XENON100 and XENON1T

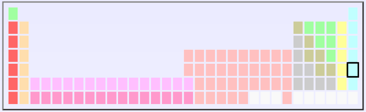
Dark Matter Search with Liquid Xenon

Gaudenz Kessler

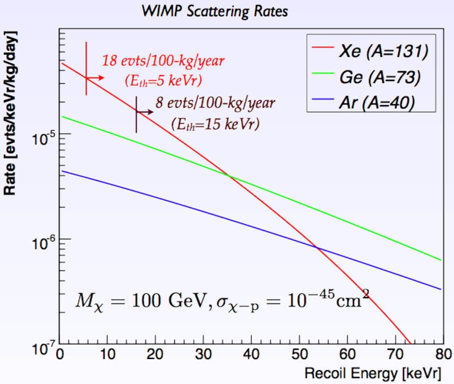
gkessler@physik.uzh.ch

PANIC 2014
Hamburg
August 25, 2014

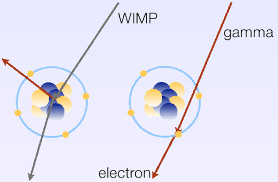
$_{54}$Xe

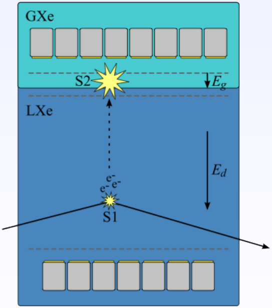


- Background suppression
  - → Good self-shielding due to a high stopping power (∼2.5 mm for a 122 keV γ)
  - → Low intrinsic radioactivity (no long-lived isotopes)
  - → Gamma background discrimination
- Efficient scintillator at 178 nm UV light (46 photons/keV)
- High atomic mass $A \sim 131$
  - → ton scale detector
  - → high WIMP rate at low threshold
- Simple cryogenics at $\sim$ 180 K

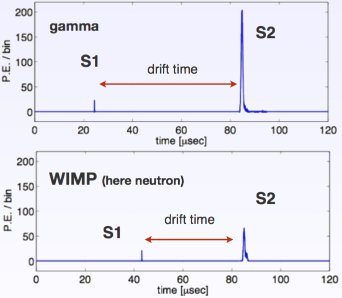


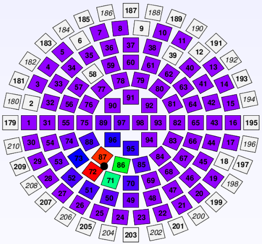
Working Principle of a Dual-Phase Time Projection Chamber





- Scintillation signal (S1)
- Charges drift to liquid-gas surface (→ S2)
  - → electron-extraction close to the top PMT array → *xy*-reconstruction
  - → *z*-reconstruction via drift time

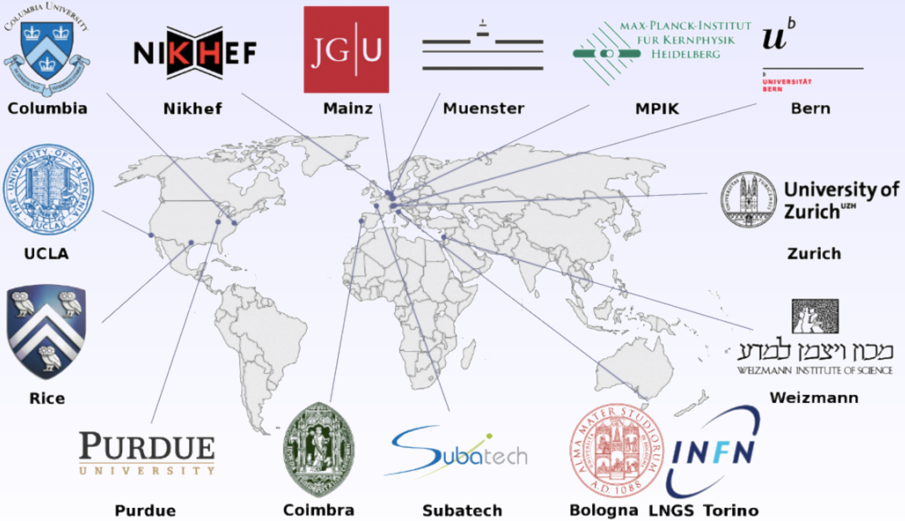




- $\left(\frac{S2}{S1}\right)_{\mathrm{WIMP}} < \left(\frac{S2}{S1}\right)_{\gamma}$ recombination stronger for NR

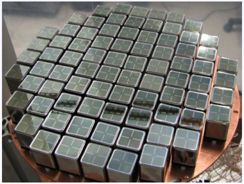
The XENON Collaboration

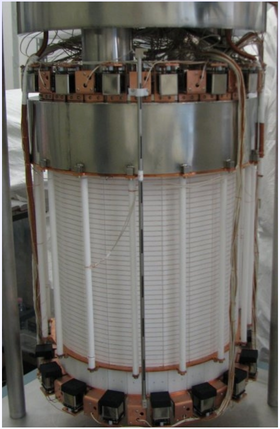
16 institutions with 120 people



XENON100 – The Detector

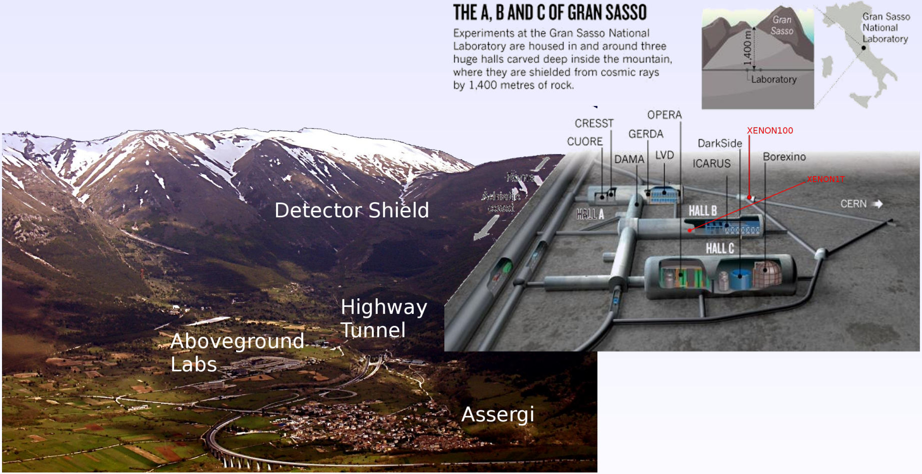
- Located in the Gran Sasso Underground Lab
  - $\rightarrow$ Muon flux reduced by $\sim 10^6$ by 1400 meters of rock
- Dual phase time projection chamber with 62 kg Xe
- Up to 30 cm drift for electrons (175μs) with 0.3 mm resolution in the *z*-position
- 99 kg Xe for veto and shielding outside the TPC
- 242 high quantum efficiency PMTs (Hamamatsu R8520)





Instrument Paper: E. Aprile et al. (XENON100), Astropart. Phys. **35**, 573 (2012)

Laboratori Nazionali del Gran Sasso (LNGS)

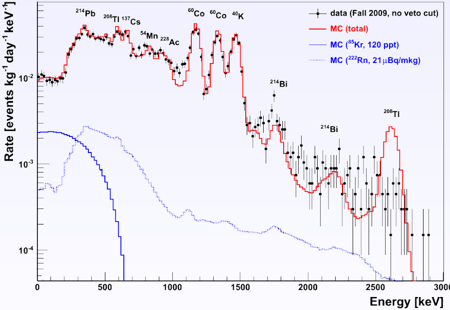


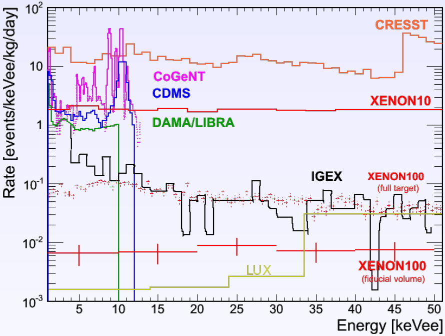
http://www.nature.com/news/gran-sasso-chamber-of-physics-1.10696

Gator and GeMPI facilities:

- Ge detector at LNGS
- Screened of radioactivity of all materials in XENON100

MC-data comparison:

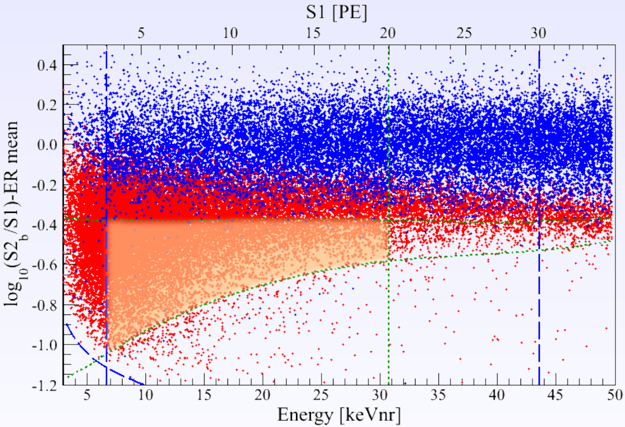




- Factor 100 lower background than in XENON10

E. Aprile et al. (XENON100), Phys. Rev. D **83**, 082001 (2011)

High statistics calibration data



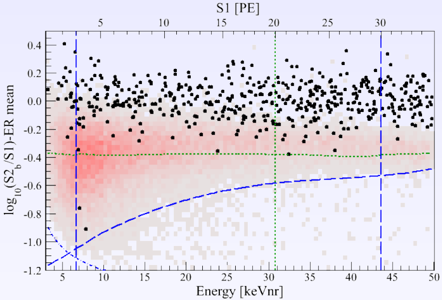
- Electronic recoil (calibration source: ^{60}Co and ^{232}Th)
- Nuclear recoil (neutrons from an AmBe source)
- Benchmark region with
  - 99.75 % ER
  - ∼97 % lower NR quantile

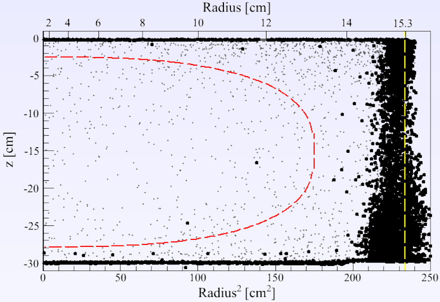
Expected background in the benchmark region: (1.0 ± 0.2) events

- γ leakage (0.79 ± 0.16)
- NR from neutrons $(0.17^{+0.12}_{-0.07})$

Last Released Results: 225 Live Days

Choose inner 34 kg (fiducial volume) to minimize background



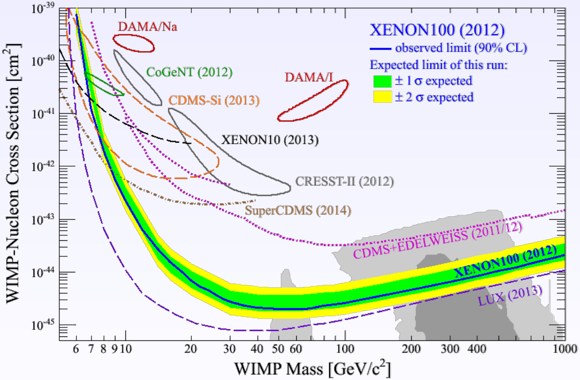


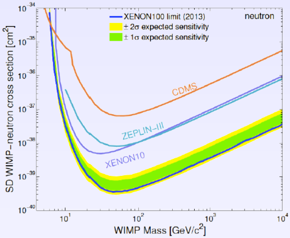
- Expected background in the benchmark region: (1.0 ± 0.2) Events
- Two events observed after unblinding
- 26.4 % probability that BG fluctuated to 2 events

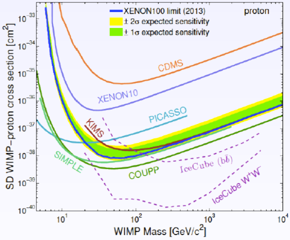
$\rightarrow$ No significant excess above the expected BG due to a signal in XENON100 data

Last Released Results: 225 Live Days

- Limit on elastic scattering spin-independent derived from profile likelihood analysis:
- ∼50% non-zero spin nuclei → SD interaction (analysis for inelastic SD scattering ongoing)





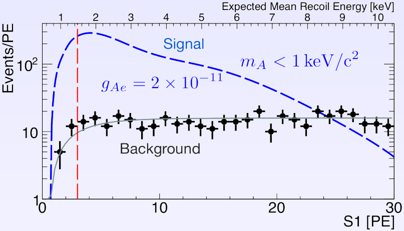


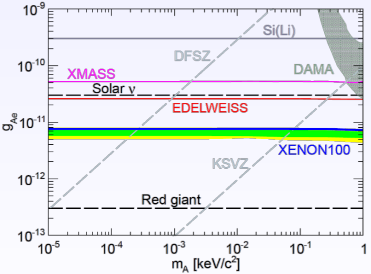
E. Aprile et al., Phys. Rev. Lett. 109 (2012) 181301

E. Aprile et al., Phys. Rev. Lett. 111 (2013) 021301

New and Upcoming Results from XENON100

- Calibrations:
  - ^{88}YBe (monoenergetic neutrons)
  - ^{83m}Kr
  - ^{220}Rn
- Low Kr contamination level, sub ppt
- 154 days of new data (unblinding soon)
- Axions and Axion Like Particles (ALP)
- Annual modulation
- Low-mass WIMPs
- Inelastic scattering on ^{129}Xe

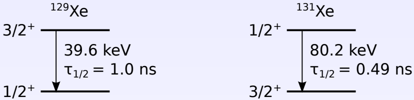




E. Aprile et al., http://arxiv.org/abs/1404.1455 (accepted by PRD)

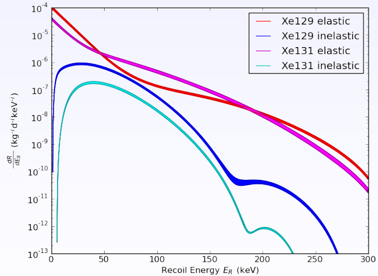
Inelastic scattering on ^{129}Xe

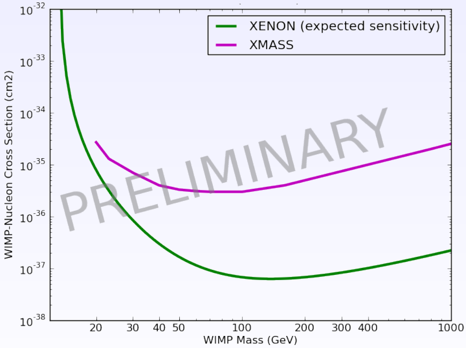
$$\chi + N \rightarrow \chi + N^*$$
$$N^* \rightarrow N + \gamma$$



Expected Signal:
Nuclear recoil together with a 40 keV Gamma

Recoil Spectrum:

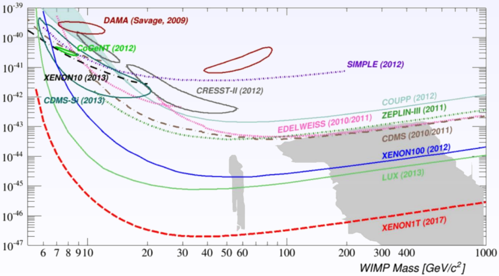




L. Baudis et al., Phys. Rev. D 88, 115014, (2013)

The XENON1T Detector

- Bigger detector under construction in Hall B of LNGS
- $\sim$1 t LXe in the fiducial volume (2 tons of sensitive LXe, total $\sim$ 3.1 t LXe)
- 1 meter drift and 1 meter diameter
- 248 PMTs for the TPC
- 100 times lower background than XENON100
  - reduction of the ^{85}Kr level to < 0.5 ppt (XENON100: few ppt);
  - ^{222}Rn level to 1μBq/kg (XENON100: 65μBq/kg)
  - 10 m water shield as active Cherenkov muon veto
  - 10 cm self-shielding
  - low radioactivity components
  - → goal: below 0.5 events / ton / year

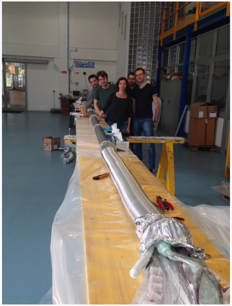


Installation Process

Watertank

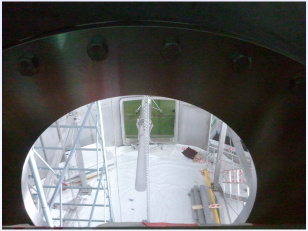
Support Structure

Cable installation ($\rightarrow$ pipe leading cables through water tank to the detector)



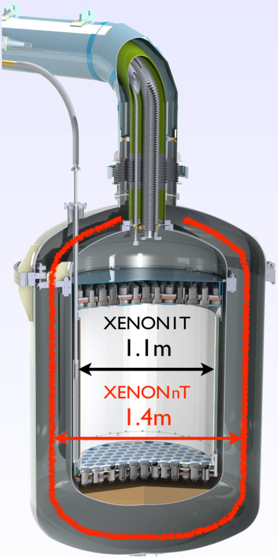
Installation Process

Pipe



Cryostat Dome

The Upgrade: XENONnT (2018-2020)



Planned to upgrade XENON1T to XENONnT

- $\rightarrow$ ~7 tons of LXe
- Cables and feedthrough flanges installed already for XENONnT
- Reuse of
  - outer cryostat,
  - water tank,
  - cryogenic system,
  - RESTOX
- Sensitivity 1 order of magnitude better than XENON1T

Future Landscape

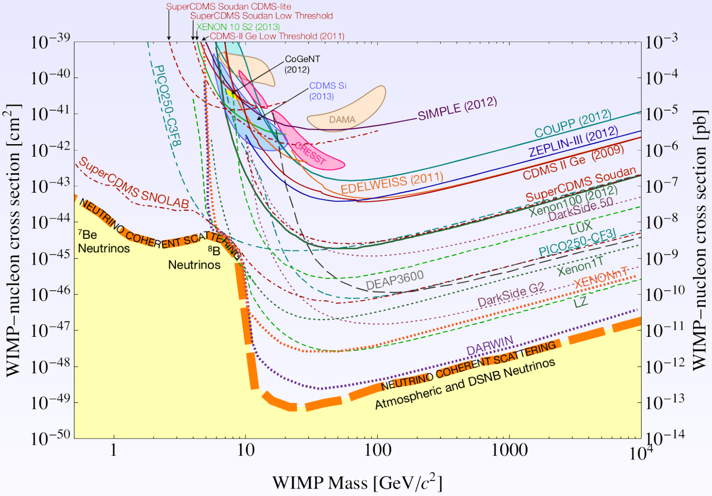


Figure adapted from http://arxiv.org/abs/1310.8327

DARWIN: Project under R&D to probe cross section down to neutrino BG

Summary

- XENON100: is running successfully
  - newest results published on
    - spin-independent and spin-dependent WIMP and
    - axion limits
  - analysis of other physics channels in progress
  - probing recoil behaviour with various calibration sources
- XENON1T: construction started last year
  - starting operation in 2015
  - expected sensitivity: 2×10^{-47} cm^2 for 55 GeV/c^2
- XENONnT: planned upgrade of XENON1T
  - upgrade after 2 years
  - increase sensitivity by 1 order of magnitude