Long-term prospects for cryogenic detectors at SNOLAB

Context

Projects of cryo experiments

Converging at SNOLAB ?

Comments

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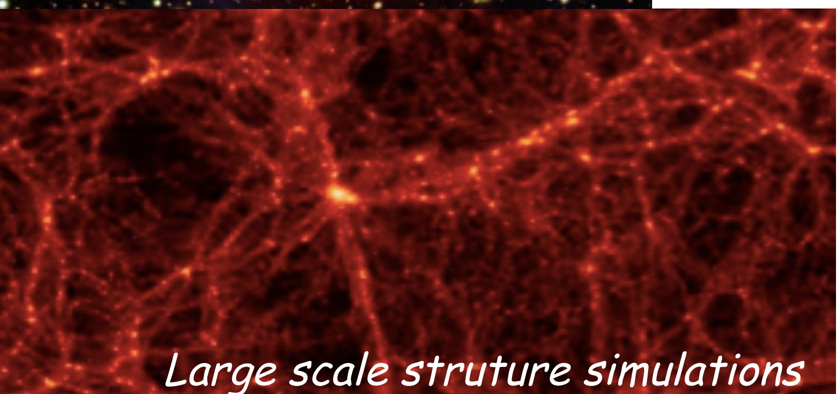
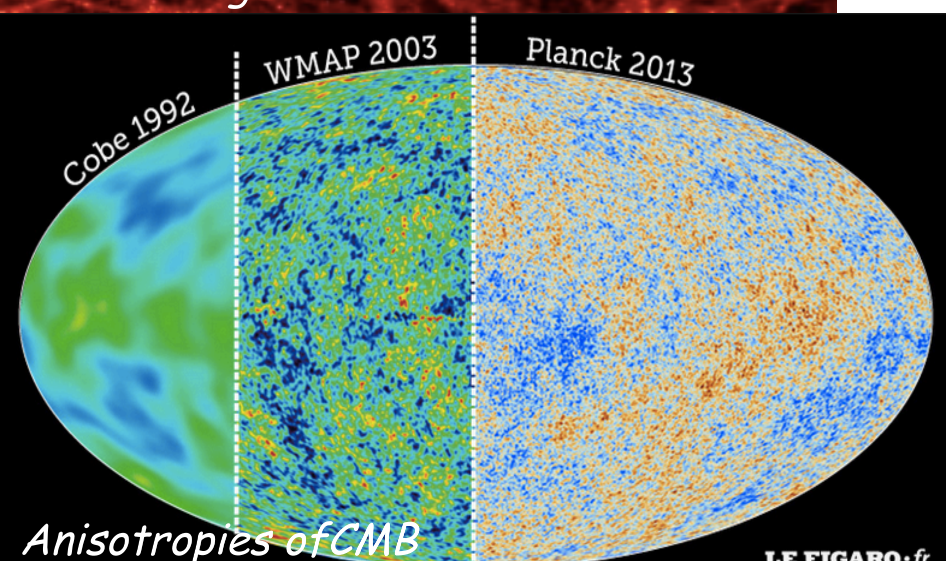
FPW 2015- SNOLAB

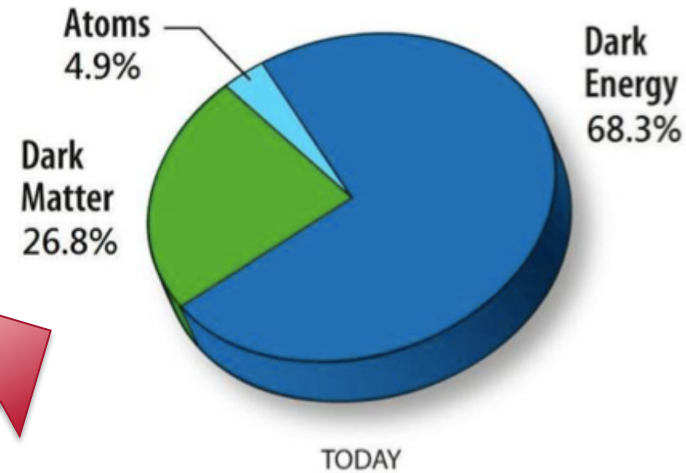
Aug 24th 0215

Canada Excellence Research Chairs

Chaires d'excellence en recherche du Canada

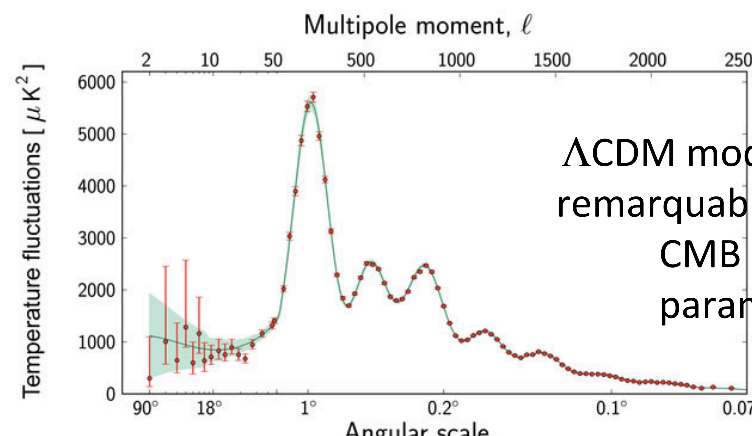






Parameter	TT,TE,EE+lowP+lensing+ext 68 % limits
$\Omega_b h^2$	0.02230 ± 0.00014
$\Omega_c h^2$	0.1188 ± 0.0010
$100\theta_{MC}$	1.04093 ± 0.00030
τ	0.066 ± 0.012
$\ln(10^{10} A_s)$	3.064 ± 0.023
n_s	0.9667 ± 0.0040

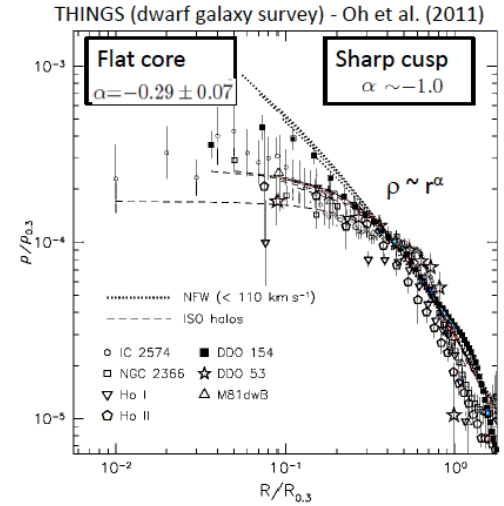
Planck 2015



ΛCDM model fits remarquably well CMB with 6 parameters

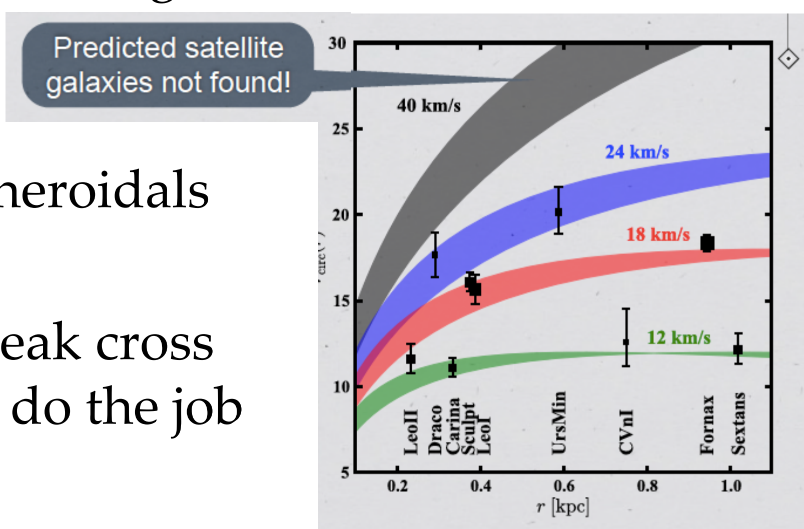
But

N body simulations based on ΛCDM collisionless cold DM fail to reproduce some basic astrophysical observations at galactic scale



1. Shape of galaxy density profile : core-vs-cusp problem

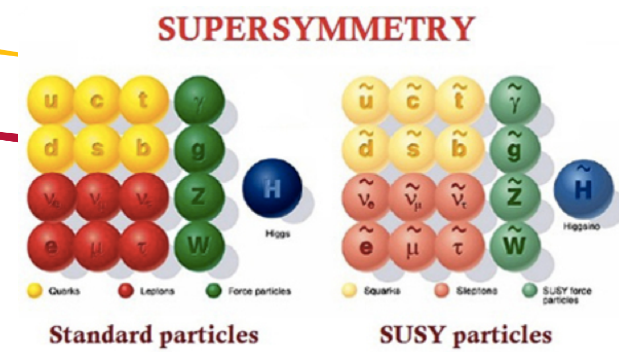
2. Missing Milky Way massive satellites : "too big to fail"



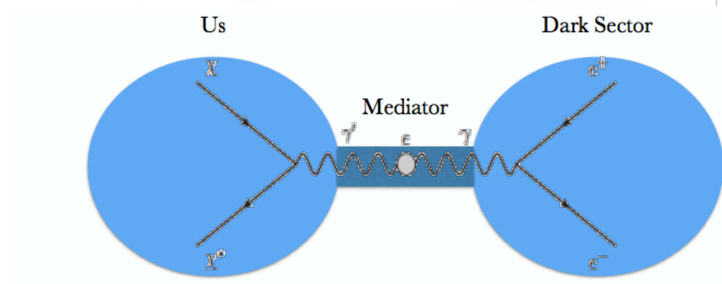
3. Missing Milky Way low mass dwarf Spheroidals

The simplest generic **WIMP** particle with weak cross section and mass in 2 to 2000 GeV does not do the job

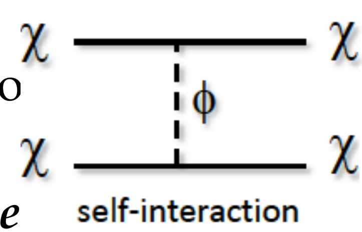
Particle physics candidates : change of paradigm



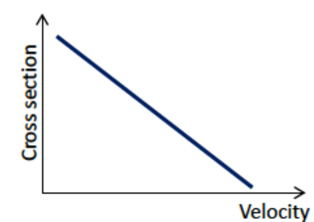
- **SUSY** "less favored "
  - LHC did not find new physics
  - New "window" for SUSY DM : high mass 1 TeV



- **Dark force sector** in development
  - Low mass mediator A' => low or high mass DM
  - ***Intense activity at accelerators to look for dark photons*** : e,p beam dumps, e fixed targets



$\sigma/m_\chi \sim 1\ \mathrm{cm}^2/\mathrm{g}$



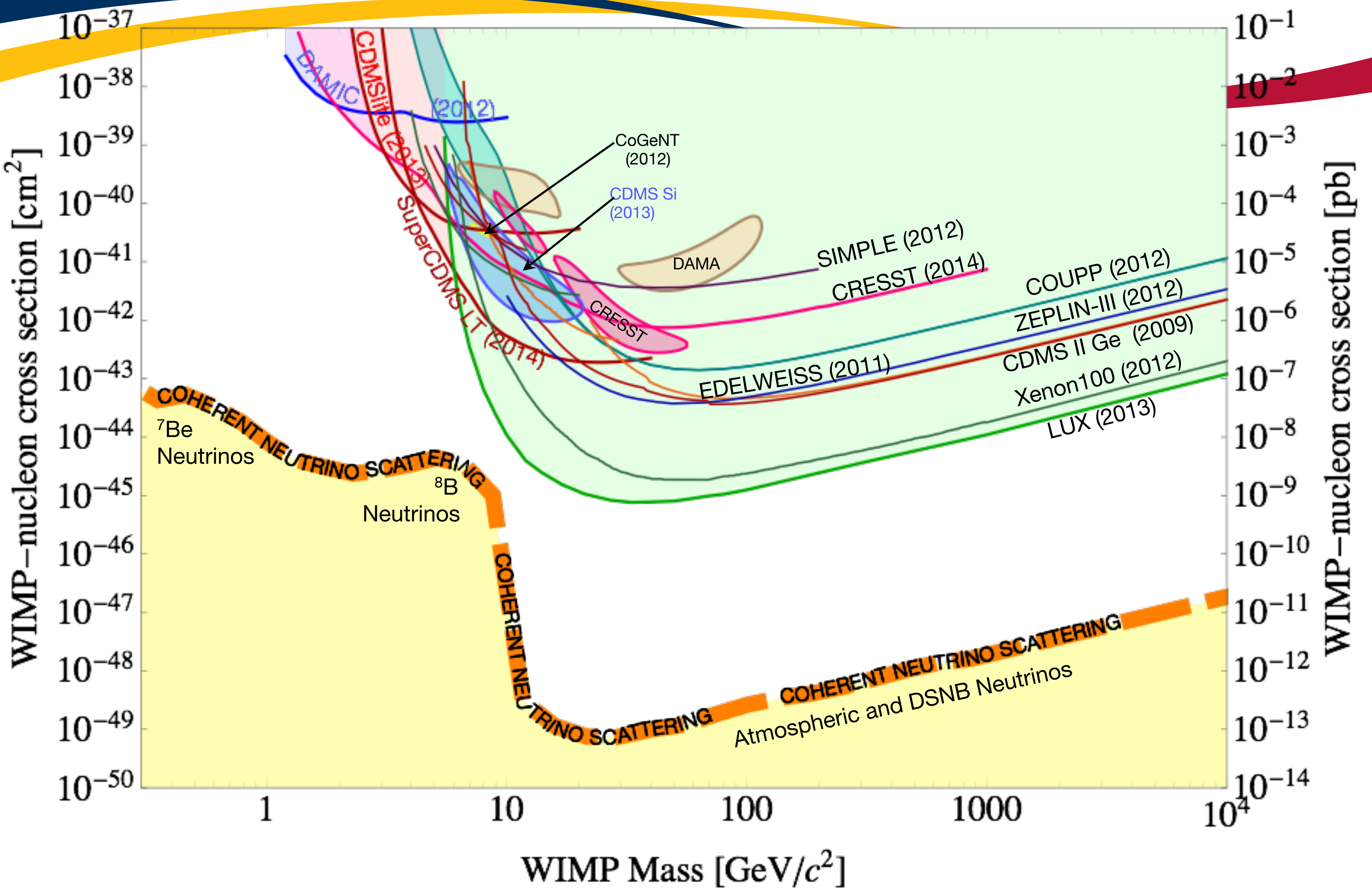
- **Self Interacting Dark Matter**
  - Solve cusp-core and "toobig to fail" questions and do not change large scale behaviour
  - ***Need enlarged strategy -multi target- to differentiate from classical "WIMPS"***
- **Asymetric** Dark Matter : ***5 GeV***
  - Similarity now of density of ordinary and dark matter => same origin ?

$\Omega_{DM}/\Omega_B = m_{DM}Y_{DM}/m_BY_B$

$Y_{DM} \sim Y_B,\ m_{DM} \sim 5\ \mathrm{GeV}$

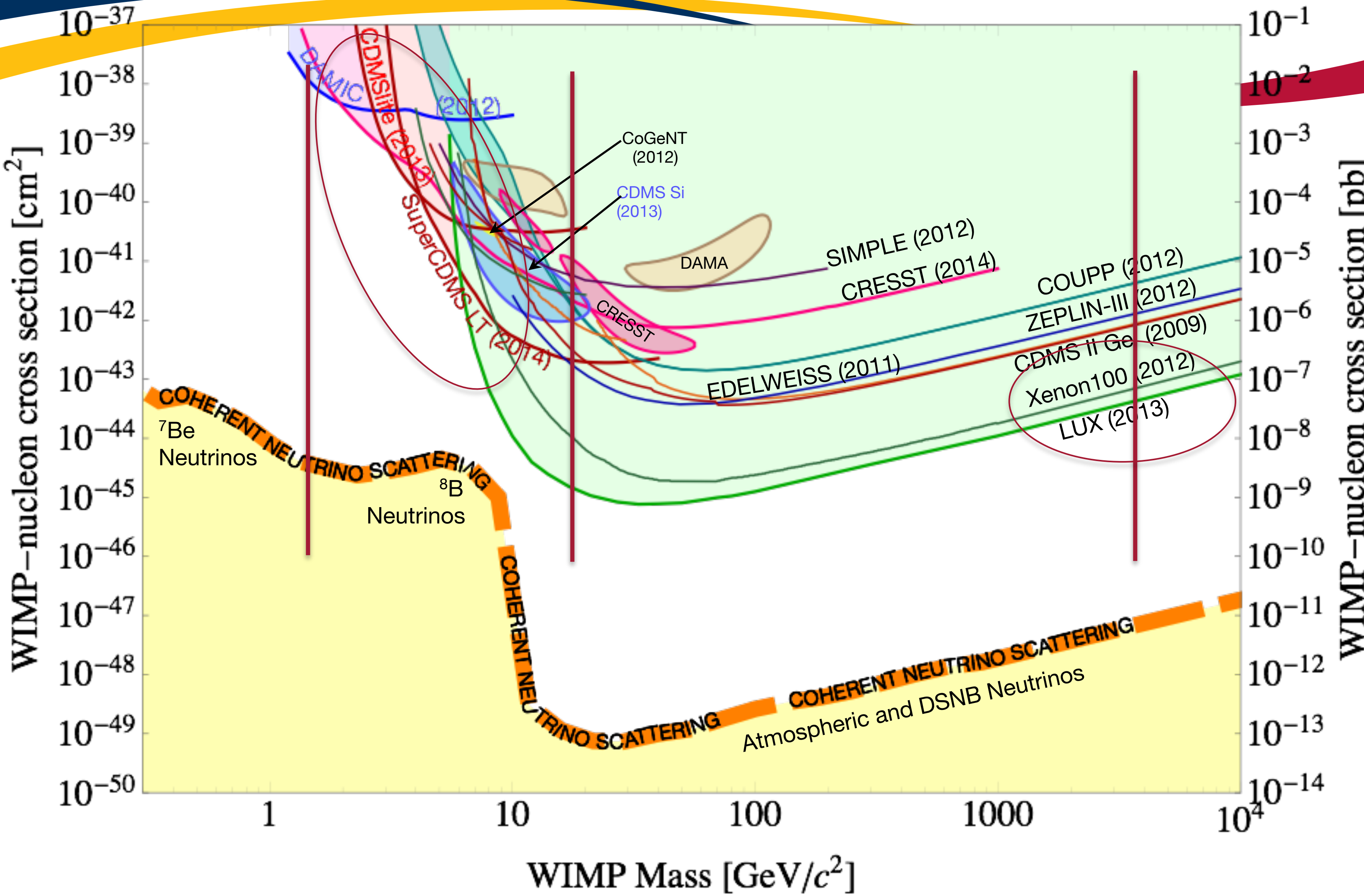
Ref : Pospelov, Tulin, Zurek, Kaplinghat, Schuster, Toro, Fayet,…

Direct detection, SI, status at sept 2014/june 2015



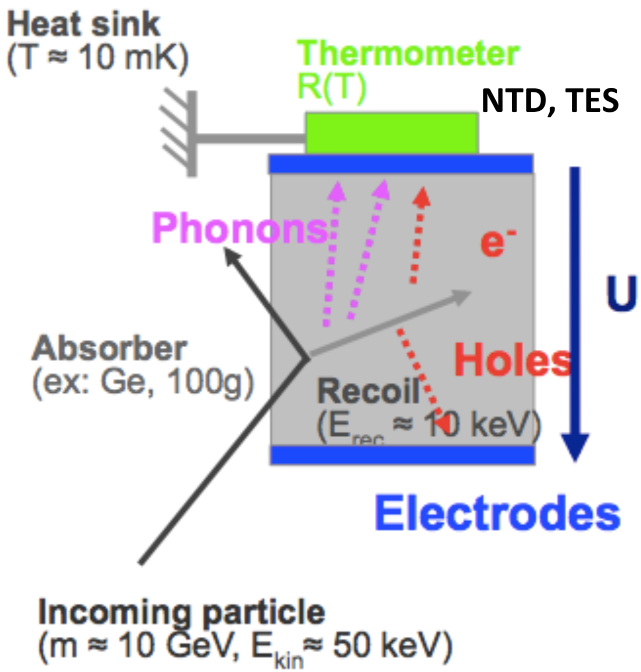
Spin Independent couplings

2 regions “High mass” 20 GeV –TeV, “low mass” 2-20 GeV



Cryogenic detectors

Phonon ionisation



Ge, Si

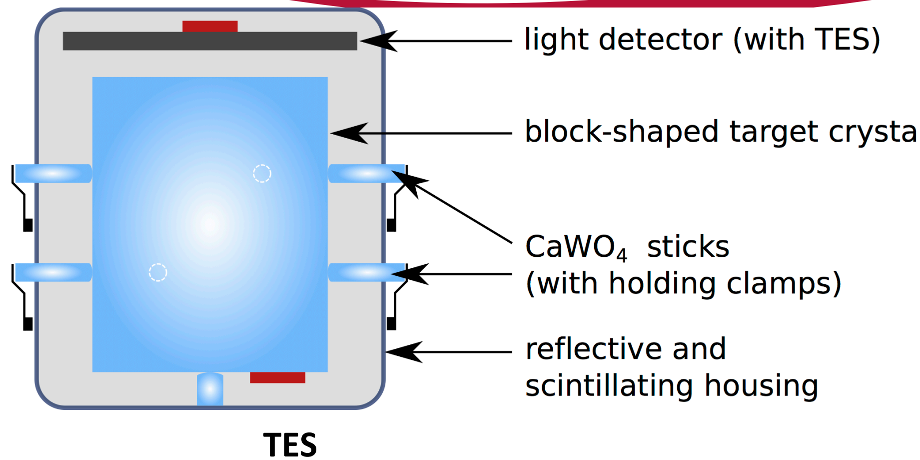
SuperCDMS- Edelweiss

2 modes :

- **-classical : U small (<8V)**
- - “NL mode”, U “high” (100 V)

amplification of Ionisation (30)

Scintillating bolometers



CaWO4

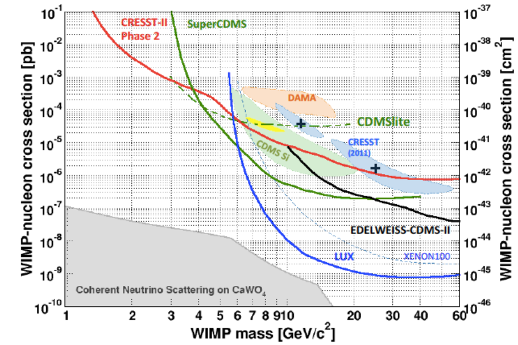
CRESST

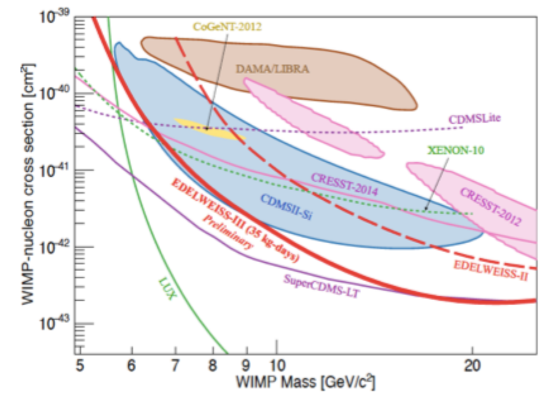
“Best” threshold E_{NR} : 0.6 keV

Cryogenic experiments - status

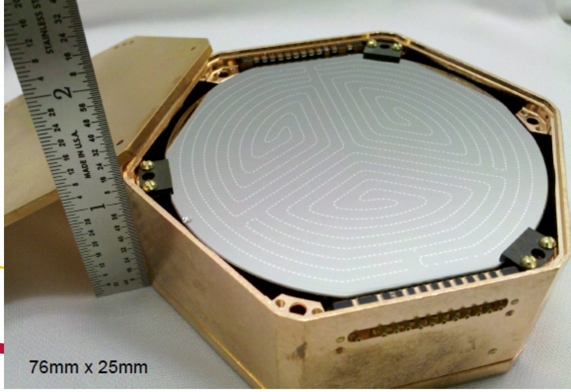
- **CRESST II** – German @ Gran Sasso
  - **TUM 40 single detector**
  - Going to 100 eV threshold
- **EDELWEISS III**– European @ LSModane
  - **FID800** Recent result at low mass with single detector
  - Prospects for use of HV
- **SuperCDMS** – US, Canada @ Soudan up to sept 15
  - **IZIP** Last result 2014
  - HV detectors being taking data
  - Towards single eh pair detection

- All aiming at "low mass"

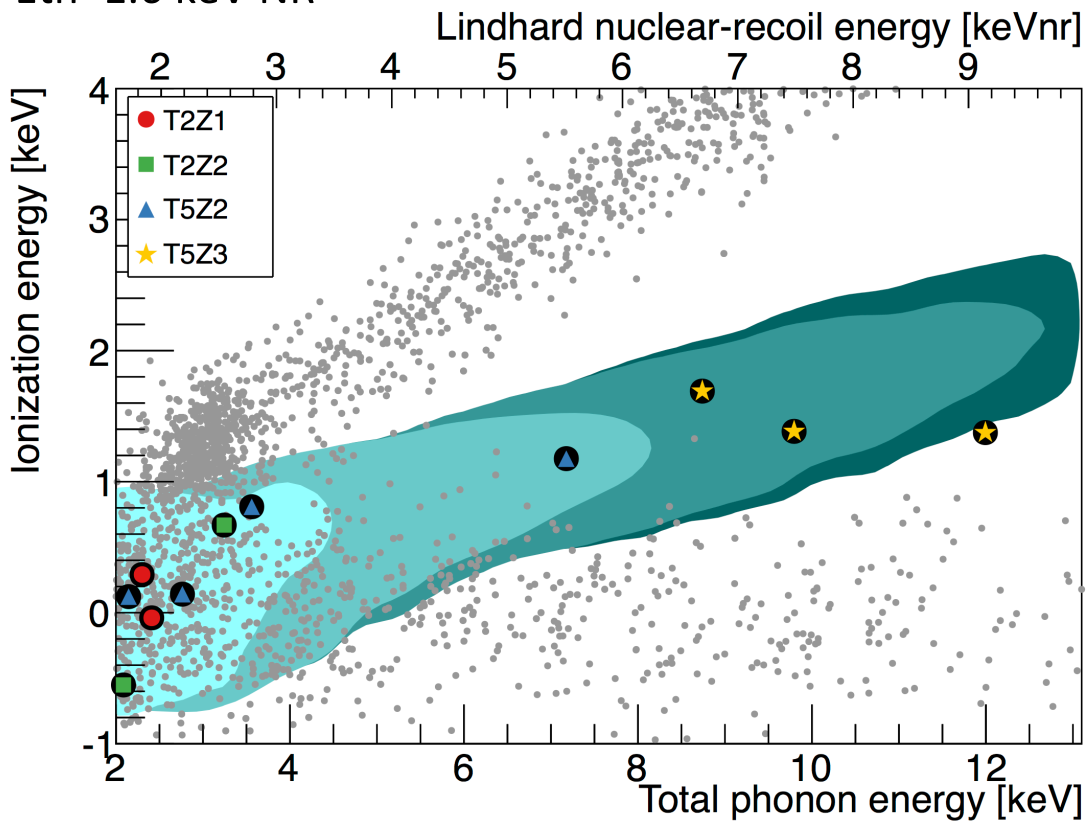




SuperCDMS Low-threshold analysis

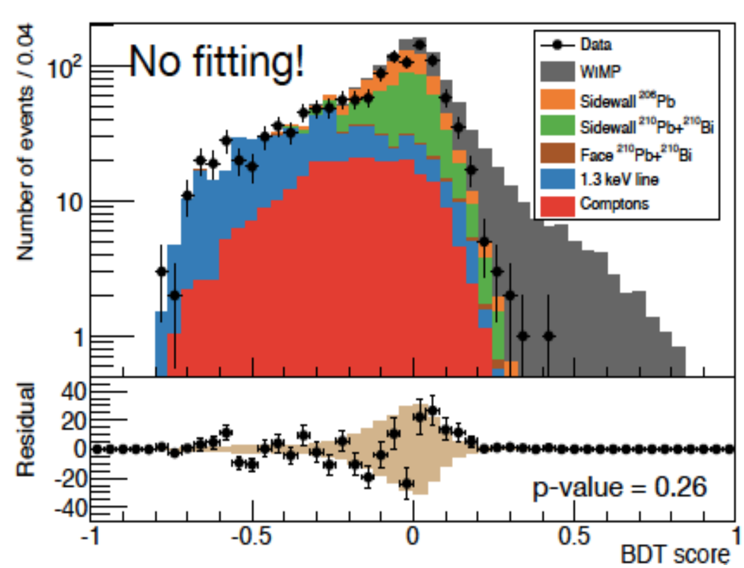


Eth=1.6 keV NR



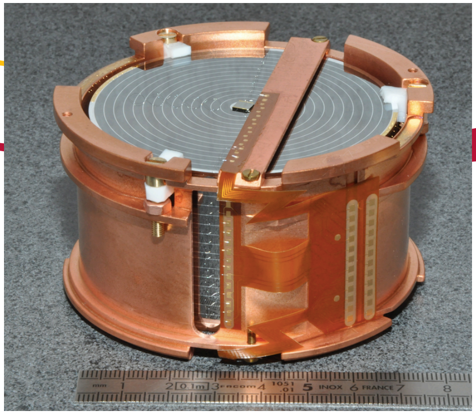
95% confidence contours for expected signal from **5**, **7**, **10** & **15** GeV/c^2 WIMPs

- $6.1^{+1.1}_{-0.8}$ evts expected
- 11 observed, including 3 at high energy from T5Z3 (with malfunctioning guard electrode)



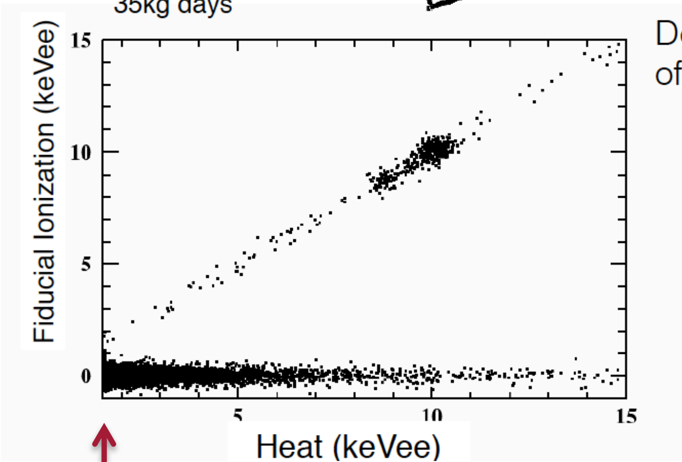
Edelweiss low energy, BDT method

Data Selection



FID800

FID837
35kg days

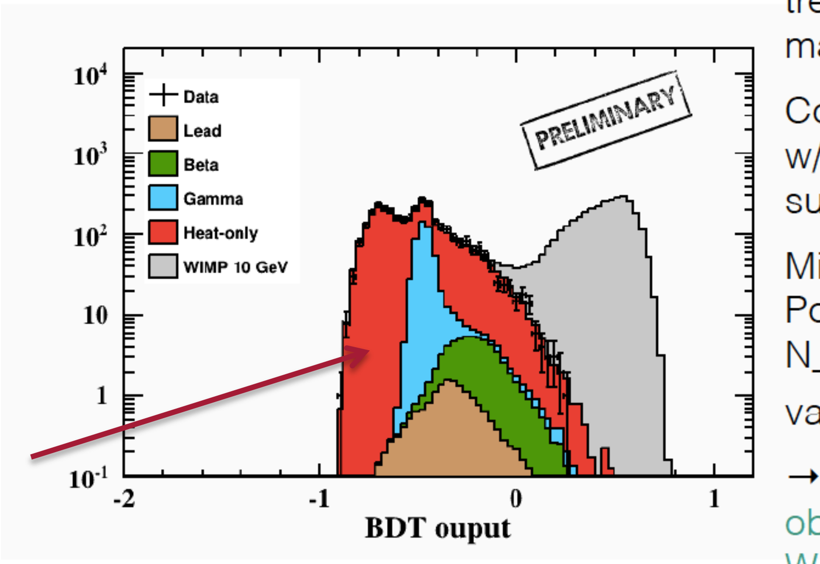


Define a rough region of interest

- Singles
- 1.5 < Eh < 15 keVee
- 0 < Ei < 15 keVee
- Ev < 5 σ

Threshold
1.5 keV phonon
⇔ 2.5 keV NR

"Heat only events"



One boosted decision tree (BDT) per WIMP mass

Conservative limit: w/o background subtraction

Minimization of Poisson(exp. bkg)/ N_Wimp for BDT cut value

→ either 0 or 1 evts observed according to WIMP mass

Luke-Neganov effect in CDMSLite: Use phonons to read charge

- Bias a standard SuperCDMS 600 g iZIP detector at 69 V (rather than 4 V)
- Phonon amplification proportional to charge, bias voltage (**CDMSLite: x24 for gammas**)

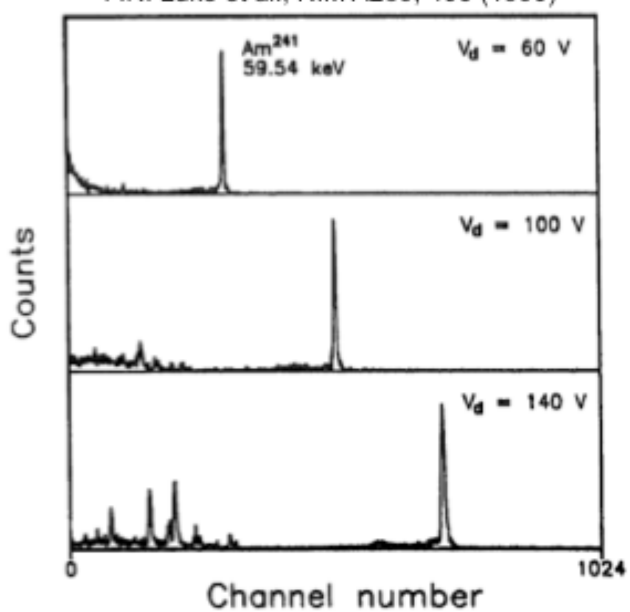
Single detector : exposure 6.3 kg.d

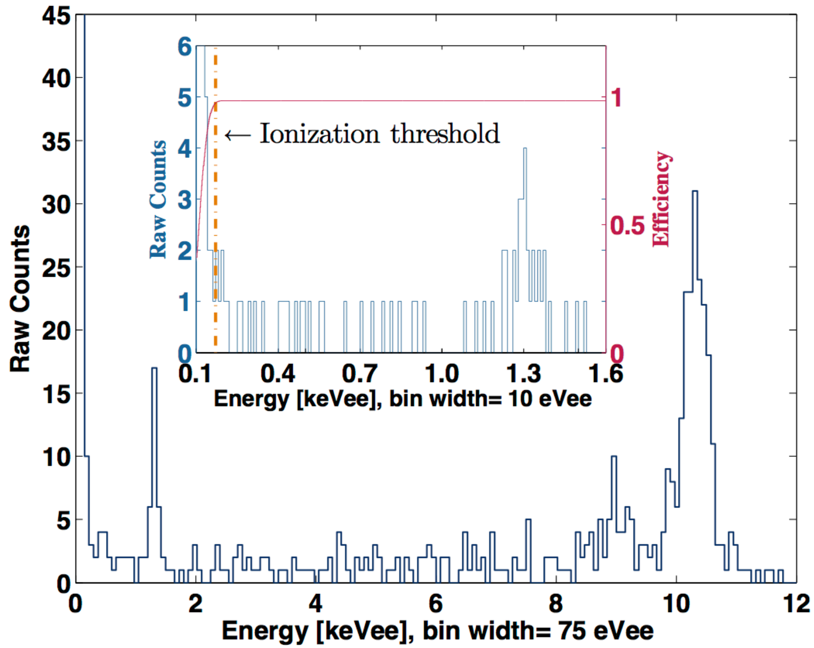
Excellent threshold (170 eVe = **840 eVNR** on Ge), resolution (1σ 43 eVee @ 1.3 keVee)

Loss of background discrimination

BG diluted with respect to signal

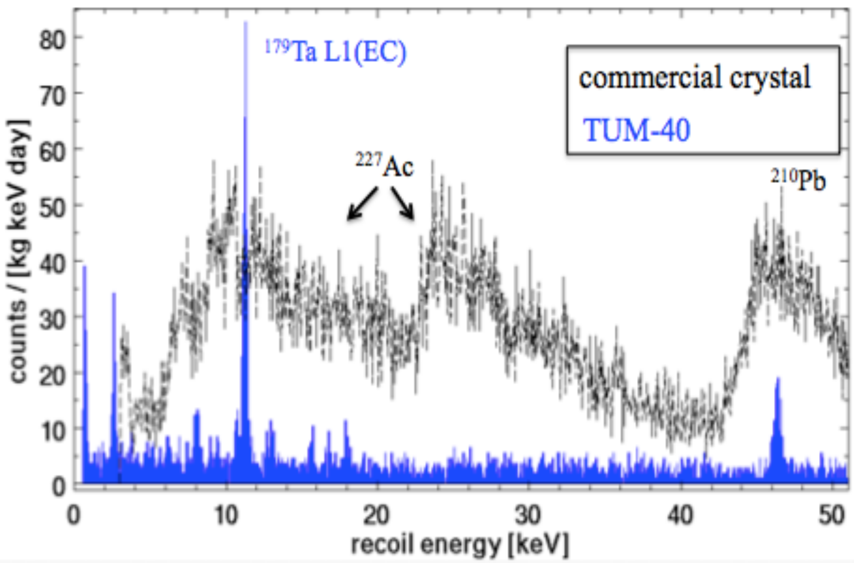
P.N. Luke et al., NIM A289, 406 (1990)

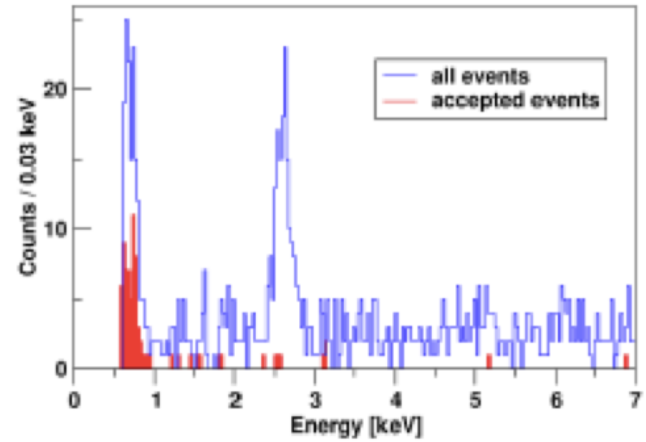


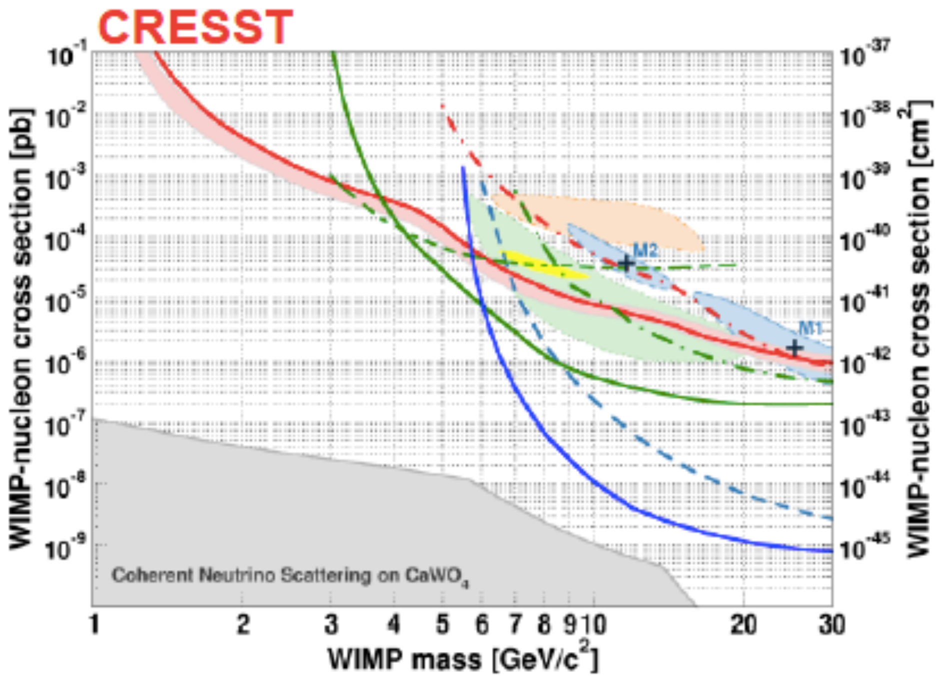


(n activation → K and L shell captures of ^{71}Ge visible)

CRESST latest results







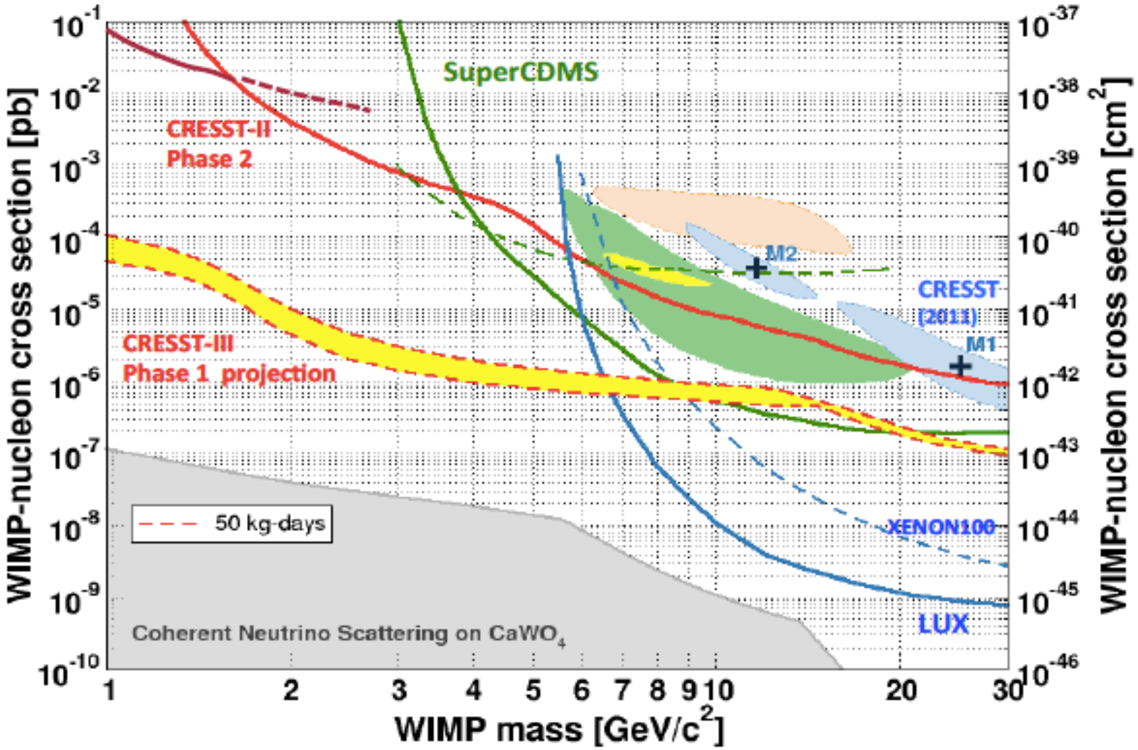
29.35 kg-d exposure
energy resolution: (107±3) eV
energy threshold: (603±2) eV

arXiv:1407.3146

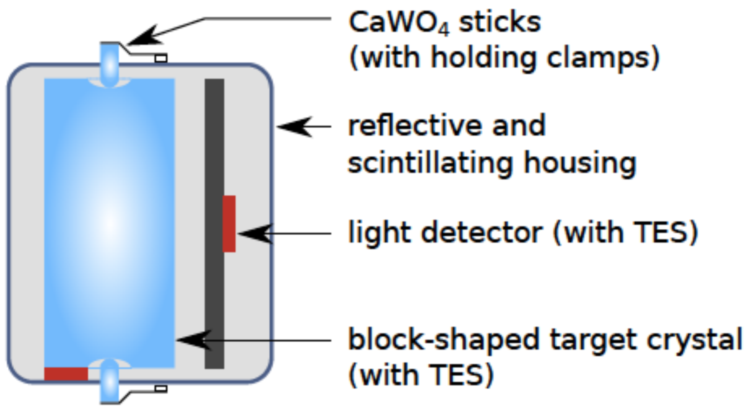
CRESST-III Phase 1

Assumptions:

- 24g $CaWO_4$ crystal
- E_{th} = 0.10 keV
- Light detector improved by factor 2 (due to smaller volume)
- 2x more detected light: due to thin crystal
- CRESST-II (Phase 2) radiopurity

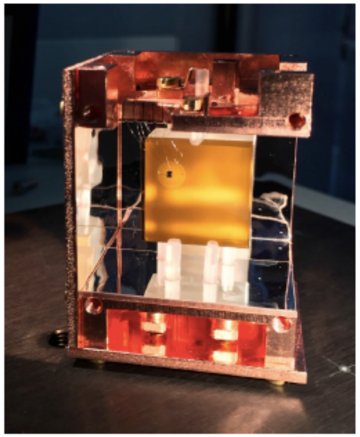


10 x 24g detectors operated for one year ≈ 50 kg-days (net)



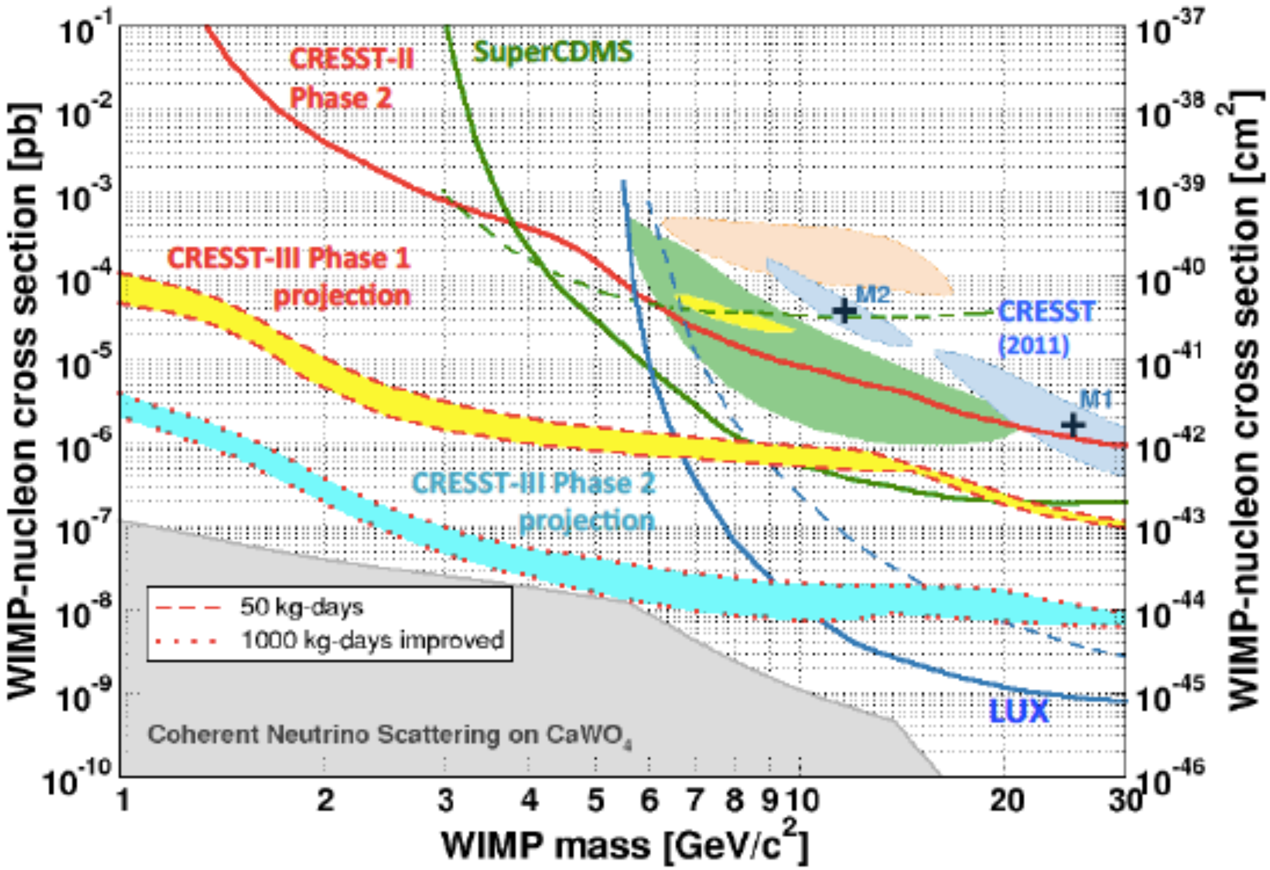
- Threshold of 100 eV (NR) on 24g detector in hand
- building 10 detectors

=> Aim at **starting end 2015** at LNGS



First modules ready

CRESST-III Phase 2

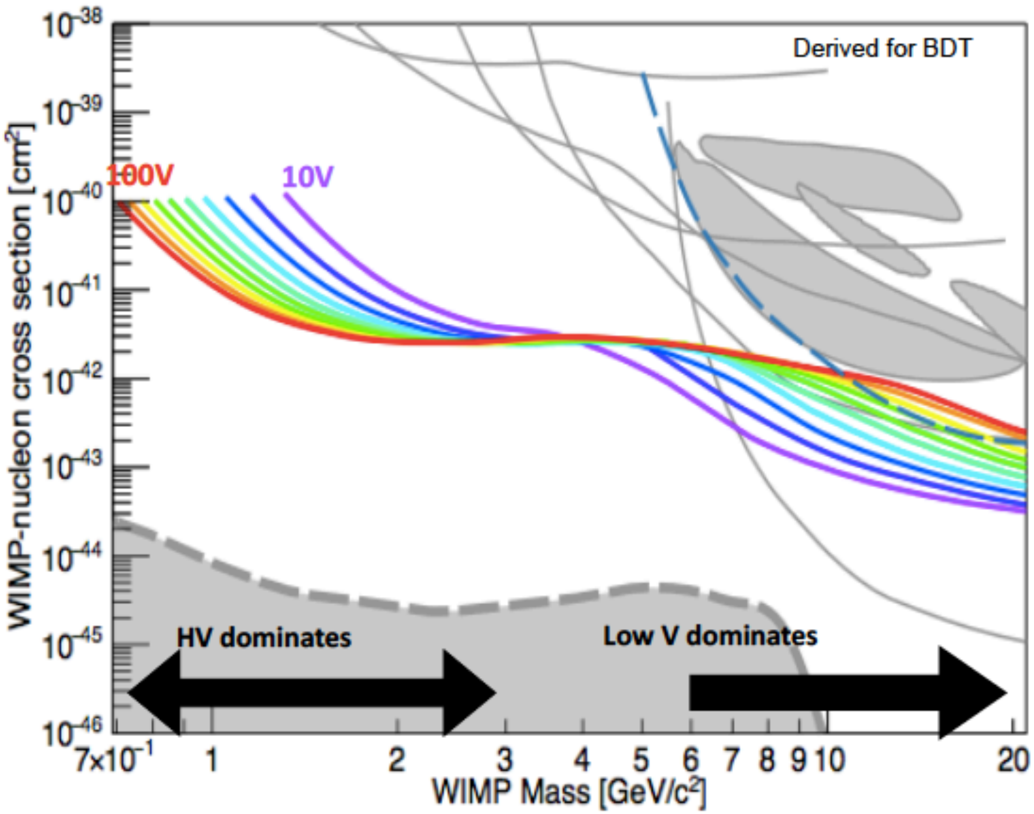


100 x 24g detectors of improved quality operated for 2 year ≈ 1000 kg-days (net)

+ reduction of intrinsic background by factor 100
+ upgrade of electronics, cabling & cryostat for 100 detectors
=> If both satisfied => start 2 year data taking from 2018-2019 ?

In SuperCDMS @ SNOLAB ??

A possible future for Edelweiss III – LEAP @ LSM

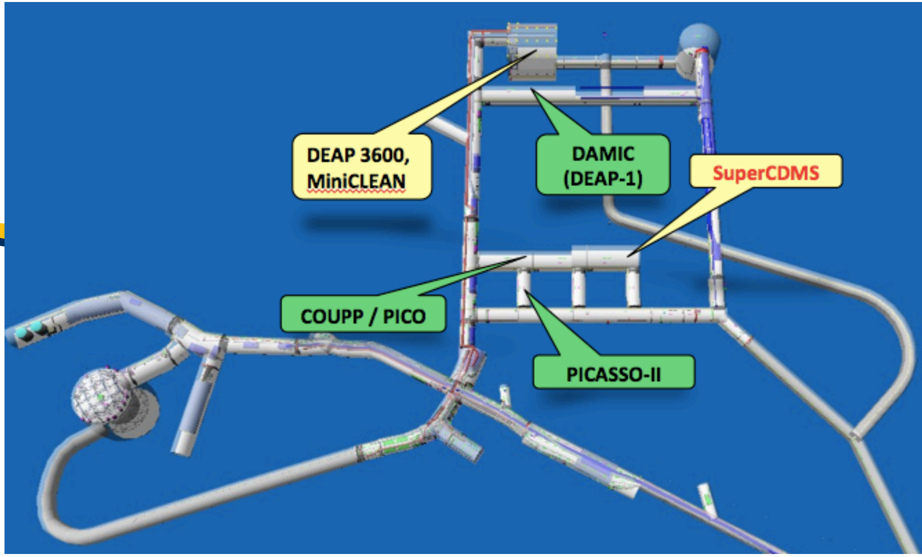


Playing with voltage for ionisation from 10 to 100 V

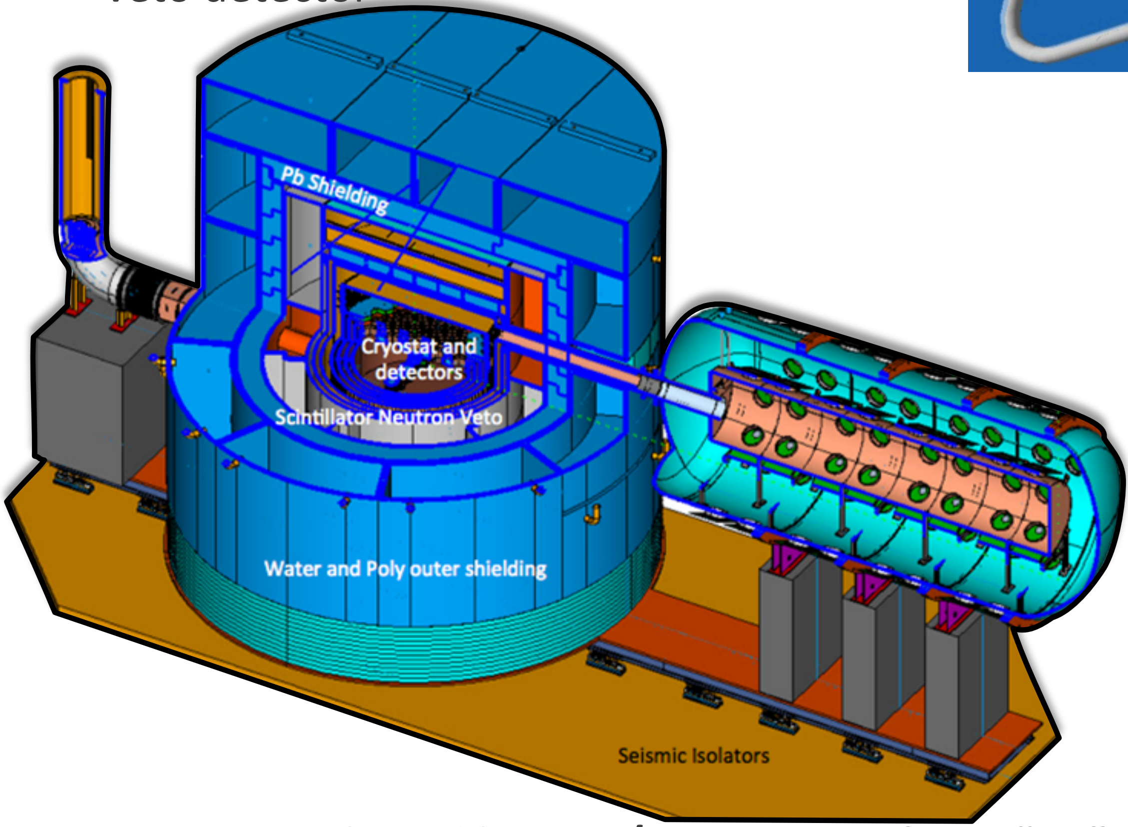
Hypothesis of the projection

- *100 eV RMS heat and ionisation*
- *(now 140 and 230 eV)*
- *Heat only evts reduced by 100*
- 350 kg.d
- Existing background extrapolated flat to LE
- QF extrapolated as $0.16Er^{0.18}$

SuperCDMS at SNOLAB



- Setup holds up to ~400 kg detectors ie 48 “towers”
- Planned shielding includes neutron veto detector



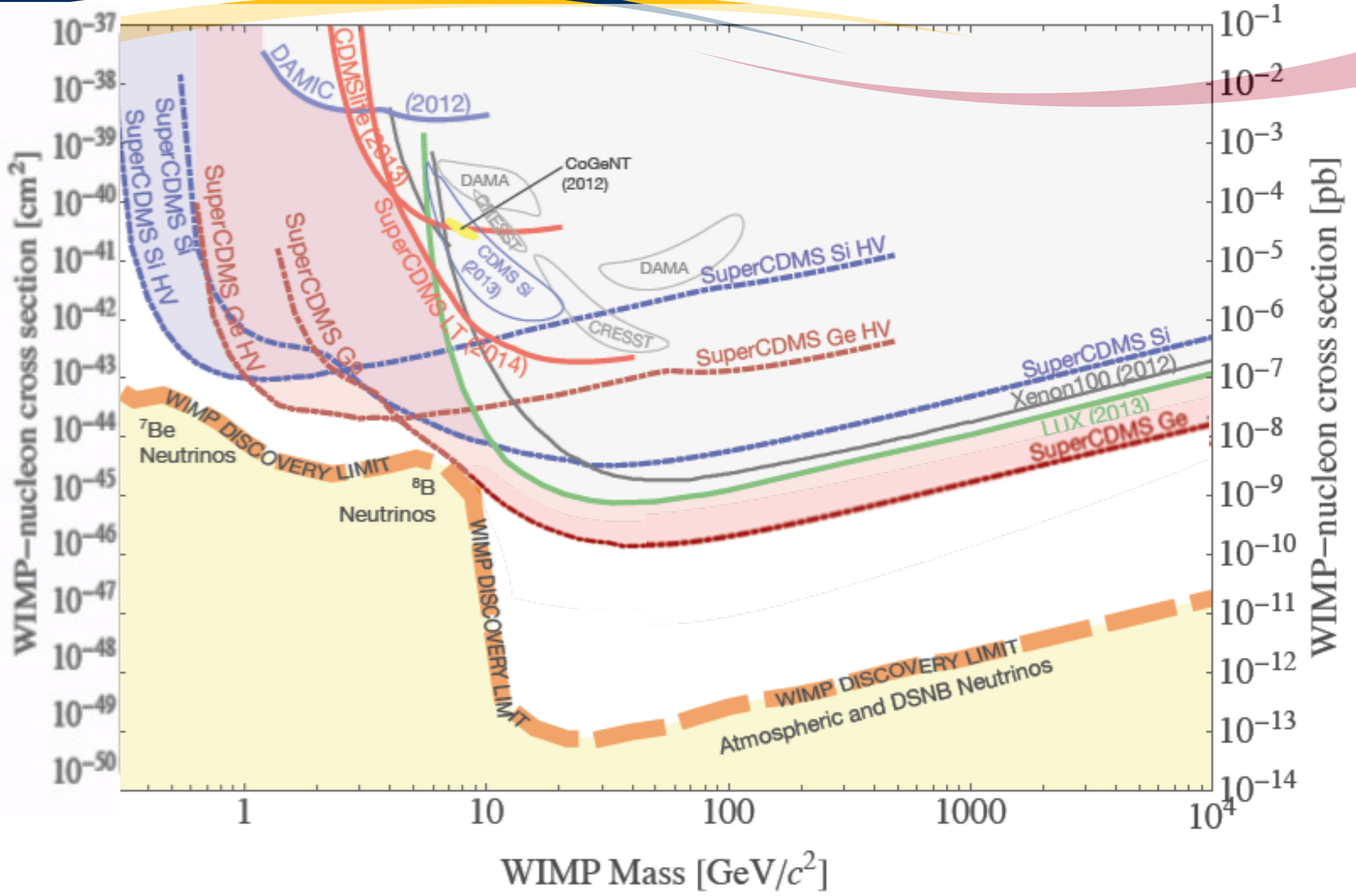
- Initial payload includes mix of standard and HV detectors

Ge/Si iZIP (50 /3.7 kg), discrimination NR/e
Ge/Si HV (4.6/1.2 kg), no discrimination NR/e
5 y operation

- **Room for significant additional payload e.g. from EURECA (CRESST, EDELWEISS) or advanced HV dets.**

- **Funding: Selected by DOE/NSF as one of two “G2” WIMP search experiments**
- Total project cost: ~$25-30 M, including $3.4M from Canada (CFI)

Super CDMS projections as of 2014



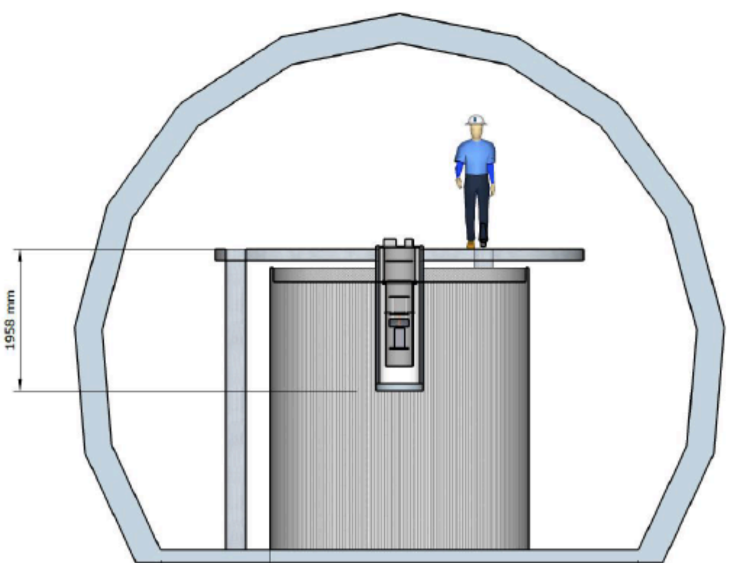
EURECA (CRESST-EDELWEISS) - SuperCDMS cooperative work on going – no MoU yet

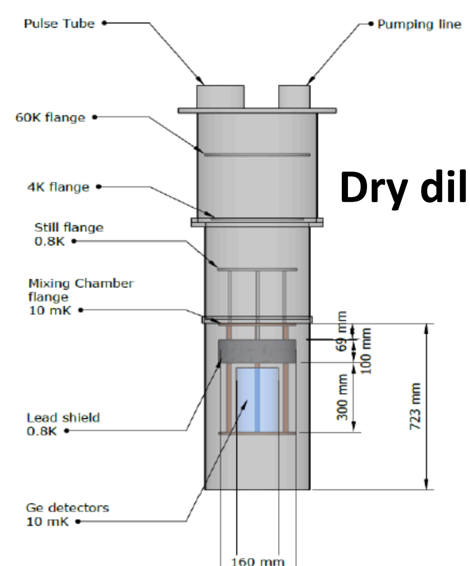
Technical meetings

141001:	cryogenics
141118:	cryogenics (@Fermilab)
141217:	electronics (general)
150107:	bolometer tower
150204:	electronics (HEMT)
150506:	low background (budget, shielding)
150601:	low background (screening, simulations)

Proposed path by Queen's for convergence : test towers from SuperCDMS and from EURECA in Cryogenic Underground Tower tEst facility in SNOLAB

GG CERC 1M$ equip + 2M$ people funding



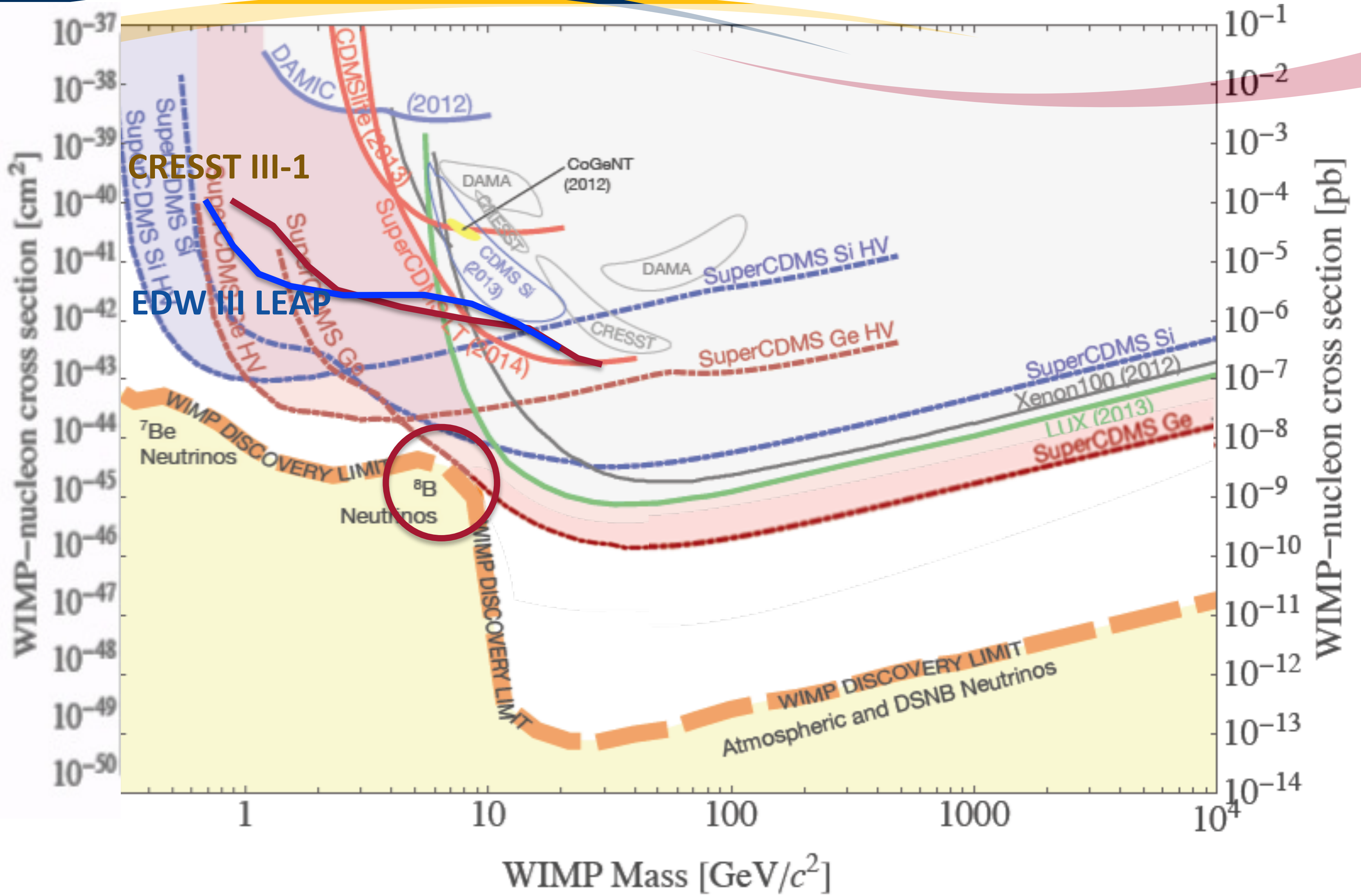


Dry dilution fridge

DOE/NSF strategy update summer 2015

- Scientific recommendation
  - go to low mass < 10 GeV
- Request to decrease cost
  - Resize cryostat and related hardware to <48 towers
  - Ge/Si HV detectors for mass < 5 GeV
  - 3 IZIP Ge towers for 5-15 GeV (15 events of ^{8}B in 5 years)
- Timeline :
  - 2019 set-up operational
  - 5 years data taking

Summary of projections, cryo



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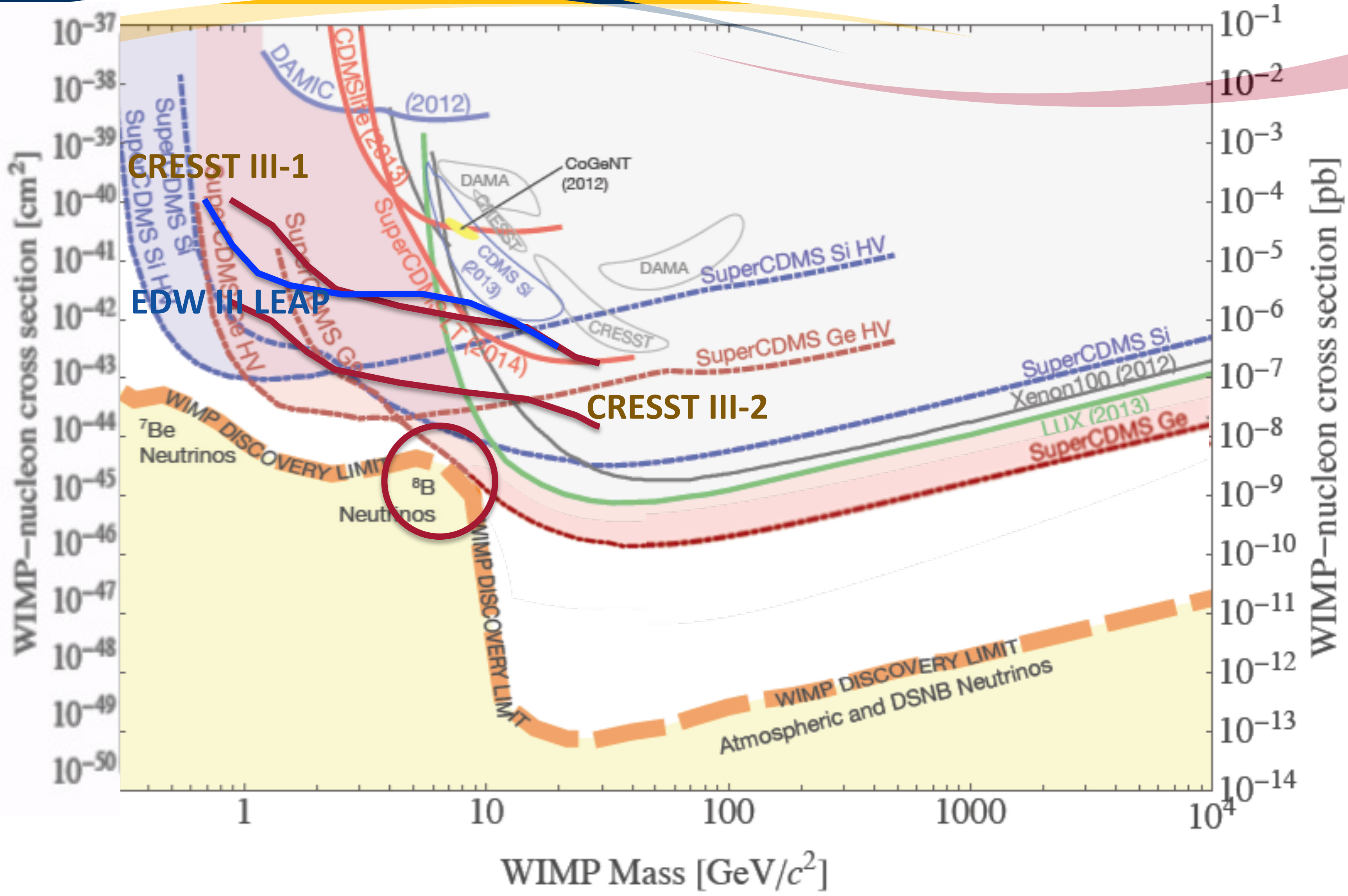

Summary – a possible -desirable- future

			2016	2017	2018	2019	2020	2021	2022	2023	2024
CRESST III phase 1	0.24 kg	LNGS	Prep	Data							
EDELWEISS LEAP	10 kg	LSModane		Prep	Data						
CUTE	10 kg	SNOLAB		Valid SuperCDMS-CRESST-EDW, Data ?							
SuperCDMS	30-40 kg	SNOLAB				Prep	Data				
CRESST III phase 2	2.4 kg	SNOLAB				Prep	Data				
EDELWEISS	36 kg FID	SNOLAB				Prep	Data				