Status of the SABRE Experiment

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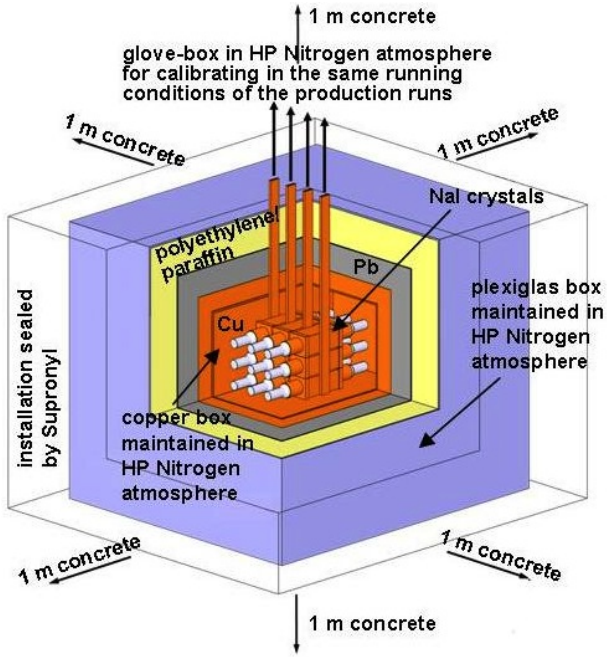
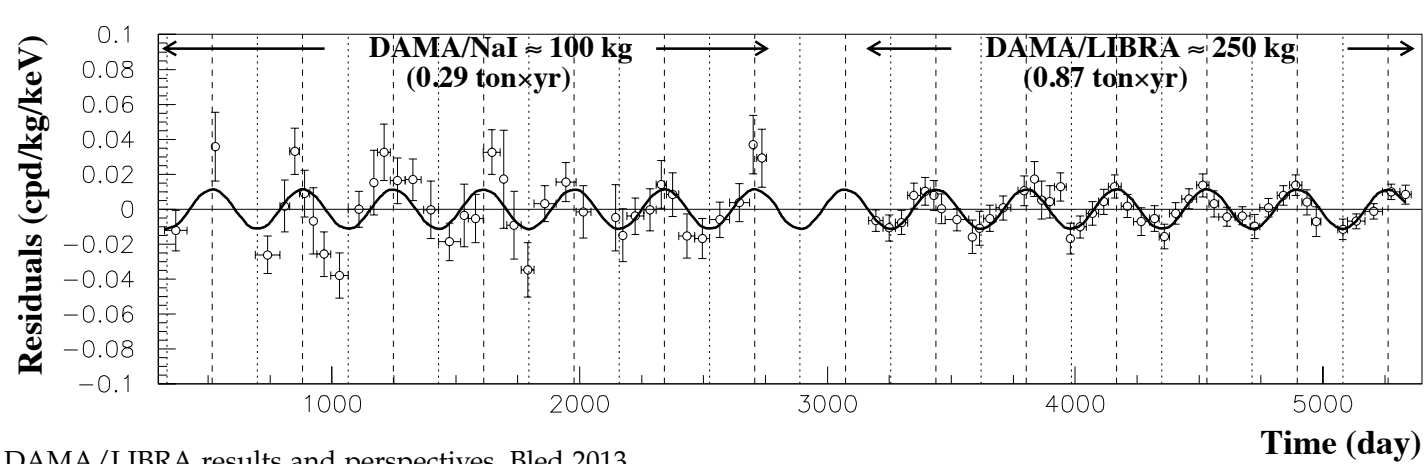
Dark Matter Signal?

Annual Modulation

The DAMA/LIBRA Experiment

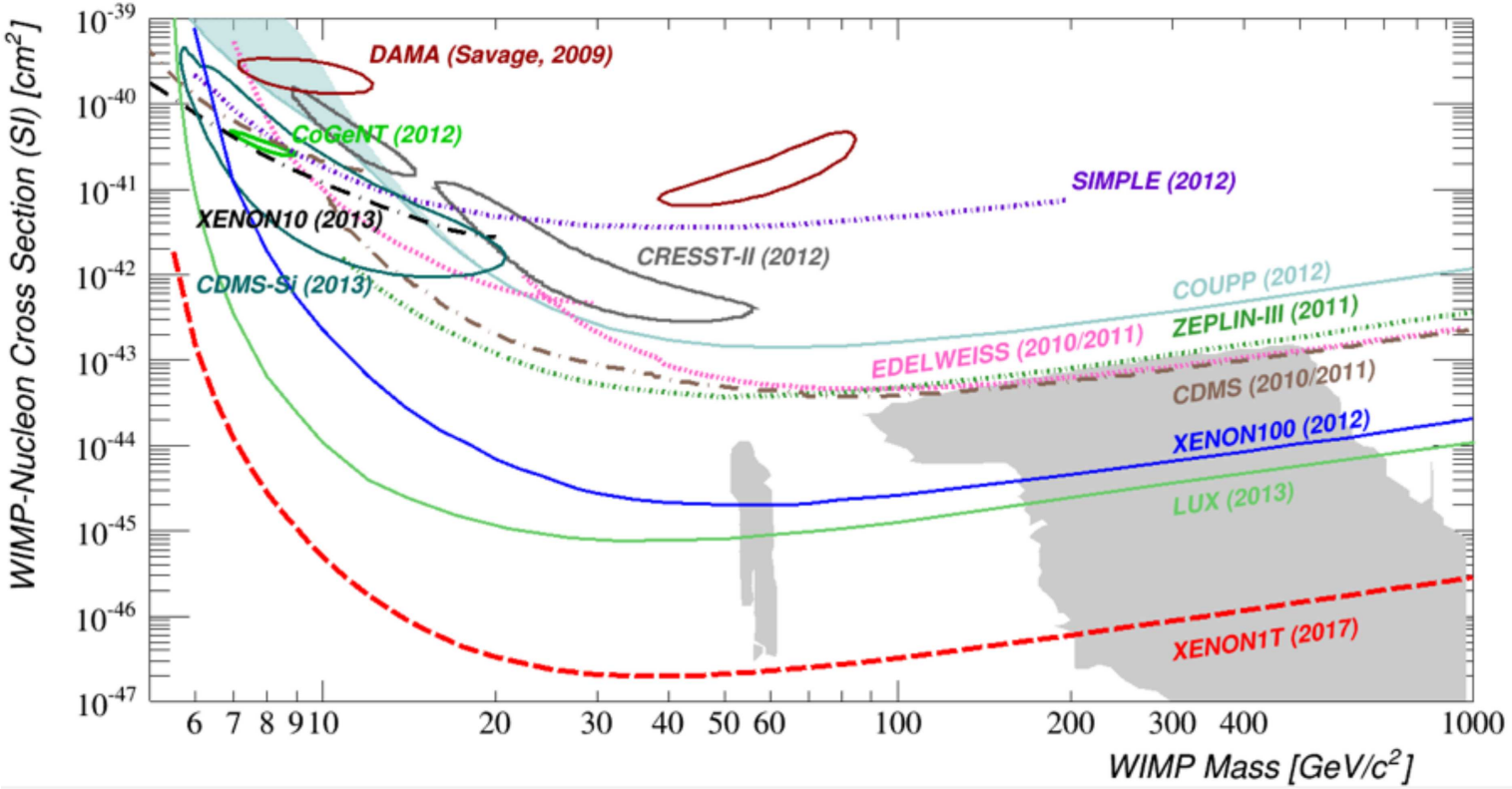
- 25 high purity NaI(Tl) crystals with 9.7 kg each
- 2 PMTs coupled via 10 cm quarz light guide to each crystal
- 1– 2 % modulation at 2– 6 keV_{ee} with 9.3 C.L.
- Peak end of May / beginning of June





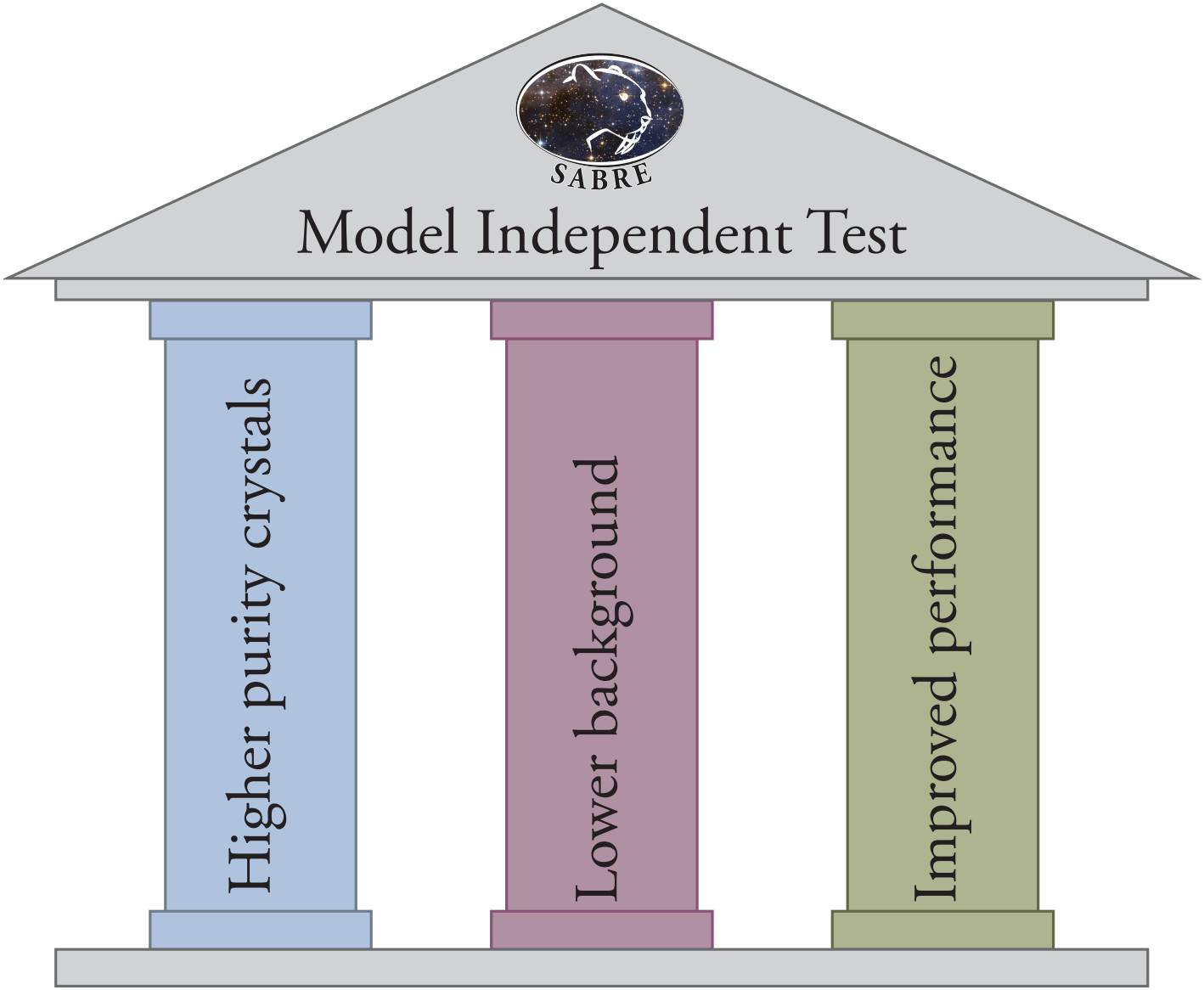
DAMA/LIBRA results and perspectives, Bled 2013

The Tension


WIMP-Nucleon Cross Section (SI) [cm^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
6 7 8 9 10 20 30 40 50 60 100 200 300 400 1000
WIMP Mass [GeV/c^2]
DAMA (Savage, 2009)
CoGeNT (2012)
SIMPLE (2012)
XENON10 (2013)
CRESST-II (2012)
CDMS-Si (2013)
COUPP (2012)
ZEPLIN-III (2011)
EDELWEISS (2010/2011)
CDMS (2010/2011)
XENON100 (2012)
LUX (2013)
XENON1T (2017)

The Sodium-iodide with Active Background REjection Experiment

The Pillars



The NaI Powder

Development of Ultra High Purity Powder

- Started $\sim$ 5 years ago by Prof. Calaprice, Prof. Benziger, and Dr. Wright
- Collaboration with 2 industrial partners for production
- Independent high sensitivity impurity measurements

Element	Seastar [ppb]	Sigma-Aldrich [ppb]	DAMA Powder [ppb]	DAMA Crystal [ppb]
K	12	3.5 (18)*	100	$\sim$13
Rb	14	0.2	n.a.	< 0.35
U	< 0.2 (3.5×10^{-3})**	< 1.7 ($< 10^{-3}$)**	~ 0.02	0.5 –7.5×10^{-3}
Th	< 0.1 ($< 10^{-3}$)**	< 0.5 ($< 10^{-3}$)**	~ 0.02	0.7 –10×10^{-3}

* Independent measurement

** Preliminary measurement at PNNL; full validation needed.

Crystal Growth

Crucible Tests

- Test growth of small crystals in different crucibles and ampules
- Careful material selection
- Precision cleaning

Crucible Ampules	Cleaning procedure	Contamination due to crystal growth [ppb] K	Rb	Th	U
# 1, # 1	Standard	65 ± 10	N.D.	0.2– 0.4	0.1– 0.2
# 1, # 2	Precision	41 ± 10	N.D.	N.D.	N.D.
# 2, # 2	Precision	63 ± 10	N.D.	N.D.	N.D.
# 3, # 3	Precision	6 ± 10	N.D.	N.D.	N.D.
Blank test	Precision	1.5	4×10^{-3}	0.4×10^{-3}	0.14×10^{-3}

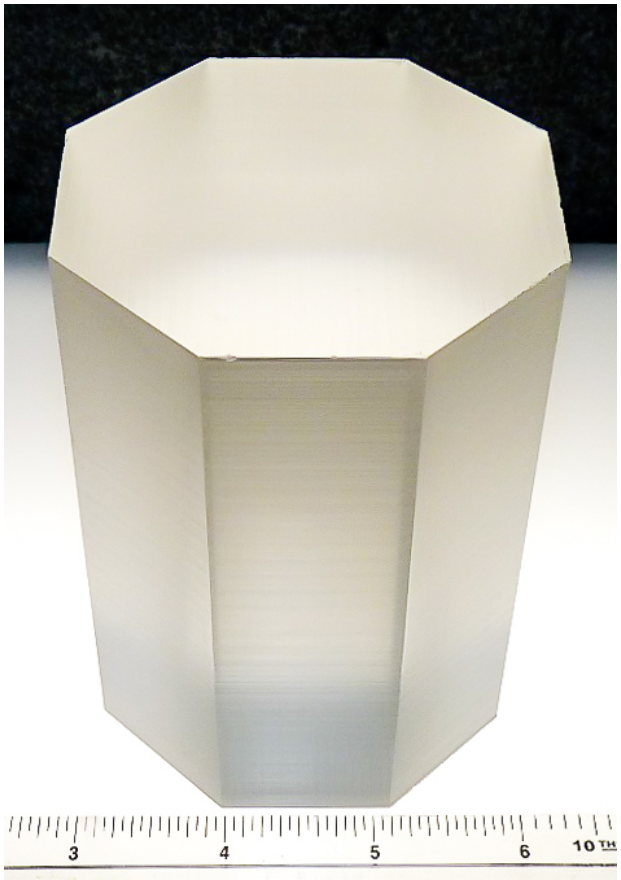
Crystal Growth

Big Standard Purity Crystal

- Grow crystal with $\sim$ 8.5 cm diameter, 10 cm length
- Same growth method as small high purity crystals

The Goal

- Validate growth method for big crystals
- Grow big ($\sim$ few kg) crystal with very good scintillation properties



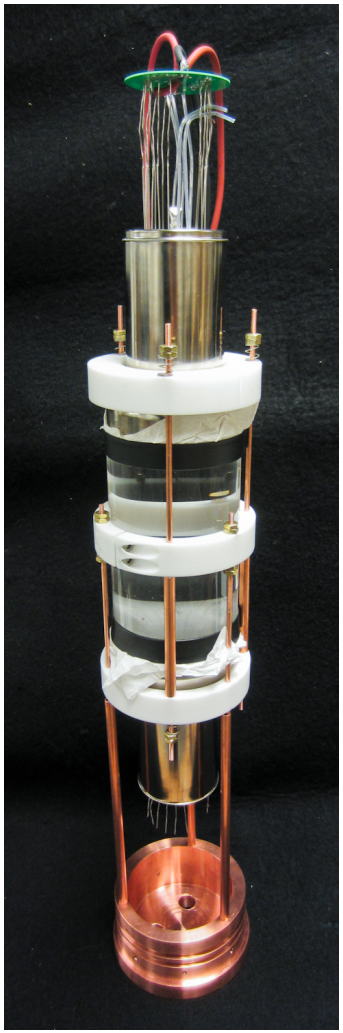
Improved Performance

Higher light yield, lower threshold

- PMTs directly coupled to crystal
- Pre-amplifier developed at LNGS to suppress afterglow coincidence rate

Improved PMTs

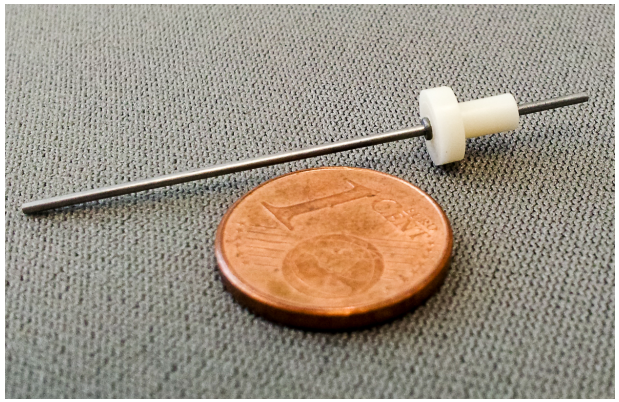
- High quantum efficiency: $\sim$ 35 %
- Low radioactivity: $\sim$ 1 mBq U, Th, Co; $\sim$ 10 mBq K
- Further improvements in development
- Development by Hamamatsu in collaboration with Princeton

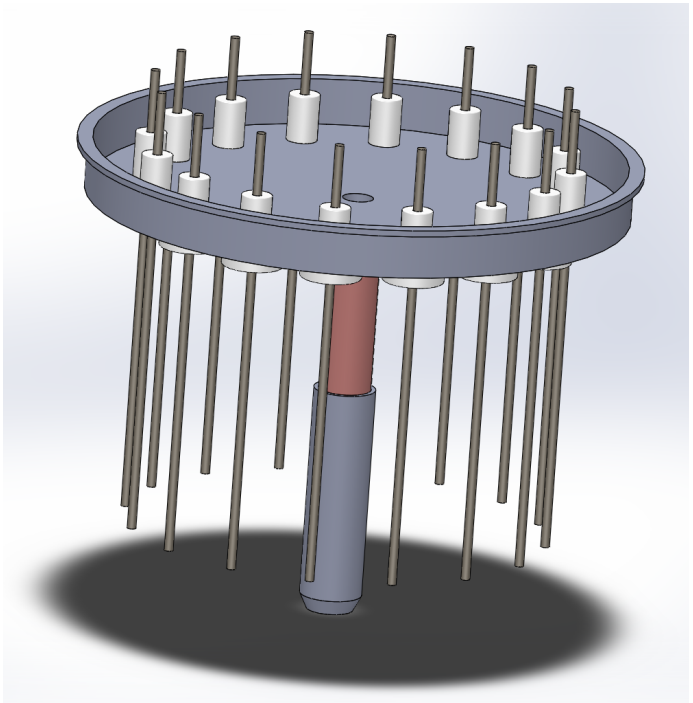


Improving PMTs

New Stem

- Designed to reach higher radio-purity and better stability
- Ceramic feedthroughs use ultra high purity alumina (Al_2O_3)
- Special brazing of feedthroughs to Kovar plate by PPPL
- High QE PMT to be built with this stem by Hamamatsu



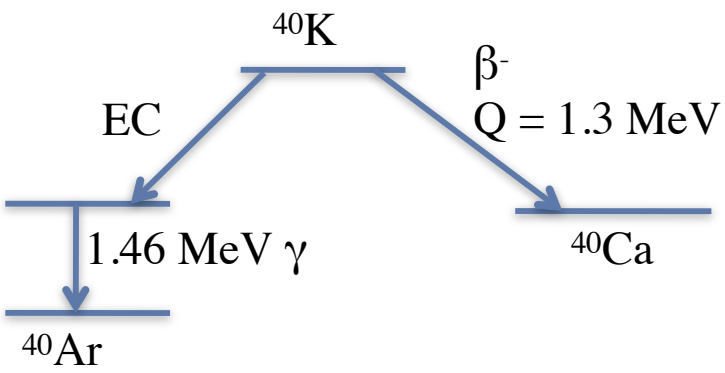


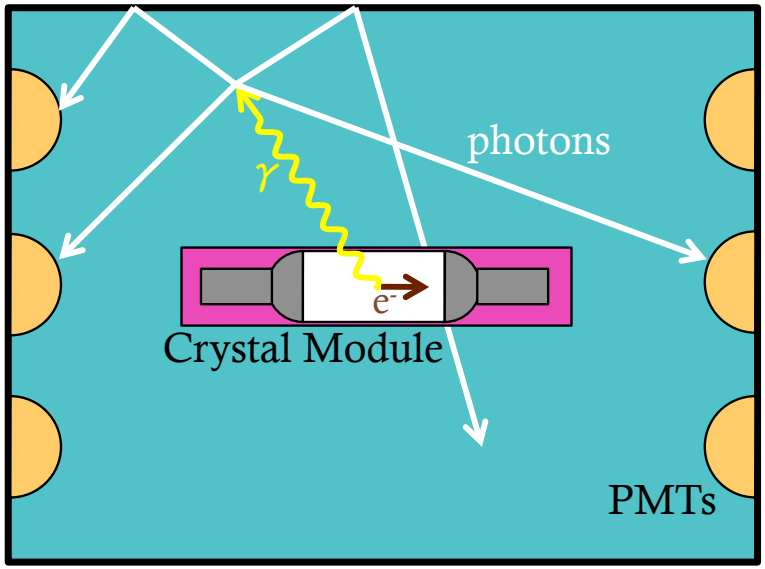
Lower Background

The Veto Principle

Dangerous Background: ^{40}K

- 3 keV Auger e^- accompanying 1.46 MeV γ after electron capture
  $\Rightarrow$ Right in the region of interest
- DAMA reports 13 ppb ^{40}K contamination in their crystals





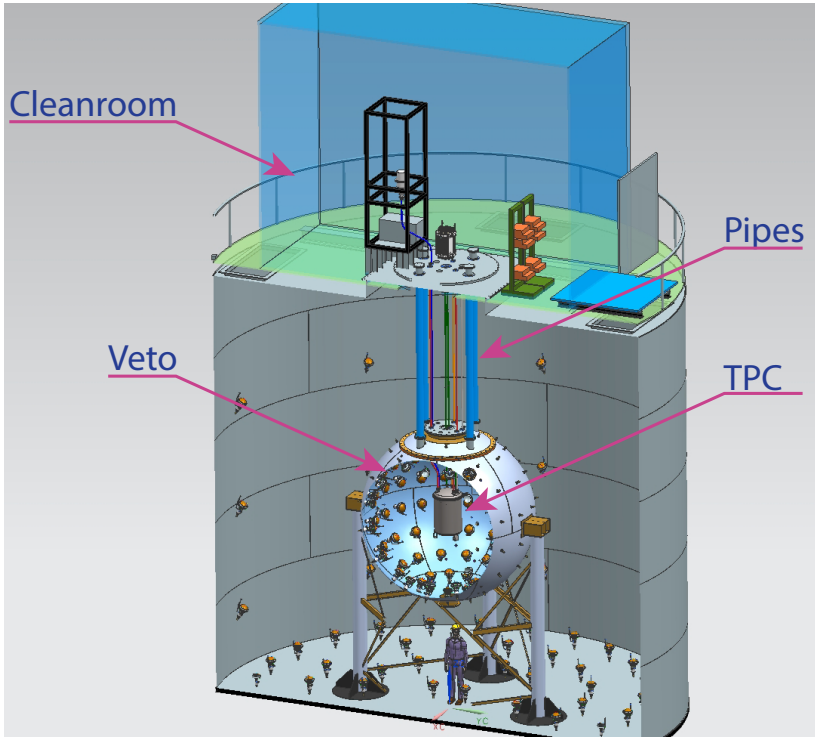
Test in DarkSide

The DarkSide LS Veto

- 4 m diameter liquid scintillator veto
- 30 tons of PC+TMB
- 110 high QE PMTs (R5912)
- Shielded by 3– 4 m of water

First Proof of Concept

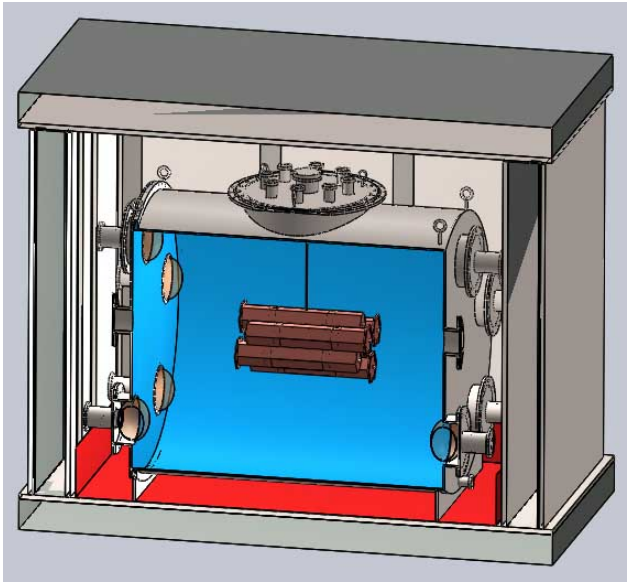
- 1 of 4 pipes available for SABRE
- First test with standard purity crystal
  $\Rightarrow$ Test of veto efficiency
- Possibility of runs with high purity crystals
  $\Rightarrow$ Test of crystal purity
  $\Rightarrow$ Maybe possibility of first DM run



The Portable Veto

The SABRE Veto Vessel

- 1.5 m diameter $\times$ 1.5 m length
- Made out of low radioactivity steel
- $\sim$ 2.3 tons of scintillator (LAB or PC)
- 10 veto PMTs (Hamamatsu R5912)
- Expected light yield $\sim$ 0.2 p.e./keV
- Shielded by 20– 25 cm steel or equivalent in lead or water

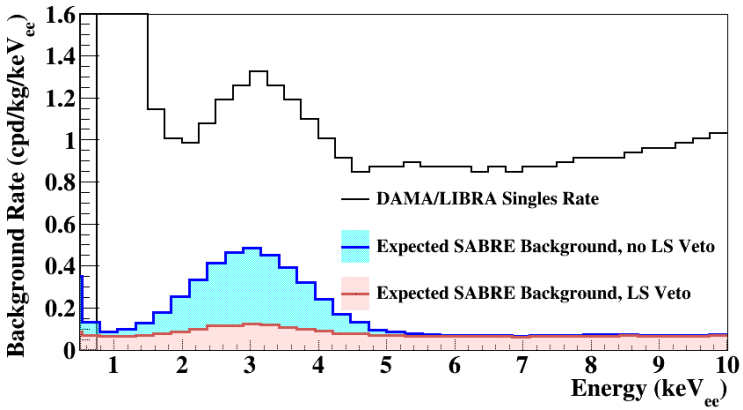


Expectations

Background

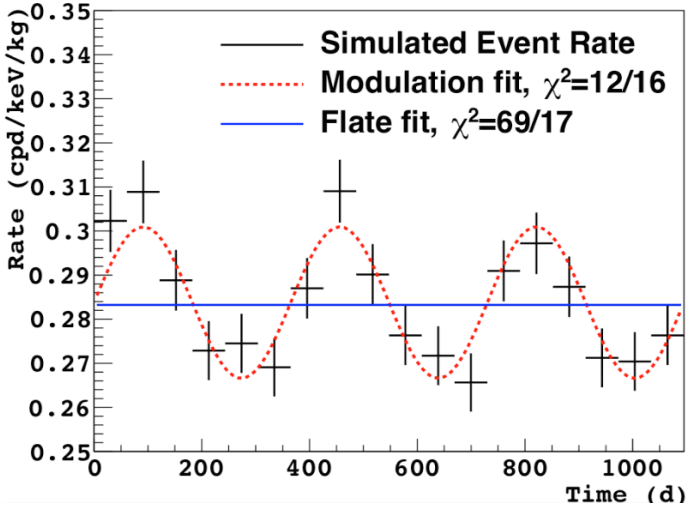
- Crystal purity same as NaI powder
- External background can be shielded
- Radioactivity of components negligible

  $\Rightarrow \sim 0.15$ cts/(keV kg d)



Sensitivity

- 3 years stable detector operations
- No other seasonal effect in ROI
- 50 kg NaI(Tl) array:
  $\sim 4\sigma$ power to verify DAMA
- 25 kg NaI(Tl) array:
  $\sim 2.5\sigma$ power to verify DAMA



Conclusions & Outlook

Conclusions

- WIMP interpretation of DAMA modulation signal in tension with other experiments
- Independent NaI(Tl) experiments needed $\Rightarrow$ SABRE
- Ultra high purity NaI powder for high purity NaI(Tl) crystals
- Low background with high purity materials and active veto
- High light yield & lower threshold due to improved, pre-amplified PMTs directly coupled to crystal

Outlook

- Proof of principle at DarkSide in preparation
- Portable SABRE veto vessel under construction