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A Study of Radon Background in the XENON100 Dark Matter Experiment

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For the XENON Collaboration

1. Introduction to XENON100

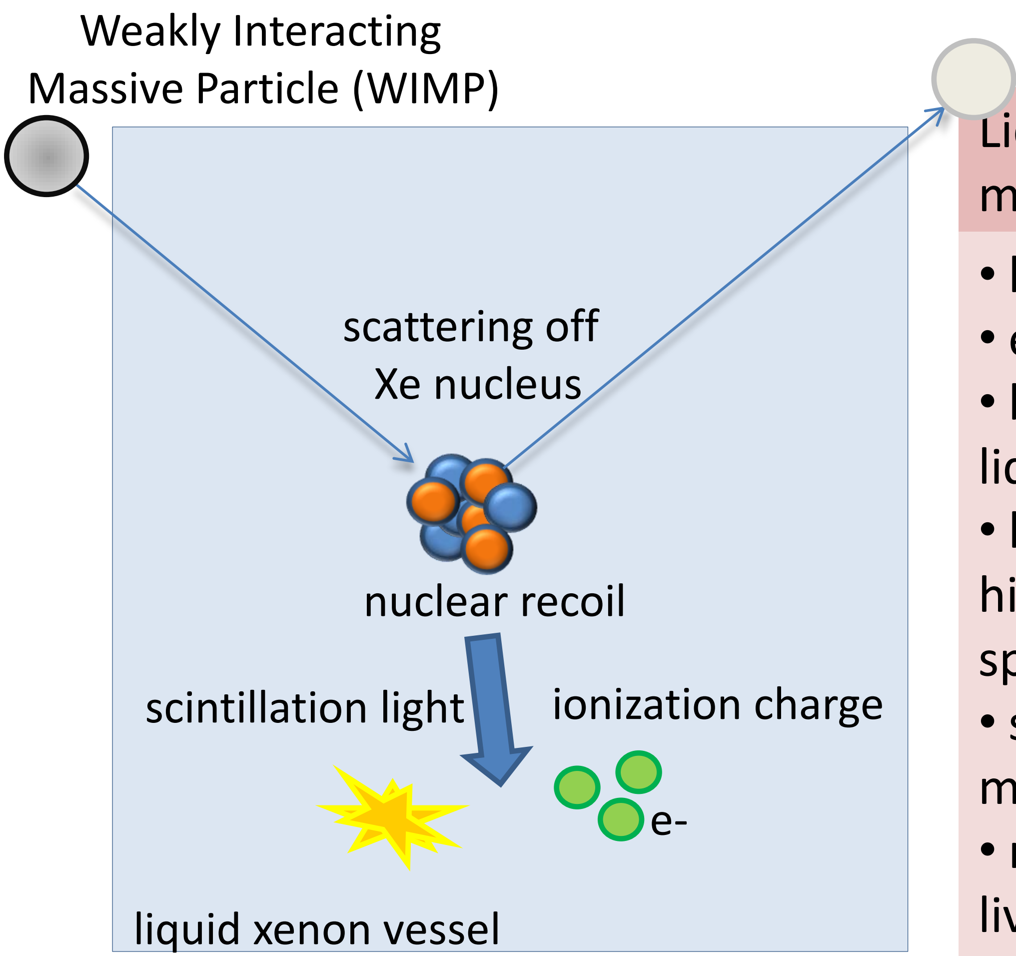
1.0 The XENON Collaboration

Columbia | Rice | UCLA | Zürich | Coimbra | LNGS | SJTU

Mainz | Bologna | Subatech | Münster | Nikhef | Heidelberg | Weizman

1. Introduction to XENON100

1.1 Liquid Xenon Detector for Dark Matter Search

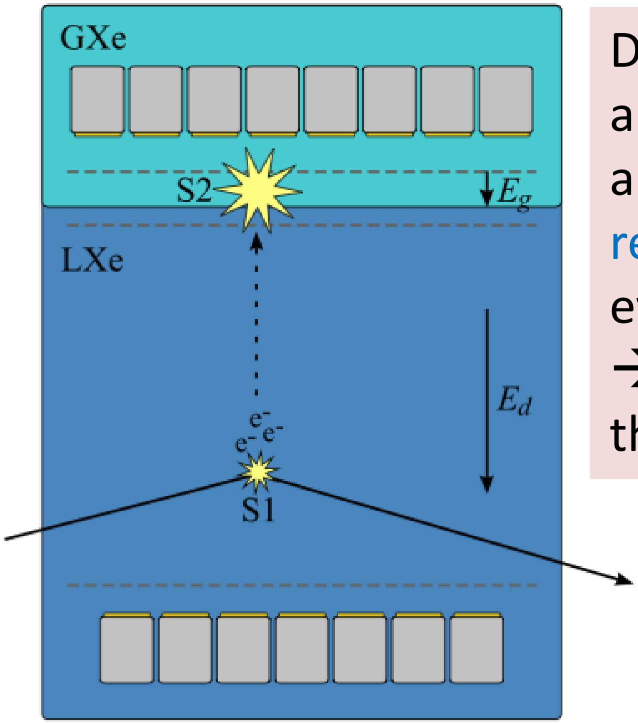


Liquid xenon - an advantageous target material

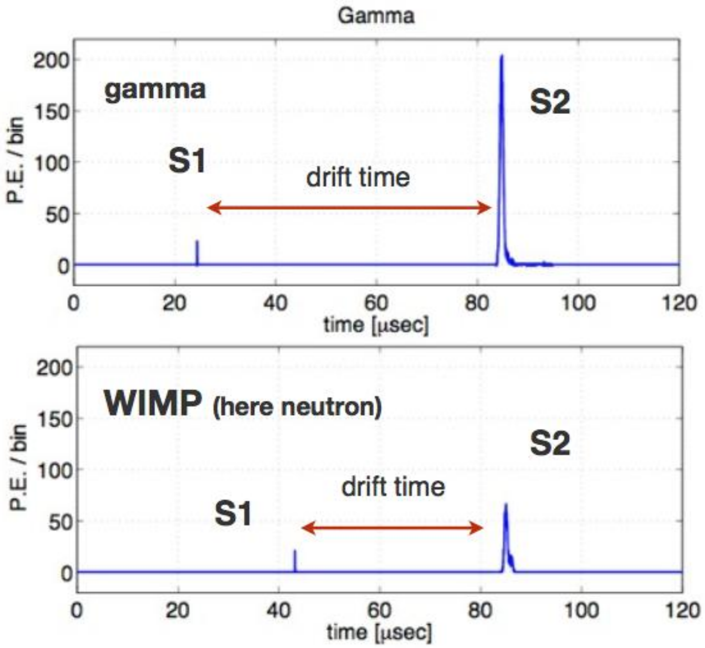
- high density and Z → self-shielding
- efficient and fast scintillator
- best ionization yield of all noble liquids (W-value = 15.6 eV)
- high mass number (A ~ 131) provides high WIMP rate at low threshold for spin-independent interaction
- simultaneous capability of measuring spin-dependent interaction
- no intrinsic background from long-lived Xe isotopes

1. Introduction to XENON100

1.2 Double-Phase Xenon TPC



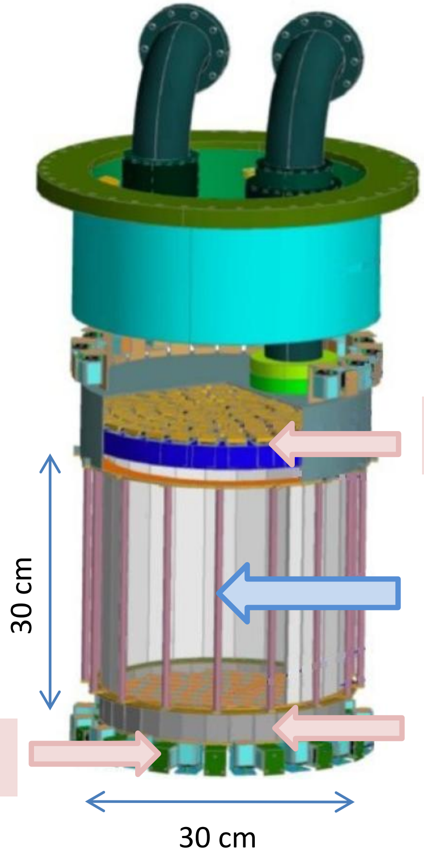
Drift time information and PMT hit pattern allow a 3D reconstruction of the event position
→ fiducialization of the target volume



Calculating charge to light ratio enables discrimination between electron and nuclear recoils.

1. Introduction to XENON100

1.3 XENON100 TPC Design



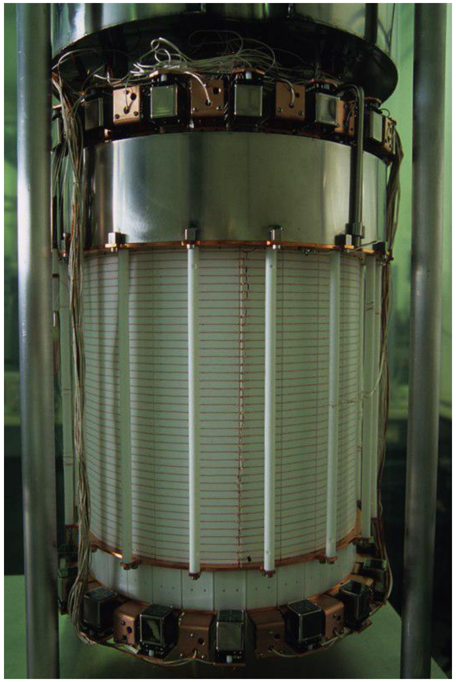
PMT array at the top

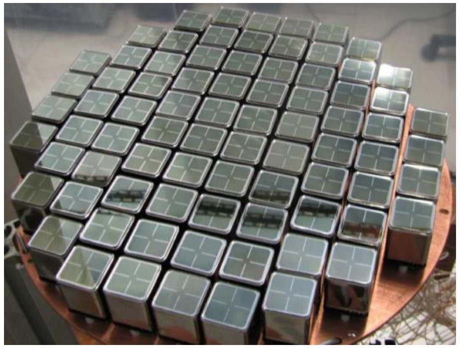
target volume confined by PTFE reflection walls contains 62kg LXe

PMT array at the bottom

veto PMTs

outer volume of another 99kg LXe

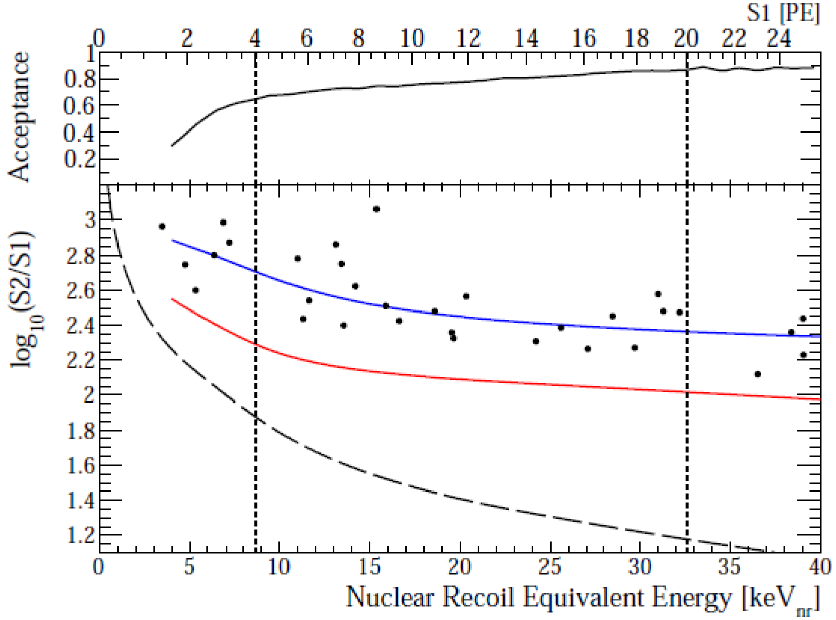


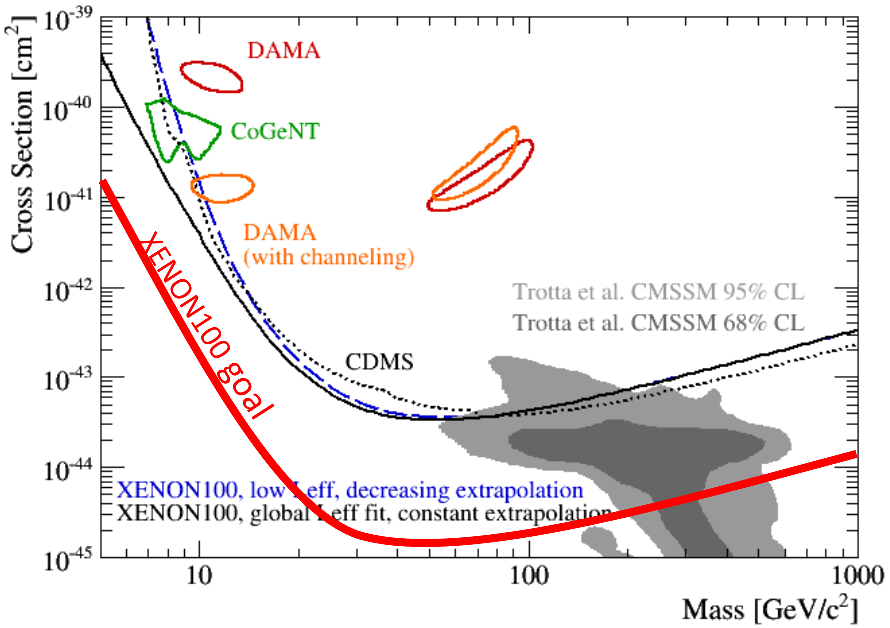


1. Introduction to XENON100

1.4 First Results (PRL in Press, arXiv: 1005.0380)

First Dark Matter Results from the XENON100 Experiment , E. Aprile et al. (The XENON100 Collaboration), arXiv: 1005.0380





In 11.2 days of background data (40kg fiducial volume) no events have been found in the nuclear acceptance region (below red line and in between dashed lines)

Spin-independent WIMP-nucleon interaction

Aimed sensitivity for XENON100
$\sigma = 2 \times 10^{-45}$ cm^2 (@100 GeV, 30kg, 200d)

2. Background and Shield Design

2.1 Background Components and Reduction

External backgrounds

- radio-impurities in construction materials (PMTs, steel vessel, ..)
- cosmic-ray muons and induced secondaries (gammas, electrons, neutrons)
- neutrons from fission and (α,n)-reactions

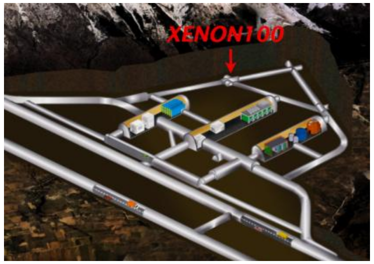
Backgrounds in the liquid

- Krypton-85 abundance in LXe
- Radon emanating into liquid phase

Applied means for BG reduction

- highly sensitive material screening and selection
- deep underground: LNGS facility
- passive shield: lead, polyethylene and copper layers around the inner vessel
- cooling system outside the shield
- self-shielding of LXe (fiducialization)
- active LXe veto around inner chamber

- krypton removal by cryogenic destillation column

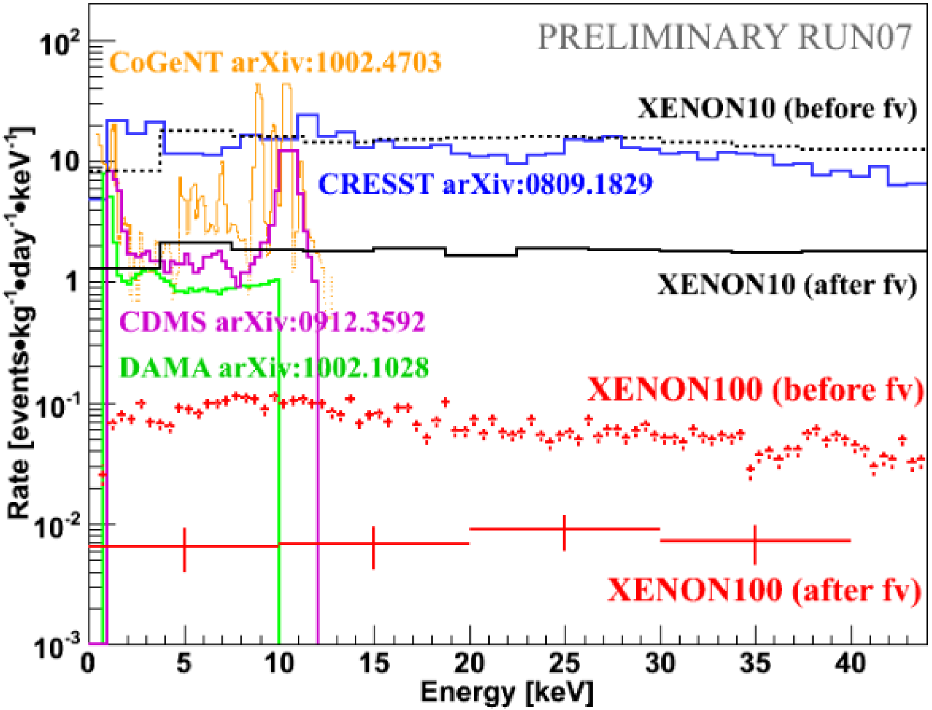


2. Background and Shield Design

2.2 Comparison of Background Levels

XENON100 background rate in the dark matter energy window was reduced by a factor 100 compared to the XENON10 level.

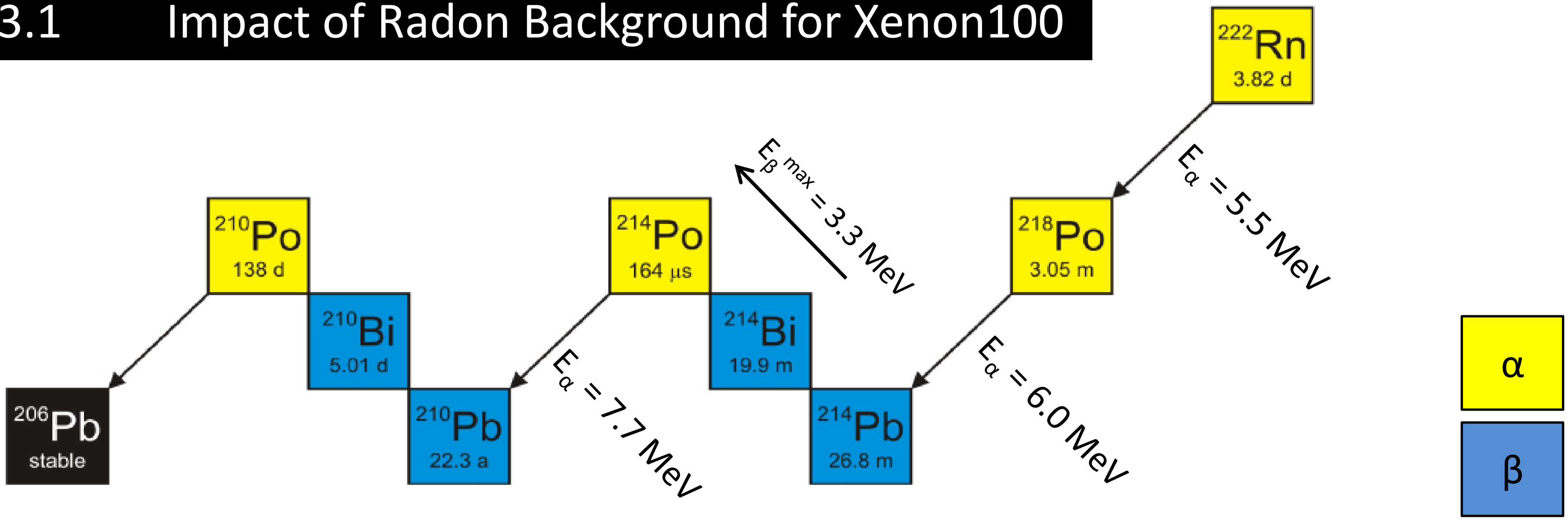
lowest rate of all dark matter experiments



Having removed external BG sources as good as possible, it is crucial to address background suppression of internal contaminants (e.g. by krypton purification, emanation-free materials).

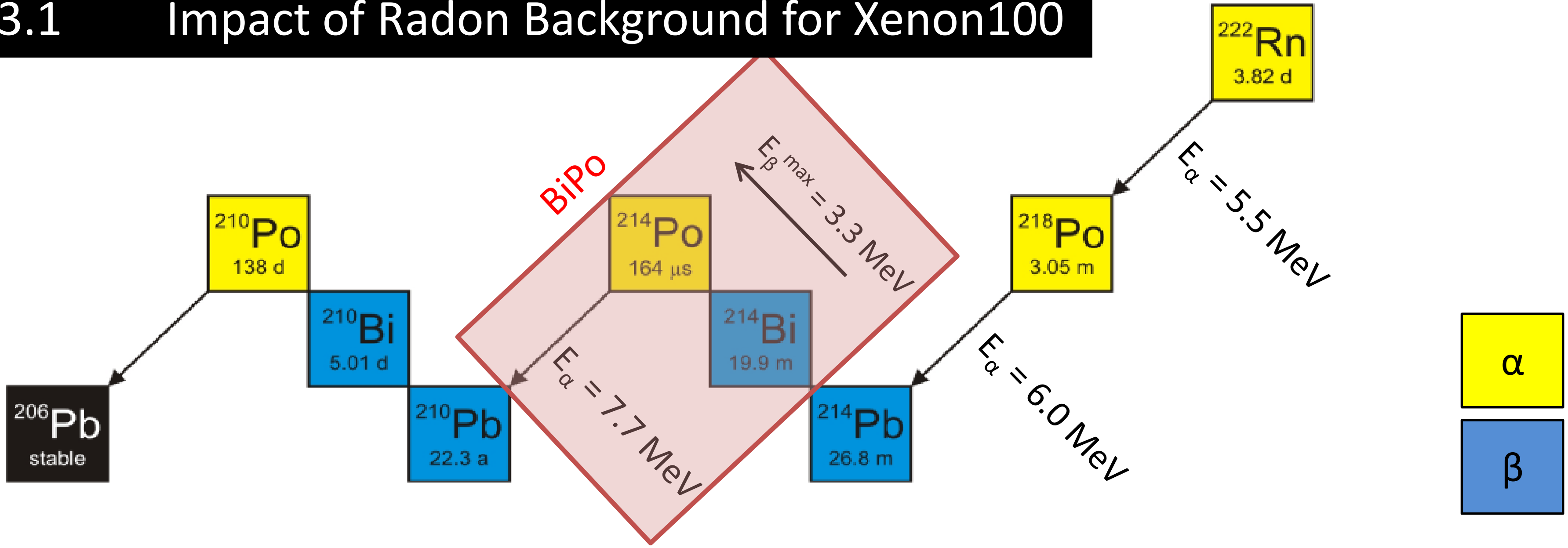
3. Tagging Radon Events

3.1 Impact of Radon Background for Xenon100



3. Tagging Radon Events

3.1 Impact of Radon Background for Xenon100



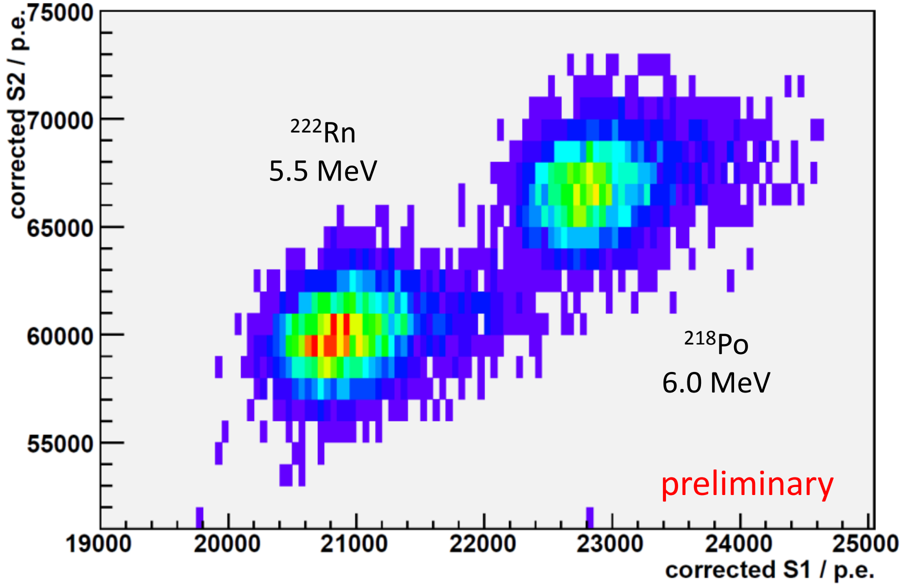
Even with a ER/NR discrimination efficiency of more than 99%, the continuous spectrum of the ^{214}Bismut β-decay implies a non-vanishing probability of mimicking a dark matter event in the low energy region.

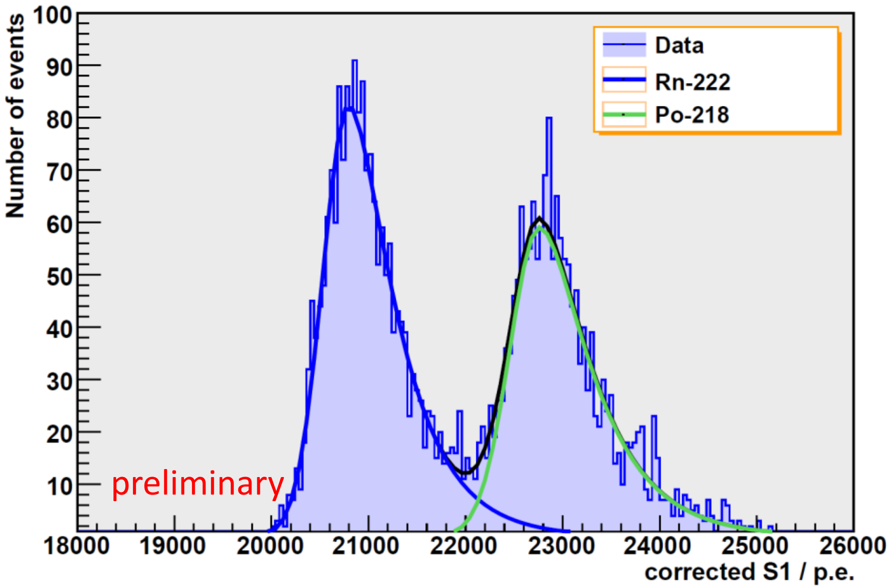
The subsequent decay of ^{214}Polonium happens after $T_{1/2}$ = 164 µs.
→ Search for a coincidence signal within 400 µs DAQ window

3. Tagging Radon Events

3.2 Selection of ^{222}Rn and ^{218}Po Events by Energy Cuts

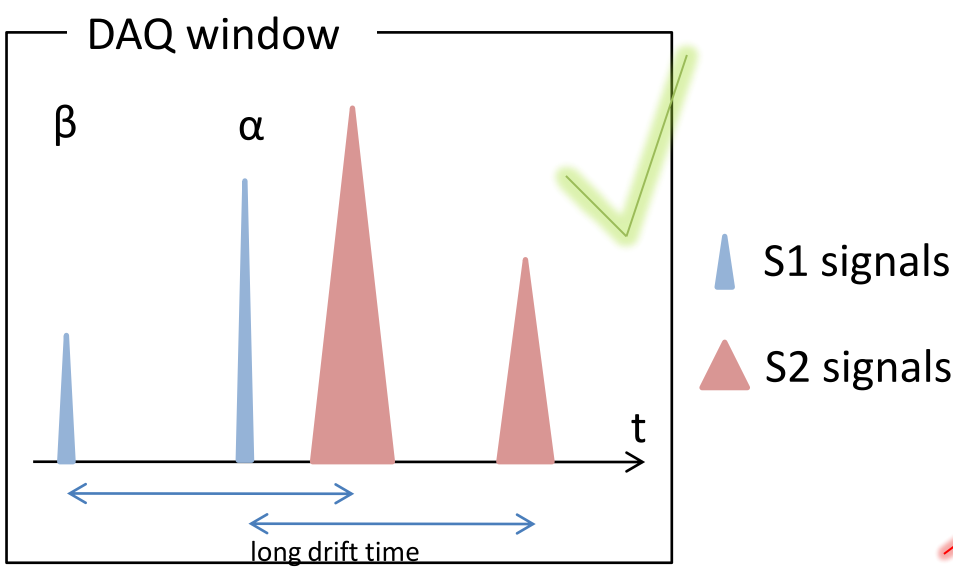
High-energy alpha events from ^{222}Rn and ^{218}Po decays can be separated and selected in scintillation light/ionization space.

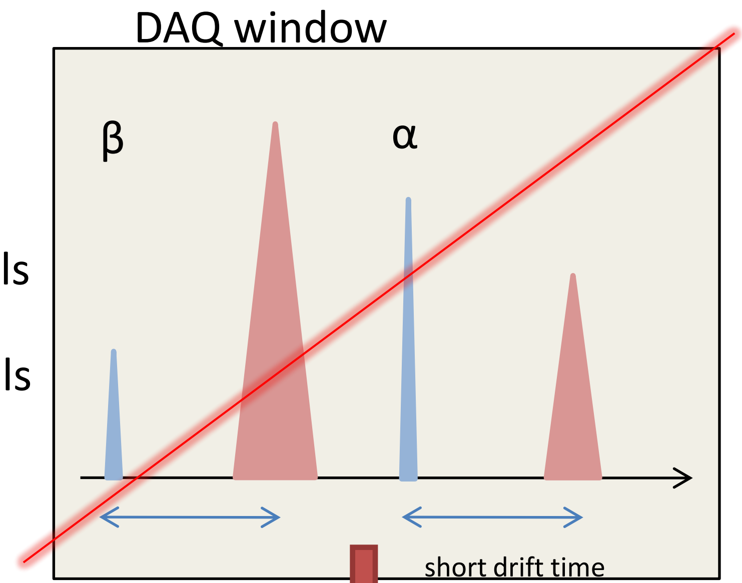


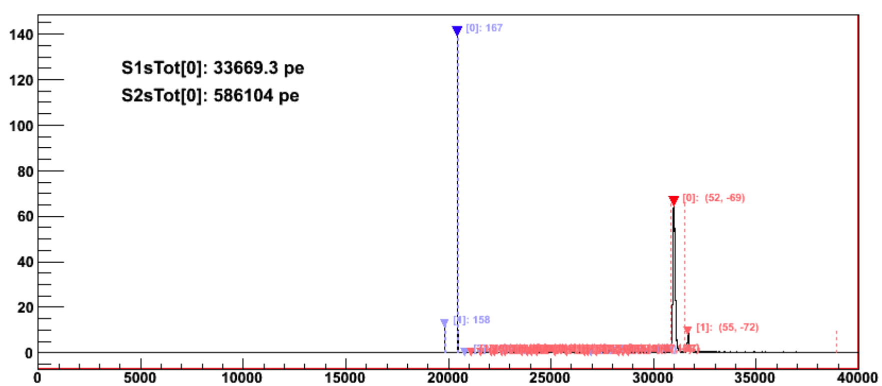


3. Tagging Radon Events

3.3 Selection of BiPo Event Topology







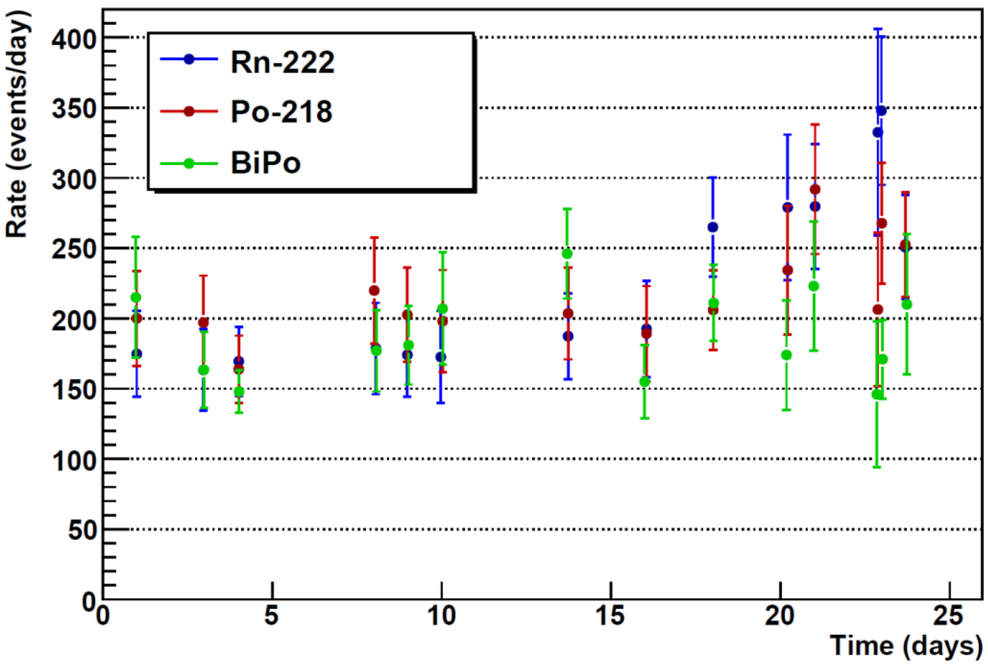
Data processor does not search for S1 signal after 1st S2 peak

drift time dependent efficiency correction of BiPo rate

3. Tagging Radon Events

3.4 Results and Comparison of Event Rates

Radon rate during the time of the First Dark Matter Results (publication of 11.2 days of effective data taking)



The inferred time averaged BiPo rate in the sensitive detector volume (no fiducialization, 62kg LXe) ,

A_{BiPo} = 33 ± 16 (sys.) ± 2 (stat.) µBq/kg

corresponds to a radon background level of

≈ $1 \cdot 10^{-3}$ events/kg/day/keV

in a 40kg fiducial volume.

⇩

≈ 2 of 22 events in First DM analysis of 11.2 days (before ER/NR discrimination)

4. Summary and Conclusion

- XENON100 is a double phase liquid xenon time projection chamber experiment

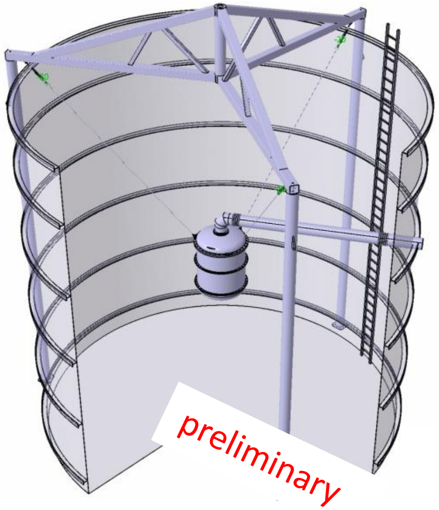
- First scientific results have been published (PRL in press) : background-free in the acceptance window

- Background event rates from ^{222}Rn and its decay daughters ^{218}Po, ^{214}Bi and ^{214}Po can be tagged and monitored separately

- Rate measurements enter dedicated MC simulation studies.

- All information from background studies have immediate impact on the ongoing development of the large scale XENON1T experiment

XENON100



XENON1T