

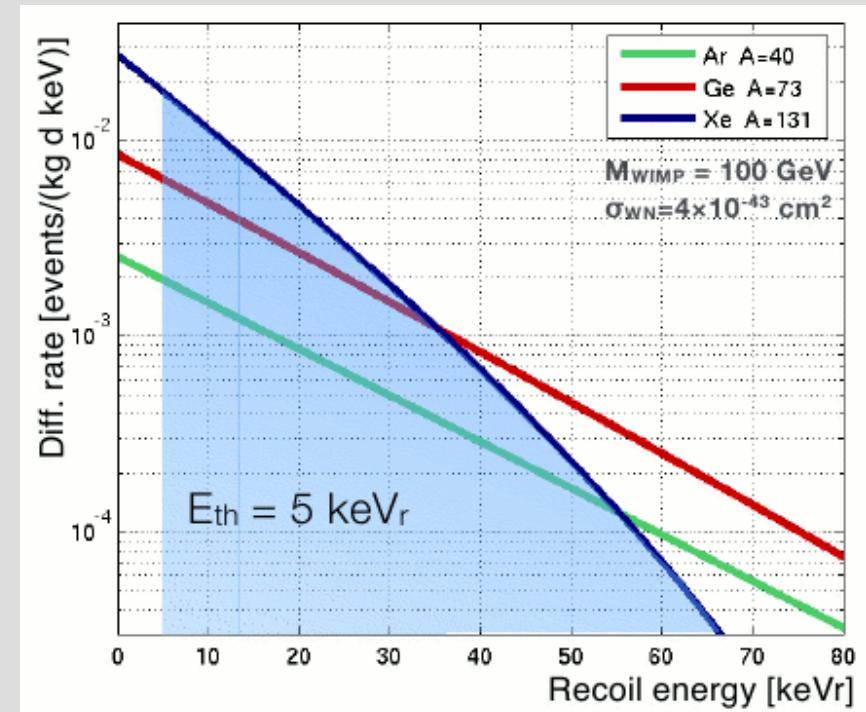
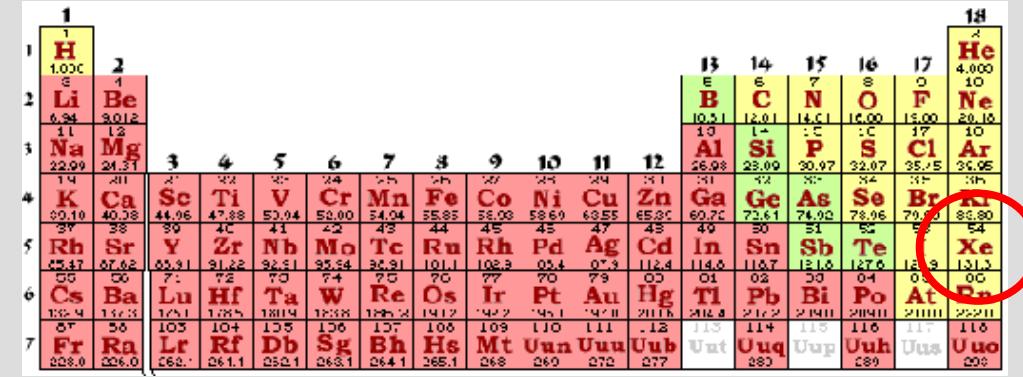
XENON100

Marc Schumann *Physik Institut, Universität Zürich*

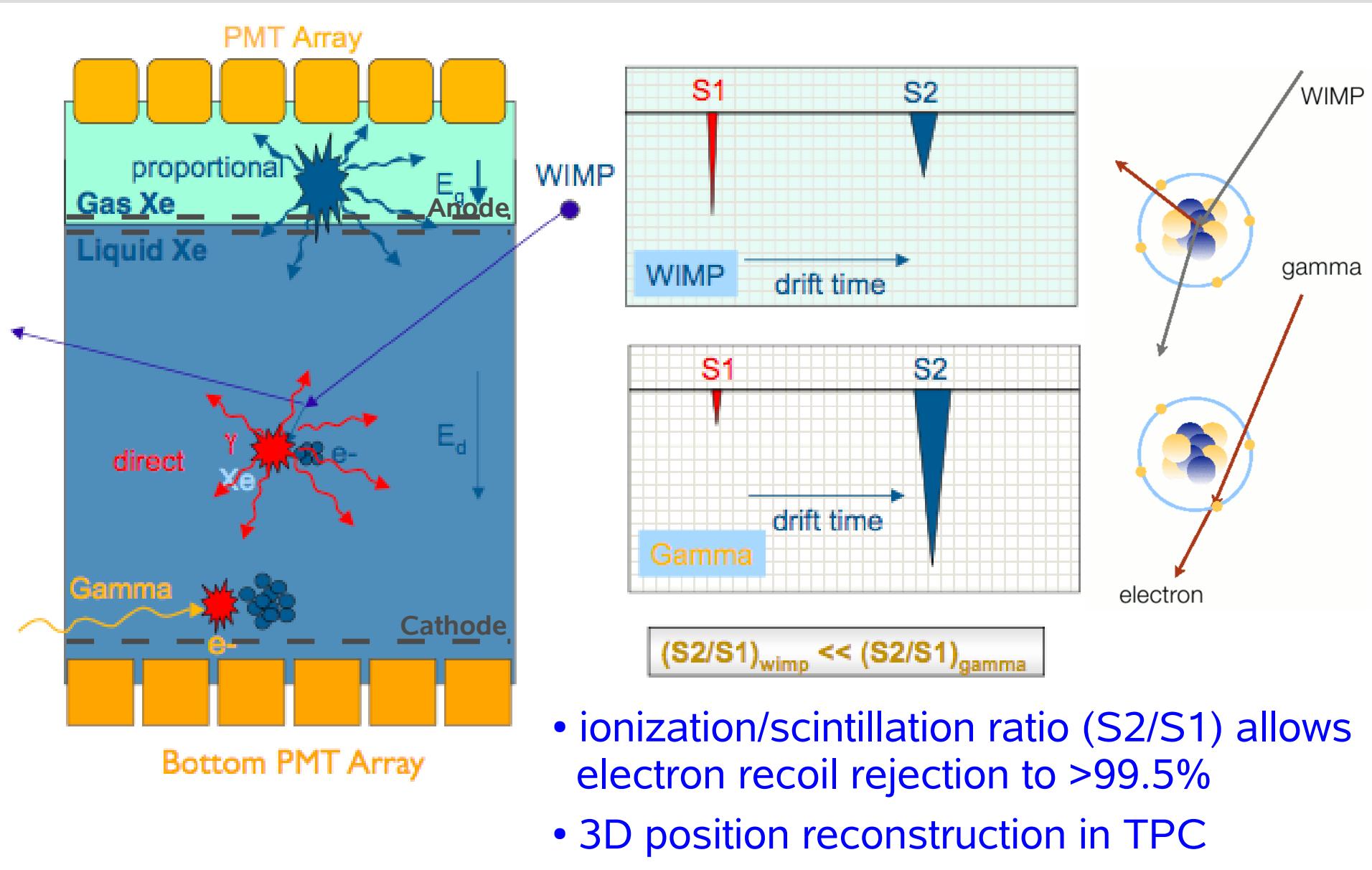
IDM 2010, Montpellier, July 26th, 2010

Why WIMP search with Xenon?

- efficient, fast scintillator (178nm)
- high mass number $A \sim 131$:
SI: high WIMP rate @ low threshold
- high atomic number $Z=54$,
high density ($\sim 3\text{kg/l}$):
self shielding, compact detector
- 50% odd isotopes
sensitive to spin-dependent couplings
- no long lived Xe isotopes,
Kr-85 can be removed to ppt
- "easy" cryogenics @ -100°C
- scalability to larger detectors
- in 2-phase TPC:
good background discrimination



Dual Phase TPC



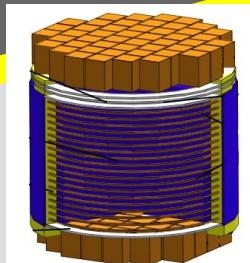
The XENON program

XENON: A phased WIMP search program

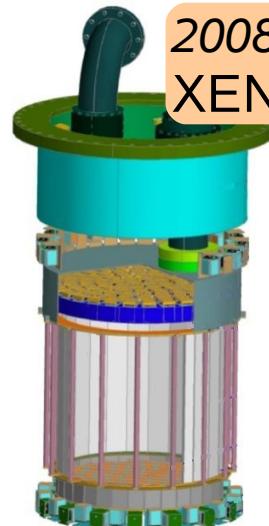


XENON
R&D

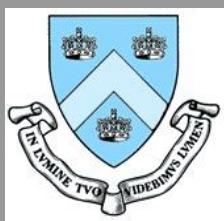
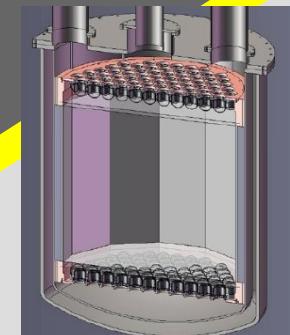
2005-2007:
XENON10



2008-2011:
XENON100



2010-2015:
XENON1T



Columbia



Rice



UCLA



U Zürich



Coimbra



LNGS



SJTU



Bologna



MPIK



NIKHEF



Mainz



Subatech



Münster WIS

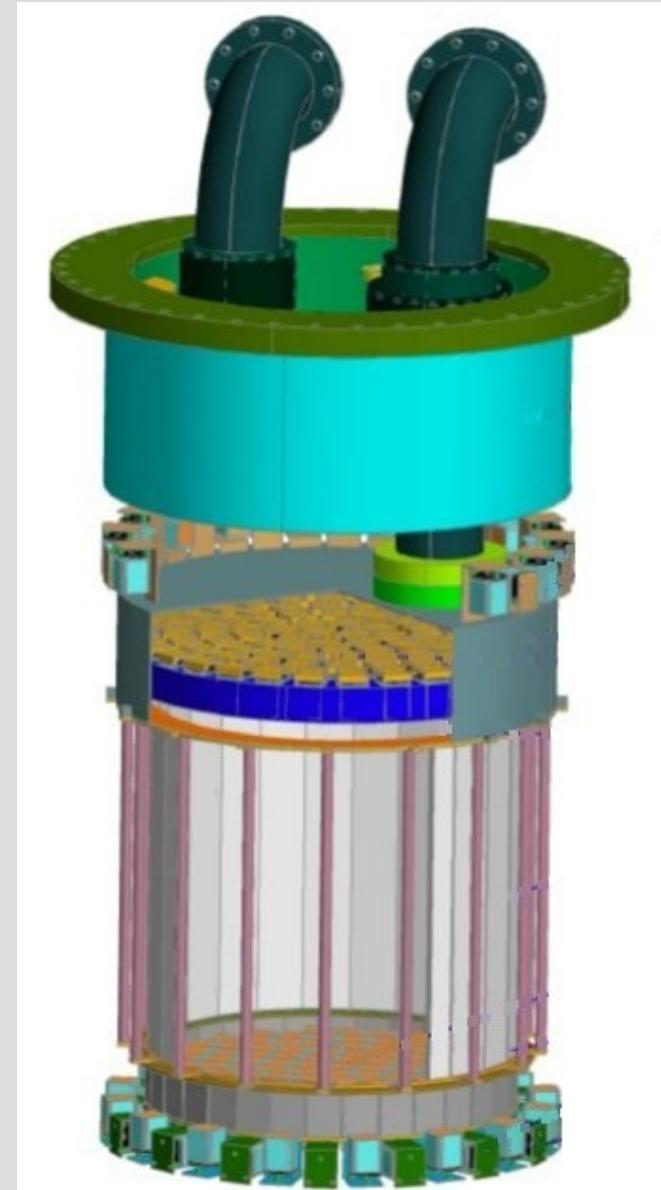
XENON100

Goal (compared to XENON10):

- increase target $\times 10$
- reduce gamma background $\times 100$
 - material selection & screening
 - detector design

Quick Facts:

- 161 kg LXe TPC (mass: $10 \times$ Xe10)
- 62 kg in target volume
- active LXe veto (≥ 4 cm)
- 242 PMTs
- improved Xe10 shield
(Pb, Poly, Cu, H₂O, N₂ purge)



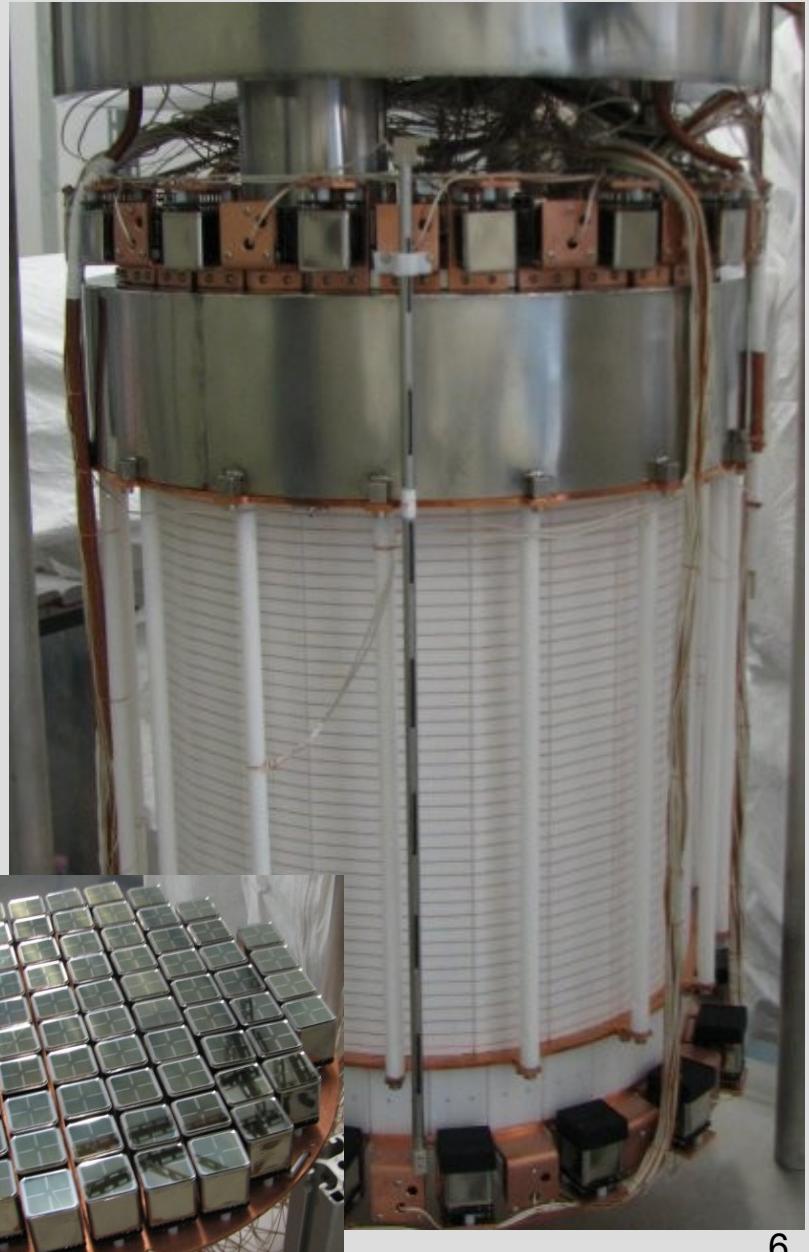
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- 242 PMTs (Hamamatsu R8520)
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(Pb, Poly, Cu, H₂O, N₂ purge)



XENON100

Goal (compared to XENON10):

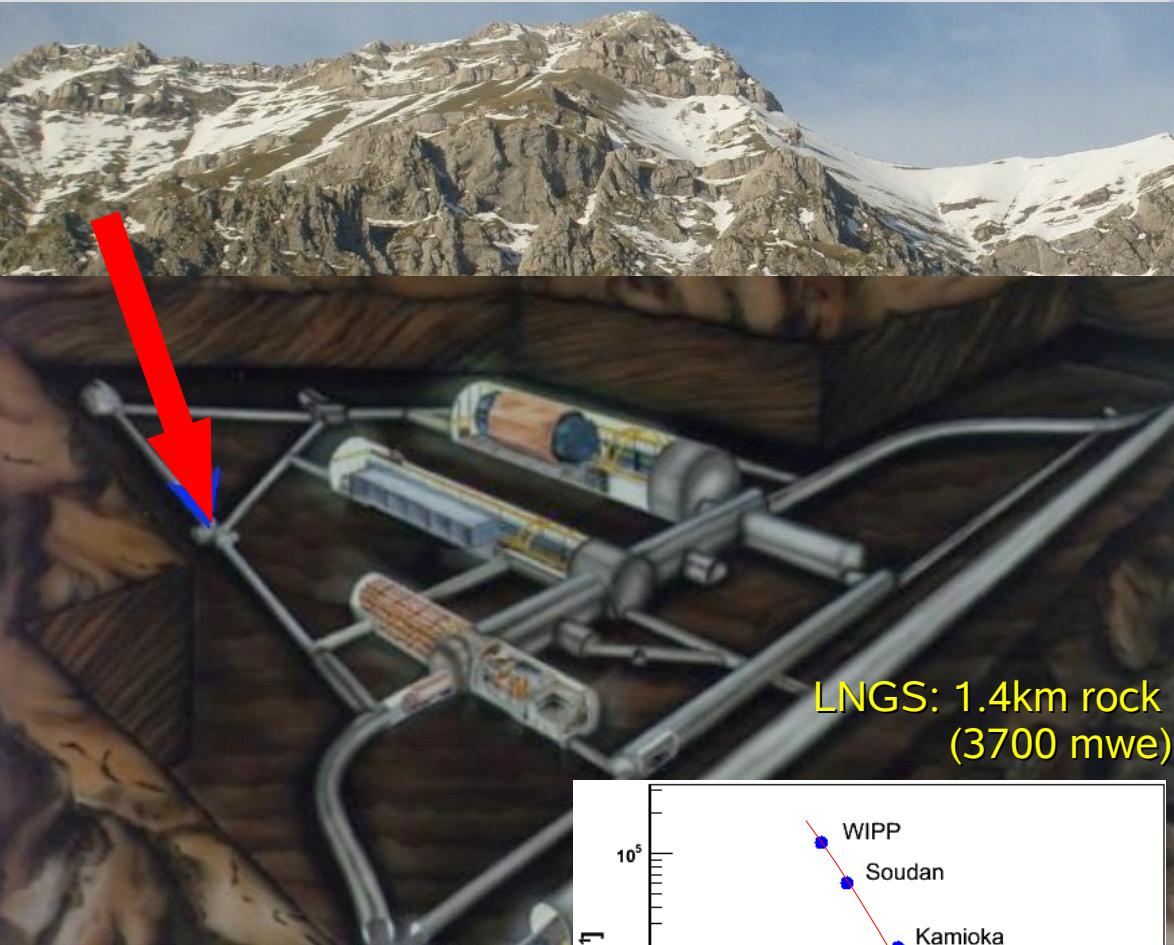
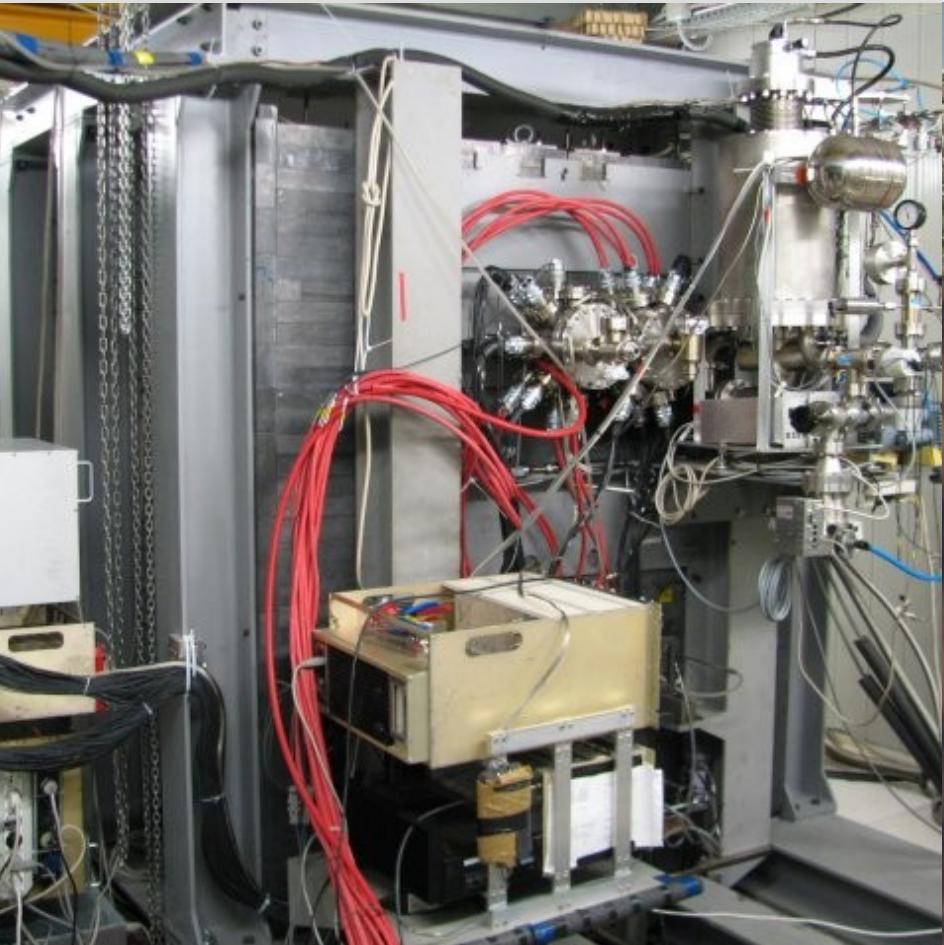
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- detector design

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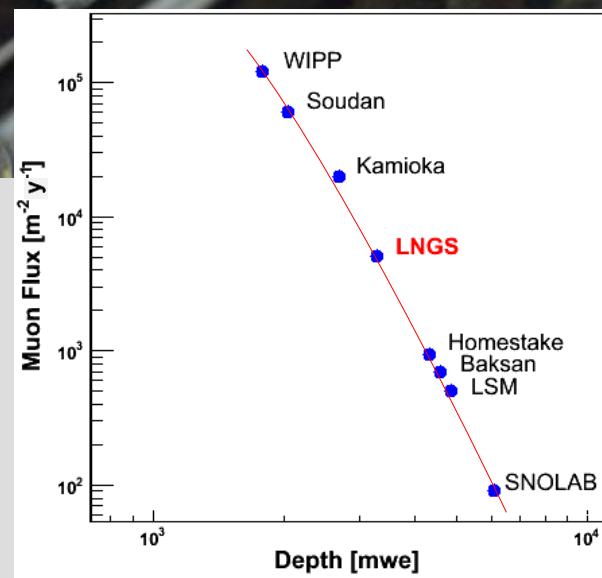
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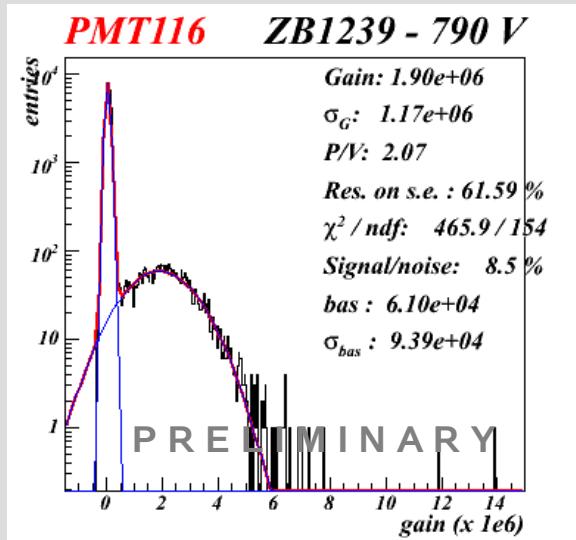
XENON100 @ LNGS



underground since end of February 08
first filled with Xe in mid May 08
extensive calibrations, first science data



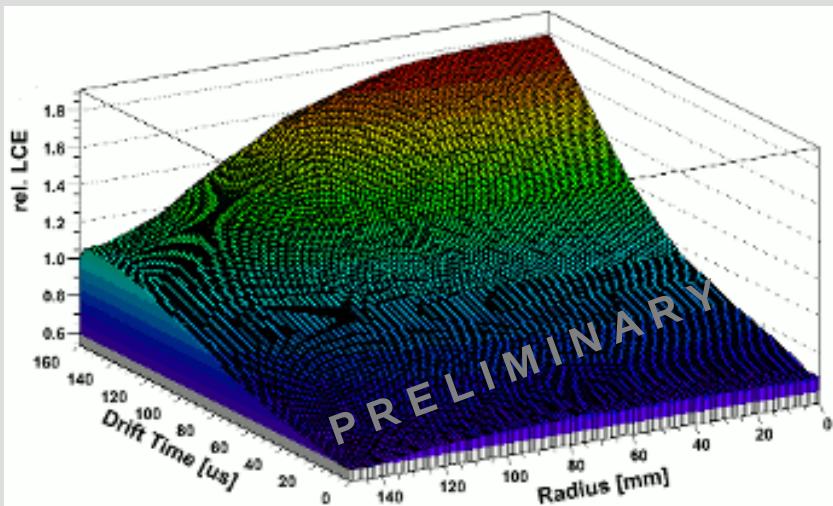
Calibration I



Gain calibration, Gain Stability:
blue LED (+optical fibers)
→ gains stable within $\pm 2\%$ (σ/μ)

Average Light Yield, combined E -Scale:
Cs-137, AmBe inelastic (40 keV, 80 keV),
Xe* (164 keV, 236 keV), Co-60, ...

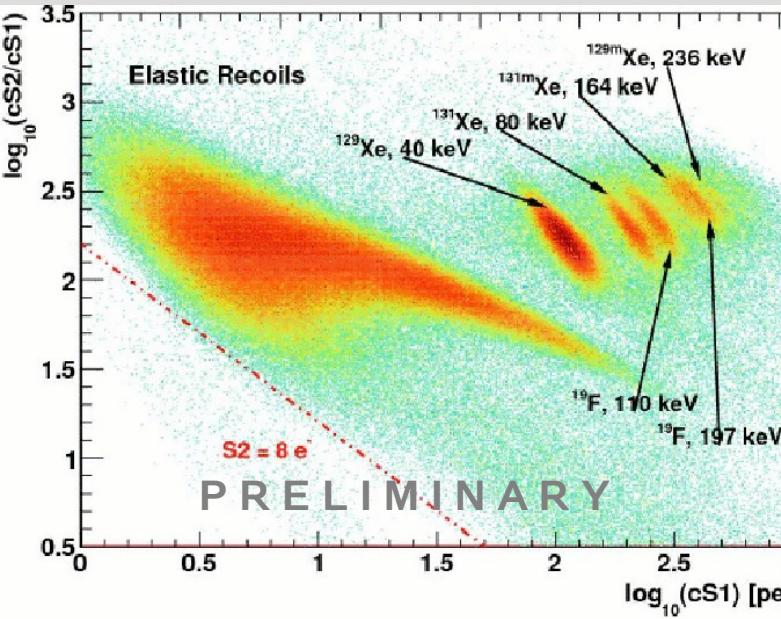
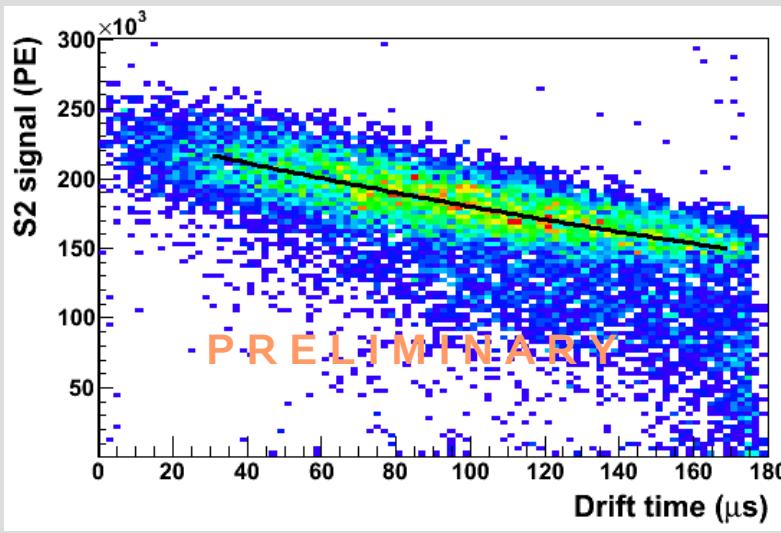
→ LY(122 keVee) = 2.20(9) PE/keVee



Position dependent Corrections:
Cs-137, AmBe inelastic (40 keV),
Xe* (164 keV)
Kr-83m (planned)

→ Agreement better than 3%

Calibration II



Electron Lifetime:
Cs-137

→ $\sim 200 \mu\text{s}$ (11.2d), up to $400 \mu\text{s}$ (run_08)

Position Reconstruction Tests:
Co-57 (collimated), Cs-137, + MC

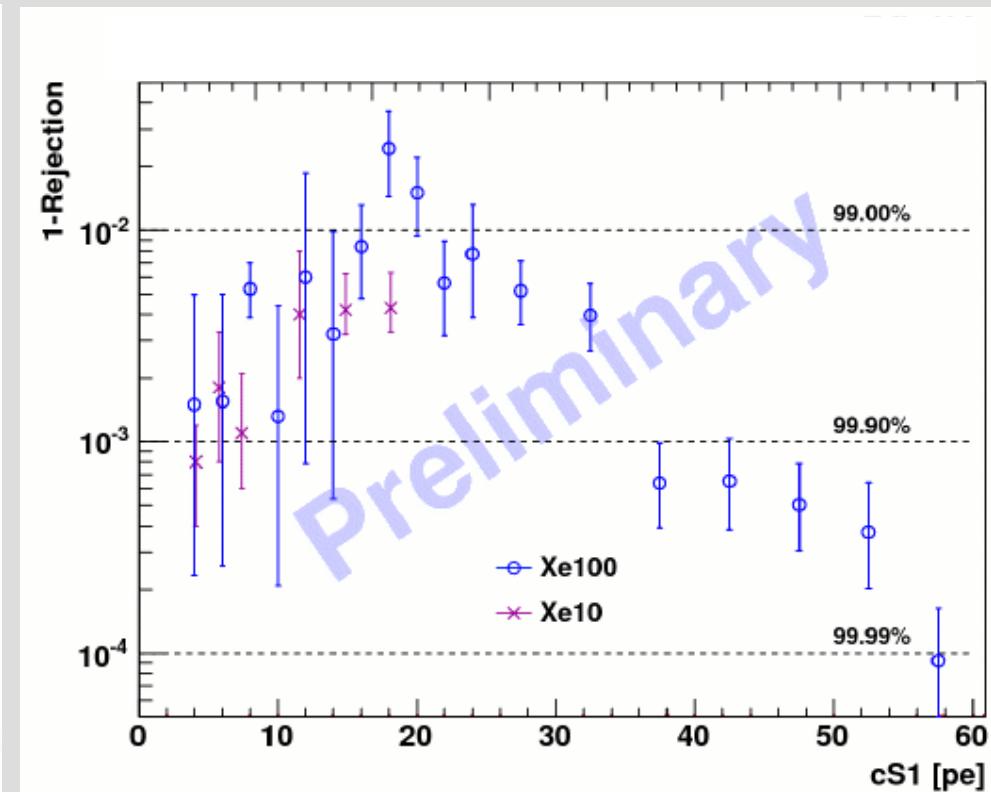
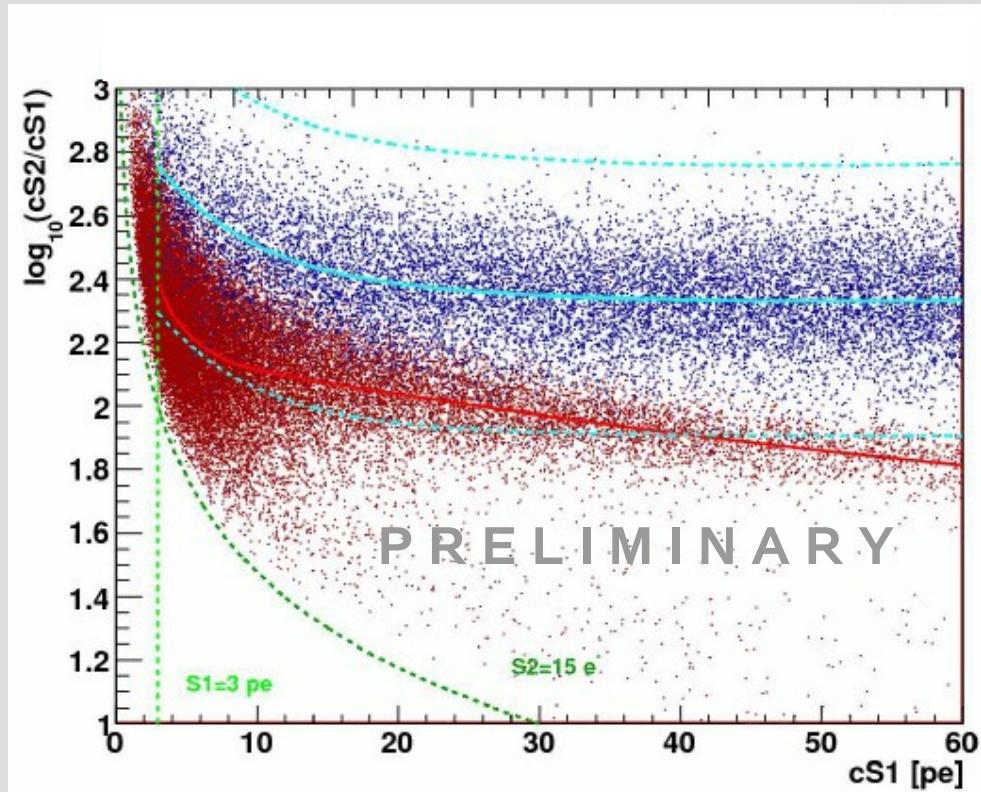
→ 3 algorithms (NN, SVM, χ^2) available:
 $\Delta r < 3 \text{ mm}$, $\Delta z < 2 \text{ mm}$

Electron Recoil Band (Background):
Co-60, Cs-137, Th-228

Nuclear Recoil Band (Signal):
Neutrons: AmBe

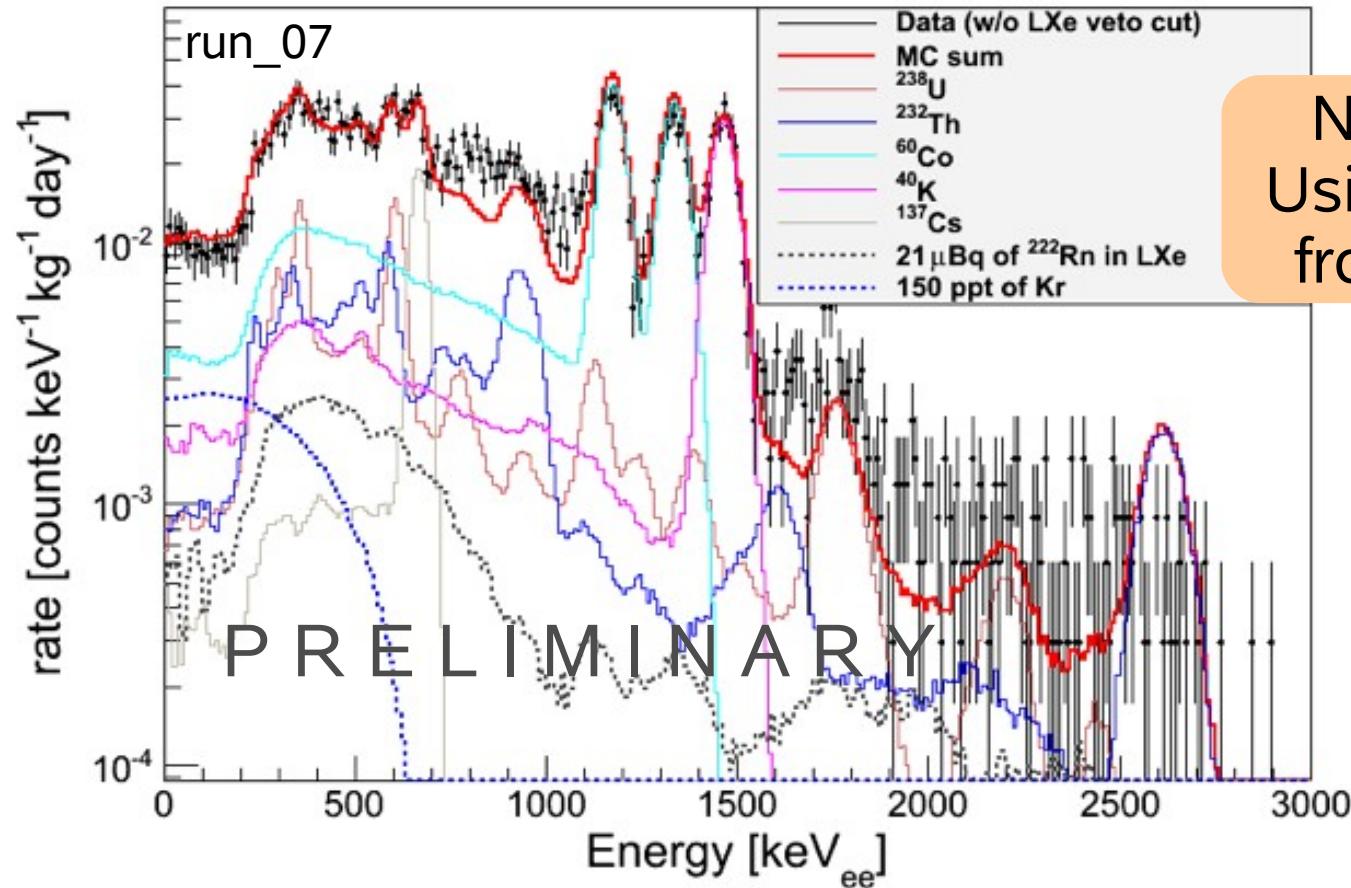
→ definition of WIMP search region,
discrimination

ER / NR Discrimination



- ER/NR discrimination via $S2/S1$ ratio
- Discrimination efficiency similar to XENON10 (>99%)

XENON100 Background

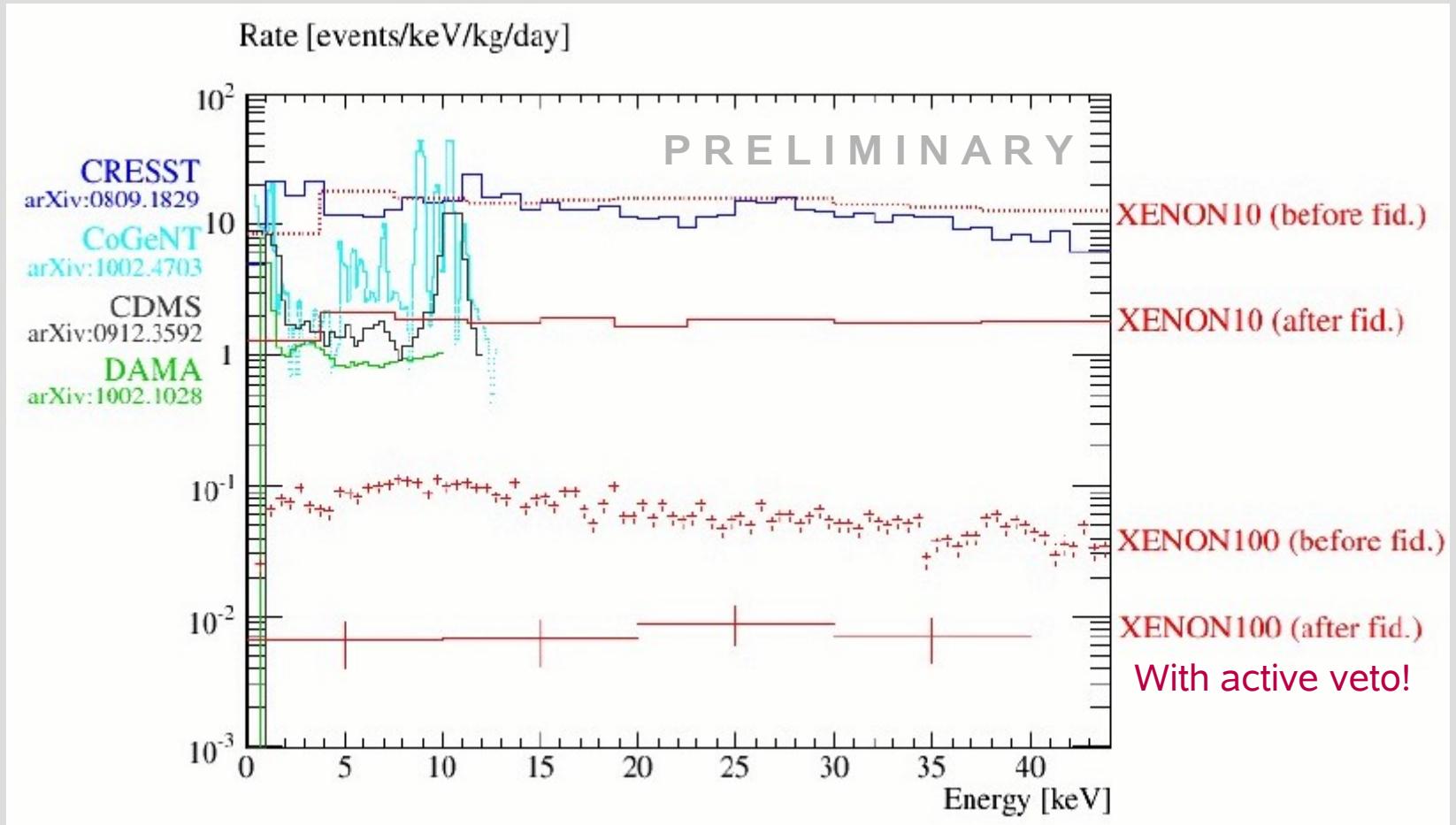


No MC tuning!
Using only values
from screening.

- 30 kg fiducial mass
- active LXe veto not used for this plot
- exploit anti-correlation between light and charge for better ER-energy scale

Measured Background in
good agreement with
Monte Carlo prediction.

Background Comparison



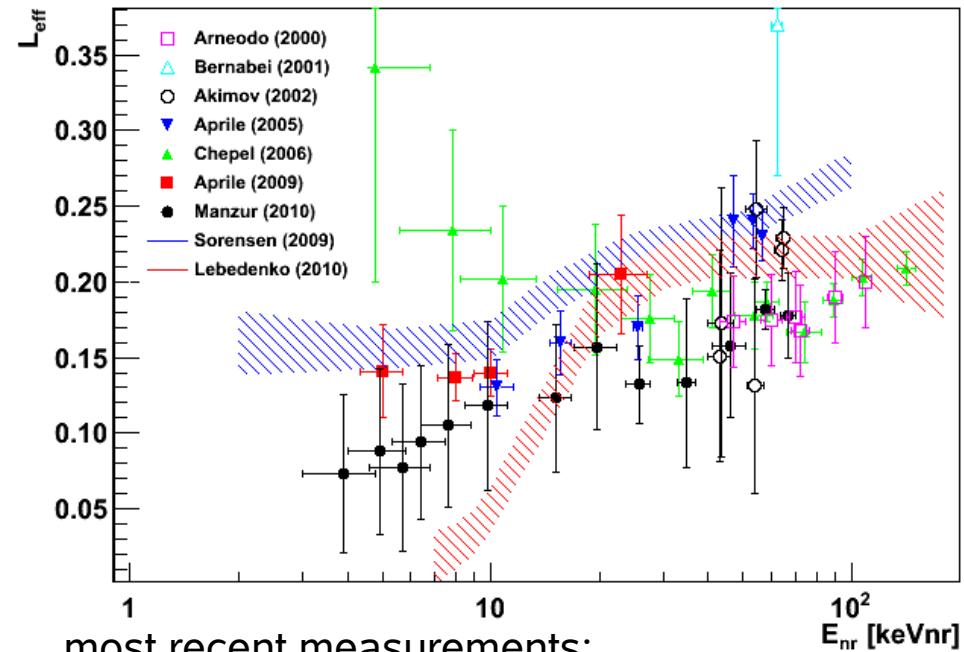
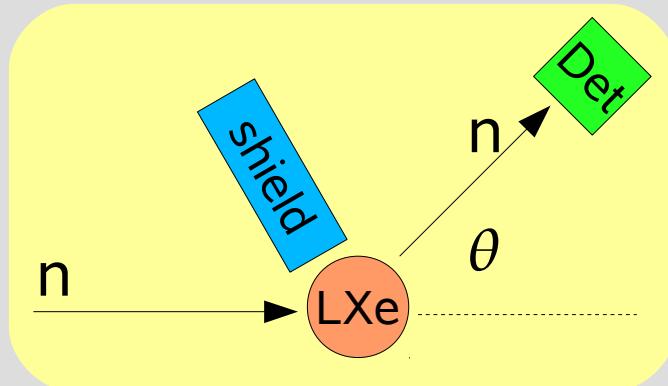
This is the lowest Background ever achieved in a Dark Matter Experiment!

Nuclear Recoil Scale

- WIMPs interact with Xe nucleus
→ nuclear recoil (nr) scintillation (β and γ 's produce electron recoils)
- absolute measurement of nr scintillation yield is difficult
→ measure relative to Co57 (122keV)
- relative scintillation efficiency L_{eff} :

$$\mathcal{L}_{\text{eff}}(E_{\text{nr}}) = \frac{\text{LY}(E_{\text{nr}})}{\text{LY}(E_{\text{ee}} = 122 \text{ keV})}$$

measurement principle:



most recent measurements:

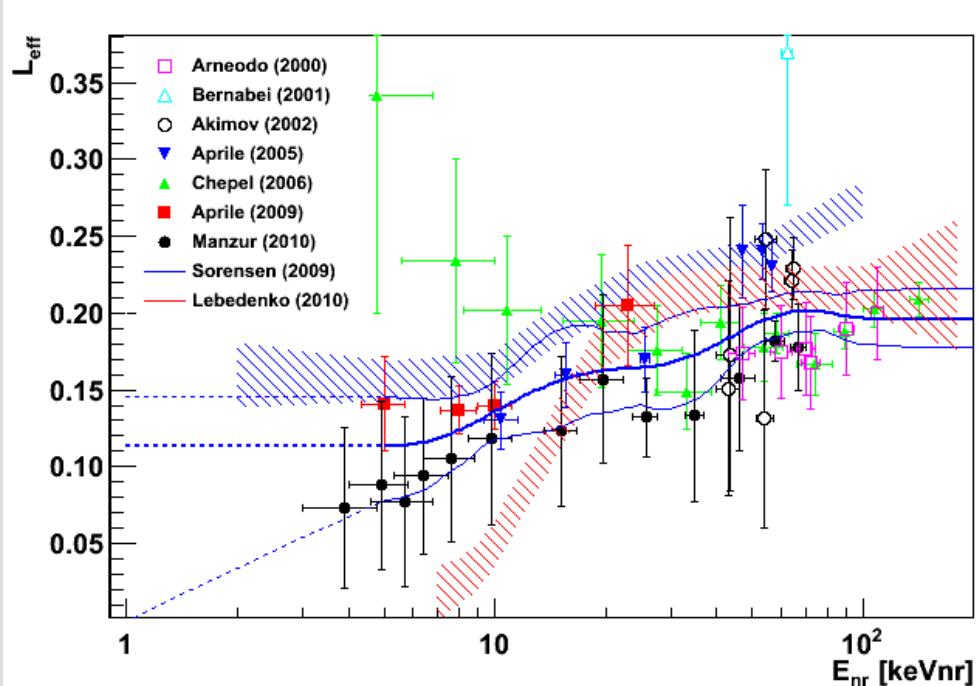
- Aprile *et al.*, PRC 79, 045807 (2009)
- Manzur *et al.*, PRC 81, 025808 (2010)

for discussion of possible systematic errors see
A. Manalaysay, arXiv:1007.3746

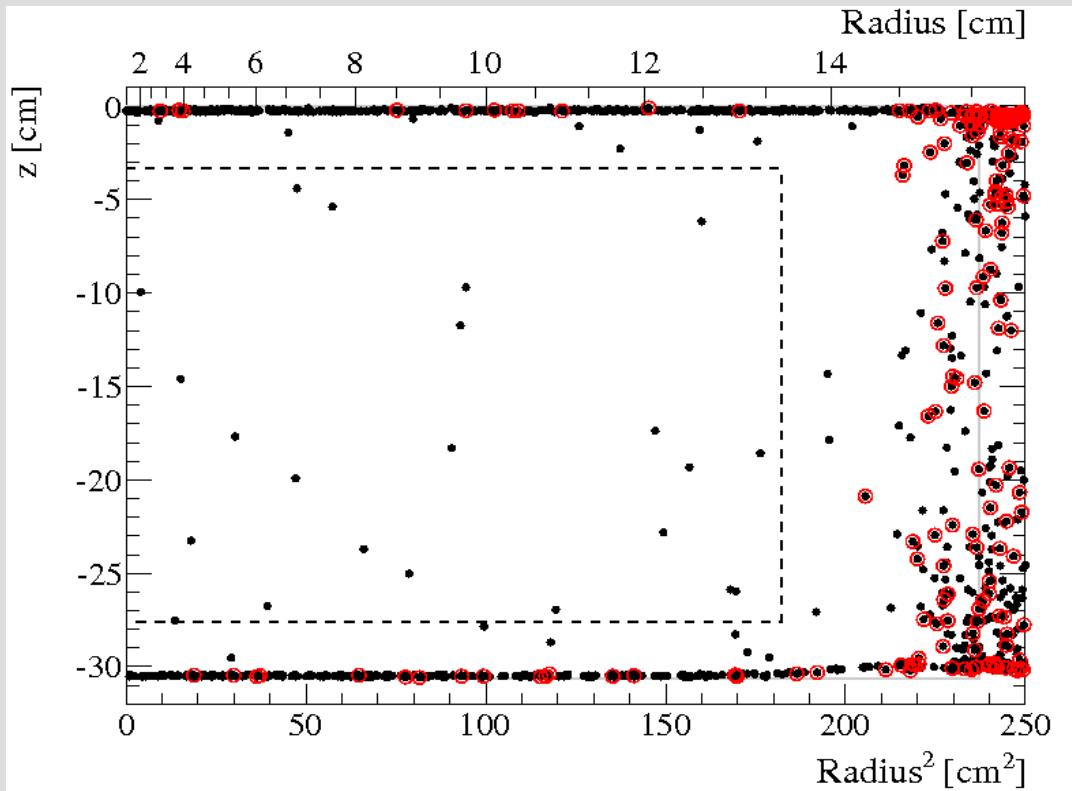
Nuclear Recoil Scale II

- difficult measurements
- measurements differ systematically
- large uncertainties
- direct measurements vs. indirect determinations
- no proper theoretical model available

- do not prefer single measurement
 (not even our own ones)
- global fit to all direct measurements
- get 90% CL from statistics
- extrapolation to low energies motivated by available data



First XENON100 Data

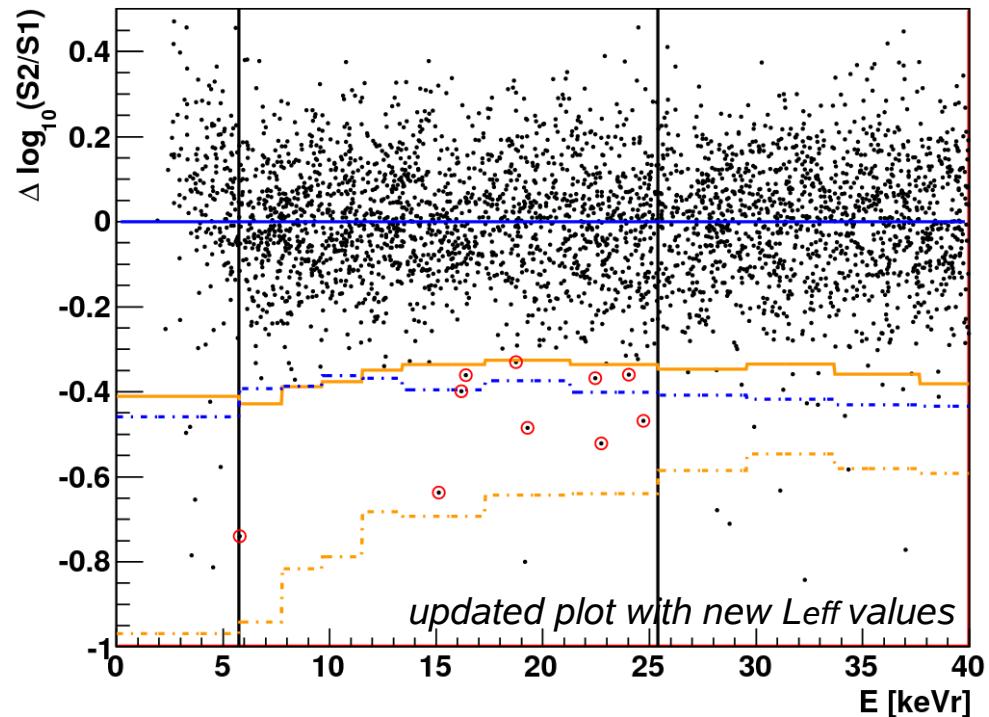


- Energy cut: <30 keVnr
- make use of excellent self-shielding capability of LXe
- 40 kg fiducial mass

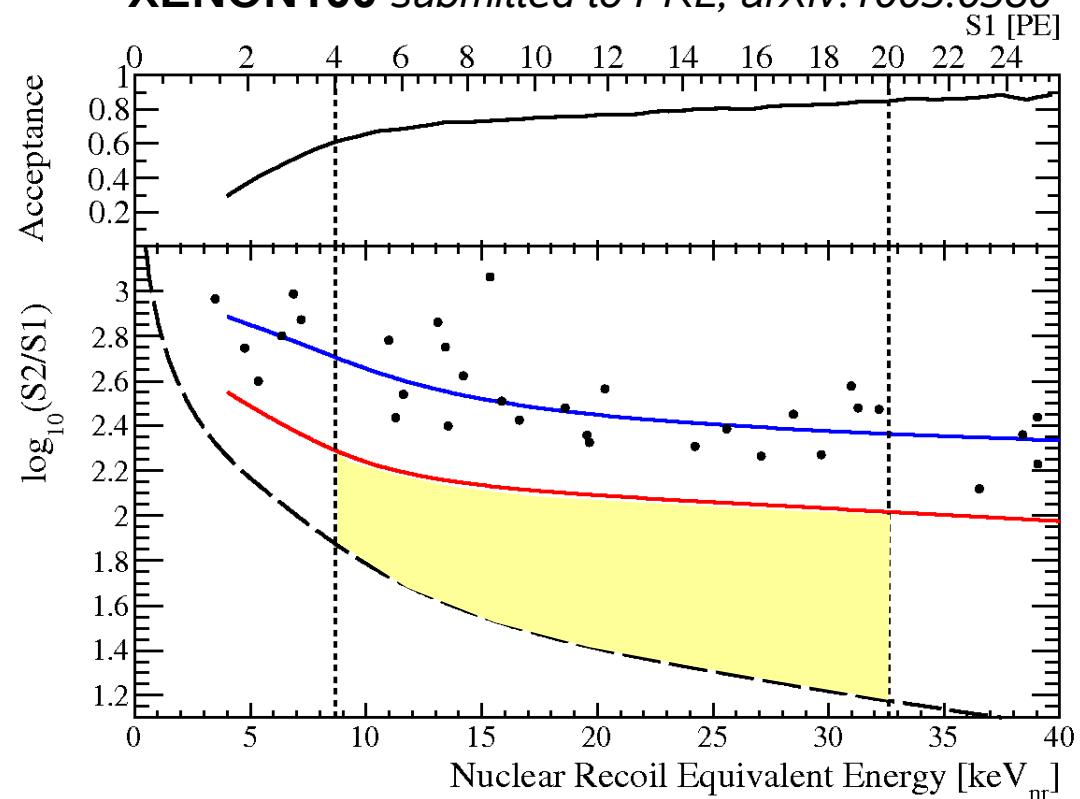
- Background data taken in stable conditions Oct-Nov 2009
- 11.2 life days
- Data was not blinded
- But: Cuts developed and optimized on calibration data only
- submitted to PRL
arXiv:1005.0380

A Look at the Bands

XENON10 PRL 100, 021303 (2008)



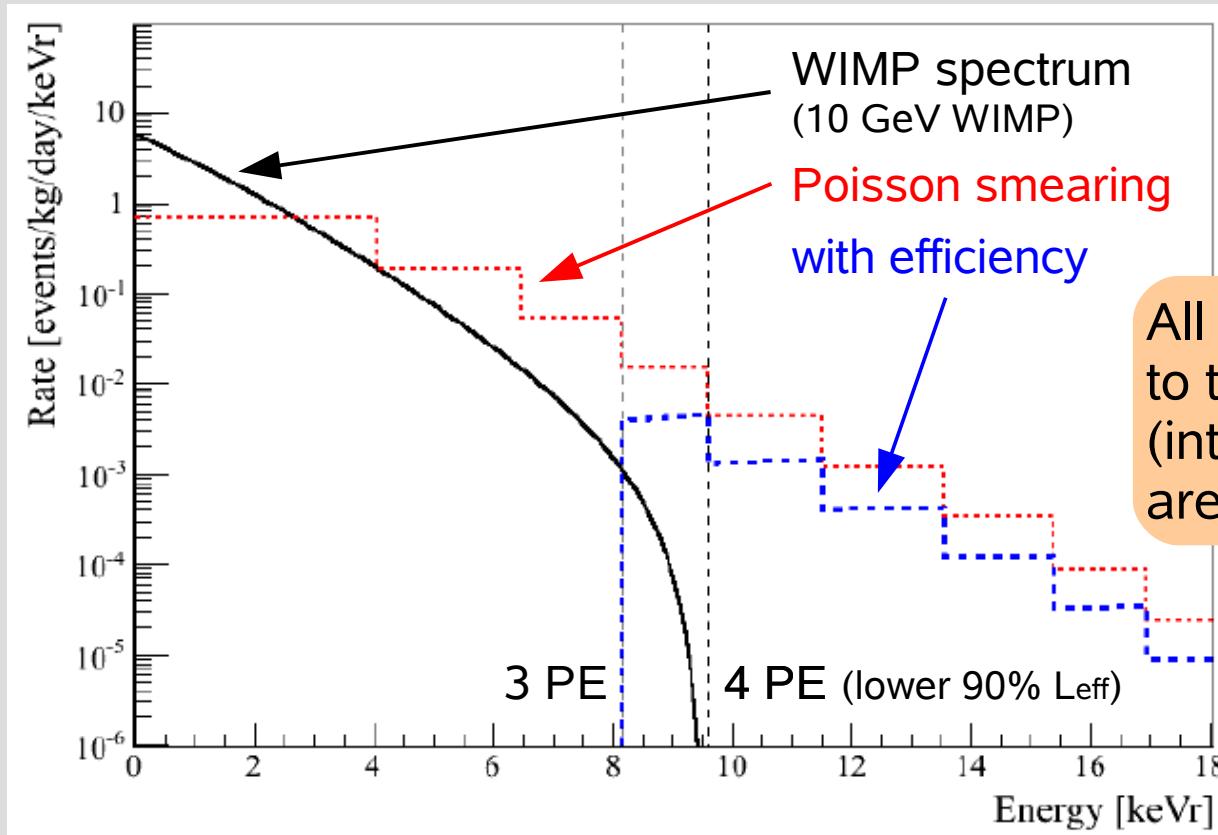
XENON100 submitted to PRL, arXiv:1005.0380



- Background free in 11.2 days after S2/S1 discrimination
- Both plots show similar exposure

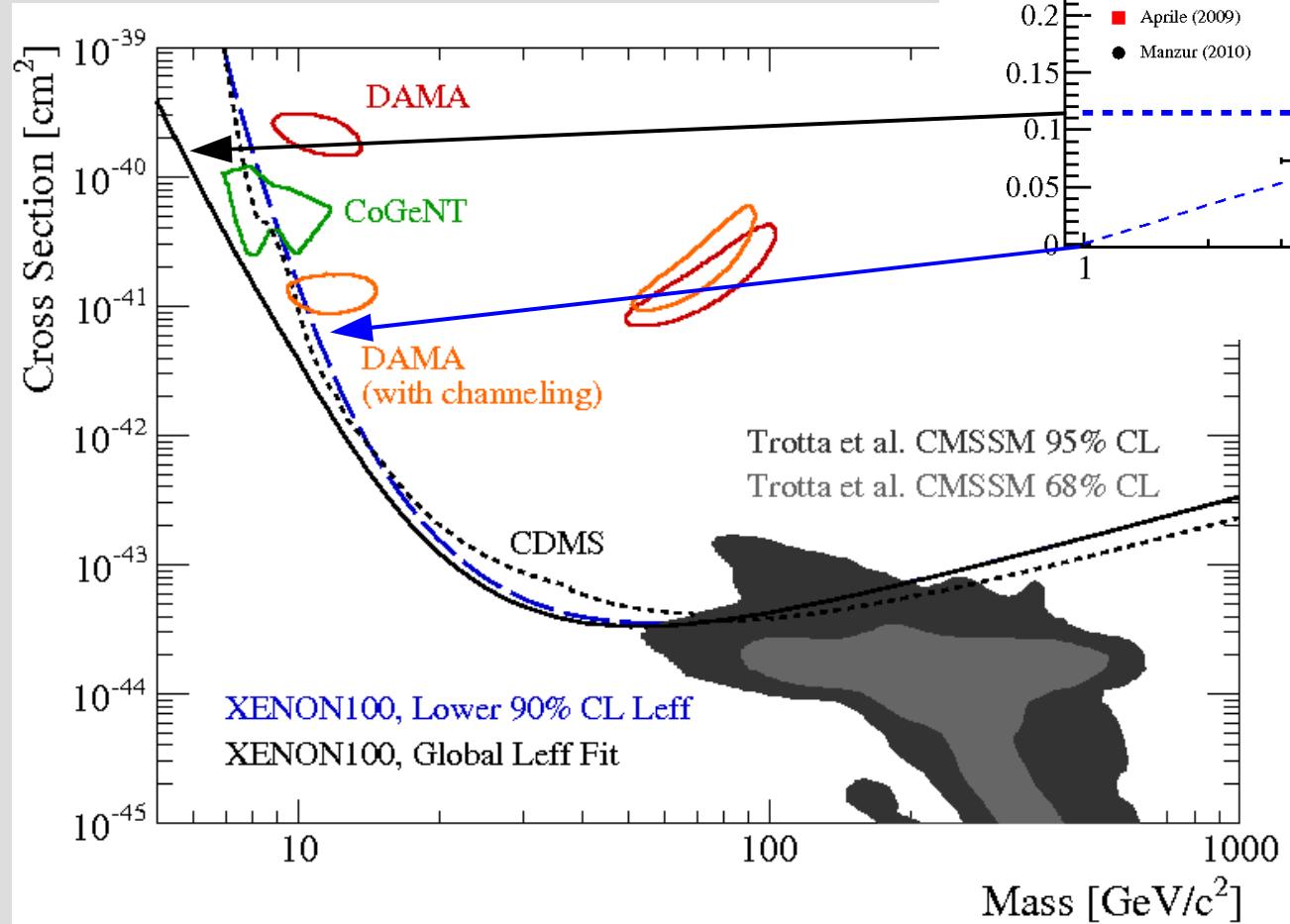
NR acceptance = 50%
cut efficiency ~ 60-85 %
(conservative)
Background expectation $\ll 1$

Poisson Smearing



- Resolution at low E is dominated by Poisson counting statistics
→ a few photoelectrons seen by PMTs
- WIMP spectrum is expected to drop exponentially with E
→ more events make it above threshold than vice versa

A first Limit from XENON100

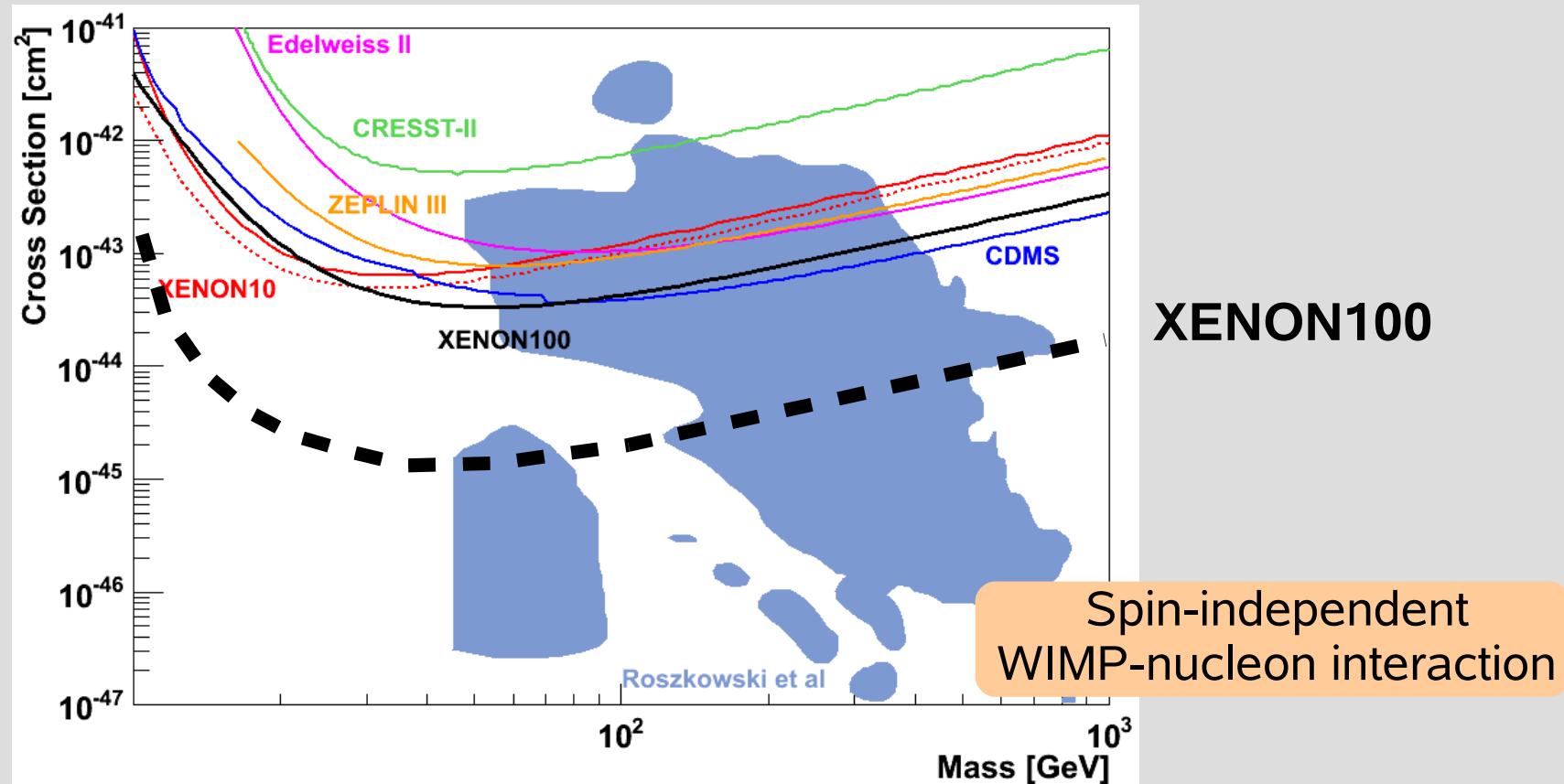


XENON100 is working extremely well and is back at the sensitivity frontier.

This is just a first glimpse! We have much more (blinded) data waiting to be analyzed.

Results submitted to PRL.
arXiv: 1005.0380

XENON100: Sensitivity



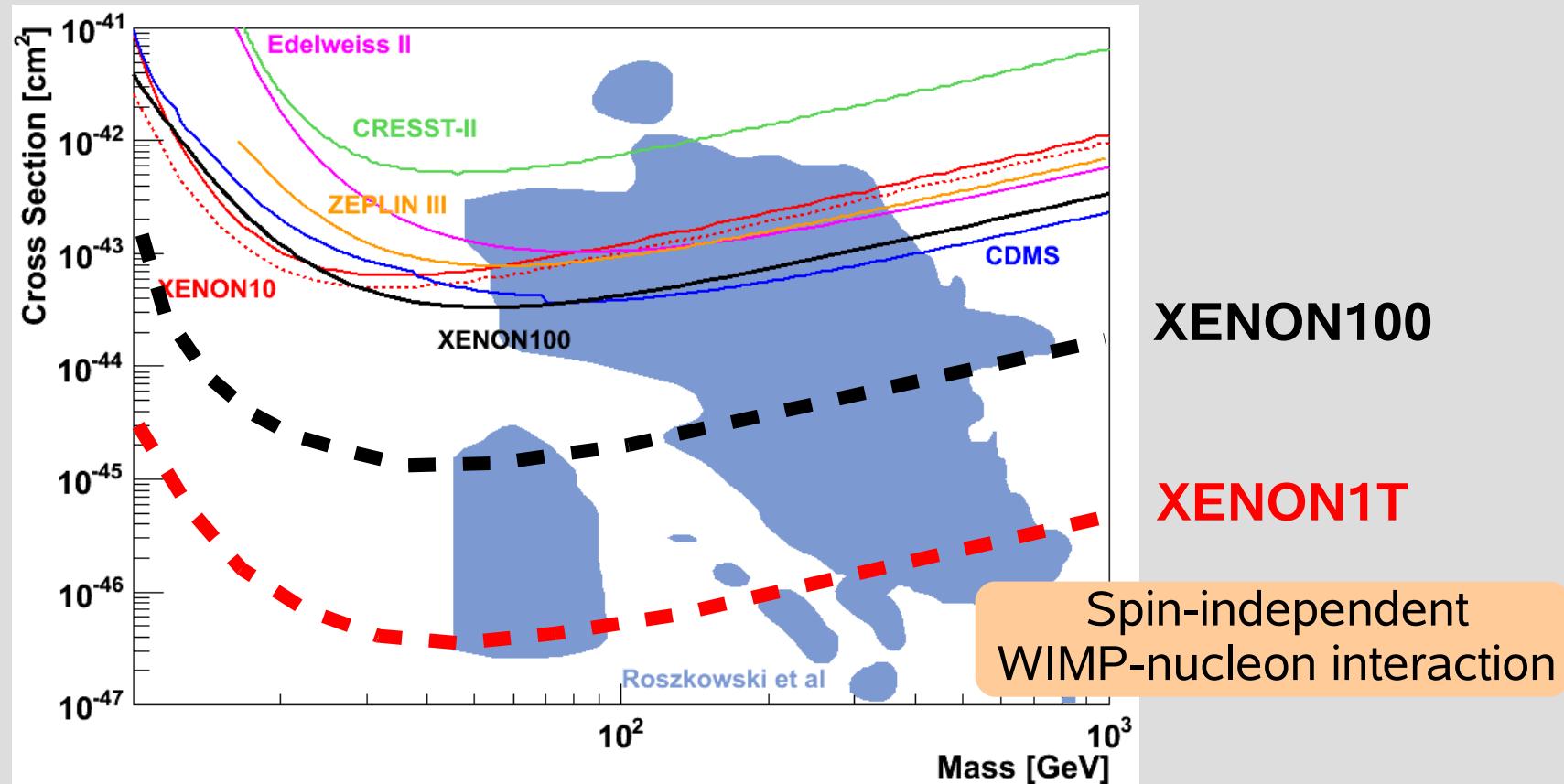
50 kg Target: 40 days

$\sigma = 6 \times 10^{-45} \text{ cm}^2$ (@ 100 GeV)

30 kg Target: 200 days

$\sigma = 2 \times 10^{-45} \text{ cm}^2$ (@ 100 GeV)

XENON100: Sensitivity



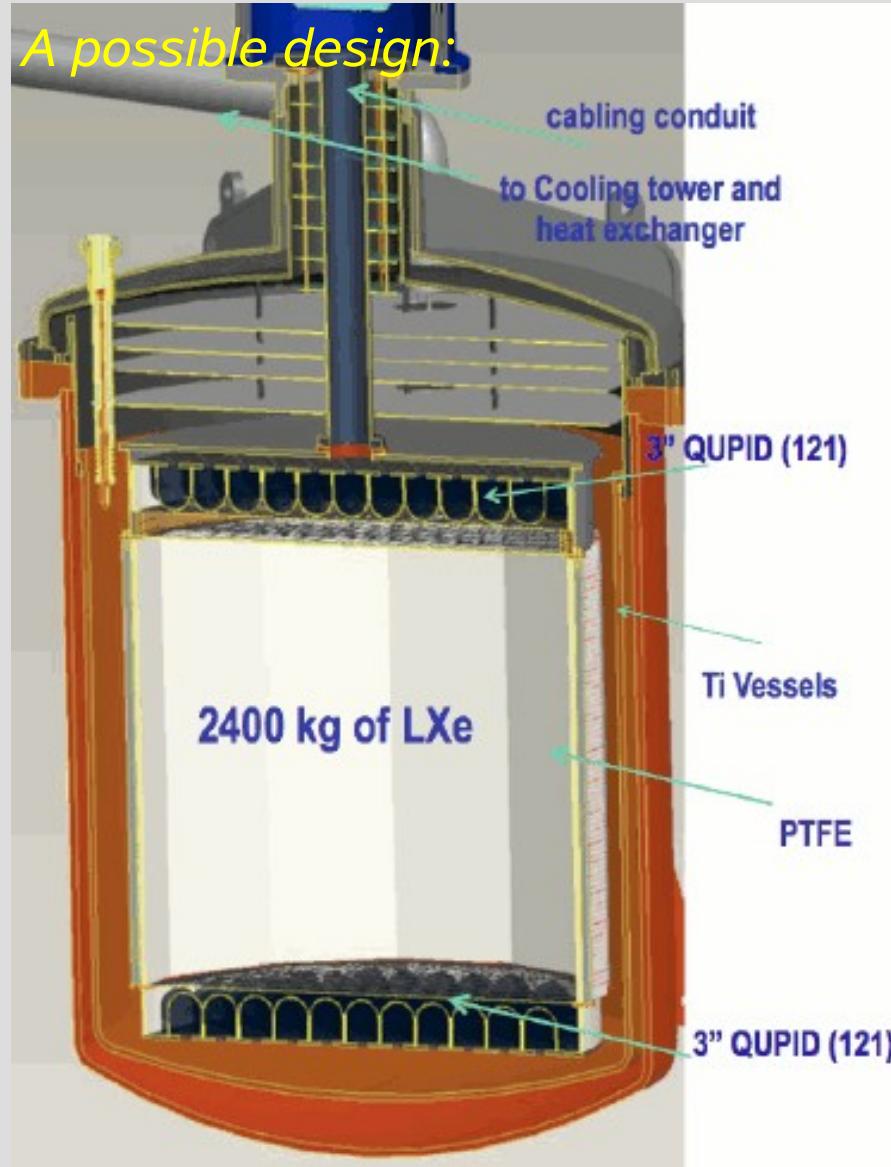
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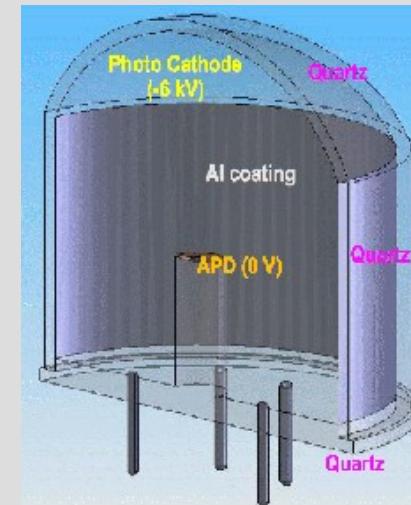
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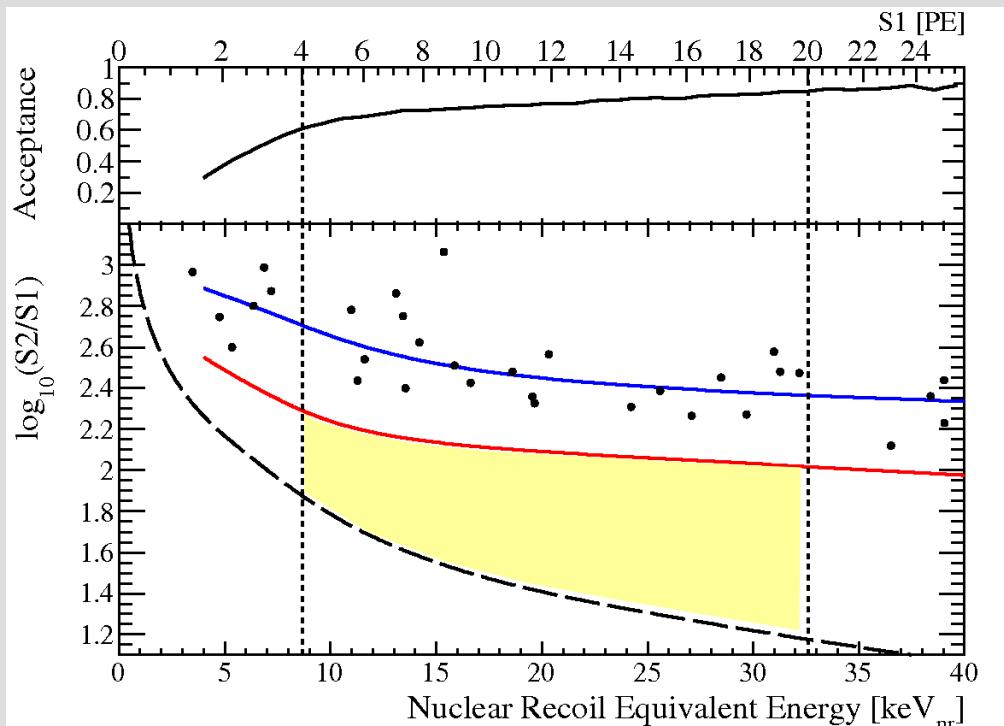
The next step: XENON1T



- 2.4t LXe ("1m³ detector")
1.1t fiducial mass
- 100x lower background
(10 cm self shielding, QUPID)
- in design phase
- bigger collaboration
- Two possible sites:
LNGS / Modane
- Timeline: 2010 – 2015 ???



Summary



- Dark Matter: One of the big unsolved puzzles
- **XENON100**
- 62 kg dual-phase TPC
- underground @ LNGS
- extremely low background
- first results from 11.2d data: [arXiv:1005.0380](https://arxiv.org/abs/1005.0380)
- stay tuned for new results...

