Universität Zürich[UZH]

XENON Dark Matter Project

Studies on the XENON100 Electromagnetic Background

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XENON Collaboration

Invisibles Workshop
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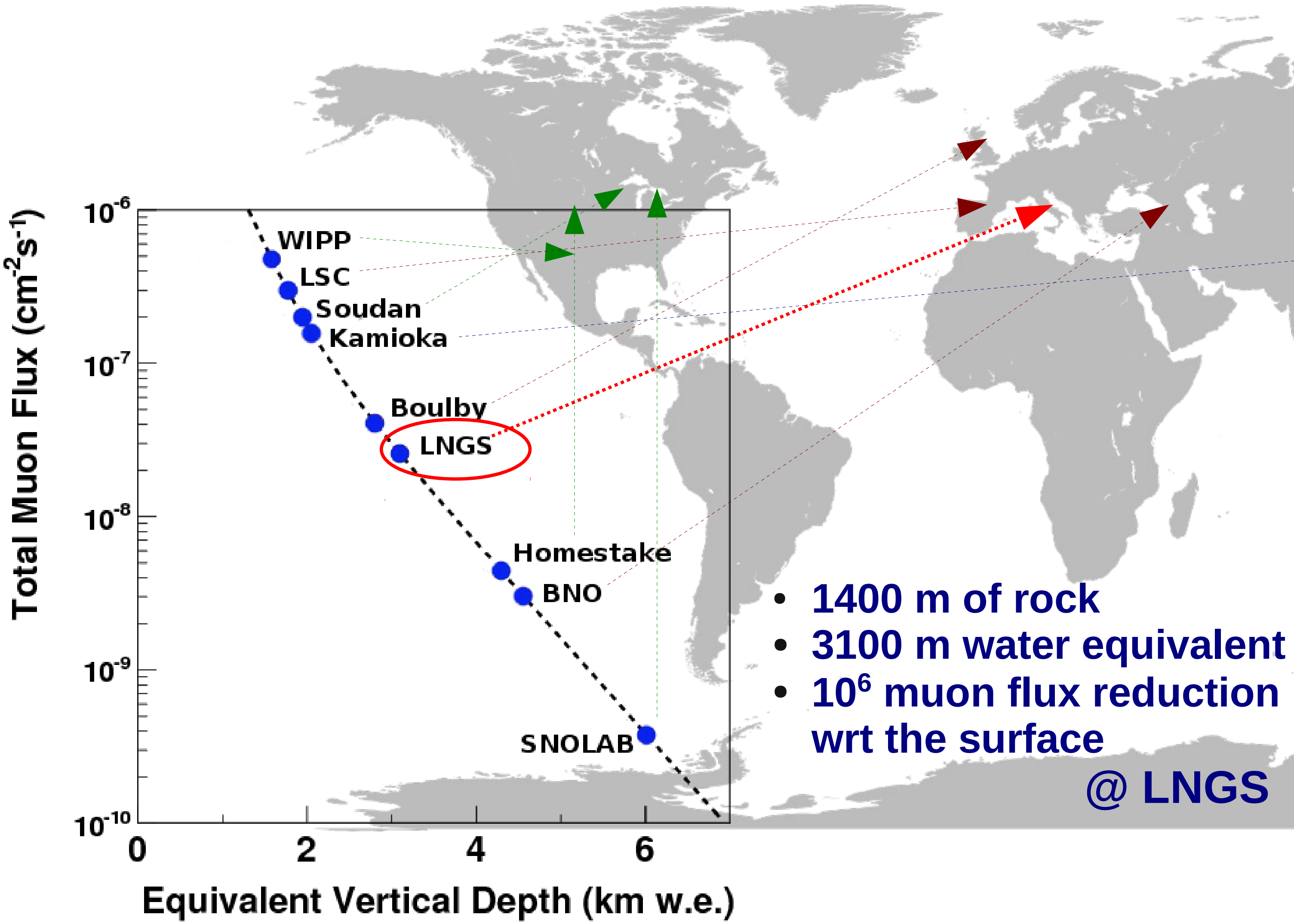
invisibles
neutrinos, dark matter & dark energy physics

XENON100 at LNGS

The main challenge for experiments searching for **dark matter** is the **reduction and discrimination** of the surrounding **background**. Installing the detectors in **underground facilities** is the first step to reach an increased sensitivity to rare events.



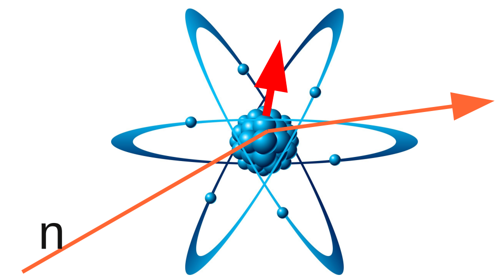
- **1400 m of rock**
- **3100 m water equivalent**
- **10^6 muon flux reduction wrt the surface**

@ LNGS

Main background sources

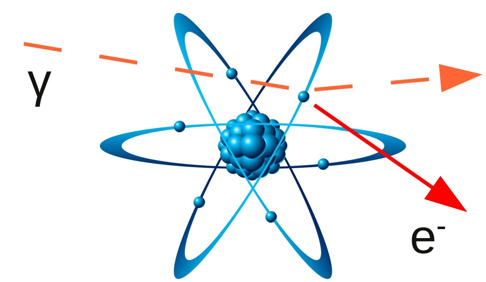
Nuclear recoil background:

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

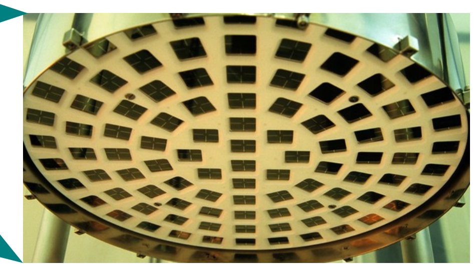


Electronic recoil background:

- 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.



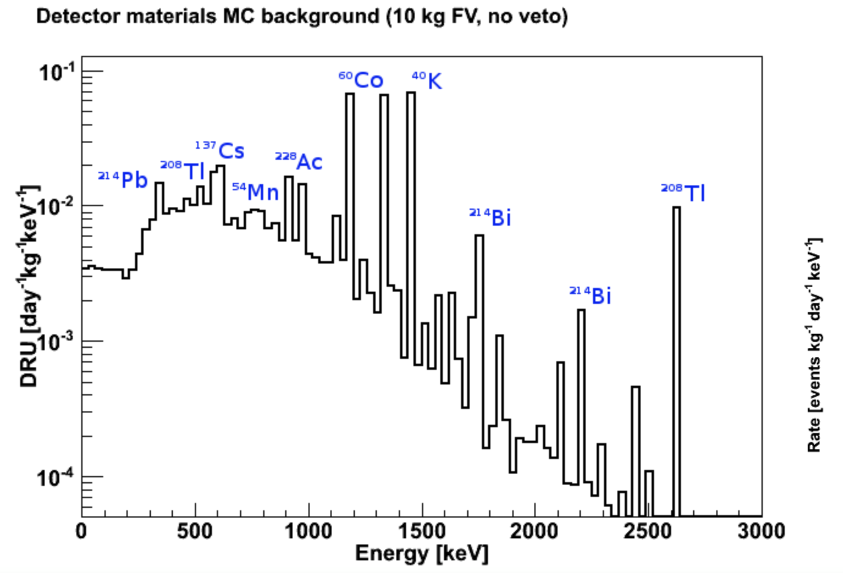
XENON100 TPC

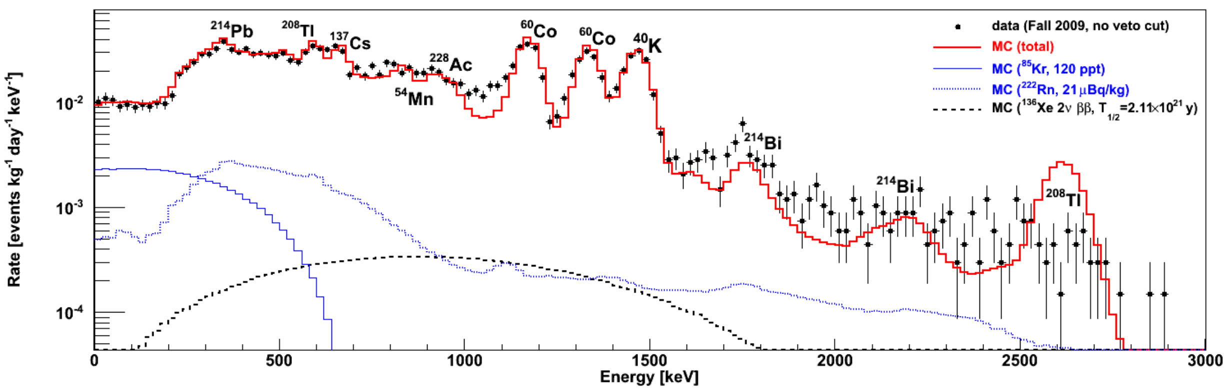


Top PMT array

Background Monte Carlo

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



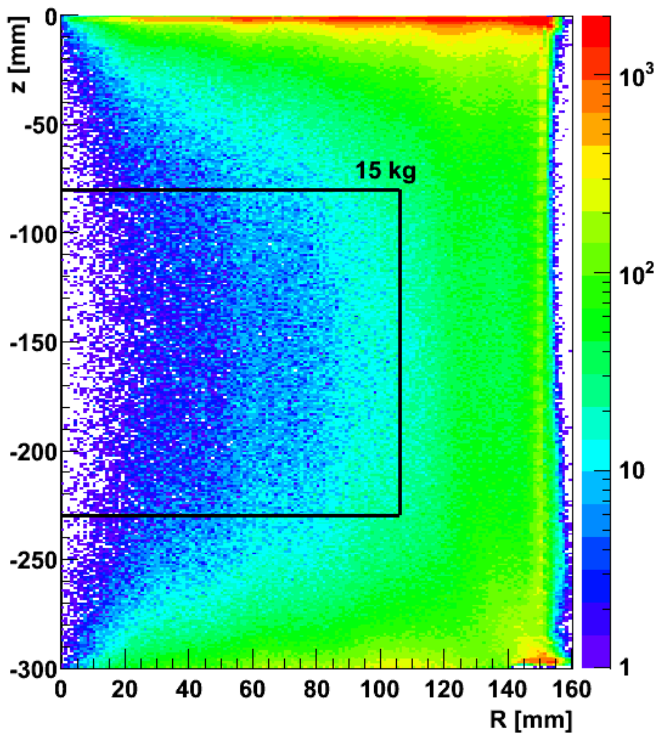


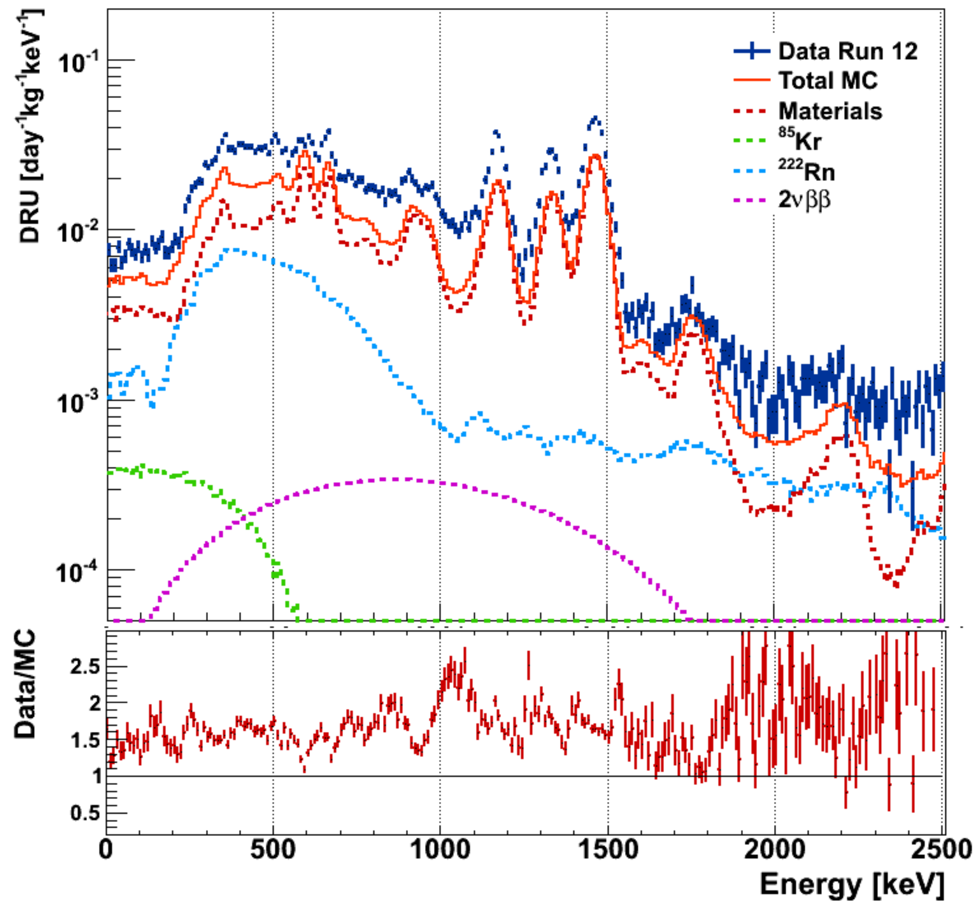
Screening results used for material selection and input in the Monte Carlo simulations with GEANT4.

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)



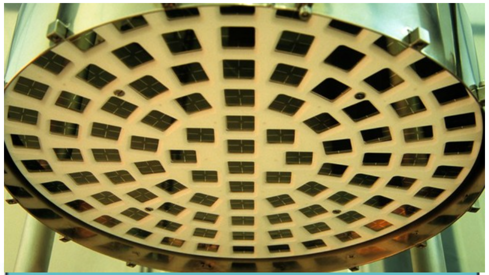


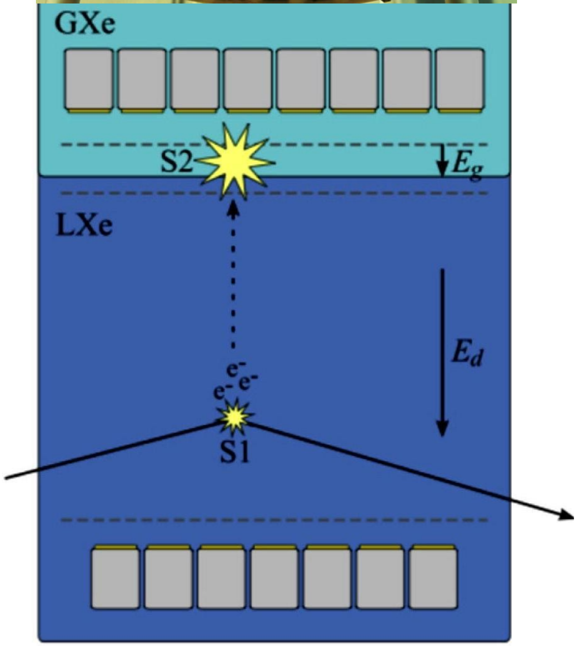
110 live days: Apr. 2013 – Jan. 2014

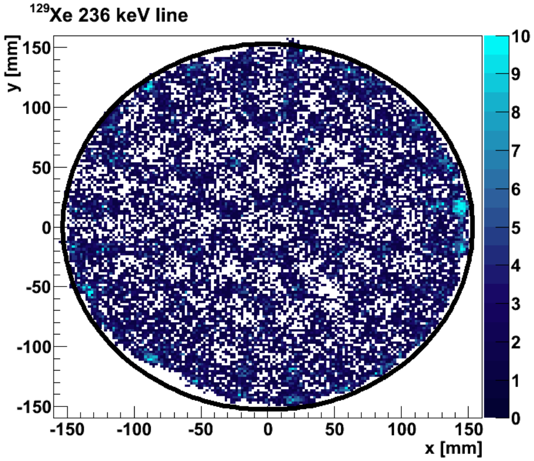
- **Kr in LXe:** Concentration of 10 ppt.
- **^{222}Rn in LXe:** Activity value of 64.1 uBq/kg.
- **Decay of ^{60}Co** (5.27y half-life). The time between materials screening run12 corresponds to roughly a half-life of ^{60}Co.
- **Detector energy resolution** as a function of energy: $\sigma(E)/E$ [%] = 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

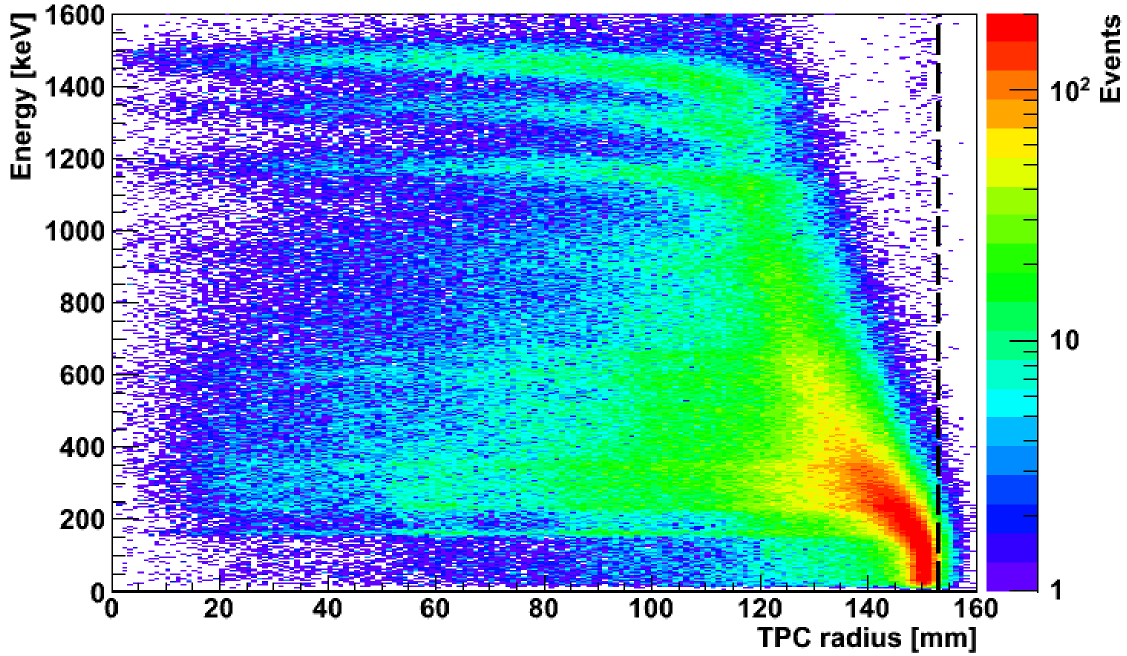






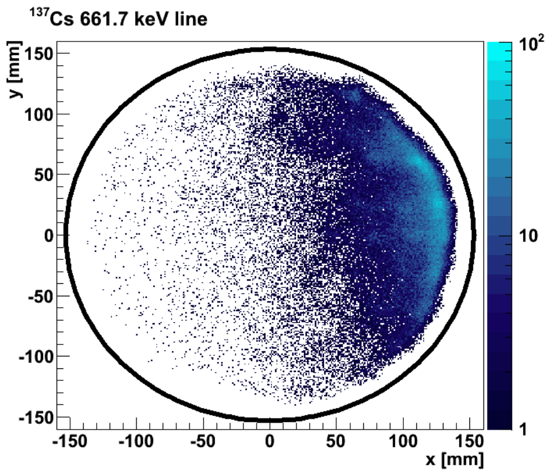
Saturation of the photomultiplier tubes (PMTs) from high S2 signals causes a mis-reconstruction of the event position.

Background spectrum, event energy vs radius

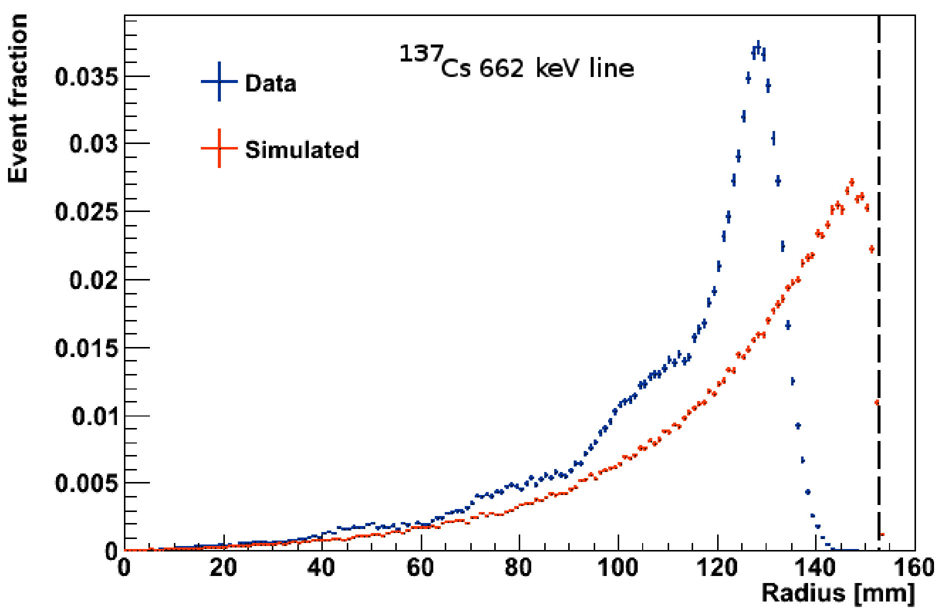


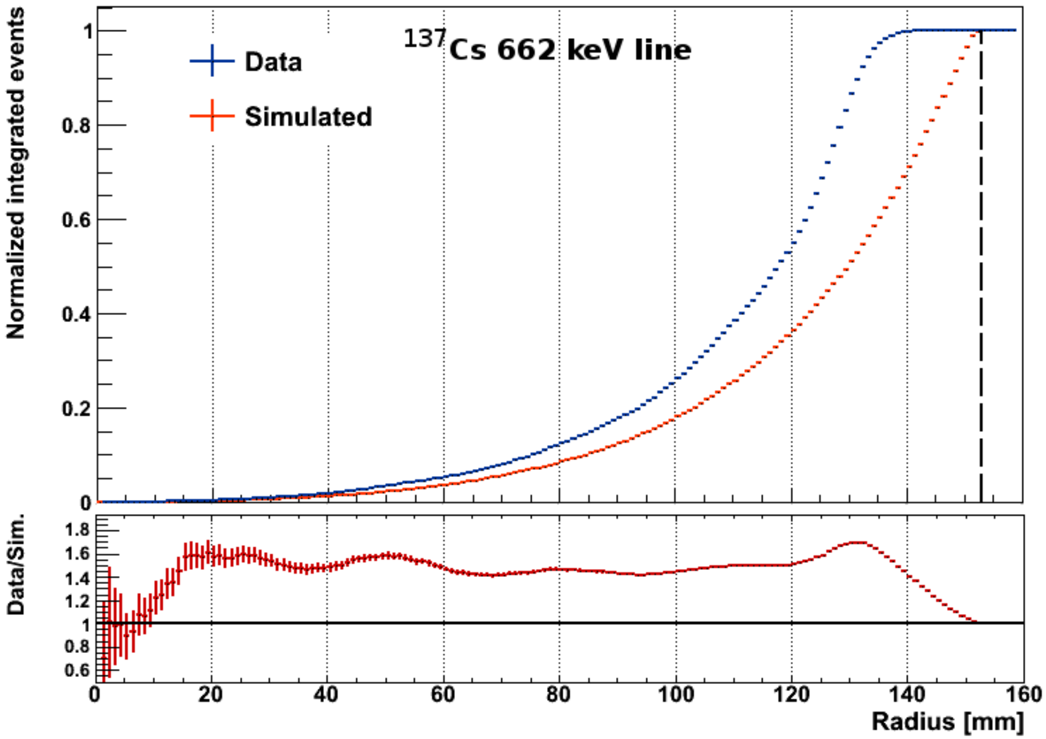
Event position reconstruction

^{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.

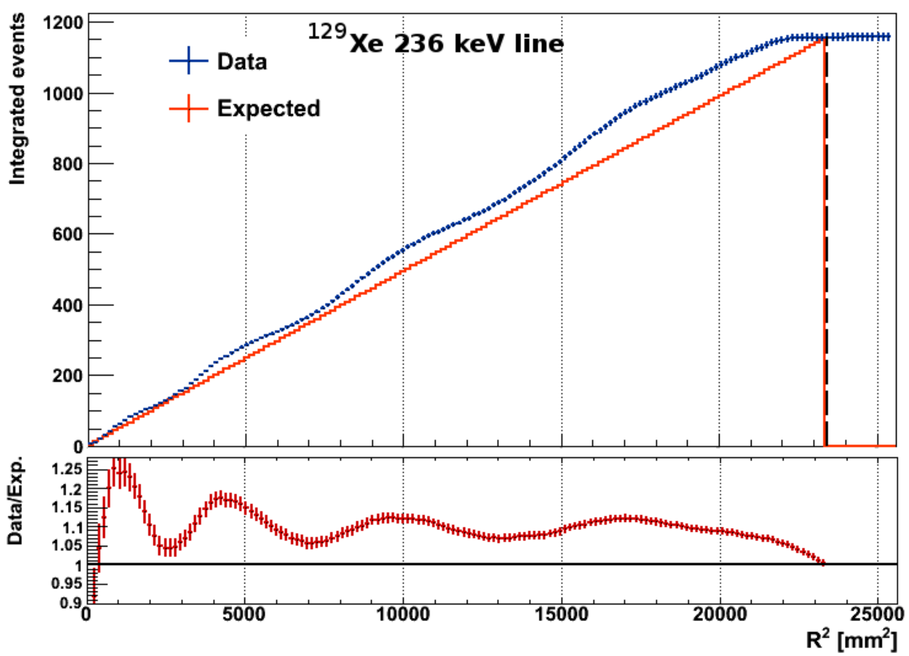




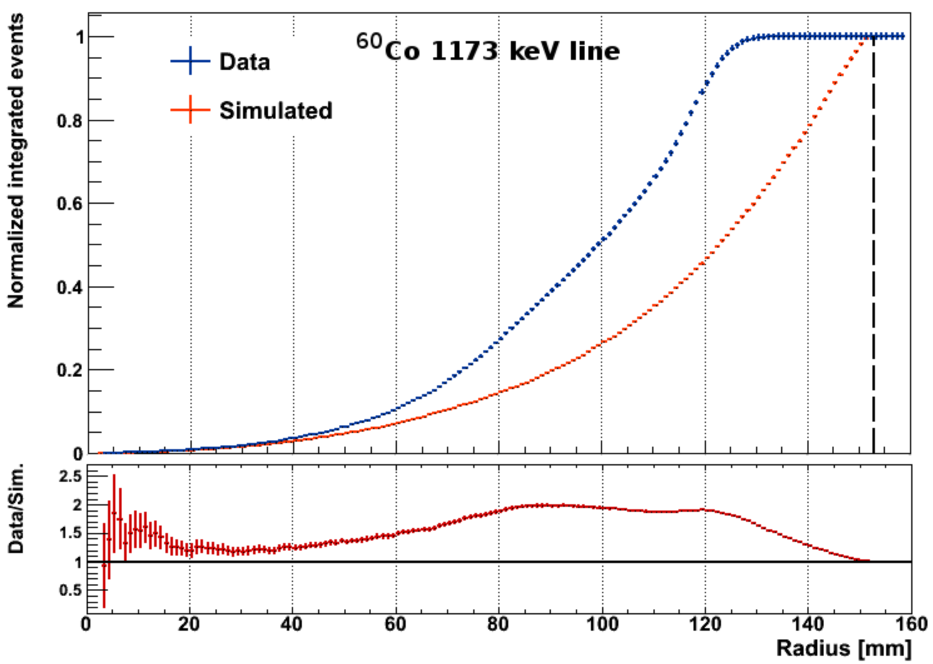
Event position reconstruction

The same analysis is performed for several sources

^{131}Xe 164 keV
^{129}Xe 236 keV



^{60}Co 1173 keV
^{60}Co 1332 keV

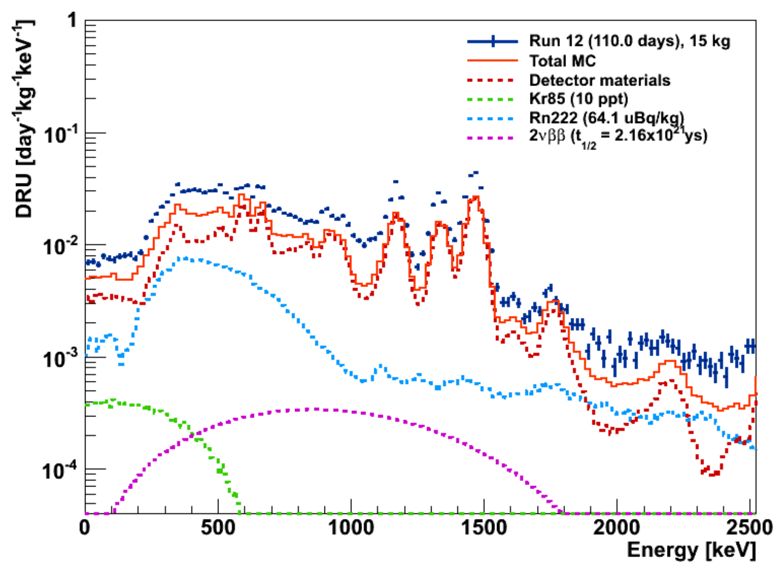


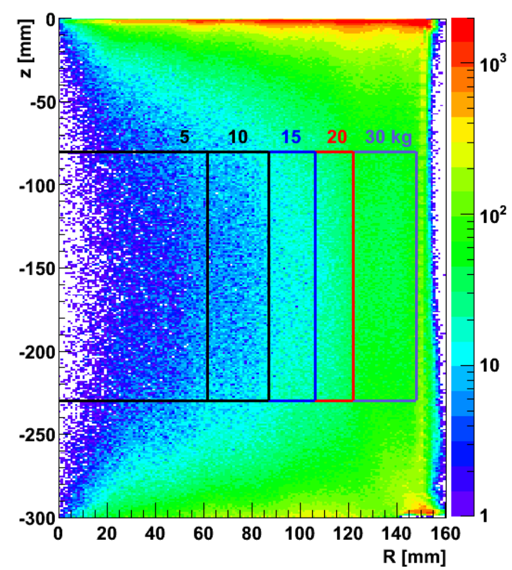
Conclusions

- Analysis of the background spectrum is important for a proper understanding of the detector and its backgrounds.

- The spectrum has been analyzed for one of the latest XENON100 runs.
- The mismatch between data and simulation rates can be understood due to the event position reconstruction discrepancy caused by saturation of the PMTs.

- Further analysis will be done for different fiducial volumes and the z dependence will be studied as well.





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**.

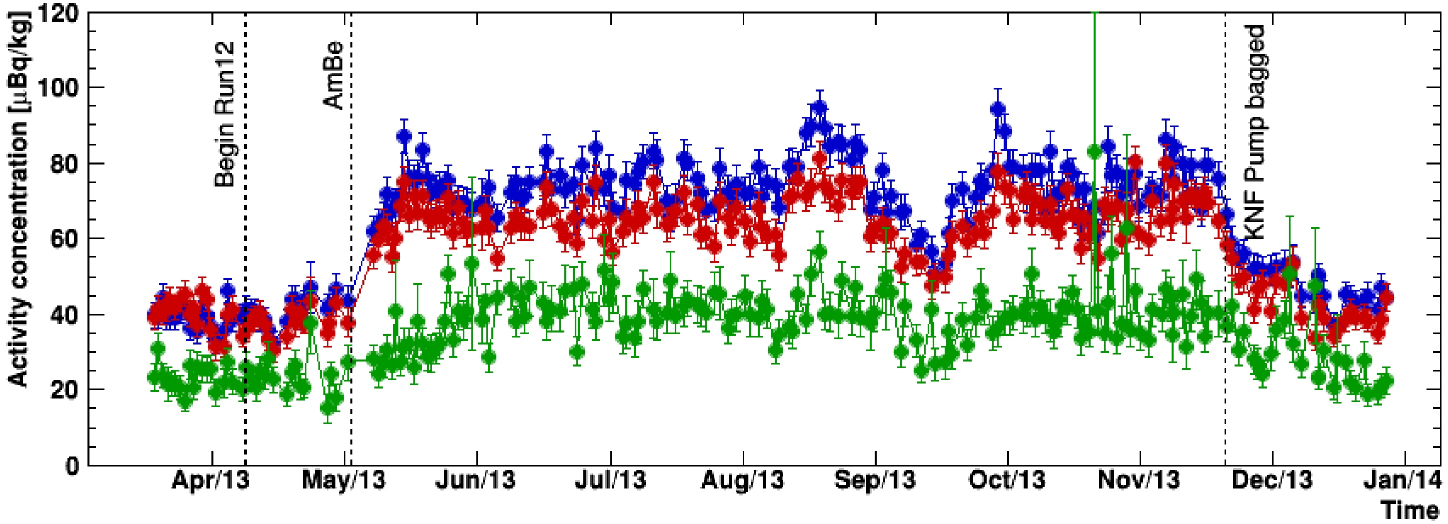
- **The isotope ^{85}Kr undergoes beta decay with a half-life of 10.76 years.**
- **Natural krypton contains 2×10^{-11} of ^{85}Kr**

Radon

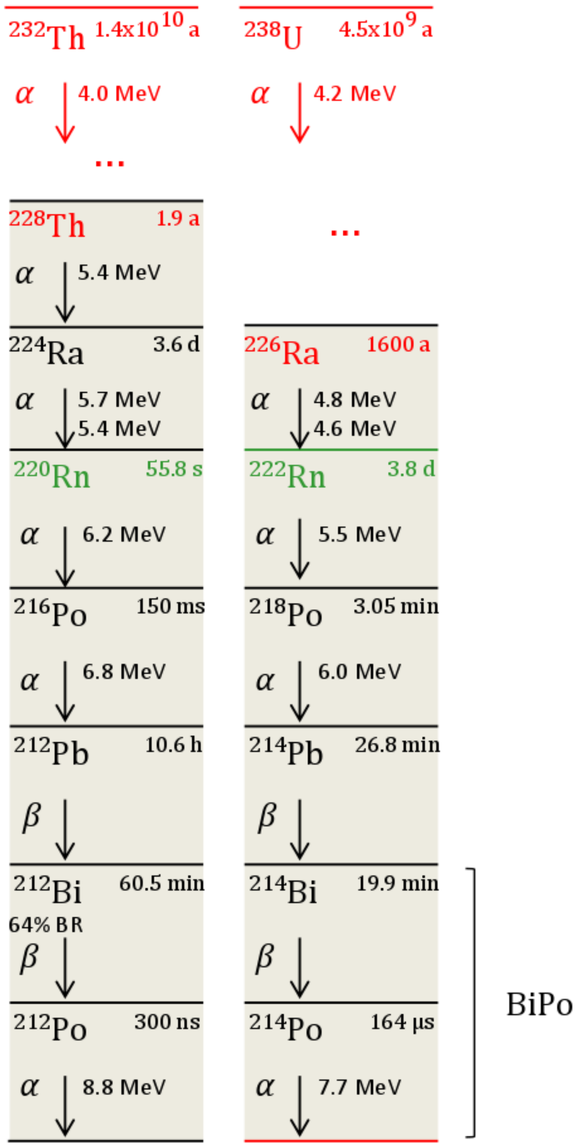
Radon is present in the liquid xenon due to emanation from detector materials and diffusion of the gas through the seals.

Radon is measured through:

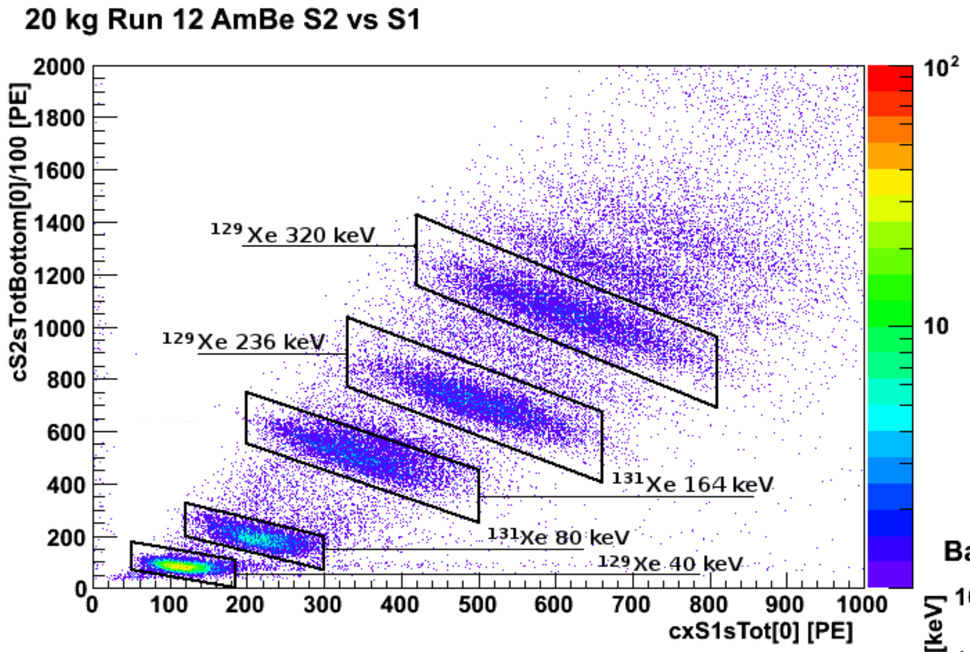
- Alpha decays of **^{222}Rn** / **^{218}Po**
- **BiPo** tagging.

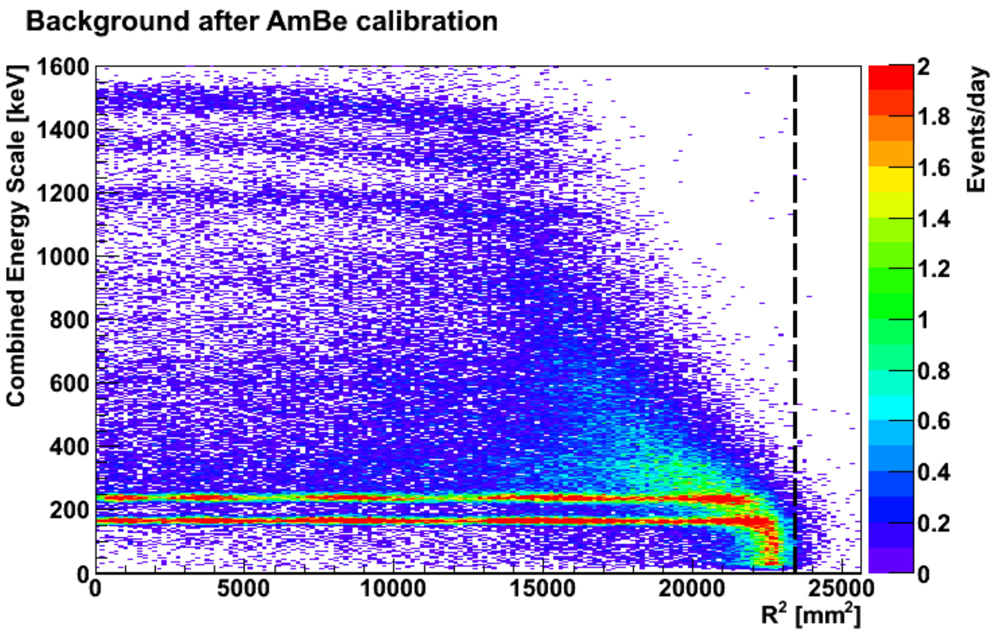


Above: Evolution of Rn concentration in Run 12 of XENON100.

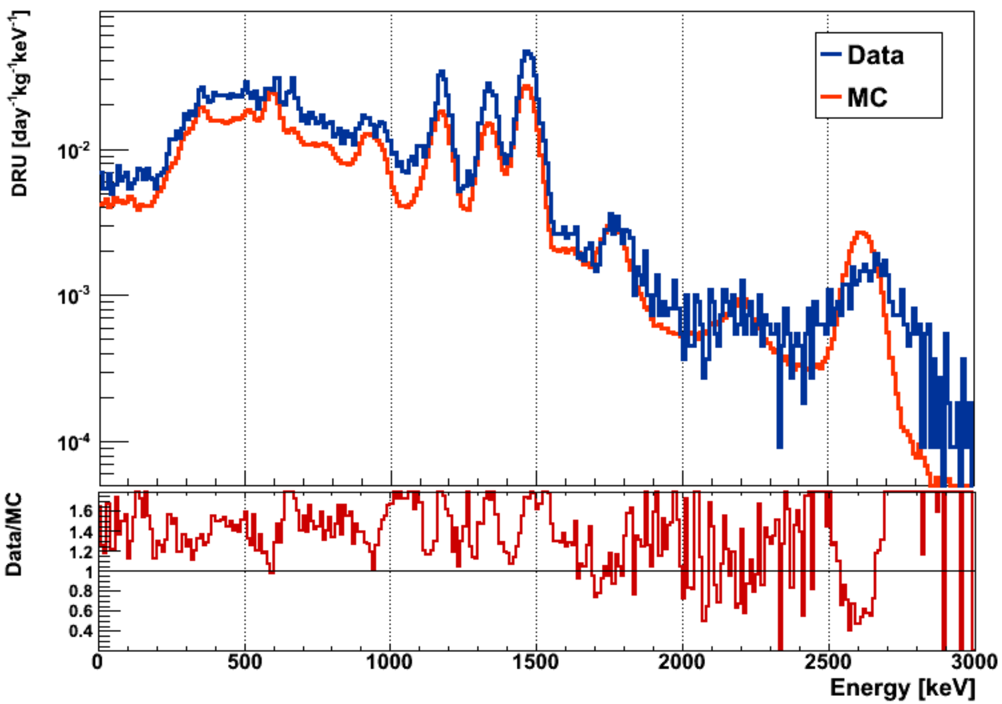


AmBe calibration





MC and data matching



The MC simulation is compared with the data collected from the XENON100 Run12.

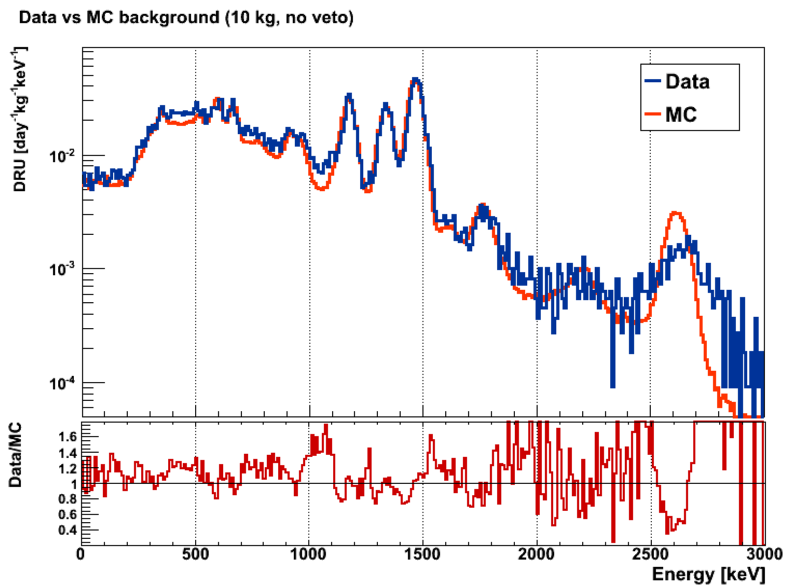
The following scaling factors allow to better match the MC with the data:

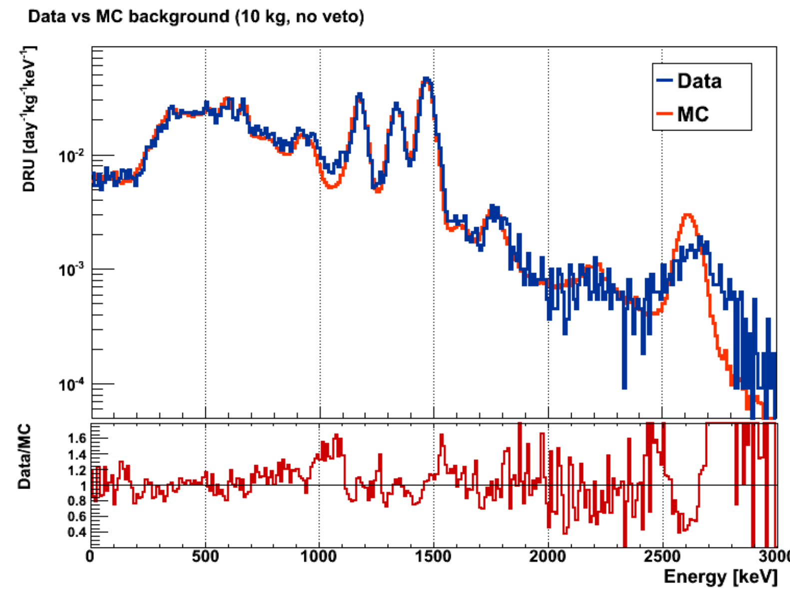
Table 1.	Scaling factors with Rn fixed	Scaling factors with 1.6 Rn
Rn	64.1 uBq/kg	x1.6 = 102..5 uBq/kg
Kr	10 ppt	10 ppt
Cs	4.5	4.0
Top PMTs		
Th232	1.6	1.4
U238	1.8	1.0
K40	2.4	2.3
Co60	2.8	2.7
Bottom PMTs		
Th232	1.2	1.0
U238	1.4	1.0
K40	1.4	1.4
Co60	1.9	1.9

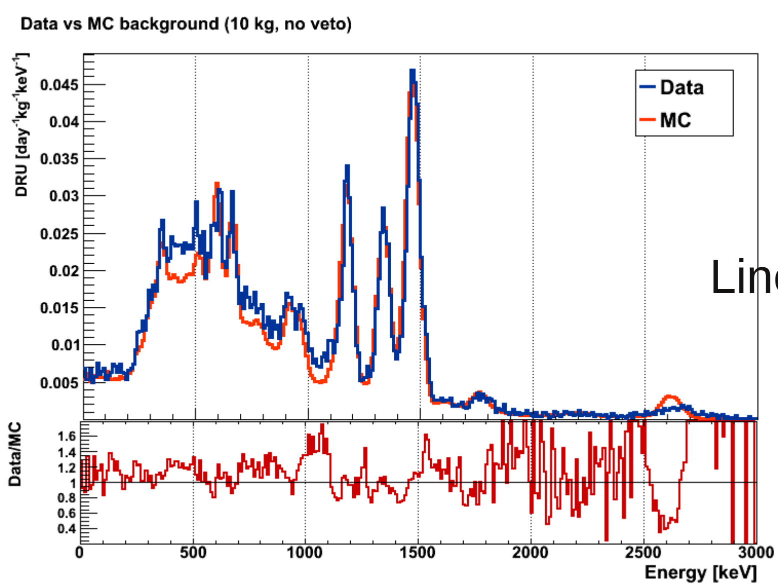
The PMTs are the largest radioactive contributors and only 85% of the top PMTs and 54% of the bottom PMTs were screened.

MC and data matching
Rescaled

Rn 64 uBq/kg | **Rn 102.5 uBq/kg**







Linear scale