XENON – Status and results

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Department of Particle Physics & AstroPhysics

On behalf of the XENON collaboration

IceCube Particle Astrophysics Symposium 2015
Madison, Wisconsin

The XENON Collaboration

~120 scientists from 19 institutions:

Columbia | RPI | Nikhef | Mainz | Stockholm | Muenster

Chicago

MPIK

UCLA

Bern

Rice

Zurich

Purdue | Coimbra | Subatech | Bologna | LNGS | Torino | Weizmann | NYUAD

The XENON Collaboration

~120 scientists from 19 institutions:


LNGS: Laboratori Nazionali
del Gran Sasso
Assergi

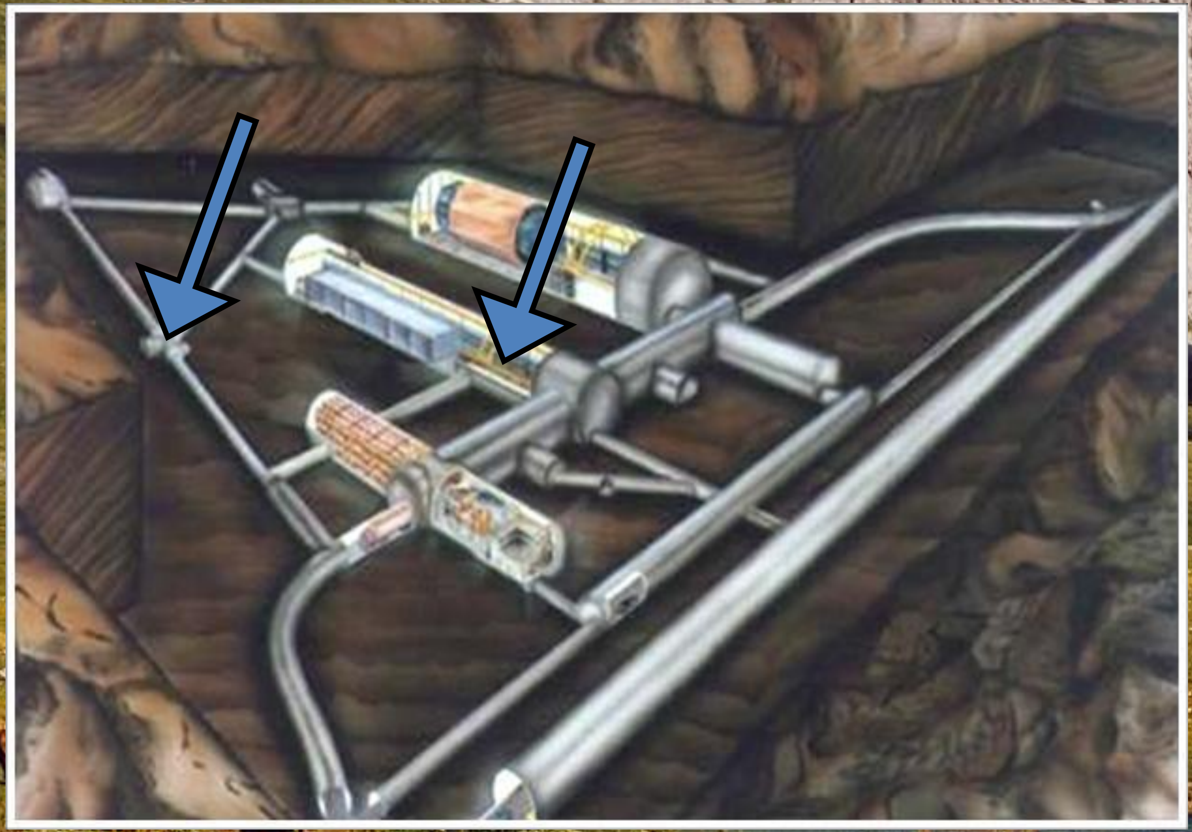

PLATFORM 9 3/4


STOP

Gran sasso laboratory

LNGS

1.4 km of rocks:
3.6 km water equiv



The Xenon Program

Direct dark matter search

PAST
(2005-2007)

XENON10

25 Kg

15 cm drift

(2007) σ_{SI} <
8.8 x 10^{-44} cm^2

PRESENT
(2008-2015)

XENON100

161 Kg

30 cm drift

(2012) σ_{SI} <
2 x 10^{-45} cm^2

Just around the corner
(2012-2017)

XENON1T

3300 Kg

100 cm drift

Proj. (2017) σ_{SI} <
2 x 10^{-47} cm^2

FUTURE
(2018-2022)

XENONnT

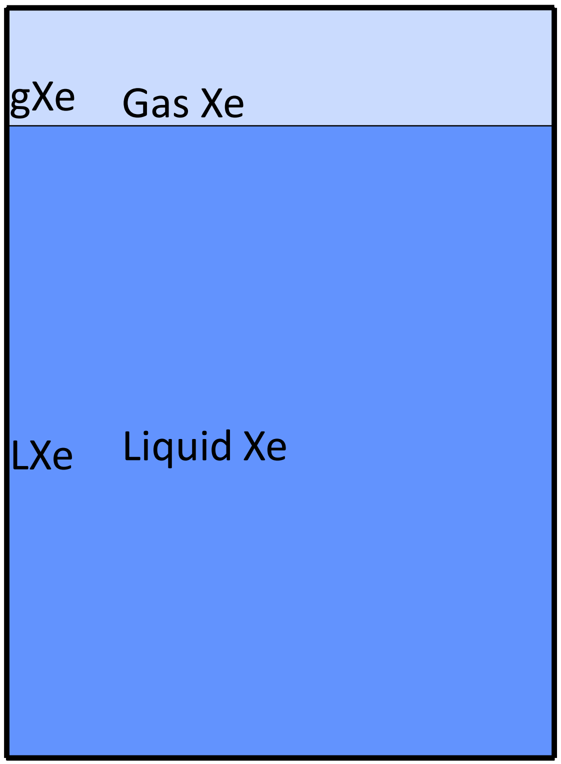
7000 Kg

100 cm drift

Proj. (2022) σ_{SI} <
2 x 10^{-48} cm^2

XENON 100 Detector

Detection volume



Dual phase Time Projection Chamber (TPC)

30 cm height, 30 cm diameter

62 Kg of Liquid Xenon inside TPC

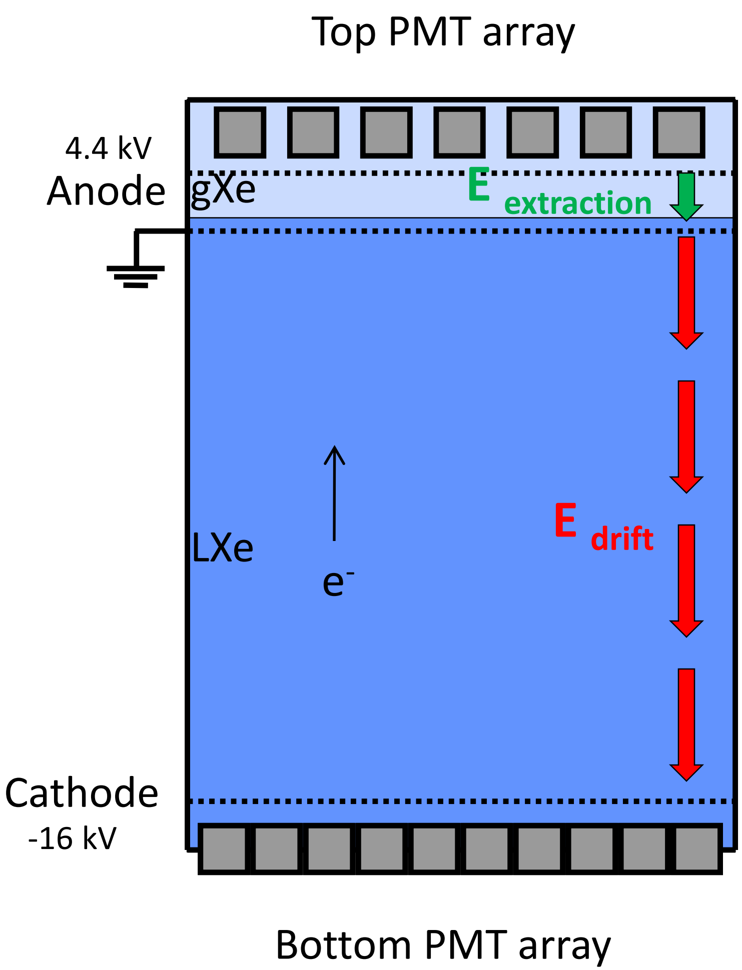
- high Z=54 , high density ρ=2.83 kg/l, large A
- Odd-nucleon isotopes: high A=131 with

  ~50% of odd isotopes. Good for SD*.

- “Easy” cryogenics: ~-90 °C
- Charge & light: highest yield among the noble liquids

** SD=Spin Dependent*

XENON 100 Detector
Electric Fields & PMT Arrays



$E_{extraction}$ = ~12 kV/cm.

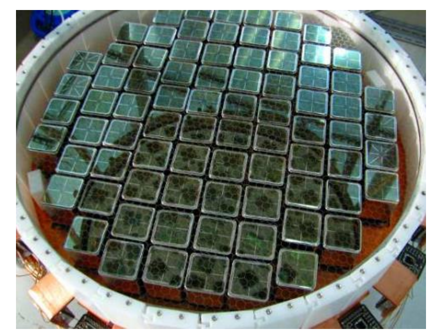
E_{drift} = 0.53 kV/cm.

242 PMTs (R8520)
1-inch x 1-inch

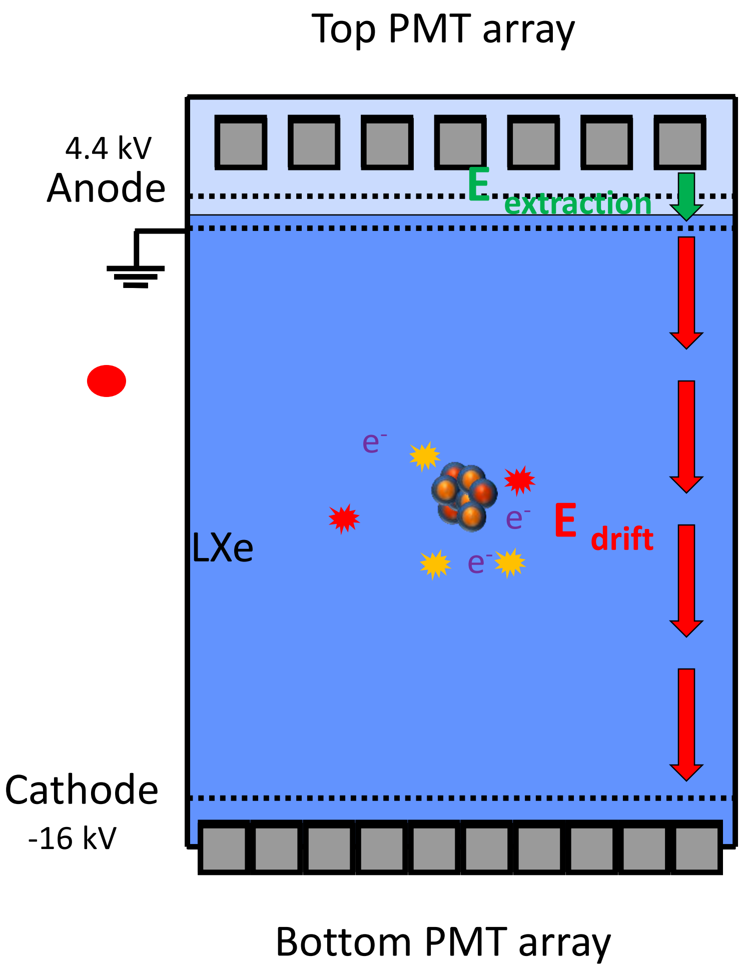
- Top array: 98 PMTs
- Bottom array: 80 PMTs
- Lxe Veto: 64 PMTs

Gain 2E6 (/pm 10%)
Top array (QE~23%).
Bottom array (QE~33%).

-

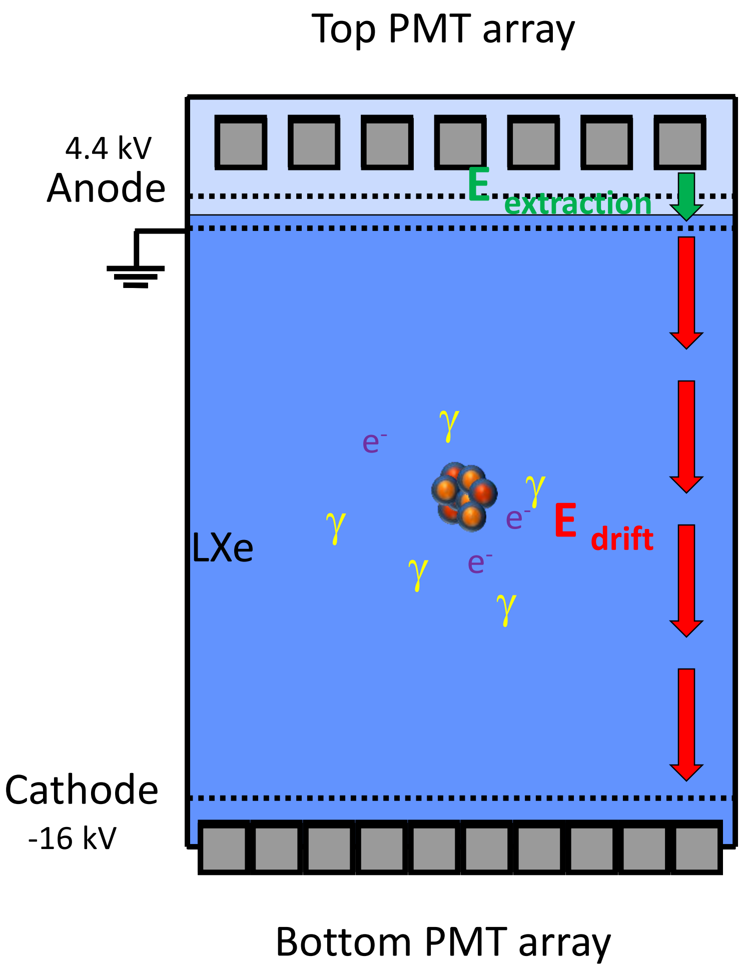


Detection Principle



- Electron or Nuclear recoils
- Prompt scintillation signal from atomic excitation “S1”
- Ionized Electrons drifts upward and electro-luminescent the gas “S2”
- Depending on the ion density (dE/dX) electrons can recombine: S2 decreases, S1 increases
  more likely to happen in Nuclear recoils

Detection Principle



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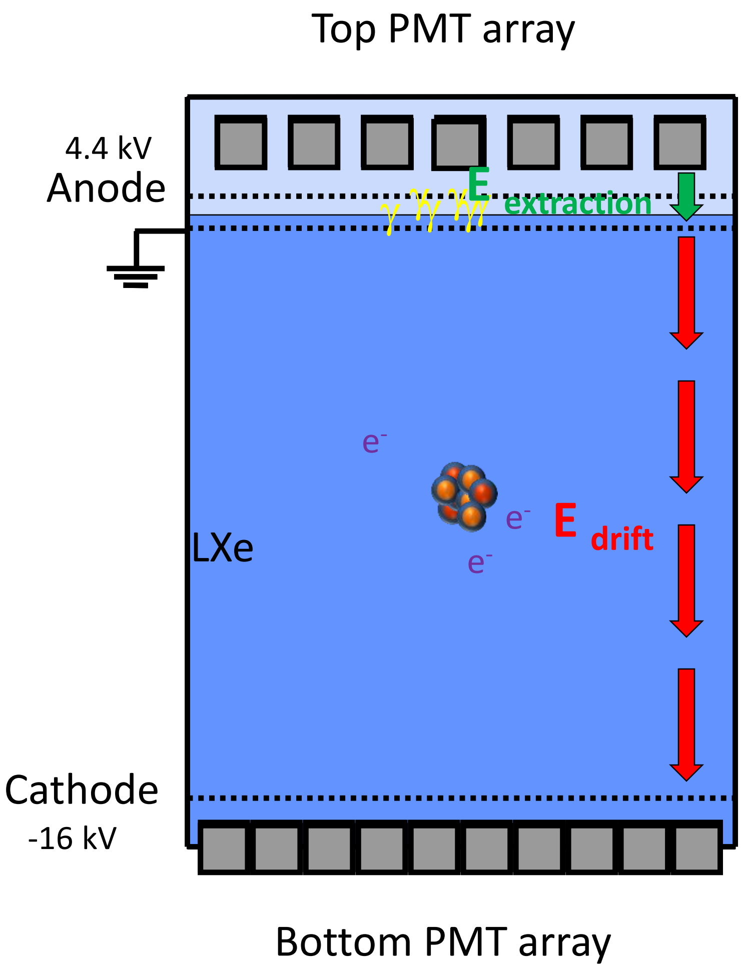

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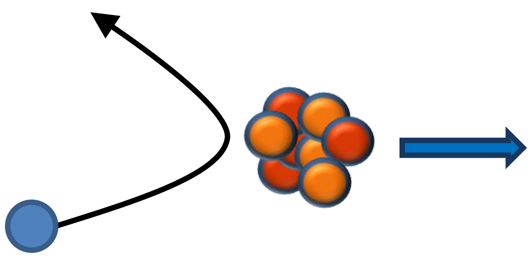
Detection Principle
Type of Recoil

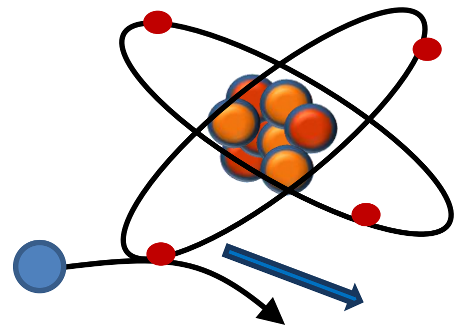
The recombination probability depends on dE/dX

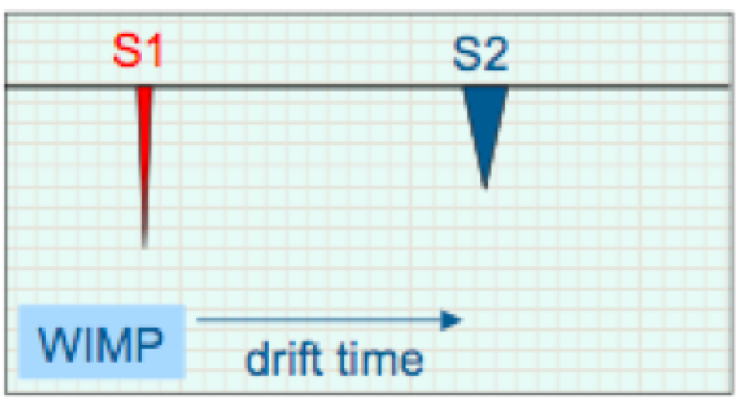
$$(S2/S1)_{n,WIMP} < (S2/S1)_{e,\gamma}$$

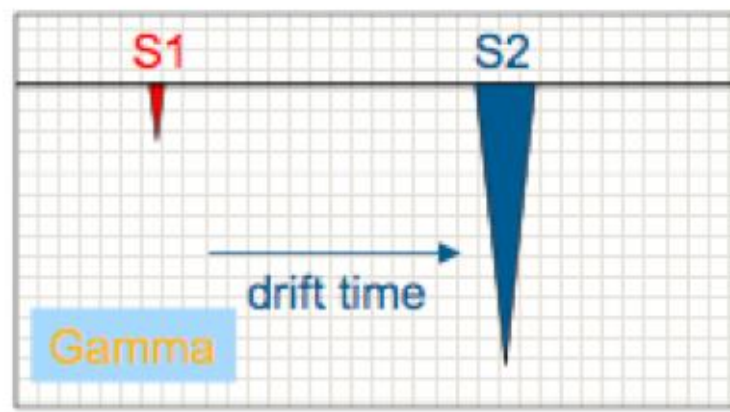
nuclear recoils

e.m. scattering off atomic shell

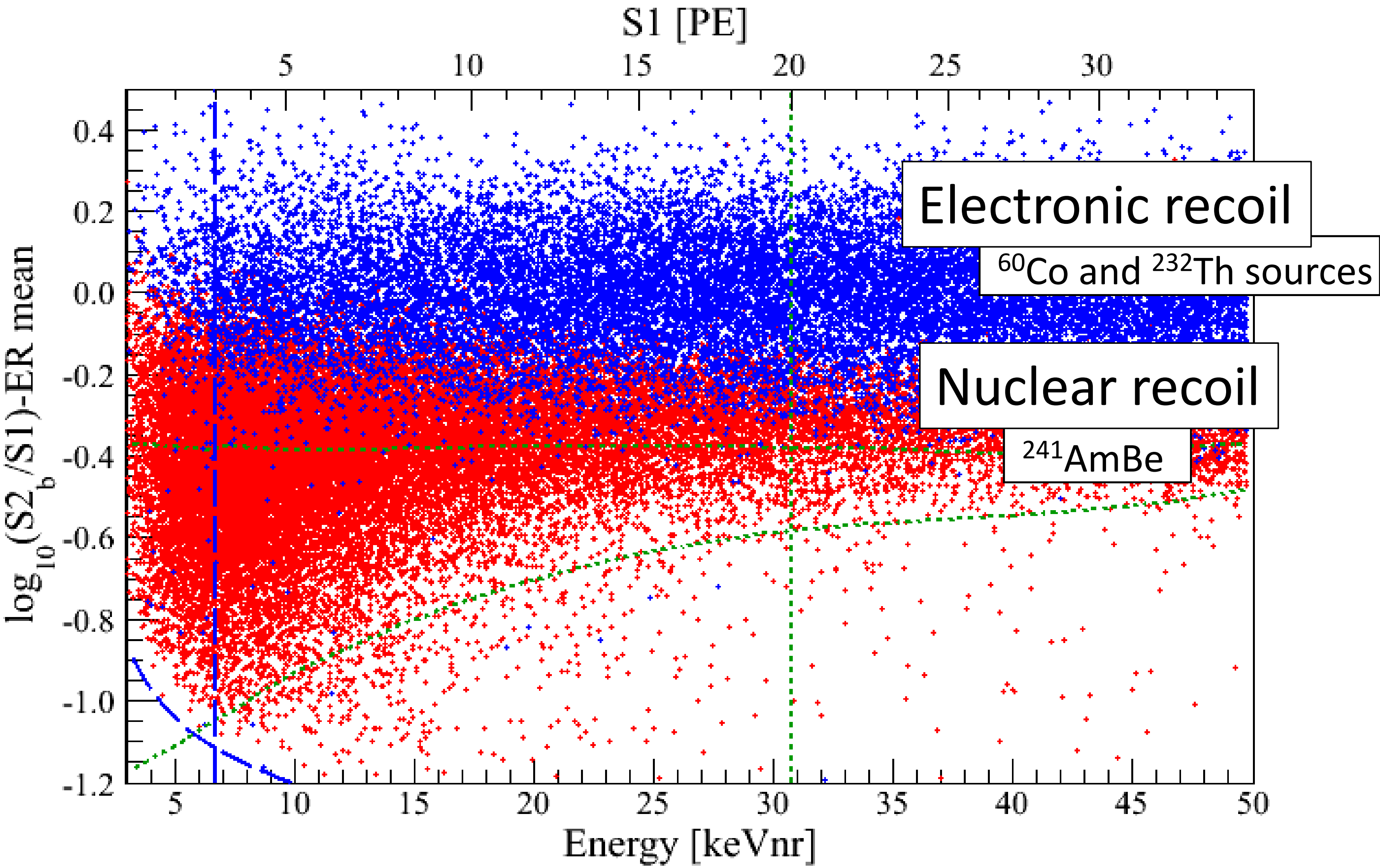








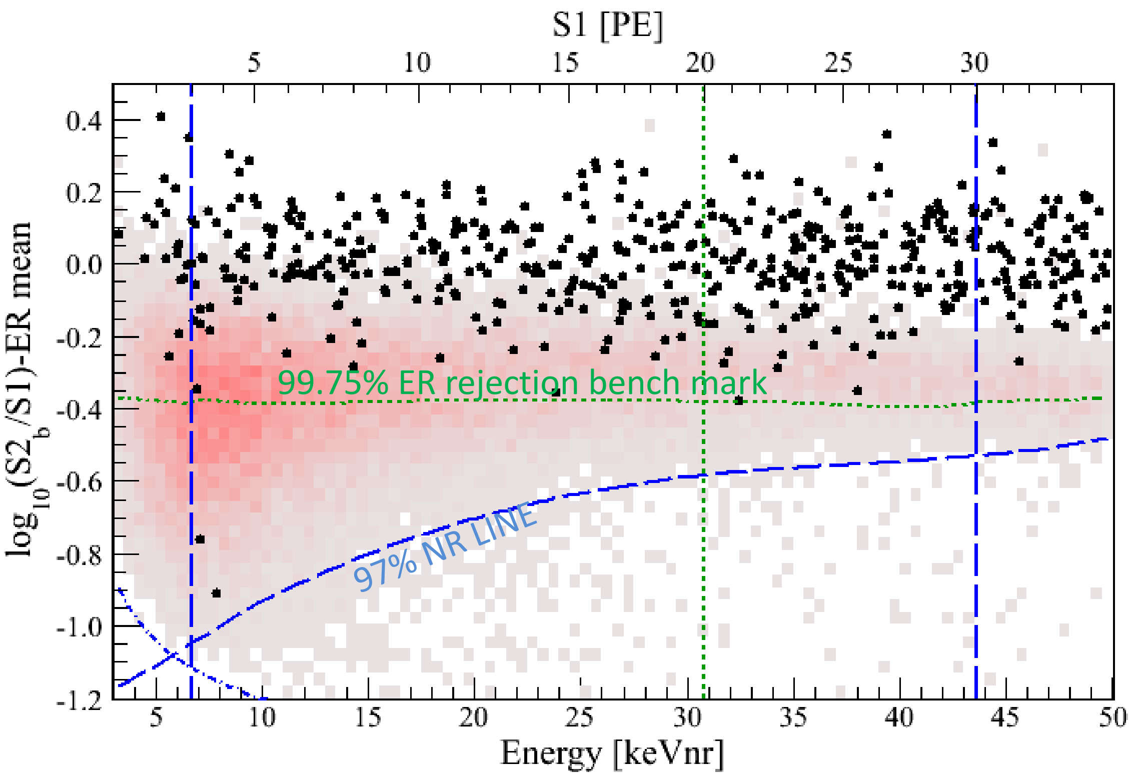
Detection Principle
Calibration runs



What do we learn from a TPC event?
Illustrated by XENON100 2011/2012 data set
225 Live days

- Event epoch time
- Energy scale
  see horizontal axis
- ER vs. NR (S1/S2)
- Vertex reconstruction
  - Fiducialization
  - Single scatter vs. Multiple scatters
- Slow control

Phys. Rev. Lett. 109,181301 (2012)



Points – Measured events
Red/Gray – Neutron calib band

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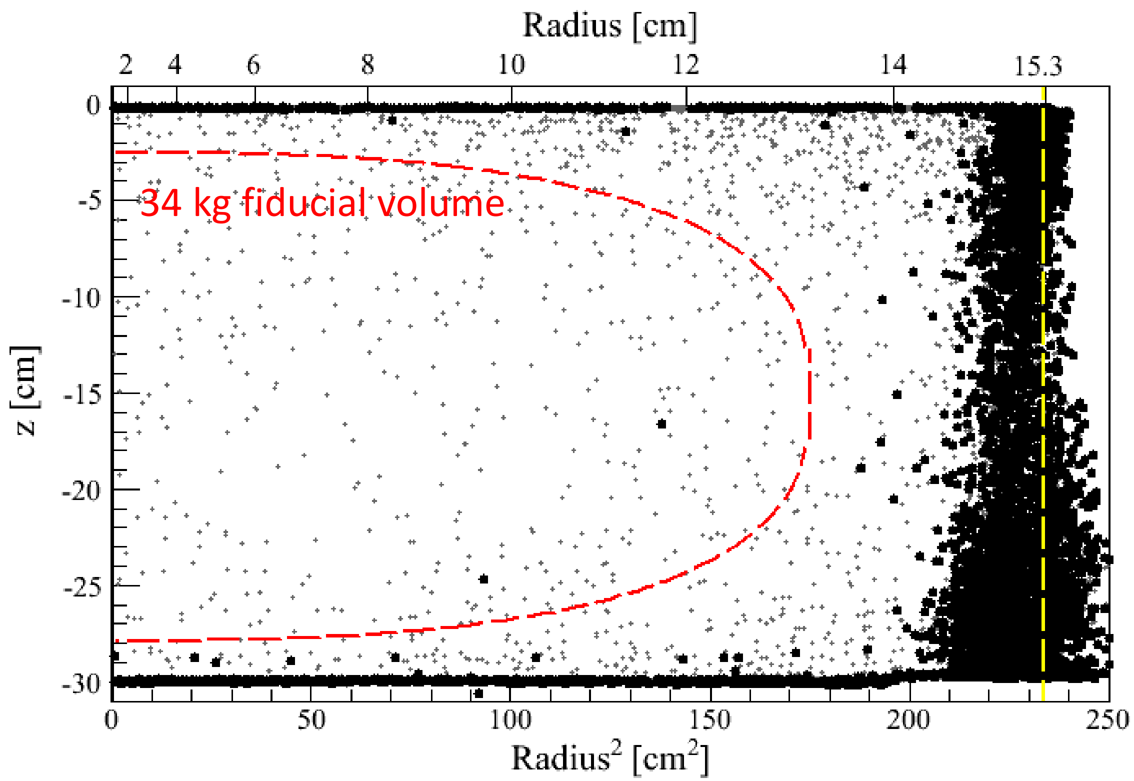


Points – Measured events

Bold – below 99.75 ER line (likely to be NR)

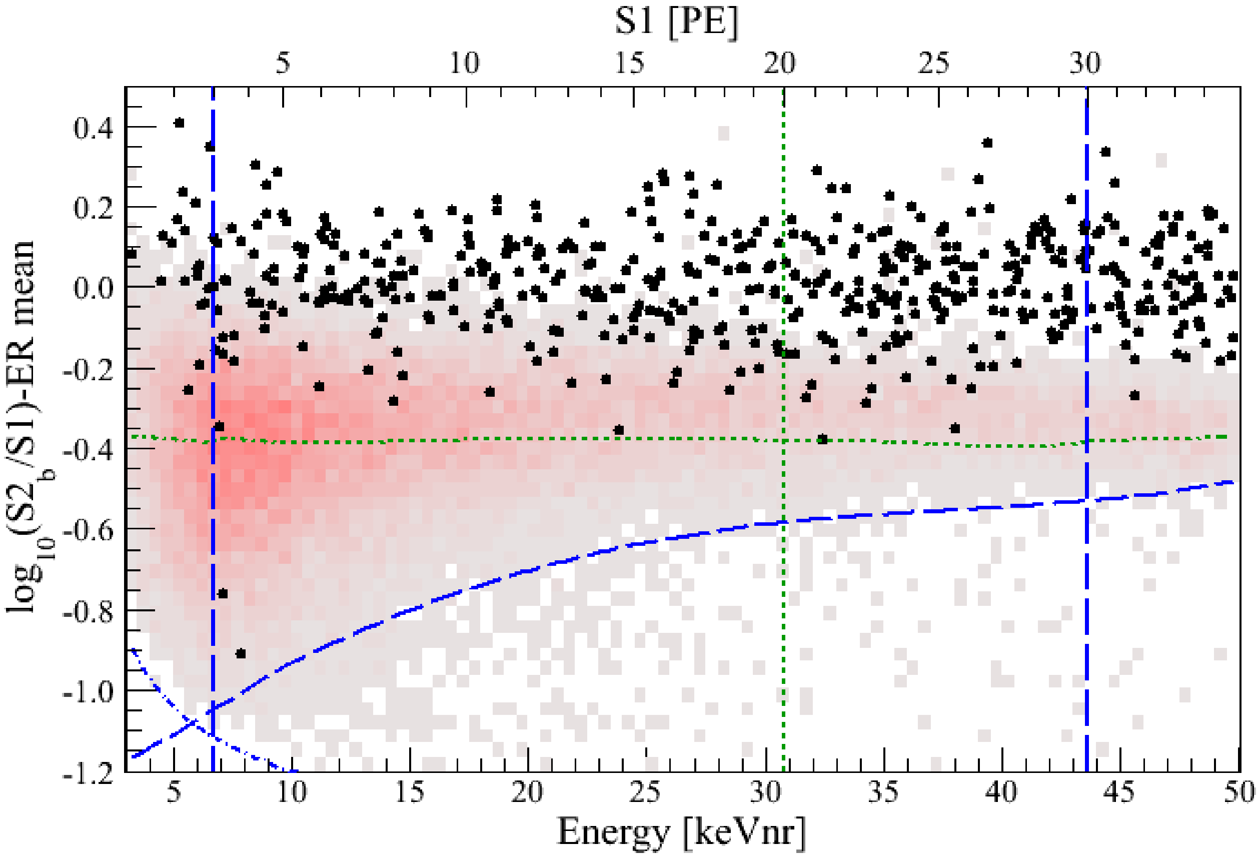
dots – above 99.75 ER line (likely to be ER)

Phys. Rev. Lett. 109,181301 (2012)

Data Analysis
Cut based Vs. Likelihood

Option 1:Cut based analysis

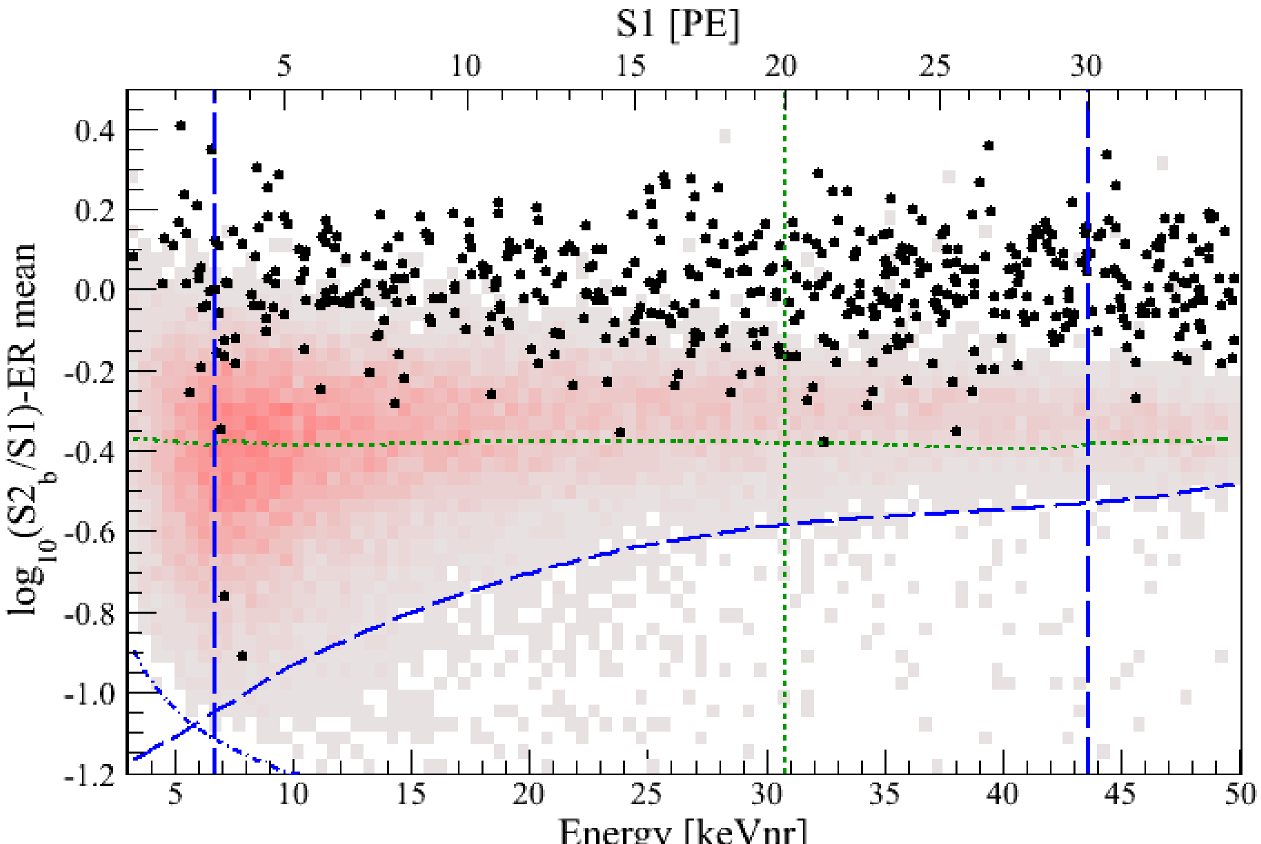
We see "2 bench mark events observed with 1 +/- 0.2 events expected"



Data Analysis
Cut based Vs. Likelihood

Option 2: use (almost) the entire S1/S2 space

- Use calibration & simulation to predict PDFs of signal & background
- Profile out uncertainties



Data Analysis
Cut based Vs. Likelihood

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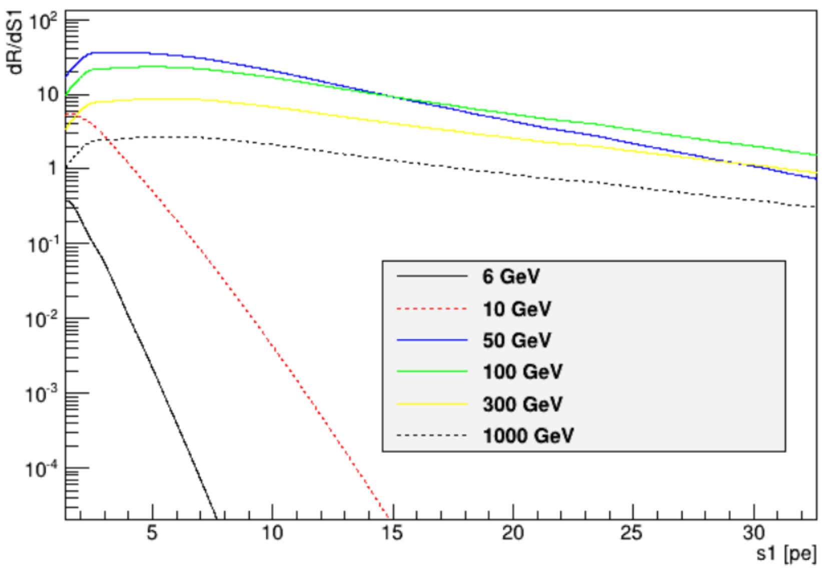
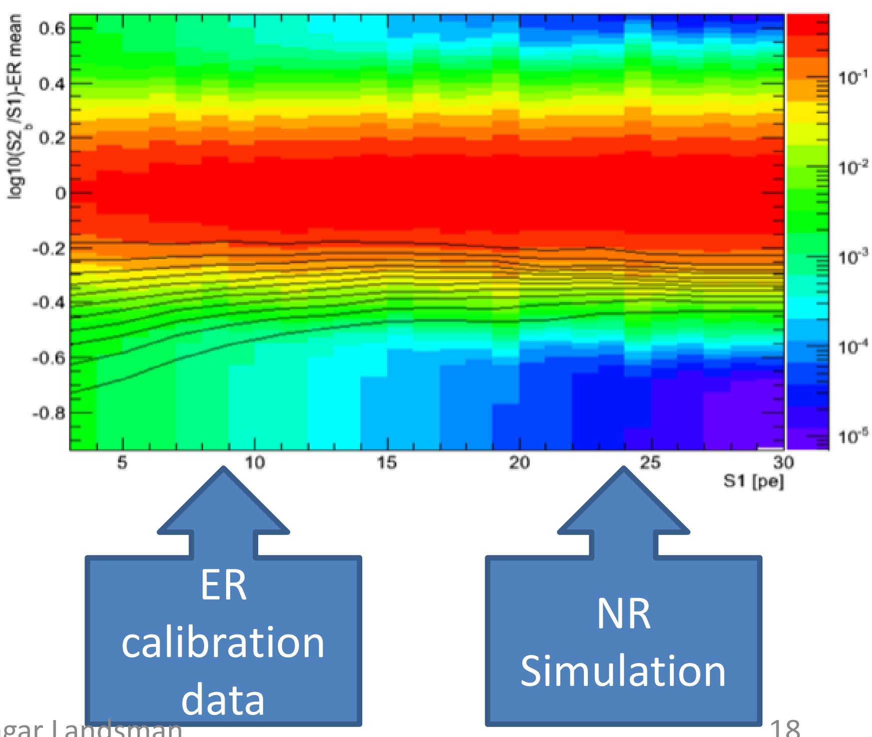
Signal model



Background model



From Int to Double
Or….Obtaining the limit

On your white board:

Choose DM Origin *Flux at detector*
e.g. mass, halo WIMPs, Solar Axions, galactic ALPs

Choose Interaction model *Event Rate*
e.g. In/Elastic, Spin in/dependent, axioelectric…..

Choose strength parameter *Your result*
e.g. Cross section, Axio-electric constant….

Rescale energy *back to reality i*
e.g. from PE to eV

Add detector effects *back to reality ii*
e.g. acceptance, deadtime, smearing, energy range….

Number of expected events in the detector

On your data:

Make data quality cuts

Make background reduction cuts

Estimate remaining background

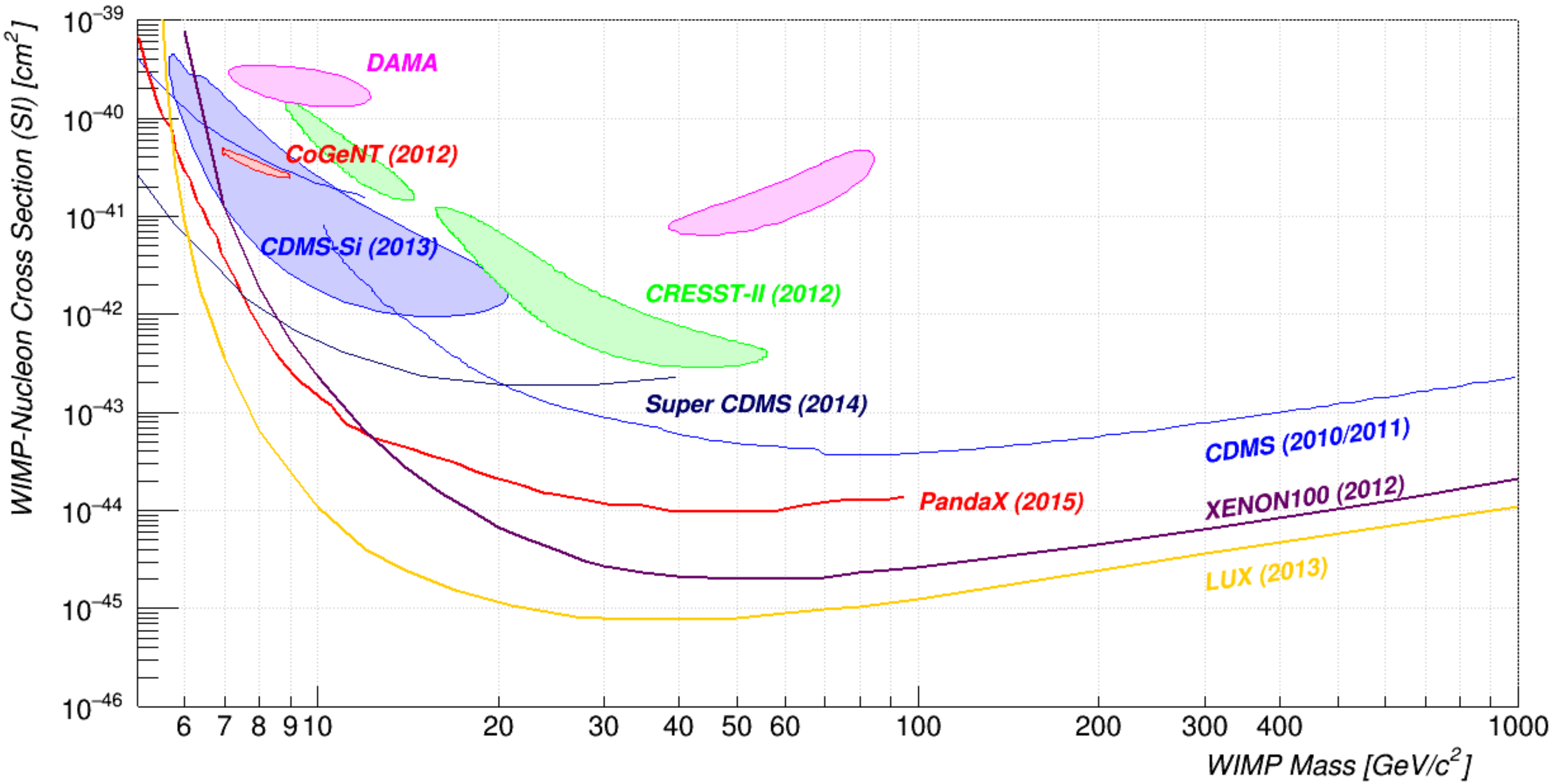
Number of observed events

Statistical inference:

Compare observed to predicted
e.g. likelihood, counting, bayesian, frequentist, nuisance parameters….

Get a limit or claim for discovery

Spin Independent Results
~6 months ago

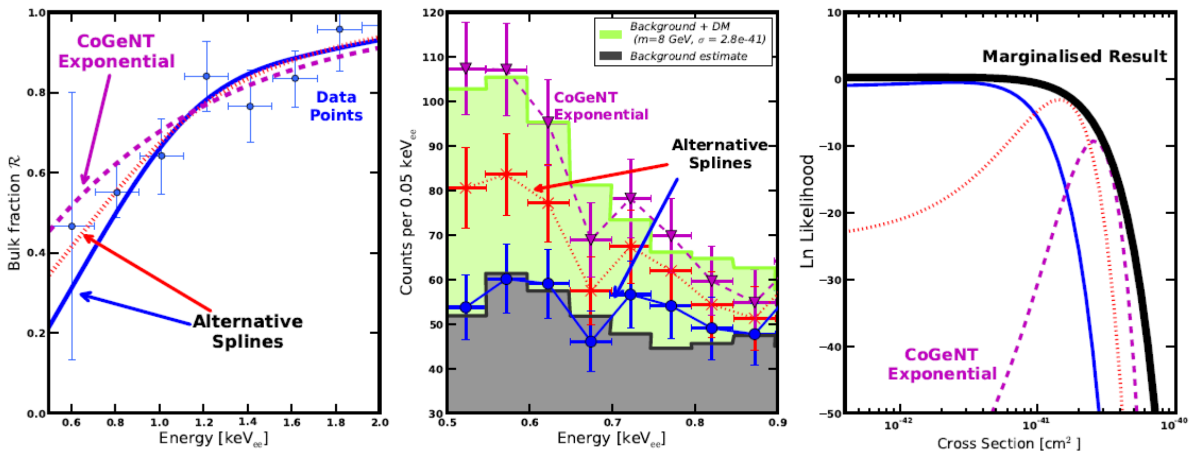


CoGeNT
Coherent Germanium Neutrino Technology

- Location: Soudan, Minnesota
- P-type Point-Contact (P-PC) Germanium crystals measure ionization charge.
- Pulse rise time to distinguish surface events (bg) from bulk (sig);
- At low energies separation is harder
- Previously reported excess of events

C.E. Aalseth et al. (CoGeNT), Phys. Rev. D 88, 012002 .(2013)

- New analysis including background model uncertainties.
 significance 1.7s and less
- Shown here work by Davis et al. Using Bayesian analysis to include bg uncertainties



C.E. Aalseth et al. (CoGeNT), arXiv:1401.6234

J. Davis, C. McCabe, C. Boehm, JCAP 1408, 014 (2014). arXiv:1405.0495

CRESST

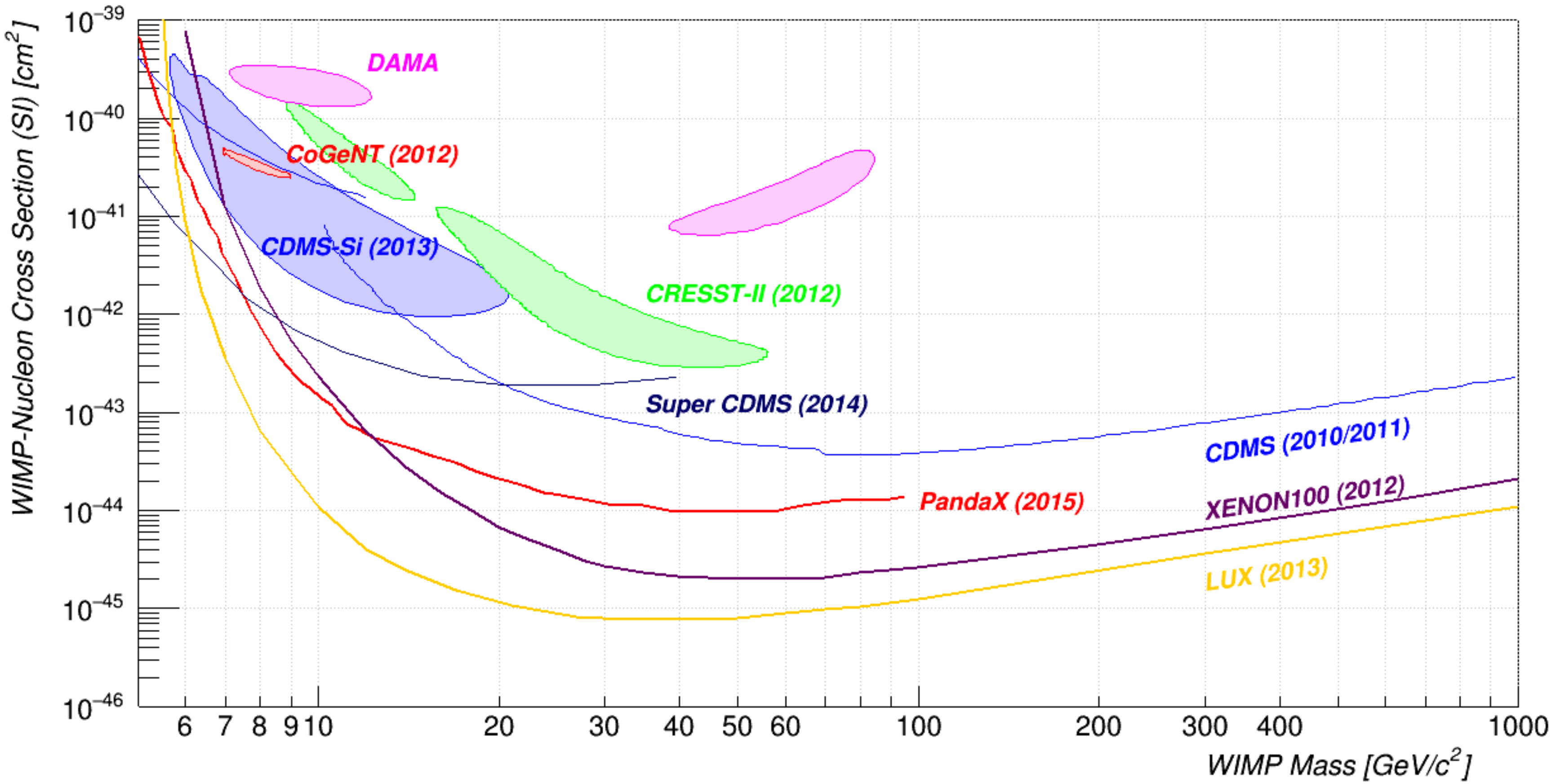
Cryogenic Rare Event Search with Superconducting Thermometers

- Location: Gran-Sasso
- Phonon/photon signals in $CaWO_4$ crystals
- 1.5-30 Gev/C2 WIMPs
- Strength: Sensitivity to low Mass wimps due to the Ca & O atoms (kink at 5 GeV/c2)
- Previously reported excess of events

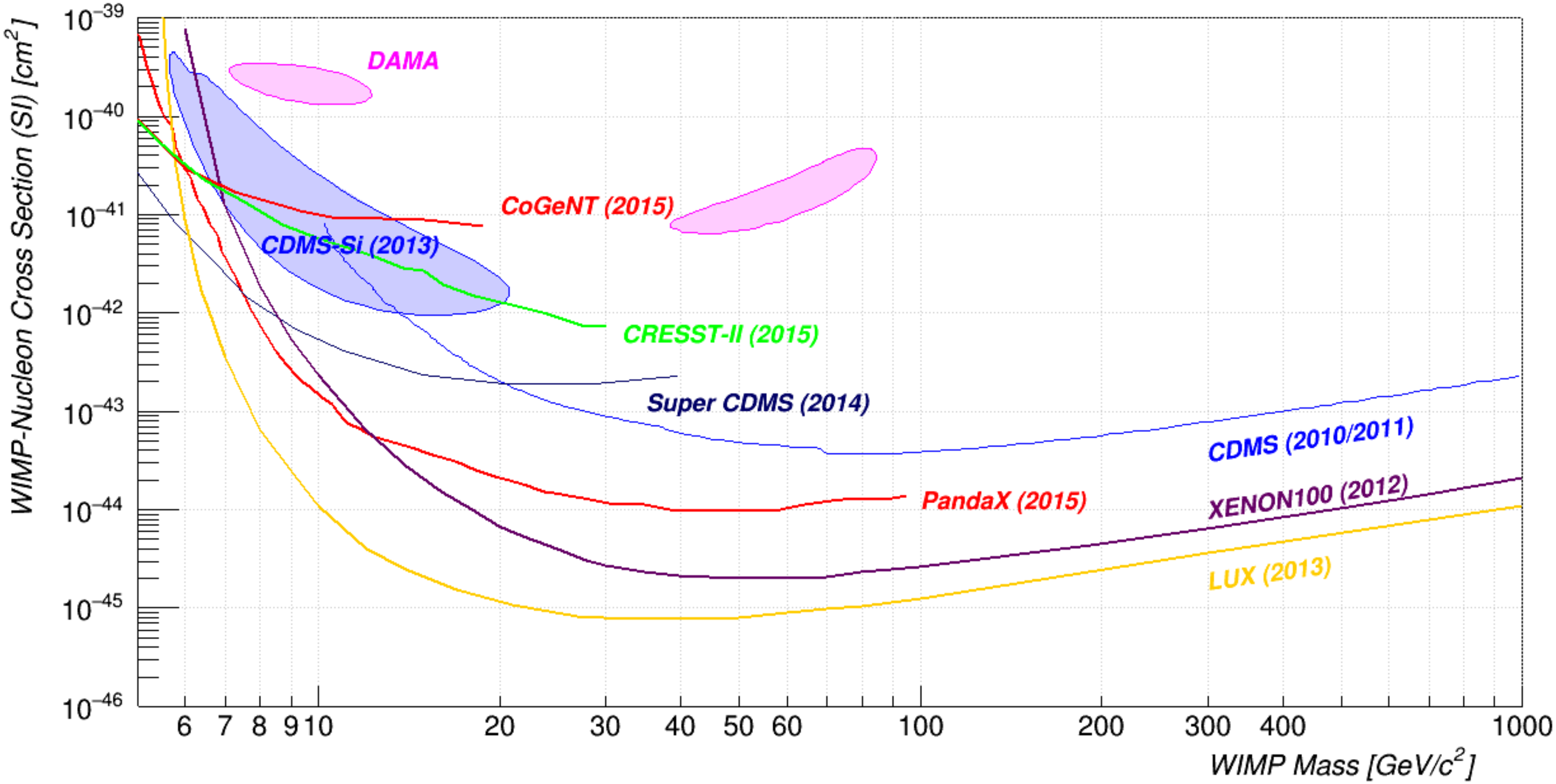
  CRESST Collaboration, G. Angloher et al., Eur. Phys. J. C 72, (2012), arXiv:1109.0702
- Lowered background rate: Clamp material, improved material selection and production control of the crystals.

  CRESST Collaboration, G. Angloher et al., Eur. Physi. J. C 74 (2014), arXiv:1407.3146v2

Spin Independent Results
~6 months ago

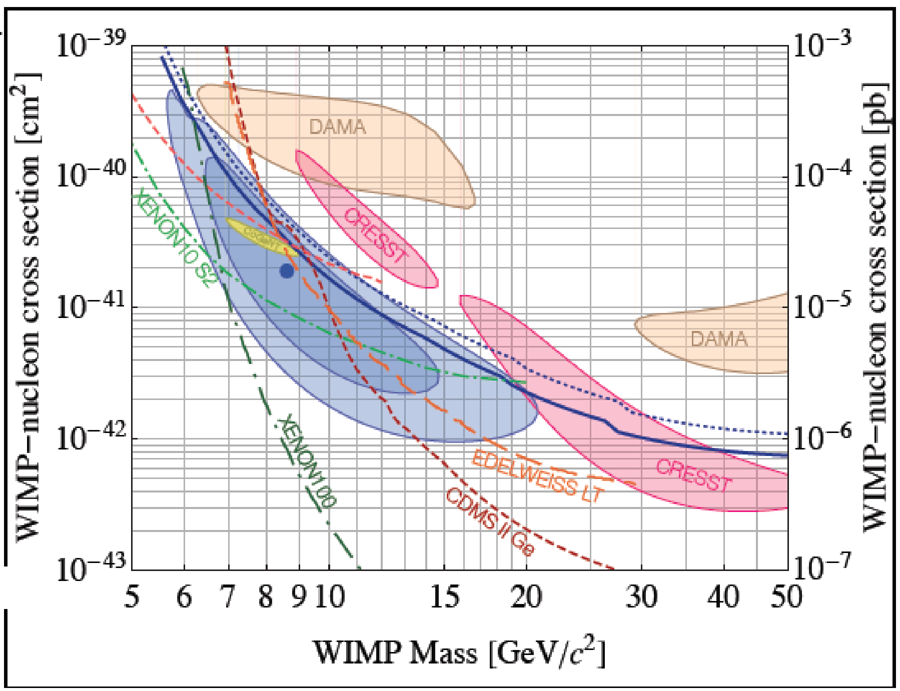


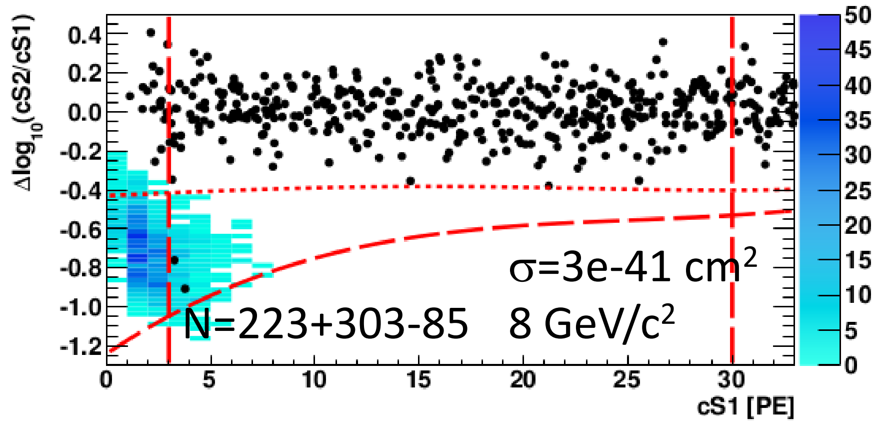
Spin Independent Results
Current Results

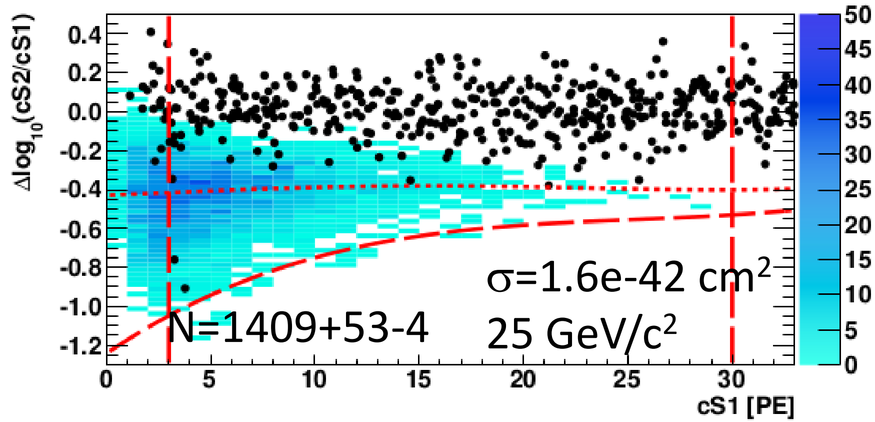


CDMS Si 2013 results
And XENON100

How would the measured signal look like in XENON100 ?

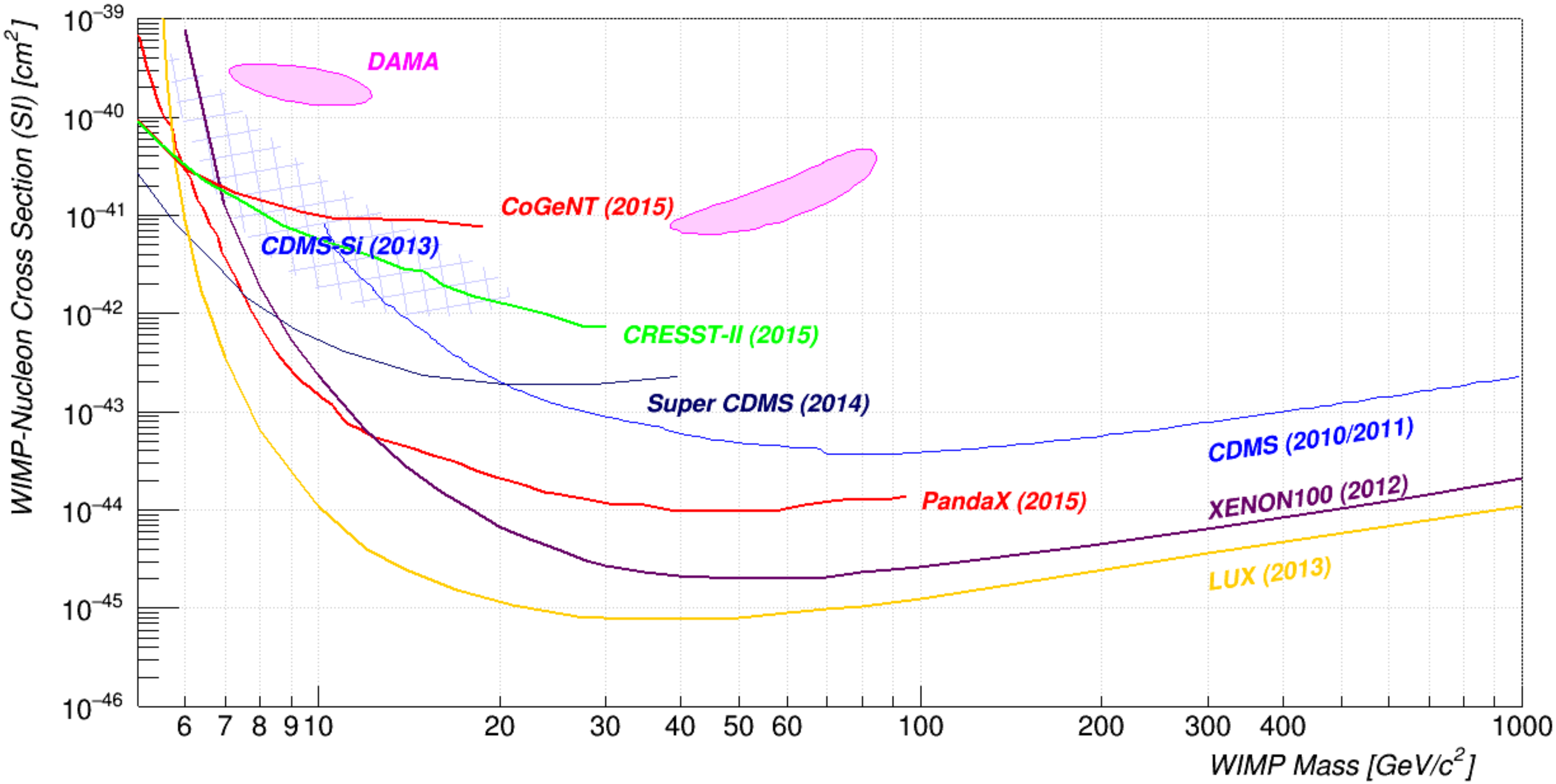




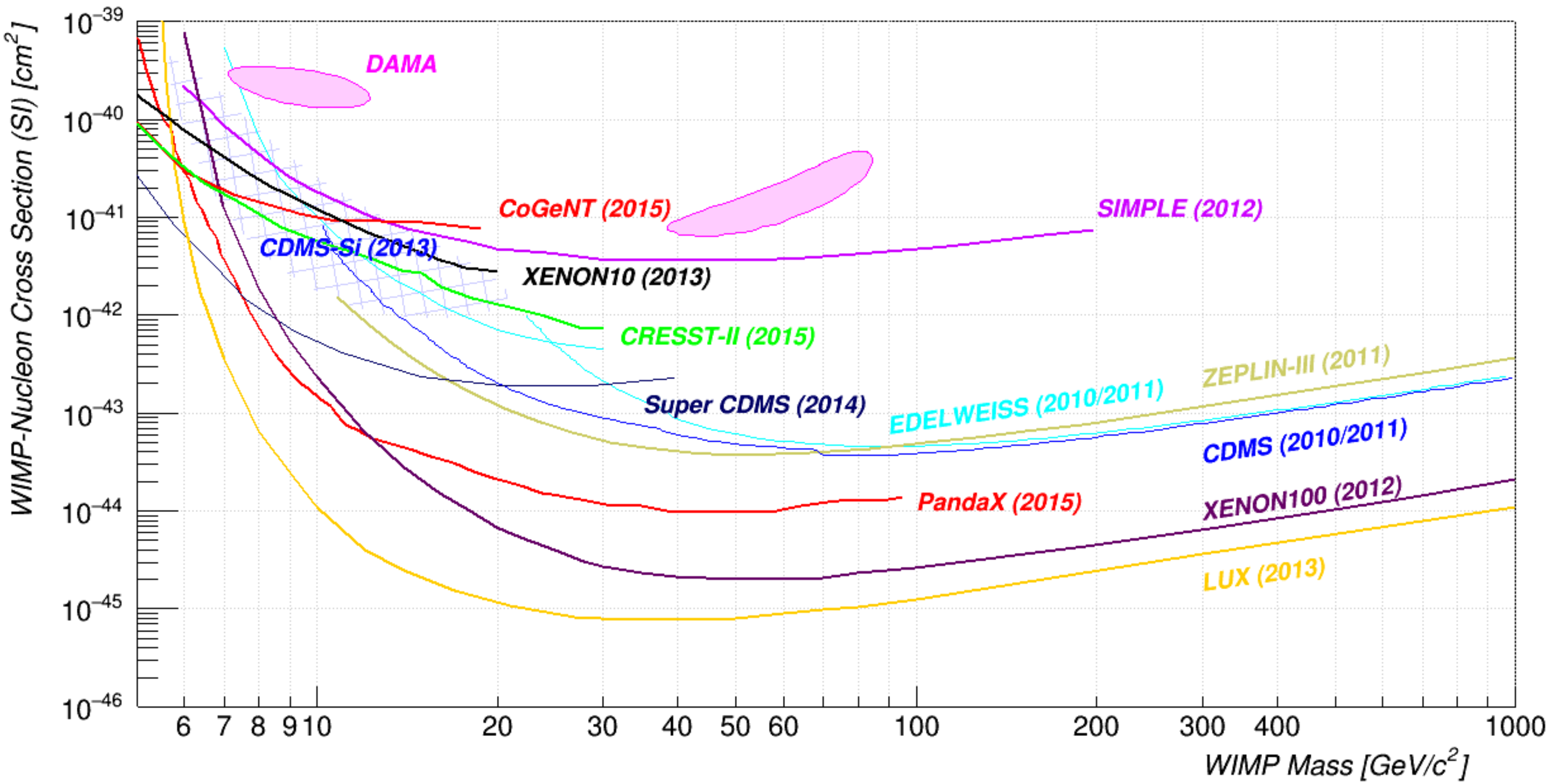


Event distribution in the discrimination space that XENON100 would observe for the CDMS best fit point

Spin Independent Results
Current Results

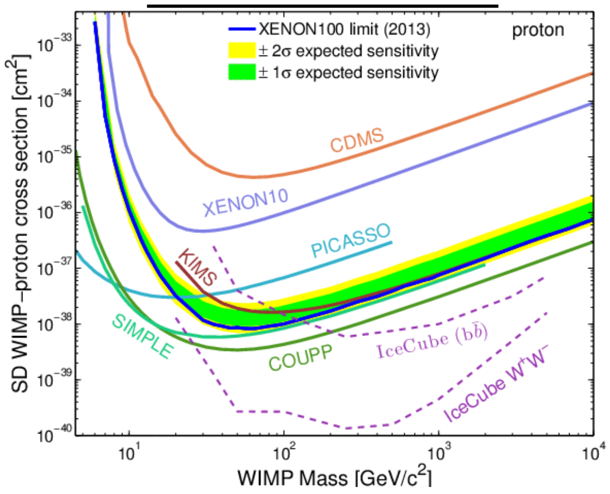


Spin Independent Results
With additional players

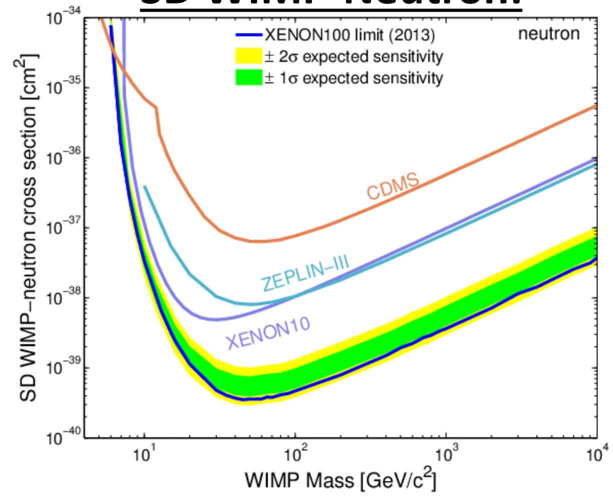


Additional models
XENON100 Results

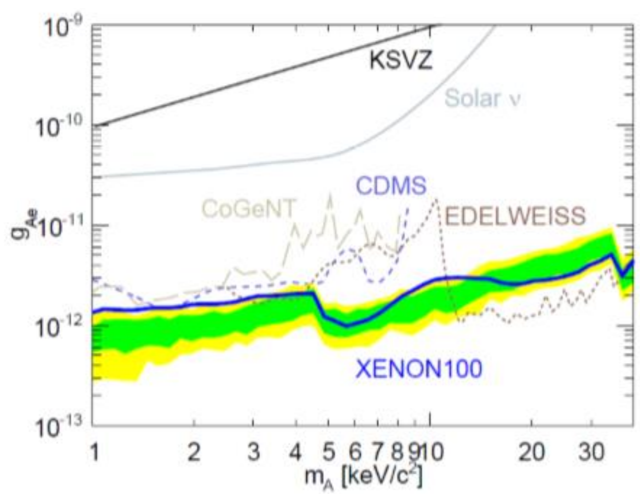
SD WIMP-Proton:



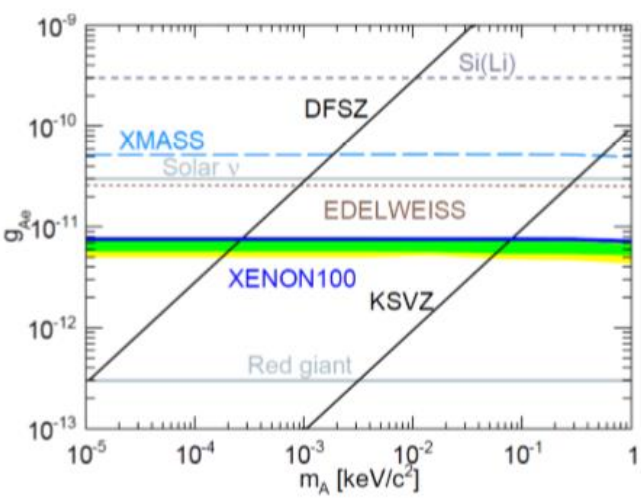
SD WIMP-Neutron:



Axion-Like DM:



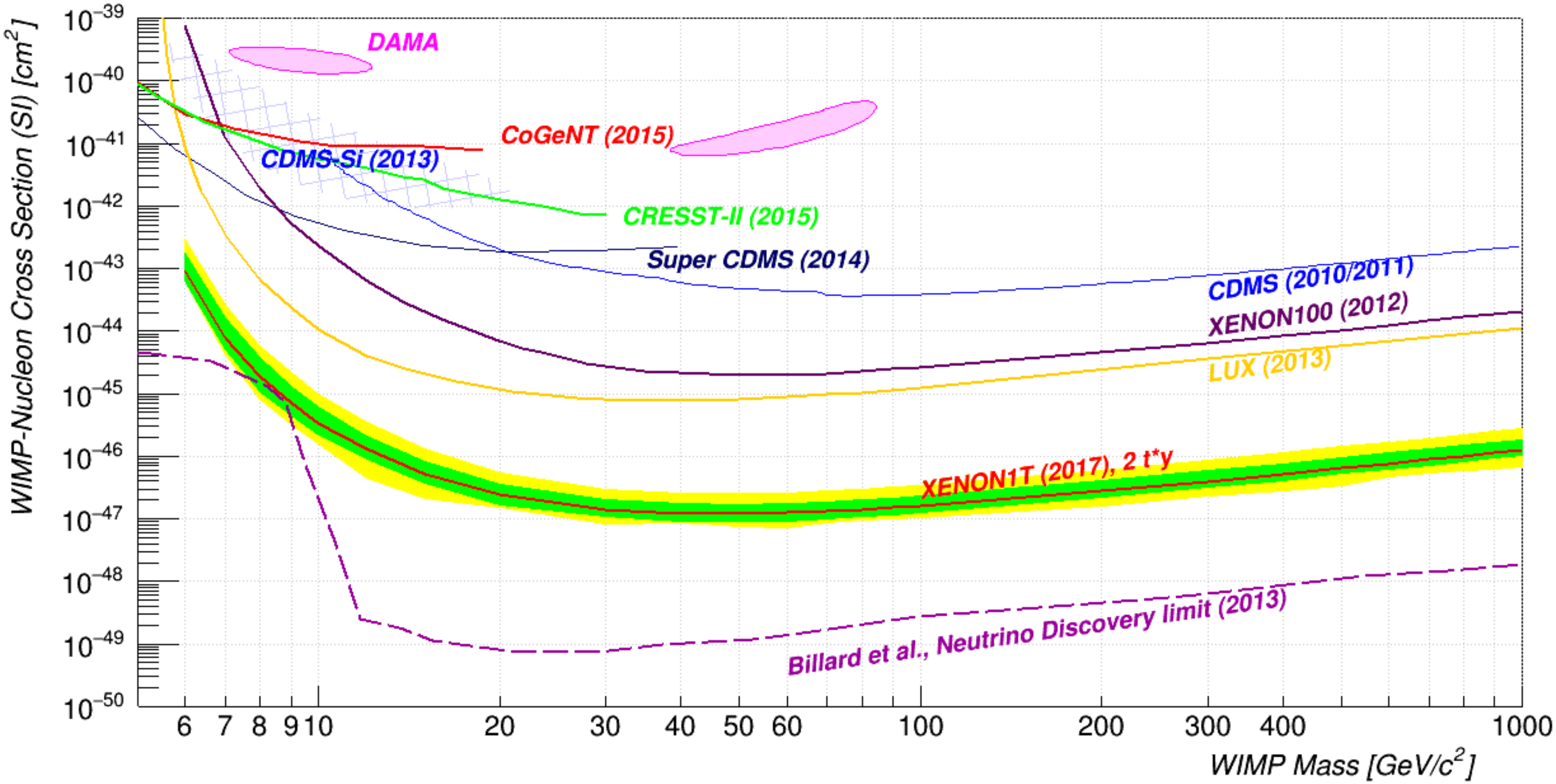
Solar Axions:



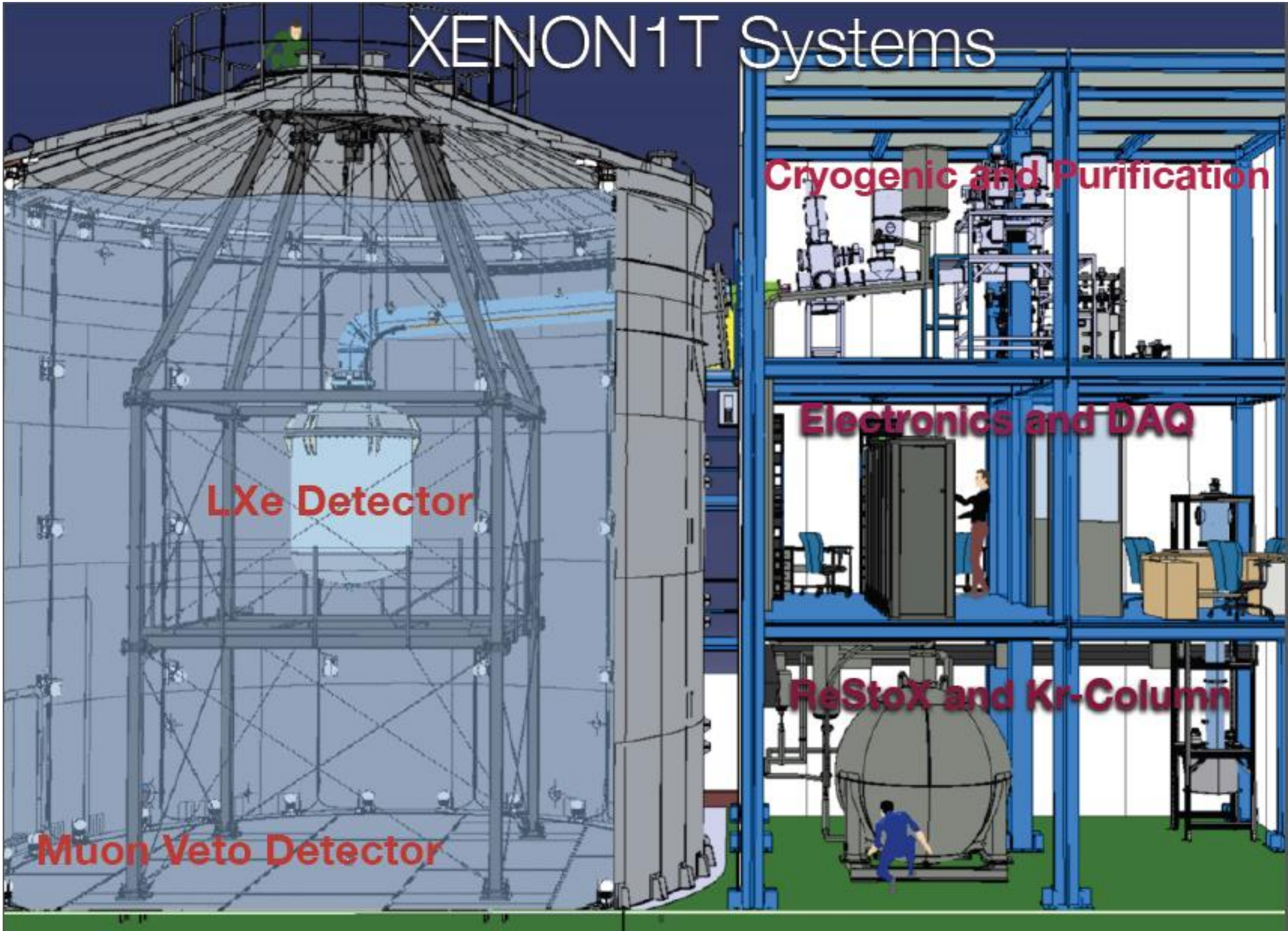
XENON1T
By the numbers

- Cost: Capital cost ~20M$ (50% from non-US groups)
- Liquid Xenon: 3.3 Tons
- # PMTs : 250 3” PMTs
- Background goal: 100 lower than XENON100: ~0.05 events/(ton*day*keV)
- Detector: 1m- drift dual-phase TPC
- Status: under Construction.
- ETA: Detector installation by Summer 2015.
  Science run by late 2015.

XENON1T Sensitivity reach
90% CLs

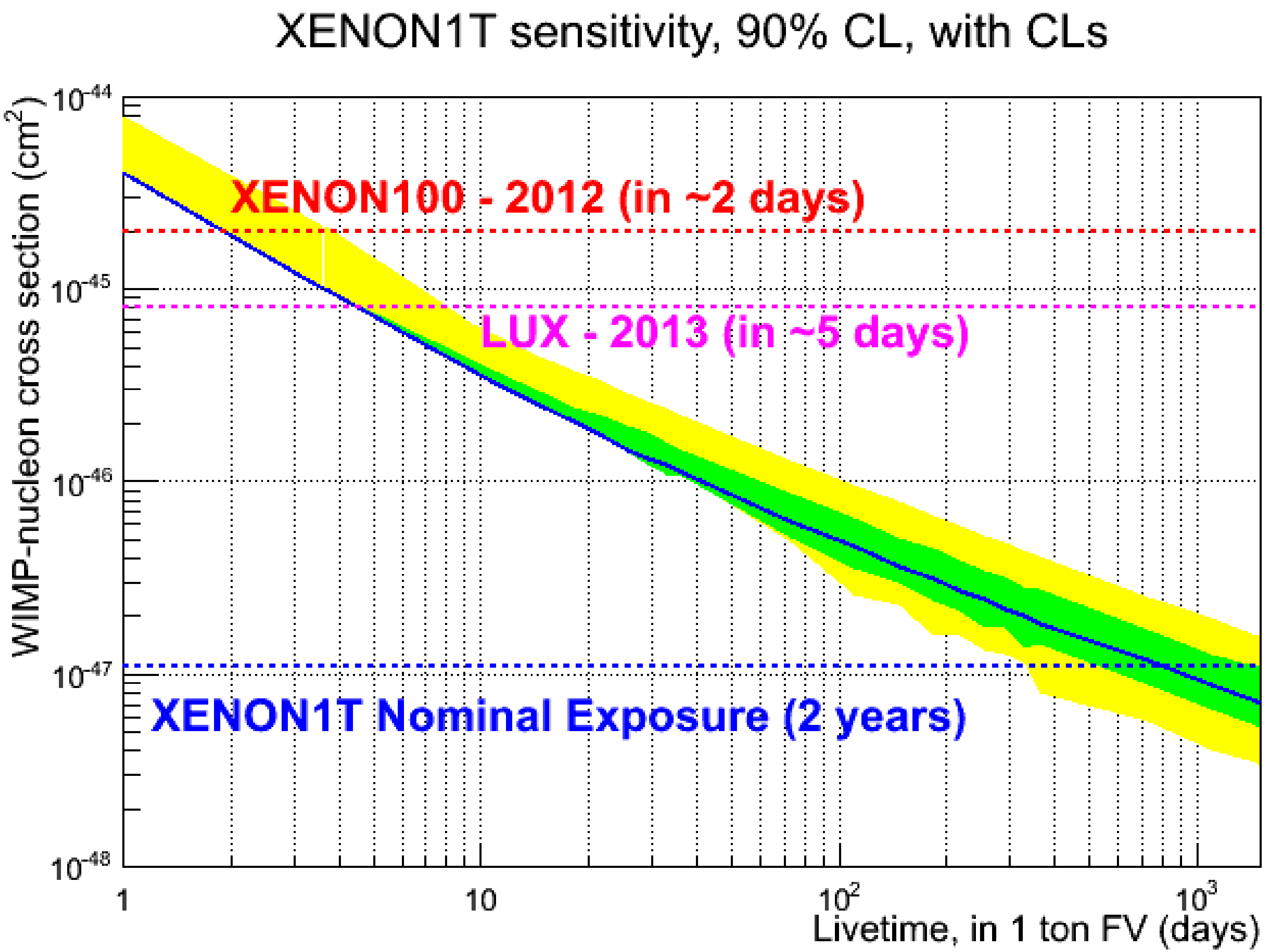


XENON1T Systems



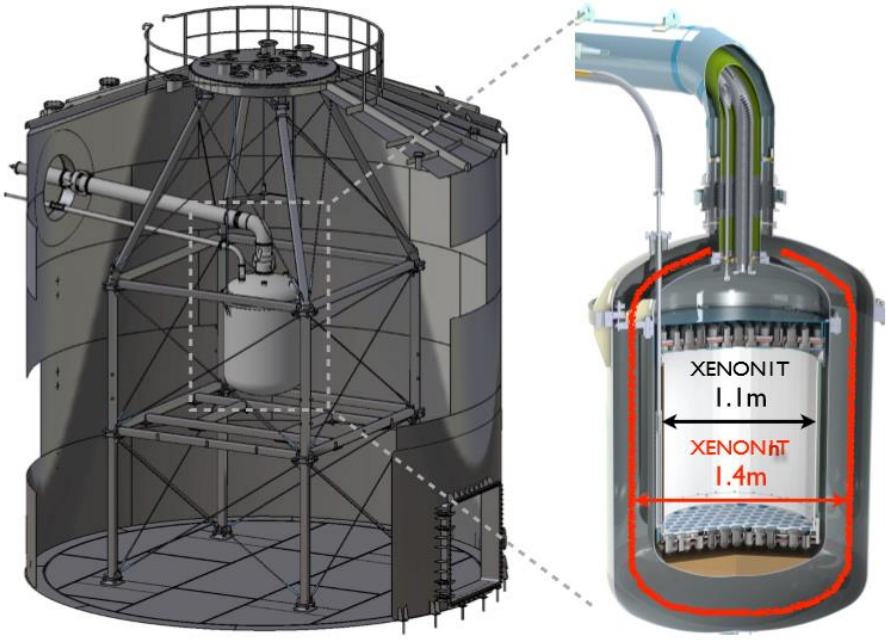
XENON1T Systems

XENON1T Sensitivity reach
90% CLs

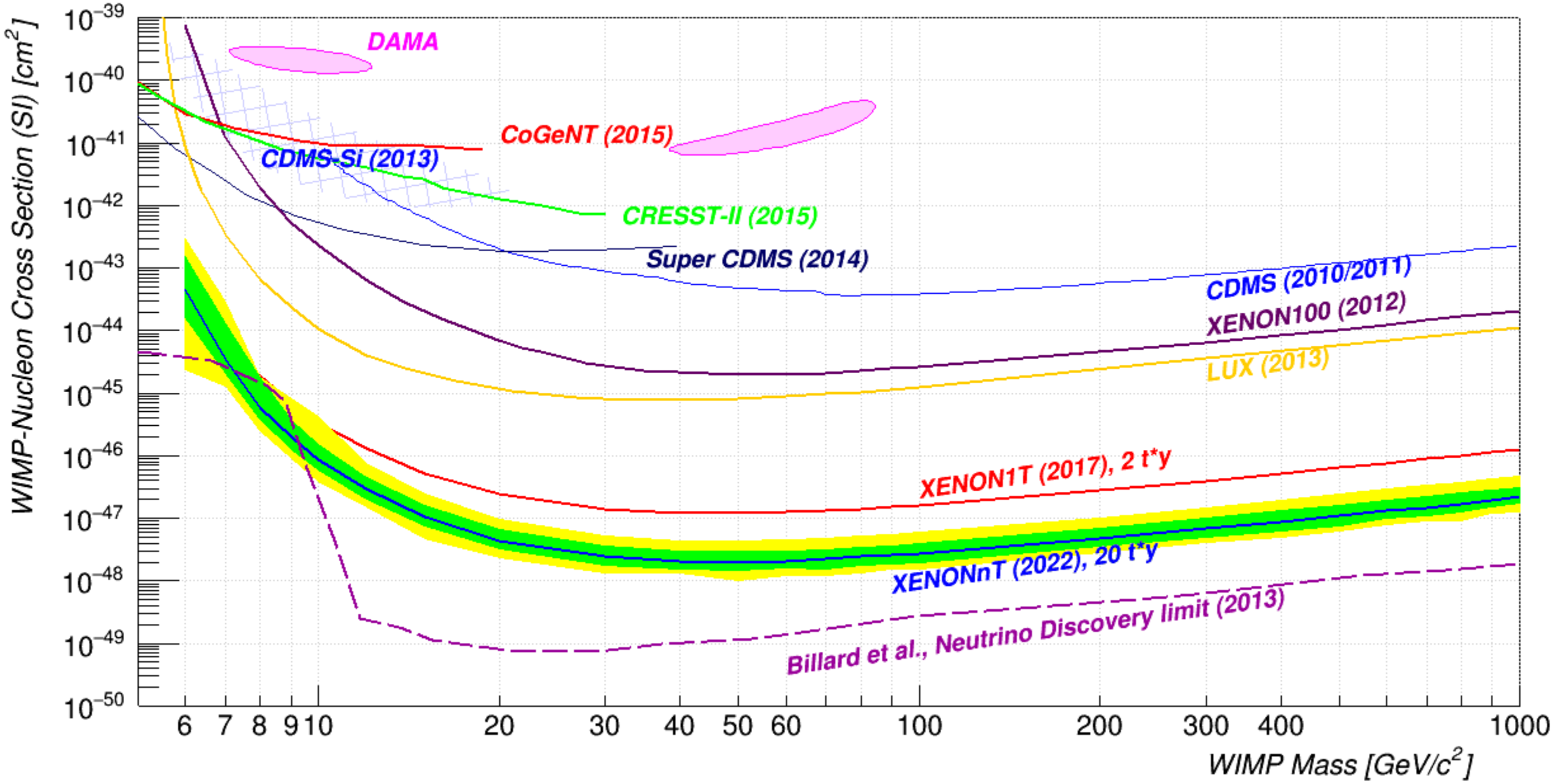


XENONnT Upgrade

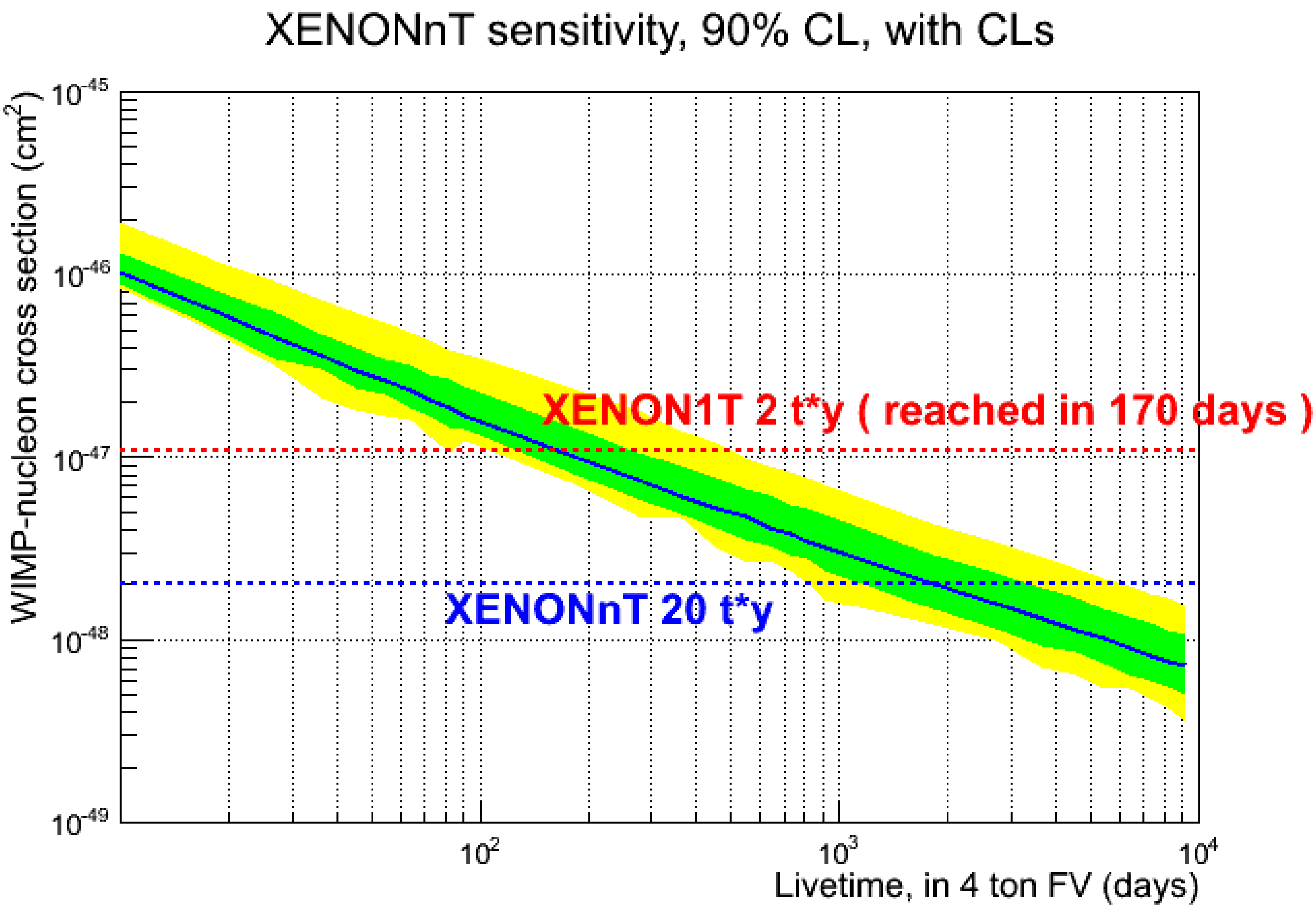
- Double the amount of Lxe (~7 tons)
- Add ~200 PMTs (~250+200=450)
- Reuse of many XENON1T subsystems:
  - Water tank + Lxe Veto
  - cryostat support
  - Cryogenics and purification
  - Lxe storage system
  - Thinking ahead:
    Already installing additional cables



XENONnT Sensitivity reach



XENONnT Sensitivity reach
4 t fiducial volume,90% CLs



Summary

- Xe100 reached sensitivity of 2×10^{-45} cm^2 for 50 GeV WIMPs for coherent elastic scattering and SI interaction.
- Additional models have been tested as well (Axions, ALP, SD)
- Soon to come:
  - Unblinding of next data run 2013-2014
  - In the press:
    - XENON100 annual modulation results
    - Leptofilic dark matter as explanation to DAMA results.
- The Construction of XENON1T is ongoing full steam. Aiming at Physics run by the end of 2015
- On going work to further improve the statistical analysis for XENON1T
- Possible larger mass (7000 kg) extension with minimal cost