Geant4 Requirements from the LZ Experiment

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on behalf of
the LZ Collaboration

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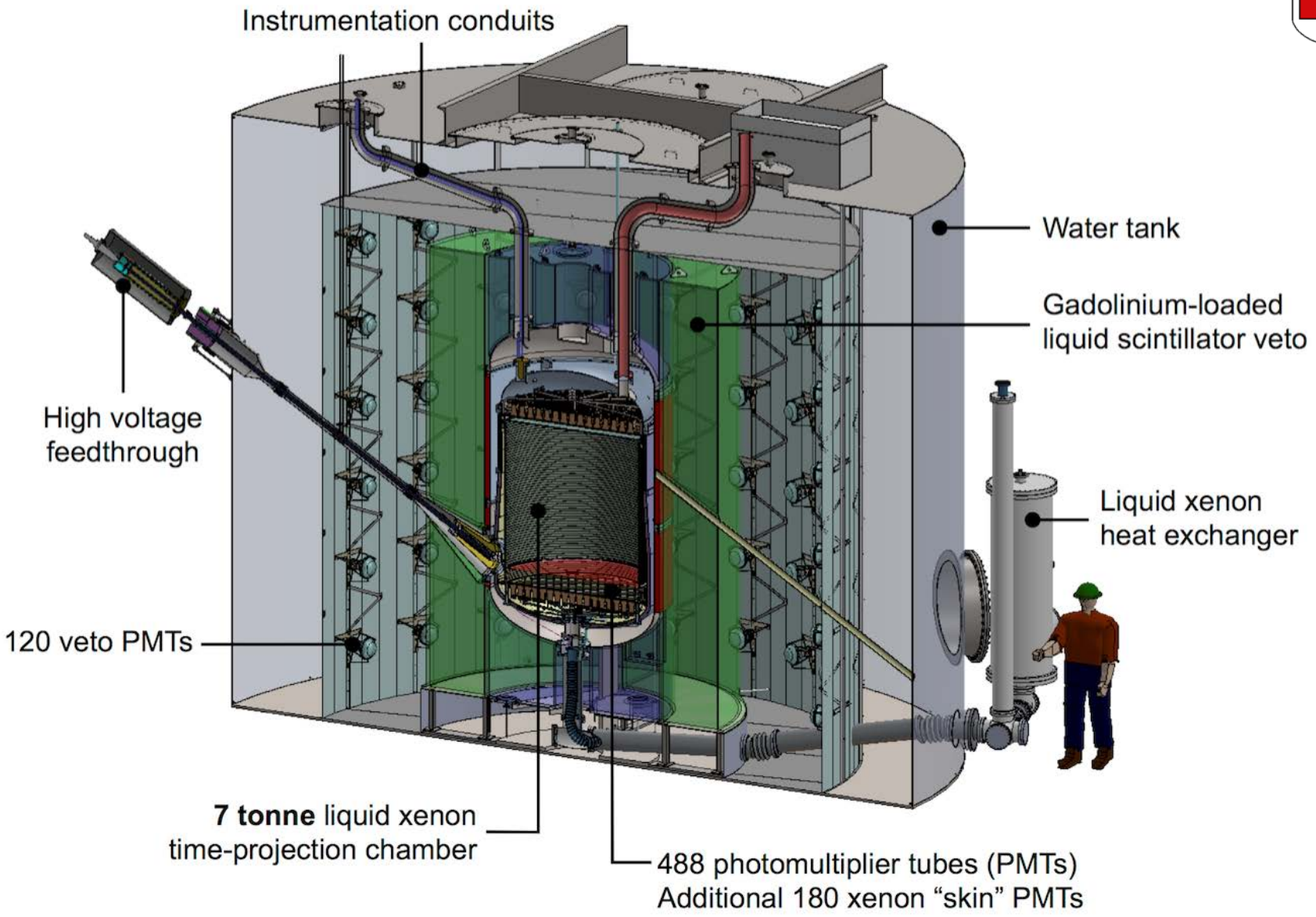
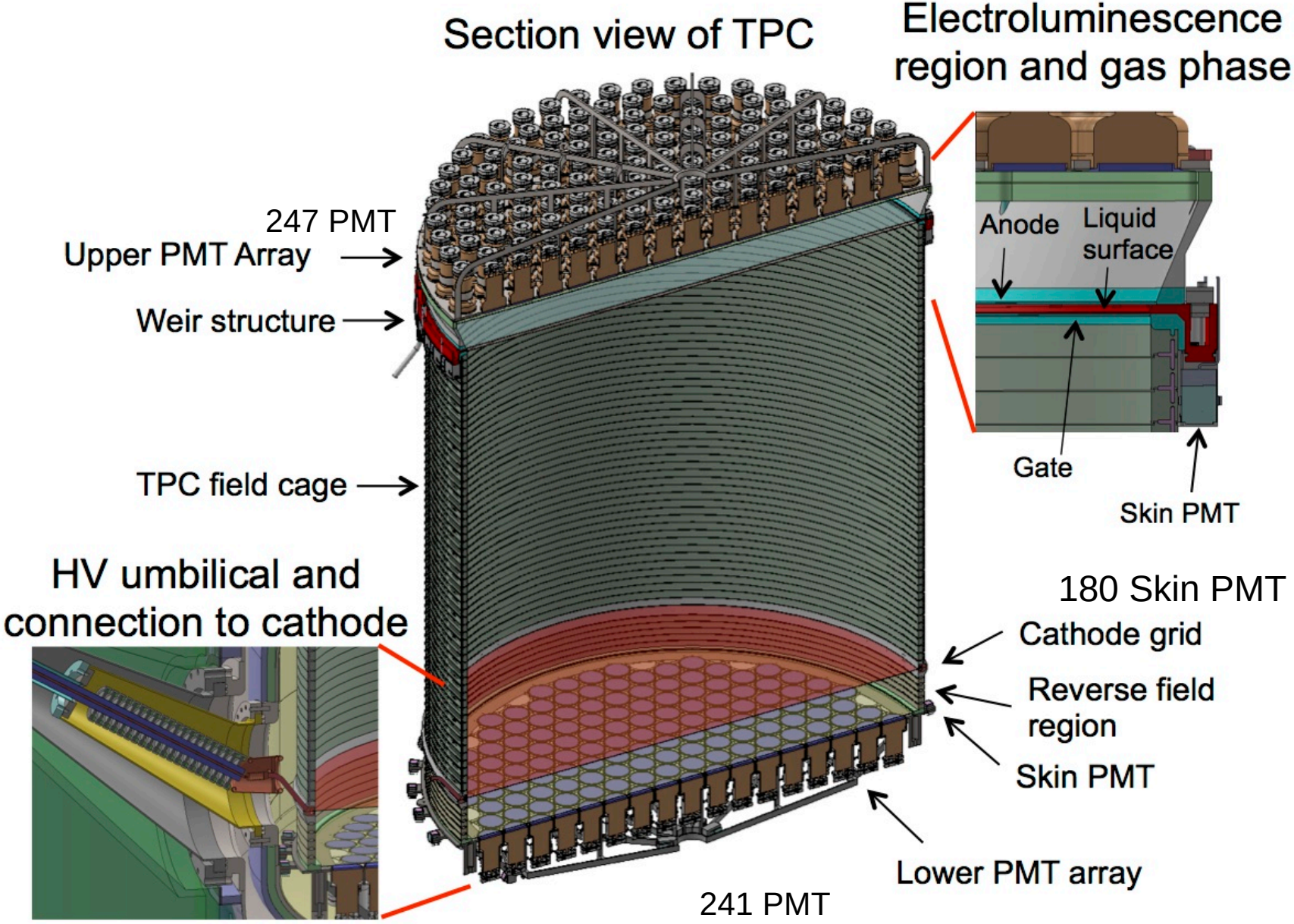
LUX-ZEPLIN Overview



The Xenon TPC Detector



Current Status of LZ Simulations

- **LUXSim / LZSim (latter has same codebase right now)**
  - Geant4-based package, with special volume properties to make any volume "sensitive detector" at run time, with "record levels" (LUXSim paper: arxiv.org/abs/1111.2074, from LUX)
  - Thoroughly vetted against experimental data from LUX
- **BACCARAT**
  - Detector-independent version of LUXSim (LUXSim without LUX or LZ geometries). Adoption by LZ is planned
- **NEST (Noble Element Simulation Technique)**
  - Detector-independent simulation code that works with Geant4
  - Models scintillation and ionization in noble liquids
  - Compatible with Geant4, but …
  - Integration issues with Geant4 when NEST overrides Geant4's scintillation mechanisms http://www.albany.edu/physics/NEST.shtml

Wish list for Geant4 – Low Energy Physics

- Updated neutron cross sections, down to thermal energies
  - Elastic cross sections for thermal neutrons on bound atoms as convenient option to replace standard cross sections
- Treatment of gamma cascades after neutron capture (Gd, Xe)
  - LZ will have Gd-loaded liquid scintillator around TPC as veto
- Shielding physics list for underground experiments should have all relevant processes on by default (e.g., muon-nuclear interactions)
- UV reflectivity data at cryogenics temperatures in RealSurface tables for Teflon/LXe and Teflon/GXe, plus other relevant interfaces (stainless steel for grid wires, aluminum, etc.)
  - Complicated profiles of reflectivity as functions of angle and wavelength, mixed between specular and diffuse
- Generators for spontaneous fission and (α, n) reactions that handle multiplicity of gammas and neutrons produced
- Time step precision of 28 significant figures to support nanosecond accuracy over billions of years for radioactive decays

Wish list for Geant4 -- Infrastructure

- **Easier updating to newer versions of Geant4**
  - **LUXsim and LZsim still on 4.9.4 patch 4**
  - **LZsim uses 4.9.5 patch 2 for some studies**
- **Convenient geometry conversion from CAD or CAD-like programs**
- **Integration of Geant4 and Gaudi (LZ analysis framework)**
- **Ability to run NEST as Geant4 module with external API call-back to allow G4Scintillation to persist for non-nobles on its own**
- **More robust visualization (breaks easily with high complexity)**
- **Method for resetting global time for a Geant4 event**
- **Faster VUV photon propagation, ala RAT/Chroma using GPUs**
  - **Especially challenging when millions of photons are created by individual "high-energy" (O(100) keV) calibration events due to electroluminescence in the gas**
- **Quantum efficiency simulation of different photo-detectors**
- **Photon group velocity ill-defined when refractive index too discrete**

Wish list for Geant4 – Validation

- Neutron production in muon showers at the %-level
- Can we find synergies in validation of generators?

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