Spatial Stability of Kr83m calibration events in XENONnT experiment

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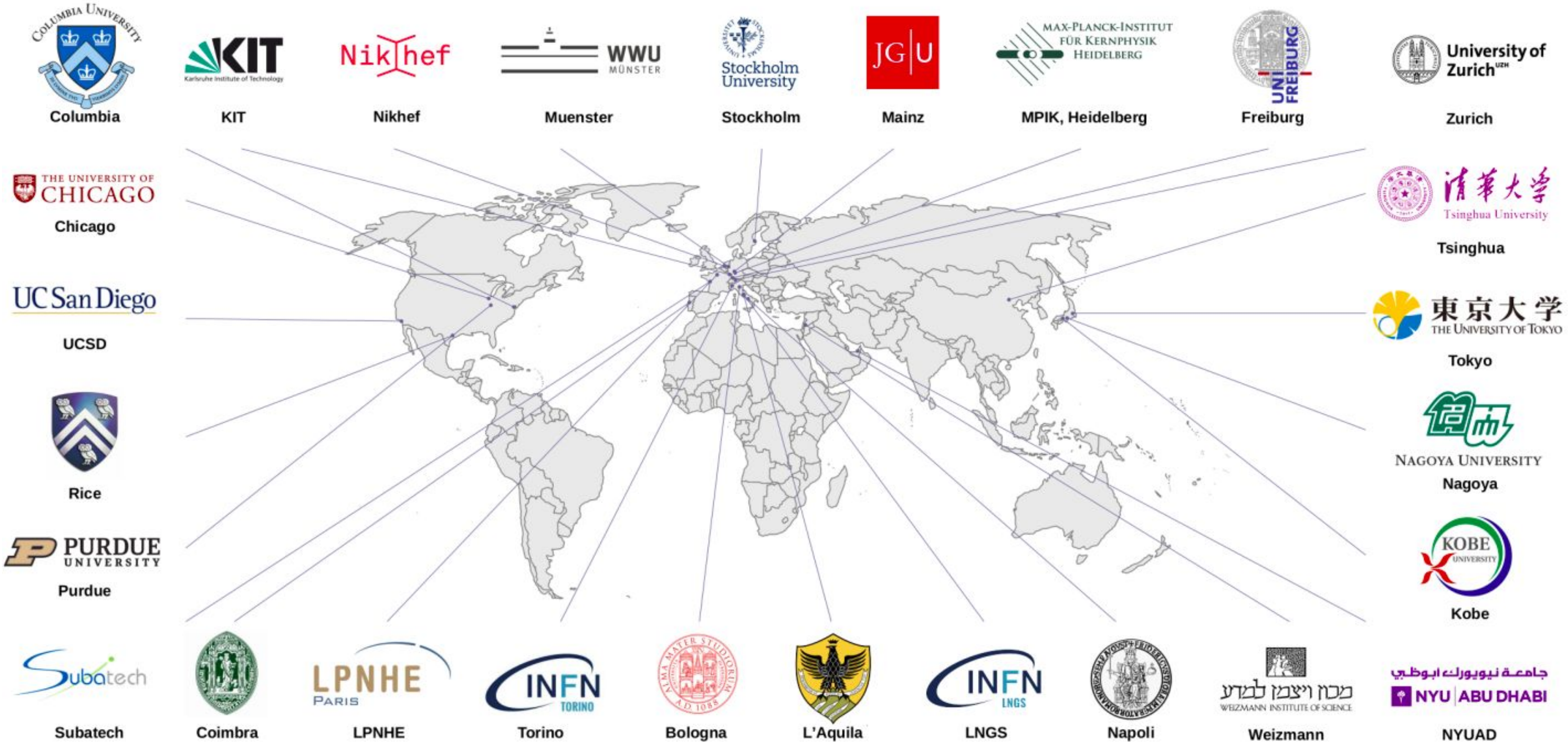
JRJC 2022

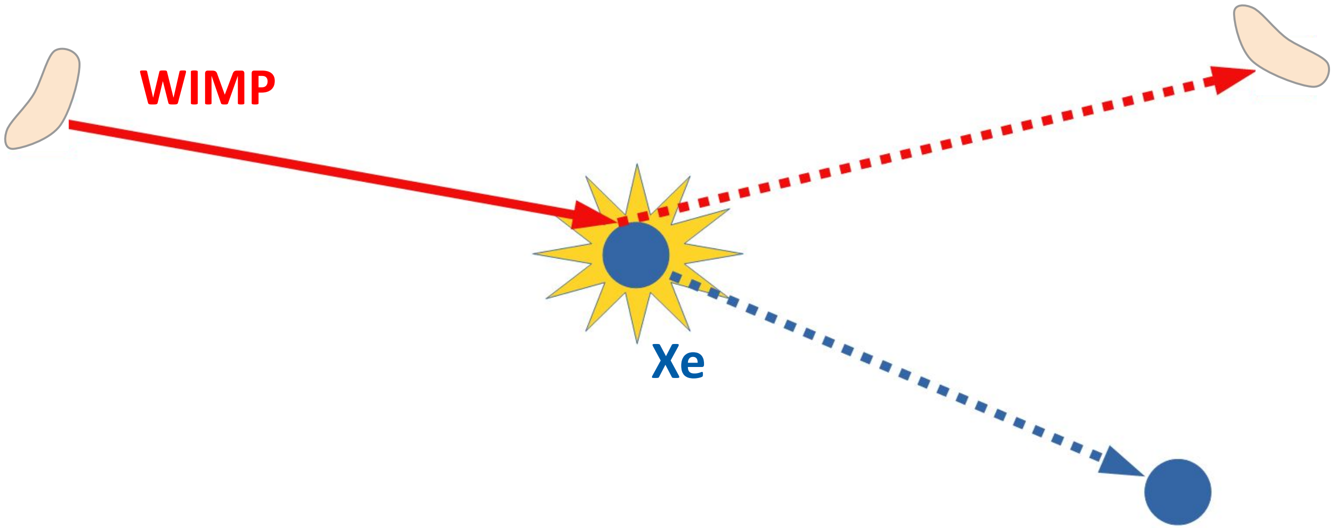
XENON collaboration

- ~170 scientists in 27 institutions worldwide
- Main goal: look for dark matter particles with a xenon TPC

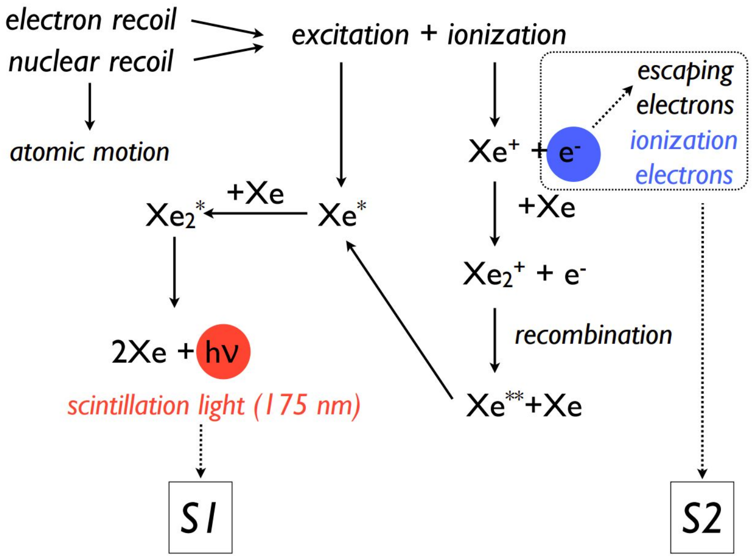


Direct detection of WIMP

- Collision between WIMP and xenon nucleus
  - Elastic collision
  - Nuclear Recoil
  - Energy 1 - 100 keV
  - Rare Event (expected 1 event.y^{-1})
  - Need a very low background noise

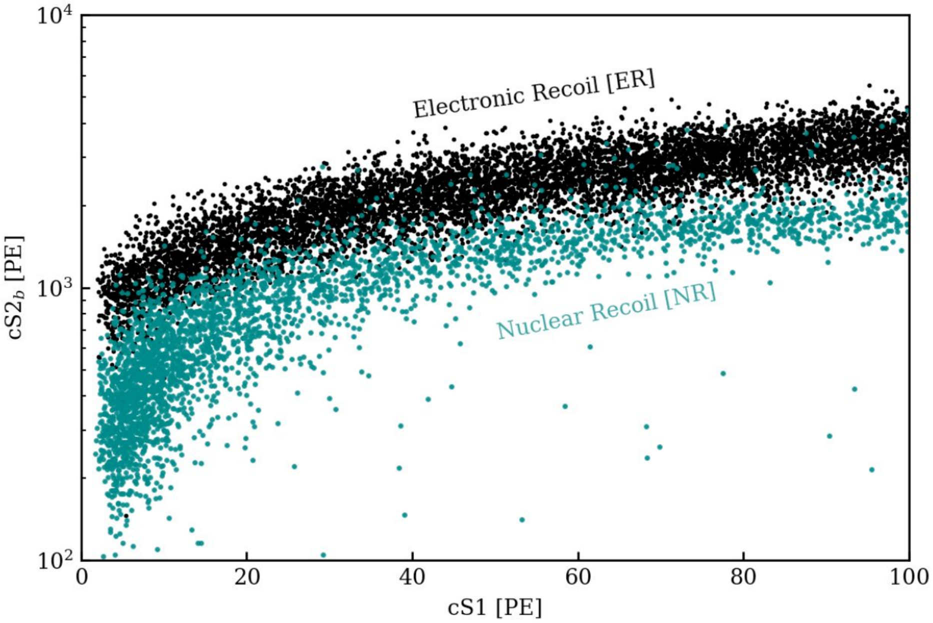


Liquid xenon as target



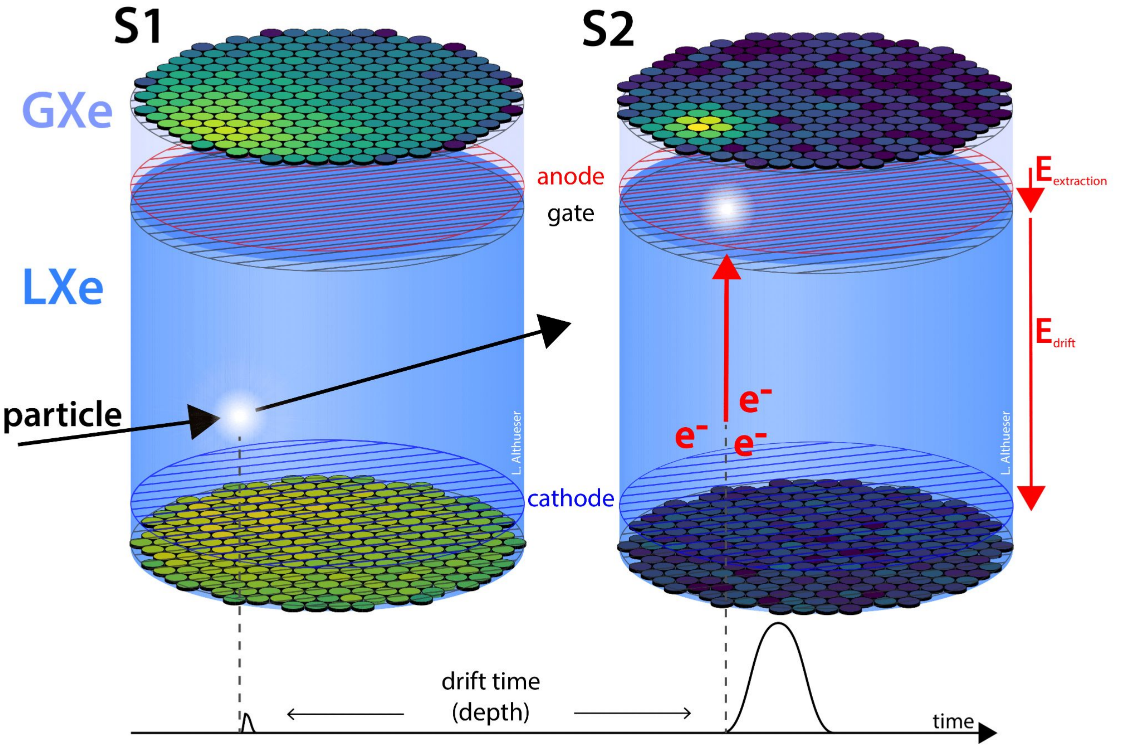
- 2 possible interactions :
  - Electronic Recoil : photon or β particle
  - Nuclear Recoil : WIMP or nucleon
- For both :
  - Production of excited and ionized xenon
  - Recombinaison of ionized xenon
  - Generation of 2 anti correlated signals

- Discriminate ER and NR thanks to S2 / S1 ratio

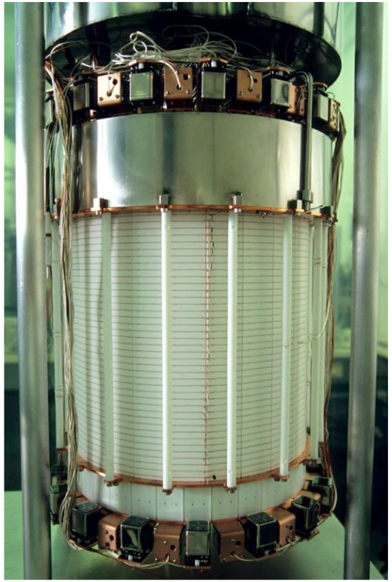


Dual phase Time Projection Chamber

- S1 signal
  - Light from collision detected by PMT arrays
- S2 signal
  - Electron drifted by electric field to a liquid-gas interface
  - Extraction to the gas phase by another electric field
  - Interaction drifted electron / gaseous xenon generating light
  - Light detected by PMT arrays
- S2 are way bigger than S1
- Position reconstruction
  - Pattern on PMT arrays give our x,y position
  - Drift time give our z

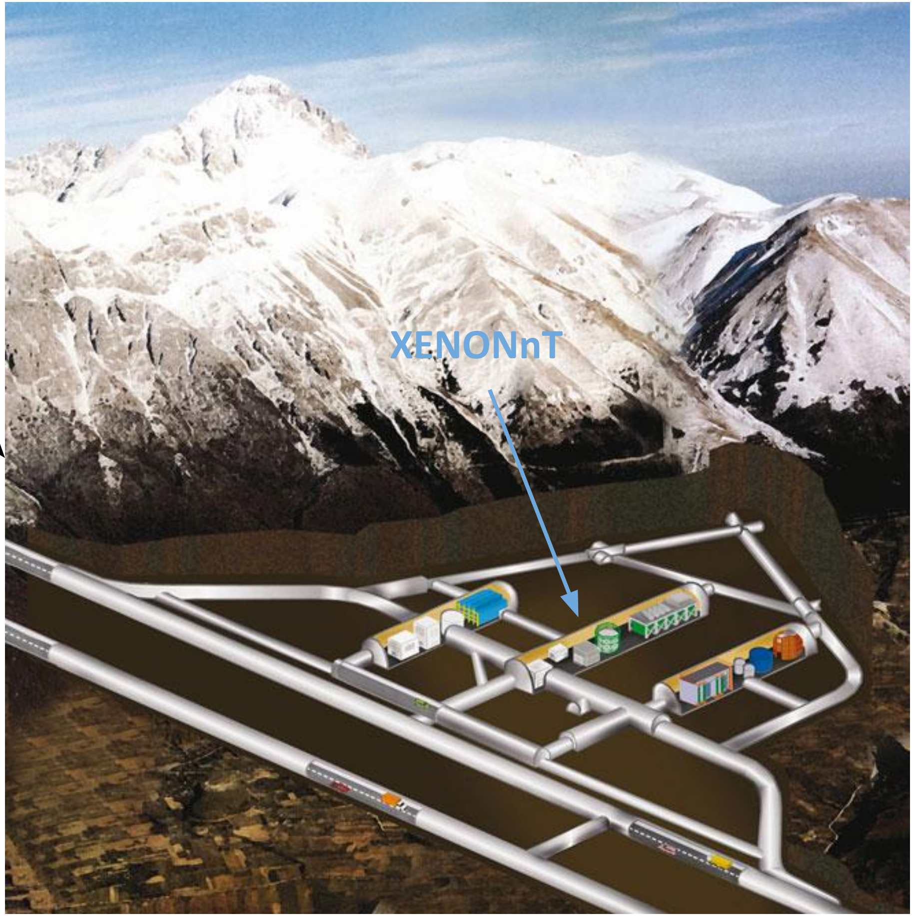


XENON program

XENON10	XENON100	XENON1T	XENONnT
			
2005 - 2007	2008 - 2016	2013 - 2018	2019 -
15 cm TPC	30 cm TPC	100 cm TPC	144 cm TPC
25kg	161kg	3200kg	~ 8000kg
$\sigma \sim 4.5 \times 10^{-44}$ cm^2	$\sigma \sim 1.1 \times 10^{-45}$ cm^2	$\sigma \sim 4.1 \times 10^{-47}$ cm^2	$\sigma \sim 1.6 \times 10^{-48}$ cm^2

XENON at LNGS

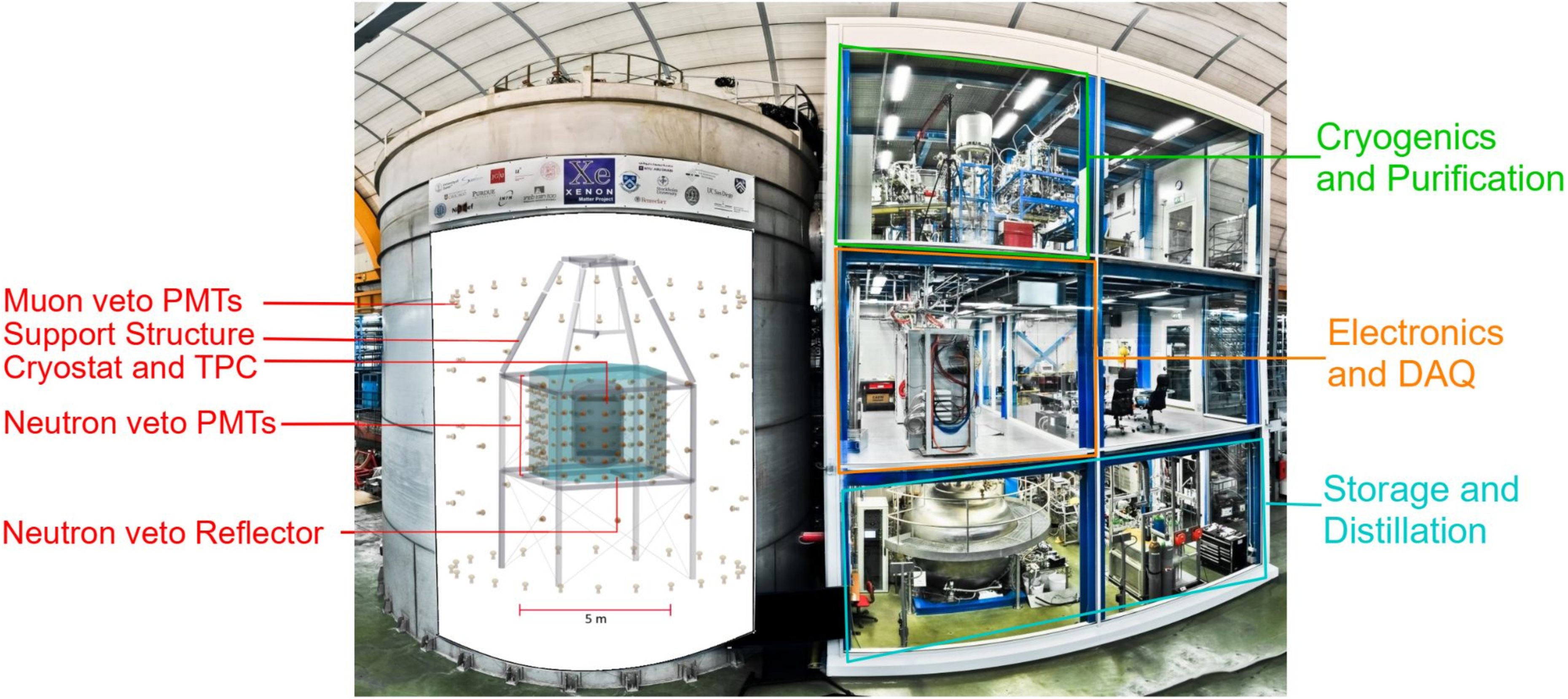
LNGS



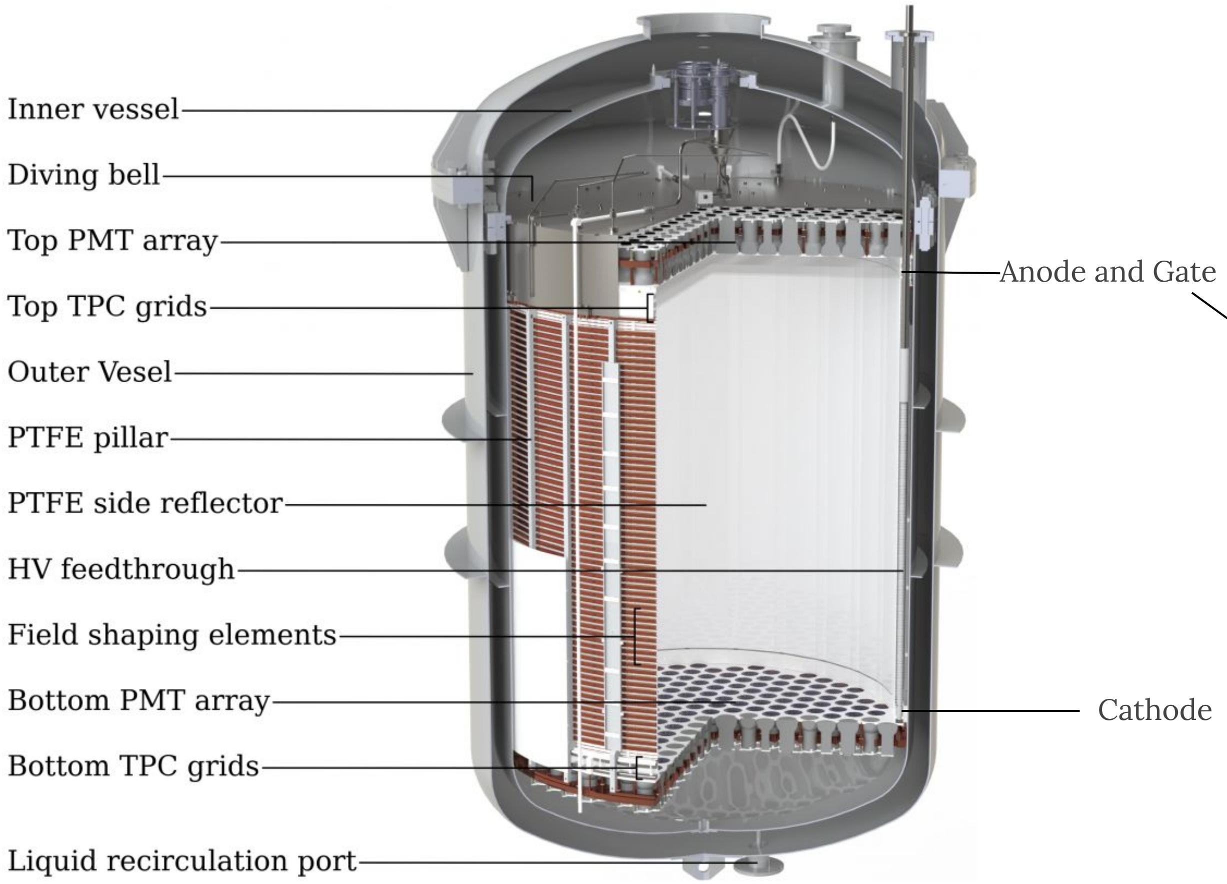
Large underground laboratory

- Below Gran Sasso massif (1400 meter-rock) → reduce cosmologic ray
- Low amount of U and Th → small neutron flux

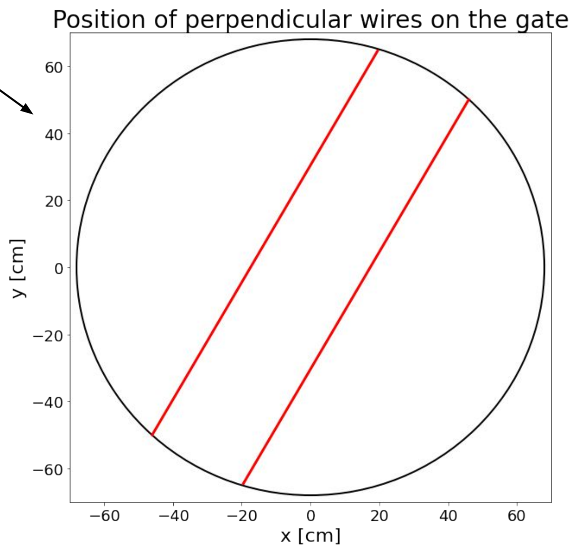
XENONnT experiment



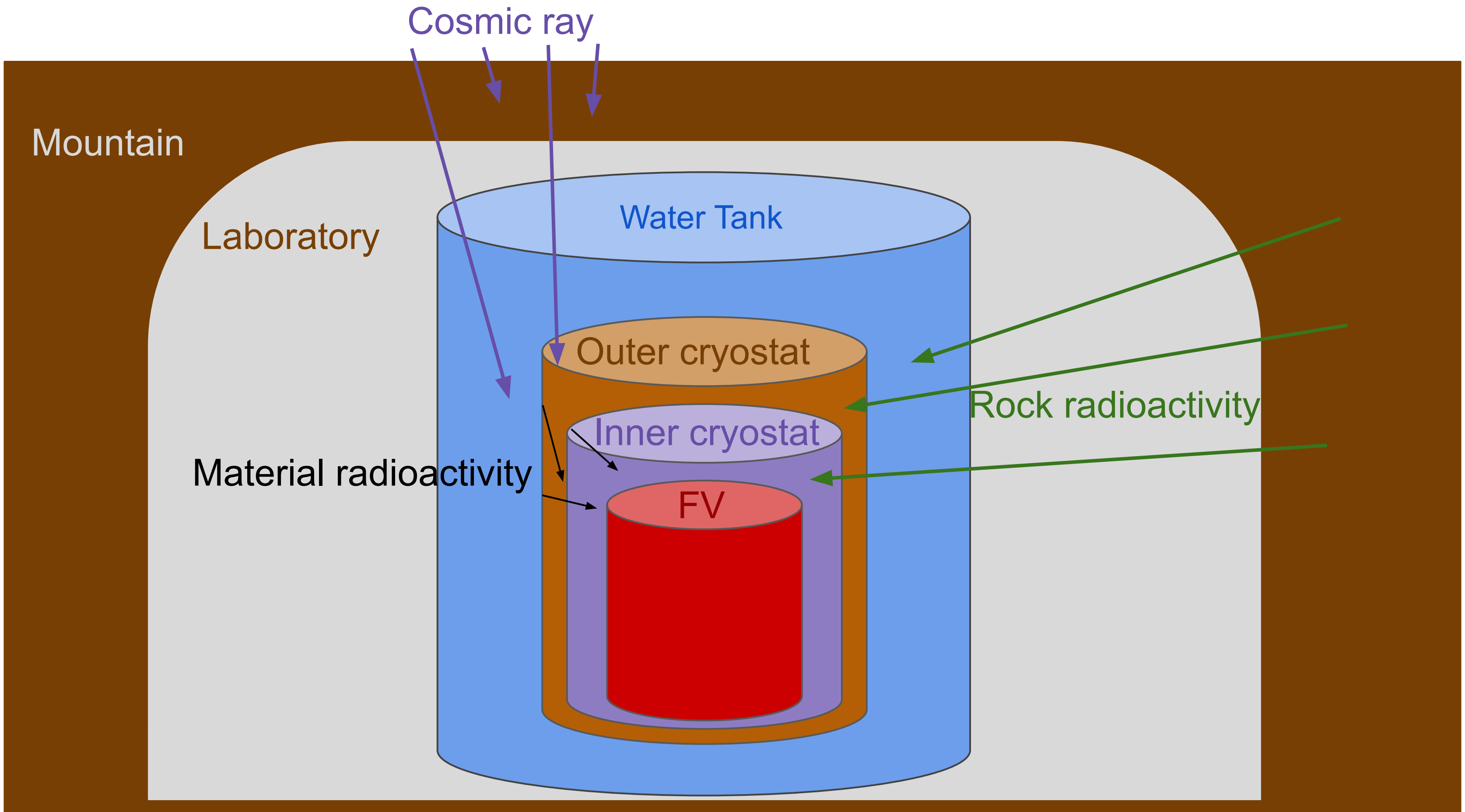
XENONnT cryostat



- Gate and anode have additional wires to counteract deformation of electrode

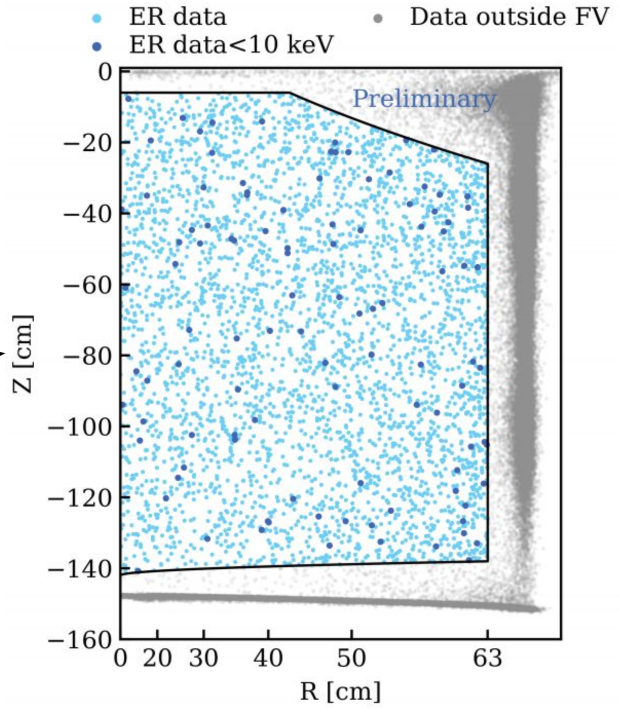


Protect from background

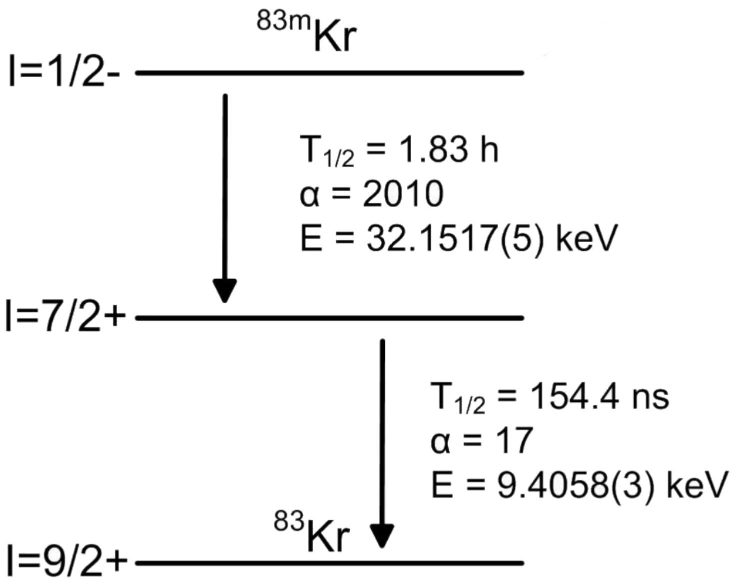


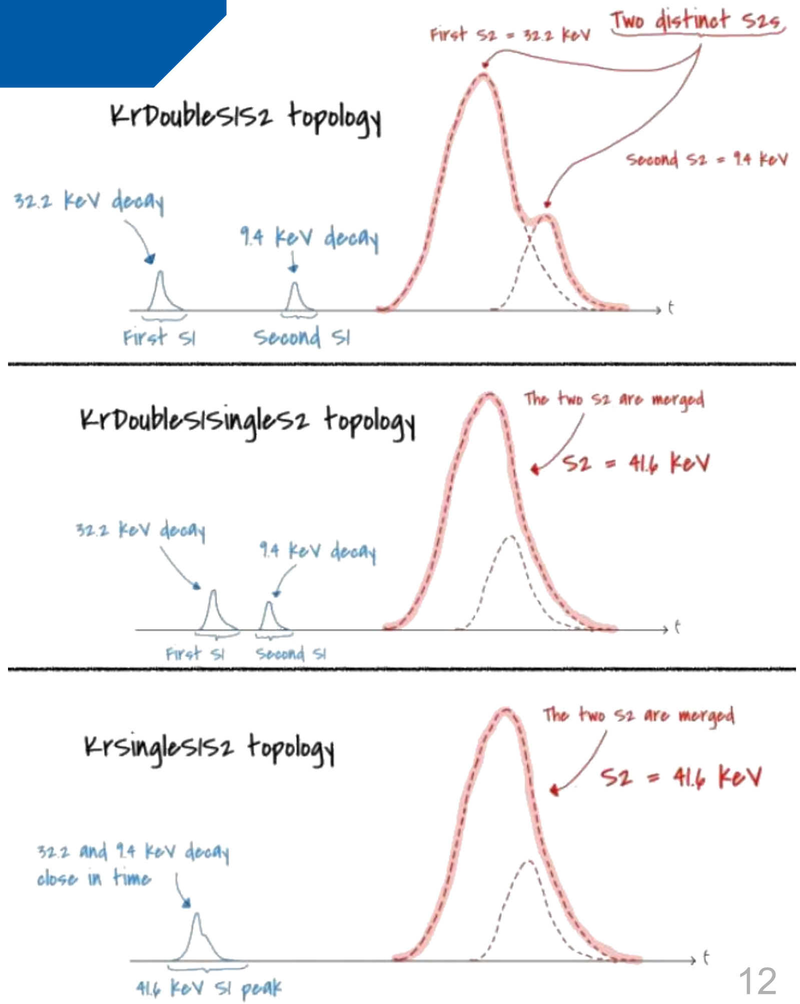
Correction and Calibration

- Correction to take into account :
  - Non uniformity of electric field
  - …
- Reconstruction of incident particle energy :
  - Gain of each signal in the TPC
  - …
- Selection of signal :
  - Fiducial Volume
  - …
- To XENONnT experiment:
  - long period of time → monitoring
  - large experiment → **spatial stability**
- **Need of calibration sources**



Kr83m calibration events

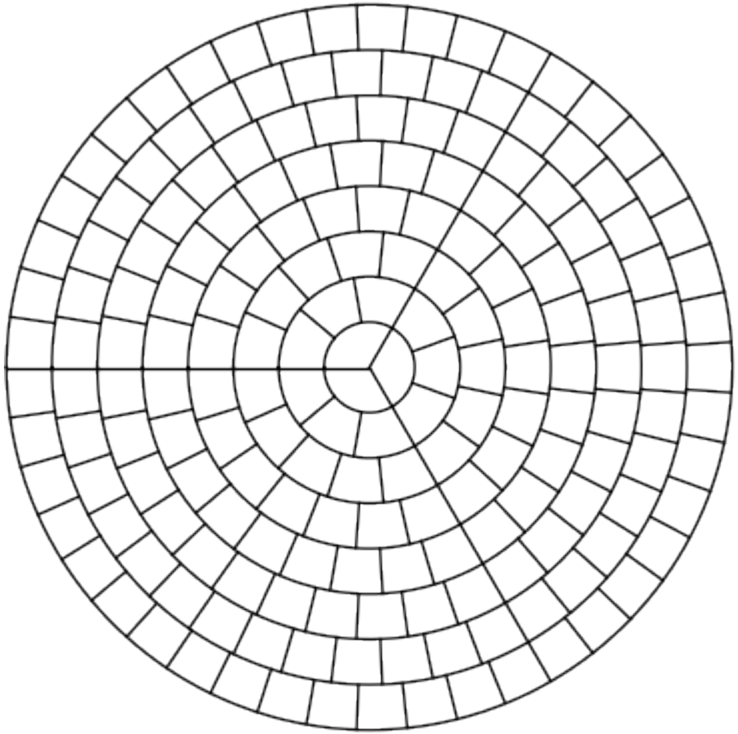




- Selecting ~ 40 000 000 SingleS1S2 events during Science Run 0 (1 May – 10 December 2021)
- Corrected peak will be used in the following and are named cS1 and cS2

Voxeling of the total volume

- Volume used :
  - -141 cm < z < -3 cm
  - r < 68 cm
- 48 slices in z :
  - Each slice is 2.875 cm high
- Each slice are divided in voxels :
  - 8 rings of 8.5 cm width
  - 192 voxels of same volume per slice
- 9216 voxels in the whole TPC
- Used to plot maps of relative variation for some values for the whole TPC volume



Double gaussian fit

- Plot the cS2 vs cS1 distribution in PE and fit by double gaussian function:

- Extracting the center value of cS1 and cS2 as their standard deviation

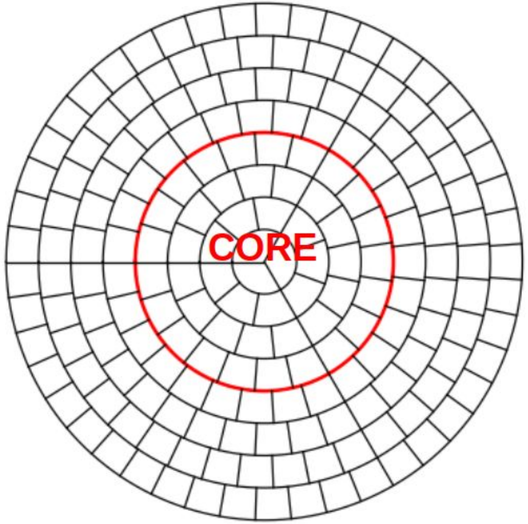
- Computing their relative variation :
  $X_{rv} = (X - X_{mean}) / X_{mean}$

- Plot maps of their relative variation in the total volume thanks to voxelling

cS1 spatial stability maps

cS1 z stability in the core

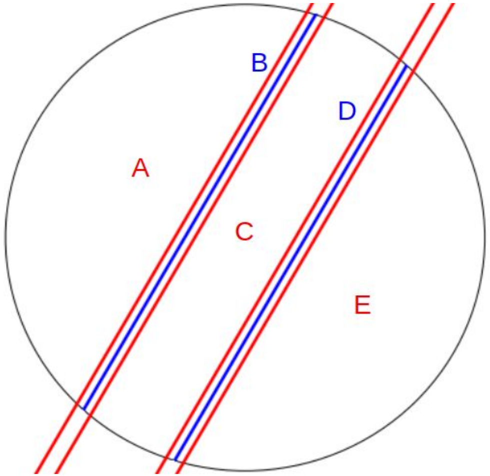
- We want to check the stability in z of cS1 without any edge effects in order to control other ones
    - Events in the core of each slice (r <= 34 cm)



cS2 spatial stability maps

cS2 z stability for 5 regions

- 5 regions of interest :
  - A : 5 cm up left to left wire
  - B : 5 cm around left wire
  - C : Between wires
  - D : 5 cm around right wire
  - E : 5 cm down to right wire



Conclusion

- XENONnT is a low background experiment searching for WIMP-Xenon interaction
- Use the Kr83m as calibration source allows to check the stability of the detector at the expected energy for WIMP collision
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- The same method can be used to check the spatial stability of the detector for future data taking or for smaller period of time reducing voxeling

Thank You

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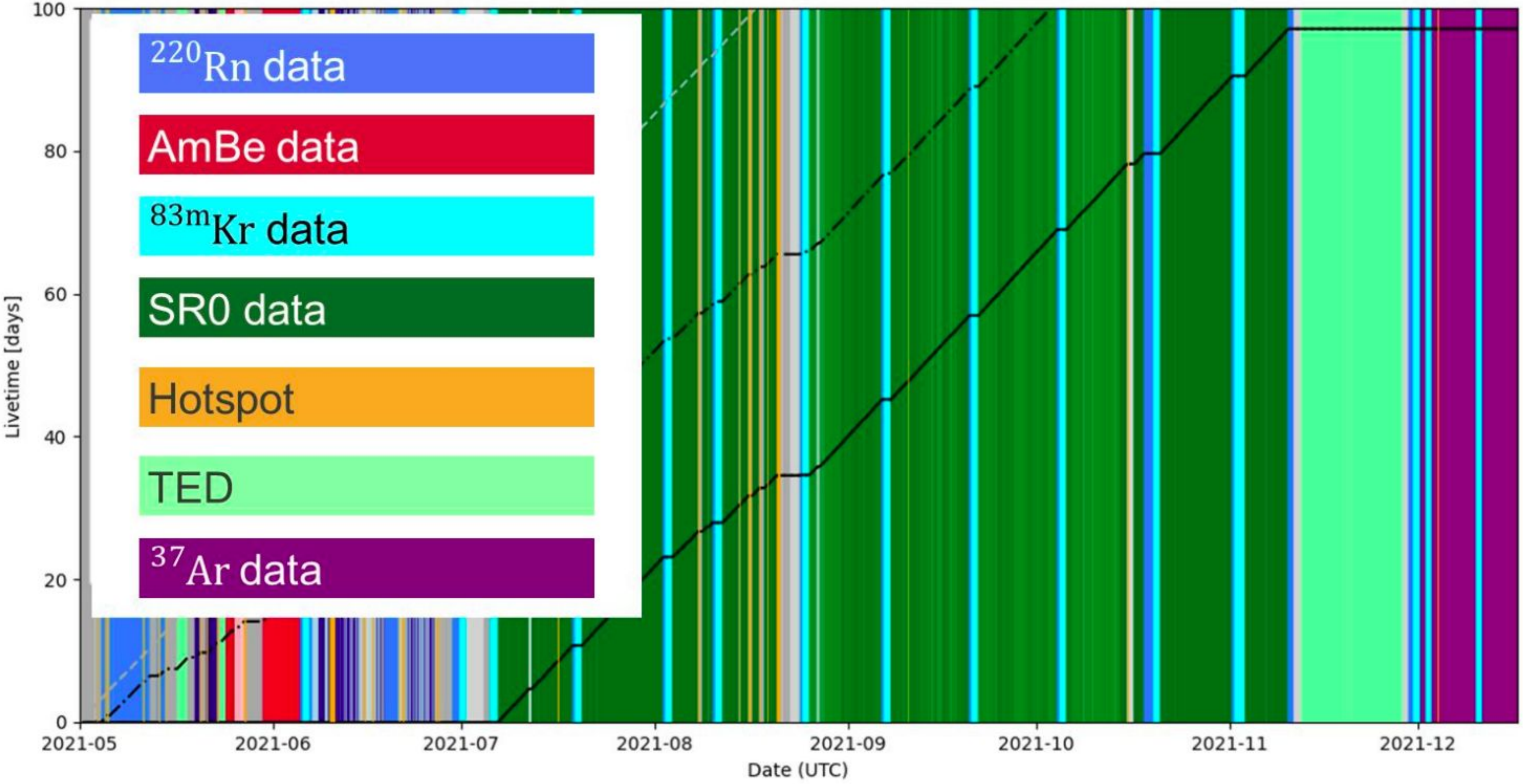
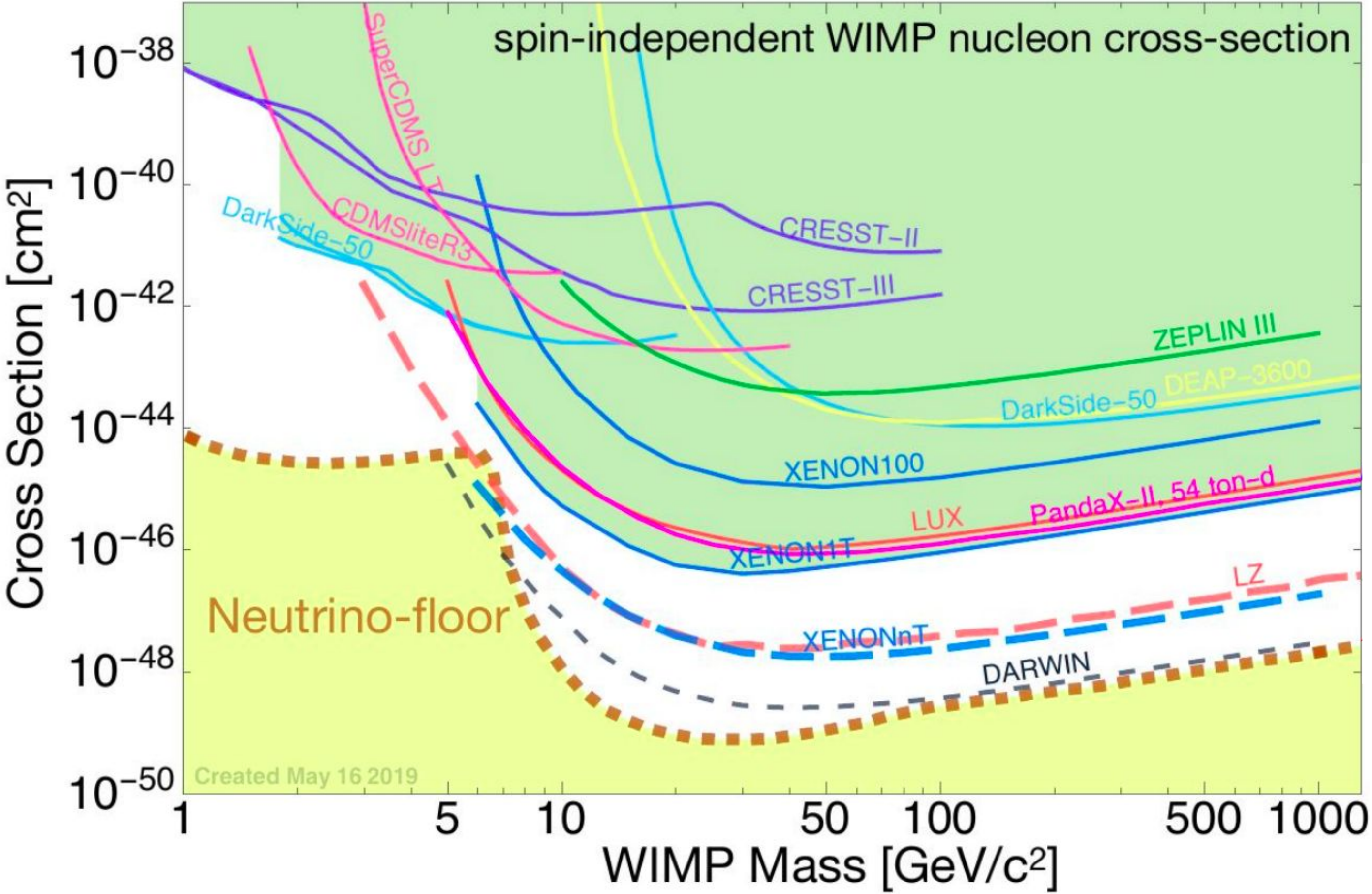
Questions ?

Backup

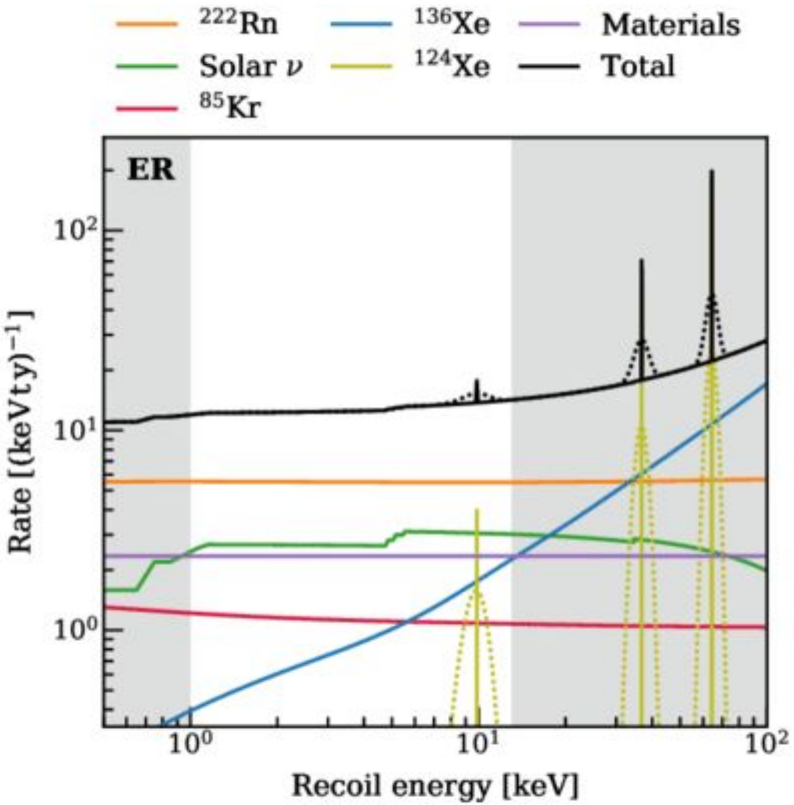
SR0 data taking and calibration

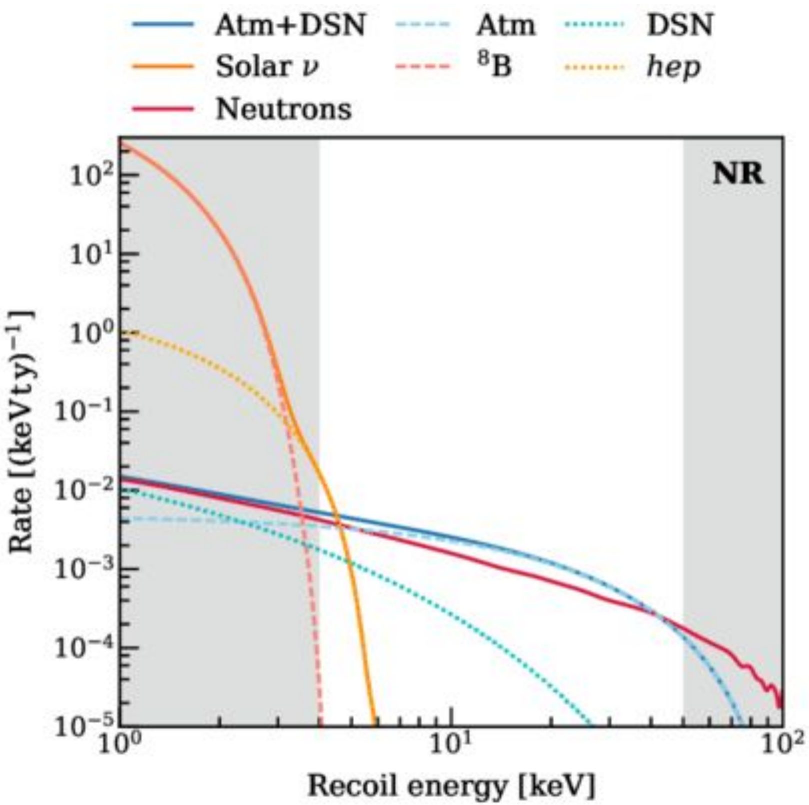


Dark matter limit



Simulated background noise





Double gaussian function

$a = (\cos^2(\theta))/(2\sigma_x^{\ 2}) + (\sin^2(\theta))/(2\sigma_y^{\ 2})$

$b = -(\sin(2\theta))/(2\sigma_x^{\ 2}) + (\sin(2\theta))/(2\sigma_y^{\ 2})$

$c = (\sin^2(\theta))/(2\sigma_x^{\ 2}) + (\cos^2(\theta))/(2\sigma_y^{\ 2})$

$f(x, y, amp, x_0, y_0, \sigma_x, \sigma_y, \theta) = amp*\exp(- (a*((x-x_0)^2) + b*(x-x_0)*(y-y_0) + c*((y-y_0)^2)))$