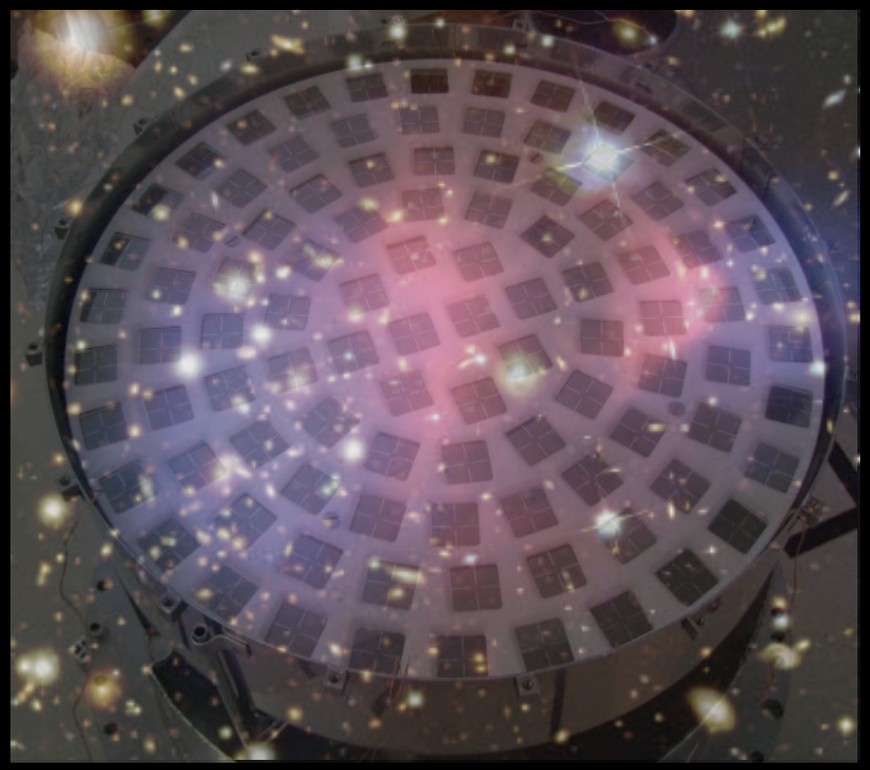
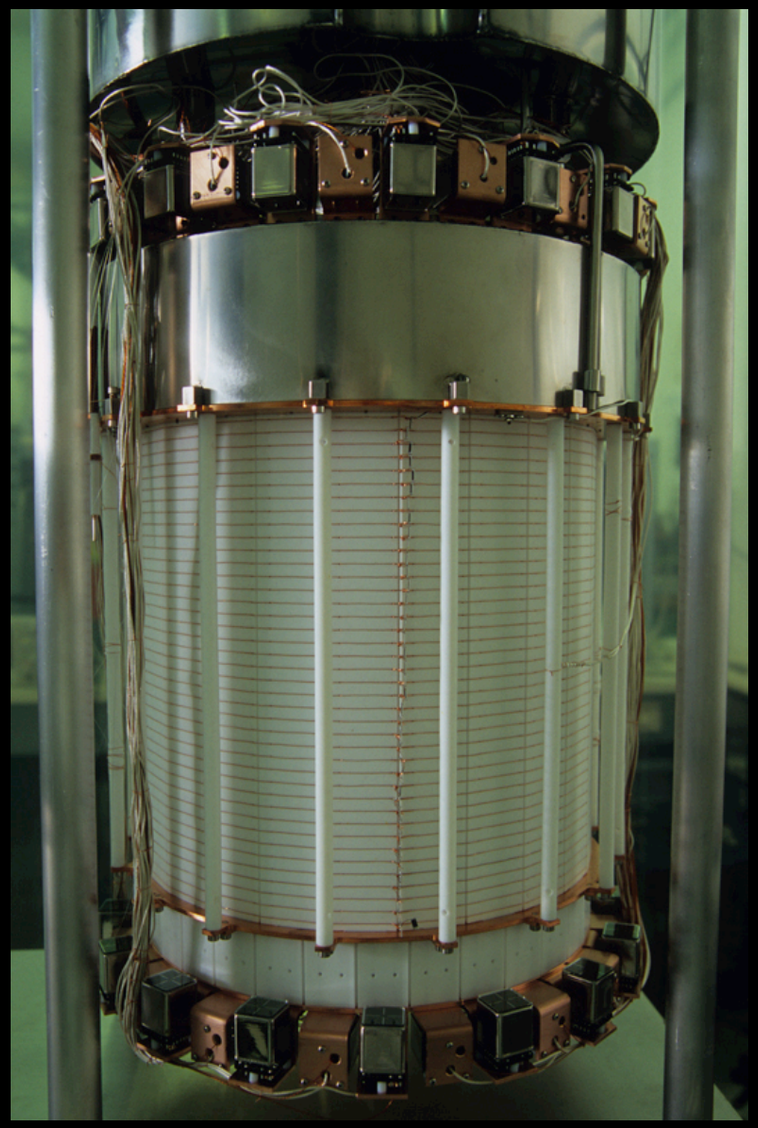
The XENON 100 Detector for Dark Matter Searches





Alexander Kish,
University of Zürich
Group of Prof. Laura Baudis

XENON-100 collaboration

45 researchers (incl. 15 graduate students and 10 postdocs)

from

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

Columbia University

University of California

University of Zürich

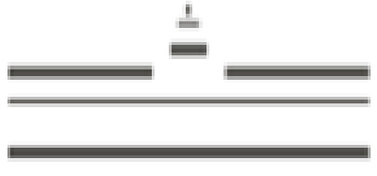
University of Coimbra

Rice University

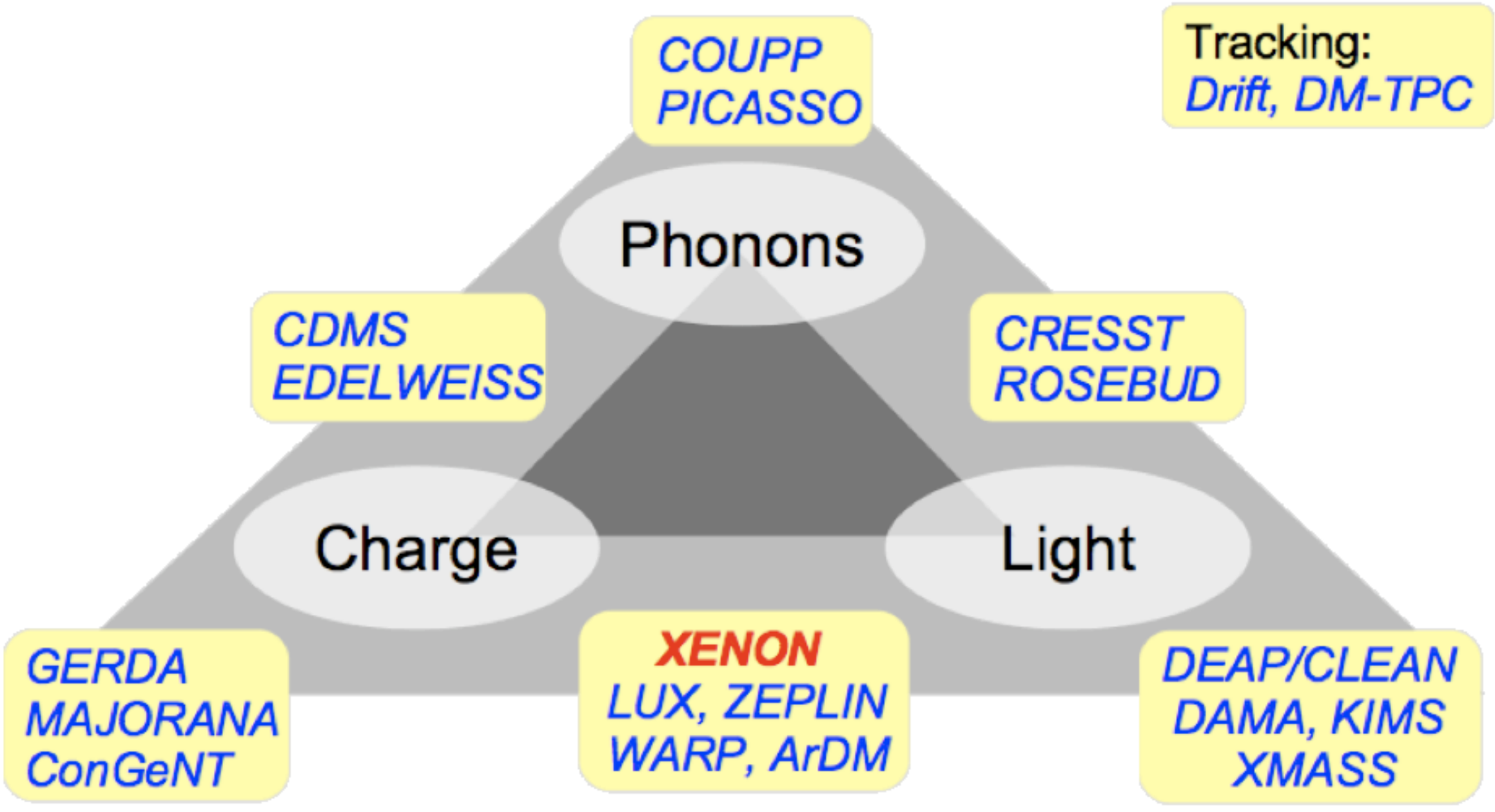
Waseda University

Laboratori Nazionali del Gran Sasso

Shanghai Jiao Tong University



Dark Matter Searches



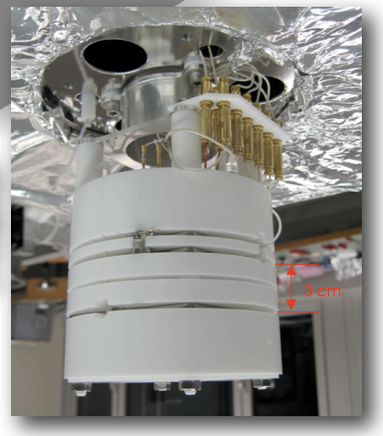
The XENON WIMP Search Program

2005 - 2007

Target Volume ~10 kg

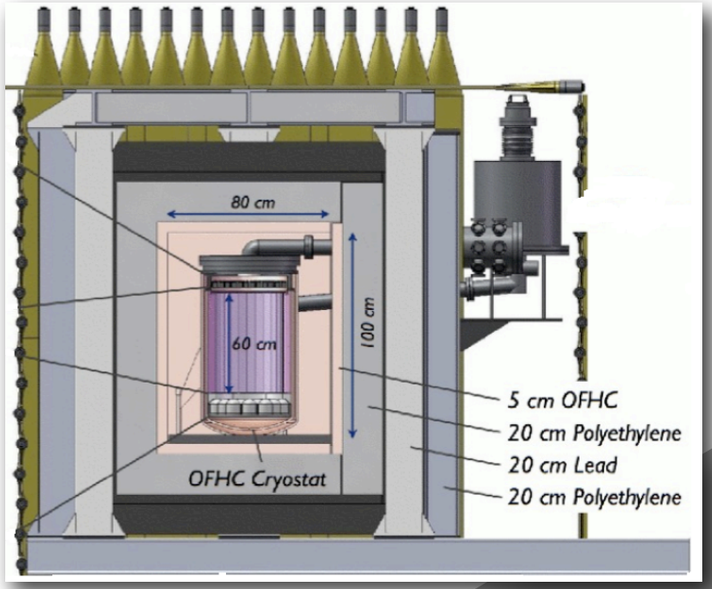
XENON 10

- R&D



ongoing...

2010 - 2012



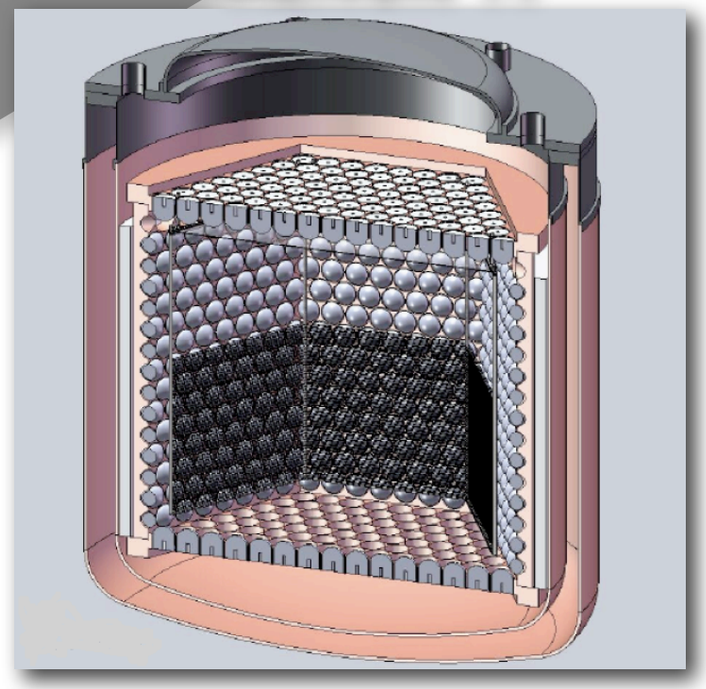
- XENON 100+

- XENON 100

2007 - ongoing...

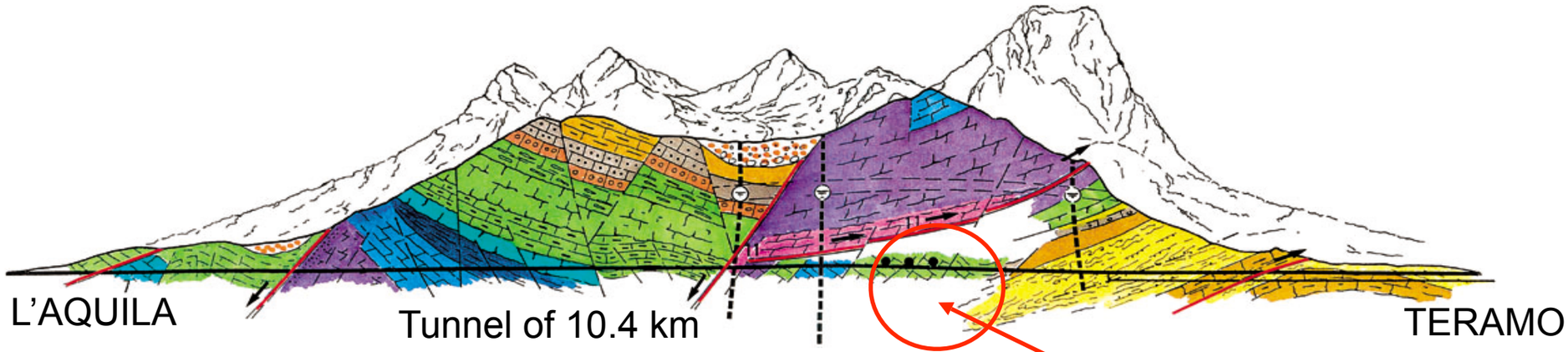
Target Volume 65 kg
Total 170 kg of LXe

- XENON 1T



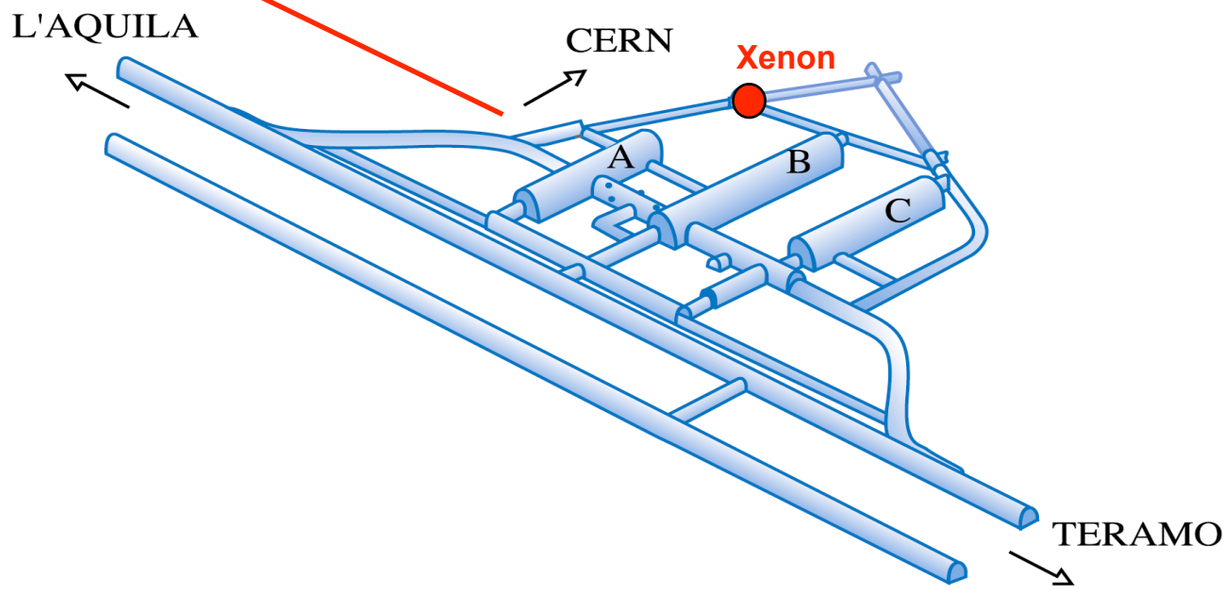
2013 - 2015

Location of the XENON-100 experiment



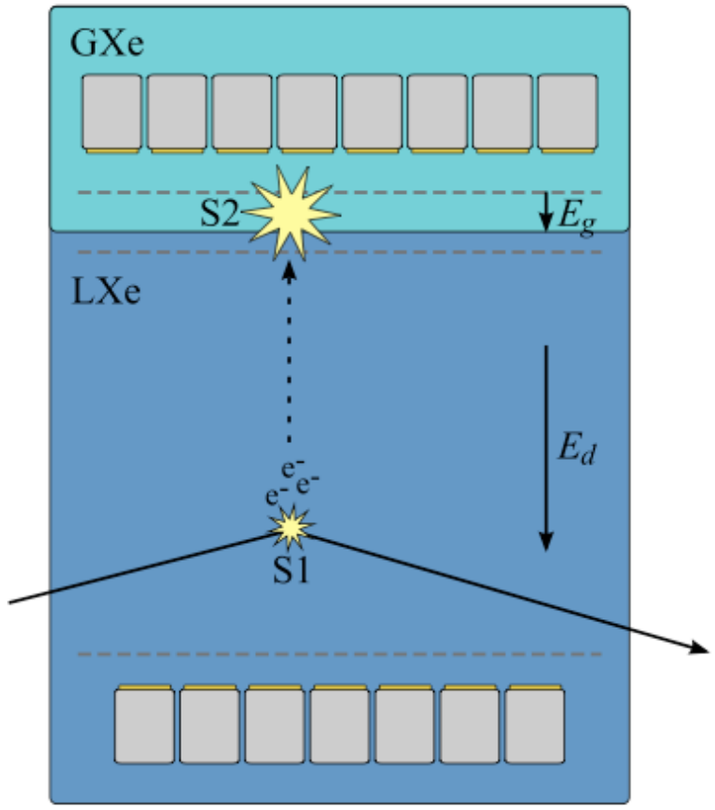
INFN Istituto Nazionale di Fisica Nucleare

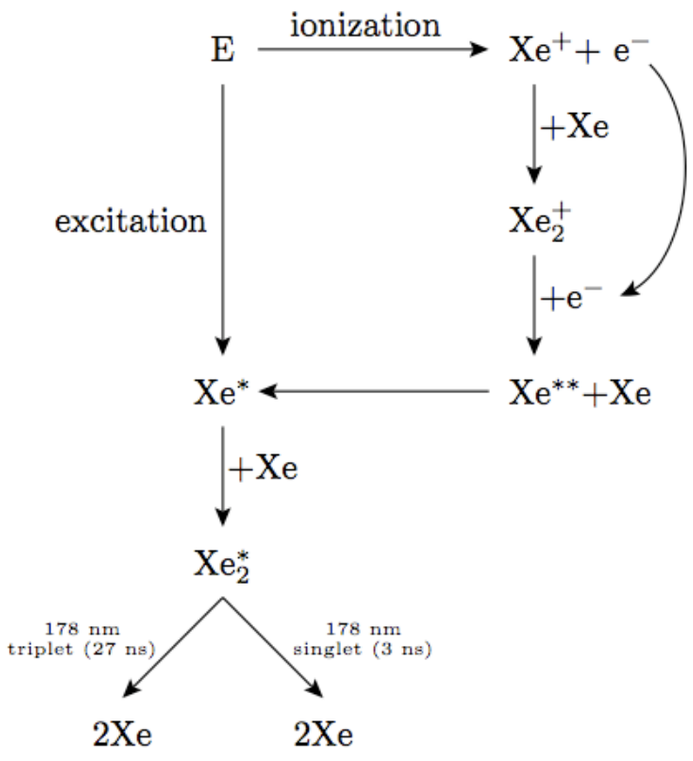
Laboratori Nazionali del Gran Sasso

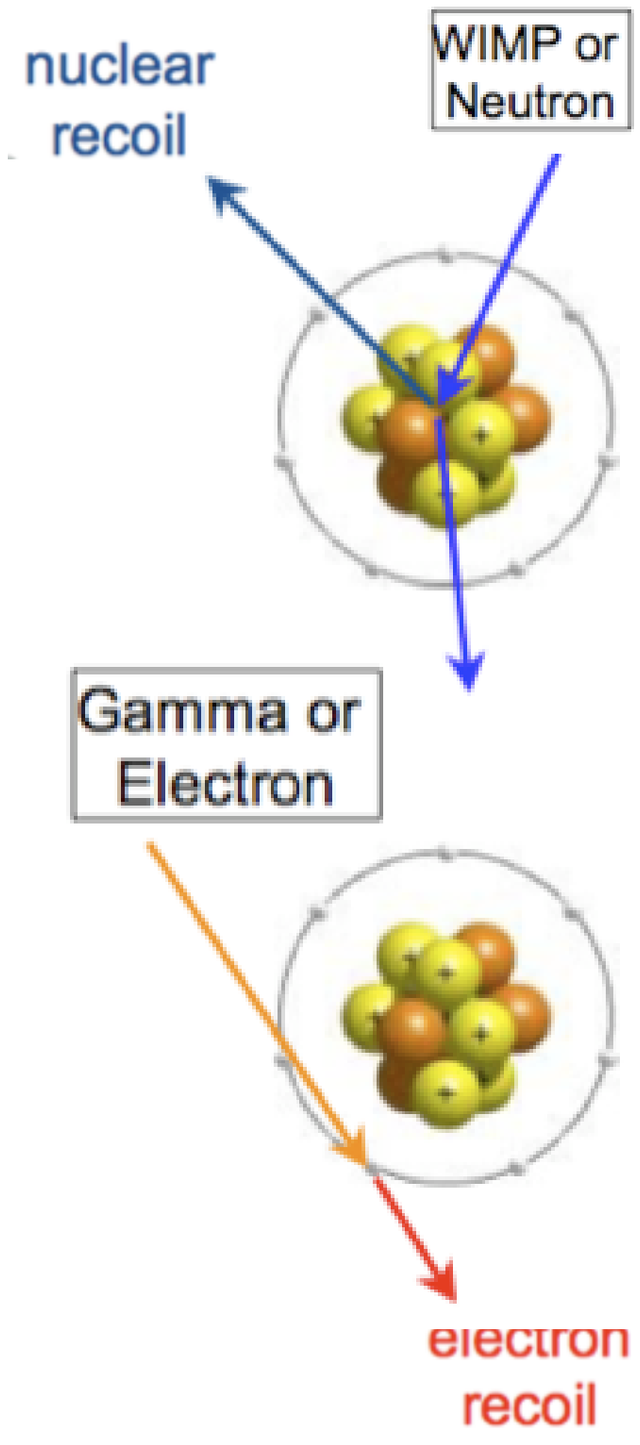


1.4 km rock
=
3100 meters water equivalent shielding from cosmic rays

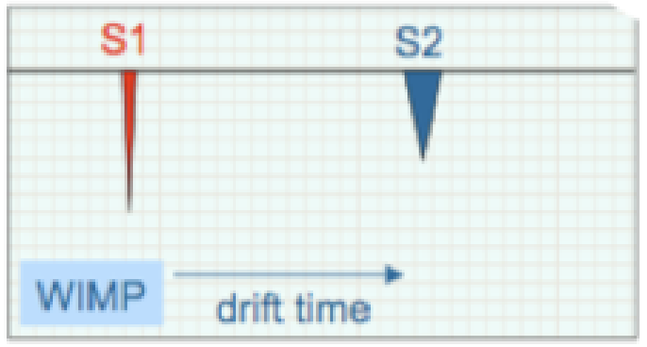
The Principle of the XENON experiment

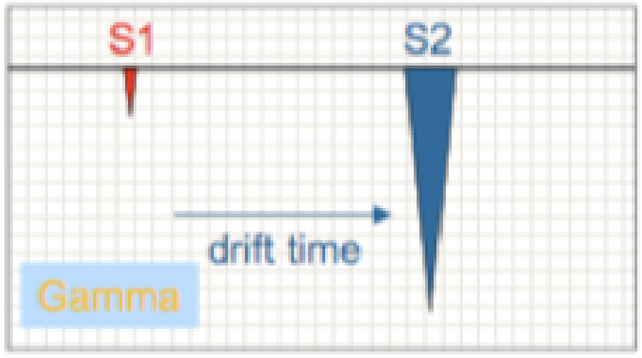






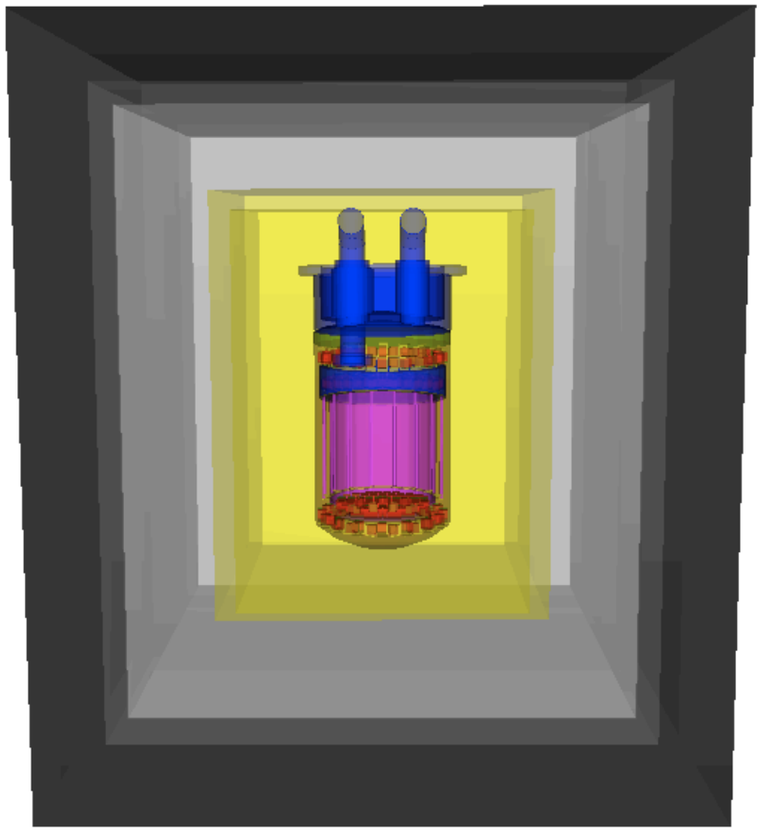
Electron/nuclear recoils discrimination based on S2/S1 ratio





$(S2/S1)_{wimp} << (S2/S1)_{gamma}$

XENON-100 Design



Shield:
- lead, 33T
- polyethylene, 1.6T
- copper, 2T

Cryostat:
- double walled (1.5 mm thick)
- low r/activity stainless steel
- total weight 70 kg

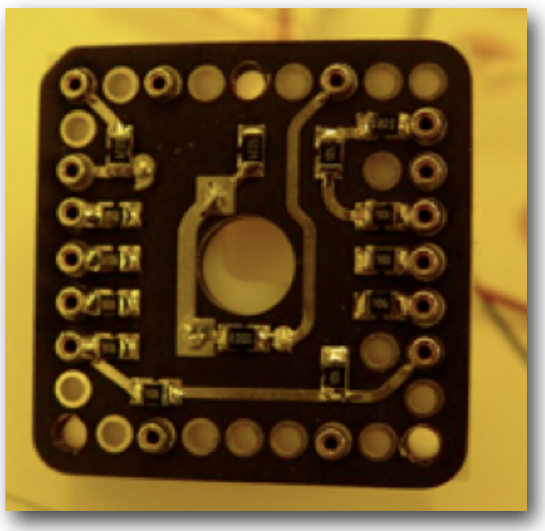
Bell:
- stainless steel
- weight 3.6 kg

PTFE structure:
- 24 interlocking panels
- enclose target volume
- support field shaping rings
- total weight of teflon 12 kg
- UV light reflector

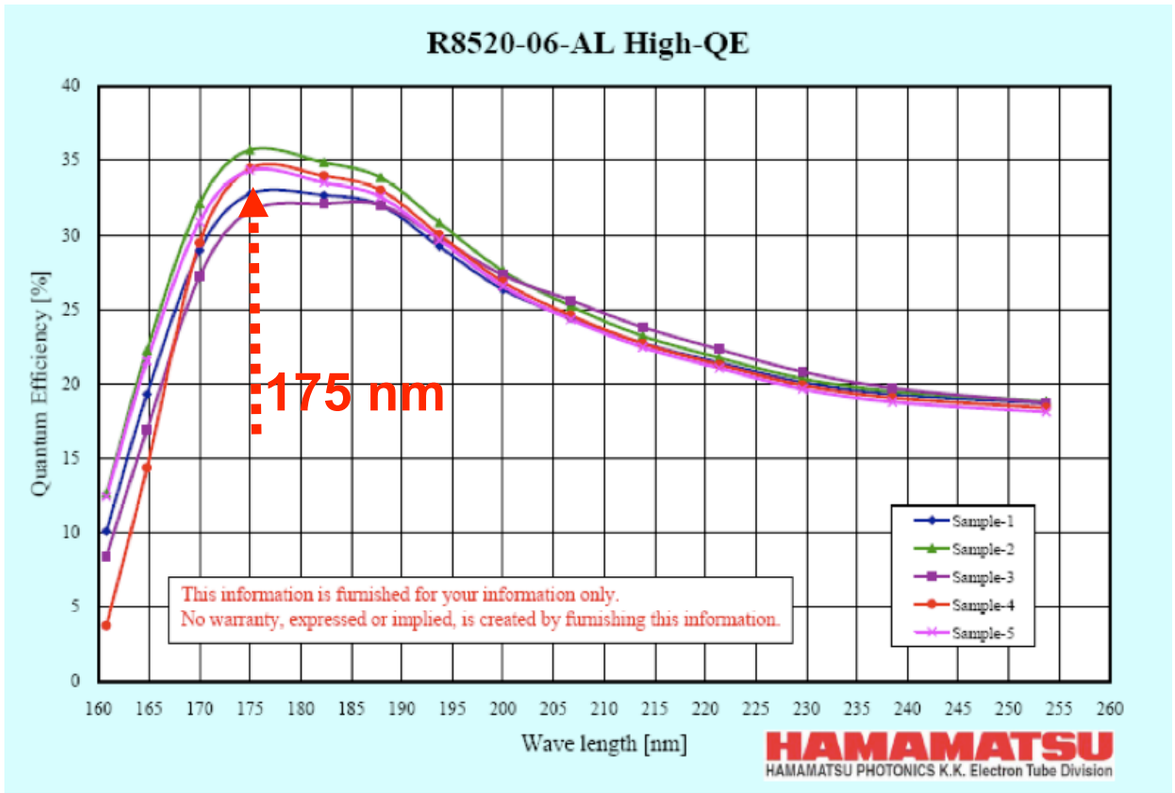
Target:
- 65 kg of LXe
(total amount 170 kg)
- 30 cm diameter,
- 30 cm height

Light Detection in the XENON-100 Detector

Hamamatsu R8520



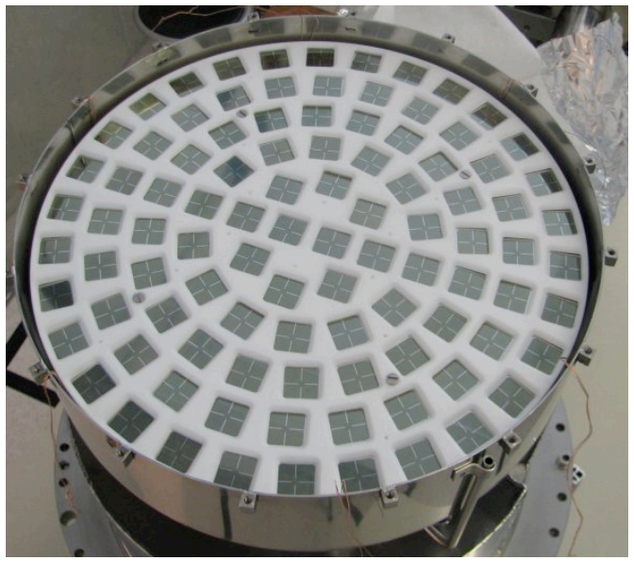
- 2.5 x 2.5 mm window
- metal channel dynodes
- Kovar housing and pins
- Stainless steel electrodes
- Synthetic quartz glass for window
- Borosilicate glass for stem
- Cirlex bases for voltage divider network
- high Quantum Efficiency (up to 35%)
- low radioactivity (~10mBq/PMT)



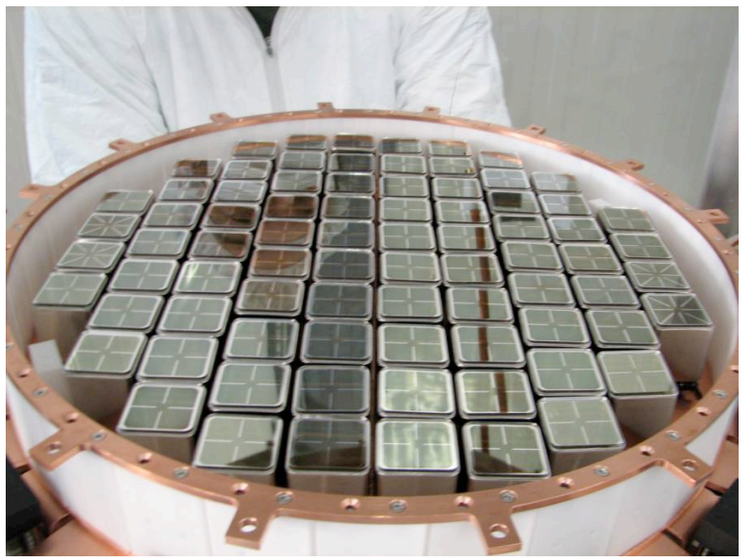
Quantum efficiency VS wavelength

Light Detection in XENON-100 Detector

Target Volume



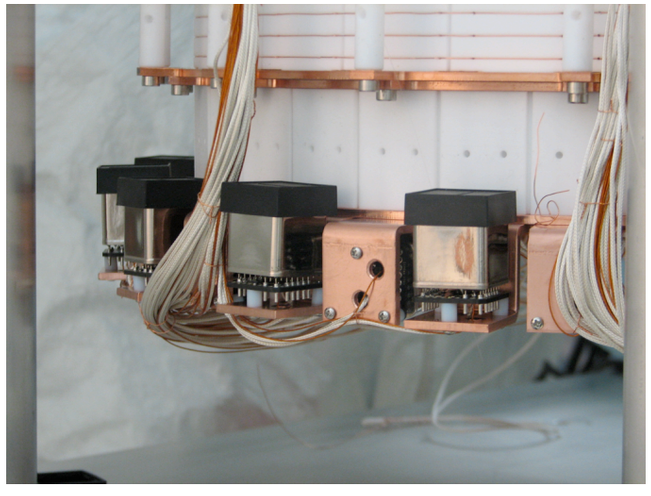
Top PMT array
(98 PMTs)



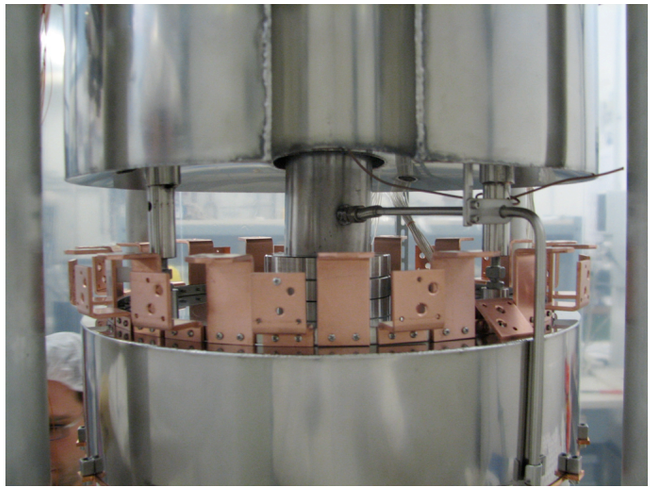
Bottom PMT array
(80 PMTs)

- Top array is enclosed in a PTFE structure and arranged in concentric circles to have good fiducial cut efficiency
- Bottom PMTs are placed in a rectangular grid to maximize photocathode coverage
- Average QE on the top array ~23%, on the bottom ~33%

Active Veto Volume



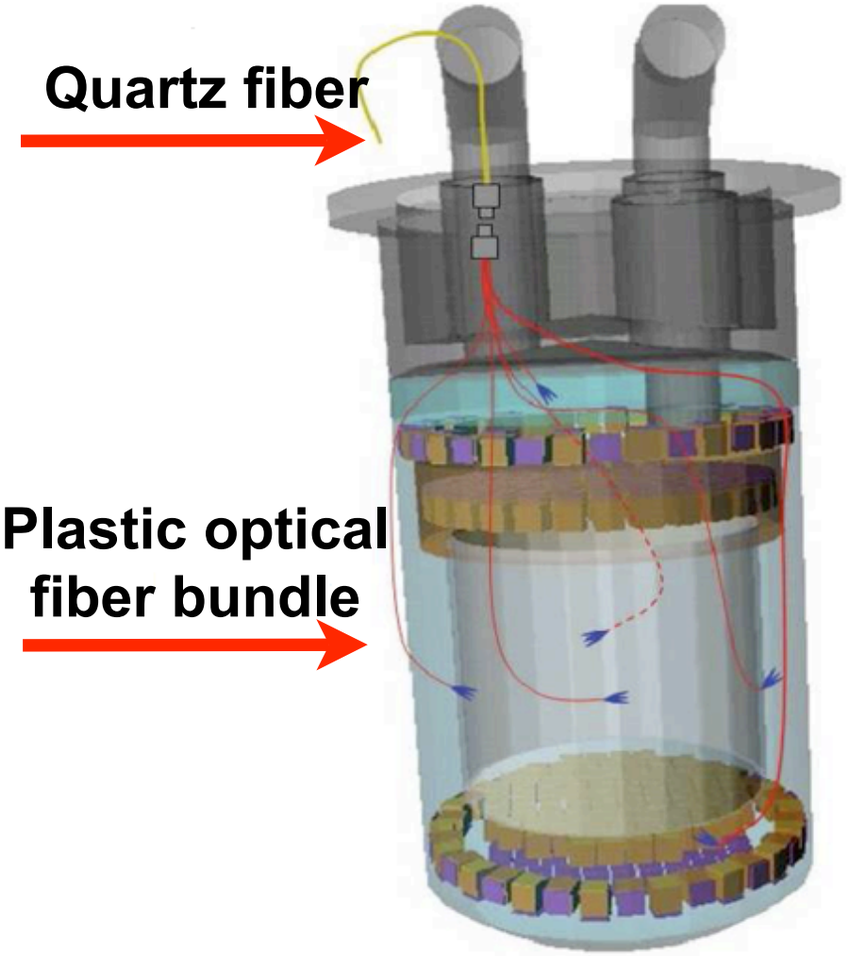
Top/Side Top arrays
(32 PMTs)

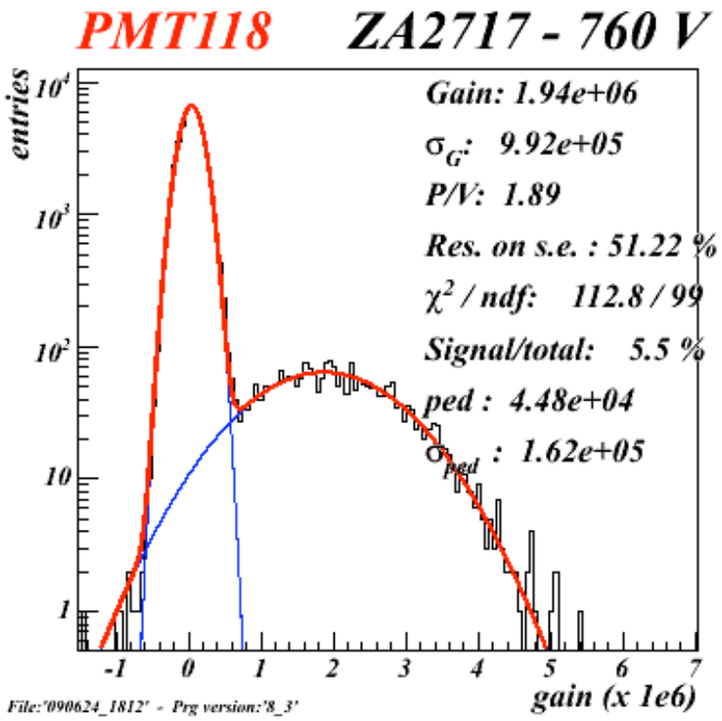


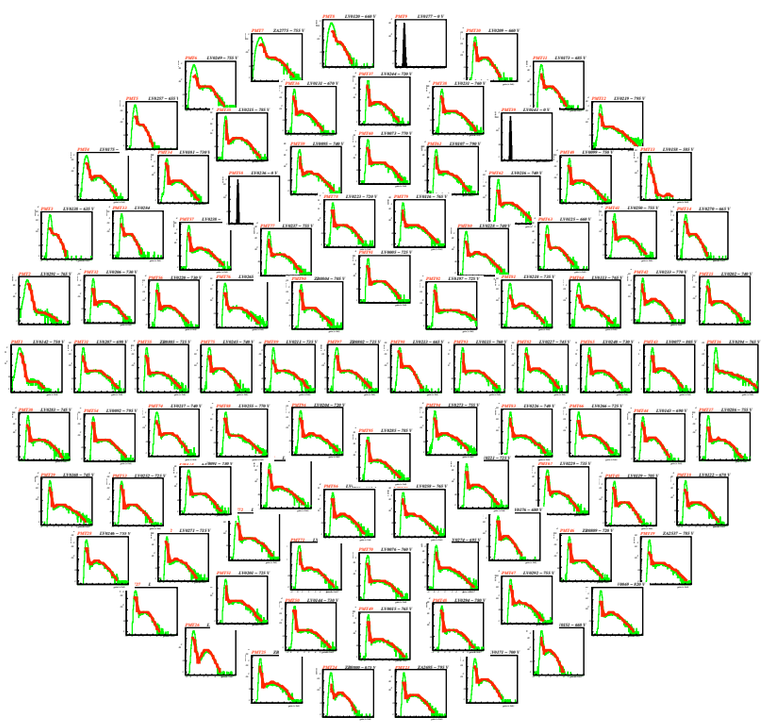
Bottom/Side Bottom arrays
(32 PMTs)

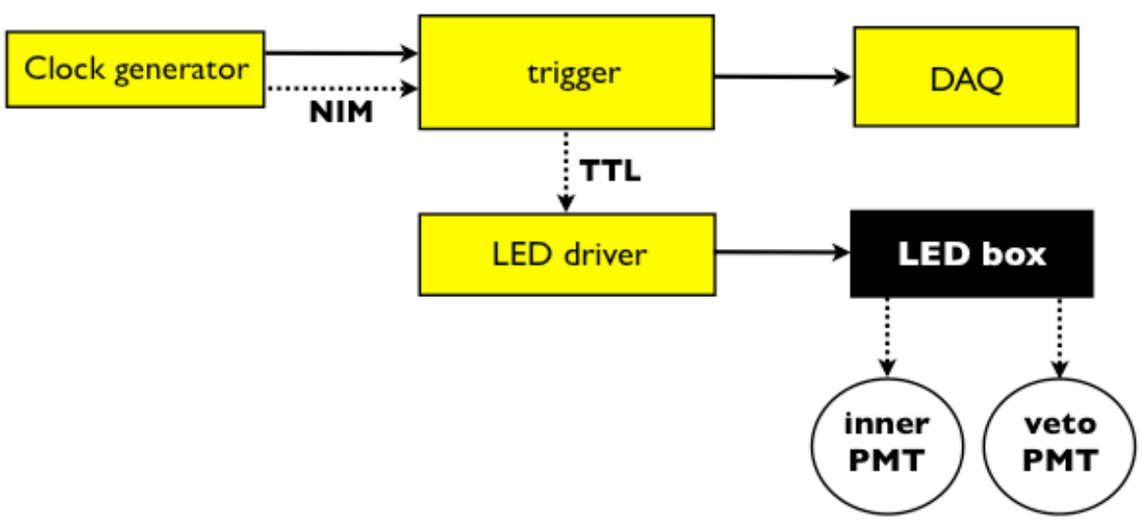
- 64 tubes in the active veto volume, alternating inwards and up/down, to view the top, bottom and sides

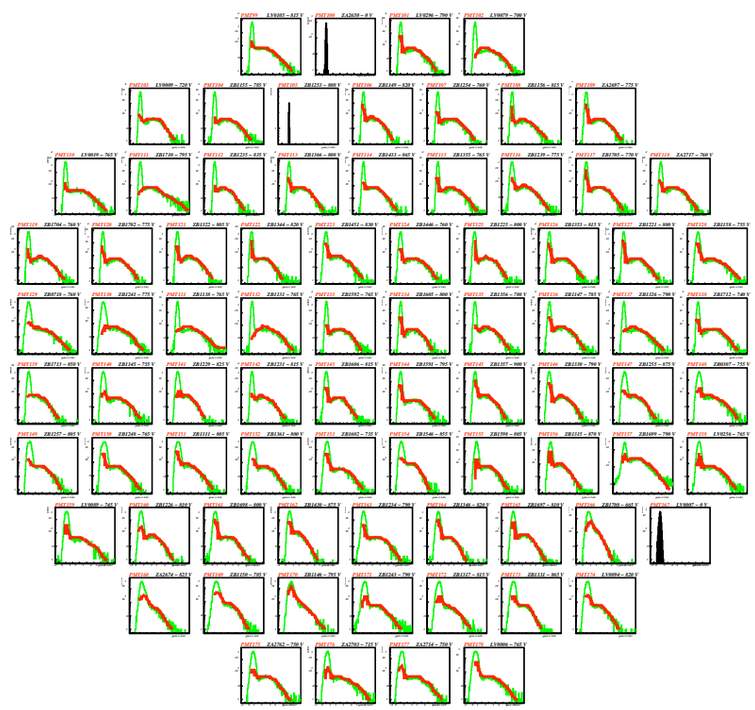
PMT Gain Calibration



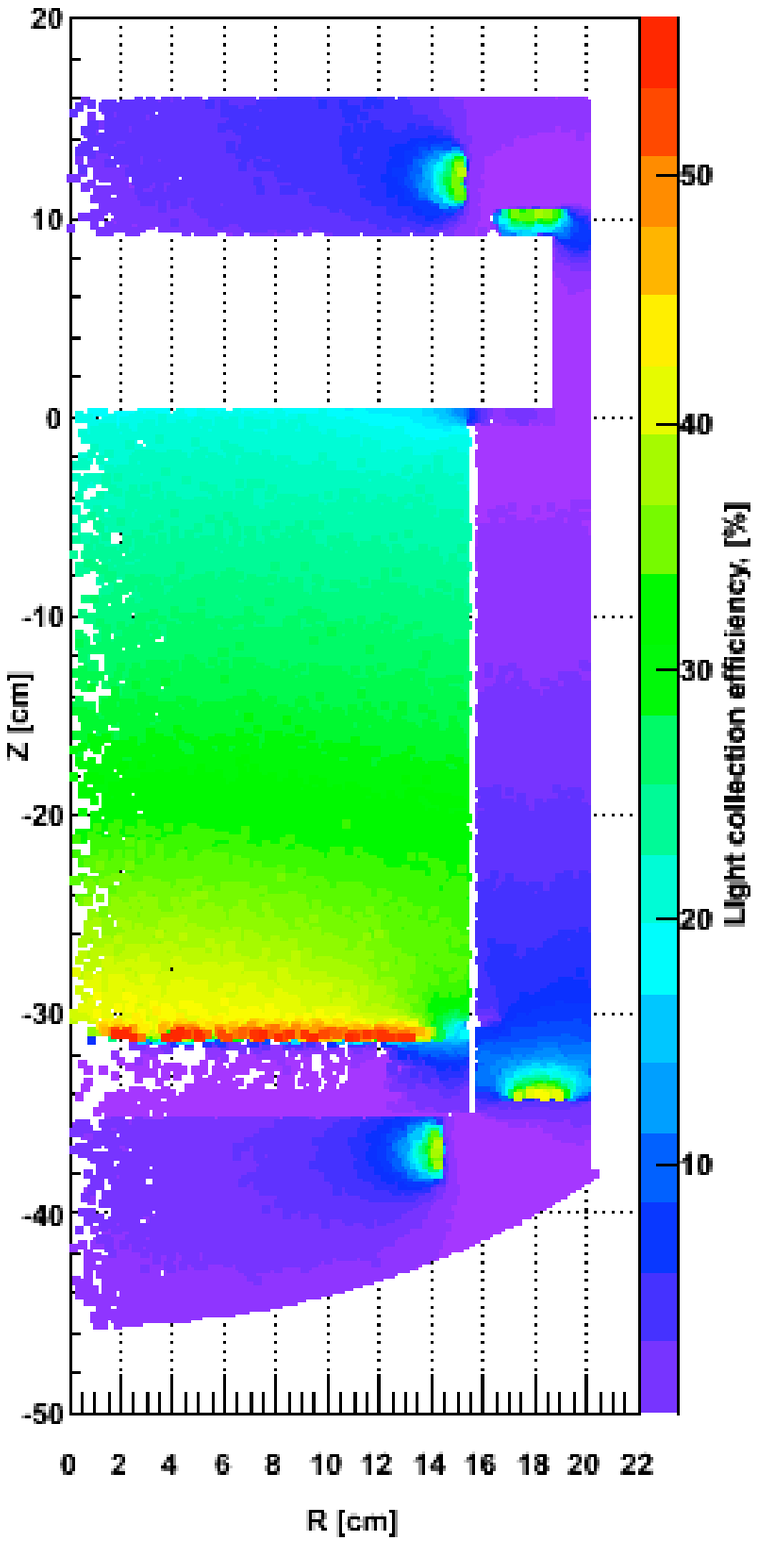








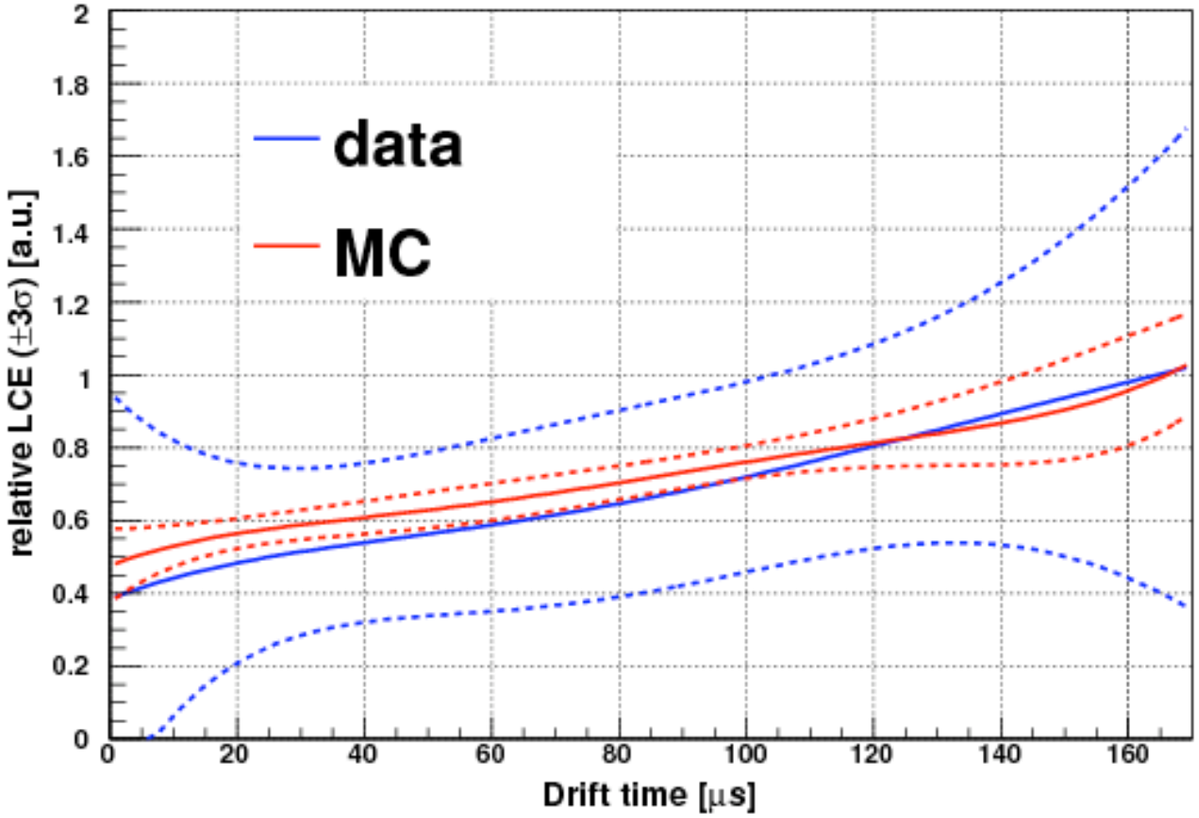
Light Collection Efficiency



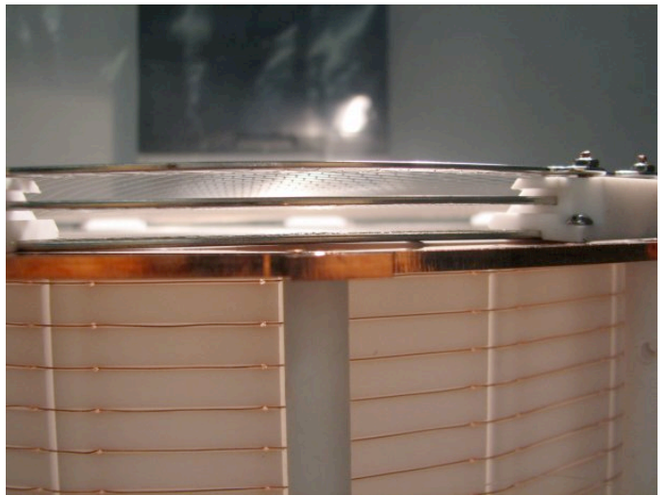
- **Average LCE in the target volume:**
  24%, 4.2 pe/keVee at zero field;
  nuclear recoil detection efficiency 100% at 5 keVr

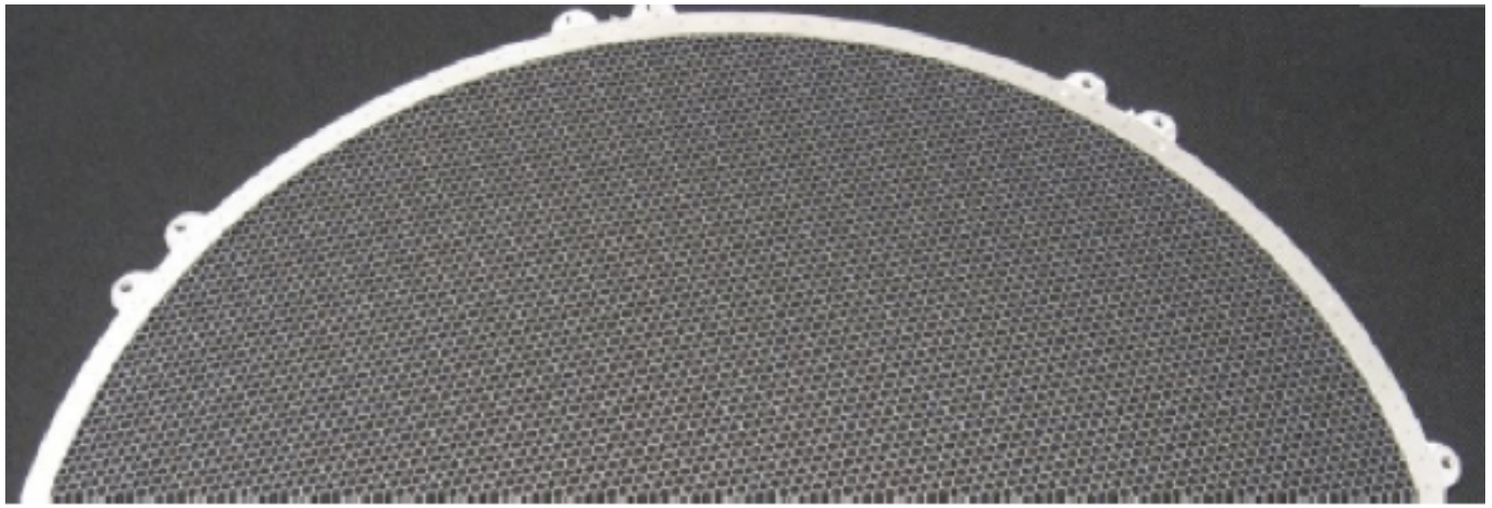
- **Average LCE in the active veto volume:**
  4.7%, trigger efficiency 90% at 50 keVee

- **Relative LCE in the target volume:**

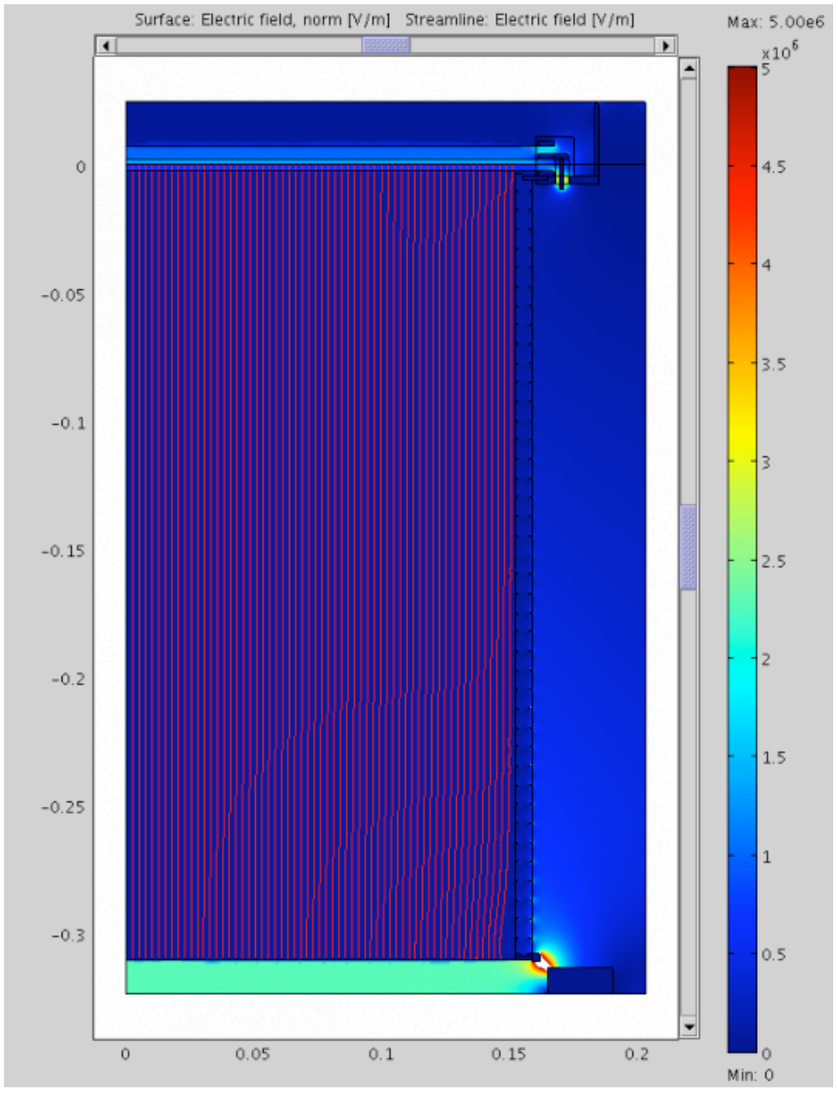


Electric Field



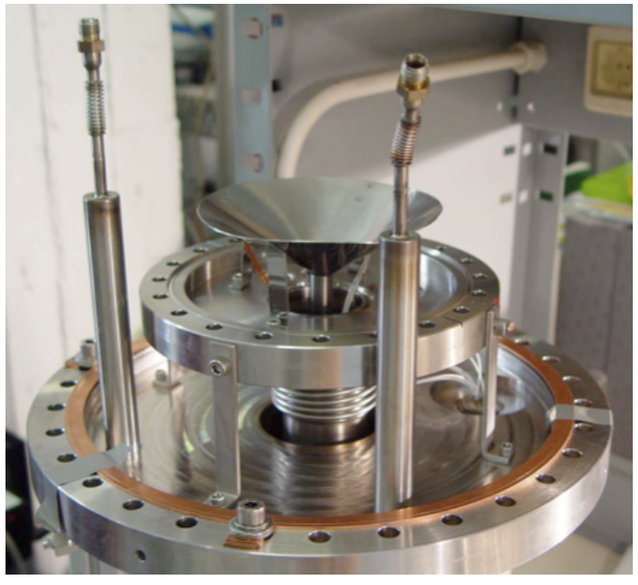


- **The field is optimized with simulations for homogeneity**
- **40 double field shaping rings**
- **Hexagonal mesh structures**
- **Anode stack is optimized for optical transparency**
- **Drift field 1kV/cm (cathode at -30kV)**
- **Extraction field 5kV**

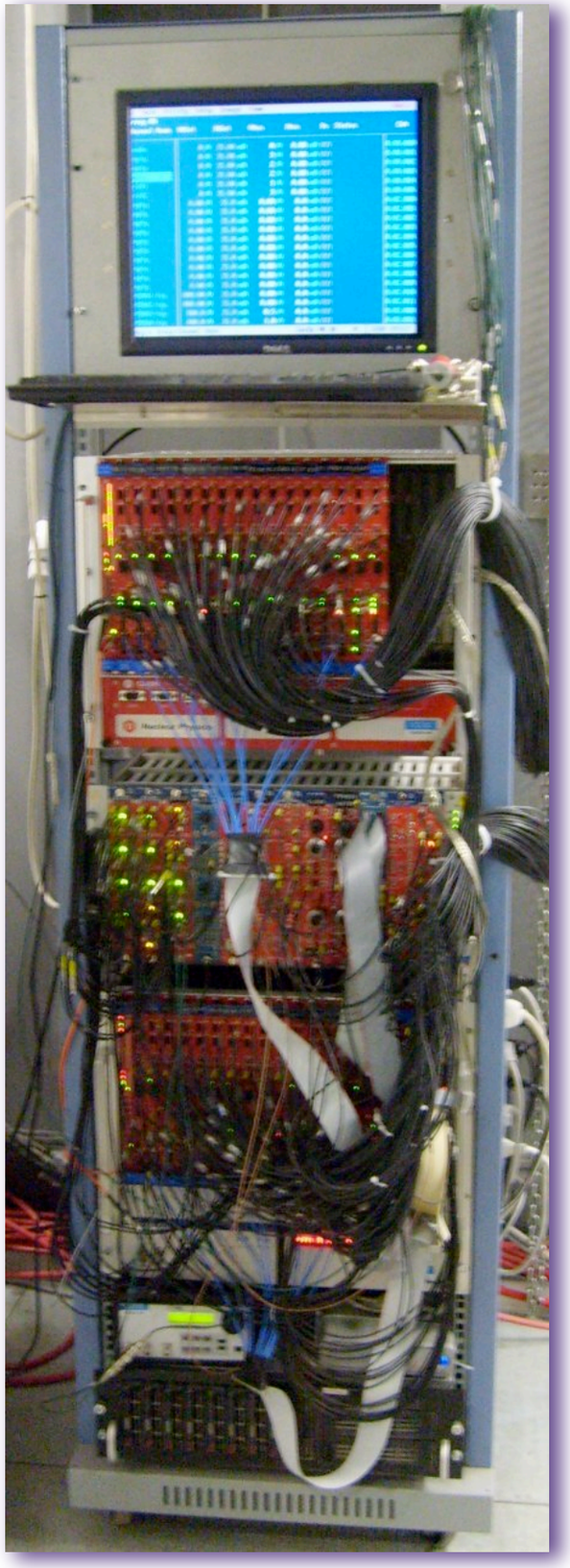


Xenon Liquefaction, Cooling Tower

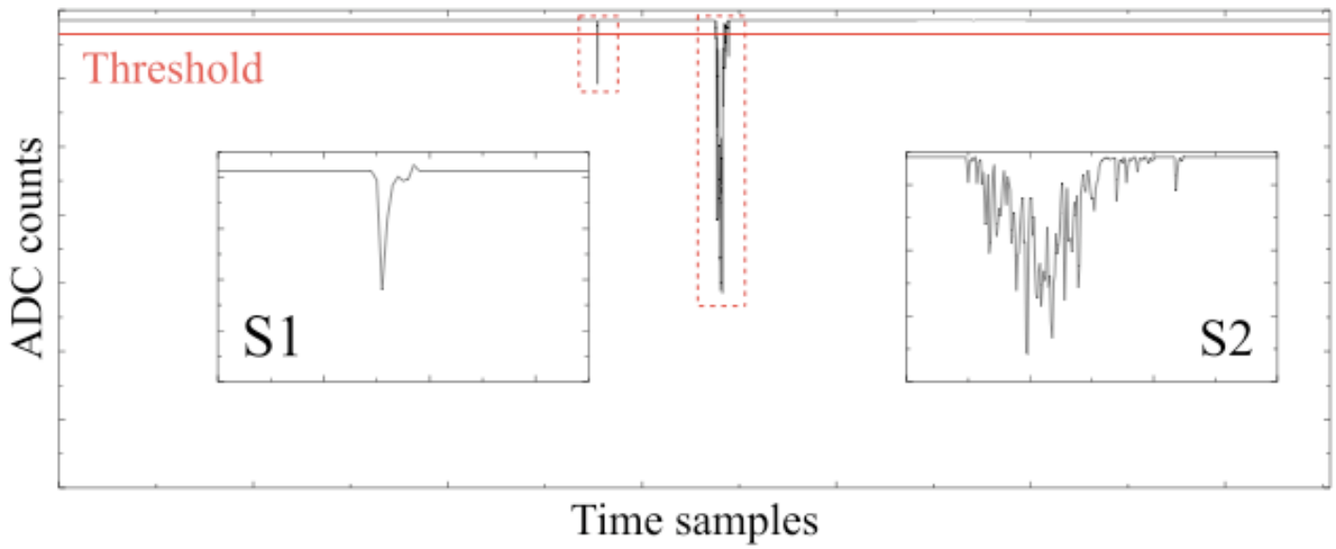
- Xe liquefaction is done with the Pulse Tube Refrigerator (160W), which is placed outside the shield
- Liquid Xe flows back into the main vessel from the cooling tower through a small pipe in the center of the double-walled vacuum insulated tube
- Cooling system is backed up with the LN2 emergency coil, which is also placed in the cooling tower



Data Acquisition System for the XENON-100 experiment



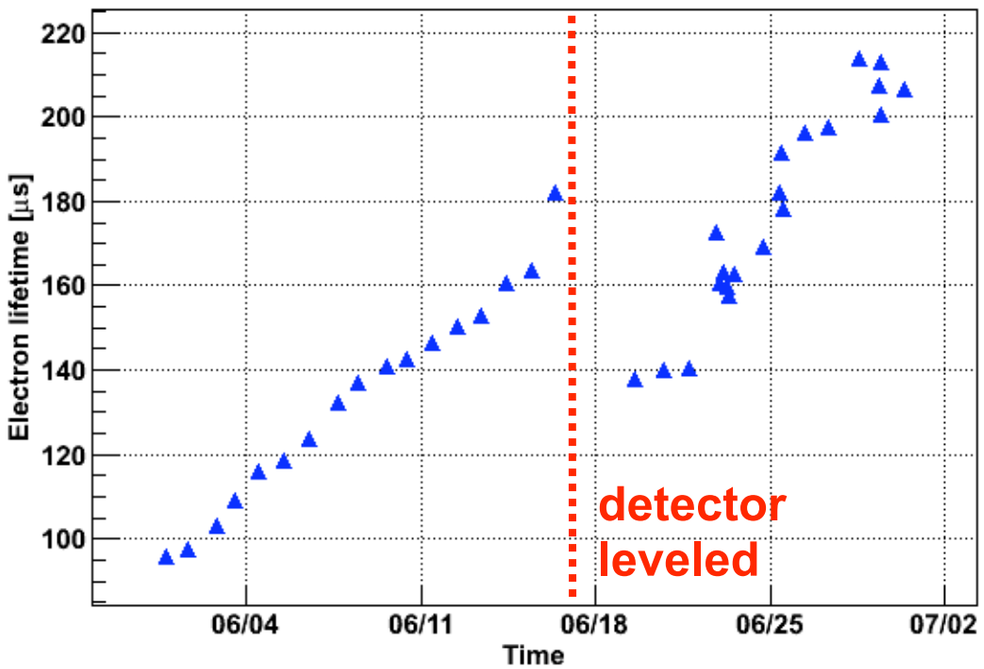
- DAQ is composed of 31 CAEN V1724 14 bit 100 MHz flash ADCs
- Digitization of the full waveforms (320 microsec) of the 242 PMTs
- Deadtime-less mode with the data written to circular buffers and multiple event buffers for storage between VME read cycles
- Digitized signals are “zero-length” encoded; only the relevant signal portions are transfered from the ADC to the DAQ computer



- High rate capability for calibration (>50 Hz)

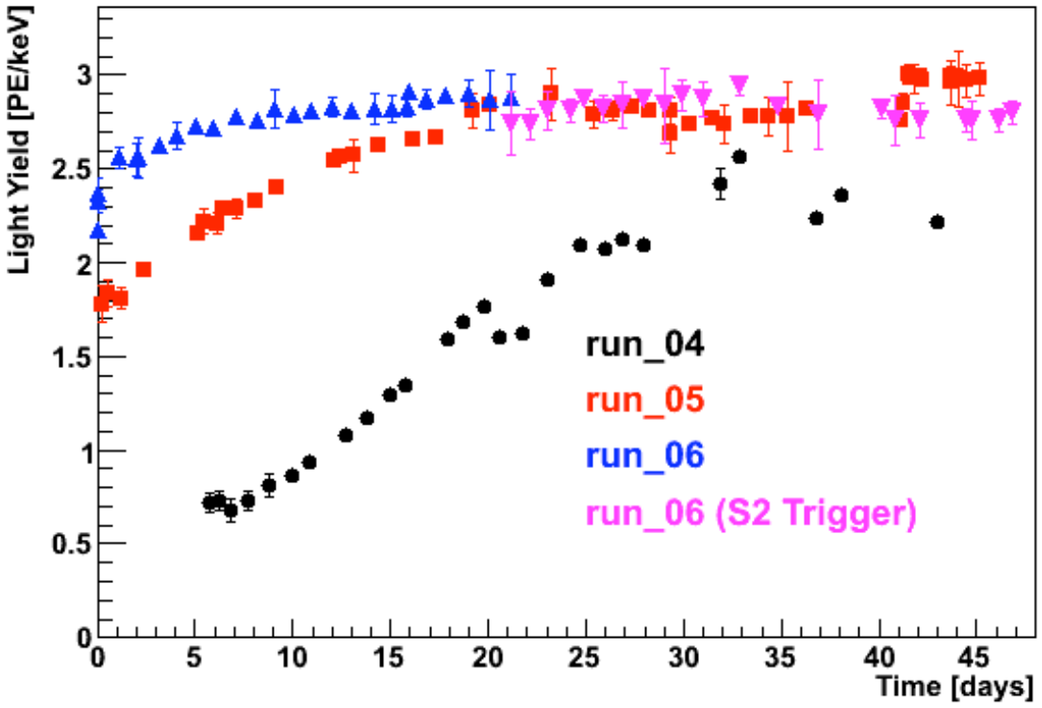
XENON-100 Status

Electron lifetime evolution

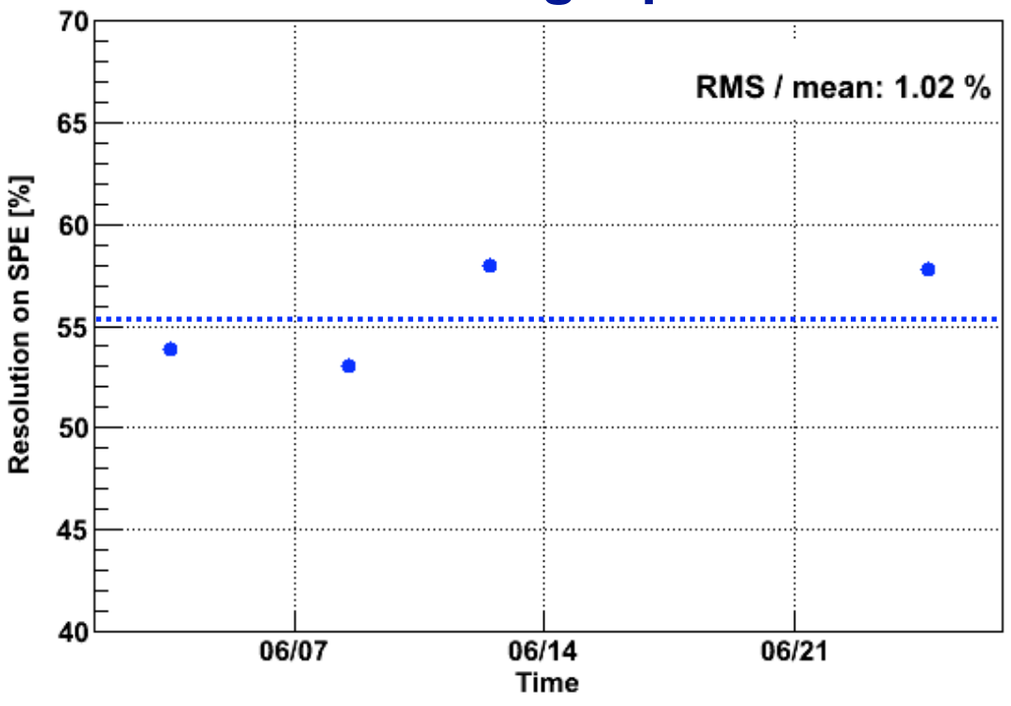


- The detector is underground since end of February 08
- First filled with Xe in mid-May 08
- Current run ('run_06') started in April after the earthquake
- Daily calibrations with ^{137}Cs sources, monitoring of the light yield and electron lifetime

Light yield evolution



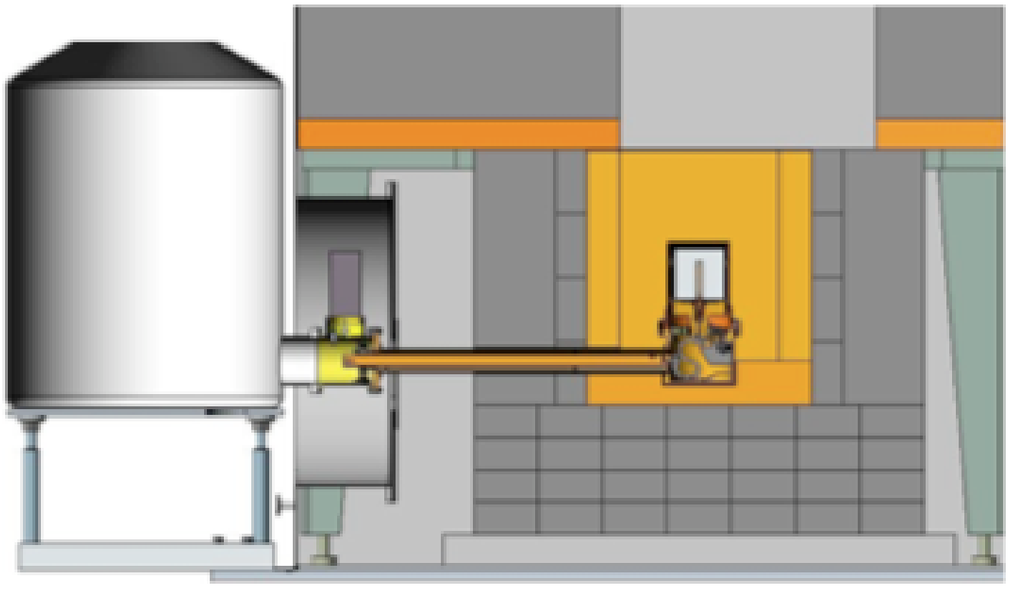
Resolution on single photoelectron



- Volume averaged LY at 'zero field; corresponds to 4.45 PE/keVee at 122 keV

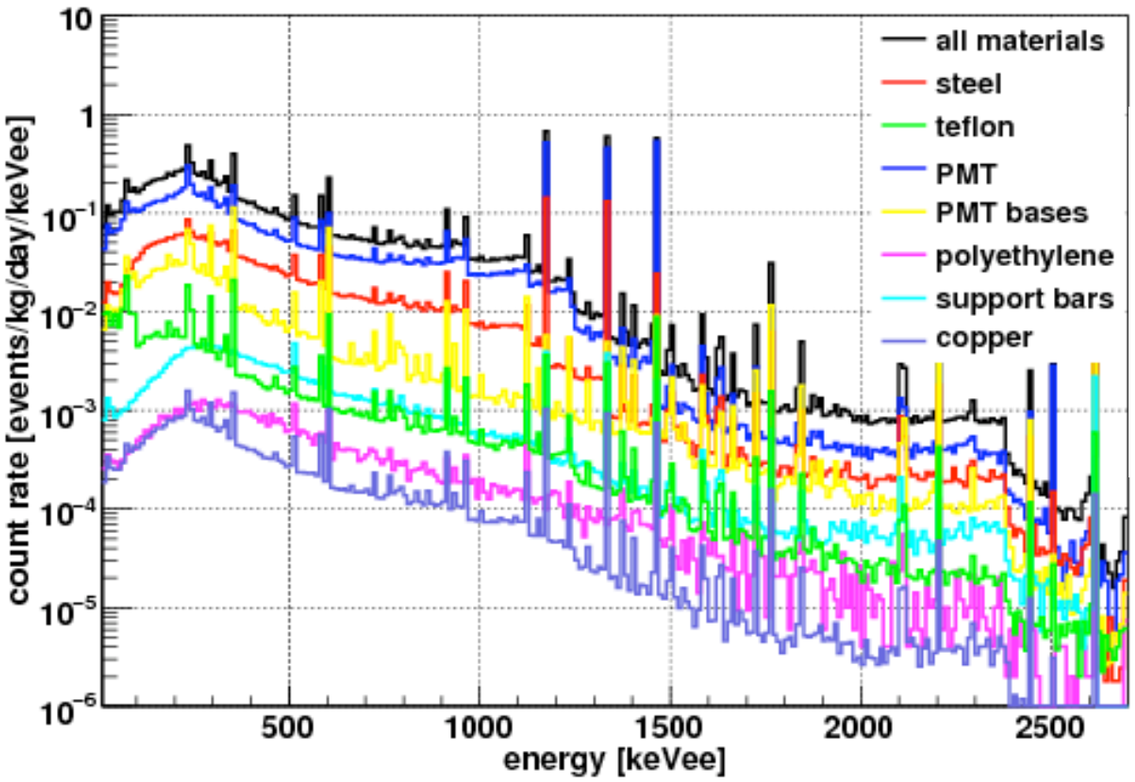
Materials Screening

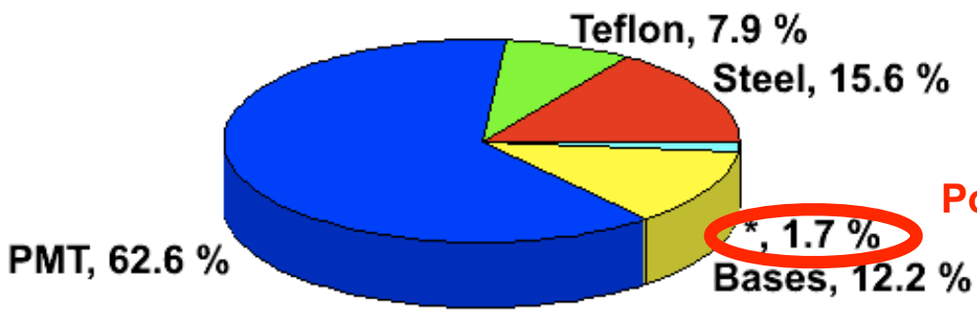
Material	Unit	U [mBq/unit]	Th [mBq/unit]	Co [mBq/unit]	K [mBq/unit]
Stainlees Steel	kg	< 1.7	< 1.9	5.5±0.6	<9.0
PTFE	kg	< 0.31	< 0.16	< 0.11	2.25
PMTs	PMT	0.15±0.02	0.17±0.04	0.6±0.1	11±2
PMT Bases	base	0.16±0.02	0.07±0.02	<0.01	<0.16
Support Bars	kg	< 1.3	2.9±0.7	1.4±0.3	< 7.1
Copper (inside)	kg	< 0.22	< 0.16	0.20±0.08	± 1.34
Resistor Chain	piece	0.027±0.004	0.014±0.003	< 0.003	0.19±0.03
Cathode	kg	3.6±0.8	1.8±0.5	7.3±1.3	< 4.92
PMT signal cable	kg	< 1.6	3.7±1.8	< 0.69	35±13
Polyethylene	kg	< 3.54	< 2.69	< 0.9	<5.9
Copper (shield)	kg	< 0.07	< 0.03	<0.0045	<0.06
Pb shield (inner)	kg	< 0.92	< 0.43	14±3	0.13
Pb shield (outer)	kg	< 0.80	< 0.72	< 1.46	< 0.11



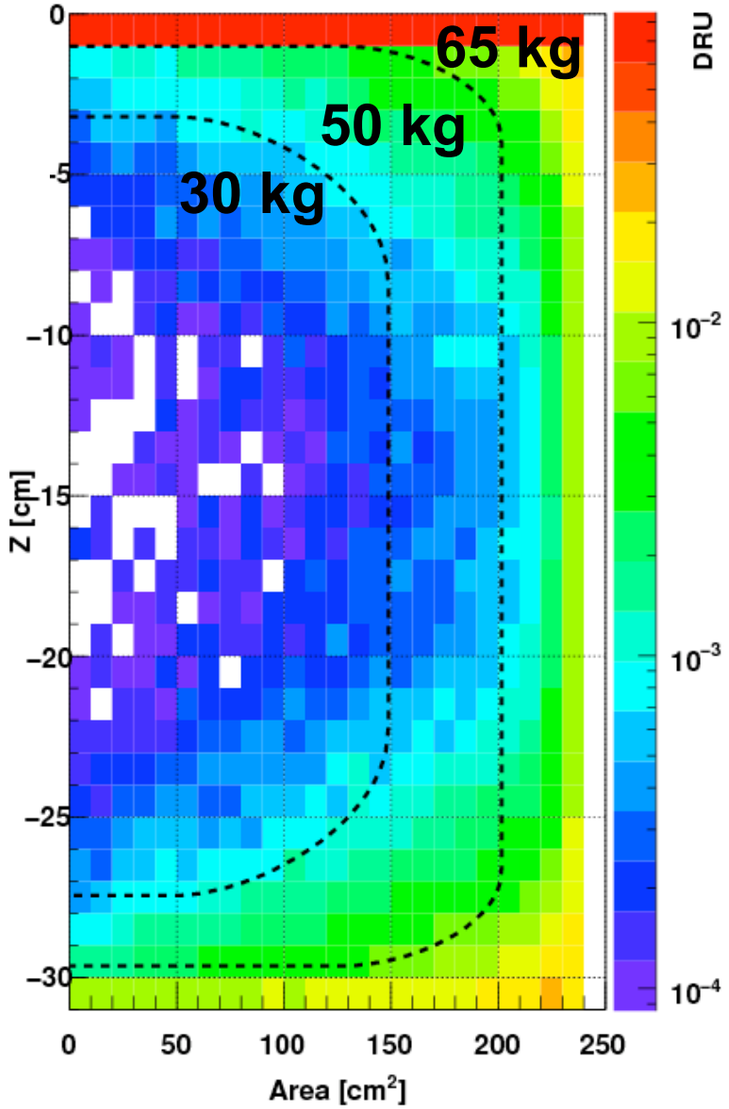
- **All materials used in the experiment are screened for the radioactive contamination with a 2.2 kg high purity Ge detector (“Gator” @ LNGS)**
- **The screening results are used for material selection and as an input for the MonteCarlo simulations**

MonteCarlo Predictions of the Background from Detector Materials

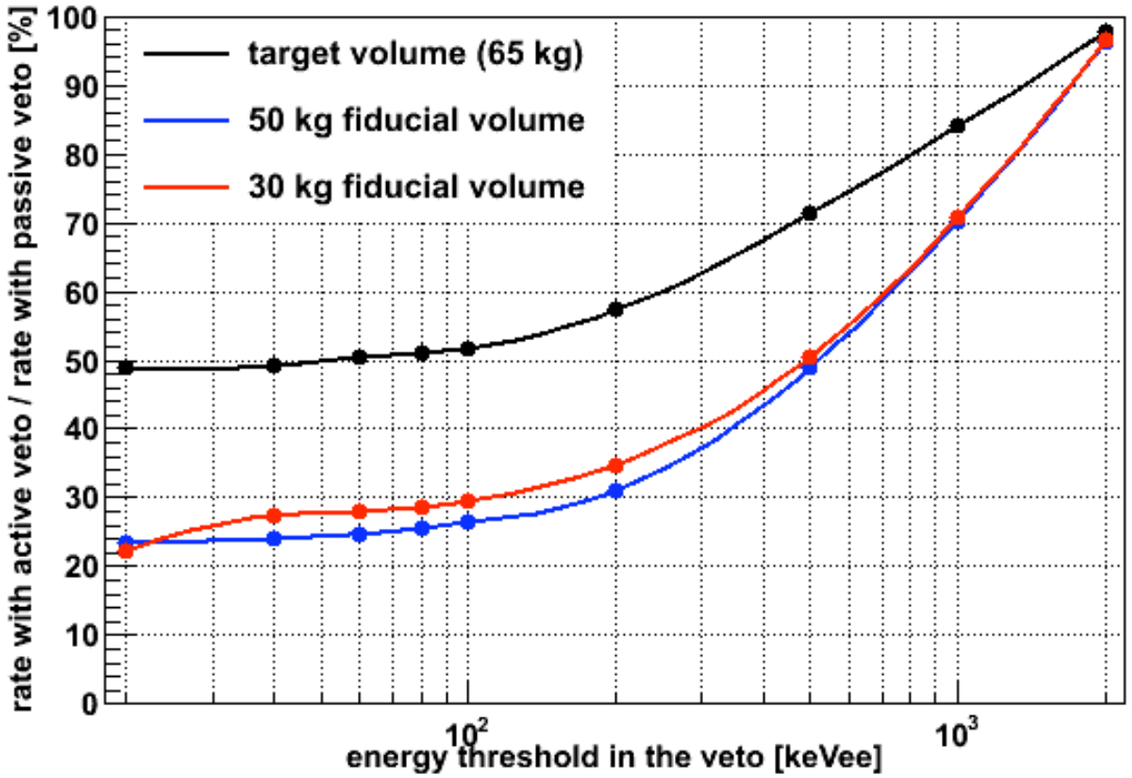




Grids,
Cables,
Support Bars,
Resistor Chain,
Polyethylene Shield

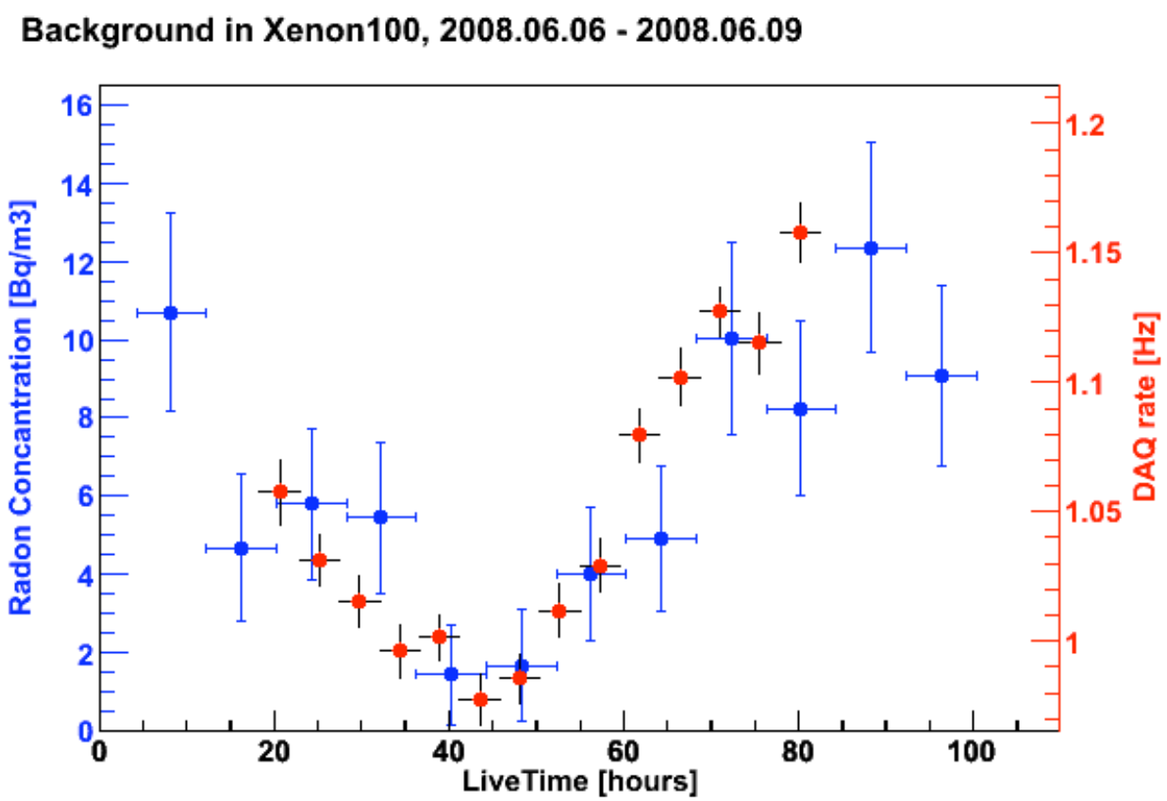


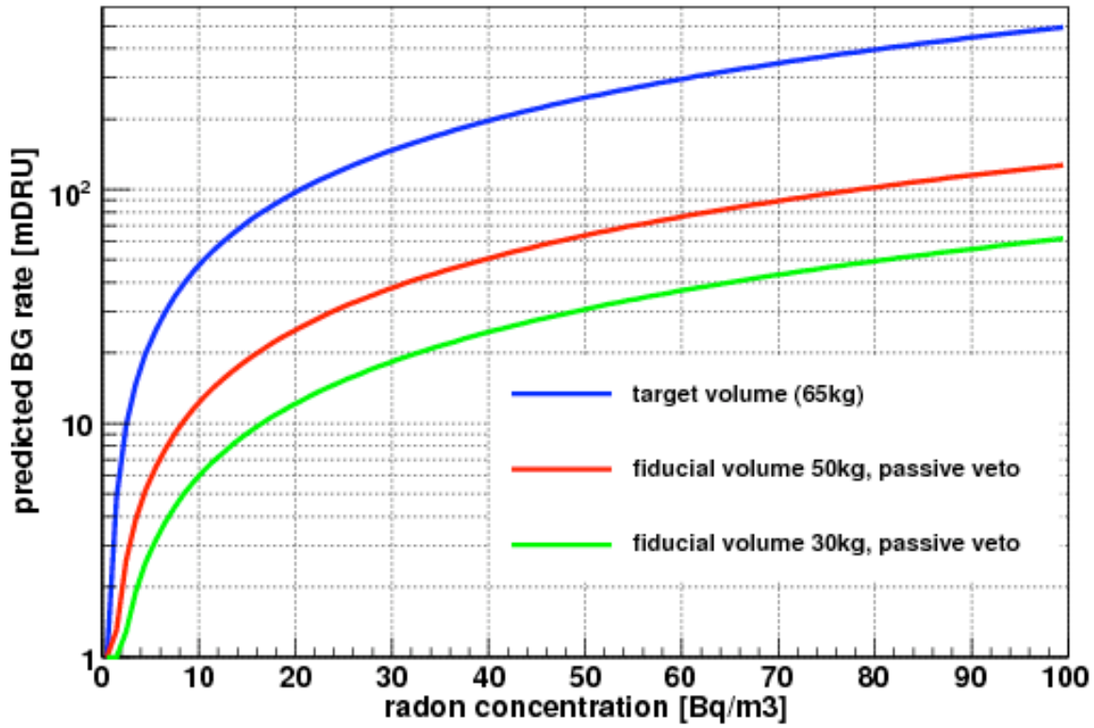
factor of 10-30 BG reduction with fiducial volume and active veto cuts



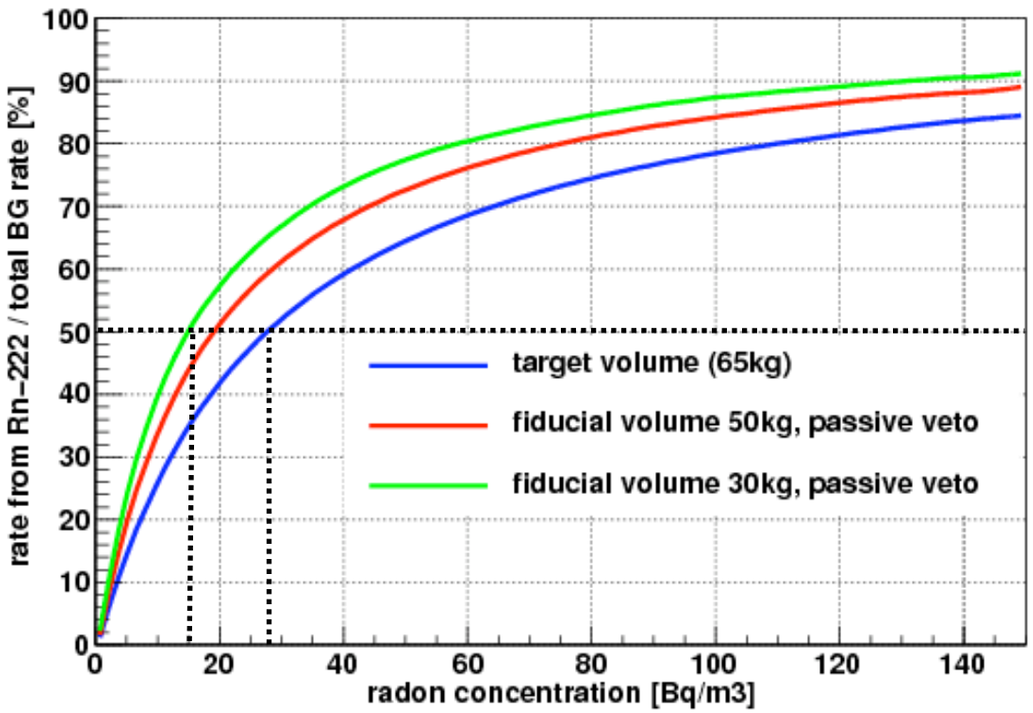
Neutron BG:
50 kg FV: 1.72 n/year
30 kg FV: 0.64 n/year

Electron Recoil Background from ^{222}Rn decay in the Shield Cavity





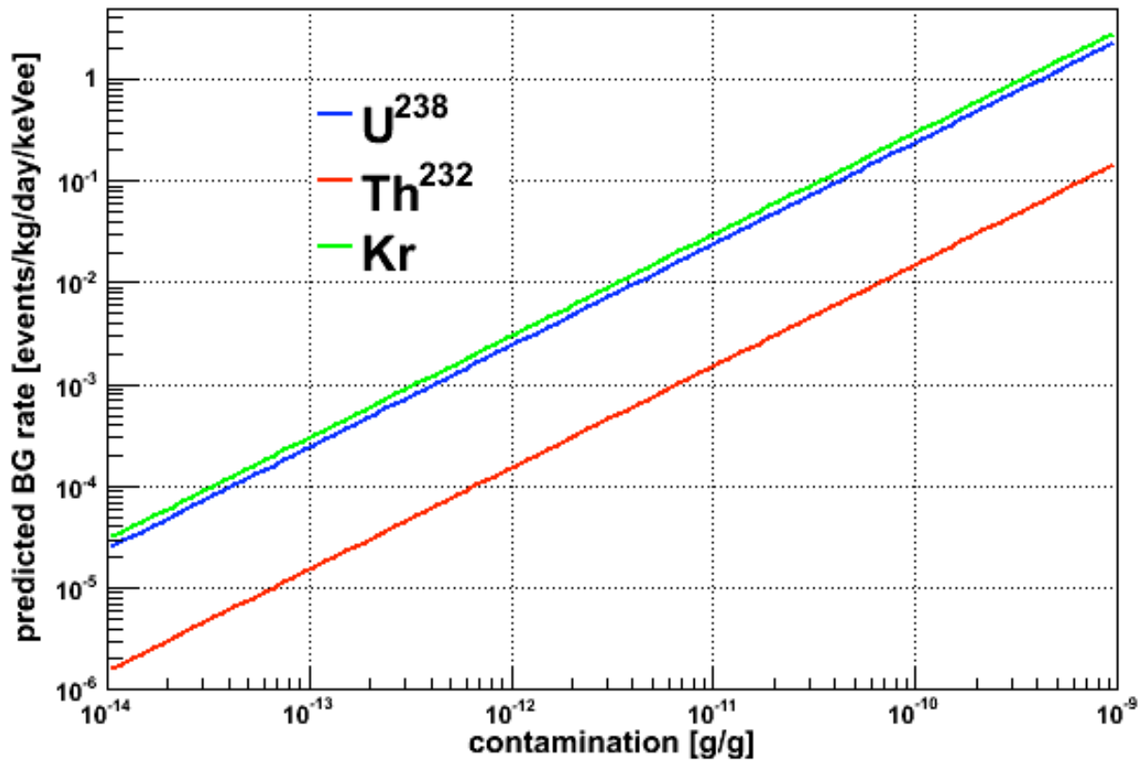
- The measured activity of radon in the tunnel is up to 140 Bq/m^3
- With the closed shield door and constant flushing with nitrogen (6 SLPM) the concentration of Rn in the shield cavity is 1-5 Bq/m^3, which is predicted to contribute up to 10 mDRU in the low energy part of the spectra (1-60 keV$_{ee}$)



Xenon Purification with the Distillation Column

- **Kr contamination of Xe is measured with the delayed coincidence analysis to be 4 ppb (BG rate >0.1DRU)**

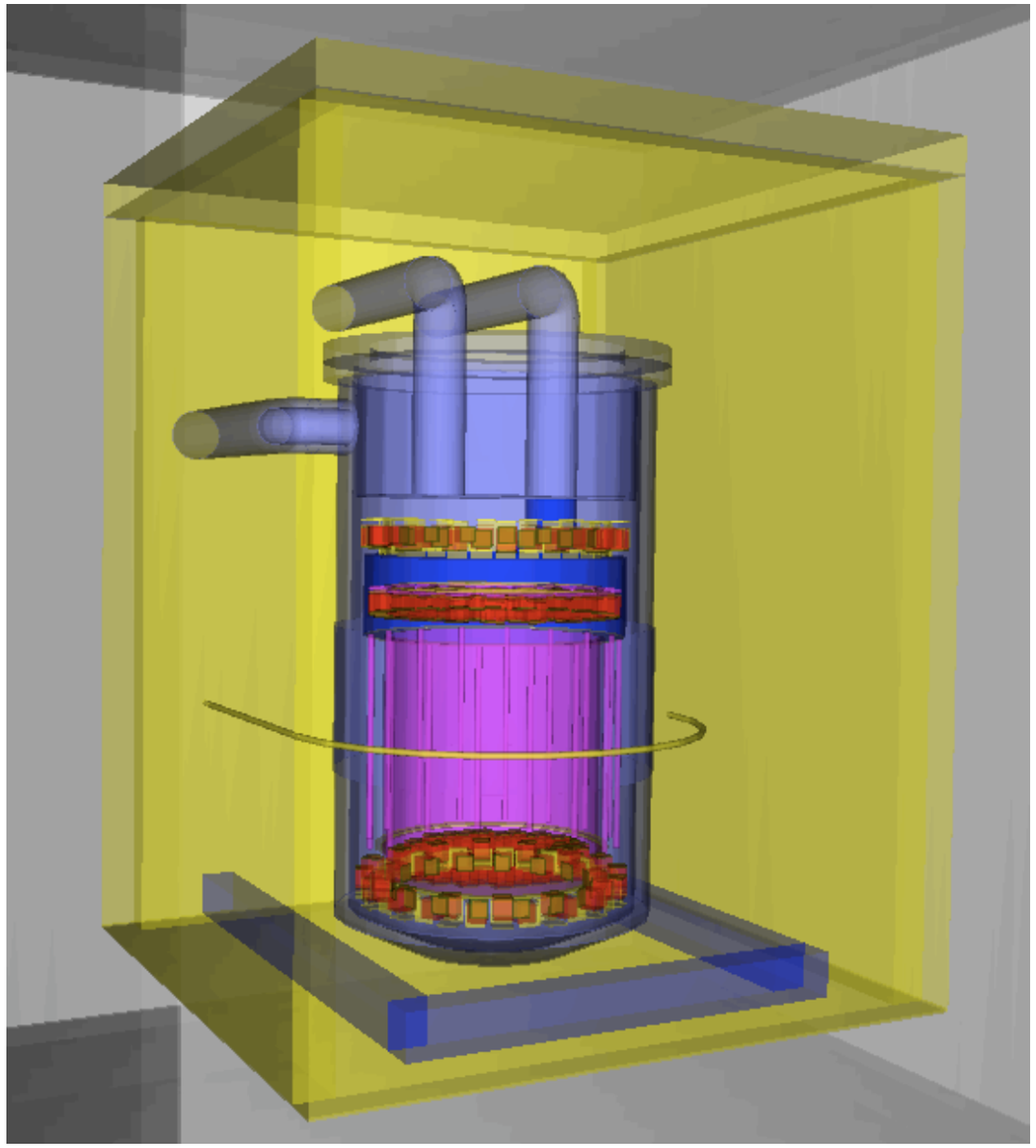
- **XENON-100 goal requires <50ppt Kr contamination (BG rate <1mDRU)**



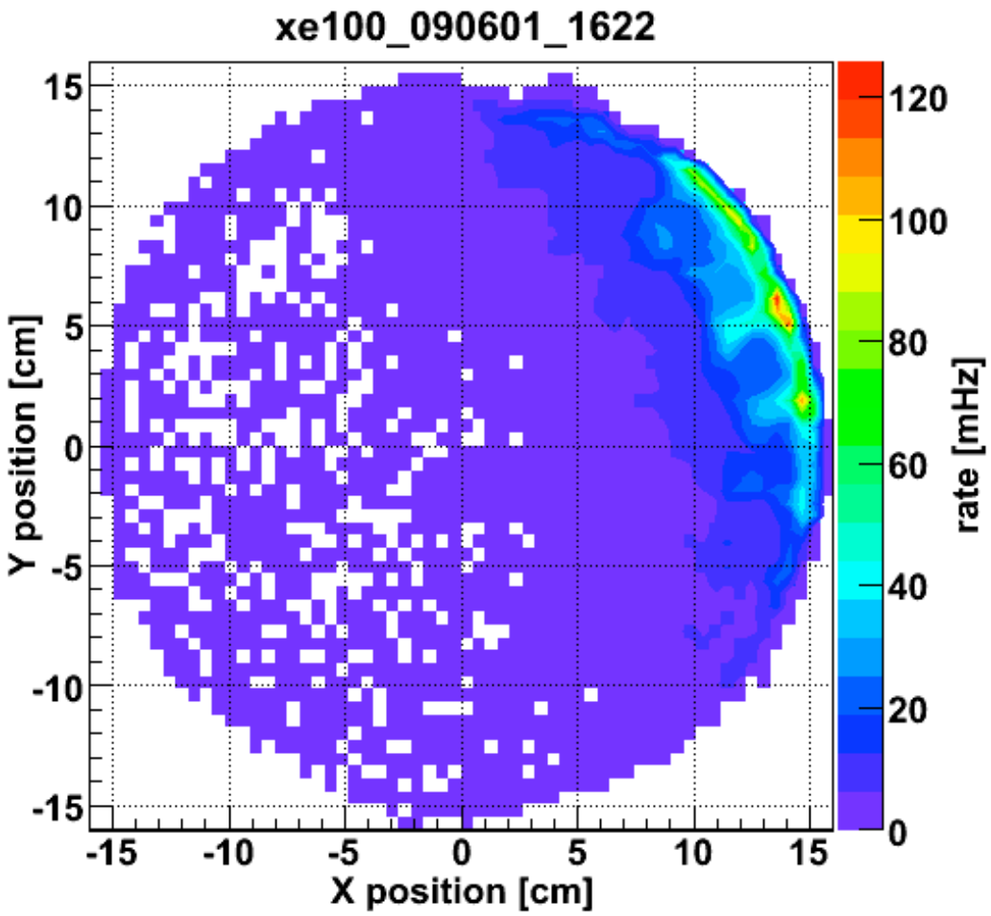
- **Distillation column (3 m high) capable to reduce Kr contamination from 'ppb' to 'ppt' level at the speed of 0.6 kg/hour (~2 weeks for 170kg)**

- **Measured contamination of LXe (delayed coincidence analysis):**
  2.5 ppt of ^{238}U (BG rate ~5mDRU)
  0.3 ppt of ^{232}Th (BG rate ~0.1mDRU)

Energy Calibration for the XENON-100 Detector



- **Position reconstruction of S2 signal with Neural Networks**



- **74kBq ^{137}Cs on the side**

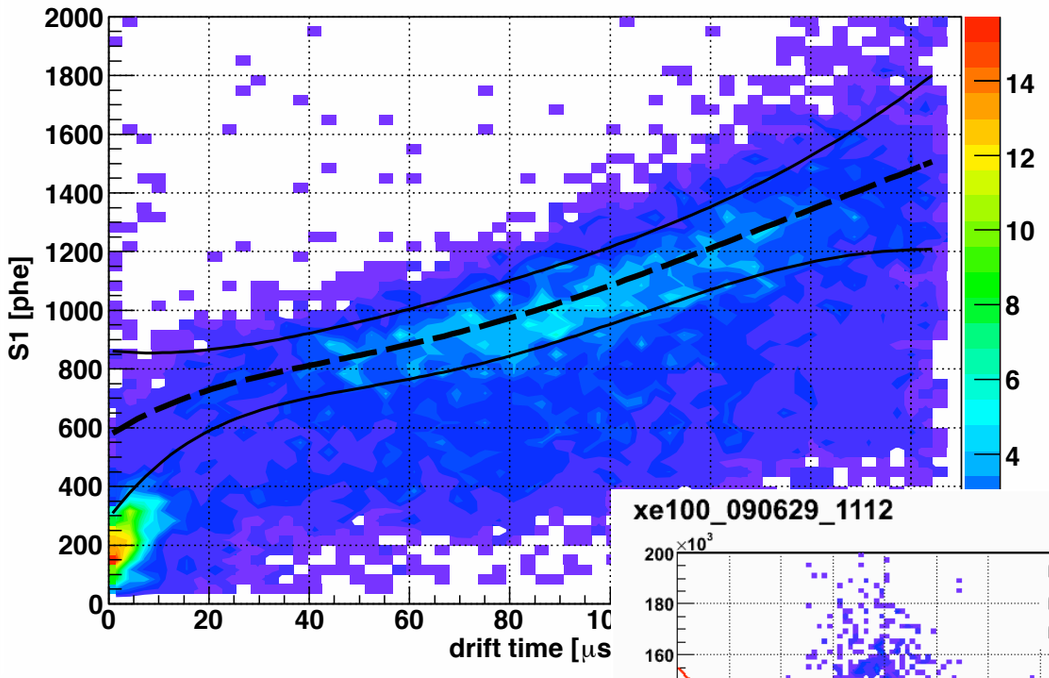
- **Calibration with gamma-sources ^{137}Cs (662 keV), ^{57}Co (122 keV), ^{60}Co (1.17, 1.33 MeV), ^{228}Th (2.6 MeV) and Am-Be (220 n/s) neutron source**

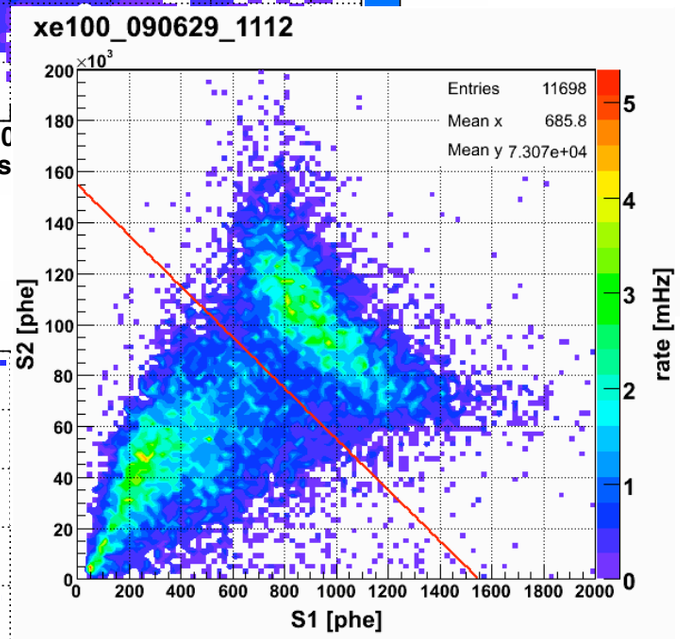
- **Calibration with internal uniformly distributed sources:**
  - neutron activated xenon: ^{131m}Xe (164 keV; 11.8 d), ^{129m}Xe (236 keV; 8.9 d)
  - ^{83m}Kr (9 keV , 32 keV; 1.8 h) from ^{83}Rb decay

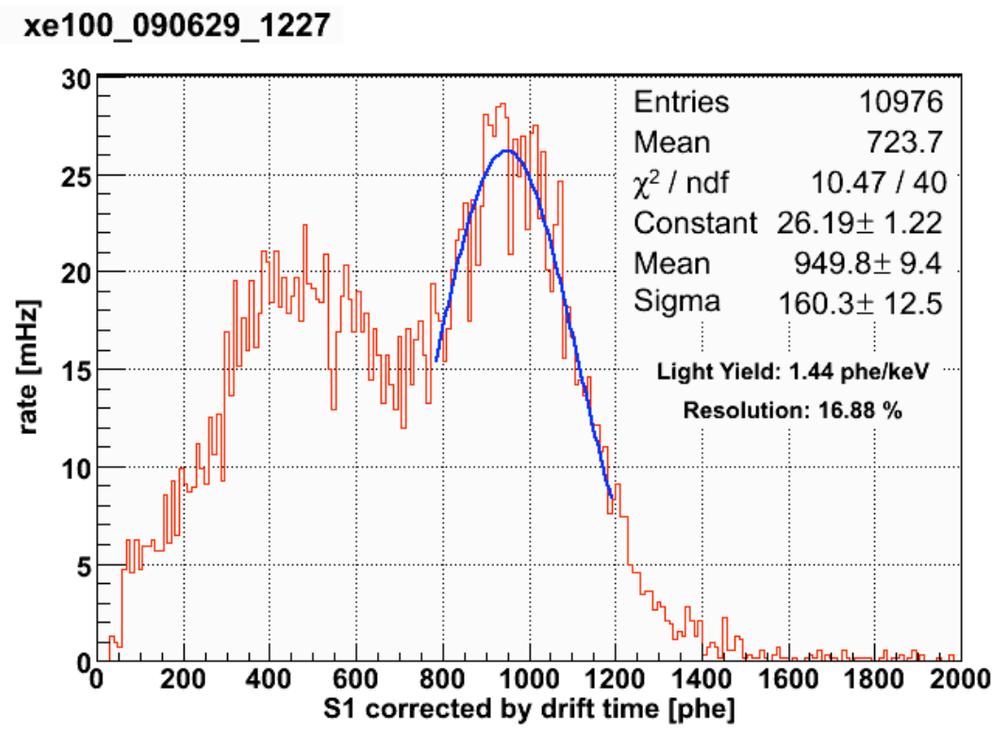
Calibration with ^{137}Cs source

Drift time correction

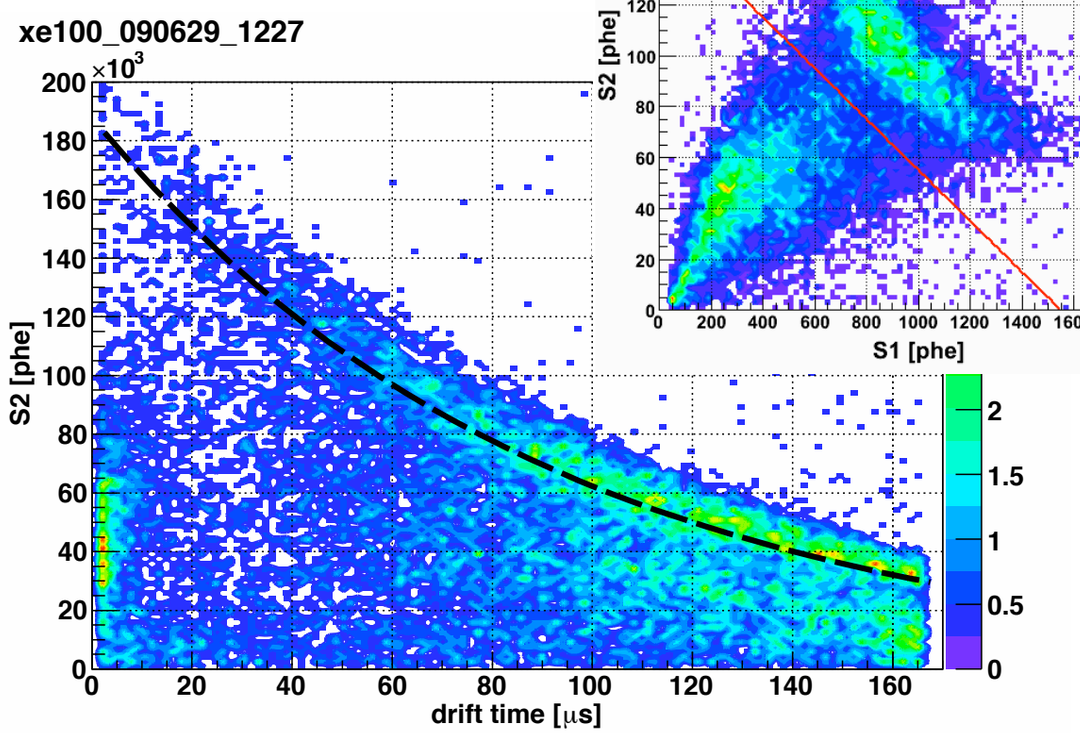
- **S1 signal**

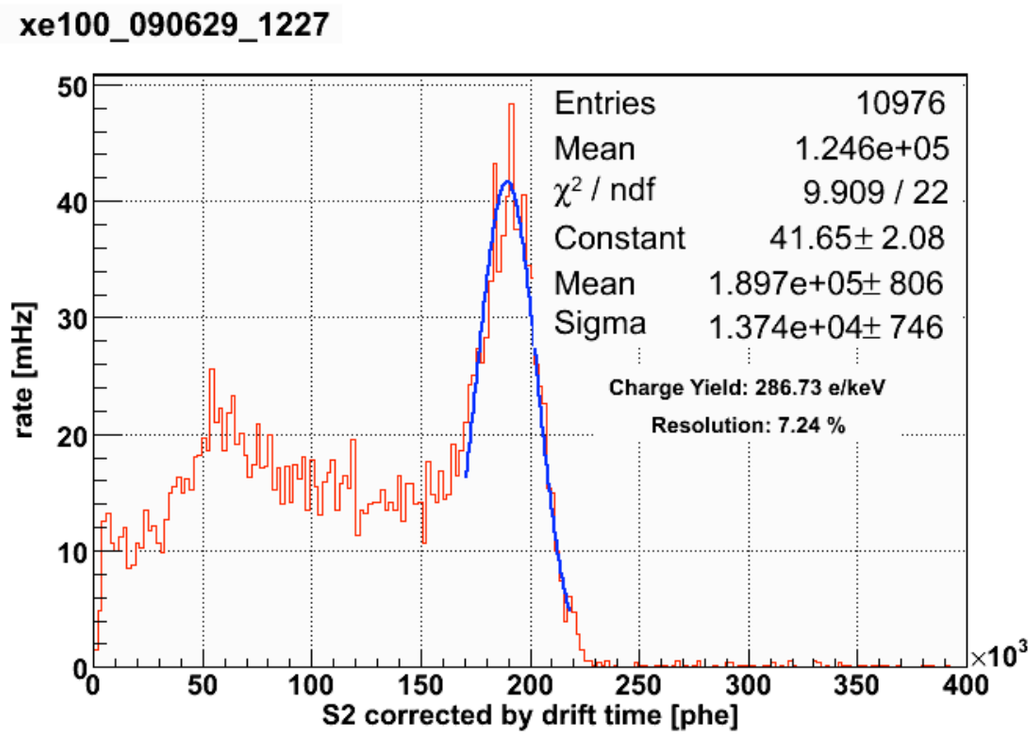






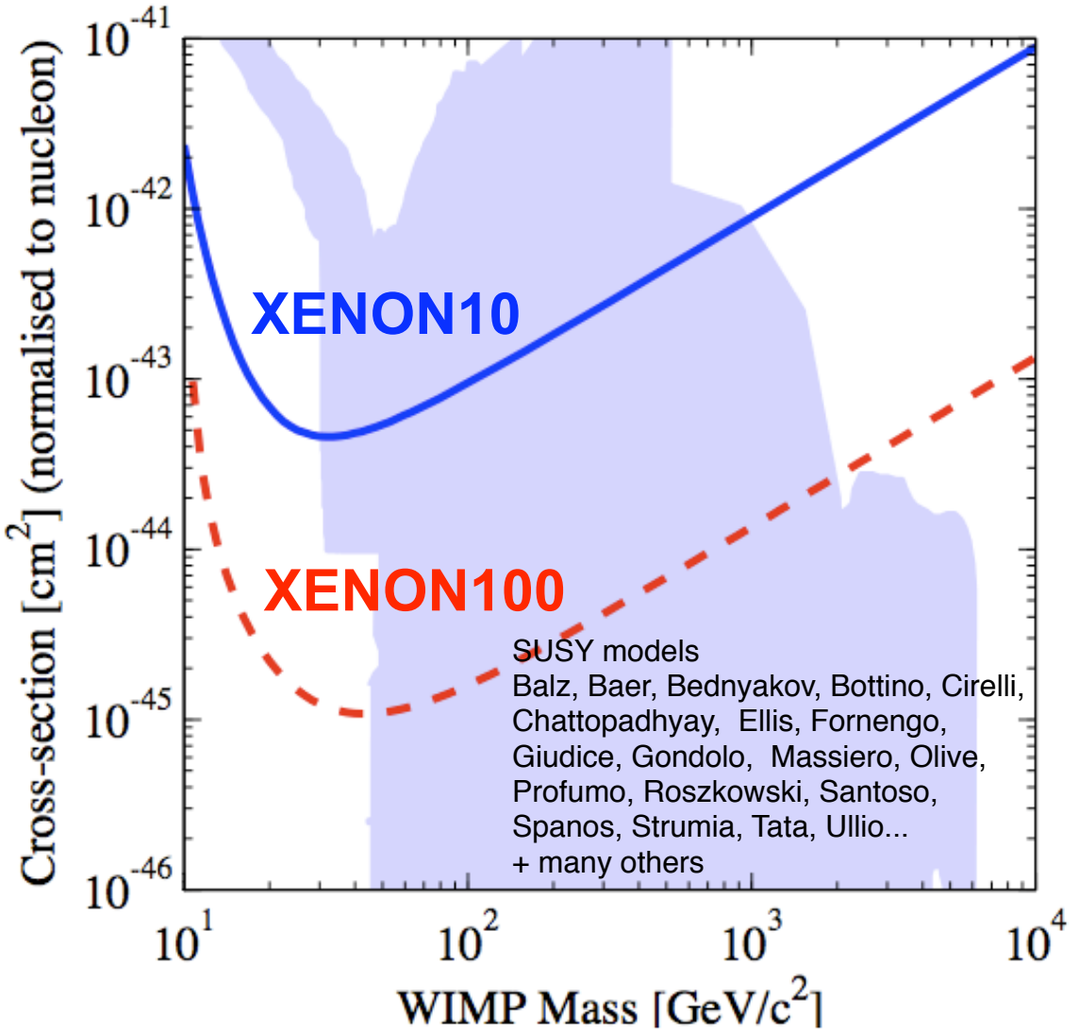
- **S2 signal**



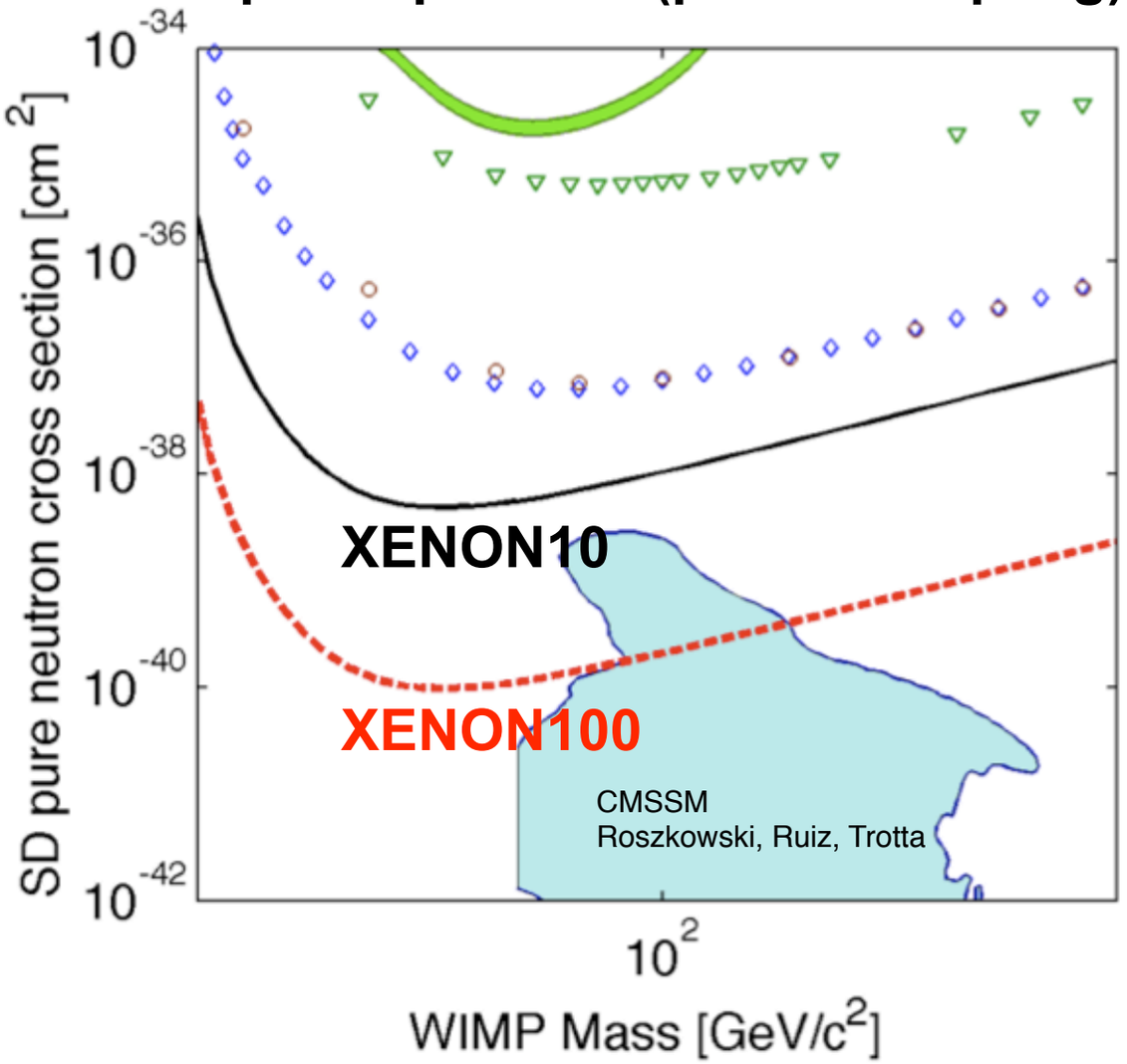


XENON100 Sensitivity Projection

Spin-independent coupling



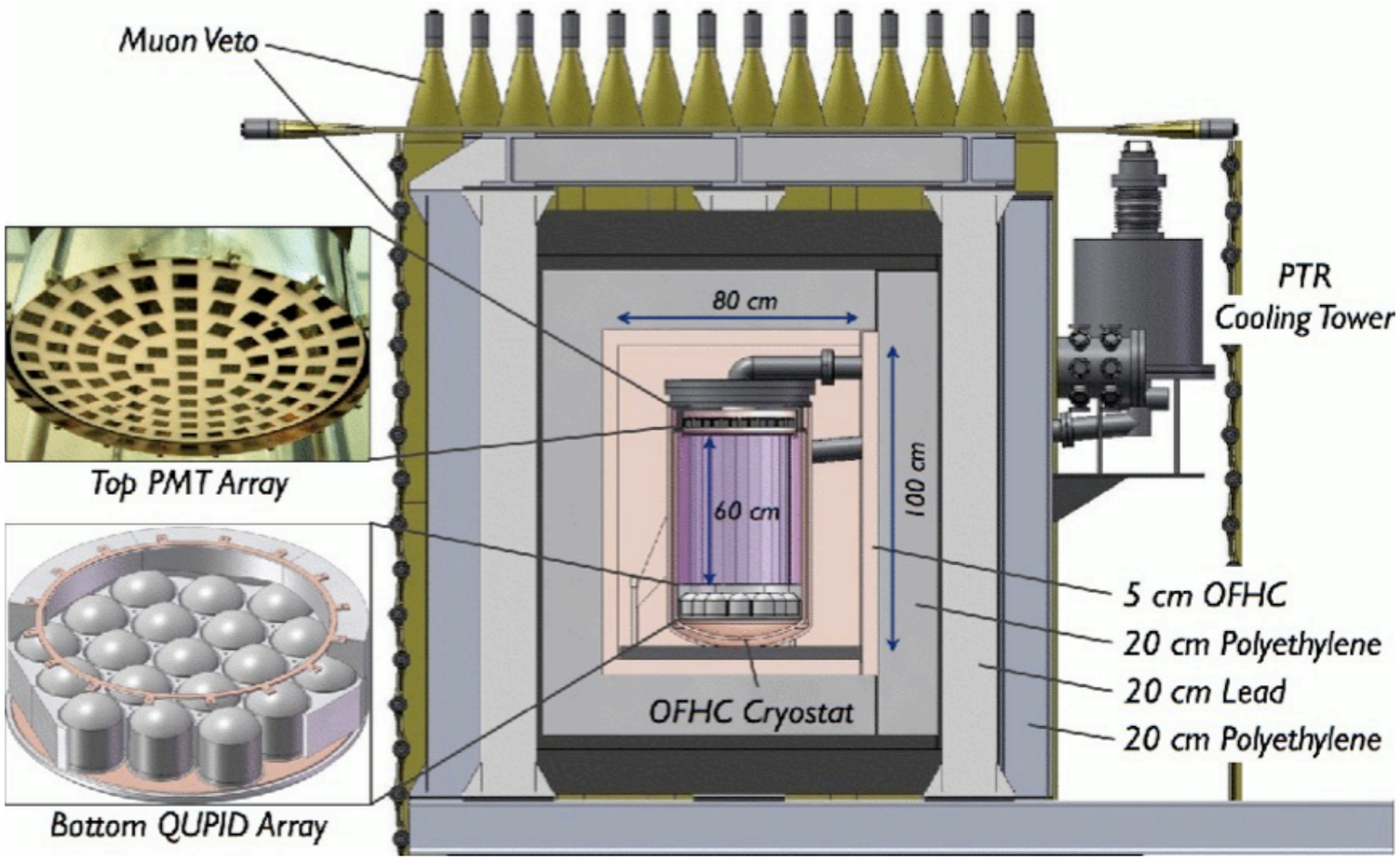
Spin-dependent (pure n-coupling)



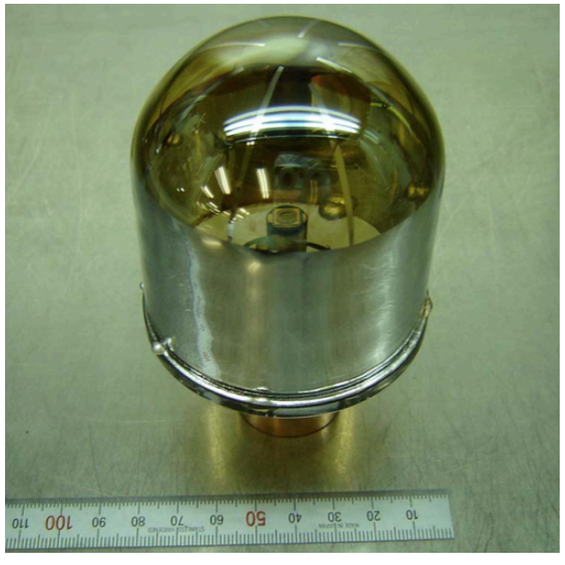
- **Sensitivity to 100 GeV WIMP (spin-independent coupling):**

  50 kg target, 40 days exposure: sensitivity $6 \cdot 10^{-45}$ cm^2
  30 kg target, 200 days exposure: sensitivity $2 \cdot 10^{-45}$ cm^2

The Next Step: XENON100+



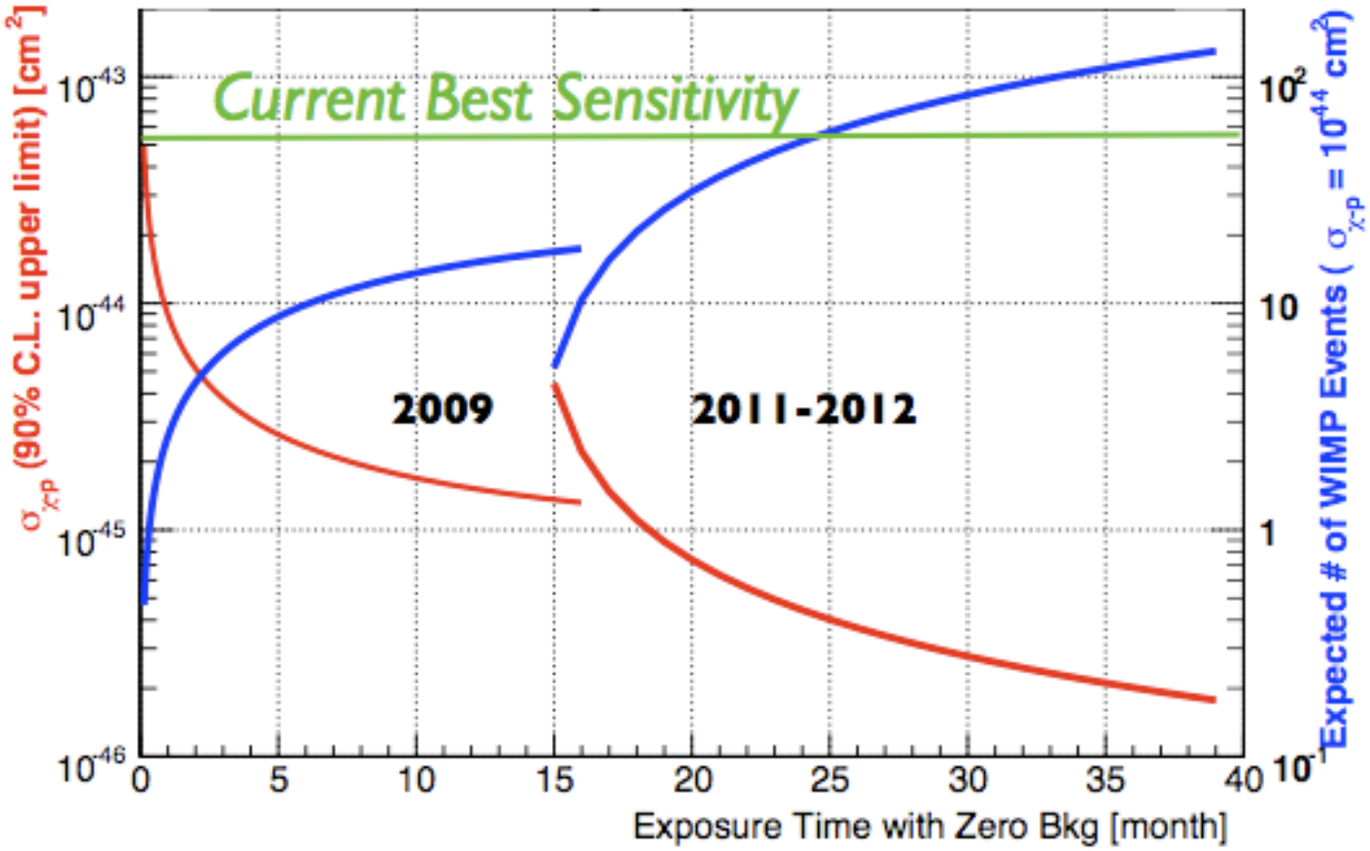
- 100 kg target volume
- lower background (QUPID, OFHC, improved shield)
- design and MC studies
- timeline 2010-2012



- QUPID (Quartz Photon Intensifying Detector):
  - large diameter (3 inch)
  - ultra-low radioactivity (~0.1mBq)
  - high collection efficiency (~100%)
  - simple HV supply (no tube-to-tube variation of gain)

Summary

- The detector is operating underground
- Light yield and electron life are continuously improving
- Processing with the distillation column, Summer 2009
- Neutron calibration with Am-Be source, Fall 2009
- First dark matter search run is planned before end of 2009
- The studies on the detector upgrade (XENON100+) and the next stage (XENON1T) are ongoing



XENON sensitivity projection (100 GeV WIMP)