# Characterization of the XENON1T liquid xenon dual-phase time projection chamber using Kr-83m


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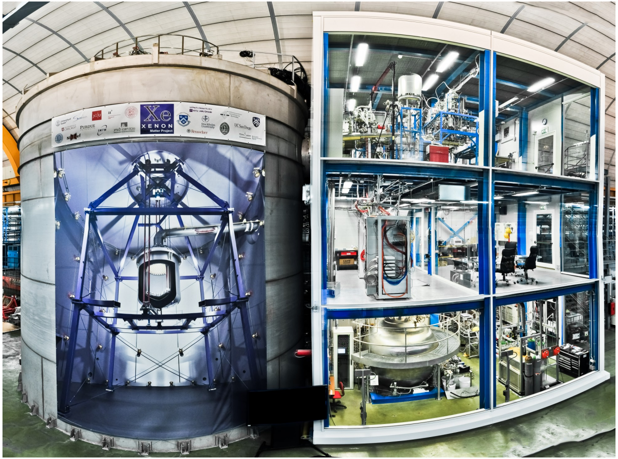
# Outline

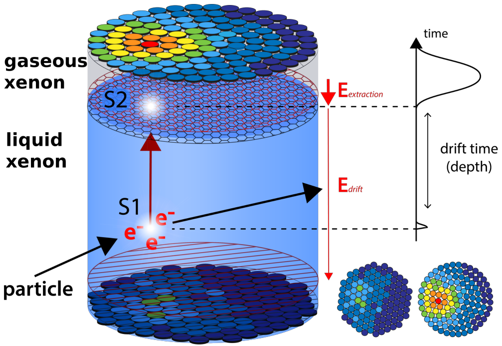
1. The XENON1T experiment
   - What is it?
   - How does it work?
2. Characterization using $^{83m}$Kr
   - Why do we use $^{83m}$Kr?
   - What can it tell us?

# XENON1T




- Goal: direct detection of dark matter (Weakly interacting massive particles: WIMPs)
- Largest liquid xenon dual-phase time projection chamber (TPC) in the world

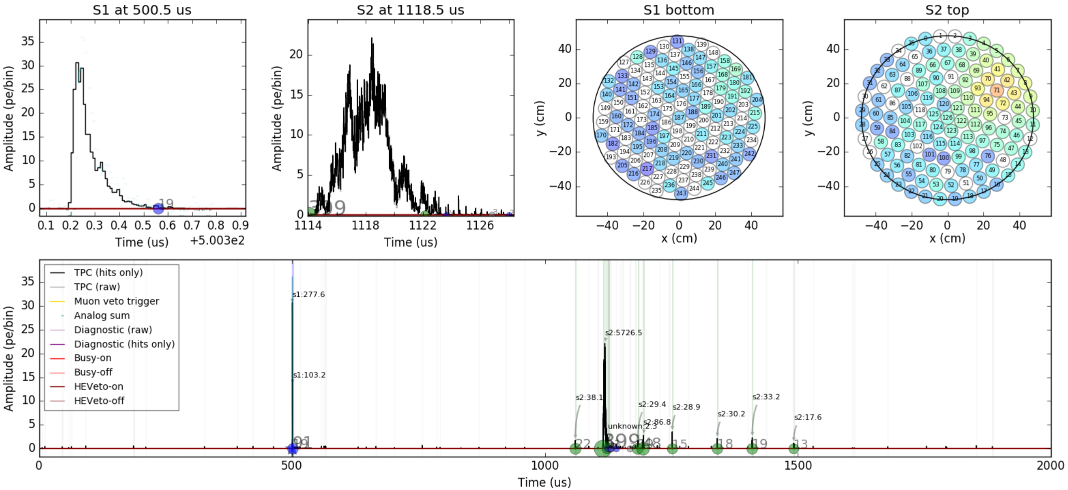
# Working principle of a LXe dual-phase TPC




Credit: *Lutz Althüser*

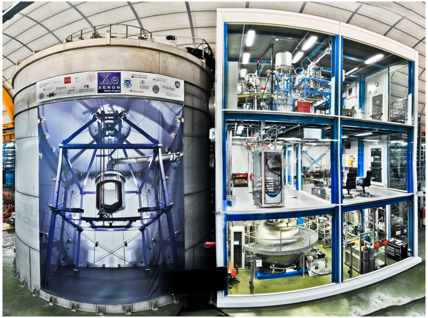
- Particle interaction causes excitation and ionization of Xe
- Excited Xe-dimers emit scintillation light (S1)
- Ionization electrons are drifted into gas phase and cause a second signal (S2)
- Due to energy conservation, signals S1 and S2 are anti-correlated
- PMT hit pattern and drift time allow for 3D position reconstruction

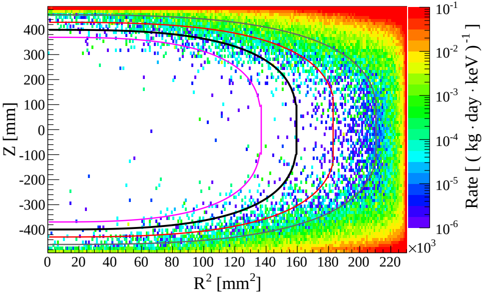
# Example waveform



# Background reduction

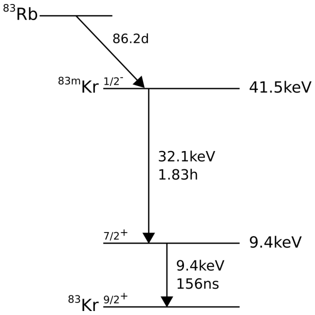
- Underground under a mountain at 3600m water-equivalent shielding
- Cherenkov muon veto: 740 $\mathrm{m}^3$ water tank, 84 PMTs
  [Conceptual design and simulation of a water Cherenkov muon veto for the XENON1T experiment, XENON1T Collaboration (Aprile, E. et al.) JINST 9 (2014) P11006]
- Removal of $^{85}$Kr by cryogenic distillation column
  [Removing krypton from xenon by cryogenic distillation to the ppq level, XENON Collaboration (E. Aprile et al.), EPJC (2017) 77:275]
- Materials carefully screened for radioactivity
- Fiducialization ⇒ self shielding ⇒ internal calibration sources required
  [Physics reach of the XENON1T dark matter experiment, XENON Collaboration (E. Aprile et al.), JCAP04(2016)027]

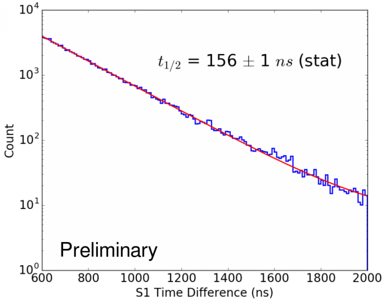


# Outline

# Decay scheme of $^{83m}$Kr

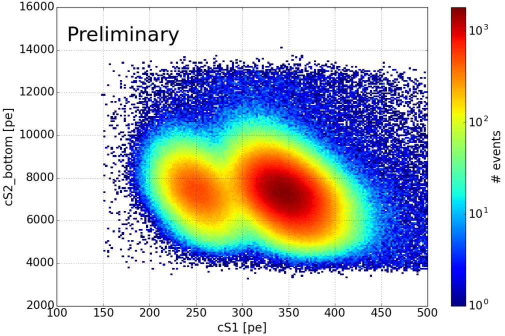


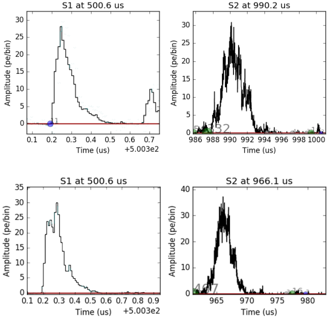




- Metastable isomer of $^{83}$Kr, produced by decay of $^{83}$Rb via EC
- Low energy
- Half-life is:
  - short enough to allow introduction into the TPC
  - long enough to allow homogeneous distribution inside the TPC
- Decay via short-lived intermediate state $\Rightarrow$ exploit coincidences for background free measurement

# $^{83m}$Kr in cS1/cS2 space

- Weekly krypton calibration runs



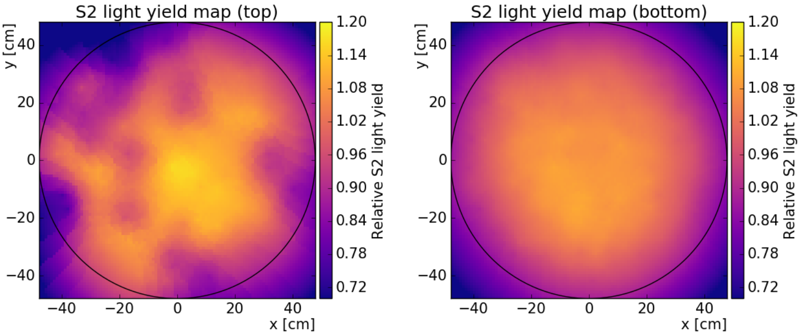




- Two populations:
  - Left: S1 of 32.1 keV paired with merged S2s
  - Right: merged 32.1 keV and 9.4 keV line
- S1 and S2 are anti-correlated

# Outline

# Light yield

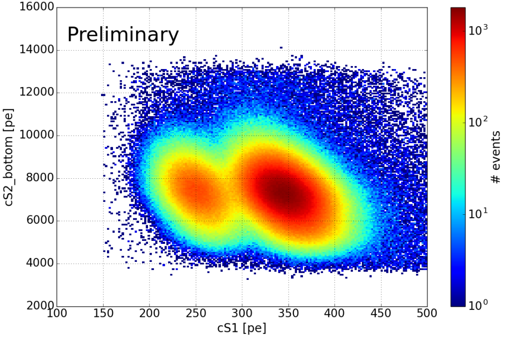
- Question: how does the size of the S2 signal depend on event position?
- Using the homogeneously distributed krypton data, we find:




- Top map shows disabled PMTs
- Bottom map is very uniform
- Energy of krypton line is constant ⇒ Use these maps to get corrected S2 signal (cS2)

# S1/S2 Stability

- Question: is the detector response stable?
- Use weekly krypton calibrations to find out:



# Summary

- External sources are not sufficient for calibration of a large LXe TPC
- Due to its half-life of 1.83h $^{83m}$Kr is an ideal internal calibration source
- Dark matter hasn't been found yet, so stay tuned
  - First Dark Matter Search Results from the XENON1T Experiment - arXiv:1705.06655
  - Follow XENON1T on twitter: @XENON1T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