# XENON1T: a ton scale Dark Matter Experiment

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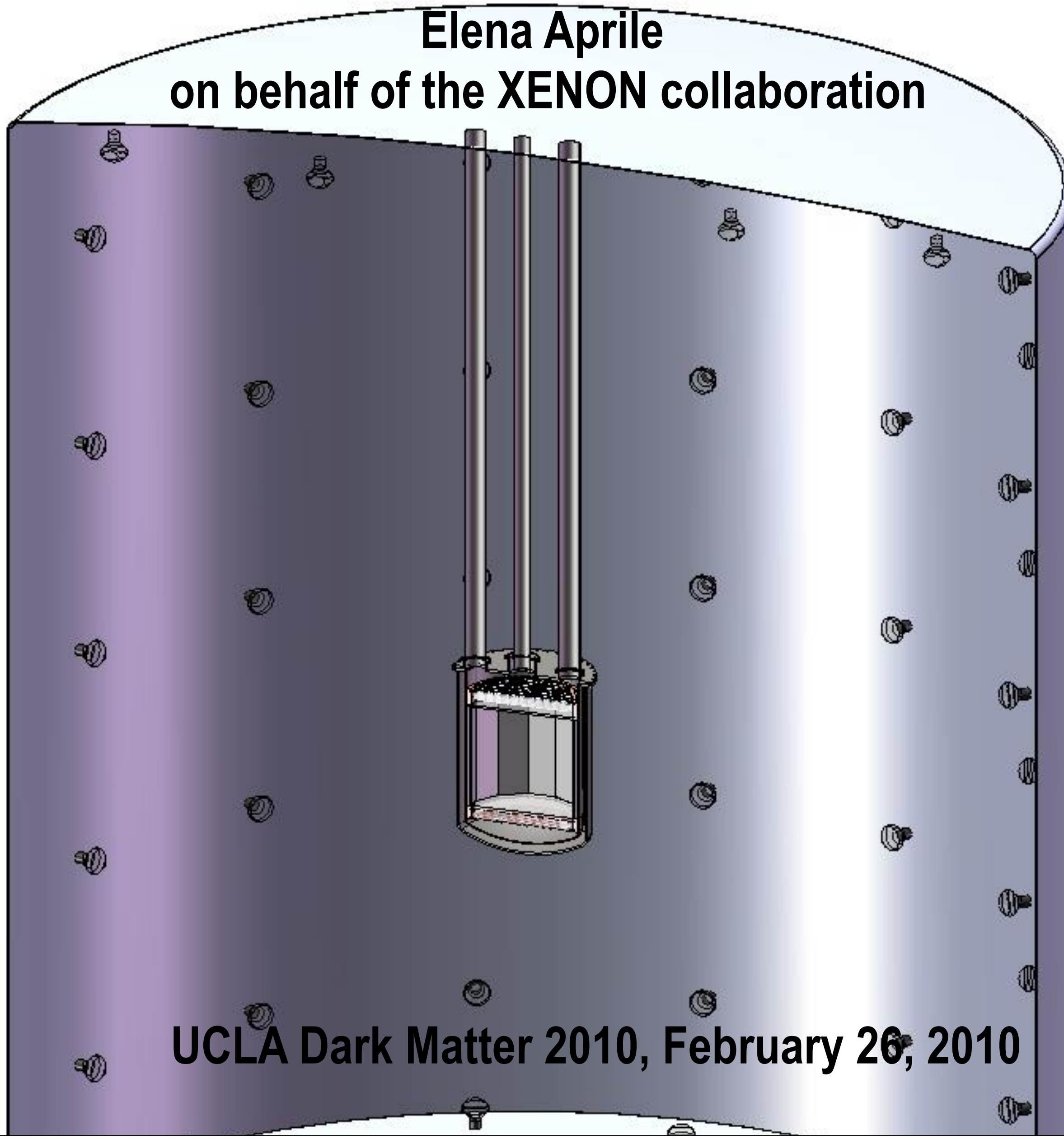
on behalf of the XENON collaboration



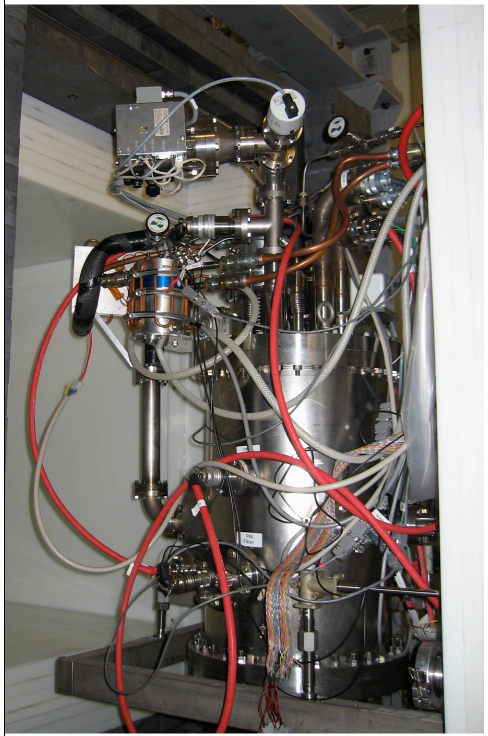
UCLA Dark Matter 2010, February 26, 2010

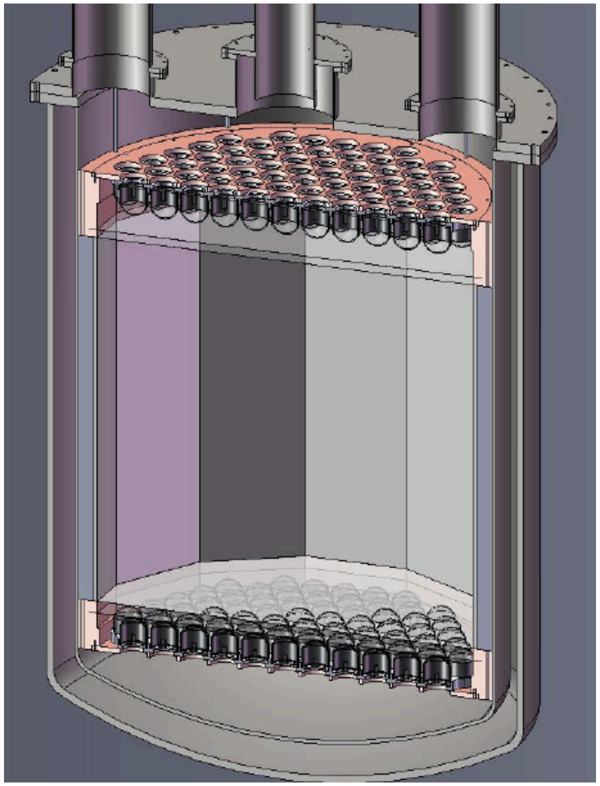
# The XENON Dark Matter Project Roadmap

*past*
*(2005 - 2007)*

*current*
*(2008-2010)*

*future*
*(2011- 2015)*





**XENON10**

*Achieved (2007)* $\sigma_{SI}$=8.8 x$10^{-44}$ cm$^2$

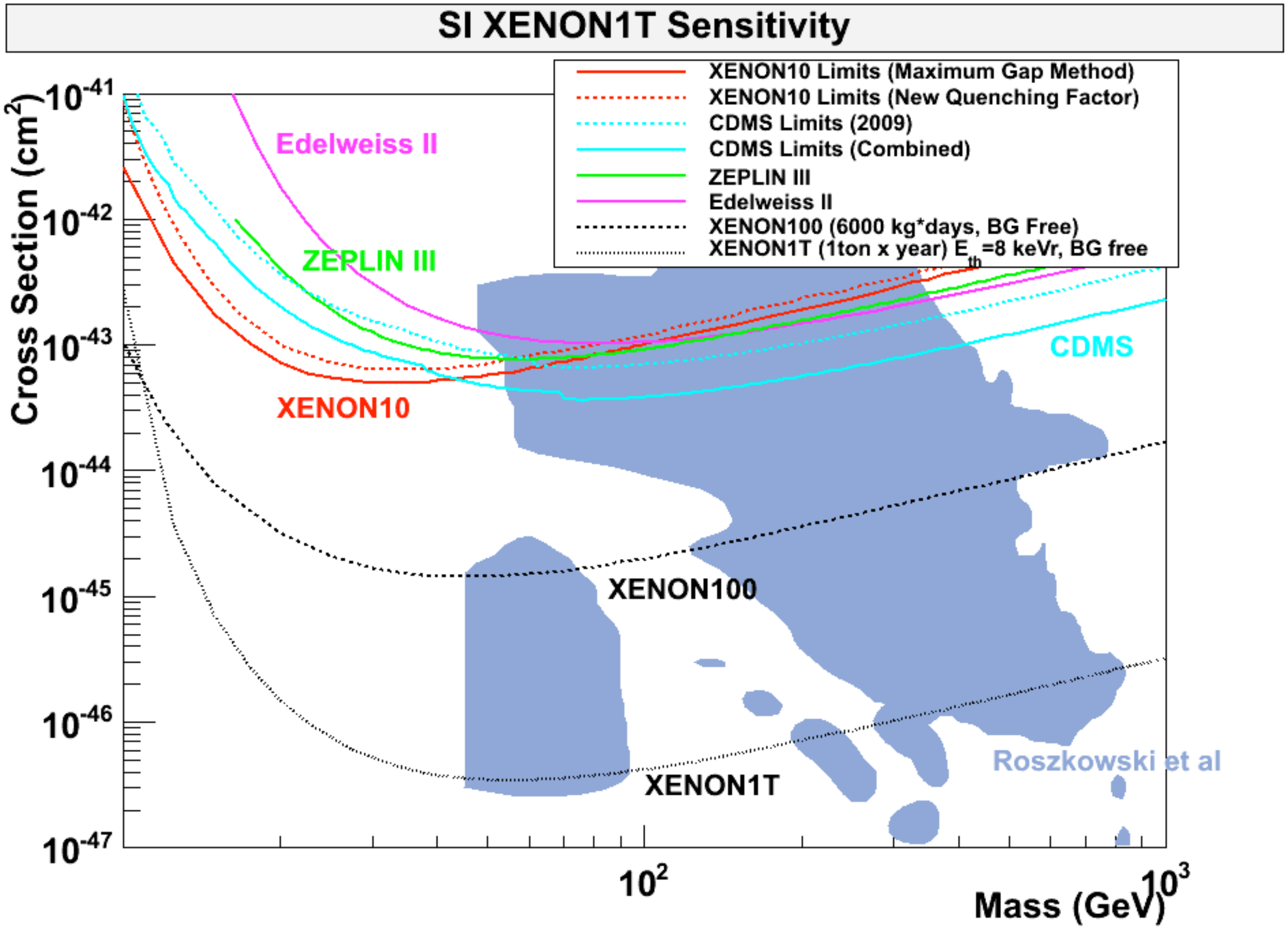
**XENON100**

*Projected (2010)* $\sigma_{SI}$~2x$10^{-45}$ cm$^2$

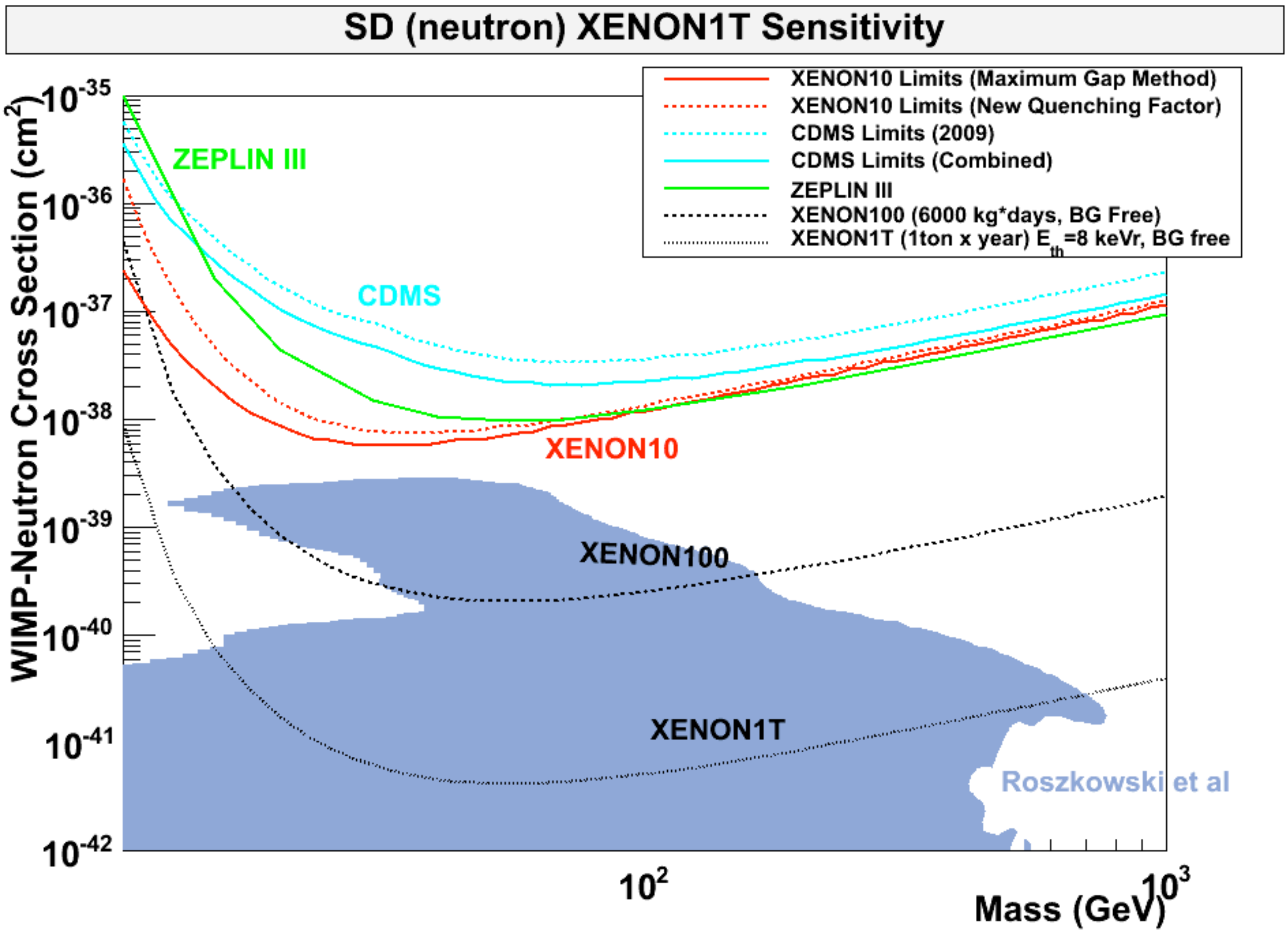
**XENON1T**

*Goal:* $\sigma_{SI}$ <$10^{-46}$ cm$^2$

# Spin-Independent Projected Sensitivity

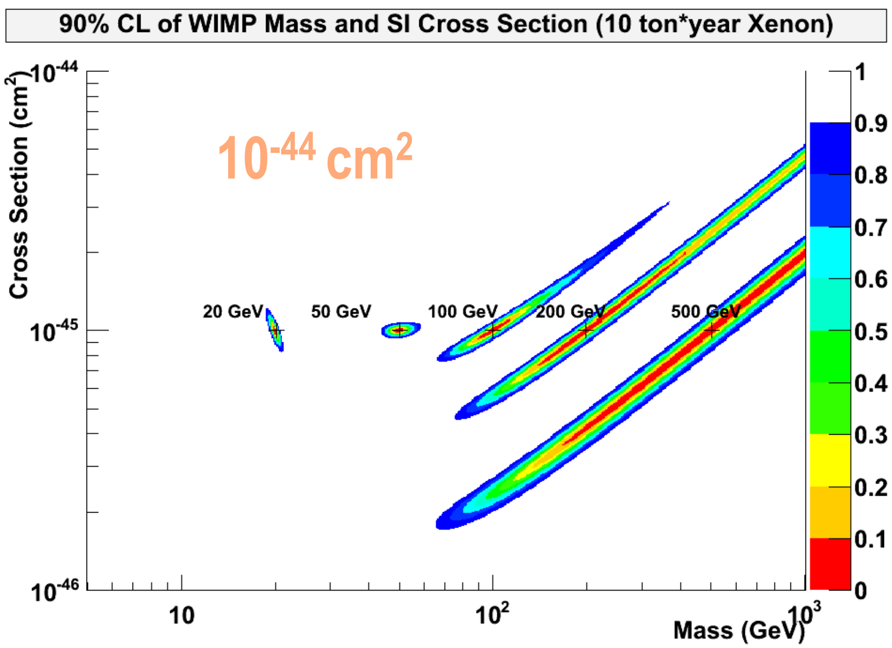


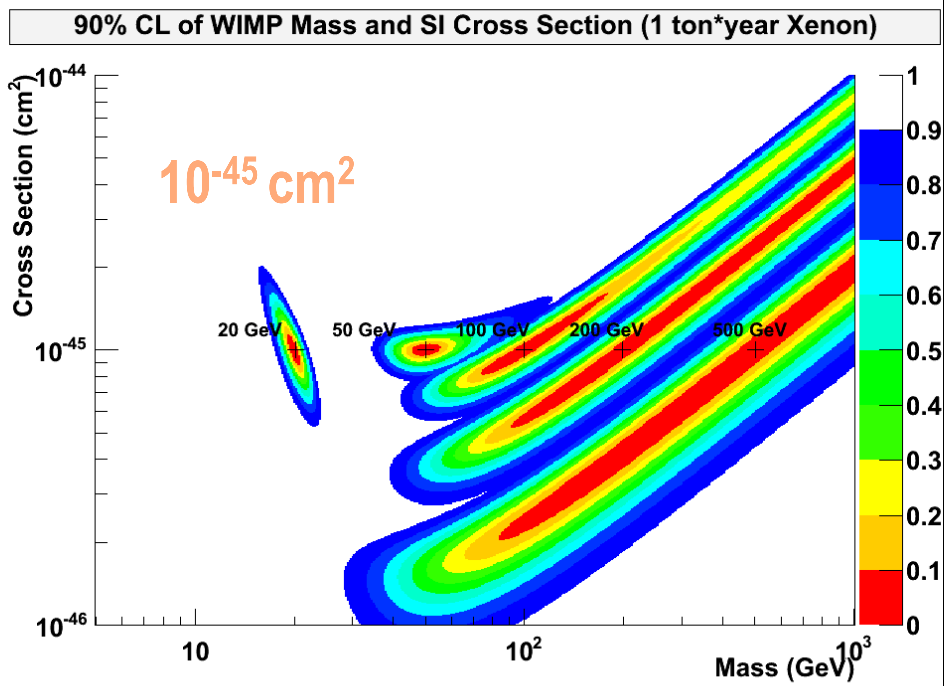
# Spin-Dependent Projected Sensitivity



# Constraints on WIMP Mass

| Number of events | | Mass (GeV) | | | | |
|---|---|---|---|---|---|---|
| | | 20 | 50 | 100 | 200 | 500 |
| Cross Section | $10^{-44}\ cm^2$ | 230 | 710 | 560 | 330 | 140 |
| | $10^{-45}\ cm^2$ | 23 | 71 | 56 | 33 | 14 |



# XENON1T Collaboration

USA, Switzerland, Portugal, Italy, Germany, France, China, Netherlands

COLUMBIA

RICE

UCLA

ZURICH

COIMBRA

LNGS

INFN

MPIK

Bologna

SJTU

MUENSTER

SUBATECH

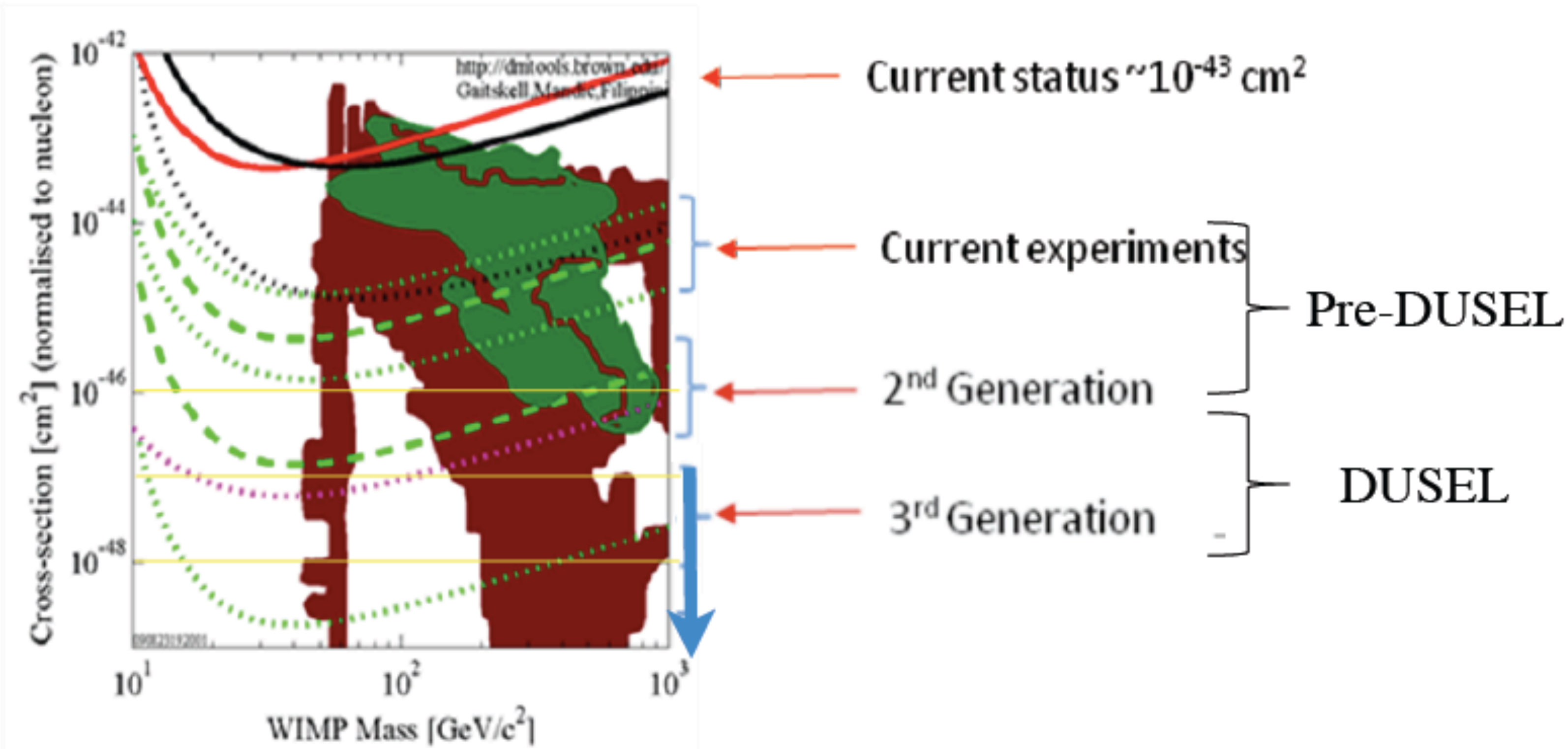
NIKHEF

# The case for XENON1T

- XENON100 is working very well. It is the largest mass and lowest background DM experiment accumulating statistics. The fiducialization allowed by the 3D TPC, the active LXe veto and the S2/S1 discrimination allow for a background free target of many tens of Kg mass.
- Within 2010 XENON100 will a) either see a signal  or b) will significantly constraint WIMP models for both SI and SD cross-section compared to current situation. Continued improvement in sensitivity with several targets will be essential for the field.
- Based on our understanding and progress achieved with critical technologies a Xe two-phase detector at the ton scale is feasible and can be realized within a few years. The risks and the costs are fully understood.
- With a strong international collaboration, with continued support from the National Science Foundation, with 50 - 50 share of resources between US and foreign groups, the goal is an experiment working before the middle of 2010.
- Three key factors have accelerated our roadmap towards XENON1T: 1) cost of Xe material; 2) QUPID development; 3) foreign collaborators with guaranteed funding.

- XENON1T is in line with PASAG recommendation of a vigorous pre-DUSEL program of G2 experiments to push technologies while achieving great science

# Generation 2 and 3: PASAG definition




G2 ≈ $10^{-46}$ cm$^2$ or lower, construction and operation cost \$15M-\$20M, ≈ 2013

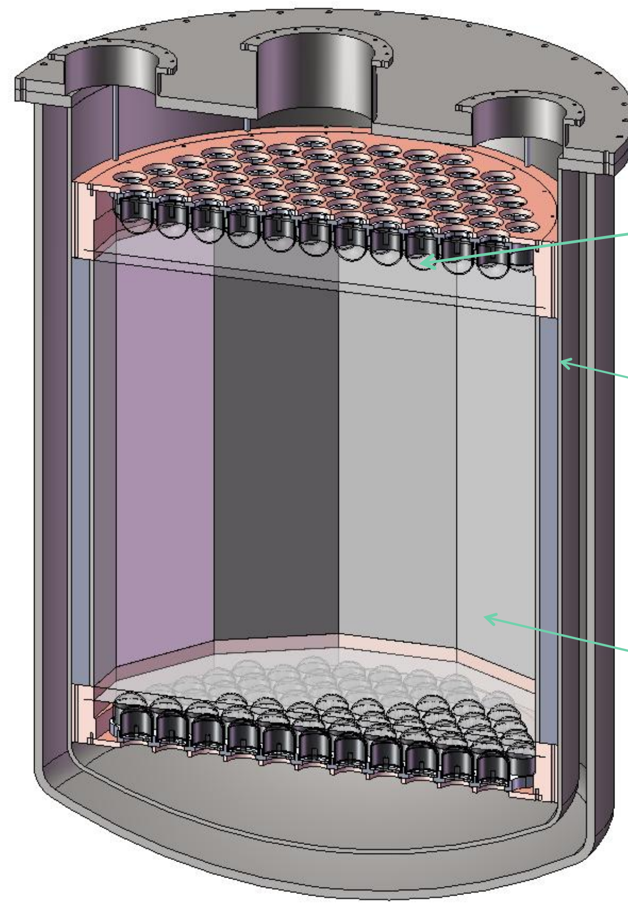
G3 ≈ $10^{-47}$ cm$^2$ or better, construction and operation cost \$50M, ≈ 2017

Note: slight disagreement between PASAG figure and text. Here the figure has been corrected

Scenario A: FY10 \$84M, 3.5%/yr, \$266M FY10-FY20 runout in FY10 dollars
B: FY10 \$94M, 3.5%/yr, \$389M ...
C: FY10 \$96M, 6.5%/yr, \$640M ...

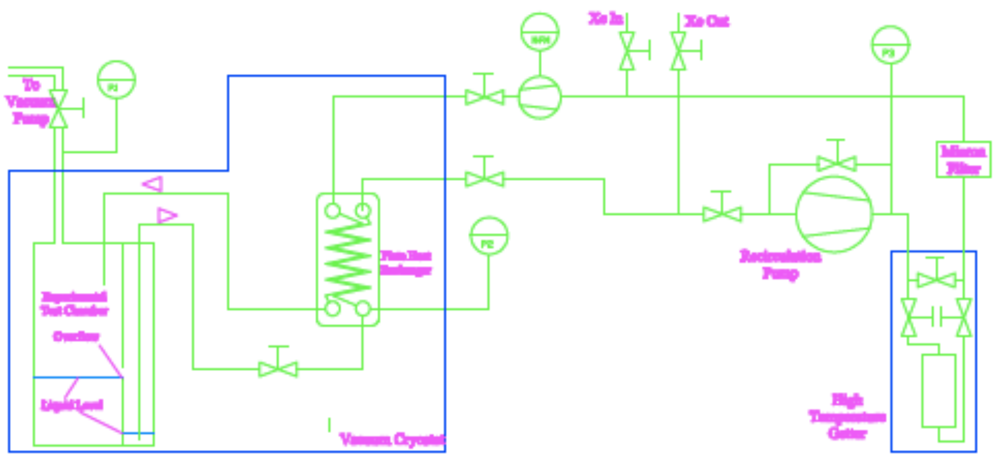
# XENON1T Cryostat and Detector

- Design follows closely the approach tested with XENON10 and XENON100, with improvements in several areas:
  - Cryostat and Detector Vessels: Lower radioactivity
  - PMTs & Cabling: Lower radioactivity QUPIDs ( see Arisakas' talk)
  - Cryogenics: Cryocooler with Heat Exchanger ( see next slide )
  - Xe storage and filling: Liquid Phase (MEG experience)
- Efficient background reduction based on:
  - 3D event imaging of a TPC
  - self-shielding of the dense LXe
  - Charge & Light discrimination
- Technical proposal in preparation with full costing and risk assessment, especially for the water shield option
- Capital cost ~8 M$ shared 50-50 between US and foreign



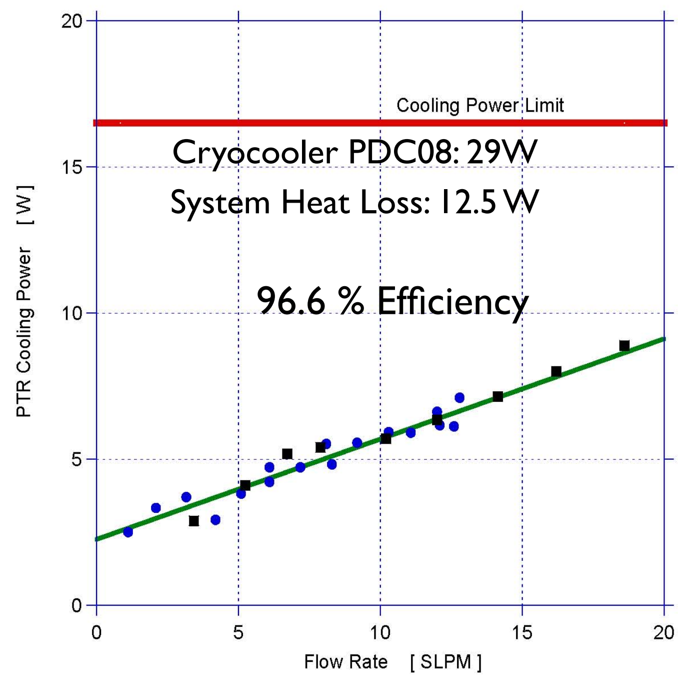
# XENON1T Cryogenics and Purification System

- Baseline design based on single 200 W Pulse Tube Refrigerator (as in XENON100 and in the MEG experiments)
- Differences:
  - Improved thermal insulation. Keep heat losses below 50 W
  - Filling and Recovery in liquid phase (as in MEG experiment) however gas phase recirculation-purification
  - Use of efficient Heat Exchanger to evaporate and recondense Xe gas for recirculation (Tested at CU)
  - With PC150 PTR, with largeer pump and getter,  gas flow rate would be ~300 SLPM
  - No need for liquid recirculation




Test Set-up at Columbia

Heat Exchanger Performance



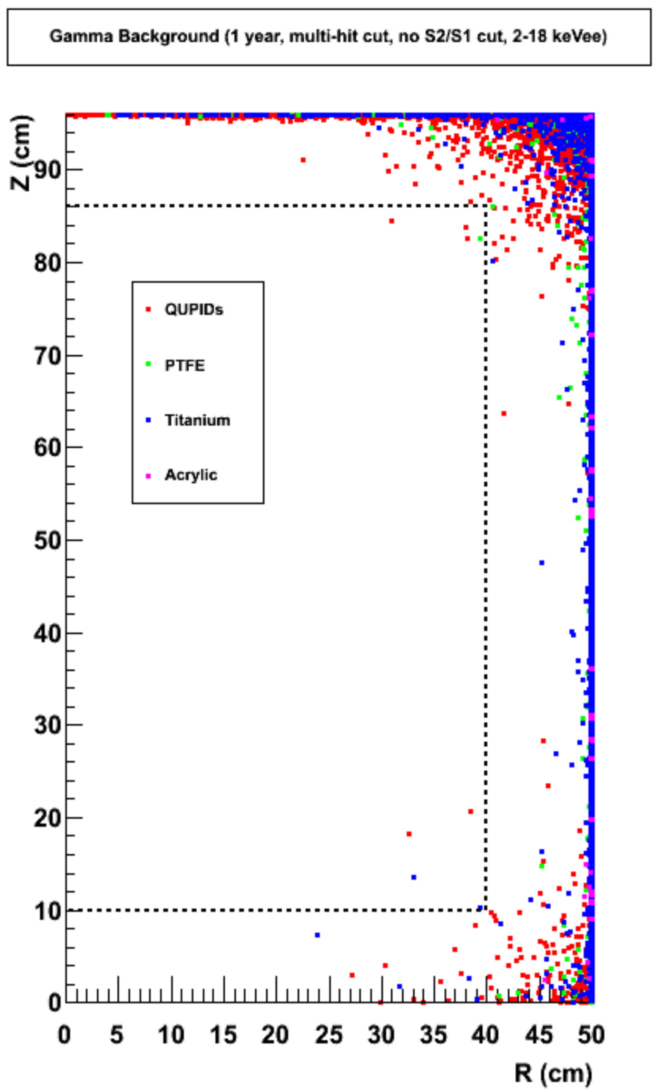
# XENON1T Gas & Liquid Storage Systems

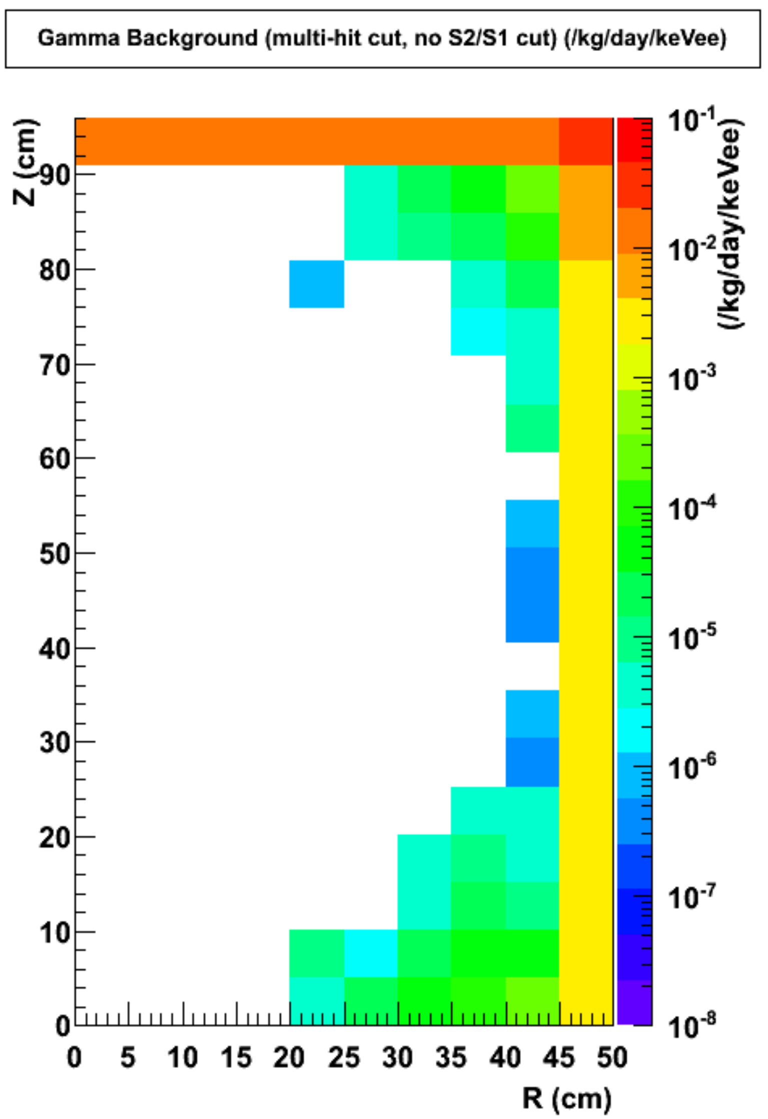
Gas Storage: 8 Tanks
250 liter each
60 bars
360 kg each


Liquid Storage:1 Tank
1000 liter
<20 W Thermal Loss
1 PTR (PC150)

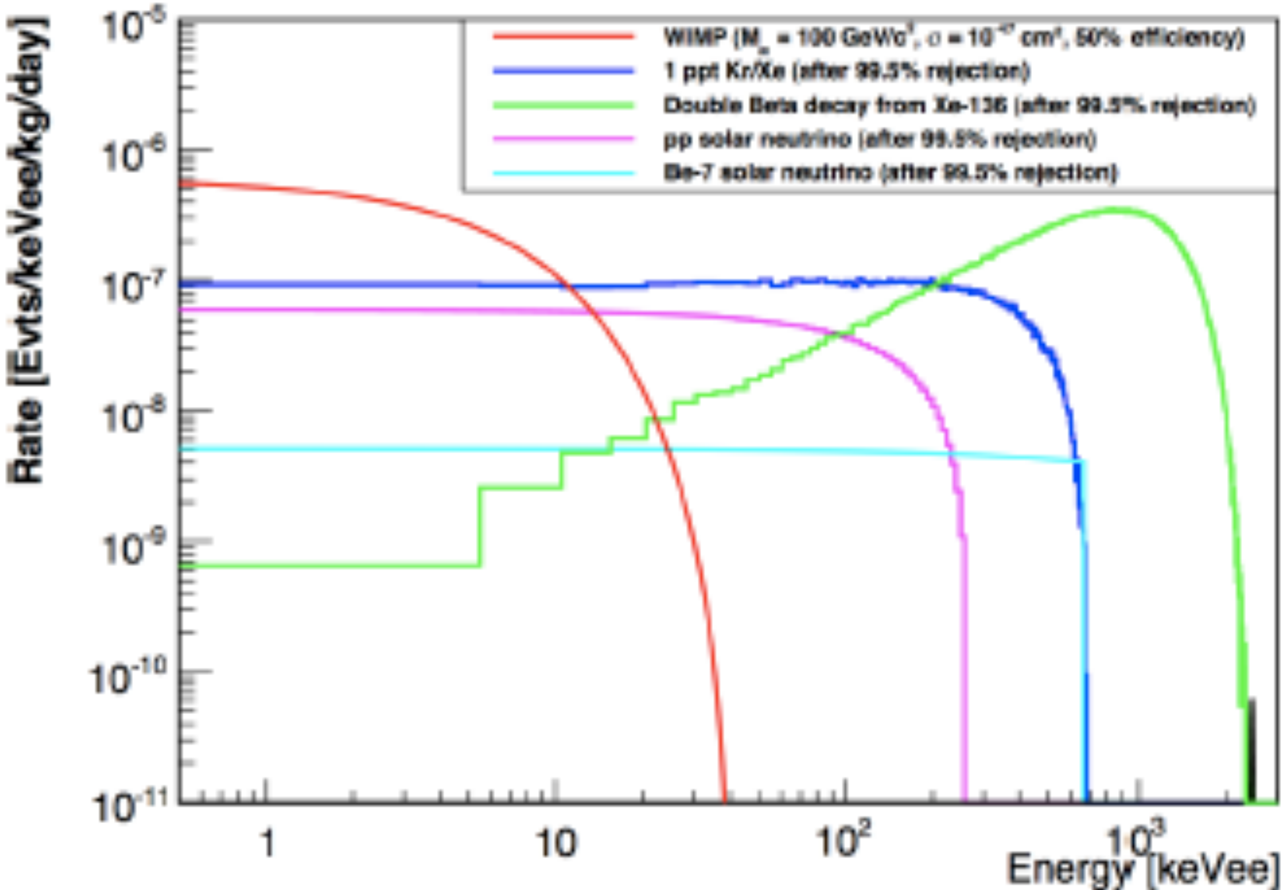
# Expected Gamma-Background

## (1 Year, Multi-hit Cut, no S2/S1 Cut)



# WIMP Signal and Gamma Background




Gamma rays: < 0.07 /ton-year

Neutrons: < 0.1 /ton-year

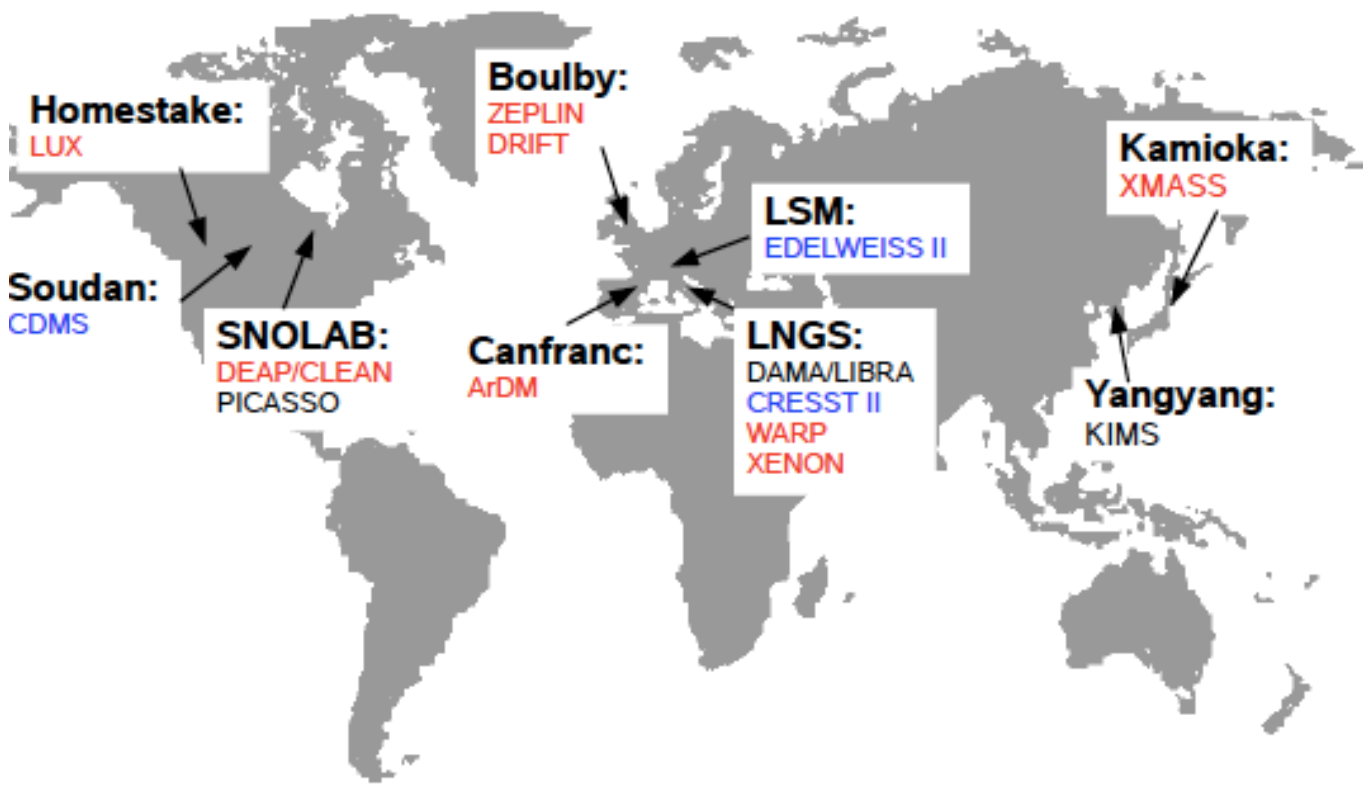
Kr85: < 1 /ton-year for 1ppt Kr/Xe

Irreducible background from pp solar neutrino ~0.5 event /ton/year

# Location for the XENON1T Experiment

Collaboration is studying two options for site and shield

- LNGS with a water tank acting as shield and muon veto
- LSM with a polyethilene-lead shield and plastic scintillators for muon veto

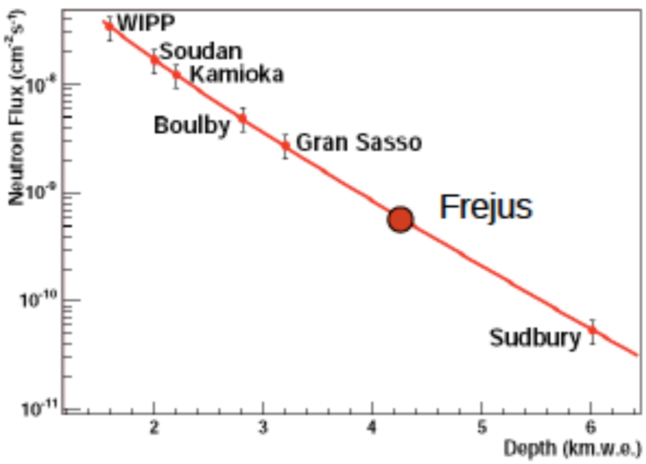


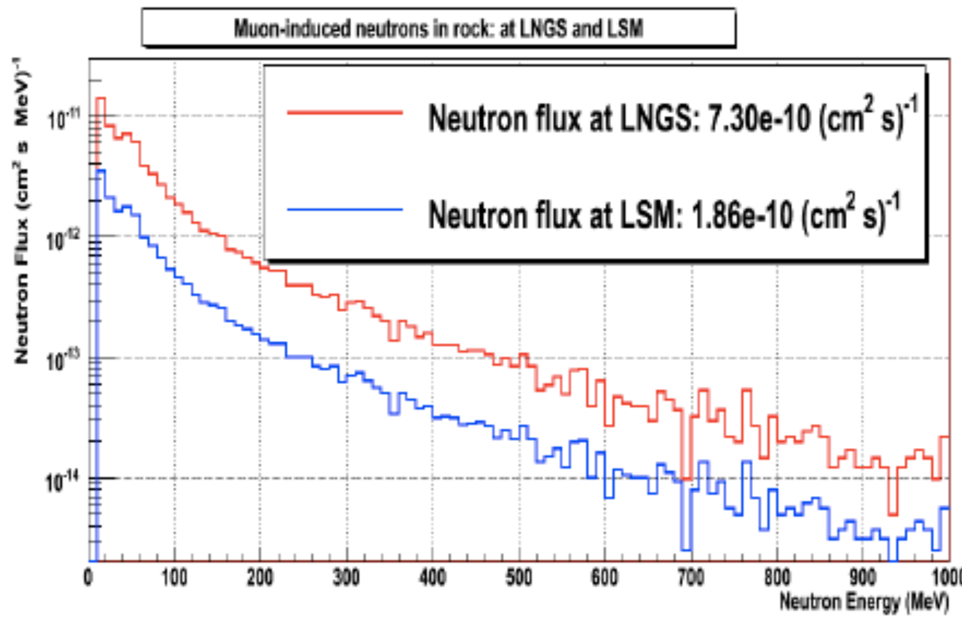
# Muon-induced Neutrons

The neutron flux ($\phi_n$) as a function of depth is shown in Fig. 14 where we have included a fit function of the following form:

$$\phi_n = P_0(\frac{P_1}{h_0})e^{-h_0/P_1}, \qquad (13)$$

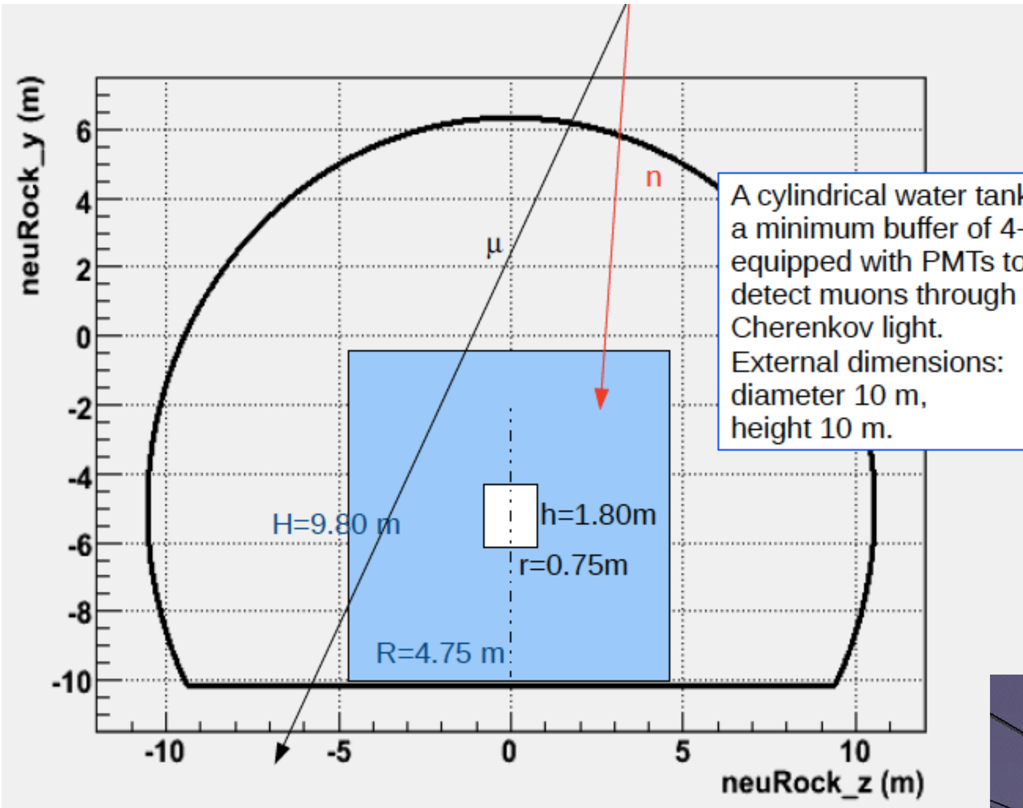
where $h_0$ is the equivalent vertical depth (in km.w.e.) relative to a flat overburden. The fit parameters are $P_0 = (4.0 \pm 1.1) \times 10^{-7}\ cm^{-2}s^{-1}$ and $P_1 = 0.86 \pm 0.05$ km.w.e..



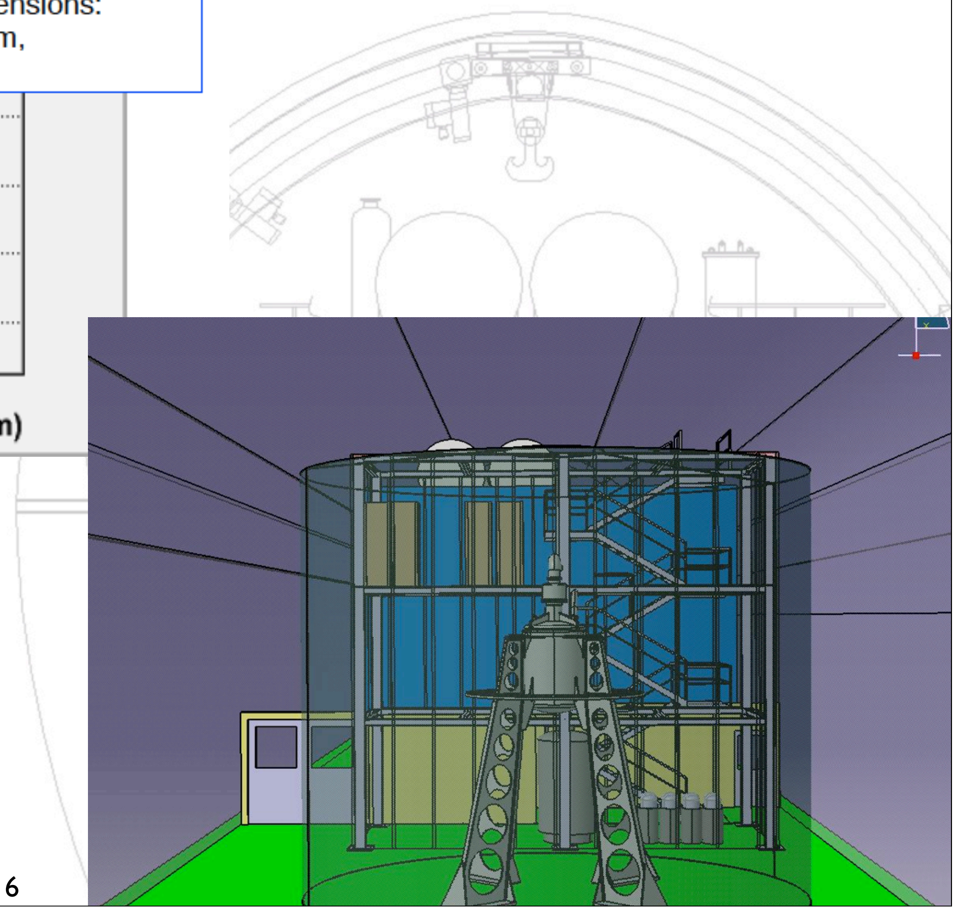




Energy spectrum from our Geant4 MC simulation of the muon induced neutrons at LNGS, rescaled for the LSM depth.
The neutron flux normalizations are taken from Mei and Hime (astro-ph/0512125v2) for $E_n$> 10 MeV.

# Water Shield at LNGS

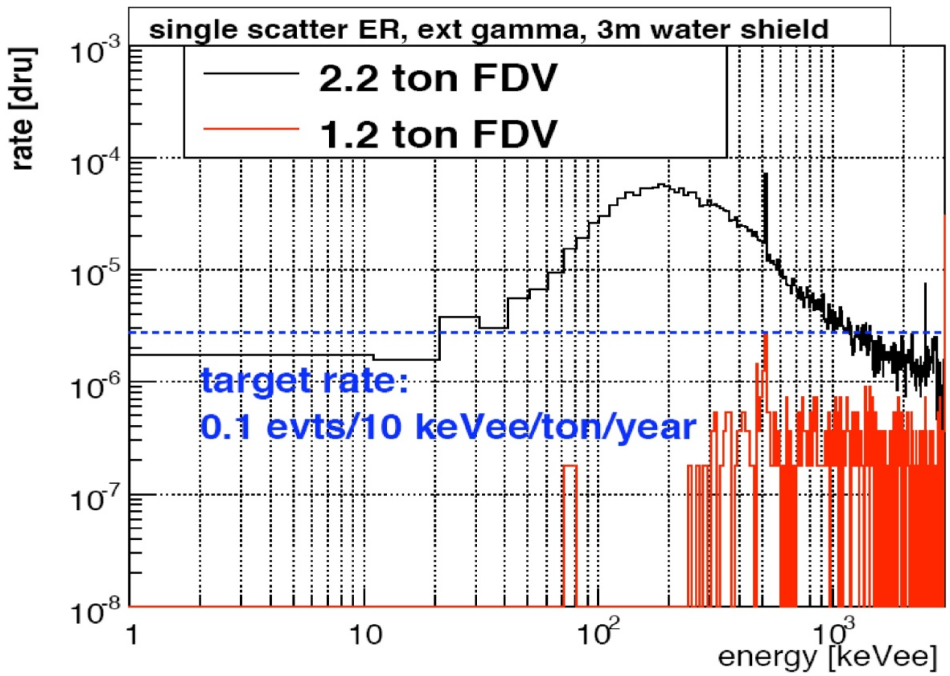



A cylindrical water tank with a minimum buffer of 4-5 m, equipped with PMTs to detect muons through Cherenkov light.
External dimensions:
diameter 10 m,
height 10 m.



# Water Shield @ LNGS

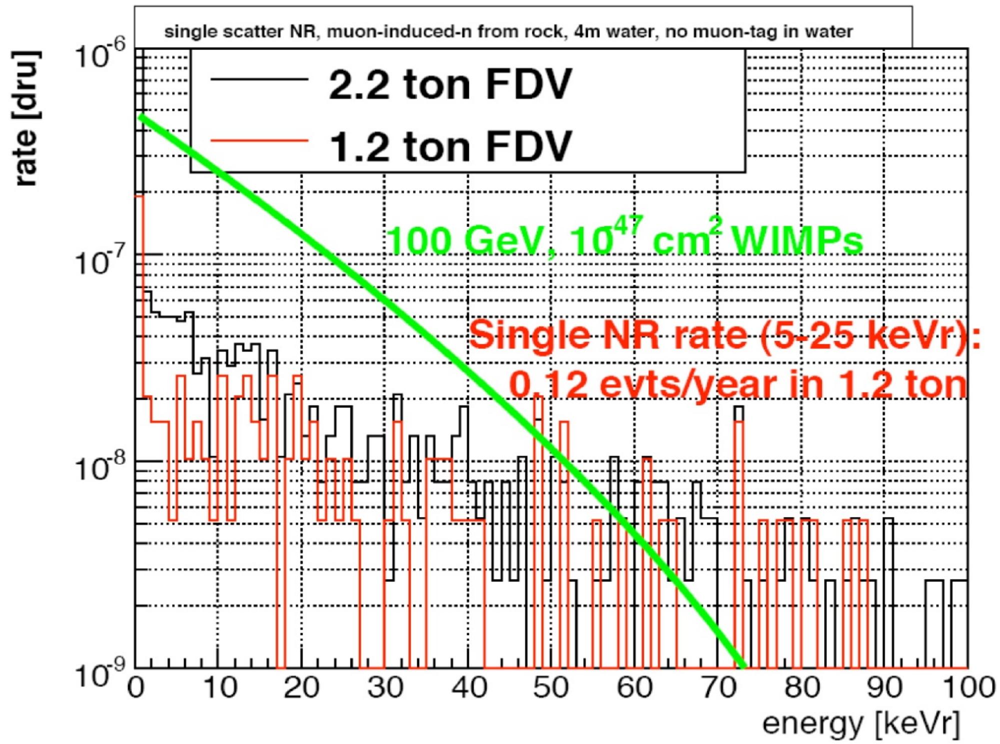
- external gamma background (0.13 $\gamma/cm^2/s$) requires at least 3m of water (reduction factor 100/m)




- with 3m water, less than 0.0001 evts/keVee/ton/year remain in the fiducial volume after electron recoil discrimination

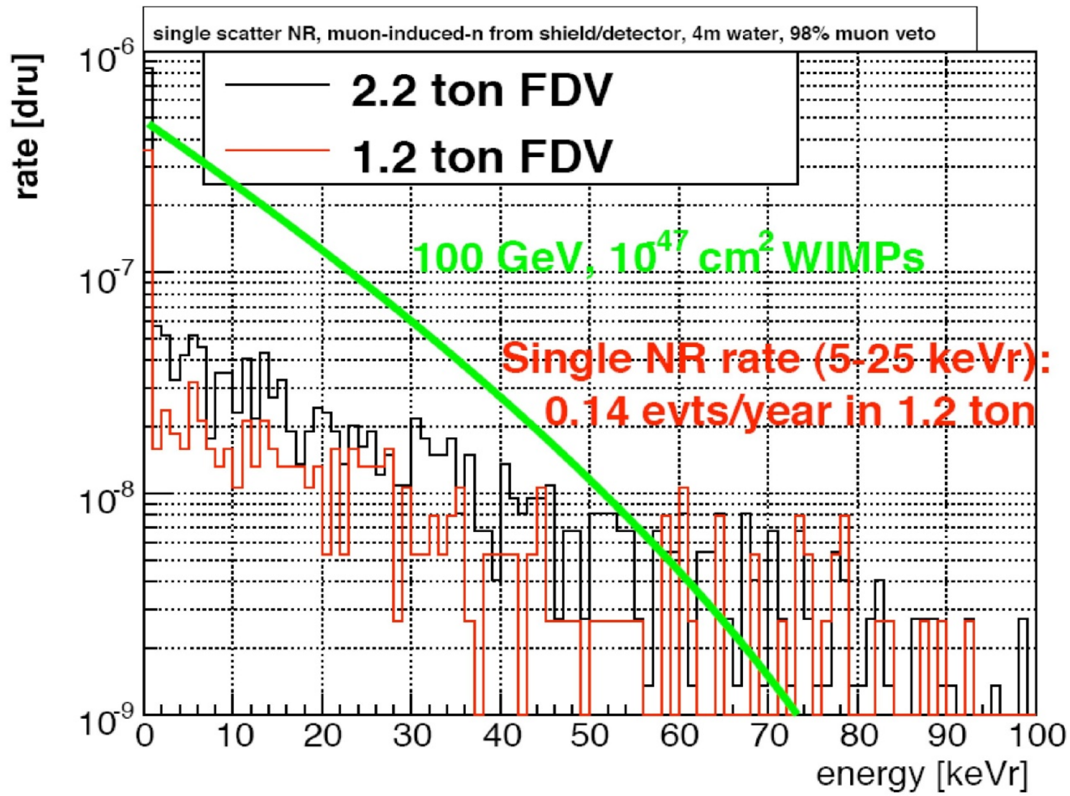
# Water Shield @ LNGS

- neutrons from radioactivity ( ($\alpha$,n), fission) negligible (reduction factor $10^5$/m)
- neutrons induced by muons in the rock require at least 4m of water at LNGS (reduction factor 3/m)



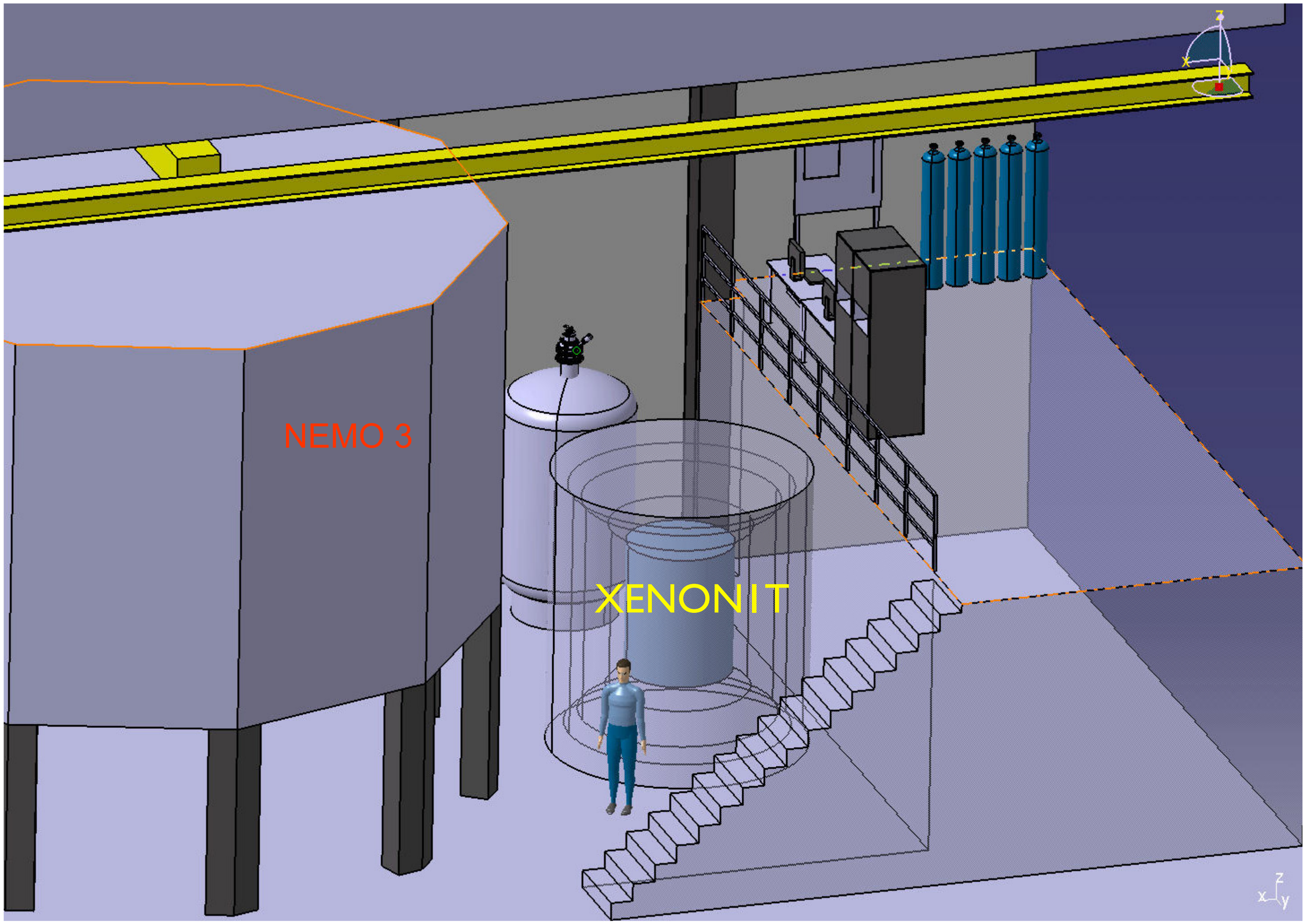
# Water Shield @ LNGS

- active muon veto against muon induced background in the shield, assumed efficiency 98%
- neutron background sufficiently low.
- gamma background negligible



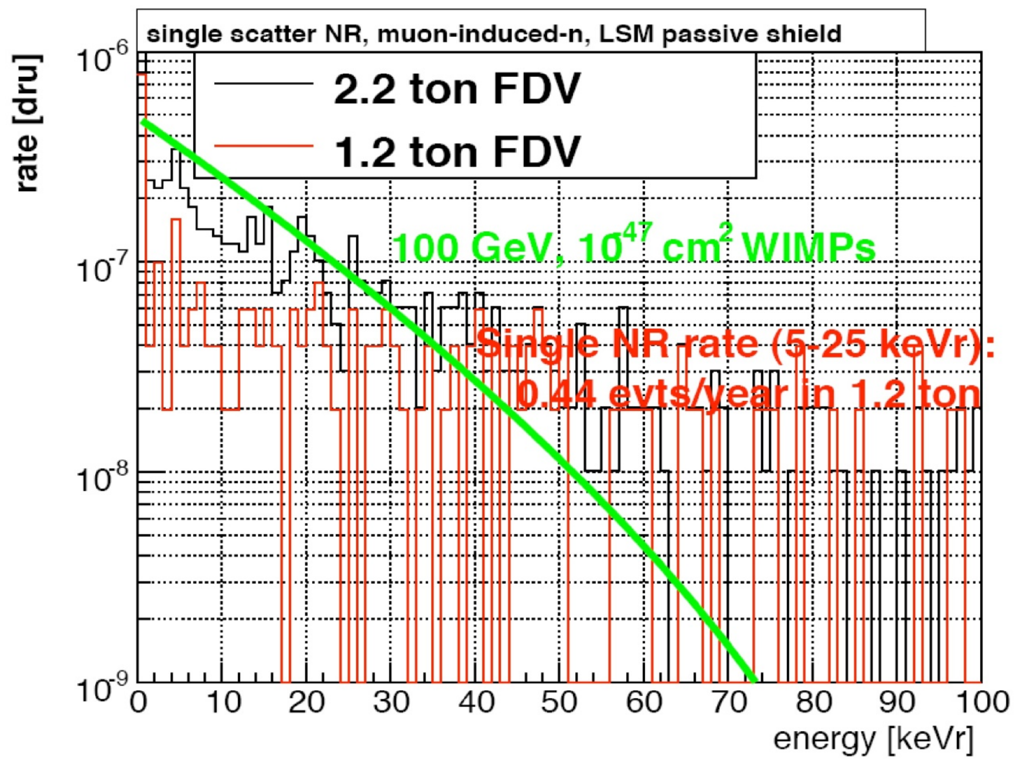
# Solid Shield at LSM

## XENON1T @ LSM



# Solid Shield @ LSM

- muon veto, 55cm PE, 20cm Pb, 15cm PE, 2cm Pb
- neutrons induced by muons in the rock can be reduced to sufficient level



# XENON1T at LNGS