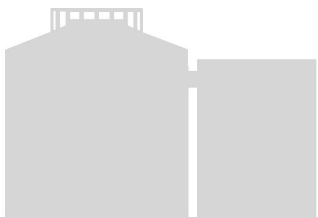


# Status of the XENON1T Experiment

D. Coderre<sup>1</sup> for the XENON1T Collaboration  
10<sup>th</sup> PATRAS Workshop, July 2014

<sup>1</sup>University of Bern, Albert Einstein Center for Fundamental Physics



*u<sup>b</sup>*

<sup>b</sup>  
UNIVERSITÄT  
BERN

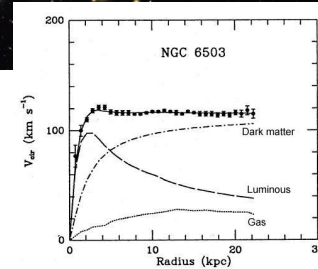
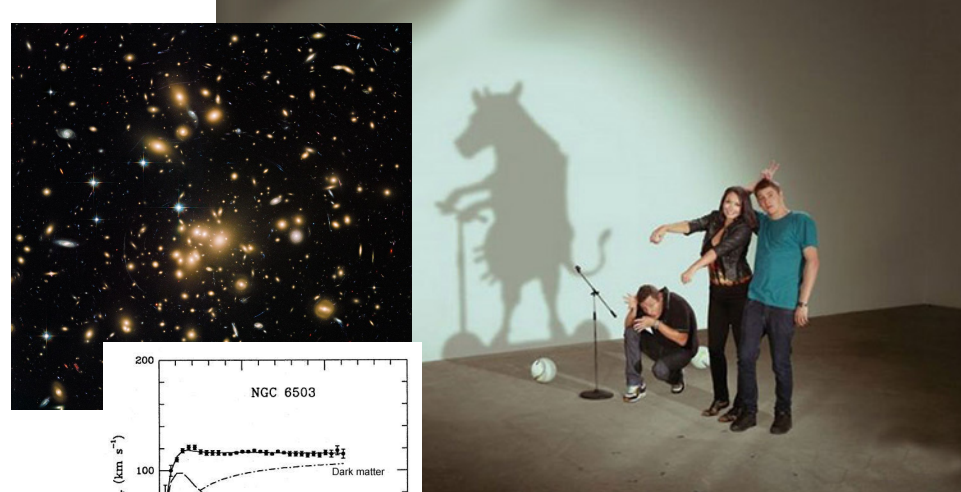
AEC  
ALBERT EINSTEIN CENTER  
FOR FUNDAMENTAL PHYSICS

# What are we doing here?

We know dark matter is out there... but we don't know what it is...

- **WIMPs**
- Axions
- Sterile neutrinos
- Heavy photons
- ... ?

So far only indirect evidence!

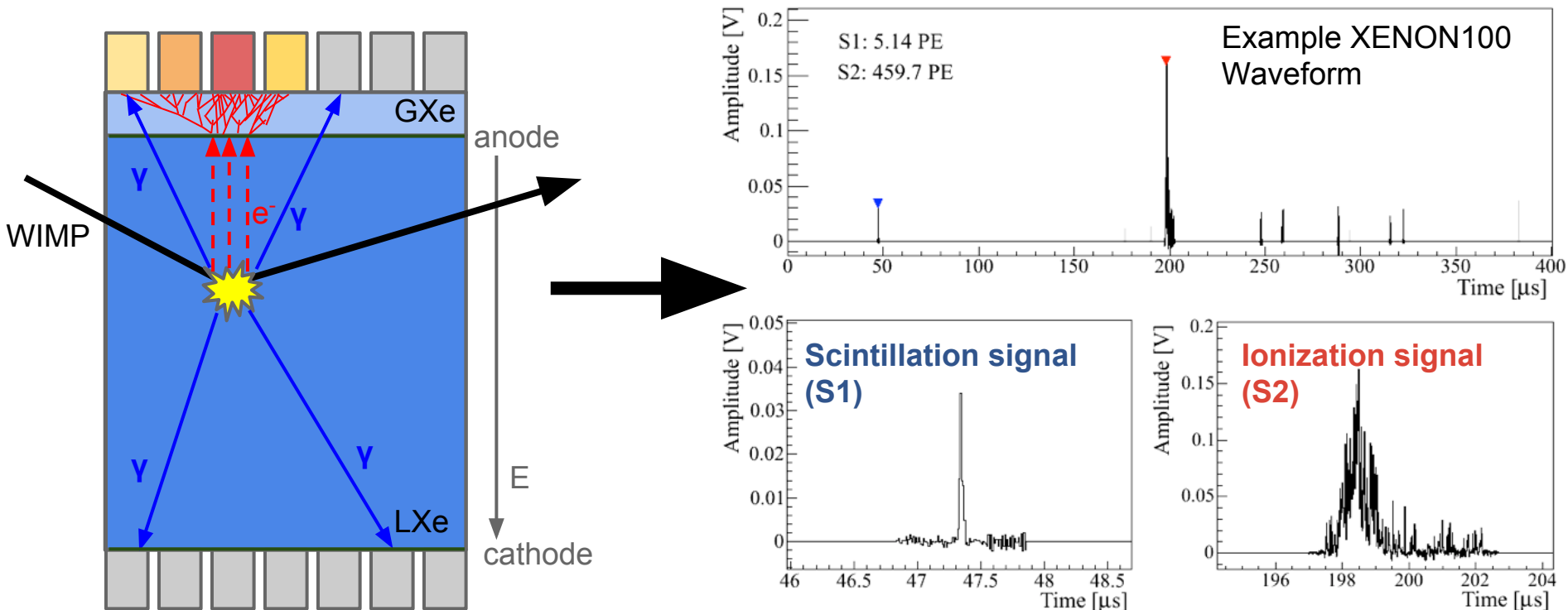


## How about WIMPs?

- Mass in 10-1000 GeV range
- Very low interaction cross section with matter
- Would provide proper relic abundance → WIMP miracle
- Predicted in several theories

**Seems reasonable → let's try to find them**

# Dual Phase TPC Principle



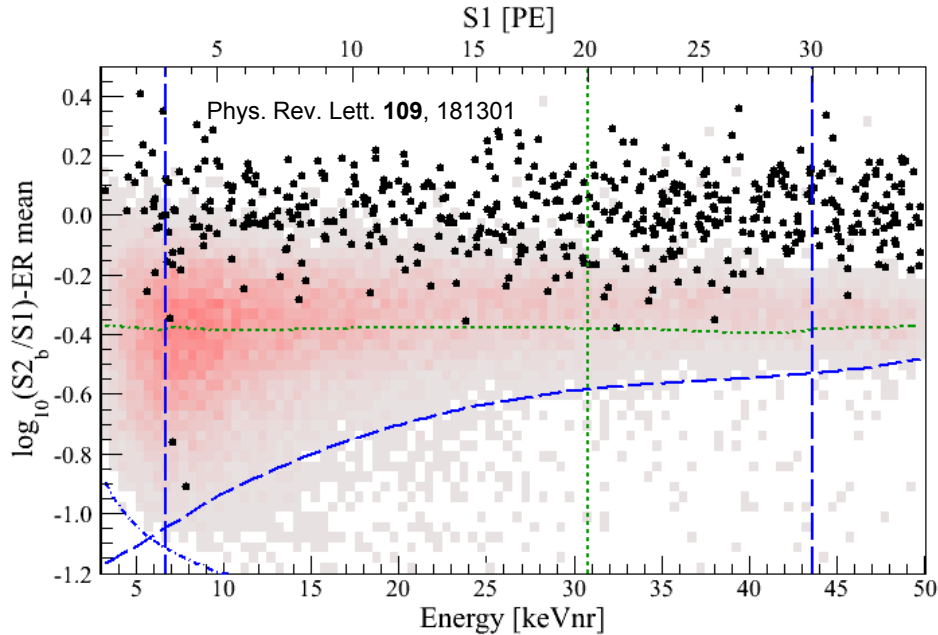
## a single collision...

- WIMP collides with xenon atom
  - Scintillation (light) signal arrives at PMTs instantaneously
  - Ionization (charge) electrons drift due to  $E$  field
    - Charge signal amplified in gas phase
    - Proportional signal recorded by PMTs

## what we learn...

- **X, Y** from hit pattern in top PMT array
- **Z** from  $t_{\text{diff}}$  between light and charge
- **Energy** from integral of signals
- **Classification** as electronic or nuclear recoil signal from charge to light ratio

# Isolating the Signal

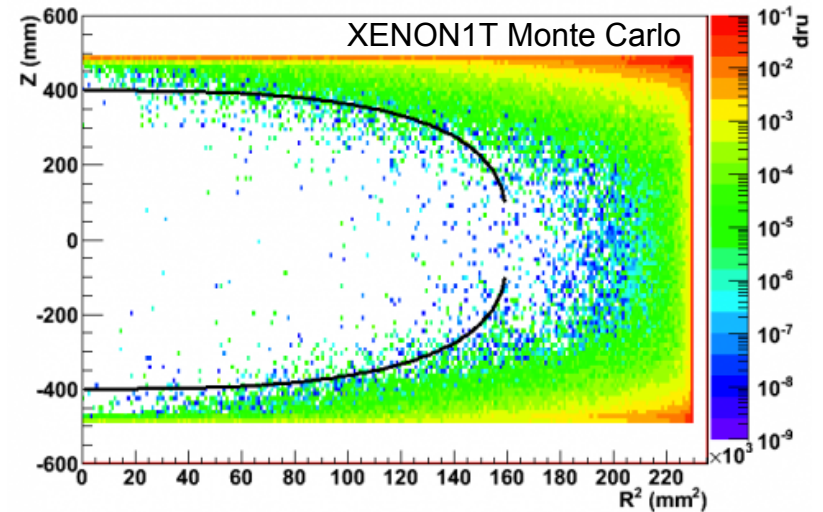


## Fiducialization

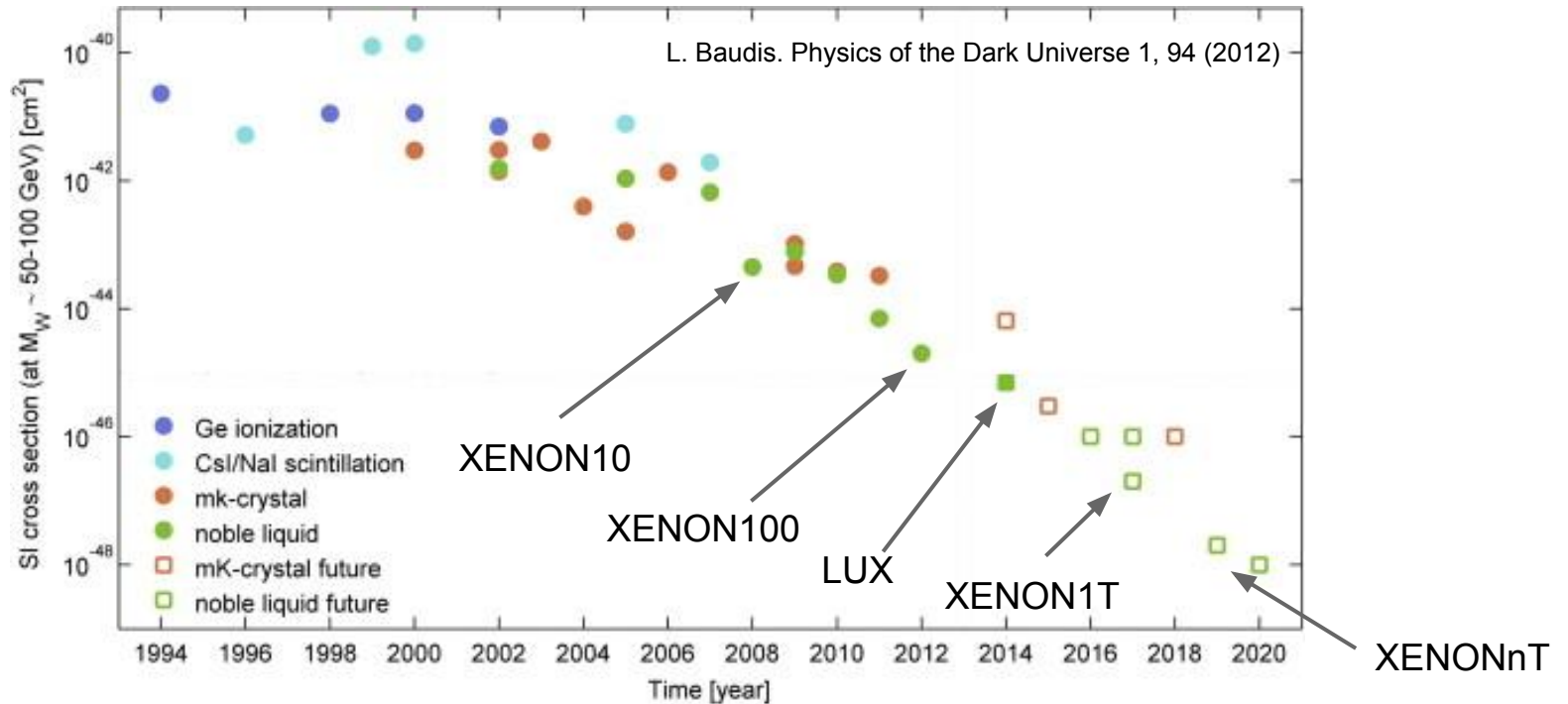
- xenon is self-shielding
- **WIMPs** don't care about self-shielding!
  - Should only scatter once
- Use calibration data to determine a fiducial volume

## Region of Interest

- Charge to light ratio versus light signal
  - Separation of E/N recoils
- **Blind analysis**
  - Reject poorly reconstructed events
  - Reject known backgrounds
  - Compute background prediction
- XENON100 best limit (left) had 2 events in ROI after unblinding, compatible with background



# Direct Detection Timeline



XENON10

**Time:** Until 2007  
**xenon:** 14kg  
**Fiducial:** 5.4kg  
**Limit:**  $\sim 10^{-43}$



XENON100

**Time:** Since 2008  
**xenon:** 161kg  
**Fiducial:** 48kg  
**Limit:**  $\sim 10^{-45}$

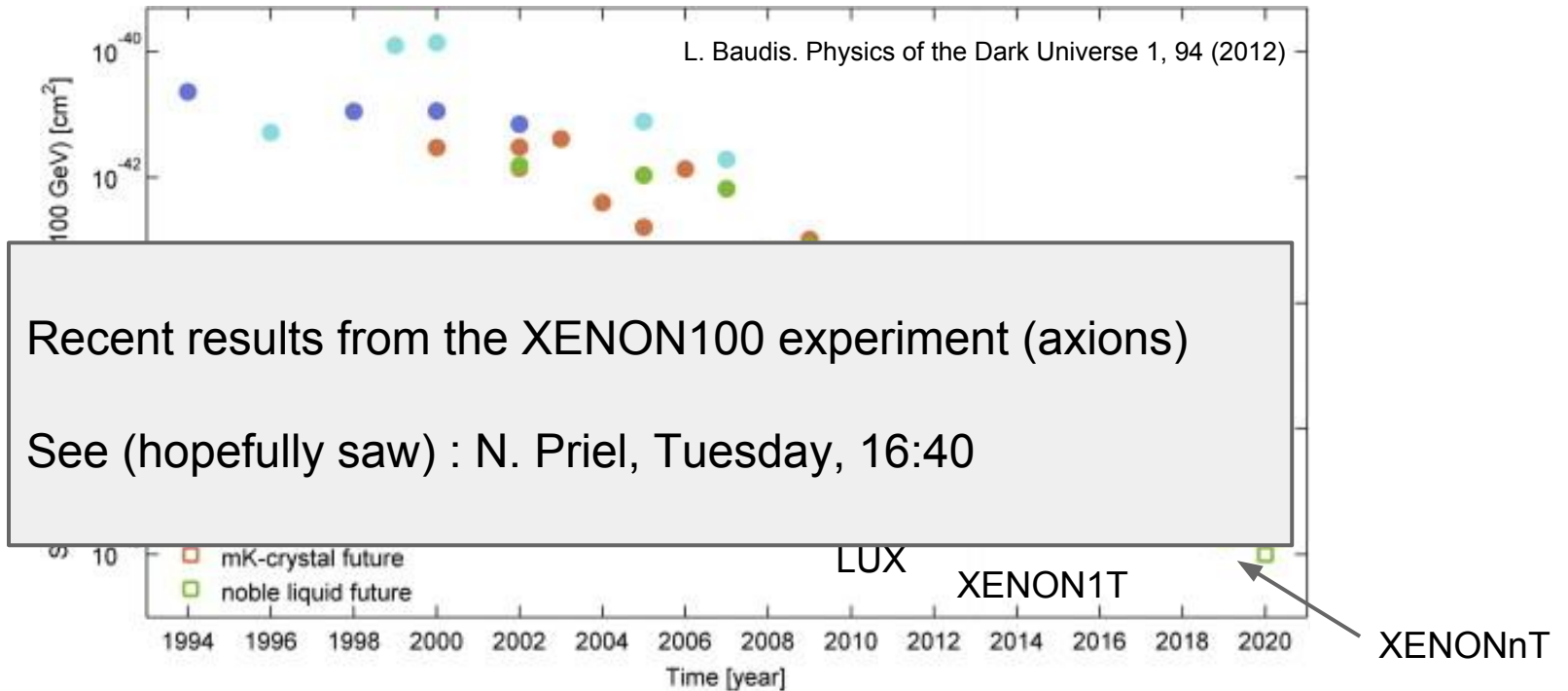


XENON1T

**Time:** From 2015  
**xenon:** 3.1 t  
**Fiducial:**  $\sim 1$ t  
**Limit:**  $\sim 10^{-47}$

About two orders of magnitude sensitivity with each iteration!

# Direct Detection Timeline



XENON10

**Time:** Until 2007  
**xenon:** 14kg  
**Fiducial:** 5.4kg  
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XENON100

**Time:** Since 2008  
**xenon:** 161kg  
**Fiducial:** 48kg  
**Limit:**  $\sim 10^{-45}$



XENON1T

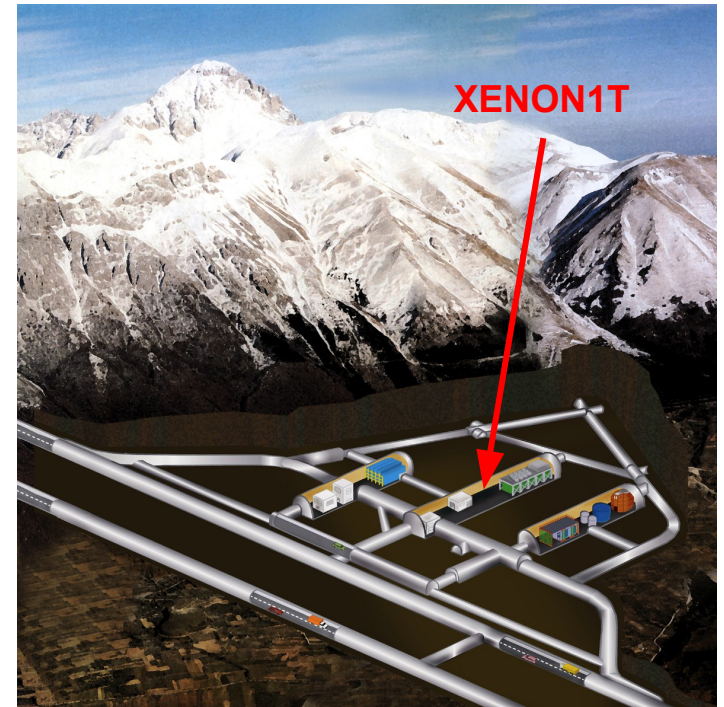
**Time:** From 2015  
**xenon:** 3.1 t  
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About two orders of magnitude sensitivity with each iteration!

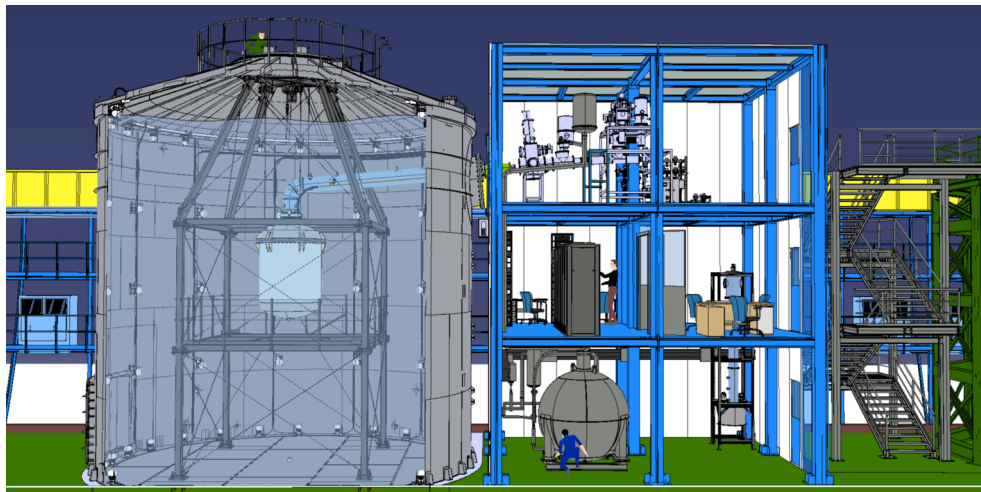
# XENON1T Experiment

## Quick facts:

<b>Location:</b>	Hall B LNGS, Italy (3600 mwe)
<b>Target:</b>	(3.1 / 2.0 / 1) ton (total/active/fiducial) xenon
<b>Readout:</b>	248 Hamamatsu R11410-21 PMTs
<b>Status:</b>	Fully funded, under construction
<b>Sensitivity:</b>	$2 \times 10^{-47} \text{ cm}^2$ (100x lower than XENON100) <ul style="list-style-type: none"><li>- Larger target volume</li><li>- Lower backgrounds</li></ul>



(ICARUS in rear of hall)

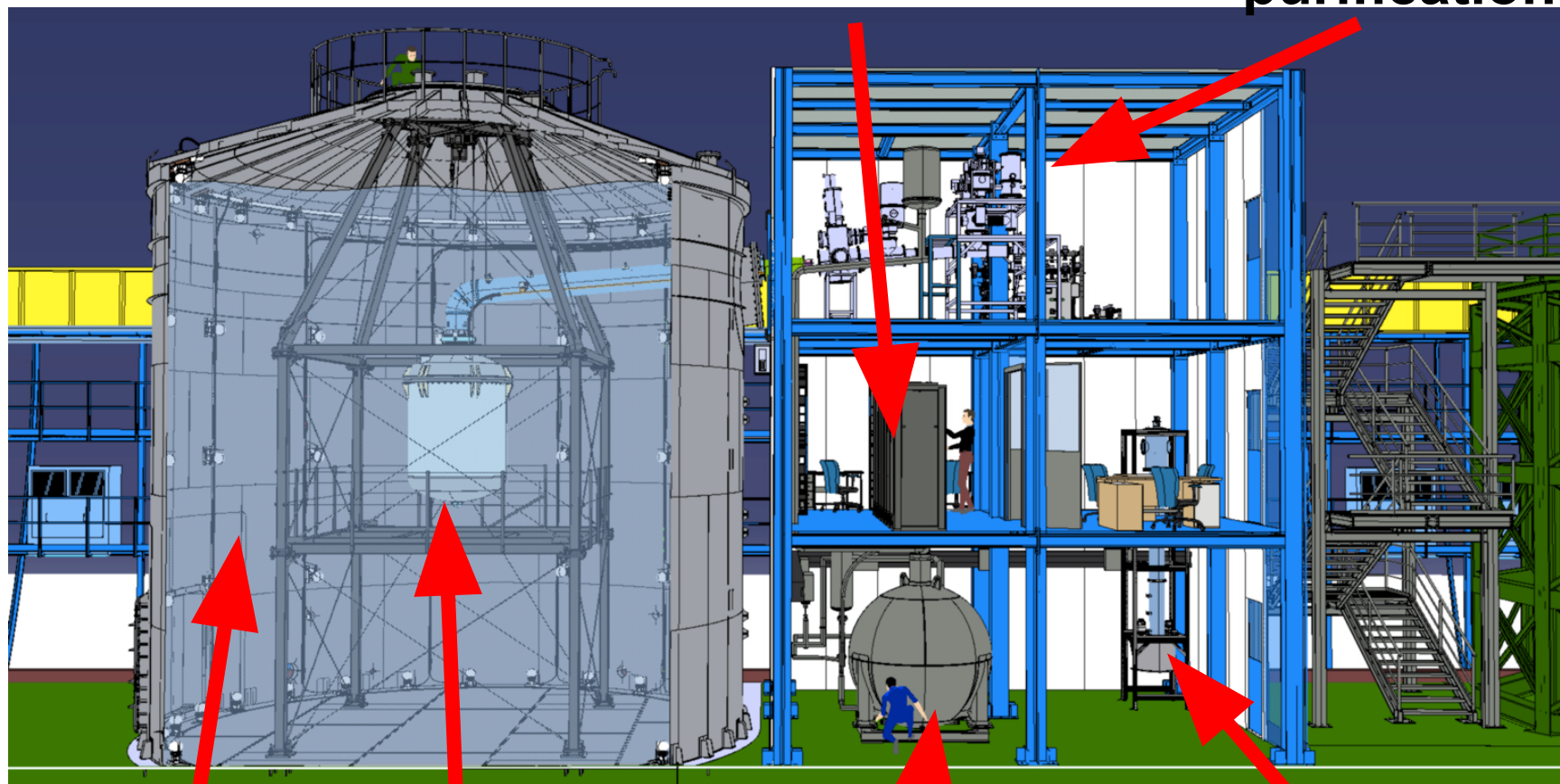


(WARP in front of hall)

# XENON1T Experiment

DAQ/Electronics

Cryogenics +  
purification



TPC

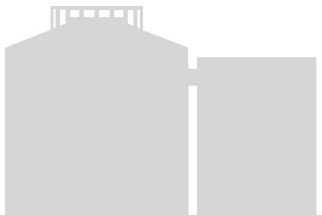
Kr85 removal

Liquid xenon  
storage

Water Cherenkov  
muon veto



# XENON1T TPC



# XENON1T TPC



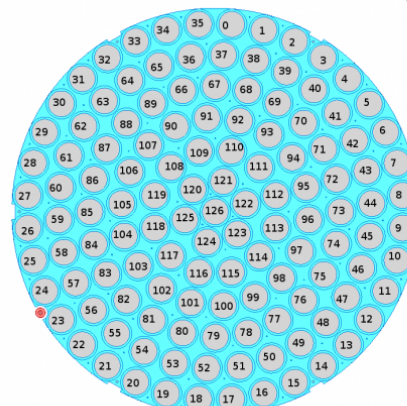
## PMTs



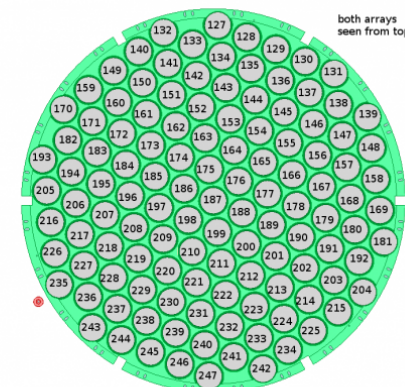
Hamamatsu R11410-21 (3")

- Low radioactivity  $<1\text{mBq/PMT}$
- High Q.E. (36% average @176nm)
- All PMTs screened with HPGe detectors (MPIK, UZH) for background estimate
- PMTs performance tested warm,  $-100\text{C}$ , subset submerged in LXe
- 248 channels (127 top 121 bottom)

WT Door Side



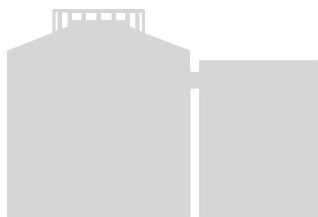
Top



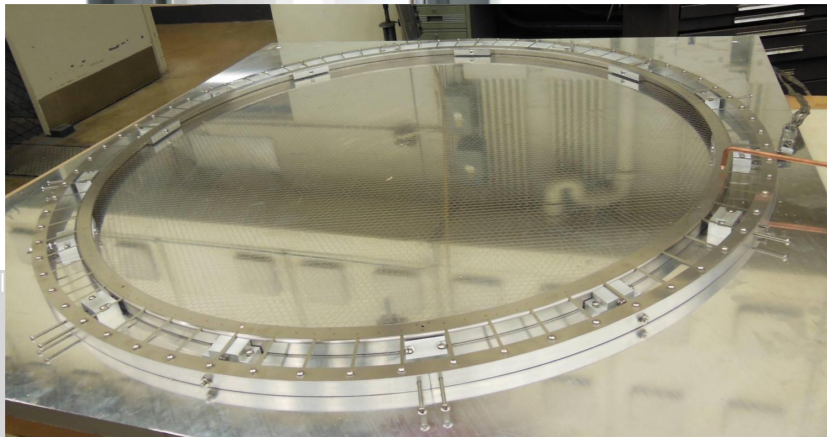
both arrays seen from top

Building Side

Bottom



# XENON1T TPC



## PMTs



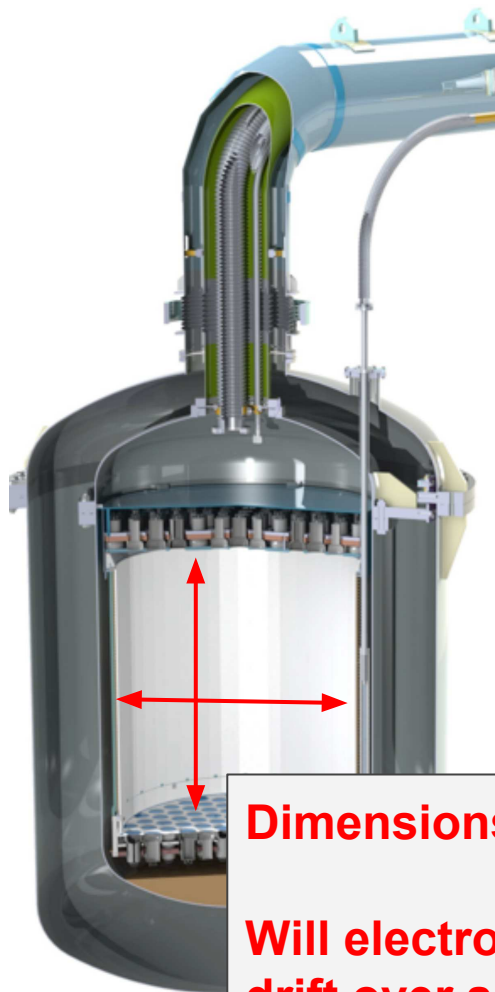
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- 248 channels (127 top 121 bottom)

## TPC Construction

- Interior  $\rightarrow$  high reflectivity teflon
- Stainless steel for TPC and cryostat screened prior to fabrication
- High-transparency field grids

# XENON1T TPC



**Dimensions 1m x 1m**

**Will electrons really drift over such a long distance? → YES!**

## PMTs



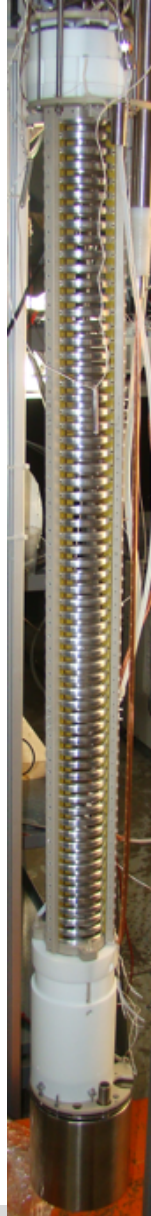
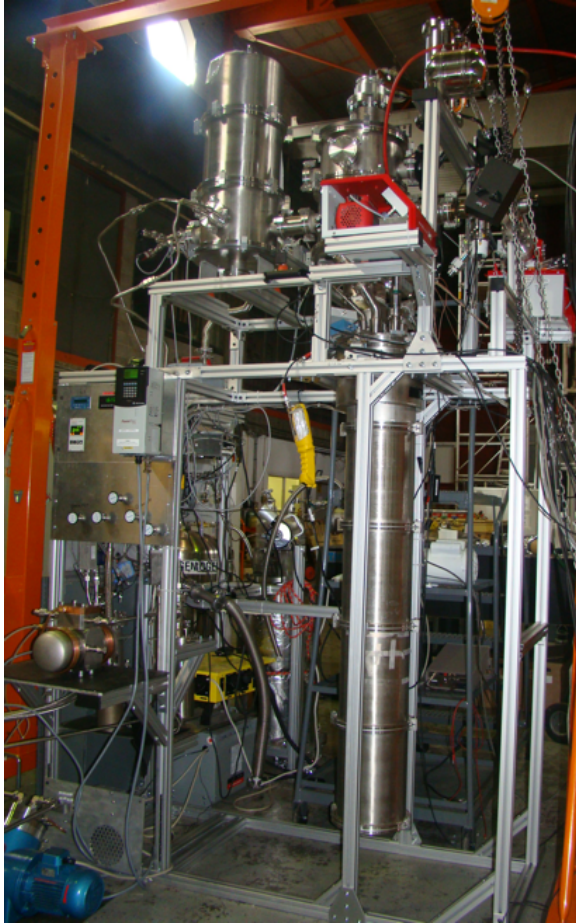
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# XENON1T R+D

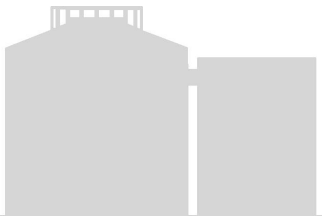


## Proven technology

- Successful operation of liquid xenon detectors over many years
- R+D projects at many partner institutes
  - Removal of radioactive impurities
  - Large-scale TPC design
  - PMT and other photosensor studies
  - etc ...

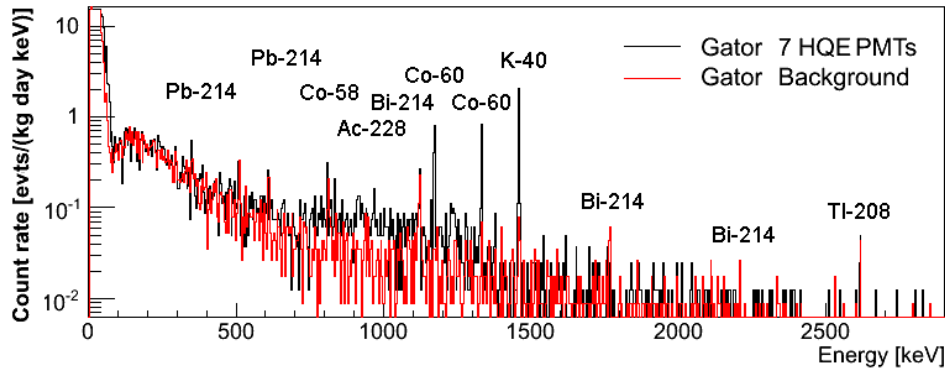
## **Example: XENON1T Demonstrator, Columbia (NYC)**

- xenon recirculation and purification through getters
- Stable, long term performance at high voltage (**100 kV field!**)
- **100cm electron drift** → same for XENON1T



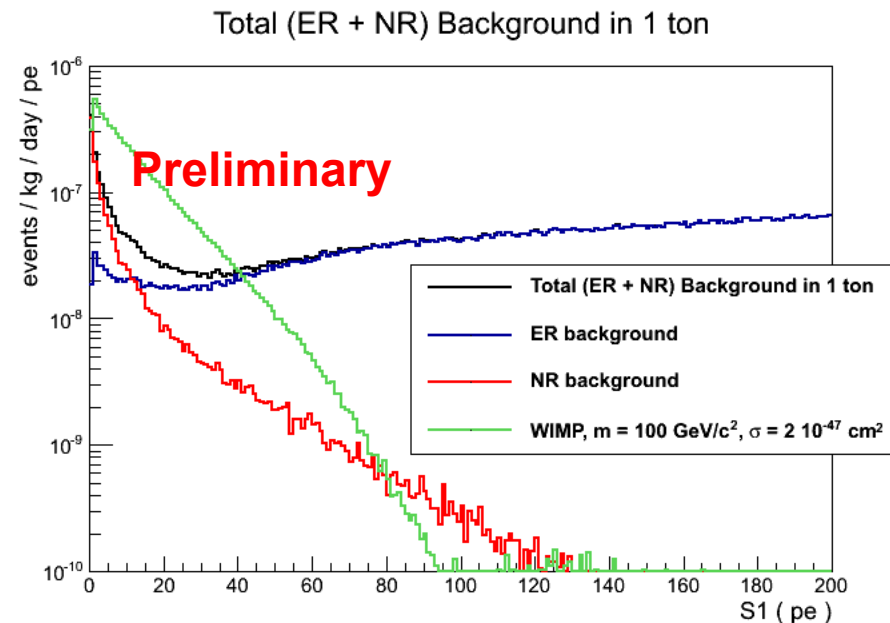
# Background Estimates

Background	Reduced via	Expected rate (ev/yr)
Muon-induced neutrons	Active muon veto	<0.01 ev/year
Contamination in xenon	Purification systems (getters/Kr column)	0.15
Contamination in materials	Material selection and screening	0.25
Neutrino (solar, $2\nu 2\beta$ )		0.09
<b>Total</b>		<b>0.5 ev/ton/year</b>



**Backgrounds** computed using Monte Carlo simulations with material-screening **measurements** as inputs.

**Background estimates** above assume 1t fiducial volume, 5-50keV nuclear recoil search window, 99.5% ER rejection, 50% NR acceptance



# DAQ

DAQ design requirements:

- **Rates** up to 1000Hz, 300MB/s
- **“No” trigger threshold** for low mass WIMP sensitivity
- **Use commercial electronics/software** limits cost and complexity

→ **Demonstrated at Bern test setup!**

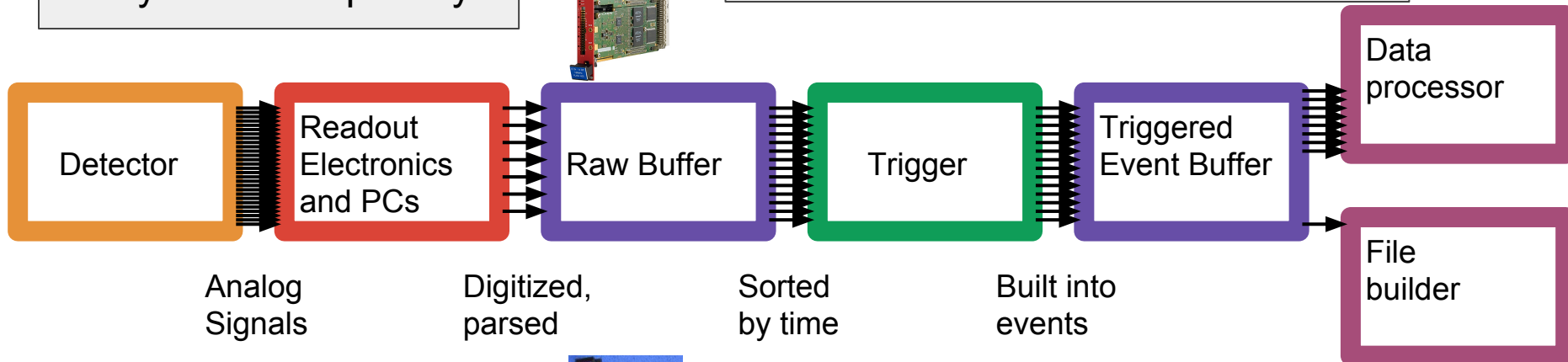
**Self-triggering** digitizers

Delayed-veto capability



**Data buffers** → mongodb database

Flexible **Software** trigger



Online high-energy veto

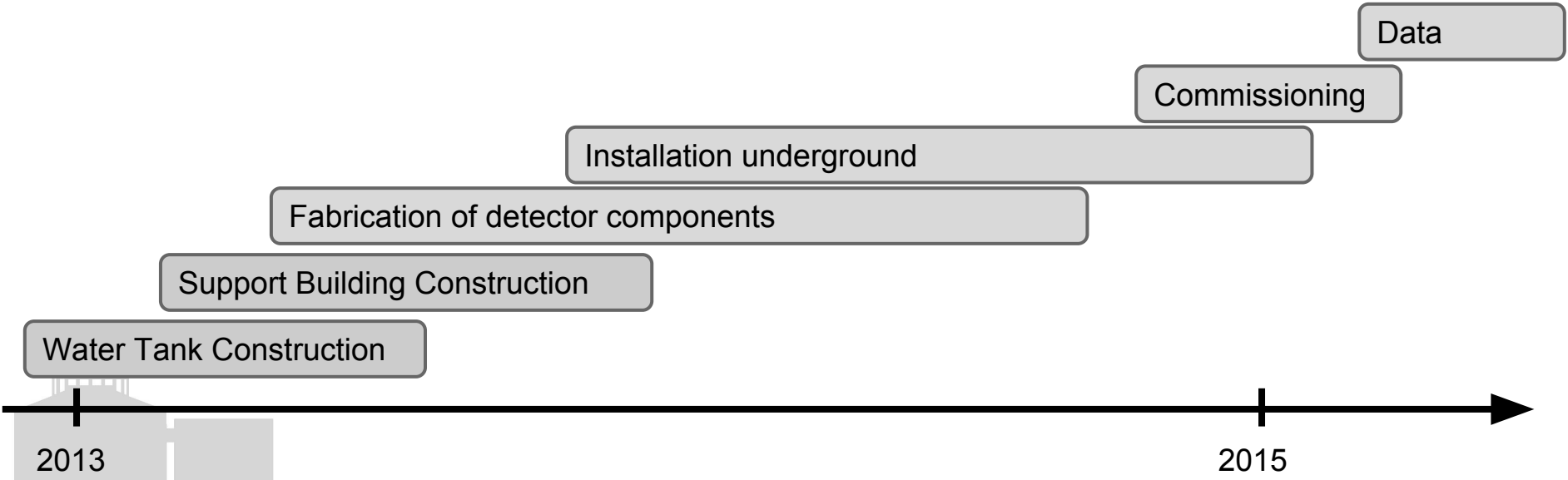
Custom FPGA routine



**Online data processing**

Real-time monitoring

# Construction Timeline





# Construction Timeline



Data

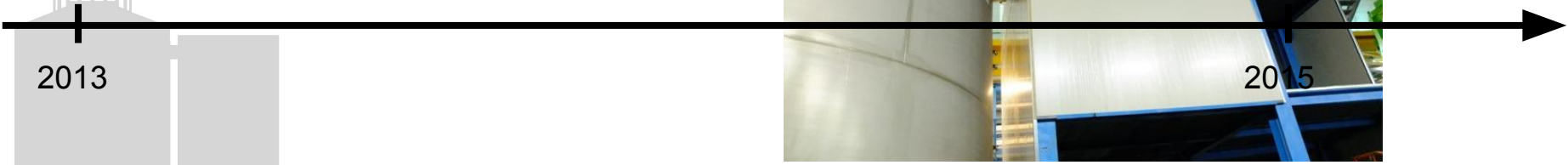
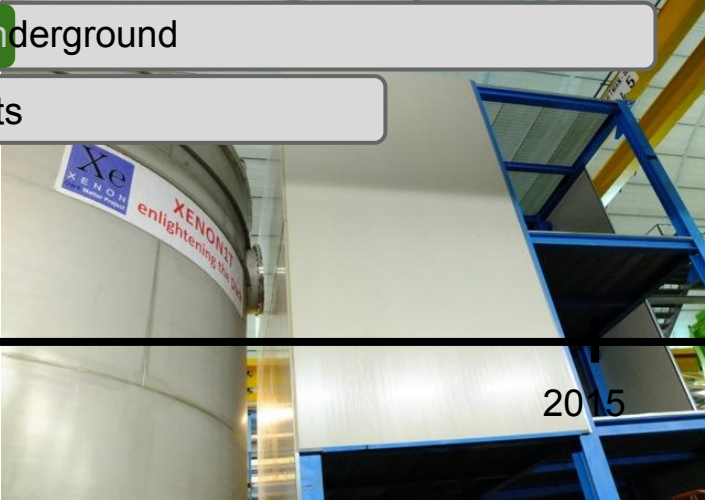
Commissioning

Installation underground

Fabrication of detector components

Support building construction

Water Tank Construction



# Construction Timeline



Data

Commissioning

Installation underground

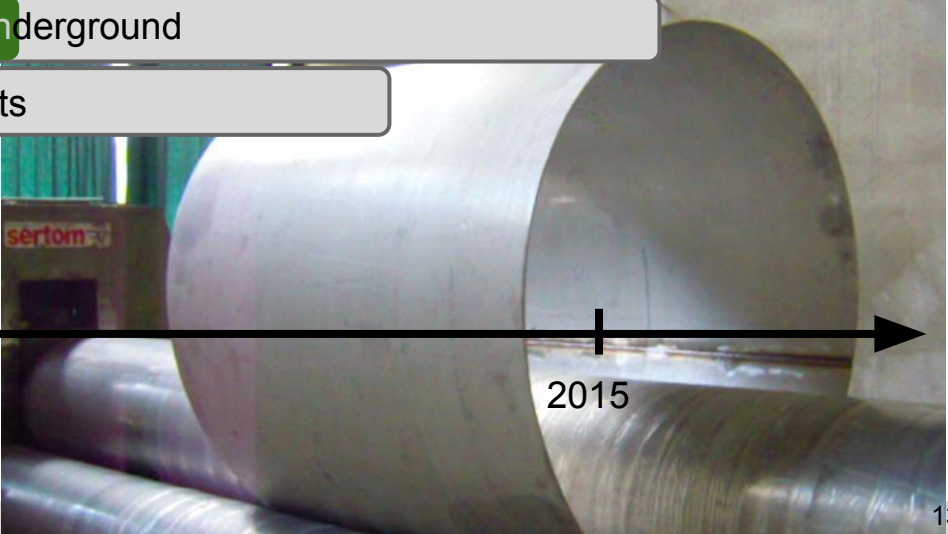
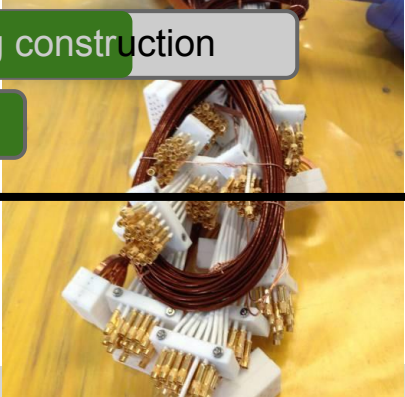
Fabrication of detector components

Support building construction

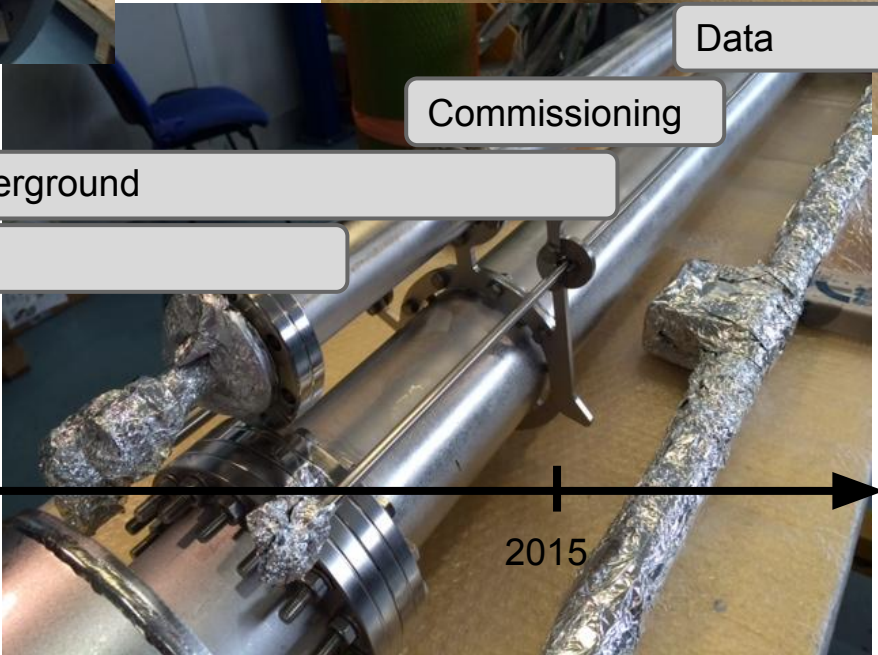
Water Tank Construction

2013

2015



# Construction Timeline



Installation underground

Fabrication of detector components

Support building construction

Water Tank Construction

Data

Commissioning

2013

2015

# Construction Timeline



Data

Commissioning

Installation underground

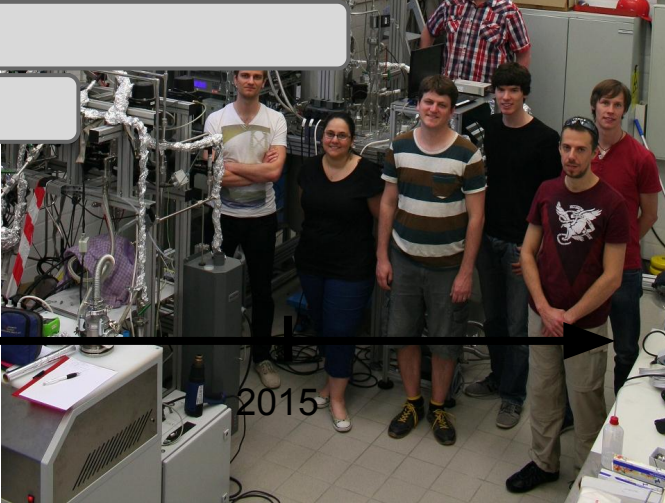
Fabrication of detector components

Support building construction

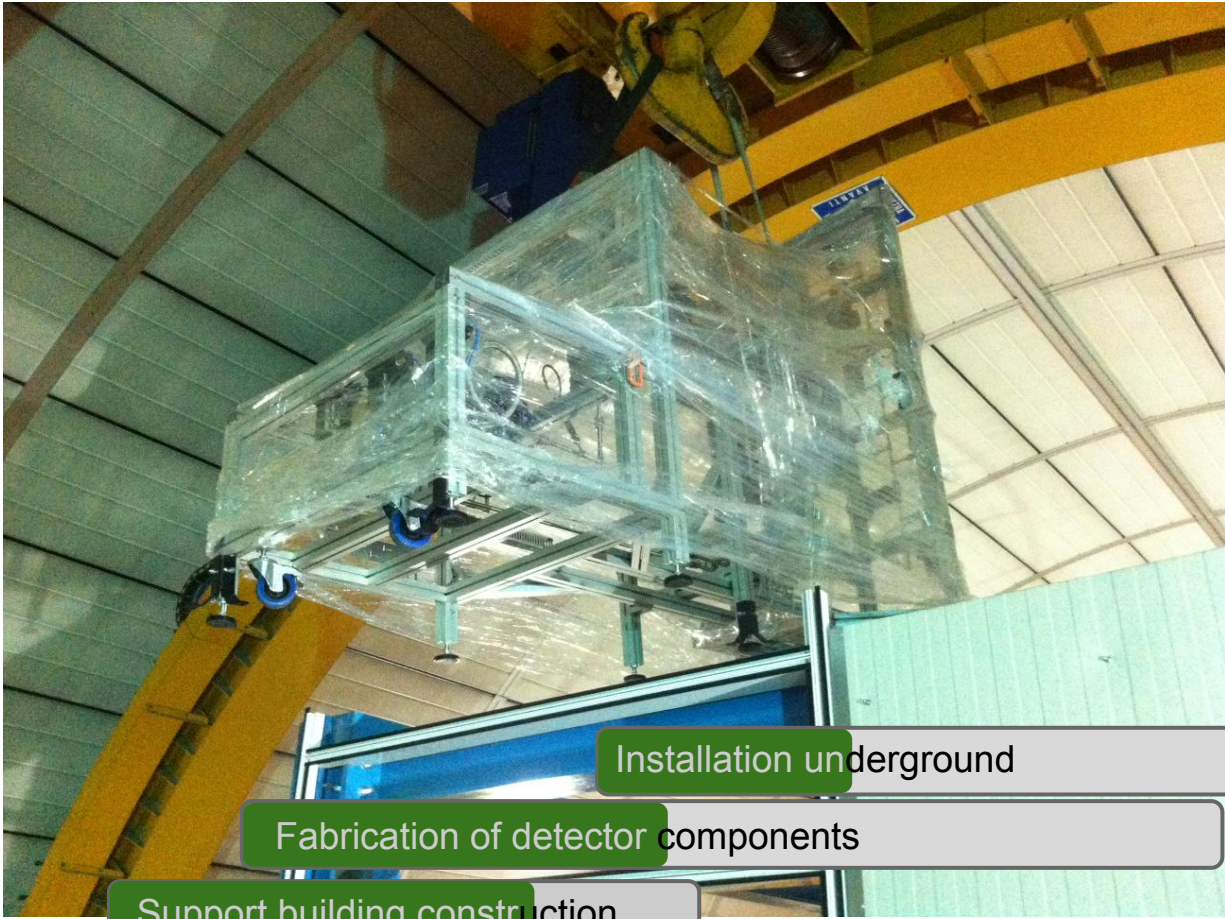
Water Tank Construction

2013

2015



# Construction Timeline



Installation underground

Fabrication of detector components

Support building construction

Water Tank Construction

Commissioning

Data

2013

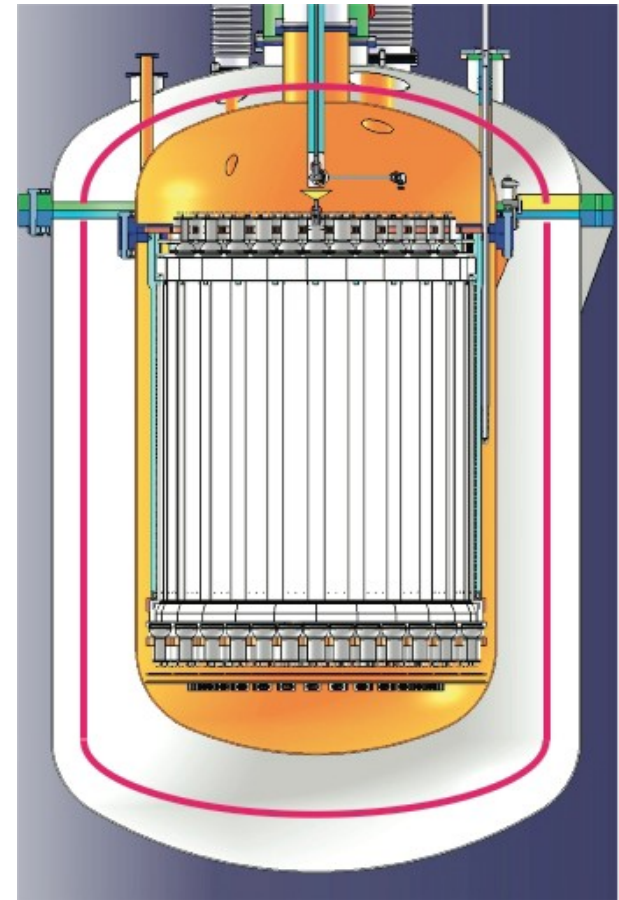
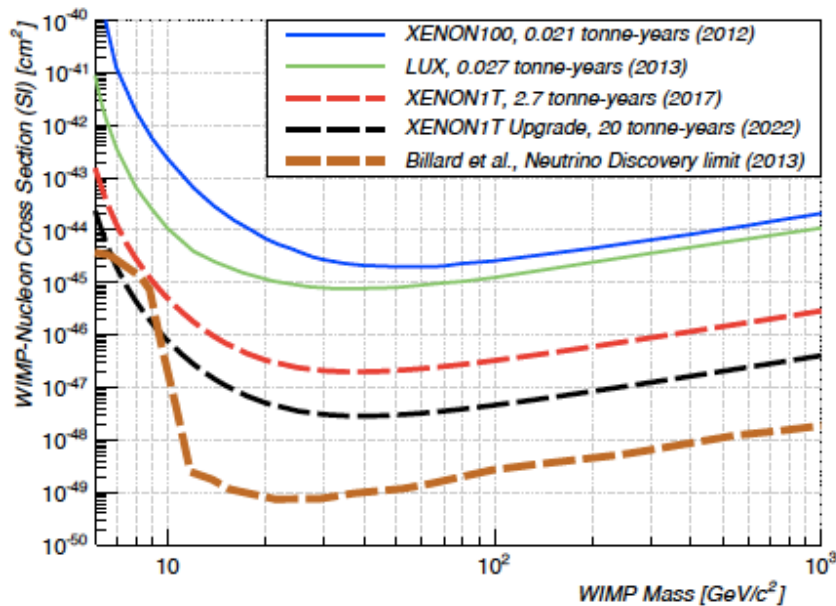
2015

# Next Phase XENONnT

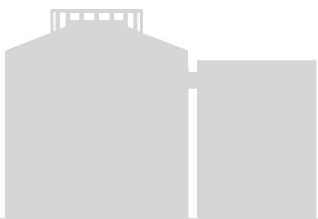
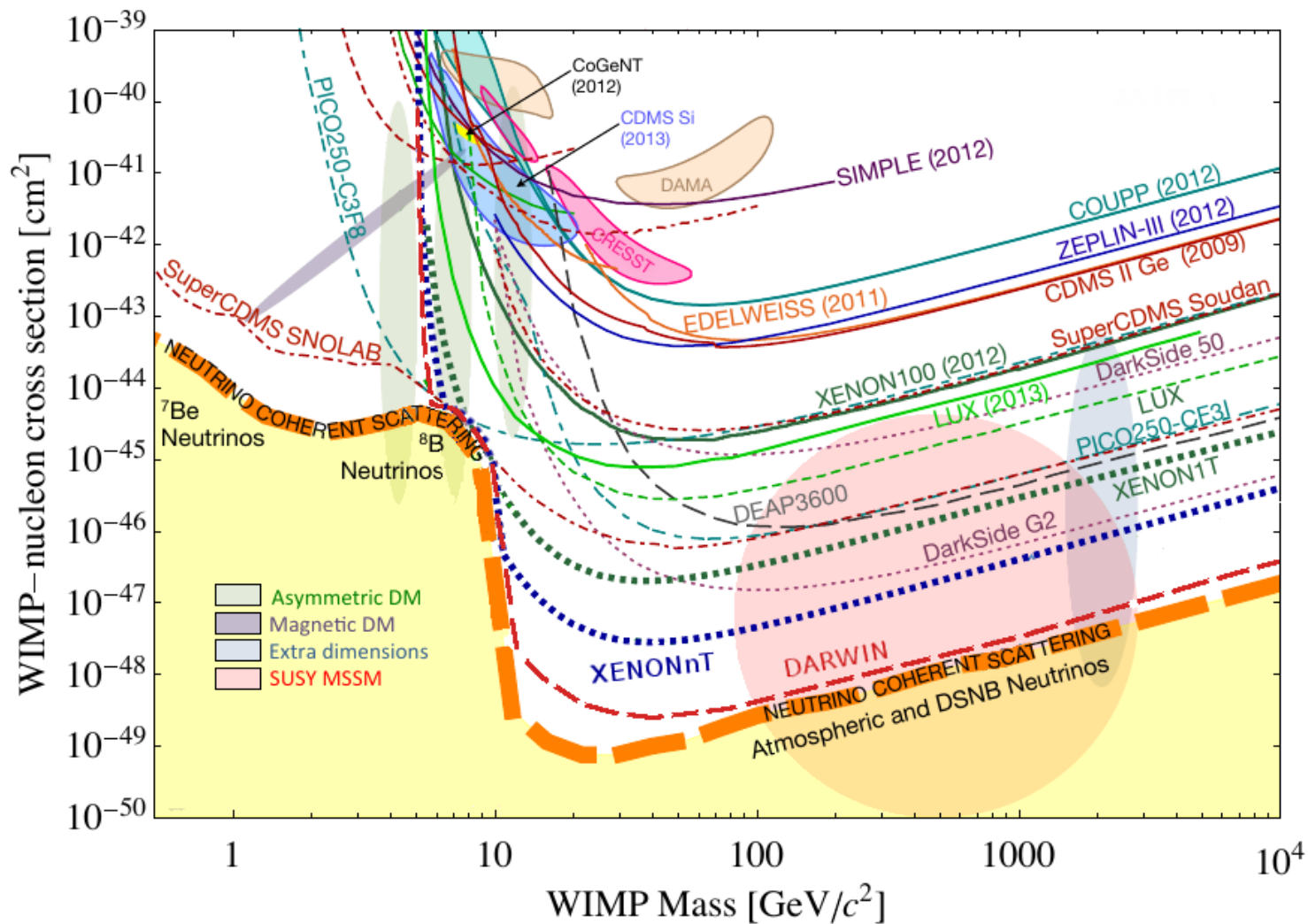
**New** TPC and inner vessel

**Reuse** cryostat, water tank, most other subsystems

- Larger volume of XENON (~7 tons)
- Goal is 20 ton-years exposure  $\rightarrow 10^{-48}$  cm sensitivity
- Start directly after XENON1T (~2018)
- Faster construction and lower cost compared to building an entirely new experiment



# State of the Direct Detection Field



# Conclusions

- XENON1T is **under construction** and **on schedule**
  - First data early next year (2015)
- XENON1T sensitivity  $\sim 2 \times 10^{-47} \text{ cm}^2$
- An upgrade to more than double the active volume of xenon, XENONnT, has been integrated into the XENON1T design
  - Time scale  $\sim 2018$

