The XENON1T Experiment for Dark Matter Detection

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XENON1T Collaboration

Columbia University
Rice University
UCLA
University of Zurich
Coimbra University
LNGS & INFN
Shanghai Jiao Tong University

MPIK
Bologna University
Muenster University
Subatech
Nikhef
Weizmann Institute
Johaness Gutenberg University Mainz

The XENON Roadmap

past
(2005 - 2007)

XENON10

Achieved (2007) σ_{SI}*=8.8 x10*$^{-44}$ *cm*^{2}

Phys. Rev. Lett. ***100****, 021303 (2008)*

Phys. Rev. Lett. ***101****, 091301 (2008)*

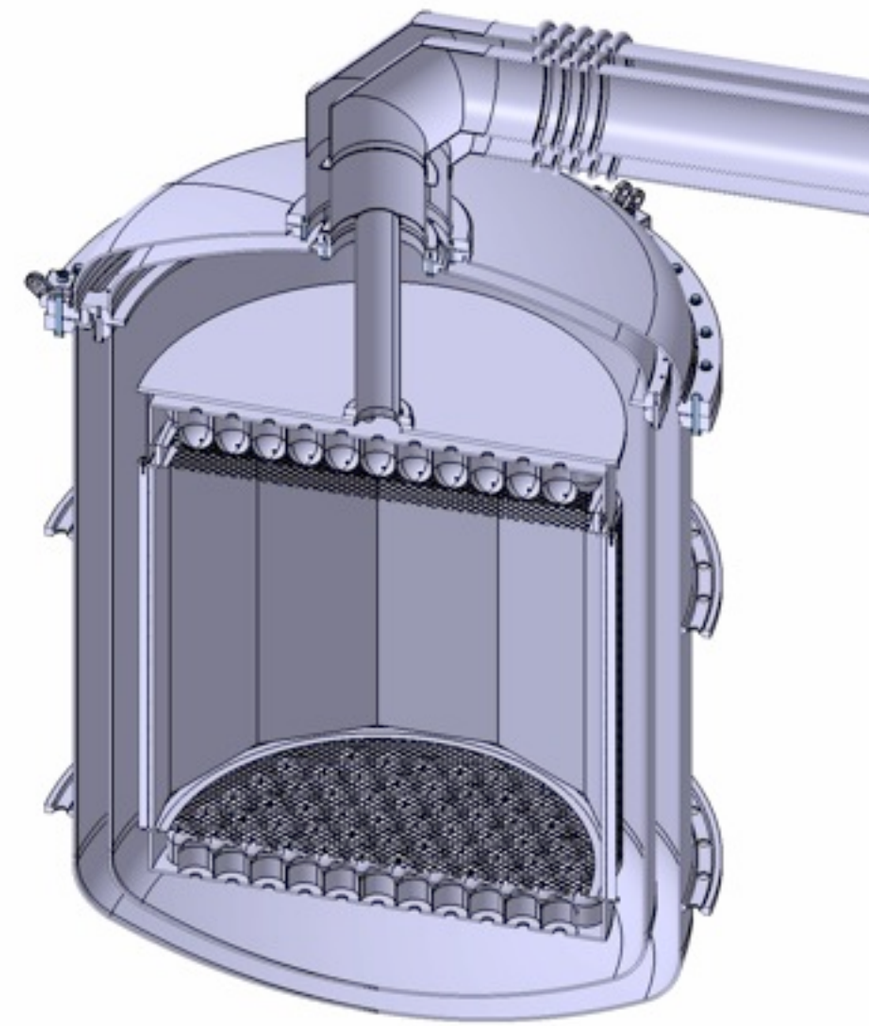
current
(2008-2010)

XENON100

Expected (2011) σ_{SI}~2x10^{-45} cm^2

Phys. Rev. Lett. ***105****, 131302 (2010)*

future
(2011- 2015)

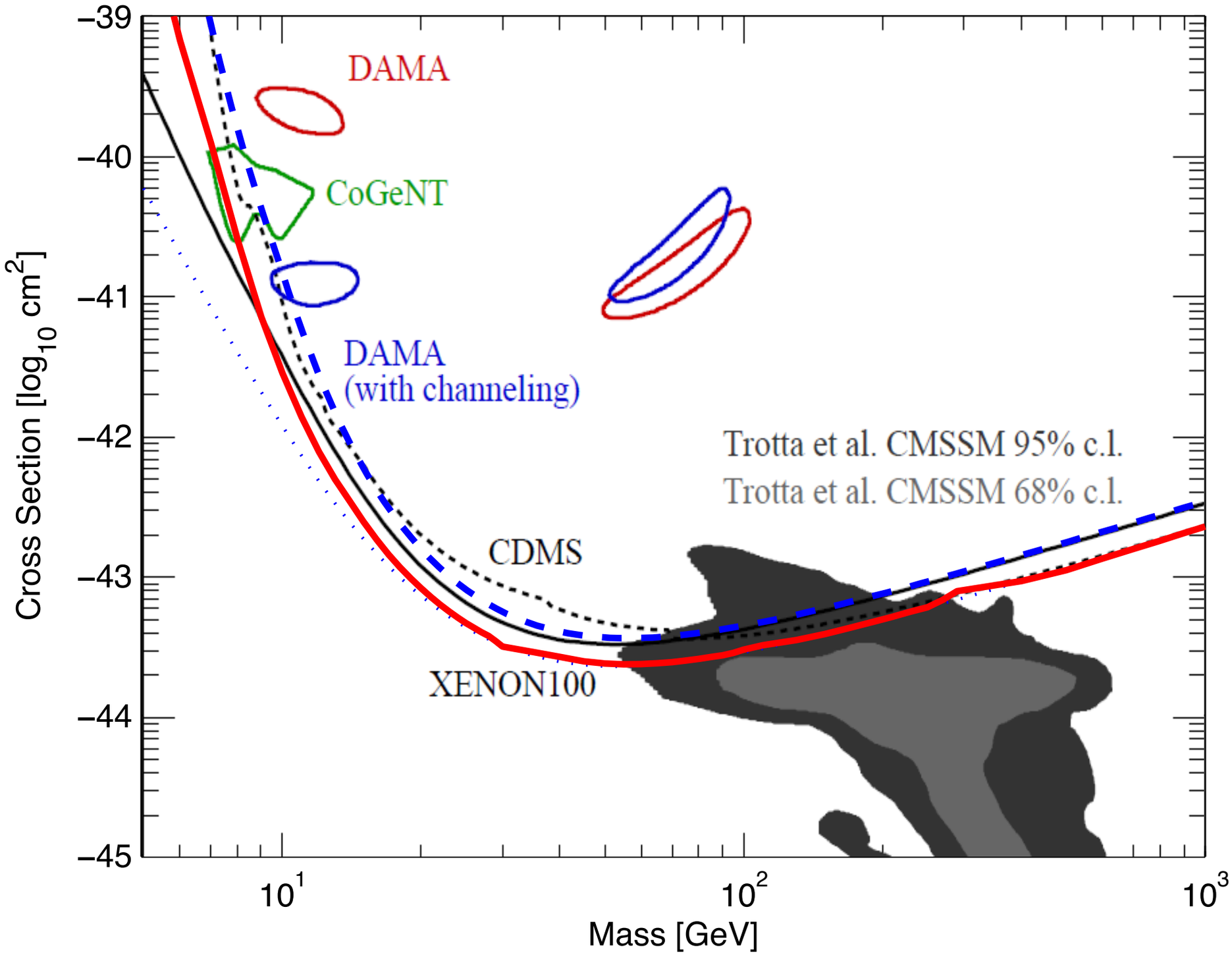


XENON1T

Goal: σ_{SI} ~10^{-47} cm^2

Dark Matter Direct Detection: State-of-the-Art

XENON100: Results from 11 days!



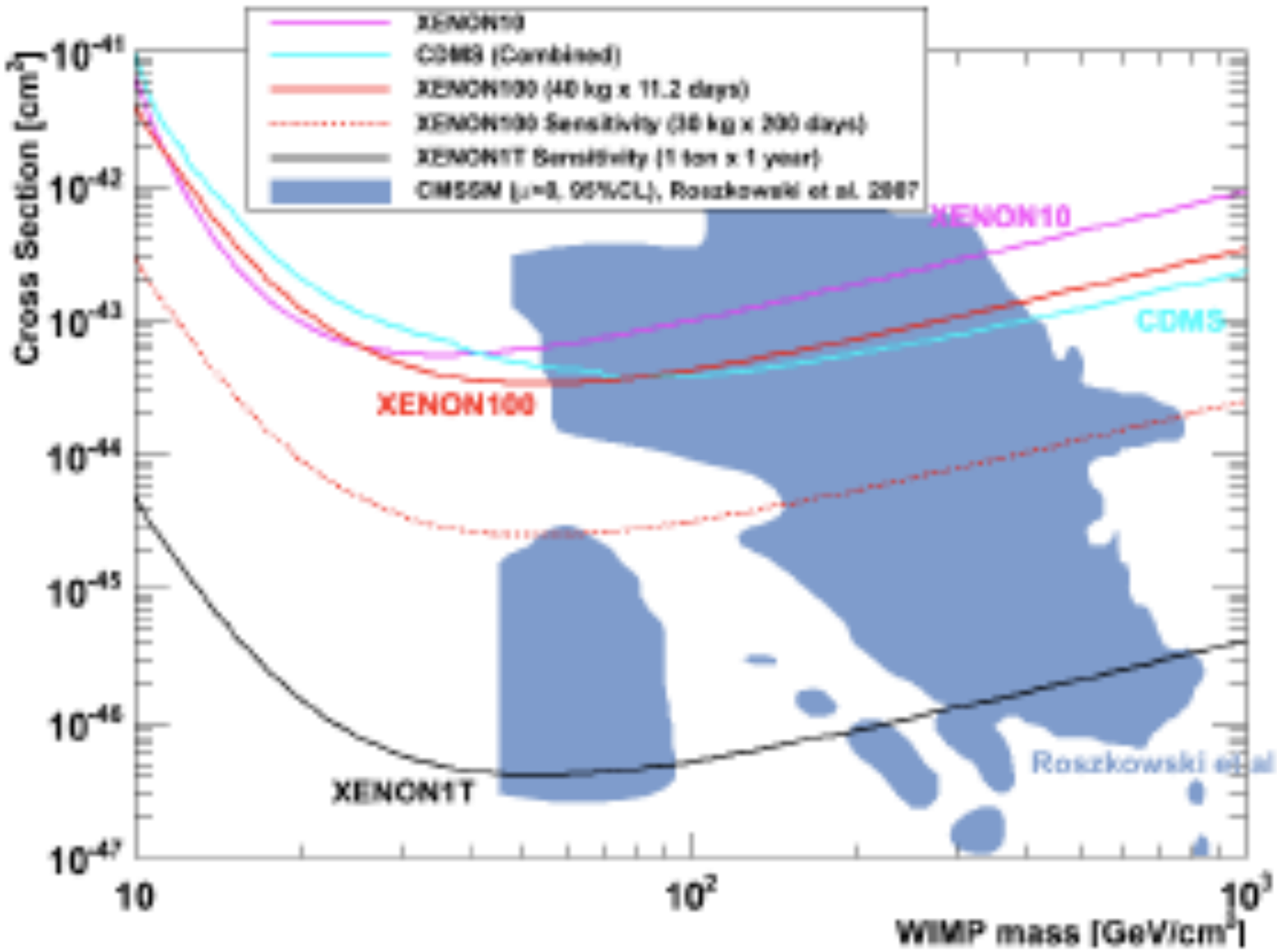
PRL conservative limit

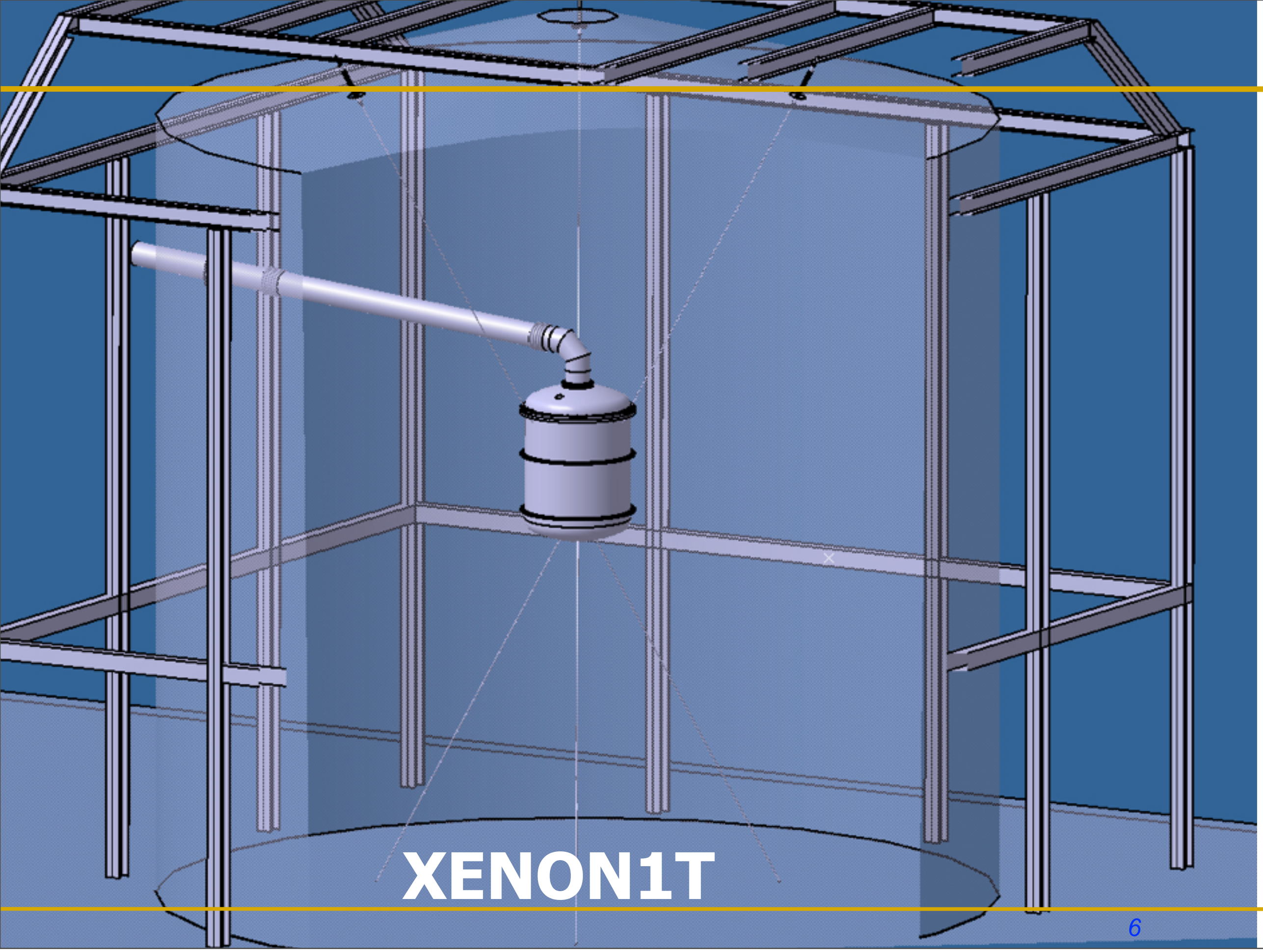
PRL best fit limit

Profile Likelihood limit taking into account full log(S2/S1)-Energy space and systematic uncertainty on Leff

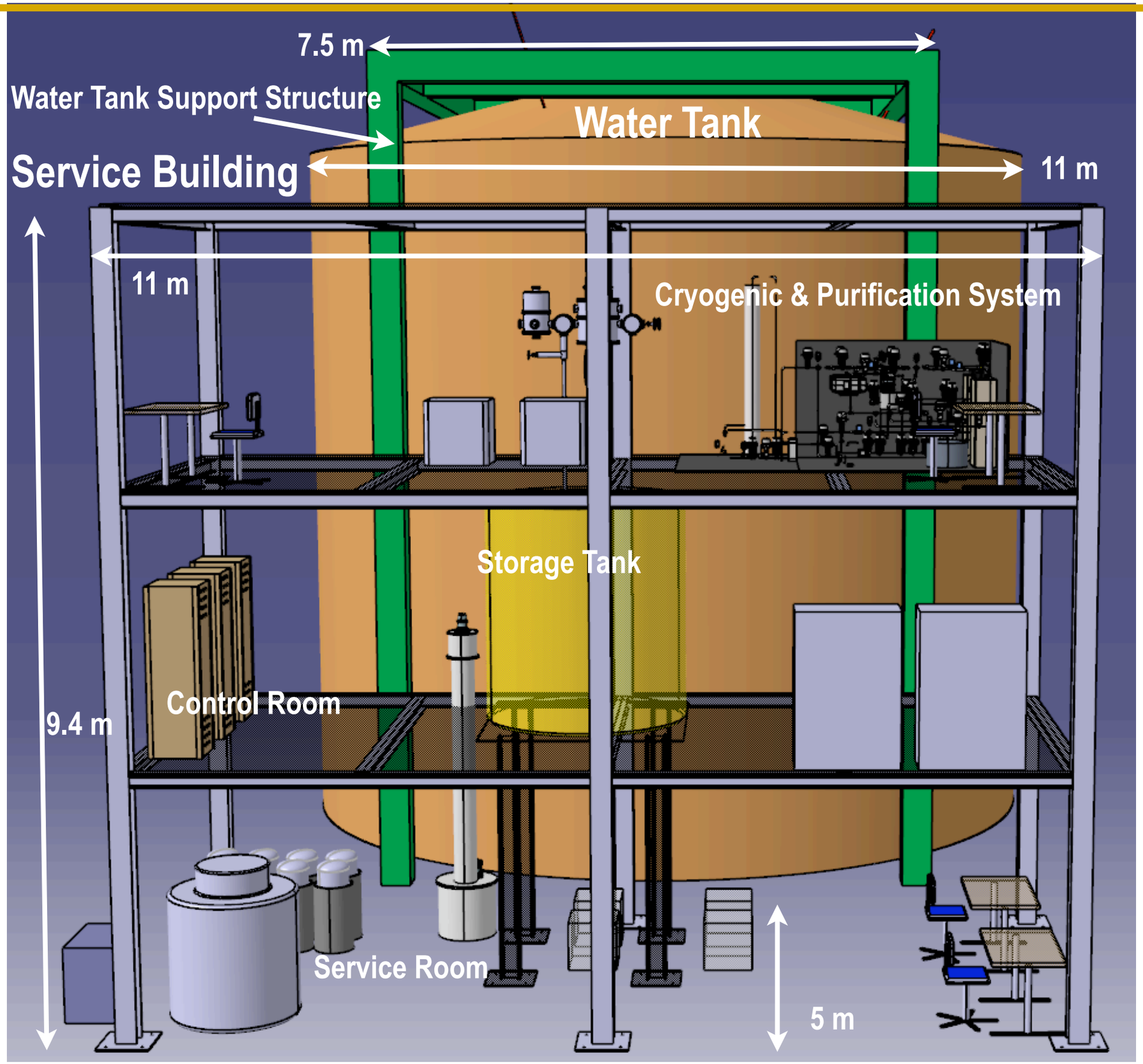
XENON1T Physics goals: 100 x more sensitivity

- XENON1T is based on a 2.5 ton XeTPC inside an active muon veto (water Cherenkov)
- aligned with US (and European) roadmaps: a G2 experiment as supported by PASAG

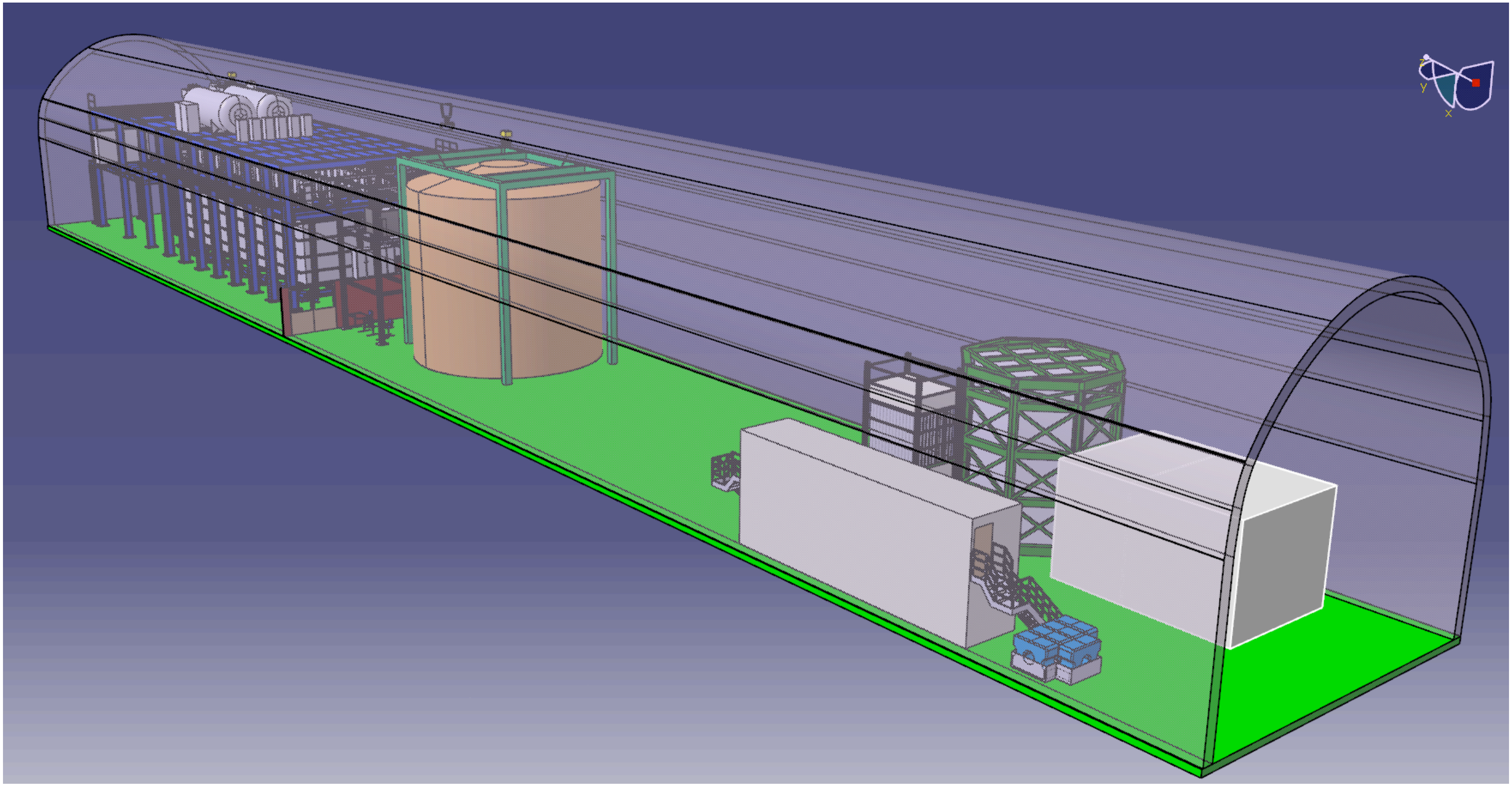



XENON1T

XENON1T Infrastructure

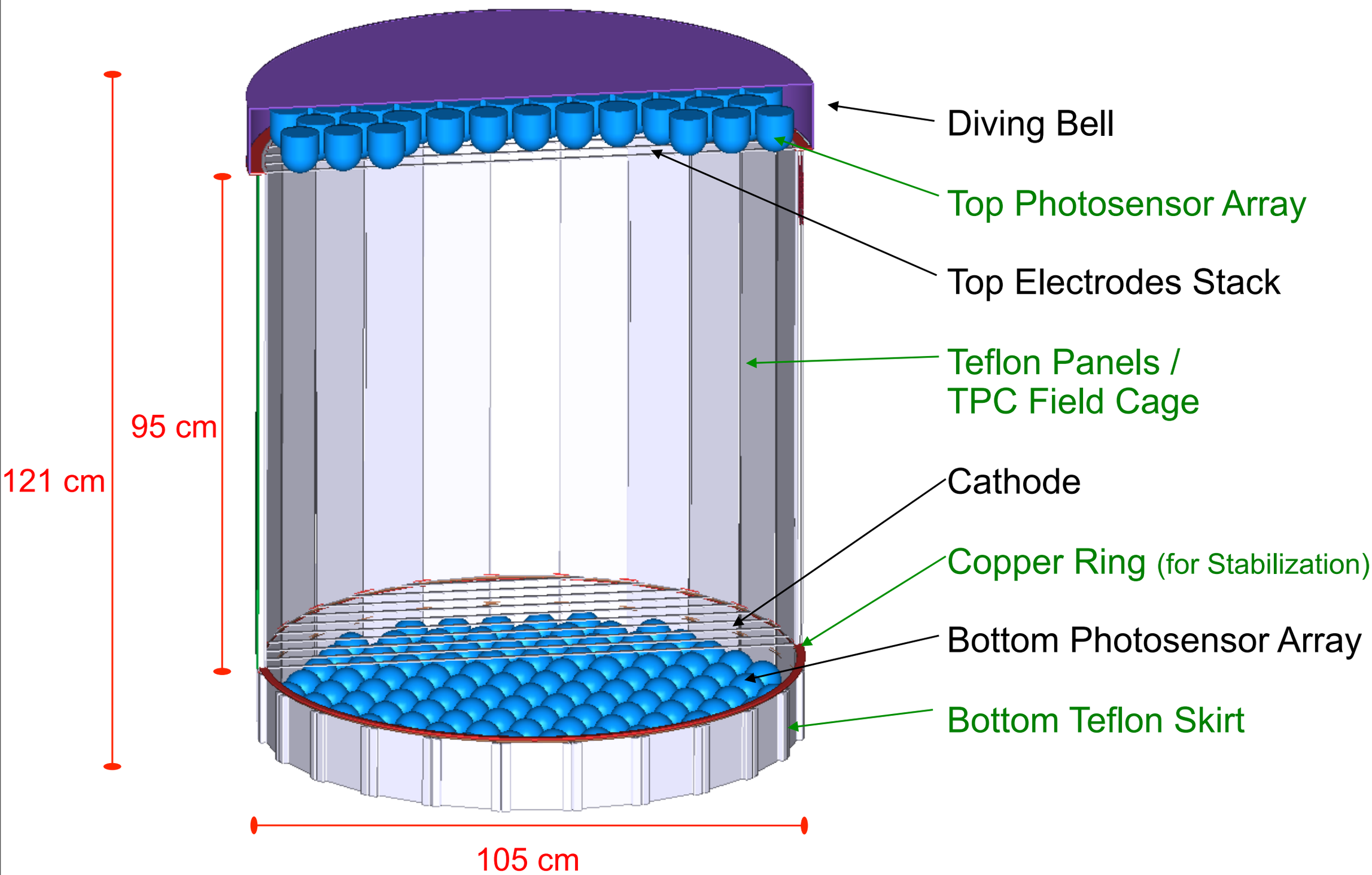


Baseline Location: LNGS

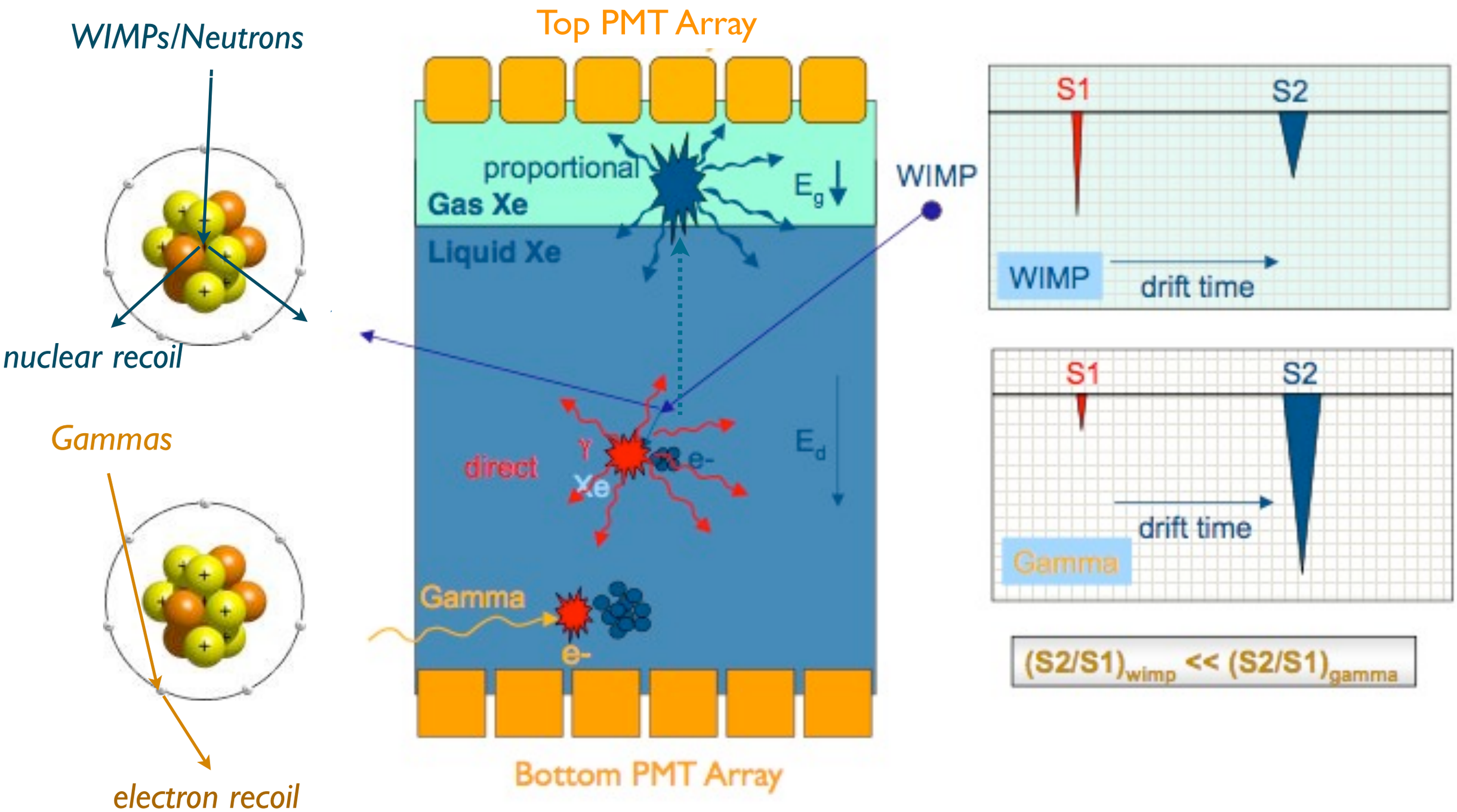


Alternative Location: LSM

The Detector



The XENON two-phase TPC



- Single electron and single photon measurement sensitivity
- > 99.5% ER rejection via Ionization/Scintillation ratio (S2/S1)
- 3D event-by-event imaging with millimeter spatial resolution

Requirements on PMTs

- Large area (~ 1 m^2) coverage
- VUV sensitive
- QE (178nm) > 30%
- operating in range -110 C to 50 C
- withstand up to 5 bar
- ultra low radioactivity (U/Th < 1 mBq/PMT)
- ideal geometry is 2” square & compact

HAMAMATSU

PRELIMINARY DATA SHEET
Oct, 2009

PHOTOMULTIPLIER TUBE

R8520-406

Bialkali Photocathode, Low Profile, Radioactivity is about 15 mBq/PMT MAX
26mm (1 Inch) Square, 10-stage, Head-on Type, Synthetic Silica Window

General

Parameter		Description / Value	Unit
Spectral Response		160 to 650	nm
Window Material		Synthetic silica	-
Photocathode	Material	Bialkali	-
	Minimum Effective Area	20.5 x 20.5	mm
Dynode	Structure	Metal channel Dynode	-
	Number of Stages	10	-
Weight		Approx. 23	g
Operating Ambient Temperature		-110 to +50	deg. C
Storage Temperature		-110 to +50	deg. C

Maximum Ratings (Absolute Maximum Values)

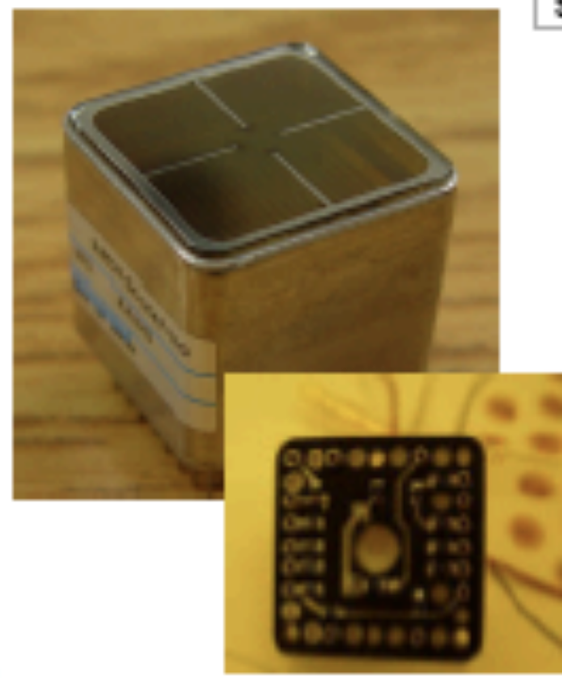
Parameter		Value	Unit
Supply voltage	Between Anode and Cathode	900	V
Average Anode Current		0.1	mA
Pressure-resistance		5	atm

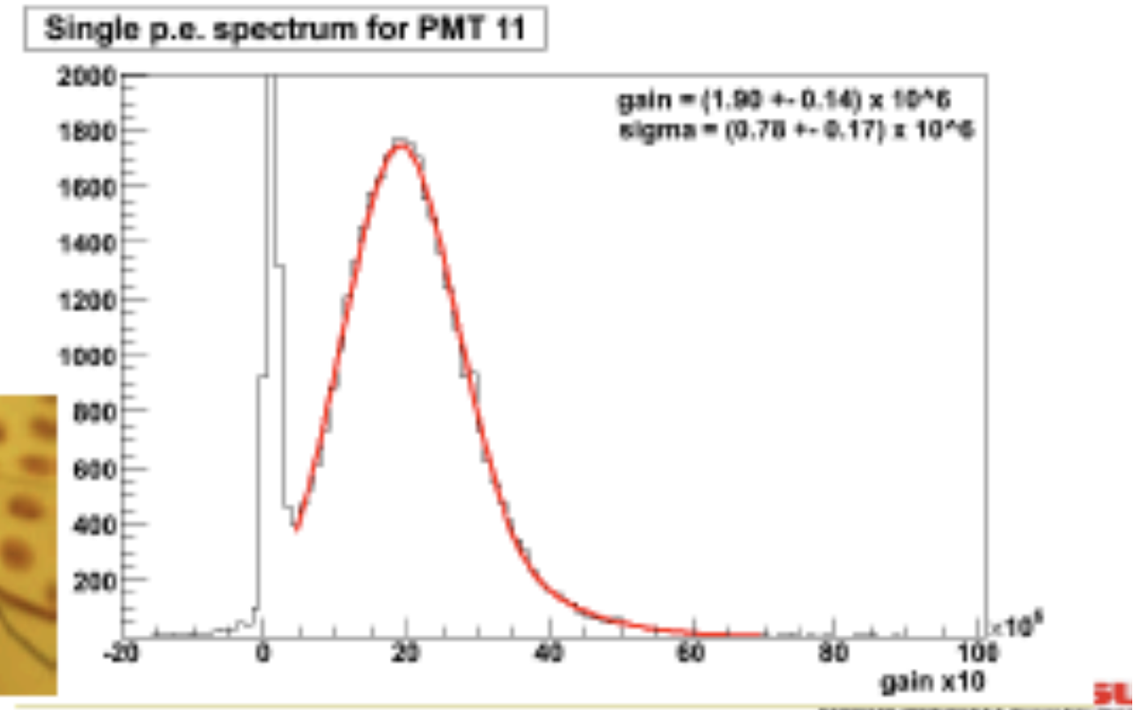
Characteristics at 25 deg. C

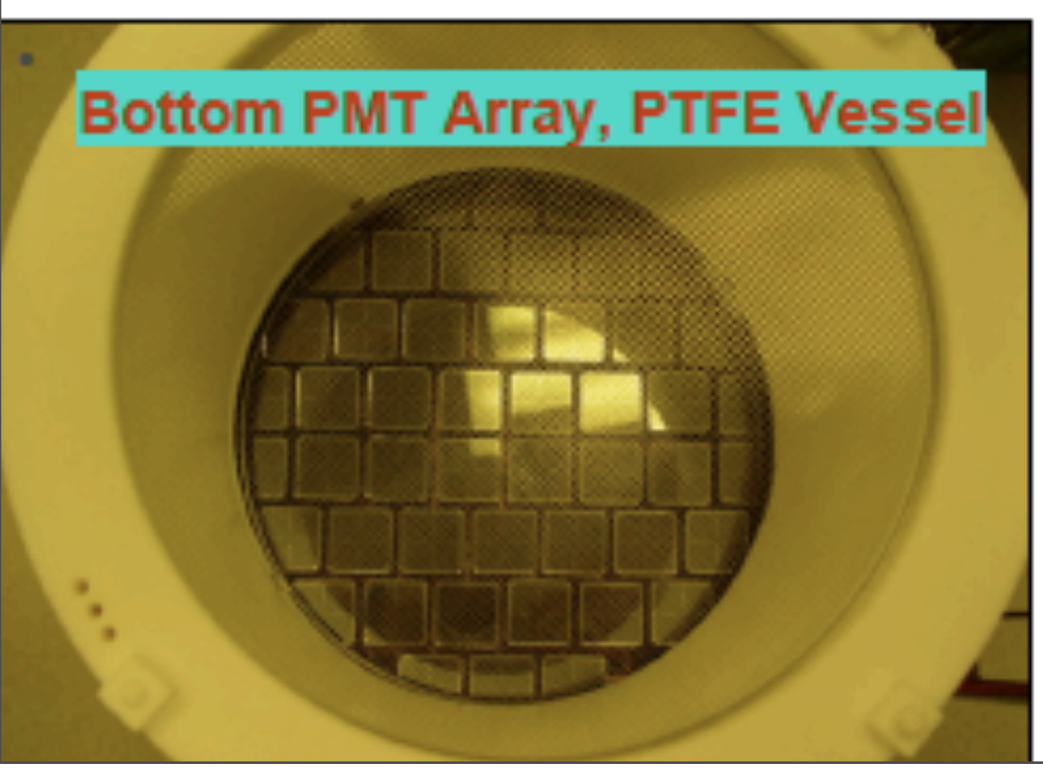
Parameter		Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856K)	-	100	-	uA/lm
	Quantum Efficiency at 175 nm	-	30	-	%
Anode Sensitivity	Luminous (2856K)	-	100	-	A/lm
Gain		-	1.0×10^8	-	-
Anode Dark Current (after 30 min. storage in darkness)		-	2	20	nA
Time Response	Anode Pulse Rise Time	-	1.8	-	ns
	Transit Time Spread (FWHM)	-	0.8	-	ns

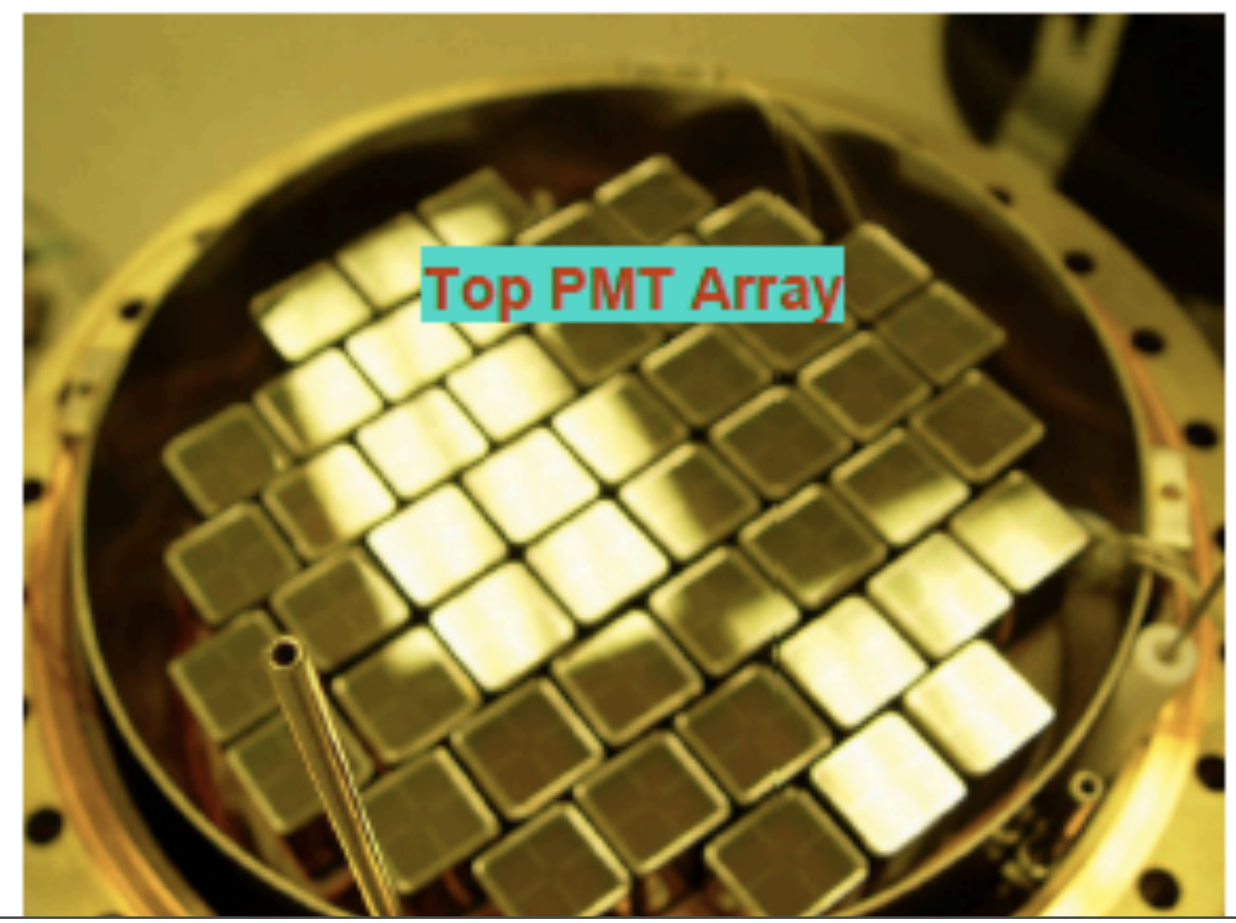
The XENON10 Photomultipliers

- Hamamatsu R8520 1" × 3.5 cm
- bialkali-photocathode Rb-Cs-Sb,
- Metal Channel; 10 dynodes
- Quartz window; at -100°C and 5 bar
- Quantum efficiency > 20% @ 178 nm
- Custom HV divider on Cirlex base

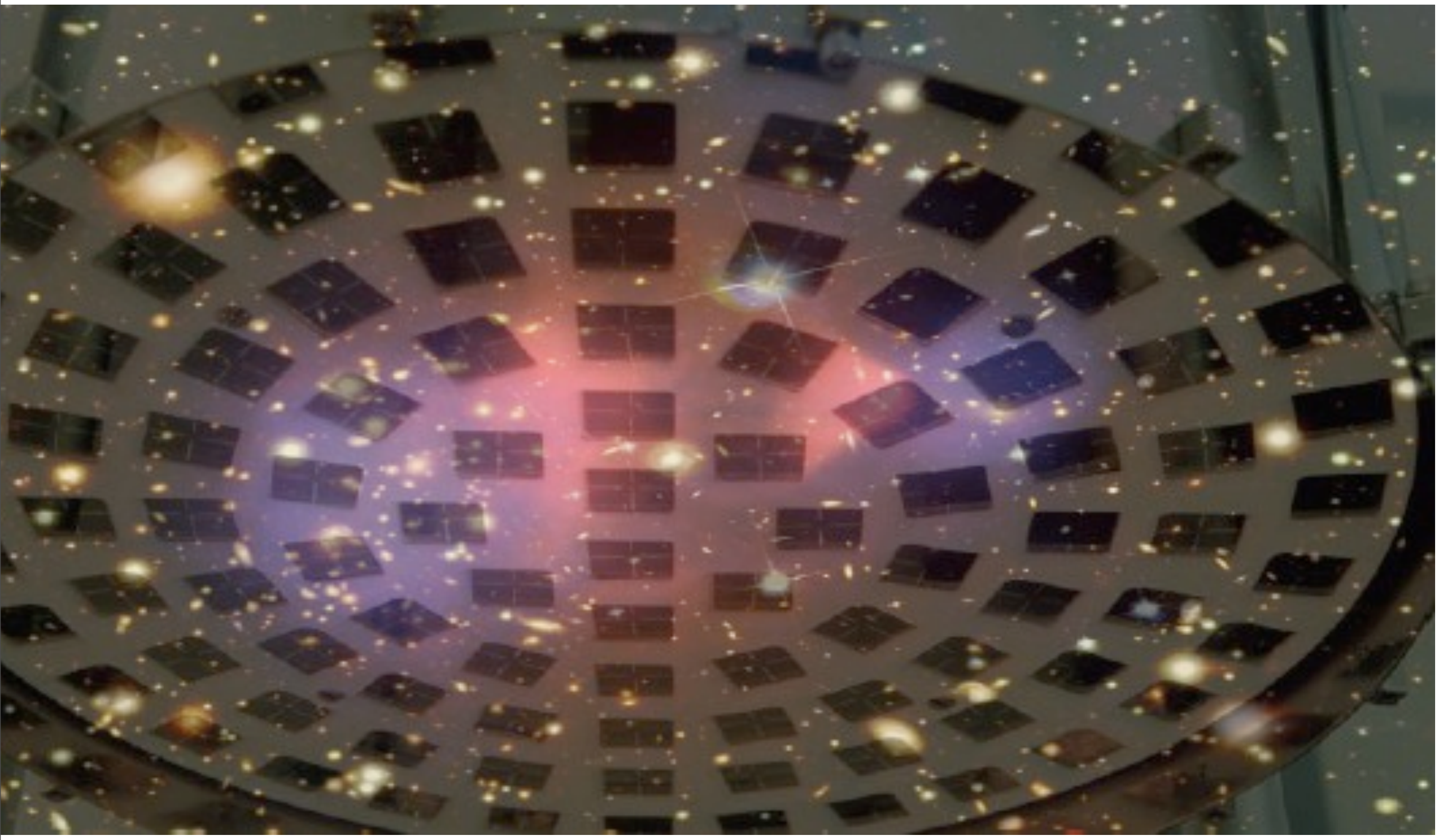






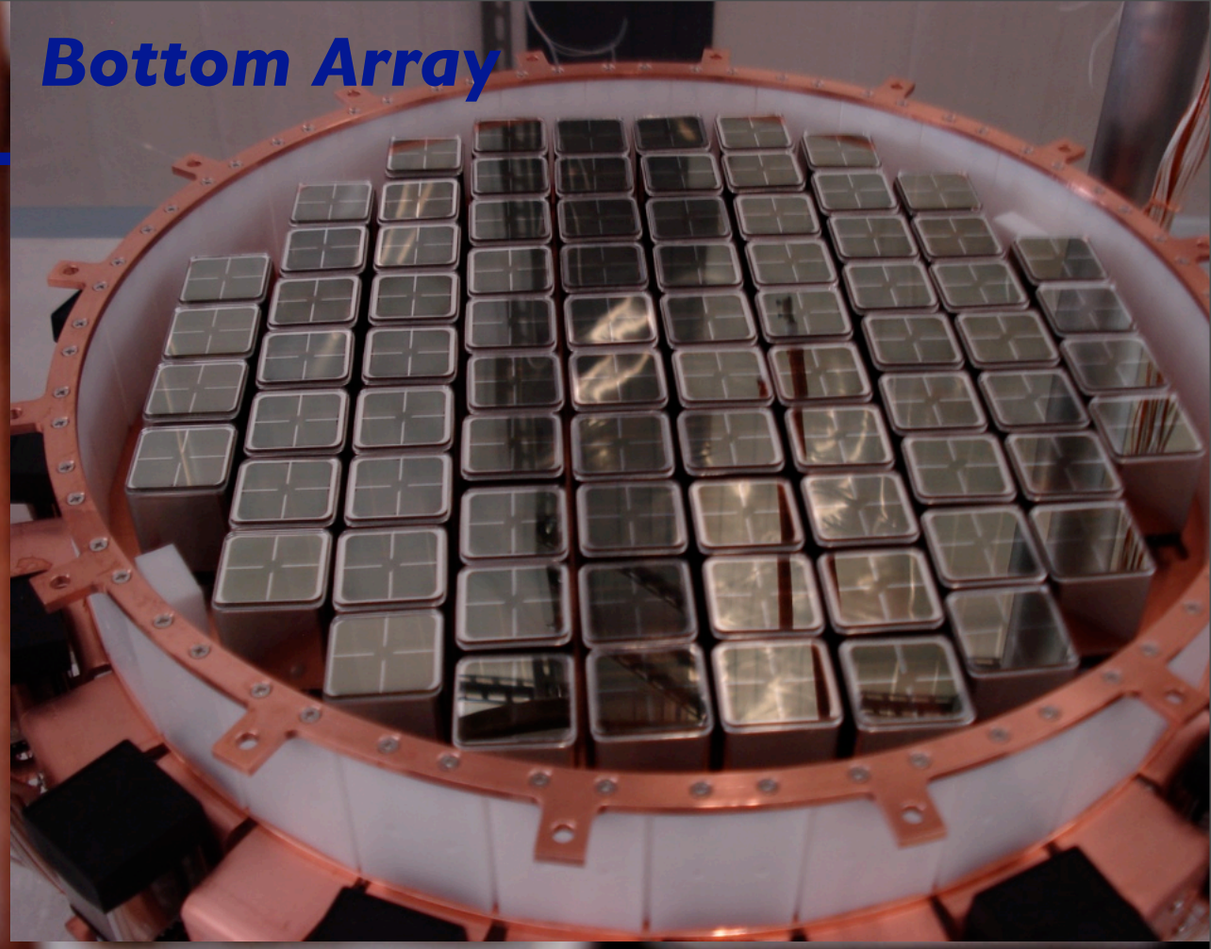


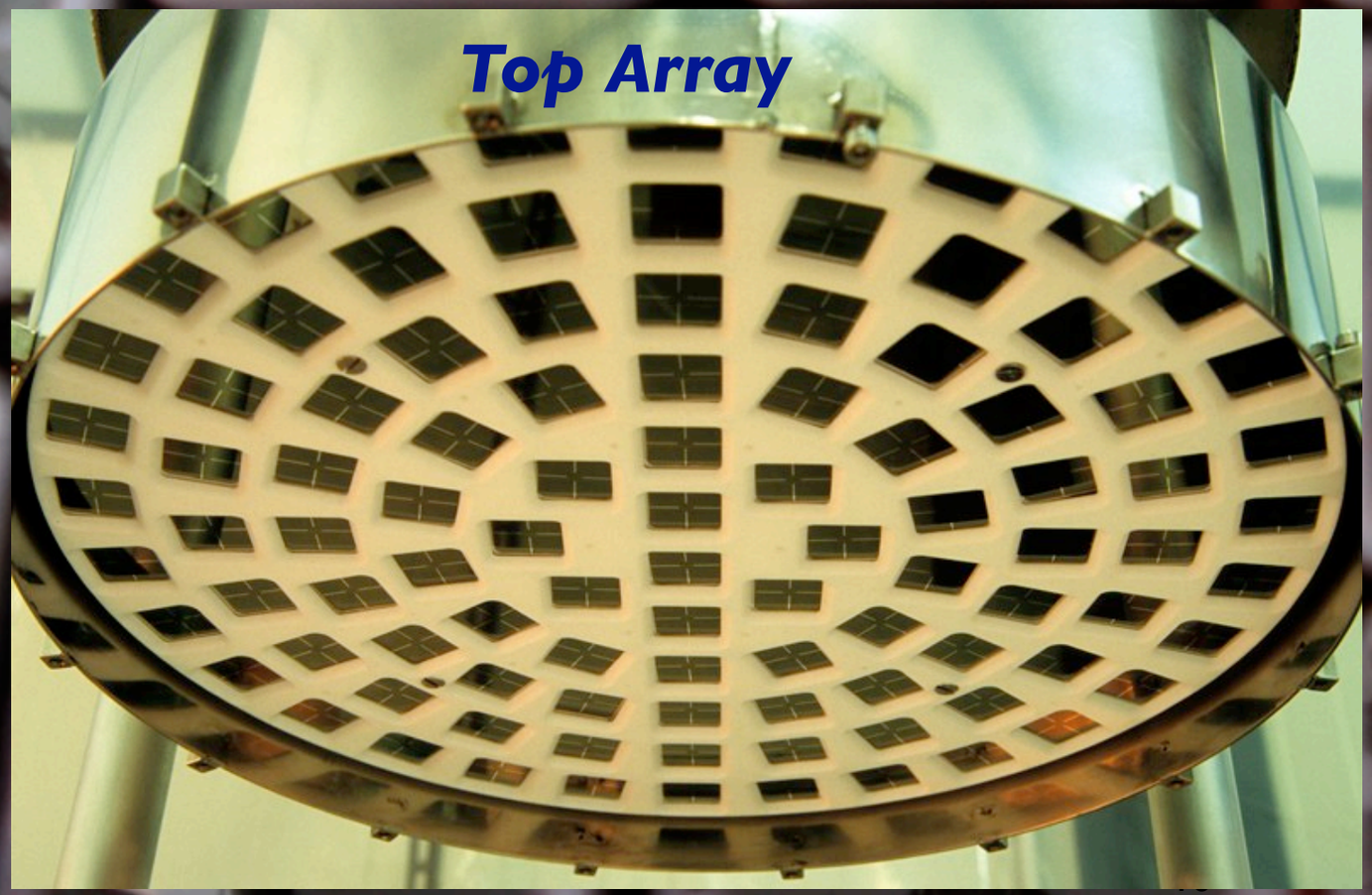
The XENON100 Photomultipliers



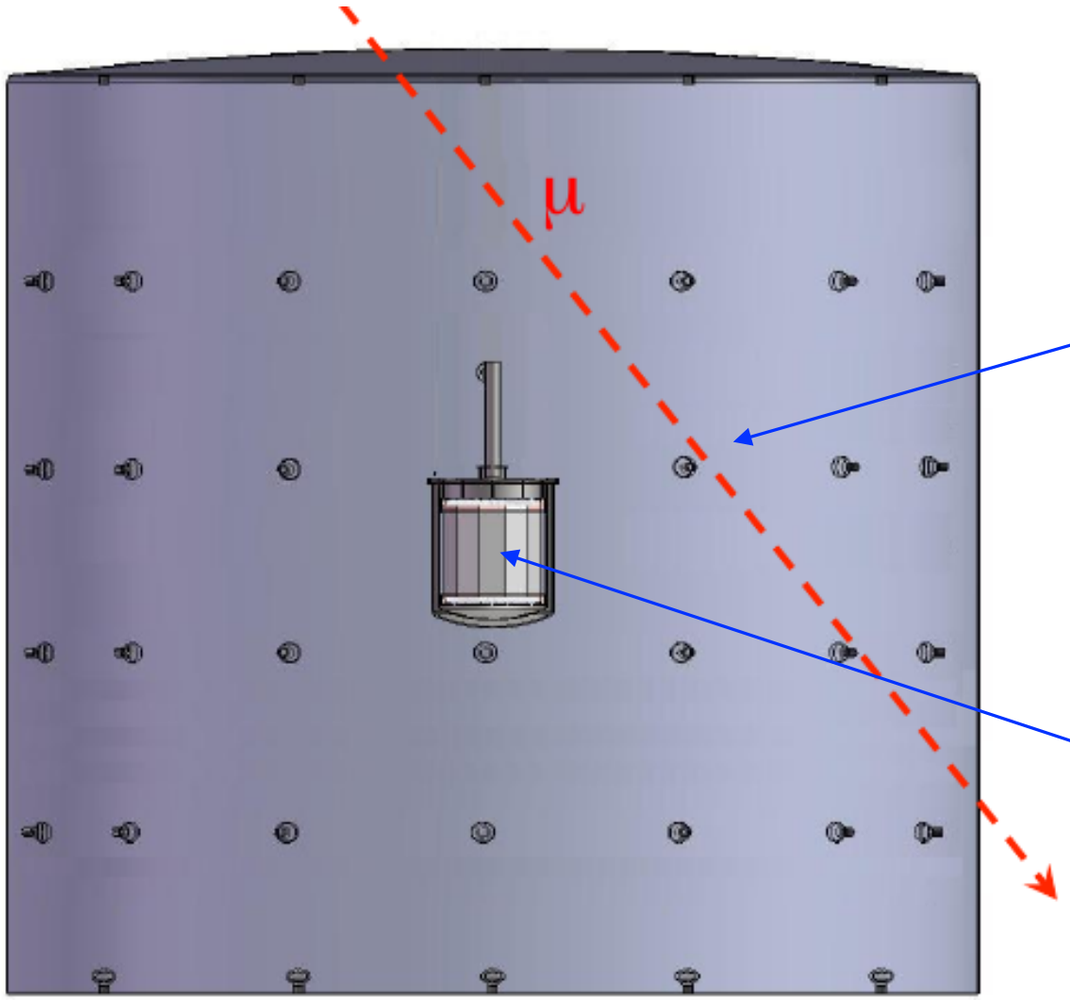
XENON100: The PMTs

- 242 PMTs (Hamamatsu R8520-06-Al)
- 1 " square metal channel developed for XENON
- Low radioactivity (<1 mBq U/Th per PMT)
- 80 PMTs for bottom array (33% QE)
- 98 PMTs for top array (23% QE)
- 64 PMTs for top/bottom/side Veto (23% QE)



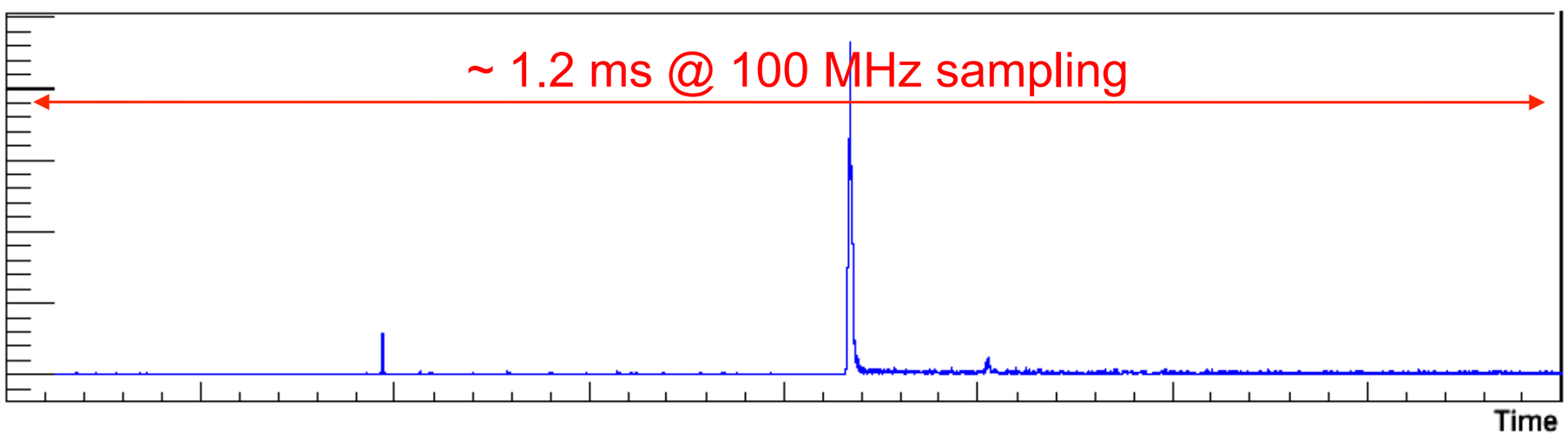


XENON1T Photosensors & DAQ Requirements

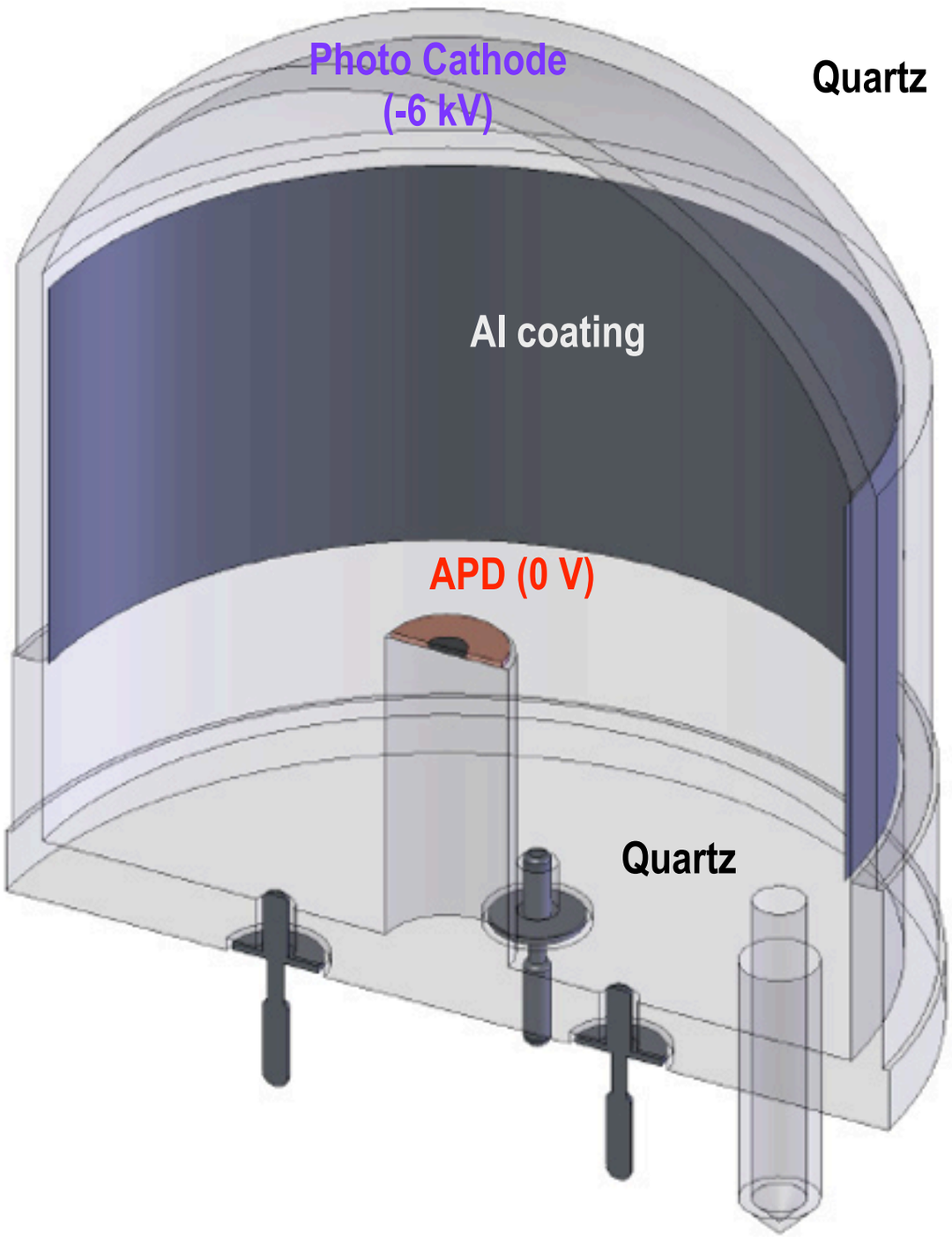


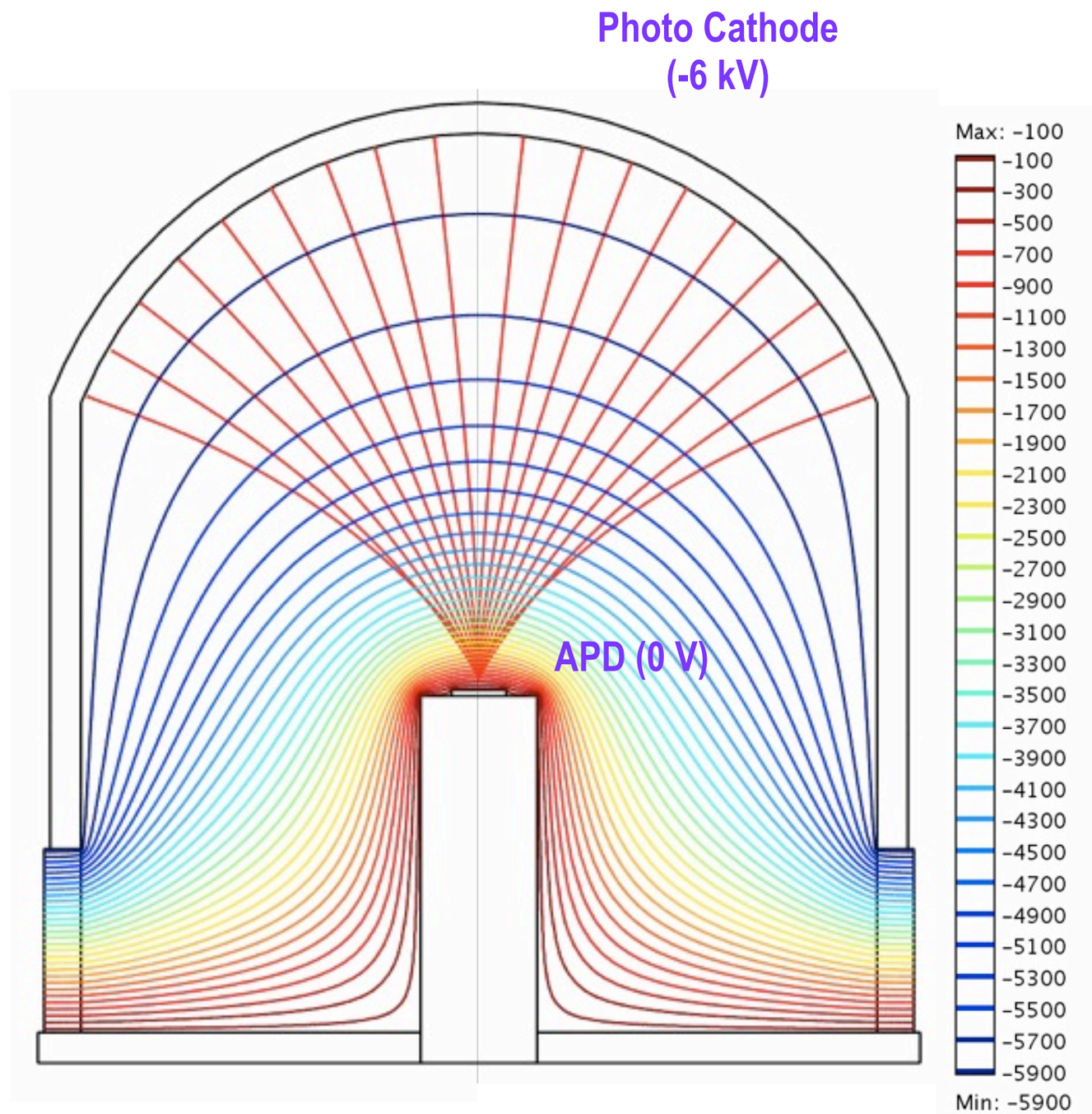
~80 Muon Veto PMTs

2 x 121 Photosensors



QUPID (QUartz Photon Intensifying Detector)

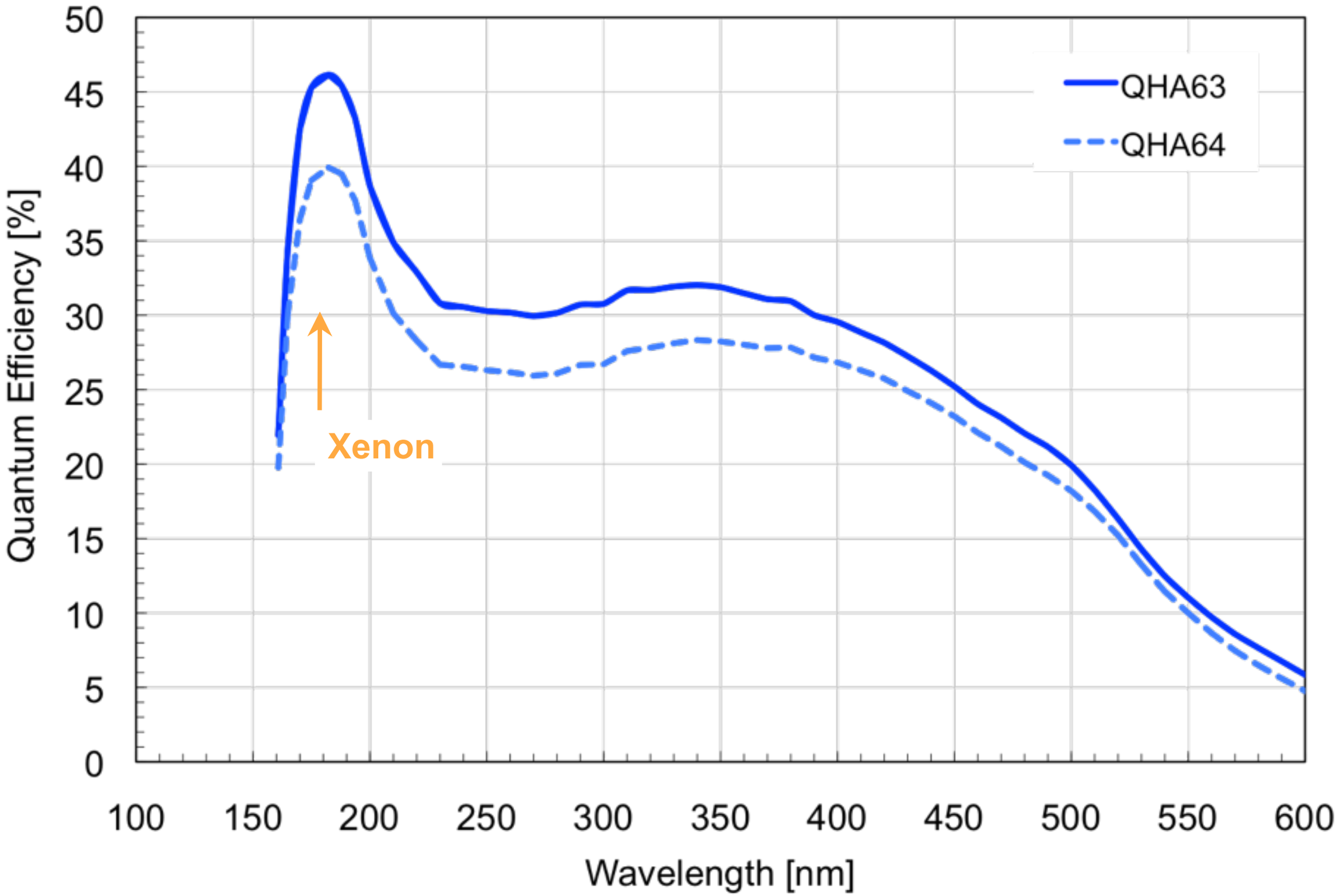




Made by Synthetic Silica only.
US Patent (No. 5374826) pending.

New 3” QUPID (Production Version)

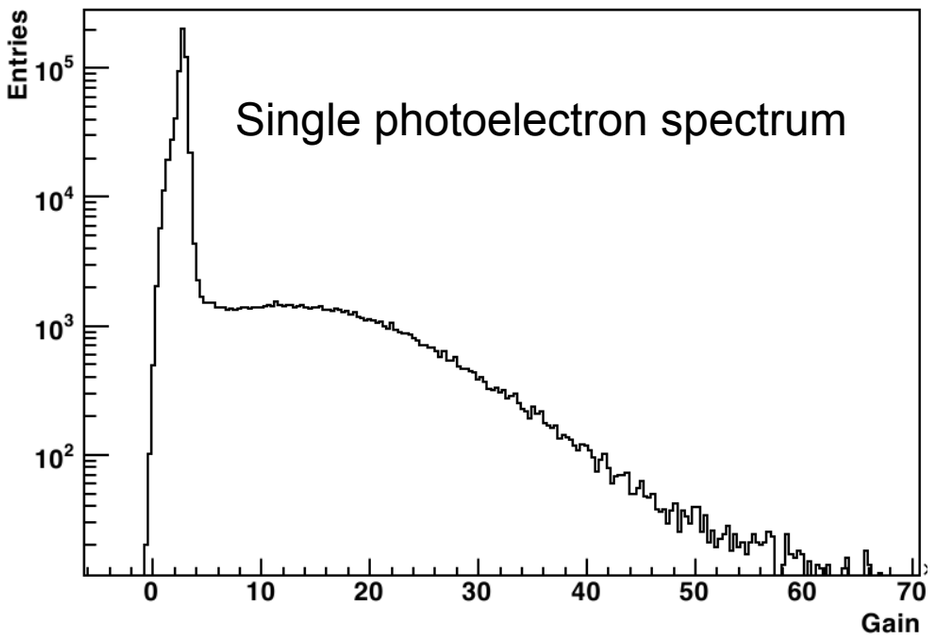
Quantum Efficiency (QHA63, 64)

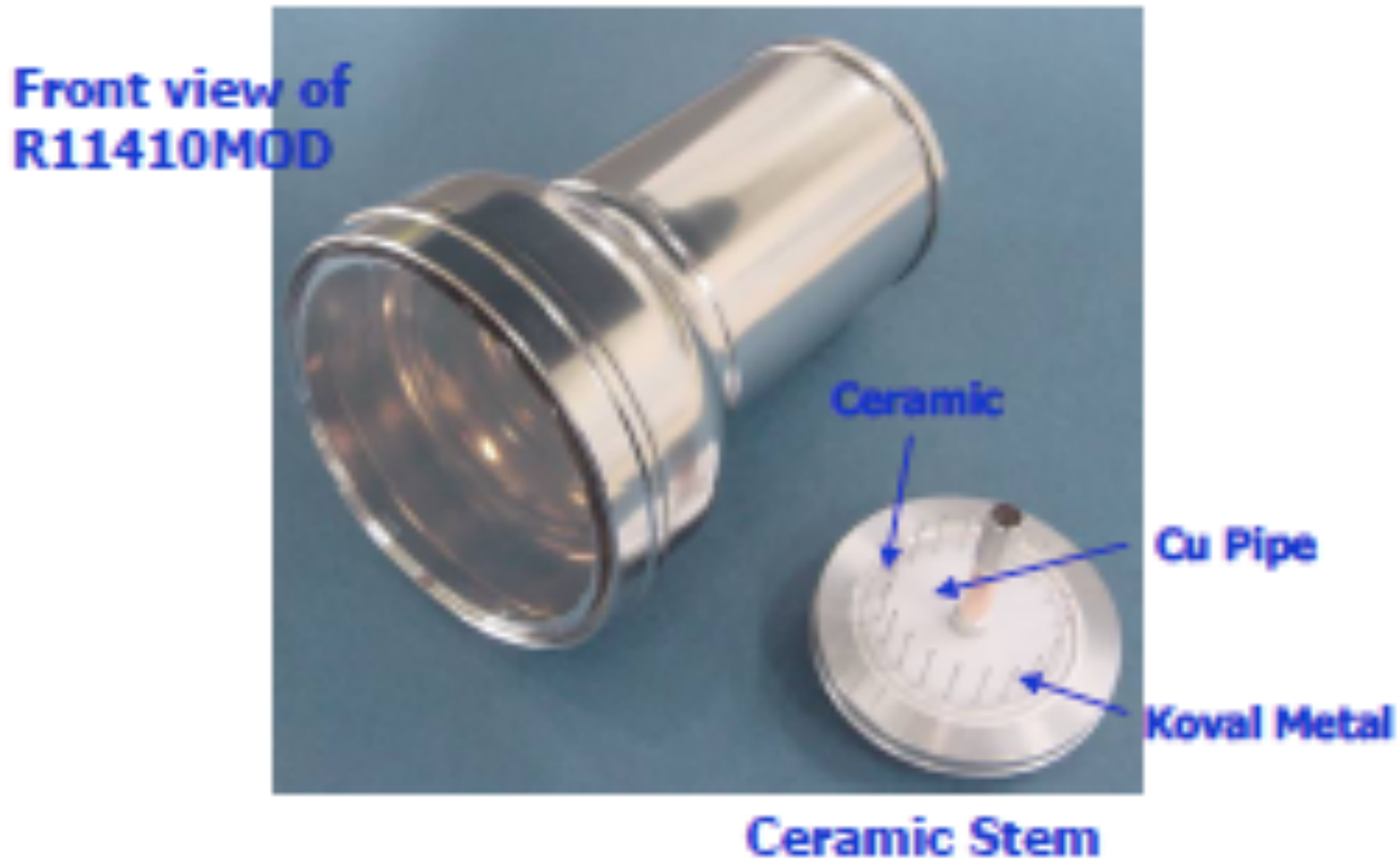


Summary of QUPID

- **Extremely low radioactivity:** < 1 mBq
  - < 0.1 neutron / year
  - << 10 times lower than conventional low radioactive PMTs.
- **Large diameter:** 3 inch
  - 6 inch is also under investigation.
- **Special Photocathode:** Bialkali LT
  - > 40 % QE at 170 – 450 nm
  - Low resistivity even at Liquid Ar temperature (- 185 ^{o}C)
- **True photon counting.**
  - 1, 2, 3… photoelectron peaks clearly visible.
  - 100% collection efficiency.
- **Simple HV supply.**
  - Common HV (-6 kV) for all QUPIDs
  - Resister chain not necessary
- **The first successful operation in LXe at UCLA**

The 3” Hamamatsu R11410-SEL-MOD





Special Bialkali Photocathode (LT)

same family as R11065 successfully tested in LAr

High Quantum Efficiency for LXe Light:

> 34% @ 175 nm

3” , 12 stages, High Gain:

> 5 x 10^6

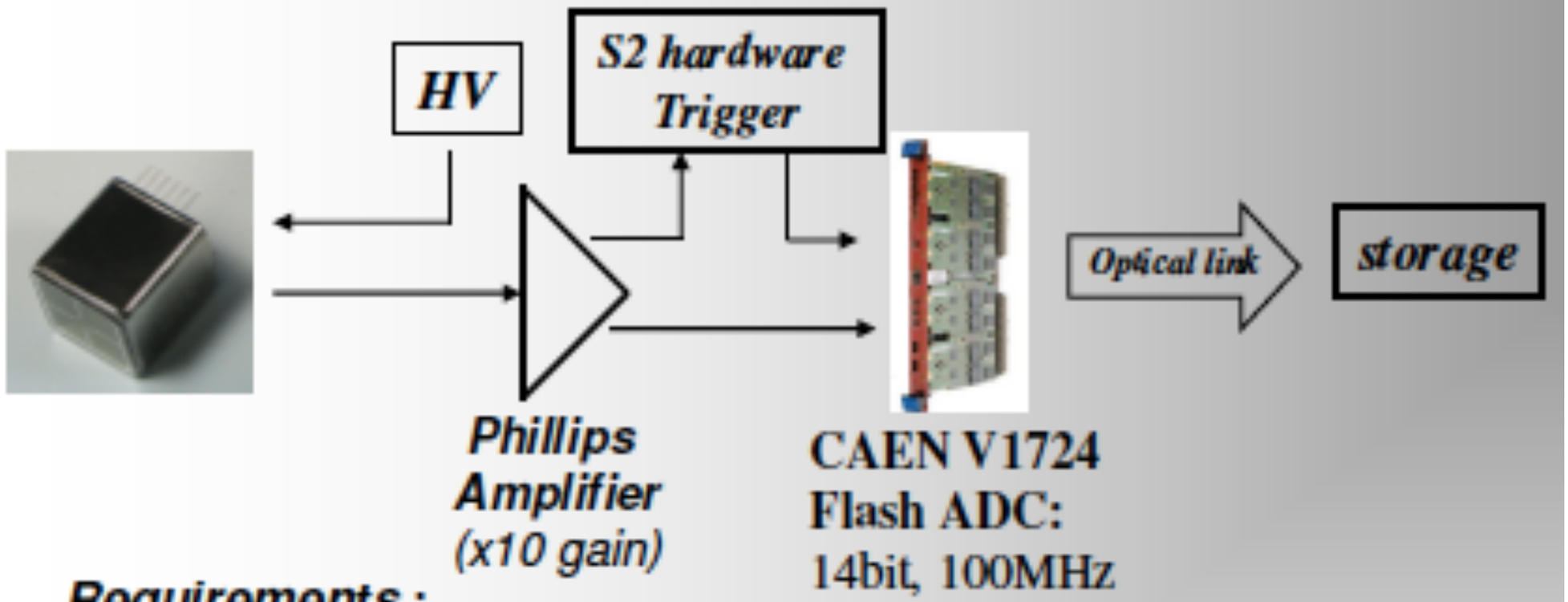
Low Radioactivity:

Original tube too high in U, Th, Co

Lower radioactivity version (R11410-SEL-MOD) currently screened

	R8520 [mBq/cm^2]	R11410 [mBq/cm^2]
^{238}U	0.023	0.134
^{232}Th	0.026	0.066
^{40}K	1.705	1.096
^{60}Co	0.093	0.184

Requirements on Electronics and DAQ
(XENON100 Example)



Requirements :

- *digitize the full waveform (up to 320μs of 242 PMTs)*
- *minimize the deadtime*
- *high rate capability for calibration*

- *Circular buffer*
- *on board FPGA for Zero length suppression*

Maximum acquisition rate ~60Hz

XENON1T: Parallelization

- idea: read clusters of ADCs independently and reconstruct events offline on cluster
- common trigger, common hardware clock, common veto