COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

Recent results from the XENON100 experiment and future goals of the XENON project

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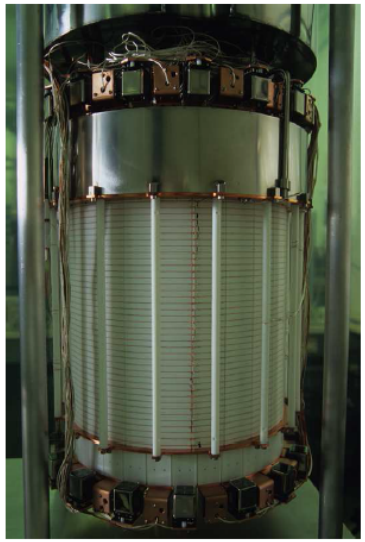
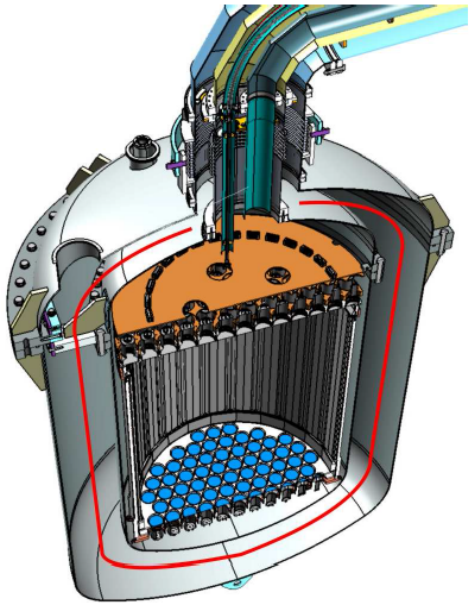
IAPS @ Gran Sasso - Particle &Astroparticle Physics Spring Event

Timeline of the XENON programme

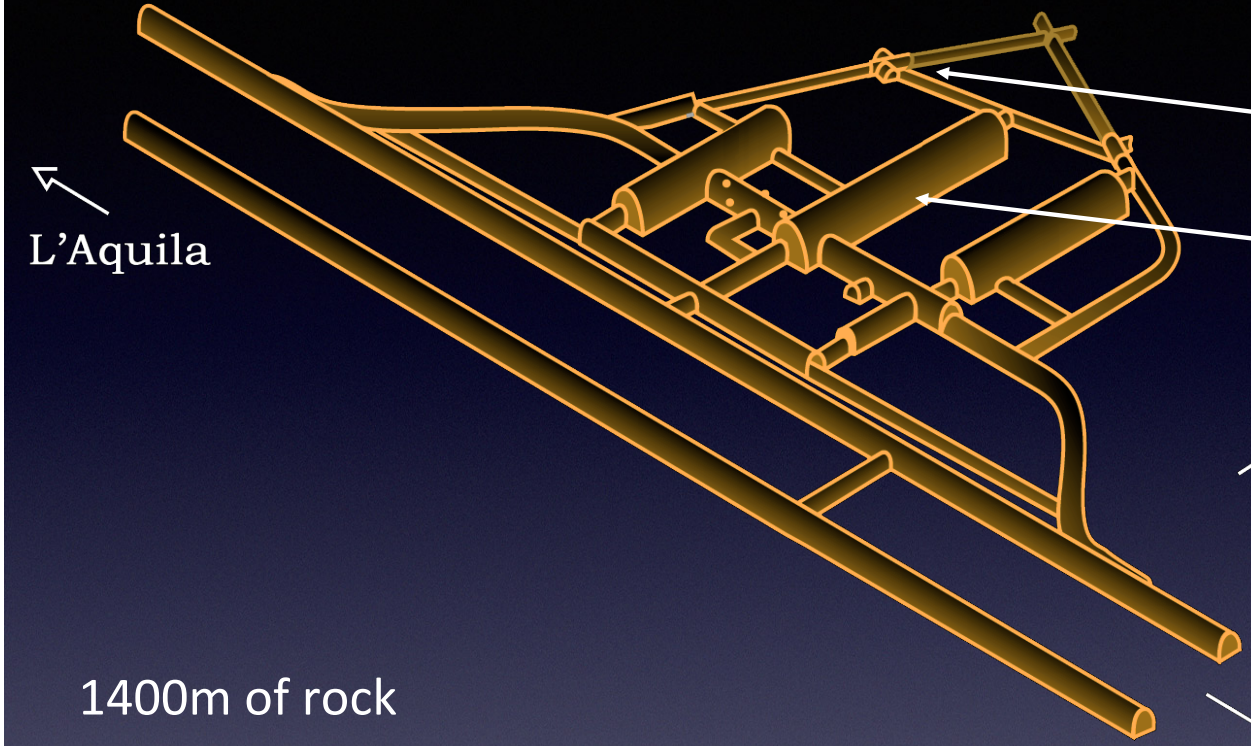
XENON10	XENON100	XENON1T	XENONnT
			
2005	2009	2015	2018+
25 kg	161 kg	3300 kg	~7000 kg
$< 8.8 \times 10^{-44}$	$< 2 \times 10^{-45}$	$< 2 \times 10^{-47}$	$< 3 \times 10^{-48}$

Time

Target mass

WIMP-nucleon cross section [cm^2]

Gran Sasso Underground Laboratory



XENON100

XENON1T

L'Aquila

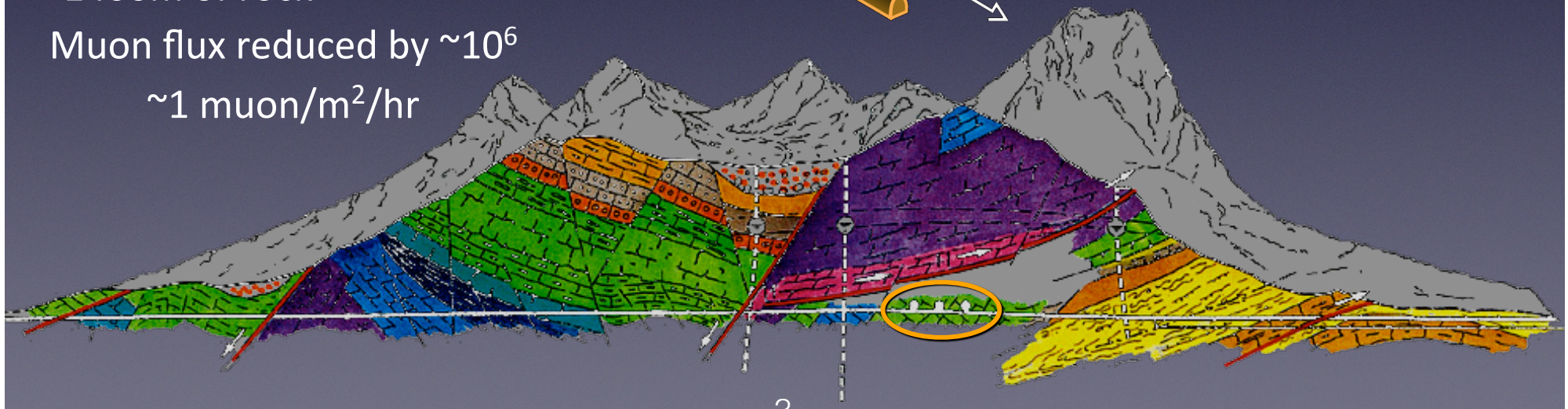
North

Teramo

1400m of rock

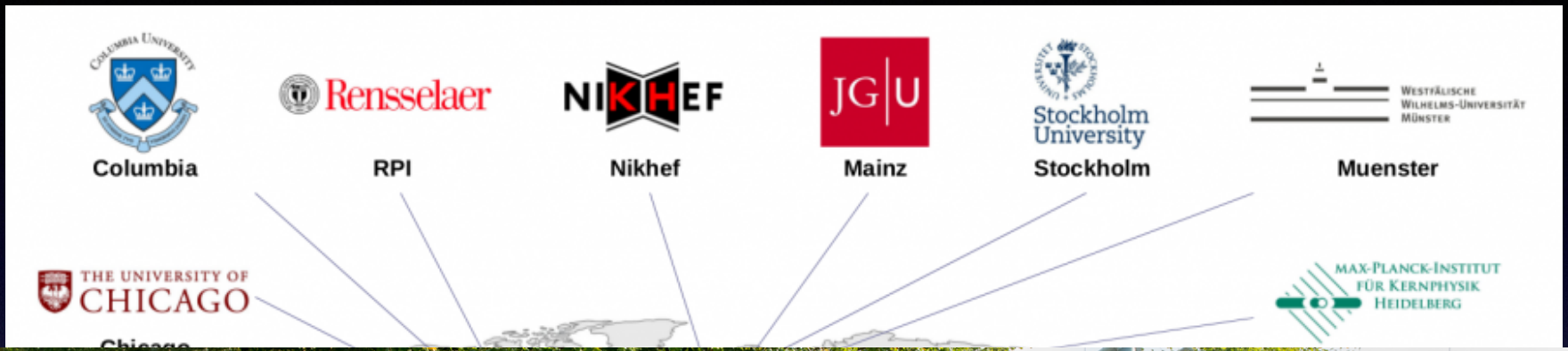
Muon flux reduced by ~10^6

~1 muon/m^2/hr



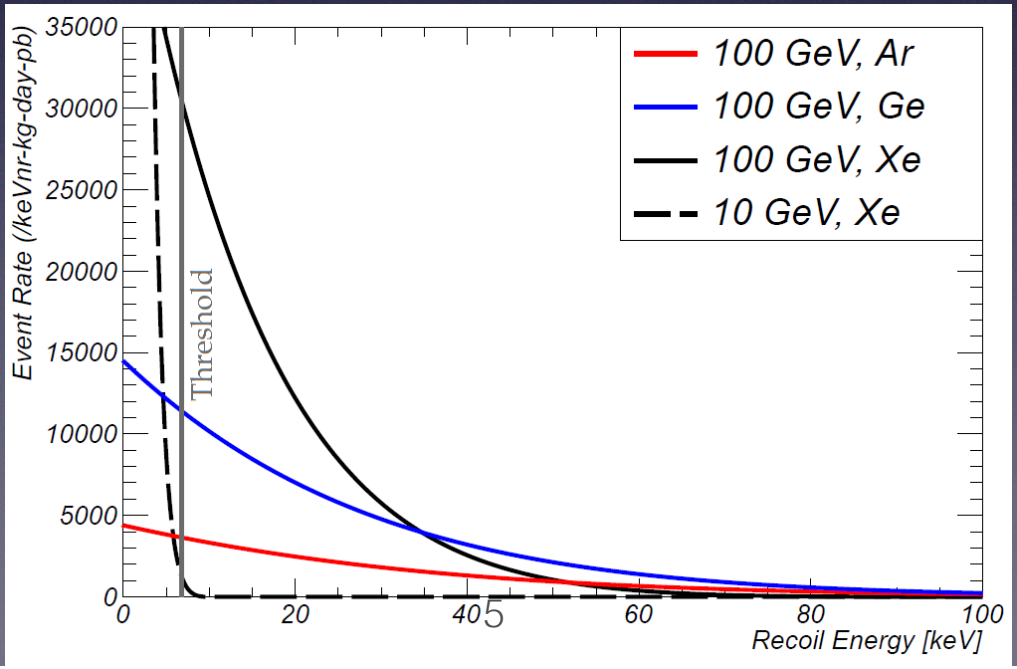
The XENON Collaboration

US led and NSF supported since start of project
~120 scientists from 20 institutions



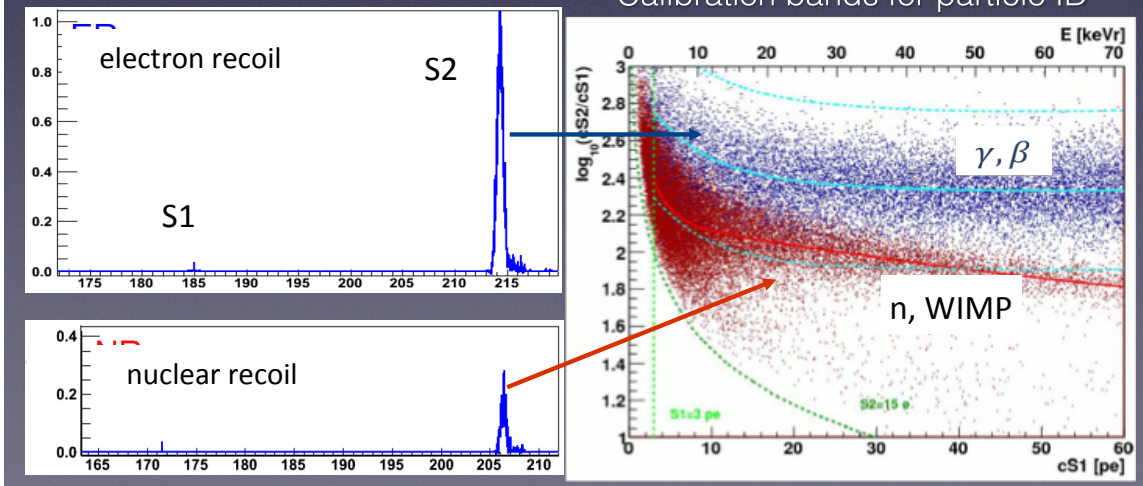
Liquid Xenon for a WIMP Detector

- Good target for both SI (A~131) and SD WIMP-N interactions (^{129}Xe & ^{131}Xe)
- Highest event rate for massive WIMPs
- Unique ability to measure single e^- with a two-phase TPC:
  - allows detection of light WIMPs through charge-channel only
- Enables large mass, homogeneous, self-shielded, easily scalable detector.
- Highest ionization and scintillation yield among all noble liquids
- Simultaneous charge and light detection enables ER/NR discrimination
- 3D event localization, double-scatter rejection and self-shielding provide powerful background rejection
- Excellent dielectric, inert, no long-lived radioactive isotopes.

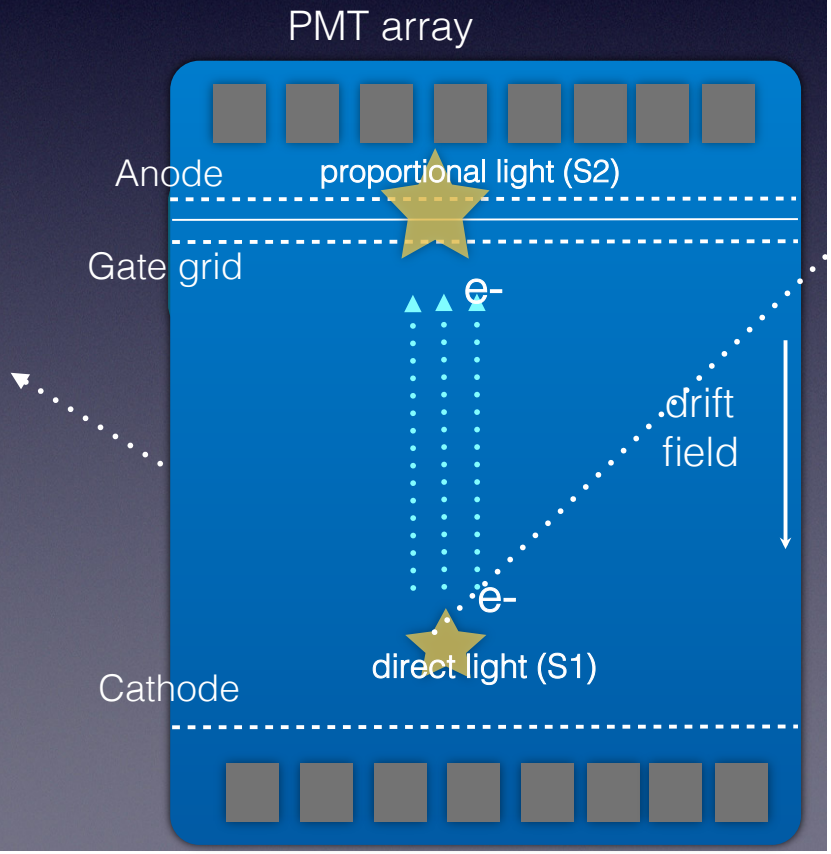


Two-phase Xe Time Projection Chamber

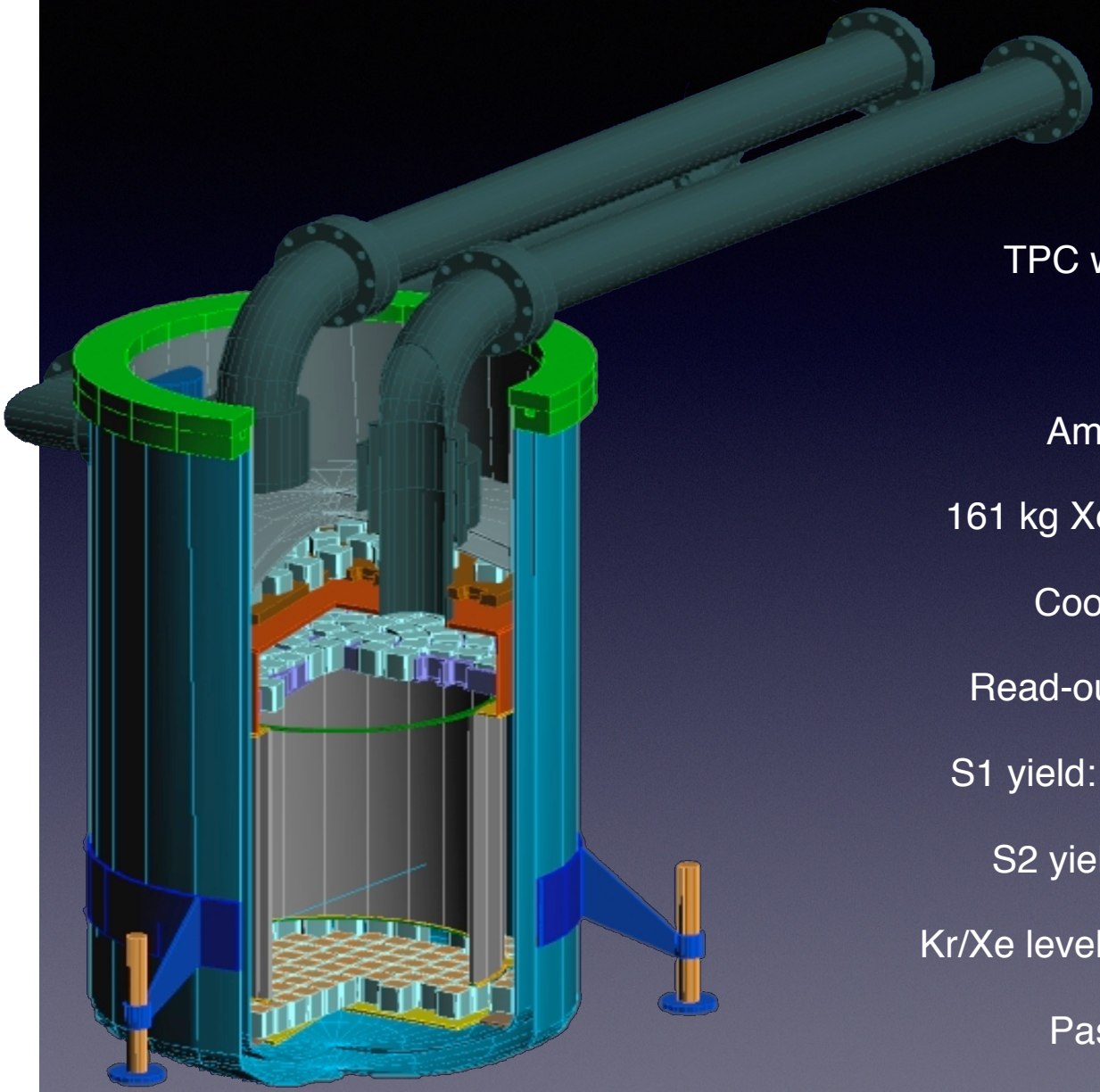
- Particle interaction in the active volume produces prompt scintillation (S1) and ionization electrons
- Electrons which reach the liquid/gas interface are extracted, accelerated in the gas gap and detected as proportional light (S2)
- PMTs in liquid and gas detect S1 and S2
- Charge/light depends on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



Calibration bands for particle ID



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)

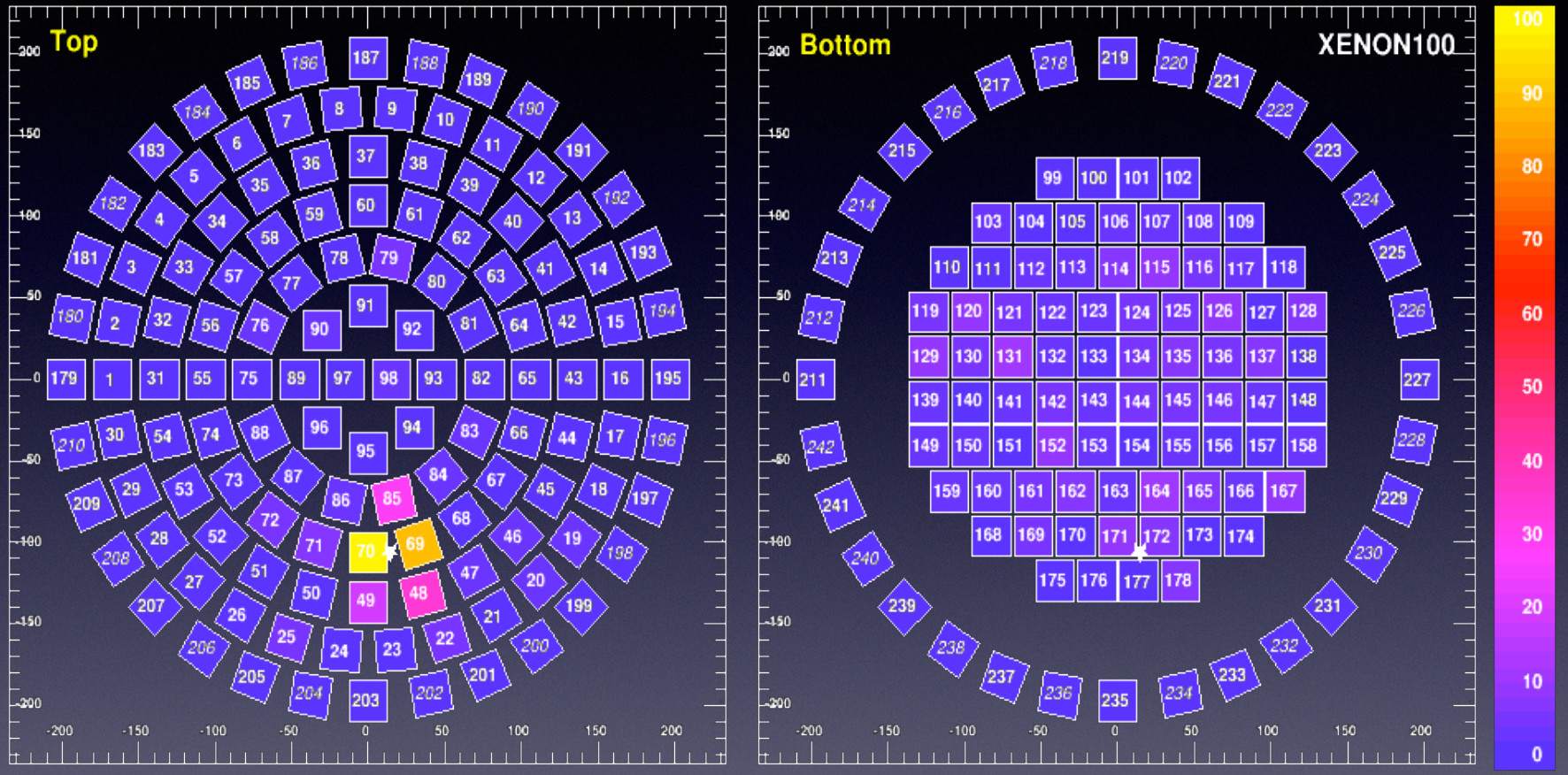
S2 yield: 19 pe/e (single electron sensitive)

Kr/Xe level reduced to ppt with cryogenic distillation

Passive shielding: water/Pb/Poly/Cu

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

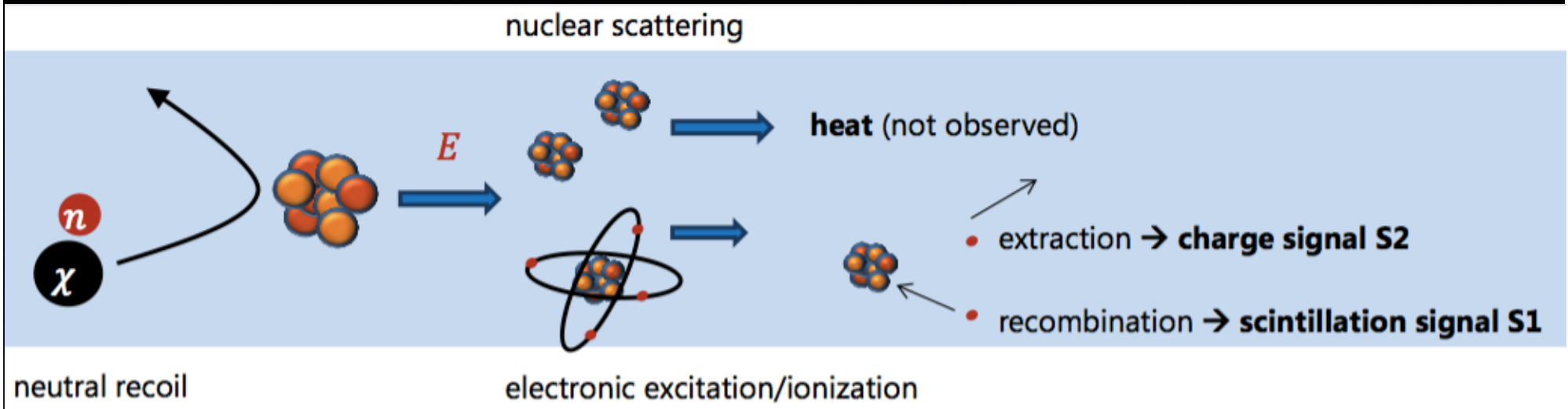
Event Localization in XENON100



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



Energy relation for **S1**

$$E = \frac{\mathrm{S1}}{L_{\mathrm{y}}} \frac{1}{\mathcal{L}_{\mathrm{eff}}(E)} \frac{S_{\mathrm{ee}}}{S_{\mathrm{nr}}}.$$

Light yield of 122keV γ-rays

Quenching-factor of nuclear recoils

Electric field dependency

Energy relation for **S2**

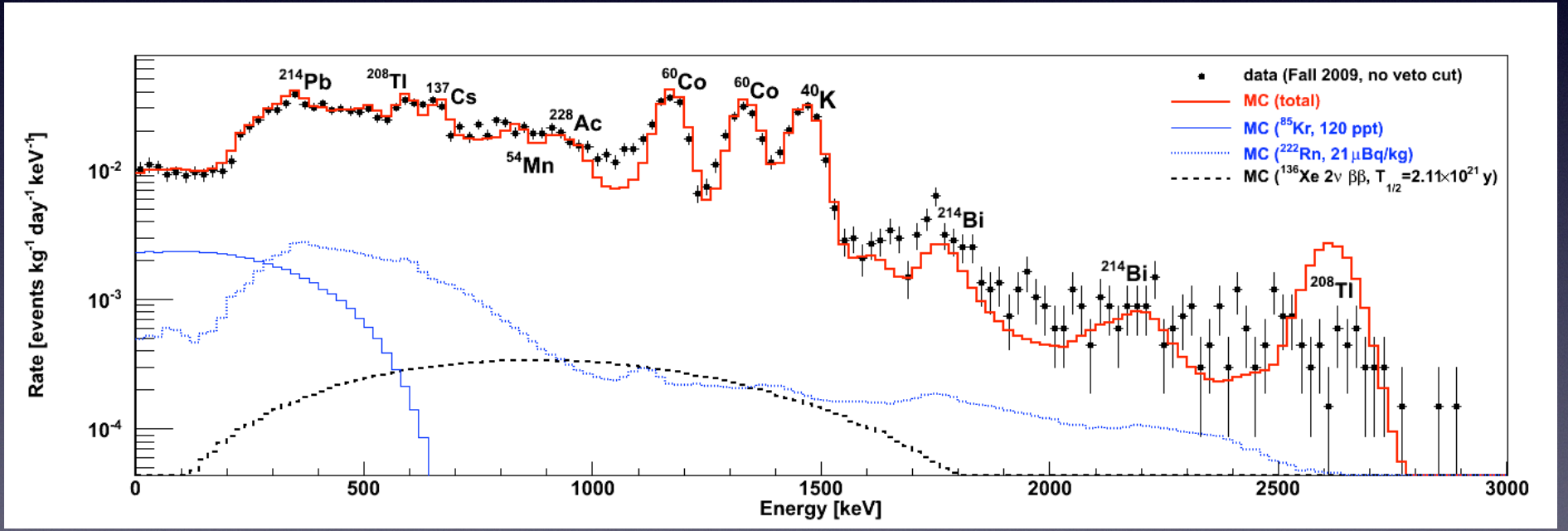
$$E = \frac{\mathrm{S2}}{L_{\mathrm{q}}} \frac{1}{\mathcal{Q}_{\mathrm{y}}(E)}$$

Secondary Amplification of electron signals

Charge yield of nuclear recoils

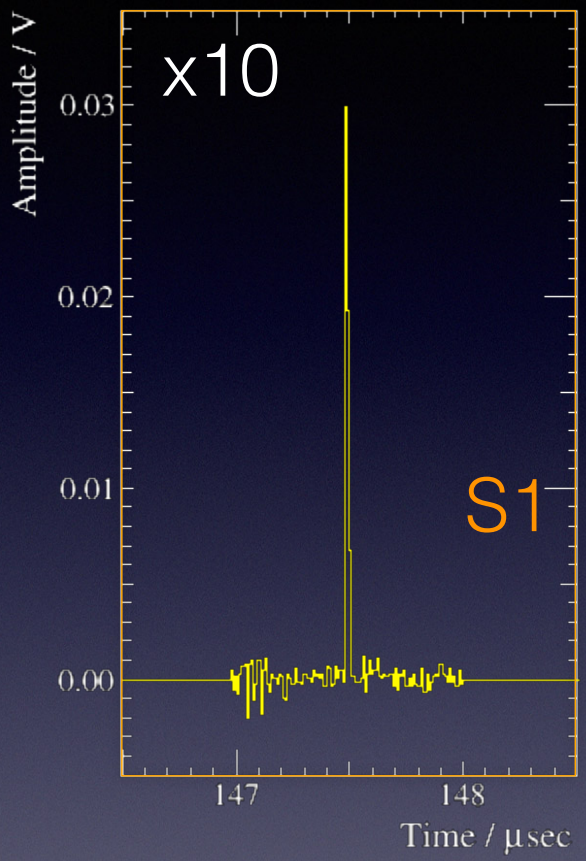
XENON100: an ultra-low background experiment

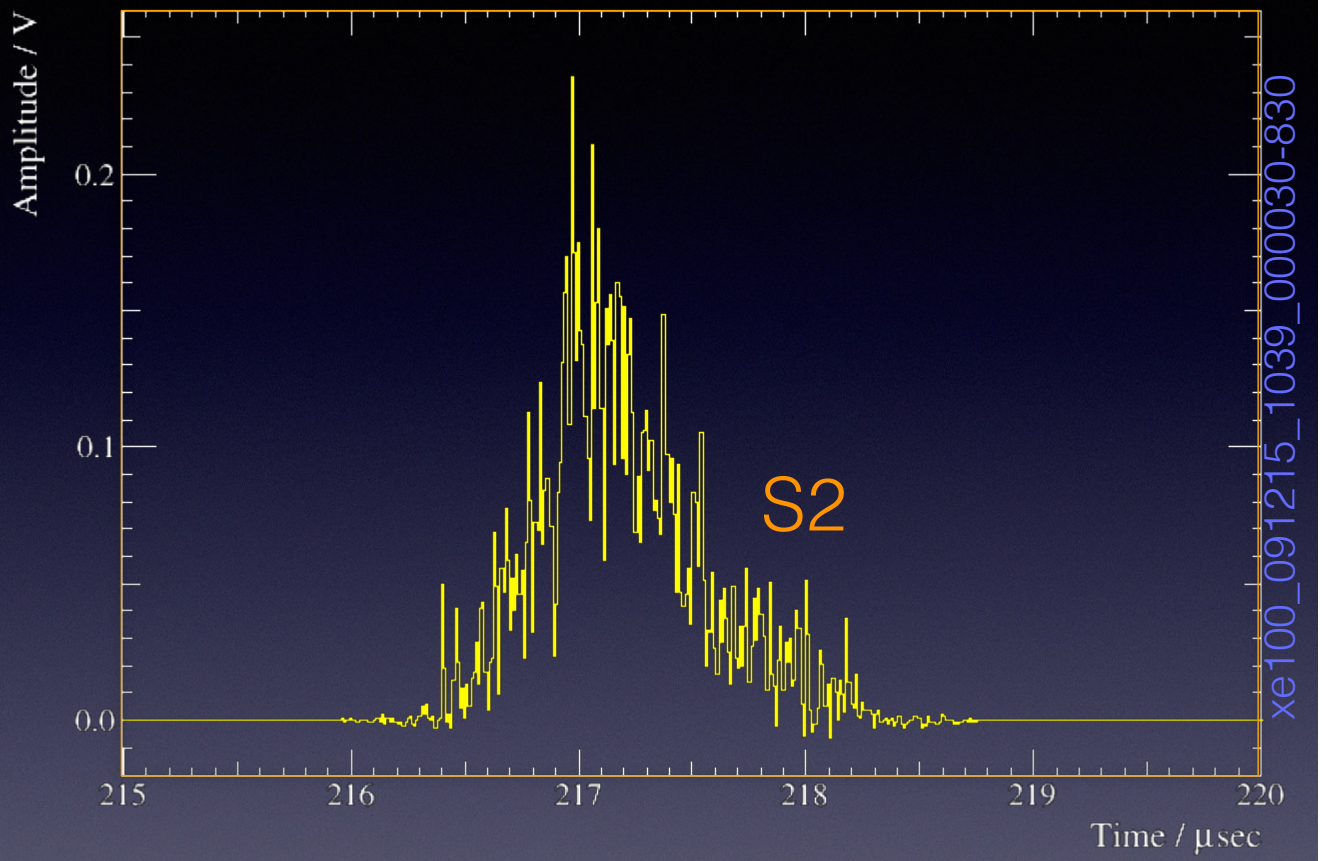
~5x 10^{-3} evts/kg/keV/day after veto cut and before S2/S1 discrimination



Phys. Rev. D 83, 082001 (2011)

WIMP-like Event as seen in XENON100



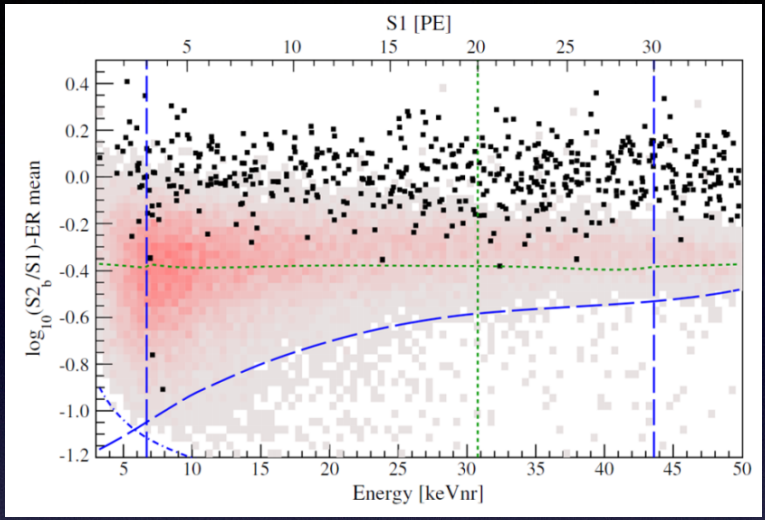


3.6 PE detected
(from ~100 S1 photons)

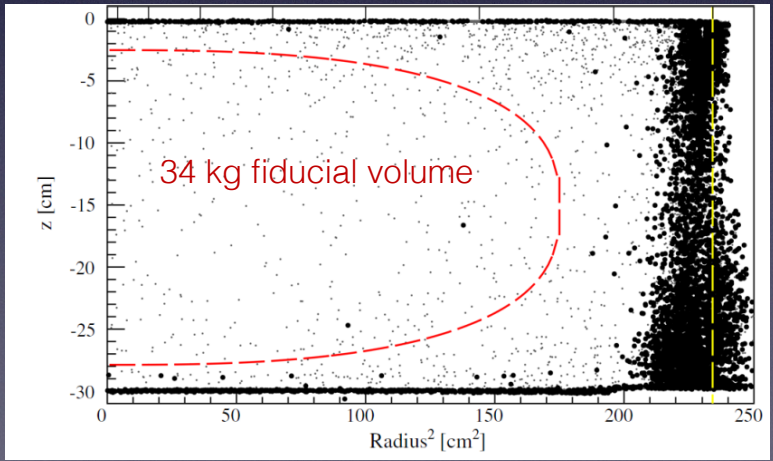
645 PE detected
(from 32 ionization electrons which generated ~13000 S2 photons)

Benchmark results from 225 live days DM search

Particle discrimination



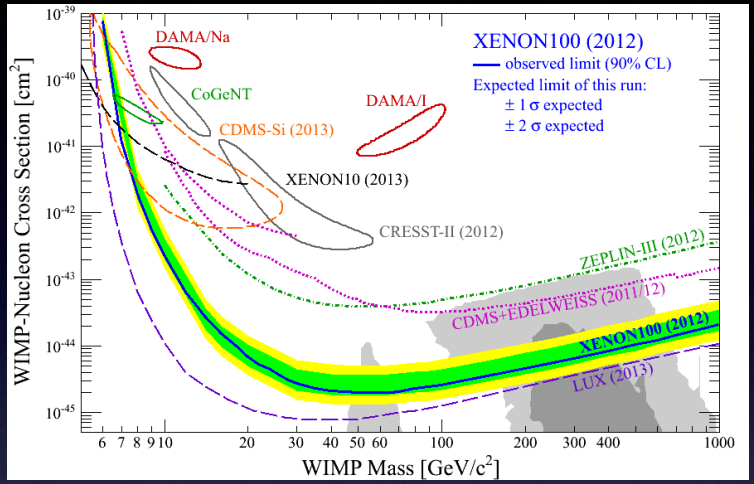
Spatial event distribution



- 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

Spin-independent WIMP-nucleon coupling

E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)



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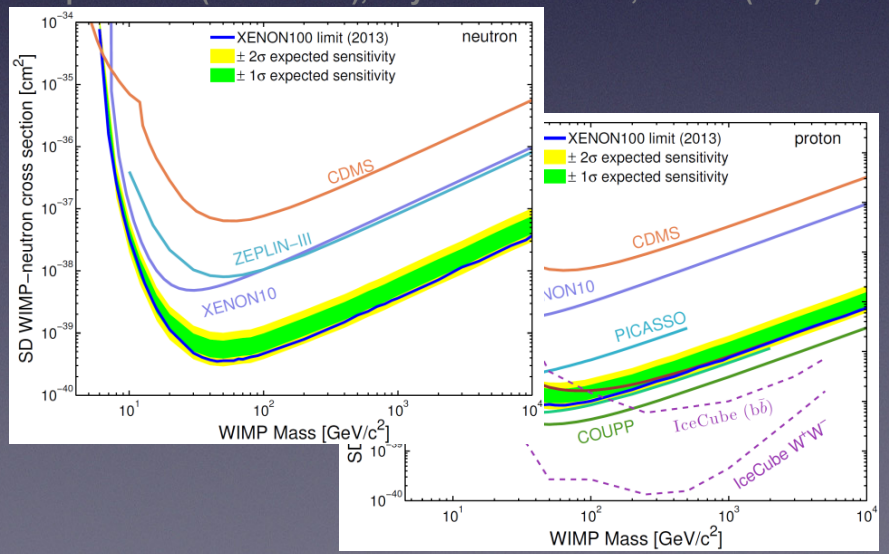
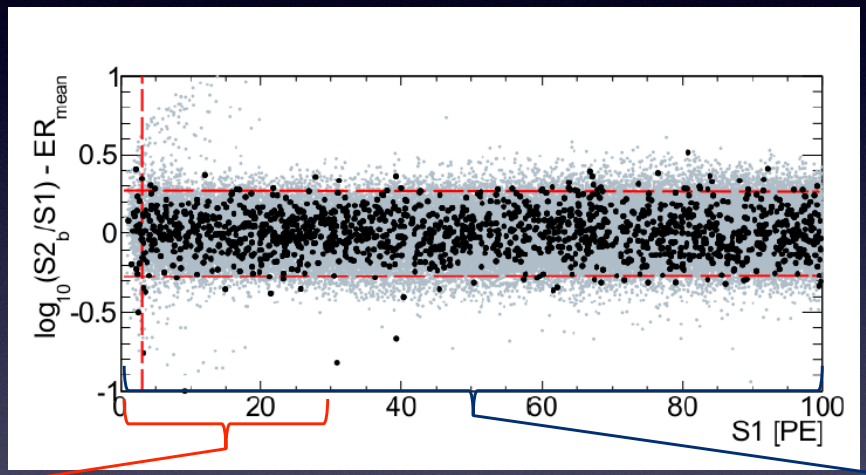
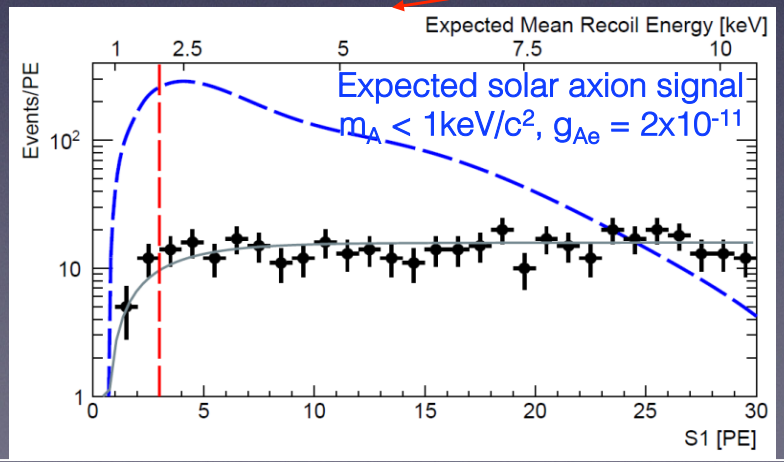


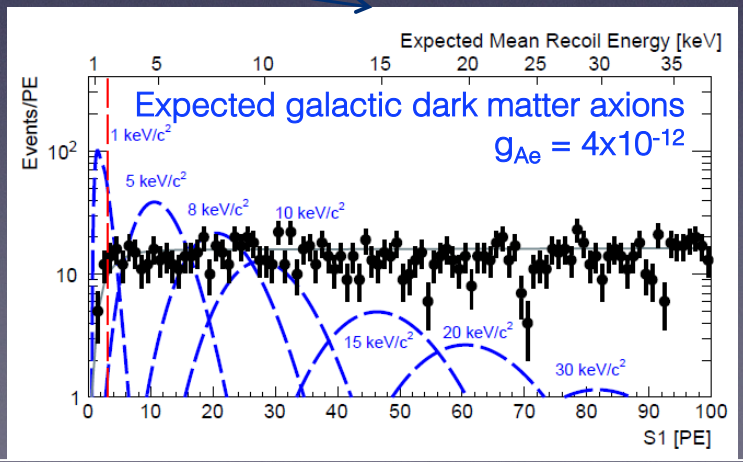
Search for solar axions and axion-like dark matter particles

E. Aprile et al. (XENON100), Phys. Rev. Lett. 111, 021301 (2013)

- Origins of axion type particles: galactic dark matter and production in the Sun
- Coupling of axions and axion-like dark matter particles (ALP) to LXe target medium via axio-eletric effect („absorption“ of axion and emission of electron from the atomic shell)
  - Signal expected to appear in the electronic recoil band (as opposed to WIMPs)





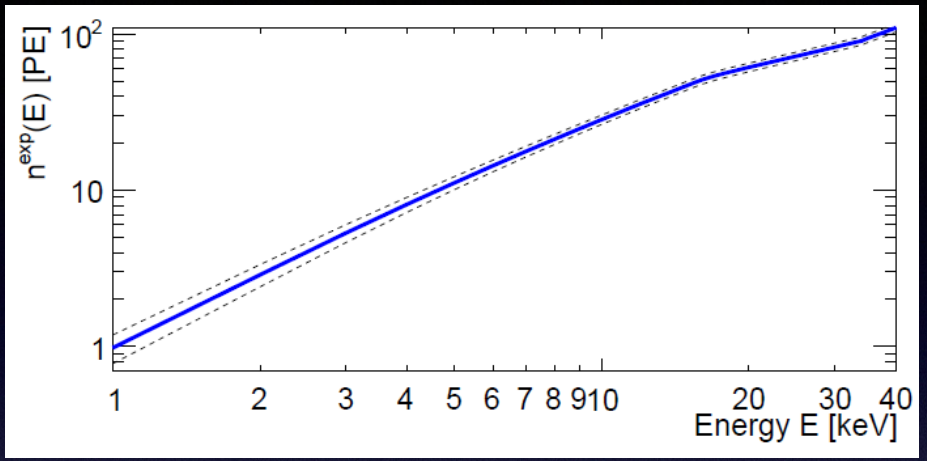


Results of axion search using 225 live days data

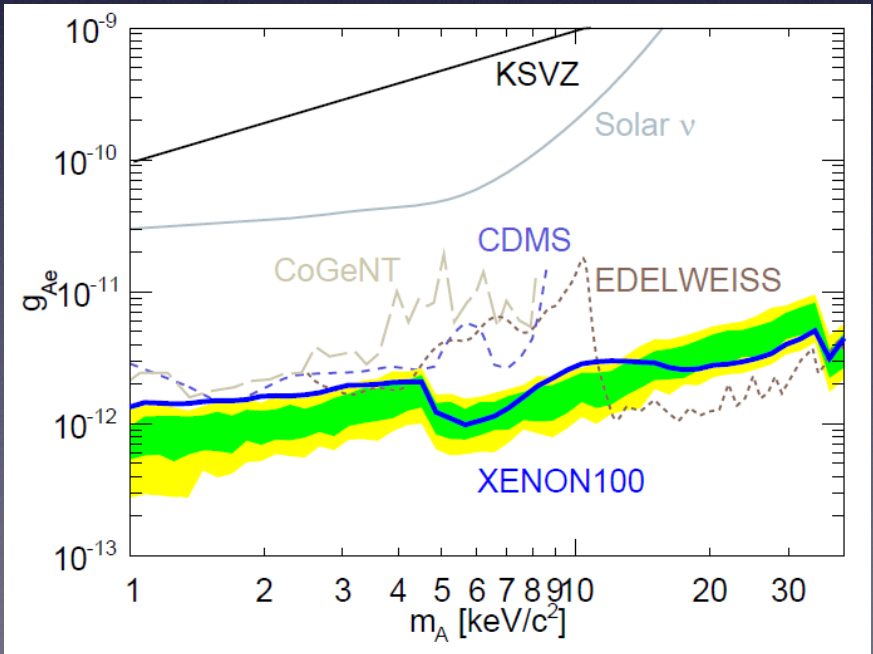
E. Aprile et al. (XENON100), Phys. Rev. Lett. 111, 021301 (2013)

- S1 energy scale conversion derived from combination of direct measurements of the scintillation light yield as function of energy and the NEST model
- Profile likelihood method to derive g_{Ae} limits and incorporate sys. uncertainties

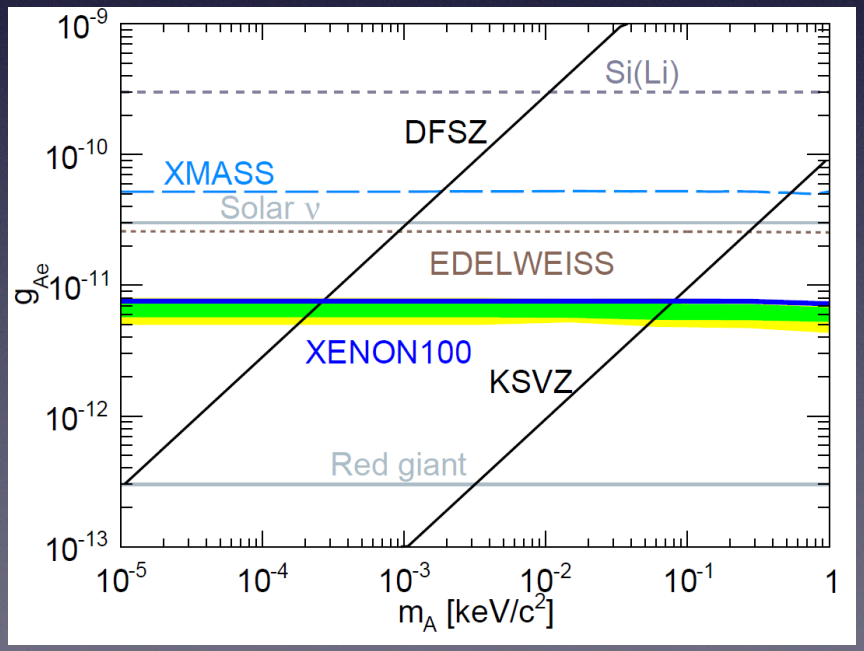
S1-Energy conversion for electronic recoils



Limit and sensitivity for axion-like DM (ALPs)



Limit and sensitivity for solar axions



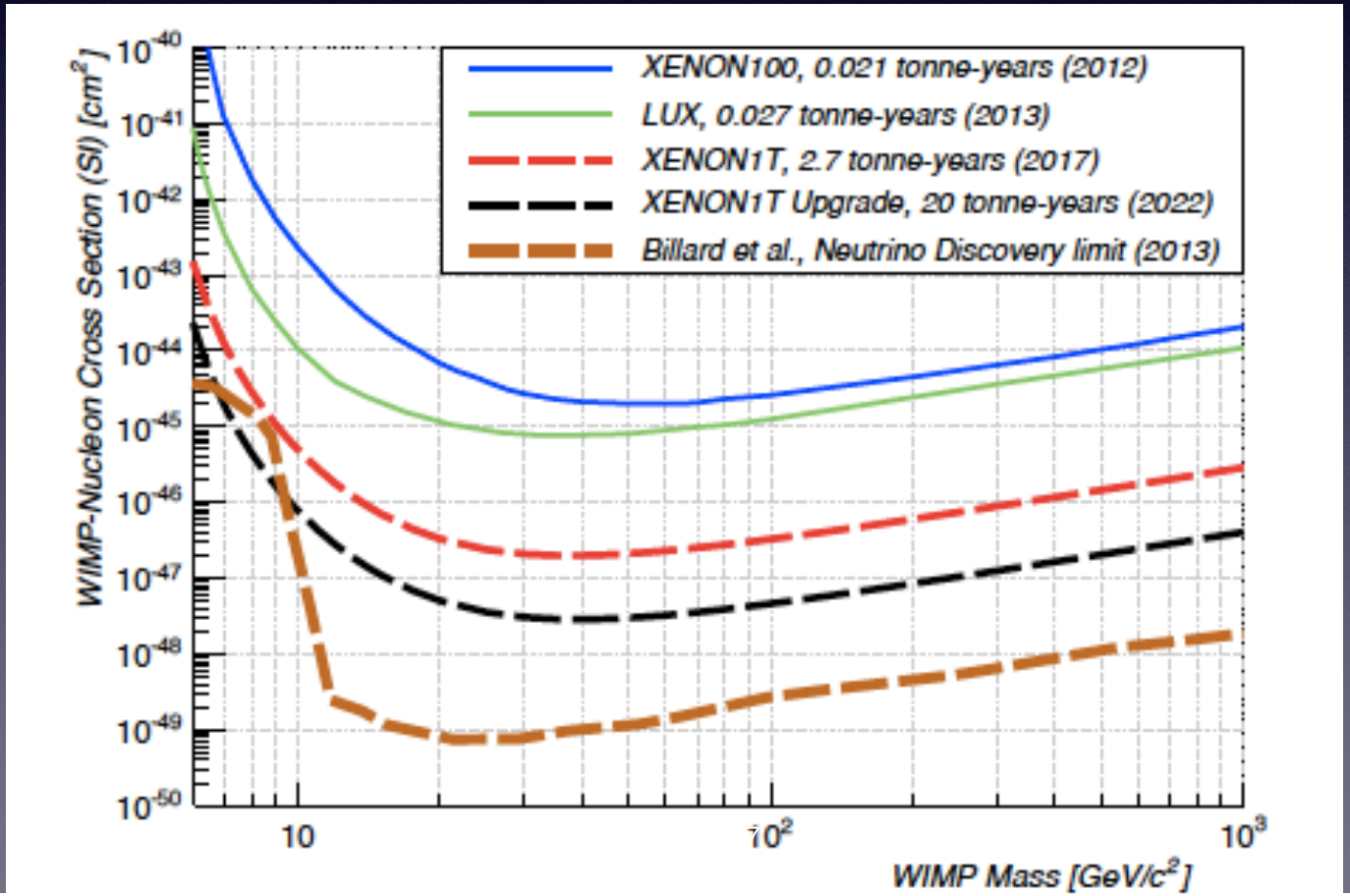
XENON1T

From XENON100 to XENON1T

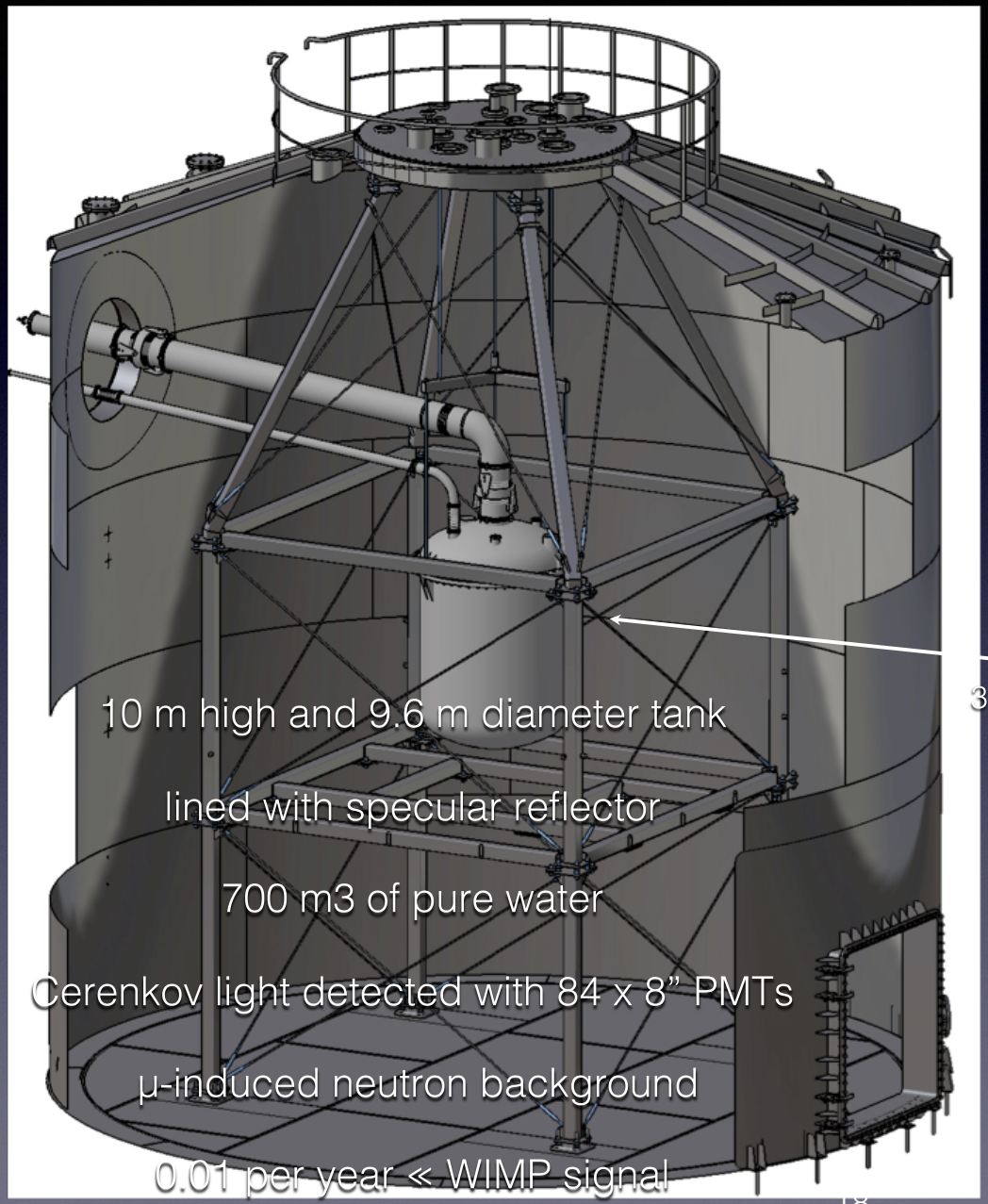
- Two-phase TPC with 1 meter drift and ~1 m diameter electrodes exploiting ~3.3 tonnes of Xe
- Experiment designed to enable a fast upgrade to a larger diameter TPC exploiting ~7 tonnes of Xe
- Detector/associated systems use largely proven technologies developed for XENON100
- New challenges presented by the scale-up addressed with multiple R&D set-ups
- New 3 inch PMTs developed for XENON1T: average QE~40% at 178 nm and low activity
- Detector shielded by water implemented as Cherenkov muon veto
- Developing methods to control the most challenging backgrounds: from ^{85}Kr beta-decays (reduce Kr/Xe < 0.5 ppt) and from ^{214}Pb beta-decays (reduce ^{222}Rn in LXe to ~1 mBq/kg)
- Schedule: under construction at LNGS started fall 2013
- Science Goal: 2×10^{-47} cm^2 with 2 ton-years of data or by 2017

Science Reach of XENON1T Program

- 100 x more sensitive than XENON100 - 1000 x more after upgrade
- either exclude much of favored SUSY WIMPs parameter space
- ~100 events from a 50 GeV WIMP at 2×10^{-47} cm^2 with 2 tonne-year



XENON1T Detector



10 m high and 9.6 m diameter tank

lined with specular reflector

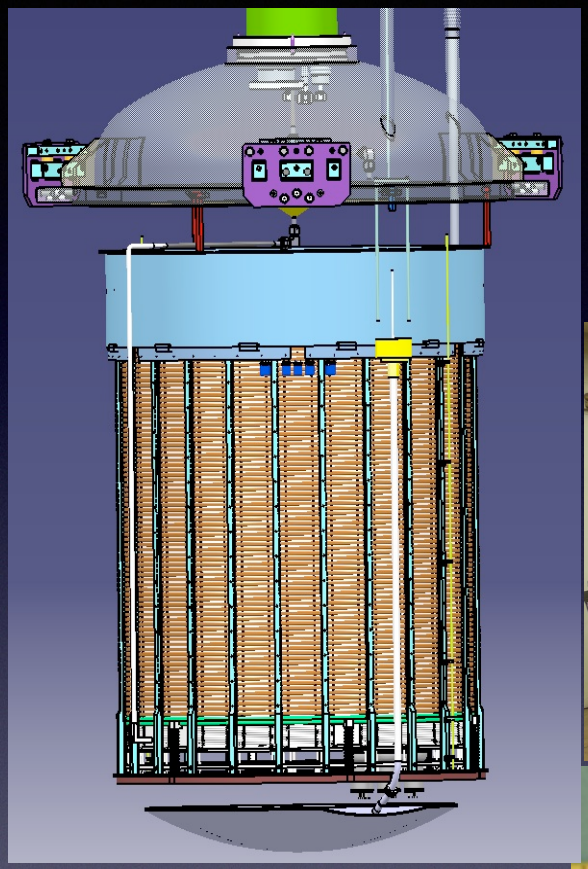
700 m3 of pure water

Cerenkov light detected with 84 x 8” PMTs

μ-induced neutron background

0.01 per year « WIMP signal

TPC details



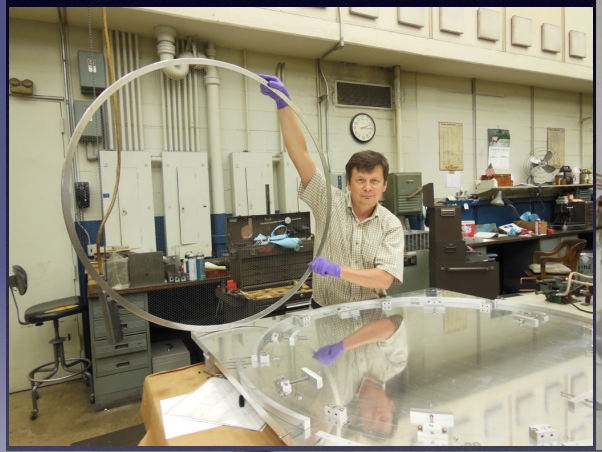
Electrodes: 1 meter diameter wire grids

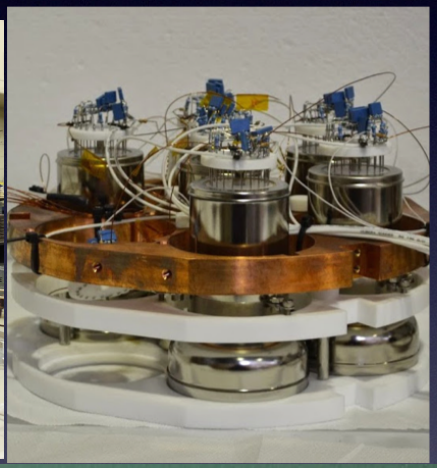
Field cage: Cu-rings; PTFE reflector

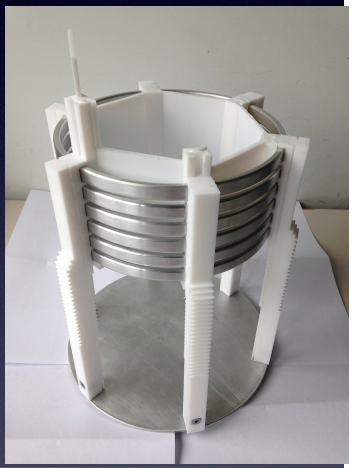
PMTs: 248 x 3” Hamamatsu R11410-21: ~40% QE @ 175 nm; <1mBq/PMT in U/Th

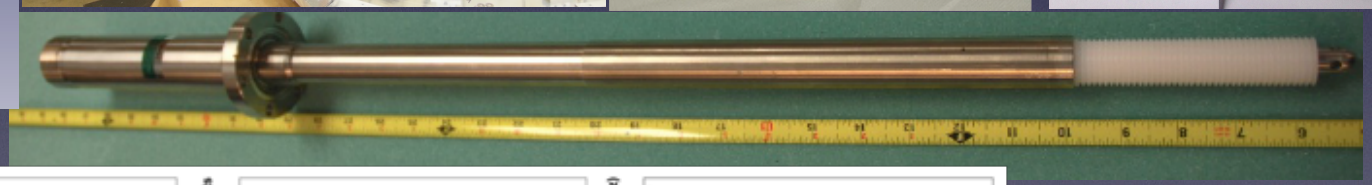
HV: 100kV custom-made feedthrough

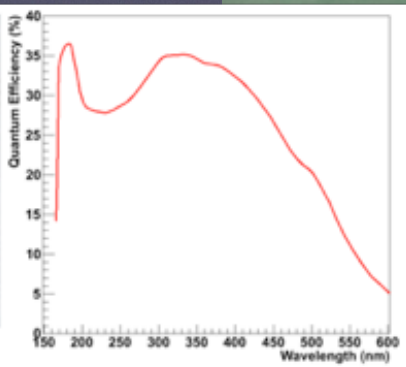
TEP mock-up at LNGS

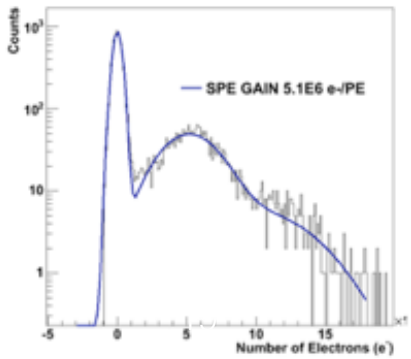


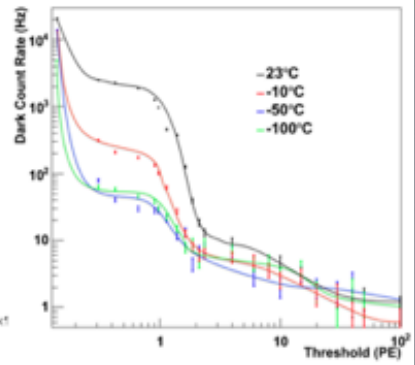




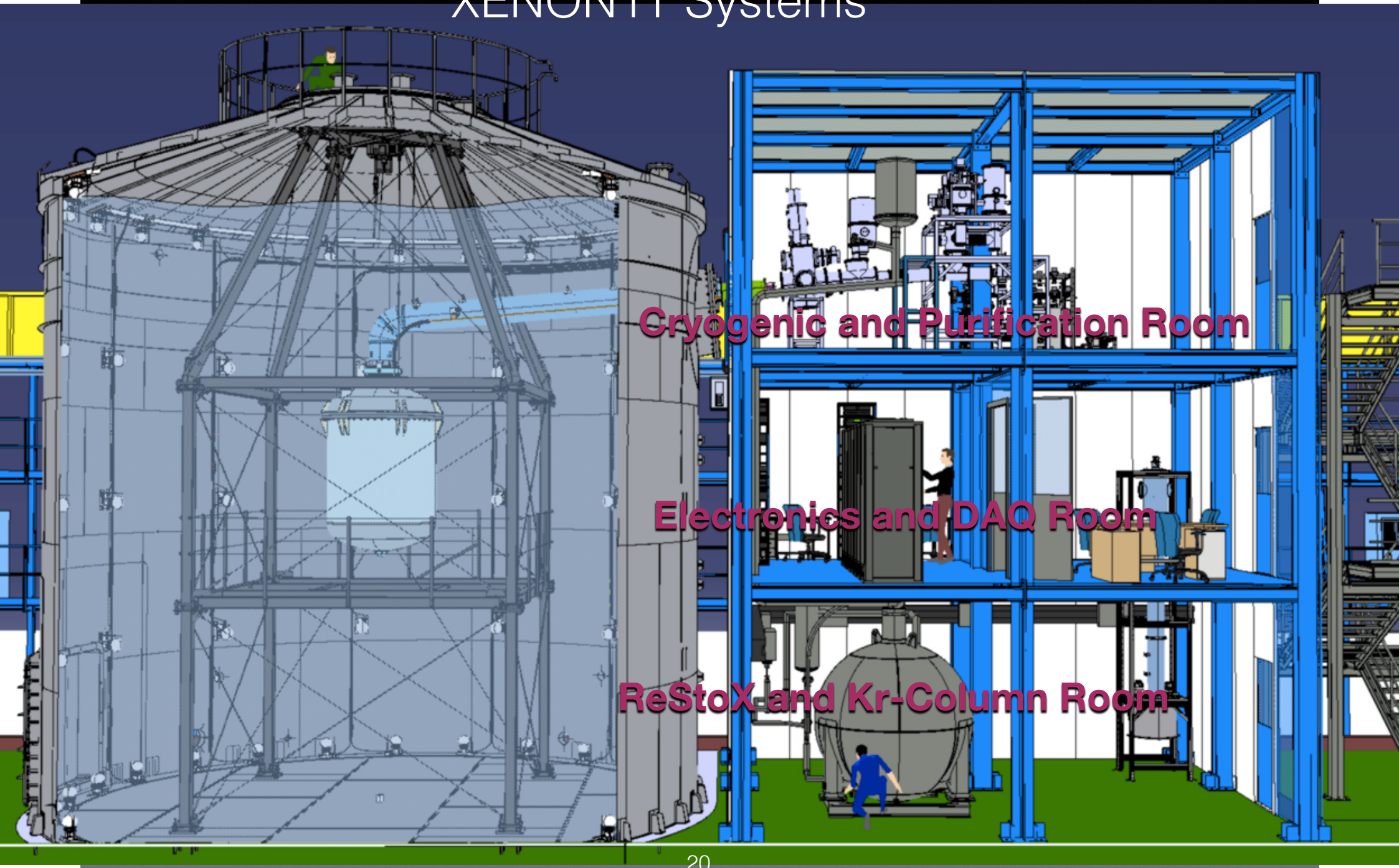




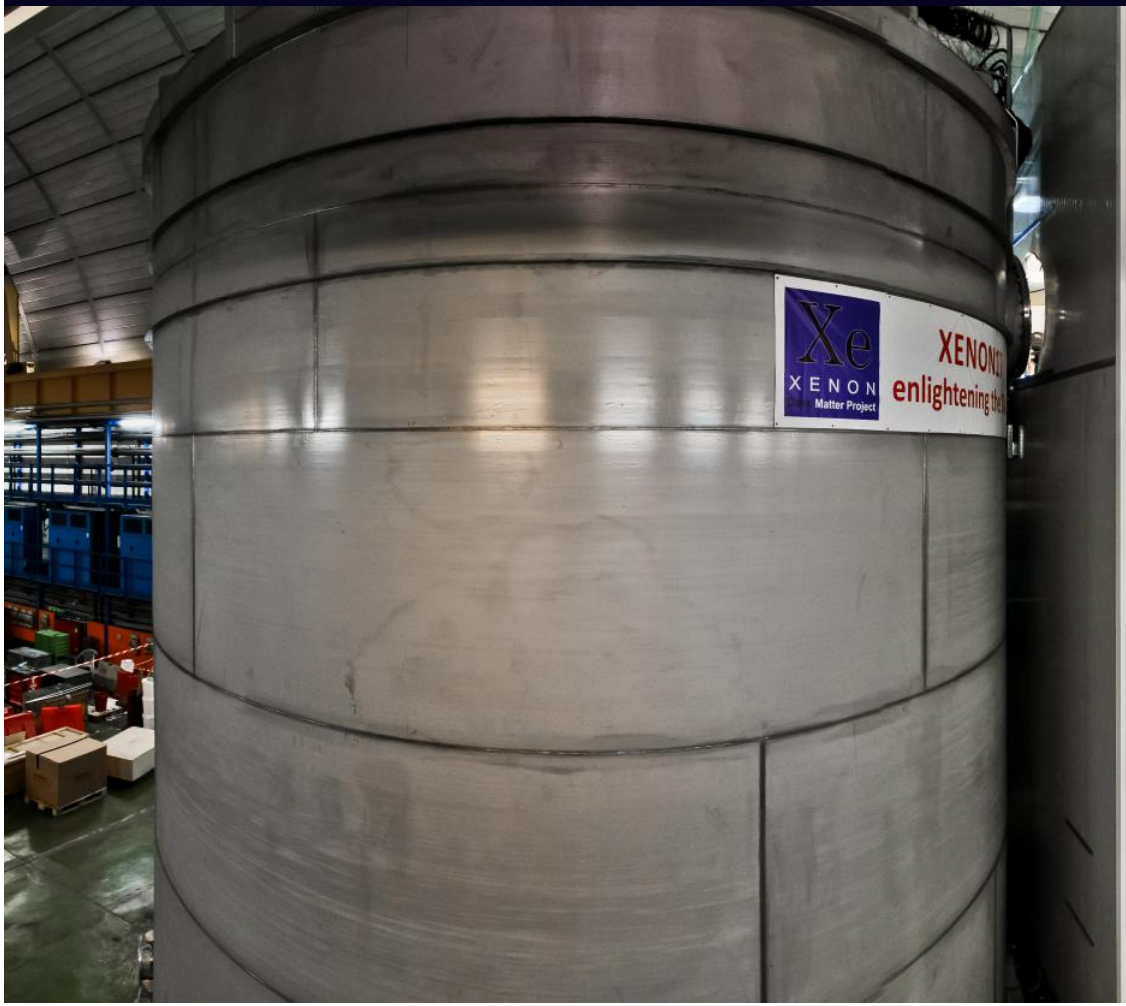




XENON1T Systems

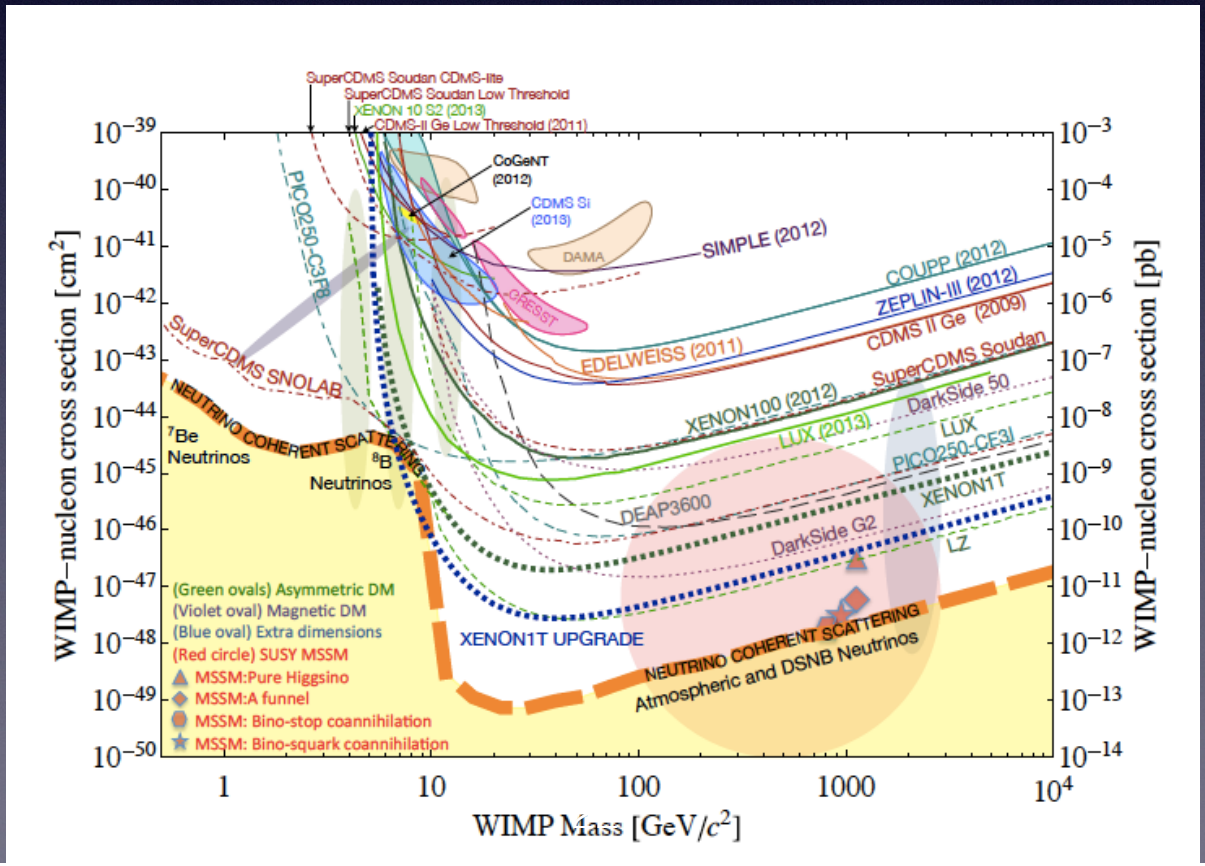


XENON1T in Hall B of LNGS



Summary

- XENON100 is still in operation after 5yr. New DM data still blinded.
- New calibration sources will be tested also for XENON1T
- XENON1T construction is on schedule
- Commissioning of cryostat and all cryogenic plants cpmpleted by July 2015.
- TPC will be installed by summer 2015
- XNON1T data taking is expected by winter 2015. After 2 ton-yr of data sensitivity reach is as shown
- An upgrade of XENON1T is panned to start in 2018



arXiv:1310.8327