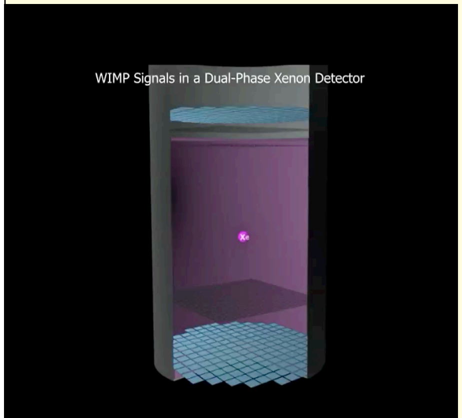
The LZD experiment

T. Shutt
On behalf of the LZ collaboration

LZ detector: 2 phase TPC

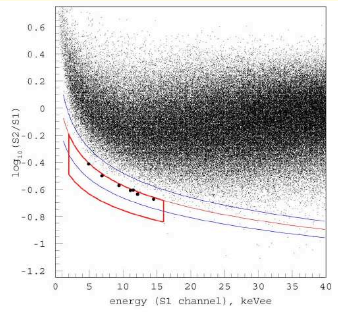
- Technology developed by Zeplin II, XENON10, Zeplin III
  - Powerful 3D imaging reduces backgrounds
  - Intrinsically clean
  - Charge + light electron recoil discrimination
- LUX design: explicit goal of scalability to multiple tons



A. Bolozdynya, NIMA 422 p314 (1999).

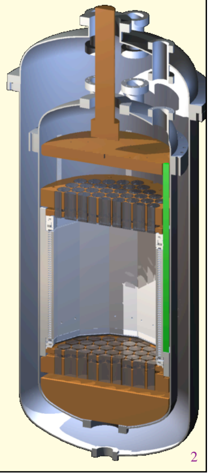
Zeplin III

background discrimination



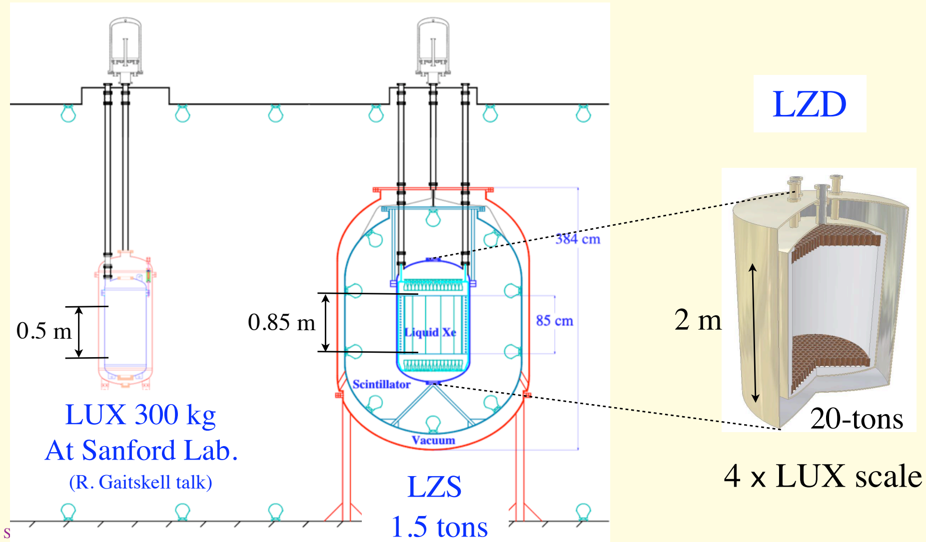
LUX

detector

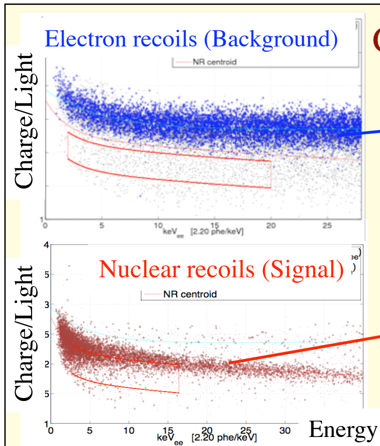


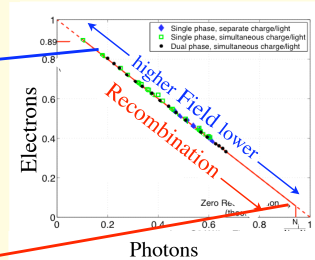
The LZ program

- LZ: LUX + ZEPLIN III + new US and European groups
- LZS: 1.5 ton instrument for Sanford Lab, just proposed.
- LZD: Scale based on technically feasibility, cost.

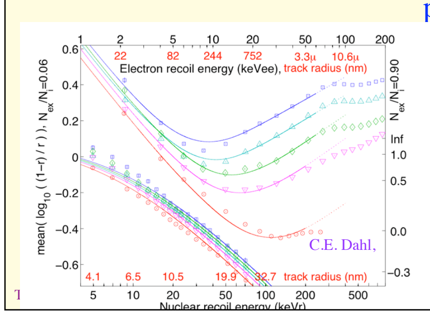


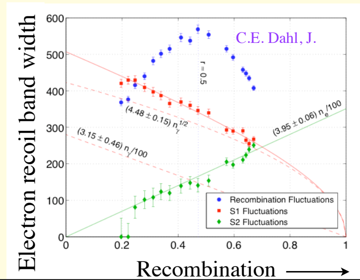
Charge / Light Background Discrimination





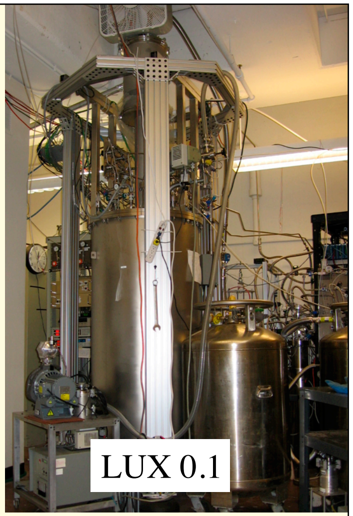
- Xe Background rejection: > 10^2, possibly much higher, down to 5 keVr
- Sophisticated understanding of underlying processes in Xe (probably applies to Ar).

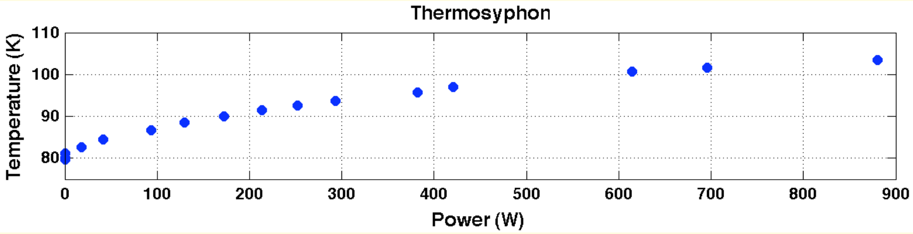




Demonstrated Cryogenics

- LUX_0.1: Full sized high-background prototype of LUX cryostat.
- Final cryogenics, Xe handling.
- Thermosyphon-based cryogenics suitable for very large scale.
  - Capacity.
  - Multiple cold head deployment

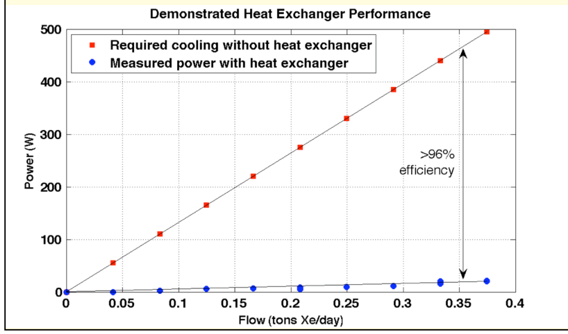


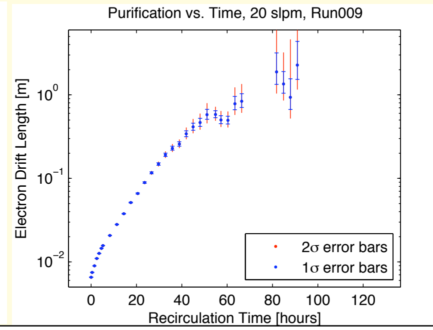


Demonstrated High Capacity Purification

- Standard gas-phase commercial getter + custom heat exchanger system
- >96% efficient heat exchanger at 0.4 tons/day
- 2 m drift length in 60 kg Xe, achieved with unprecedented speed
- Method scalable to multi-ton Xe/day processing

- R&D: knowledge of impurities, analytical capability, liquid-phase purification.

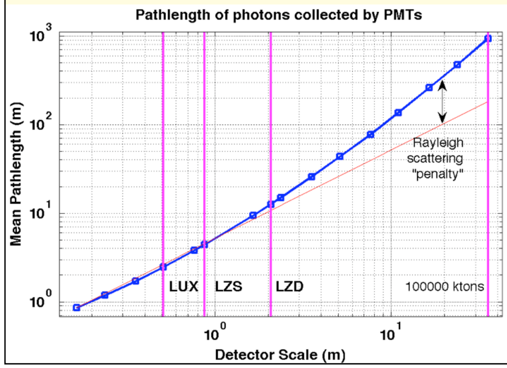


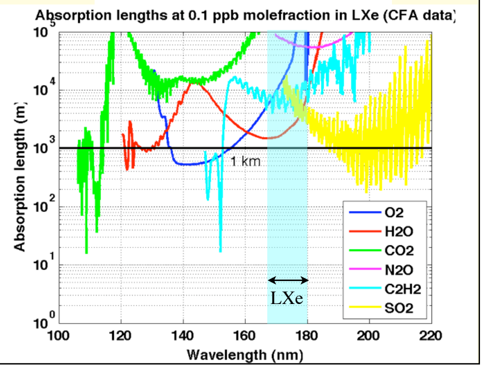


Light collection at large scales

- PTFE walls: extraordinarily reflective at 175 nm (7eV)
  - Should be verified independently.
- Rayleigh scattering not yet dominant
  - *Light collection independent of size (with low absorption) well past 100 tons.*
- We predict > 70% light collection with top/bottom PMT coverage.
- Absorption: Need ~0.1 ppb of common gasses, comparable to requirements for charge drift

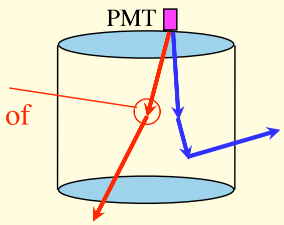
0.1 ppb: 1 km => <2% loss



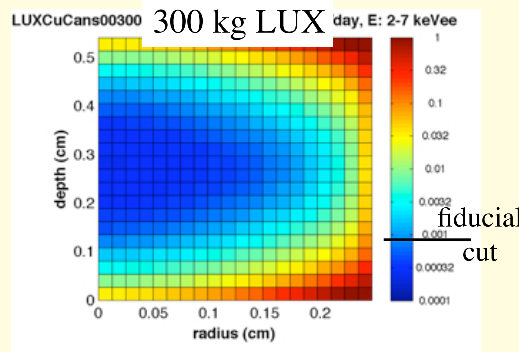


Backgrounds

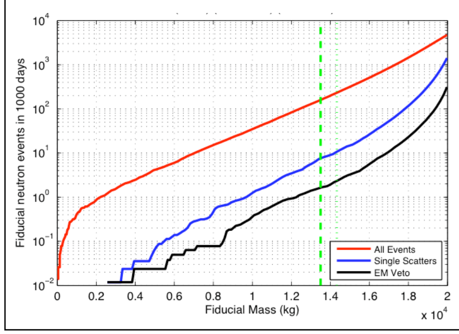
Dominant Background: single, low-energy scatter of MeV gammas from PMTs

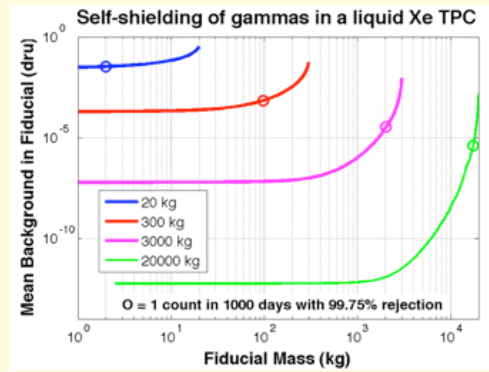


Shielding effective when $L > \lambda$:
Mass ~300 kg and up



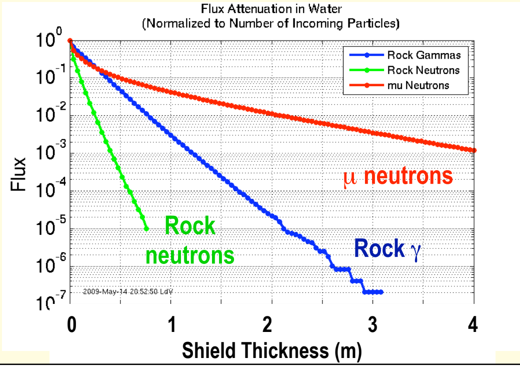
Neutrons in 20 ton LZD





Shielding

- 4 m water shield + 4850 ft depth adequate up to at least 20 ton scale.
- Liquid scintillator shield: primary option beyond S4 baseline.
  - Being developed for LZS (1.5 ton): gammas reduced by 50, neutrons by >10.
  - Cold scintillator: maximum efficiency, safety.
- Titanium cryostat material
  - Significant new construction material for low background experiments
  - No measured contamination at limits of Oroville capability (< ~0.2 mBq/kg)
  - Enables active shield

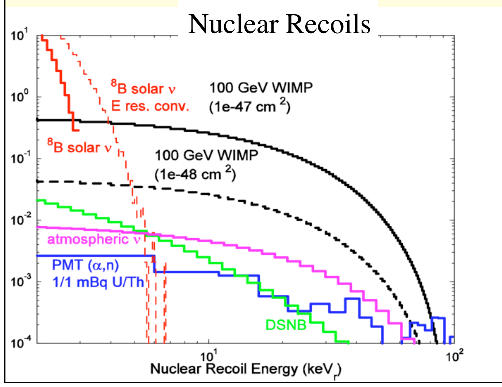


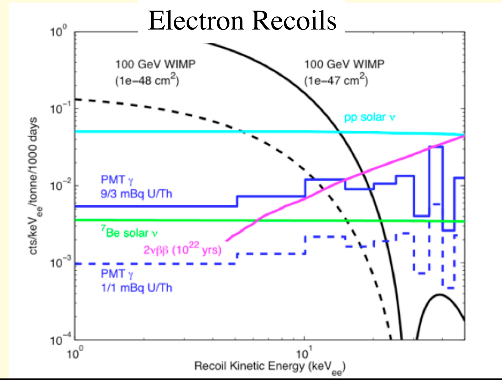
Internal backgrounds

- Noble gasses *significantly* easier to purity than water, scintillator: Borexino, SNO.
  - Goals less stringent than achieved in Borexino, SNO.
  - Primary internal backgrounds: Rn + daughters, Kr, Ar.
  - Vacuum vessel much better platform for controlling gaseous impurities.
- ^{85}Kr
  - Conservative goal for 20 tons scale: 10^{-14} Kr/Xe.
  - First attempt chromatographic system: 2 kg/day, < ~2 ppt
    - 20 tons: Simple scaling of column, increased concentration measurement.
- Rn: require ~ mBq in detector. Compare: μBq SNO, Borexino.
- Other gasses: ^{3}H, ^{14}C.
  - Requirements less than for charge drift.
- Solids, ions: readily filtered, chemically removed.

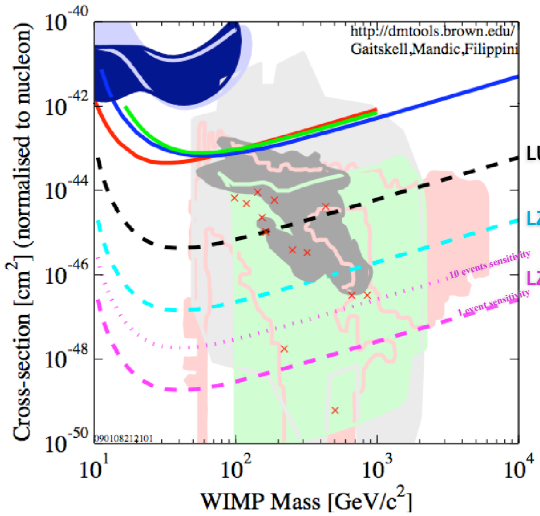
Backgrounds and Sensitivity

- Electron recoil signal limited by p-p solar neutrinos
  - Subdominant with current background rejection.
  - ^{136}Xe subdominant to pp neutrinos at WIMP energies.
- Nuclear recoil "background": coherent neutrino scattering
  - ^{8}B solar neutrinos
  - Atmospheric neutrinos
  - Diffuse cosmic supernova background





LZ Program - WIMP Sensitivity

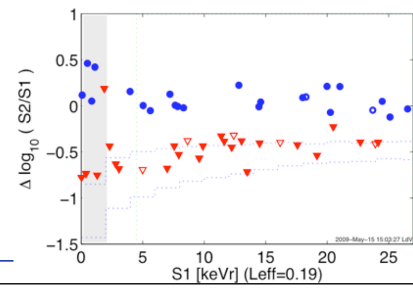


- Projections based on
  - Known background levels
  - Previously obtained e$^-$ attenuation lengths and discrimination factors
- < 1 NR background in full exposure fiducial

LUX (constr: 2008-2009, ops: 2010-2011)
100 kg x 300 days

LZS 3 T (constr: 2010-2011, ops: 2012-2013)
1,500 kg x 500 days

LZ20 (constr: 2013-2015, ops: 2016-2019)
13,500 kg x 1,000 days



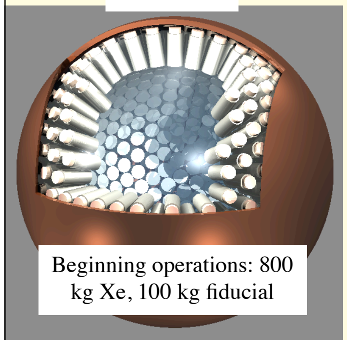
Other physics

- Reasonable sensitivity to neutrinoless ßß decay of ^{136}Xe
  - With current PMT backgrounds: $t_{1/2}$ =1.3x10^{26} yr.
  - With 1 mBq/PMT: $t_{1/2}$ =3.5x10^{26} yr, m_{nu}=66 (170) meV QRPA(NSM).
- At 20 tons, begin to measure coherent neutrino scattering:
  - ^{8}B solar neutrinos
  - Atmospheric neutrinos
  - Diffuse cosmic supernova background
- pp solar neutrinos: well-defined target mass, background-free for energies below ~50 keV.

International Context for Xe

- Zeplin III group: proposed to STFC as part of LZS, overall commitment to DUSEL program as LZ partner
- Very strong DUSEL-era competition:

XMASS



Beginning operations: 800 kg Xe, 100 kg fiducial

DUSEL era: 10 tons Xe

European Effort

DARWIN
(DARk matter WImp search with Noble liquids)

- Design study for **Next-generation noble liquid facility in Europe** submitted (in response to the first ASPERA common call) on June 4th, 2009, 3:57 pm
- **Goals:**
  - ➡ **unify and coordinate extensive existing expertise in Europe** (XENON, WARP, ArDM plus new groups, including US groups from XENON and WARP)
  - ➡ **study both argon and xenon as WIMP target media** and provide recommendation for facility (full technical design report) in 2-3 years from now
  - ➡ submit full proposal in response to second ASPERA call
- **Possible locations**: LNGS (Italy), ULISSE (Modane extension, France), or SUNLAB (Poland)
- **Participants: Switzerland** (ETHZ, UZH), **Germany** (MPIK, KIT, Münster), **France** (Subatech), **Italy** (INFN: L'Aquila, Milano, Napoli, Padova, Pavia, Torino), **Netherlands** (Nikhef), **Poland** (IFJ PAN, US, PWr), **USA** (Columbia, Princeton, Rice, UCLA)
- **CH:** UZH **L. Baudis (PC)**, A. Ferella, T. Marrodan, M. Schumann, R. Santorelli, T. Bruch, A. Manalaysay, A. Behrens;
- UZH: **C. Amsler**, C. Regenfus, P. Otyugova, L. Scotto, W. Creuss; ETH: **A. Rubbia,** A. Badertscher, A. Marchionni, A. Curioni, S. Horikawa, L. Epprecht, F. Resnati, D. Lussi, U. Degunda, C. Lazzaro
- **Funding:** provided by the national instruments of each participant ('virtual pot')
- **Decision:** expected in fall 2009, start in October 2009

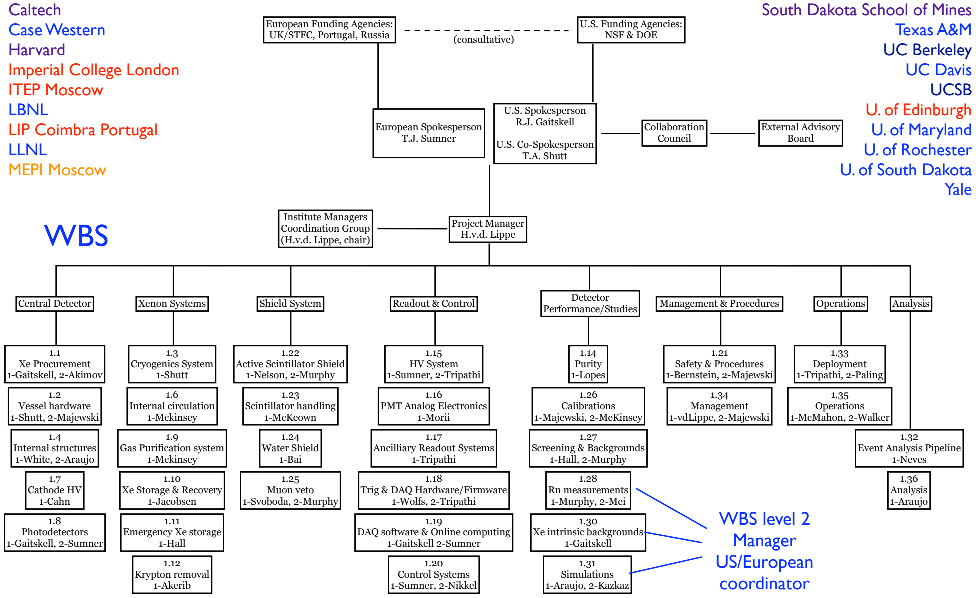
Laura Baudis, University of Zurich, CHIPP Plenary Meeting, Appenberg, August 24-25, 2009

Tuesday, August 25, 2009

LZ Governance Structure

Brown
Caltech
Case Western
Harvard
Imperial College London
ITEP Moscow
LBNL
LIP Coimbra Portugal
LLNL
MEPI Moscow

RAL UK
South Dakota School of Mines
Texas A&M
UC Berkeley
UC Davis
UCSB
U. of Edinburgh
U. of Maryland
U. of Rochester
U. of South Dakota
Yale



Baseline LZD Design

- S4 proposal - 20 ton version fully analyzed
- Water shield deployment method based on LUX developments
- *In hand* PMTs, Ti, other materials
  - Expect factor of several improvement
- Conservative background discrimination: 99.5%
  - Zeplin III result: x10 better discrimination
- Light collection from XENON10
  - LUX 0.1: 8 pe/keVeezf - factor of ~1.8 better.
- No liquid scintillator shield
  - Additional gamma reduction by 10-100, neutron reduction > 10.
- Custom DAQ electronics under development by LUX
- Most internal backgrounds well below state-of the art
  - Rn levels well below current limits
  - Kr just beyond current capability

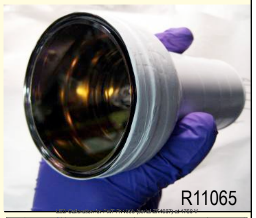
Development program

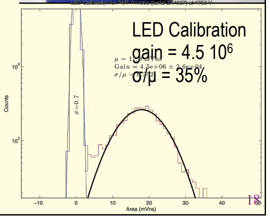
- Bread and Butter design / development:
  - Large-scale vessels, tank mechanics, infrastructure -> PDR
  - Internals: 2m Ø grid structures
  - Cryogenics
  - Control systems
  - Kr removal at larger scale
  - Rn emanation, Rn in water, Rn plateout
  - Liquid scintillator
- Key Developments to reduce risk:
  - Internal sources
  - PMTs: 3” tubes, with reduced activity
  - Xe procurement. Buyback scheme, procurement schedule.
  - High voltage feedthrough
- Safety Development
  - Xe storage and emergency recovery.
  - Cryogenic Safety
  - Ice Shield
- R&D to reduce risk
  - Impurity analytical techniques, trapping cross section measurements
  - Liquid-phase purification
  - Cold liquid scintillator
  - Full optical characterization
- R&D to increase reach
  - Active / ultra-low mass internal structures:
  - Full mapping of discrimination vs field; possibly very high field design.
  - Advanced readout

S4 funding, also seeking DOE. International component.

Development highlights

- Safety
  - LUX serves as significant test bed
  - LLNL + LBNL engineering
  - LZS: enhanced cryogen volume
- Purification (already discussed)
- PMTs
  - LUX 350: 2” Hamamatsu R8778
    - U/Th 9/3 mBq/PMT, QE 35%
  - LZS and L-D
    - DUSEL R&D for 3” PMTs for LXe: Hamamatsu R11065mod
    - Tested QE/LXe operation - same as R8778
    - Background - factor 2 better than R8778
    - Goal: reduce to ~1/1 mBq/PMT
    - XMASS/Suzuki (2008) achieved 2” R8778mod <0.7/<1.0 mBq/PMT





Roadmap

- LUX
  - Above ground integration: starting Oct 2009.
  - Underground running: summer 2009 - end 2011.
- LZS, 1.5 tons.
  - Proposals now, for July 2010 start.
  - Underground operations 2012 - 2014.
- LZD:
  - Goal: FDR so that funding alligned with DUSEL
    - Seeking additional DOE support to assist with this goal
  - CDR + elements of PDR: April 2010
    - The LZ S4 proposal was at CDR level.
  - MREFC submission to NSB: Dec 2010. Substantial completion of PDR.
  - PDR: June 2011
  - FDR: Oct 2012