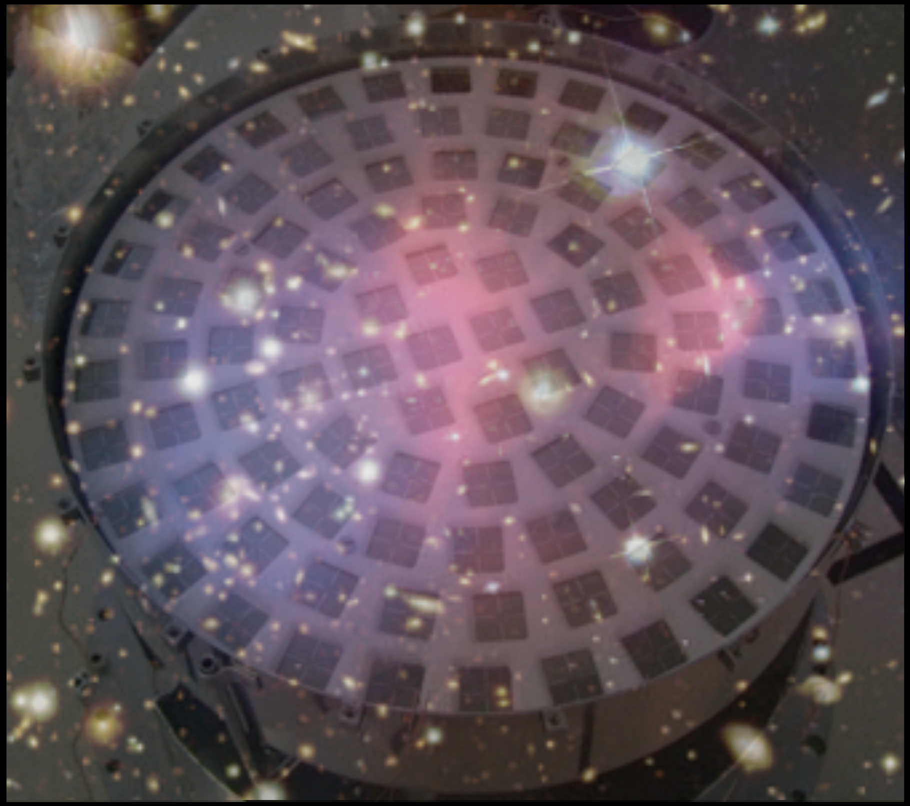
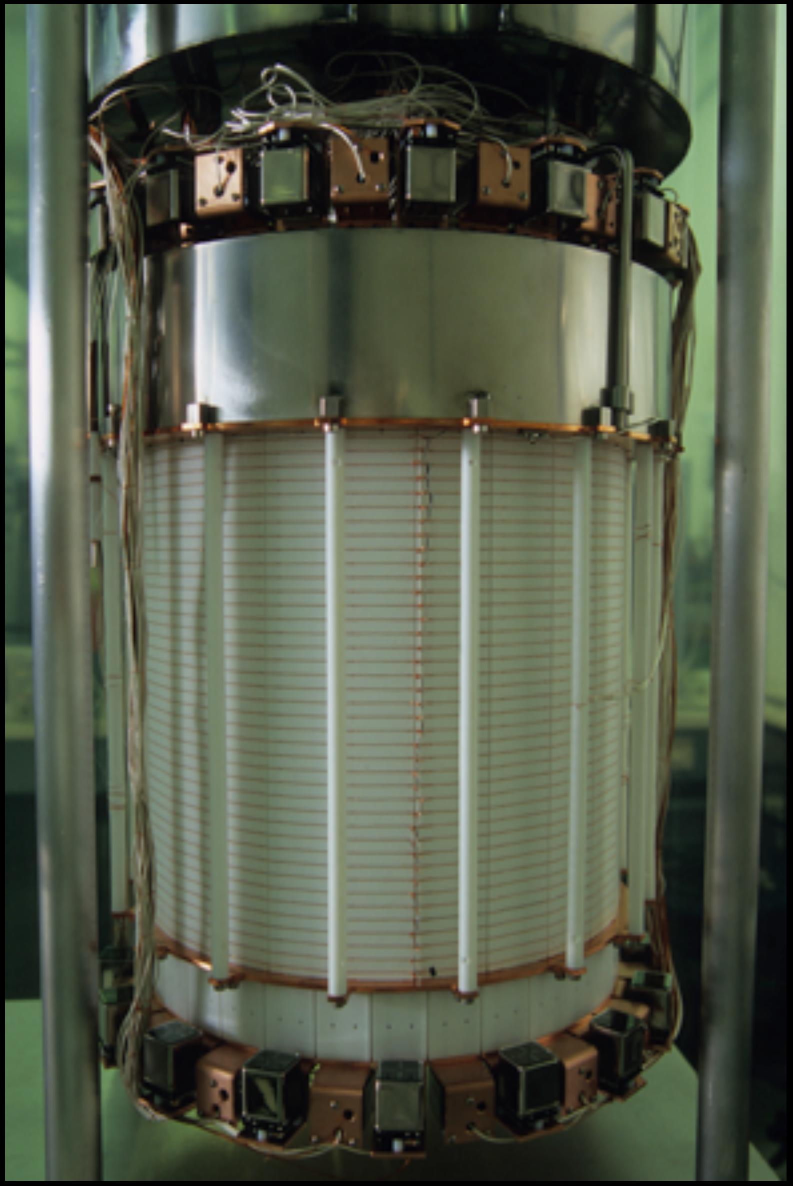
The XENON 100 Detector for Dark Matter Searches





Alexander Kish
University of Zürich

XENON-100 collaboration

~40 researchers from **USA, Switzerland, Italy, Portugal, Germany, France, China**

Columbia University

University of California

University of Zürich

University of Coimbra

Rice University

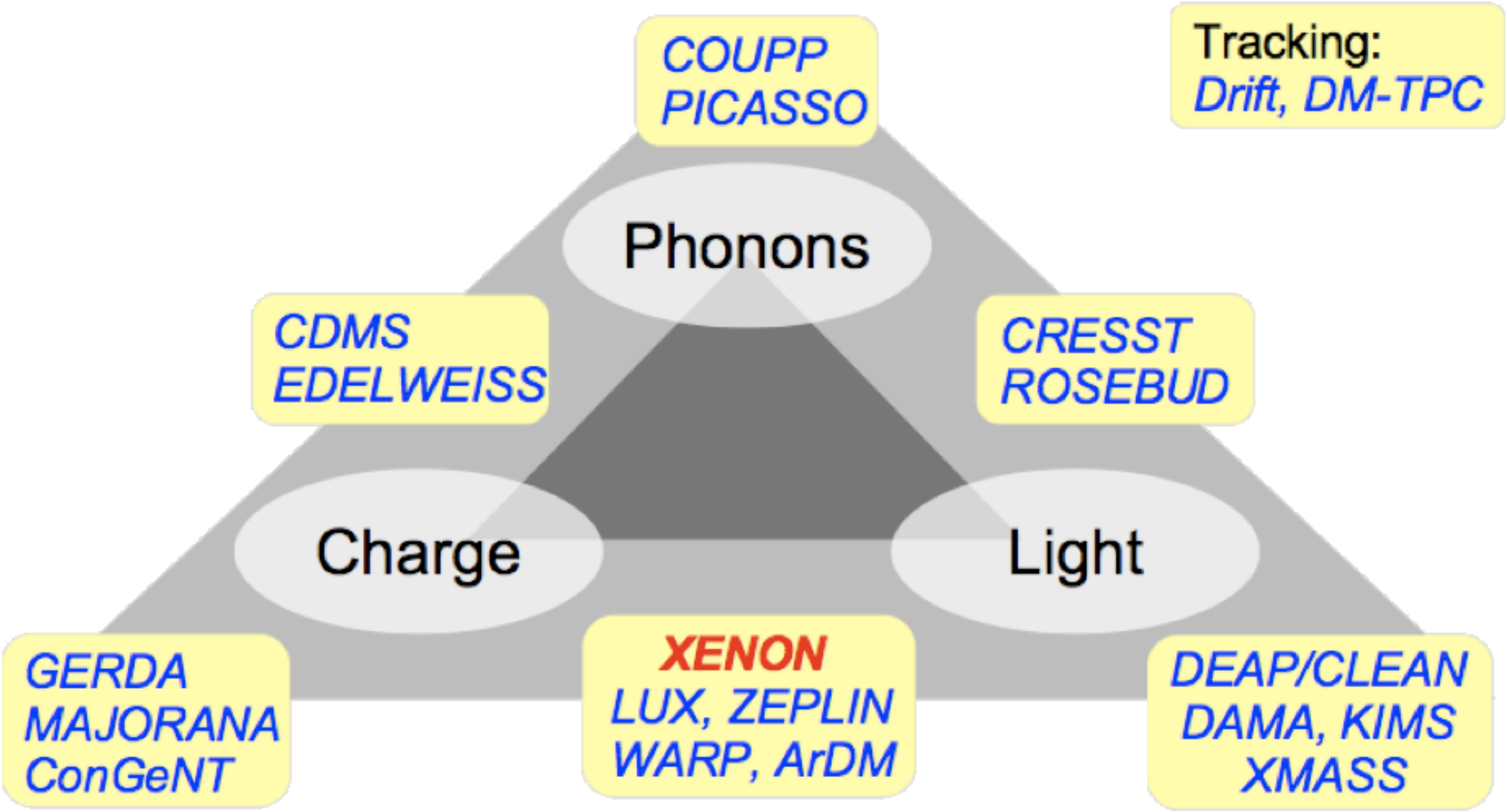
Shanghai Jiao Tong University

Laboratori Nazionali del Gran Sasso

Subatech

Westfälische Wilhelms-Universität Münster

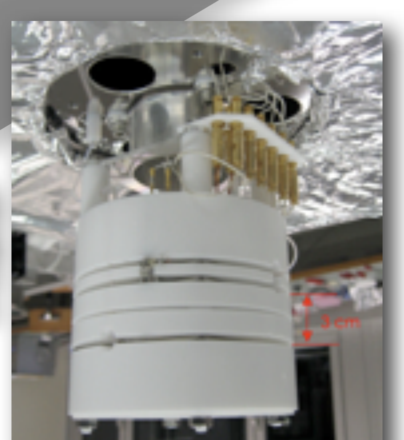
Dark Matter Searches



The XENON WIMP Search Program

R&D

ongoing...



XENON 10

2005 - 2007

Target Volume ~10 kg

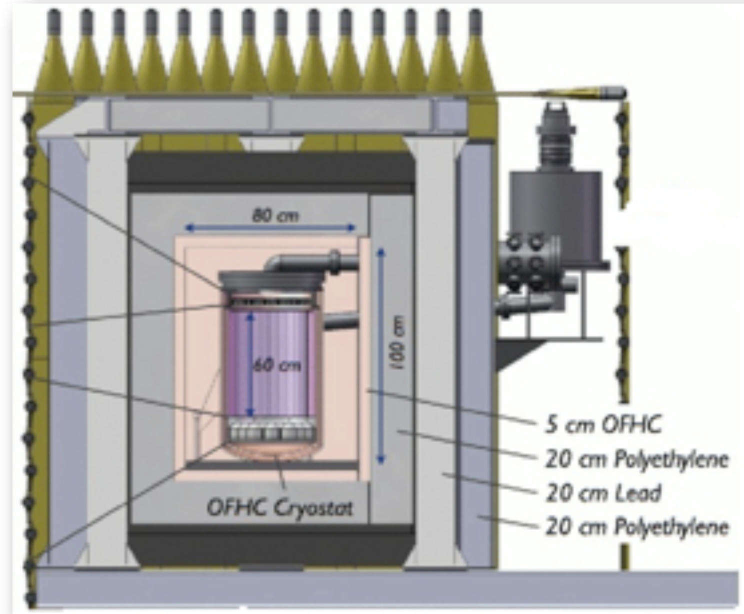
XENON 100

2007 - ongoing...

Target Volume 65 kg
Total 170 kg of LXe

XENON 100+

2010 - 2012

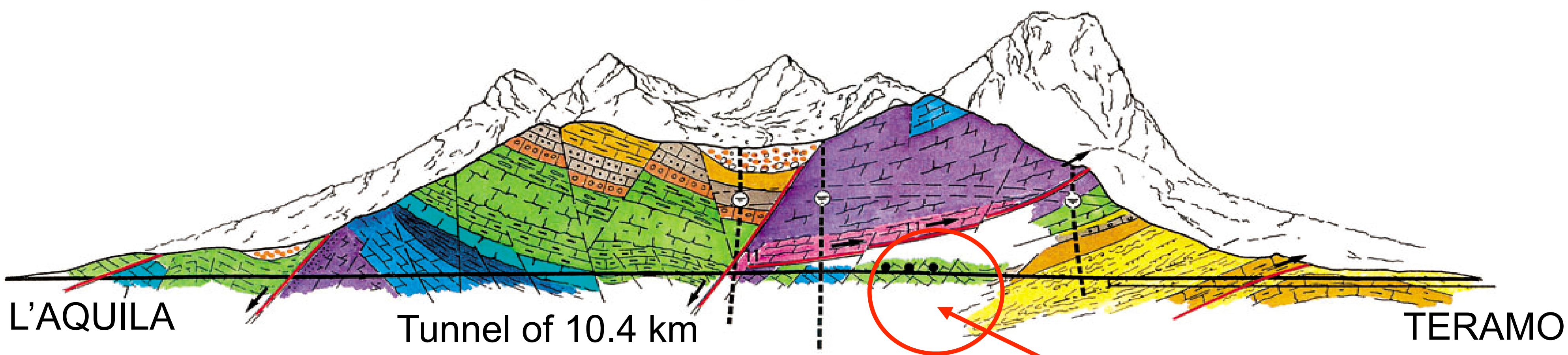


Target Volume ~100 kg
Muon Veto
QUPIDs

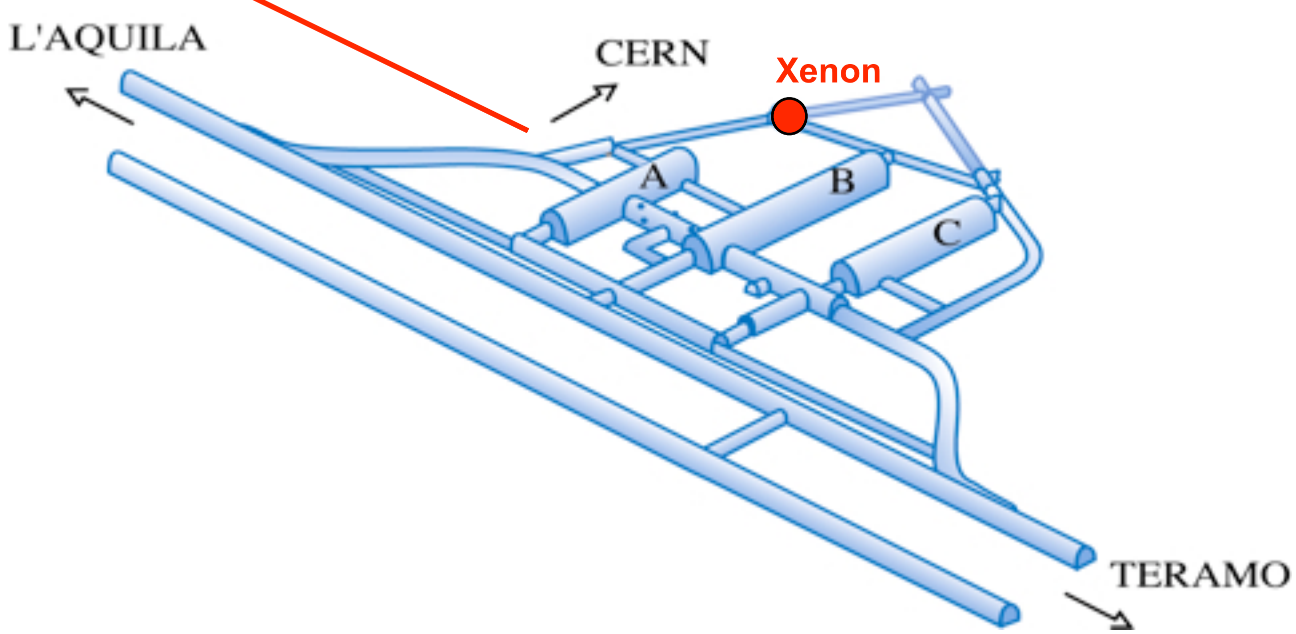
XENON 1T

2013 - 2015

Location of the XENON-100 experiment

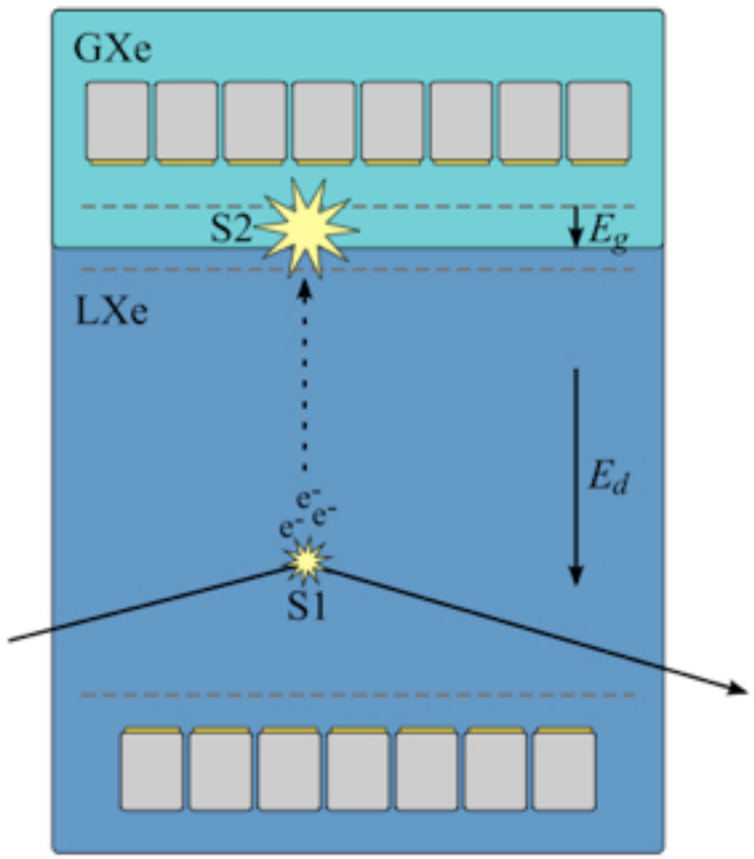


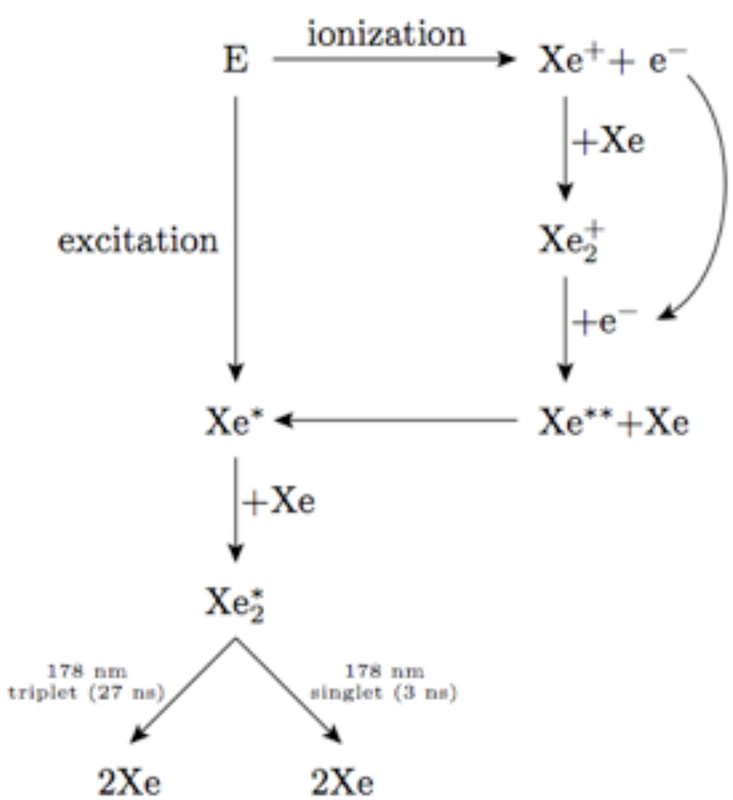
INFN
Laboratori Nazionali del Gran Sasso

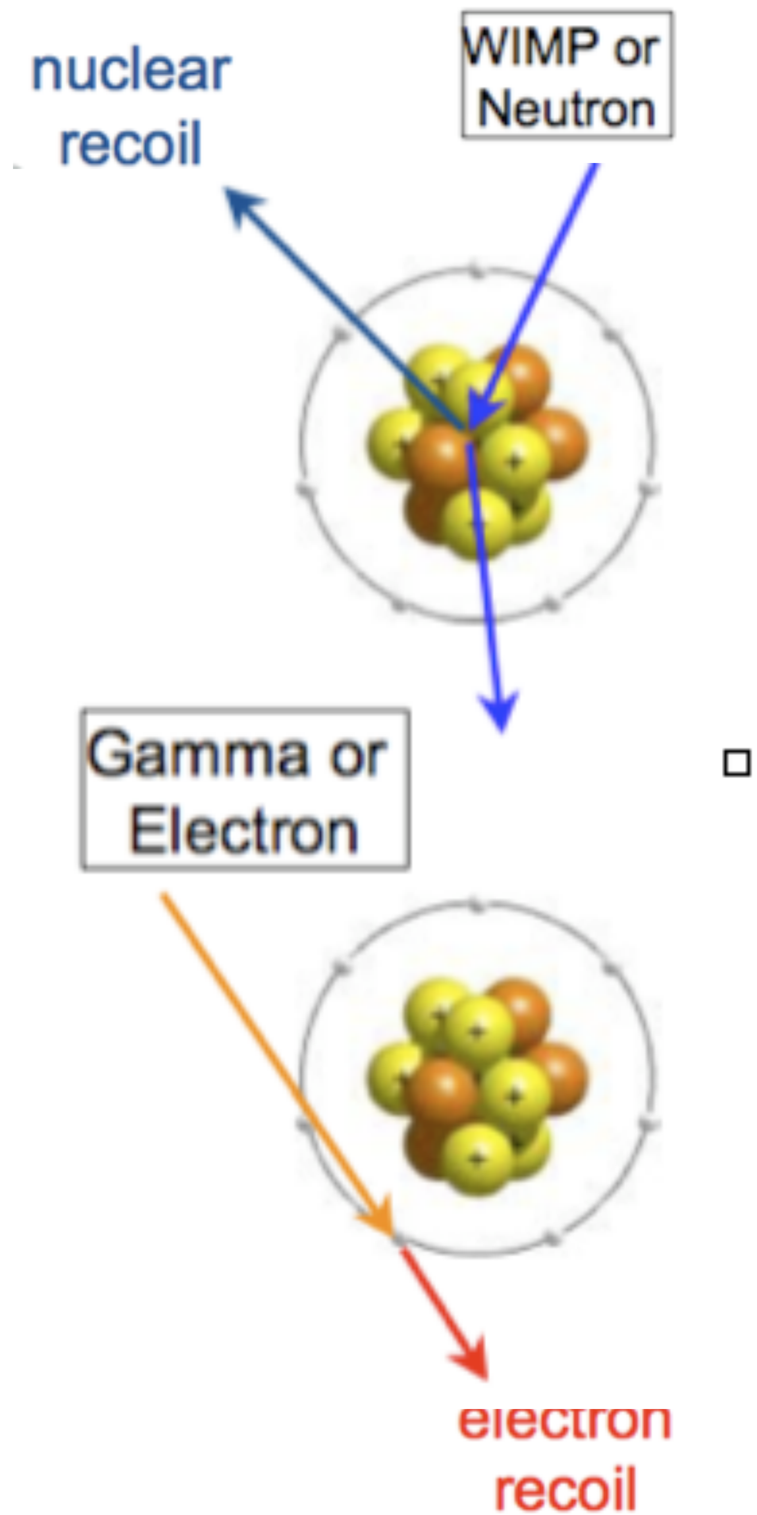


1.4 km rock
=
3100 meters water equivalent shielding from cosmic rays

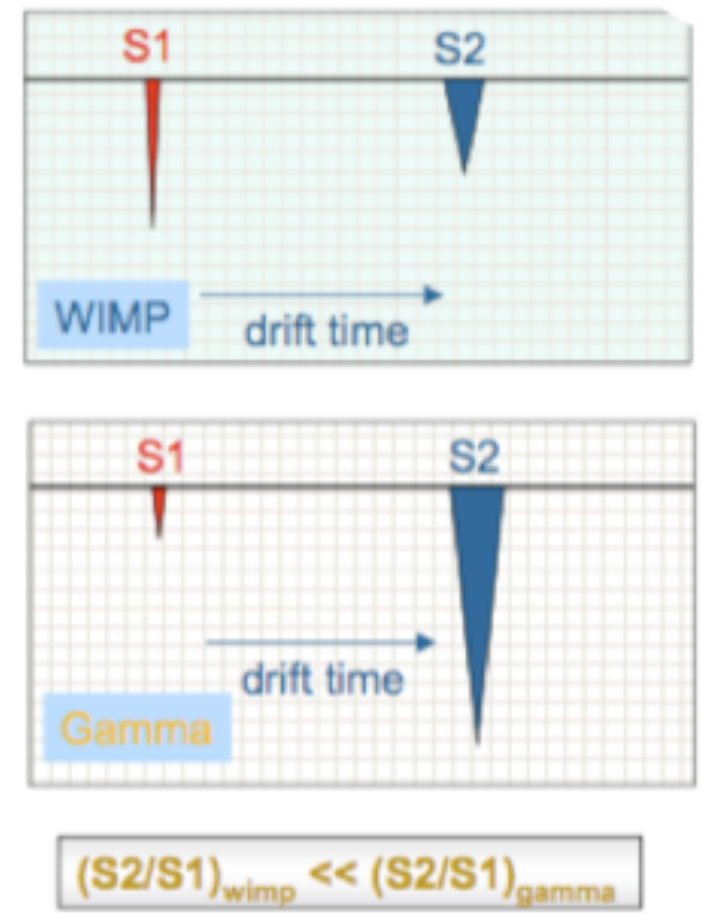
The Principle of the XENON experiment



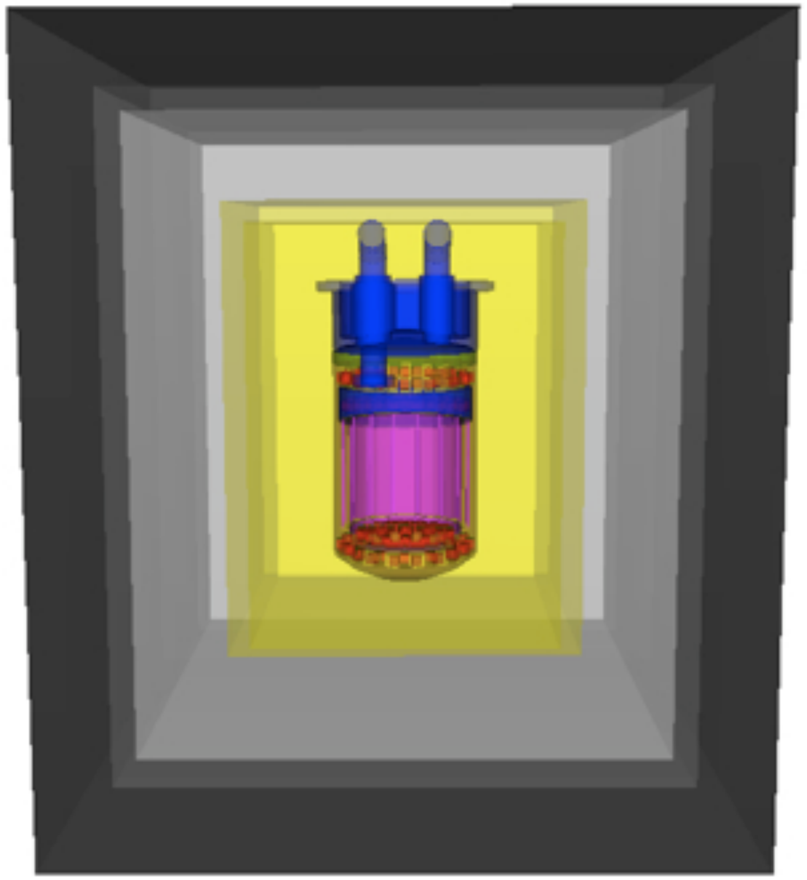




Electron/nuclear recoils discrimination based on S2/S1 ratio

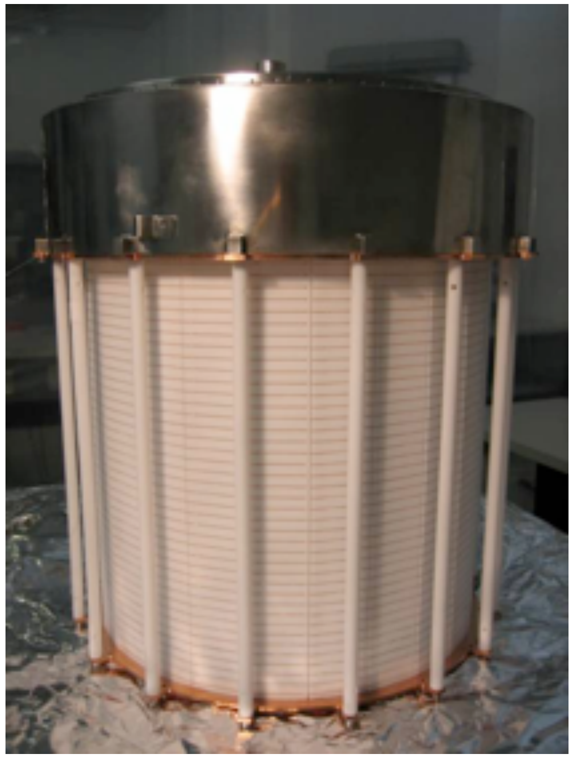


XENON-100 Design



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

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



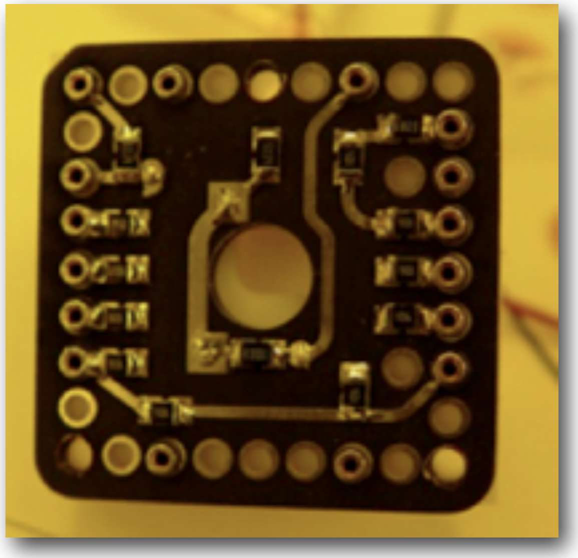
Bell:
- stainless steel
- weight 3.6 kg

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

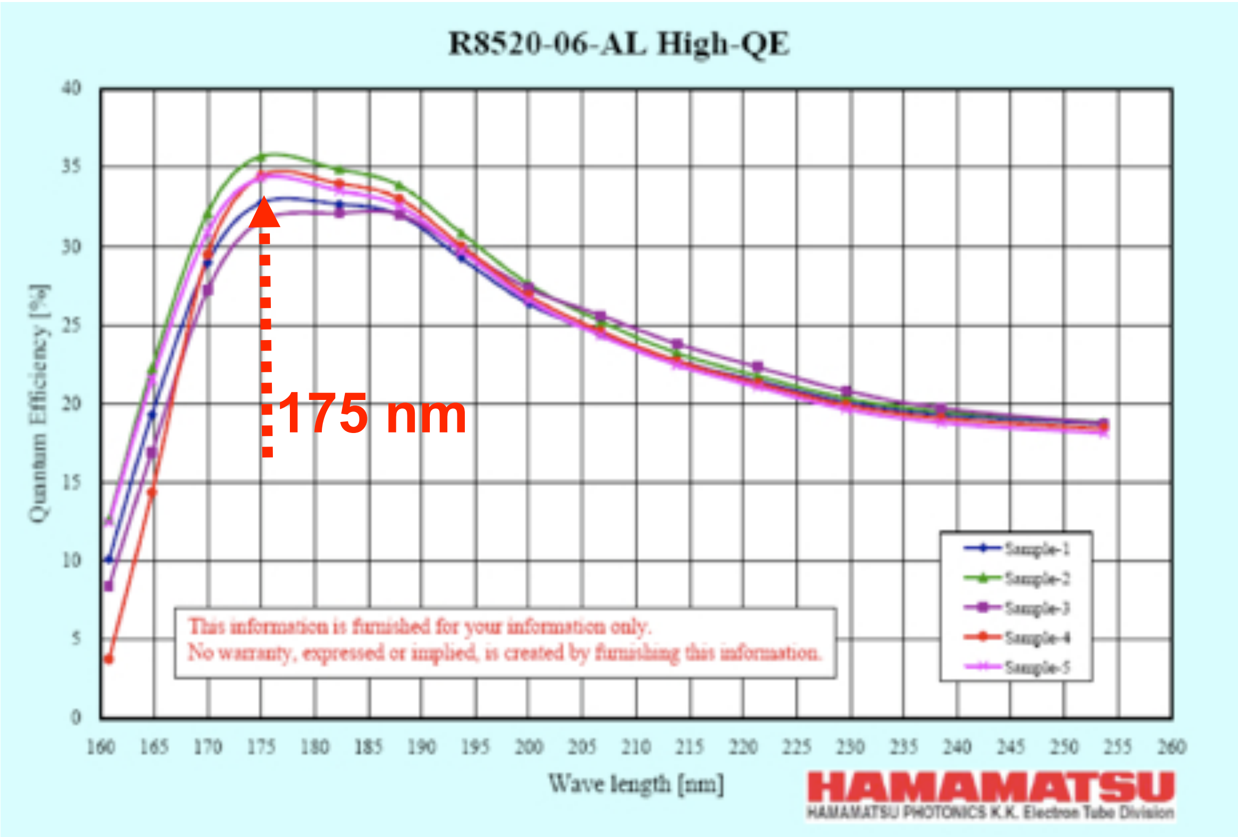
Target:
- 65 kg of LXe
(total amount 170 kg)
- 30 cm diameter,
- 30 cm height

Light Detection in the XENON-100 Detector

Hamamatsu R8520



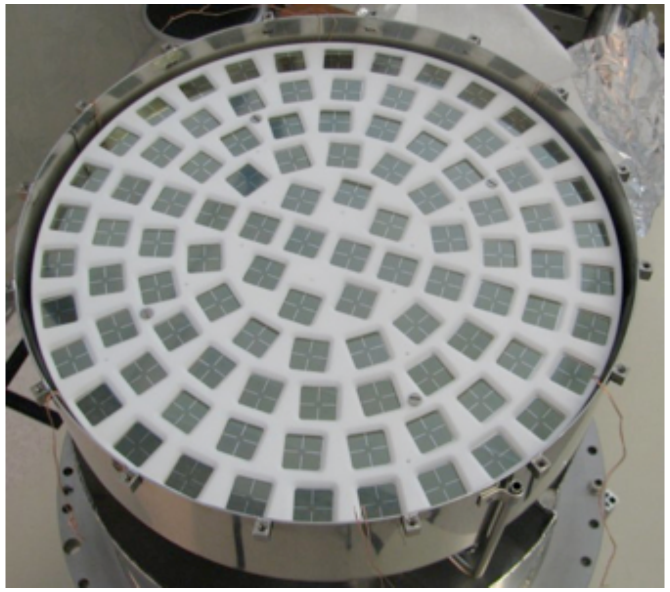
- 2.5 x 2.5 mm window
- metal channel dynodes
- Kovar housing and pins
- Stainless steel electrodes
- Synthetic quartz glass for window
- Borosilicate glass for stem
- Cirlex bases for voltage divider network
- high Quantum Efficiency (up to 35%)
- low radioactivity (~10mBq/PMT)



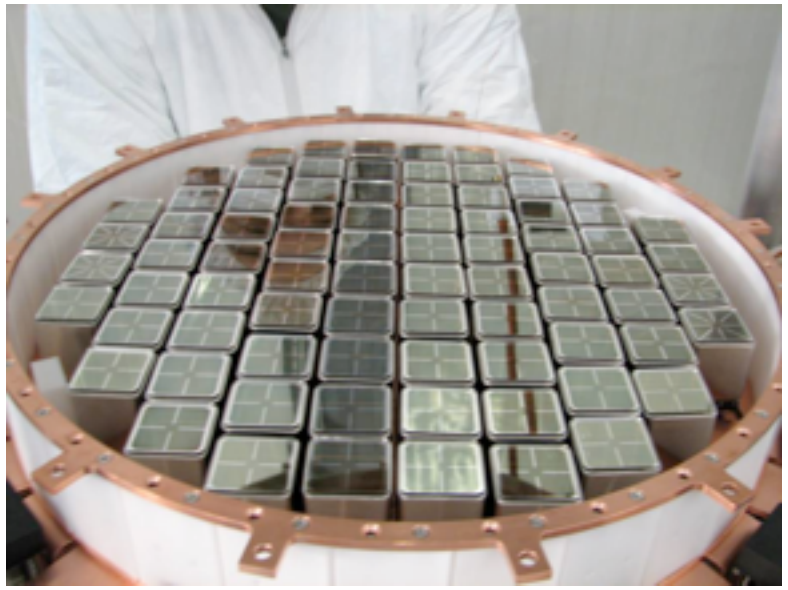
Quantum efficiency VS wavelength

Light Detection in XENON-100 Detector

Target Volume



Top PMT array
(98 PMTs)

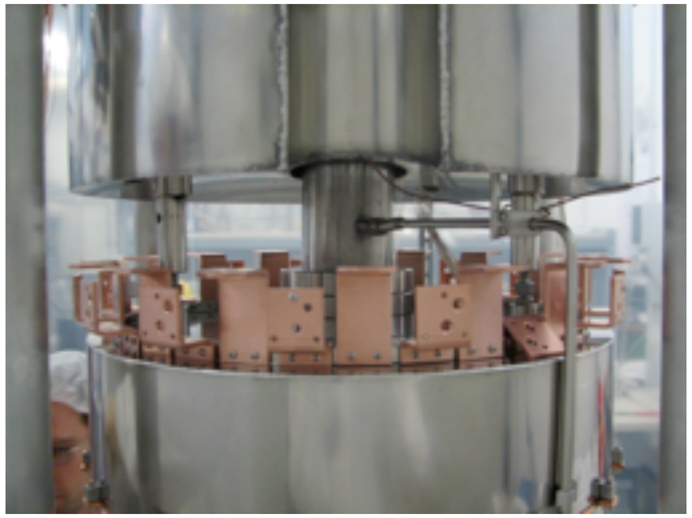


Bottom PMT array
(80 PMTs)

- 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

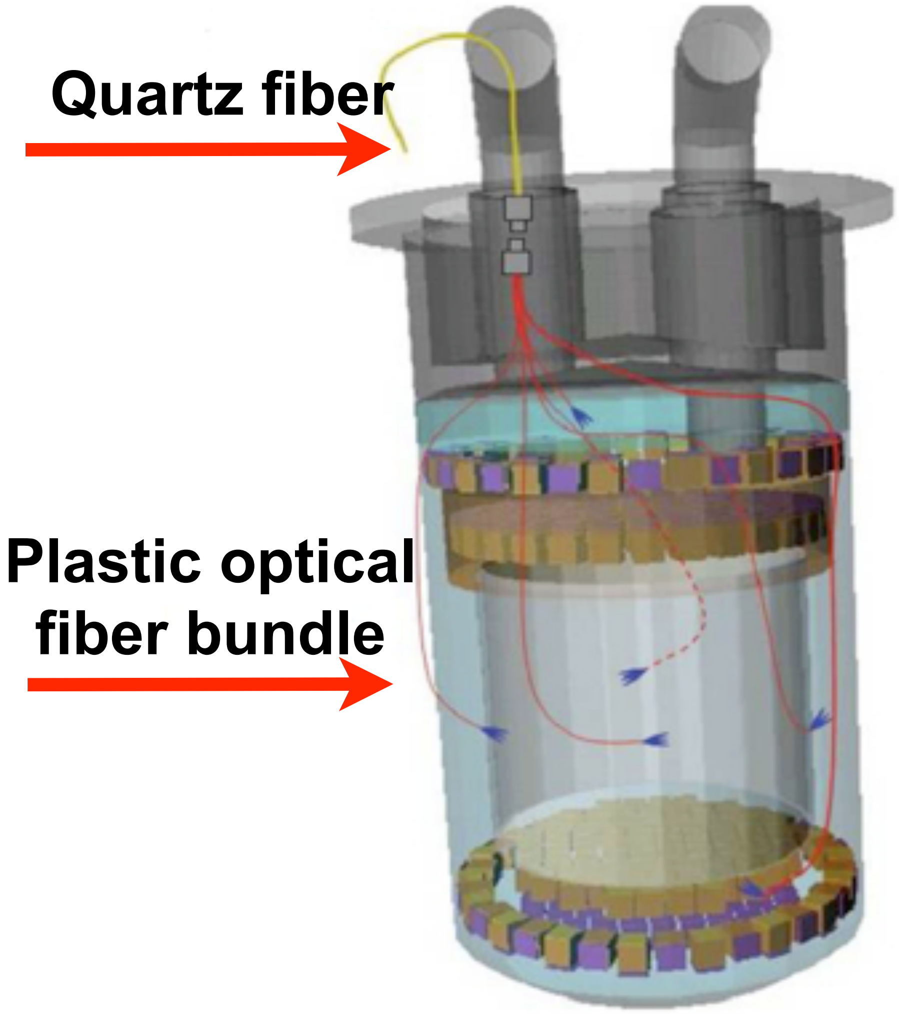
Top/Side Top arrays
(32 PMTs)

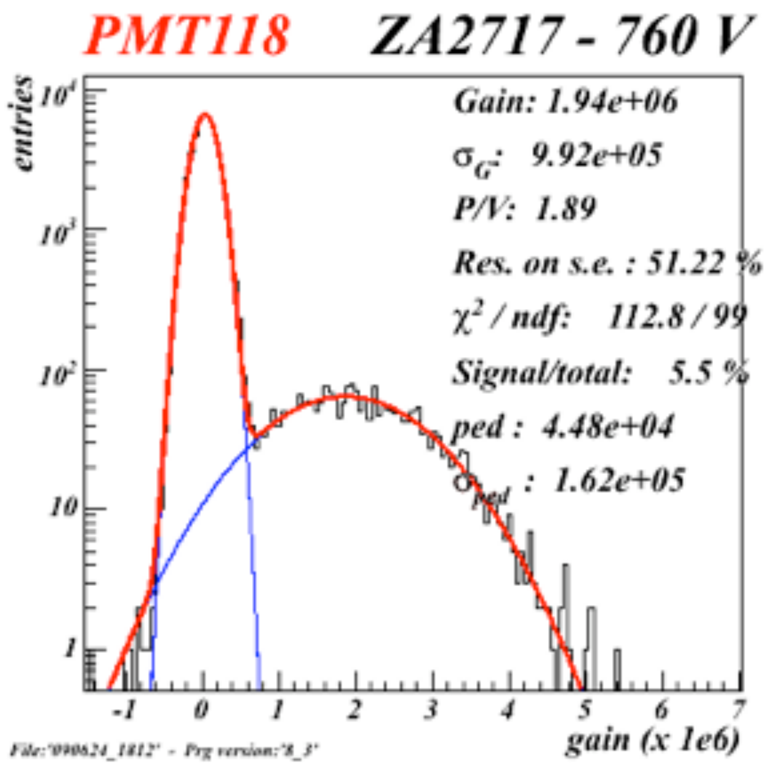


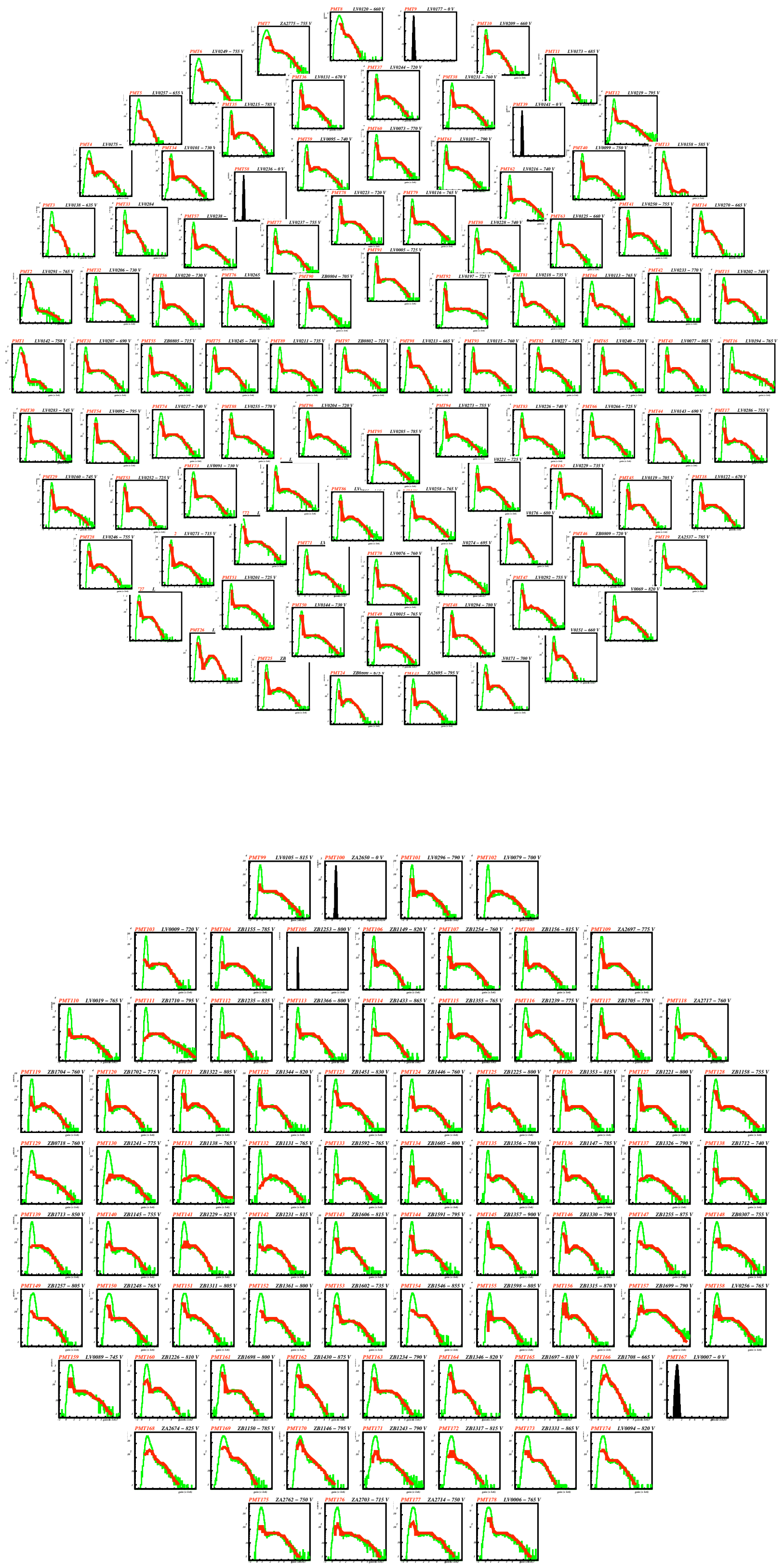
Bottom/Side Bottom arrays
(32 PMTs)

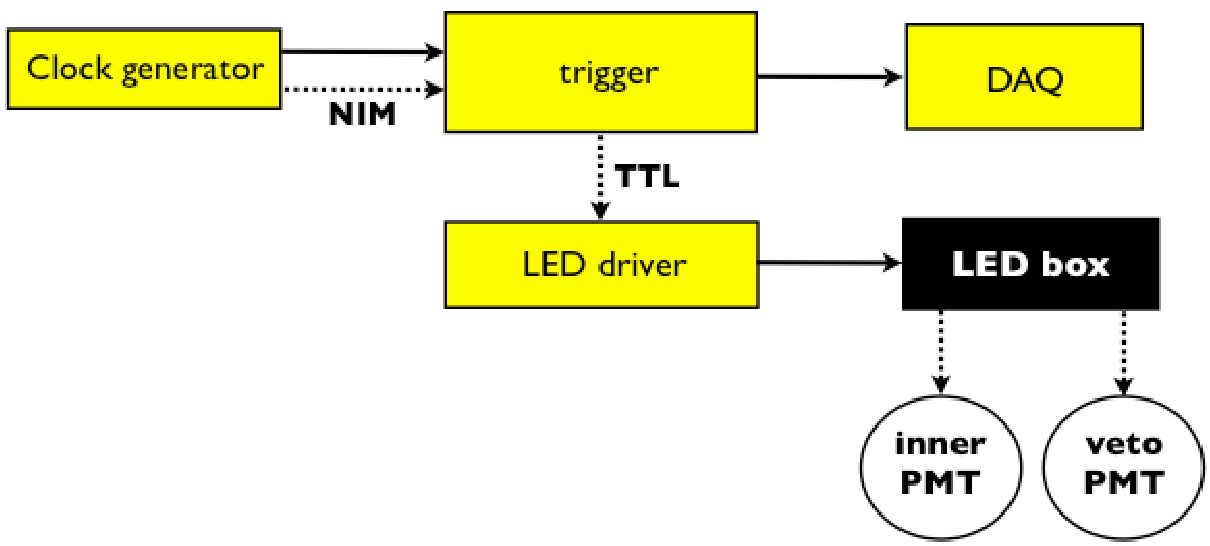
- 64 tubes in the active veto volume, alternating inwards and up/down, to view the top, bottom and sides

PMT Gain Calibration

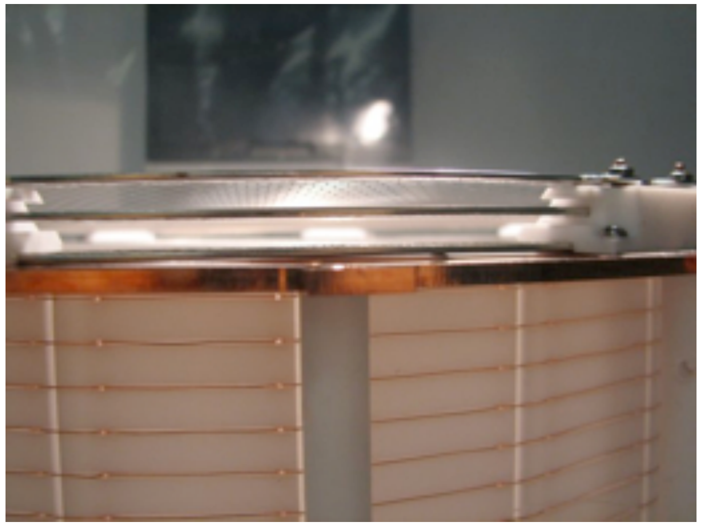


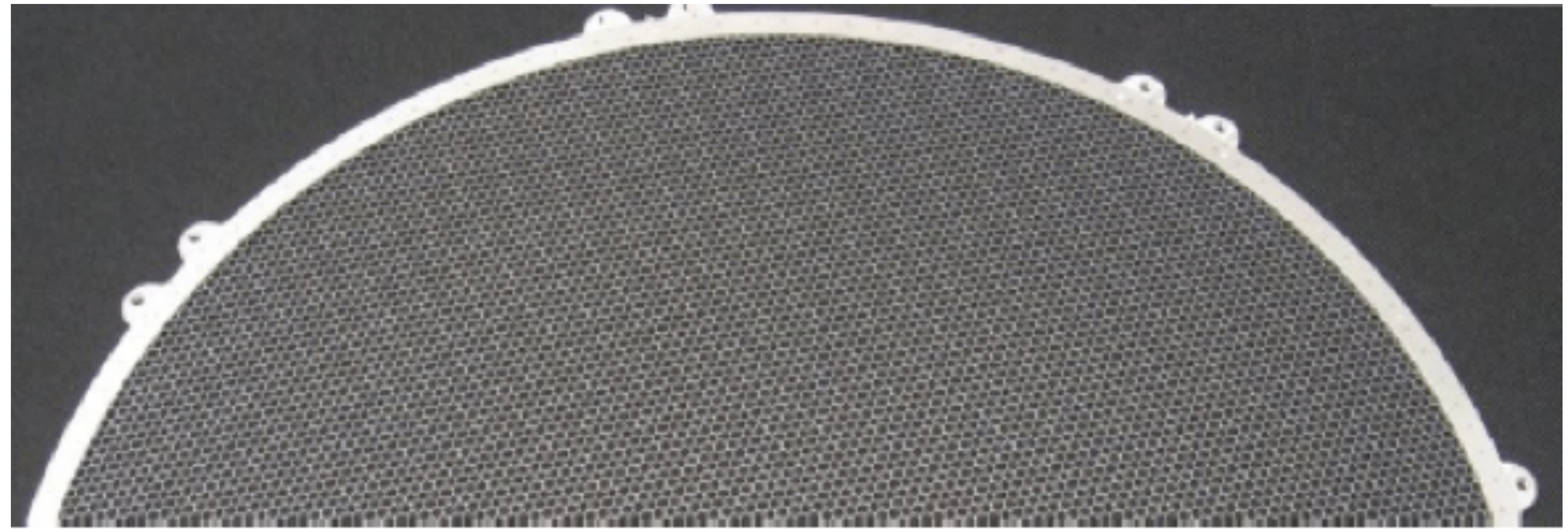




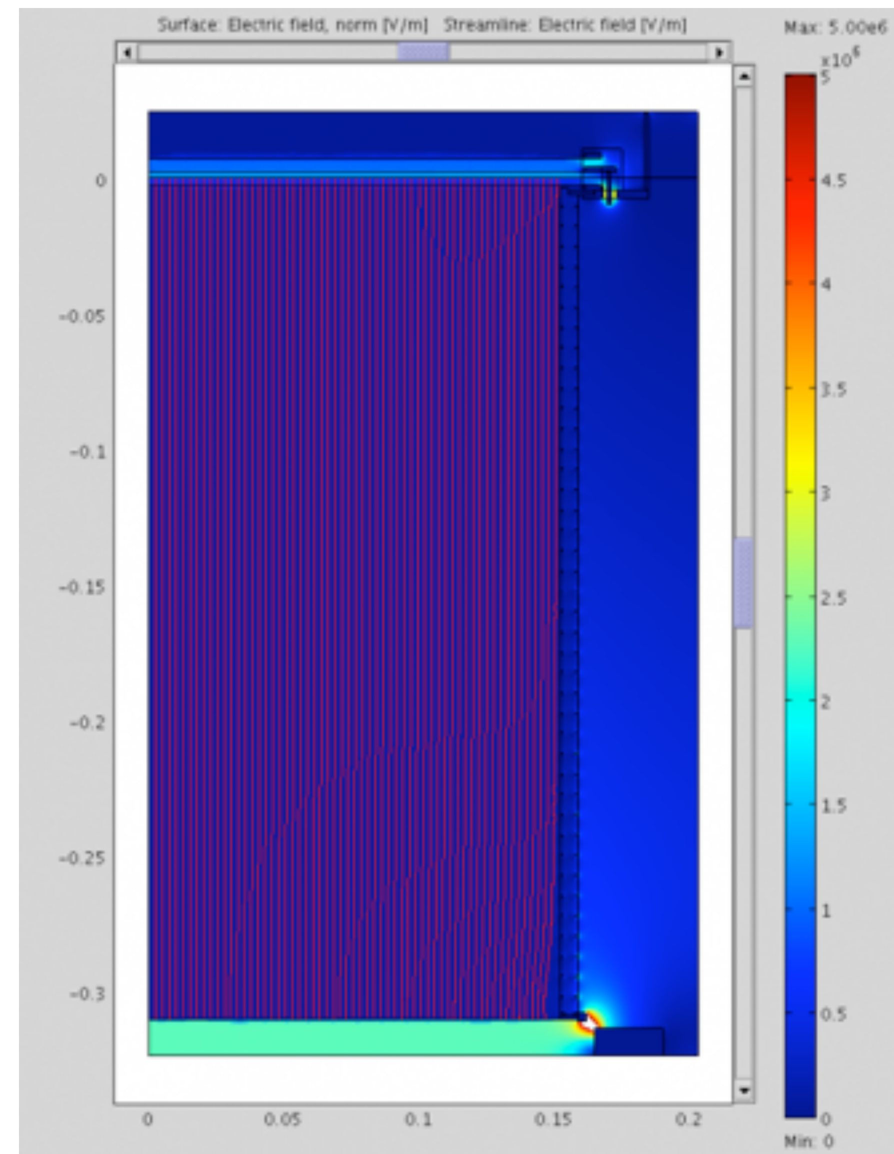


Electric Field

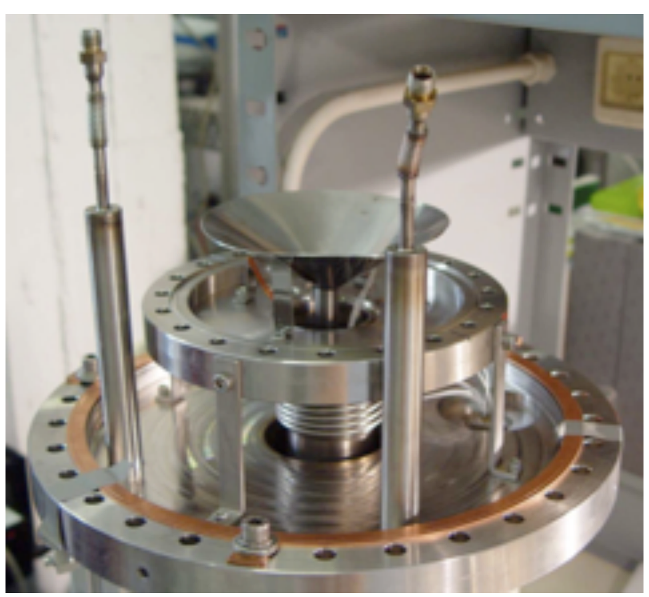




- The field is optimized with simulations for homogeneity
- 40 double field shaping rings
- Hexagonal mesh structures
- Anode stack is optimized for optical transparency
- Drift field 1kV/cm (cathode at -30kV)
- Extraction field 5kV

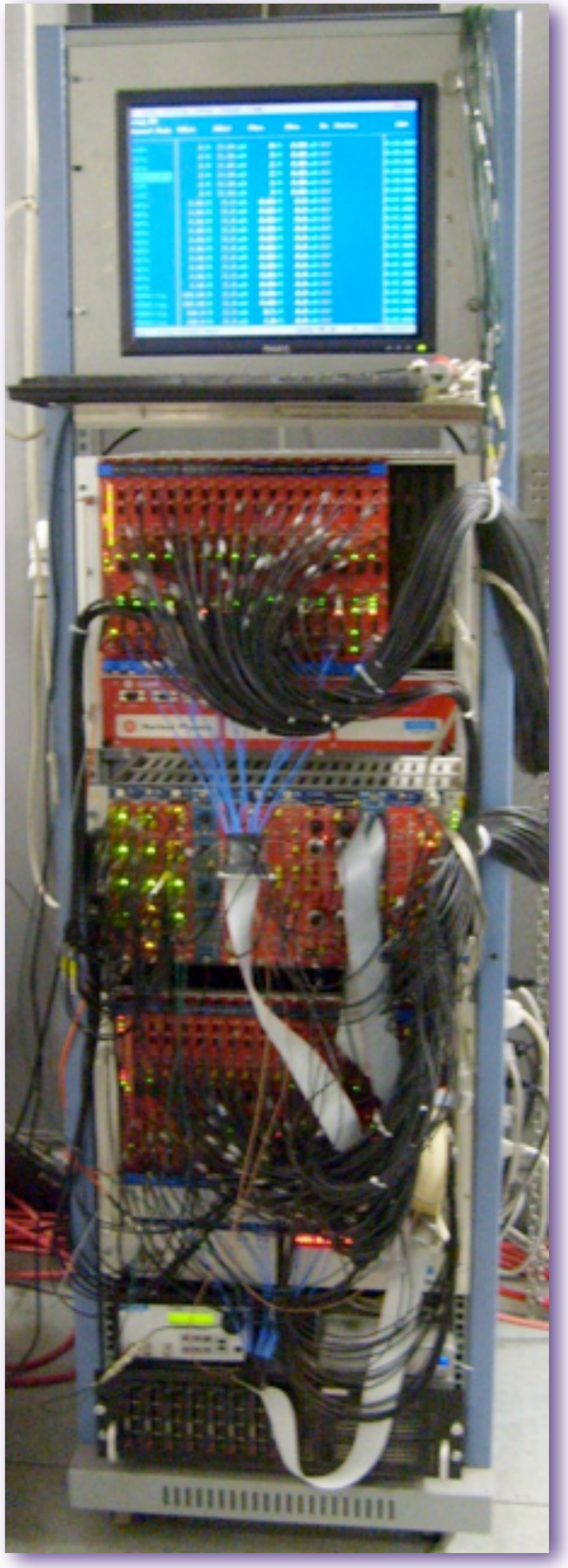


Xenon Liquefaction, Cooling Tower and

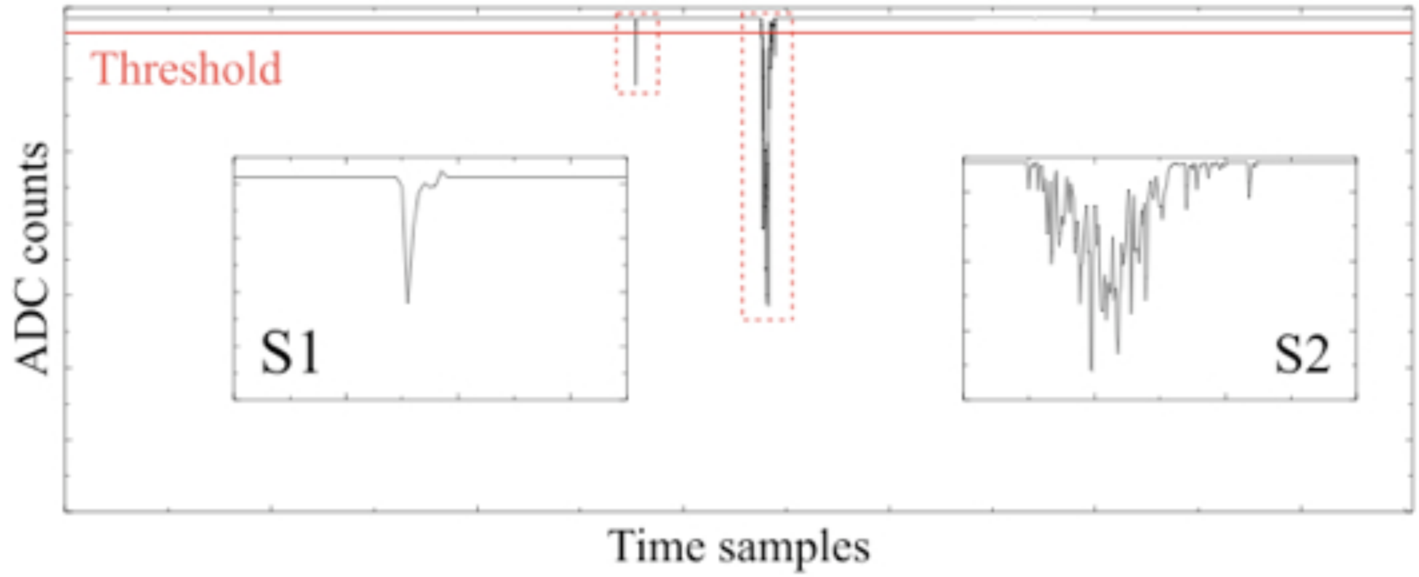


- Xe liquefaction is done with the Pulse Tube Refrigerator (160W), which is placed outside the shield
- Liquid Xe flows back into the main vessel from the cooling tower through a small pipe in the center of the double-walled vacuum insulated tube
- Cooling system is backed up with the LN2 emergency coil, which is also placed in the cooling tower
- Distillation column (3 m high) for Kr removal, processing at speed of 0.6 kg/hour (~2 weeks for 170kg)

Data Acquisition System for the XENON-100 experiment

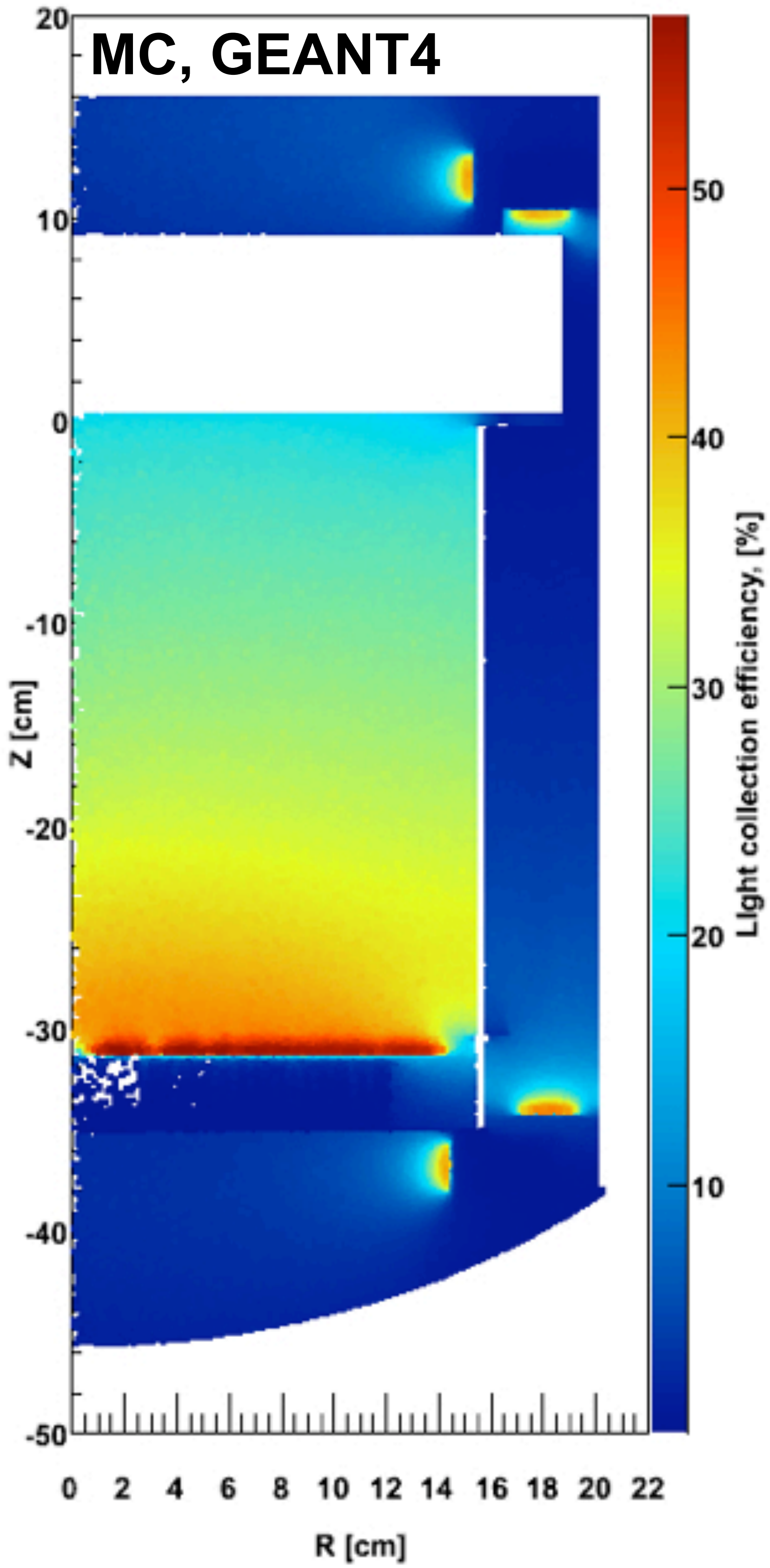


- **DAQ is composed of 31 CAEN V1724 14 bit 100 MHz flash ADCs**
- **Digitization of the full waveforms (320 microsec) of the 242 PMTs**
- **Deadtime-less mode with the data written to circular buffers and multiple event buffers for storage between VME read cycles**
- **Digitized signals are "zero-length"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

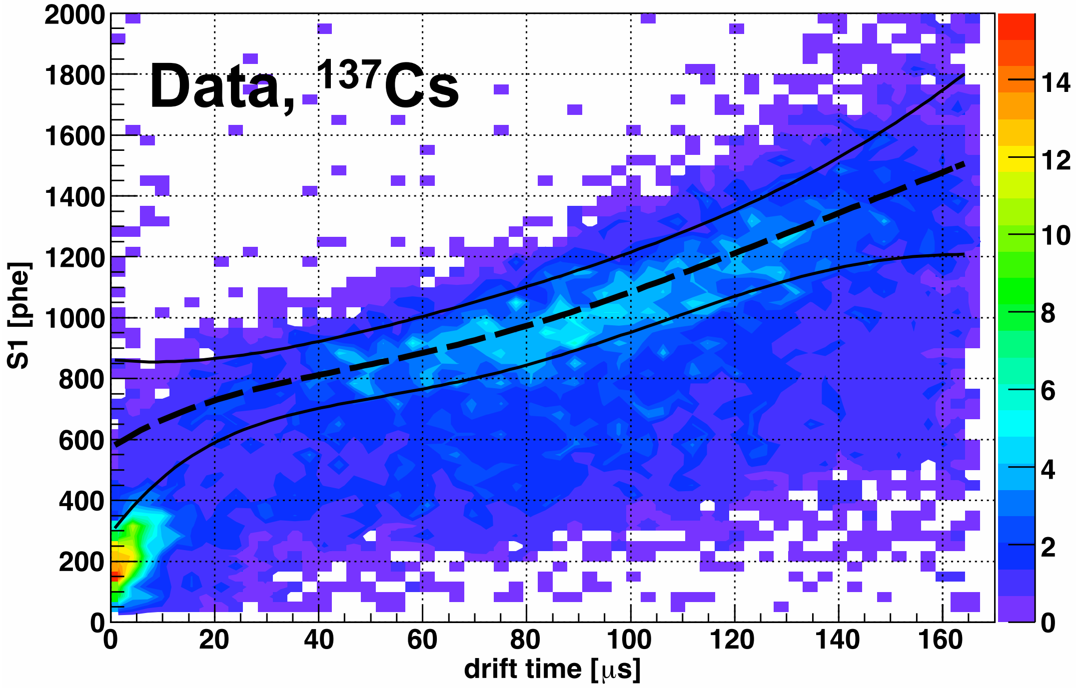


- **High rate capability for calibration (>50 Hz)**

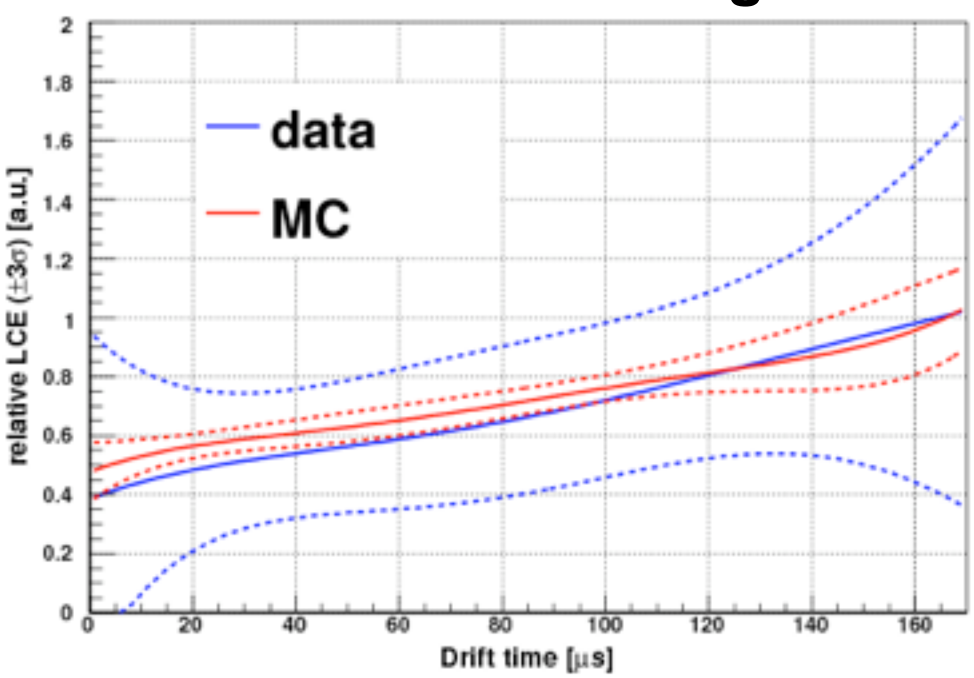
Light Collection Efficiency



- **Average LCE in the target volume: 24%**
- **Average LCE in the active veto volume: 4.7%**

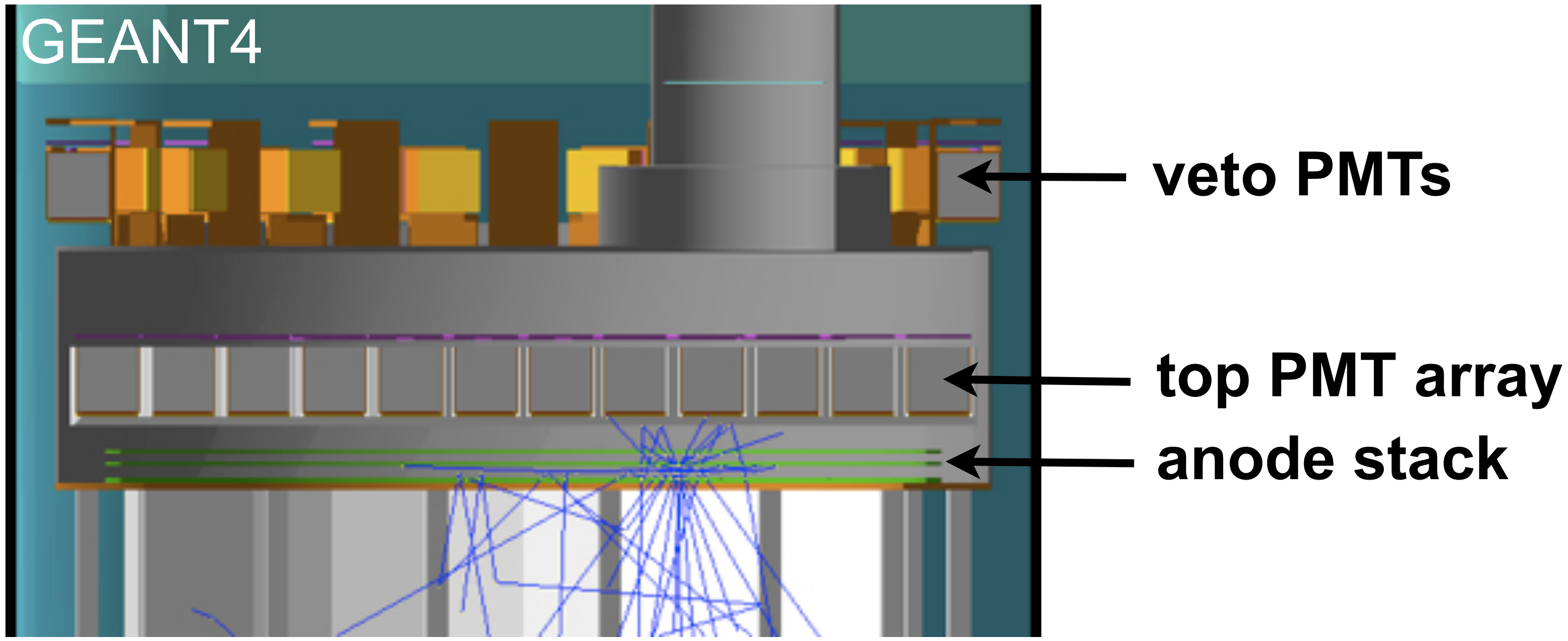


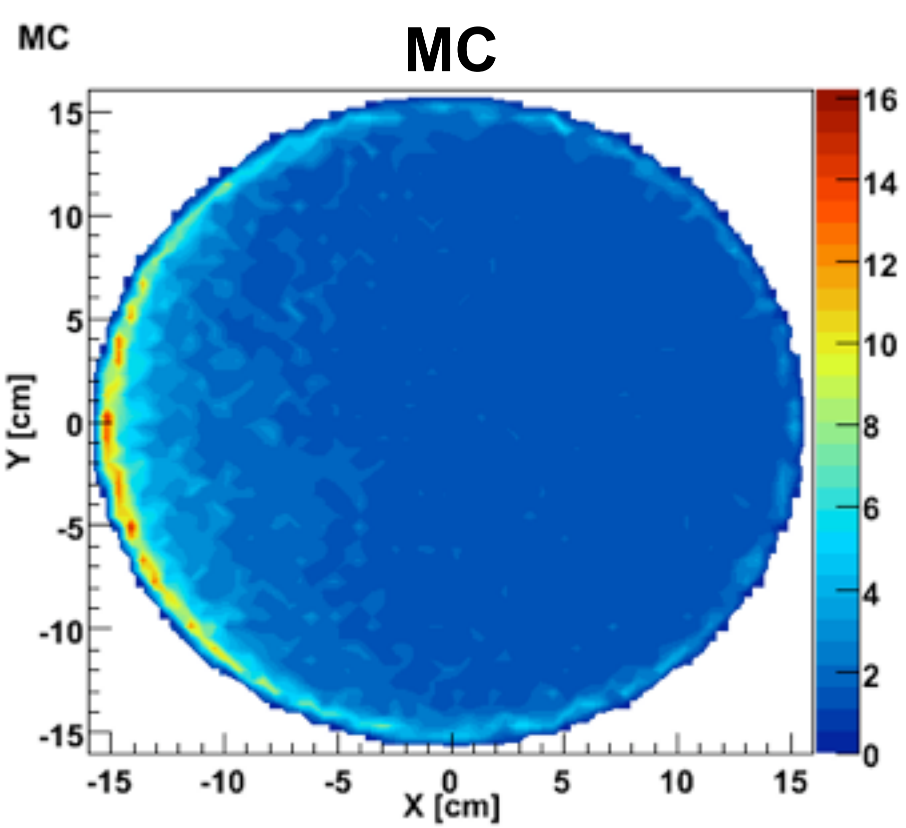
- **Relative LCE in the target volume:**

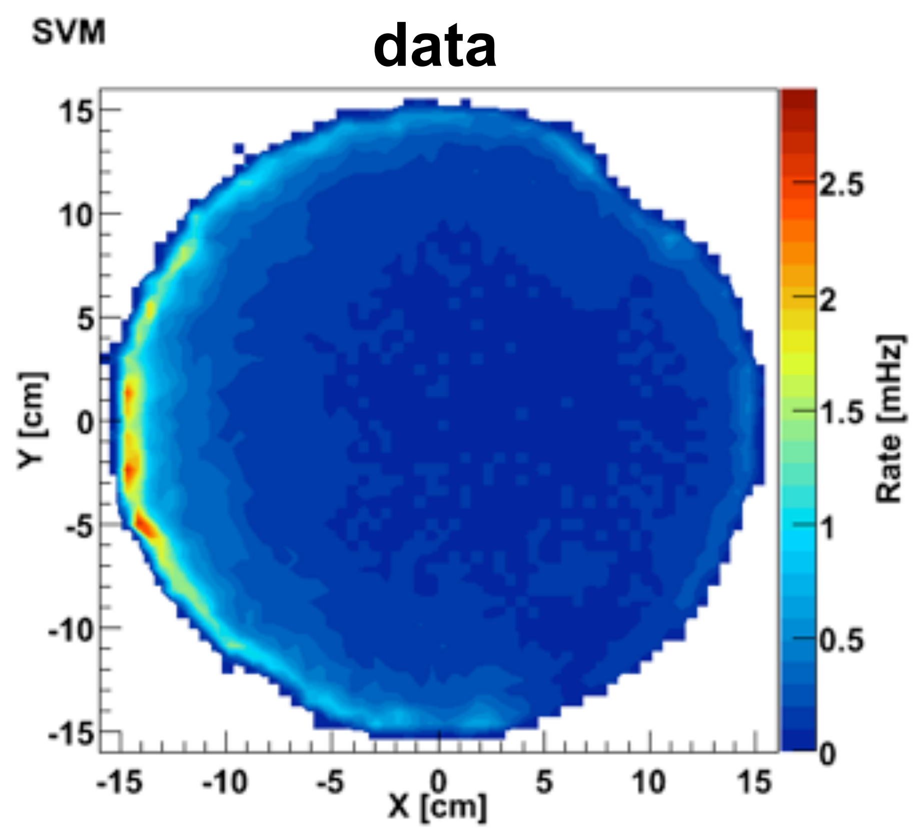


Position Reconstruction

- Z-position inferred by the delay time between the S1 and S2
- XY reconstruction algorithms with support vector machines, neural networks, and $\chi 2$ minimization, based on simulated light patterns



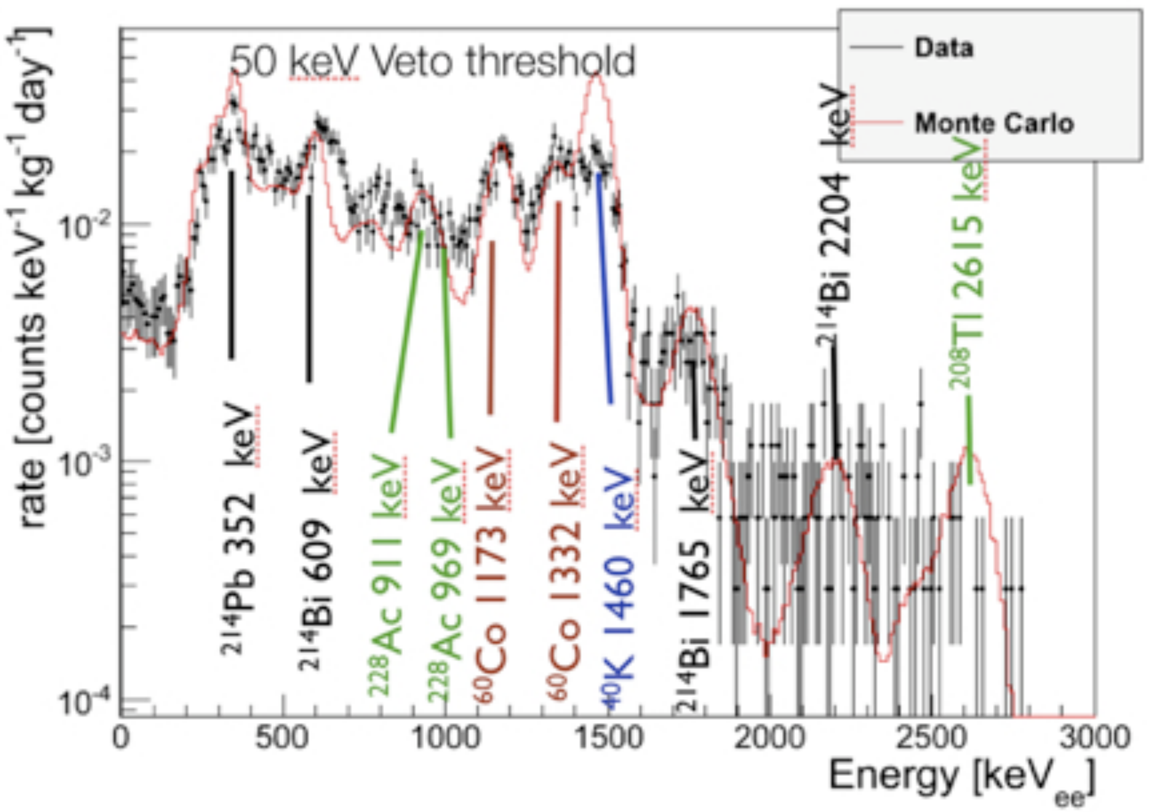




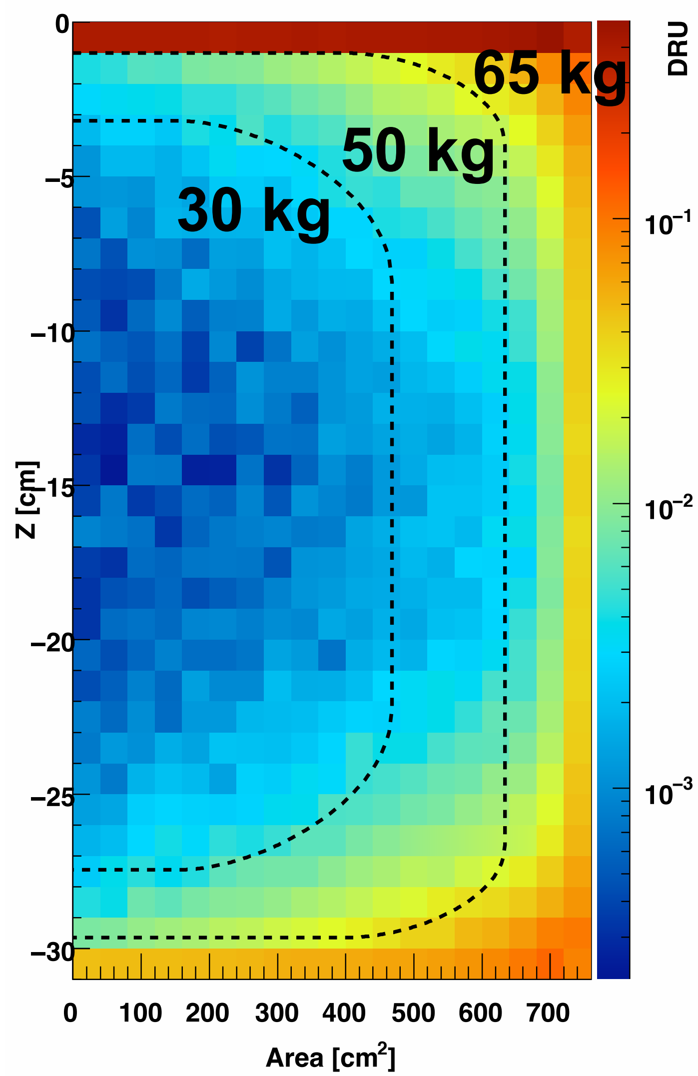
Background predictions

- All materials used for detector construction were screened with high purity Ge detectors
- Intrinsic contamination (^{238}U, ^{232}Th, ^{85}Kr) is measured with delayed coincidence analysis
- ^{222}Rn concentration in the shield is continuously monitored with RAD-7
- Obtained values are used as an input for the background model and MC simulations with GEANT4 of electron and nuclear background from various sources

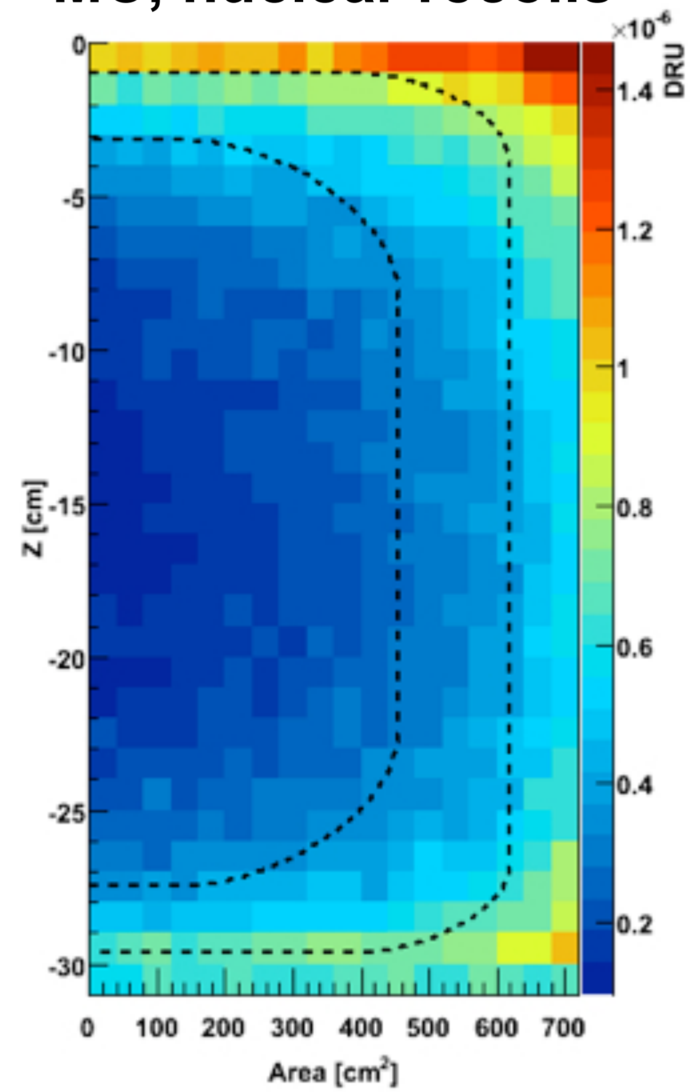
Data and MC are in good agreement



MC, electron recoils

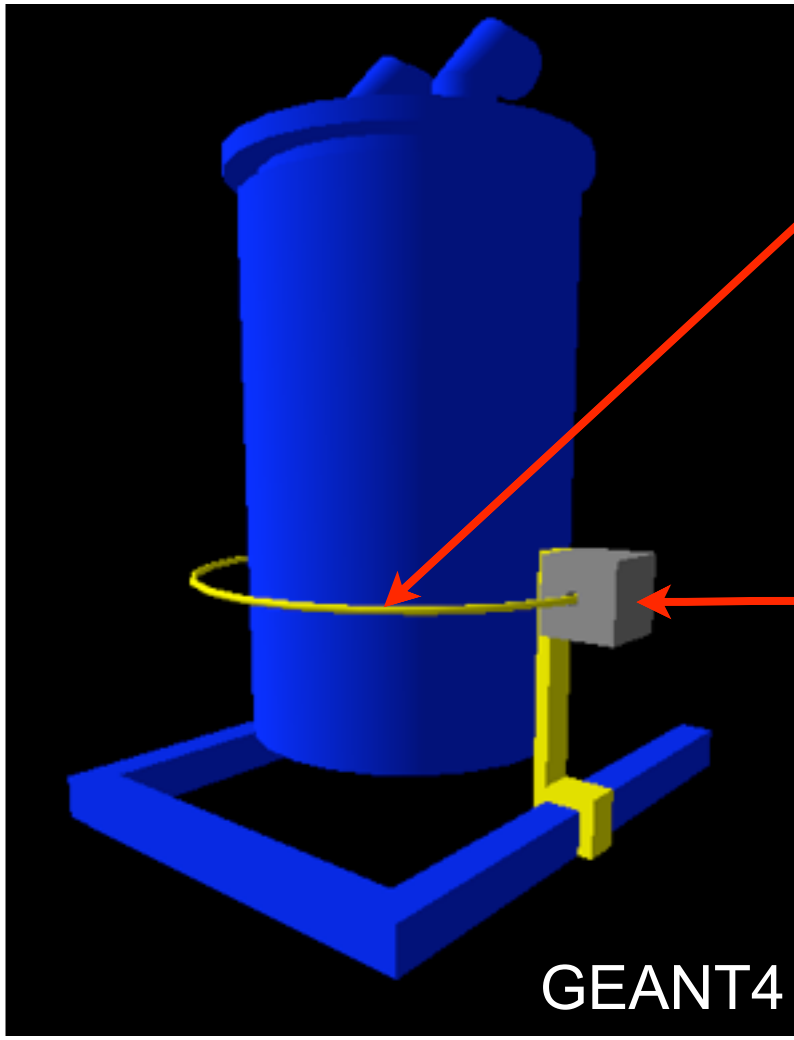


MC, nuclear recoils



Energy Calibration for the XENON-100 Detector

- Calibration with ^{137}Cs (662 keV), ^{57}Co (122 keV), ^{60}Co (1.17, 1.33 MeV), and Am-Be sources



Copper pipe around the cryostat for the source capsule

Lead brick for Am-Be calibration (to shield from 4.4MeV gammas)

- 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, 41 keV; 1.8 h) from ^{83}Rb decay

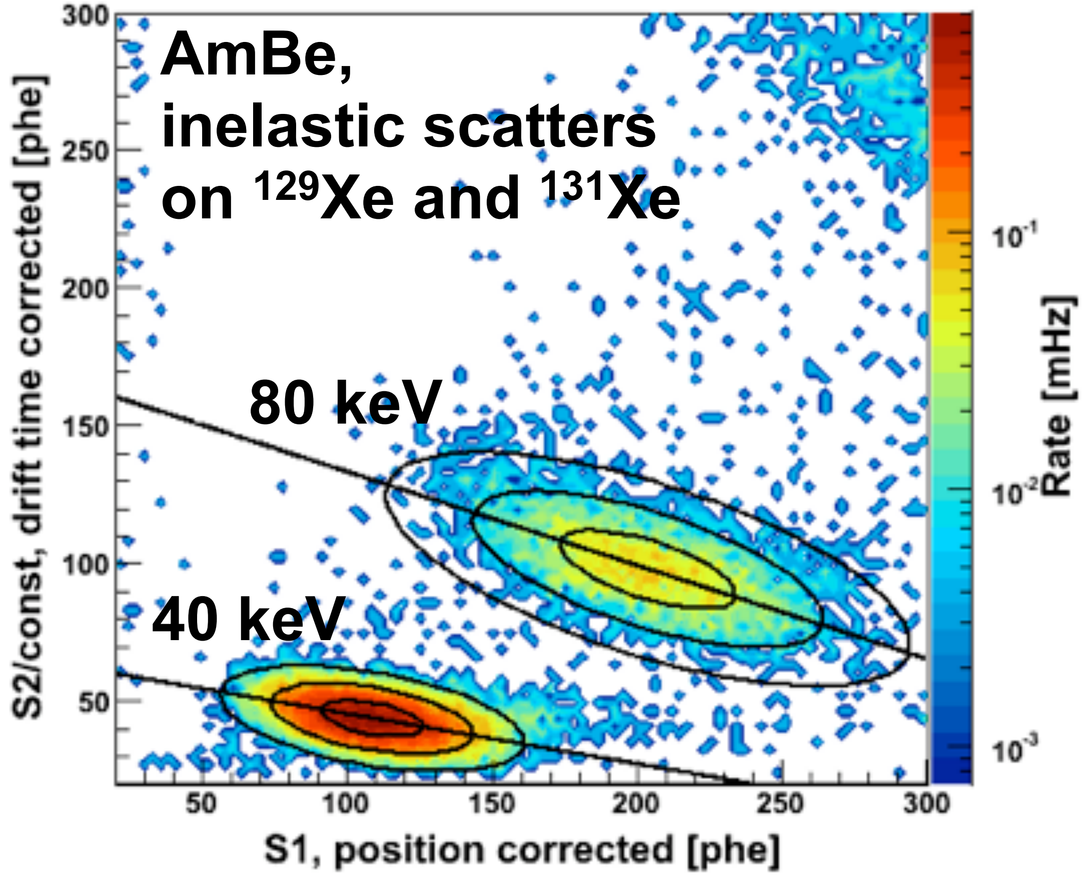
Spatially uniform calibration of a liquid xenon detector at low energies using ^{83m}Kr

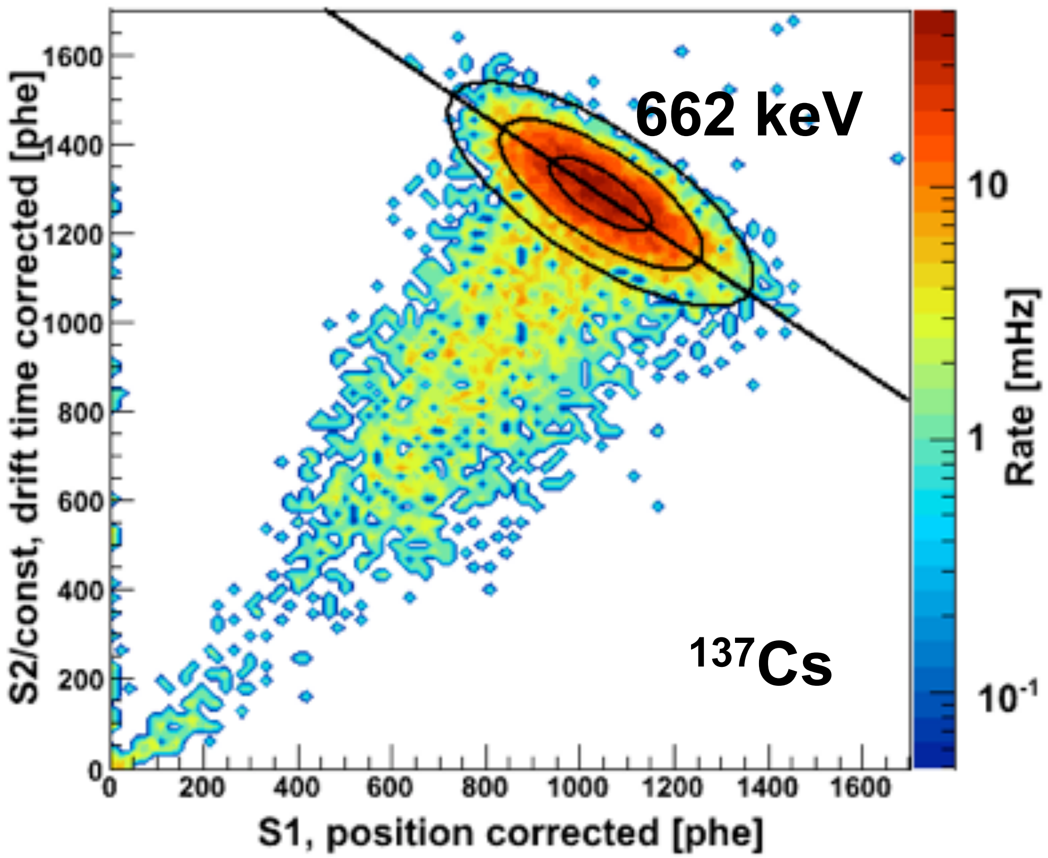
A. Manalaysay,[1,2,*] T. Marrodán Undagoitia,[1] A. Askin,[1] L. Baudis,[1] A. Behrens,[1] A. D. Ferella,[1] A. Kish,[1] O. Lebeda,[3] R. Santorelli,[1] D. Vénos,[3] and A. Vollhardt[1]

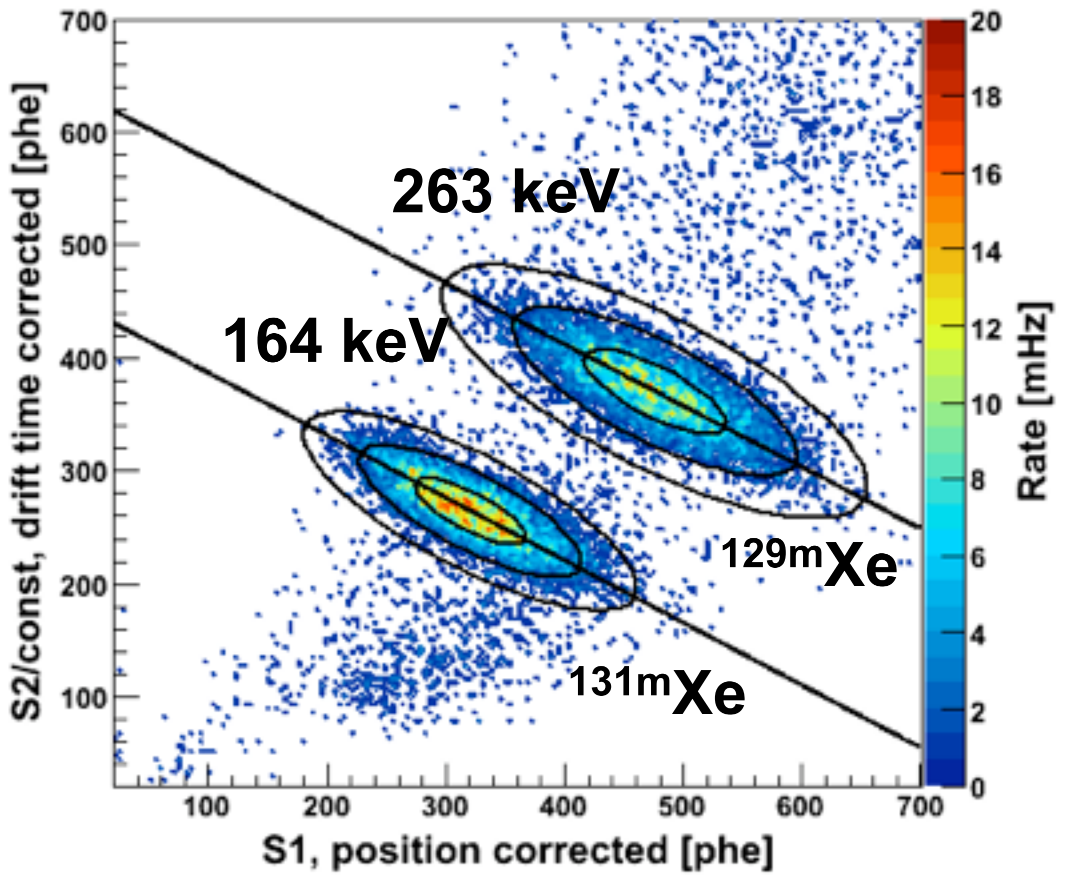
arXiv:0908.0616

Energy Calibration and Combined Energy Scale

- S1 and S2 signals are anti-correlated
- Distribution of S2 vs S1 can be fitted with an elliptical gaussian function
- Projection along the major axis of an ellipse gives field-independent combined energy scale

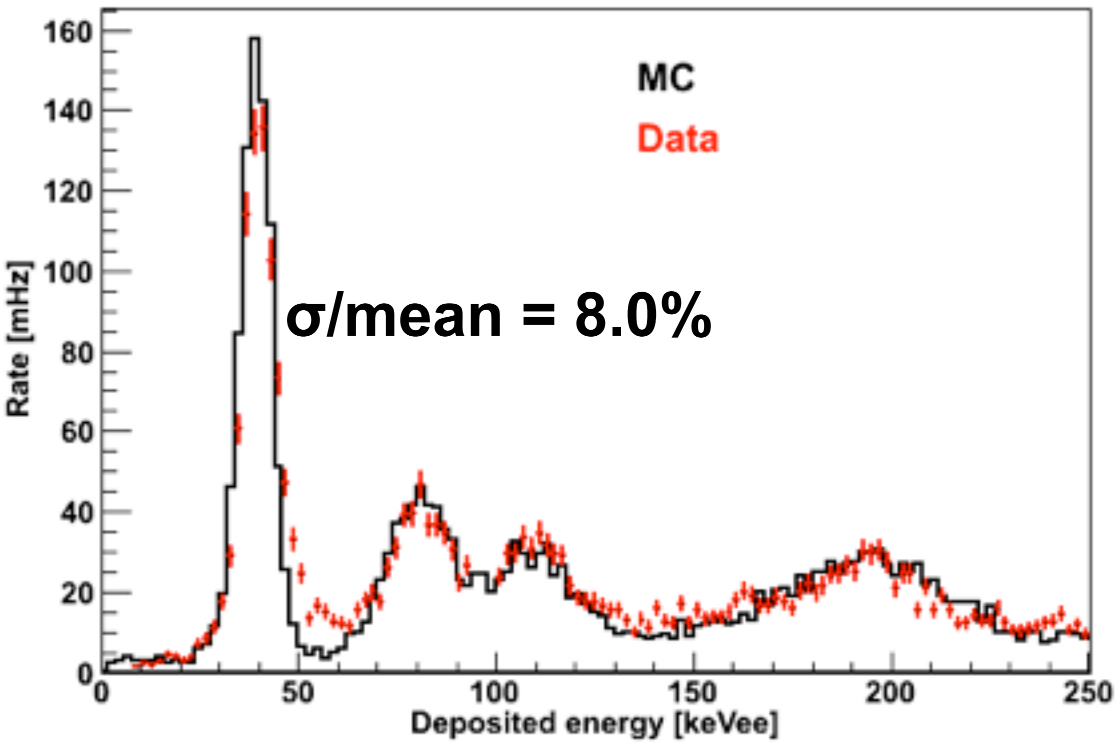




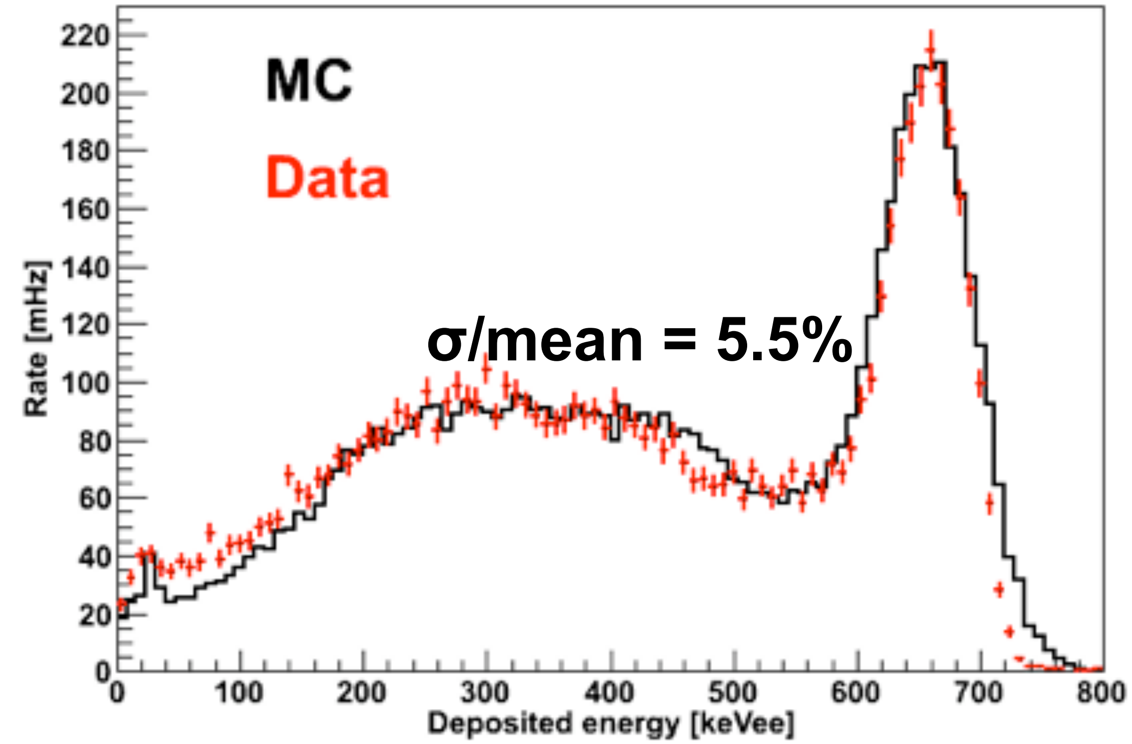


Energy Calibration and Combined Energy Scale

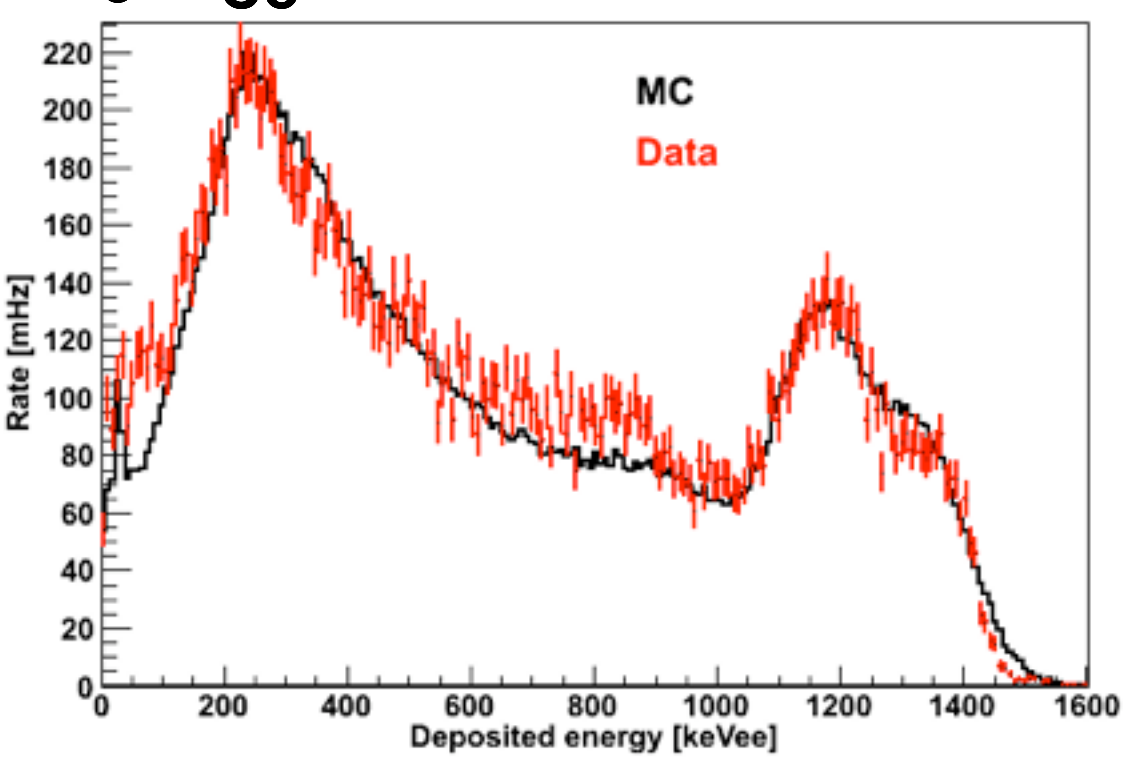
- **Am-Be**



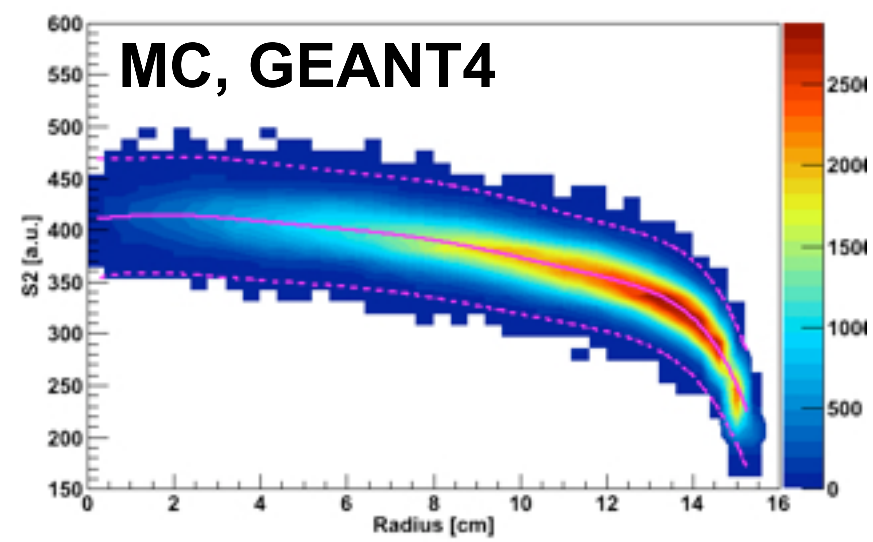
- **^{137}Cs**



- **^{60}Co**



Resolution can be improved with radial correction of ionization signal (S2 light collection is not uniform)

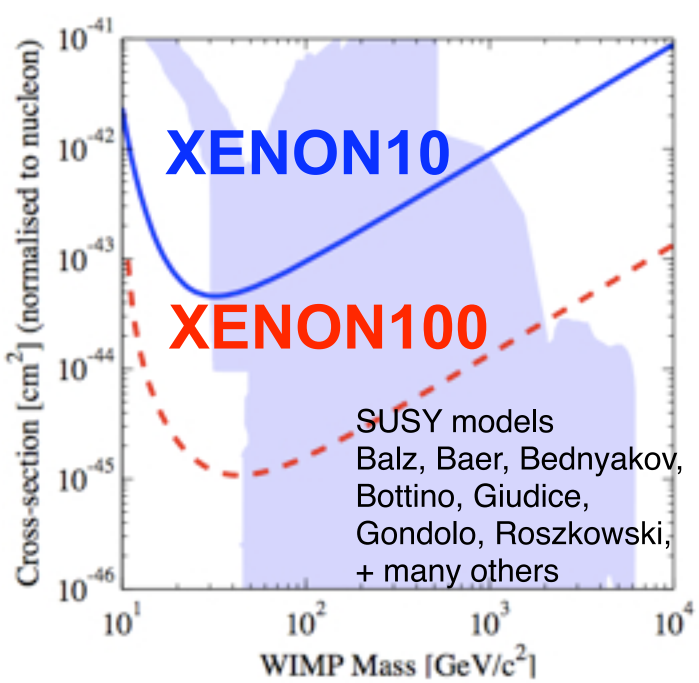


Summary

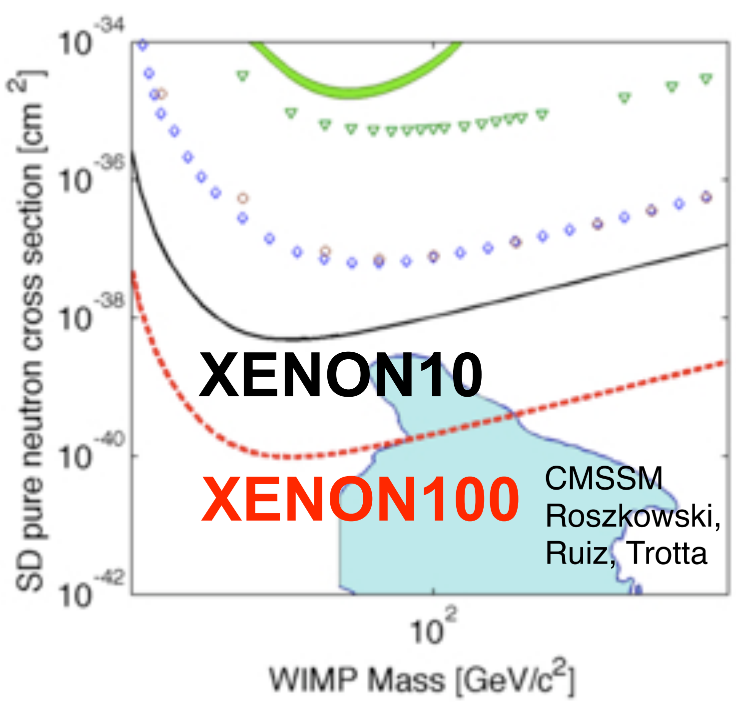
- The detector is operating underground
- Electron lifetime is enough to drift charge through the whole TPC
- Gamma band calibration data with ^{60}Co source
- Neutron calibration with Am-Be source was done in December
- Energy calibration in the range 40keV-1MeV, good agreement with MC
- BG model developed within GEANT4 reproduces the data

- Projected 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



Spin-independent coupling



Spin-dependent (pure n-coupling)