Status of the XENON1T experiment

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on behalf of the XENON Collaboration

XXV European Cosmic Ray Symposium

4-9 September 2016 *Torino*
Europe/Rome timezone

The XENON Collaboration

10 countries, 21 institutions,130 scientists

Columbia

RPI

Nikhef

Mainz

Stockholm

Muenster

Chicago

MPIK

UCLA

Bern

UCSD

Zurich

Rice

NYUAD

Purdue

Coimbra

Subatech

Bologna

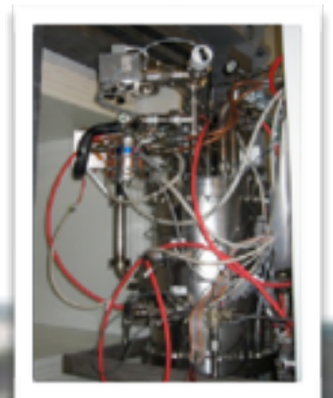
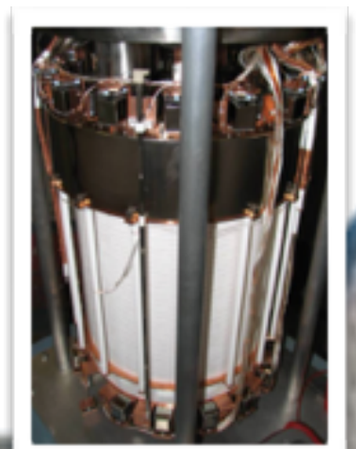
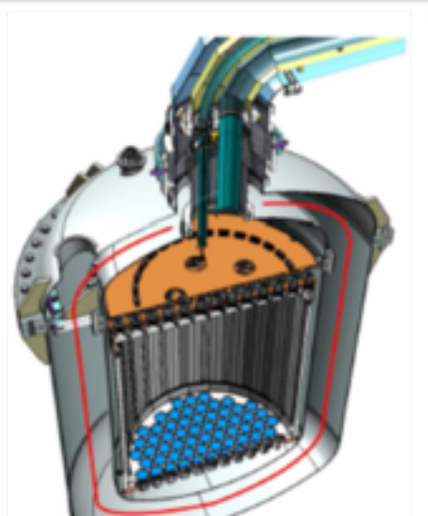
LNGS

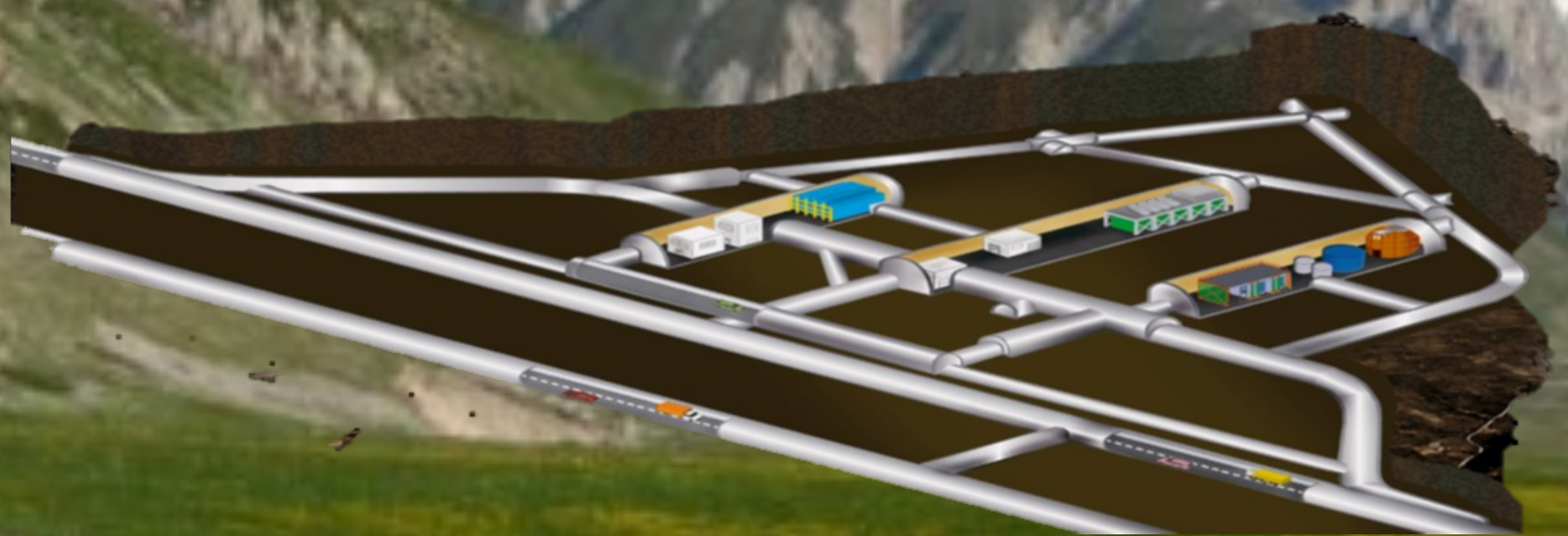
Torino

Weizmann

The XENON Program @ LNGS

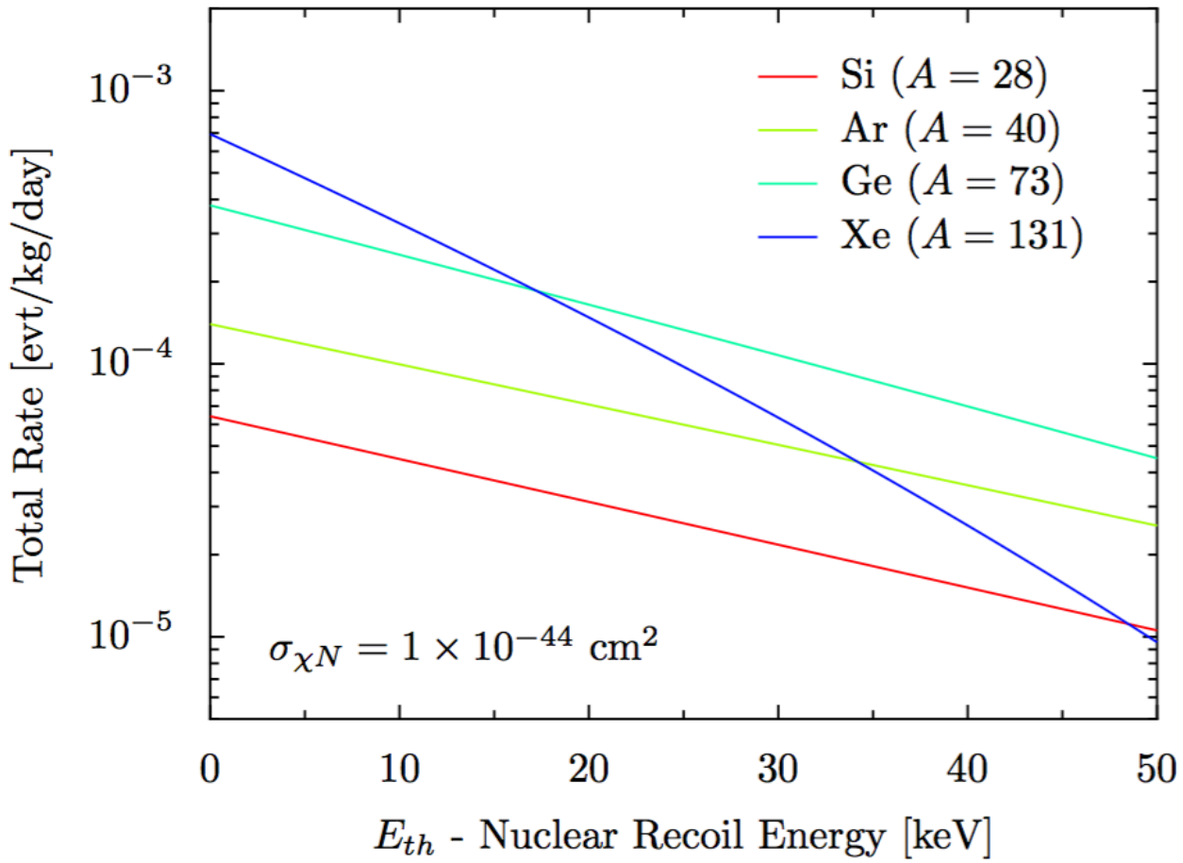
Direct Dark Matter Search using a dual phase Xenon TPC

XENON10 (2005~2007)	XENON100 (2008~2016)	XENON1T (2015-)	XENONnT (2018+)
Time →			
			
Target →			
Total: 25 kg Target: 14 kg Limit ~ 10^{-43} cm^2	Total: 161 kg Target: 62 kg Limit ~ 10^{-45} cm^2	Total: 3.2 t Target: 2 t Sensitivity ~ 10^{-47} cm^2	Total: ~ 8 t? Target: ~ 6 t? Sensitivity ~ 10^{-48} cm^2



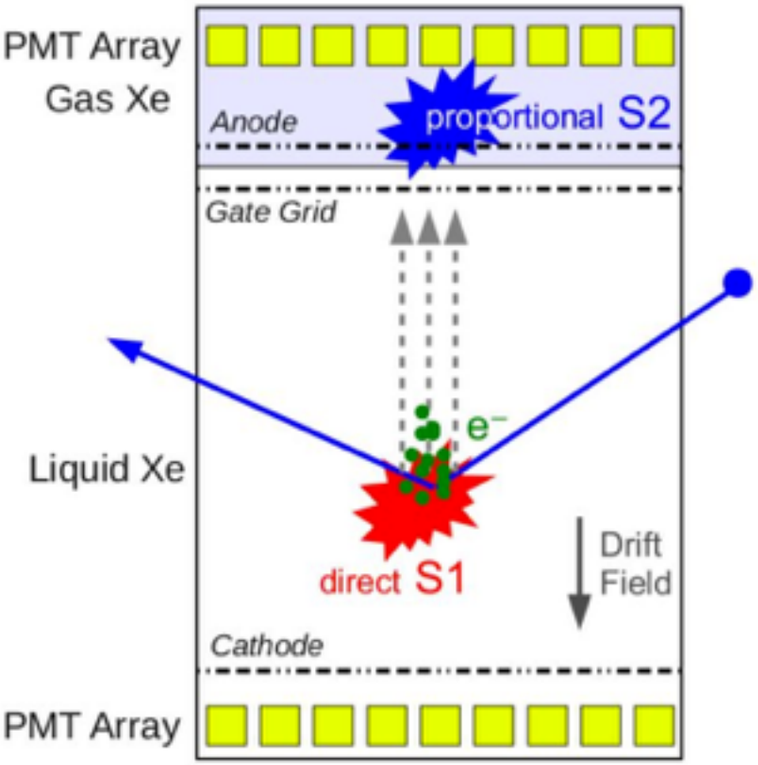
Why Xenon?

- ***Large mass number A (131) (Interaction cross section ∝ A^2)***
- ***50% odd isotopes (^{129}Xe, ^{131}Xe) for Spin-Dependent interactions***
- ***No long-lived radioisotopes, Kr can be reduced to ppt levels***
- ***High stopping power, i.e. active volume is self-shielding***
- ***Efficient scintillator (178 nm)***
- ***Scalable to large target masses***
- ***Electronic recoil discrimination with simultaneous measurement of scintillation and ionization***

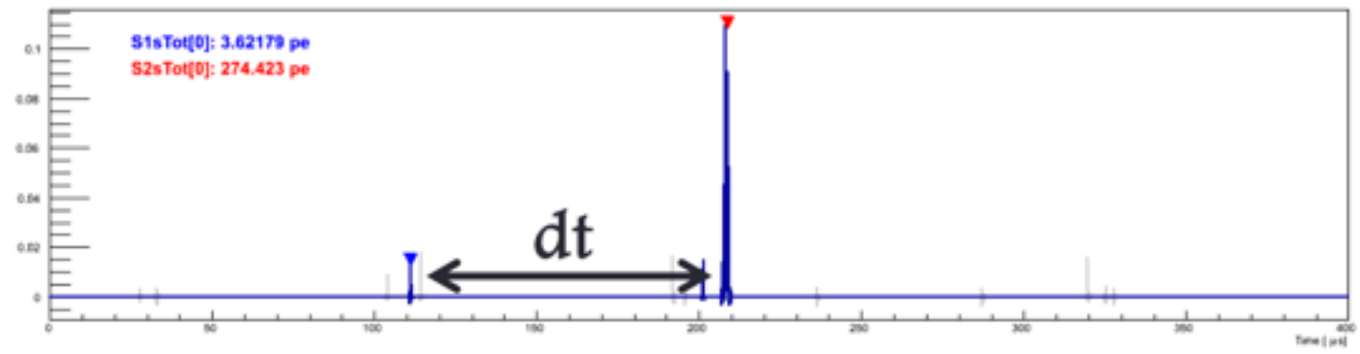


How we use Xenon

Interaction in the Liquid Xenon

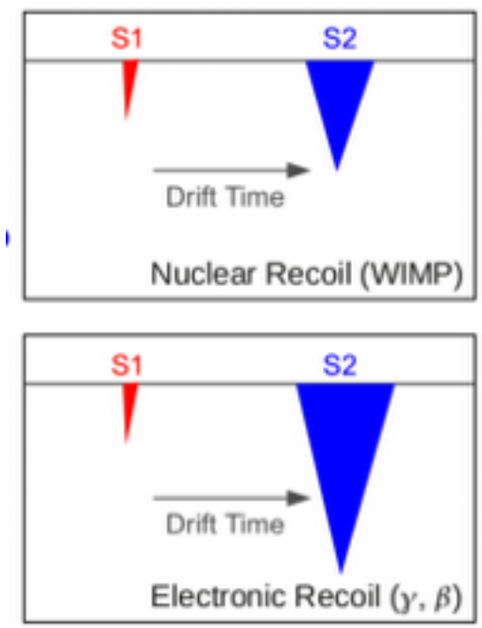


- ✅ *Scintillation signals (S1)*
- ✅ *Ionisation signals (S2)*
- ✅ *The time between them → z coordinate*
- ✅ *Pattern on PMTs array → x-y coordinates*



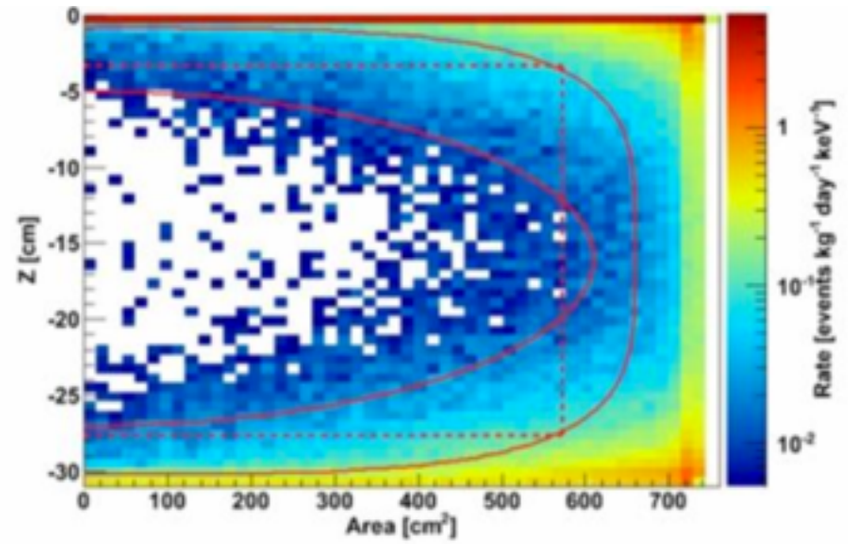
Particle Identification

$(S2/S1)_{wimp} < (S2/S1)_{ER}$



+

Vertex identification



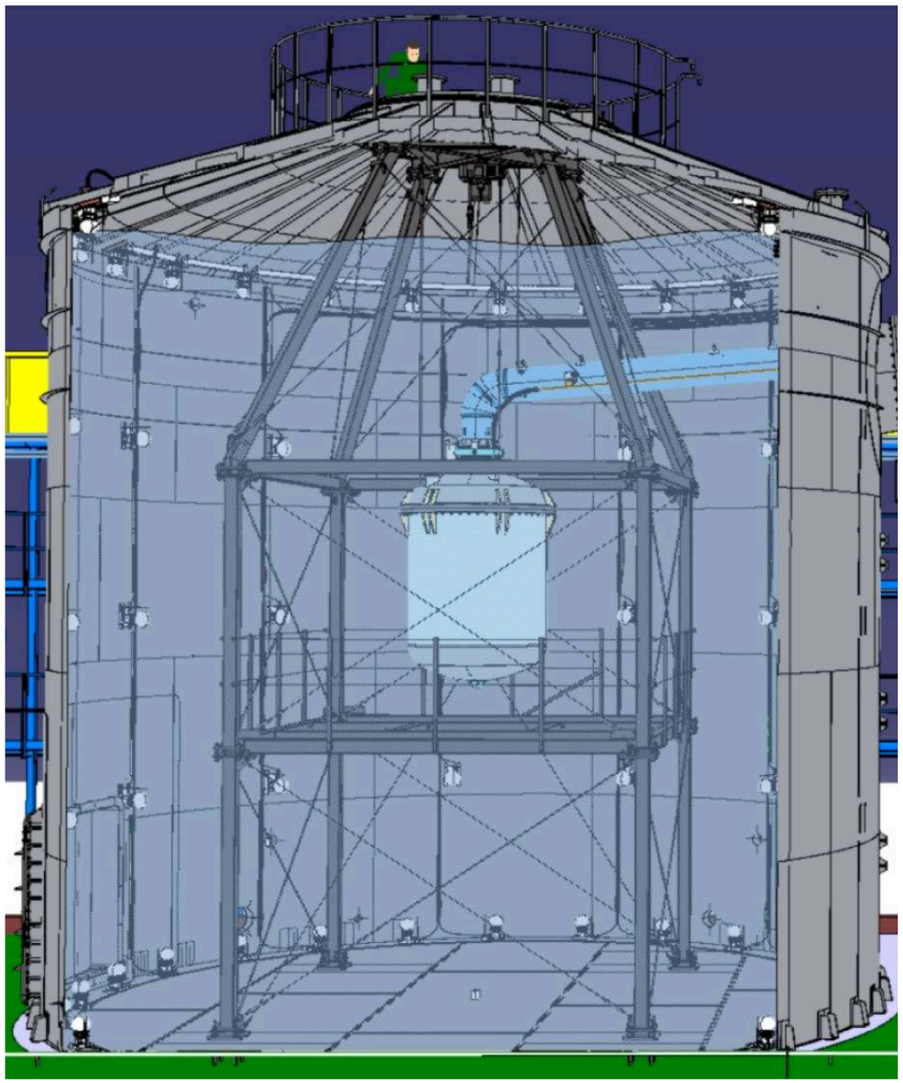
XENON1T

First ton scale Xe dual phase TPC for direct dark matter search

- Total Xe mass: 3.2 t
- Active Xe in the TPC: 2 t, readout by 248 PMTs
- Water Cherenkov muon veto
- Cooling/purification/distillation/storage systems designed to handle up to 10 tonne of Xe. Upgrade to a larger detector (XENONnT) planned for 2018
- Expected sensitivity 1.6×10^{-47} cm^2 @ 50 GeV WIMP 2ty (100 times more sensitive than XENON100)

The XENON1T

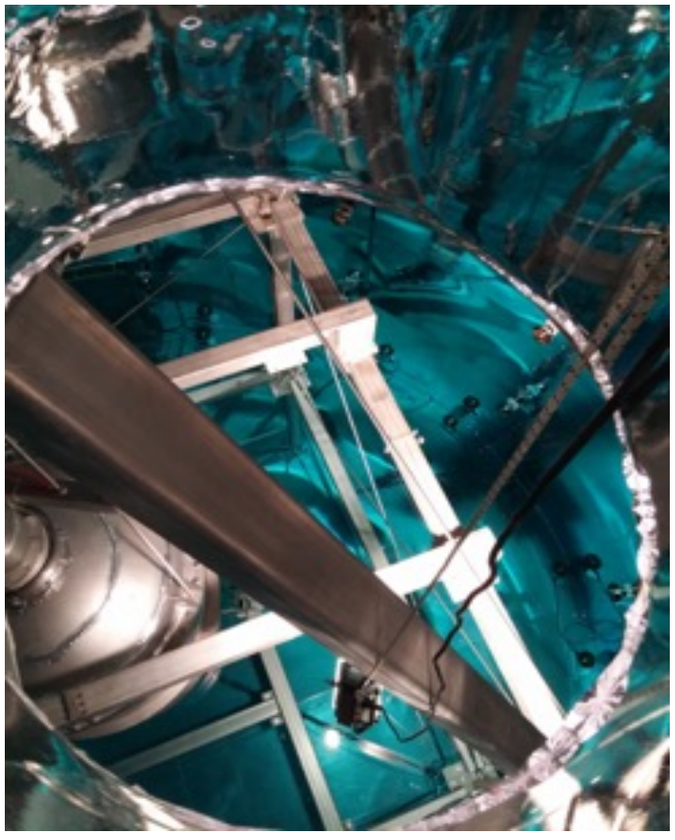
Water Tank with Muon Veto & XENON1T Detector



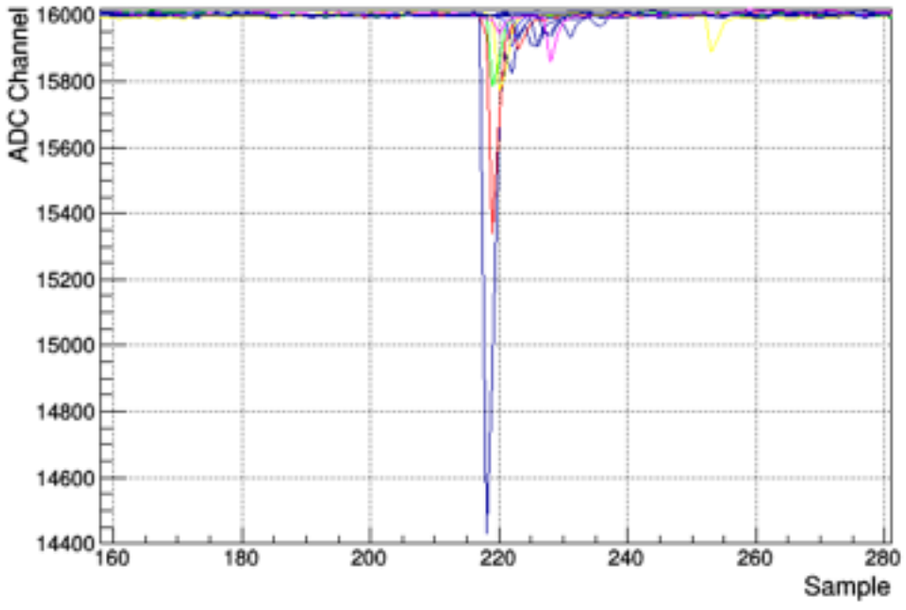
Water Shield & Muon Veto

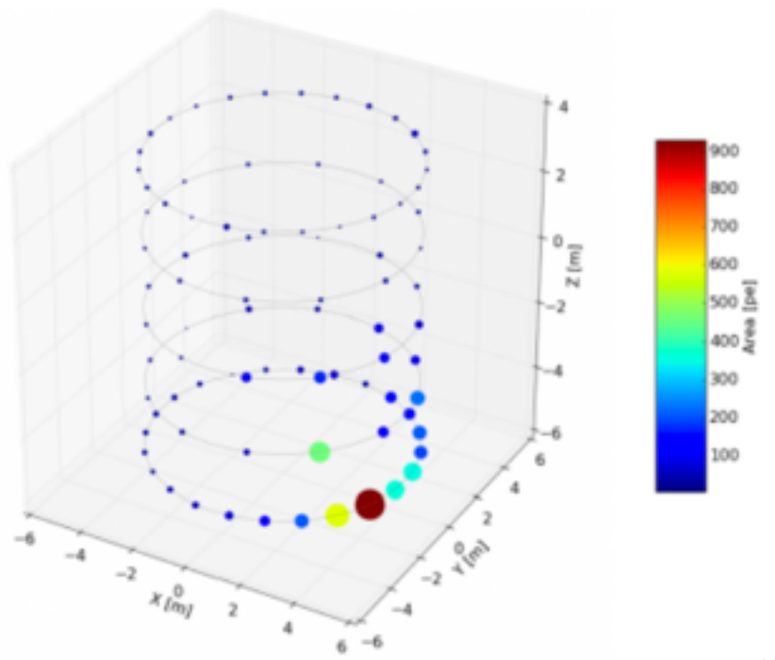
- The XENON1T cryostat is immersed in a tank filled with 700 tonnes of pure water
- Reflective film foil on inner surface
- Instrumented with 84 high-QE, 8” PMTs to detect Cherenkov light
- cosmogenic-induced background <0.01 events/y
- The muon veto has been commissioned in March 2016.

E. Aprile et al., JINST 9 (2014) 11006

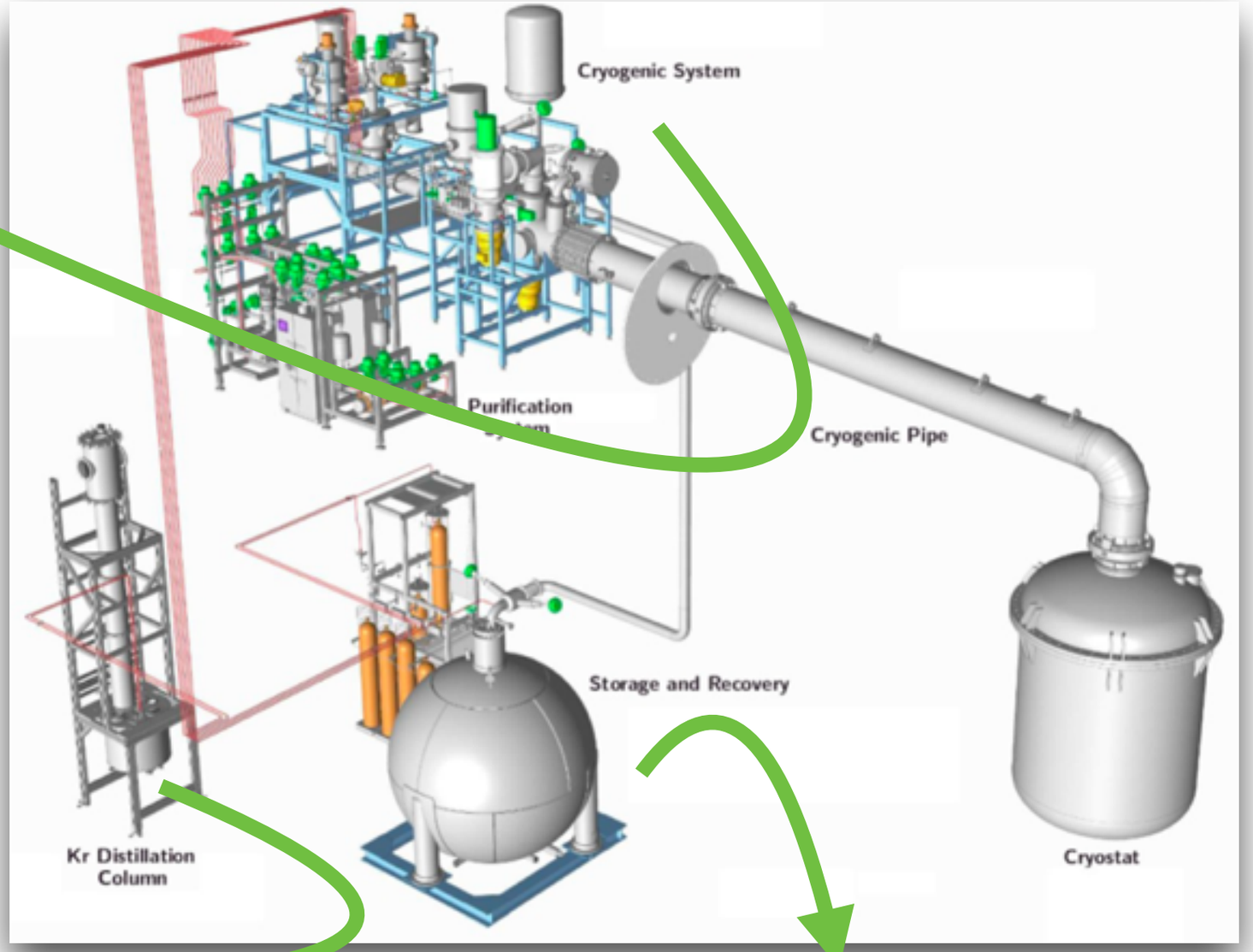


First Muons





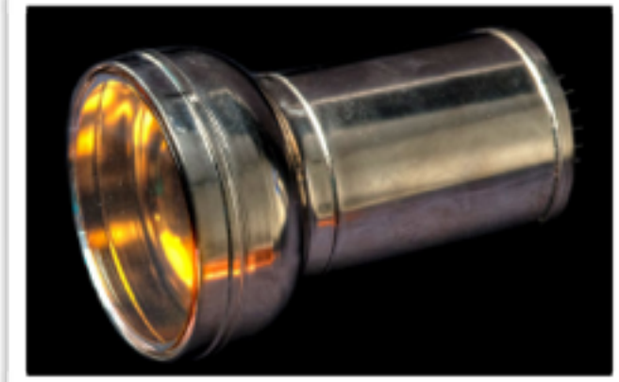
Cryo/Storage/Purification



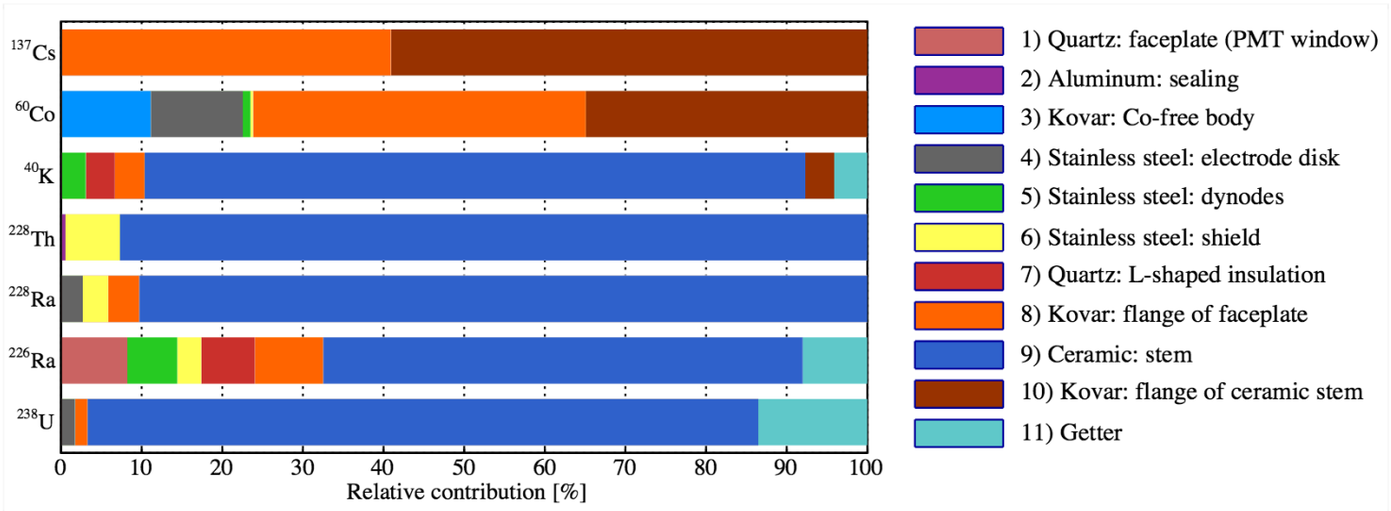
Xenon Handling System commissioned
Both for XENON1T & XENONnT

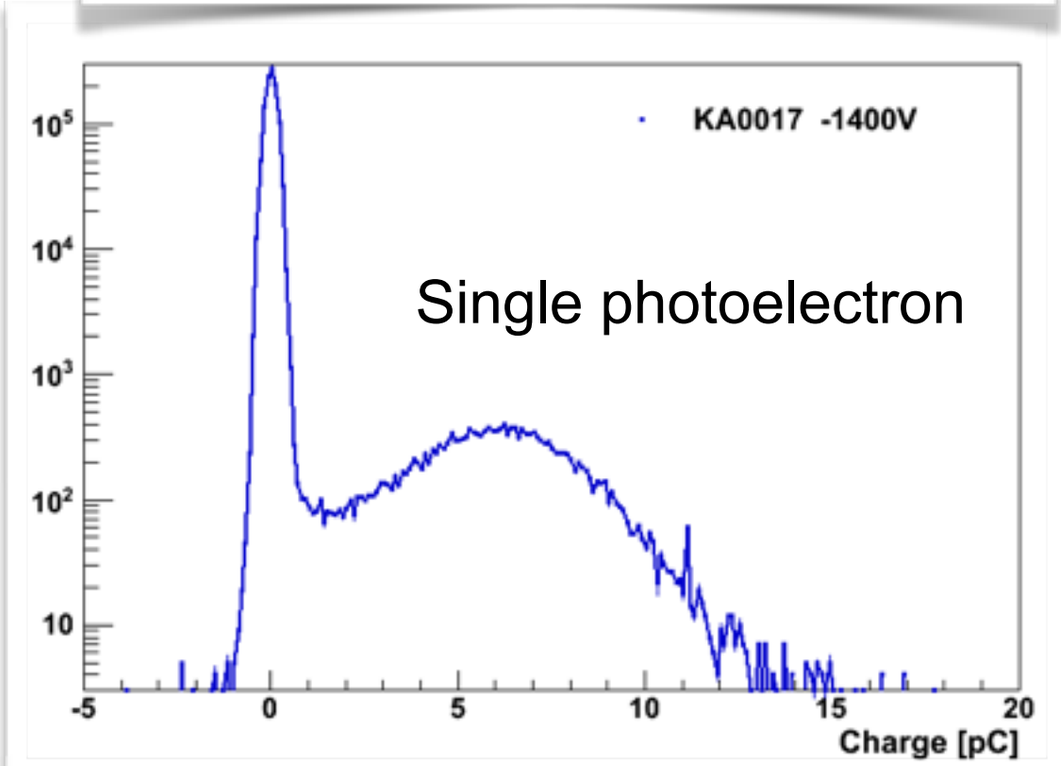
PMTs

✦248 PMTs: 3” Hamamatsu R11410



✦Custom designed for low radioactivity
34.5% average QE @ 175 nm





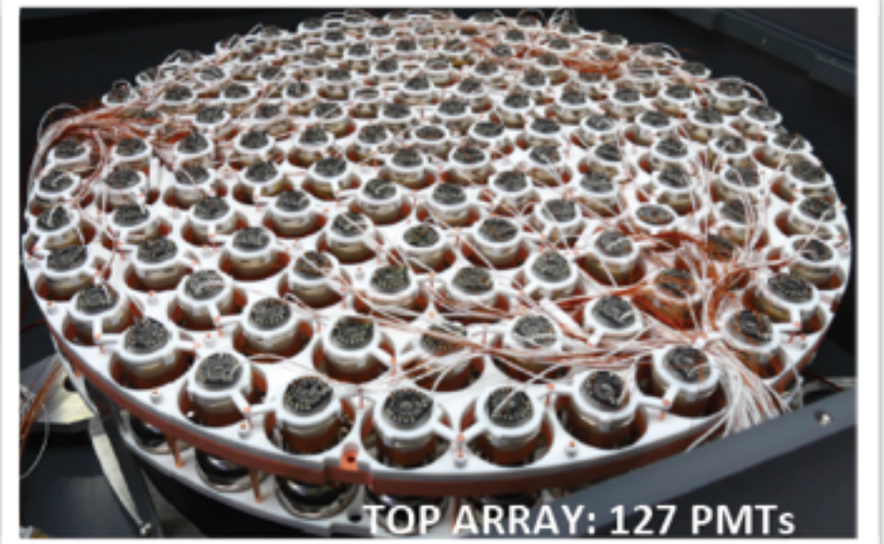
✦ Low T tests and characterisation prior to installation

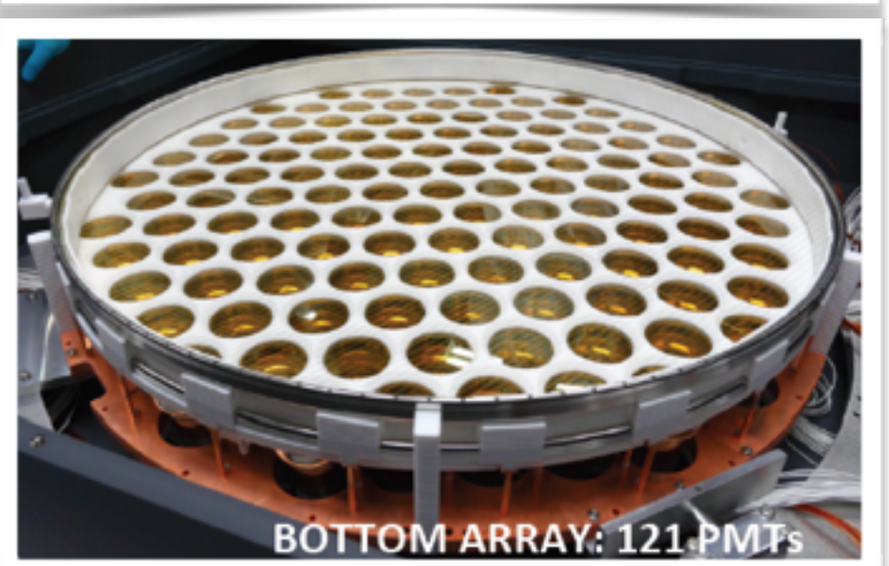
✦In situ calibration

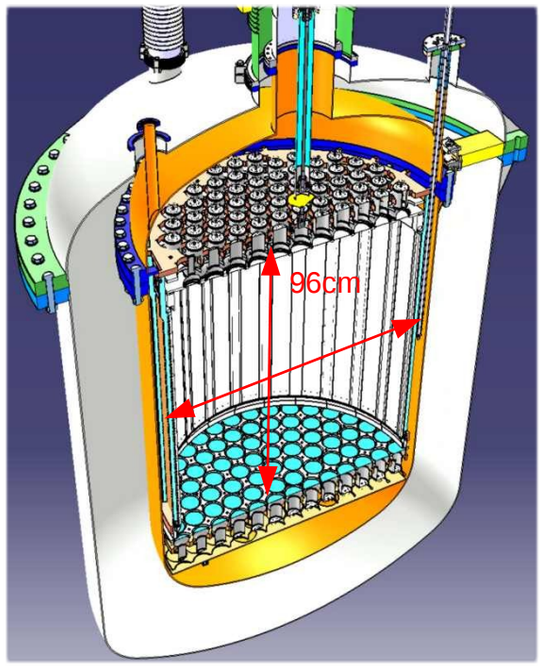
E. Aprile et al., Eur. Phys. J. C75 (2015) 11, 546

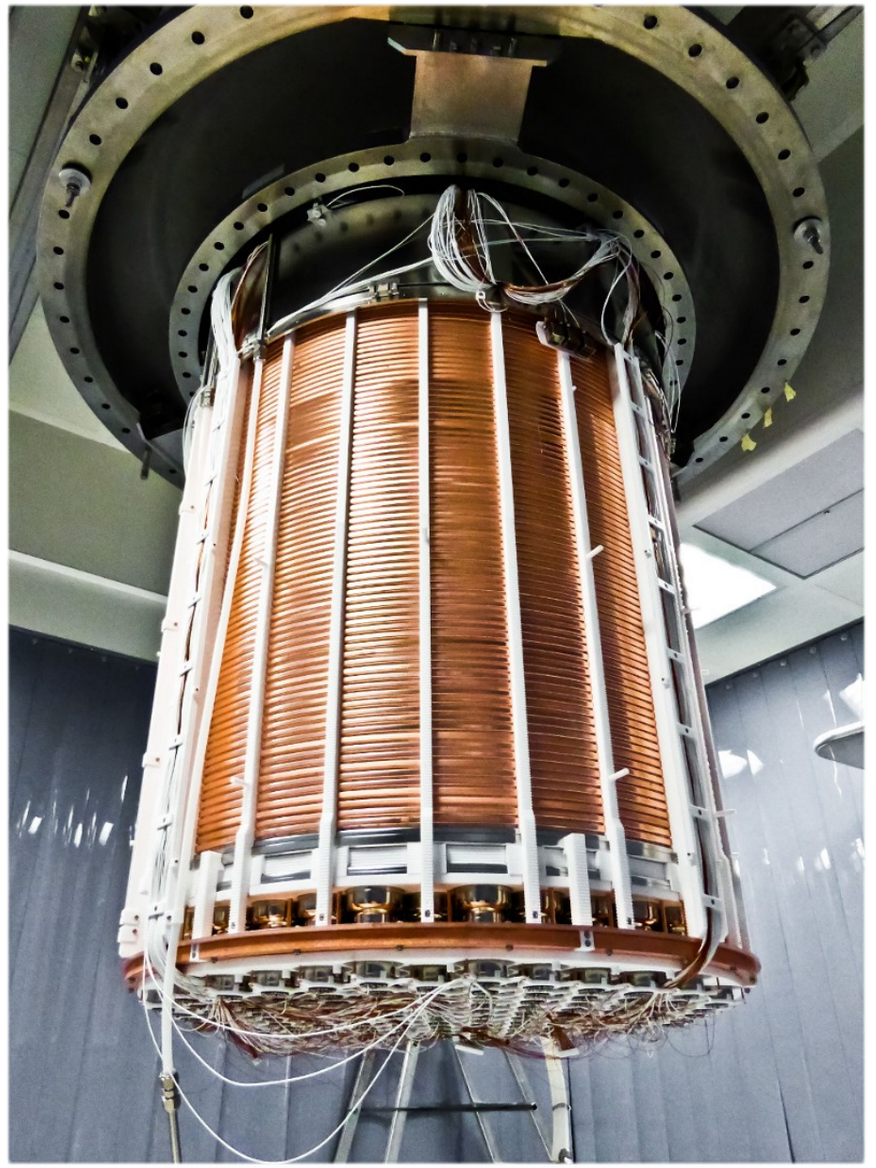
The TPC

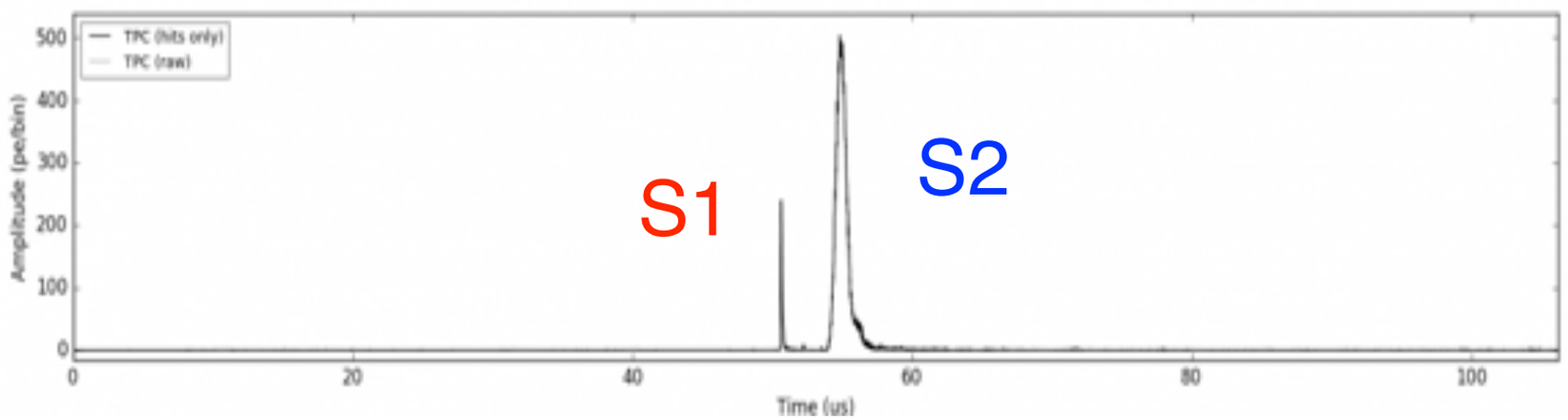
- **96 cm drift x 96 cm diameter TPC**
- **Filled with 2 t of high-purity Xenon (active liquid target)**
- **248 low radioactivity PMTs**



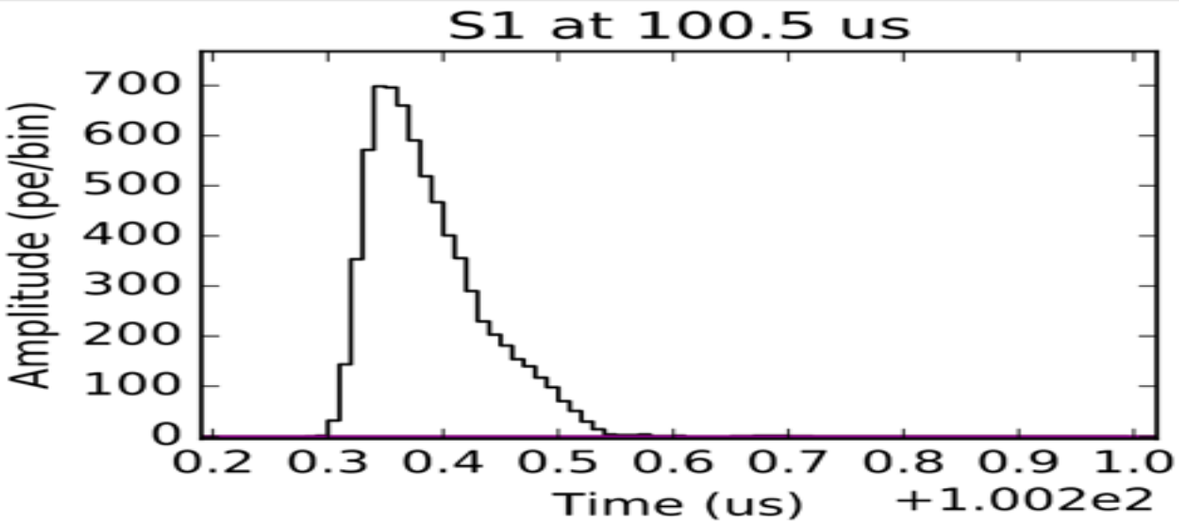


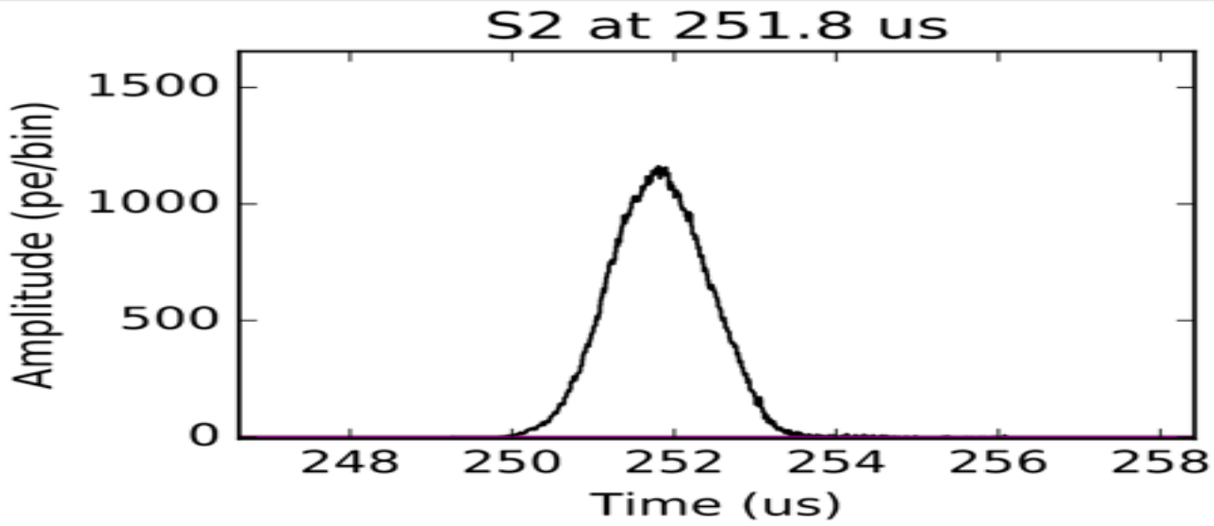


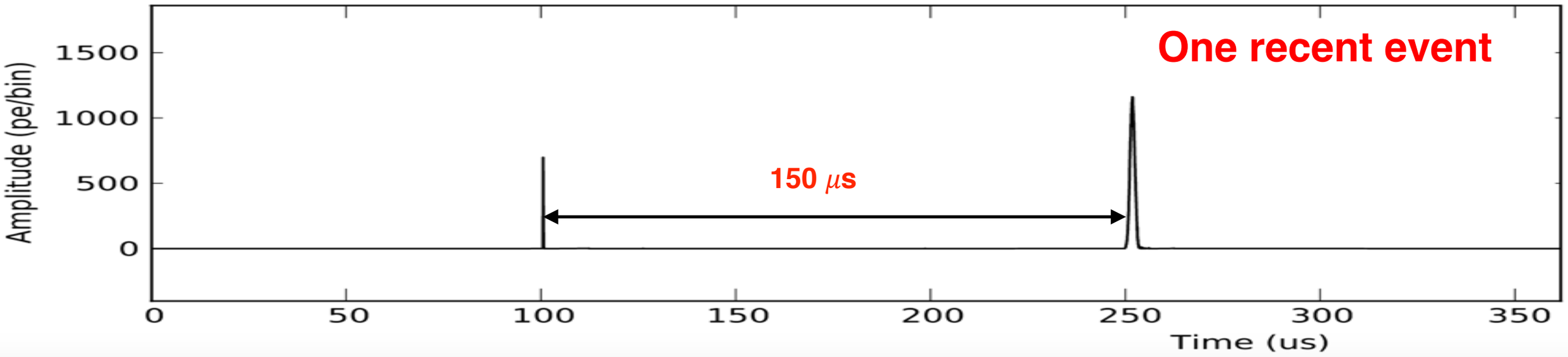




Commissioning ongoing





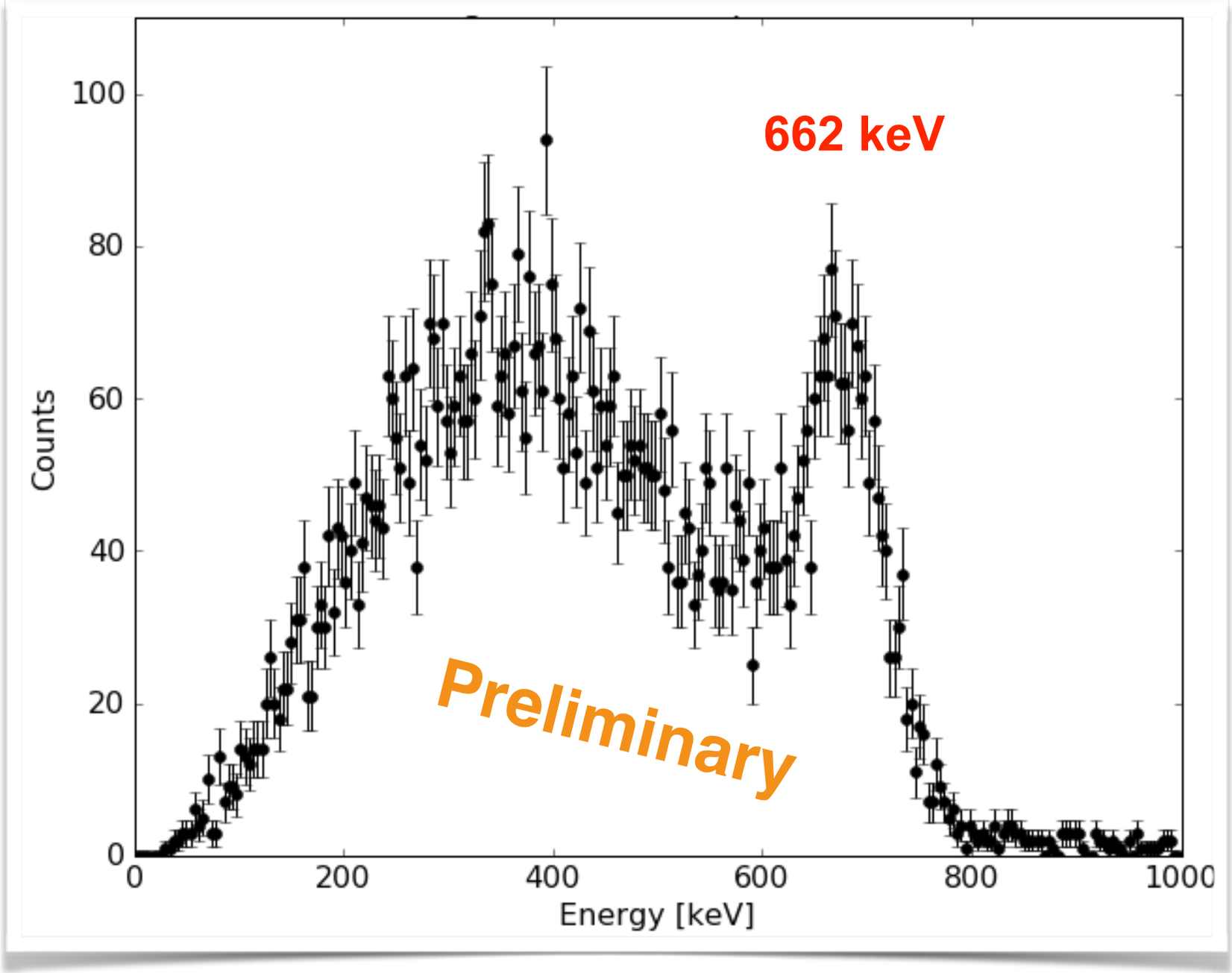


- ✦The XENON1T Time Projection Chamber and associated cryogenic system are currently under commissioning.
- ✦Detector is responding to radiation as expected, with both charge and light being detected. The LXe is being continuously purified to reach the desired charge yield at the applied field.

Calibrations

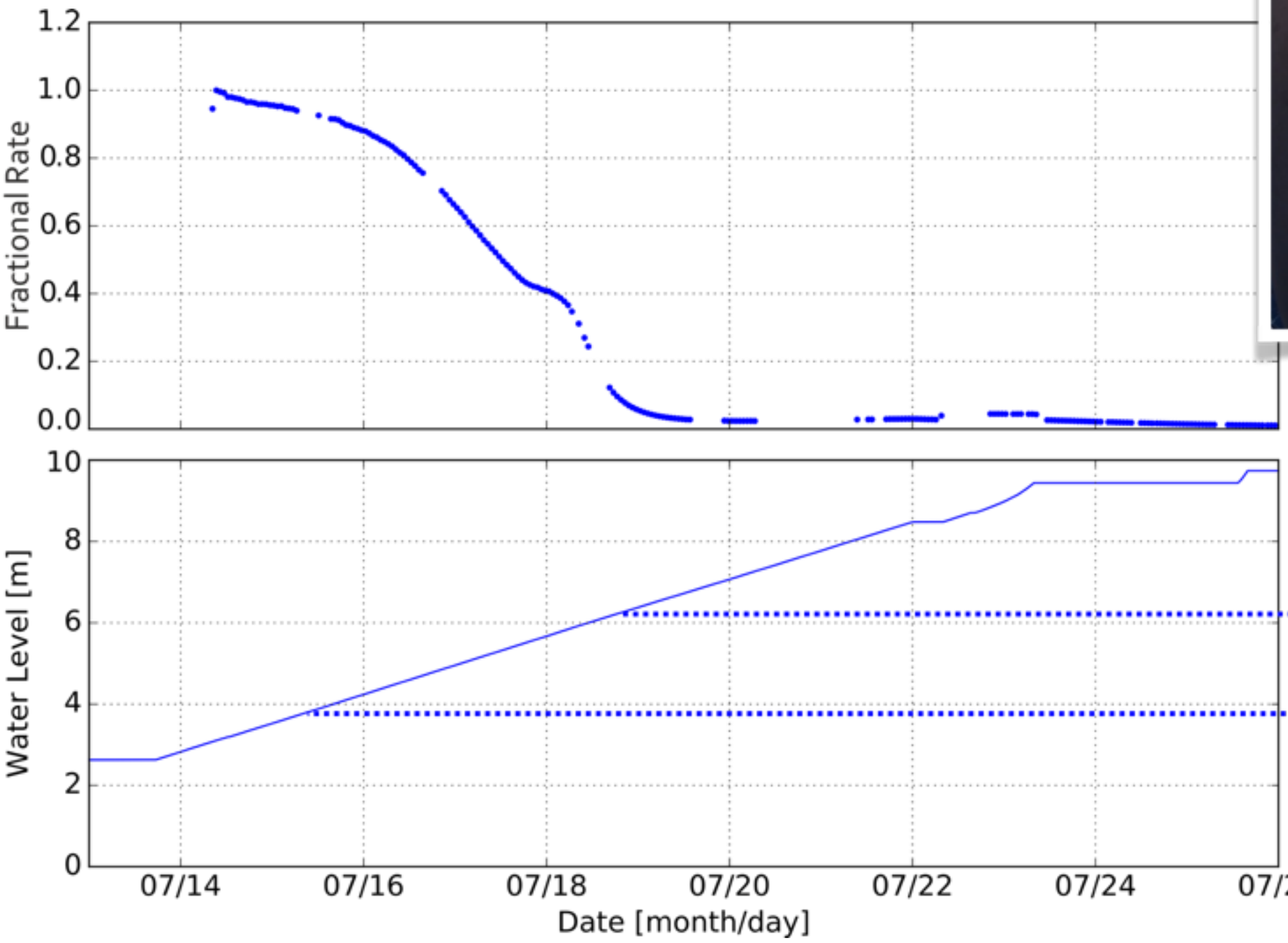
First gamma ray spectrum (Cs-137 external)

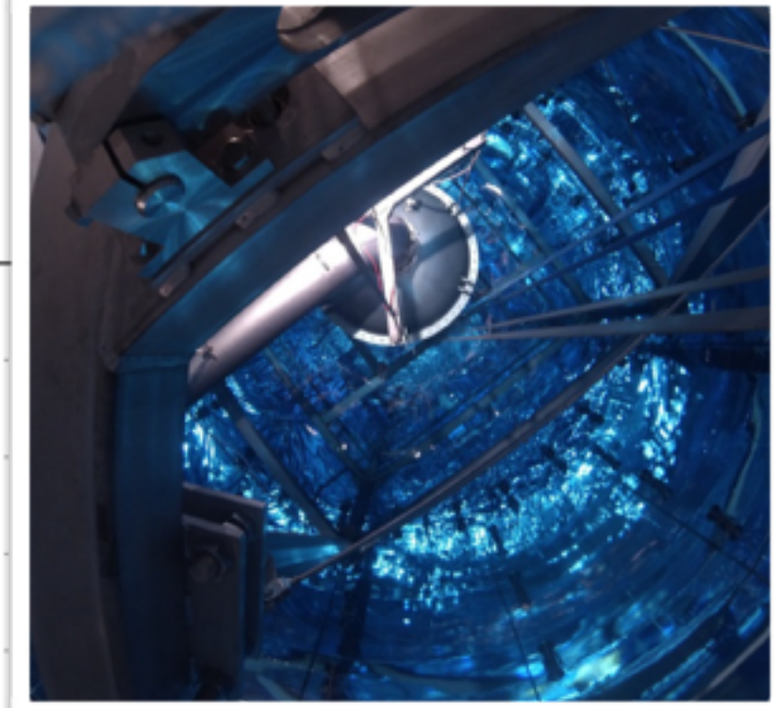
- ✦Spectrum obtained with detector unshielded.
- ✦Full absorption peak clearly separable

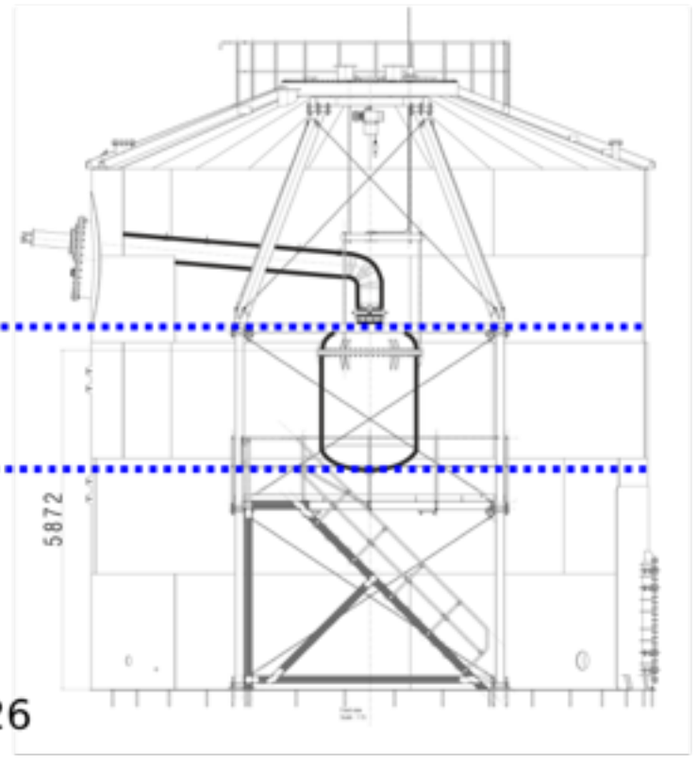


Entering Low Background mode

Rate decrease with increasing Water level







MC:Expected Electronic Recoil background

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

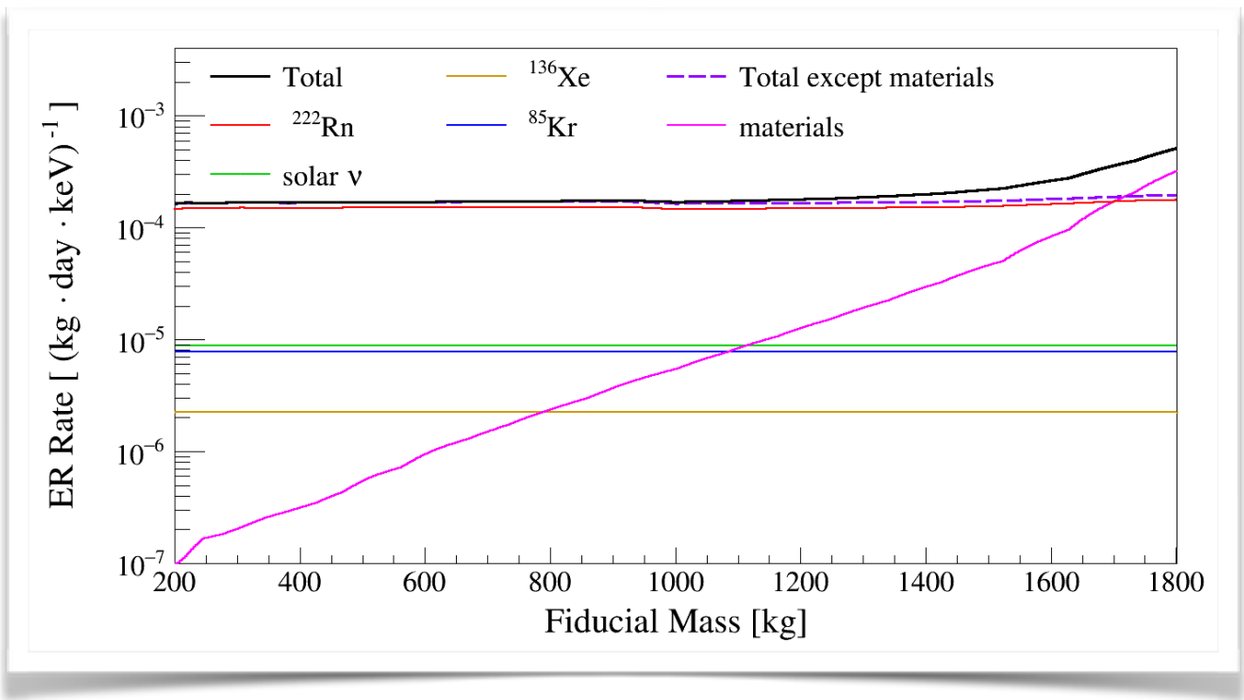
From Materials

✦Extensive screening campaign

Intrinsic

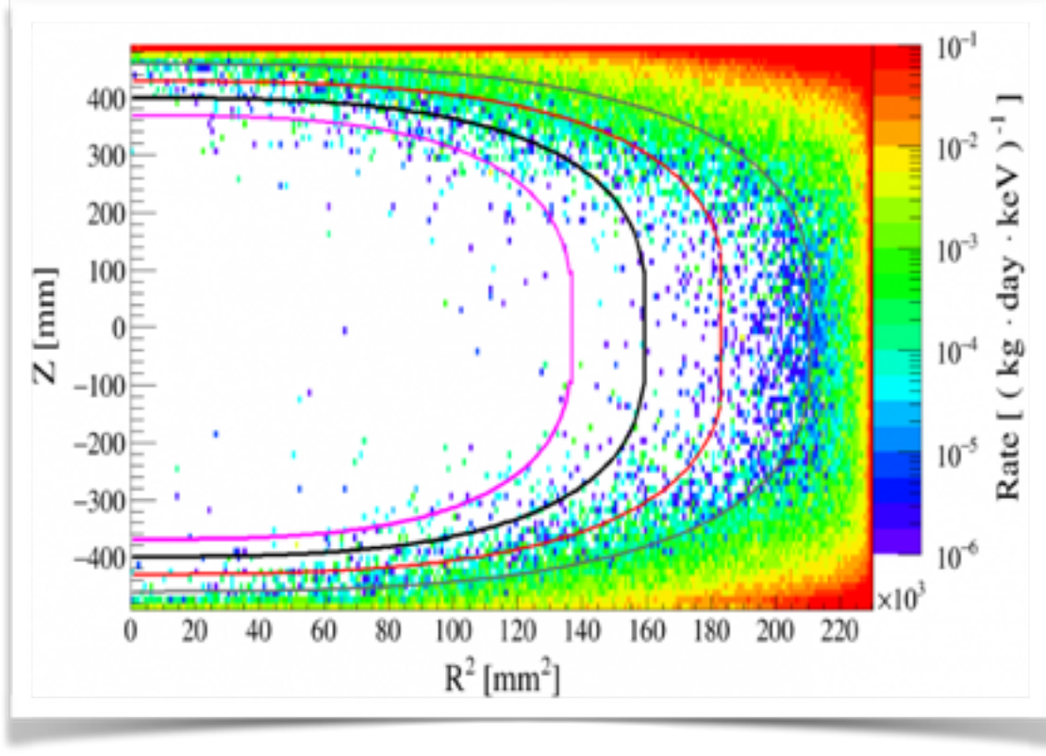
✦0.2 ppt of ^{nat}Kr (achieved in distillation column tests)

✦10 μBq/kg ^{222}Rn (estimation based on Rn emanation measurements)



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

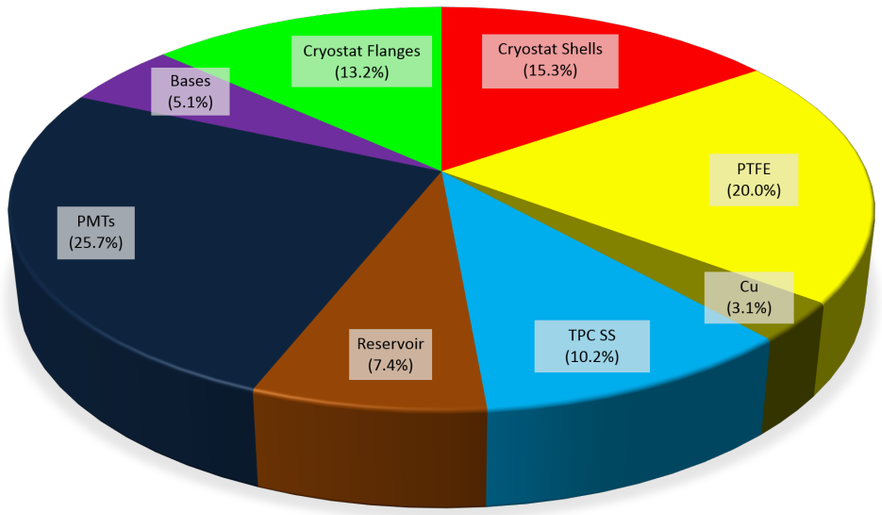
Source	Background (evts/y)
Materials	0.07
^{85}kr	0.05
^{222}Rn	1.4
^{136}Xe	0.02
pp+^{7}Be neutrinos	0.08

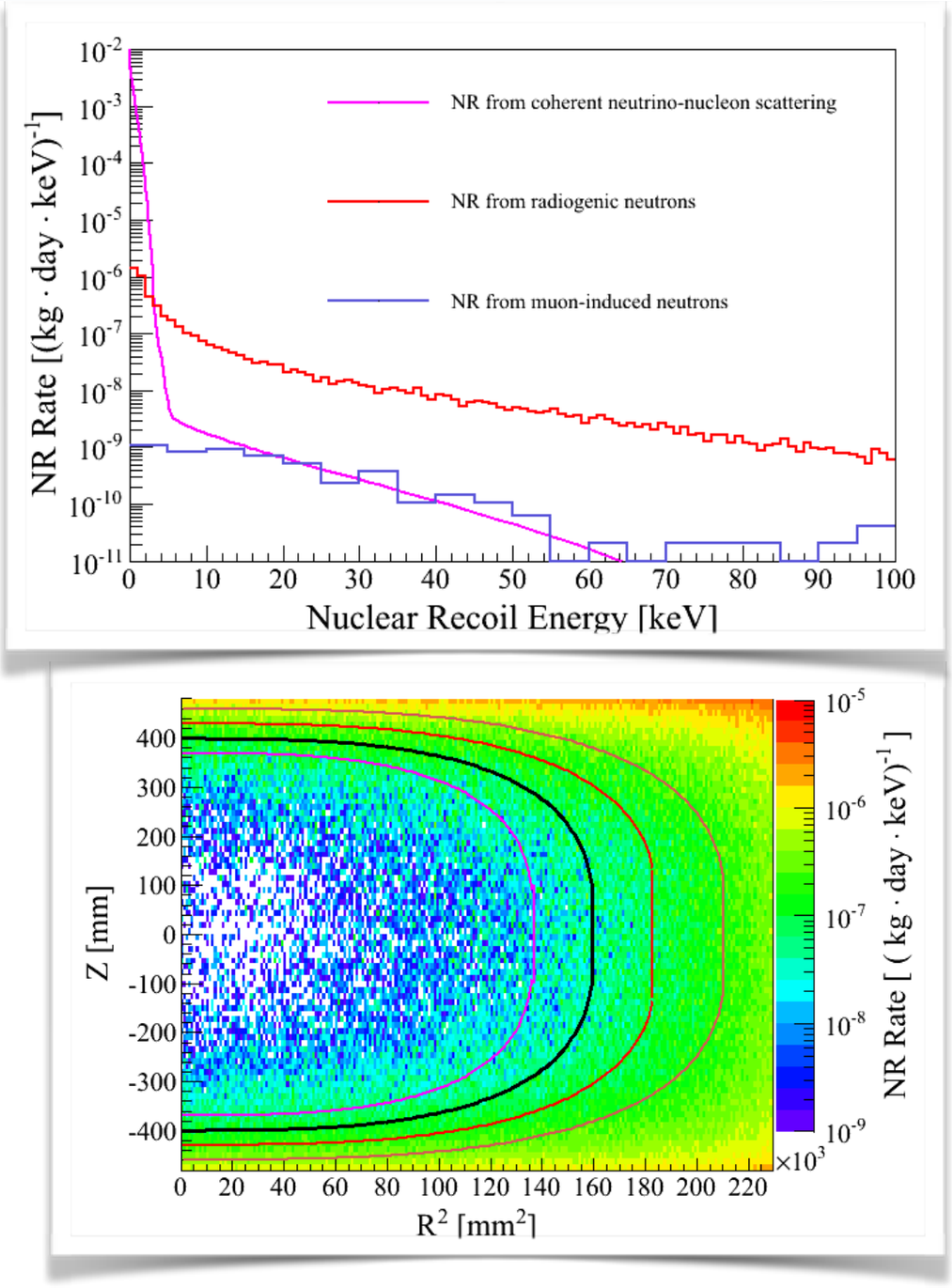


~ 1.62 evts/t/y after discrimination

MC:Expected Nuclear Recoil background

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



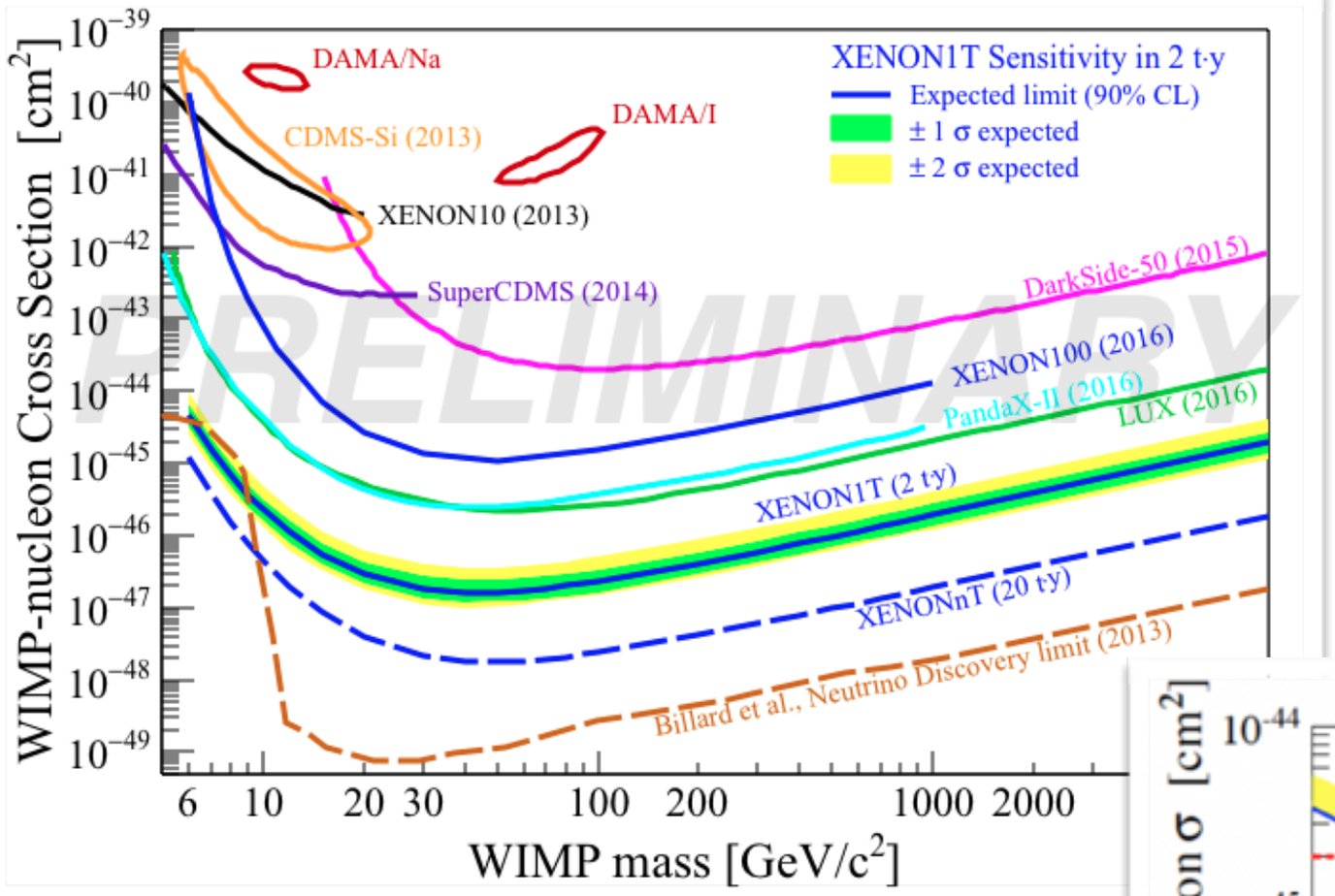


Source	Background (evts/y)
Radiogenic	0.22
Muon-induced neutrons	<0.01 (Muon Veto ON)
Neutrinos	0.23

~ 0.45 evts/t/y after Discrimination

Total expected background (ER+NR) ~ 2 evts/t/y
Total expected for WIMP mass~100 GeV (σ~ 10^{-47} cm^2) ~ 2-3 evts/1t/yr

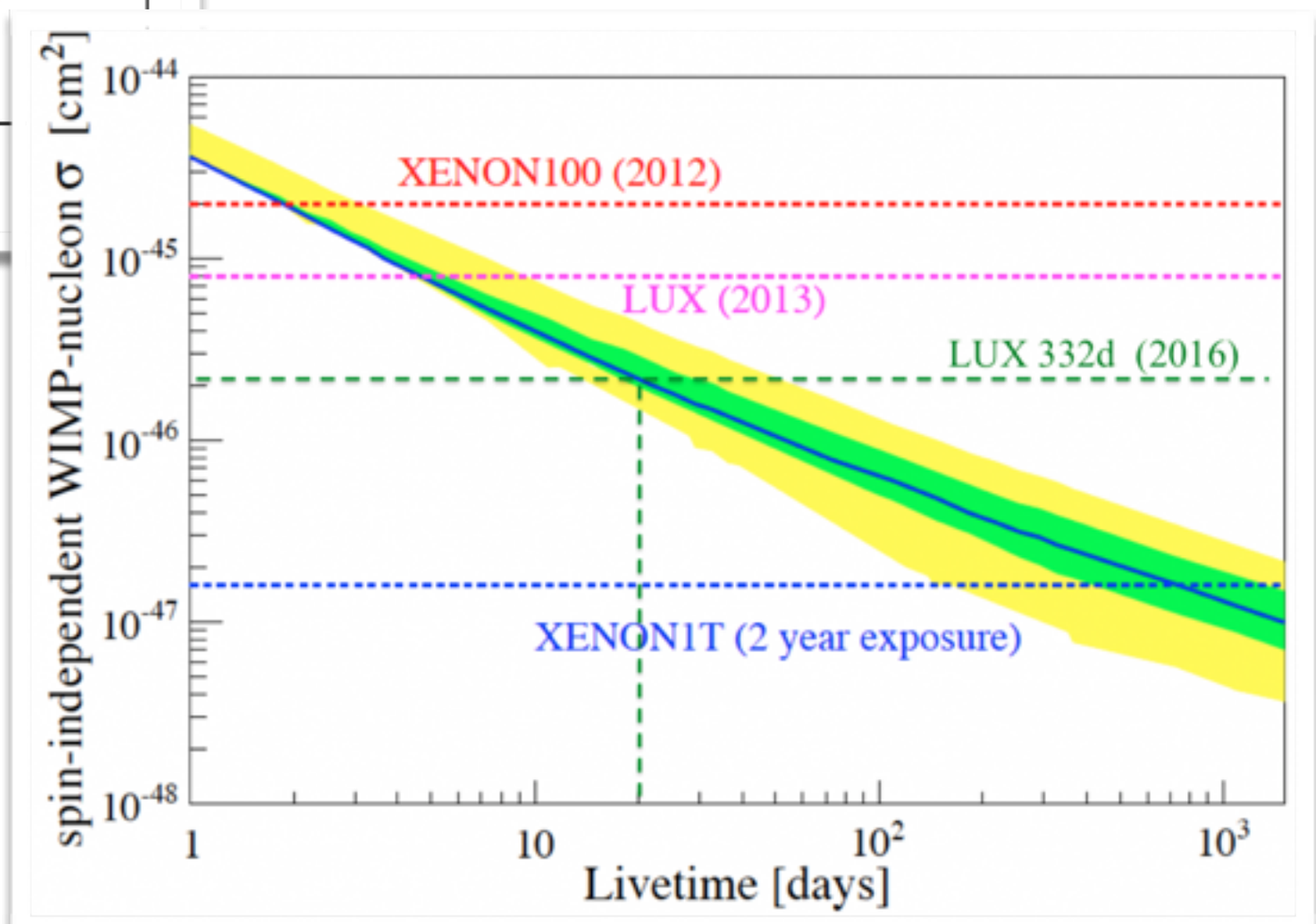
Expected Sensitivity



1.6×10^{-47} cm^2 @ 50 GeV WIMP

2 t • y data

Only need 20 days to reach LUX/PandaX sensitivity

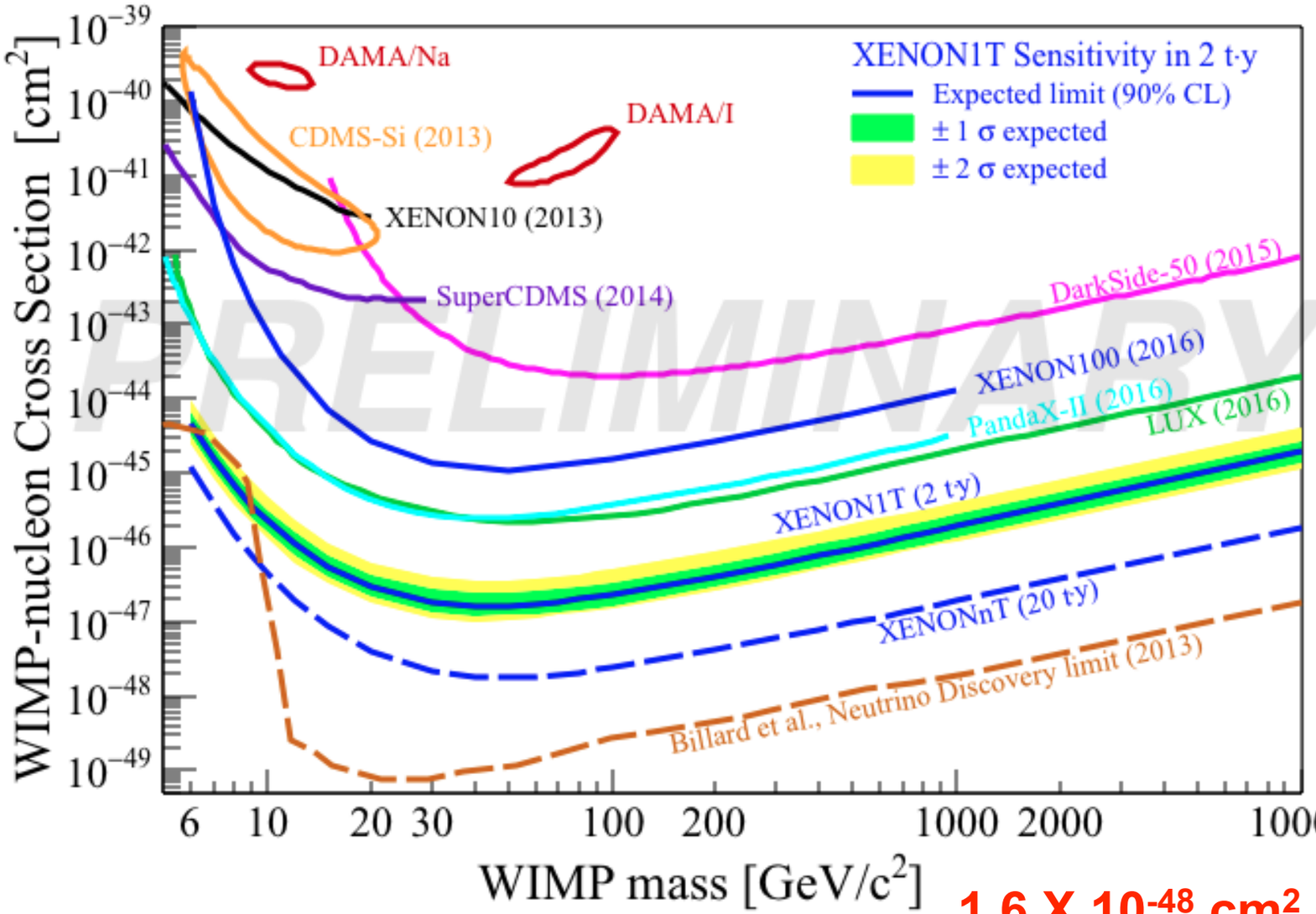


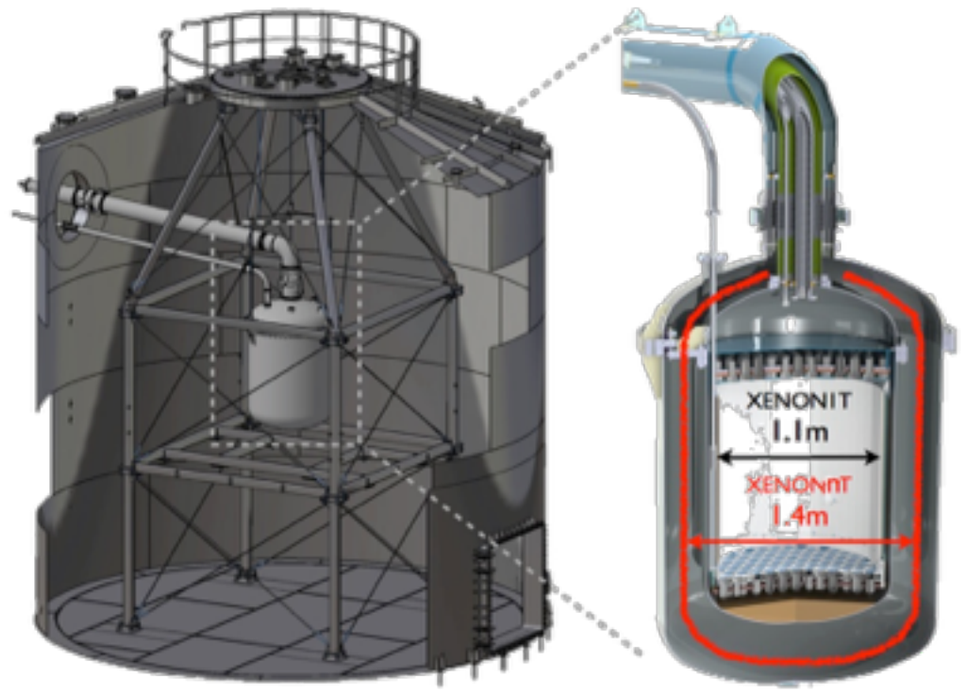
Conclusions

- ***XENON1T, the largest two phase Xenon TPC ever built, is starting operations***
- ***The Detector is filled with 3.2 tonnes of Xenon***
- ***The commissioning demonstrated that all the systems are behaving has expected***
- ***First studies are promising***
- ***Now in"low-background" commissioning***
- ***First DM data expected in fall 2016***

Next..nT

- ✦The total mass of Xenon will be **> 7 t**.
- ✦The **systems developed for XENON1T can be used to operate XENONnT**: Water Tank, Muon Veto, support structure, Cryogenics and Purification systems, LXe storage and recovery system.
- ✦The inner cryostat number of PMTs (~ 200 more) and TPC will be modified





1.6 X 10^{-48} cm² @ 50 GeV WIMP 20 t-yrs exposure

E. Aprile et al, JCAP 1604 (2016) 027

Backup

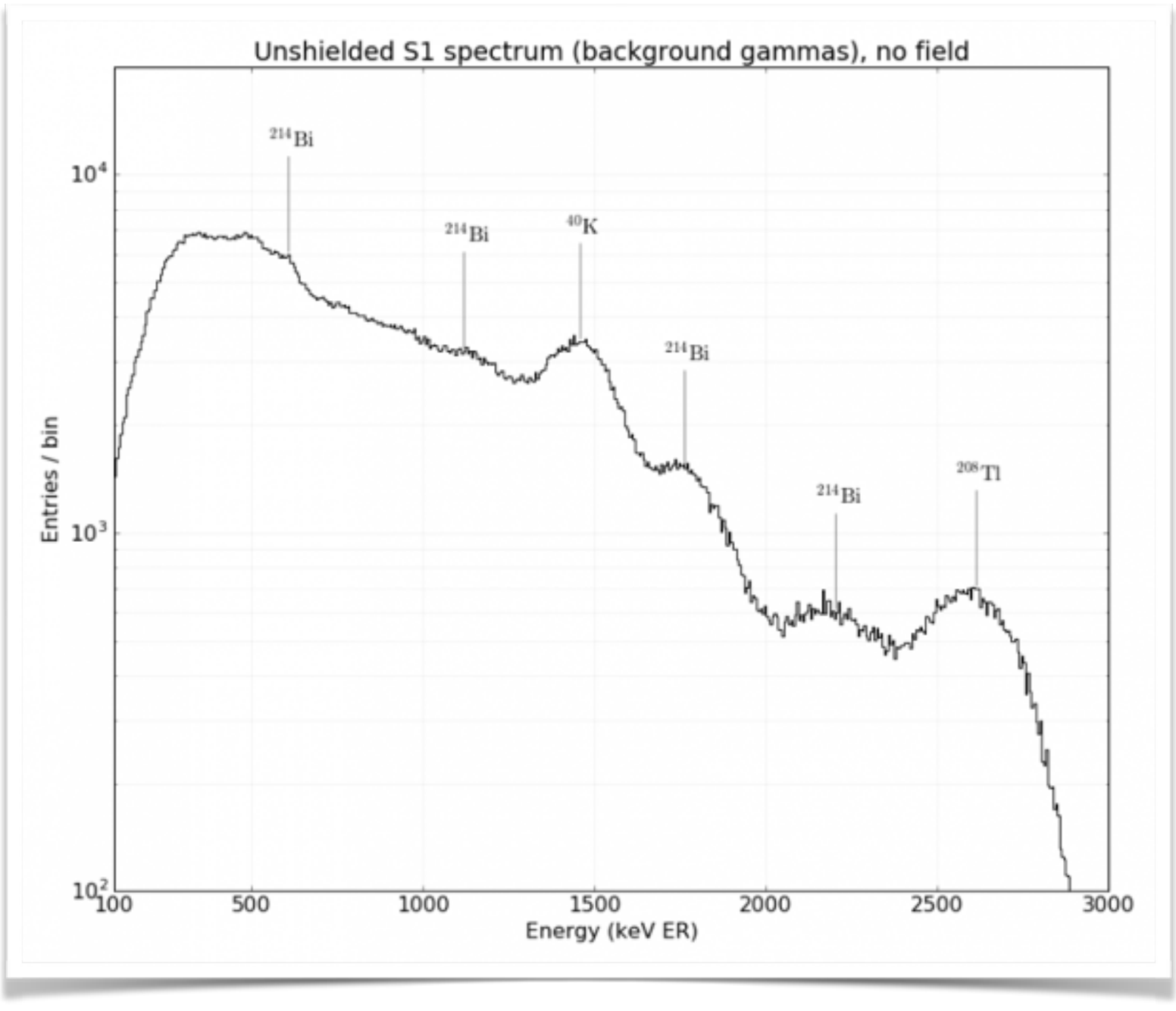
First look at Background

Background studies started

✦Detector filled with LXe

✦No Electric field applied

✦No shielding

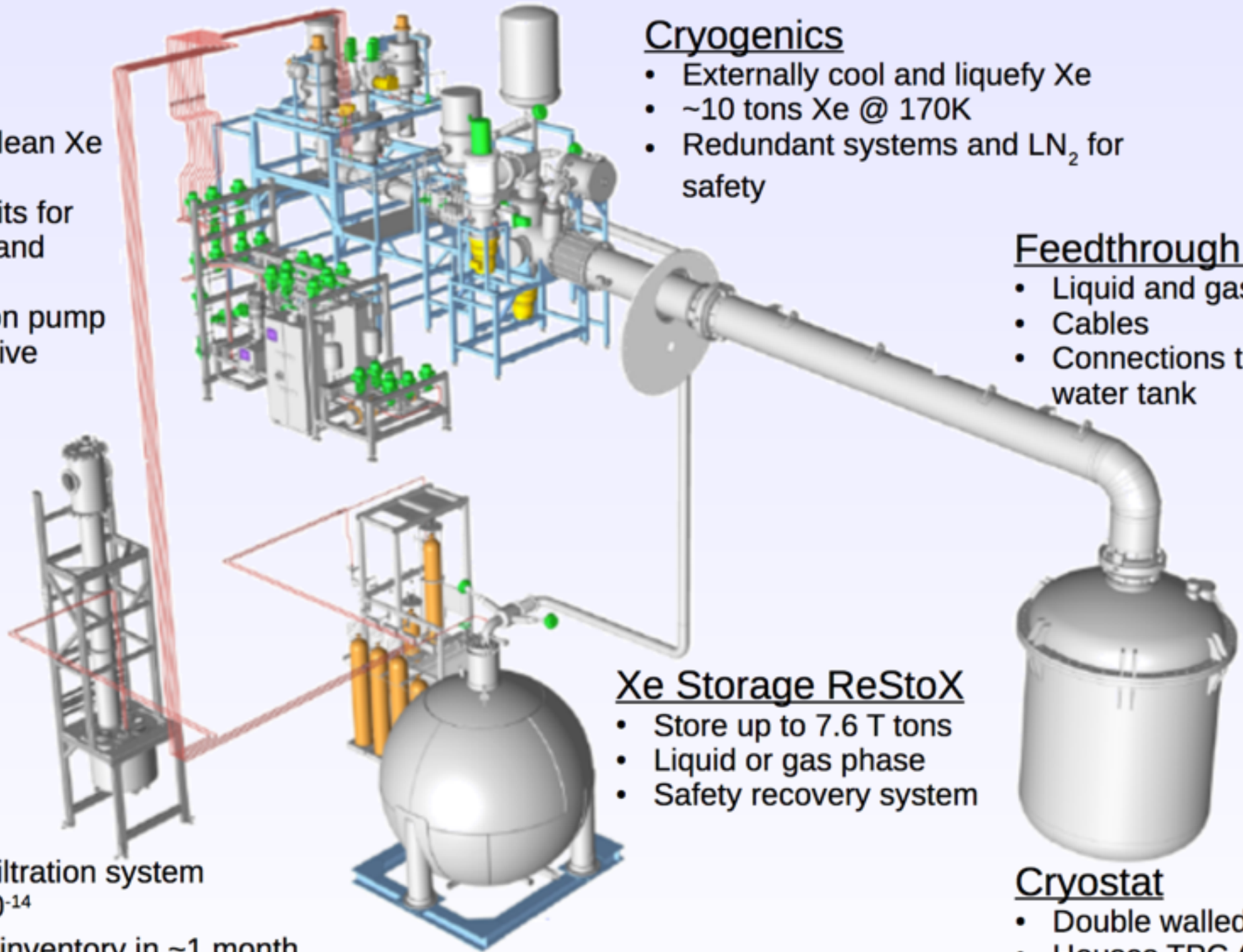


Systems:Some Details

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 LN_2 for safety

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



Distillation
- Custom Kr filtration system
- $Kr_{nat}/Xe \sim 10^{-14}$
- Process Xe inventory in ~1 month

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!