After LUX: The LZ Program

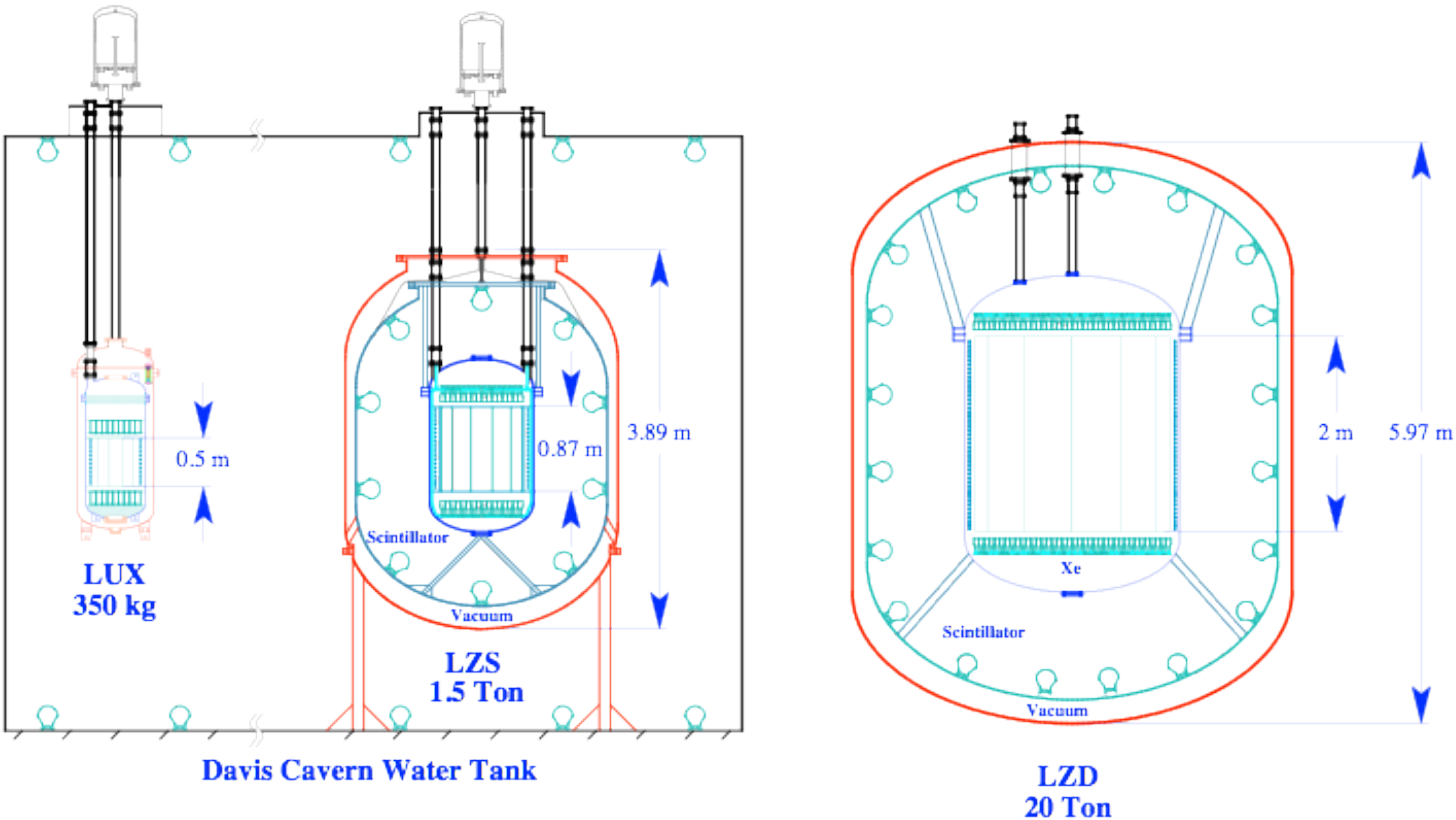
David Malling
Brown University
Brookhaven Forum 2011
October 20, 2011

BROWN

The LZ Program

- LZ ≡ LUX-ZEPLIN
- LUX (14 U.S. institutions) + new collaborators from ZEPLIN, other U.S. institutions
- Two phases
  - LZ-S (1.5T - 3T)
    Construction early 2013; running 2014-2016
  - LZ-D (20T)
    Construction 2014; running 2018 onward

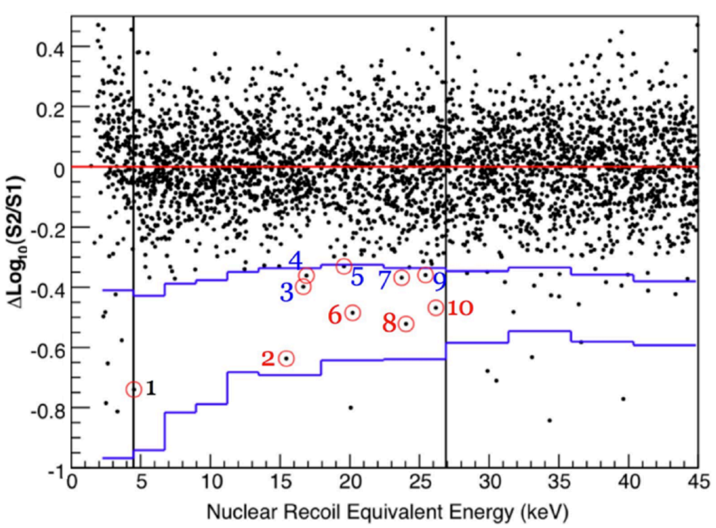
LZ at a Glance



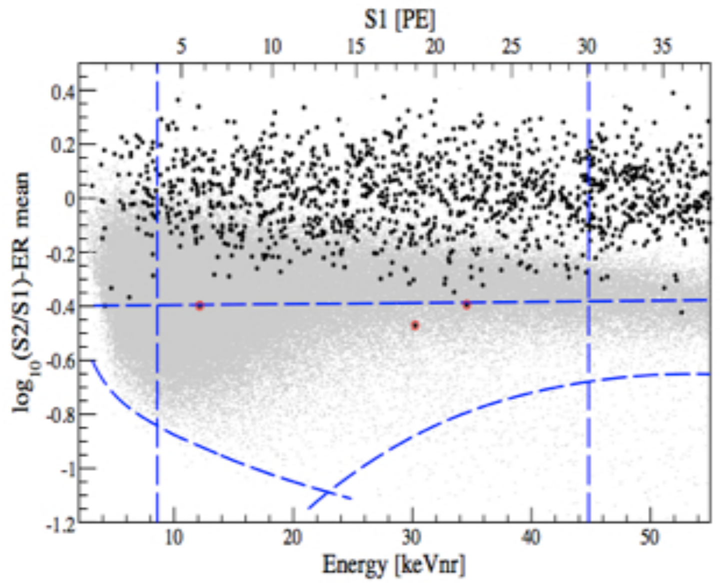
BG Subdominance

- Goal for next generation detectors: Move into a mode where signal dominates over background

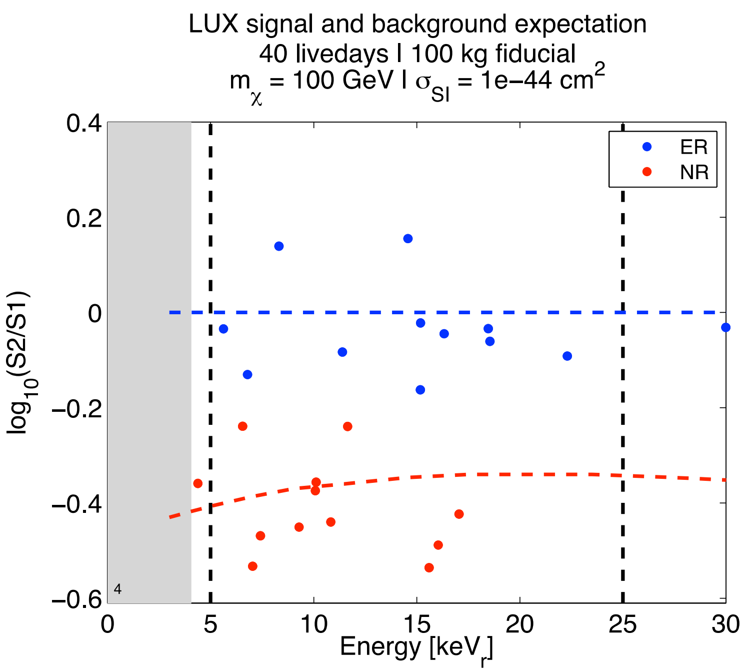
XENON10



XENON100



LUX



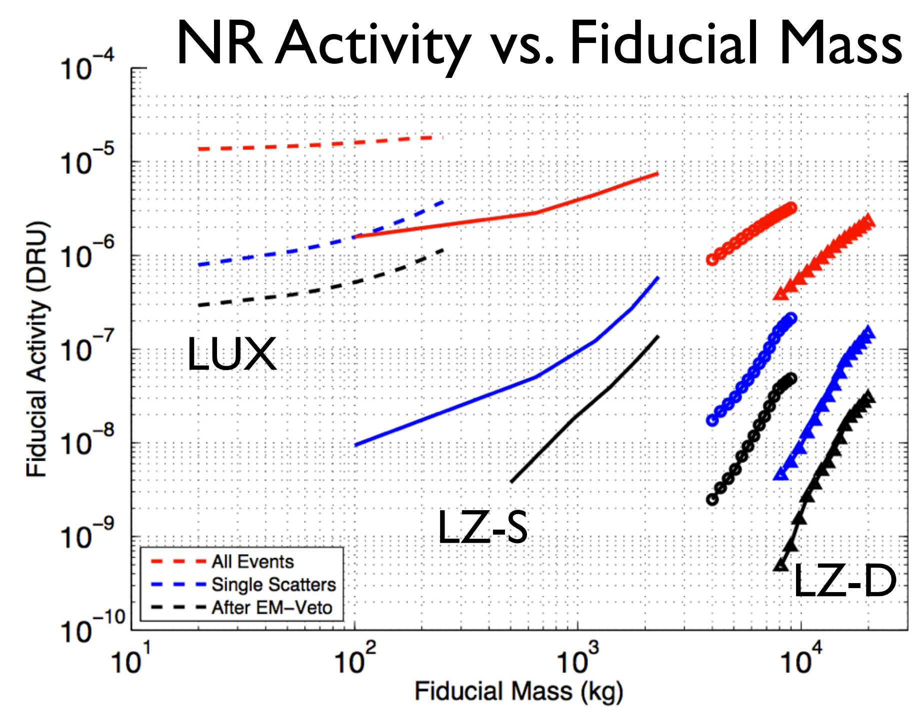
BROWN

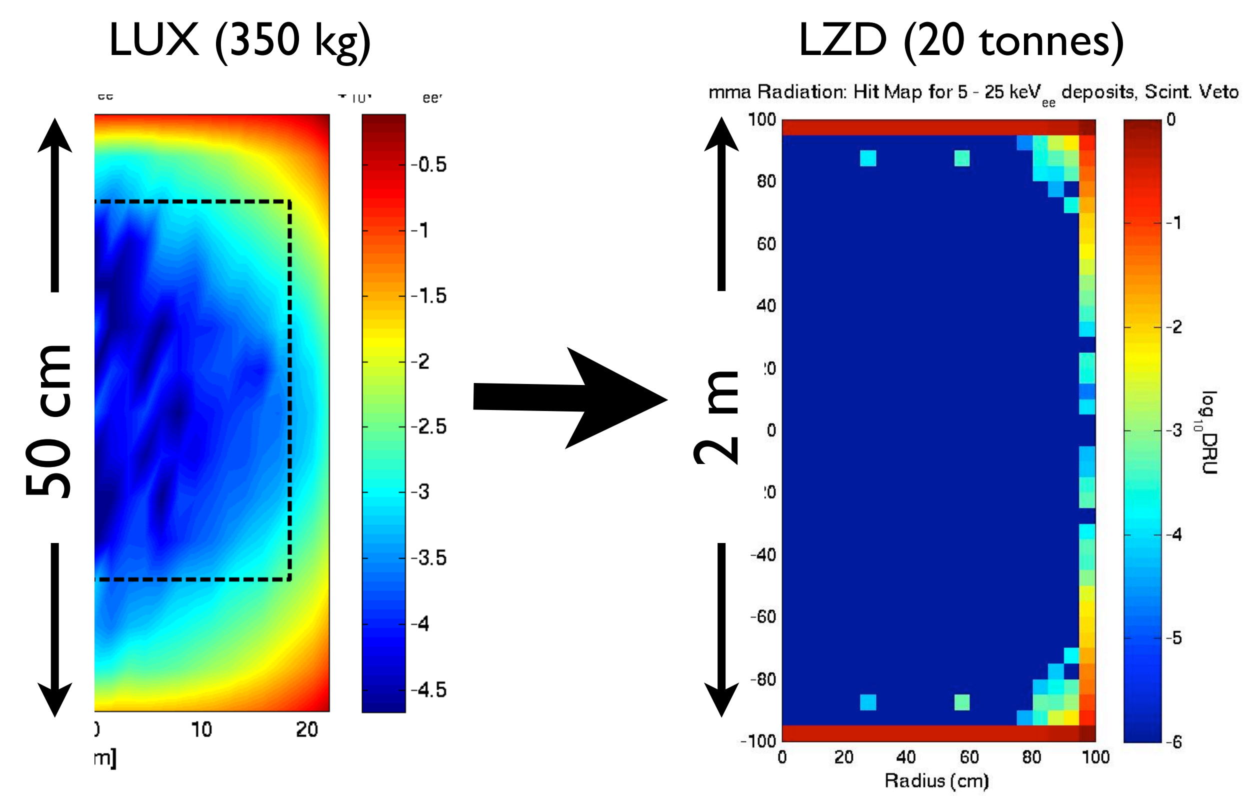
BG Subdominance How?

- More mass => greater self-shielding
- Improved library of low-background materials
- Extensive study of intrinsic / cosmogenic backgrounds
- Massive external shielding
- Aim to push detector backgrounds below floor created by neutrinos

Xe Self-Shielding

- Low-energy / single-scatter requirement heavily suppresses backgrounds in detector center
- Growth in linear dimension enhances self-shielding against BG
- Can encompass larger fractions of total target mass within fiducial region





BROWN

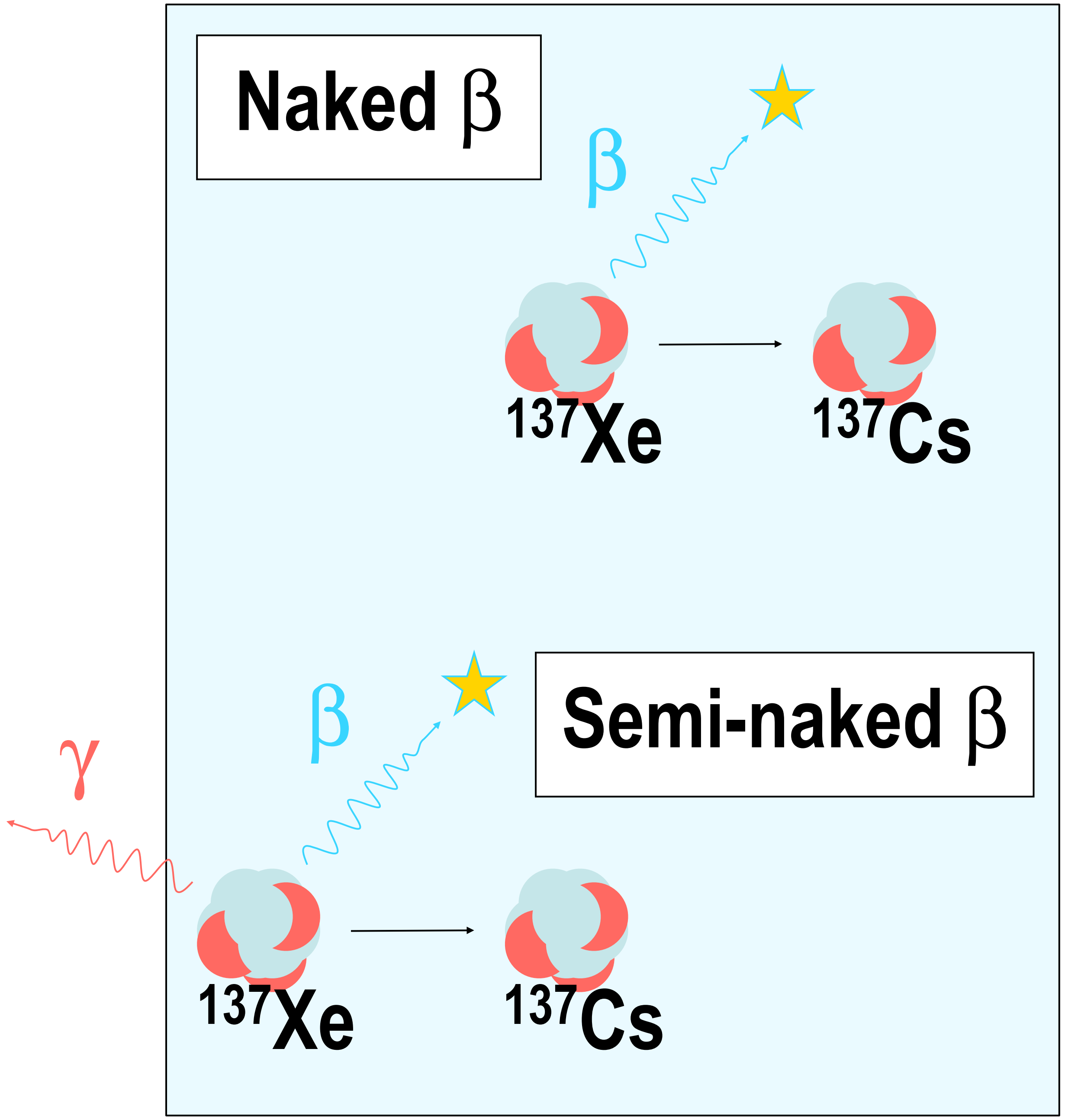
Ultra-Radiopure Materials

- Backgrounds traditionally dominated by PMTs, cryostat materials
- PMTs
  - Increase photocathode area => fewer PMTs overall
  - Reduce radioactivity
  - LZ candidate PMT Hamamatsu R11410 MOD: <0.4 ^{238}U / <0.3 ^{232}Th mBq/PMT
    - Better than LUX PMTs by x1/20 ^{238}U / x1/9 ^{232}Th, concurrent with doubling of photocathode area
- Cryostats
  - Ti new favored material: strong, light, radiopure
  - LUX Ti cryostats: BG expectation <0.02 WIMP-like evts during experiment lifetime
- LZ internal backgrounds: <1 WIMP-like evt / 1000 livedays / 13.5 T fiducial

R8778 R11410 MOD

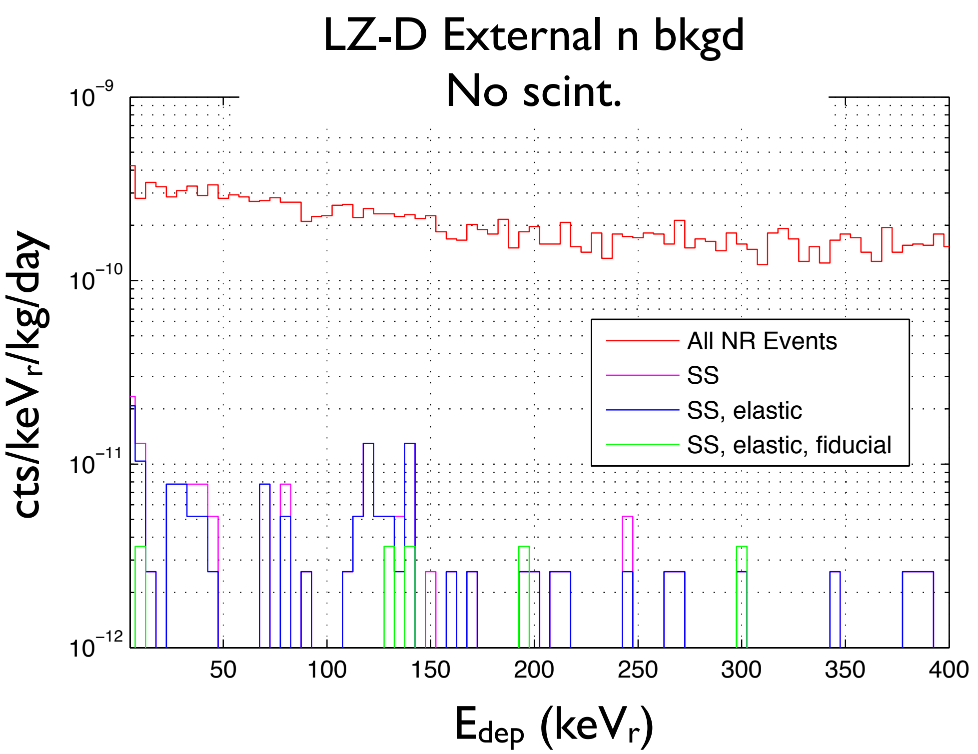
Intrinsic Backgrounds

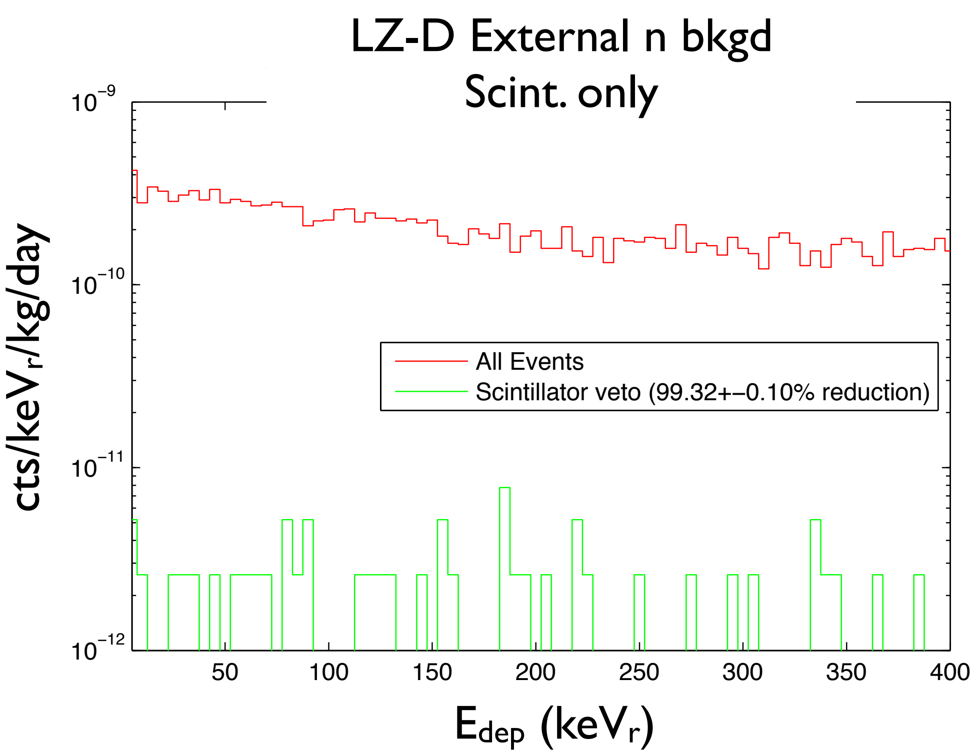
- LZ-D Xe mass x67 above LUX -- must search for cosmogenic products previously overlooked
- Xe activation by muon capture, neutron capture, fast neutron activation, etc.: >200 isotopes produced
- Only worry about naked or semi-naked beta emitters
- ~10^{-7} /keV/kg/day event rate, primarily from fast neutron activation (^{137}Xe) (0.04 evts / 1000 livedays / 13.5 T fiducial)



External Backgrounds

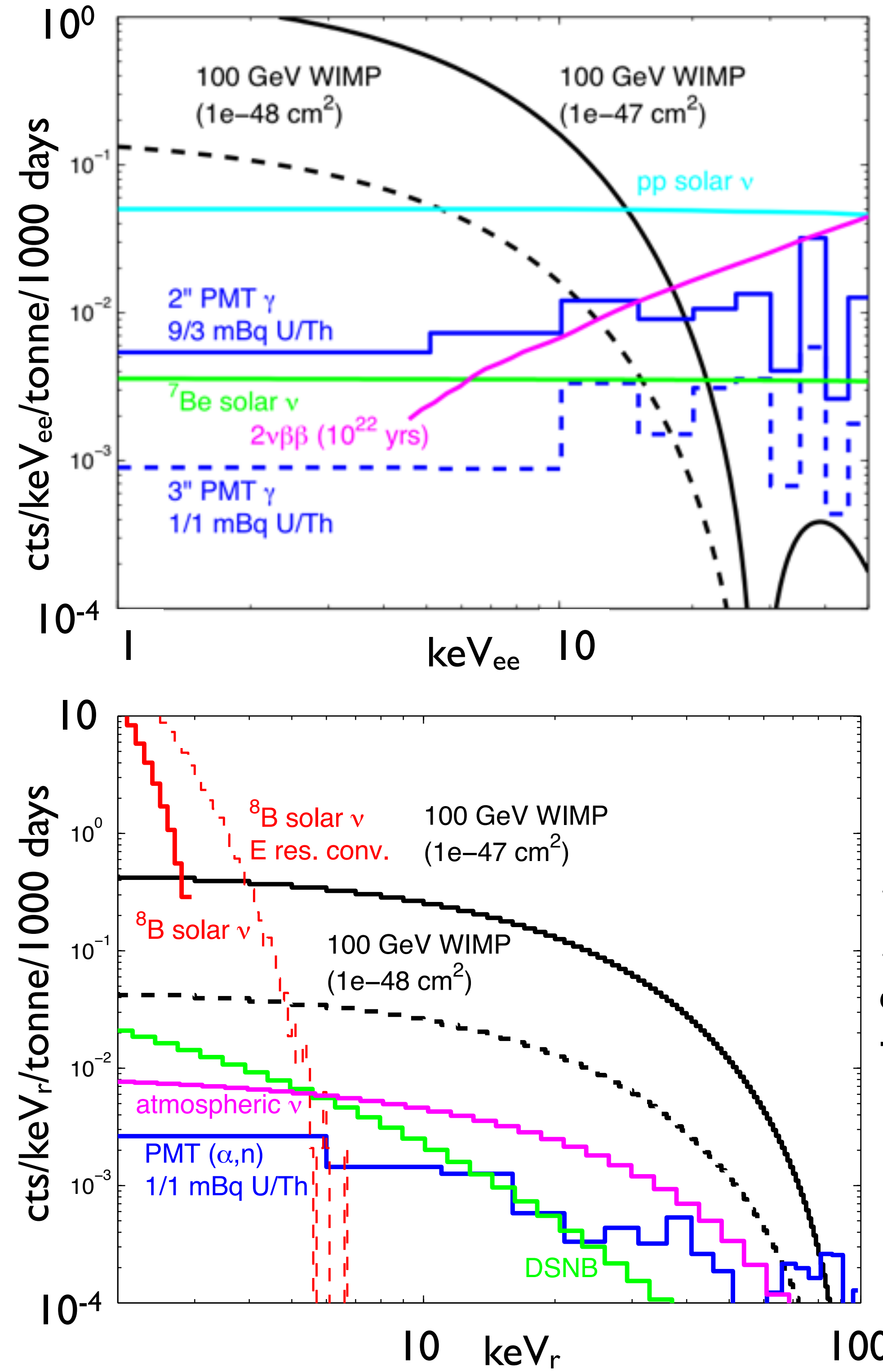
- LZ-D uses 12m x 12m water shield instrumented as Cherenkov detector / veto
- Water shield alone reduces fast neutron BG <0.05 WIMP-like evt / 1000 days
- Addition of scintillator veto: x1/100 further suppression
- Further factor of x1/100 reduction from standard analysis cuts
- Comparable reductions in neutrons produced in water shield itself
- Conservative estimates ignore Cherenkov veto, shower correlations, etc.





Neutrino Backgrounds

- Dark matter signal search fundamentally limited by neutrinos
- Electron recoil signal limited by p-p solar neutrinos
  - LZ-D: 5 evts (1-10 keV_{ee}) / 1000 days before ER rejection
- Neutron recoil signal limited by coherent neutrino scattering
  - ^{8}B
  - DSNB
  - Atmospheric
  - LZ-D: ~1 evt (5-25 keV_r) / 1000 days

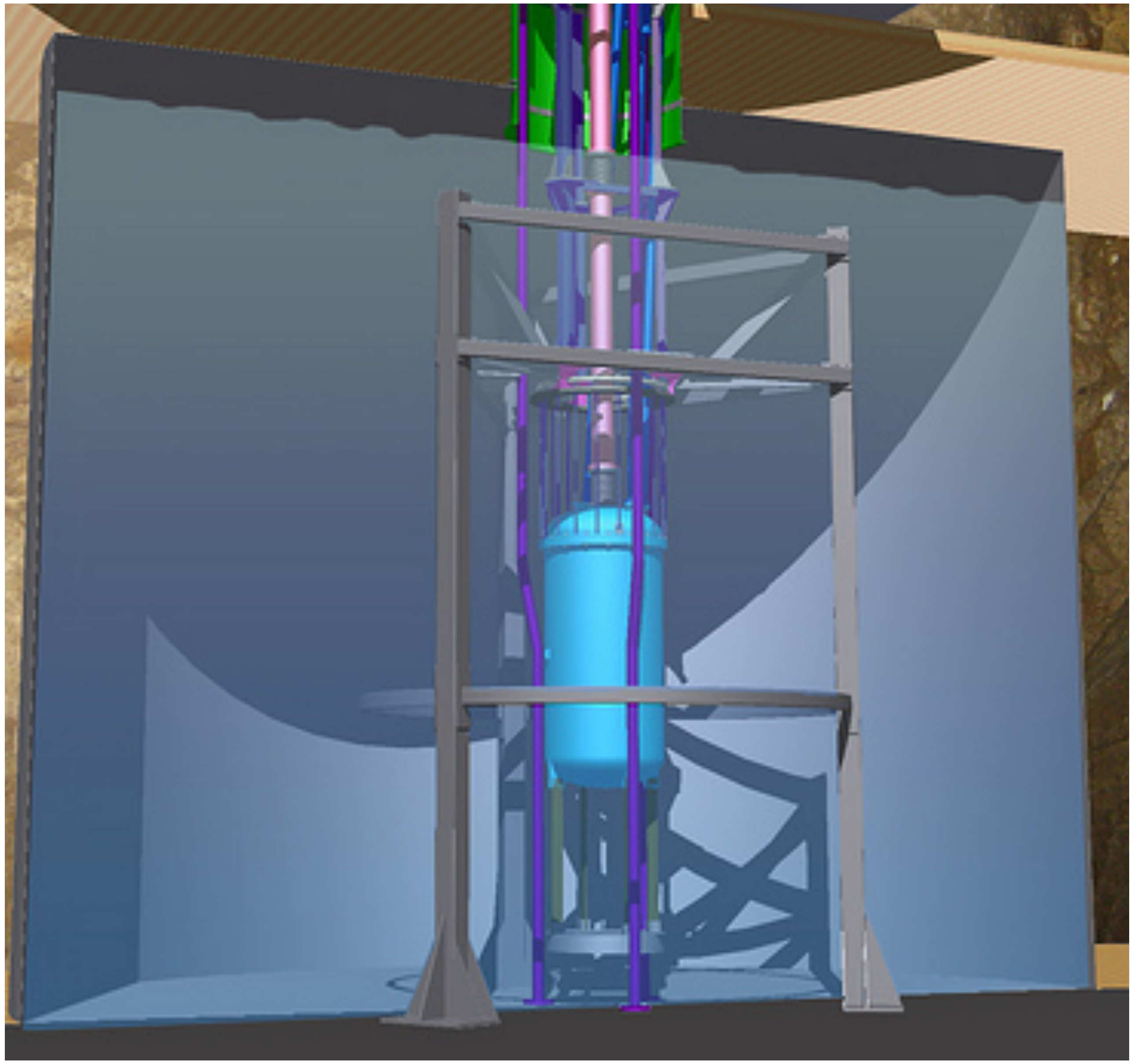


L. Strigari
arXiv:0903.3630

BROWN

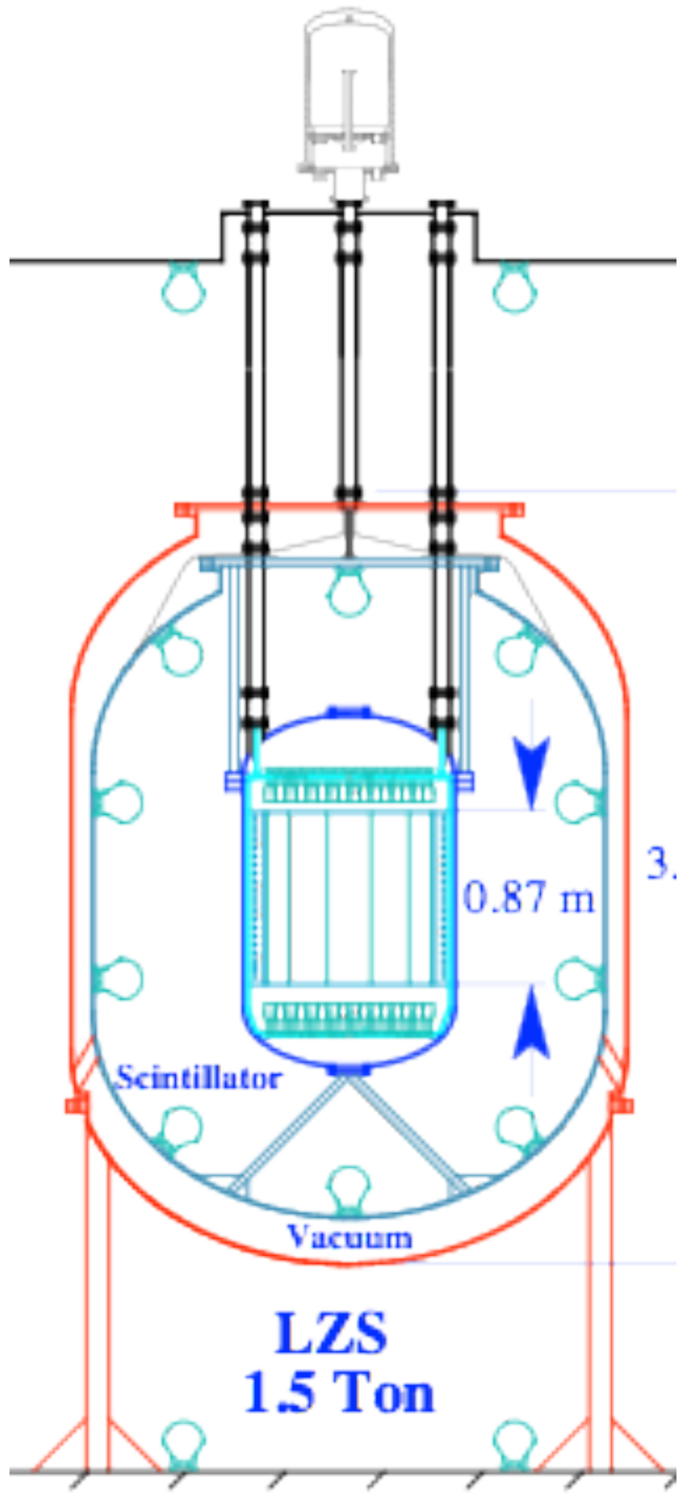
LUX Innovations for LZ

- Davis Cavern infrastructure, water shield: ready for up to 3 ton instrument
- Heat exchanger, high flow rate Xe purification system
- Remote feedthroughs and cryogenics
- Low-background titanium cryostat & internal materials
- Scalable internals construction
- Scalable trigger and DAQ (DDC-8)
- ^{83m}Kr, ^{3}H calibration sources
- Automated Control and Emergency Recovery systems



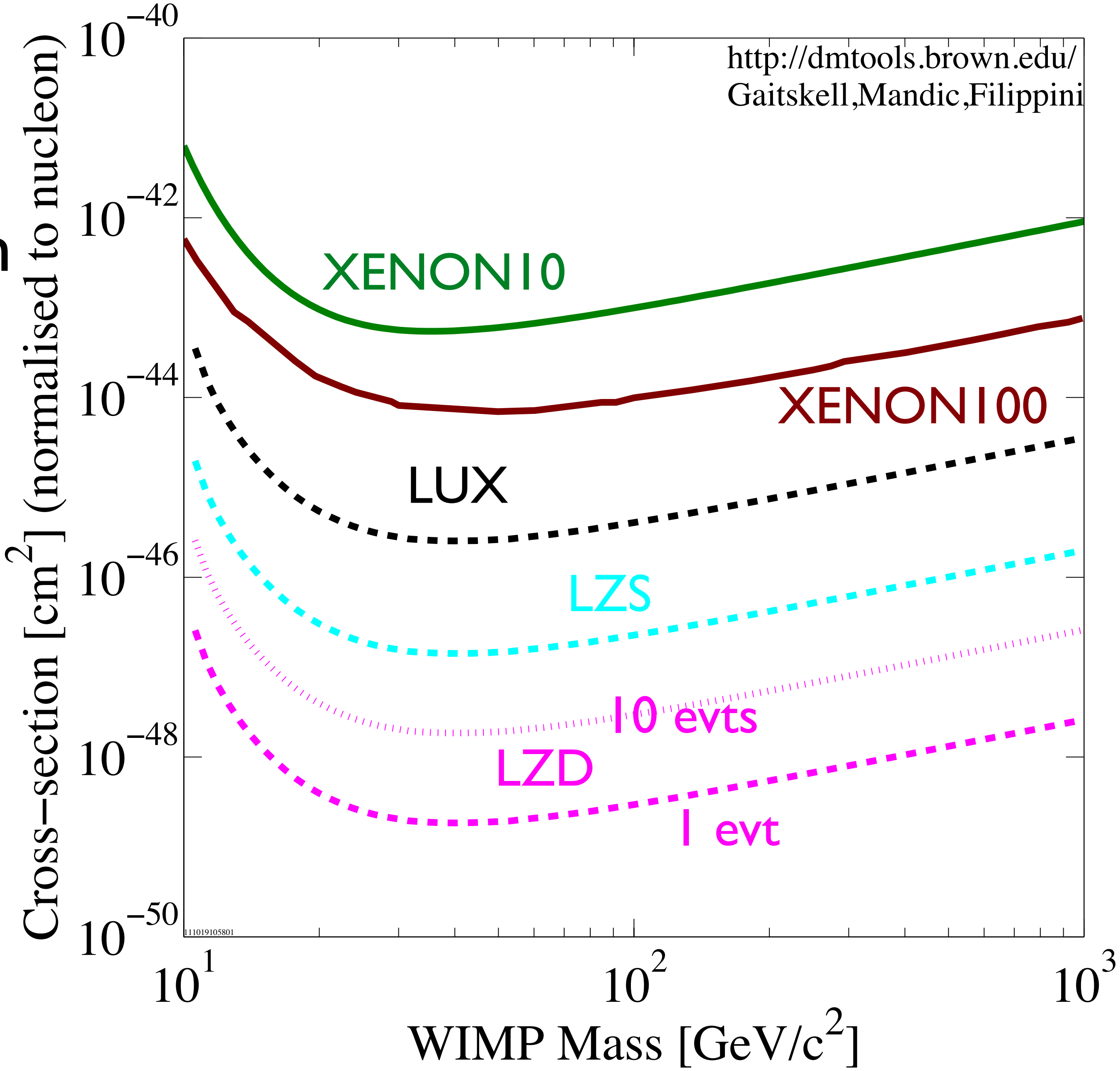
LZ Innovations

- 3" PMTs at <1 mBq $^{238}U+^{232}Th$
- Liquid scintillator shield/veto
- Internal active plastic veto
- Internal imaging system



SI WIMP Sensitivity

- Fiducial volumes for projections selected to match <1 NR event in experiment lifetime
- LUX (black): 100 kg x 300 days
- LZ-S (cyan): 1200 kg x 600 days
- LZ-D (purple): 13500 kg x 1000 days



BROWN

Summary

- Goal of next-gen detectors: virtually 0 BG during WIMP search -- WIMP signals should stick out clearly
- LZ tonne-scale Xe detectors will use technology tested in LUX
  - Cryogenics, purification, low-background construction materials, internal calibration sources, etc.
- LZ-D will push LXe dark matter detection to its final limit from neutrino signals
- More information on LZ: arXiv:1110.0103