

The Latest from XENON

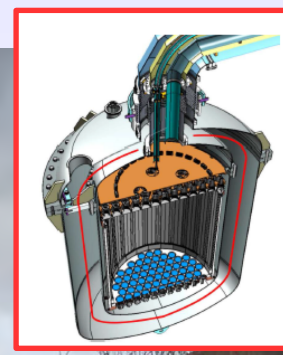
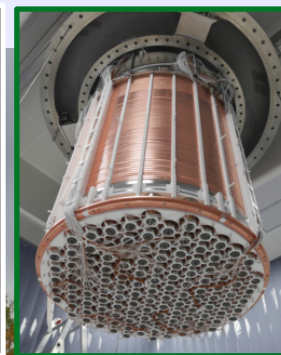
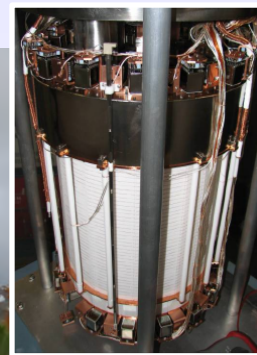
Ethan Brown – Rensselaer Polytechnic Institute
On behalf of the XENON collaboration

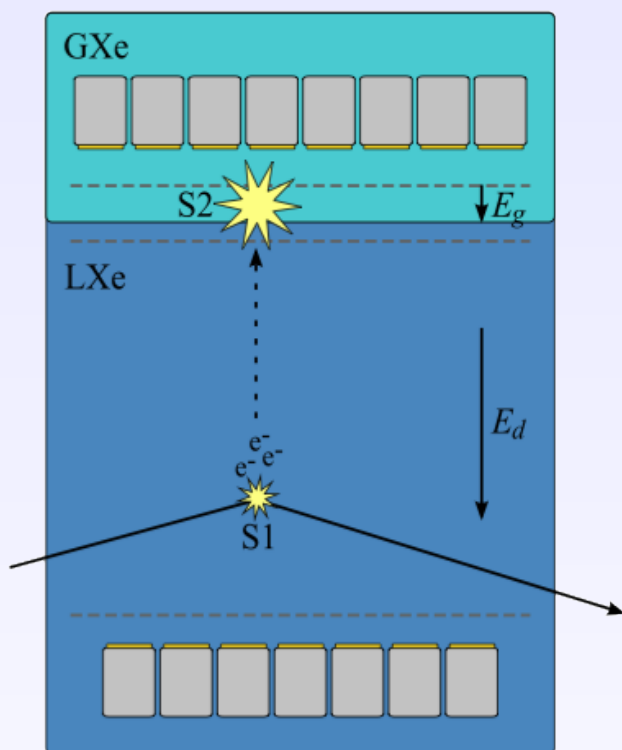


- 21 Institutions
- 10 Countries
- 130 Scientists

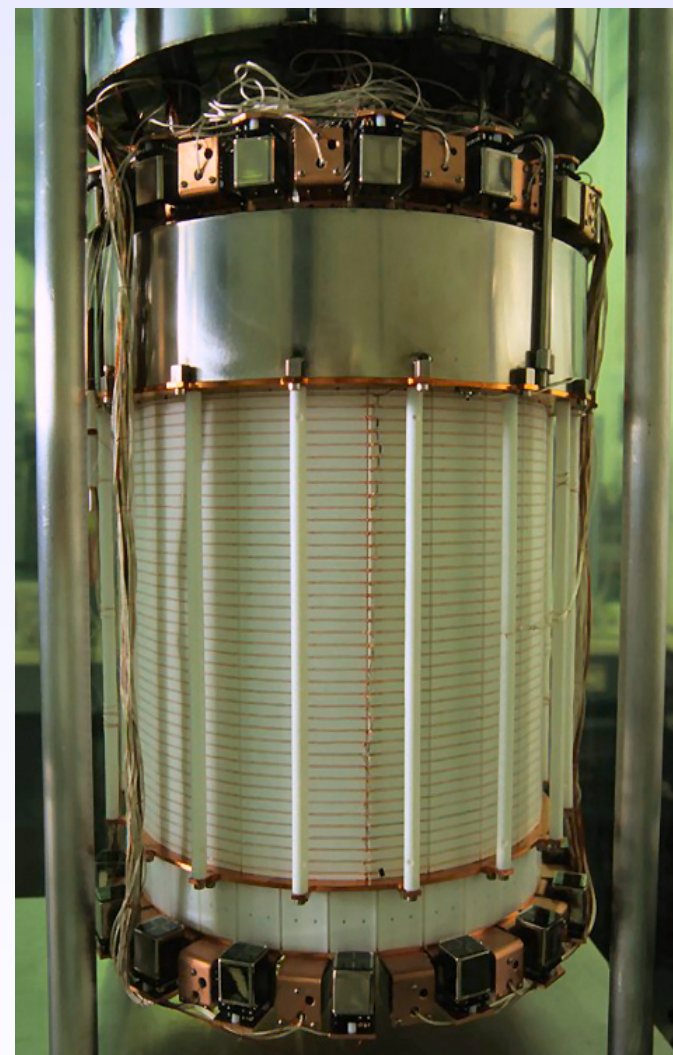
Institutions:

- Columbia
- RPI
- Nikhef
- JGU Mainz
- Stockholm University
- Muenster
- Max-Planck-Institut für Kernphysik Heidelberg
- MPIK
- Universität Bern
- University of Zurich
- جامعة نيويورك أبوظبي NYU Abu Dhabi
- NYUAD
- מכון ויצמן למדע Weizmann Institute of Science
- Purdue
- Coimbra
- Subatech
- Bologna
- LNGS
- Torino
- INFN
- UCLA
- UC San Diego
- UCSD
- Rice
- THE UNIVERSITY OF CHICAGO



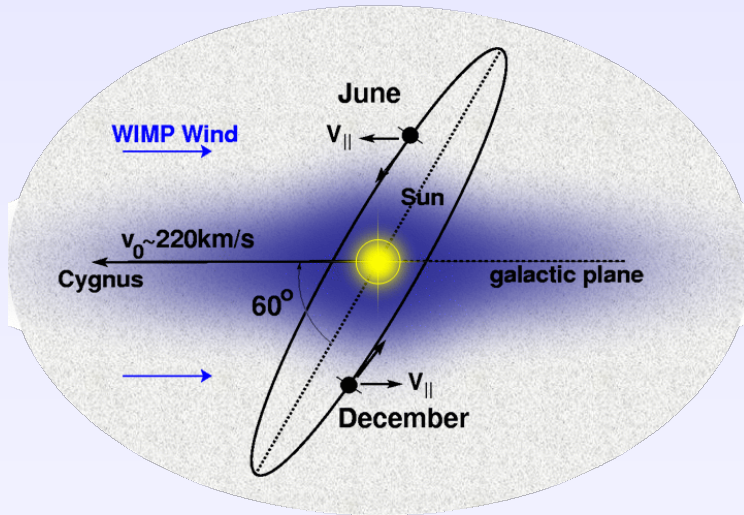


- Dual phase xenon TPC
- Located at LNGS
- 161 kg liquid xenon (62 kg sensitive volume)
- Active liquid xenon veto
- Careful material screening and selection
- Long term operation
 - >450 live days



E. Aprile et al. (XENON100), Phys.Rev.D83:082001,2011

E. Aprile et al. (XENON100), Astroparticle Physics 35, 573 (2012).



- Time dependence of DM scattering rate
- Due to Earth-Sun motion in galaxy
- Earth-WIMP velocity different summer vs winter
- Higher rate in summer than winter

DAMA/LIBRA

- Observes modulation in 2 – 6 keV range
 - 1.3 ton-yr exposure
 - 14 annual cycles
 - 9.3σ
- Claim due to DM
 - Correct period and phase
 - Not seen in other experiments

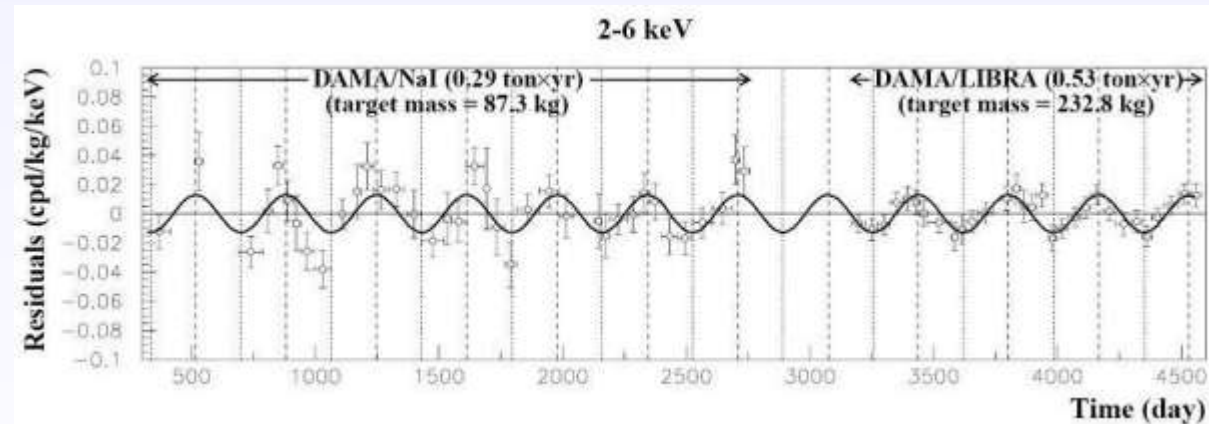
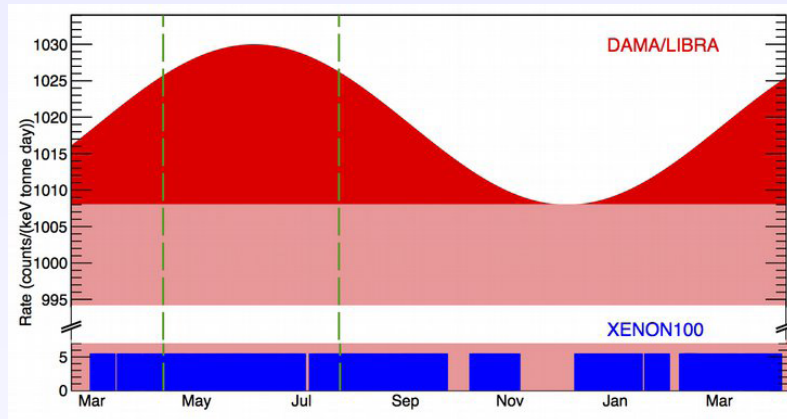
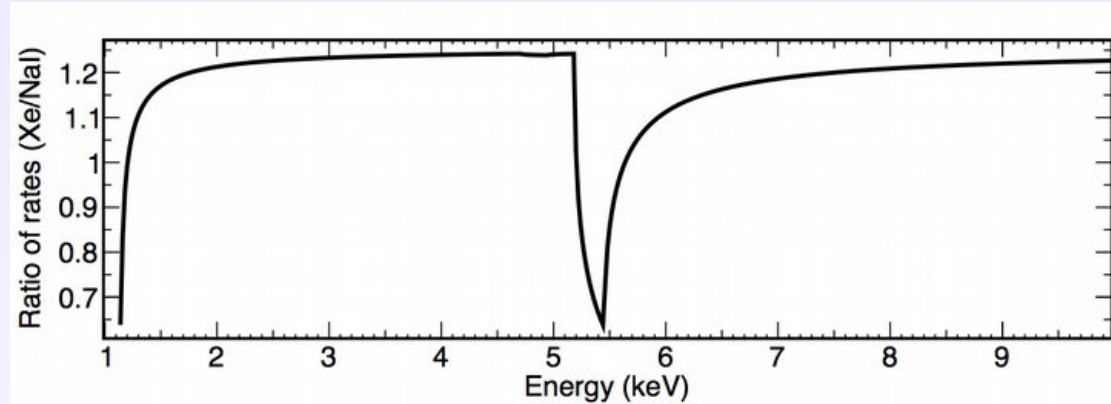


Figure from R. Bernabei et al., Eur. Phys. J. C 56 (2008) 333

Leptophilic dark matter

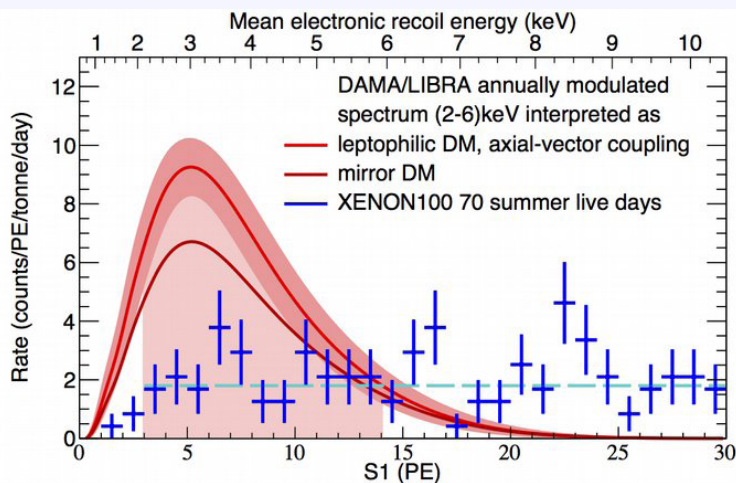
- Axial vector coupling
- Dominant scattering with electrons
- Nuclear recoils → Electronic recoils
- Look for DM in ER spectrum

Capitalize on similar electronic structure of Xe and NaI

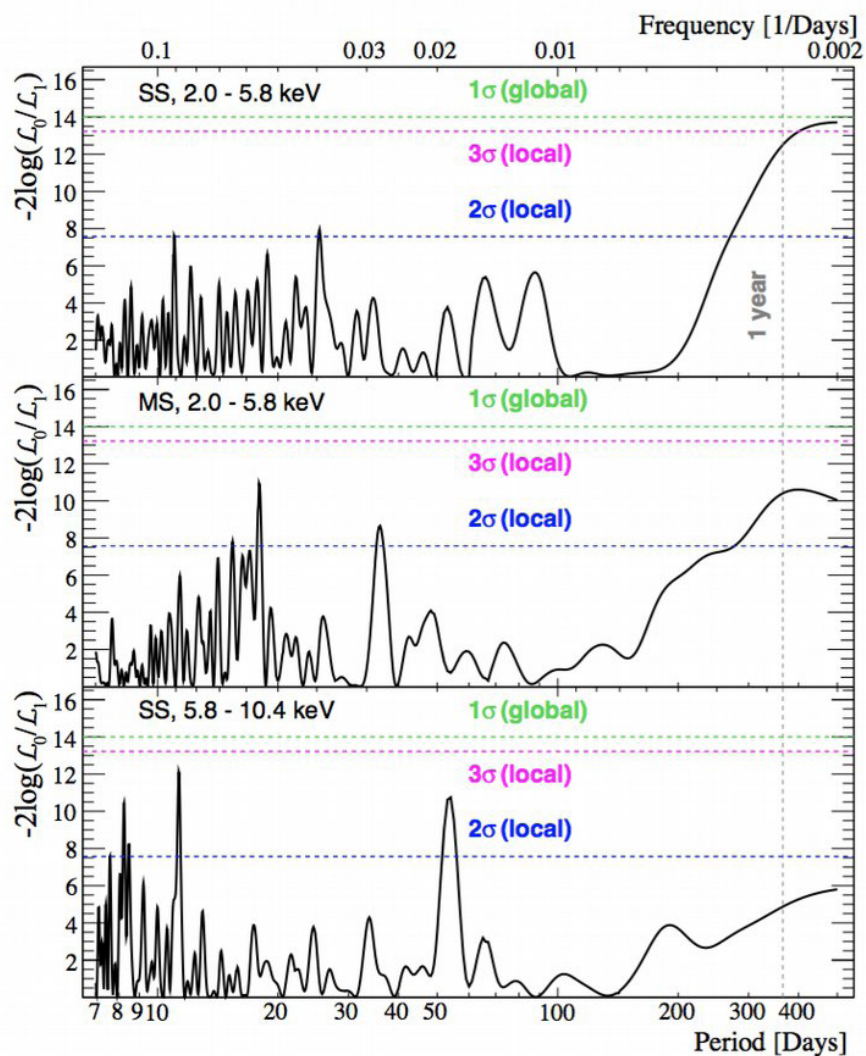


- Look for DC rate in summer data
- Consider all events as DM candidates
- Exclude:
 - WIMP-electron axial vector coupling @ 4.4σ
 - Luminous DM @ 4.6σ
 - Mirror DM @ 3.6σ

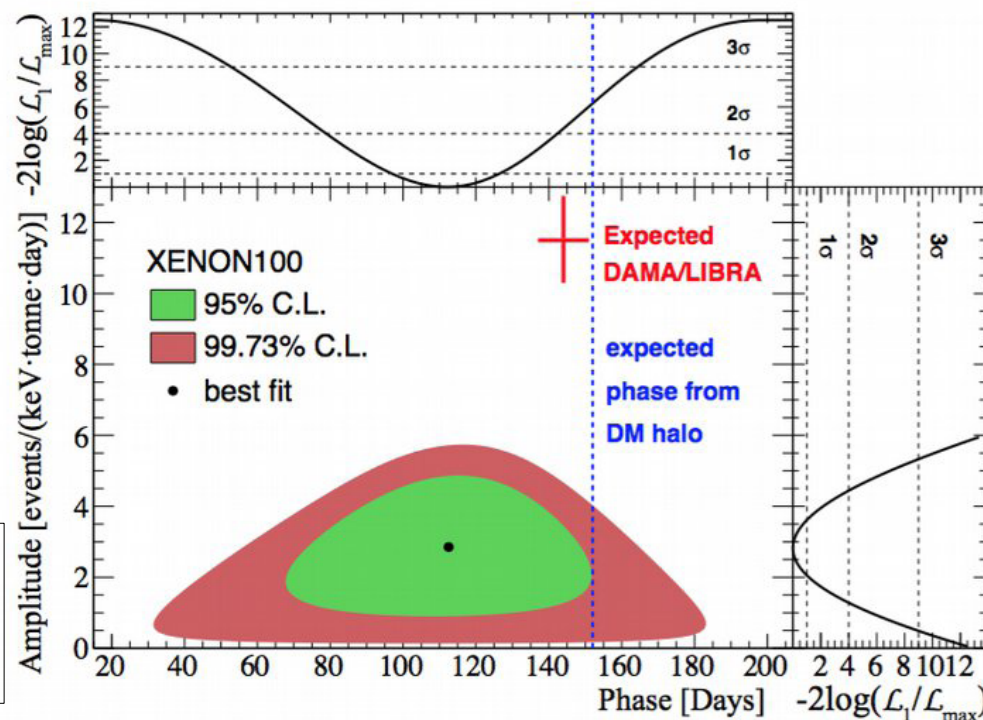
XENON Coll., Science 349 no. 6250 pp. 851-854 (2015)

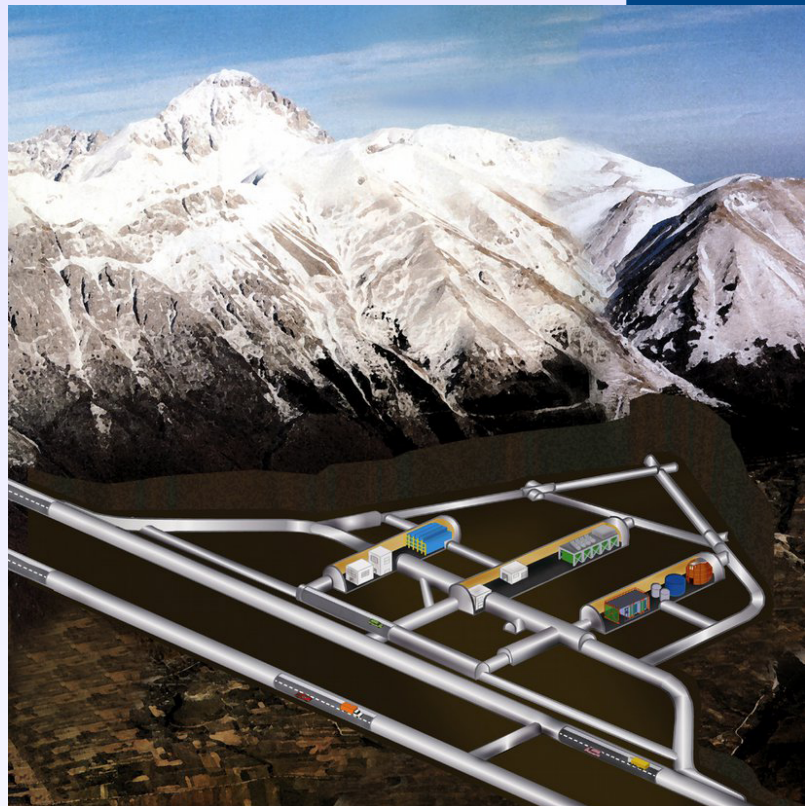


- Unbinned profile likelihood
- 225 live day data sample from XENON100
- Random period: **No significant signal!**
- Fixed 1 yr period, unconstrained phase
- Weak signal in 2.0 – 5.8 keV range
- Combination of phase/amplitude **inconsistent with DAMA interpretation as axial-vector coupling @ 4.8σ**



- New combined data result coming soon
 - New and published data
- Will constrain periods $> 1\text{yr}$





- Reduce background 100X from XENON100
 - Goal: 2 t-yr exposure
- Increase sensitivity by factor 100 compared to XENON100
 - $1.6 \times 10^{-47} \text{ cm}^2 @ 50 \text{ GeV WIMP}$

- Located in LNGS
- Many systems upgraded from successful operation of XENON100
- 3.2 tons Xe (2.0 t active volume)
- Water Cherenkov muon veto
- Cryogenics plant for high purity xenon (~10t)



Purification

- Continually clean Xe
- ~100 SLPM
- Parallel circuits for optimization and maintenance
- Custom xenon pump
 - Chart QDrive

Cryogenics

- Externally cool and liquefy Xe
- ~10 tons Xe @ 170K
- Redundant systems and LN₂ for safety

Feedthrough Pipe

- Liquid and gaseous Xe
- Cables
- Connections through water tank

Xe Storage ReStoX

- Store up to 7.6 T tons
- Liquid or gas phase
- Safety recovery system

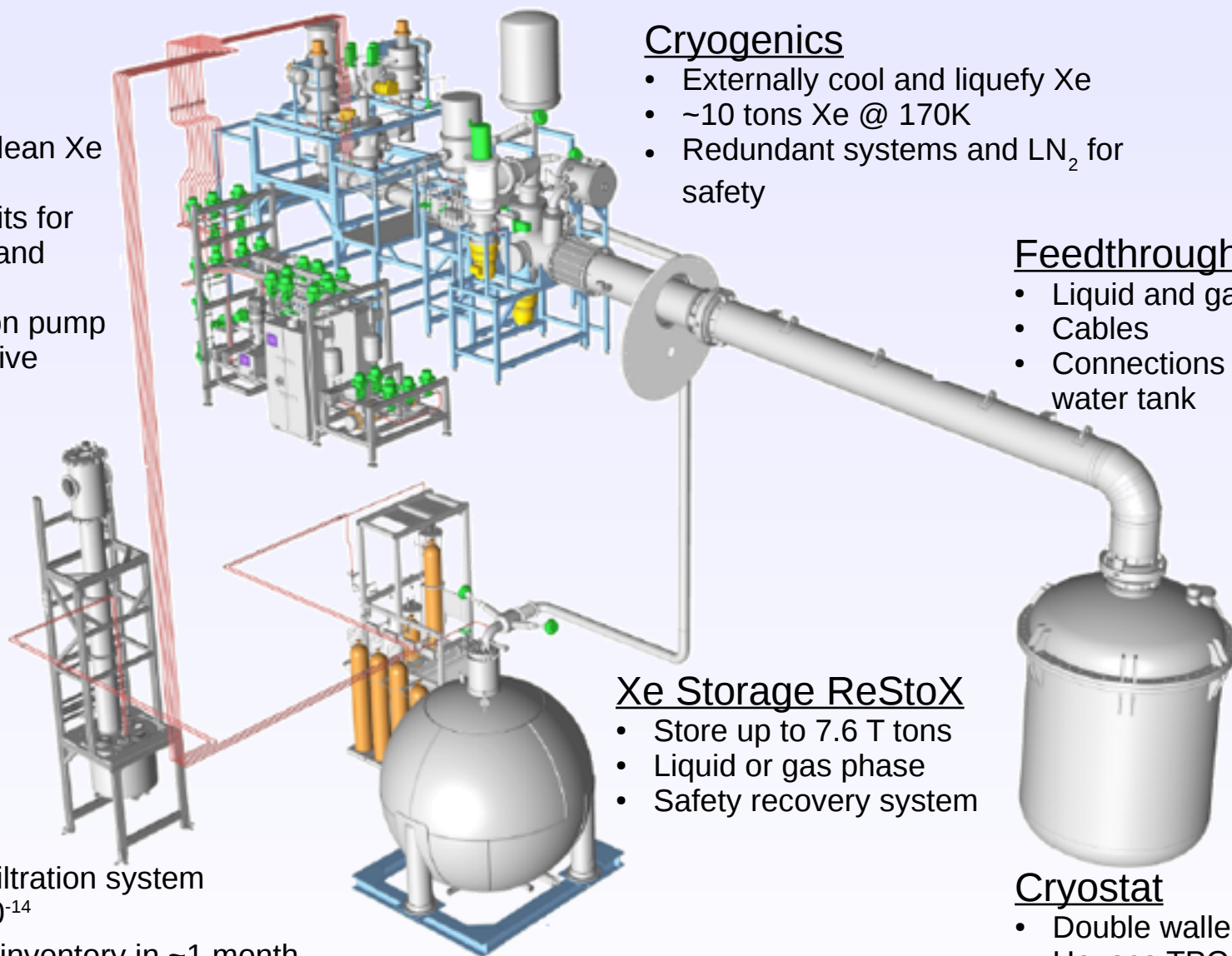
Cryostat

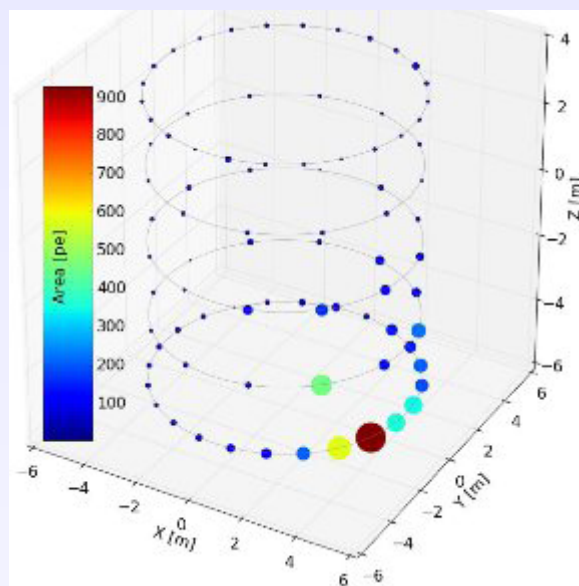
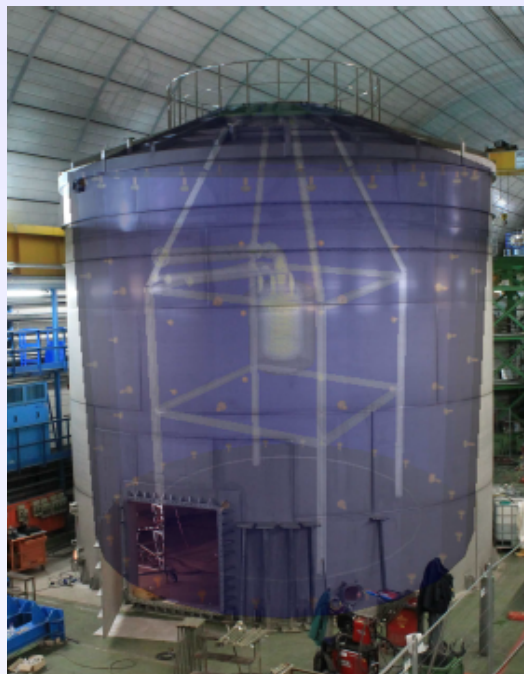
- Double walled SS vessel
- Houses TPC (for 1T and nT!)

All designed for XENON1T
and XENONnT!

Distillation

- Custom Kr filtration system
- Kr_{nat}/Xe ~ 10⁻¹⁴
- Process Xe inventory in ~1 month



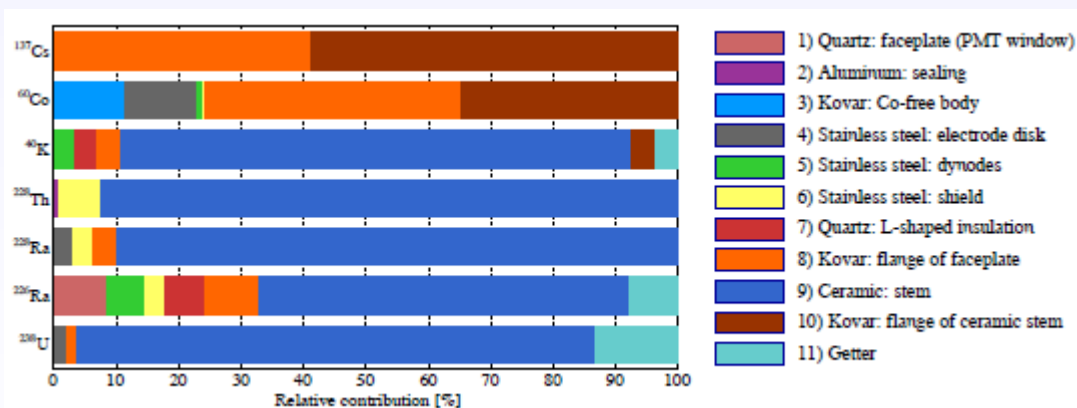
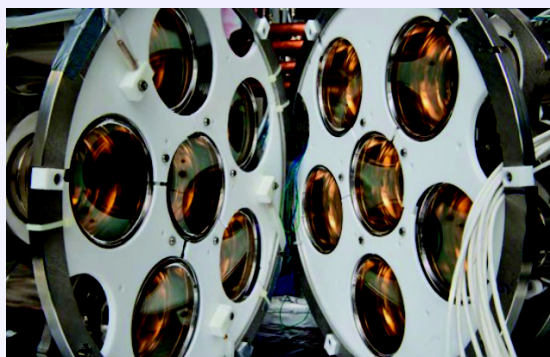


- 10 m high X 9.6m diameter
- Interior lined with 3M specular reflector foil
- 84 high QE 8" Hamamatsu PMTs R5912
- Muon induced neutron background $< 0.01\text{evt/yr}$
- Trigger efficiency $> 99.5\%$ for neutrons with muons in water tank, $\sim 78\%$ with muons outside
- Construction done in December 2013

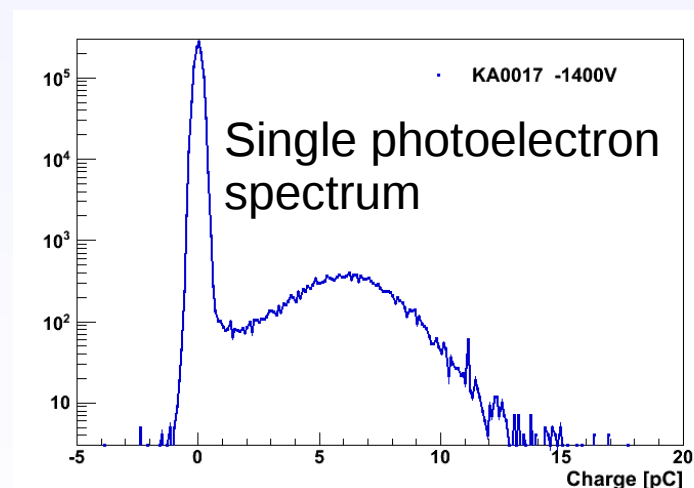
E. Aprile et al. (XENON Collaboration), JINST 9, P11006 (2014)

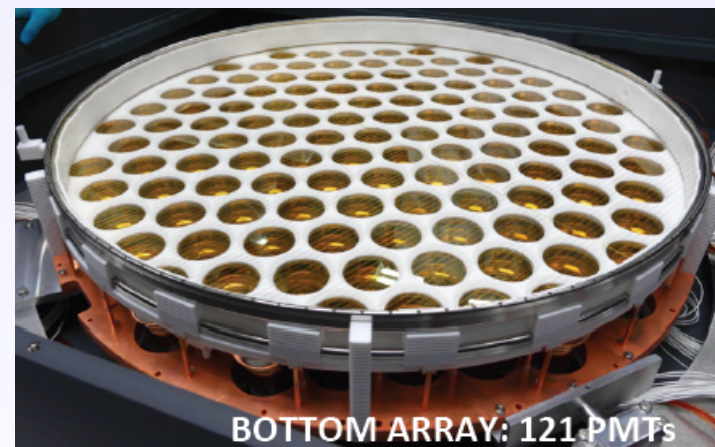
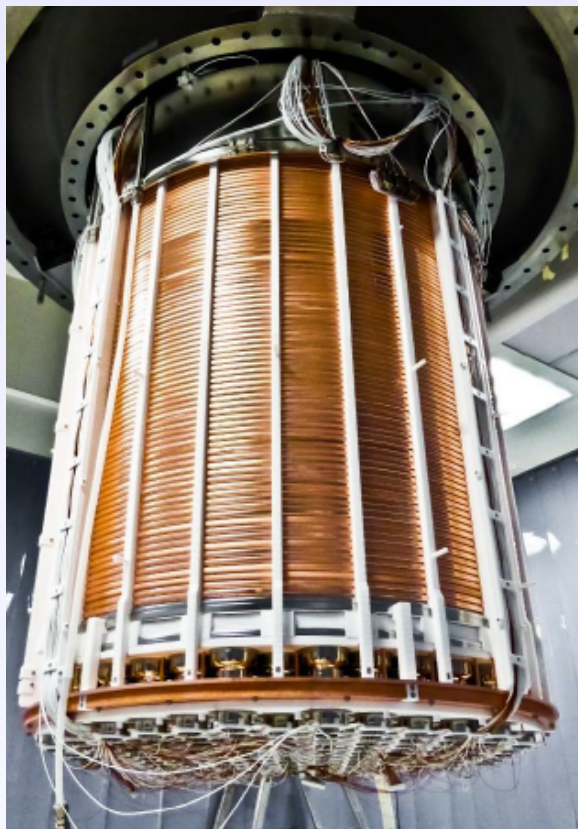
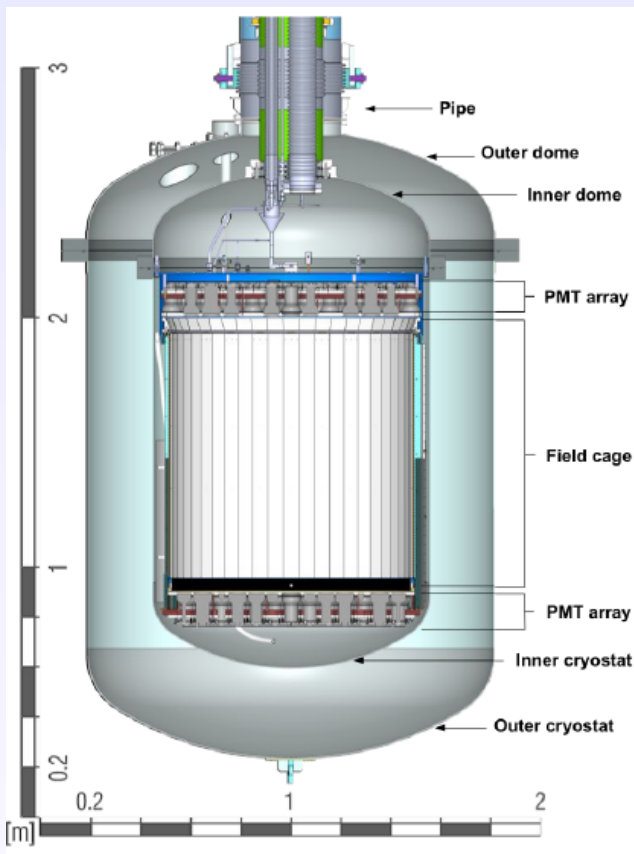


- 3" Hamamatsu R11410
- Custom designed for low radioactivity
- 34% QE @ 175 nm
- Low T tests and characterization prior to installation
- In situ calibration



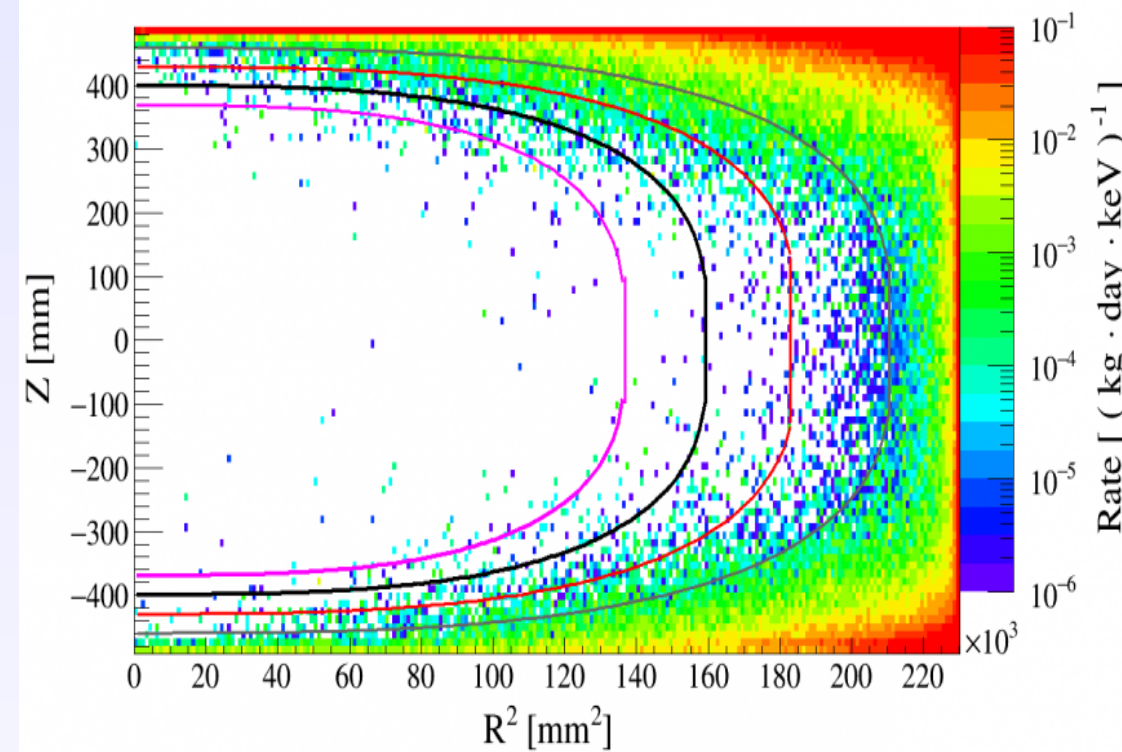
XENON Collaboration (E. Aprile et al.). Mar 26, 2015. 10 pp. Eur. Phys. J. C75 (2015) 11, 546





- Largest DM detector ever built!
- Filled with LXe since April 2016
- 248 PMTs
- 96 cm drift X 96 cm diameter
- High reflectivity teflon walls

- TPC now operational!
- In conjunction with commissioning of remaining systems



Impurities in the xenon:

- ^{222}Rn
 - Minimize leakage into system
 - Orbital welds, metal seals, hermetically sealed pumps
 - Low Rn emanation materials
 - Dedicated emanation measurements
- ^{85}Kr
 - Custom distillation column
 - Reduce to $\text{Kr/Xe} < 10^{-14}$

Source	Background [y^{-1}]	Fraction [%]
Materials	30 ± 3	4.1
^{222}Rn	620 ± 60	85.4
^{85}Kr	31 ± 6	4.3
^{136}Xe	9 ± 1	1.4
Solar neutrinos	36 ± 1	4.9
Total	720 ± 60	100

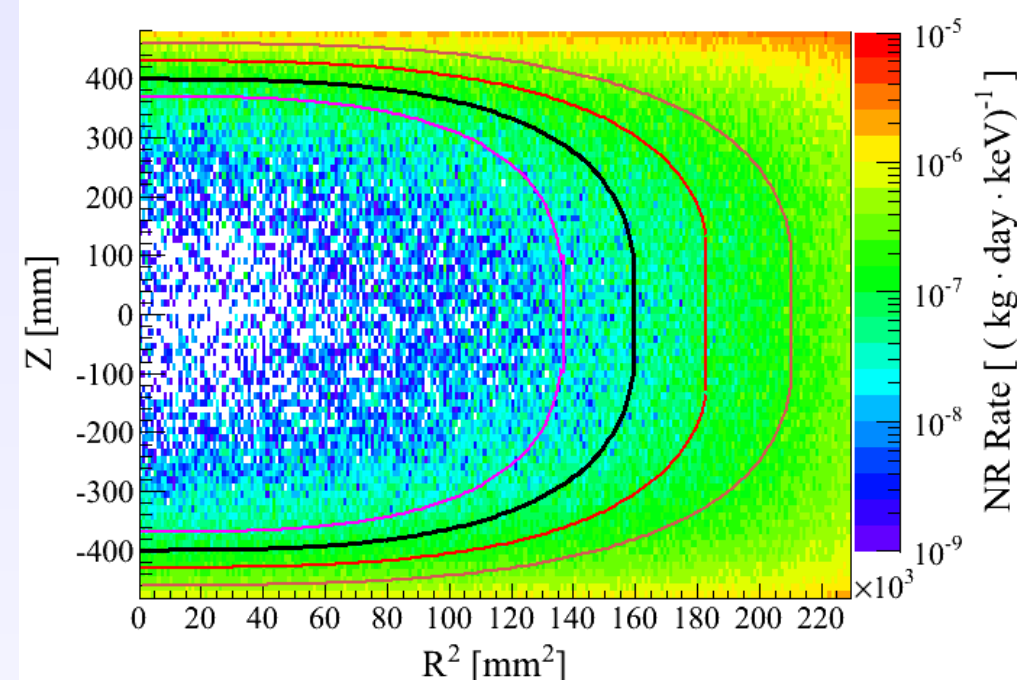
2 – 12 keVee, 1t fiducial, before ER discrimination

Materials:

- 60% from cryostat
- 25% from PMTs and bases
- 15% from TPC stainless steel
- 1% from copper and PTFE

Eur. Phys. J. C (2015) 75: 546.
XENON Collaboration, JCAP04 (2016)027.

XENON Collaboration, JCAP04 (2016)027.



Source	Count [$t^{-1}y^{-1}$]
Radiogenic	0.5 ± 0.1
Muon	<0.01
Neutrino	$(1.1 \pm 0.2) \times 10^{-2}$
Total	<1

5-50 keVr, 1T fiducial, before ER discrimination

Radiogenic neutrons:

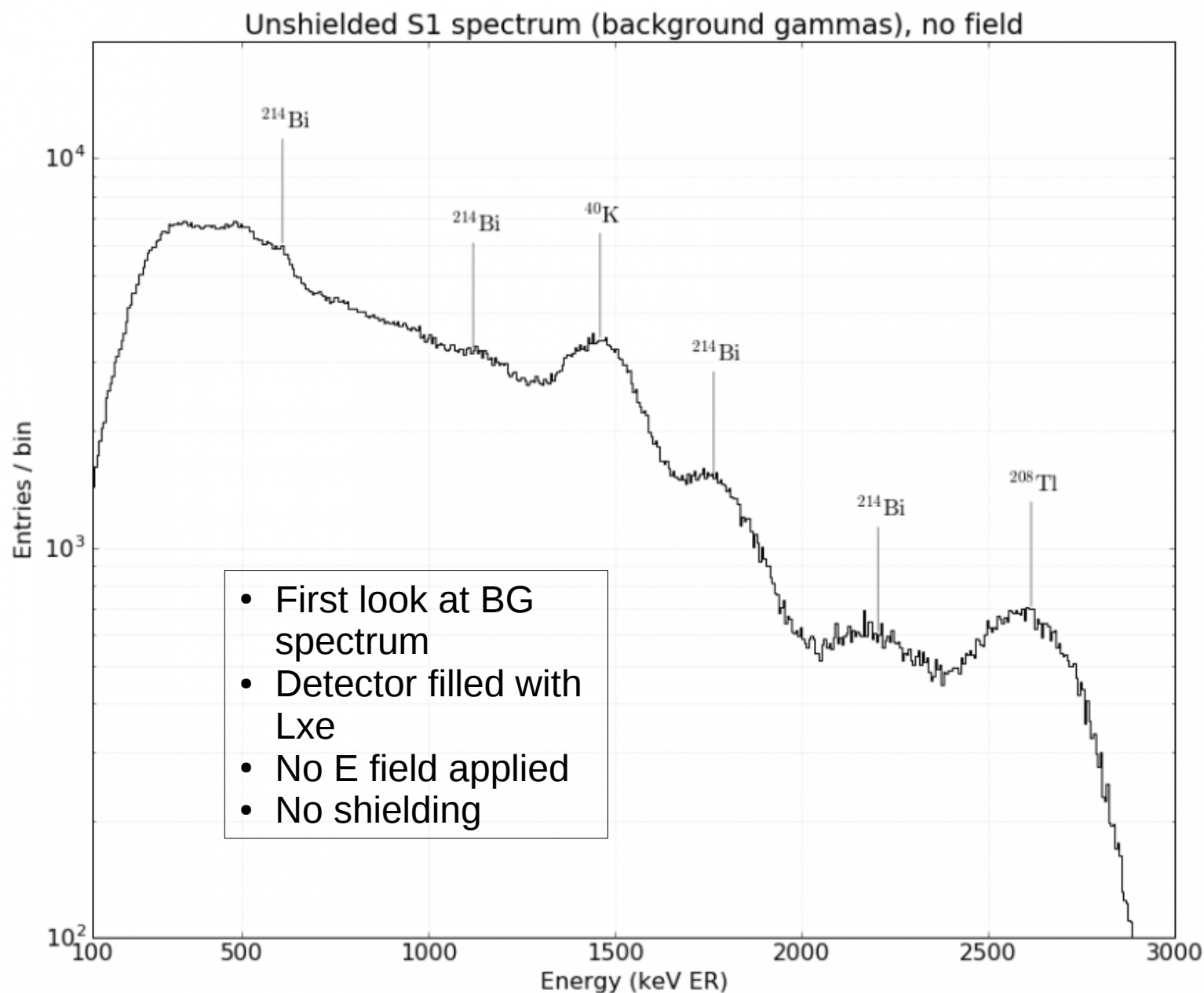
- (α, n) reactions from U and Th chains and spontaneous fission
- Single scatters look like WIMP signal
- Reduction via careful material selection and minimization of material

Muon induced neutrons:

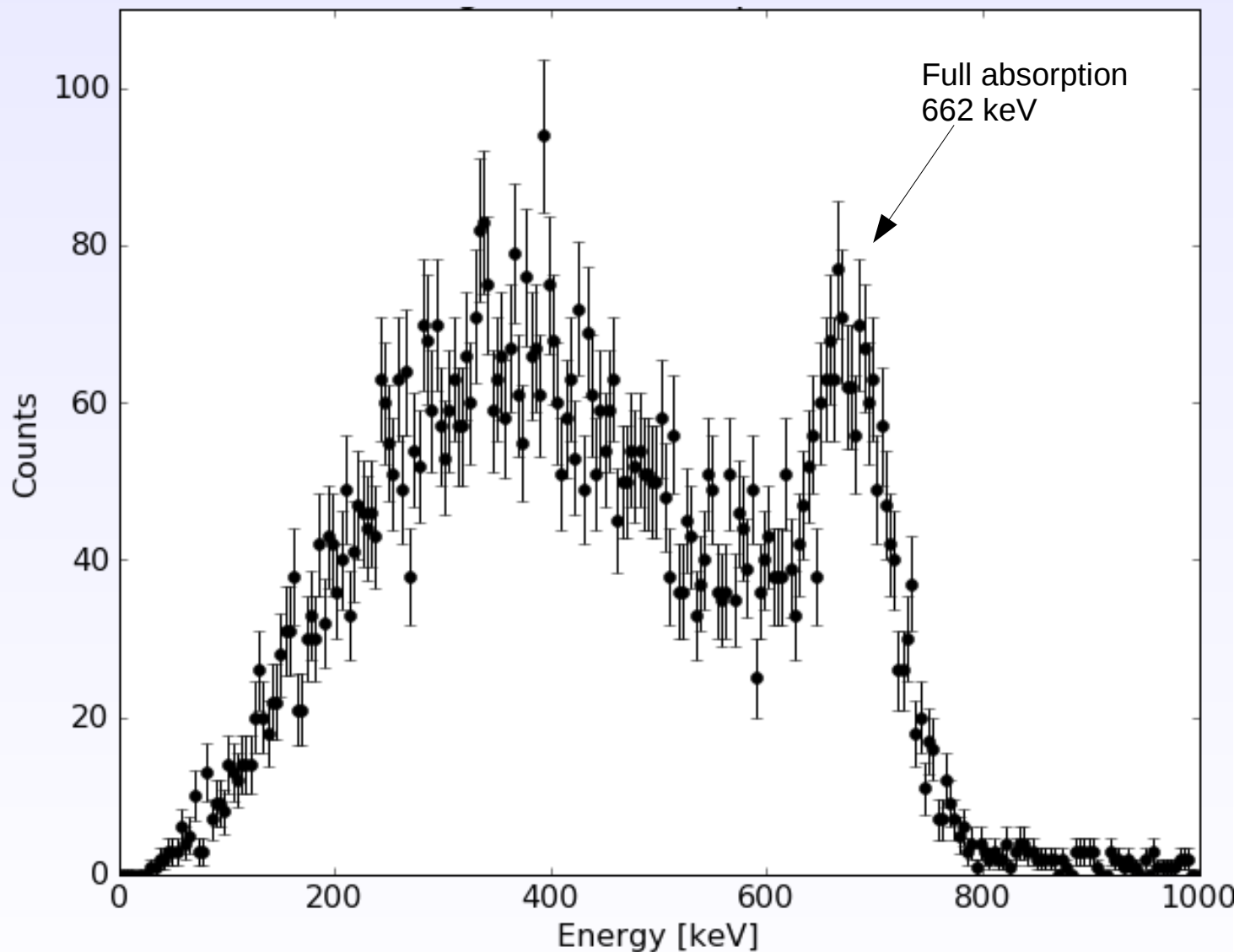
- Muon interactions in rock and detector
- Active muon veto
 - $> 95\%$ tagging efficiency for muons crossing veto
 - $> 70\%$ tagging efficiency for only showers in veto

Coherent neutrino scattering:

- Nearly no contribution above 5 keV threshold
- Decreased threshold will allow “new physics channel”

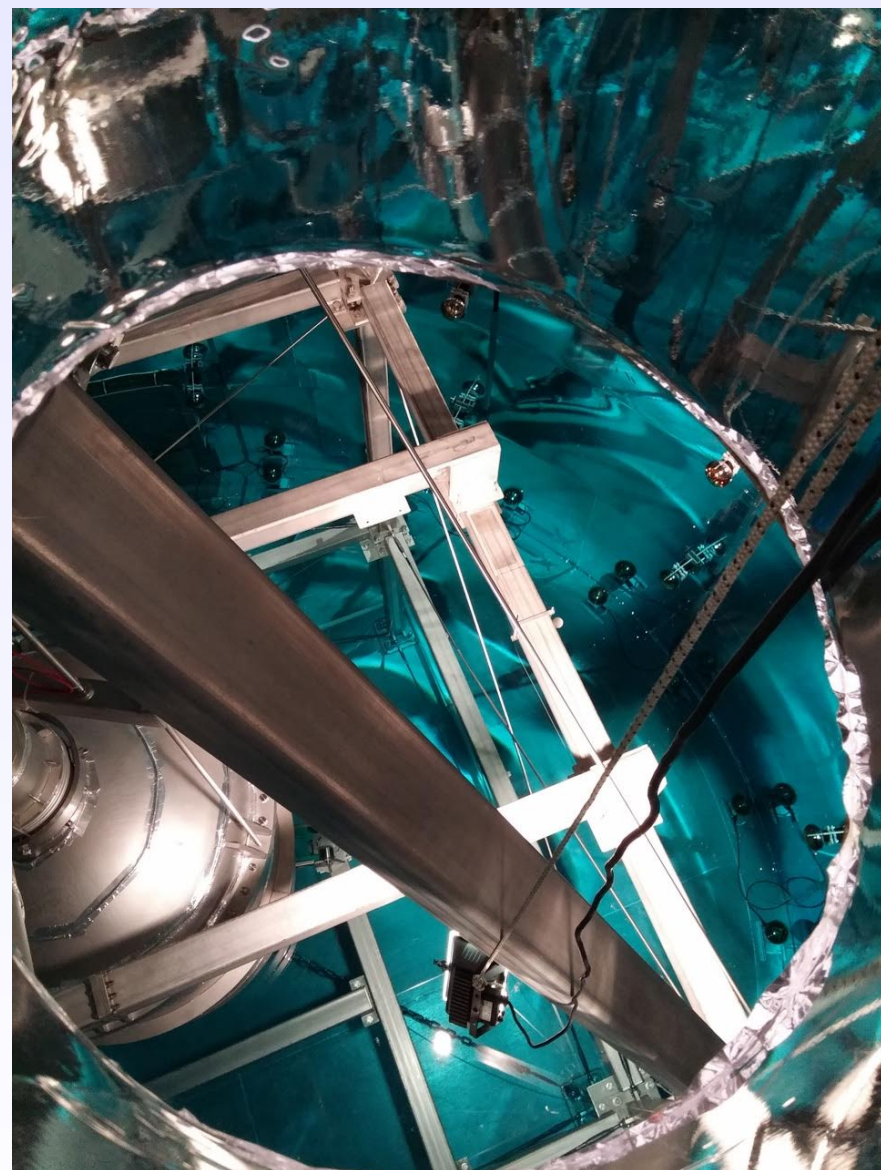
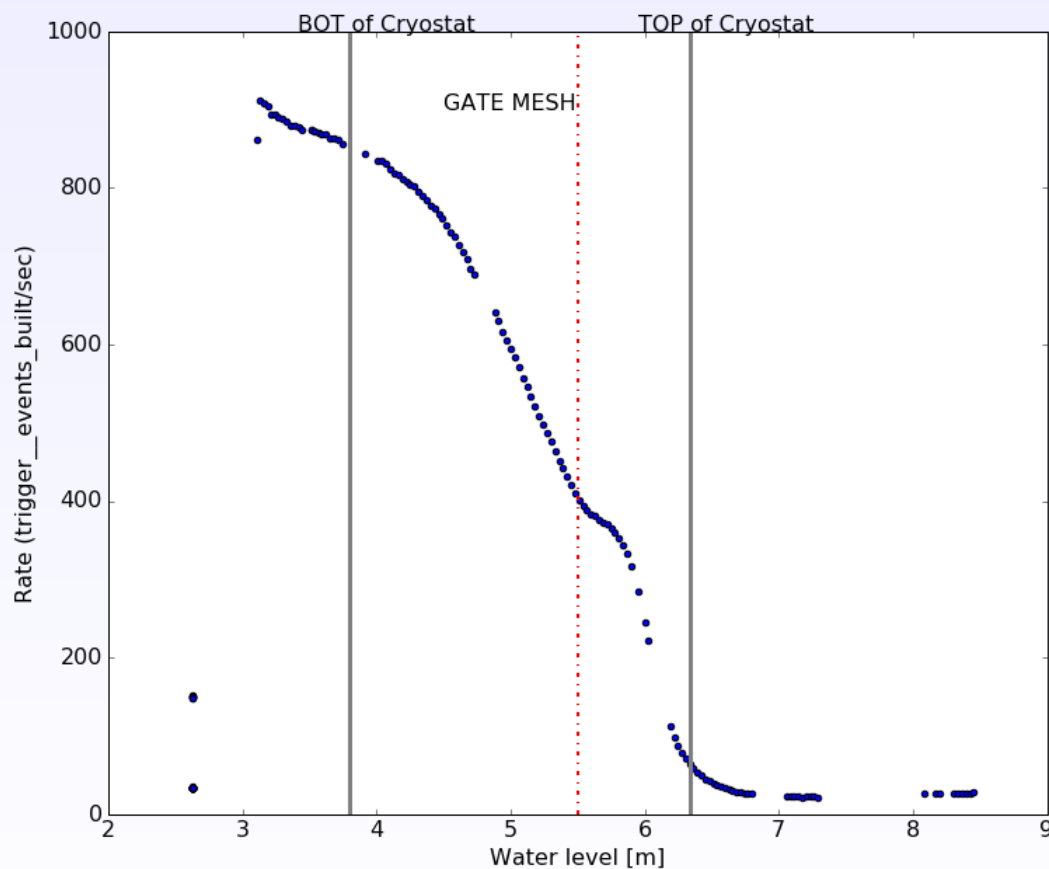


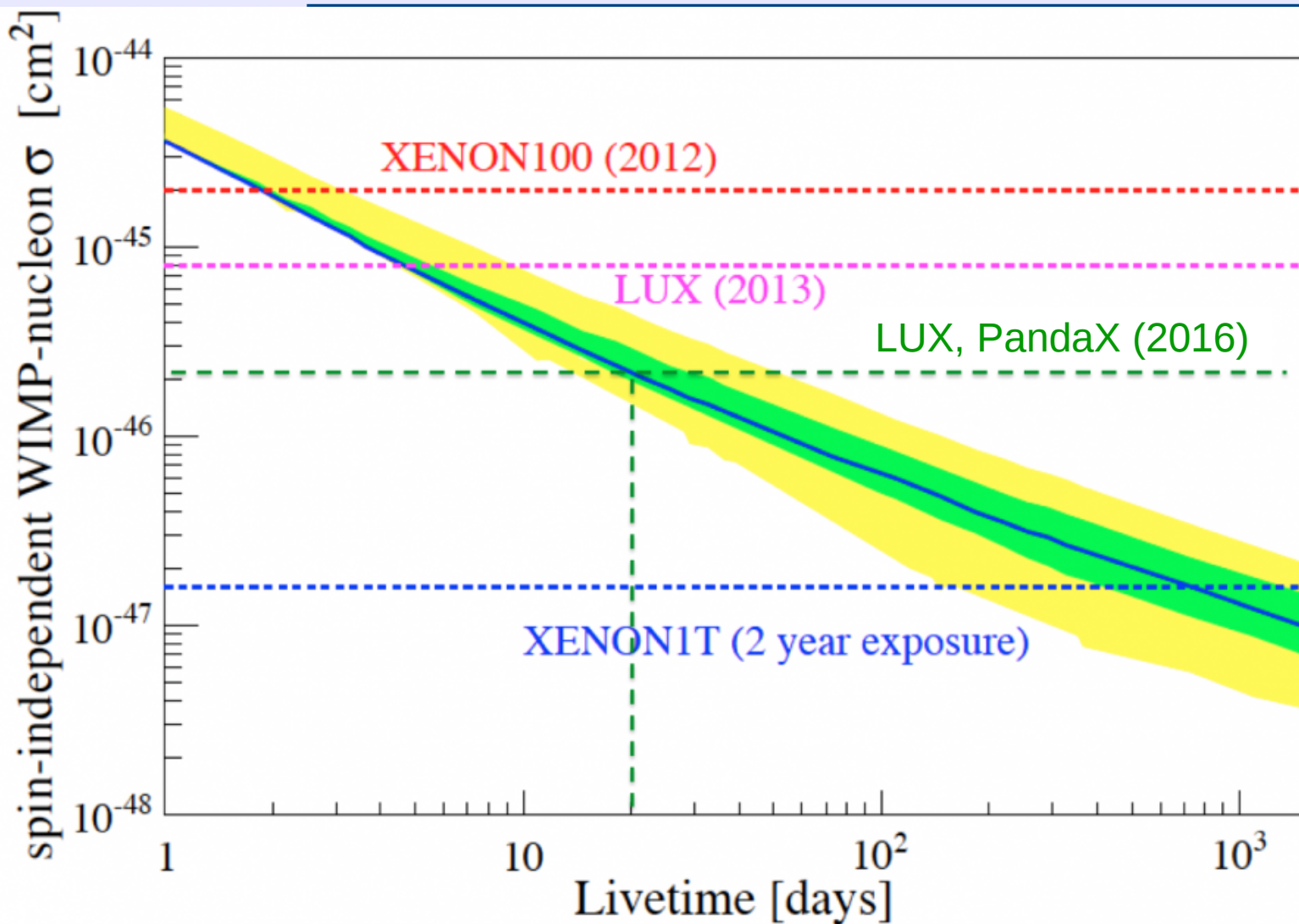
- External ^{137}Cs source
- Detector unshielded!
- Full absorption peak clearly separable
- First look at combined S1 + S2 energy scale
- Corrected for light collection and electron lifetime
- Already very impressive
- Will improve with shielding and better detector characterization



Muon veto now full of water

- Water goes up
- Rate goes down!
- Only shielding, no veto yet!



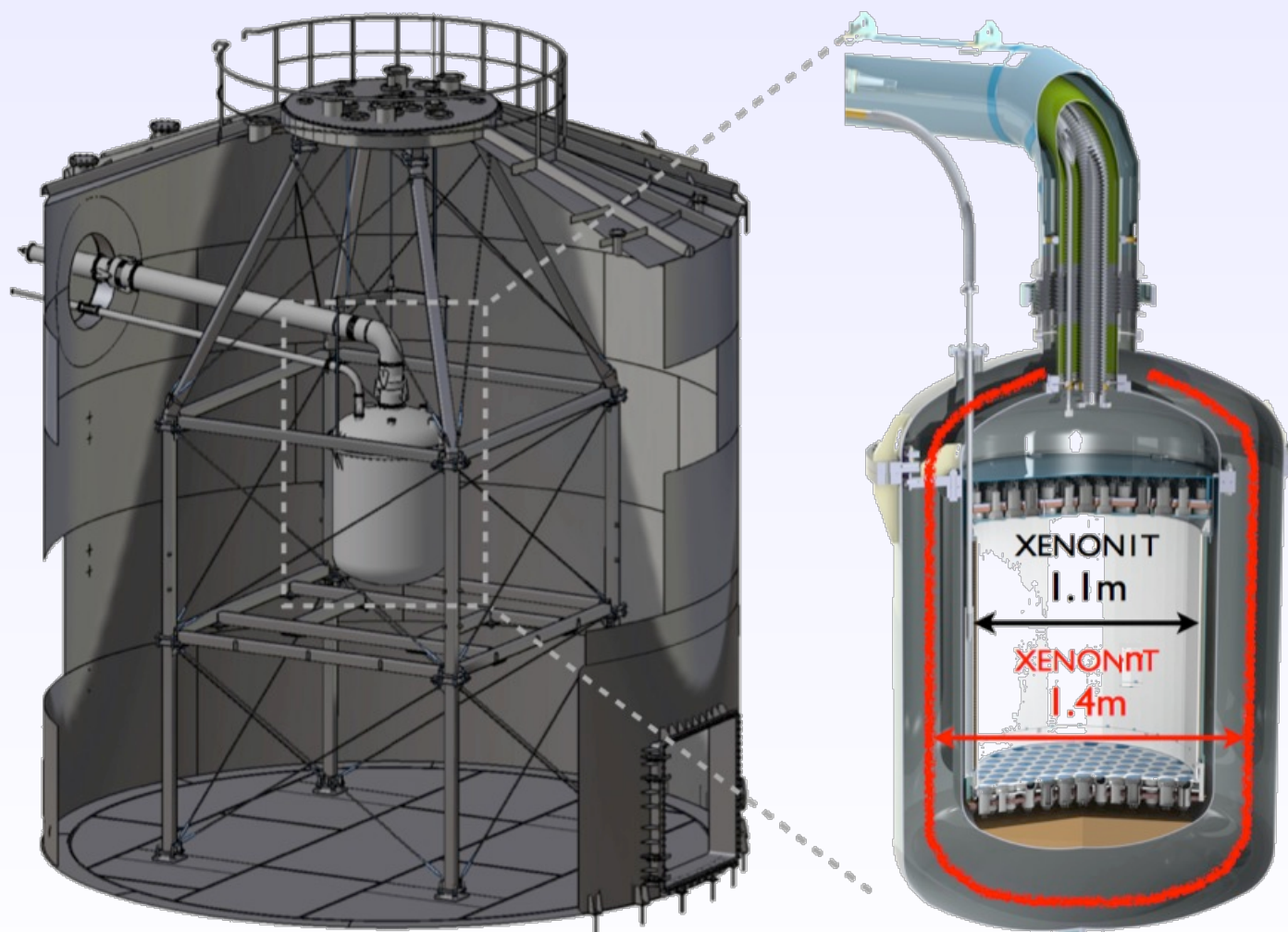


- Only need 20 days to reach LUX/PandaX sensitivity!
- Commissioning nearly complete
- Operations of TPC and other systems already underway

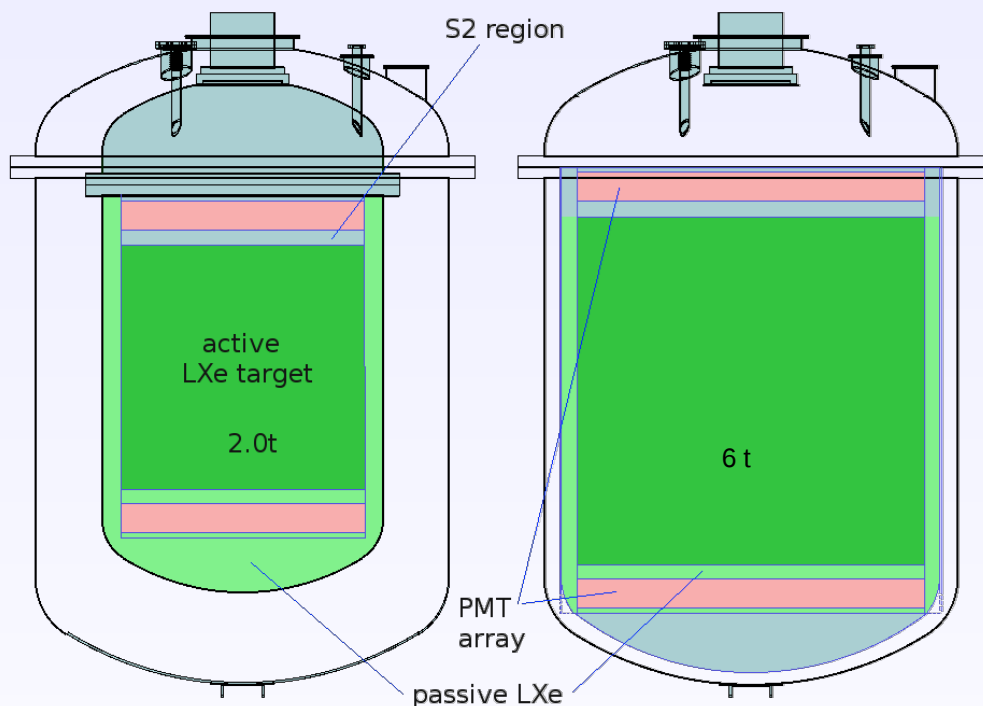
- $2.0 \times 10^{-47} \text{ cm}^2$
- @ 50 GeV WIMP
- 2 t-yr data

Upgrade: XENONnT

- Quick upgrade of TPC and inner cryostat
- All major systems remain unchanged
- Construct TPC in parallel to XENON1T operation
- Start data taking by 2019

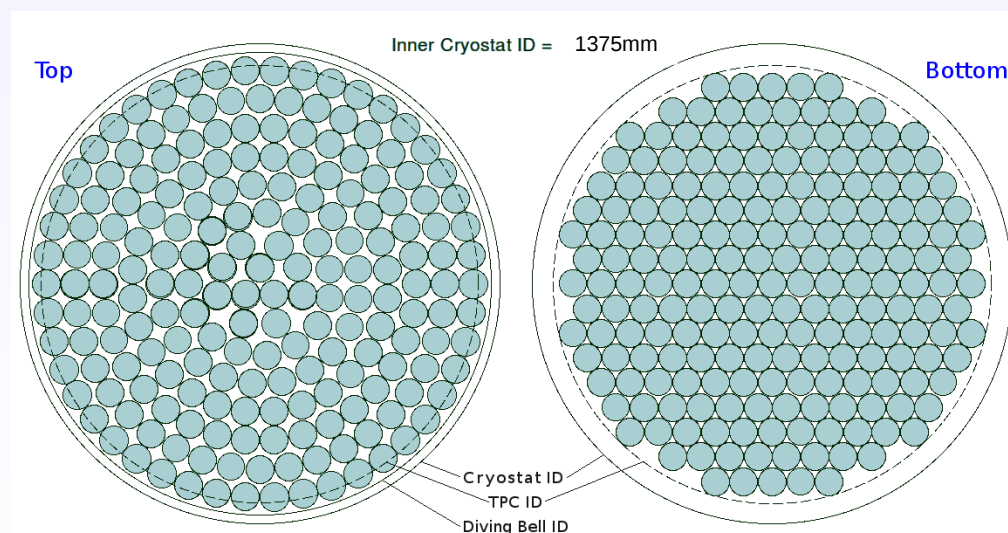


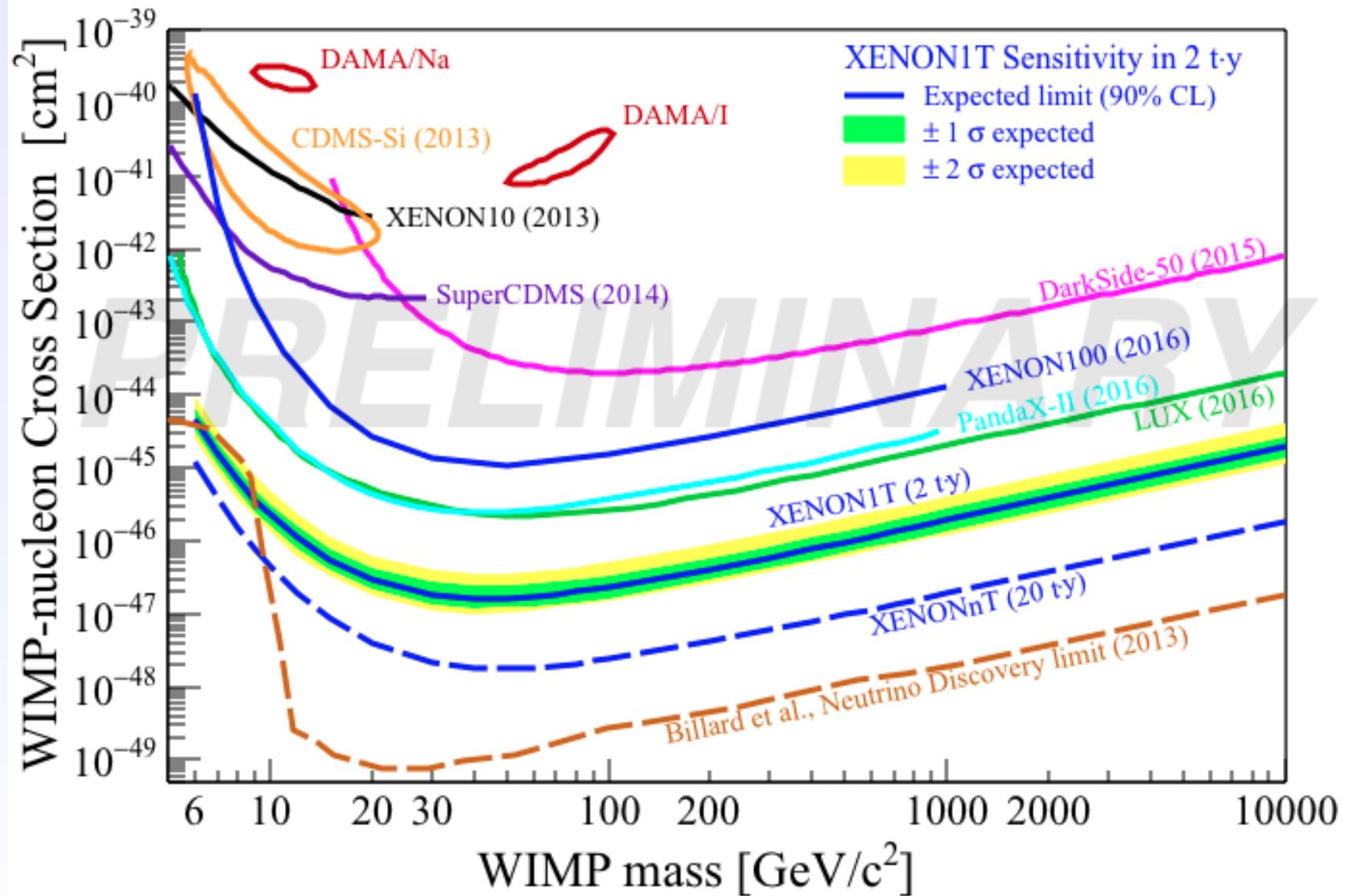
- New TPC dimensions
- Optimize target mass
- Fit inside existing cryostat



- Additional PMTs
 - Same Hamamatsu R11410
 - Reuse the XENON1T PMTs
 - ~500 total (250 top and bottom)
- Additional gas
 - 7.25 t needed (7.5 t including gas)
 - 3.7 t already in place
 - Acquisition ongoing

All other systems will be reused!





- $1.6 \times 10^{-48} \text{ cm}^2$ @ 50 GeV WIMP
- 20 t-yrs exposure

XENON100:

- Longest running LXe DM detector to date!
- New constraints of “exotic” DM models
- Axial vector coupling constrained
- Disagrees with DAMA @ $> 4\sigma$ for varied models

XENON1T:

- Commissioning nearly complete
- First DM data expected in 2016
- **20 days** to reach LUX/Panda X sensitivity
- 2 t-yr exposure $\rightarrow 1.6 \times 10^{-47} \text{ cm}^2 @ 50 \text{ GeV}$

XENONnT:

- Quick upgrade of TPC
- Designed/built in parallel to 1T operation
- DM run to begin by 2019
- 20 t-yr exposure $\rightarrow 1.6 \times 10^{-48} \text{ cm}^2 @ 50 \text{ GeV}$