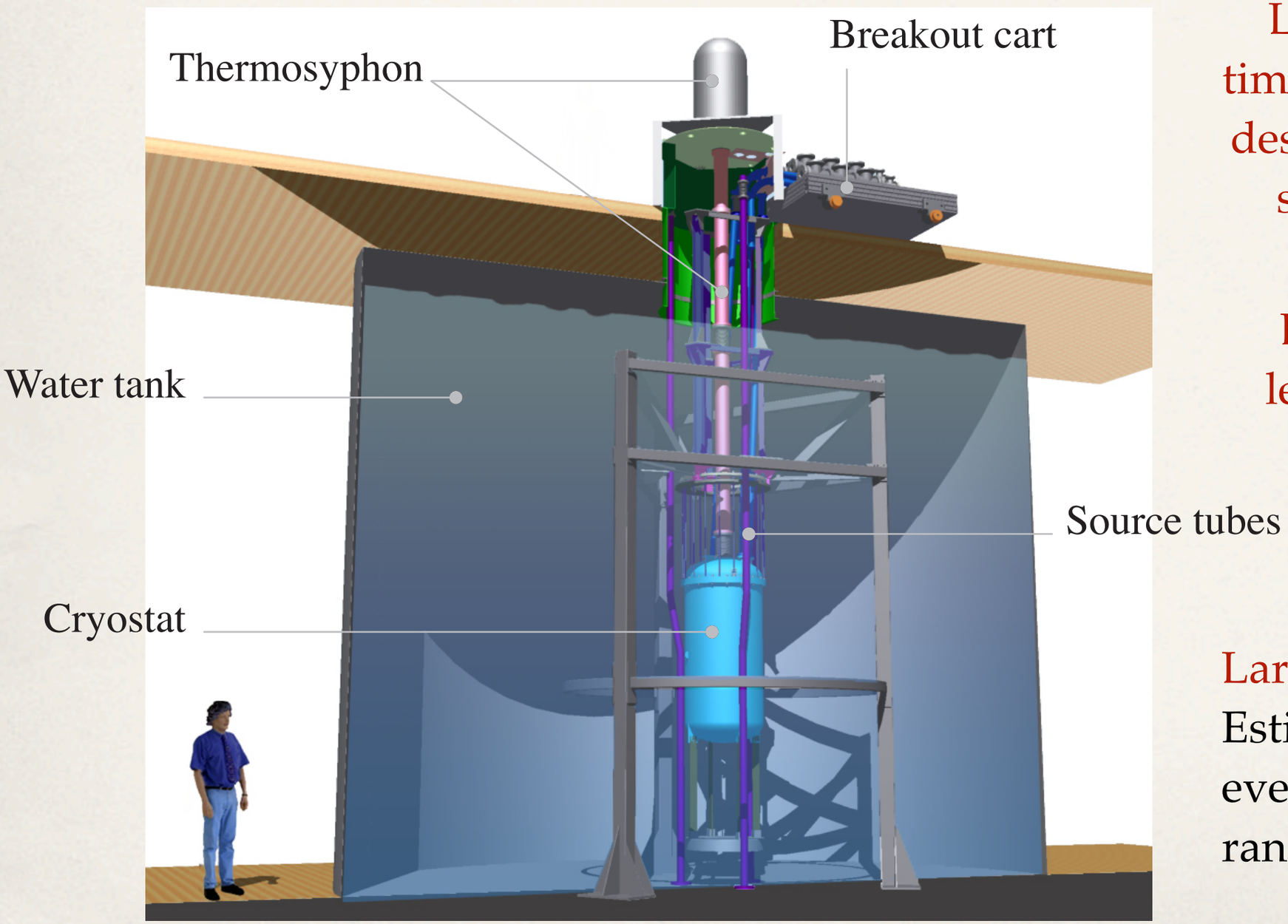
The LUX Experiment

Karen Gibson *on behalf of the LUX Collaboration*

Identification of Dark Matter
July 26, 2012

Large Underground Xenon experiment



LUX is a two-phase xenon time-projection chamber (TPC) designed to search for WIMPs scattering off of Xe nuclei

Begin data-taking at 4850′ level of Homestake mine in Lead, SD by end of 2012

Large, very quiet fiducial region

Estimate ~1 electron recoil event every 4 days in 100 kg in energy range of interest: 5-25 keVr

LUX Collaboration consists of 16 member institutions, 12 from the US and 4 from Europe

Brown

Richard Gaitskell	PI, Professor
Simon Fiorucci	Research Associate
Monica Pangilinan	Postdoc
Jeremy Chapman	Graduate Student
Carlos Hernandez Faham	Graduate Student
David Malling	Graduate Student
James Verbus	Graduate Student

Case Western

Thomas Shutt	PI, Professor
Dan Akerib	PI, Professor
Mike Dragowsky	Research Associate Professor
Tom Coffey	Research Associate
Carmen Carmona	Postdoc
Karen Gibson	Postdoc
Adam Bradley	Graduate Student
Patrick Phelps	Graduate Student
Chang Lee	Graduate Student
Kati Pech	Graduate Student
Tim Ivancic	Graduate Student

University of Rochester

Frank Wolfs	PI, Professor
Wojtek Skutski	Senior Scientist
Eryk Druszkiewicz	Graduate Student
Mongkol Moongweluwan	Graduate Student

Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors Group
Dennis Carr	Mechanical Technician
Kareem Kazkaz	Staff Physicist
Peter Sorensen	Staff Physicist
John Bower	Engineer

SD School of Mines

Xinhua Bai	PI, Professor

University of South Dakota

Dongming Mei	PI, Professor
Chao Zhang	Postdoc
Dana Byram	Graduate Student
Chris Chiller	Graduate Student
Angela Chiller	Graduate Student

University of Maryland

Carter Hall	PI, Professor
Attila Dobi	Graduate Student
Richard Knoche	Graduate Student

Texas A&M

James White	PI, Professor
Robert Webb	Professor
Rachel Mannino	Graduate Student
Clement Sofka	Graduate Student

UC Davis

Mani Tripathi	PI, Professor
Robert Svoboda	Professor
Richard Lander	Professor
Britt Hollbrook	Senior Engineer
John Thomson	Senior Machinist
Matthew Szydagis	Postdoc
Richard Ott	Postdoc
Jeremy Mock	Graduate Student
James Morad	Graduate Student
Nick Walsh	Graduate Student
Michael Woods	Graduate Student
Sergey Uvarov	Graduate Student

Lawrence Berkeley + UC Berkeley

Bob Jacobsen	PI, Professor
David Taylor	Engineer
Mia ihm	Graduate Student

Yale

Daniel McKinsey	PI, Professor
Peter Parker	Professor
James Nikkel	Research Scientist
Sidney Cahn	Lecturer/Research Scientist
Alexey Lyashenko	Postdoc
Ethan Bernard	Postdoc
Markus Horn	Postdoc
Blair Edwards	Postdoc
Nicole Larsen	Graduate Student
Evan Pease	Graduate Student
Brian Tennyson	Graduate Student

UC Santa Barbara

Harry Nelson	PI, Professor
Mike Witherell	Professor
Dean White	Engineer
Susanne Kyre	Engineer

Imperial College London

Henrique Araujo	PI, Senior Lecturer
Tim Sumner	Professor
Alastair Currie	Postdoc

University of Edinburgh

Alex Murphy	PI, Reader
Lea Reichhart	Graduate student

University College London

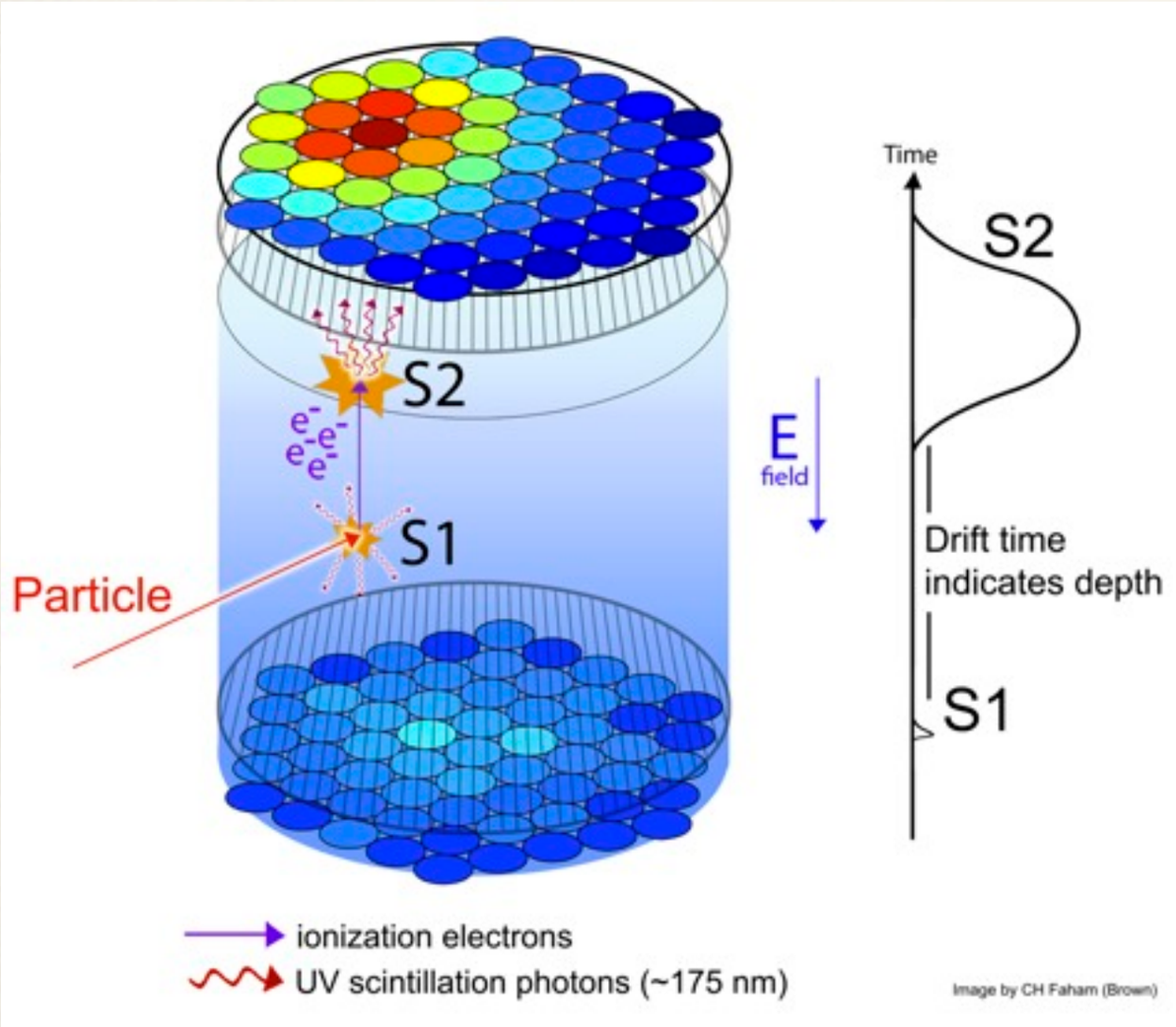
Chamkaur Ghag	PI, Lecturer

LIP Coimbra

Isabel Lopes	PI, Professor
Jose Pinto da Cunha	Assistant Professor
Vladimir Solovov	Senior Researcher
Luiz de Viveiros	Postdoc
Alexander Lindote	Postdoc
Francisco Neves	Postdoc
Claudio Silva	Postdoc

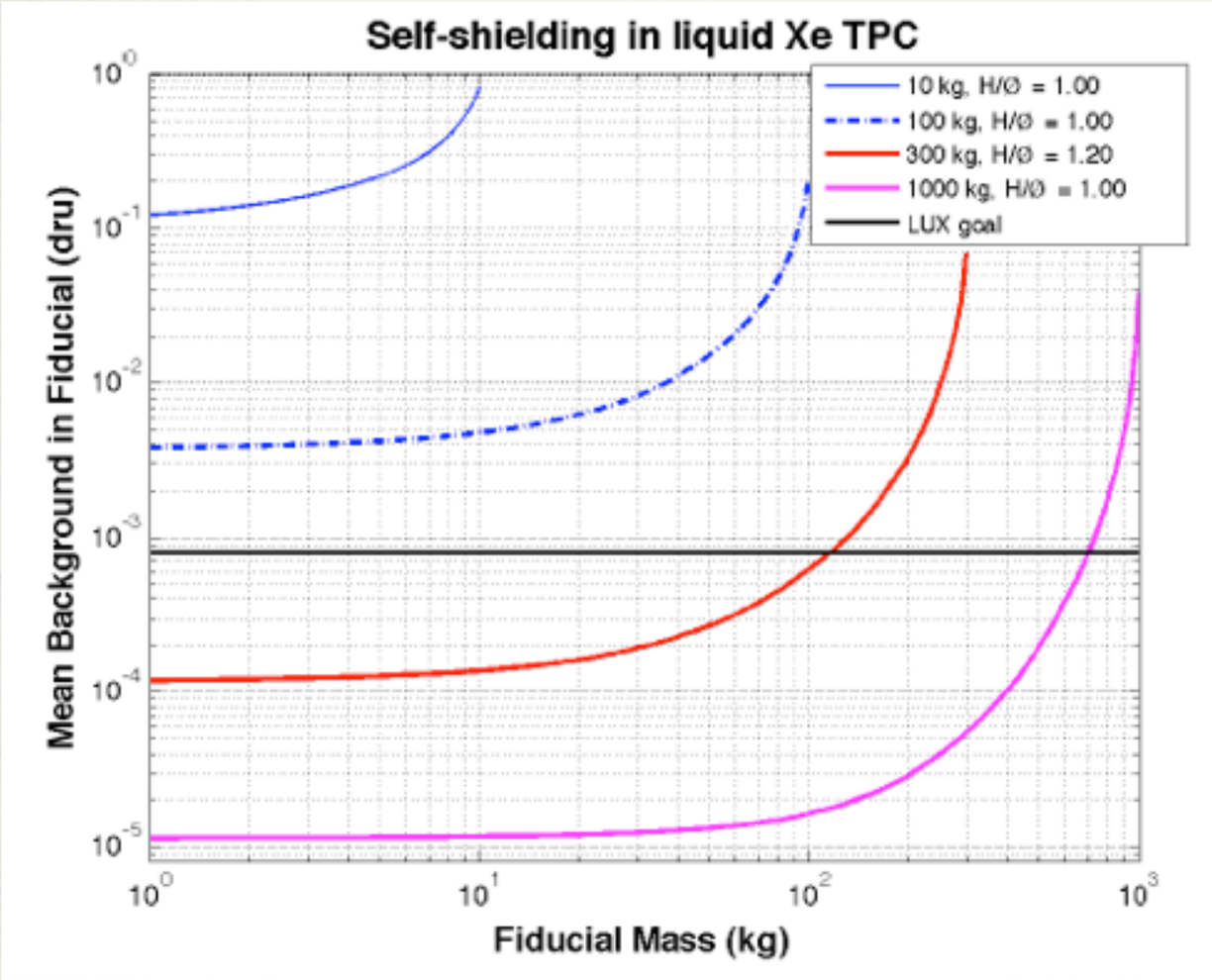
LUX - A Xenon Time Projection Chamber

Liquid Xe TPC detectors



- Look for scintillation signals
  - Need good scintillator
    - Xe has excellent ph. absorption ⇒ full energy deposit at WIMP energies (5-25 keV)
  - Need few / removable radioactive backgrounds
    - ^{85}Kr - readily removable to ppt level
  - Need good light collection
- Get best background separation via two-phase detector

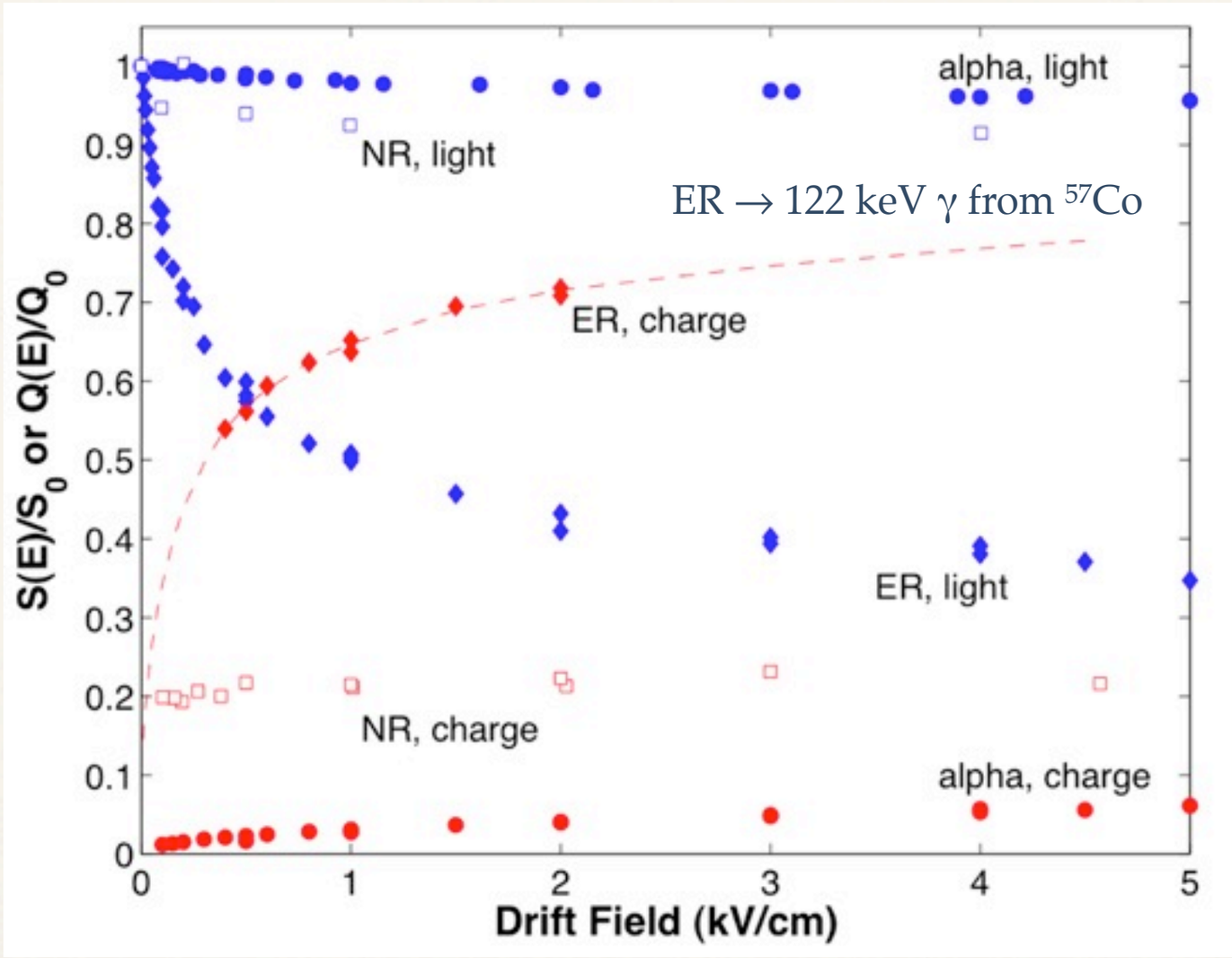
Advantages of noble liquid detectors



Scalability!!!

- Current/future DM searches need $\geq O(100\ \text{kg})$ target mass
- Cryogenic problem is generally much simpler for noble liquids $O(100\ \text{K})$ than for crystal or semiconductor detectors $O(10\ \text{mK})$
  - $T_{LXe} \approx 170$ K at 2 atm
- Self-shielding increases active volume as detector size increases

Use charge vs light to identify NR



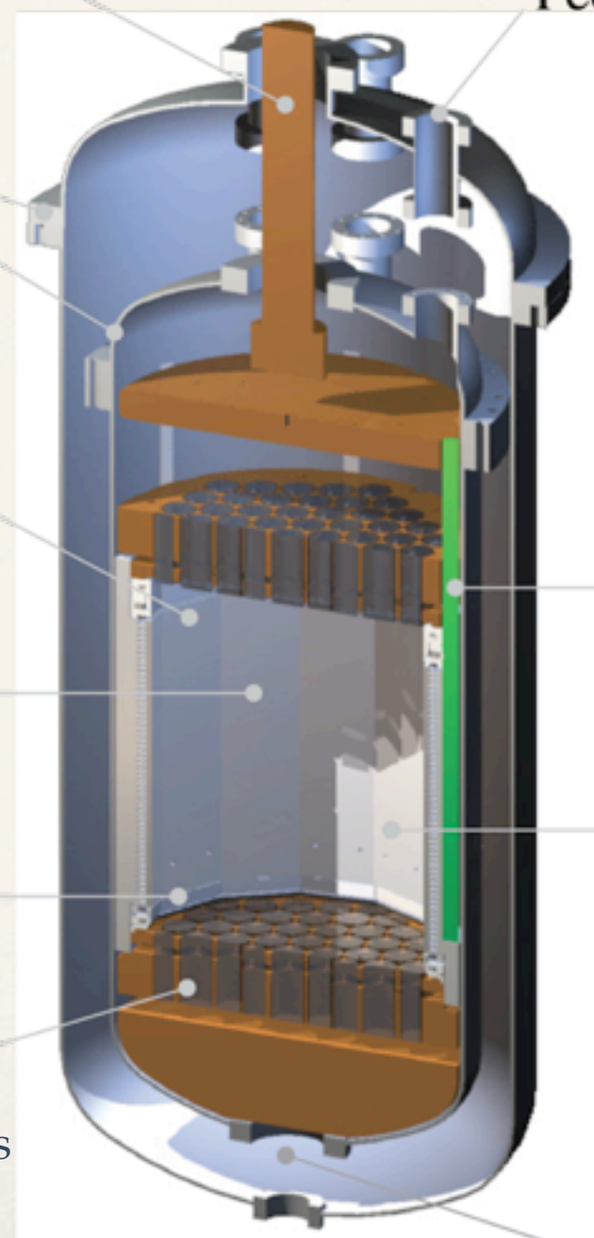
Aprile *et al.*, Phys. Rev. Lett., 97, 081302 (2006)

Ratio of electrons to photons produced in interaction distinguishes between electronic and nuclear recoil

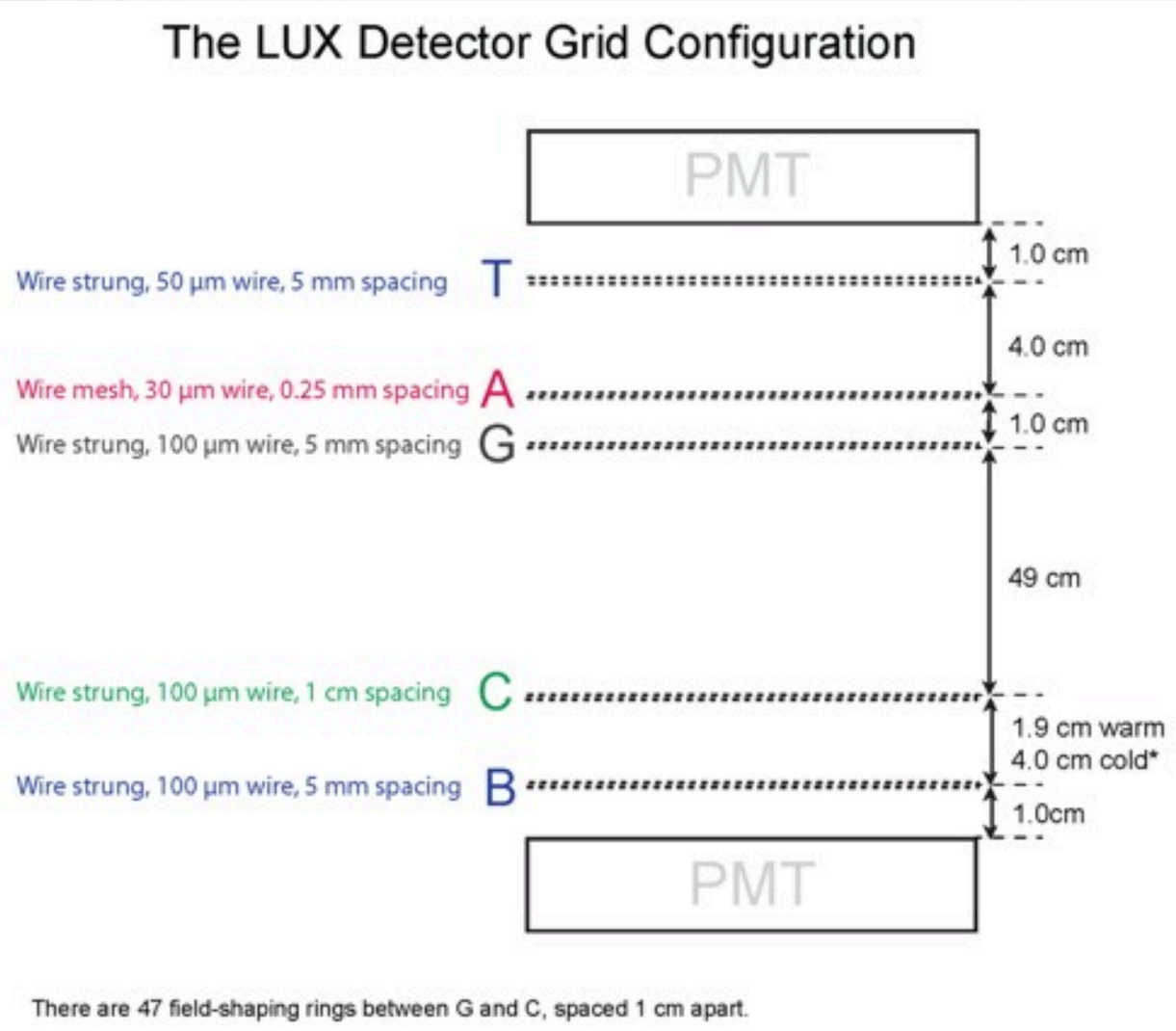
The LUX Detector

See Carmen Carmona's talk for details

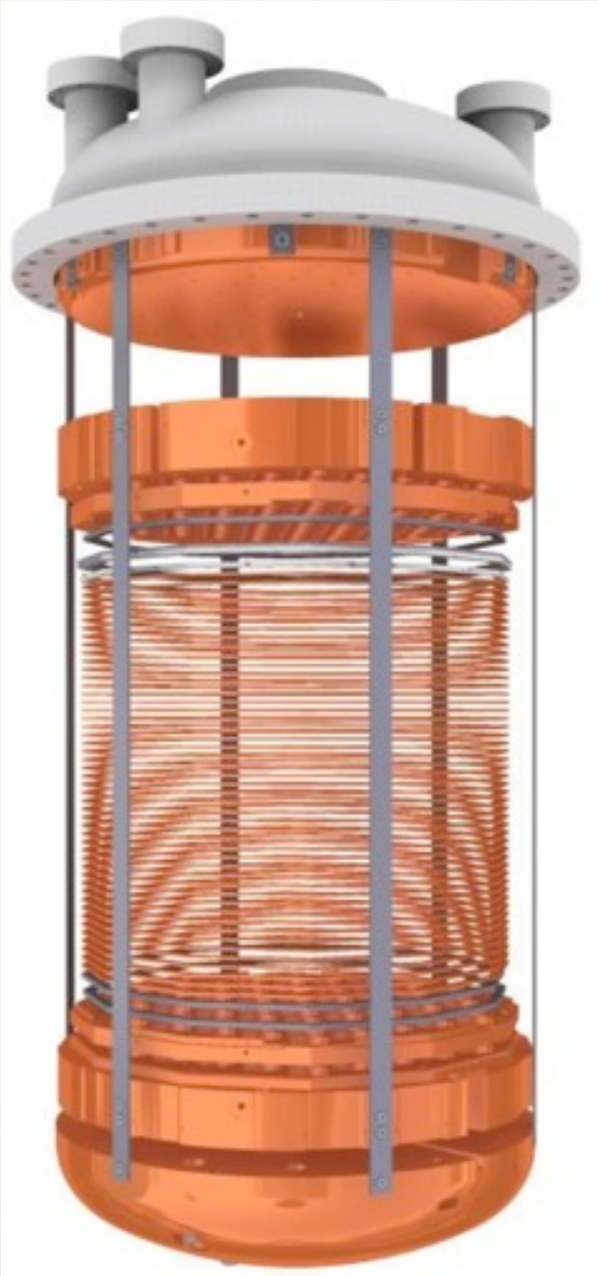
Cryostat


Top thermosyphon
Feedthroughs
Titanium cryostats
Anode and electron extraction grids
Expect ~ 1 kV/cm in liquid
Xenon recirculation and heat exchanger
Constantly circulate and purify Xe in gas phase
300 kg active liquid xenon
PTFE reflector panels
Expect reflectivity in liquid > 95%
Cathode grid
Photomultiplier tubes
122 Hamamatsu R8778, 12 stage 2.2" PMTs
Bottom thermosyphon

Detector "internals"



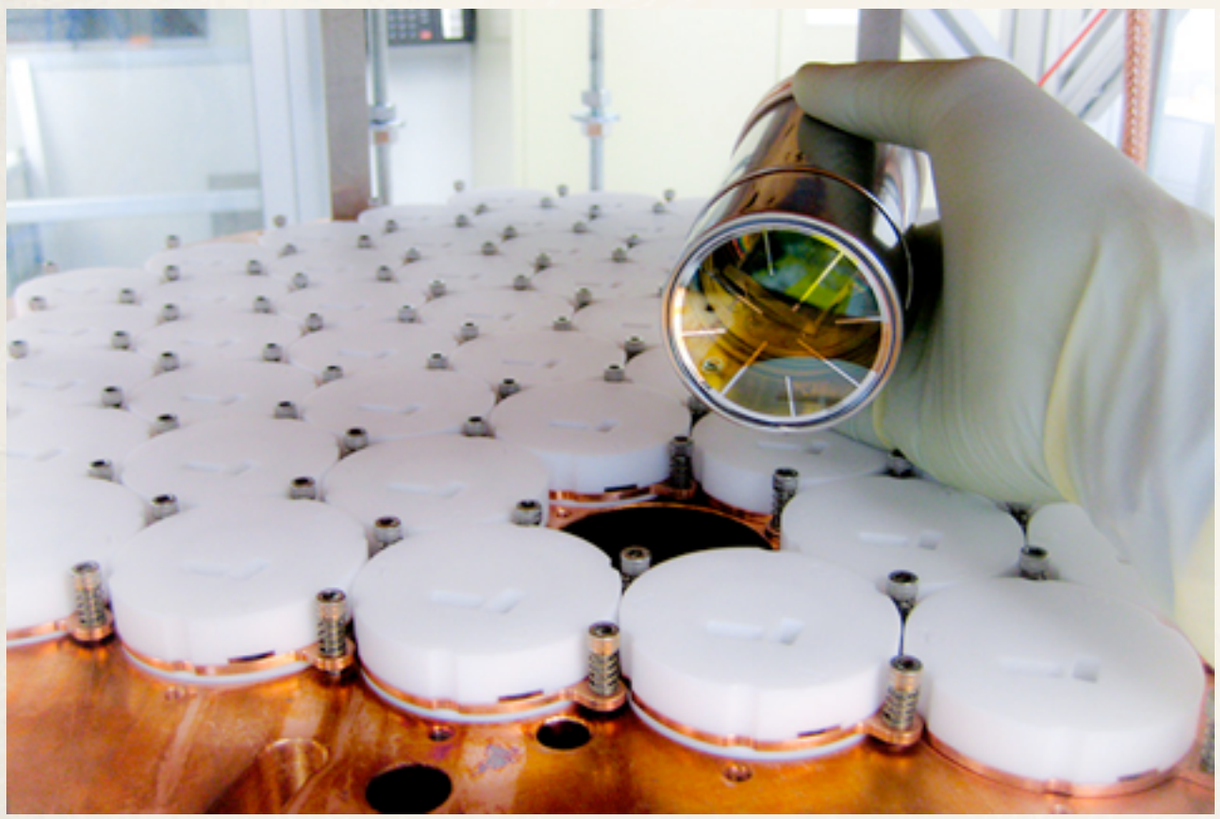
Liquid level ≈5 mm above gate grid



Aim to achieve ~1 kV/cm between cathode and gate grids

PMTs

Hamamatsu R8778, 12 stage 2.2″ PMTs



Developed for XMASS experiment
⇒ sensitive to 175 nm scintillation
⇒ can withstand pressures up to 5 atm
⇒ can operate at 170 K
⇒ quantum efficiency ~33%

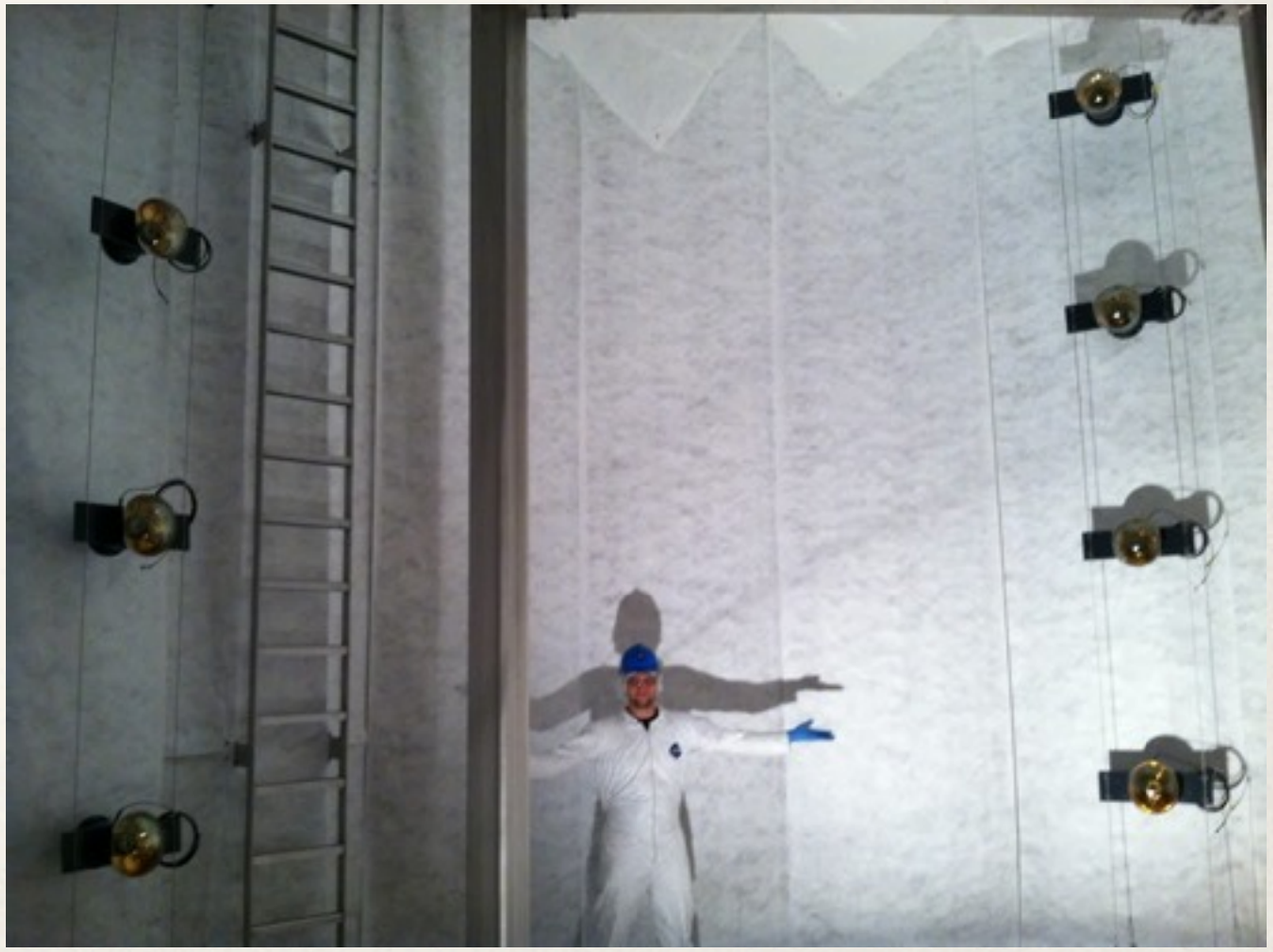
Expect 1.2 n/yr/PMT
⇒ 150 n/yr total

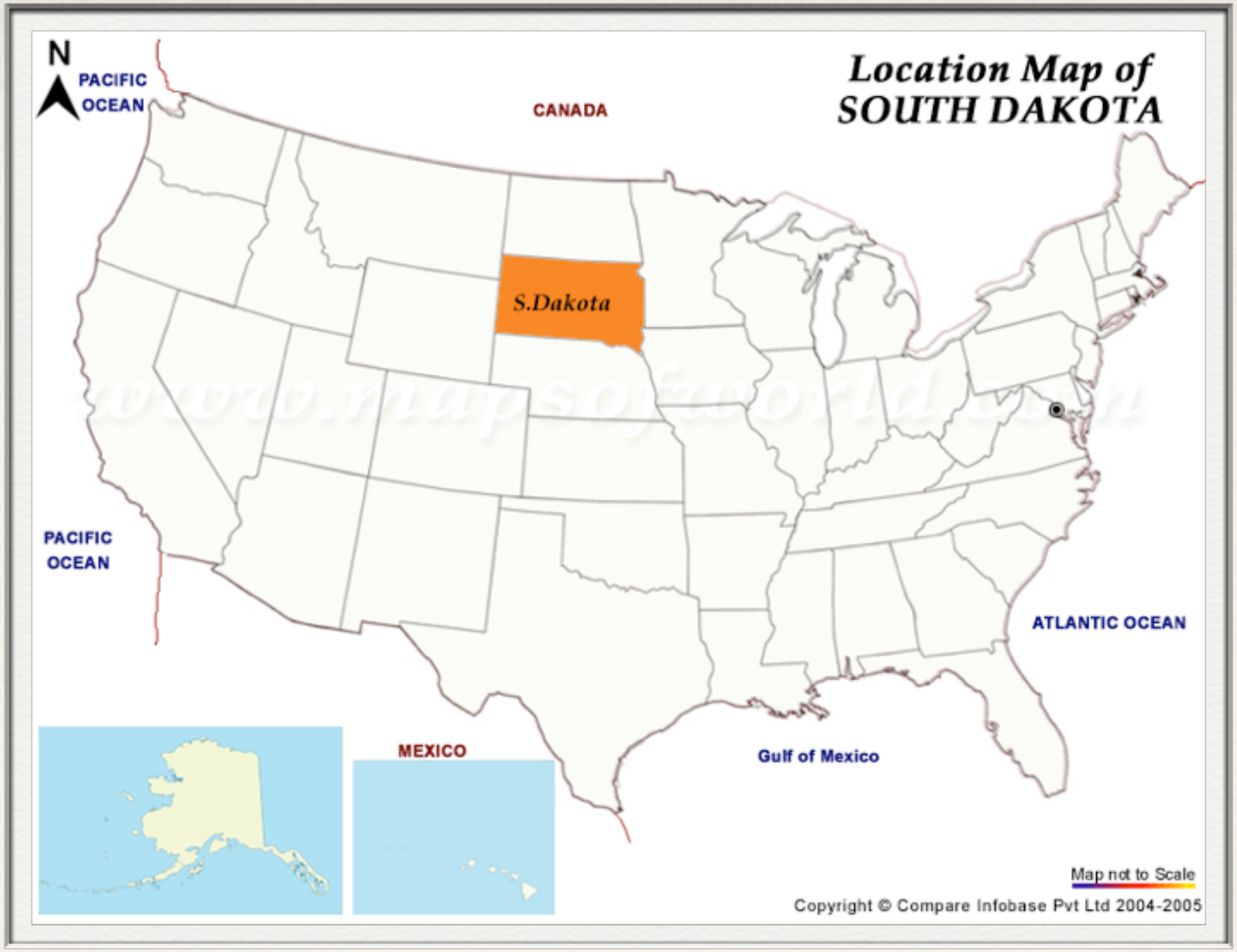
Dominant expected background in WIMP search!

Water shield

300 T de-ionized water shield,
20′ high, 25′ diameter SS tank
- reduce cavern & cosmogenic backgrounds

Instrumented with 20 Hamamatsu R7081 10″ diameter PMTs for veto of coincident NR candidates

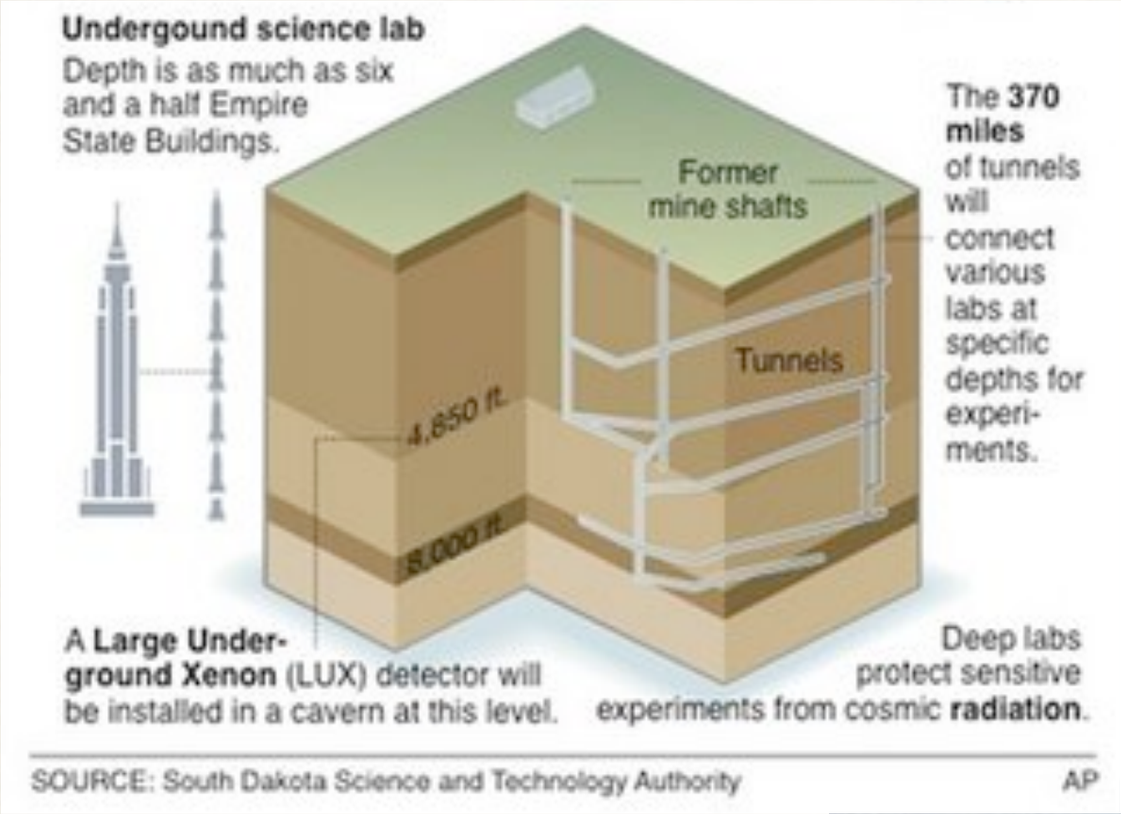




Sanford Underground Research Facility

Sanford Underground Research Facility

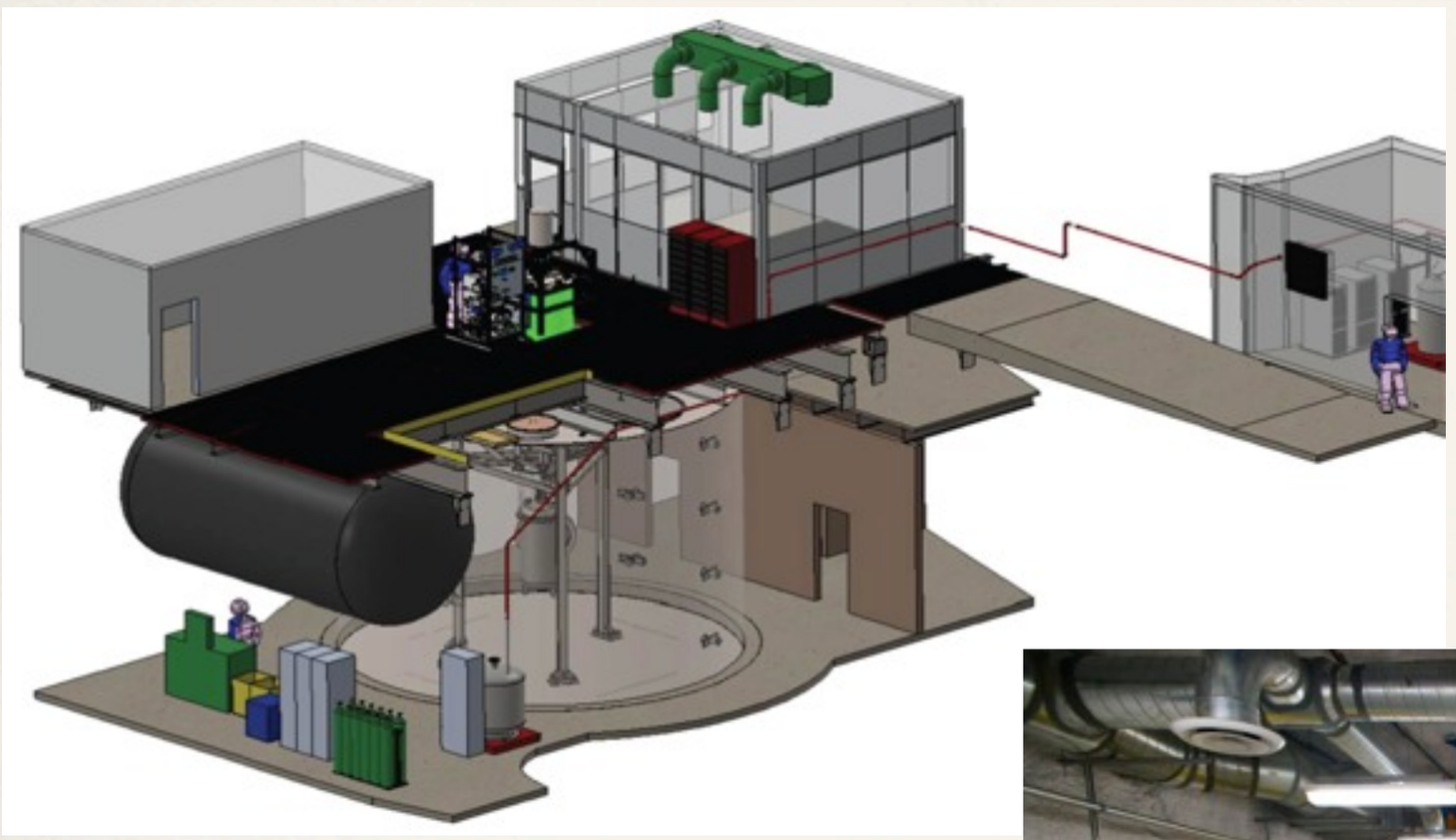
Deadwood, SD is down the street...

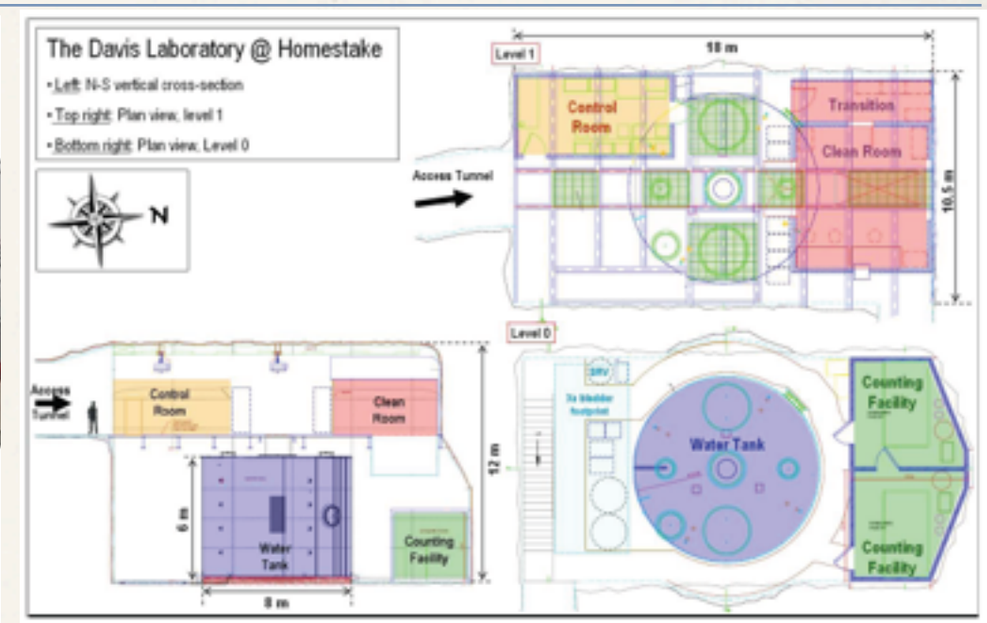


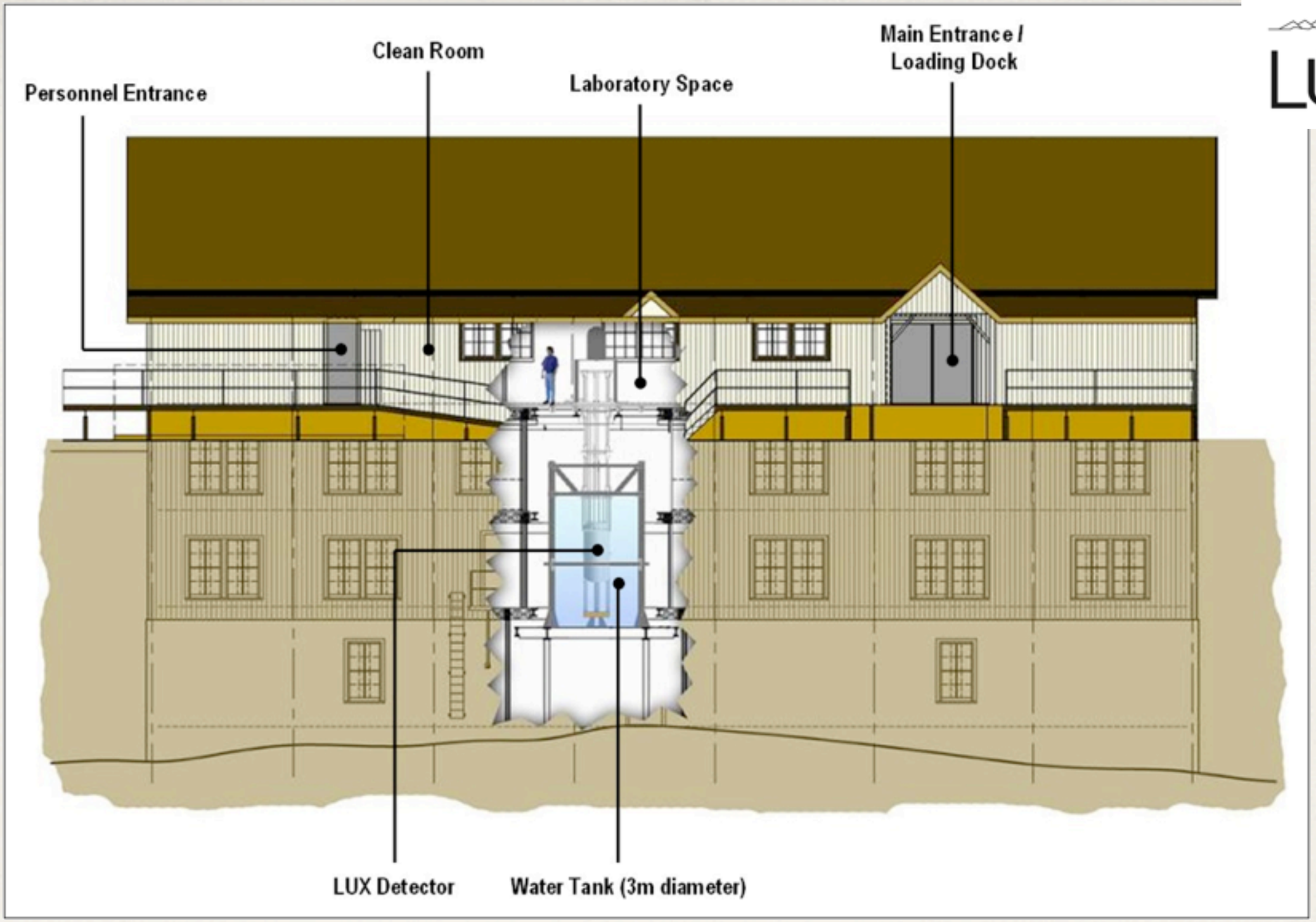
4.3 km.w.e. shielding at 4850′ level

Former Homestake gold mine is now home of low background science

Davis campus at 4850' level



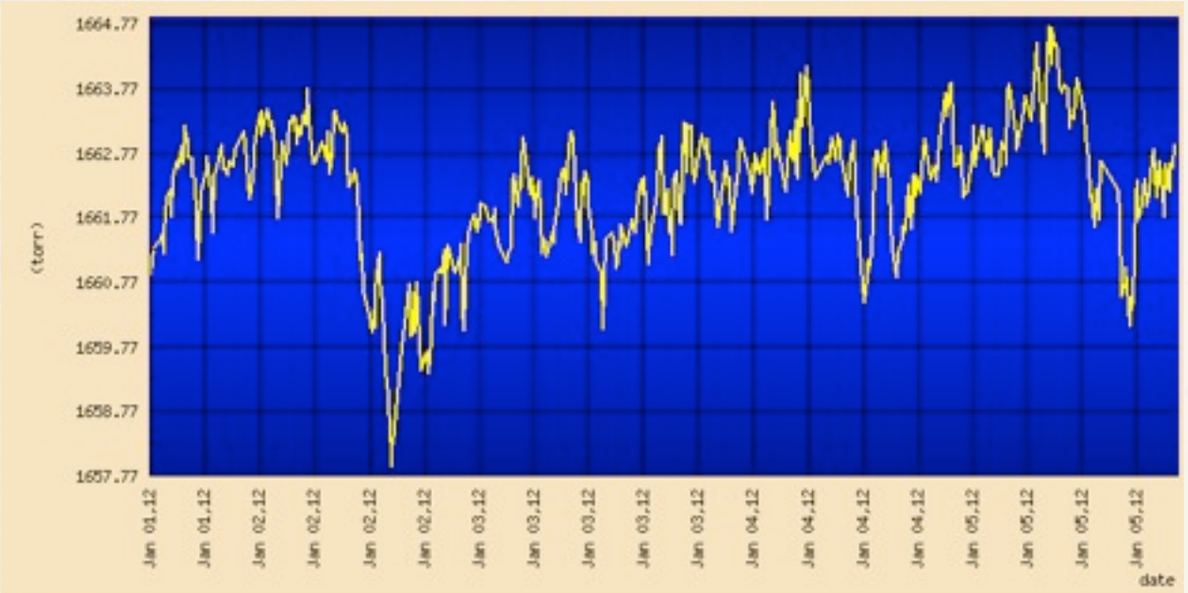




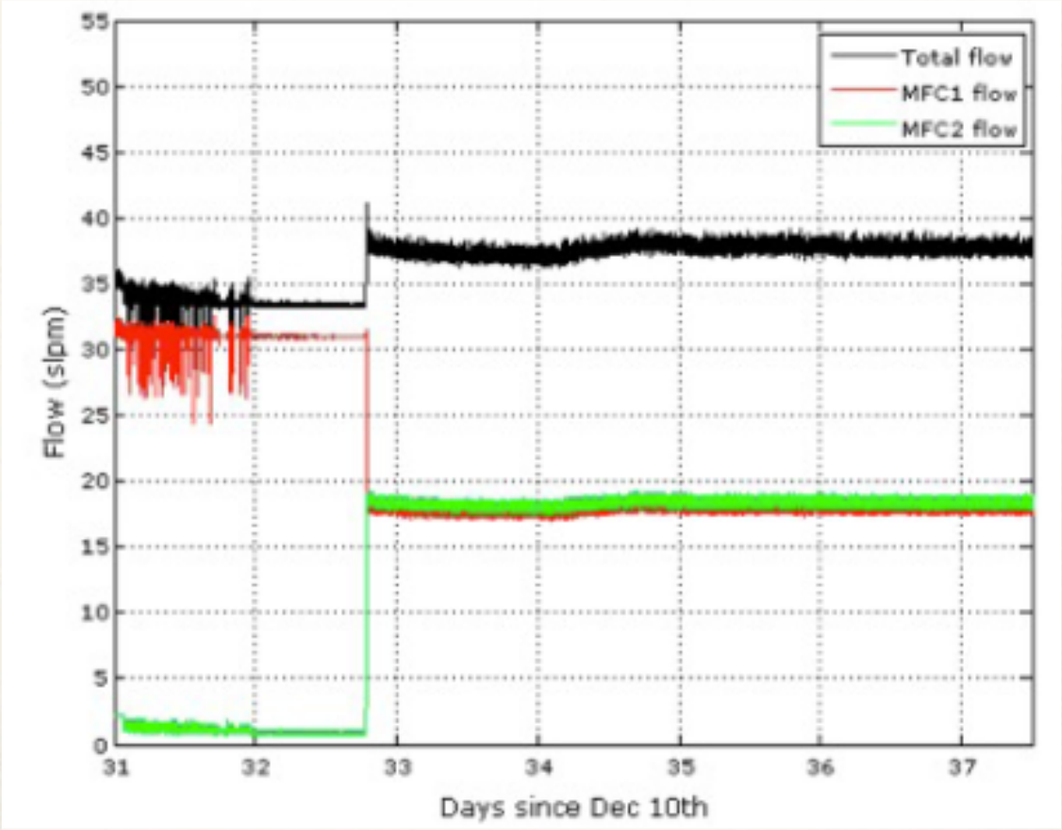
Surface commissioning

Spent autumn 2011 through winter 2012 commissioning LUX detector systems above ground while Davis campus was under preparation

First things first - stable operation!



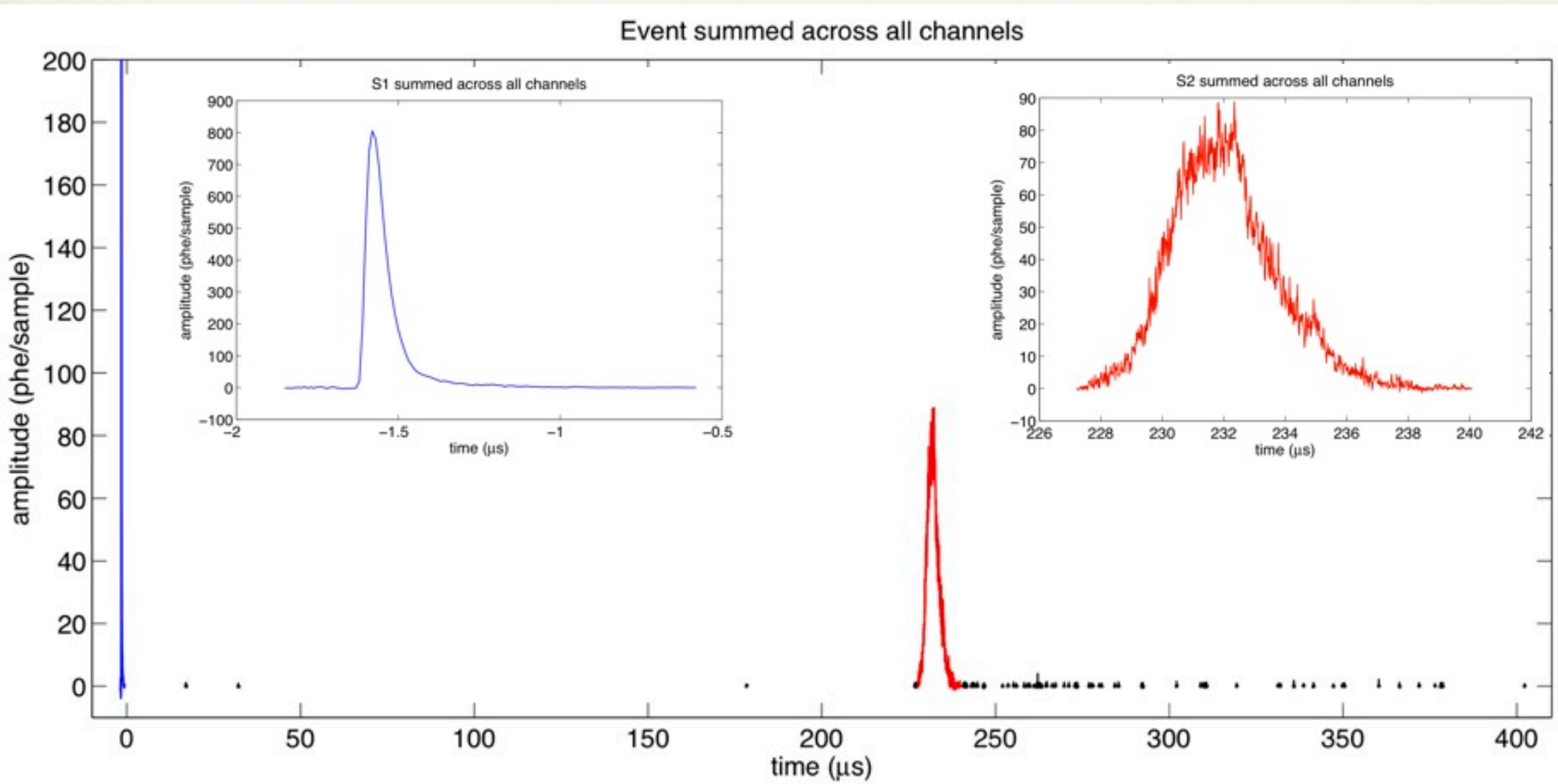
Pressure stability ~0.4% over 5 days



Stable circulation of 35 slpm $\Rightarrow$ 300 kg/day
with < 5 W heat load

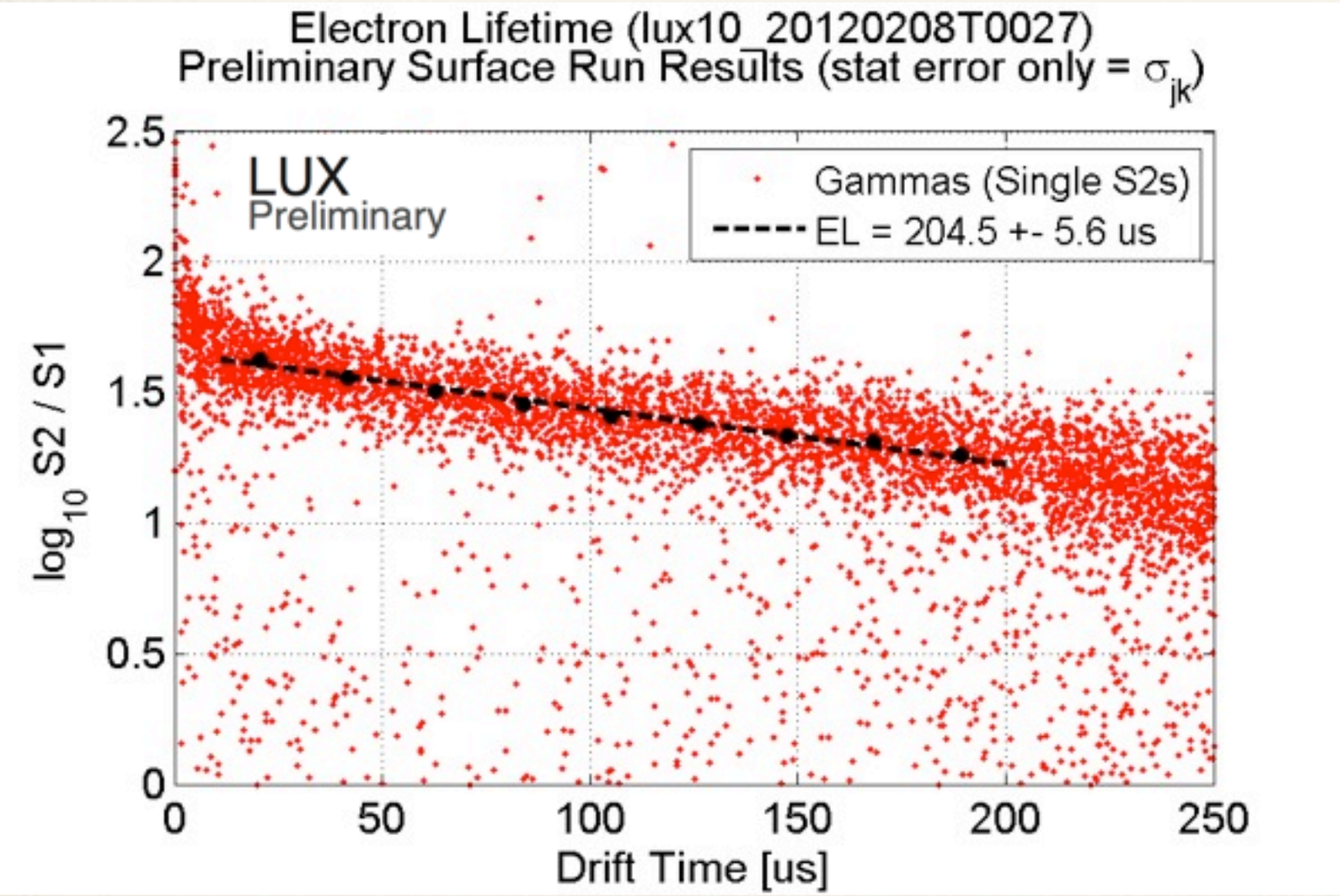
We see signals!

In fact, we see a lot of signals!



50 cm drift region

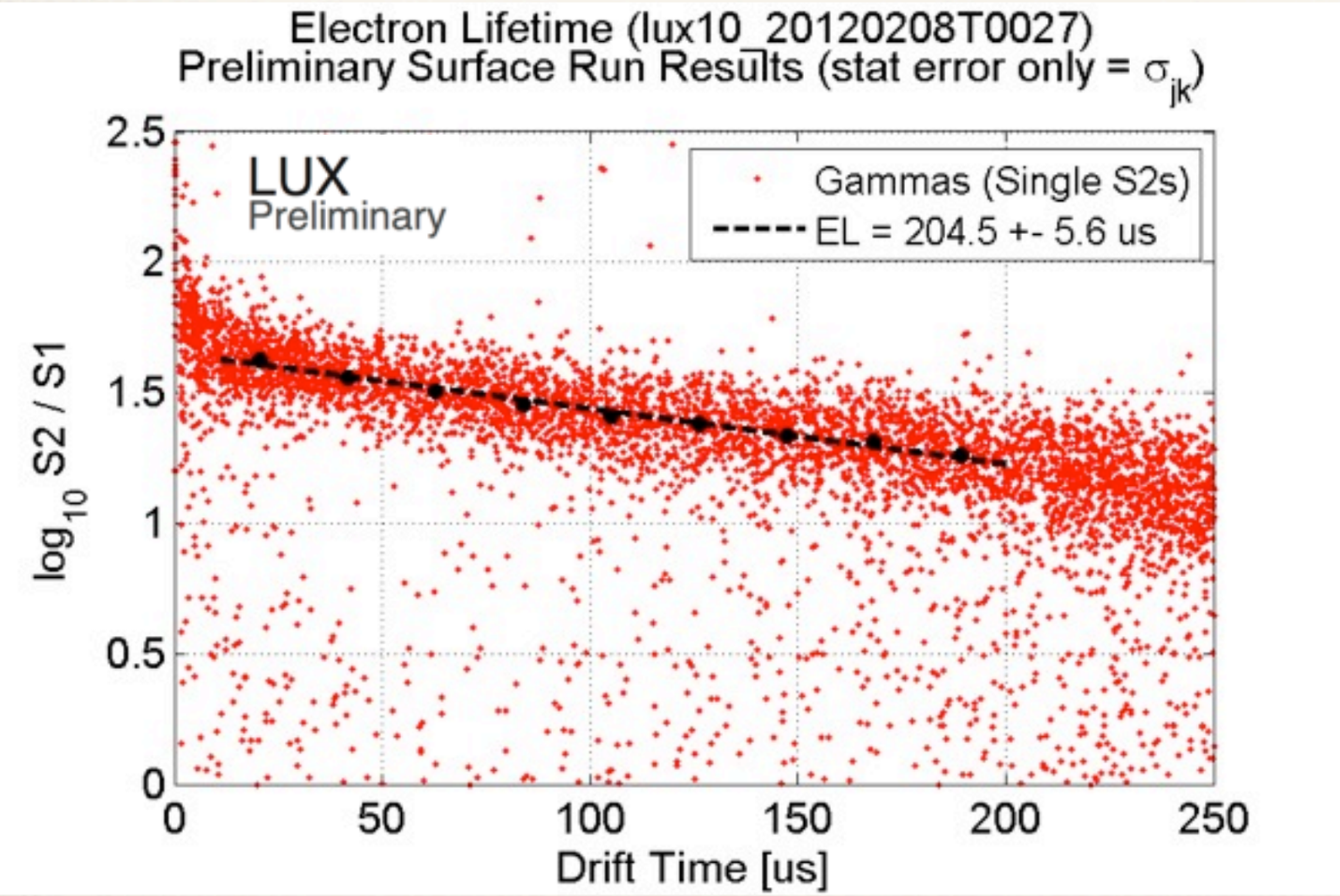
Obtain fair xenon purity



Obtain 204 ± 6 (stat) μs despite non-optimal circulation path ⇒ 25 cm electron drift length

Aim for 1 m electron drift length for DM search

Obtain fair xenon purity

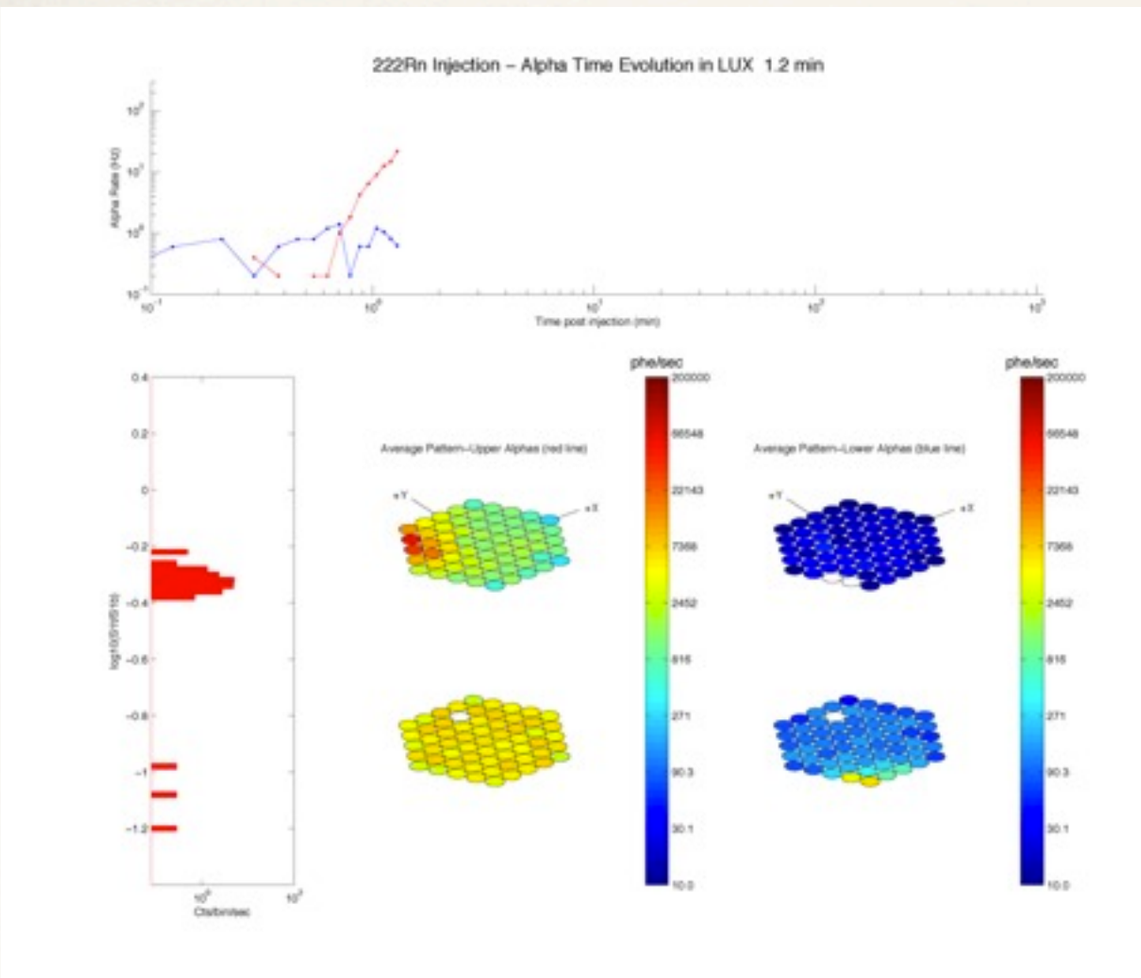


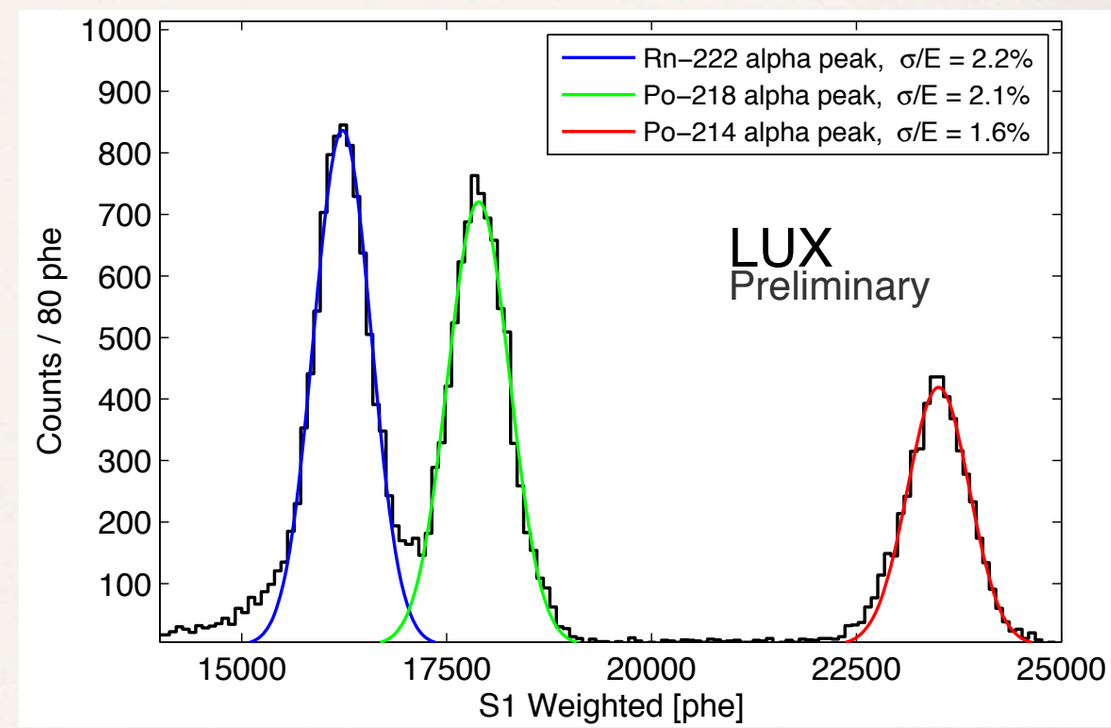
Obtain 204 ± 6 (stat) μs despite non-optimal circulation path ⇒ 25 cm electron drift length

Aim for 1 m electron drift length for DM search

Studies of ^{222}Rn α daughters

We made a diagnostic ^{222}Rn injection to image the circulation path after discovering the compromise





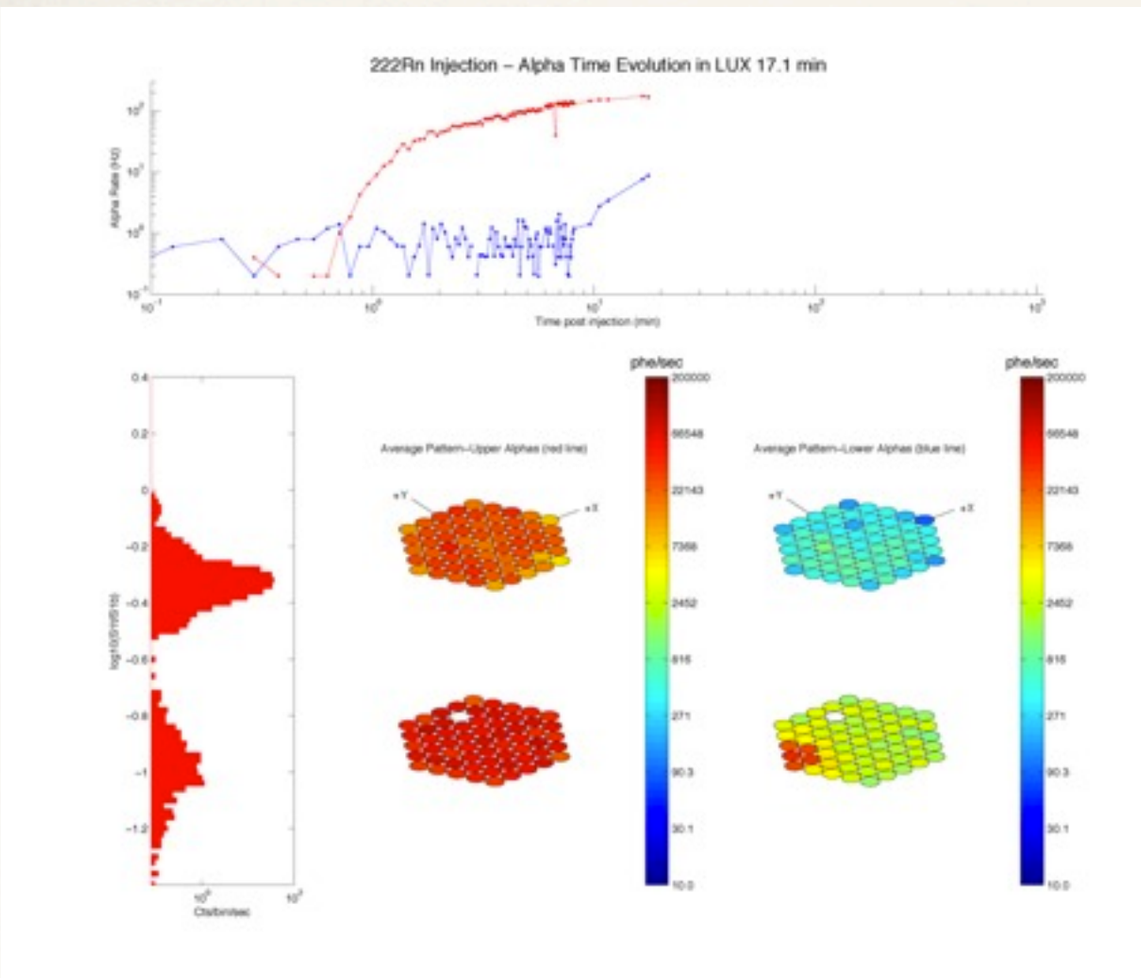
$S1_{weighted} = S1_{top}*\cos(0.33)+S1_{bottom}*\sin(0.33)$

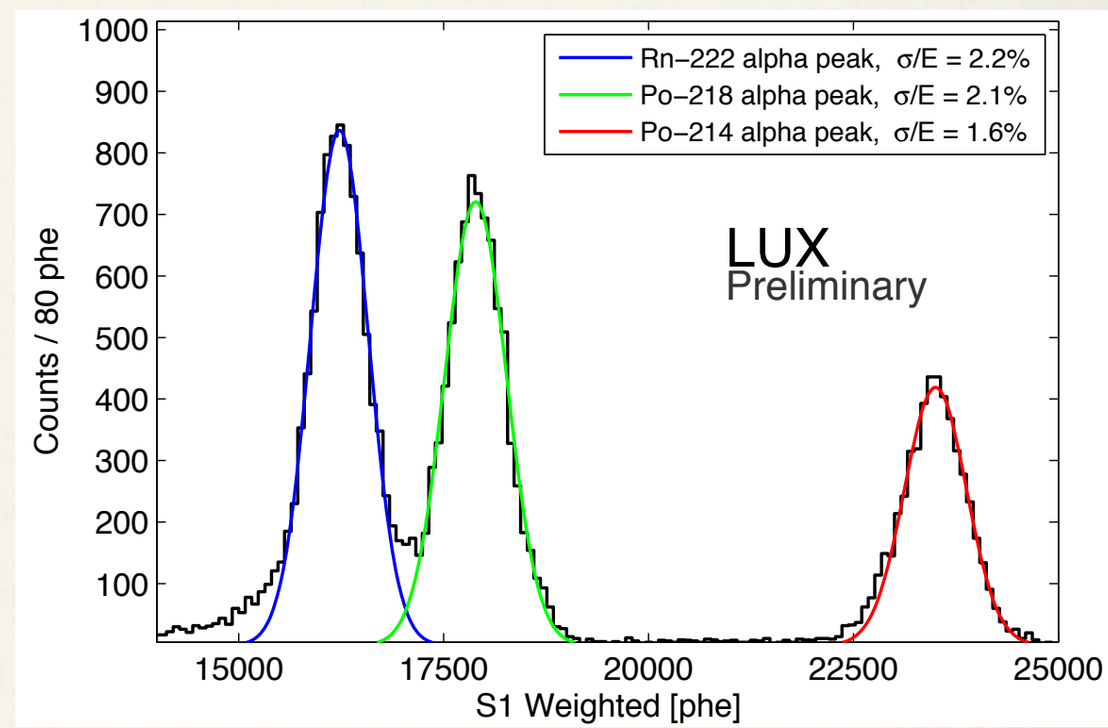
Estimate extremely pessimistic contamination of 11 n/yr from ^{222}Rn injection, 7.5% of PMTs

See Carlos Faham's talk for details

Studies of ^{222}Rn α daughters

We made a diagnostic ^{222}Rn injection to image the circulation path after discovering the compromise



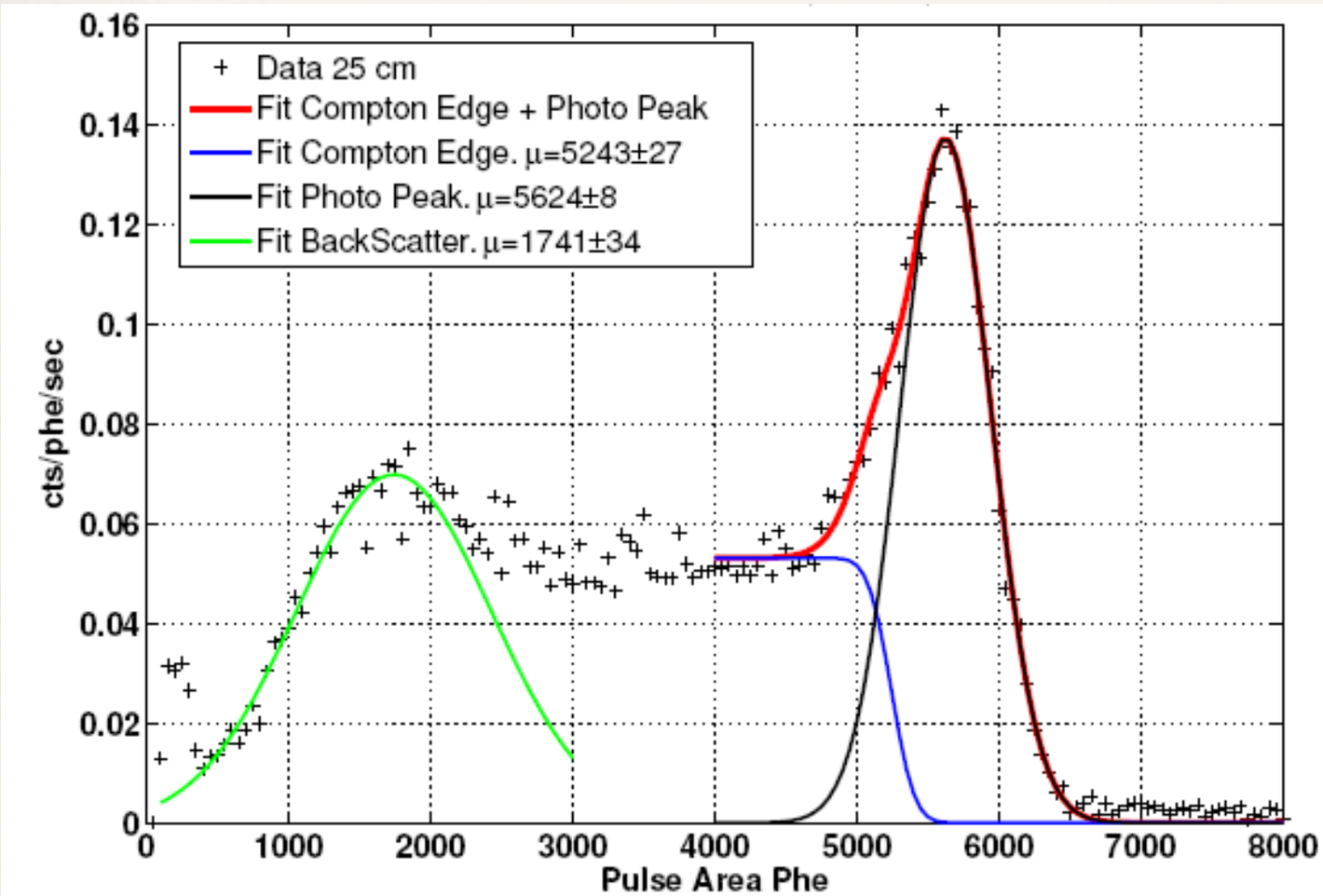


$S1_{weighted} = S1_{top}*\cos(0.33)+S1_{bottom}*\sin(0.33)$

Estimate extremely pessimistic contamination of 11 n/yr from ^{222}Rn injection, 7.5% of PMTs

See Carlos Faham's talk for details

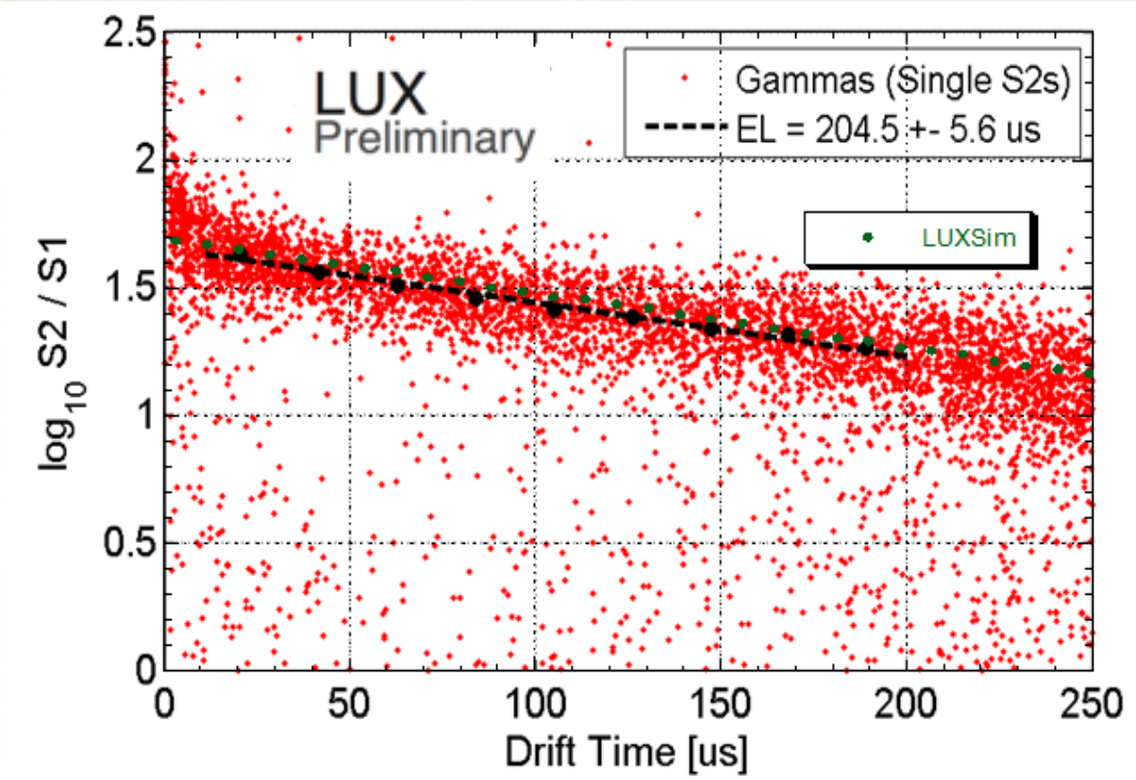
We find excellent light collection



Obtain 8 phe/keV from 662 keV γ (^{137}Cs source) ⇒ scaling to 122 keV at 500 V/cm gives 6 phe/keV

See Matthew Szydagis's talk for details

Realistic LUX simulation



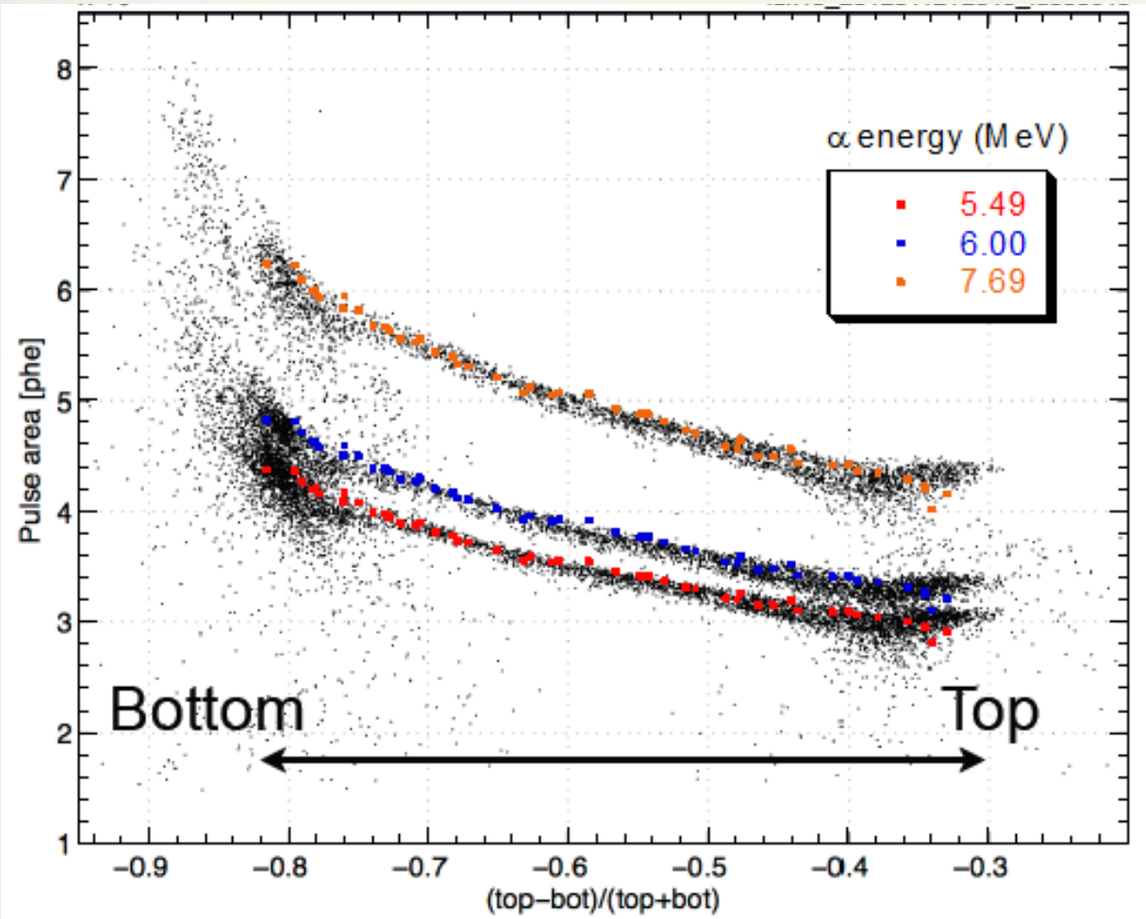
LUX has developed a realistic, Geant4-based simulation of detector geometry, which utilizes a data-motivated scintillation model

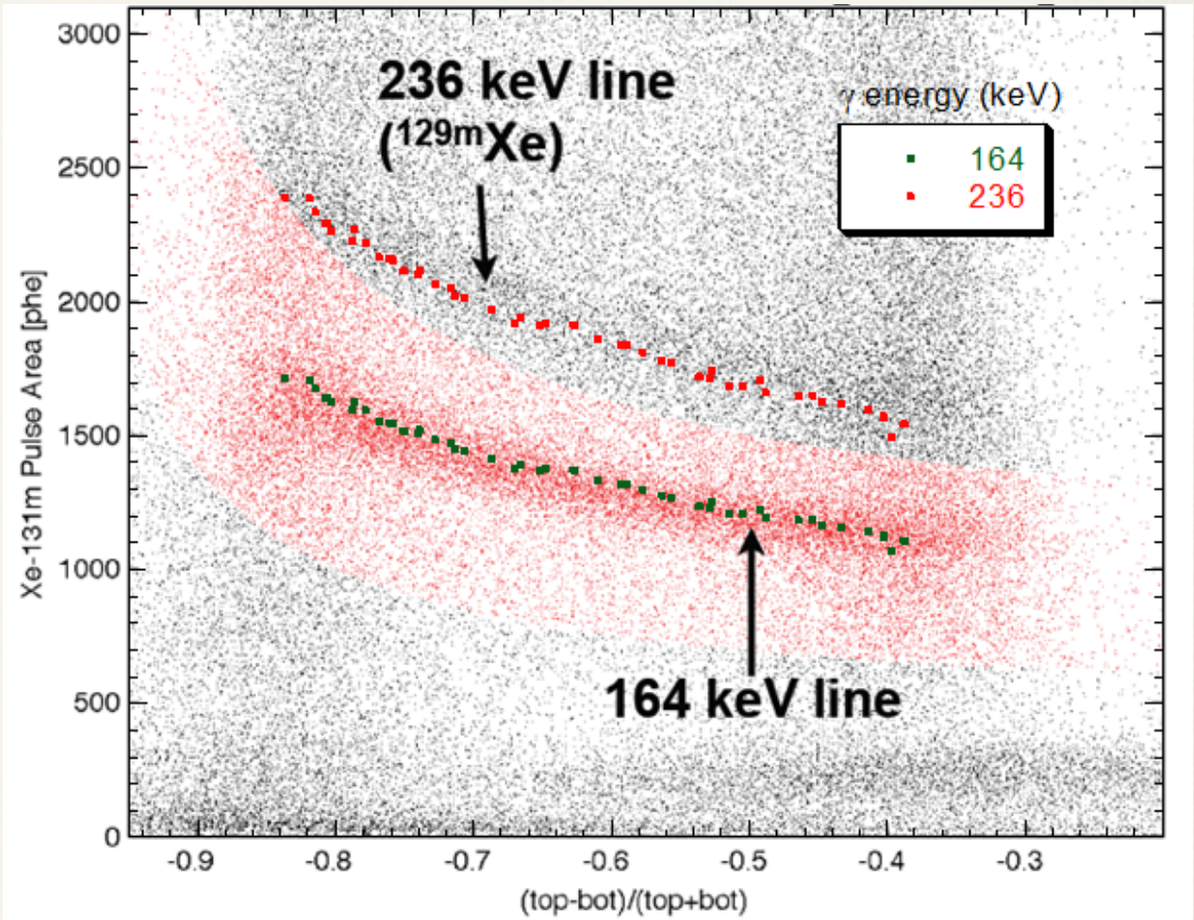
Akerib et al., "LUXSim: A Component-Centric Approach to Low-Background Simulations", Nucl. Instrum. Meth. A **675**, 63 (2012)

Szydagis et al., "NEST: A Comprehensive Model for Scintillation Yield in Liquid Xenon", JINST **6,** P10002 (2011)

Simulation provides accurate estimates of S1 and S2 signals, given tuning of light collection parameters on S1 calibration signals

Comprehensive study of light collection using simulation

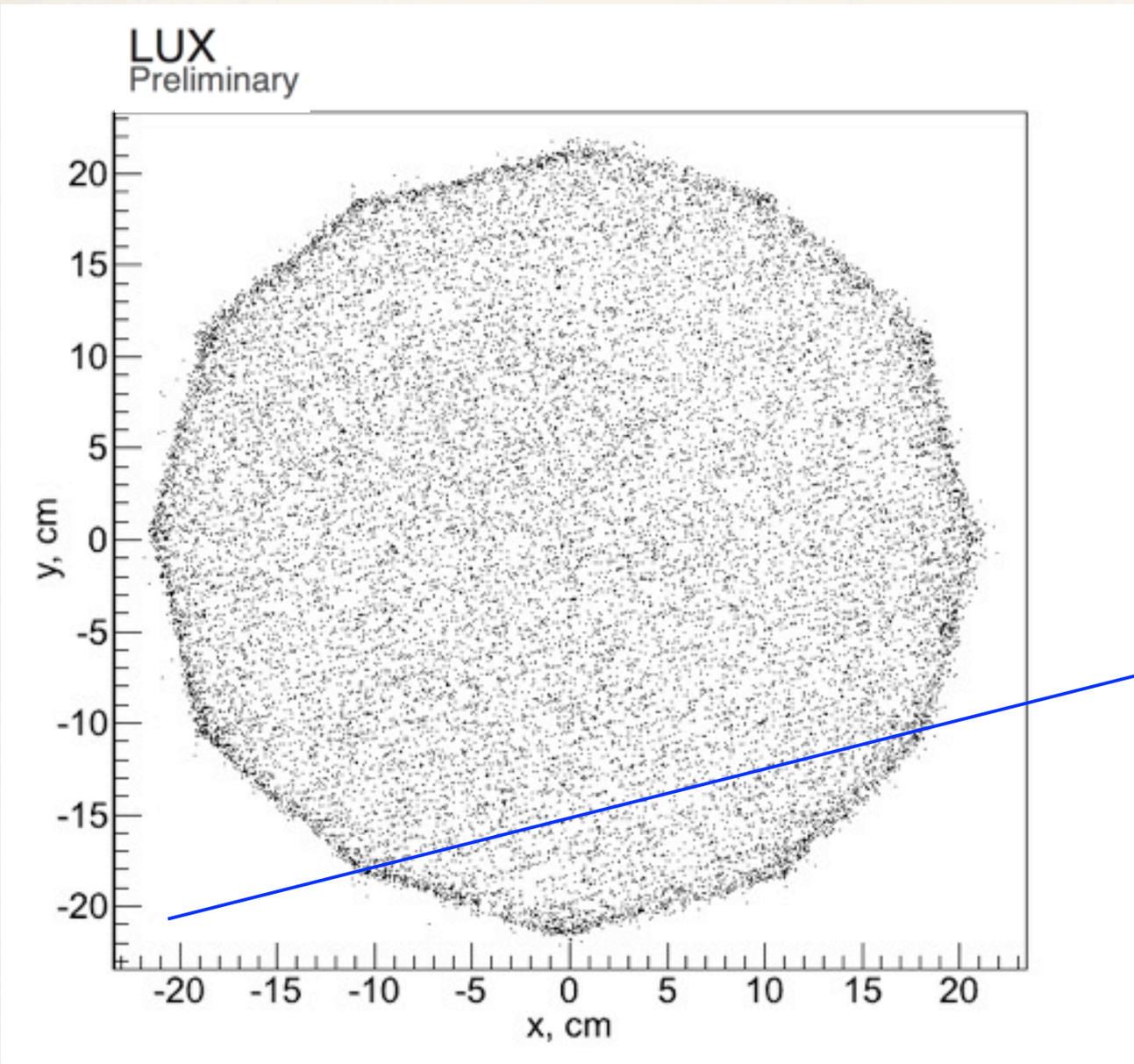


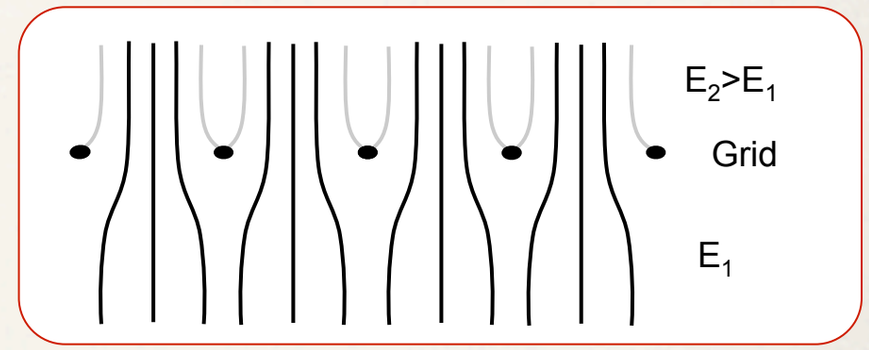


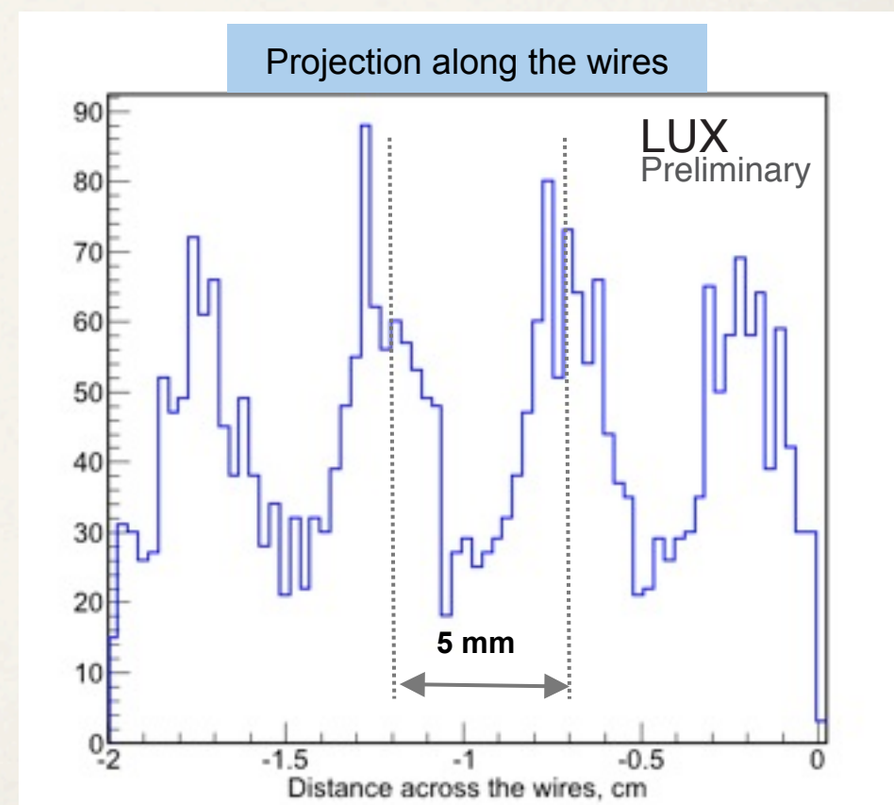
Simulation estimates PTFE reflectivity > 95 % and photoabsorption length > 5 m from study of ^{137}Cs, activated Xe, and α daughters from ^{222}Rn decay chain

See Matthew Szydagis's talk for details

x-y position reconstruction



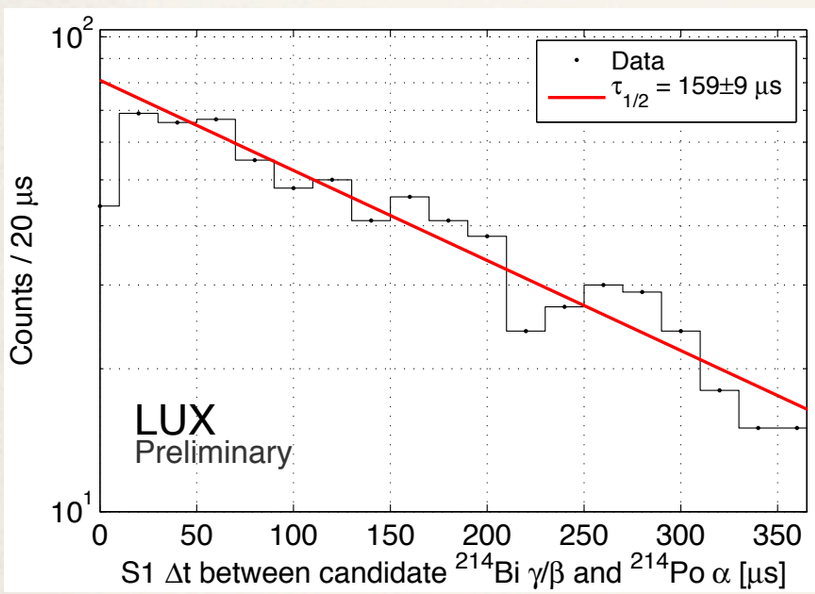


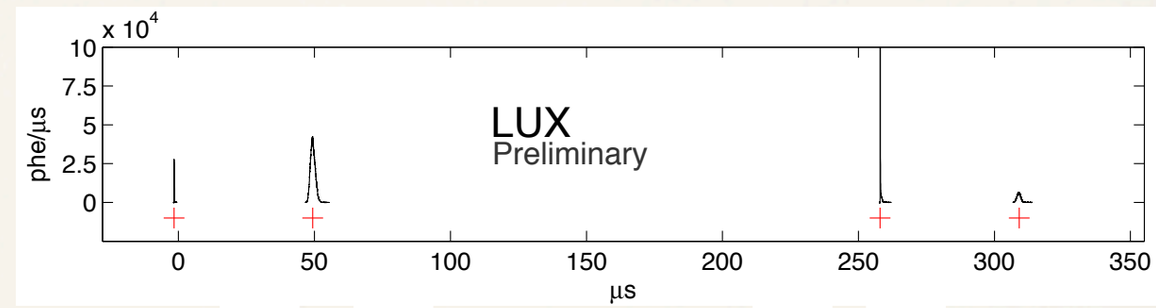


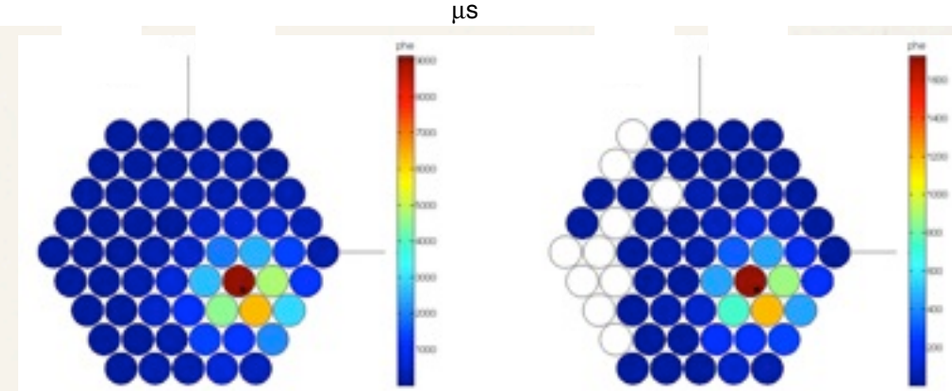
Position reco obtained using ZEPLIN III Mercury algo
(V. Solovov *et al.*, arXiv:1112.1481v1)

See Carlos Faham's talk for details

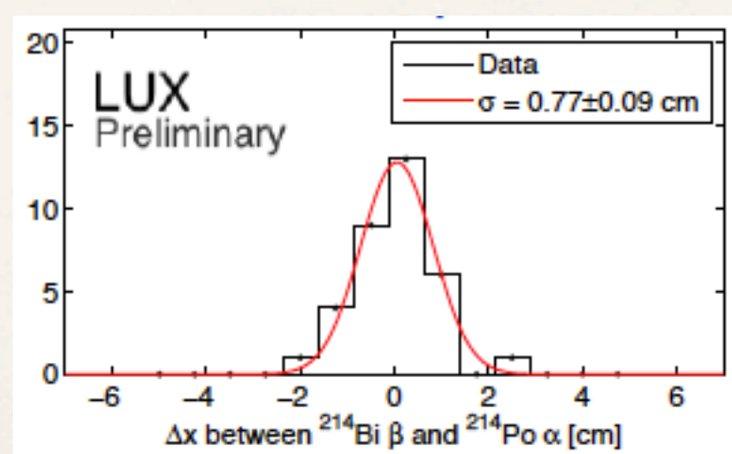
Estimate of x-y position resolution

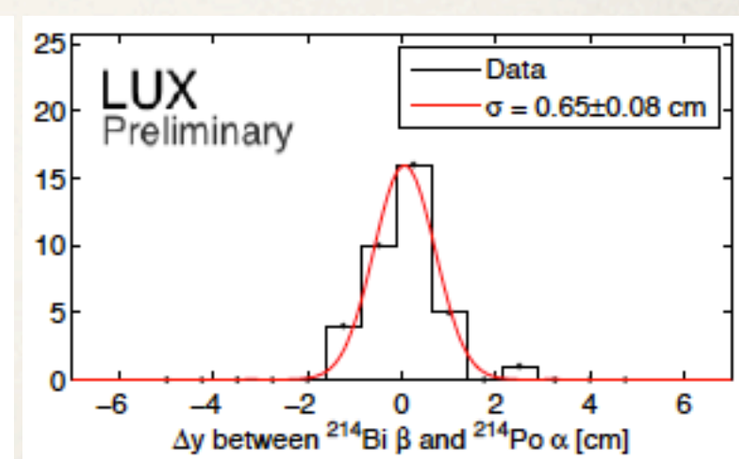






Can identify ^{214}Bi-^{214}Po coincident events and use it to probe the statistical component of the position resolution



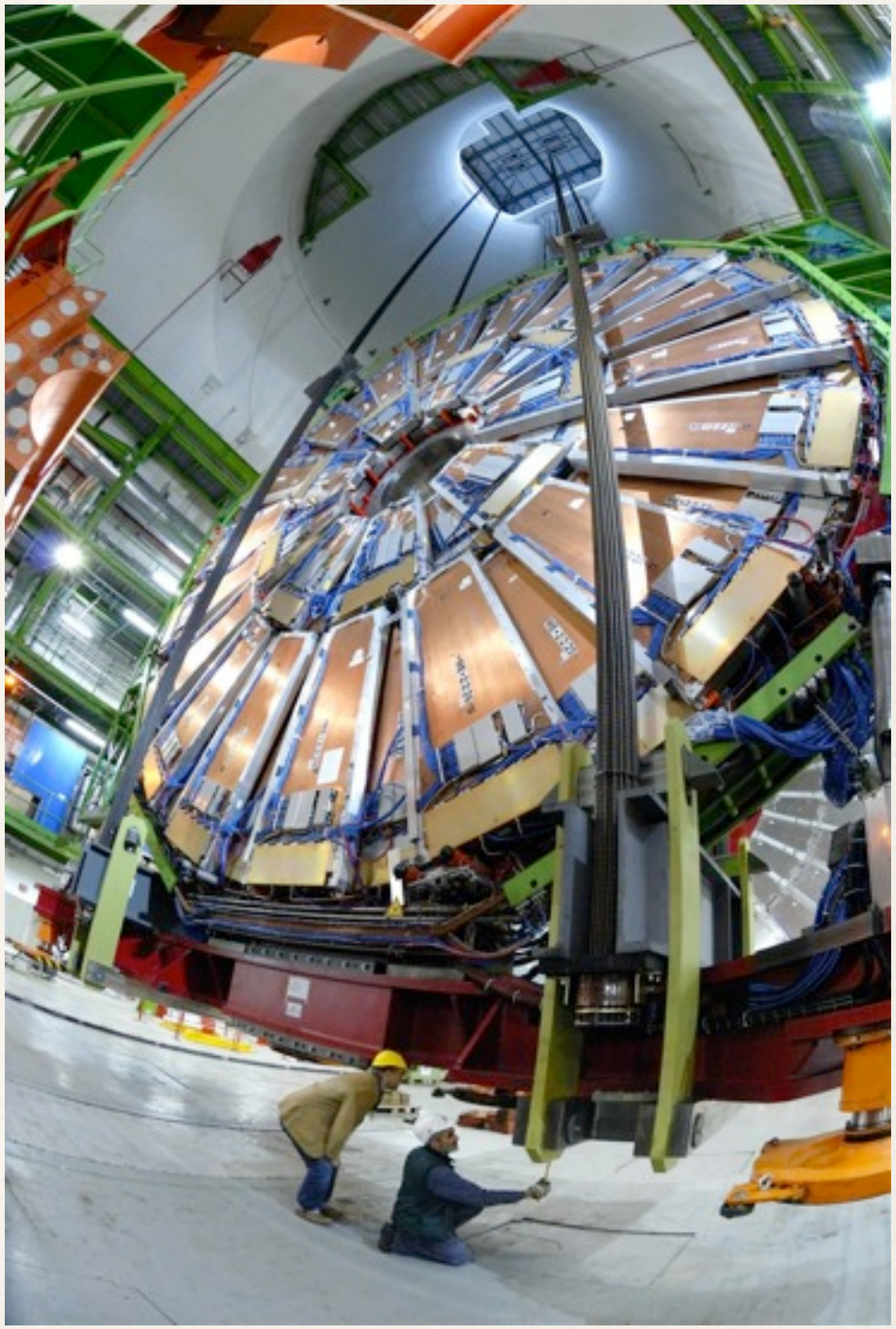


We estimate ~7mm stat. resolution in x or y for α's in the detector bulk

See Carlos Faham's talk for details

Going underground...

CMS detector lowered 100 m in sixteen pieces, ranging from 300 T to 1900 T



Conclusion

We have observed a new boson with a mass of

125.3 ± 0.4 (stat) ± 0.5 (syst)

at significance level of 5 σ

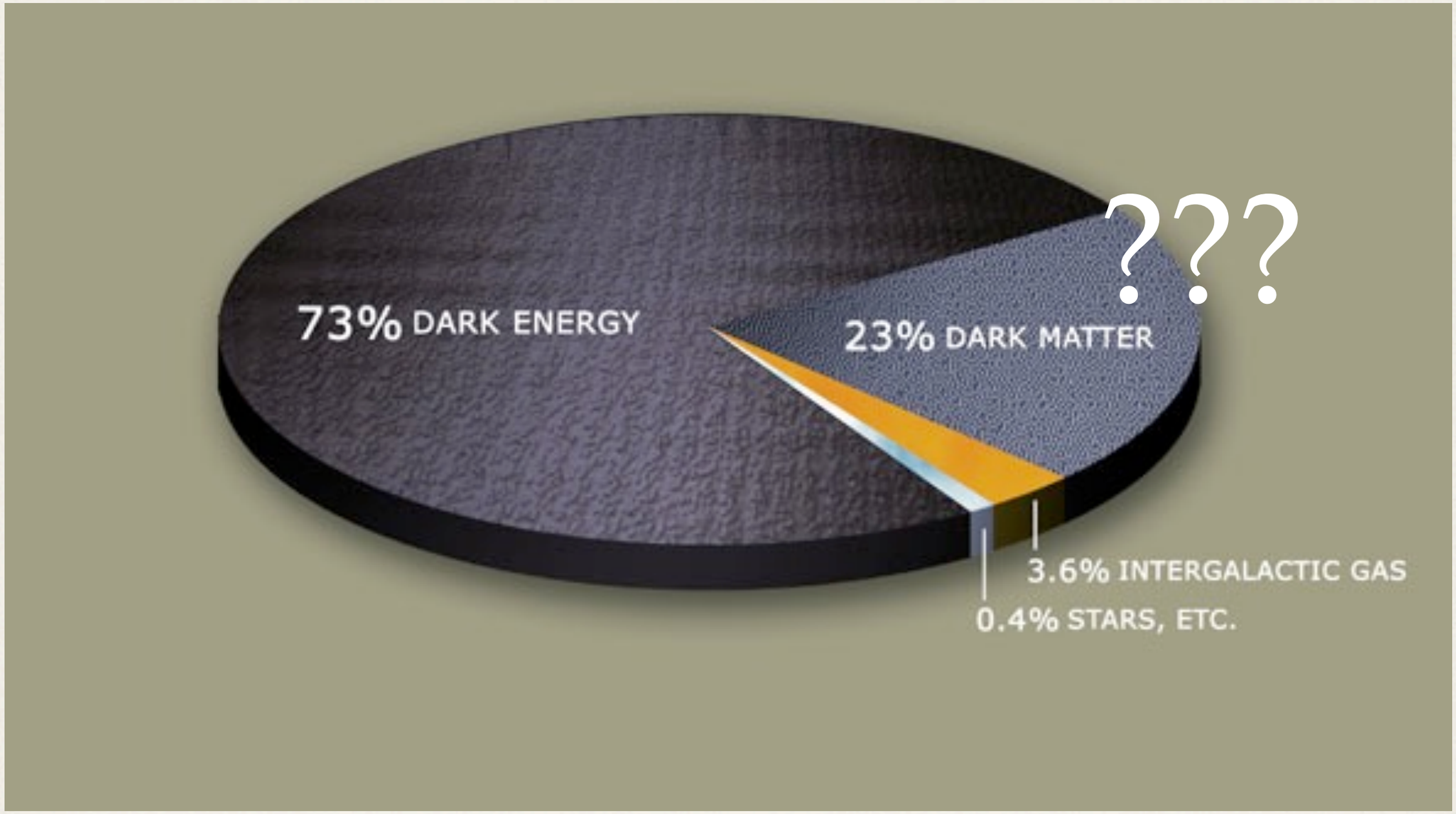
July 9th 2012 ICHEP CMS Higgs J. Incandela for the CMS COLLABORATION

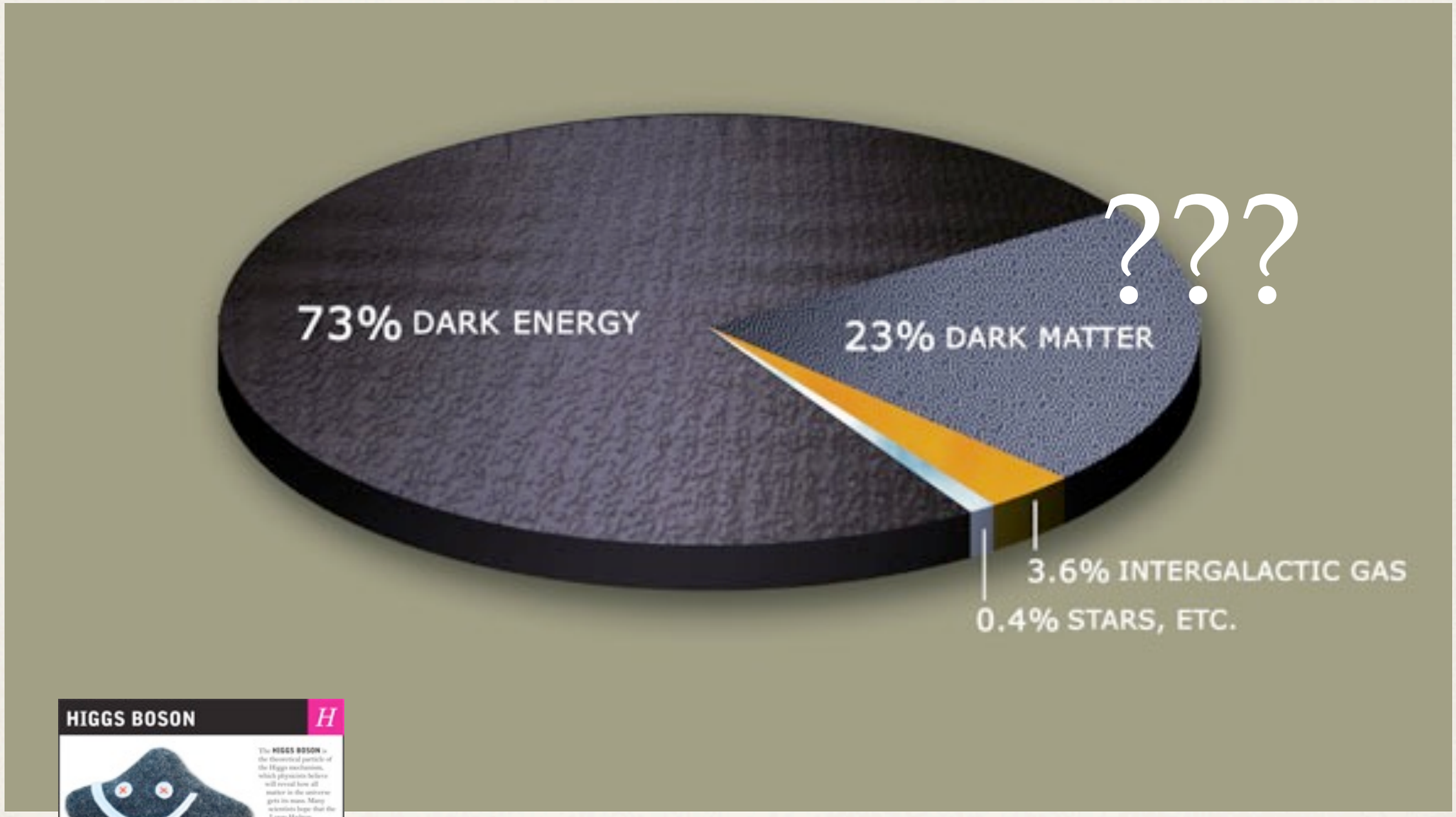
Joe Incandela's talk at ICHEP

LUX detector was moved underground July 11-12, 2012

LUX detector was moved underground July 11-12, 2012

LUX detector (3 T) transported 1.9 km,
420 m of which were linear translation!


???
73% DARK ENERGY
23% DARK MATTER
3.6% INTERGALACTIC GAS
0.4% STARS, ETC.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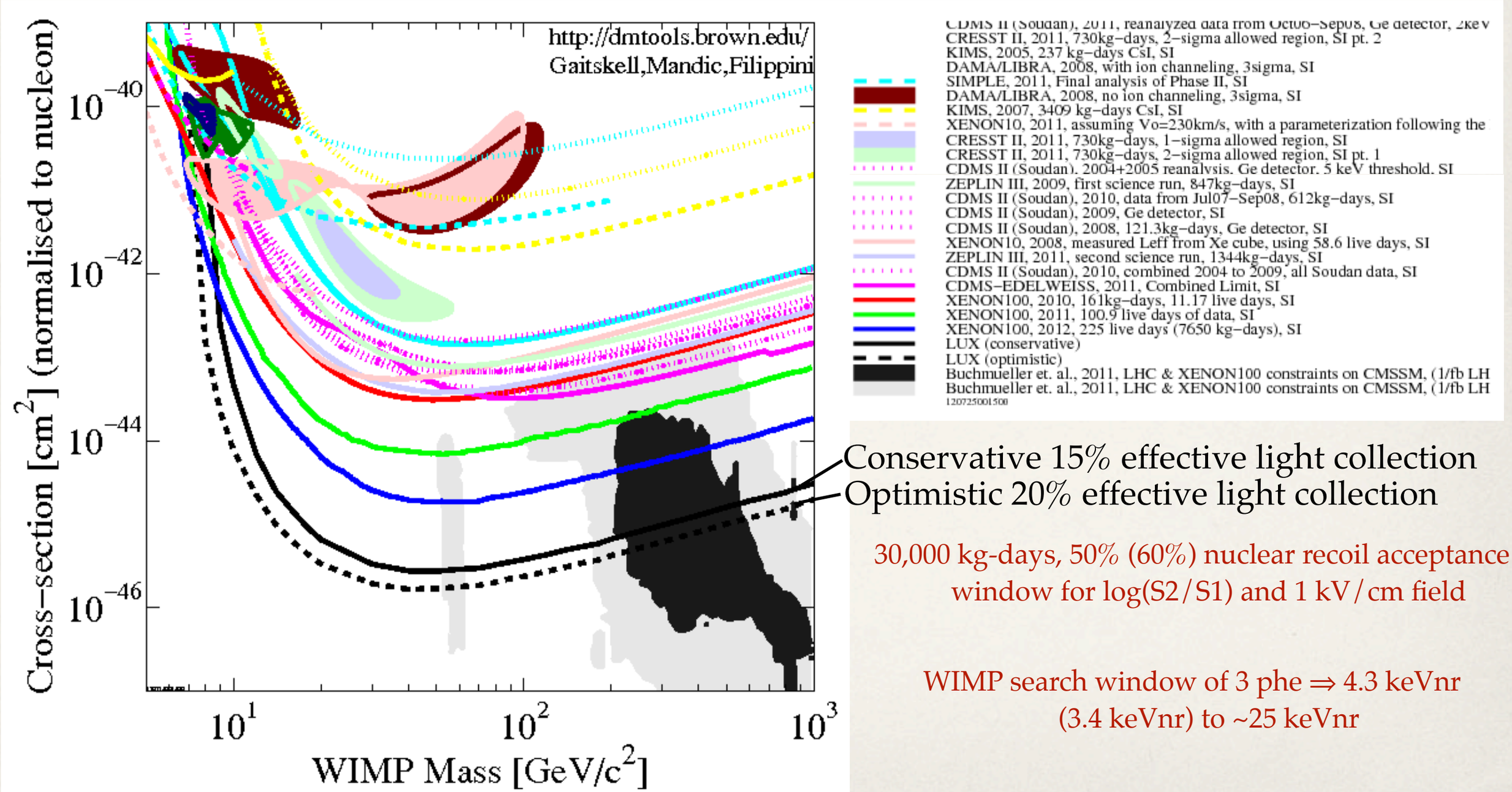
HIGGS BOSON
H
$10.49
PARTICLEZOO

Projected LUX sensitivity



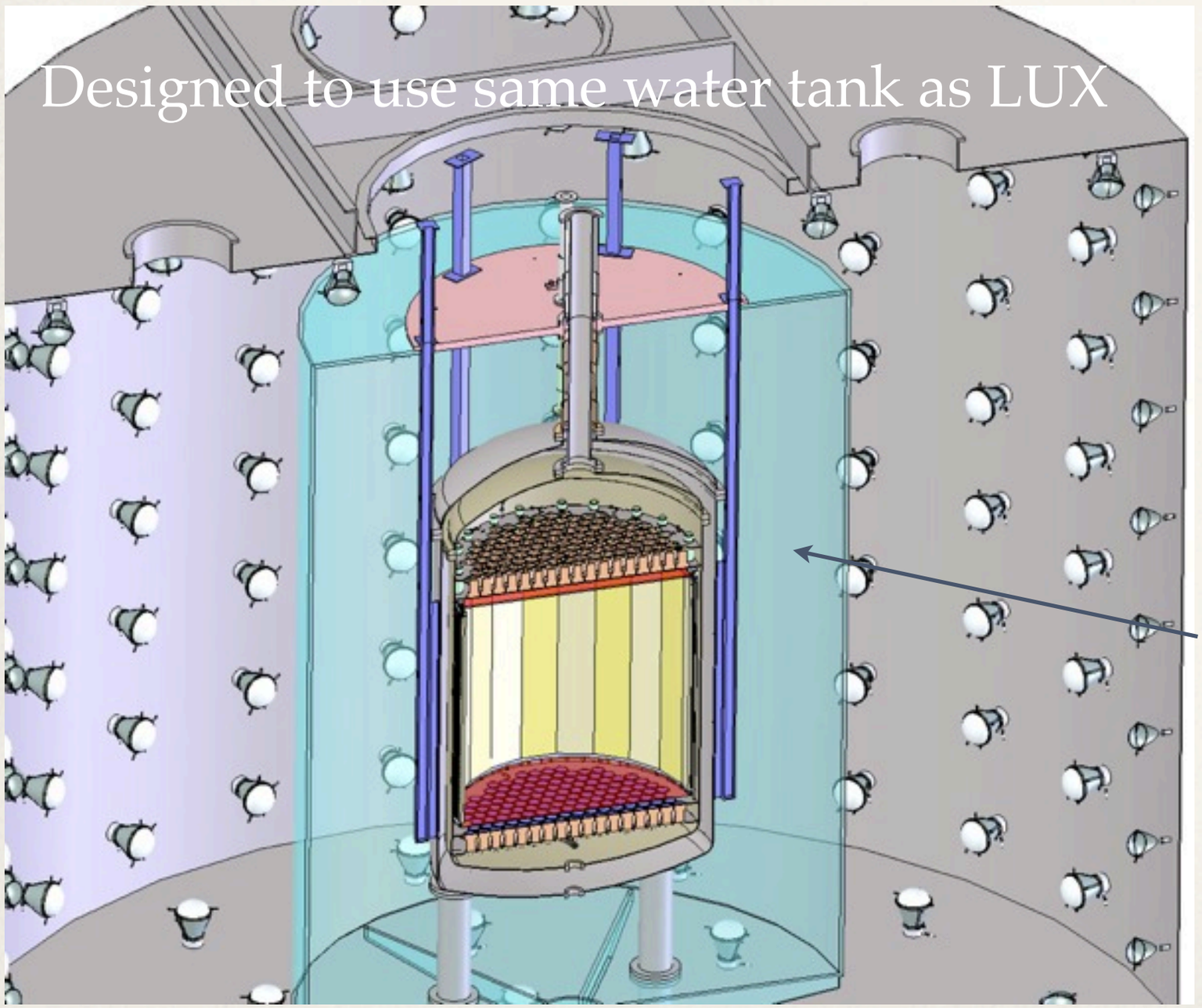
Conservative 15% effective light collection
Optimistic 20% effective light collection

30,000 kg-days, 50% (60%) nuclear recoil acceptance window for log(S2/S1) and 1 kV/cm field

WIMP search window of 3 phe ⇒ 4.3 keVnr (3.4 keVnr) to ~25 keVnr

See Matthew Szydagis's talk for details

Beyond LUX, LUX+ZEPLIN=LZ

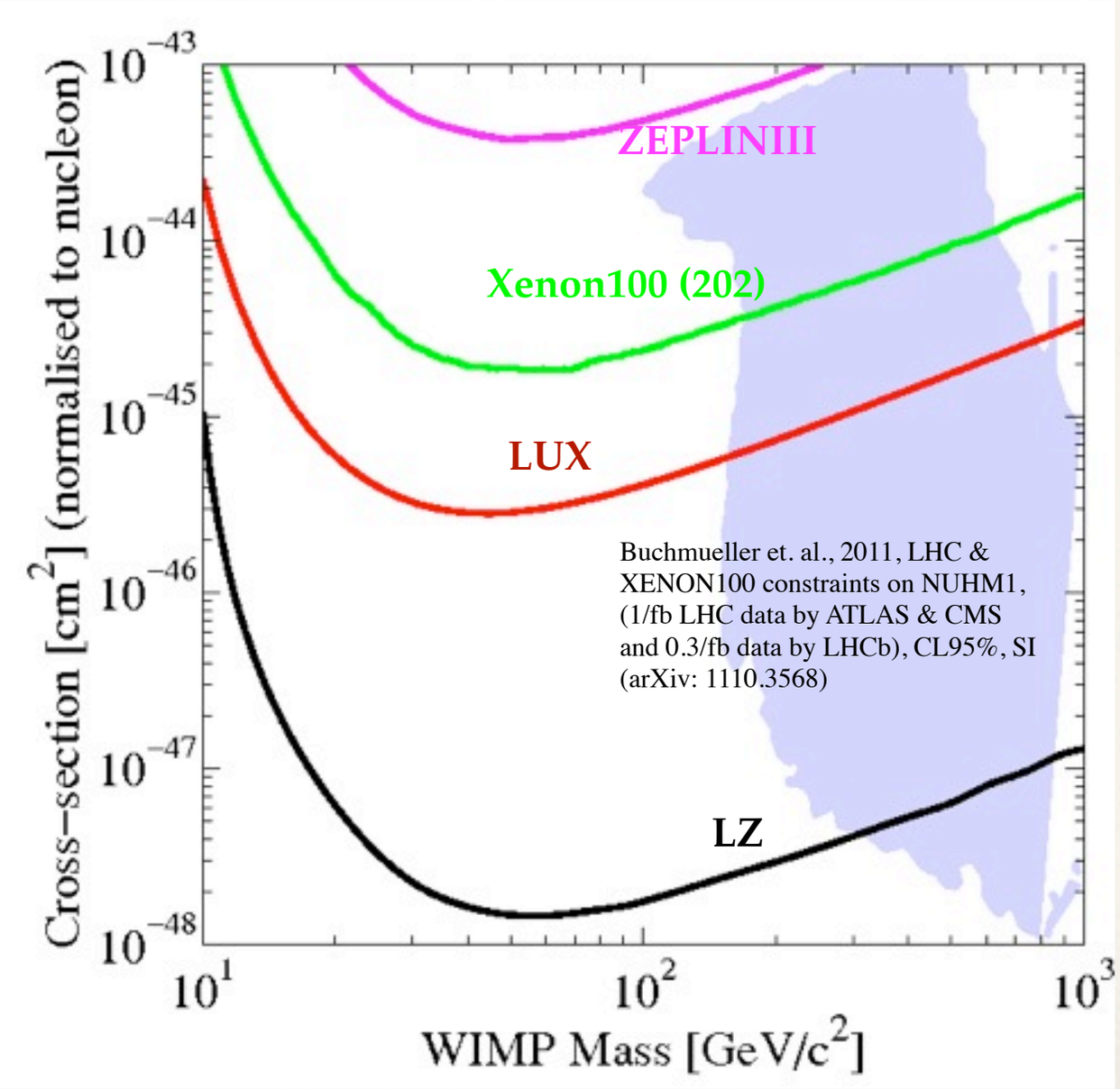


7 T fiducial Xe, 8.6 T total, scintillation signals read out with ≈500 Hamamatsu R11410 3" PMTs

Two-step veto uses water shield + liquid scintillator in acrylic vessel, as well as instrumented Xe outside active region

See Tom Shutt and Dave Malling's talks for details

Conclusions



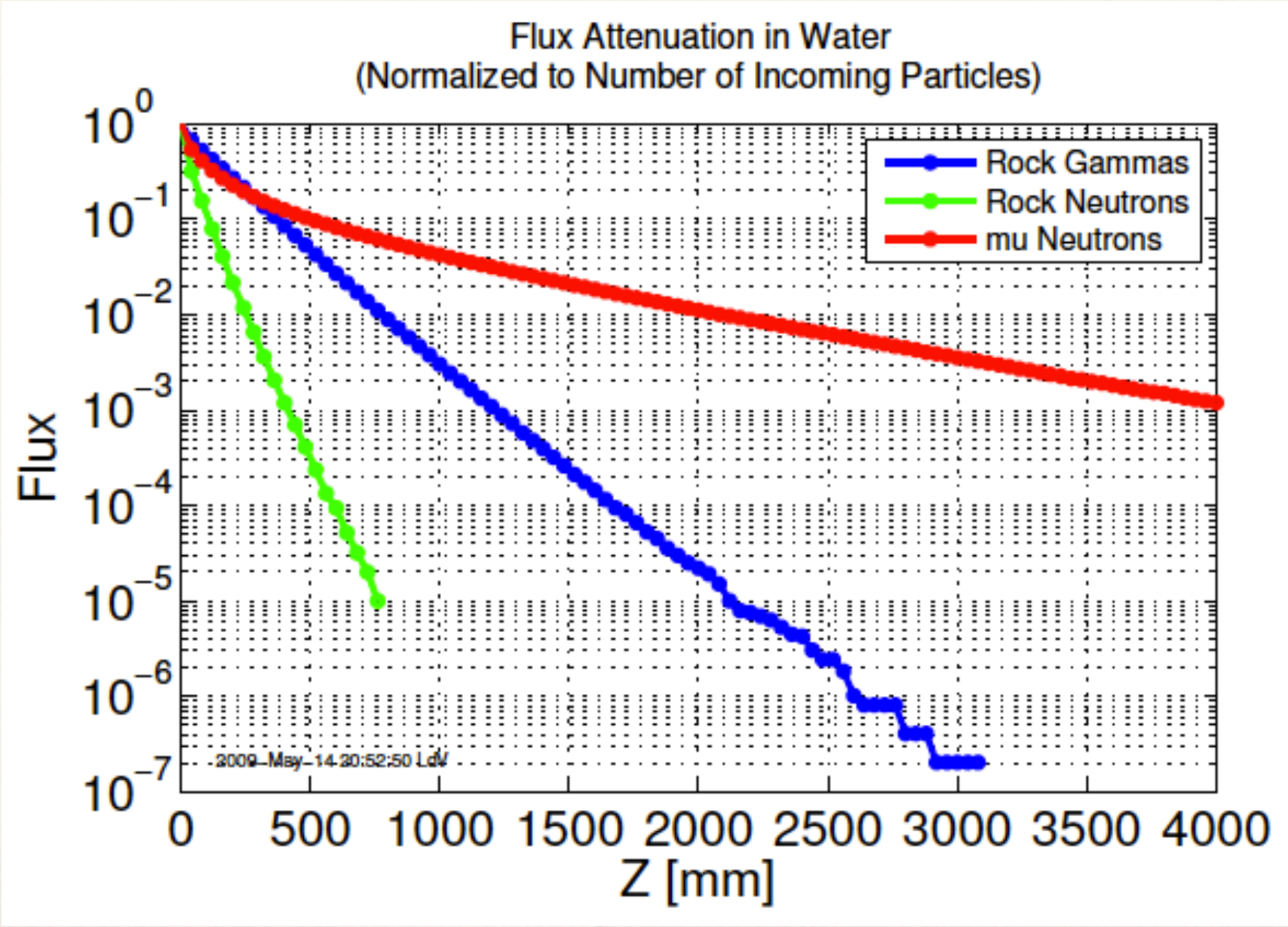
We look forward to interesting results from the LUX program in the next year!

Liquid xenon detectors are very powerful tools in the direct search for dark matter!

Hopefully we will be able to present something exciting at the next IDM!!!

Back-up

Water shield background reduction



Translation between (T-B)/(T+B) and z-position in active region