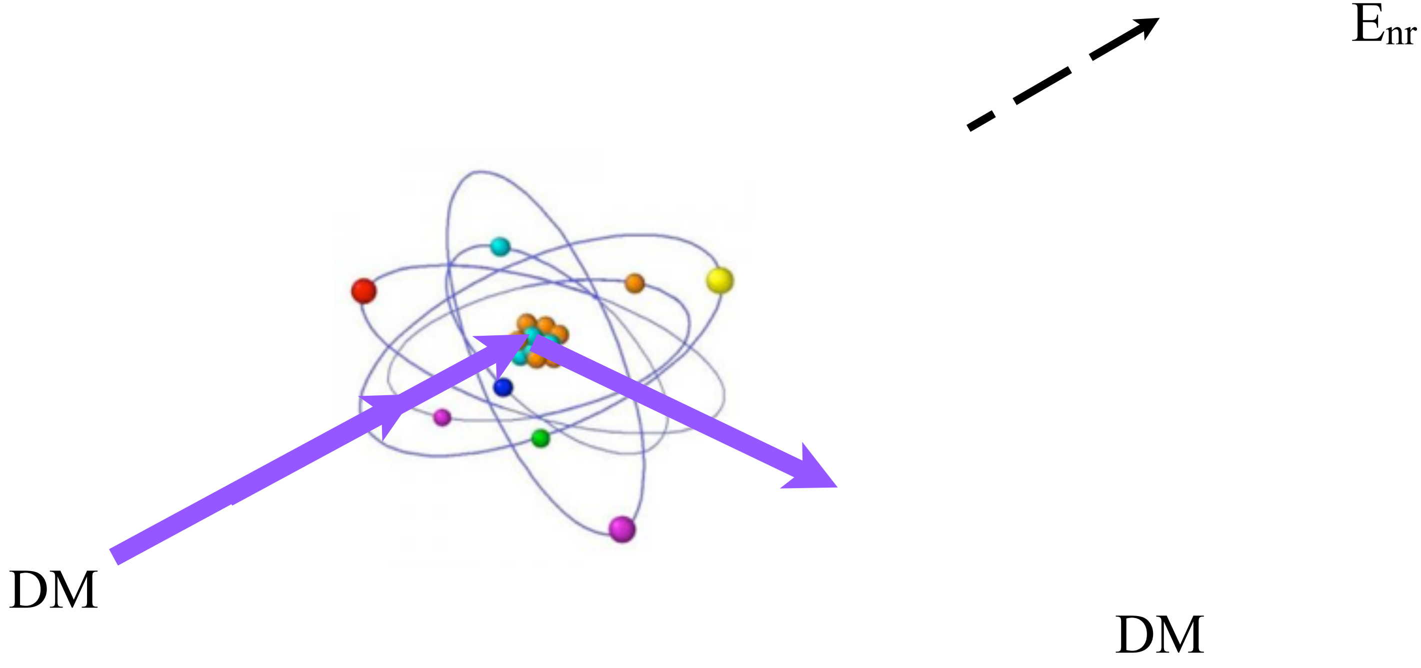
Search for leptophilic Dark Matter and modulation rate in XENON100

J. Masbou, on behalf of the
XENON Collaboration

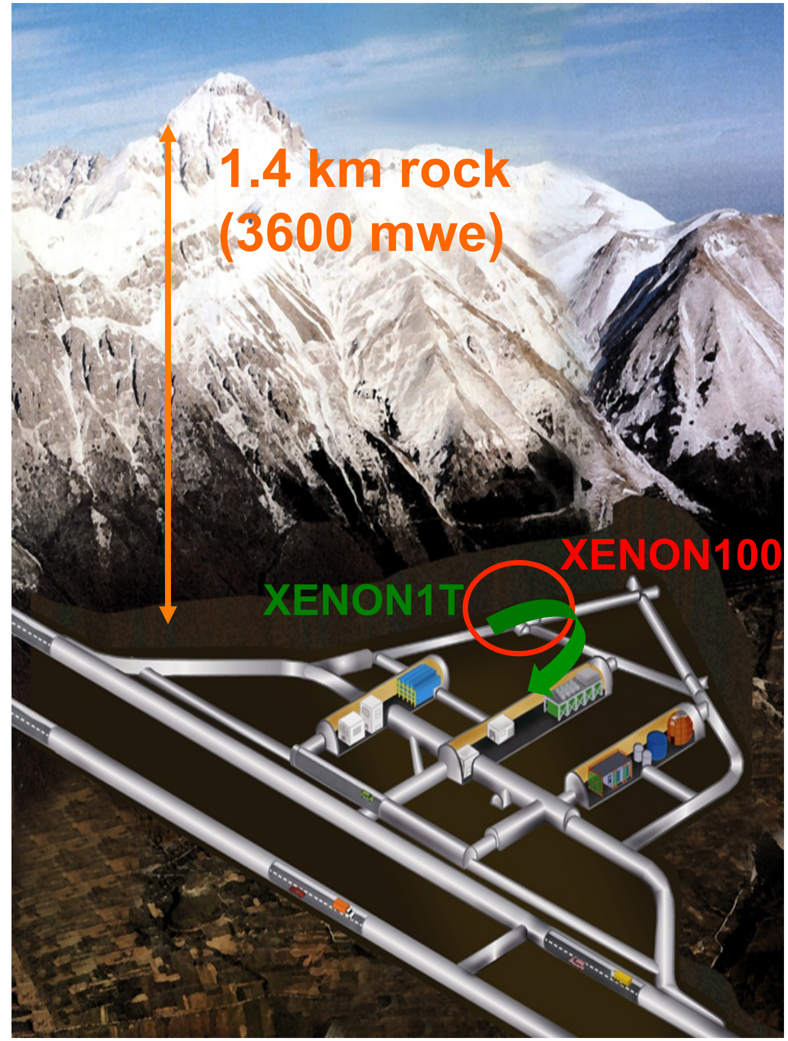
Our goal

Discover Dark Matter
with the most sensitive liquid xenon imaging detector
located in LNGS



Location of the XENON experiment & Collaboration

21 Institutes
~150 members



The XENON Dark Matter Program

XENON10

Achieved (2007)

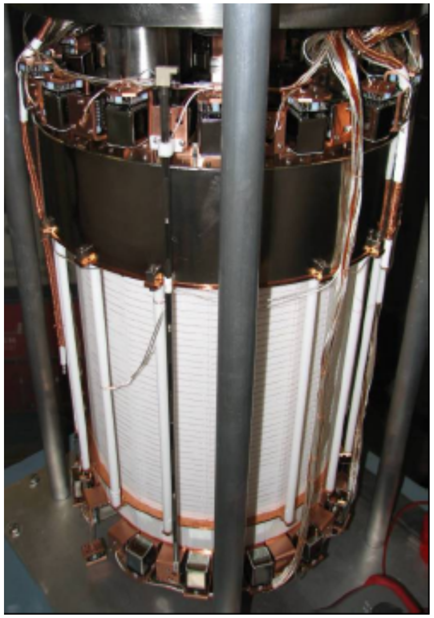
σ_{SI} = 8.8 · 10^{-44} cm^2 @ 100 GeV/c^2

Phys.Rev.Lett. 100 (2008) 021303

Light DM:

σ_{SI} = 7 · 10^{-42} cm^2 @ 7 GeV/c^2

Phys.Rev.Lett. 107 (2011) 051301



XENON100

Achieved (2012)

σ_{SI} = 2.0 · 10^{-45} cm^2 @ 55 GeV/c^2

E. Aprile et al. (XENON100),
Phys. Rev. Lett. 109 (2012)
arXiv:1207.5988

In operation since 2009

XENON1T

Projected (2017)

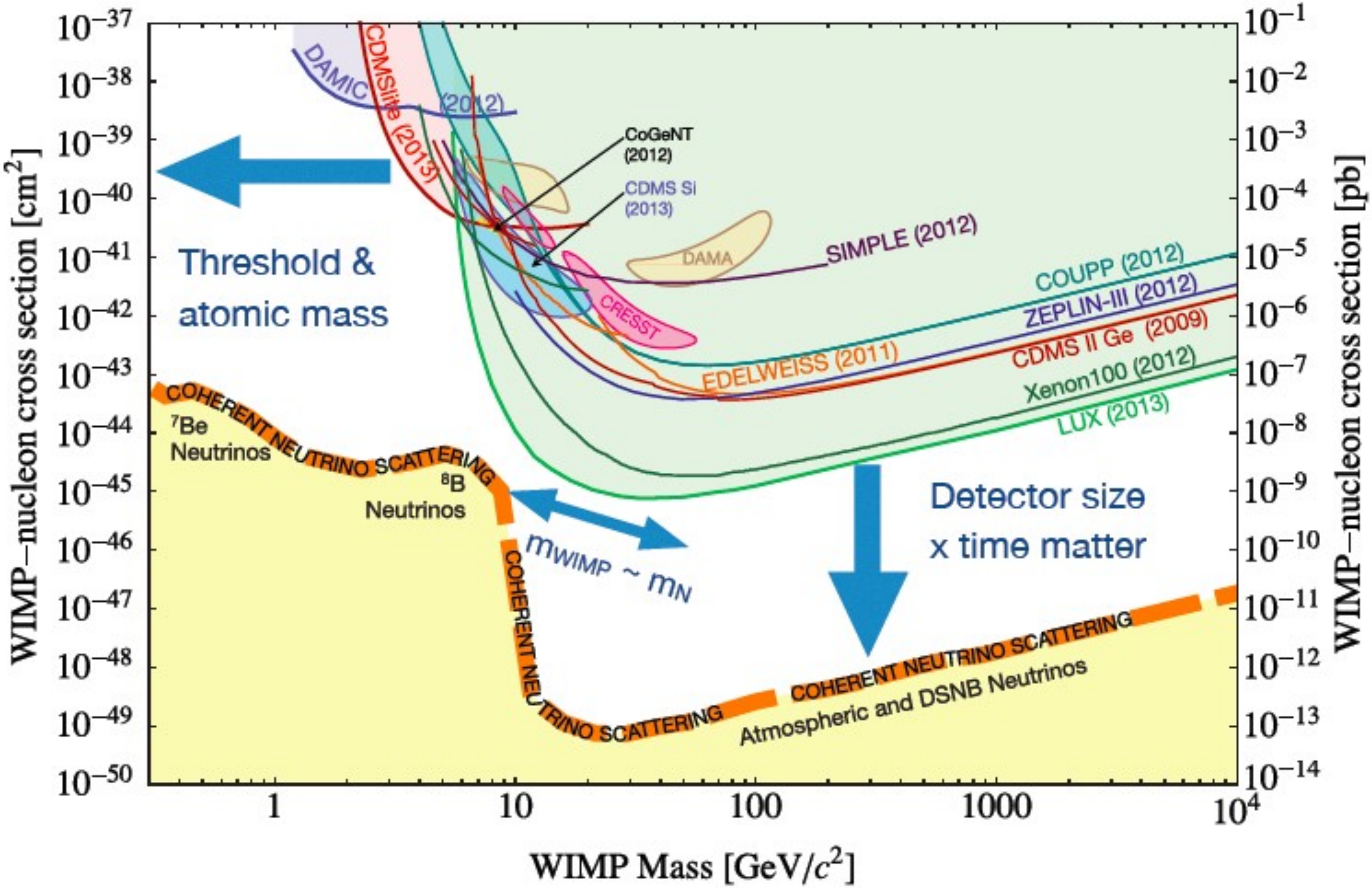
σ_{SI} = ~ 2.10^{-47} cm^2

Science data by spring 2016

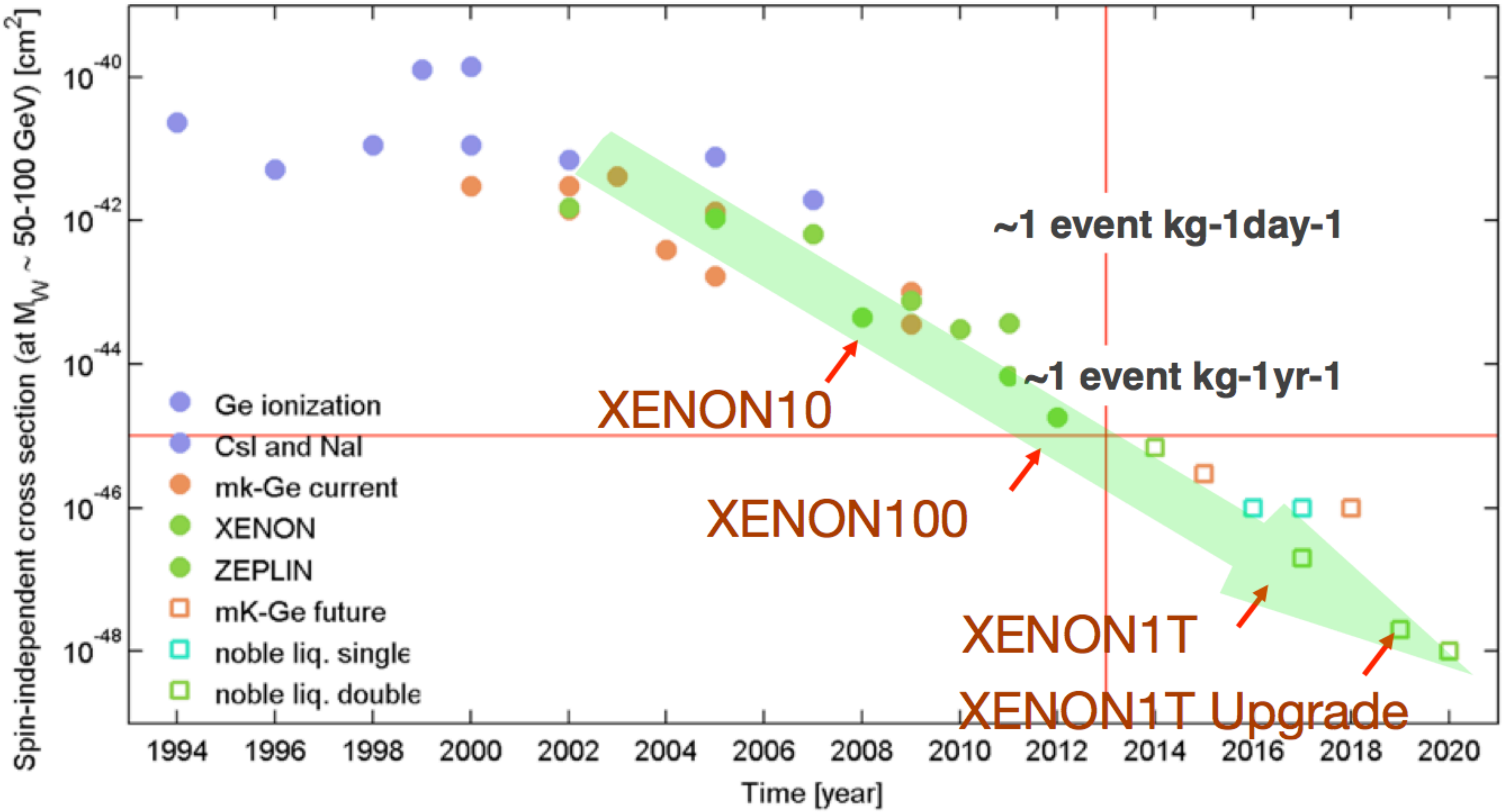
Upgrade : XENONnT

σ_{SI} = ~ 2.10^{-48} cm^2

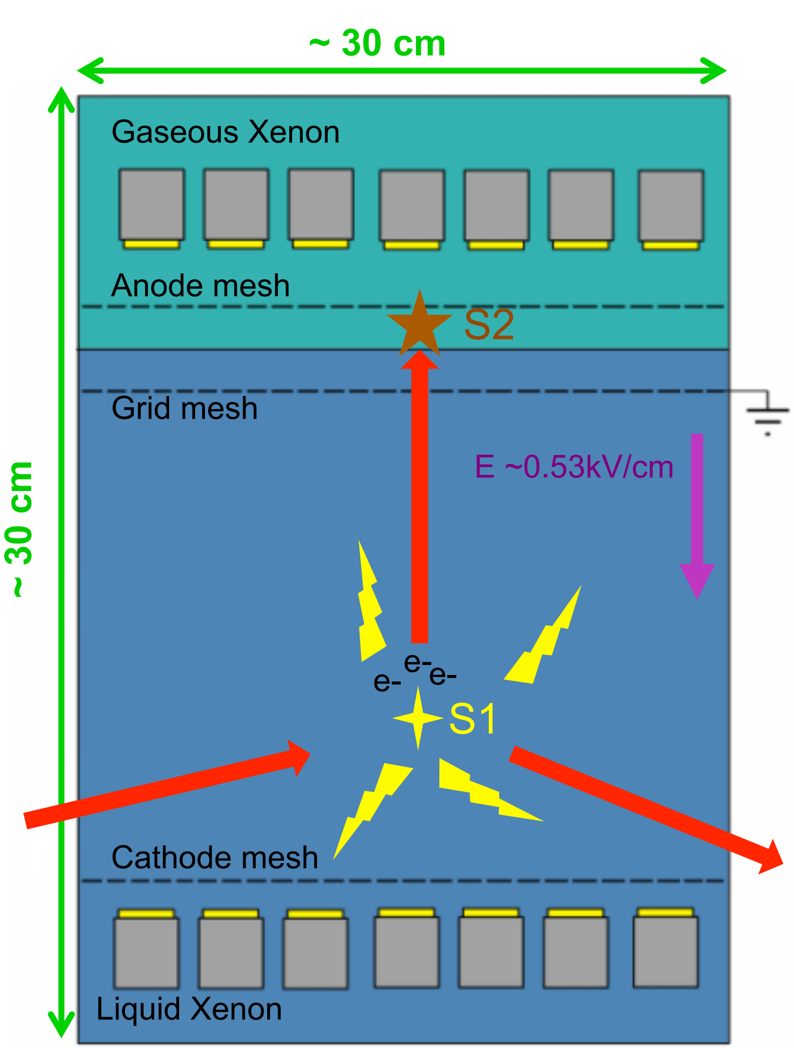
Where is the field of Direct Detection Today?



Direct detection : progress over time



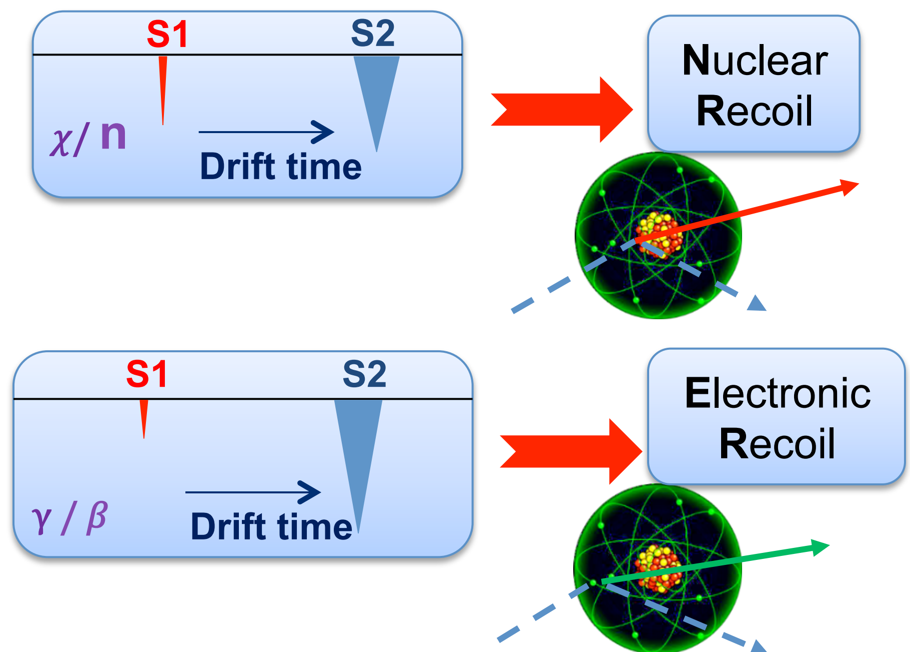
Two phase XENON TPC principle



S1:
→ Photon (λ = 178 nm) from Scintillation process → Dectected by PMTs (mainly botton array)

S2:
→ Electrons drift
→ Extraction in gaseous phase
→ Proportional scintillation light

3D reconstruction :
→ X,Y from top array
→ Z from Drift time



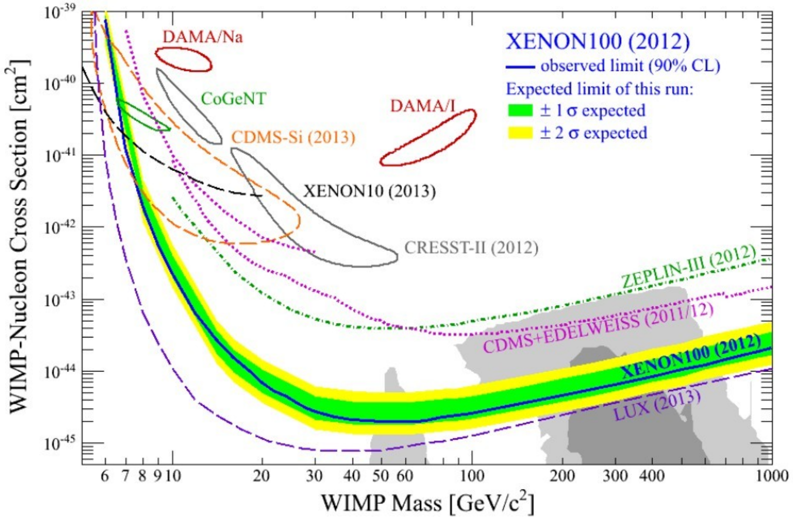
E. Aprile et al. (XENON100), Astropart. Phys. 35, 573-590 (2012)

Xenon100 : Past Achievements

225 live days x 34 kg exposure

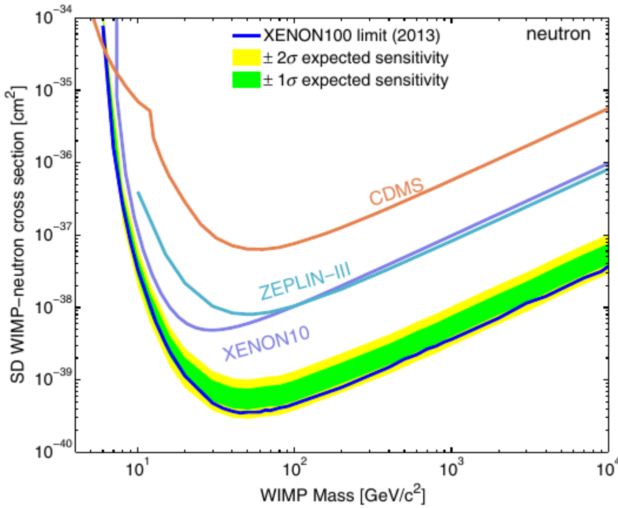
Profile likelihood analysis allows to set limits in the (m_χ ,σ) parameter space

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

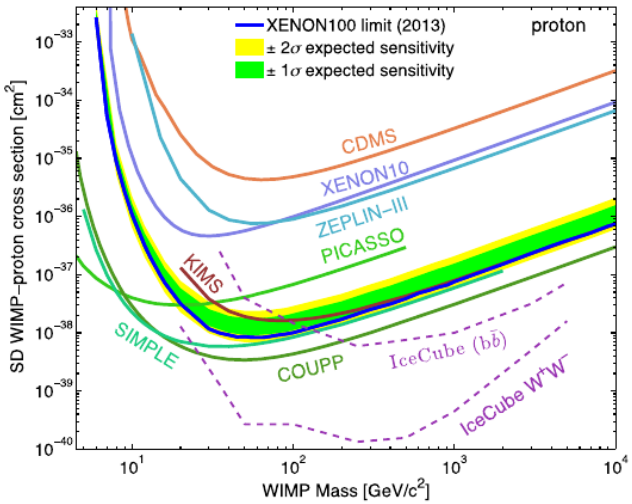


Spin-independent interaction

Phys. Rev. Let. 111, 021301 (2013)



Neutron coupling



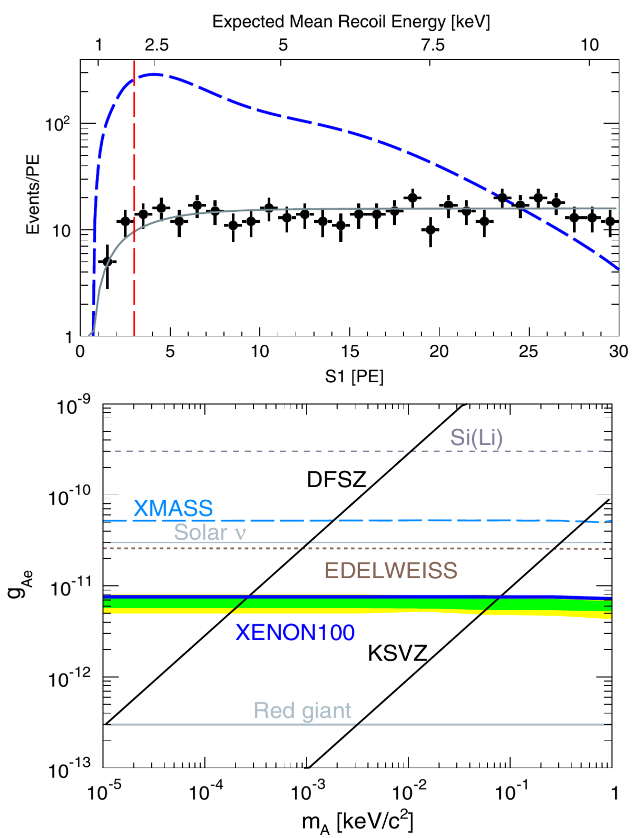
Proton coupling

Spin-dependent interaction

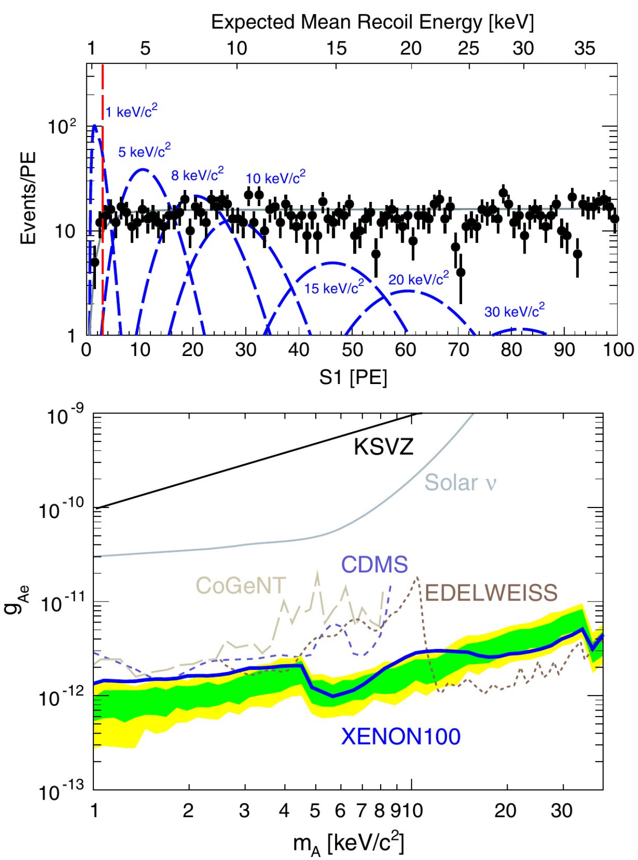
Xenon100 : Past Achievements

225 live days x 34 kg exposure

- First axion results from the XENON100 experiment analyzing ER data
- Probing axion-electron coupling constant by exploiting the axioelectric effect in LXe



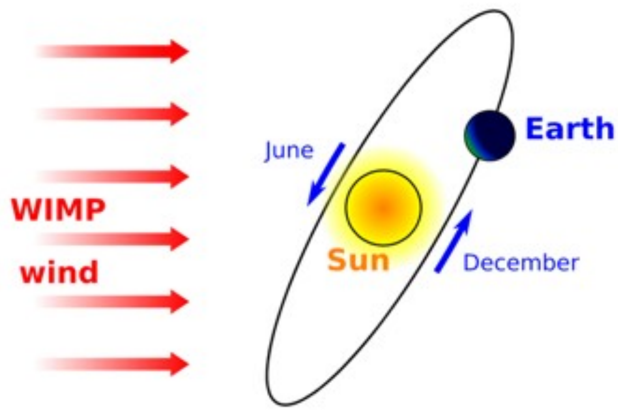
Solar Axions



Galactic ALPs (DM candidates)

Phys. Rev. D 90, 062009 (2014)

Annual modulation and DAMA/LIBRA



Dark matter (DM) signal rate is expected to be annually modulating

peak phase 152 days (June 1)

A key feature to distinguish signals from overwhelming backgrounds

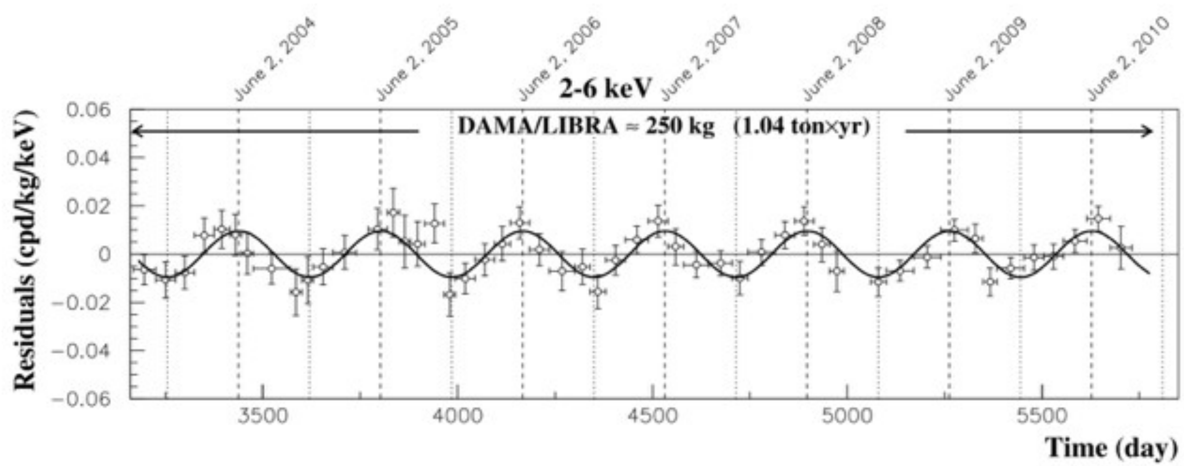
Freese *et al.*, Rev. Mod. Phys. 85, 1561 (2013)

DAMA/LIBRA:

9.3 sigma significance only for

single hit Phase (144 +- 7) days

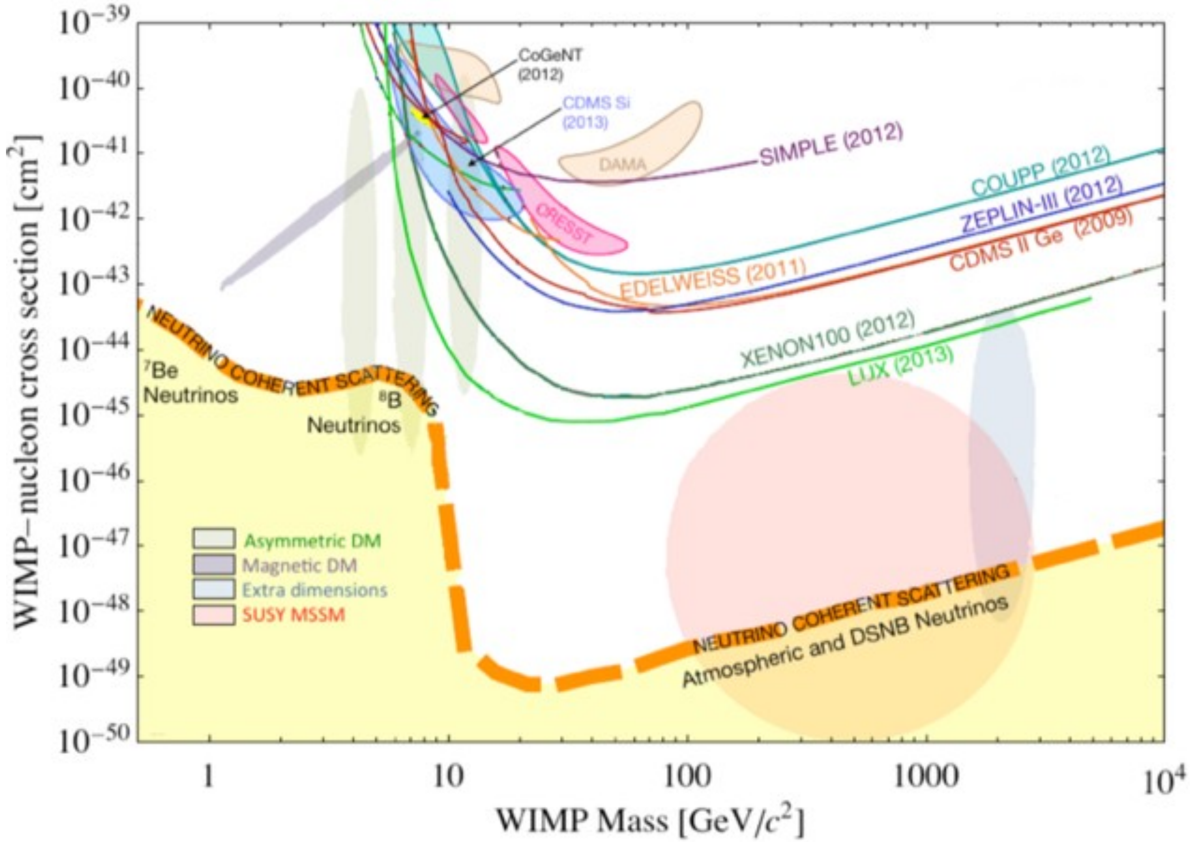
No signal above 6 keV



Bernabei *et al.*, Eur. Phys. J. C 73, 12 (2013)

Seems to be a convincing evidence,
HOWEVER…

Nuclear Recoil Interpretation



Nuclear recoil interpretations of DAMA/LIBRA modulation have been challenged by several more sensitive experiments with background rejection power

Exclusion of leptophilic Dark Matter

- DAMA/LIBRA experiment observes annual modulation interpretable with leptophilic DM

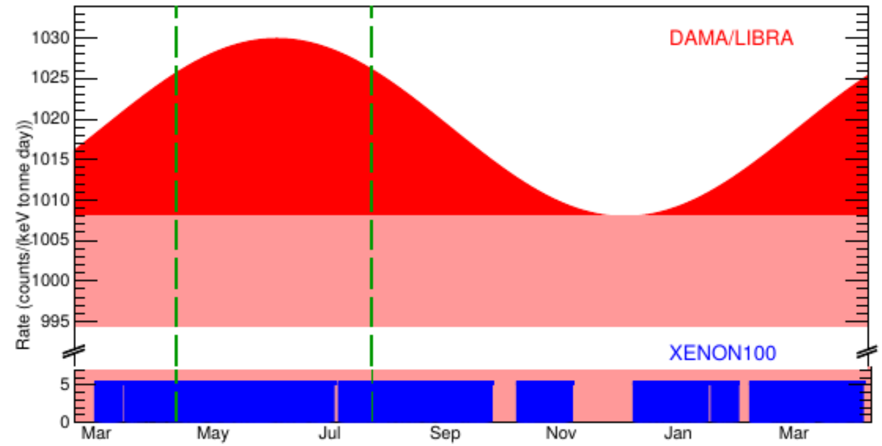
- Selection of 70 live days of electronic recoil XENON100 data, where DAMA signal is highest

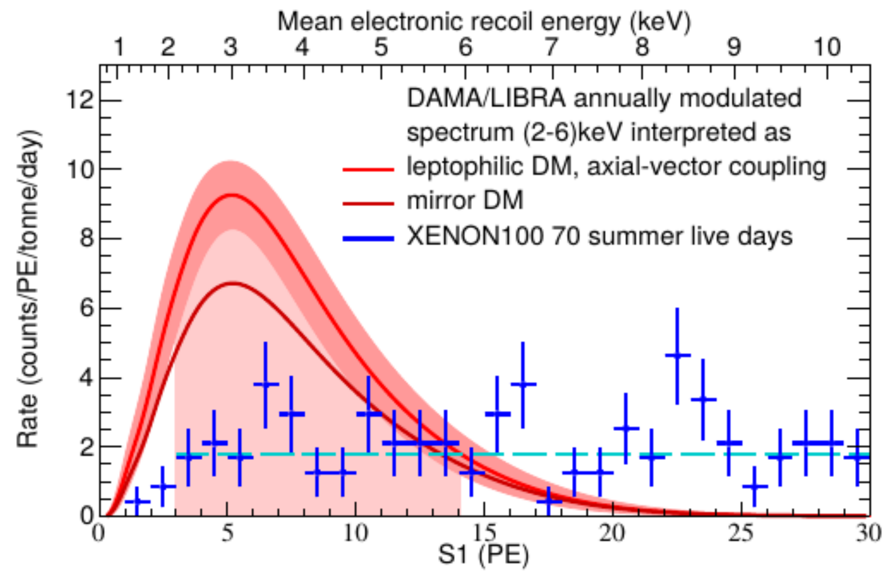
- Assume some model of WIMP coupling to e^- to estimate expected signal in XENON100

- XENON100 steady background level lower than DAMA modulation signal

- **Exclusion of several types of DM models as the cause of the annual modulation**

Kinematically mixed Mirror DM: 3.6σ
ExclusionLuminous DM: 4.6σ Exclusion
Axial-vector coupling: 4.4σ Exclusion





Science 349, 851 (2015)

Search for Modulations

- The first LXe TPC with more than one year of stable running conditions

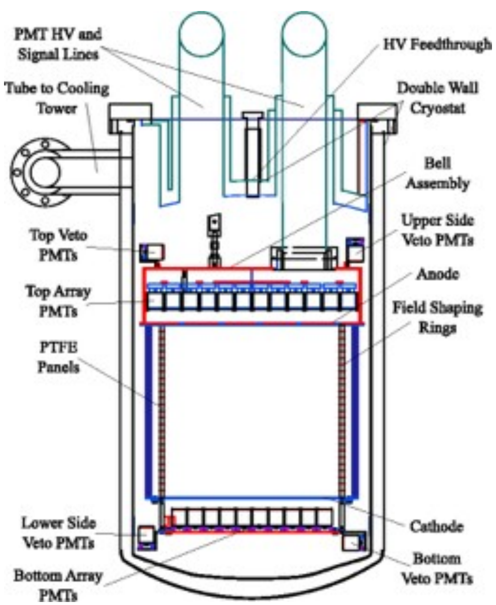
- The first modulation search for DM at Gran Sasso Lab after DAMA/LIBRA

- Demonstration for future XENON modulation searches Search for leptophilic DM signals

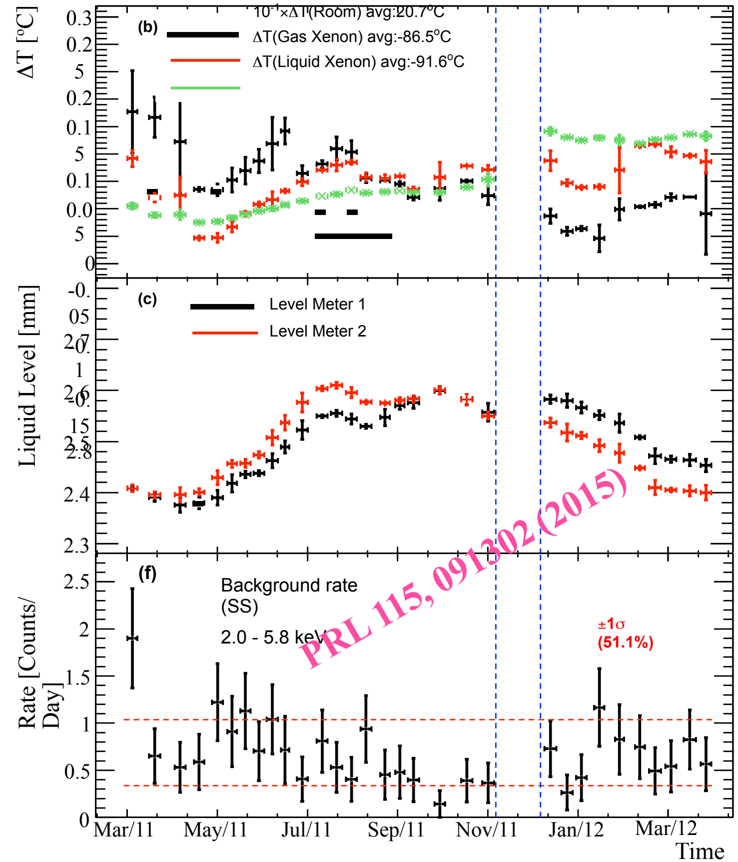
- Require good understand the stability of detector and backgrounds

Stability of the Detector

Aprile *et al.*, Astropart. Phys., 35, 573-590 (2012)



- Detector pressor
- Room pressor
- LXe temperature
- PTR temperature
- Room temperature
- Purification flow rate
- LXe levels
- PMT gain
- Radon level

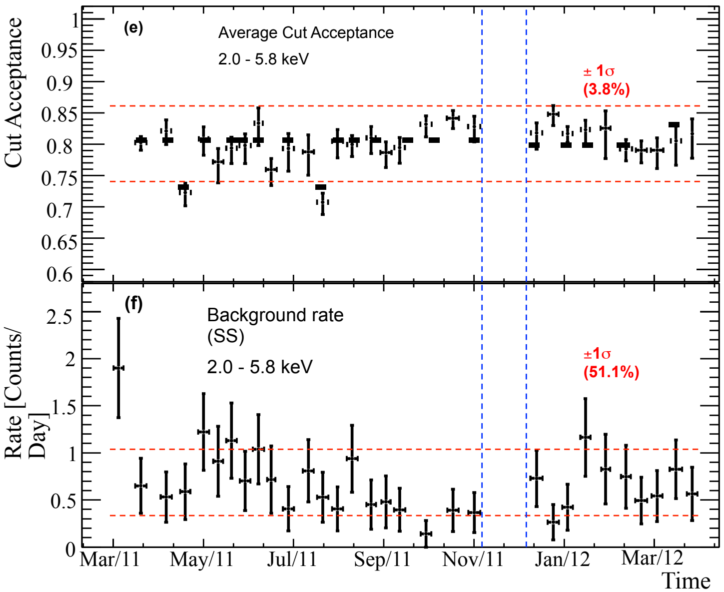


Very tiny absolute variations
No correlations with ER rate

No significant impact on ER rate!

Stability of Cut Acceptance

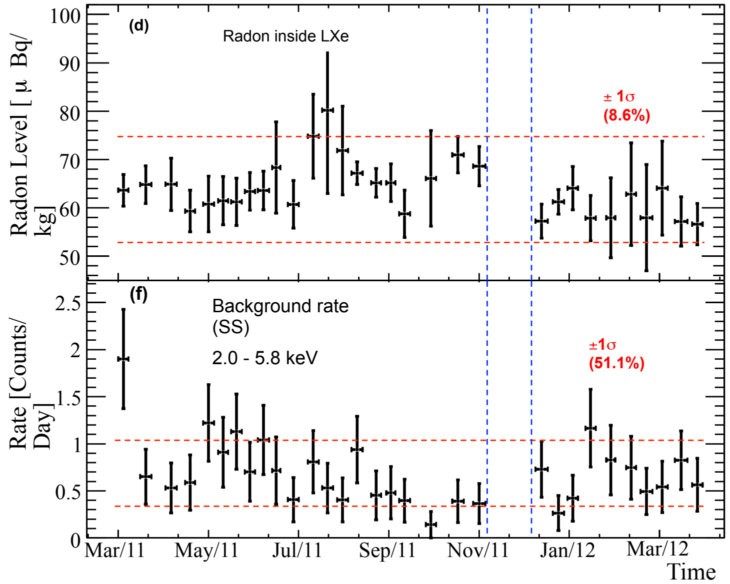
- Stability of cut acceptance is derived from weekly ER calibrations sources
- The acceptance variation further accounts for the variation of the detector parameters like LXe level.
- The dips of acceptance are due to increment of noise level.
- The fluctuation of acceptance is taken into account for the event rate modulation analysis.



PRL 115, 091302 (2015)

Stability of Backgrounds

- Co60 ($T_{1/2}$ = 5.3 year) gamma background is time dependent, but the absolute contribution is negligible.
- Radon and krypton background concentration are time dependent due to tiny air leak
- Radon contributes to the overall background by less than 20%. Hence the absolute contribution to fluctuation is negligible.
- No correlation between radon and ER rate.
- Krypton concentration varies in time due to air leak. The size of its variation is taken into account.



Discovery Potential

Acceptance · Background from known air leak · Modulation

$$f(t) = \epsilon(t)\left(C + Kt + A\cos\left(2\pi\frac{(t-\phi)}{P}\right)\right)$$

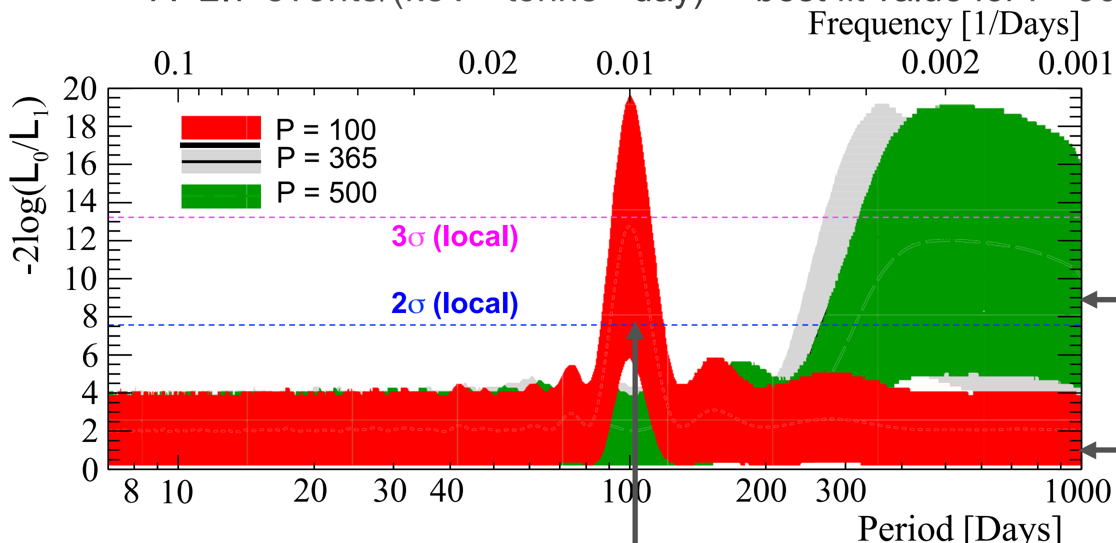
Normalized

$$\mathcal{L} = \left(\prod_{i=1}^{n} \tilde{f}(t_i)\right) \mathrm{Poiss}\left(n|N_{\mathrm{exp}}(E)\right) \mathcal{L}_{\epsilon}\mathcal{L}_{K}\mathcal{L}_{E}$$

Total observed events · Constraint terms

Simulated modulation signals

A=2.7 events/(keV · tonne · day) ~ best fit value for P=365.25 days



PRL 115, 091302 (2015)

Characteristic plateau
no resolution on period

no rise at large period

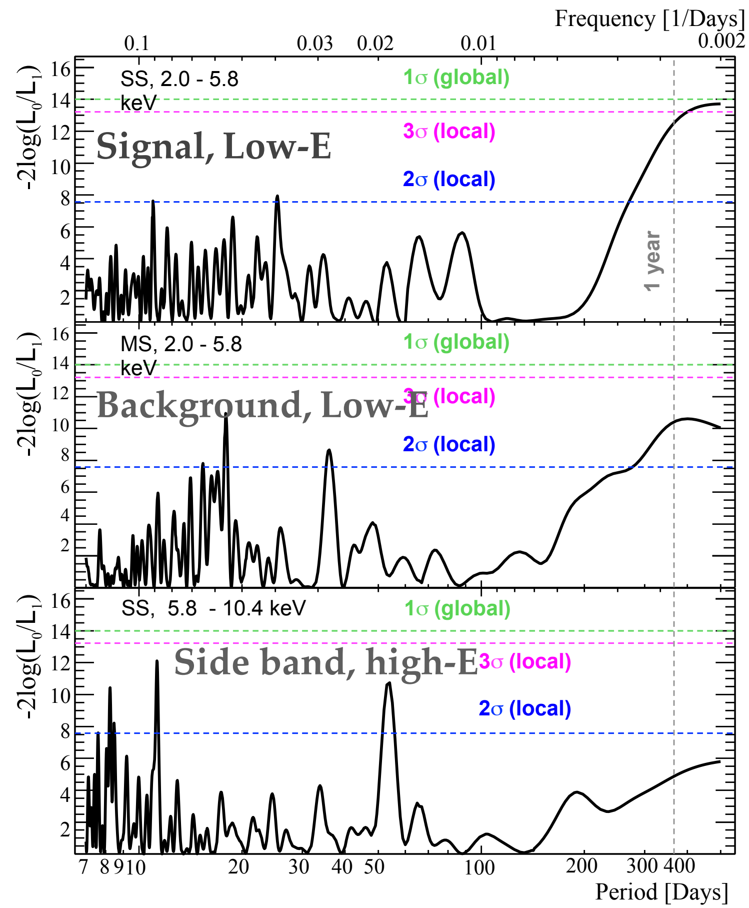
good resolution on period

Average significance of 3 sigma assuming ~25% DAMA/LIBRA modulation

The data is only sensitive to modulation with period < 500 days

Modulation Search Results

- No evident peak crossing the 1-sigma global significance threshold!
- SS in the Low-E (2.0-5.8 keV) range shows increasing significance at long period region. 2.8-sigma local significance at one year period
- MS background only control sample in Low-E range shows similar power spectrum as SS. This disfavors an WIMPs interpretation of the SS spectrum
- SS in high-E (5.8-10.4 keV) does not show high significance at long period region

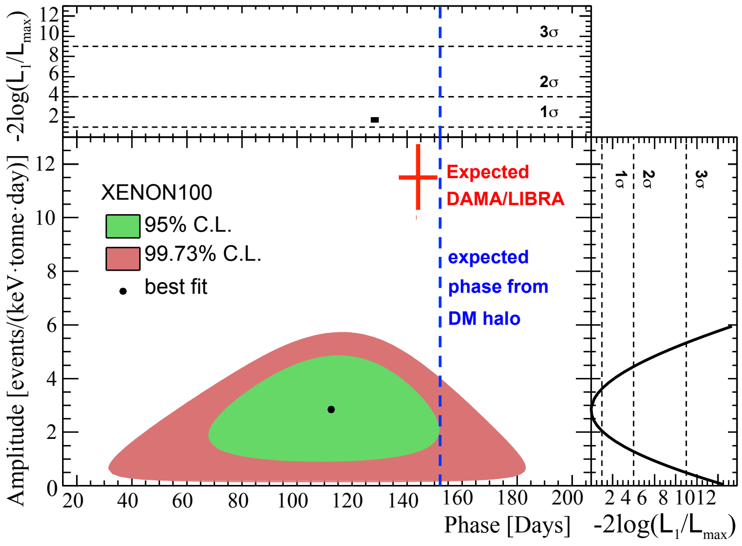


PRL 115, 091302 (2015)

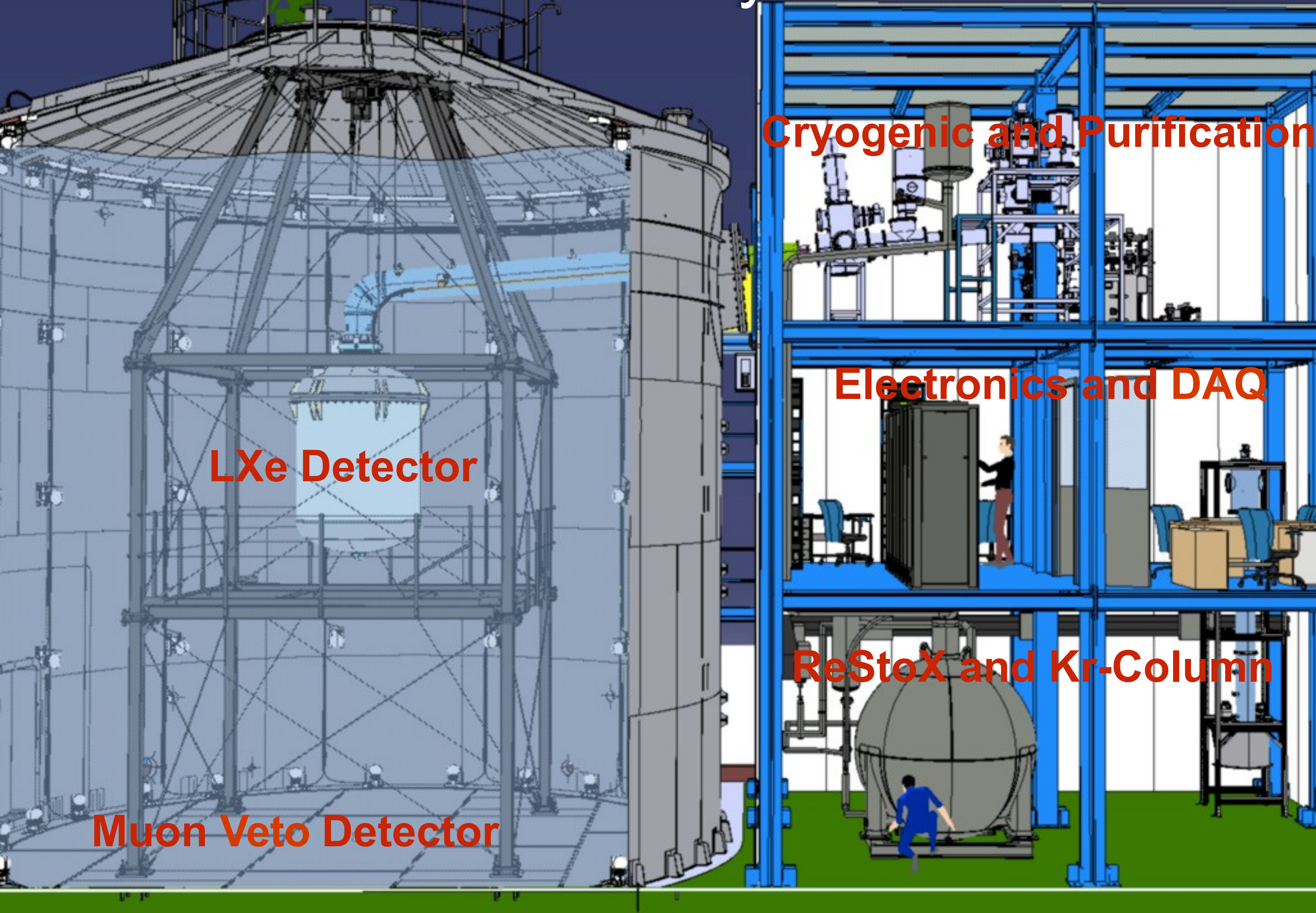
DAMA/LIBRA Comparison (2D)

- The phase (112+-15) days (April 22) is not consistent with the standard halo model (June 2) at 2.6-sigma
- The amplitude of is also too small (only~25%) compared with the expected DAMA/LIBRA modulation signal in XENON100.
- The DM interpretation of DAMA/ LIBRA annual modulation as being due to WIMPs electron scattering through axial vector coupling is disfavored at 4.8-sigma from a PL analysis

PRL 115, 091302 (2015)



XENON1T Systems




Xe
XENON
Matter Project
enlightening

XENON1T : Expected Background and Sensitivity

Source	Background (ev/y)
ER (Material+Intrinsic +solar ν)	0.32
NR from radiogenic neutrons	0.22
NR form neutrino Coherent Scattering	0.21
TOTAL	**0.75**