The XENON1T Experiment

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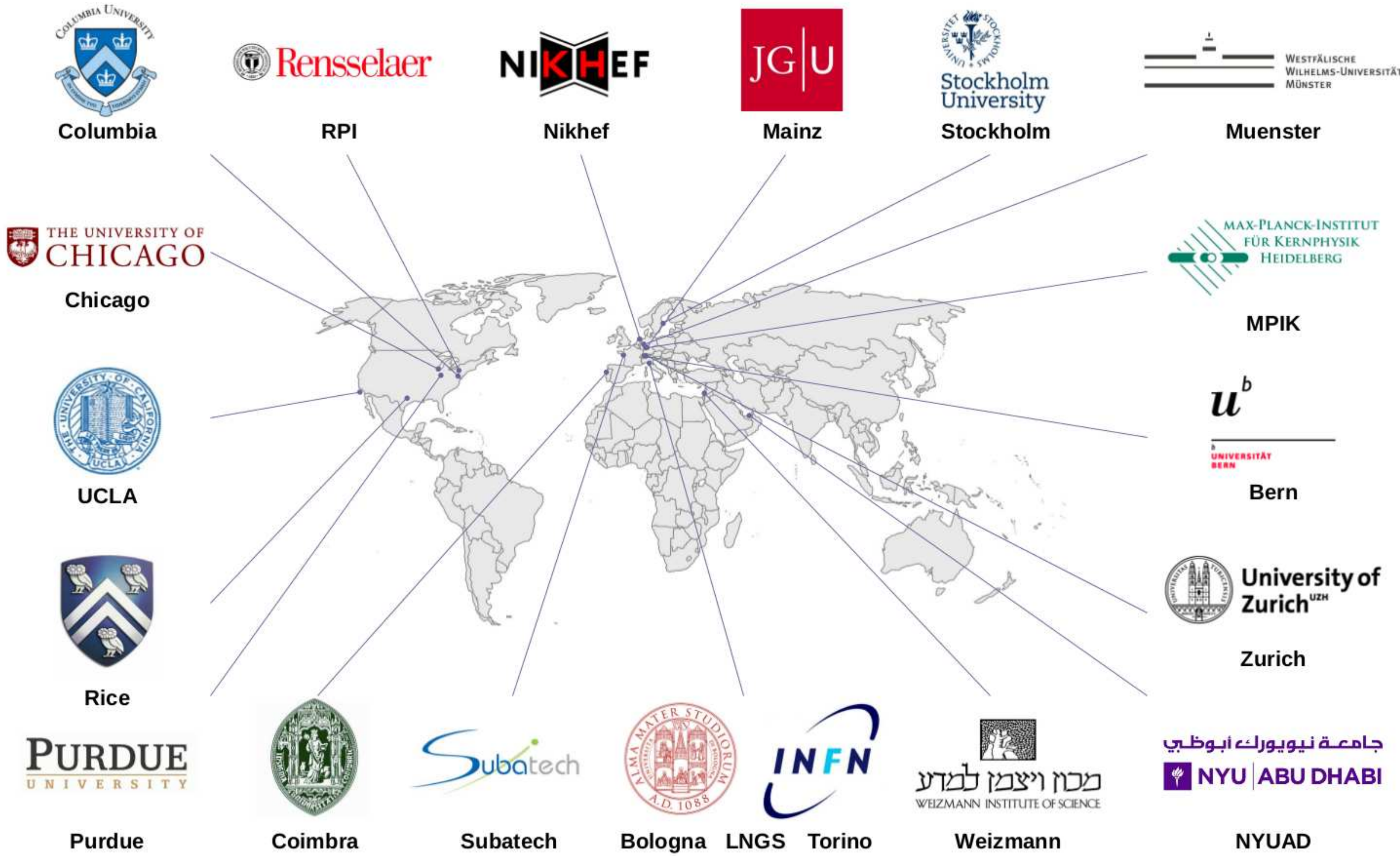
on behalf of the XENON Collaboration

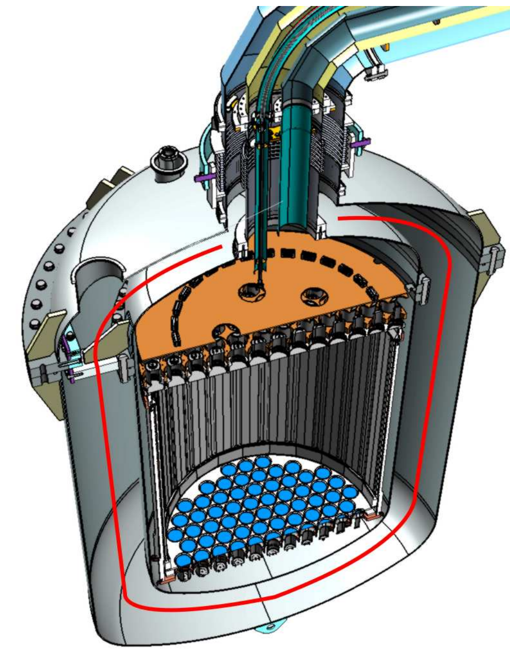
13th Pisa Meeting on Advanced Detectors - May 29, 2015

XENON Collaboration

XENON Dark Matter Project

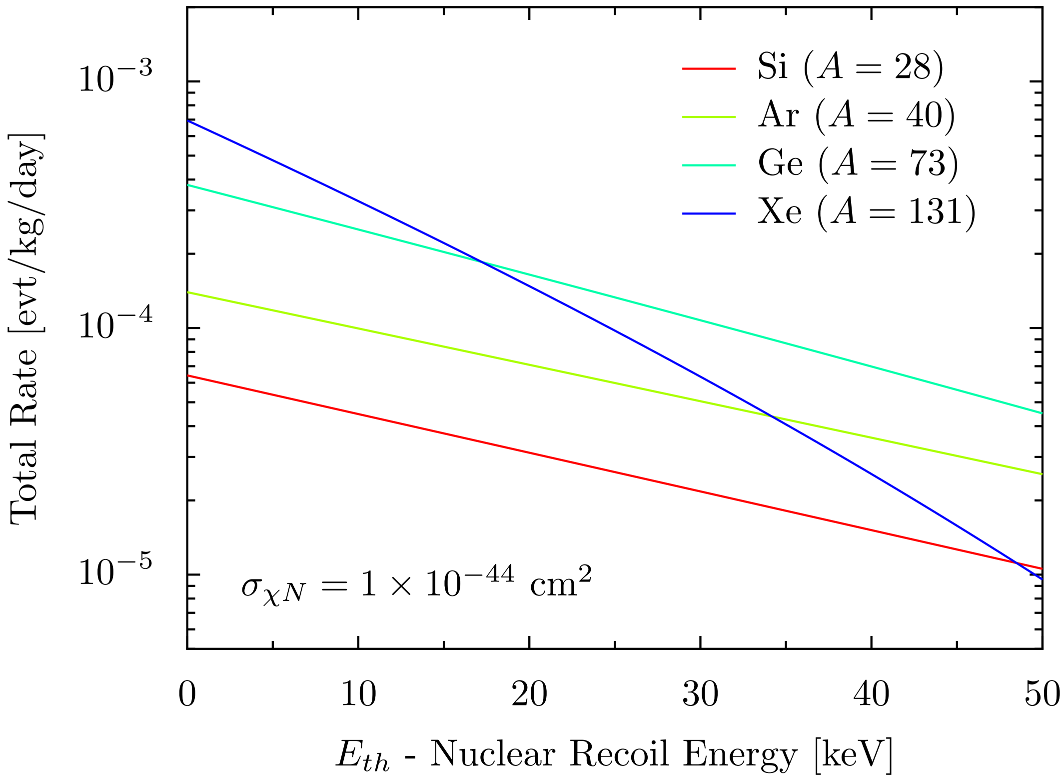


XENON Program

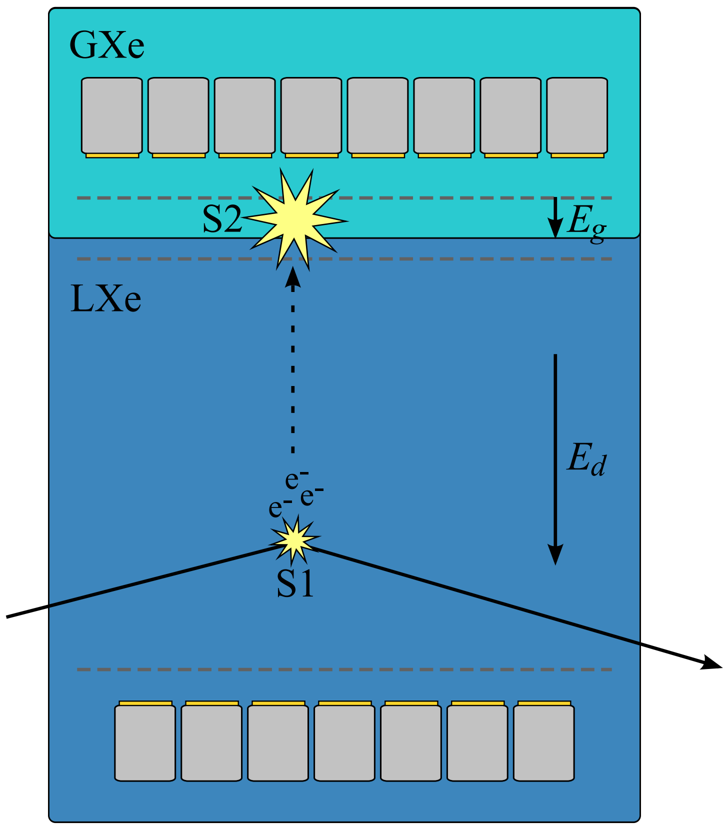
XENON10	XENON100	XENON1T/XENONnT
		 
2005-2007	2008-2015	2012-2018 / ~2018-2022
25 kg	161 kg	3300 kg / 7000 kg
Achieved (2007) $\sigma_{SI} = 8.8 \times 10^{-44}\,\text{cm}^2$	Achieved (2011) $\sigma_{SI} = 7.0 \times 10^{-45}\,\text{cm}^2$ Achieved (2012) $\sigma_{SI} = 2.0 \times 10^{-45}\,\text{cm}^2$	Projected (2018) / Projected (2022) $\sigma_{SI} \sim 2 \times 10^{-47}\,\text{cm}^2$ / $\sigma_{SI} \sim 3 \times 10^{-48}\,\text{cm}^2$

Why Xenon?

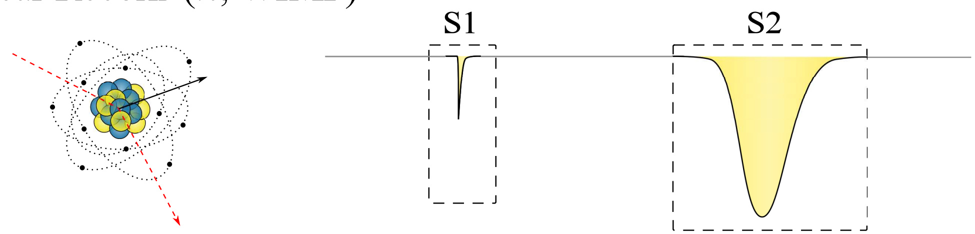
- Large mass number A ($\sim$131), expect high rate for SI interactions ($\sigma \sim A^2$) if energy threshold for nuclear recoils is low
- $\sim$50% odd isotopes ($^{129}\mathrm{Xe}$, $^{131}\mathrm{Xe}$) for SD interactions
- No long-lived radioisotopes (with the exception of $^{136}\mathrm{Xe}$, $T_{1/2} = 2.2 \times 10^{21}\,\mathrm{yr}$), Kr can be reduced to ppt levels
- High stopping power ($Z = 54$, $\rho = 3\,\mathrm{g\,cm^{-3}}$), active volume is self shielding
- Efficient scintillator ($\sim$80% light yield of NaI), fast response
- Scalable to large target masses
- Nuclear recoil discrimination with simultaneous measurement of scintillation and ionization



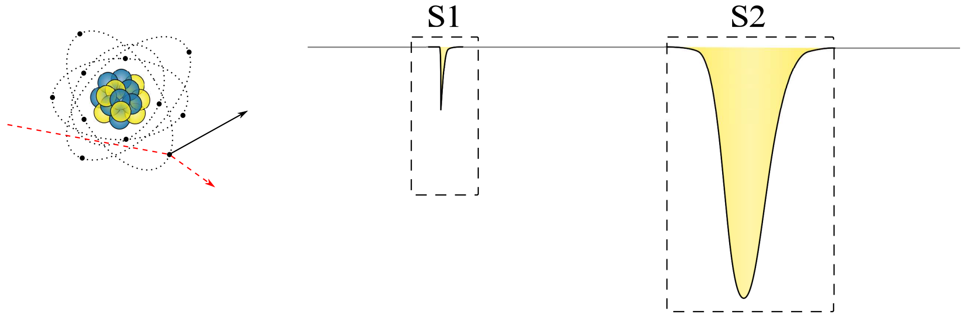
Dual Phase TPC Principle



Nuclear Recoils (n, WIMP)

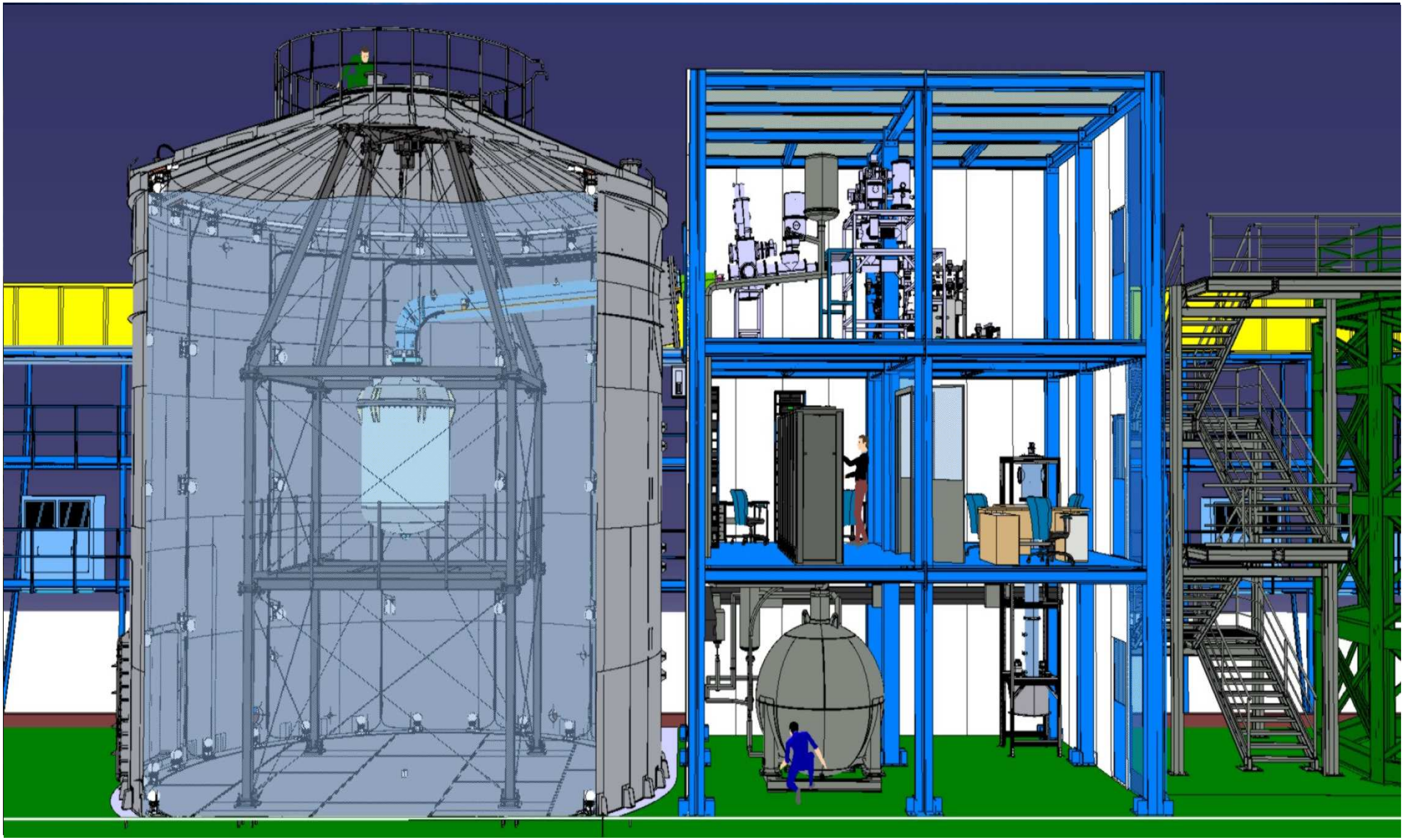


Electronic Recoils (γ, β)



- Bottom PMT array below cathode, fully immersed in LXe to efficiently detect scintillation signal (S1).
- Top PMTs in GXe to detect the proportional signal (S2).
- Distribution of the S2 signal on top PMTs gives xy coordinates while drift time measurement provides z coordinate of the event.
- Ratio of ionization and scintillation (S2/S1) allows discrimination between electron and nuclear recoils.

XENON1T@LNGS




Xe
XENON
Matter Project
XENON1
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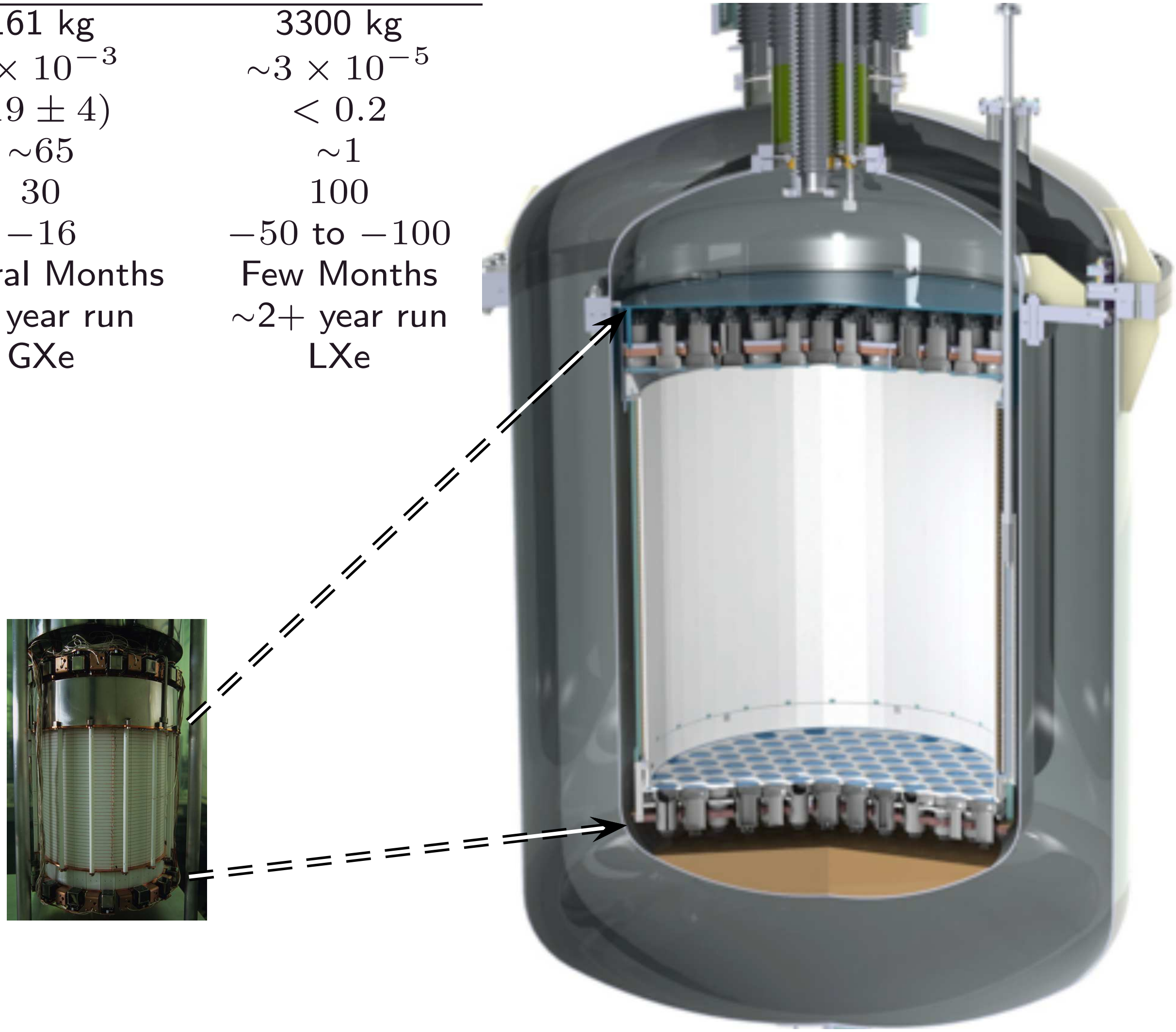
From XENON100 to XENON1T: A Few of the Challenges

	XENON100	XENON1T
LXe Mass (kg)	161 kg	3300 kg
ER Bkgnd (evts/keV/kg/d)	5×10^{-3}	$\sim 3 \times 10^{-5}$
Kr Concentration (ppt)	(19 ± 4)	< 0.2
Rn Concentration (μBq/kg)	~ 65	~ 1
Charge drift (cm)	30	100
Cathode HV (kV)	-16	-50 to -100
LXe Purification	Several Months	Few Months
Cryogenics	~1 year run	~2+ year run
Storage/Recovery	GXe	LXe



XENON1T: Construction Milestones

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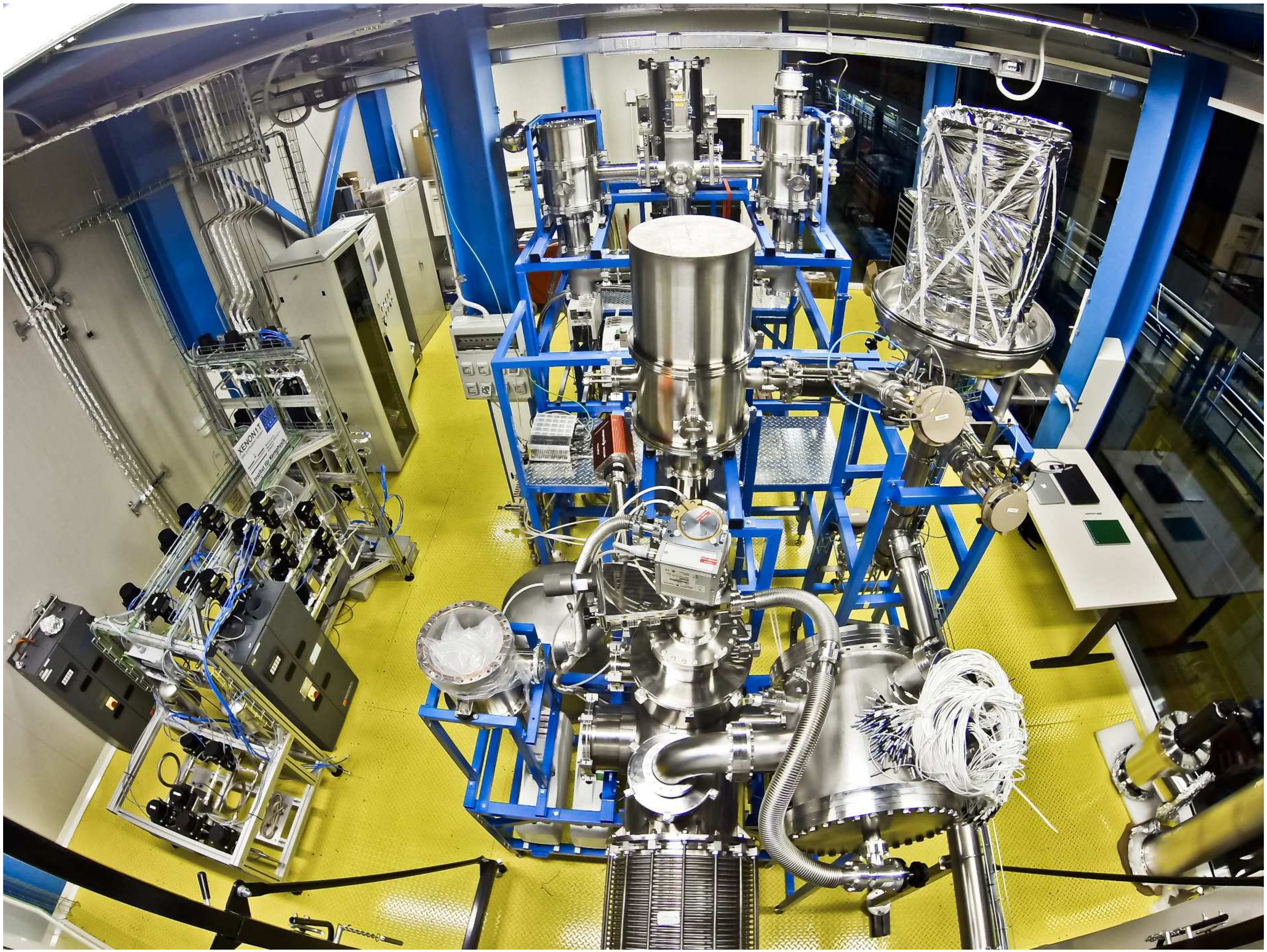
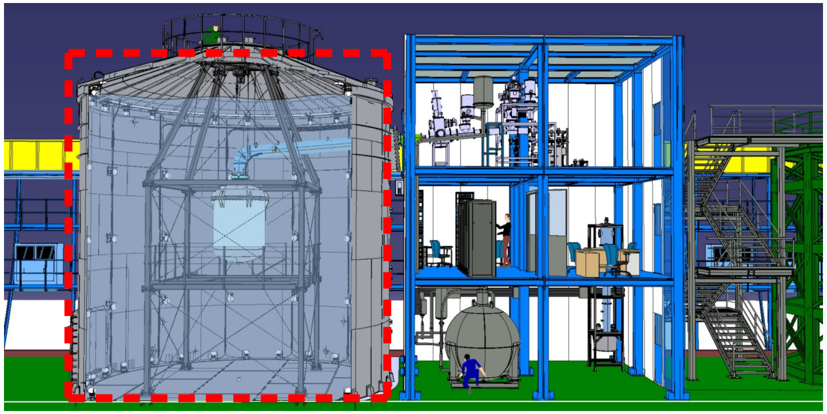
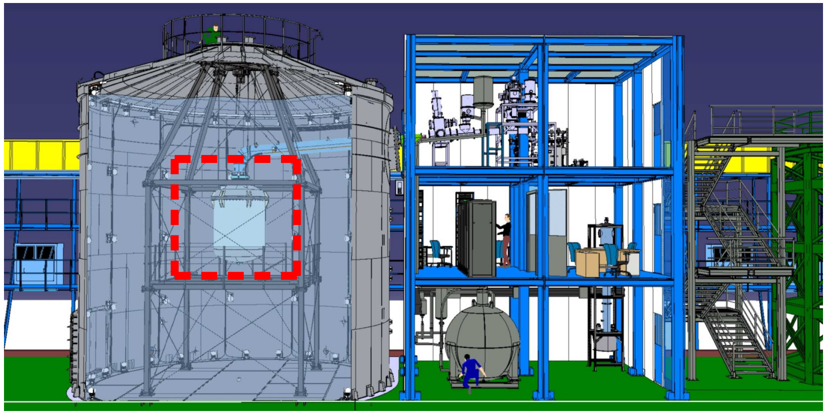
Xe
XENON
Dark Matter Project





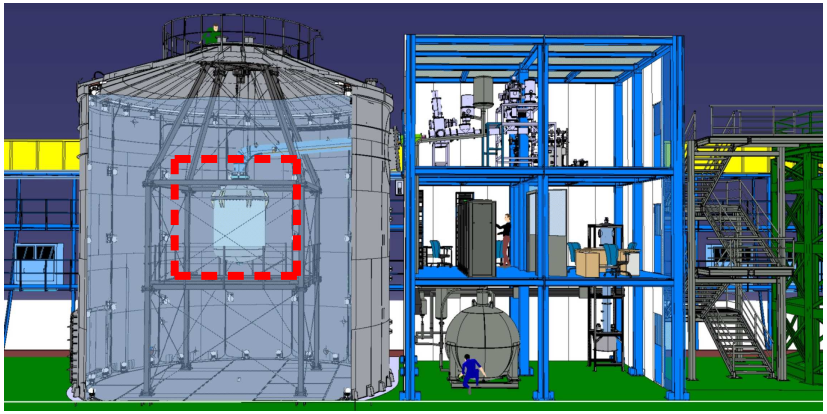
- Water tank $10\,\mathrm{m}$ high and $9.6\,\mathrm{m}$ diameter
- Interior lined with 3M specular reflector foil
- Water tank construction completed 2013/12
- 84 high QE 8" Hamamatsu R5912 PMTs
- μ-induced neutron background < 0.01 evt/yr
- Trigger efficiency $> 99.5\%$ for neutrons with μ in water tank, ~78% with μ outside
- Details in Aprile *et al.*, JINST **9**, P11006, 2014

XENON1T: Cryostat, TPC



- Double-wall vacuum insulated cryostat, constructed from selected low-activity stainless steel
- Outer vessel $2.4\,\mathrm{m}$ high, $1.6\,\mathrm{m}$ diameter, inner vessel $\sim 2\,\mathrm{m}$ high, $1.1\,\mathrm{m}$ diameter
- 3.3 tons LXe, $\sim 0.7\,\mathrm{m}^3$ TPC, active target mass of 2 tons
- 248 3" PMTs Hamamatsu R11410-21, 36% average QE, $< 1\,\mathrm{mBq/PMT}$ in U/Th
- Background $\times 100$ lower than XENON100
- Custom low-activity high voltage feedthrough

XENON1T: Cryostat, TPC



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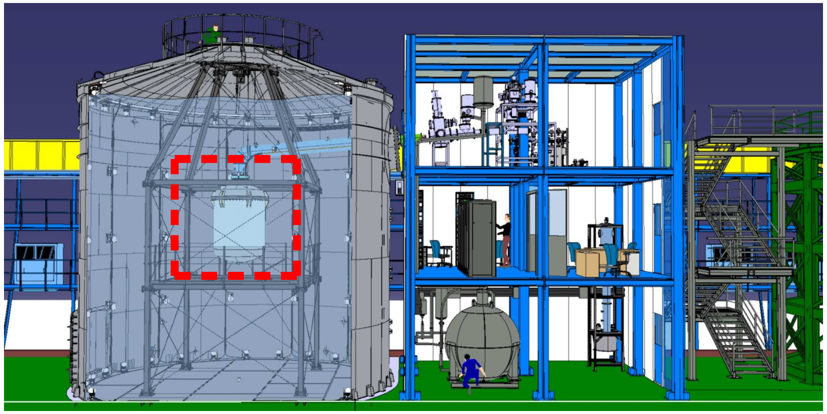

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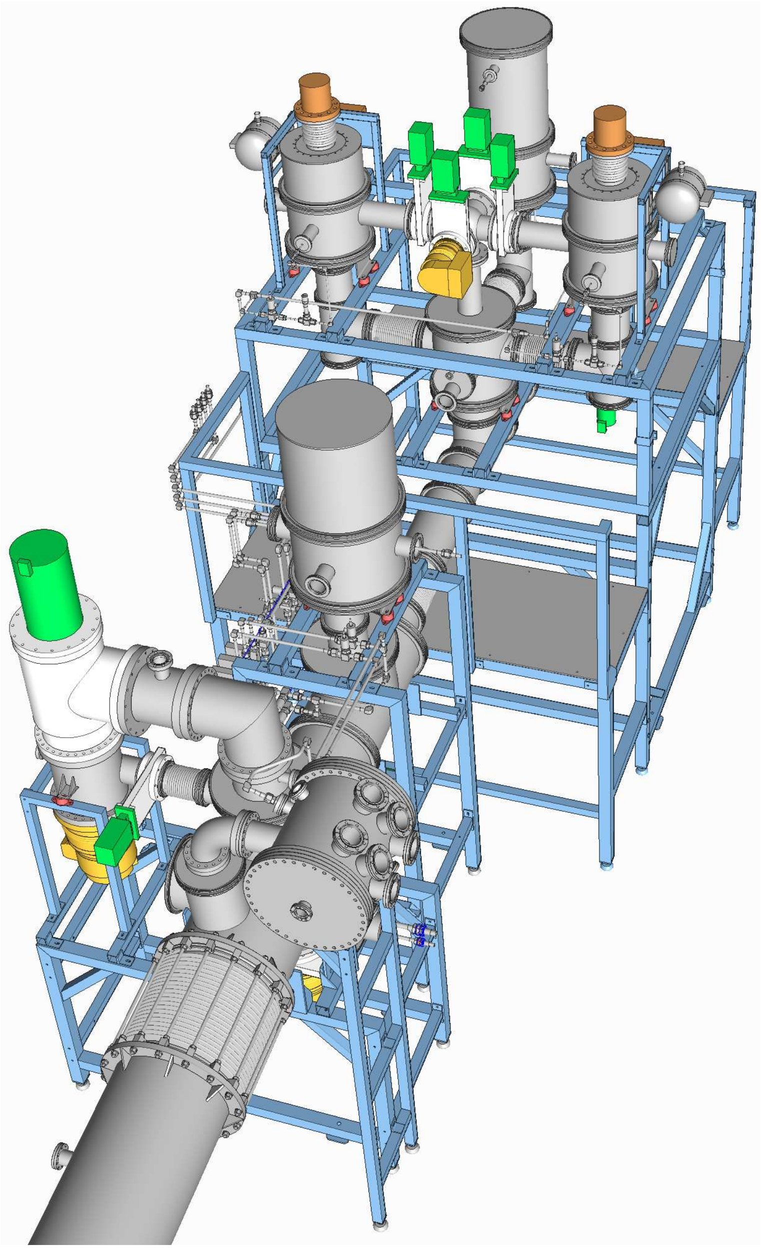
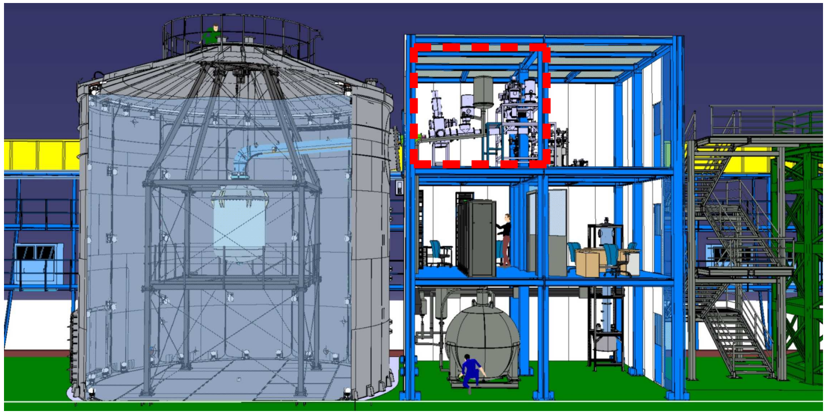
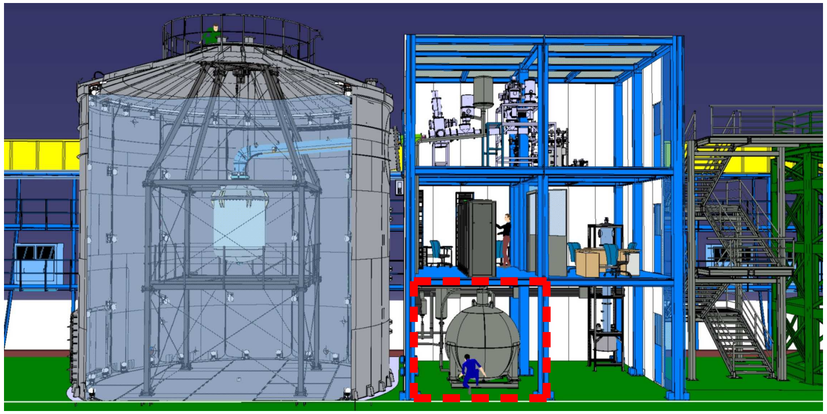




- Design based on experience acquired by operating XENON10, XENON100, and XENON1T Demonstrator
- Heat load below 50 W (without circulation)
- Redundant 200 W pulse tube refrigerators
- One PTR can be serviced while the other is in operation
- Backup liquid nitrogen cooling
- Circulation at ∼100 slpm through heat exchangers

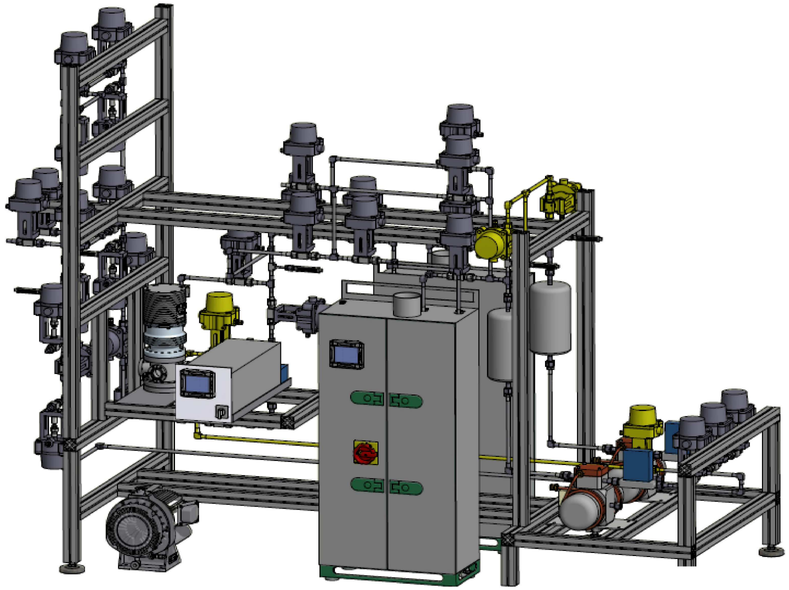
XENON1T: Cryogenics

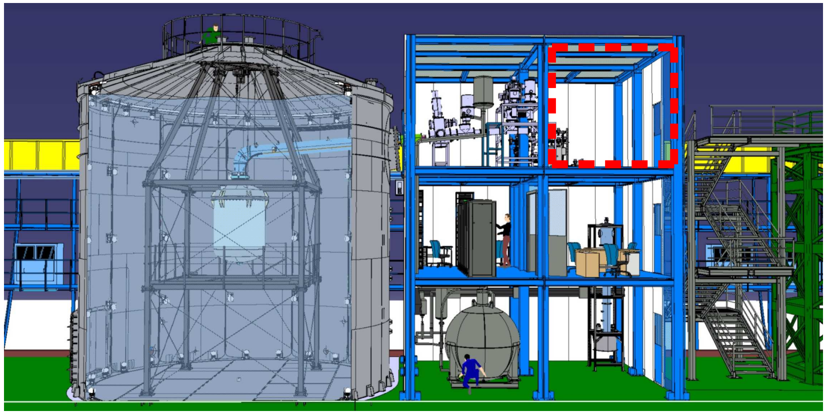
XENON1T: Xe Storage



- Double-wall, high-pressure (70 atm), vacuum insulated, LN2 cooled sphere
- Designed to store ∼7.6 tons of xenon, in liquid form at $-100^{\circ}\mathrm{C}$ or in gaseous form at room temperature
- Detector can be filled with liquid xenon directly instead of condensing xenon gas
- In case of emergency, liquid xenon from the detector can be recovered in a few hours

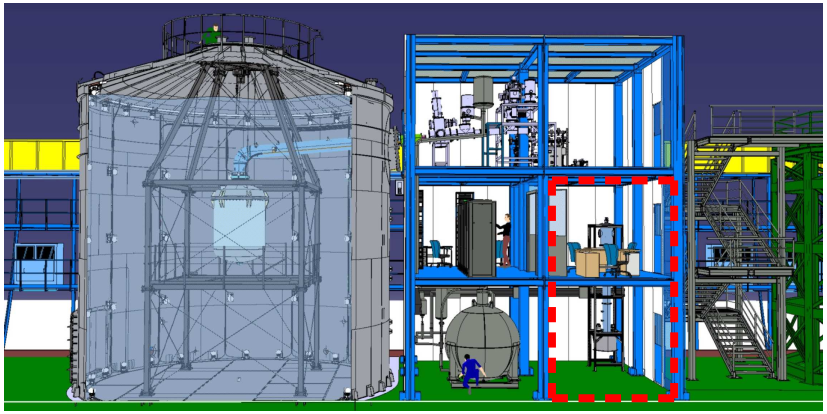
XENON1T: Purification





- Continuous GXe circulation at ∼100 slpm
- Purification using high-flow heated getters
- Two parallel circulation pumps and purification circuits
- GXe purity in-situ analytics
- Continuous monitoring of impurity concentrations (e.g. H_2O)

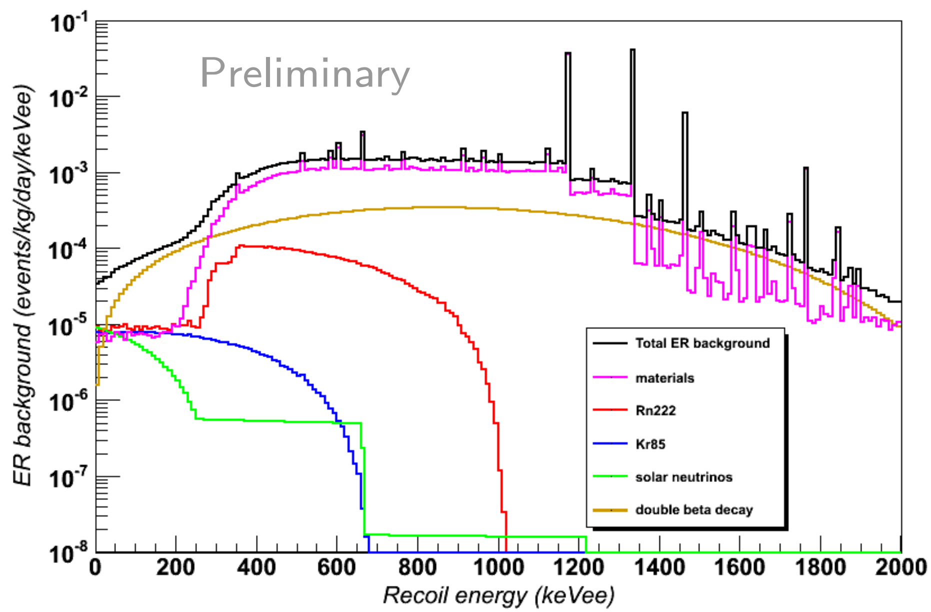
XENON1T: Kr Removal

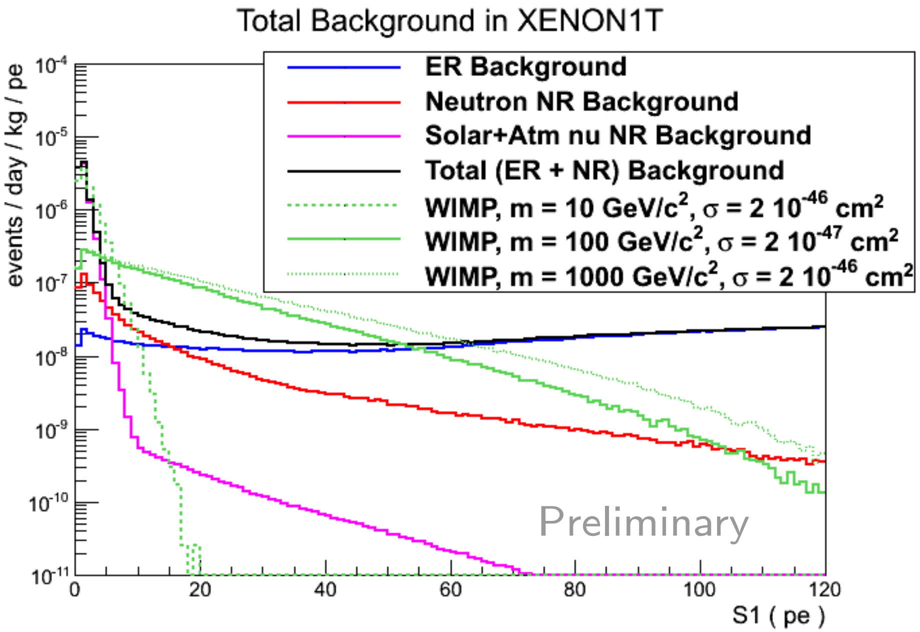


- Building custom designed cryogenic distillation column for Kr removal
- XENON1T Kr/Xe concentration requirement is $< 0.2\,\mathrm{ppt}$, aim at $< 0.1\,\mathrm{ppt}$ with the column
- High throughput, $3\,\mathrm{kg/hr}$ at 10^4 separation
- 3.5 tons in ~1.8 months (single pass)
- Custom gas purity diagnostics (online, $^{83m}\mathrm{Kr}$ tracer, and offline, ATTA, RGMS, RGA + cold trap)

XENON1T: Expected Backgrounds

ER background, before S2/S1 discrimination



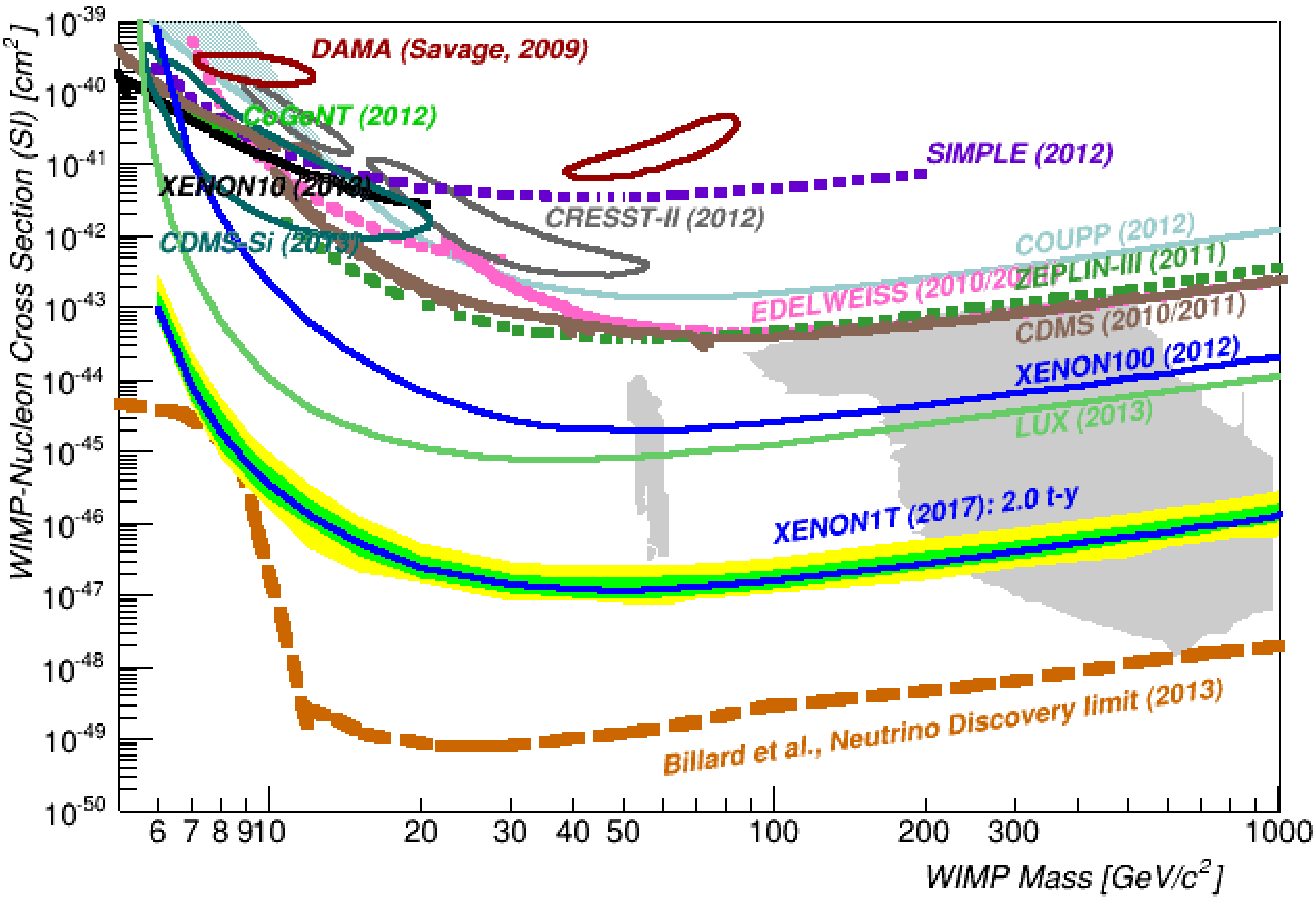


- Full MC simulation of the detector (TPC, PMTs, cryostat, water shield) with GEANT4 to predict ER background
- Neutrons from (α, n) calculated with SOURCES-4A
- Total ER background rate expected to be $\sim 3 \times 10^{-5}\,\mathrm{evts/keV_{ee}/kg/day}$ before S2/S1 discrimination

- Single scatters, 1 ton fiducial volume, $[2, 12]$ keVee, $[5, 50]$ keVr, 99.75% S2/S1 discrimination, 40% NR acceptance

Source	Background (evts/yr)
ER from materials	0.06
$^{85}\mathrm{Kr}$ (0.2 ppt $^{\mathrm{nat}}\mathrm{Kr}$)	0.07
$^{222}\mathrm{Rn}$ (1 μBq/kg)	0.08
Solar neutrinos	0.08
$2\nu 2\beta$	0.02
NR from materials	0.25
Total	0.56

XENON1T: Sensitivity



- Spin-independent WIMP-nucleon interaction cross section sensitivity of $2 \times 10^{-47}\,\mathrm{cm}^2$ for WIMPs with a mass of $50\,\mathrm{GeV}/c^2$

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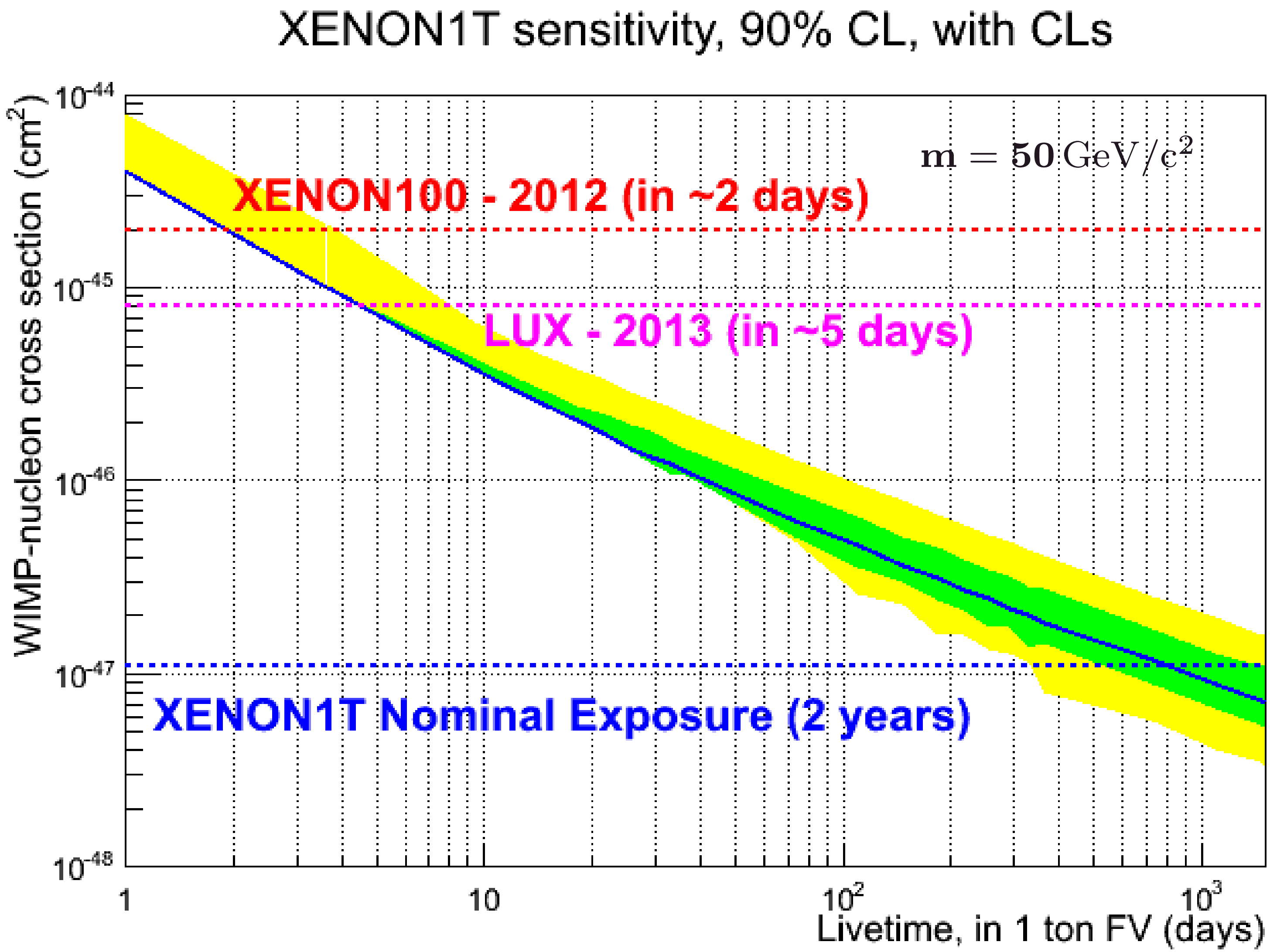

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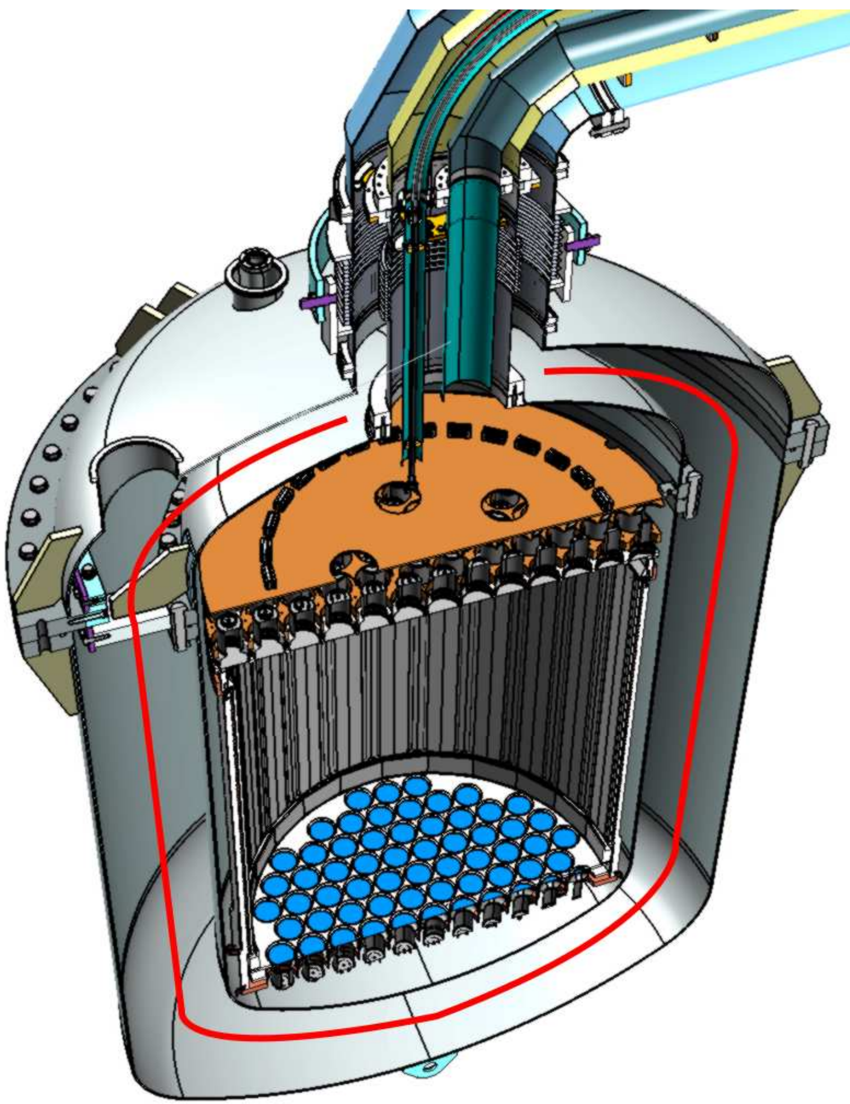

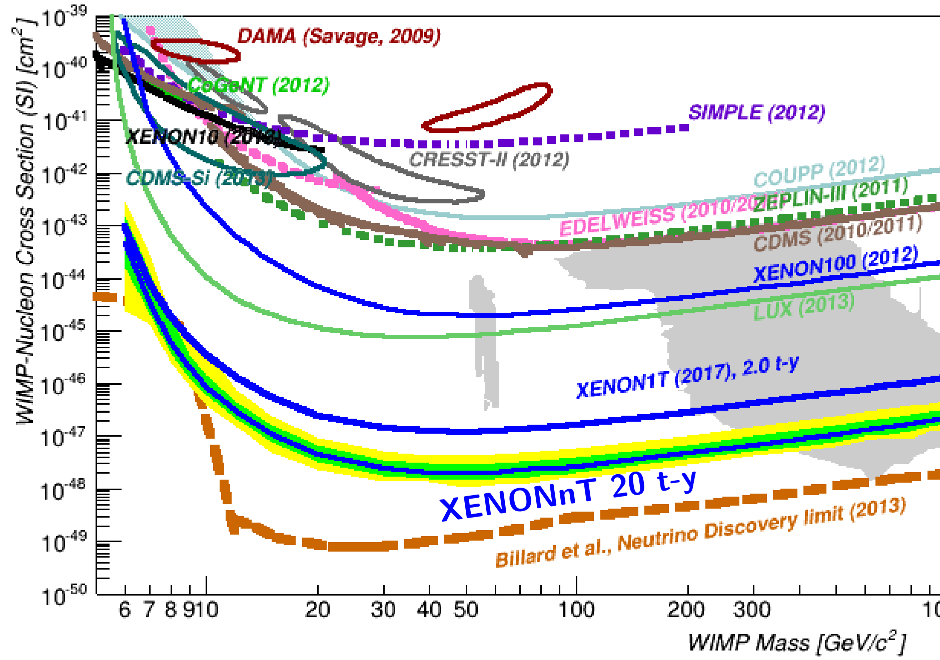

- Rapid deployment possibility: no modifications to infrastructure required, only construction of a larger inner vessel and TPC
- Additional ∼200 PMTs and DAQ electronics channels for the upgraded TPC
- Target mass of ∼6 tons, sensitivity to spin-independent WIMP-nucleon elastic scattering cross sections of $3 \times 10^{-48}\,\mathrm{cm}^2$

Conclusion

- XENON1T under construction at LNGS, water tank, service building, cryostat support, cryostat, storage, cryogenics, and purification completed
- Integration of primary systems (cryostat, cryogenics, storage, purification) completed
- Primary systems currently under commissioning
- TPC assembly in summer 2015 at LNGS, installation in early fall
- Aiming at science run starting before the end of 2015!
- XENONnT, possibility of a rapid upgrade path included in the XENON1T design