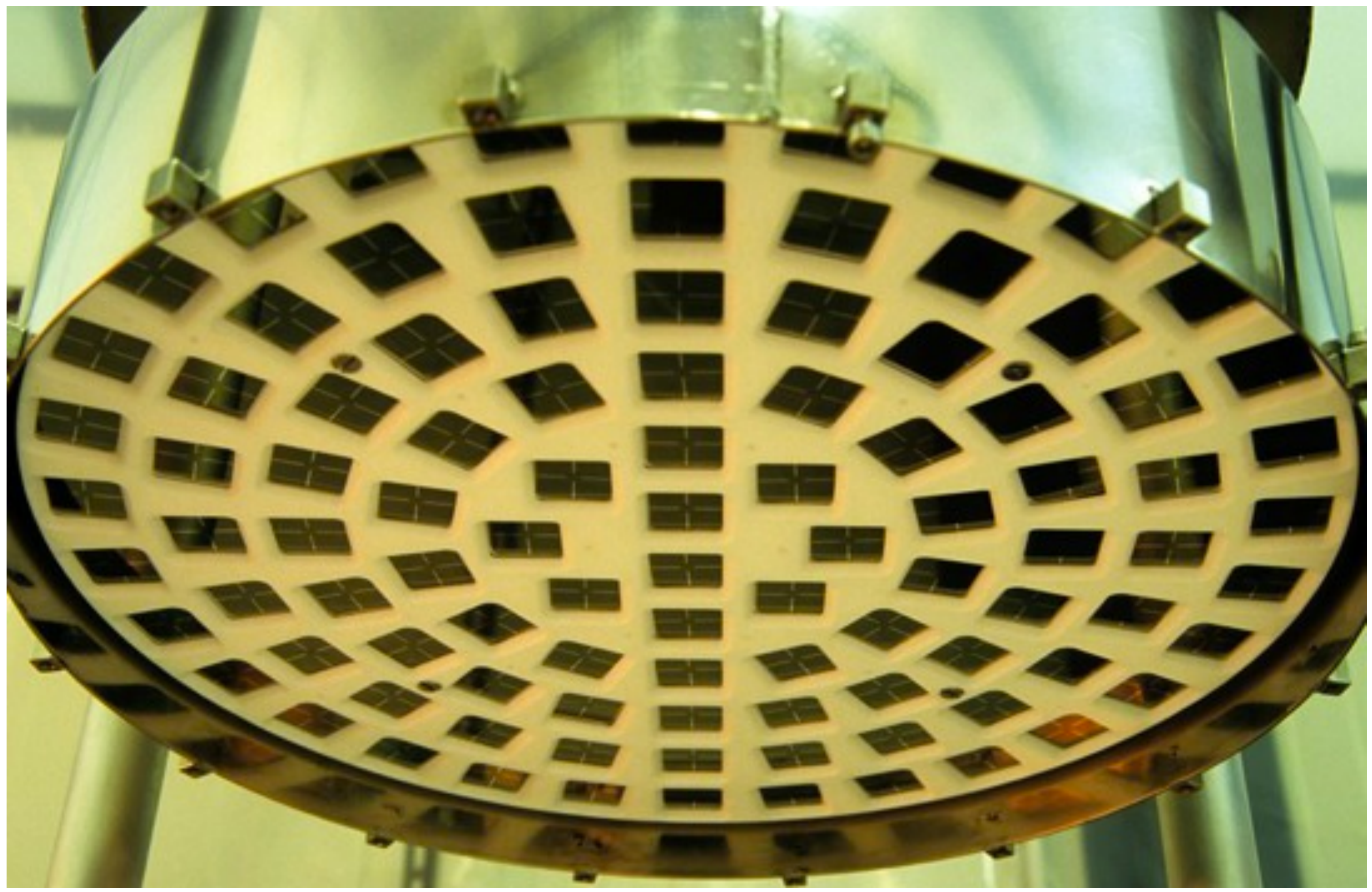
Proposal for detailed studies of shielding of external backgrounds at XENON1T

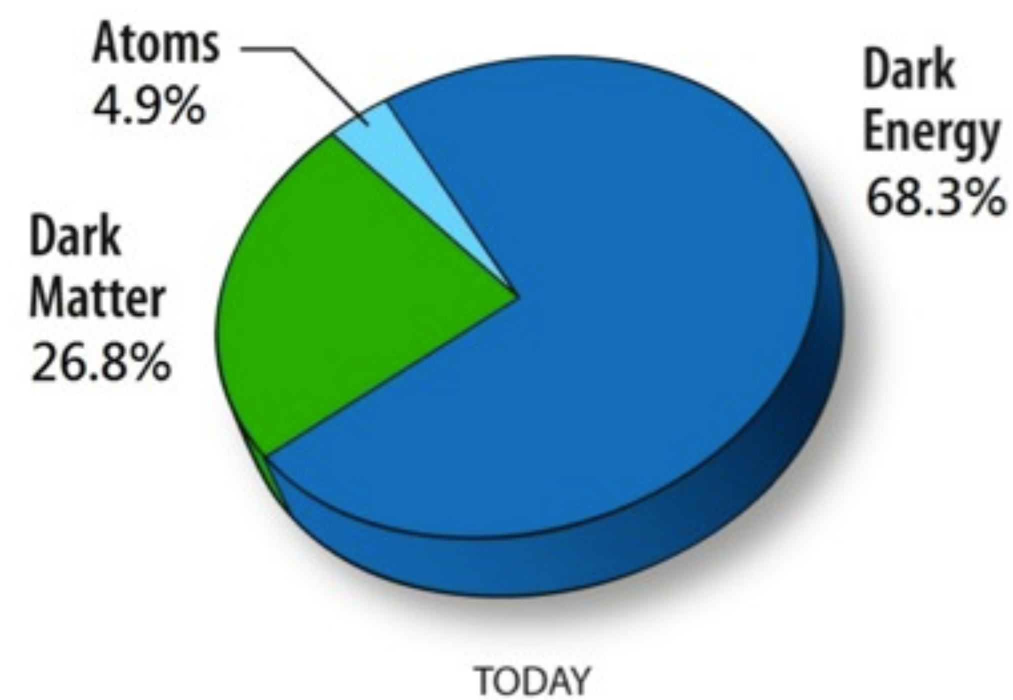


Benedict Winter, Sebastian Wahrmund, Tan Wang, Stephanie Yuen, Andrea Dubla

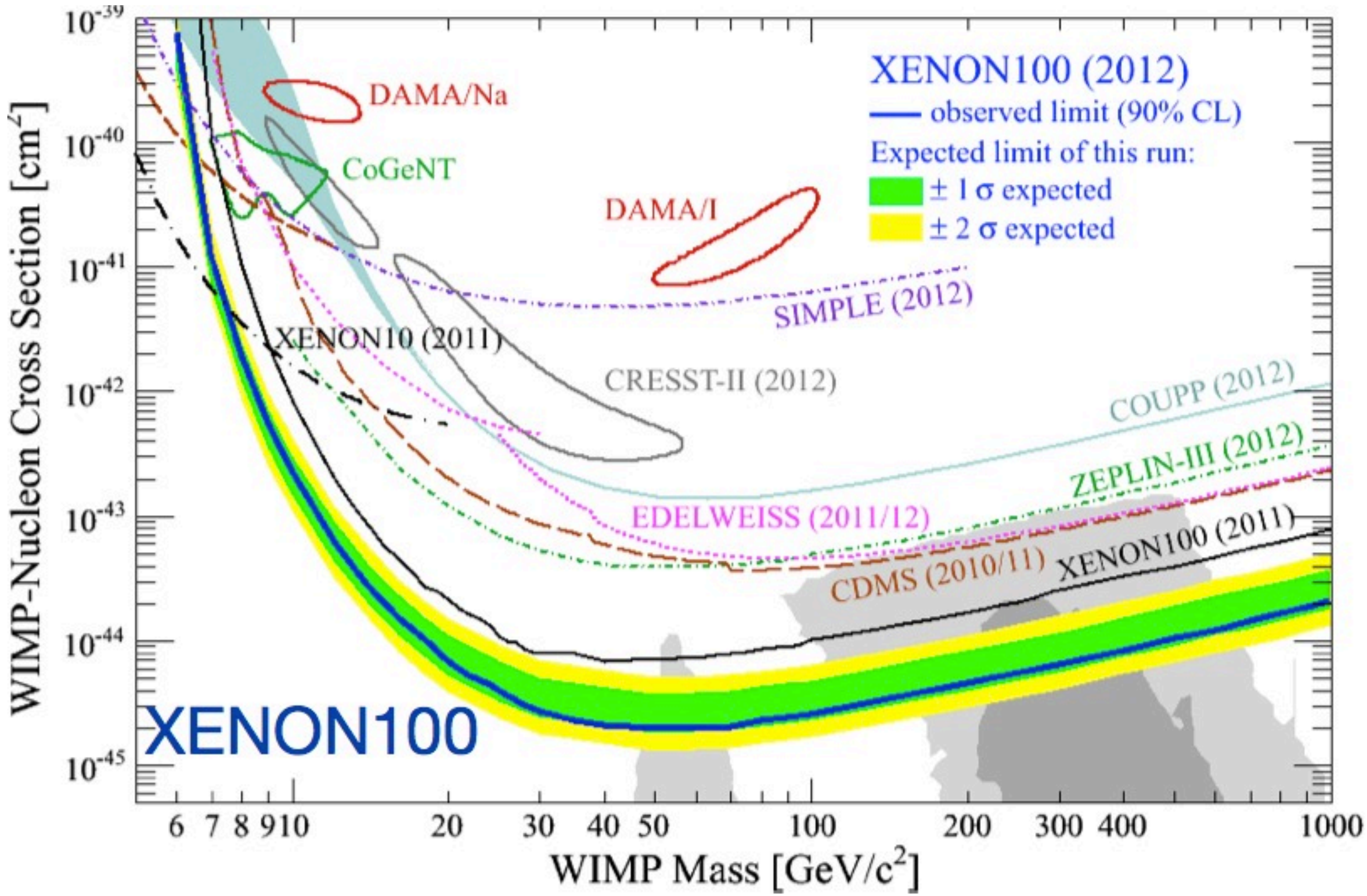
September 3, 2013

Why is Dark Matter search interesting

- Evidence for the existence of Dark Matter
  - Rotation curves of galaxies
  - Gravitational lensing due to DM
  - Latest result after Planck: about 27% of the energy content of the universe is cold dark matter
- One promising candidate for DM: WIMPs



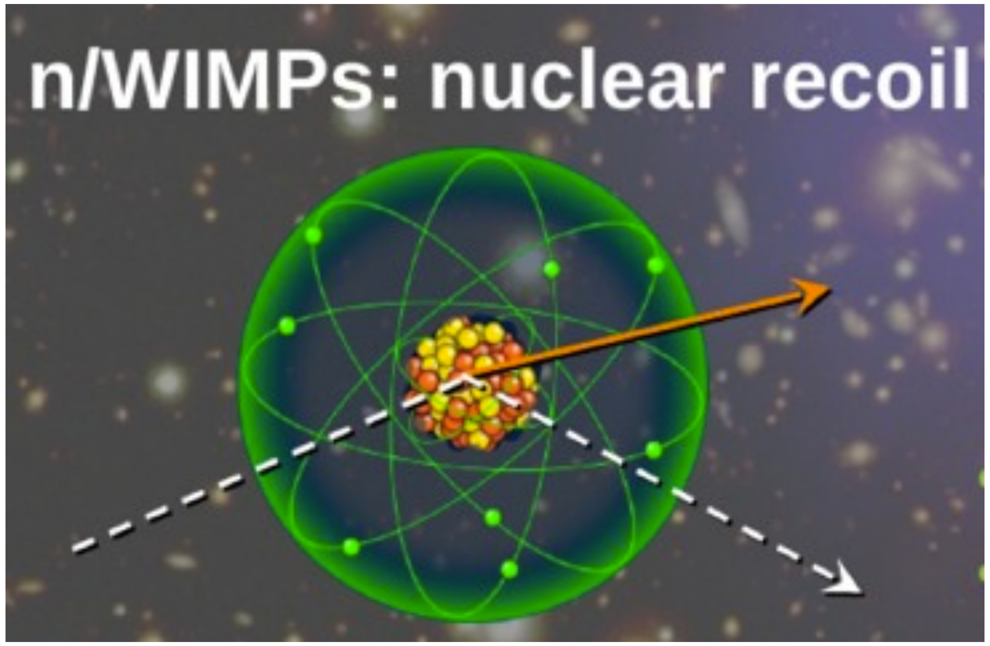
Current Status of direct DM search

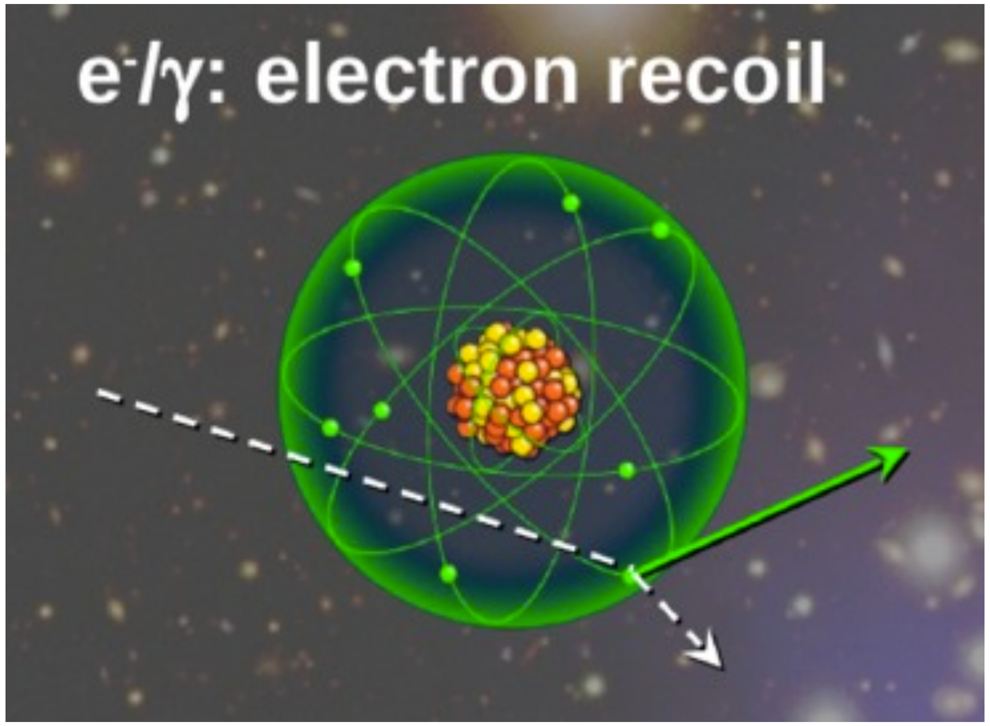


- Most interesting distribution for DM searches: Cross section at which WIMP interact with nucleons

Detection Principle

- Principle: nuclear recoil
  - Elastic collisions with nuclei
  - Energy of recoiling nucleus: ~ *keV*
  - Low expected signal rate
  - Expected background 10^6 higher
- Background sources
  - External and internal radioactivity
  - Cosmic background





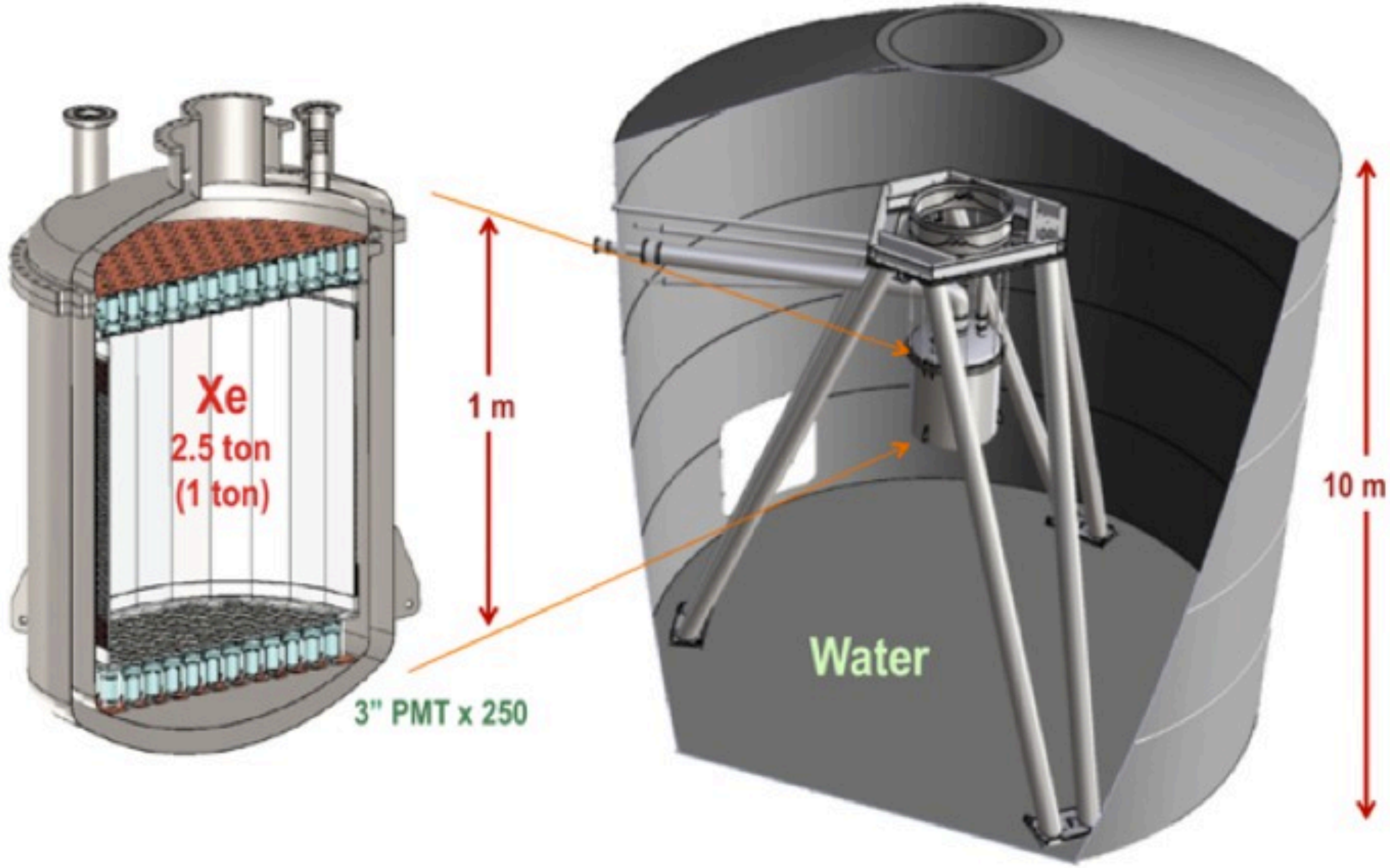
Experimental Setups (1/2)

- Cryogenic Solid State detectors
  - Detect phonons in Ge, $CaWO_4$ or Si induced by collisions with DM
  - Excellent energy resolution
  - Good sensitivity at low mass
  - Experiments: EDELWEISS, CRESST, CDMS
- Liquid Argon detectors
  - Detect scintillation light induced by elastic collisions of DM with Ar nuclei
  - Amount of scintillation light $\propto$ total energy
  - Good discrimination between electron recoils and nuclear recoils
  - Good sensitivity at high mass
  - Experiments: MiniCLEAN, DEAP

Experimental Setups (2/2)

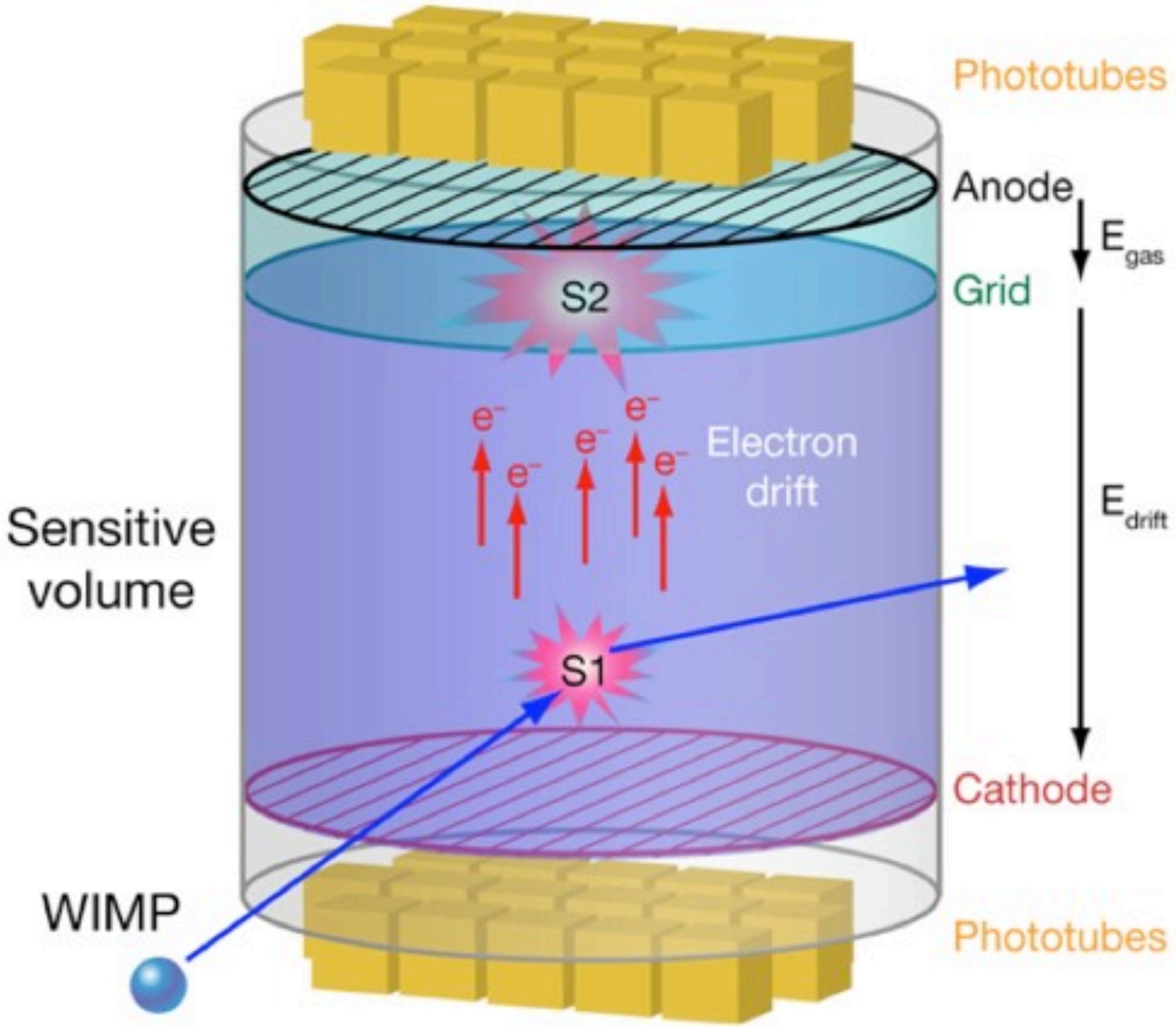
- Liquid Xenon detectors
  - Can be highly purified, chemically inert, radiopure
  - Large, spin independent cross section: $\sigma \propto A^2$; A=131
  - Self-shielding versus external background
  - Xe: good scintillator
  - Good sensitivity from low to high masses
  - Experiments: XENON, LUX, PandaX
- Threshold detectors, bubble chambers, scintillating crystal detectors, directional detectors

XENON 1T



- Location: Hall B at LNGS (Gran Sasso)
- TPC containing 2.2 T pure (ppb level) LXe, about 1.1 T fiducial volume
- 250 PMT (Hamamatsu R11410) with maximum sensitivity at 180 nm
- Additional component w.r.t. Xenon100: 9.6m diameter water tank as shield + Cherenkov muon veto

XENON 1T



- Dual-phase TPC
- S1: primary scintillation light at WIMP interaction point
- S2: electrons drift towards the top array and produce scintillation light produced in gas phase
- Reconstruct interaction point by using S1 and S2 pattern
- High density ionisation for nuclear recoil -> more recombination than for gamma/ electron recoil

-> **S2/S1(ER) >> S2/S1(NR)**

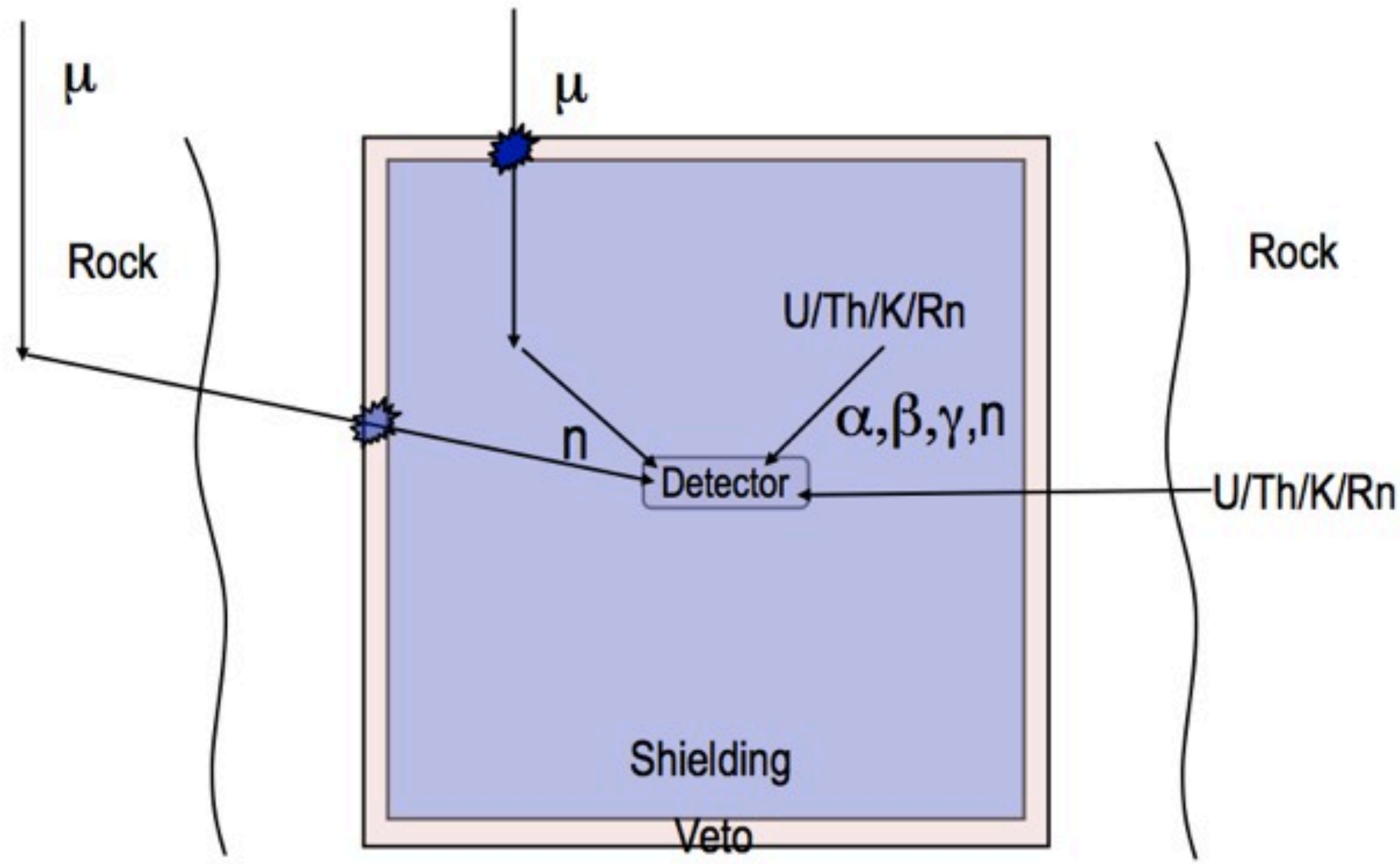
XENON 1T vs. XENON 100

- Similar principle as XENON100, based on the well estabilished technologies
- ~10 more signal and ~100 less background
  - Reduced background due to increased self-shielding (higher Xe volume)
  - New: water tank to shield neutron induced by cosmic radiation
- Lower recoil threshold
- Identical particle identification techniques

Current Status of the Experiment

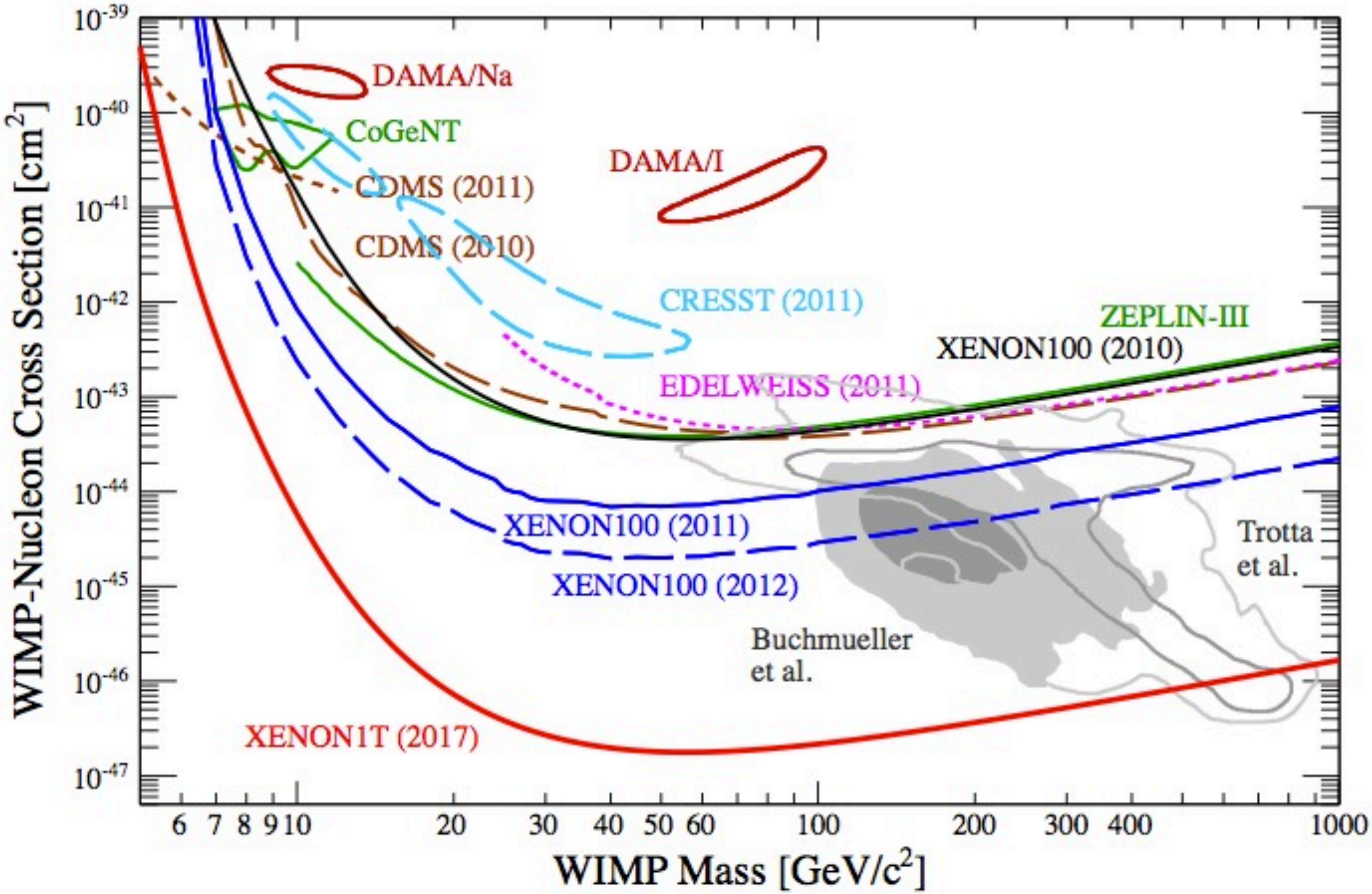
- XENON1T is currently under construction
- Commissioning planned in 2014
- First run planned in 2015
- Guaranteed funding: ~11 million dollar; ~50% by USA; rest from other sources

Proposal: Study of Shielding



- Principle: veto incoming particles using Cherenkov radiation in water
- Water tank is new component in detector design to further reject background
- Necessity proved by Monte Carlo simulation
- We intent to perform detailed studies of the background rejection performance using the water shield

Expected Sensitivity for XENON1T



- Able to test a favourite parameter space of cMSSM
- Expected: 100 events in 2 yrs for $\sigma \sim 10^{-45}$ cm² and $m_\chi \sim 100$ GeV
- Sensitivity for XENON100: $\sim 10^{-45}$ cm²; Expected for XENON1T: $\sim 10^{-47}$ cm²

Summary

- Dark matter is one of the key points to understand the structure of the universe
- Cross section limit improved by 5 orders of magnitude in last 30 years
- In absence of signal XENON1T will be able to improve the exclusion limit by another 2 orders of magnitude, probing favourite parameter space of e.g. cMSSM
- Detector design similar to XENON100, except for addtional water tank to reject external background
- We intent to perform detailed studies of the rejection of external backgrounds using the water shield