Recent results from the XENON100 experiment

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on behalf of the XENON Collaboration

WESTFÄLISCHE
WILHELMS-UNIVERSITÄT
MÜNSTER

50th Rencontres de Moriond 2015, March 16th

The XENON Dark Matter Program

2005 - 2007

XENON10

15 cm drift TPC - 25 kg

Achieved in 2007

$\sigma_{SI} = 8.8 \times 10^{-44} cm^2$

2008-2015

XENON100

30 cm drift TPC - 161 kg

Achieved in 2011

$\sigma_{SI} = 7.0 \times 10^{-45} cm^2$

Achieved in 2012

$\sigma_{SI} = 2.0 \times 10^{-45} cm^2$

2012- 2017

XENON1T/XENONnT

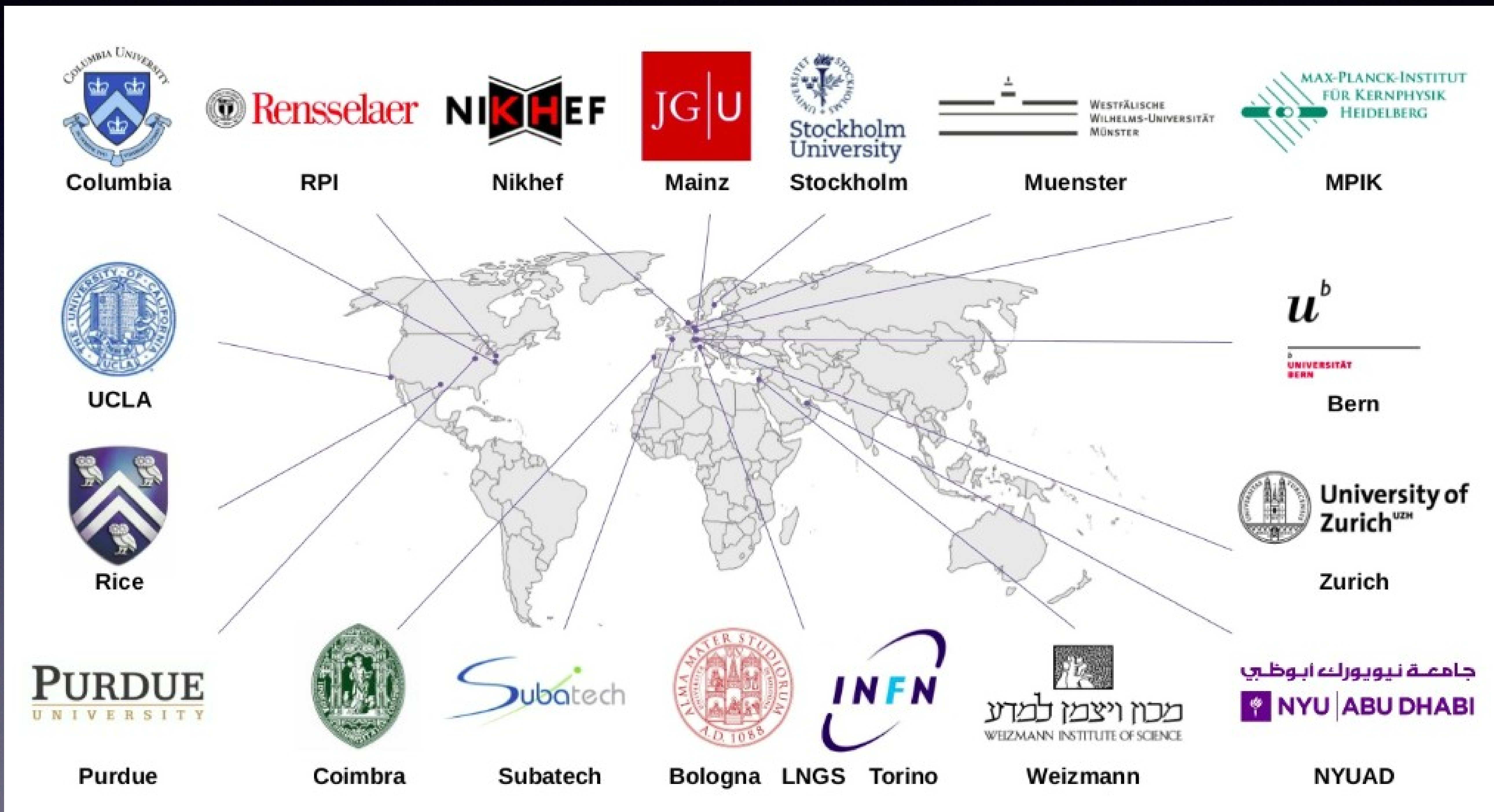
96/130 cm drift TPC - 3300/7000 kg

Projected to 2017/2022

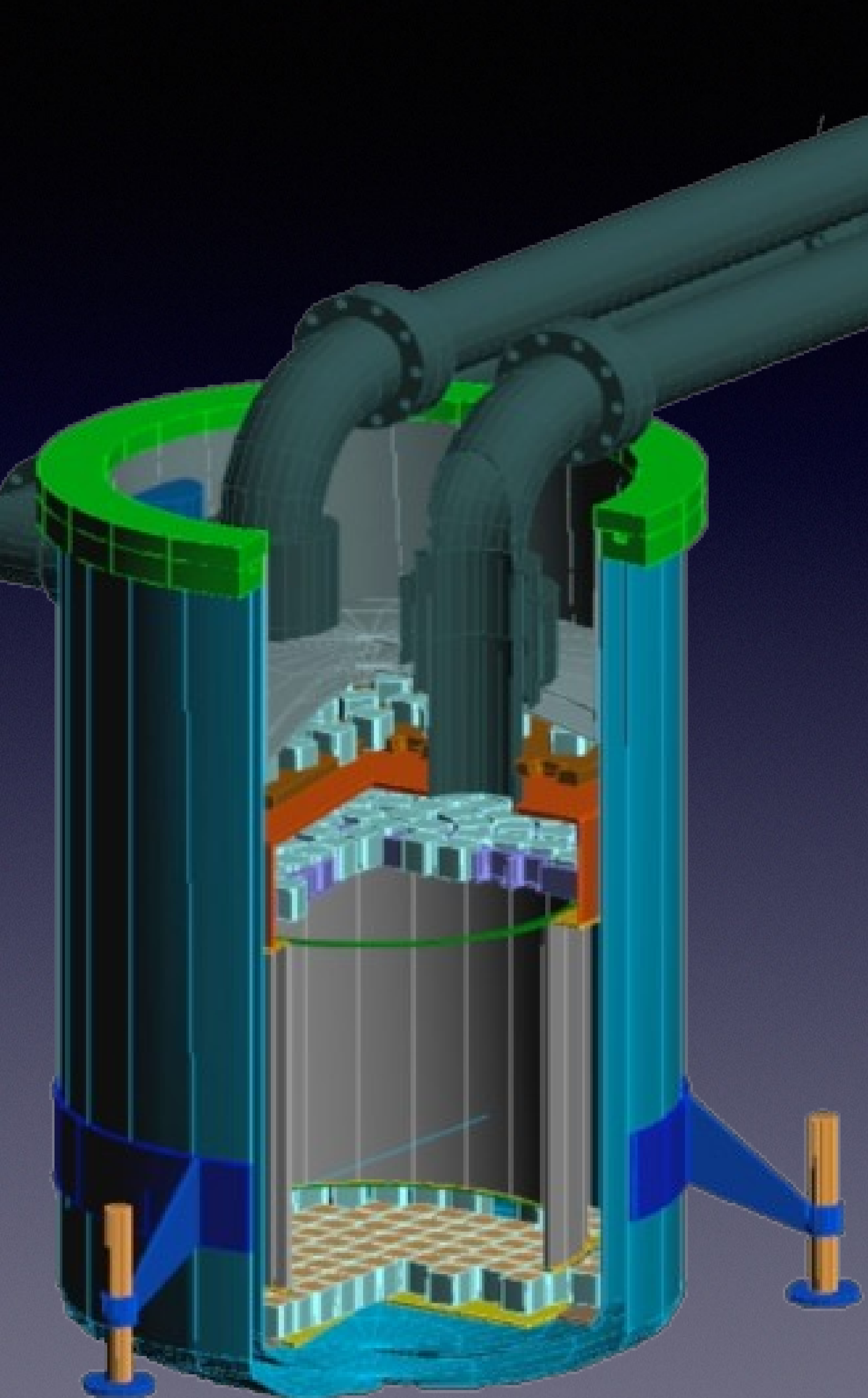
$\sigma_{SI} = 2.0 \times 10^{-47} cm^2 / \sigma_{SI} = 3.0 \times 10^{-48} cm^2$

The XENON Collaboration

Currently ~120 scientists from 18 institutions



The XENON100 Experiment



TPC with 30 cm drift and 30 cm diameter

Drift field in LXe ~ 0.5 kV/cm

Amplification field in GXe ~10 kV/cm

161 kg Xe (62 kg as target; 99 kg as active veto)

Cooled with 200W PTR outside shield

Read-out with 242 PMTs with ~1 mBq (U/Th)

S1 yield: 2.3 pe/keV (@122 keV and 0.5 kV/cm)

S2 yield: 19 pe/e (single electron sensitive)

Kr/Xe level reduced to ppt with cryogenic distillation

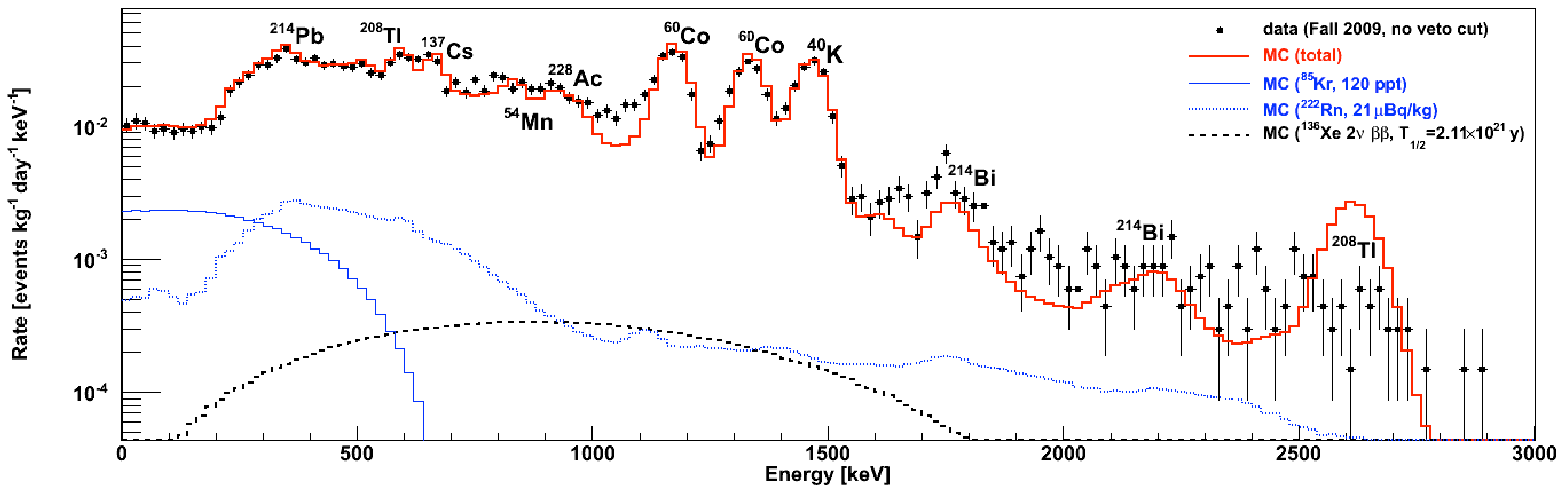
Passive shielding: water/Pb/Poly/Cu

3600 m water equivalent rock overburden

Aprile et al., Astropart. Phys. 35, 573 (2012)

XENON100: an ultra-low background experiment

Phys. Rev. D 83, 082001 (2011)

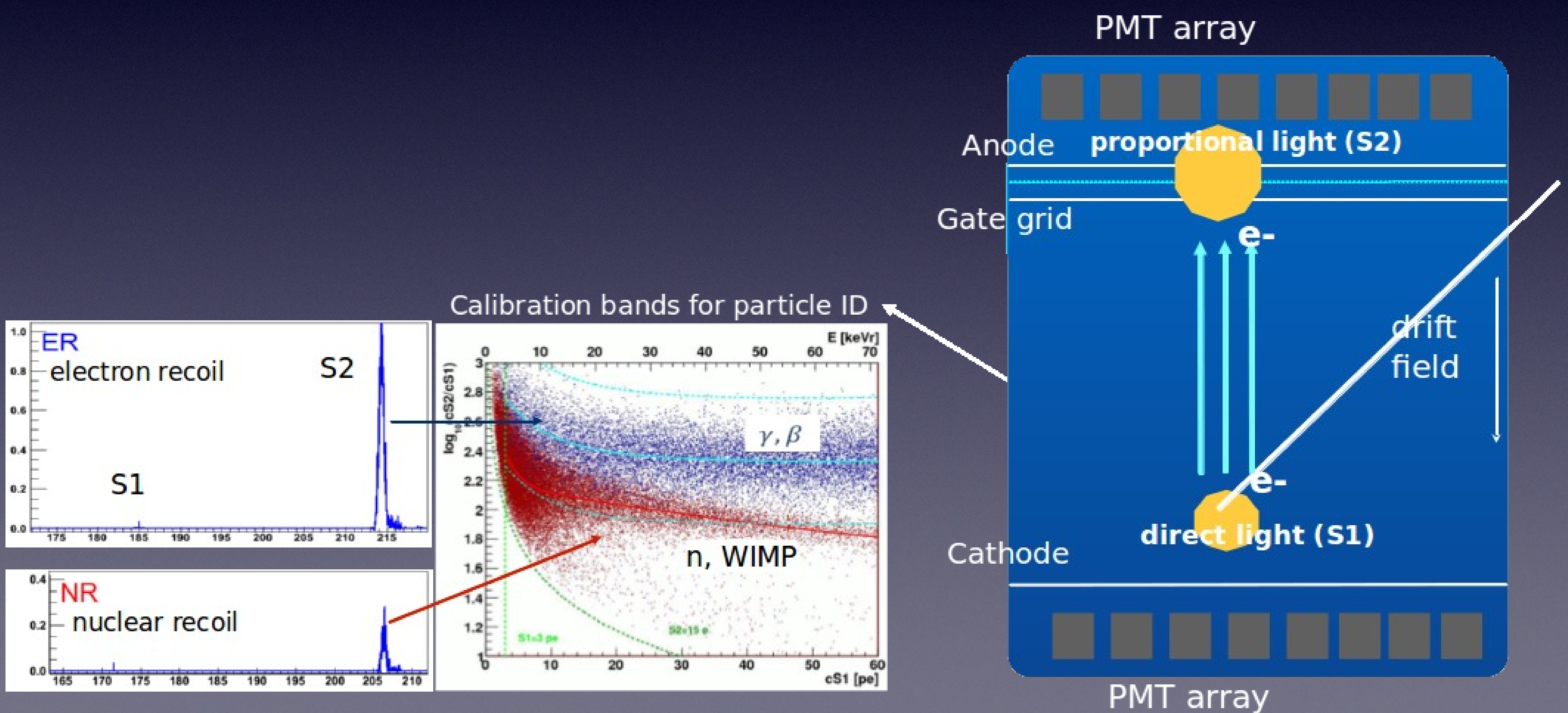


- No Parameter tuning
- Activity taken from screening measurement

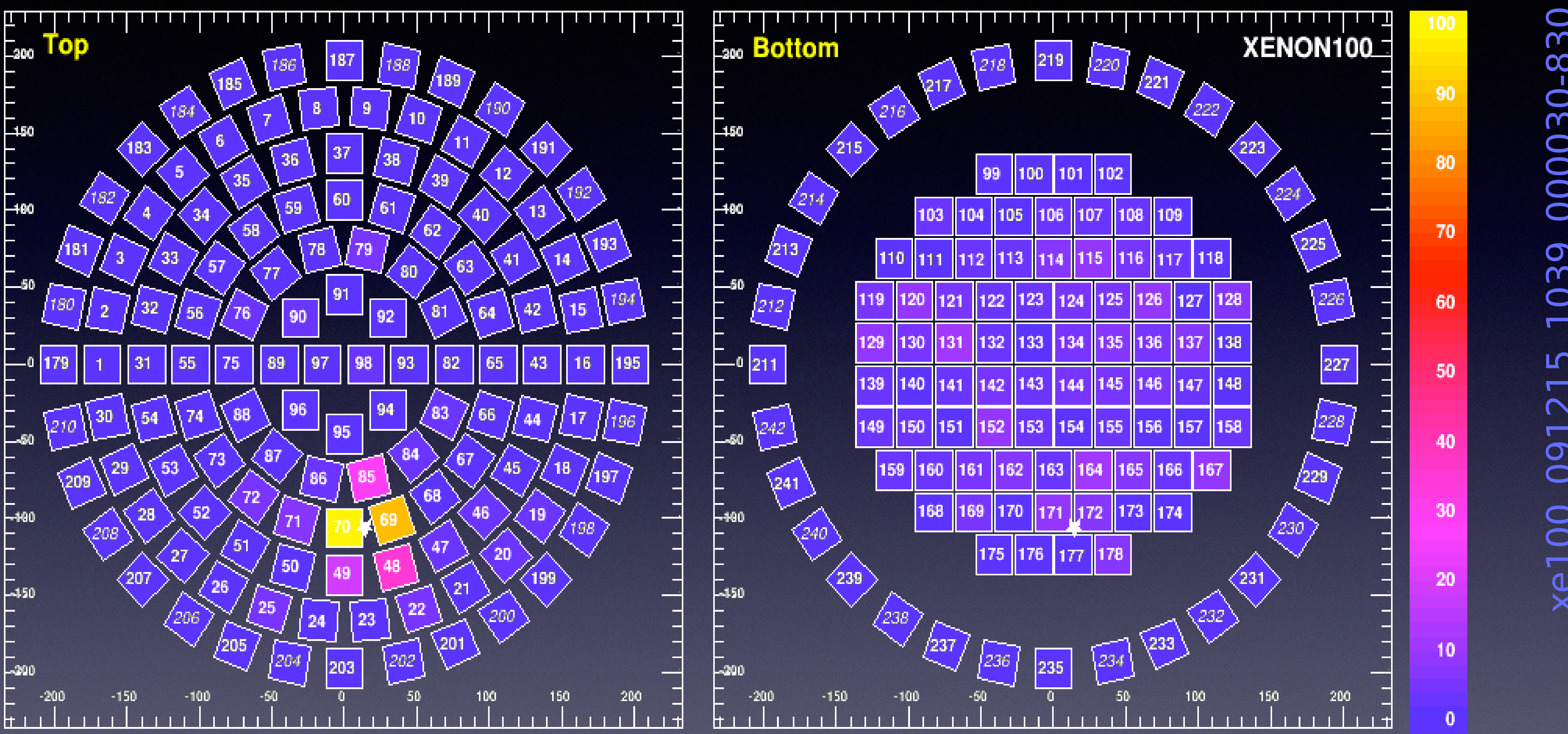
~5x 10-3 evts/kg/keV/day after veto cut and before S2/S1 discrimination

Two-phase Xe Time Projection Chamber

- Particle interaction in the active volume produces prompt scintillation (S1) and ionization electrons
- Electrons which reach the liquid/gas interface are extracted, accelerated in the gas gap and detected as proportional light (S2)
- PMTs in liquid and gas detect S1 and S2
- Charge/light depends on dE/dx: *(S2/S1)WIMP* < *(S2/S1)gamma*
- 3D-position sensitive detector with particle ID



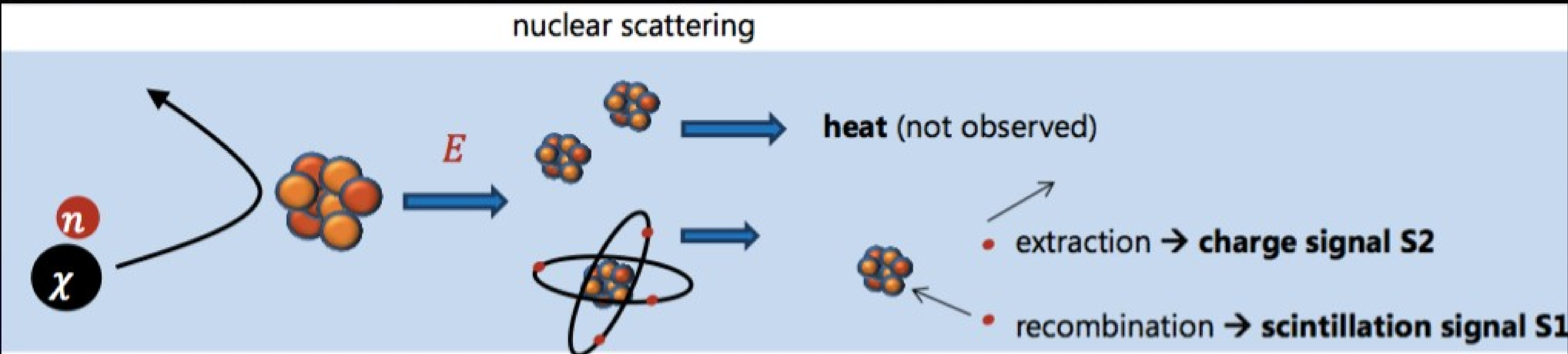
Event Localization in XENON100



position reconstruction based on top S2 hit pattern

Δr<3 mm   Δz<0.3 mm, Δz<2 mm for double-scatter separation

Energy Scale: from measured photoelectrons to keV

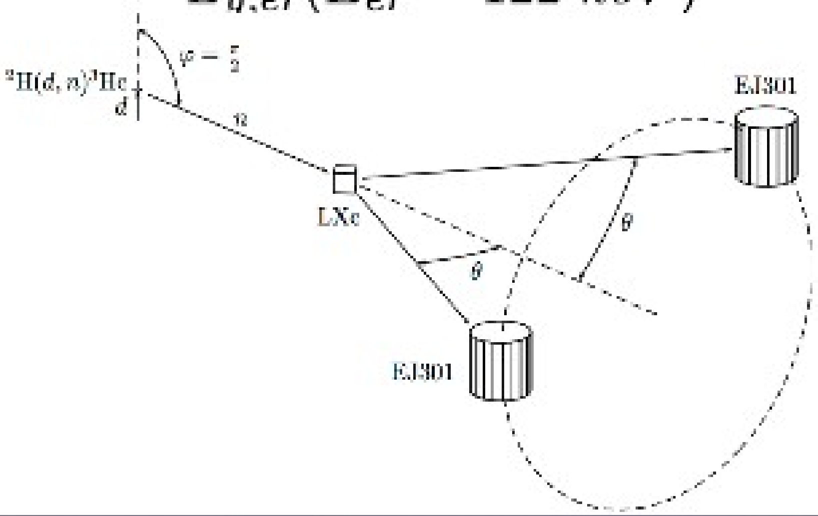


Nuclear recoil energy scale $$E_{nr} = \frac{cS1}{L_{y,er}} \frac{1}{\mathcal{L}_{eff}(E_{nr})} \frac{S_{er}}{S_{nr}}$$

$L_{y,er} = 2.28 \pm 0.04 pe/KeV_{ee}$ Light yield of electron recoil at 122 keV γ rays

$S_{er} = 0.58, S_{nr} = 0.95$ Scintillation light quenching at given field (drift)

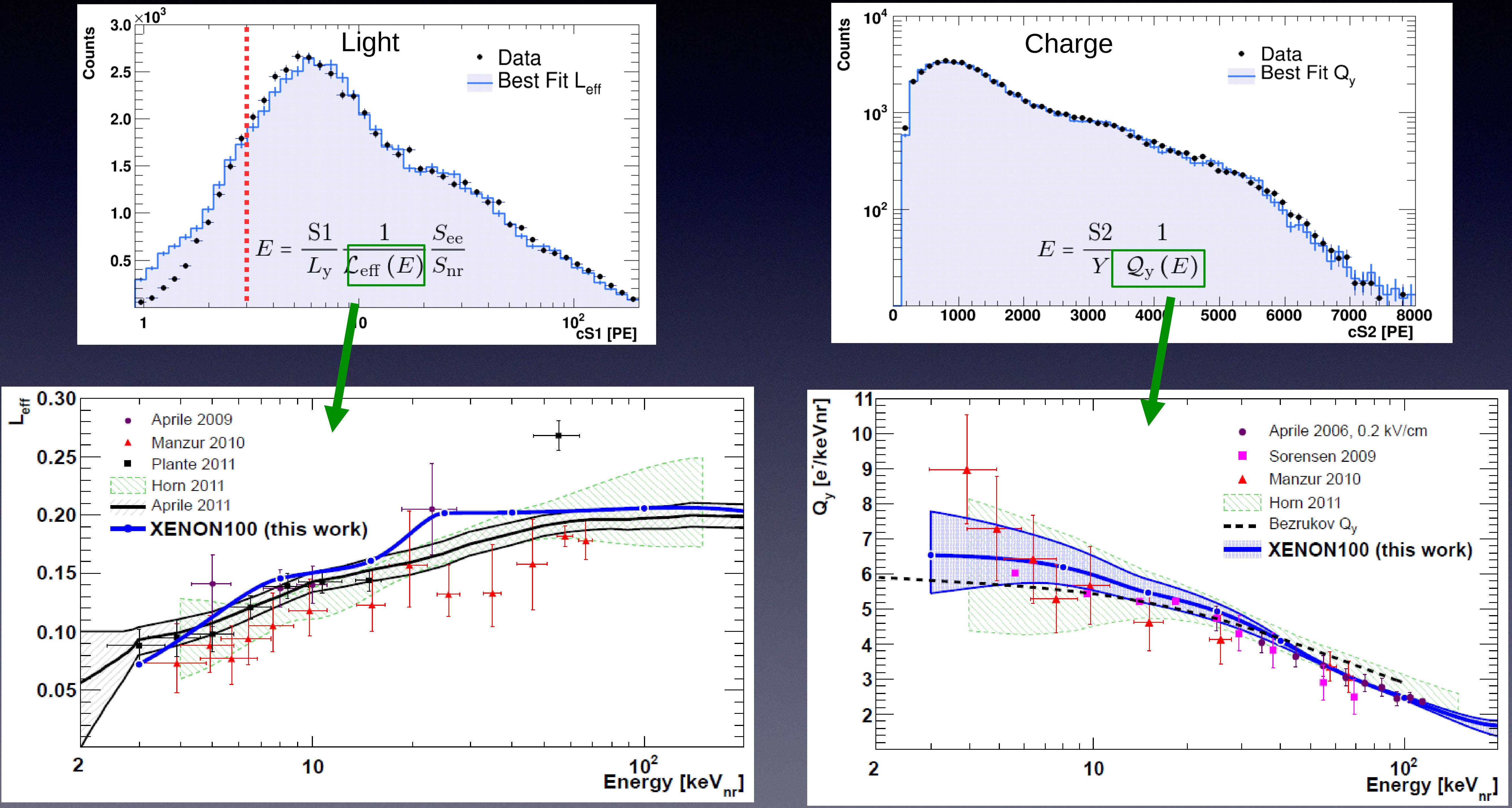
$$\mathcal{L}_{eff}(E_{nr}) = \frac{L_{y,nr}(E_{nr})}{L_{y,er}(E_{er} = 122\ keV)}$$



- Measure fixed-angle elastic scattering of mono-energetic neutrons detected by organic scintillator with n/γ separation capability
- Measurement done at Columbia University with lowest threshold at 3 keV

Plante et **al.**, Phys. Rev. C 84 045805 (2011)

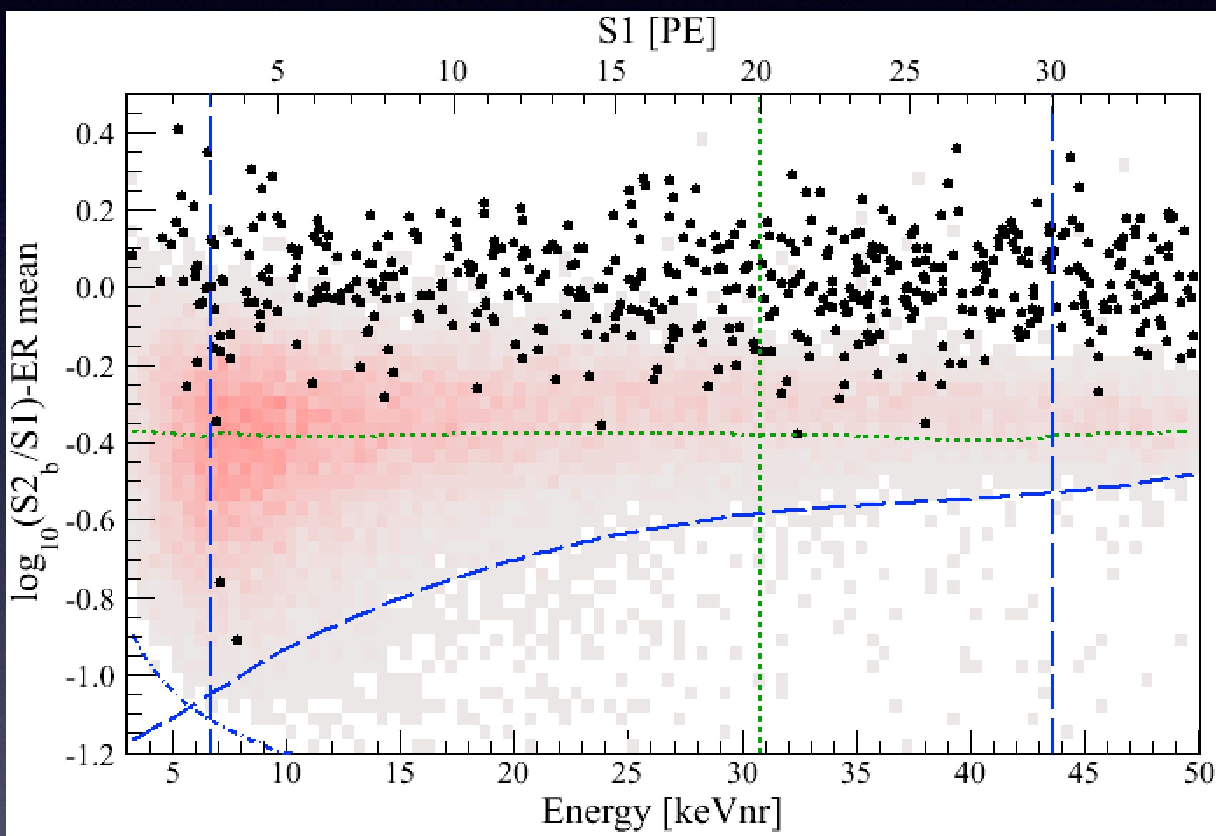
XENON100 Response to Nuclear Recoils

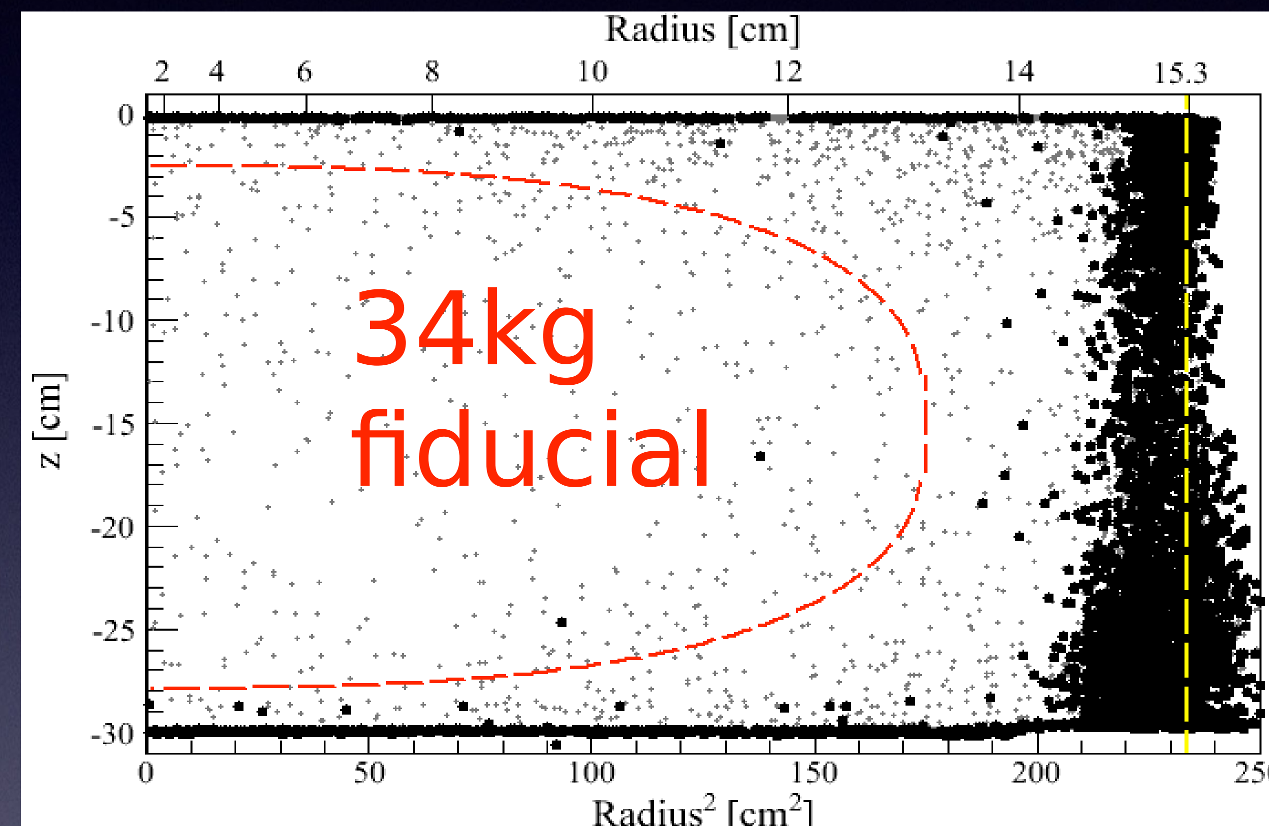


Aprile et al. (XENON100) PRD 88, 012006 (2013)

Enables powerful background suppression by volume fiducialization and event multiplicity

single scatter events after 225 live days of data taking 2011/2012: (trigger rate ~1Hz)
E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

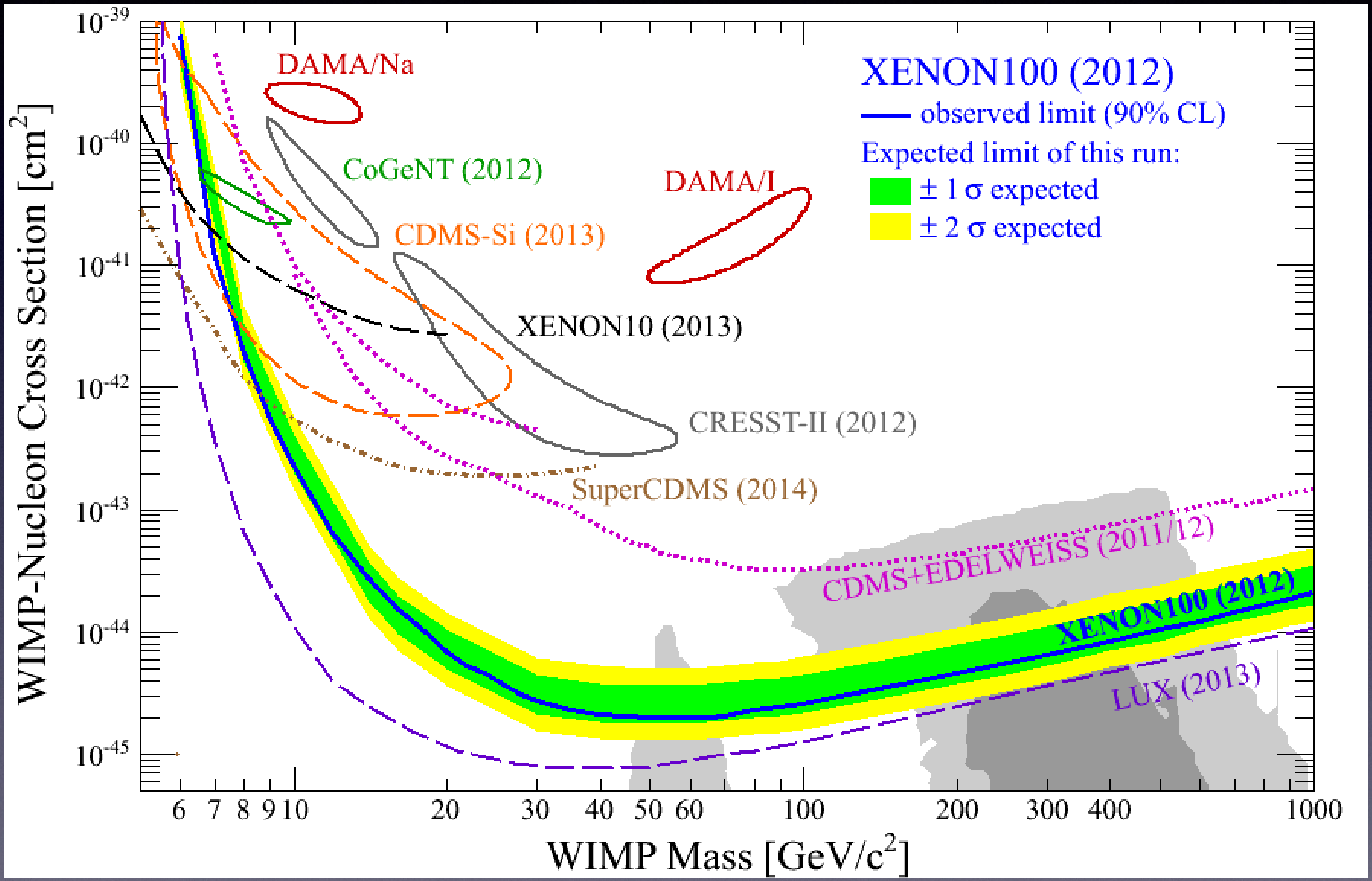




- 2 events observed with 1.0 ± 0.2 events expected
- 26.4% probability of upward background fluctuation
- No significant excess due to signal seen in XENON100 data

XENON100: Spin Independent/Dependent Limit

Aprile et al.(XENON100),Phys. Rev. Lett. 109 (2012)



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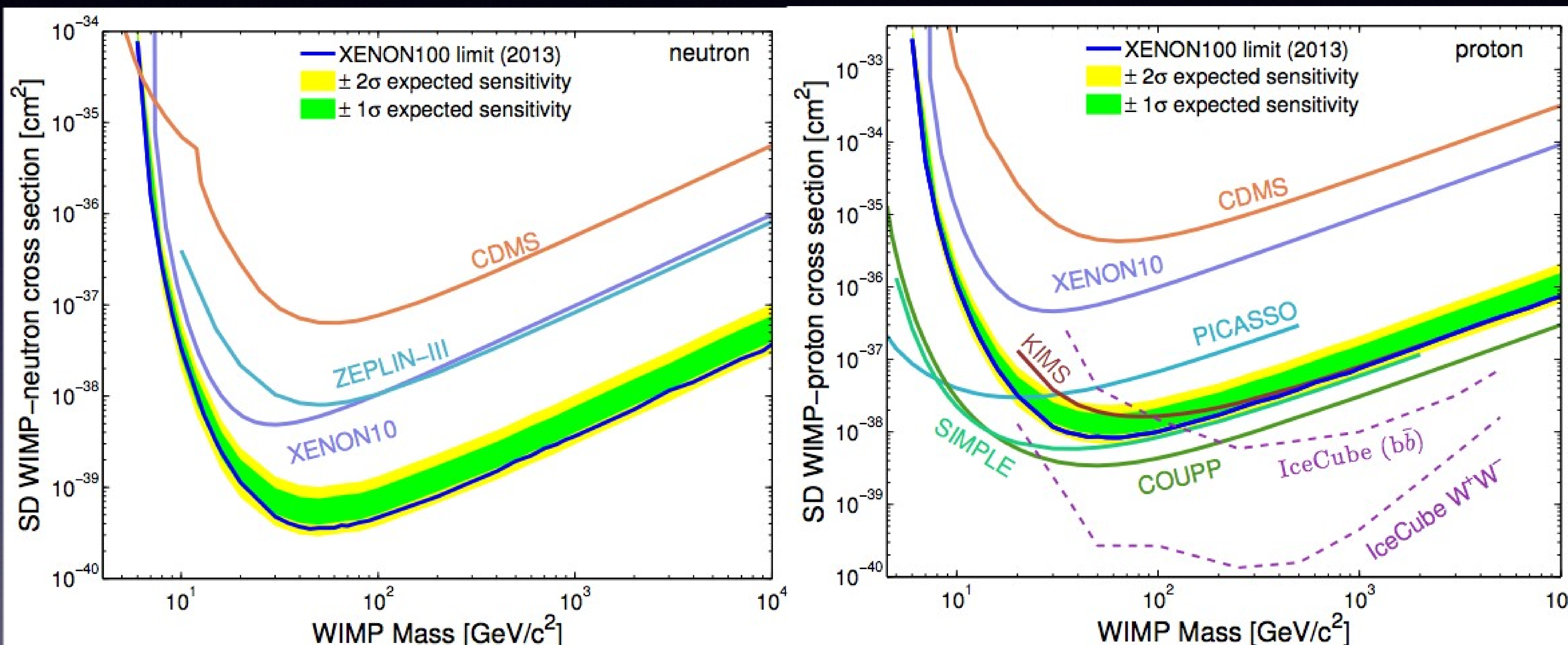


Aprile et al. (XENON100) Phys. Rev. Lett. 111 (2013)

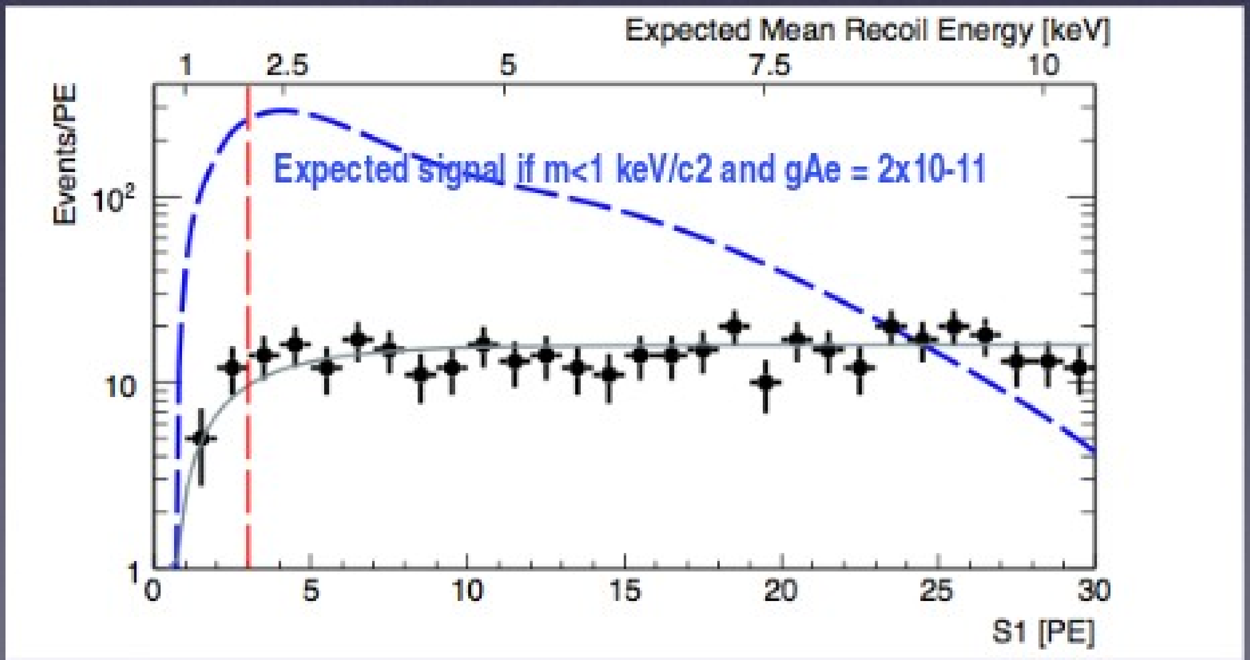
Axion Search with XENON100 Data

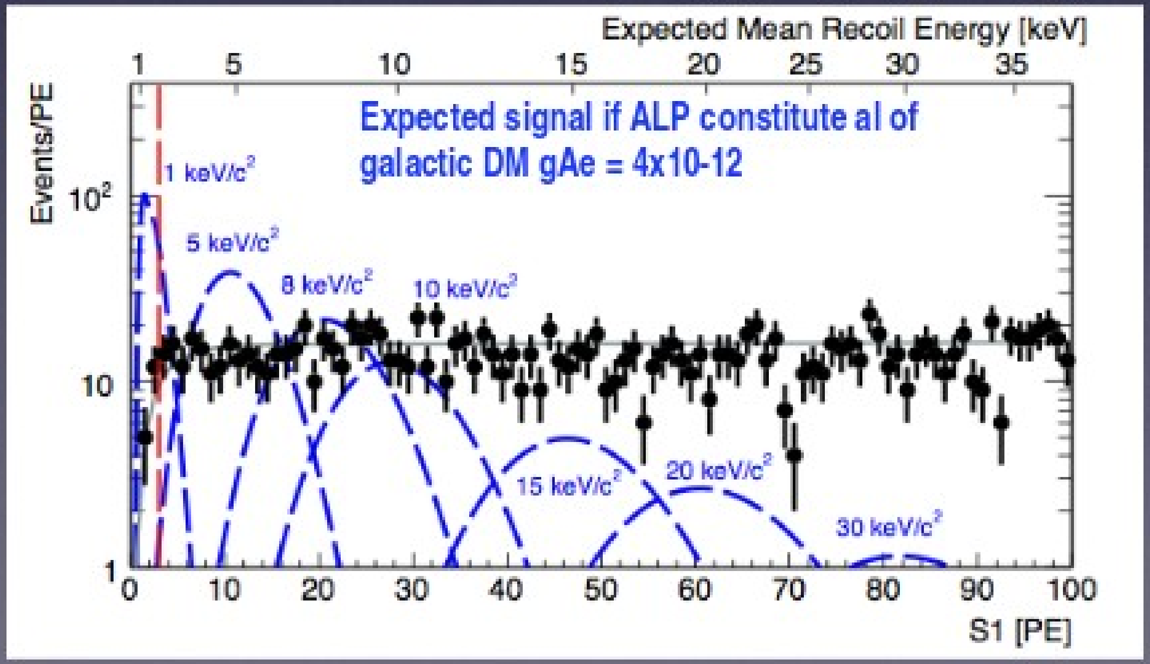
Phys. Rev. D 90, 062009 (2014)

$$\sigma_{Ae} = \sigma_{pe}(E)\frac{g_{Ae}^2}{\beta}\frac{3E^2}{16\pi\alpha m_e^2}\left(1-\frac{\beta^{2/3}}{3}\right)$$

- Axions and ALPs can interact with atomic electrons via the axioelectric effect producing ERs with energy equal to axion mass minus e-binding energy in Xe → solar axions (continuum spectrum) and galactic (monoenergetic) ALP.

- The low background in XENON100 and its low ER threshold allows a very sensitive search. S1(PE) converted to keVee based on recent measurements of scintillation efficiency and its quenching with field by Columbia and UZH groups. 3 PE threshold corresponds to 2 keVee.





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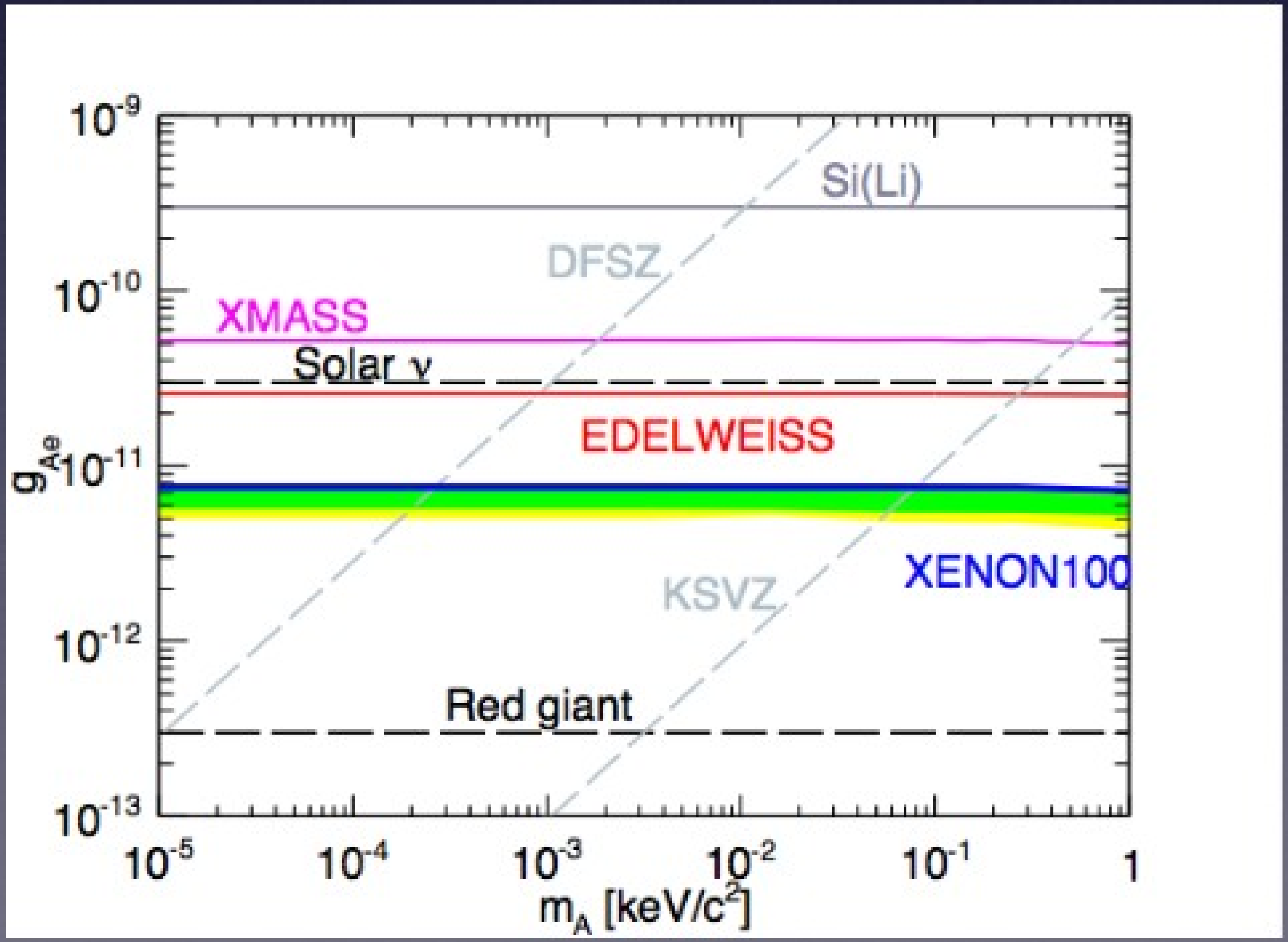
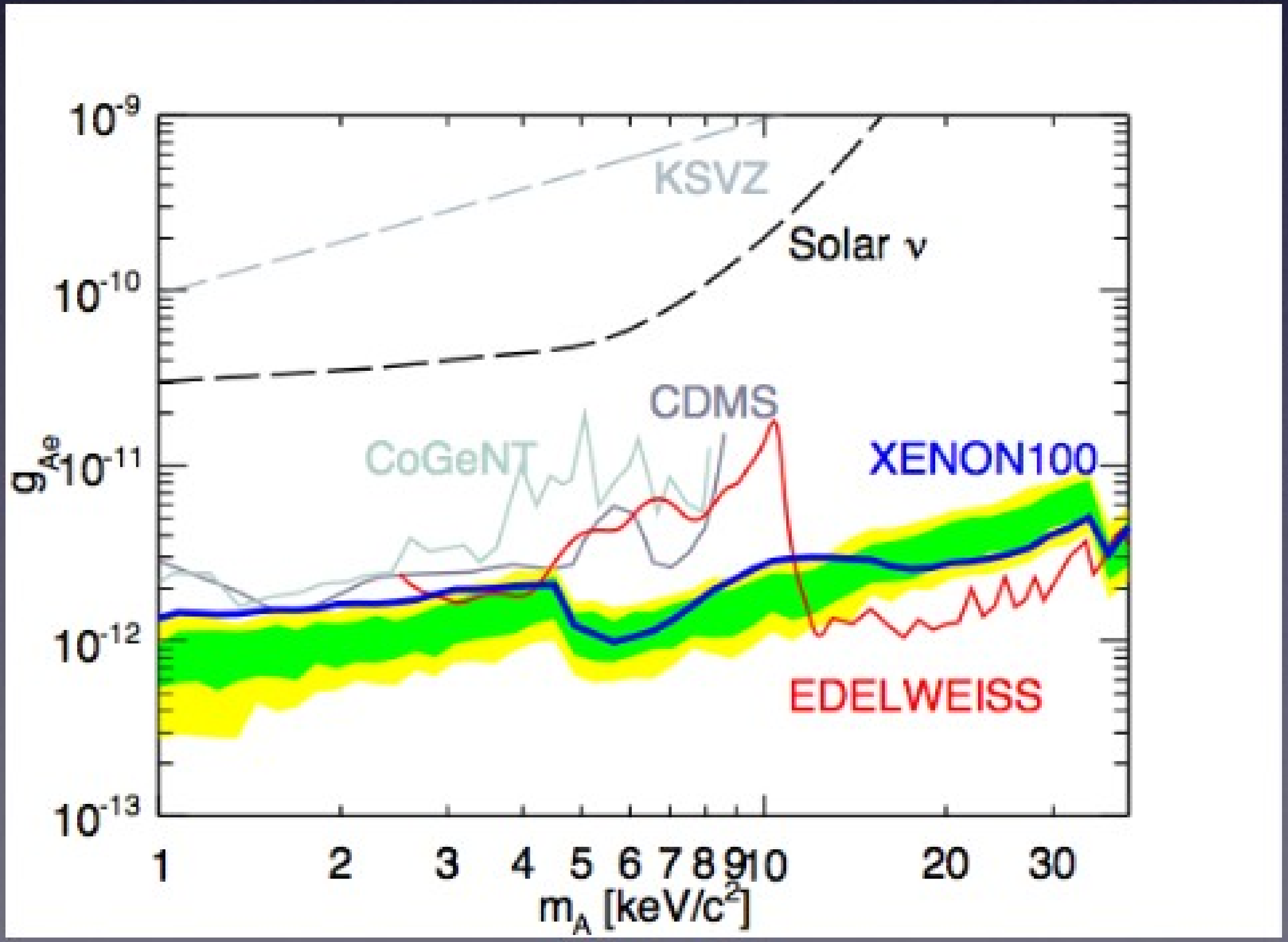




XENON100 Still Taking Data

- 150 days of new DM data in 2013 (blinded) under analysis
- Combine with previous data to look for long-term periodicities
- YBe source for low energy NR calibration
- Rn removal techniques tested for XENON1T

From XENON100 to XENON1T

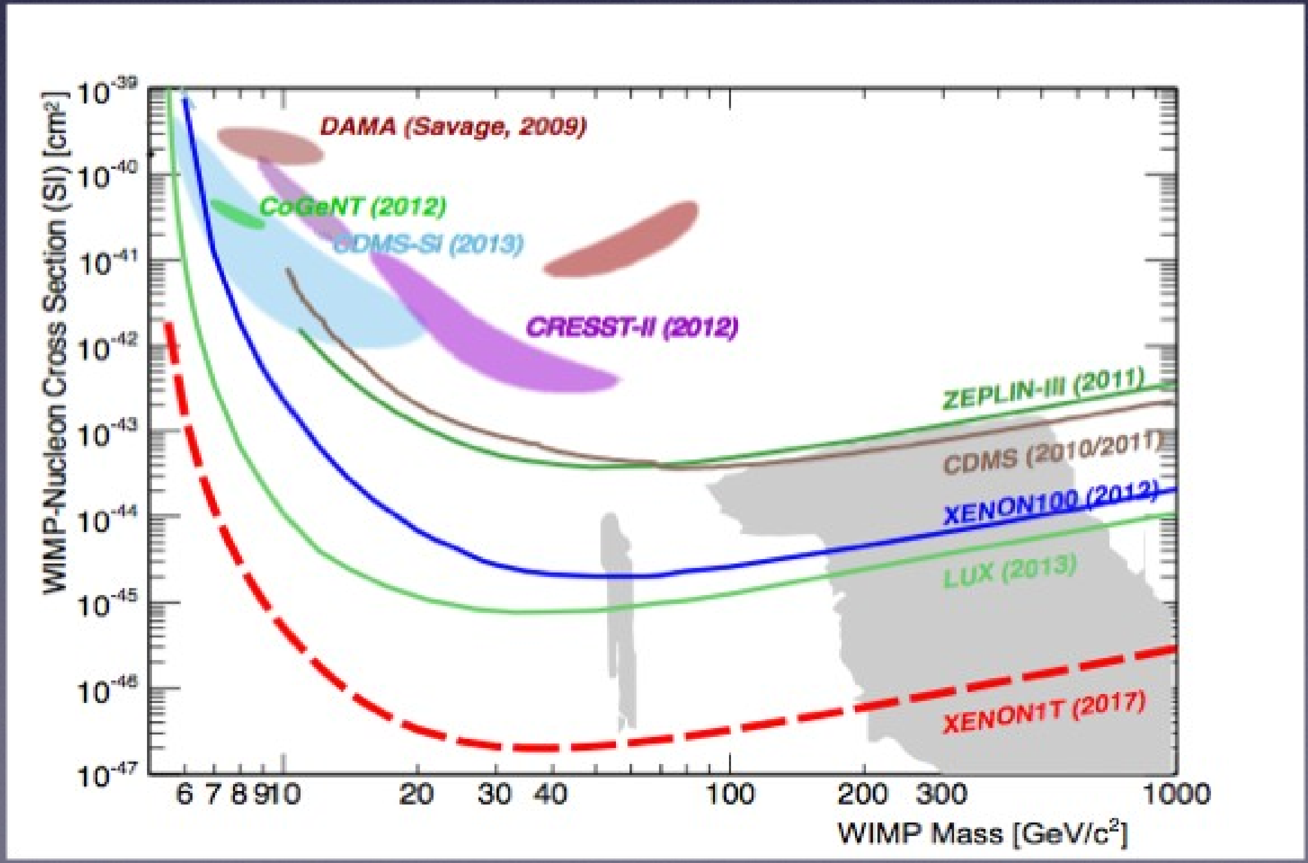
- Two-phase TPC with 1 meter drift and ~1 m diameter field cage
- Detector designed to enable a fast upgrade to a larger diameter TPC: from 3.3 to 7 tonnes of Xe.
- Detector/associated systems use largely proven technologies developed for XENON100
- New challenges presented by the scale-up addressed with multiple R&D set-ups
- New 3 inch PMTs developed for XENON1T (Hamamatsu R11410-21) average QE~35% at 178 nm and low activity
- Detector shielded by water implemented as Cherenkov muon veto
- Developing methods to control the most challenging backgrounds: from 85Kr beta-decays (reduce Kr/Xe < 0.2 ppt) and from 214Pb beta-decays (reduce 222Rn in LXe to ~1 μBq/kg)

Single Scatter, 1 ton Fiducial Volume, [2, 12] keVee, [5, 50] keVr, 99.75% S2/S1 discrimination, 40% NR acceptance

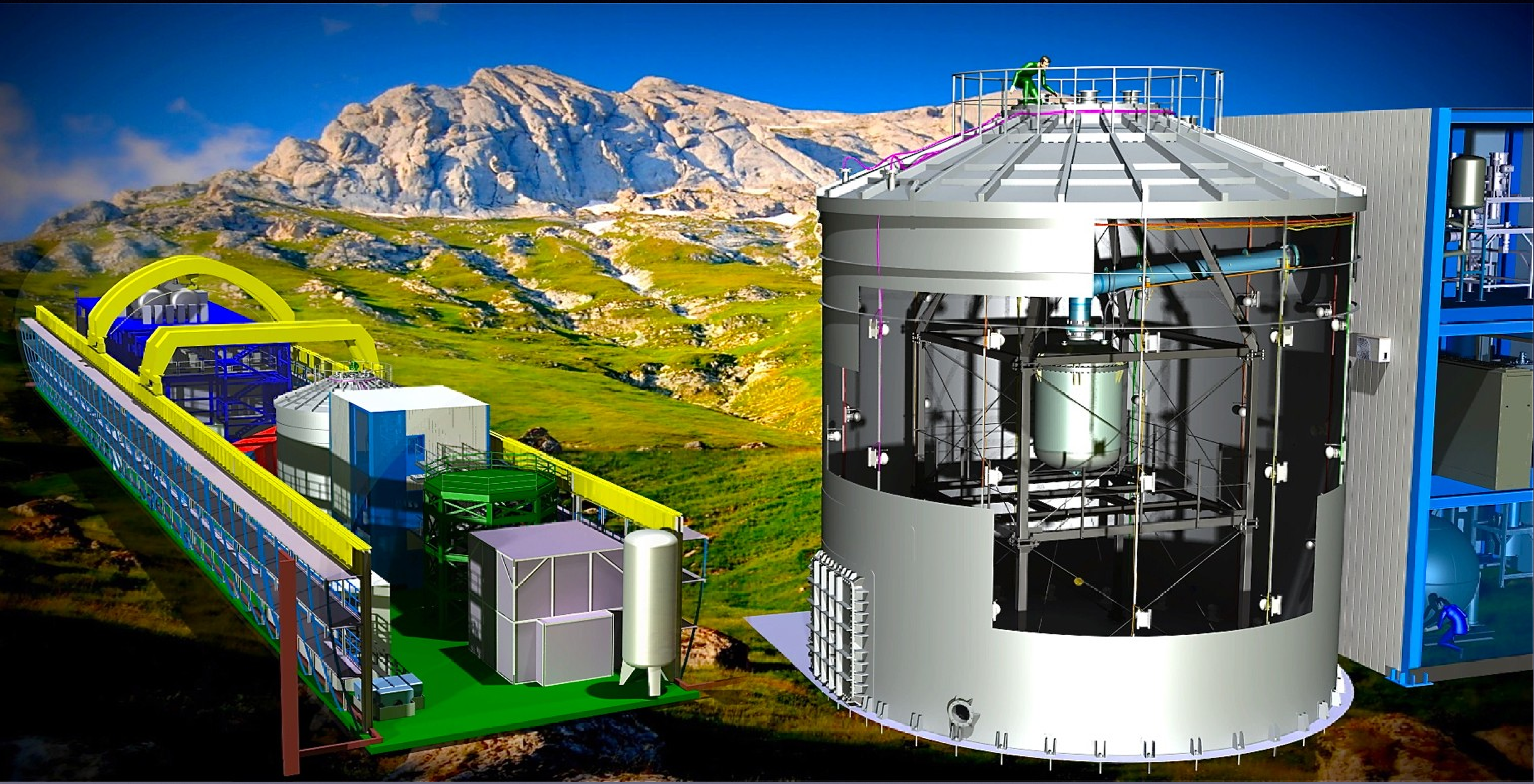
Source	***Background (eV/y)***
Er from material	***0.05***
85Kr (0.2 ppt of natKr)	***0.07***
222Rn (1 μBq/kg)	***0.08***
Solar neutrinos	***0.08***
NR from materials	***0.24***
Total	***0.52***

PRELIMINARY

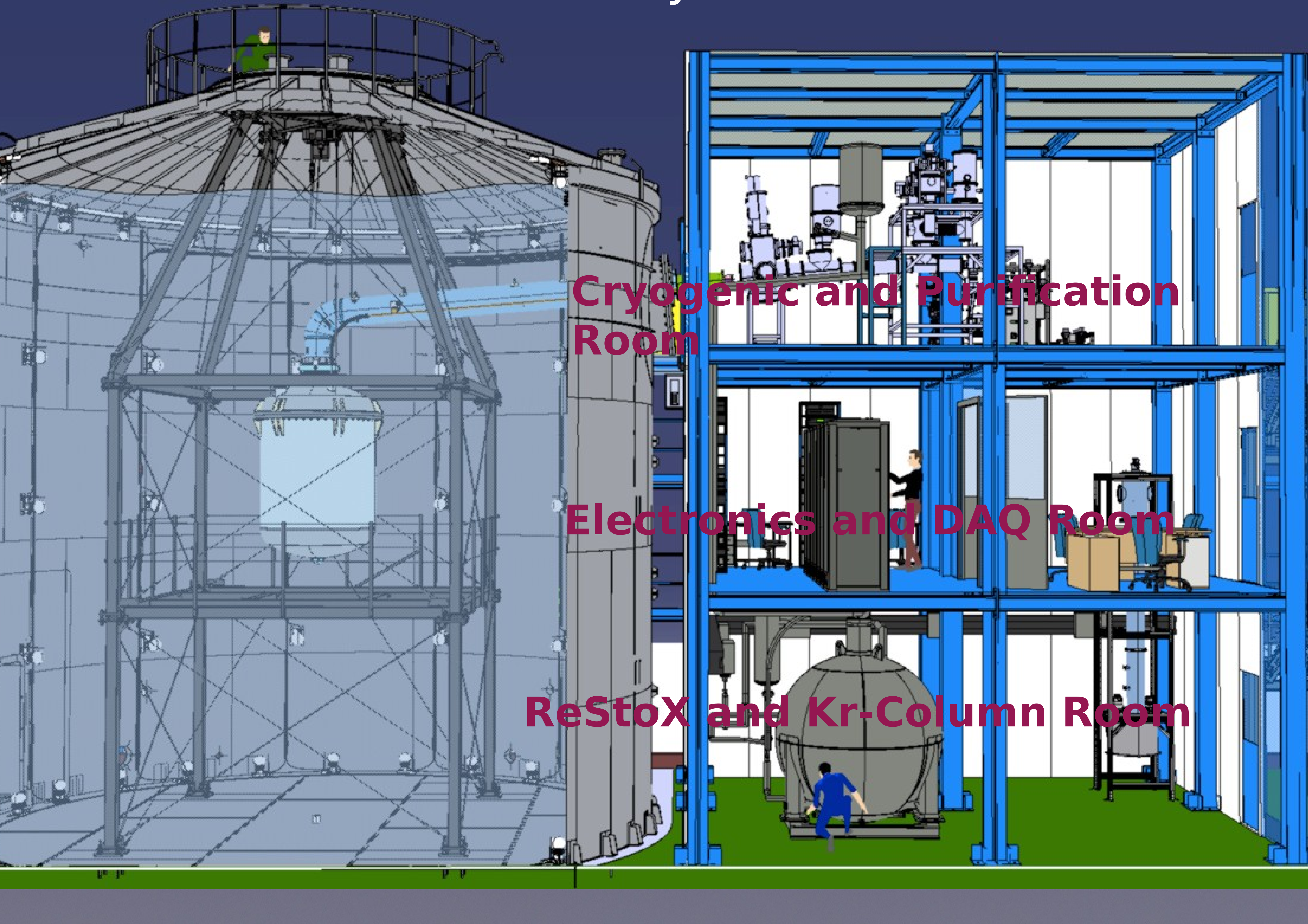
100 sensitivity improvement w.r.t. to XENON100



XENON1T

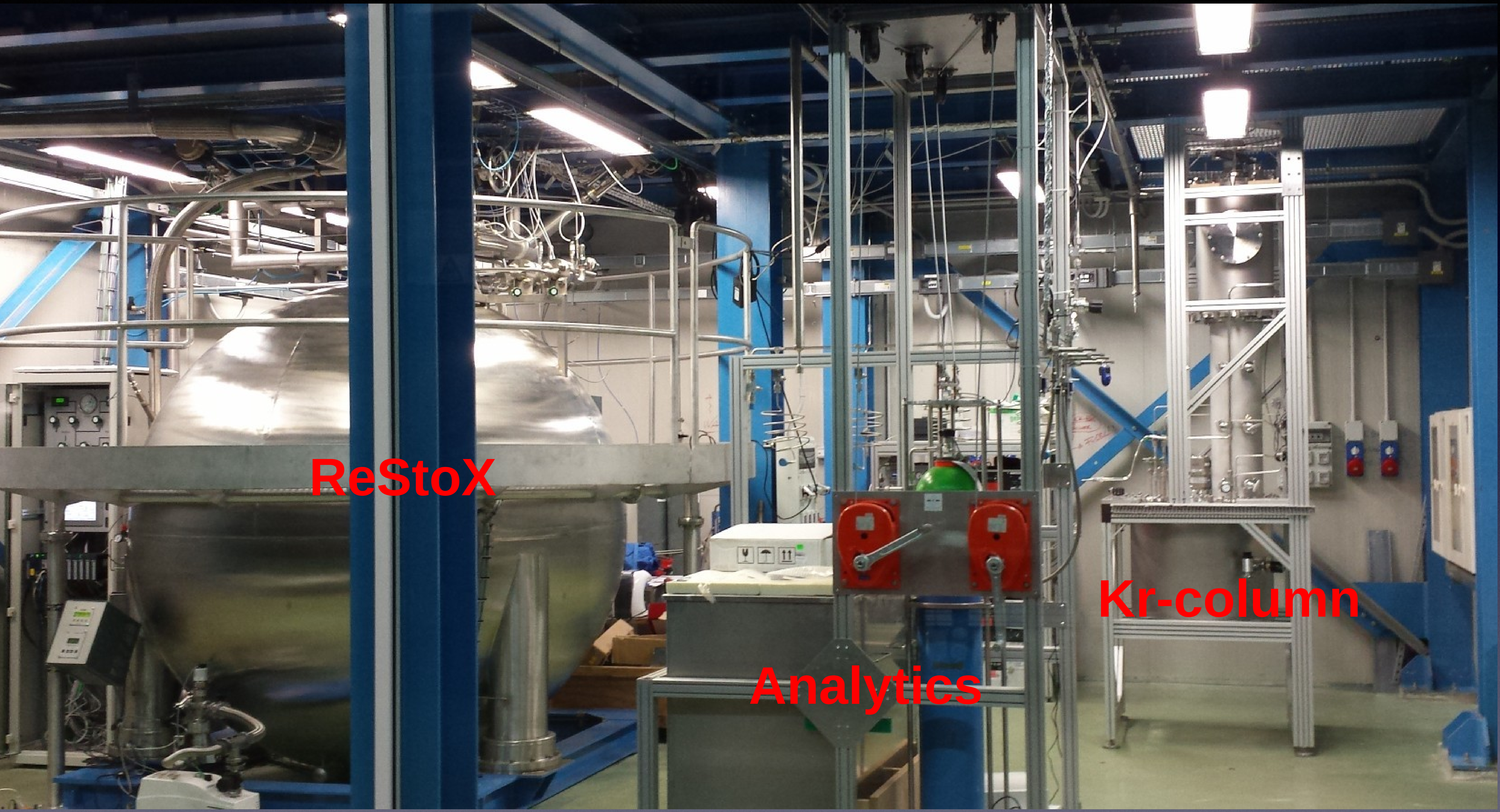


XENON1T Systems

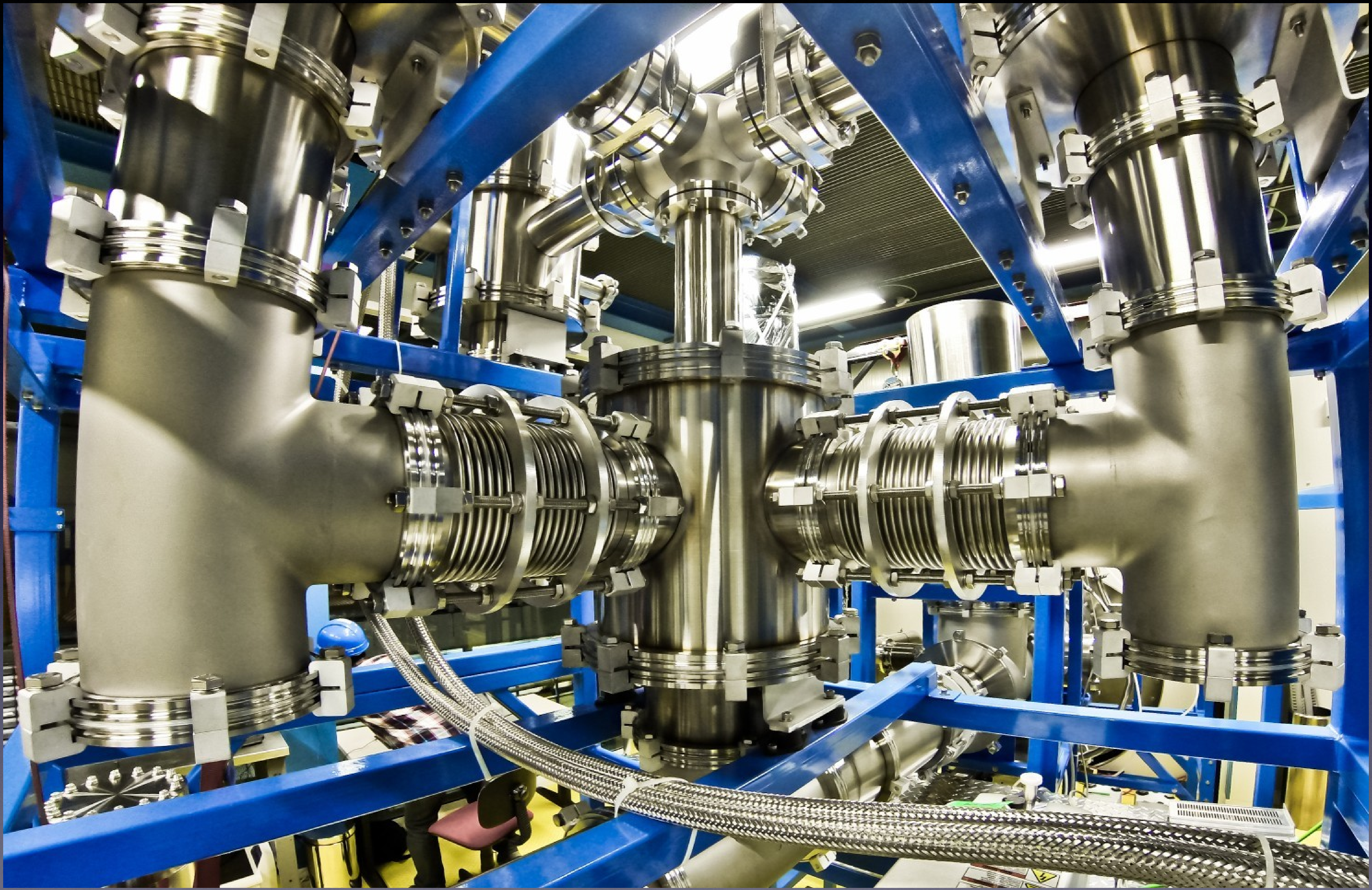


XENON1T: Building and Water-tank

XENON1T: ReStoX, Analytics and Kr-column

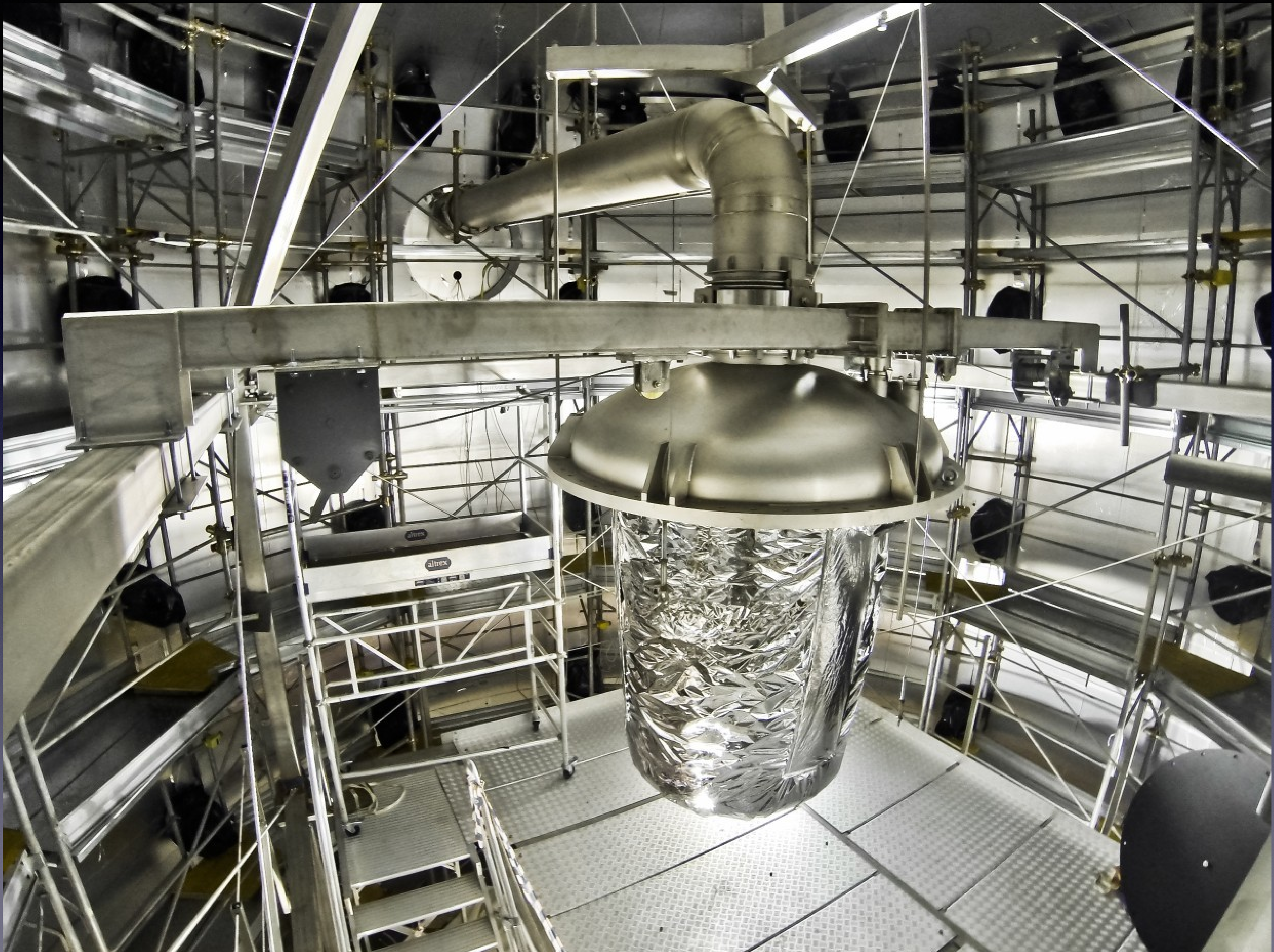


XENON1T: Cryogenics



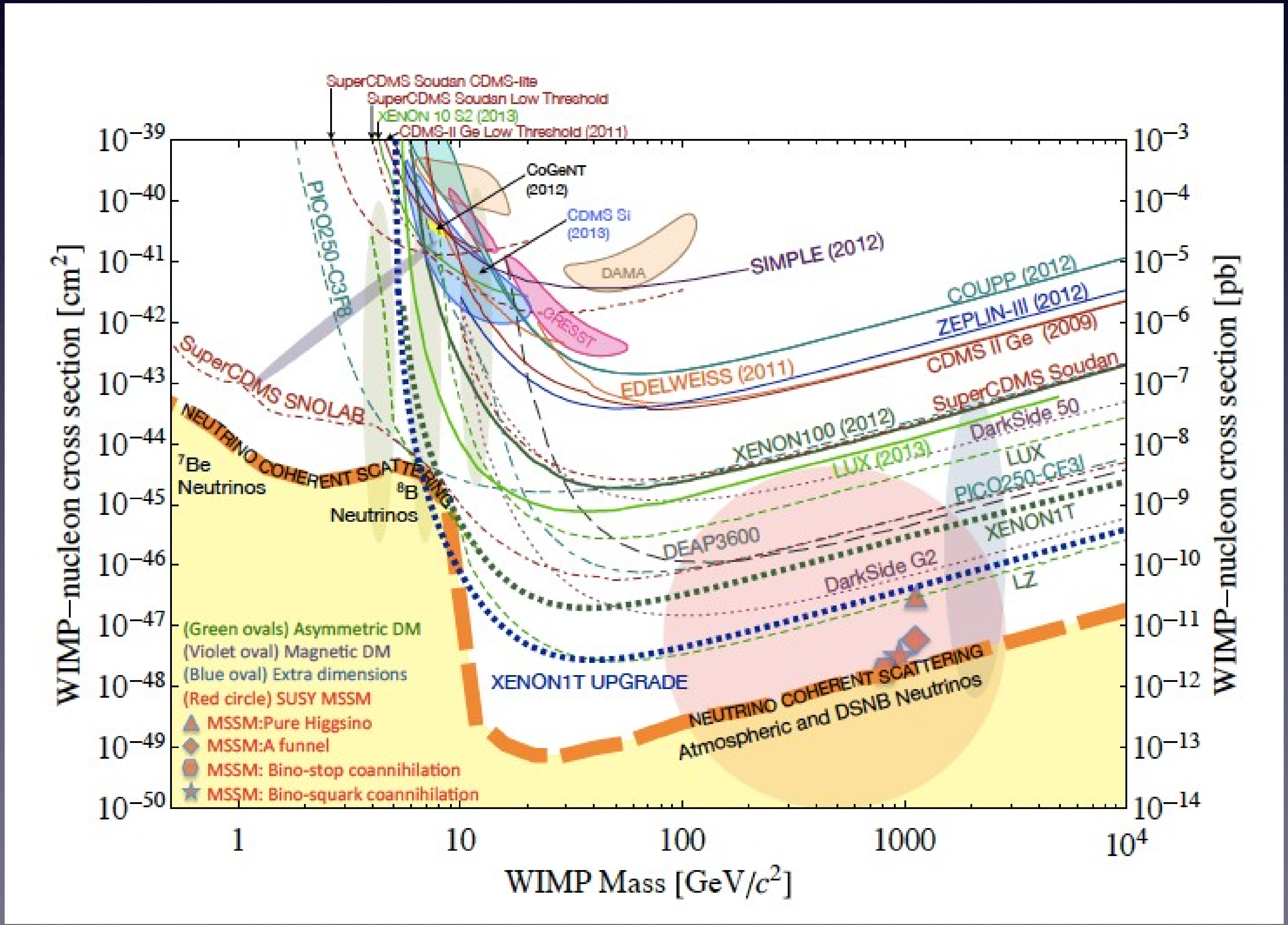
XENON1T: Purification

XENON1T: Cryostat



Summary

- XENON100 is still in operation after 5yr. New DM data still blinded but… unblinding coming soon…
- New calibration sources under test for XENON1T
- The construction of XENON1T started in fall 2013. Commissioning at LNGS is on going.
- After 2 ton-yr of data the sensitivity reach is as shown
- The design of XENON1T allow to increase the mass of Xe to 7 tonnes, by changing the inner vessel and the TPC. The expected sensitivity is 10 times better.



arXiv:1310.8327