

Status of the XENON100 experiment

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On Behalf of the XENON100 Collaboration

Physik Institut
Universität Zürich

Cambridge, 3.08.2010



www.physik.uzh.ch/groups/groupbaudis/xenon/

Outline

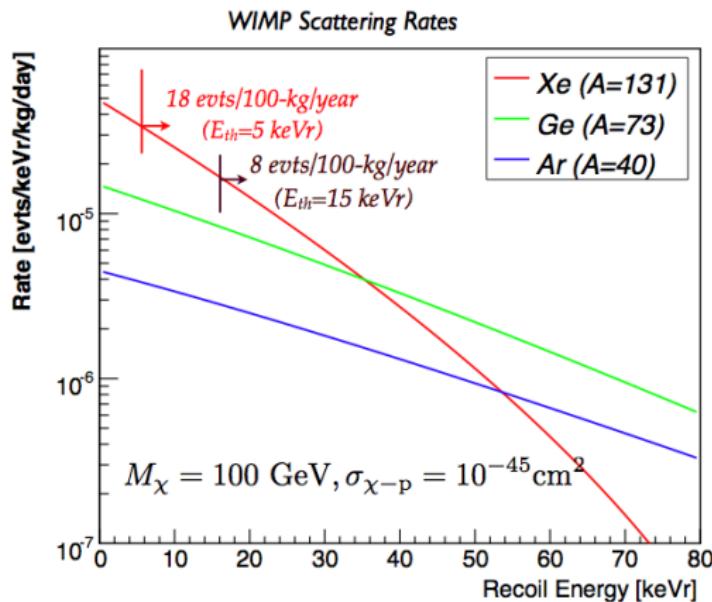
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- 2 The XENON experiment
- 3 Detector calibration
- 4 First XENON100 results
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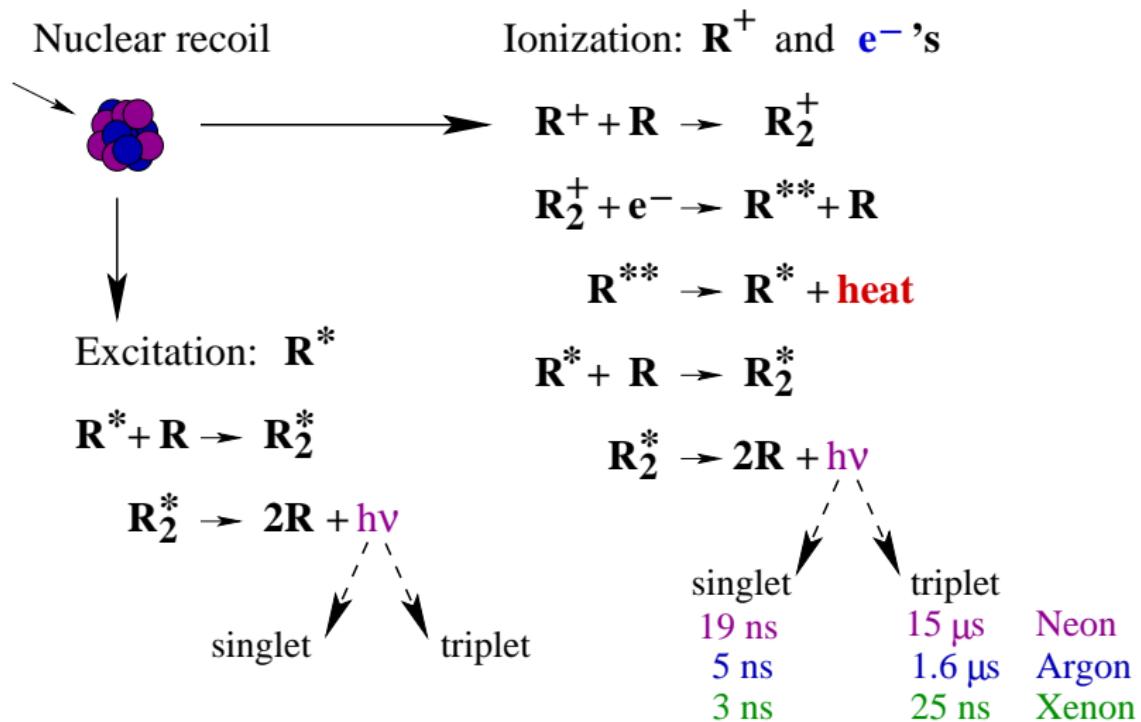
Xenon as detection medium

Detection via scatter off nuclei

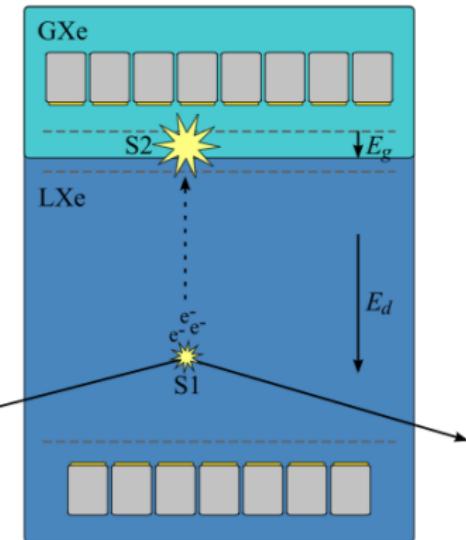


- Self-shielding
 - High stopping power
- 178 nm UV photons
 - No wavelength-shifter
- Simple cryogenics
 - ~ 180 K = -93°
- High atomic mass $A \sim 131$
 - spin-indep. interactions
- ^{129}Xe and ^{131}Xe
 - spin-dep. interactions

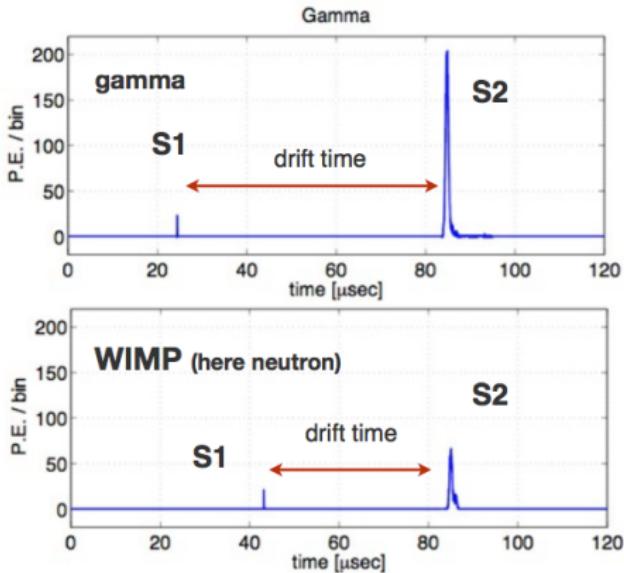
Noble gas scintillation process



Two phase noble gas TPC



- Scintillation signal (S1)
- Charges drift to the liquid-gas surface
- Proportional signal (S2)



Electron recombination is stronger for nuclear recoils

→ Electron- / nuclear recoil discrimination

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XENON experiment



- Laboratori Nazionali del Gran Sasso (Italy)
- $\sim 3\,650$ m.w.e. shielding

- **XENON10**: 15 kg active volume
 - Finished: No evidence for DM
- J. Angle *et al.*, Phys. Rev. Lett. 100, 021303 (2008)
J. Angle *et al.*, Phys. Rev. Lett. 101, 091301 (2008)
J. Angle *et al.*, Phys. Rev. D80, 115005 (2009)
- **XENON100**: 62 kg active volume
 - Currently running



XENON100 Collaboration



Columbia



Rice



UCLA



Zürich



Coimbra



LNGS



SJTU



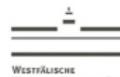
Mainz



Bologna



Subatech



Münster



Nikhef



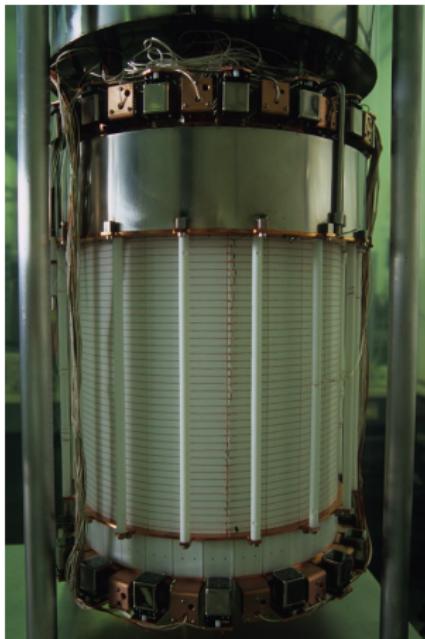
Heidelberg



Weizman

US, Switzerland, Portugal, Italy, China, Germany, Holland, France and Israel

XENON100 detector



- 30 cm drift length and 30 cm \varnothing
- 161 kg total (30-50 kg fiducial volume)
- $\sim 100\times$ less background than XENON10
- Material screening and selection
- 242 low activity 1" PMTs (R8520)
- Cooling (PTR) outside the shield
- Active liquid xenon veto



1 inch PMTs



30 cm \varnothing meshes

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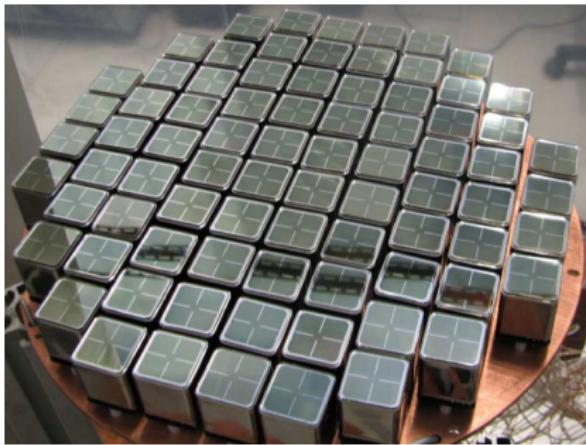
1 inch PMTs



30 cm \varnothing meshes

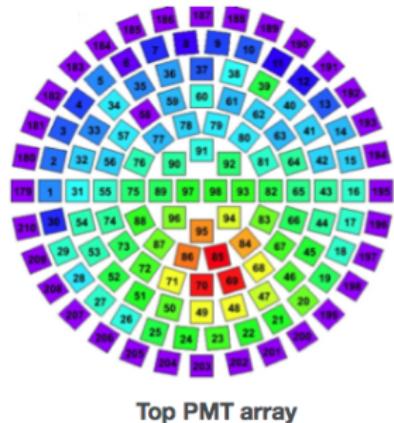
Light and charge read out

- Bottom PMTs: high quantum efficiency
(on average >30% @178 nm)

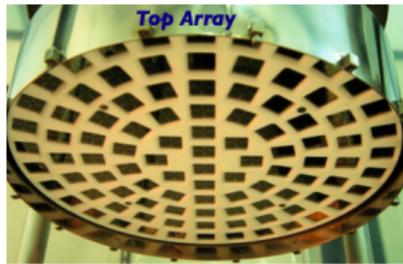


- 3 Dim. position reconstruction
 - XY from light pattern in the PMTs
 - Z from the drift time
- 3 mm resolution in XY and 2 mm in Z

gamma event localized

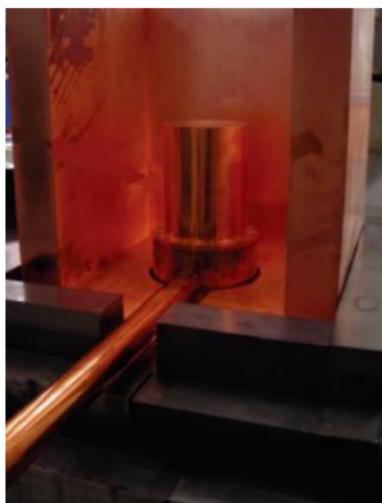


Top PMT array

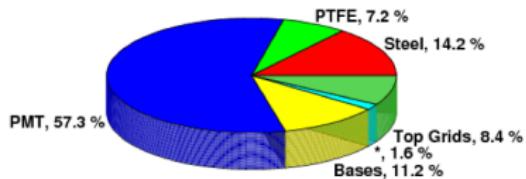


Background prediction

Material screening underground with a 2.2 kg HP Ge detector



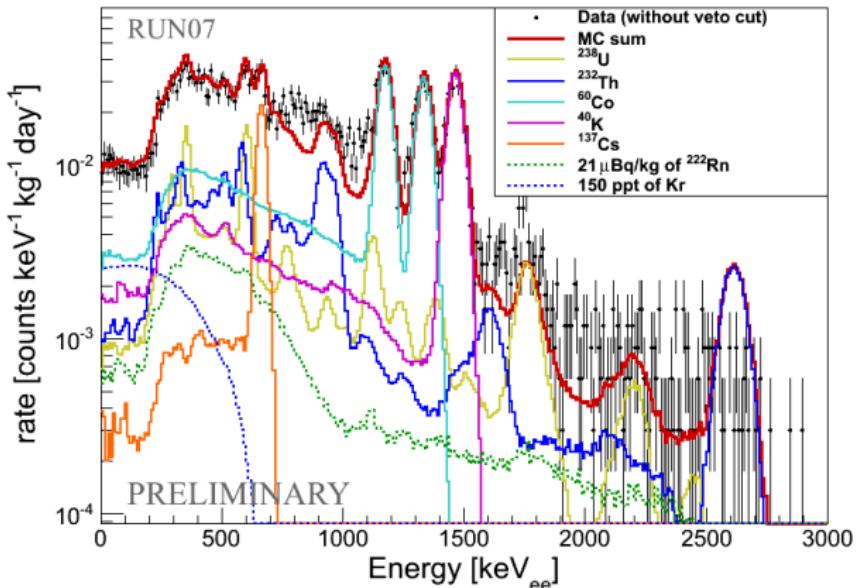
- Gamma background expected in WIMP search region:
 - $5 \cdot 10^{-3}$ evts/kg/keV/d
(before S2/S1 discrimination)



- Neutron bg from simulations:
 - 2/3 from radioactivity and 1/3 muon-induced

- Removal of ^{85}Kr : distillation column
 - Kr/Xe \sim ppm-ppb commercially available
 - Measurement in XENON100 after purification:
→ RUN07: $\sim 150\text{ ppt}$ via delayed gamma-beta coincidence

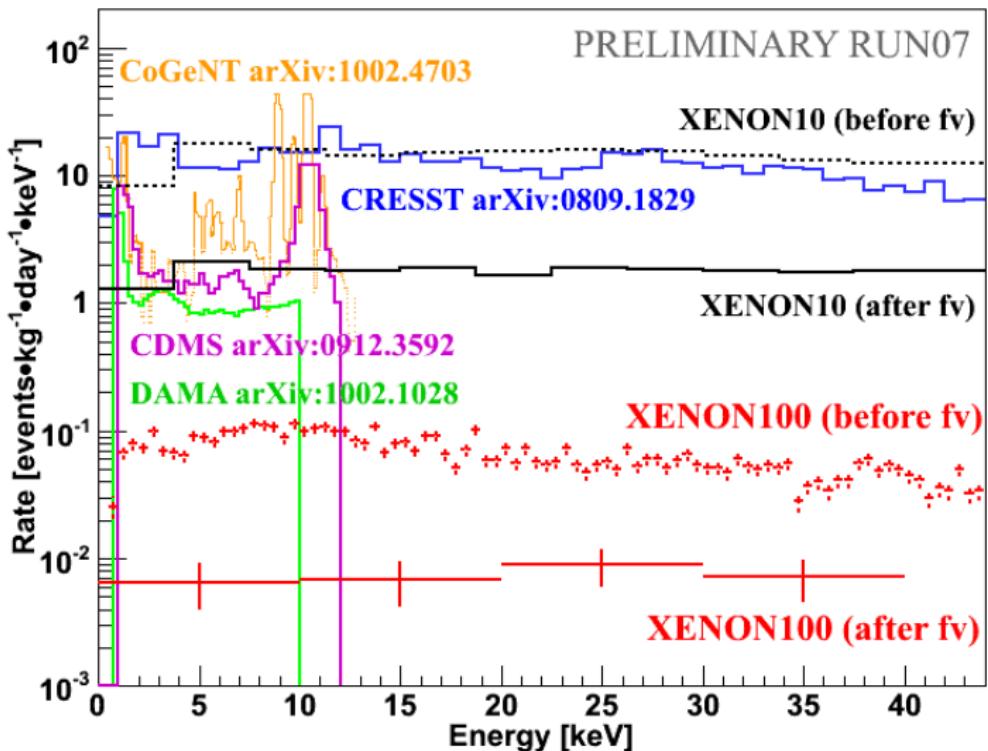
Measured background spectrum



- No tuning of the Monte Carlo
- The measured single scatter rate below 100 keVee is 10^{-2} evts/kg/keV/d without veto cut
 - is reduced by 50% with veto cut!
- Factor 100 less than in XENON10 achieved!

→ currently optimizing the data/MC comparison

Background in the low energy range

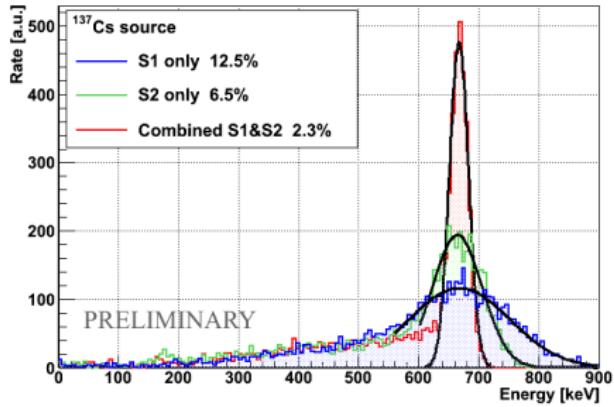
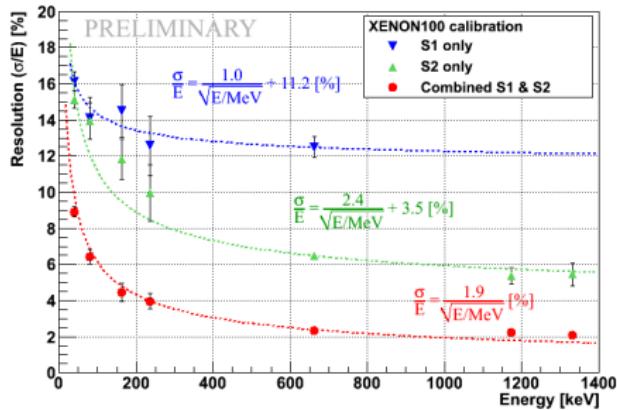
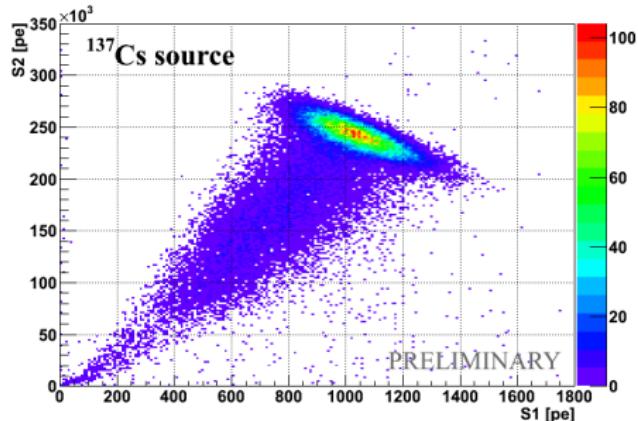


→ Lowest ever measured background rate in a dark matter experiment

Outline

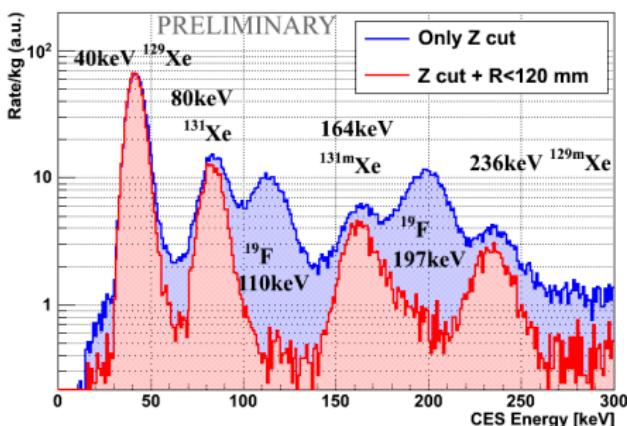
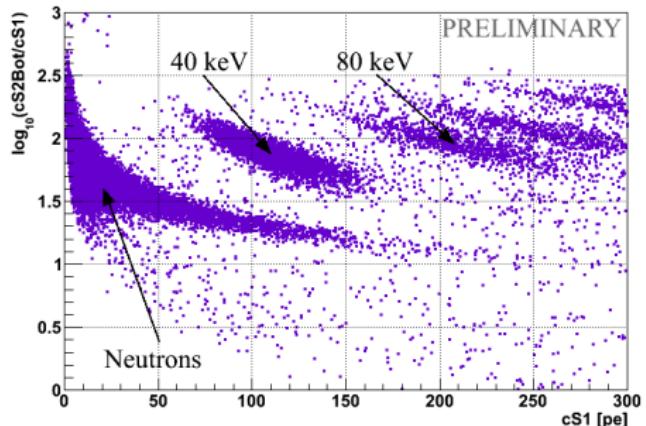
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Calibration with gamma sources



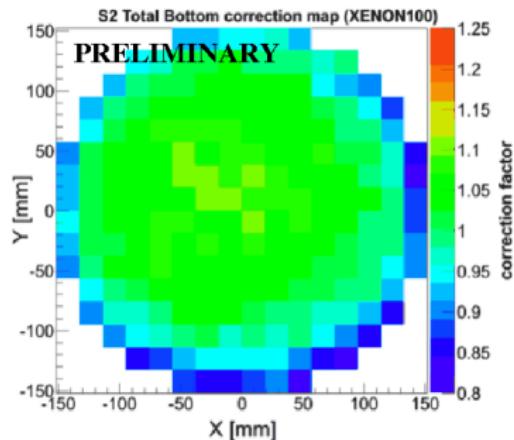
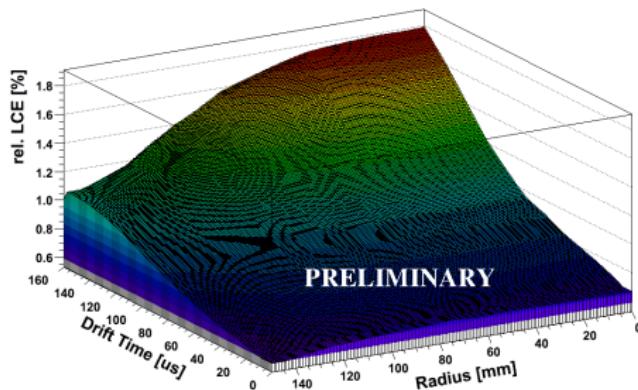
- Energy dependence of resolution in light (**S1**), charge (**S2**) and **CES** signals
- CES: combined energy scale
→ using anticorrelation between S1 and S2 signals

Neutron calibration



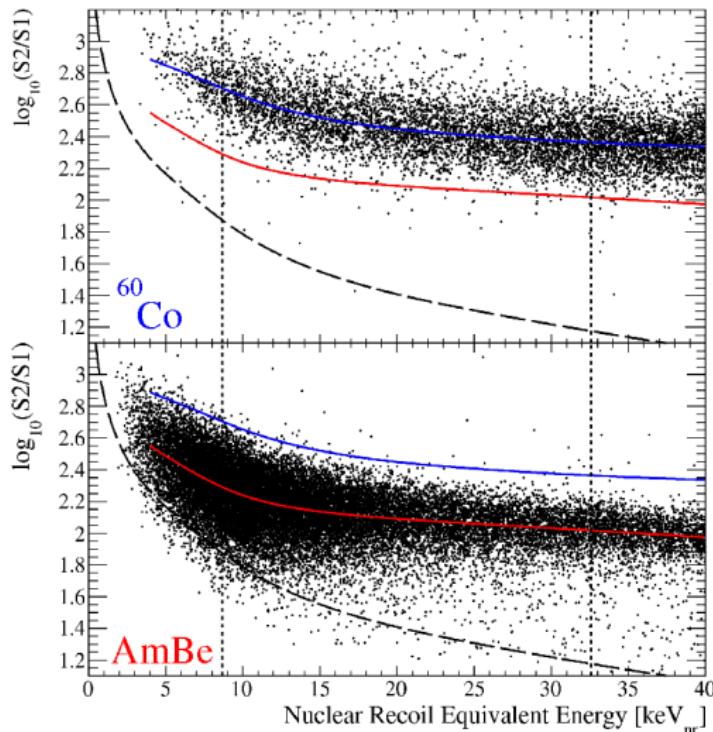
- Source: AmBe with 220n/s
- Determination of nuclear recoil band
- Further calibration lines from inelastic recoils in xenon

Corrections on the S1 and S2 signals



- Data is corrected for:
 - S1 light collection
 - S2 XY-collection
 - Electron lifetime
 - Sources used for corrections:
 - 40keV, inelastic line
 - ^{137}Cs (external)
 - 164 keV, activated xenon
- Results from different sources compatible within few %

Electronic and nuclear recoil bands



- Electronic recoil band:
defined with ^{60}Co source
- Nuclear recoil band:
defined with AmBe neutron source
- Discrimination better
than 99% @ 50% nuclear
recoil acceptance

Low energy calibration of xenon detectors

- ^{83m}Kr calibration source:

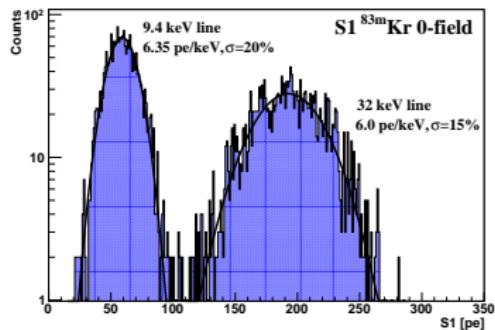
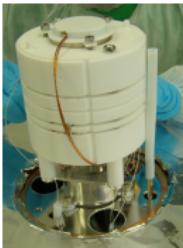
- EC decay-product of ^{83}Rb
- Lines at 9.4 and 32.1 keV
- Uniform distribution

^{83m}Kr ————— 41.5 keV (1.83 h)

↓ 32.1 keV

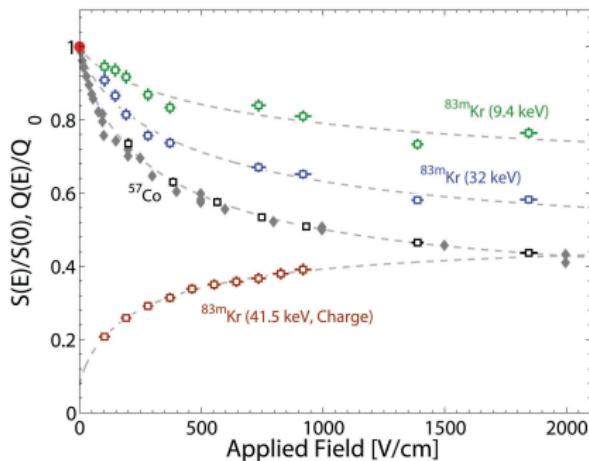
————— 9.4 keV (154 ns)

^{83}Kr ————— ↓ 9.4 keV



→ ^{83m}Kr calibration planned in XENON100

- Target mass: ~ 0.1 kg Xe
- Volume: 3 cm drift length and 3.5 cm diameter
- Two R9869 PMTs
- **6 pe/keV** in double phase
- at University of Zürich



A. Manalaysay *et al*, Rev. Sci. Instrum. **81**, 073303 (2010)

Calibration of the nuclear recoil energy scale

- Nuclear recoil energy (E_{nr}):

$$E_{nr} = \frac{S_1}{L_y L_{eff}} \times \frac{S_e}{S_r}$$

S_1 : measured signal in p.e.

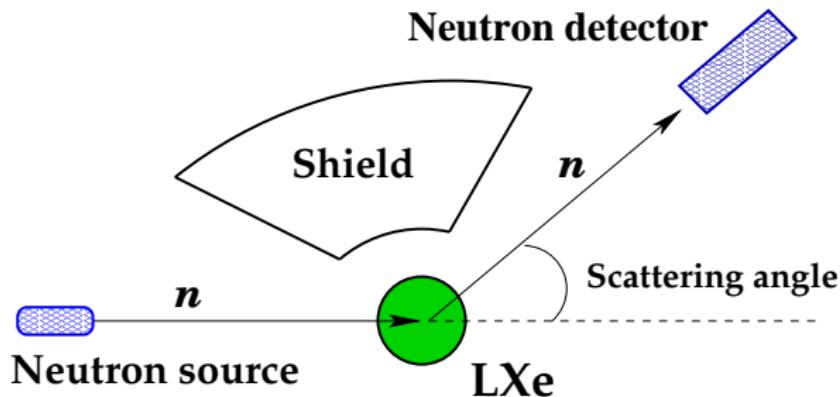
L_y : LY for 122 keV γ in p.e./keV

S_e/S_r : quenching for 122 keV γ /NR due to drift field

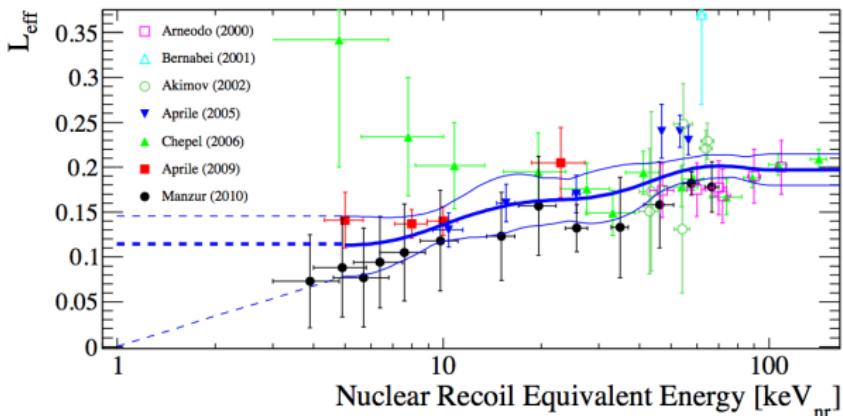
- Relative scintillation efficiency of NR to 122 keV γ at 0-field

$$L_{eff} = q_{nucl} \times q_{el} \times q_{esc}$$

- q_{nucl} : Linhard quenching
- q_{el} : Electronic quenching
- q_{esc} : Escape e^- 's at 0-field



Measuring the nuclear recoil scale



- Efforts within the collaboration to measure below 5 keV_{nr}



- Columbia and Zürich chambers
- First measurements done at Columbia!

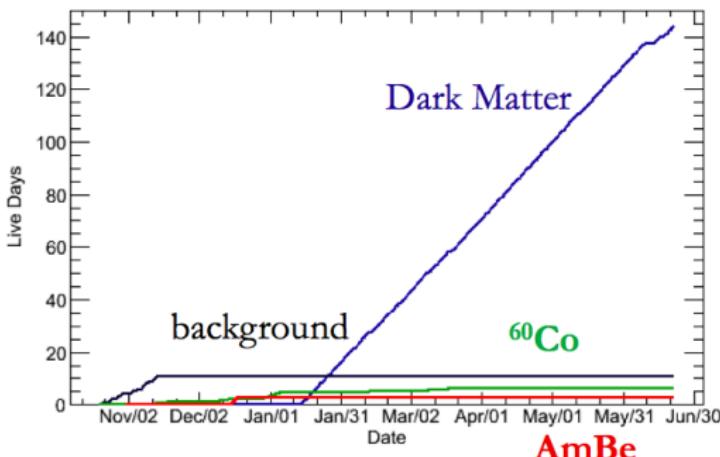
Discussions on L_{eff} measurements:
A. Manalaysay, arXiv:1007.3746

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Data sample

Overview of the data taking:



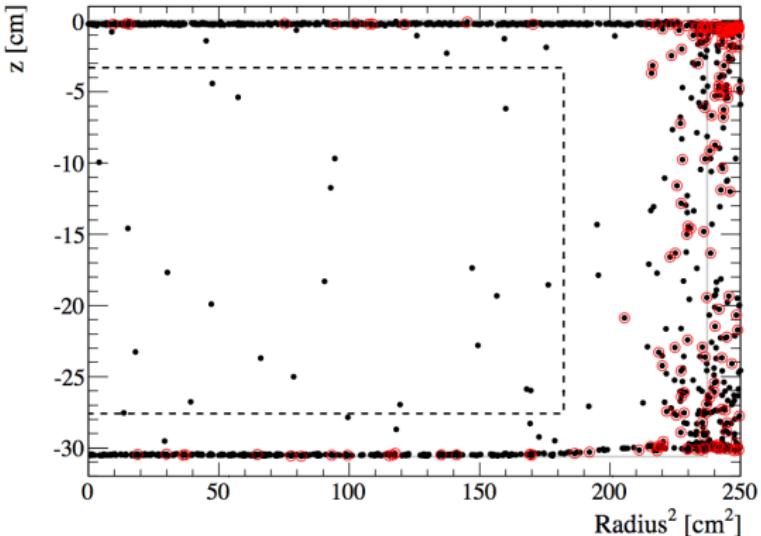
- Analysis of **non-blinded** data
- Main data sample (blinded) not yet analyzed!

- **11.17 life days**
- Data selection based on **stable conditions**:
 - no activation
 - stable HV operation
 - low and constant Rn level
- Period:
October-November 2009
- Cuts defined on calibration data: **AmBe** and **^{60}Co**

Cuts applied to the data

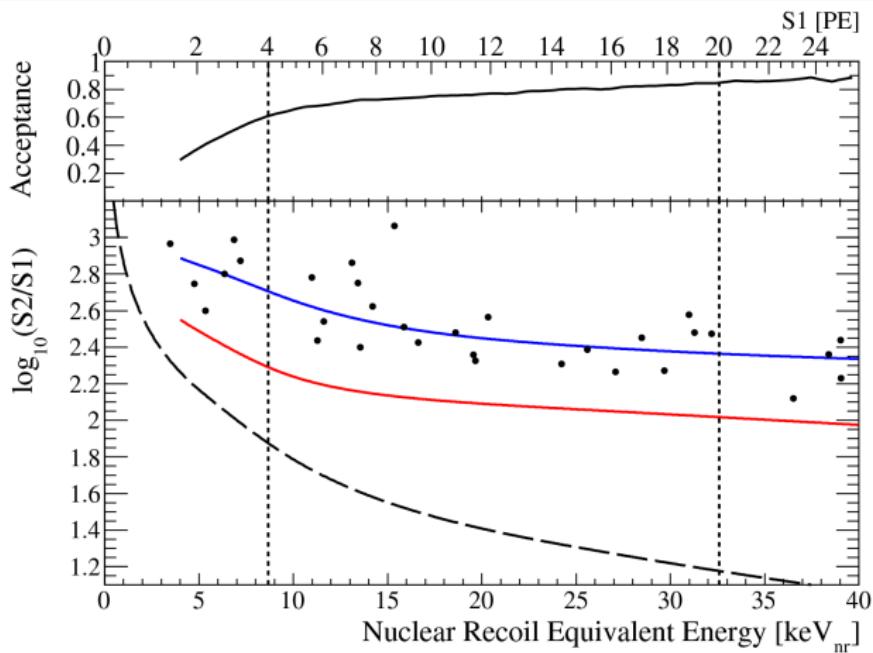
- Signal/noise ratio cut
 - Single S1 peak: remove accidental coincidences
 - Single S2 peak: select single scatter events
 - Remove events in gas phase
 - Apply active veto cut
-
- Energy cut: Select events with energies lower than 28 keV_{nr} (keV nuclear recoil equivalent)
-
- !! Self-shielding: Most of the low energy events are located close to the edges of the detector
→ remaining events in fiducial volume: mostly intrinsic contamination

Fiducial volume



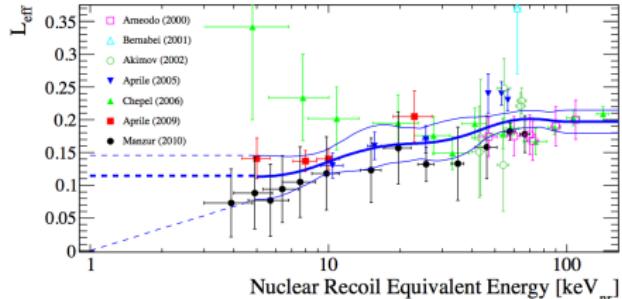
- **3-D position reconstruction:**
allows the selection of the inner part of the detector
 - events with energies below 28 keV_{nr}
- **Current fiducial volume:** cylindrical shape with **40 kg** mass
→ will be further optimized

Background data

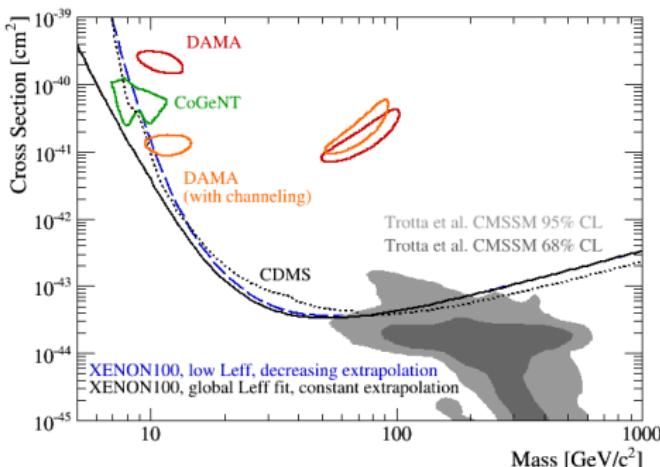


- 'Background free': in the 11.17 days after discrimination
- Comparison to **XENON10**: for approximately the same exposure
→ much cleaner detector

Limit from non-blinded data analysis



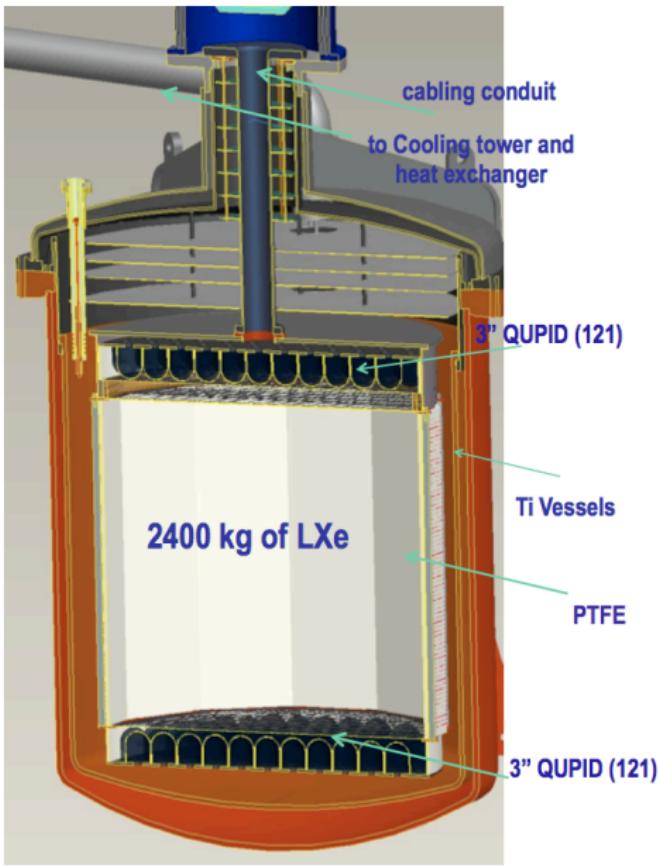
- **Spin independent limit:** for standard halo parameters



E. Aprile *et al.*, arXiv:1005.0380
accepted for publication in PRL

- Excellent sensitivity: even for few days of data
- Sensitivity to low WIMP masses depends on L_{eff}
- Much more data recorded in blind mode
 - + analysis in the high nuclear-recoil energy region

Future: XENON1T

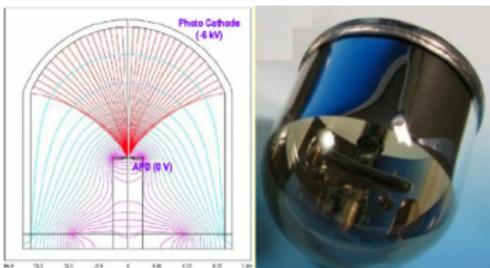
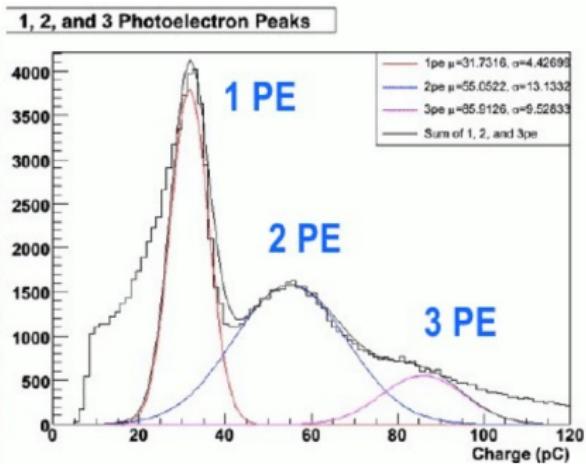


- 1.2 ton fiducial mass (total of 2.4 ton LXe)
- Drift length = ~ 90 cm
- 100x background reduction
- Muon veto
- Copper/titanium cryostat
- New photo-detectors: QUPIDs
 - New collaborators
 - Currently working on MC simulations and design + secure remaining funding
- Timeline: 2010 - 2015

QUPIDS for light readout

- QUartz Photon Intensifying Detector (hybrid detector)
- Development by UCLA & Hamamatsu for LXe and LAr detectors

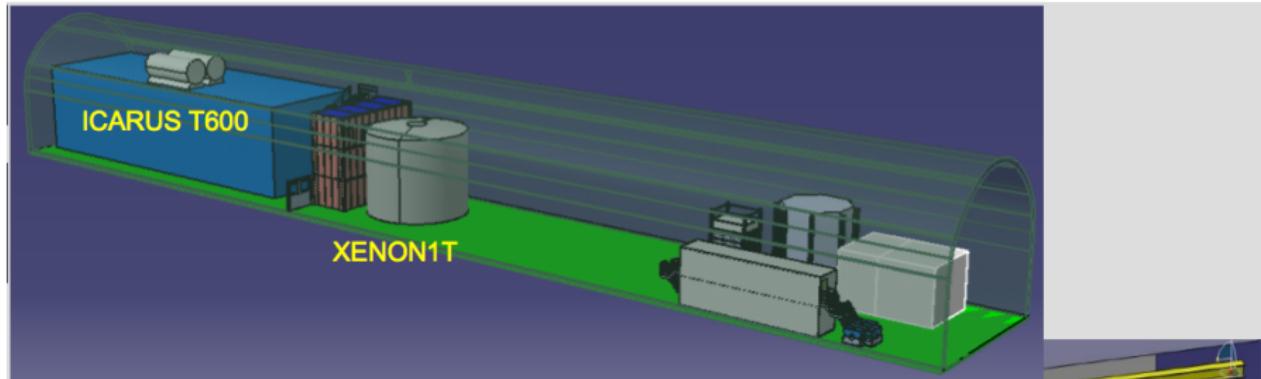
- Ultra-low radioactivity (~ 0.1 mBq)
- High QE and high SPE resolution



- First test at UCLA
- QUPID working in LXe!
 - single electron response

K. Arisaka *et al.*, Astroparticle Physics 31 (2009) 63

Location under discussion ...

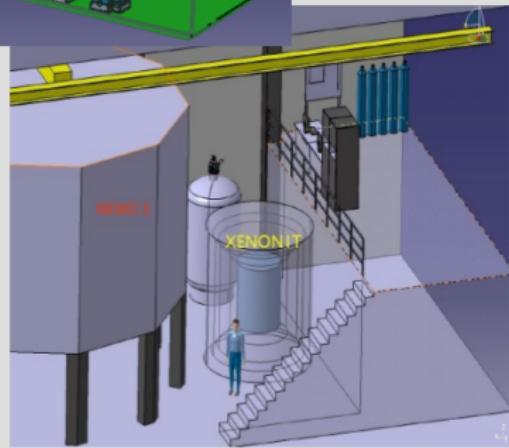


XENON1T @ LNGS (Hall B)

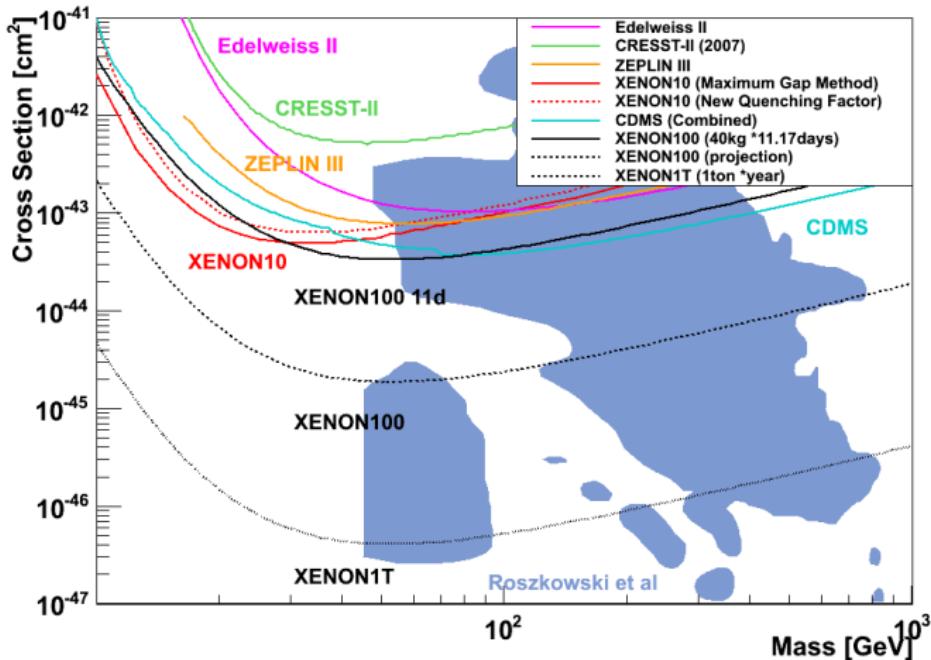
→ 4 m water shield

XENON1T @ LSM

→ solid shield (55cm poly,
20cm Pb, 15cm poly,
2cm ancient Pb,
>99% muon veto)



XENON sensitivity



- XENON100 sensitivity for 6 000 kg days (200 d × 30 kg bg free)
- Capability to detect about 10 events for 100 GeV mass for a WIMP-nucleon cross section of $\sim 10^{-44}$ cm² within 2010

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Summary

- Liquid xenon is a promising detector material to discover dark matter
 - Large nucleus (A^2 enhancement on σ)
 - Dual-phase: particle discrimination and fiducialization
 - Self-shielding (large detectors)
- XENON100 is taking dark matter data
 - Design low background level achieved!
 - First non-blinded data analyzed
→ first results accepted for publication in PRL! arXiv:1005.0380
 - New results coming ...
- XENON1T currently under design