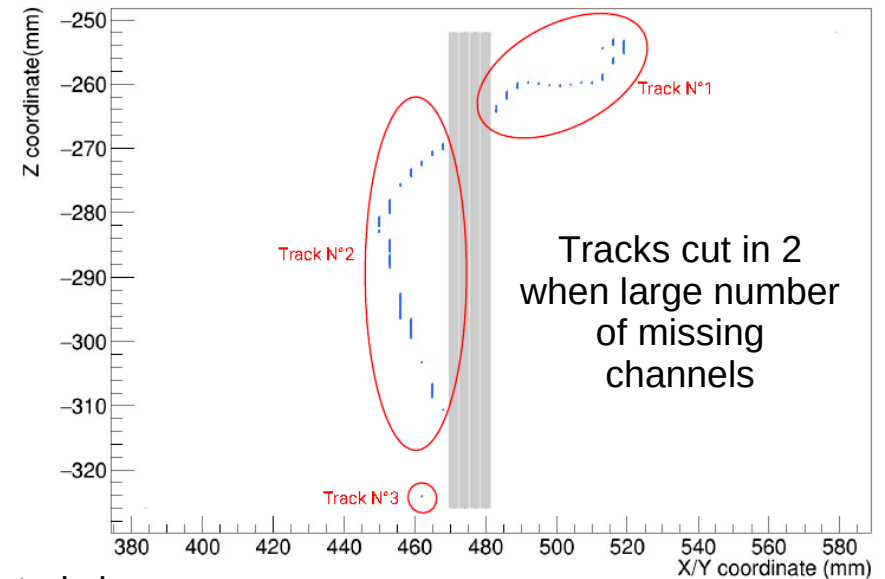


How to repair data with missing channels

View of TRestHits(Gen0) for a PandaX-III MM

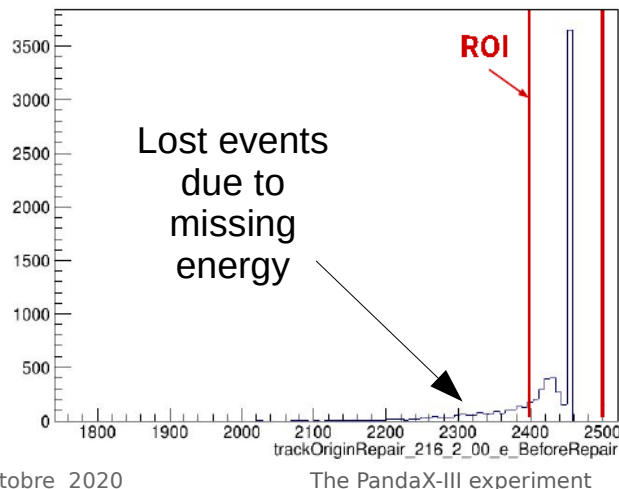


View of TRestHits(Gen0) for a PandaX-III MM

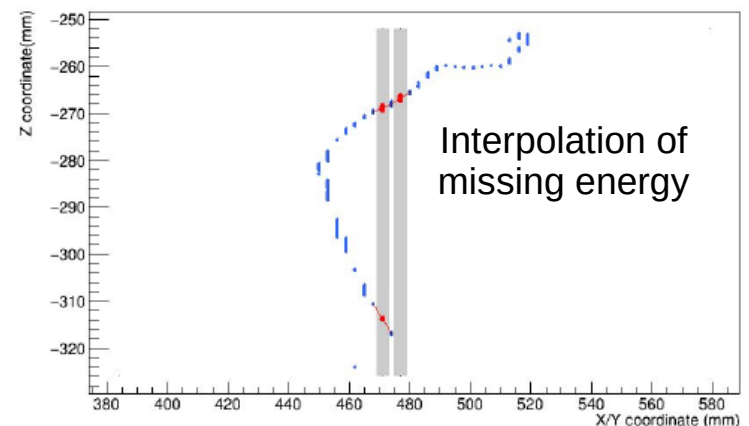


Very preliminary, study in progress

Energy spectrum with cut



View of TRestHits(Gen0) for a PandaX-III MM



Plots from Benjamin Manier (Saclay)

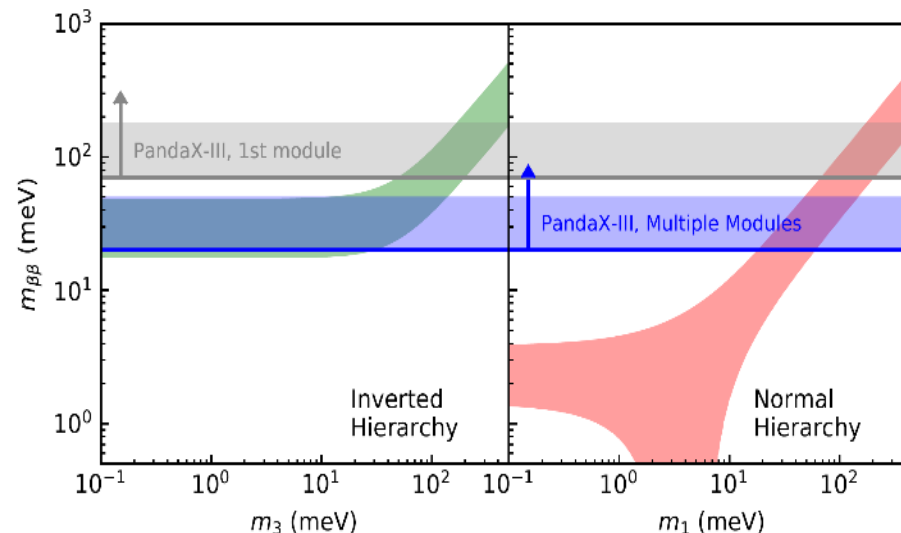
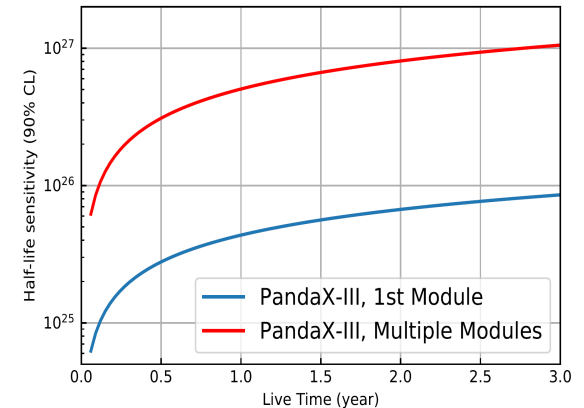
Background budget and expected sensitivity

Background rate

Study with two different Geant 4 MC
Analytical and NN topological analysis
Expected rate 10^{-4} hit/keV/kg/year in the ROI

Sensitivity with 3 years data taking

1st module: 8.5×10^{25} years half-life limit
5 modules (1t): 10^{27} years half-life limit



Conclusions

Summary

High pressure gas TPC with charge readout based on Micromegas detectors

1st module using 145kg of ^{136}Xe

Final goal: 5 modules of 200kg

Unique background suppression based on tracking capability

Large effort to reduce U and Th contamination

Perspectives

Construction of the experimental setup in progress

- Underground cave ready
- Clean room and support structures designed, production launched
- Stainless steel TPC vessel built, leak tests ongoing, procurement of radiopure copper for internal shielding in progress
- New design of field cage ongoing, successful tests done on prototype TPC
- Front-end cards in production, back-end cards built
- Tests on Microbulk prototypes still ongoing, tests on Micromegas (bulk, thermal bonded) also done in parallel, decision to be taken early 2021

Expected to begin commissioning end of 2021