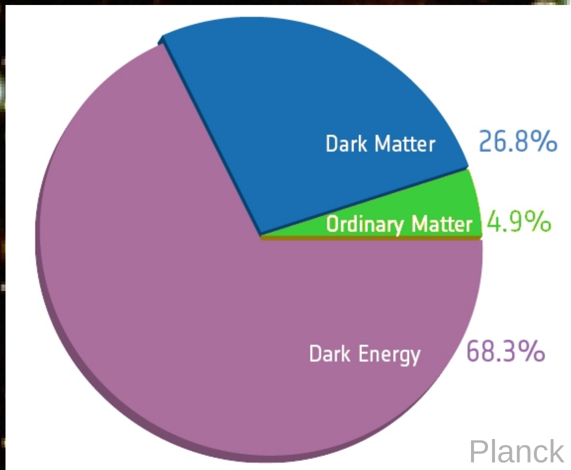
# XENON1T

Marc Schumann
*Universität Freiburg*

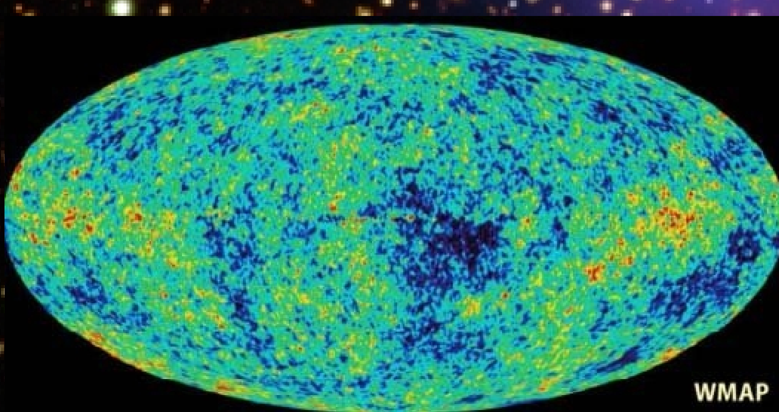
KAT Strategietreffen 2016, Bad Honnef, 25.11.2016

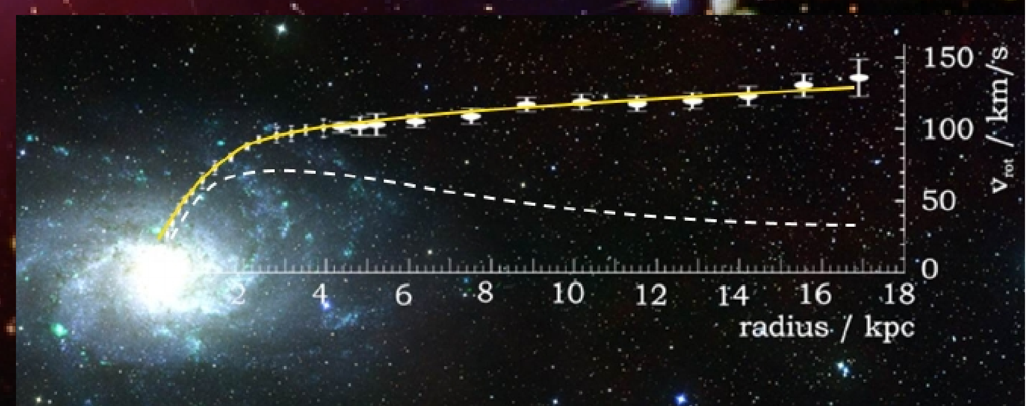
# Dark Matter: (indirect) Evidence



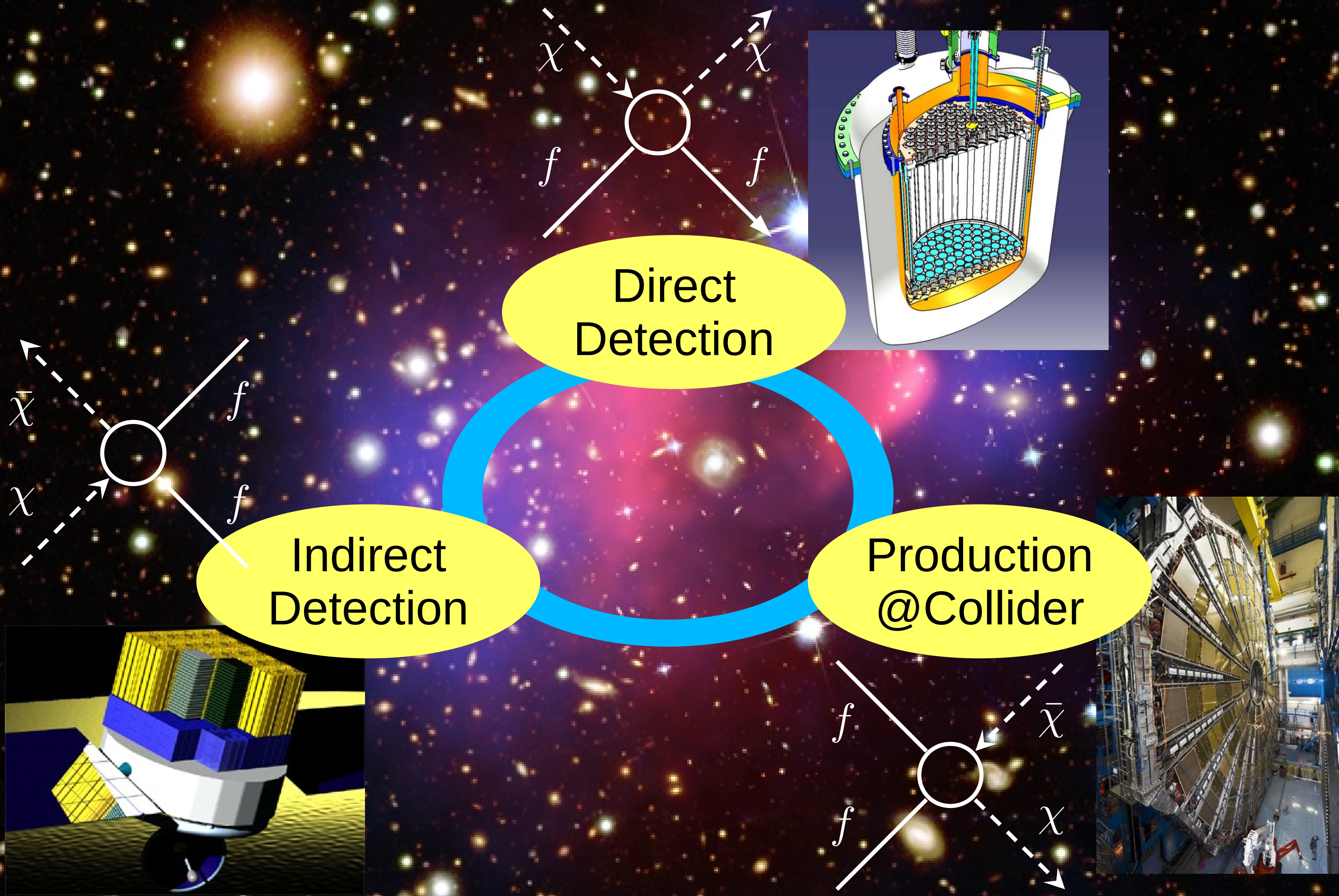

Particle Dark Matter Candidates:
- **WIMP** → *„WIMP miracle"*
- Axion
- SuperWIMPs
- sterile neutrinos
- WIMPless dark matter
- Gravitino
- ...

**The indirect evidence of the existence of dark matter is a clear indication for physics beyond the Standard Model**



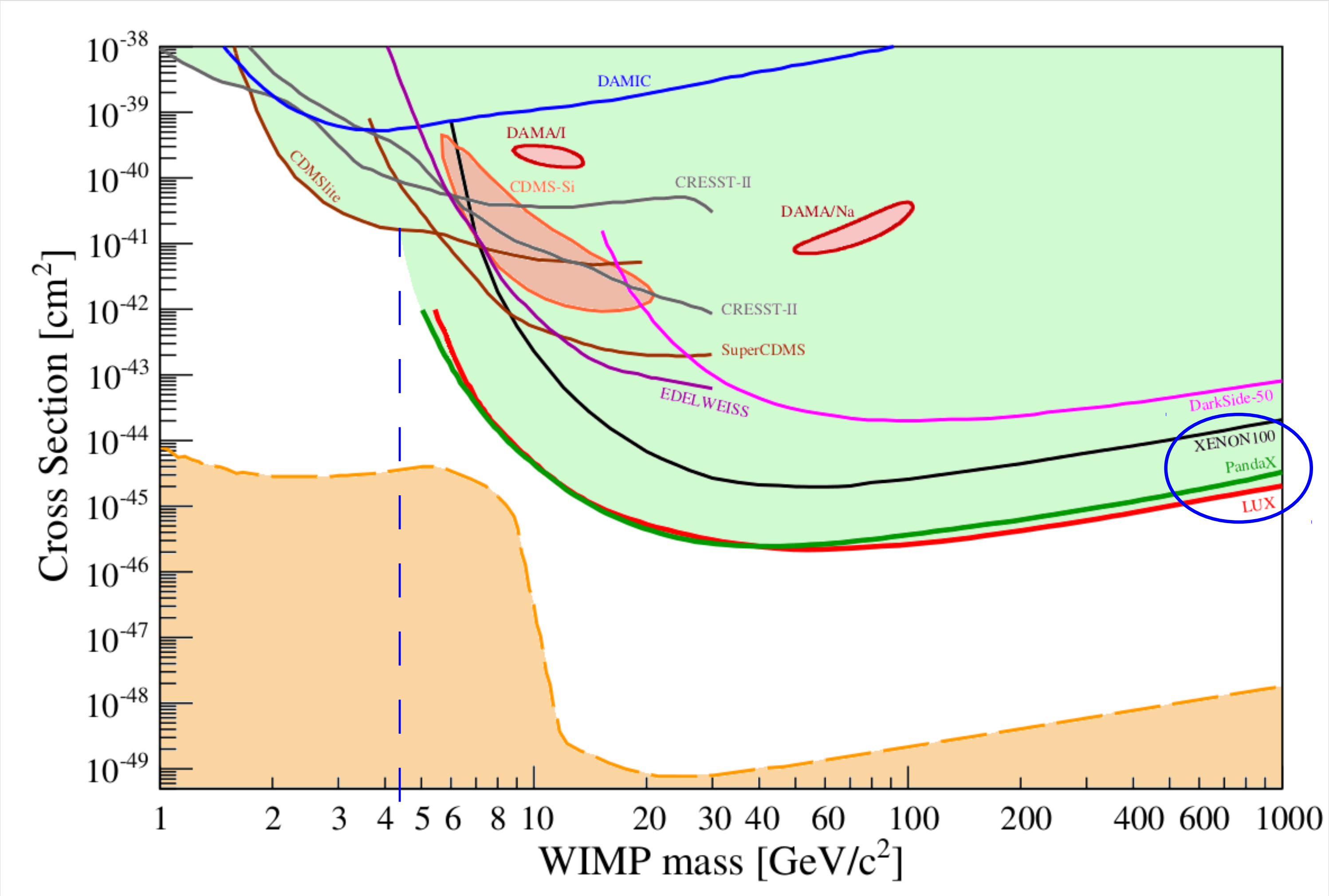



# Dark Matter WIMP Search



# Direct Detection: State-of-the-Art

spin-independent WIMP-nucleon interactions



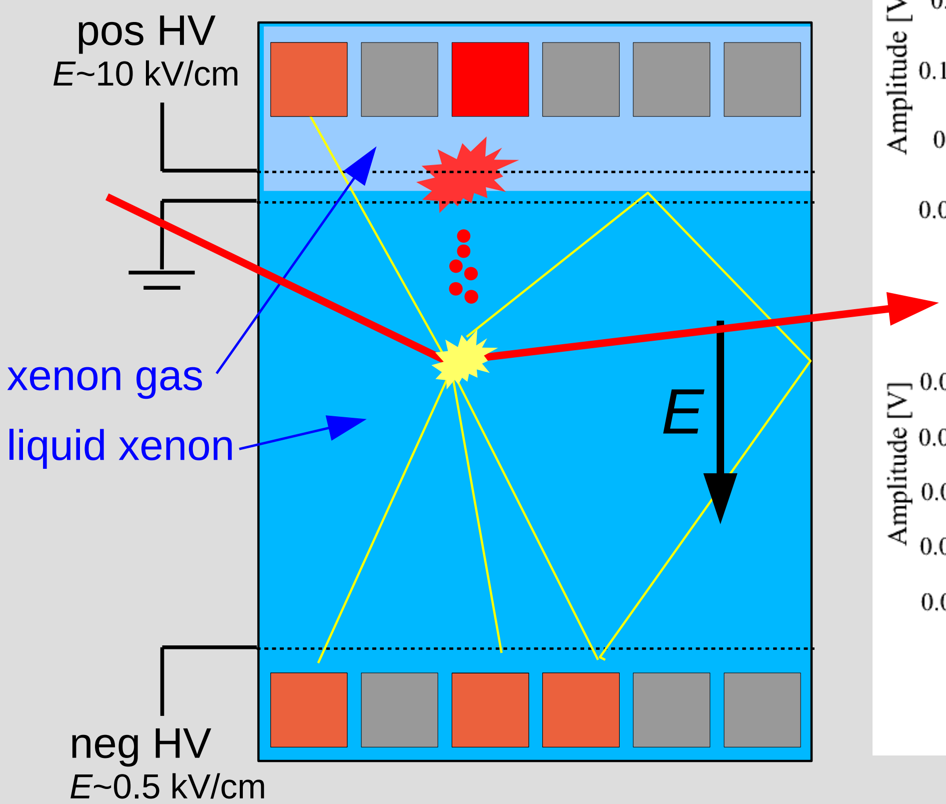

dominated by liquid xenon TPCs above ~4.5 GeV/c²

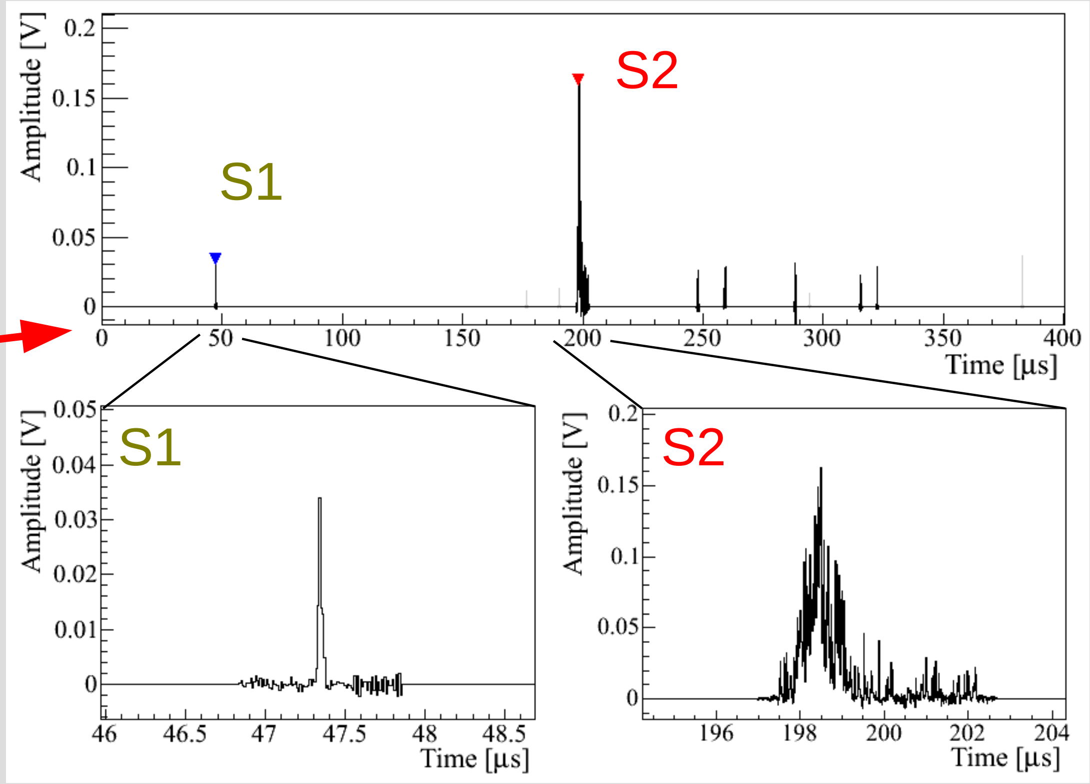
*some results are missing...*

# Dual Phase TPC

*Dolgoshein, Lebedenko, Rodionov, JETP Lett. 11, 513 (1970)*

TPC = time projection chamber



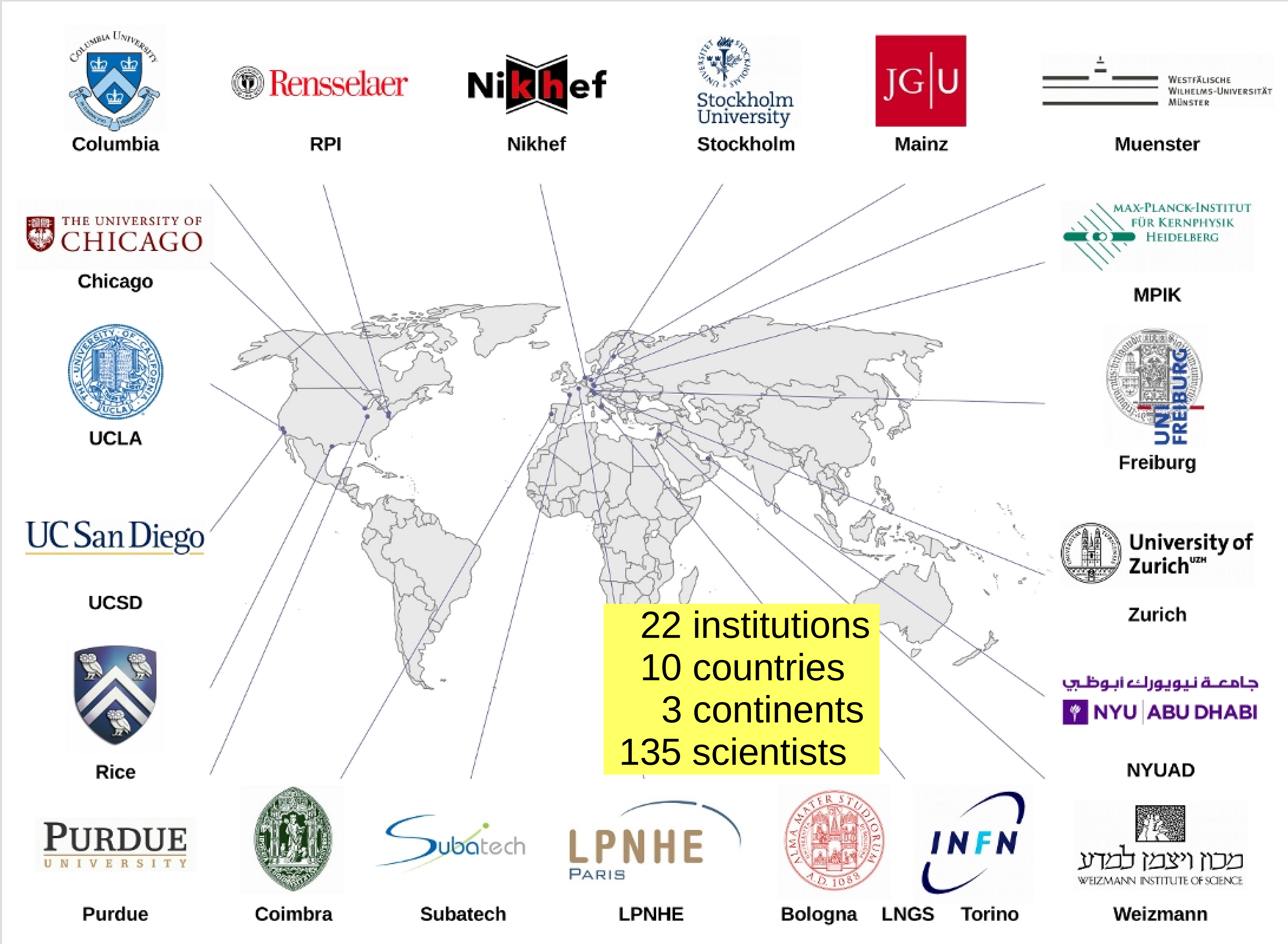




- 3dim vertex reconstruction
  → target fiducialization
- double-scatter rejection
- ER rejection via charge-to-light ratio

} background reduction

# The XENON Collaboration

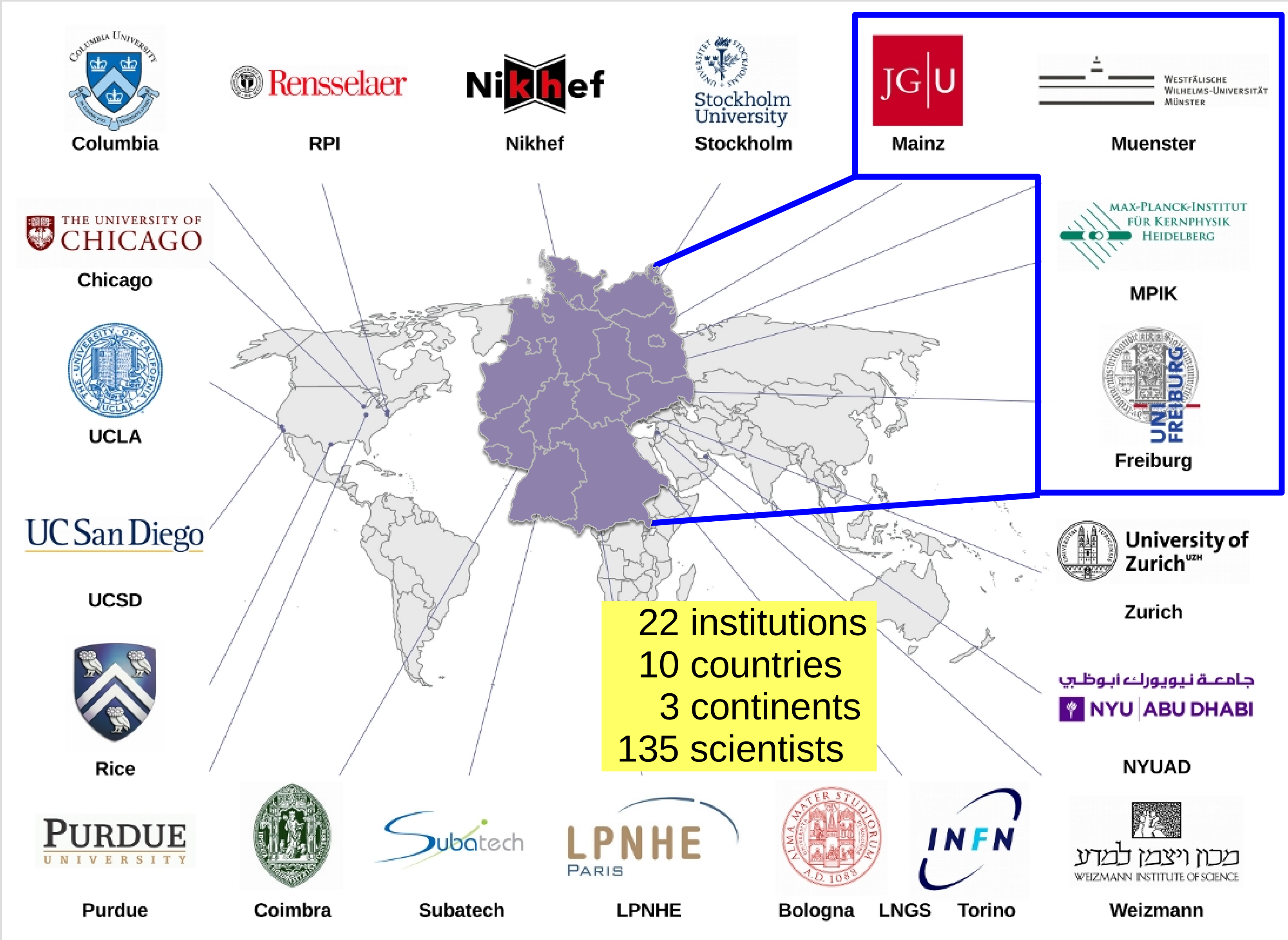
www.xenon1t.org



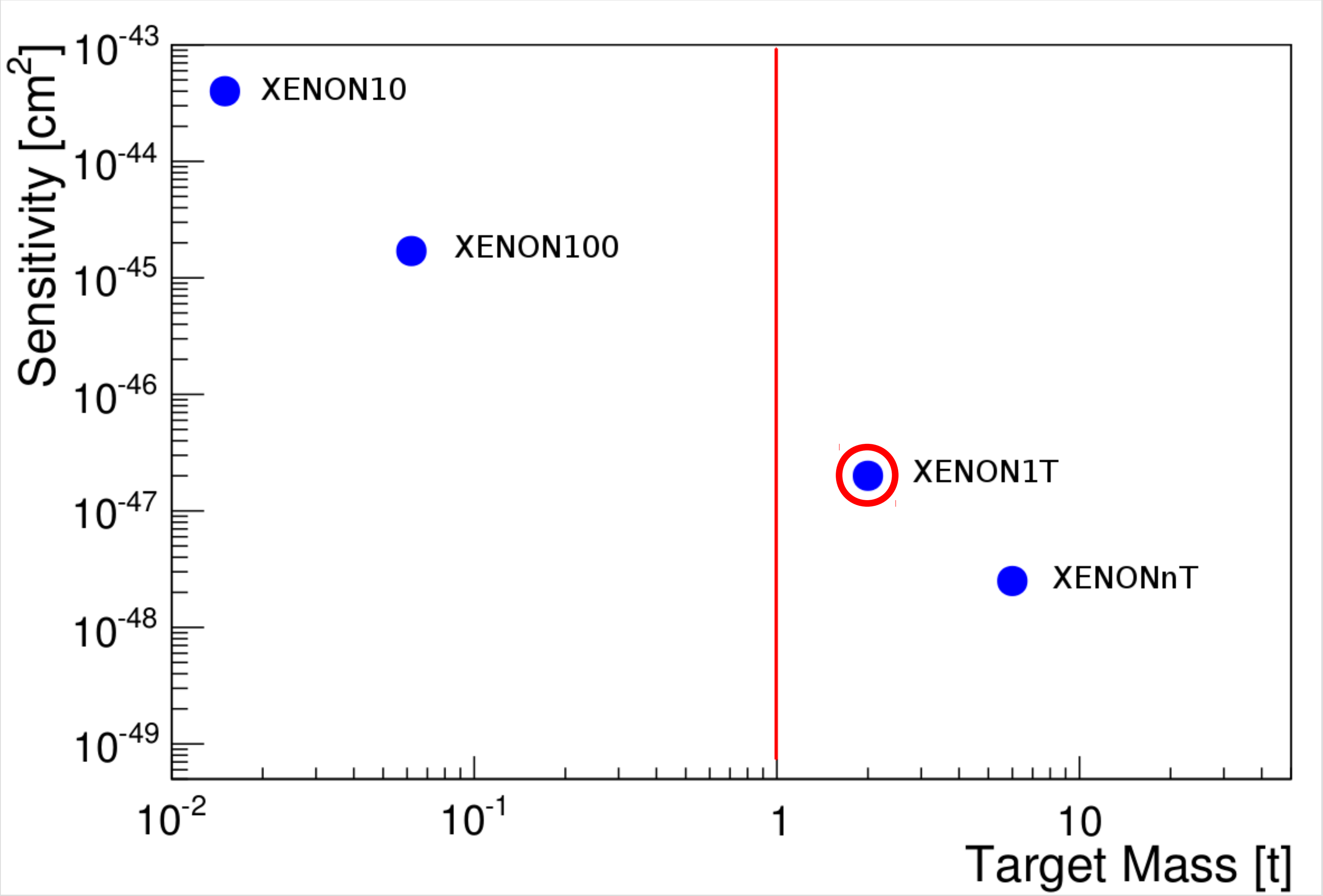
# The XENON Collaboration

www.xenon1t.org

XENON Dark Matter Project



# XENON Instruments

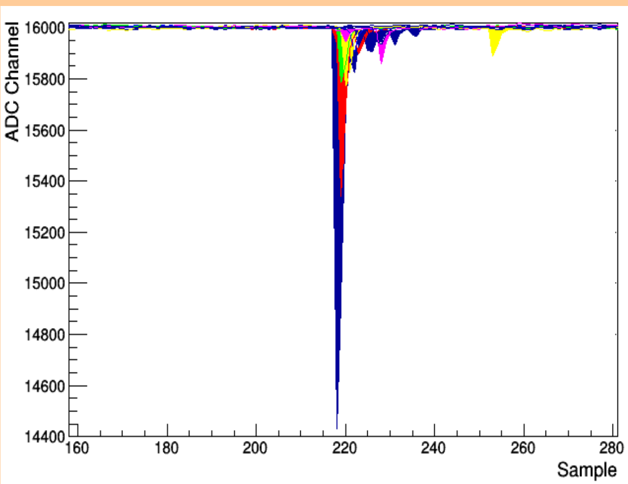


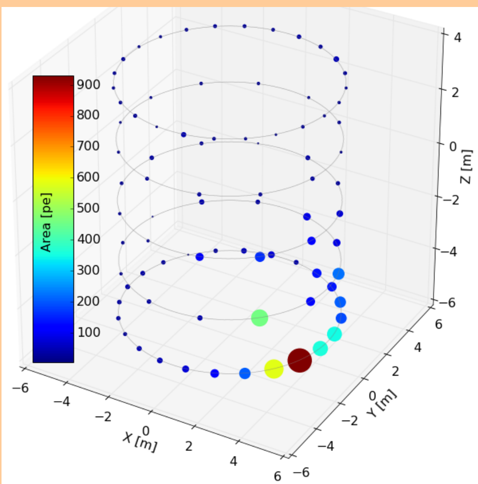

The XENON collaboration develops and operates
dark matter detectors of increasing size and sensitivity

# XENON1T @ LNGS

# XENON1T @ LNGS

Cerenkov detector sees muons...



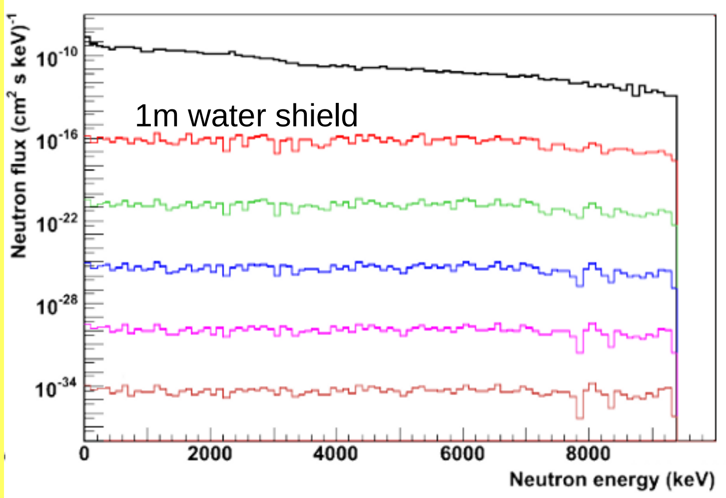

Mainz

Water Cerenkov Shield

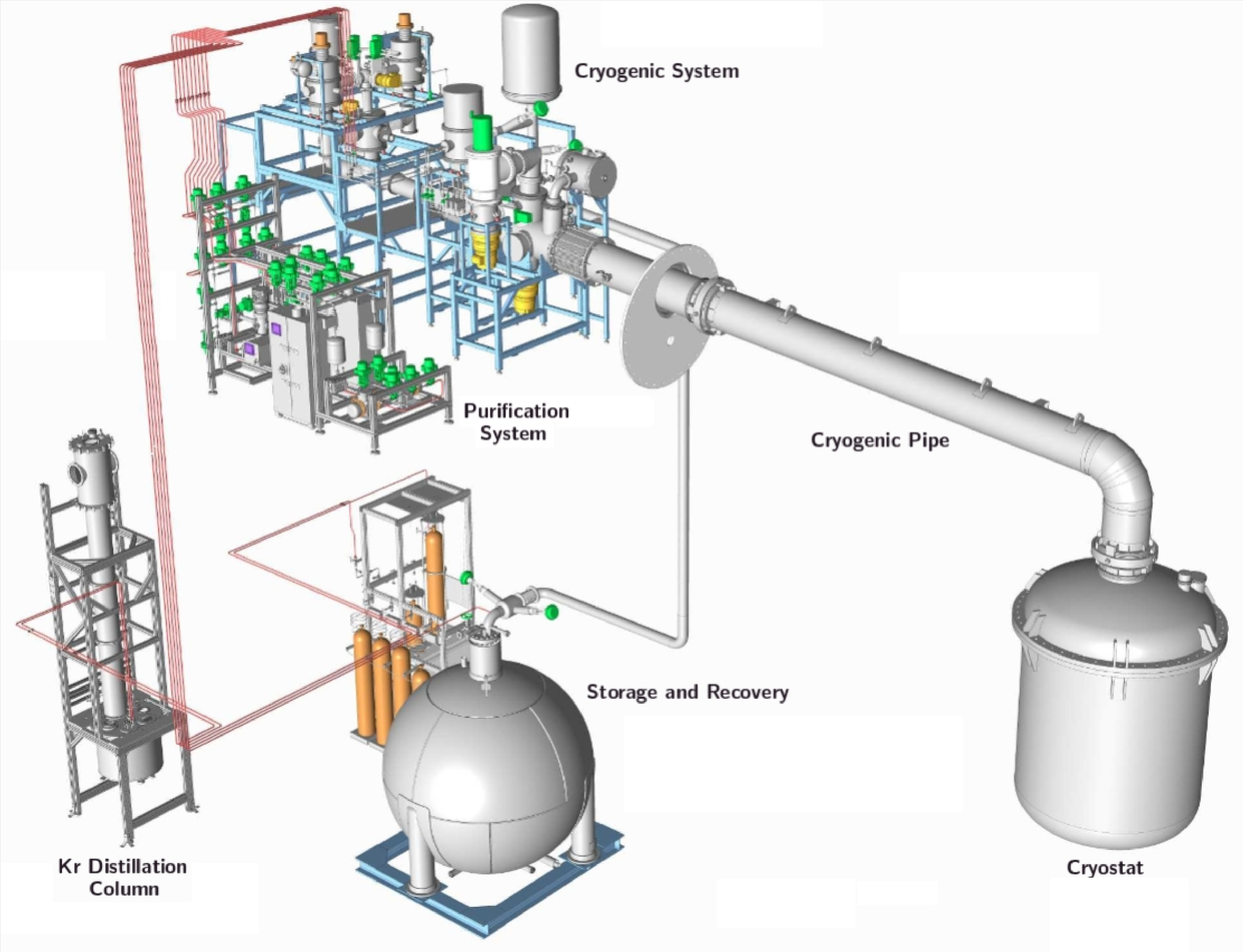
*JINST 9, P11006 (2014)*

- 9.6m diameter, 10m height
- external γ, neutrons irrelevant
- muon induced NRs irrelevant

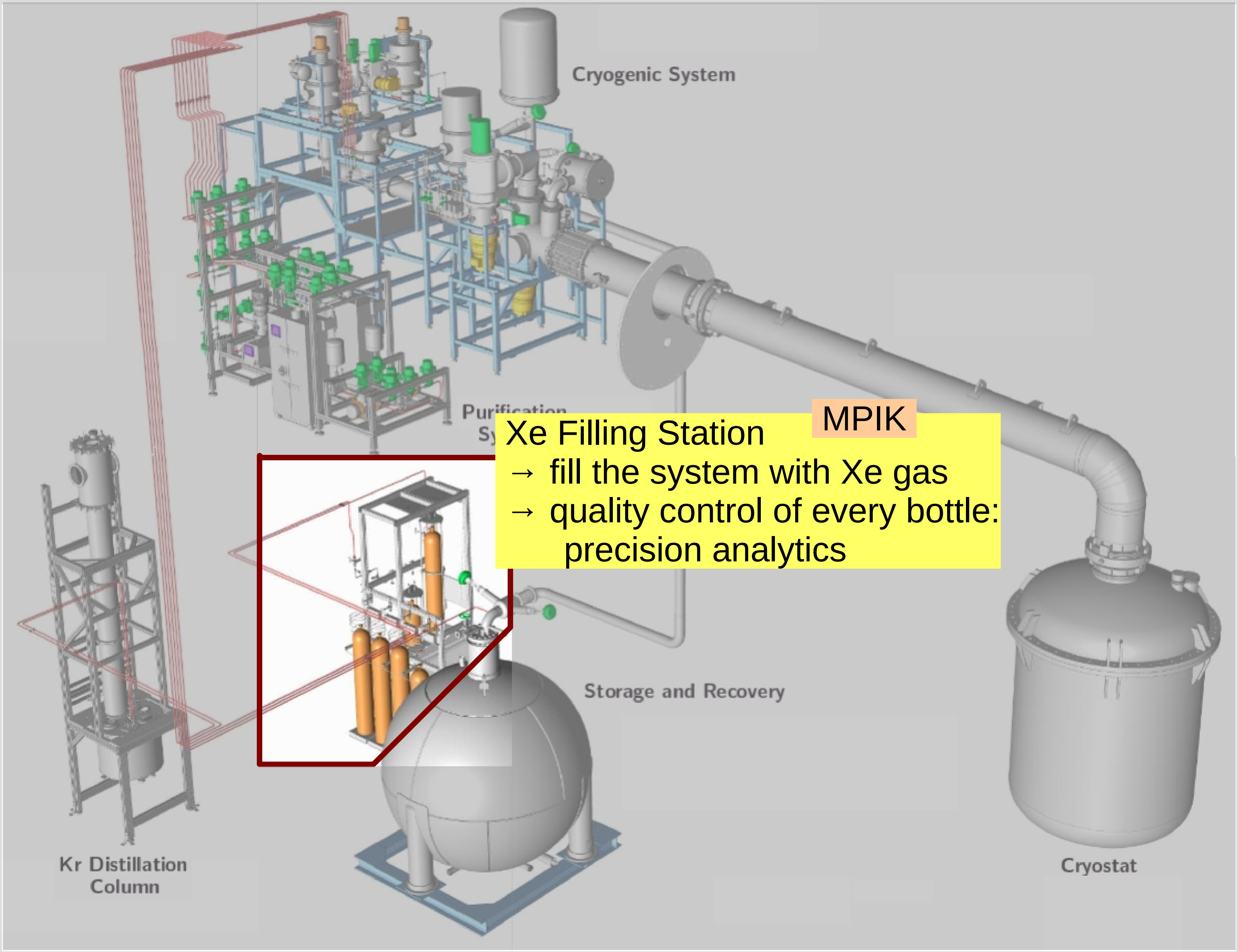
→ dominating background of XENON1T will be intrinsic



# Cryo-Systems



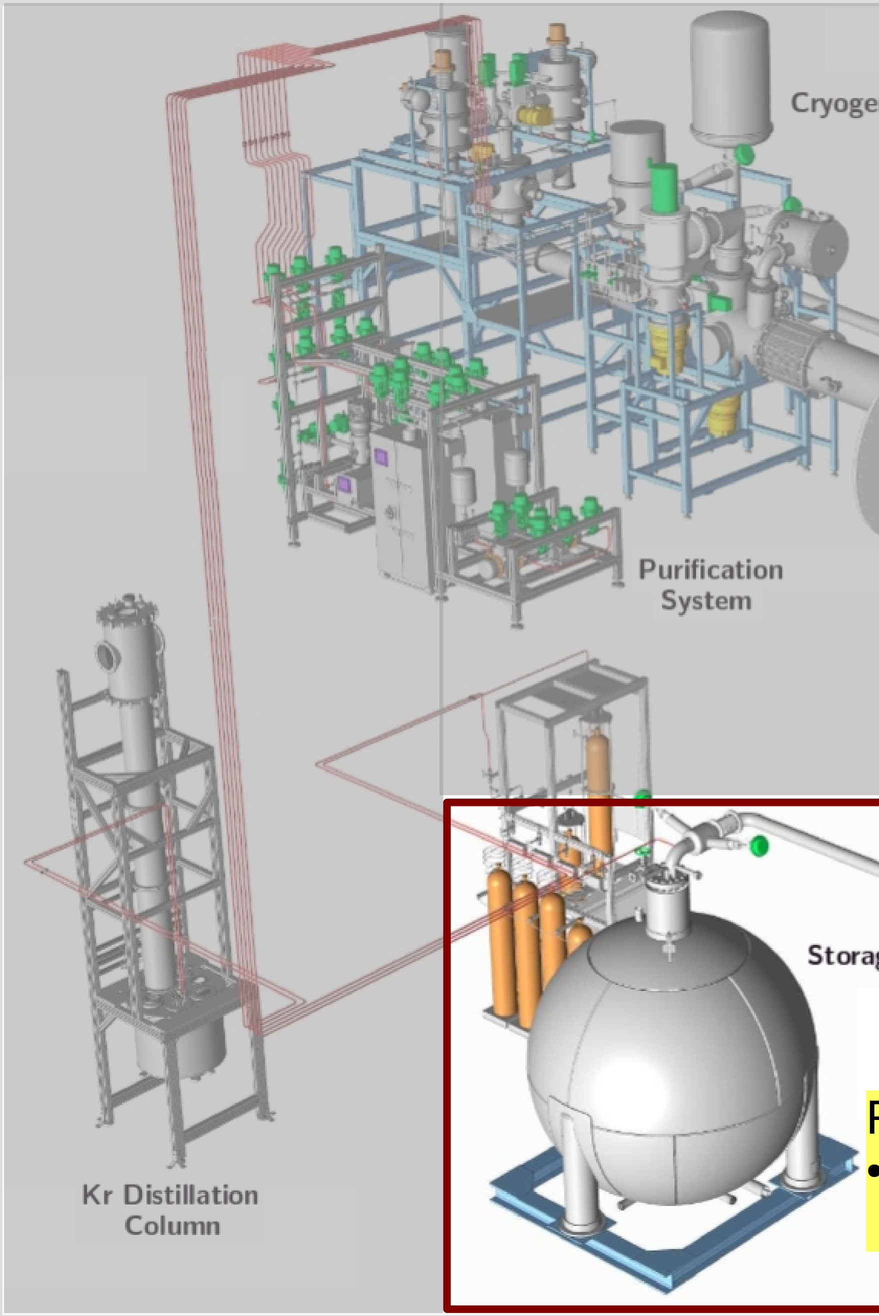
# Cryo-Systems




MPIK

Xe Filling Station
→ fill the system with Xe gas
→ quality control of every bottle:
precision analytics

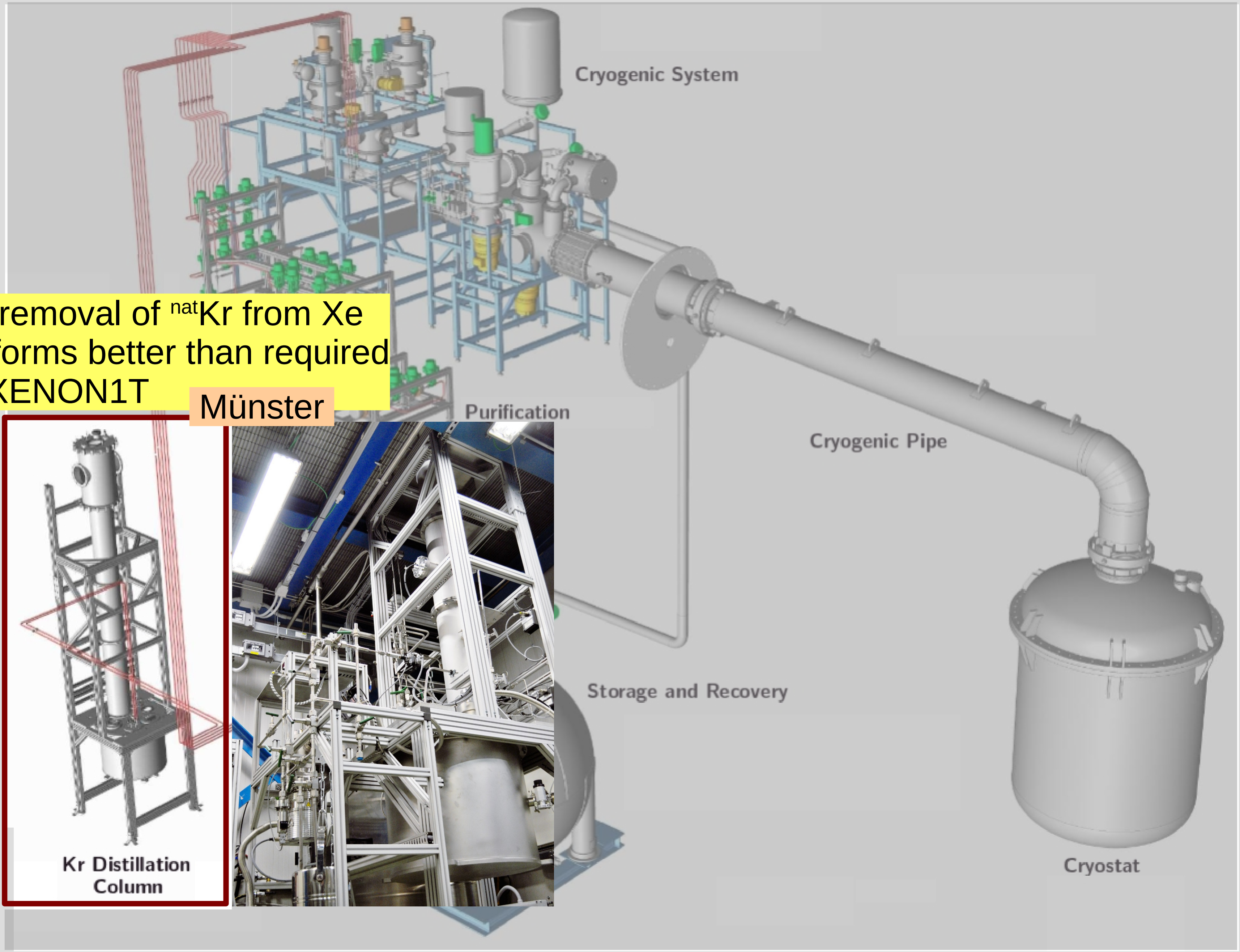
# Cryo-Systems




ReStoX: Storage and Recovery
- can store ~8t of LXe
  → sufficient for upgrade XENONnT

Mainz contributions

# Cryo-Systems

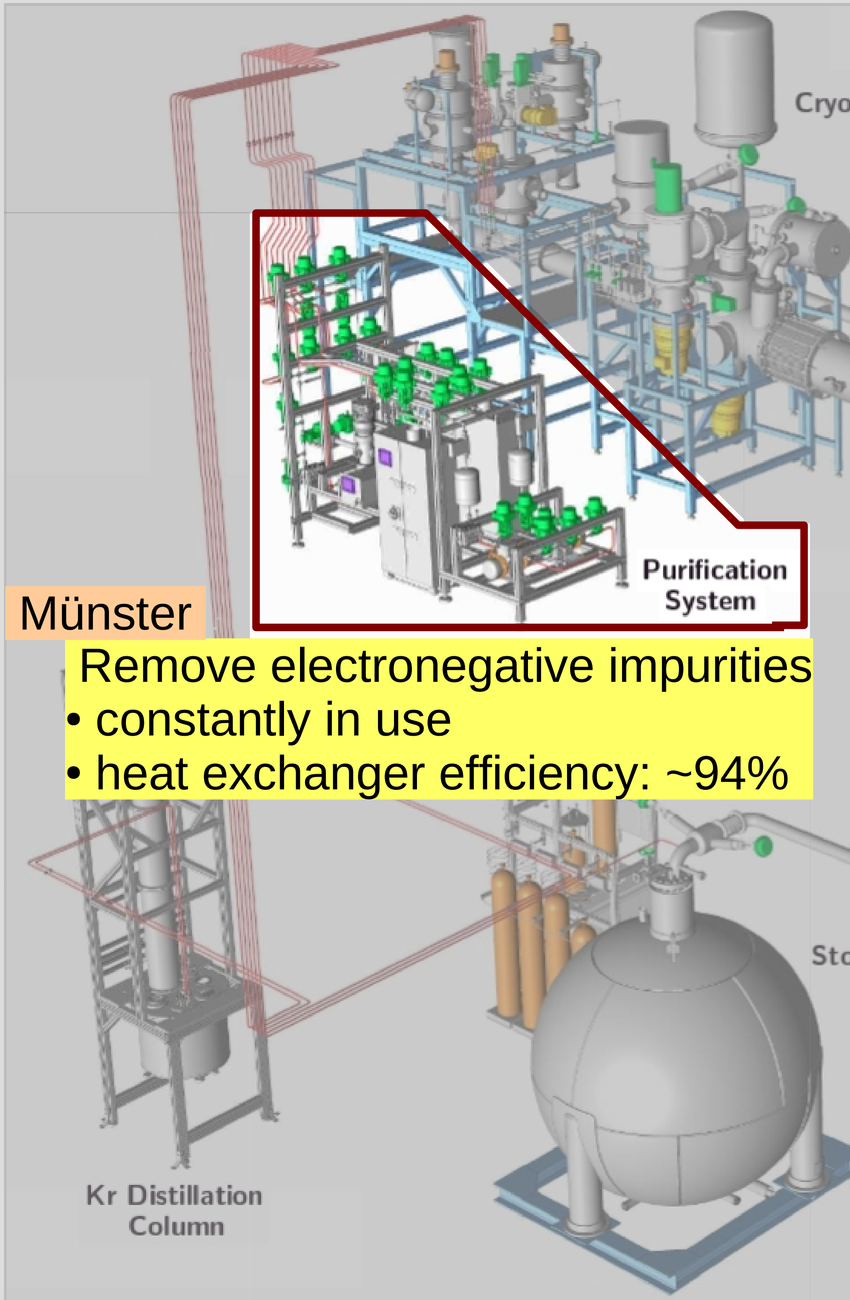



online removal of $^{nat}$Kr from Xe
→ performs better than required for XENON1T

Münster

# Cryo-Systems

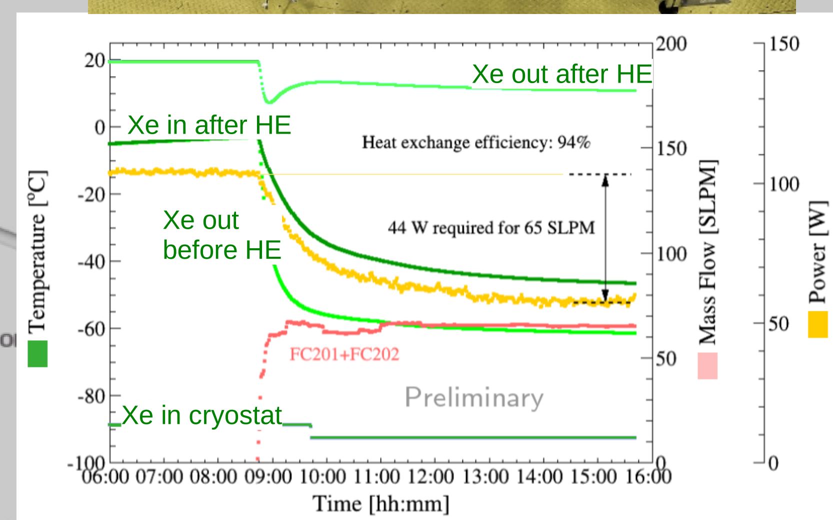
Xe XENON Dark Matter Project



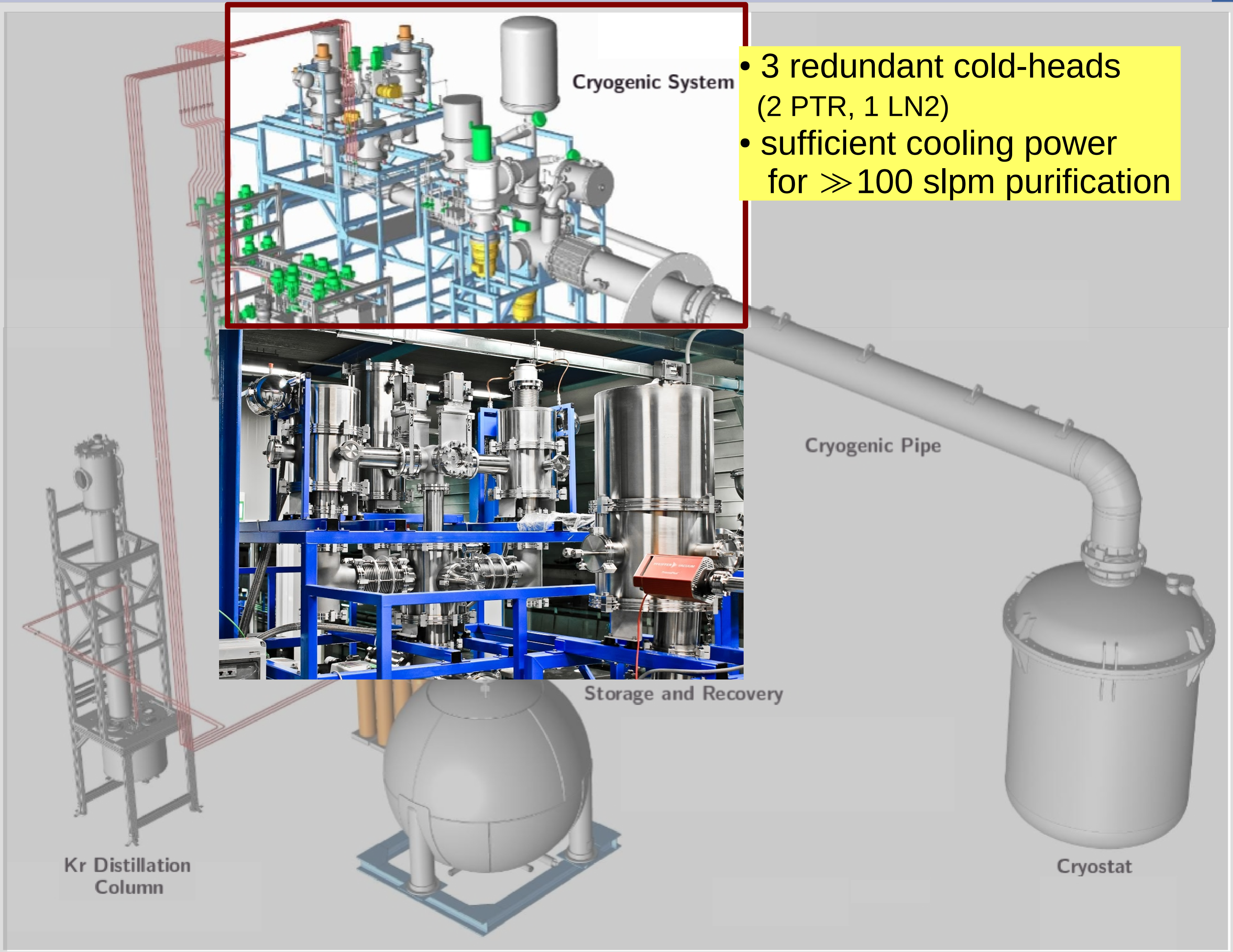


Münster

Remove electronegative impurities
- constantly in use
- heat exchanger efficiency: ~94%

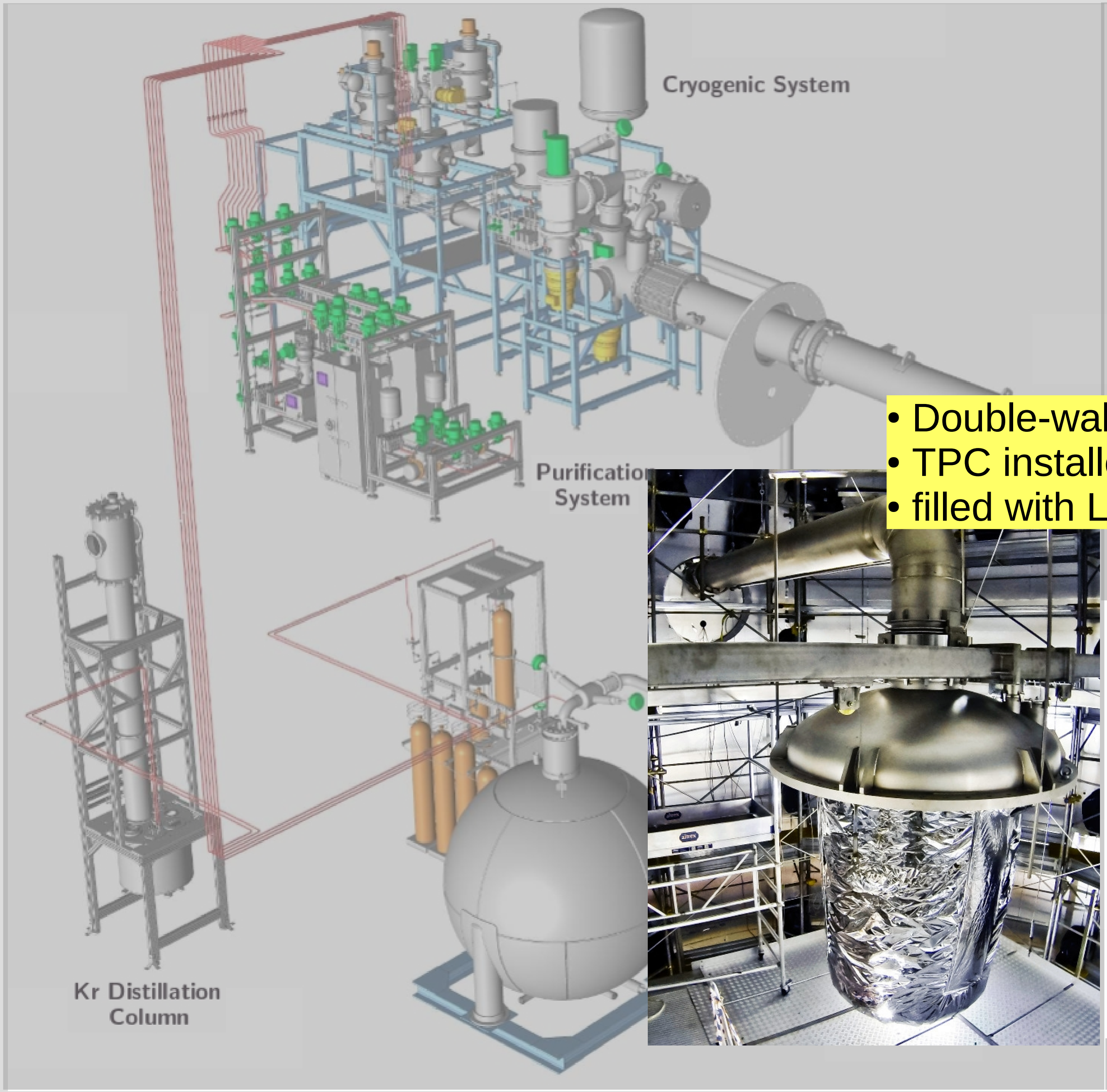


# Cryo-Systems




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

# Cryo-Systems




- Double-wall low-background cryostat
- TPC installed Fall 2015
- filled with LXe since early 2016


TPC
Freiburg: TPC design, coordination
Mainz, Münster, MPIK contributions
Xe
XENON
Dark Matter Project

# PMTs: Hamamatsu R11410-21

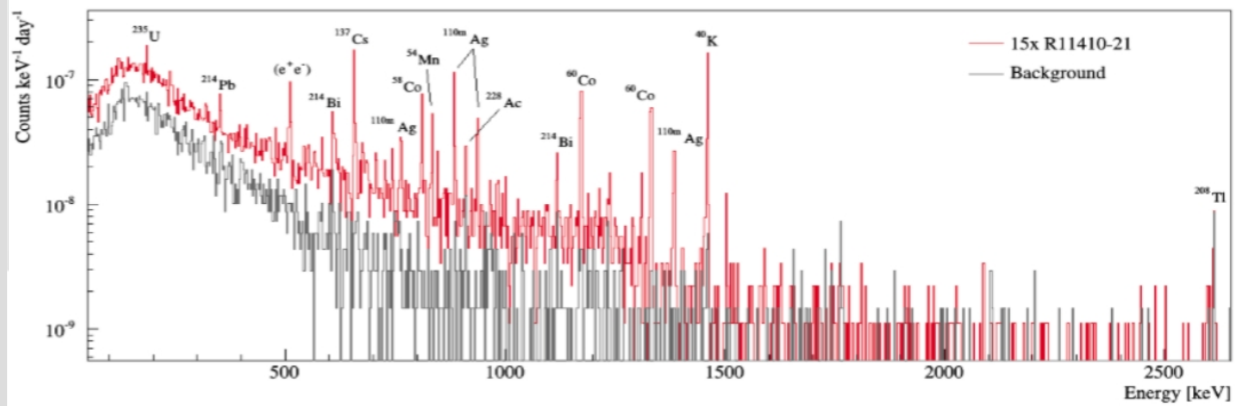
MPIK

XENON Dark Matter Project

*JINST 8, P04026 (2013)*
*EPJ C 75, 546 (2015)*

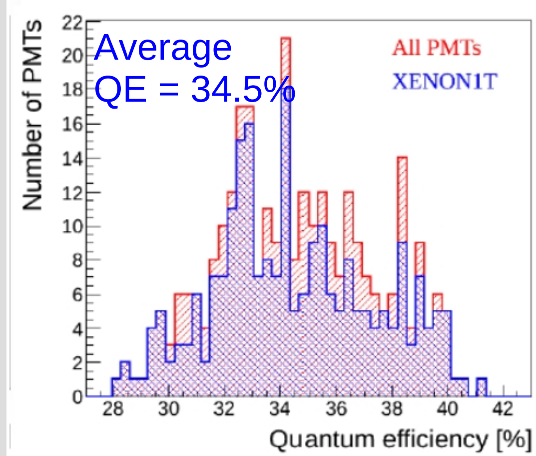


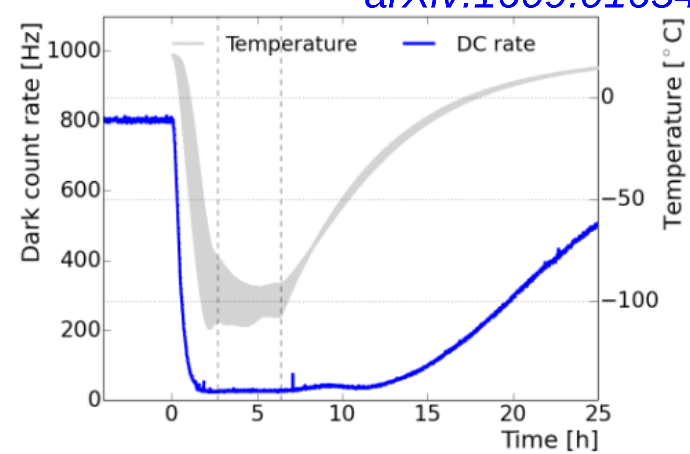

Low-background PMT developed with Hamamatsu



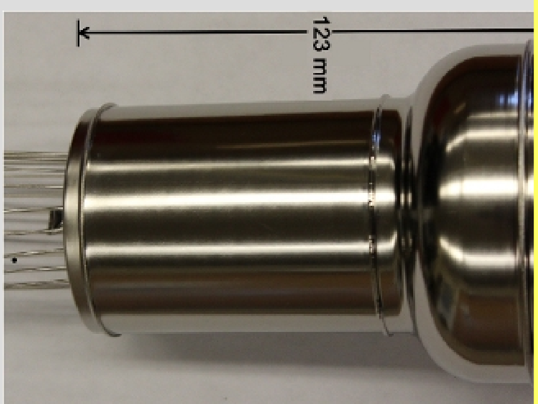

Extensive pre-testing/characterization campaign

*arXiv:1609.01654*



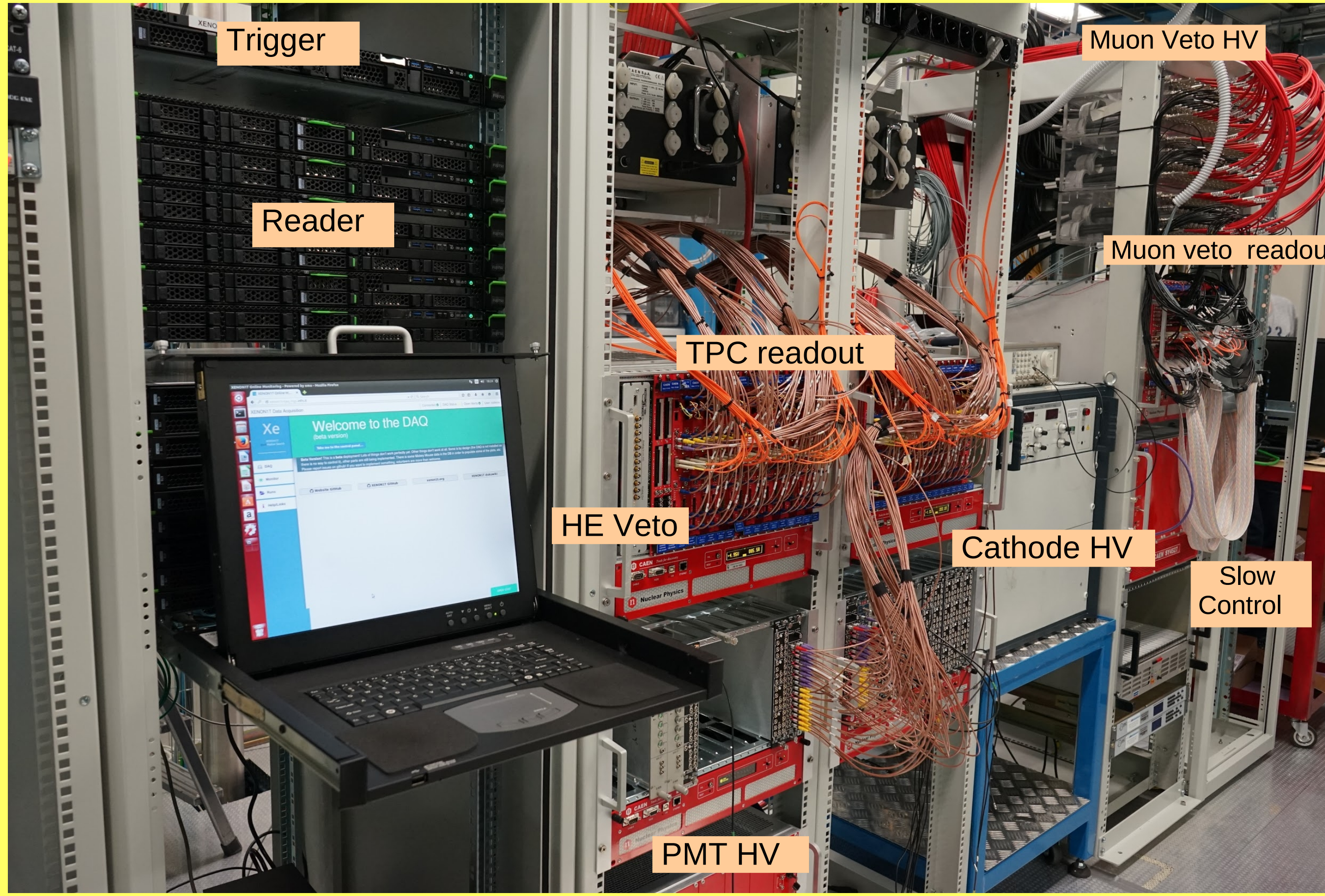



# PMTs: Hamamatsu R11410-21


## TPC Data Acquisition, Electronics

Freiburg




Parallel, trigger-less readout: → low threshold

→ high throughput (>300 MB/s achieved → 0.8 TB/d):

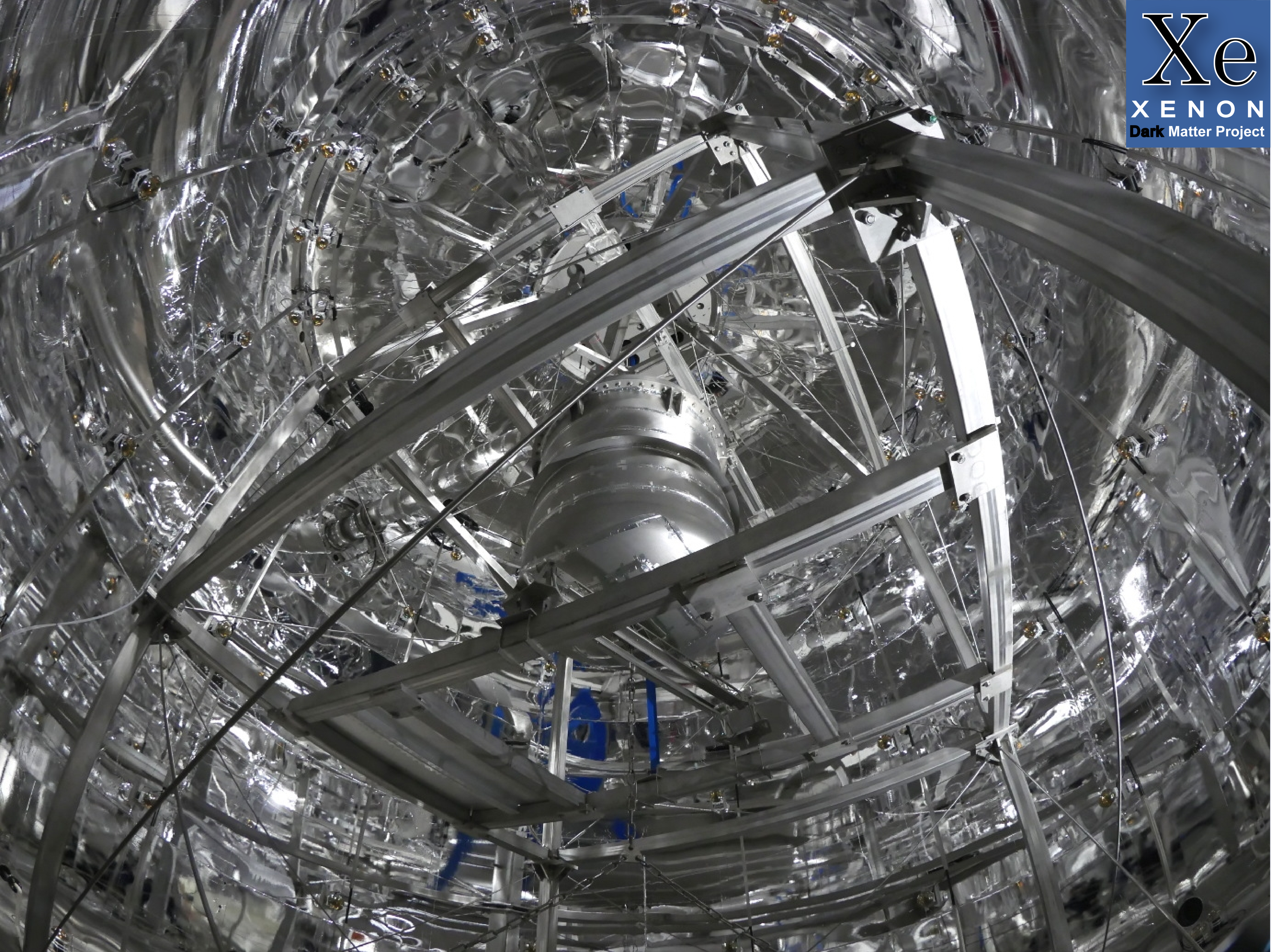
raw data → database → software trigger → file

veto — inhibit


Xe
XENON
Dark Matter Project

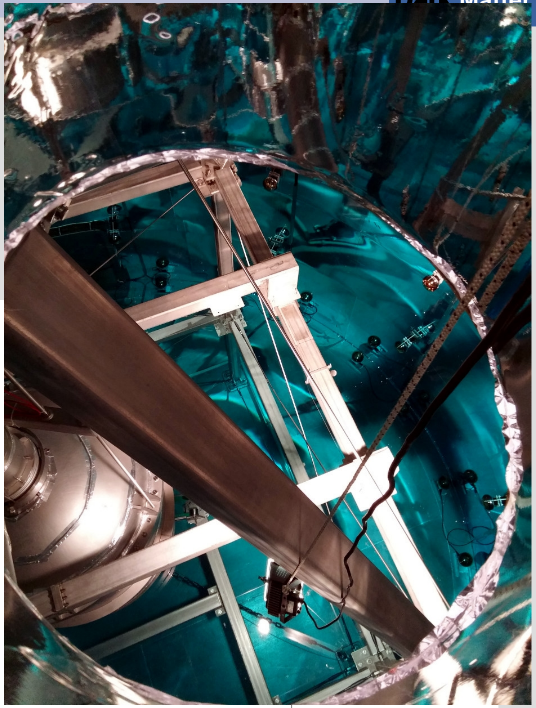
# XENON1T

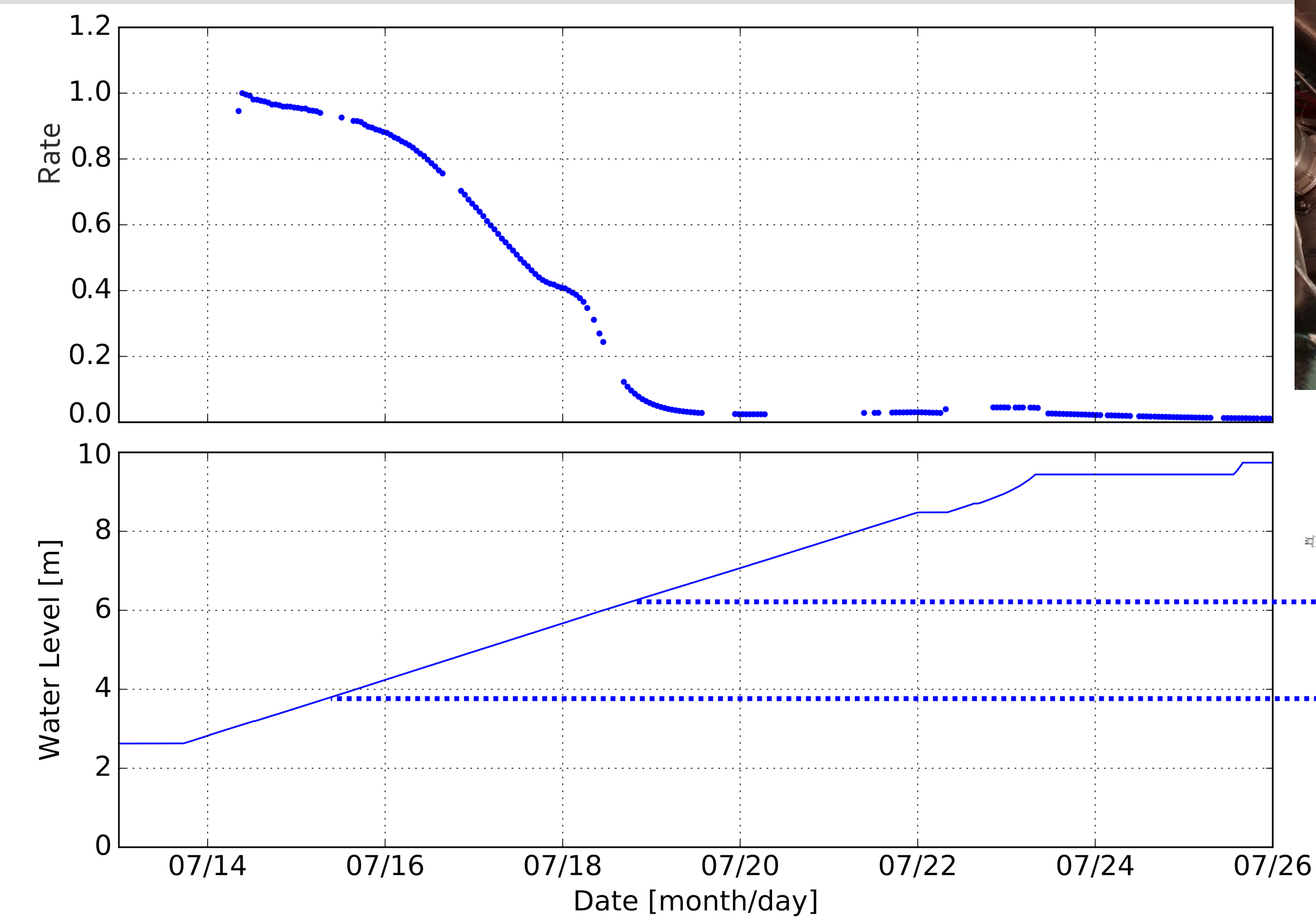
- **largest LXe TPC**
  **cylinder: 96 cm**
  **active LXe target: 2.0t**
  **248 PMTs**
- operating
- first science data in 2016

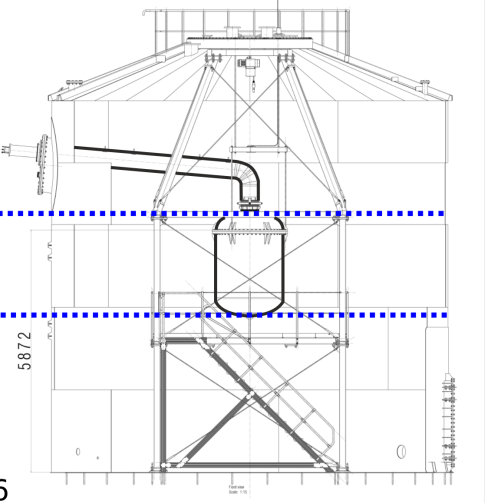

Xe
XENON
Dark Matter Project

# XENON1T Performance

Water shield filled since Summer...

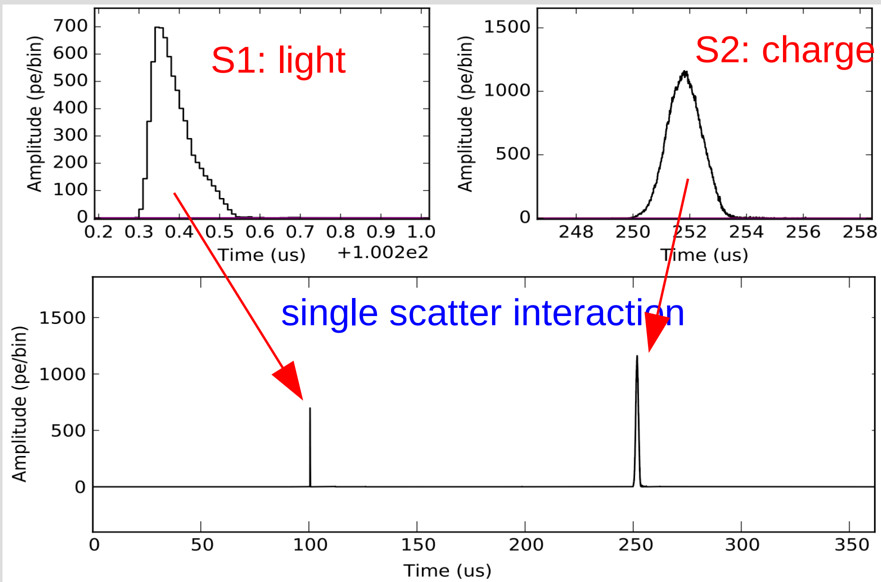


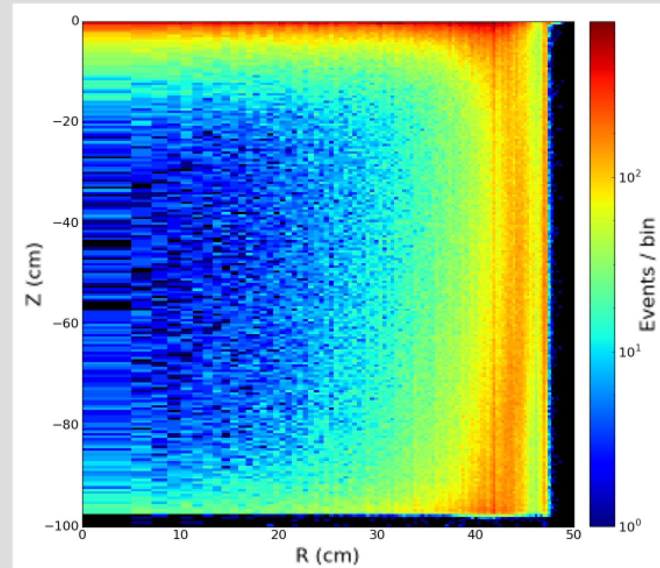


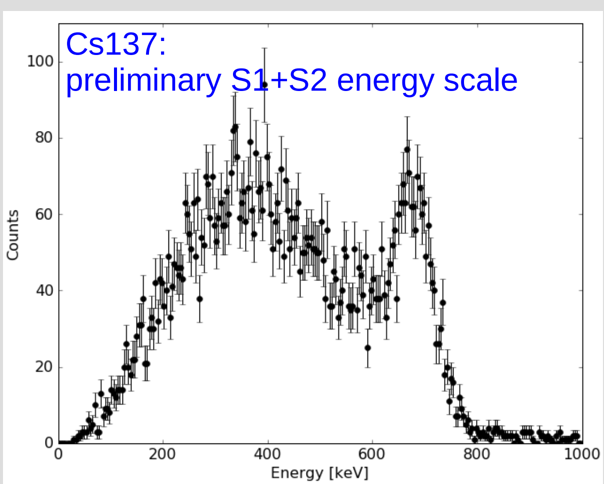
# XENON1T Performance

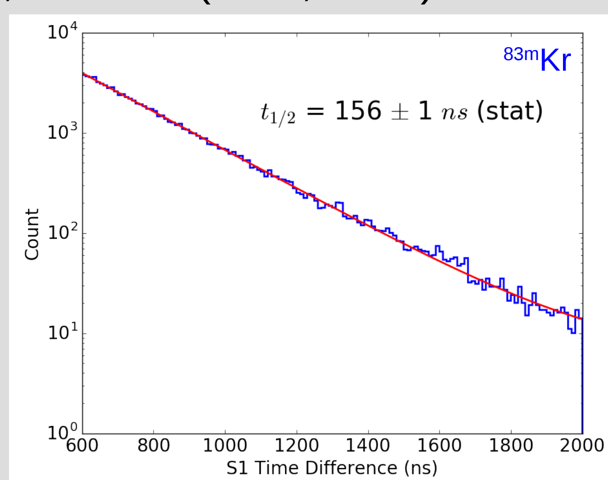
Recording light (S1) and light signals (S2) from the entire detector




Calibration: external ($^{137}$Cs, AmBe), internal ($^{83m}$Kr, $^{220}$Rn)

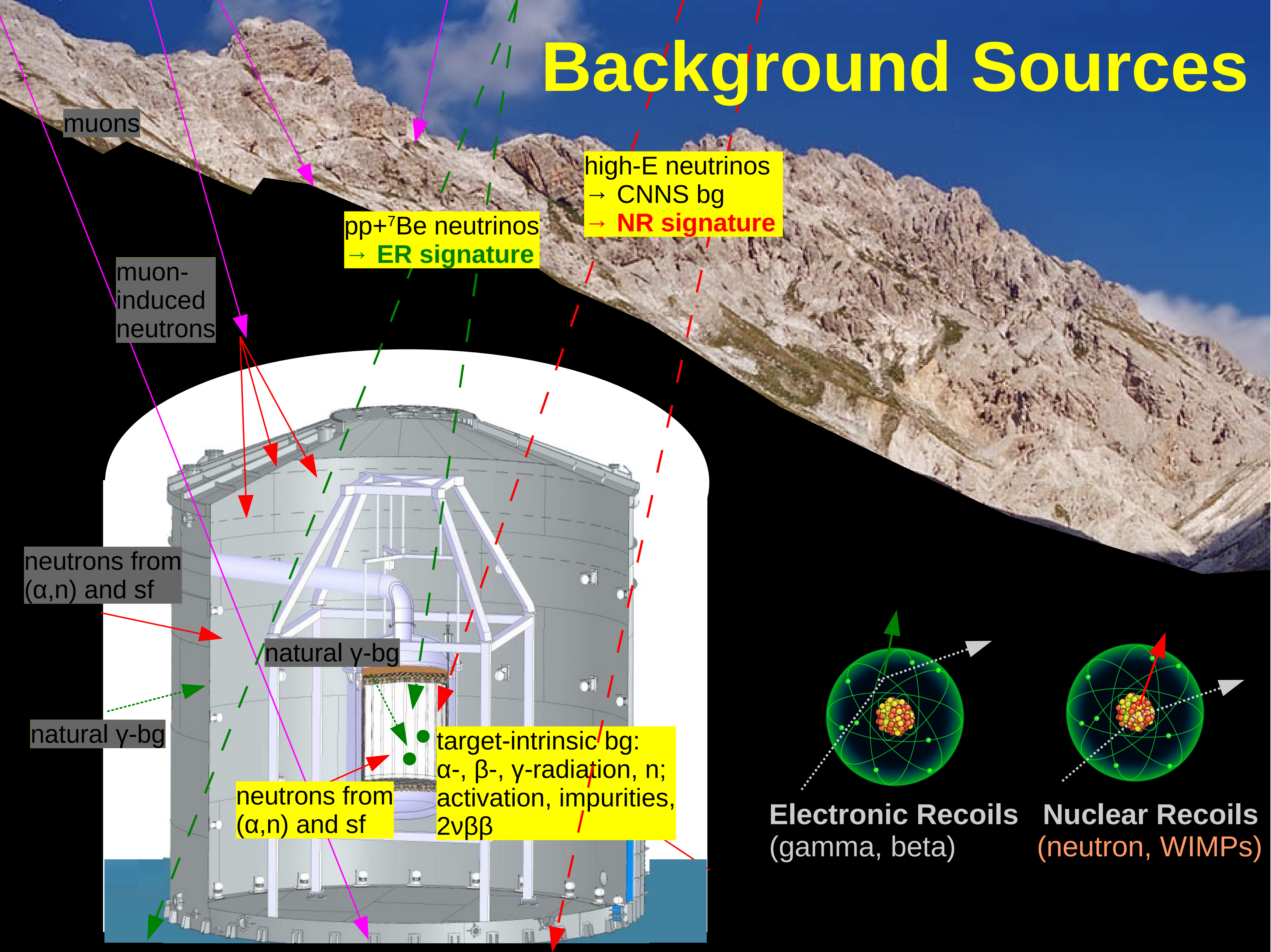



**Backgrounds**

- material background low, self-shielding effective
- $^{222}$Rn background agrees with predictions
- online removal of $^{85}$Kr via cryogenic distillation started

# Background Sources

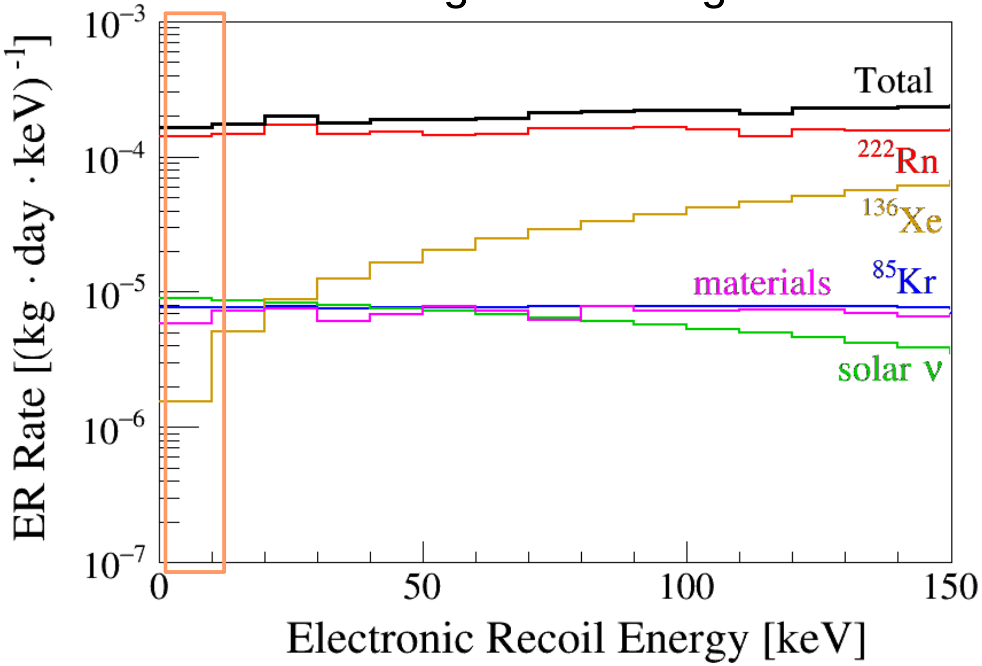


# Background: Electronic Recoils

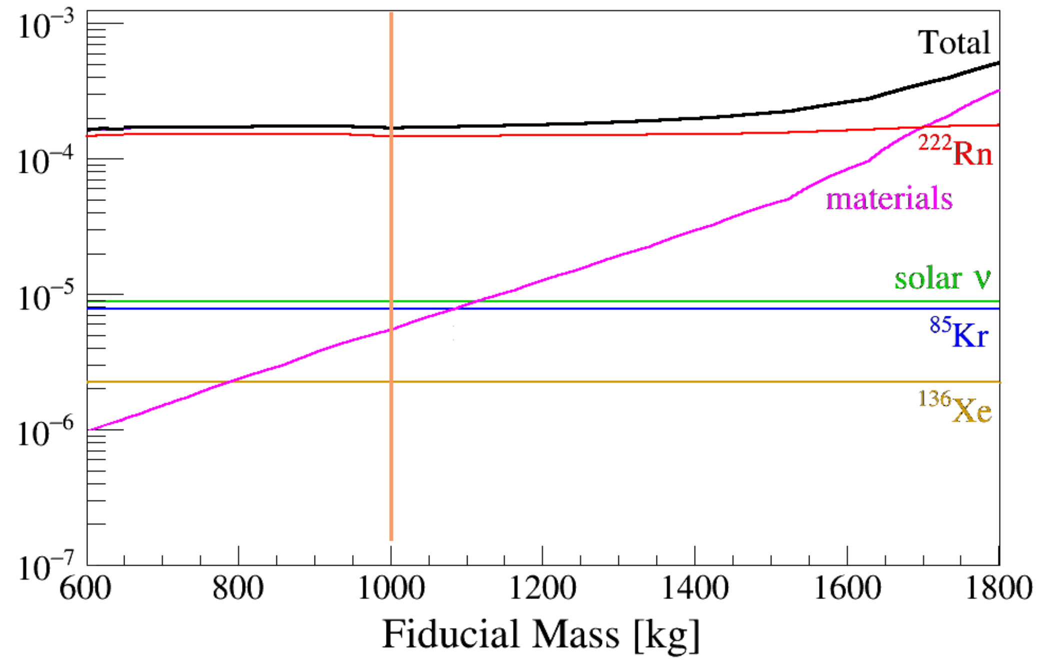
*JCAP 04, 027 (2016)*

corresponding author from Mainz

1000 kg fiducial target

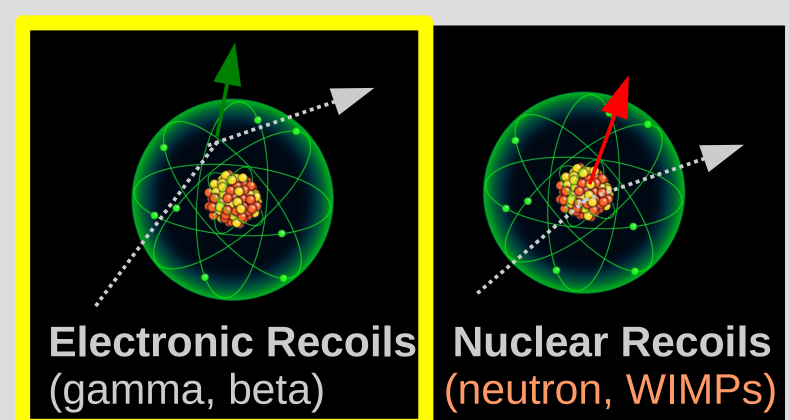



1–12 keV interval



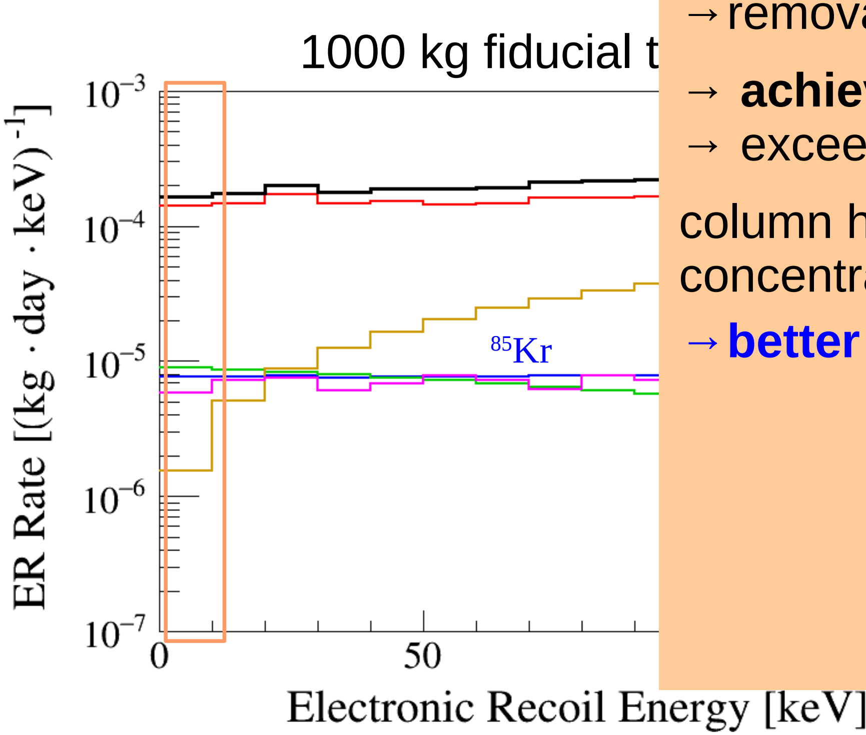

**Assumed contamination:**

- $^{222}$Rn: 10 µBq/kg
- $^{nat}$Kr: 0.2 ppt
- $^{136}$Xe: 8.9% natural abundance



# Background: Electronic Recoils

*JCAP 04, 027 (2016)*




different boiling points of Xe and Kr
→ removal of Kr by cryogenic distillation

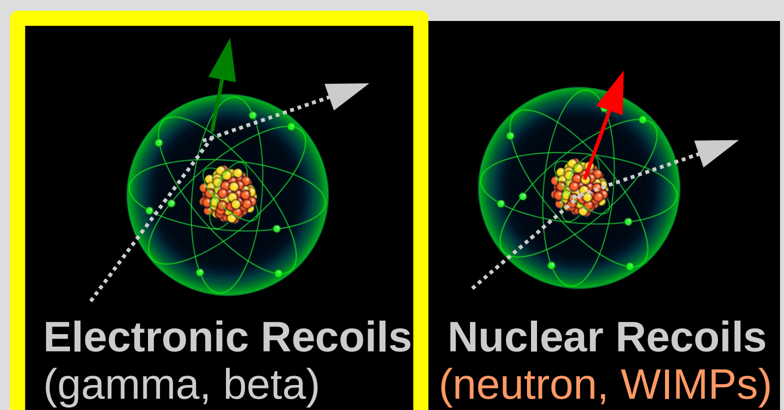
→ **achieved reduction factor ~5×10$^5$**
→ exceeds the design goal of 10$^4$!

column has already delivered a concentration of **<0.026 ppt** = 2.6×10$^{-14}$

→ **better than required for XENON1T**


Fiducial Mass [kg]

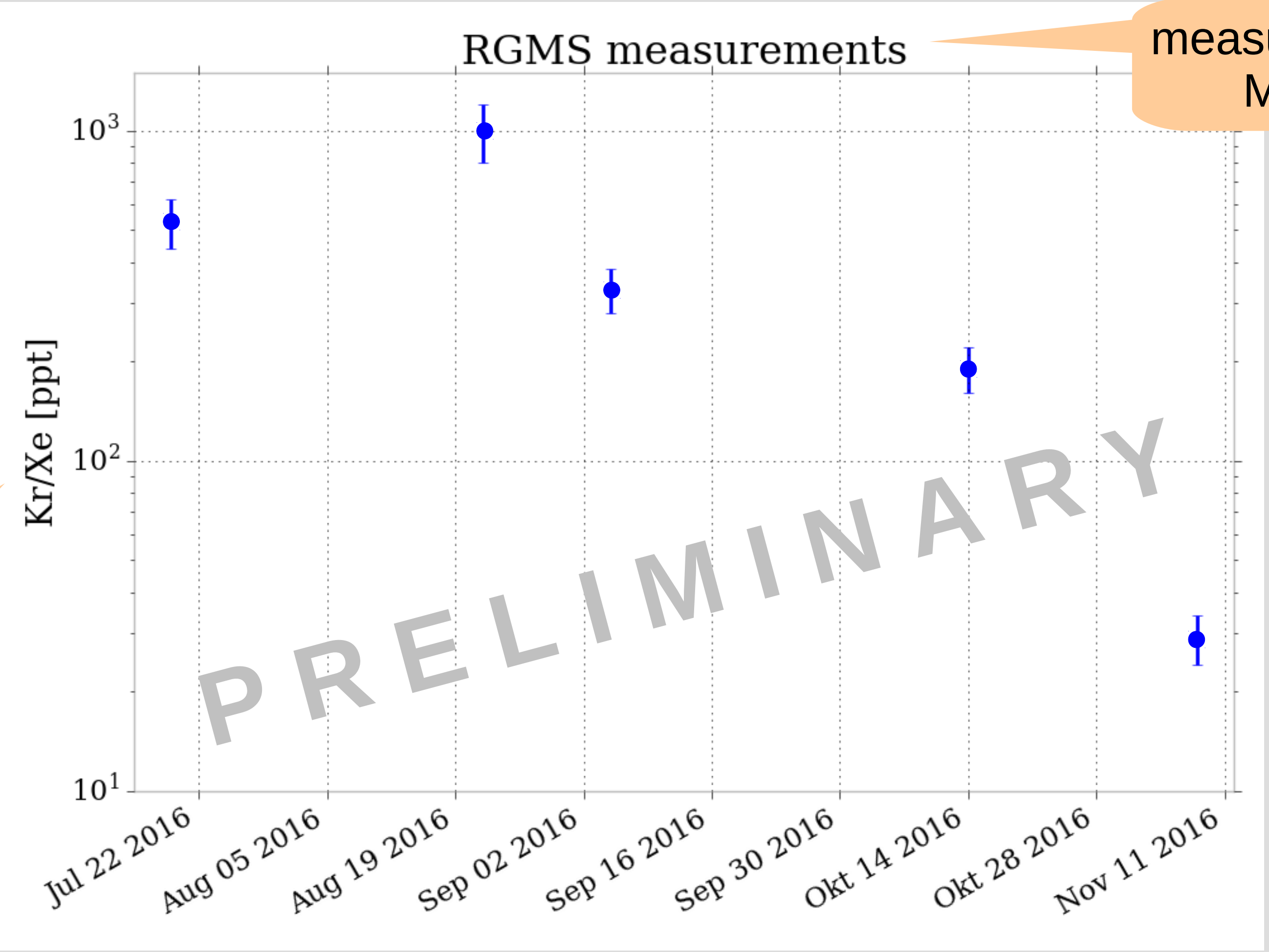
Assumed contamination:
$^{222}$Rn: 10 µBq/kg
$^{nat}$Kr: 0.2 ppt
$^{136}$Xe: 8.9% natural abundance



# Online Kr-Distillation

Online = Kr removal from Xe while the detector is filled **NEW!**

→ no interruption of data acquisition




measurement: MPIK

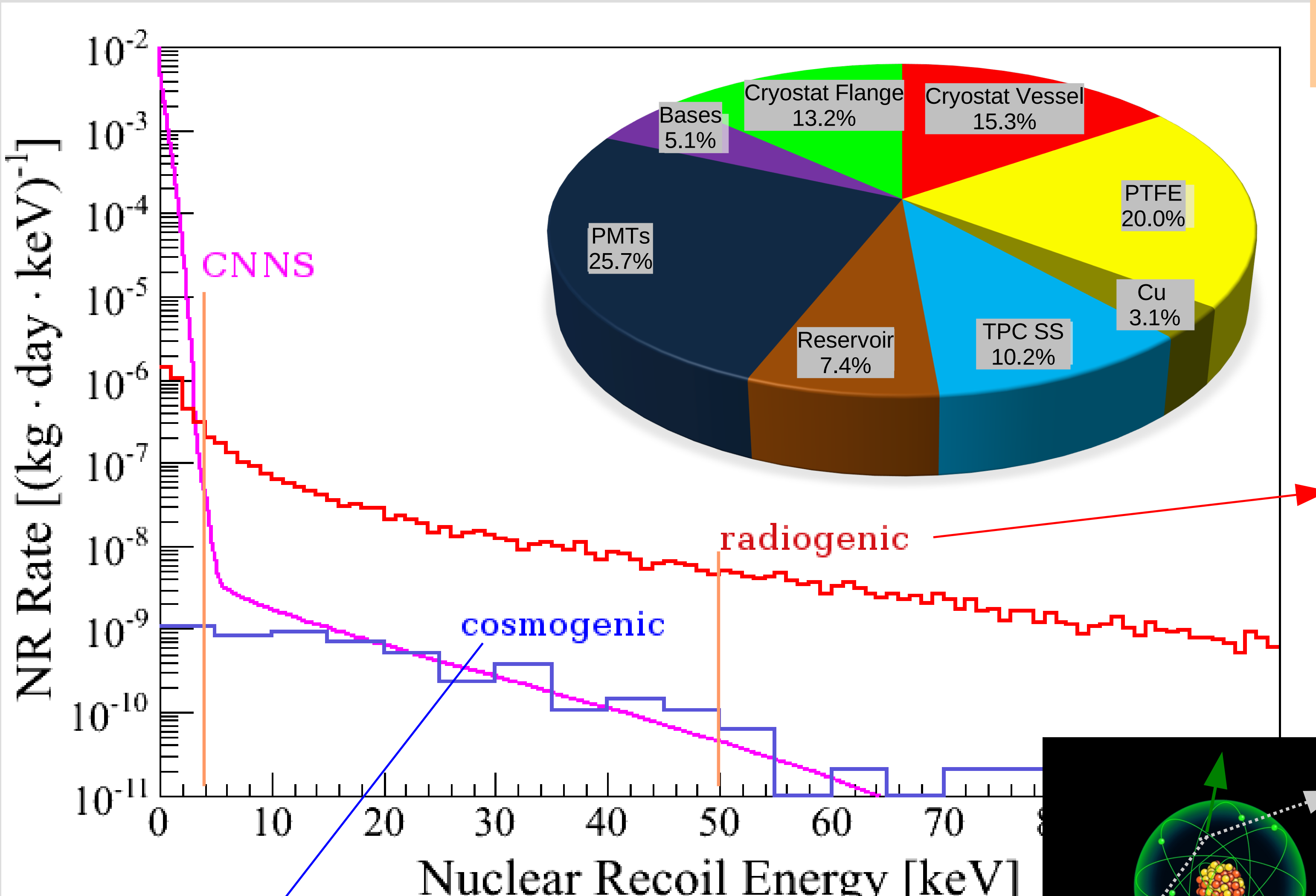
Distillation: Münster

Approaching the level required for a first (short) dark matter run.

# Background: Nuclear Recoils

*JCAP 04, 027 (2016)*

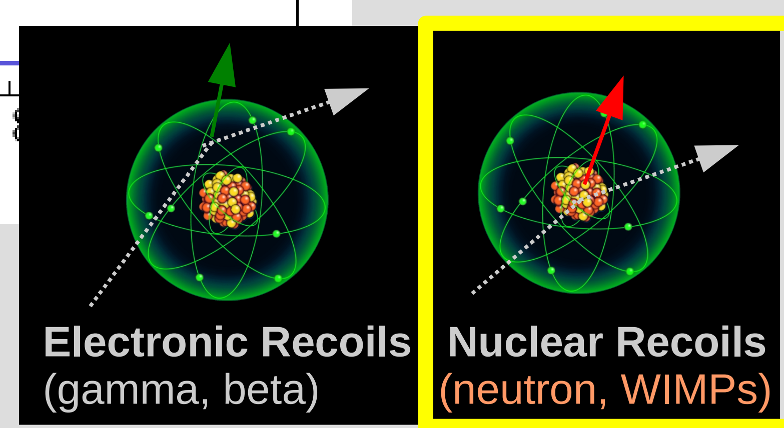
corresponding author from Mainz




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

MPIK

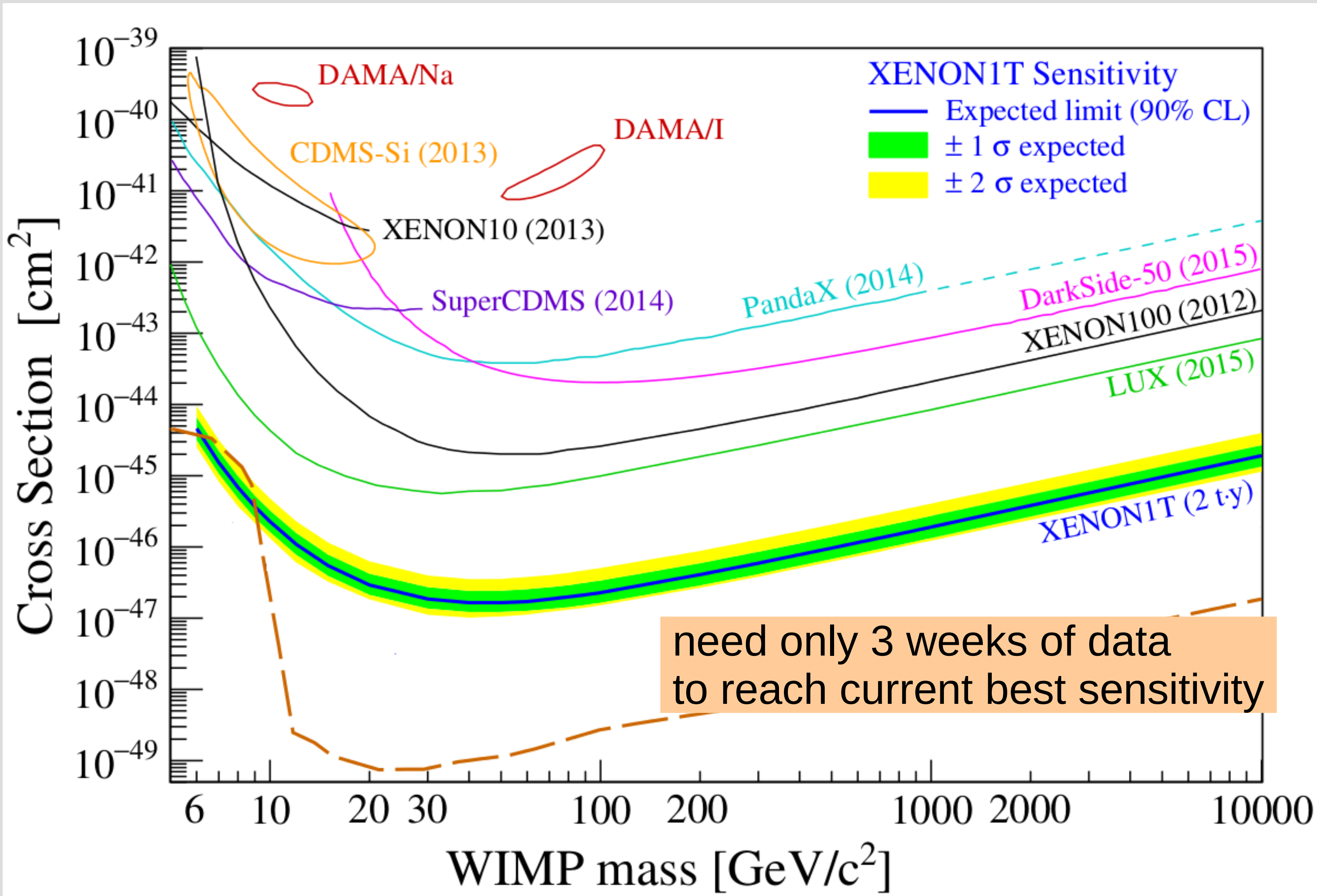
*Muon veto design and performance: XENON1T, JINST 9, P11006 (2014)*



# XENON1T Sensitivity

JCAP 04, 027 (2016)

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

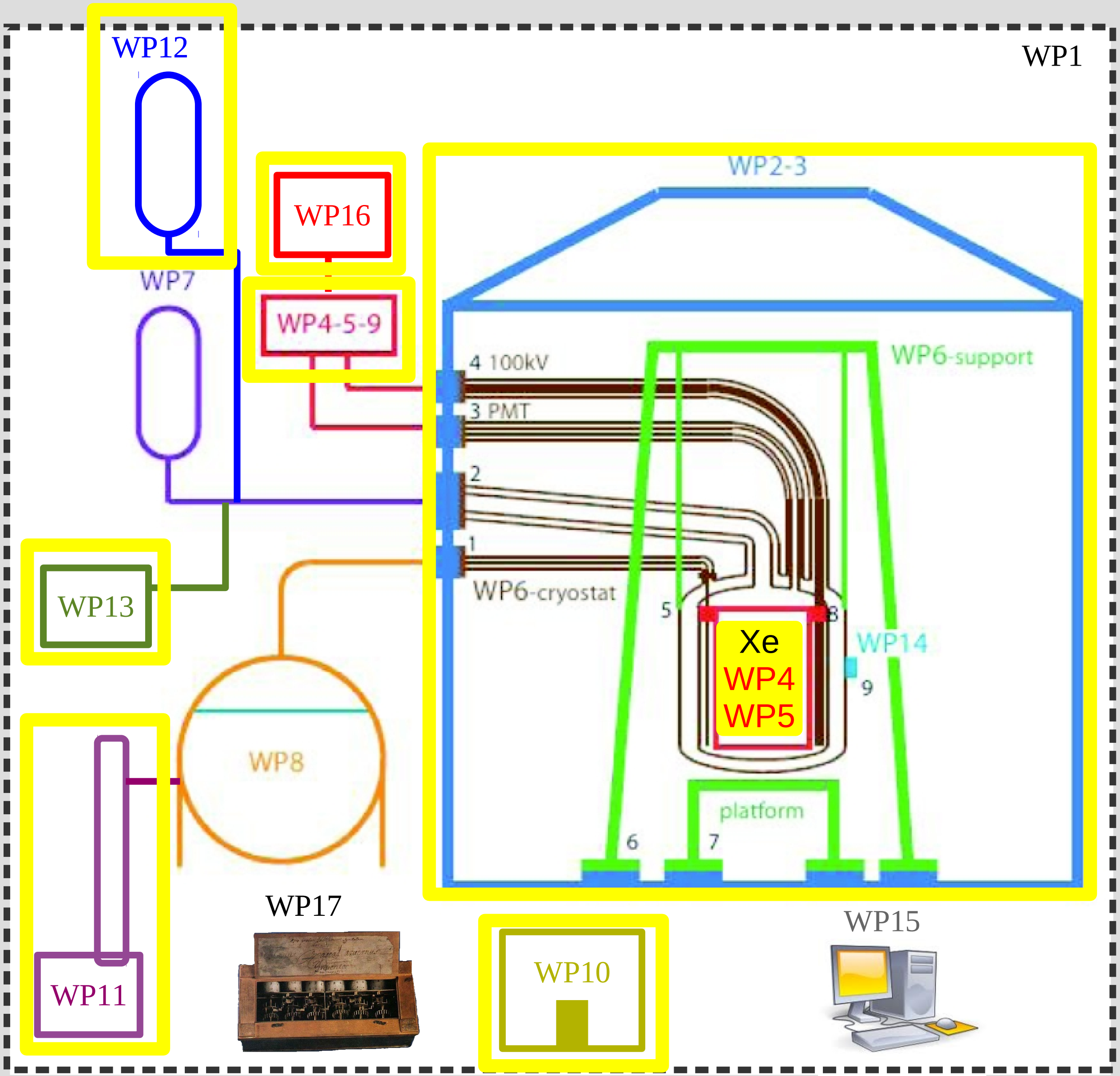



*assumptions*: energy interval: 4 – 50 keV, ER rejection as XENON100: 99.5% @ 50% NR acc.

→ expected LY is 2x higher than in XENON100!

↪ confirmed by measurement!

# XENON1T: Contributions D




- **0. Xenon gas** 50% from MPG/BMBF
- **1. Infrastructure**
- **2. Muon veto**
- **3. Water tank**
- **4. Detector: TPC, Grids, HV**
- **5. PMTs**
- **6. Cryostat & Support Platform**
- **7. Cryogenics**
- **8. Cryogenic storage vessel**
- **9. Slow control**
- **10. Material screening and selection**
- **11. Distillation column**
- **12. Xe Purification**
- **13. Gas purity and analytics**
- **14. Calibration**
- **15. Monte Carlo simulation**
- **16. DAQ and Trigger**
- **17. Computing**

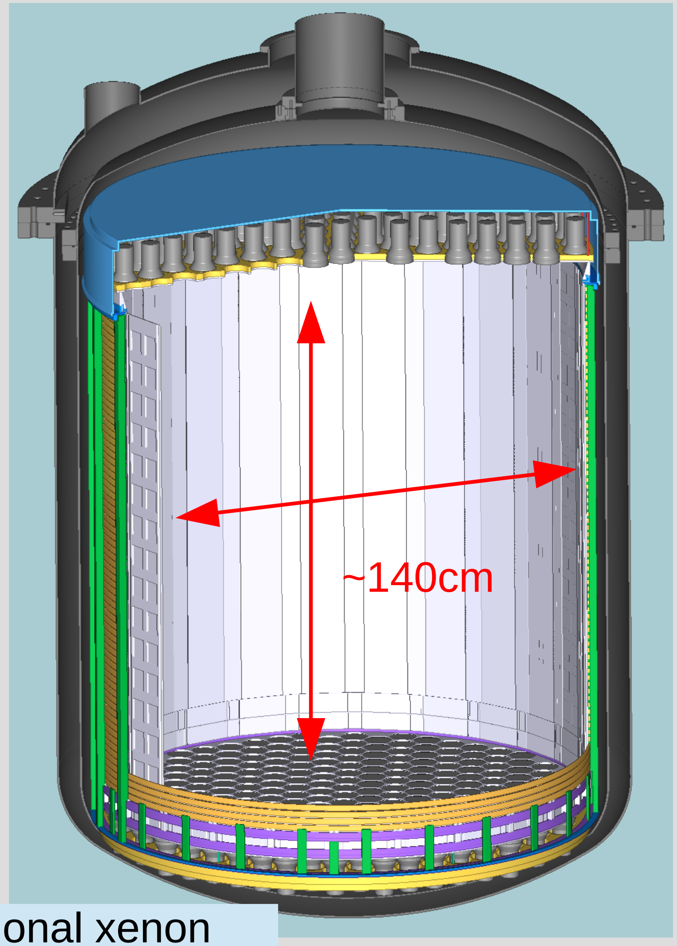
# XENON1T → XENONnT

JCAP 04, 027 (2016)

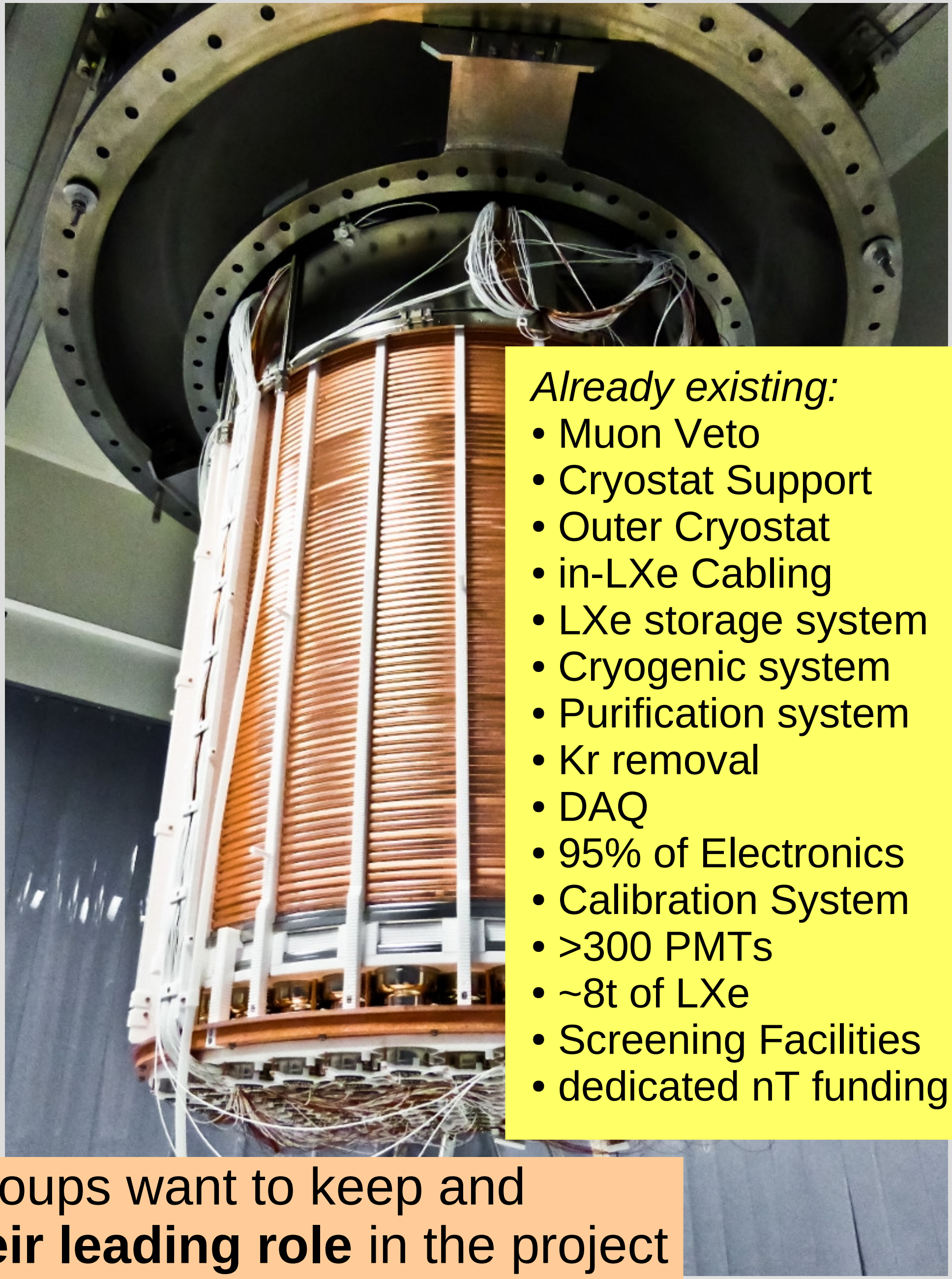
XENON Dark Matter Project

**XENON1T**
- **2t** active LXe target
- operating
- first science data in 2016

**XENONnT**
- **6t** active target
- projected to start in 2018



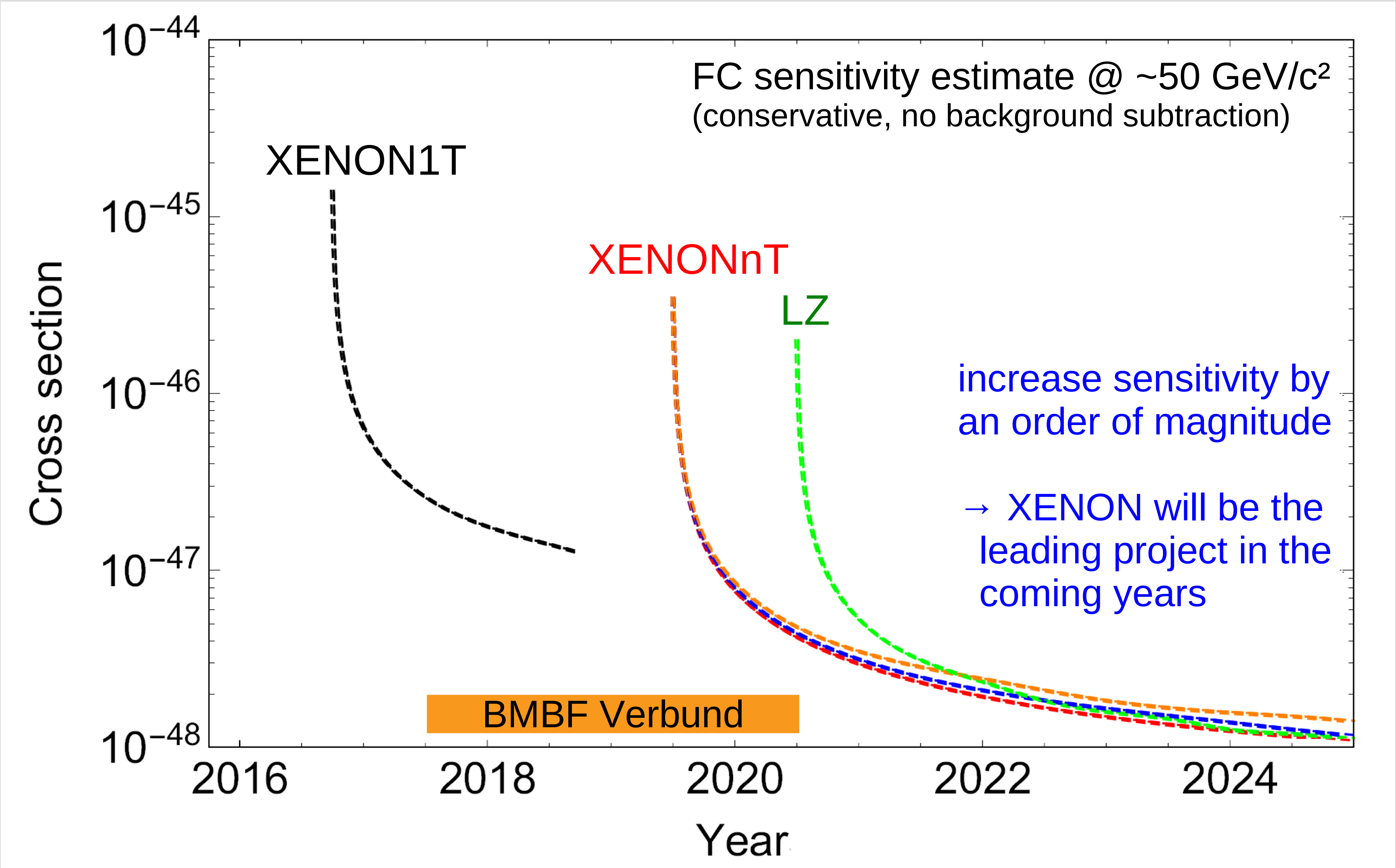

4.5t additional xenon
228 additional channels



*Already existing:*
- Muon Veto
- Cryostat Support
- Outer Cryostat
- in-LXe Cabling
- LXe storage system
- Cryogenic system
- Purification system
- Kr removal
- DAQ
- 95% of Electronics
- Calibration System
- >300 PMTs
- ~8t of LXe
- Screening Facilities
- dedicated nT funding

German groups want to keep and **extend their leading role** in the project

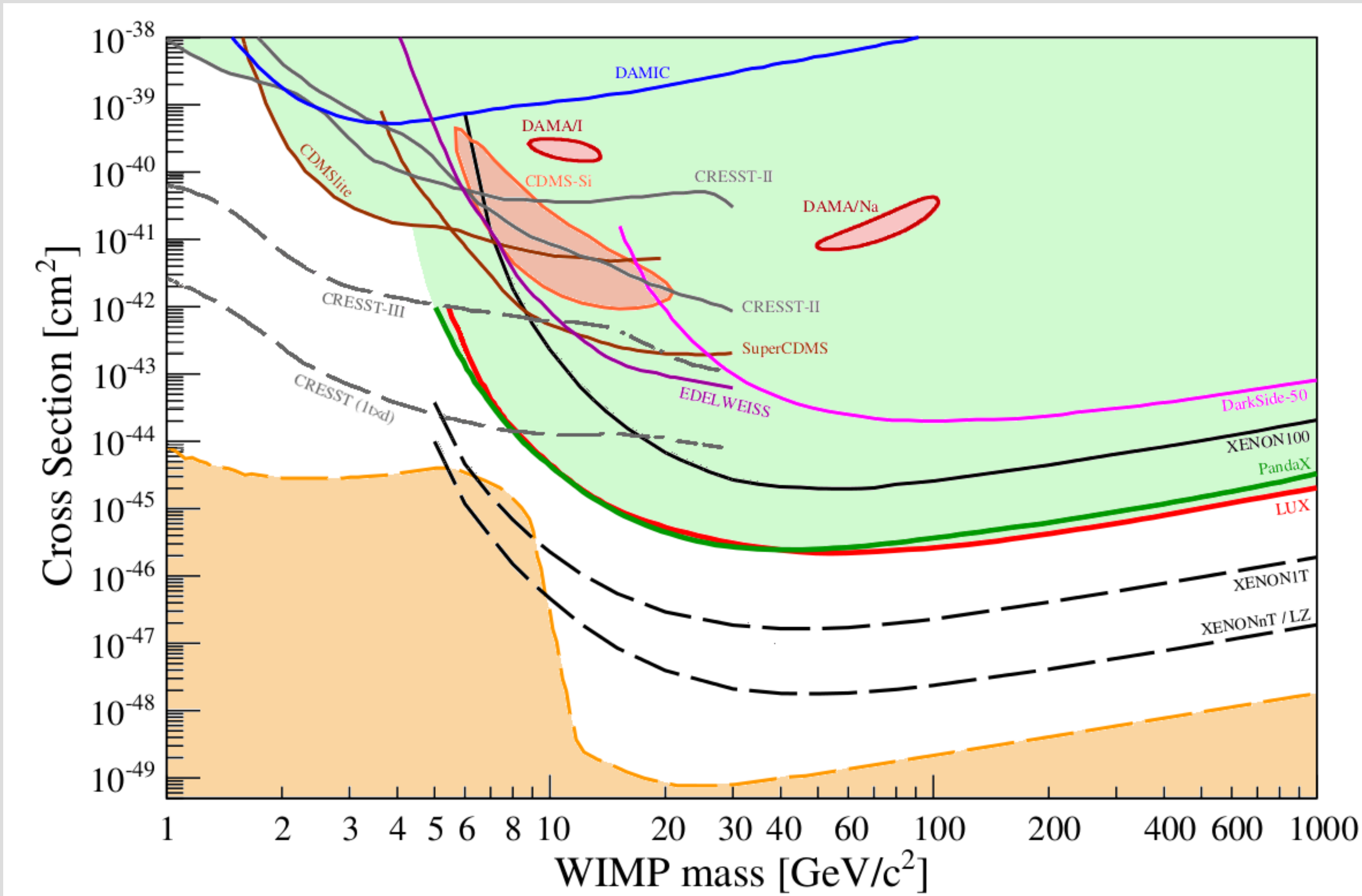
# XENONnT: Sensitivity vs. time




LZ information taken from: https://idm2016.shef.ac.uk/indico/event/0/contribution/69/material/slides/0.pdf

# The XENON Future

spin-independent WIMP-nucleon interactions




*some projects are missing...*