Direct Dark Matter search with noble liquids

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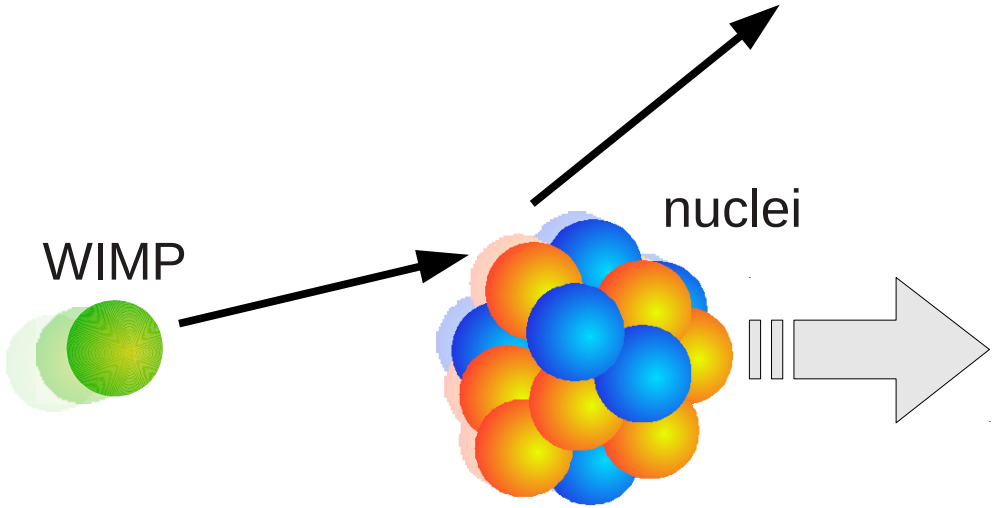
WIMP-nucleon scattering

WIMP elastically scatters off nuclei → nuclear recoils



$$\chi + N \rightarrow \chi + N$$

$v \sim 230\ km/s$

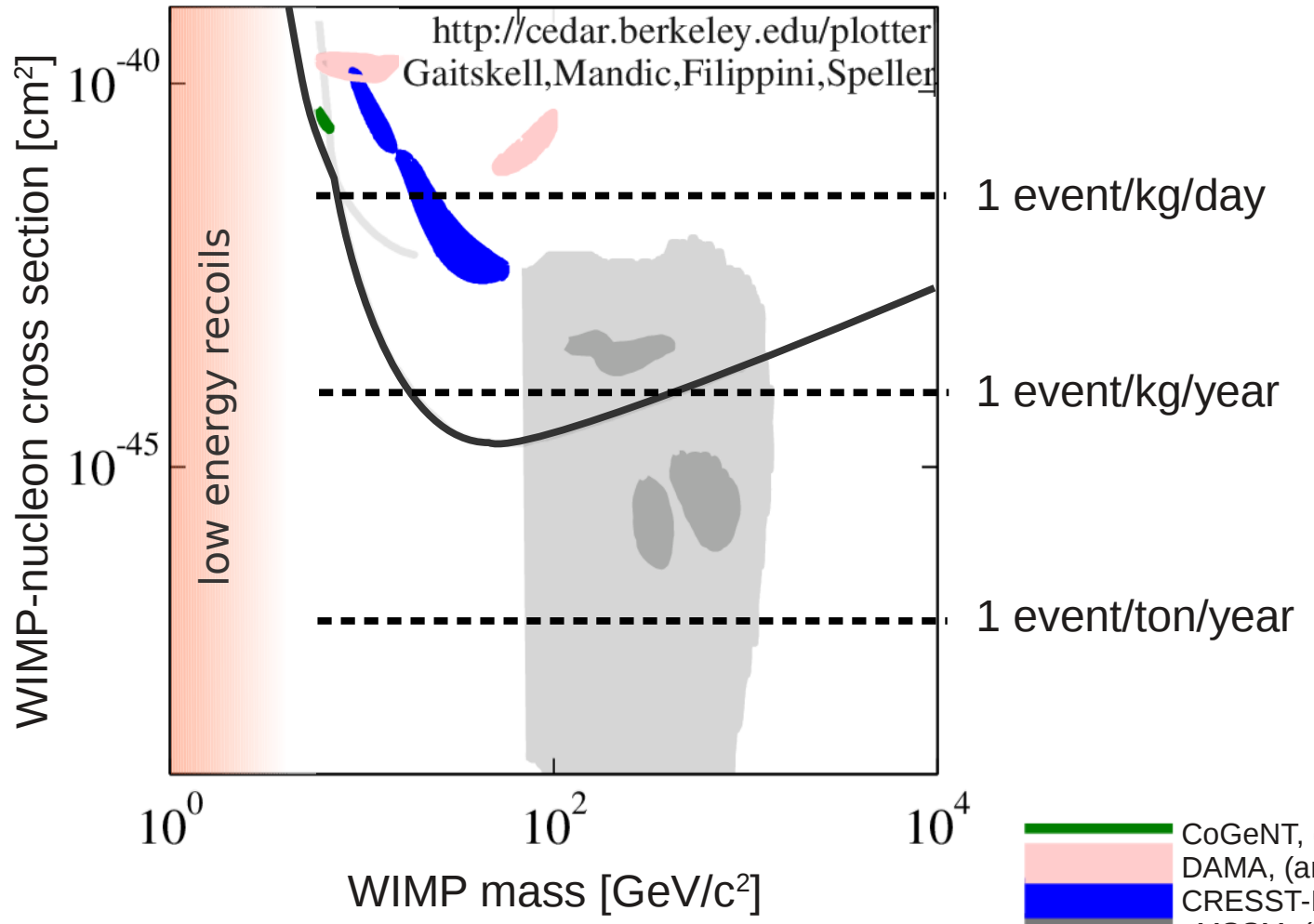
$m_\chi = 10 - 10^4\ GeV/c^2$

$\rho_\chi \sim 0.3\ GeV/c^2/cm^3$

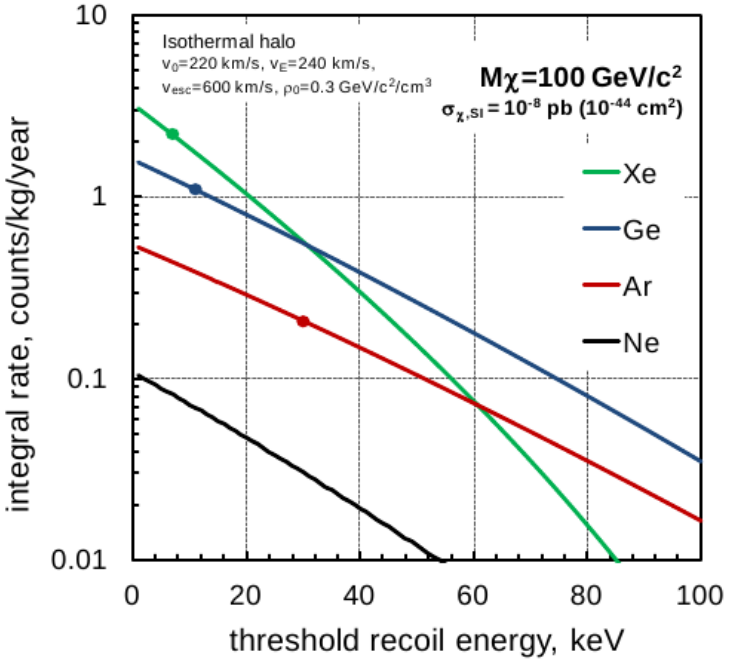
Small recoil energy $$E = \frac{\mu^2 v^2}{m_N}(1 - cos\theta) \lesssim 100keV$$

Small event rate $$\frac{dR}{dE} = \frac{\rho_\chi}{m_\chi}\frac{\sigma|F(E)|^2}{2\mu_p^2}\int_{v_{min(E)}}^{v_{esc}} d^3v \frac{f_\oplus(\vec{v},t)}{v}$$

Hunting WIMPs ...



Noble gases used as target for direct Dark Matter search



	Neon	Argon	Xenon
Atomic number	10	18	54
Atomic mass	20.2	40.0	131.3
Boiling point [K]	27.1	87.3	165.0
Liquid density @ T_b [g/cm^3]	1.21	1.40	2.94
Ionization (W [eV])		23.6	15.6
Scintillation ($W_{ph}^{\alpha,\beta}$ [eV])		27.1, 24.4	17.9, 21.6
Scintillation wavelength [nm]	78	128	178
Abundance [ppm]	18.2	9340	0.09

Argon

Ar

- Large abundance (~1% of air)
  - → modest prices in natural composition
  - → huge detectors feasible
- Relatively compact detectors
  - → exploit self shielding
- Cryogenics at –180°C
- Scalability to larger detectors
- Excellent background discrimination
  - scintillation/ionization
  - pulse shape discrimination (scintillation)

WARP, ArDM, DEAP, CLEAN, DarkSide, . . .

- Small λ = 128nm
  - → need to „shift“ light

→

- Wavelength shifters on PMTs and/or TPC surfaces (e.g. TPB → 420 nm)

- Very high background from ^{39}Ar ($^{39}Ar/^{40}Ar \sim 8 \cdot 10^{-16}$) ($\beta^-$ emitter: Q=565 keV, $t_{1/2}$=269y), ~1 Bq/kg
  - → limitation on detector size
  - → limitation on energy threshold

→

- Use of low-radioactivity Argon:
  - depleted Argon
  - underground gas wells
  - → Concentration <<5% than natural one

Xenon

- No long lived Xe isotopes
- High mass number (A~131)
  → high rates
- High atomic number (Z=54) and density (ρ~3kg/l)
  → compact detectors
  → self shielding
- 50% non-zero spin isotopes
- Cryogenics at –100°C
  → relatively easy to handle
- Scalability to larger detectors
- Good background discrimination
  - scintillation/ionization

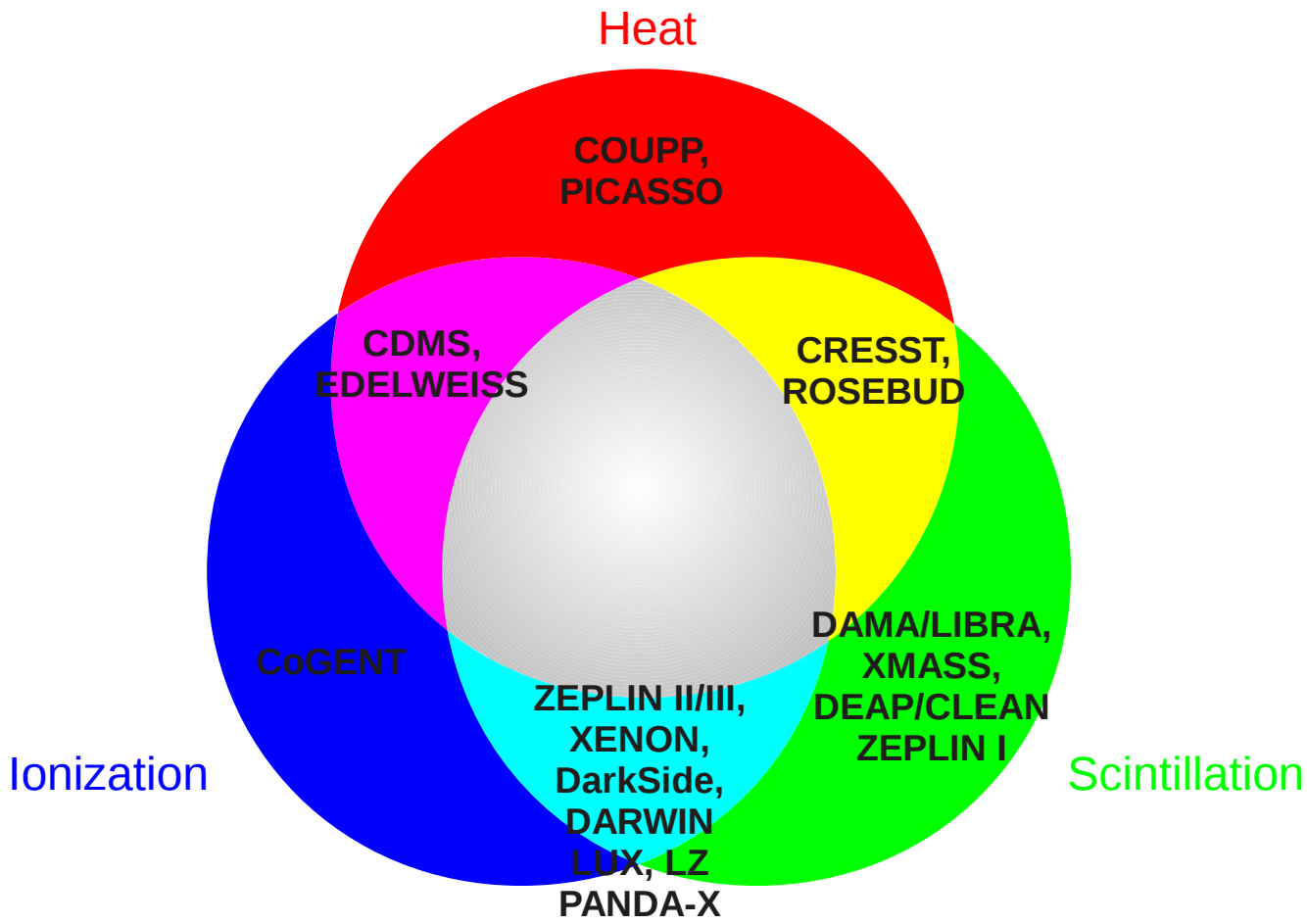
- Pulse shaping discrimination not used
  → τ = O(1) - O(10) ns

- Quite expensive

ZEPLIN, XENON, PandaX, XMASS, LUX, . . .

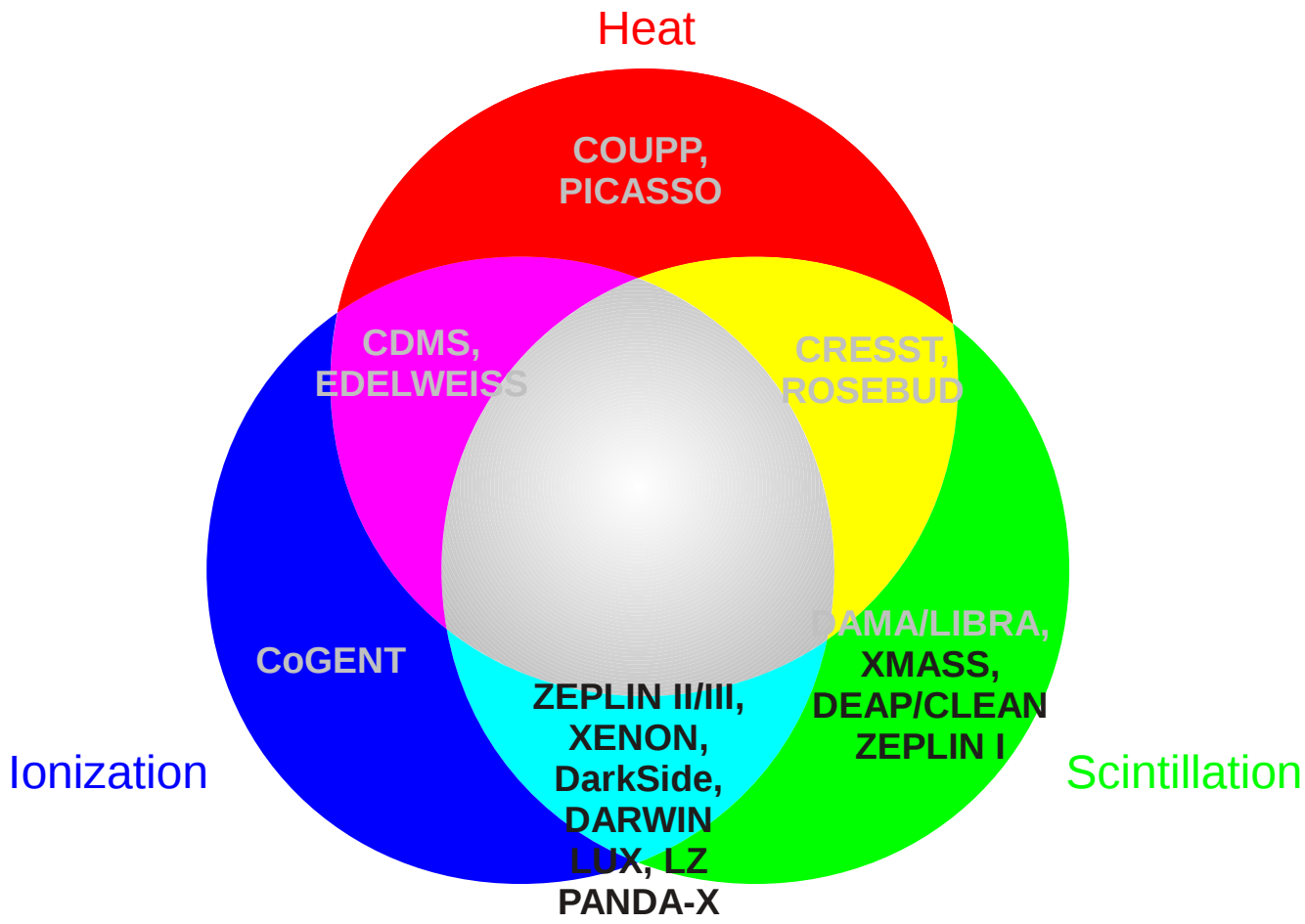
Energy recoil detection

Energy recoil is transferred to three possible phenomena: **scintillation**, **ionization**, **heat**
One or two among these three signals are used for particle detection.



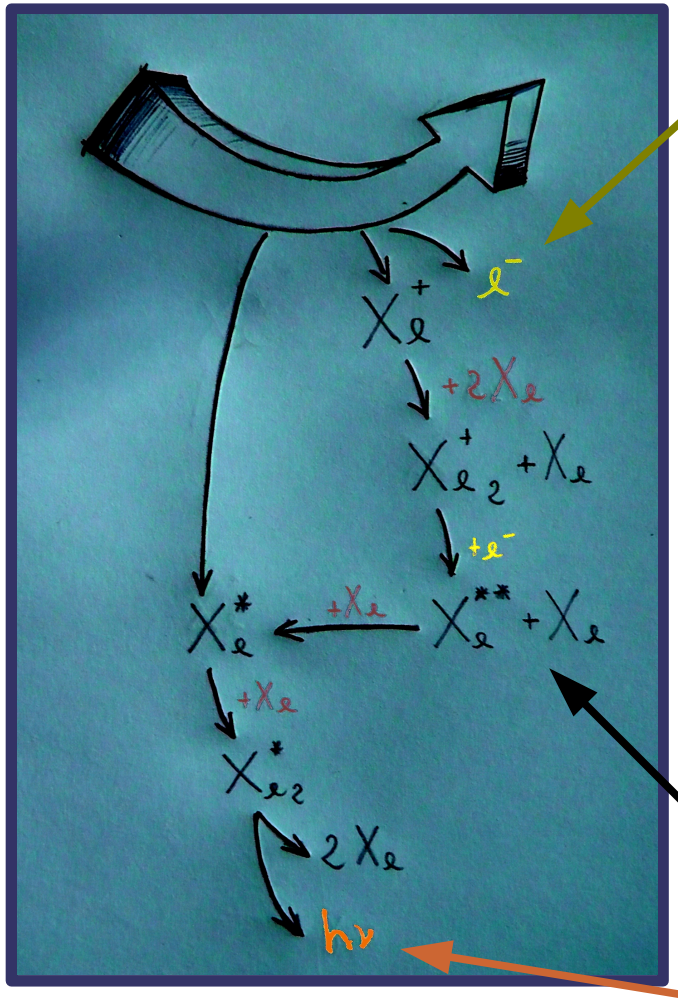
Neon, Xenon and Argon based detectors

Energy recoil is transferred to three possible phenomena: **scintillation**, **ionization**, **heat**
One or two among these three signals are used for particle detection.
This talk will focus only on detectors using Ne, Xe, Ar

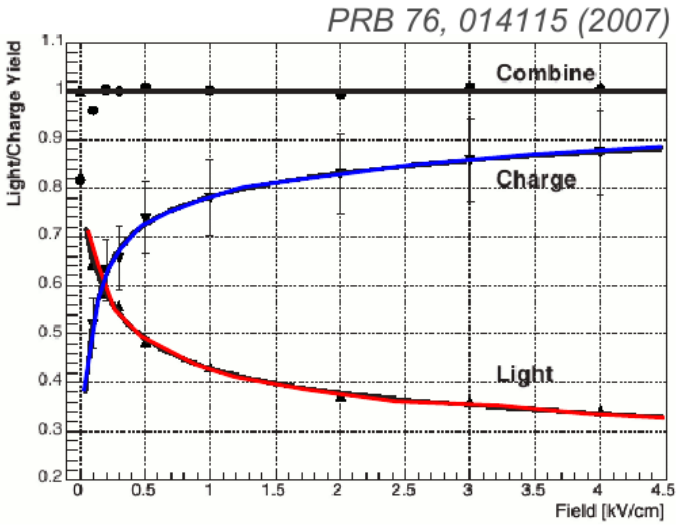


Focusing on scintillation and ionization

Argon and xenon : similar mechanism

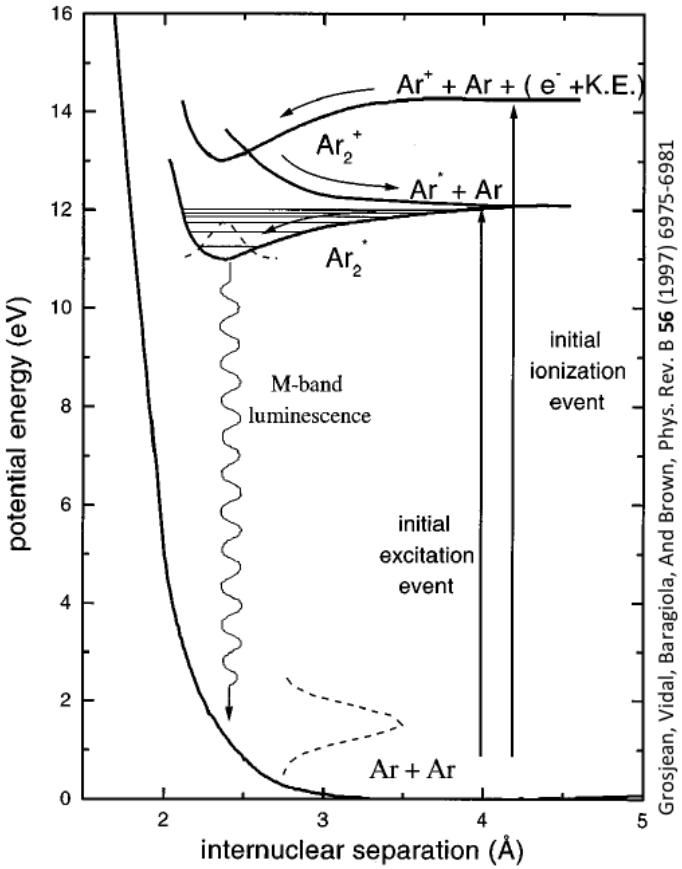


Extracted with an E field



Recombination, absent at high fields (few kV/cm)

VUV



Response depends on particle type and energy!

The nuclear recoil energy scale

The energy deposit of a nuclear recoil is usually computed through the expression:

Detected scintillation signal

$$E_{nr} = \frac{S1}{L_{eff} \cdot Y_{er}} \cdot \frac{S_{er}}{S_{nr}}$$

Field quenching corrections

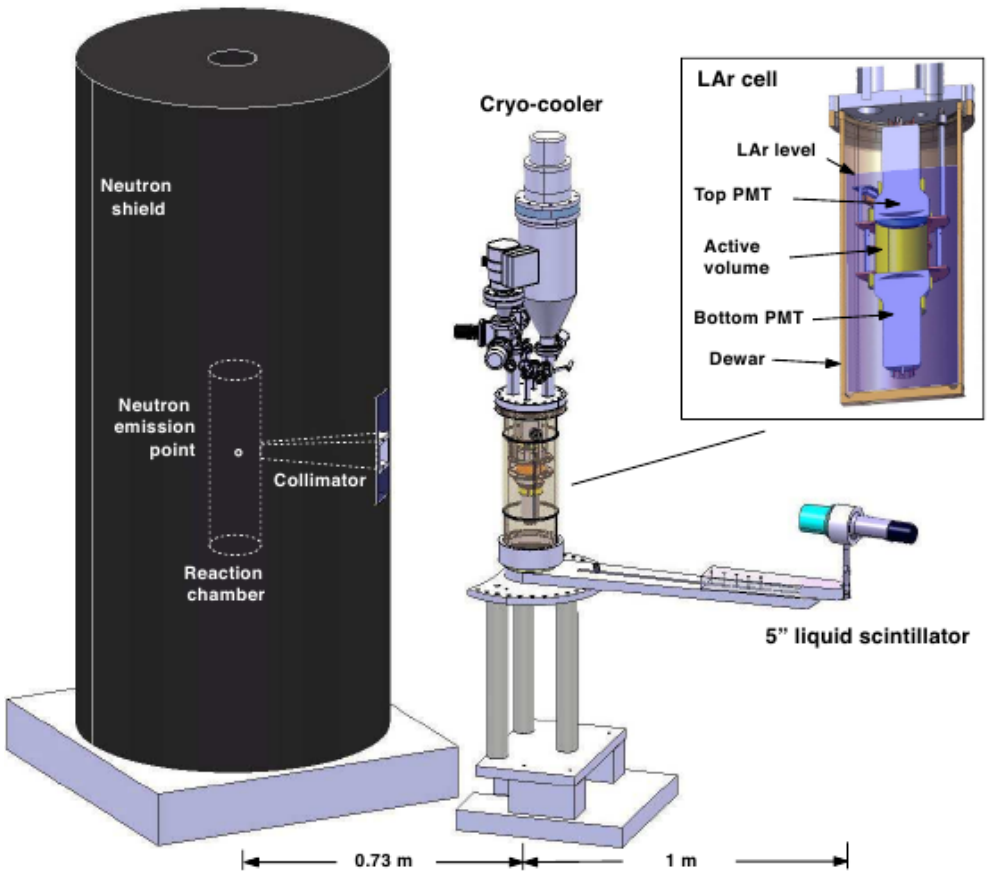
Measured light yield for a reference γ-ray line (detector dependent)
Usually reference is the 122 keV gamma from ^{57}Co

$$L_{eff}(E_{nr}) = \frac{S1/E_{nr}}{Y_{er}} \cdot \frac{S_{er}}{S_{nr}} \longrightarrow \frac{Y_{nr}(E_{nr})}{Y_{er}(E_{ee} = 122\ keV)}$$

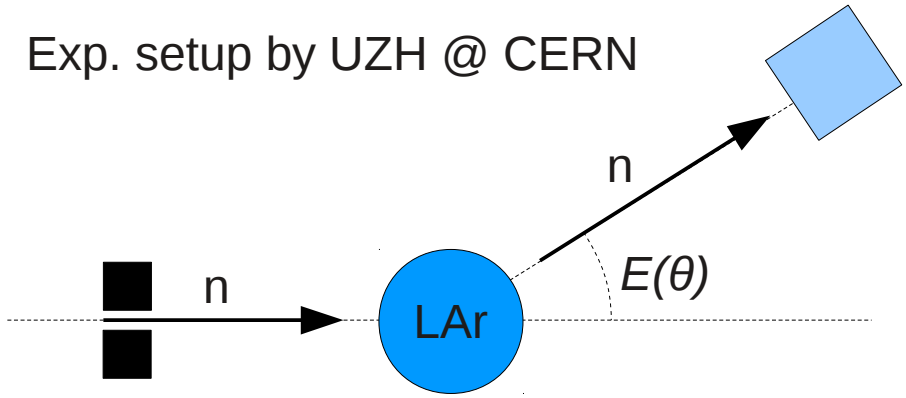
L_{eff} is the ratio of the scintillation yield for a nuclear recoil of given energy E_{nr} and the scintillation yield of an electronic recoil of 122 keV at 0 field

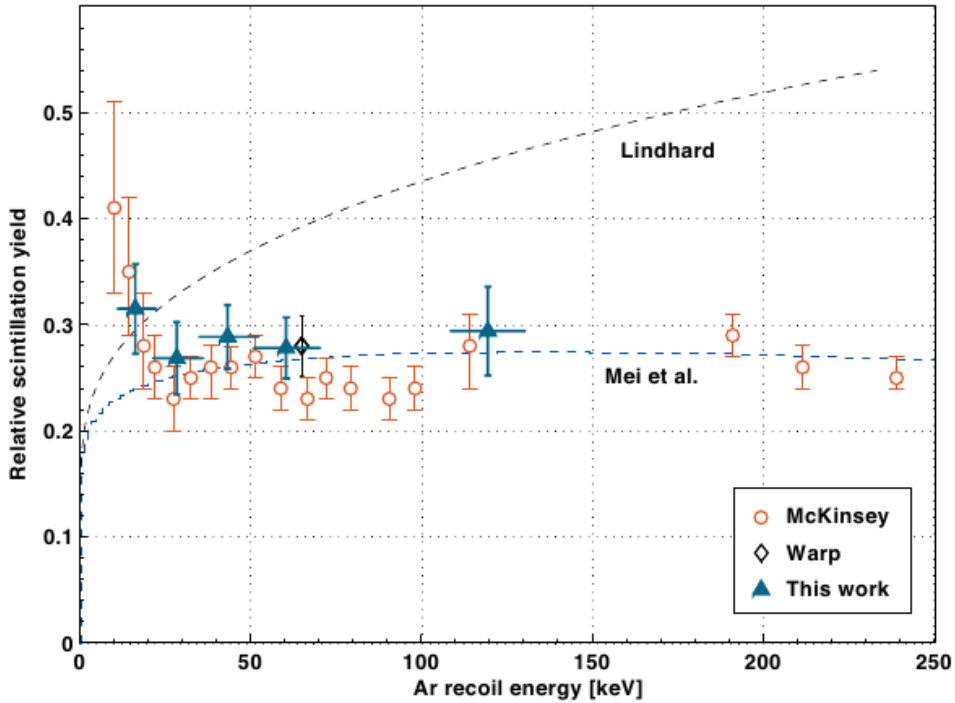
It is a property of target material, it does NOT depend on the detector !

L_{eff} in Argon



Exp. setup by UZH @ CERN

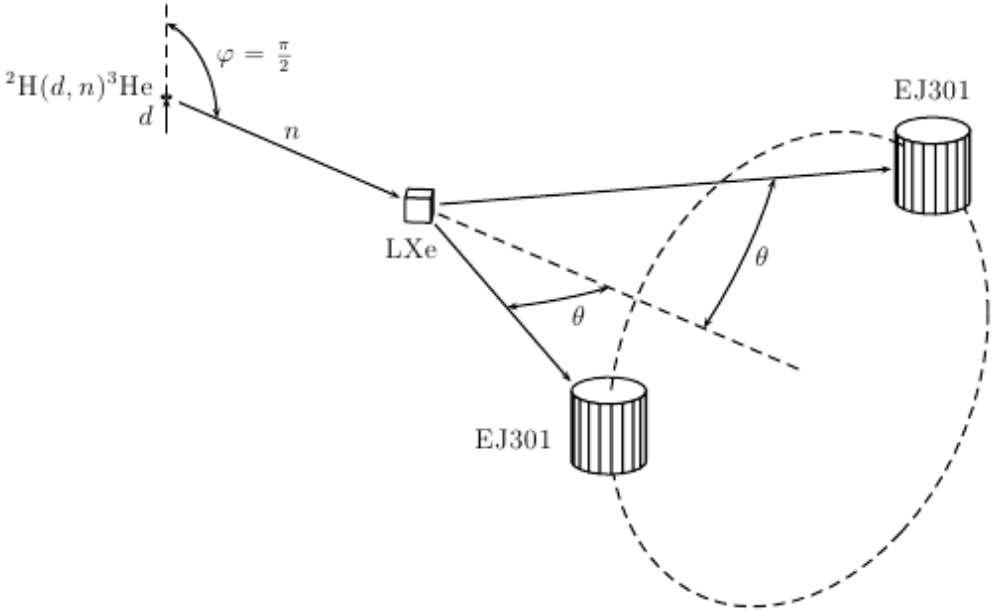




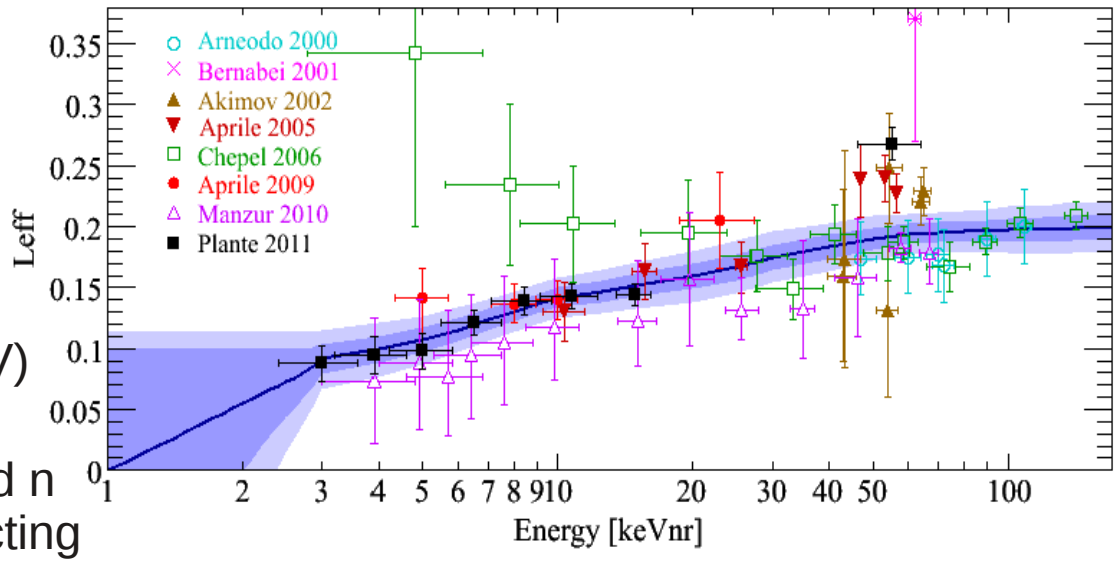
- dd fusion neutron generator (E_n = 2.45 MeV)
- LAr cell as active target
- Organic liquid scintillator to detect scattered n

Regenfus et al, J.Phys.Conf.Ser. 375 (2012) 012019, arXiv:1203.0849

L_{eff} in Xenon



Exp. setup at Columbia University



- dd fusion neutron generator (E_n = 2.45 MeV)
- LXe cell as active target
- Organic liquid scintillator to detect scattered n
- TOF cut to select only neutrons non interacting in the detector materials

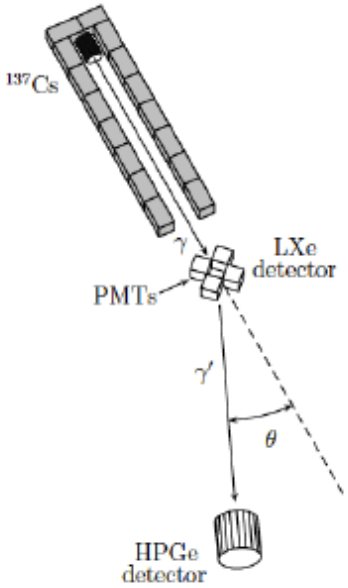
Plante et al, Phys.Rev. C84 (2011) 045805, arXiv:1104.2587

The electron recoil energy scale in xenon

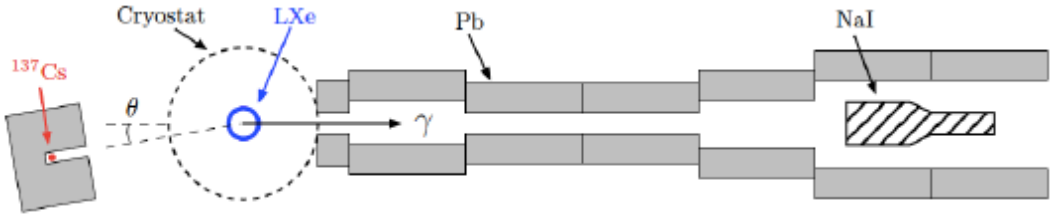
- Knowledge of the response of LXe to low energy ER is extremely important
- ^{83m}Kr provides 32.1 and 9.4 keV lines; but this is still “high” energy (DAMA annual modulation signal is in the 2-6 keV energy window)

Recent measurements using the “Compton coincidence” technique

$$E_{\mathrm{er}} = E_\gamma - E'_\gamma = E_\gamma - \frac{E_\gamma}{1 + \frac{E_\gamma}{m_e c^2}(1 - \cos\theta)}$$



Columbia : *Aprile et al., Phys. Rev. D 86, 112004 (2012)*

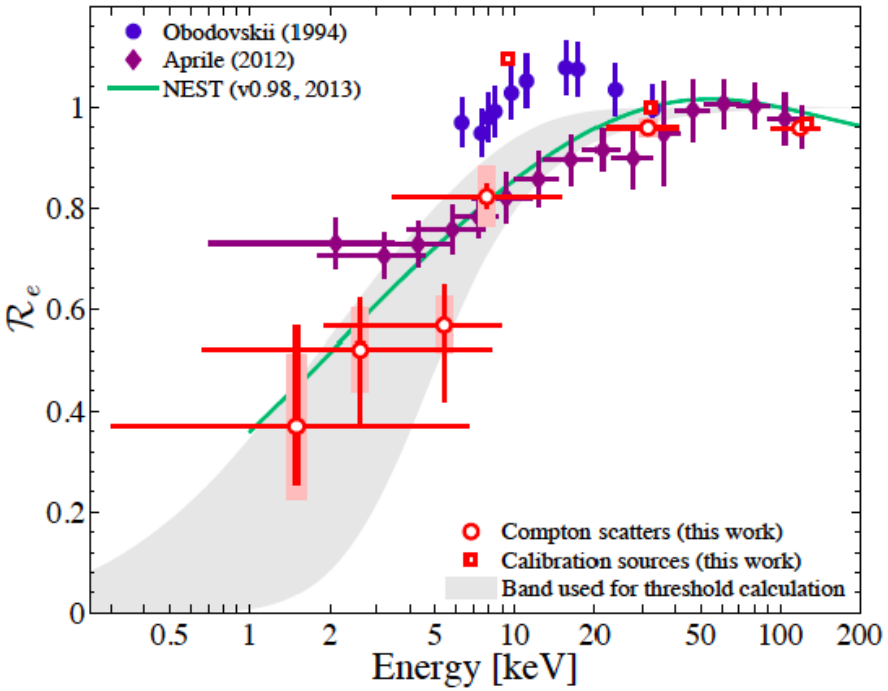


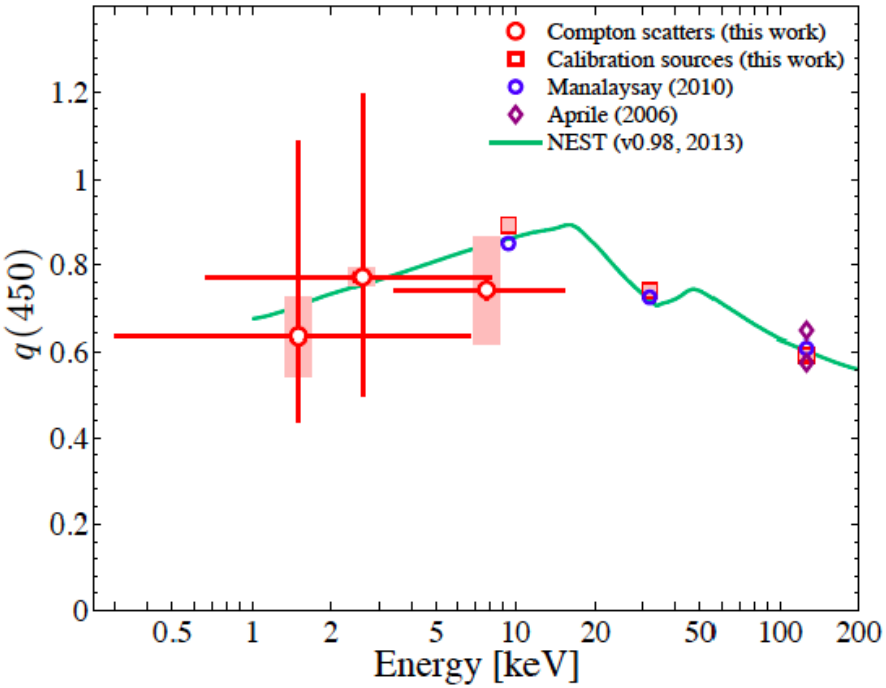
Zurich : *Baudis et al., Phys. Rev. D 87, 11501 (2013)*
Including field quenching

The electron recoil energy scale in xenon

Results of the measurements

Baudis et al., Phys. Rev. D 87, 11501 (2013)



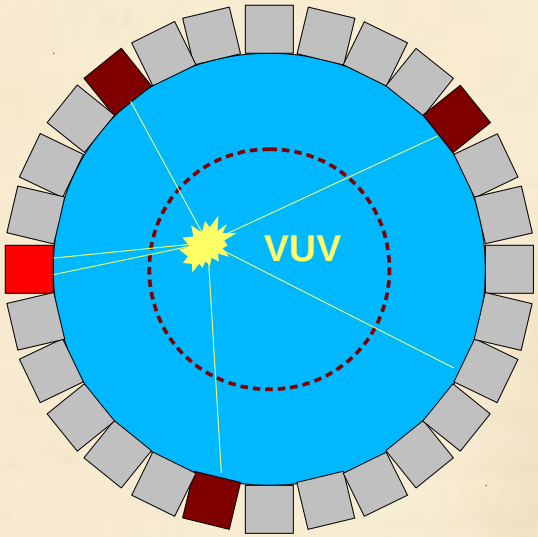


Light yield decreases at 0-field below 50 keV

- Field quenching ~ 75% at low energies
- Derived XENON100 energy threshold: 2.3 keV
  → sensitive to DAMA signal! Results coming soon

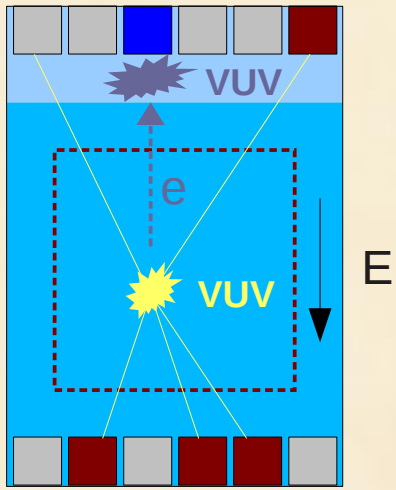
Detecting WIMPs : single-phase vs. double-phase

Single-phase detector



DEAP-3600 (3.6ton LAr)
MiniCLEAN (360kg LAr / 310kg LNe)
XMASS (835kg LXe)
ZEPLIN I (3.1kg LXe)

Dual-phase detector (TPC)



ArDM (1ton LAr)
DarkSide-50 (50kg LAr)
LUX (350kg LXe)
PANDA-X (1ton LXe)
XENON (14kg, 62kg, 2ton, … LXe)
ZEPLIN II/III (31kg, 6kg LXe)

Background sources

Neutrons :

(Th,U chains assumed in secular equilibrium)

- (α,n) reactions through Th, U chains

Source → site (surrounding rock), detector components
Estimations → More complex: material-dependent cross-section of (α,n) reactions and branching ratios for transitions to excited states. To be calculated for each relevant material in the detector

- Spontaneous U fission (mostly ^{238}U)
- Induced by cosmic rays muons

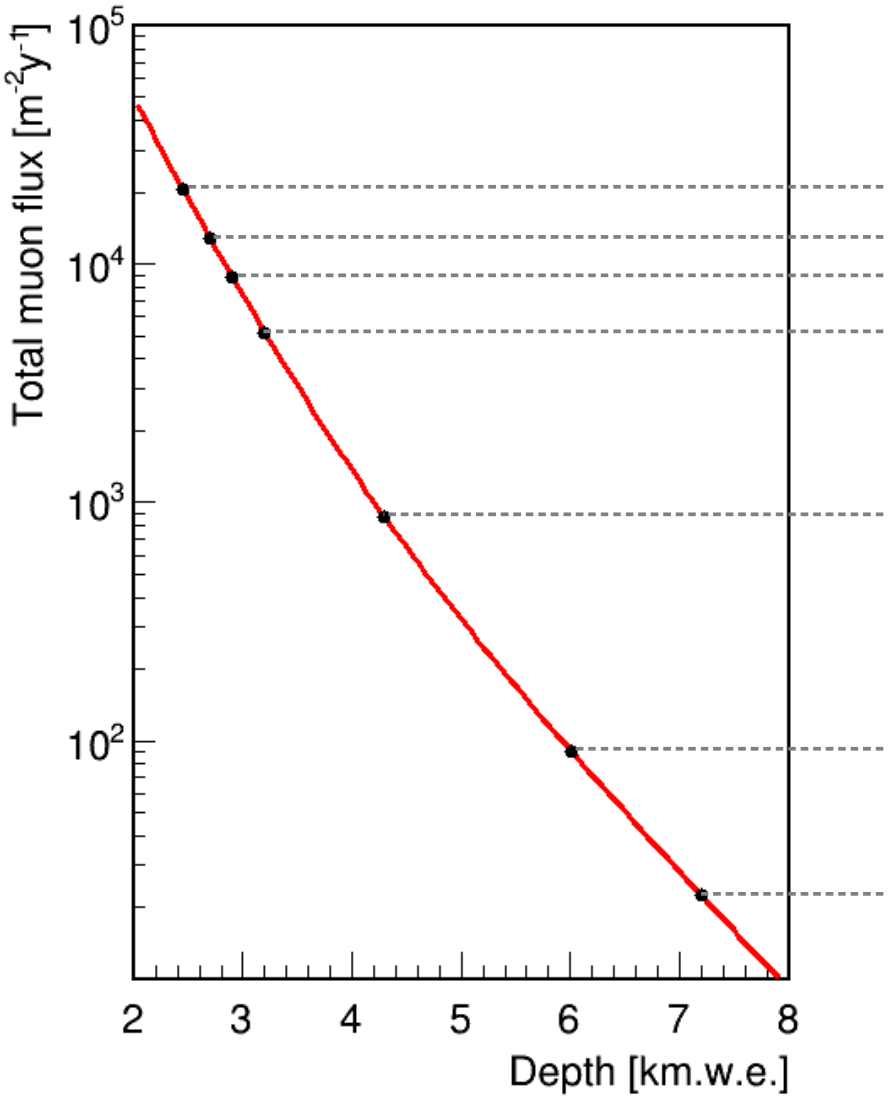
Gamma and beta :

- ^{238}U, ^{235}U, ^{232}Th chains and ^{40}K, ^{60}Co
- “intrinsic bg” (i.e. diluted in the target): ^{85}Kr, ^{39}Ar, Rn

Physical backgrounds :

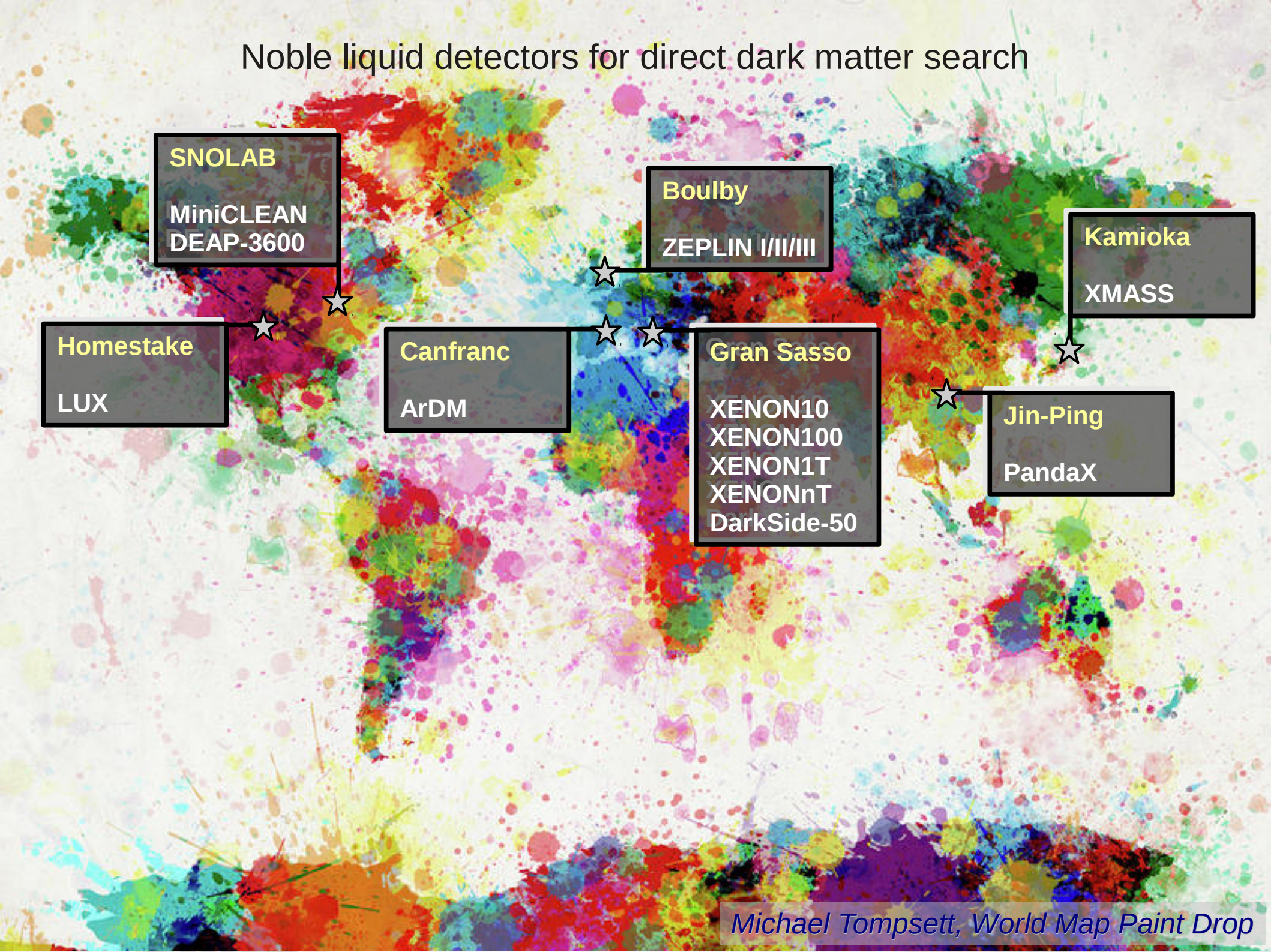
- Solar neutrinos
- ^{136}Xe 2νββ decay

Background suppression : natural shielding



Canfranc, Spain (tunnel) : ArDM
Kamioka, Japan (mine) : XMASS
Boulby, UK (mine) : ZEPLIN I/II/III
Gran Sasso, Italy (tunnel) : XENON10/100/1T/nT, DarkSide
Homestake, USA (mine) : LUX
SNOLAB, Canada (mine) : MiniCLEAN, DEAP-3600
Jin-Ping, China (tunnel) : PandaX

Noble liquid detectors for direct dark matter search



Background suppression : detector design

Goal: avoiding background particles entering in the fiducial volume of the detector

Use of radiopure materials :

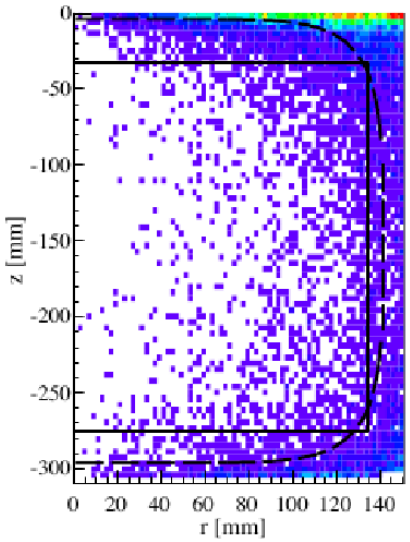
- Screening of all detector components close to the active region

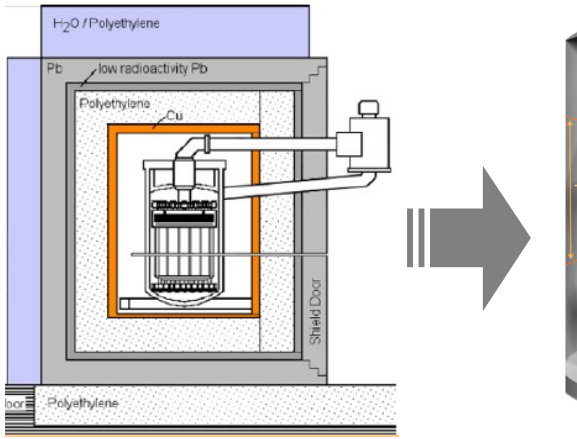
Shielding :

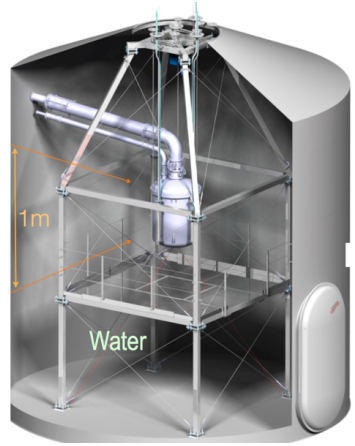
- Large shield (Pb, water, plastics)
- Water / liquid scintillator tanks very important for large scale detectors (~>1 ton)
  → Water: passive or used as an active veto for muons with PMTs (Cherenkov light)

Self-shielding :

- Active veto
- Fiducial volume cuts







Example: from XENON100 to XENON1T

Background suppression : signal analysis

Goal: using knowledge about the expected WIMP signal

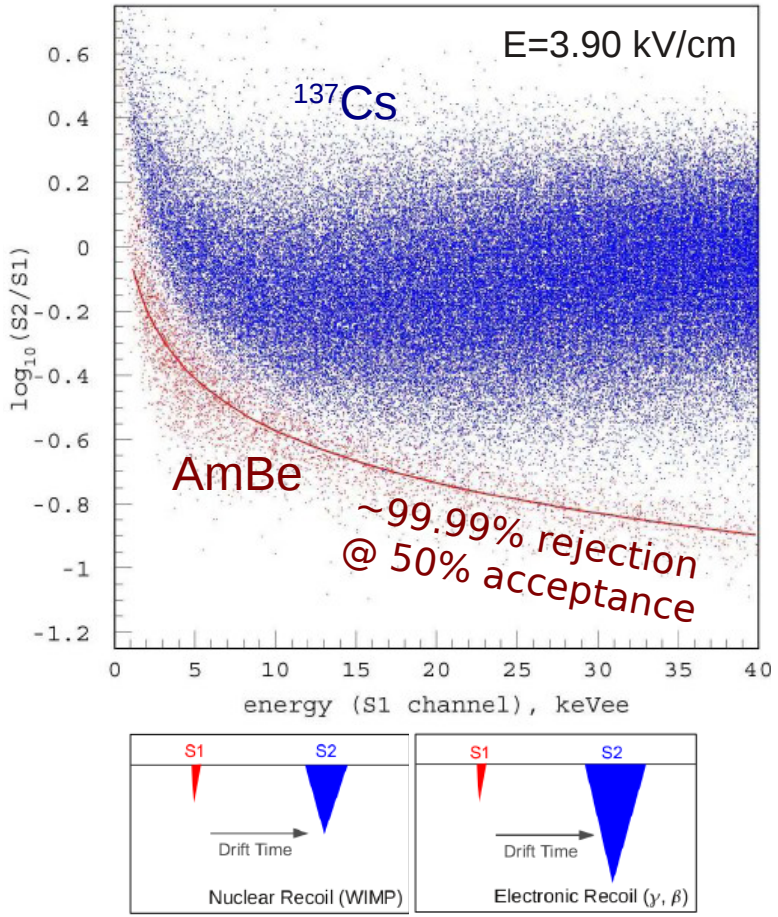
Very low WIMP-nucleus cross section :

- Single scatter process → 3D reconstruction ability

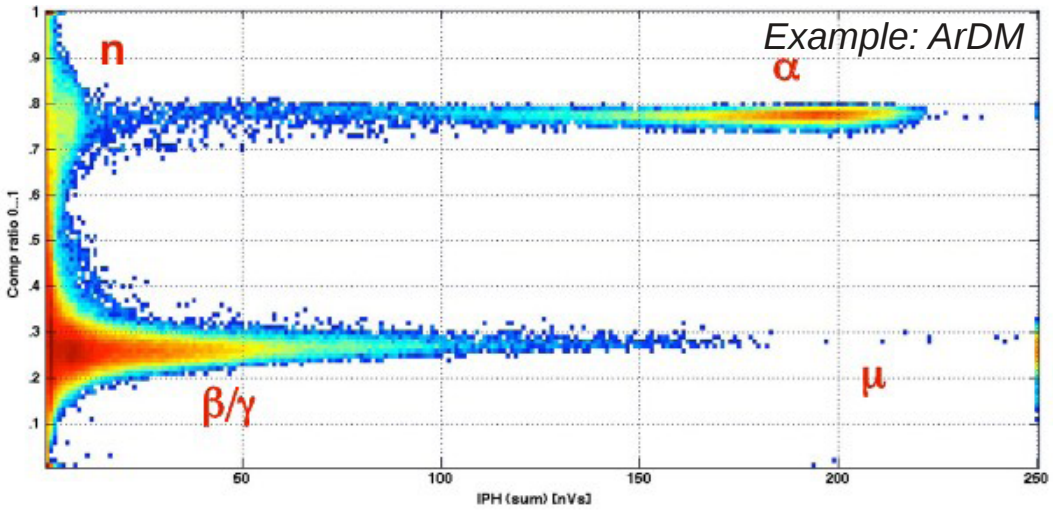
WIMPs interact with target nuclei :

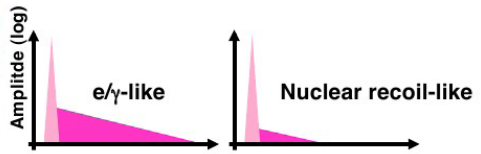
- Nuclear recoil vs. electron recoil
  - → Ionization/scintillation ratio
  - → Pulse Shape Discrimination on scintillation process (strong discriminations (~10^{-8}) with Argon)

Example: ZEPLIN-III, PRD 80, 052010 (2009)



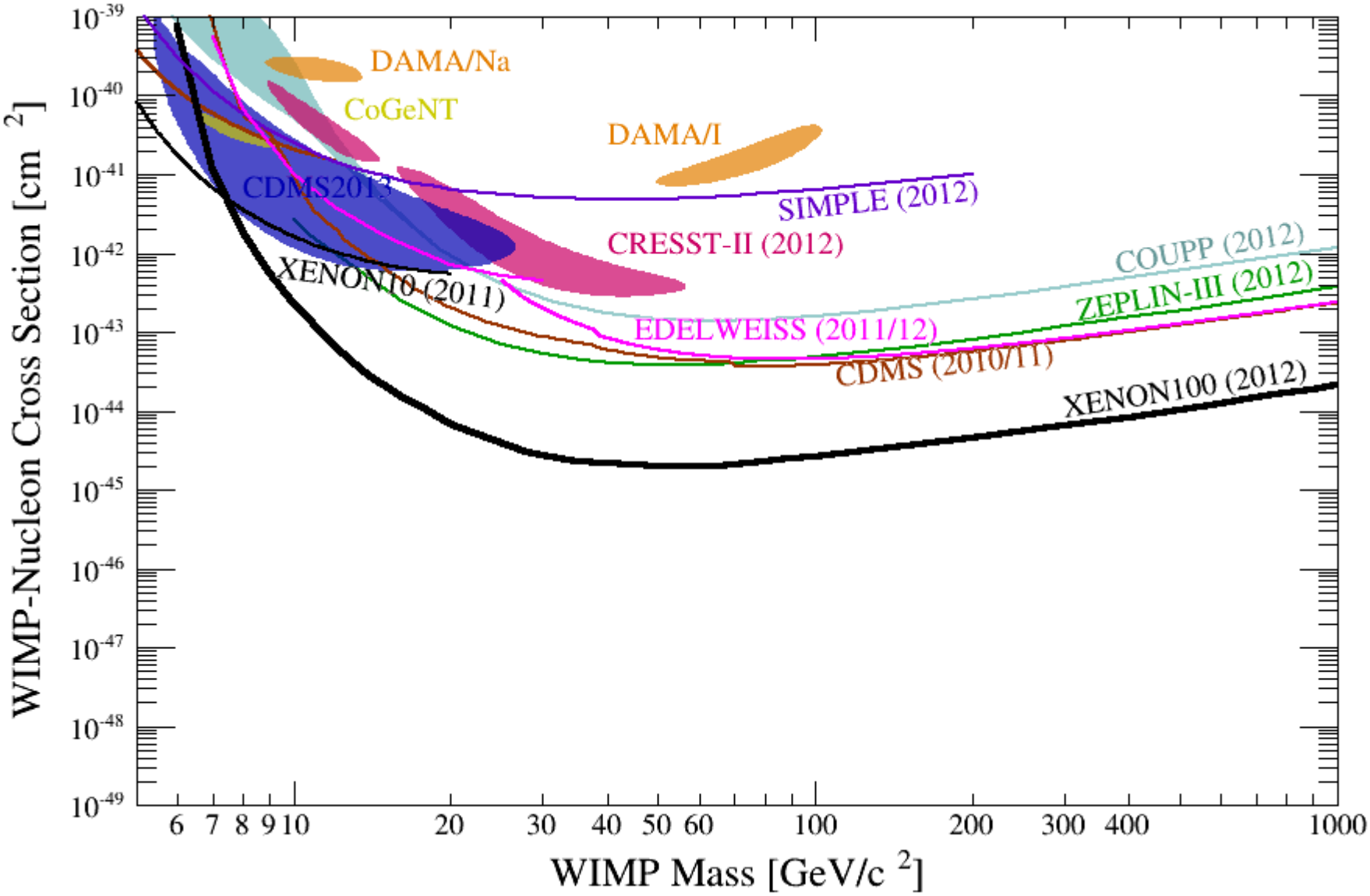
Example: ArDM





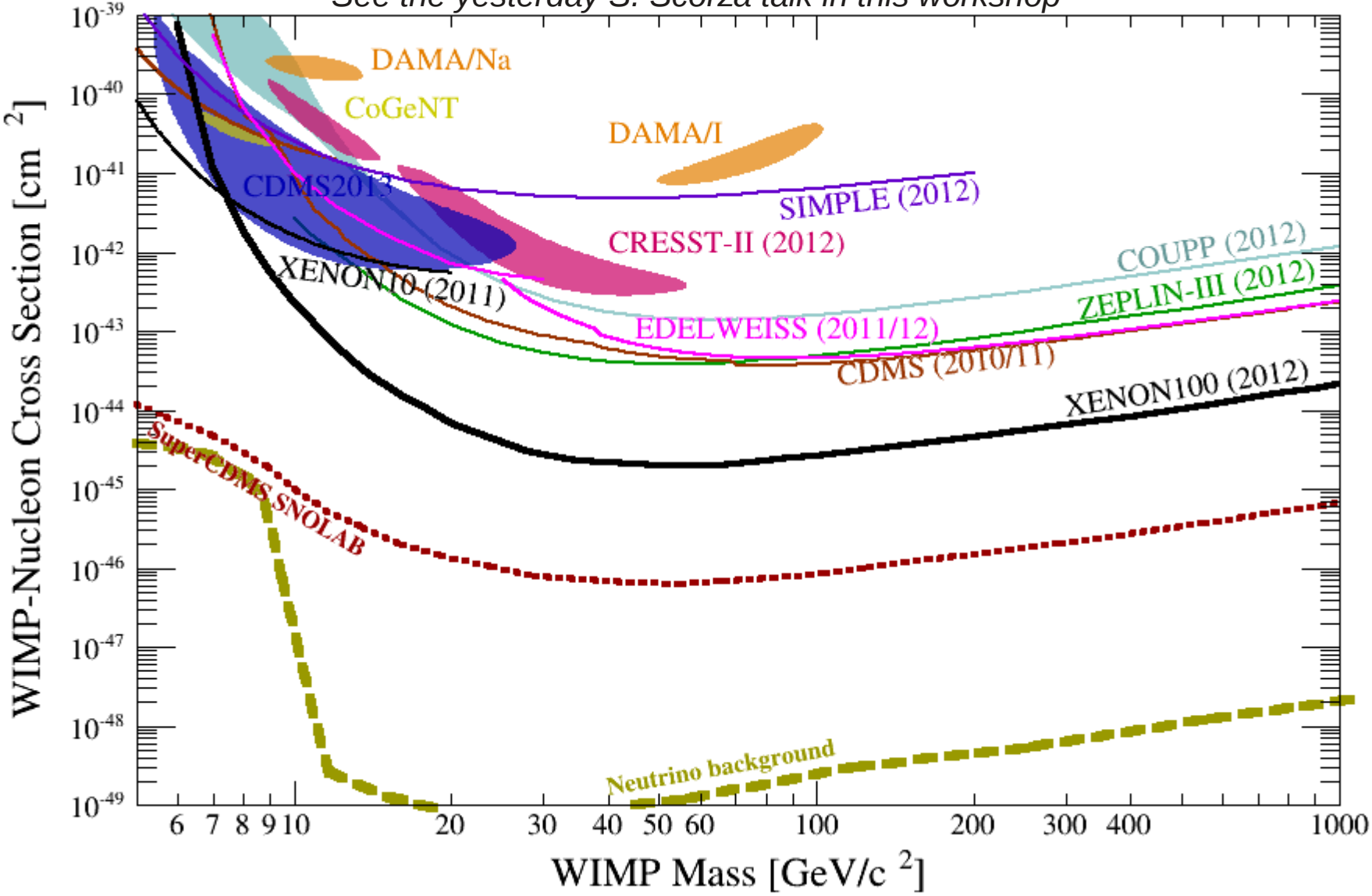
Update on current detectors

WIMP hunting : the current WIMP hints and exclusion limits



WIMP hunting : adding neutrino bg limit and some reference

See the yesterday S. Scorza talk in this workshop



XENON100

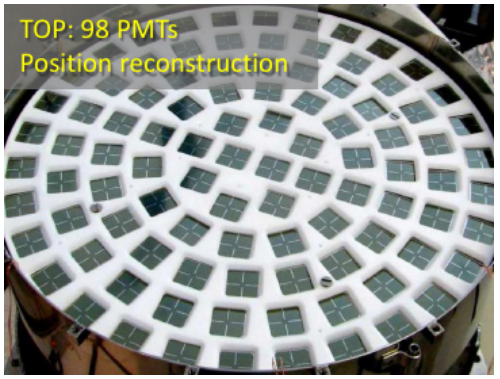
Detector :
Dual phase TPC
Target : 62 kg LXe in TPC (161 kg total)

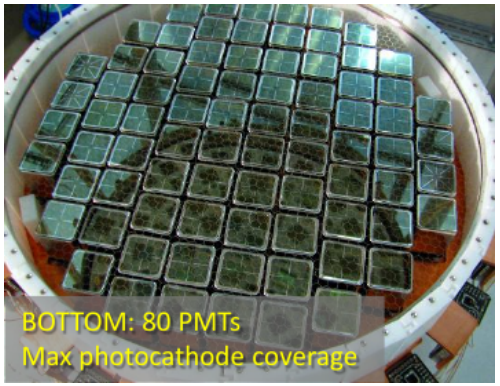
PMTs :
242 PMTs (low radioactivity <10 mBq/PMT)
Hamamatsu R8520-06-Al 1"x1"
QE > 30% @178 nm

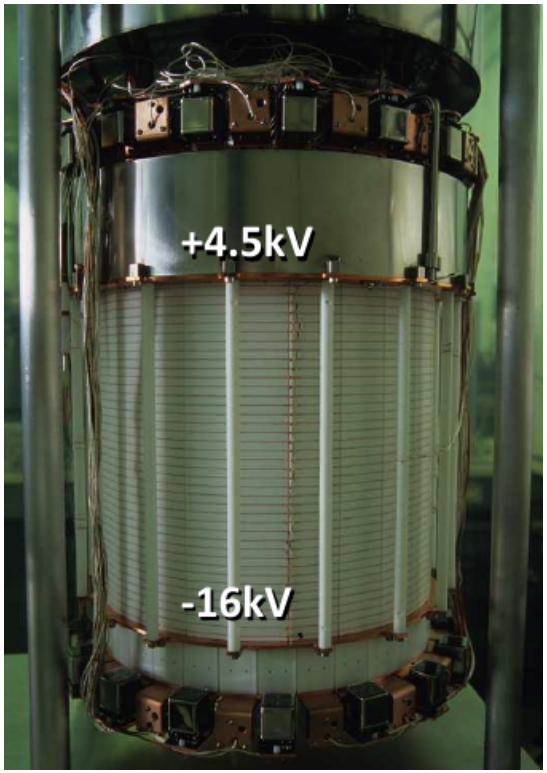
Electric fields :
Drift = 0.533 kV/cm
Extraction = 12 kV/cm (100% extraction)

Shielding :
Passive and active (LXe veto)

E. Aprile et al. (XENON100), Astropart. Phys. 35, 573 (2012)







Recent physics runs :

Run 8 : 100 live days (took in 2010)
E. Aprile et al. (XENON100), Phys. Rev. Lett. 107, 131302 (2011)

Run 10 : 225 live days (took in 2011-2012)
E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

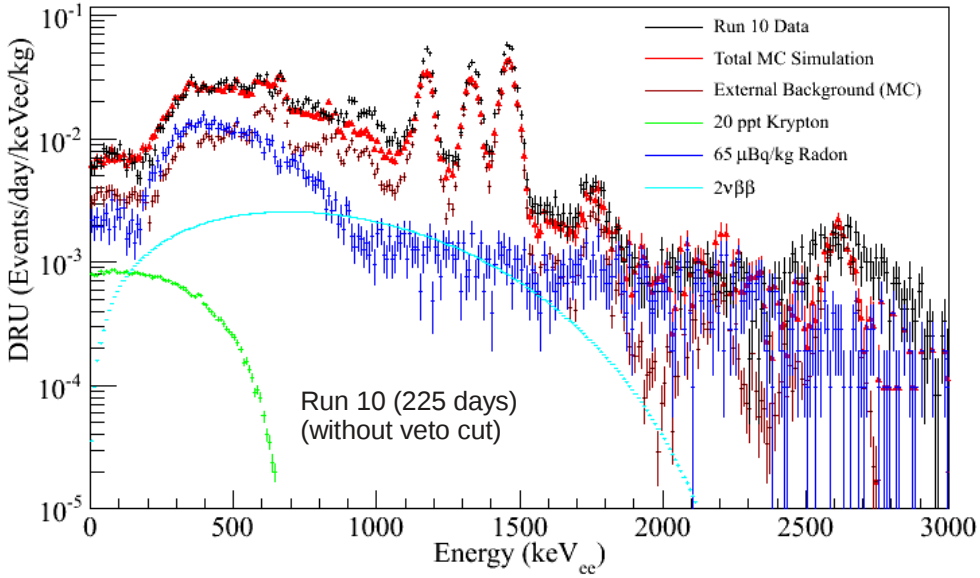
Still running! (run 12, collected already >90 live days)

XENON100 : background

Electromagnetic background

E. Aprile et al. (XENON100), Phys. Rev. D 83, 082001 (2011)
E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

- Krypton: reduced by cryogenic distillation at 19±4 ppt
- Excellent data/MC agreement in the full energy range
- Activity taken from screening measurements only
  (No MC rate tuning!)
- Lowest BG ever achieved in DM experiments
- BG expectation for run 10 : 0.79 ± 0.16 events
- Main source of background

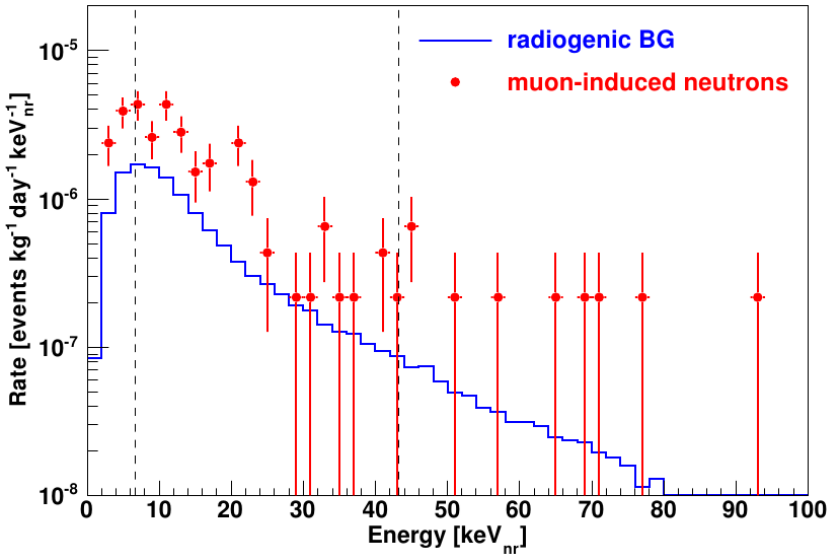


Total background for run 10 : 1.0±0.2 events

Nuclear recoil background

E. Aprile et al. (XENON100), J. Phys. G: Nucl. Part. Phys. 40 (2013) 115201

- BG prediction based on MC simulations with exact geometry and measured radioactive contaminations of all the detector components
- Expectation for run 10 : 0.17 $^{+0.12}_{-0.07}$ events
- Not limiting the sensitivity of the experiment



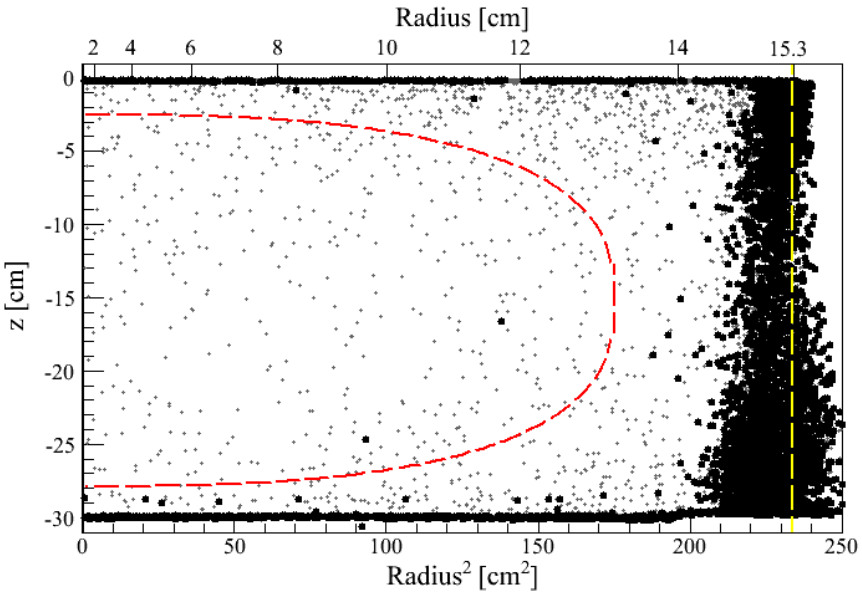
XENON100 : latest results

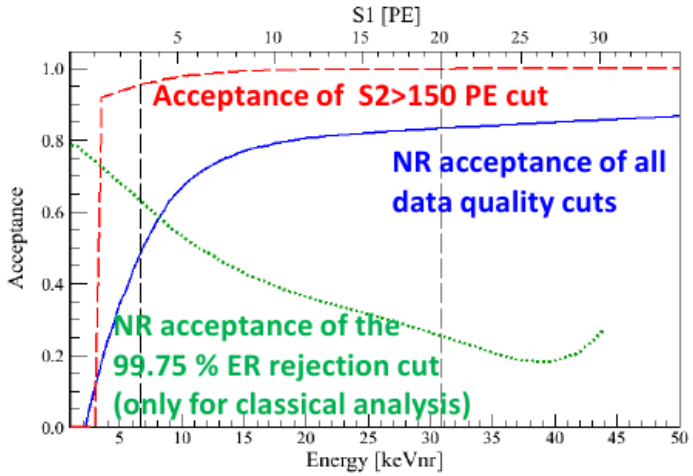
Analysis of latest published data

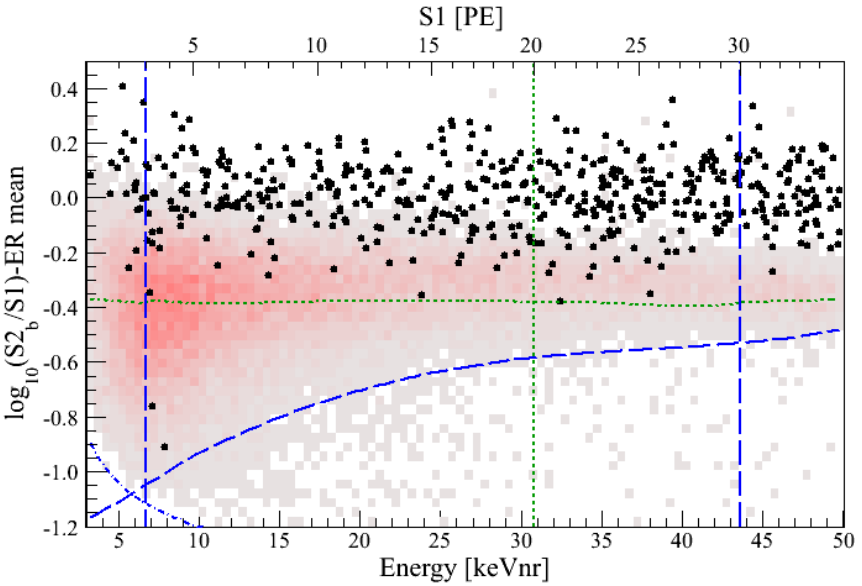
E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

- run 10
- 224.6 live days
- 34 kg fiducial volume
- Data blinded in WIMP region of interest
- Analysis fixed before data unblinding
- 2 candidates found (7.1 and 7.8 keV_{nr}) in the predefined benchmark region where 1.0±0.2 events were expected
- 26.4% Poisson probability that background oscillated to 2 events
- PL analysis does not reject the background only hypothesis
  - → No evidence of dark matter in the data
  - → Calculate upper limit with Profile Likelihood method

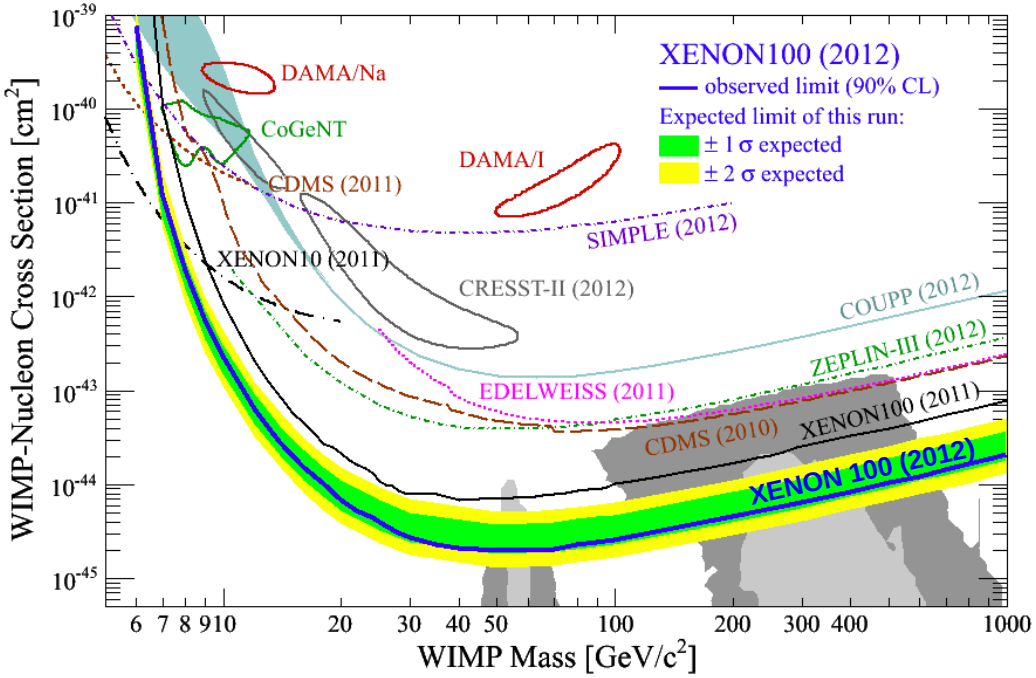
  (E. Aprile et al. (XENON100), Phys. Rev. D 84, 052003 (2011))







XENON100 : Spin-Independent cross section



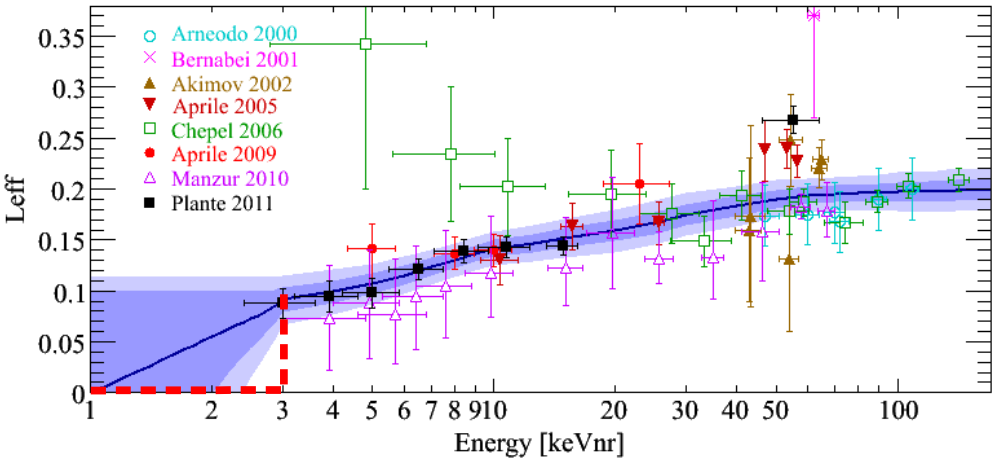
Spin-independent cross section

E. Aprile et al. (XENON100), Phys. Rev. Lett. 109, 181301 (2012)

- World's most sensitive limit over a large WIMP mass range : $\sigma_{SI} < 2.0 \times 10^{-45}$ cm² @ 55GeV/c² 90% CL
- It excludes part of the predicted region for SUSY candidates and other signal indications above (CoGeNT, DAMA, CRESST-II)

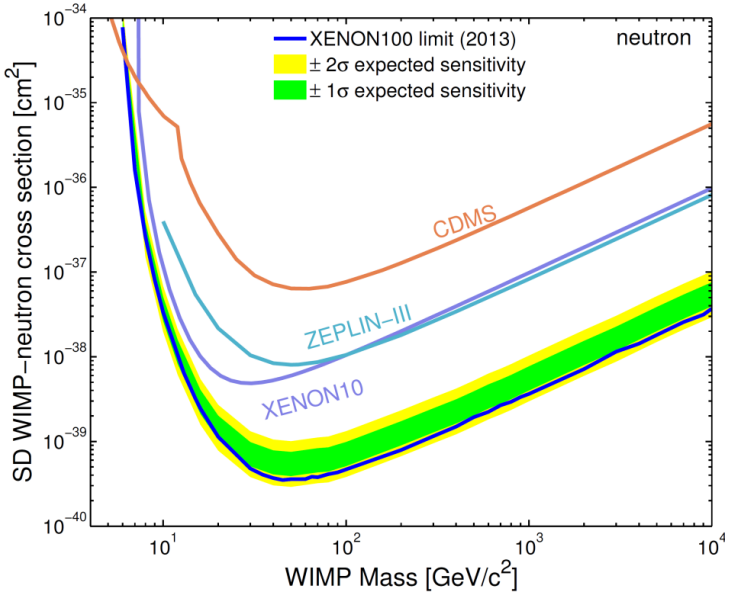
Theory region combined from:
Strege et al., JCAP 1203, 030(2012)
Fowlie et al., arXiv:1206.0264
Buchmueller et al., arXiv:1112.3564

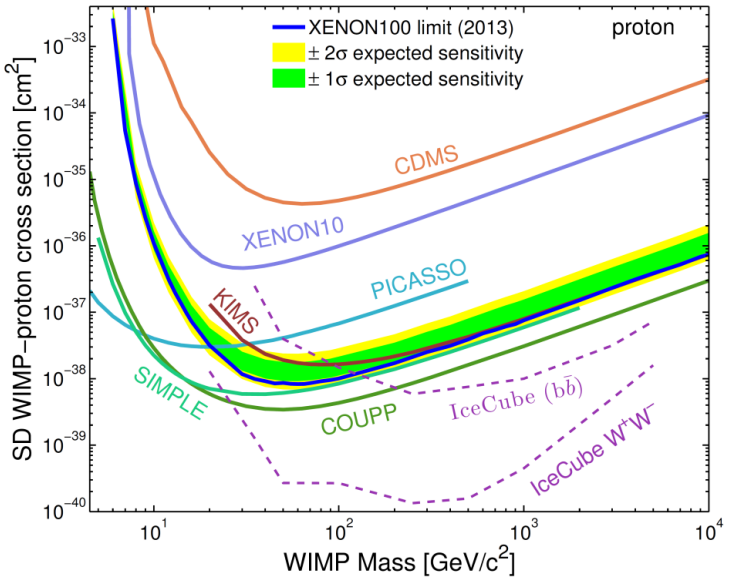
v_0 = 220 km/s v_{esc} = 544 km/s ρ_0 = 0.3 GeV/cm³



- L_{eff} global fit of available data
- Blue band represents uncertainties
- Logarithmic extrapolation below 3keV$_{nr}$ to L_{eff} = 0 at 1keV$_{nr}$ (including large uncertainty)
- Result fluctuates by just 5% if we use the strong assumption that L_{eff} = 0 at E < 3keV$_{nr}$ (dashed red line)

XENON100 : Spin-Dependent cross section





Spin-independent cross section

E. Aprile et al. (XENON100), Phys. Rev. Lett. 111, 021301 (2013)

- Isotopes with a non-zero nuclear spin:
  → 26.2% of ^{129}Xe ($J^\pi = 1/2^+$) and 21.8% of ^{131}Xe ($J^\pi = 3/2^+$)
- Set limit on pure WIMP-neutron and pure WIMP-proton cross sections
- Same data and event selection as the SI search
- Nuclear model used: *Menendez et al., Phys. Rev. D86, 103511 (2012)*

- Most sensitive limit on pure neutron coupling above 6 GeV/c^2
  → $\sigma_n < 3.5 \times 10^{-40}$ cm^2 @ 45GeV/c^2 90% CL

- Competitive limit on pure proton coupling
  → weaker sensitivity because ^{129}Xe and ^{131}Xe have an unpaired neutron but even number of protons

XENON100 : Control on systematics with AmBe data

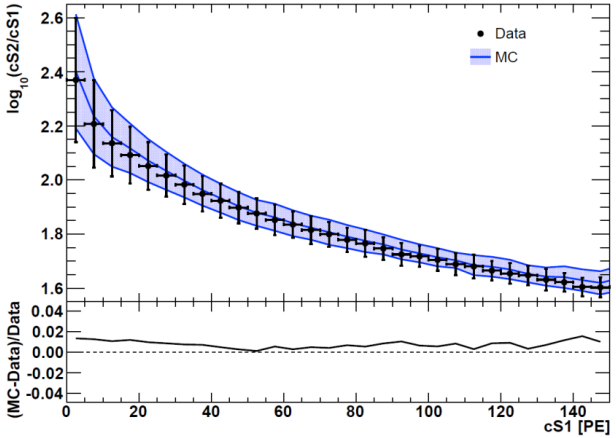
Response of the XENON100 dark matter detector to nuclear recoils

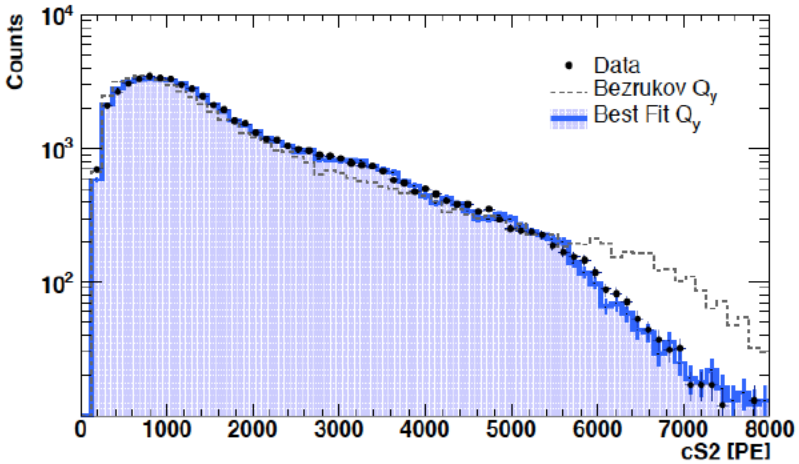
E. Aprile et al. (XENON100), Phys. Rev. D 88, 012006 (2013)

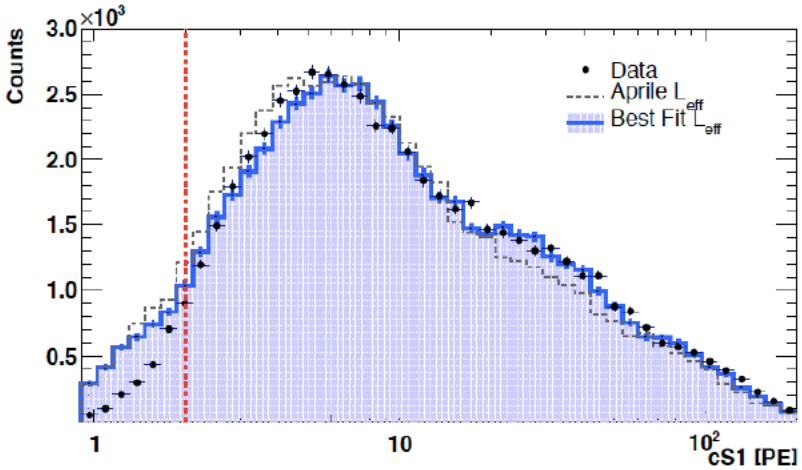
Analysis principle :

- AmBe spectrum with strength of (160±4) n/s measured by PTB in Germany
- Convert the deposited energy to S1 (scintillation) and S2 (ionization) signal using L_{eff}, Q_y, thresholds, resolutions and acceptances from data

→ Reproduces both spectra and 2D parameter space







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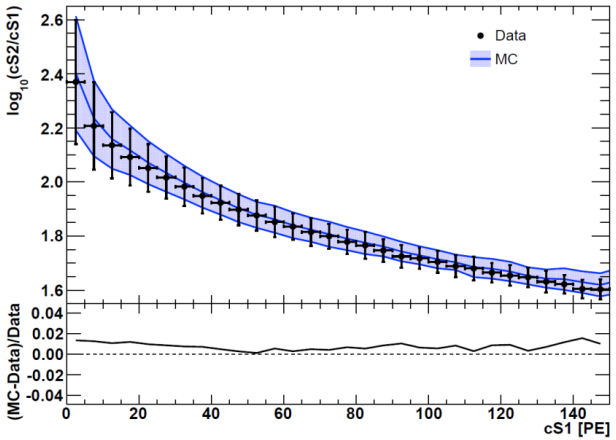
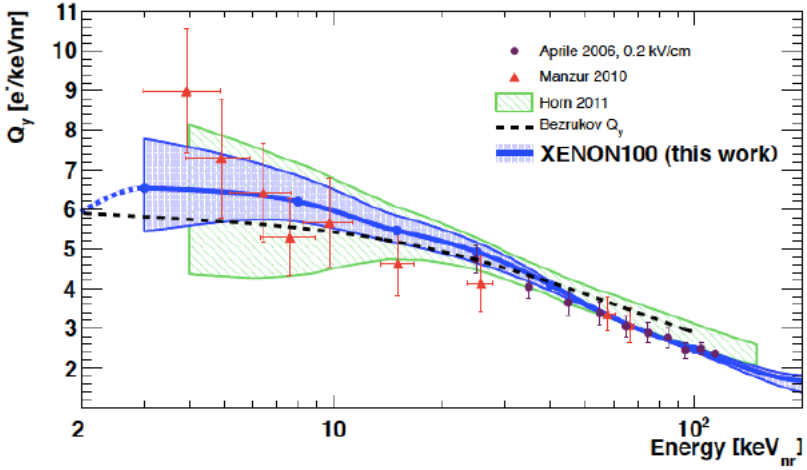
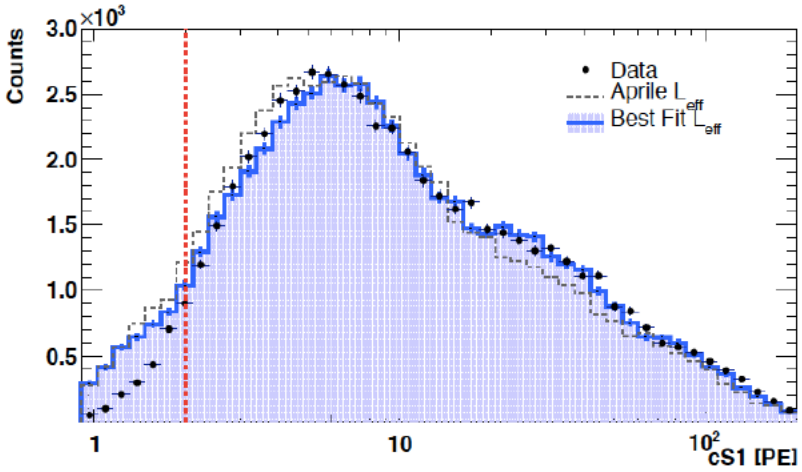


Step 1 : Using L_{eff} from measurements, reproduce S2 spectrum

→ Obtaining the optimum Q_y





XENON100 : Control on systematics with AmBe data

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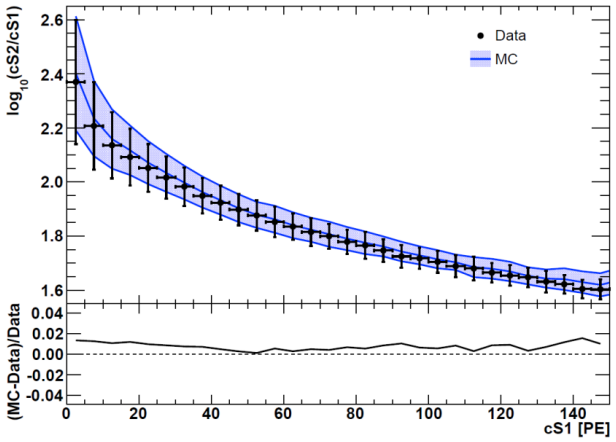

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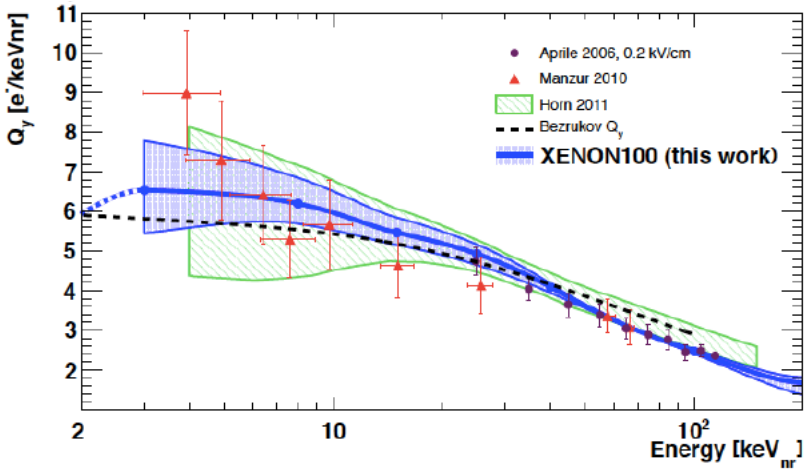
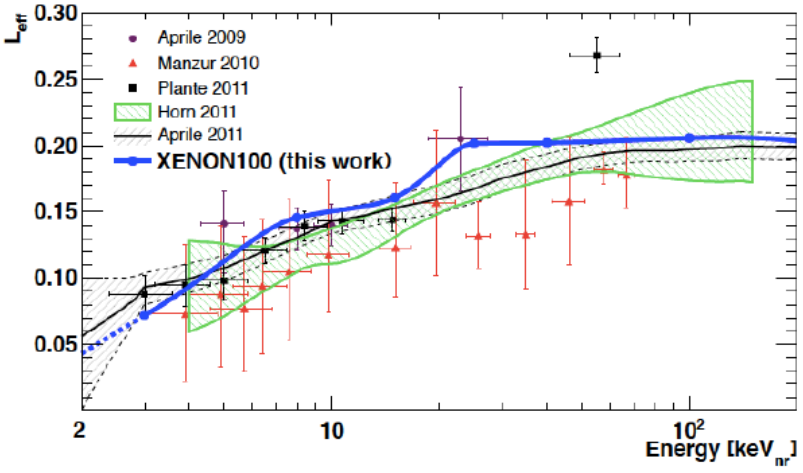


Step 2 : Using the obtained Q_y reproduce S1 spectrum

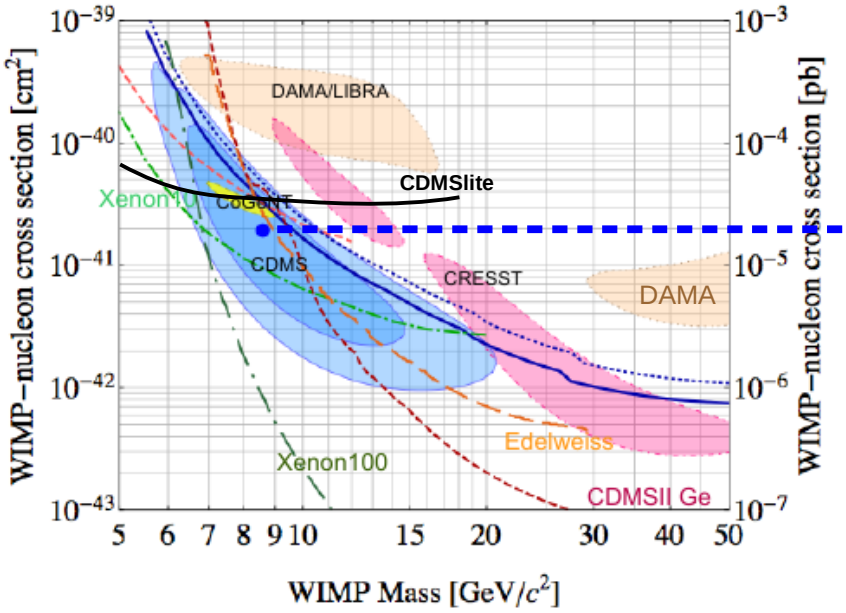
→ Obtaining a new L_{eff}

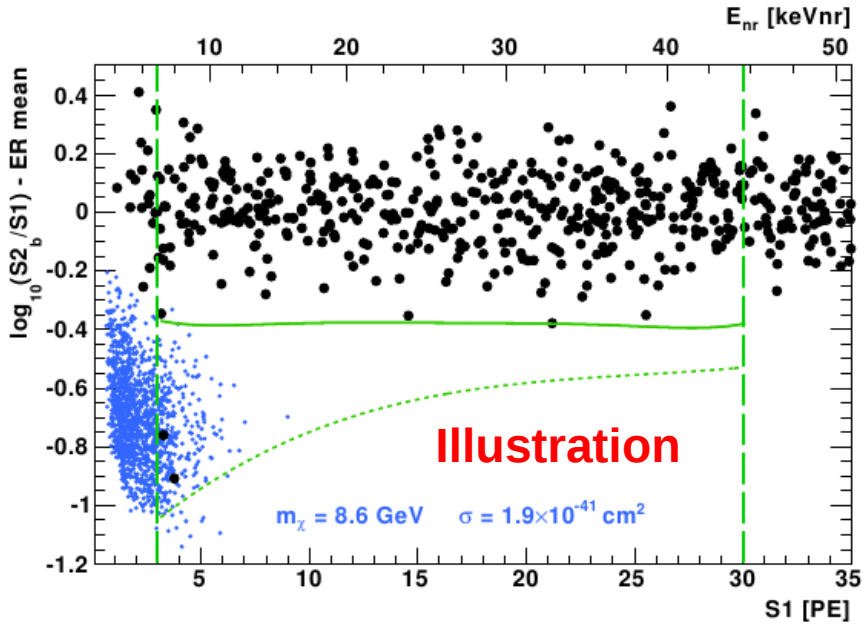


Excellent agreement down to 2 PE (~5keVr) → Strengthens reliability in the XENON100 analysis

XENON100 and CDMS : What if ?

(CDMS Collaboration) Sumbitted to Phys.Rev.Lett. arXiv: 1304.4279





- CDMS Best fit:
  1.9 x 10^{-41} cm² @ 8.6 GeV/c² WIMP mass

PL analysis : 0.19% probability for the known-background-only hypothesis when tested against the alternative WIMP+background hypothesis

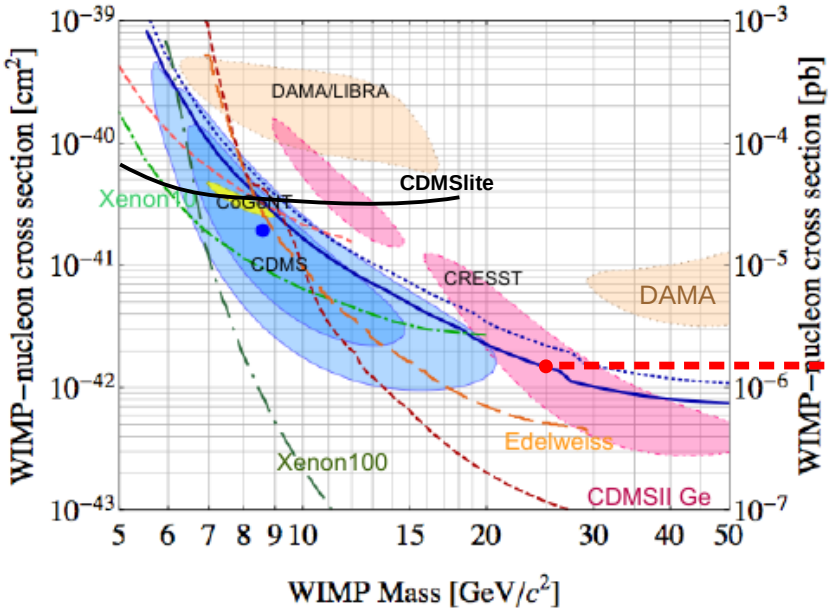
New results of CDMSlite (*arXiv:1309.3259*) cut away the upper part of the CDMS allowed region

Black points :
→ what XENON100 sees

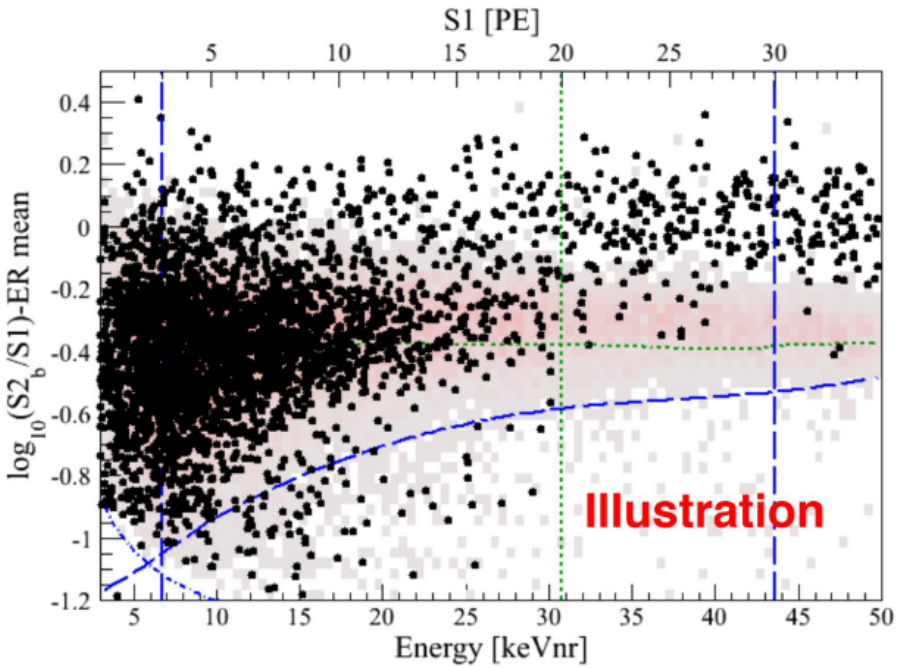
Plus blue points :
→ what XENON100 would observe (i.e., after correction on acceptances) for the best fit point of CDMS

223^{+303}_{-85} (sys) events would be observed

XENON100 and CRESST : What if ?



- CRESST Best fit:
  M1 maximum:
  2.2 x 10^{-42} cm² @ 21 GeV/c² WIMP mass



Black points :

→ what XENON100 would observe (i.e., after correction on acceptances) at WIMP mass of 25 Gev/c² and cross section 1.6 x 10^{-42} cm²

1409^{+53}_{-4} (sys) events would be observed

XENON1T

Detector :
Dual phase TPC
Target : 2 kg LXe in TPC (3.5kg total)

PMTs :
248 PMTs Hamamatsu R11410 3”
QE > 35% @178nm

Electric fields :
Drift = 1.0 kV/cm, 1 m of drift

Purification :
^{85}Kr : Aimed ^{nat}Kr/Xe < 0.5 ppt
^{222}Rn : Aimed ^{222}Rn < 1 µBq/kg

Shielding :
10 m water tank as passive neutron shield with active Cherenkov muon veto (PMT Hamamatsu R5912)

Water tank

Timescale :
- XENON1T : construction started in summer 2013, commissioning in late 2014, science data in 2015
- XENONnT : larger TPC and inner cryostat. All other systems the same. Aimed exposure: 20 ton-year. Starting from 2018. Science data in 2021

Factor 100 lower background than XENON100
- Low radioactivity components
- ~ 10 cm self-shielding

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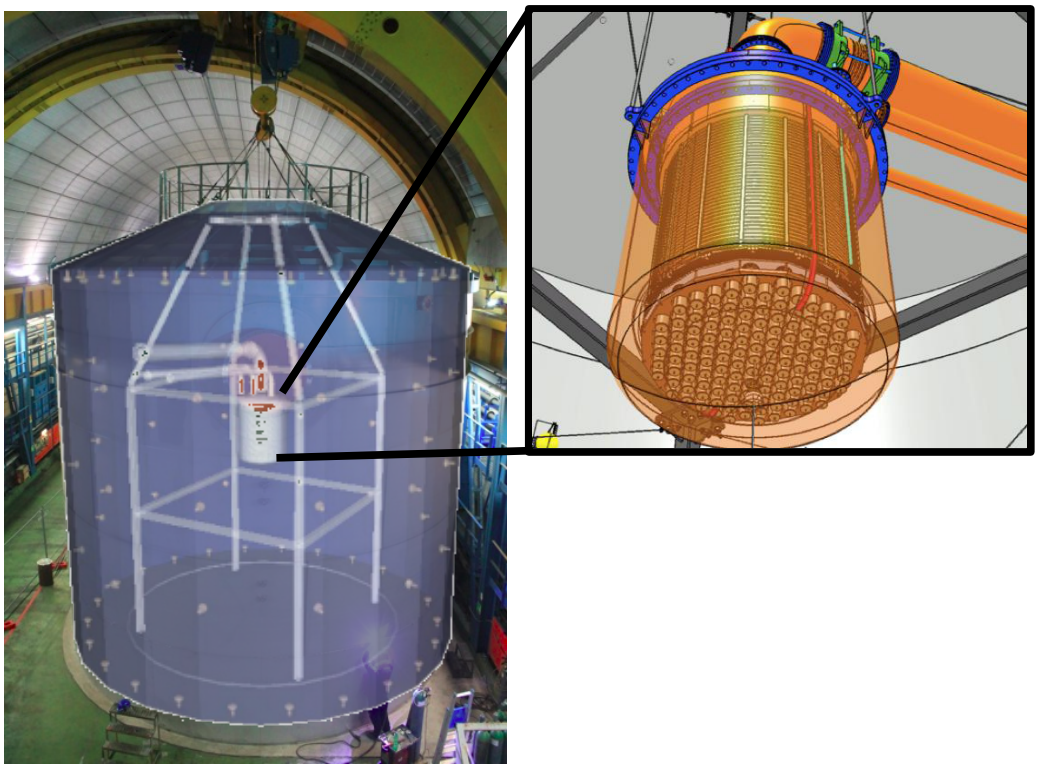

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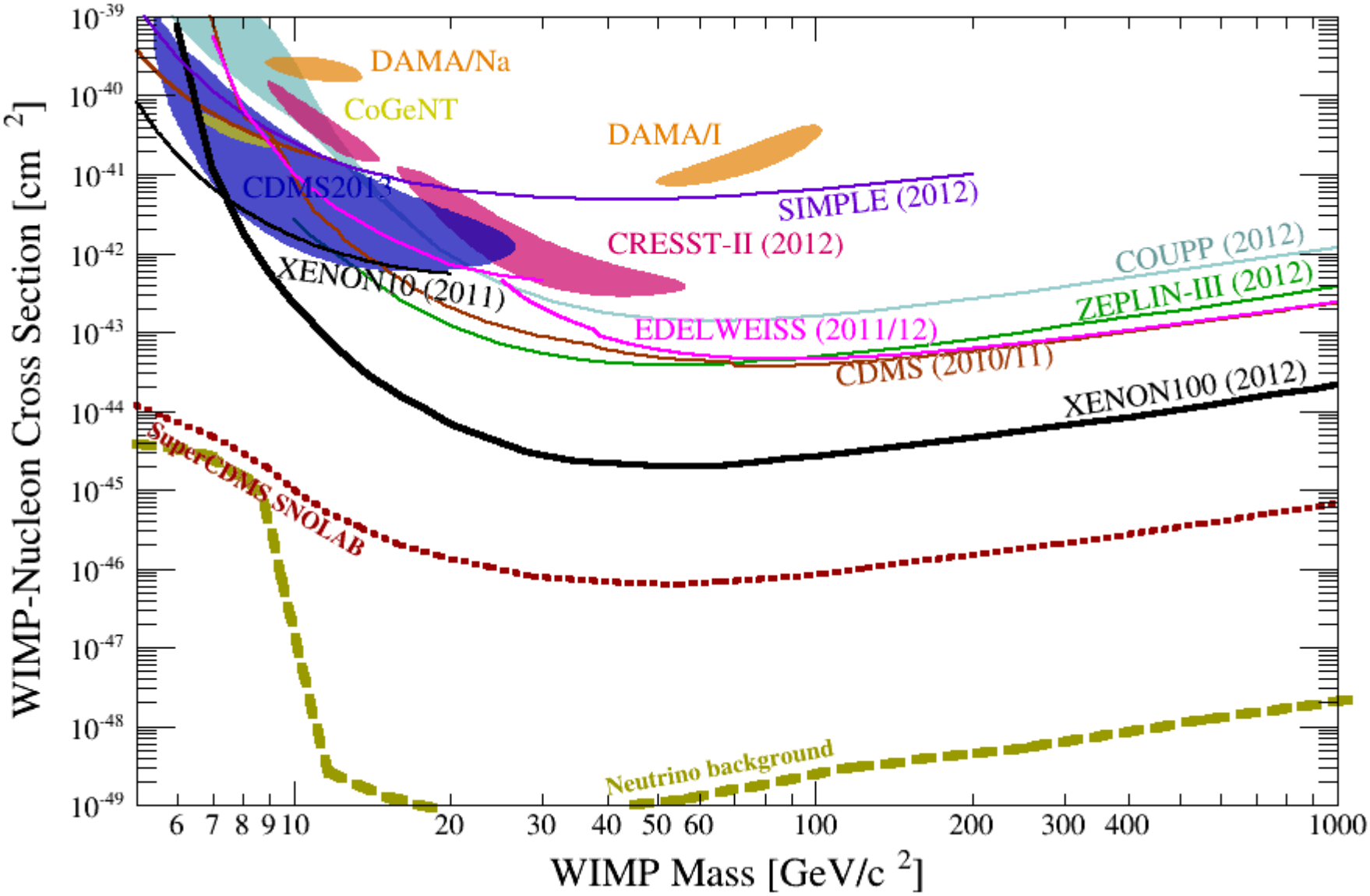
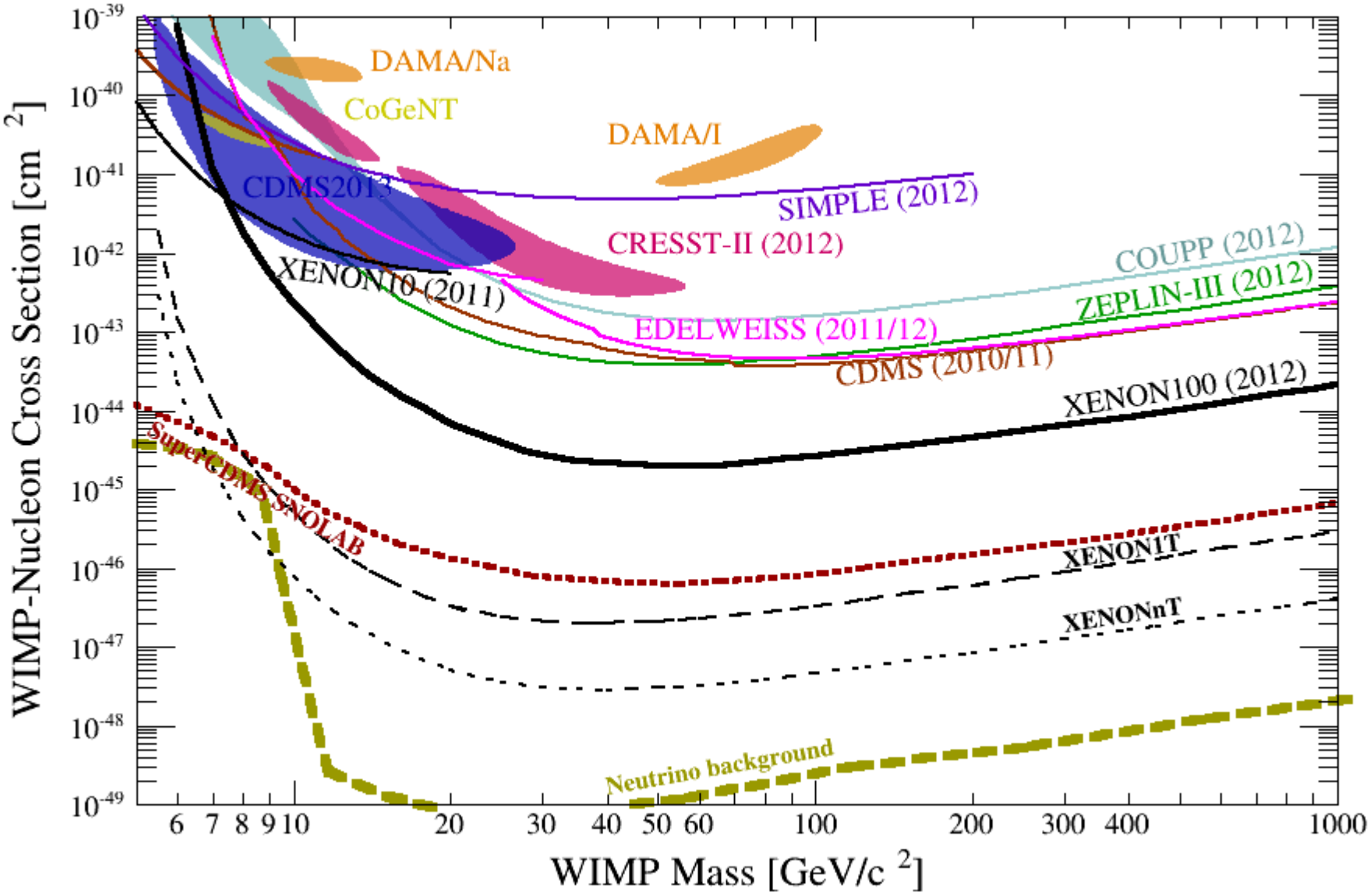
WIMP hunting...



WIMP hunting : XENON1T and XENONnT



XMASS-I

Detector :
Single phase
Target : 100 kg LXe fiducial volume (835kg total)

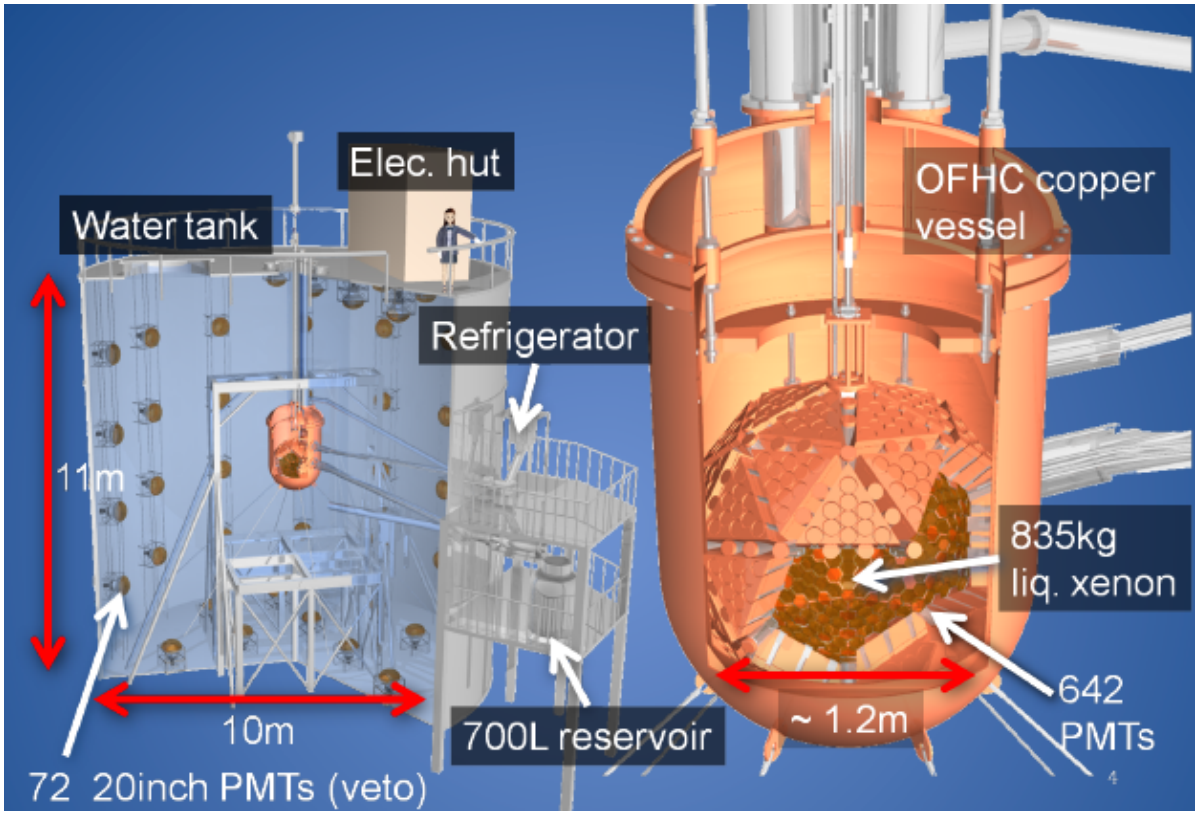
PMTs :
642 PMTs
Hamamatsu R-10789
Covering 60% of the surface

Yield :
Very high (~14 PE/keV) and at low energy threshold (~0.3keVee). Good for light mass WIMP search

Background :
Low background without particle ID

Shielding :
Water tank as active muon veto

J. Liu, Nucl.Phys.Proc.Suppl. 229-232 (2012) 564



Recent physics runs :
- Completed commissioning data-taking and analysis started
- 835kg times 6.70 days of live time

K. Abe et al. (XMASS Collaboration), PLB 719 (2013) 78-82

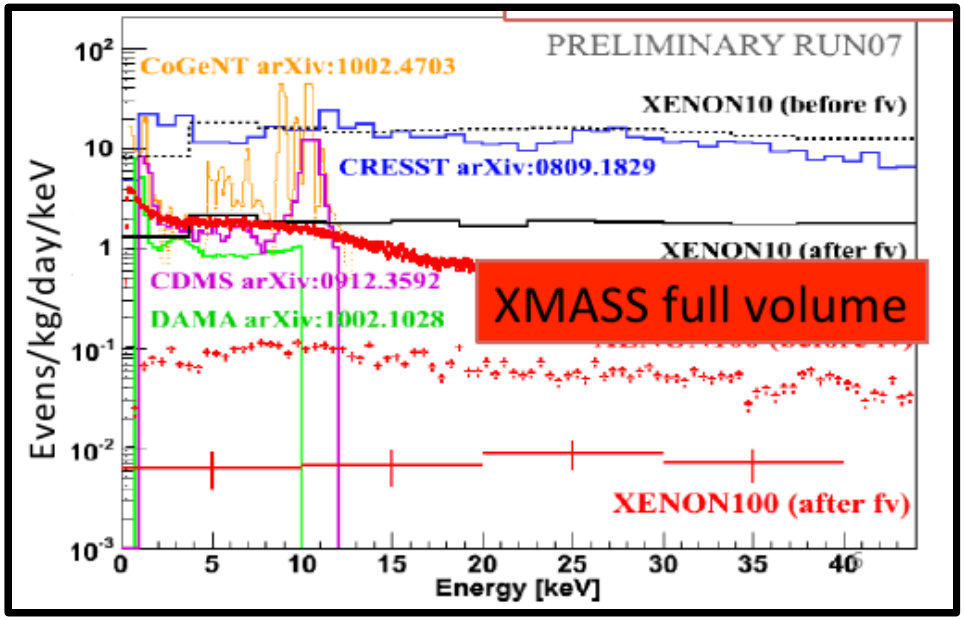
XMASS-I : latest results

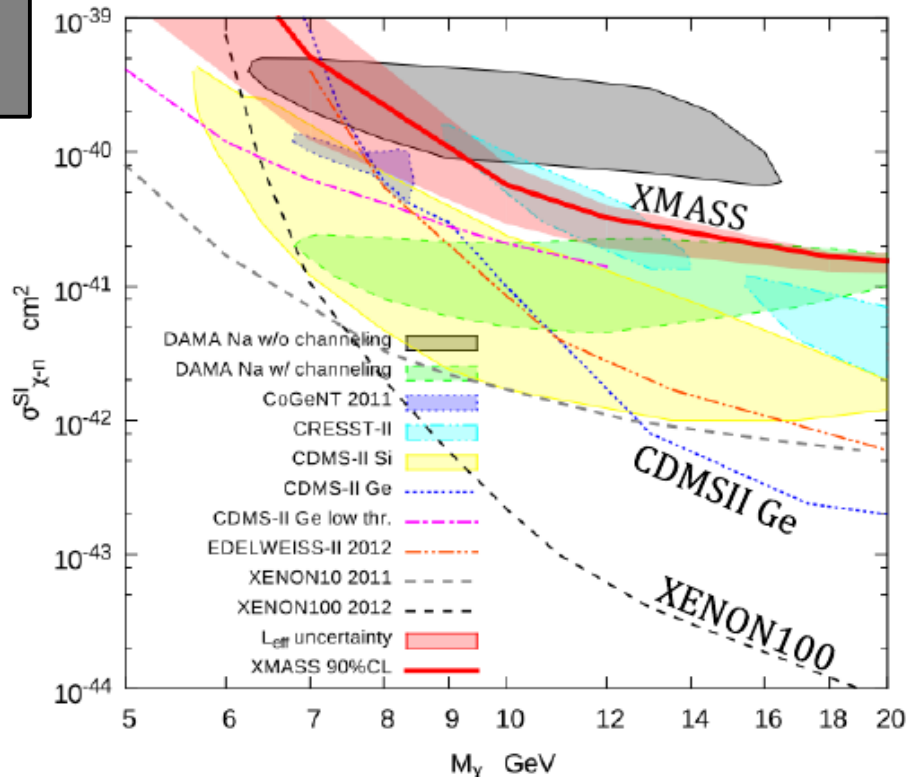
Light mass WIMP search

K. Abe et al. (XMASS Collaboration), PLB 719 (2013) 78-82

- 6.70 live days collected with low trigger threshold
- Whole volume (835kg) used

- The result excludes part of the parameter space favored by other measurements
- After the refurbishment, they will expect 1 to 2 orders of magnitude improvement

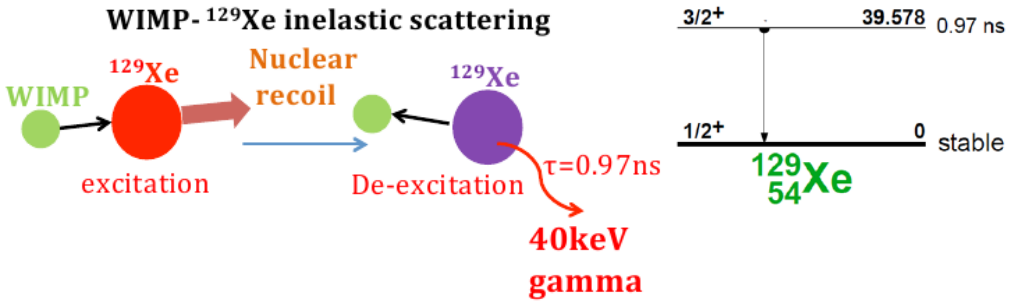


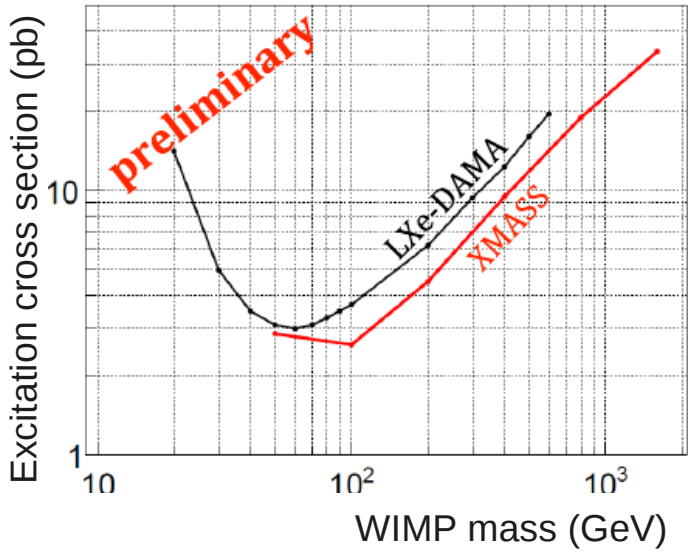


XMASS-I : latest results

WIMP-129Xe inelastic scattering

- 6.70 live days collected with low trigger threshold
- R < 15cm
- Still a preliminary study (presented at CYGNUS 2013@Toyama)



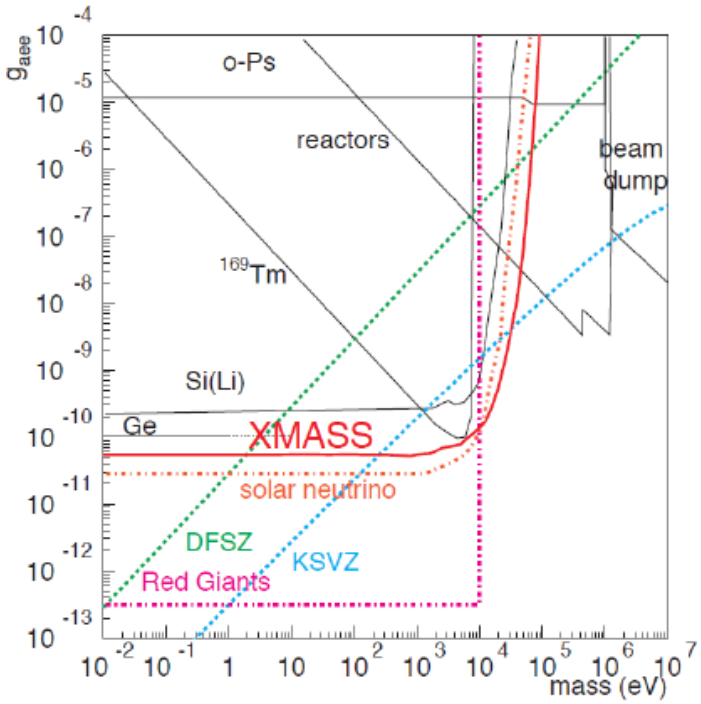


Solar axion search

ArXiv:1212.6153, Accepted for publication in PLB

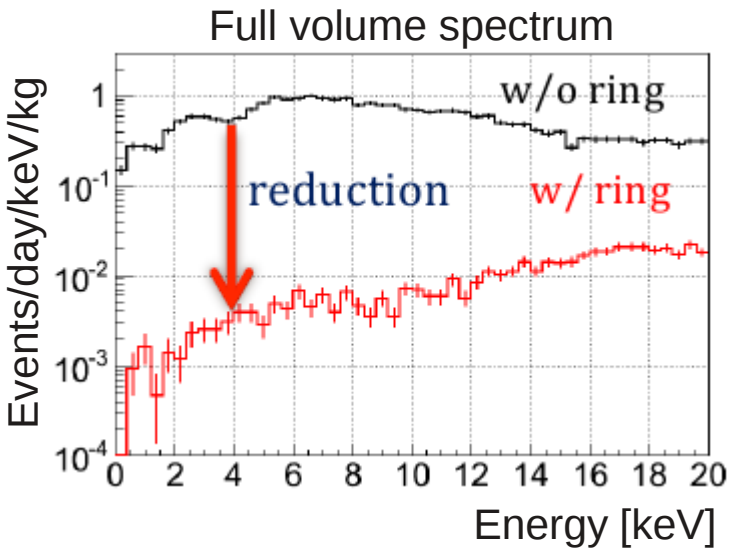
- 6.70 live days collected with low trigger threshold
- Whole volume (835kg) used

- mass < 1 keV is $|g_{Ae}| < 5.4\times10^{-11}$ (90% C.L.)

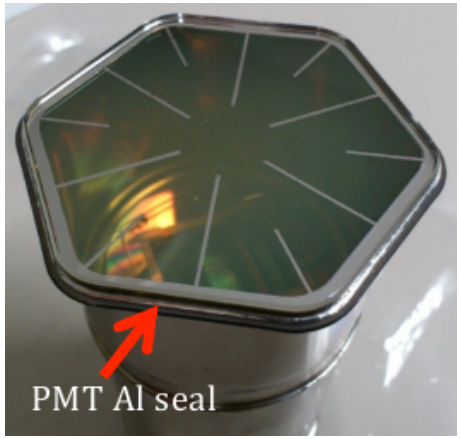


XMASS-I : refurbishment

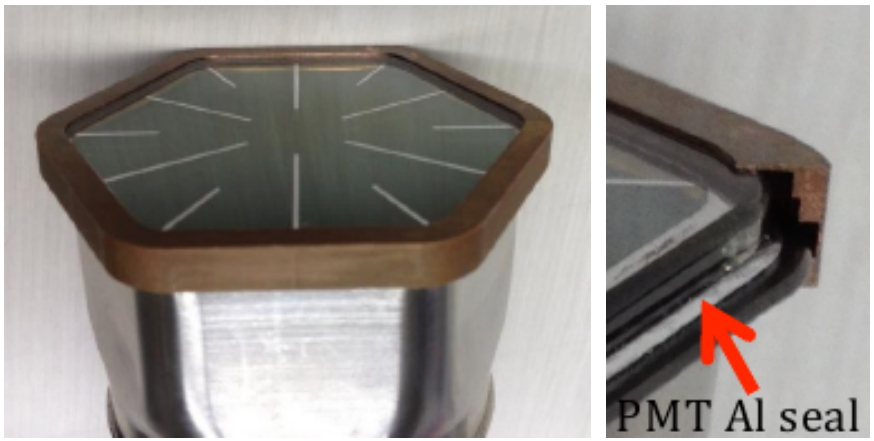
- XMASS-I discovered an unexpected source of background in the aluminum seal of PMTs
  - → Background ~100 times larger than expected
- A campaign of refurbishment started. Purposes are:
  - → Confirmation of background reduction by shielding of scintillation light originated from PMT aluminum by a copper ring
  - → Also to demonstrate the reduction of ^{210}Pb (second largest background component) with electropolishing and special clean environment
- The refurbishment should be completed before the end of 2013



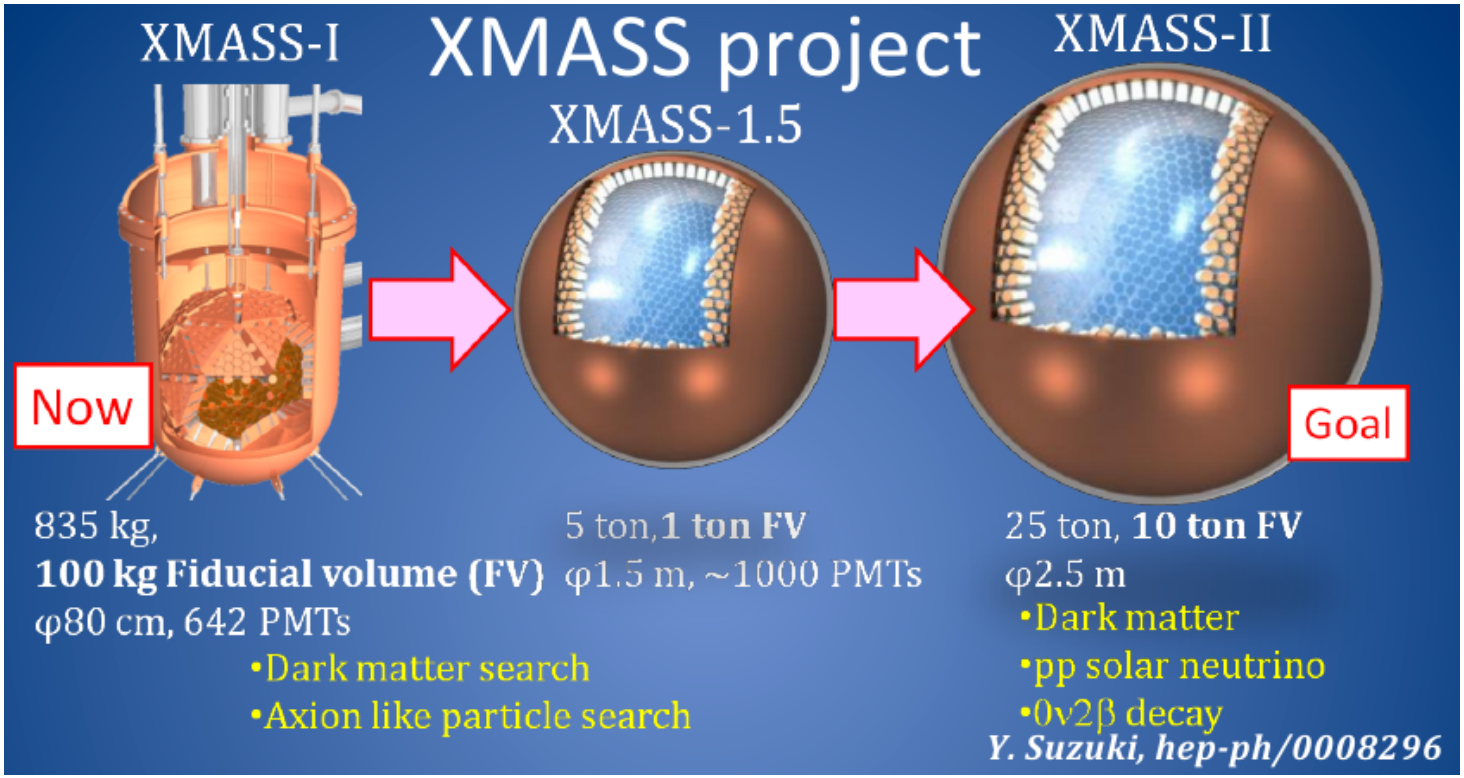
Before the installation of the ring



After the installation of the ring



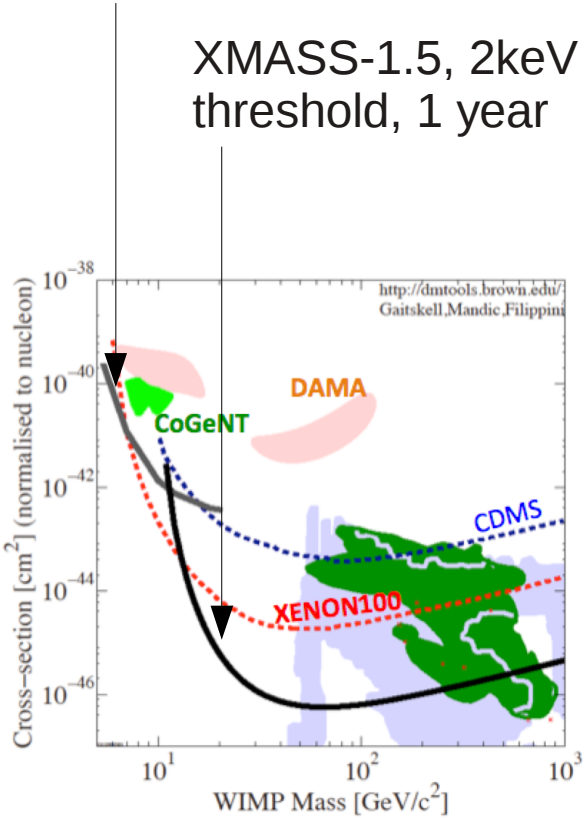
XMASS-1.5 and future



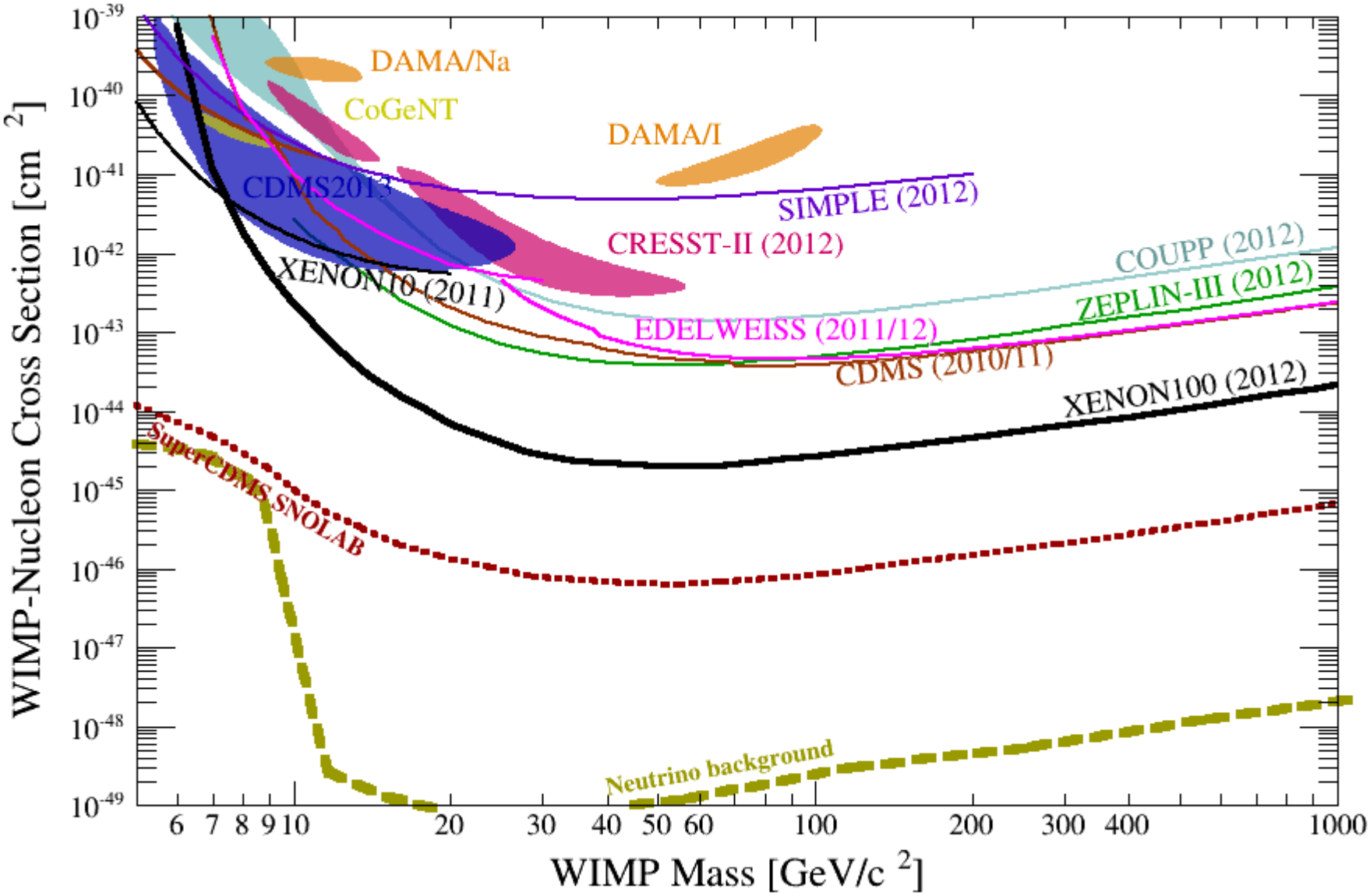
- Final goal of the program is a 25 ton detector: XMASS-II
- Next step: XMASS-1.5
- New PMTs will be developed without aluminum

XMASS-1.5 full volume

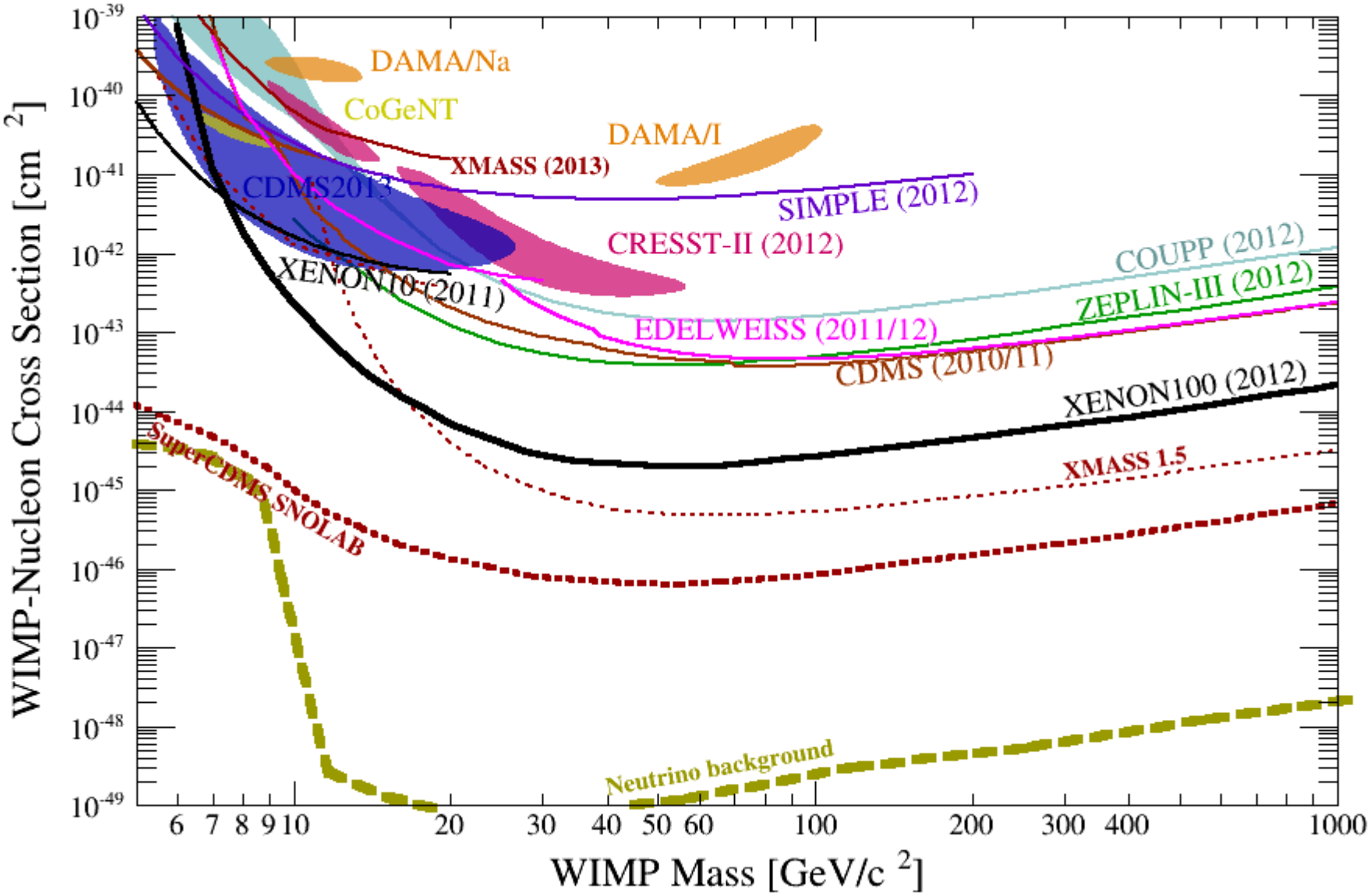
XMASS-1.5, 2keV threshold, 1 year



WIMP hunting...



WIMP hunting : XMASS



PandaX

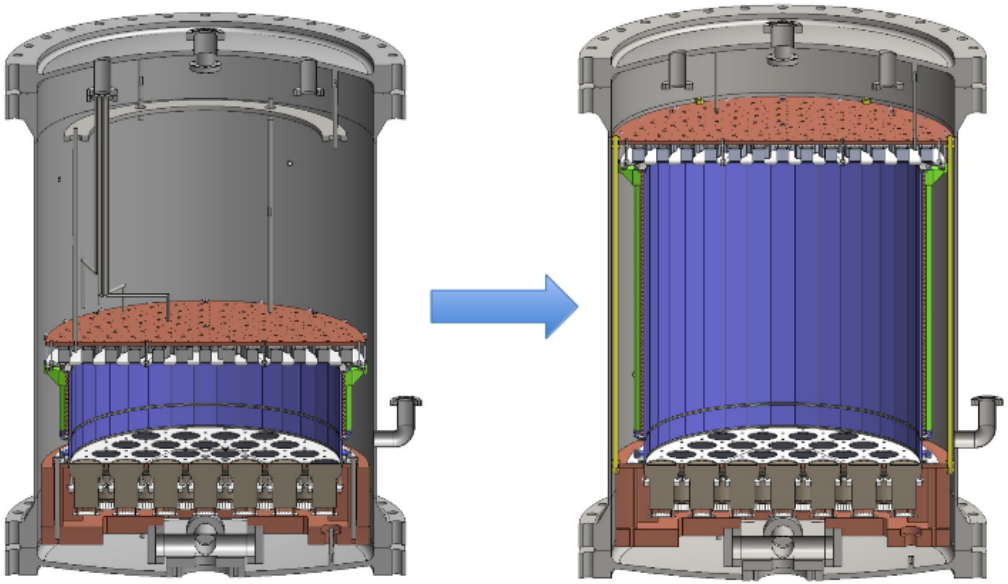
Detector :
Two phase TPC
Target : 25 kg LXe fiducial volume (125kg total)

PMTs :
180 PMTs
- 143 Top PMT Hamamatsu R-8520
- 37 Bottom PMT Hamamatsu R-11410

Yield :
Expected 4-5 PE/keVee

Goal :
Low threshold (1.5 keVee) for light WIMPs

Background :
Dominated by ERs from Vessel and PMTs

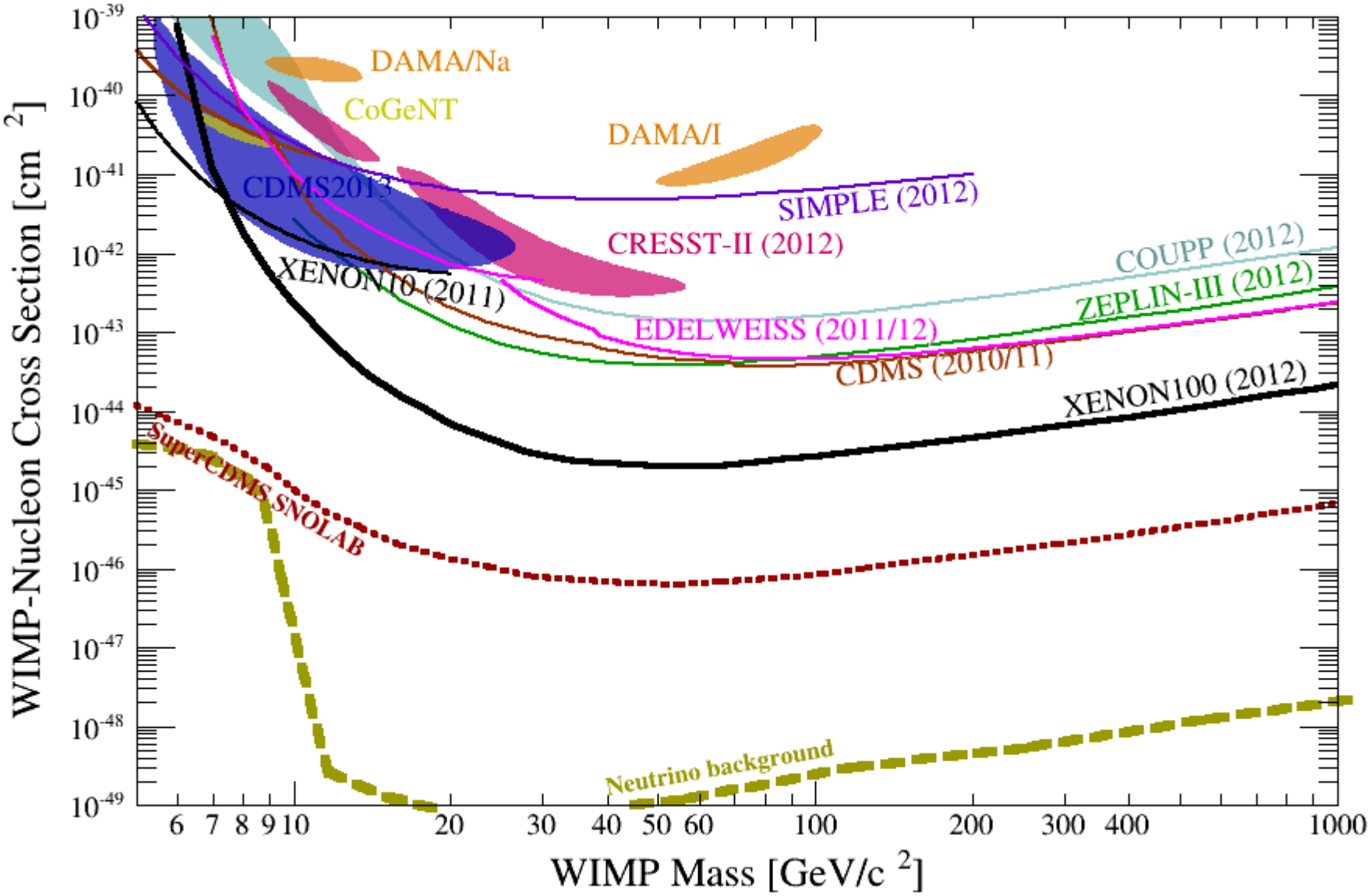


Stage-1a (125 kg target)

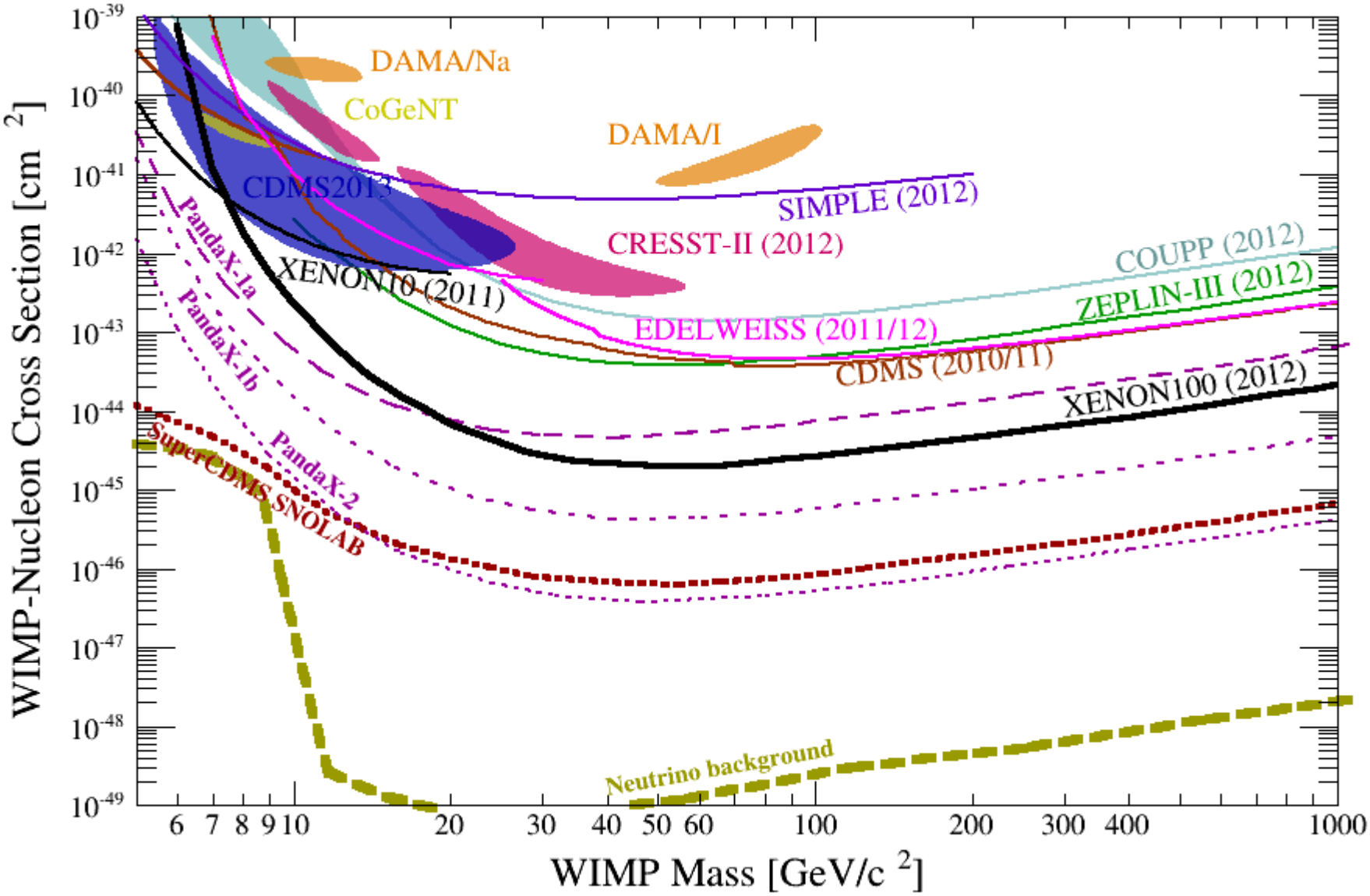
Stage-1b (500 kg target)

Timeline :
- Stage 1a (125kg total) : commissioning and operation in 2013
  → Planned 60 days of exposure
- Stage 1b (500kg total) : commissioning and operation in 2014
  → same vessel but higher TPC (yield goes down to 2.5 PE/keVee)
- Stage 2 (2400kg total) : construction (start 2014), commissioning and operation (2015-2017)

WIMP hunting...



WIMP hunting : PandaX



ArDM

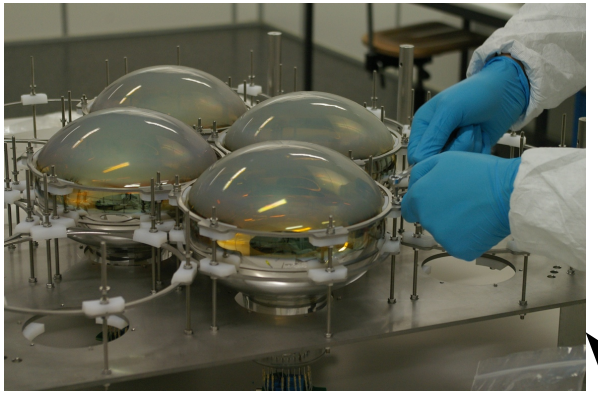
Detector :
Dual phase TPC
Target : 0.8 ton LAr in TPC

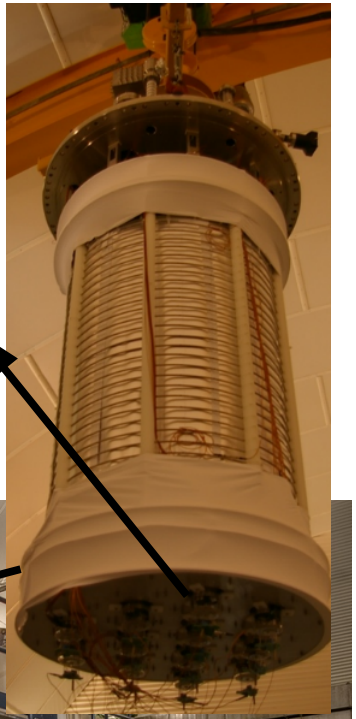
PMTs :
24 PMTs
Hamamatsu R5912-02MOD-LRI 8”
Coated with wavelength shifter PTB

Field :
E ~ 1 kV/cm, drift length 110 cm

Light yield :
Expected 2 PE/keVee at E=0 in LAr

Shielding :
polyethylene passive neutron shield





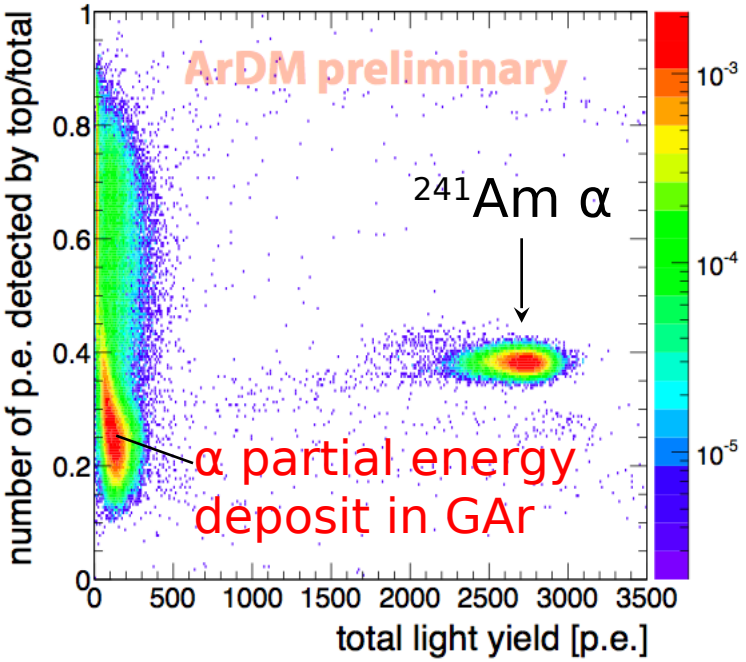
Timeline :
● Surface operation (2012 at CERN)
● Underground operation I : (at LSC) installation completed In March 2013. Presently commissioning in GAr
● Underground operation II : (at LSC) LAr tests (purification, HV, cryogenics)
● Physics runs : beginning 2014

ArDM : results in GAr

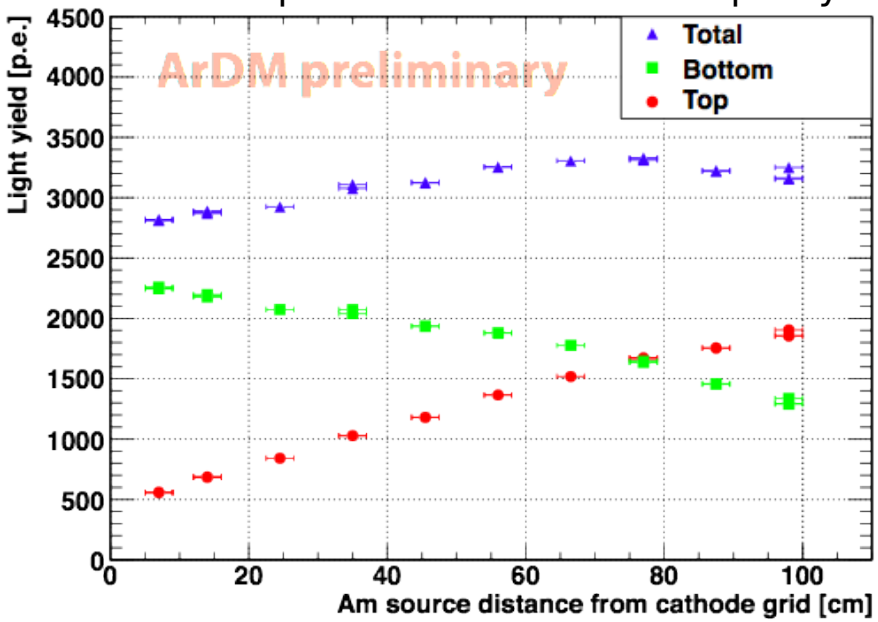
Ongoing now :
- Commissioning in gas argon (Gar)
  - → Improved LY and uniformity measured in data taking using α source

Next phase :
- Material screening campaign using Ge@LSC in-situ
  - → Neutron background measurement (liq. scint.)

GAr data@LSC F. Resnati, LIDINE 2013



LY extrapolated to ultimate GAr purity



DarkSide-50

Detector :
Dual phase TPC
Target : 50 kg LAr in TPC

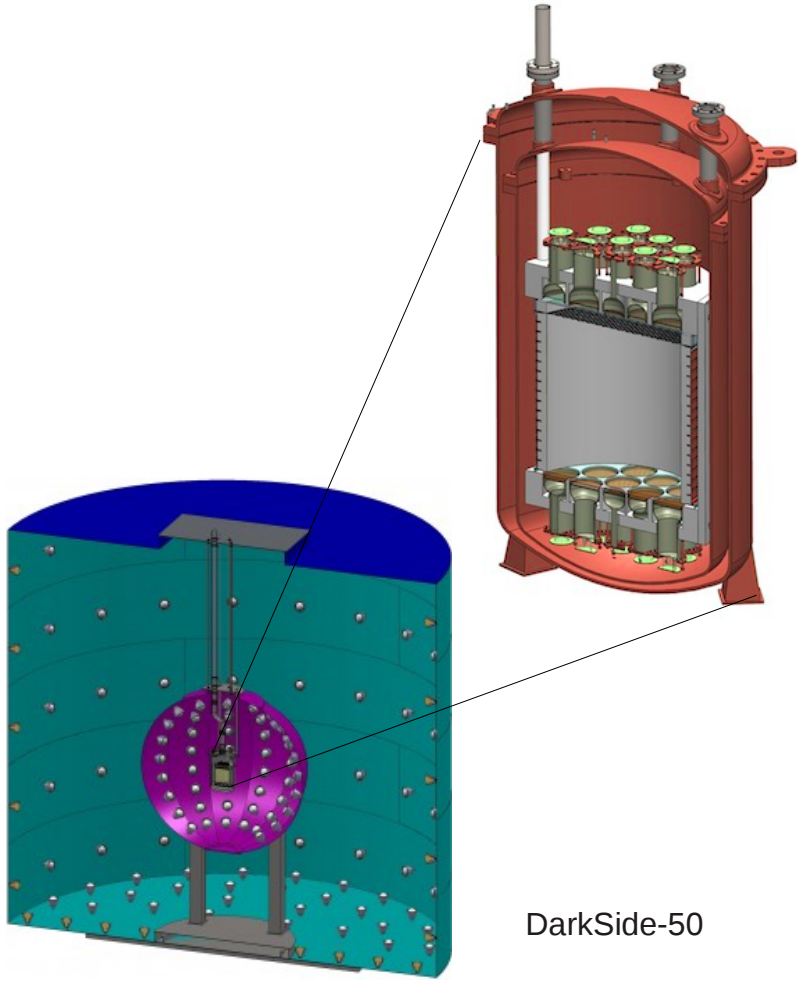
PMTs :
642 PMTs
Hamamatsu R11065s 3”
Average QE ~33.9%

Argon :
From underground (low ^{39}Ar concentration)

Light yield :
Reached 9 PE/keV with DarkSide-10
arXiv:1204-6218

Shielding :
borated liquid scintillator-based neutron veto (LSV), inside a water Cherenkov muon veto (Borexino tank)

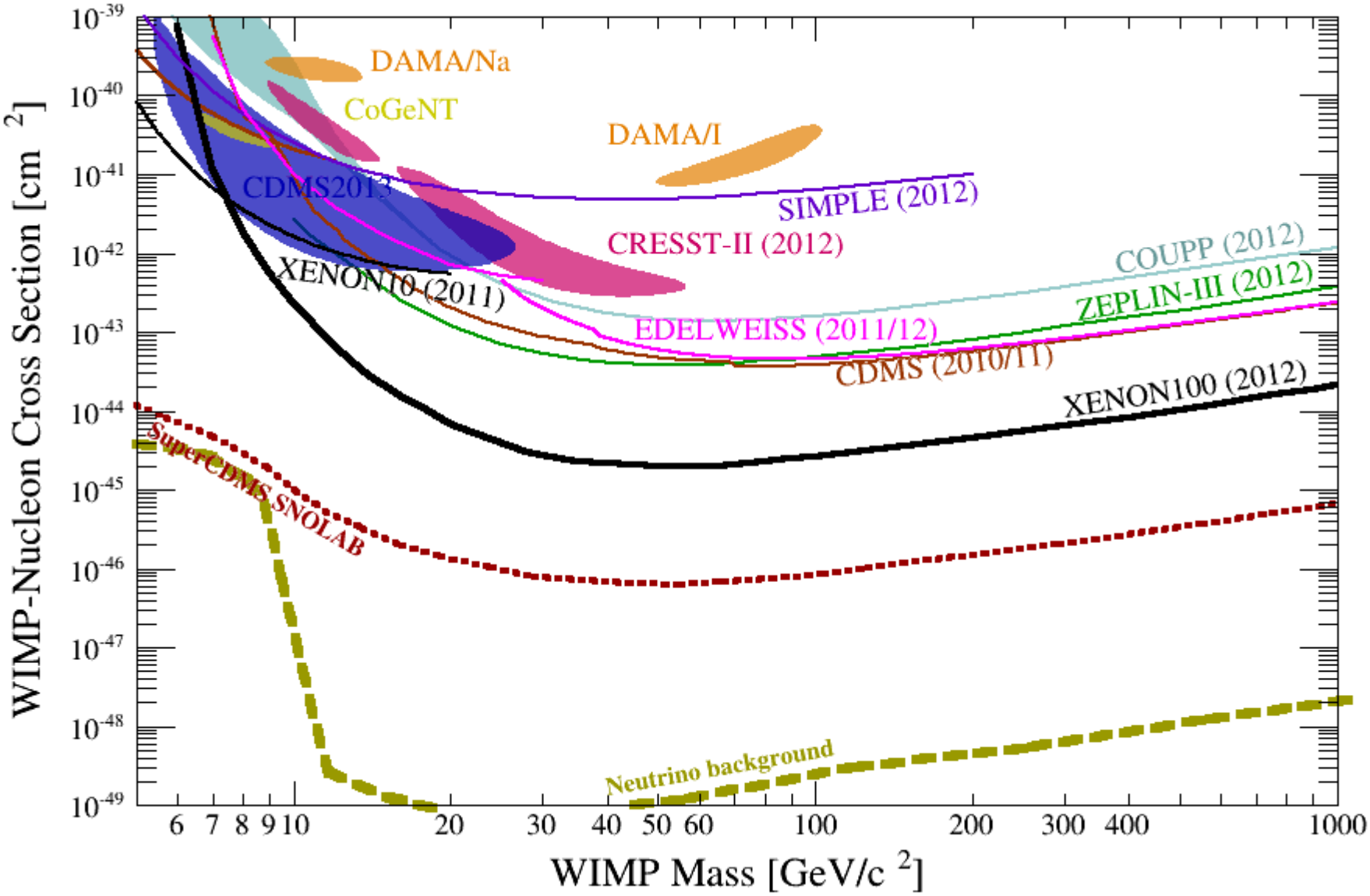
DarkSide-10



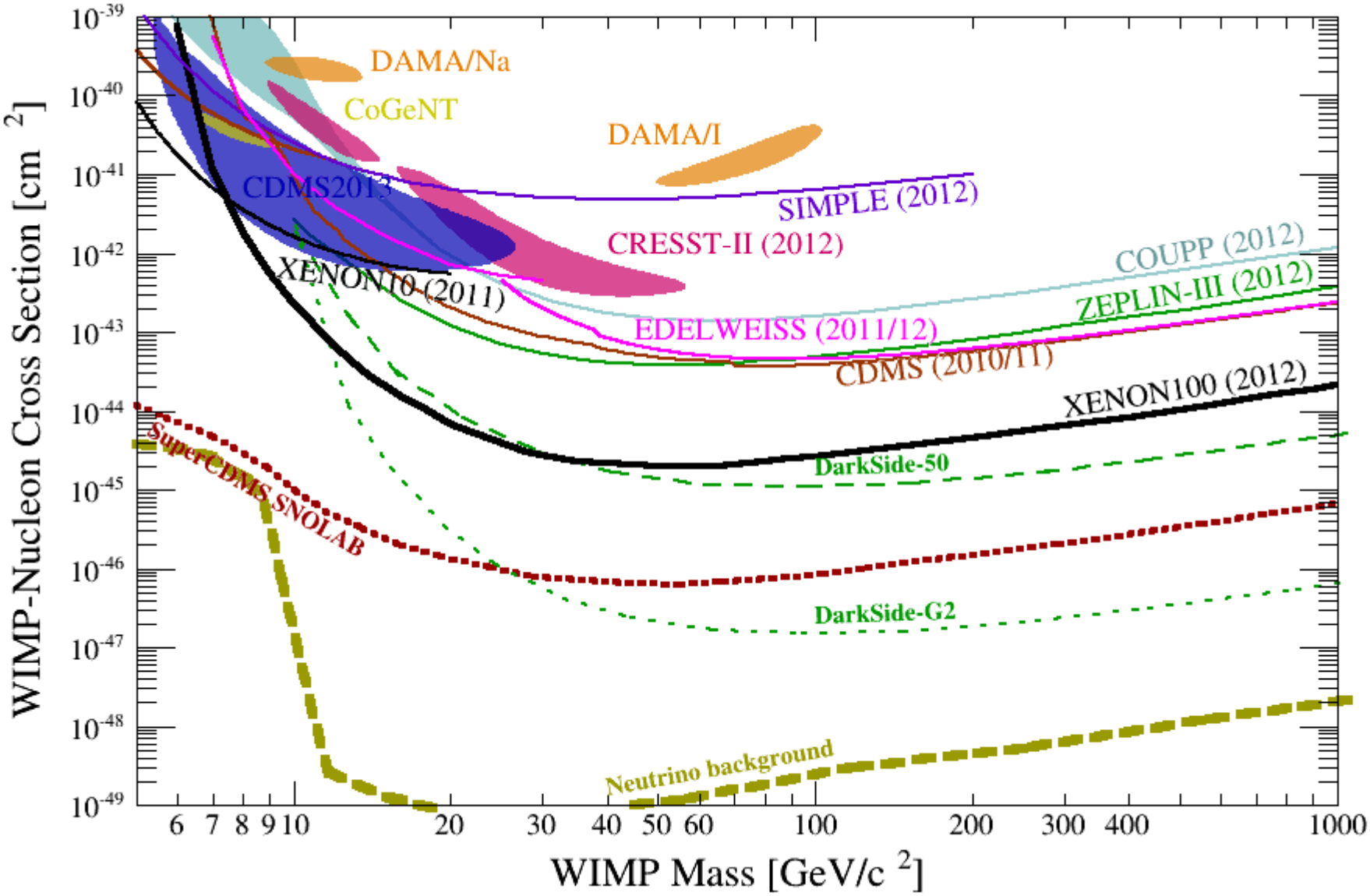
DarkSide-50

Timeline :
- DarkSide-10 : 10kg prototype
  built at Princeton, then moved to Gran Sasso in 2011
- DarkSide-50 : 50 kg
  under commissioning (first physics run expected before end of 2013)
- DarkSide-G2 : 3.3 tons (currently in R&D phase)

WIMP hunting...



WIMP hunting : DarkSide



LUX

Detector :
Dual phase TPC
Target : 350 kg LXe (100kg fiducial)

PMTs :
122 PMTs
Hamamatsu R-8778 2”
QE ~30% @175nm
ArXiv:1205.2272

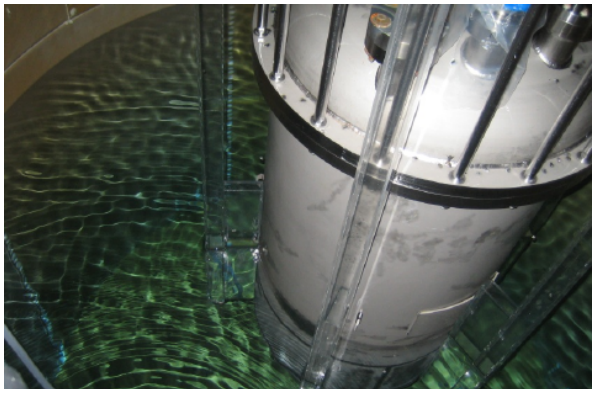
Cryostat :
Radio-pure titanium

Electric fields :
Drift length = 49 cm

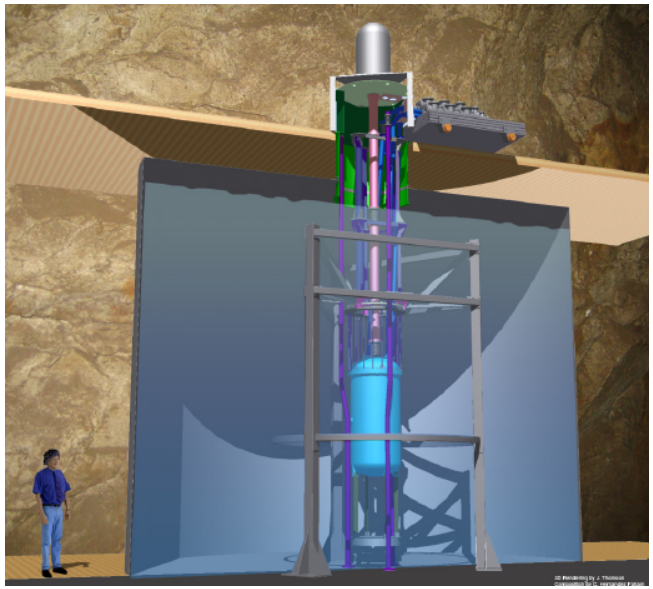
Shielding :
DI Water tank, dissolved O_2<0.5 ppb

Timeline :
- LUX 0.1 (2007-2009)
- LUX Surface running (2010-2012)
- Underground transport (2012)
- LUX Underground run (2012-2013) – Results public in October 30th!
- Year-long science run (2014-2015)

In surface (2011)



Underground



LUX : progresses and waiting for the announcement

Surface run

D.S. Akerib (LUX Collaboration), Astropart. Phys. 45 (2013) 34–43

- Measured light collection efficiency ~8phe/keVee
- 6% energy resolution (@662keV, ^{137}Cs)
- event reconstruction ~7mm

Underground

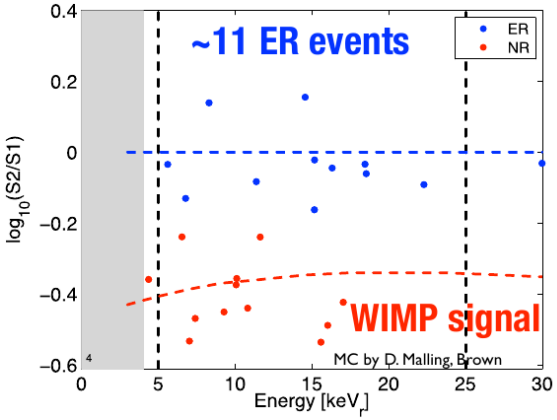
- Xe circulation system
  → electron mean free path > 100 cm (March 2013)

- ^{85}Kr removal. Gas chromatography
  → 4ppt achieved *arXiv:1103.2714v3*

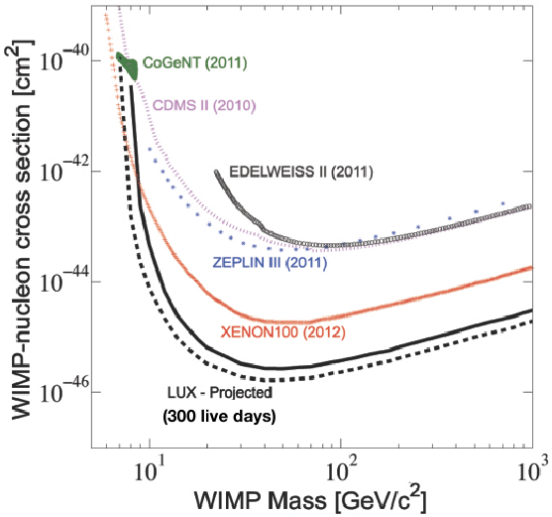
- ^{222}Rn decay chain, primarily ^{214}Pb
  → upper limit of < 0.23 mDRU$_{ee}$ or 0.1 ER event / day (fiducial)

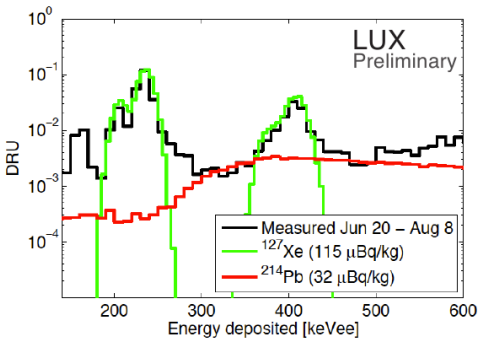
Expectations (MC):

With 40 live days → ~11 ER events



Projections

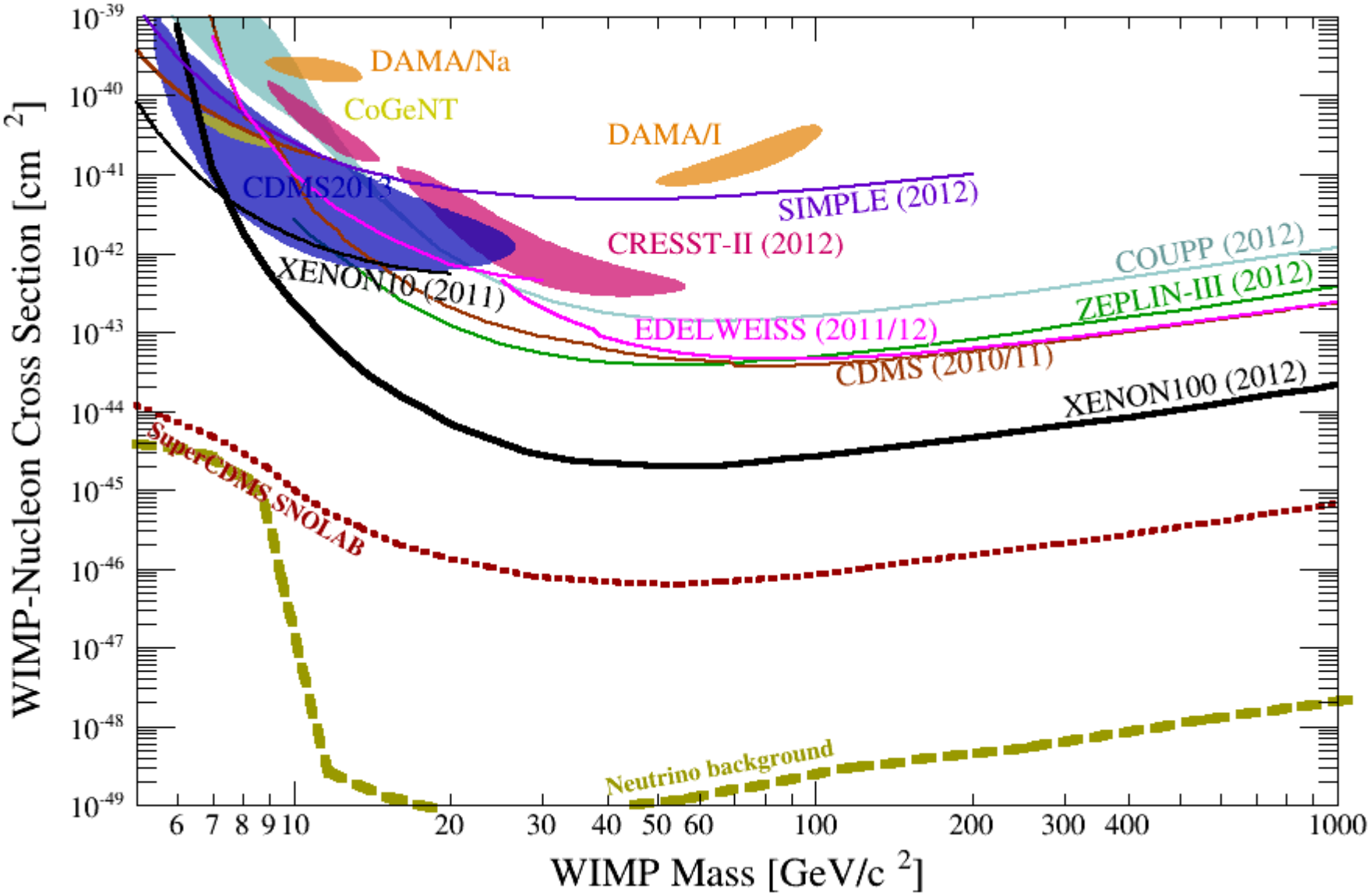




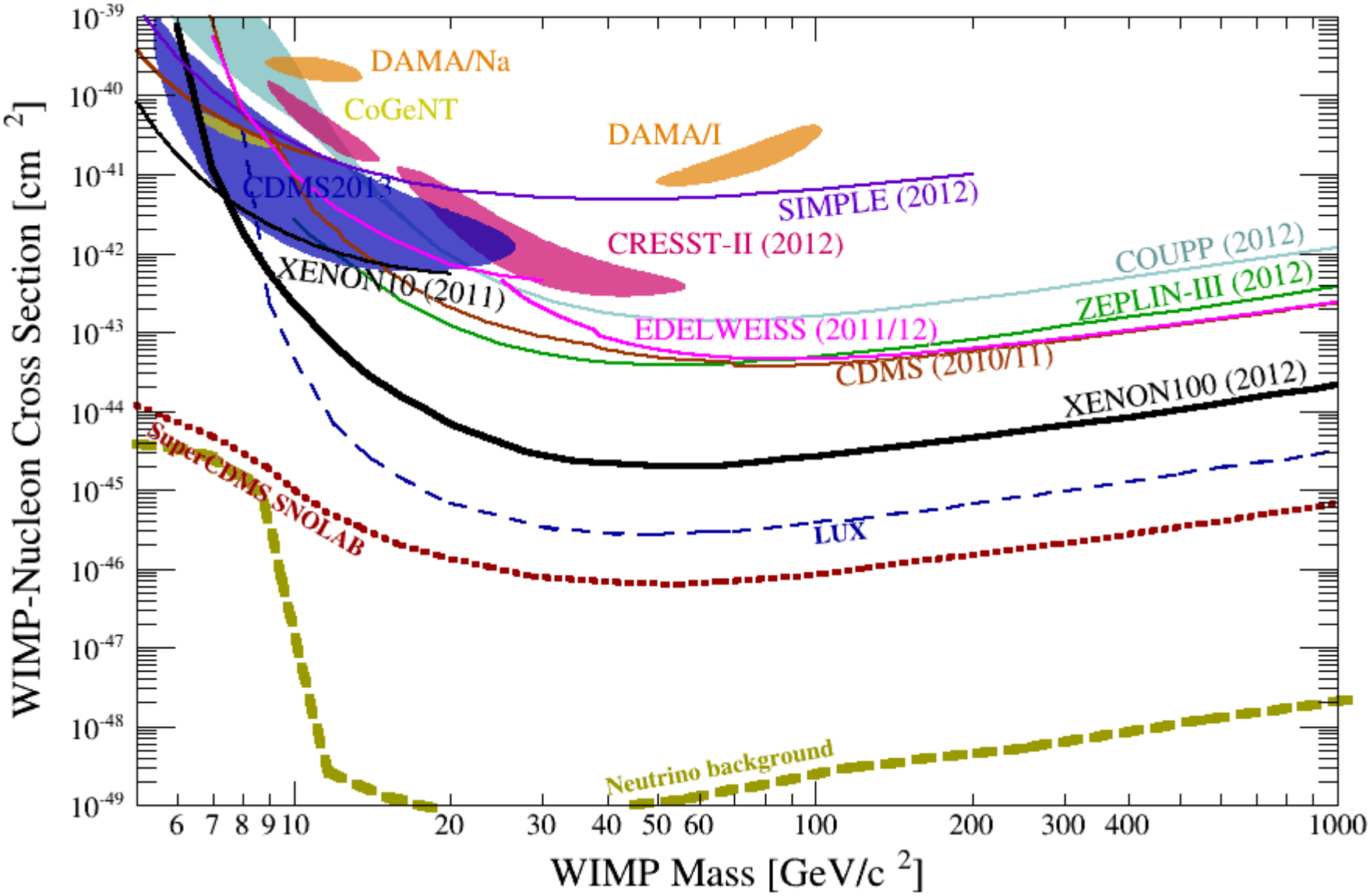
- LUX has been operating underground since spring 2013
- stable detector operation achieved
- first WIMP search result announced on Oct 30

Plots presented by M. Horn, WIN2013

WIMP hunting...



WIMP hunting : LUX



DEAP-3600

Detector :
Single phase
Target : 3.6 ton LAr (1ton fiducial)

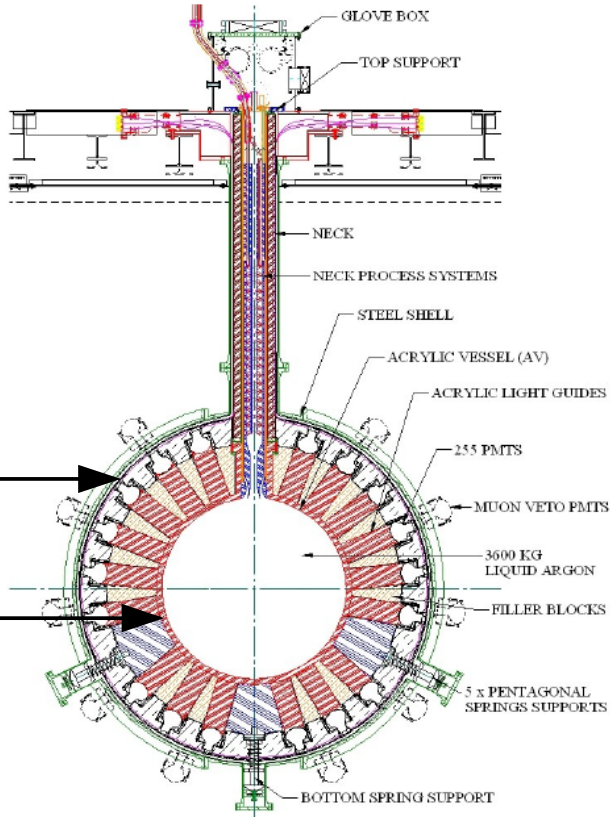
PMTs :
255 “warm” PMTs
Hamamatsu R-5912 8"
(32% QE, 75% coverage)

Cryogenic containment :
Steel shell and a monolithic acrylic vessel

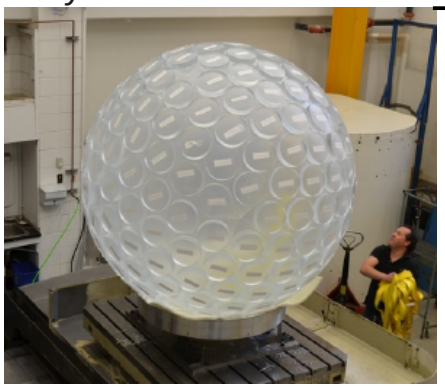
Shielding :
8 m water shield
50 cm acrylic
Background dominated by (alpha, n) neutrons from PMT glass

Timeline :
- DEAP-0 (R&D)
- DEAP-1 (2008) : 7kg LAr, 2 PMTs
- DEAP-3600 (from 2012) : 3600 kg cooldown in Jannuary 2014, plus 2 months of commissioning
- Future: 50 tons

Steel shell in the water tank



Acrylic shell



MiniCLEAN

Detector :
Single phase
Target : 500 kg LAr (150 fiducial), but also LNe

PMTs :
92 optical cassettes with PMTs

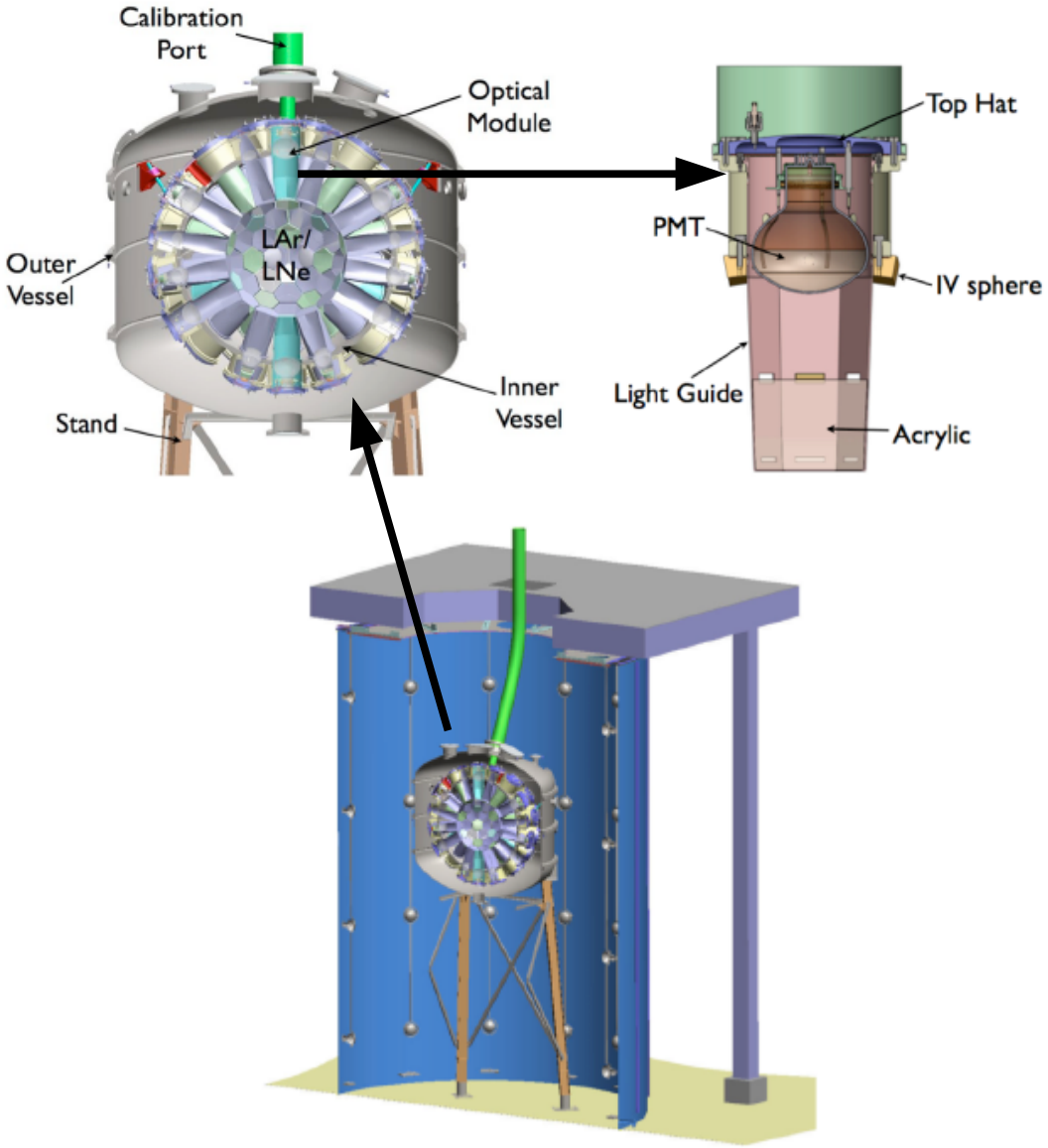
Yield :
3.5 PE/keV in neon
(arXiv:1111.3260)

Cryogenic containment :
Stainless steel

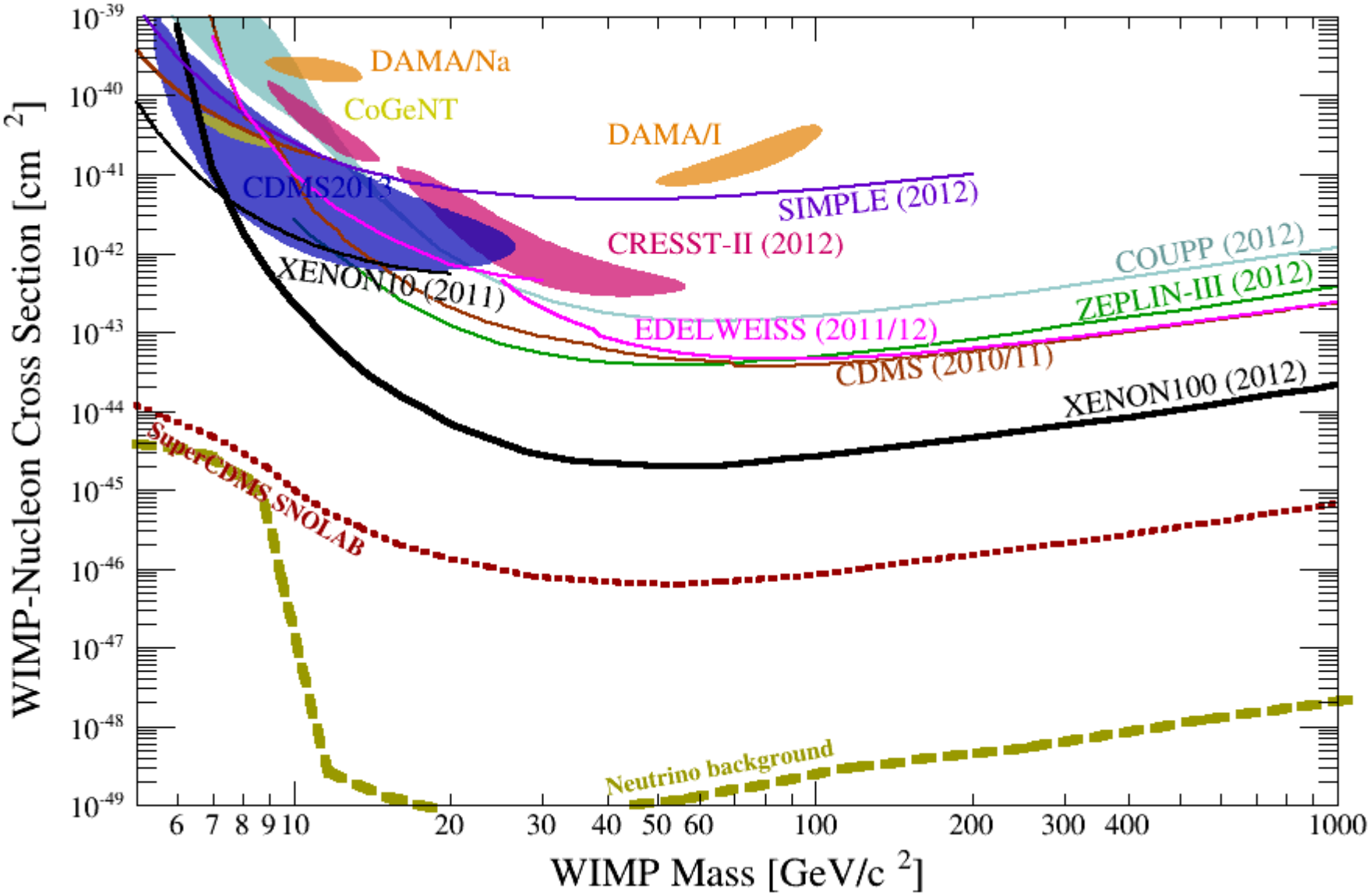
Shielding :
8 m water shield with muon veto with 48 PMTs
10 cm acrylic + 20 cm cryogen

Strategy :
PSD with Ar. If signal, then using enriched ^{39}Ar to check for an increase of rate. Finally, run with LNe

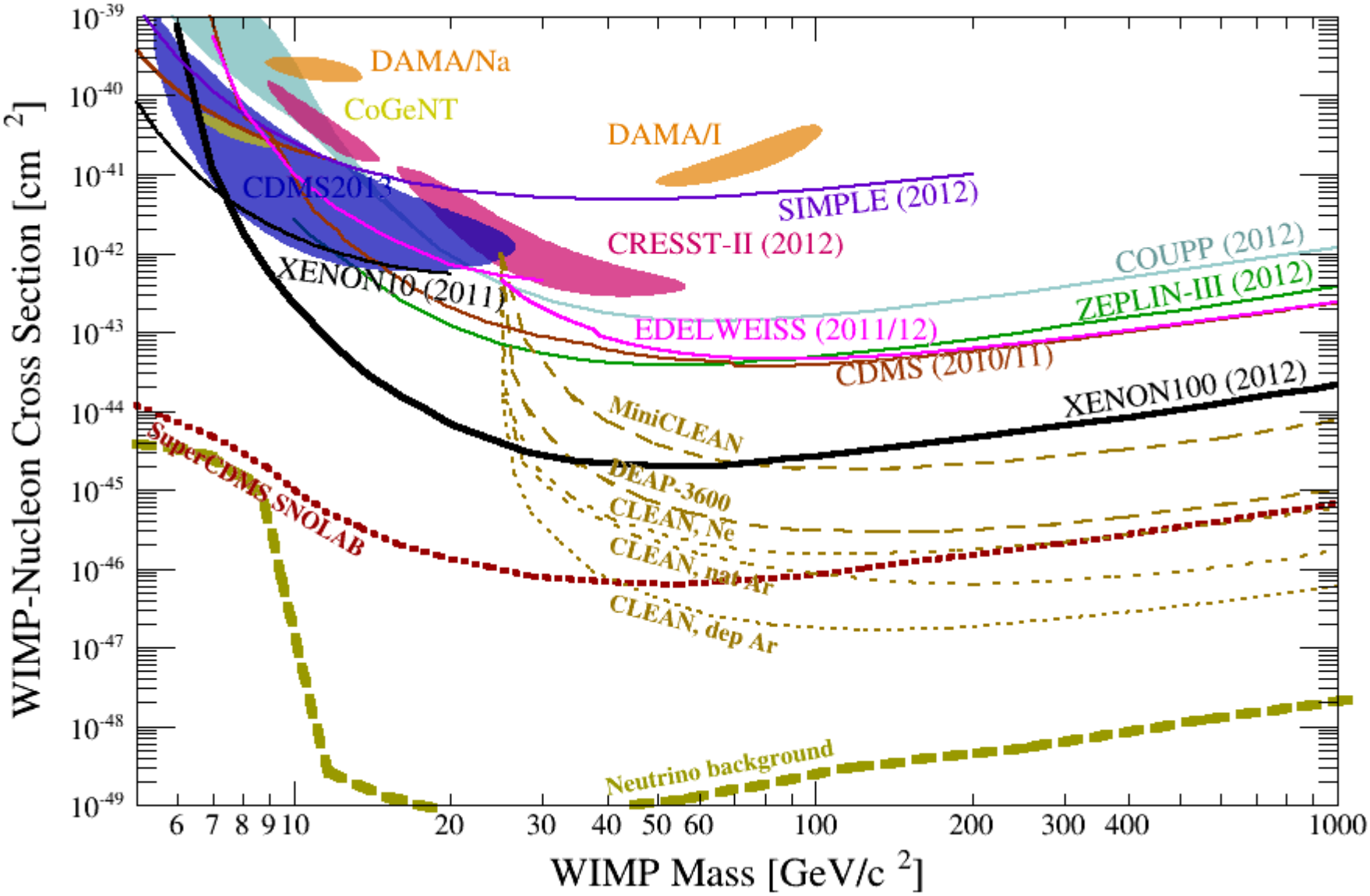
Timeline :
- picoCLEAN (R&D)
- microCLEAN : 4kg Lar or LNe, 2 PMTs (tests at Yale)
- MiniCLEAN (from 2011)
- Future: 50 tons



WIMP hunting...



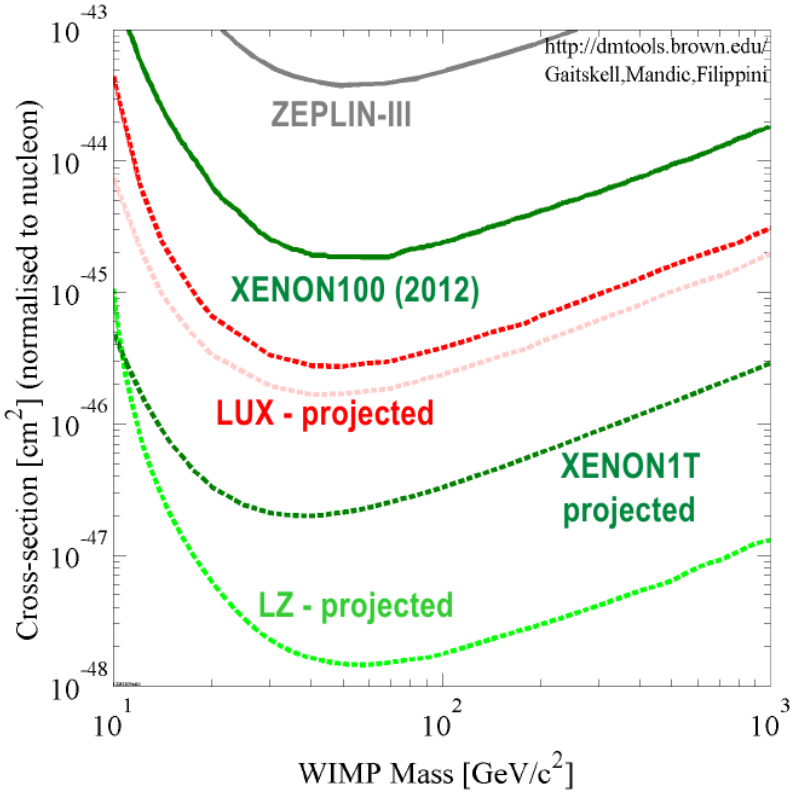
WIMP hunting : DEAP/CLEAN



Ultimate WIMP facilities: DARWIN, LZ, ...

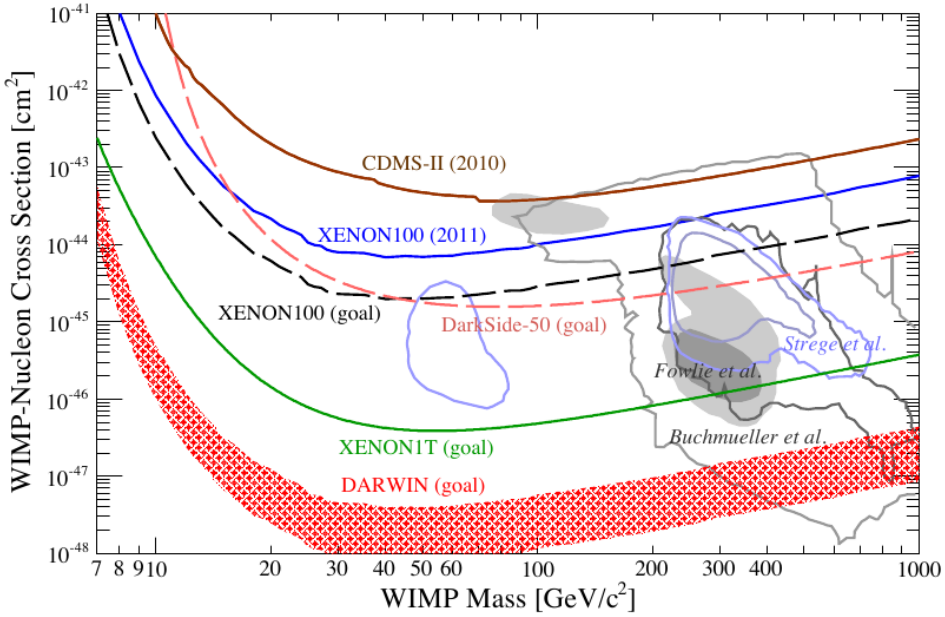
Beyond LUX : LZ = LUX + ZEPLIN

- 7 tons of LXe (6tons fiducial)
- 500 3” PMTs (@1 mBq level)
- liquid scintillator veto
- construction 2015 - 2016
- operation 2016 – 2019...

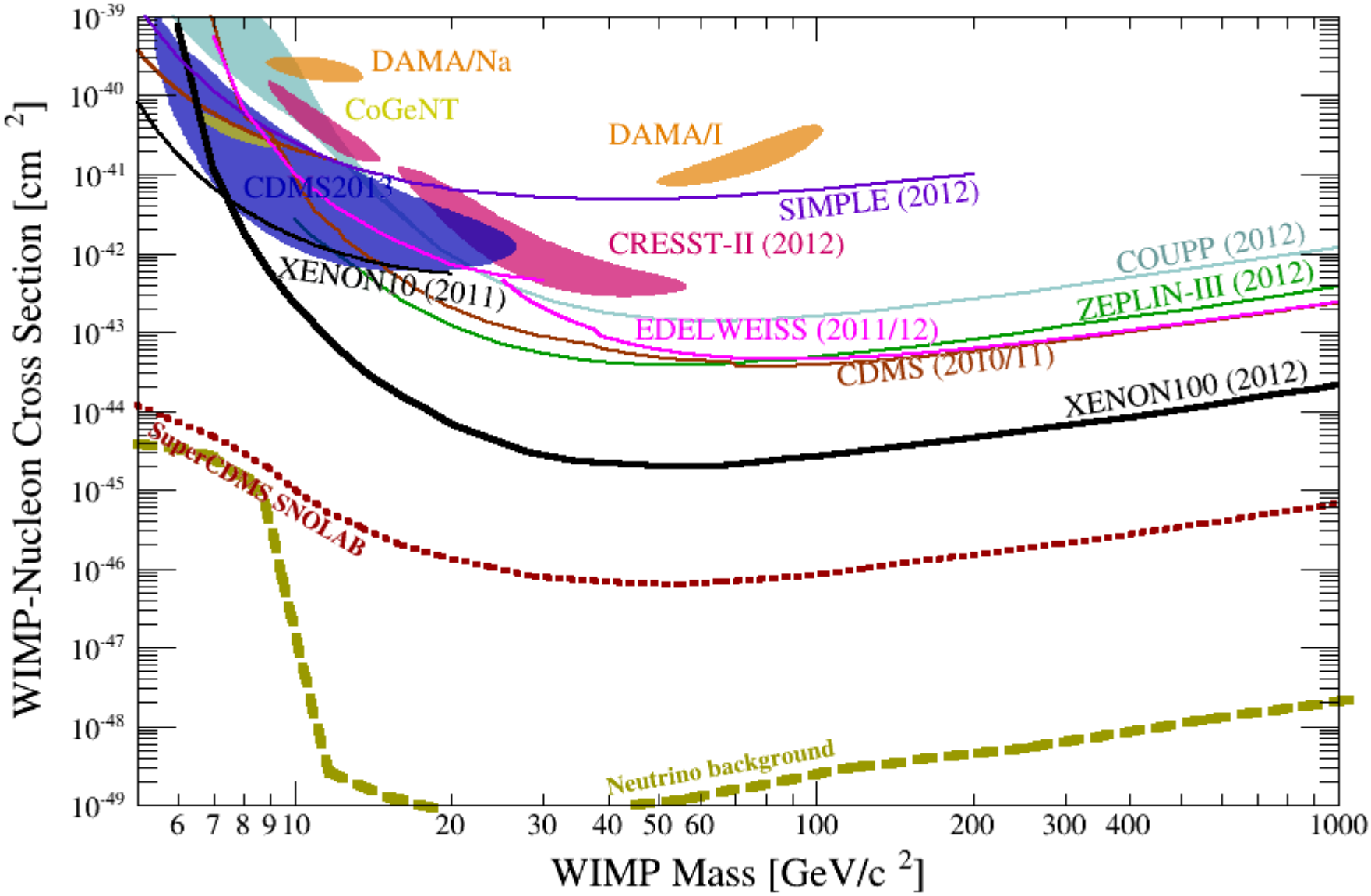


Beyond XENON and DarkSide : DARWIN

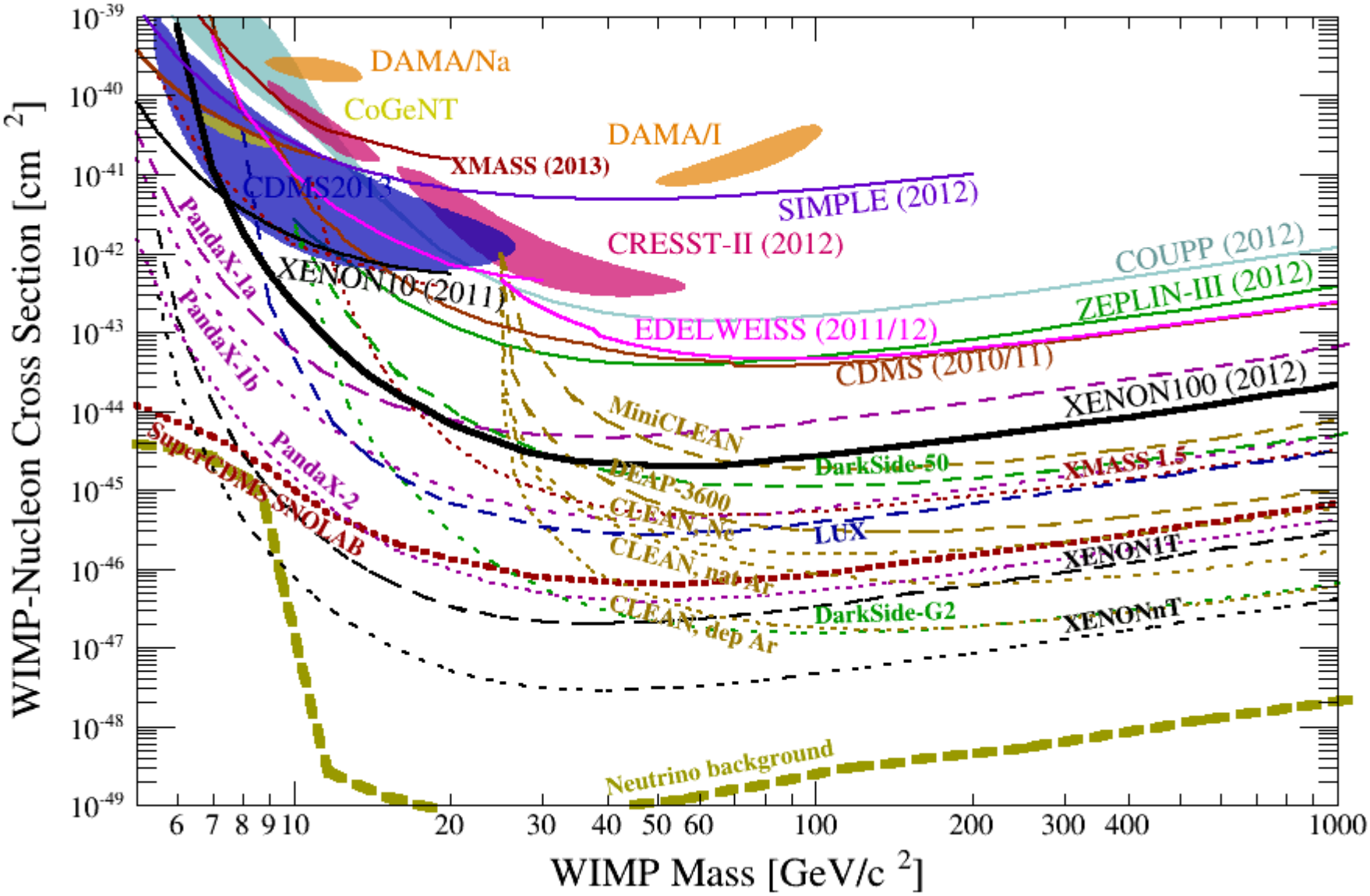
- Baseline scenario:
  → 20 t (10 t) total (fiducial) LAr/LXe mass
- Supported by ASPERA



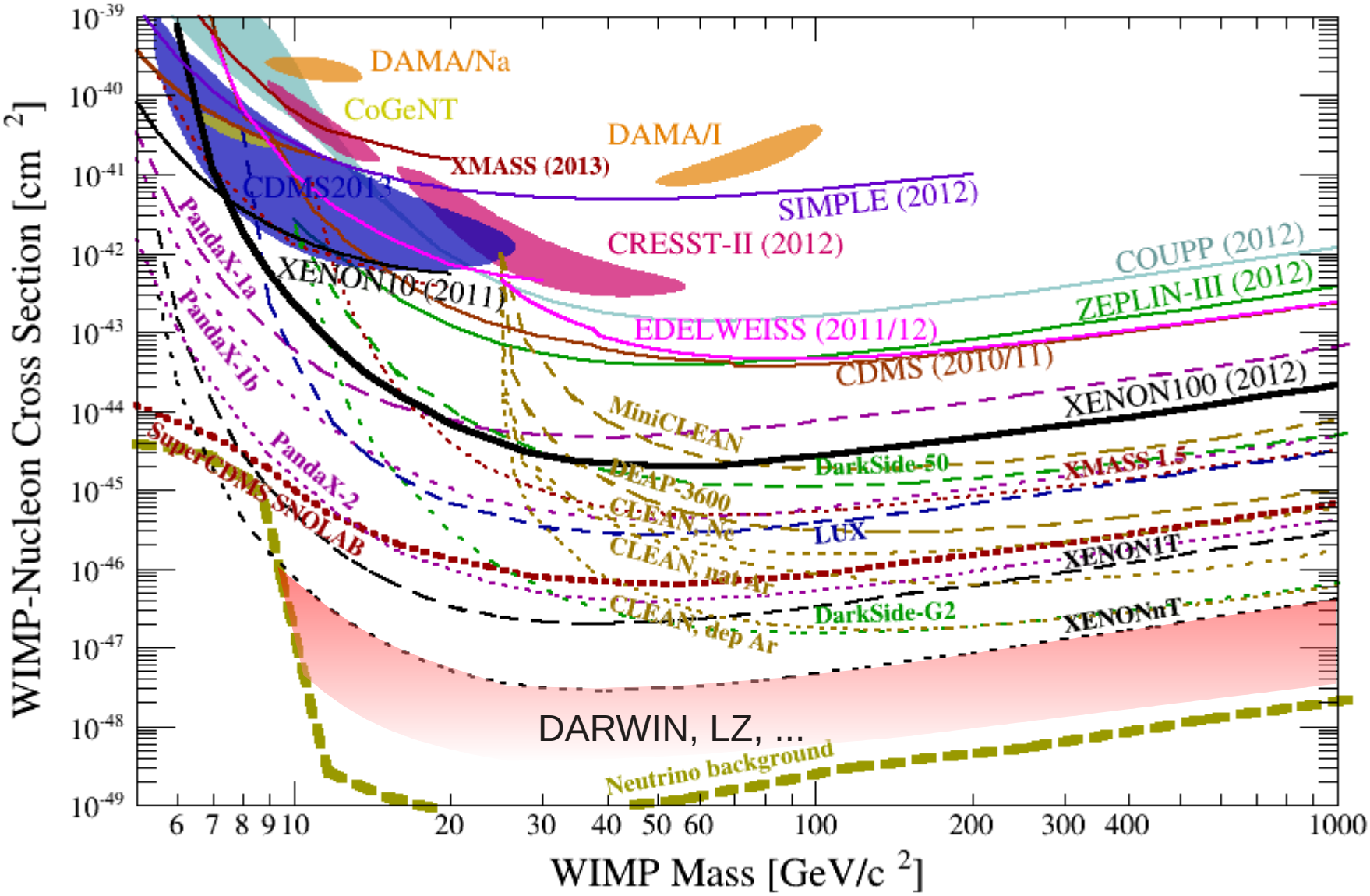
WIMP hunting...



WIMP hunting : huge activity and competition within next decade . . .



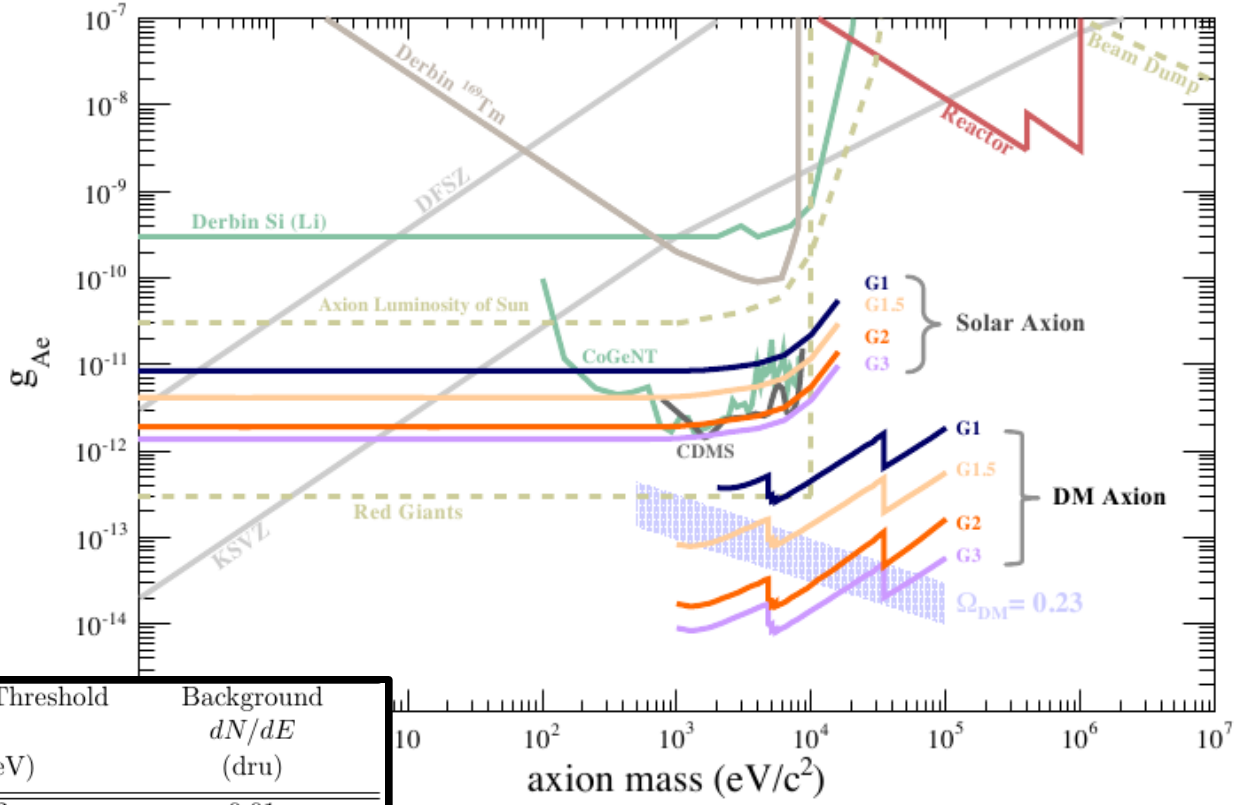
WIMP hunting : ultimate detectors?



Search for axions with present and future liquid xenon detectors

- Search for the existence of axions or axions-like-particles (ALPs) through their coupling to electrons g_{Ae} (axio-electric effect)
- Dual phase xenon TPCs have good potentiality for this search, as described in:
  K. Arisaka et al. Astropart.Phys. 44 (2013) 59-67

The potentiality of four LXe detector generations are studied, with different target masses and with an assumed level of expected background



		Weight W (kg)	Live Time T (years)	Resolution b ($\sqrt{\text{keV}}$)	Energy Threshold (keV)	Background dN/dE (dru)
G1	XENON100	34	$\frac{1}{2}$	0.6	2	0.01
G1.5	LUX/XMASS	100	1	0.4	1	5×10^{-4}
G2	XENON1T	1000	2	0.4	1	$(1.4+.07\text{E}) \times 10^{-5*}$
G3	XAX	10000	2	0.4	1	$1.4 \times 10^{-5\dagger}$

Summarising

Liquid noble gas detectors currently dominate the field
on direct dark matter searches (XENON100)

About 7 Collaborations are presently engaged in 7 long term LXe and LAr projects

Most of the projects are based on scalable detectors with increasing sensitivity.
For all of them, the technology is mature and the background sources are taken under control

Very few “ultimate” WIMP detectors (i.e. close to the neutrino background limit) are planned