

# THE STATUS OF DIRECT DARK MATTER SEARCHES

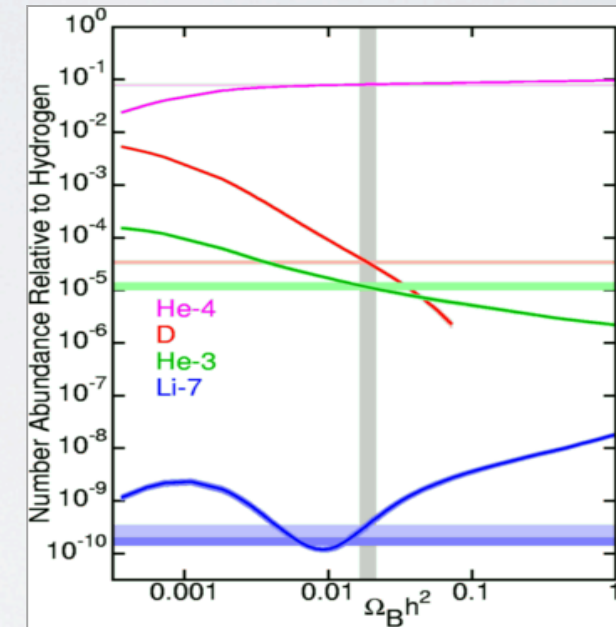
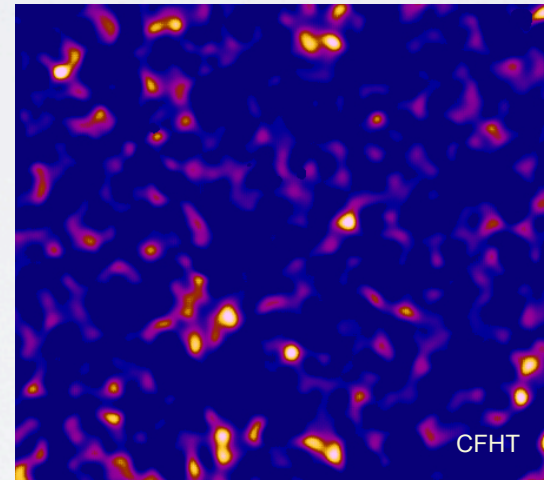
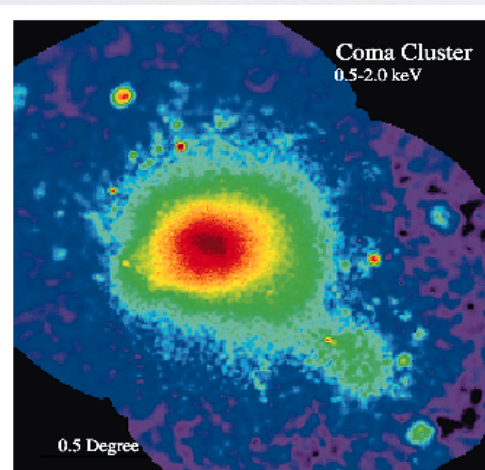
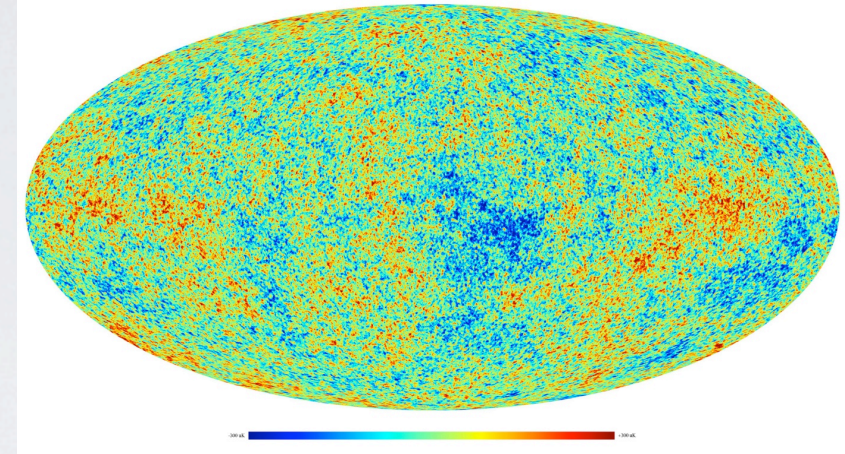
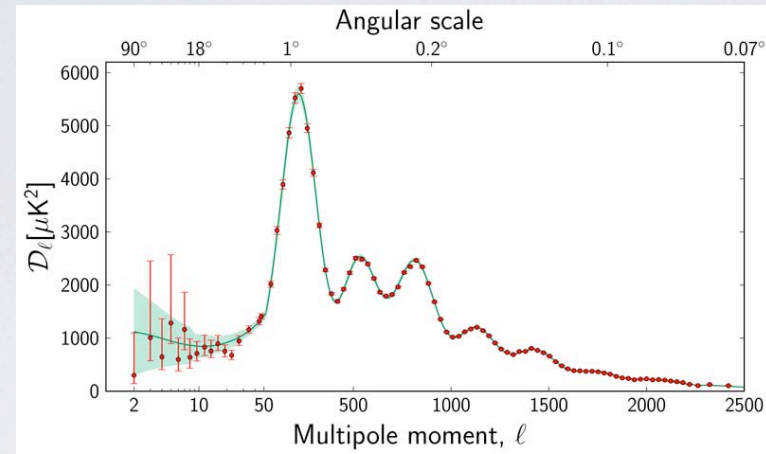
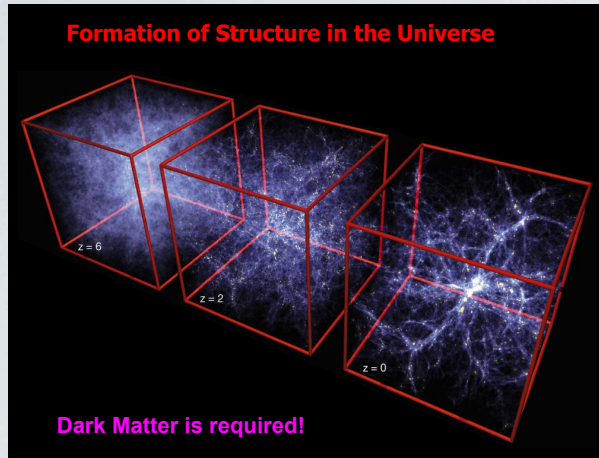
Chamkaur Ghag  
University College London

# Outline

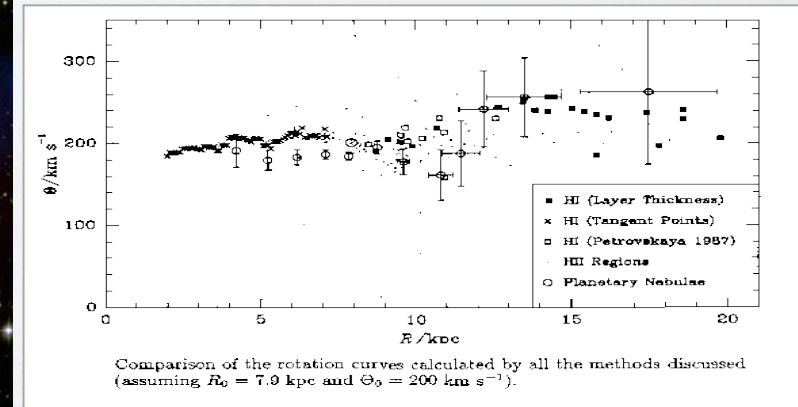
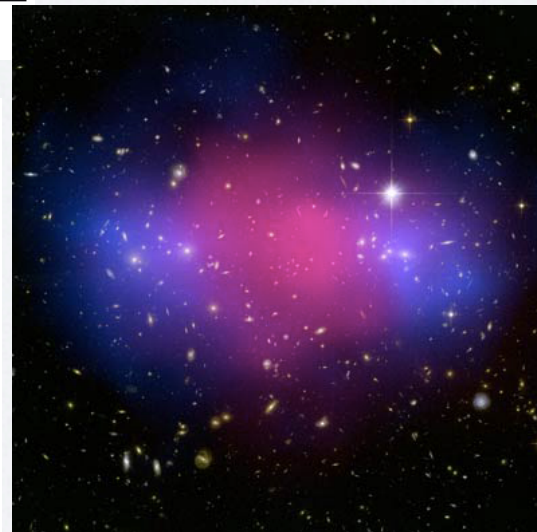
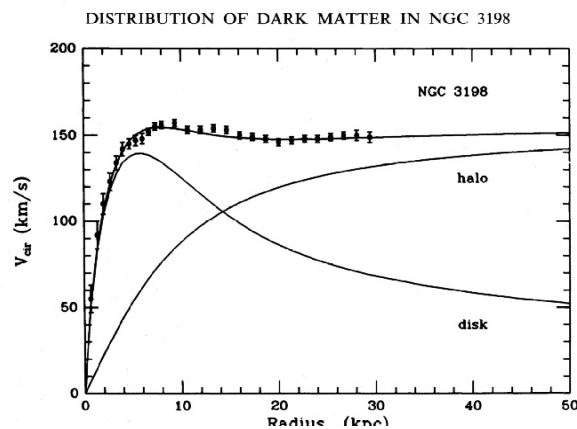
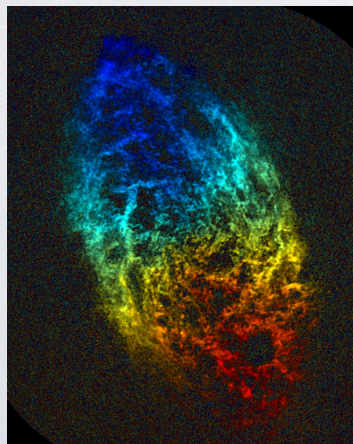
- Evidence and direct detection
- Current state of play
- The next crop
- Tonne scale experiments



# Evidence for Dark Matter

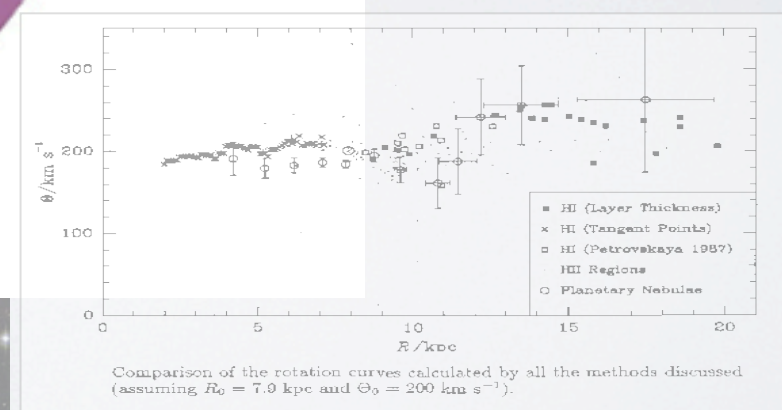
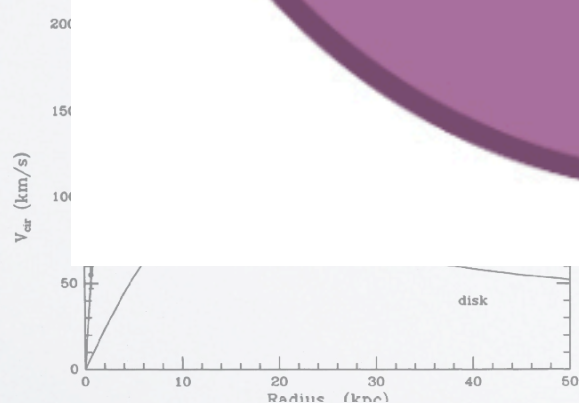
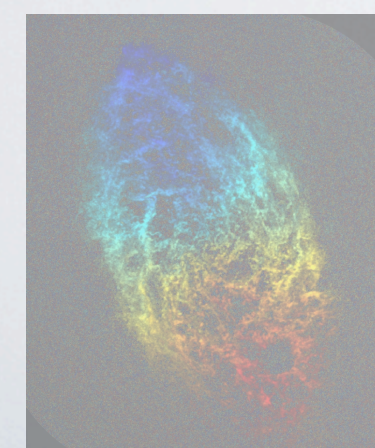
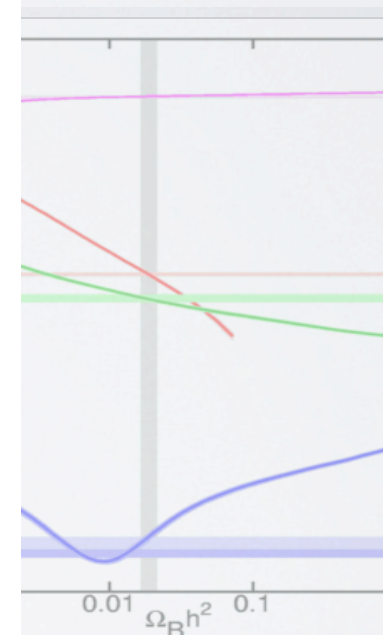
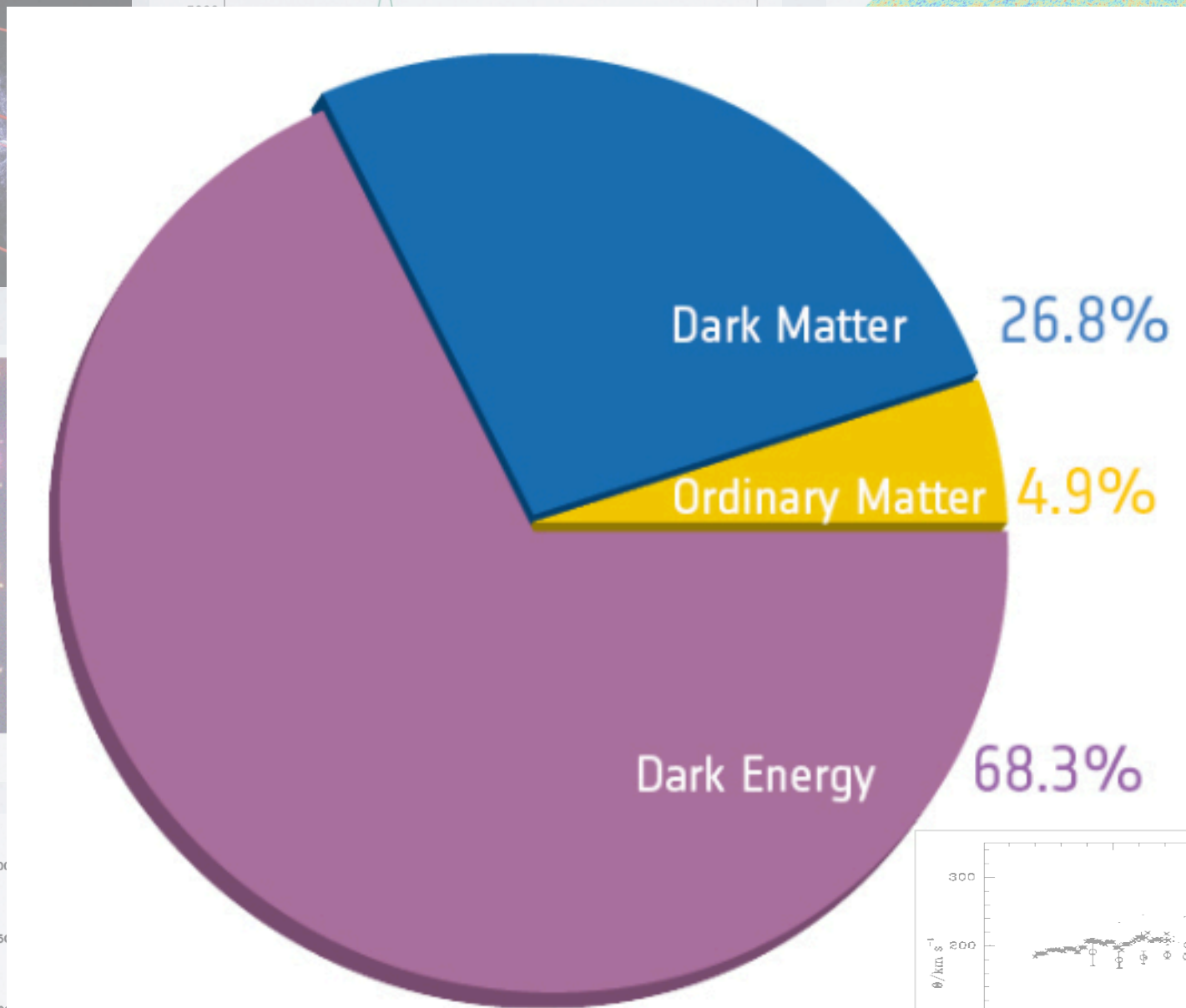
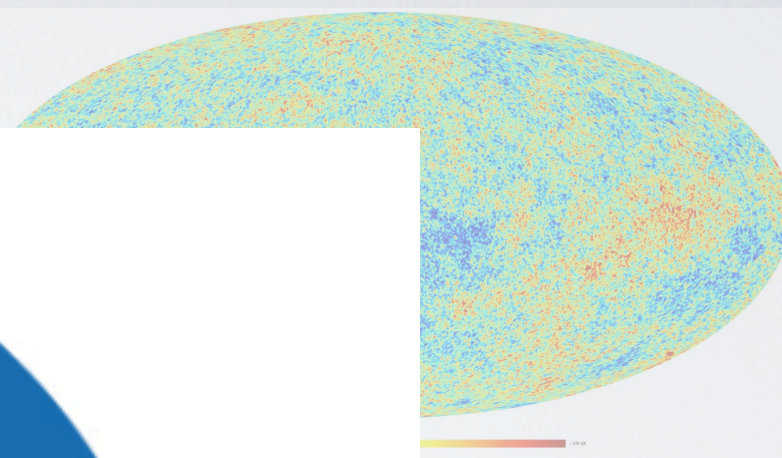
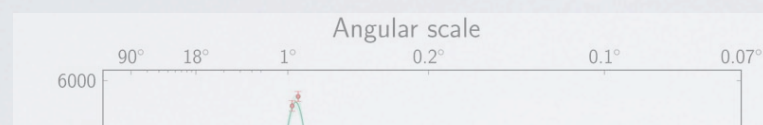
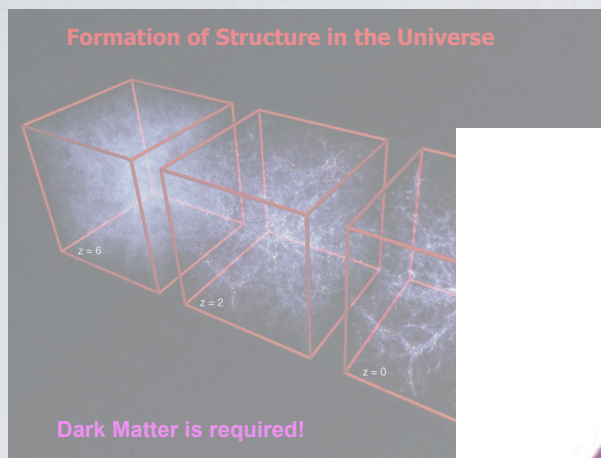


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# Evidence for Dark Matter





# Dark Matter Properties

- No electromagnetic interaction
- No strong interaction
- Stable
- Neutrinos are too hot
- Likely weak interaction (WIMPs)
- One possibility is LSP of SUSY



$$\chi = \alpha \tilde{B} + \beta \tilde{W} + \gamma \tilde{H}_1 + \delta \tilde{H}_2$$

- If SUSY is wrong that won't stop galaxies rotating too fast!
- Zoo of WIMP candidates - direct searches must be broadband



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The existence of Dark Matter points to BSM physics



# Dark Matter Searches

Collider



Production

Indirectly



Annihilation

Directly

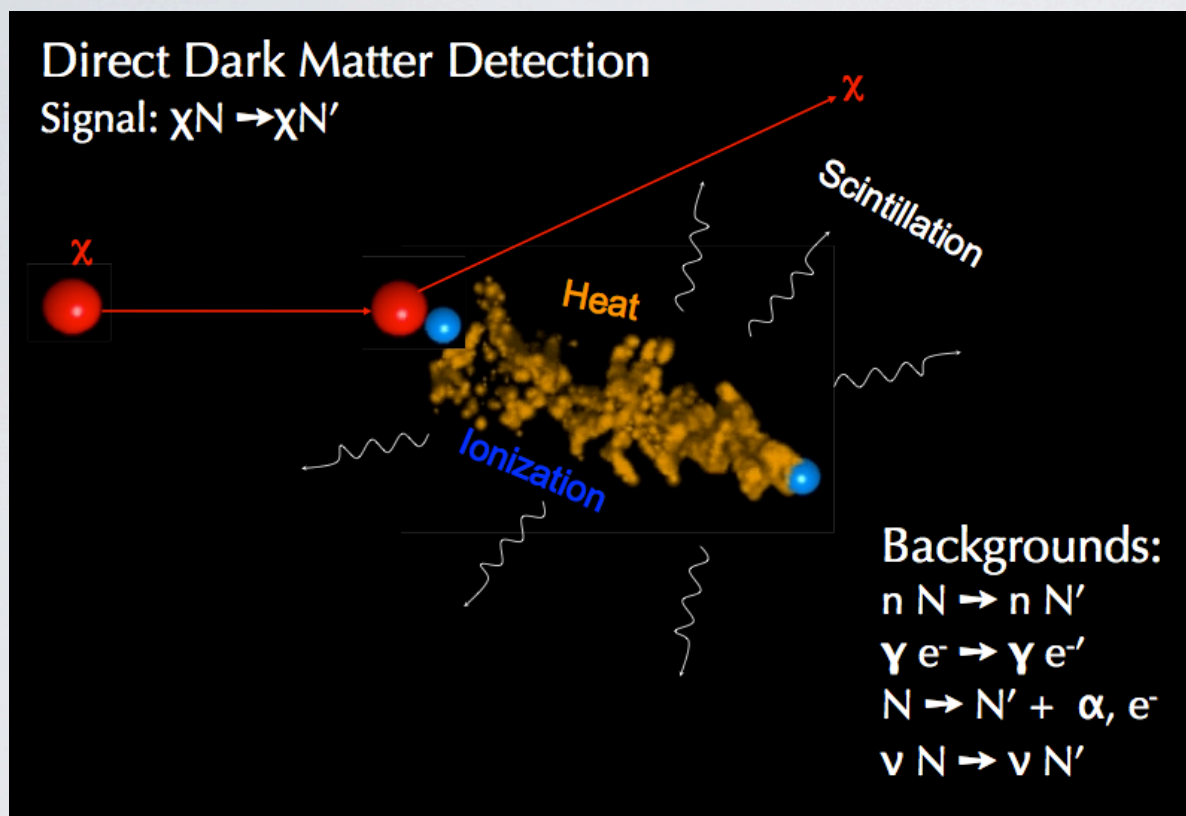


Scattering

*see M. Gustaffson's talk on indirect detection with Fermi - 5:30pm tomorrow*



# Direct Detection



- Weak elastic scatters
- ~tens of keV nuclear recoils
- Underground operation
- Background rejection

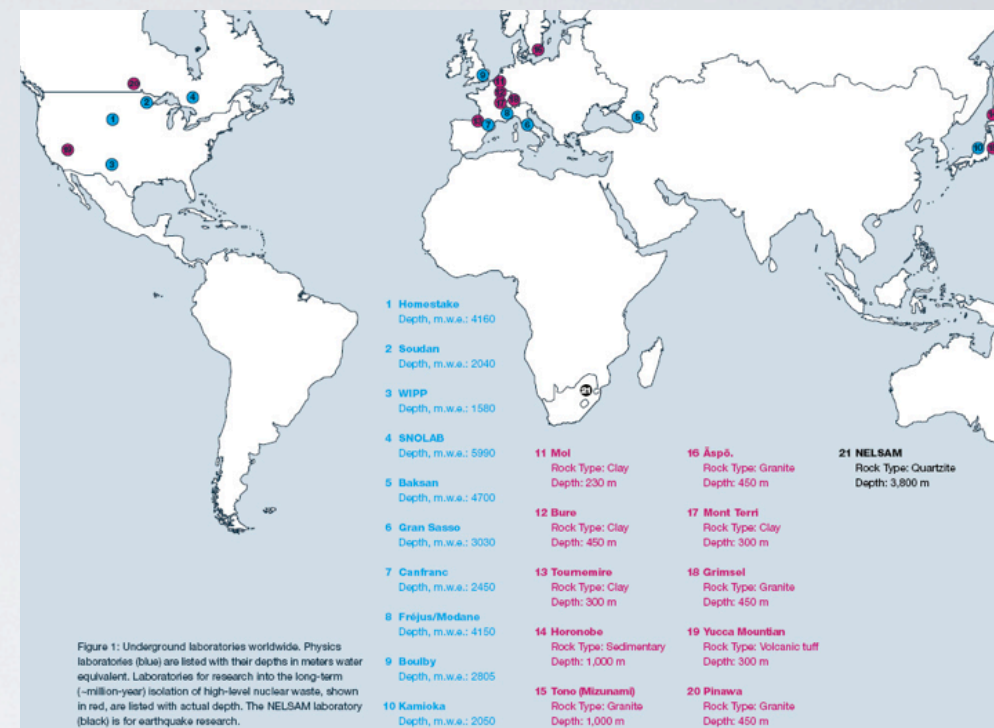
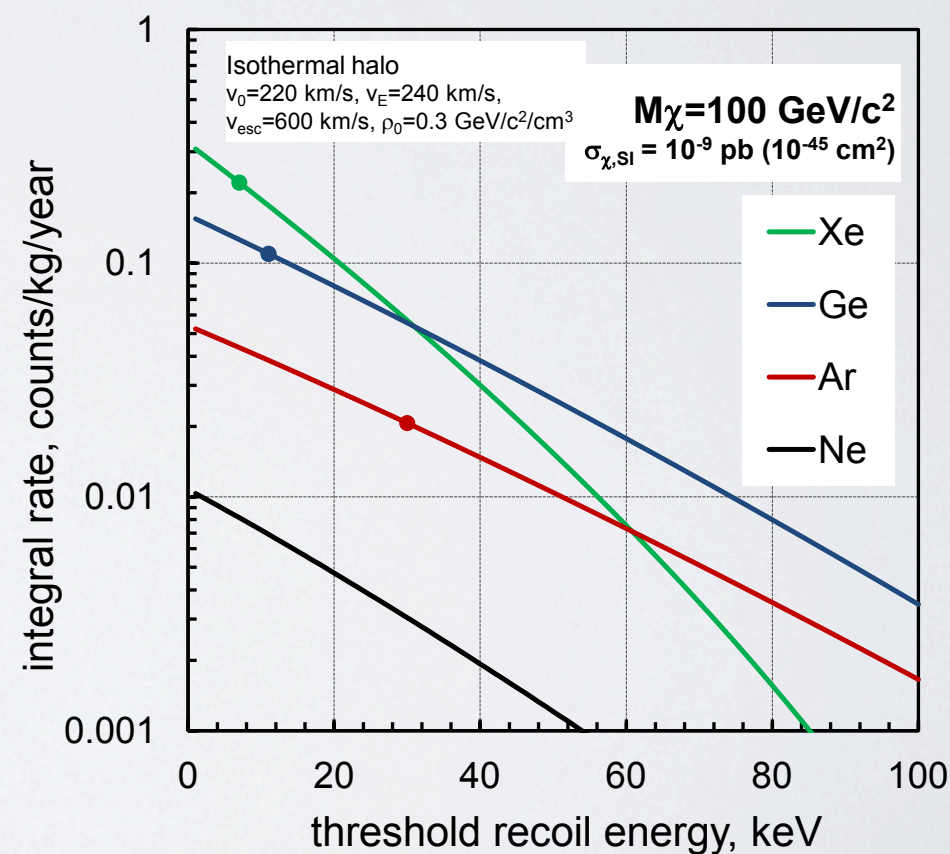


Figure 1: Underground laboratories worldwide. Physics laboratories (blue) are listed with their depths in meters water equivalent. Laboratories for research into the long-term (~million-year) isolation of high-level nuclear waste, shown in red, are listed with actual depth. The NELSAM laboratory (black) is for earthquake research.

[http://www.deepscience.org/contents/facilities\\_popup01.shtml](http://www.deepscience.org/contents/facilities_popup01.shtml)

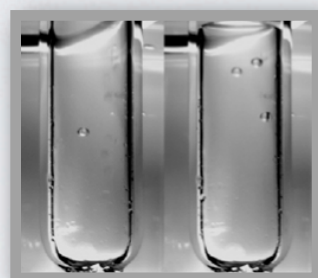


V. Chepel & H. Araujo 'Liquid noble gas detectors for low energy particle physics'  
arXiv:1207.2292



# Detector Technologies

CDMS  
EDELWEISS

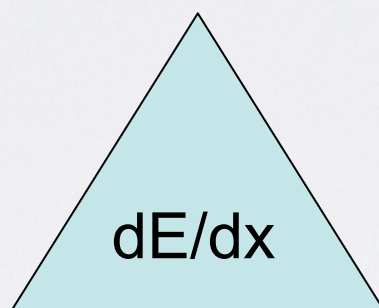


CUOPP  
PICASSO  
SIMPLE

Phonons



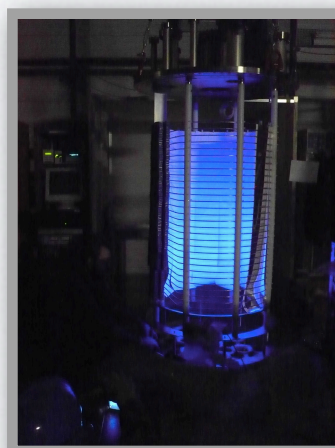
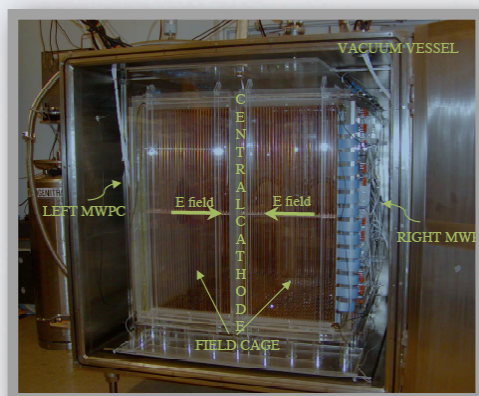
CRESST  
ROSEBUD



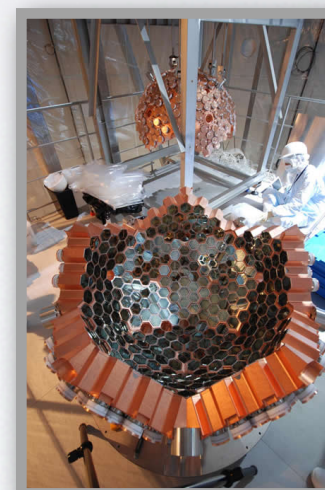
Charge

Light

DRIFT  
DMTPC  
GENIUS  
NEWAGE



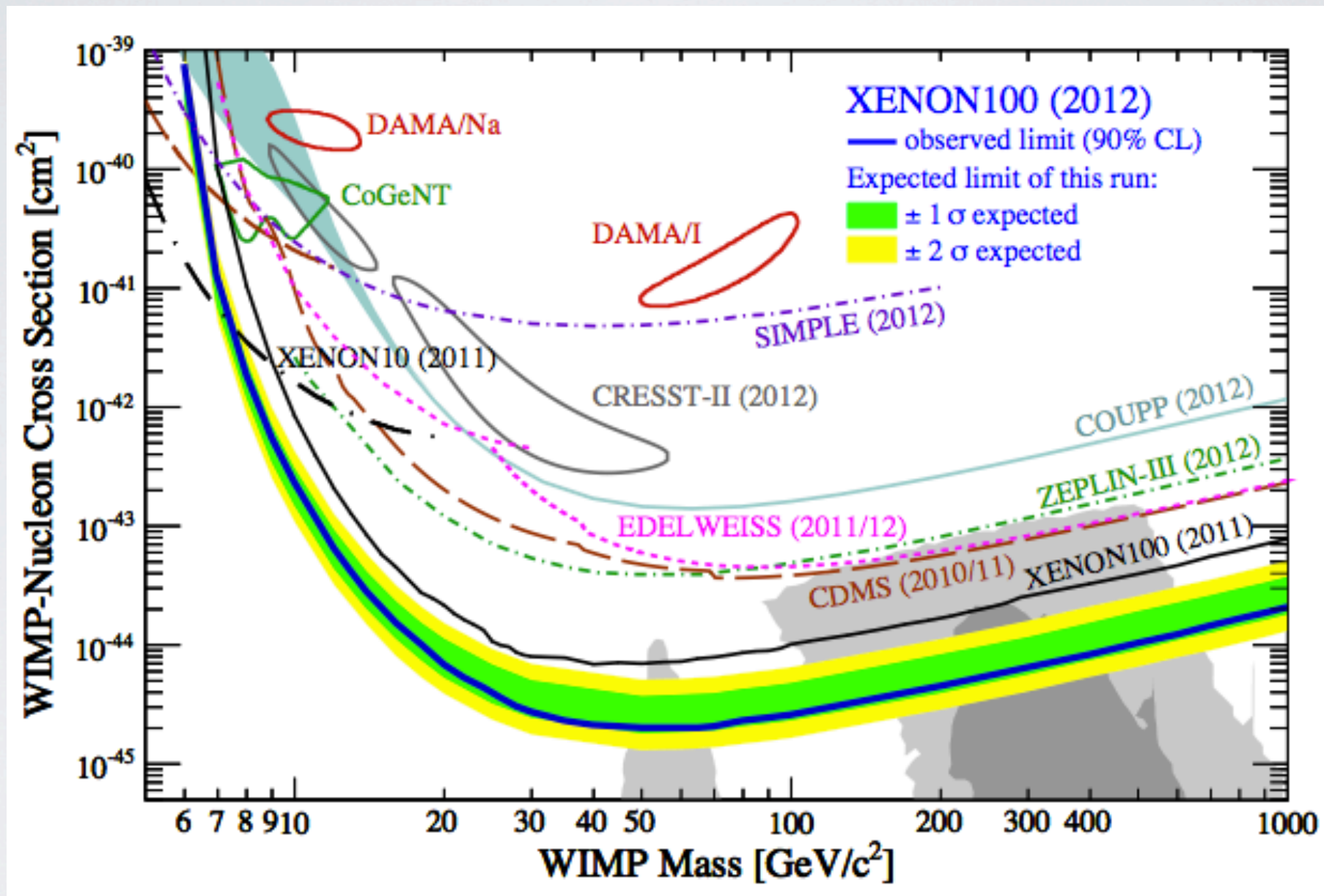
LUX  
XENON  
WARP  
ArDM  
ZEPLIN  
DARKSIDE



DAMA  
LIBRA  
XMASS  
CLEAN  
ANAIS  
KIMS  
DEAP/CLEAN

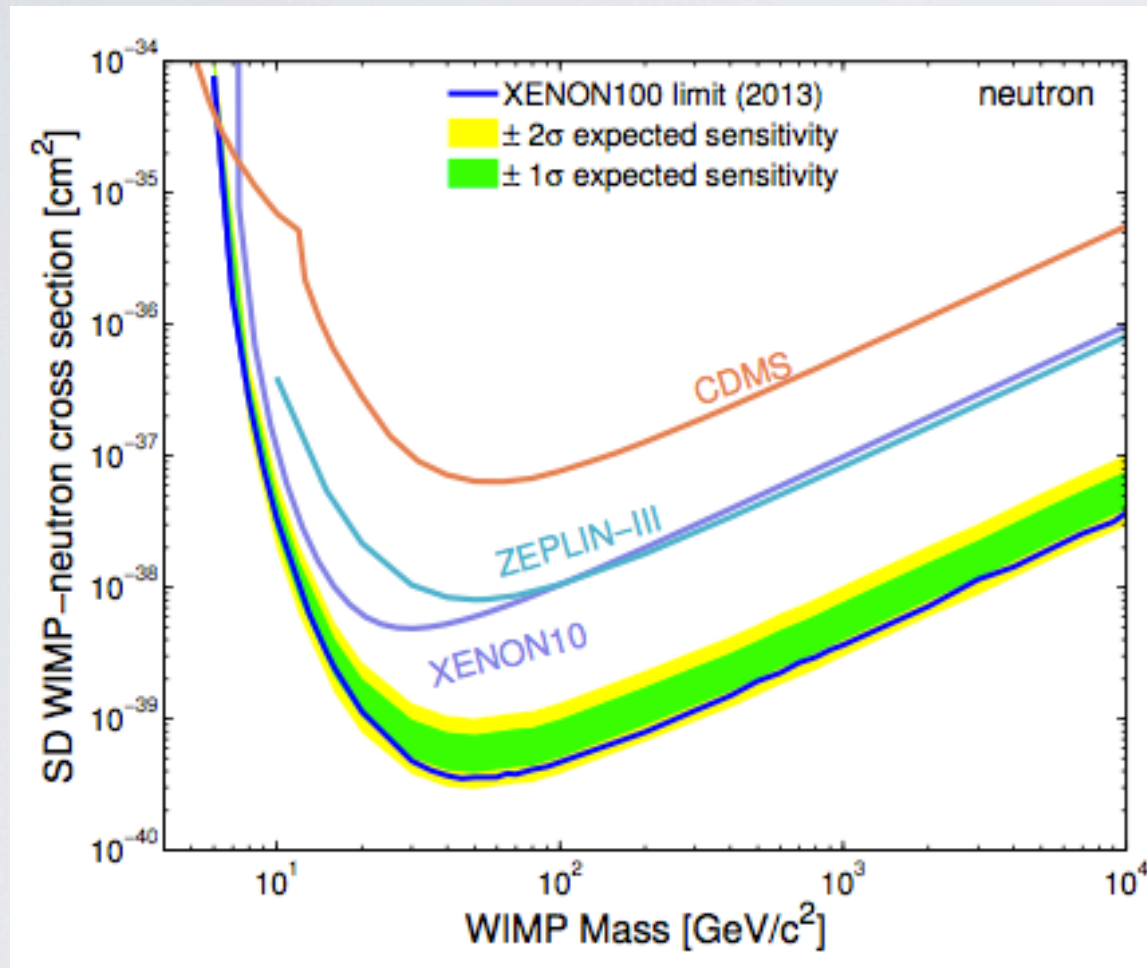


# Current state of play

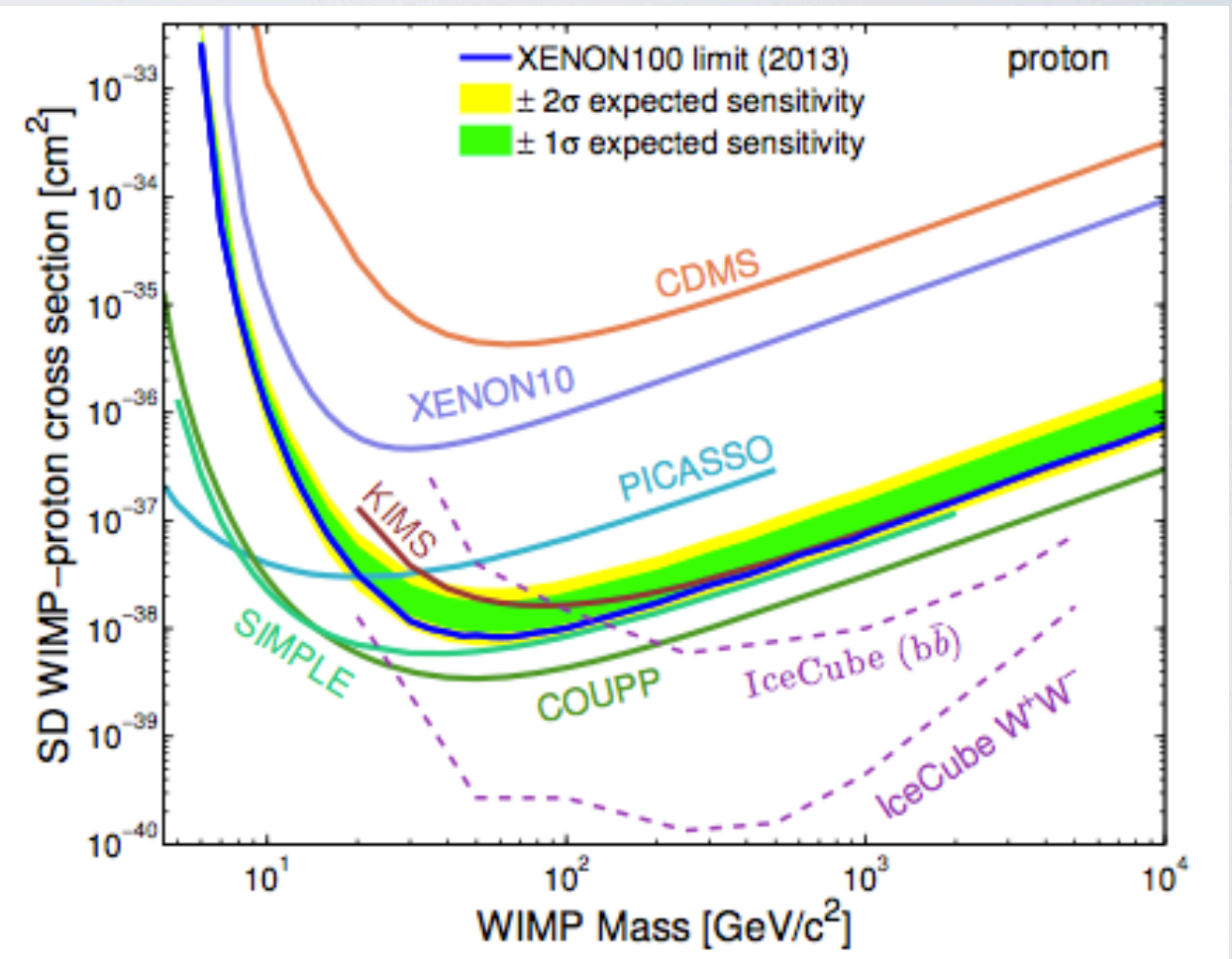




# Current state of play (SD)

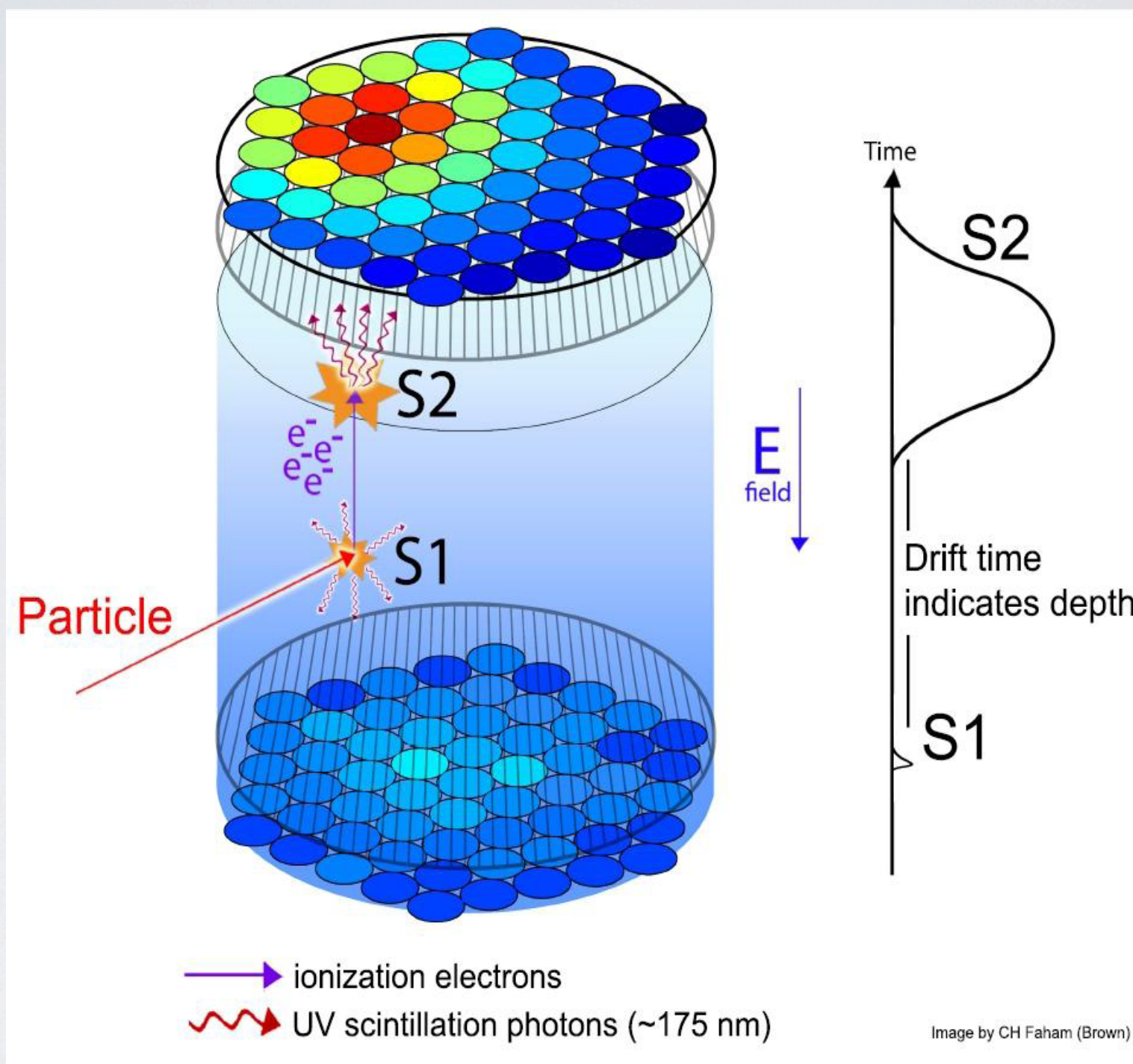


*WIMP-Neutron*



*WIMP-Proton*

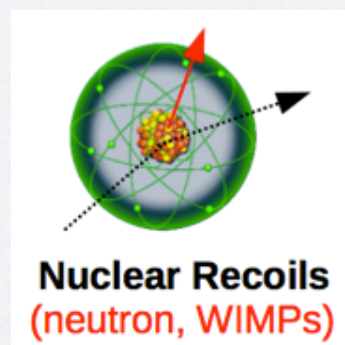
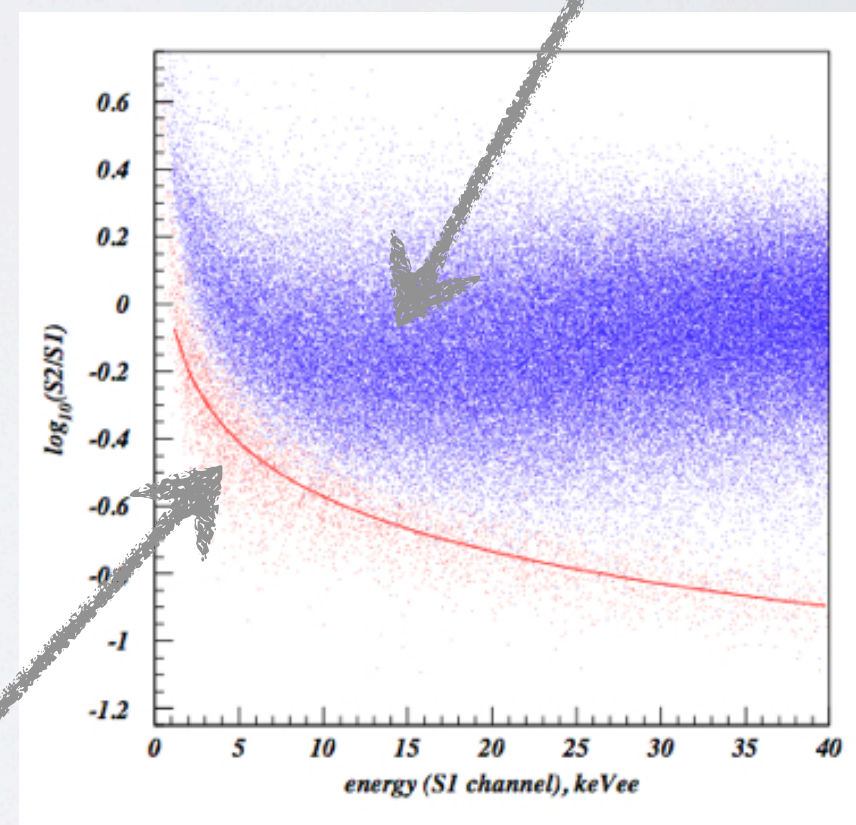
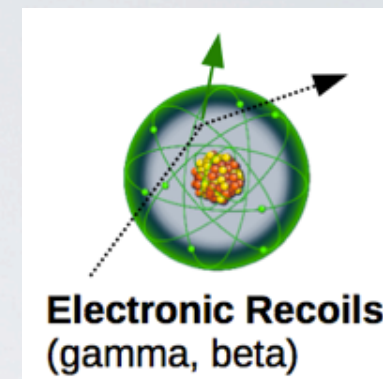
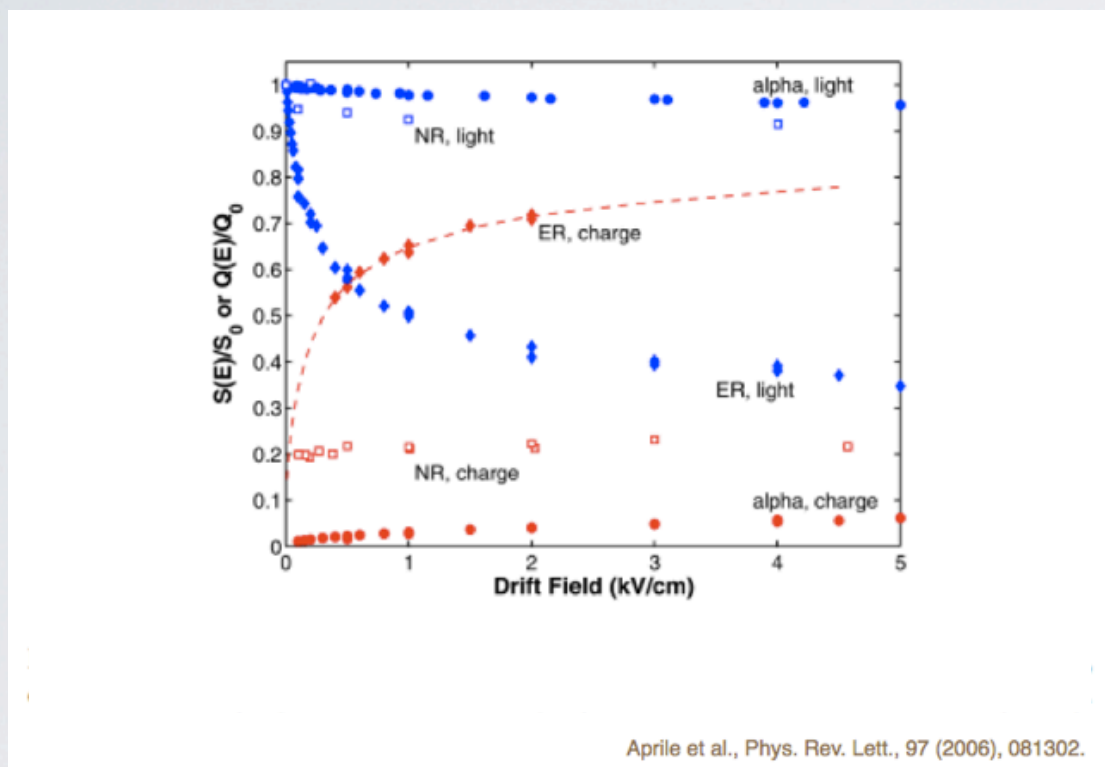






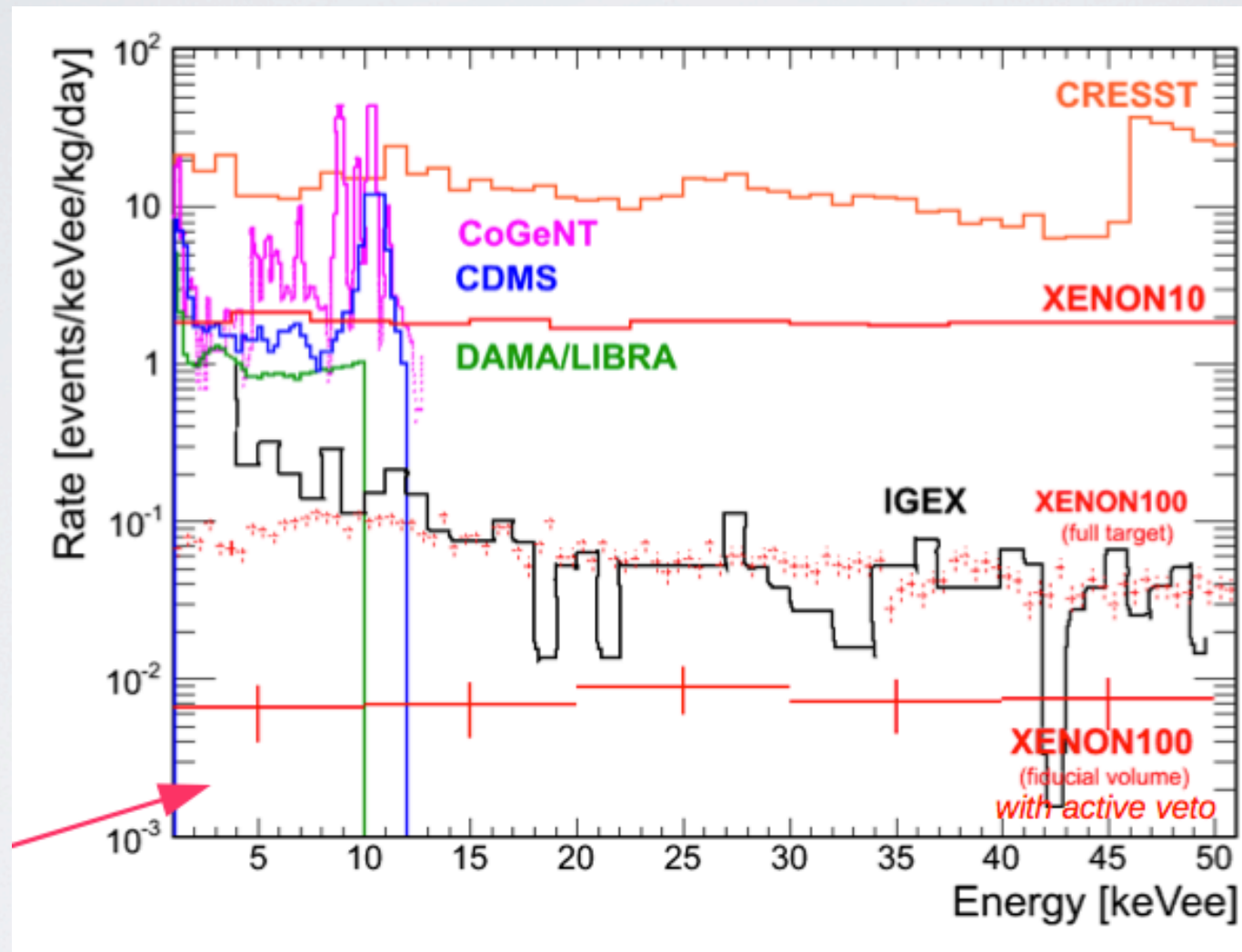
# Particle Discrimination

Light (S1) and charge (S2) depend on recoil  $dE/dx$





# Fiducialisation

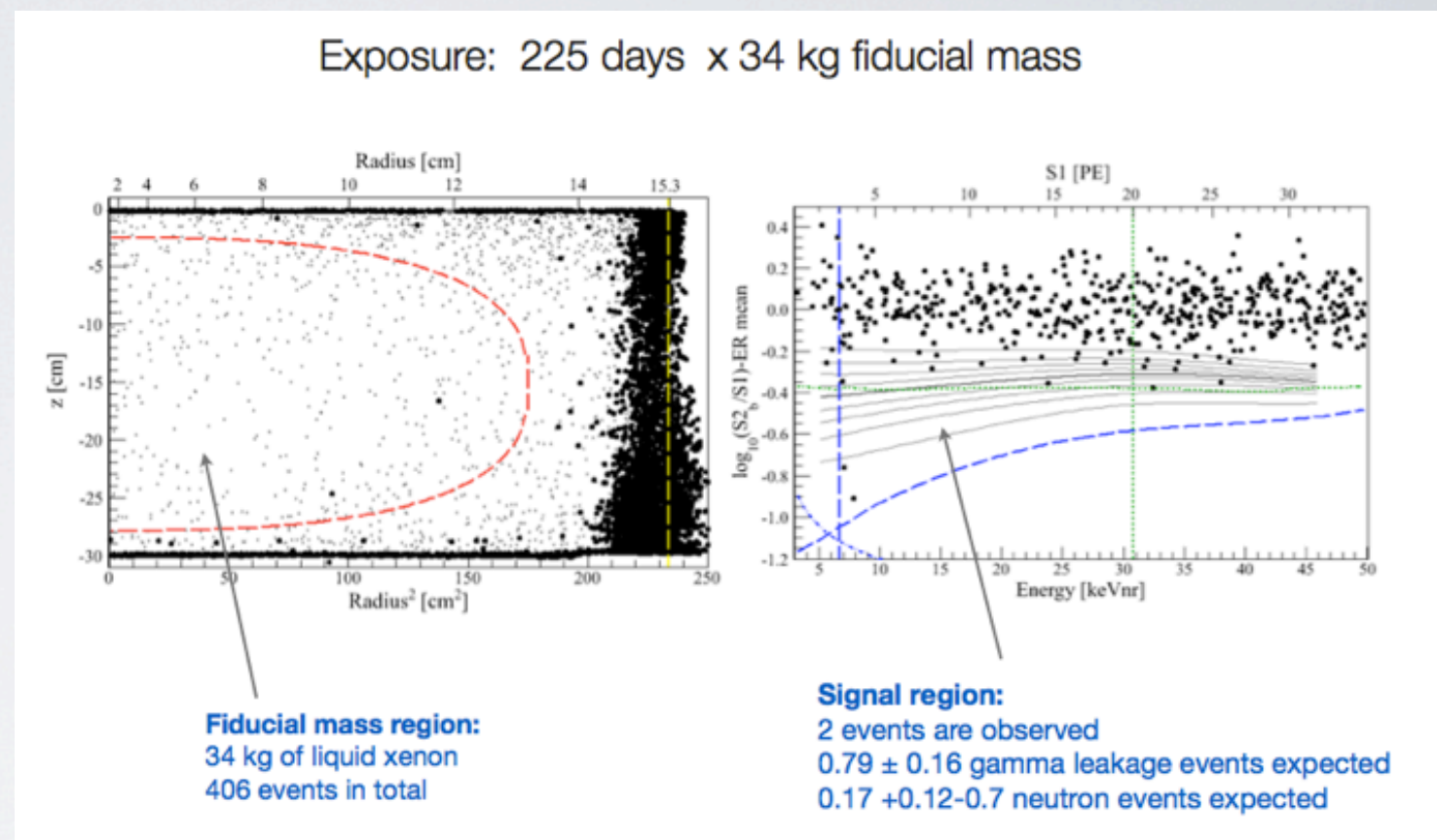


XENON100



# XENON100

- LNGS
- 100x less bkgd than XENON10
- 62 kg target (34 kg fiducial)
- 99 kg LXe active veto
- 1" square PMTs
- 225 day WIMP run 2011-2012
- S.I. limit:  $2 \times 10^{-47} \text{ cm}^2$



$(1.0 \pm 0.2)$  events expected  
**2 events observed**  
 → 26.4% probability that background fluctuated to 2 events  
 → PL analysis cannot reject the background only hypothesis  
**No significant excess due to a signal seen in XENON100 data.**



Next up!

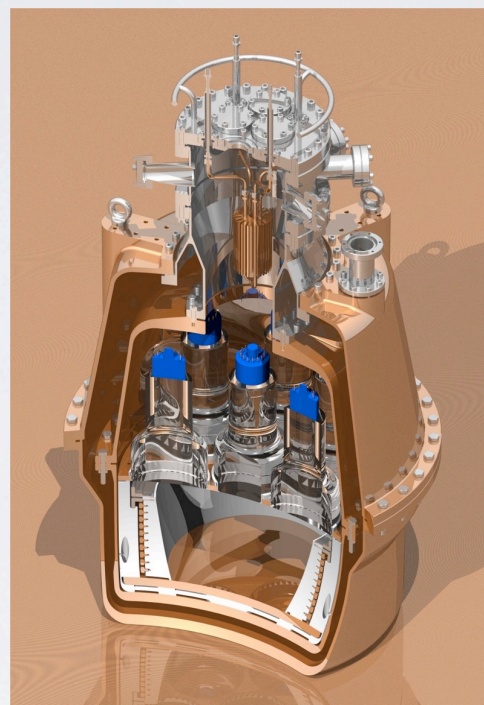


# ZEPLIN Programme



## **ZEPLIN I**

Single phase, 3 PMTs, 5/3.1 kg  
Run 2001-04  
Limit:  $1.1 \cdot 10^{-6}$  pb



## **ZEPLIN II**

Double phase, 7 PMTs,  
moderate E field, 31/7.2 kg  
Run 2005-06  
Limit:  $6.6 \cdot 10^{-7}$  pb



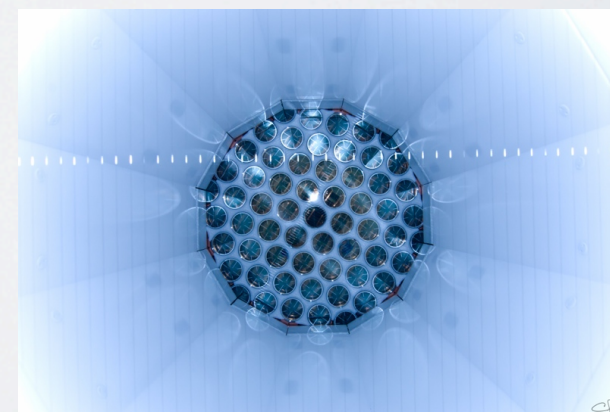
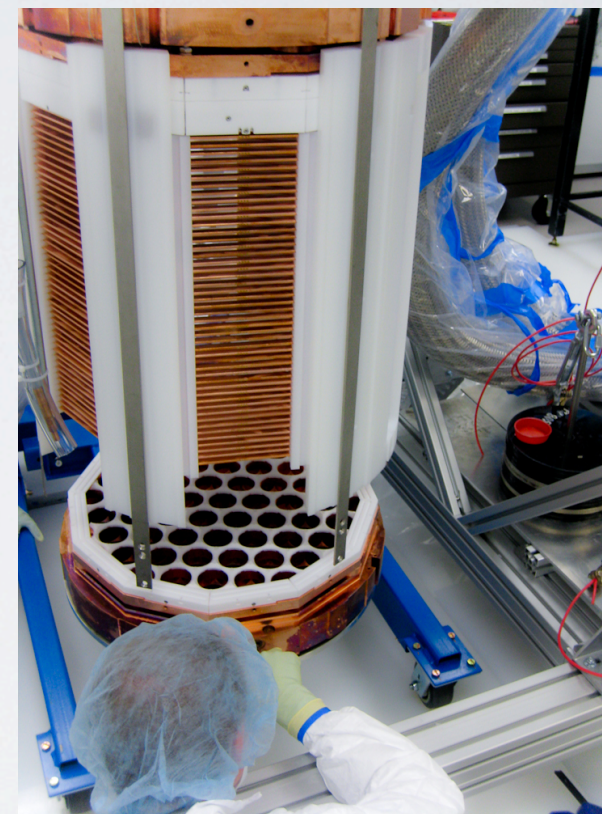
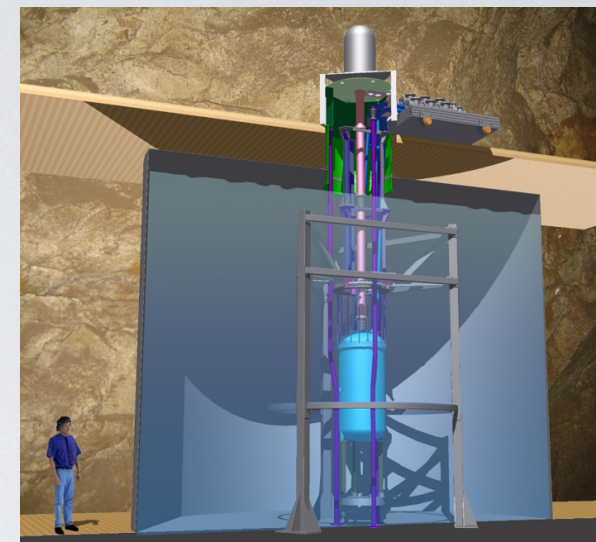
## **ZEPLIN III**

Double phase, 31 PMTs,  
high E field, 10/6.4 kg  
Run 2009-11  
Limit:  $3.9 \cdot 10^{-8}$  pb





- 350 kg LXe TPC
- Homestake Mine (Davis cavern 4850ft)
- 122 low bkgd PMTs and Ti cryostat
- Sensitivity reach x10 over XENON100
- Active water Cerenkov shield
- Fully assembled and tested in surface facility before underground deployment





Could surpass **XENON100** sensitivity in **2013**

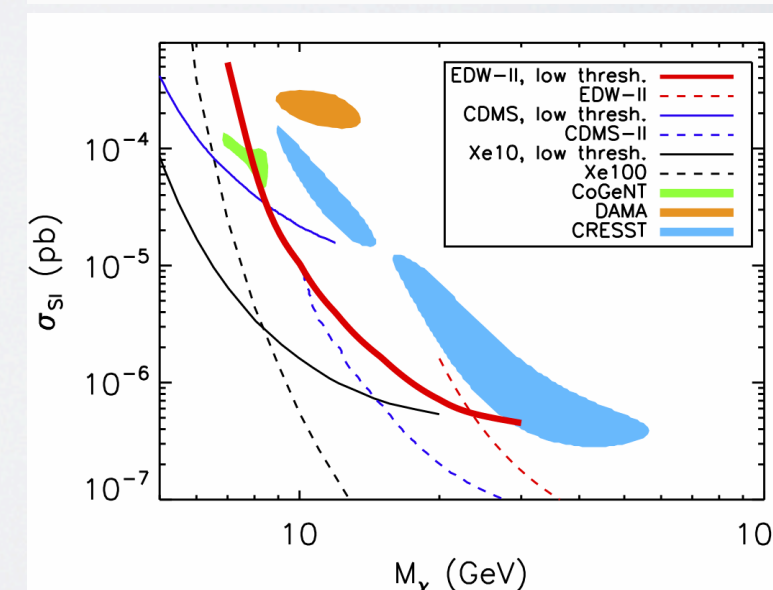
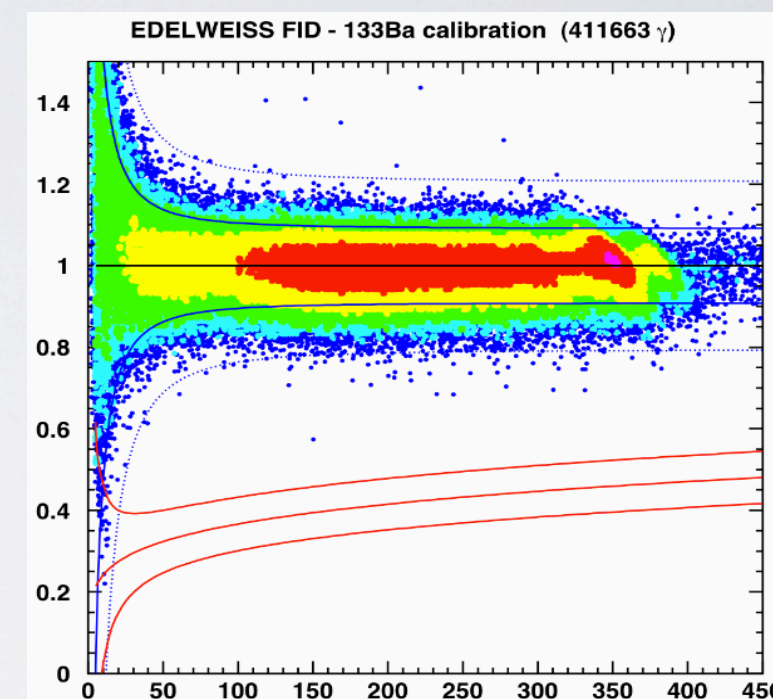
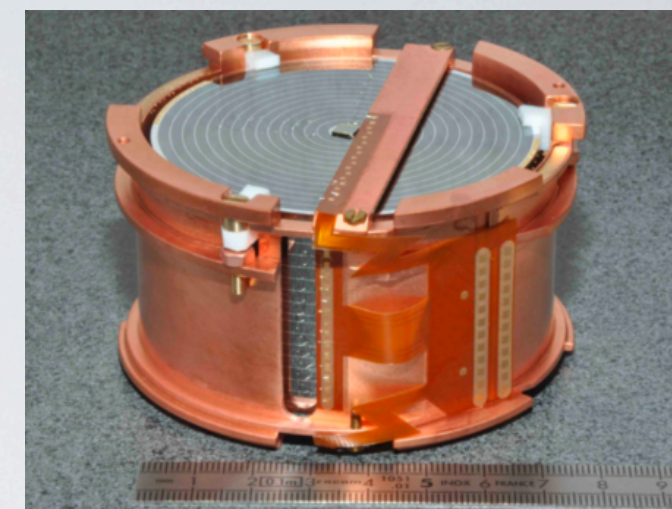


*see H. Araujo's talk - Wed 9:30am, Track 4*



# EDELWEISS-III

- Laboratoire Souterrain de Modane
- 40 cryogenic germanium detectors
- Phonon-ionisation for discrimination
- 5 keV recoil threshold
- 24 kg fiducial mass
- Upgrading to 32 kg Ge in summer 2013
- 2 year WIMP run to begin by end 2013
- Sensitivity of few  $\times 10^{-9}$  pb (depending on backgrounds)





# DEAP-3600 & miniCLEAN

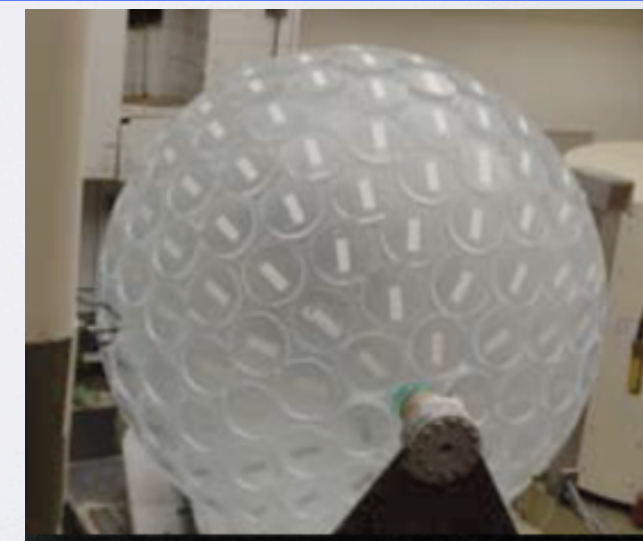
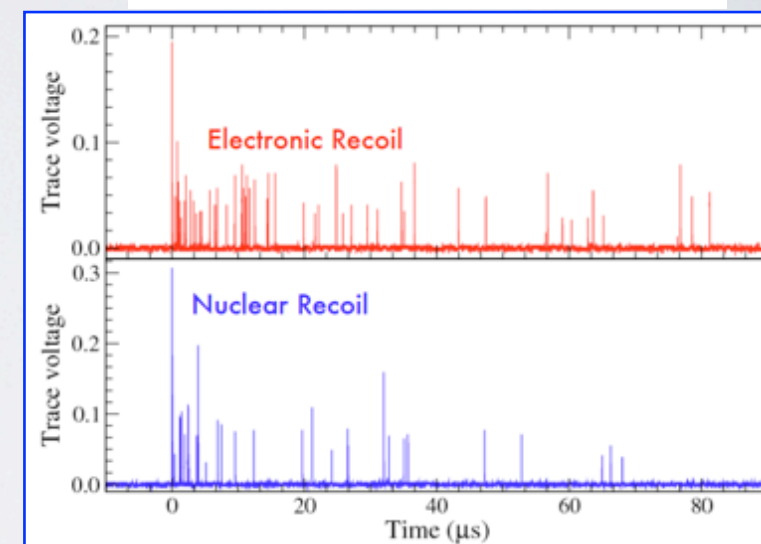
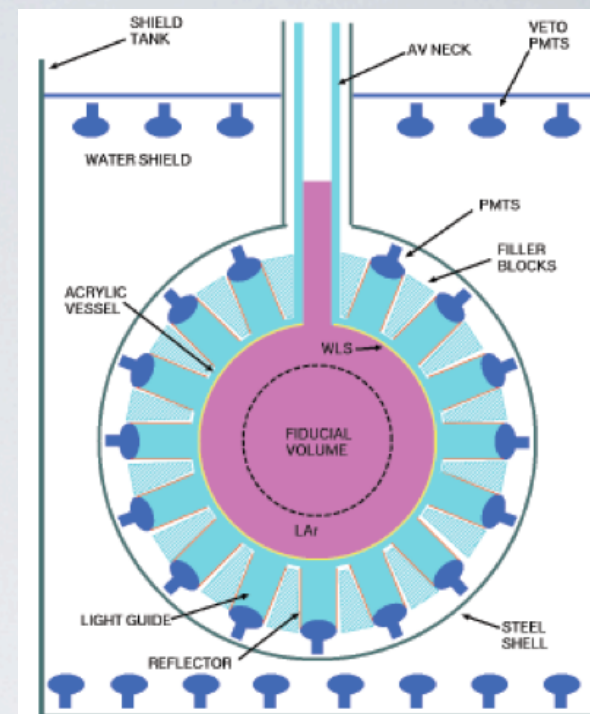
- SNOlab, Canada
- Single phase open volume,  $4\pi$  PMT coverage
- No E-field (maximize phe/keVee)
- Pulse shape discrimination,  $\sim 40$  keV thresh.
- Active water shield
- MiniCLEAN (150 kg fiducial)

construction: 2011-2013, run: 2013-2014  
 sensitivity:  $1\text{E-}45$   $\text{cm}^2$

- DEAP-3600 (1 tonne fiducial)

construction: 2011-2013, run: 2014-2017  
 sensitivity:  $1\text{E-}46$   $\text{cm}^2$

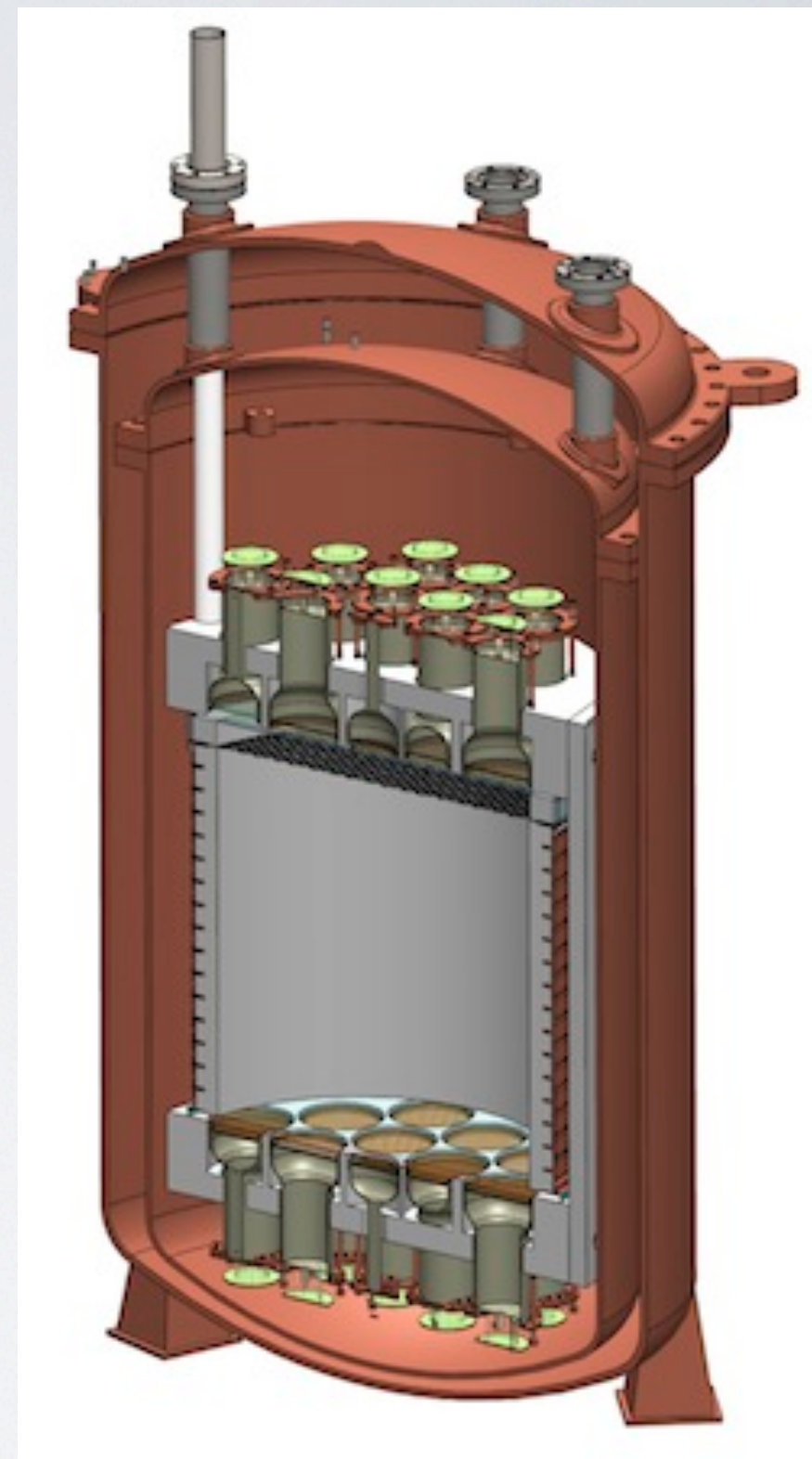
*see J. Walding's talk - Wed 9:20am Track 3*





# DarkSide-50

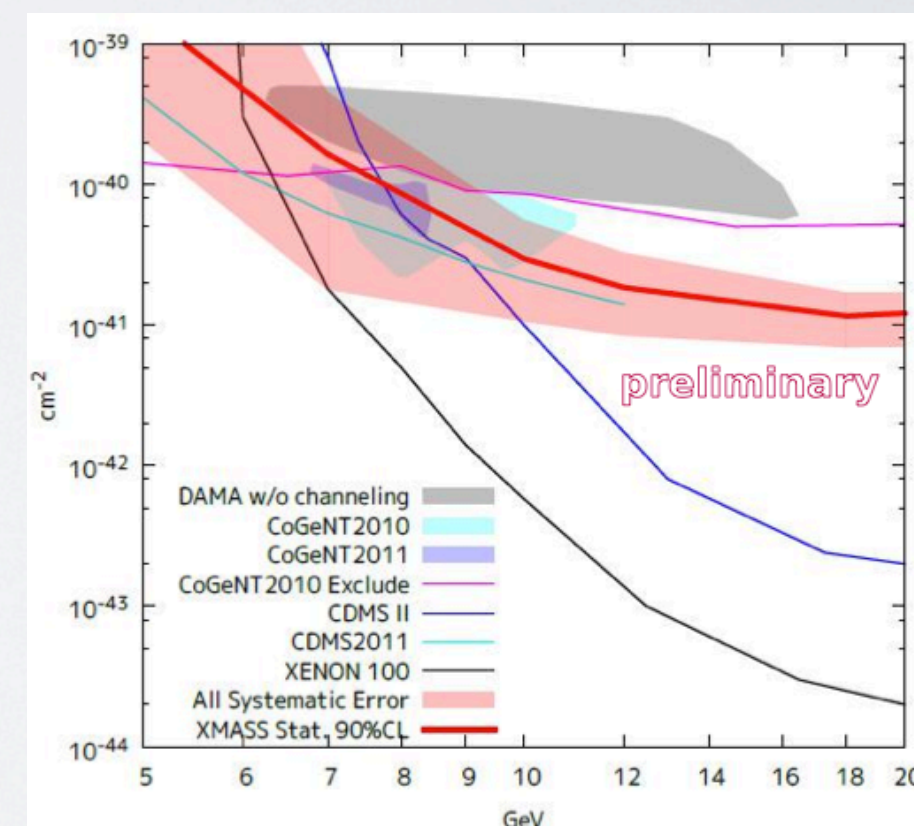
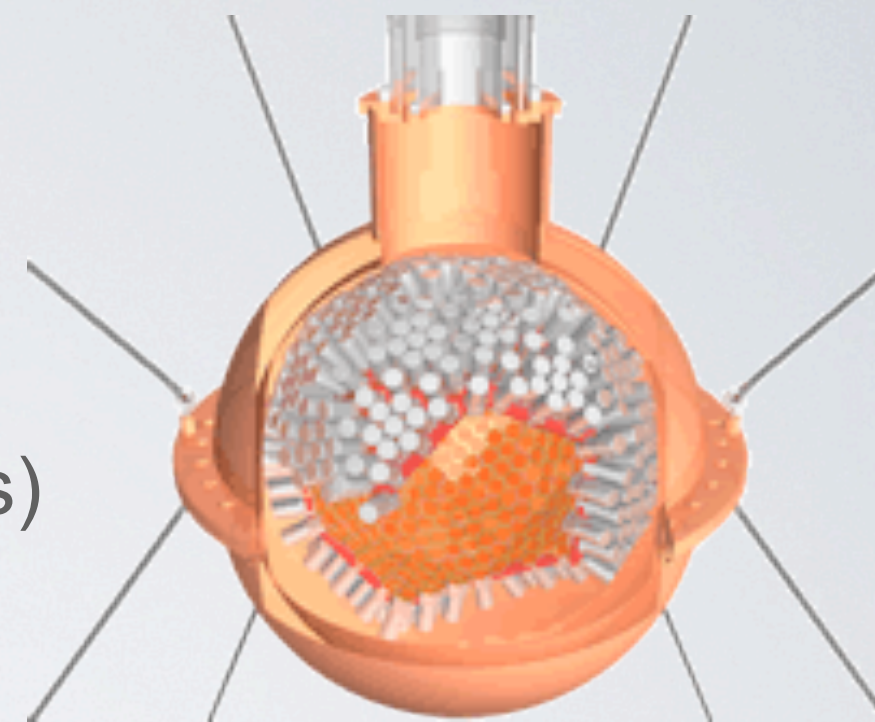
- Based at LNGS, under construction
- Liquid Ar 2-phase TPC
- Low background science device (unlike DS-10)
- Neutron veto inside Borexino CTF
- Used underground (depleted) Ar target
- Adopts v. successful Xe technology
- PSD + S2/S1 discrimination
- 3D position reconstruction for surface background rejection (ala LXeTPCs)
- DarkSide-10 decommissioned last month





# XMASS

- Based at Kamioka, Japan
- Single phase detector (no E-field so no S2's)
- 100 kg Xe fiducial (800 kg active)
- $4\pi$  PMT coverage
- Unexpected background observed
- Performance severely compromised
- Undergoing refurbishment of PMTs
- Data taking to begin 2014





# Acoustic Bubble Chambers



1st generation\* : 10ml



2nd generation : 1L



3rd generation : 4.5L

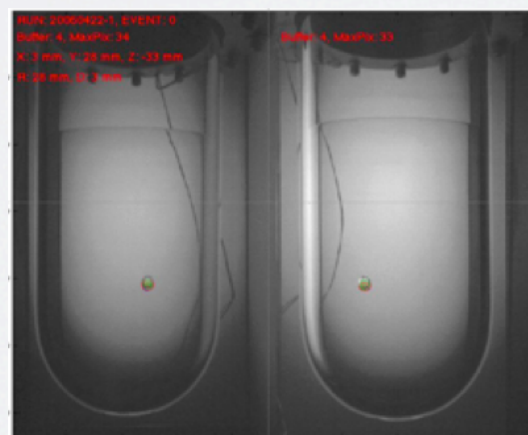
*Picasso*



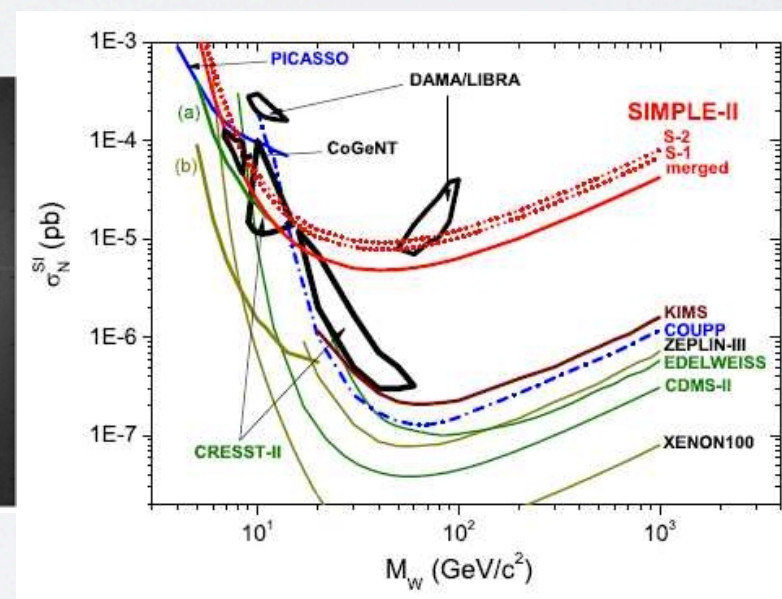
SNOLAB, Ca



**SIMPLE** (Freon target)



**COUPP** (CF<sub>3</sub>I)





# Directional Gas TPCs

## DRIFT-III/III

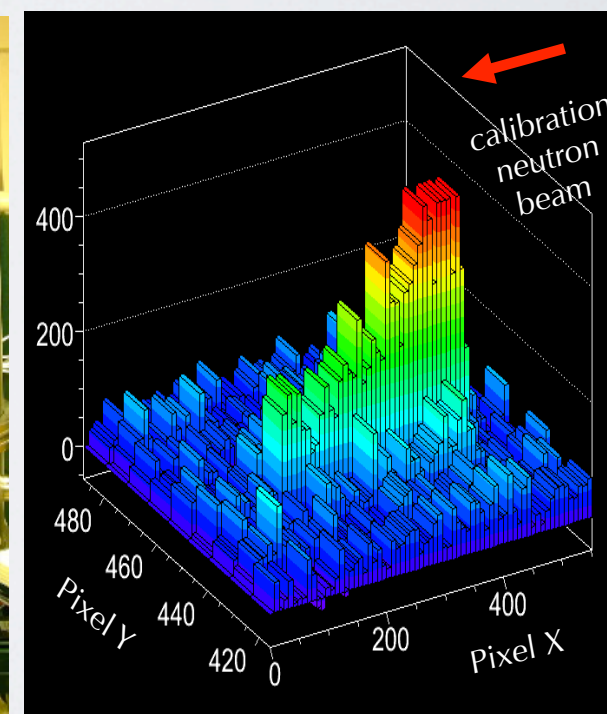
- CS<sub>2</sub>:CF<sub>4</sub> low pressure target (33 g fid.)
- MWPC readout for 3D track reconstruction
- 1 m<sup>3</sup> modules in Boulby Mine, UK
- DRIFT-IIe incorporates major modifications to improve backgrounds and track reconstruction
- DRIFT-III plans for 24 m<sup>3</sup>



see *S. Sadler's talk - tomorrow 3pm, Track 3*

## DMTPC

- CF<sub>4</sub> target (10l prototype)
- 1 m<sup>3</sup> modules under development presently
- Charge *and* optical readout for background rejection





# Next generation (tonne scale) Experiments



# EURECA

European Underground Rare Event Calorimeter Array  
*The future European 1-tonne cryogenic dark matter search*

Aim:	$<10^{-10}$ pb
Detectors:	Cryogenic Ge (from EDELWEISS) and scintillator calorimeters (from CRESST)
Shielding:	Radiopure Cu, polyethelene, 3m water tank with PMTs
Infrastructure:	Cryostat to cool 1-tonne target
Collaboration:	EDELWEISS, CRESST, new members

*see X. Zhang's talk - tomorrow 3pm, Track 4*



# Global convergence of CryoDetectors

phonon –  
ionization

Germanium

**SuperCDMS**

Soudan, 10kg

$5 \times 10^{-9} \text{pb}$



**SuperCDMS**

SNOLAB

200kg,  $8 \times 10^{-11} \text{pb}$

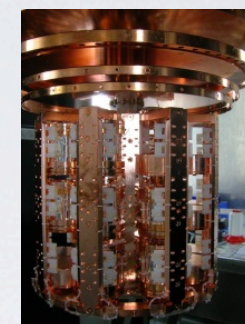


LSM

Germanium

10 – 32 kg

$2 \times 10^{-9} \text{pb}$

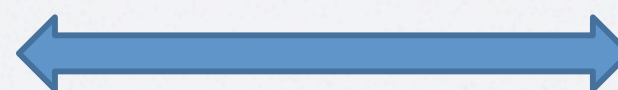
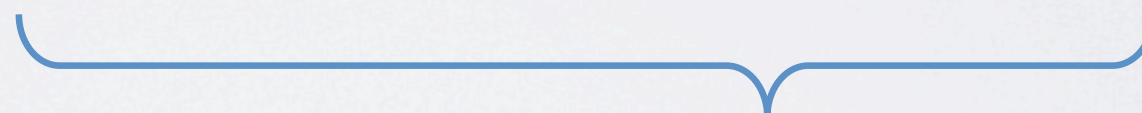


**CRESST**

Gran Sasso

$\text{CaWO}_4$

phonon – scintillation



MoU since 2009  
Increasing collaboration  
towards common  
experiment



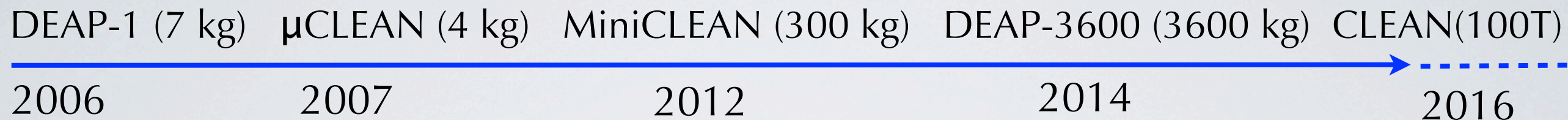
150 – 1000 kg

$3 \times 10^{-10} \text{pb}$  to

$2 \times 10^{-11} \text{pb}$



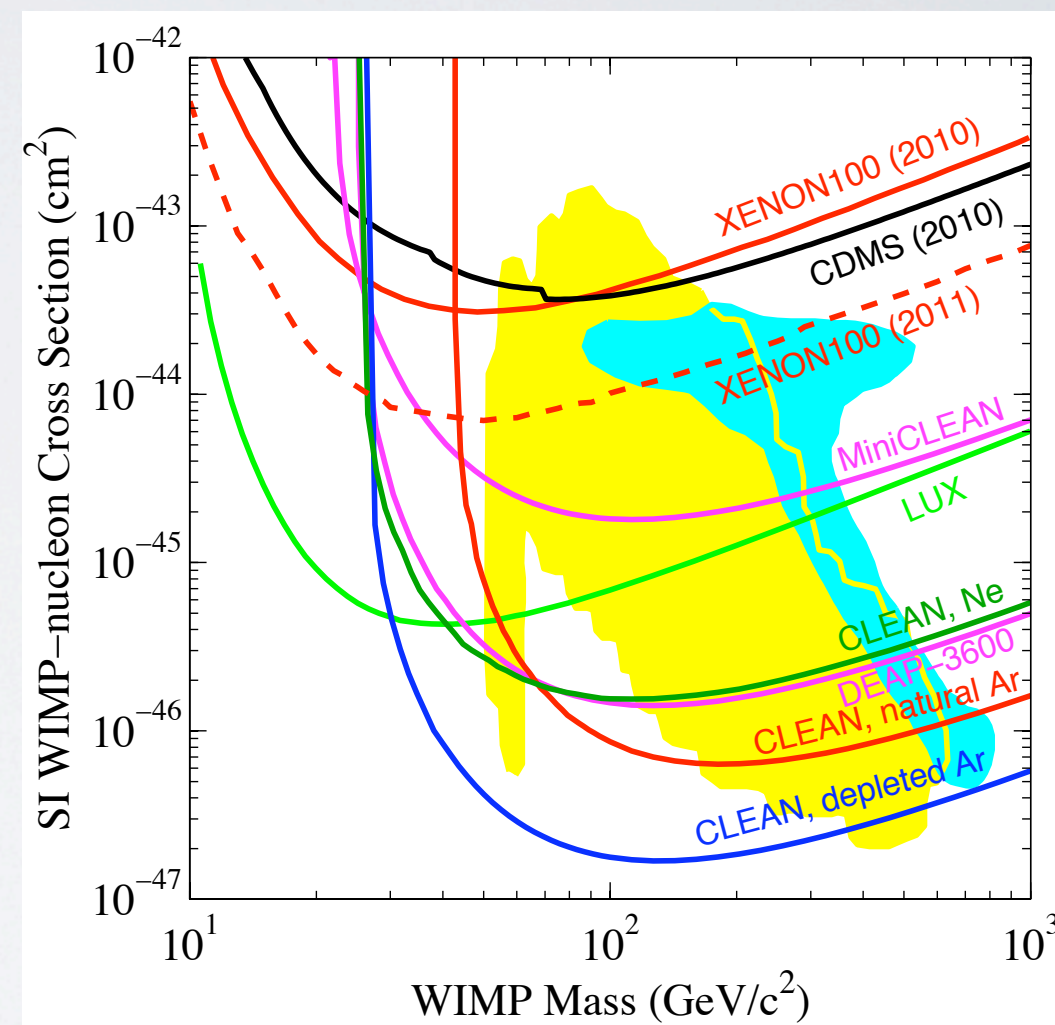
# DEAP/CLEAN



DEAP/CLEAN

O(10) tonne fiducial

future goal,  $1 \text{ E-}47 \text{ cm}^2$  sensitivity

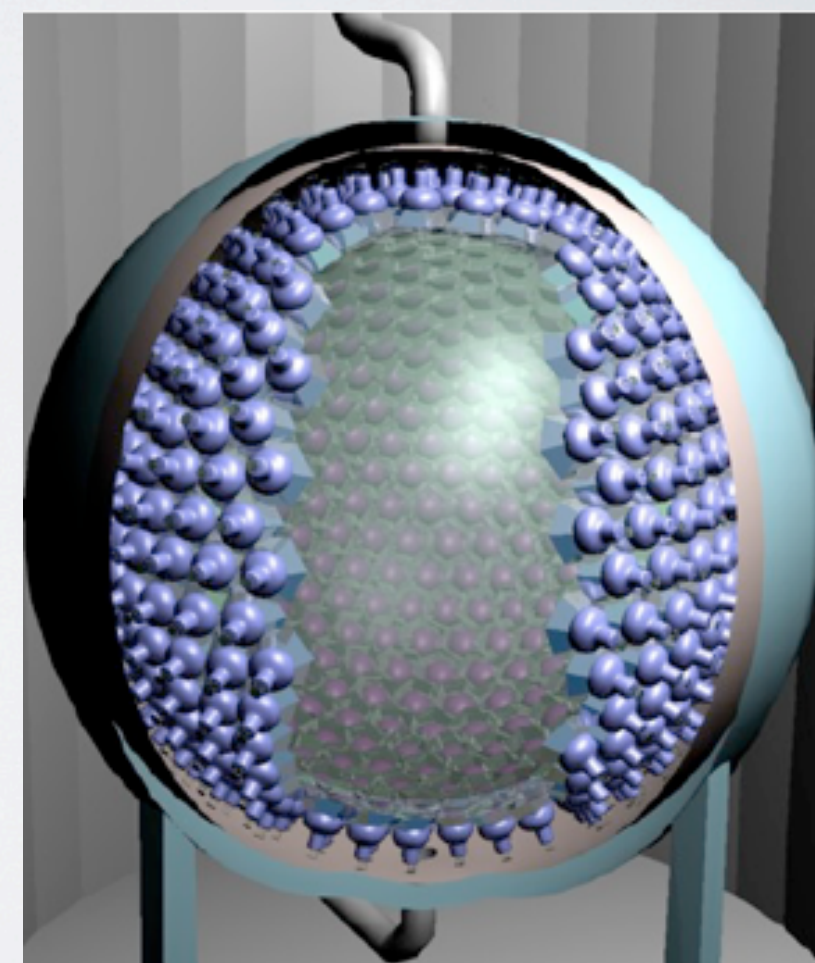
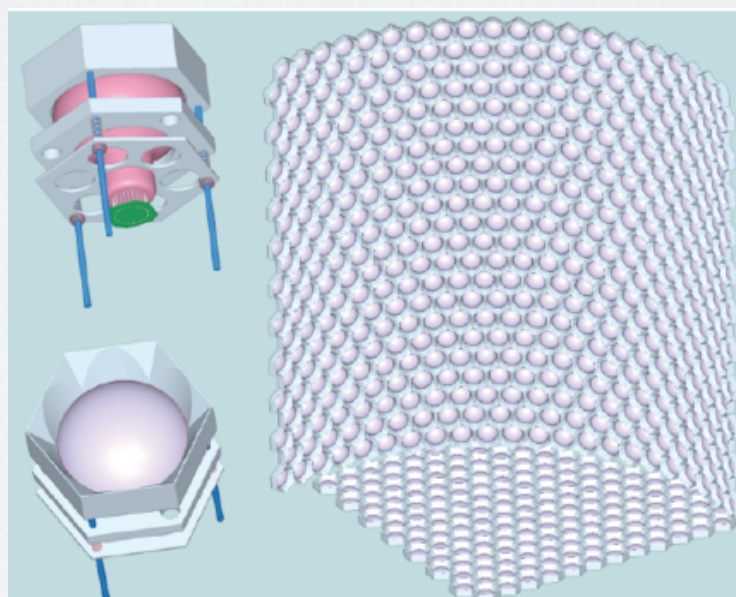


*emphasis on scalability to 100T-scale, for dark matter and solar neutrino physics*



# DEAP/CLEAN

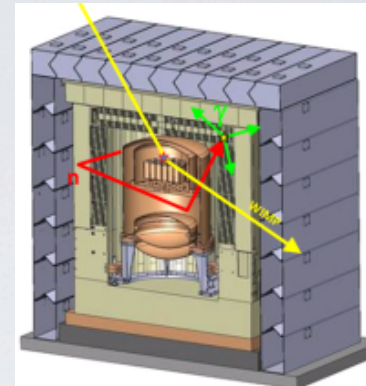
- Concept design: 140 tonne fiducial mass single phase detector with PMT readout, in SNOLAB Cryopit Hall
- technical design based on MiniCLEAN, DEAP3600 technology, R&D + MicroBooNE
- active Gd-doped veto
- same scale as MicroBooNE@FNAL, exploring similar cylindrical cryostat
- coordinated proposals to NSERC (CA), STFC (UK), DOE (US) planned for 2014
- UK group activities: detector design, background model, calibration R&D, technology synergy with LAr  $\nu$  efforts





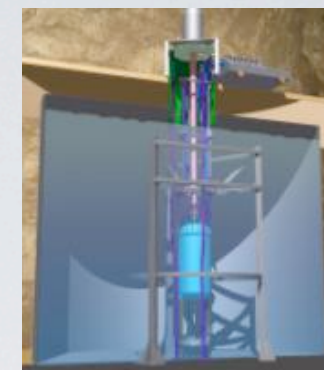
# LUX-ZEPLIN (LZ)

ZEPLIN-III



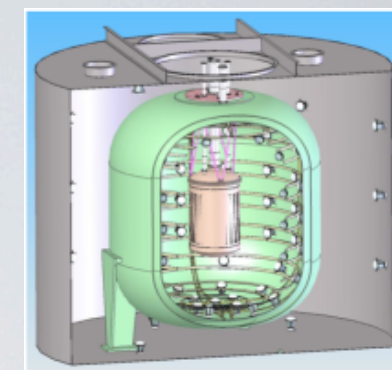
6 kg LXe (fid)

LUX350



100 kg

LZ



5,000 kg

## Next-generation LXe experiment

### building on LUX and ZEPLIN programmes

- **Route to detection & study: a progressive programme**

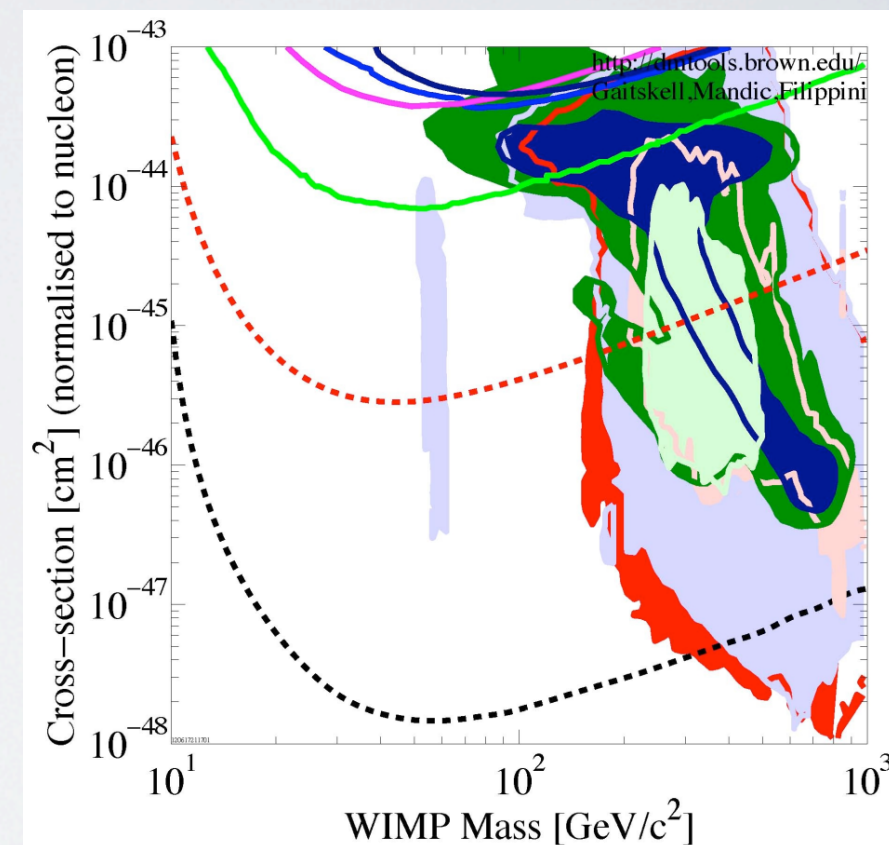
- UK-led **ZEPLIN** programme pioneered liquid xenon for WIMP searches
- **LUX** (now with UK) about to turn on – expect leading sensitivity in 2013
- **LZ** could discover at  $10^{-11}$  pb or exclude at  $10^{-12}$  pb with 3 year run

- **Experimental approach: a low risk and aggressive programme**

- Background free strategy (self-shielding, modest discrimination assumed)
- Two-phase Xe technology: high readiness level (ZEPLIN, XENON, LUX)
- Teams with huge track record in DM searches
- Much infrastructure inherited from LUX350

- **LXe provides exciting physics for light & heavy WIMPs (GeV-TeV)**

- Since we do not yet know what BSM physics looks like!





# Down-selects



- Science Board Sub-Group convened in 2012 to review UK involvement in DDMS...

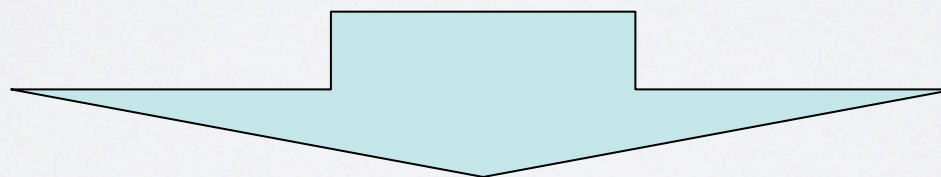
*“...the UK undoubtedly possesses unique expertise and has the potential to secure significant leadership within the relatively large international collaborations currently forming...”*

- ...and propose a coordinated strategy for supporting next generation DDMS experiments that could potentially position the UK for leadership

*“...it should be made clear to the community that further consolidation of activities would be viewed as a strength of any proposal.”*



DEAP/CLEAN DRIFT EDELWEISS EURECA LUX LZ



*spokesperson: H. Kraus, Oxford*



# DMUK 'down-select'

- DMUK founded to focus UK effort and as a body in which we build on mutual strength
- DMUK groups currently active in selecting the UK 'flagship' DM experiment
- Selected experiment(s) should seek to absorb UK expertise across DMUK
- Next meeting: 15th April 2013
- Next generation experiment selection coupled to international partners and funding



# U.S. 'down-select'

- DOE conducting down-select in two phases: R&D and then Project
- From 13 proposals to DOE, 5 selected for R&D funds and continuation in the down-selection process:
  - LZ
  - SuperCDMS
  - DarkSide-G2
  - COUPP
  - ADMX (axion search)
- 2-3 of these Next Generation ("G2") experiments to be funded
- Pursuit of a wide-range of technologies is not expected
- Merging of the communities is expected after down-select



# Summary

- The nature of Dark Matter remains one of the most fundamental questions today
- Direct detection experiments have accelerated rapidly in sensitivity, with high technology readiness levels or advanced detector development for the Next Generation tonne scale devices
- Tonne scale experiments have sensitivities ideally matched to probe the bulk of the favoured parameter space on timescales compatible with accelerator and indirect
- DMUK making excellent progress in consolidating UK direct detection activity



# Back-up Slides