Dark Matter Direct Detection

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What Dark Matter it not

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➔Barnard 68 : cold molecular cloud ~ 500 ly.
Transparent in infrared

Definition

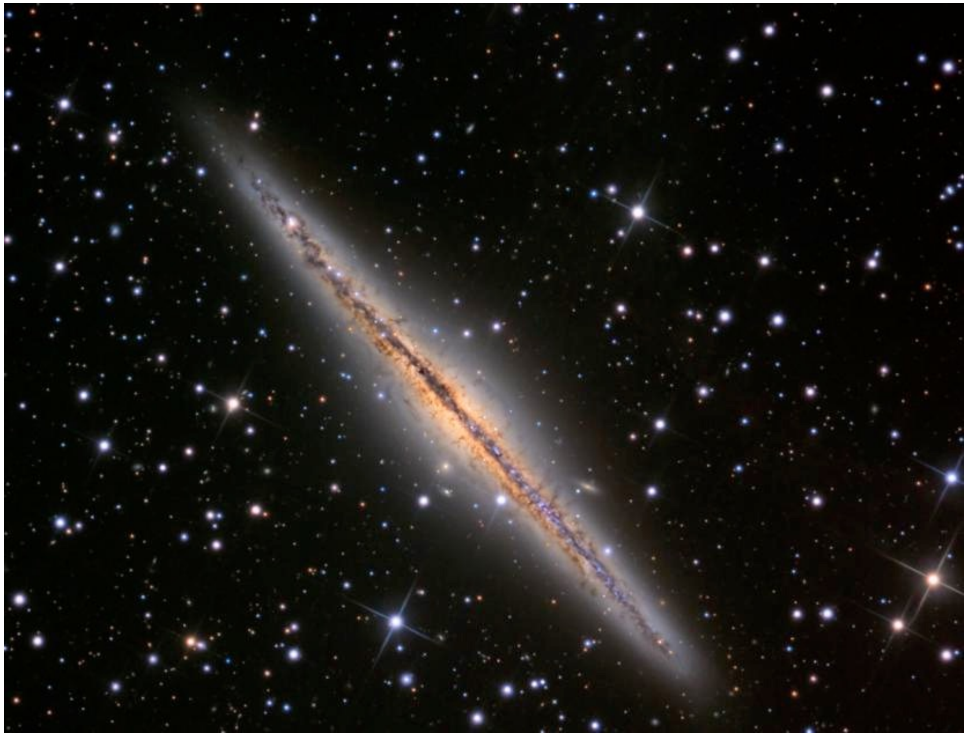
By « Dark Matter » we mean non-luminous matter :
no associated emission of light (visible, UV, IR, radio, etc...)

... But we assume its existence by its gravitational effect in:

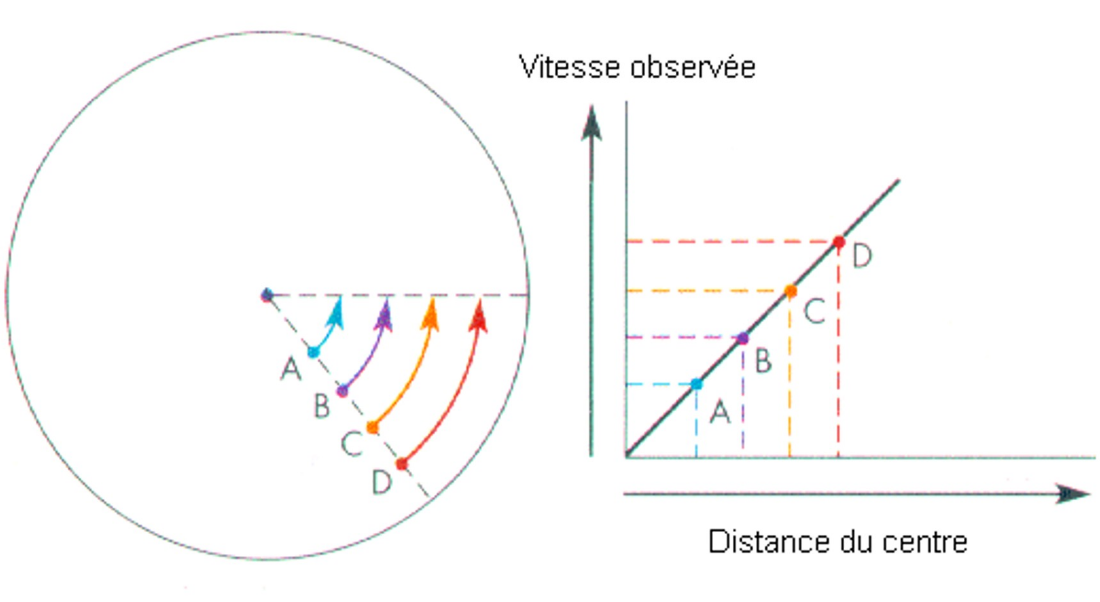
1) Galaxies
2) Galaxy clusters
3) Cosmology

Galaxies

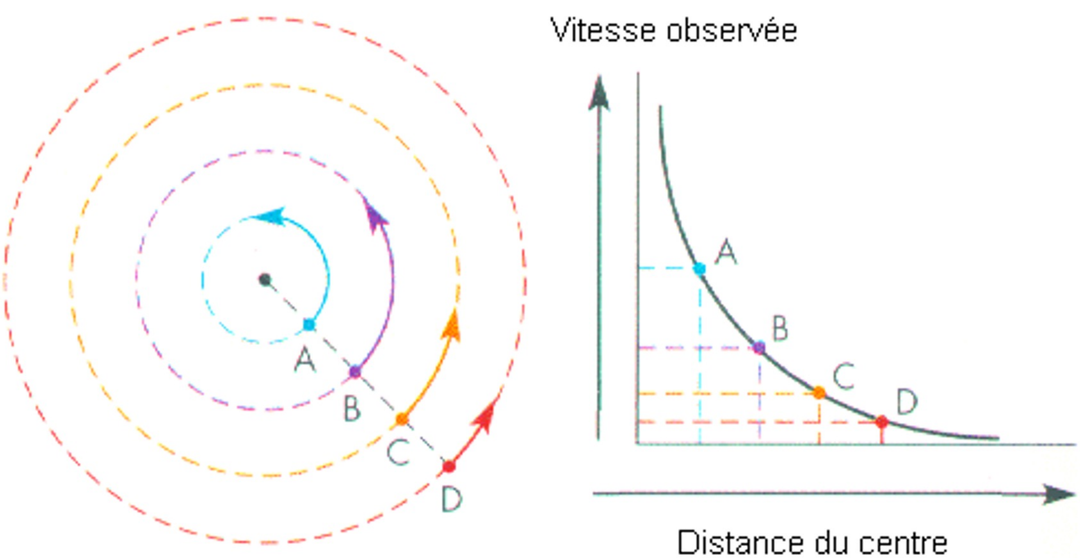
In galaxies, stars are not statics but turns around the galactic center. Thanks to the rotation, the centrifugal force compensates the gravitational force, which prevents stars to collapse in the core.



Galaxies

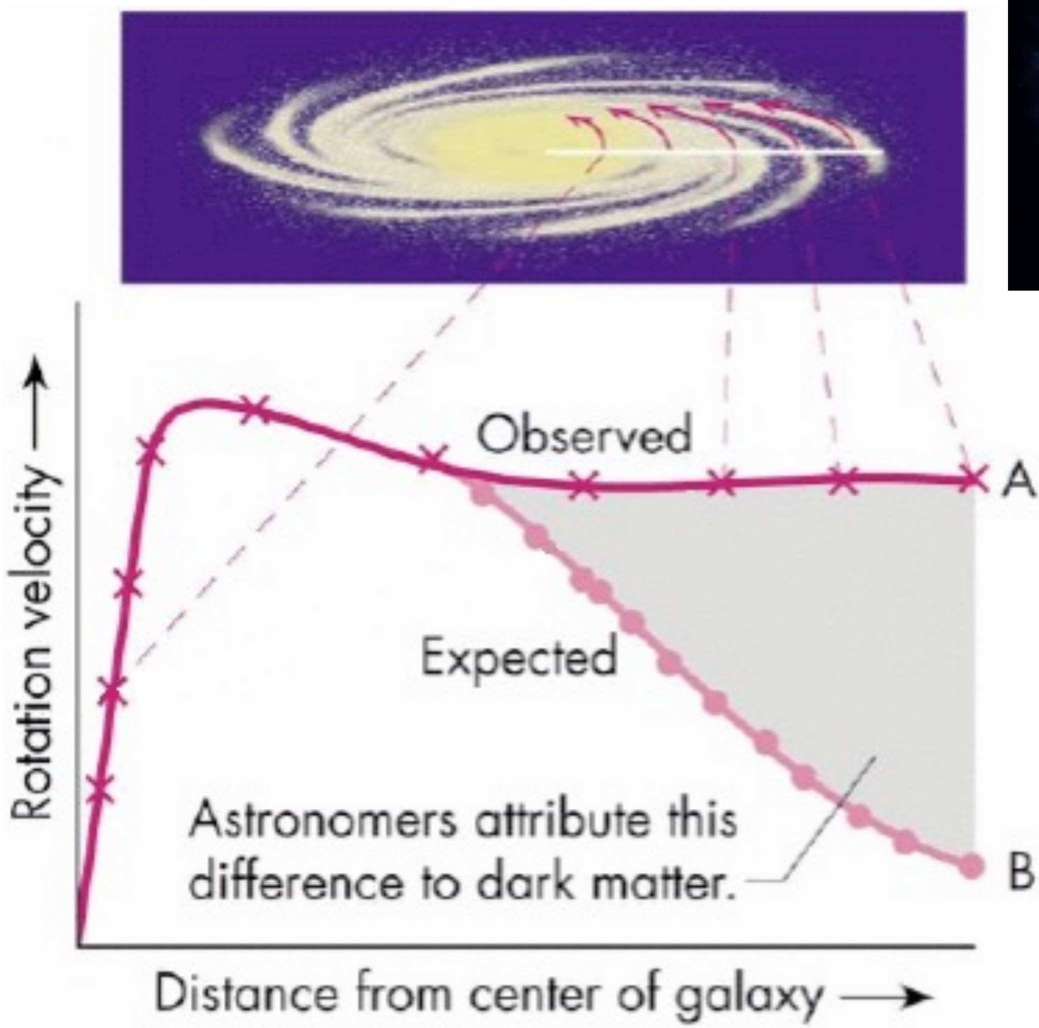


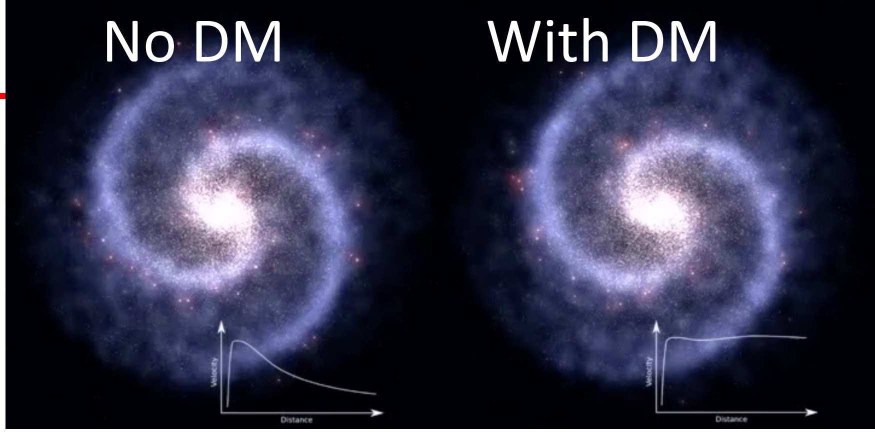
Solid rotation



Planetary rotation

Galaxies



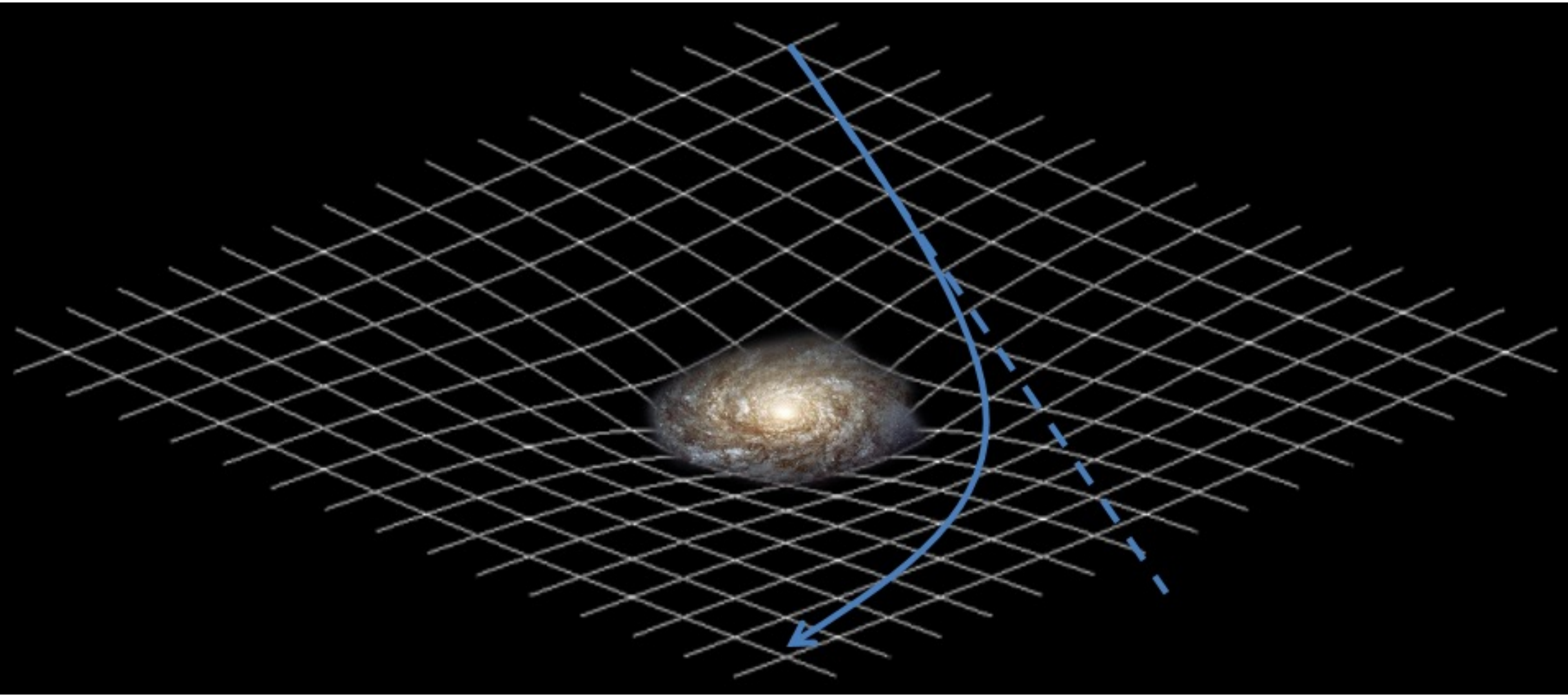


Rotation velocity almost constant at all radius !

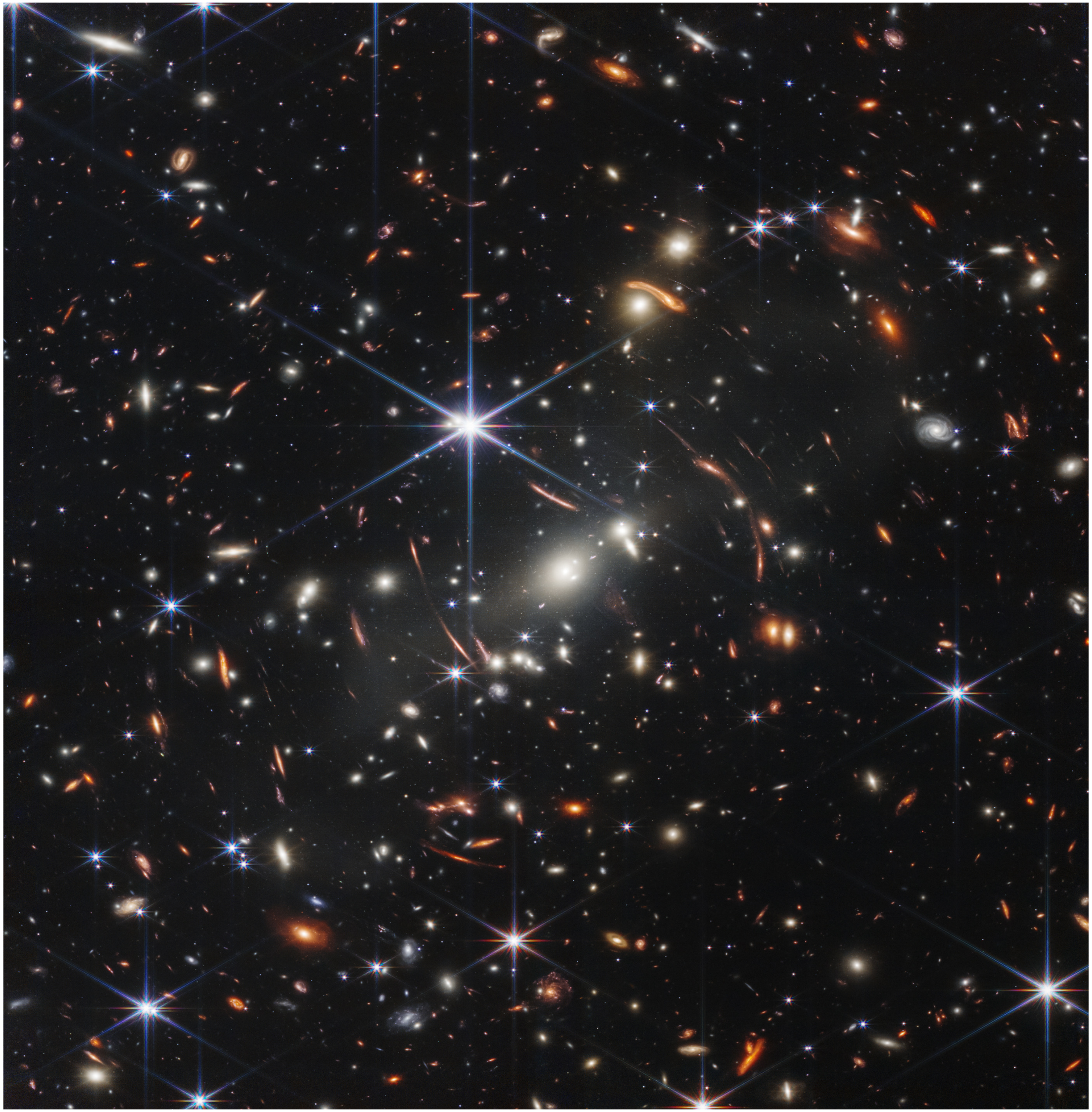
➔ Presence of a halo of invisible matter, 5-10 times heavier than standard matter

Vera Rubin ~1970

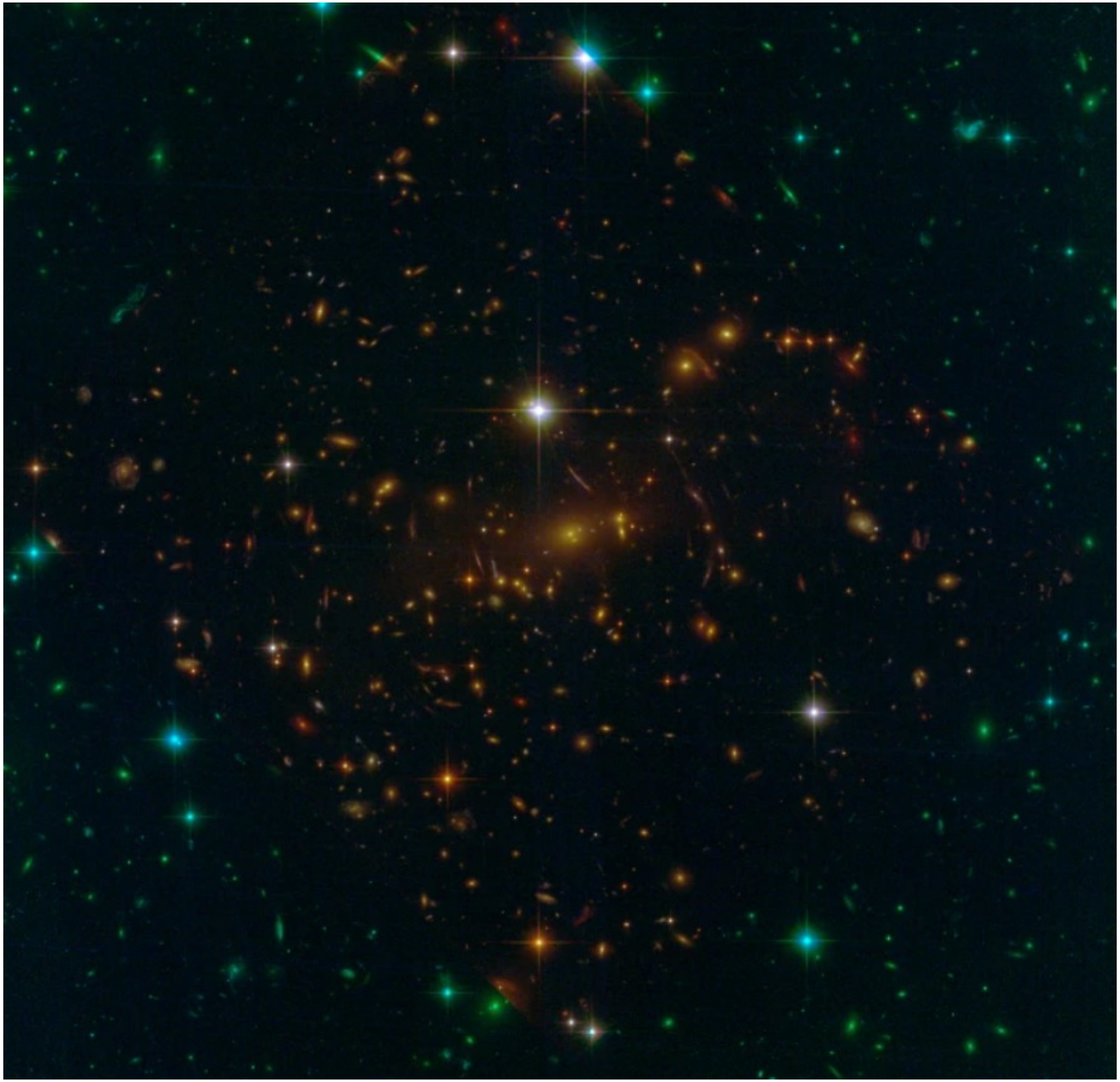
Gravitational lenses



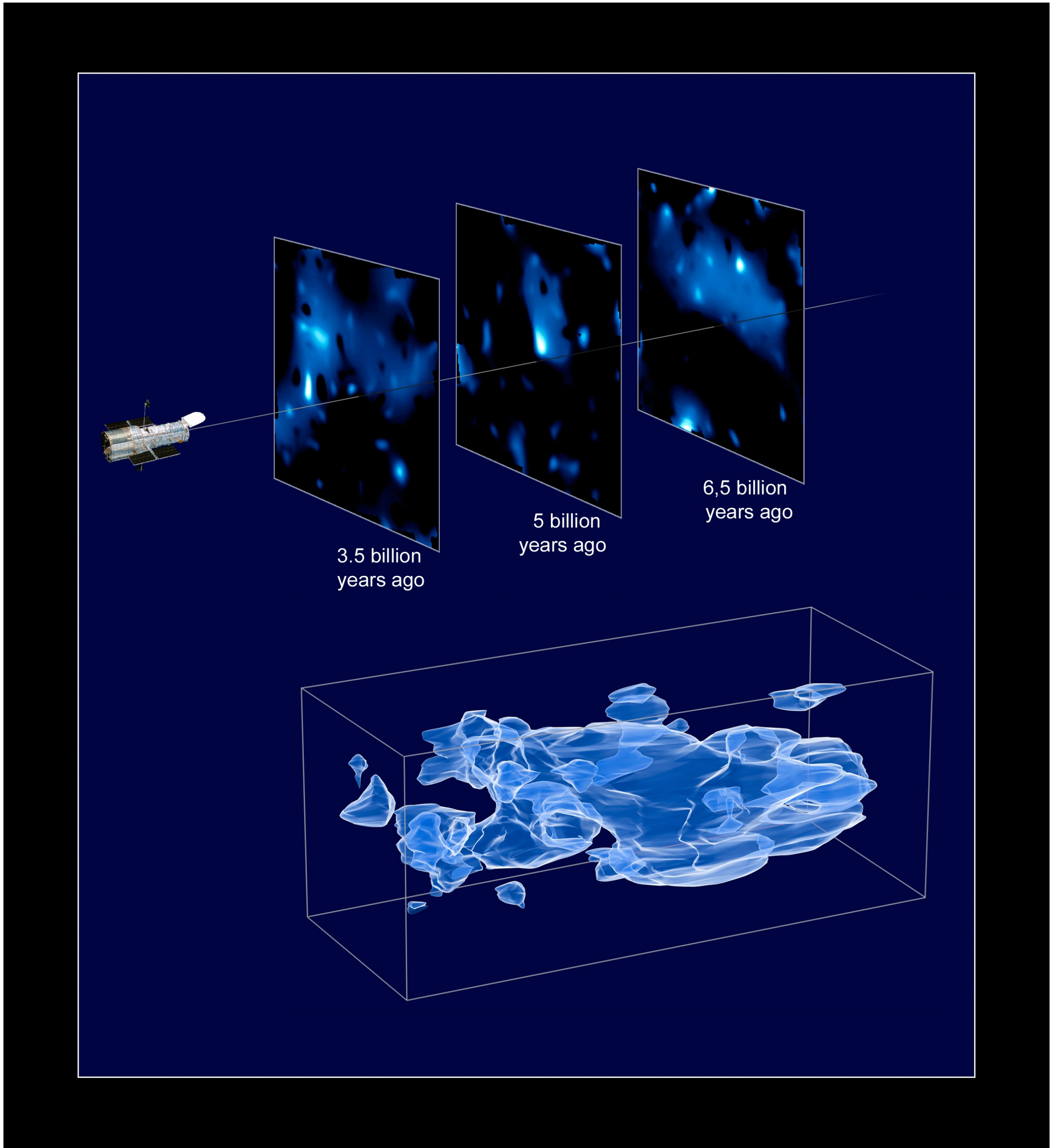
Gravitational lenses



Gravitational lenses

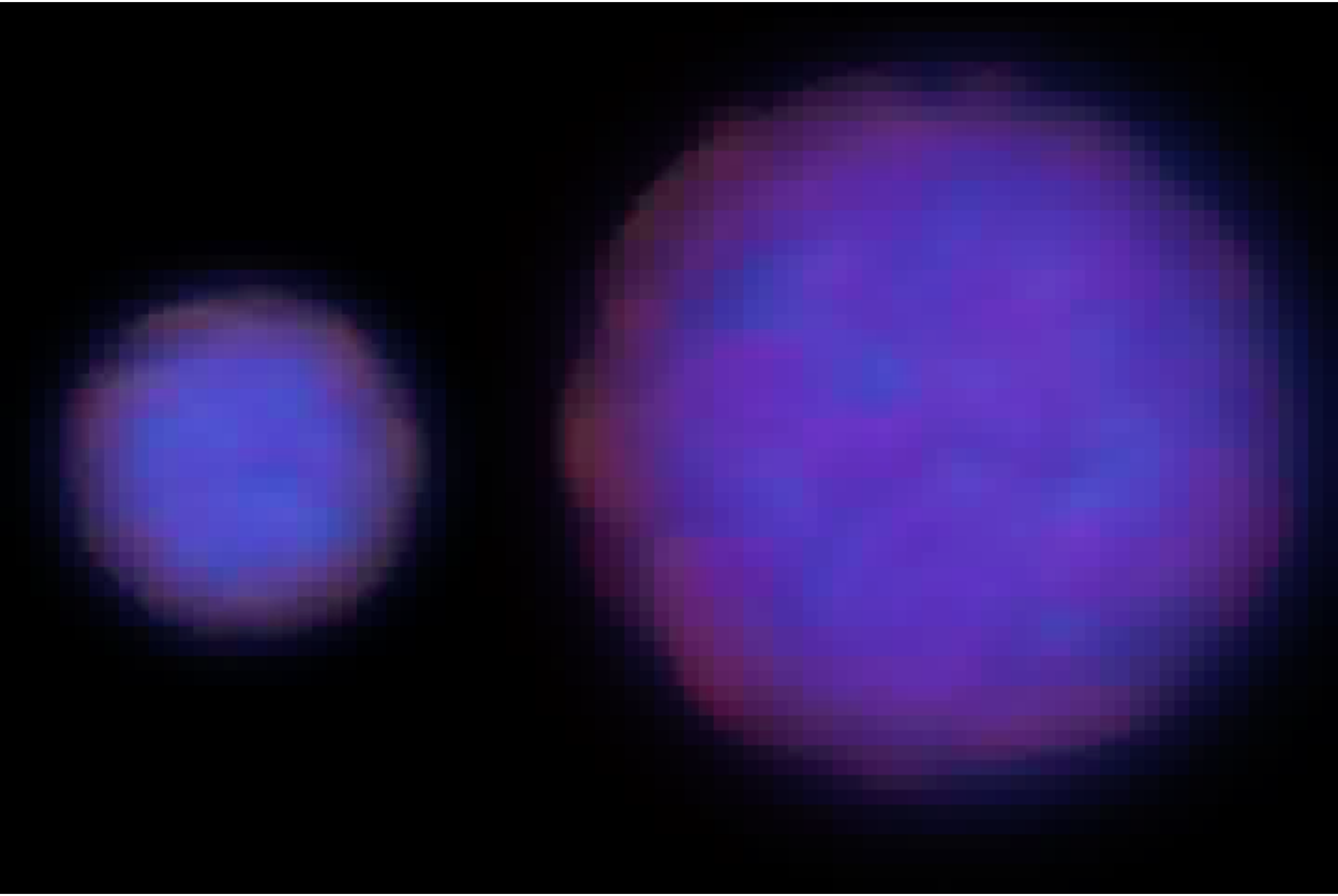


Dark Matter 3D-map

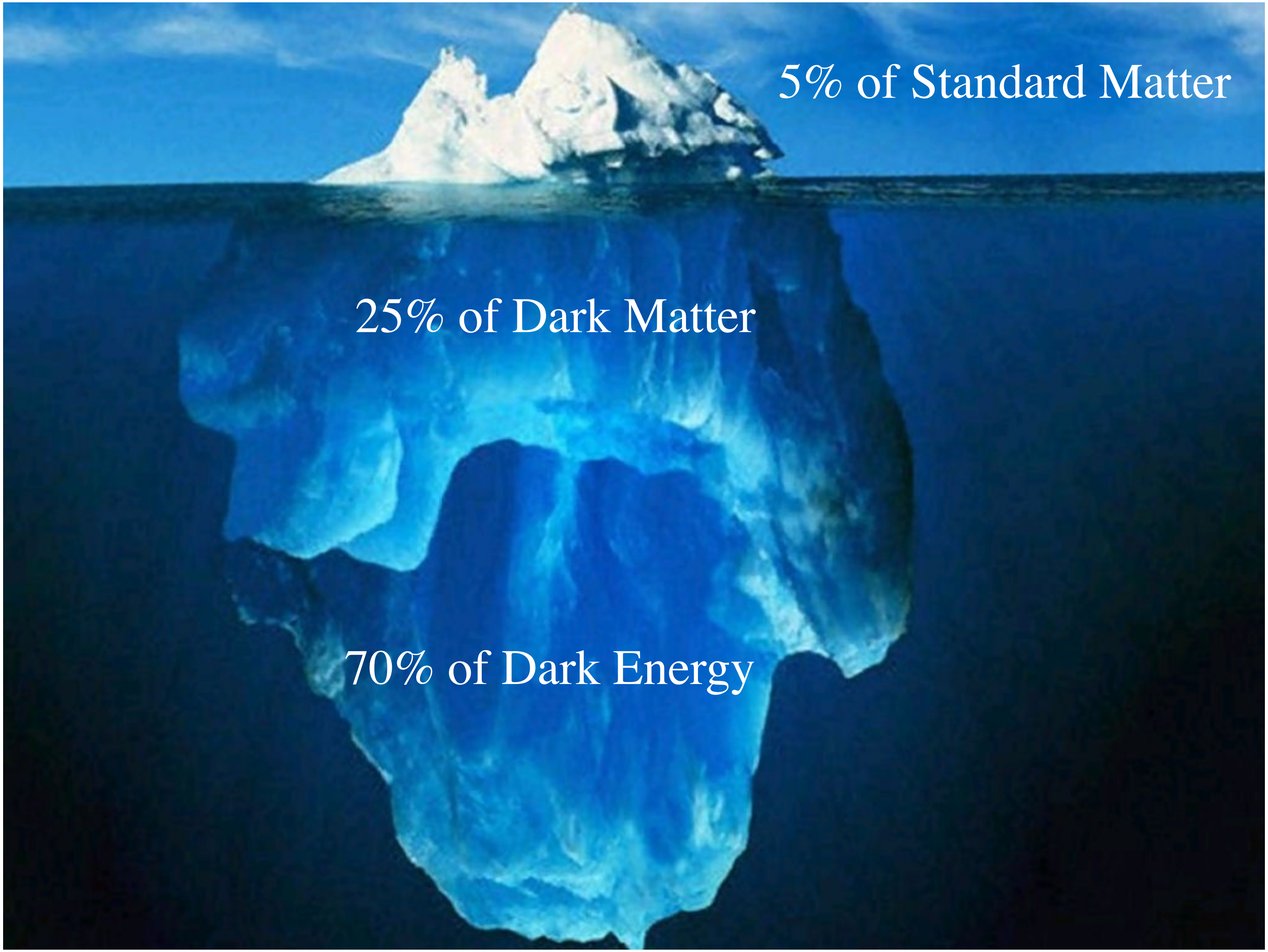


Colliding clusters

Colliding clusters

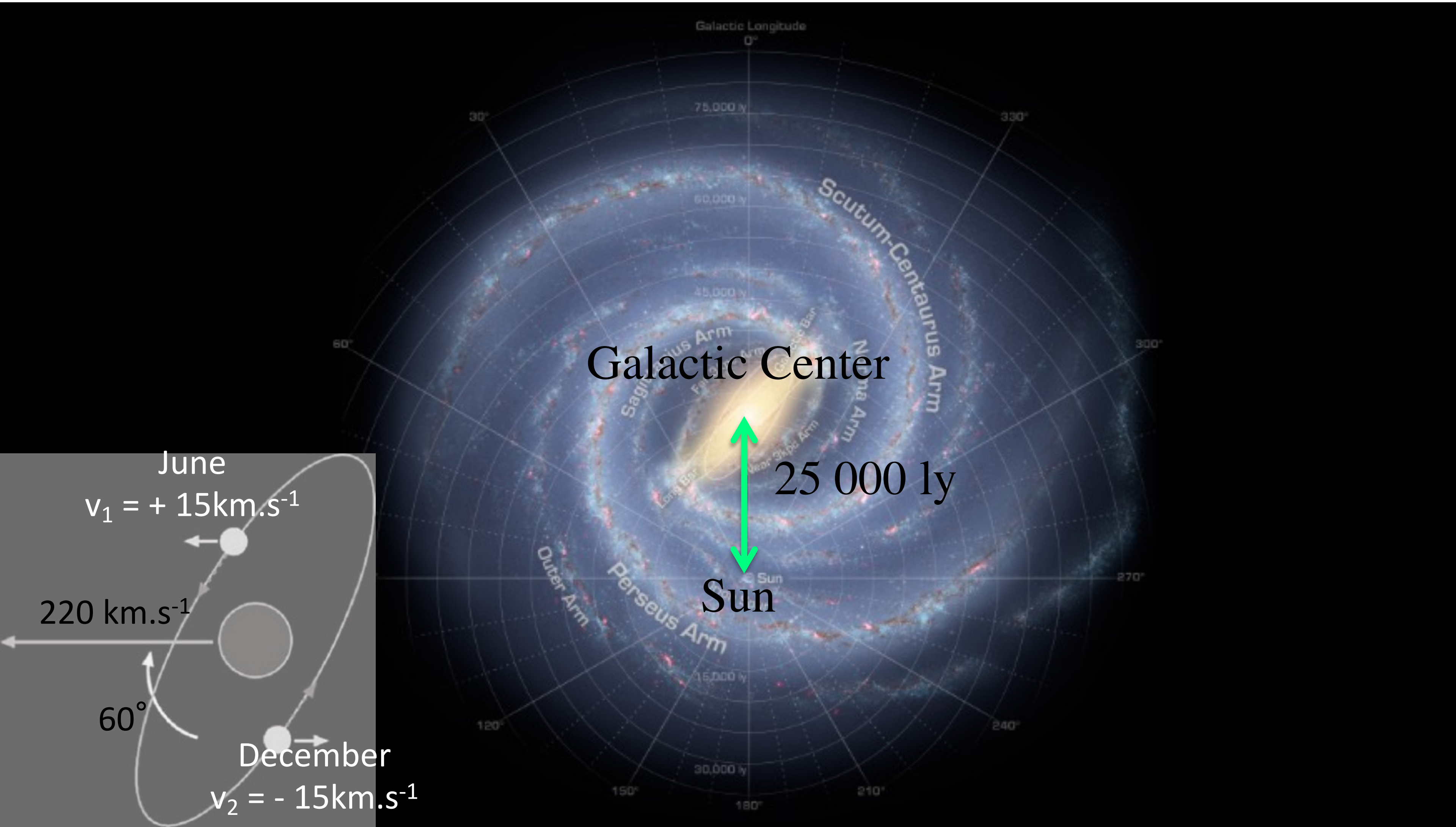


Energy composition of the universe



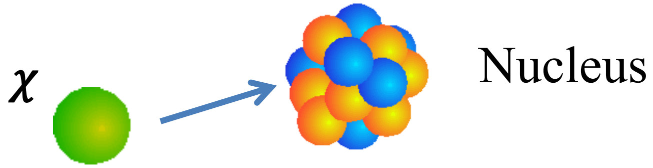
Characteristics of Dark Matter Particles

- Weak interaction
- Stable
- Non-baryonic Matter
- Non relativistic



Direct dark matter detection principle

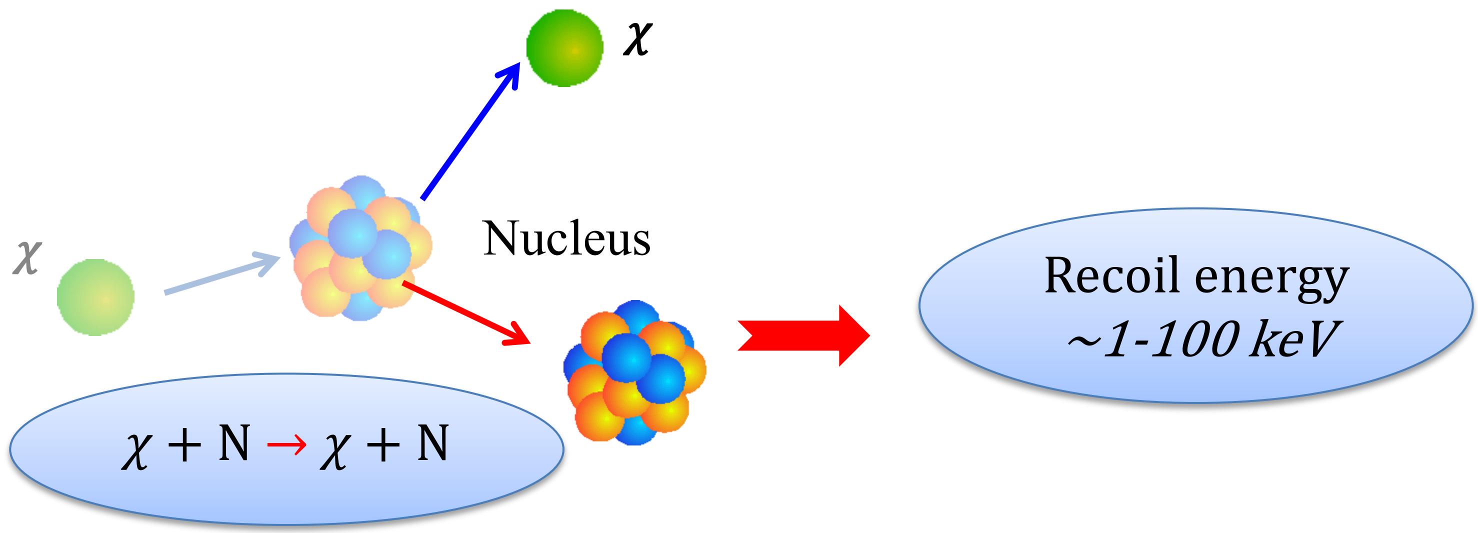
Nuclear Recoil (NR)

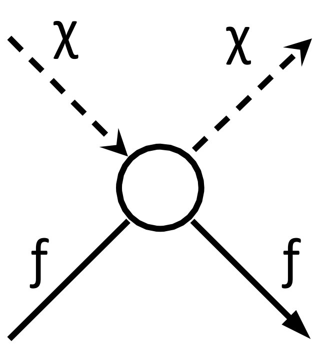


$$\chi + \mathrm{N} \rightarrow \chi + \mathrm{N}$$

Direct dark matter detection principle

Nuclear
Recoil
(NR)

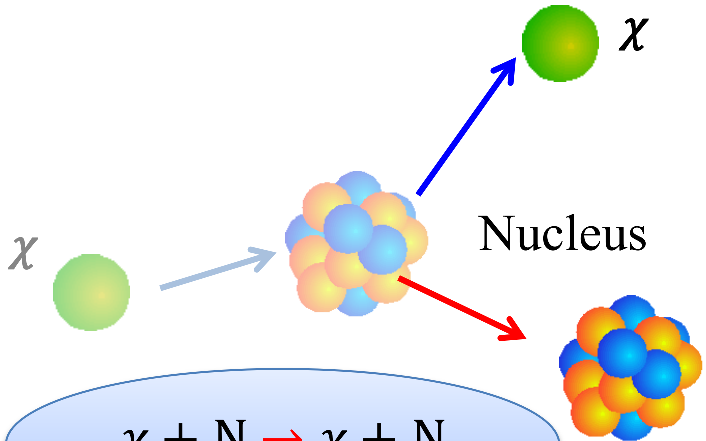




- **Direct detection**
- Indirect detection
- Production

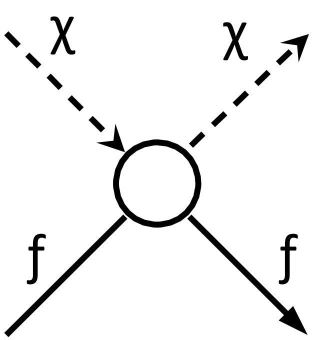
Direct dark matter detection principle

Nuclear Recoil (NR)



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

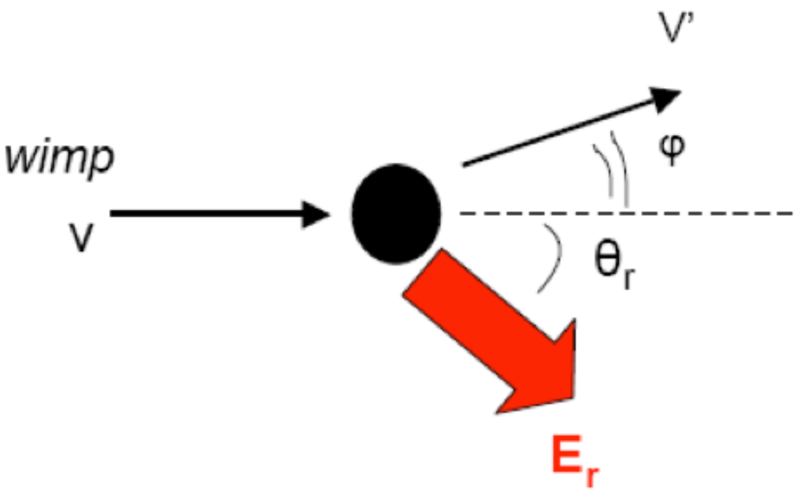
Recoil energy
~1-100 keV



Electronic Recoil (ER)

γ and β particles
interact with the atomic electrons
→ background

Cinematic



$$\frac{m_\chi}{2}v^2 = \frac{m_\chi}{2}v'^2 + E_r \qquad \left(E_r = \frac{1}{2}m_N w^2 \right)$$

$$m_\chi v = m_\chi v' \cos\varphi + m_N w \cos\theta_r$$

$$m_\chi v' \sin\varphi = m_N w \sin\theta_r$$

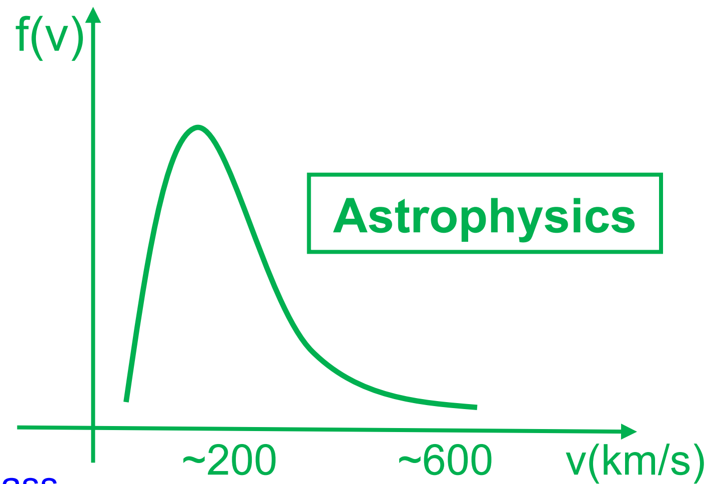
$$\Rightarrow \quad E_r = \left(\frac{m_\chi}{2}v^2\right) \times \frac{4 m_N m_\chi}{(m_N + m_\chi)^2} \times \cos^2\vartheta_r$$

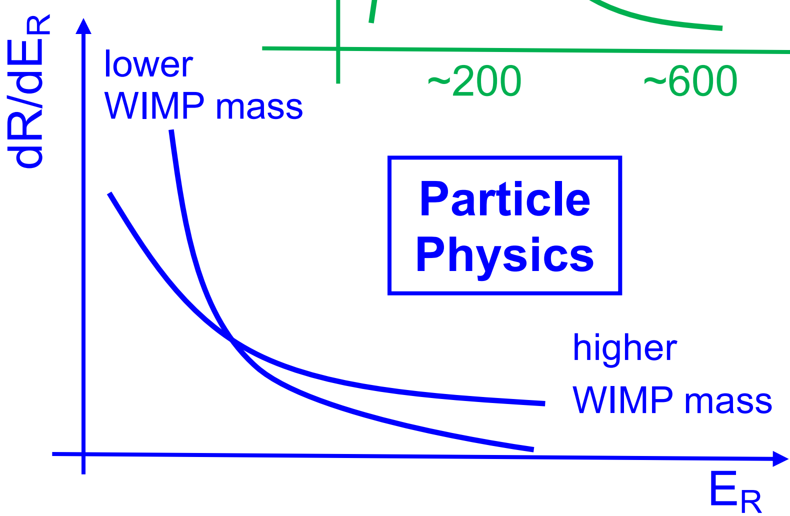
~ 1 - 100 keV

Expected rate for terrestrial detector

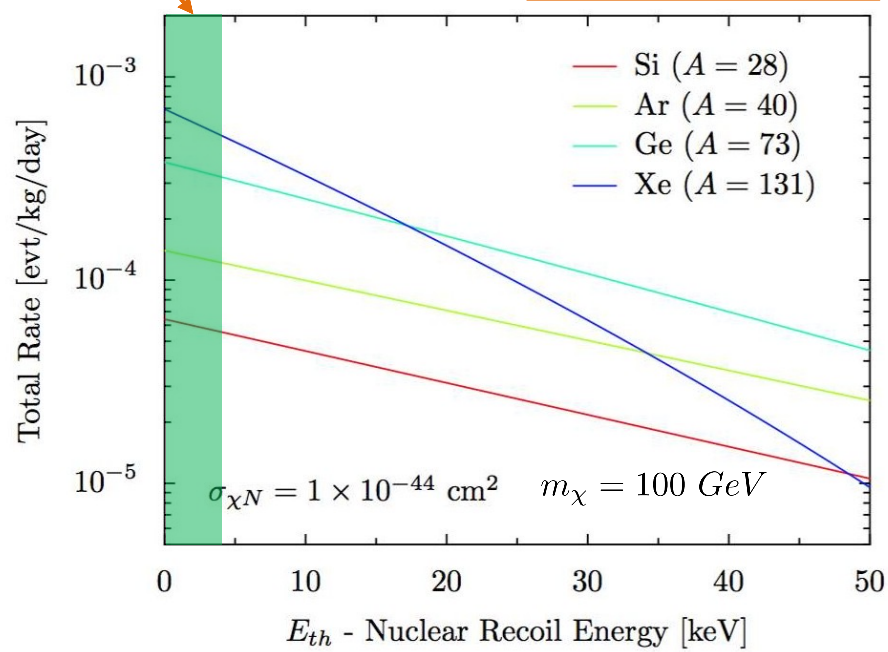
$$\frac{dR}{dE_R} = N_N \frac{\rho_\odot}{m_\chi} \int_{v_{min}}^{v_{max}} f(v) v \frac{d\sigma}{dE_R} dv$$

$$v_{min} = \sqrt{\frac{m_N E_{th}}{2\mu}}$$



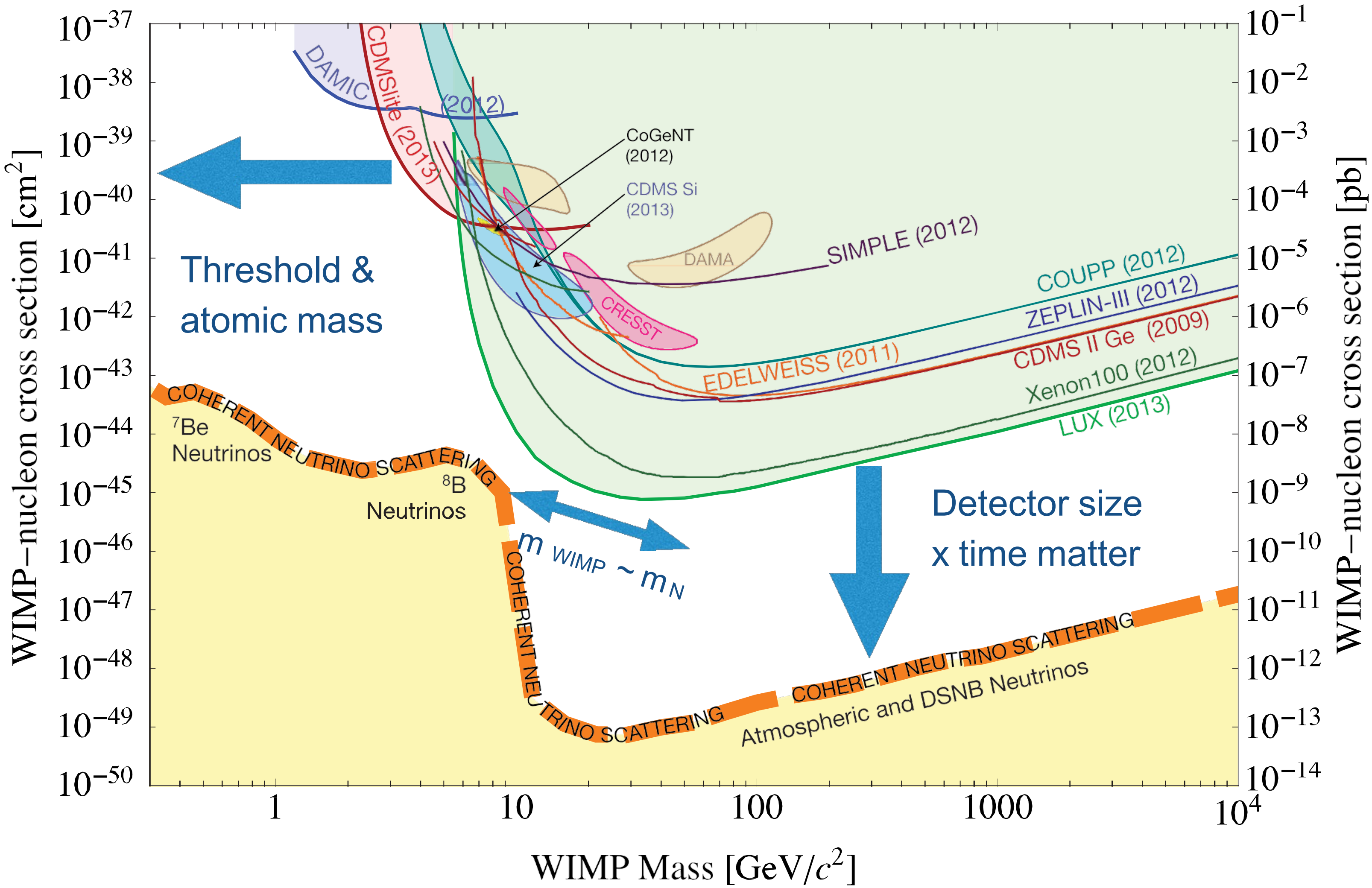


Detector

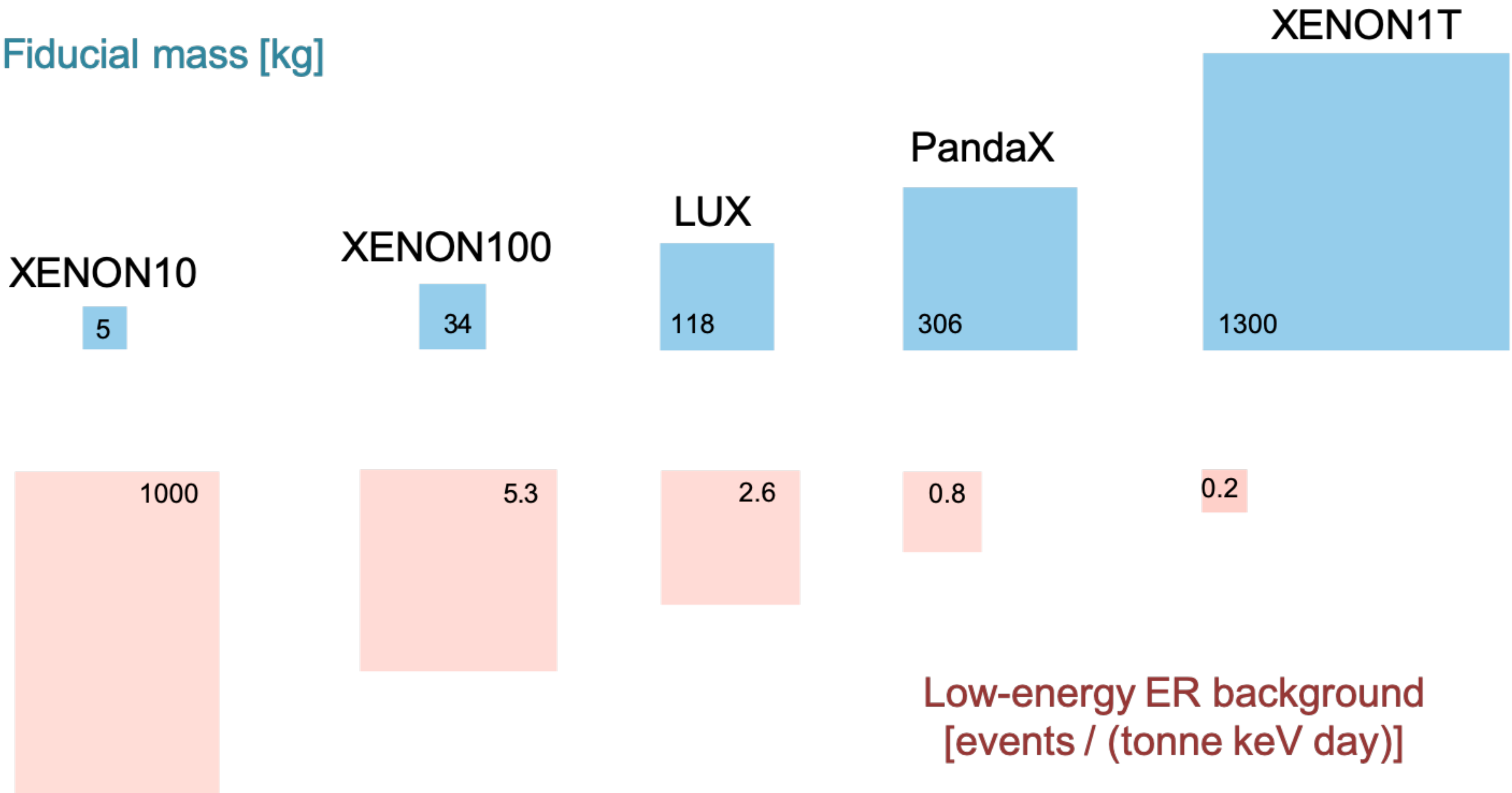


How is evolving the field of Direct Detection ?

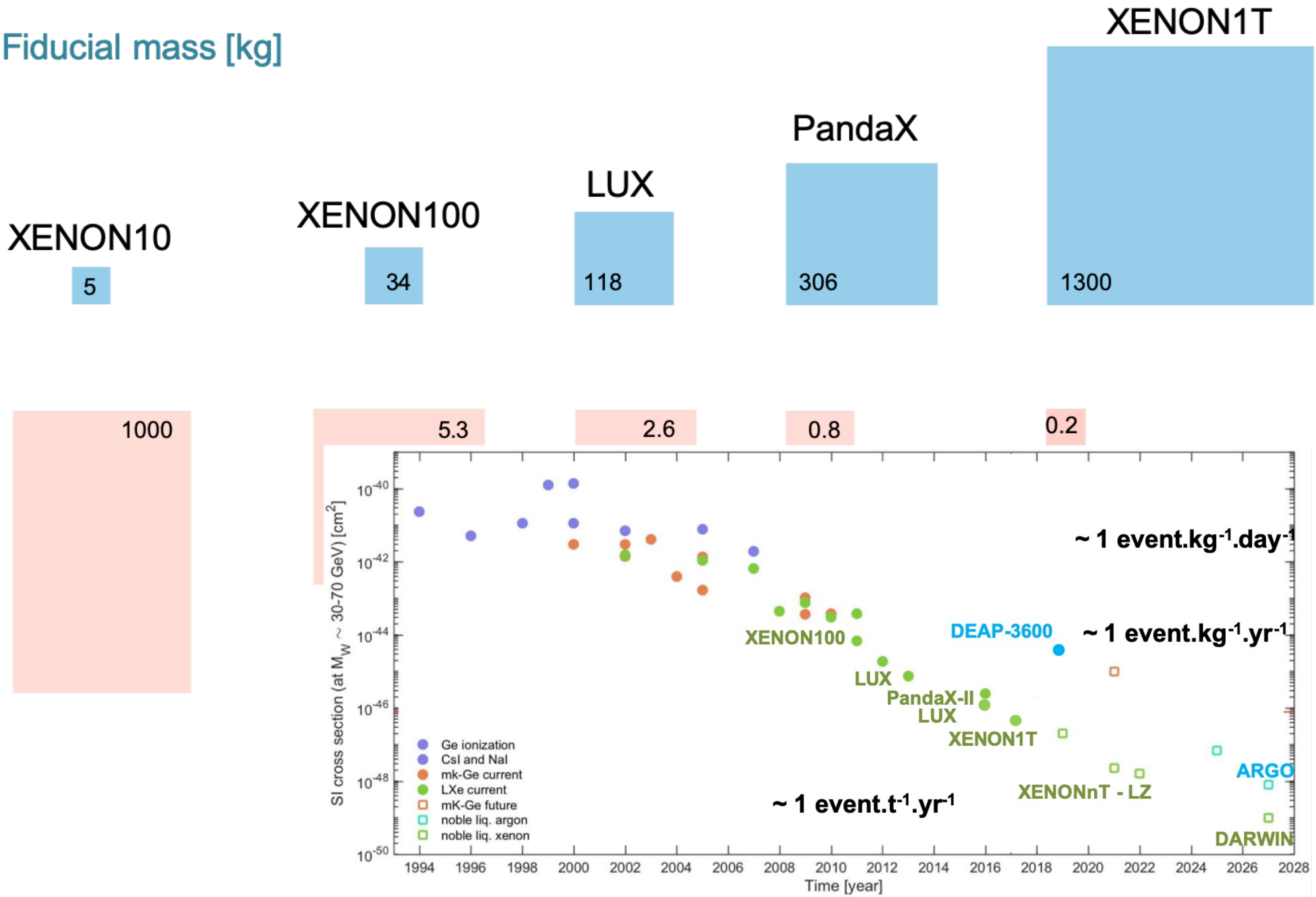
$$R \sim 0.13 \frac{\text{events}}{\text{kg . year}} \left[\frac{A}{100} \times \frac{\sigma_{\chi N}}{10^{-38}\ \text{cm}^2} \times \frac{\langle v \rangle}{220\ \text{km.s}^{-1}} \times \frac{\rho_\odot}{0.3\ \text{GeV.cm}^{-3}} \right]$$



Evolution of LXe TPC as WiMP detectors



Evolution of LXe TPC as WiMP detectors



Detectors needs

- ultra-low background experimental environment
- low energy threshold to detect small recoil energy signals
- good discrimination power against particle that might mimic WIMP collision
- large detector mass to enhance the interaction probability inside the target

Hunts Needle in a Haystack

Detectors needs

- ultra-low background experimental environment
- low energy threshold to detect small recoil energy signals
- good discrimination power against particle that might mimic WIMP collision
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The fight against the background

- **Use WIMP properties**

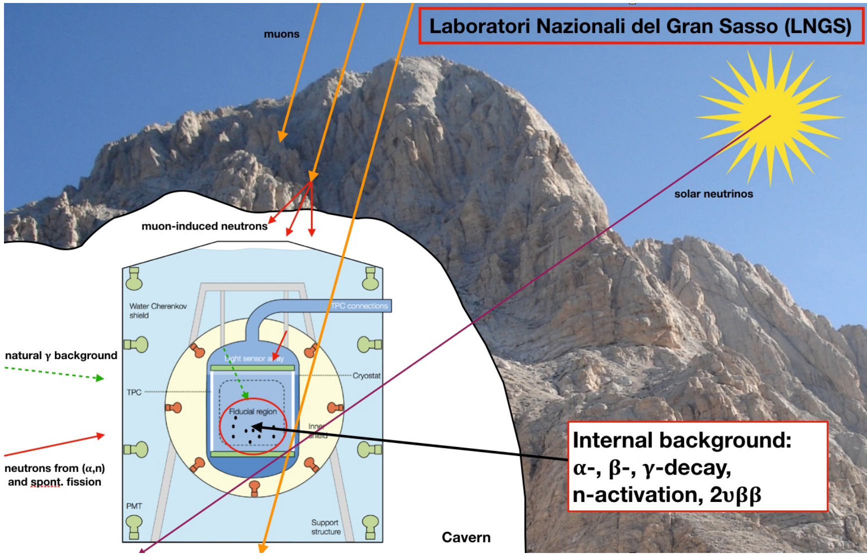
  - No double scatter
  - Homogeneously distributed
    → *Position reconstruction*
  - Nuclear recoils
    → *ER/NR Discrimination*

- **Avoid background**

- **External γ's** from natural radioactivity
- Material screening
- Self shielding (fiducialization)

- **External neutrons**
  muon-induced (α,n) and fission reaction
- Material screening (low U and Th)
- Underground experiments
- Shield & active veto

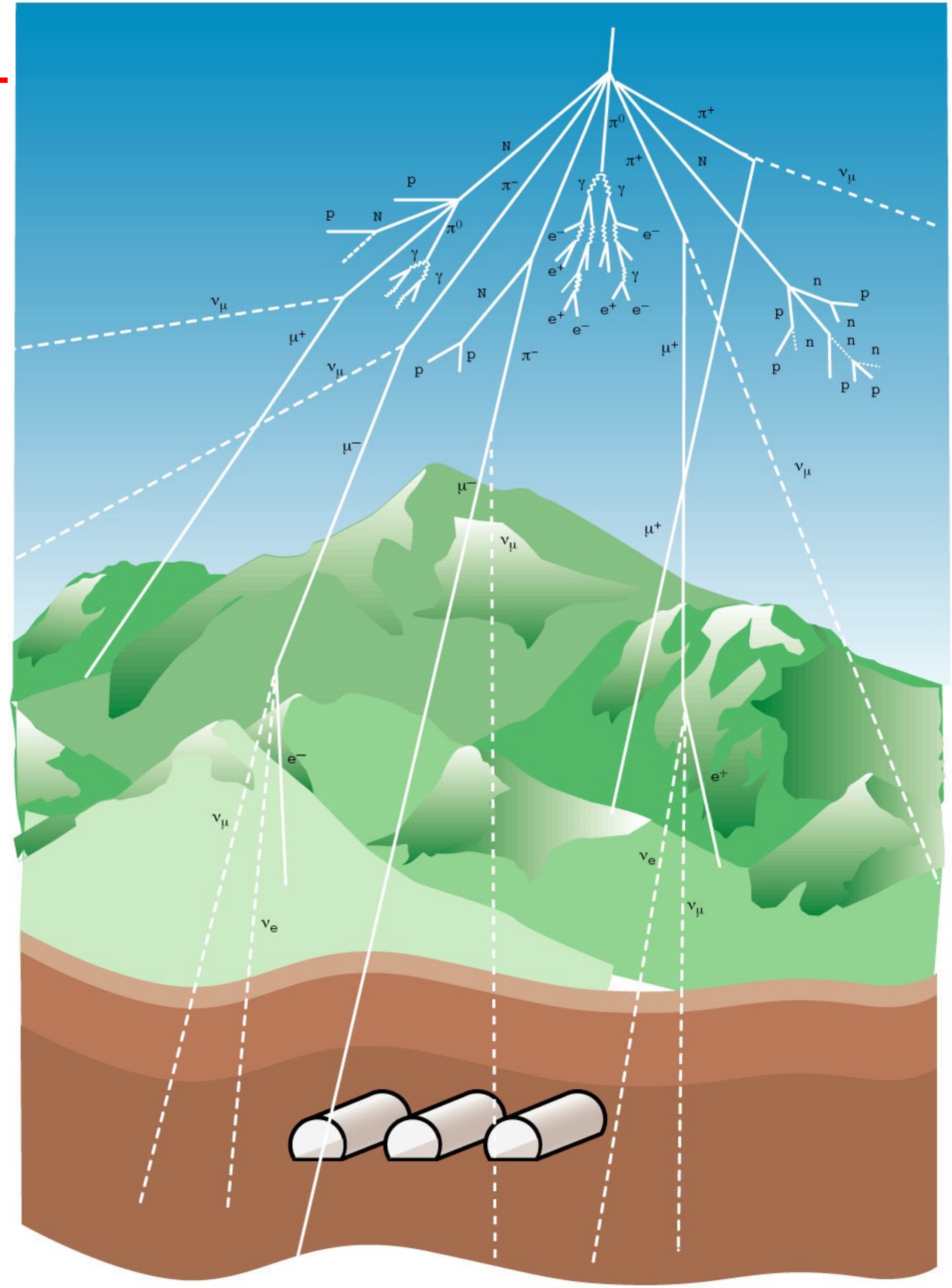
- **Internal contamination**
- ^{85}Kr : removed by cryogenic distillation
- ^{222}Rn : removed by cryogenic distillation
- ^{136}Xe : ββ decay, long lifetime ($T_{1/2}$ = 2.2x10^{21} years)



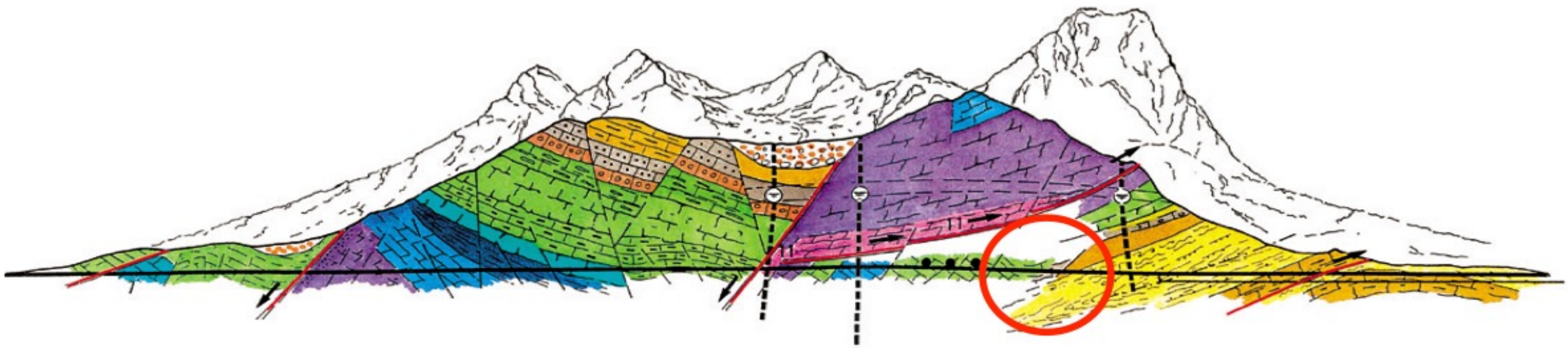
Cosmic Rays

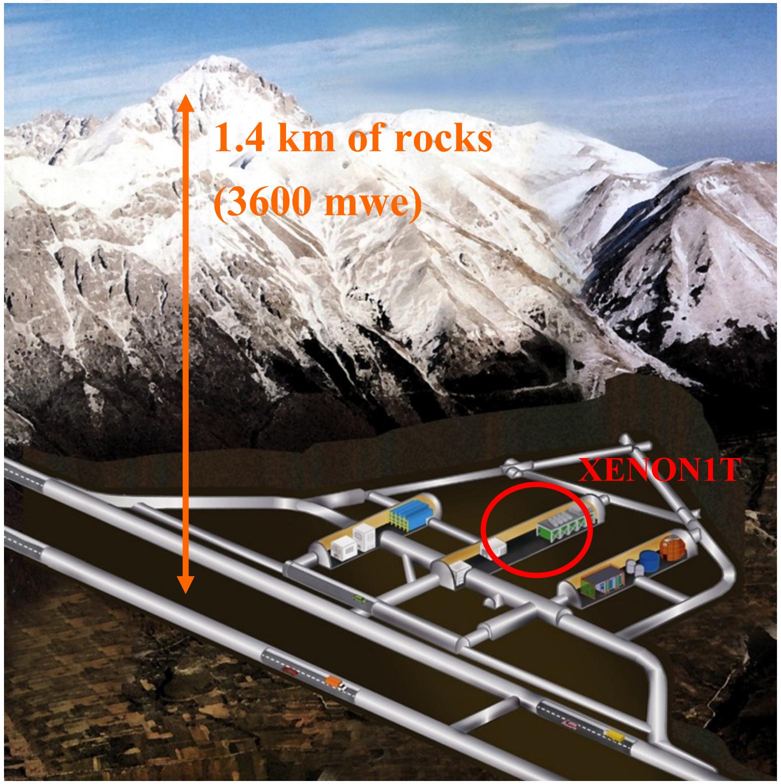
To increase the sensitivity of the experiments, we need:

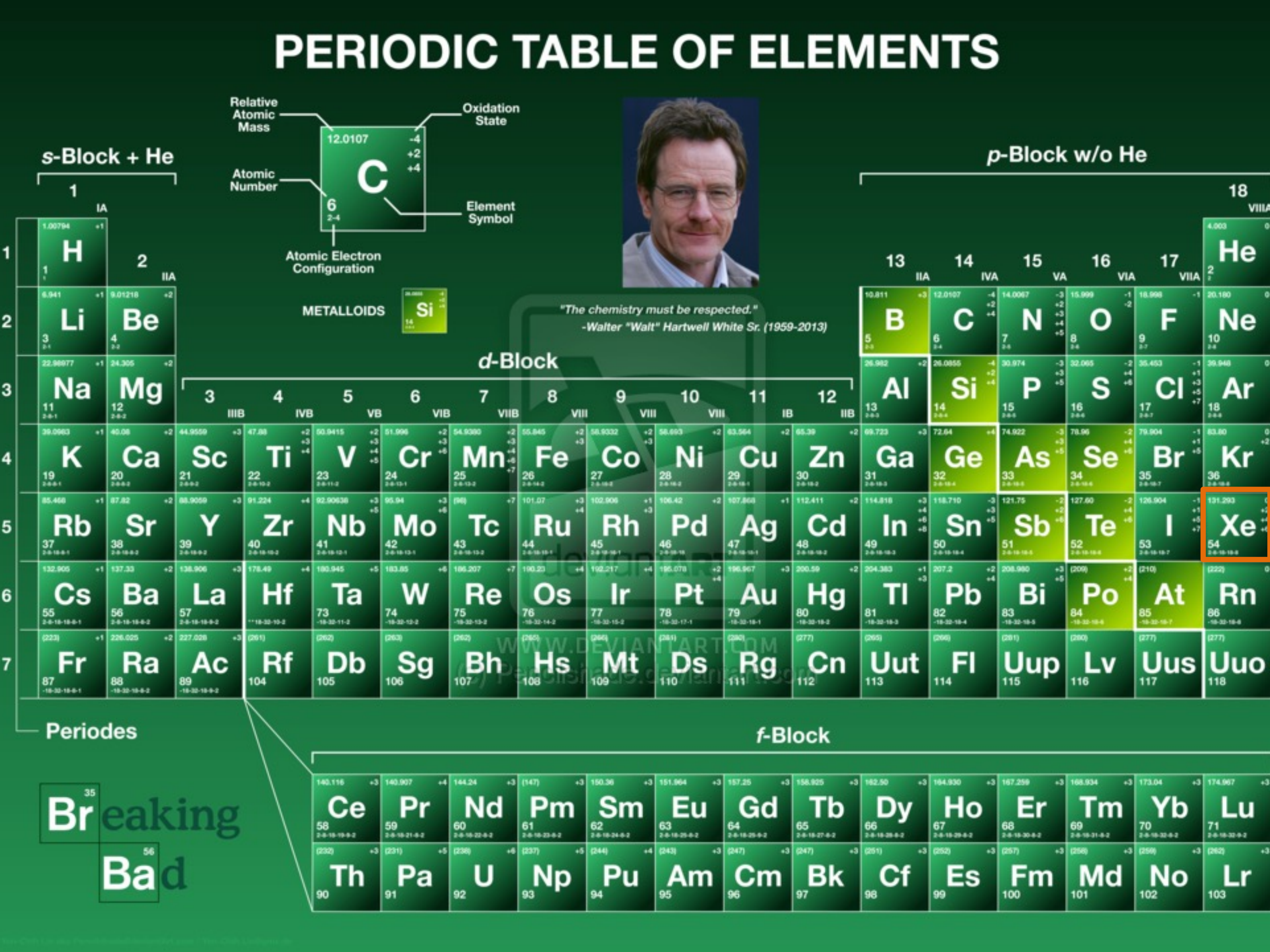
- To hide under a mountain to be protected from cosmic rays (100 per second across ou body),
- To be protected from natural radioactivity from rocks
- To purify from materials of the detector



XENON1T experiment site

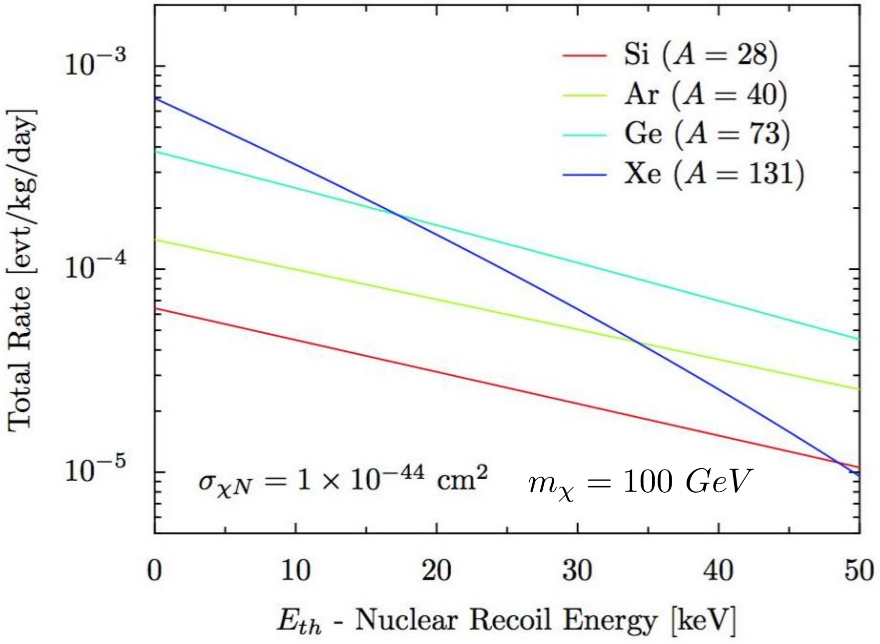





PERIODIC TABLE OF ELEMENTS
s-Block + He
Relative Atomic Mass
Oxidation State
Atomic Number
Element Symbol
Atomic Electron Configuration
12.0107
C
6
2-4
-4 +2 +4
METALLOIDS
Si
"The chemistry must be respected."
-Walter "Walt" Hartwell White Sr. (1959-2013)
p-Block w/o He
d-Block
f-Block
Periodes
1 IA
2 IIA
3 IIIB
4 IVB
5 VB
6 VIB
7 VIIB
8 VIII
9 VIII
10 VIII
11 IB
12 IIB
13 IIIA
14 IVA
15 VA
16 VIA
17 VIIA
18 VIIIA
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra Ac Rf Db Sg Bh Hs Mt Ds Rg Cn Uut Fl Uup Lv Uus Uuo
Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
Breaking Bad
WWW.DEVIANTART.COM

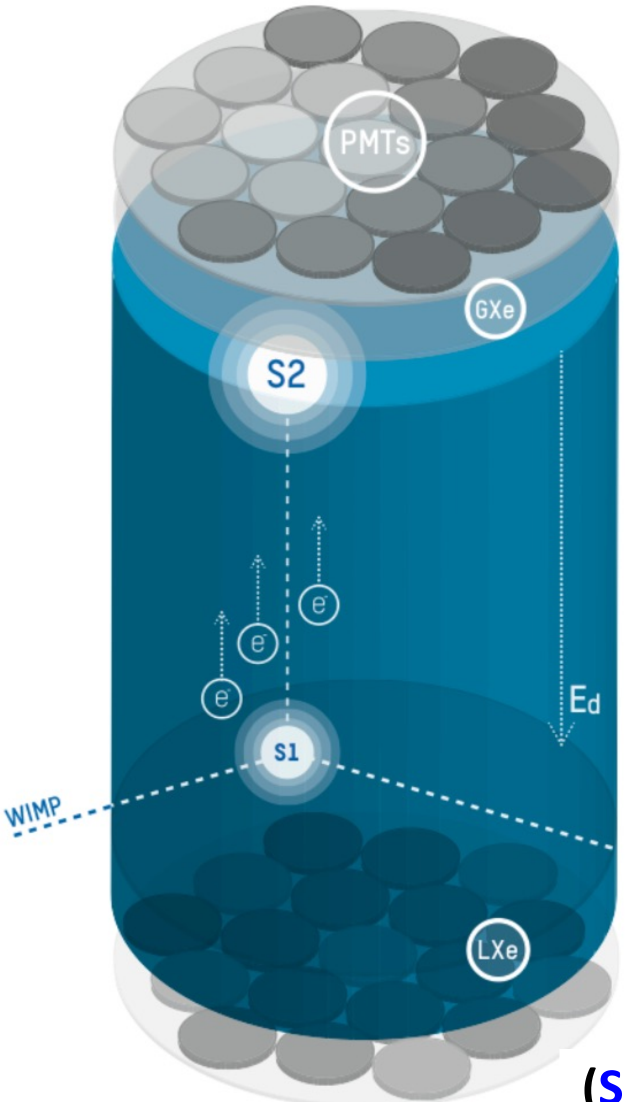
Why Xenon ?

- Large mass number A (131) (Interaction cross section ∝ A^2)
- 50% odd isotopes (^{129}Xe, ^{131}Xe) for Spin-Dependent interactions
- Kr can be reduced to ppt levels
- High stopping power, i.e. active volume is self-shielding
- Efficient scintillator (178 nm)
- Scalable to large target masses
- Electronic recoil discrimination with simultaneous measurement of scintillation and ionization



Dual phase TPC: principle

TPC = Time Projection Chamber



S1:

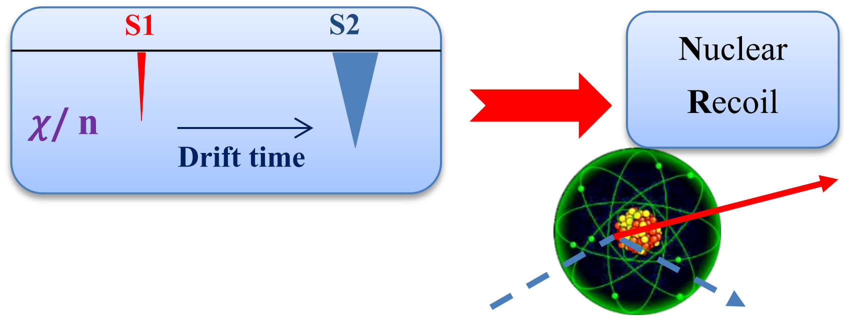
→ Photon (λ = 178 nm) from Scintillation process → Dectected by PMTs (mainly botton array)

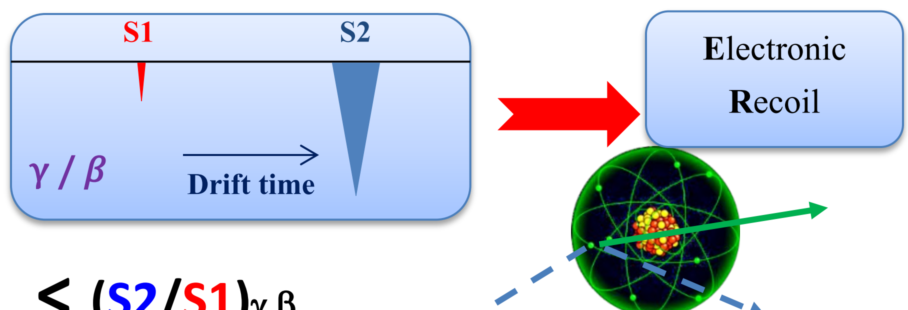
S2:

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

3D reconstruction :

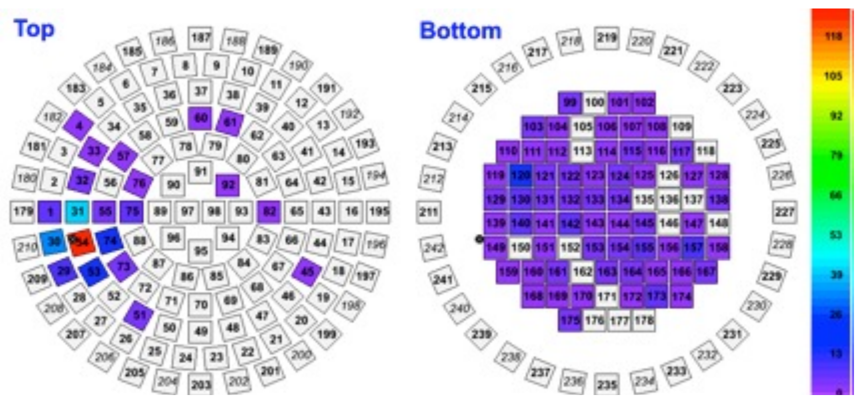
→ X,Y from top array
→ Z from Drift time



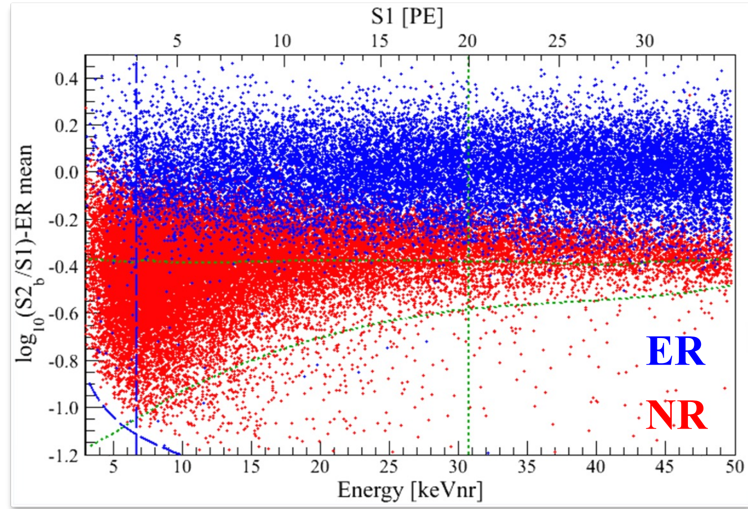


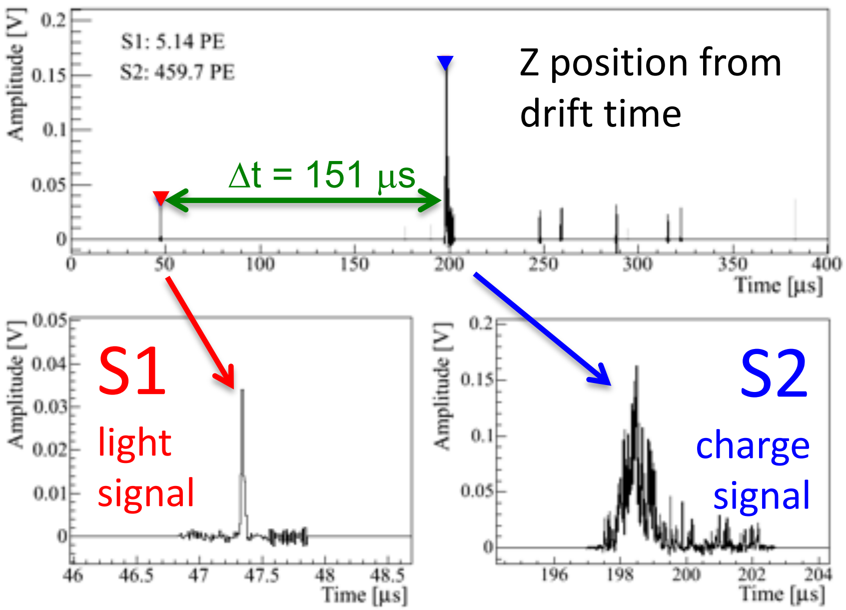
$$(S2/S1)_{WIMP,n} < (S2/S1)_{\gamma,\beta}$$

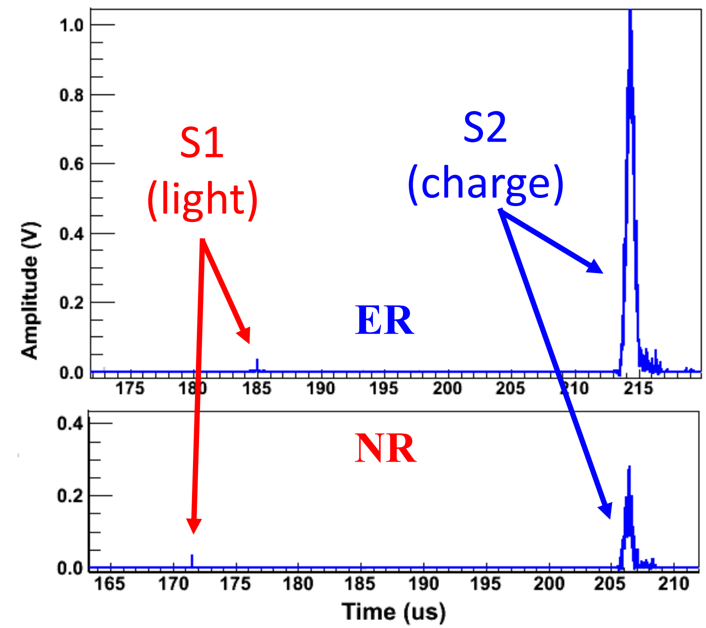
Dual phase TPC: real life



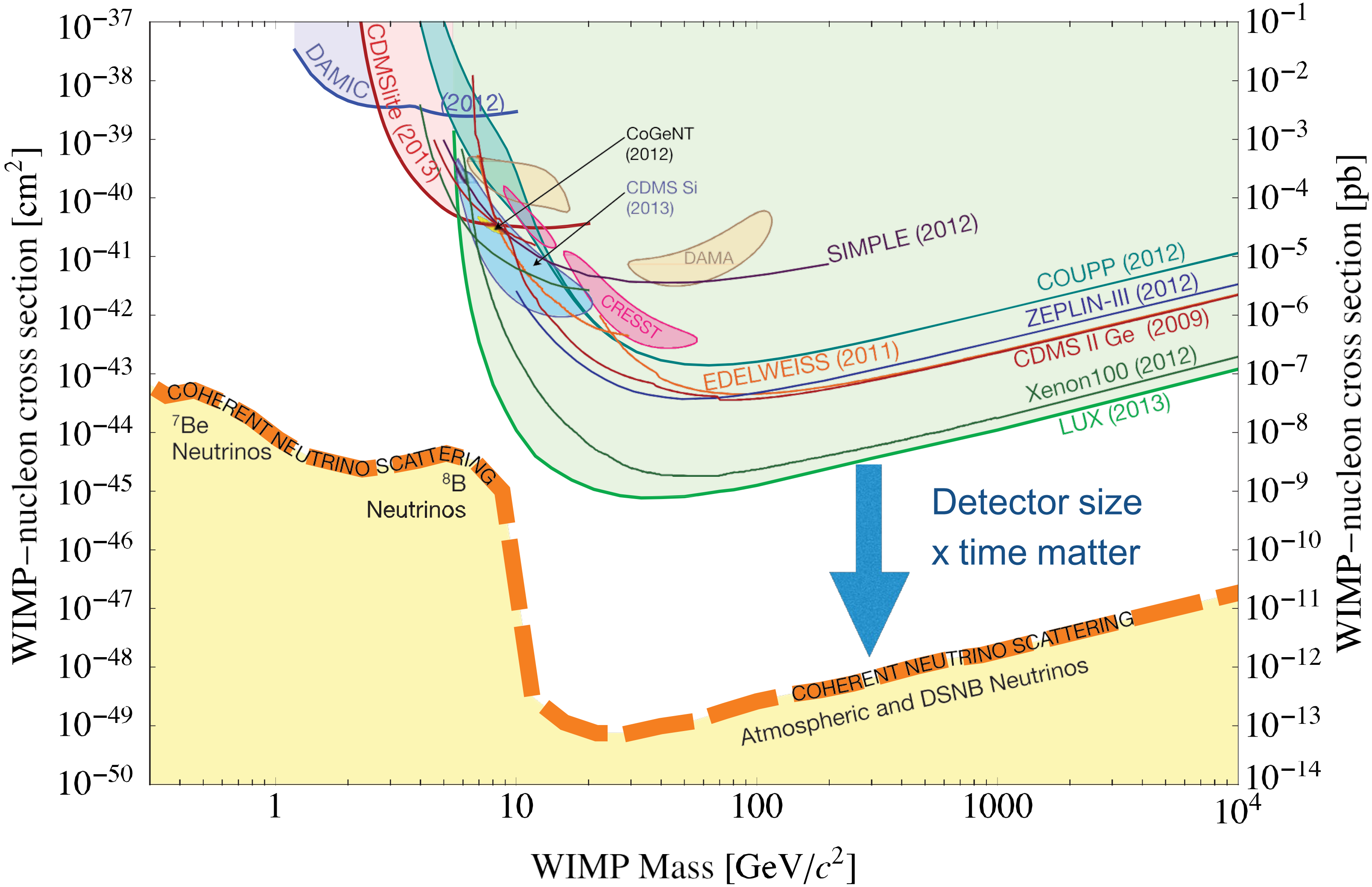
X and Y position from S2 hit pattern on the top PMTs







How is evolving the field of Direct Detection ?



XENON World

25 Institutions
11 Countries
165 Scientists

Columbia, RPI, Nikhef, Muenster, Stockholm, Mainz, MPIK, Freiburg, Zurich

Chicago, UCLA, UCSD, Rice

Tokyo, Nagoya, Kobe

Purdue, Coimbra, Subatech, LPNHE, LAL, Bologna, LNGS, Torino, Napoli, Weizmann, NYUAD

XENON1T facility

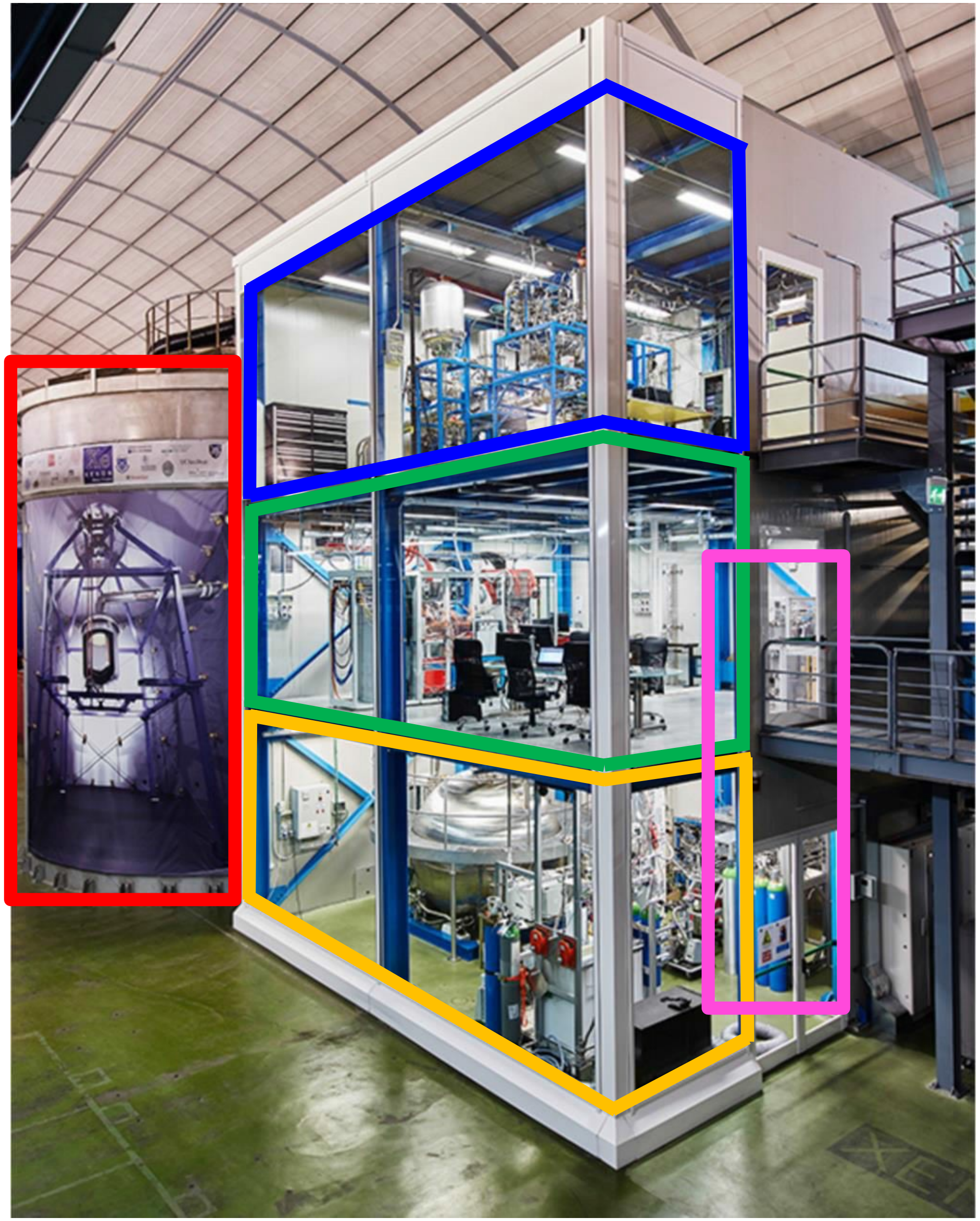
Water shield: deionized water as passive radiation shield
Muon veto: Active muon veto against muon induced neutrons (84 PMTs)

Cryogenics: Stable conditions(3.2t LXe)
Purification: LXe flow through getters, remove impurities

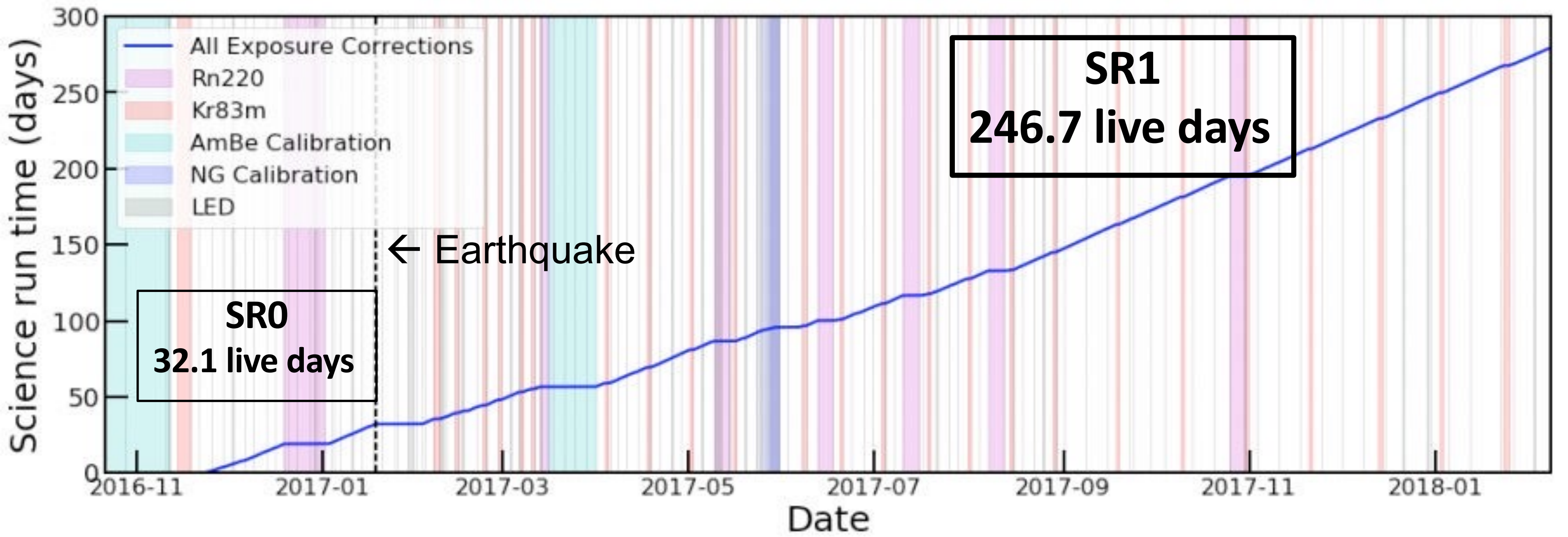
DAQ: Each channel has its own threshold, Flexible software algorithms
Readout: Up to 300MB/s for high rate calibrations

ReStoX: Emergency recovery up to 7.6 tons of LXe
Passive: No active cooling required to keep Xe contained

Kr Distillation: Remove Kr from system during fill or online
Rn Distillation: Initial tests show promising reduction for Rn



XENON1T Data Taking



- DM total exposure SR0+SR1: 278.8 Live days
  ➔ Largest exposure reported to-date with this type of detector

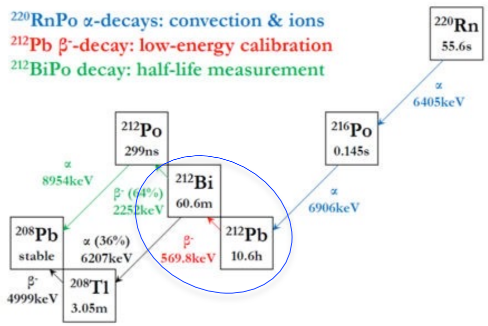
- Calibration Data:
  - 83mKr ➔ Spacial Response (electron lifetime,…)
  - 220Rn ➔ ER-Band
  - 241AmBe & NG➔ NR-Band
  - LED ➔ PMT gain monitoring

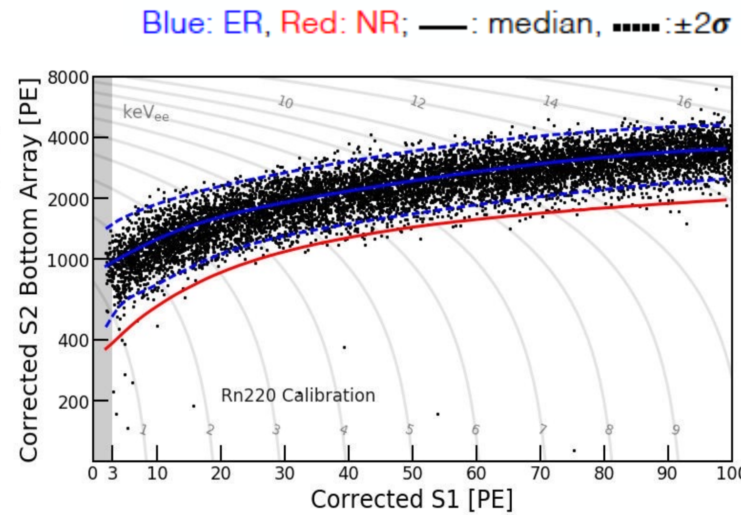
Calibrations

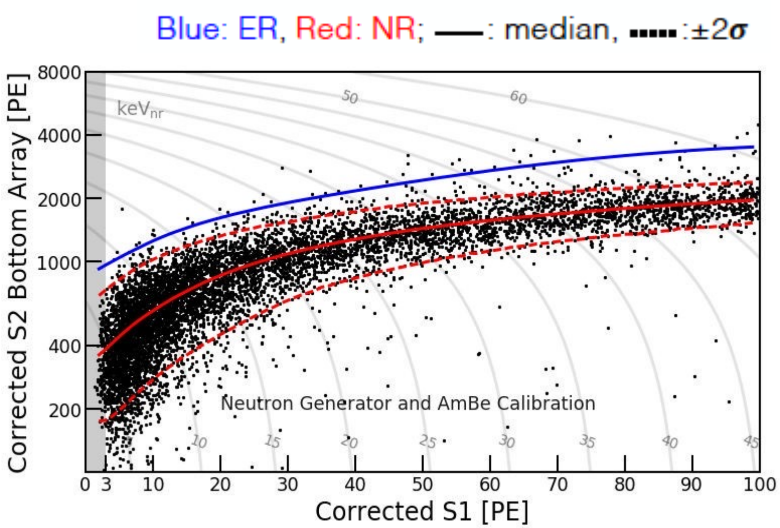
Electronic Recoils

Internal source

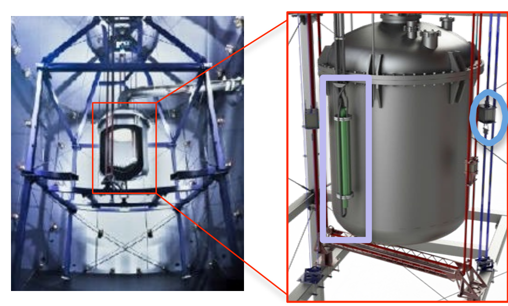
- ^{228}Th source emanates ^{220}Rn into LXe
- β-**decay** of ^{212}Pb to ^{212}Bi
  ➔ **low energy** events (2–20 keV)
- Decay of activity dominated by ^{212}Pb half-life (10.6 h)







External source

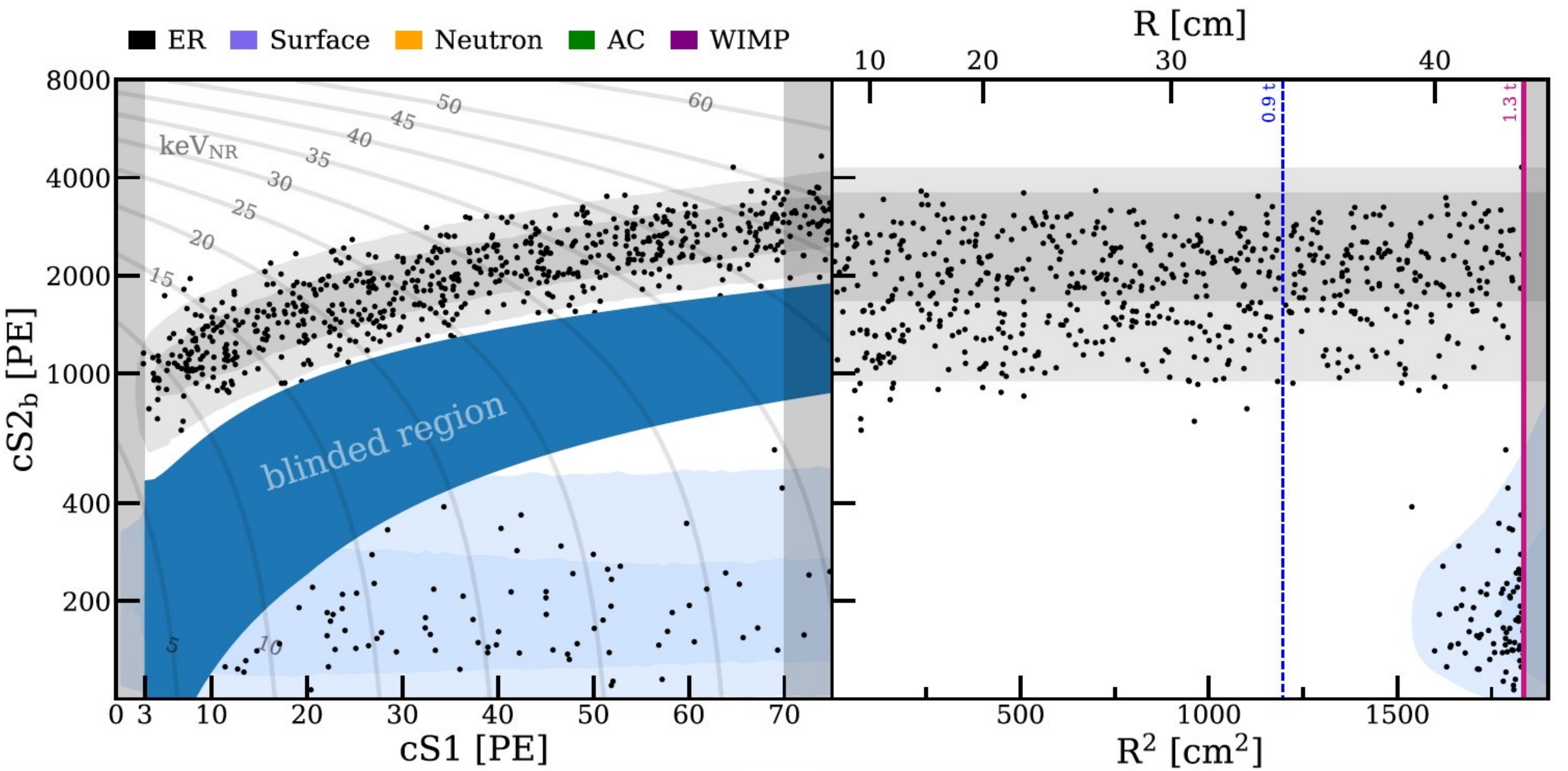


Nuclear Recoils

- External ^{241}AmBe source mounted on a belt
  - The α particles emitted by the decay of the Am collide with the light Be nuclei producing fast neutrons
- Neutron Generator

Dark Matter Search Data

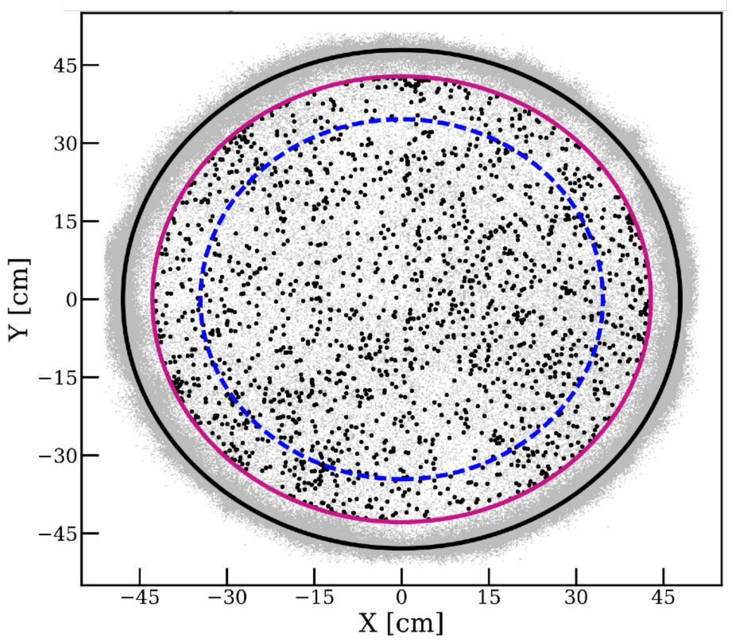
- **Blinding ➔** to avoid biases in event selection and signal/background modeling
- **Salting** (addition of fake events) ➔ to protect against post-unbliding tuning of the cuts and background models

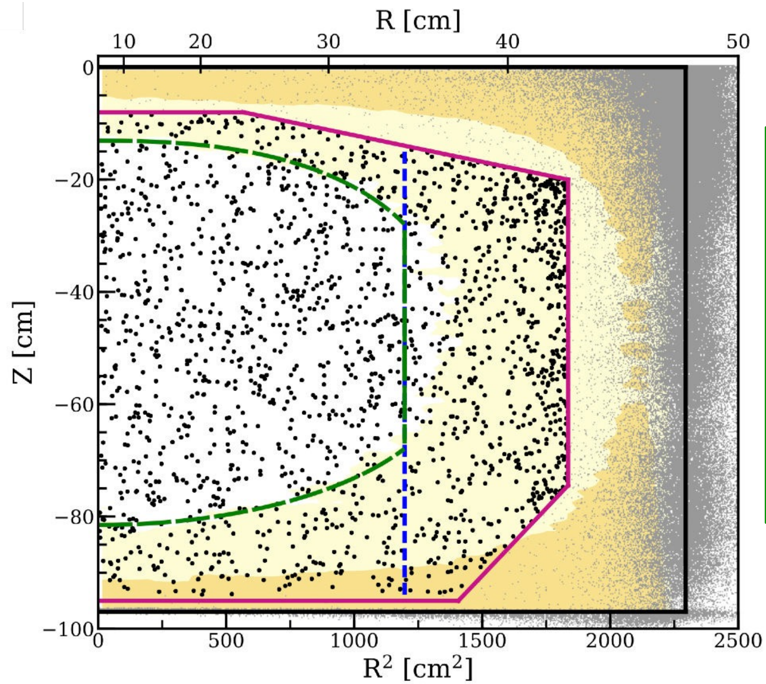


Fiducial Volume Optimization

Optimize fiducial volume before unblinding by using improved understanding

- position reconstruction
- detector response
- correlations between spectral and spacial distribution
- include knowledge on background distributions in statistical framework
- MC simulations





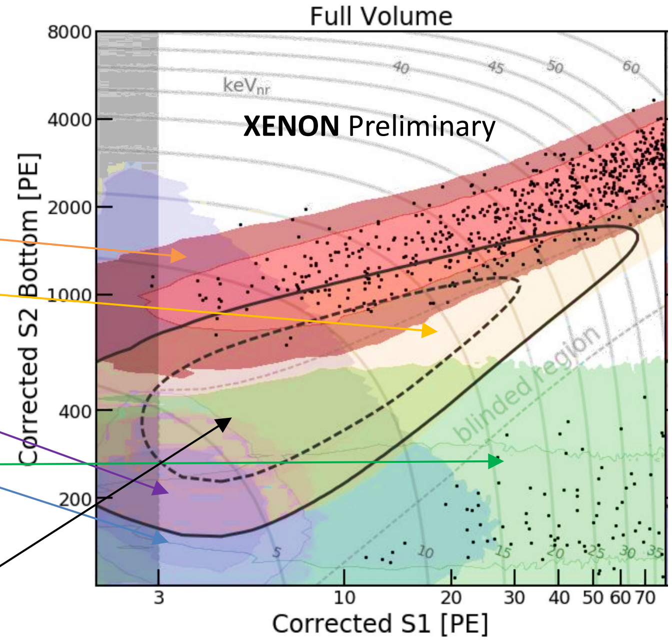
Aim at optimal S/B

larger FV

1 t → 1.3 t

XENON1T Expectations

278.8 days live-time	1.3 t Full ROI	0.65 t NR Reference	Mass (S2,S1) region
ER	627 ± 18	0.60 ± 0.13	
neutron	1.43 ± 0.66	0.14 ± 0.07	
CEνNS	0.05 ± 0.01	0.01	
AC	0.47 $^{+0.27}$	0.04 $^{+0.02}$	
Surface	106 ± 8	0.01	
TOTAL BKG	**735 ± 20**	**0.80 ± 0.14**	



Background models

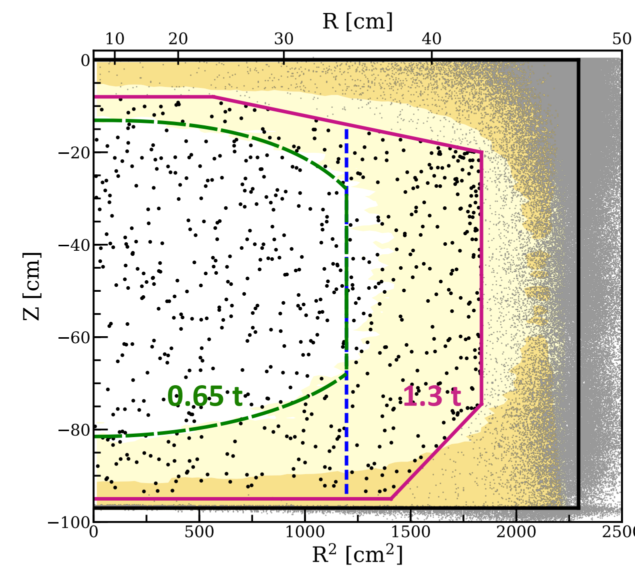
In 4-dimensional space: S1, S2, r, z

Statistical inference

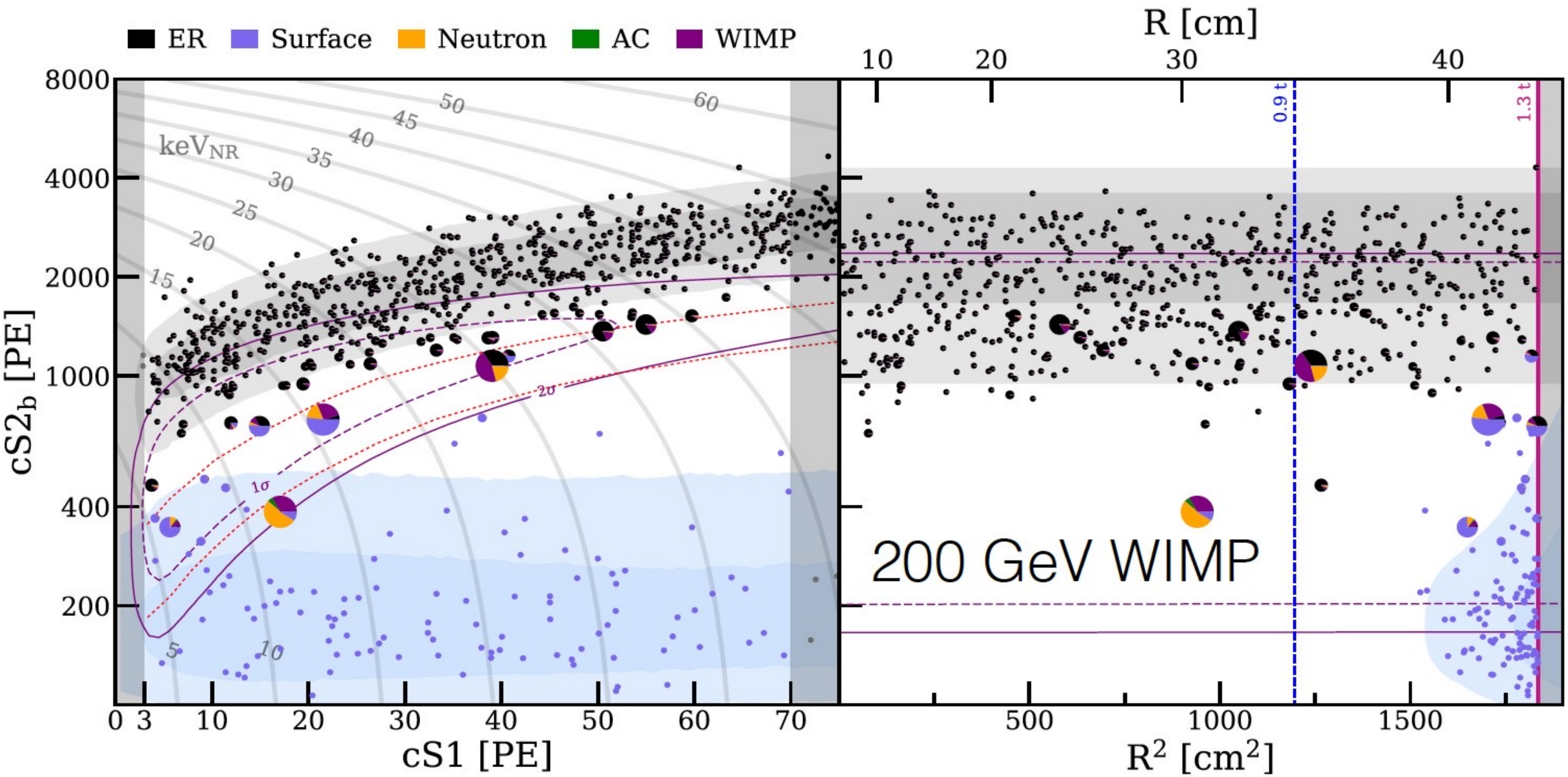
Done with PLR analysis in 1.3 t fiducial volume and full (S1,S2) space, corresponding to [4.9, 40.9] keV$_{nr}$ and [1.4, 10.6] keV$_{ee}$.

NR reference region

Between NR median and -2σ quantile. Numbers in table are for illustration; final results from complete PLR statistical inference.

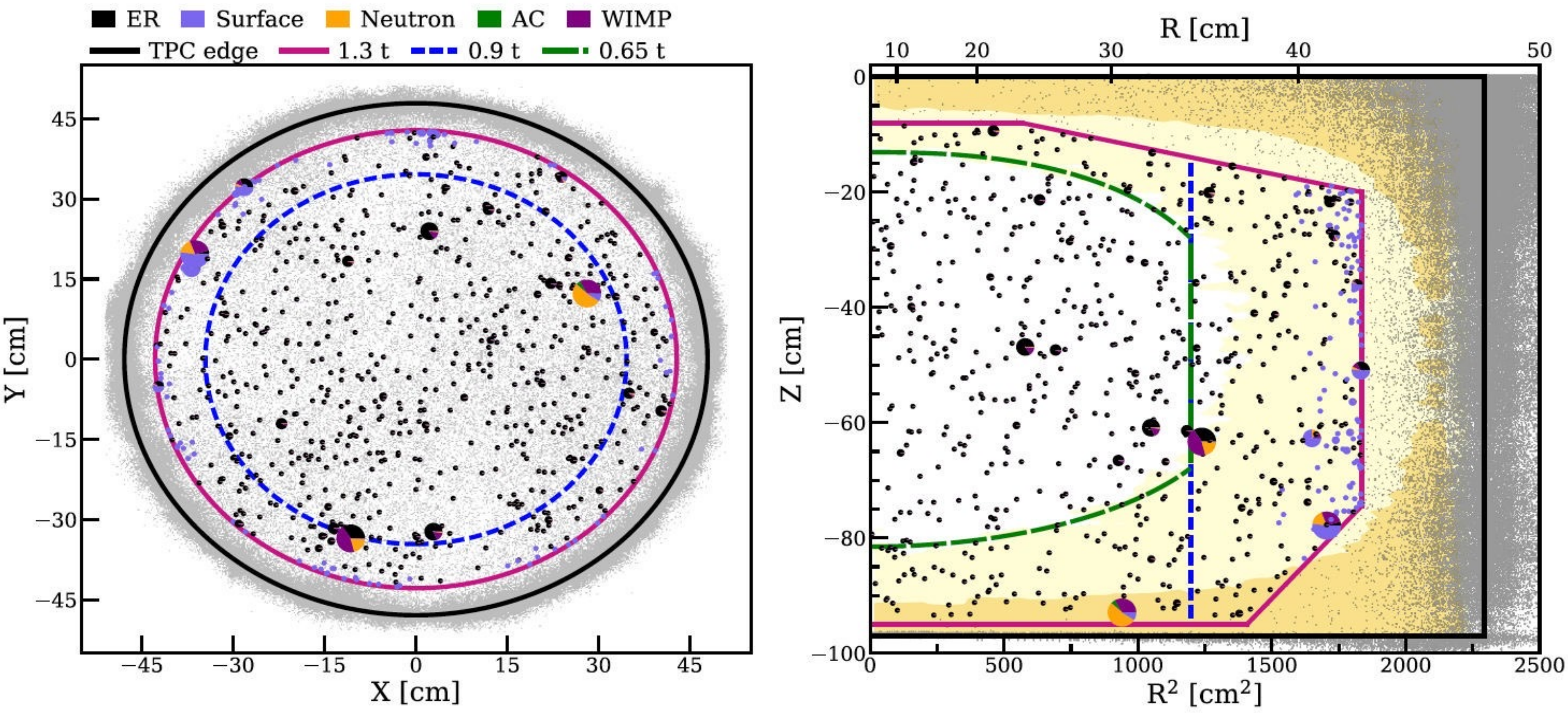


Dark Matter Search Results



- Results interpreted with unbinned profile likelihood analysis in cs1, cs2, R space
- Piechart indicate the relative probabilities of this event to be of a certain class for a best fit to a 200 GeV/c^2 WIMPs with a cross-secl on of 4.6 x 10^{-47} cm2

Spacial Distribution of Dark Matter Search Results

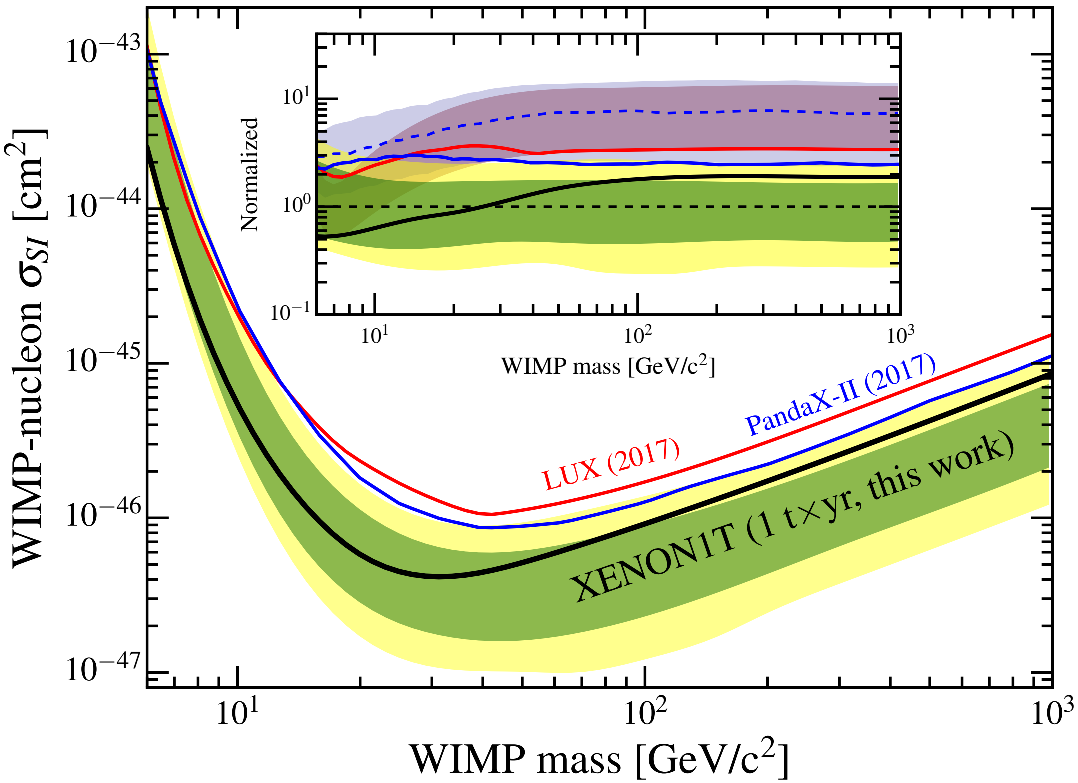


- Core volume to distinguish WIMPs over neutron background
- Yellow shaded regions display the 1σ (dark), and 2σ (light) probability density percentiles of the radiogenic neutron background component

XENON1T Results

- **Spin-independent WIMP-nucleon cross section**

Strongest exclusion limits (at 90% CL) on WIMPs > 6 GeV/c^2.



7 times better sensitivity compared to previous experiments (LUX, PANDAX-II)

World best limit:
First 1 ton x years exposure !

σ_{SI} < 4.1.10^{-47} cm^2 at 30 GeV/c^2

- **1 sigma upper fluctuation at higher WIMP masses**

No significant excess (>3 sigma) is observed.

Phys. Rev. Lett. 121, 111302 (2018)

Phases of the XENON Program

XENON10

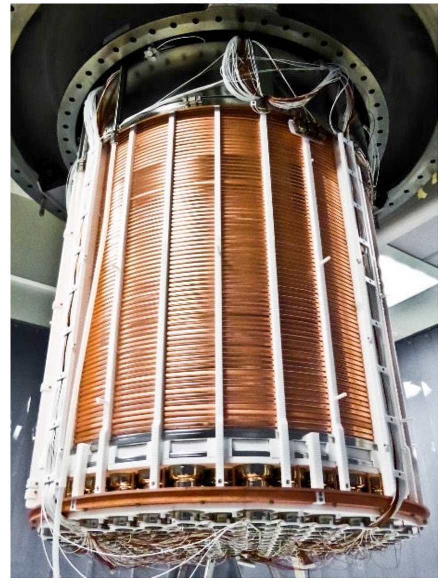
2005 – 2007
15 cm drift TPC
Total: 25 kg
Target: **14** kg
Fiducial: 5.4 kg

Achieved (2007)
$\sigma_{SI} = 8.8 \cdot 10^{-44}$ cm^2
@ 100 GeV/c^2

XENON100

2008 – 2016
30 cm drift TPC
Total: 161 kg
Target: **62** kg
Fiducial: 34/48 kg

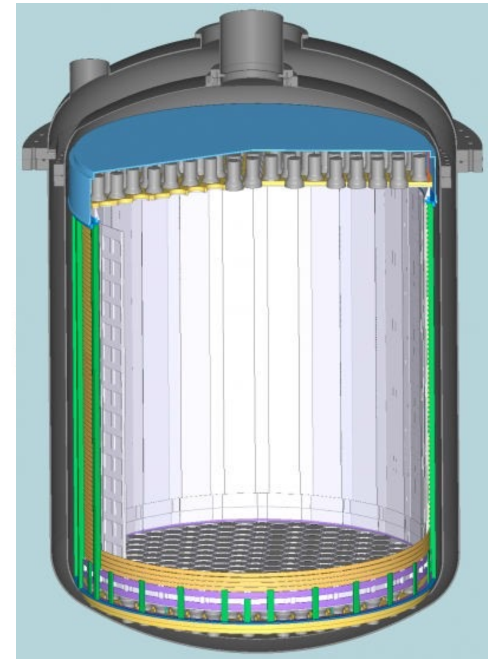
Achieved (2016)
$\sigma_{SI} = 1.1 \cdot 10^{-45}$ cm^2
@ 55 GeV/c^2



XENON1T

2012 – 2019
100 cm drift TPC
Total: 3 200 kg
Target: **2 000** kg
Fiducial: 1 000 kg

Achieved (2018)
$\sigma_{SI} = 4.1 \cdot 10^{-47}$ cm^2
@ 30 GeV/c^2

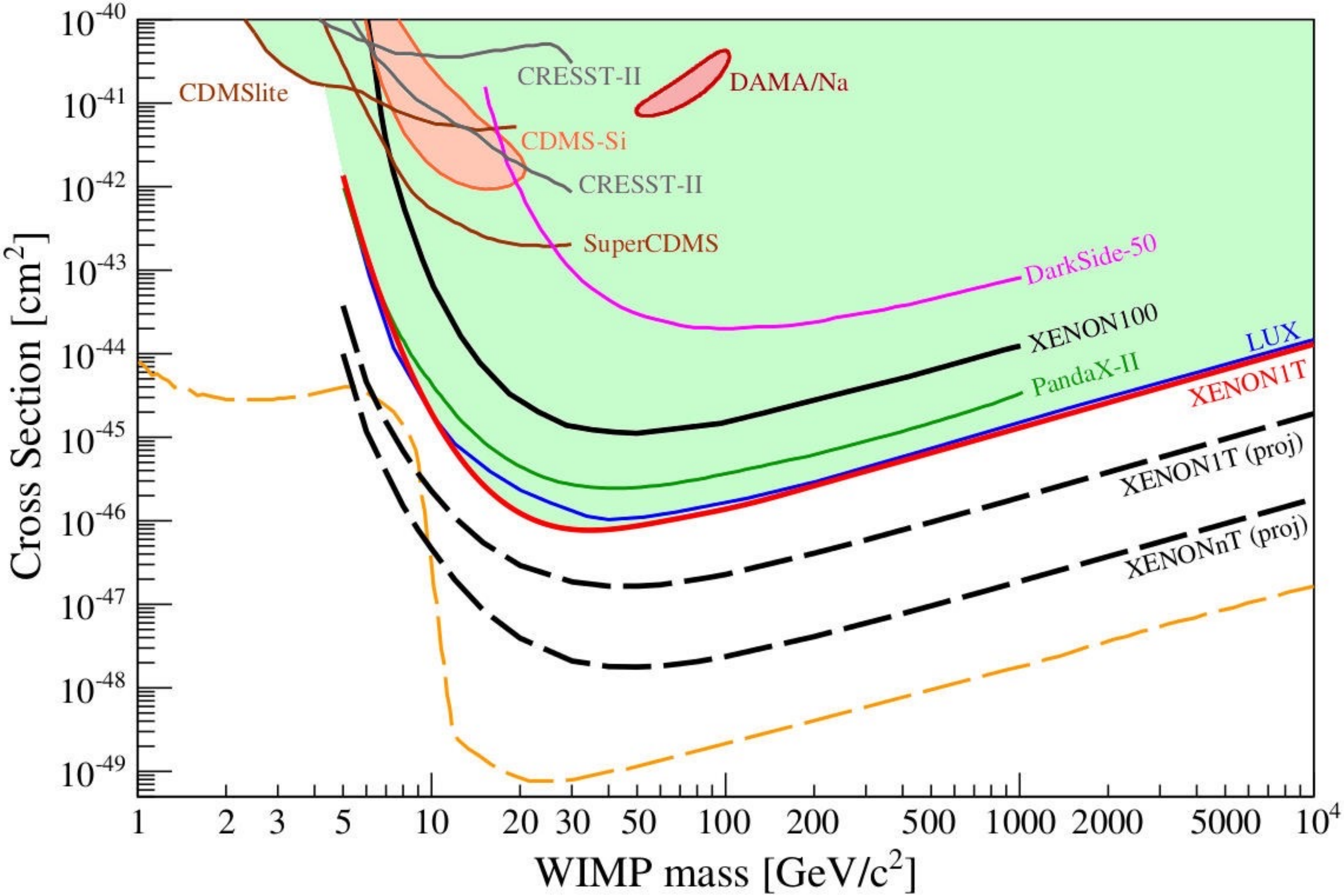


XENONnT

2017 (R&D) – 2023
144 cm drift TPC
Total: 8 000 kg
Target: **6 000** kg
Fiducial: 4 500 kg

Projected (2022)
$\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2
@ 50 GeV/c^2

From XENON1T to XENONnT

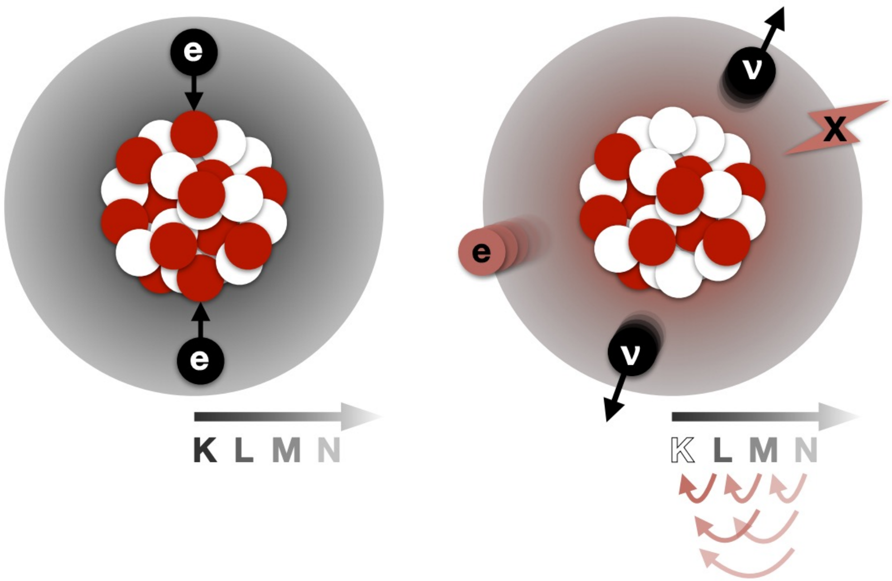


Double electron capture (DEC) with ^{124}Xe

- $^{124}Xe + 2e^- \rightarrow {}^{124}Te + 2\nu_e$
- Vacancies on the K shell : Detectable cascade of X-rays and Auger electrons in the **keV-range (64.3 keV)**
- Large half-lives : > 10^{12}. $T_{univers}$
- Needs very **low background** experiment

XENON1T

^{124}Xe ~ 1 kg / t



Double electron capture (DEC) with XENON1T

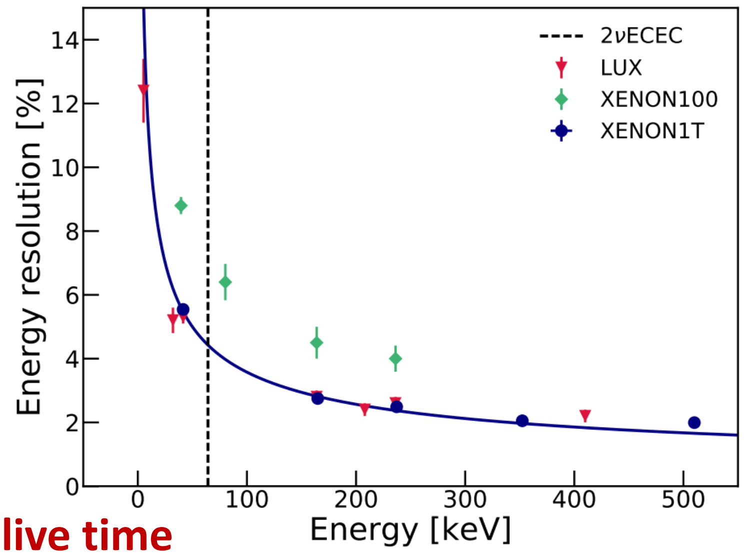
^{124}Xe ⇔ Double K-shell capture :

X-rays and Auger electrons

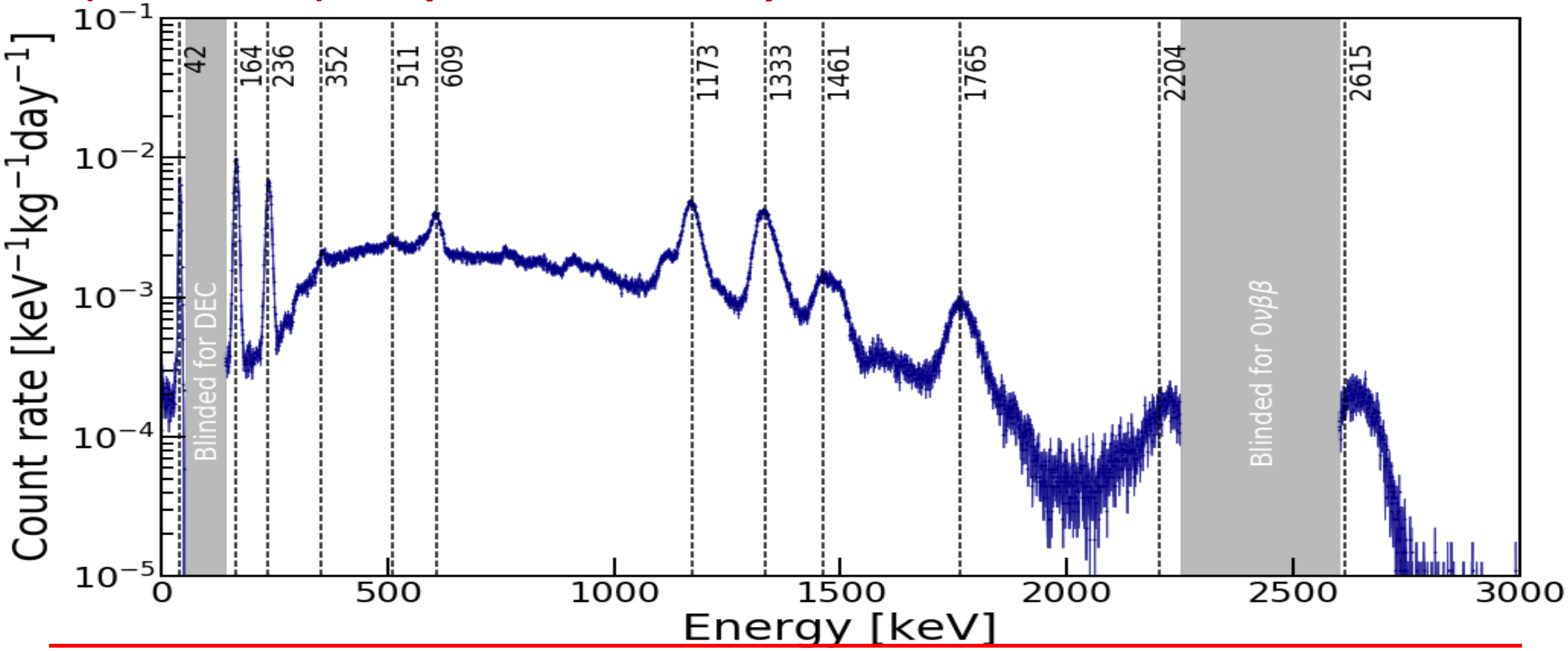
Single peak @64.3 keV

Energy resolution @64.3 keV:

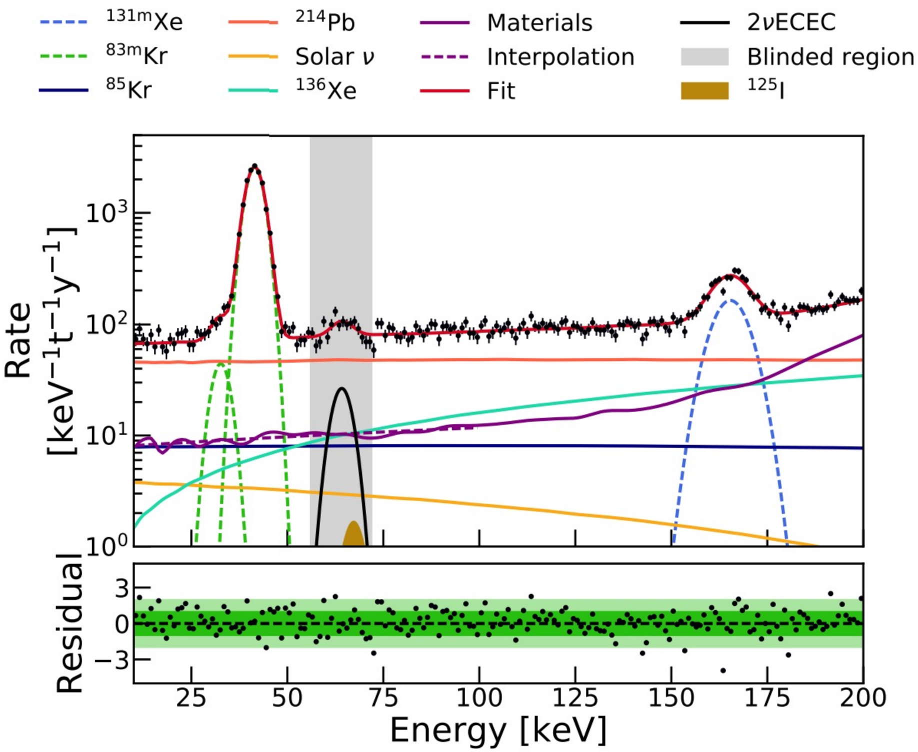
$$\frac{\sigma}{\mu} = (4.1 \pm 0.4)\ \%$$

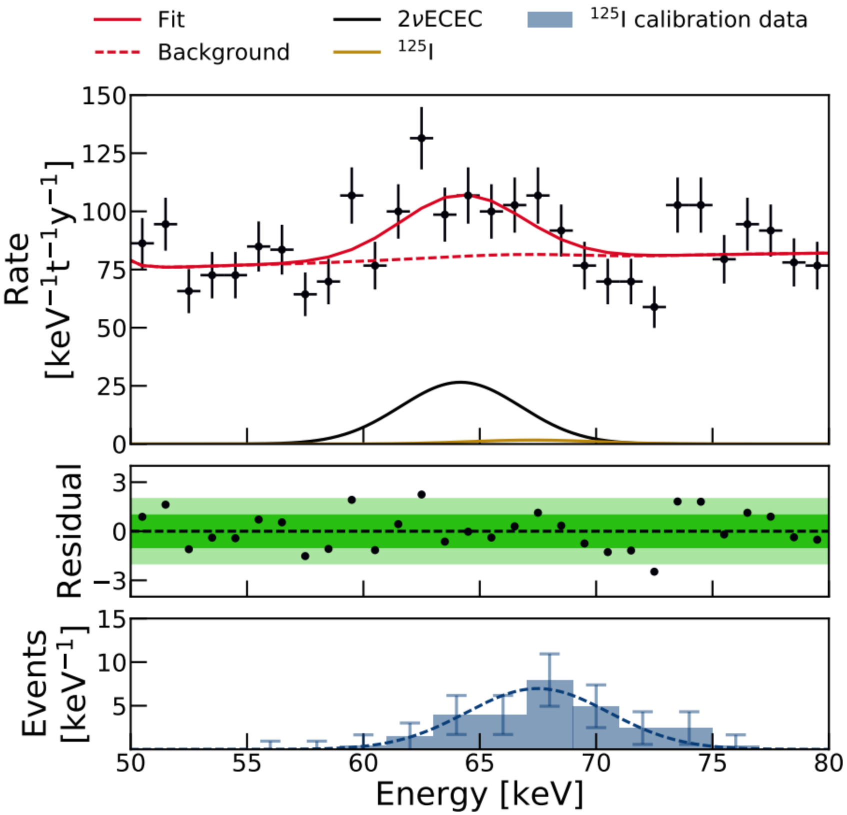


Blinded (56 – 72 keV) analysis with 177.7 days of live time



Double electron capture (DEC) Results



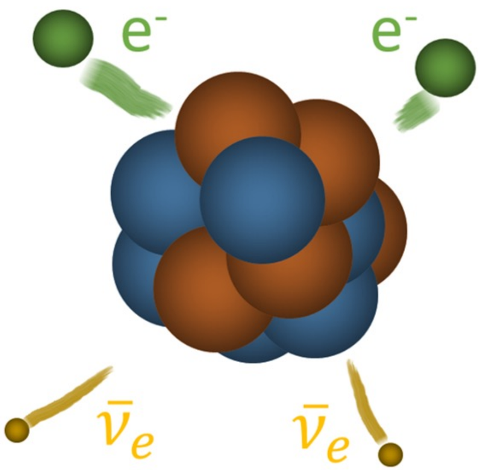


- Blinded region from 56 keV to 72 keV
- Ellipsoidal 1.5 t inner fiducial volume
- Peak at E = (64.2±0.5) keV and σ = (2.6±0.3) keV
- Significance 4.4σ

Half-life $T_{1/2}$ = $(1.8 \pm 0.5_{stat} \pm 0.1_{sys}) \times 10^{22}$ y

Double β decay with and without neutrinos

$(Z, A) \rightarrow (Z+2, A) + 2\,e^- + 2\overline{\nu}_e$



Rare process :

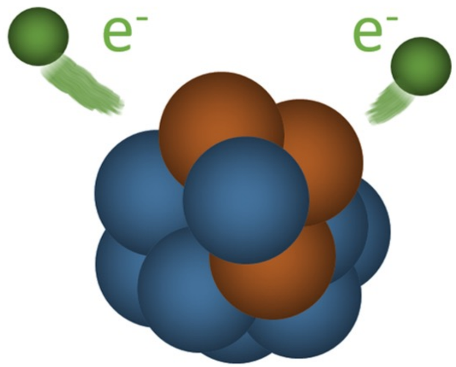
$T^{1/2}$ = 21x10[20] yr

$T^{1/2}$ = 10[11] * T[Univers]

✔ Observed

(EXO & NEXT)

$(Z, A) \rightarrow (Z+2, A) + 2\,e^-$



Rare process :

$T^{1/2} > 1.07\times10^{26}$ yr

$T^{1/2} > 10^{16} * T^{Univers}$

✗ Observed

(Limit by KamLandZen)

Why searching at it ?

- Neutrino = Majorana particle ?
- Lepton number violation
- Absolute mass of neutrino
  - Number of events is related to the effective majorana neutrino mass ($m_{\beta\beta}$)

$$N = \log 2\ \frac{\epsilon\, m_{Xe} \mathcal{N}_a}{M_{Xe}} \frac{t}{T^{0\upsilon}_{1/2}}$$

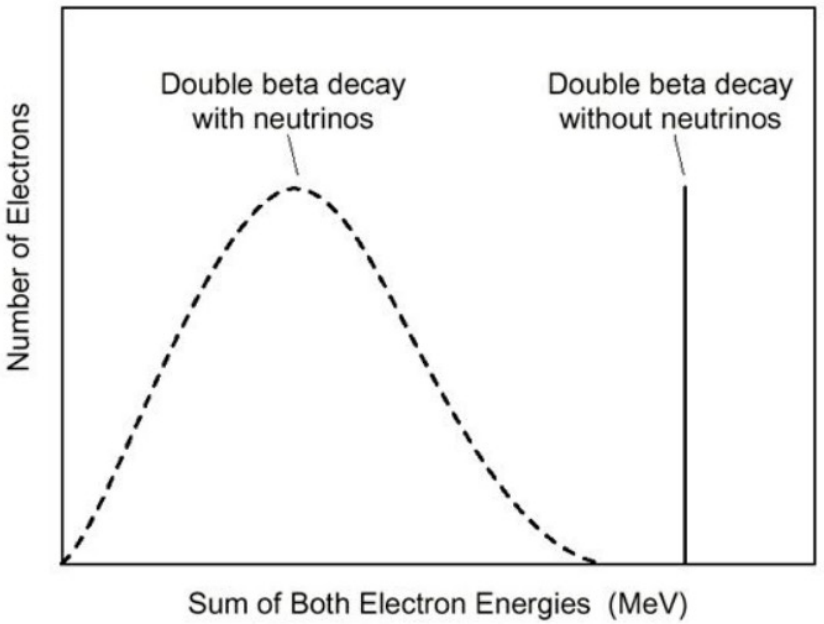
$$(T^{0\upsilon}_{1/2})^{-1} = G^{0\upsilon} |M^{0\upsilon}|^2 \left(\frac{m_{\beta\beta}}{m_e}\right)^2$$

Rare event = Need a low background experiment

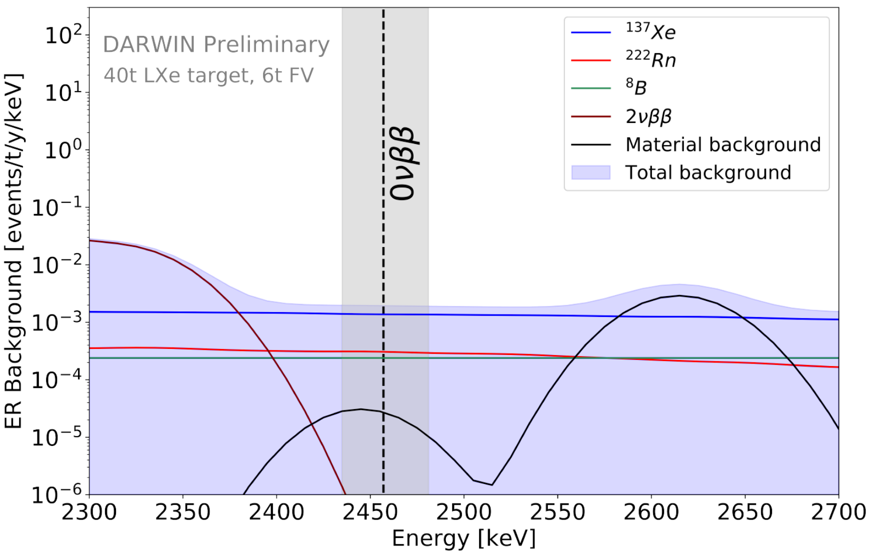
Double β decay with and without neutrinos

^{136}Xe isotope

- Double β emitter
- Naturally present in XENON1T (abundance of 8.49%)
- **Detection of electrons ⇔ Electronic Recoil**
- Peak @2.457 MeV
- High stopping power of LXe ⇔Single Scatter
  - Need a good discrimination between Single Scatter and Multiple Scatter
  - Multiple Scatter :
    - More abundant at high energy: background ***γ***–lines ⇔ Compton scattering



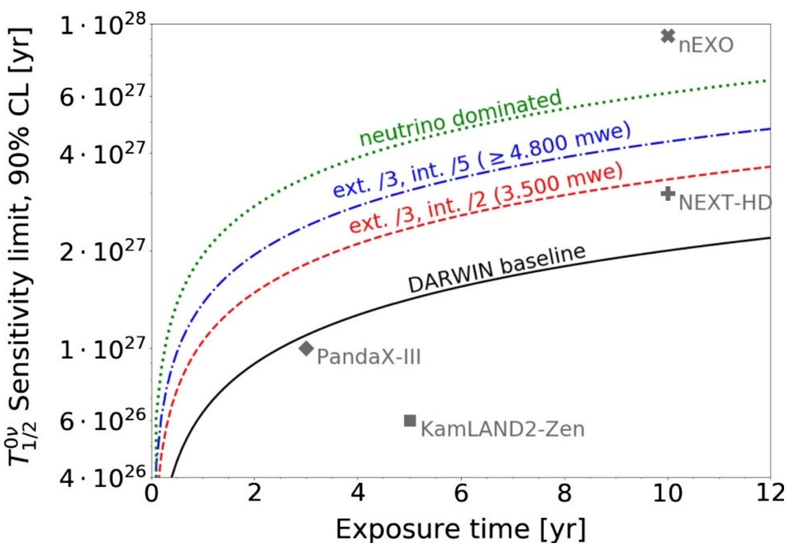
Double β decay with and without neutrinos

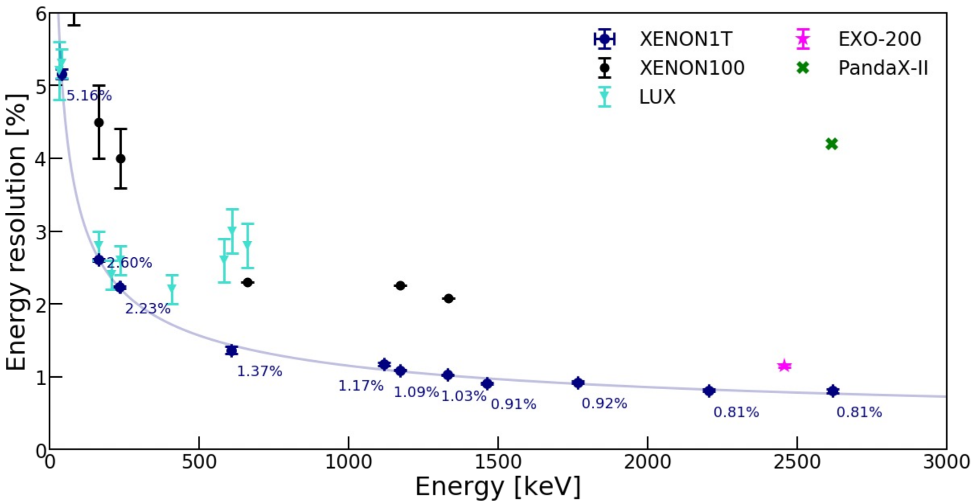


Preliminary background estimation for :

- Dark matter
- $0\nu\beta\beta$

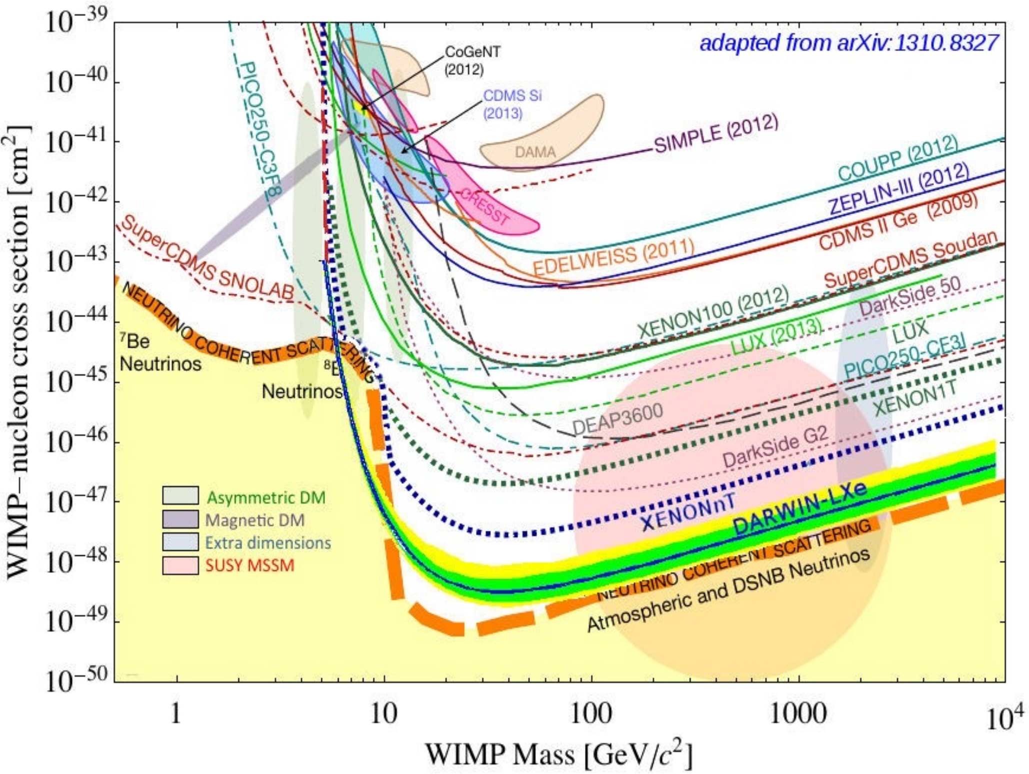
Expected sensitivity according to the baseline design





Conclusions

- **Liquid Xenon is the world leading technique of DM searches**
- First multi-ton scale LXe-TPC successfully operated for more than 1 year
- **Strongest limit** on WIMP-nucleon SI cross-section above 6 GeV/c^2: minimum at $4.1 \cdot 10^{-47} cm^2$ for a WIMP of 30 GeV/c^2
- Double Electron Capture detection : longest half-life ever measured directly
- Proof that xenon-based Dark Mater search experiments are sensitive for rare event searches



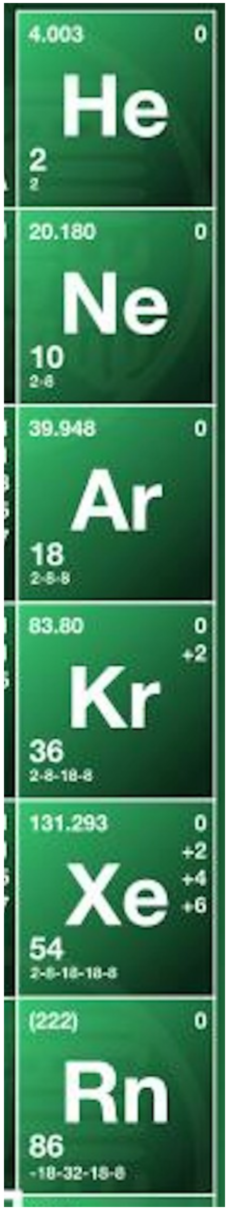
- ***Dark matter is highly searched***
- *Solution to an astrophysics / particle physics / Cosmological problem*

Other XENON1T analysis:

- S2 only analysis channel
- Annual modulation
- Migdal effect
- Light dark matter searches
- $0\nu\beta\beta$ of ^{136}Xe

Stay Tuned!

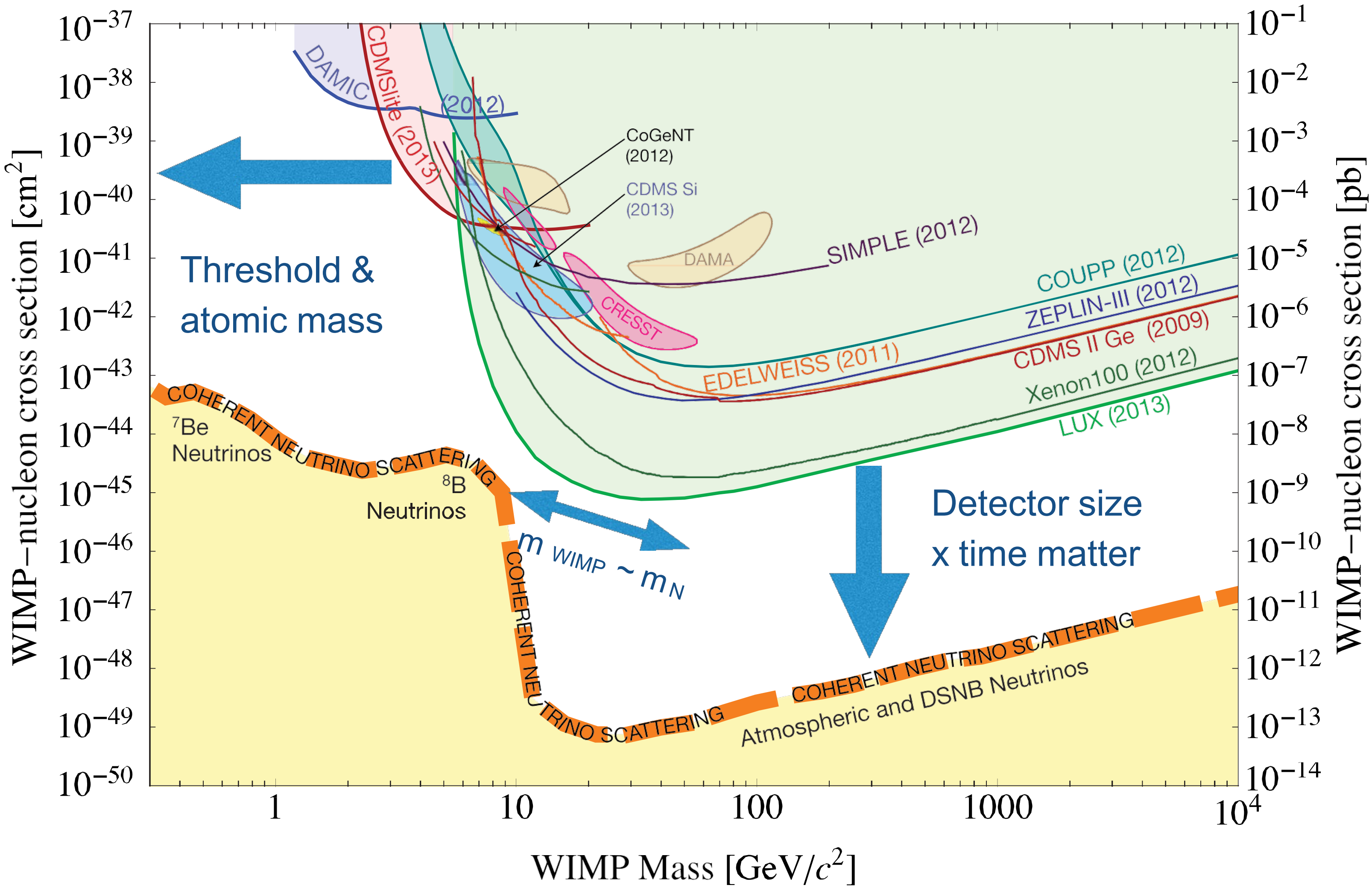
Noble gases



	Neon	Argon	Krypton	Xenon
Atomic Number	10	18	36	54
Density	1.2	1.4	2.4	3
Scintillation (γ/keV)	30	40	25	42
Wavelength (nm)	85	128	150	178
Decay Time (ns)	15400	6.3, 1500	2, 91	2.2, 27, 45
Ionization (e-/keV)	46	42	49	64
Boiling Point (K)	27.1	87.3	119.8	165.0
Radioactivity	No	^{39}Ar 1Bq/kg (1mBq/kg)	Yes	^{136}Xe / Kr can be removed to ppt level
Price	$$	$ ($$$)	$$$	$$$$

How is evolving the field of Direct Detection ?

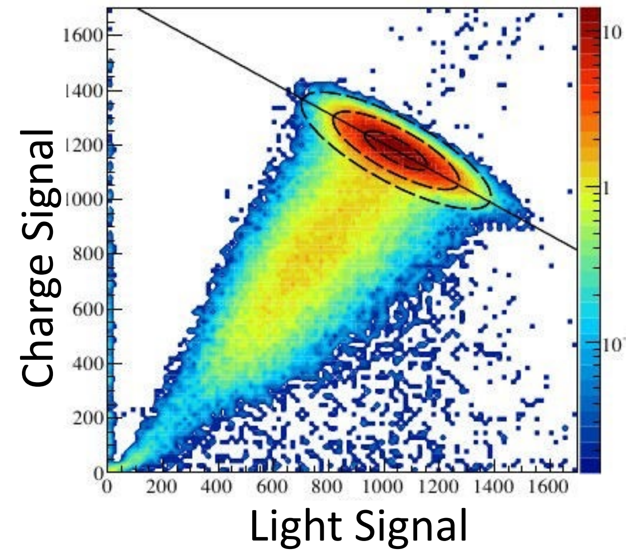
$$R \sim 0.13 \frac{\text{events}}{\text{kg . year}} \left[\frac{A}{100} \times \frac{\sigma_{\chi N}}{10^{-38}\ \text{cm}^2} \times \frac{\langle v \rangle}{220\ \text{km.s}^{-1}} \times \frac{\rho_\odot}{0.3\ \text{GeV.cm}^{-3}} \right]$$

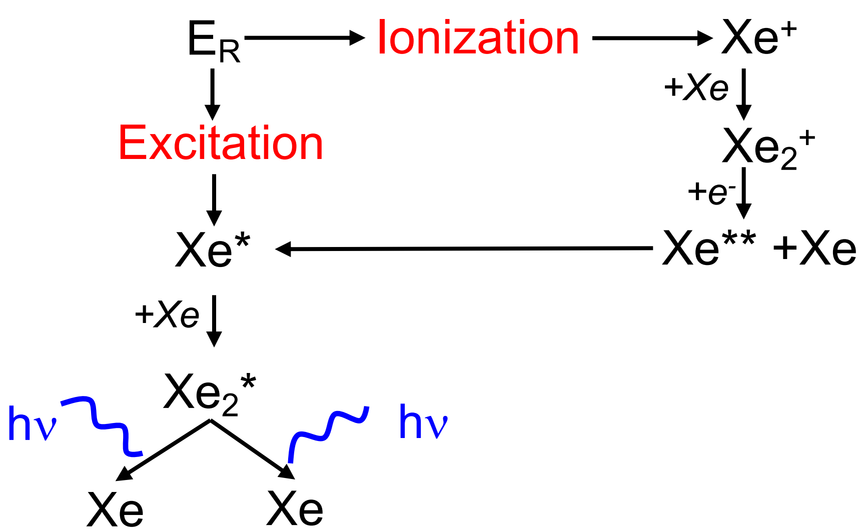


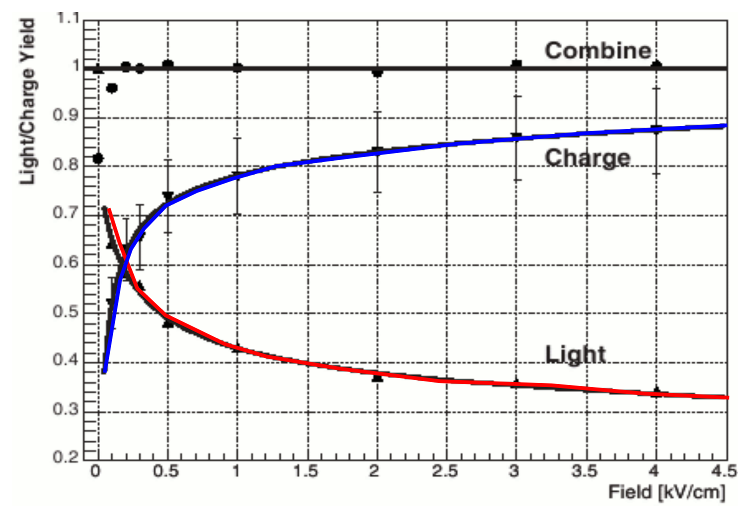
Scintillation and ionization in noble liquids

- Energy deposit produce both:
  - Electron-ion pair
  - Excited atom states

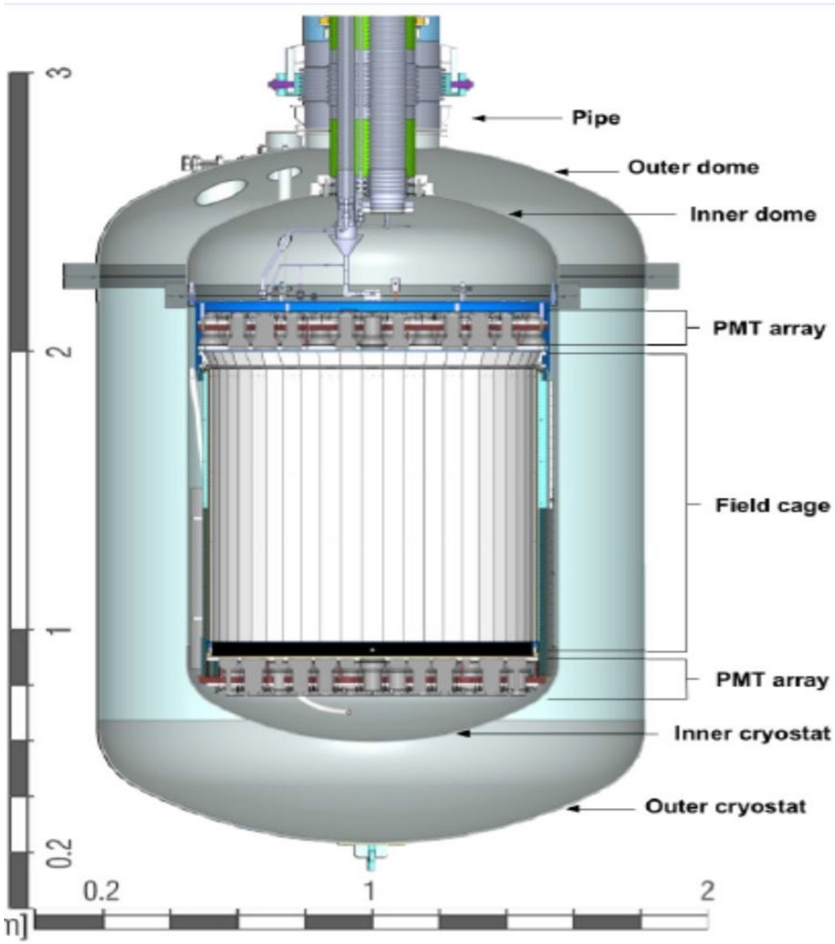
- Anti-correlation between charge and light
  → Improve energy resolution
- Excitation depends on dE/dx
  → Discrimination capabilities

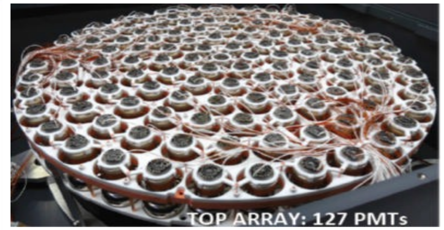






The largest Xe double-phase TPC ever built !

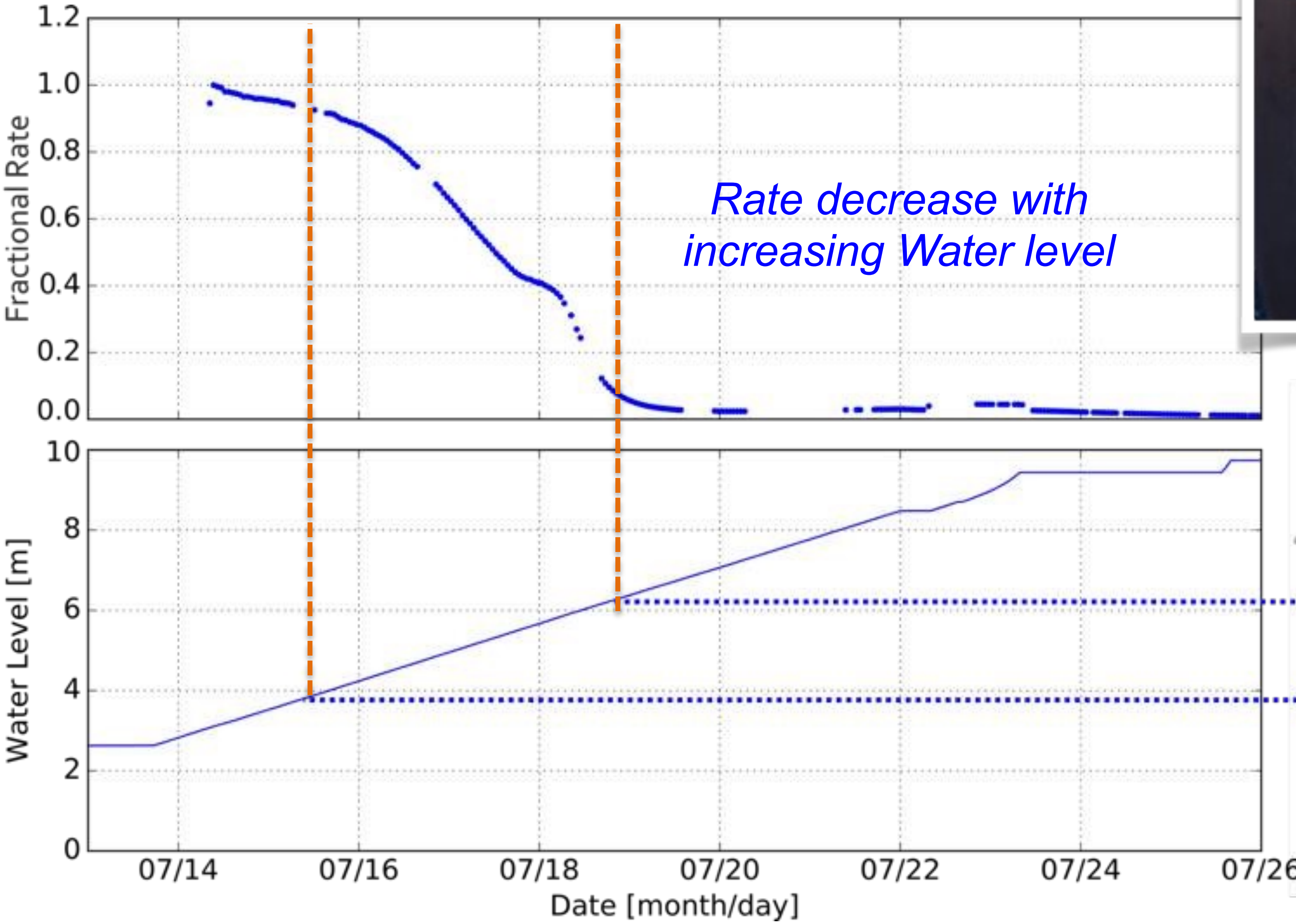


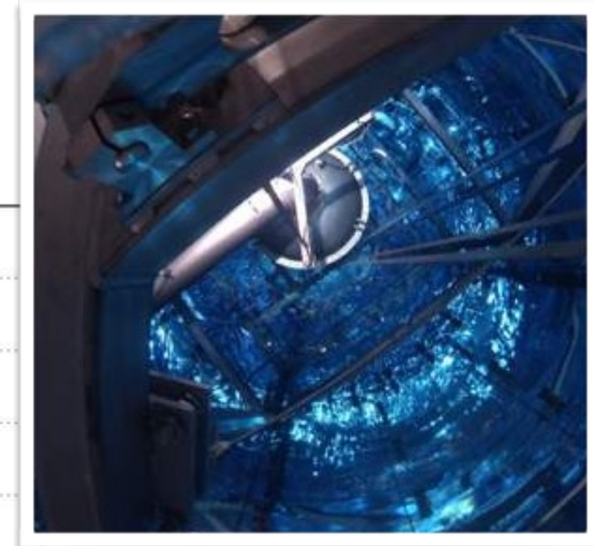


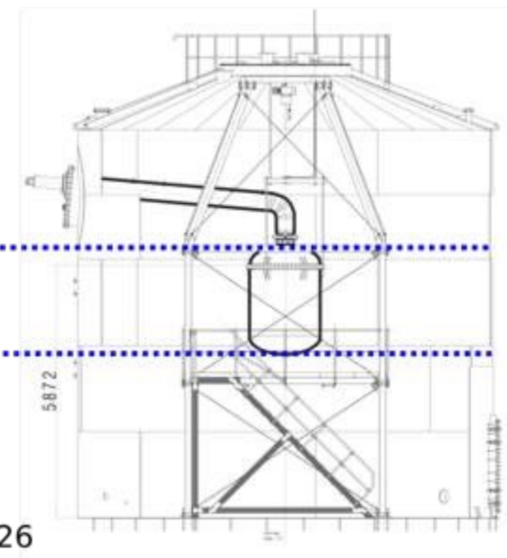
- Active Xe mass:
  2 tons.
- Light sensors:
  127+121 3" PMTs
  average QE = 35%
- Fully covered with high reflectivity PTFE to maximize light collection.
- Drift region:
  1m height,
  1m diameter.

Water Shield filling

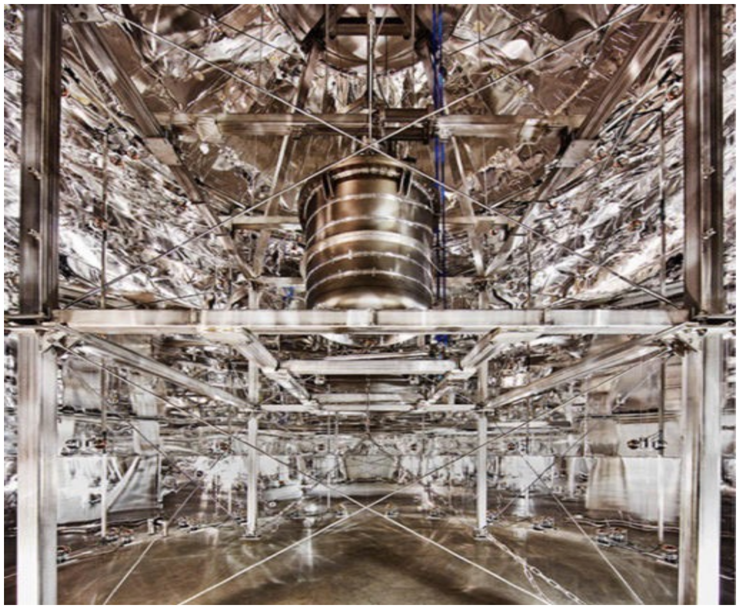
- TPC fully immersed in water since July 2016
- Background studies and calibration runs started



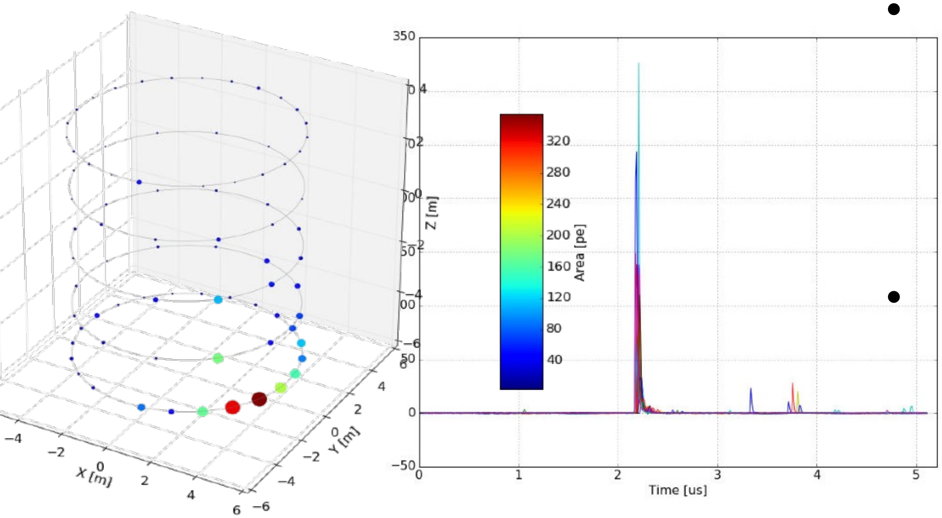




Muon Veto Cherenkov Detector

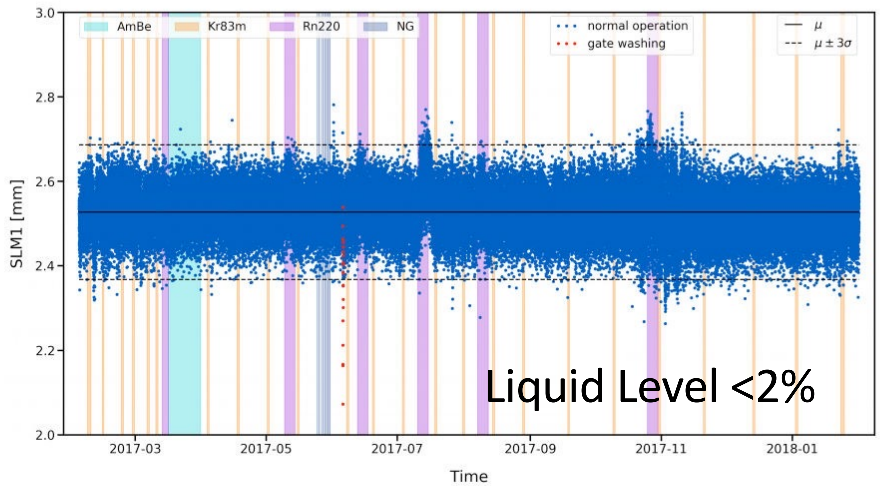


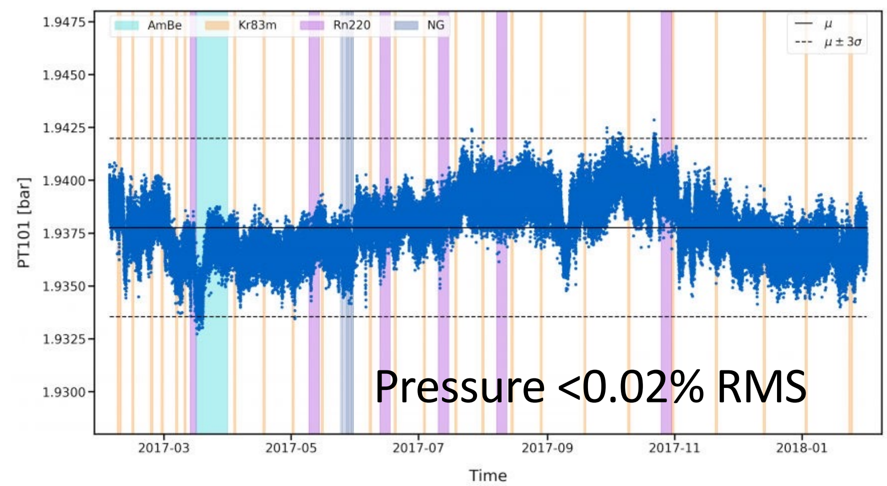
- The cryostat is immersed in a water shield filled with 700 tons of water
- Deionized water is used as passive shield from environmental radiation
- Water is constantly purified
- Equipped with 84 high-QE, 8" PMTs
- All walls are covered with reflective foil Detects Cherenkov light to tag muons.
- Expected muon flux underground is 1.2 $/m^2h^{-1}$ → muon-induced neutron background is reduced to less than 0.01 ev/y thanks to muon tagging
- No coincidences with TPC found in this science run



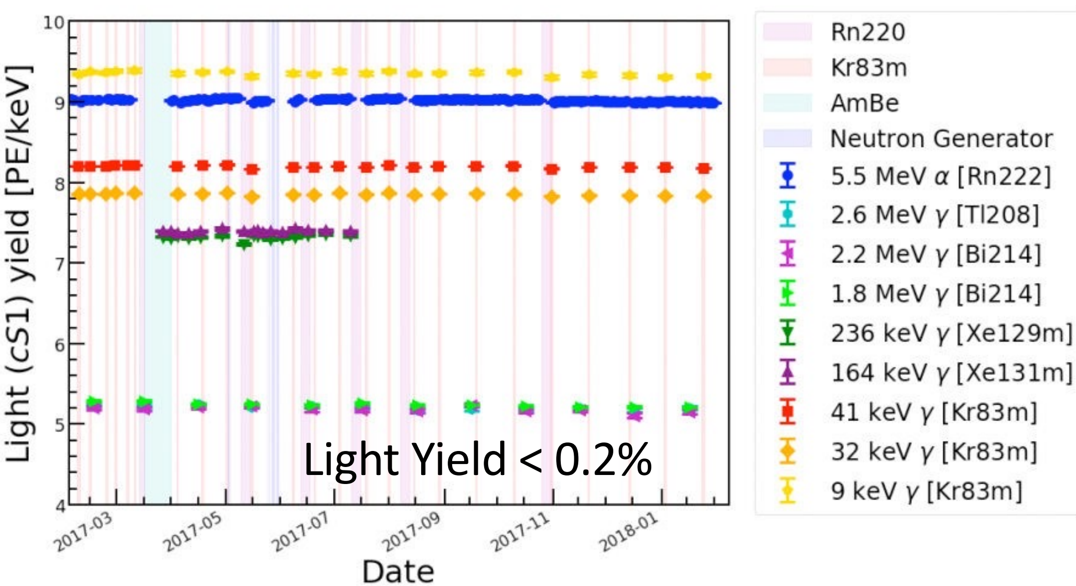
JINST 9 P11006 (2014)

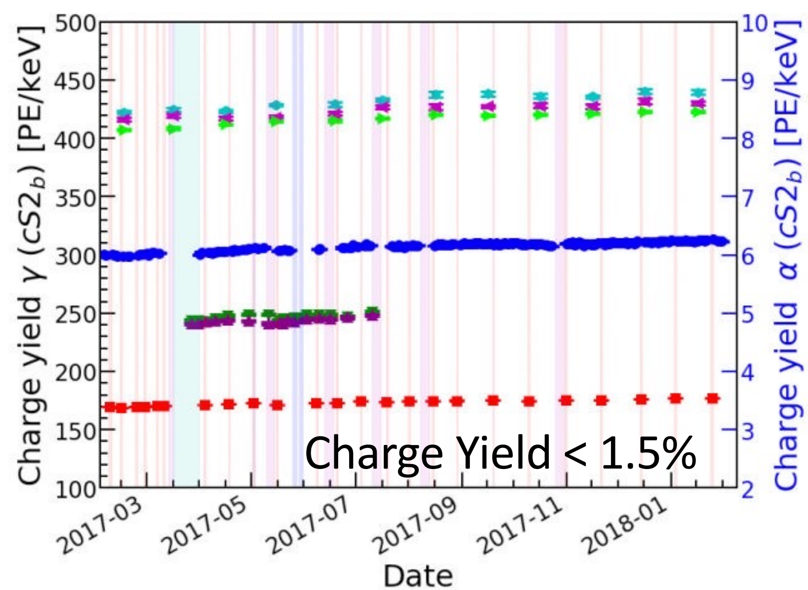
Detector Stability





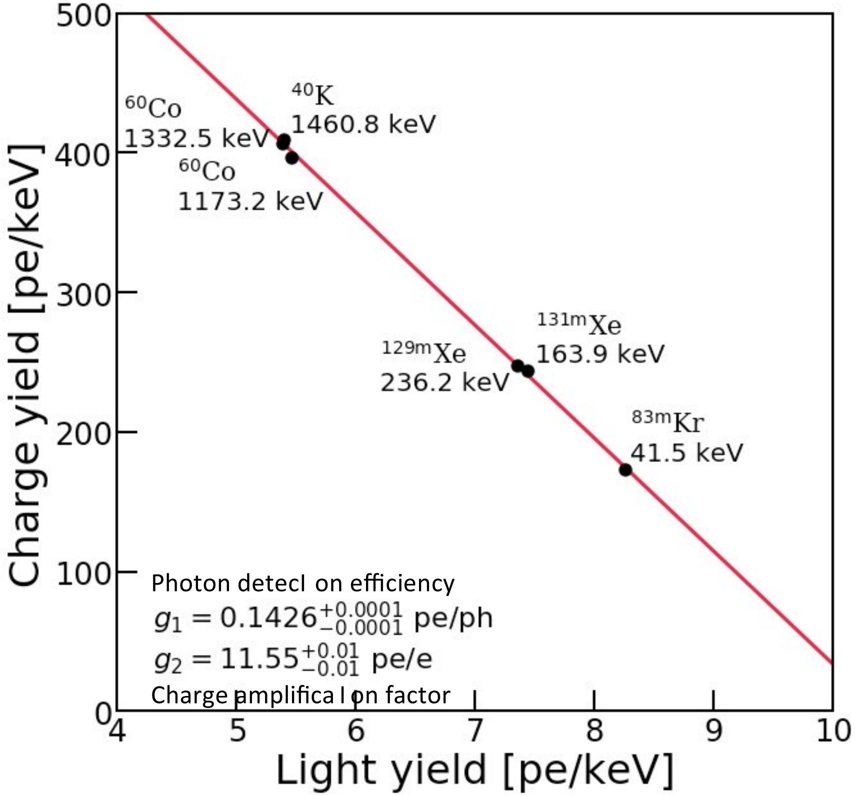
All relevant parameters look stable throughout science runs





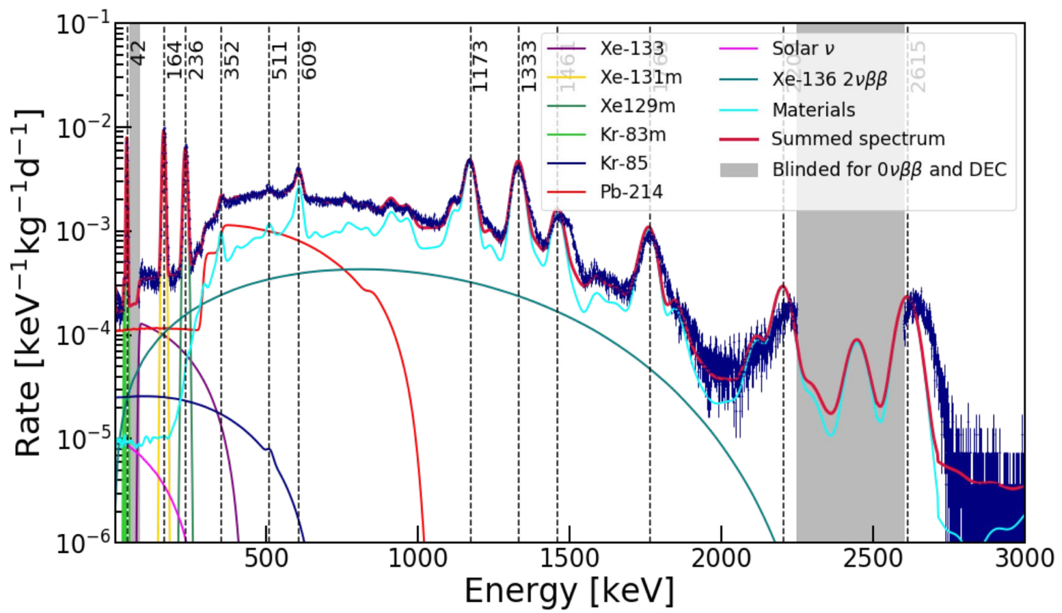
Energy Reconstruction

$$E = (n_{ph} + n_e) \cdot W = (\frac{S1}{g1} + \frac{S2}{g2}) \cdot W$$



- Good agreement between predicted and measured background spectrum

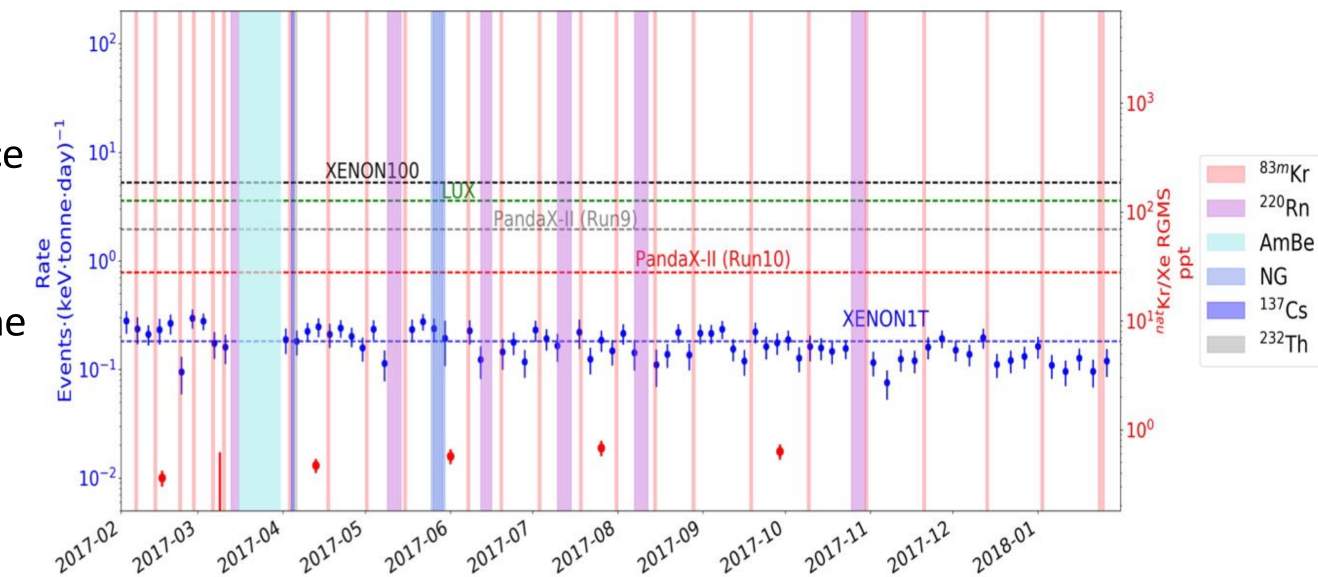
- Energy loss to either light or charge channel
  ➔S1/S2 anl correla l on
- γ-lines from known sources
  - Internal source: ^{83m}Kr
  - Activated lines in NG: ^{129m}Xe, ^{131m}Xe
  - Detector material: ^{60}Co, ^{40}K
- Linear from keV to MeV



Electronic Recoil Background

- ^{222}Rn : 10 μBq/kg
  - Achieved with careful surface emana I on control and measurements
  - Further reduction with online cryogenic distillation
- ^{85}Kr: sub ppt Kr/Xe
  - Achieved with online cryogenic distillation
- Material radioactivity is subdominant
- Select fiducial volume in the TPC

lowest ER background ever in DM detectors
< 0.2 evt /(ton.year.kev)



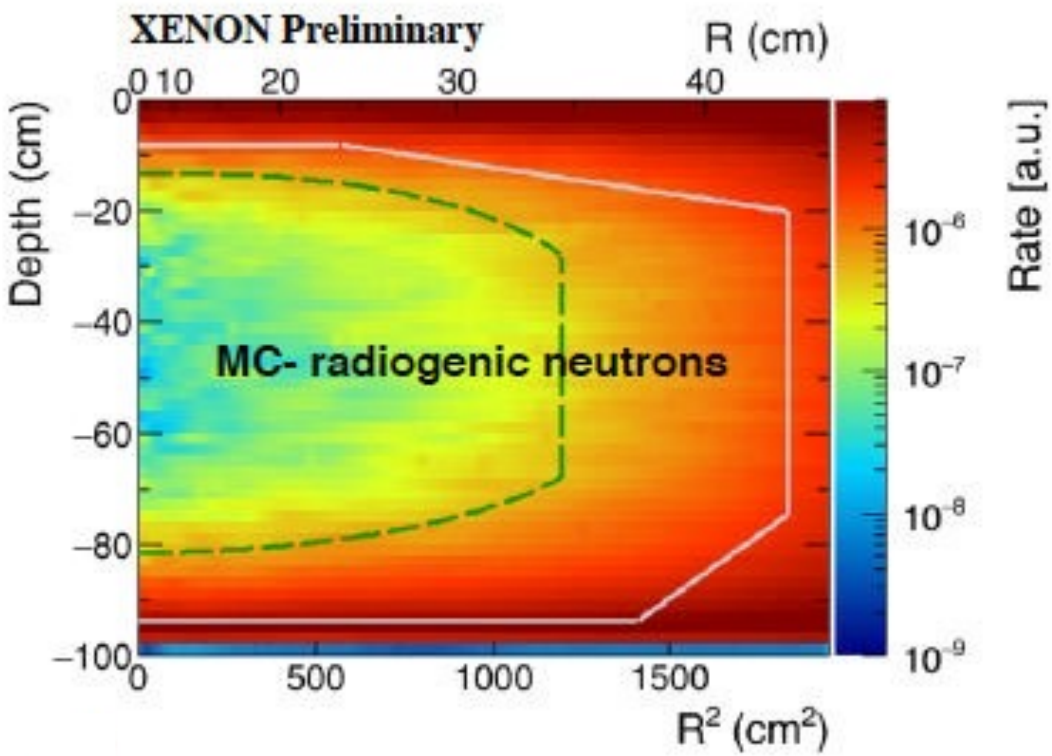
Source	Rate [t^{-1} yr^{-1}]	FracAon [%]
^{222}Rn	620 ± 60	84.5
^{85}Kr	31 ± 6	4.3
^{136}Xe	9 ± 1	4.9
materials	30 ± 3	4.2
solar ν	36 ± 1	1.4
Total	**720 ± 60**	**100**

Expecta I ons in 1-12 keV search window, 1t FV, single scatters, before ER/NR discrimination.

JCAP04 (2016) 027

Nuclear Recoil Background

- Radiogenic neutrons from (α, n) reactions and fission from ^{238}U and ^{232}Th: reduced via careful materials selection, event multiplicity and fiducializa1on
- Cosmogenic μ–induced neutrons significantly reduced by rock overburden and muon veto
- Coherent elastic ν–nucleus scattering, constrained by ^{8}B neutrino flux and measurements, is an irreducible background at very low energy (1 keV)



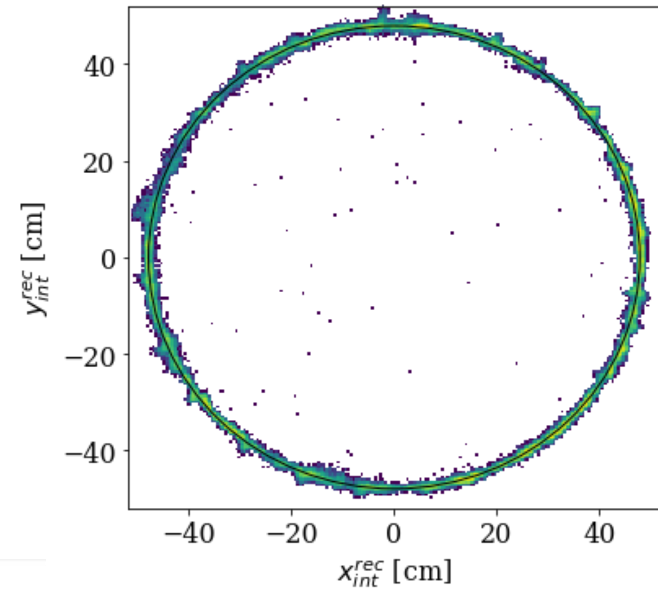
Source	Rate [t^{-1} yr^{-1}]	FracAon [%]
Radiogenic	0.6 ± 0.1	96.5
Cosmogenic	< 0.01	<2.0
Coherent ν scattering	0.012	2.0

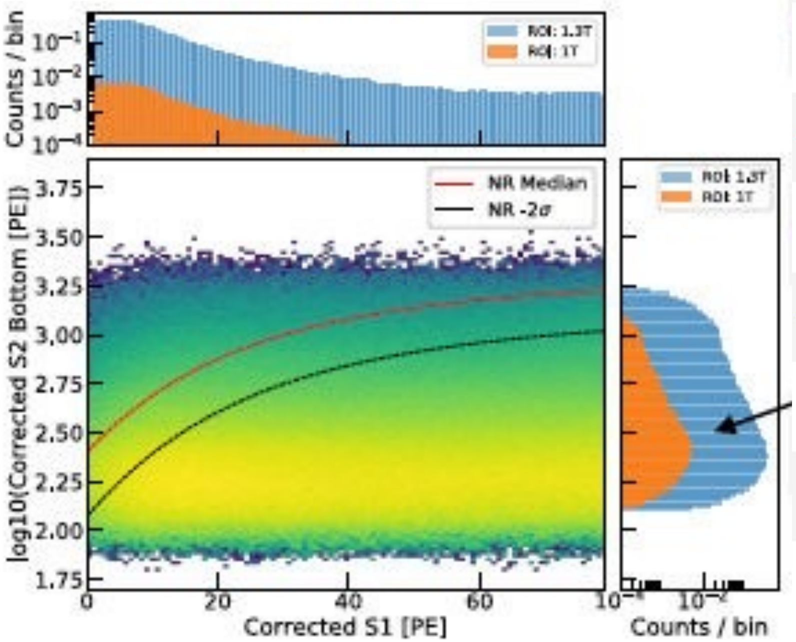
Expectations in 4-50 keV search window, 1t FV, single scatters

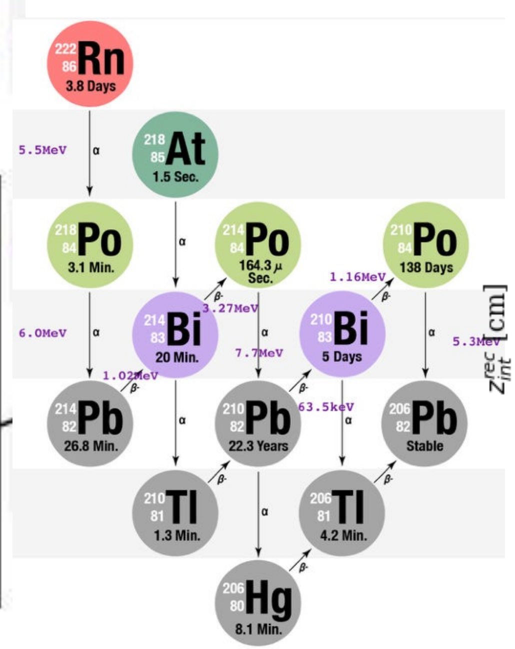
JCAP04 (2016) 027

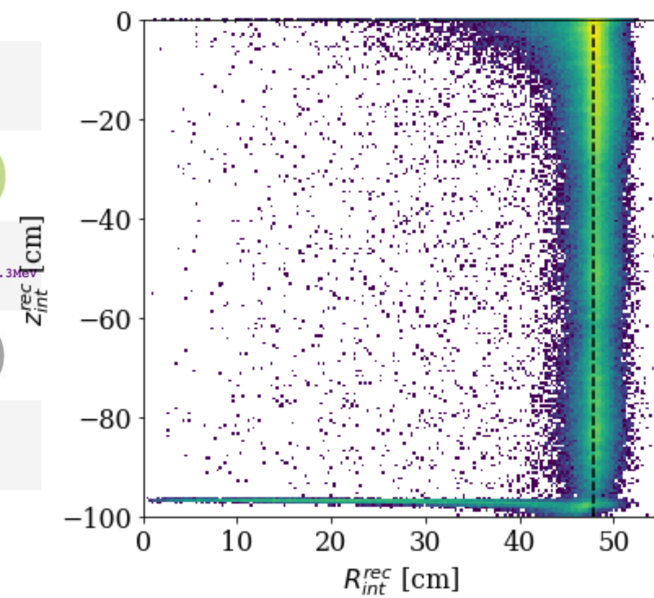
Surface Background

- Charge accumulation on the PTFE surfaces
  ➔ ^{222}Rn progeny (Pb210 and Po210) plate-out on PTFE surface produce events with reduced S2
  ➔ S2 can be mis-reconstructed into NR signal region
- Suppressed by fiducialization of volume
- Data-driven model derived from surface event control samples





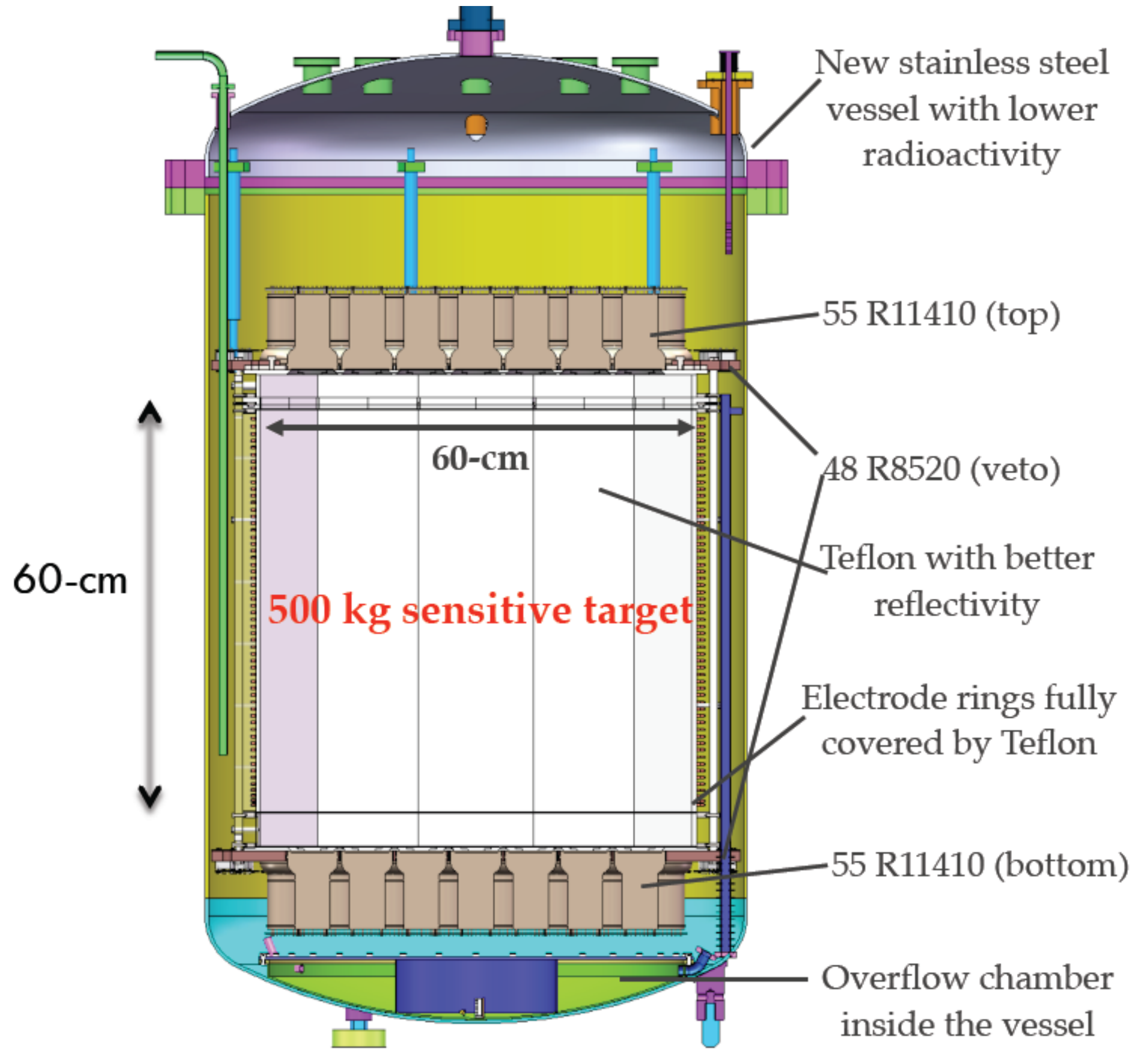




PandaX II

PANDA X

Particle and Astrophysical Xenon Experiments



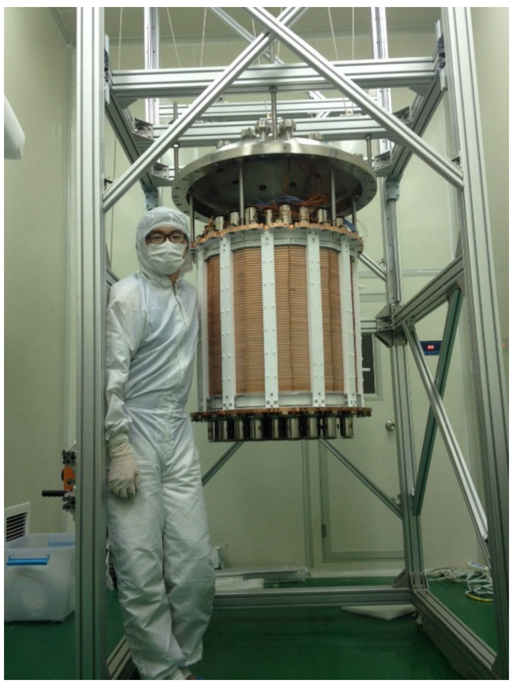
Mar. 9-Jun 30 2016, in total 98.7 live-day of under slightly different conditions (optimization of drift and extraction fields).

Condition	live time (day)	E_{drift} (V/cm)	E_{extract} (kV/cm)
1	7.76	397.3	4.56
2	6.82	394.3	4.86
3	1.17	391.9	5.01
4	63.85	399.3	4.56

PandaX II new results SI limits

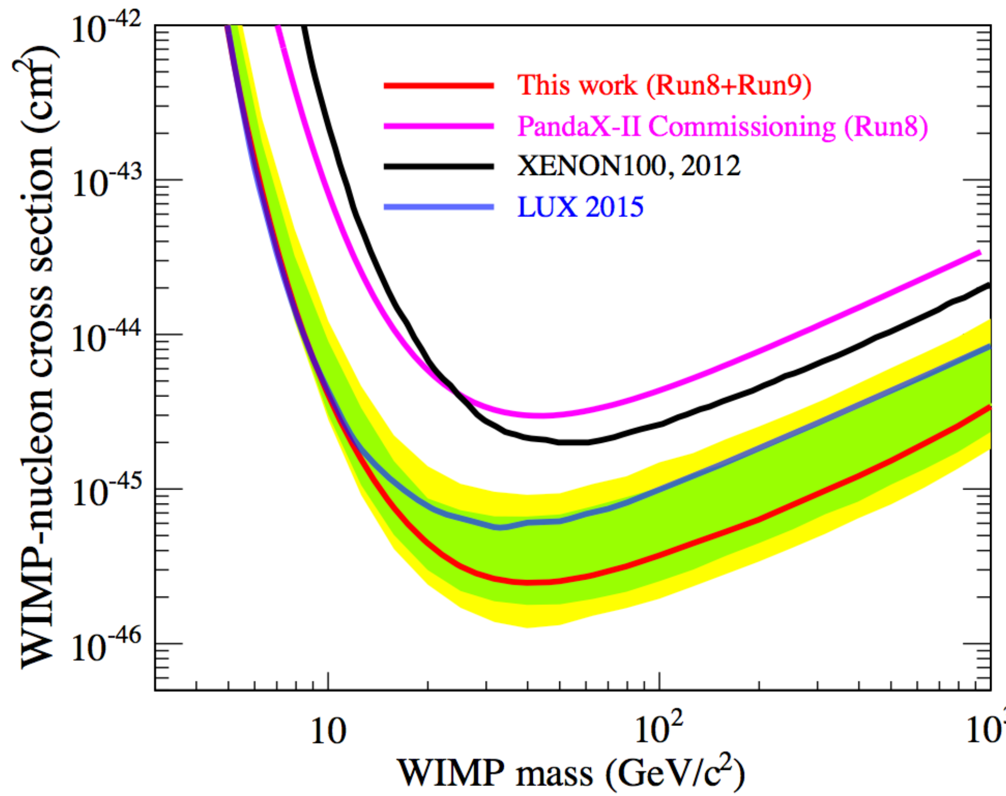
PandaX-II
@ CJPL (China)

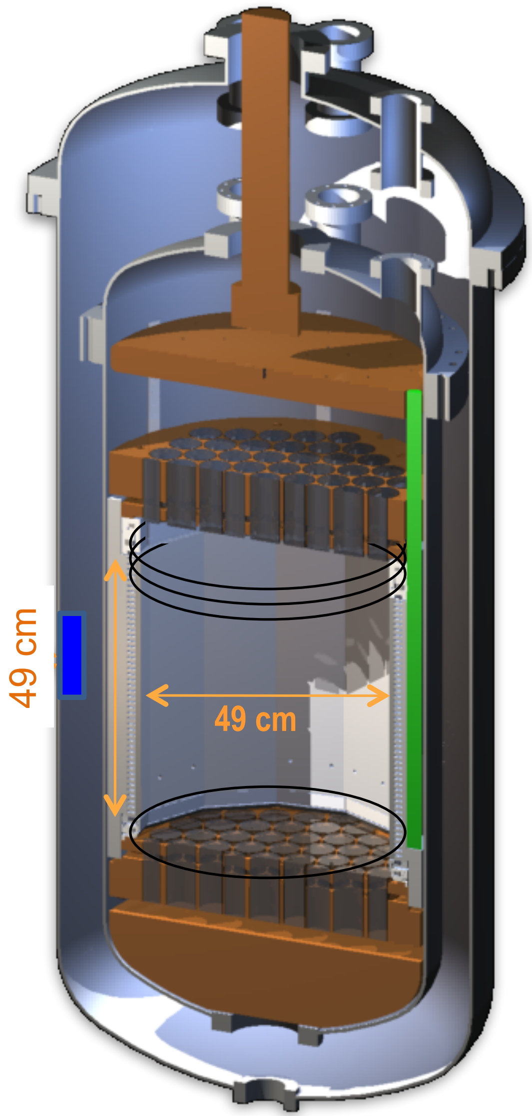
- 60 cm x 60 cm, ~400 kg fiducial
- 2^{nd} largest operating LXe TPC
- 3.3 x 10^4 kg.day = 0.1 t.year
- No excess
- Data tacking for the 2 next years



Particle and Astrophysical Xenon Experiments

Phys. Rev. Lett. 117, 121303 (2016)
arXiv:1607.07400

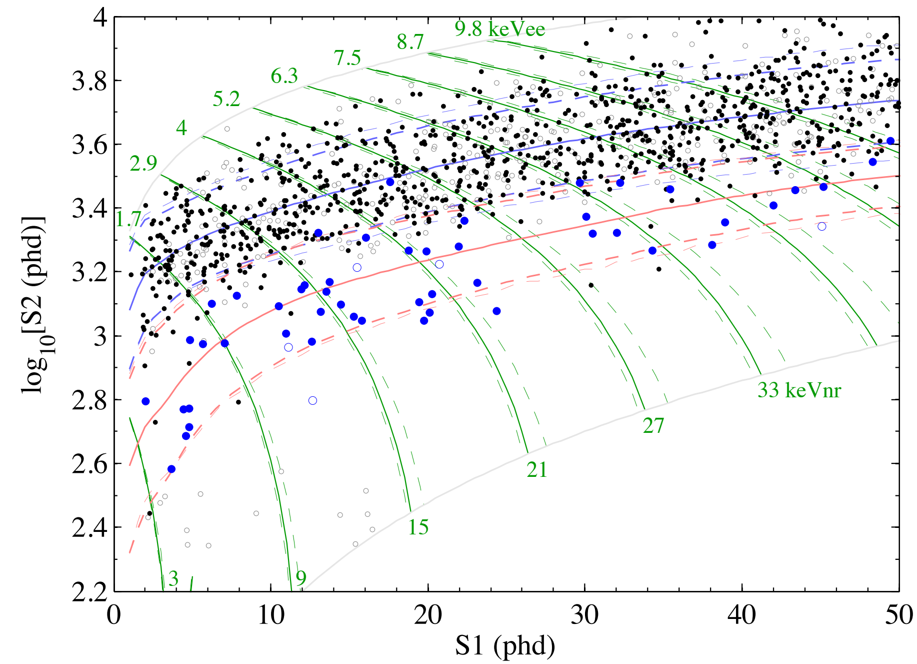




370 kg

A common approach is to blind oneself to events in the signal regions but it often blinds us to rare backgrounds and pathologies

Large **U**nderground **X**enon experiment



Instead of traditional blinding, we employ a technique where fake signal events ("salt") are injected into data stream. NOT SIMULATION!!

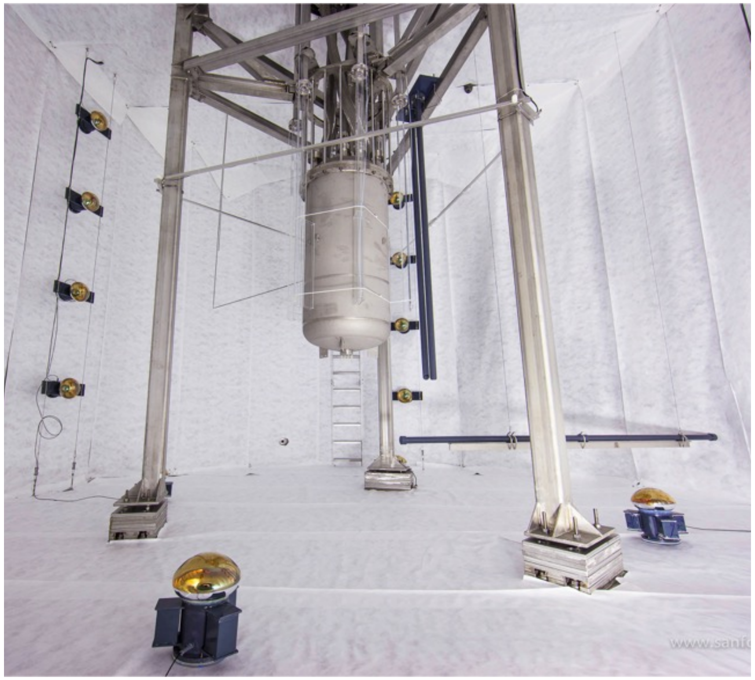
LUX new results SI limits

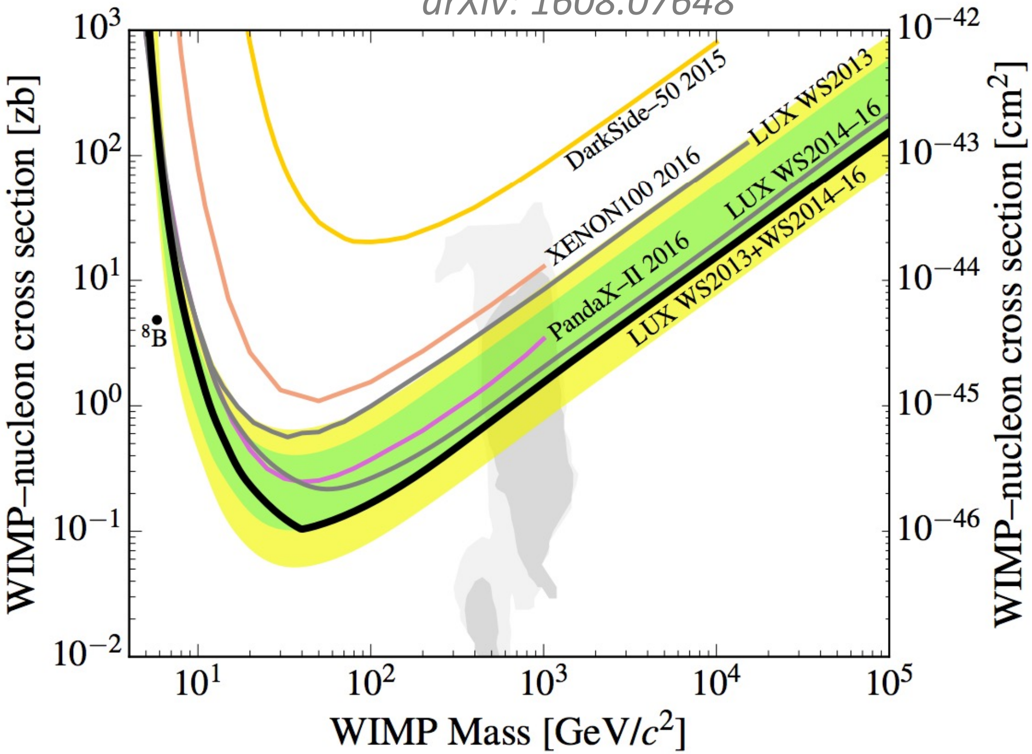
LUX
@ SURF (USA)

- 49 cm x 49 cm, ~100kg fiducial
- 332 live-days
- 3.4 x 10^4 kg.day = 0.1 t.year
- No excess
- Stopped

Large Underground Xenon experiment

PRL, 116, 161301 (2016)
arXiv: 1608.07648





Julien Masbou, Moriond EW 2017, 23rd March 2017

LUX new results SD limits

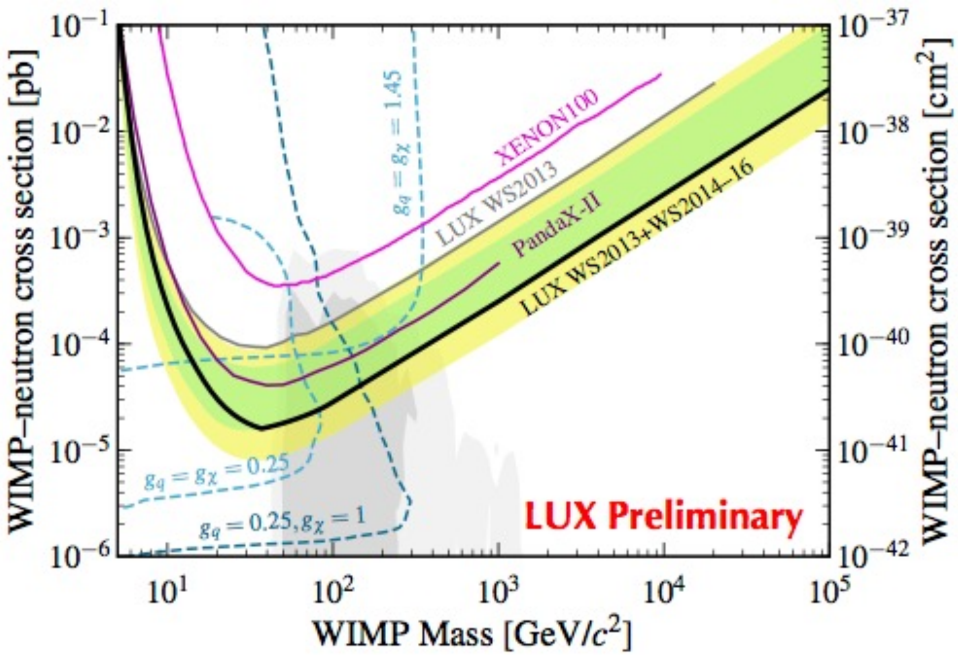
- 48 cm x 48 cm, ~100kg fiducial
- 332 live-days
- 3.4 x 10^4 kg.day = 0.1 t.year
- No excess

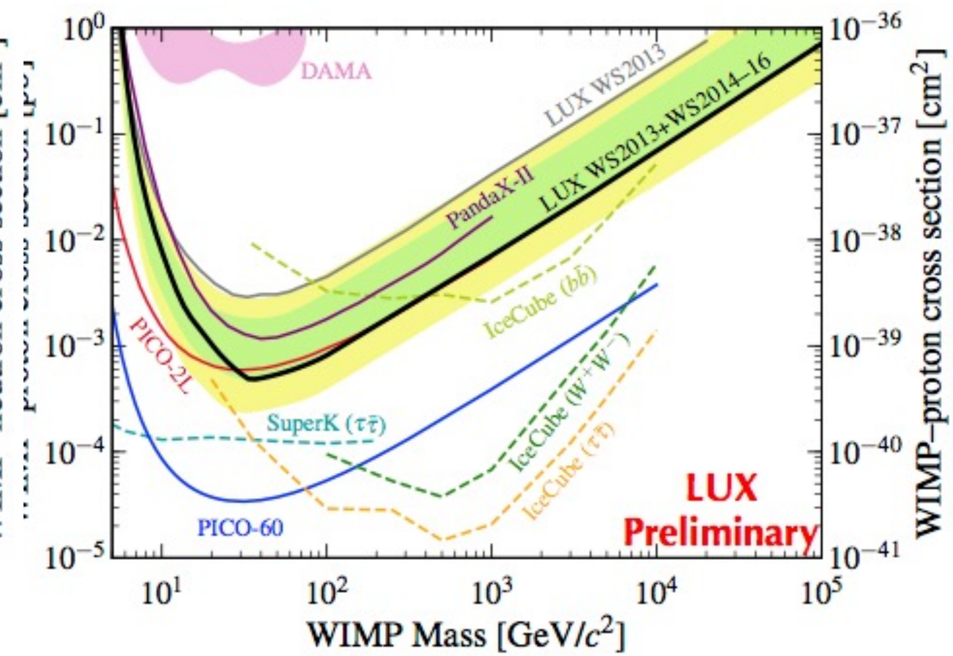
Results shown 3 days ago @ Moriond VHEPU

Large Underground Xenon experiment

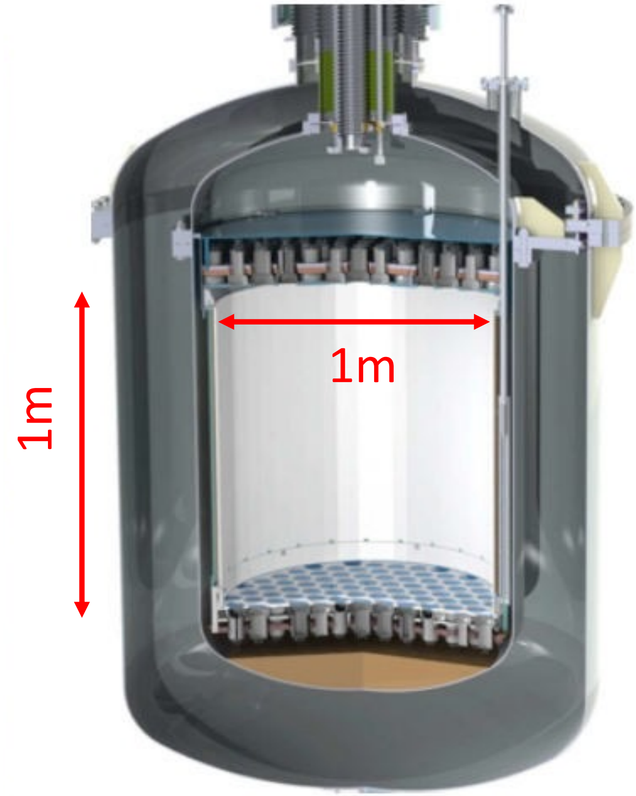
Improvement of a factor of six compared with the results from the first science run – 95 days (PRL, 116, 161302 (2016))

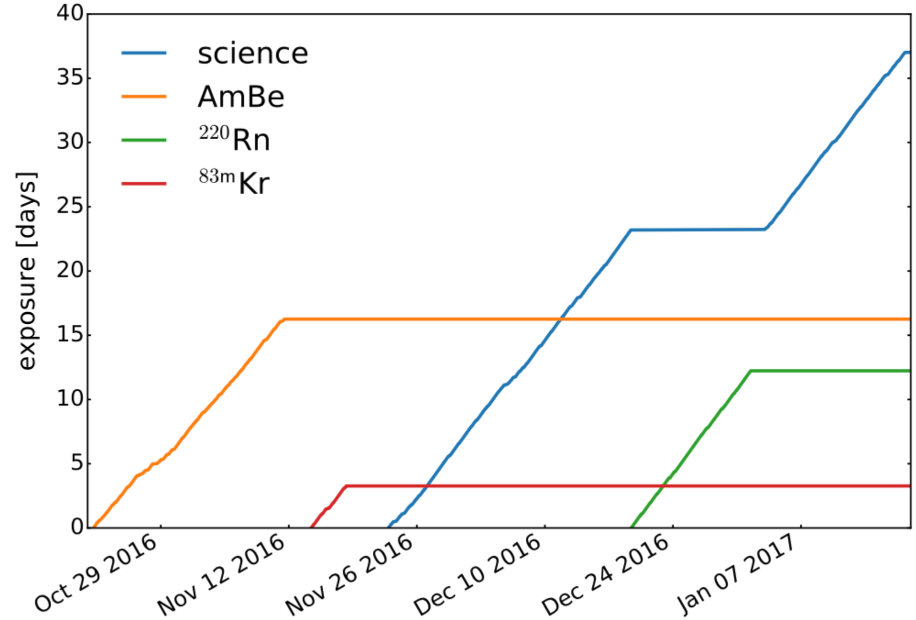
(pictures with the courtesy of Cláudio Silva - LUX Collaboration)





XENON1T : the near future

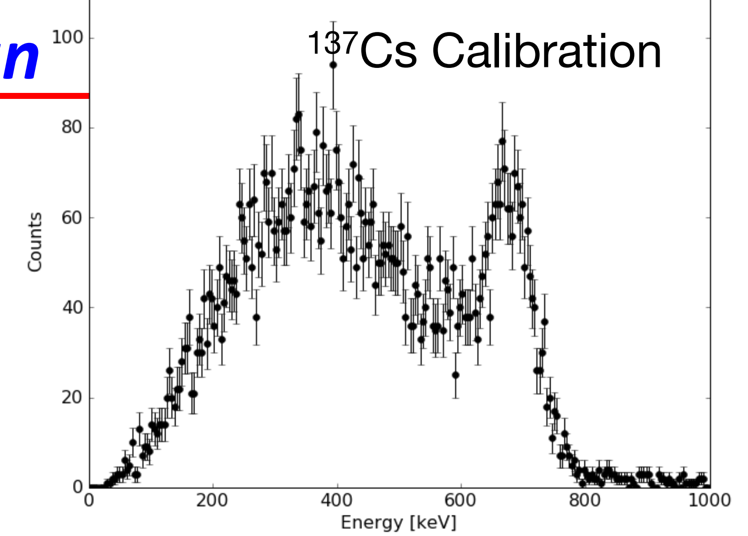


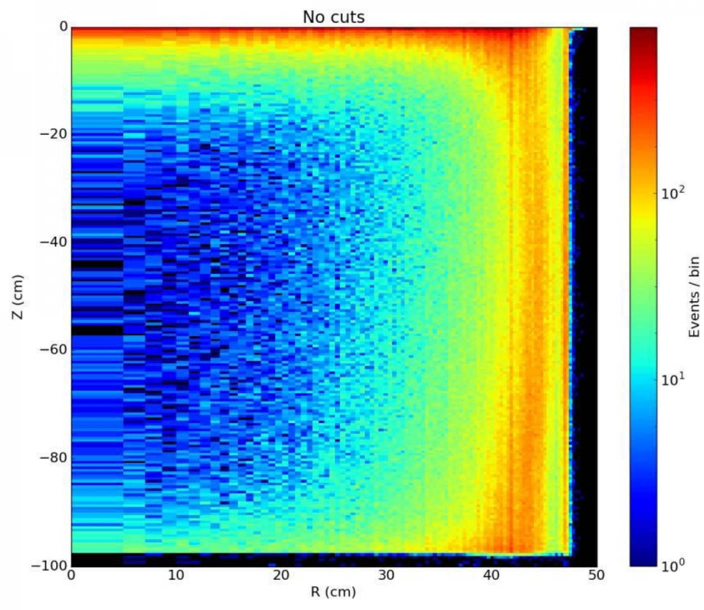


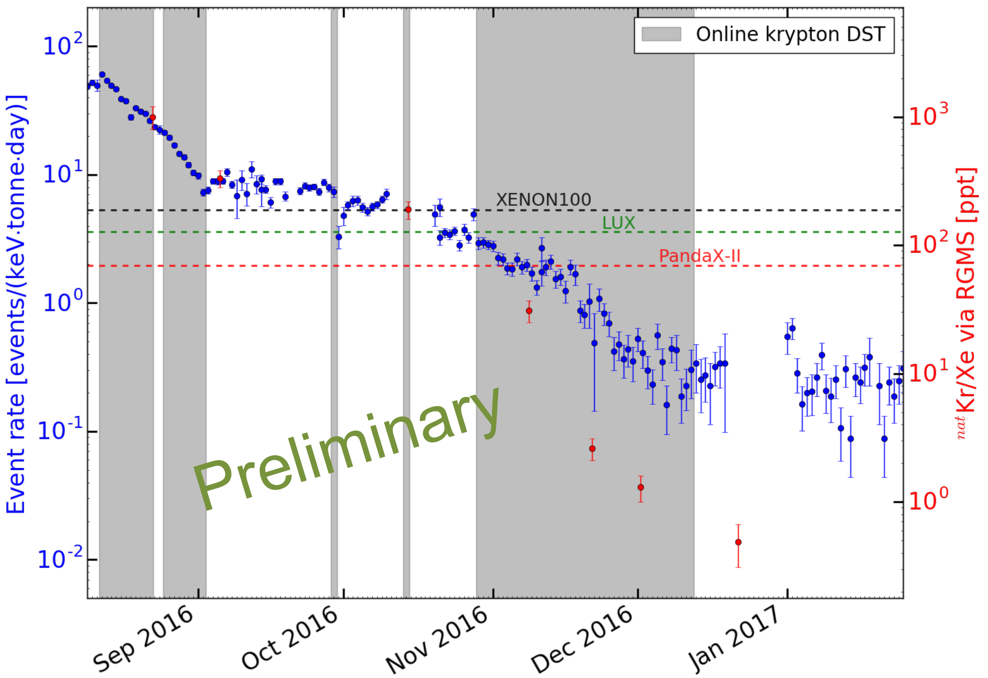
- **Science data** acquired until the earthquake (Jan. 18th) being analyzed
- Electronic recoil band determined from **Rn220 calibration**
- Nuclear recoil (signal region) data from **AmBe neutron source**
- Data corrections and processor performance tested on **^{83m}Kr data**

XENON1T: Commissioning & First Run

- Started commissioning in April 2016 with first fill
  Other subsystems came online
- First Calibration with ^{137}Cs γ source
- Purity have increase – Full TPC visible
- Lowest background level of all LXe experiments



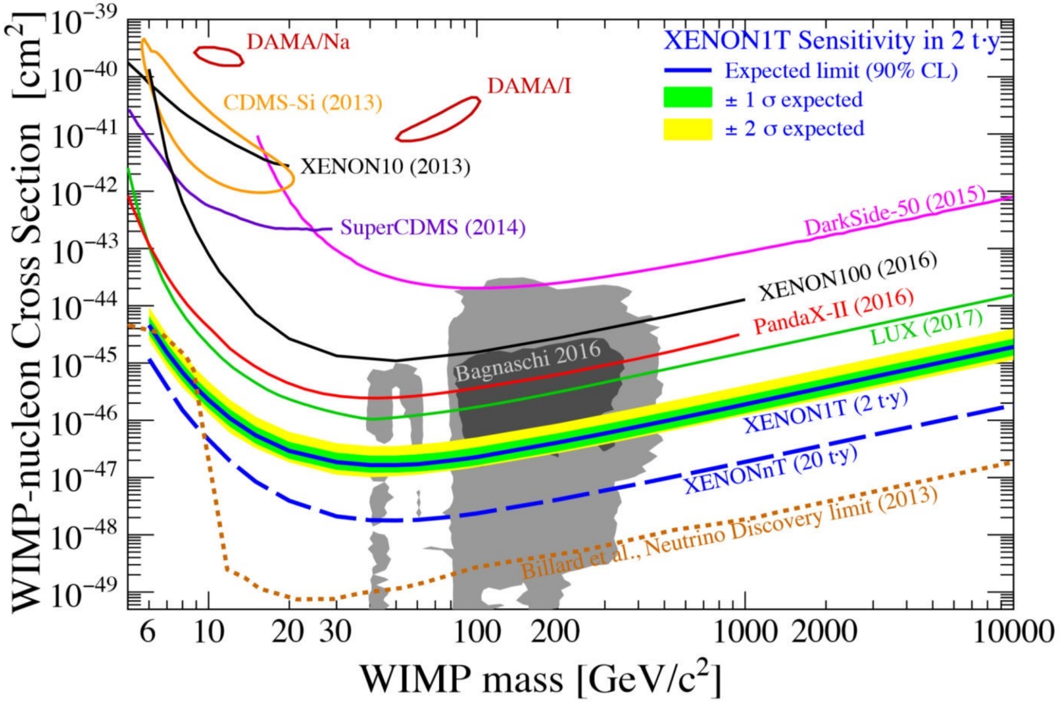


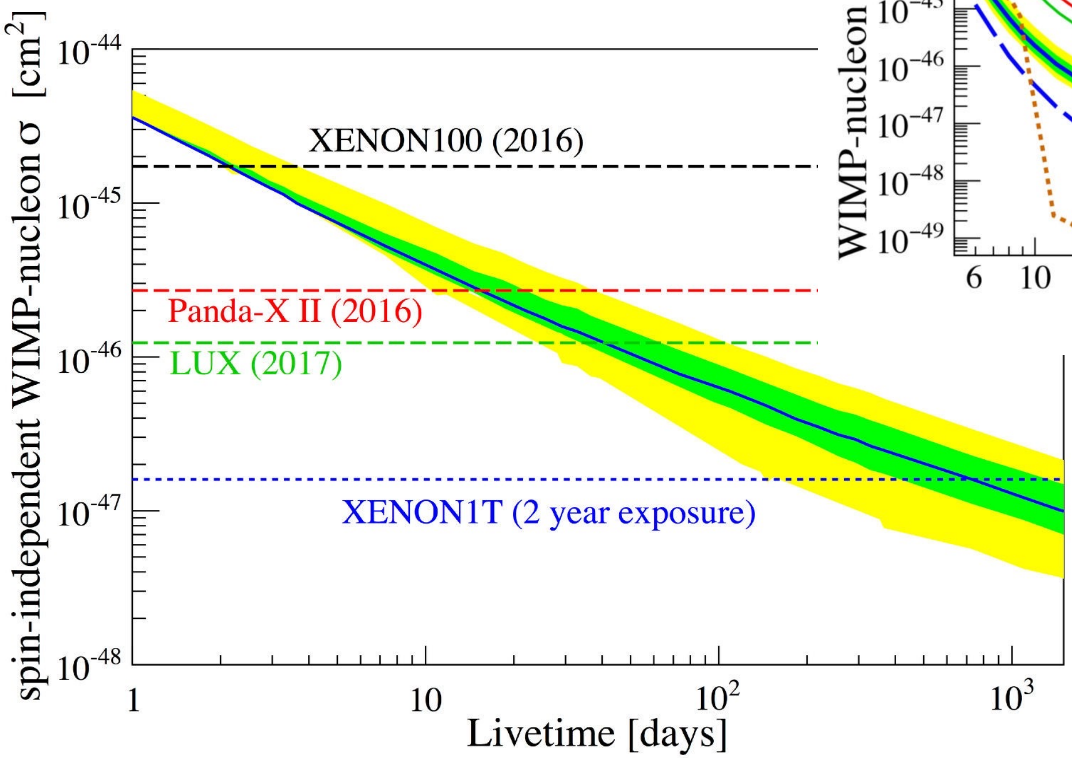


XENON1T: Expected sensitivity

JCAP04(2016)027

based on background predictions
2 t × y exposure

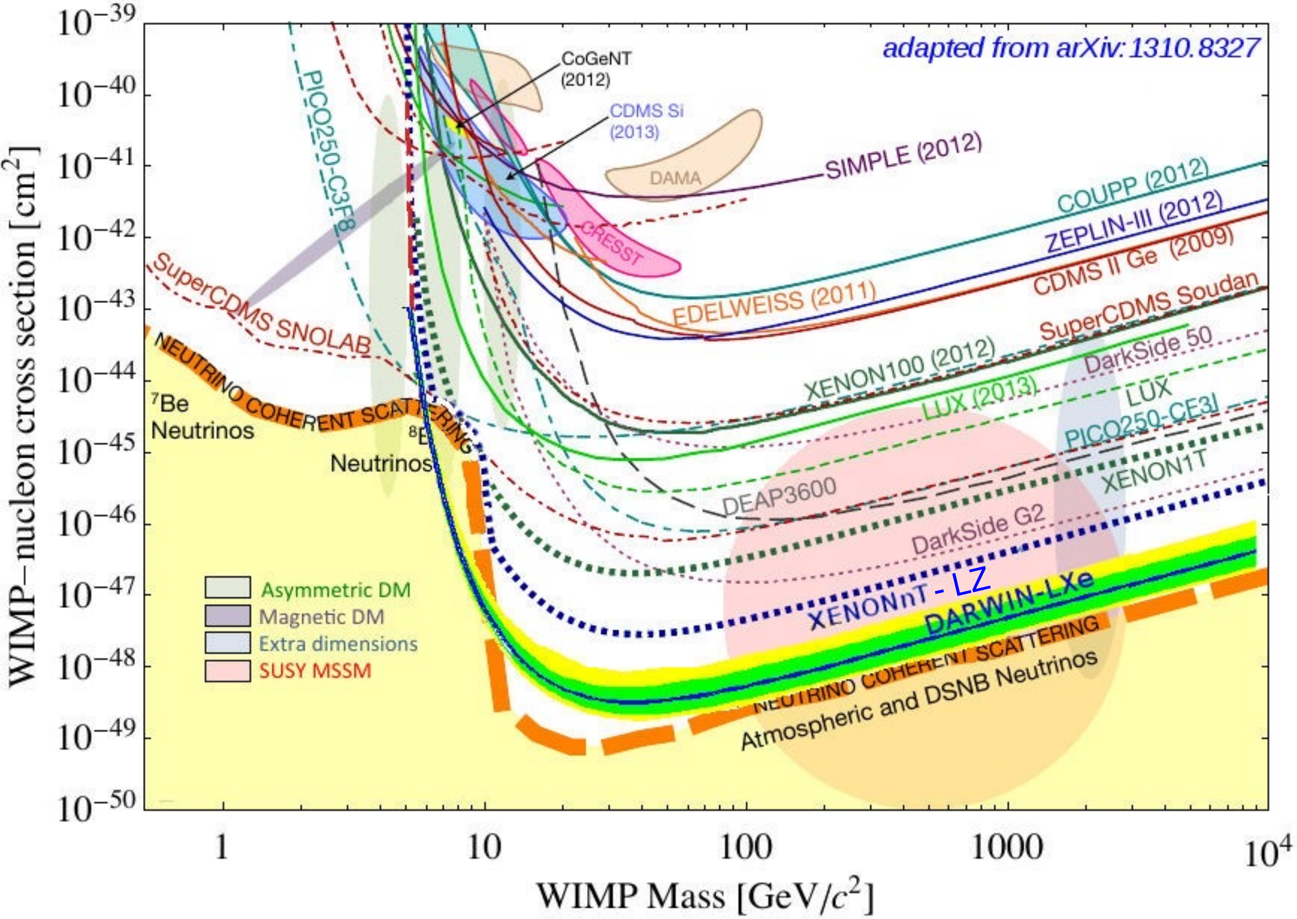




assumptions: S1 interval: 3 – 70 PE

ER rejection 99.5% @ 50% NR acceptance
→ measured LY is ~2x higher than in XENON100!

Perspectives



And other analysis already published or to come:

- Axions / ALP
- 2ν double electron capture on ^{124}Xe
- Low mass
- Effective field theories
- Calibration
- …
- Stay tuned !

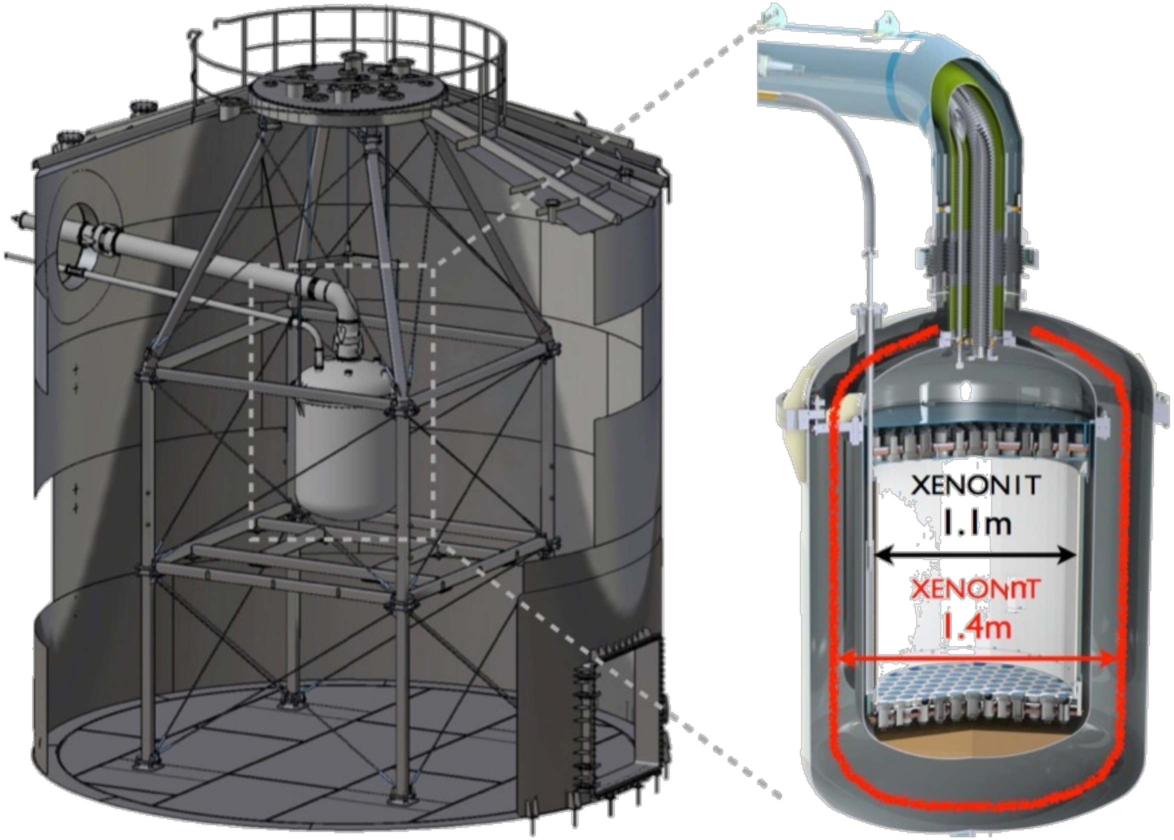
PandaX-II continue data taking with ~400kg

XENONnT & LZ construction is starting…

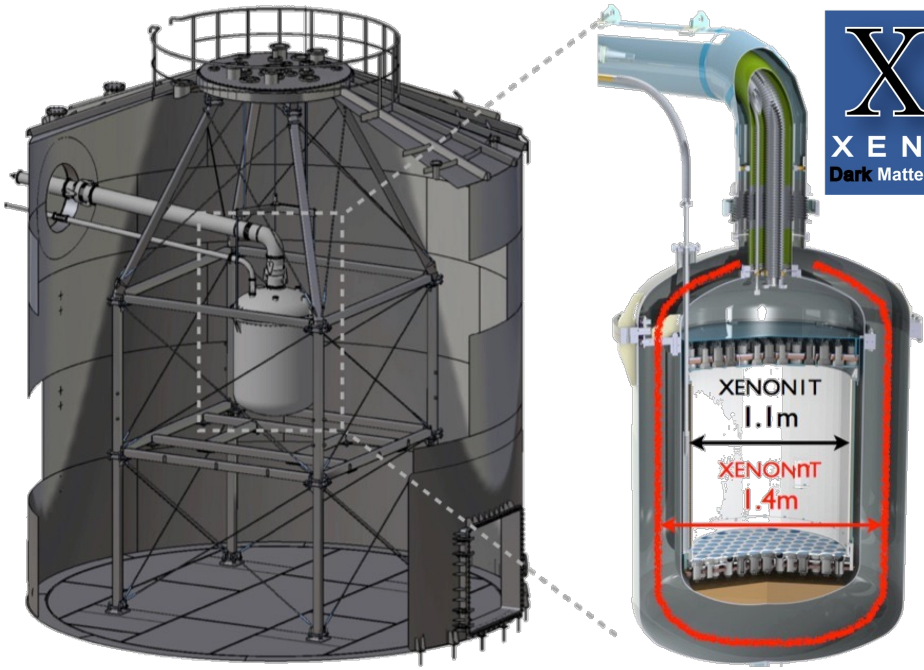
XENON1T is analyzing Science Run 0 !

Upgrade: XENONnT

- Quick upgrade of TPC and inner cryostat
- All major systems remain unchanged
- Construct TPC in parallel to XENON1T operation
- Upgrade starting 2018

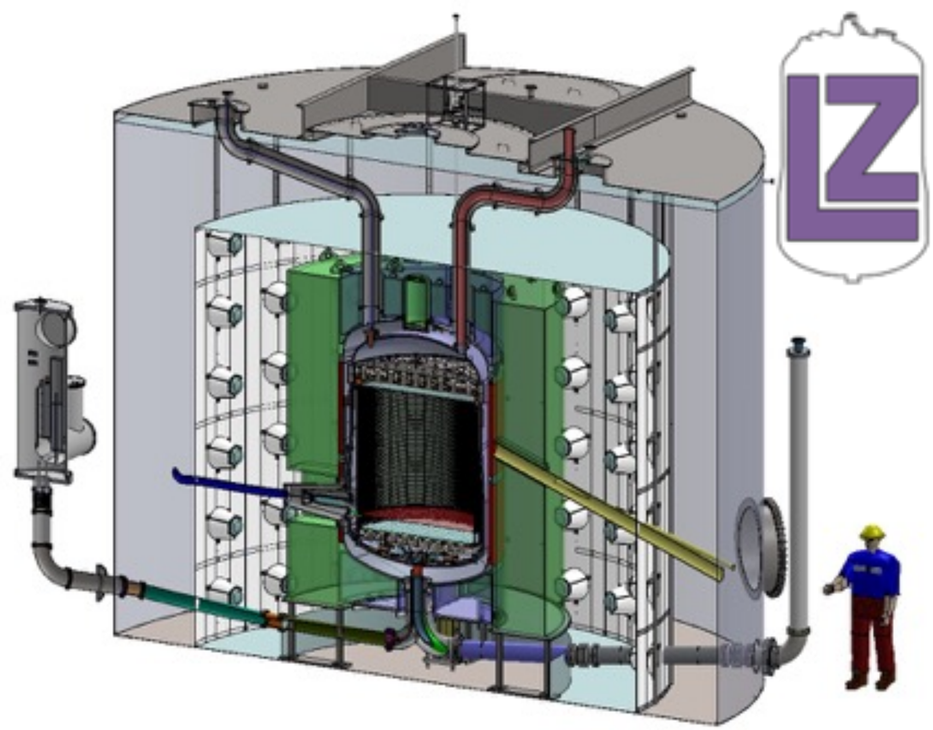


Future: LZ & XENONnT



LZ = LUX + ZEPLIN

- Same location than LUX
- Turning on by 2020 with 1 000 initial live-days
- 10 tons total, 7 tons active,

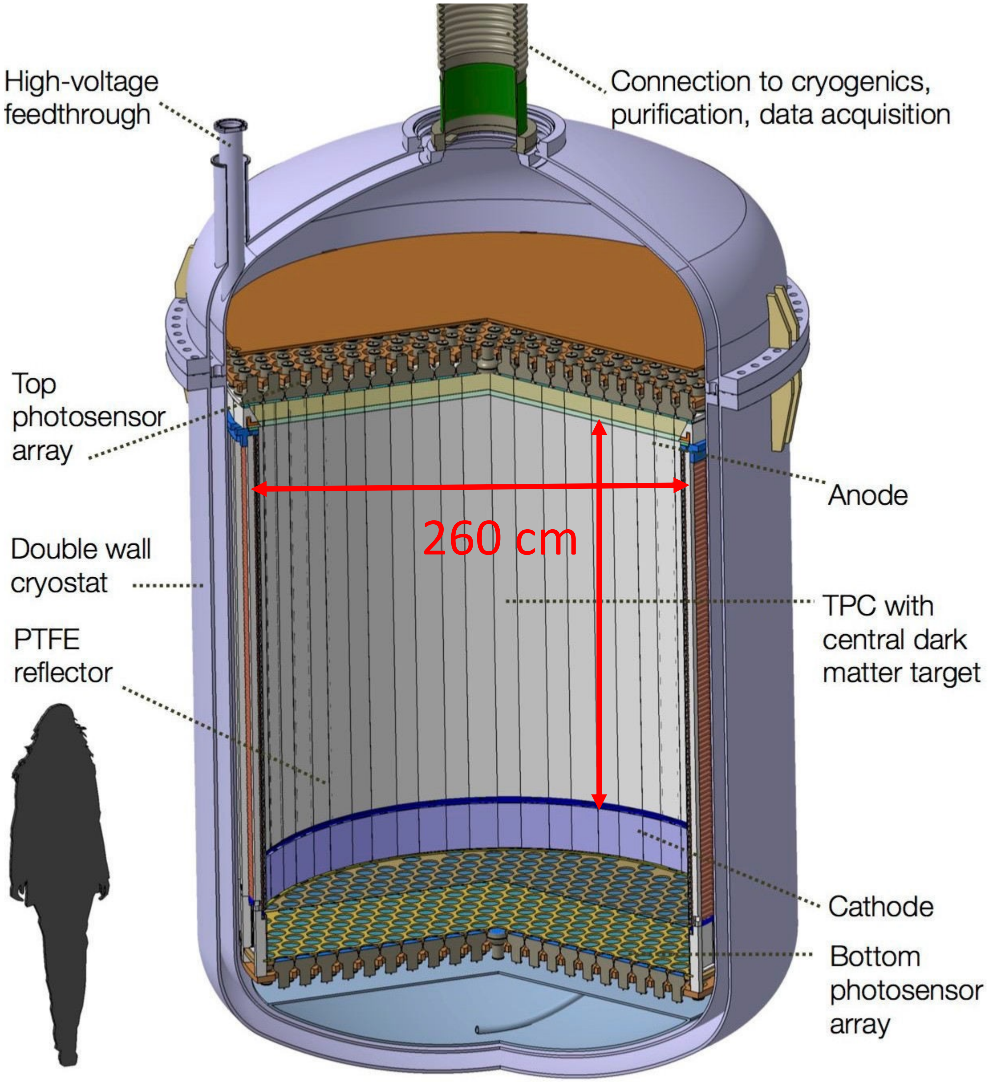


XENONnT:

- Quick upgrade of TPC and inner cryostat
- All major systems remain unchanged
- Construct TPC in parallel to XENON1T operation
- Upgrade starting 2018
- 8 tons total, 6 tons active

Far future: DARWIN the ultimate detector

JCAP 1611 (2016) no.11, 017
arXiv:1606.07001



- Aim at sensitivity of a few 10^{-49} cm^2, limited by irreducible ν-backgrounds
- R&D started
- 50 tons total LXe
  40 tons TPC
  30 tons fiducial