Direct dark matter search with the XENON100 experiment

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Outline

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Indications from astronomy and particle candidates

Star rotation curves

- Measurement: 21 cm H-line
- Dark matter halo explanation

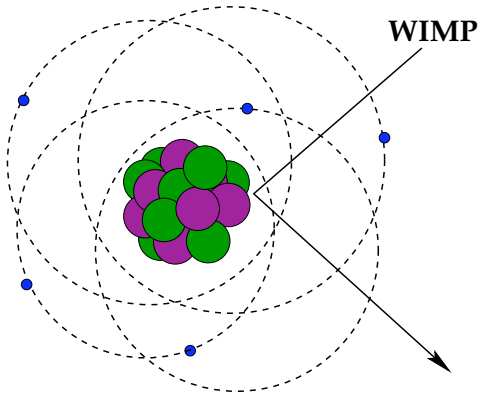
Galaxy clusters

- Baryonic matter in red (X-rays)
- Matter distribution in blue (gravitational lensing)

Most general theoretical approach:

WIMP

(**W**eak **I**nteracting **M**assive **P**article)

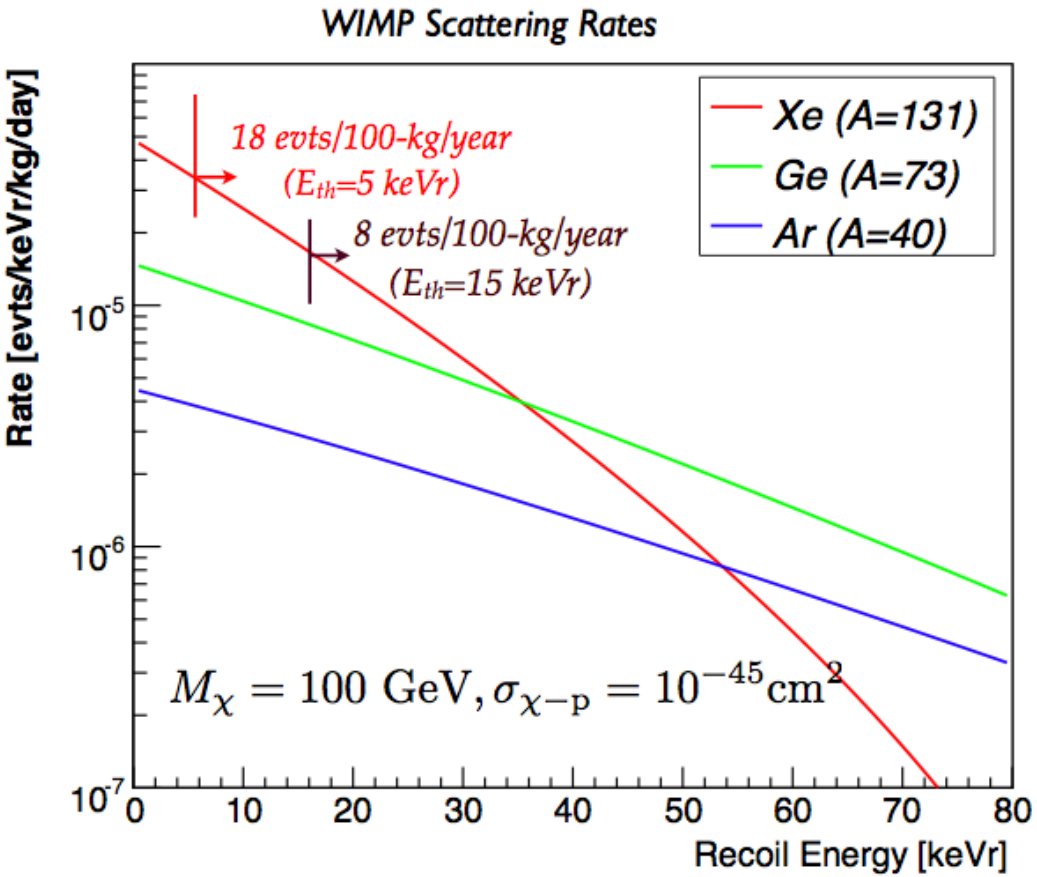


Example: SUSY particles

- Neutralino χ
- CMSSM predictions around $10^{-44\pm2}\,\mathrm{cm}^{-2}$

Xenon as detection medium

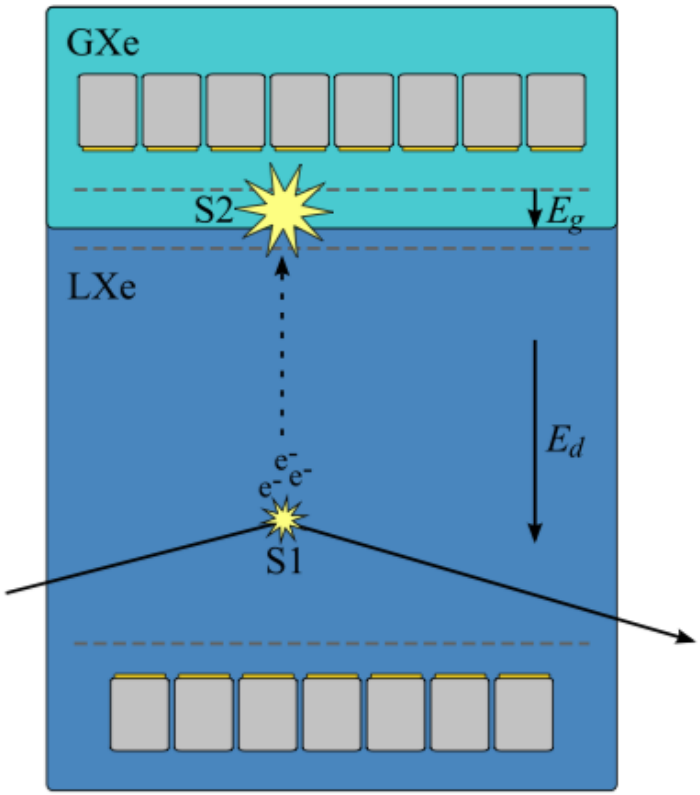
Detection via scatter off nuclei



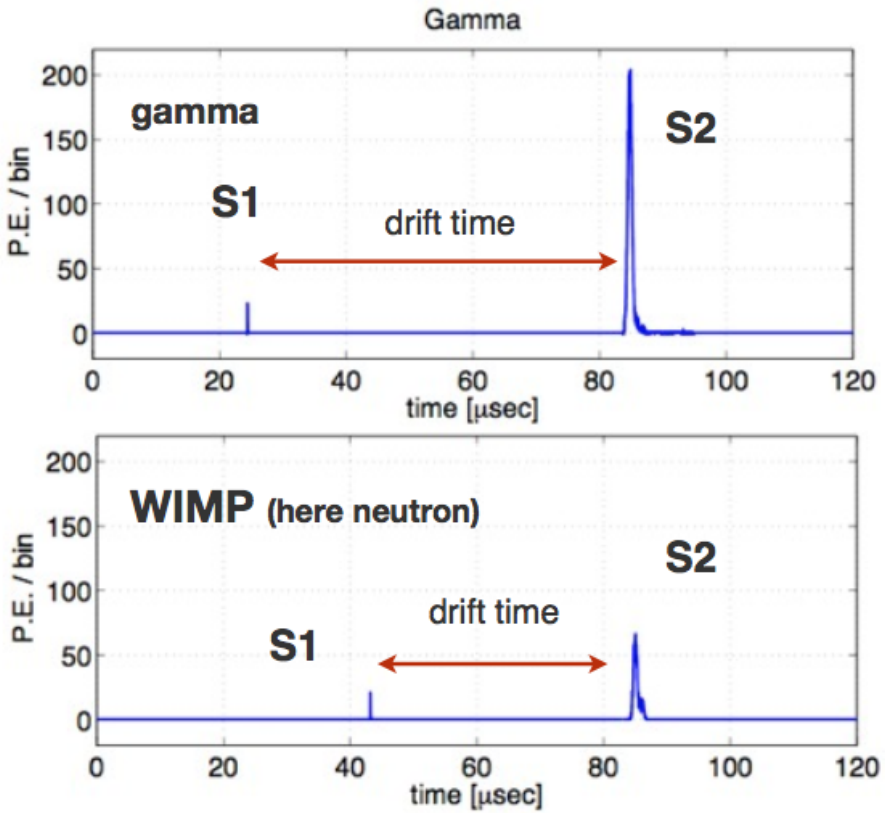
Xe

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

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

Outline

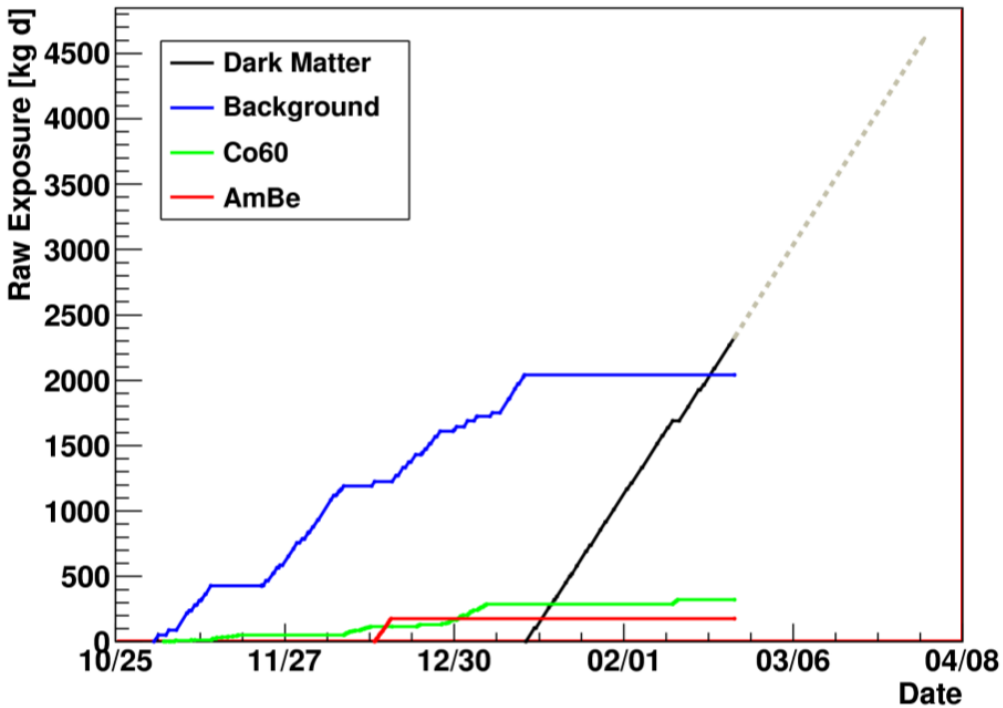
XENON experiment

- Laboratori Nazionali del Gran Sasso (Italy)
- 3 500 m.w.e. shielding

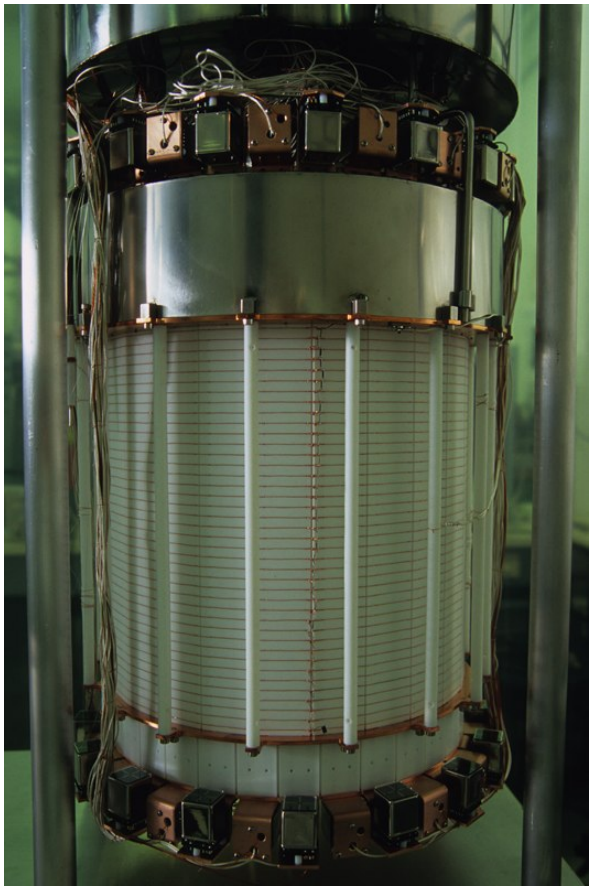
- XENON10: 15 kg active volume
  - Finished: No evidence for DM

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)

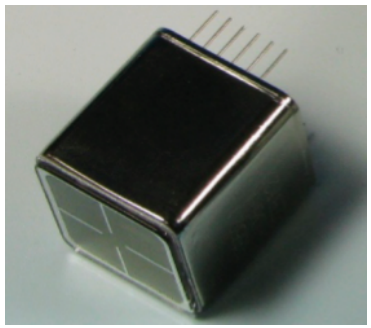
- XENON100: 65 kg active volume
  - Currently taking science data



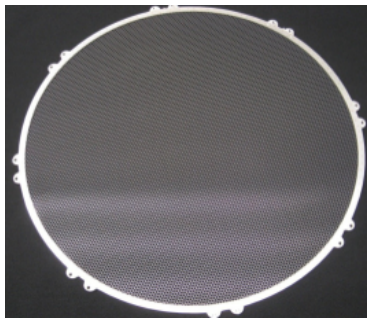
XENON100 detector



- 30 cm drift length and 30 cm ∅
- 165 kg total (30-50 kg fiducial volume)
- ∼ 100x less background than XENON10
- Improved shielding
- Material screening and selection
- Cooling (PTR) outside the shield
- Active liquid xenon veto



1 inch PMTs



30 cm ∅ meshes

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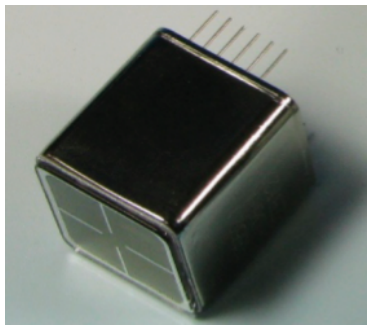
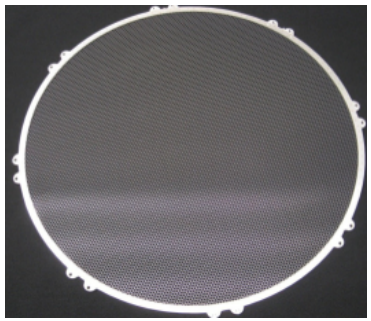
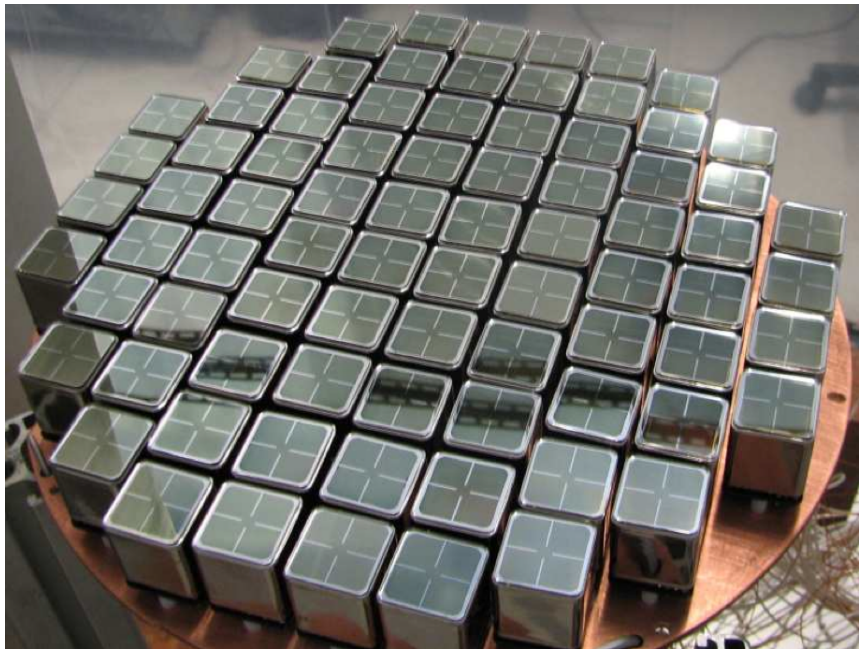


1 inch PMTs

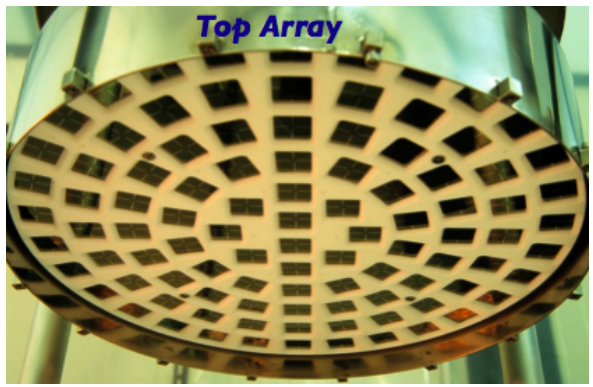


30 cm ∅ meshes

Light and charge read out

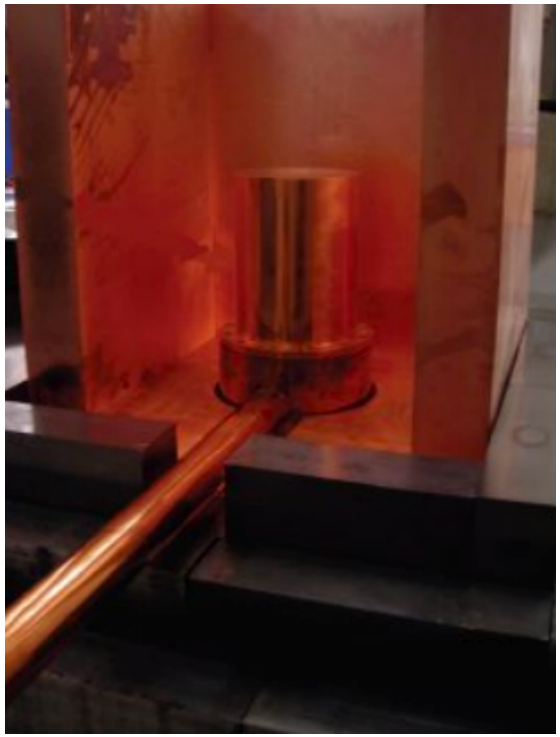


- High quantum efficiency PMTs
  in the bottom array (>32% @178 nm)
- 3 Dim. position reconstruction
  - XY from light pattern in the PMTs
  - Z from the drift time
- 2 mm resolution in XY and in Z

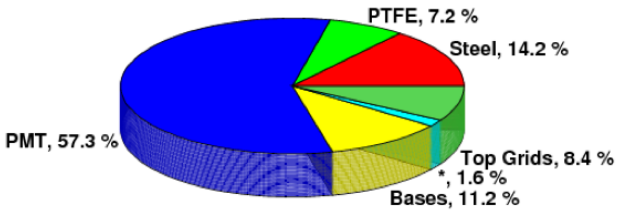


Background prediction

Material screening underground with a 2.2 kg HP Ge detector



- Gamma background expected:
  - $5 \cdot 10^{-3}$ evts/kg/keV/d (before discrimination cuts)



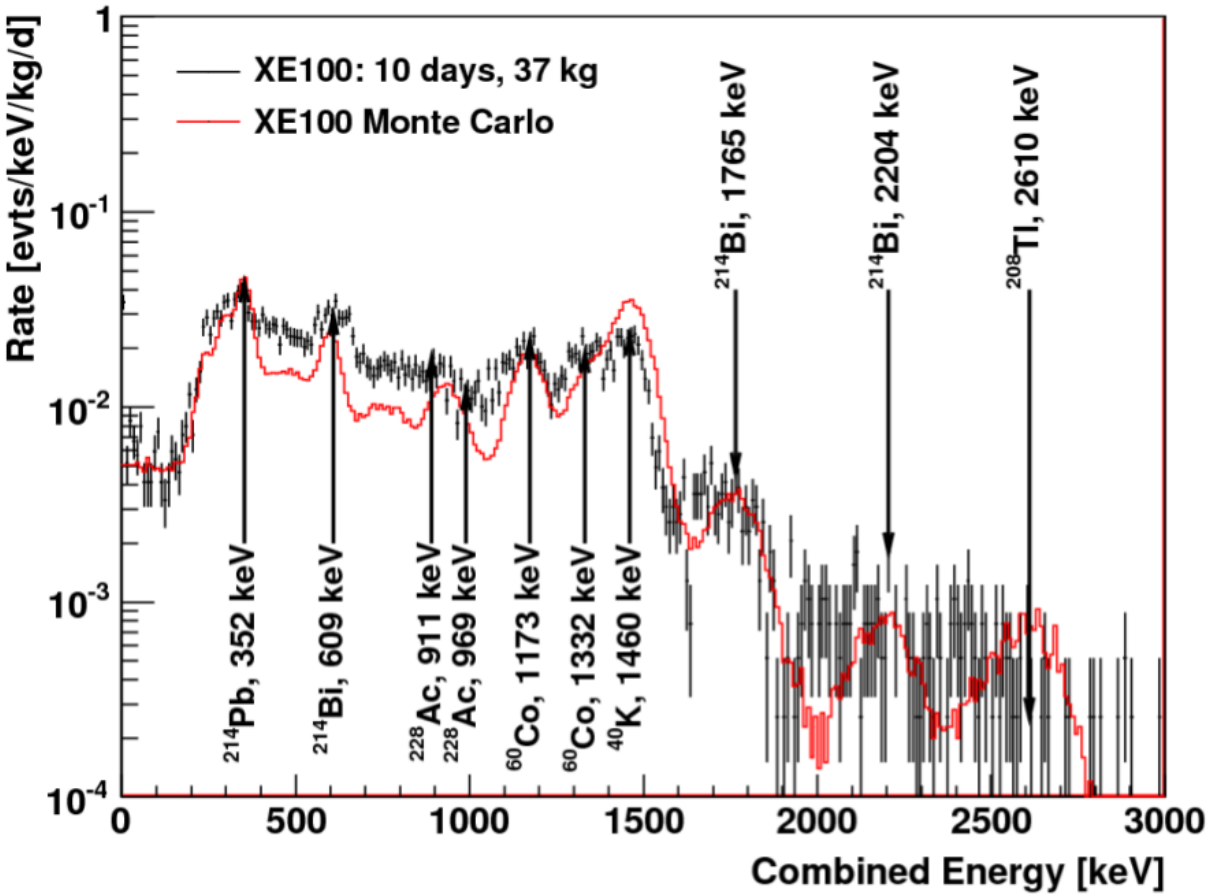
- Neutron bg from simulations:
  - 0.64* events/year
  - 2/3 from radioactivity and 1/3 muon-induced

*in the WIMP search energy range with 30 kg fiducial volume

- Removal of ^{85}Kr: distillation column
  - Kr/Xe $\sim$ ppm-ppb commercially available
  - Measurement in XENON100 after purification:

  $\rightarrow$ currently $\sim$ 140 ppt via delayed gamma-beta coincidence

Measured background spectrum

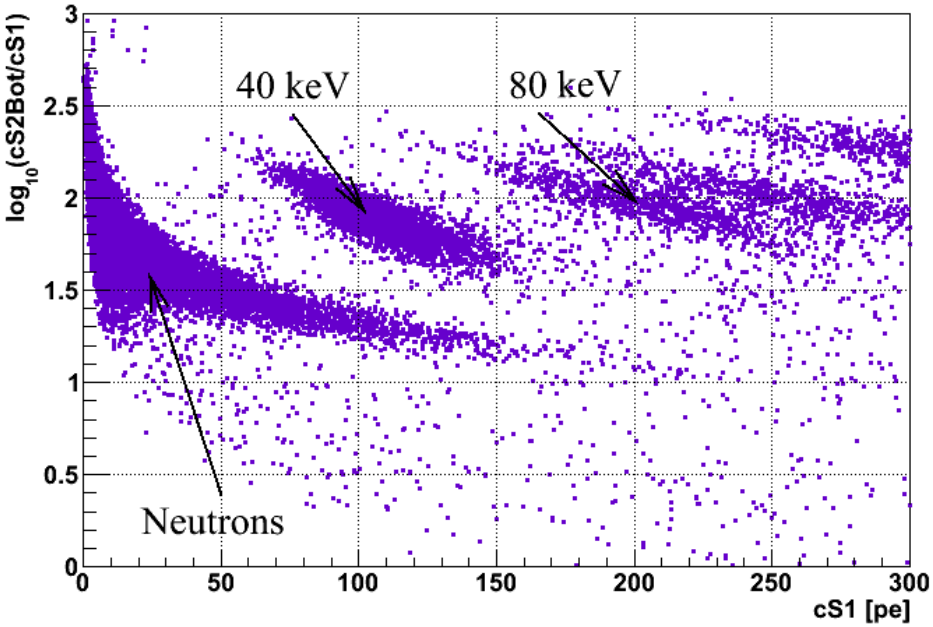


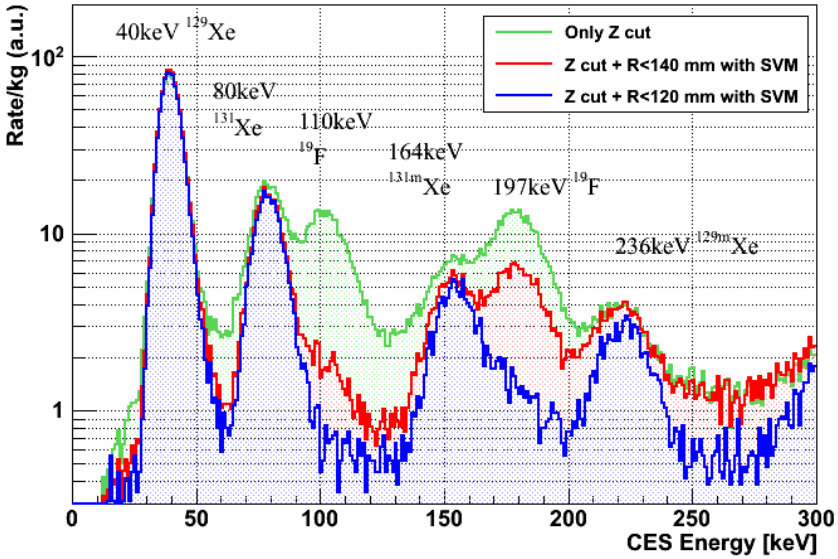
- Background at the level of the predictions
- No tuning of the Monte Carlo
- The measured single scatter rate below 100 keVee is $5 \cdot 10^{-3}$ evts/kg/keV/d
- Factor 100 less than in XENON10 achieved!!

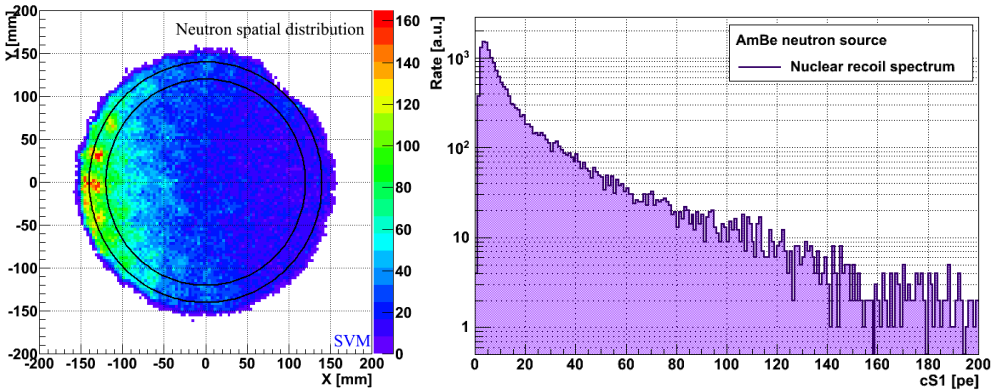
→ currently optimizing the data/MC comparison

Outline

Neutron calibration

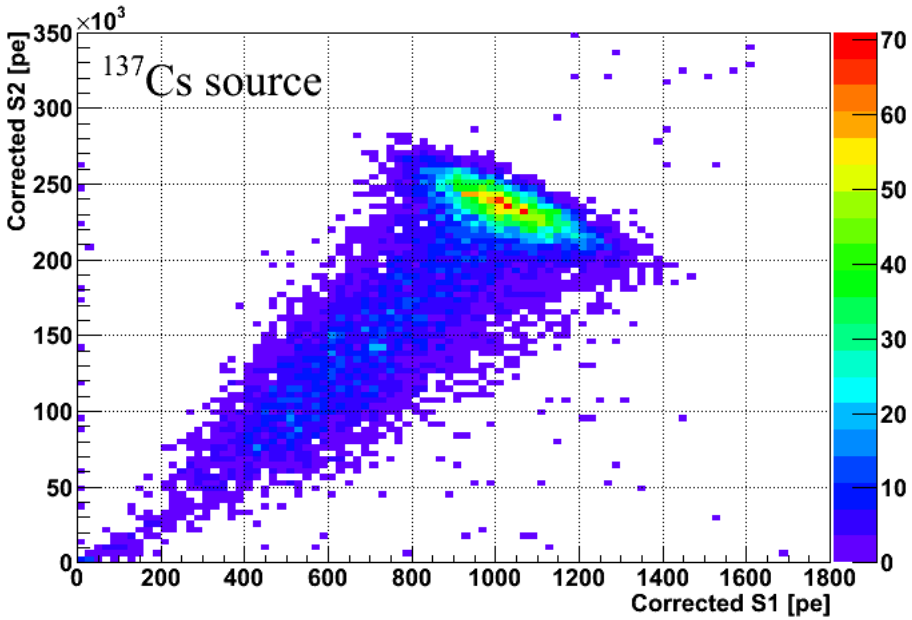


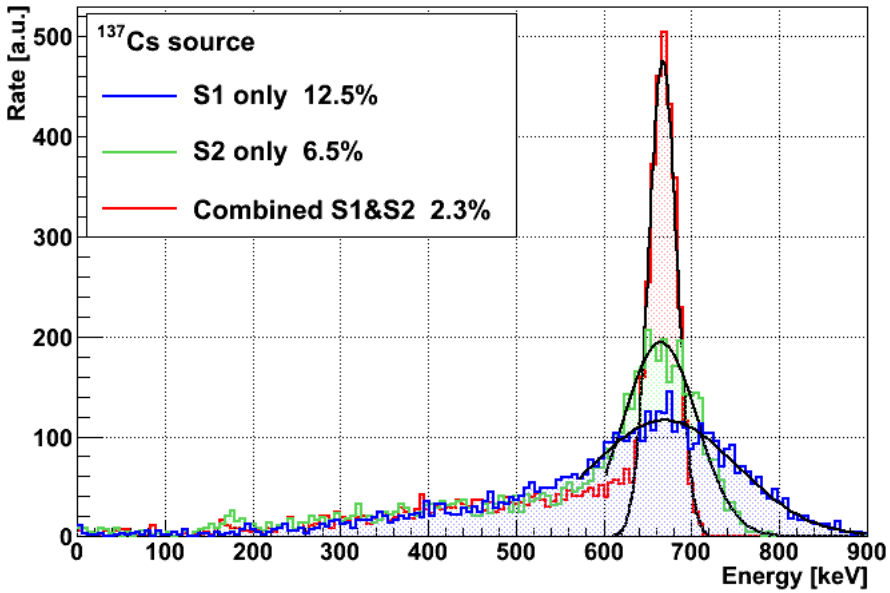


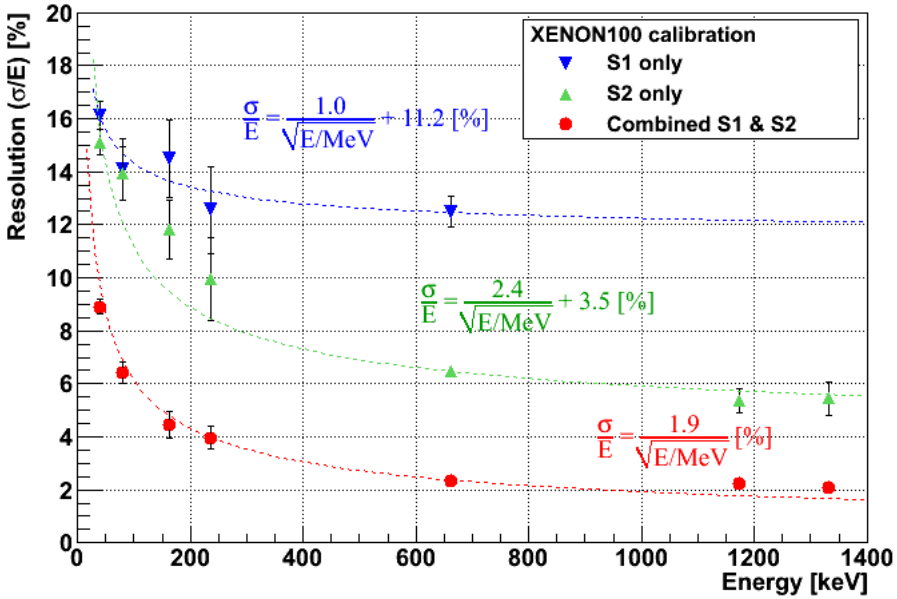


- Source: AmBe with 220n/s
- Determination of nuclear recoil band
- Further lines from inelastic recoils in xenon

Calibration with gamma sources



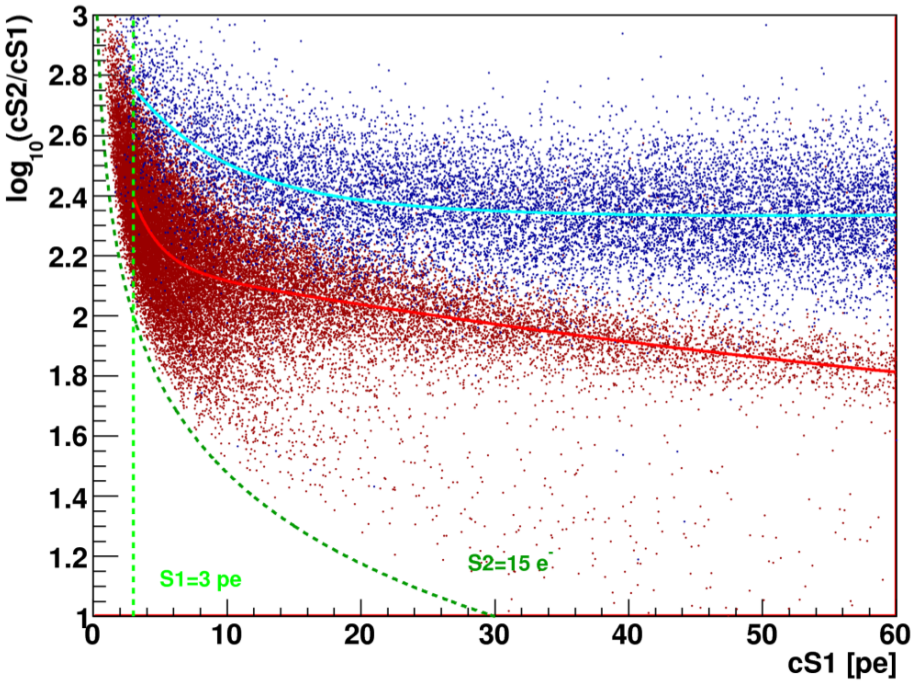


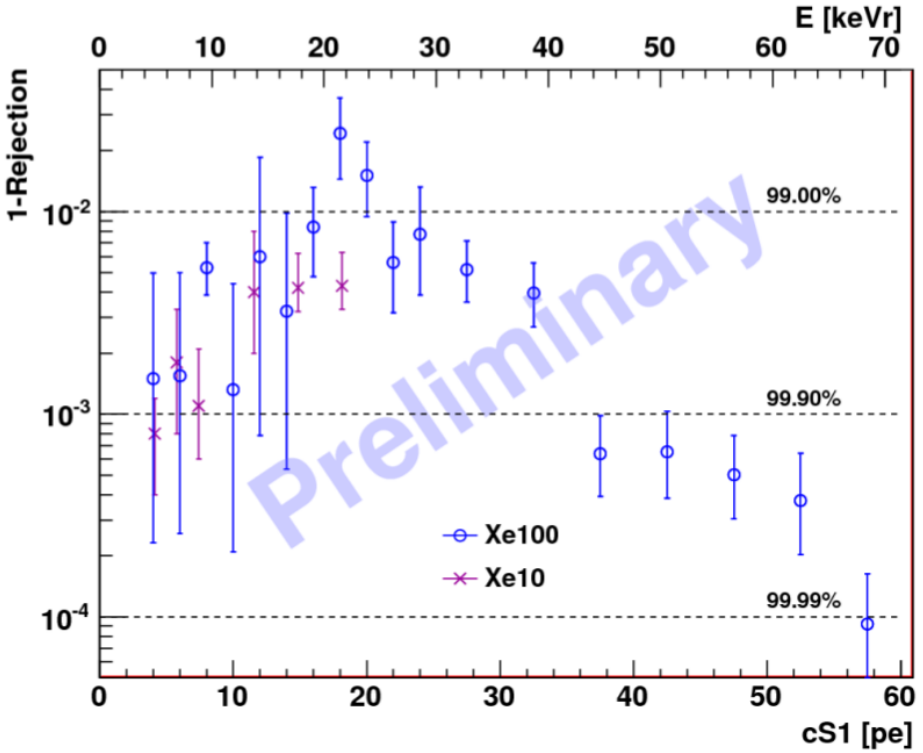


- Energy dependence of resolution in S1, S2 and CES
- CES: combined energy scale

→ anticorrelation between S1 and S2

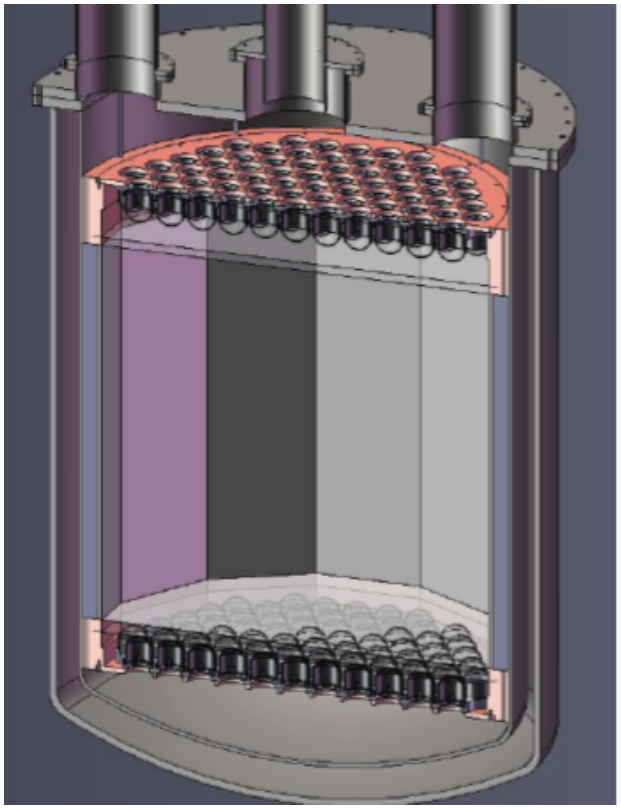
PRELIMINARY discrimination





- Band determination using: ^{60}Co and AmBe data
- Discrimination similar to XENON10 @ about 50% NR acceptance

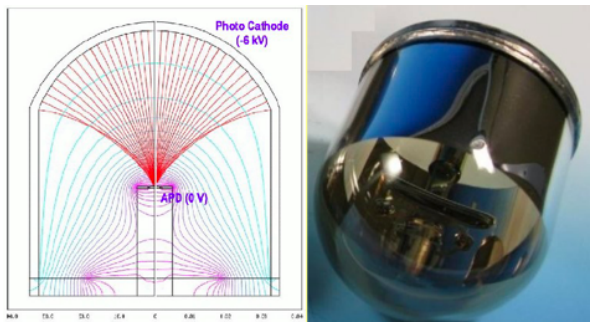
Future: XENON1t



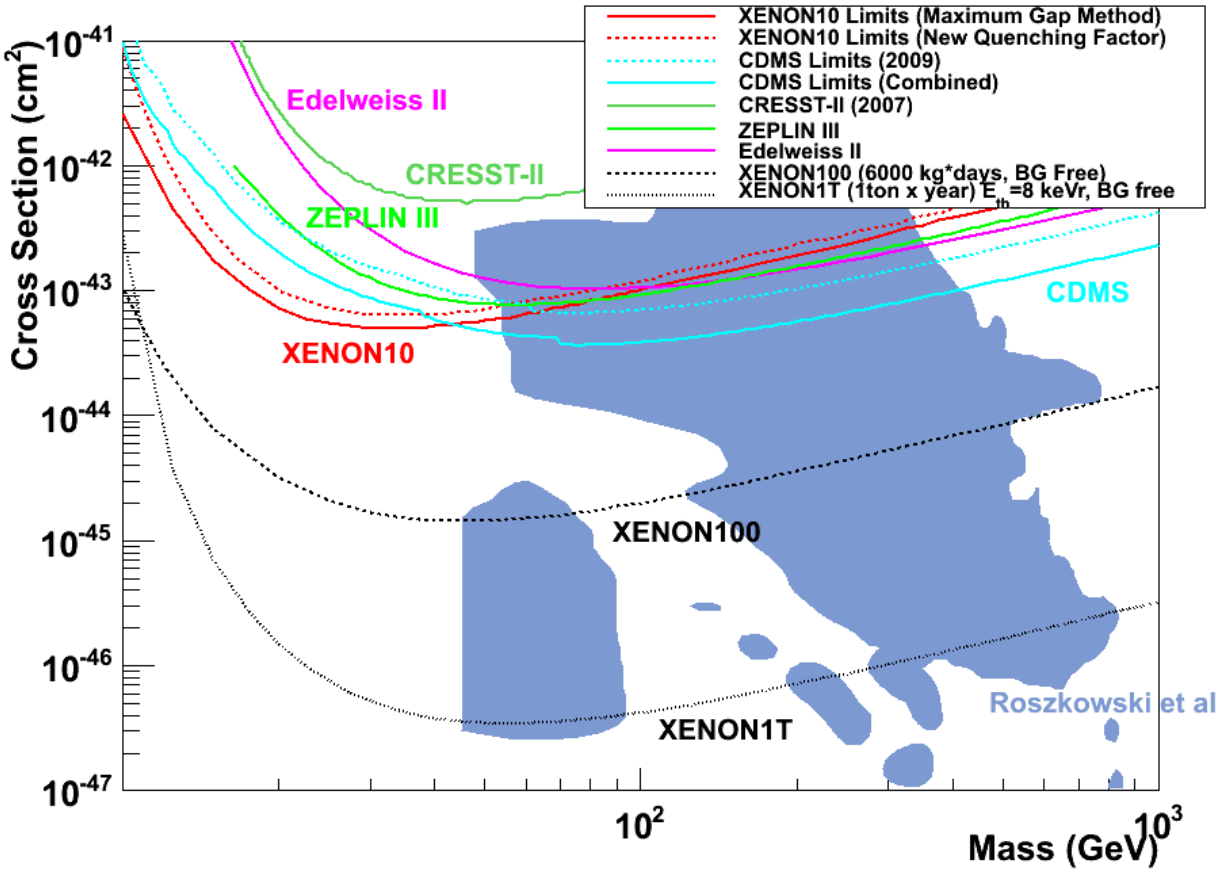
→ talk by M. Haffke (107.3)

- 1 ton fiducial mass
  (total of 2.2 ton LXe)
- Drift length = ∼ 90 cm
- 100x background reduction
- Muon veto
- Copper/titanium cryostat
- New photo-detectors?

- **QUPIDS** for light readout
  (**QU**artz **P**hoton **I**ntensifying **D**etector)
  - Ultra-low radioactivity (∼ 0.1 mBq)
  - High QE and high SPE resolution
  - Development UCLA & Hamamatsu



XENON sensitivity

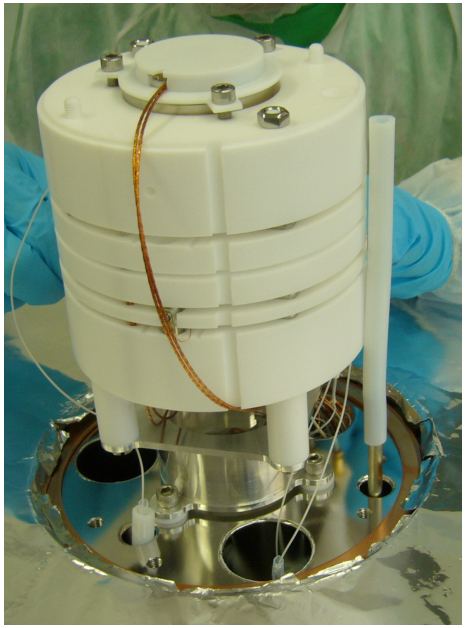


- XENON100 sensitivity for 6 000 kg days (200 d $\times$ 30 kg bg free)
- Capability to detect about 10 events for 100 GeV mass for a WIMP-nucleon cross section of $\sim 10^{-44}$ cm^2 within 2010

Outline

R&D with the Xürich detector

Two-phase xenon detector at UZH

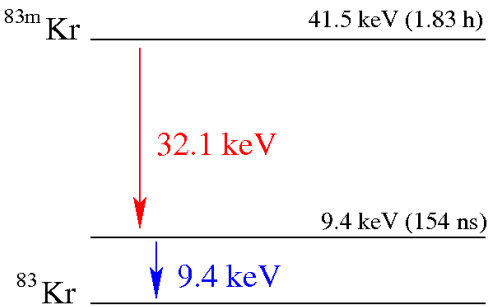


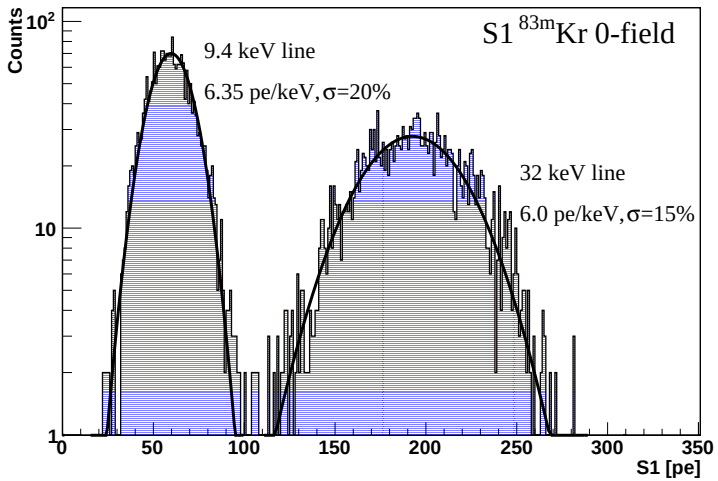
- Investigate light and charge production by different types of particles (electron/neutron)
- Test of calibration sources for xenon detectors

- Target mass: $\sim$ 0.1 kg Xe
- Volume: 3 cm drift length and 3.5 cm diameter
- Two R9869 PMTs
- 10 pe/keV in single phase
- 6 pe/keV in double phase

Low energy calibration of xenon detectors

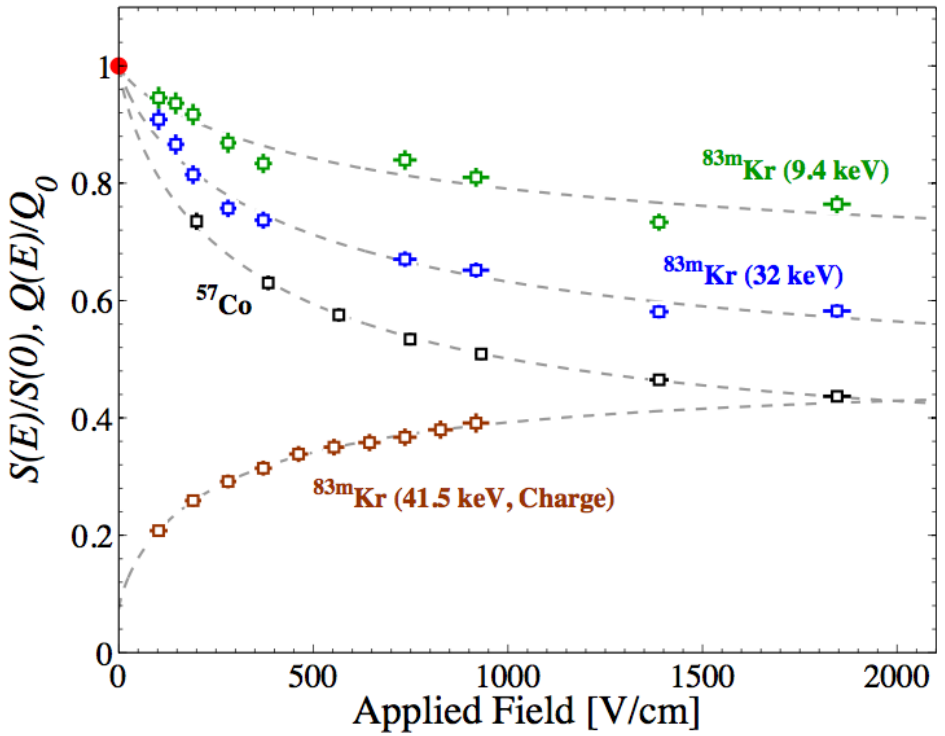
- ^{83m}Kr calibration source:
  - EC decay-product of ^{83}Rb
  - Lines at 9.4 and 32.1 keV
  - Uniform distribution





- ^{83m}Kr calibration planned in XENON100

  → Poster HK 36.29 by K. Hugenberg



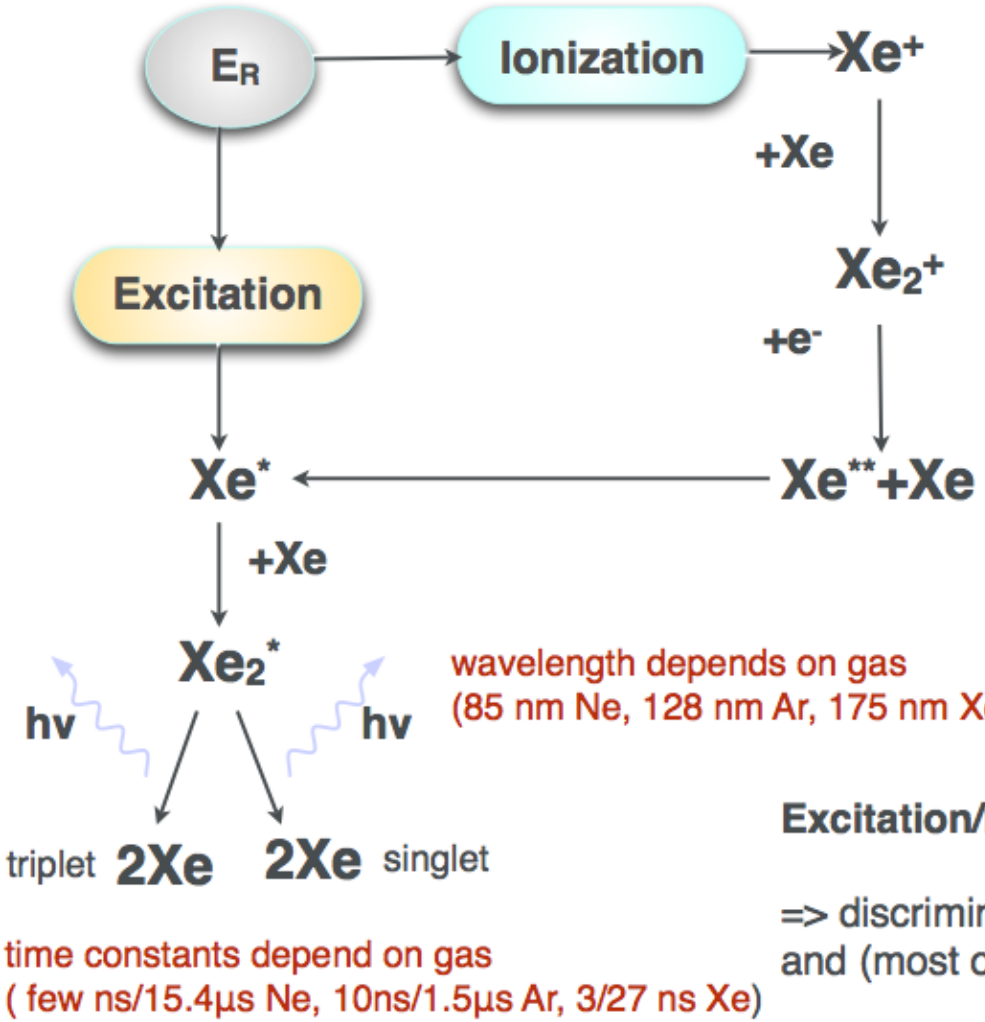
A. Manalaysay *et al*, under review at Rev. Sci. Instrum. (2010)

- Future: n-generator facility
  - monoenergetic D-D fusion source
  - charge and light yield of NR

Outline

Summary

- Liquid xenon is a promising detector material to discover dark matter
  - Large nucleus (A^2 enhancement on σ)
  - Dual-phase: particle discrimination
  - Self-shielding (large detectors)
- XENON100 is taking dark matter data
  - Design background level achieved
  - First calibration data has been shown
- R&D ongoing to test new calibration sources
- XENON1t currently under design



$$Xe^* + Xe \rightarrow Xe_2^*$$

$$Xe_2^* \rightarrow 2Xe + h\nu$$

$$Xe^+ + Xe \rightarrow Xe_2^+$$

$$Xe_2^+ + e^- \rightarrow Xe^{**} + Xe$$

$$Xe^{**} \rightarrow Xe^* + \text{heat}$$

$$Xe^* + Xe \rightarrow Xe_2^*$$

$$Xe_2^* \rightarrow 2Xe + h\nu$$

Excitation/Ionization depends on dE/dx!

=> discrimination of signal (**WIMPs=>NR**)
and (most of the) background (**gammas=>ER**)!