dark matter wimp search in noble liquids

DARWIN

XENON100, XENON1T and DARWIN

Universität Zürich UZH

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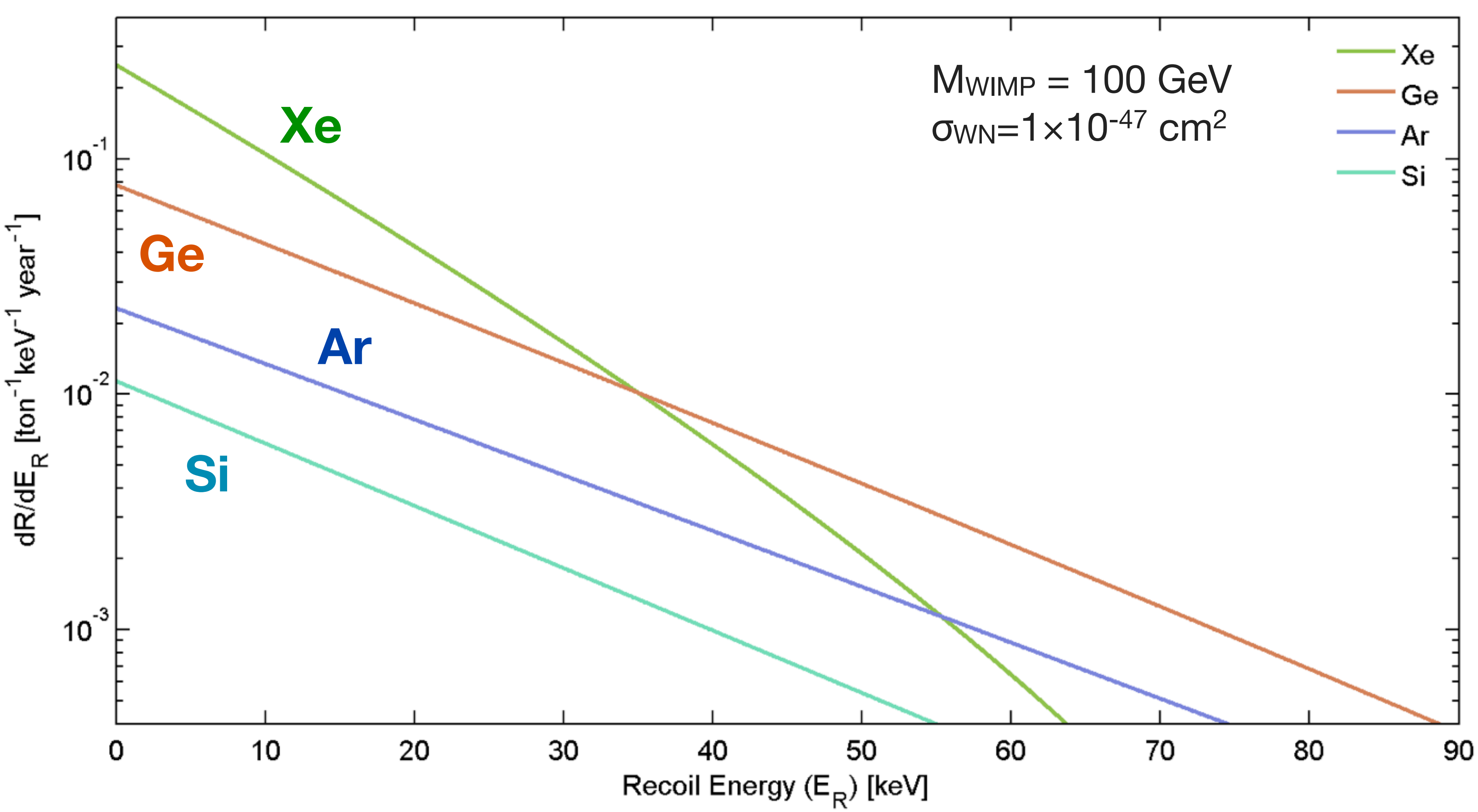
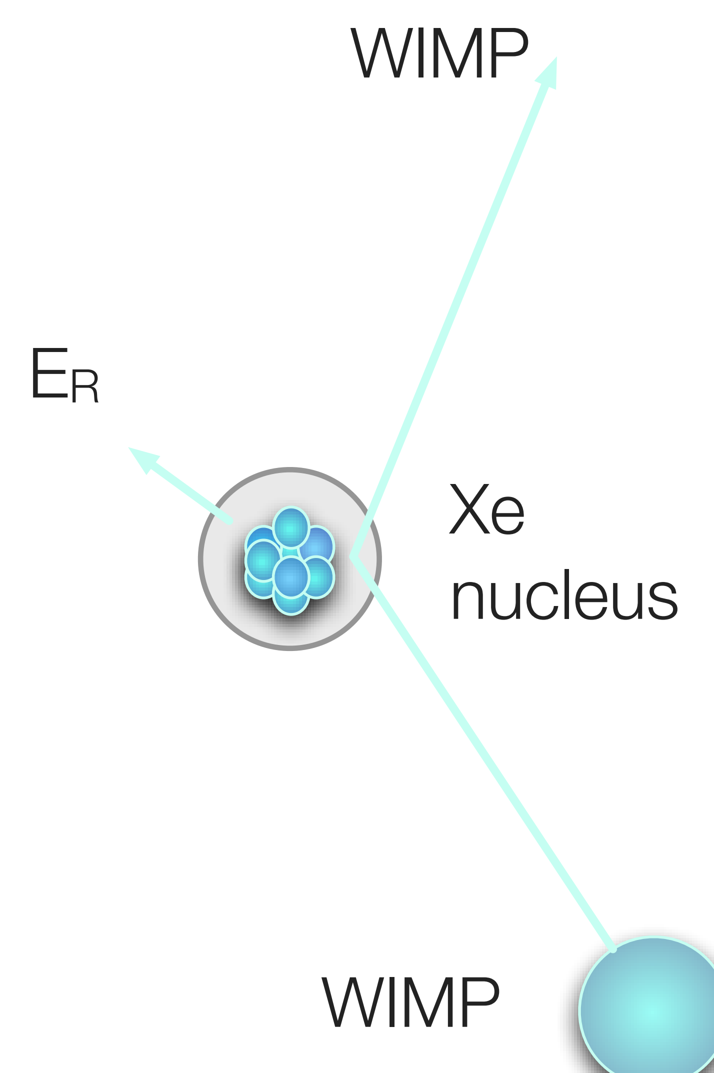
CHIPP plenary meeting
Campus Sursee, June 26, 2013

Physics aim of liquid xenon dark matter experiments

- Observe WIMP dark matter via elastic scattering off xenon nuclei
- The expected scattering rate is:

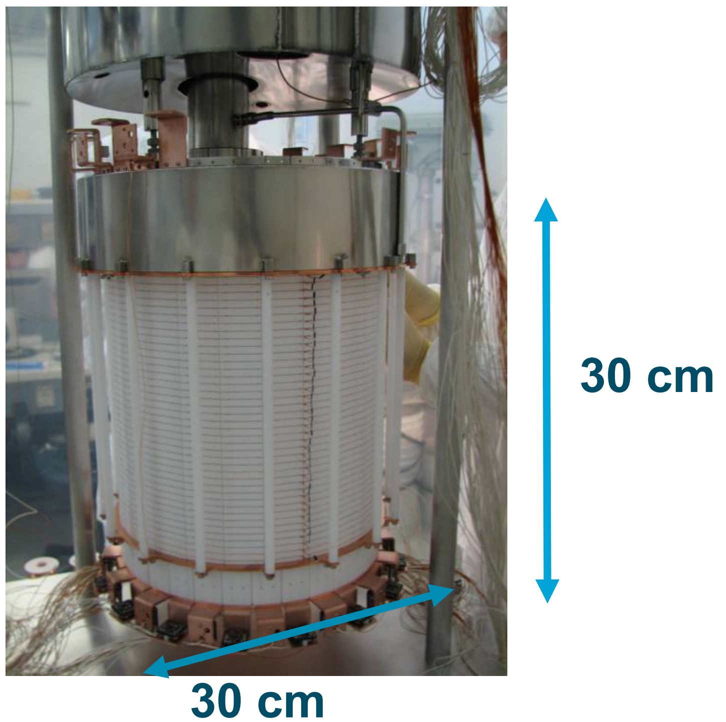
$$R \sim 0.13 \ \frac{\text{events}}{\text{kg year}} \left[\frac{A}{100} \times \frac{\sigma_{WN}}{10^{-38}\,\text{cm}^2} \times \frac{\langle v \rangle}{220\,\text{km}\,\text{s}^{-1}} \times \frac{\rho_0}{0.3\,\text{GeV}\text{cm}^{-3}} \right]$$

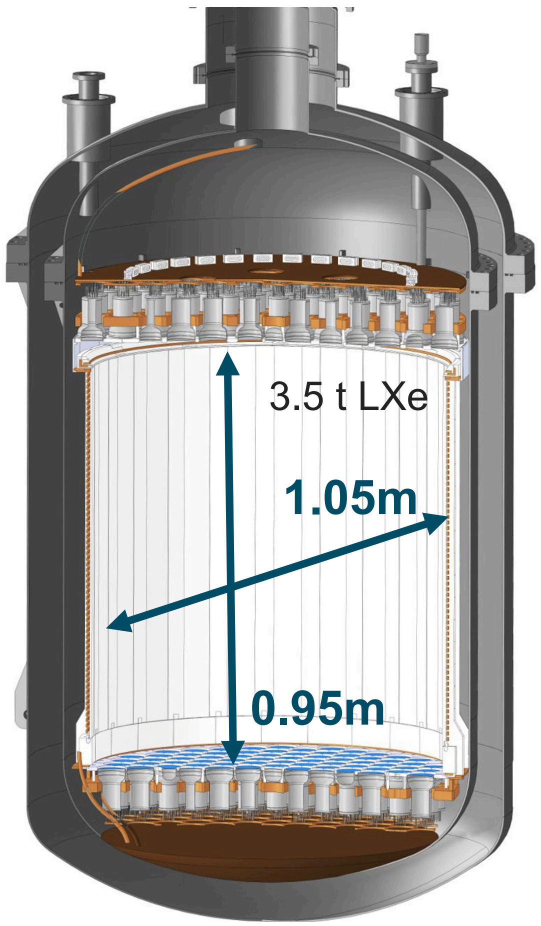


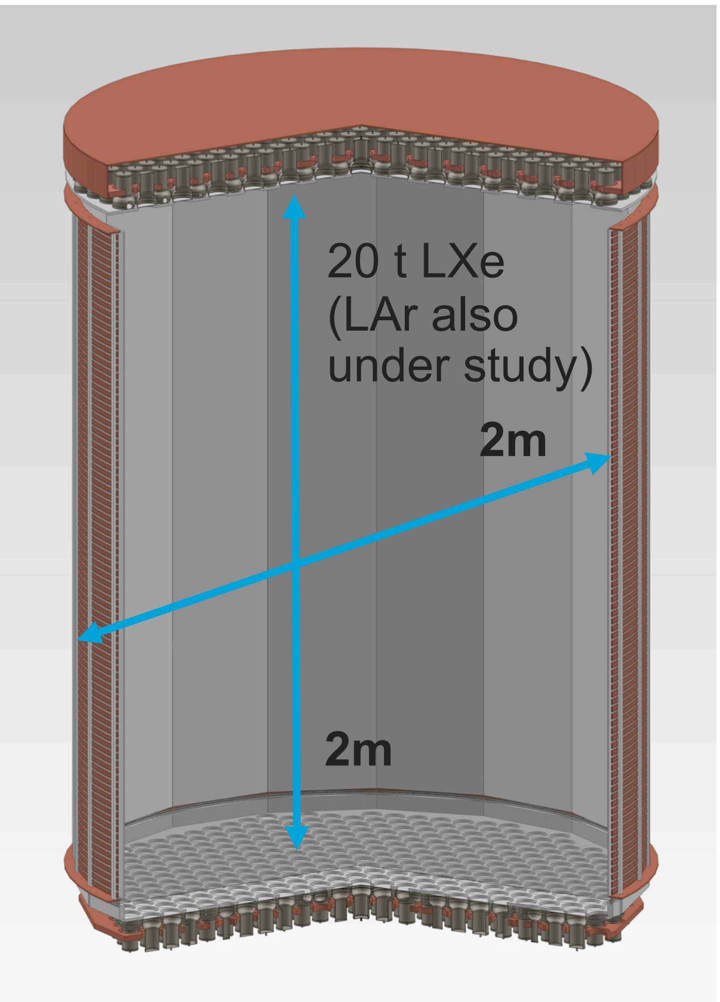


Xenon time projection chambers

XENON collaboration
Astroparticle Physics 35, 573-590, 2012







XENON100 in Pb/Poly/Cu shield at LNGS:

161 kg LXe (~50 kg fiducial), dual-phase, 242 PMTs
taking science data

XENON1T: under construction at LNGS

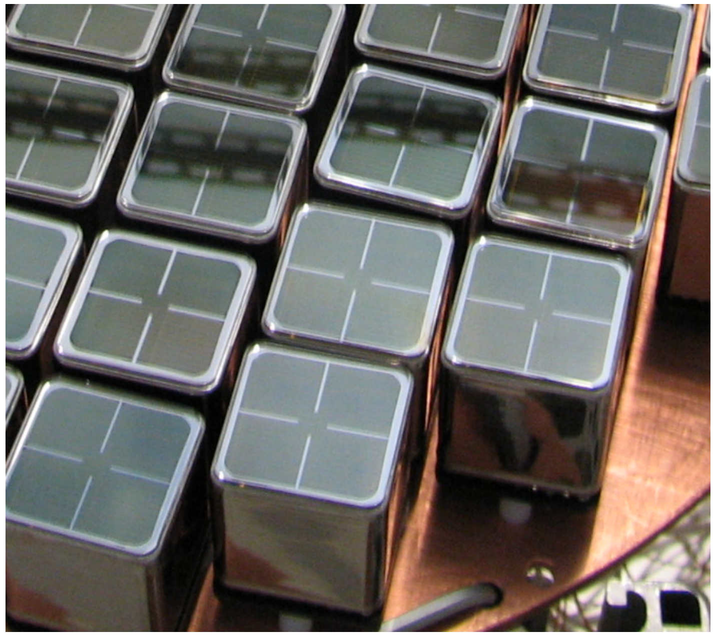
3500 kg LXe (~2000 kg fiducial), dual-phase, 248 PMTs, physics run to start in 2015

DARWIN: R&D and design stage; LNGS or Modane extension

20 t LXe (~12 t fiducial); ~ 1050 PMTs, physics run to start in 2018

Photosensors

XENON100



1-inch square Hamamatsu R8520 PMTs
^{226}Ra/^{228}Th: ~1mBq/PMT
QE: ~ 30% at 178 nm

XENON1T

JINST 8 P04026 (2013)

3-inch Hamamatsu R11410-21 PMTs
^{226}Ra/^{228}Th: ~1 mBq/PMT
QE: ~ 34% at 178 nm

DARWIN

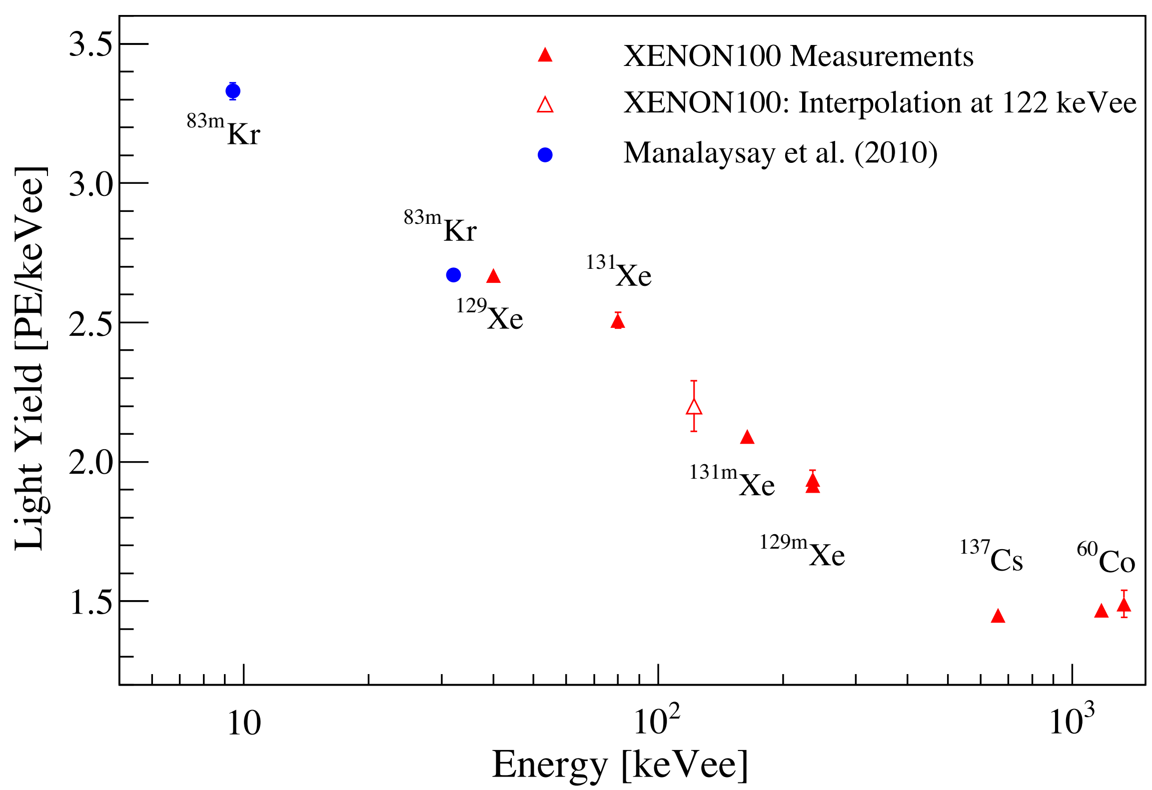
NIM A 654 (2011) 184–195

R11410-21 (baseline)
QUPIDs
^{226}Ra/^{228}Th: <1 mBq/QUPID
LAAPDs, SiPMs
Gas PMs
R&D ongoing

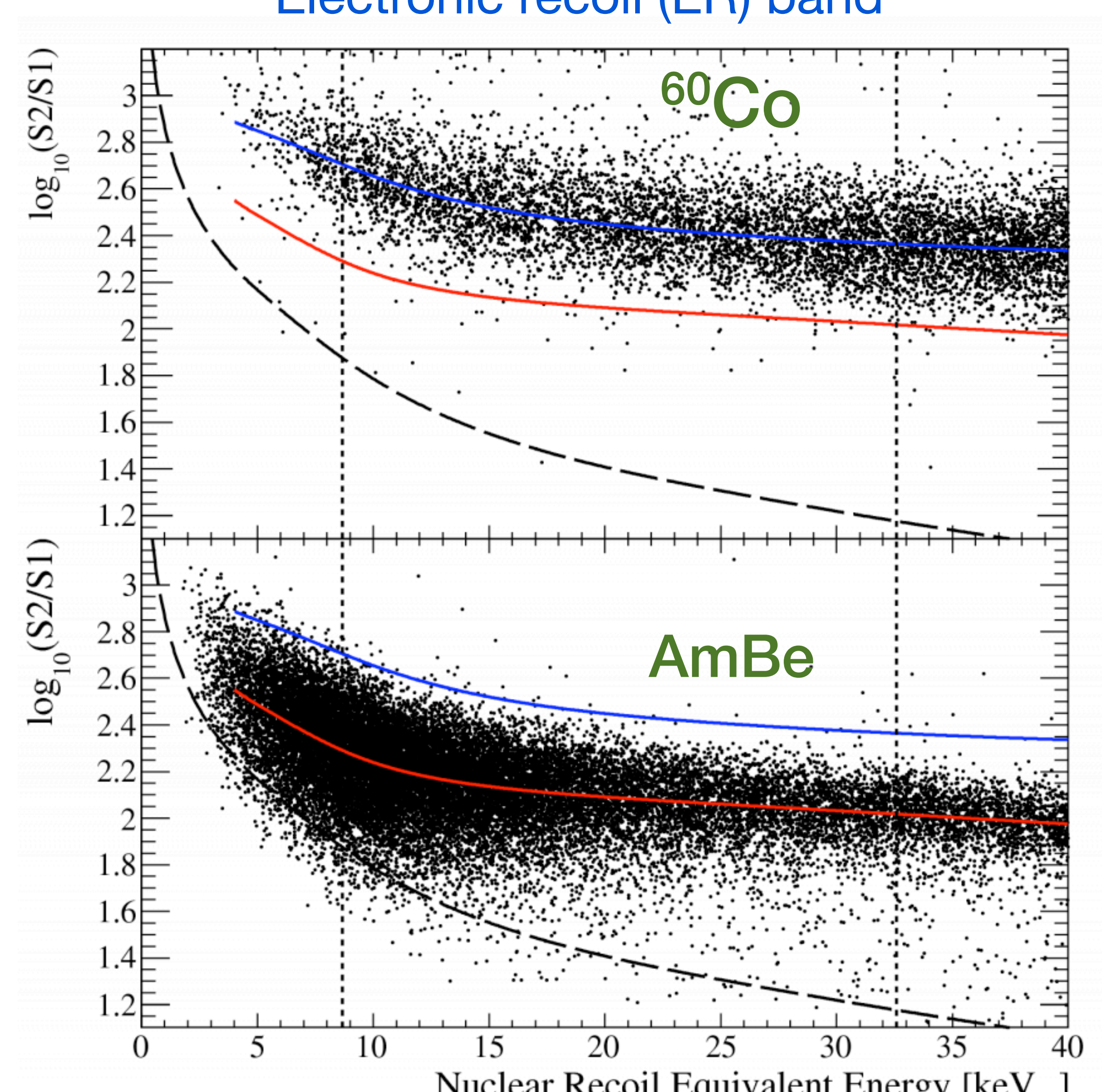
Calibration: energy scale and ER/NR bands

- ^{83m}Kr, ^{129}Xe, ^{131}Xe, ^{137}Cs: charge & light yields in the TPC
- ^{60}Co, ^{232}Th: electronic recoil band; AmBe: nuclear recoil band

^{83m}Kr data: Xurich detector at UZH



Electronic recoil (ER) band



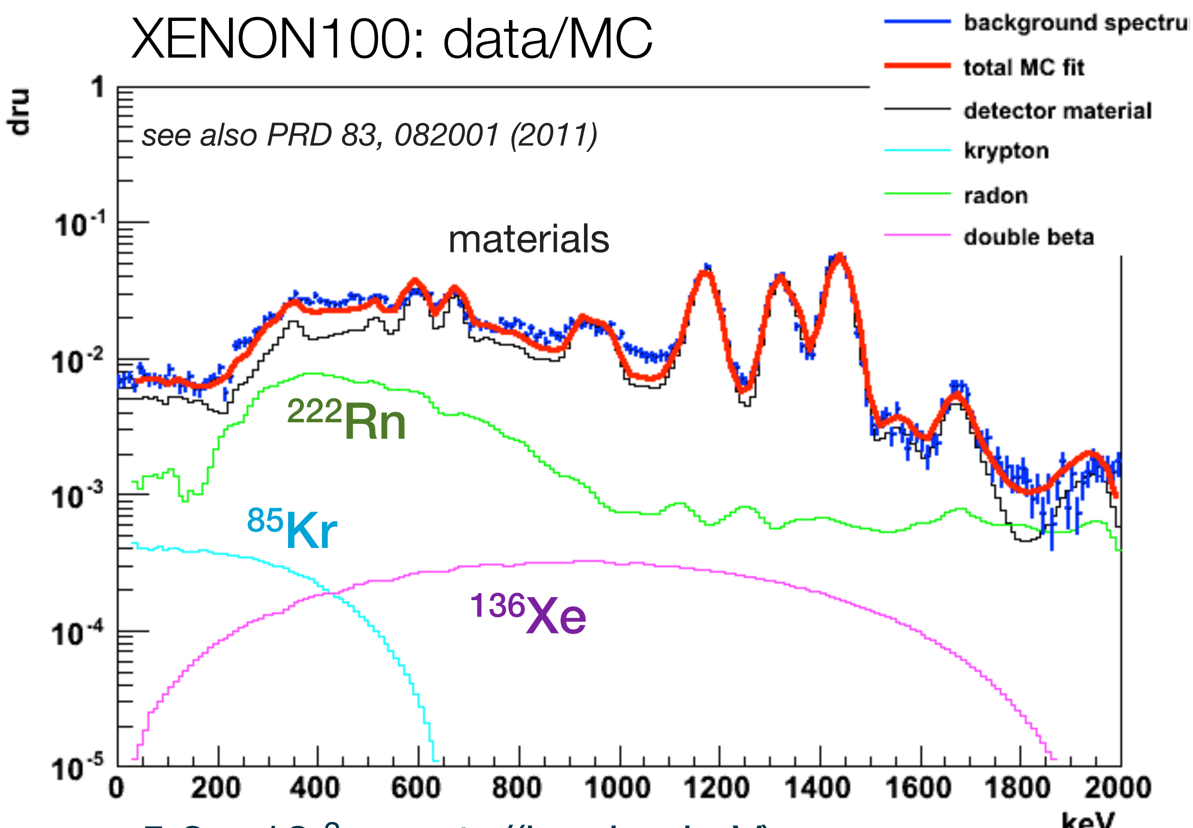
Nuclear recoil (NR) band

- XENON1T: use ^{220}Rn, and n-generator
- DARWIN: use also pp-neutrinos, and, possibly a ^{51}Cr neutrino-source:~6 events/(t d) in [2-15]keV

(E=426 keV, 10%; E = 746 keV, 90%; A = 10 MCi)

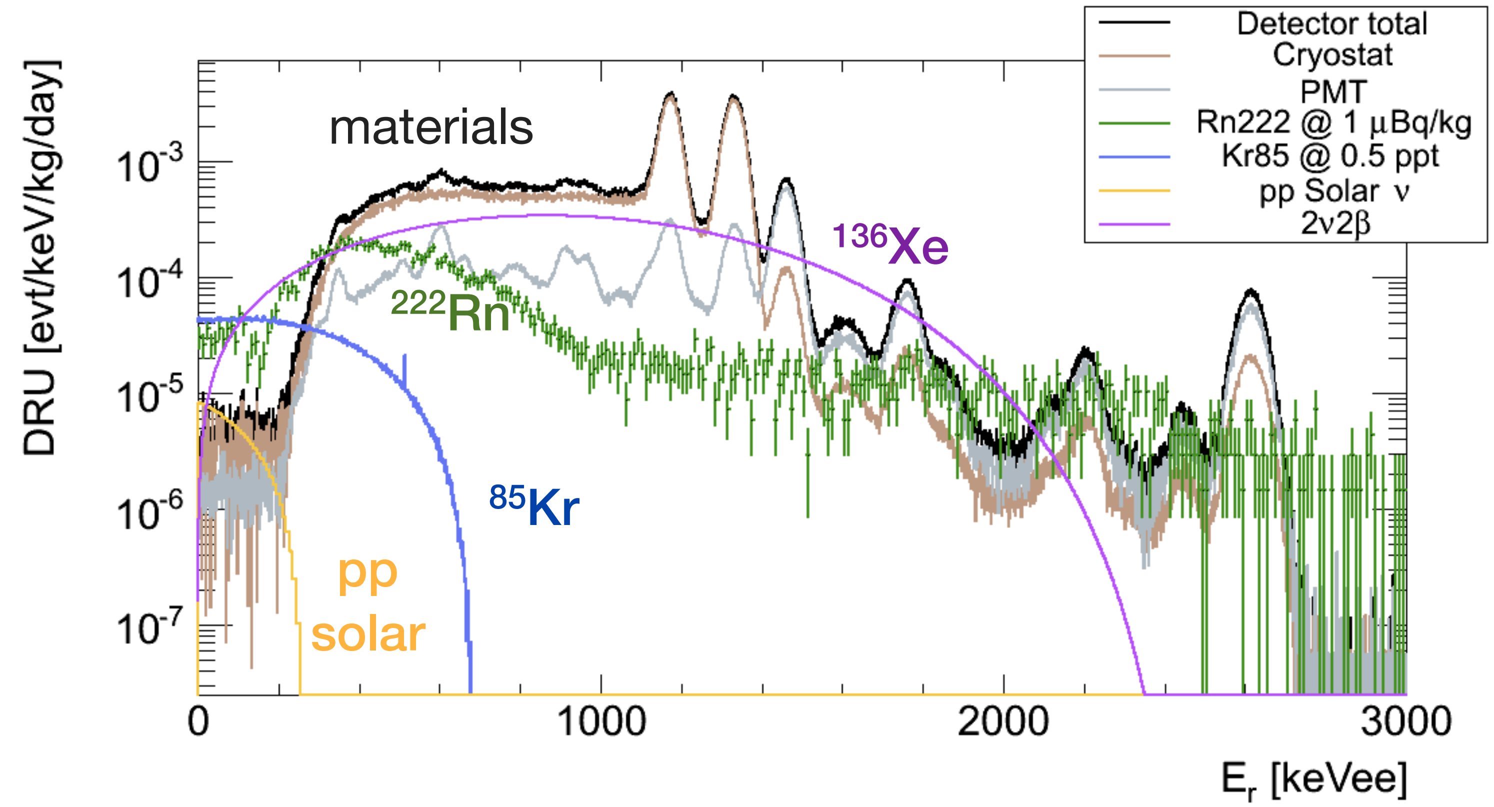
Backgrounds

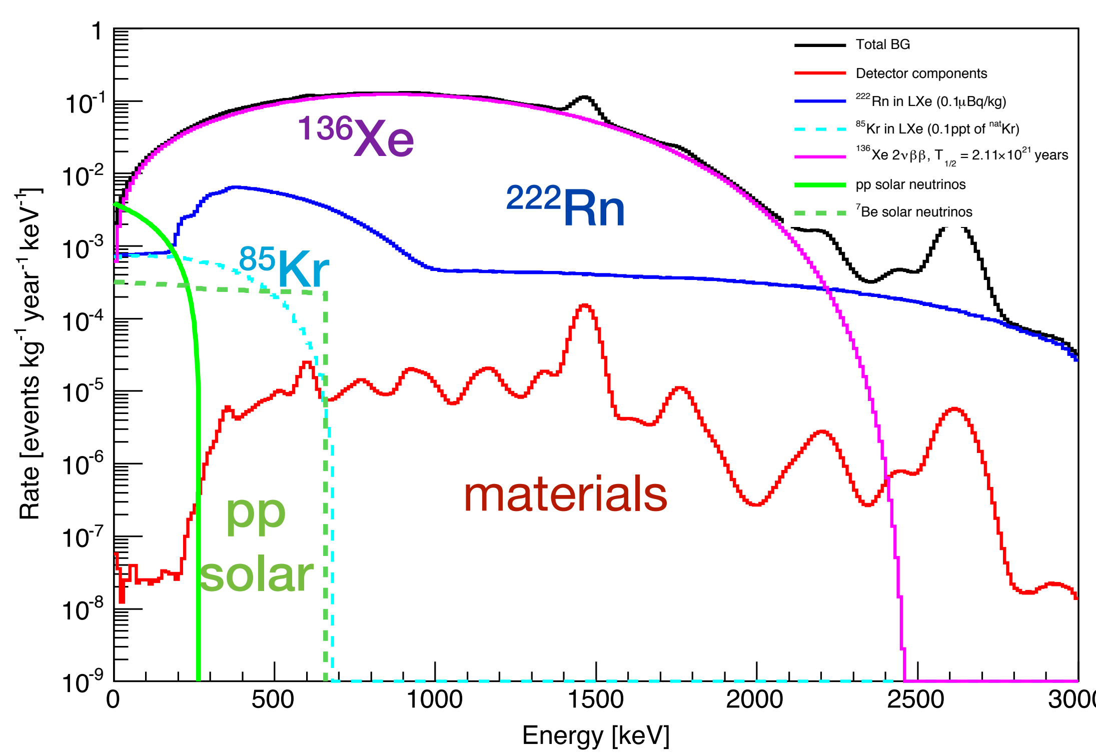
XENON100: data/MC



- 5.3×10^{-3} events/(kg day keV)

XENON1T: MC





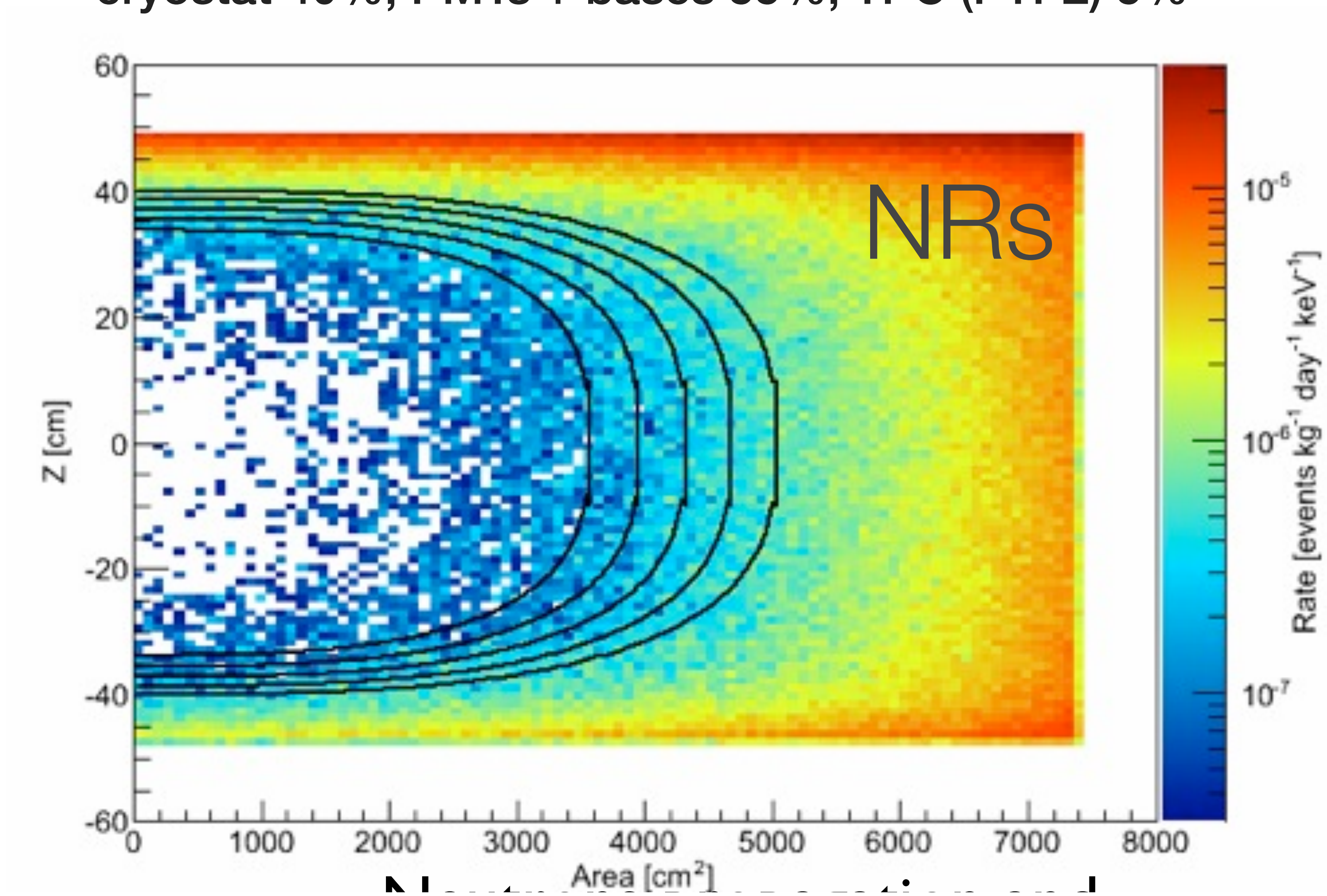
DARWIN: MC
- pp-neutrinos
- bb-decay
- radon
- krypton
- materials

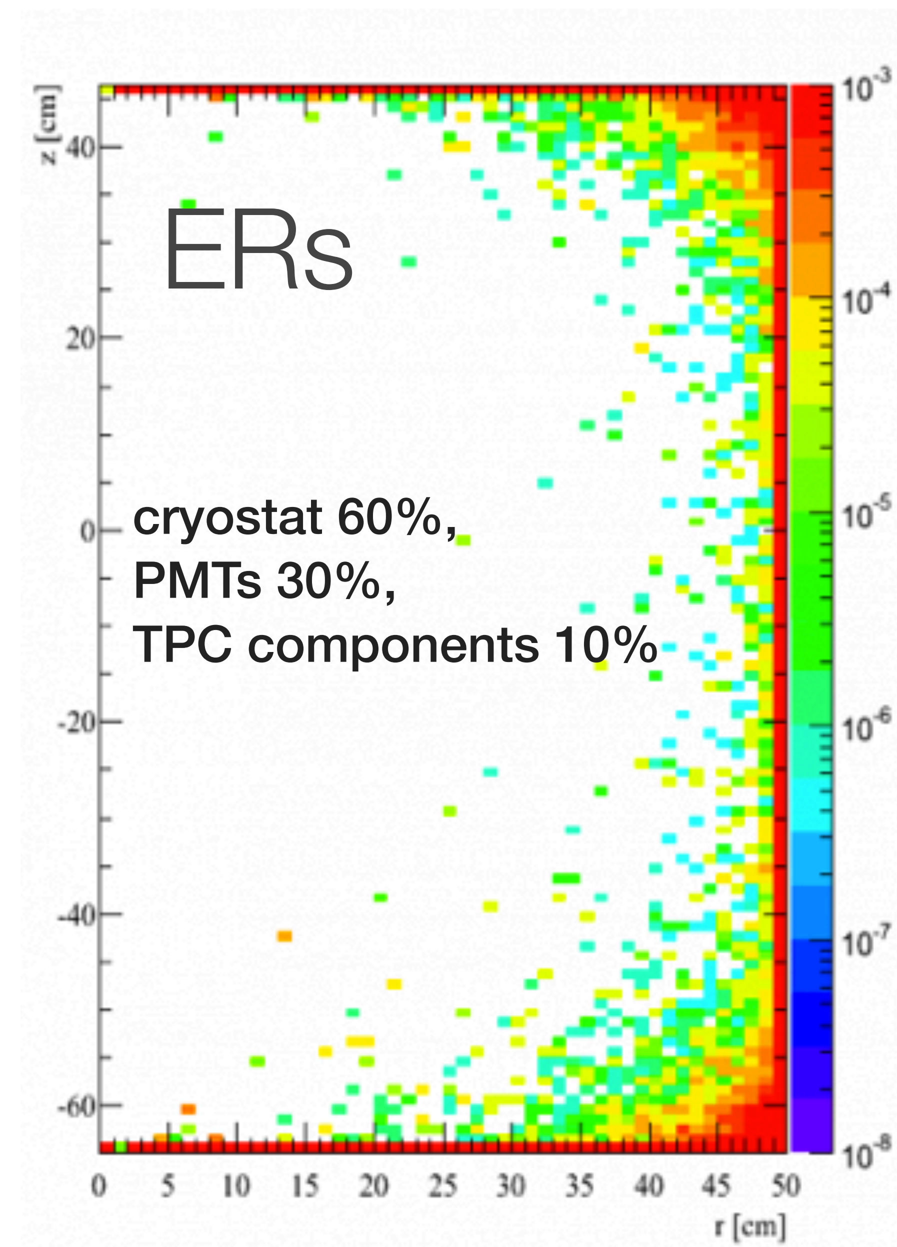
XENON1T: MC
- radon
- krypton
- pp-neutrinos
- materials
- bb-decay

Example: XENON1T backgrounds

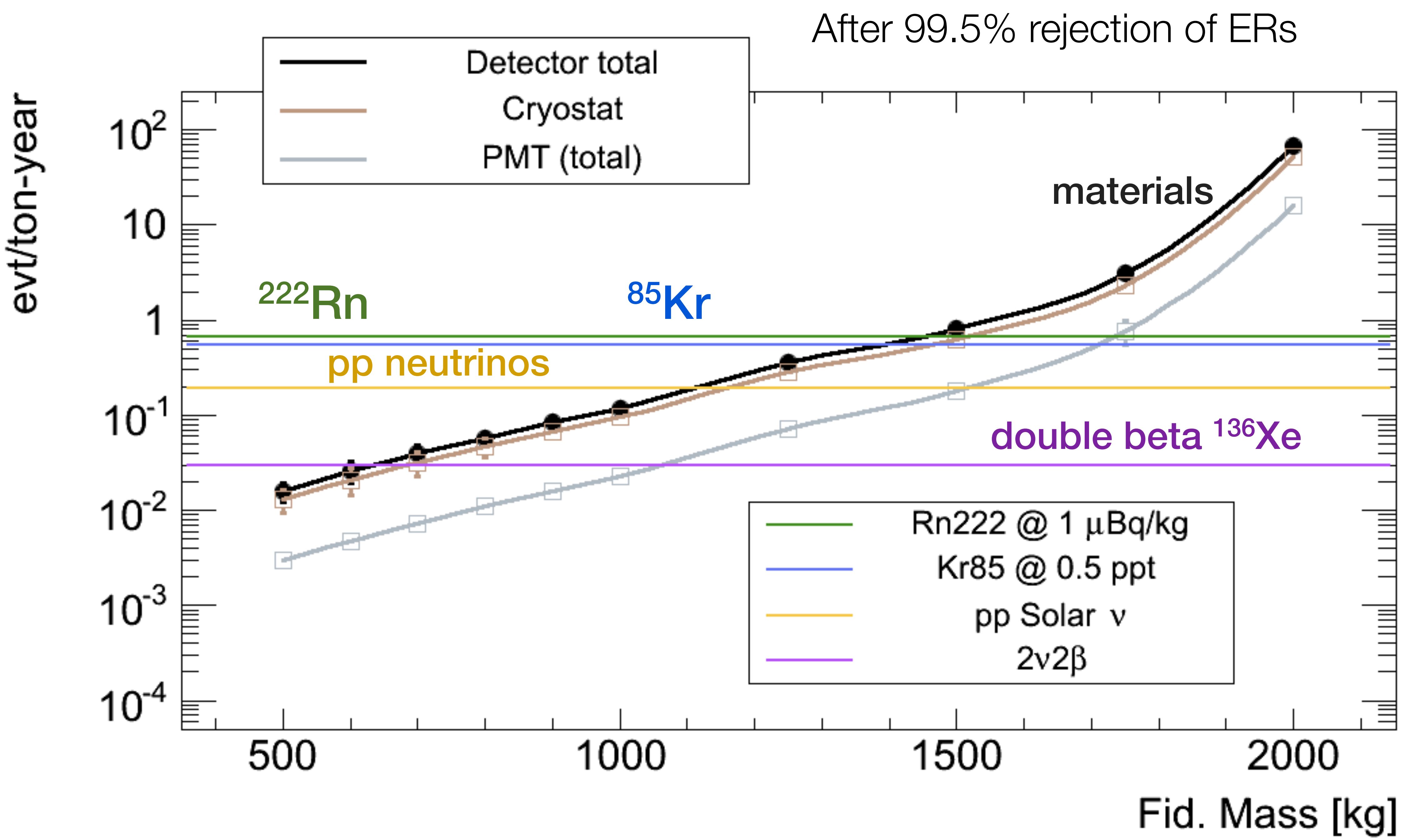
- Material screening campaign of all the materials is in progress
- Detailed MC simulations of ER and NR background component
- ER: [2 - 15] keV_{ee}, 99.5% S2/S1 rejection, 1 ton fiducial mass -> 0.2 events/year
- NR: [8 - 45] keV_{nr}, single-scatters, 1 ton fiducial mass -> 0.4 events/year (muon-induced n-BG < 0.01 ev/year)

cryostat 40%, PMTs + bases 55%, TPC (PTFE) 5%



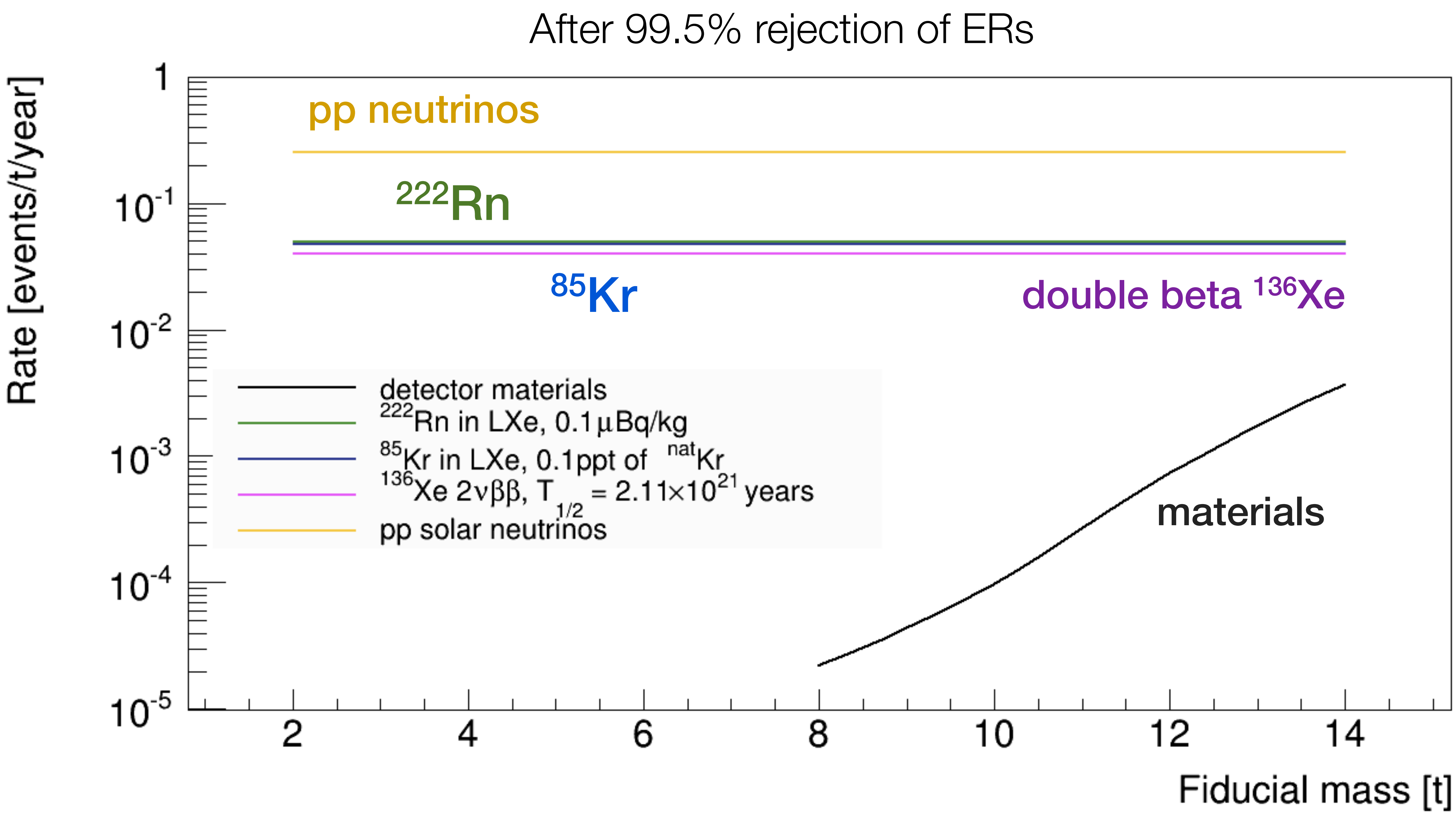


XENON1T: rate as a function of mass



Material background quickly drops below internal background from ^{85}Kr and ^{222}Rn, and below the one from solar neutrinos and double beta decay of ^{136}Xe

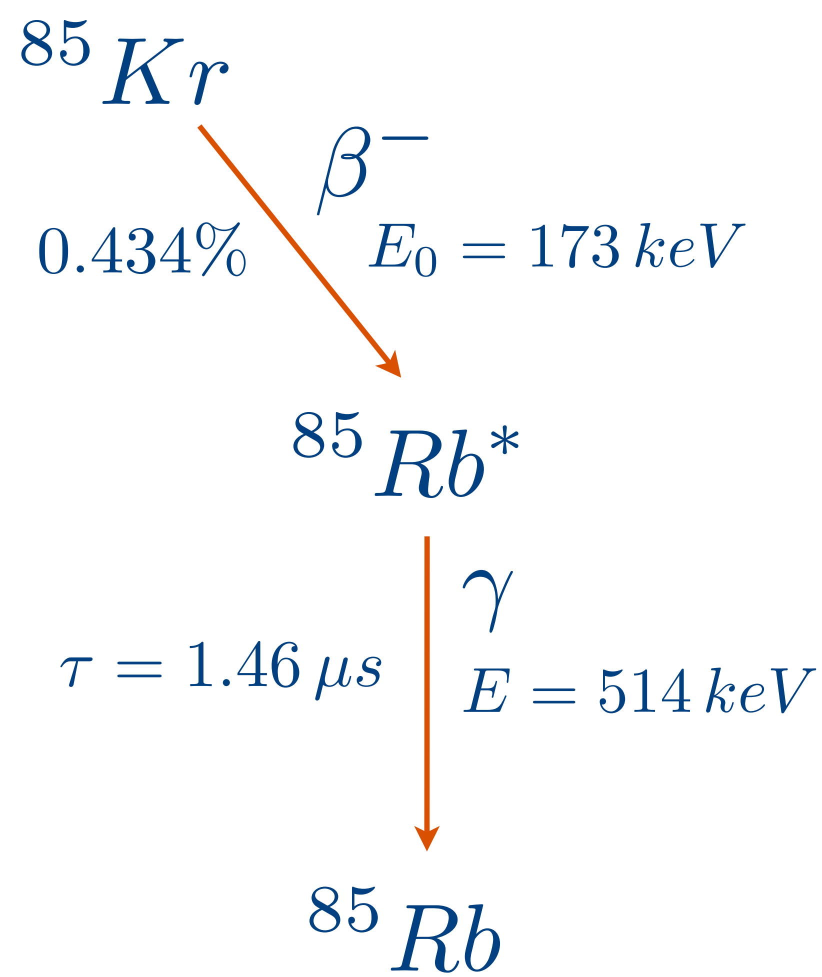
DARWIN: rate as a function of mass



Material background is subdominant; main contribution comes from one from solar neutrinos and double beta decay of ^{136}Xe , from ^{85}Kr and ^{222}Rn

Backgrounds

- XENON100: materials, radon, krypton
  - current run: < 1.3 ppt (90% C.L.) ^{nat}Kr=> < 0.05 mdru from ^{85}Kr (^{85}Kr present at 10-11 mol/mol in ^{nat}Kr); 65 μBq ^{222}Rn
- XENON1T: radon, krypton, materials, solar neutrinos
  - assumptions 0.5 ppt ^{nat}Kr; 1 μBq/kg ^{222}Rn
- DARWIN: solar neutrinos, double beta decay (^{136}Xe), ^{85}Kr, ^{222}Rn, detector components
  - assumptions 0.1 ppt ^{nat}Kr; 0.1 μBq/kg ^{222}Rn

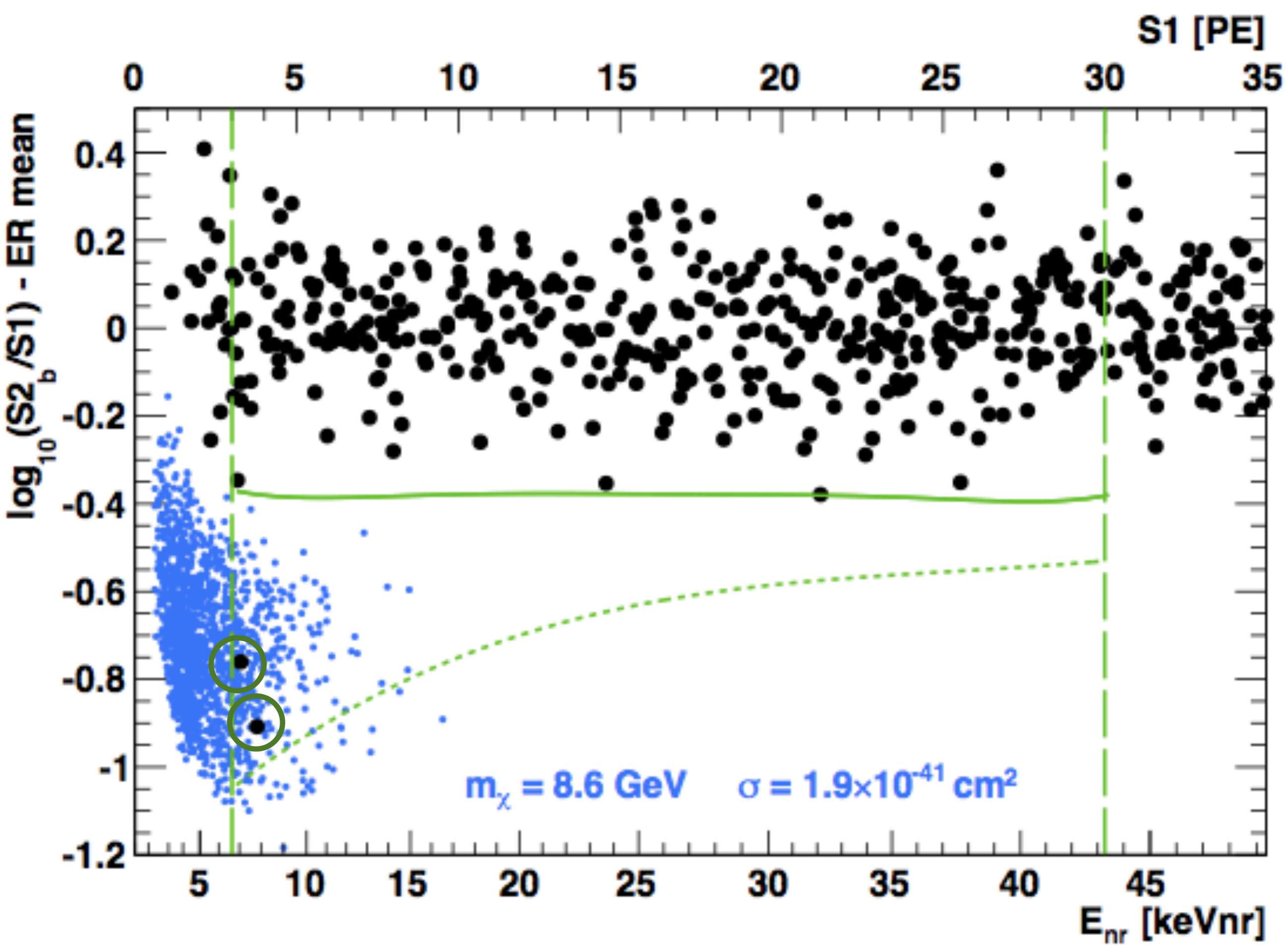


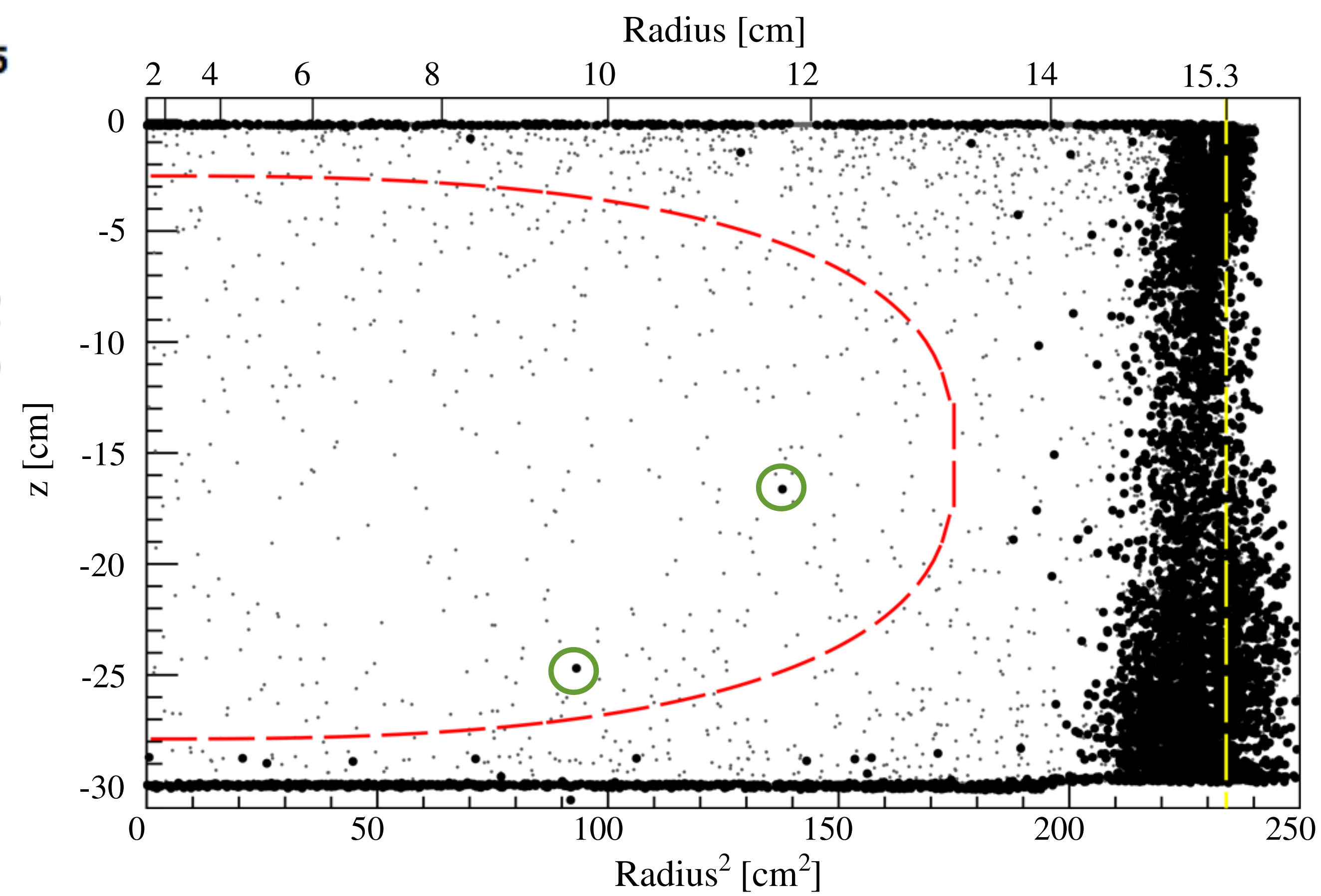
- NR background: sub-dominant

Signals, and background reduction

- Fiducial volume and ER/NR discrimination cut

XENON100: WIMP with m_W = 8.6 GeV

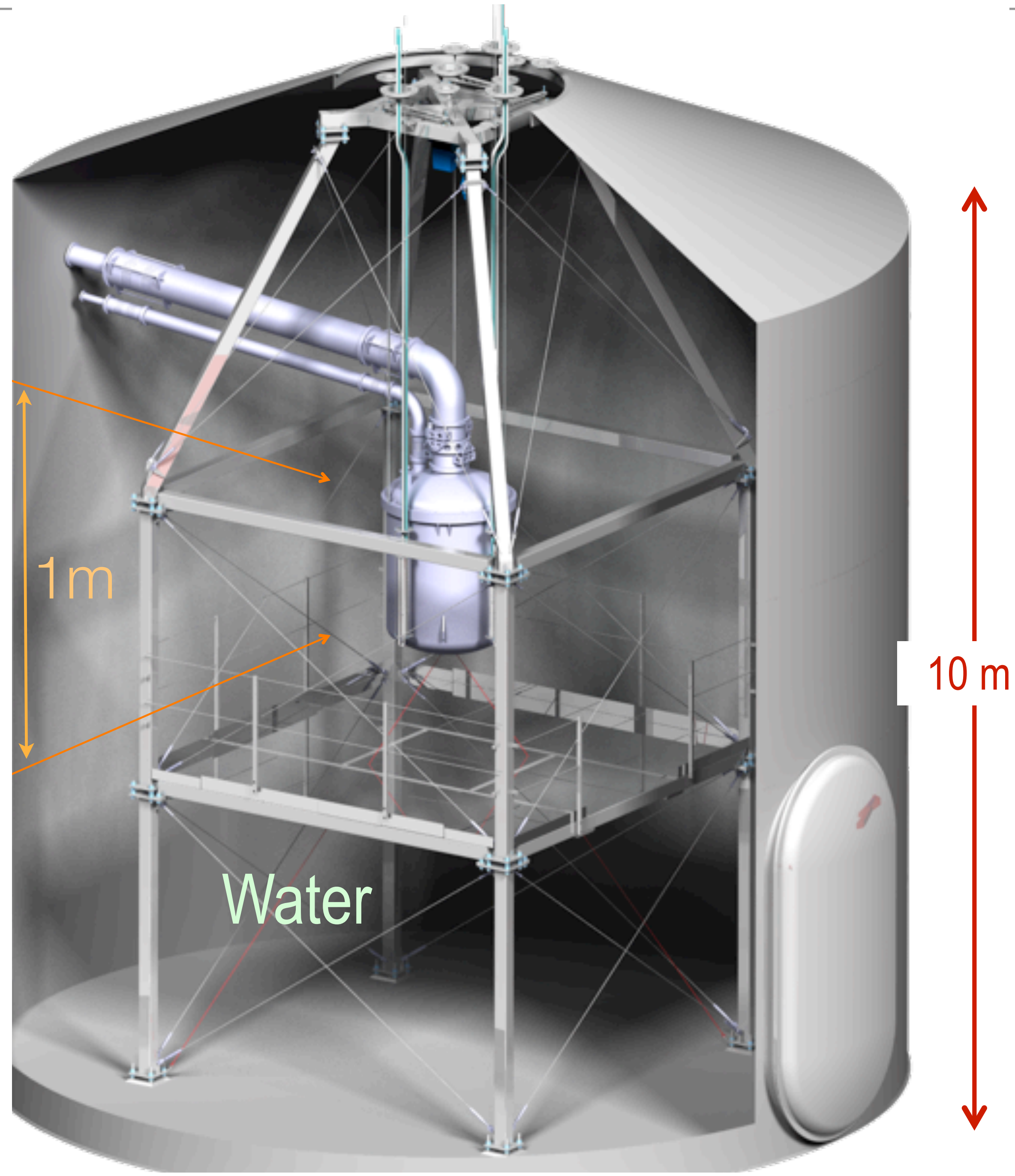




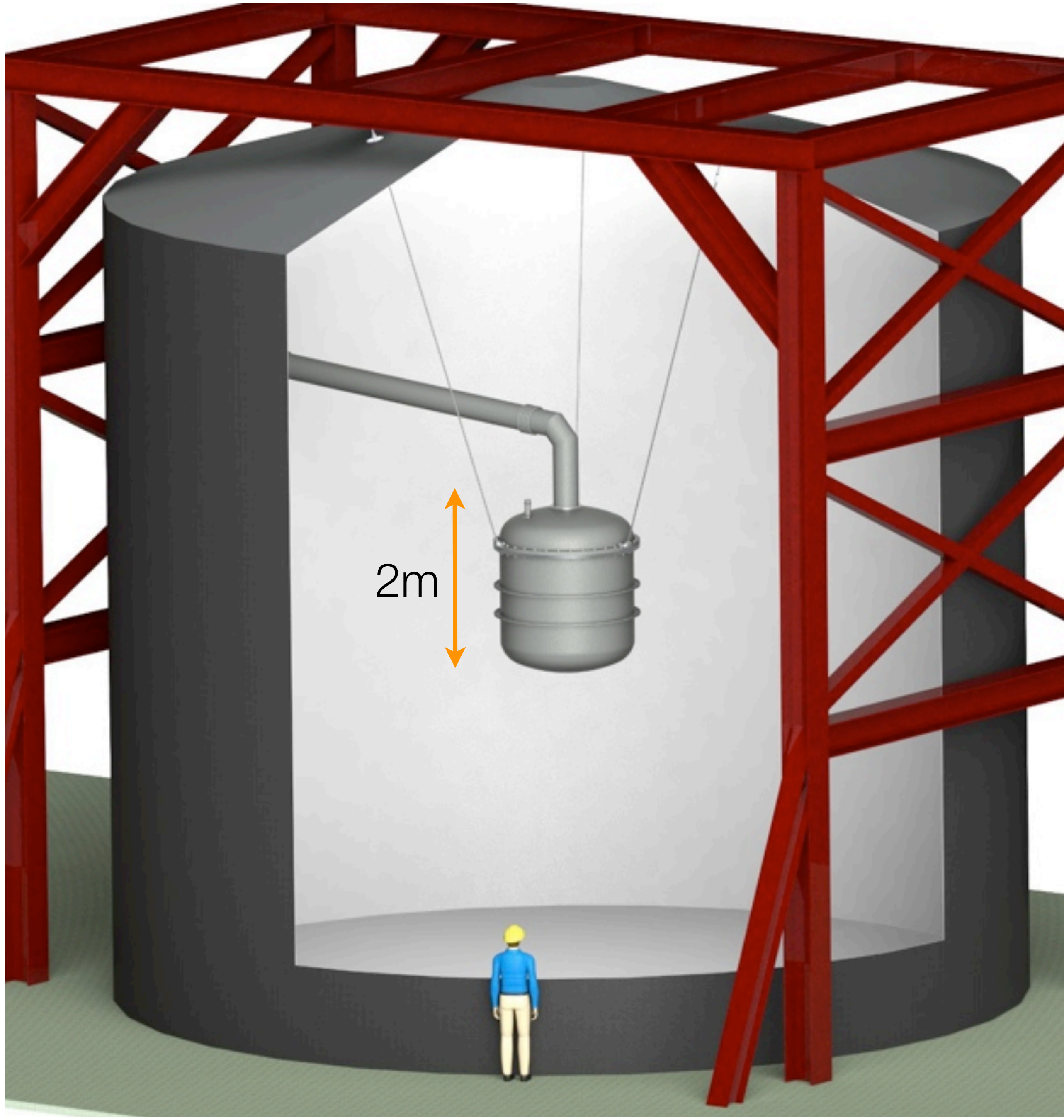
WIMP-nucleon cross section : 1.9 x 10^{-41} cm^2;
CDMS Si results, 140 kg d

observed: 224.6 live days, 34 kg,
1 background event expected

XENON1T and DARWIN at Gran Sasso



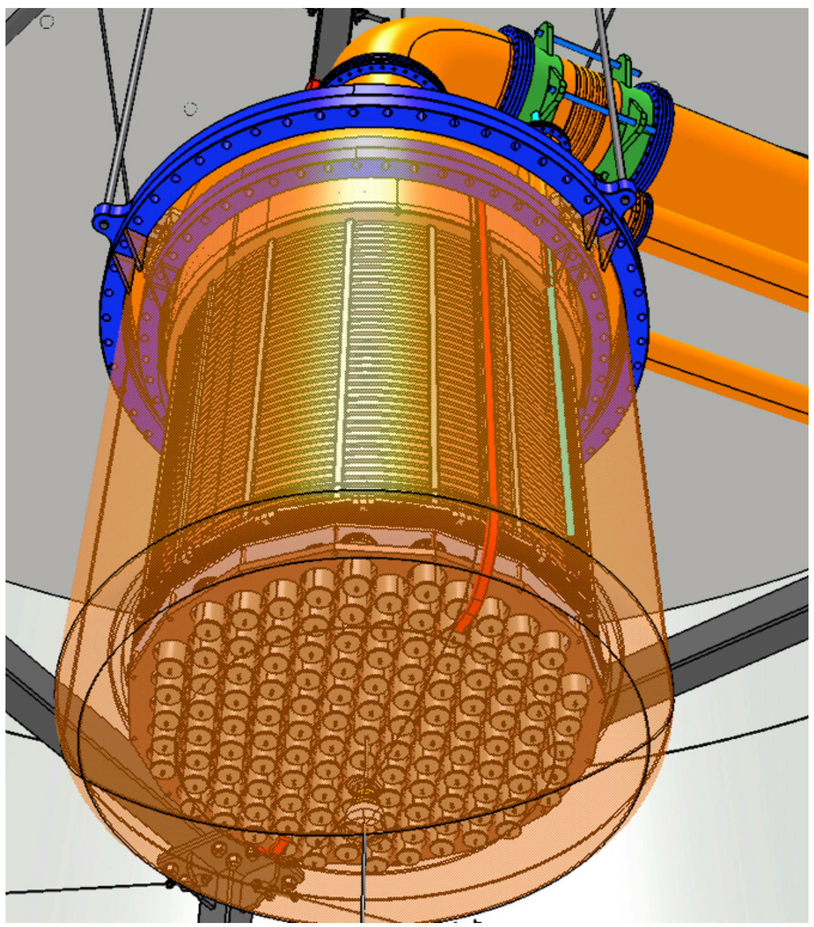
Construction starts now...



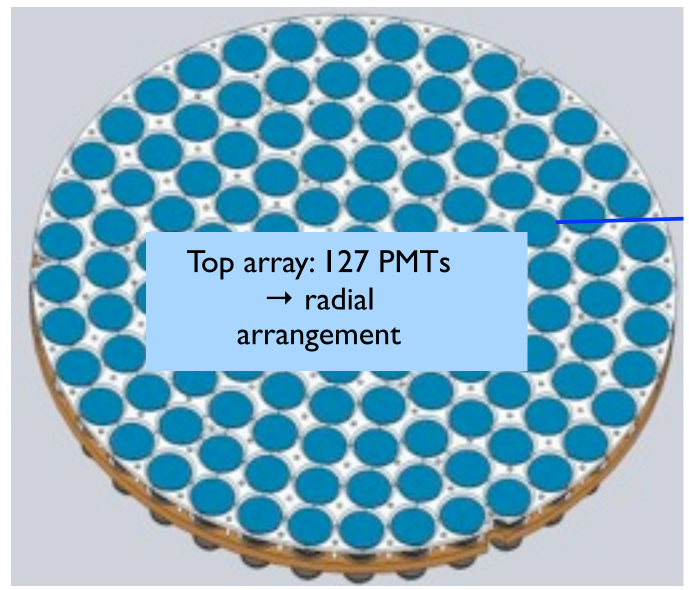
Construction to start in 2017
(Lab: the Modane extension is also under consideration)

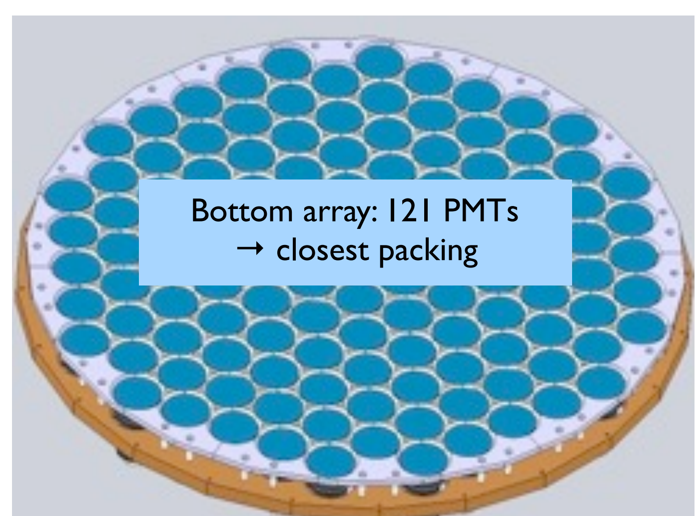
The XENON1T inner detector

The TPC

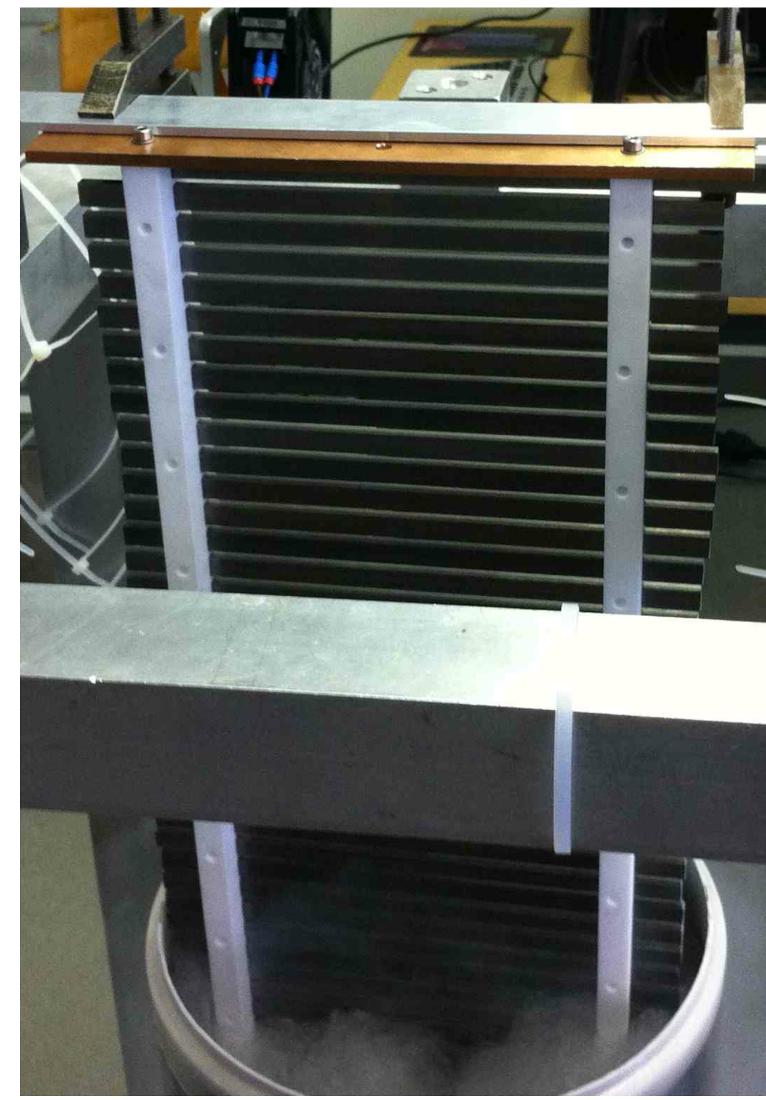


127 3" sensors top





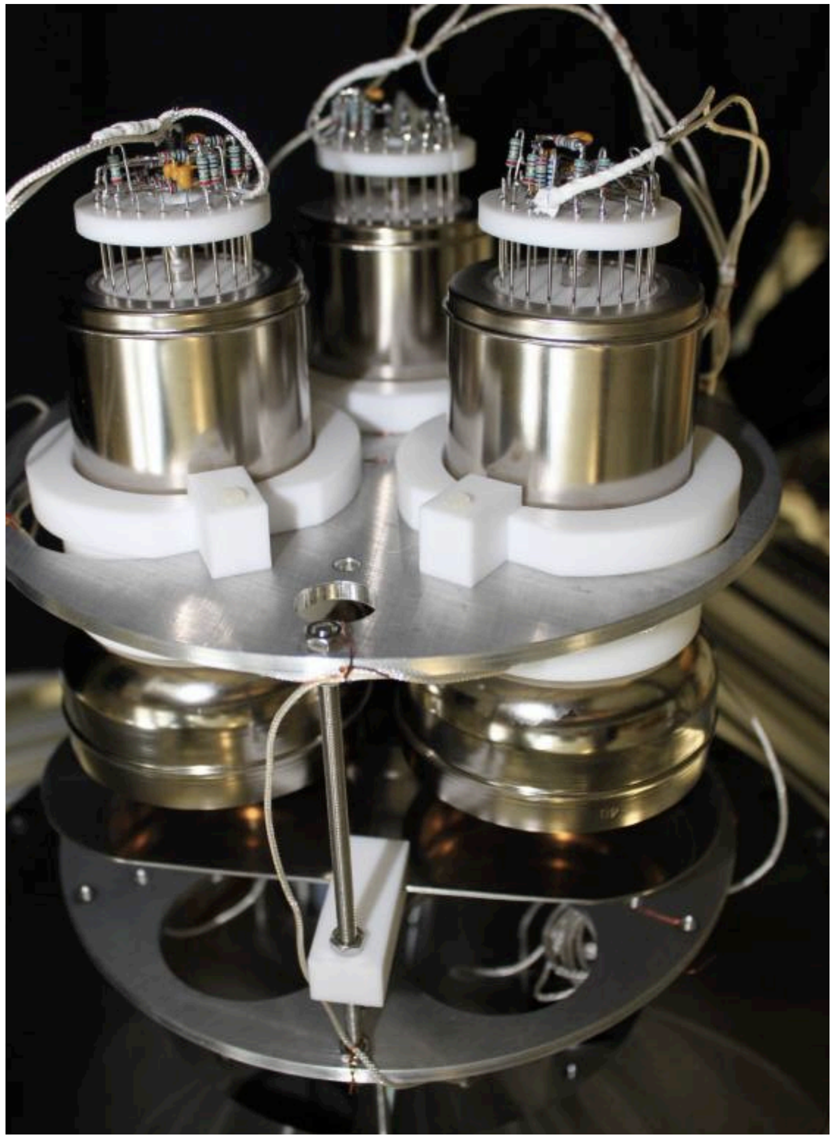
121 3" sensors bottom



First tests of TPC segment prototype at UZH

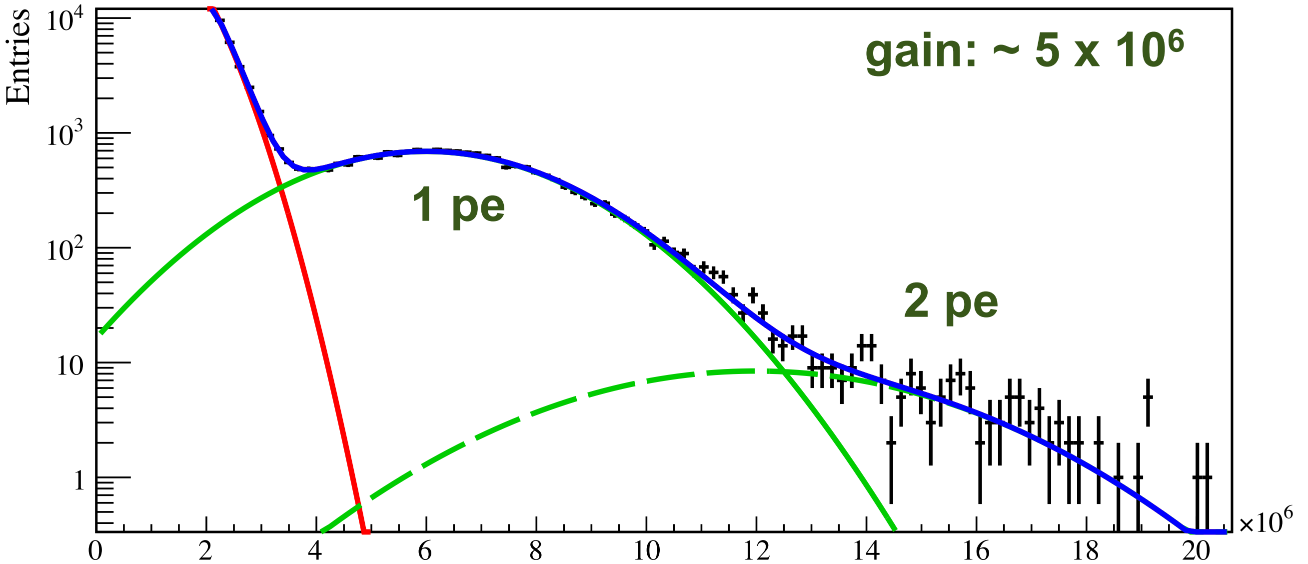
The XENON1T photosensors

Hamamatsu 3-inch R11410, QE > 30% at 175 nm
(here being tested in LXe at UZH, in MarmotXL)



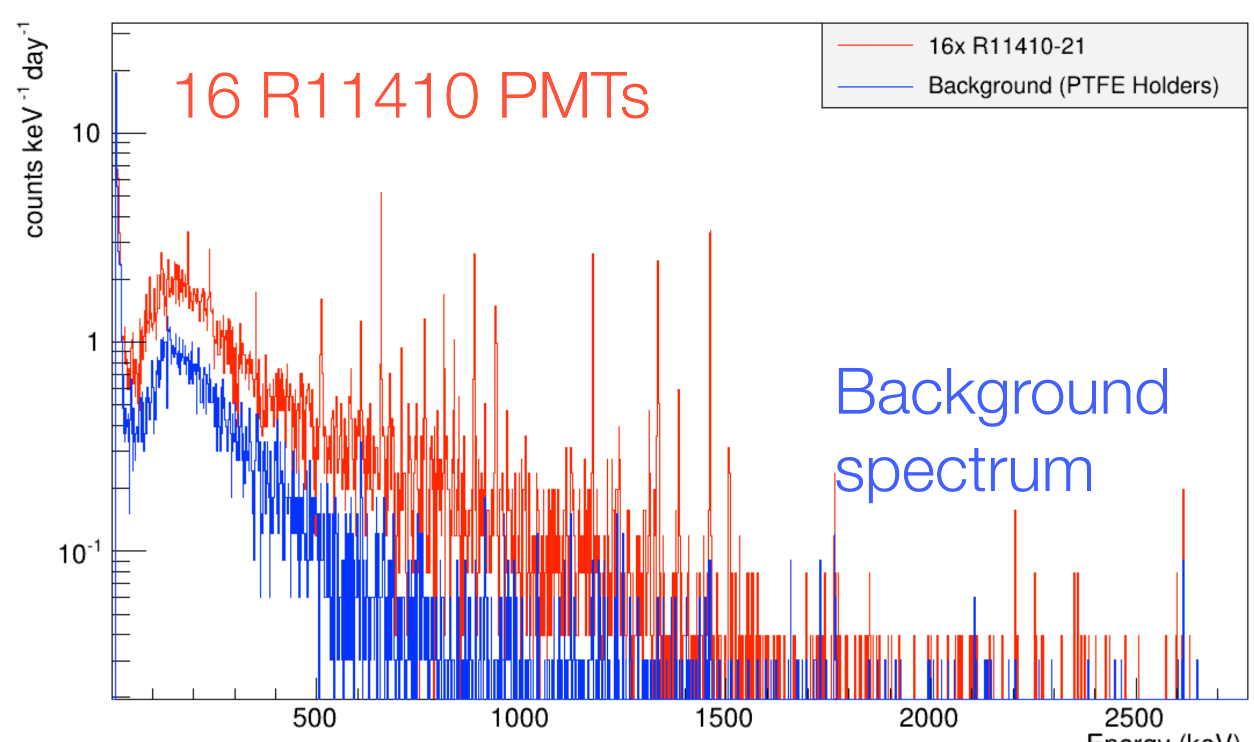
The MarmotXL detector

LB et al, JINST 8, P04026, 2013 (arXiv:1303.0226)



The XENON1T photosensors

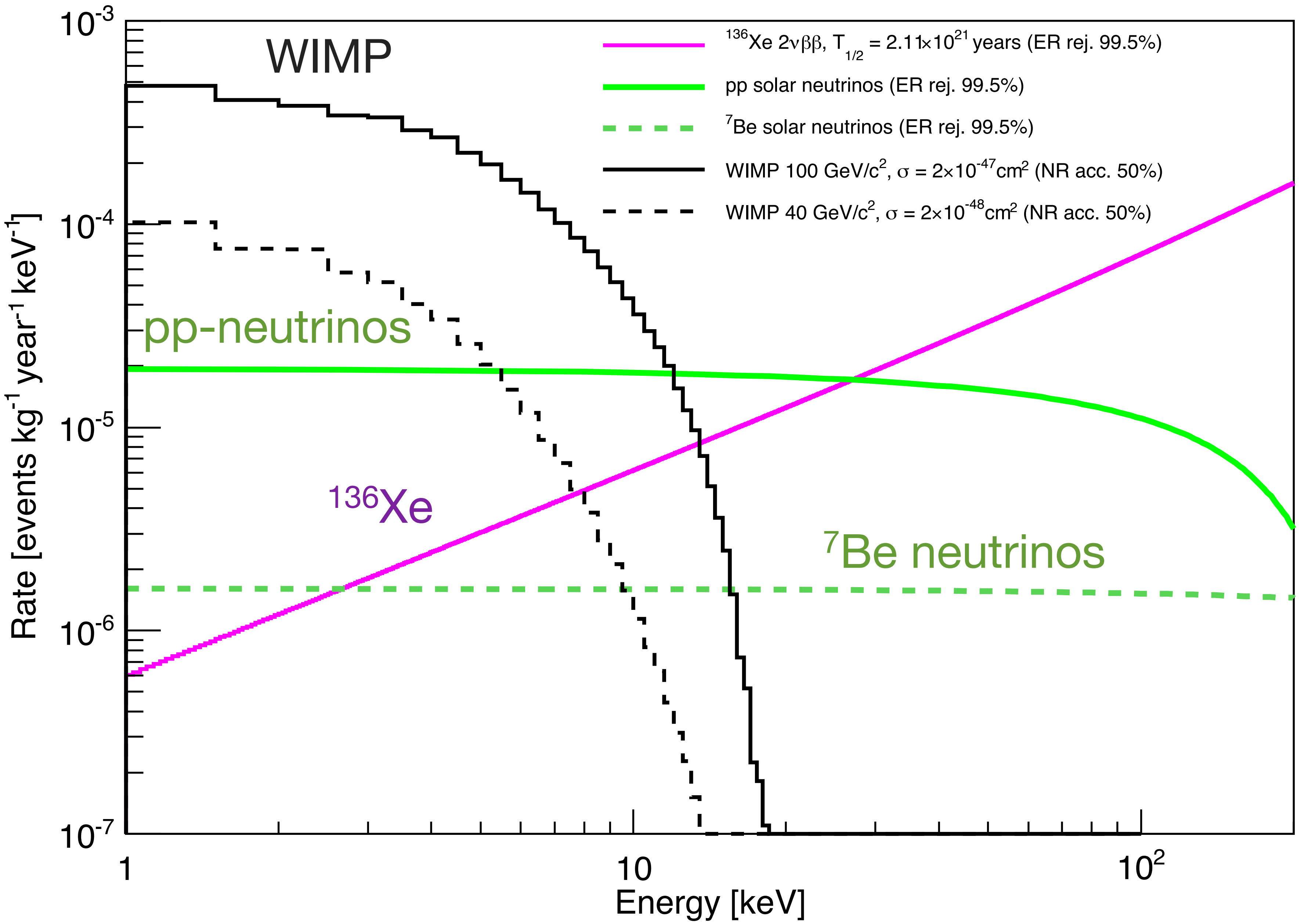
All ~300 R11410-21 PMTs to be screened at LNGS with Gator



Gator: LB et al, JINST 6 P08010, 2011

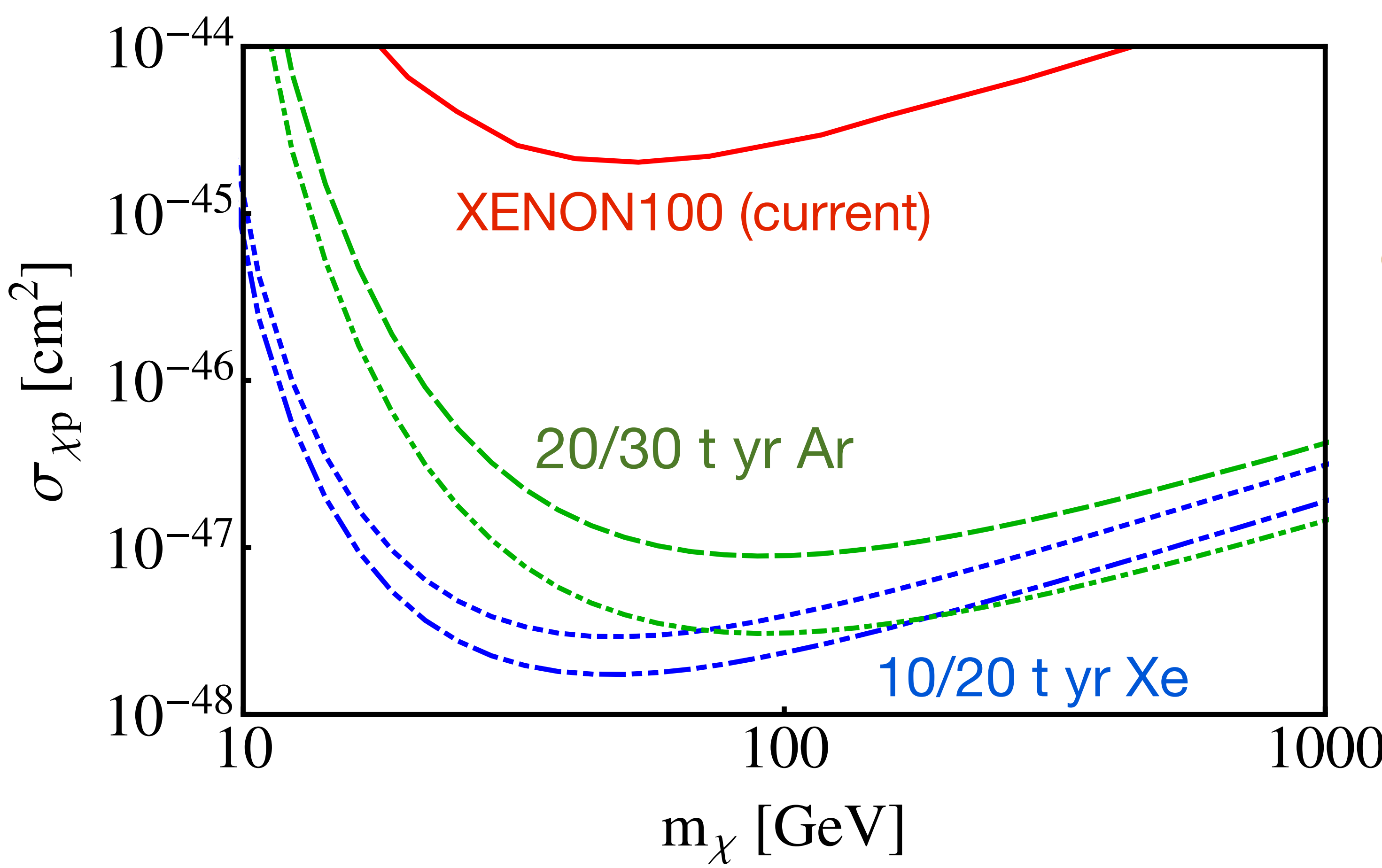
DARWIN: WIMPs and solar neutrinos

- pp solar neutrinos: limit the WIMP sensitivity down to ~ 10^{-48} cm^2
- Expected neutrino rate [2 - 30] keV: ~ 4000/year in 12 tons fiducial mass

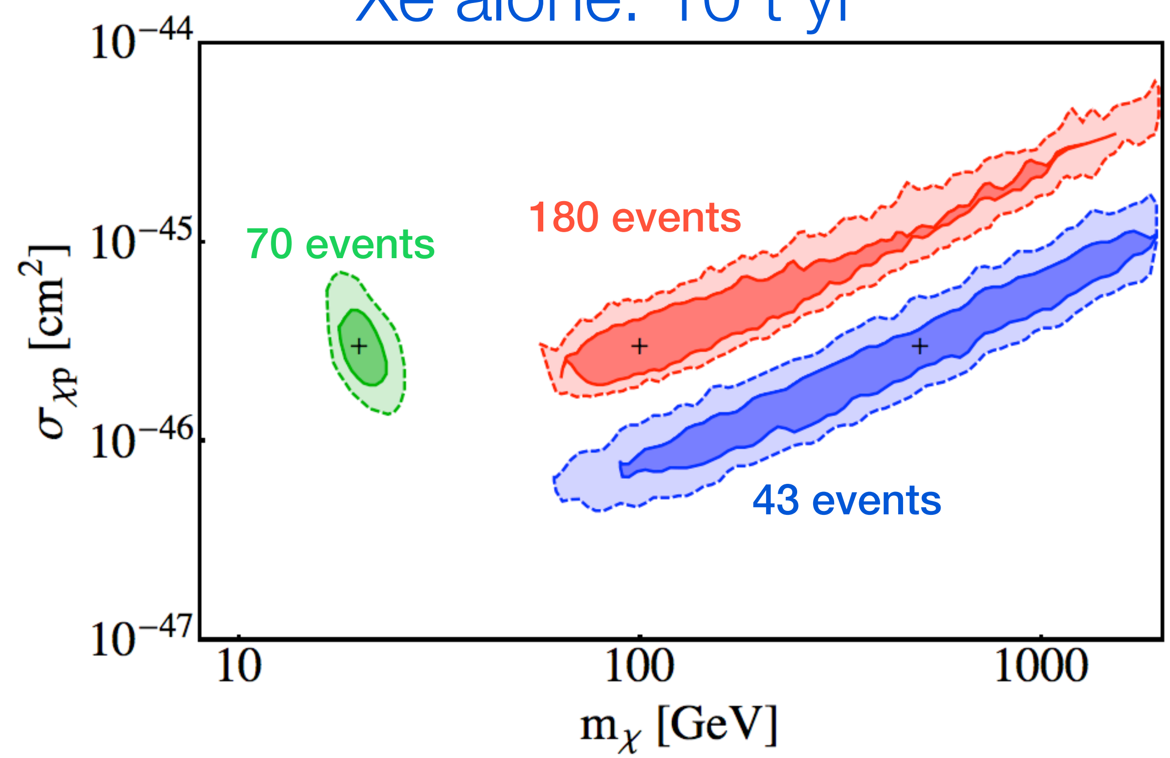


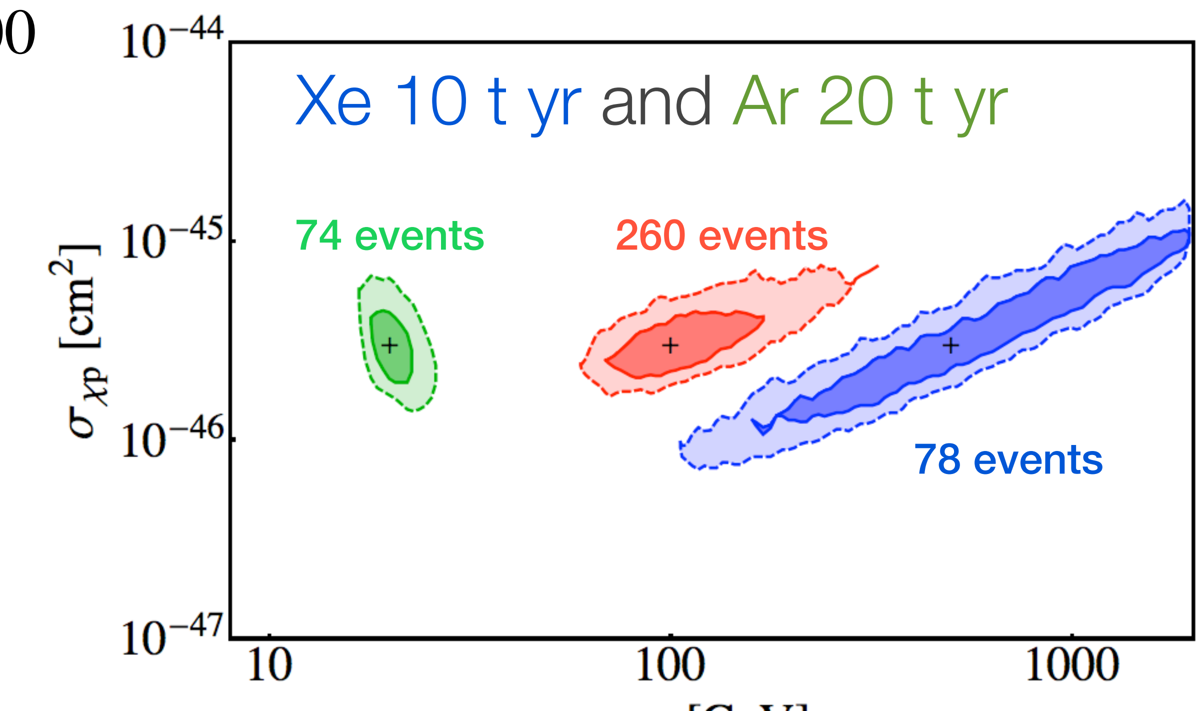
DARWIN: argon and xenon complementarity

arXiv:1306.3244



Xe alone: 10 t yr





$$v_{esc} = 544 \pm 40\,\mathrm{km/s}$$

$$v_0 = 220 \pm 20\,\mathrm{km/s}$$

$$\rho_\chi = 0.3 \pm 0.1\,\mathrm{GeV/cm^3}$$

DARWIN time schedule

2010 - 2013

First R&D phase, Aspera funded

June 2013: Aspera final report
end of 2013: technical report

2014 - 2016

Design and engineering studies

2014: LoI, CDR
2015: TDR
2016: proposals

2017 - 2019

Construction, commissioning

2017: major components at home institutions

2018: construction/integration at UL

2019: commissioning

2020 - 2025

physics runs

DARWIN costs (LXe part)

Item	Total costs [in 10^6 CHF]
Photosensors, 1000	7.0
Xenon, 30 t	22.5
Detector (TPC, grids, HV)	1.5
Cryostat	4.5
Cryostat support	0.5
Cherenkov shield	0.5
Water tank	0.4
Xenon storage	1.6
Infrastructure	1.4
Electronics, DAQ, cables	1.8
Calibration system	0.3
Slow control	0.3
Screening (HPGe, ICP-MS)	0.4
LXe purification (Rn, Kr)	1.5
Demonstrator vertical (drift, HV)	0.5
Demonstrator horizontal (grids)	0.5
Sum	**54.2**

The DARWIN Consortium

Universität Bern — **C. Amsler**, **M. Schumann**

ETH — Eidgenössische Technische Hochschule Zürich / Swiss Federal Institute of Technology Zurich — **A. Rubbia**

Universität Zürich UZH — **L. Baudis**, **B. Kilminster**

Westfälische Wilhelms-Universität Münster

NIKHEF

Subatech

UCLA

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

Purdue University

INFN

JGU

Oskar Klein centre

Max-Planck-Institut für Kernphysik

LNGS

Alma Mater Studiorum — Università di Bologna — A.D. 1088

Stockholm University

ASU School of Earth & Space Exploration — Arizona State University

Technische Universität Dresden

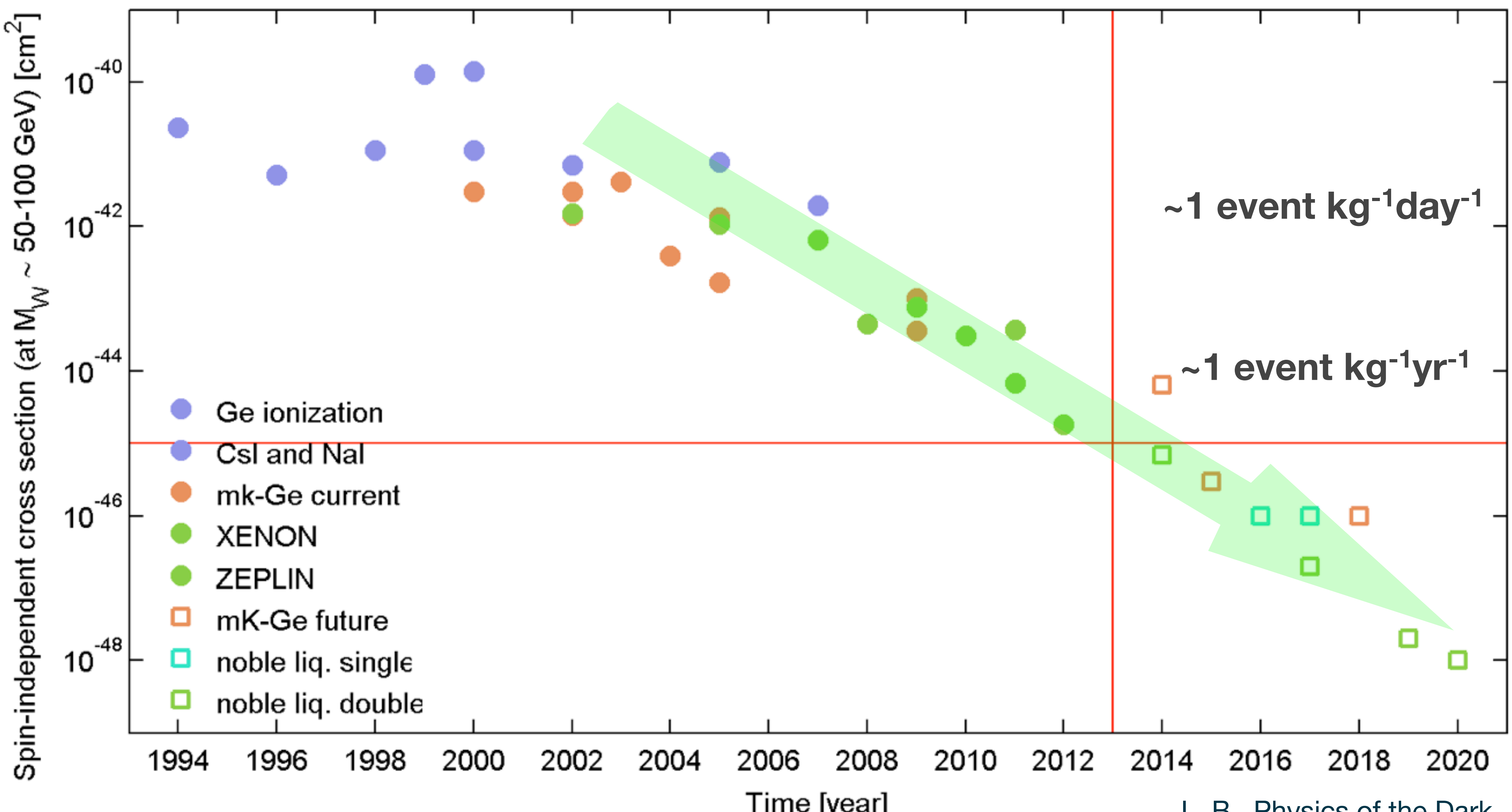
Imperial College London

Columbia University — In lumine tuo videbimus lumen

29 groups from 9 countries

Direct detection: sensitivity versus time

Factor ~ 10 every two years!

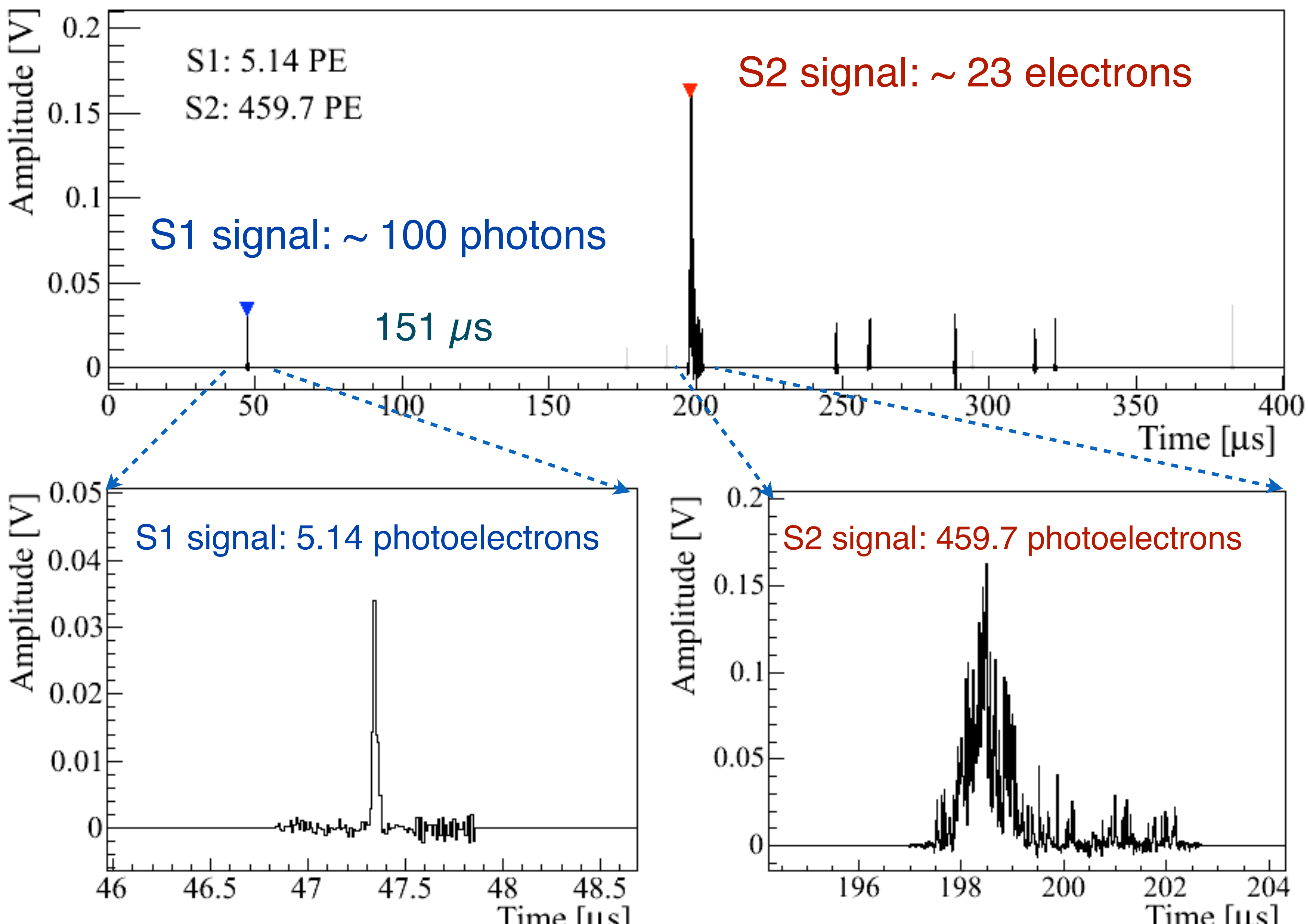


L. B., Physics of the Dark Universe 1, 94 (2012)

Finis

Events in XENON...

The maximum electron drift time at 0.53 kV/cm is 176 μs



Run10 SI Results

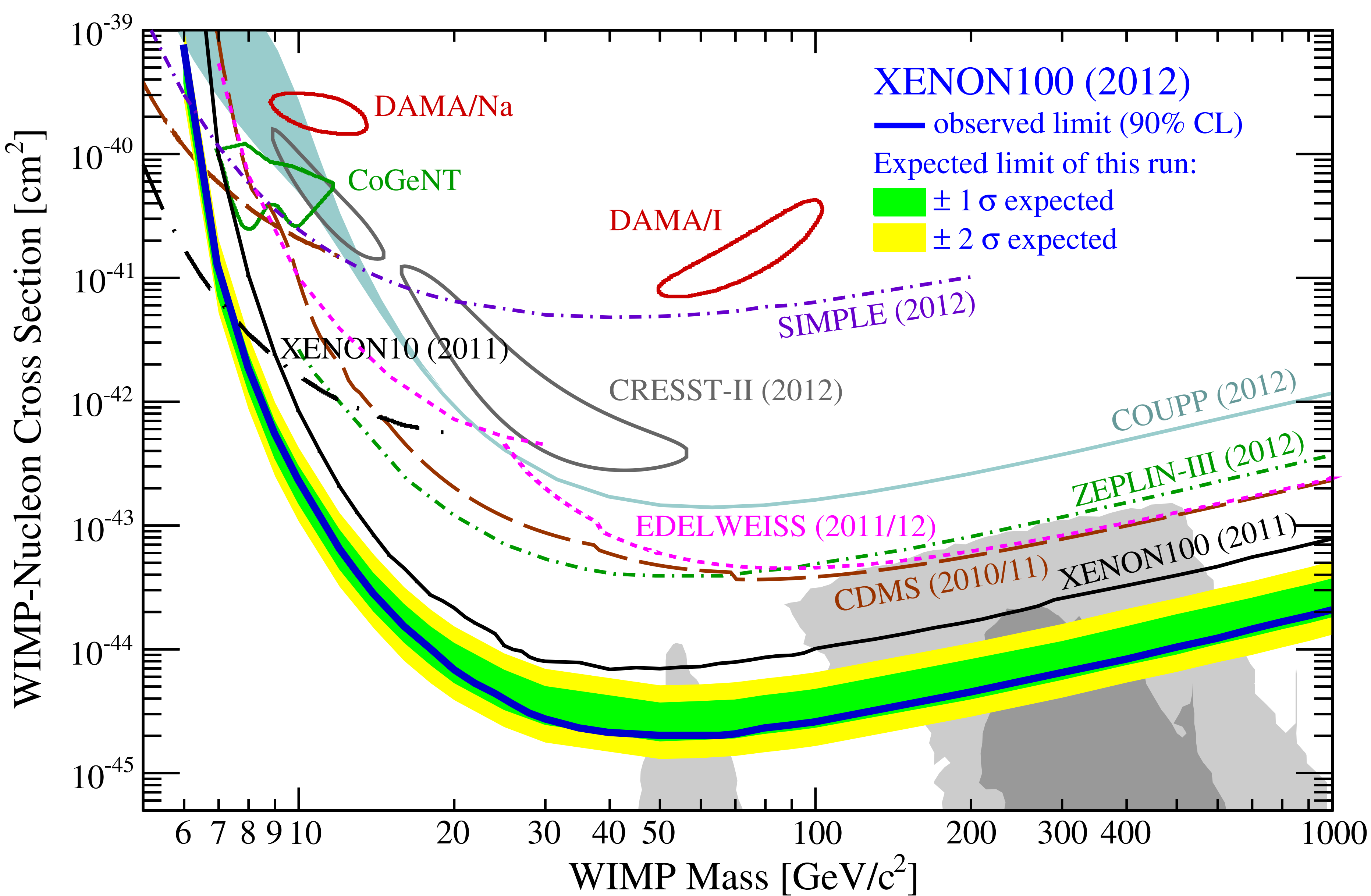
PRL 109, 181301 (2012) PHYSICAL REVIEW LETTERS week ending 2 NOVEMBER 2012

Dark Matter Results from 225 Live Days of XENON100 Data

E. Aprile,[1] M. Alfonsi,[2] K. Arisaka,[3] F. Arneodo,[4] C. Balan,[5] L. Baudis,[6] B. Bauermeister,[7] A. Behrens,[6] P. Beltrame,[3] K. Bokeloh,[8] E. Brown,[8] G. Bruno,[4] R. Budnik,[1] J. M. R. Cardoso,[5] W.-T. Chen,[9] B. Choi,[1] D. Cline,[3] A. P. Colijn,[2] H. Contreras,[1] J. P. Cussonneau,[9] M. P. Decowski,[2] E. Duchovni,[10] S. Fattori,[7] A. D. Ferella,[6] W. Fulgione,[11] F. Gao,[12] M. Garbini,[13] C. Ghag,[3] K.-L. Giboni,[1] L. W. Goetzke,[1] C. Grignon,[7] E. Gross,[10] W. Hampel,[14] F. Kaether,[14] A. Kish,[6] J. Lamblin,[9] H. Landsman,[10] R. F. Lang,[15,1] M. Le Calloch,[9] C. Levy,[8] K. E. Lim,[1] Q. Lin,[12] S. Lindemann,[14] M. Lindner,[14] J. A. M. Lopes,[5] K. Lung,[3] T. Marrodán Undagoitia,[6] F. V. Massoli,[13] A. J. Melgarejo Fernandez,[1,*] Y. Meng,[3] A. Molinario,[11] E. Nativ,[10] K. Ni,[12] U. Oberlack,[7,16] S. E. A. Orrigo,[5] E. Pantic,[3] R. Persiani,[13] G. Plante,[1] N. Priel,[10] A. Rizzo,[1] S. Rosendahl,[8] J. M. F. dos Santos,[5] G. Sartorelli,[13] J. Schreiner,[14] M. Schumann,[6,†] L. Scotto Lavina,[9] P. R. Scovell,[3] M. Selvi,[13] P. Shagin,[16] H. Simgen,[14] A. Teymourian,[3] D. Thers,[9] O. Vitells,[10] H. Wang,[3] M. Weber,[14] and C. Weinheimer[8]

(XENON100 Collaboration)

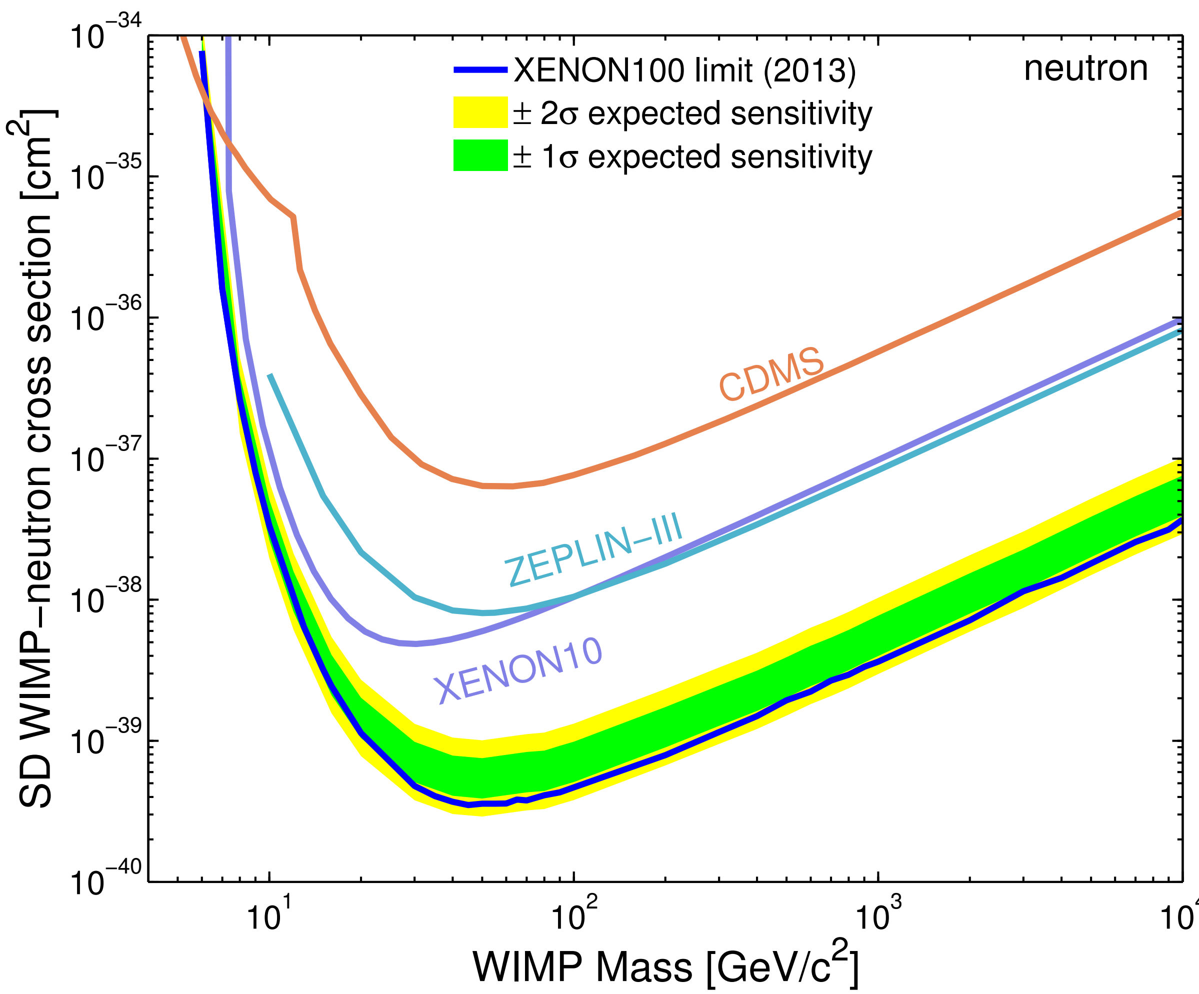
- No evidence for WIMPs
- Upper limit on SI WIMP-nucleon cross section is $2x10^{-45}$ cm^2 at M_W = 55 GeV

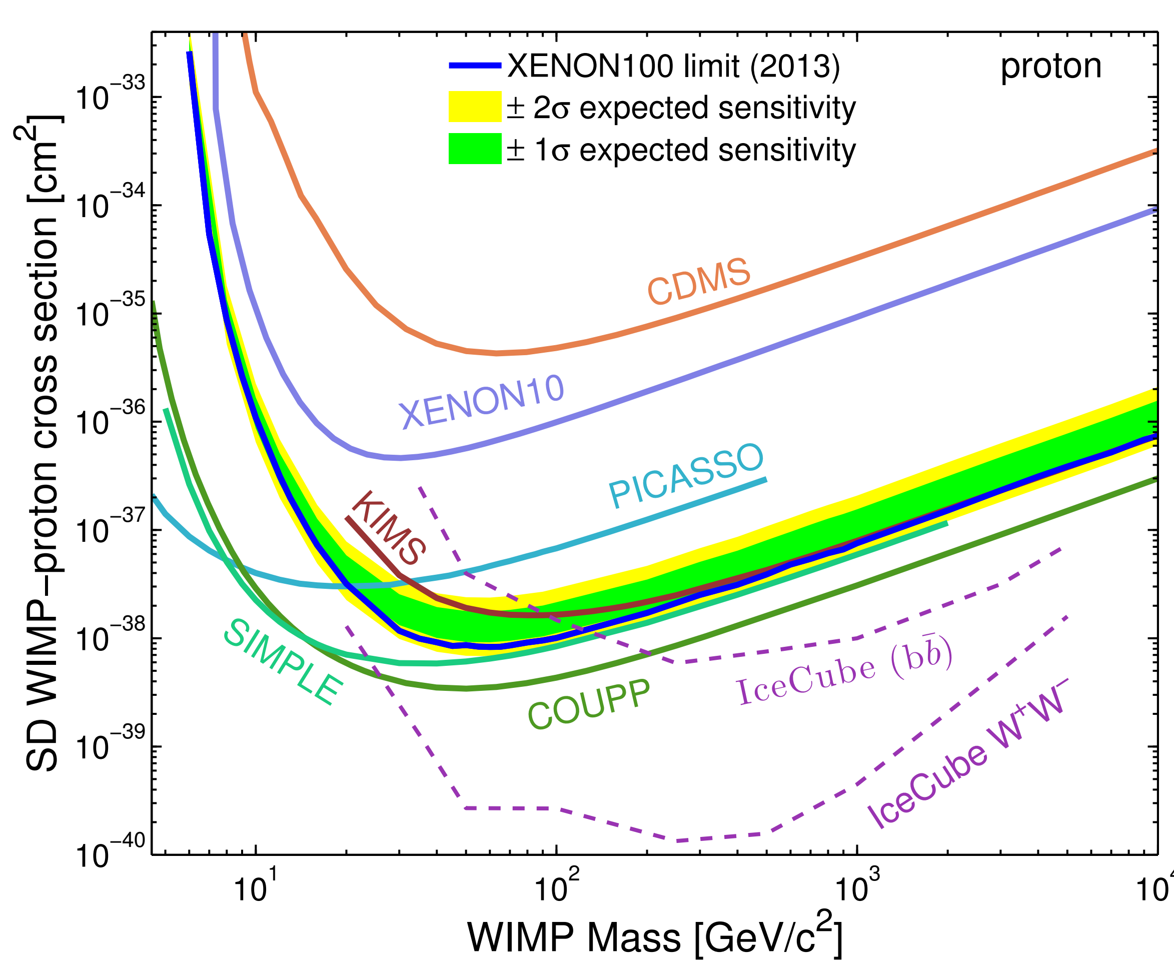


Run10 spin dependent results

- ^{129}Xe (spin-1/2) and ^{131}Xe (spin-3/2), two isotopes with $J \neq 0$ and abundance of 26.2% and 21.8% in XENON100

$$\frac{d\sigma_{\rm SD}(q)}{dq^2} = \frac{8G_F^2}{(2J+1)v^2} S_A(q) \qquad S_A(0) = \frac{(2J+1)(J+1)}{\pi J}[a_p\langle S_p\rangle + a_n\langle S_n\rangle]^2$$





arXiv:1301.6620v2 [astro-ph.CO]