

# R2D2 (Rare Decays with Radial Detector) status

## & Projects @ LSM

DUPhy GDR Meeting – 19-21/10/2022

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On behalf of the R2D2 collaboration

R2D2 IN2P3 Master-project

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# R2D2 motivation: Development of a single anode HP-TPC with $^{136}\text{Xe}$ for $2\beta 0\nu$ search

**Assets of our approach** (relative to imagers like NEXT or PANDA-X):

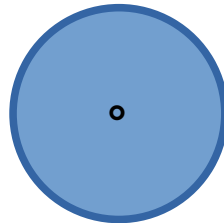
- 1) Simplest mechanical structure  $\Rightarrow$  reduction of the near-background
  - 2) Energy resolution  $\sim 1\%$  FWHM @  $Q_{\beta\beta}$
- Track localization (NEWS-G: point-like)
  - 2-tracks recognition (at least for background)
- }  $\Rightarrow$  rejection of the background

## **Choice of gas & pressure:**

- *Low Mass Dark Matter "à la NEWS-G"*
- *Solar Kaluza-Klein axion (Q. Arnaud et al., PHYSICAL REVIEW D 105, 012002 (2022) )*
  - *Neutrino Magnetic Moment (Article in preparation C. Jollet et al.)*

## **Recent developments:**

- SPC (Spherical Prop. Counter)  $\Rightarrow$  CPC (Cylindrical Prop. Counter)  $\Rightarrow$   $1/r$  field
- Proportional / ionization regime (choice of ion or  $e^-$  mode)  $\Rightarrow$  choice in 2023, (sensor diameter, HV parameter, FEE)

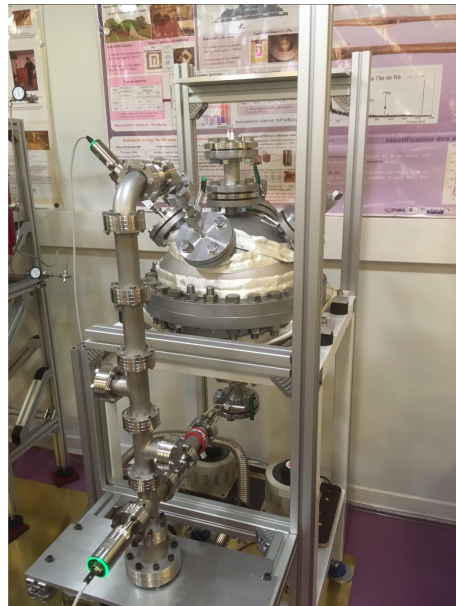


# Prototypes evolution

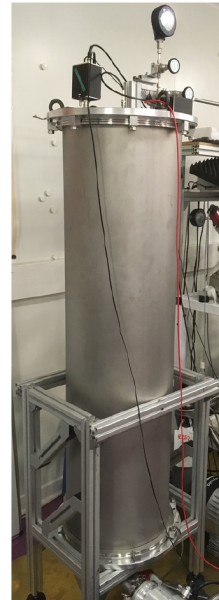
Test facility @ CENBG (no radio-purity)



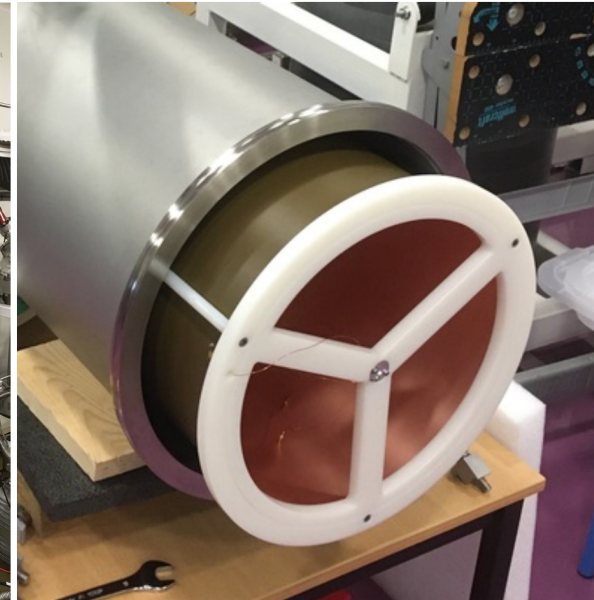
SPC-1 (2018)  
0.4 m diam., 1 mm ball  
(pressure certification =>  
1 bar)



SPC-2 (2021)  
0.4 m diam.  
(40 bar)



Inverted CPC-1 (2022)  
1 x 0.37 m, wire of 20  $\mu\text{m}$   
(1 bar)  
Our backup modular option



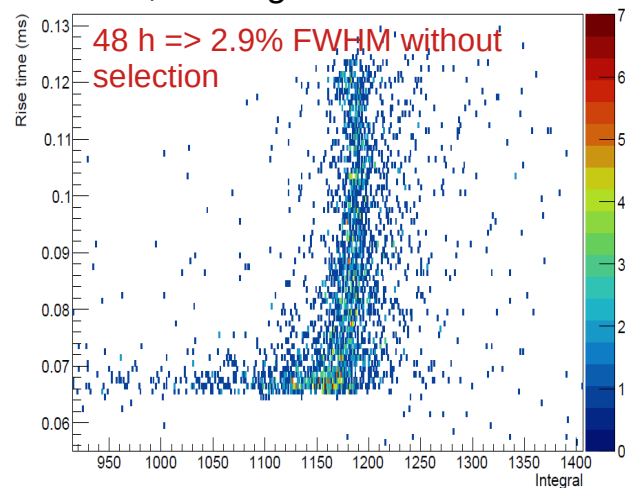
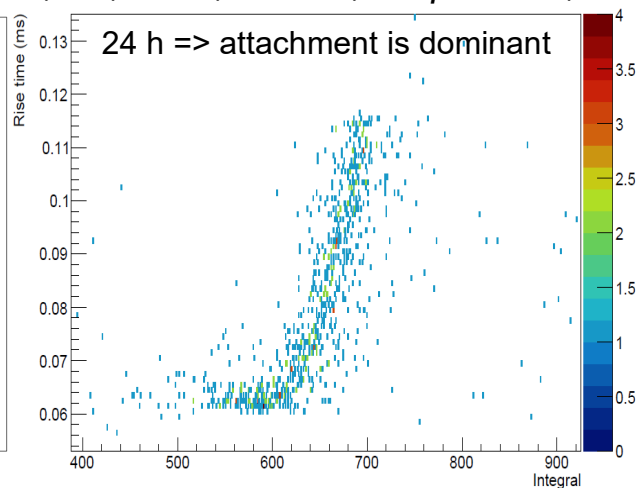
# Recent results: Energy resolution

**Numerical treatment of the signal (deconvolution, filtering, etc.) is stabilized**

- Xe filling available since July 2022
- SPC with Xe => only in ionization mode @1bar (HV insulation)

*CPC, Xe, 1 bar, 1200 V, Prop. Mode,  $^{210}\text{Po}$  source, raw signal*

After filling  
(during some  
hours)  
=>  
No observed  
source signal  
(except cosmic  
tracks)



=> 1.8 % with  $R_t > 80 \mu\text{s}$  (incoming  $\alpha$ )  
=> 1.4% with cosmic rejection

Rise time vs integral of  
a CPC in Xe according  
to the time of gas  
cycling



**Gas purity is an  
key point**

# Recent results: Gas purification



- Not crucial with Ar
- **Crucial with Xe (drift velocity)**

A simple system based on a circulating pump and 2 cold getters to trap electronegative molecules in Xe

=> Upgrade of the system adding a hot getter (pending)  
Additional stage ? use of spark discharge purifier ?

S.G. Pokachalov et al. NIM A327 (1993)

- Xe recovery: cryogenic pumping (=> will benefit in the future from the expertise of the Xe group of SUBATECH)
- Removal of Rn in the Xe is under study @CCPM (With the mixtures of light gases of NEWS-G, this is being solved)

# Recent results: Track localization

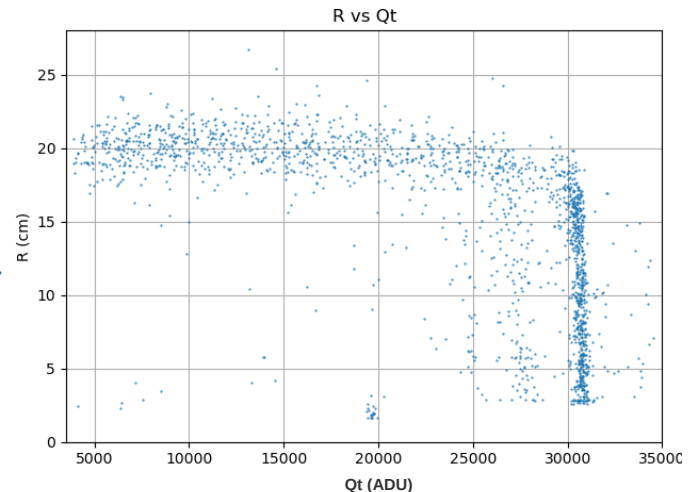
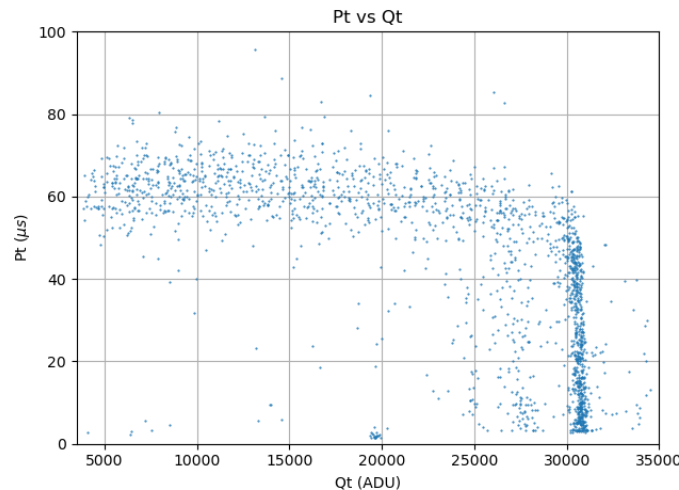
A macroscopic model of the signal formation has been developed.

Combined to our signal treatment => the peak time (Pt) of the induced anode signal (this is our deconvolved signal) mainly depends on:

- The diffusion of the primaries during their drift
- The minimal distance of energy deposition relative to the anode

+ From simulations and experimental calibrations => Pt varies as :  $Pt = Pt_{max} * (R/R_{max})^\alpha$

*SPC, ArP2,  
0.2 bar, 800 V,  
Prop. mode,  
 $^{210}\text{Po}$  source,  
deconv. signal*

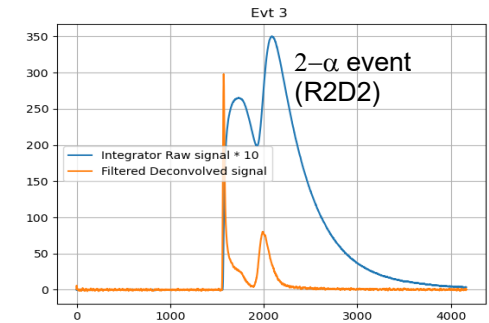
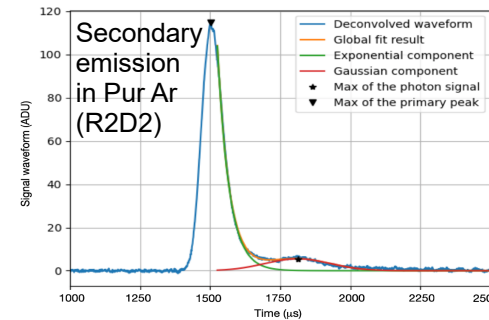
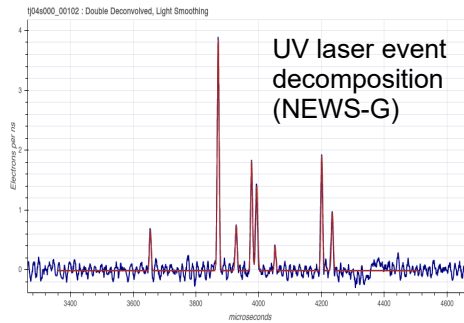
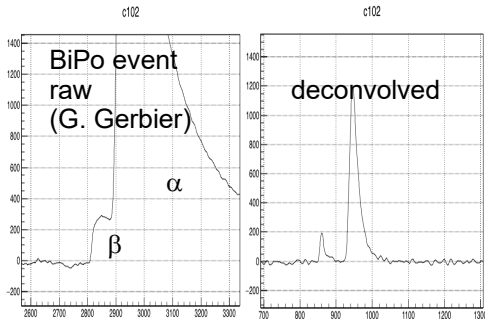
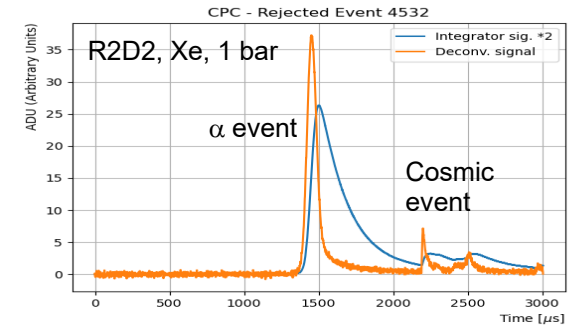


# Recent results: Multi-tracks recognition

- Efficient recognition of background events (Compton, cosmics, etc.) should be achieved  
(=> tests of CPC response without cosmics @LSM in 2023)

@ low pressure:

- For low energies => decomposition in elementary  $e^-$  (in routine in NEWS-G)
- For strongly ionizing tracks (Alpha) => use of the Bragg peak signal



@ high pressure:

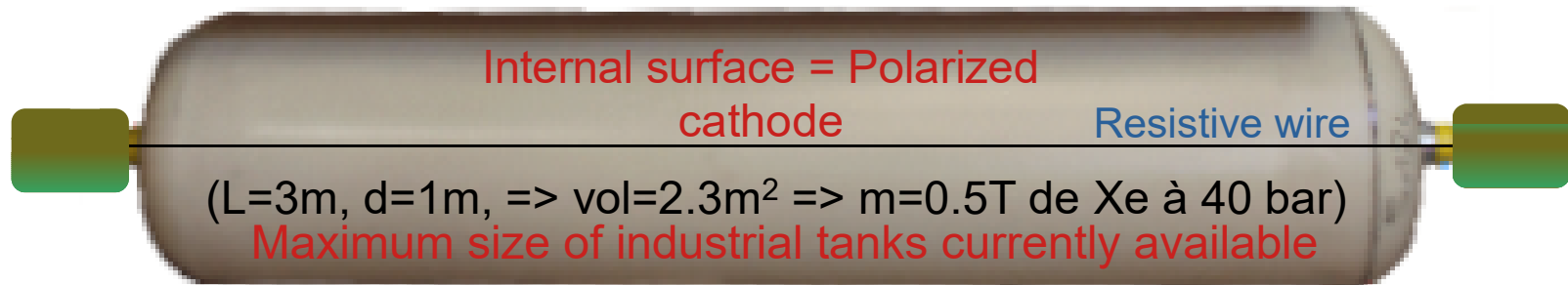
- Except for cosmics, all interactions appear as point-like => recognition of the 2-tracks of  $2\beta 0\nu$  decay is very challenging => work is in progress

# Recent results: CPC option

Based on composite tank technology (600 bars) for H<sub>2</sub> storage

- Drift field in  $1/r$  instead of  $1/r^2$  (SPC) => relax gas purity ?
- Resistive wire => additional localization capacity along the longitudinal axis => background rejection
- Non-polarized anode => FEE noise + easier insulation
- Easy detector scalability up to tons (& cost)
- Internal structure (< 1 gram of metal) => **composite-induced background ? composite conductivity (cathode) ? => to be checked in 2023**

=> 2023 : development of the process of the tank instrumentation





**2023: Recent tests of the CPC (1 x 0.4 m) shows a sensibility to cosmics (rate of several hundred of Hz @ 1 bar) => This will increase with the gaz pressure**  
**=> Test of the CPC response without cosmics @LSM (not low background)**

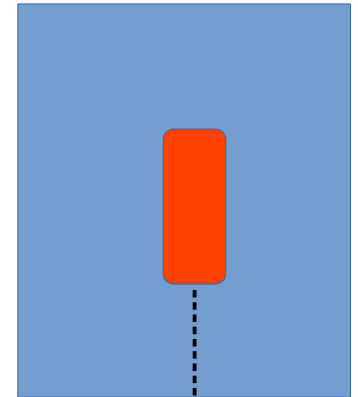
**2023–2024: Towards a low background composite detector**

- 2023: Material screening @LSM and @LP2I (**especially for composite material**)  
Construction and commissioning of a low background prototype @LP2I and @SUBATECH
- **2024: Background measurements in Edelweiss shielding**

**By 2025-2026: Towards a full scale experiment @LSM**

- Shielding optimization (active/passive) from data with prototype
- Footprint roughly 10m x 10m for detector, shielding and utilities  
+ top to bottom occupancy of the main hall (gantry needed)

**Low energy impact expected with the R2D2 experiment (no cryogenics)**



Hanging TPC  
in a pool ?  
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