The XENON1T EXPERIMENT AT LNGS

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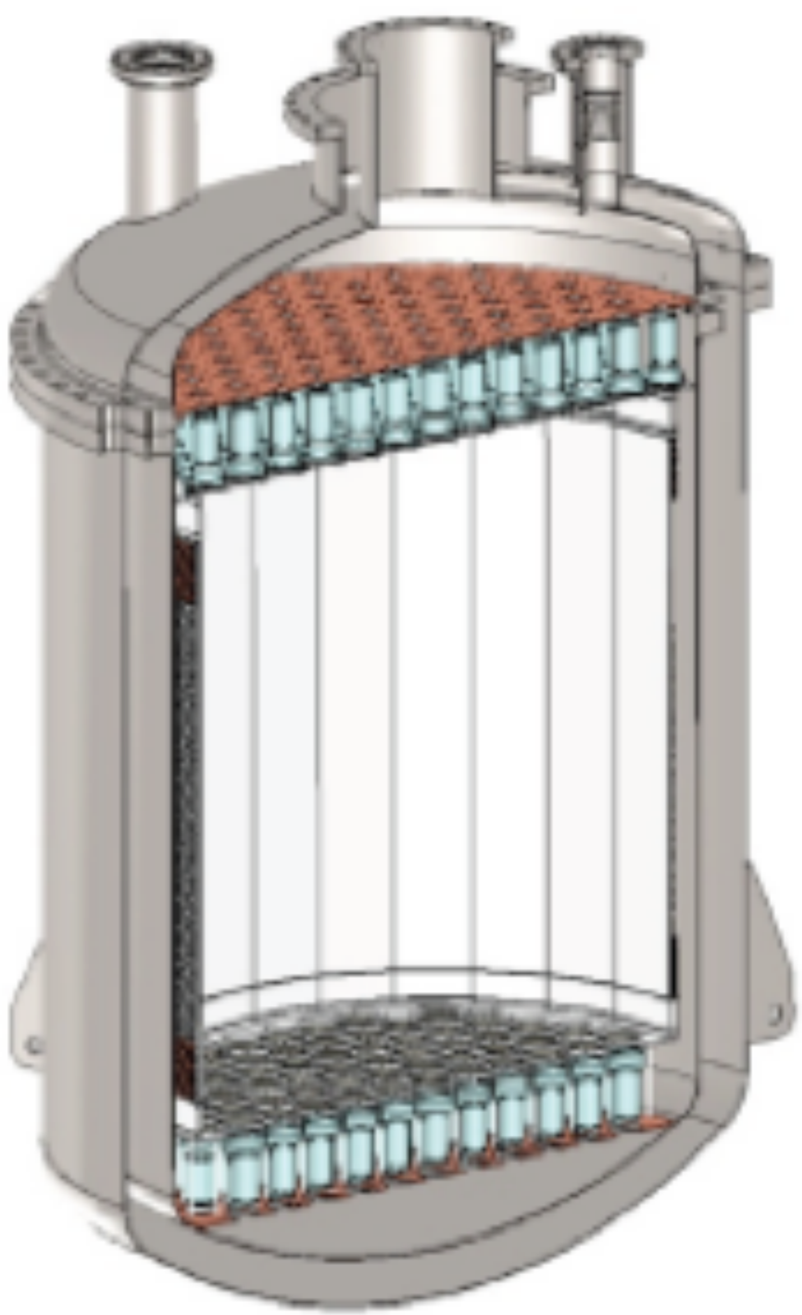
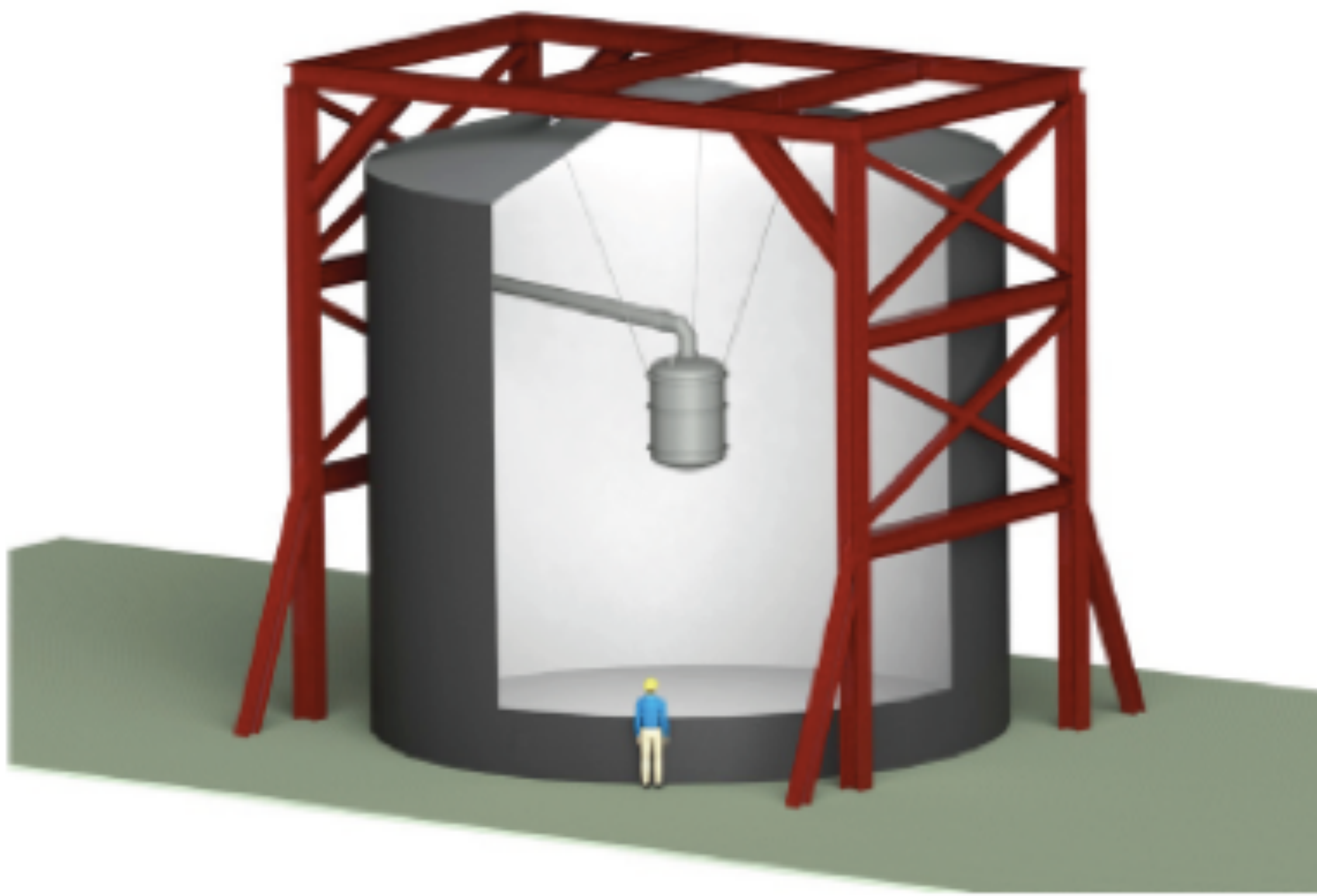
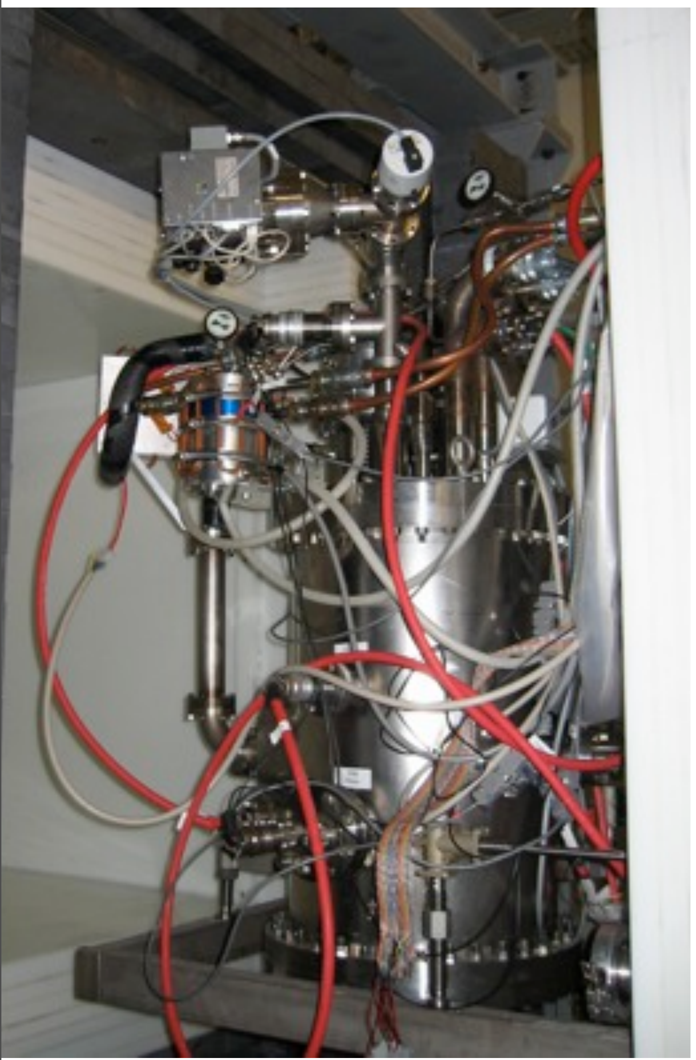
Columbia University
DM2012 - 02/24/12





The XENON Dark Matter Program

past (2005 - 2007)	*current* (2007-2012)	*future* (2012-2017)



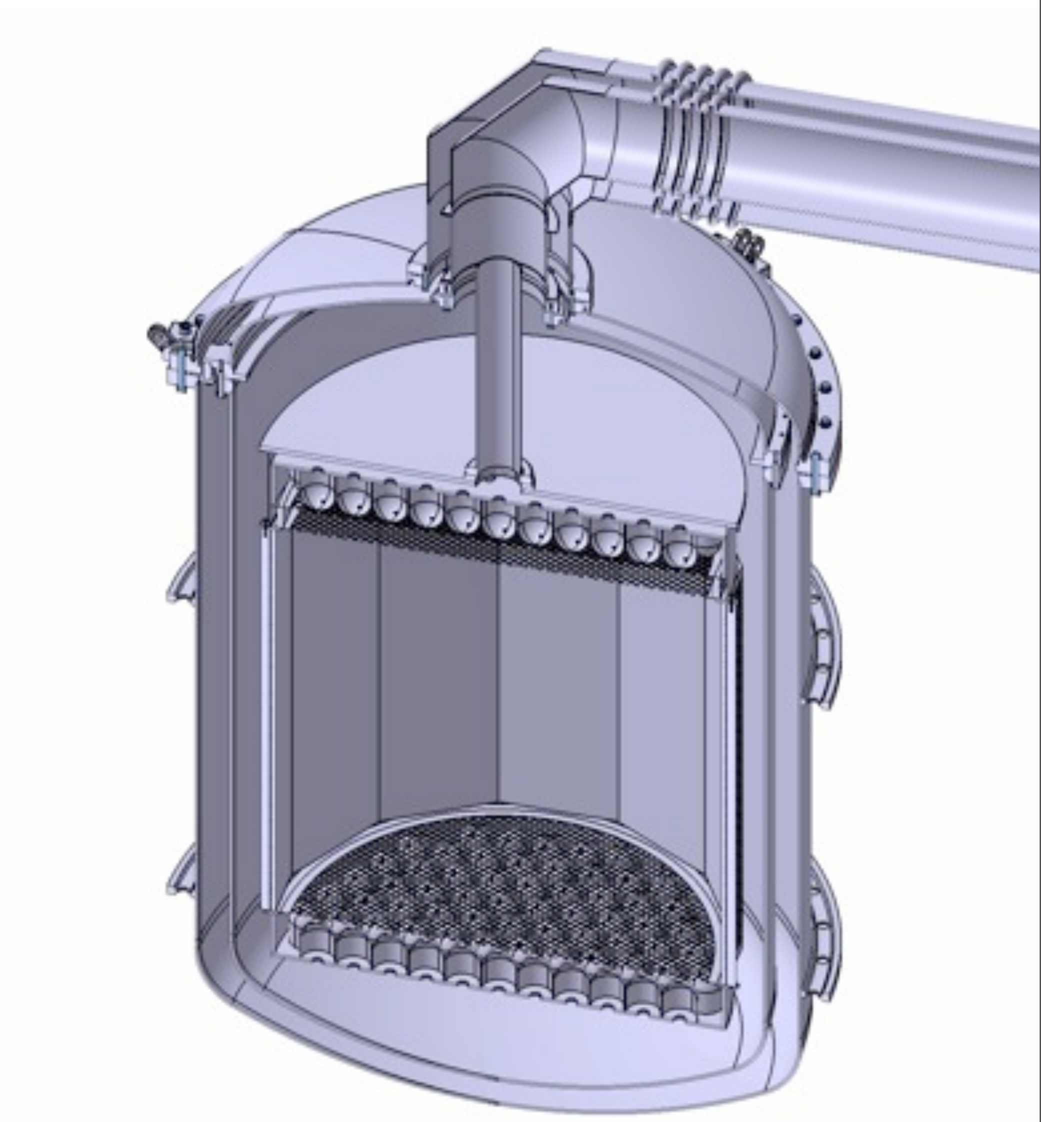
XENON10

Achieved (2007) σ_{SI}=8.8 x10^{-44} cm^2

XENON100

Achieved (2011) σ_{SI}=7.0 x10^{-45} cm^2

Projected (2012) σ_{SI}~2x10^{-45} cm^2



XENON1T

Projected (2017) σ_{SI} ~10^{-47} cm^2

XENON1T: OVERVIEW

- Detector: 1m drift TPC with 2.2 ton LXe target
- Shield: ~10 m x 10 m Water Cherenkov Muon Veto
- Background: 0.01 mdru (100 lower than XENON100
- Location: approved by INFN for LNGS Hall B
- Capital Cost: ~11 M$ (50% US and 50% non-US)
- Status: Construction start in Fall 2012
- Science Run: projected to start in 2015
- Sensitivity: 2 x 10^{-47} cm^2 at 50 GeV with 2.2 ton-years

The XENON COLLABORATION

COLUMBIA RICE UCLA PURDUE ZURICH COIMBRA

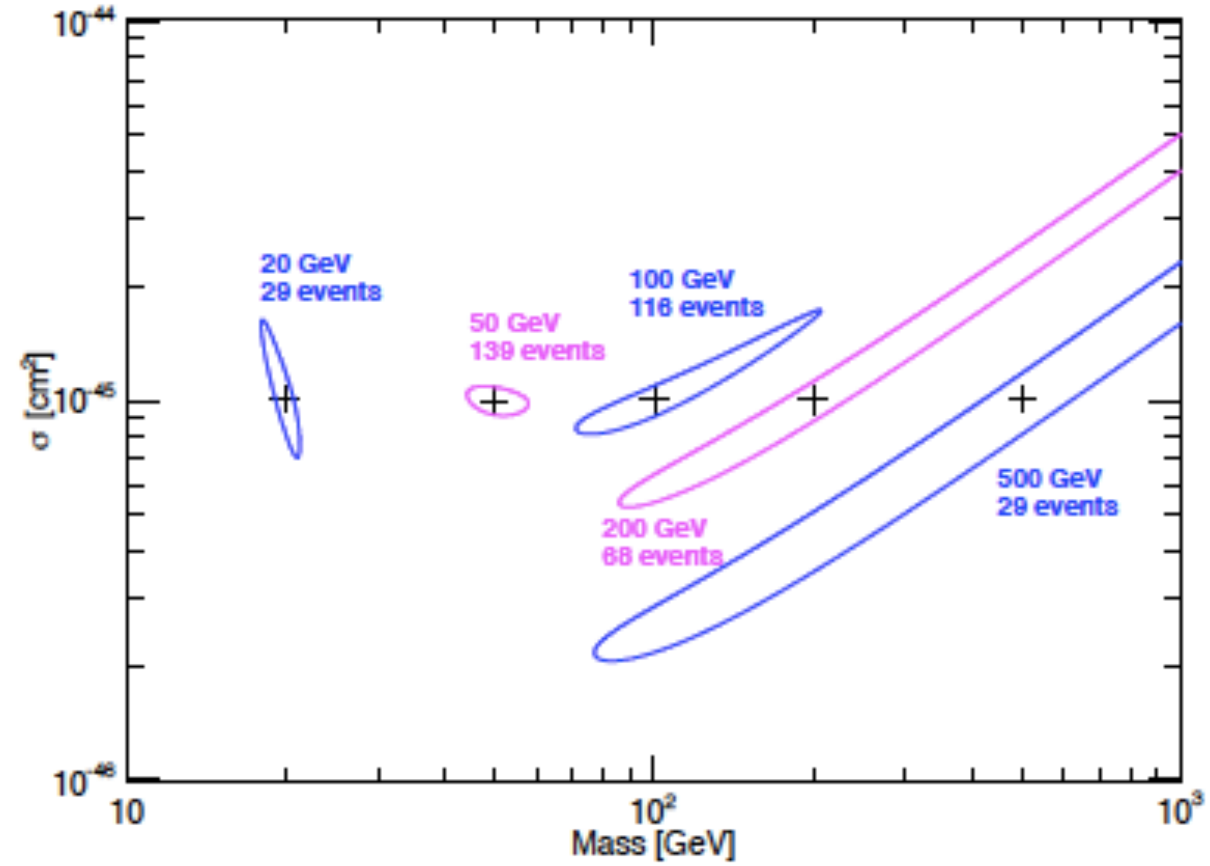
LNGS INFN MPIK BOLOGNA SJTU

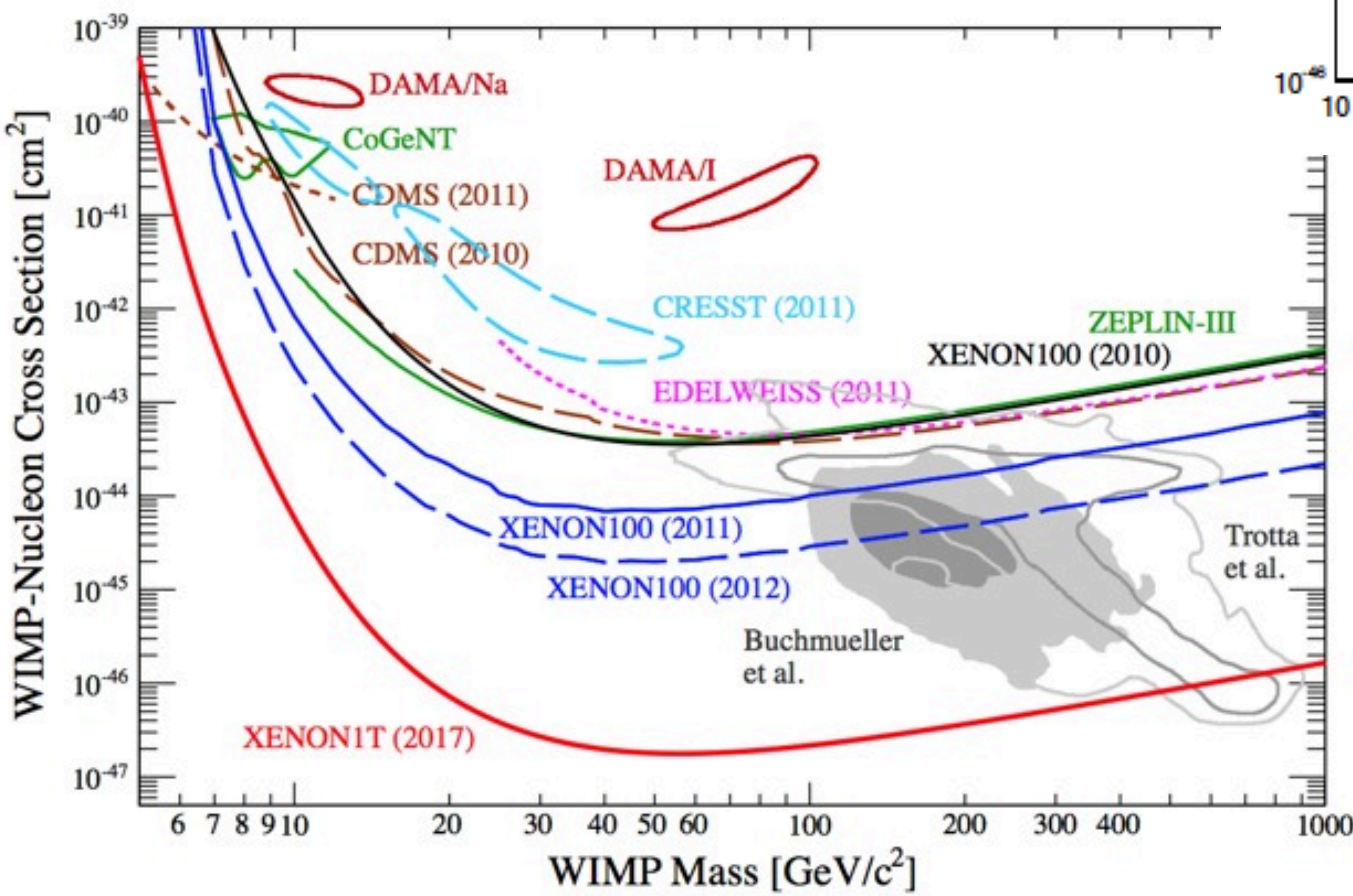
MUENSTER SUBATECH NIKHEF WEIZMANN

The XENON1T Science Case

a statistically significant WIMP signal after 2.2 ton-years of data

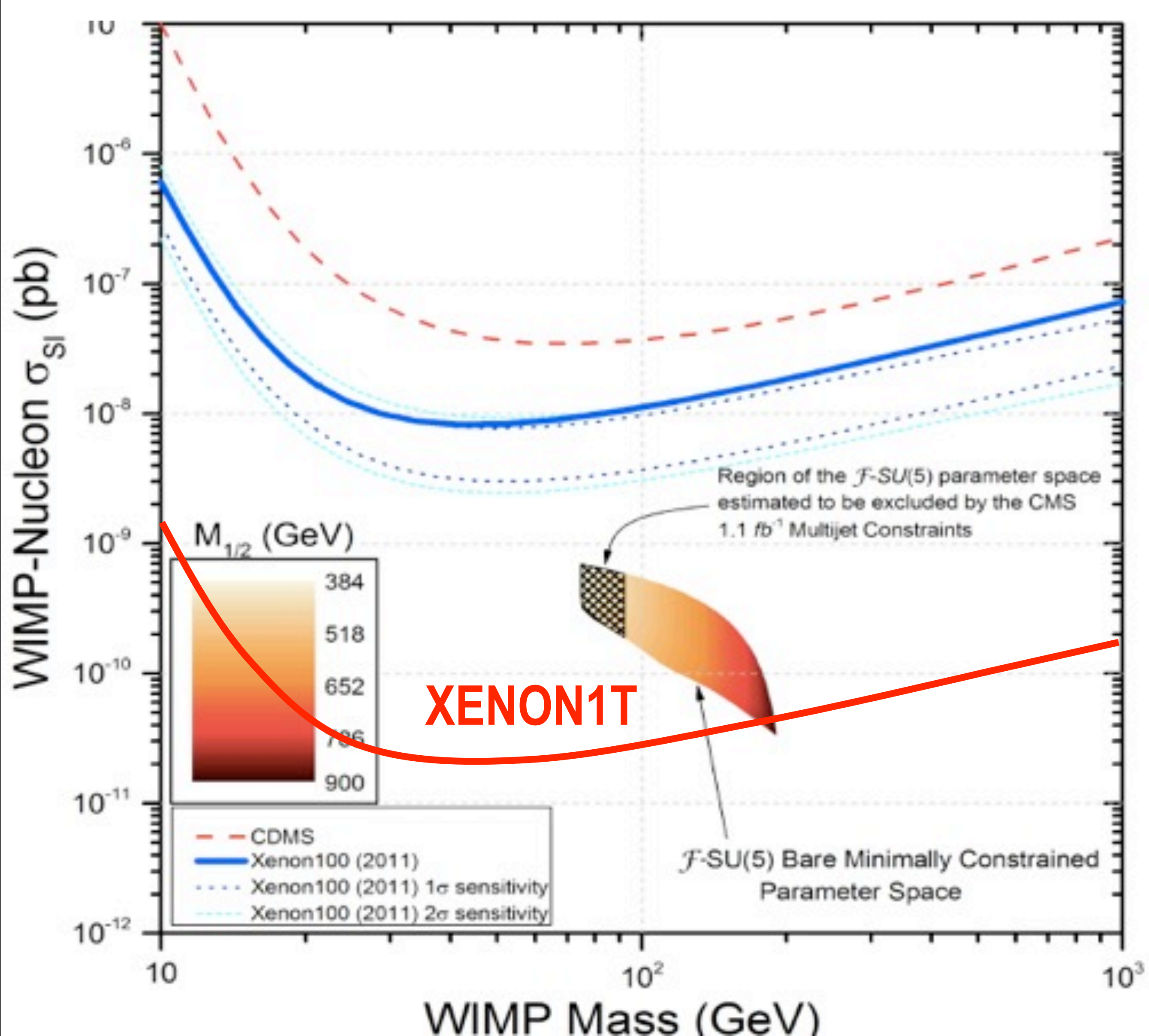
~100 events if cross section at 10^{-45} cm^2



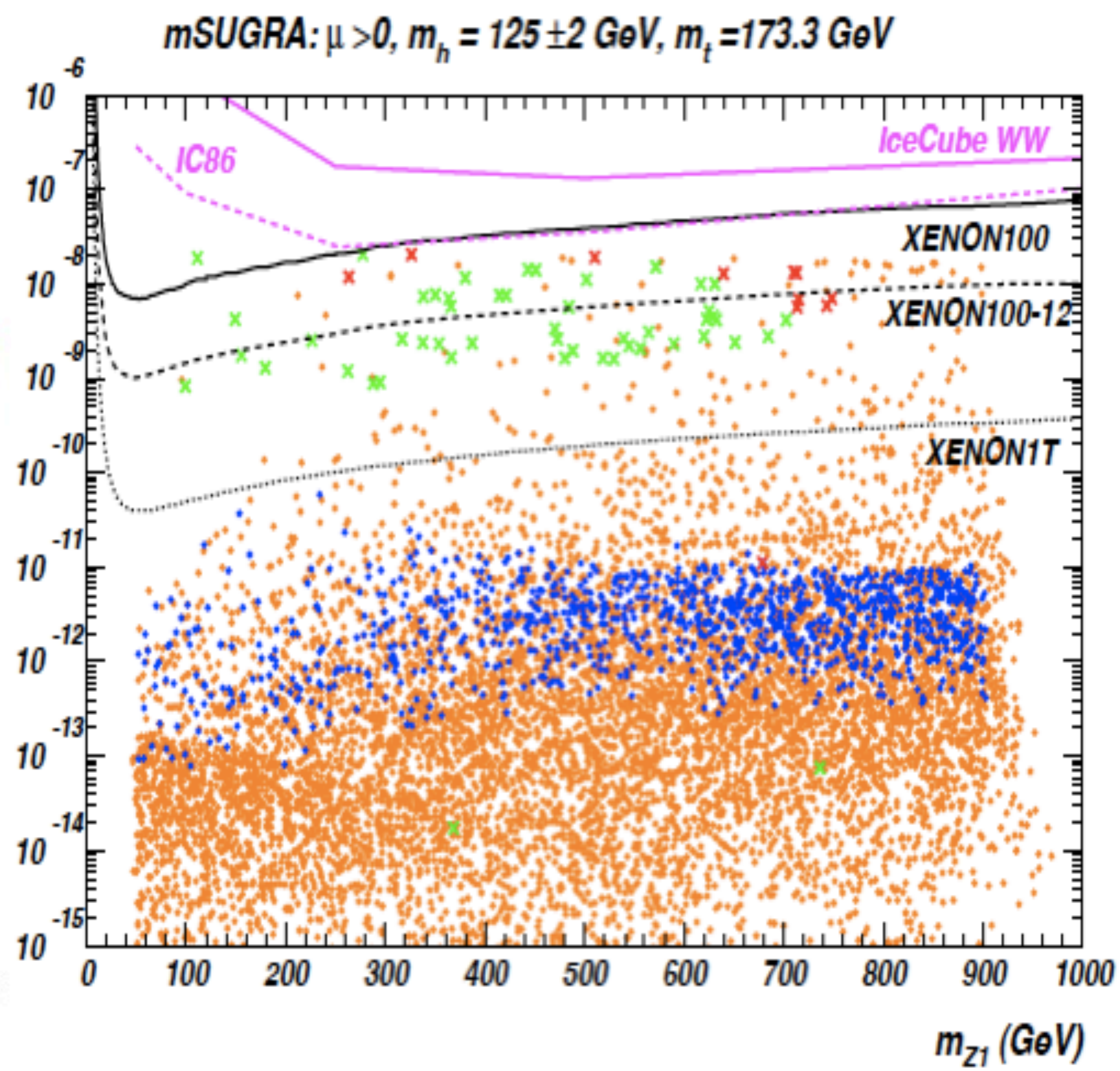


two orders of magnitude improvement in SI cross-section sensitivity w/r to XENON100

The XENON1T Science Case



F-SU(5) Supersymmetry
Dimitri Nanopoulos

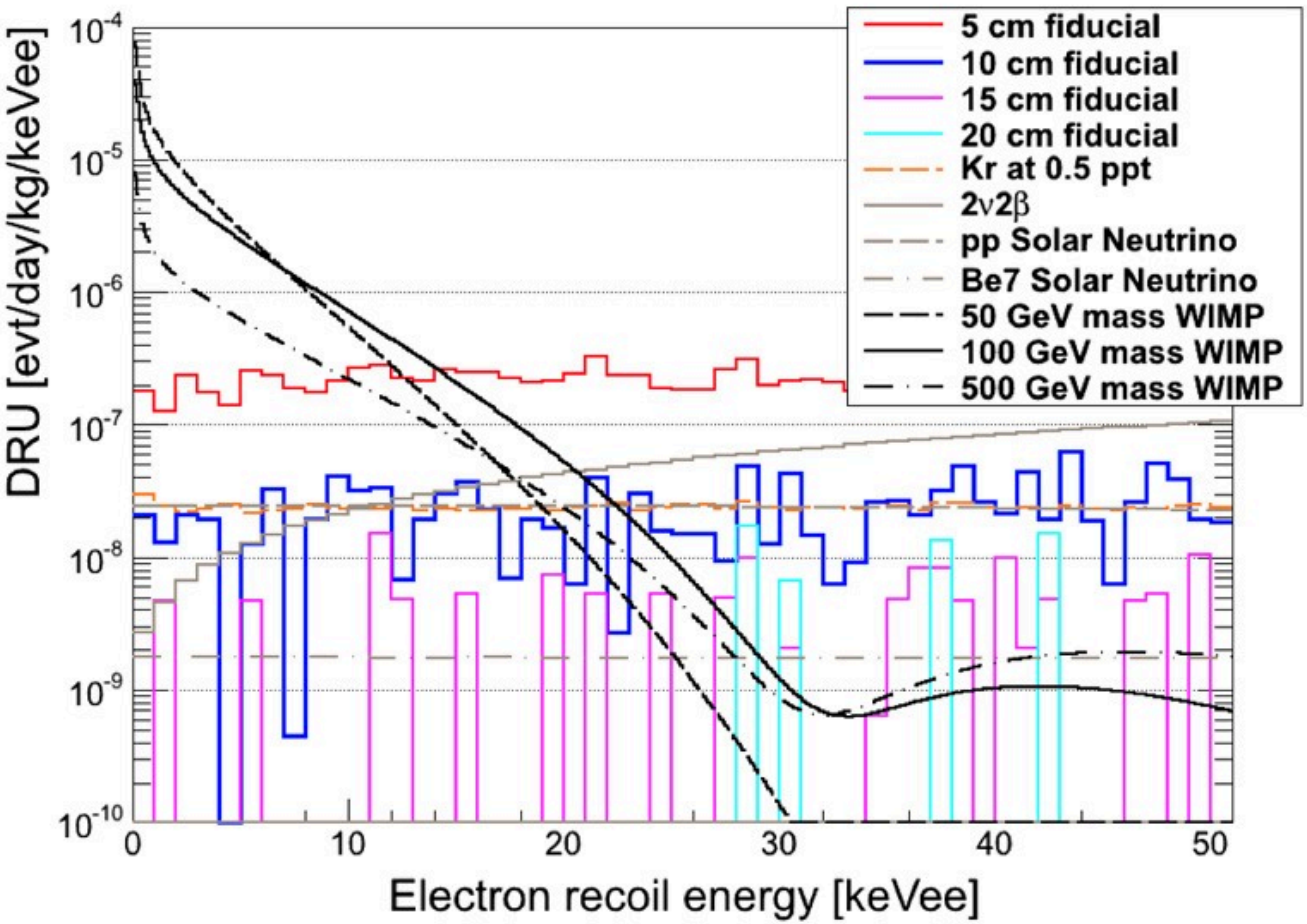


Neutralino dark matter in mSUGRA/CMSSM with a 125 GeV light Higgs scalar

Howard Baer[a], Vernon Barger[b] and Azar Mustafayev[c]

Expected Backgrounds in XENON1T

Expected Backgrounds in XENON1T



Expected Backgrounds in XENON1T
(100 Year Simulation Livetime)

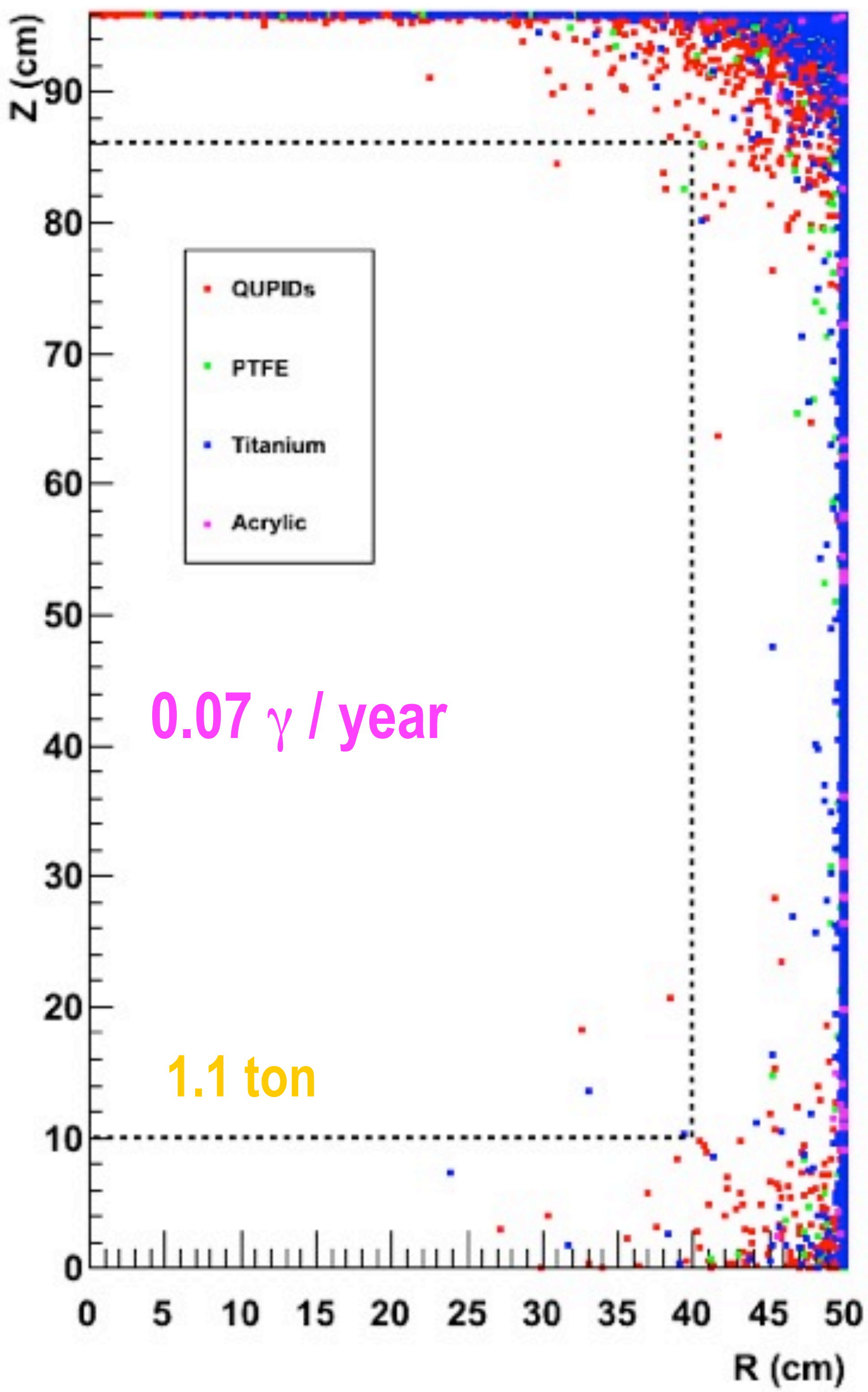
0.07 γ / year

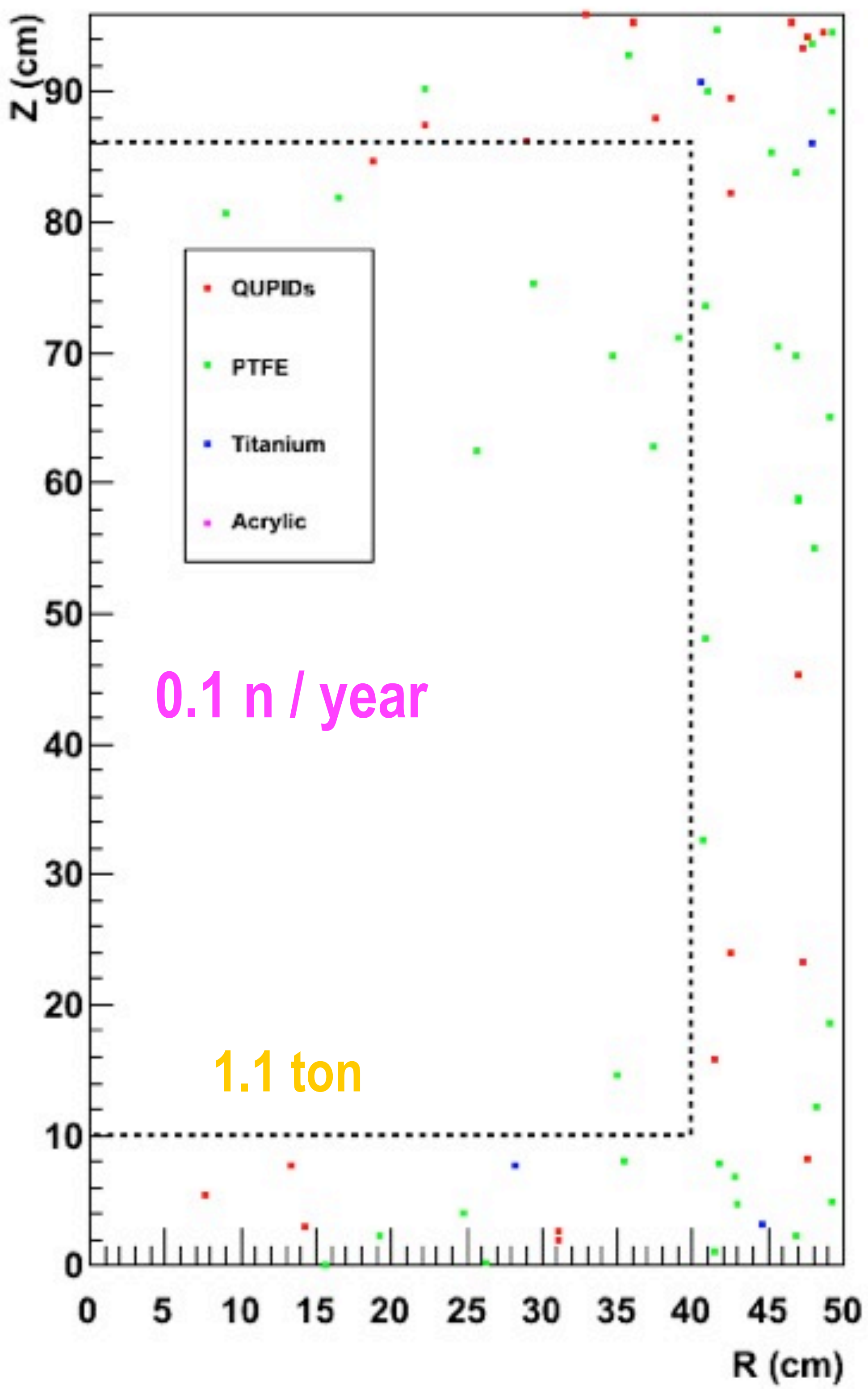
0.1 n / year

1.1 ton

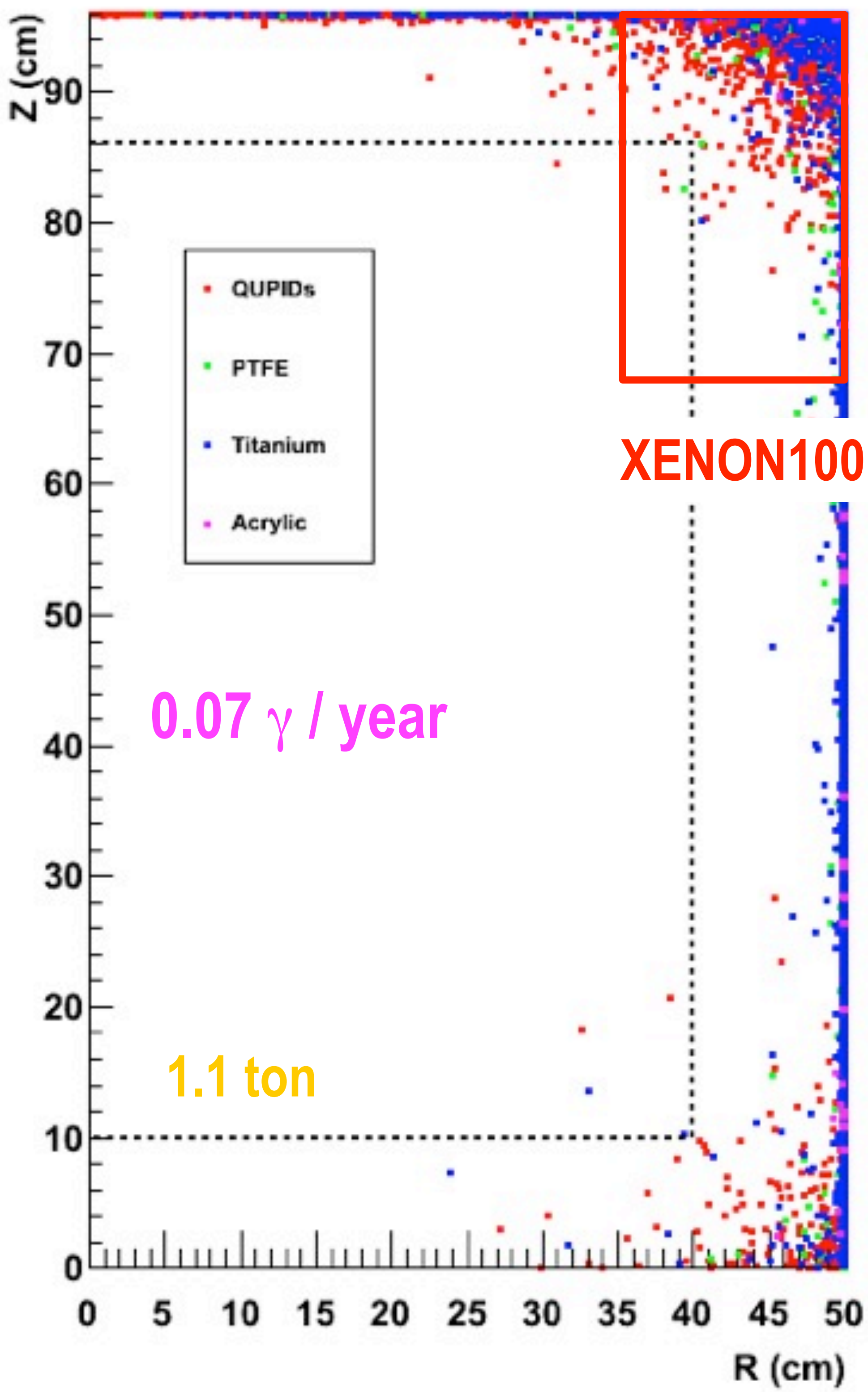
1.1 ton

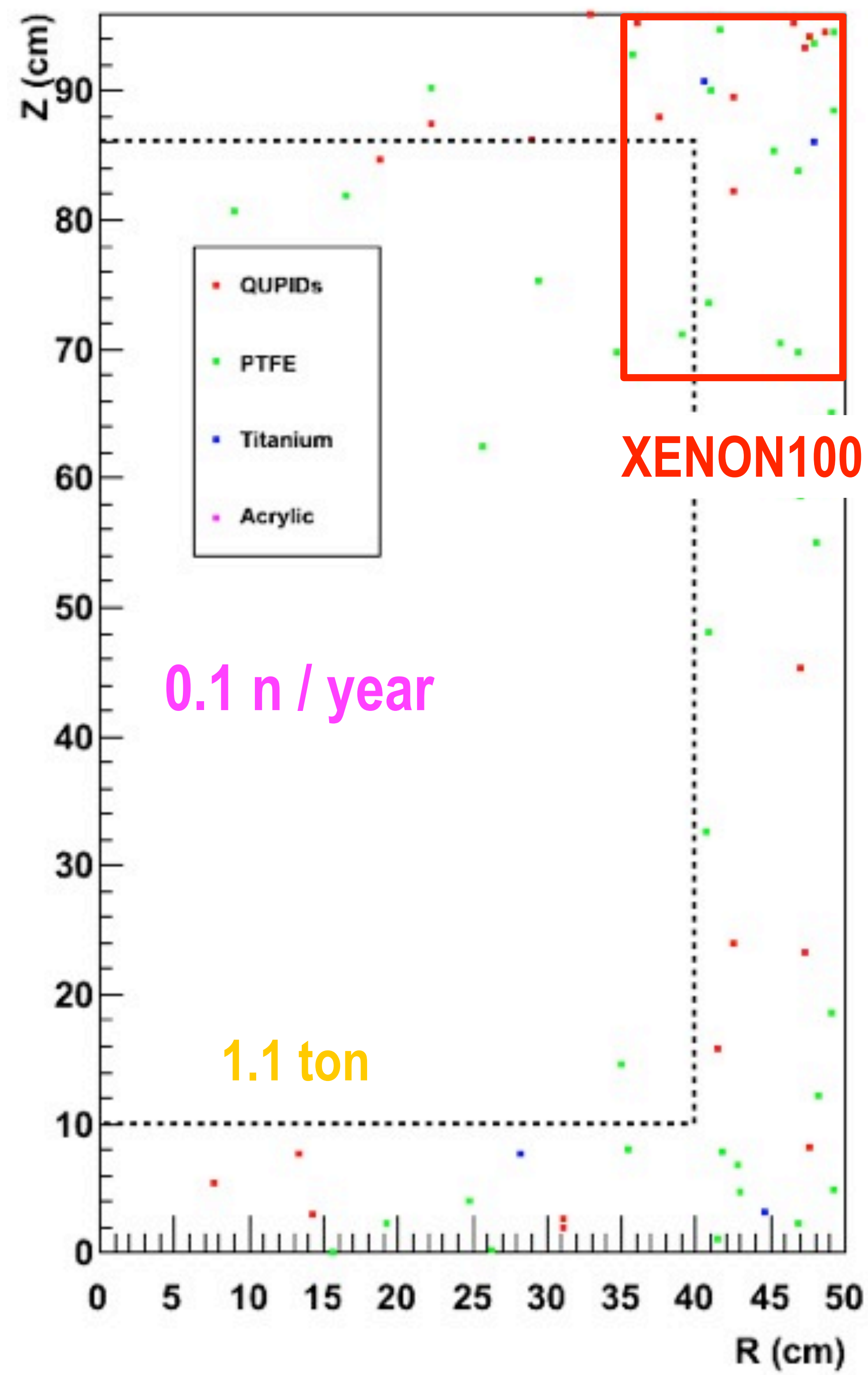
Expected Backgrounds in XENON1T
(100 Year Simulation Livetime)



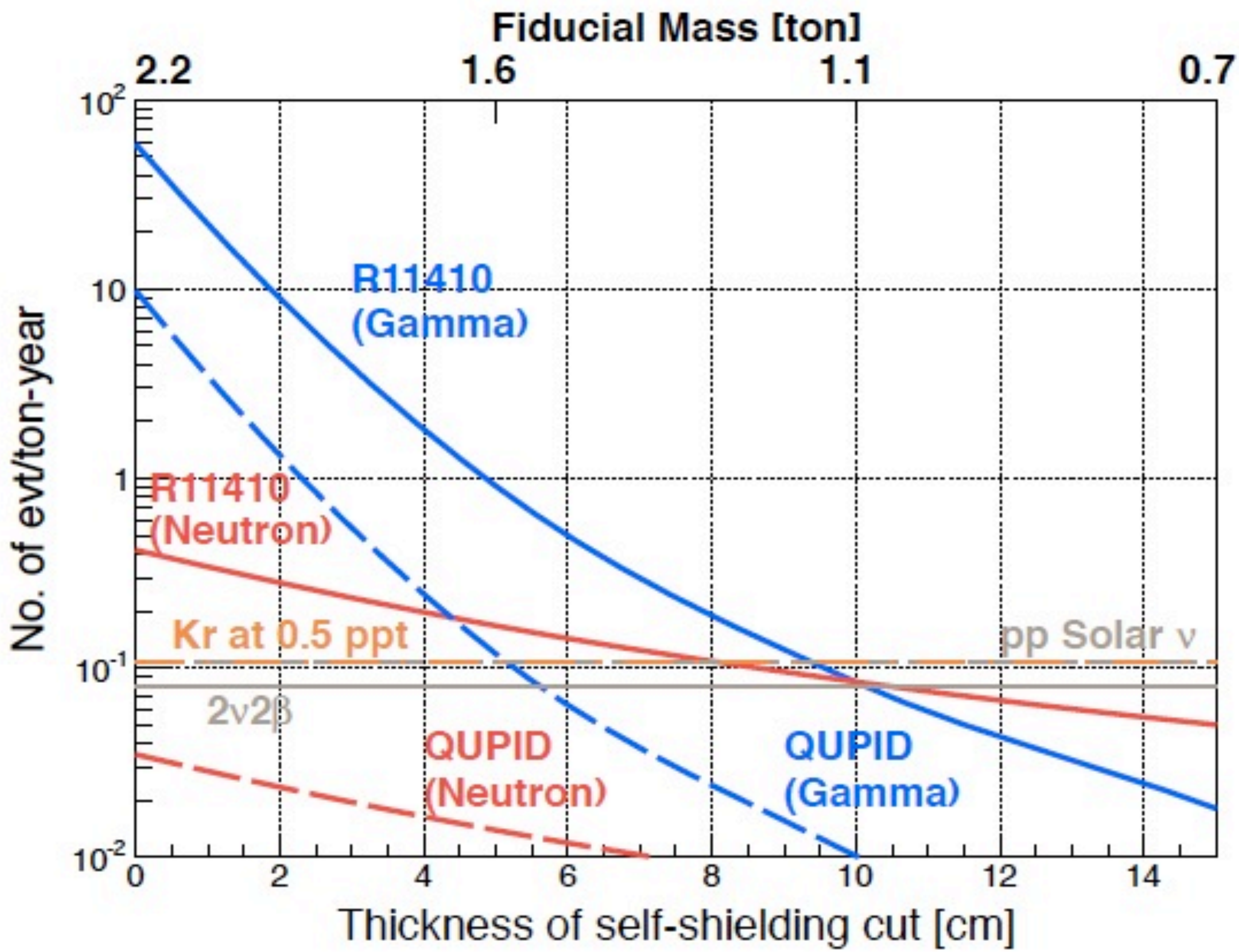


Expected Backgrounds in XENON1T
(100 Year Simulation Livetime)

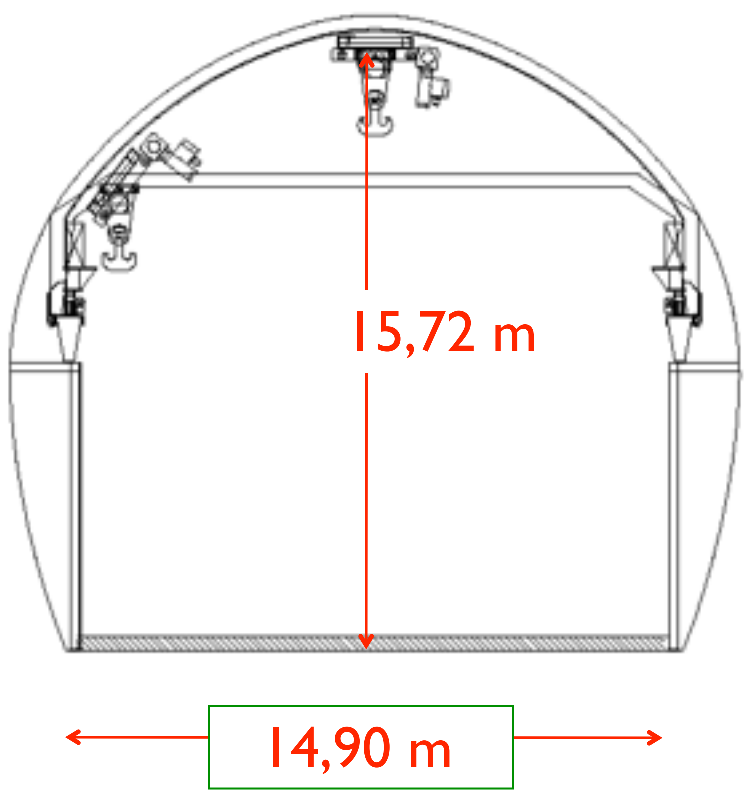


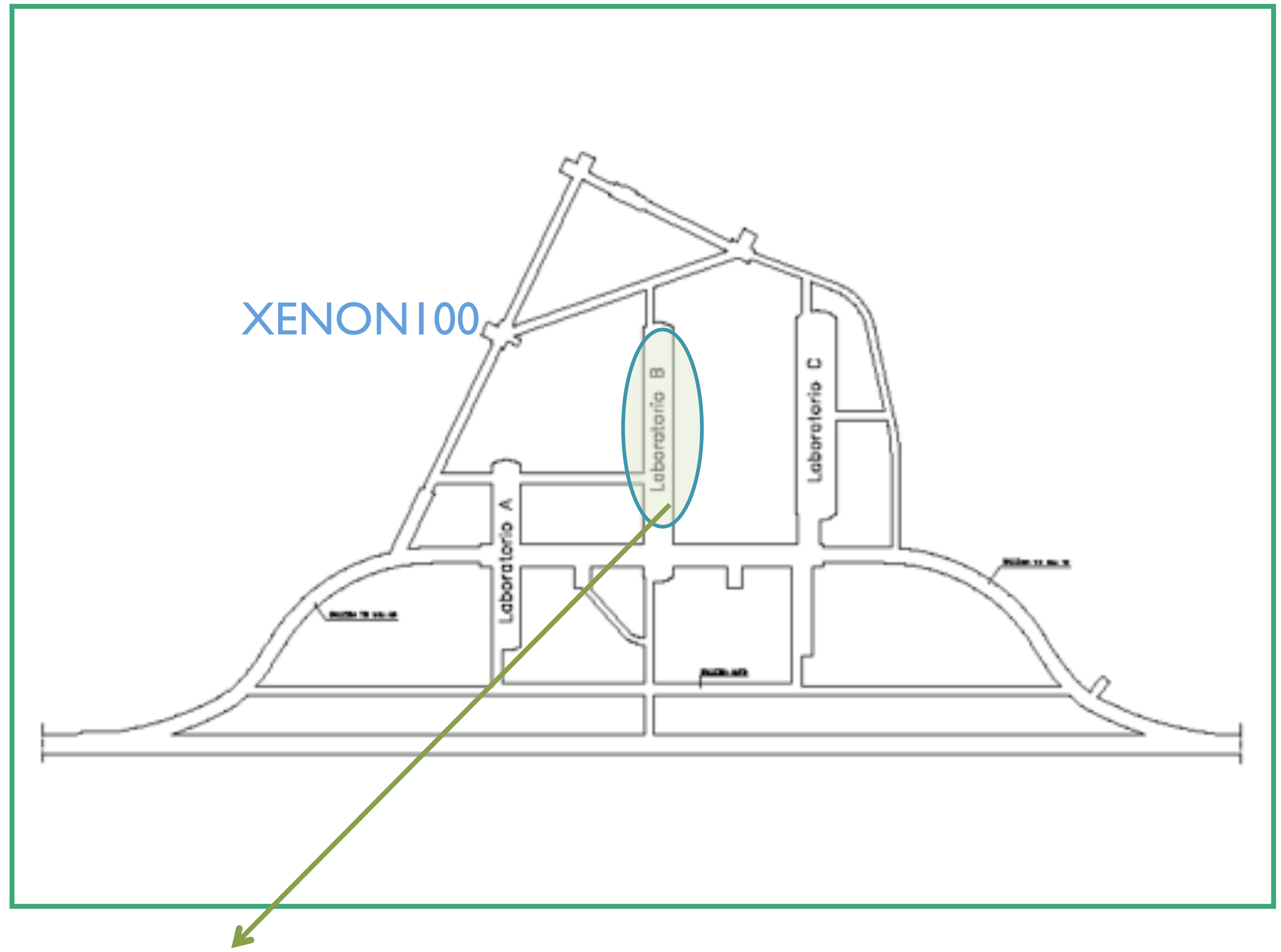


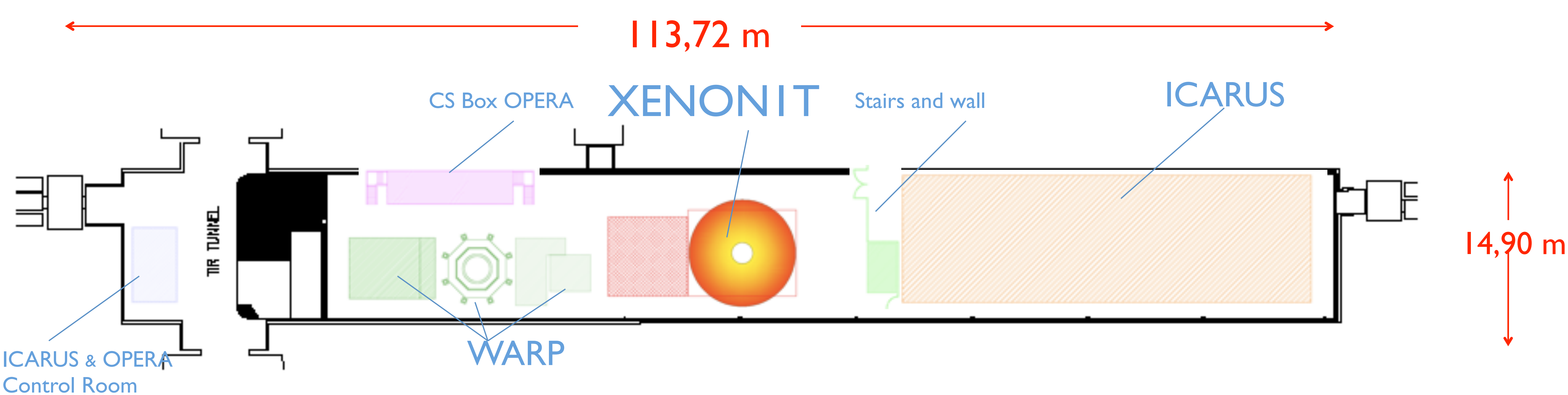
Effectiveness of Self Shielding



LNGS Underground Laboratory – Hall B







LNGS Underground Laboratory – Hall B

LNGS Underground Laboratory – Hall B

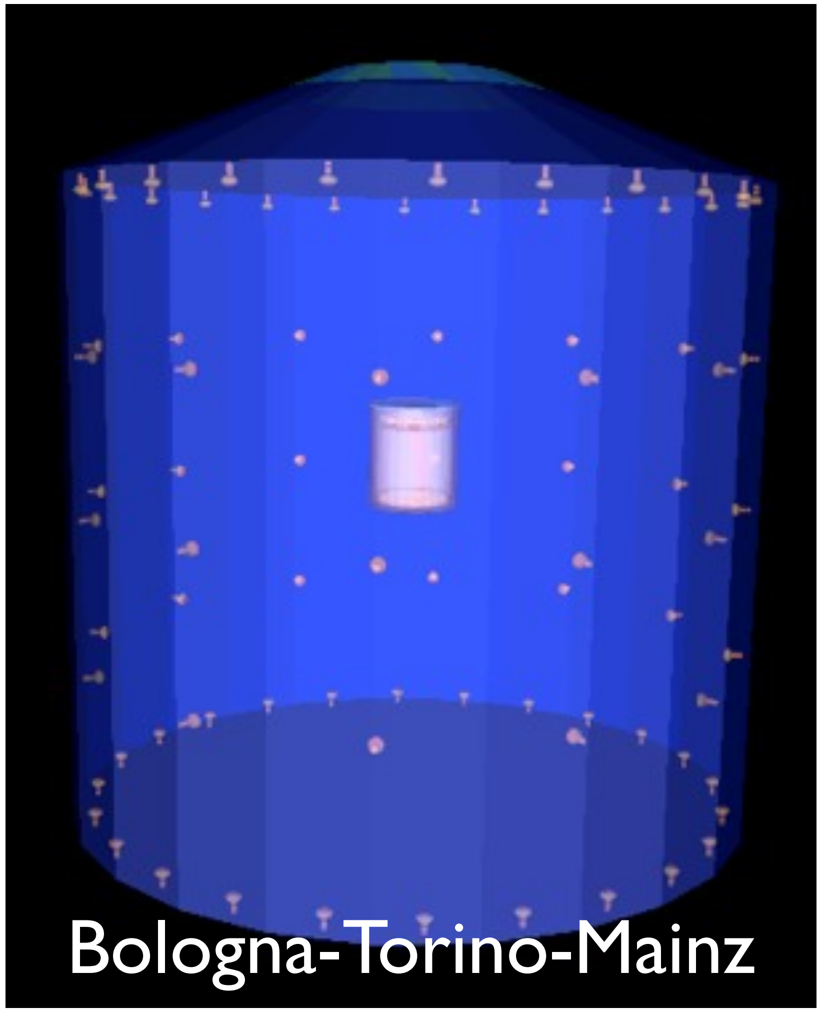
XENON1T Water Cherenkov Shield

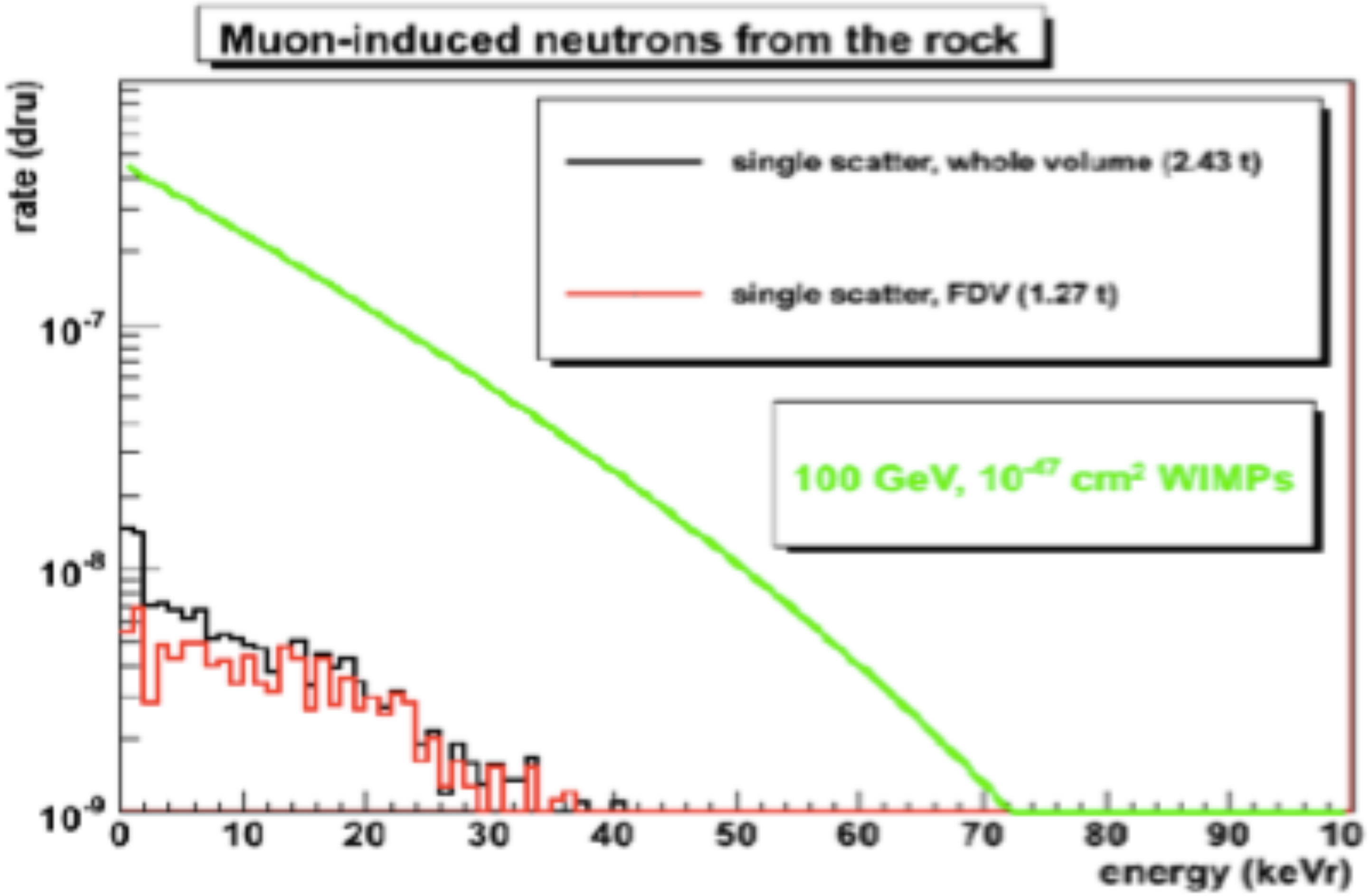
650 m^3 Water Tank Instrumented with 8˝ PMTs as Active Veto

Muon-induced neutrons are the dominant external background

(n and γ from radioactivity well shielded by ~4.5 m water buffer)

Flux @ LNGS generated with G4, normalized to Mei-Hime, PRD 73 053004 (2006)
(conservative estimate: GEANT4 predicts a ~6 times lower neutron yield)





With ~85% efficiency for tagging neutrons entering the Water Tank, we expect a rate of **0.01 neutrons/ year** in LXe fiducial volume well below the signal rate from **100 GeV WIMP** with **10^{-47} cm^2**.

XENON1T CRYOSTAT

Double walled vacuum insulated vessel

1.3 m diameter x 1.5 m height

Holds 2.5 tons of Xenon @ -100°C

Holds instrumented TPC

Made of low-background Ti

Manufactured according to ASME code

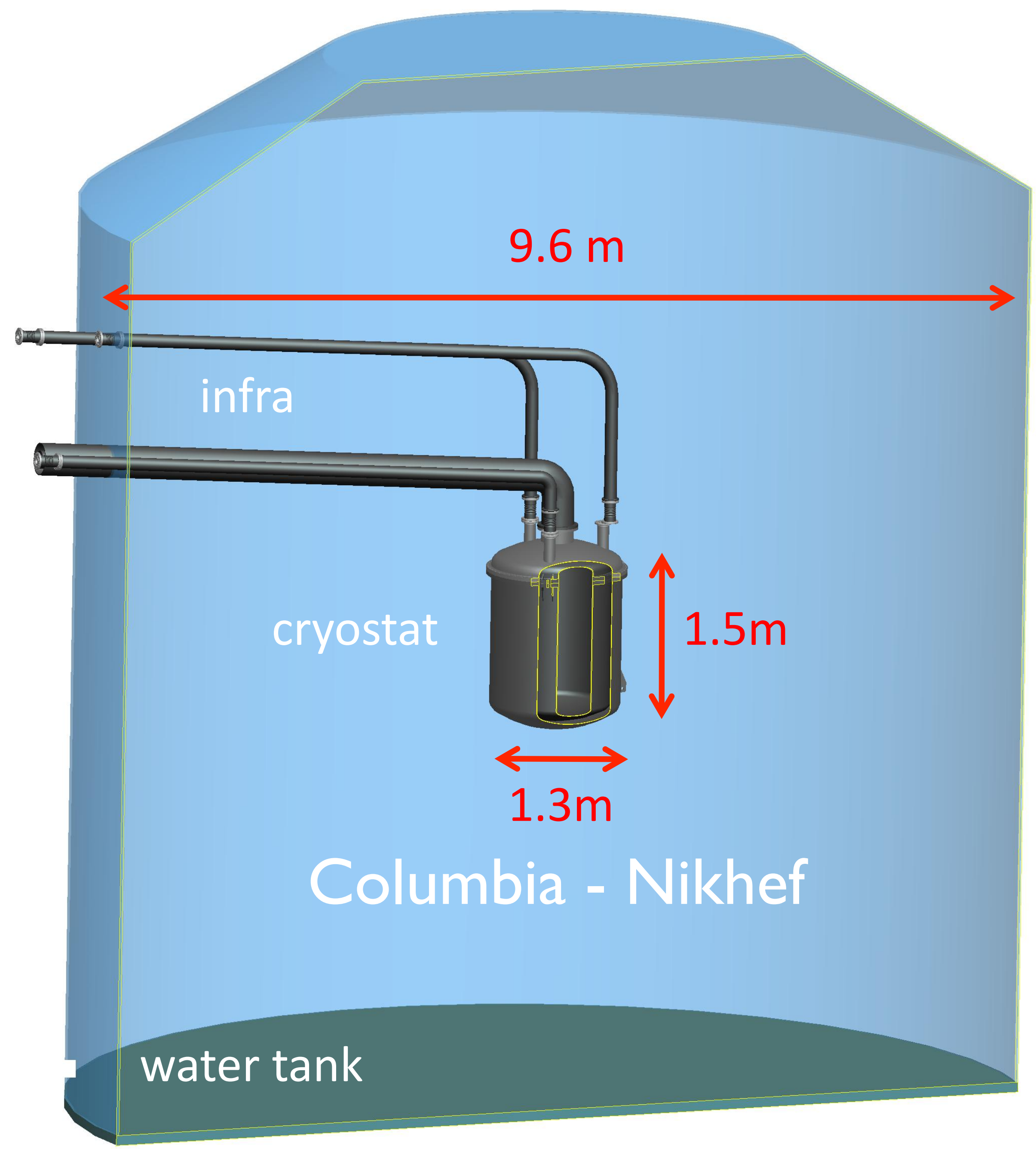
Heat load < 50W

Hexapod Support Structure inside tank

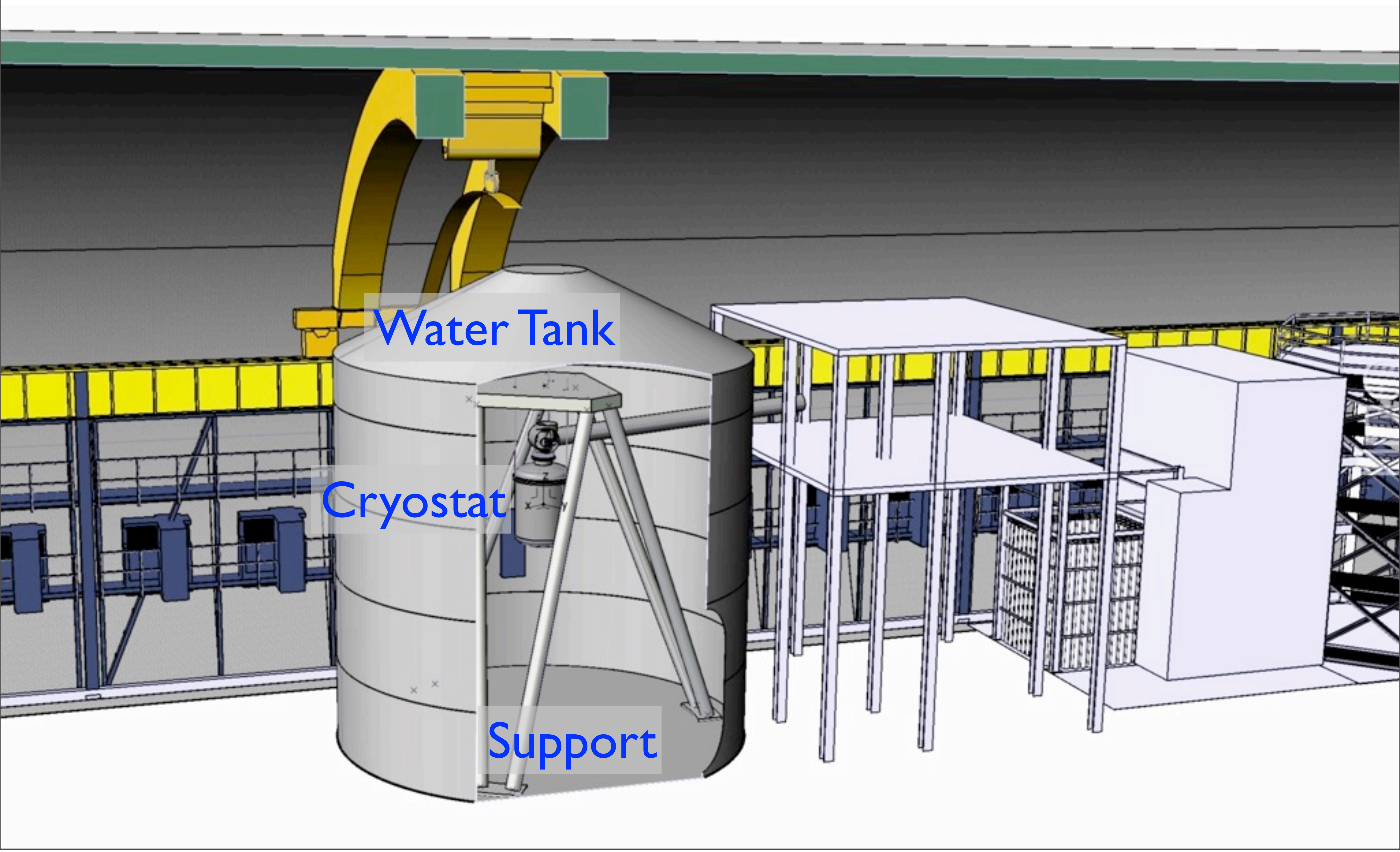
Linear actuators for leveling to 100μm

Must satisfy buoyancy loaded condition

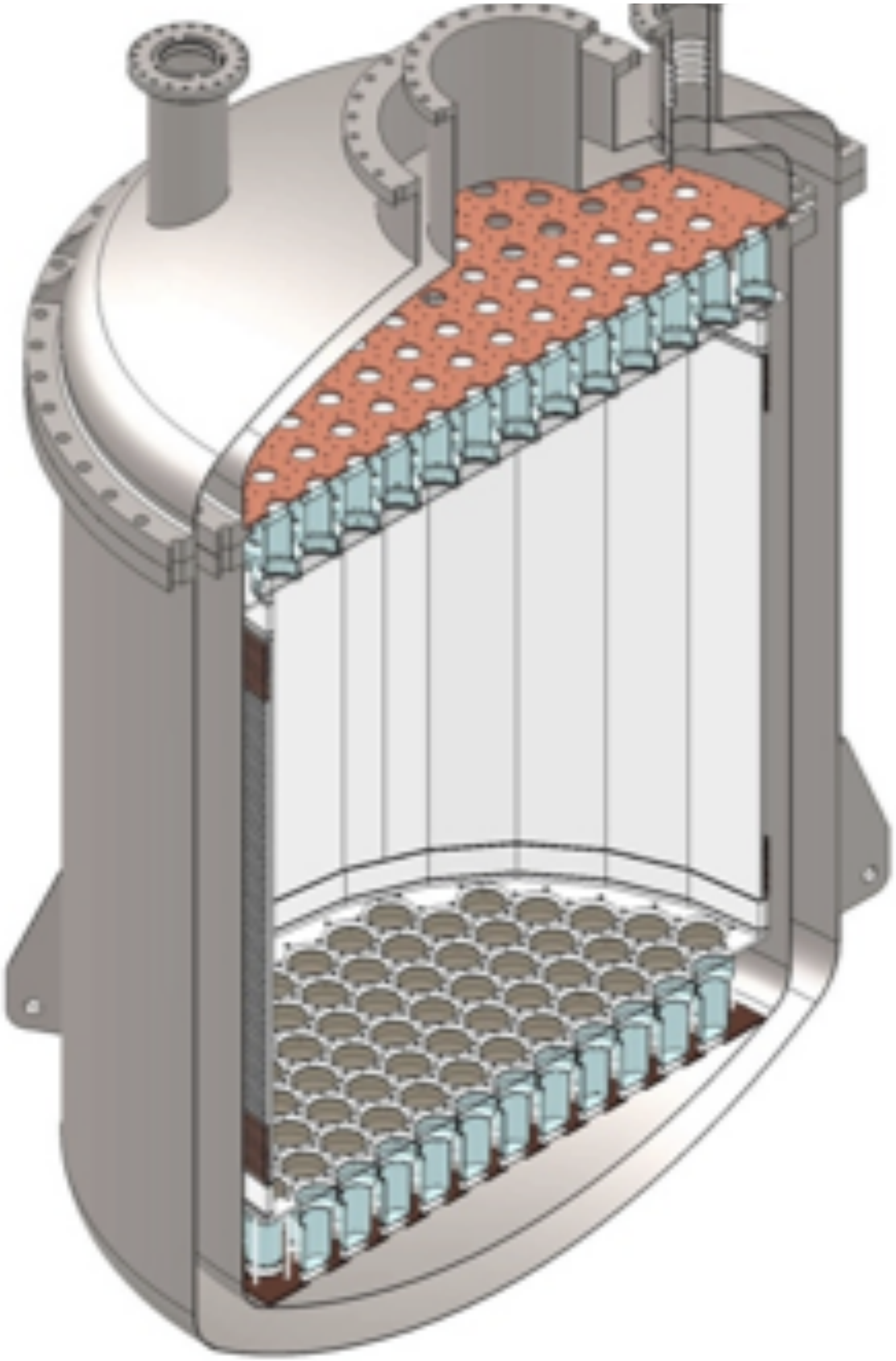
& LNGS seismic environment `

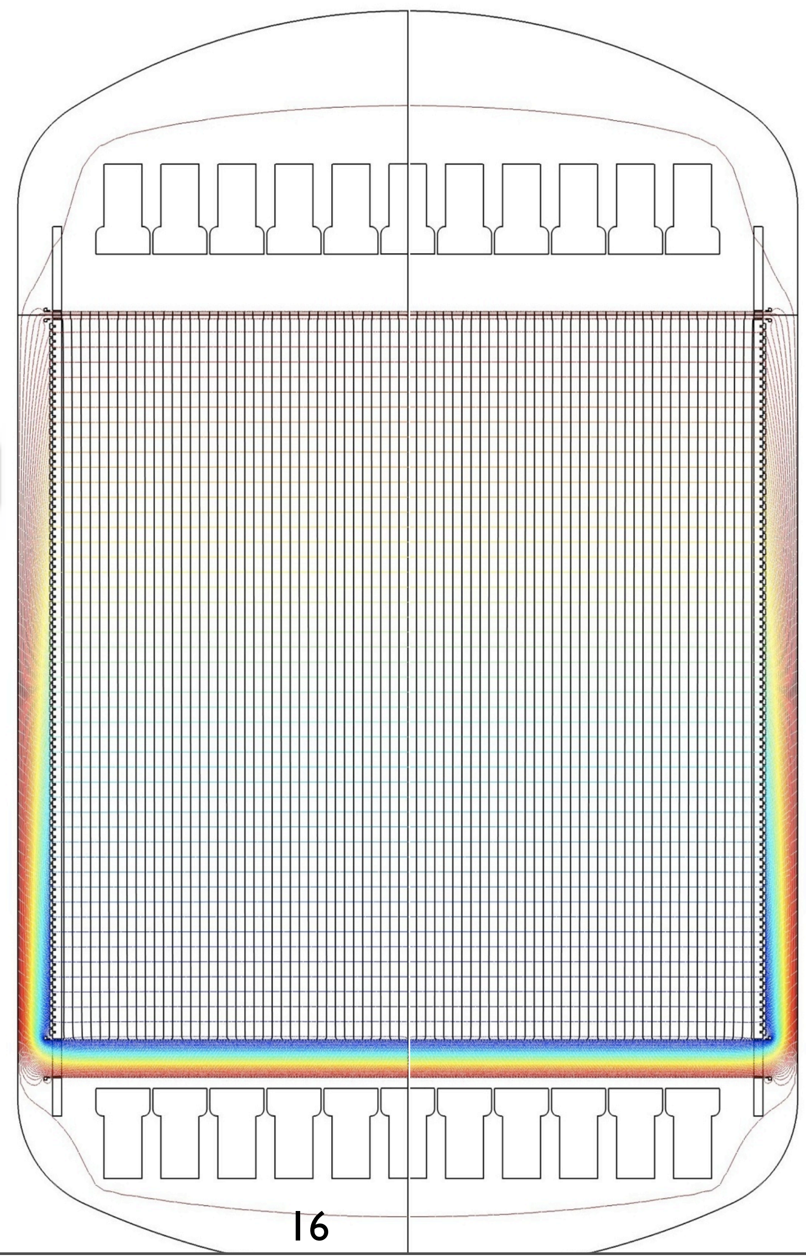


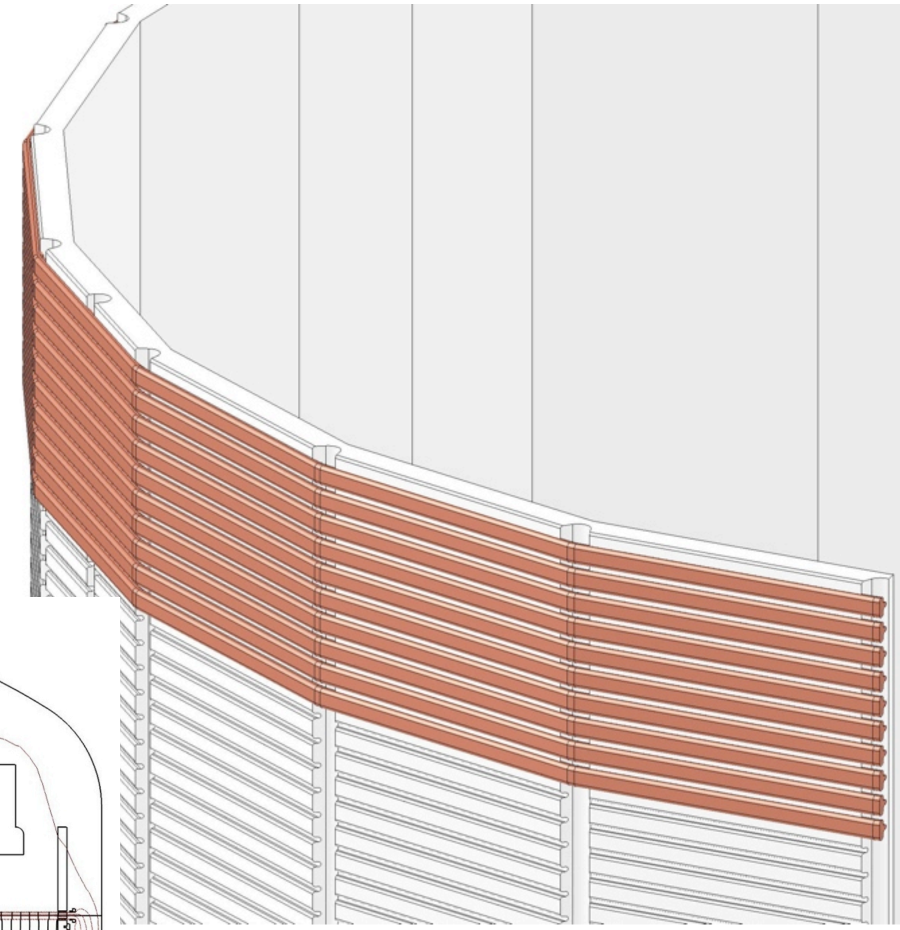
XENON1T CRYOSTAT & SUPPORT

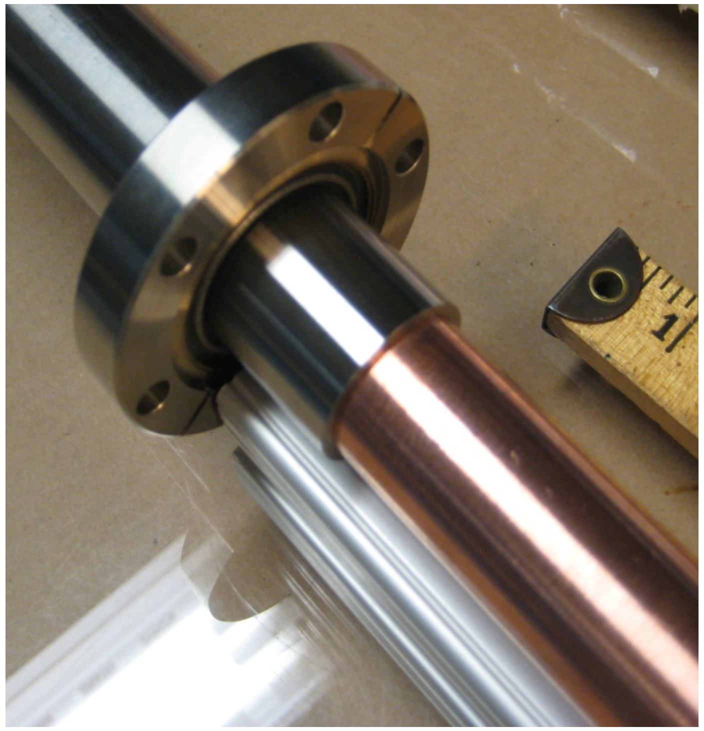


XENON1T TPC



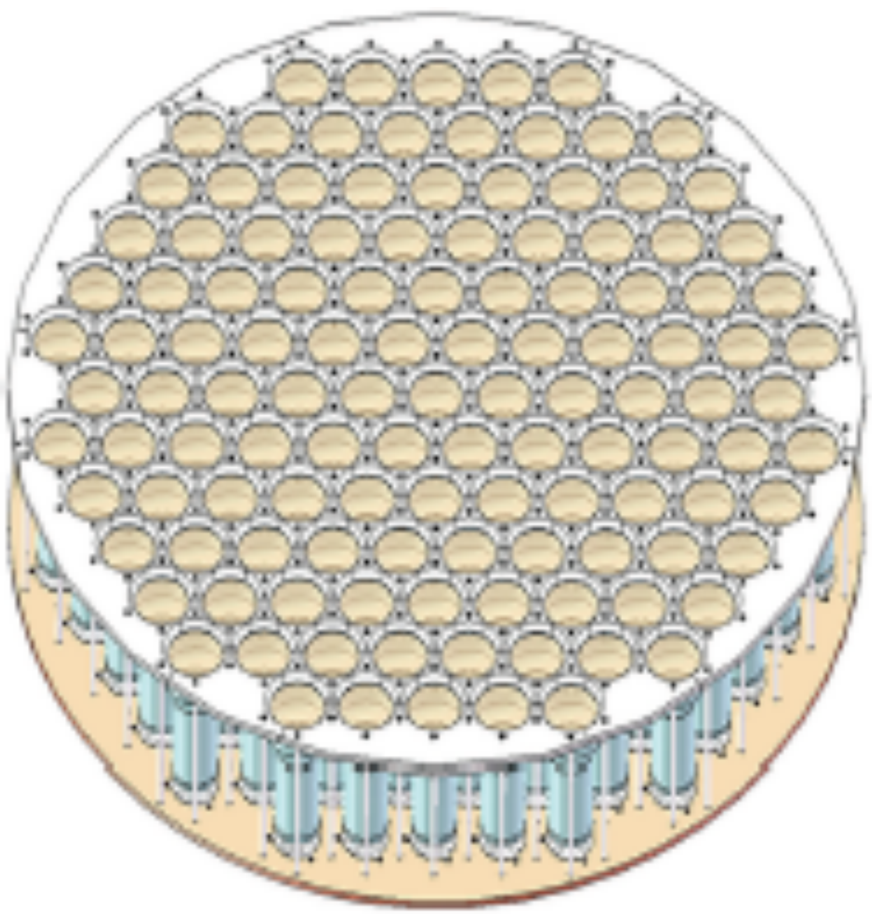


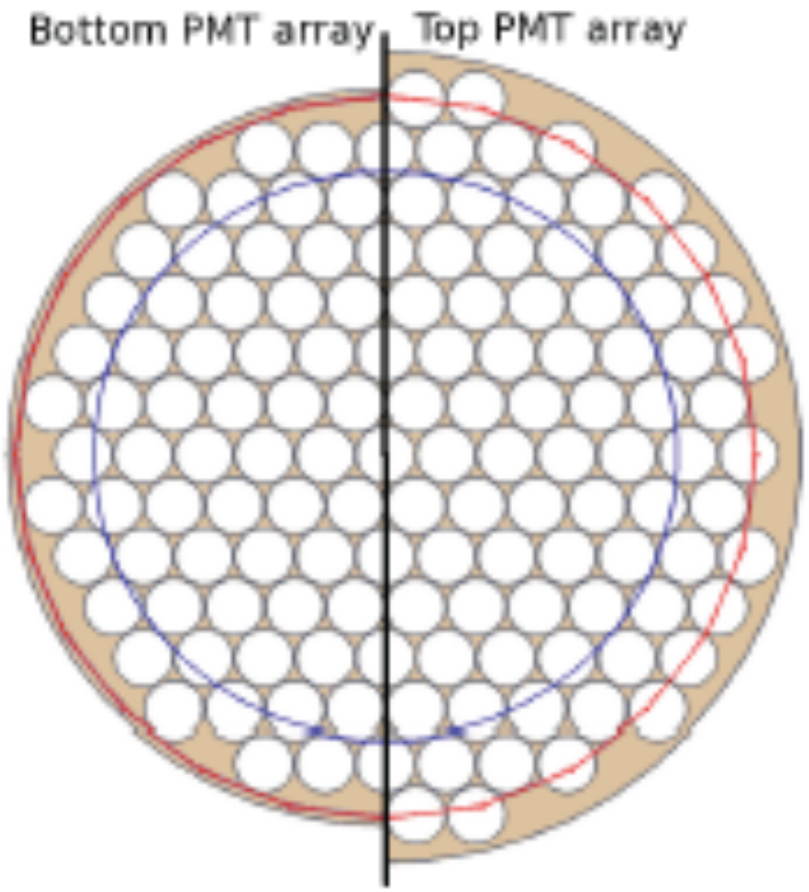


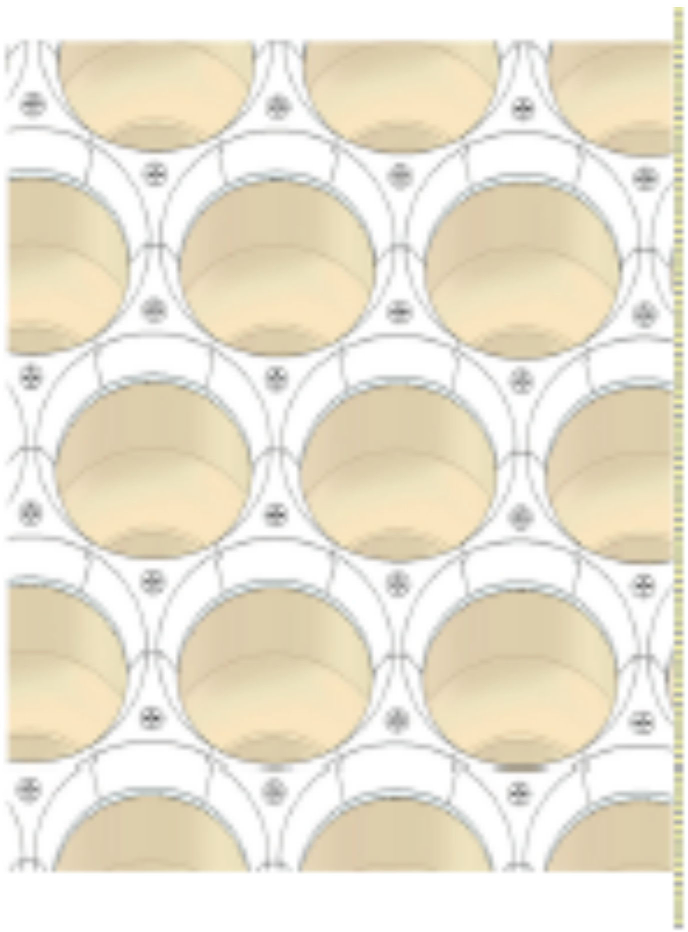


Columbia-UCLA-Rice-Zurich

XENON1T PMT ARRAYS

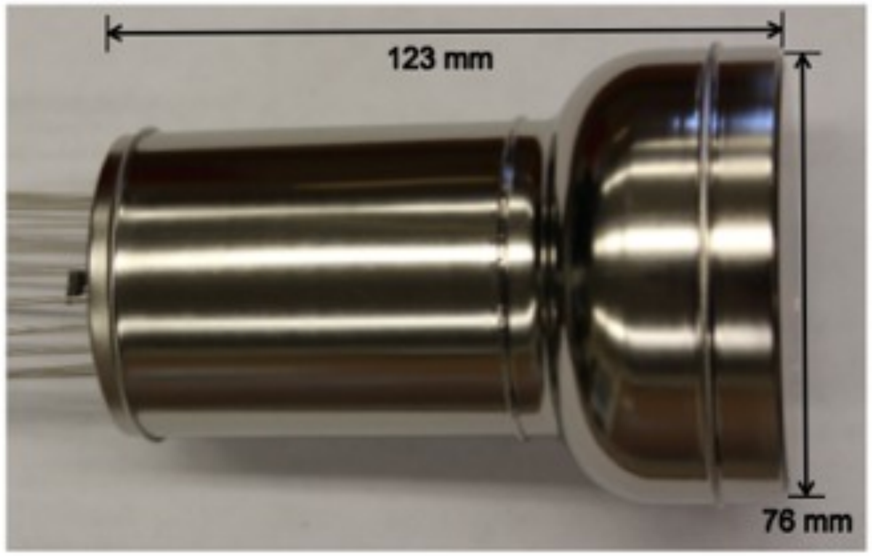


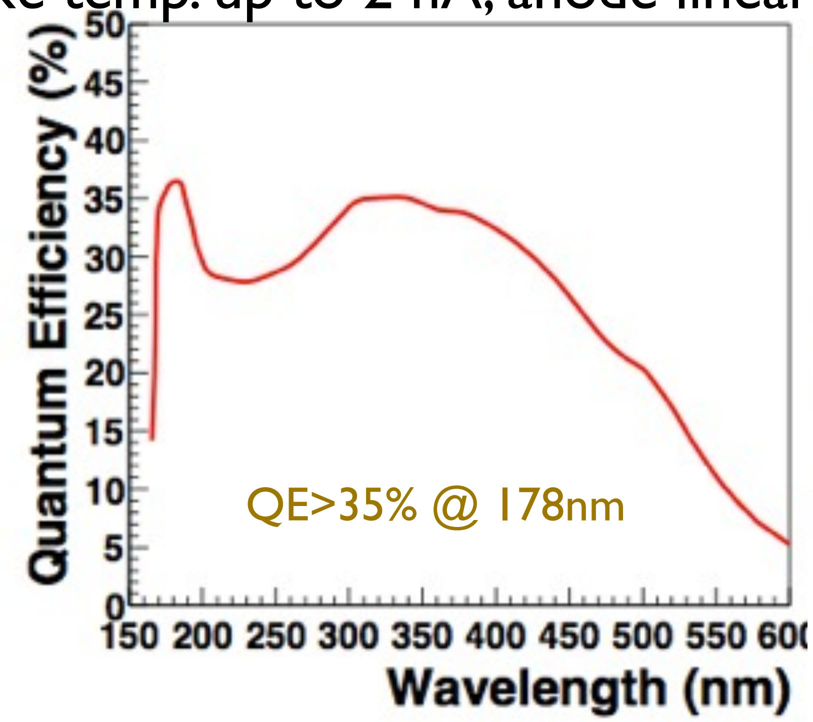


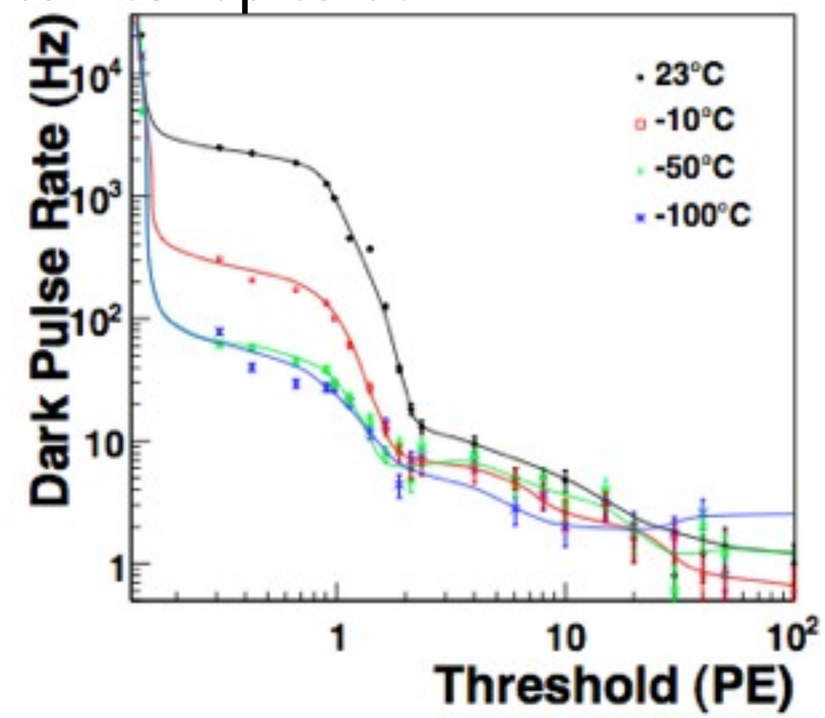


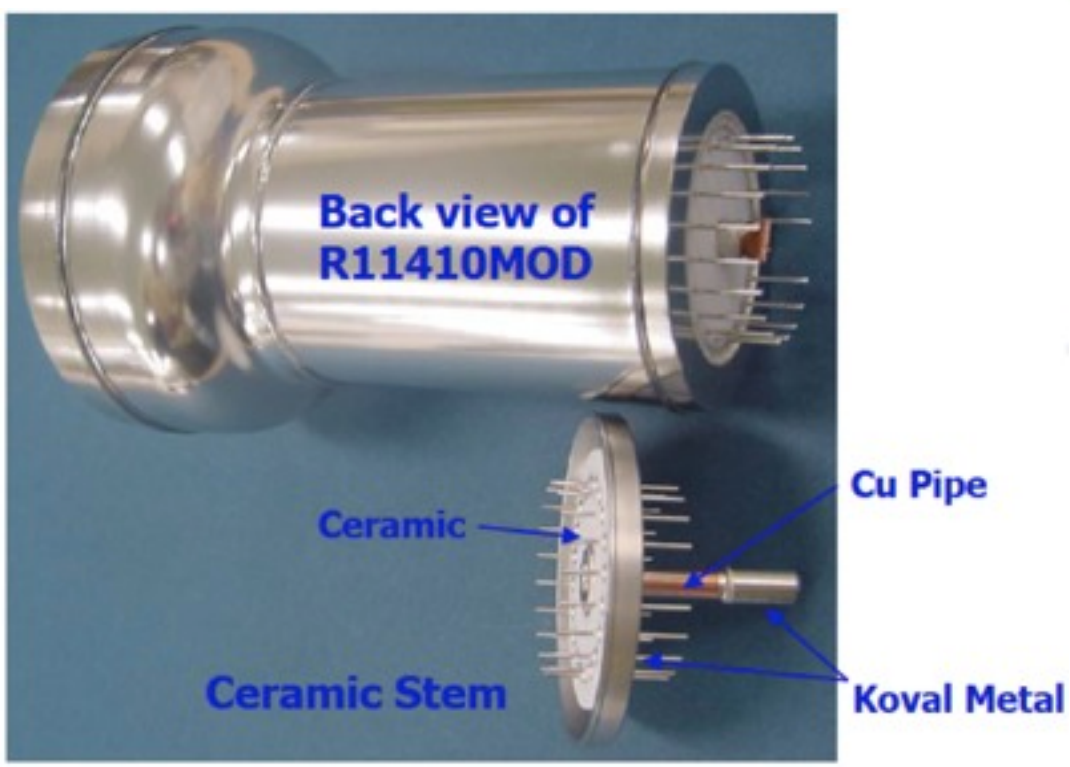
XENON1T PMTs

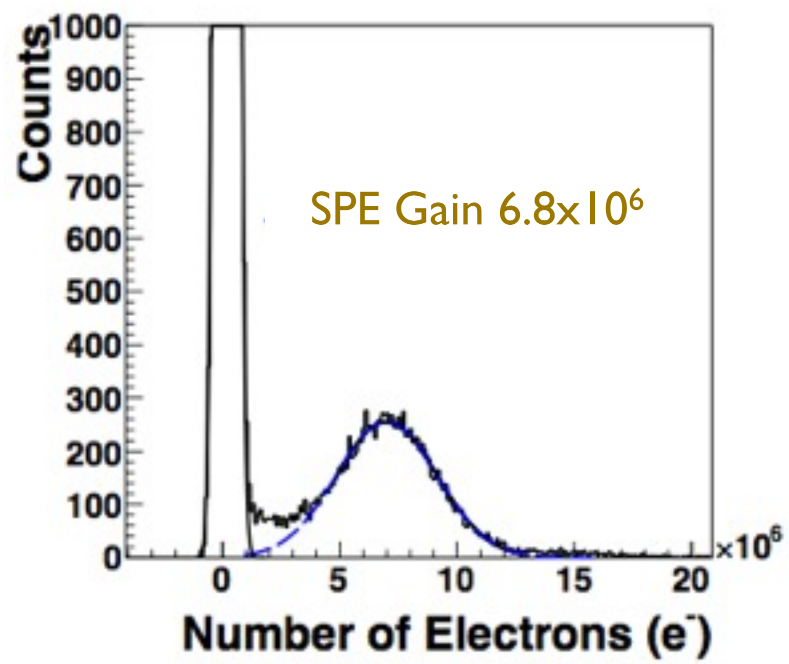
Baseline photosensor is the Hamamatsu R11410-10 3” PMT
LT bialkali photocathode; 12 stage box and linear focused style dynode structure
QE > 35% at 178 nm
50 Hz dark count rate
Cathode linear to <5% at LXe temp. up to 2 nA; anode linear to <5% up to 80nA

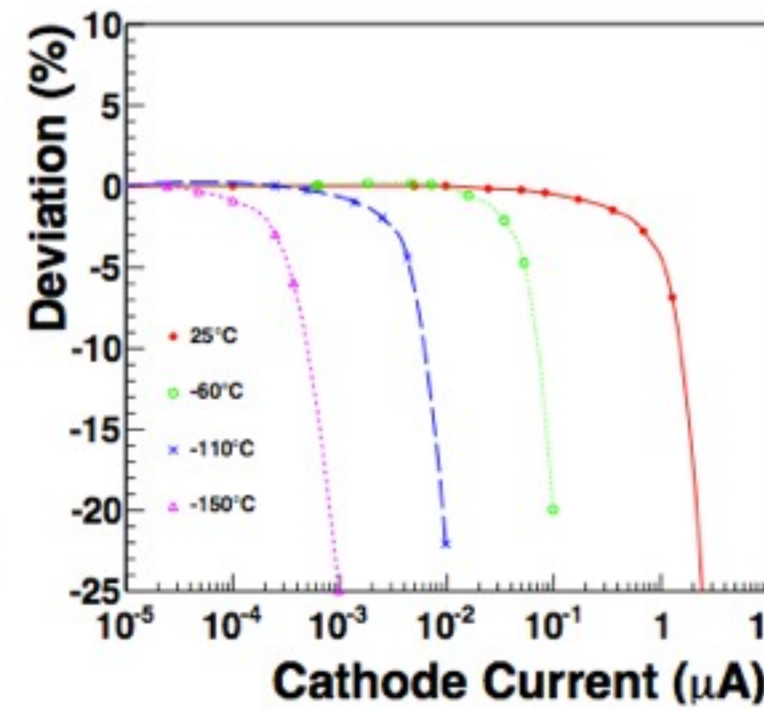








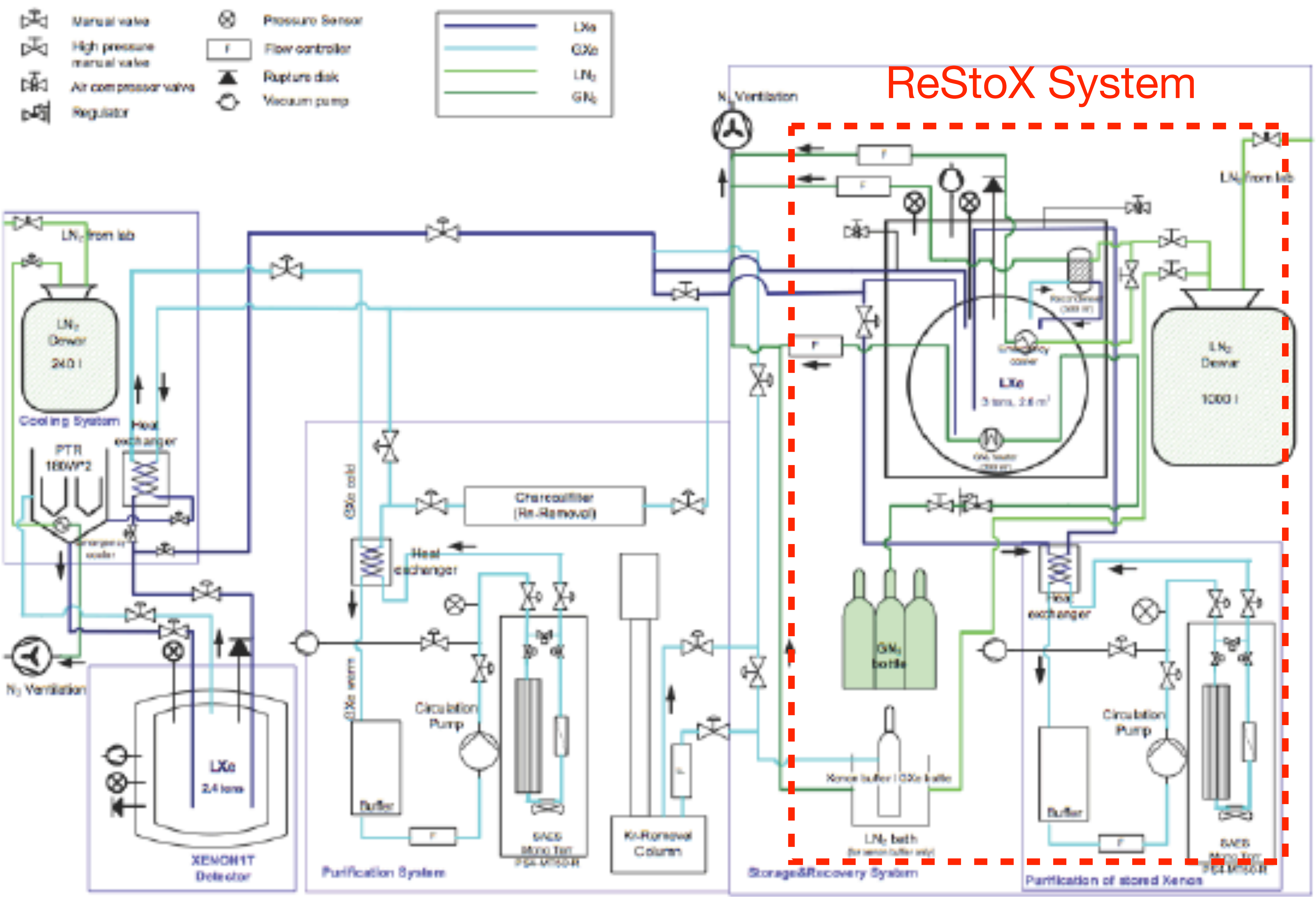




XENON1T GAS SUPPLY

- 2.5 tons of HP Xe procured by Coll.
- All gas with <1 ppm O2 equivalent impurities and < 10 ppb Kr/Xe
- Purity level of each Xe bottle validated with dedicated measurements at MPIK
- Gas cylinders stored underground to minimize activation

XENON1T CRYOGENIC INFRASTRUCTURE

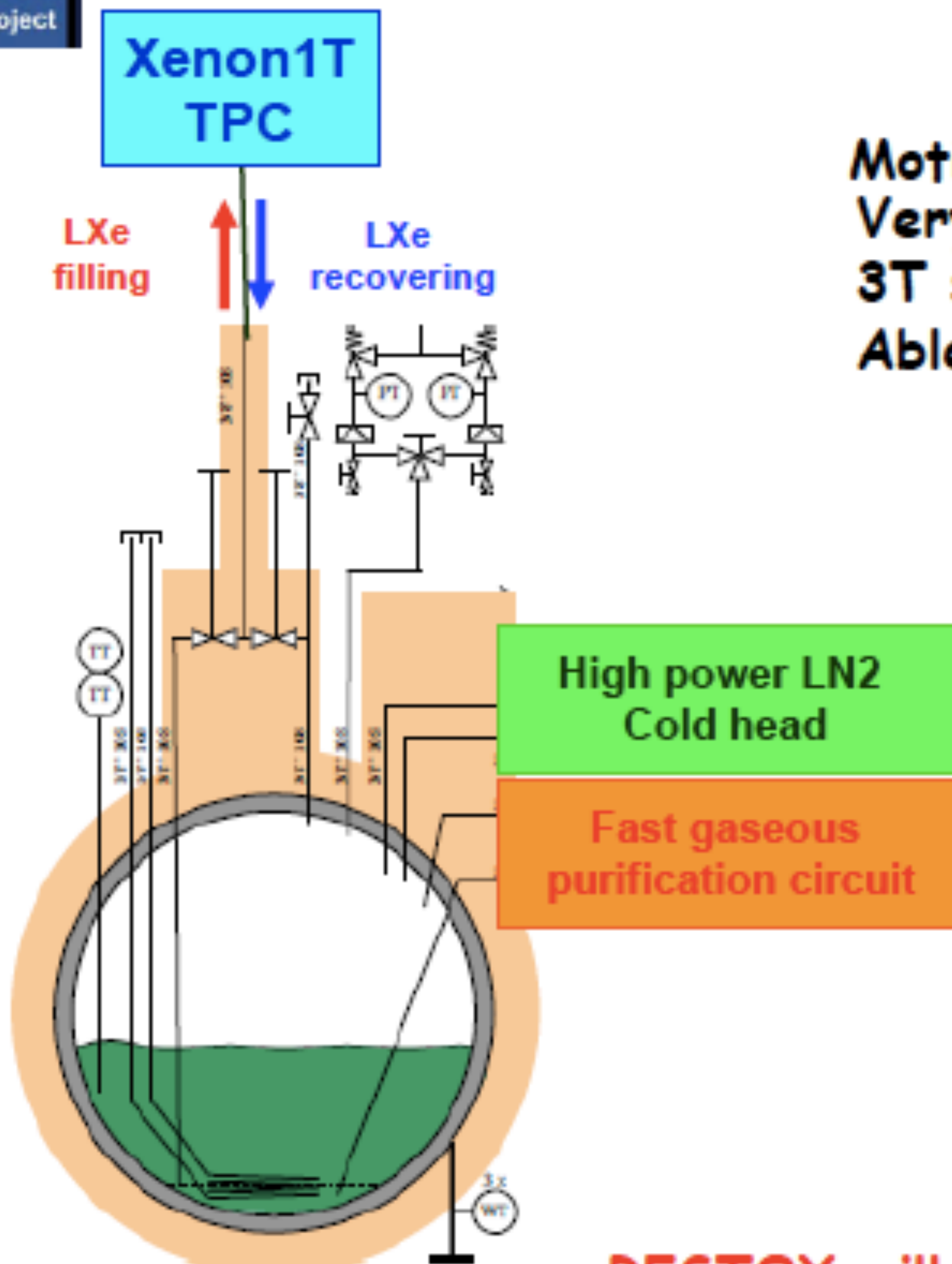


XENON1T GAS/LIQUID STORAGE SYSTEM

XENON Dark Matter Project

RESTOX : A Liquid Xenon station

(REcovering and STOrage system of Xenon1T)



Motivations :
Very compact station
3T storage capacity from 20°to -108°C
Able to keep high purity all the time

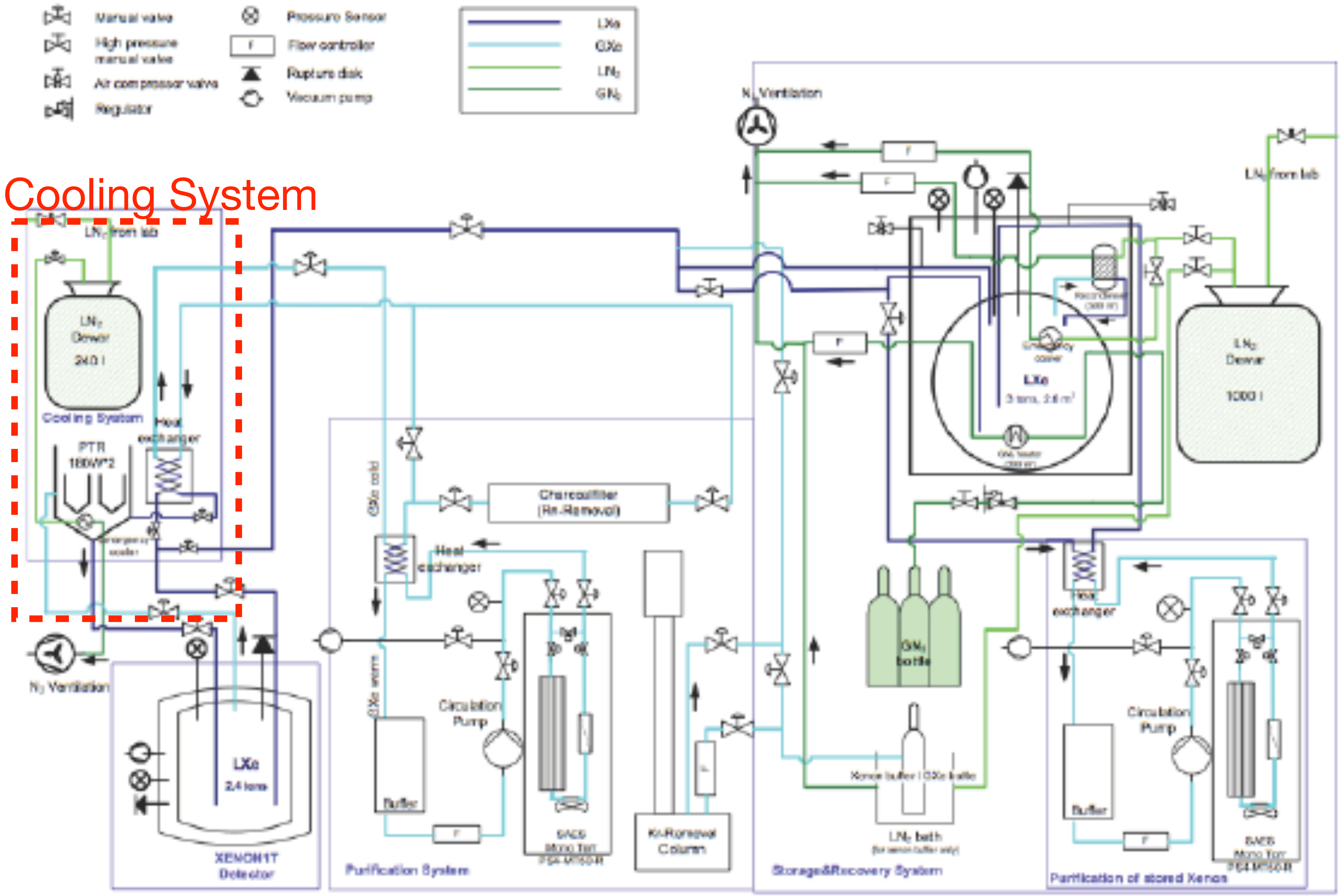
Subatech

AIR LIQUIDE TECHNIQUES AVANCEES

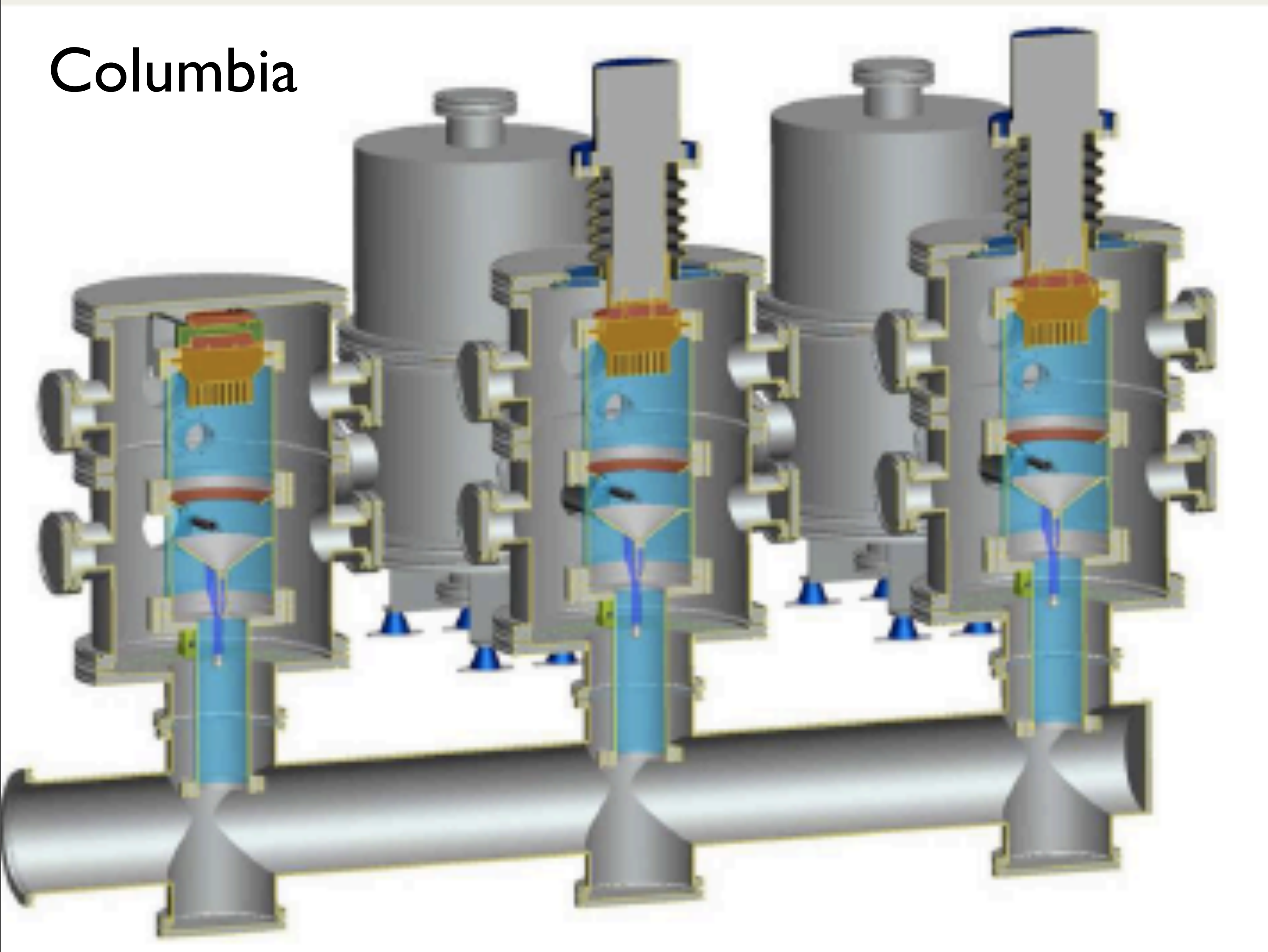
Time schedule:
Construction will start in summer 2012
Installation for end of 2013

RESTOX will be easily scalable to larger sizes

XENON1T CRYOGENIC INFRASTRUCTURE



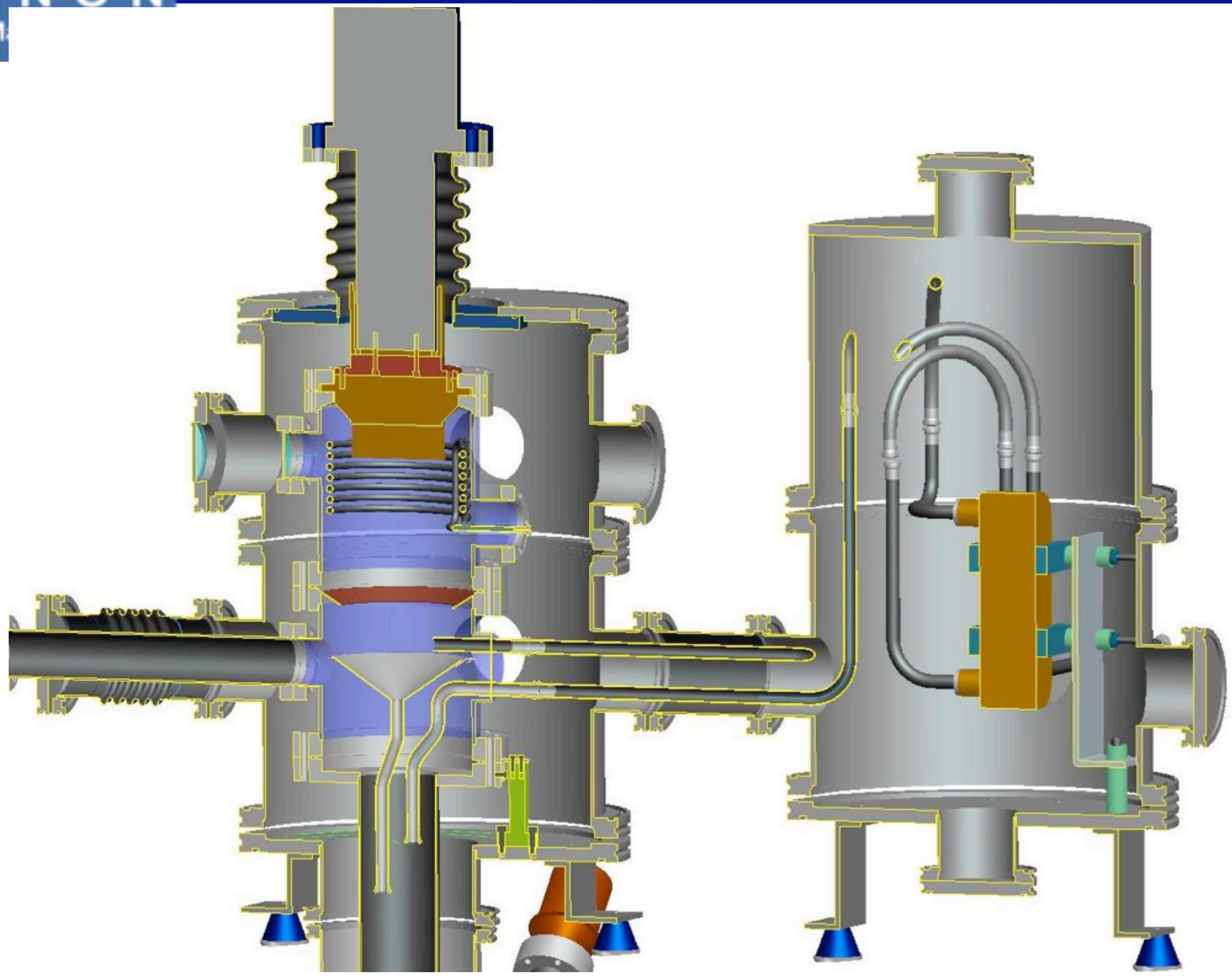
XENON1T COOLING SYSTEM



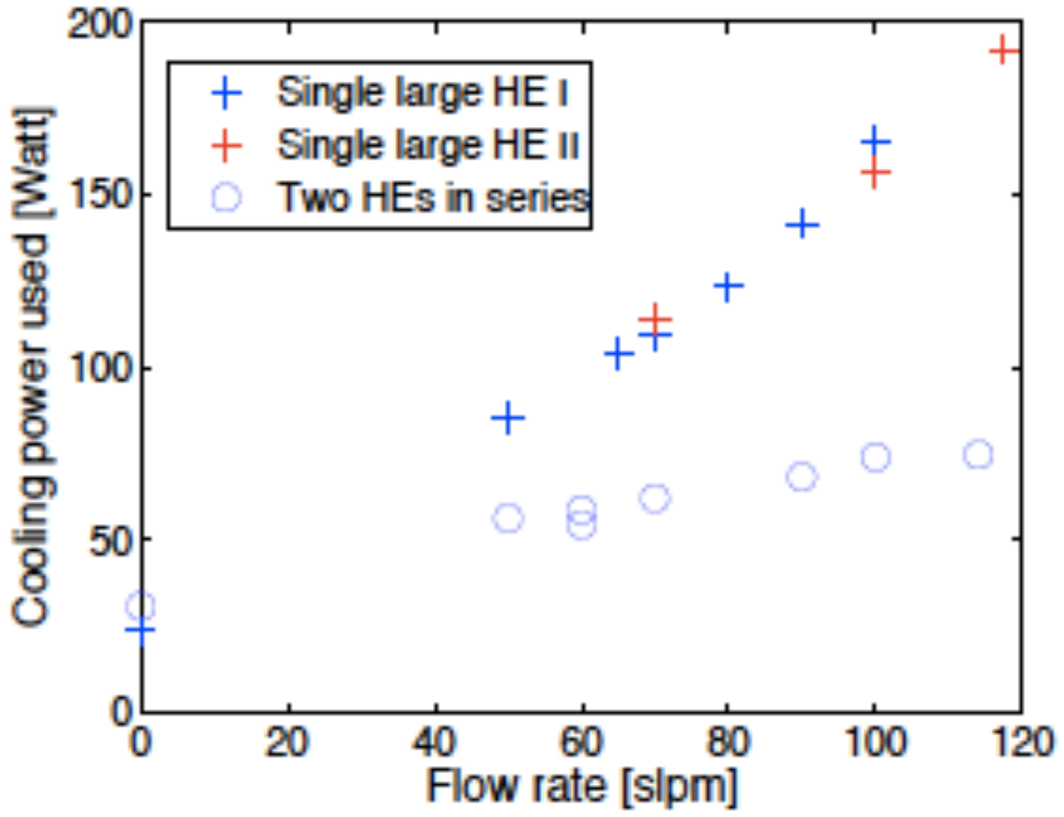
- Use the same remote cooling principle as used in XENON100, with a cooling tower outside the water tank. LXe flows back into the detector vessel via gravity.
- Composed of three independent cooling towers: 2 for PTRs, 1 for emergency cooling.
- Each PTR can be serviced without exposing the inside volume to air (like XENON100).
- Each cooling tower has an independent vacuum cryostat.

- The novelty is the ability to replace a PTR while the other is in operation or while the emergency cooling is in operation.
- A junction box outside of the water tank will provide enough surface area for the many ports needed for pressure and temperature sensors, rupture disks, etc.

XENON1T COOLING SYSTEM

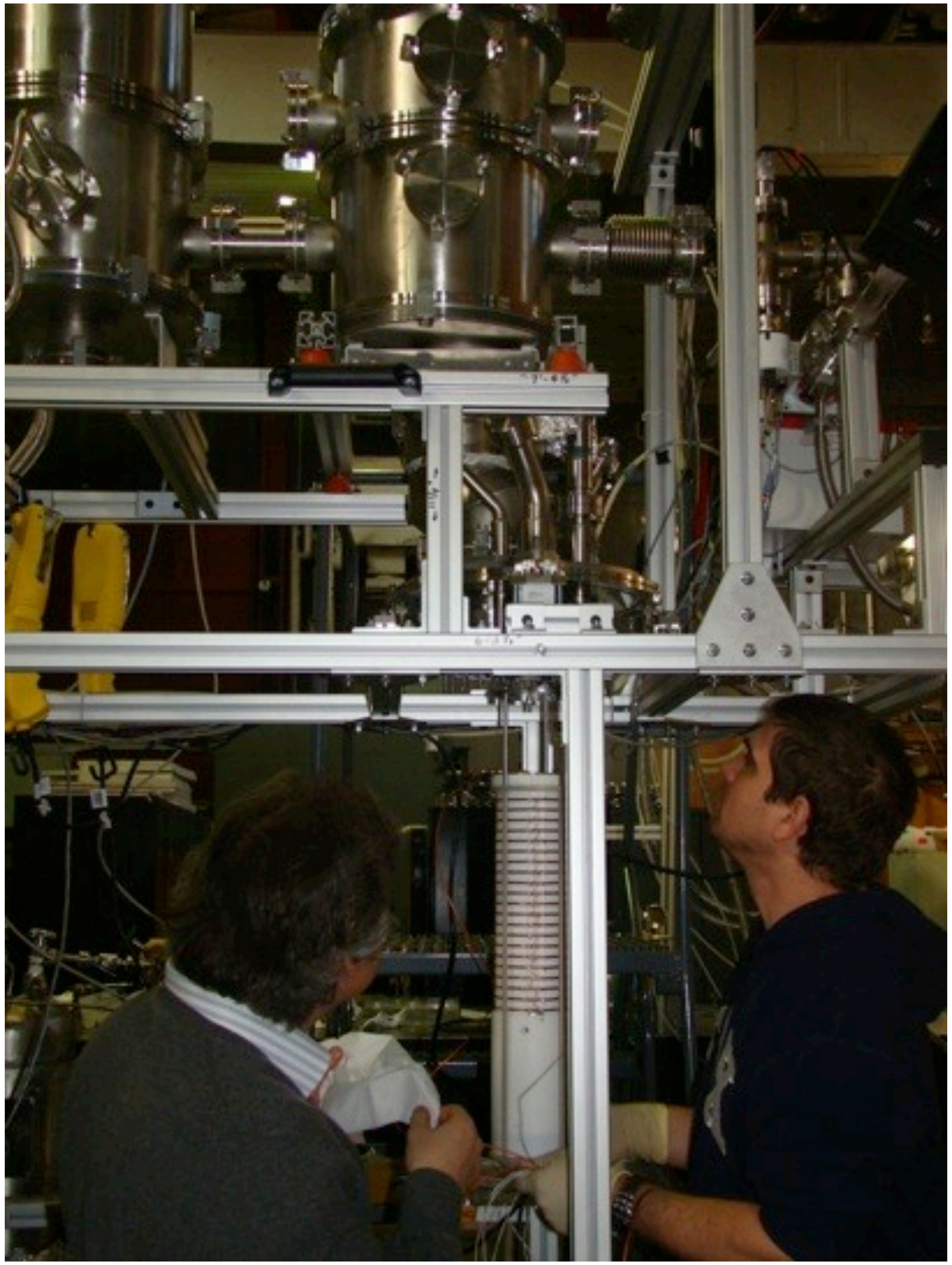


- Each 200W PTR tower has a heat exchanger (HE) tower where incoming GXe from recirculation is liquefied by outgoing LXe
- Enables recirculation flow rates of >100 SLPM
- Most of the ~1.1KW cooling power required to liquefy GXe at this flow rate provided by outgoing LXe
- Demonstrated 96% efficiency with two HEs
- At 114 SLPM available cooling power left is ~130 W



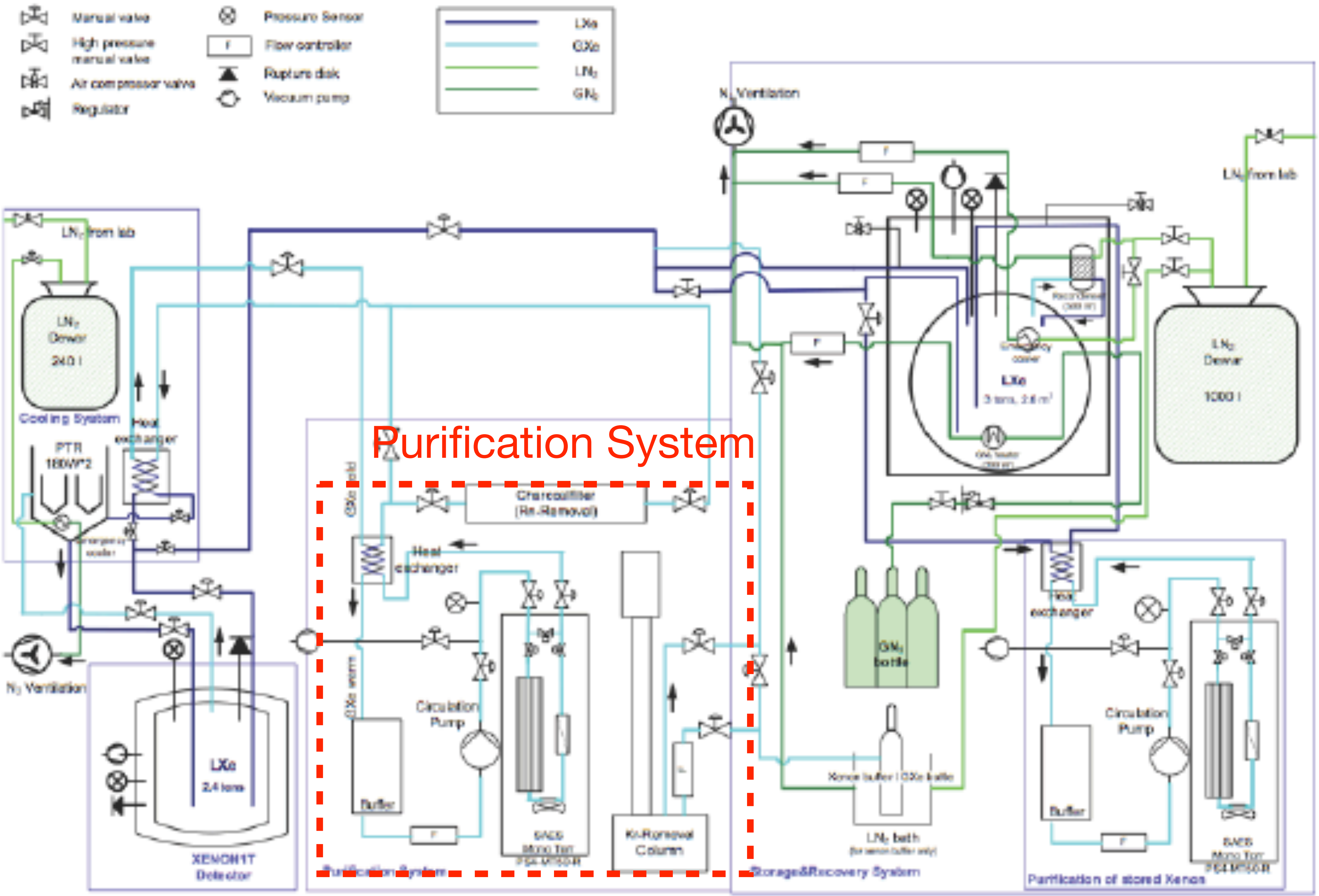
XENON1T Demonstrator Facility @ Columbia

- Demonstrate high flow rate purification (~100 SLPM) for long drift in LXe
- Demonstrate performance of a 100 kV feedthrough made of low radioactivity materials
- Demonstrate performance in LXe of new PMTs (R11410 and QUPID)
- Validate these technologies in a dual-phaseTPC like XENON100 but with 1 meter drift and 1 kV/cm field



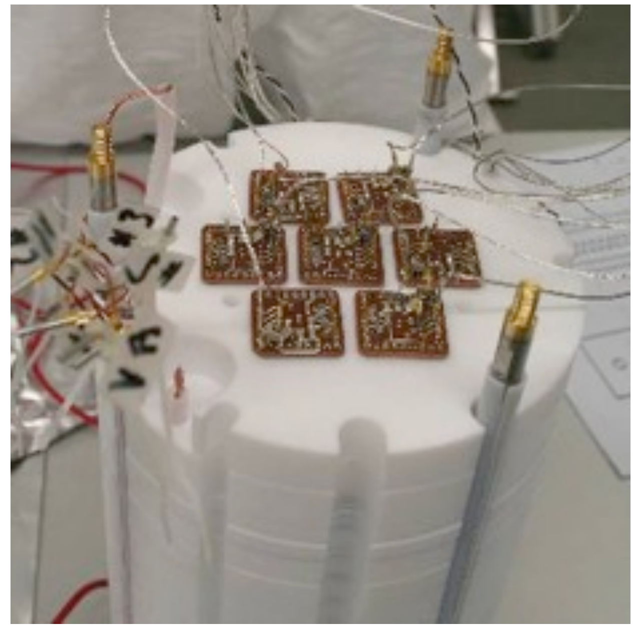
Xe XENON Dark Matter Project

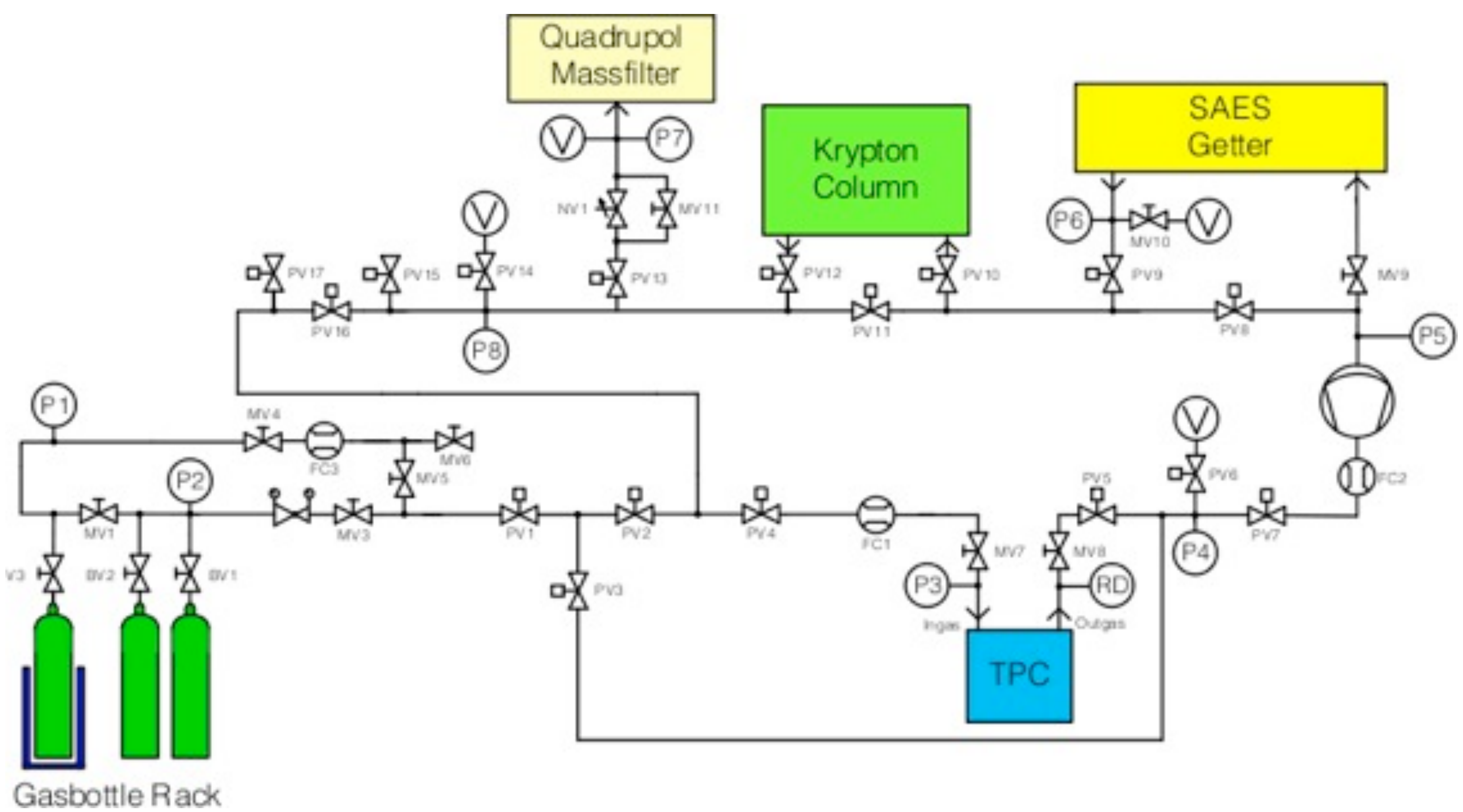
XENON1T CRYOGENIC INFRASTRUCTURE



XENON1T Prototype Purification Facility @ Munster

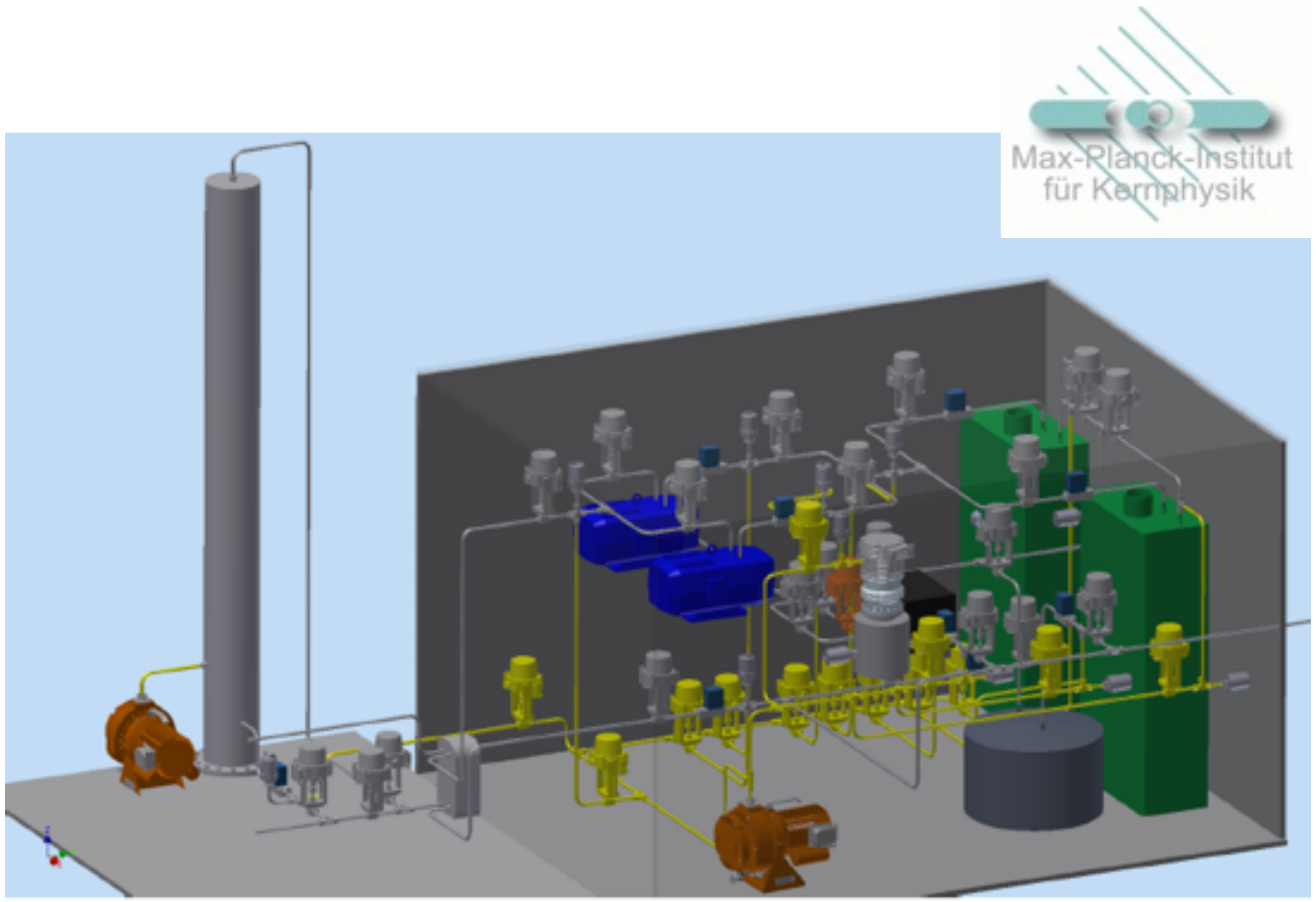
- ½ inch gas lines
- VCR connections
- Orbitally Welded
- Pneumatic valves
- SAES PS4-MT50 getter
- QDrive and KNF pumps
- Dedicated devices for ppb H_2O/Xe
- Custom ^{83m}Kr detector





^{222}Rn Removal in Online Purification

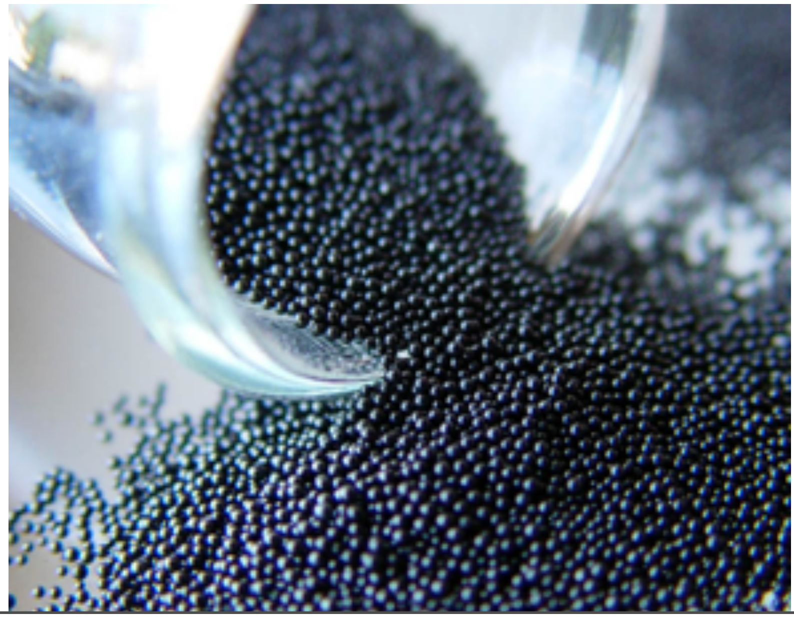
Rn can be removed by cryo-adsorption on charcoal
Demonstrated in Borexino (for LN_2) and GERDA (for LAr)



Xenon purification loop with large charcoal tower

Mobile Radon Extraction unit (MoREx) @ MPIK to test efficiency of various charcoals for Rn removal from Xe

Optimization of purification efficiency by selection of charcoal with appropriate micro-pore structure

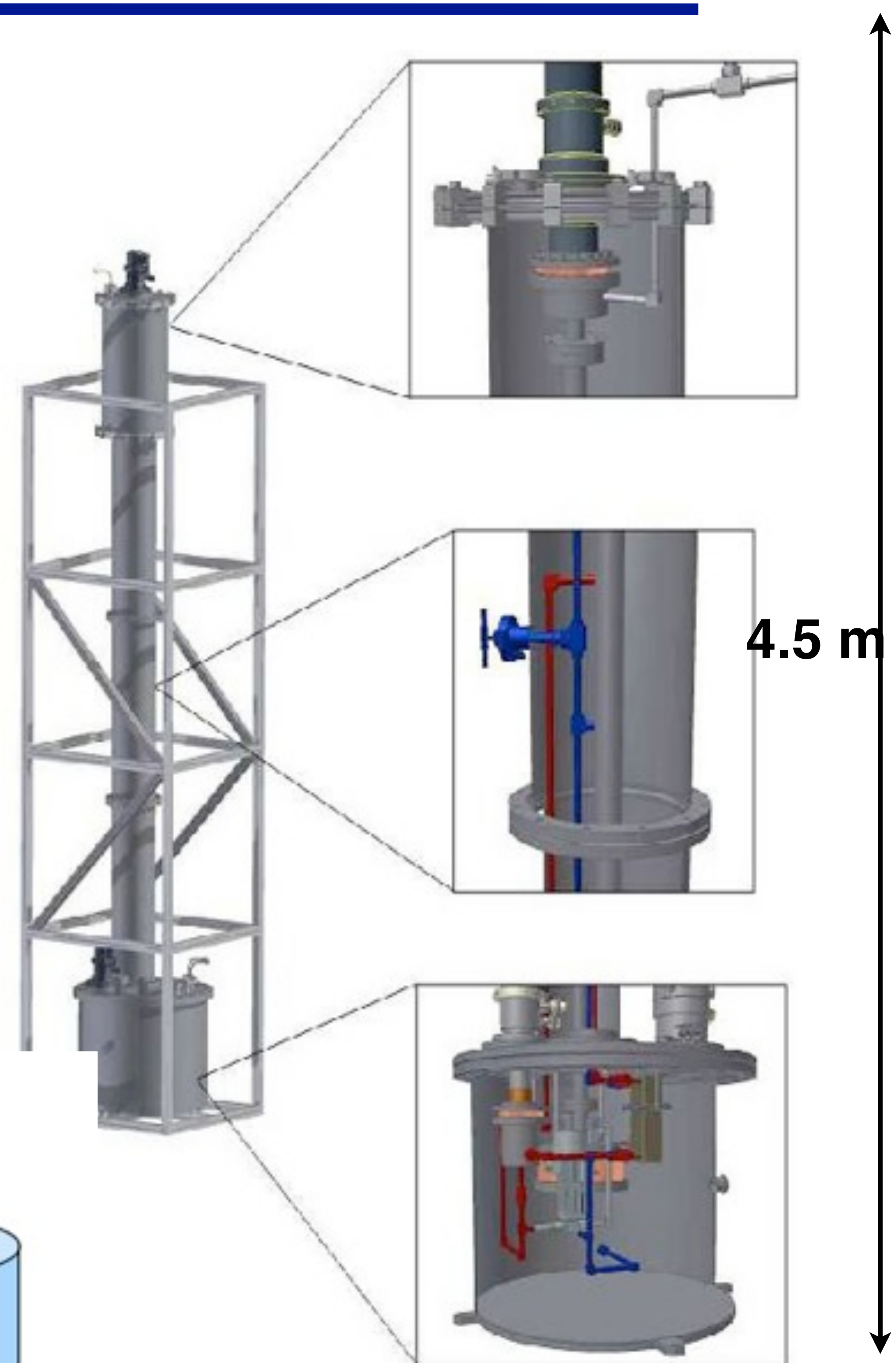


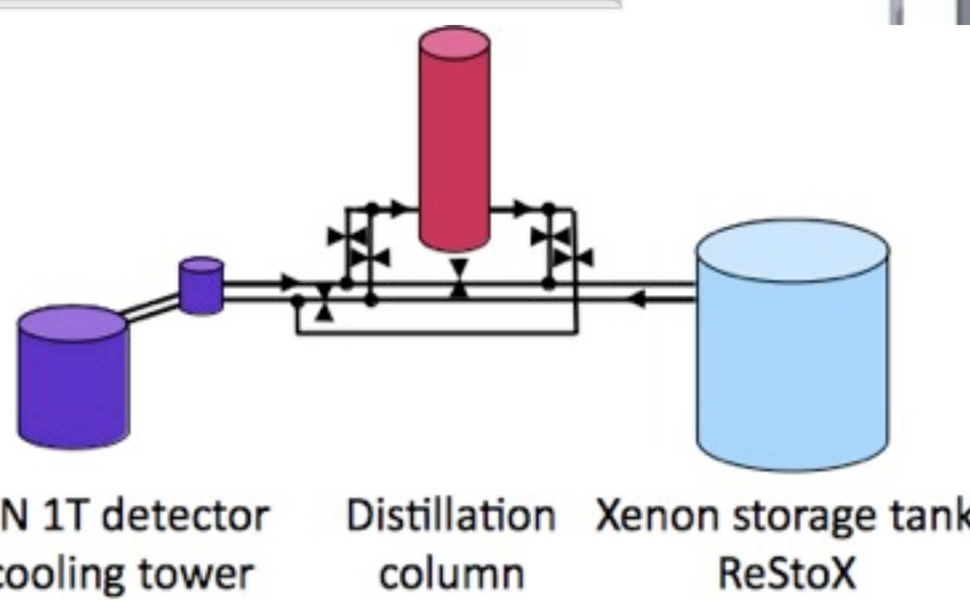
Cryogenic Distillation Column for Kr

- proven technique, currently used in XENON100
- utilize different boiling temperature of Xe and Kr
- liquid Xe passes through, Kr gas removed

Design Parameters fo XENON1T

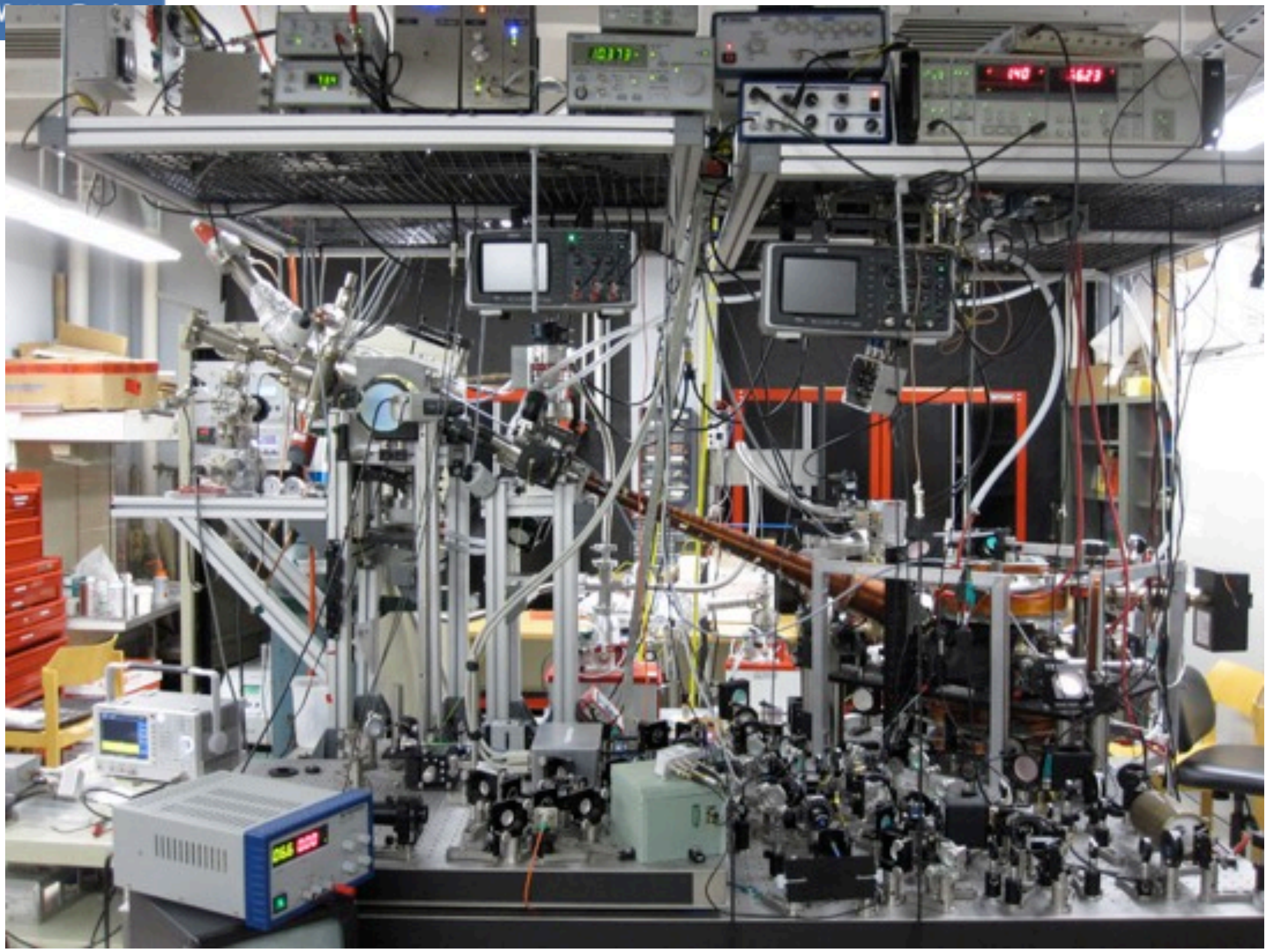
- through-put: 3 kg/hr
- factor of 10^4-10^5 separation
- final Kr/Xe < 1 ppt

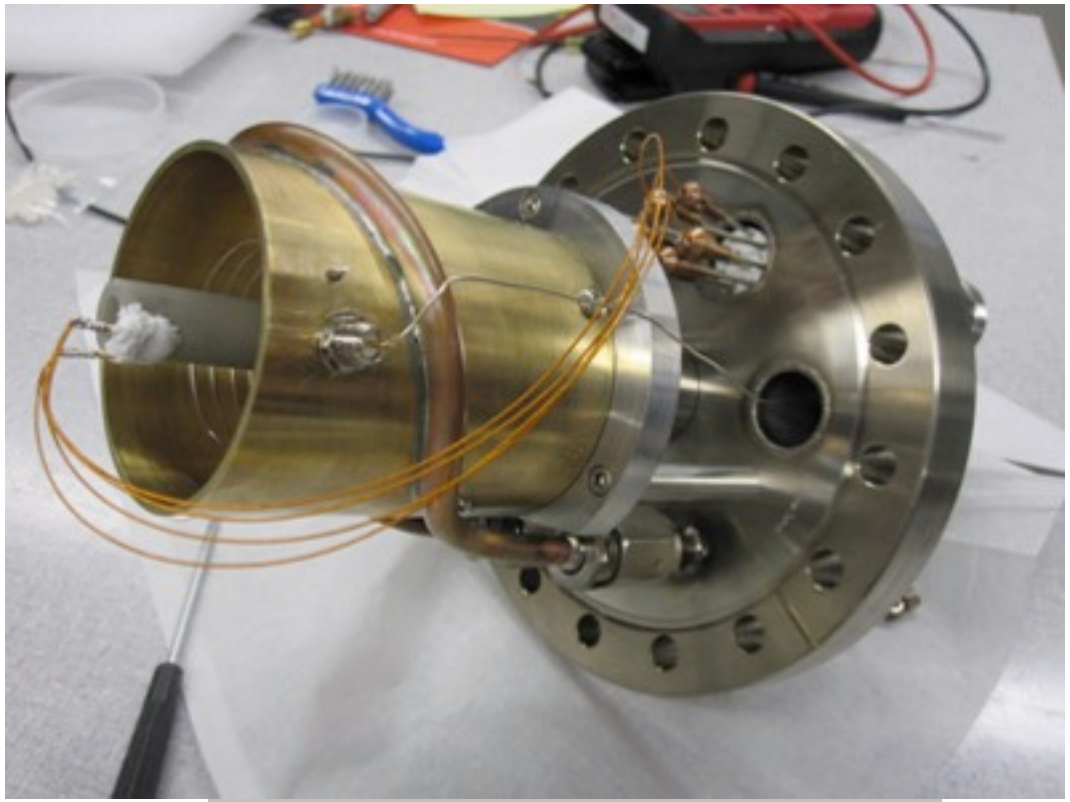




Westfälische Wilhelms-Universität Münster

Columbia Atom Trap to Measure Kr Contamination



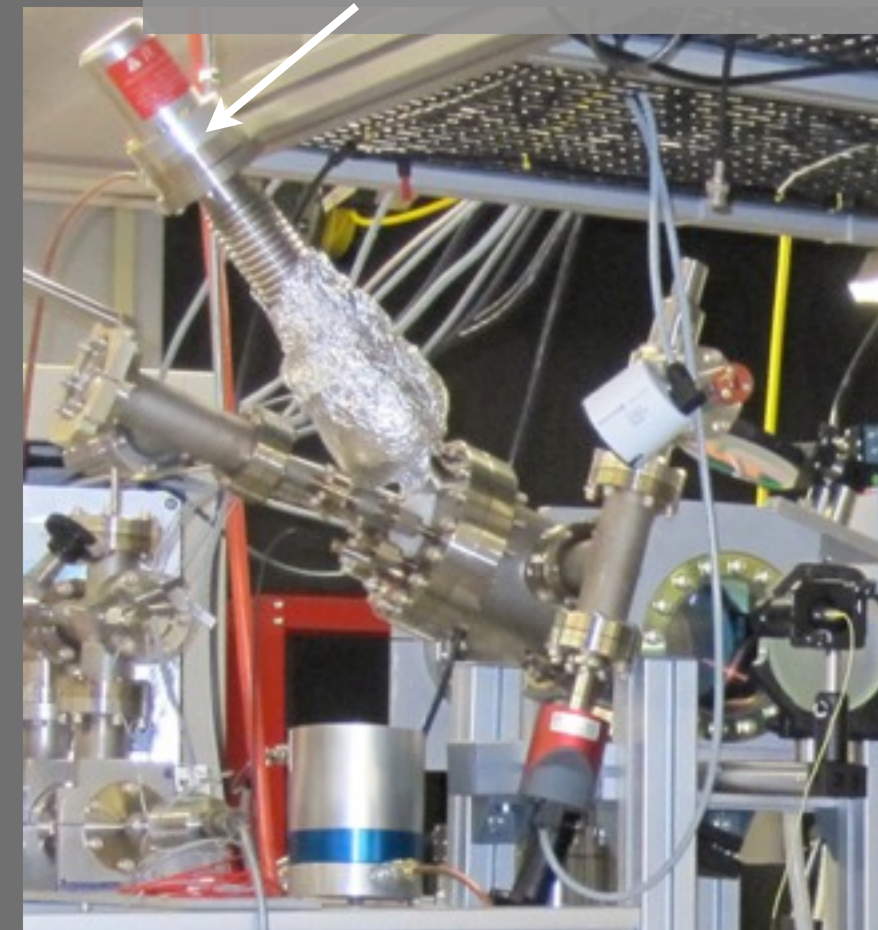


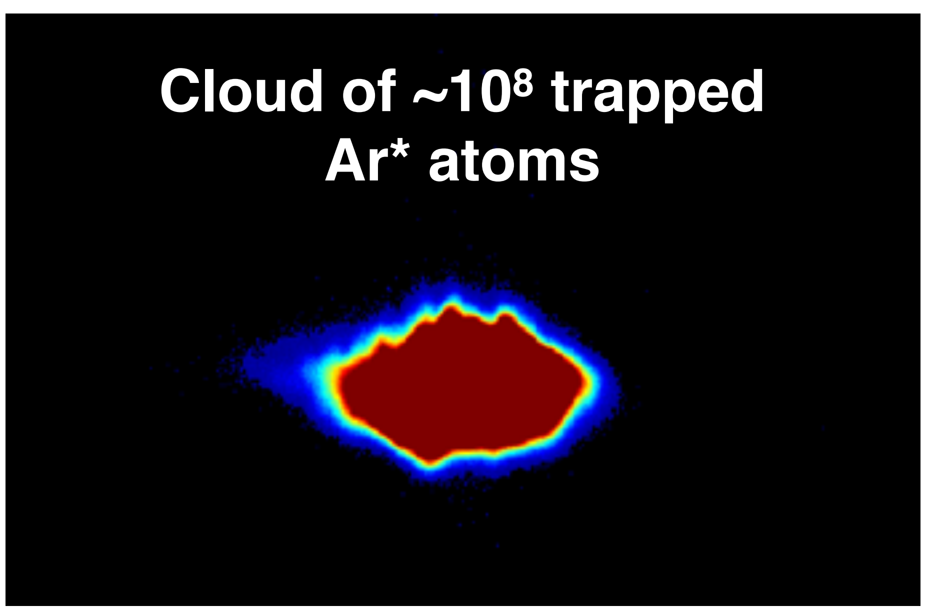
RF plasma discharge source

Measurement Technique

- Traditional laser cooling and trapping techniques allow single $^{84}Kr^*$ atoms to be counted with extremely high isotopic selectivity
- Will measure $^{84}Kr/Xe < 1$ ppt in ~several hours
- Amount of $^{85}Kr/Xe$ extrapolated from known ratio of $^{85}Kr/^{84}Kr$

CU Atom Trap to Measure Kr Contamination





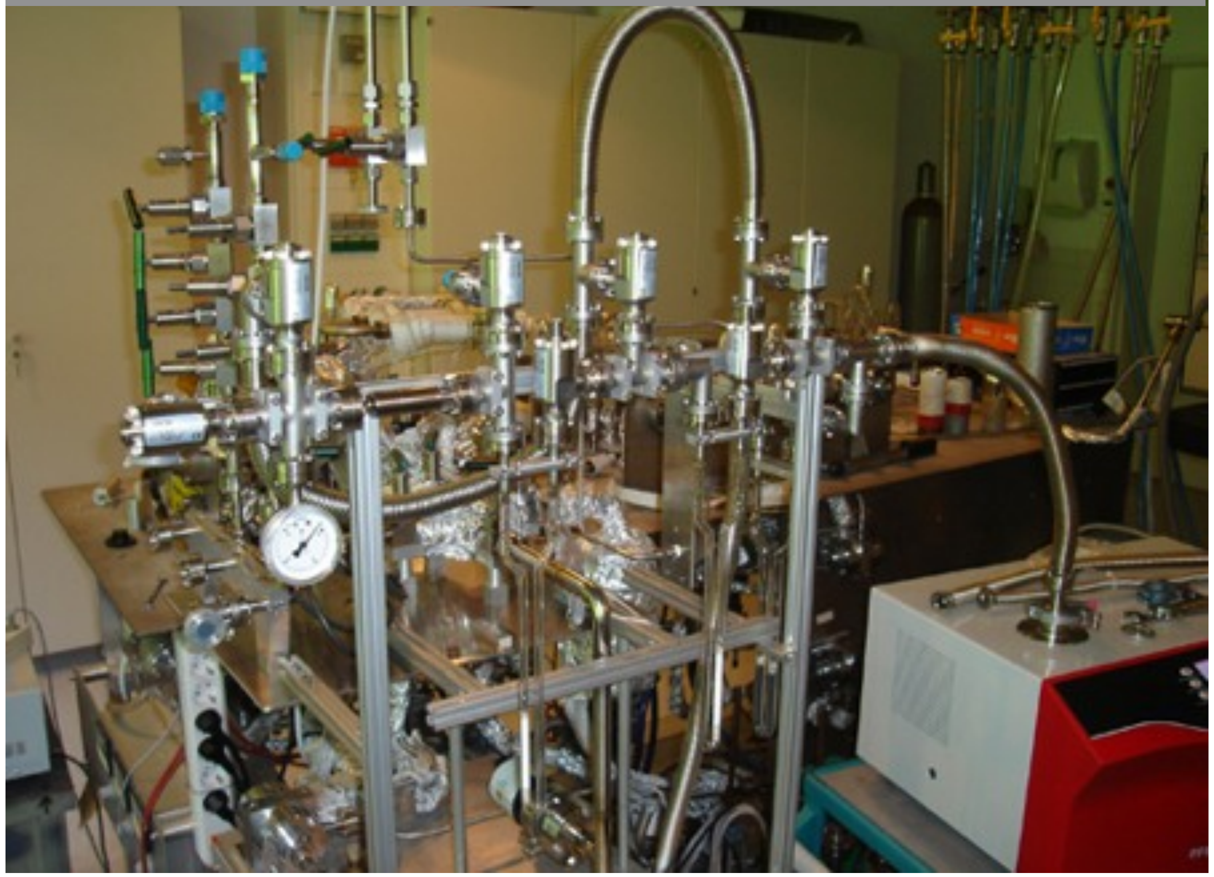
Current Status

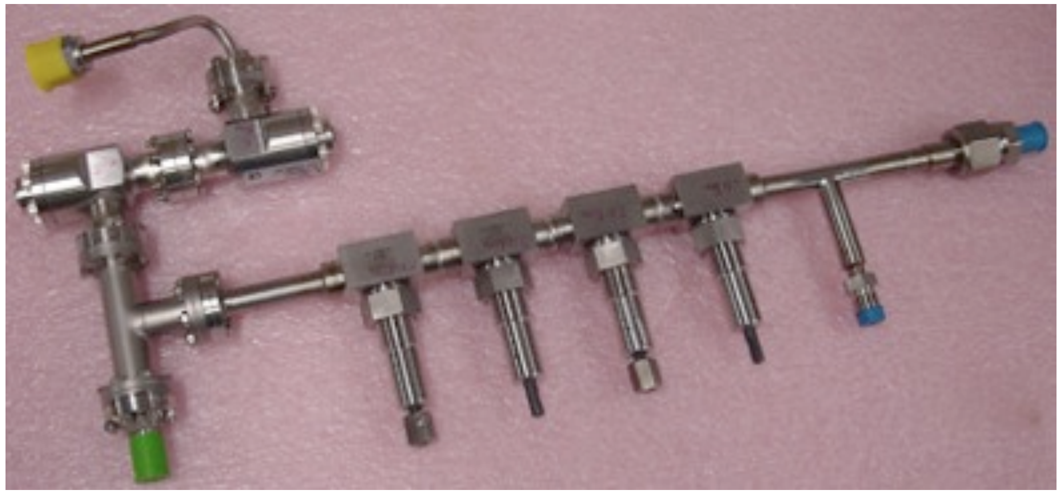
- Atom trap operational and efficient for Ar*
- RF discharge source cooling implemented
- Single Ar* atom detection and Kr* calibration Mid 2012
- First Kr/Xe measurements for XENON100 by Fall 2012

MPIK Mass Spectrometer to Measure Kr Contamination

Rare Gas Mass Spectrometer (RGMS)

gas chromatograph to separate Kr from Xe sample

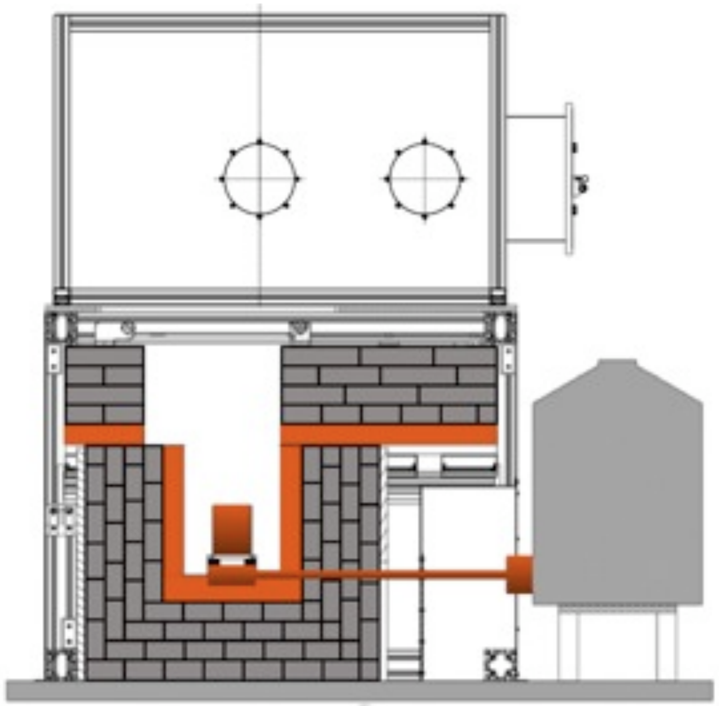


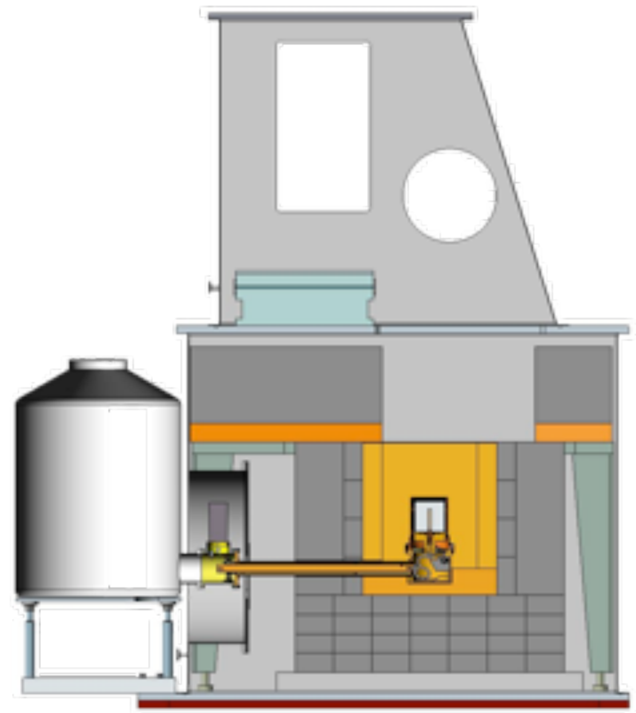


Pipette to inject gas sample

- Kr separated from Xe sample by chromatography
- Kr gas loaded into the UHV RGMS
- Sensitivity to 1 ppt Kr/Xe
- System fully operational

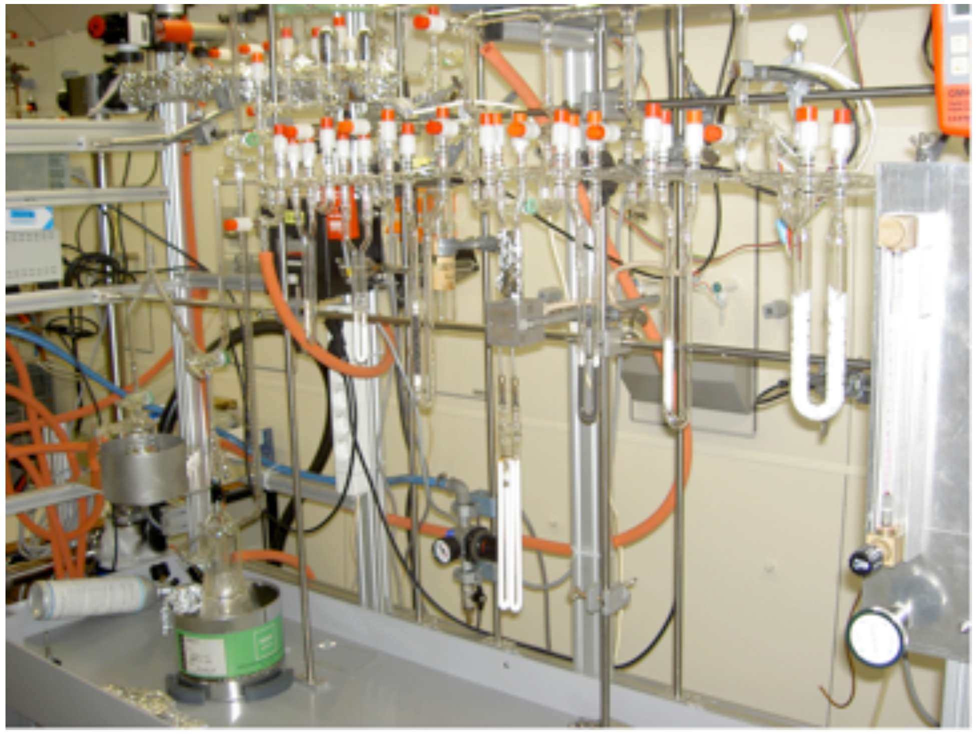
Materials Screening for XENON1T





Access to various ultralow background screening facilities in above-ground, shallow depth and deep underground labs, amongst them:

* GeMPIs @ LNGS (MPIK)
* GATOR @ LNGS (UZH)
for gamma-ray screening with ~10 μBq/kg sensitivity



* Gas counting systems @ LNGS and @ MPIK
for ^{222}Rn emanation measurement with a few atom sensitivity

Summary and Prospects

- We have entered a data driven era for Dark Matter : direct detection, the LHC, indirect detection
- Combination of large target mass, low background and innovative sensor technology has advanced noble liquids to the forefront of direct detection
- Exciting time for XENON100 with 200 days of data to be unveiled soon: original goal of 2×10^{-45} cm^2 within reach in 2012
- The next generation experiment, XENON1T, will have two orders of magnitude better sensitivity enabling to test many models
- Realistic WIMP discovery potential by the middle of this decade