Dark Matter Detection with XENON100

Accomplishments, Challenges and the Future

http://xenon.astro.columbia.edu

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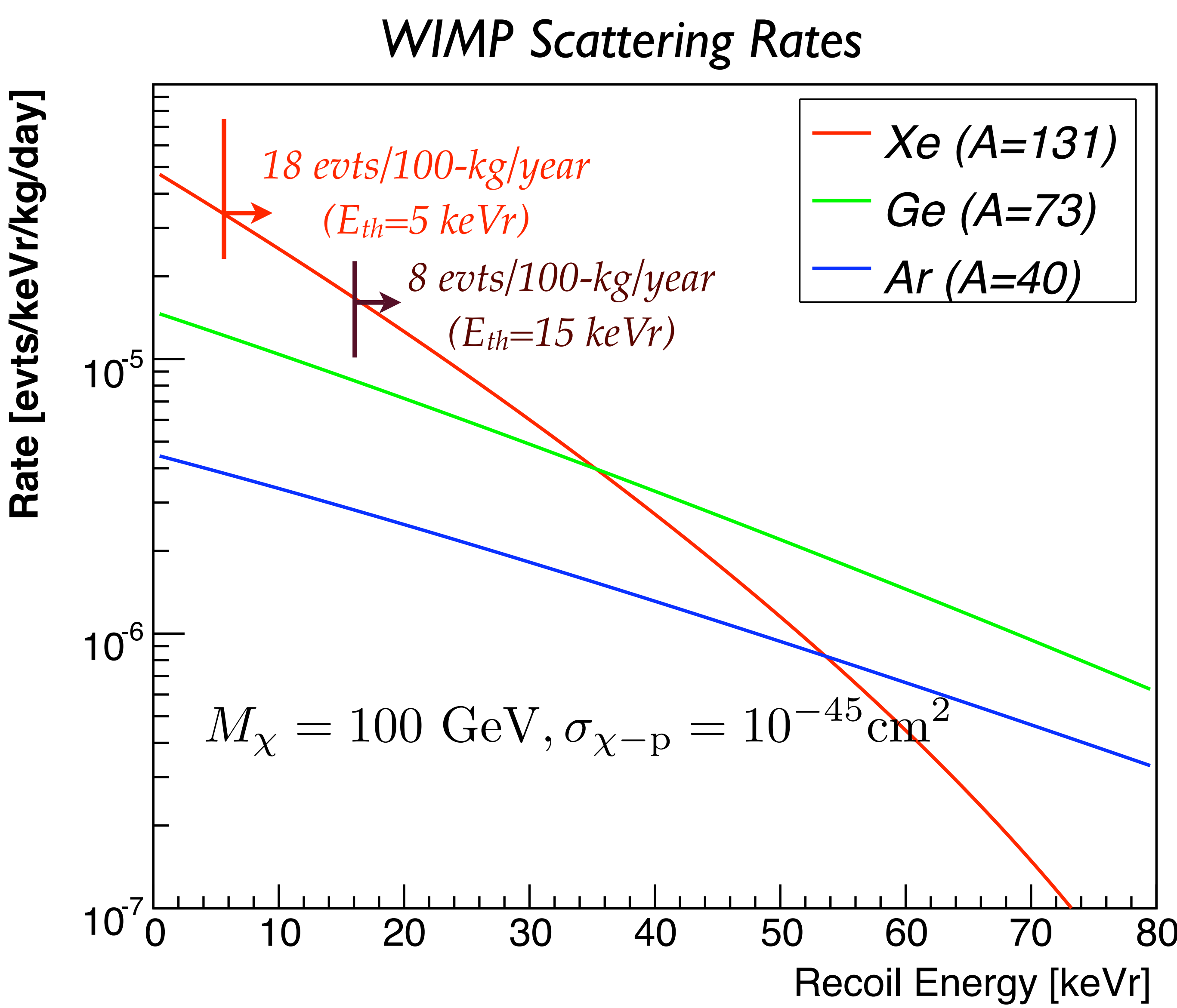
TeV Particle Astrophysics
IHEP, Beijing, Sep.24-28, 2008

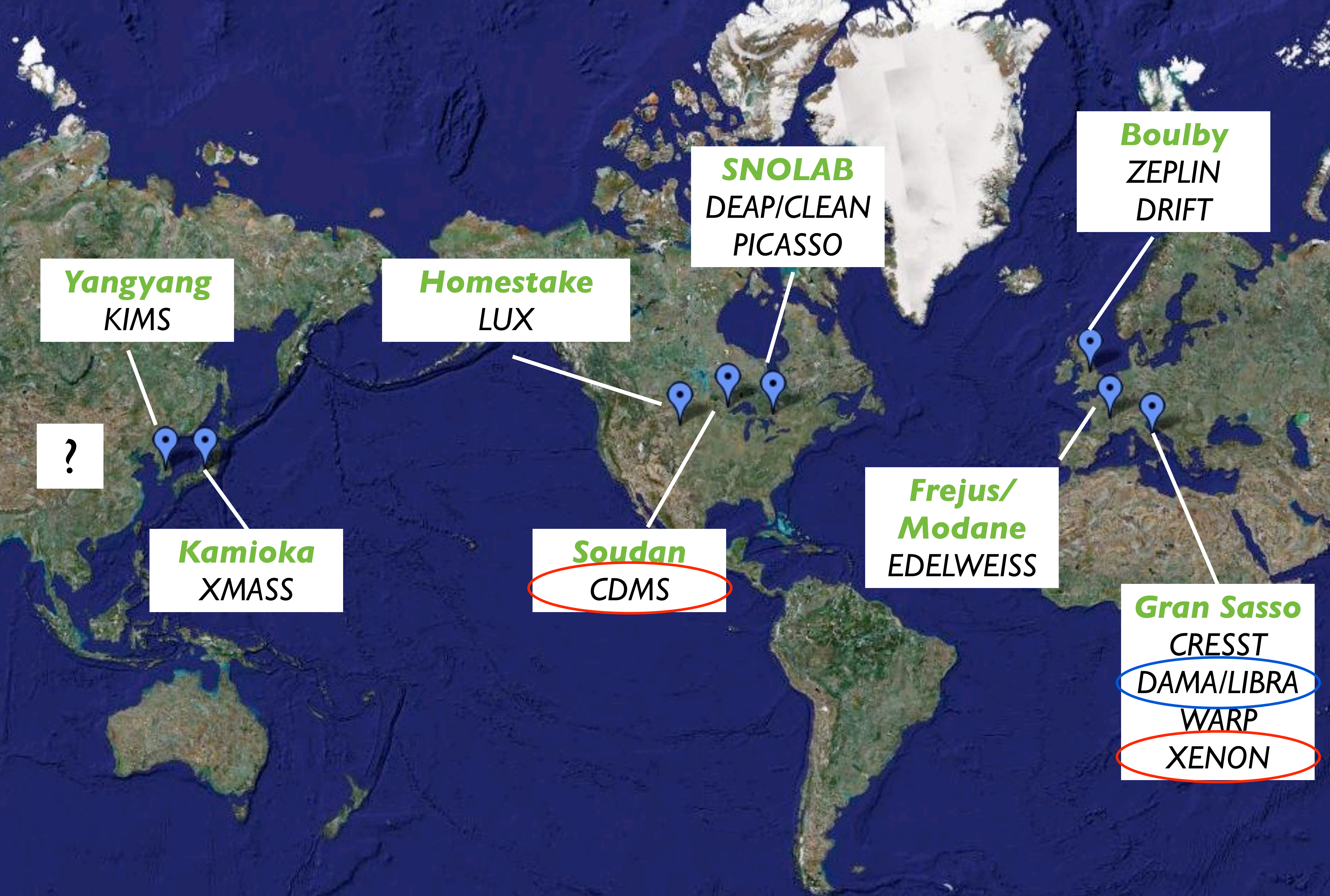
The Challenges for Direct DM Detection

$$R \sim \frac{M_{det}}{M_\chi} \rho \sigma \langle v \rangle$$



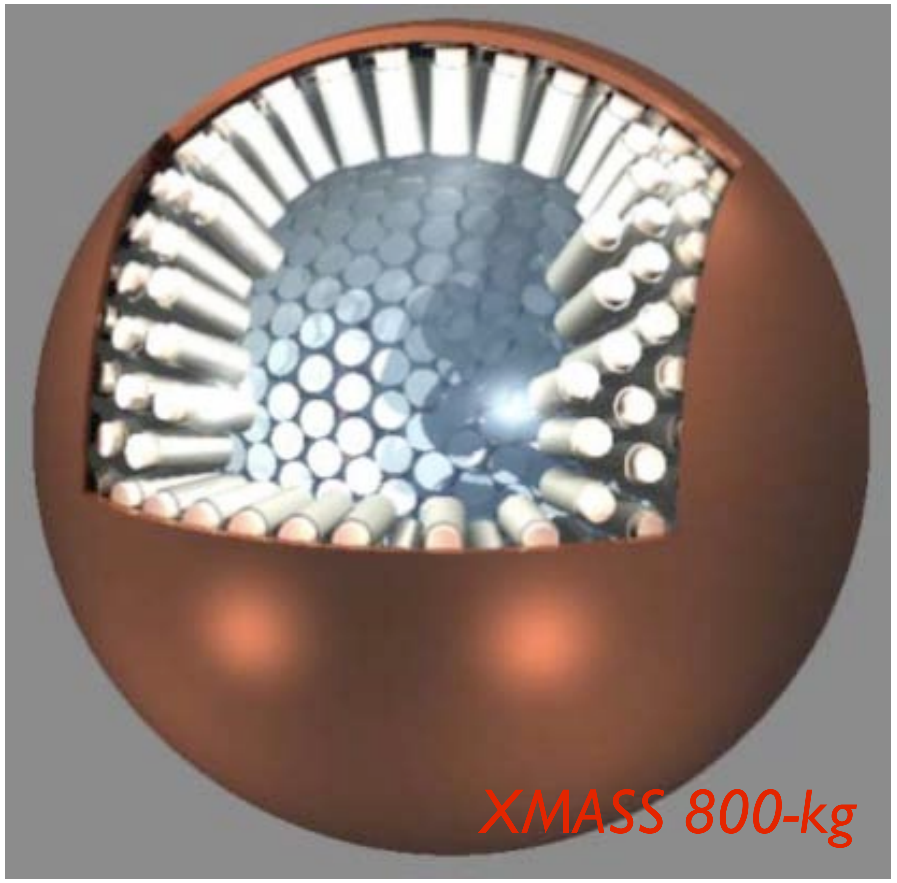
- *large mass (ton scale)*
- *low energy threshold (a few keV)*
- *background suppression*
  - *deep underground*
  - *passive shield*
  - *low intrinsic radioactivity*
  - *gamma background discrimination*

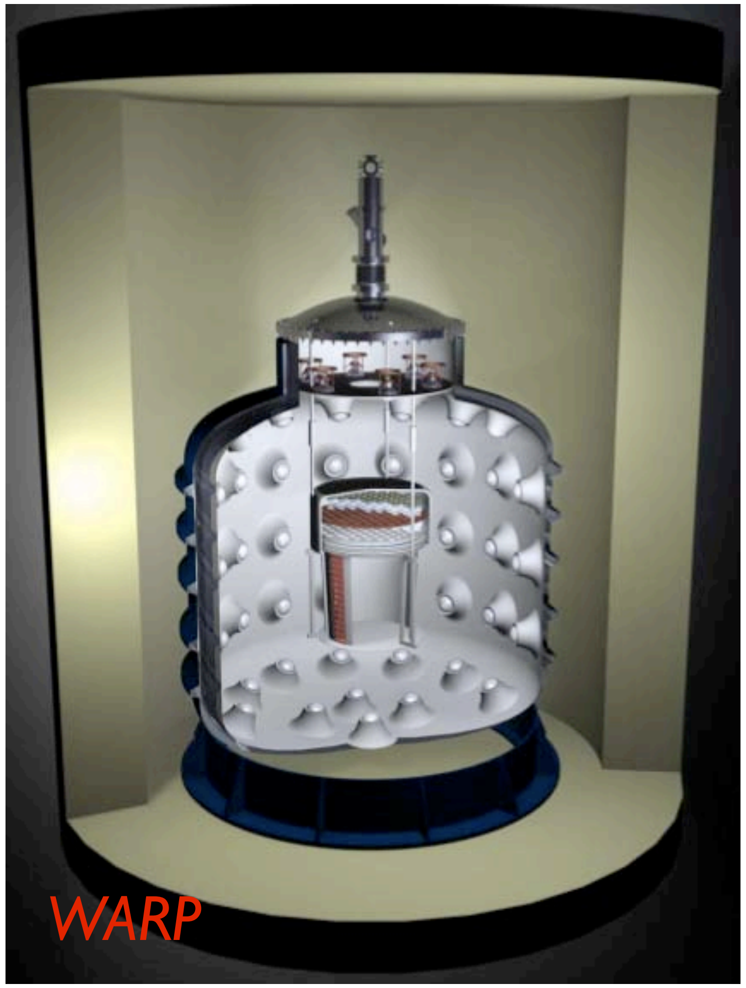
World Wide Dark Matter Searches



The Noble Liquid Revolution

- *Noble liquids (LAr, LXe) are relatively inexpensive, easy to scale up*
- *Self-shielding reduce external background*
- *Excellent gamma background rejection (pulse-shape, or ionization/scintillation)*

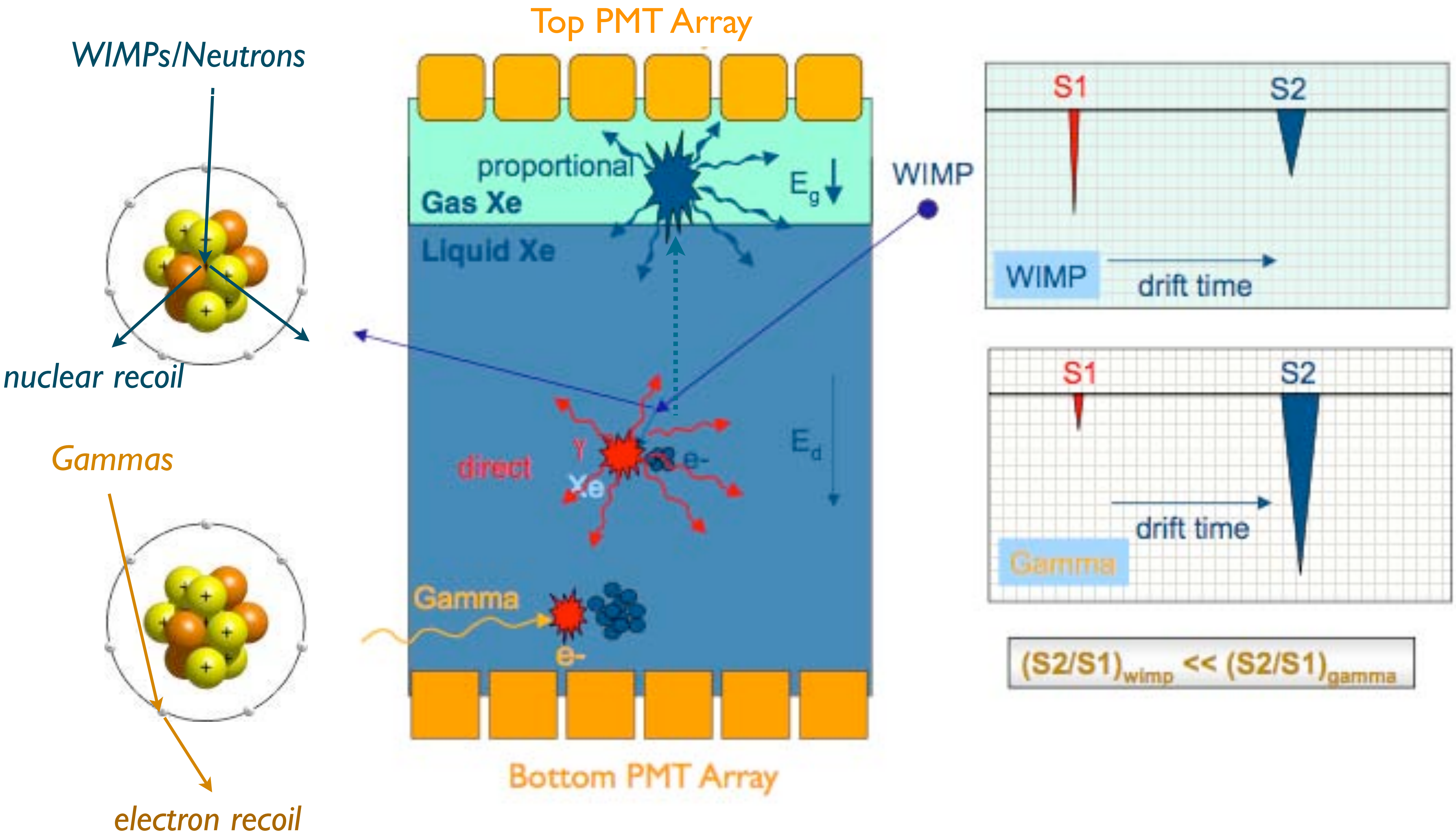




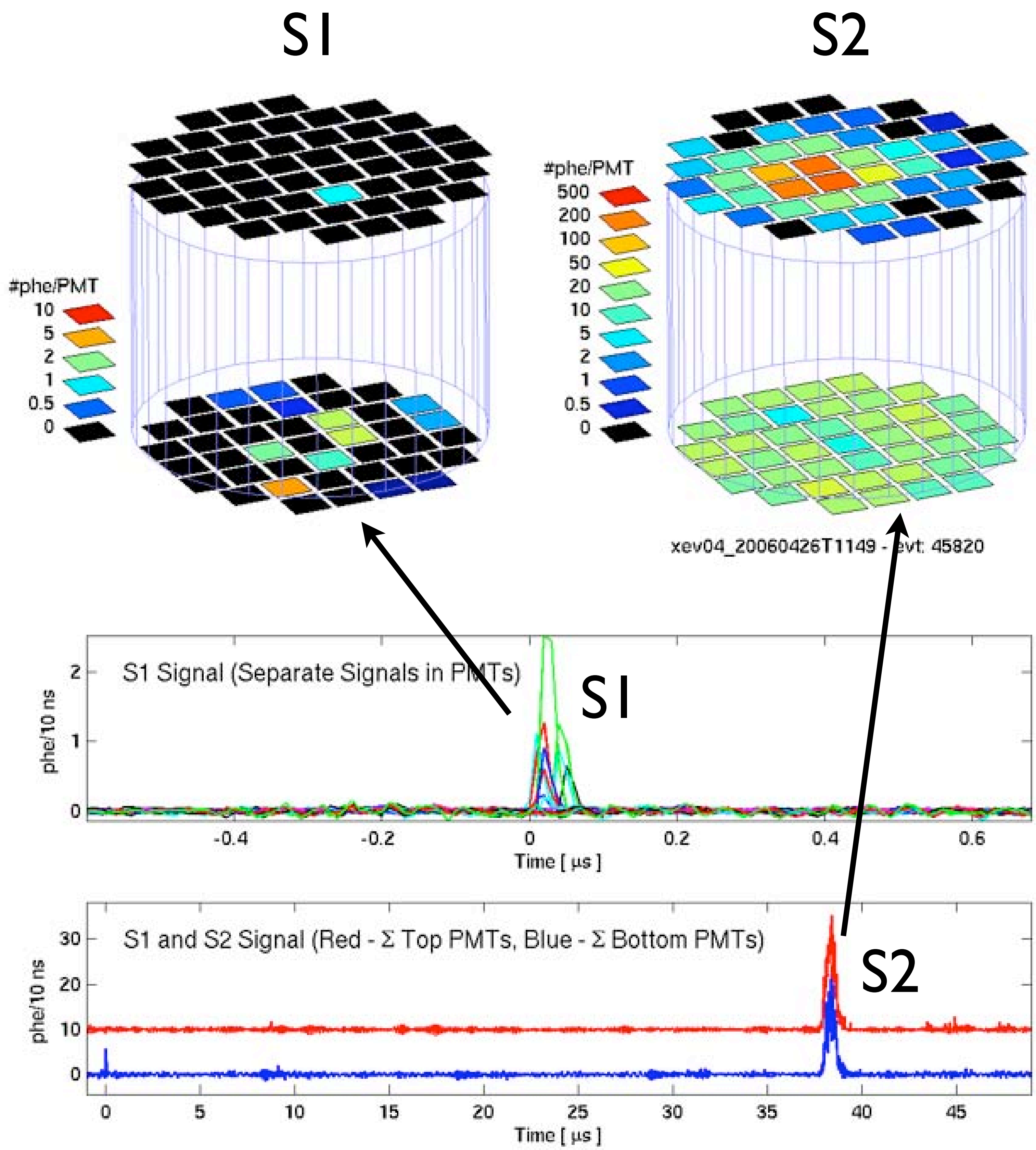
Single Phase
(XMASS, CLEAN/DEAP)

Two Phase
(**XENON**,ZEPLIN II/III,WARP,ArDM,etc.)

Two-phase Xenon Detectors for Dark Matter Detection



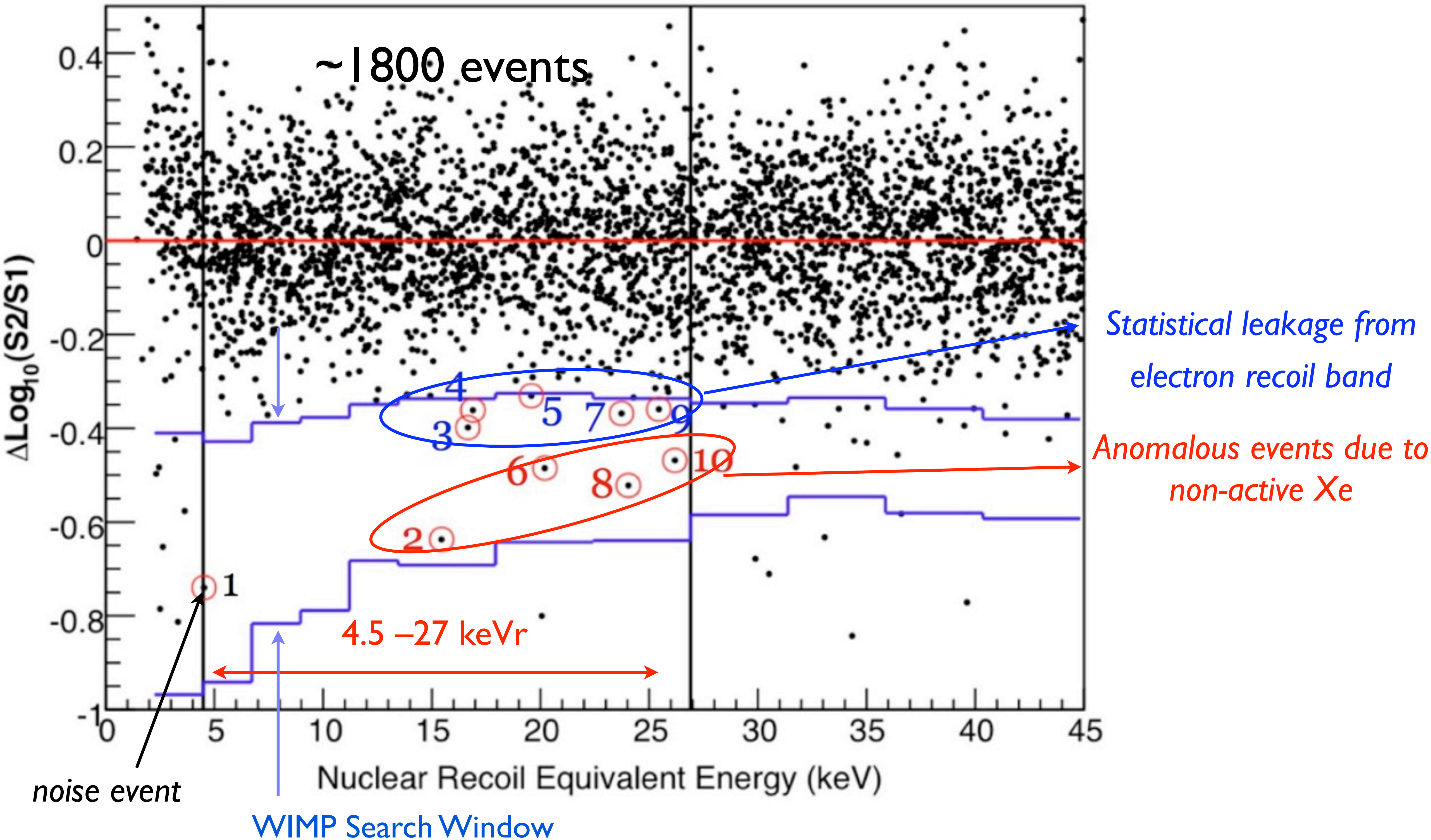
Signals from XENON10



XENON10 WIMP Search Data

136 kg-days Exposure= 58.6 live days x 5.4 kg x 0.86 (ε) x 0.50 (50% NR)

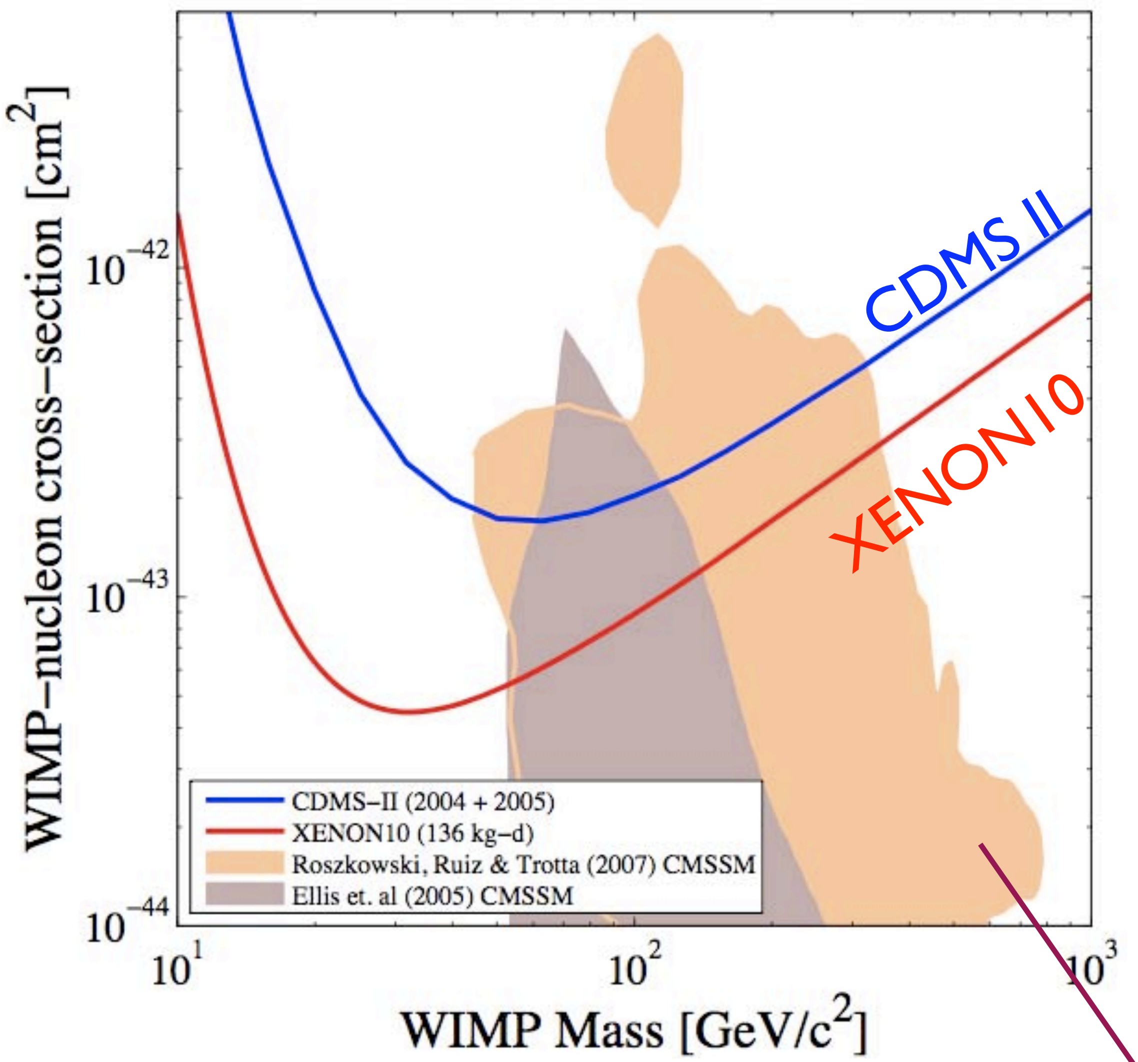
(data collected between Oct.2006 and Feb.2007)



XENON10 WIMP-Nucleon Cross-Section Upper Limits

Spin-independent

Phys. Rev. Lett. ***100****, 021303 (2008)*



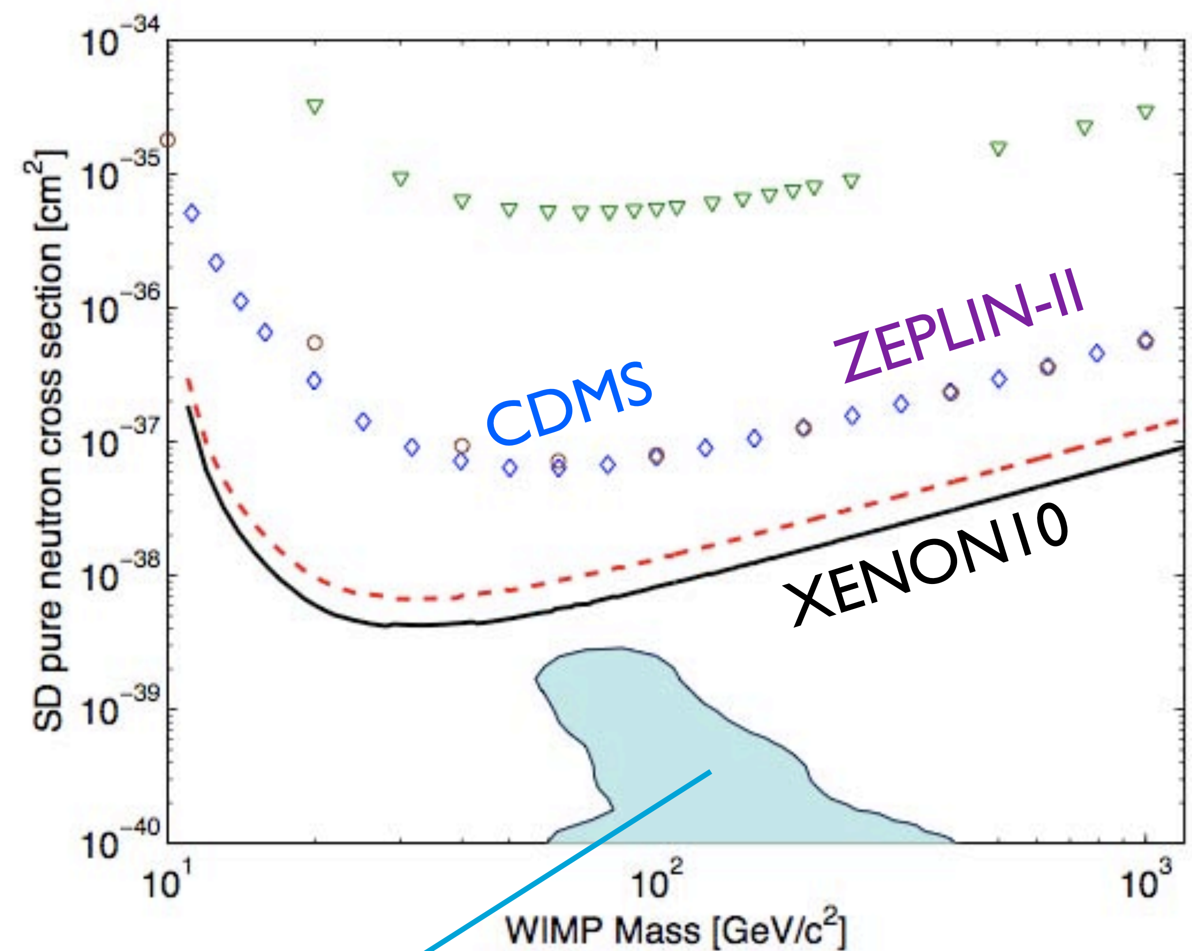
(NO BKG SUBTRACTION)

8.8 x 10^{-44} cm^2 at 100 GeV

4.5 x 10^{-44} cm^2 at 30 GeV

Spin-dependent, pure neutron coupling

Phys. Rev. Lett. ***101****, 091301 (2008)*



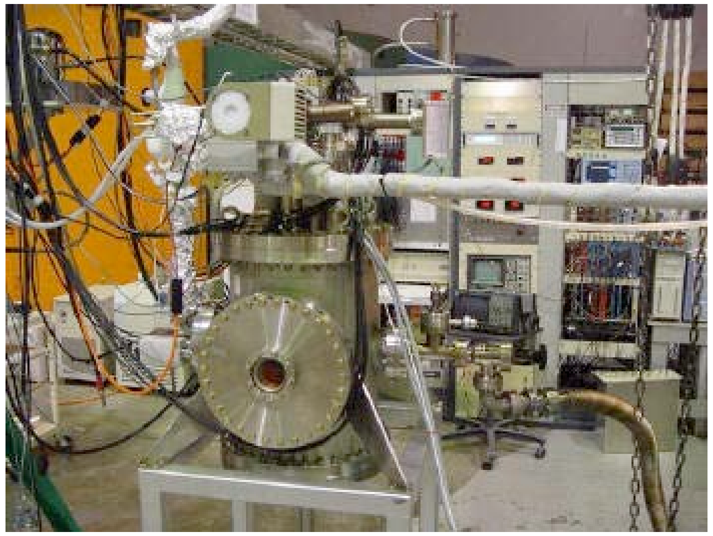
(NO BKG SUBTRACTION)

6 x 10^{-39} cm^2 at 30 GeV

Constrained Minimal Supersymmetric Model

the phased XENON dark matter search program

the past
(2006 - 2007)

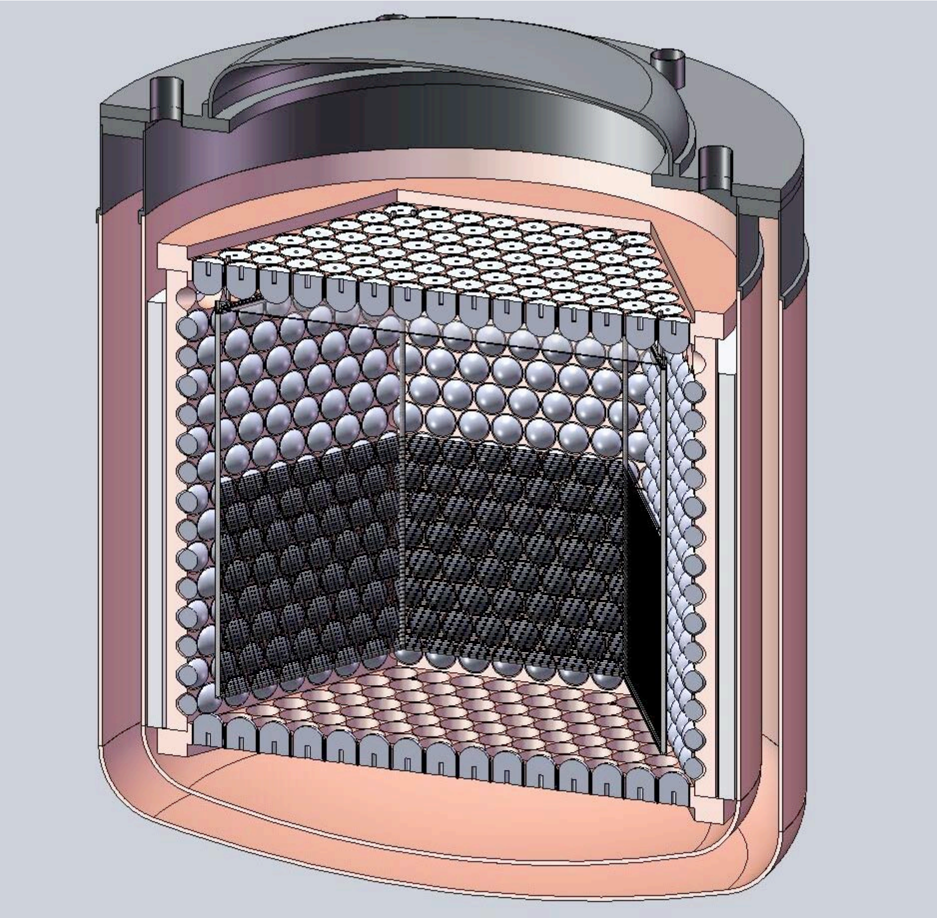


XENON10

the current
(2007-2009)

XENON100

the future
(2009-2013)



XENON1T

The XENON100 Collaboration

LNGS Collaboration Meeting, July 15,2008

Columbia University

Elena Aprile(Spokesperson), Bin Choi, Karl-Ludwig Giboni, Kyungeun Elizabeth Lim, Antonio Jesus Melgarejo, Kaixuan Ni, Guillaume Plante, Taehyun Yoon

Rice University

Uwe Oberlack, Yuan Mei, Marc Schumann, Peter Shagin

University of California, Los Angeles

Katsushi Arisaka, Hanguo Wang, David Cline, Ethan Brown, Artin Teymourian

Gran Sasso National Laboratory, Italy

Francesco Arneodo, Serena Fattori

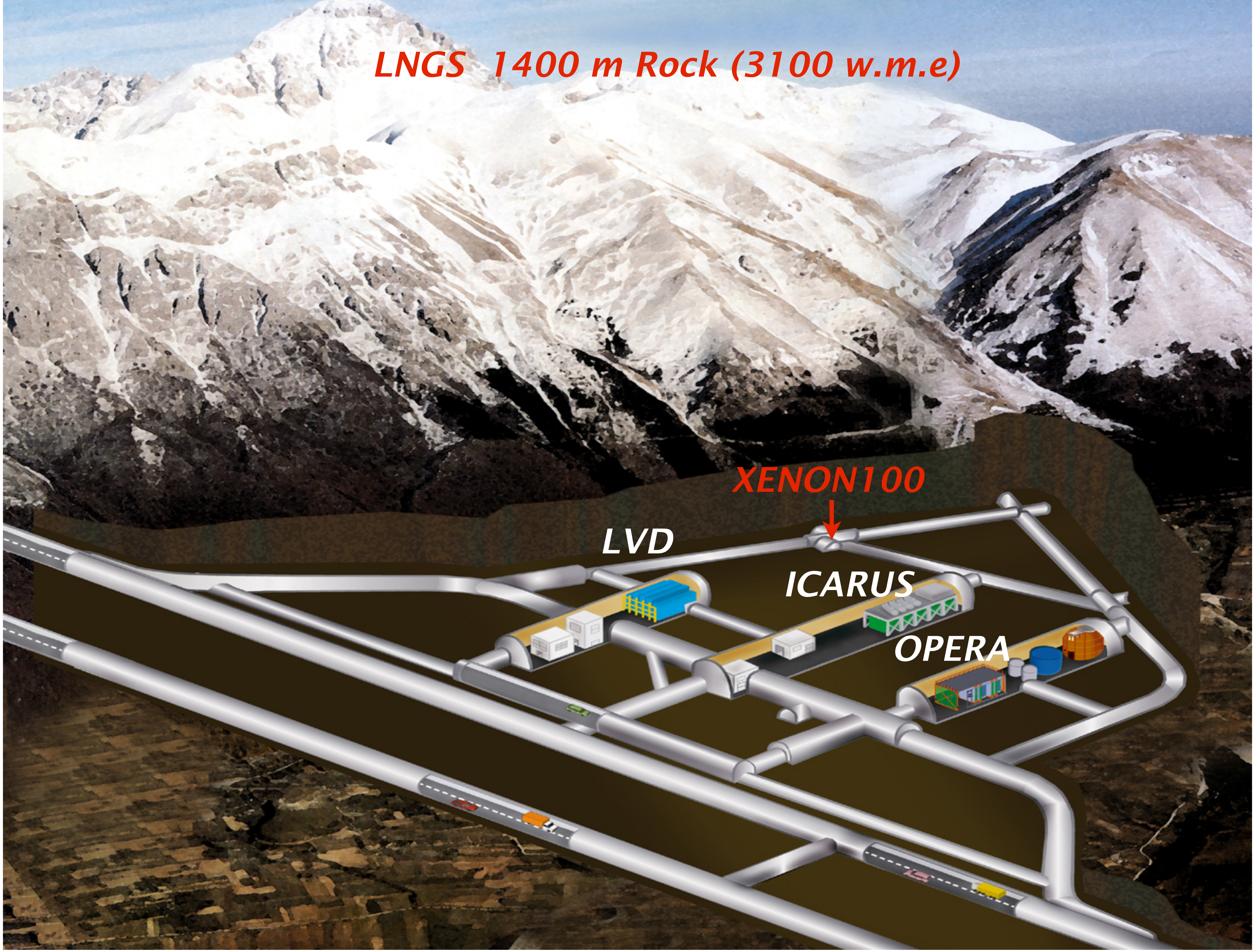
University of Coimbra, Portugal

Jose A Matias Lopes, Joao Cardoso, Luis Coelho, Joaquim Santos

University of Zurich

Laura Baudis, Ali Askin, Alfredo Ferella, Marijke Haffke, Alexander Kish, Roberto Santorelli, Eirini Tziaferi

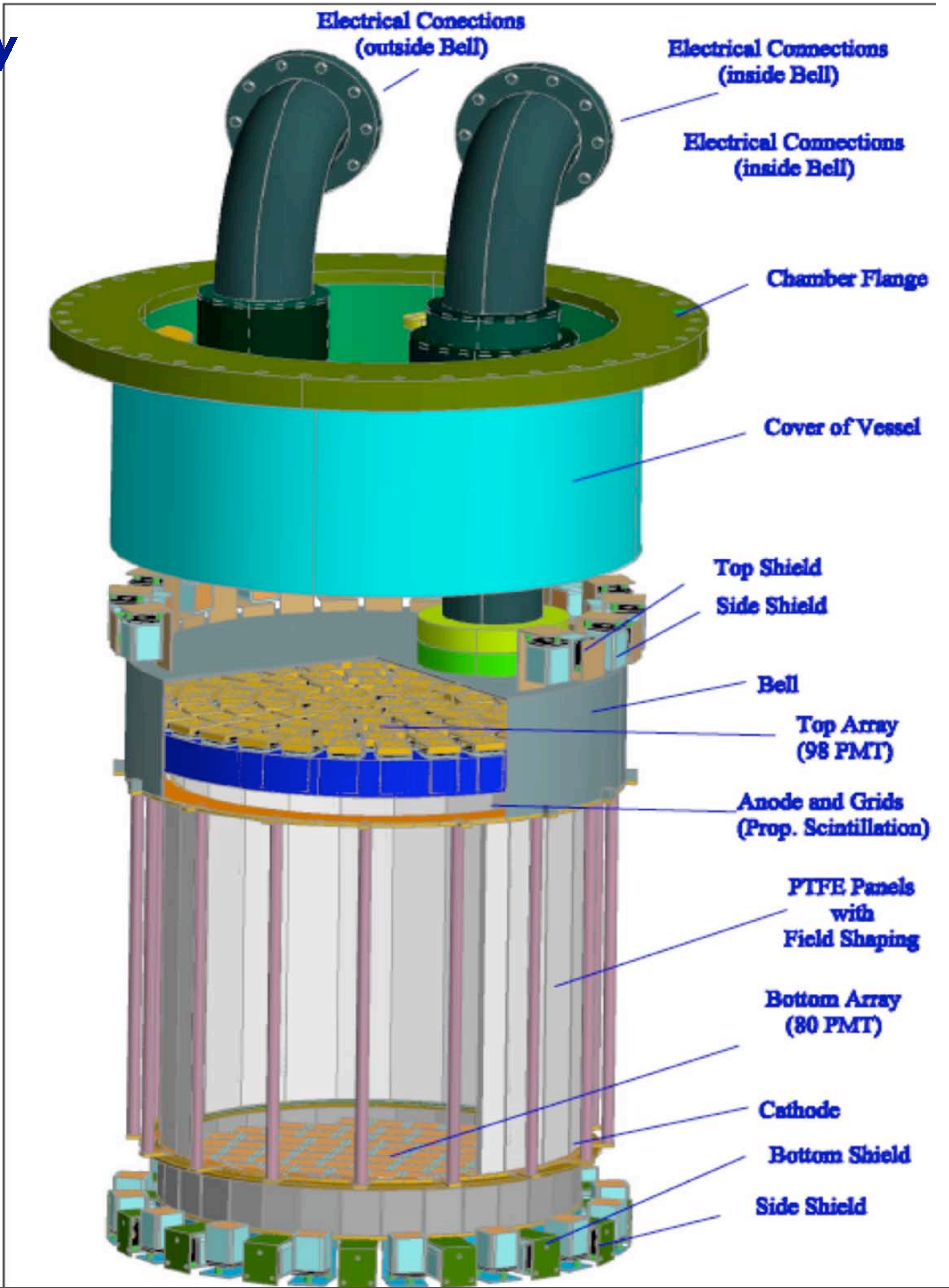
Laboratori Nazionali del Gran Sasso, Italy



XENON100 Underground at the Laboratori Nazionali del Gran Sasso

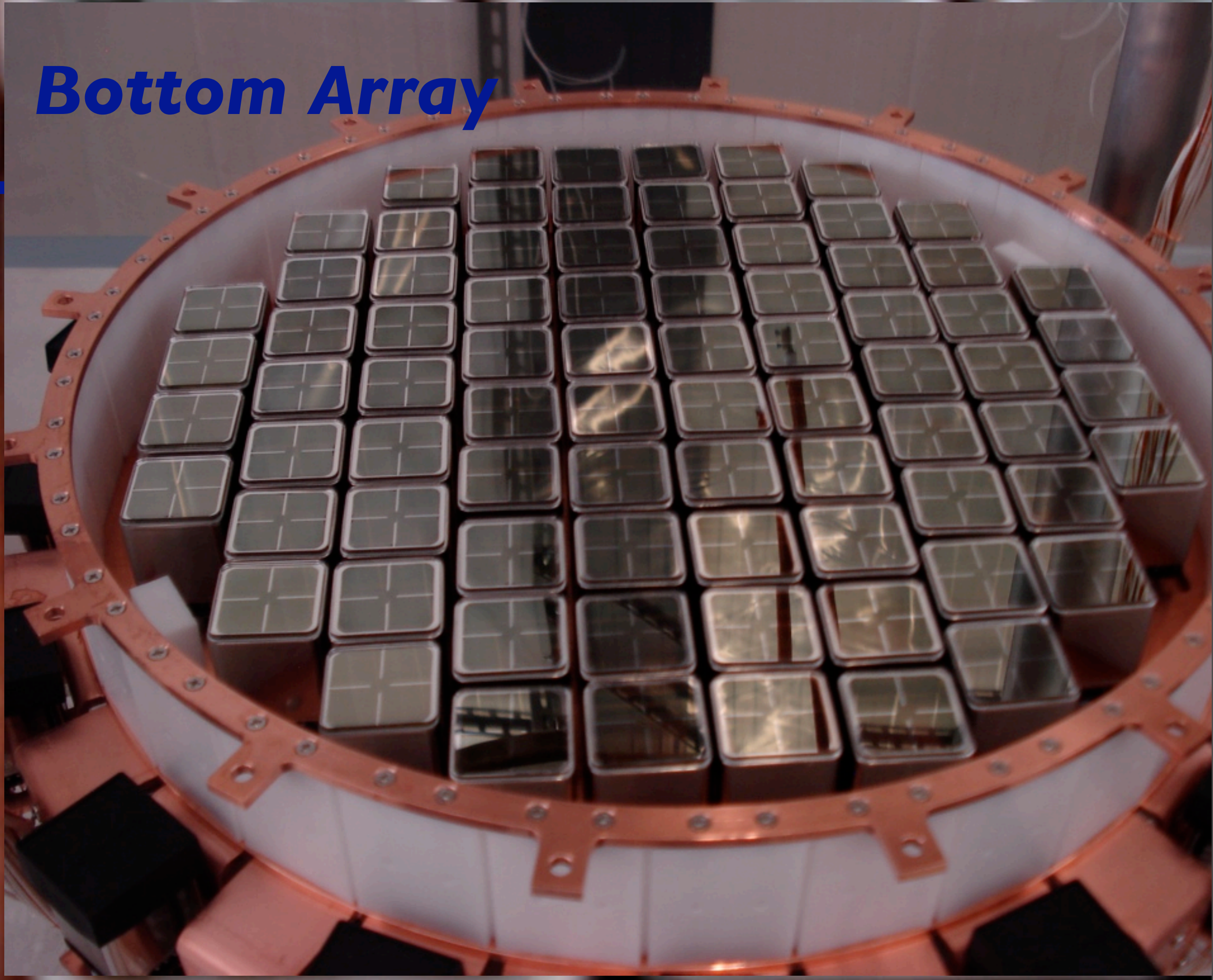
LNGS: 1.4km rock (3100 mwe)

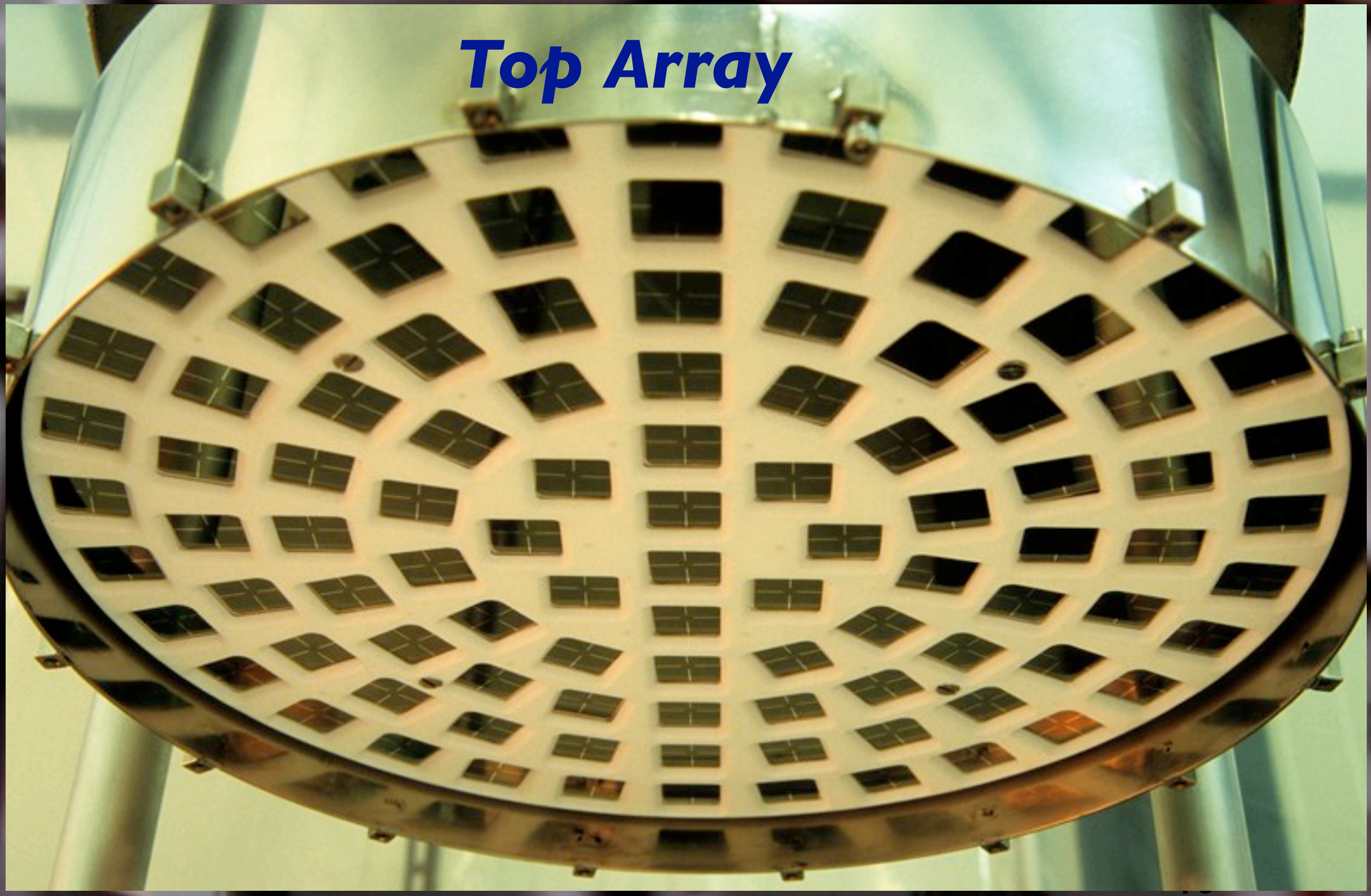
XENON100: The TPC Assembly



XENON100: The PMTs

- 242 PMTs (Hamamatsu R8520-06-Al)
- 1 “ square metal channel developed for XENON
- Low radioactivity (<1 mBq U/Th per PMT)
- 80 PMTs for bottom array (33% QE)
- 98 PMTs for top array (23% QE)
- 64 PMTs for top/bottom/side Veto (23% QE)



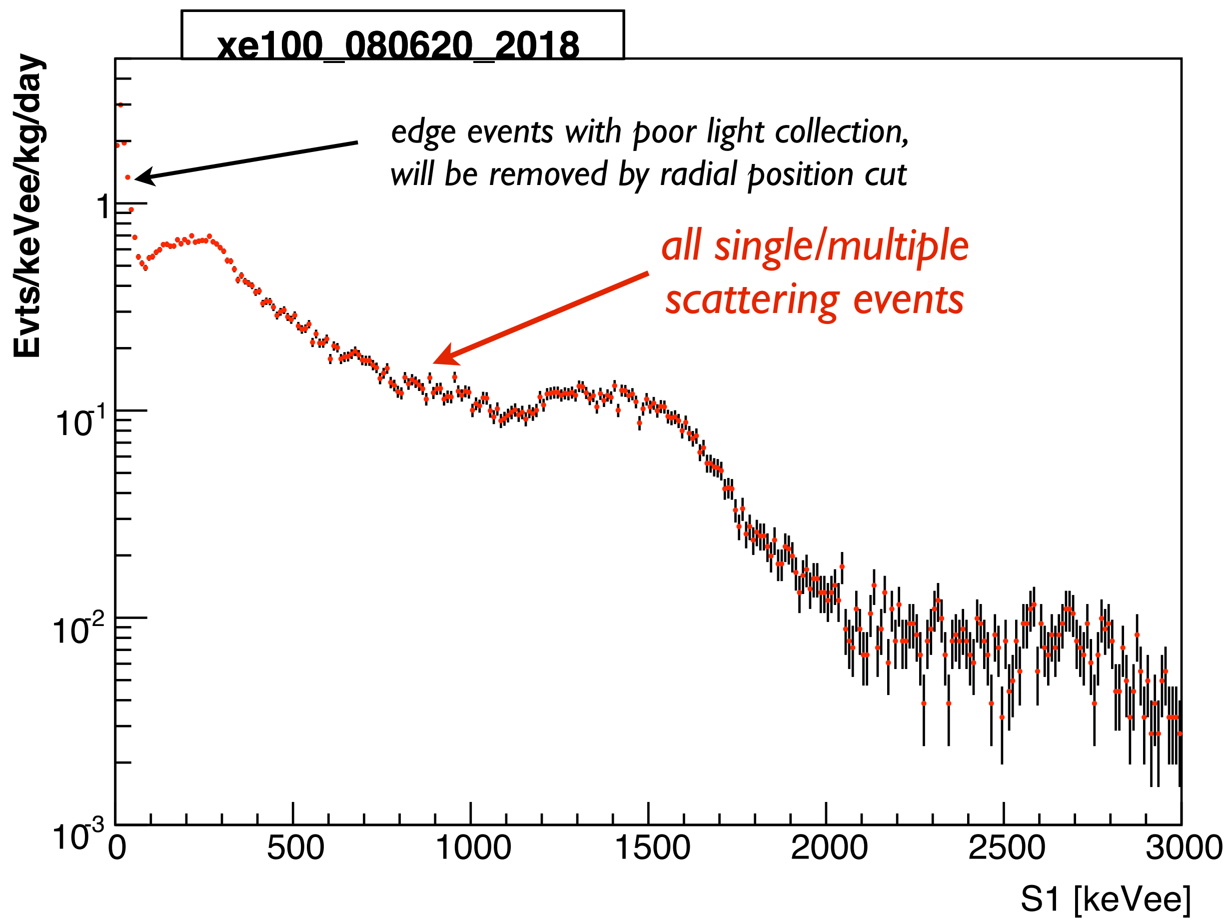


XENON100 Material Screening

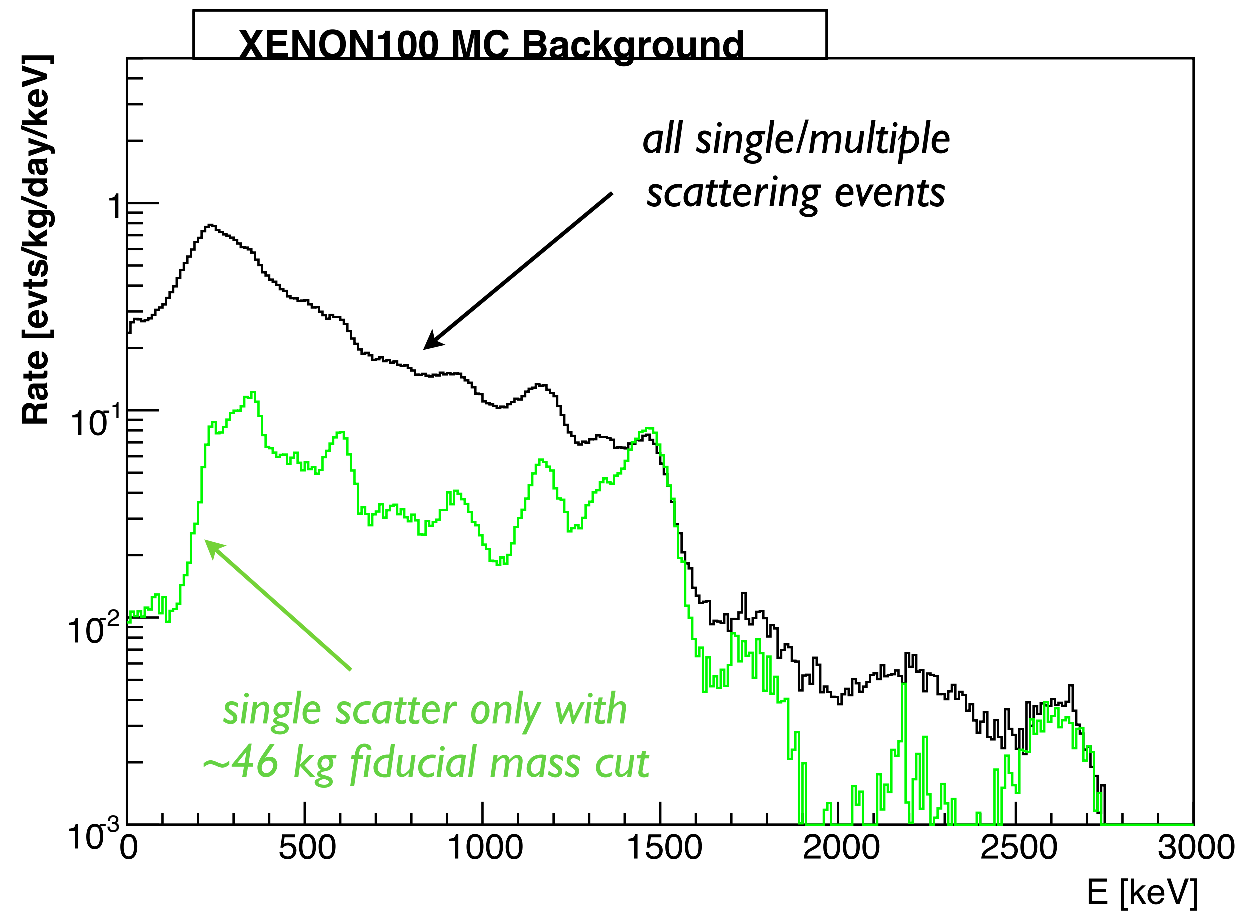
Material*	^{238}U	^{232}Th	^{40}K	^{60}Co
Stainless Steel 1.5 mm (316Ti, Nironit; cryostat)	<2 mBq/kg	<2 mBq/kg	10.5 mBq/kg	8.5 mBq/kg
Stainless Steel 25 mm (316Ti, Nironit, cryostat)	<1.3 mBq/kg	<0.9 mBq/kg	<7.1 mBq/kg	1.4 mBq/kg
PMTs (R8520-AL)	< 0.24 mBq/PMT	0.18 mBq/PMT	7.0 mBq/PMT	0.67 mBq/PMT
PMT Bases	0.16 mBq/pc	0.10 mBq/pc	<0.16 mBq/pc	<0.01 mBq/pc
Teflon (TPC)	< 0.3 mBq/kg	<0.6 mBq/kg	< 2.3 mBq/kg	--
Poly I (shield)	< 3.8 mBq/kg	< 2.9 mBq/kg	< 5.88 mBq/kg	--
Poly II (shield)	2.43 mBq/kg	< 0.67 mBq/kg	<4.66 mBq/kg	--
Polish Pb (outer shield)	< 5.7 mBq/kg	< 1.6 mBq/kg	14 mBq/kg	< 1.1 mBq/kg
French Pb (inner shield)	< 6.8 mBq/kg	< 3.9 mBq/kg	< 28 mBq/kg	< 0.9 mBq/kg

XENON100 Current Status

<u>*data*</u>



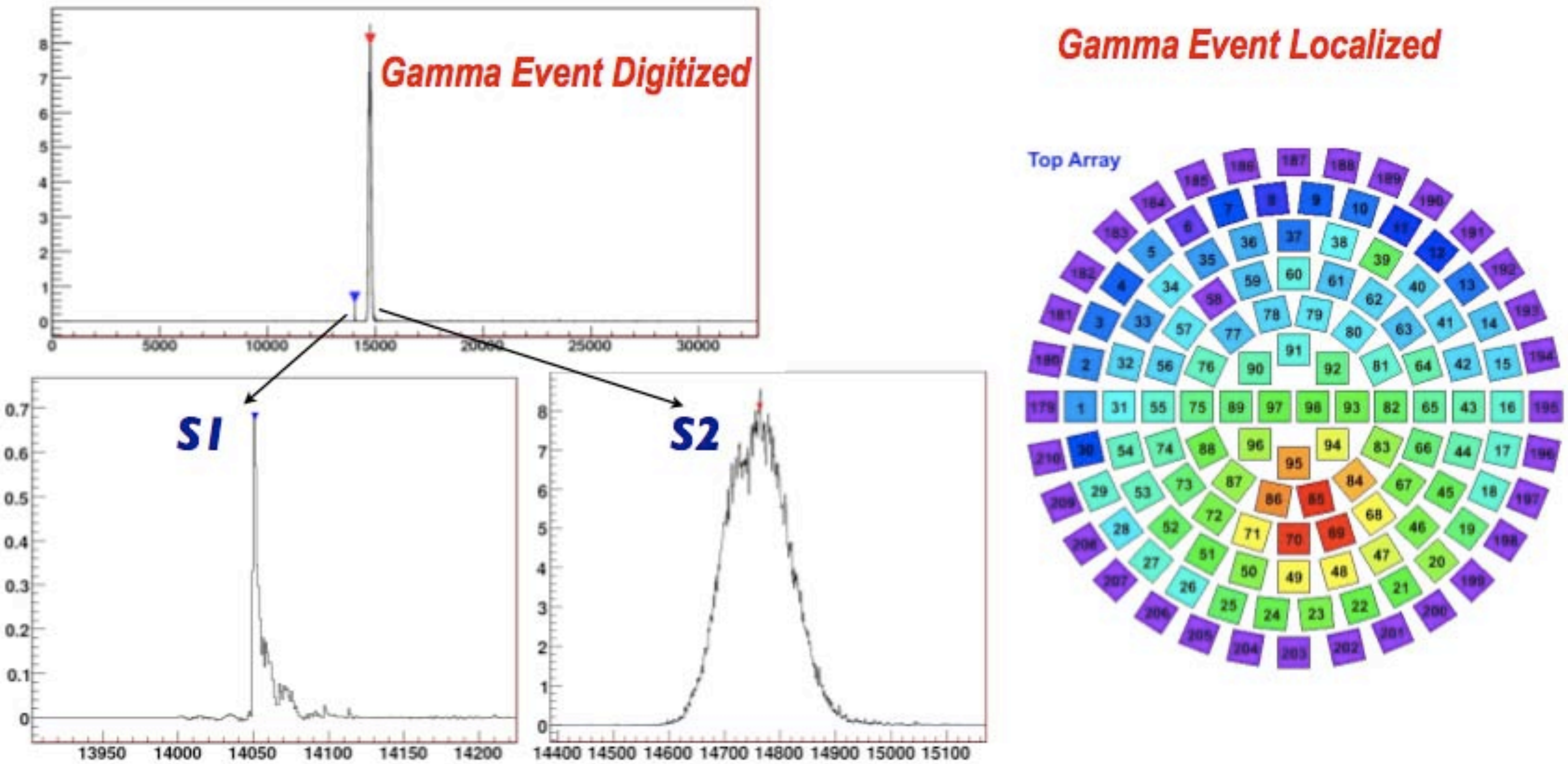
<u>*MC*</u>



Detector has been fully filled with liquid xenon.

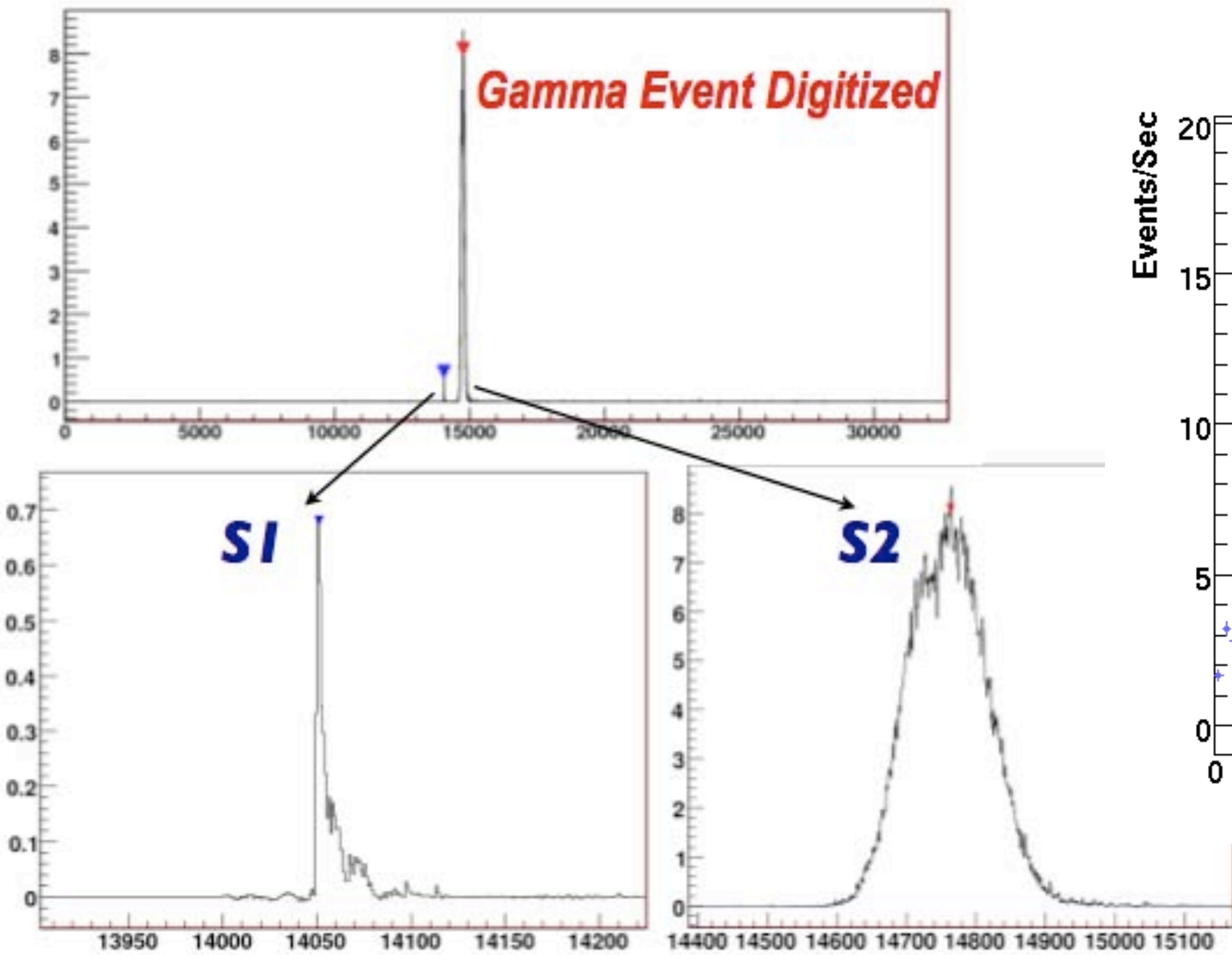
First Measured background Spectrum in good agreement with MC prediction!

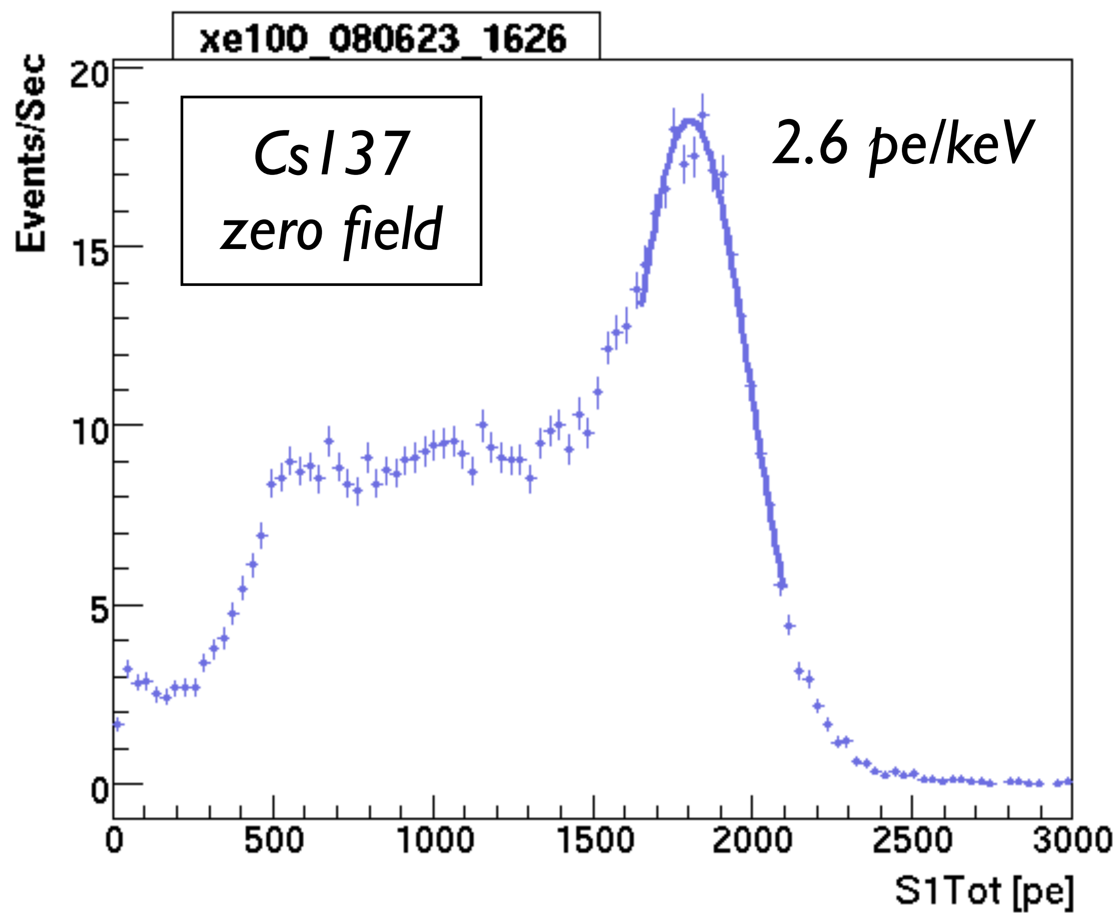
XE100: First Light & Charge Signals (Cs137)



Current effort: Liquid Xenon is continuously purified to achieve better purity

XE100: First Light & Charge Signals (Cs137)





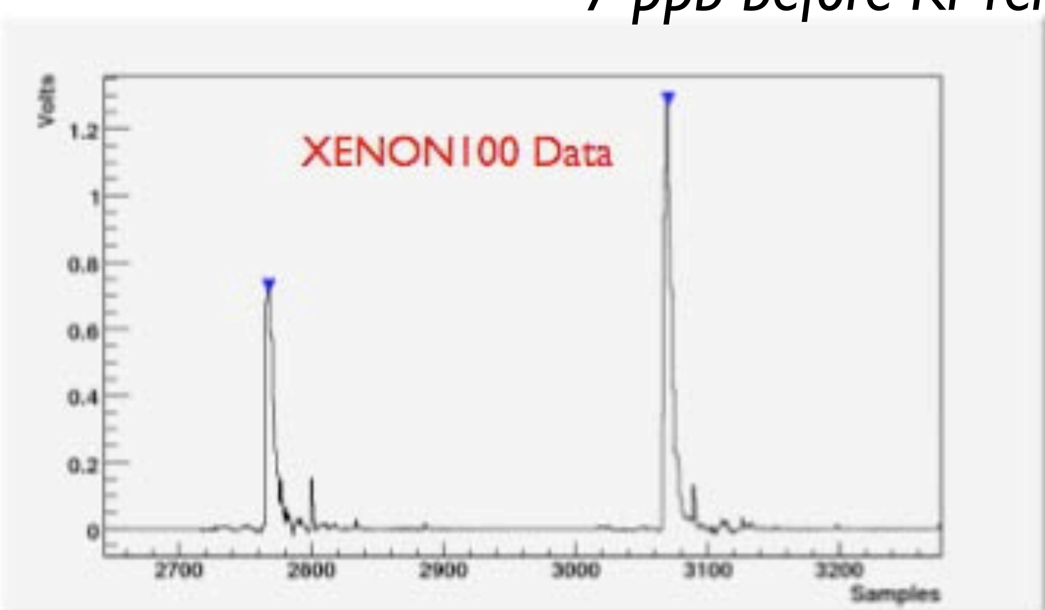
Current effort: Liquid Xenon is continuously purified to achieve better purity

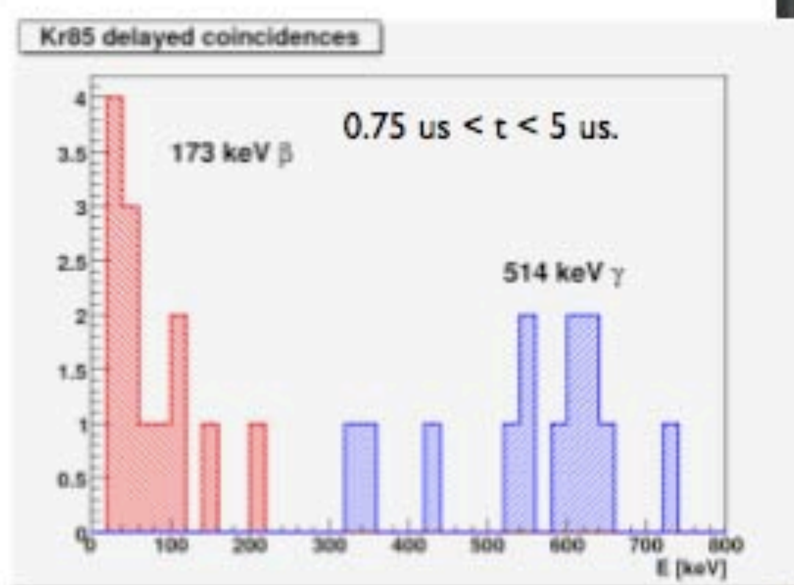
XENON100: Kr Removal

Kr removal process was finished on Sep.24. Currently we are taking data to verify the Kr concentration in Xe.

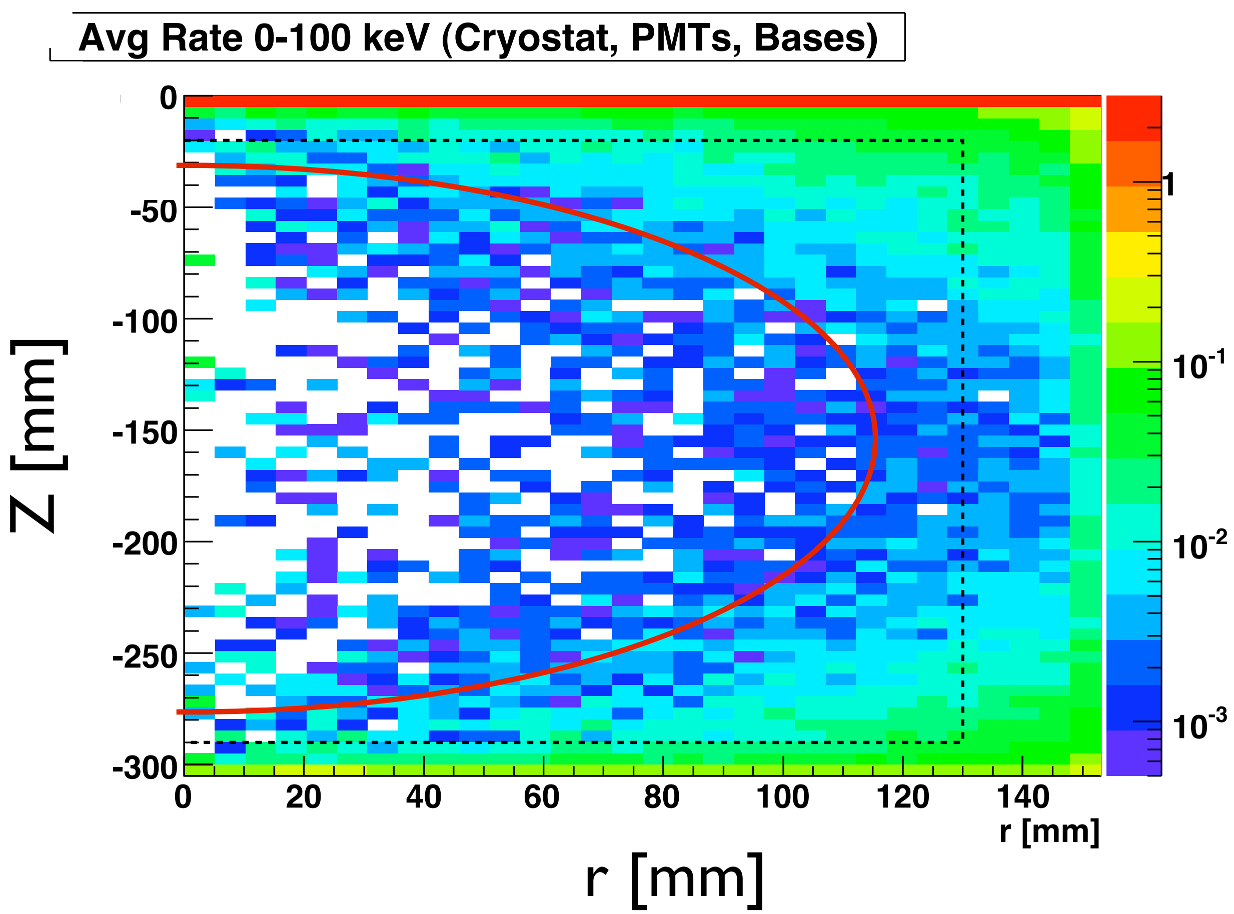
Less than 50 ppt Kr/Xe expected.

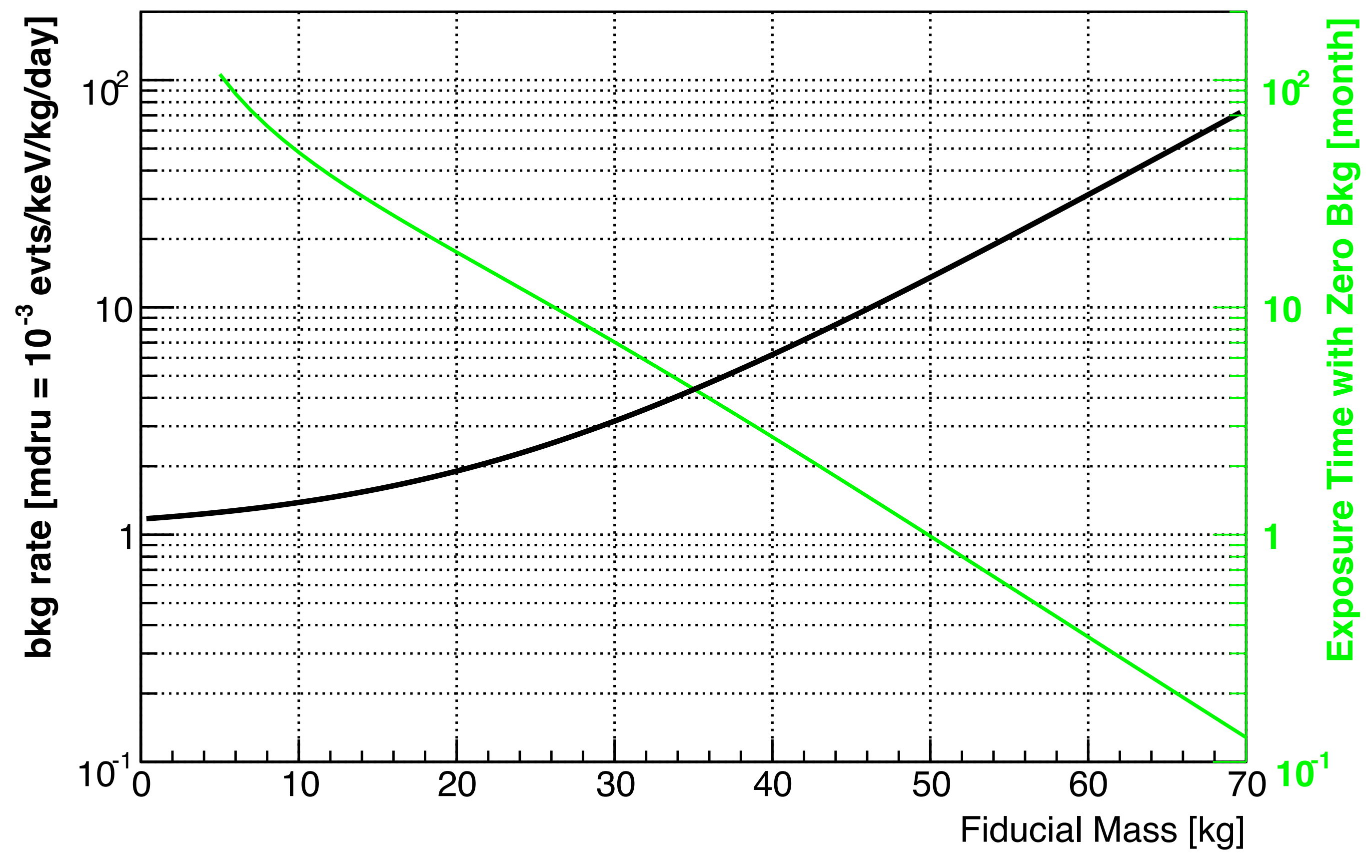
~7 ppb before Kr removal process





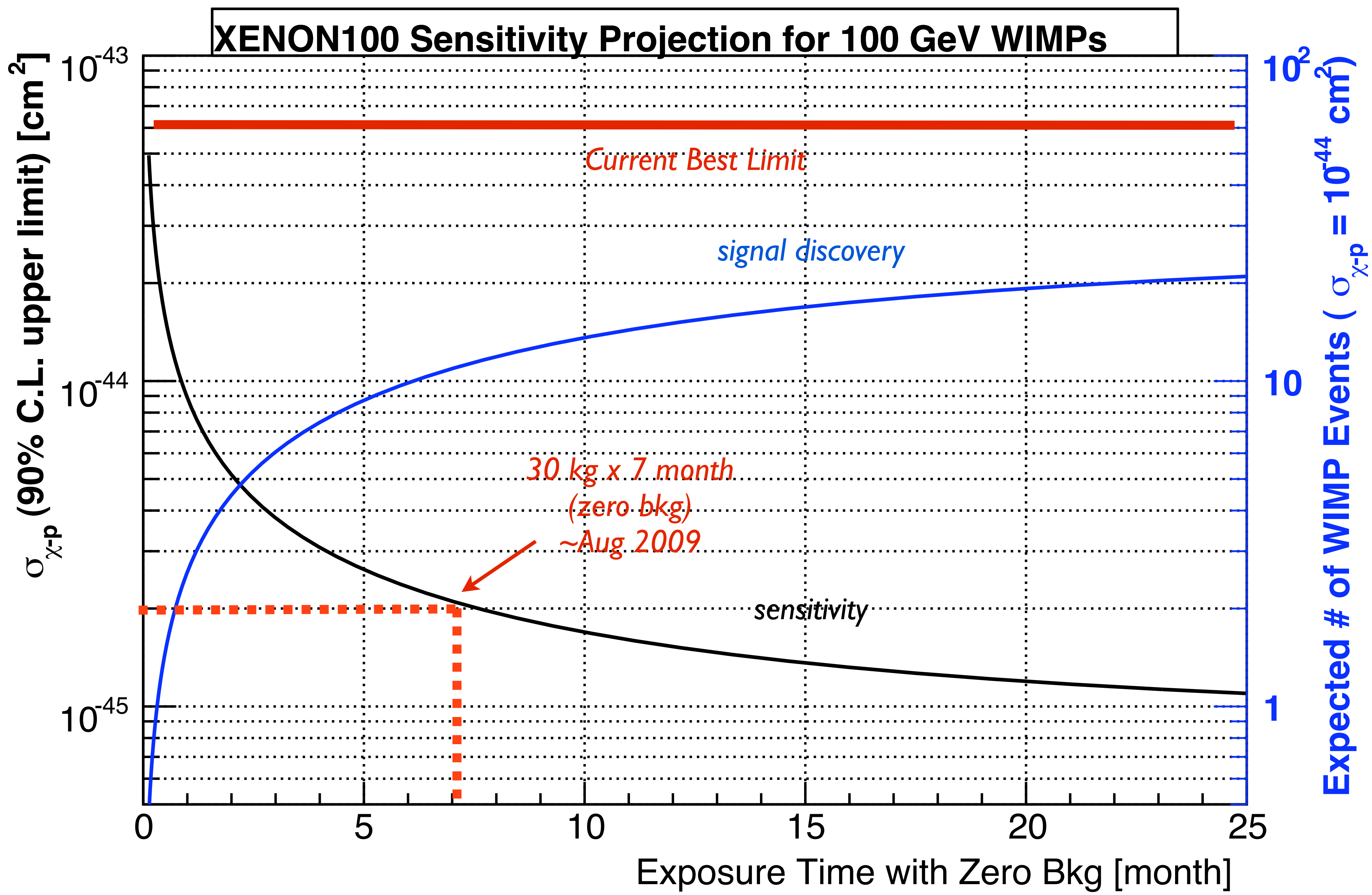
XENON100 Background Prediction from Simulation





- *different fiducial volume cuts (spherical vs cylindrical) to achieve the best bkg rate vs fiducial mass*
- *~6 mdru for a fiducial mass of 40 kg (no gamma background for 3 months)*
- *~2 mdru for a fiducial mass of 20 kg (no gamma background for 1.5 year)*

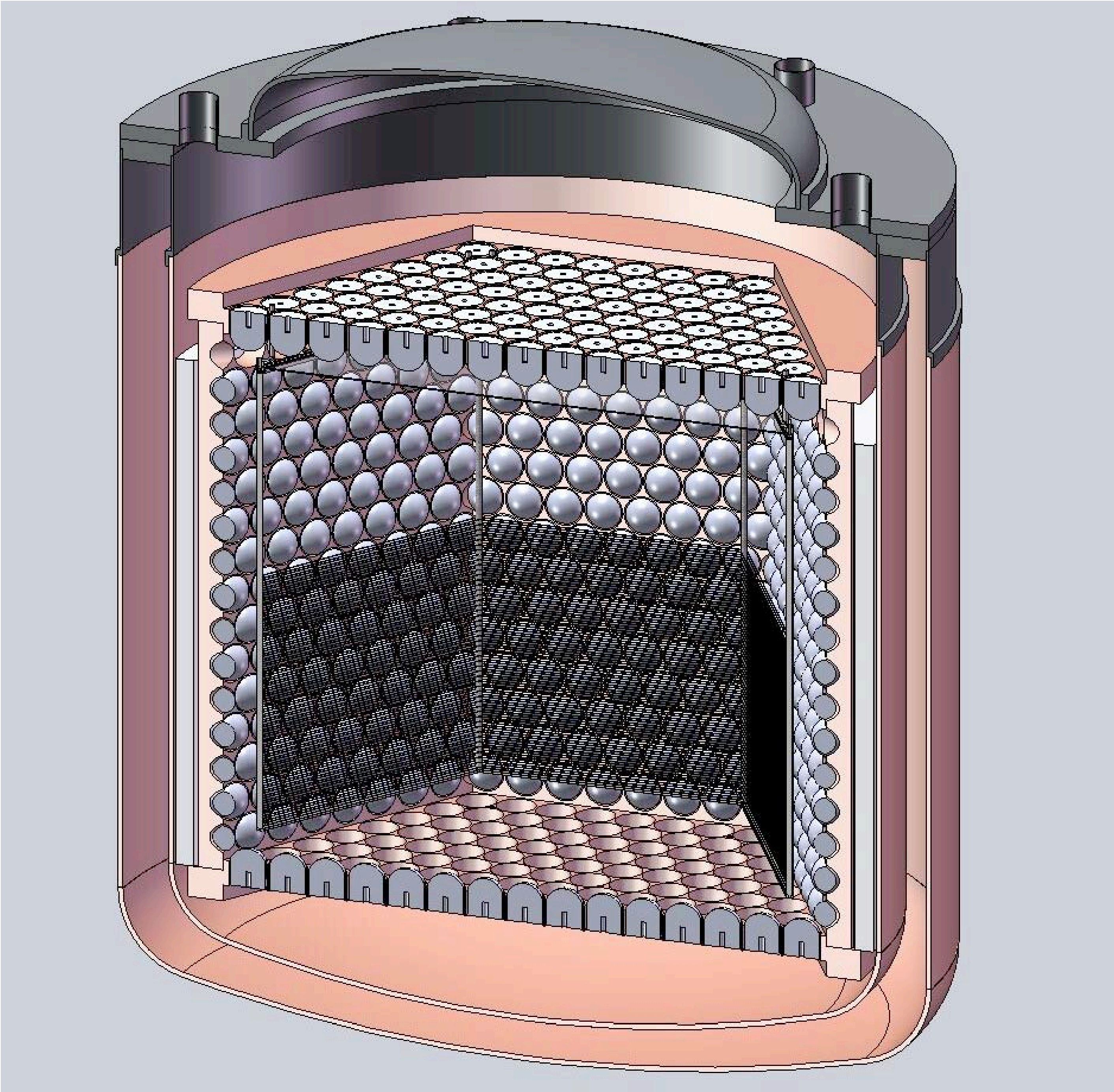
XE100 sensitivity projection

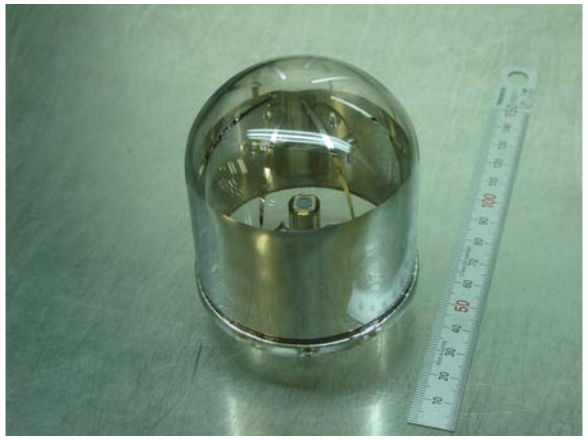


- *XENON100 experiment can probe down to 10^{-45} cm^2, but also has great discovery potential!*

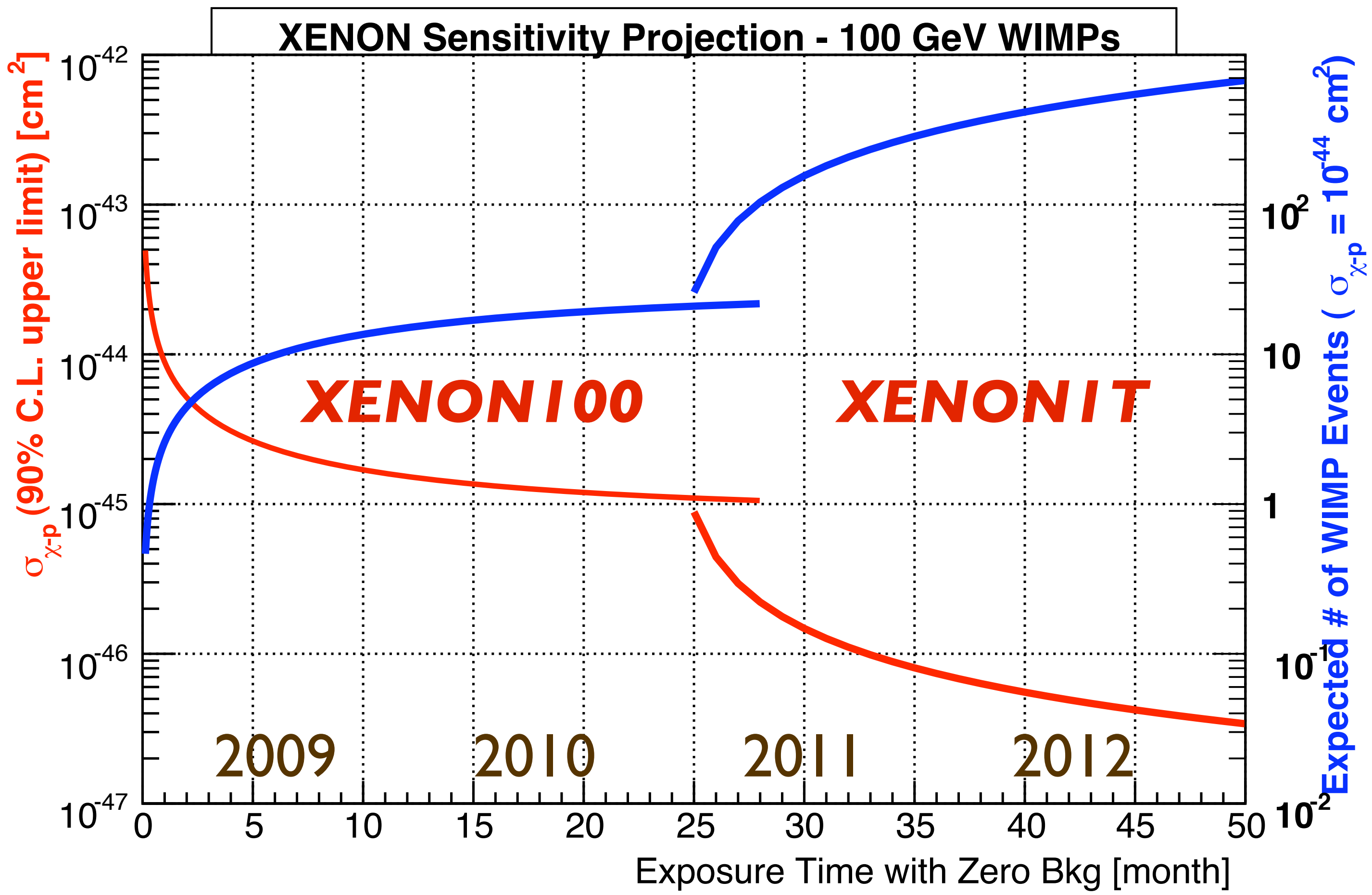
XENON1T - the ultimate dark matter detector

- *Explore the full region in CMSSM space*
- *New design with full coverage of ultra-low background photodetectors and cryostat*
- *Need a deeper underground lab (or efficient muon veto) and larger space*
- *Larger International Collaboration*
- *To be proposed for 2009-2013*
- *Total project cost: estimate ~$20M*





The Road to Direct DM detection: from XENON100 to XENON1T



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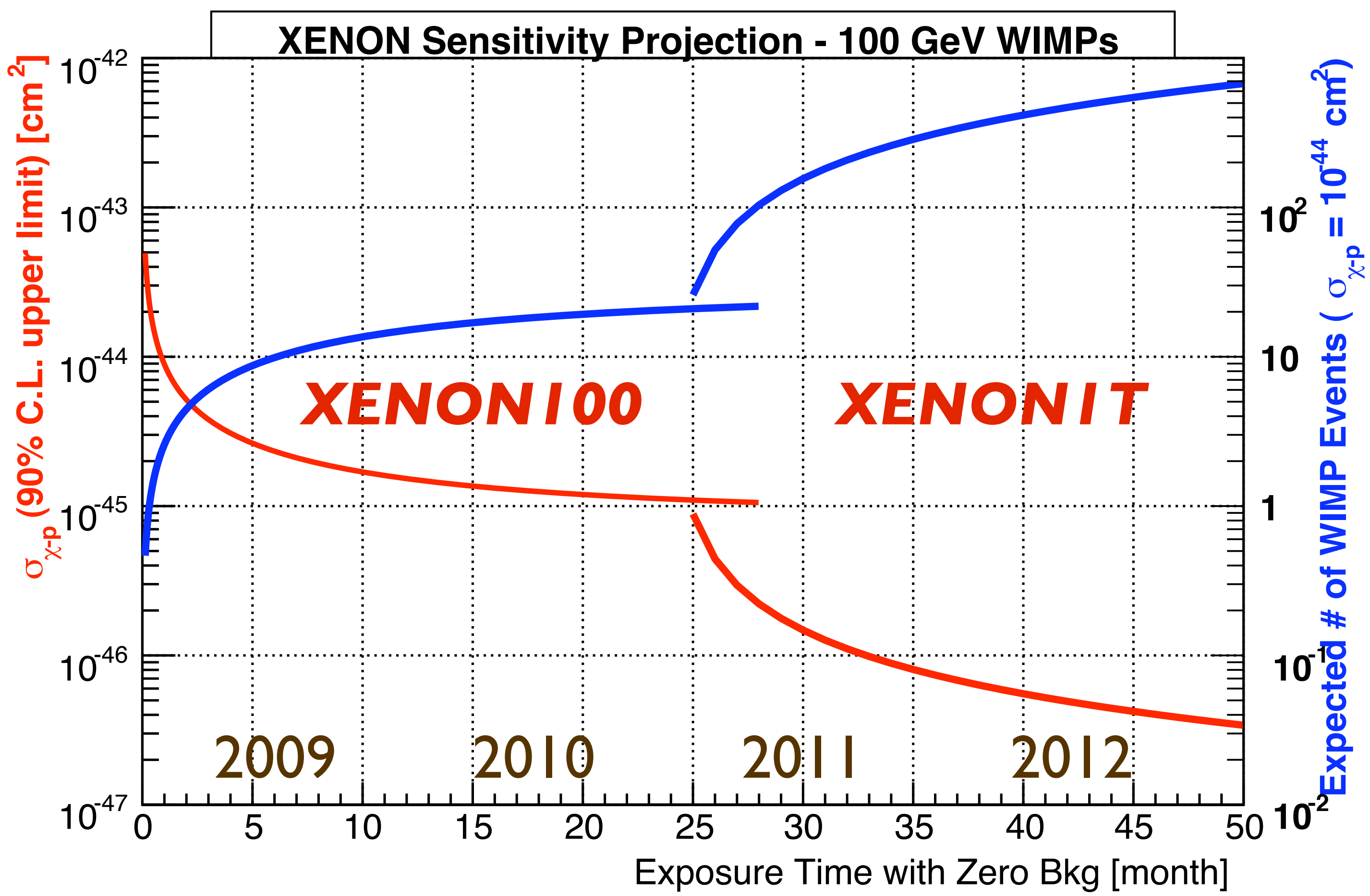

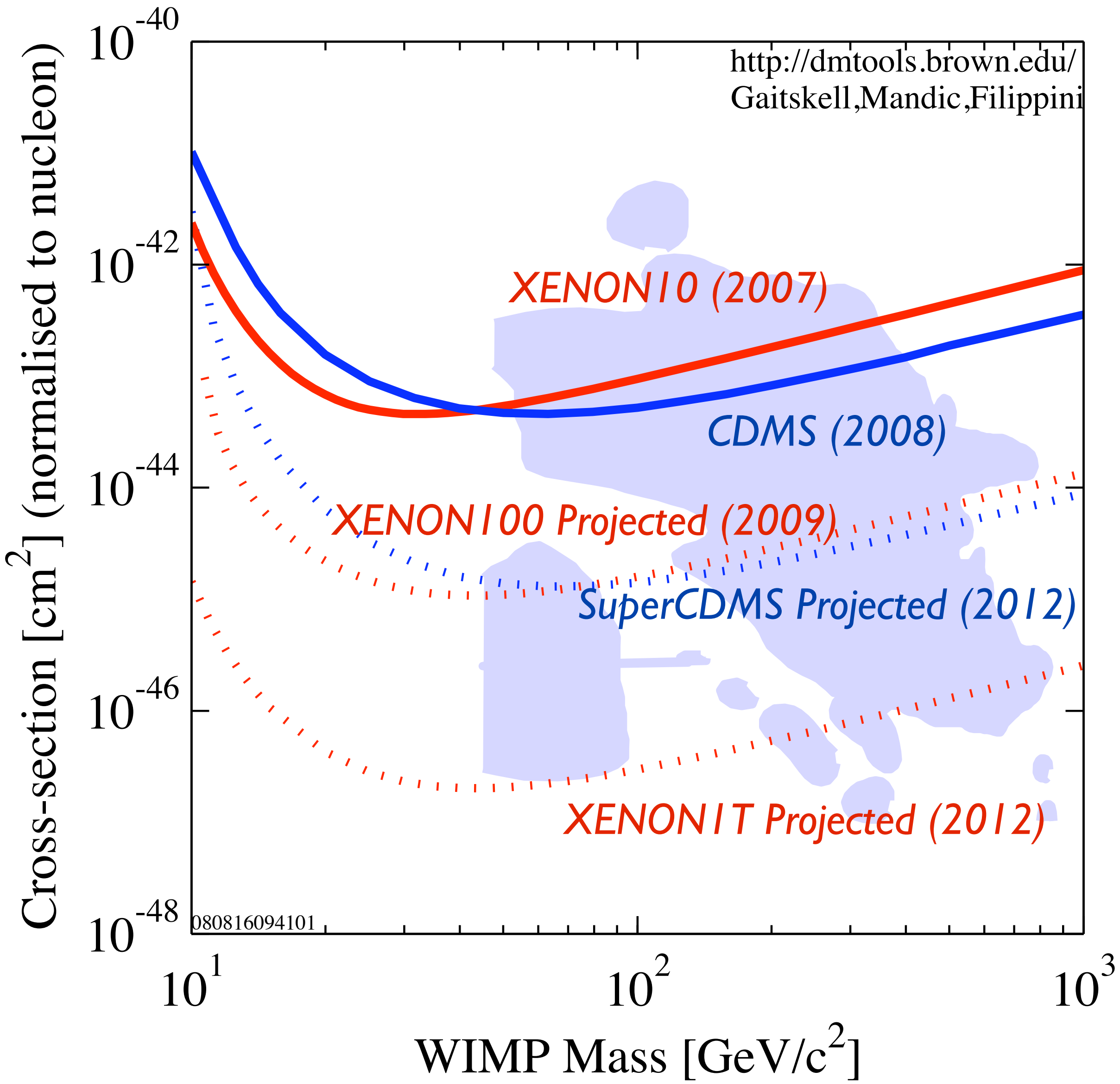

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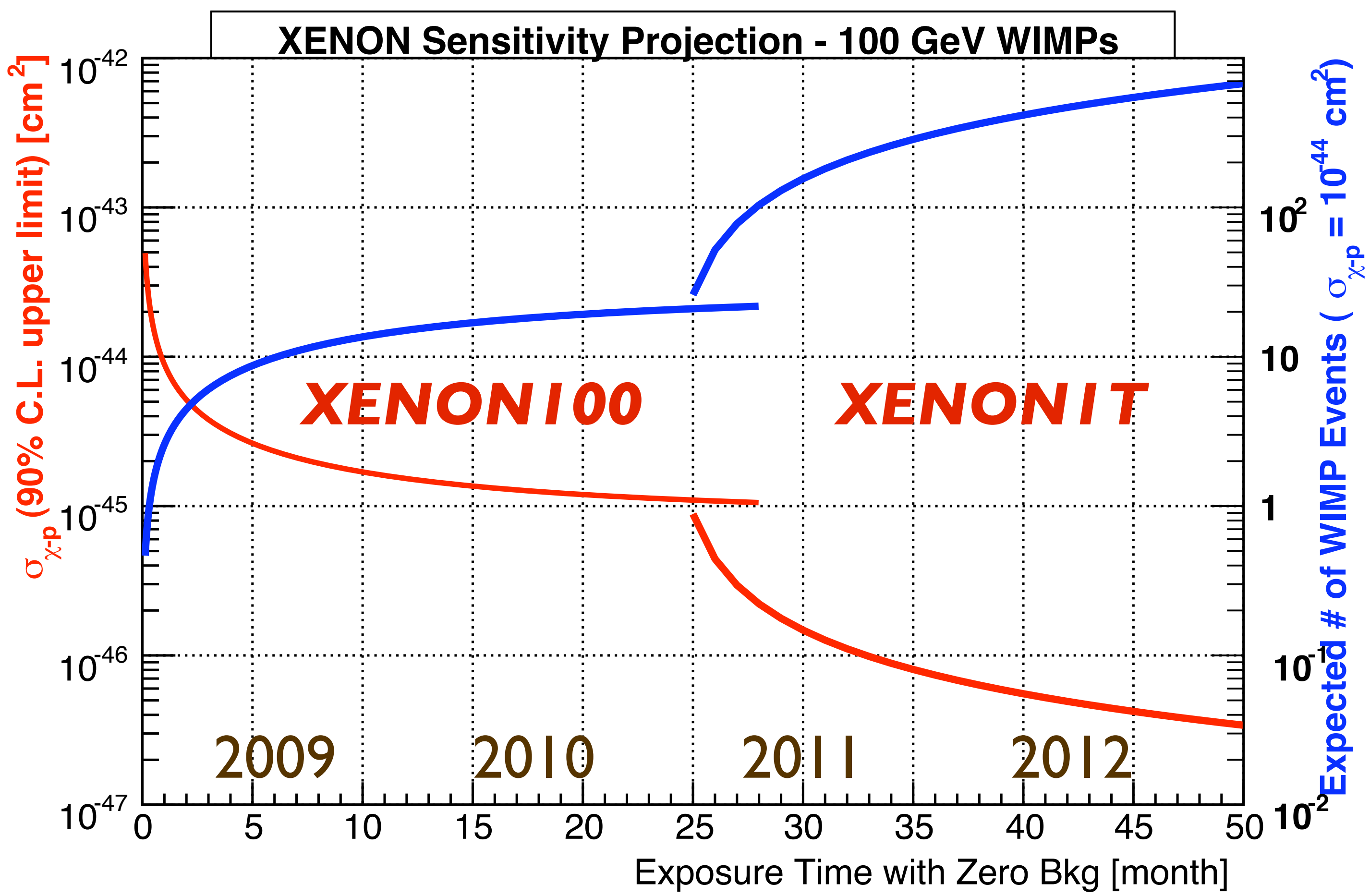
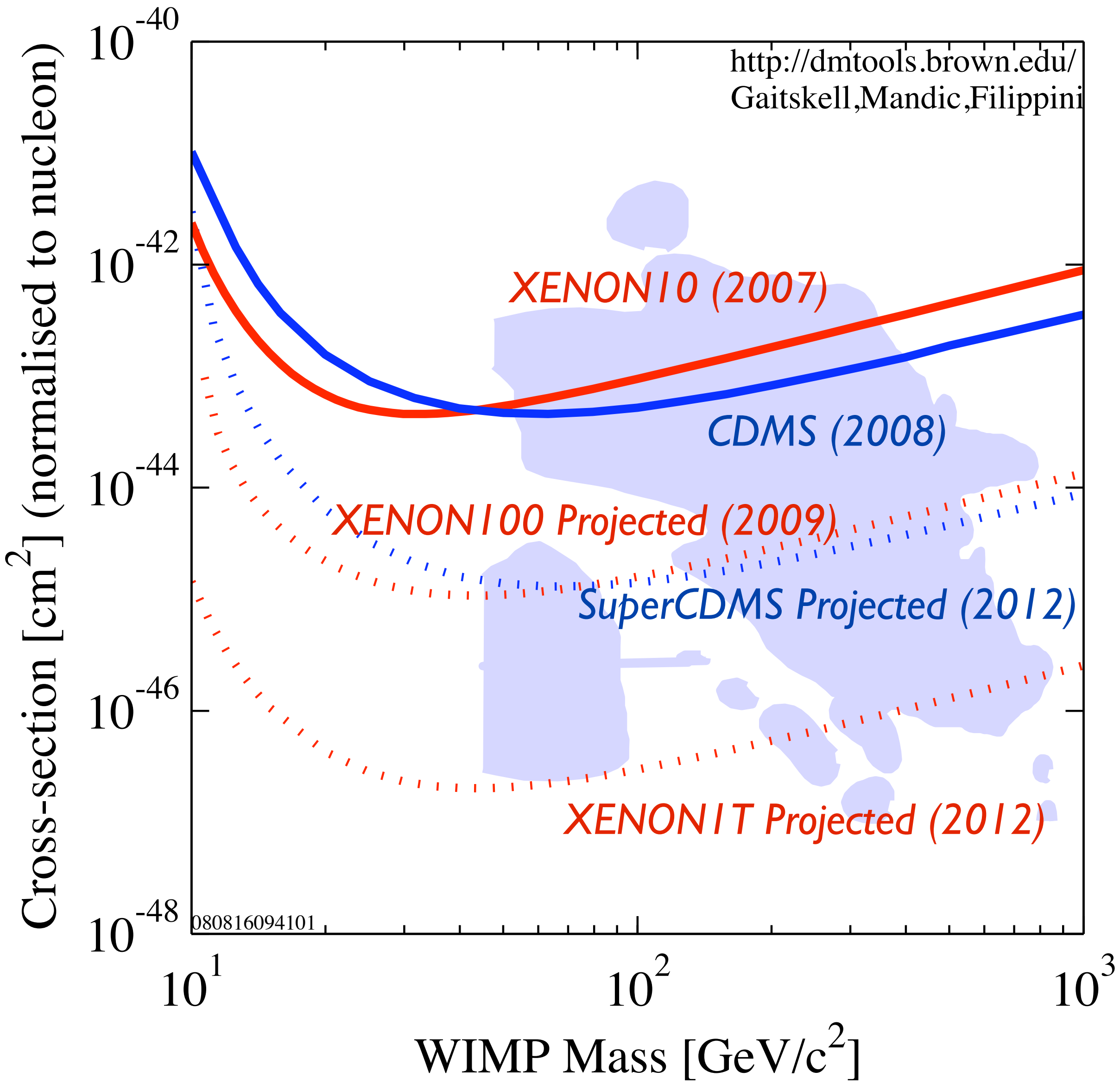
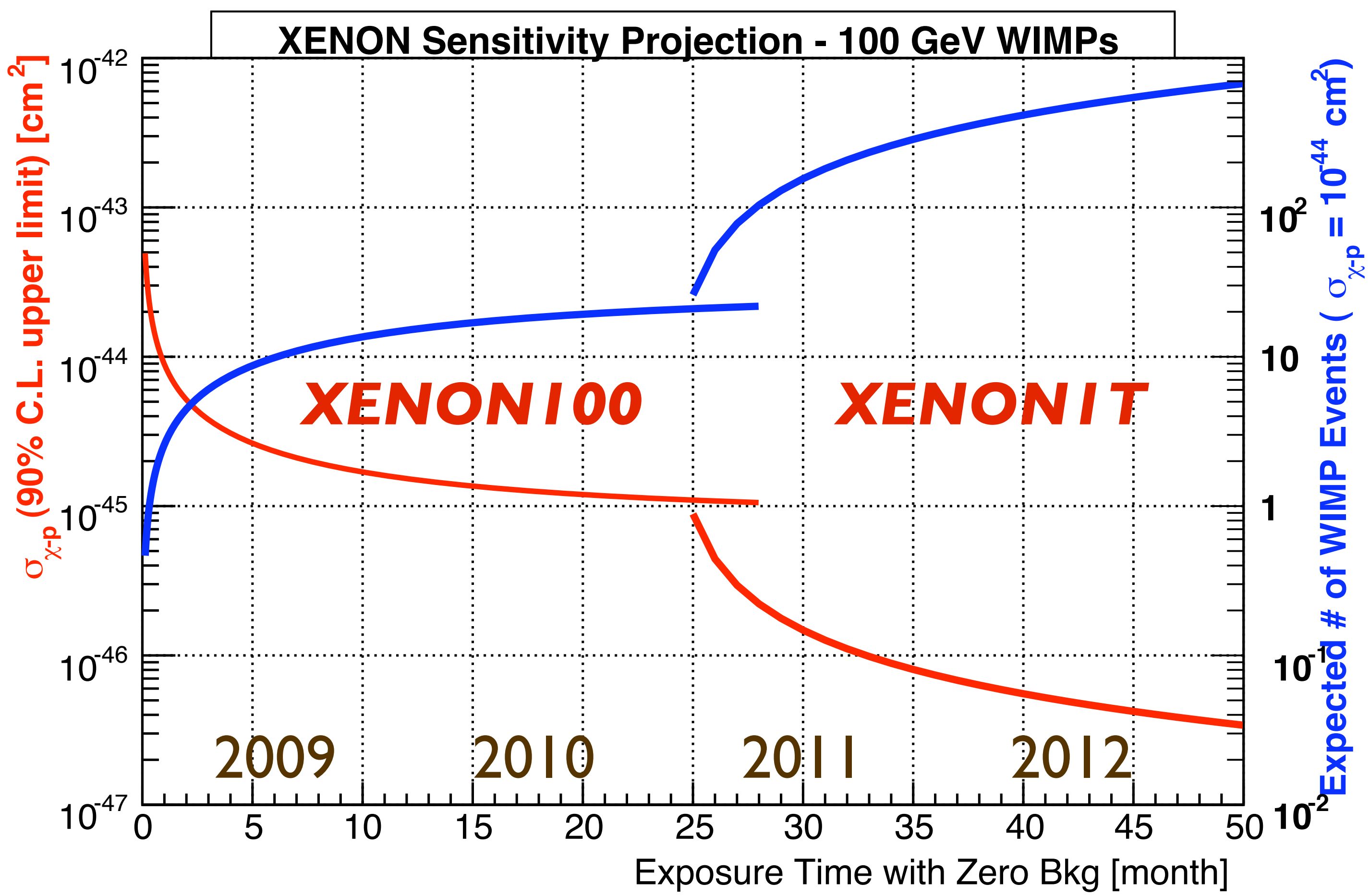
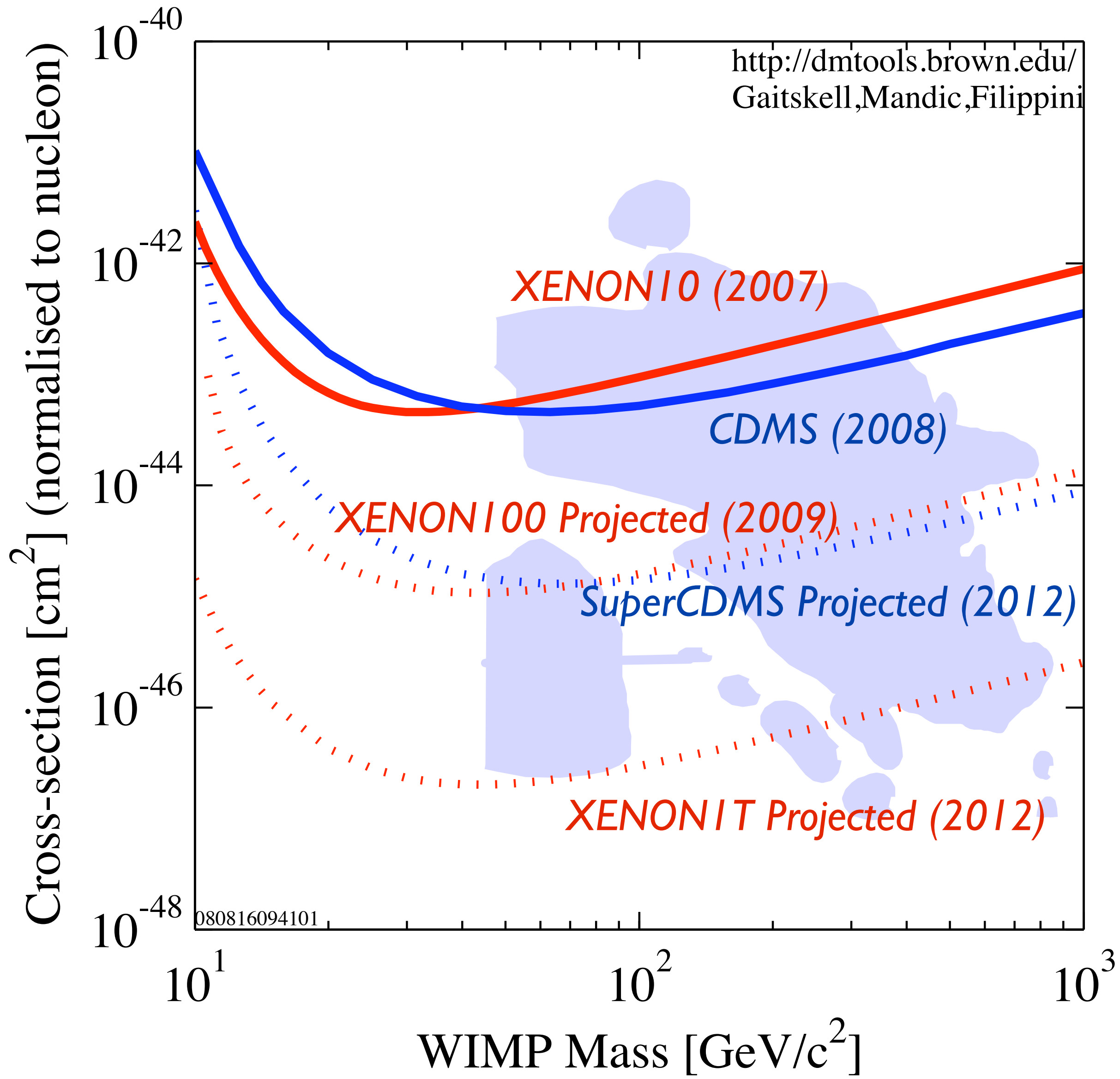




- ***"Two-Phase Xenon"*** *is currently the most promising technology for DM detection*

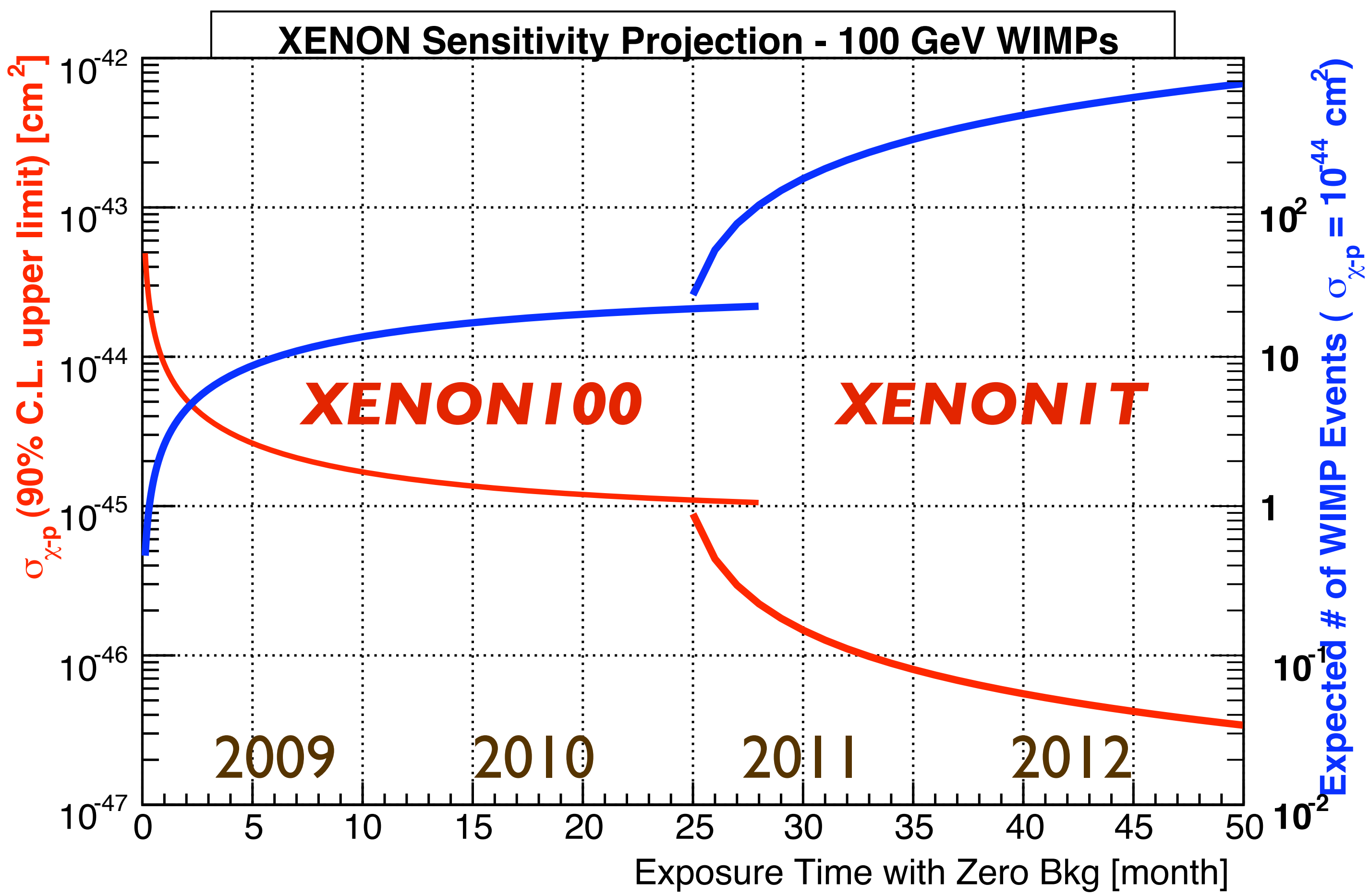
The Road to Direct DM detection: from XENON100 to XENON1T

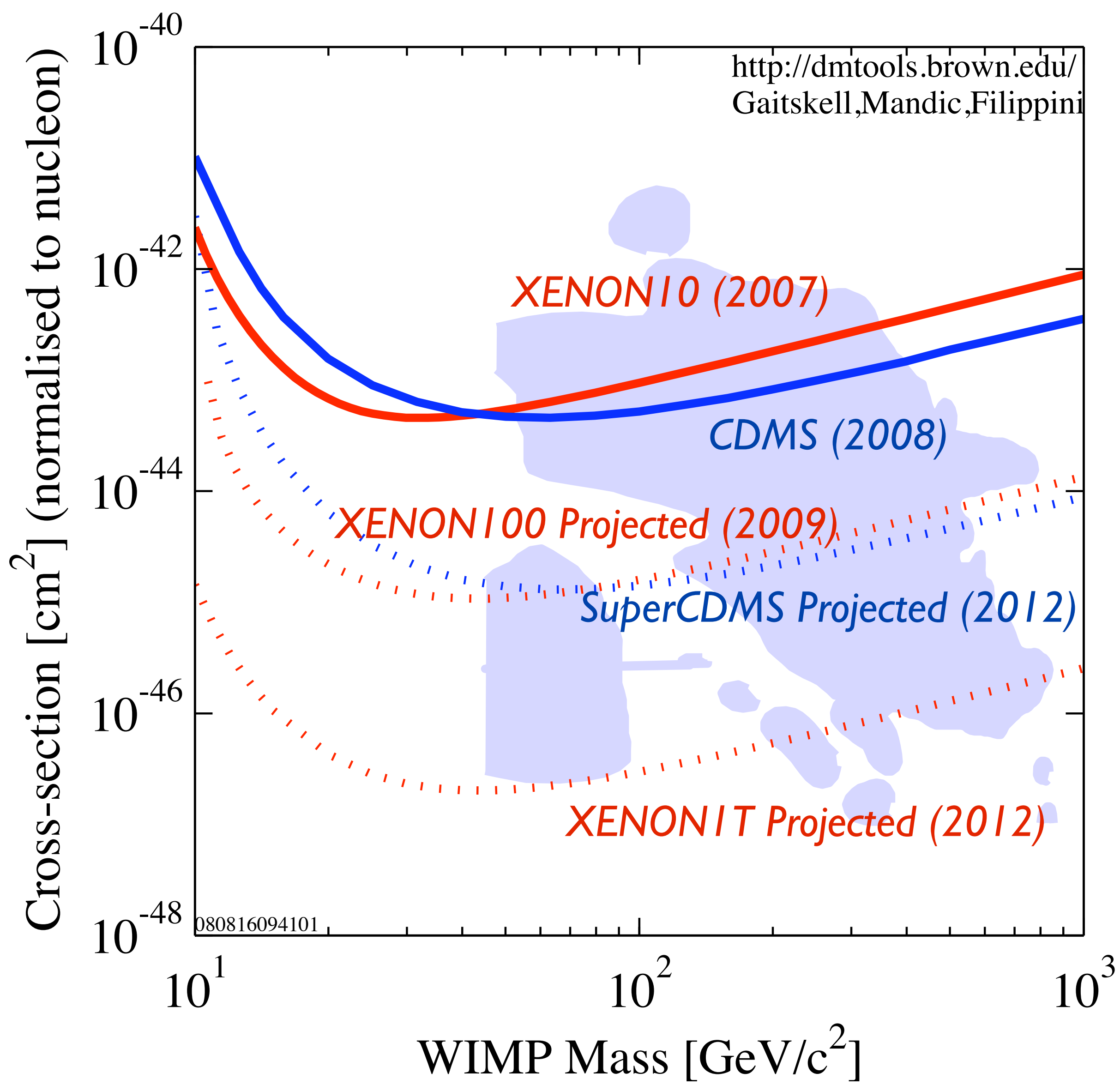




- ***"Two-Phase Xenon"*** *is currently the most promising technology for DM detection*
- ***XENON100*** *is currently the largest "two-phase xenon" detector under operation*

The Road to Direct DM detection: from XENON100 to XENON1T





- ***"Two-Phase Xenon"*** *is currently the most promising technology for DM detection*
- ***XENON100*** *is currently the largest "two-phase xenon" detector under operation*
- ***Let's hope we will see WIMPs in 2009!***