Studying the purification of ton-scale LXe detectors with XENON1T

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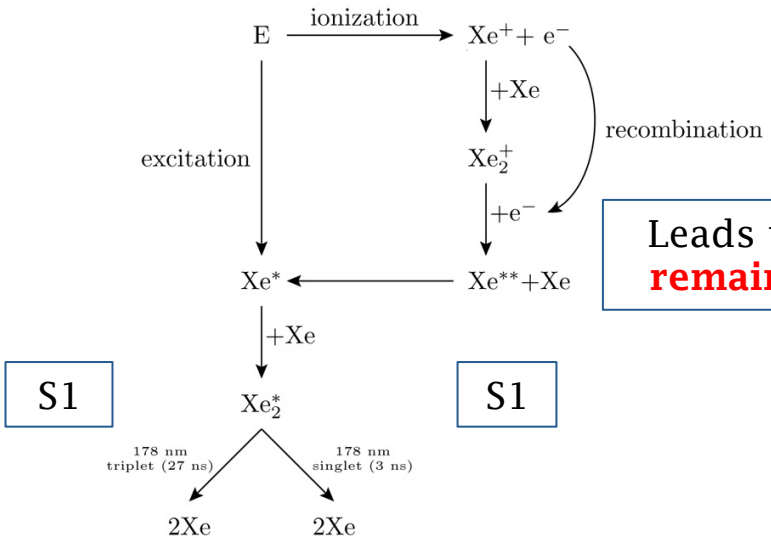
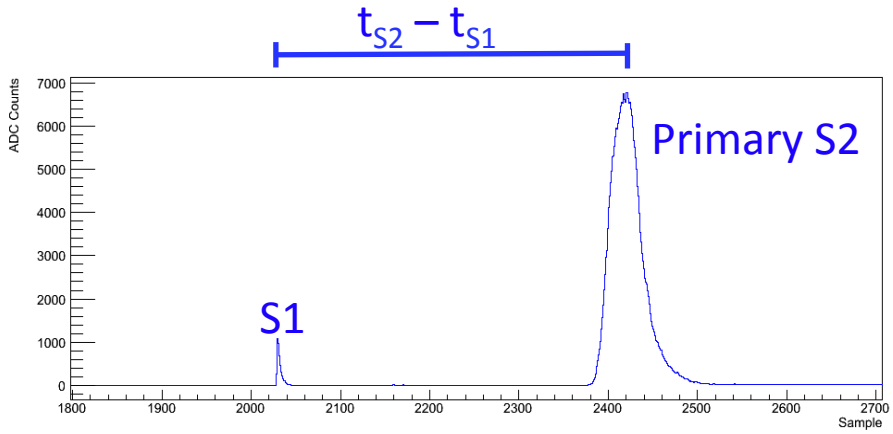
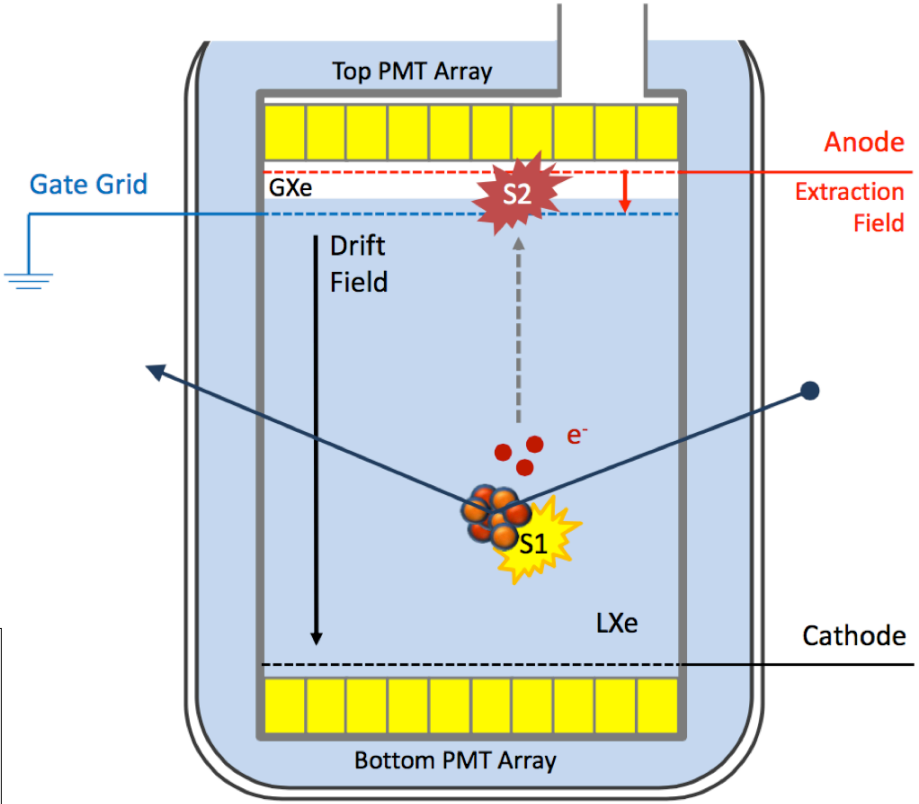
Time Projection Chamber (TPC)



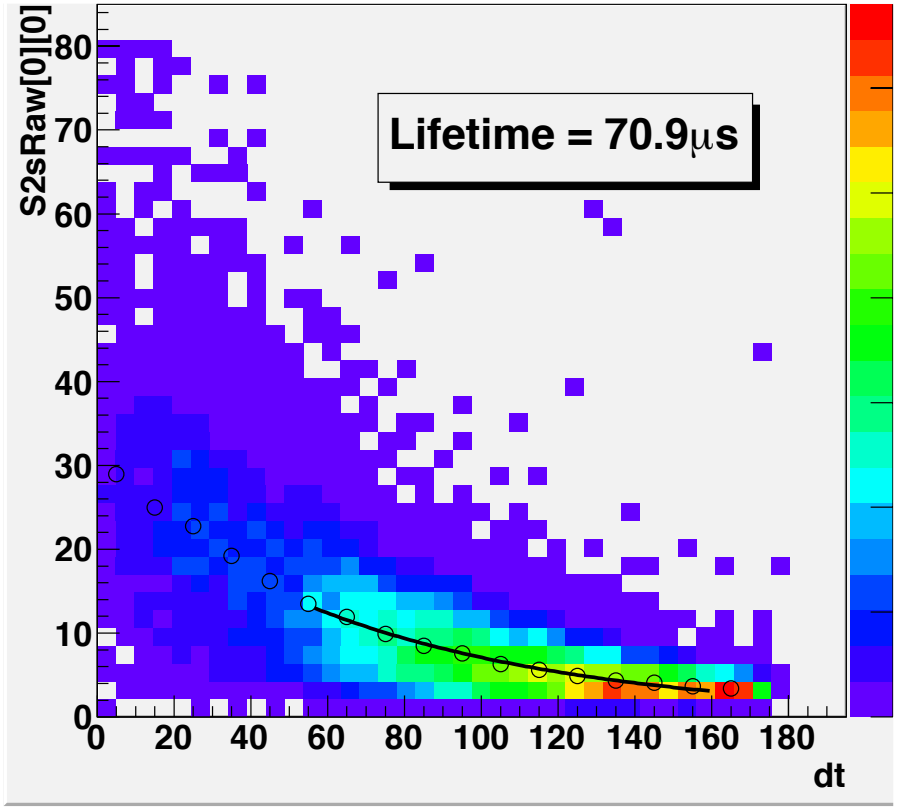
Leads to S2 **if remains free**





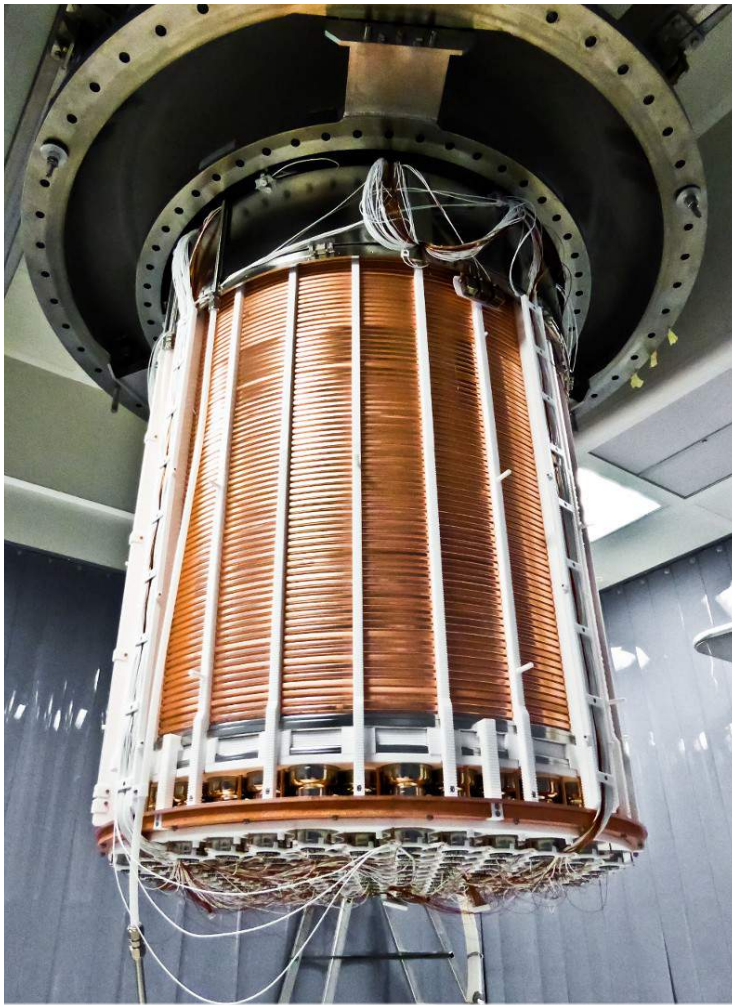
Impurities in LXe

- Outgassing from detector materials contaminates Xe
- Impurities in Liquid Xenon (LXe) attenuate light and charge
- Free electrons attach to impurities so do not contribute to S2
- Requires continuous purification of Xe to maintain high purity



Challenges in XENON1T

- First ton-scale LXe TPC detector (3.5 tons compared to 150 kg in XENON100)
- Need electronegative impurity level below 1 ppb – (electron lifetime of > 1 ms)
- Strategy:
  - Screen detector materials for outgassing rate
  - Build prototype to test new design/ components
  - Add gaseous xenon (GXe) purification



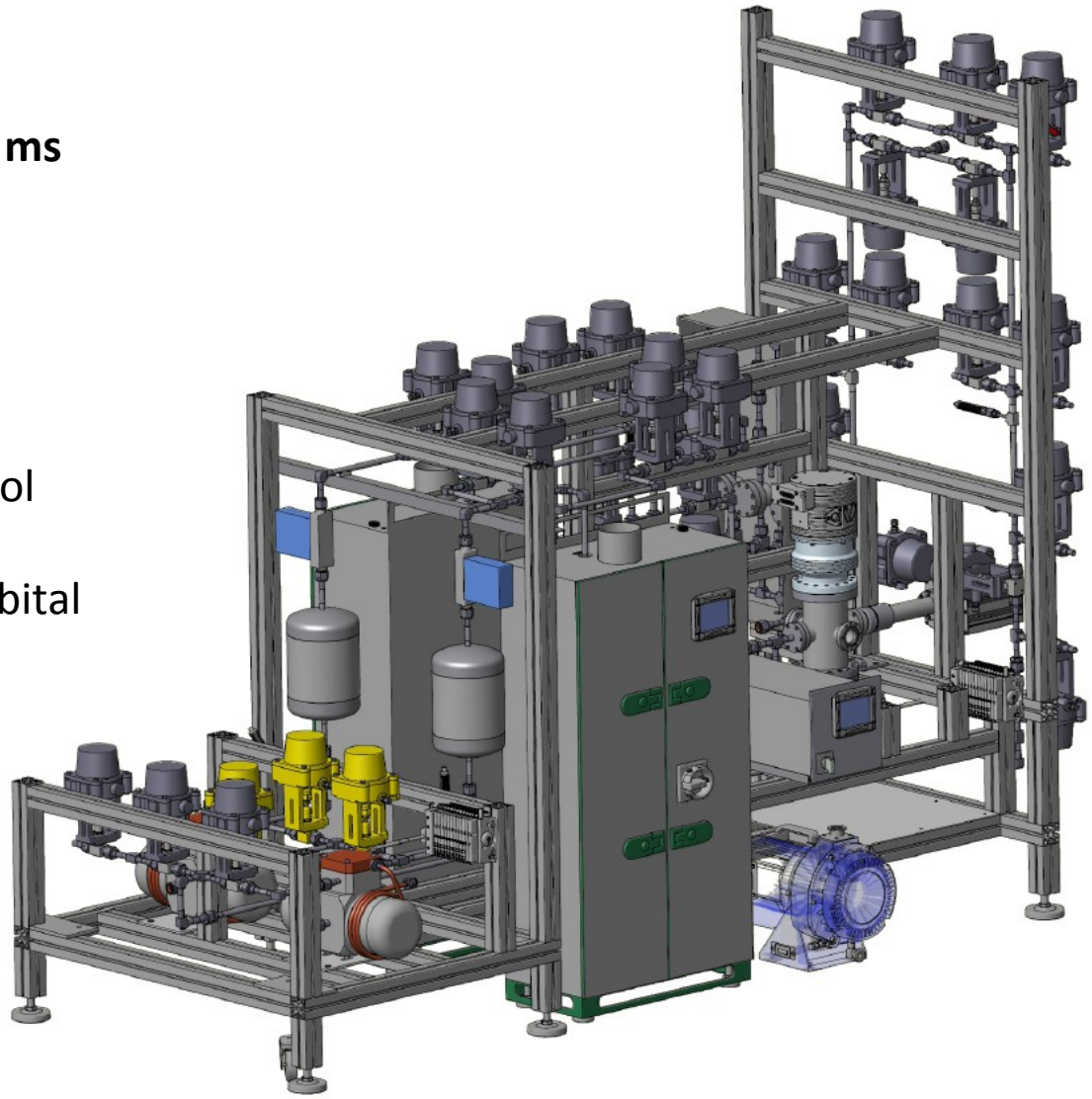
Purification Design

Goal: achieve electron lifetime > 1 ms

- Key Components:
  - Q-drive
  - Getter
  - HALO+ H_2O monitor
  - Remote Monitor and Control
  - Pressure sensors
  - Electropolished tubing + orbital welding

- Parallel lines for approximately 2x speed + redundancy

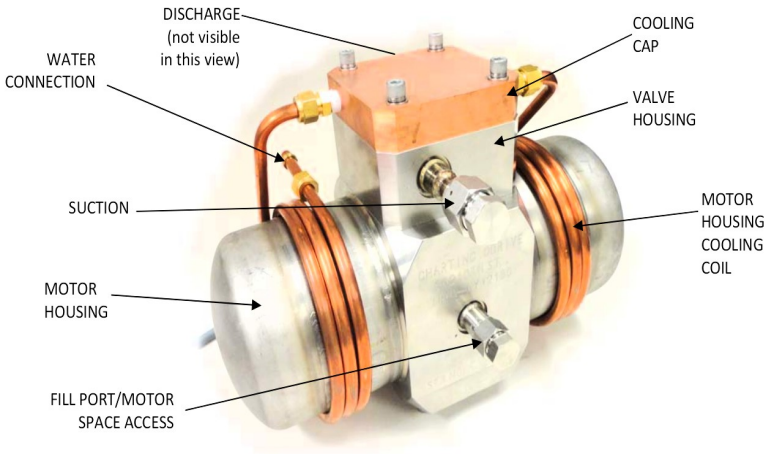
- Scalable



Purification Components

Q-Drive

- Magnetic resonance pump
- High flow (> 50 standard liters per minute)
- Remotely monitored and controlled



Gas Purification Getter

- Heated (450˚ C) zirconium pellets absorb electronegative impurities (e.g. H_2O, O_2) without removing Xe

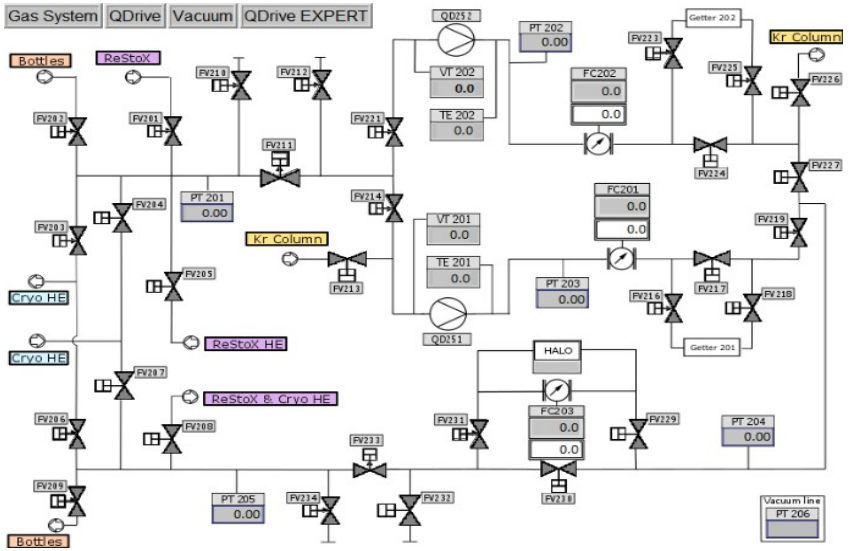
Purification Components

HALO+ H_2O Monitor

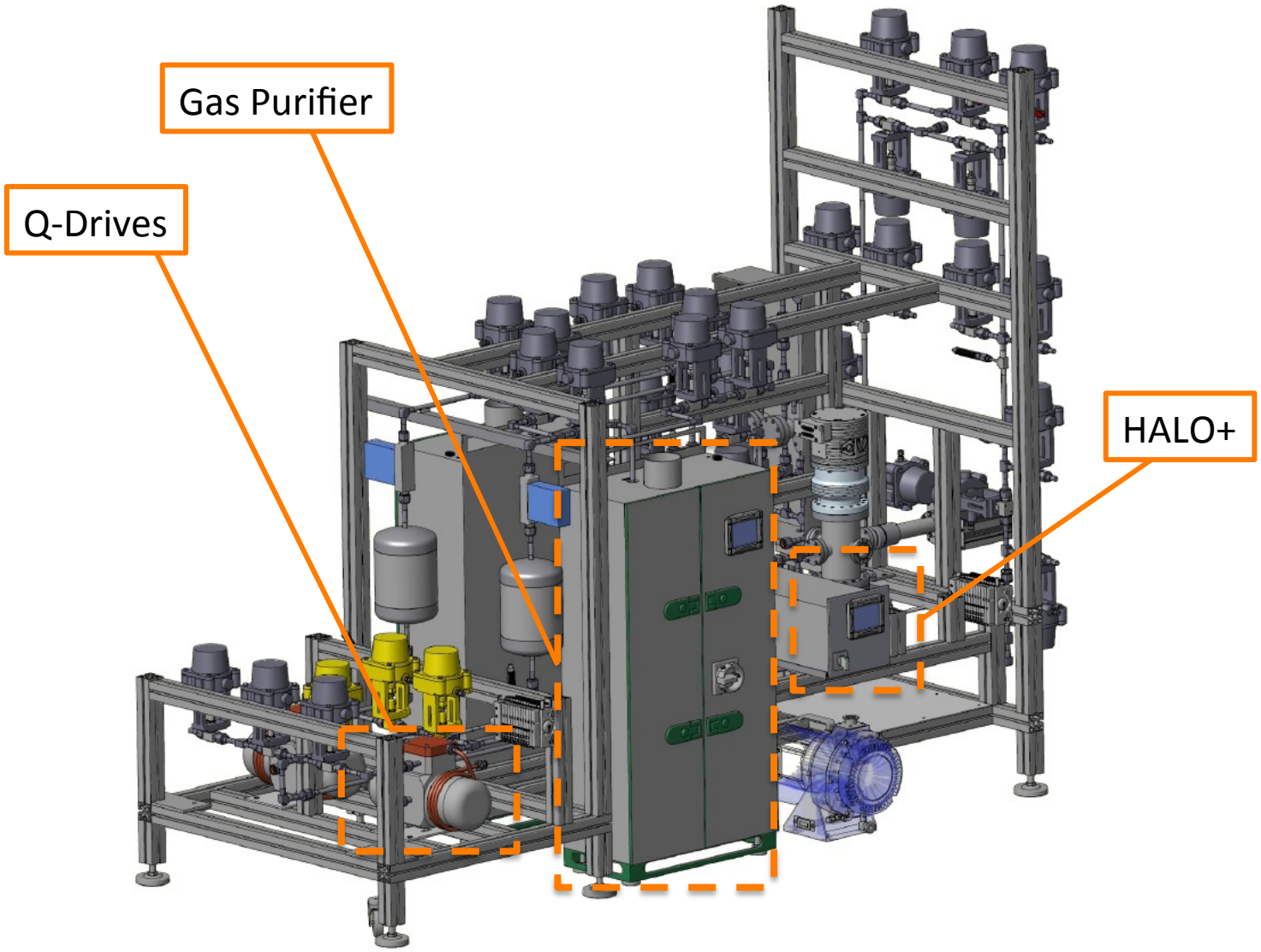
- Continuously measure H_2O concentration
- Monitor performance of purification getters
- Identify potential internal leaks

Remote Monitor and Control

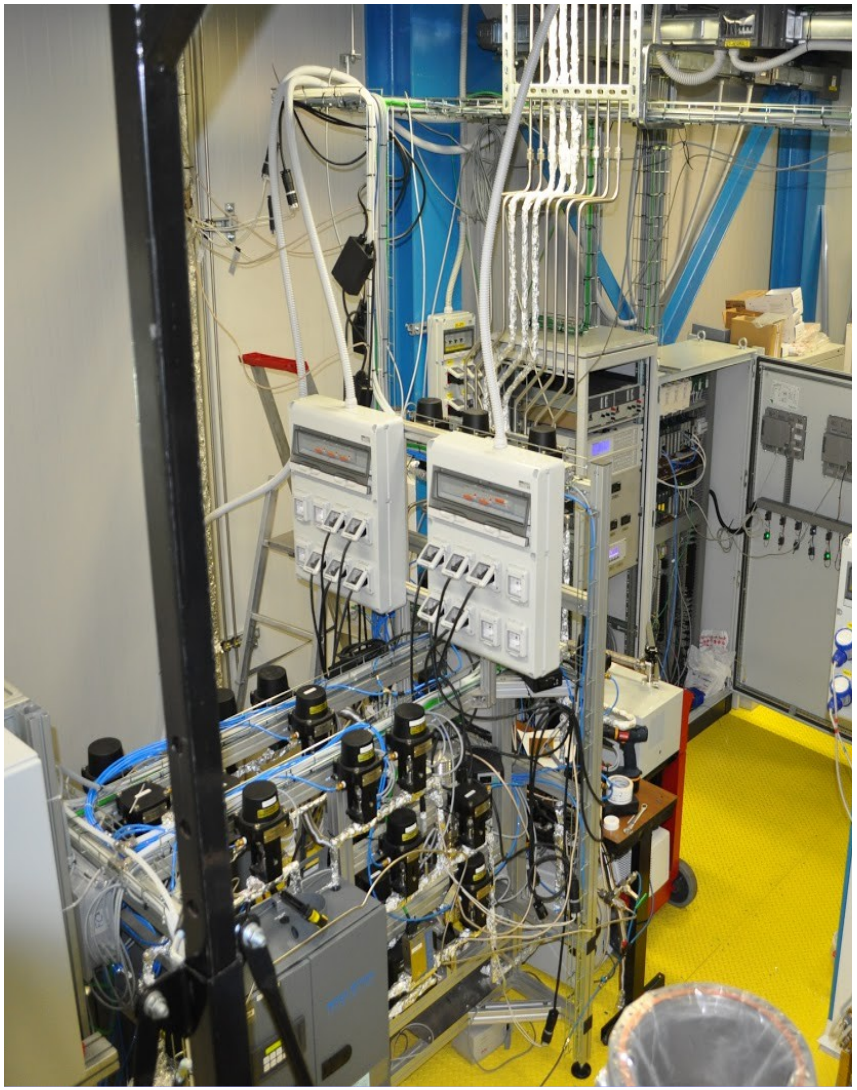
- Monitors and displays measurements from system components (e.g. pressure sensors, HALO+, etc.)
- Ability to open/close valves and control components (e.g. Q-Drives, flow controllers)



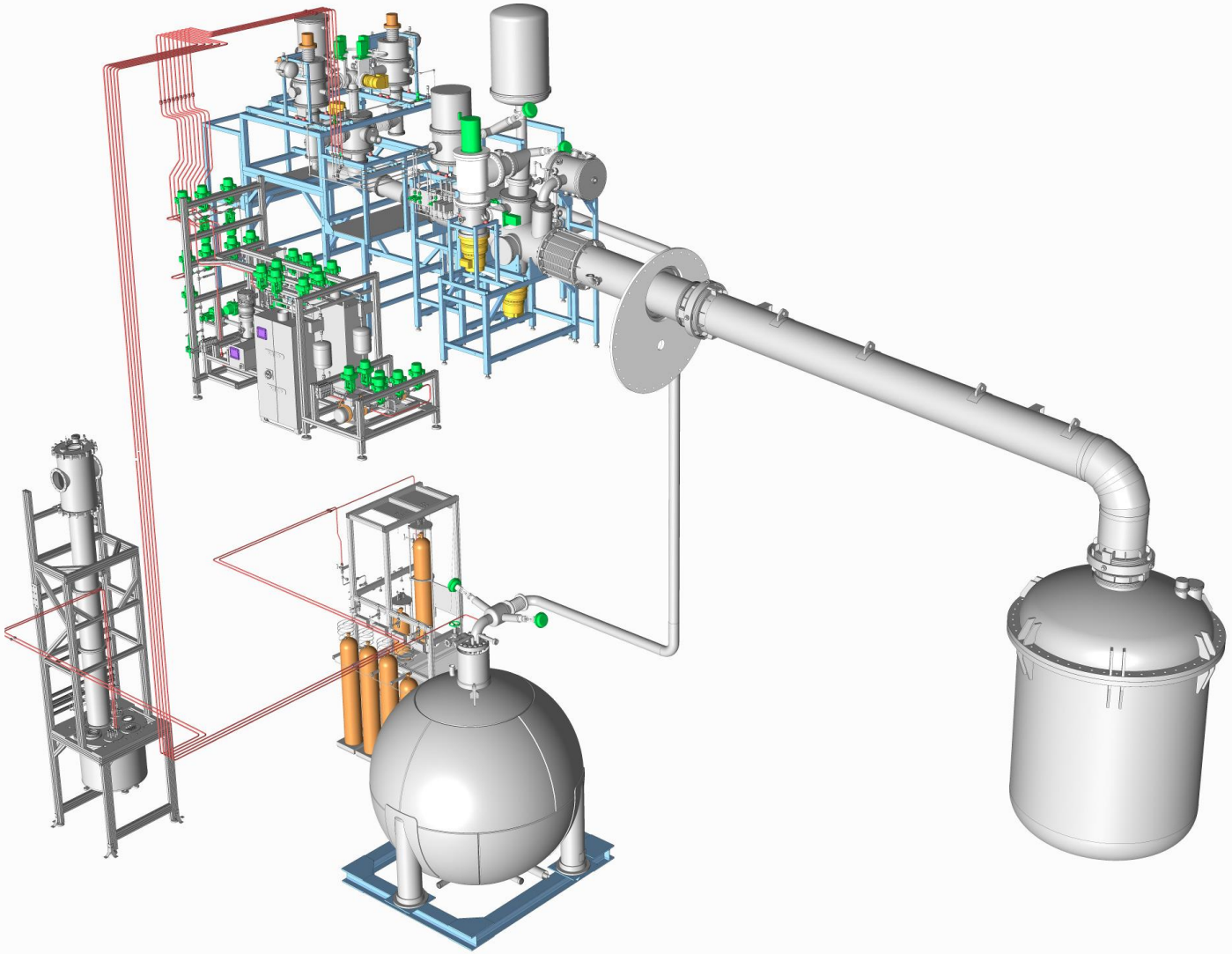
Purification System



Purification System

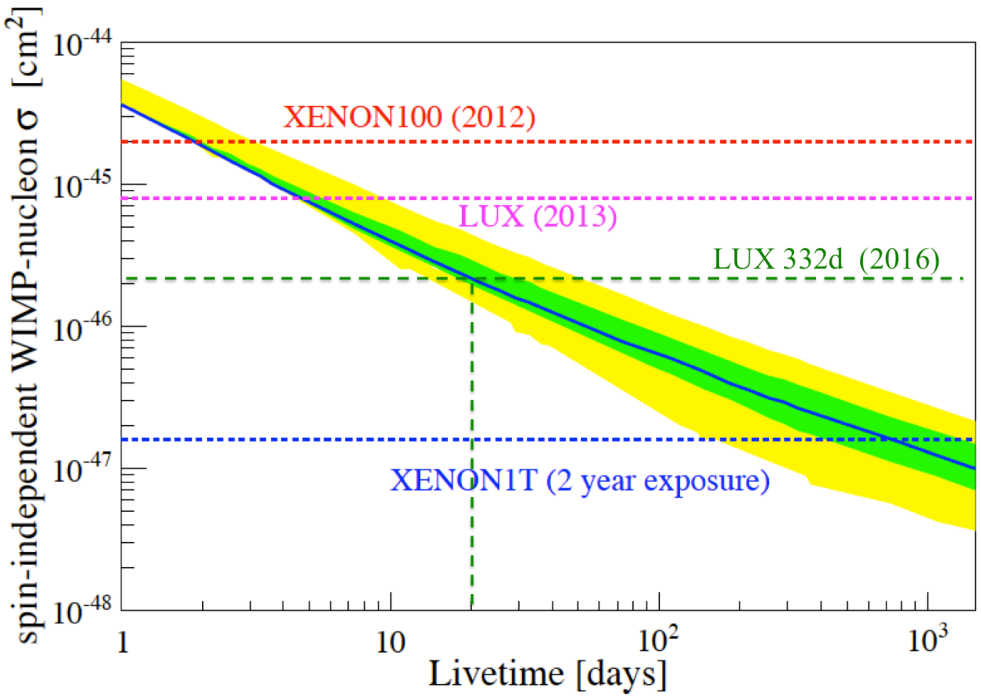


Outgassing



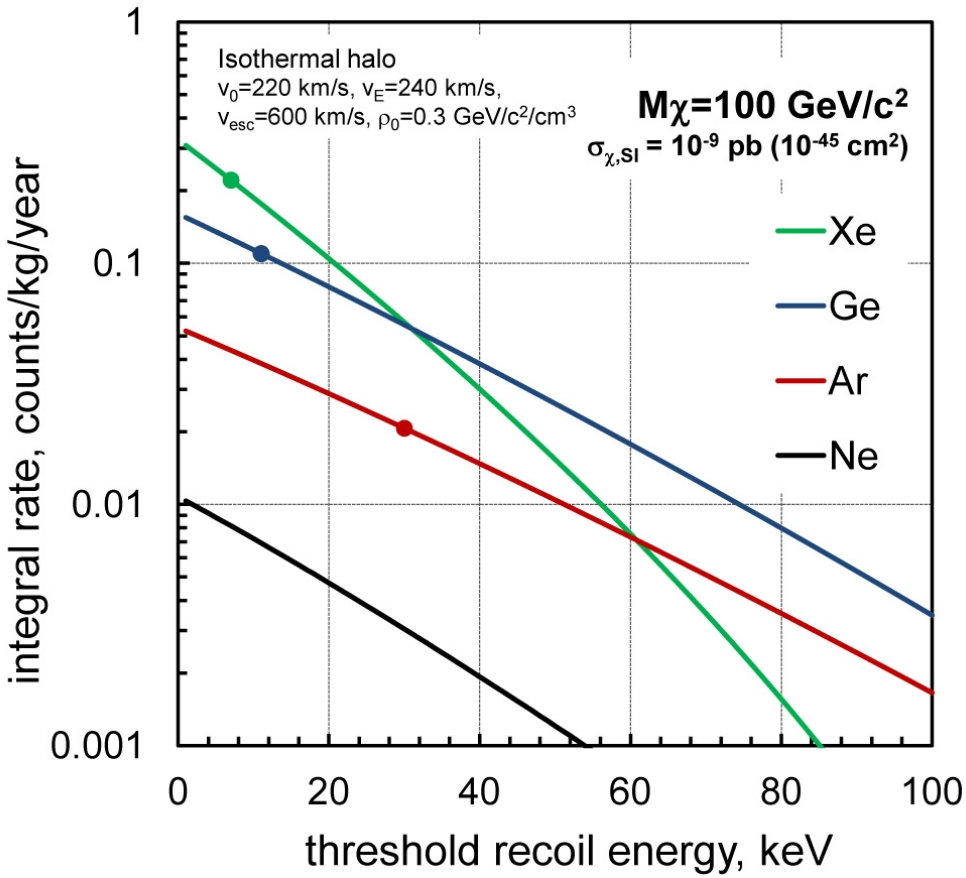
Conclusions

- XENON1T faces purity challenges new to direct detection
- Prototype for testing various components and design configurations
- Screening materials, high flow rate, and GXe circulation
- XENON1T science run expected by end of year



Why Xenon?

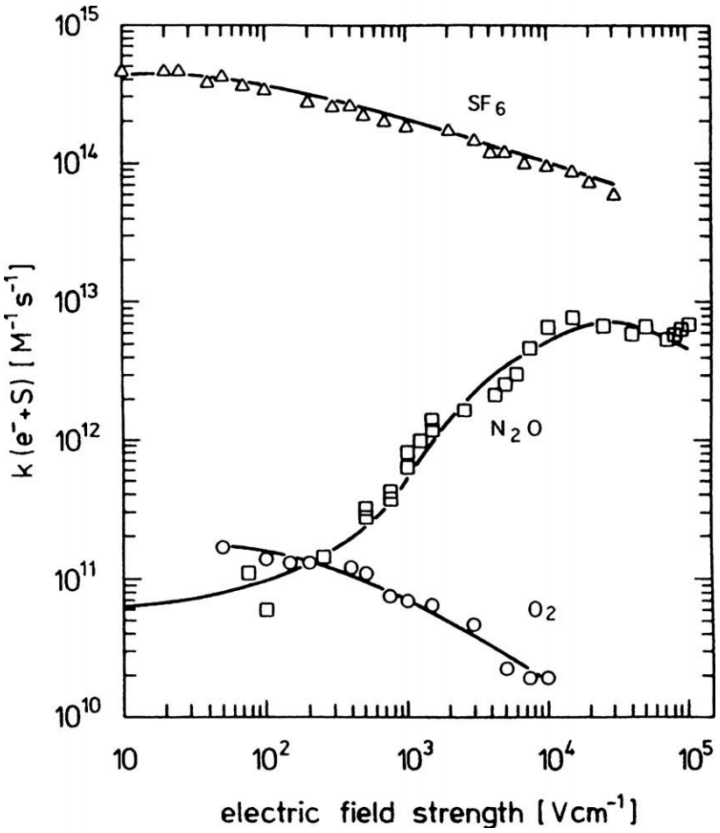
- **scalability**: ton scale detector at modest cost (~$2,000/kg)
- **Xe nucleus (A~131)**: expect high rate due to coherent scattering (goes as A^2)
- **50% odd isotopes**: 131 and 129, probe both SD and SI
- **intrinsically pure**: no long lived radioactive isotopes (besides Kr, which can be removed)
- **self-shielding**: high stopping power (Z=54) and density (2.8kg/l) density
- **charge and light**: highest yields among noble liquids. Simultaneously detected for NR discrimination. 3D event reconstruction.



SNOWMASS, arXive:1310.8327v2 (2013)

Impurity Attachment Rate

Attaching rate vs. electric field



G. Bakala, U. Sowadaand, and W. F. Schmidt, 1976, J. Phys. Chem. 80, 2556