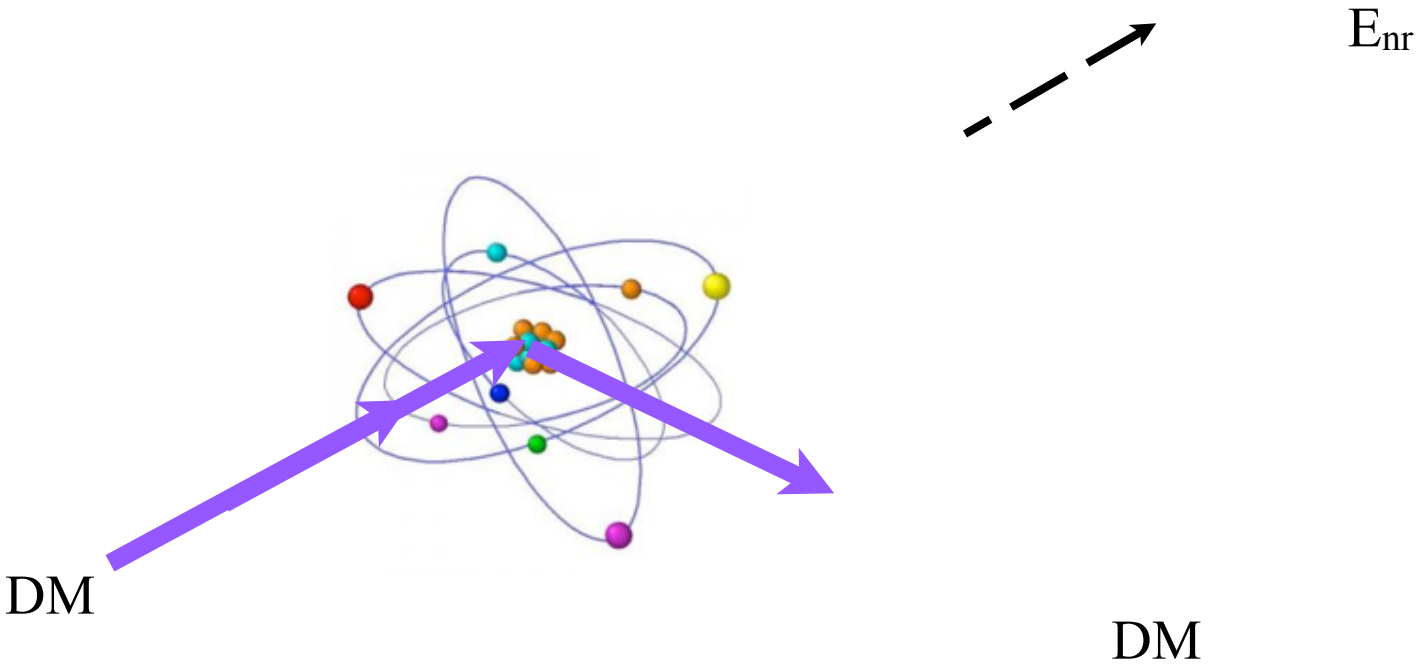
Status of the XENON Program:
The fight against the background

J. Masbou, on behalf of the
XENON Collaboration

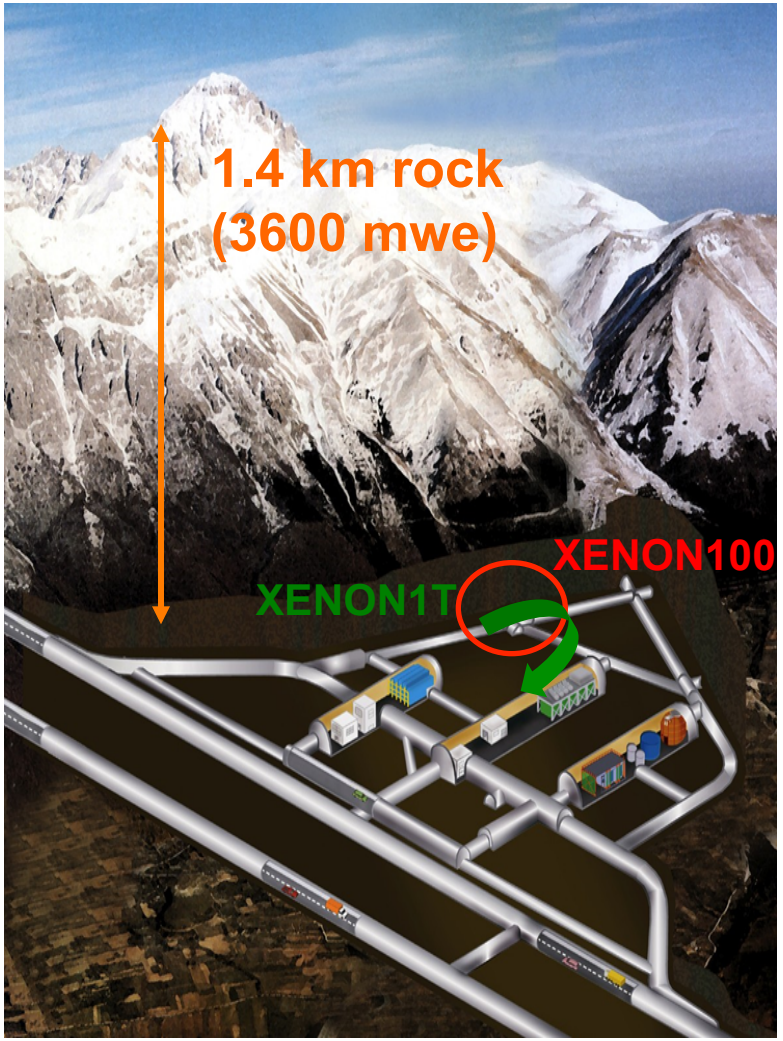
Our goal

Discover Dark Matter
with the most sensitive liquid xenon imaging detector
located in LNGS

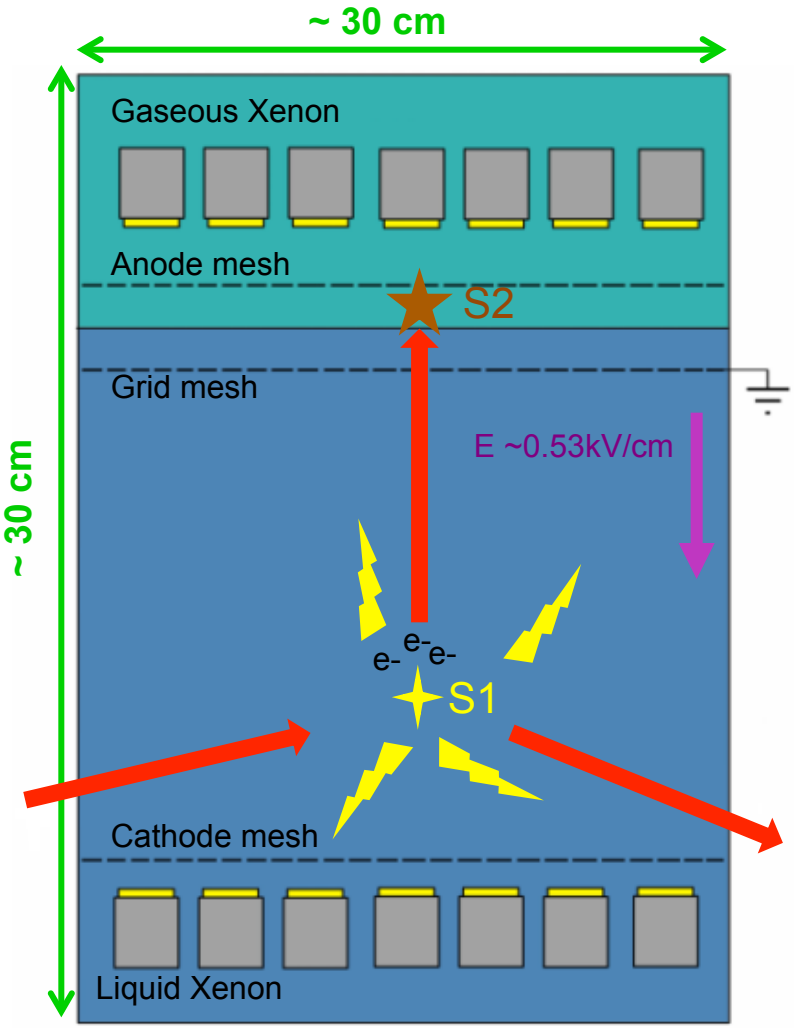


Location of the XENON experiment & Collaboration

21 Institutes
~150 members



Two phase XENON TPC principle



S1:

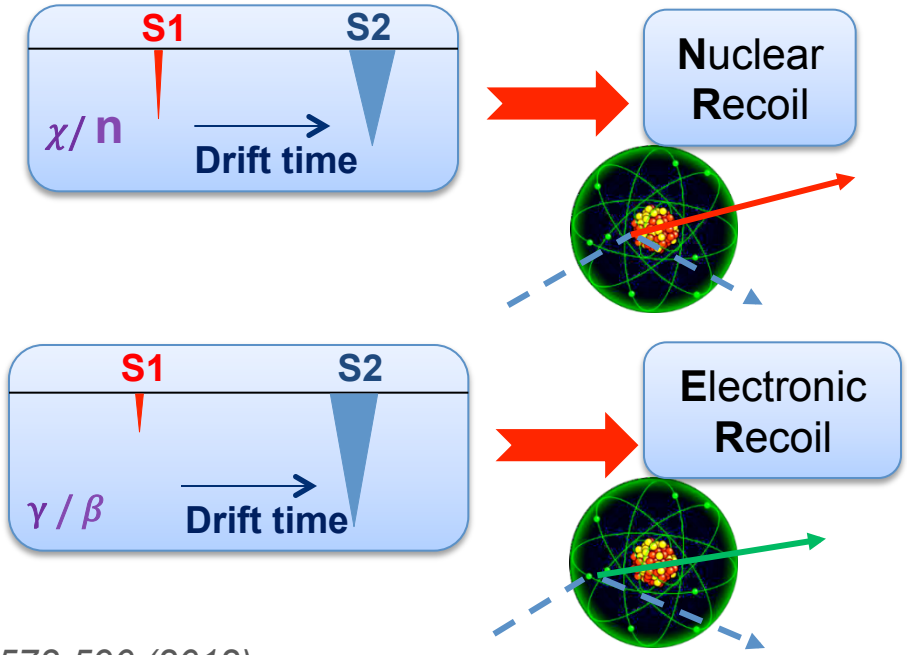
→ Photon (λ = 178 nm) from Scintillation process → Dectected by PMTs (mainly botton array)

S2:

→ Electrons drift
→ Extraction in gaseous phase
→ Proportional scintillation light

3D reconstruction :

→ X,Y from top array
→ Z from Drift time



E. Aprile et al. (XENON100), Astropart. Phys. 35, 573-590 (2012)

The XENON Dark Matter Program

XENON10

Achieved (2007)

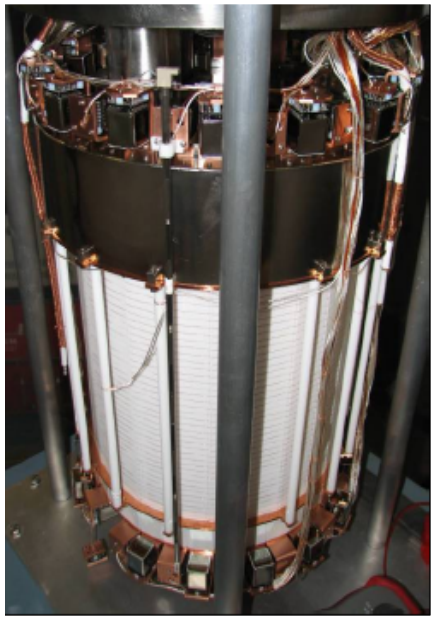
σ_{SI} = 8.8 · 10^{-44} cm^2 @ 100 GeV/c^2

Phys.Rev.Lett. 100 (2008) 021303

Light DM:

σ_{SI} = 7 · 10^{-42} cm^2 @ 7 GeV/c^2

Phys.Rev.Lett. 107 (2011) 051301



XENON100

Achieved (2012)

σ_{SI} = 2.0 · 10^{-45} cm^2 @ 55 GeV/c^2

E. Aprile et al. (XENON100),
Phys. Rev. Lett. 109 (2012)
arXiv:1207.5988

In operation since 2009

XENON1T

Projected (2017)

σ_{SI} = ~ 2.10^{-47} cm^2

Science data by spring 2016

Upgrade : XENONnT

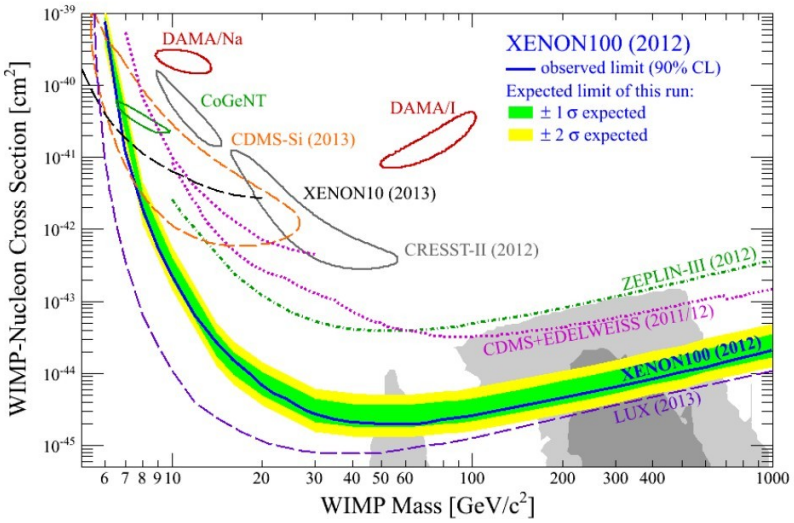
σ_{SI} = ~ 2.10^{-48} cm^2

XENON100 : Past Achievements

225 live days x 34 kg exposure

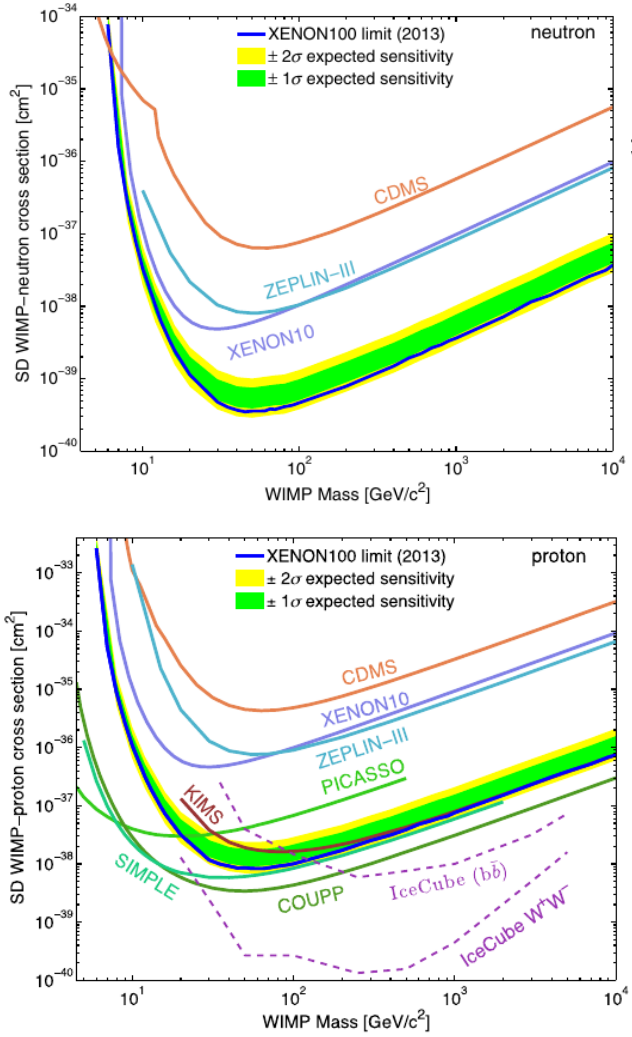
Profile likelihood analysis allows to set limits in the $(m\chi, \sigma)$ parameter space

Phys. Rev. Let. 109, 181301 (2012)



Spin-independent interaction

Phys. Rev. Let. 111, 021301 (2013)

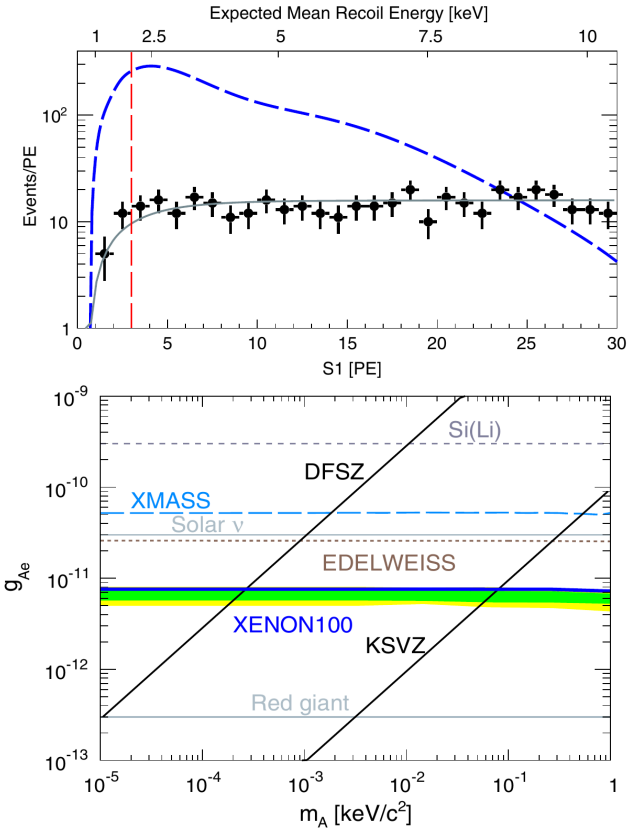


Spin-dependent interaction

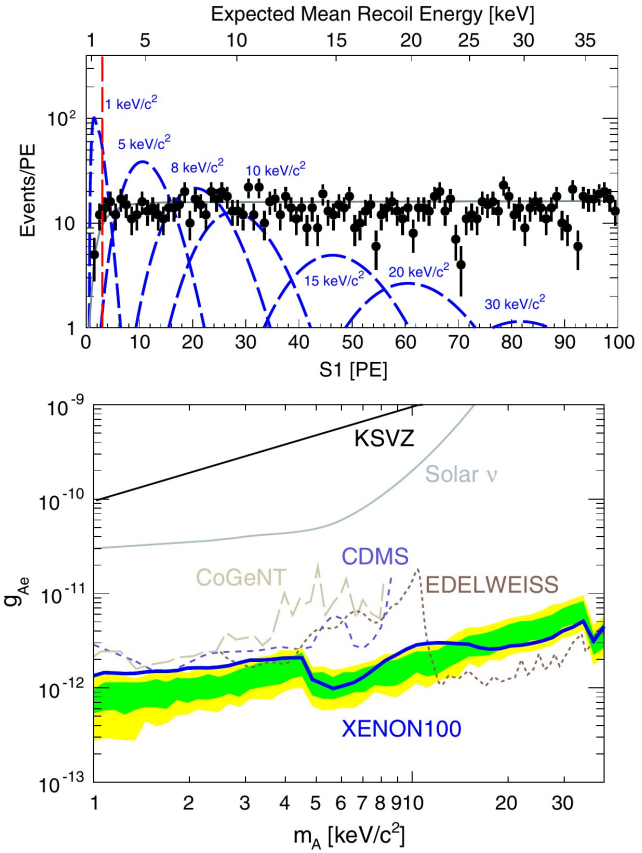
XENON100 : Past Achievements

225 live days x 34 kg exposure

- First axion results from the XENON100 experiment analyzing ER data
- Probing axion-electron coupling constant by exploiting the axioelectric effect in LXe



Solar Axions



Galactic ALPs (DM candidates)

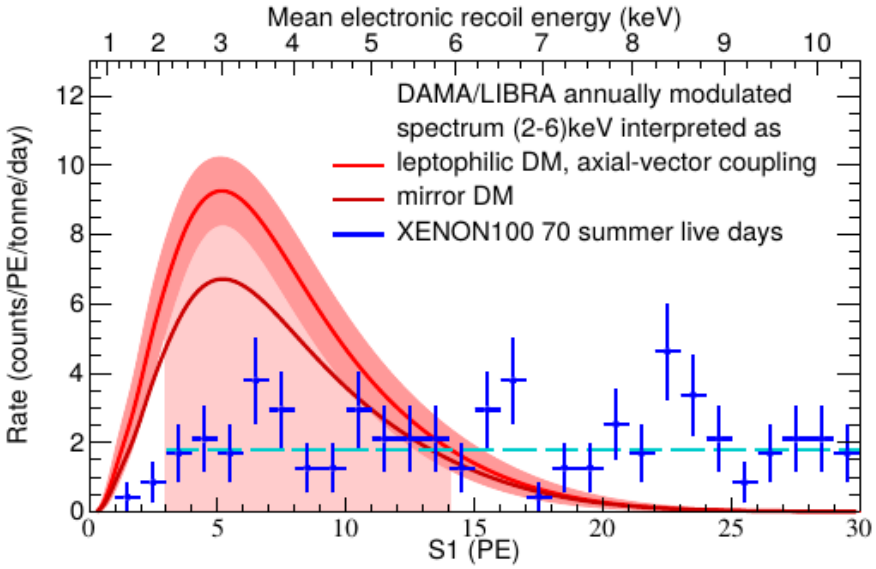
Phys. Rev. D 90, 062009 (2014)

XENON100 : Past Achievements

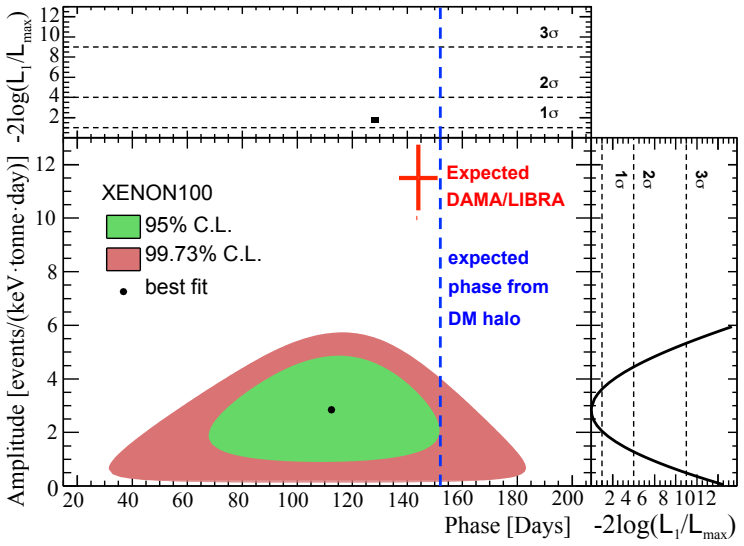
225 live days x 34 kg exposure

- Exclusion of several types of DM models as the cause of the annual modulation
- The DM interpretation of DAMA/ LIBRA annual modulation as being due to WIMPs electron scattering through axial vector coupling is disfavored at 4.8-sigma from a PL analysis

Science 349, 851 (2015)



PRL 115, 091302 (2015)

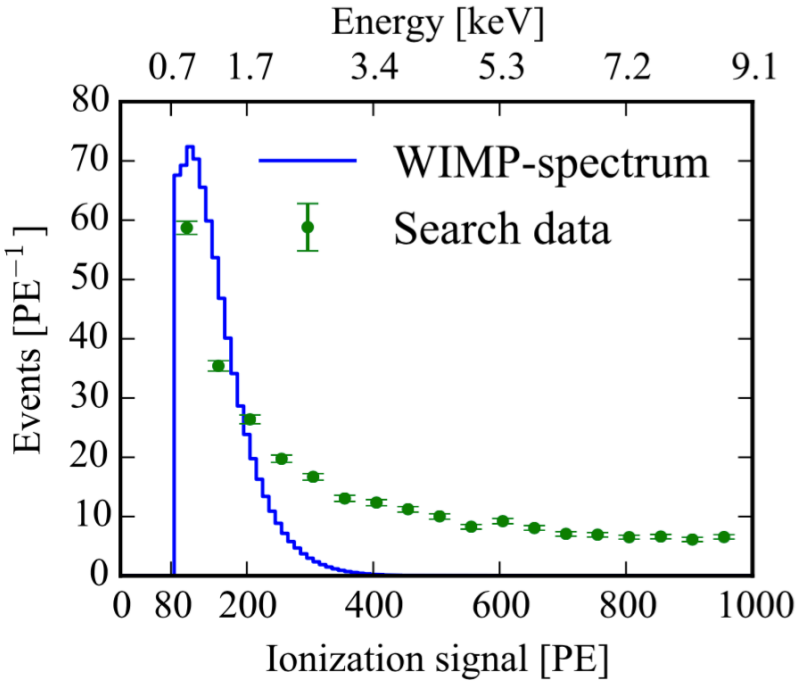


XENON100 : Low-mass dark matter

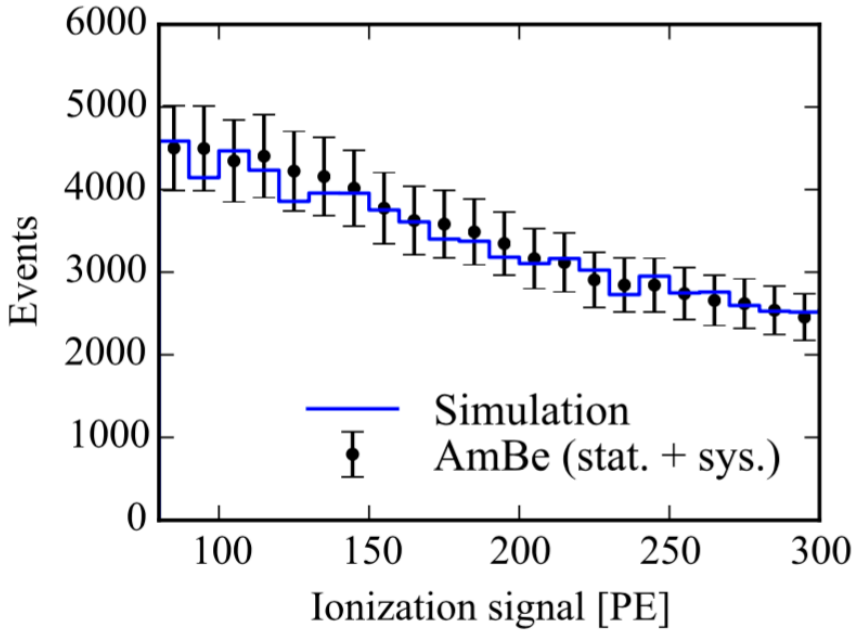
225 live days x 34 kg exposure

- No S1 signal → No 3D position reconstruction

→ 0,7 keV threshold nuclear recoil

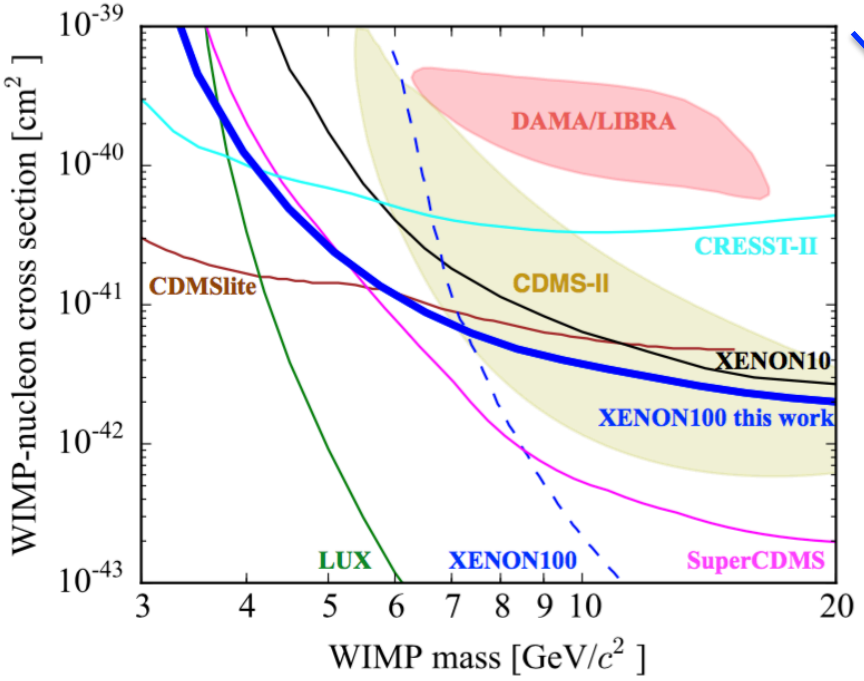


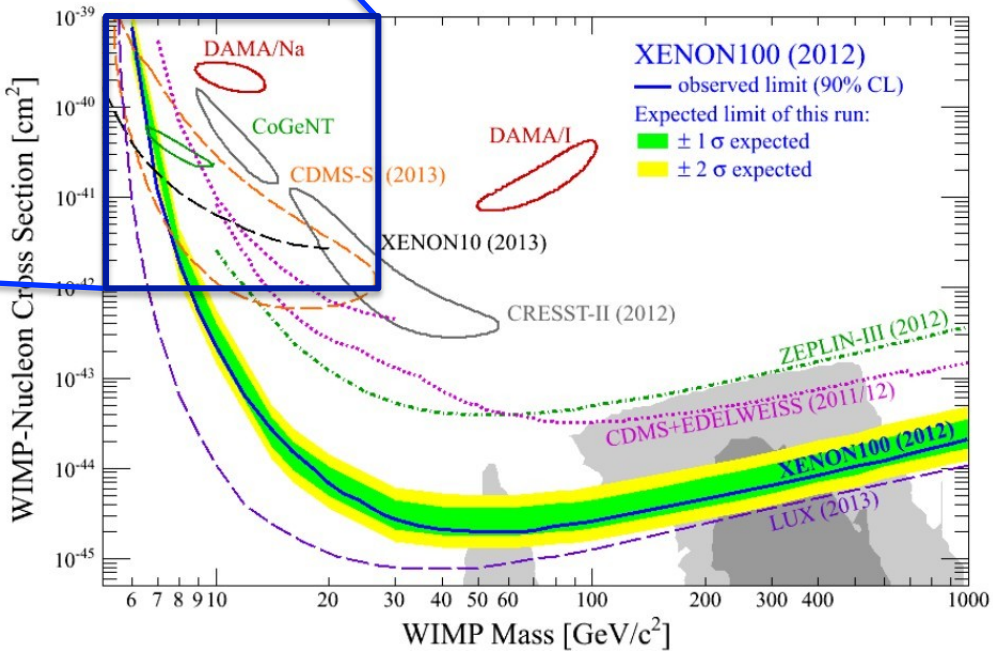
Expected Spectrom for a 6 GeV WIMP



S2 spectrum of 241AmBe

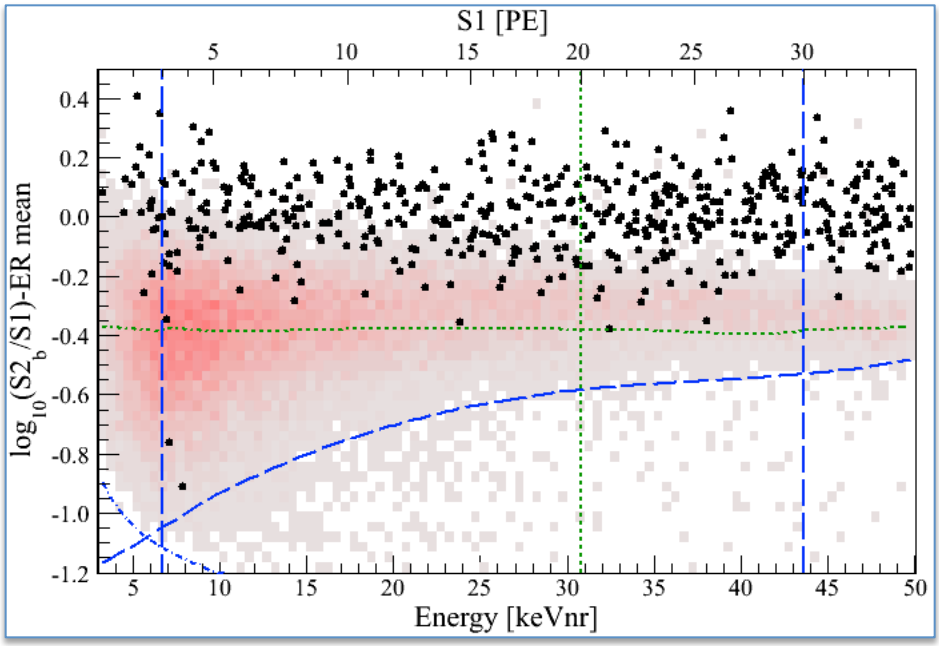
XENON100 : Low-mass dark matter

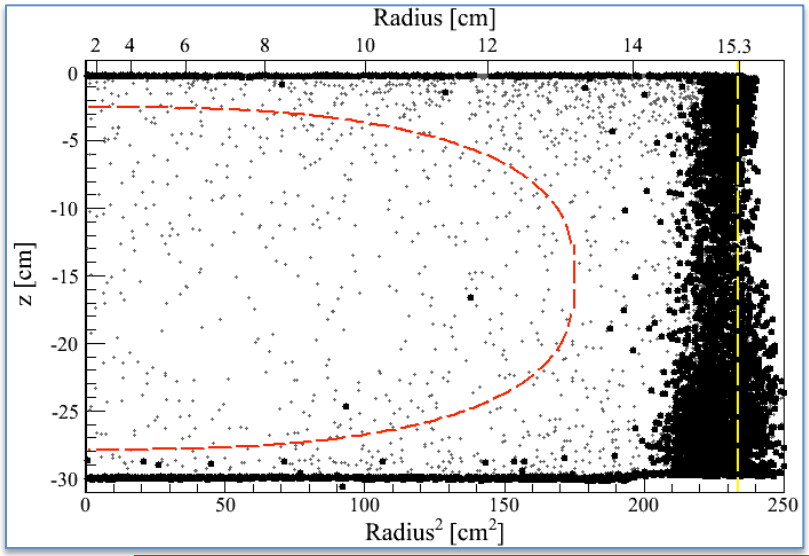




XENON100 : Blind analysis

- XENON100 did a blind analysis
- Event discrimination by S2/S1 separation
- Defined WIMP searching region:
  - S1 with benchmark region (3 - 30 pe)
  - S2 threshold cut (S2 > 150 pe)
  - 99.75 % ER rejection line



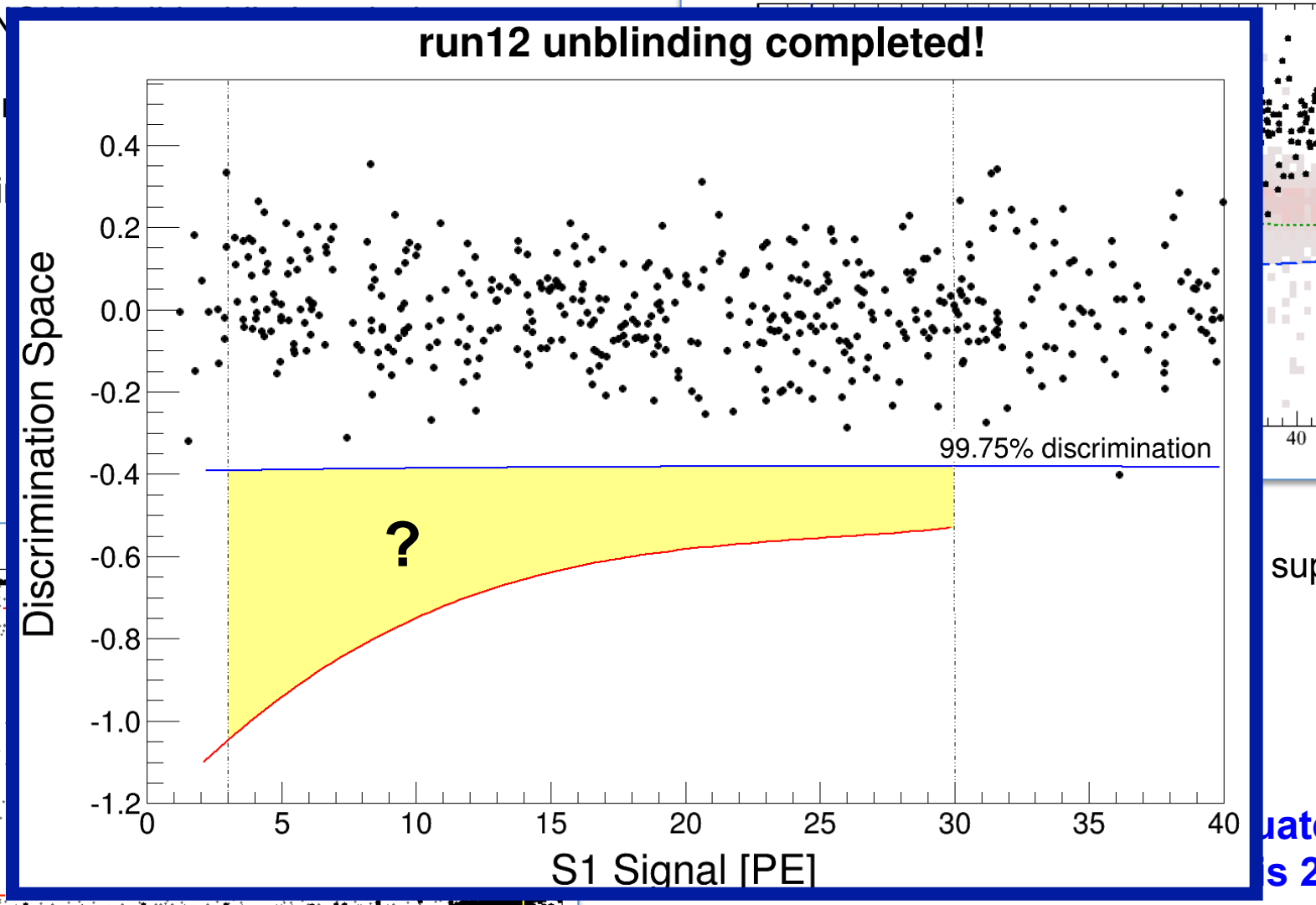


- Event rejection by defining a 34kg super-ellipse
- Double scatters excluded

Probability that 2 events fluctuate over the background expectation is 26.4%

XENON100 : New result is coming!

- XEN
- Ever
- Defi

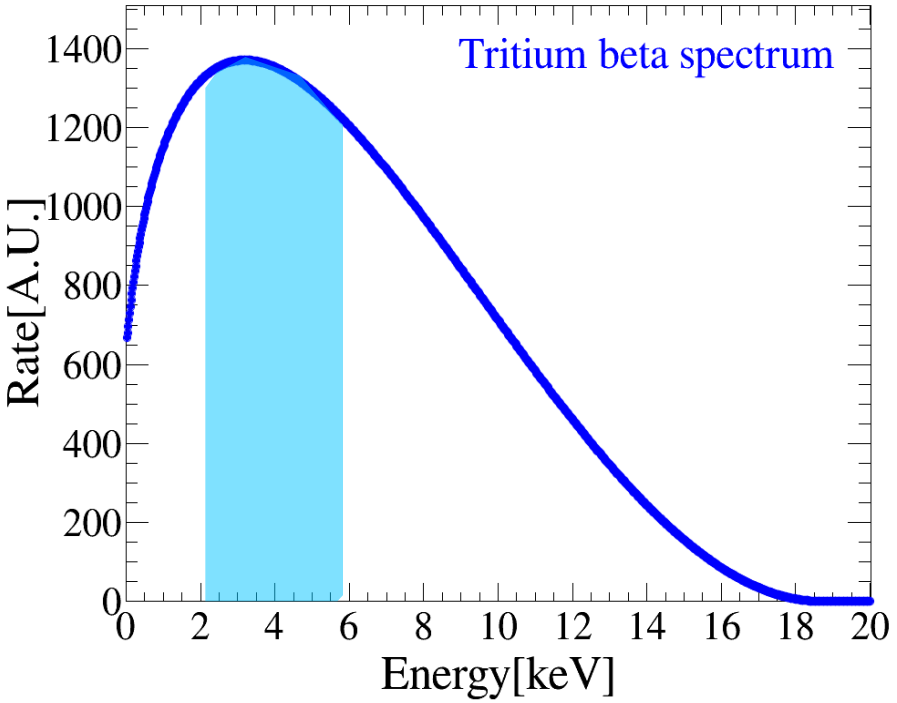


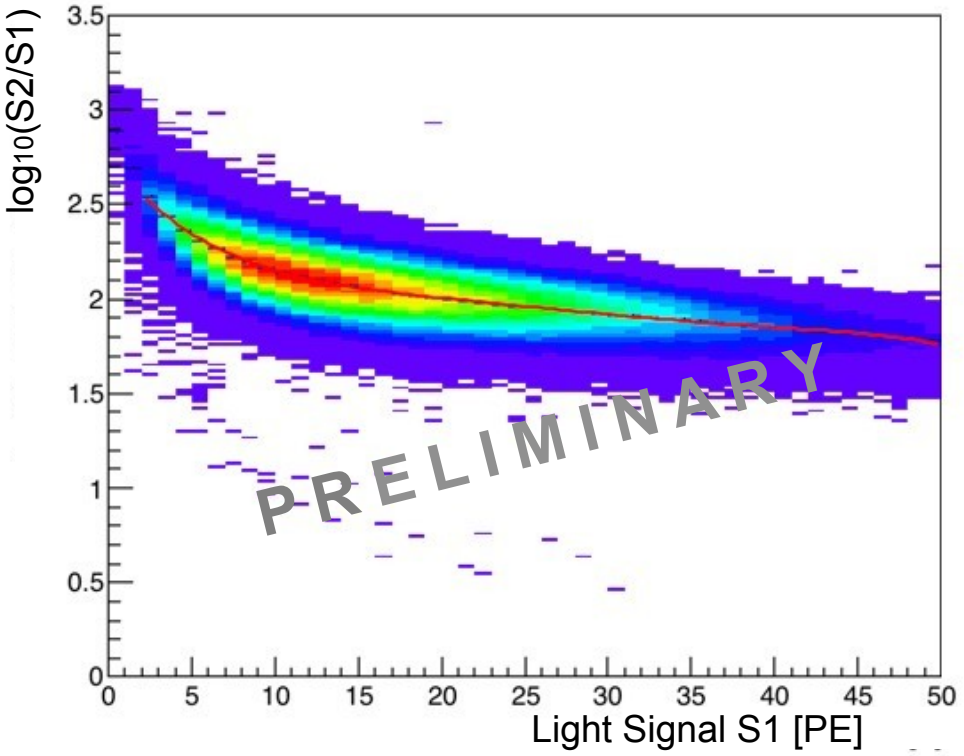
super-

uate over
s 26.4%

XENON100 : Low-mass dark matter

Intrinsic ER calibration with tritiated methane: pioneered by LUX *arXiv:1512.03133*

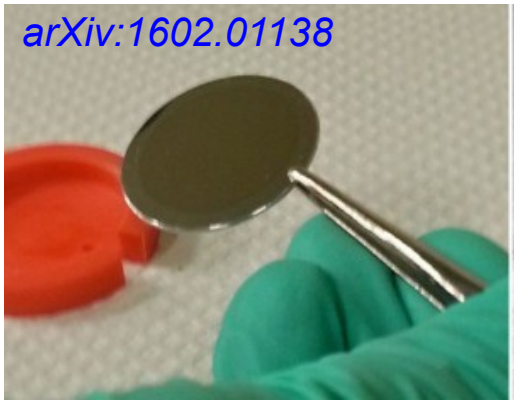


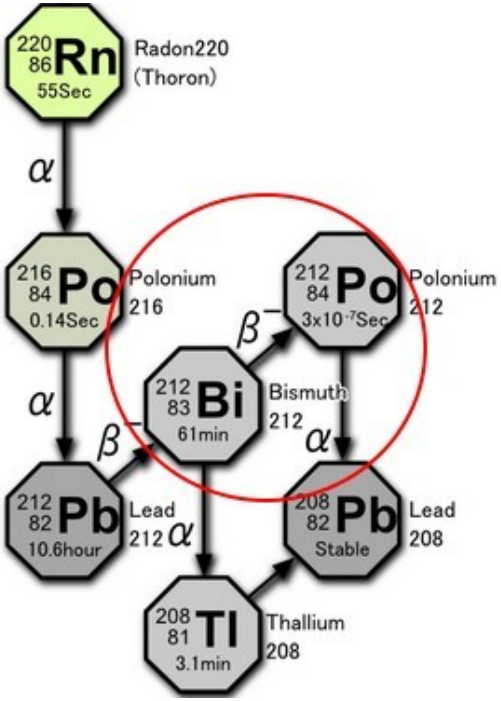


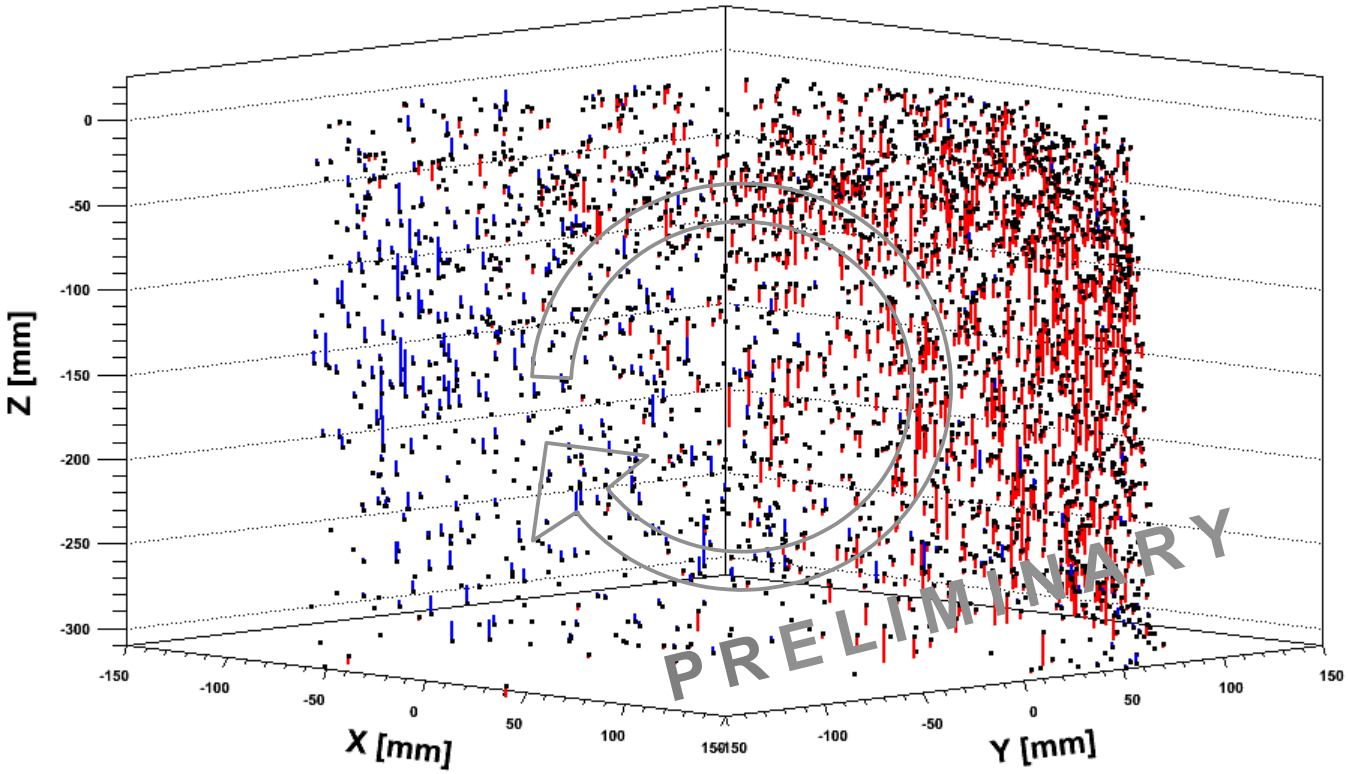
- high-stats calibration of XENON100 successfully performed twice
- ongoing: data analysis, removal strategies, application to XENON1T

XENON100 : Low-mass dark matter

- ^{228}Th source emanates ^{220}Rn
- ^{220}Rn is very short-lived (55 s)
- use beta-decays following ^{220}Rn to characterize low-E ER response
- prepare XENON1T use

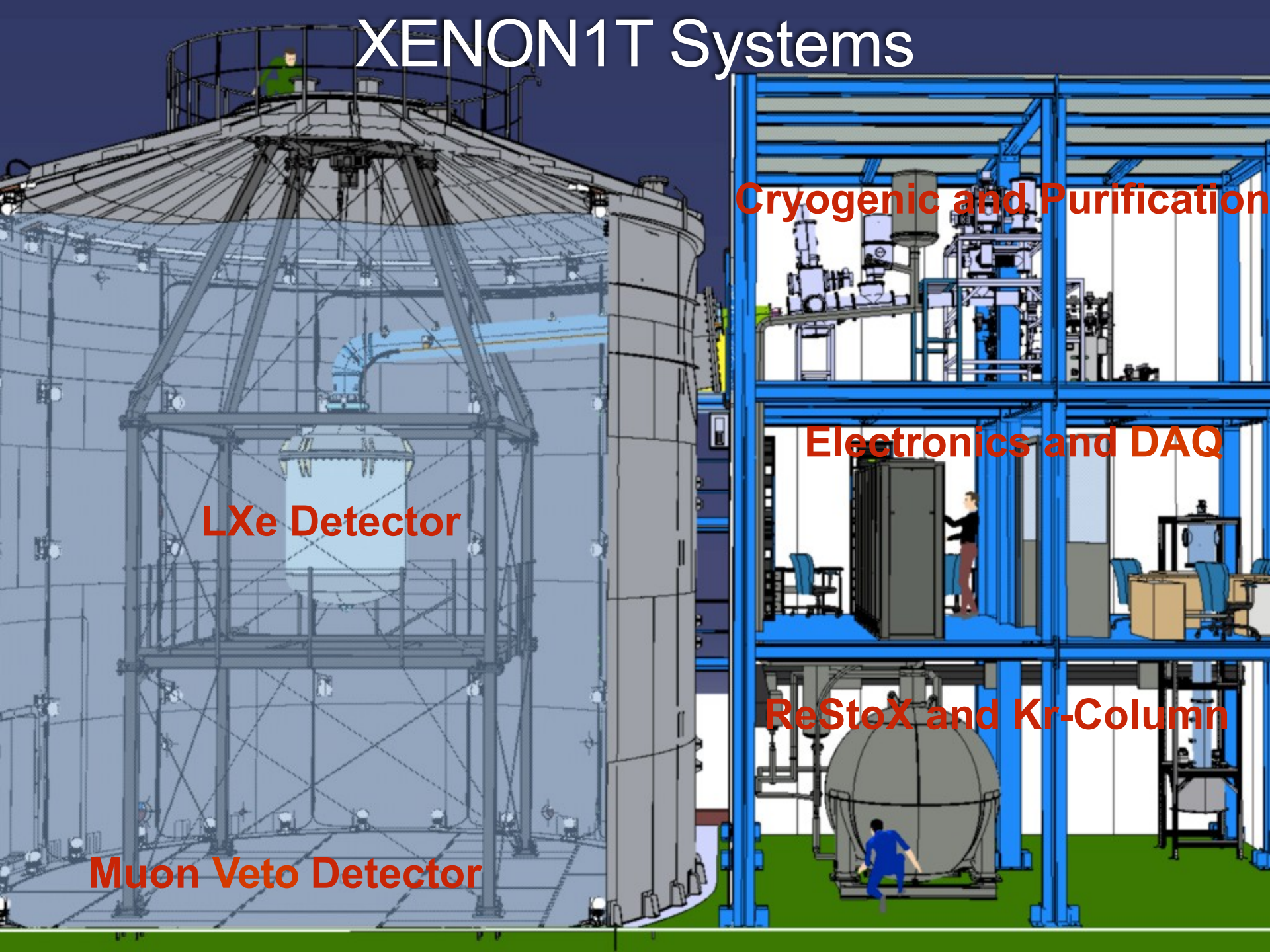






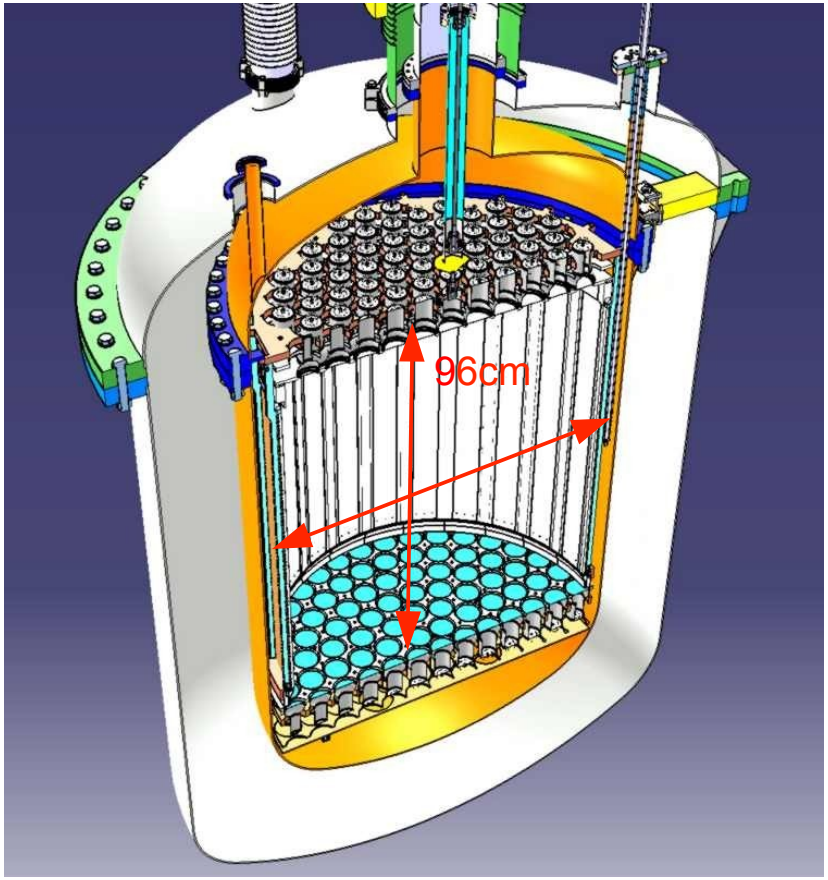
Mapping of convection inside XENON100 with ^{220}Rn

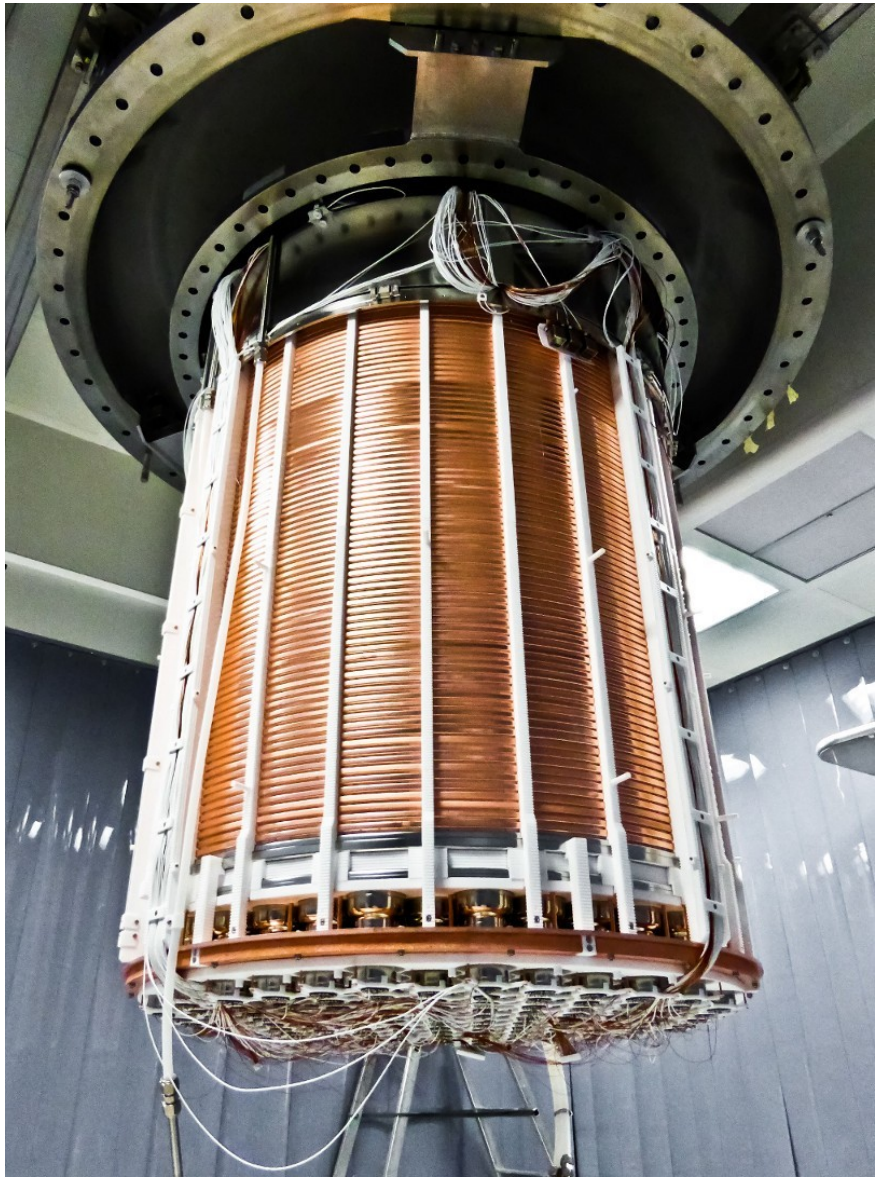
XENON1T Systems




Xe
XENON
Dark Matter Project

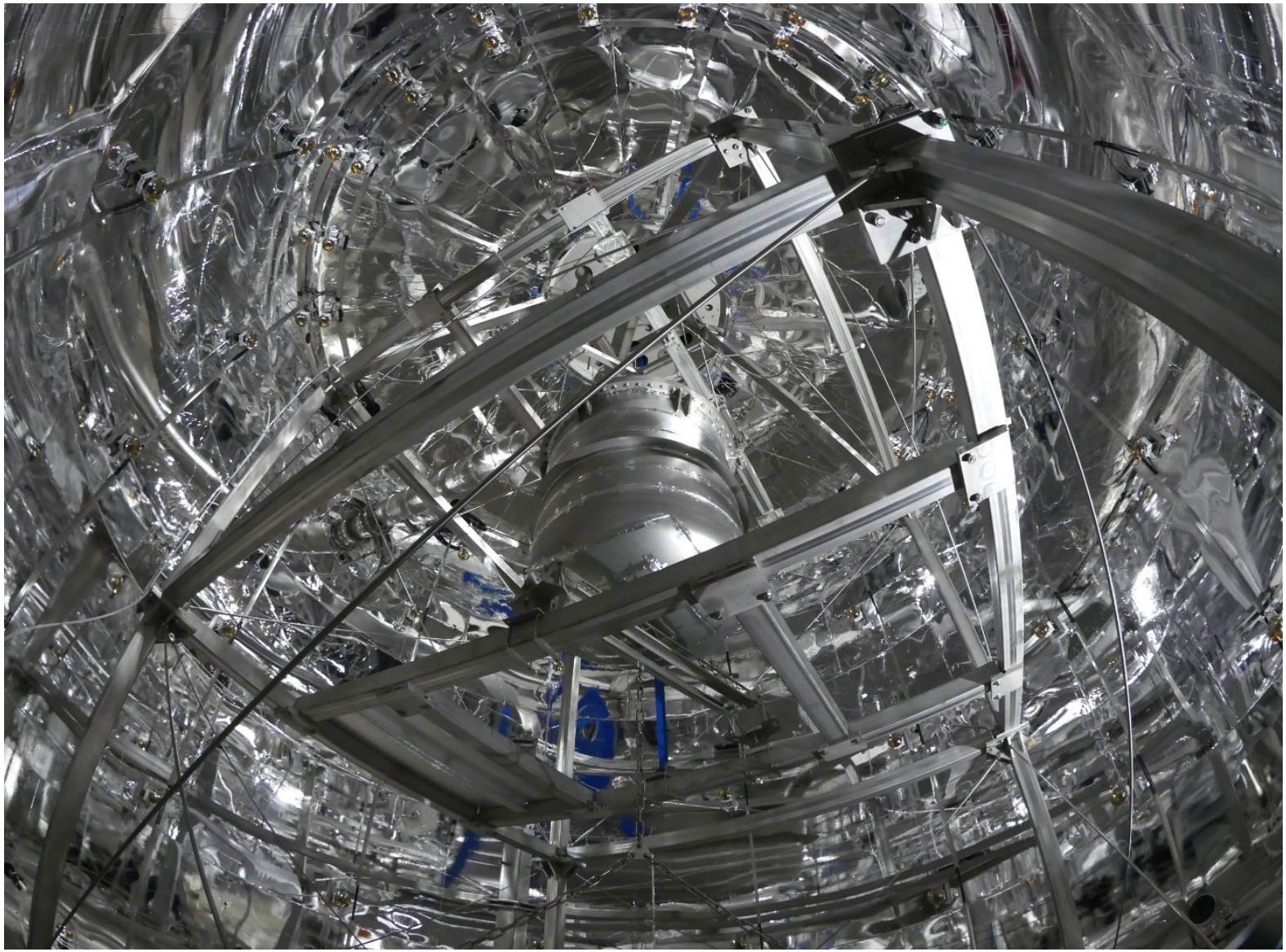
XENON1T: TPC



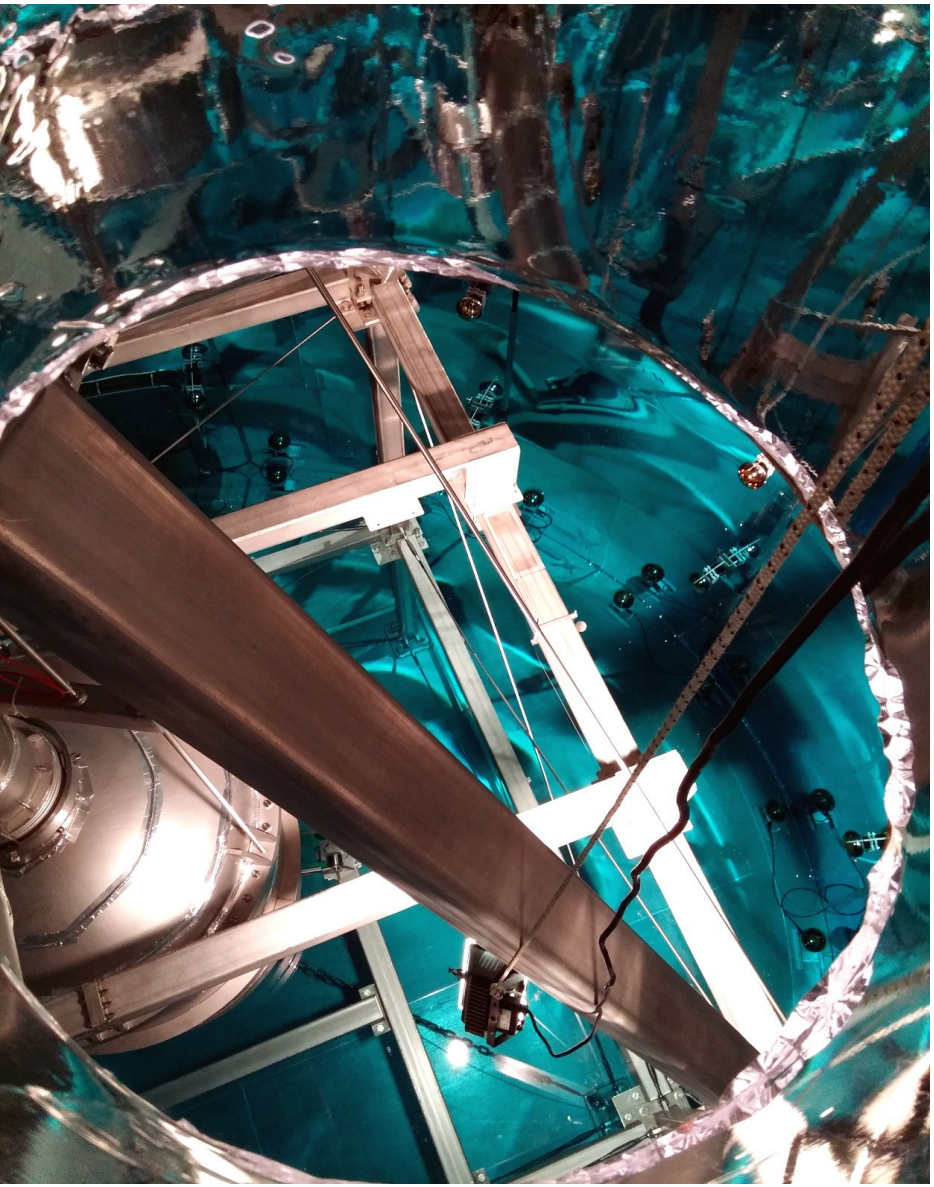


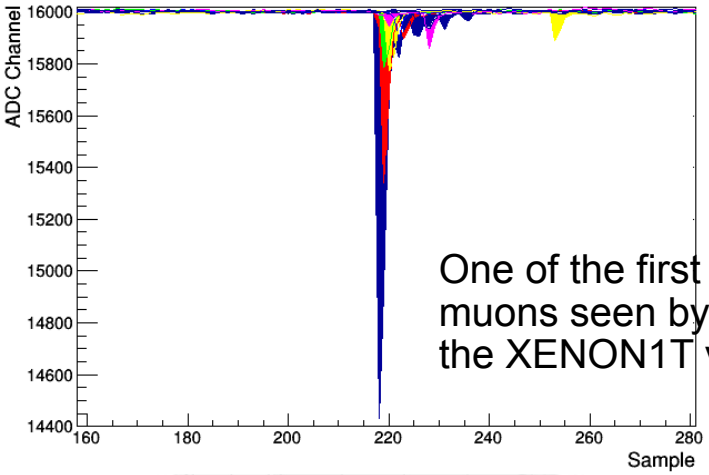
- 3.5 t liquid xenon in total
- **2.0t active target**
- ~1t after fiducialization
- 248+6 PMTs

XENON1T: TPC in the Water Tank

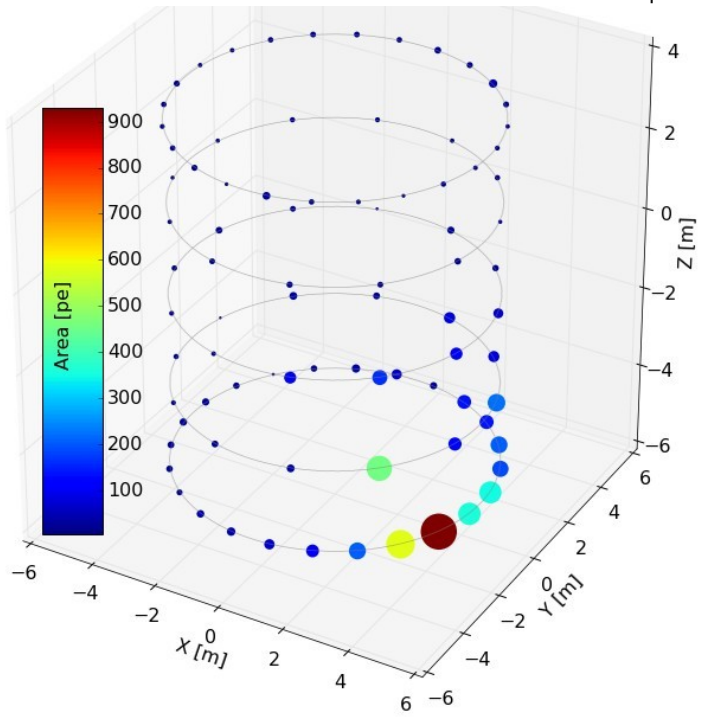


XENON1T: Muon Veto

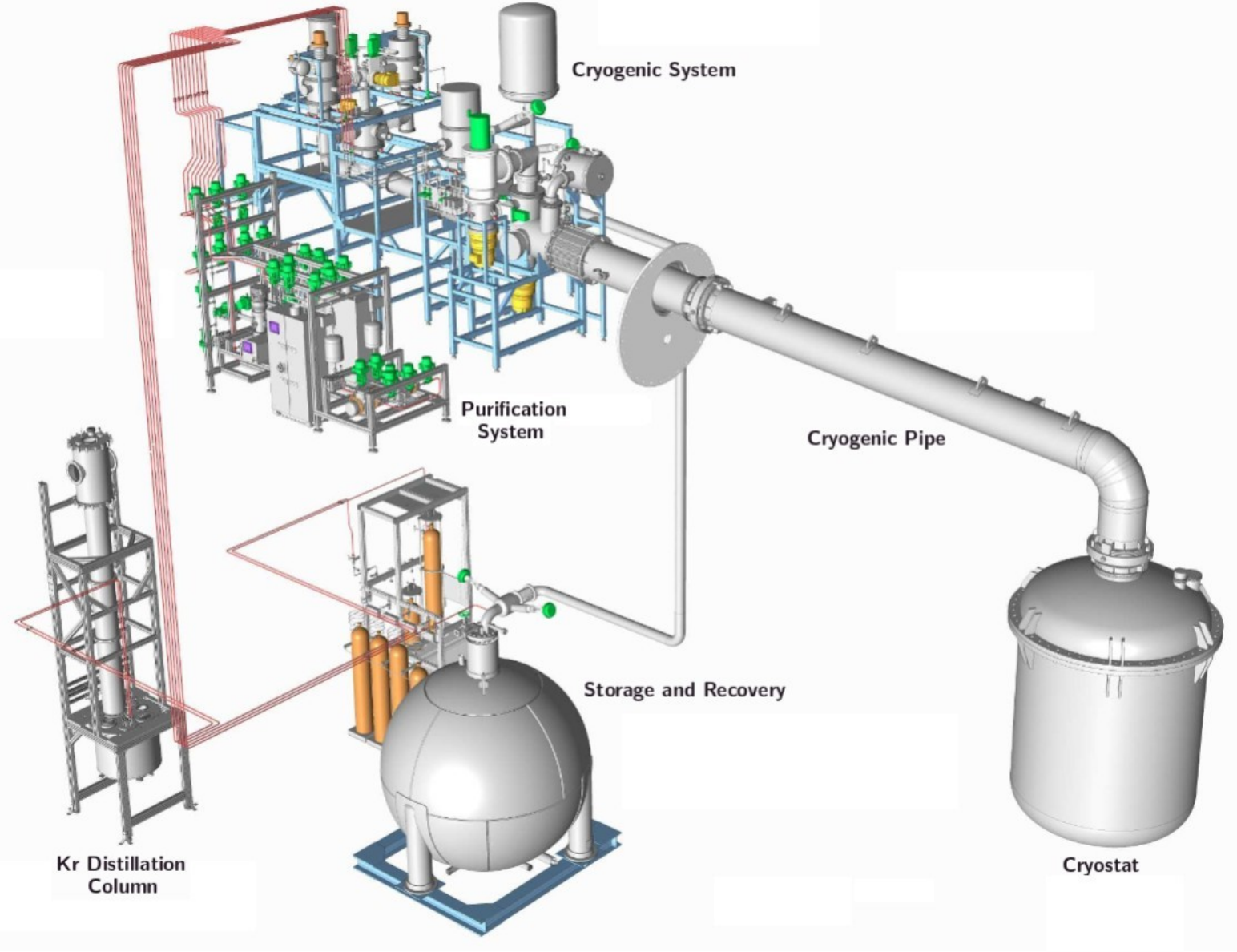




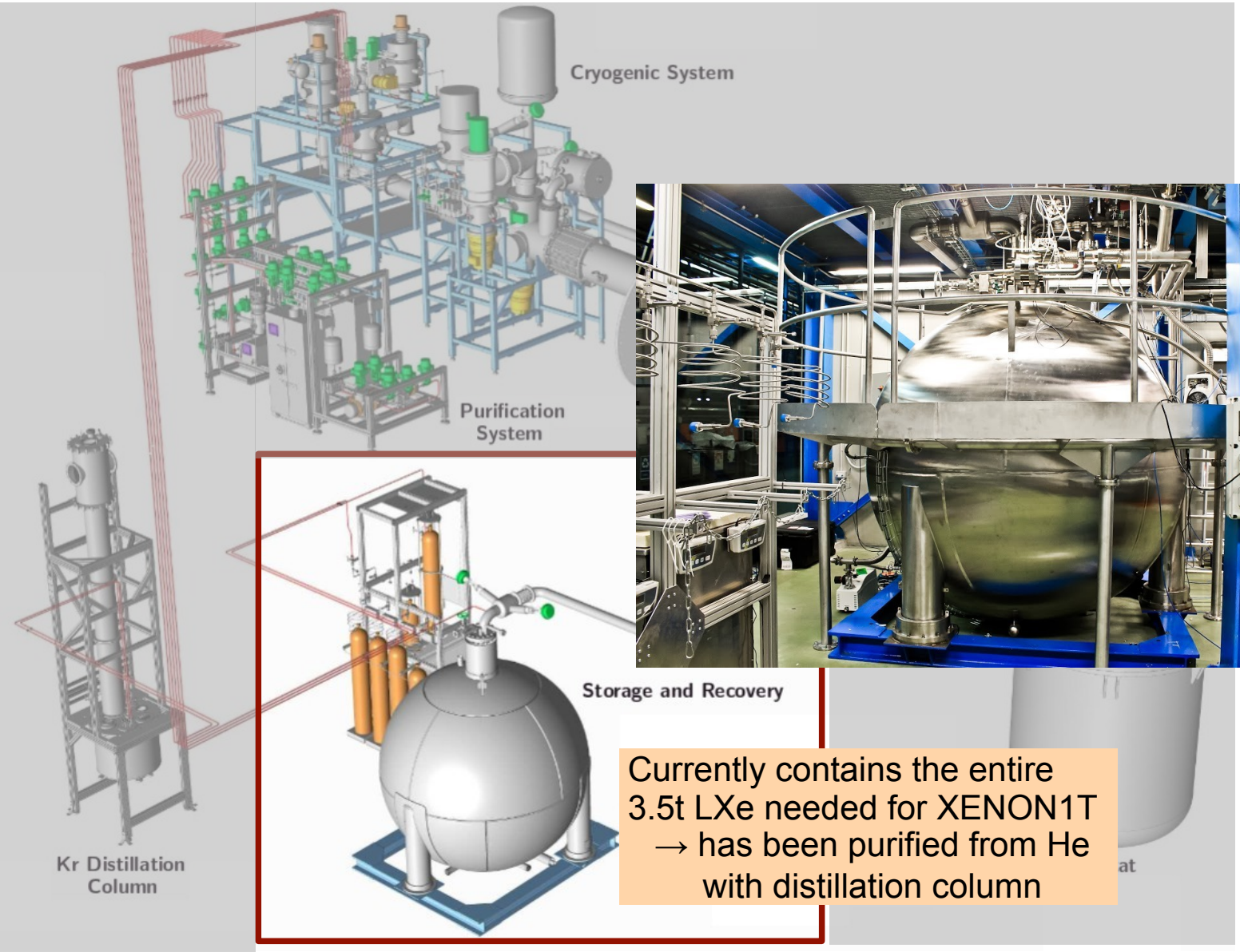
One of the first muons seen by the XENON1T veto



XENON1T: Cryogenic System



XENON1T: ReStoX



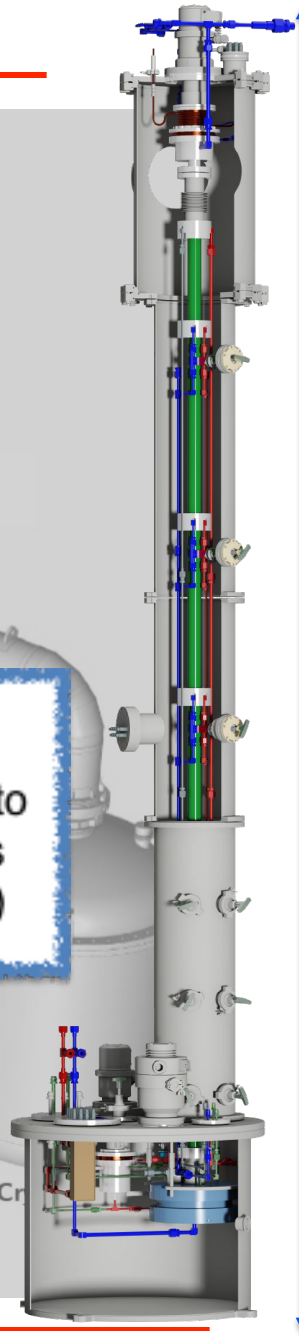
Currently contains the entire 3.5t LXe needed for XENON1T
→ has been purified from He with distillation column

XENON1T: Kr Column

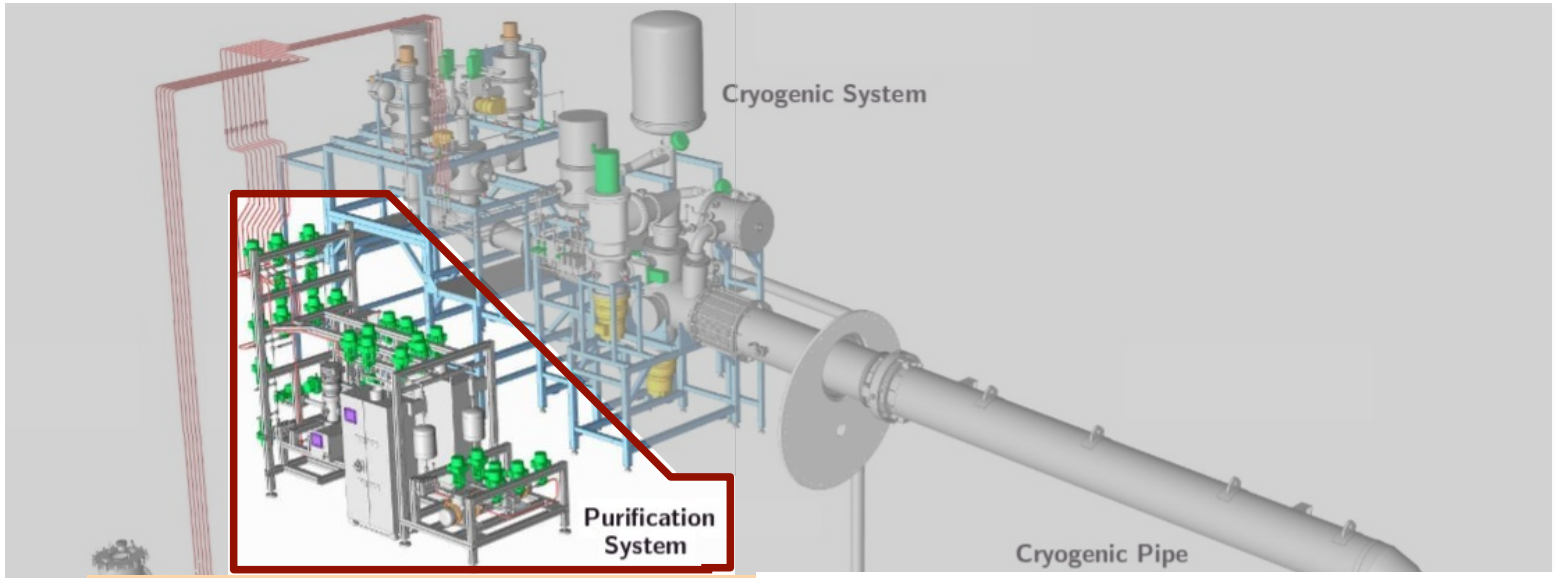
Separation factor: 10^4 - 10^5
Kr removal : ^{Nat}Kr/Xe < 0.026 ppt
Factor 10 better than required

ready to remove
^{nat}Kr from Xe

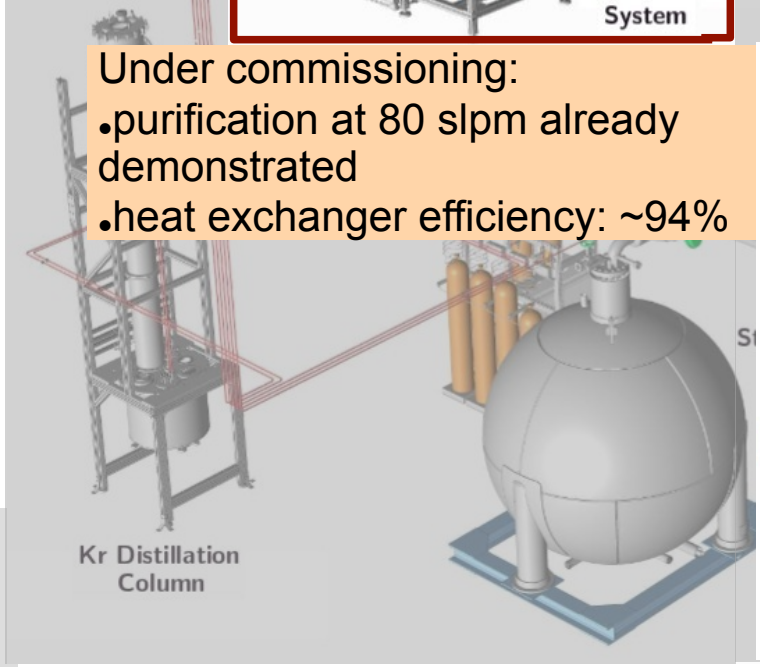
The ^{85}Kr concentration in the atmosphere is strongly related to nuclear proliferation (weapons testing, nuclear plant accident)

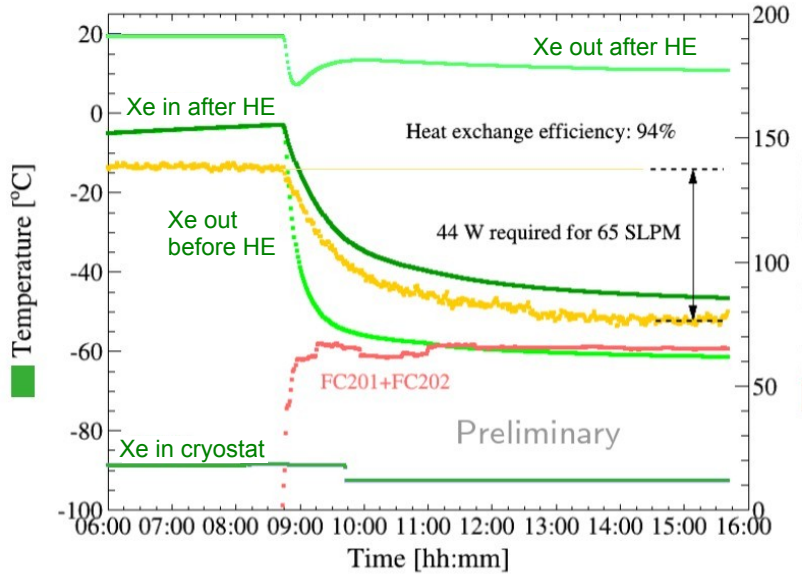


XENON1T: Purification System

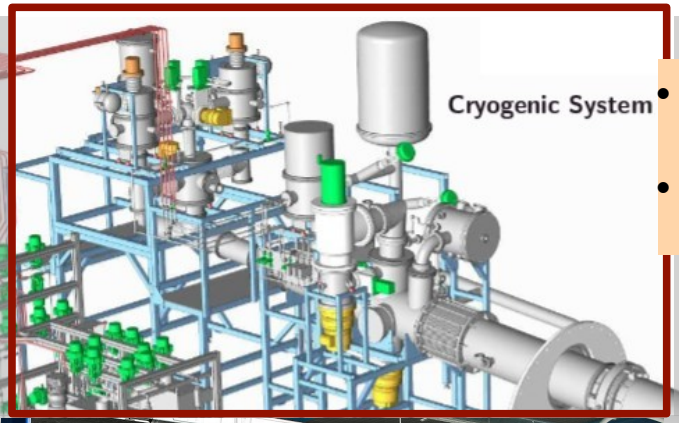


Under commissioning:
- purification at 80 slpm already demonstrated
- heat exchanger efficiency: ~94%





XENON1T: Cryogenic System



- 3 redundant cold-heads (2 PTR, 1 LN2)
- sufficient cooling power for $\gg$100 slpm purification

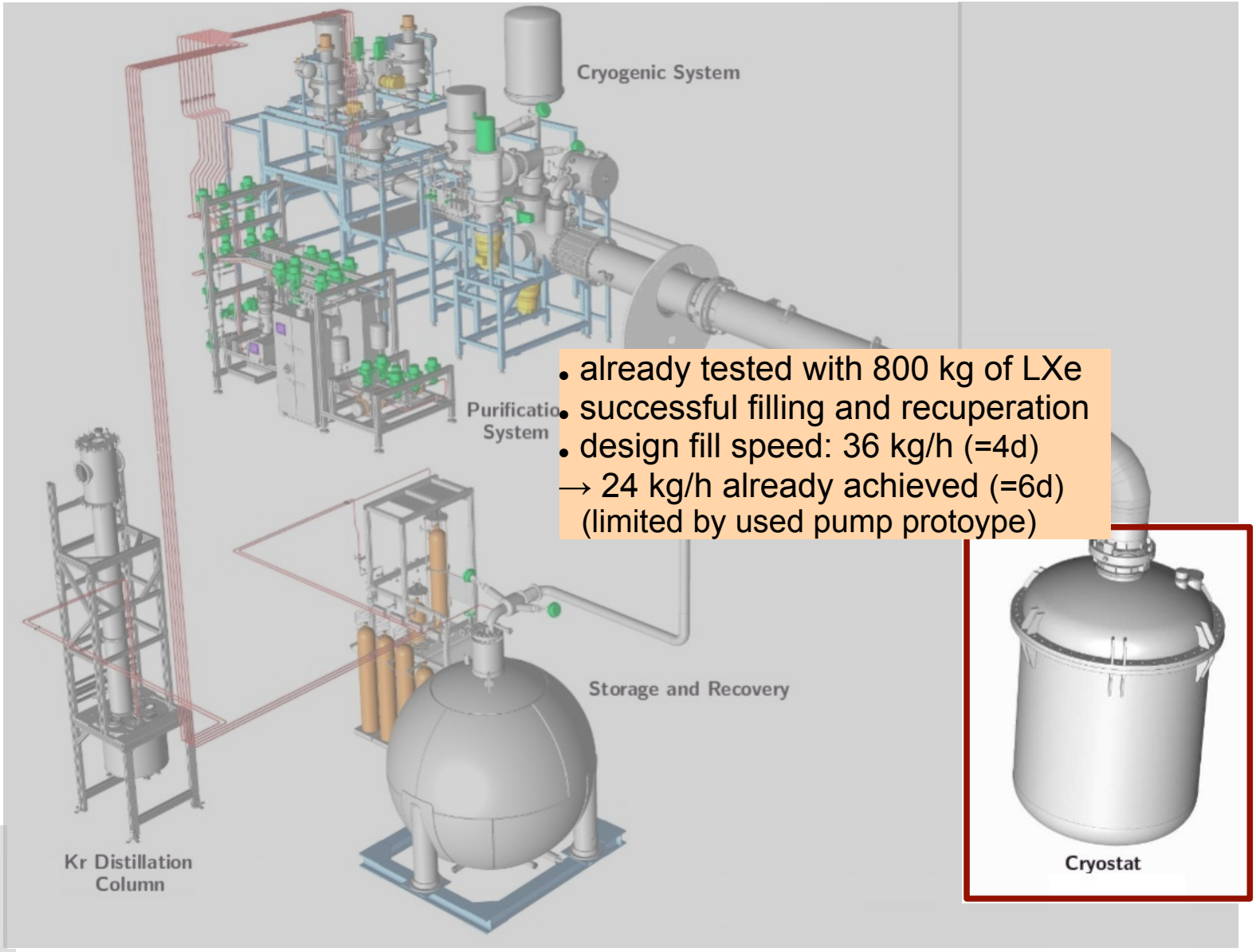
Cryogenic Pipe

Storage and Recovery

Kr Distillation Column

Cryostat

XENON1T: Cryostat

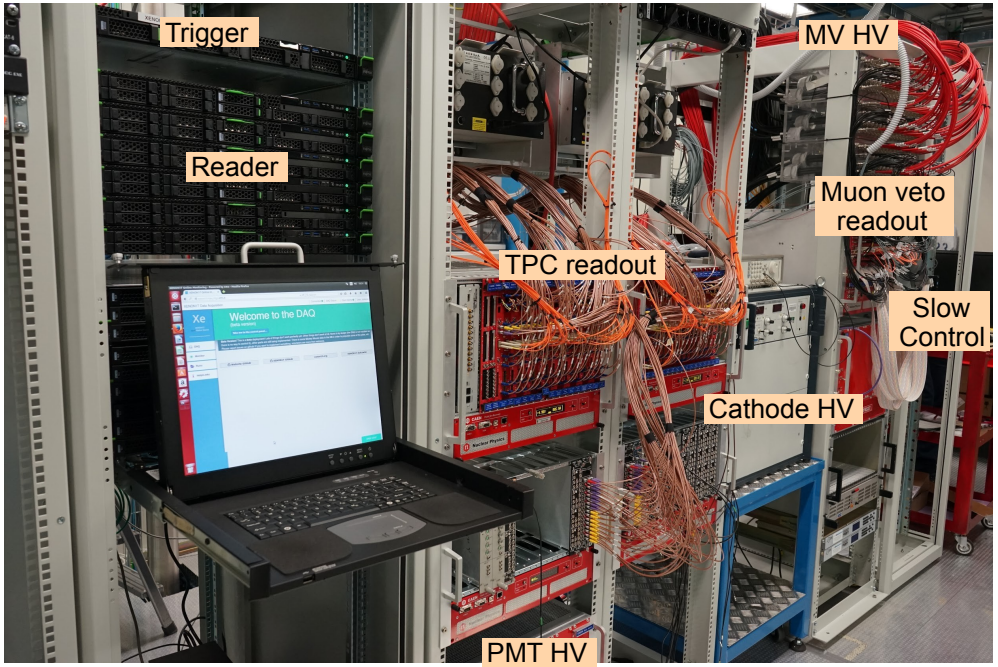


- already tested with 800 kg of LXe
- successful filling and recuperation
- design fill speed: 36 kg/h (=4d)

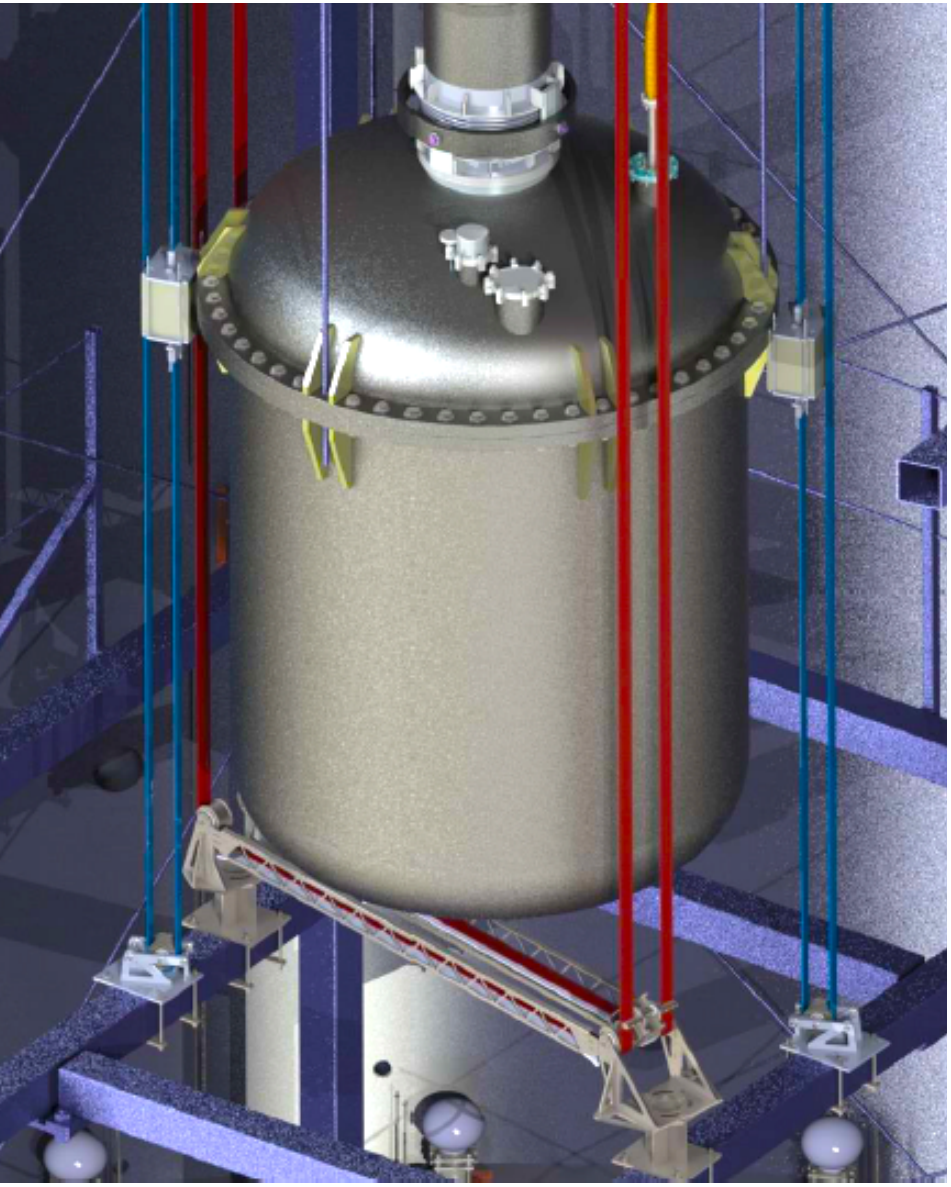
→ 24 kg/h already achieved (=6d)
(limited by used pump protoype)

XENON1T: PMT, DAQ, Electronics

- all 254 PMTs operational
- DAQ electronics for TPC and muon veto installed in T-stabilized DAQ room
- detectors can be operated simultaneously (and time-synced) or independently
- PMT/DAQ commissioning ongoing



XENON1T: Calibration



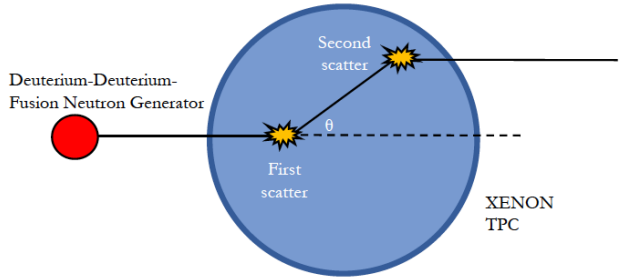
XENON1T is calibrated via:

LED: to periodically measure the gain of the PMT inside the TPC

INTERNAL CALIBRATION SOURCES: short-lived radioactive isotopes mixed to the xenon stream:

- ^{83m}**Kr** to calibrate the ER energy scale
- ^{220}**Rn and TCH$_3$** for low-energy ER

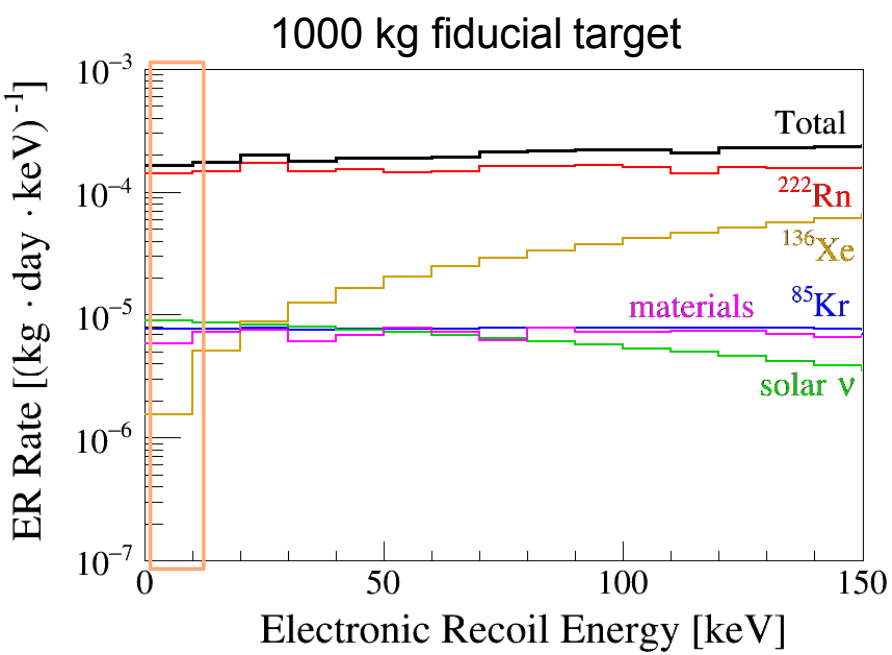
NEUTRON GENERATOR: the size of the XENON1T TPC allow to identifying double scatters of 2.5 MeV mono energetic neutrons produced by a D-D neutron generator

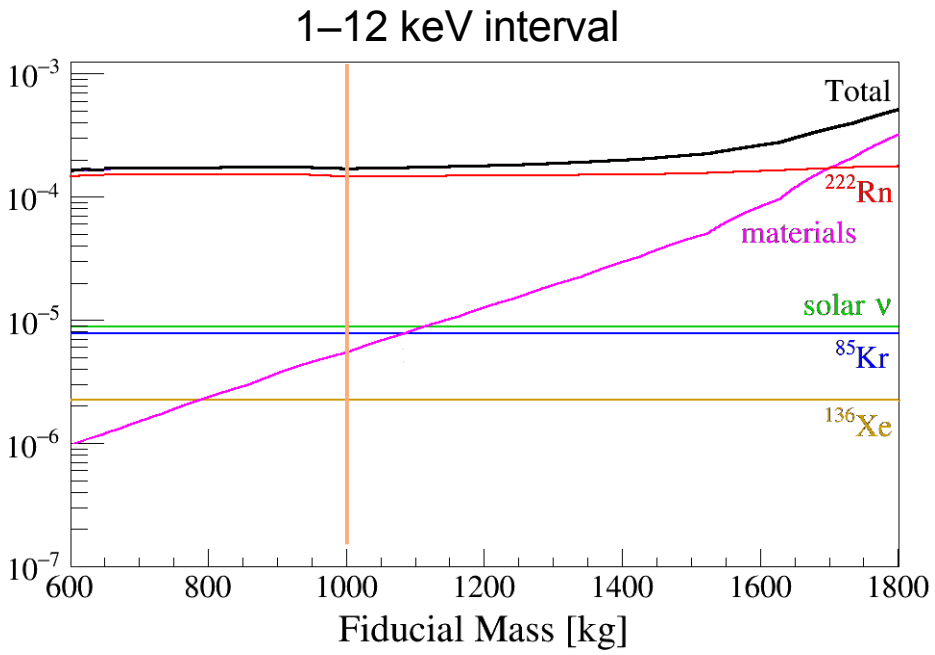


EXTERNAL CALIBRATION SOURCE to measure the purity of the LXe in the target and self shielding capability

XENON1T: Electronic Recoil

arXiv:1512.07501, accepted by JCAP





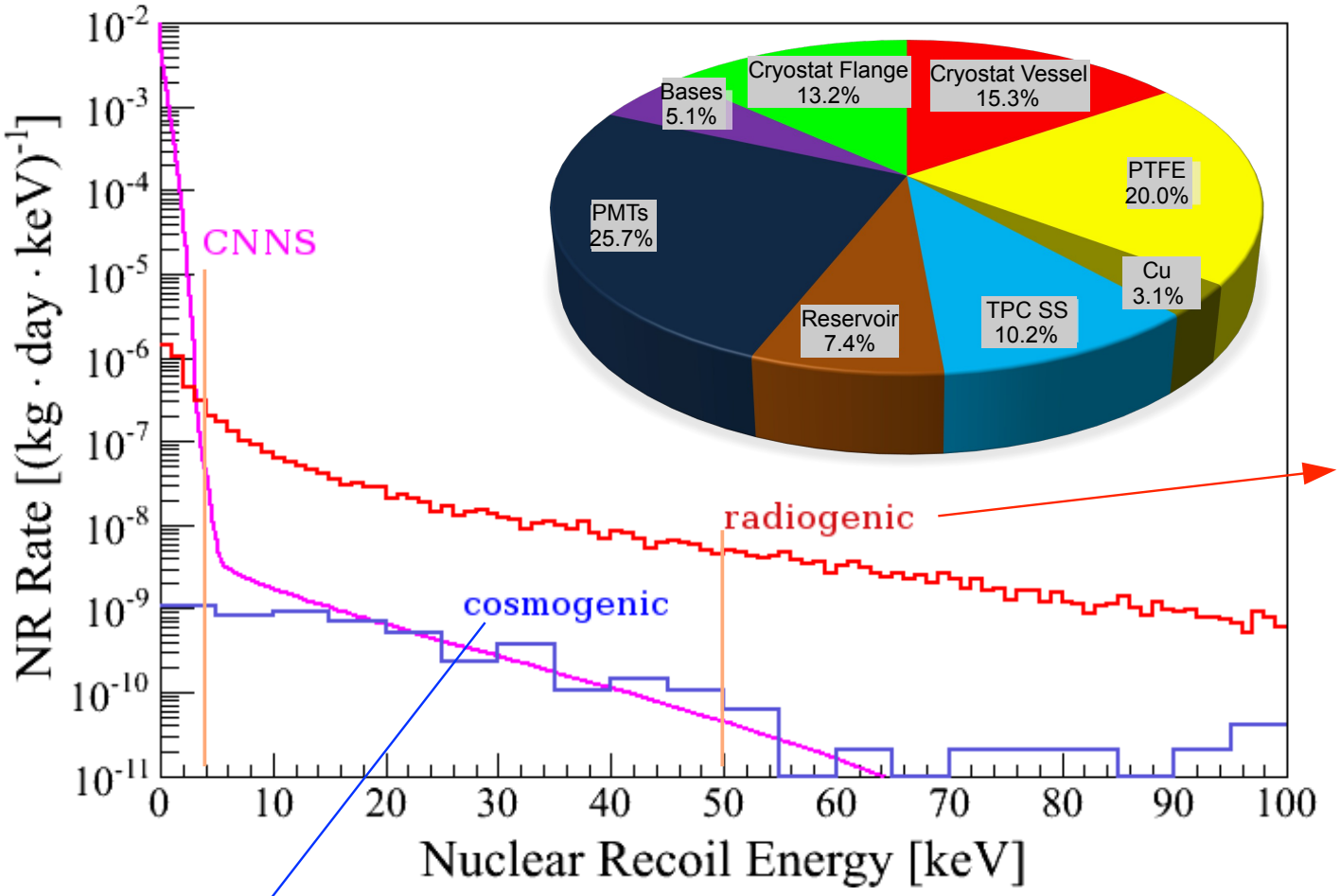
Assumed contamination:

^{222}Rn: 10 μBq/kg (measured 19 ± 4 → 8 expected after purification)

^{nat}Kr: 0.2 ppt

^{136}Xe: 8.9% natural abundance

XENON1T: Nuclear Recoil



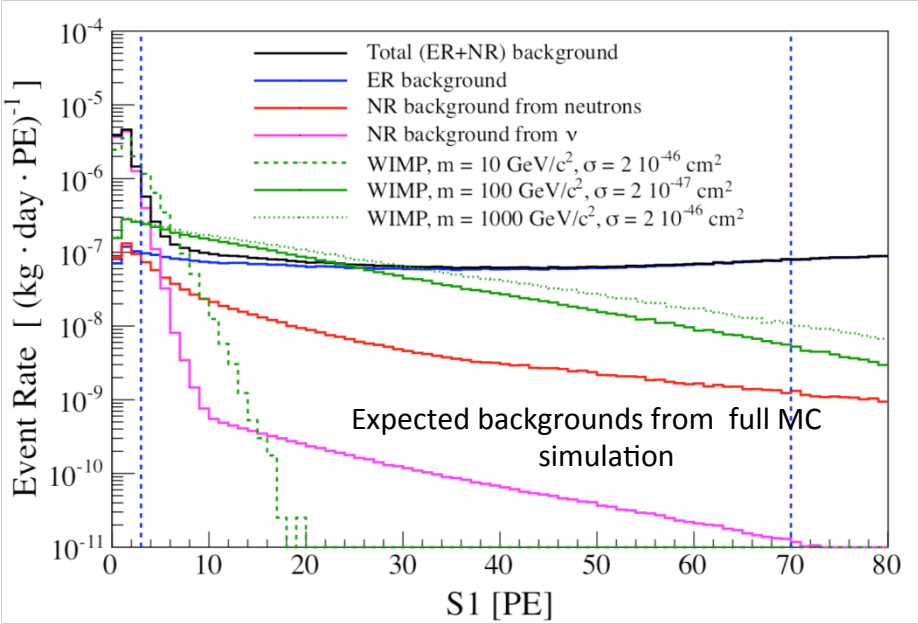
material screening, e.g. EPJ C 75, 546 (2015)

Muon veto design and performance: XENON1T, JINST 9, P11006 (2014)

Monte Carlo Simulation

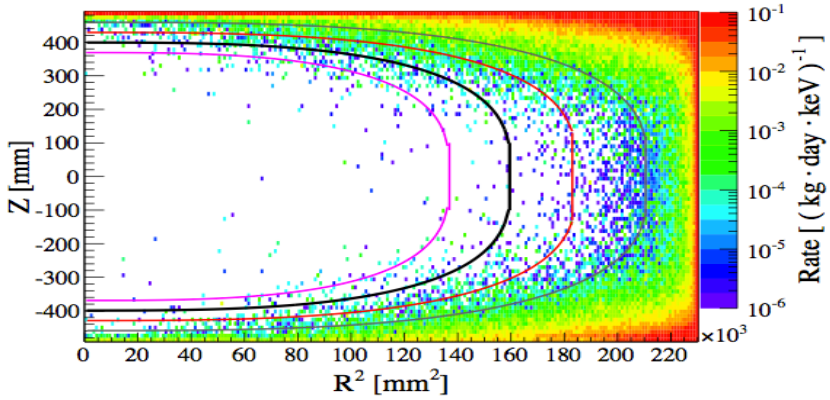
Reproduce via software the performance of the XENON1T detector, and predict the sensitivity of the experiment

arXiv:1512.07501 [physics.ins-det]



1 ton fiducial volume S1 in [3,70] PE
ER discrimination 99.75%
NR acceptance 40%

Position of the ER background from the materials, negligible inside the 1 ton fiducial volume



Method:

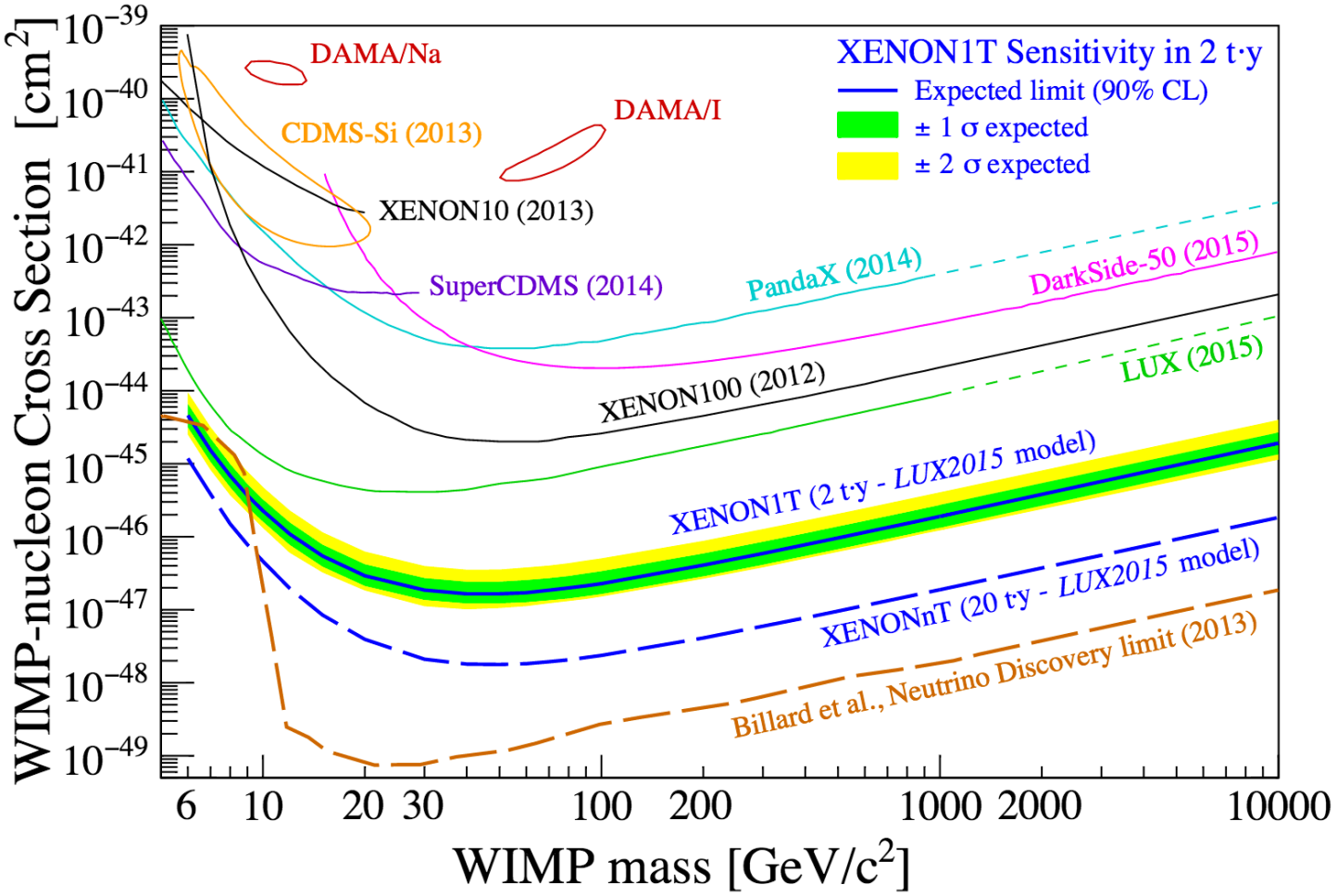
- Input from screening campaign by all detector components
- Monte Carlo simulation with GEANT4
- Statistical treatment

Source	Bkg (evts/ton/year)
ER (materials + intrinsic + solar ν)	1.6
NR from radiogenic neutrons	0.22
NR from ν coherent scattering	0.23
Total	2.05

XENON1T: Sensitivity

arXiv:1512.07501, accepted by JCAP

based on background predictions shown before, 2 t×y exposure:



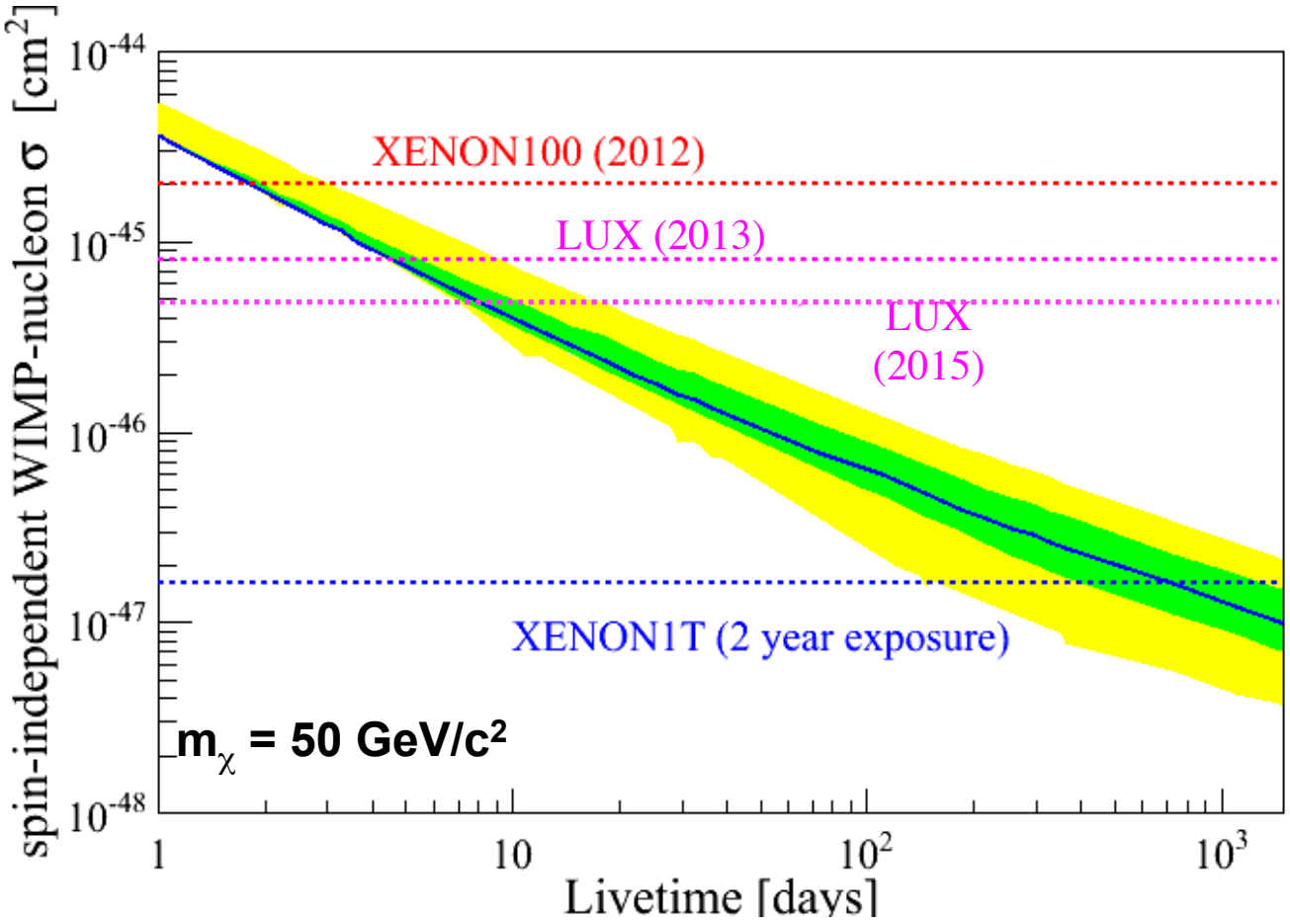
assumptions: energy interval: 4 – 50 keV,

ER rejection as XENON100: 99.5% @ 50% NR acc.
→ expected LY is 2x higher than in XENON100!

XENON1T: Sensitivity Vs Time

arXiv:1512.07501, accepted by JCAP

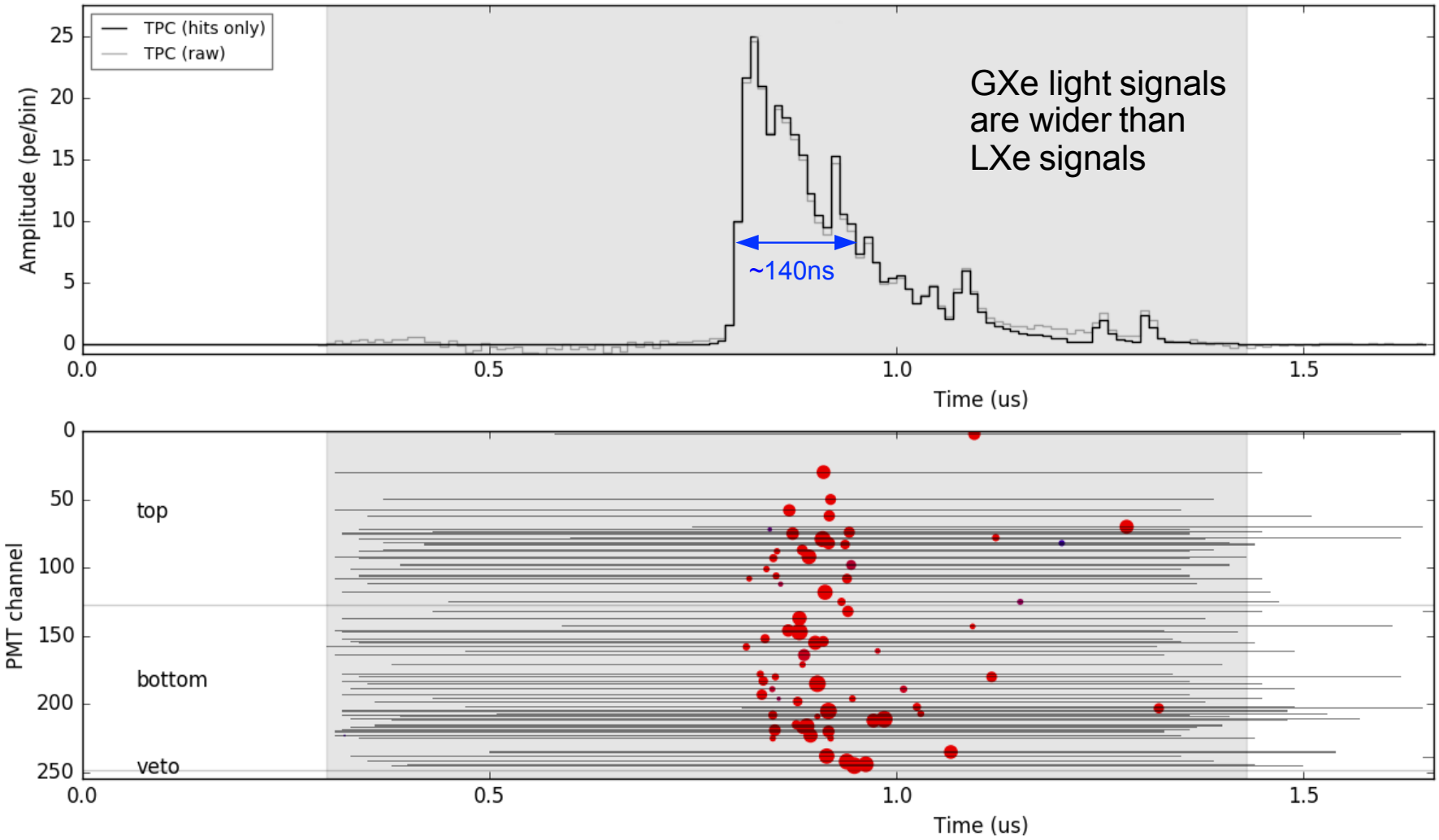
based on background predictions shown before, 2 t×y exposure:



In less than 10 days we expect to reach the sensitivity of the currently running experiments

XENON1T: First GXe event

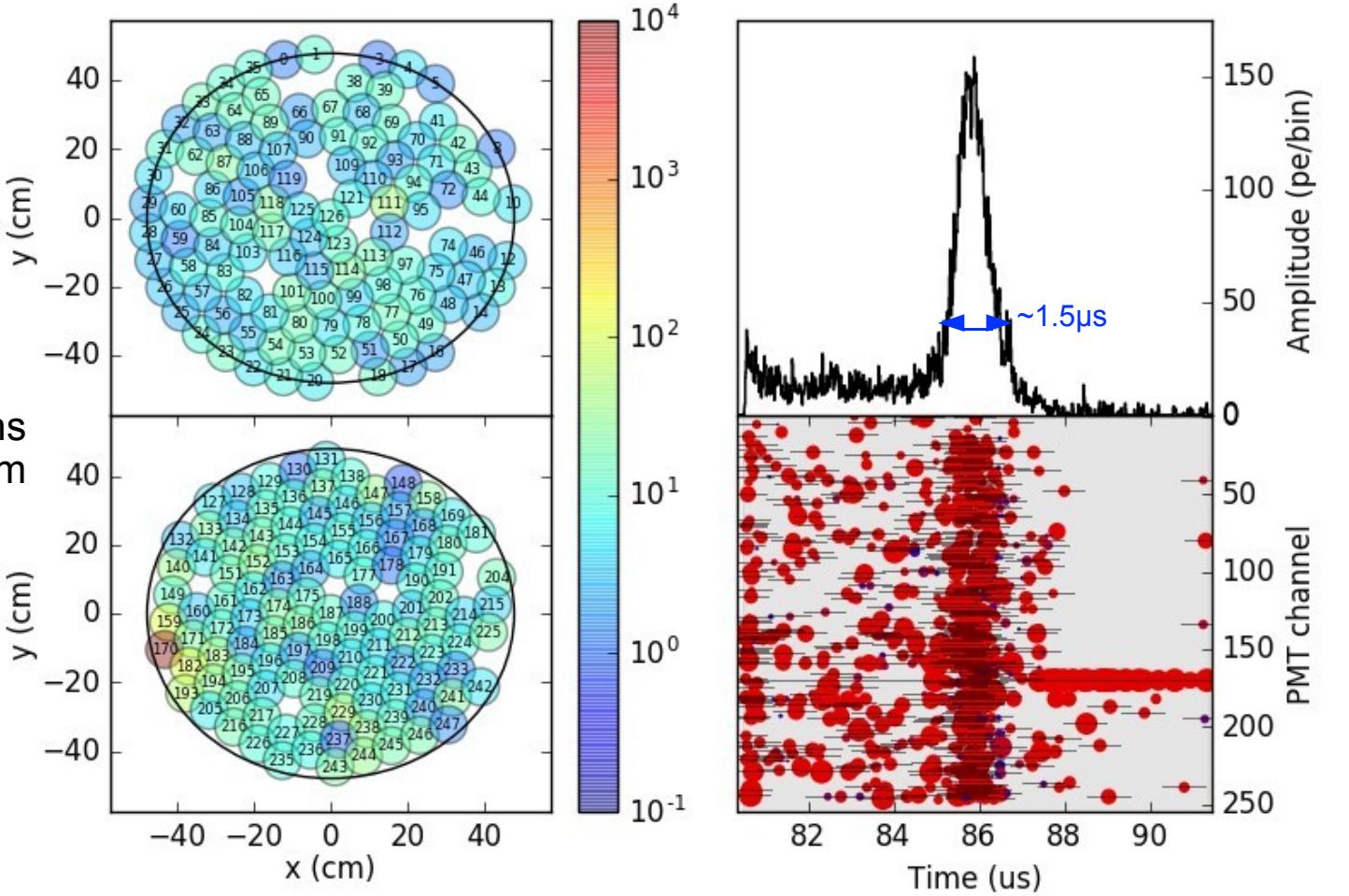
March 2016: TPC filled with GXe
→ start commissioning of **PMTs**, **DAQ** and **analysis** with particle interactions



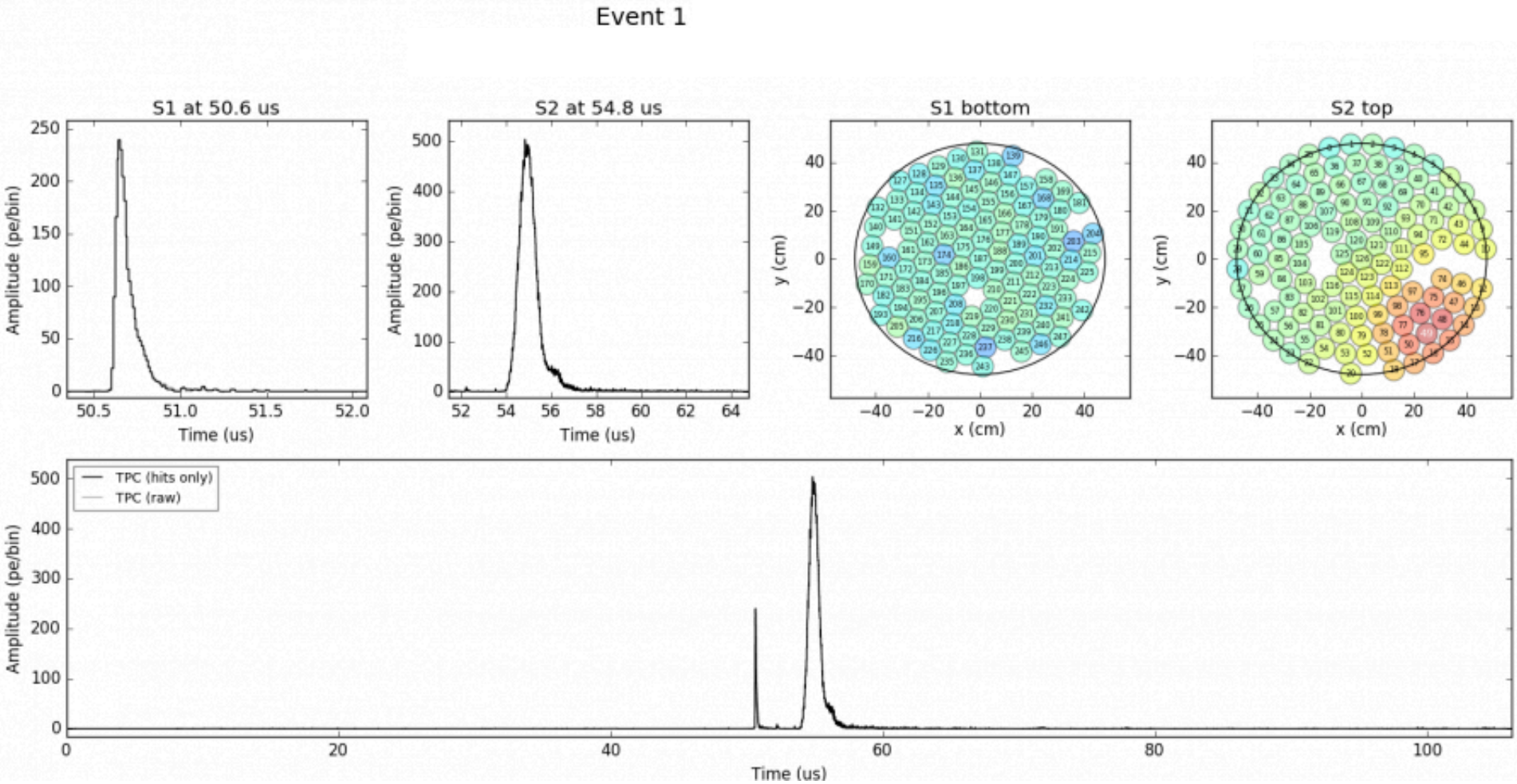
XENON1T: First Charge Signal

the main TPC electrodes were not yet biased
→ we still see first S2 peaks, thanks to the fields
between the PMTs and the screening electrodes (~2.1 kV/cm)

Event happens close to bottom PMT array



XENON1T: First S1 + S2 LXe Signal!




XENON1T is coming…
The hunt is about to start !