

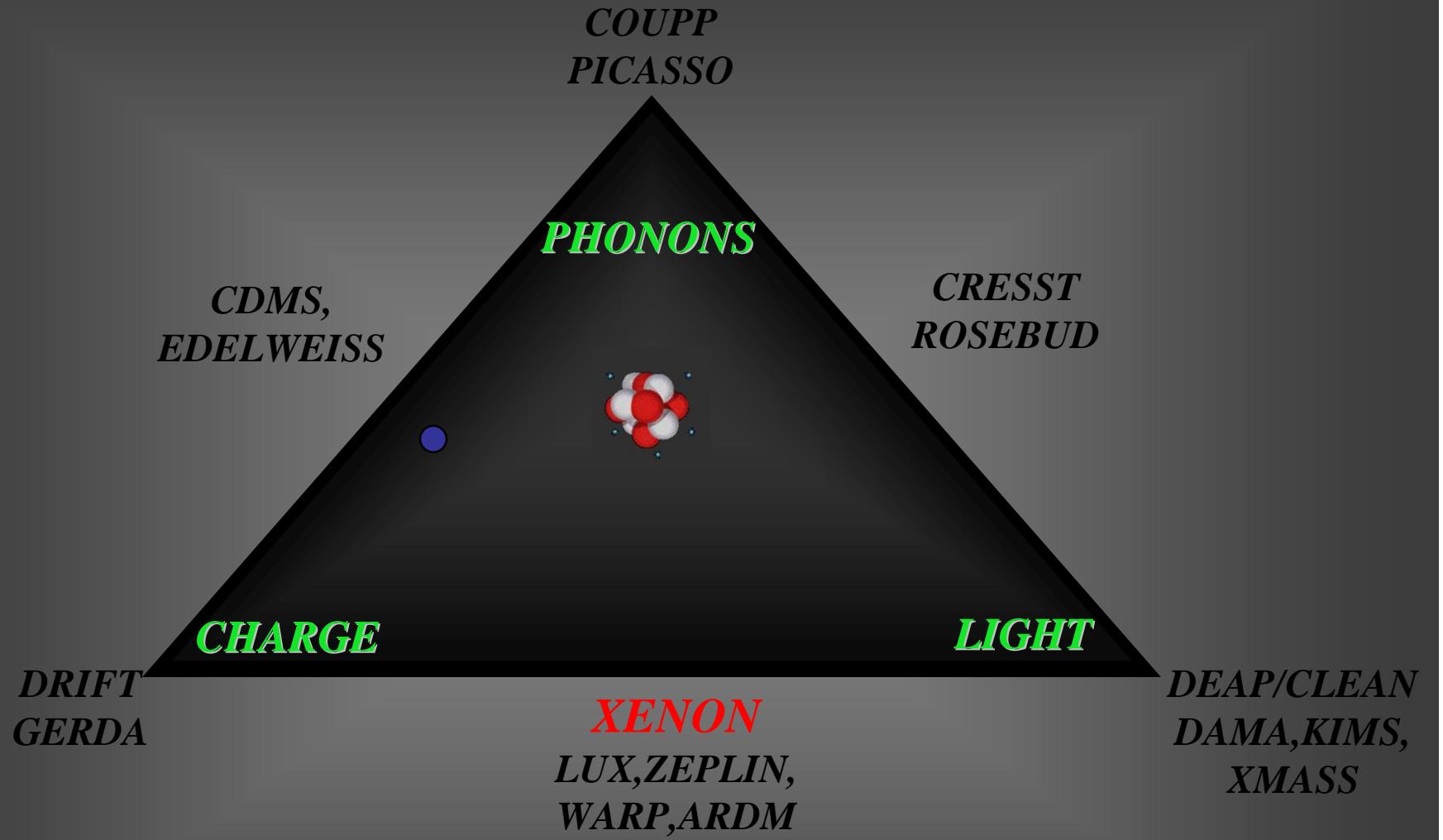
THE XENON 100 DARK MATTER EXPERIMENT



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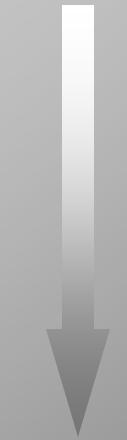
OUTLINE

- *LXe for dark matter research*
- *The XENON project*
- *Reminder: XENON10*
- *XENON100*
- *Present status*
- *Future plans*



NOBLE LIQUIDS AS DETECTOR MEDIUM

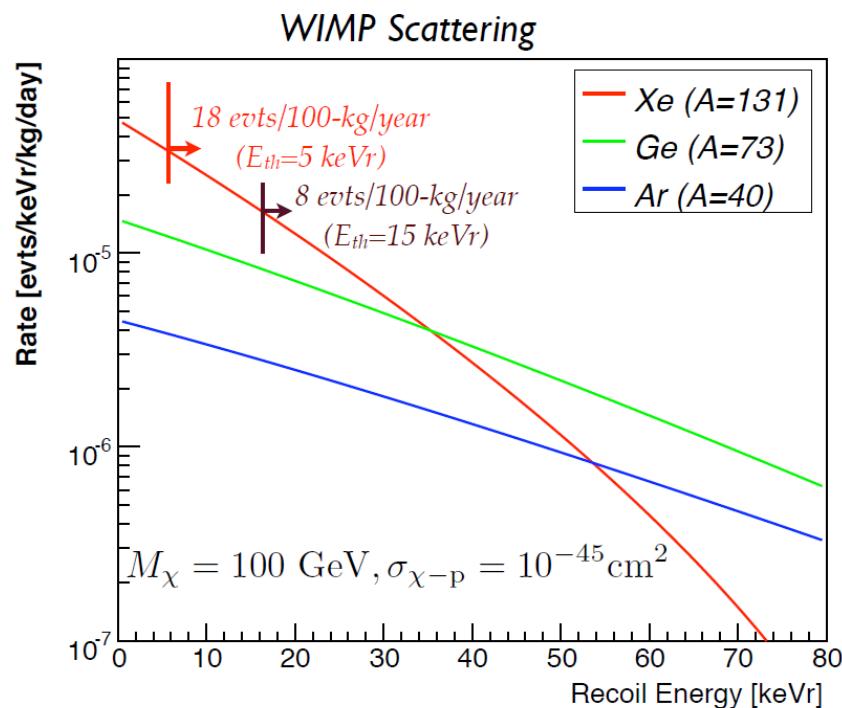
Liquid rare gas give both scintillation and ionization signals

<i>Element</i>	<i>Z(A)</i>	<i>Boiling point (T_b) @1bar [k]</i>	<i>Liquid density @T_b [g/cm³]</i>	<i>Energy loss dE/dx (MeV/cm)</i>	<i>Radiation length X₀(cm)</i>	<i>Collision length λ(cm)</i>	<i>Ionization [e⁻/keV]</i>	<i>Scintillation [γ/keV]</i>	<i>Cost</i>
<i>Ne</i>	10(20)	27.1	1.21	1.4	24	80	46	7	
<i>Ar</i>	18(40)	87.3	1.40	2.1	14	80	42	40	
<i>Kr</i>	36(84)	119.8	2.41	3.0	4.9	29	49	25	
<i>Xe</i>	54(131)	165.0	3.06	3.8	2.8	34	64	46	

Experimental Requirements for DM research:

- *good event discrimination*
- *ultra low background*
- *low energy threshold*
- *large mass*

LIQUID XENON FOR DARK MATTER DETECTION



$$\lambda_{LXe} \sim 175 \text{ nm} \quad \lambda_{LArc} \sim 128 \text{ nm} \quad \lambda_{LN_{\text{He}}} \sim 77.5 \text{ nm}$$



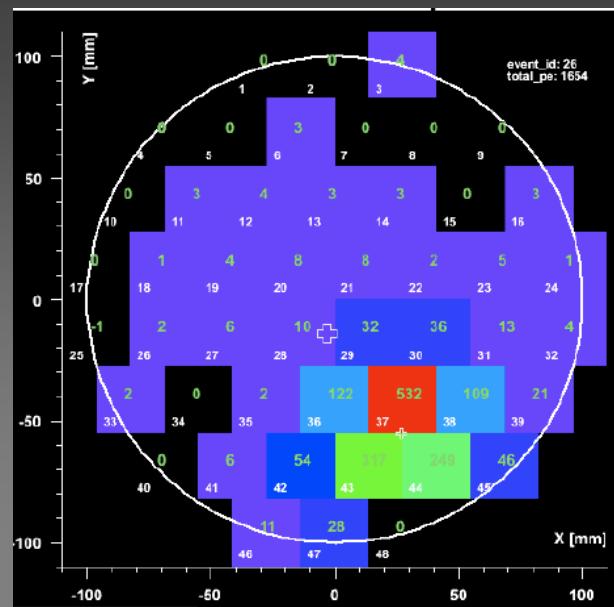
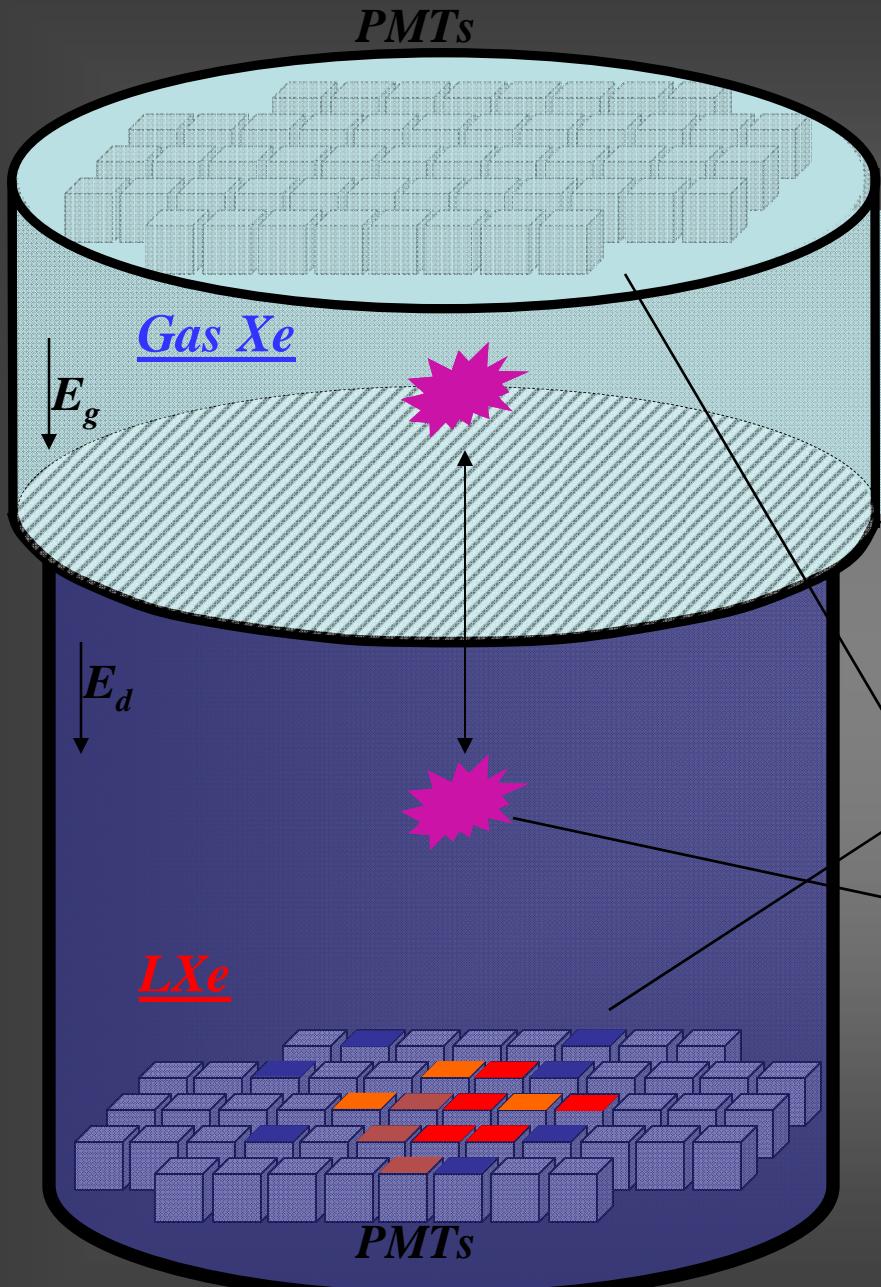
No need for wavelength shifter with Quartz windows

- **High atomic number** ($Z=54, A \sim 131$) and **density** ($\rho=3 \text{ g/cm}^3$) good for compact and flexible detector geometry. Good stopping power (i.e. self shielding active volume)
- ~50% odd isotopes ($^{129}\text{Xe}, ^{131}\text{Xe}$) for spin dependent interactions
- “Easy” cryogenics at -180K
- **No long-lived radioactive isotopes.** ^{85}Kr contamination reducible to ppb level or less
- **High scintillation** ($W \sim 13 \text{ eV}$) yield with fast response (yield $\sim 80\%$ of NaI)
- **High ionization** ($W=15.6 \text{ eV}$) yield and small Fano factor for good $\Delta E/E$ (long electron drift)
- low diffusion for excellent spatial resolution. Calorimetry and 3D event localization powerful for background rejection based on fiducial volume cuts and event multiplicity
- Different charge/light ratios for electron/nuclear interactions **good background discrimination**
- Available in large quantity and “easy” to purify with a variety of methods ($\sim 5\text{k\$}/\text{kg}$).

THE XENON DARK MATTER PROGRAM

LXe **double-phase TPC**, 3D position sensitive detector

- **XENON10** first implementation of the concept. Data taken in 2006/2007.
(Reached sensitivity $\sim 10^{-43} \text{cm}^2$ at 100GeV WIMP mass)
- Event by event discrimination (>99.5%) by simultaneous charge and light detection
- Low energy threshold (~5keVr with 89 PMTs readout - light yield $\sim 3\text{pe}/\text{keV}$)
- **XENON100** currently operating at Gran Sasso laboratory
Goal: gamma background reduction by ~ 100 and fiducial mass increase by ~ 10
Sensitivity: up to $\sim 2 \times 10^{-45} \text{cm}^2$ ($M_W=100\text{GeV}$) - $\sim 2 \times 10^{-46} \text{cm}^2$ projected 2012
- Ultimate goal **XENON1T** $\rightarrow \sigma_{\text{SI}} \sim 10^{-47} \text{cm}^2$ ($M_W=100\text{GeV}$)



Primary scintillation S1 (interaction in LXe) : spread signal mostly on the bottom PMTs (20/80 top/bottom)

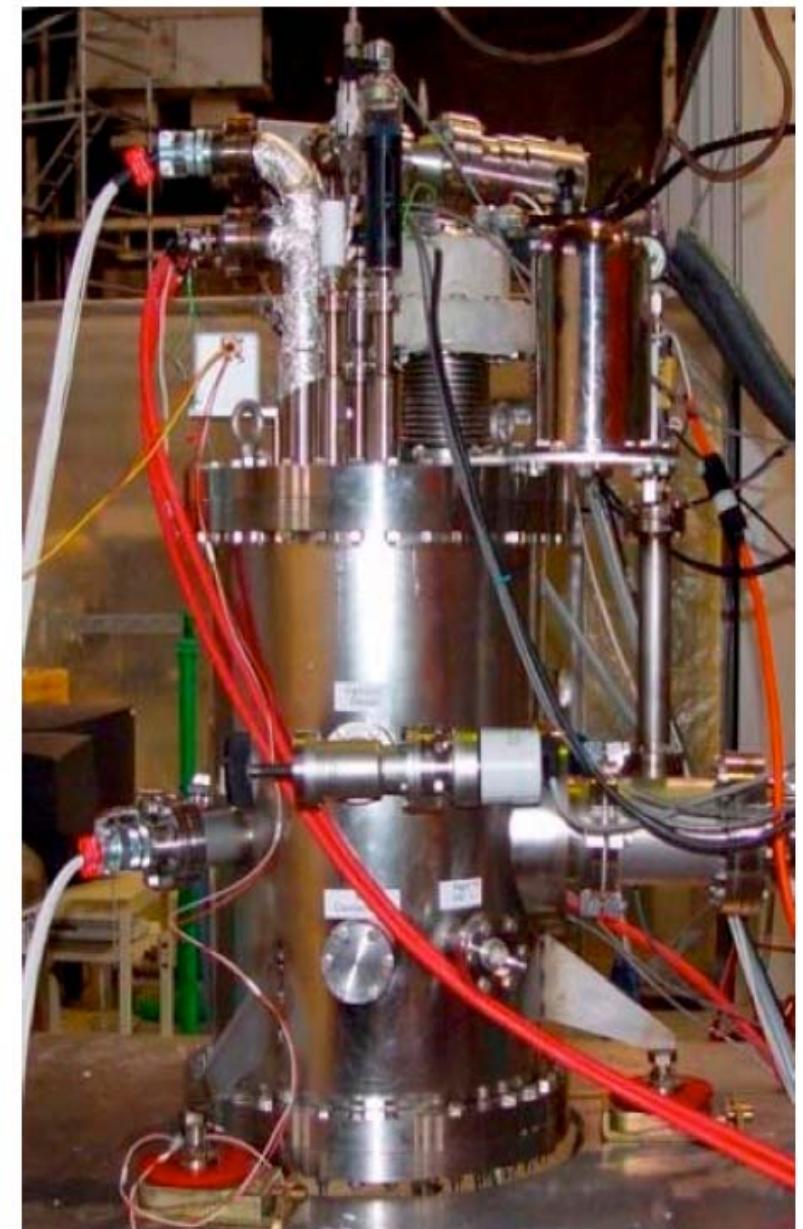
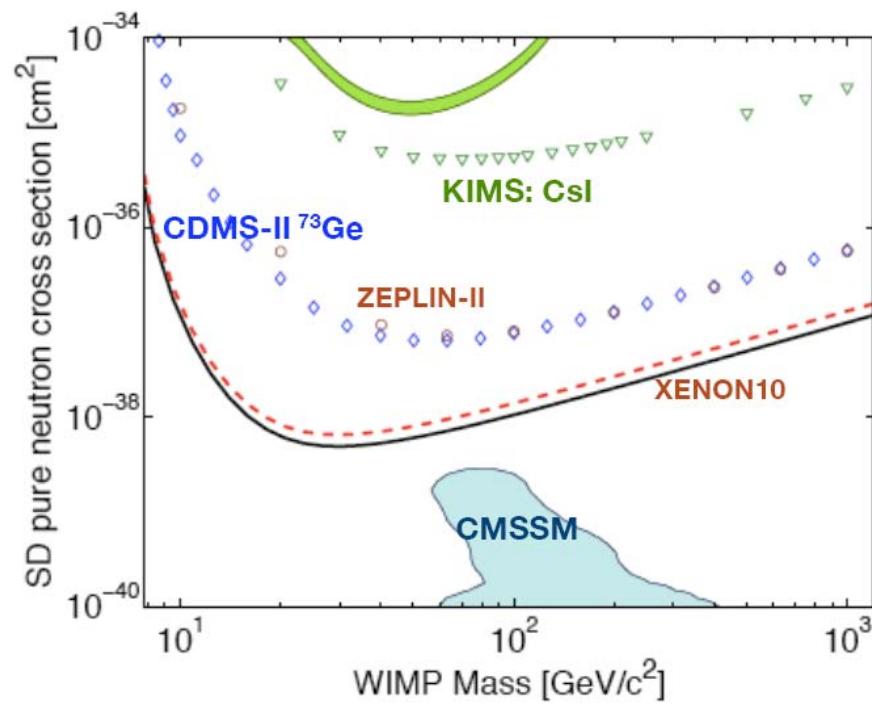
Secondary scintillation S2 (proportional signal in gas Xe) : mostly on the top array

- ✓ **xy position** reconstructed through the S2 light pattern on the top array ($Xe10 \sigma_{xy} \sim 1 \text{ mm}$)
- ✓ **Z position** reconstructed through the *Drift time* ($Xe10 \sigma_z \sim 0.3 \text{ mm}$)

REMINDER: XENON10

In operation at LNGS 2006-2007

- Physical **active region** : cylinder $r=10\text{cm}$ $z=15\text{cm}$
22 kg LXe, 15 kg active, 5.4 kg fiducial
- **Shielding** 20 cm poly + 20 cm lead
- **Readout** : 89 PMTs Hamamatsu R8520 (48T+41B)
1"- Al body
Bialkali photocathode Rb-Cs-Sb
Quantum efficiency > 20% @ 178 nm



Roberto Santorelli – TeVPA 13/7/09

XENON100 collaboration

Roberto Santorelli – TeVPA 13/7/09



UCLA



Columbia



Rice



Zurich



Coimbra



Gran Sasso



MUENSTER



SUBATECH



WASEDA

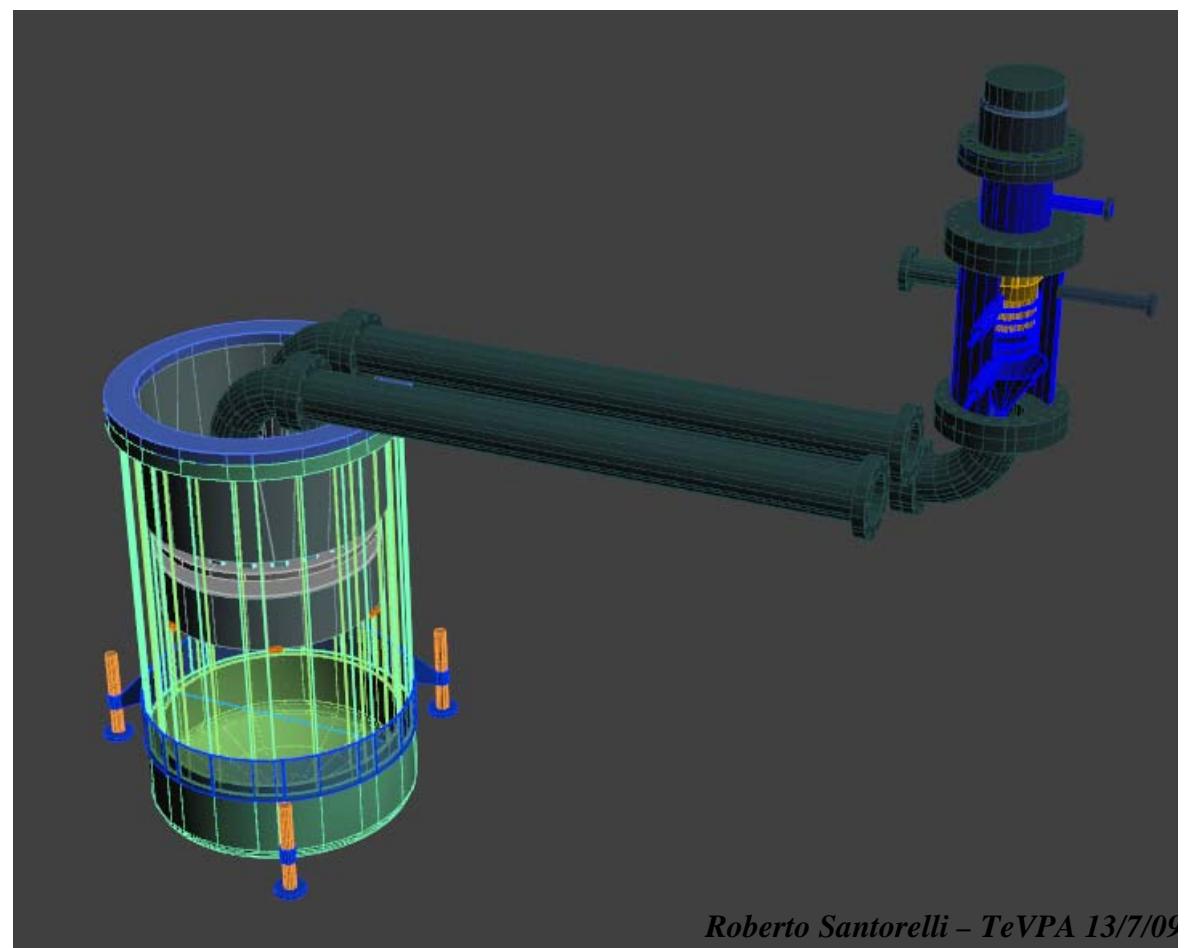
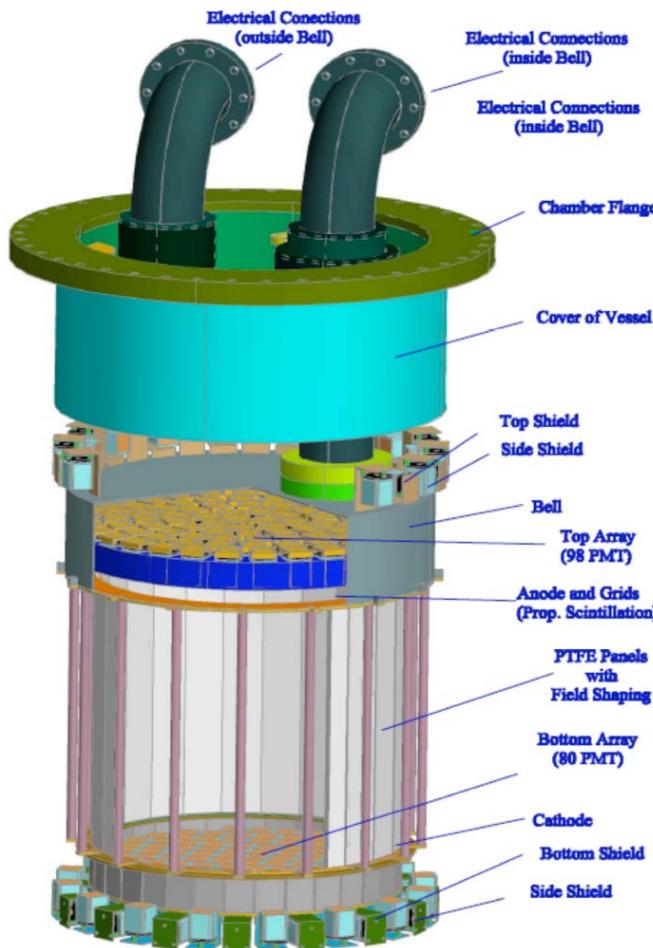


SJTU

Goal: gamma background reduction by ~100 and fiducial mass increase by ~10 respect to XENON10

XENON100 DETECTOR

- New detector in the same location at LNGS
- ~170 kg total / ~65 kg target LXe (15 cm radius , 30 cm drift)
- Active LXe veto – improved shield (Pb,Poly,Cu,N₂ purge)
- New high QE (>32% @175nm) low activity 1" R8520 PMTs (total 242 PMTs)
- Cryocooler and feed-through outside the shield
- Material screening facility at LNGS (gamma background reduction ~100))





DETECTOR: COOLING AND PURIFICATION

- 200 W PTR cryocooler
- Continuous Xe purification (Getter) →
- Kr distillation column
- 10 slpm recirculation (5 slpm Xe10)
- H₂O level < 1 ppb
- Electron drifted through the full gap



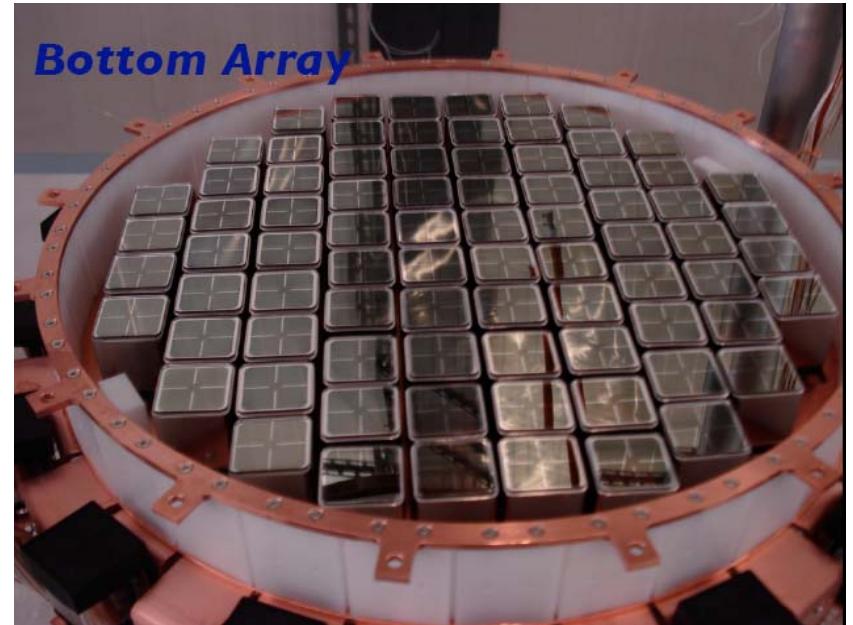
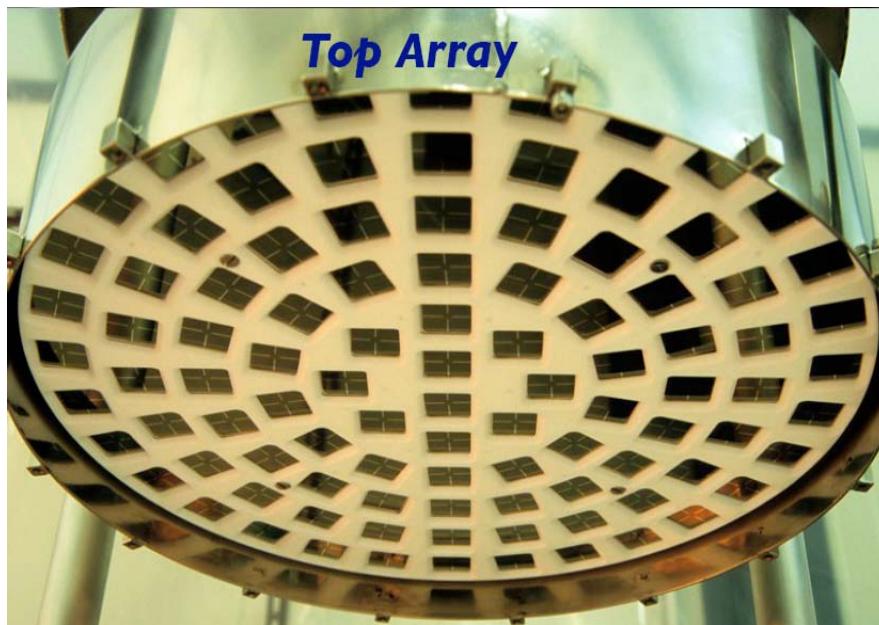
DETECTOR: PMTs

Roberto Santorelli - TeVPA 13/7/09

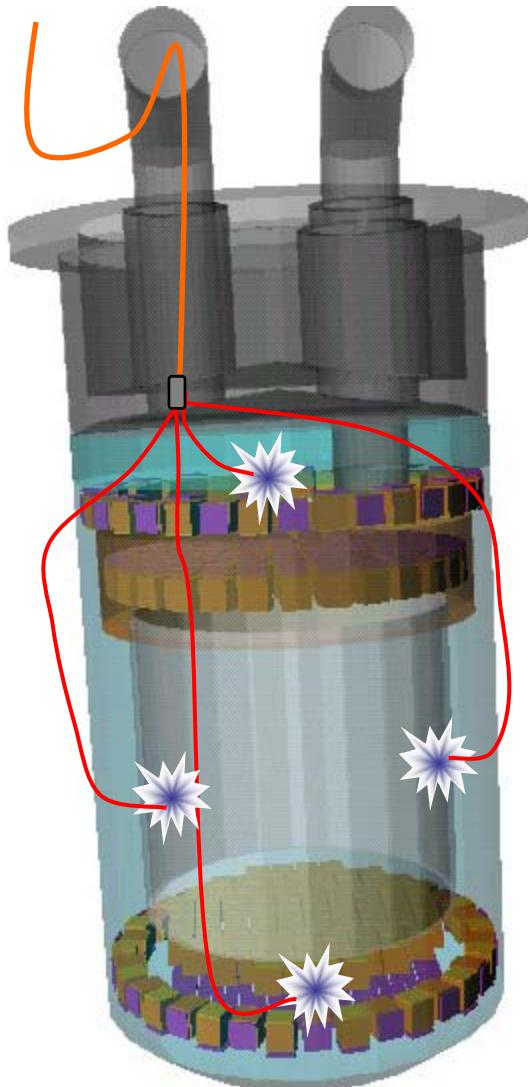
242 Hamamatsu R8520 :
*1" x 1" active area,
low radioactivity,
high QE (~ 33% @ 175 nm)*



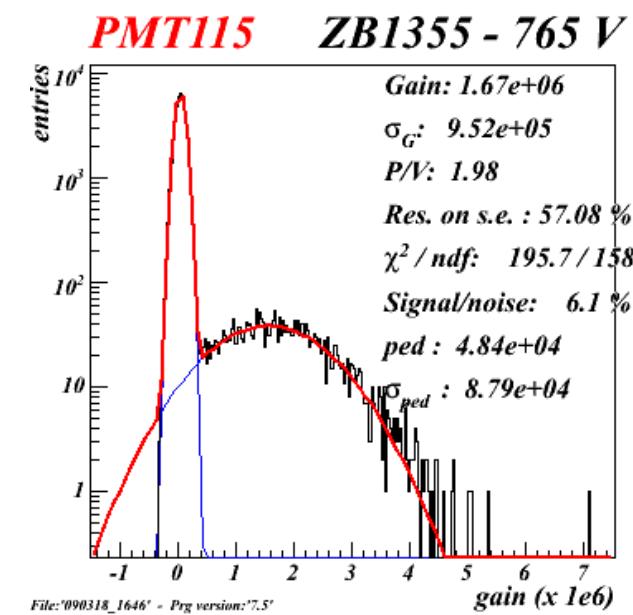
- 98 PMTs top array: selected for good position reconstruction (fiducial volume)
- 80 PMTs bottom array: selected for optimizing S1 light collection (low threshold)
- 64 PMTs active veto: Average LCE 4.7% → trigger efficiency in veto ~90% at 50 keVee



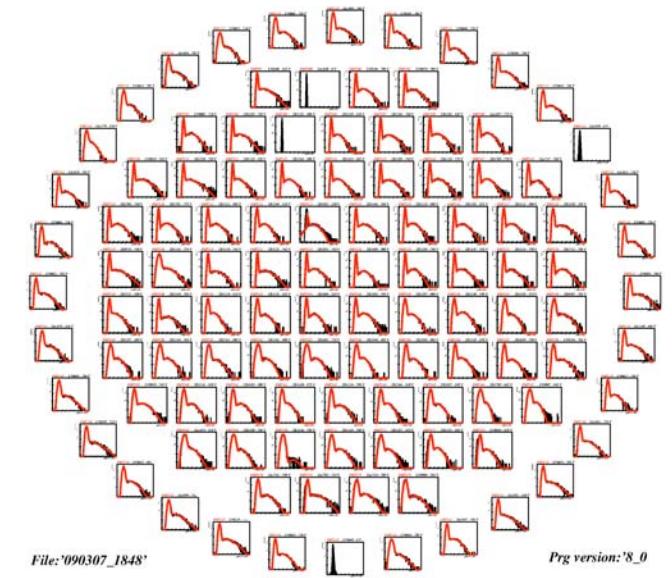
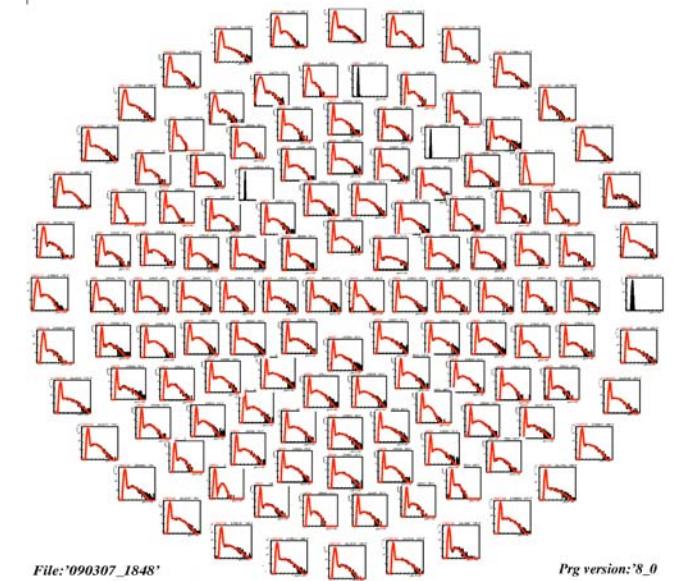
CALIBRATION : LIGHT



12 fibers ($200\mu m$ core)

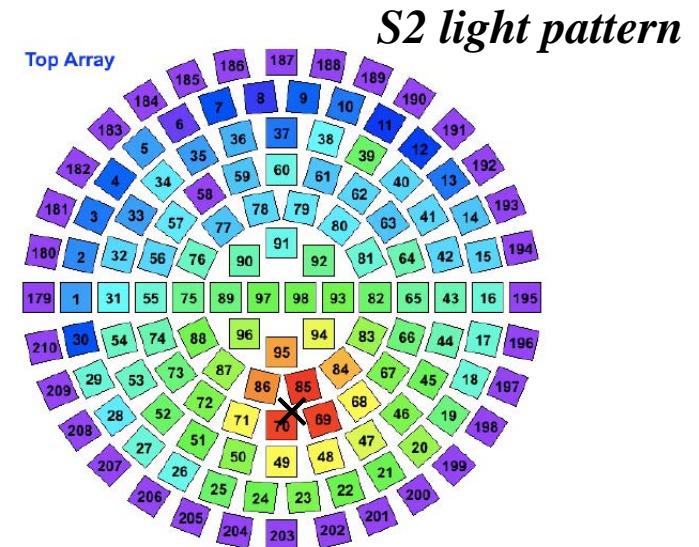
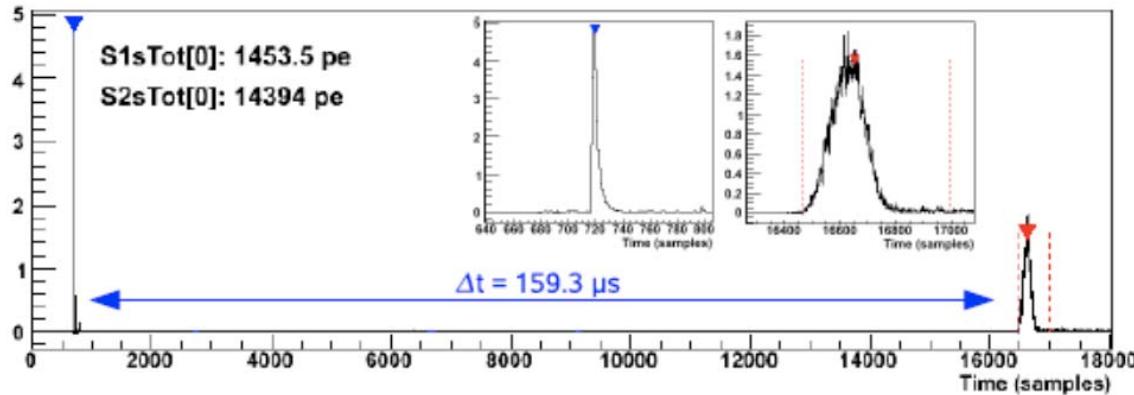


$\sim 1.7 \times 10^6$ equalized gain for all the PMTs

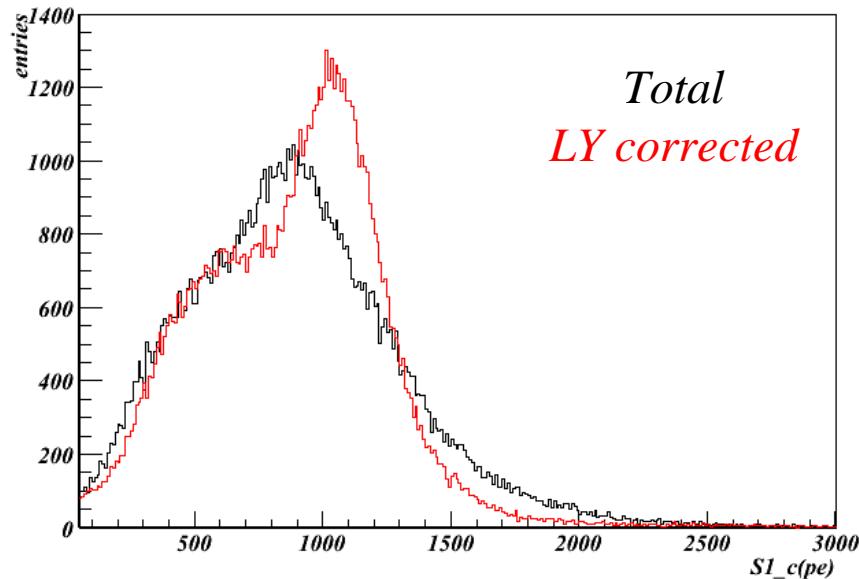


CALIBRATION: ENERGY

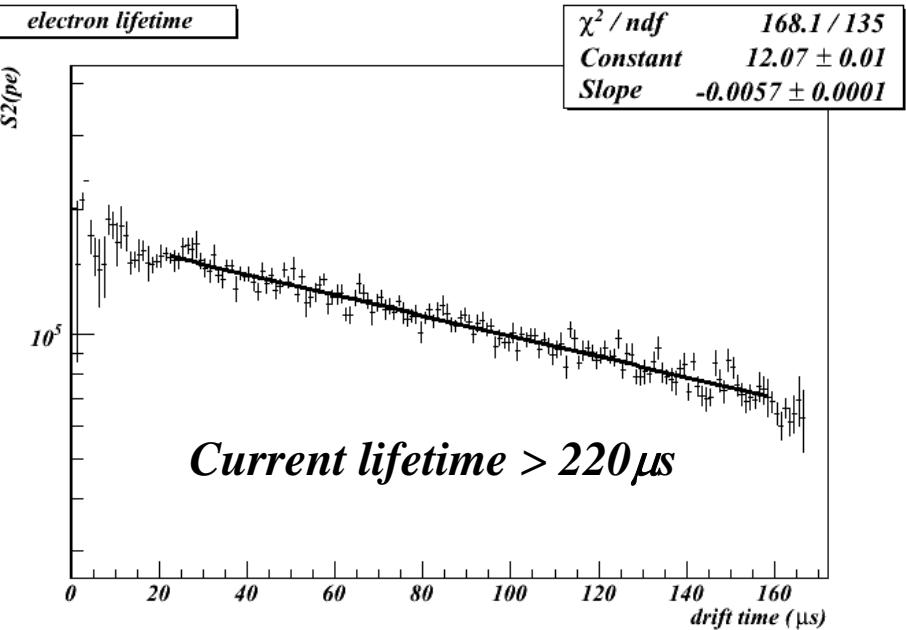
Cs^{137} source



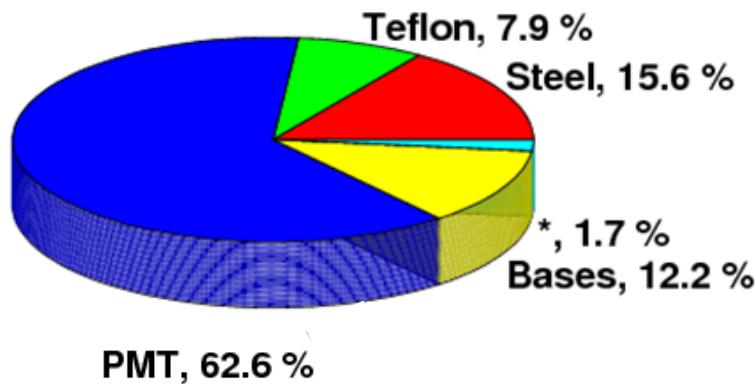
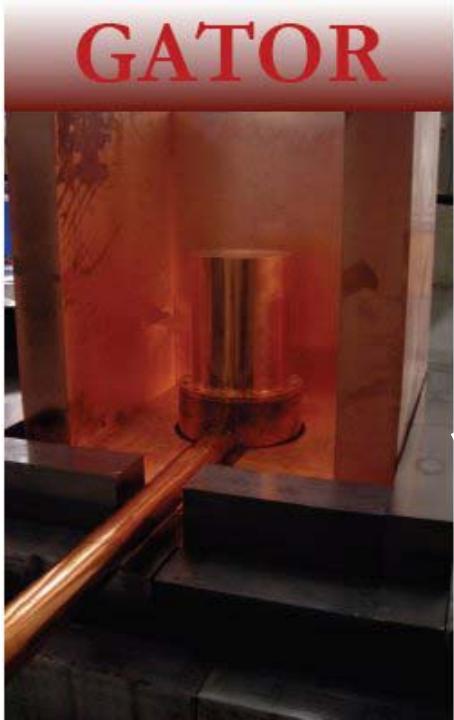
$S1$ corrected - ^{137}Cs



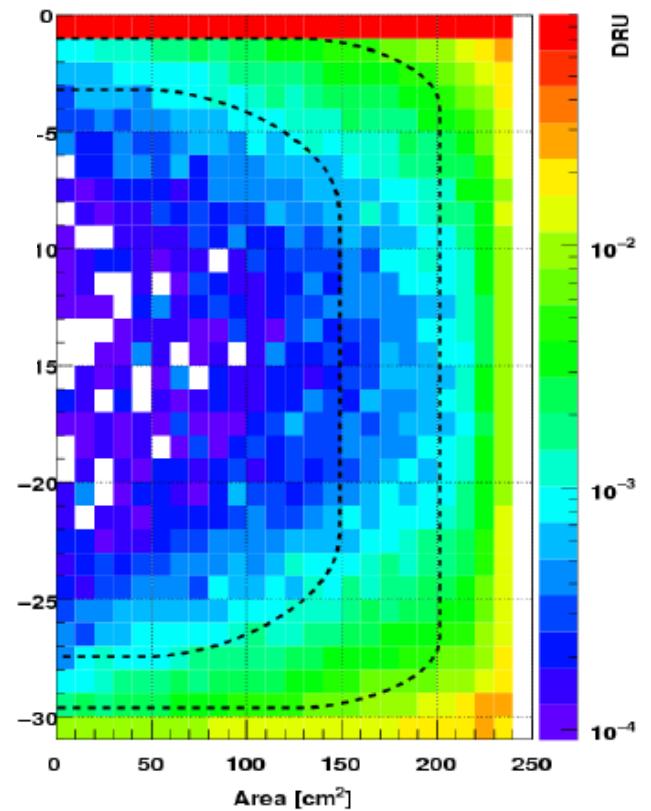
electron lifetime



BACKGROUND: GAMMA



Material	Rate[m dru] 50kg FV	Rate[m dru] 30kg FV
SS	3.98	1.68
Teflon	0.24	0.09
PMT	14.55	5.21
PMT Bases	1.61	0.49
Polyethylene	0.07	0.005
Support Bars	0.28	0.12
Copper	0.04	0.02
Total	<20.92	<7.69



*Single scatter event rate in
the region of interest (0-100keVee)*

Factor 2-3 reduction with active veto cuts

BACKGROUND: NEUTRON

Single nuclear recoil rated in WS region (4.5-26 keVr)

Materials	Rate [per year] in 50 kg FV mass	Rate [per year] In 30 kg FV mass
Stainless Steel	0.078	0.035
PMTs	0.255	0.108
Teflon	0.241	0.097
Lxe	0.002	0.001
Copper	0.105	0.048
Lead	0.004	0.002
Polyethylene	0.002	0.0006
Total material radioactivity	0.69	0.29
Rock-Concrete*	0.49 +/- 0.15	0.25 +/- 0.11
Muon-induced neutrons	0.54 +/- 0.24	0.10
Total neutron background	1.72	0.64

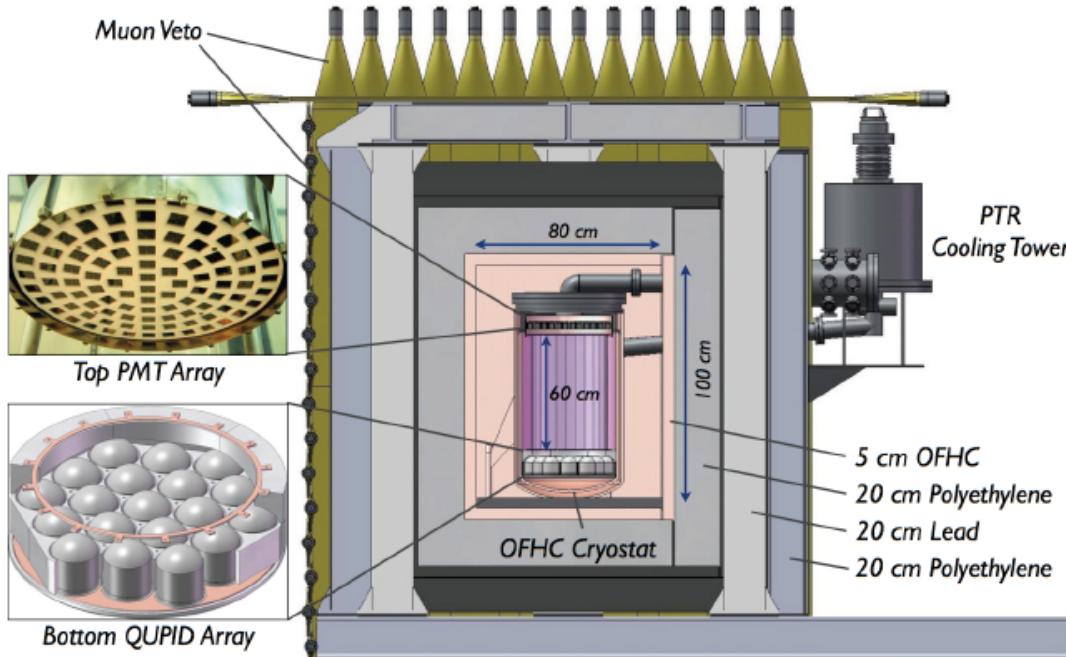
BACKGROUND : PRELIMINARY DATA

Rate (events/kg/day/keVee)

Energy (keVee)

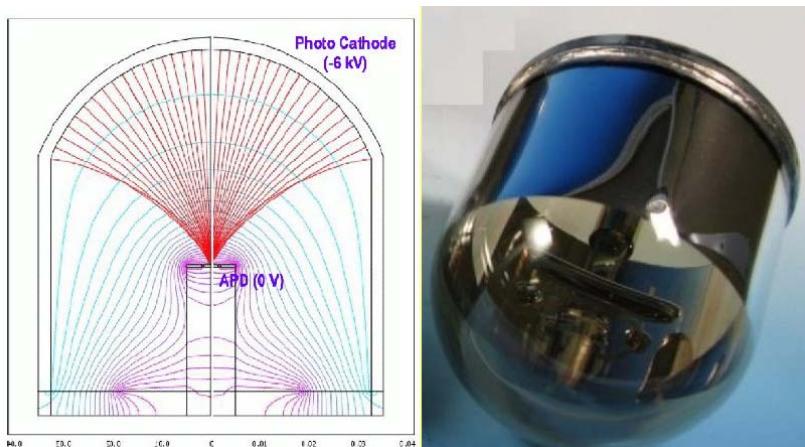
PRELIMINARY

XENON100+ (2010 - 2012)



- *Fiducial mass > 100 kg*
- *Decrease background by a factor 10*
- *Increase sensitivity by a factor 10*

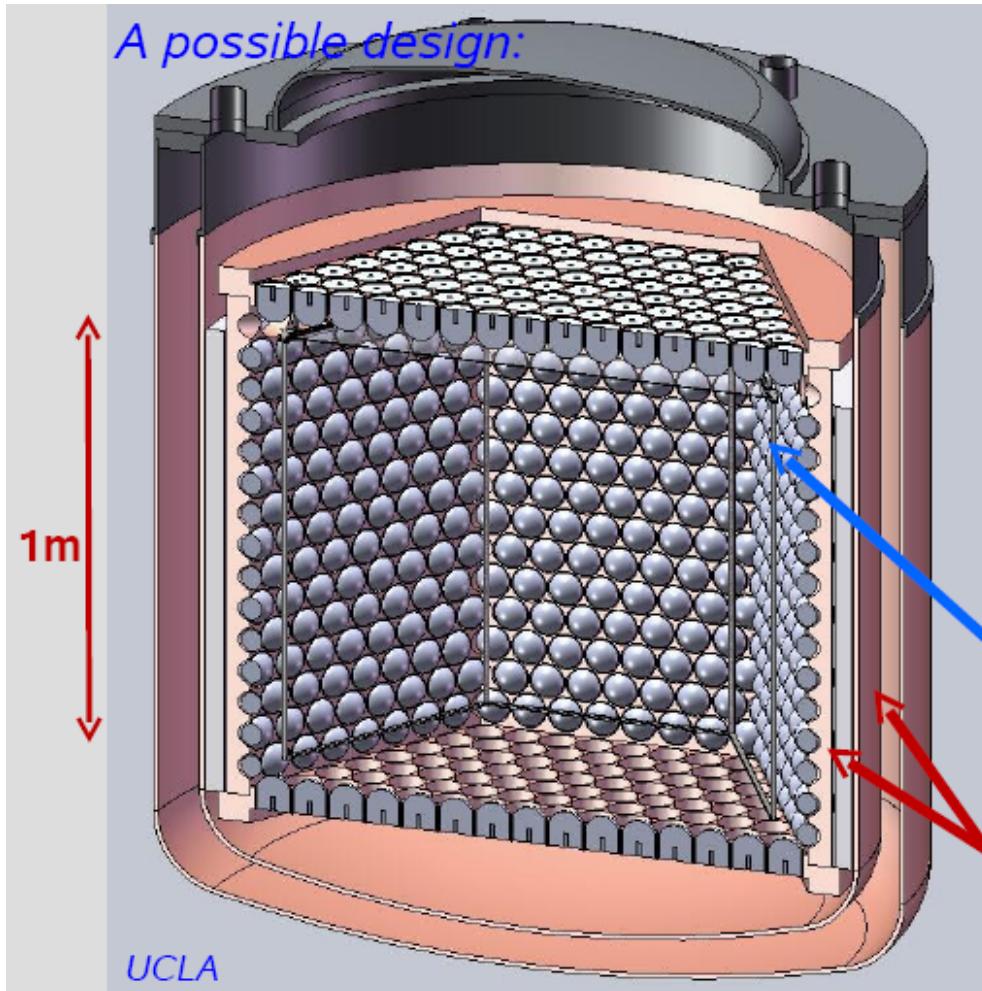
Funded by NSF
Strong non-US support



Quartz Photon Intensifying Detector

- Low radioactivity (<1mBq)*
- Large area (3")*
- High QE (>30%)*
- High spe resolution*

ULTIMATE GOAL: XENON 1t

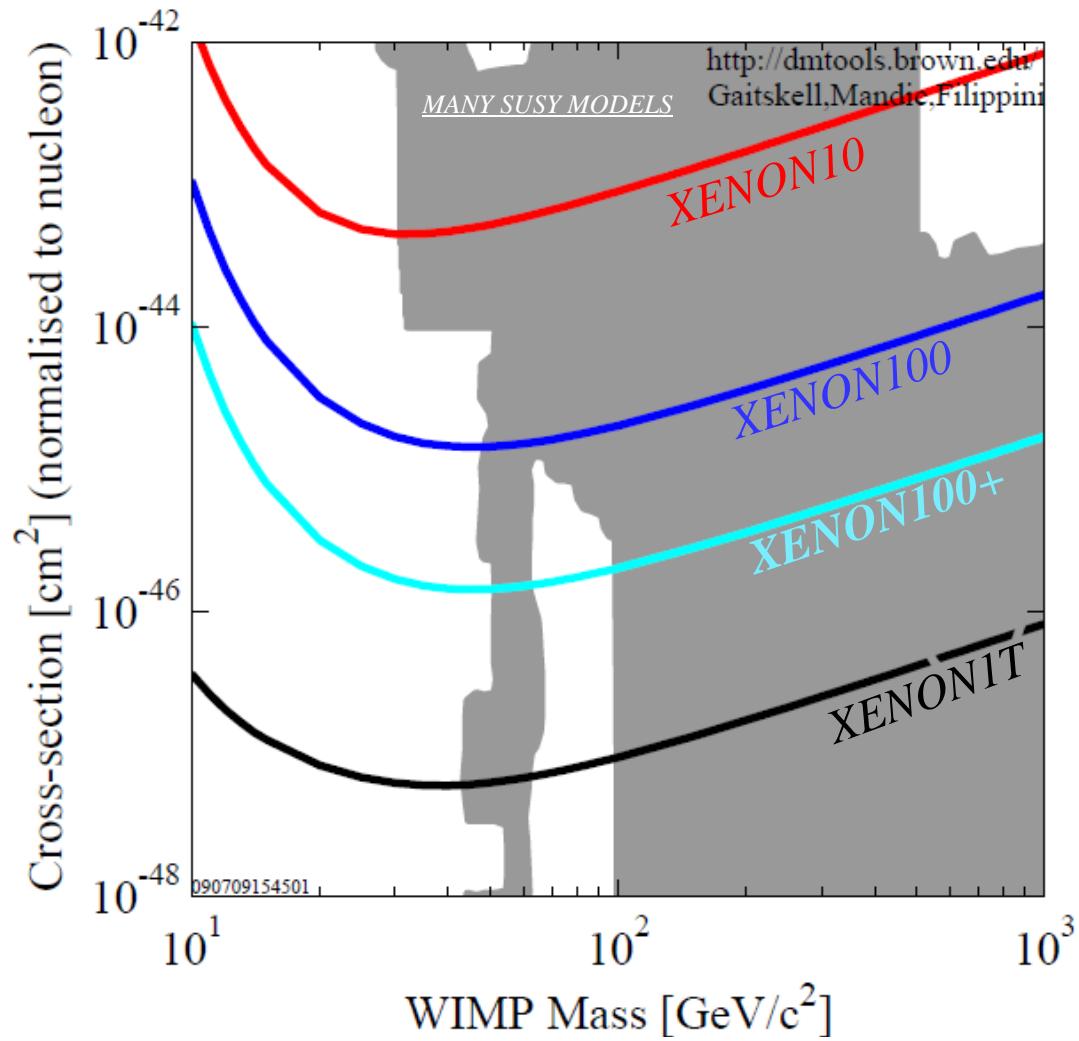


- *3t LXe total, 1t fiducial*
- *MC studies on going*
- *Timeline: 2013 - 2015*

Radiation free photon detectors

*OFHC cryostat
(Oxygen free high conductivity copper)*

PROJECTED SENSITIVITY



SUMMARY

- XENON10 → 1ST demonstration of the concept – result published in 2008
- XENON100 → increased mass, reduced background
fully operational – taking gamma calibration
preliminary data show the expected bkg level
- XENON100+ → Planned for 2010 -2012
Funded by NSF
- MC studies on XENON1T started