

Gaseous Time Projection Chamber for Radioactive Material Screening

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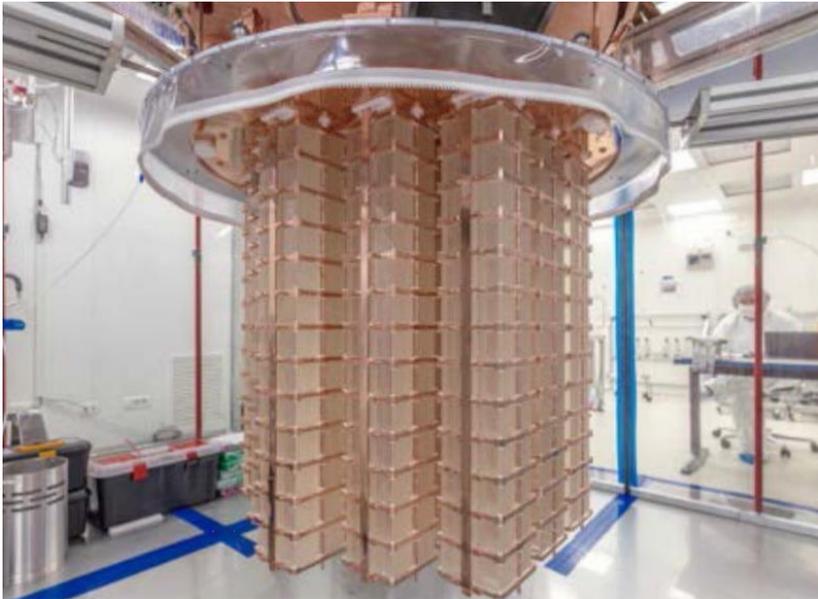
outline

- 1. Motivation**
- 2. Advantage of gaseous TPC**
- 3. Background estimation and sensitivity projection**
- 4. Prototype TPC**
- 5. Summary**



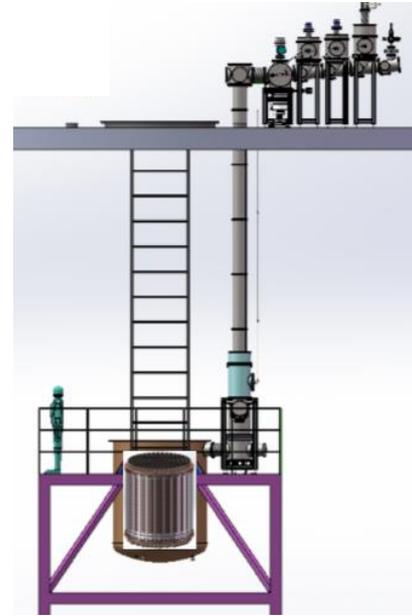
Motivation

- Surface radioactivity measurement is key to low background experiments
- Sensitive surface measurement is not as widely available



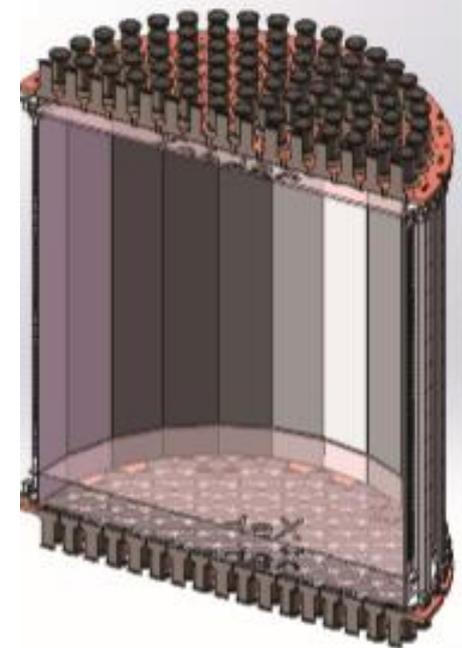
CUORE: Neutrinoless double β decay bolometer array

(alpha from detector surface)



PandaX-4T: dark matter liquid xenon detector

(Radon emanation)

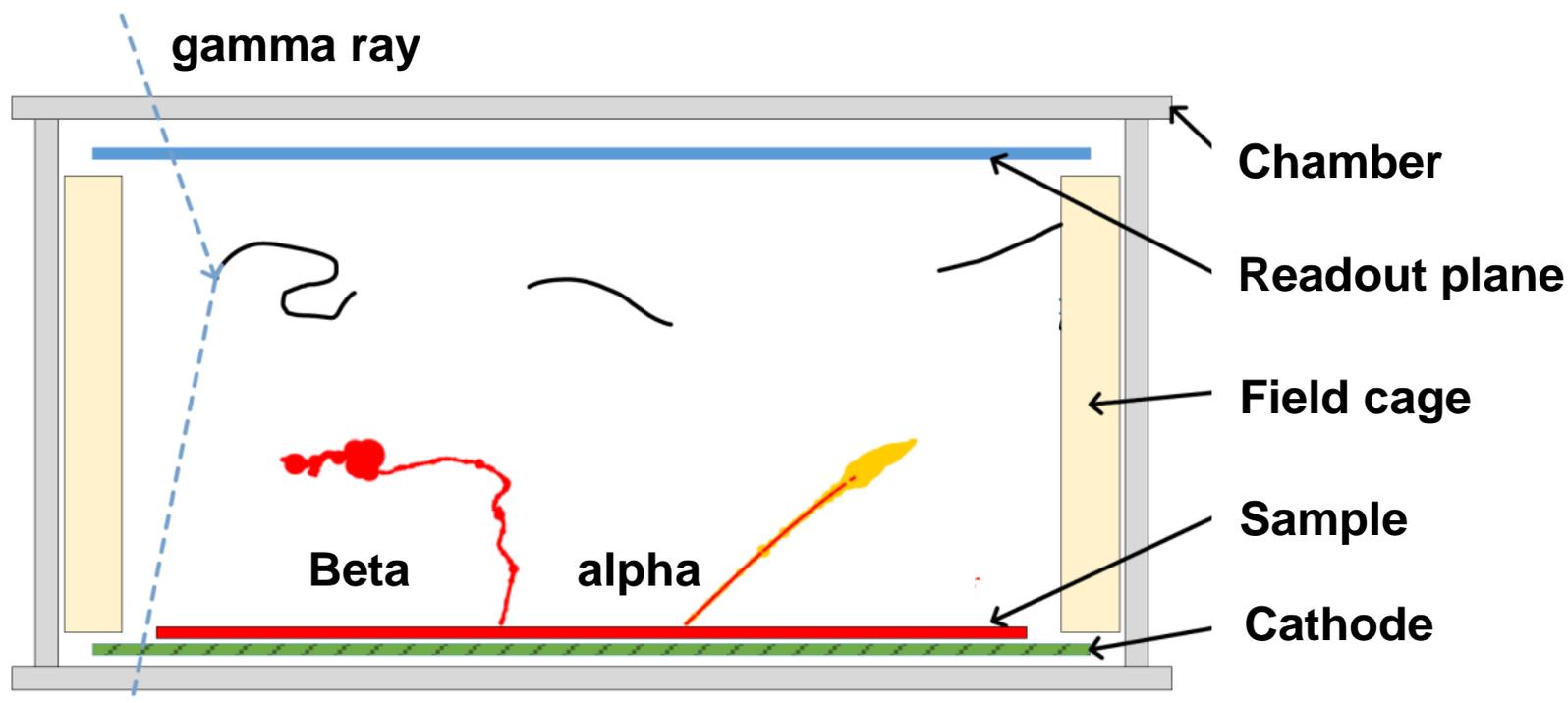


The gaseous TPC

The gaseous TPC to measure particle **energy** and **track**

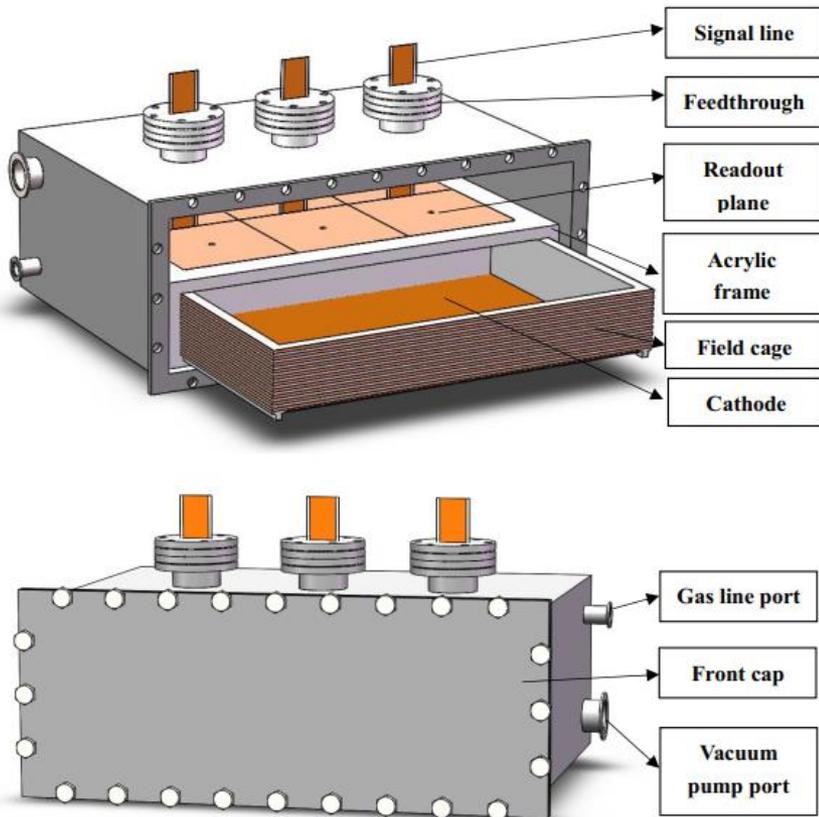
- Sample inside the TPC, **high detection efficiency**
- Combine energy and track information to **identify particle type and source**
- Easy to realize a **large measuring area** ($\sim 2000\text{cm}^2$), shorten measuring time

all the features help improve the sensitivity of measurement



schematic diagram

Detector overview



The gaseous TPC design
(construct with low background materials)

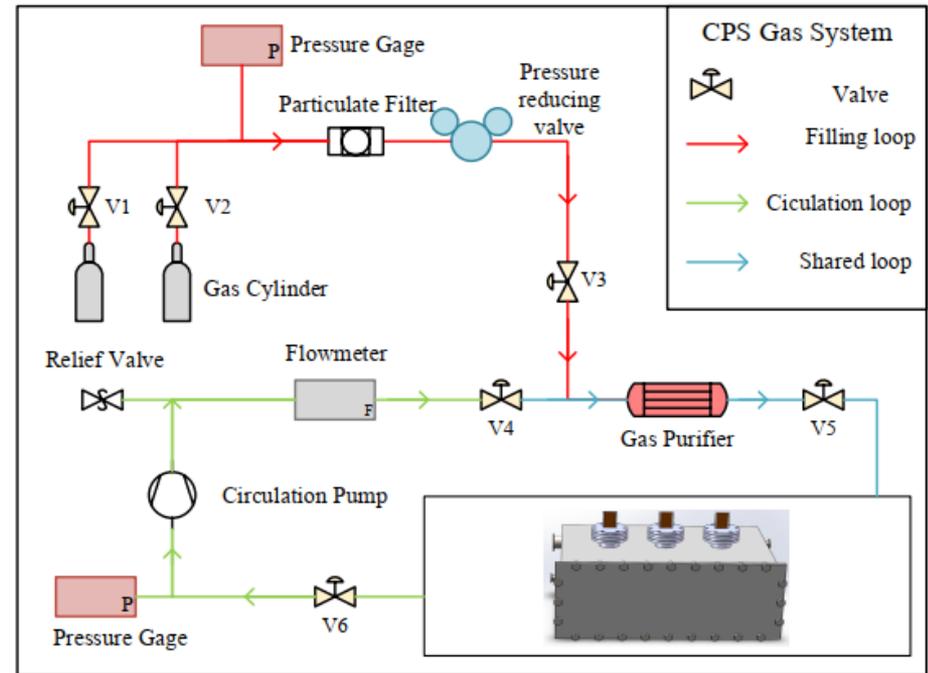
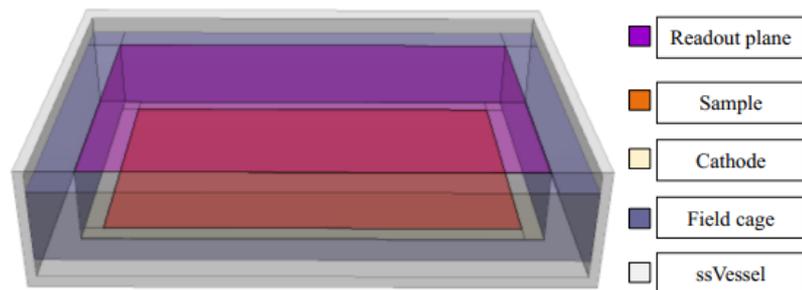


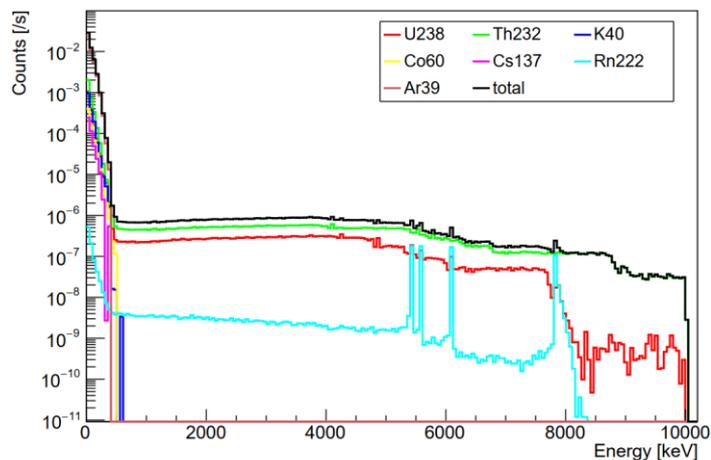
Diagram of gas system
Circular purify the working gas
(for a long term stable run)

Simulation for background study



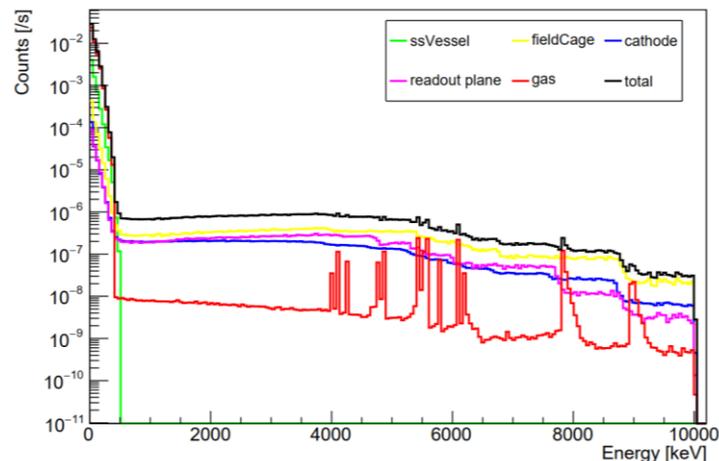
sensitive volume: $60 \times 40 \times 10 \text{ cm}^3$
gas: one bar Argon+5% isobutane

Geometry of the gaseous TPC simulation



Background energy spectrum of different source

(Alpha background from ^{238}U , ^{232}Th and ^{222}Rn)

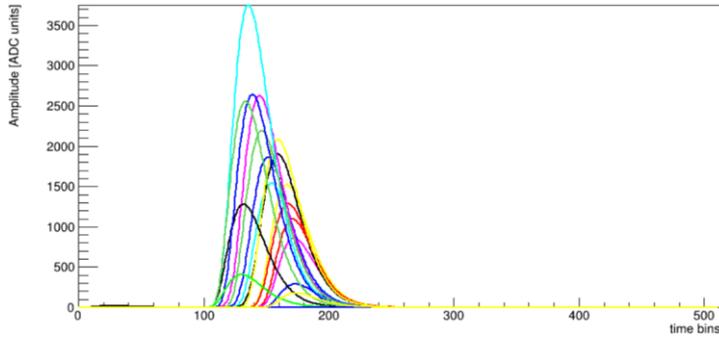


Background energy spectrum of the components

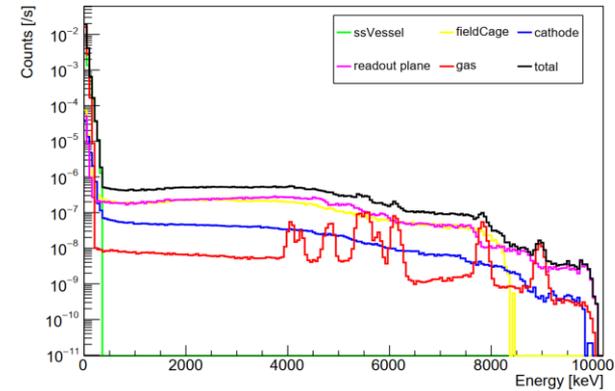
(Alpha background from argon gas, readout plane, field cage, and cathode)



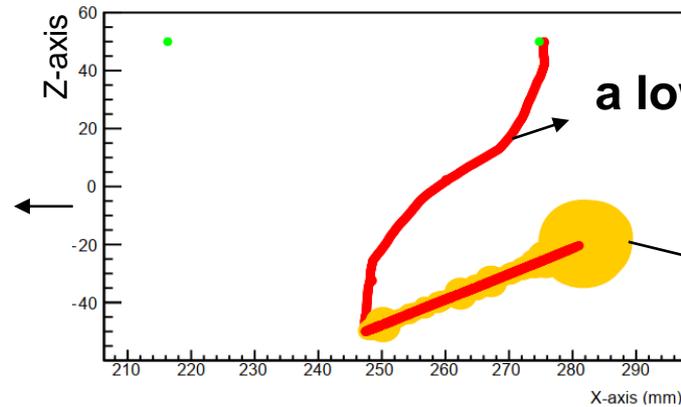
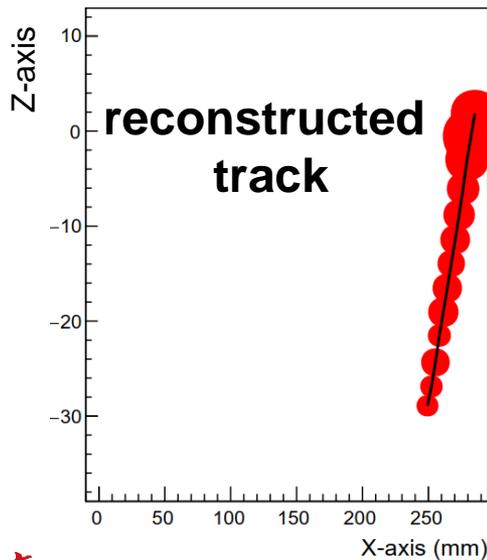
Detector response simulation and track reconstruction



Mock signals after detector response simulation



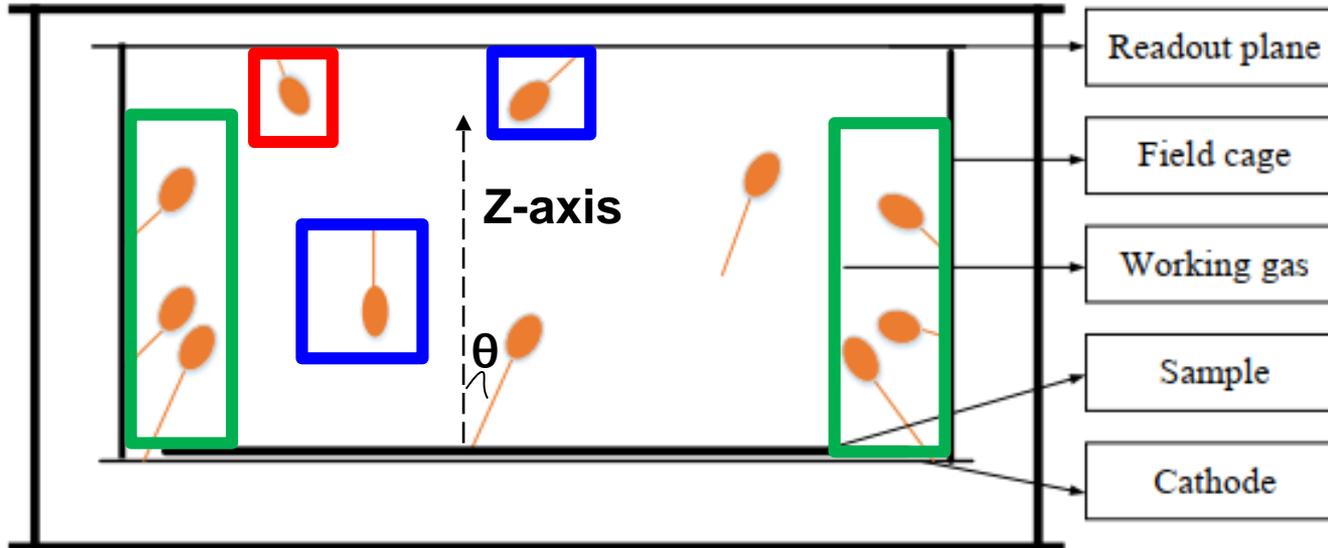
The background energy spectrum after detector response simulation



BiPo coincident event from Geant4 simulation



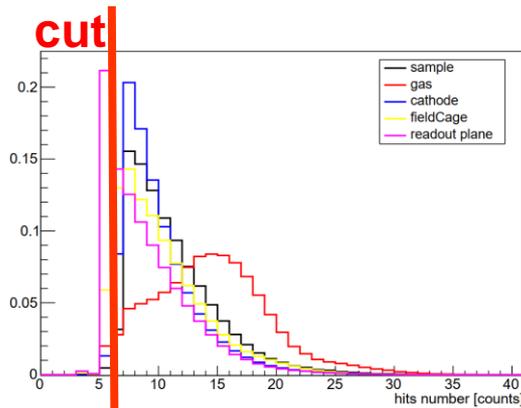
Background suppression



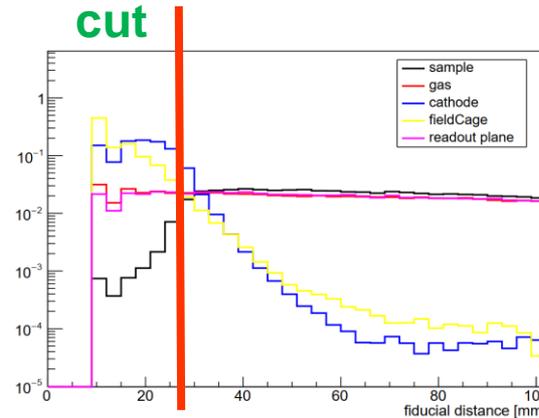
After all cuts

Signals:
~ 68% reserved

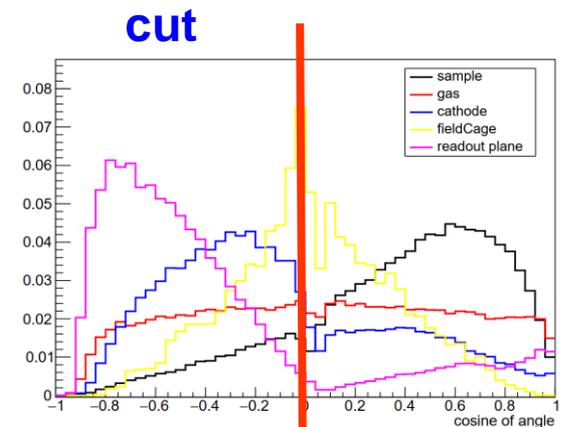
Background:
suppressed from
4.8 to 0.26 (counts
per day)



Number of hits
(cut ~50% readout plane
background)



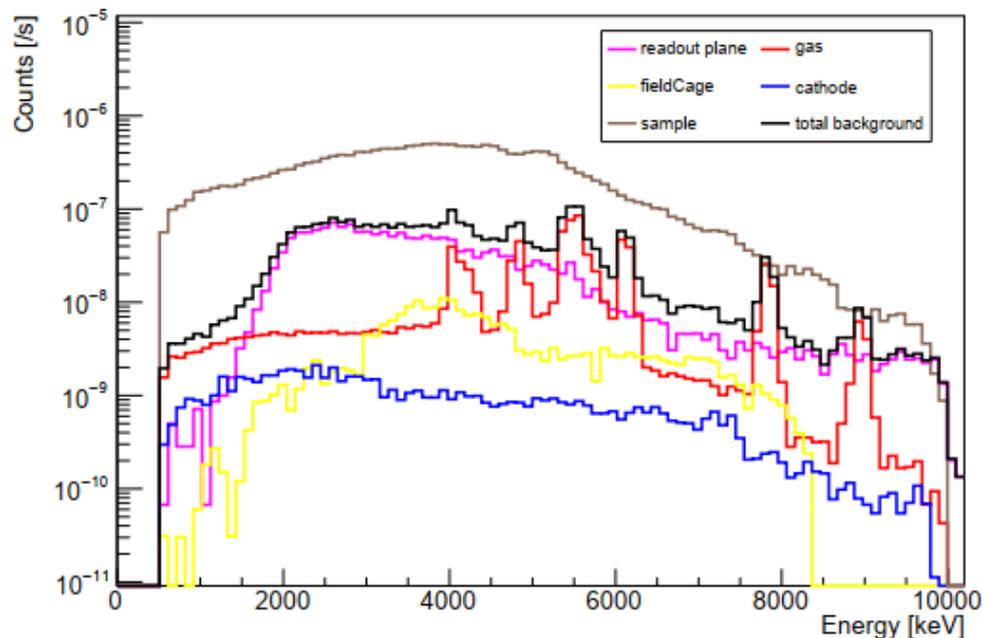
Track origin points
(cut almost all field cage
and cathode background)



The cosine of θ
(cut readout plane
background and half of
gas background)



Measurement sensitivity



The energy spectra of backgrounds after suppression

Sensitivity analysis of the gaseous TPC (90%C.L)

| measurement time (day) | background events (counts) | sensitivity ($\mu\text{Bq}\cdot\text{m}^{-2}$) |
|---------------------------|-------------------------------|---|
| 1 | 0.26 | 82 |
| 3 | 0.77 | 43 |



Prototype TPC

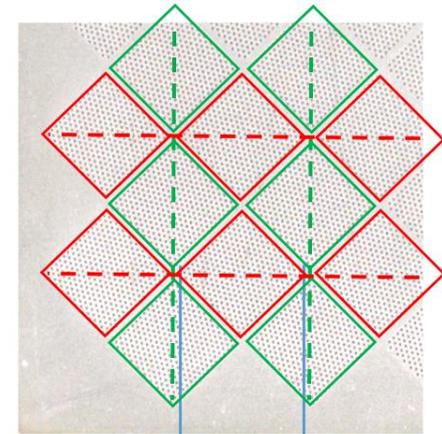
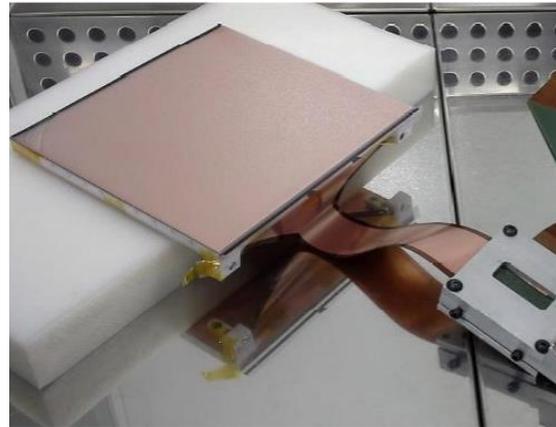


Prototype TPC



active volume
high:10cm

Field cage and readout plane



Zoom view of the corner of the Micromegas surface

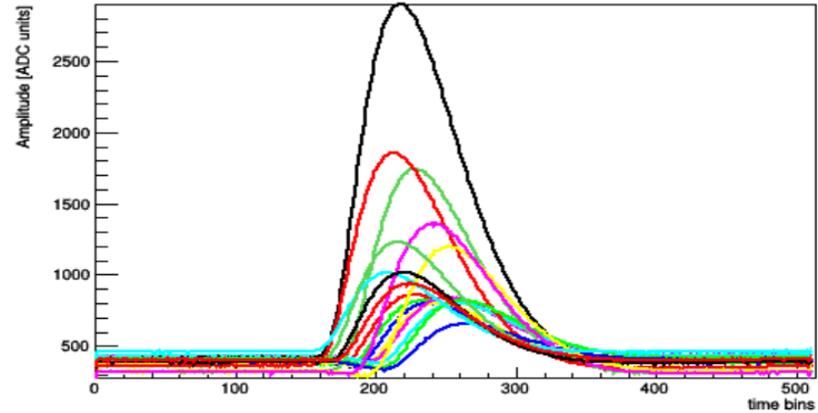
The Micromegas readout module
(20 x 20 cm²)
Read out with 64 **Y strips** and 64 **X strips**



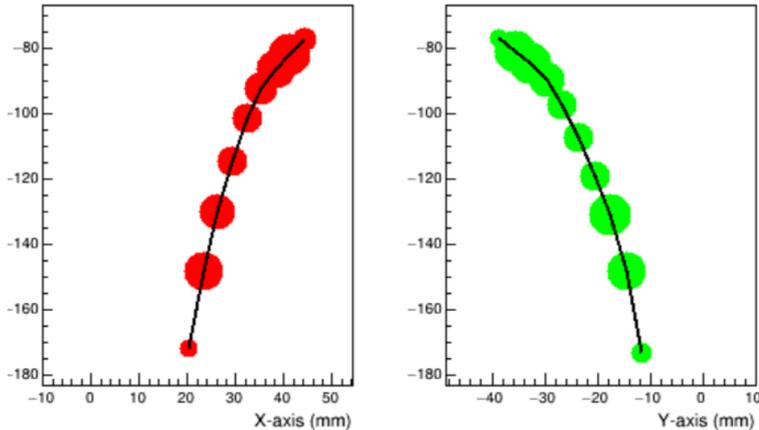
The preliminary test of prototype TPC(^{241}Am)



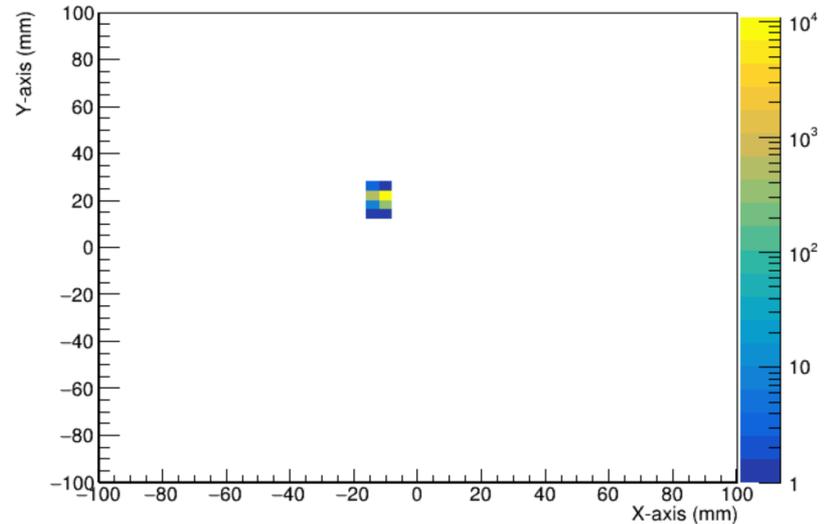
^{241}Am source: 3mm dot



Signals collected from the prototype TPC



Track reconstruction



Hit map of the origin source



Summary

- Surface contamination control is a critical part of low background experiments and surface radioactivity measurement is desirable.
- We propose a low-background, large-area (about 2000cm²), and high-efficiency gaseous TPC with Micromegas readout for measurement of surface radioactivity.
- With the energy and track recorded by the TPC, TPC background can be further suppressed.
- The sensitivity of surface alpha measurement will be better than 100 $\mu\text{Bq}/\text{m}^2$ at 90% C.L. of one day measurements.
- A prototype TPC is constructed to verify the detector's design and the analysis protocol.



Thanks for your attention!

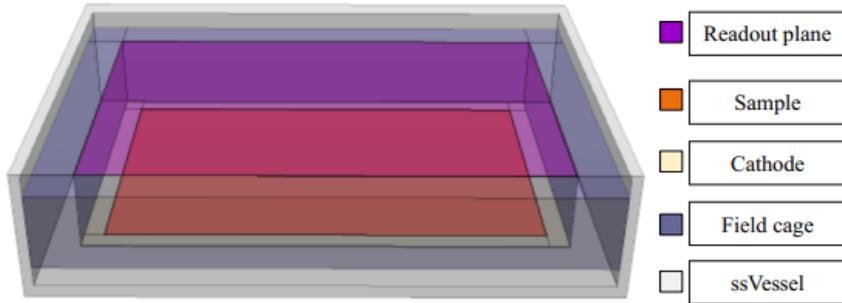


Backup



Simulation for background study

| Material | Gaseous argon | Acrylic | Oxygen-free copper | Stainless steel | Readout plane |
|-------------------|---------------------------|---------|--------------------|-----------------|--------------------------|
| ^{238}U | 1.8×10^{-3} | 0.088 | 0.38 | 1.7 | 45 nBq.cm^{-2} |
| ^{232}Th | 0.4×10^{-3} | 4.63 | 0.51 | 2.74 | 14 nBq.cm^{-2} |
| ^{222}Rn | 0.01 mBq.m^{-3} | | | | |
| ^{40}K | | 0.09 | 4 | 13.95 | |
| ^{60}Co | | | 0.2 | 1.03 | |
| ^{137}Cs | | | 0.16 | 2.36 | |
| ^{39}Ar | 1022 | | | | |



Sensitivity volume: $60 \times 40 \times 10 \text{ cm}^3$

Readout plane (Microbulk Micromegas)

: $58.03 \times 38.55 \text{ cm}^2$, 0.1mm thick

Cathode: $60 \times 40 \text{ cm}^2$, 2mm thick

Field cage: A 4 cm thick acrylic frame

ssVessel: $80 \times 60 \times 15 \text{ cm}^3$, 1cm thick

Sample: $55 \times 35 \times 0.01 \text{ cm}^3$

Geometry of the gaseous TPC simulation