The SABRE Dark Matter Search Experiment

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DMUK
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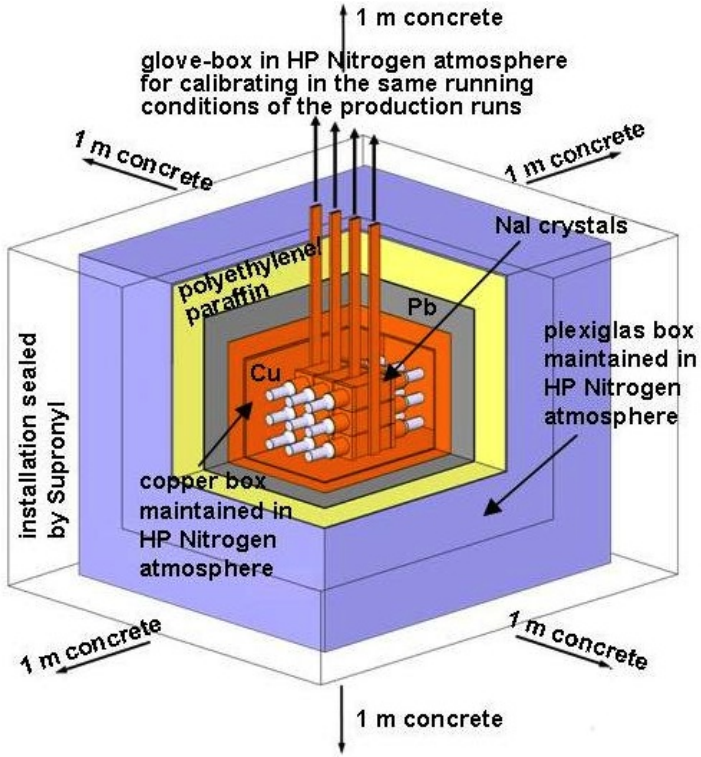
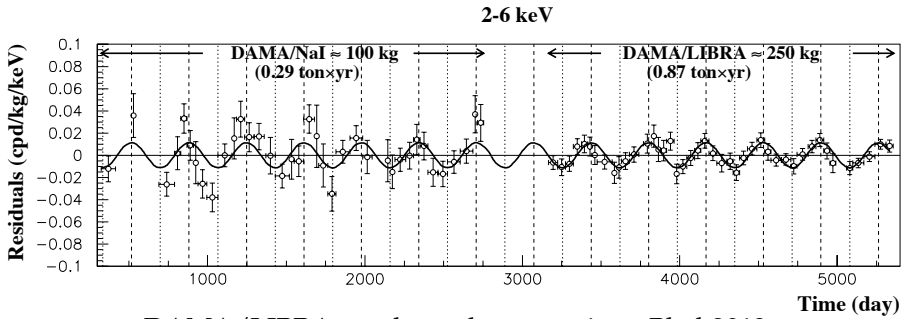
The DAMA/LIBRA Experiment

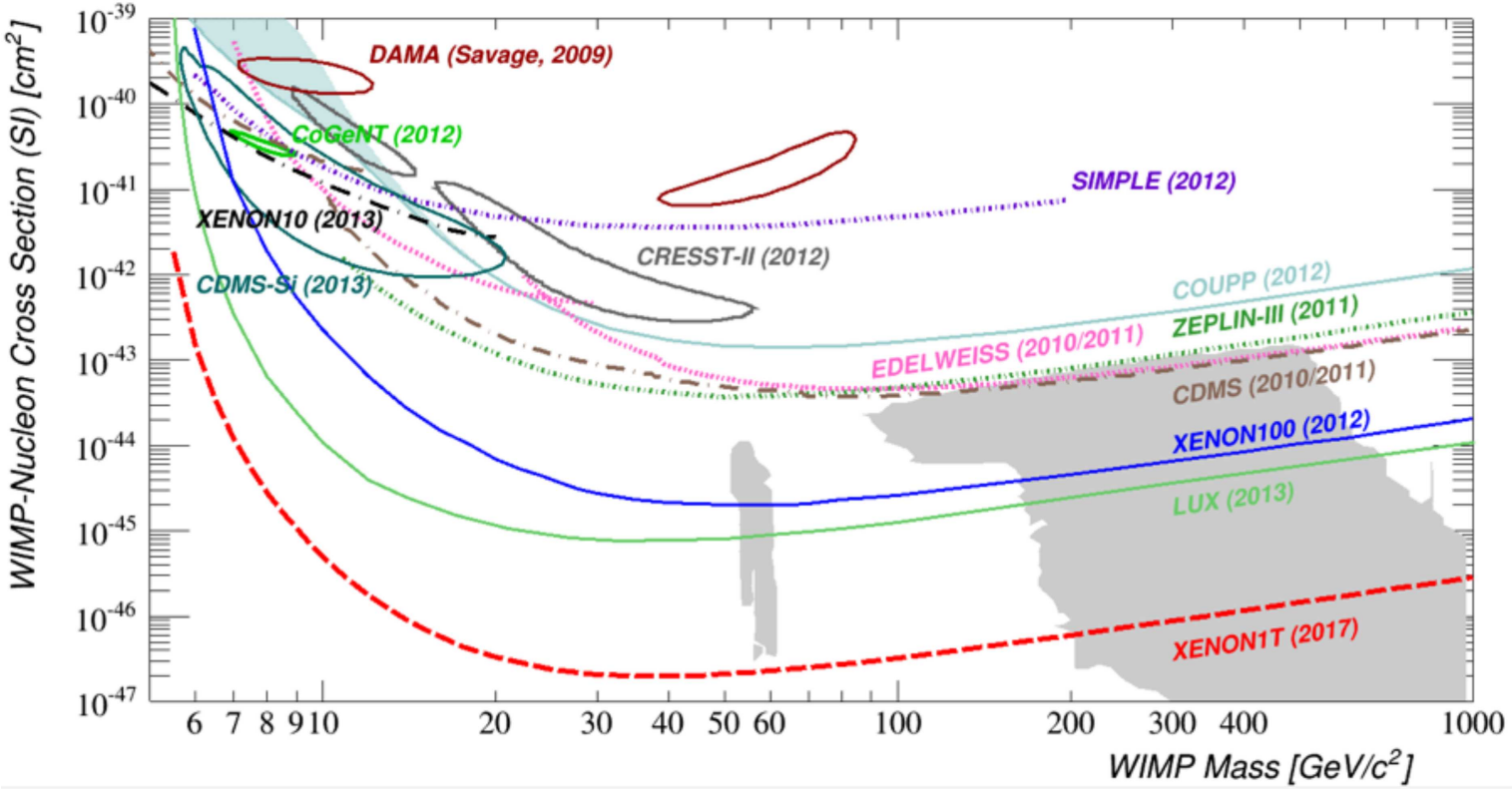
- 25 high purity NaI(Tl) crystals with 9.7 kg each
- 2 PMTs per crystal coupled via quartz light guide
- Passive external shielding
- Located at LNGS ($\sim$ 3200 m.w.e.)
- Modulation at 2– 6 keV_{ee}
- Effect $\sim$ 2 %, 9.3σ C.L.
- Peak end of May / beginning of June





DAMA/LIBRA results and perspectives, Bled 2013

Not So Current Status - The Tension



What Makes SABRE Special?

SABRE: Sodium iodide with Active Background REjection

High purity NaI(Tl) crystals

Improve background by reducing ^{40}K, ^{87}Rb, and others

Active veto

Further reduce background, especially ^{40}K

Improved performance

Better sensitivity in the low energy region

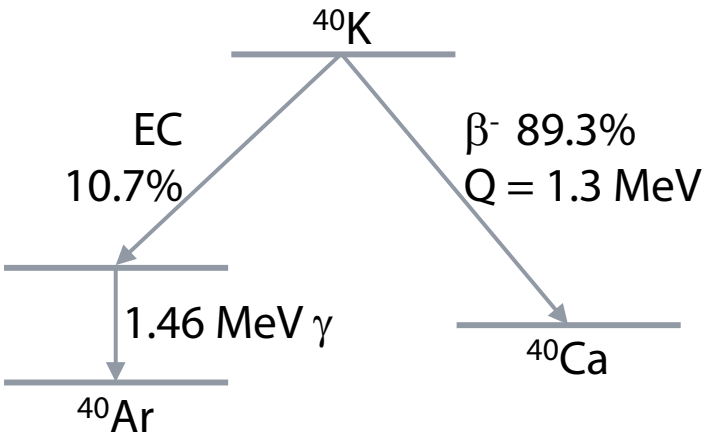
Two locations

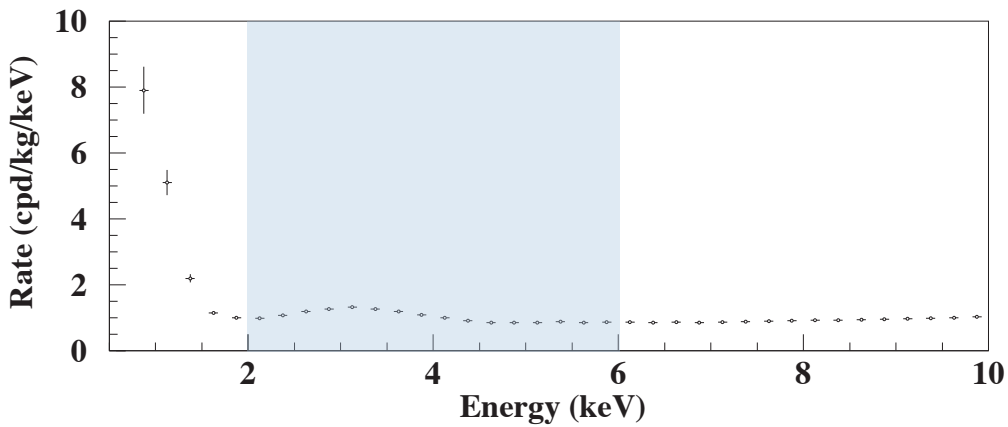
Powerful test against environmental effects

Active Veto: The Principle

^{40}K Decay

- ^{nat}K $\simeq$ 93% ^{39}K + 0.012% ^{40}K + 7% ^{41}K
- 3 keV Auger e$^-$ accompanying 1.46 MeV γ after electron capture
  $\Rightarrow$ Right in the region of interest
- DAMA reports 13 ppb ^{nat}K contamination in their crystals





Active Veto: The Principle

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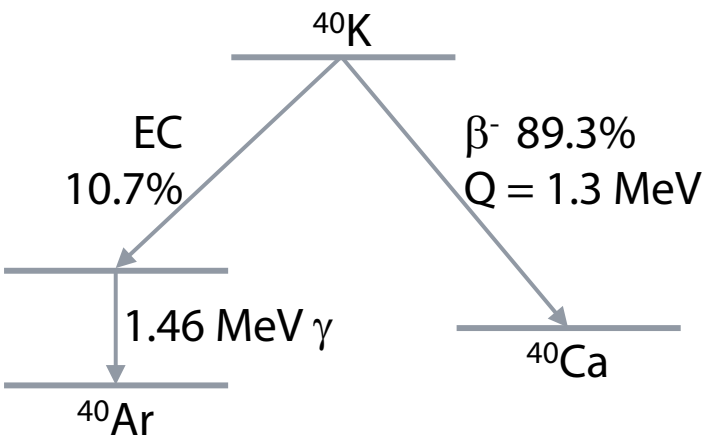
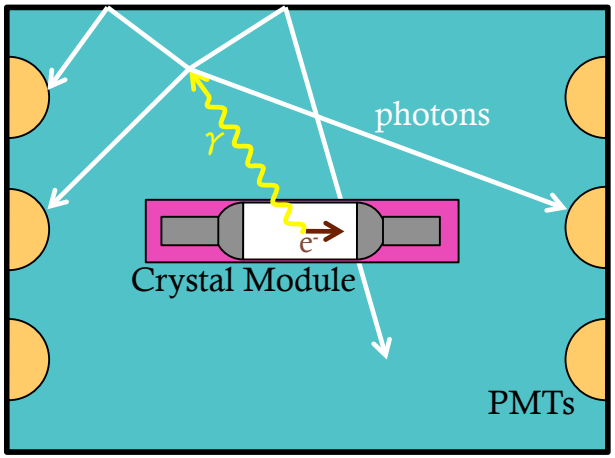
- 3 keV Auger e^- accompanying 1.46 MeV γ after electron capture
  $\Rightarrow$ Right in the region of interest
  $\Rightarrow$ Coincidence between e^- and γ can be used to veto such events
- DAMA reports 13 ppb ^{nat}K contamination in their crystals





High Purity Crystals

The NaI Powder

Development of Ultra High Purity Powder

- Collaboration with 2 industrial partners for production
- Independent high sensitivity impurity measurements
- R&D on further purification ongoing

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

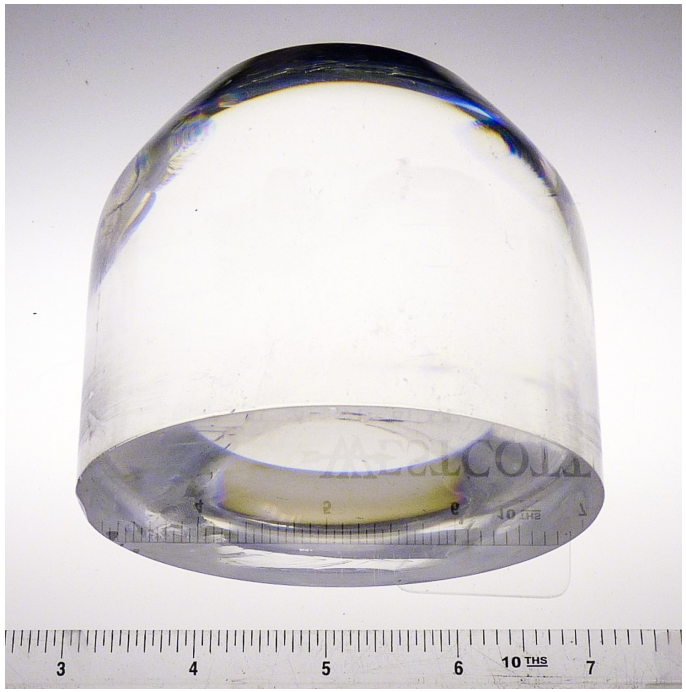
* Independent measurement
** Preliminary measurement at PNNL; full validation needed.
Bernabei et al., NIM A592 (2008) 297-315

High Purity Crystal

First Larger Crystal

- 2-kg crystal made out of Astrograde powder
- 88-mm diameter similar to final crystals
- Good scintillation properties
- $\langle \mathrm{Rb} \rangle < 0.1$ ppb (DAMA < 0.35 ppb)

^{39}K [ppb]	Seastar	PNNL	DAMA
A	9 ± 1	10.0 ± 0.7	
B	7 ± 1	9.1 ± 0.3	
D	11 ± 1	9.7 ± 0.4	
E	9 ± 1	9.8 ± 0.4	
Average	9	9.6	13



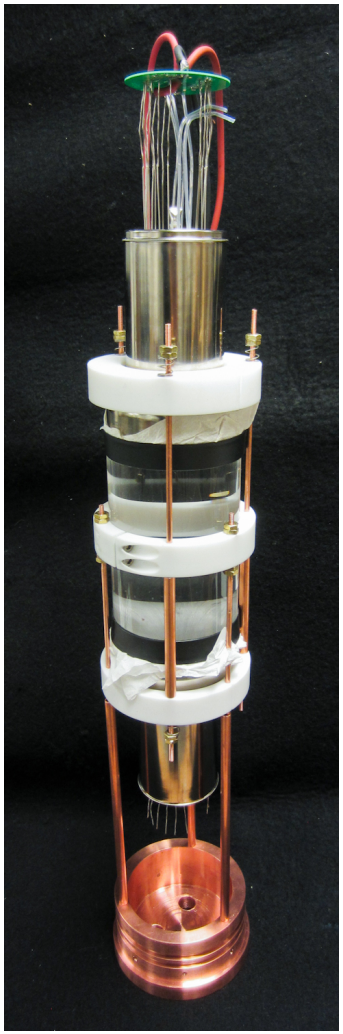
Improved Performance

Higher light yield, lower threshold

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

Improved PMTs

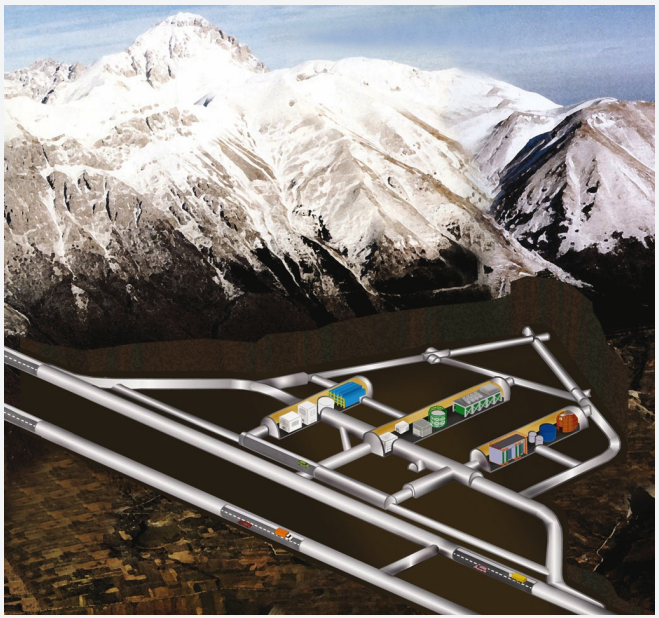
- High quantum efficiency: $\sim$ 35 %
- Low radioactivity: $\sim$ 1 mBq U, Th, Co; $\sim$ 10 mBq K
- Further improvements in development
- Development by Hamamatsu in collaboration with Princeton



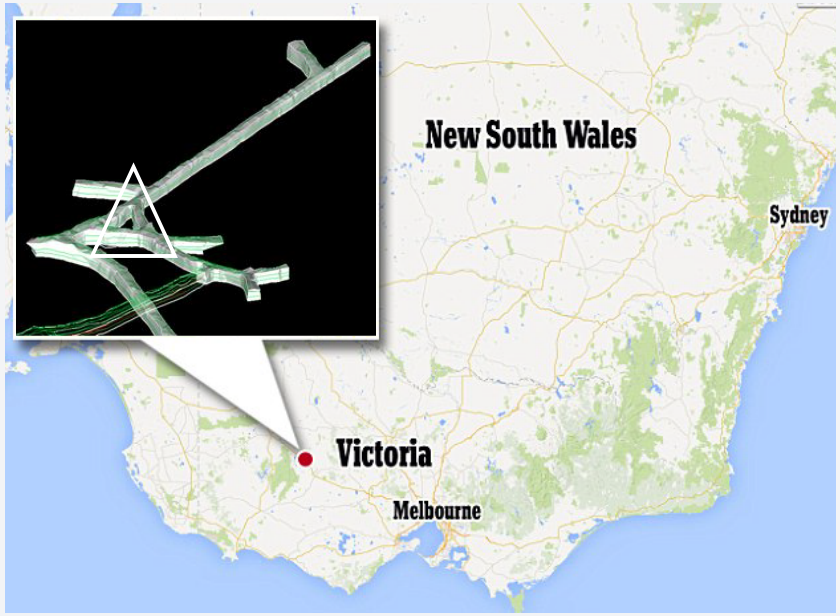
Two Locations: Northern and Southern Hemisphere

- $\sim$ 3000 m.w.e shielding at both locations
- Twin detectors for optimum comparability
- Both detectors will run in parallel

LNGS, Italy

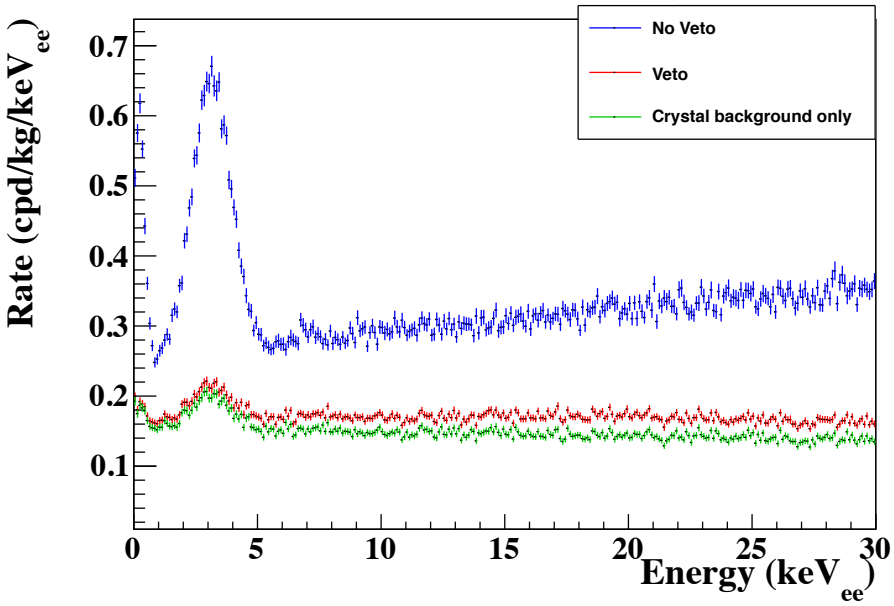


SUPL, Australia

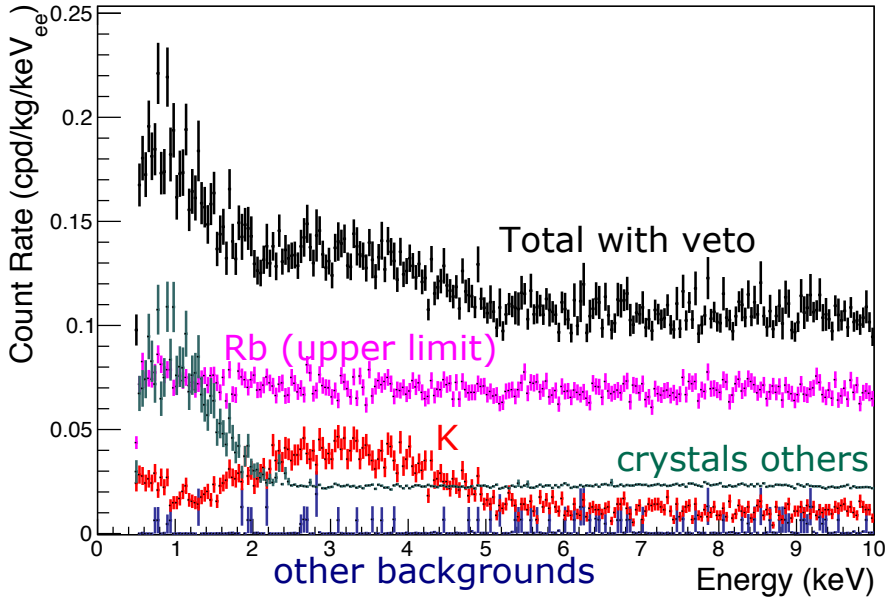


Background Expectations

Total Background



Crystals



Expectations

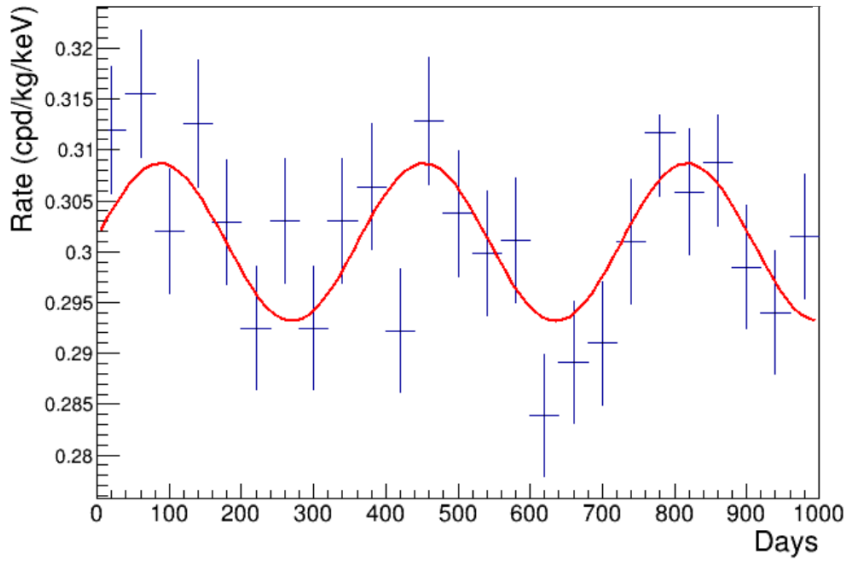
Sensitivity

Sensitivity

- 3 years stable detector operations
- No other seasonal effect in ROI (2-6 keV_{ee})
- 50 kg NaI(Tl) array
- 0.15 cpd/kg/keV total background in ROI

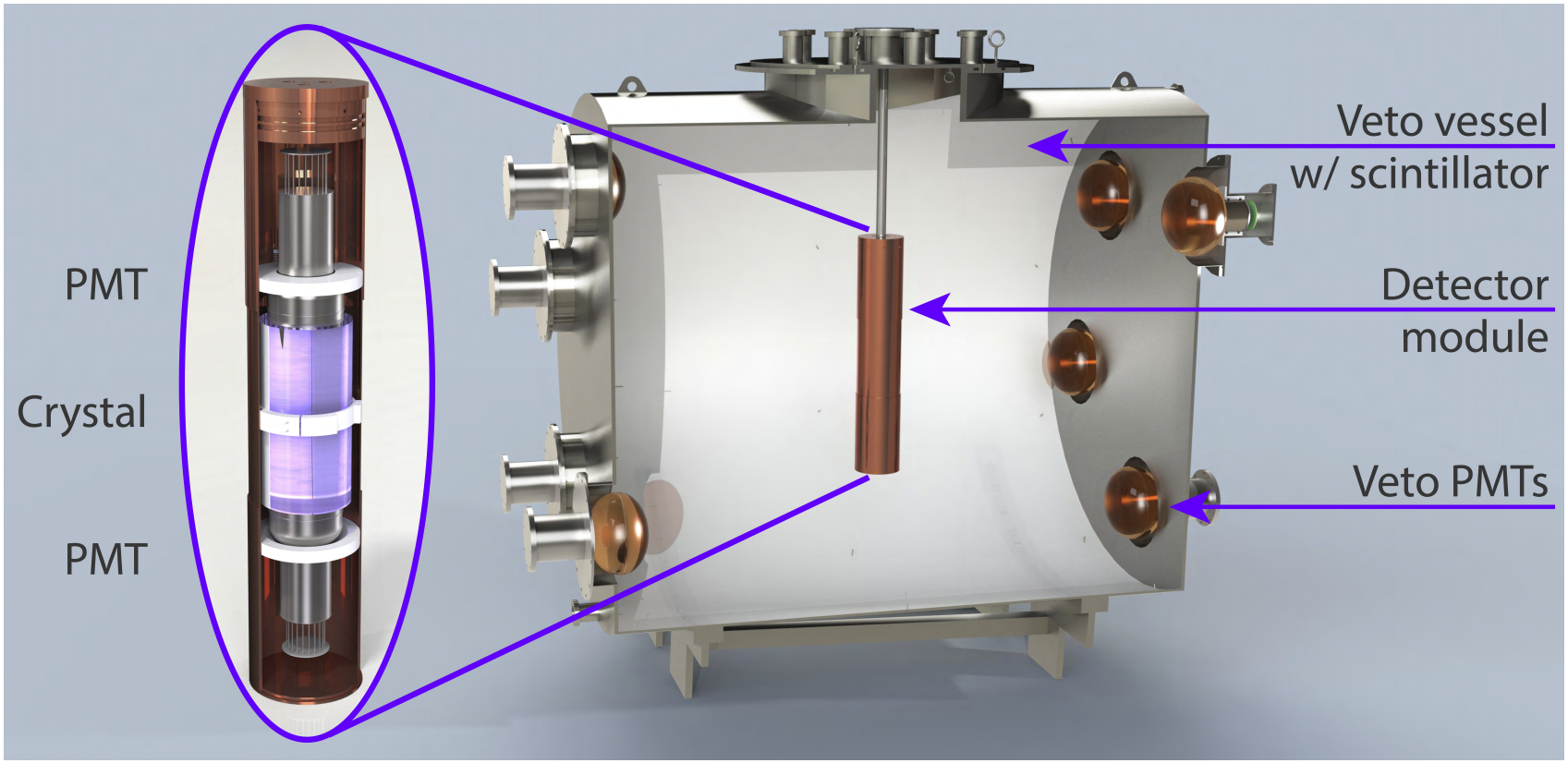
  $\Rightarrow$ 6σ to refute modulation

  $\Rightarrow$ 4σ to verify modulation



SABRE North: Proof of Principle

- Proof-of-Principle: 5.5-kg ultra high-purity NaI(Tl) crystals
- $\phi 1.4 \times 1.5$ m veto filled with pseudocumene + PPO
- Additional water / lead / polyethylene shielding around the veto



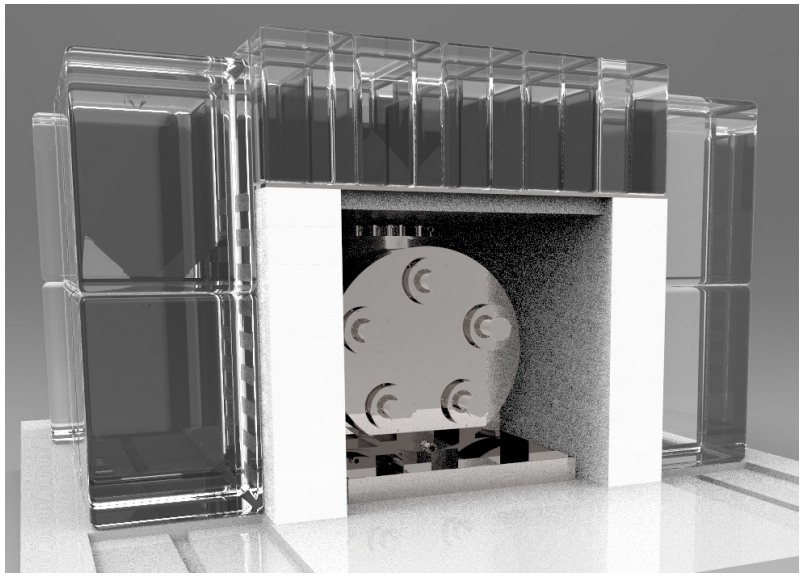
Proof of Principle

Goals

- Measure impurity levels of first high-purity crystal(s)
- Determine effectiveness of veto

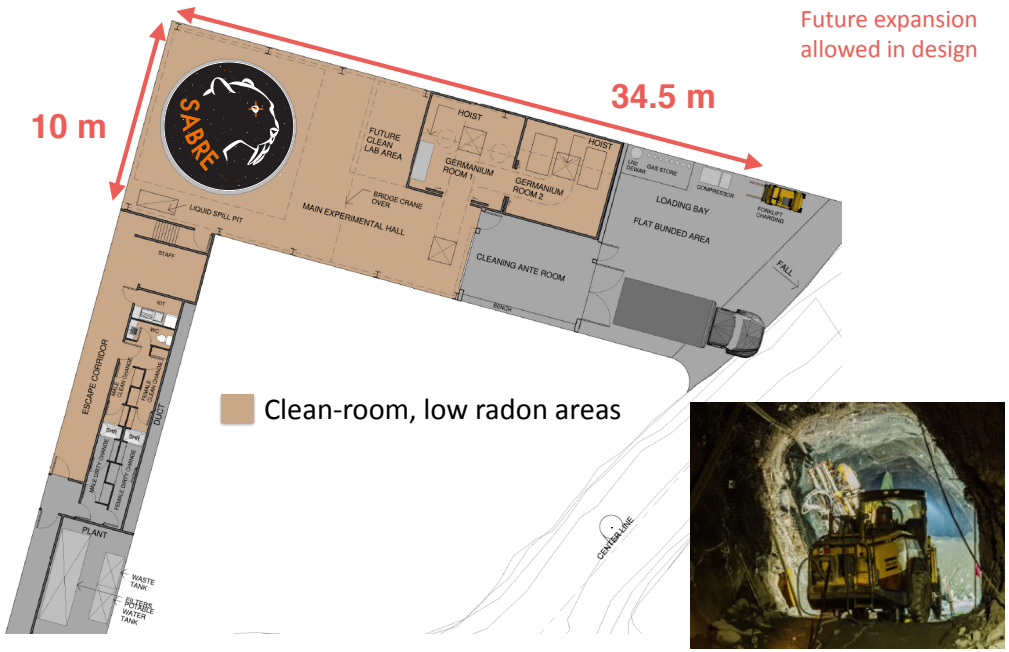
Status

- Many components available
- Commissioning of vessel in Princeton completed, delivered to LNGS
- Preparations at LNGS in progress



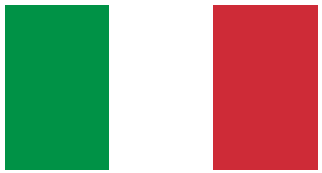
Stawell Underground Physics Laboratory (SUPL)

- First underground lab in southern hemisphere
- $\sim$ 240 km west of Melbourne
- Decline gold mine
- Site 1.02 km deep ($\sim$ 3 km.w.e. similar to LNGS)
- Electricity & optical fibre available
- Can be reached by truck/car
- Clean room design similar to SNOLab
- Construction started; expected to finish in late 2017



Collaboration

Adelaide University
Australian National University
Swinburne University
University of Melbourne



LNGS & GSSI
INFN Rome
University of Milano & INFN

Imperial College London

LLNL
PNNL
Princeton University

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(Tl) in preparation $\Rightarrow$ first breakthrough!
- 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

- First high-purity NaI(Tl) crystal grown
- Proof of principle at LNGS in preparation
- Full-scale twin detectors in preparation at LNGS (Italy) and SUPL (Australia)