Studies of the XENON100 Electromagnetic Background

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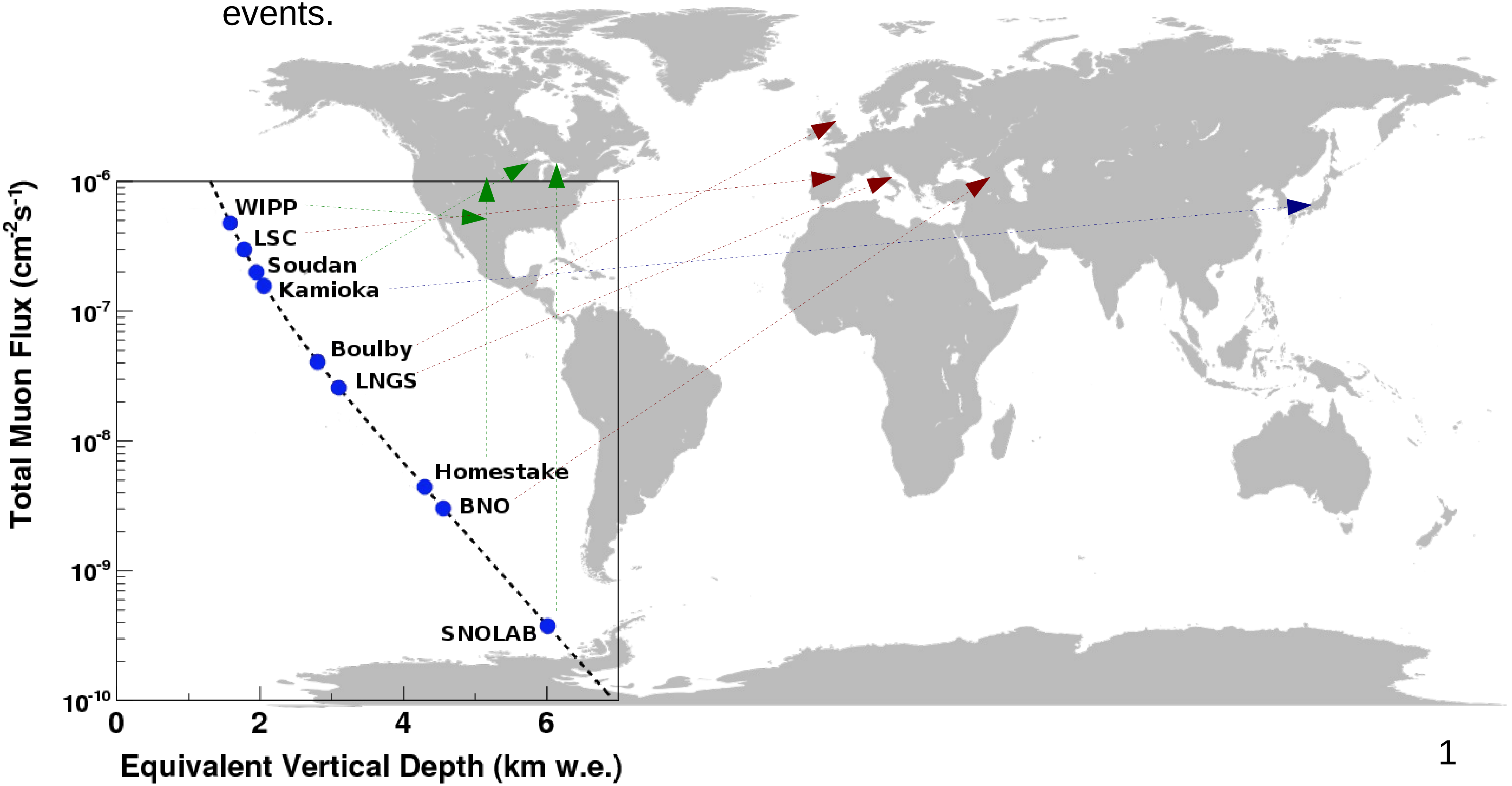
Searching for elusive particles

The main challenge for experiments searching for low event rate phenomena, such as **dark matter**, is the **reduction and discrimination** of the **background radiation**. Installing the detectors in **underground facilities** is the first step to reach an increased sensitivity to such rare events.



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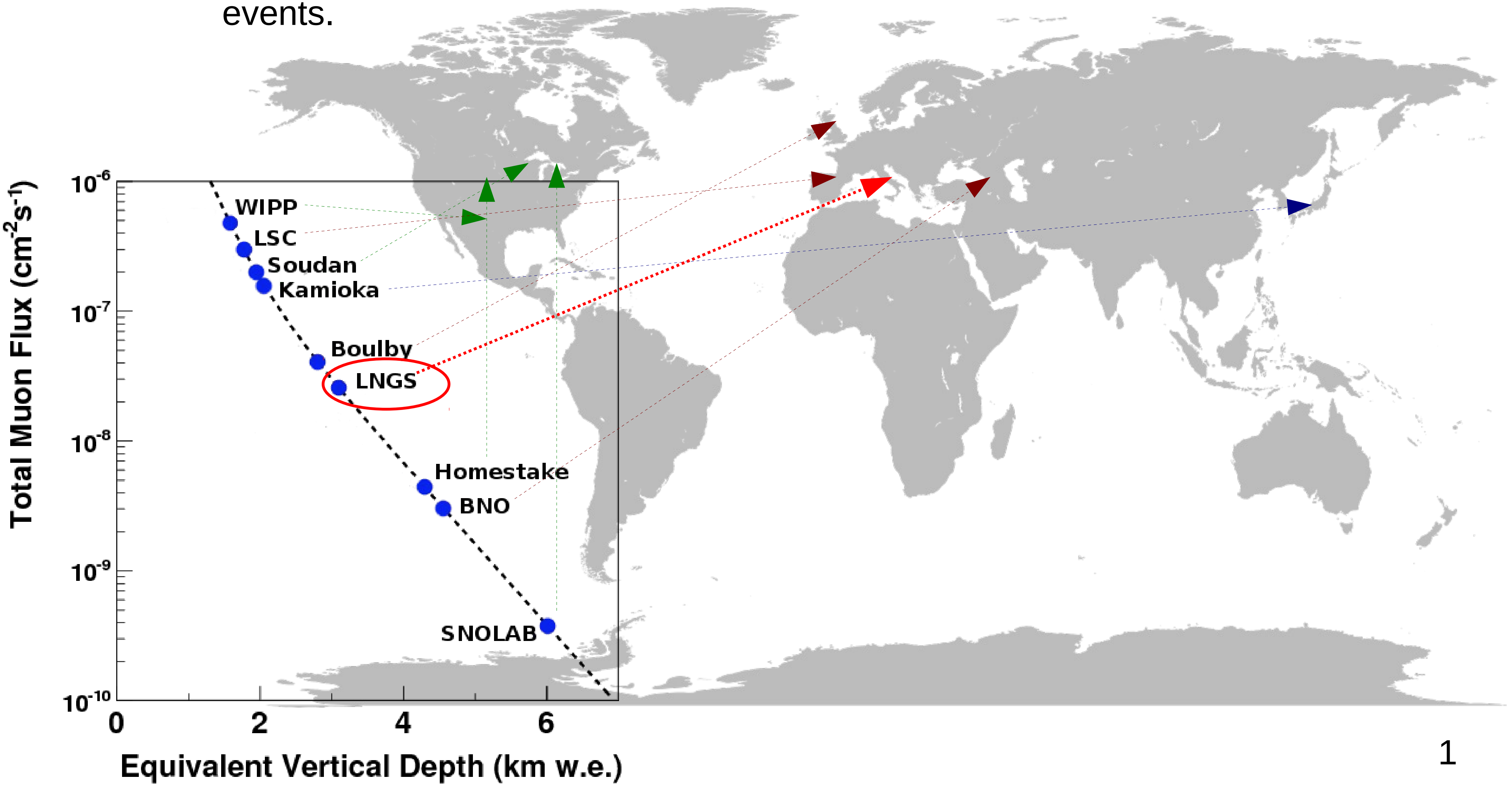
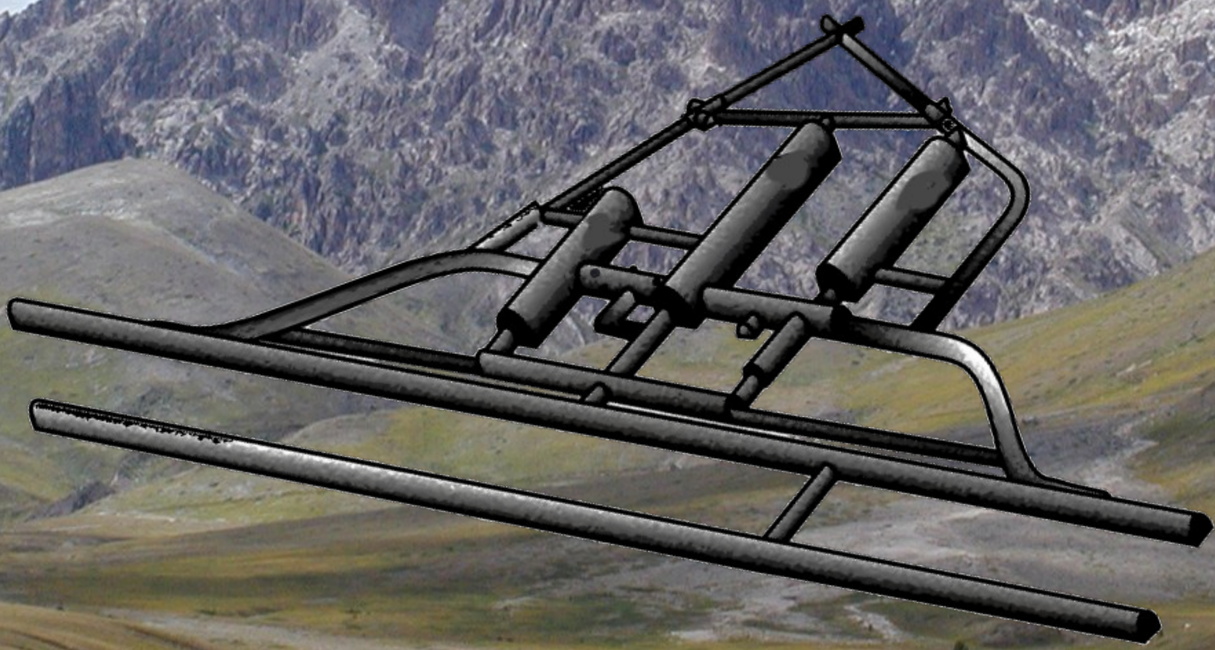


XENON at LNGS

Laboratori Nazionali del Gran Sasso:

- **1400 m of rock overburden**
- **3100 m water equivalent**
- **10^6 muon flux reduction wrt the surface**



Xe
XENON
Dark Matter Project

XENON at LNGS

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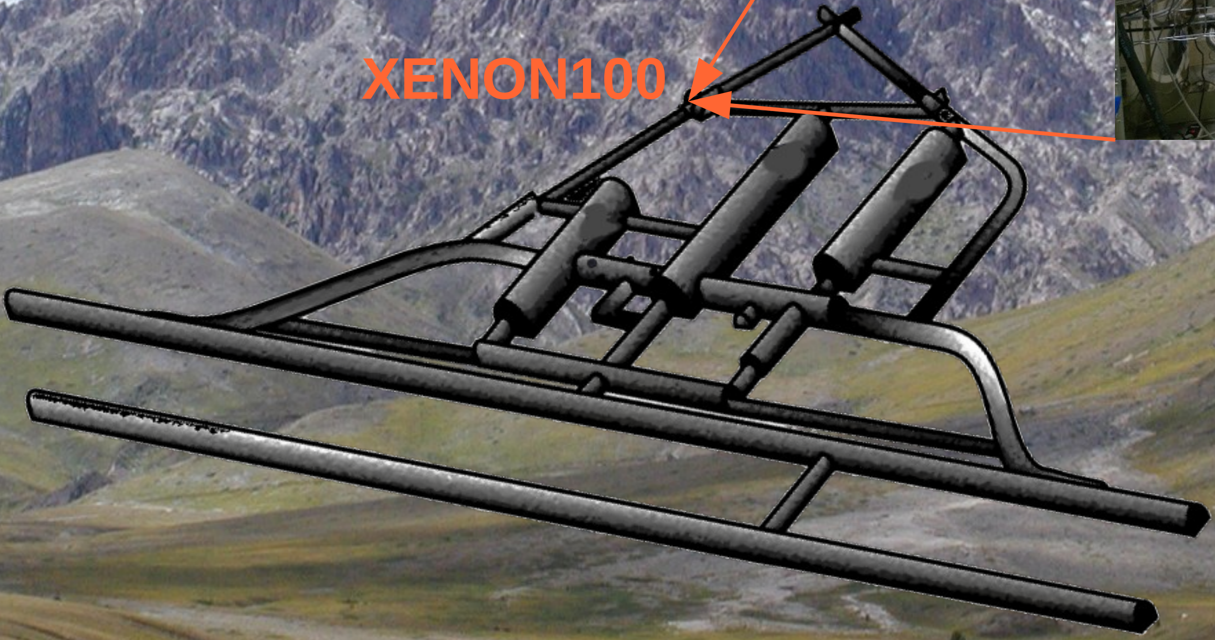
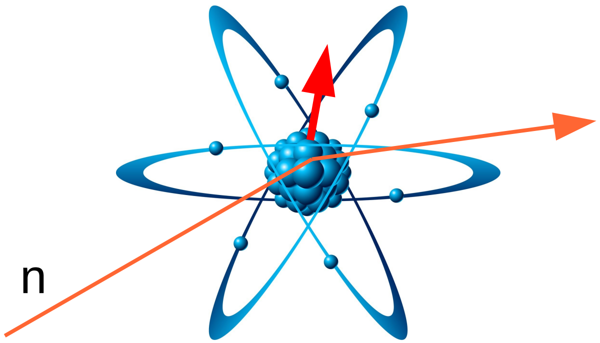
XENON100



Background sources

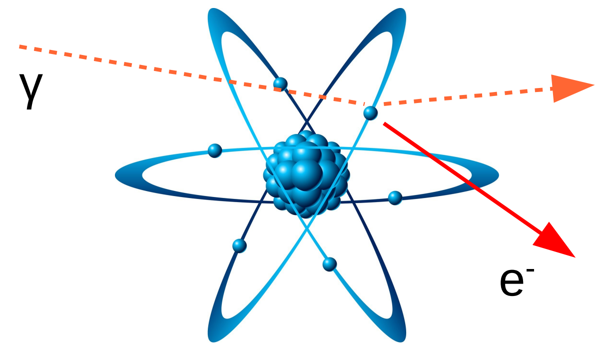
Nuclear recoil background:

- Neutrons induced by muon interactions.
- Neutrons from alpha collisions and spontaneous fission from natural radioactivity in the detector and shield materials.



Electronic recoil background:

- Natural radioactivity in the detector and shield materials.
- ^{222}Rn contamination in the shield cavity.
- Intrinsic contamination of ^{222}Rn, ^{85}Kr in the liquid xenon.
- Cosmogenic activation of the detector components during construction and storage at the surface.



The XENON100 shield

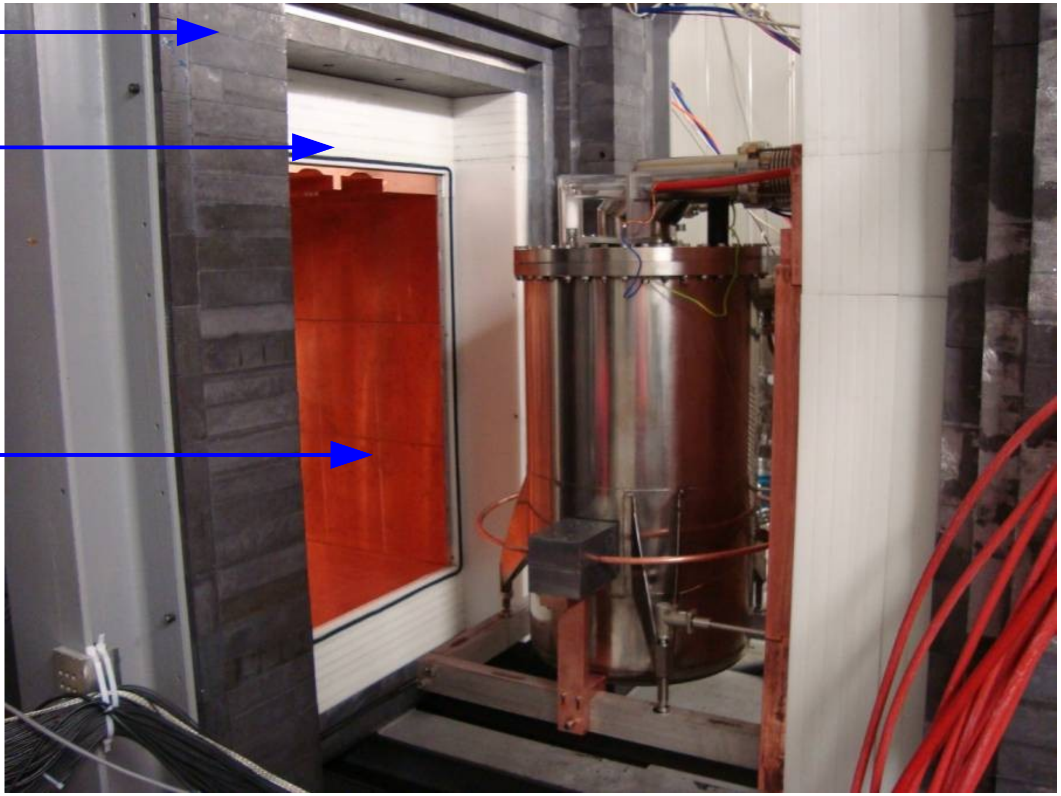
The passive shield layers, with 360º coverage of the detector, absorb gamma and neutron radiation.

Lead:
15 + 5 cm,
Low ^{215}Pb,
33 tons,
Gamma absorption.

Polyethylene:
20 cm thick,
1.6 tons
Neutron absorption.

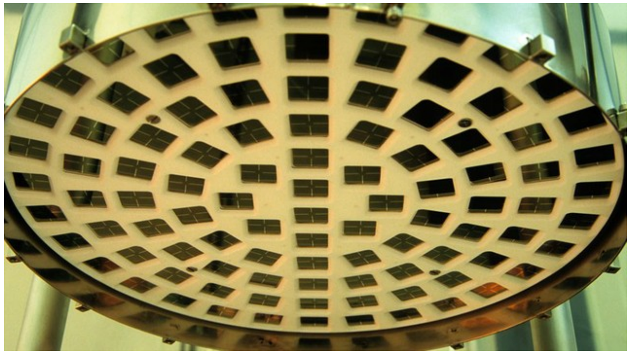
Copper:
5 cm thick,
2 tons,
Absorption of **gammas** from outer shield.

Water tanks:
20 cm thick, **neutron** absorption.



The XENON100 components

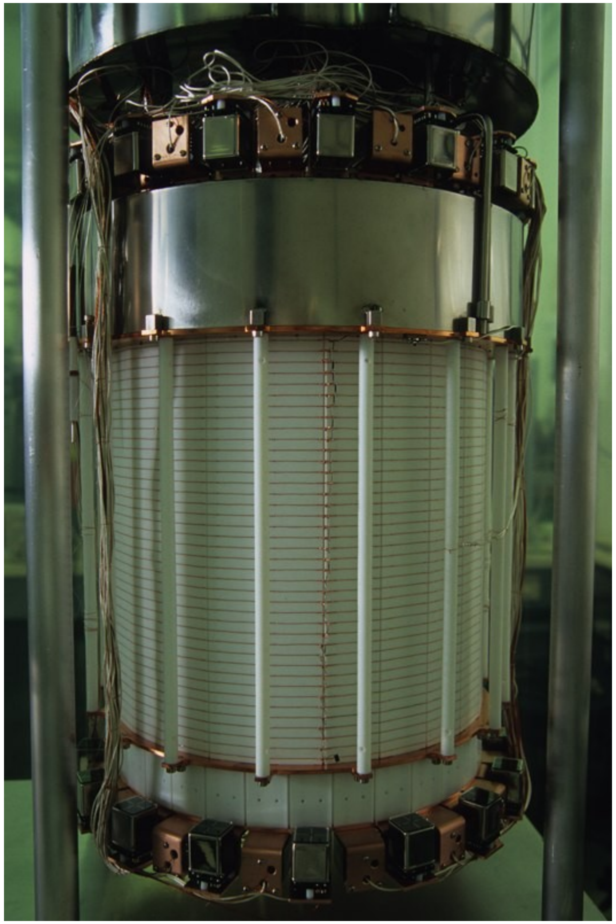
PMTS:
- Hamamatsu R8520
- 98 top array
- 80 bottom array
- 64 veto



Cryostat:
- Double walled (1.5 mm thick)
- Low radioactivity stainless steel
- 70 kg total

Bell:
- Stainless steel
- 3.6 kg

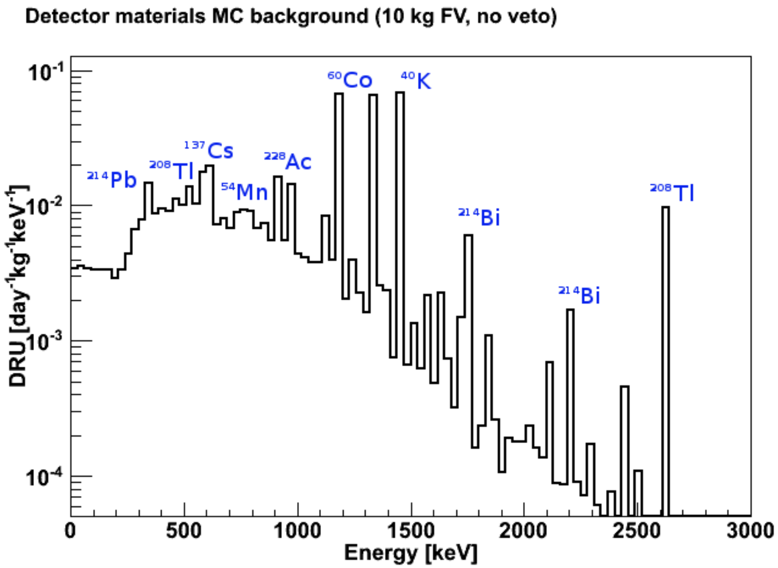
PTFE structure:
- 24 interlocking panels
- 12 kg of teflon
- UV light reflector

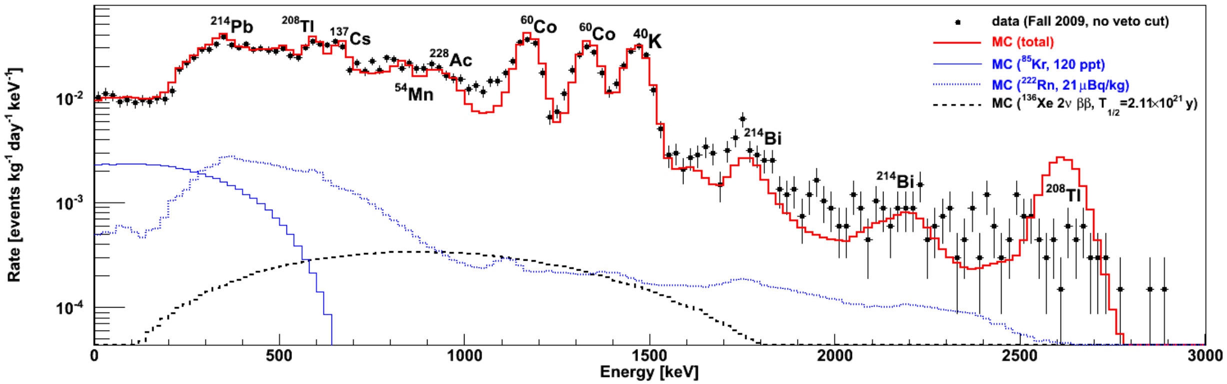


Background Monte Carlo

All materials screened for radioactive contamination with high purity Ge detectors at LNGS. **Astropart. Phys. 35:43-49, 2011**

More details in talk by Francesco Piastra



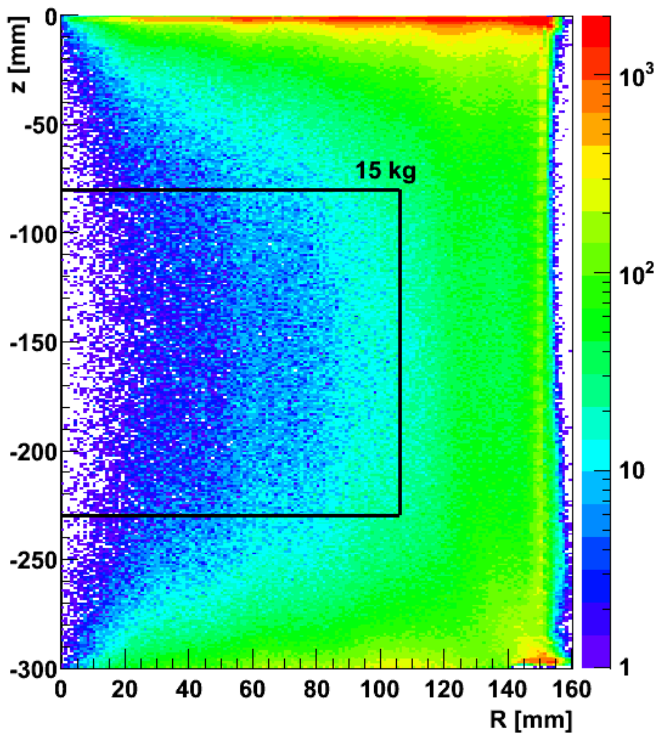


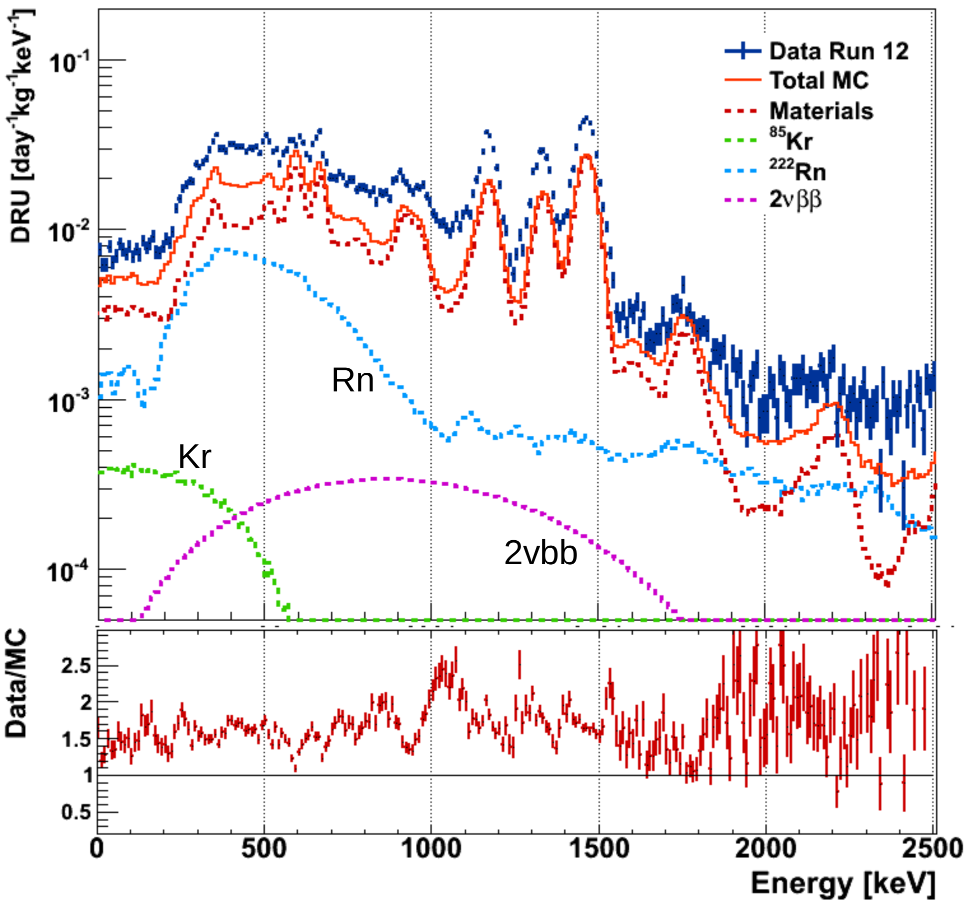
Screening results used for material selection and input in the Monte Carlo simulations with GEANT4.

Simulated spectrum in very good agreement with data taken during the commissioning of the detector in Fall 2009.
Phys. Rev. D83:082001, 2011

Comparing data and simulation

15 kg Fiducial volume (Run 12 data)



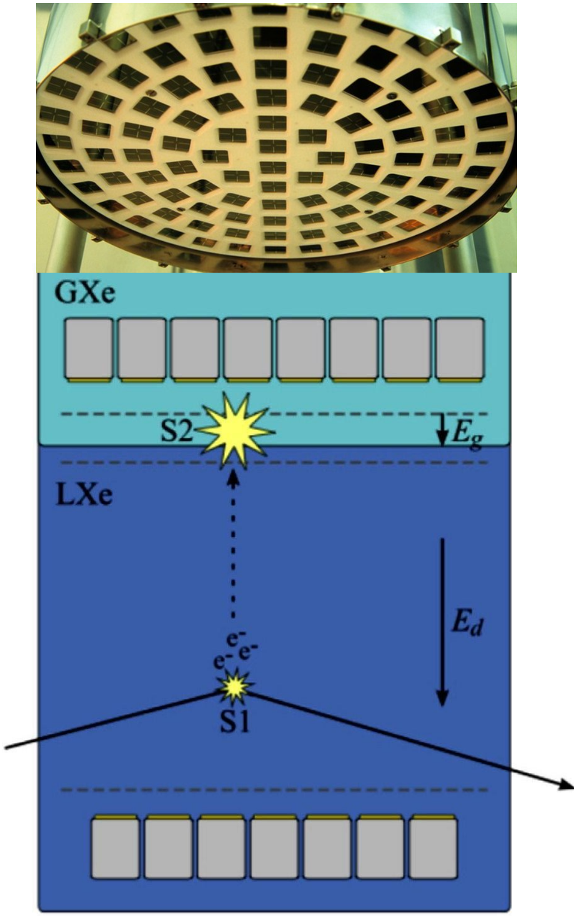


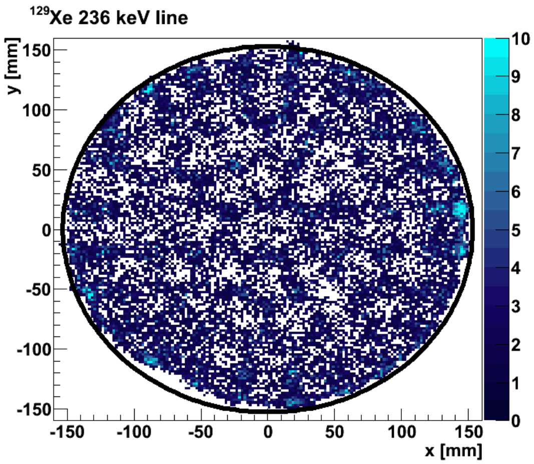
110 live days: Apr. 2013 – Jan. 2014

- **Kr in LXe:** Concentration of 10 ppt.
- **^{222}Rn in LXe:** Activity value of 64.1 uBq/kg.
- **Decay of ^{60}Co** (5.27y half-life). The time between materials screening run12 corresponds to roughly a half-life of ^{60}Co.
- **Detector energy resolution** as a function of energy: $\sigma(E)/E$ [%] = 0.9 + 45/√(E[keV])
- **Two neutrino double beta decay** in ^{136}Xe with halflife of 2.165 x 10^{21} years (EXO 2014).

Event position reconstruction

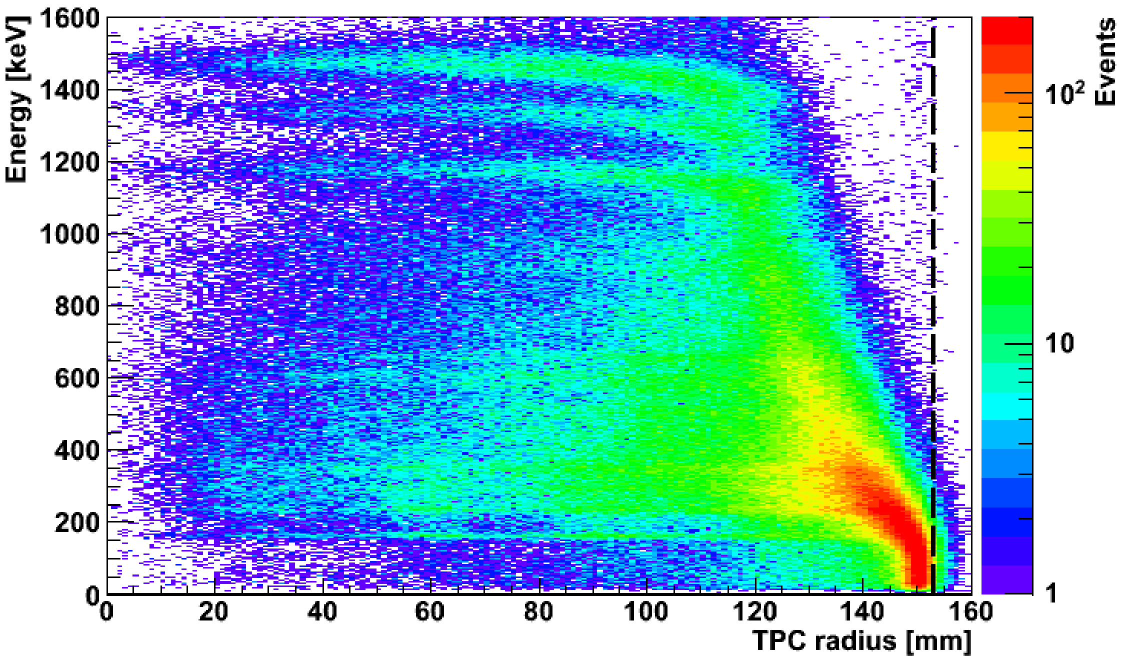
Top PMT array





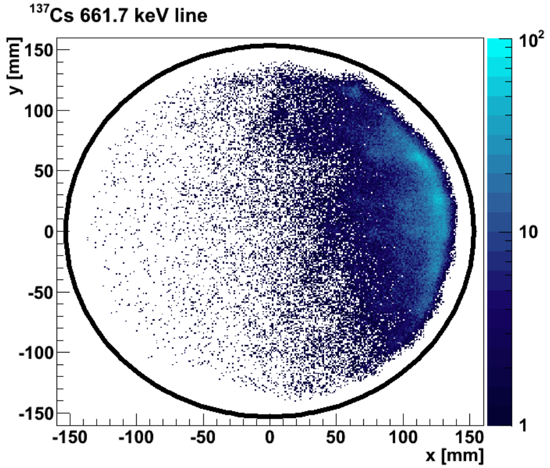
Saturation of the photomultiplier tubes (PMTs) from high S2 signals causes a mis-reconstruction of the event position.

Background spectrum, event energy vs radius

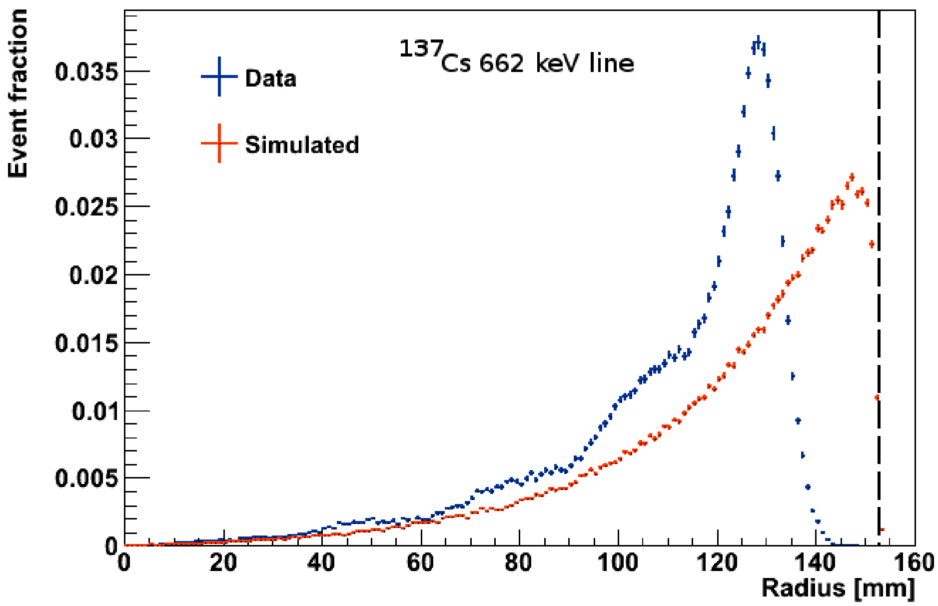


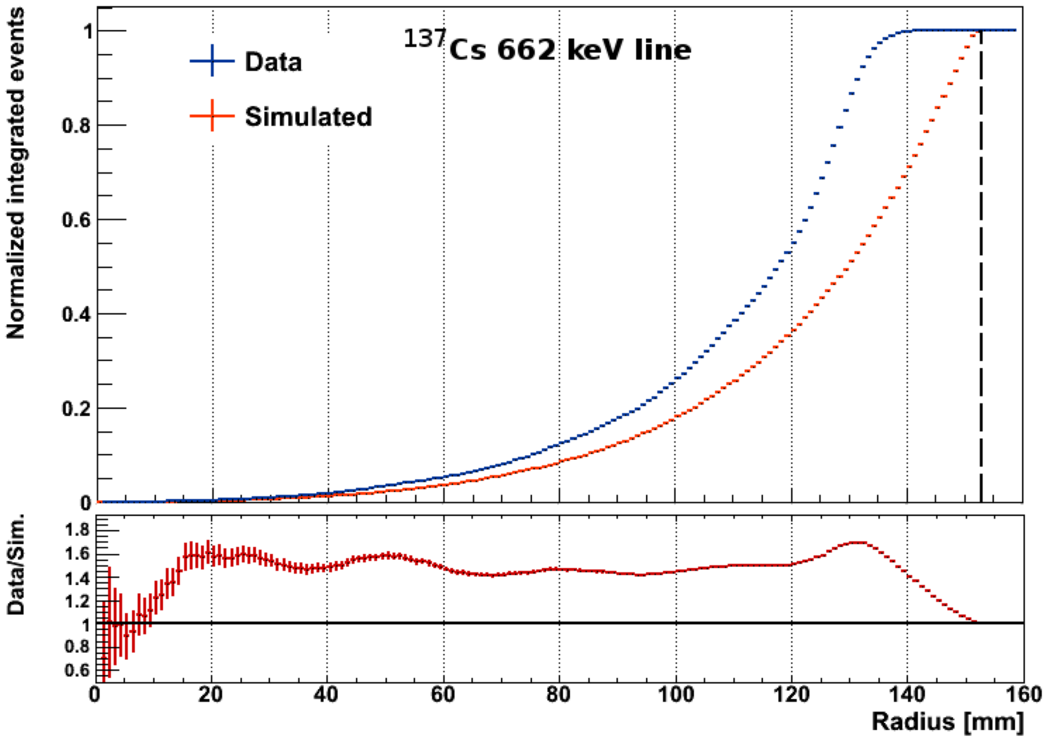
Event position reconstruction

^{137}Cs source data
662 keV gammas

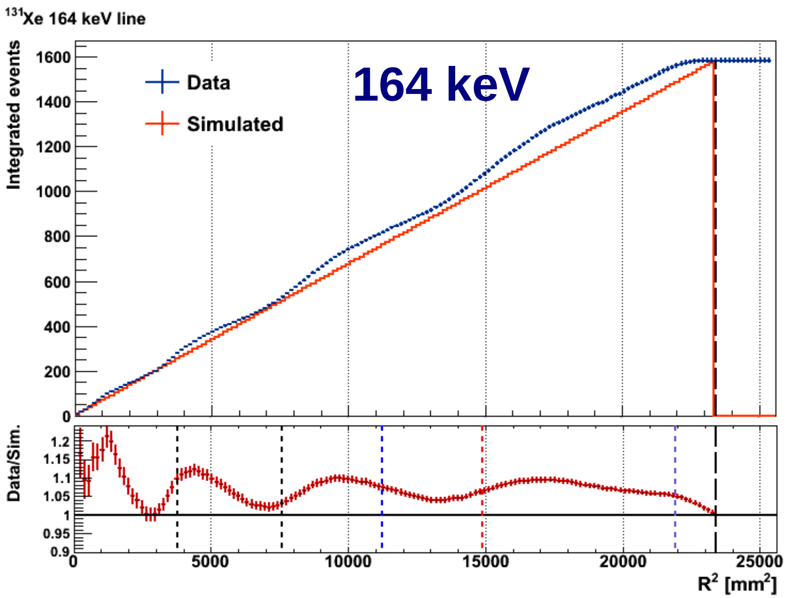


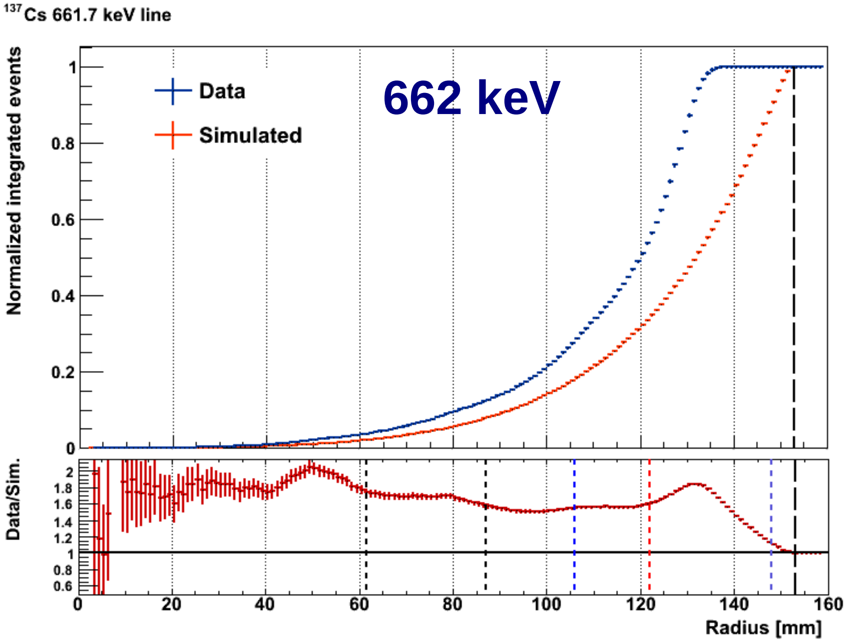
The inwards reconstruction of events as a function of **radius** and **energy** is studied with various calibration sources.



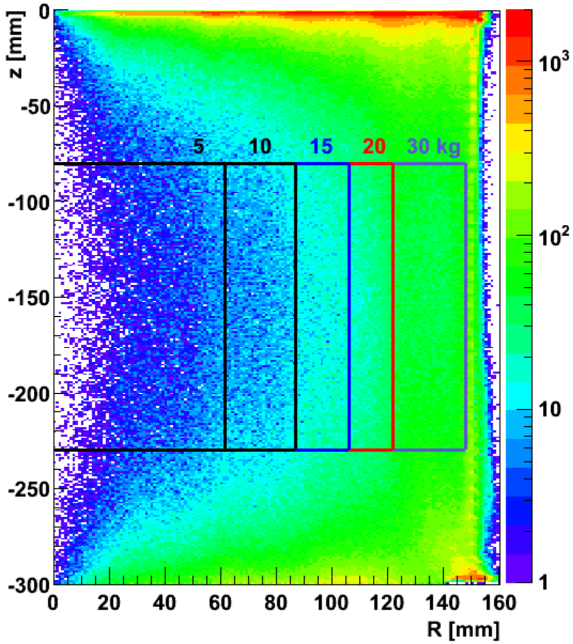


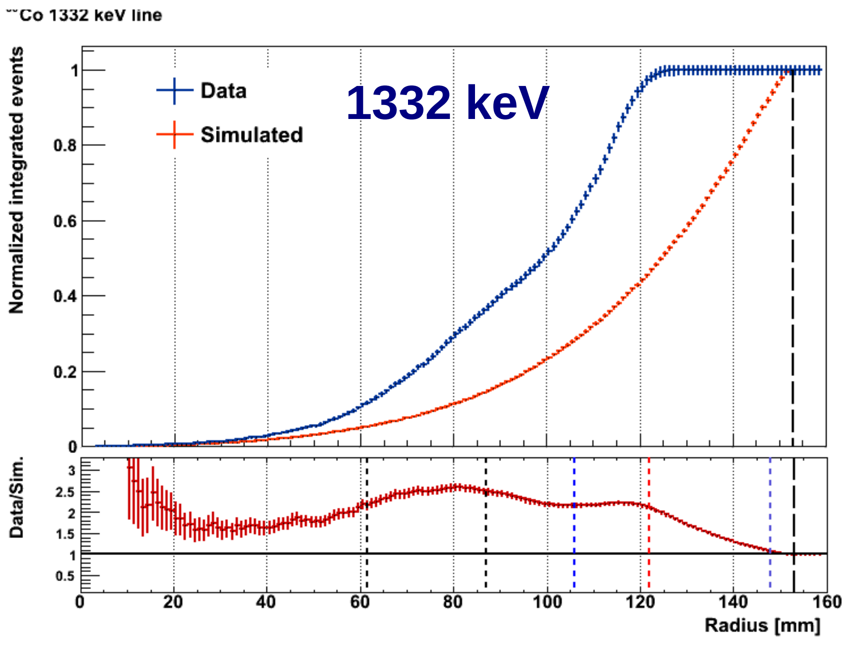
Event rate correction factor





Cylindrical fiducial volumes in the TPC →





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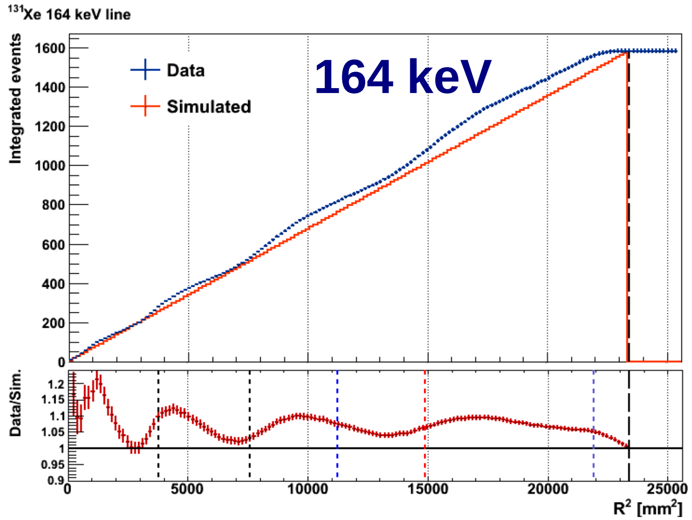
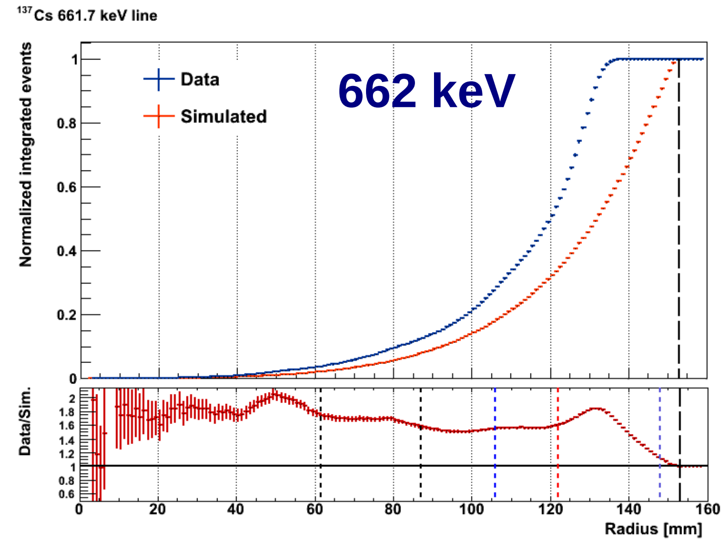
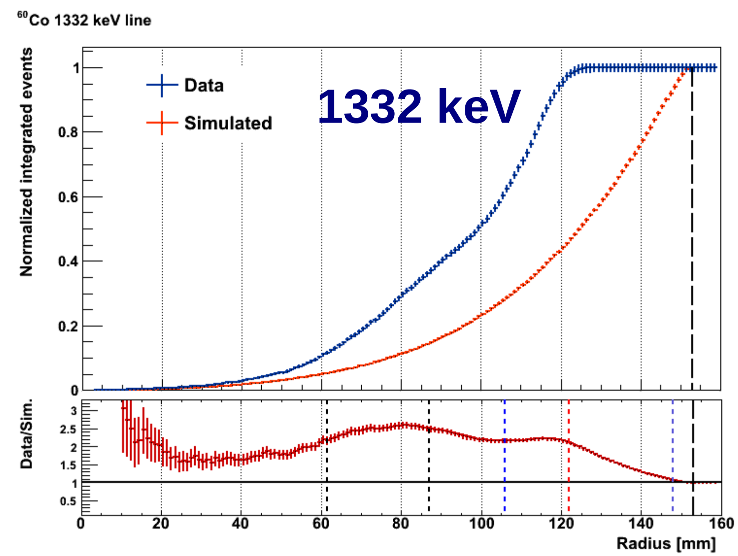
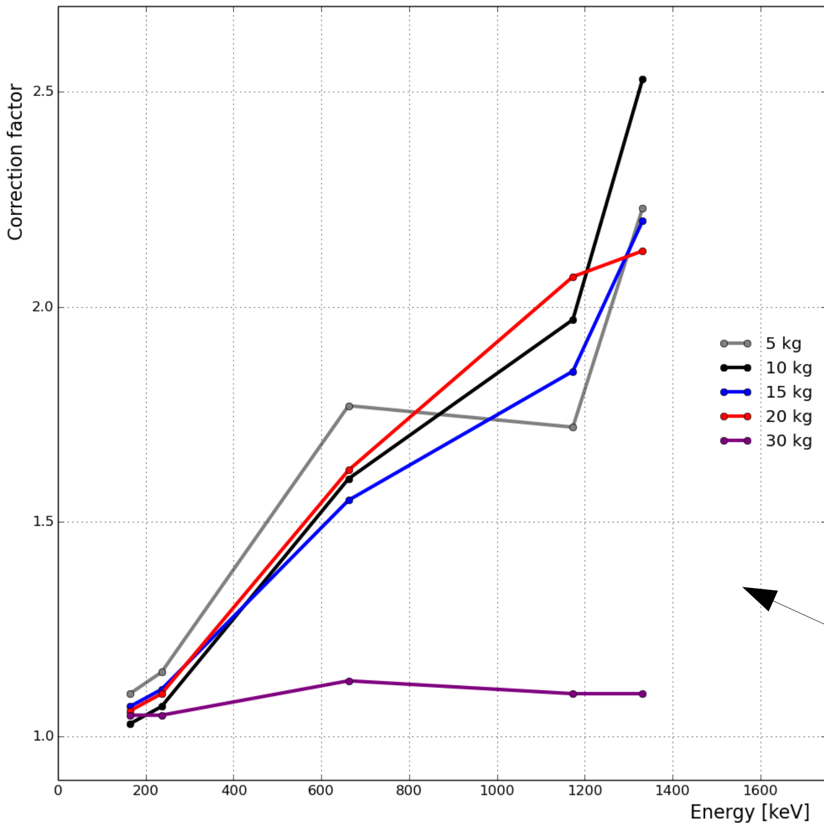


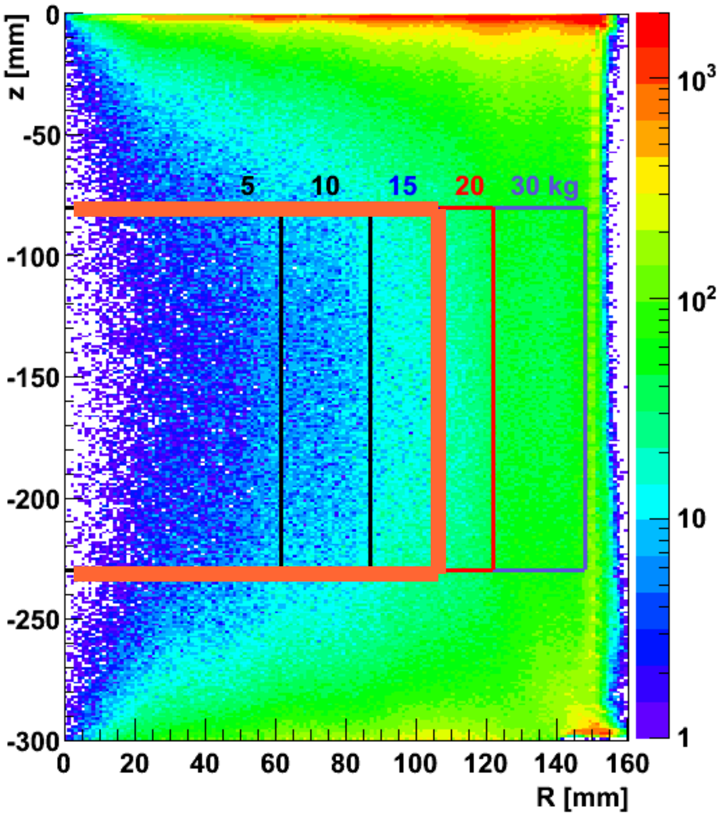




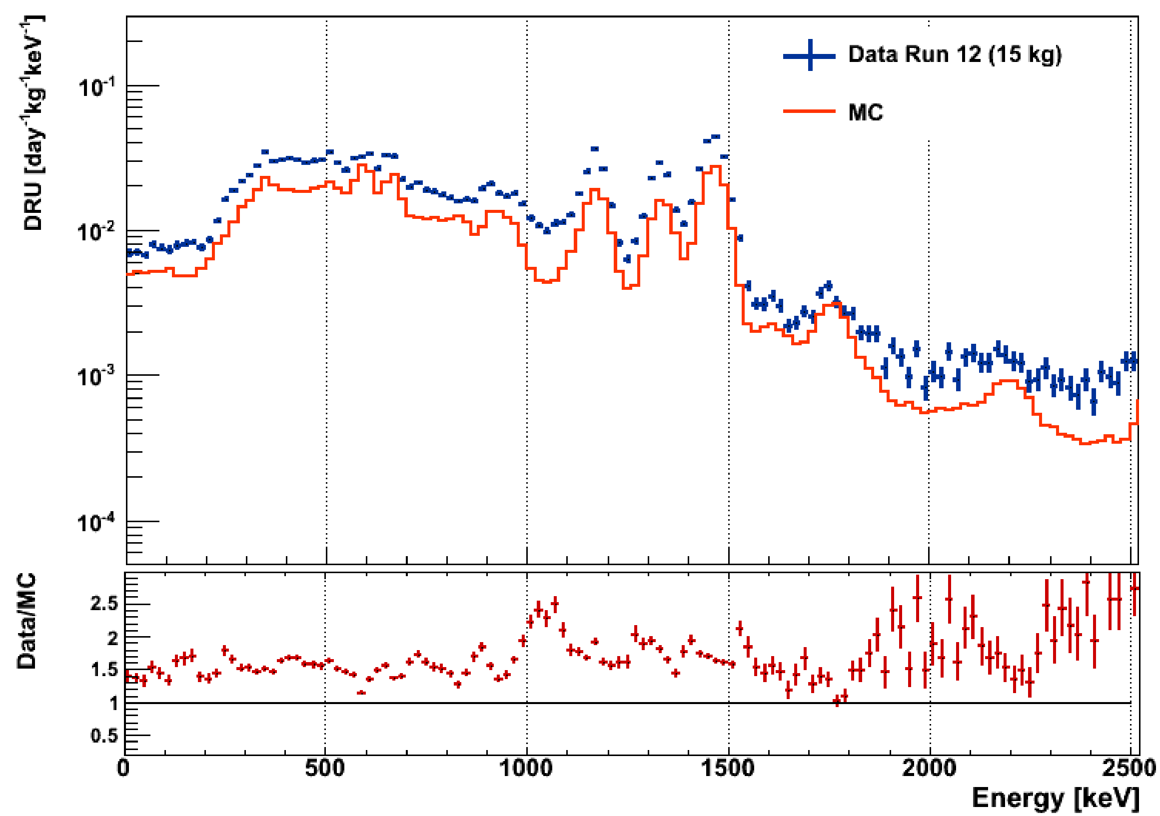


Correction factors as a function of energy for different radii.

Data vs MC for different FVs



15 kg FV



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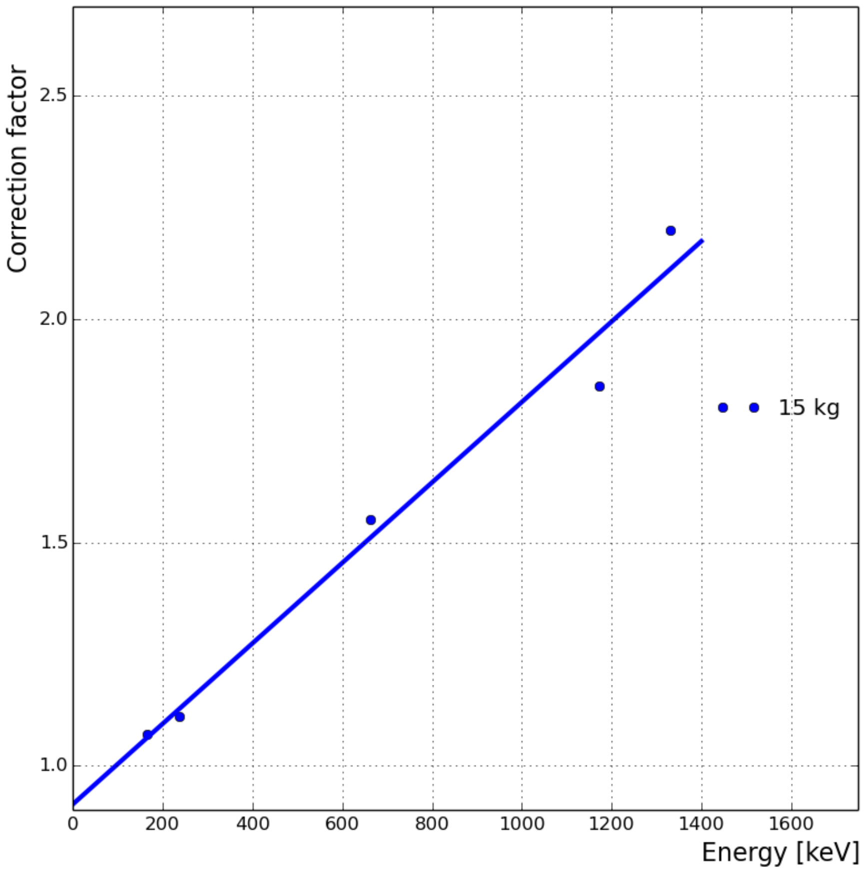
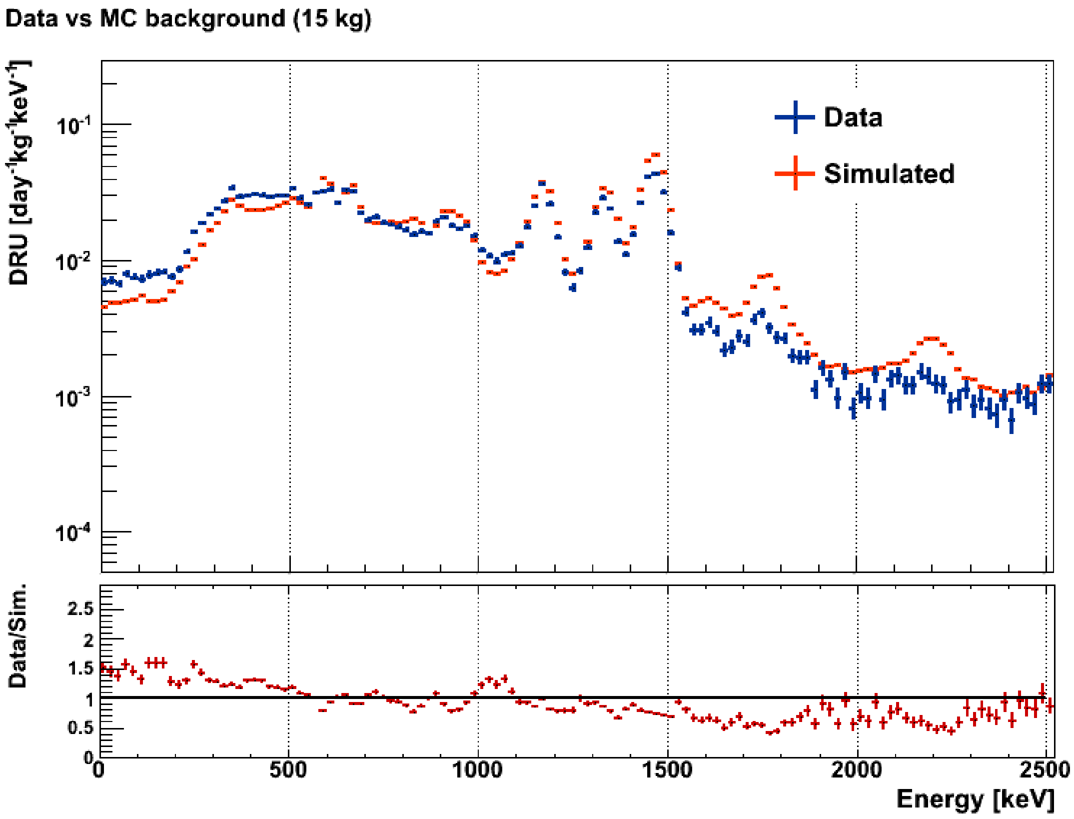
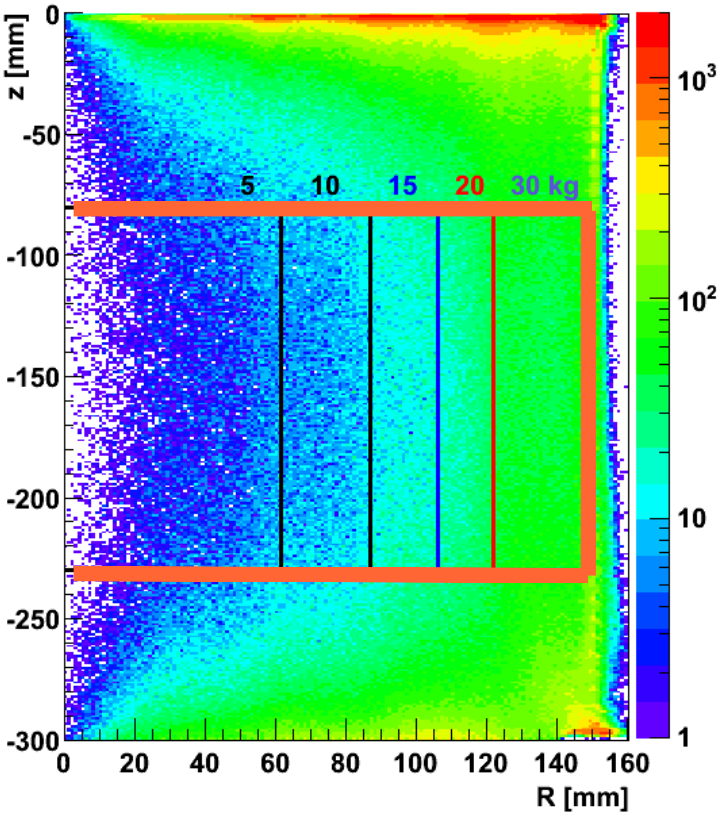


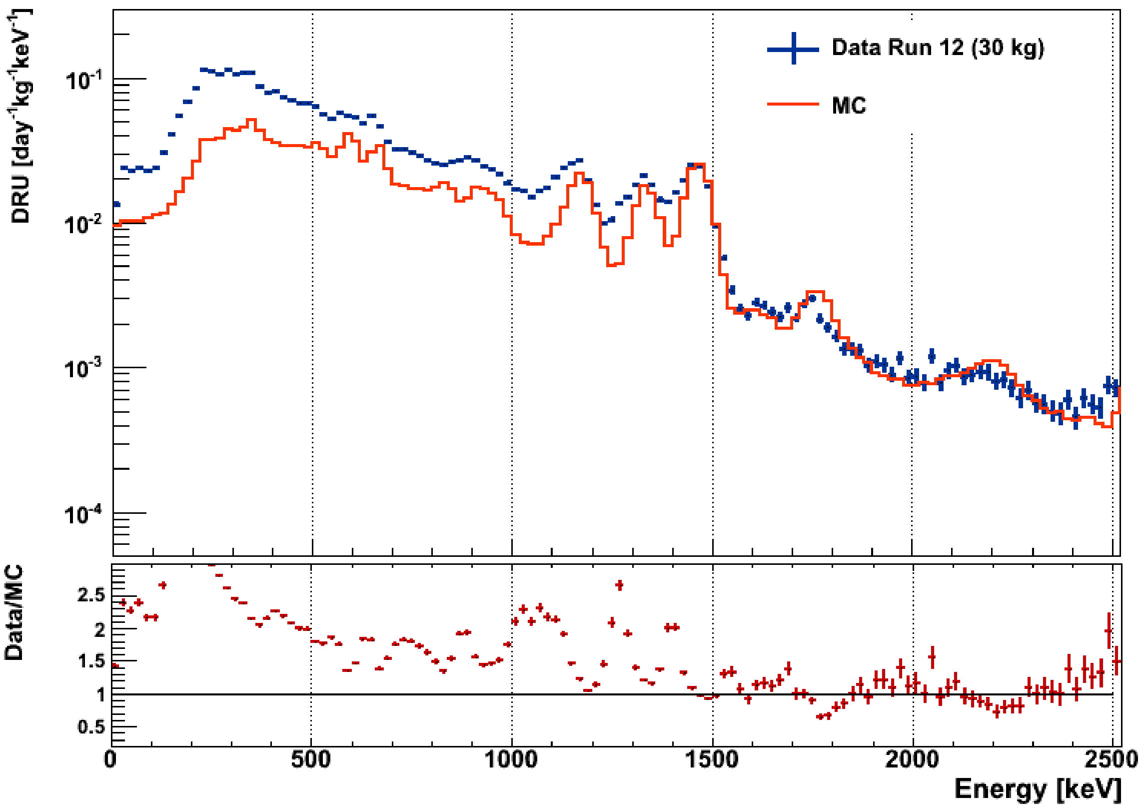
15 kg FV Corrected



Data vs MC for different FVs



30 kg FV



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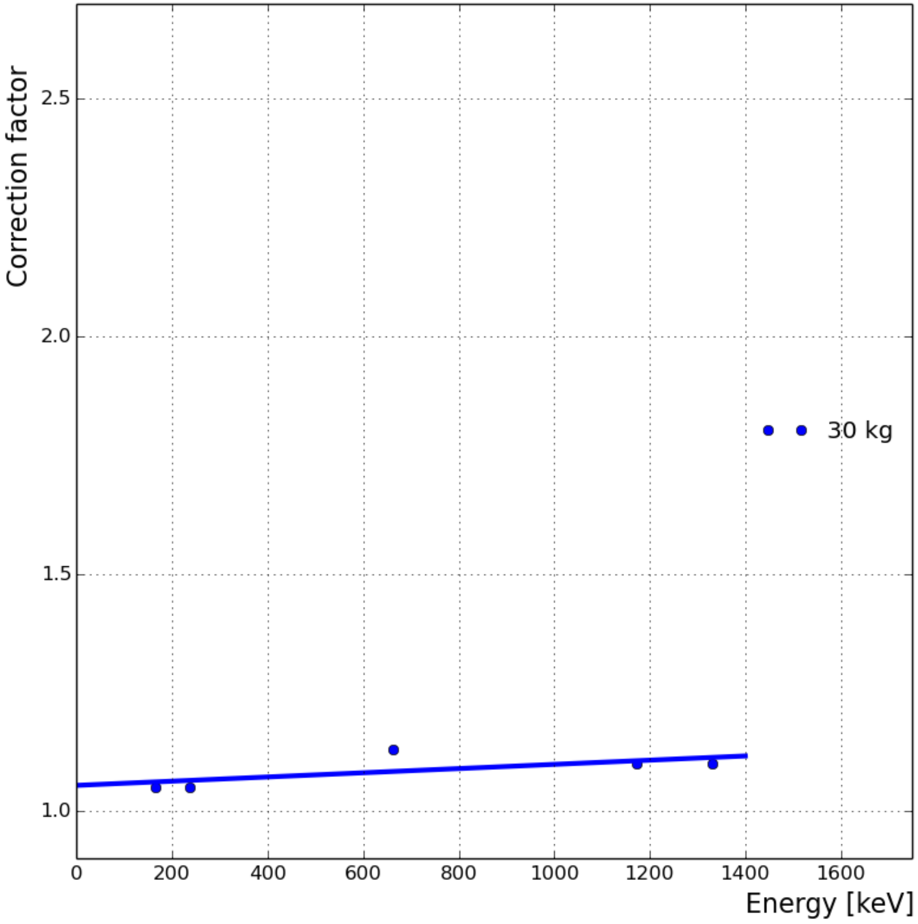
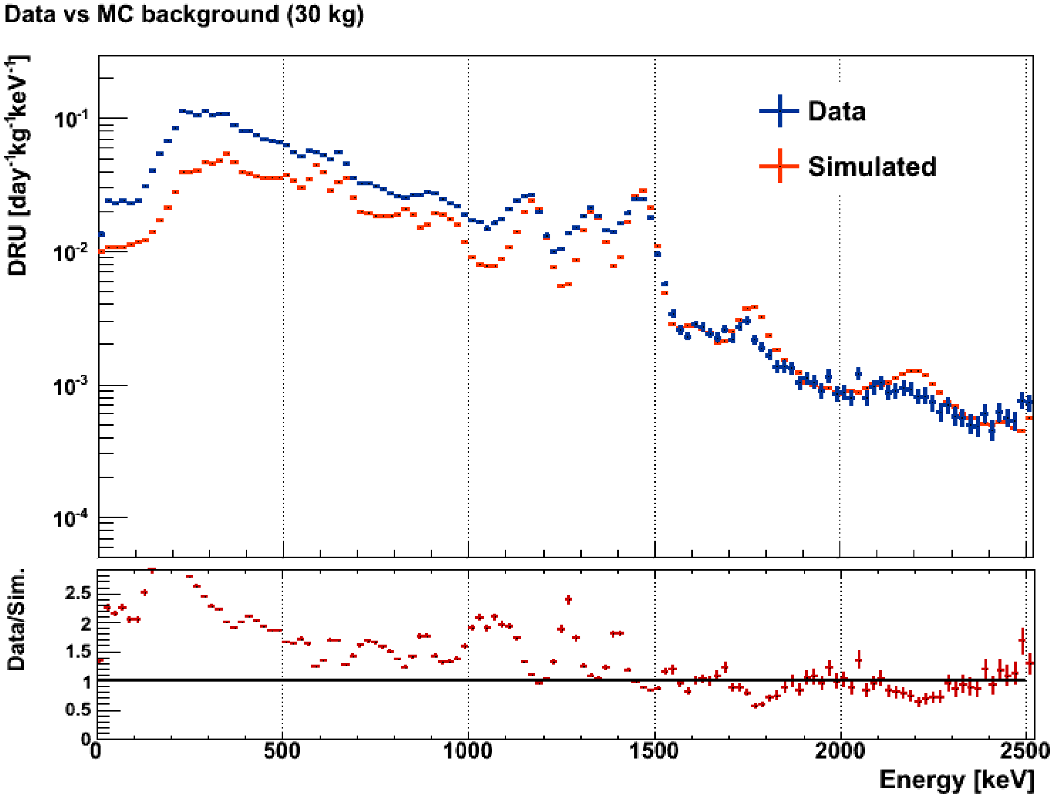


30 kg FV Corrected



Outlook

- In general, the analysis of the background spectrum is important for a proper **understanding of the detector and its backgrounds**.
- The main goal is to **match the Kr and Rn levels** measured in XENON100 and those implemented in the simulation.
- A mismatch between data and simulation event rates is observed and can be understood due to the **event position reconstruction discrepancy** caused by saturation of the PMTs.
- I have studied the saturation effects for different energies and radii, obtaining a **preliminary correction function for the MC event rates**.
- To do:
  - Understand **over-correction**, which may be attributed to using the **upper limits** of screening results.
  - Determine a more appropriate correction function.
  - Evaluate the systematic errors in the determination of the correction factors.

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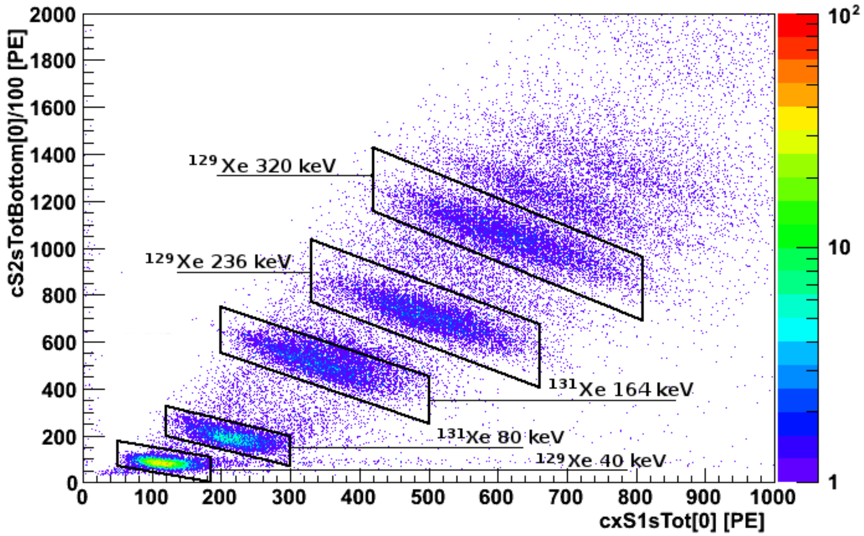
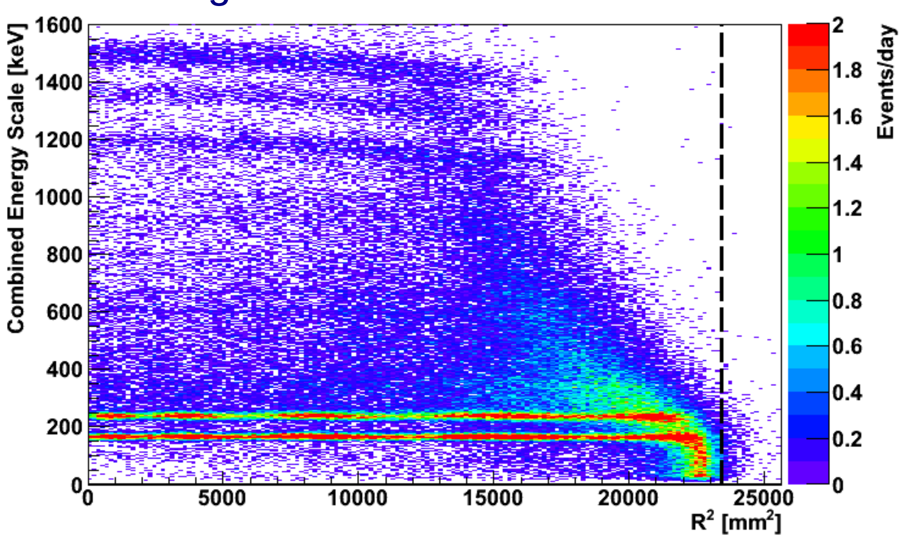
^{131}Xe and ^{129}Xe



Selection of activated Xe lines with AmBe calibration data.

Only ^{131}Xe and ^{129}Xe survive due to their higher half-lives: 12 and 9 days, respectively.

Background after AmBe calibration



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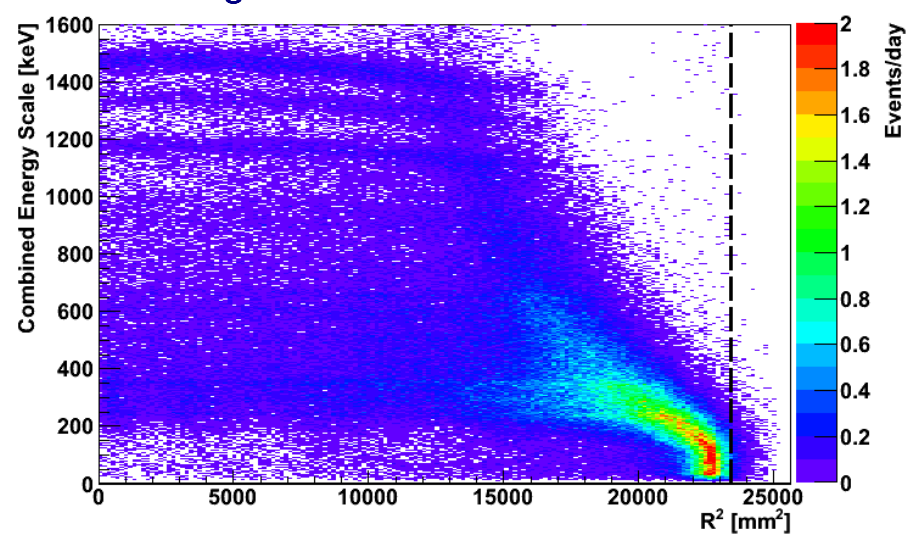
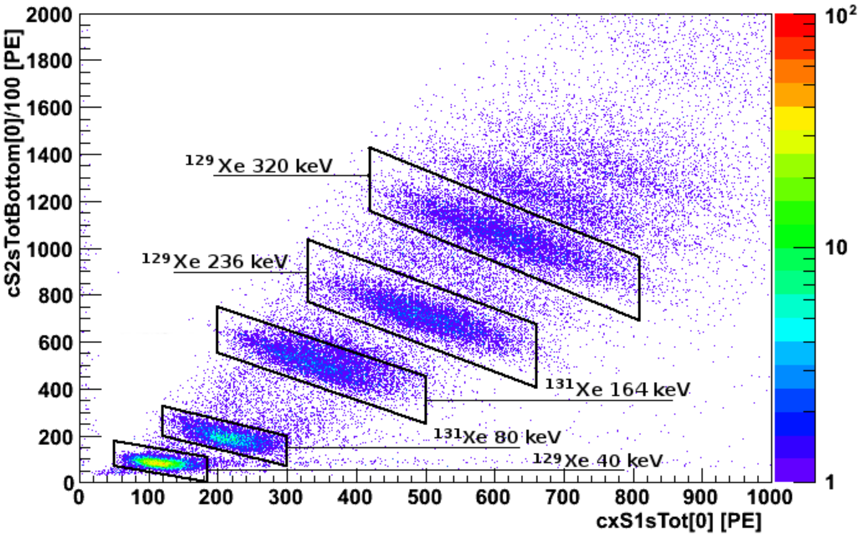
Background without act Xe lines



^{131}Xe and ^{129}Xe



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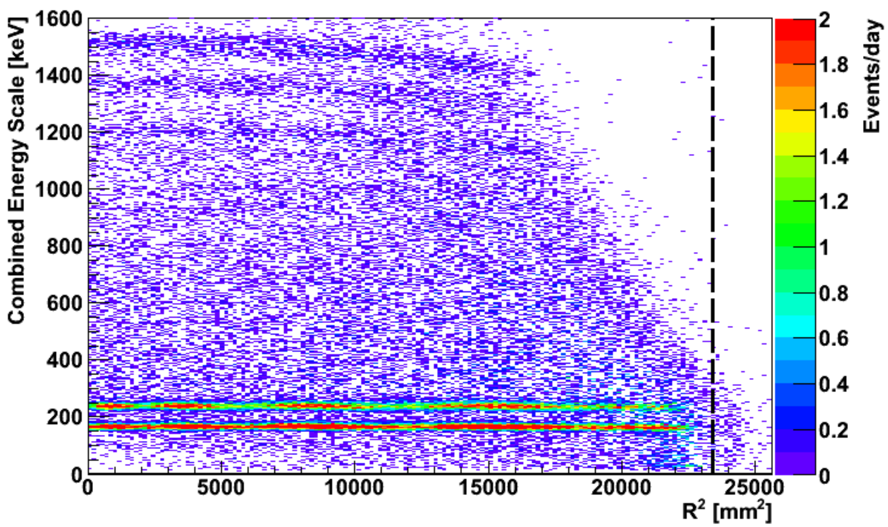
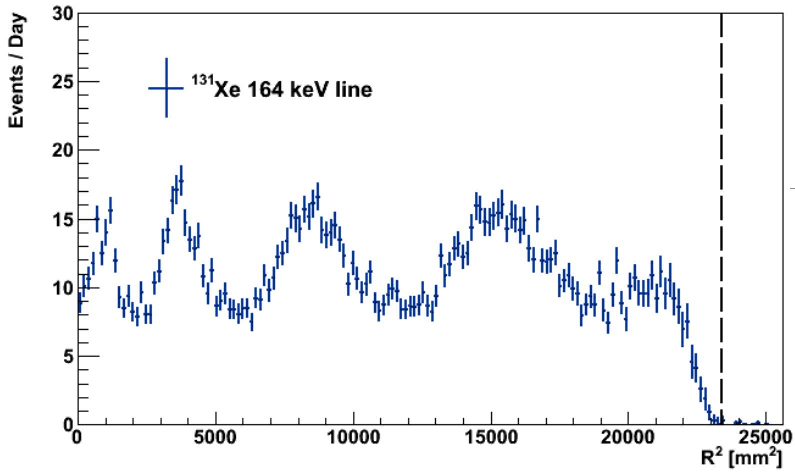
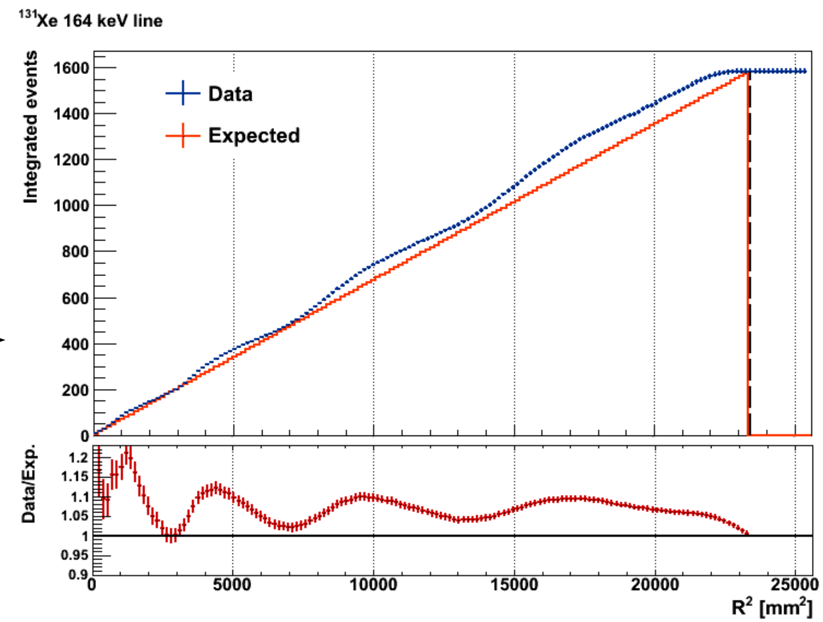
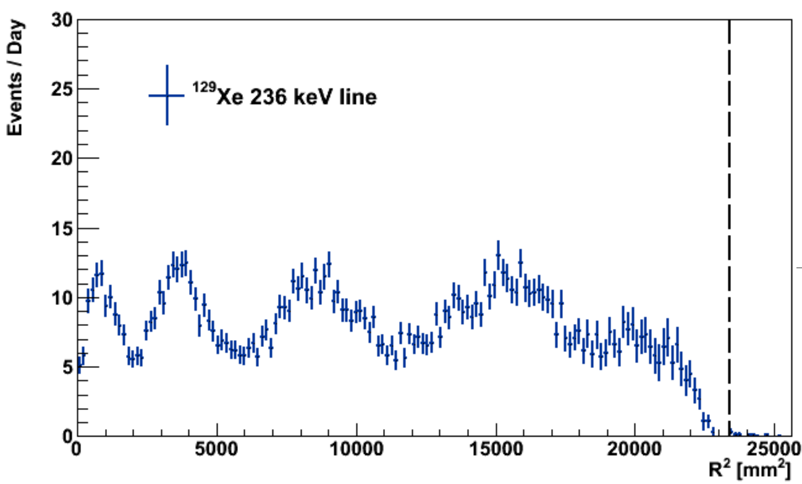


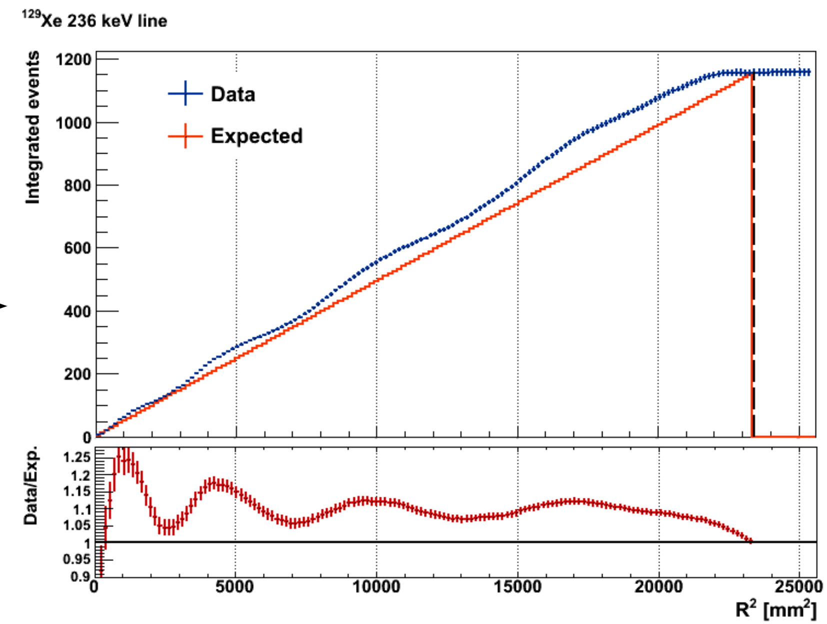
Bin by bin subtraction of activated Xe data and background

^{131}Xe and ^{129}Xe



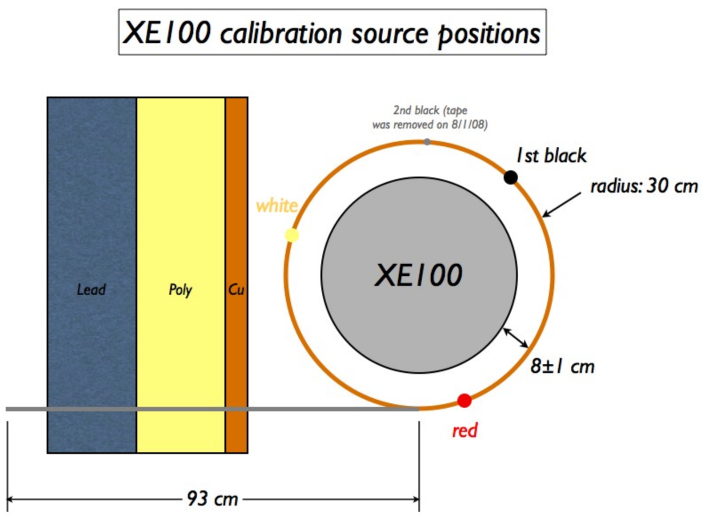






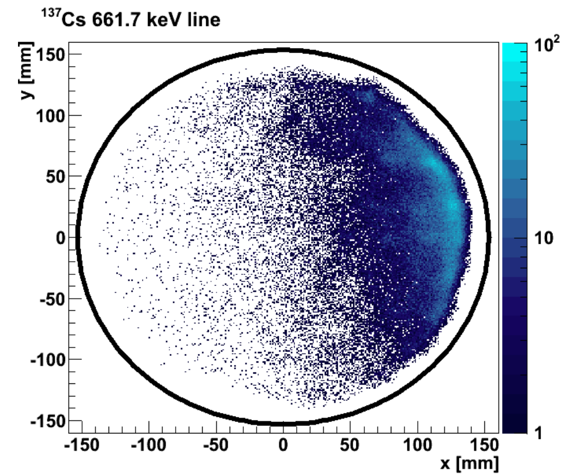
A3

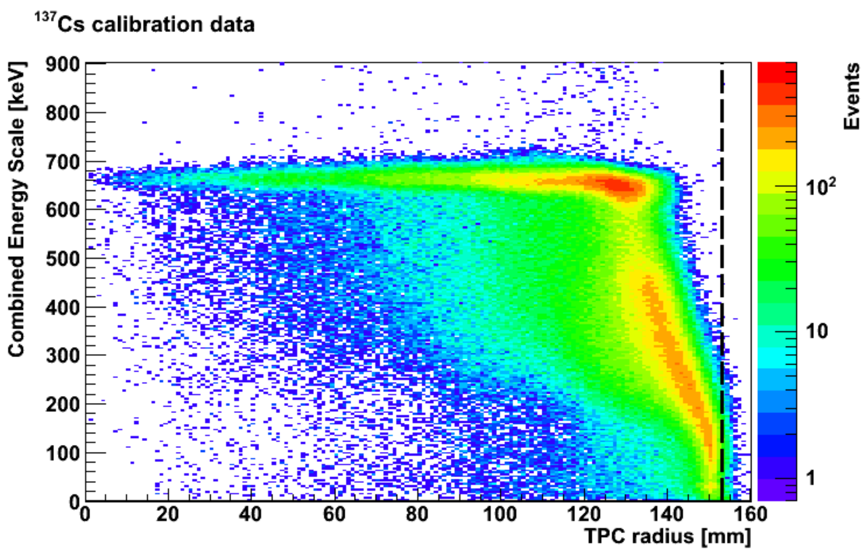
^{137}Cs - 662 keV

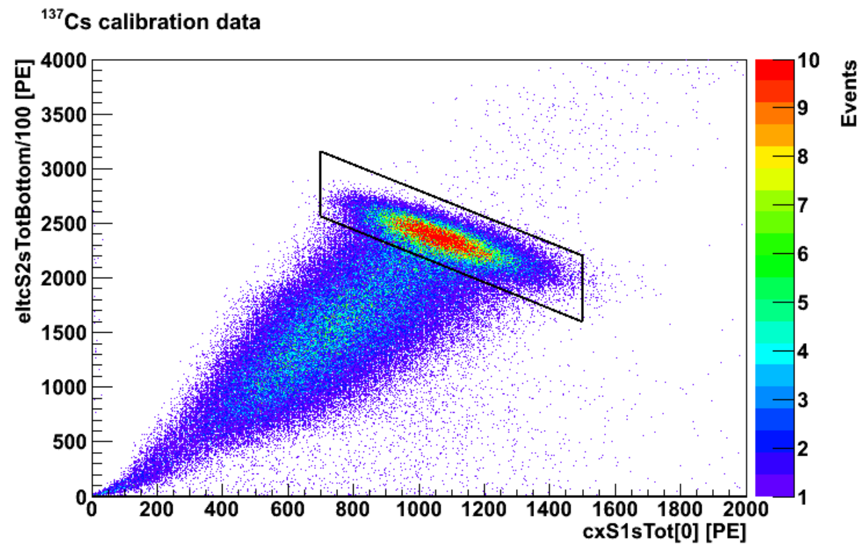


Data from source position red

Data corrected for electron life time.

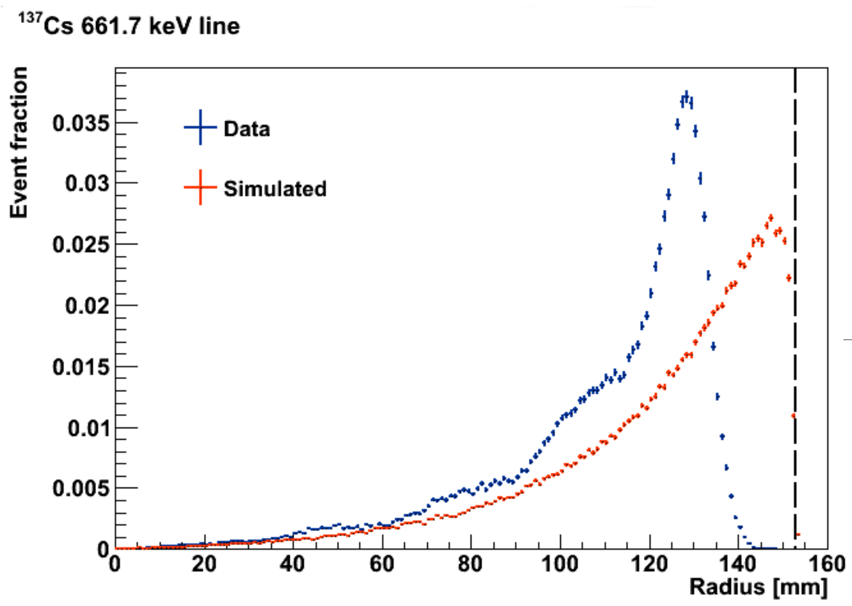




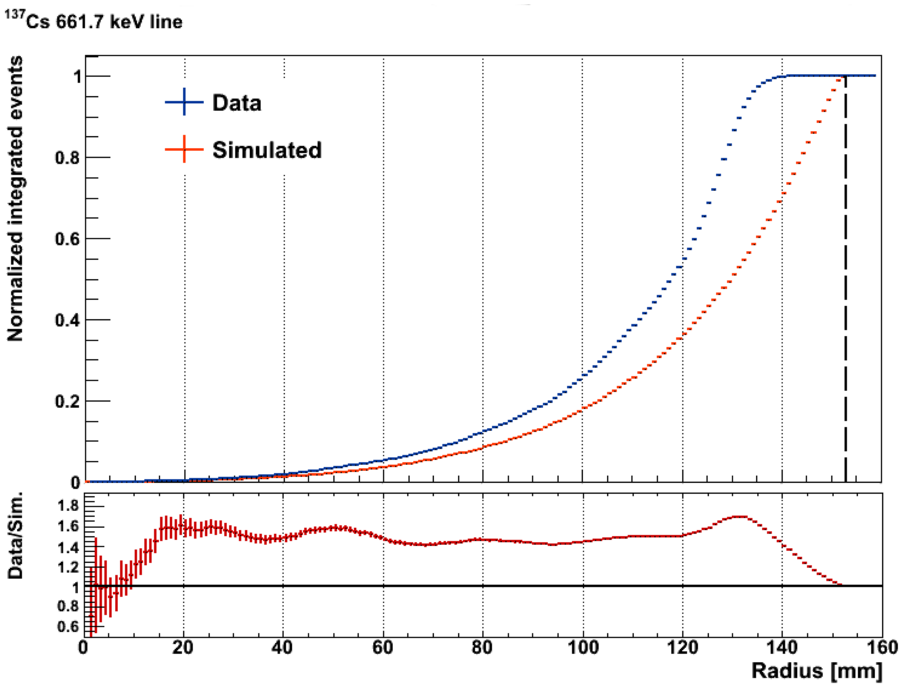


^{137}Cs - 662 keV

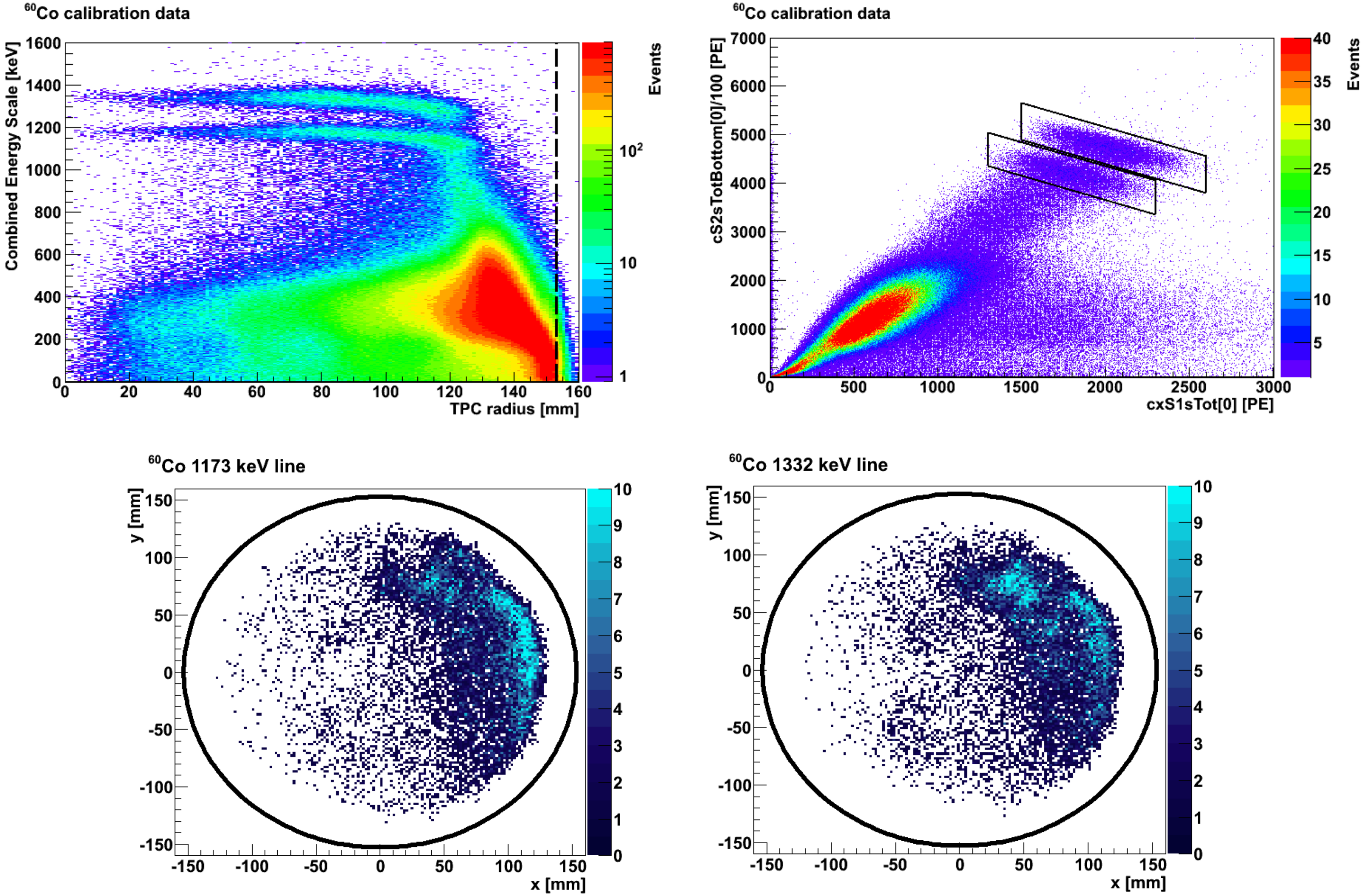
Events as a function of radius in the TPC



Integrated events within a certain radius of the TPC



^{60}Co – 1173 and 1332 keV



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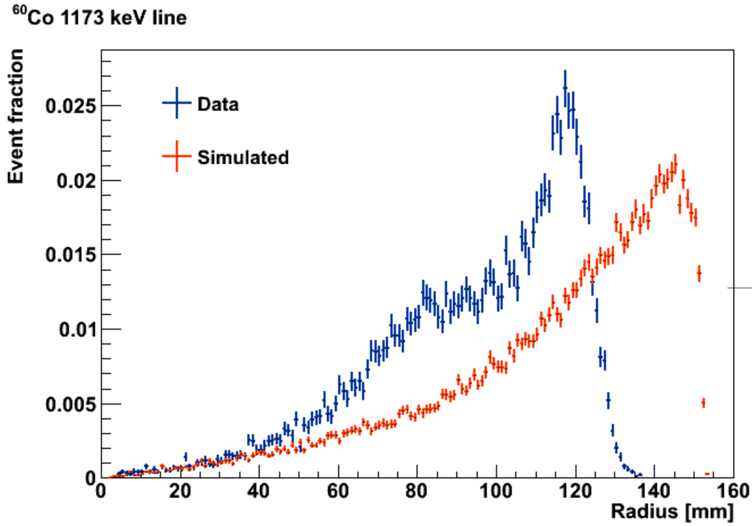
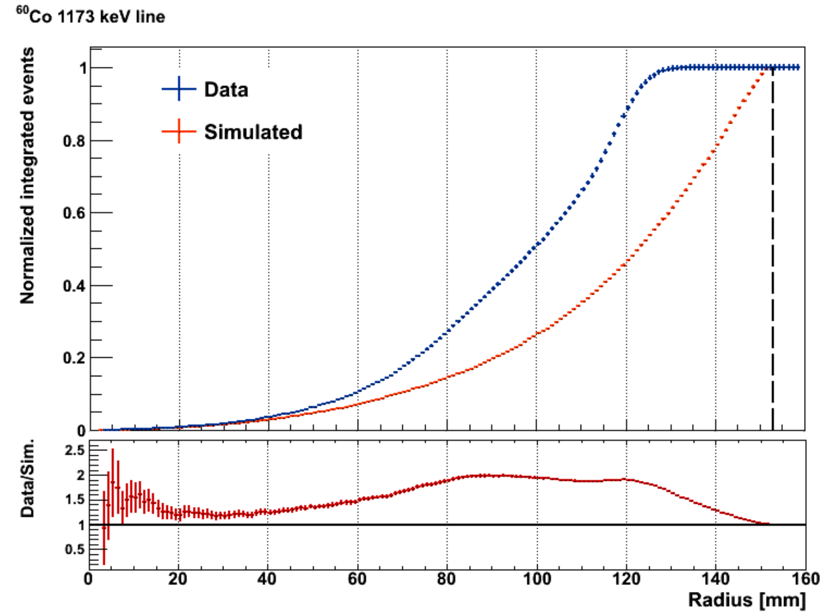
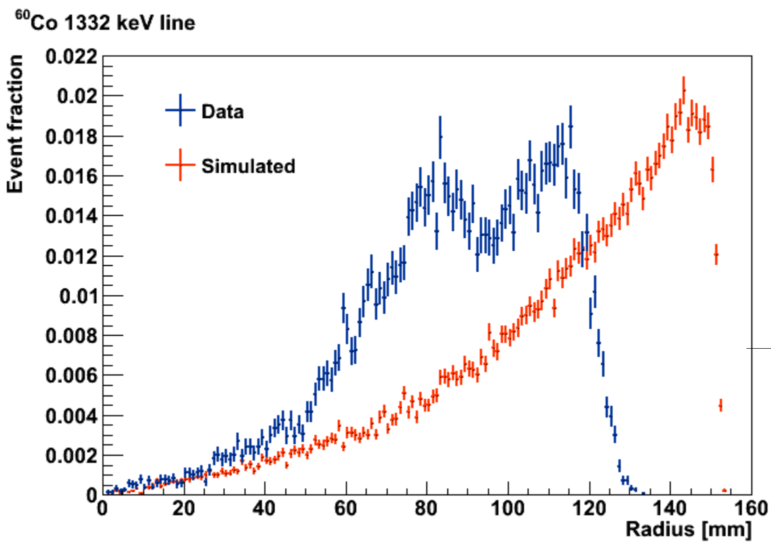
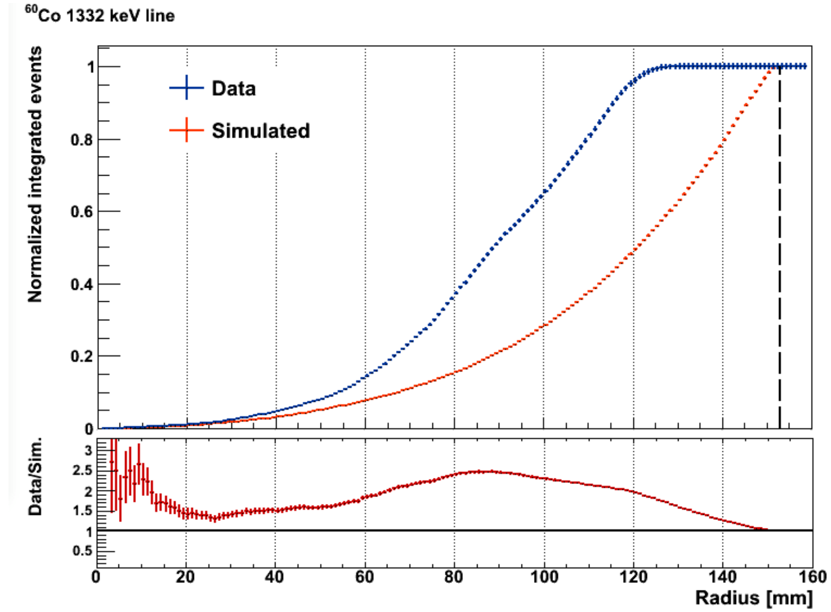








Krypton

- Commercially available xenon gas has a concentration of **natural krypton at the ppm** (parts-per-million) level.
- The gas used in XENON100 has been processed to reduce the concentration of krypton below 10 ppb.
- In addition, a **krypton distillation column** is used that can lower the concentration to the **ppt level**.

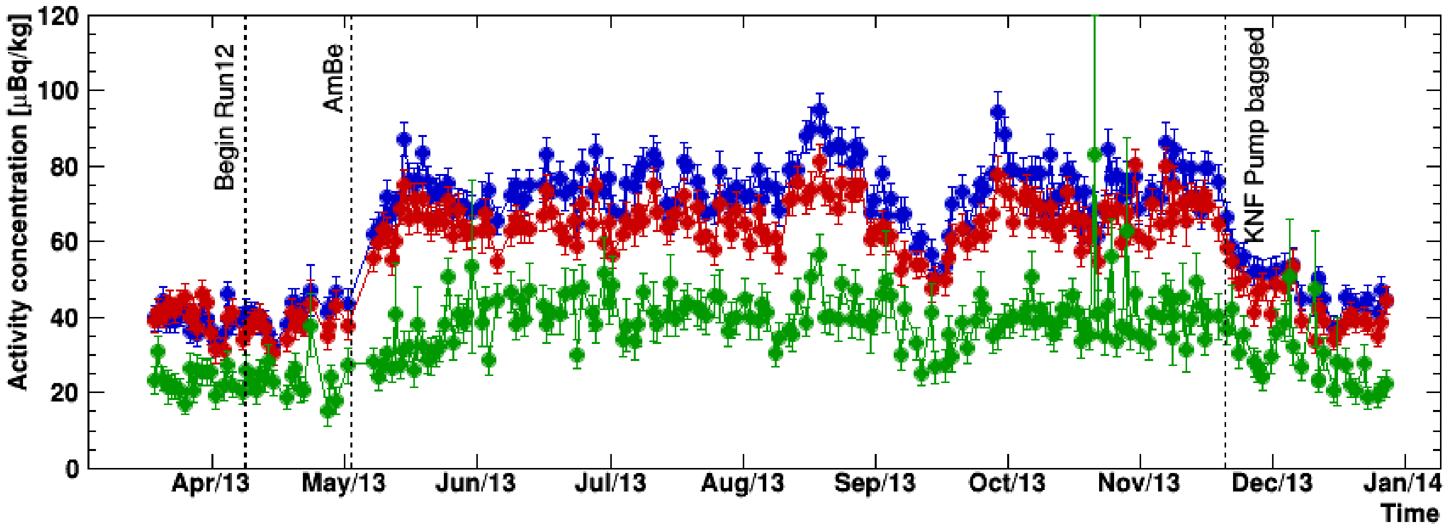
- **The isotope ^{85}Kr undergoes beta decay with a half-life of 10.76 years.**
- **Natural krypton contains 2×10^{-11} of ^{85}Kr**

Radon

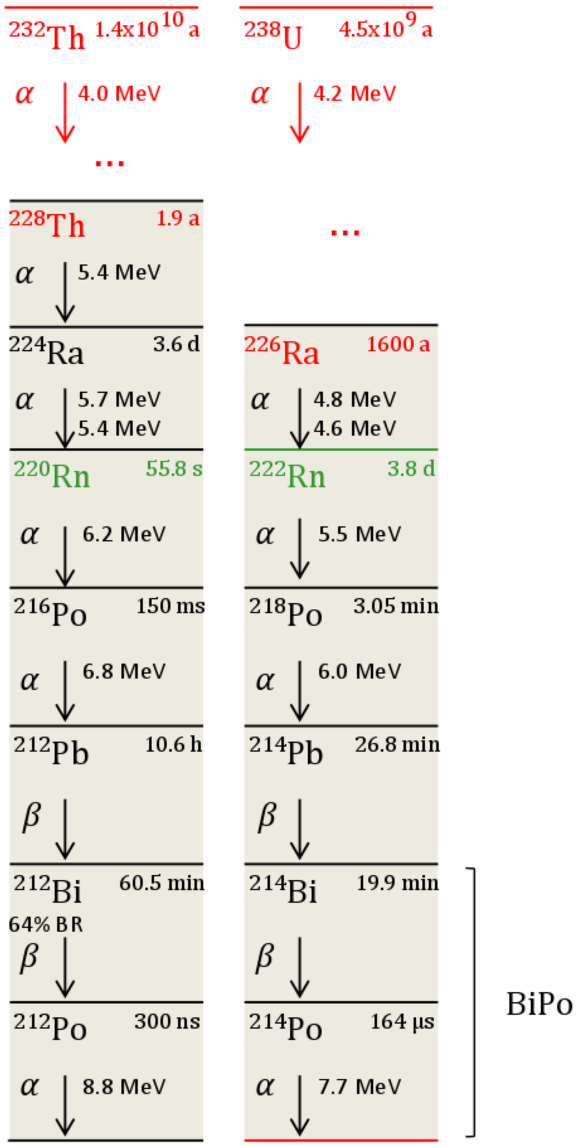
Radon is present in the liquid xenon due to emanation from detector materials and diffusion of the gas through the seals.

Radon is measured through:

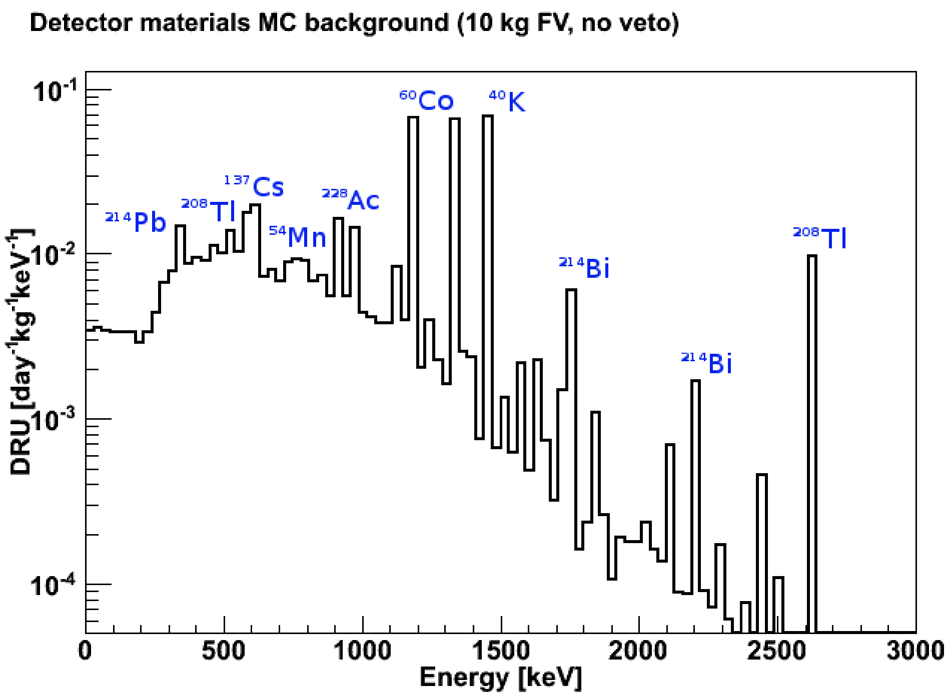
- Alpha decays of ^{222}**Rn**
  ^{218}**Po**
- **BiPo** tagging.

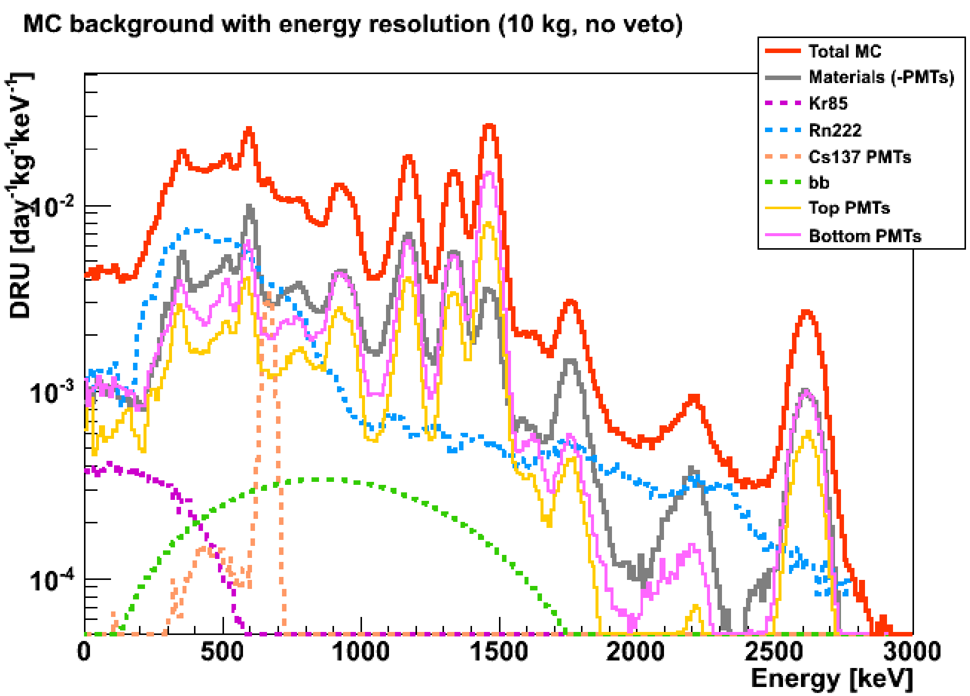


Above: Evolution of Rn concentration in Run 12 of XENON100.



Monte Carlo of the XENON100 Background





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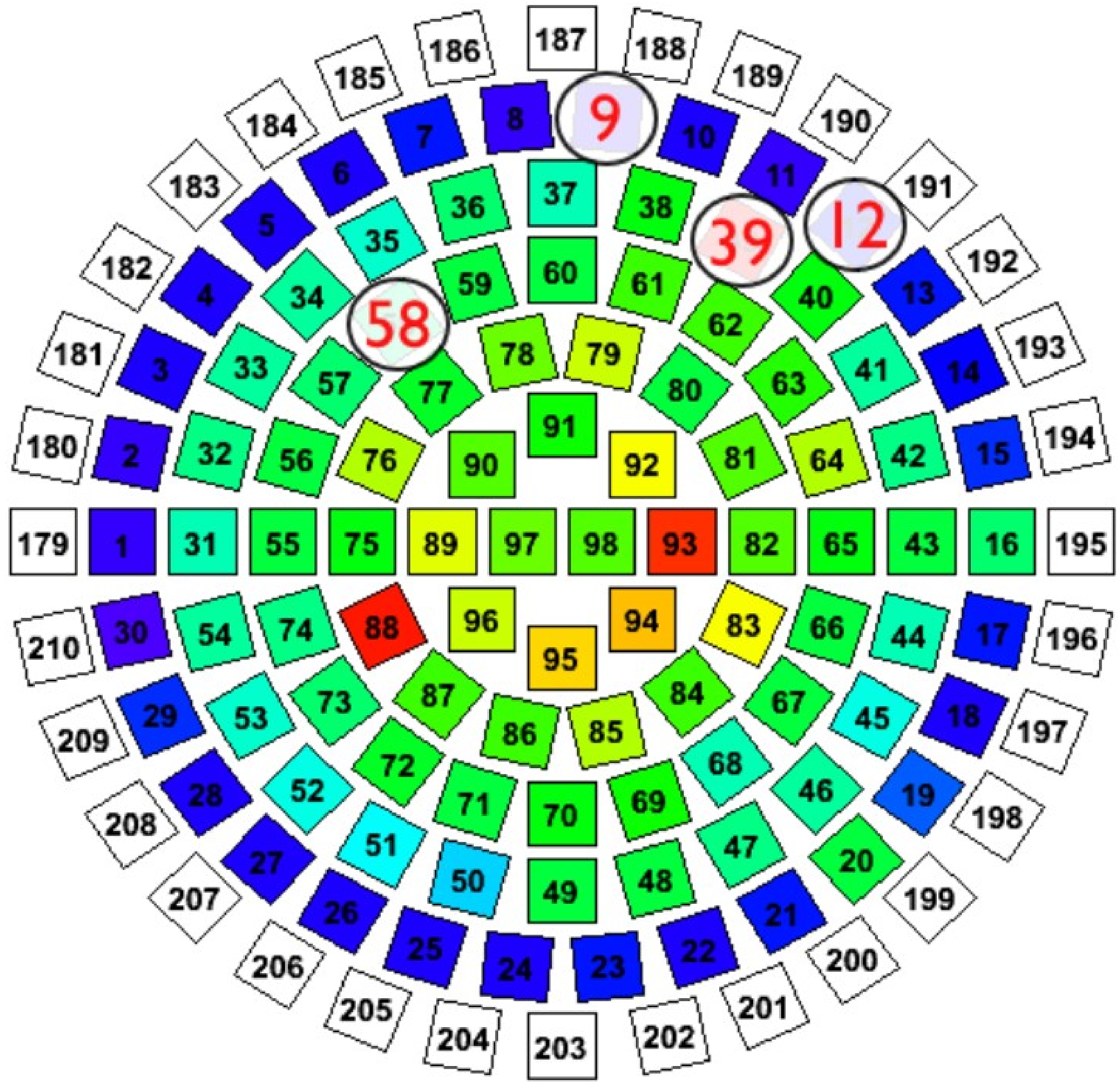
- **Detector energy resolution** as a function of energy: σ(E)/E [%] = 0.9 + 45/√(E[keV])
- **Two neutrino double beta decay** in ^{136}Xe with halflife of 2.11 x 10^{21} years.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