This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

LUX

Large Underground Xenon experiment

R.Svoboda, UC Davis/LLNL

LUX Collaboration

- Groups from Xenon10: Brown(Gaitskell), Case(Shutt), LLNL(Bernstein)
- Groups from Zeplin II: UCLA(Cline,Wang), Rochester(Wolfs), Texas A&M(White)
- Groups from neutrino and gamma ray experiments: UC Davis(Svoboda,Tripathi), LBNL(Lesko),LLNL(Dazeley)

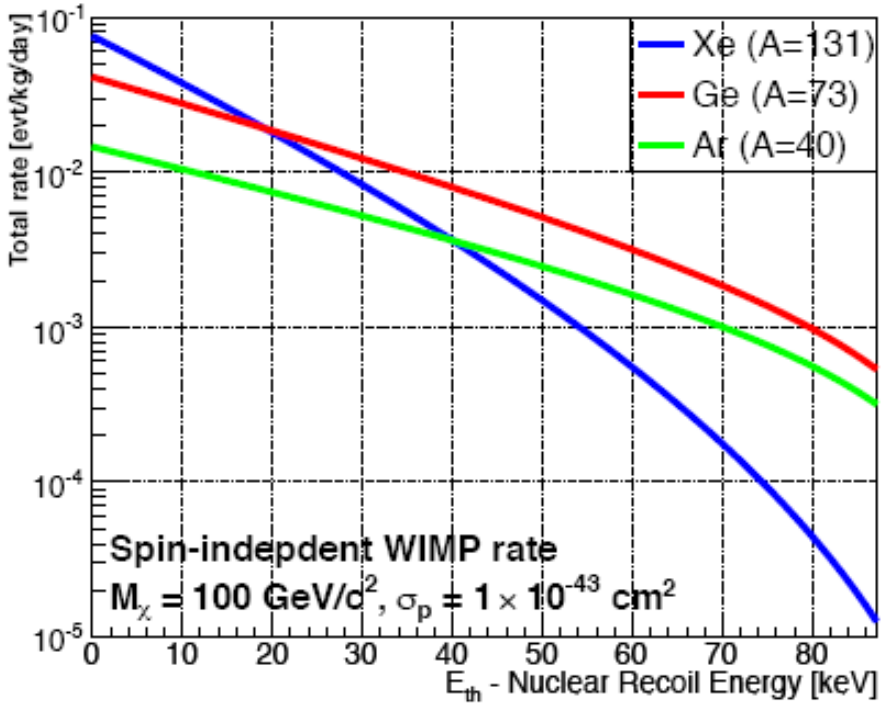
Direct detection of WIMPs

Large flux on earth:

$v \sim c/1000$,

$m_c \sim 100\ m_{proton}$

$flux \sim 10^5\ /(cm^2\ s)$



Scatter on nuclei

E_{recoil} ≈ 0-50 keV

Scatter coherently from whole nucleus: $\sigma = \sigma_{proton}\mu^2 A^2$

μ = reduced mass

$$\lambda_{m=300\ \mathrm{GeV}} = \frac{h}{m \cdot v} = 5\ \mathrm{fm} \sim R_{Xenucleus} = 6\ \mathrm{fm}.$$

Experimental Technique

Ionization in liquid:

- About one electron-ion pair /15 eV of deposited energy

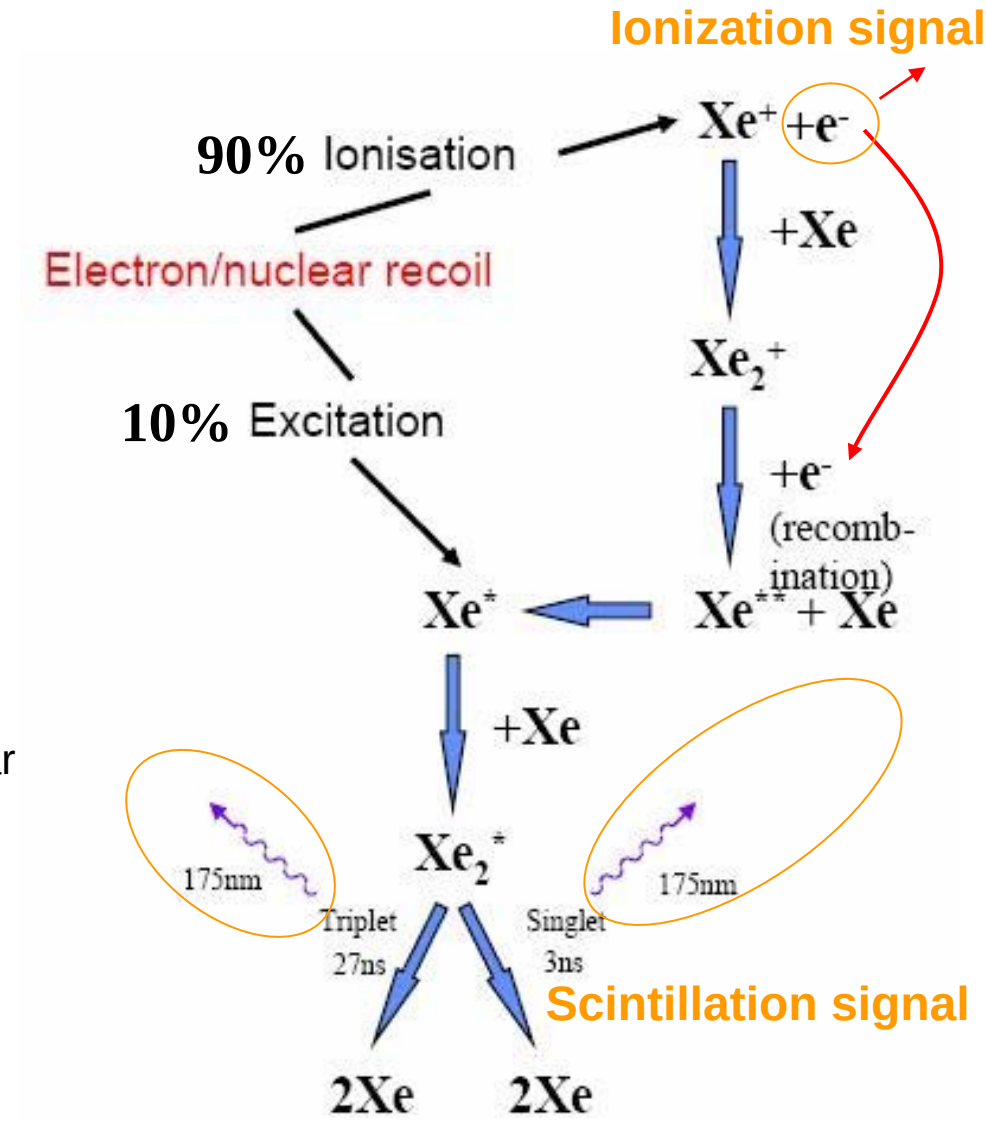
175 nm Scintillation:

- About one photon/20 eV of deposited energy

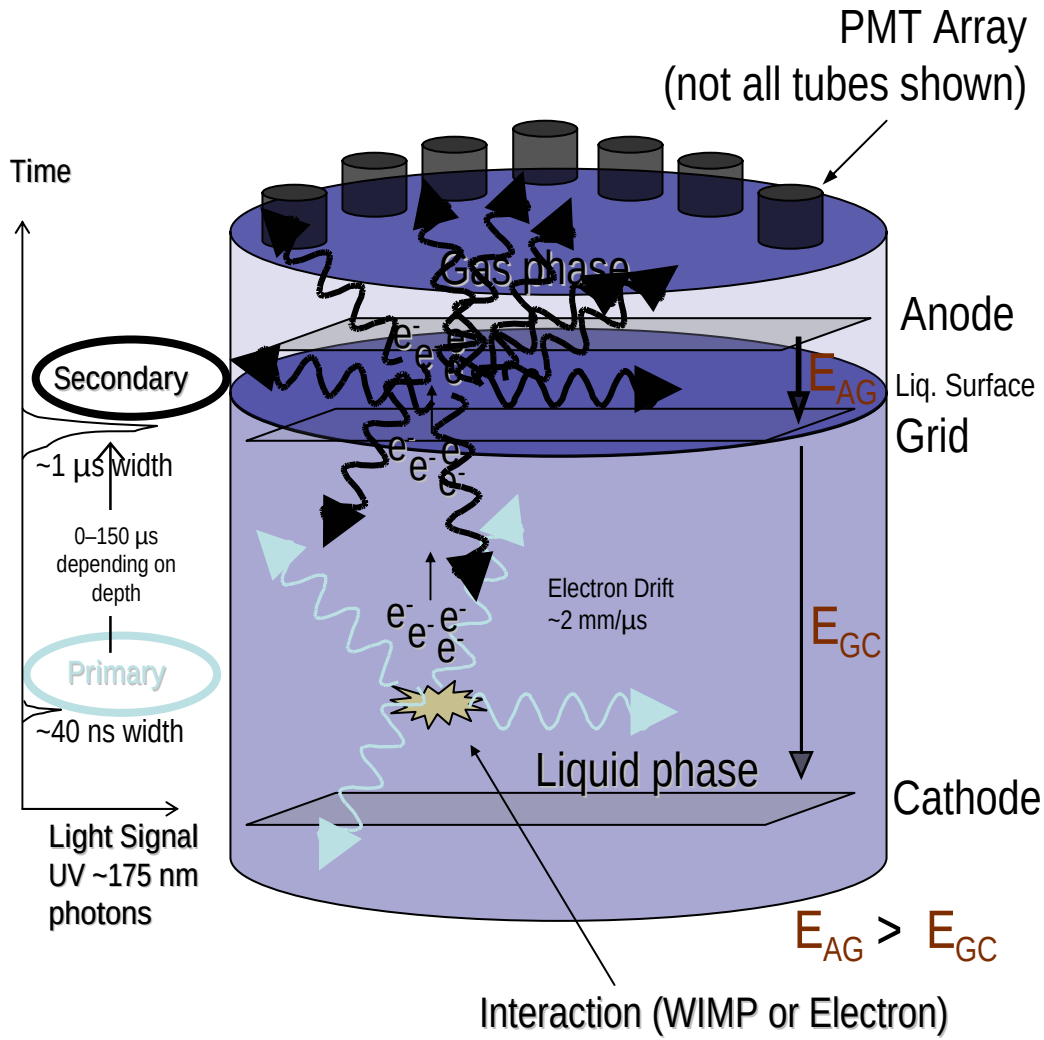
- Ionization/Scintillation ratio changes with interaction type

  Ion pairs more likely to recombine in the dense tracks generated by nuclear interactions

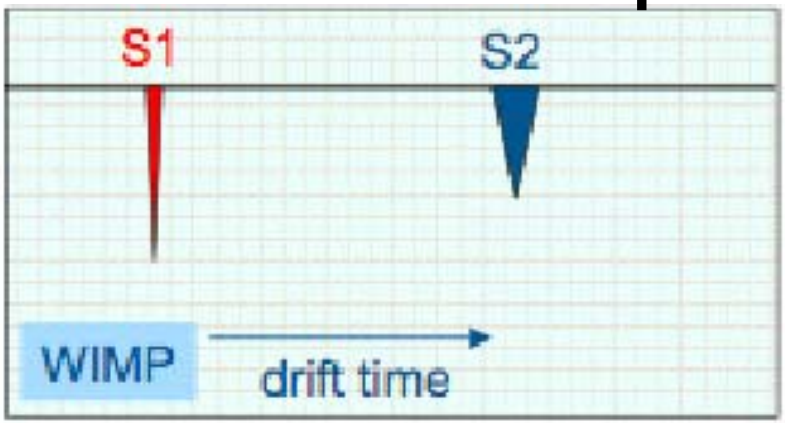
- A strong anti-correlation between ionization and scintillation

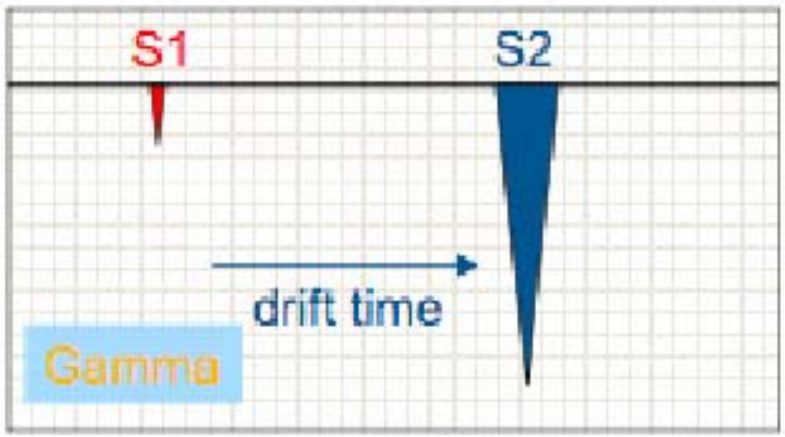


The Basic Idea

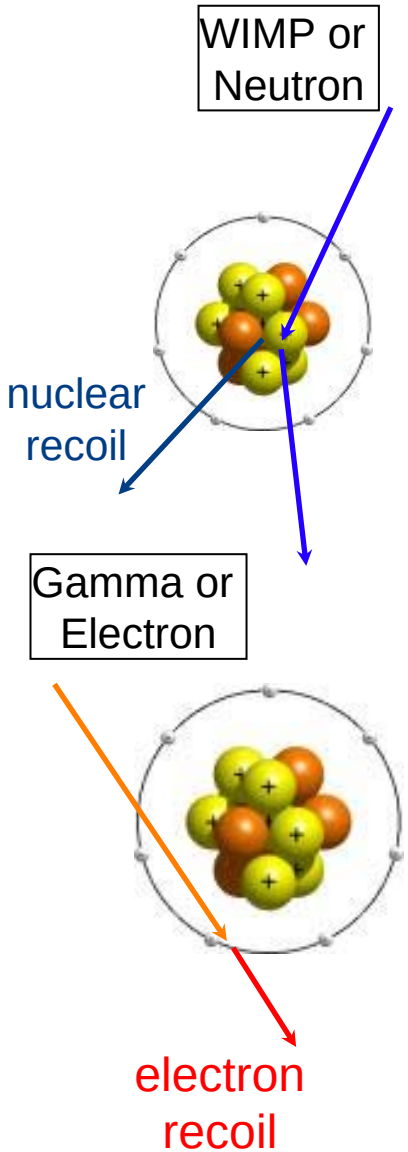


Ionization/scintillation response in dual-phase detector





$(S2/S1)_{wimp} << (S2/S1)_{gamma}$



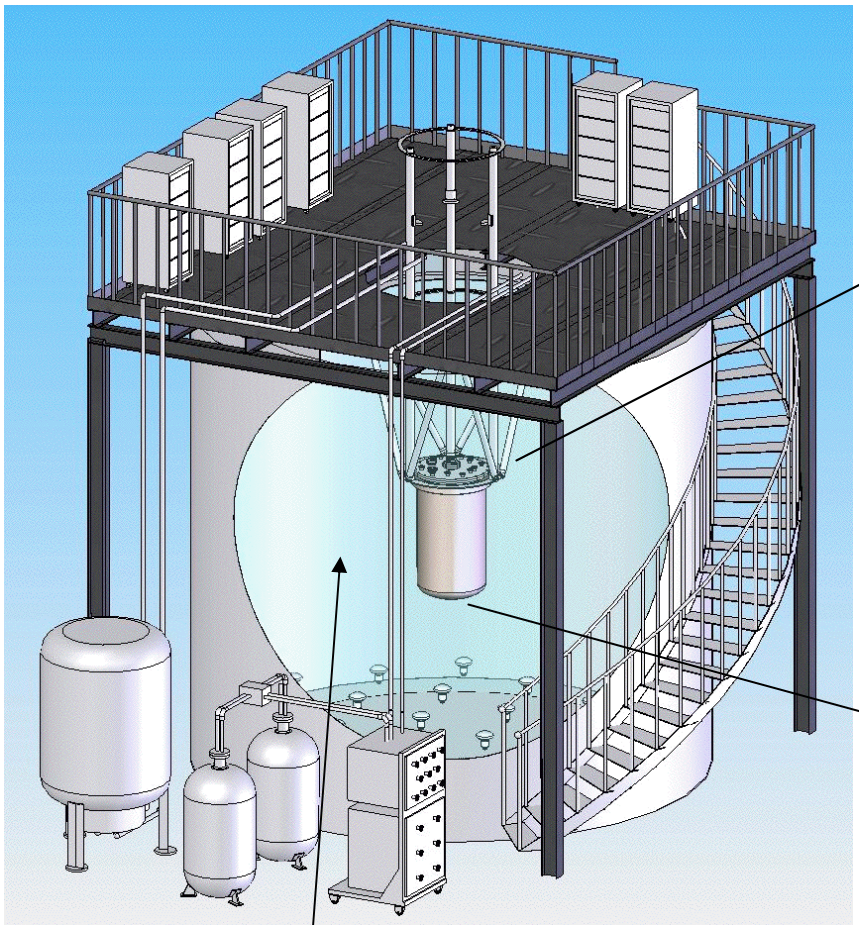
Nuclear recoil:
Electrons recombine in the liquid due to higher ionization density
- fewer primary electrons

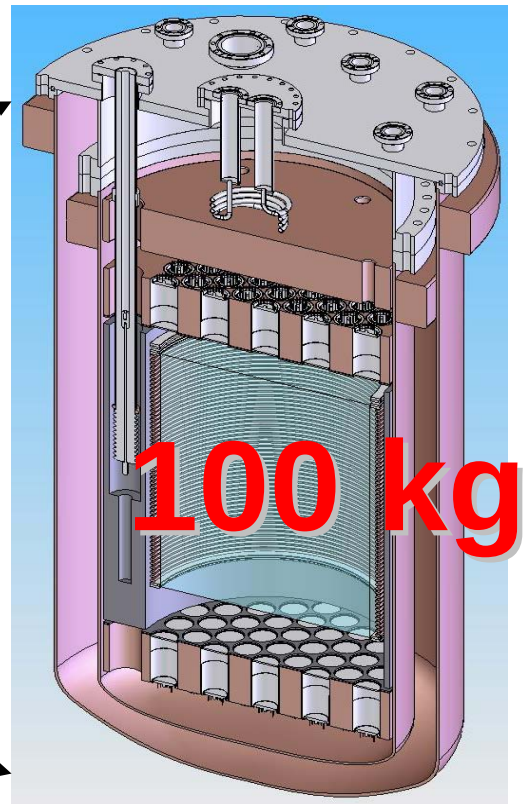
Also overall **quenching** of scintillation relative to electron recoil

Gamma recoil:
Less recombination in the liquid due to lower ionization density
more primary electrons

(October, 2006)

The LUX detector and shield

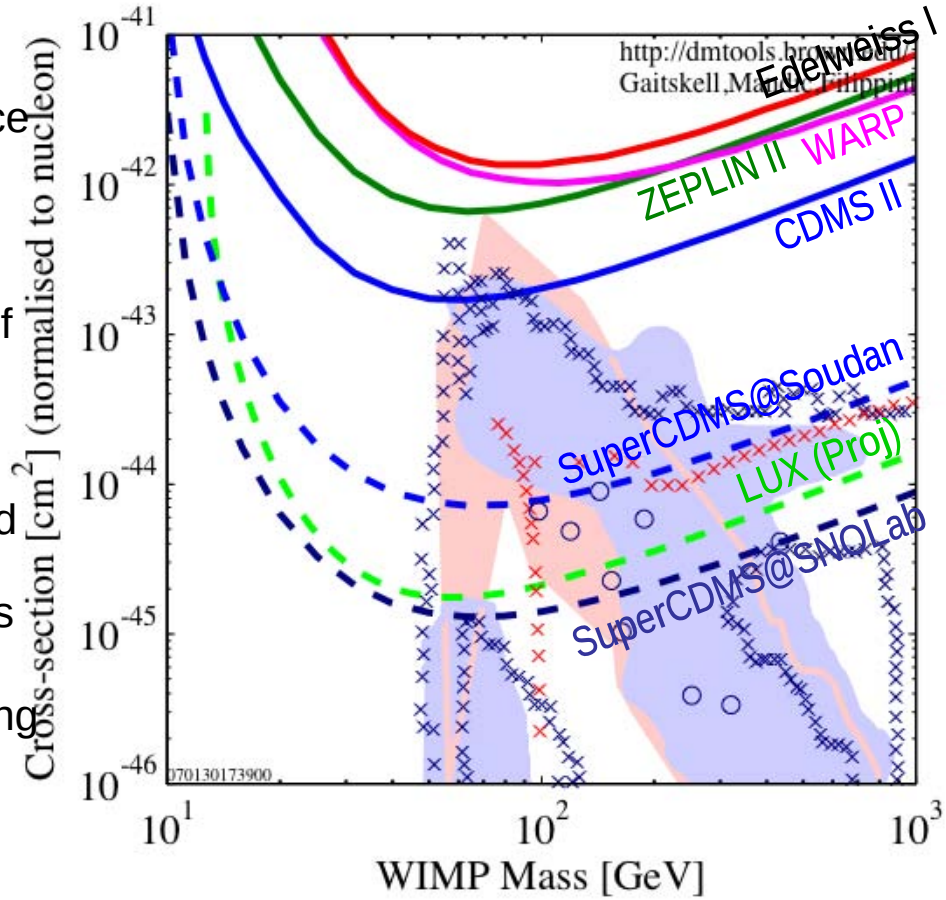




Water Cerenkov Muon shield (low cost)
roughly 6 meters in diameter

tall dual phase detector
Aspect ratio = 1.5

- Dark Matter Goal
  - LUX - Sensitivity curve at 2×10^{-45} cm^2 (100 GeV)
    - Exposure: Gross Xe Mass 300 kg
      Limit set with 120 days running
      x 100 kg fiducial mass x 50% NR acceptance
      - If candidate dm signal is observed, run time can be extended to improve stats
    - ~1 background event during exposure assuming most conservative assumptions of ER 7×10^{-4} /keVee/kg/day and 99% ER rejection
      - ER bg assumed is dominated by guaranteed Hamamatsu PMT background (R8778 or R8520) - recent PMTs from Hamamatsu achieving lower backgrounds
      - Improvements in PMT bg (and rejection power) will extend background free running period, and DM sensitivity

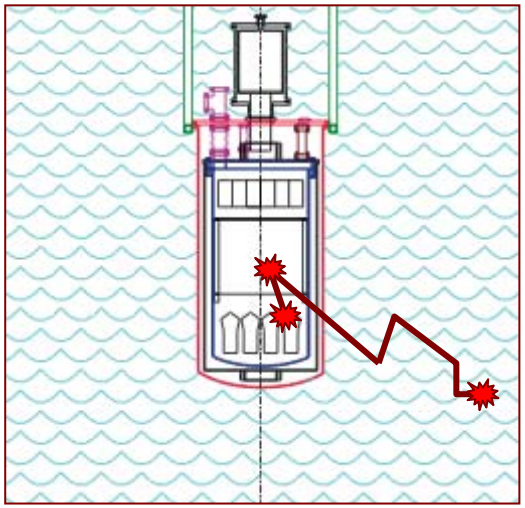


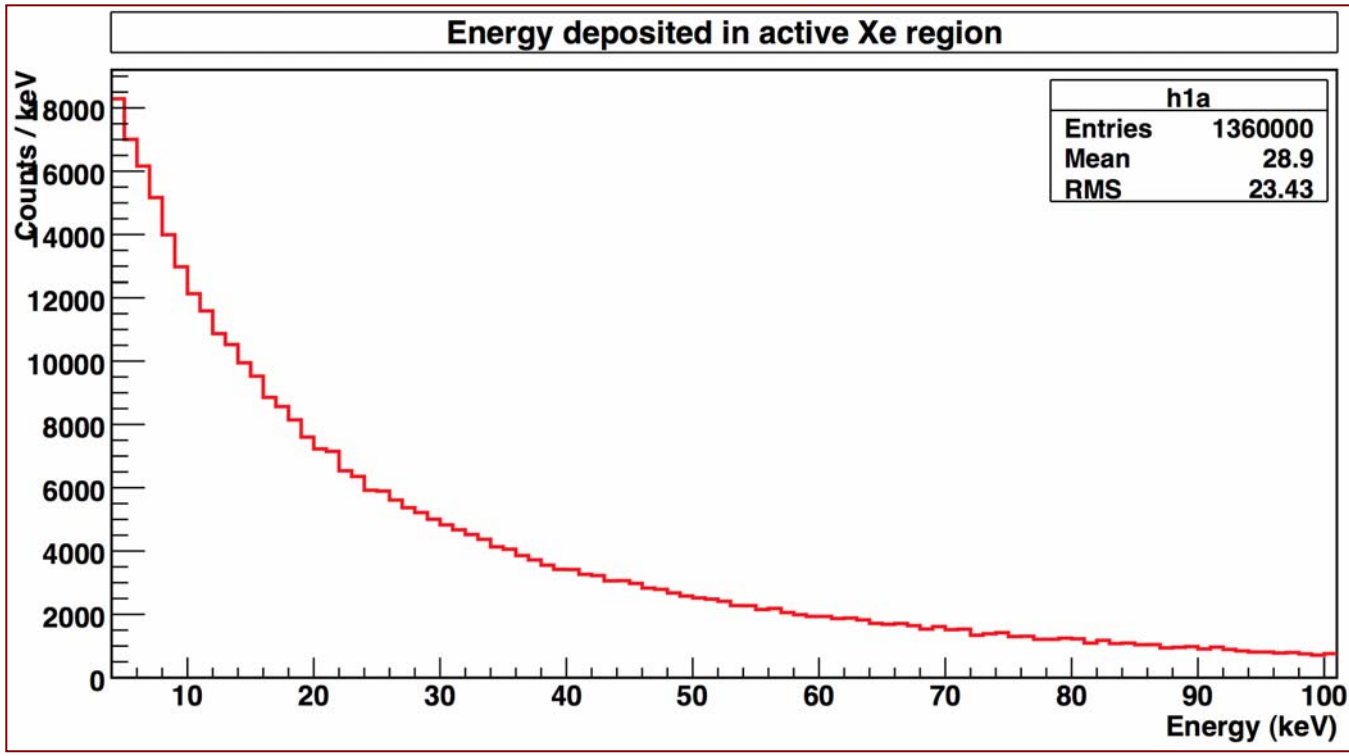
  - Comparison
    - SuperCDMS Goal @ SNOLab: Gross Ge Mass 25 kg
      (x 50% fid mass+cut acceptance)
      Limit set for 1000 days running x 7 SuperTowers

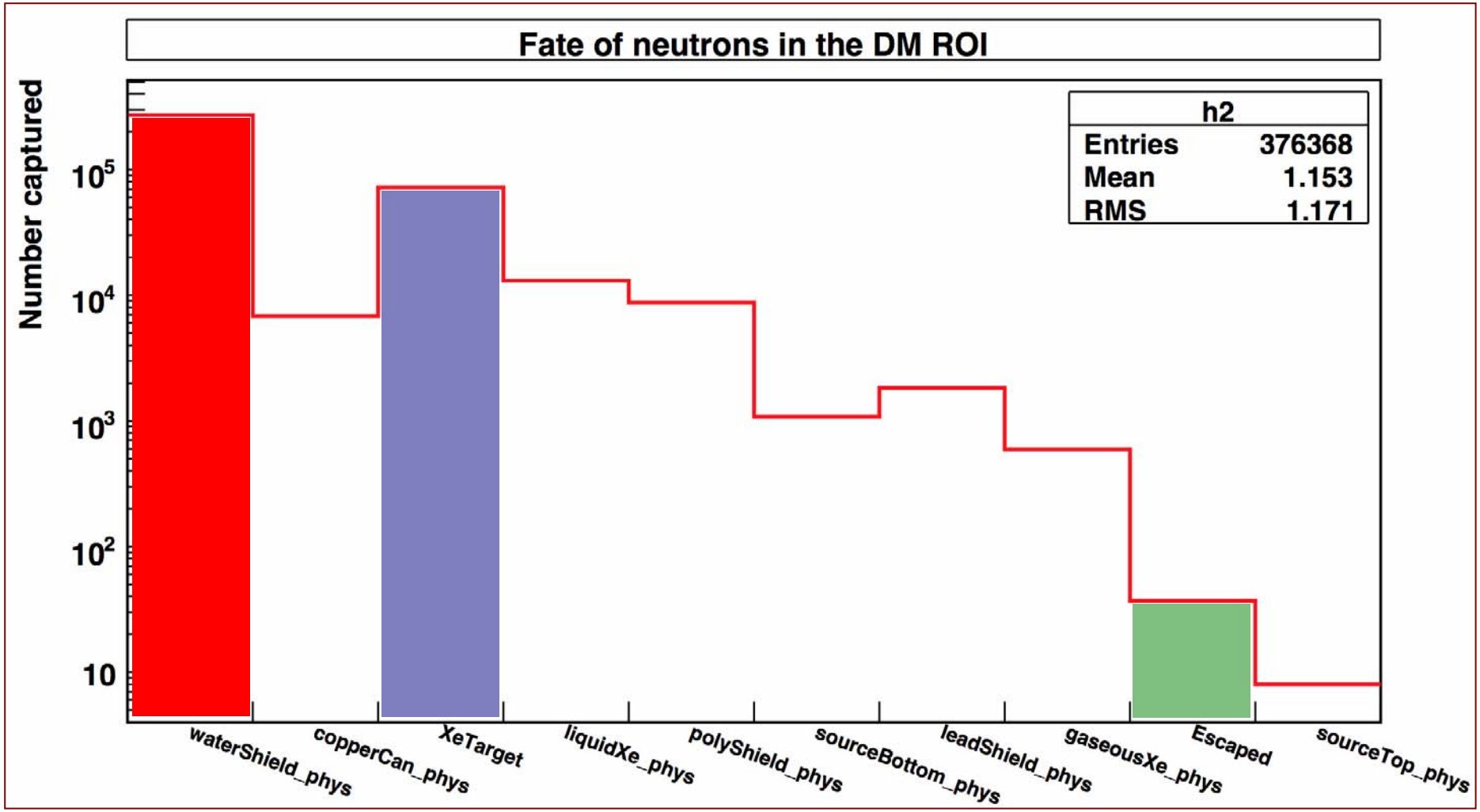
An Active Neutron Shield

Assumed source of neutrons → (α,n) reactions on Si and O

Use Monte Carlo (GEANT) simulation to learn the ultimate fate of neutrons







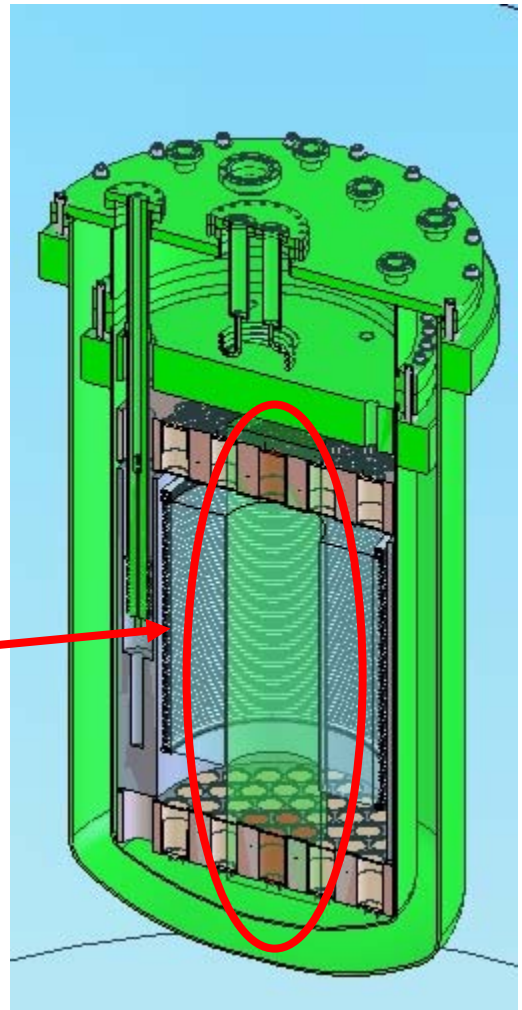
72% of ROI neutrons capture in the Gd-H_2O shield

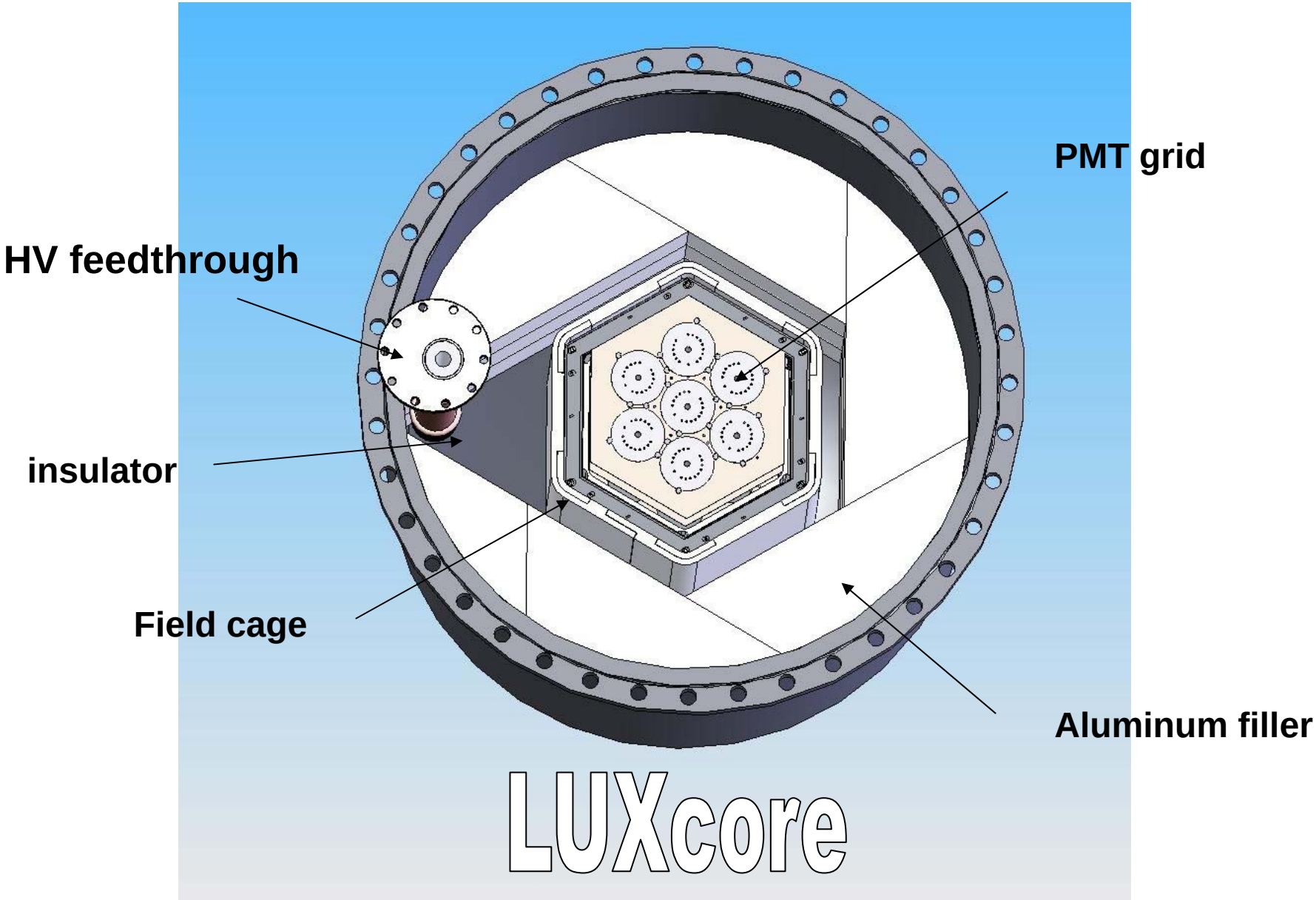
19% of ROI neutrons capture in the active Xe target

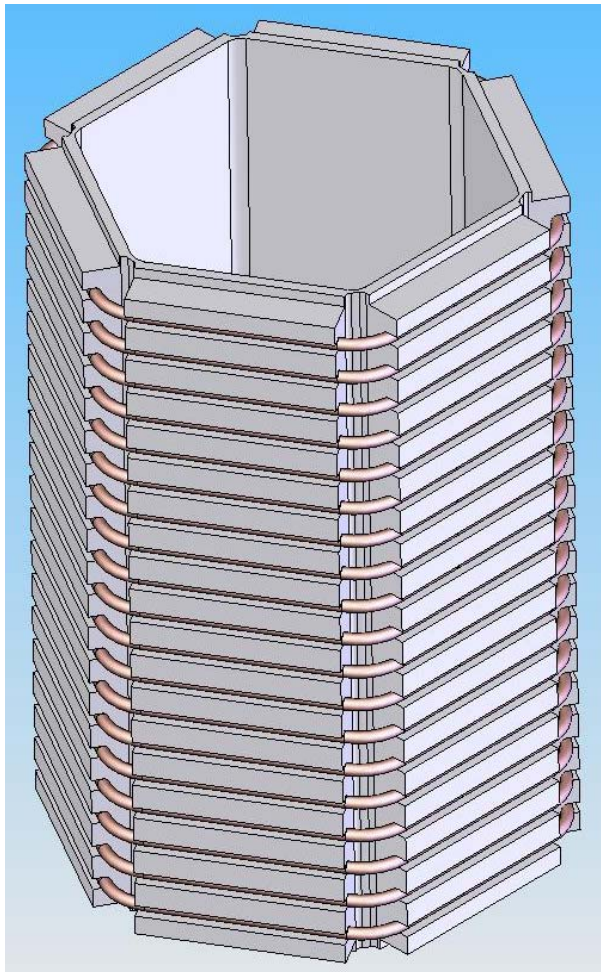
99% reduction!

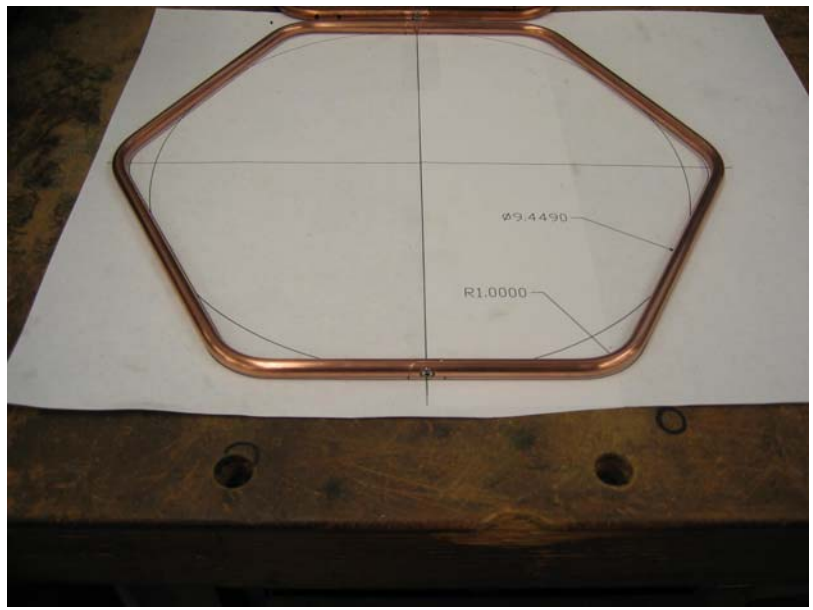
LUXcore

- A full-scale engineering model of 100 kg LUX
- Goal: reduce time to actual LUX detector by starting engineering process
- standard materials, commerical parts
- central 10% will have LXe and PMT coverage
- will be available for engineering tests in about three months
- Design will allow being submerged in water – we will engineer this aspect also

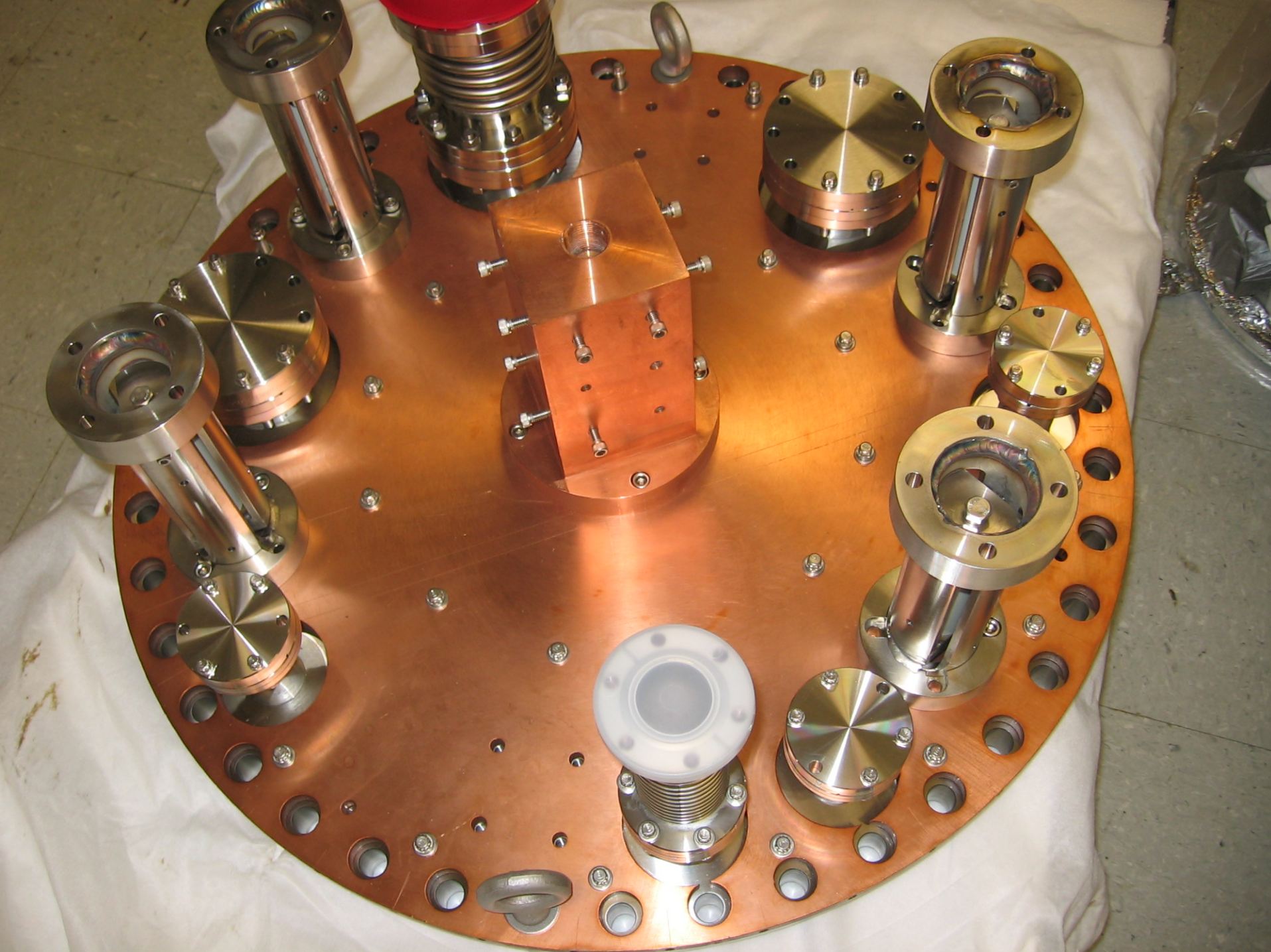


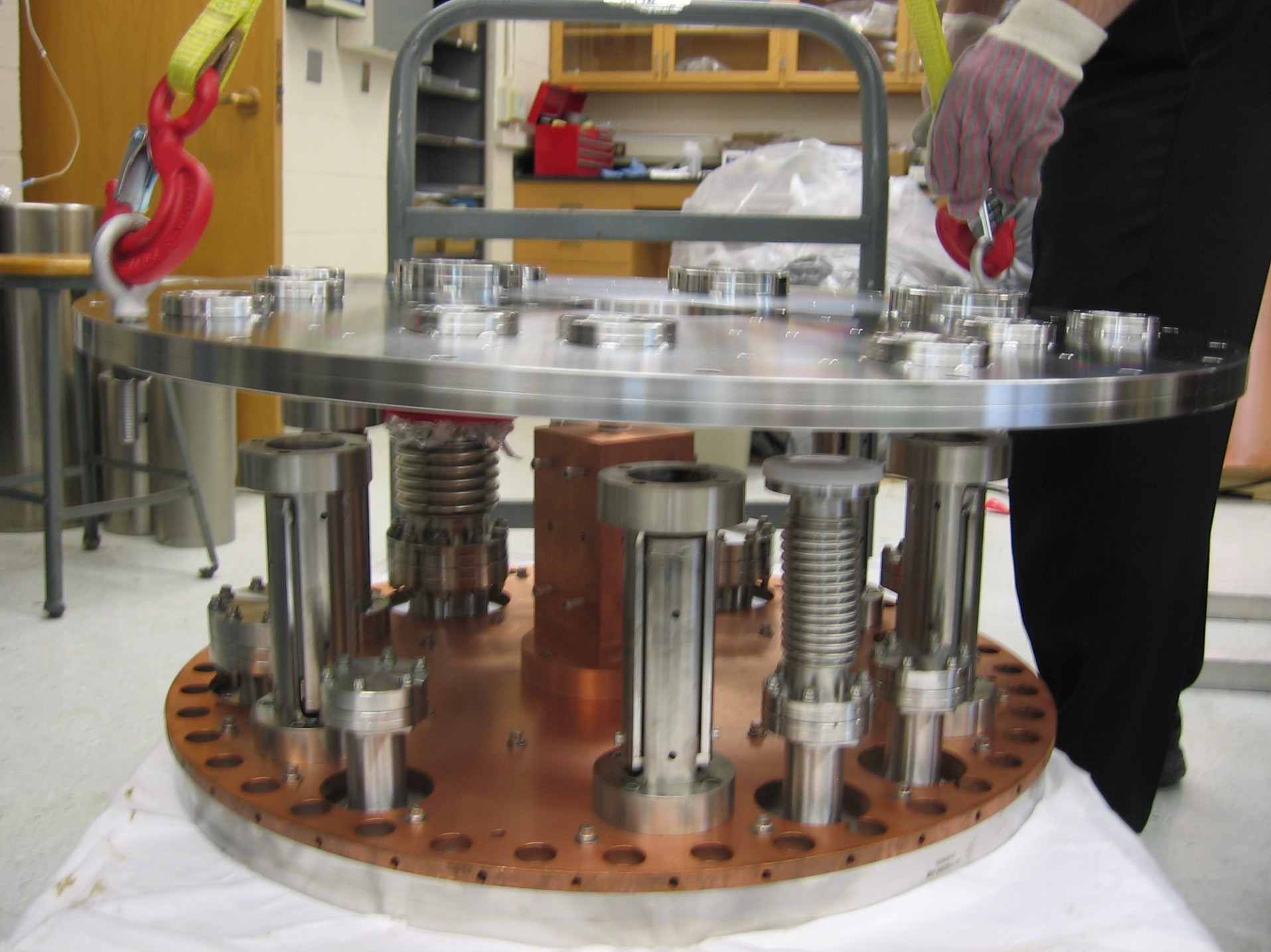

PMT grid
HV feedthrough
insulator
Field cage
Aluminum filler
LUXcore

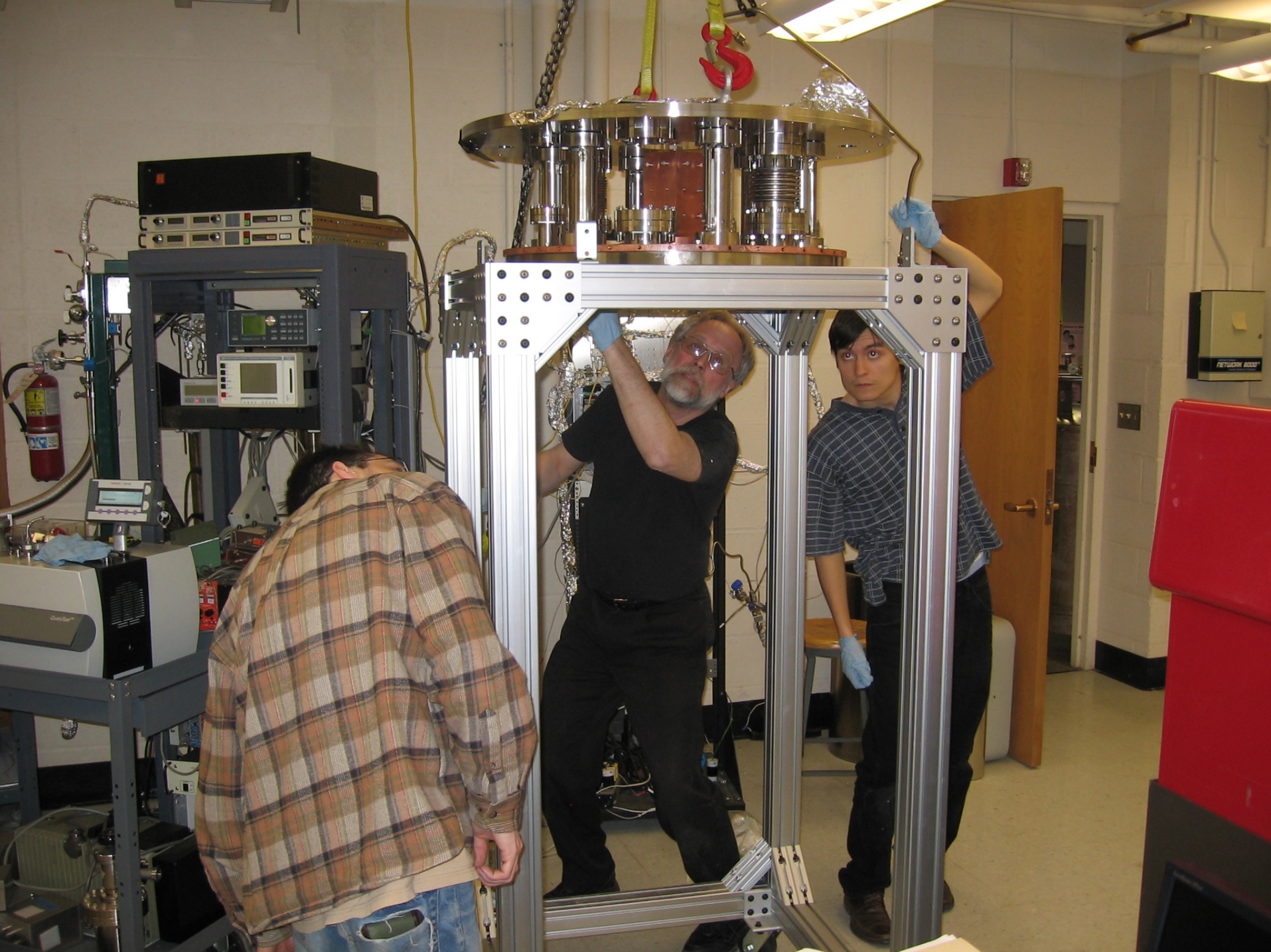




LUXcore field cage design







Deep Underground Science and Engineering Lab

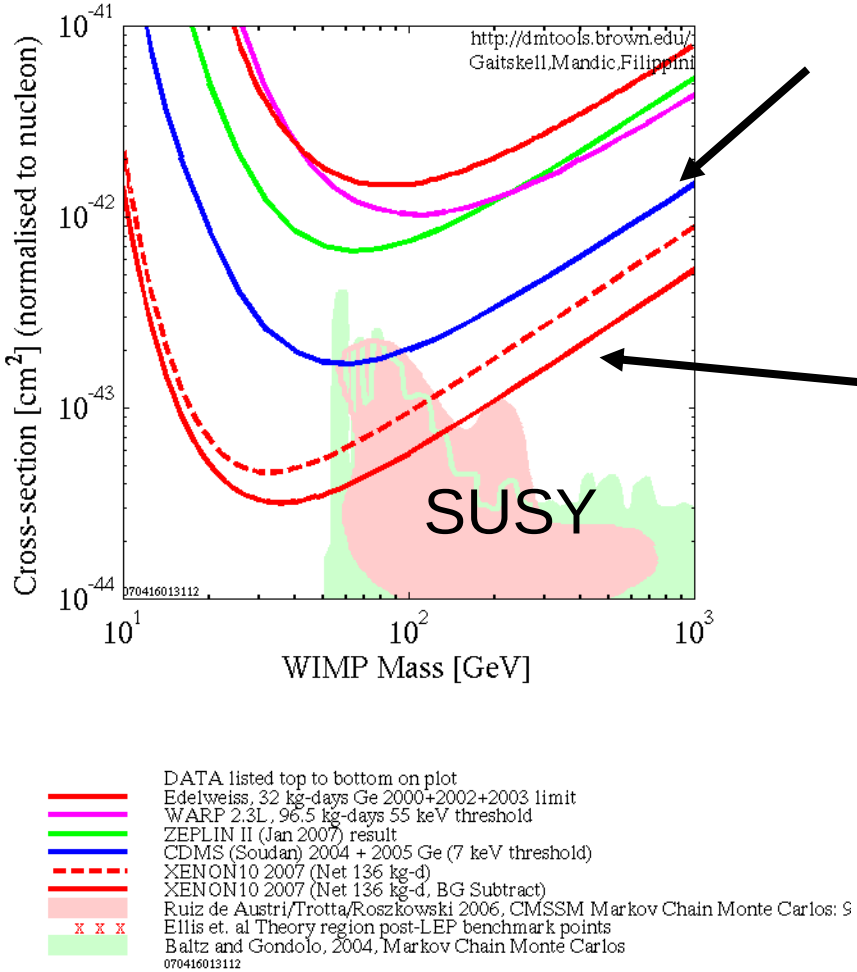
- 2004-2005 “S1” workshops and “S2” proposals.
- July 2005 – Colorado and South Dakota sites selected for funding to develop “S3” proposal (2 other sites also allowed to submit)
- 2006/07 site visits and “S3” proposals completed.
- 2007 Site decision in ***next few weeks***
- 2008 Major Research Equipment and Facility Construction (MREFC)
- 2009 earliest possible start of experiments (with an EIP). 2010 “official” early start date.

Conclusions

- 300 kg Dual Phase liquid Xe TPC with 100 kg fiducial
  - >99% ER background rejection for 50% NR acceptance, E>10 keVr
  - 3D-imaging TPC eliminates surface activity, defines fiducial
- Backgrounds:
  - Internal: strong self-shielding of PMT activity
    - $\gamma/\beta < 7\times10^{-4}$ /keVee/kg/day, from PMTs (Hamamatsu R8778 or R8520).
    - Neutrons (α,n) & fission addressed with neutron tag plus work on low activity PMT
  - External: large water shield with muon veto.
    - Very effective for cavern γ+n, and HE n from muons
    - Very low gamma backgrouns with readily achievable $<10^{-11}$ g/g purity.
- DM reach: 2×10^{-45} cm^2 in 4 months
  - Possible ~5×10^{-46} cm^2 reach with recent PMT activity reductions, longer running, active shield

backup

Recent Dramatic Improvement in DM Sensitivity!

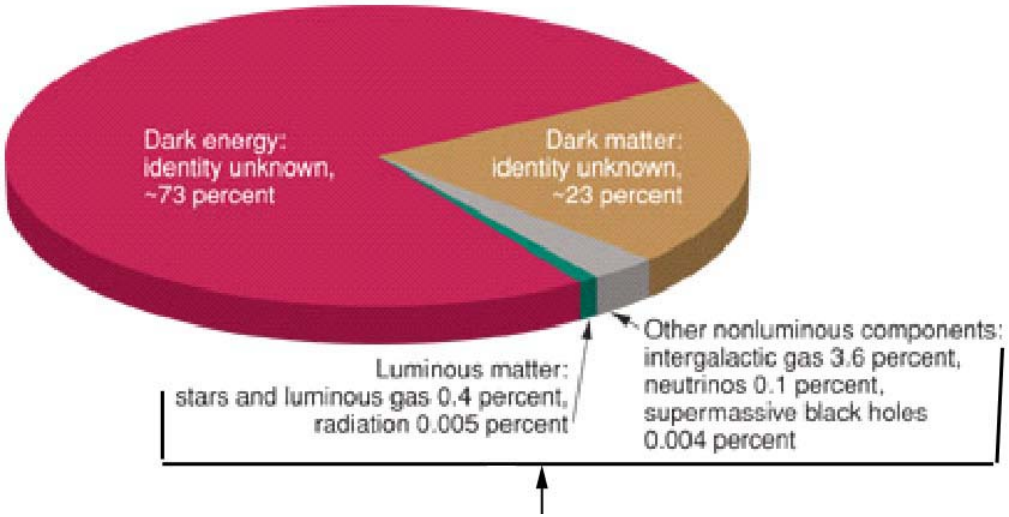


previous best experiment

10 kg fiducial dual phase xenon10 detector ~60 days

April 17, APS meeting

Recent and Various Astrophysical Data Indicate The Universe is mostly Dark - 73% Dark Energy, 23% Dark Matter



All of standard model physics is in this slice of the pie

FERMIONS matter constituents spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2			Quarks spin = 1/2		
Flavor	Mass GeV/c²	Electric charge	Flavor	Approx. Mass GeV/c²	Electric charge
ν_e electron neutrino	$<1\times10^{-8}$	0	u up	0.003	2/3
e electron	0.000511	−1	d down	0.006	−1/3
ν_μ muon neutrino	<0.0002	0	c charm	1.3	2/3
μ muon	0.106	−1	s strange	0.1	−1/3
ν_τ tau neutrino	<0.02	0	t top	175	2/3
τ tau	1.7771	−1	b bottom	4.3	−1/3

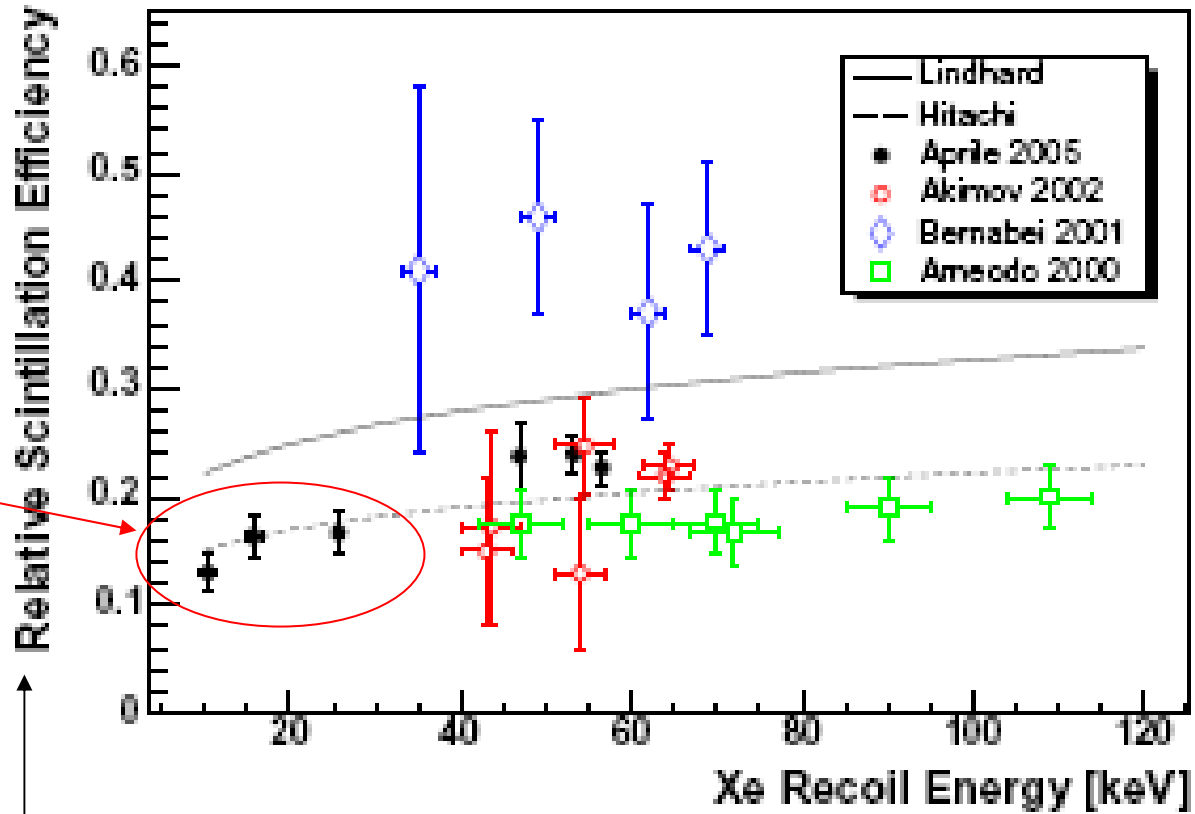
BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1			Strong (color) spin = 1		
Name	Mass GeV/c²	Electric charge	Name	Mass GeV/c²	Electric charge
γ photon	0	0	g gluon	0	0
W^-	80.4	−1			
W^+	80.4	+1			
Z^0	91.187	0			

WMAP Cosmological Parameters Model: lcdm Data: all	
$10^2\Omega_b h^2$	$2.193^{+0.067}_{-0.068}$
$\Delta^2_{\mathcal{R}}(k = 0.002/\mathrm{Mpc})$	$(24.0 \pm 1.3) \times 10^{-10}$
h	$0.708^{+0.015}_{-0.016}$
H_0	$70.8^{+1.5}_{-1.6}$ km/s/Mpc
$n_s(0.002)$	$0.938^{+0.015}_{-0.014}$
$\Omega_b h^2$	$0.02193^{+0.00067}_{-0.00068}$
Ω_Λ	0.738 ± 0.016
Ω_m	0.262 ± 0.016
$\Omega_m h^2$	$0.1307^{+0.0039}_{-0.0040}$
σ_8	$0.751^{+0.032}_{-0.031}$
A_{SZ}	$0.81^{+0.61}_{-0.56}$
t_0	13.84 ± 0.14 Gyr
τ	$0.070^{+0.027}_{-0.028}$
θ_A	0.5941 ± 0.0019 °
z_r	$9.4^{+2.6}_{-2.7}$

Extend Measurements of Nuclear Recoil Scintillation Light to Low Energies

Low energy points key for the WIMP measurement

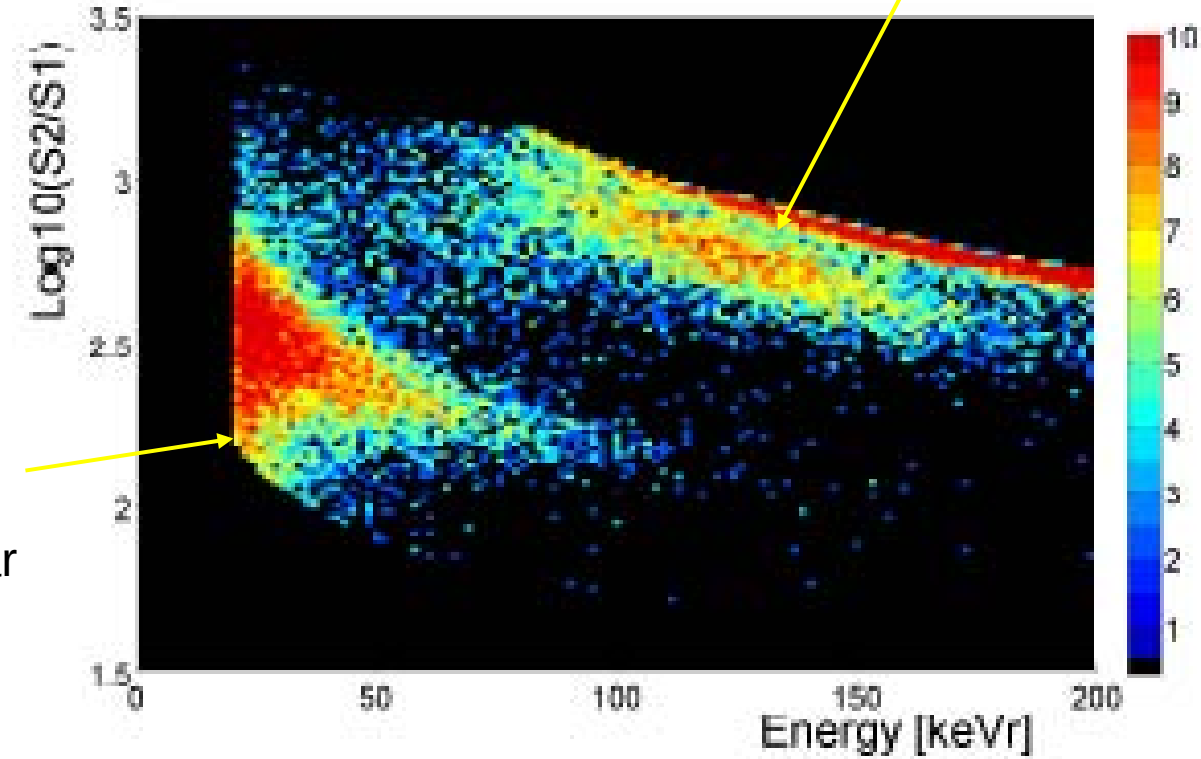


$$\textbf{Quench Factor} = \frac{\textbf{Detected scintillation from a nuclear recoil}}{\textbf{Detected scintillation from an electromagnetic recoil}}$$

Reject Electromagnetic Interactions With Ionization/Scintillation Ratio Cut

Cf-252 n/gamma source

Electromagnetic recoils



Neutron recoils:
WIMPs would appear here

Projected result for XENON10 **reject** 99% of electron recoils
accept 50% of WIMP events