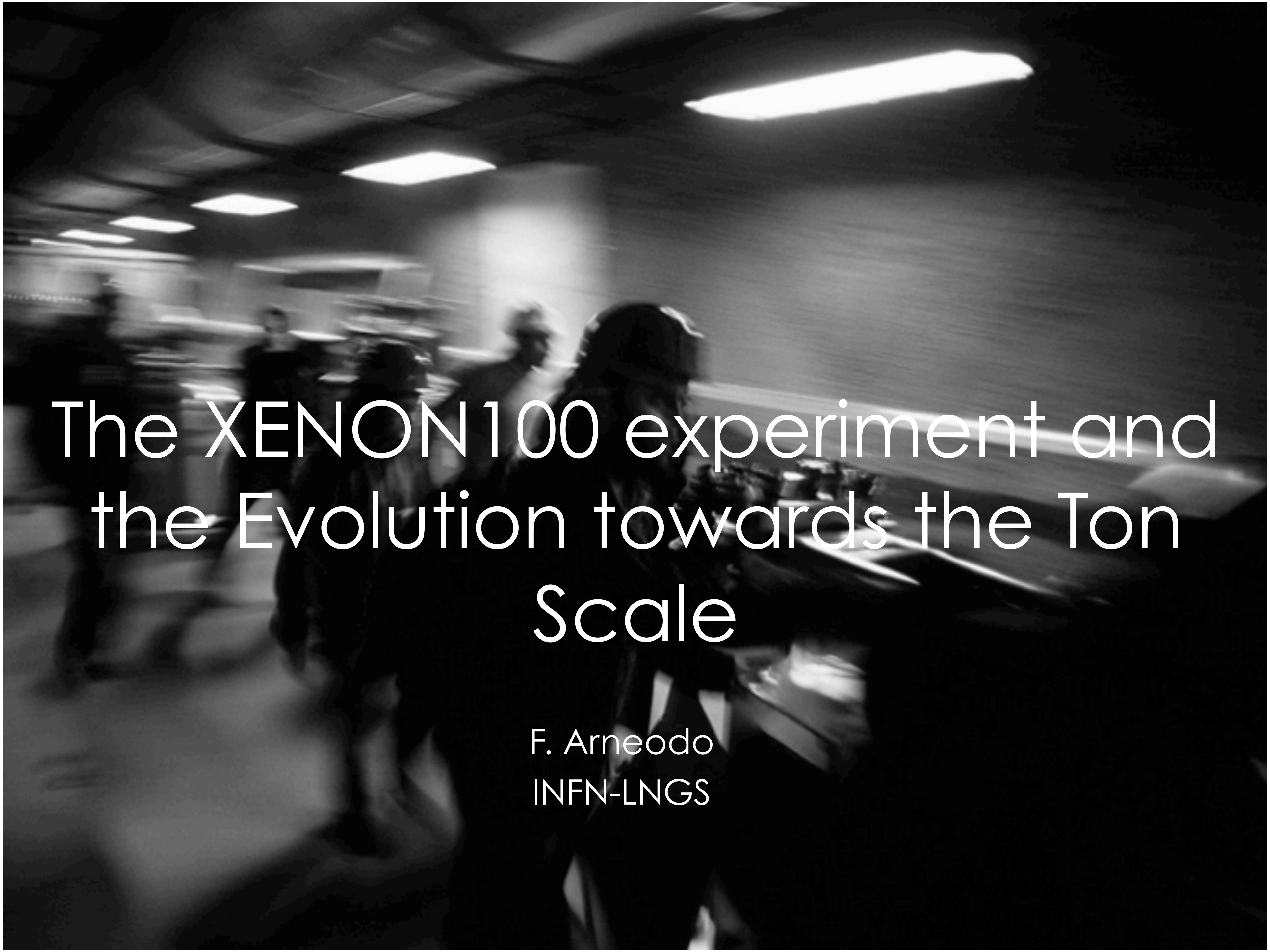


The XENON100 experiment and the Evolution towards the Ton Scale

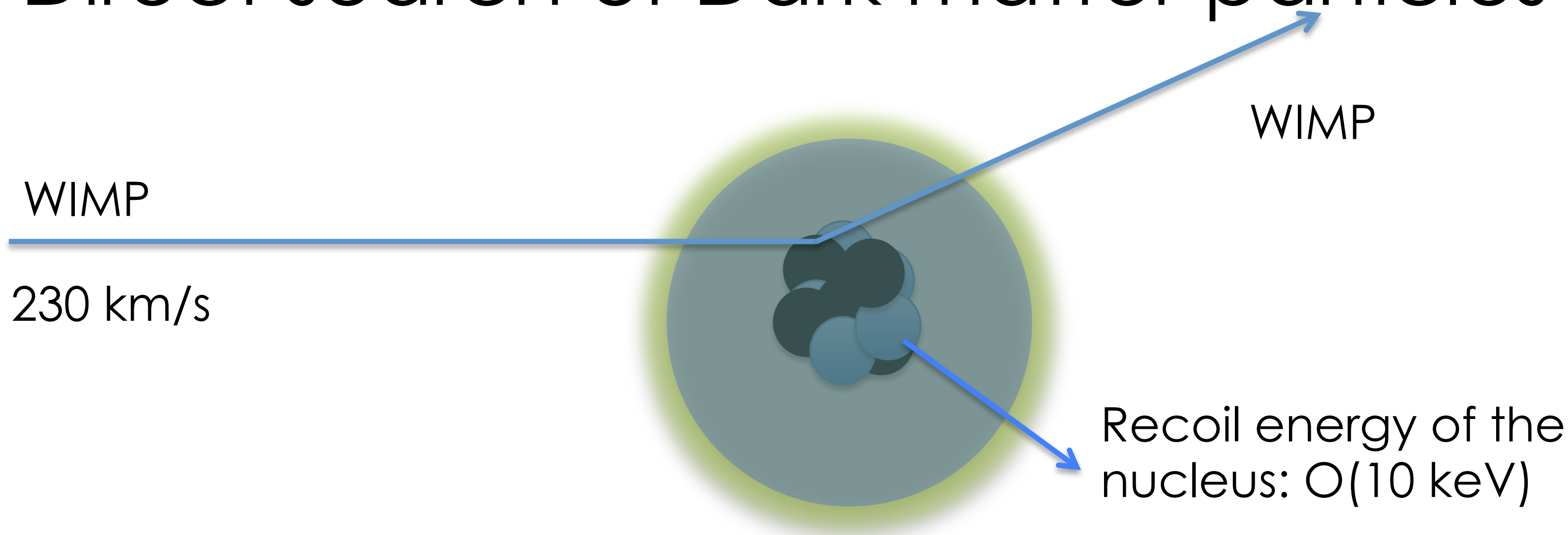
F. Arneodo
INFN-LNGS

Outline

- Dark Matter direct search
- The double phase LXe TPC
- The XENON100 experiment
- The XENON1T detector: status of the project

Sorry but….no new data for the next couple of weeks!

Direct search of Dark matter particles

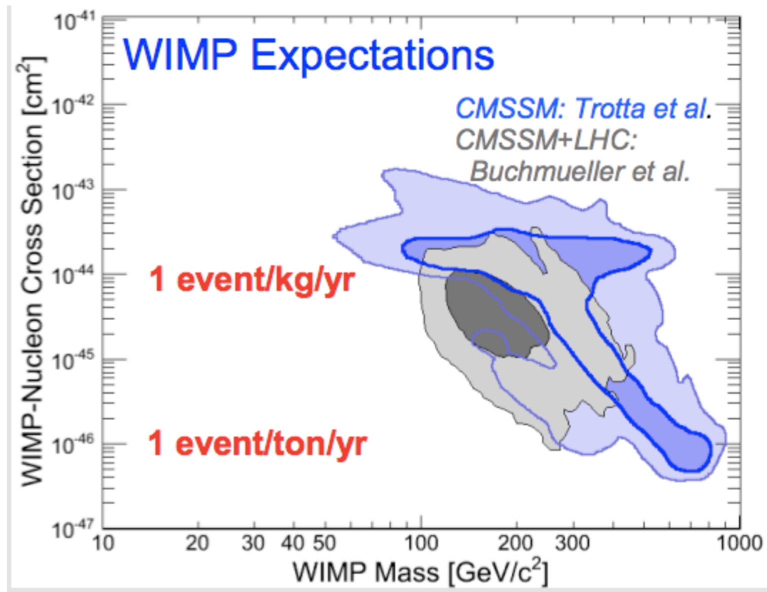


- 'scalar' coupling $\propto A^2$
- 'vector coupling' $\propto J(J+1)$

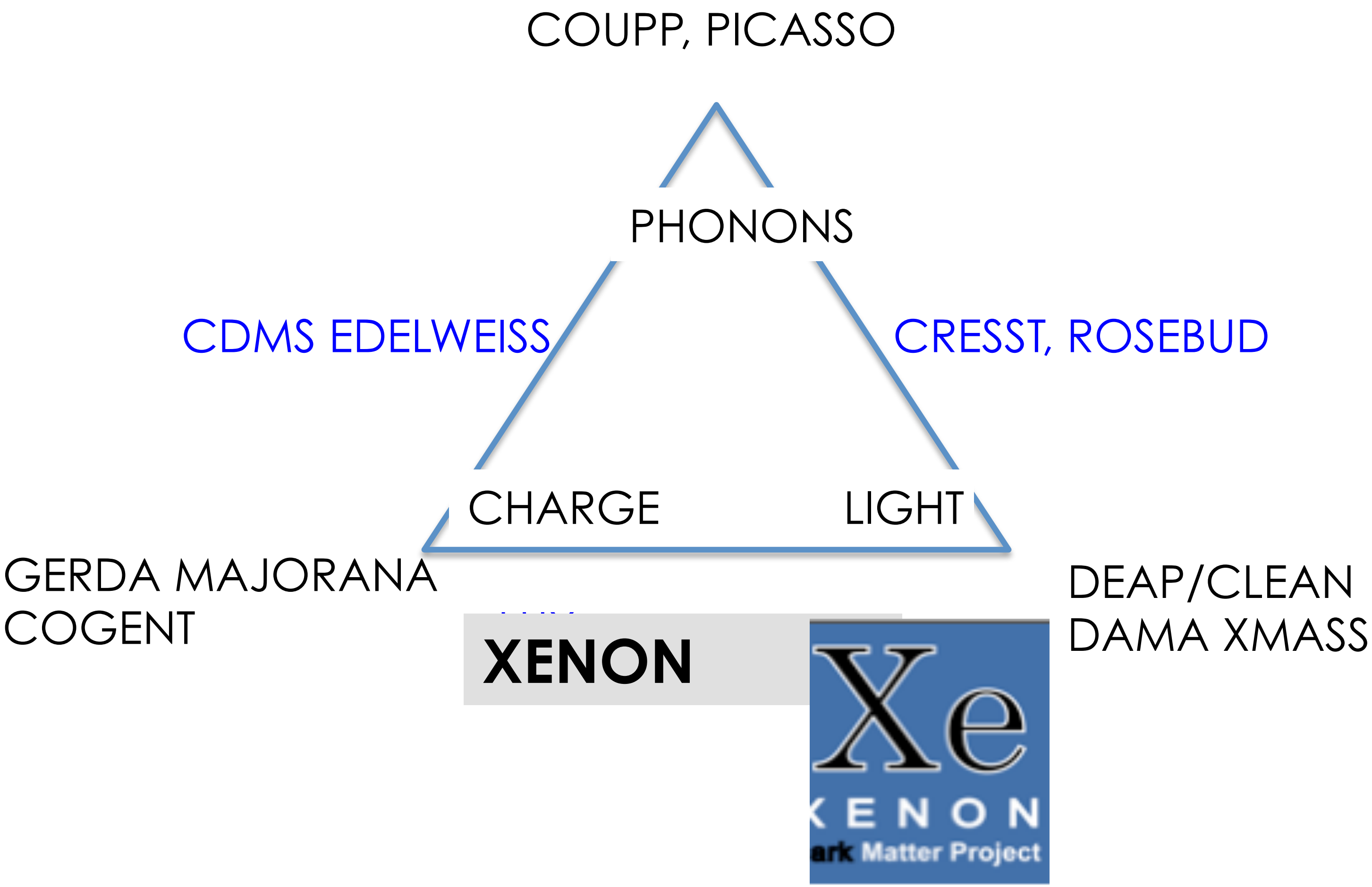
Expected event rate

$$\approx 0.01 evt/kg/day$$

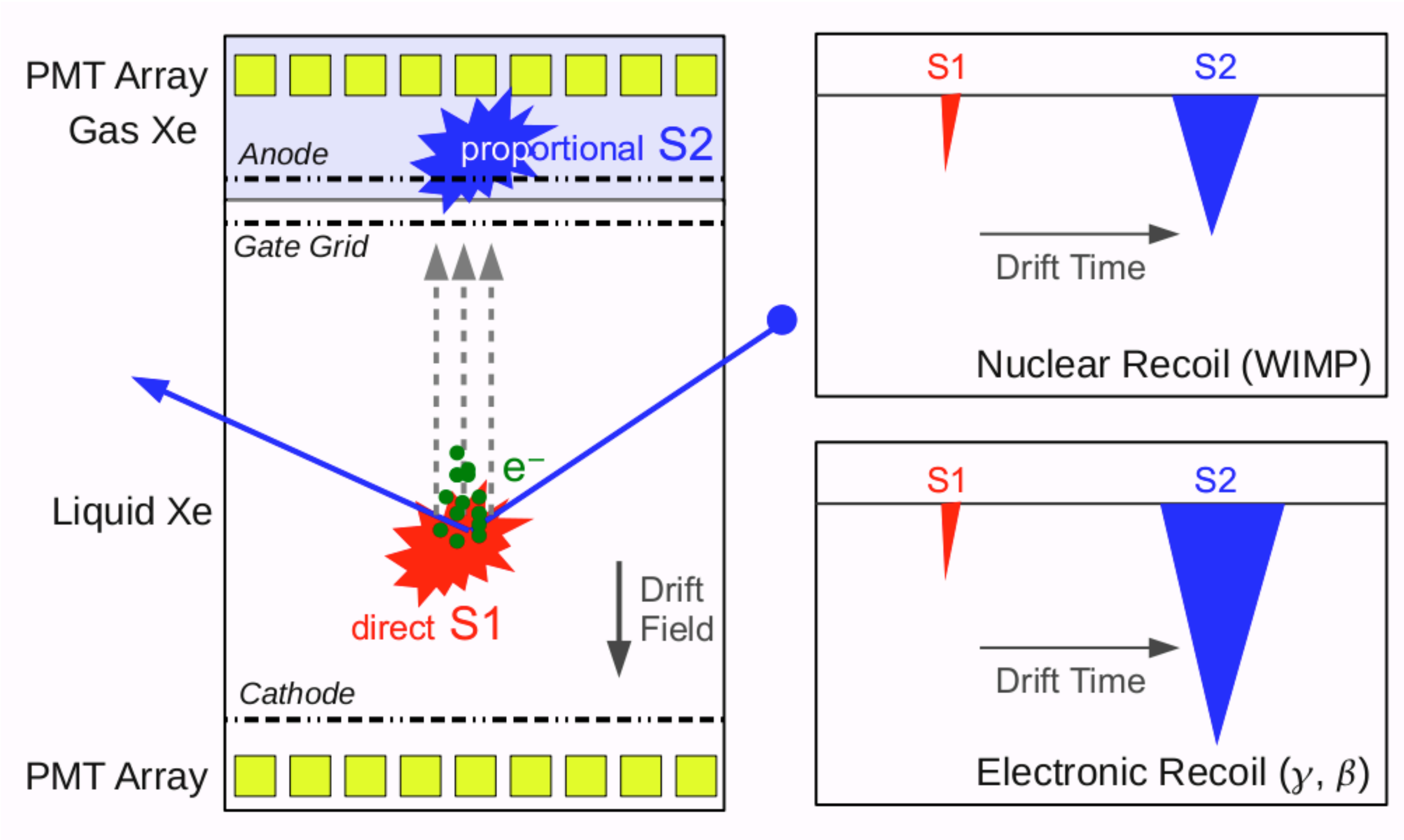
Expected energy release O (10-100kev)



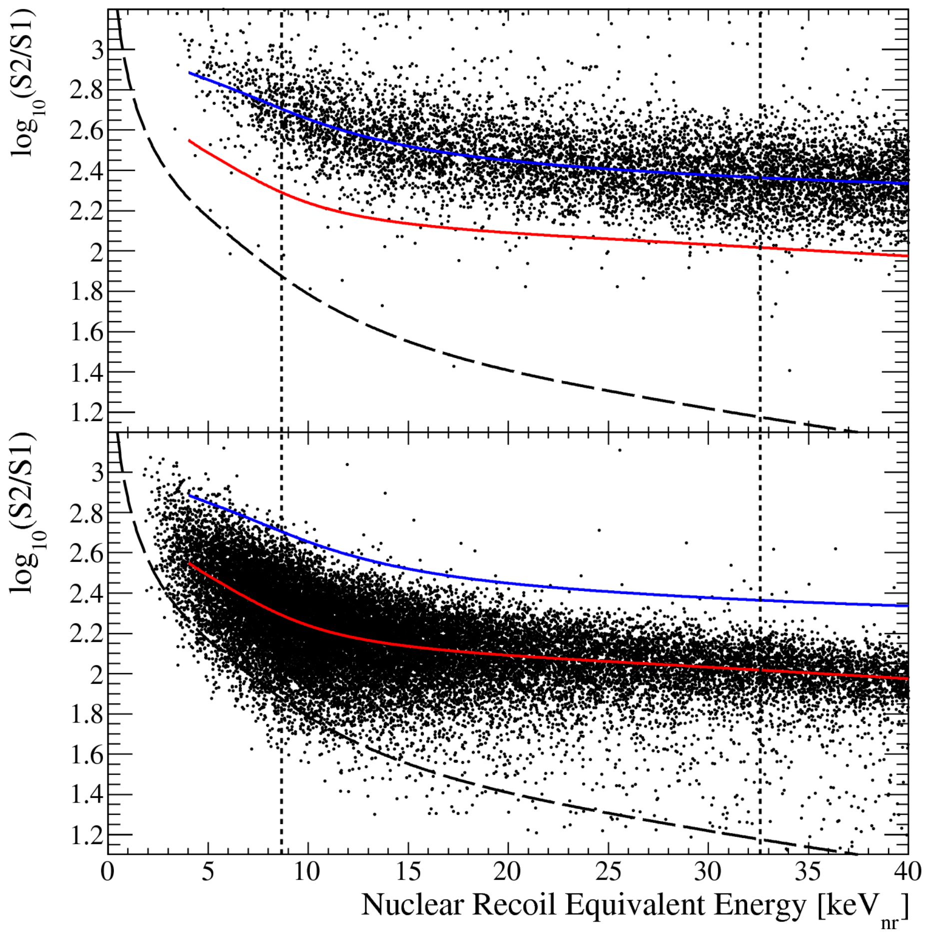
Better two signals than one



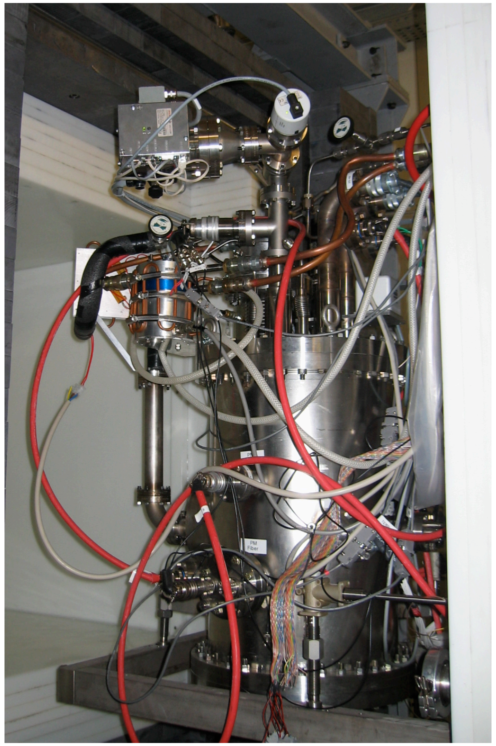
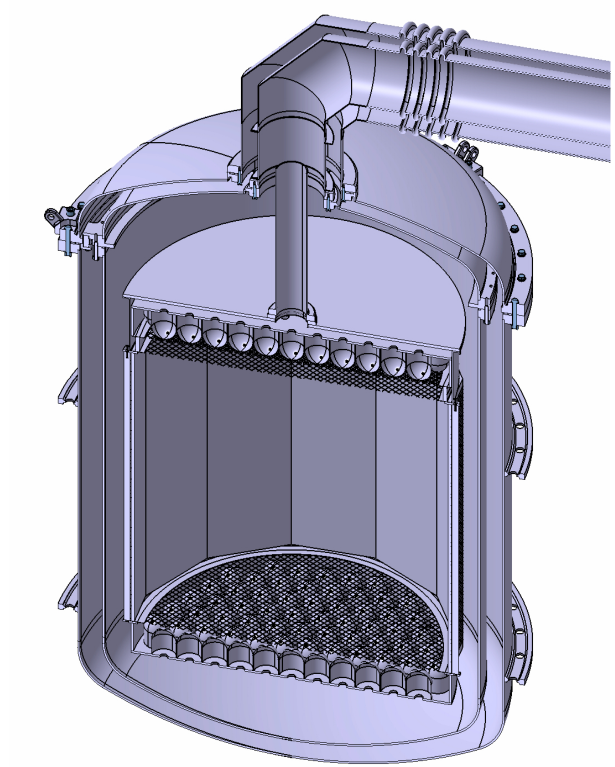
The double phase TPC approach

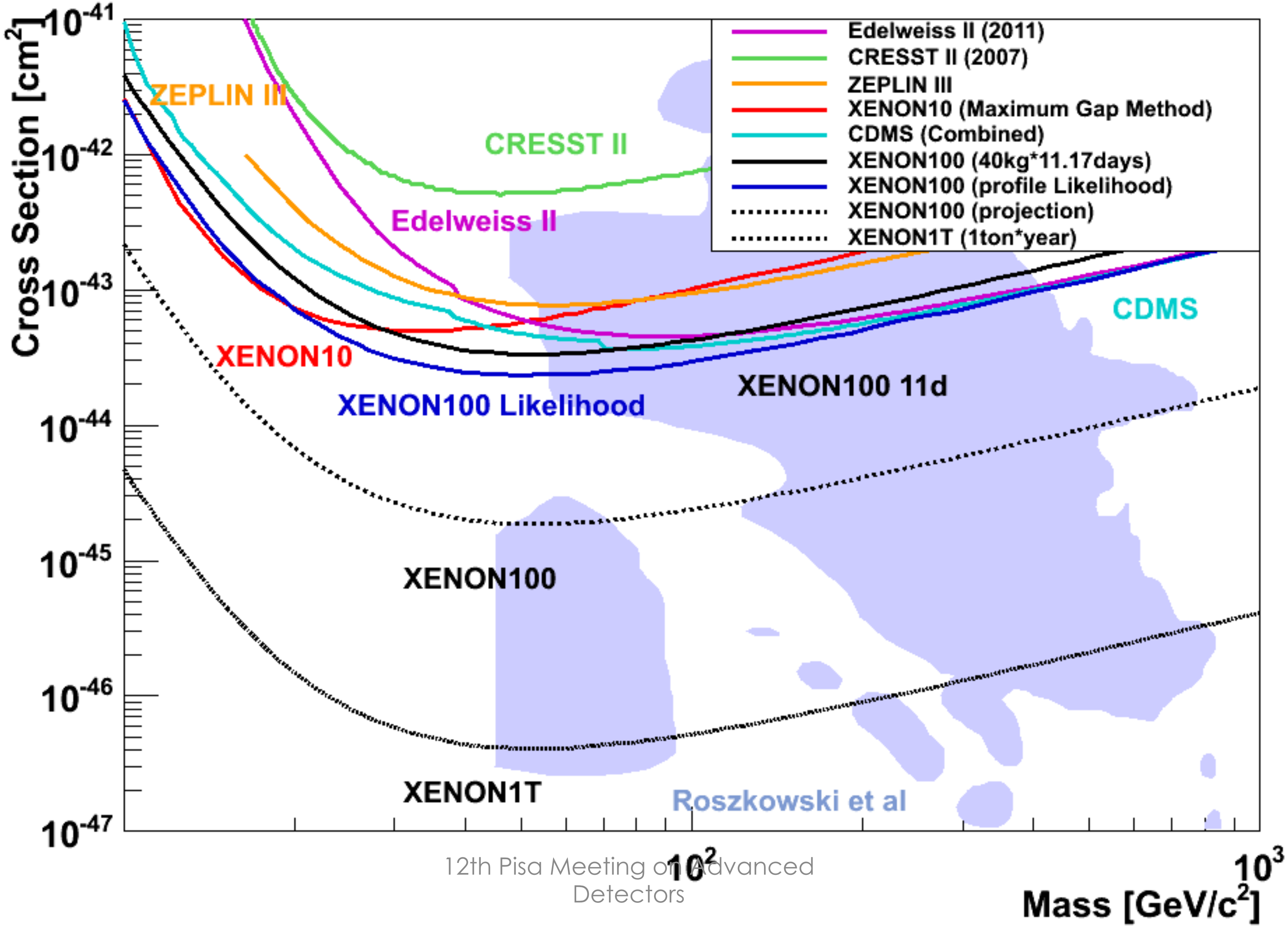


The power of discrimination

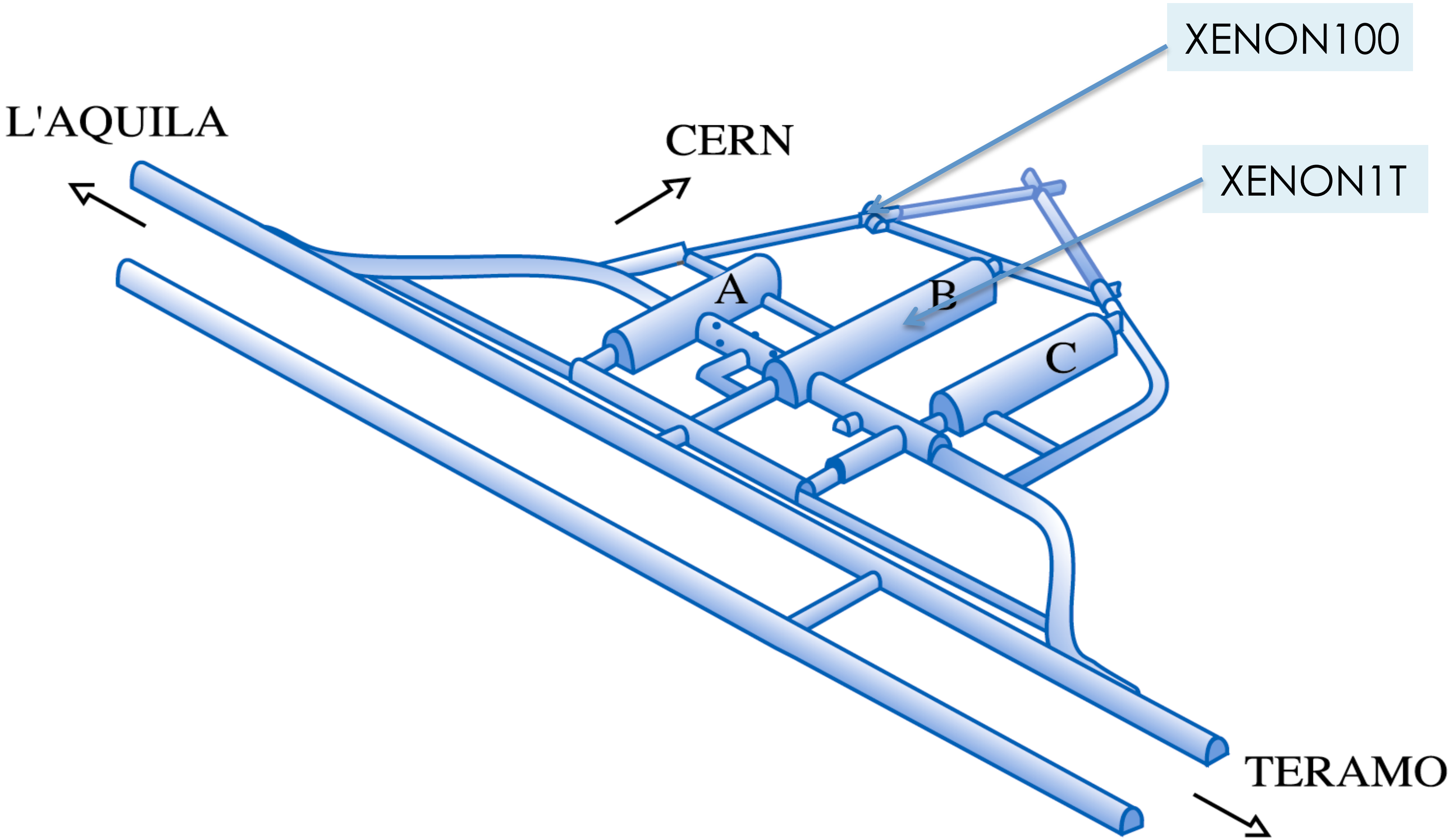


The XENON Dark Matter Program

past (2005 - 2007)	current (2008-2011)	future (2011-2015)
		
XENON10	**XENON100**	**XENON1T**
Achieved (2007) σ_{SI}*=8.8 x10*$^{-44}$ *cm*^{2}	*Achieved (2010)* σ_{SI}*=2.4 x10*$^{-44}$ *cm*^{2} *Projected (2011)* σ_{SI}~2x10^{-45} cm^2	*Projected (2015)* σ_{SI} ~10^{-47} cm^2

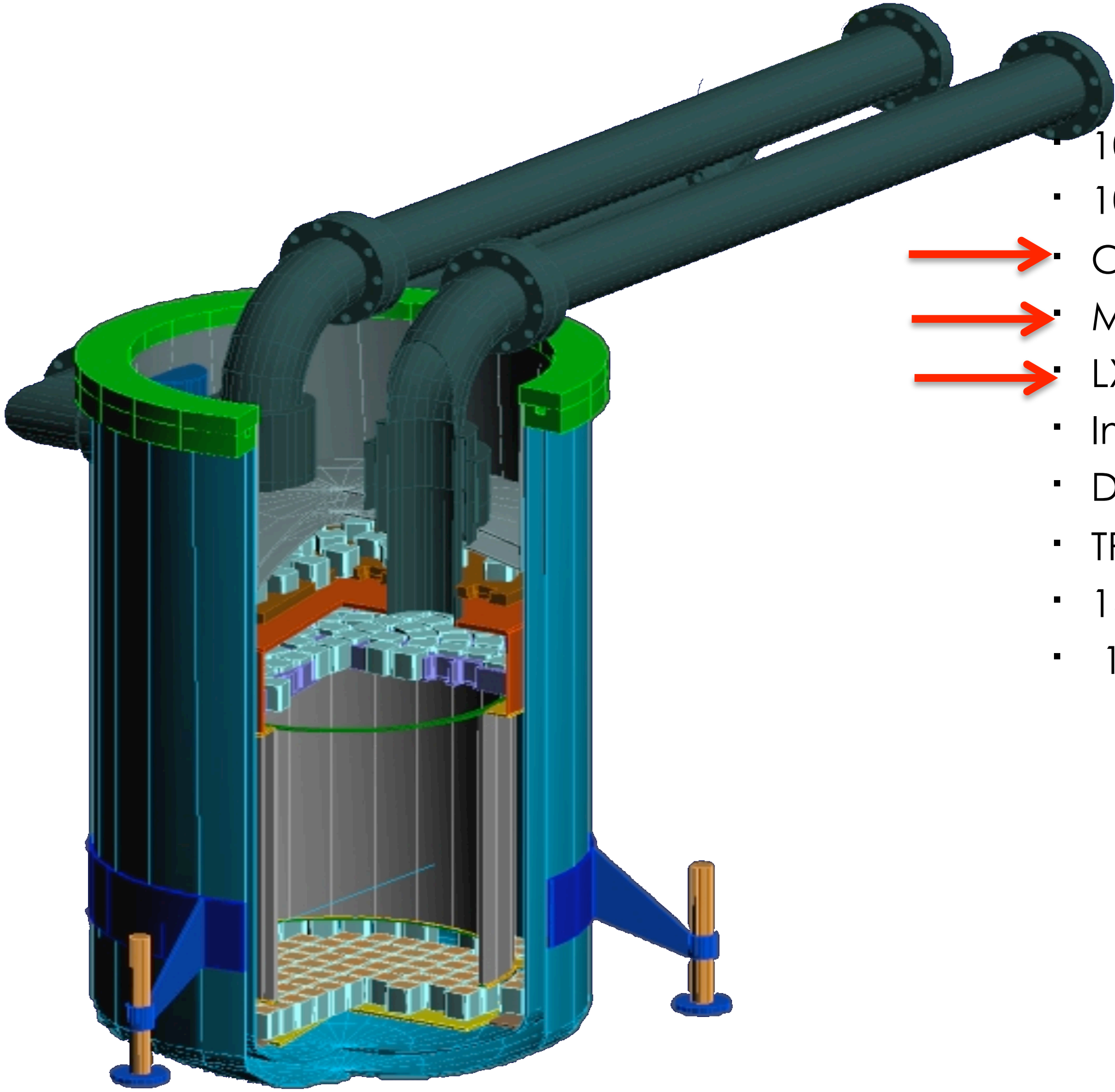

Cross Section [cm^2]
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^2
10^3
Mass [GeV/c^2]
Edelweiss II (2011)
CRESST II (2007)
ZEPLIN III
XENON10 (Maximum Gap Method)
CDMS (Combined)
XENON100 (40kg*11.17days)
XENON100 (profile Likelihood)
XENON100 (projection)
XENON1T (1ton*year)
ZEPLIN III
CRESST II
Edelweiss II
XENON10
XENON100 Likelihood
XENON100 11d
CDMS
XENON100
XENON1T
Roszkowski et al

I Laboratori del Gran Sasso



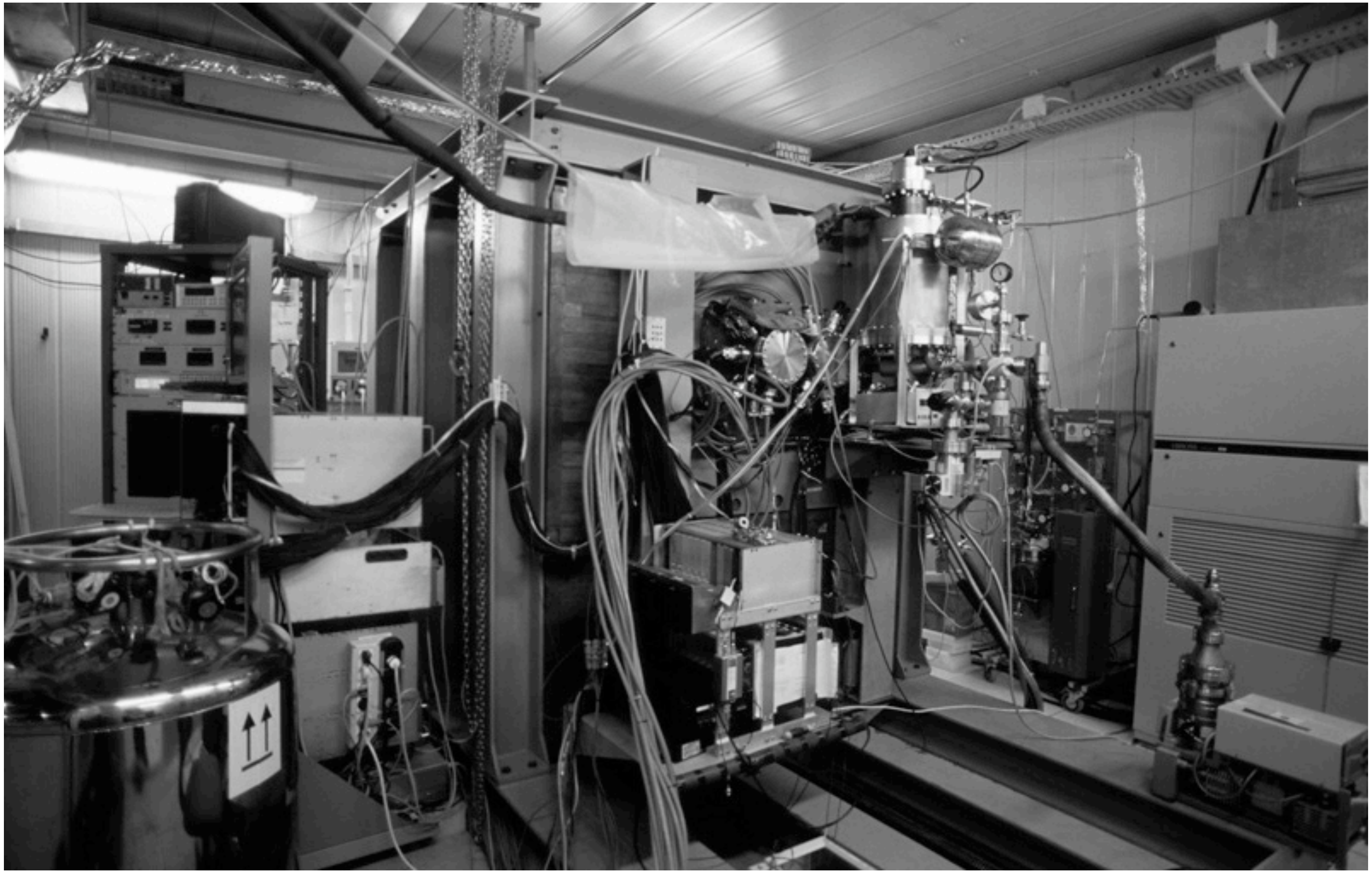
The XENON Collaboration

The XENON100 Detector



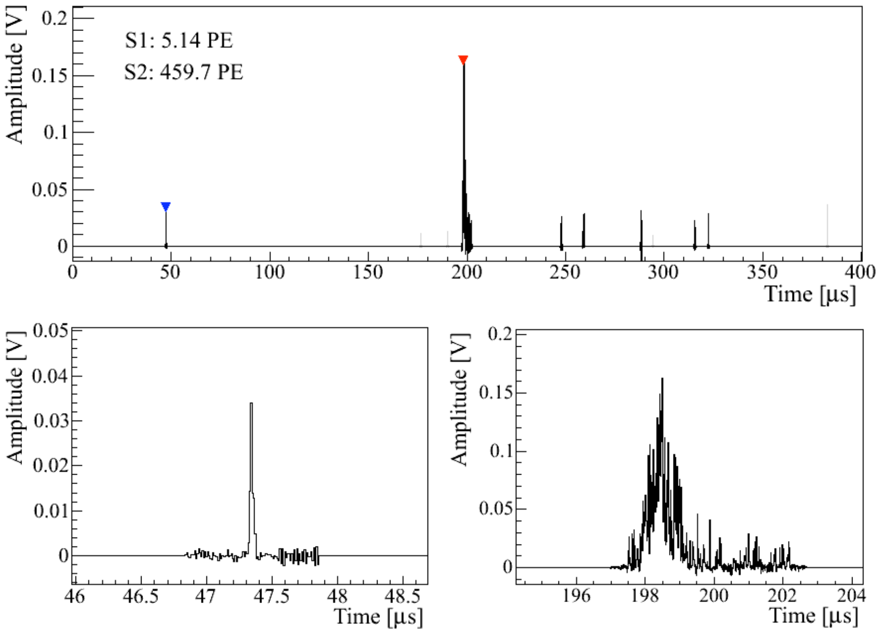
- 100 x less background than XENON10
- 10 x more fiducial mass than XENON10
- Cryocooler and FTs outside shield
- Materials screened for low radioactivity
- LXe scintillator active veto system
- Improved passive shield system
- Dedicated Kr Distillation Column
- TPC with 30 cm drift x 30 cm diameter
- 162 kg ultra pure LXe - 62 kg as target
- 1” square PMTs with ~1 mBq (U/Th)
    - R8520-06-Al 1
    - 98 PMTs in the gas phase
    - 80 in the liquid, below the cathode
    - 64 in the veto

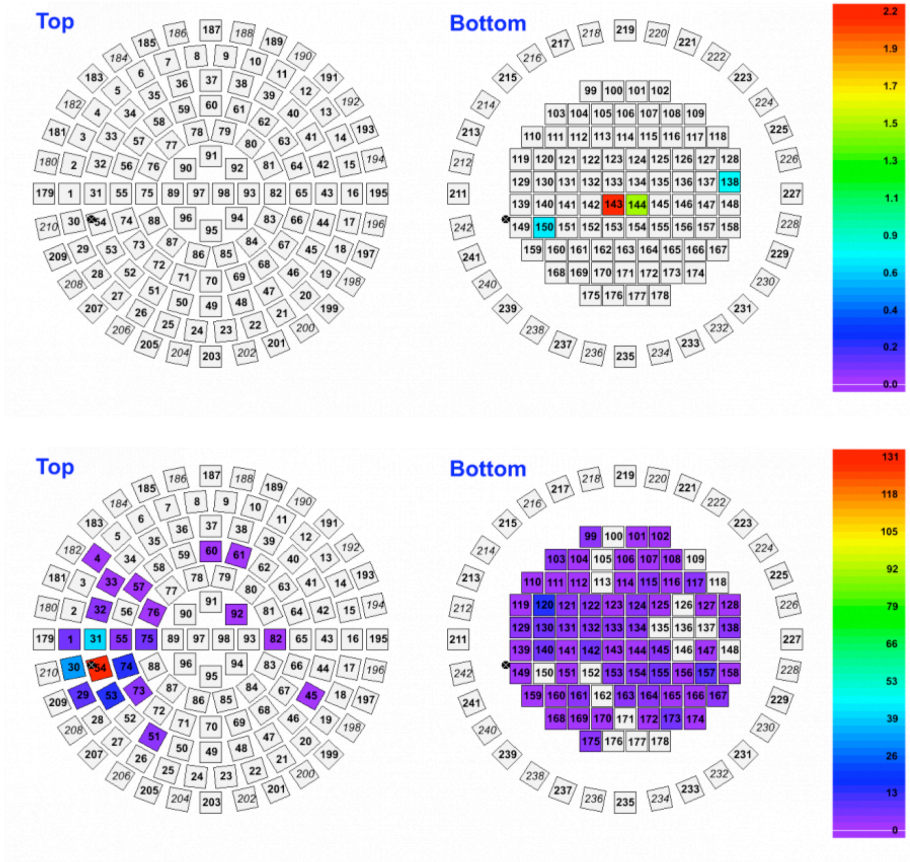
XENON100 @LNGS



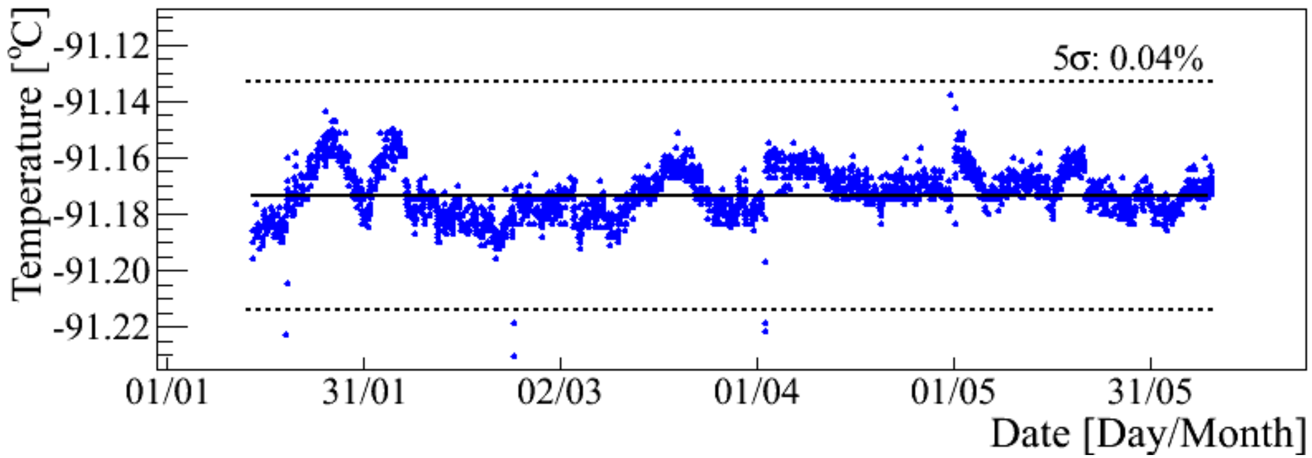
F. Arneodo, XCVII Congresso SIF,
L'Aquila, 27 Settembre 2011

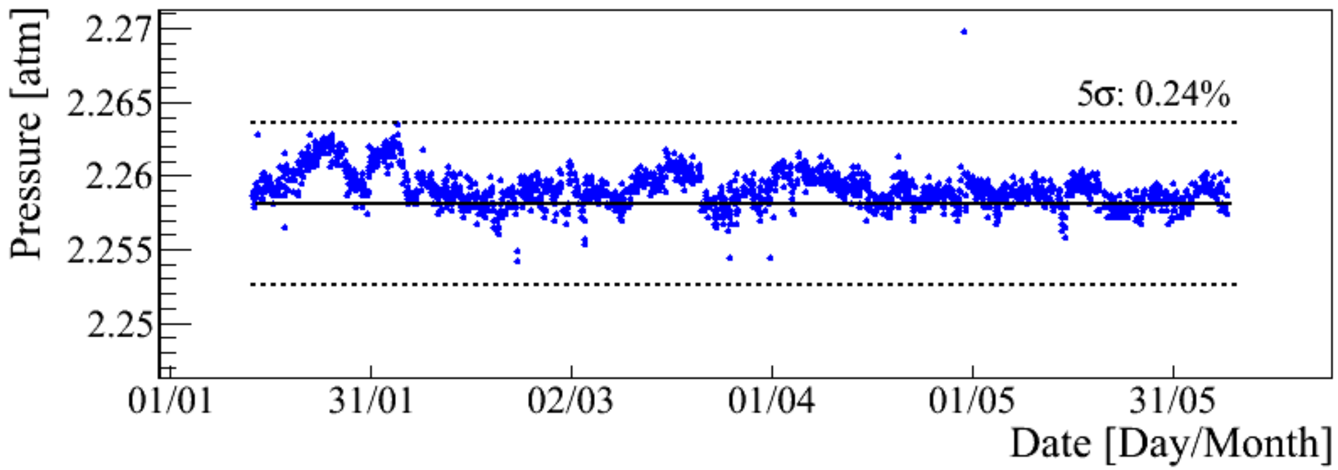
Typical low energy event



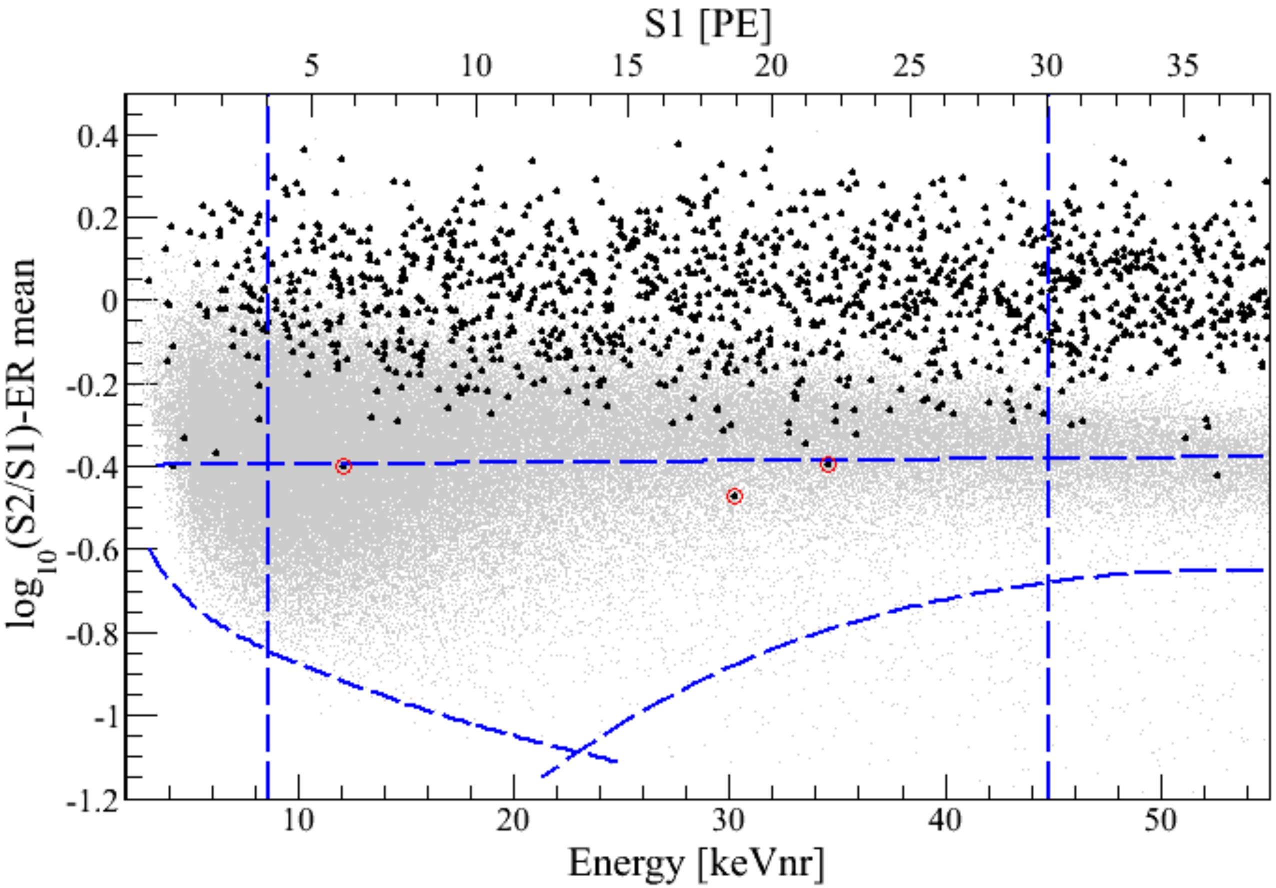


Detector stability



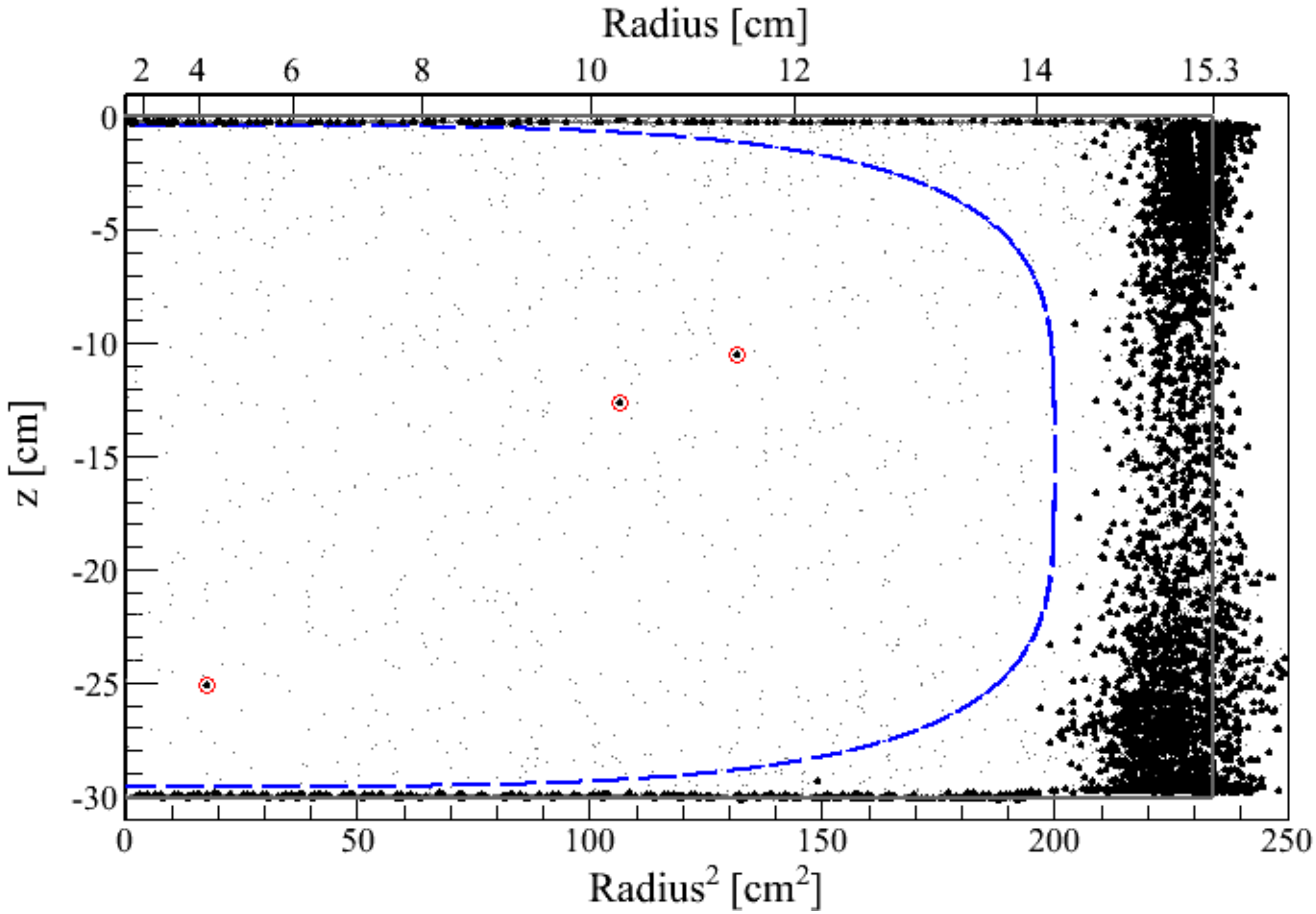


The unblinding of 100 days of data

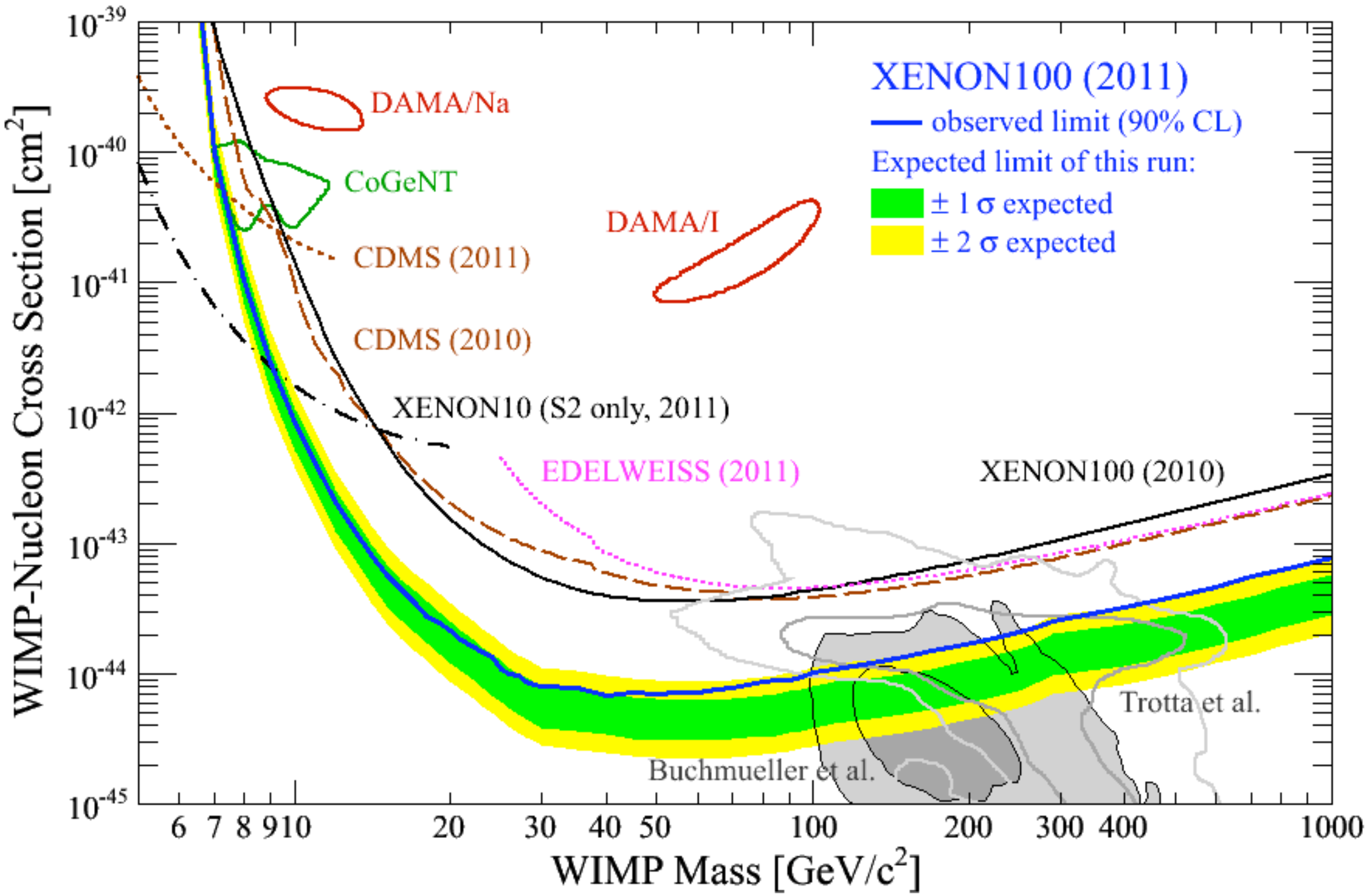


Aprile et al. Dark Matter Results from 100 Live Days of XENON100 Data. Physical review letters (2011) vol. 107 (13) pp. 131302

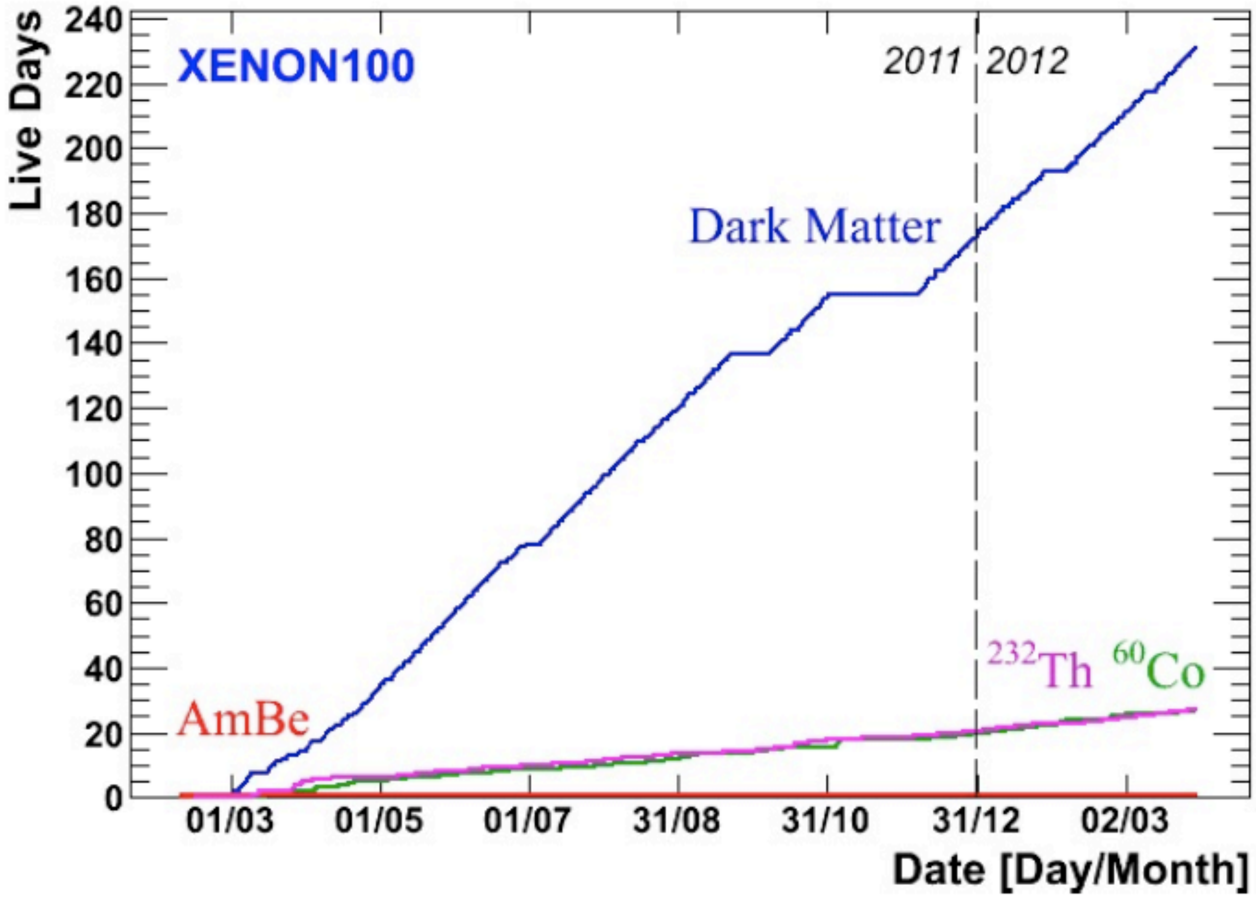
Why a self shielding TPC



Current limit

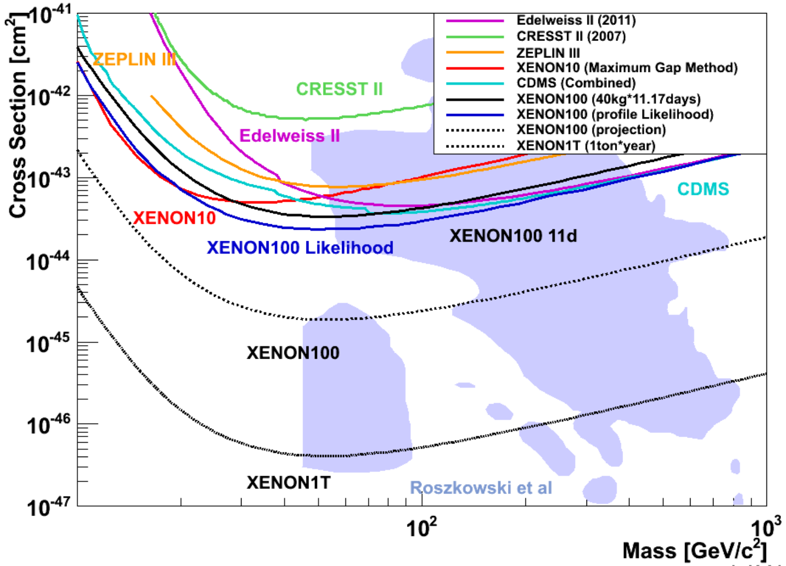


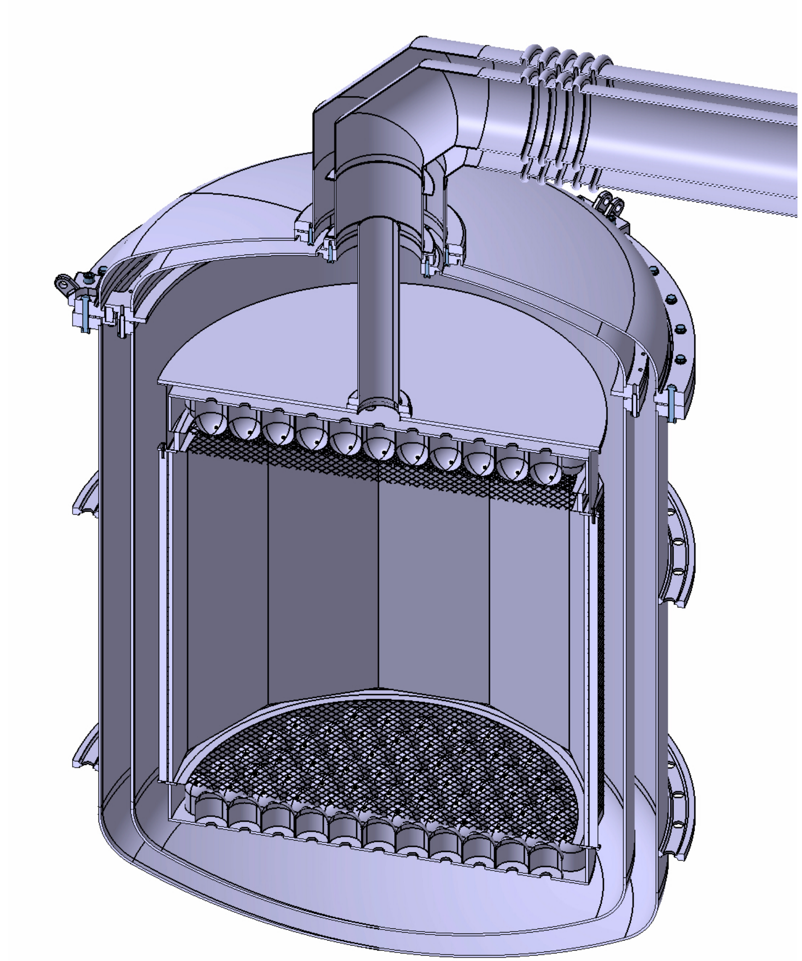
Integrated 2011/2012 livetime



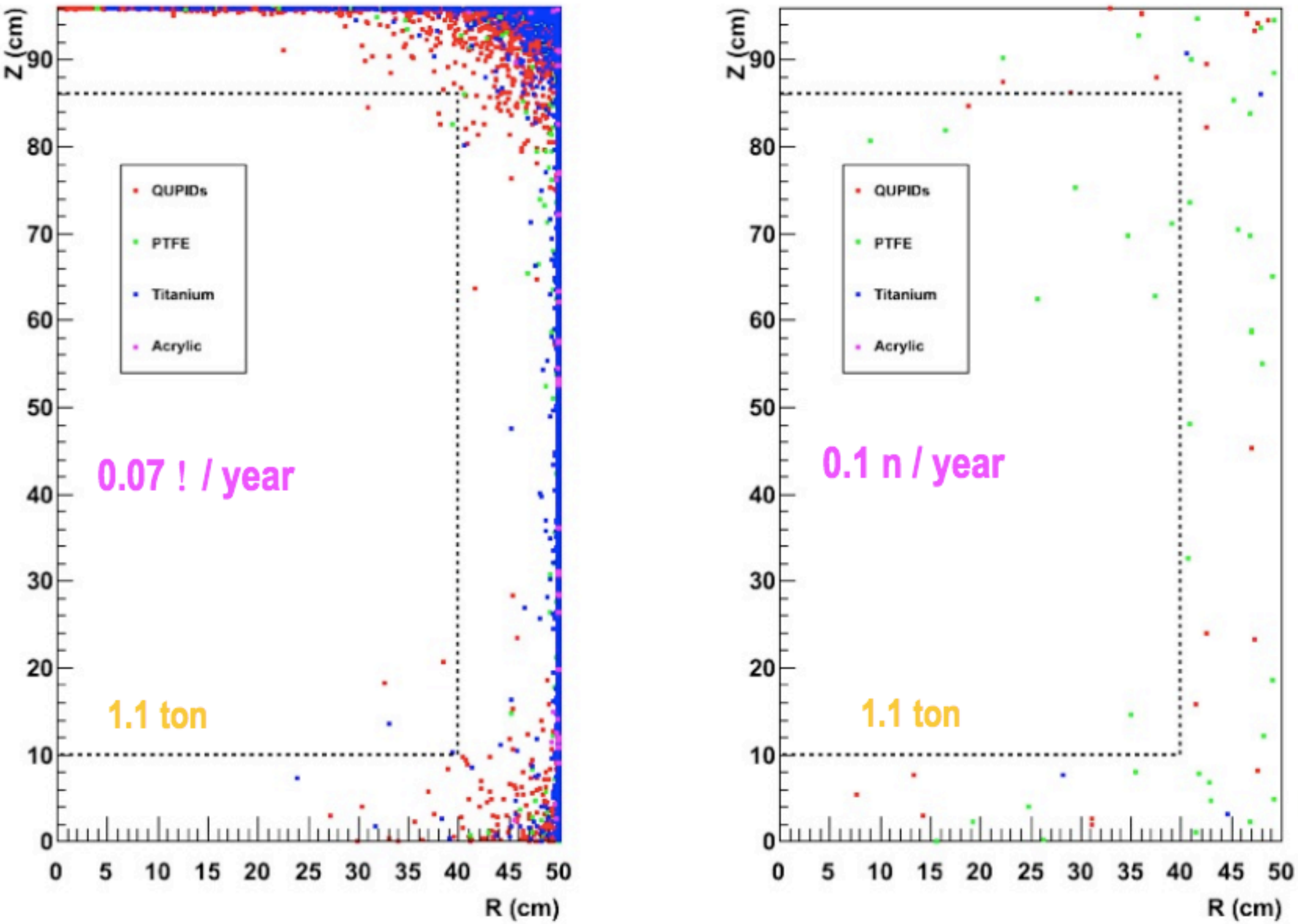
Scaling towards larger masses

- Larger target masses are needed to explore the WIMP allowed region
- 2.5 t of liquid xenon are possible with the same technology
- Backgrounds must be totally under control (especially neutrons)
- Neutron rate in fiducial volume must be < 1evt/year

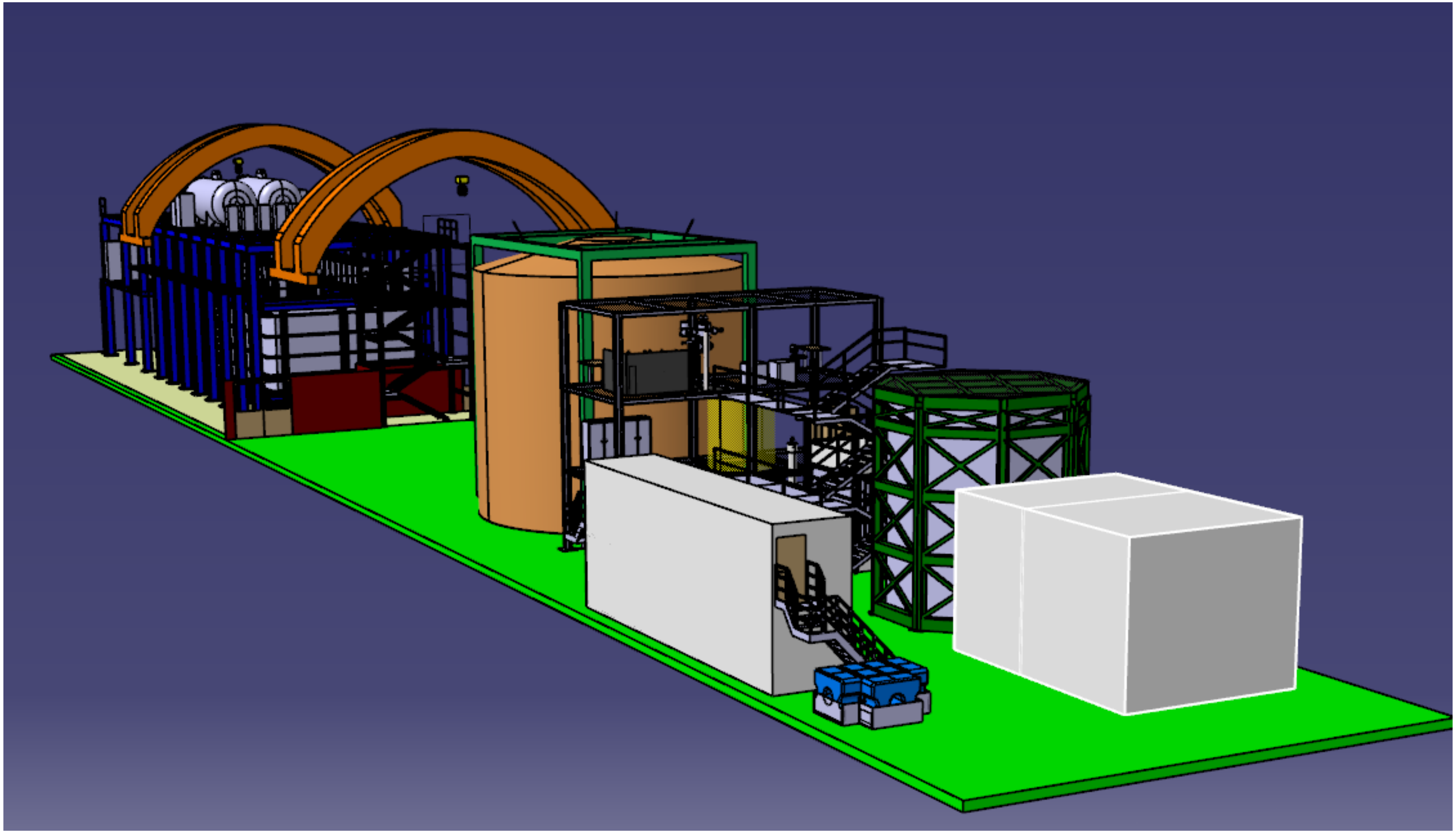




Expected Backgrounds in XENON1T
(100 Year Simulation Livetime)

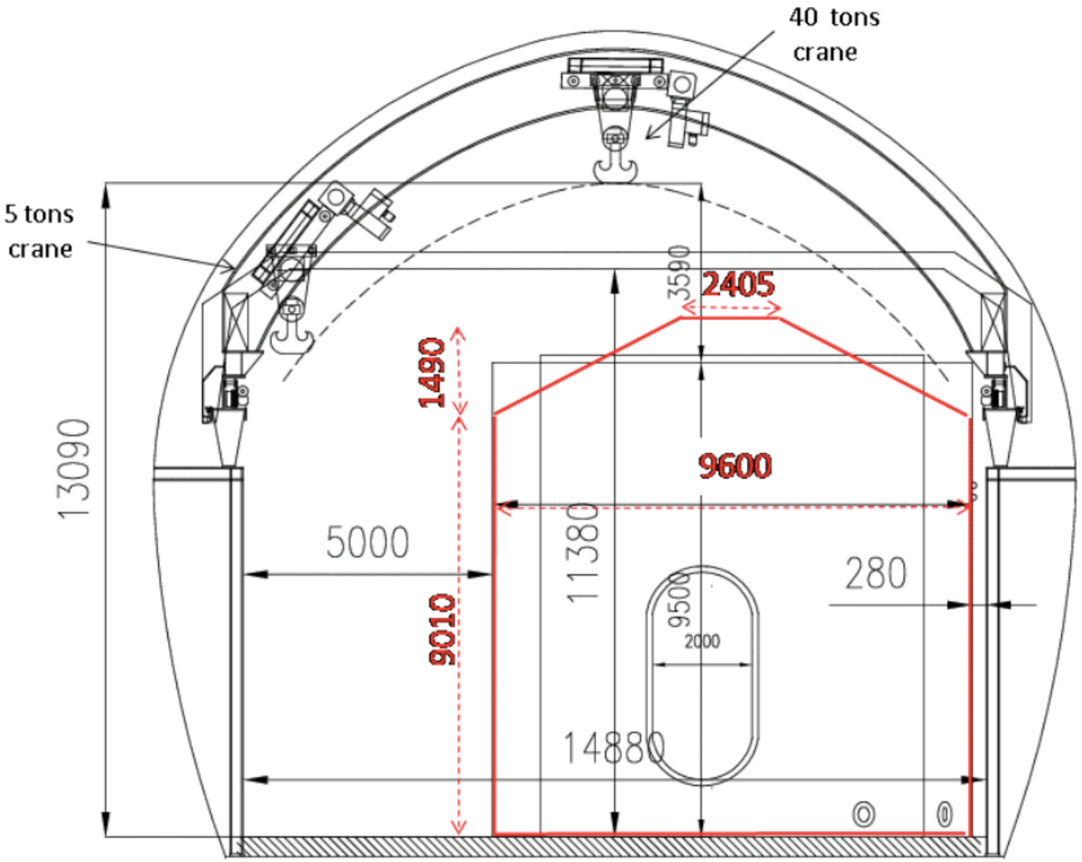


Gran Sasso Hall B



The water shield

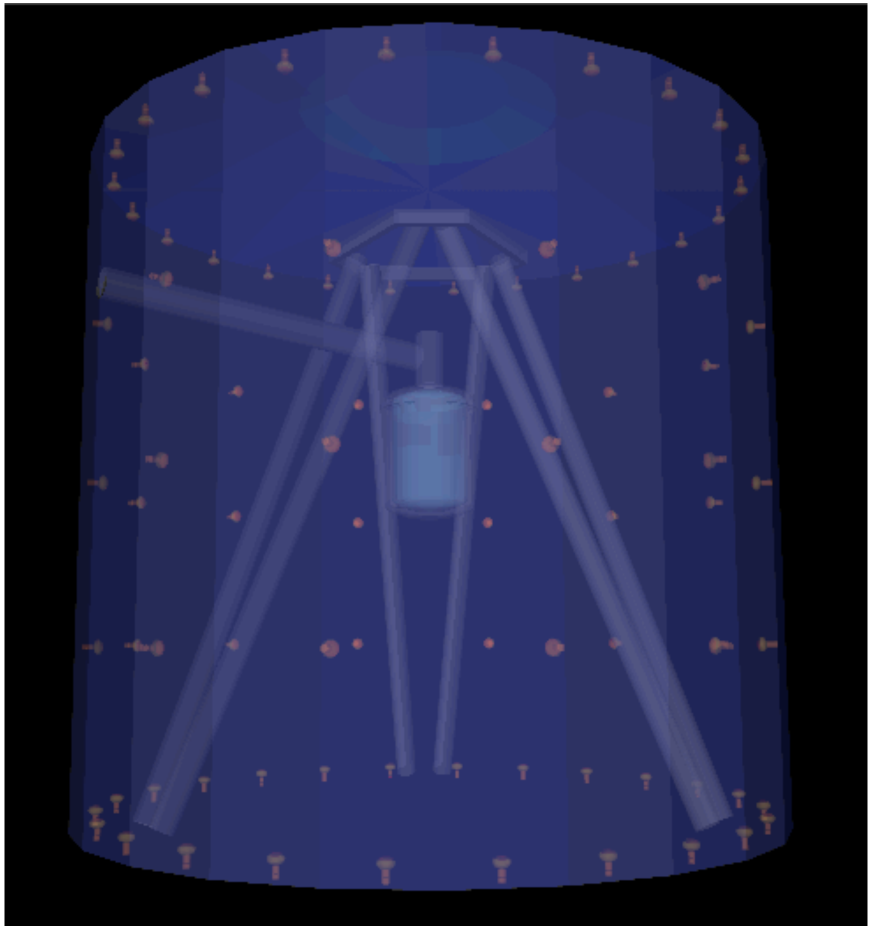
Characteristics	Stainless steel, welded
Dimensions	Φ 10.98x11.2 m
Effective Capacity	975 m^3
Proper Weight	26 Tons
Mains Openings	Manhole: 2x2 m Xenon Pipe: Φ 40 cm
Water Recirculation Plant	Deionization, Radon stripping, Particulate removal
Water Recirculation	3-5 m^3/hr



Muon veto

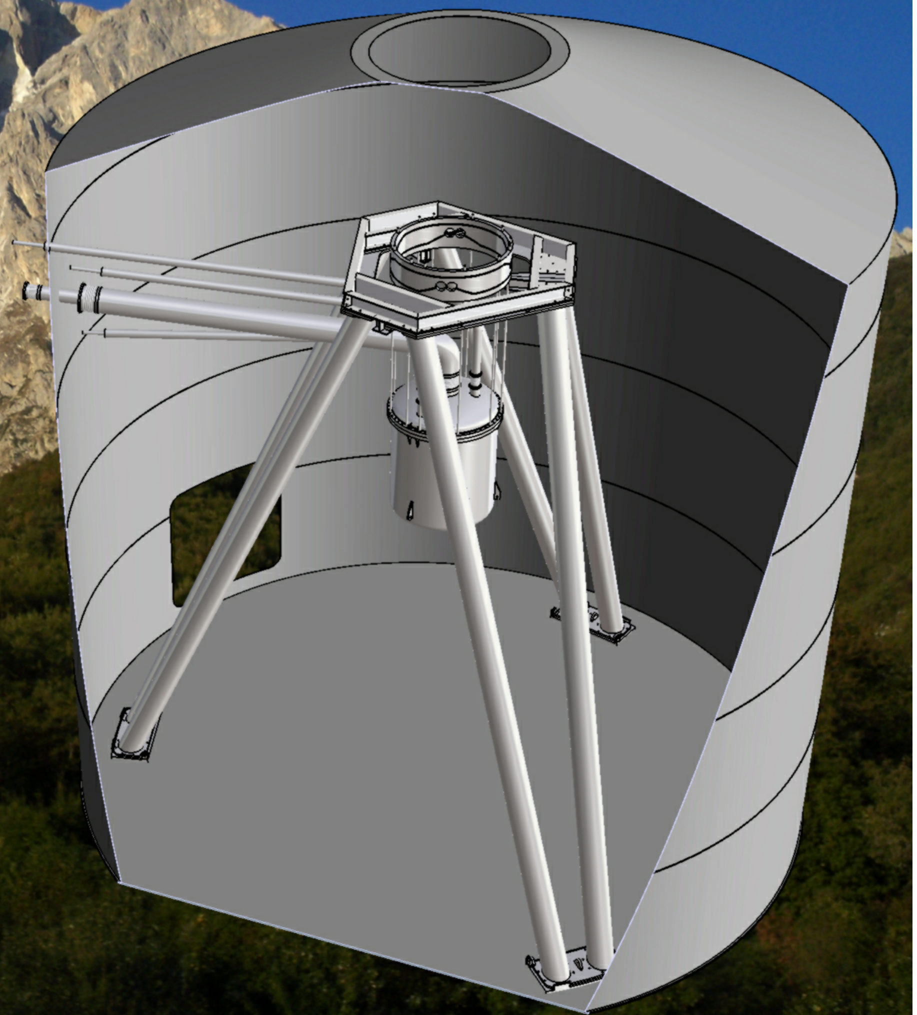
- Key element to reduce n background
- 650t of water
- 84 Hamamatsu R5912assy PMTs
- VM2000 reflective foil
- ~99% efficiency for Xing muons
- ~78% efficiency for shower events

See **Serena Fattori's** poster

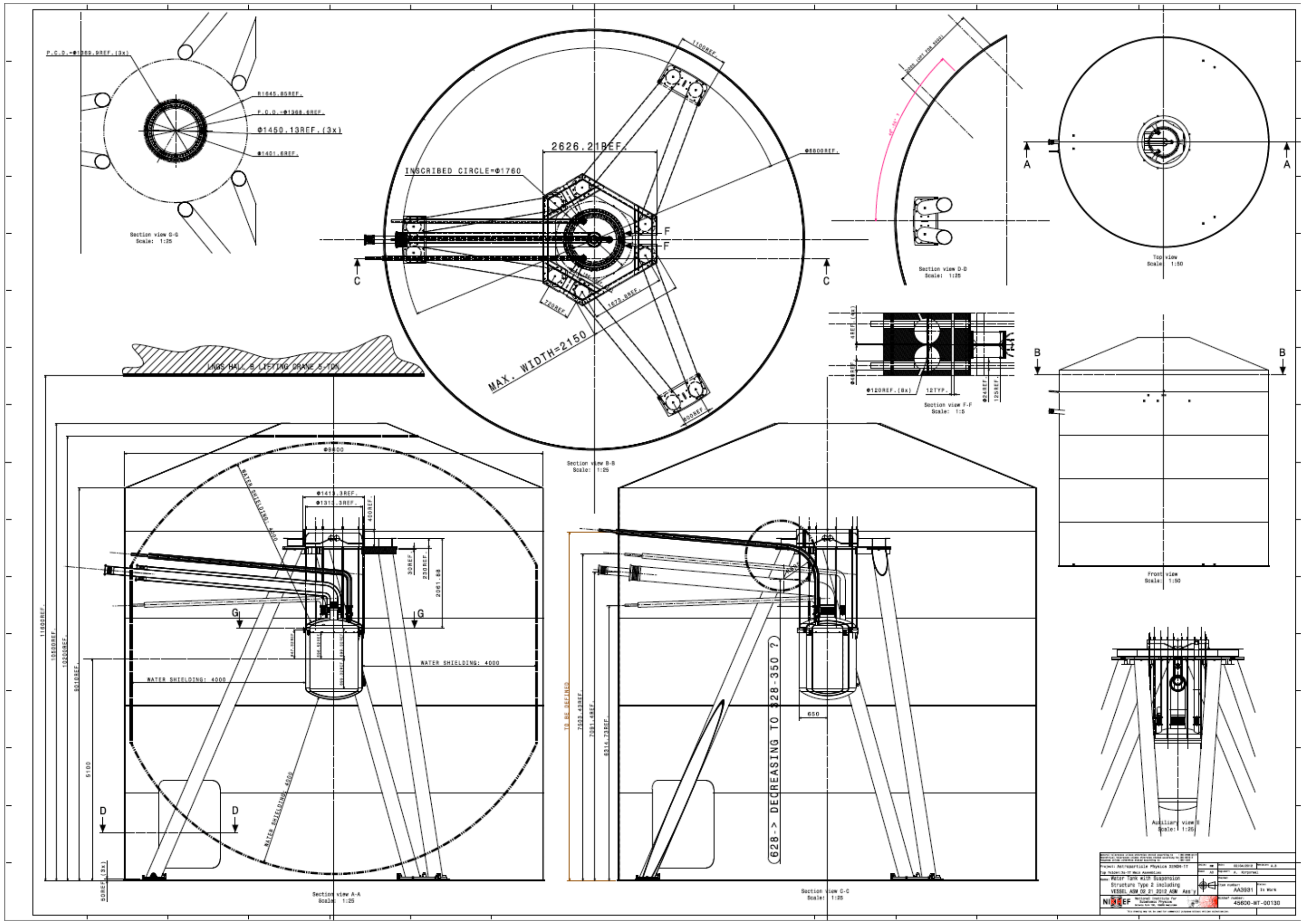


Cryostat

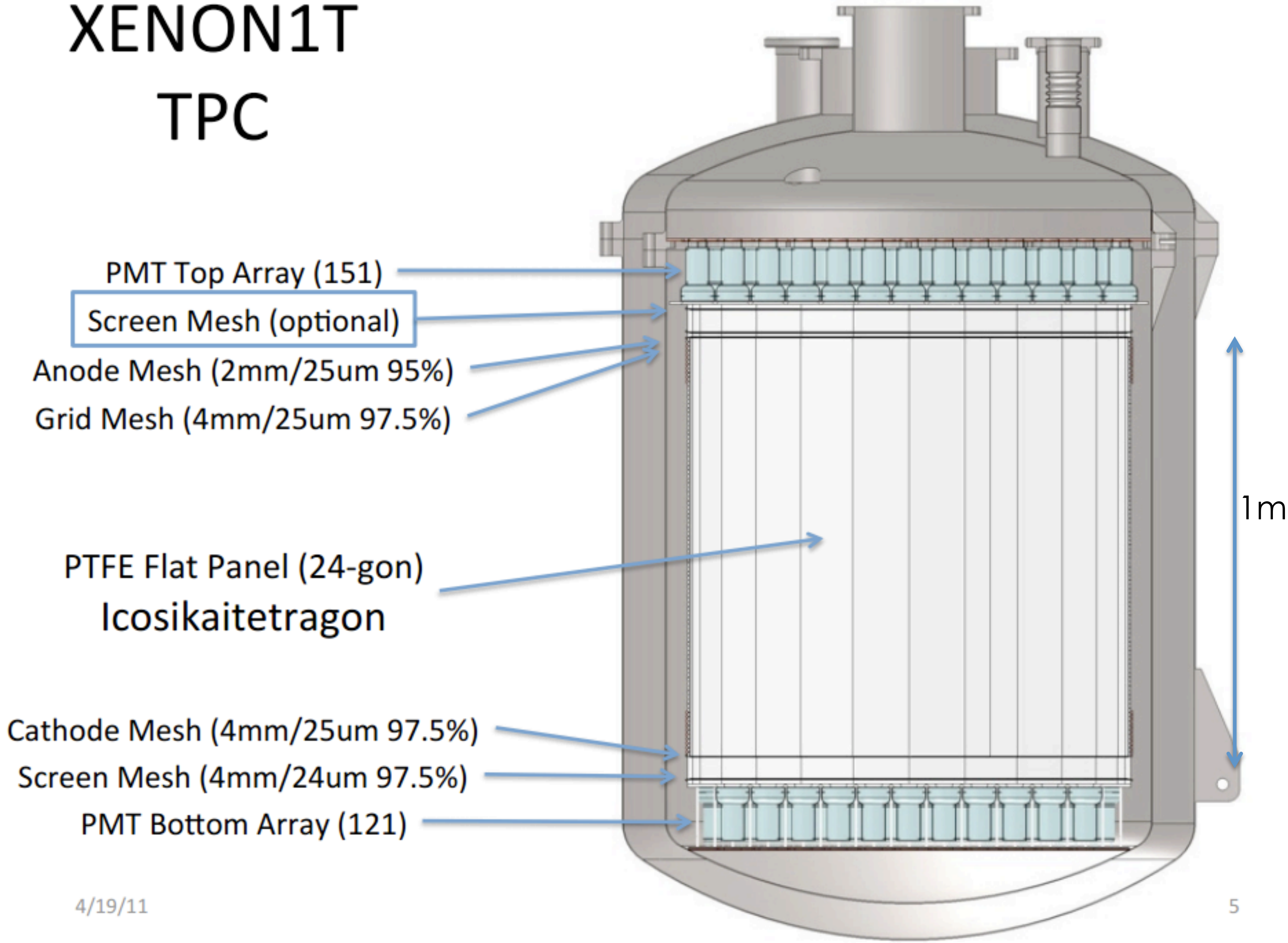
- Double walled vacuum insulated vessel
- 1.3 m diameter x 1.5 m height
- Holds 2.5 tons of Xenon @ -100°C
- Holds instrumented TPC
- Made of low-background Ti
- Heat load < 50W
- Hexapod Support Structure inside tank
- Linear actuators for leveling to 100 μ m
- Must satisfy buoyancy loaded condition & LNGS seismic environment



Hexapod

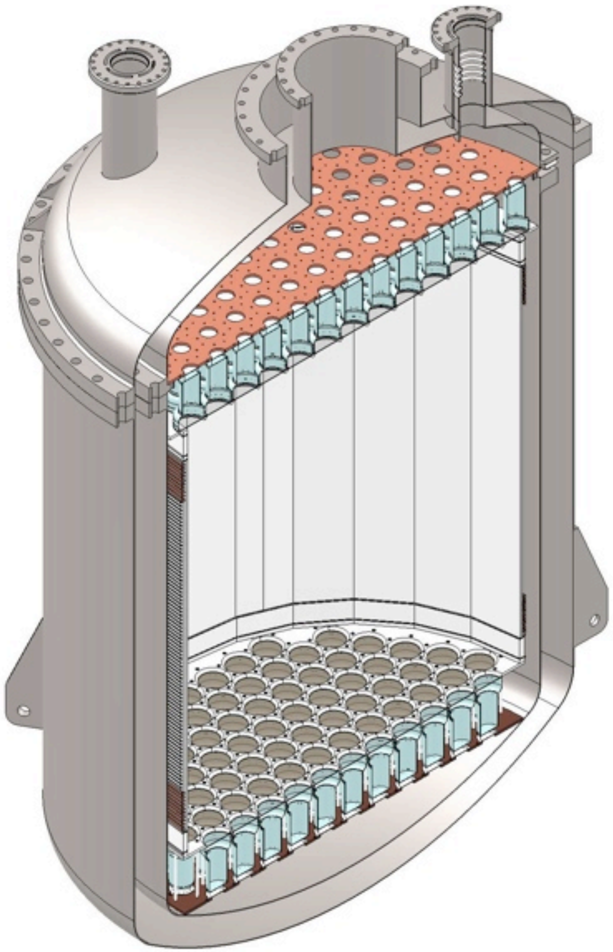

2626.218REF.
INSCRIBED CIRCLE=Ø1760
MAX. WIDTH=2150
628 -> DECREASING TO 328-350 ?

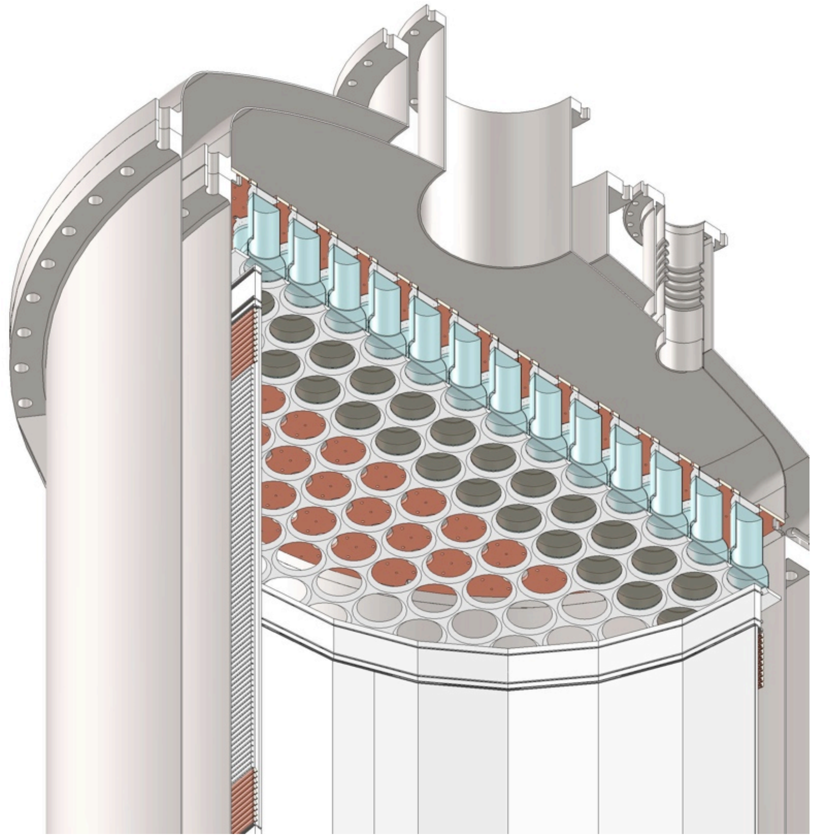
XENON1T TPC



PMT Top Array (151)
Screen Mesh (optional)
Anode Mesh (2mm/25um 95%)
Grid Mesh (4mm/25um 97.5%)
PTFE Flat Panel (24-gon)
Icosikaitetragon
Cathode Mesh (4mm/25um 97.5%)
Screen Mesh (4mm/24um 97.5%)
PMT Bottom Array (121)
1m

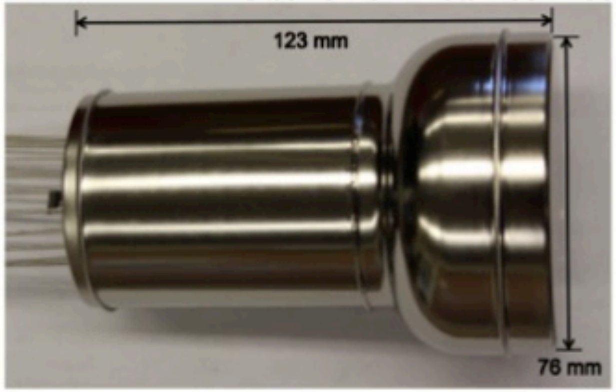
TPC

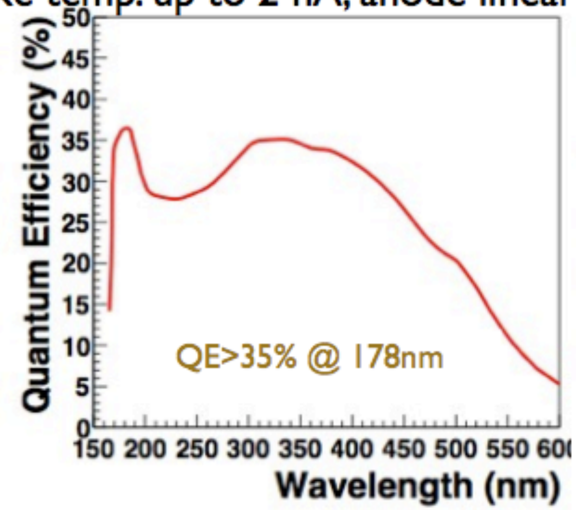


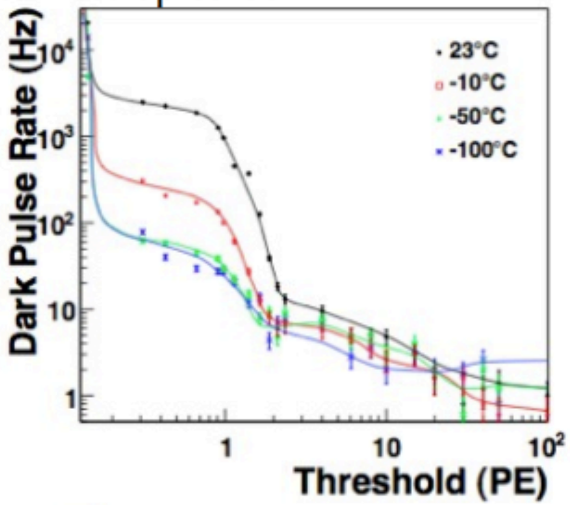


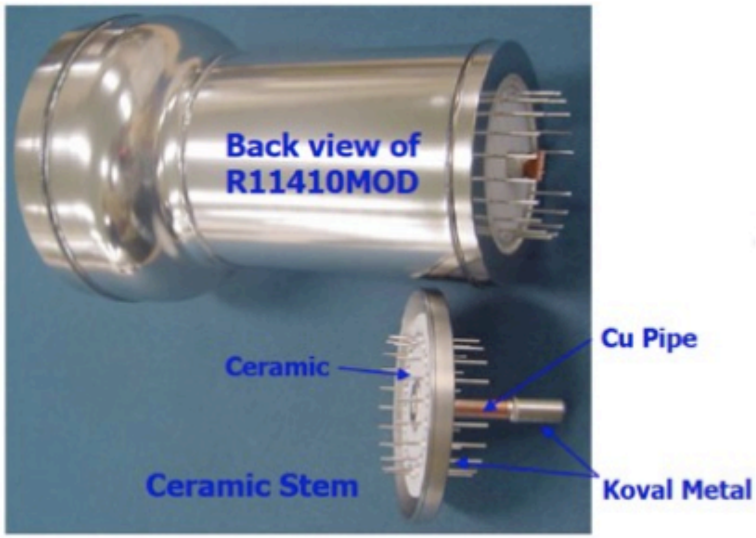
XENON1T PMTs

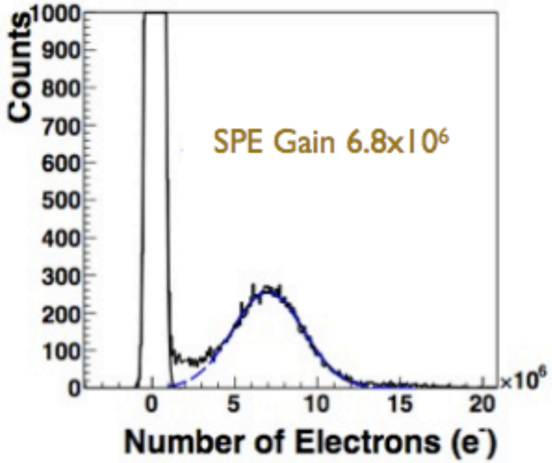
Baseline photosensor is the Hamamatsu R11410-10 3" PMT
LT bialkali photocathode; 12 stage box and linear focused style dynode structure
QE > 35% at 178 nm
50 Hz dark count rate
Cathode linear to <5% at LXe temp. up to 2 nA; anode linear to <5% up to 80nA

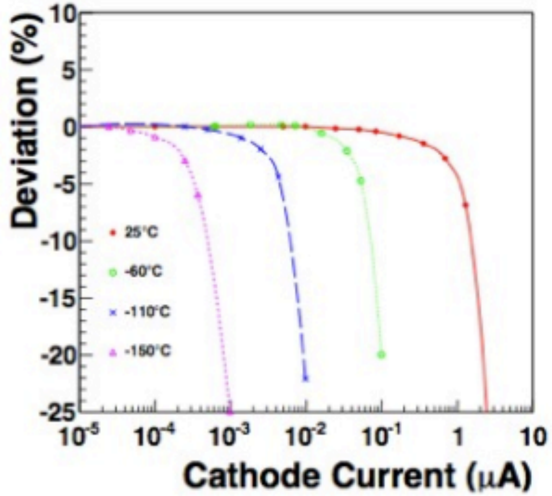




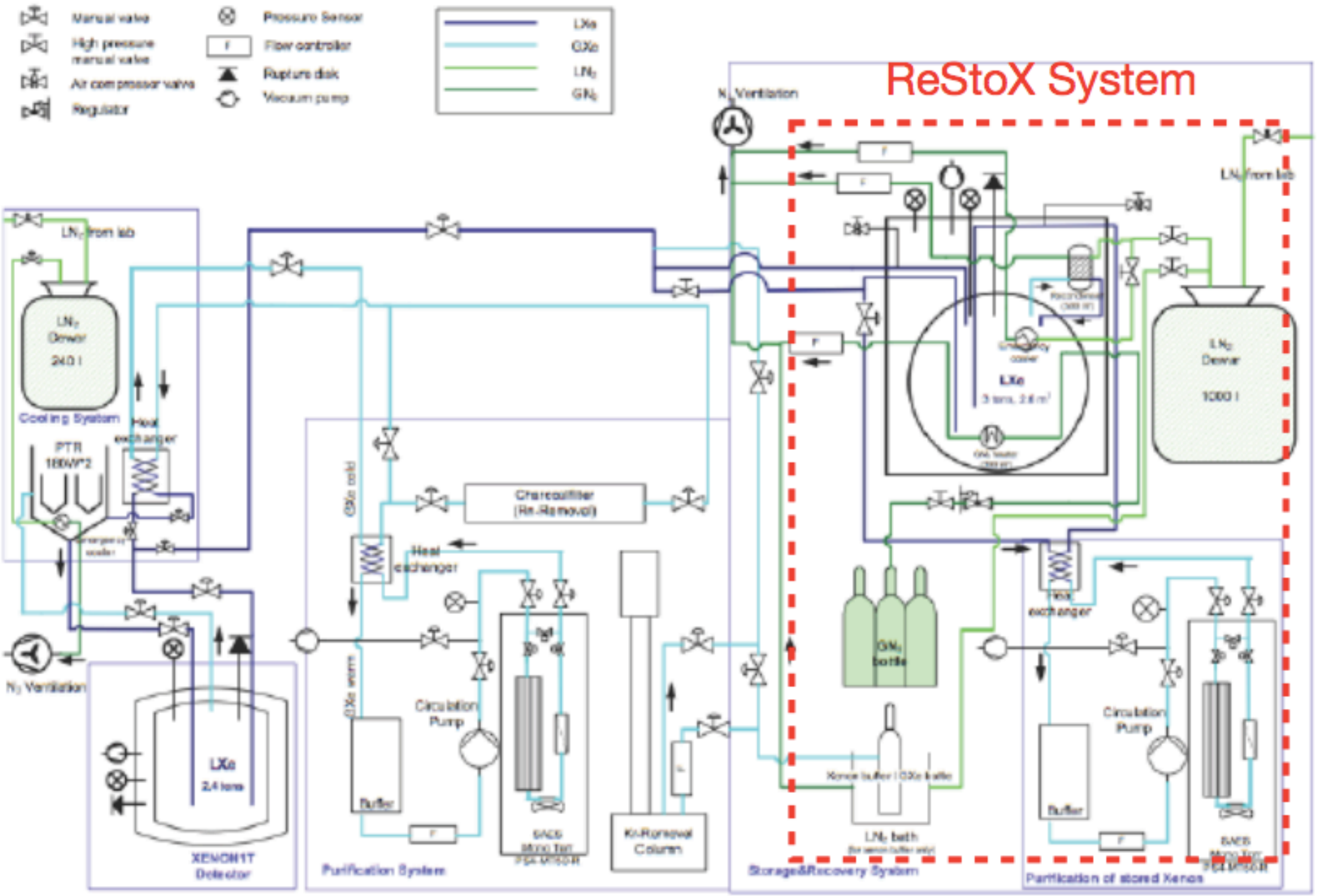








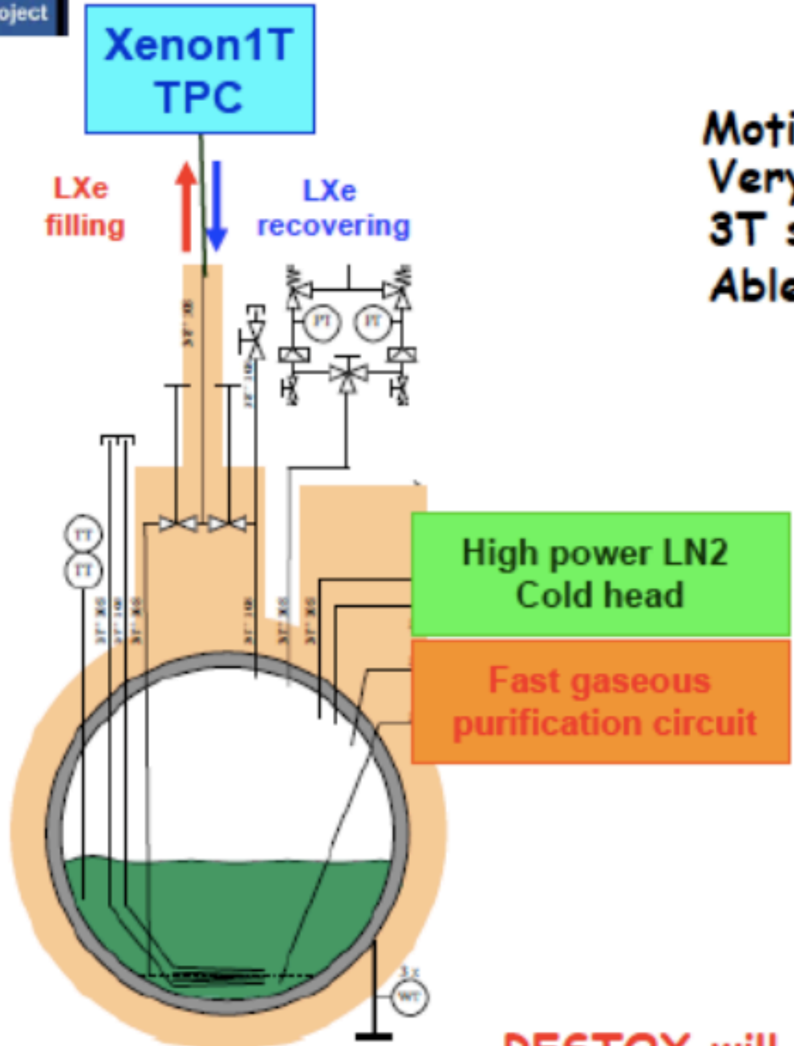
XENON1T CRYOGENIC INFRASTRUCTURE



XENON1T GAS/LIQUID STORAGE SYSTEM

RESTOX : A Liquid Xenon station

(REcovering and STOrage system of Xenon1T)



Motivations :
Very compact station
3T storage capacity from 20°to -108°C
Able to keep high purity all the time

Time schedule:
Construction will start in summer 2012
Installation for end of 2013

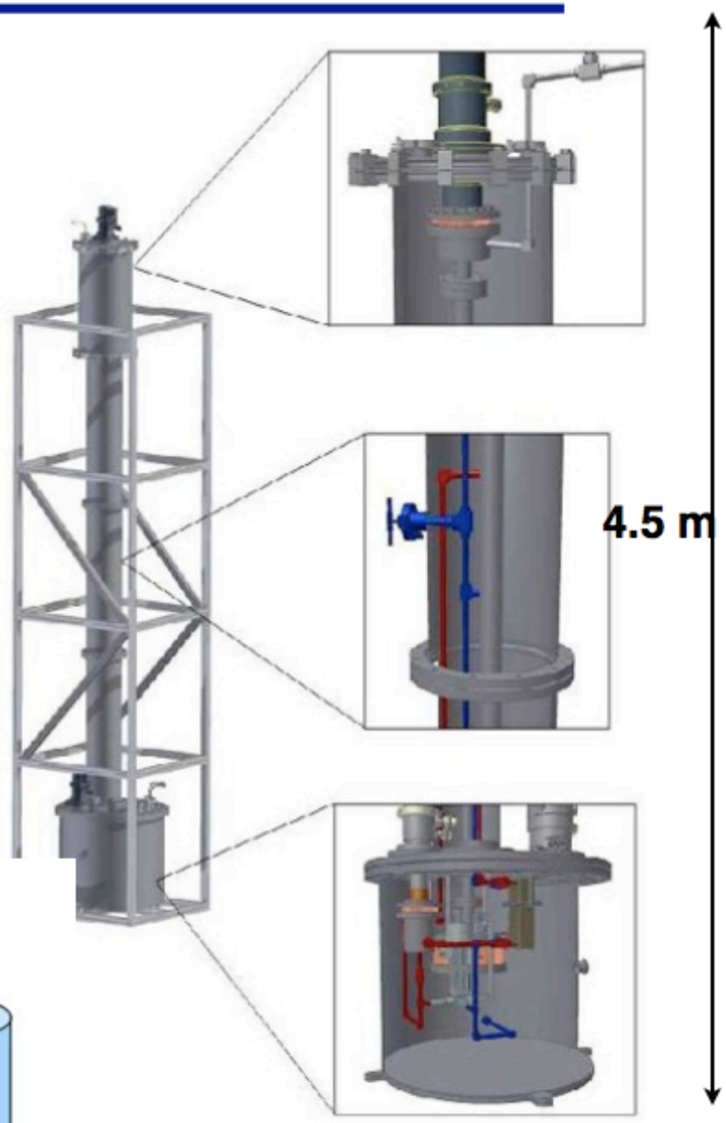
RESTOX will be easily scalable to larger sizes

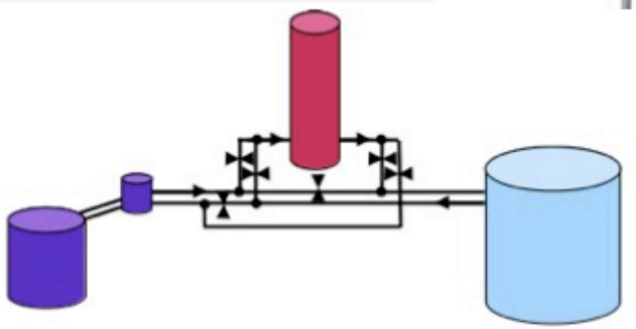
Cryogenic Distillation Column for Kr

- proven technique, currently used in XENON100
- utilize different boiling temperature of Xe and Kr
- liquid Xe passes through, Kr gas removed

Design Parameters fo XENON1T

- through-put: 3 kg/hr
- factor of 10^4-10^5 separation
- final Kr/Xe < 1 ppt





Westfälische Wilhelms-Universität Münster

Conclusions

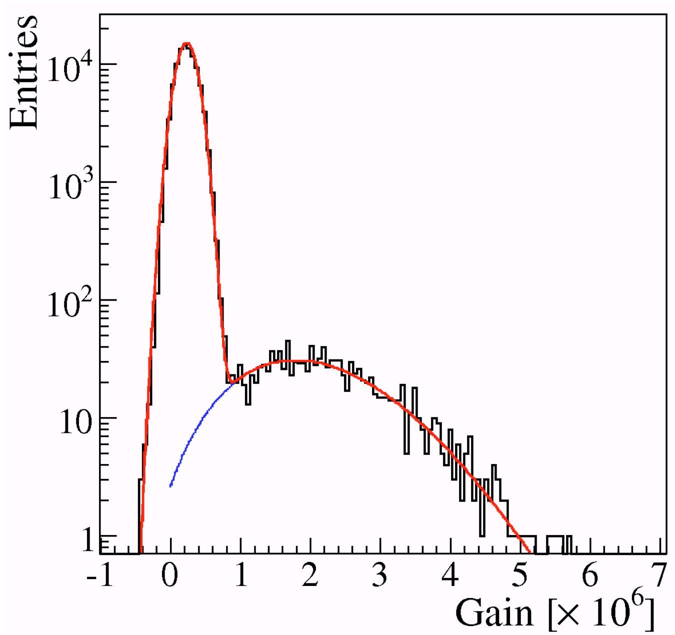
- XENON100 is actually the lowest background experiment for WIMP scattering search
- New data about to be released
- Construction phase of XENON1T about to begin
- Data taking foreseen for early 2015

Thank you!

Backup slides

PMT Calibration

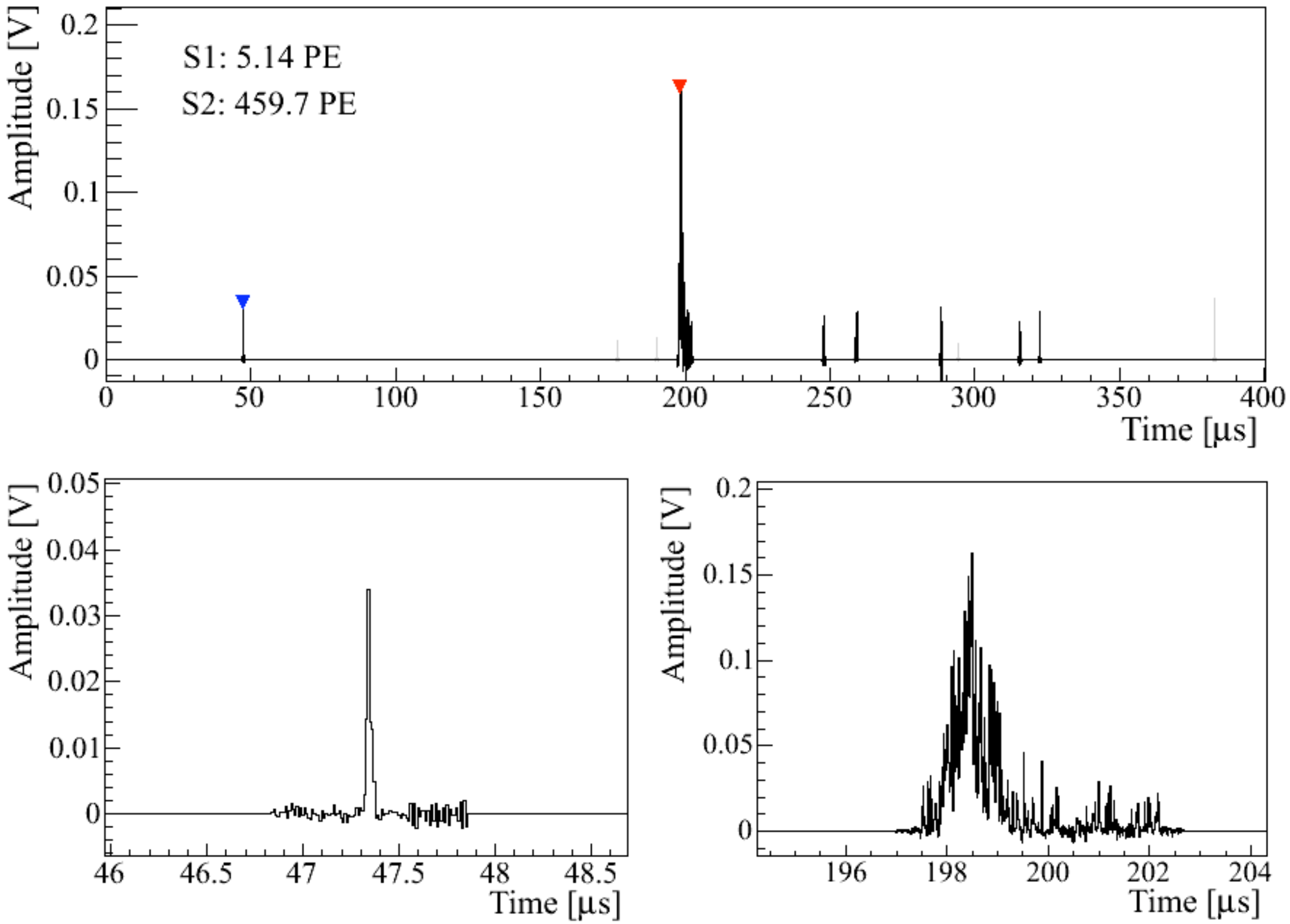
- Gain close to 2.0×10^6
- Calibrated through SPE with a blue LED + optical fiber
- Light level such as in less than 5% of LED pulses, a PMT has 1 PE
- Pulse calibration frequency 100Hz
- Spectrum fitted wih a gaussian (background) + $$y(x) = \frac{\mu e^{-\mu}}{\Gamma(x+1)}$$
- Gains measured once a week
  - Fluctuations within ± 2%



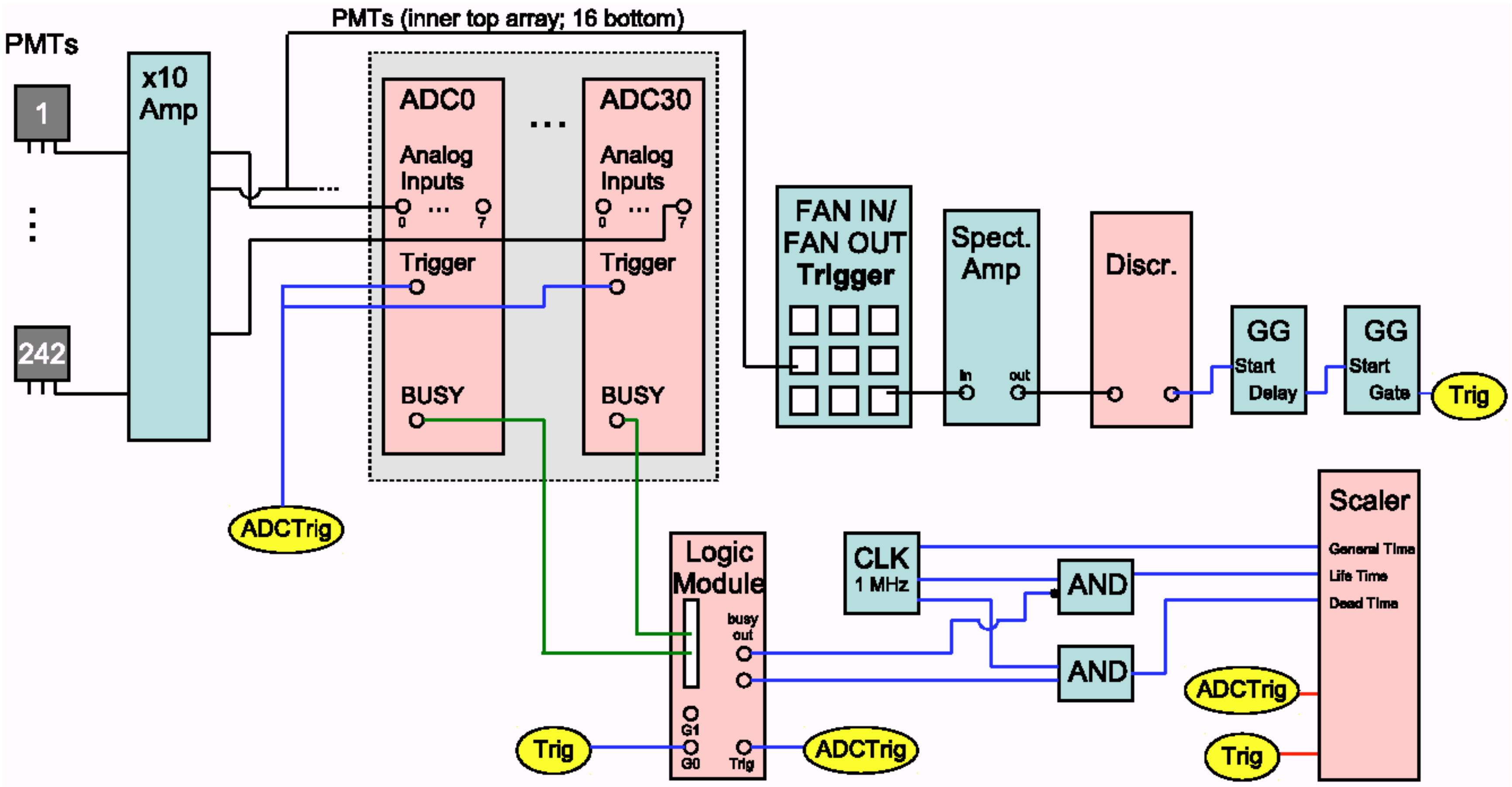
Data processing

- Raw data processor based on Root
- An event consists of the traces of all 242 PMTs (~400 μ s, with zero-length-encoding)
- Steps:
  - Waveforms reconstructed
  - Baseline calculated and subtracted
  - Amplitudes converted to voltage
  - All waveforms of inner PMTs summed
  - Low-pass filter applied
  - S2 peak recursive finding algorithm
  - S1 finding algorithm
    - Efficiency >80% for SPEs
  - Peak properties determined

Typical waveform



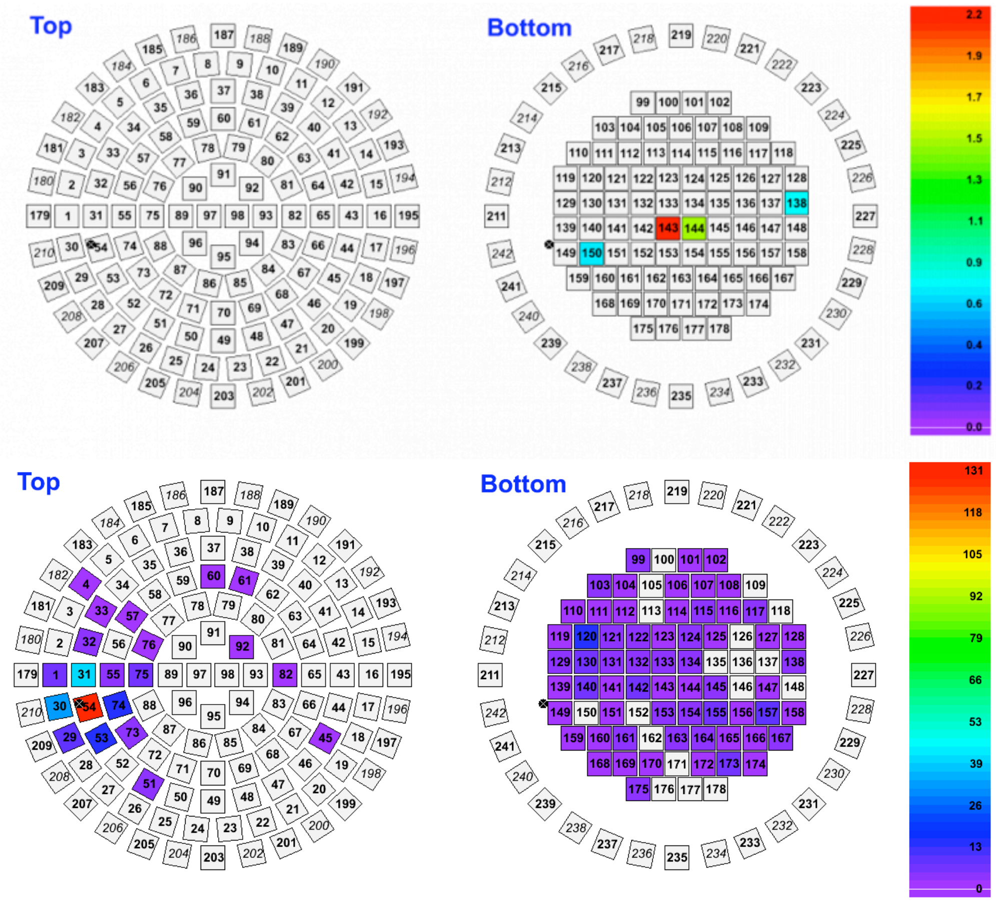
The XENON100 DAQ scheme



3-D vertex reconstruction

- Z coordinate given by time difference $T_{s2} - T_{s1}$ (drift velocity 1.73 mm/s)
- X,Y given by the position of the charge cloud on the top PMT array
  - 3 algorithms used: χ^2, "support vector machime – SVM", and neural network
  - All three give consistent results
  - NN chosen because more homogeneous and better agreement with MC

Event pattern

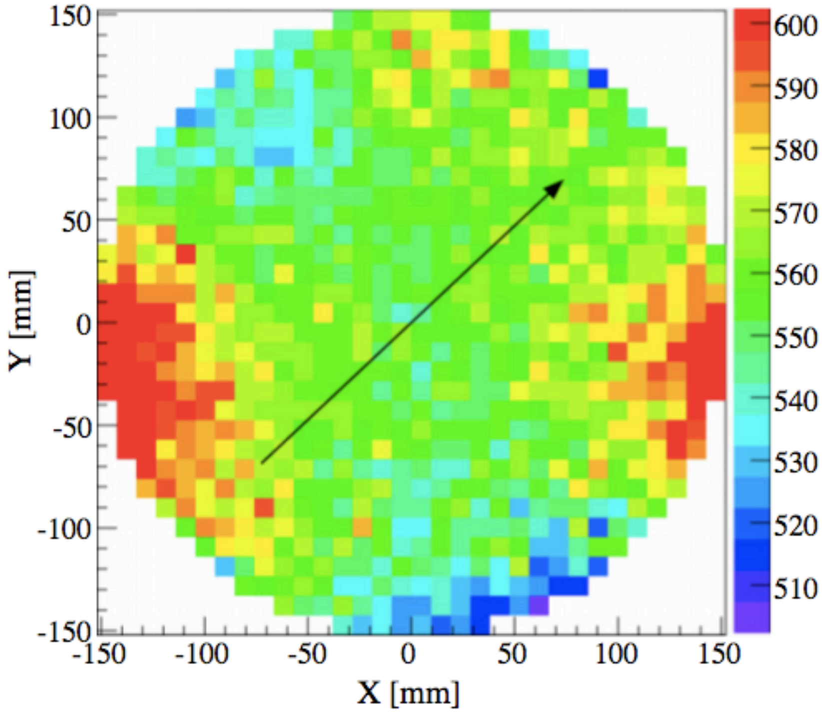


Calibration

- Calibration sources can be inserted in the shield through a copper tube wound around the cryostat.
- The sources are ^{37}Cs (661.7 keV), ^{57}Co (836 keV), ^{60}Co (1.17 – 1.33 MeV), ^{232}Th (4MeV).
- The electronic recoil band in log10($S2/S1$) vs. energy space is calibrated with the low energy tail of the Compton spectrum.
- The response to single scatter nuclear recoil with an AmBe source, shielded with 10cm of lead to get rid of the 4.4MeV γ rays
  - This calibration provides additional calibration lines due to the activation of xenon and fluorine

Detector leveling and S2 optimization

- The size of S2 depends on the width between the anode and the liquid level
  - liquid must be leveled
    - Leveling screws outside the shield
- S2 is proportional to the gap
- Leveling is checked by scanning the surface with a 137Cs source
- Backscattering
- No events coming from the borders of the TPC
- S2 also optimized from the point of view of the absolute level of the liquid
- Best resolution on S2 with the liquid 2.5mm above the gate grid



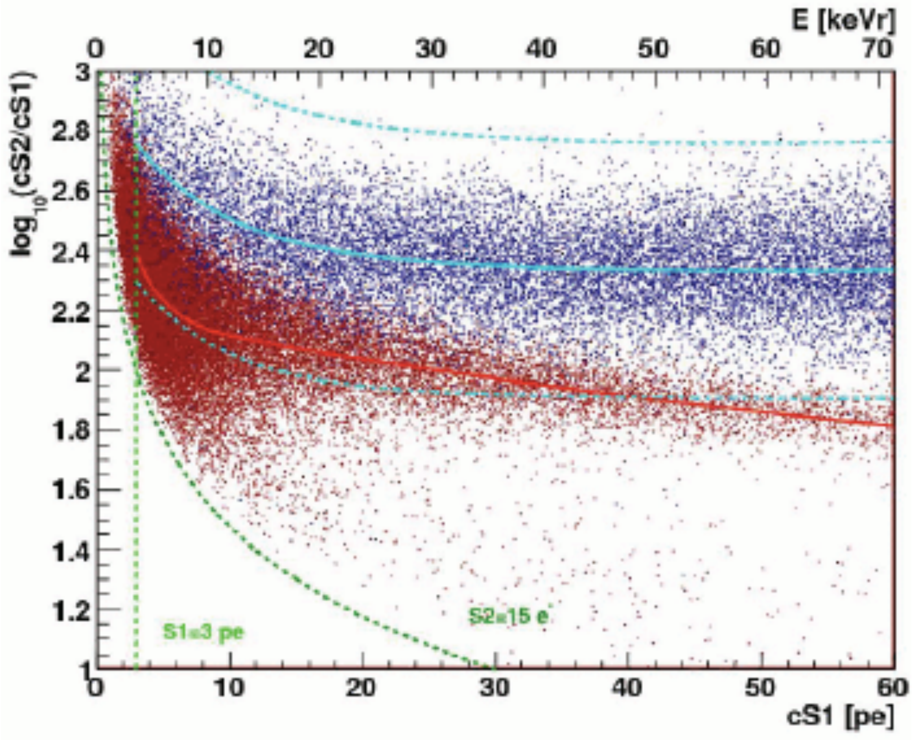
Nuclear Recoil Equivalent Energy

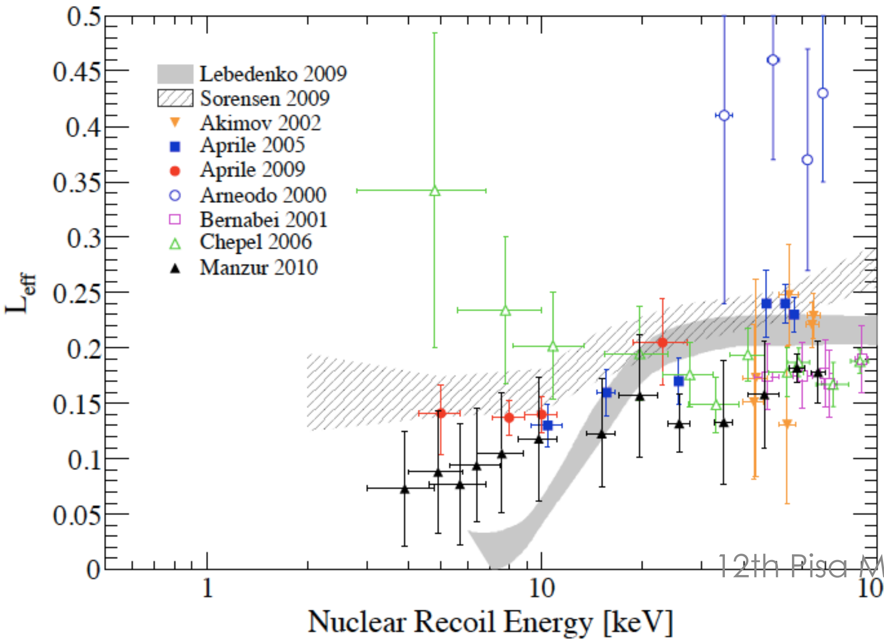
$$E_{nr} = \frac{S1}{L_{\rm y}} \cdot \frac{S_{\rm ee}}{S_{\rm nr}} \cdot \frac{1}{\mathcal{L}_{\rm eff}}$$

$$L_{\rm y}(122{\rm keV_{ee}}) = (2.2 \pm 0.1)\frac{\rm p.e.}{\rm keV_{ee}}$$

$$S_{\rm nr} = 0.95$$

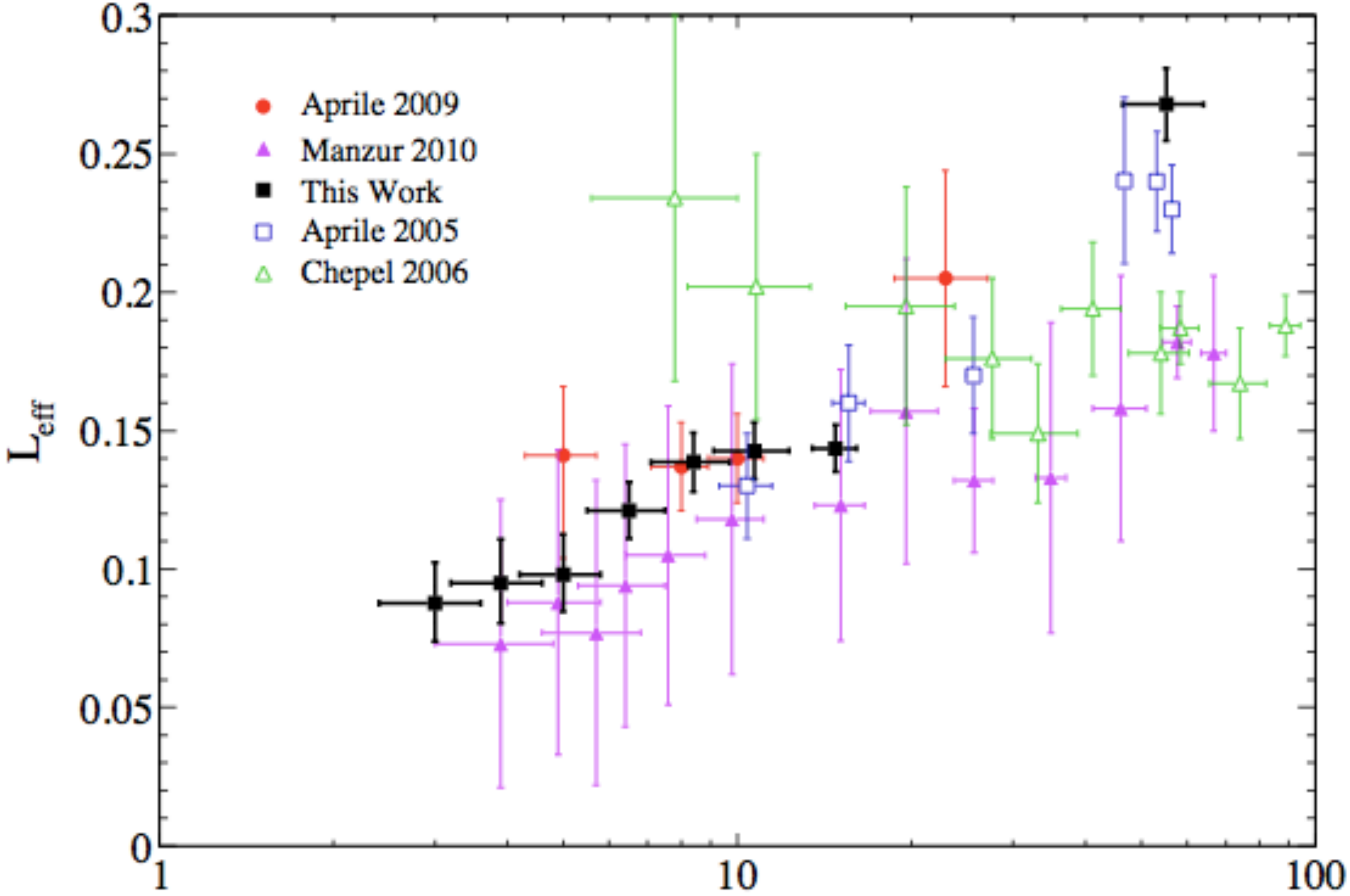
$$S_{\rm ee} = 0.58$$



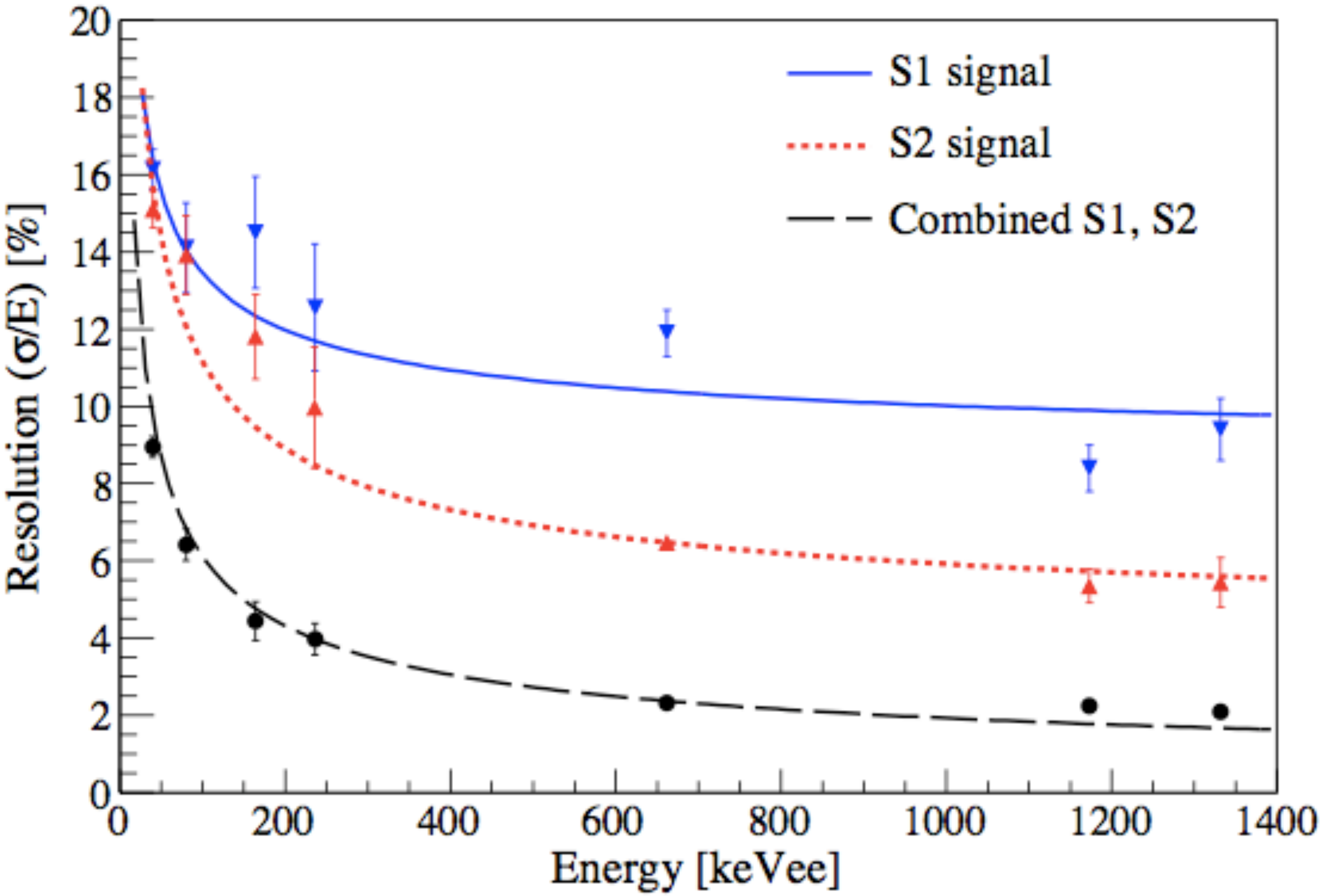


Plante et al. - submitted to Phys. Rev. C

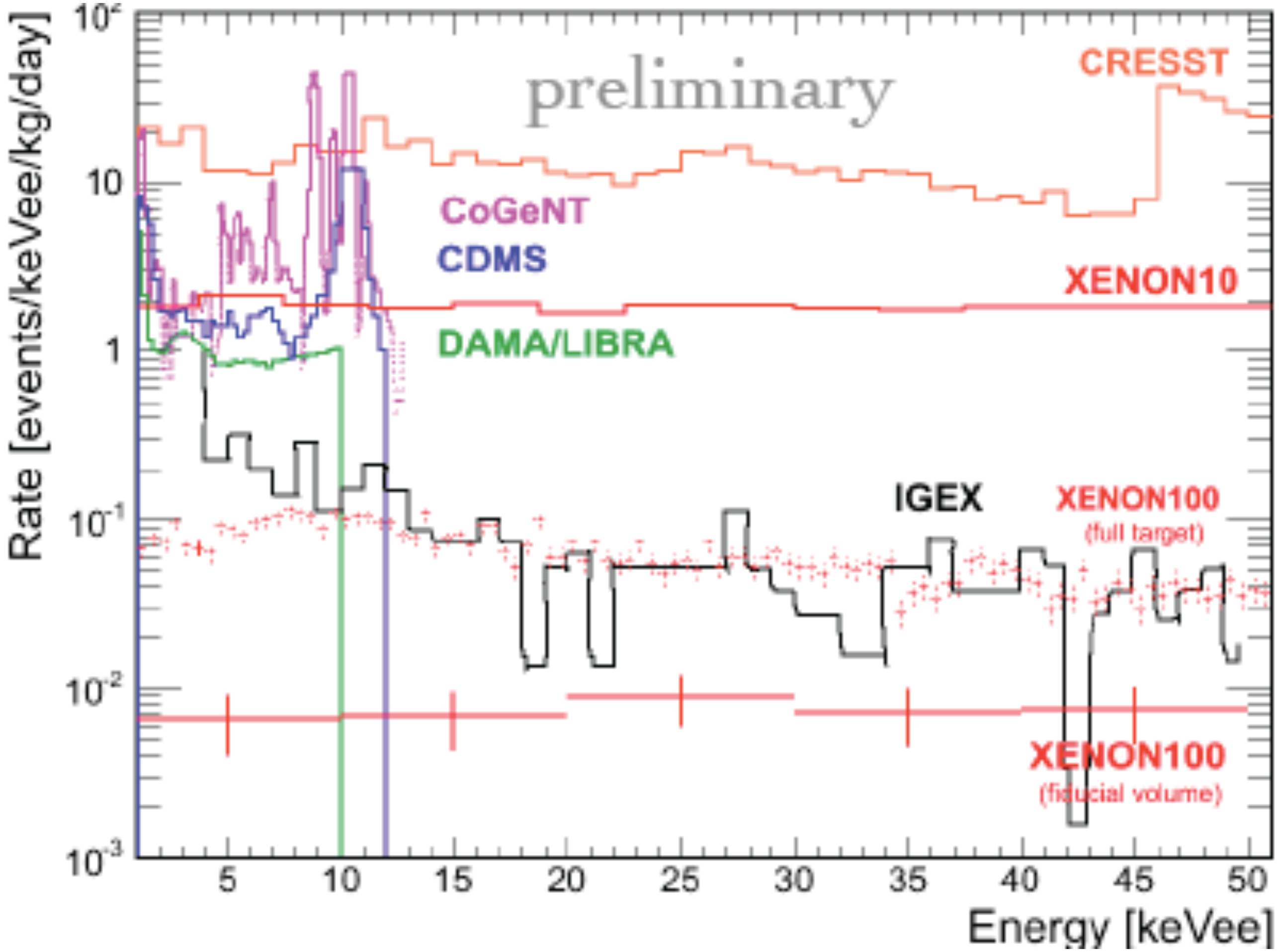
arxiv:1104.2587



Energy resolution

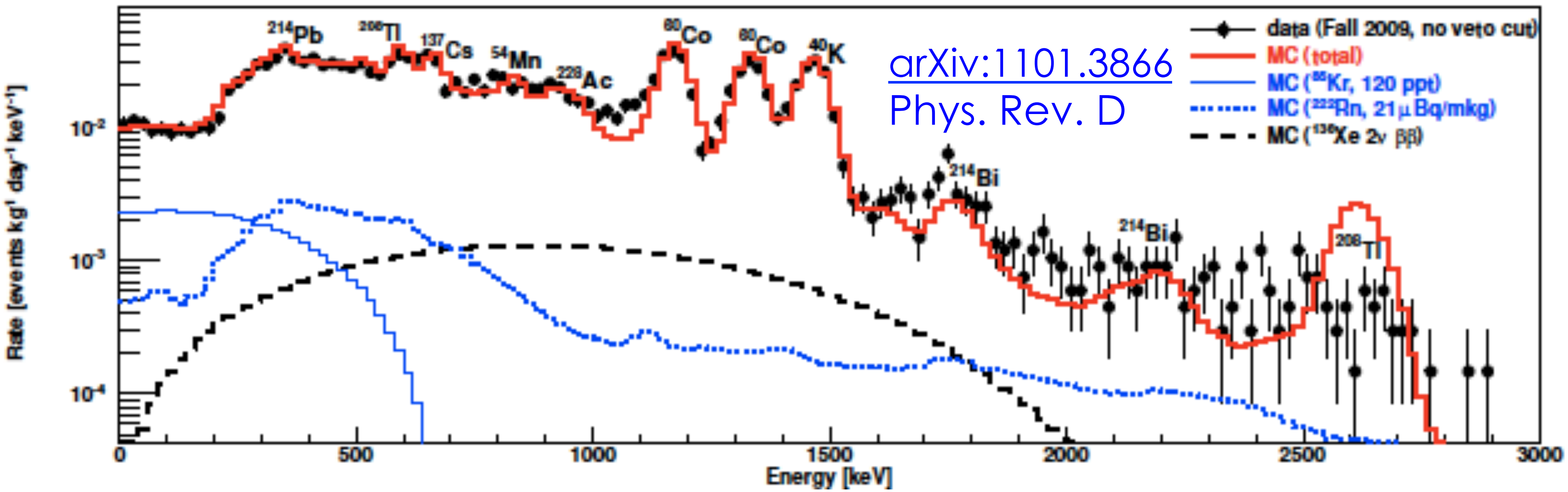


Background



preliminary
CRESST
CoGeNT
CDMS
XENON10
DAMA/LIBRA
IGEX
XENON100
(full target)
XENON100
(fiducial volume)
Rate [events/keVee/kg/day]
Energy [keVee]

XENON100 Measured Background



- In good agreement with Monte Carlo simulations based on detailed mass model and measured radioactivity of XENON100 materials

- In WIMP search region background is at level of 10^{-4} evts/kg/keV/day after S2/S1 discrimination

- The LXe veto further reduces the background to 5x 10^{-5} evts/kg/keV/day), where ^{85}Kr in LXe starts to dominate