Laboratoire Leprince-Ringuet
15th May 2017

Unraveling the mystery of Dark Matter's annual modulation

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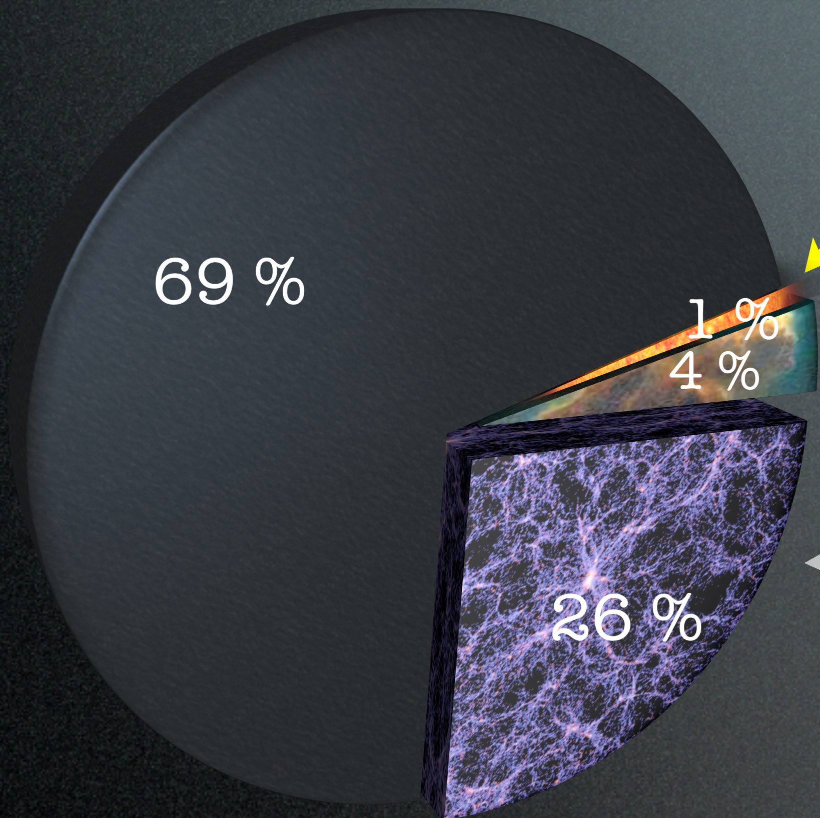
Energy Budget of the Universe



$\Omega_{\rm lum} \sim 0.01$

$\Omega_{\rm b} \simeq 0.040 \pm 0.005$

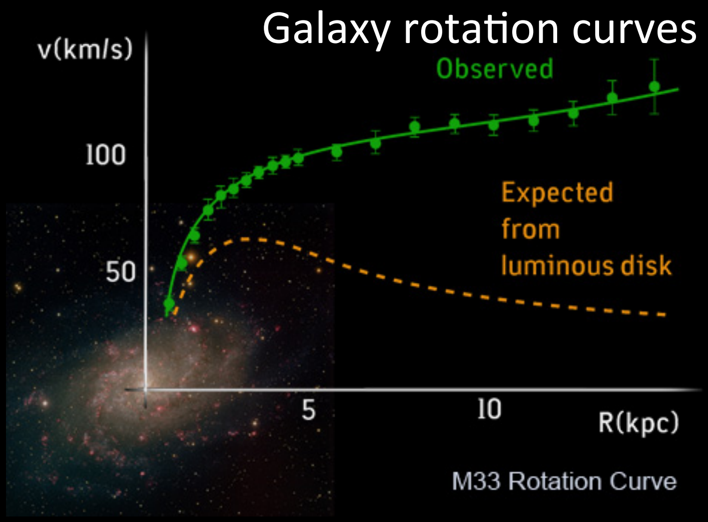
-BBN
-CMB

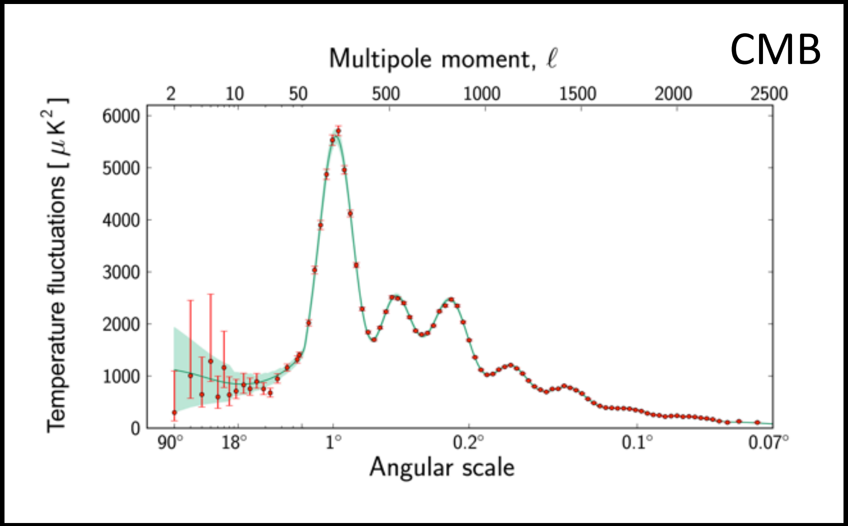
$\Omega_{\rm DM} \sim 0.26$

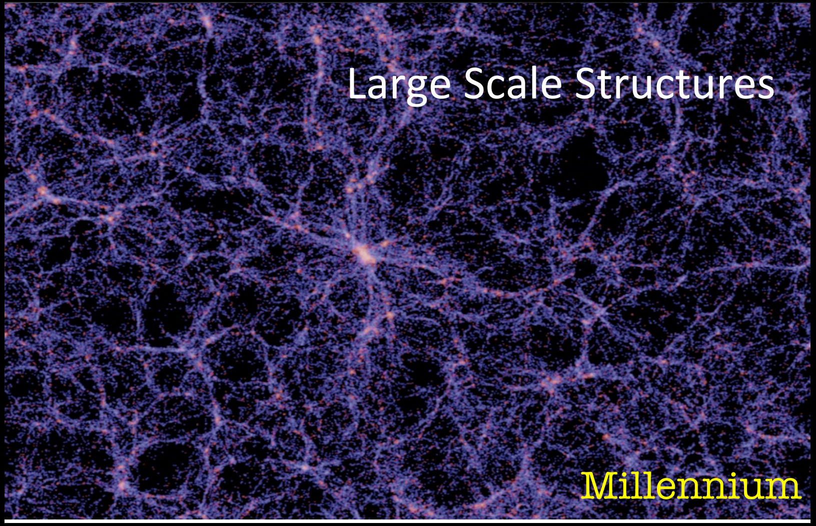
$\Omega_{\rm de} \sim 0.69$

- CMB + SNIa
- CMB - DM
- acoustic peak in baryons

Evidences of Dark Matter



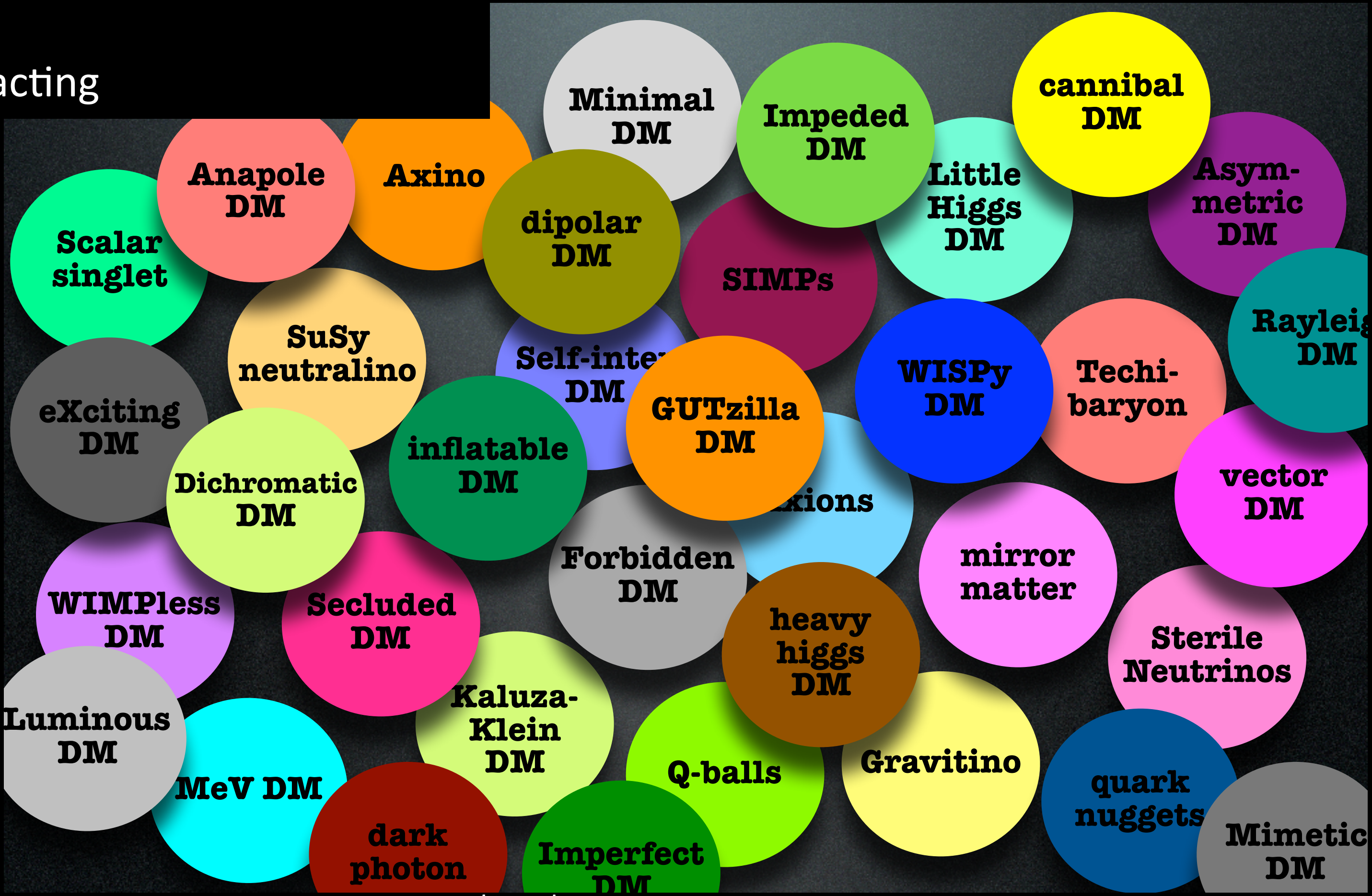




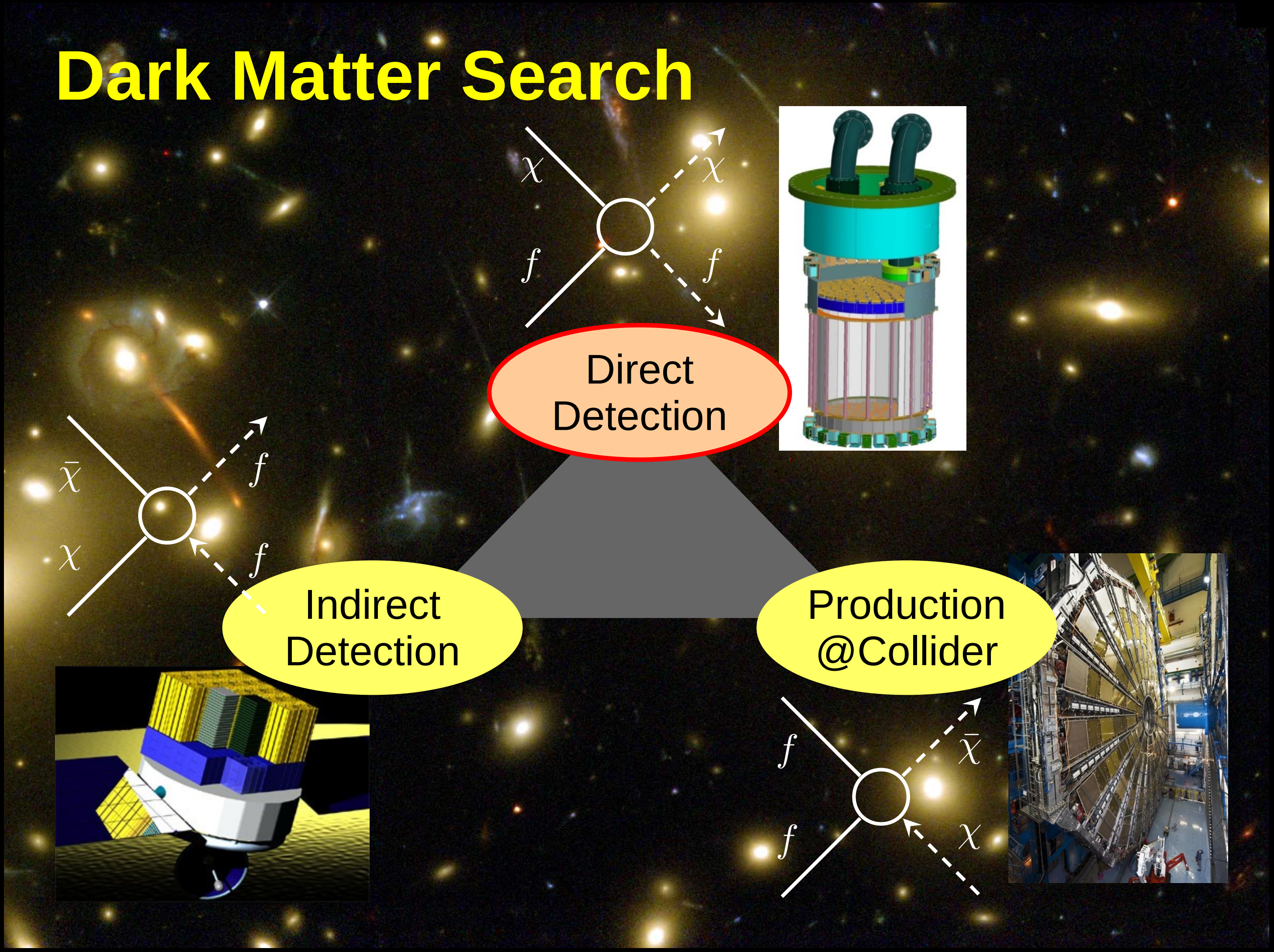
Several models proposed

New particle with general characteristics:
- Stable on a cosmological scale
- Neutral
- Massive
- Weakly Interacting

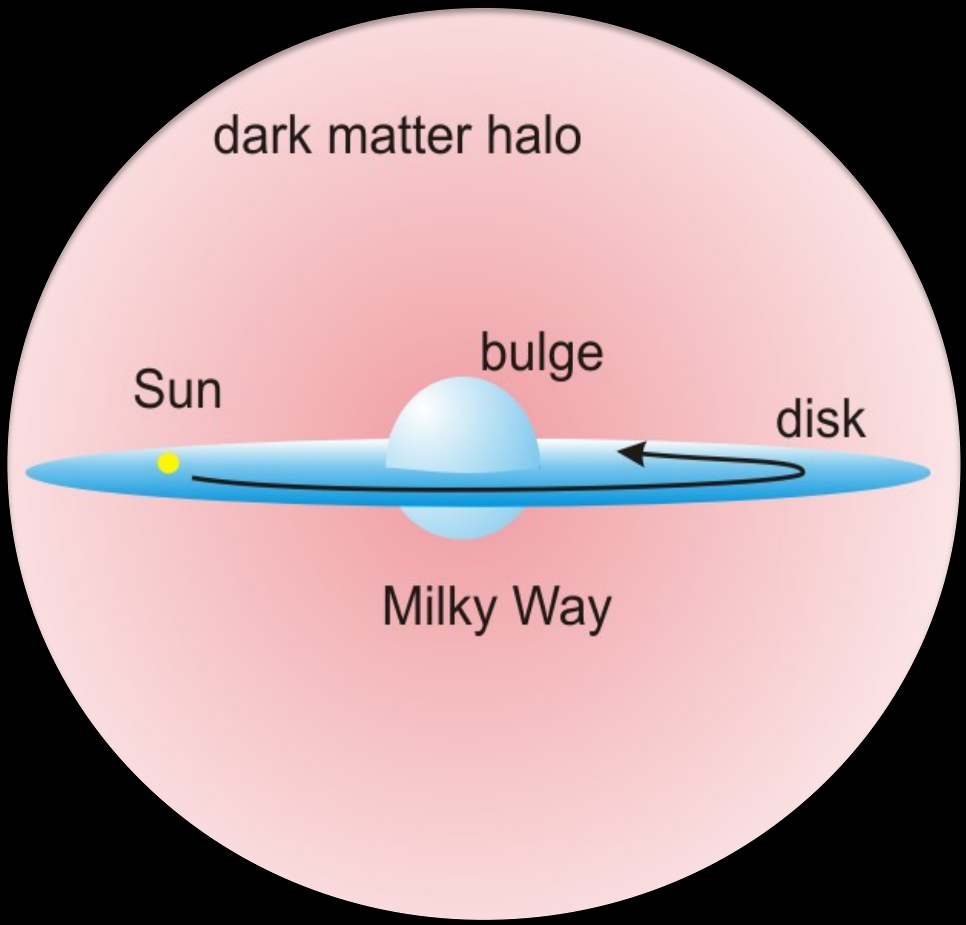
Courtesy M. Cirelli



Experimental approaches to



Dark Matter Halo



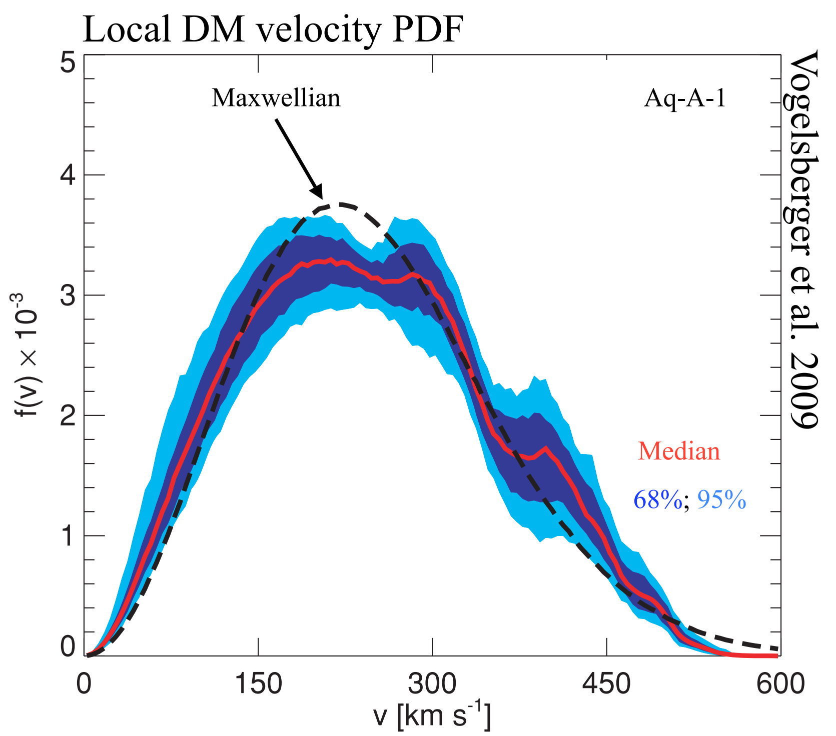
- ✓ The solar system rotates within the DM halo
- ✓ Earth experiences the so called “WIMP wind”
- ✓ Coming from the direction of the Cygnus constellation

Dark Matter Halo

$$\rho(R_0) = (0.3 \pm 0.1)\frac{GeV}{cm^3} = (0.008 \pm 0.0003)\frac{M_\odot}{pc^3}$$

J.Bovy, S Tremaine, APJ 756, 2012

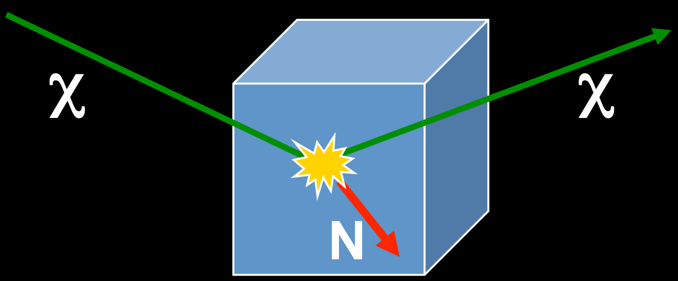
WIMP flux on Earth: ~10^5 cm^{-2} s^{-1}
(assuming M_W=100 GeV)



First order approximation: maxwellian v distribution with
v_{mean} ~ 230 km/s
v_{escape} ~ 600 km/s

Direct DM interaction signature

- Interaction type: elastic scattering off nuclei (but other proposed…)
- Signal: nuclear recoil energy

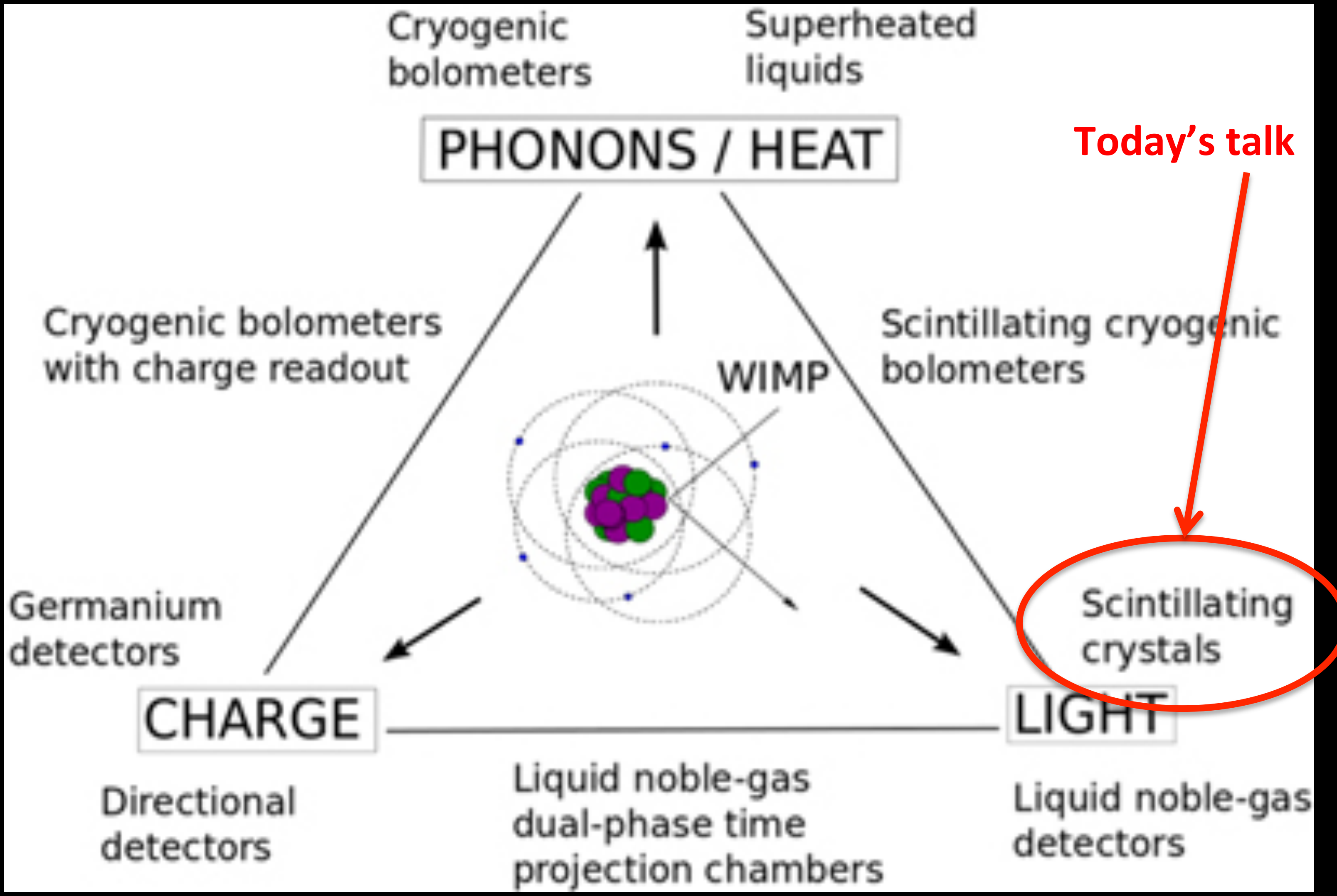


- For WIMP masses in the 10 GeV – 1 TeV range:
  typical recoil energy is 1keV – 50keV

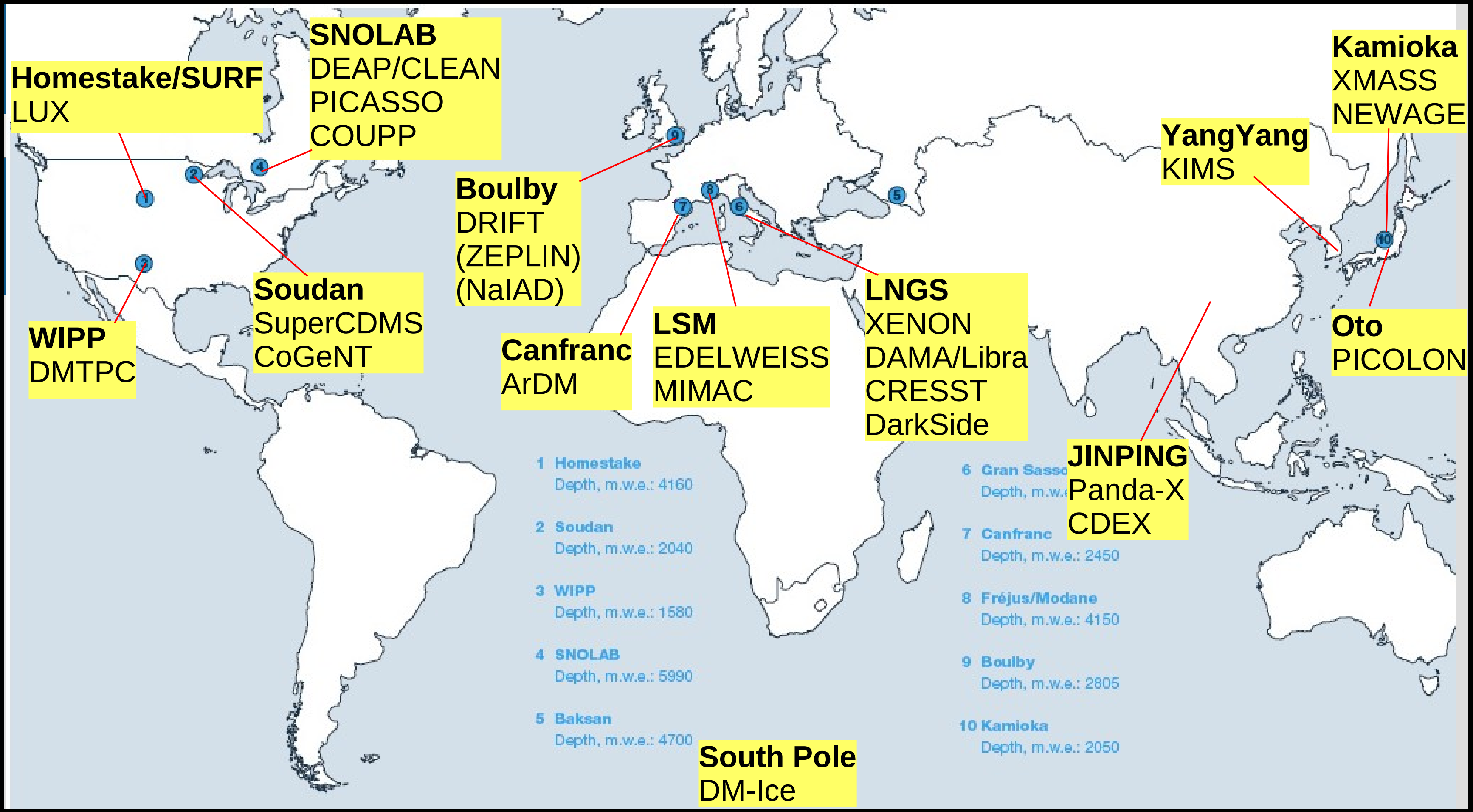
- Interaction cross-section is mostly unknown, though different models have their own estimates in the range $\sigma = 10^{-48}$–10^{-41} cm^2
- Interaction could be Spin Independent (SI) or Spin Dependent (SD).

<u>Very low expected rate ~ 10^{-1} to 10^{-6} events/kg/day</u>

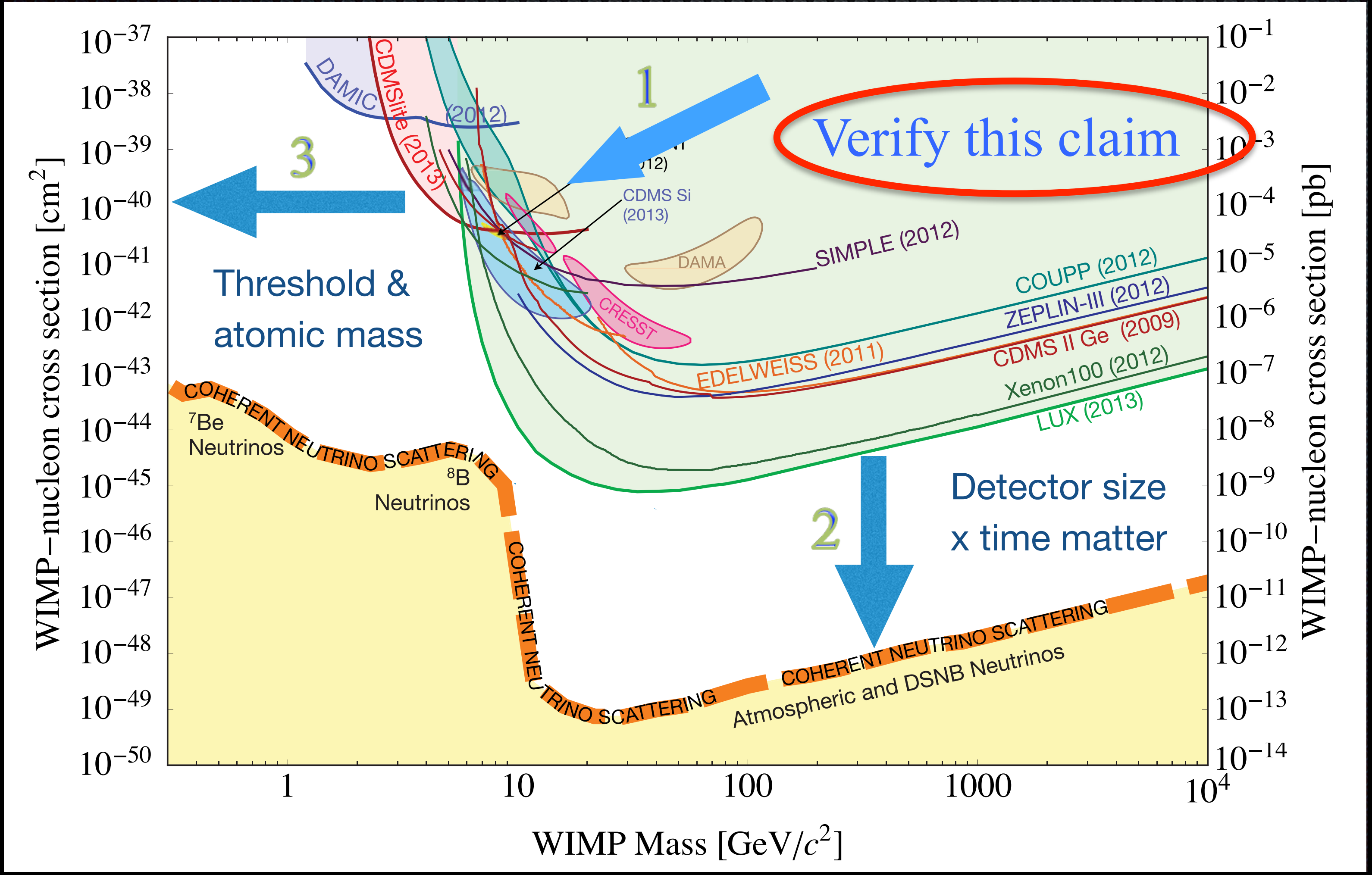
Direct WIMP interaction signature



Direct Dark Matter experiments



The Dark Matter roadmap



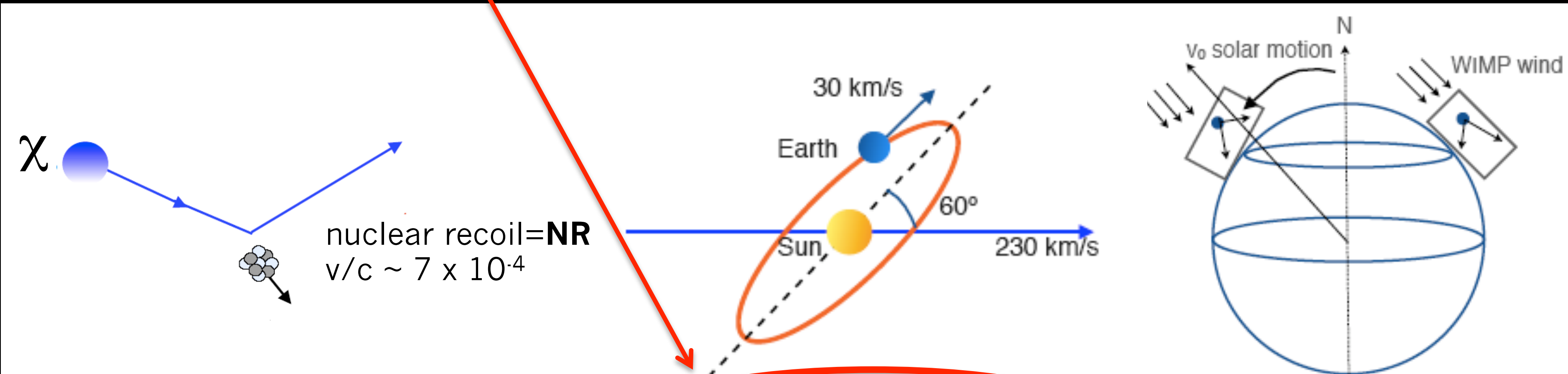
Dark matter signatures

Motion of the Earth and the detection of weakly interacting massive particles

David N. Spergel*
Institute for Advanced Study, Princeton, New Jersey 08540
(Received 21 September 1987)

If the galactic halo is composed of weakly interacting massive particles (WIMP's), then cryogenic experiments may be capable of detecting the recoil of nuclei struck by the WIMP's. Earth's motion relative to the galactic halo produces a seasonal modulation in the expected event rate. The direction of nuclear recoil has a strong angular dependence that also can be used to confirm the detection of WIMP's. I calculate the angular dependence and the amplitude of the seasonal modulation for an isothermal halo model.

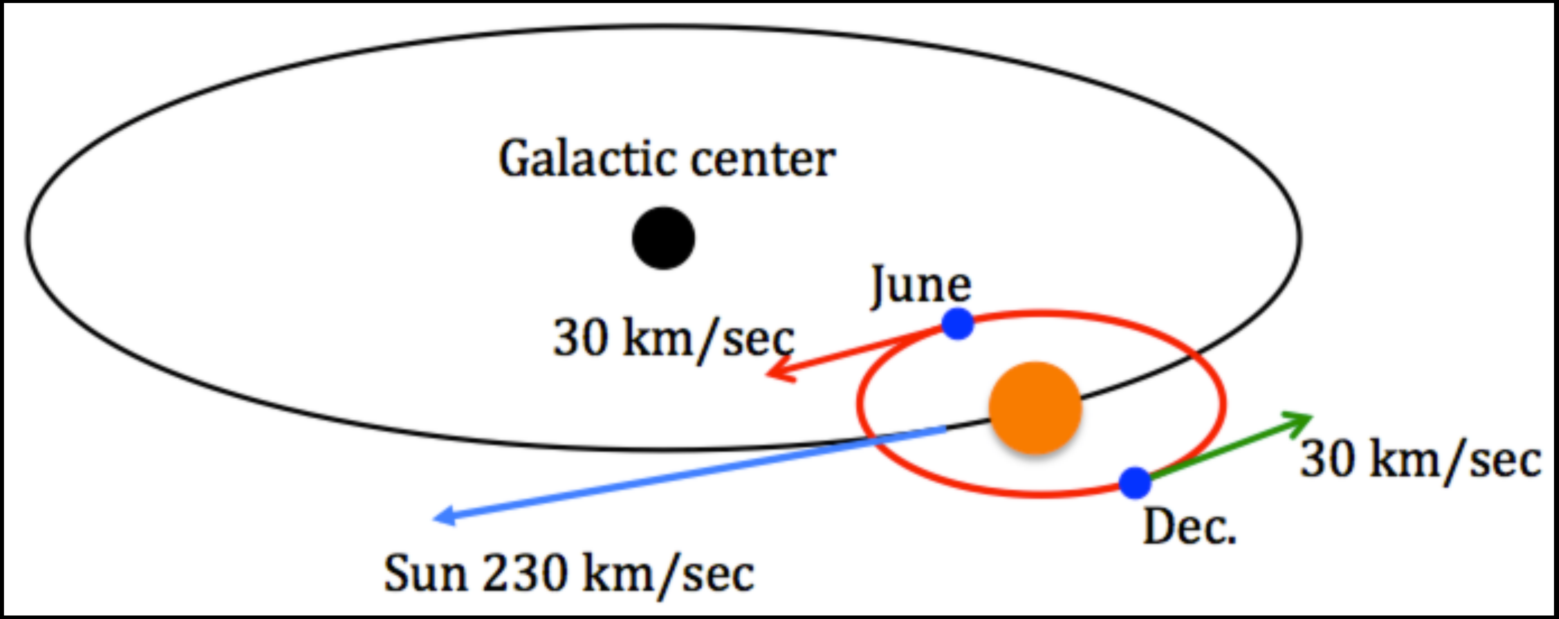
Today's talk



Count nuclear recoils | annual flux variation | diurnal directional modulation

background must be very low or zero (*background-free* experiments)	signal must be high enough to show the modulation, even at the price of more and not totally known background	Detector must have a direction of signal enhancement [Future]

The Modulation DM signature

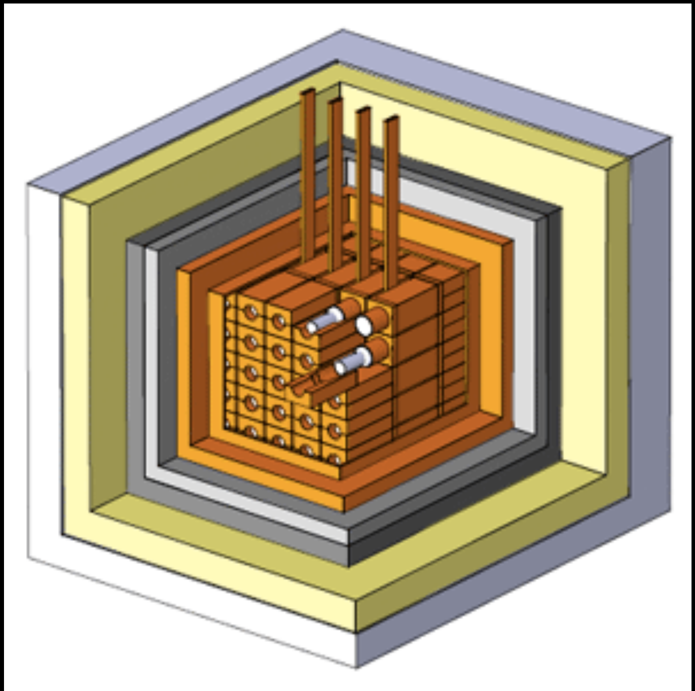


$$\frac{dR}{dE_R}(t) = S_0(E_R) + S_m(E_R)\cos\omega(t - t_0)$$

Annual modulation is a <u>model independent</u> signature of Dark Matter interaction

DAMA/LIBRA

- Underground location: LNGS
- Technique: NaI scintillating crystals
- Detector's module:
  10kg crystal
  paired with two 3" PMTs
  - Light guides are used to keep PMTs distant from crystals and reduce background
- Geometry: 5x5 crystal matrix
- Total mass: 250kg
- Energy threshold: 2keV

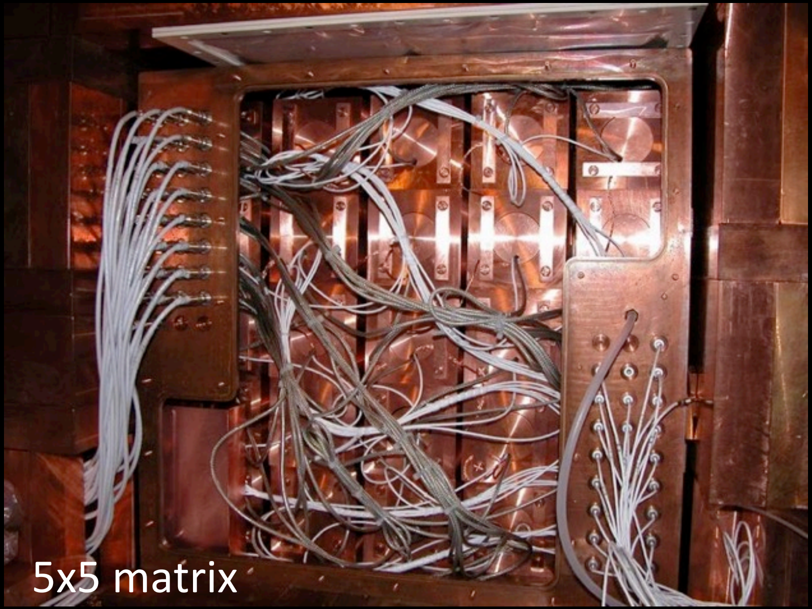


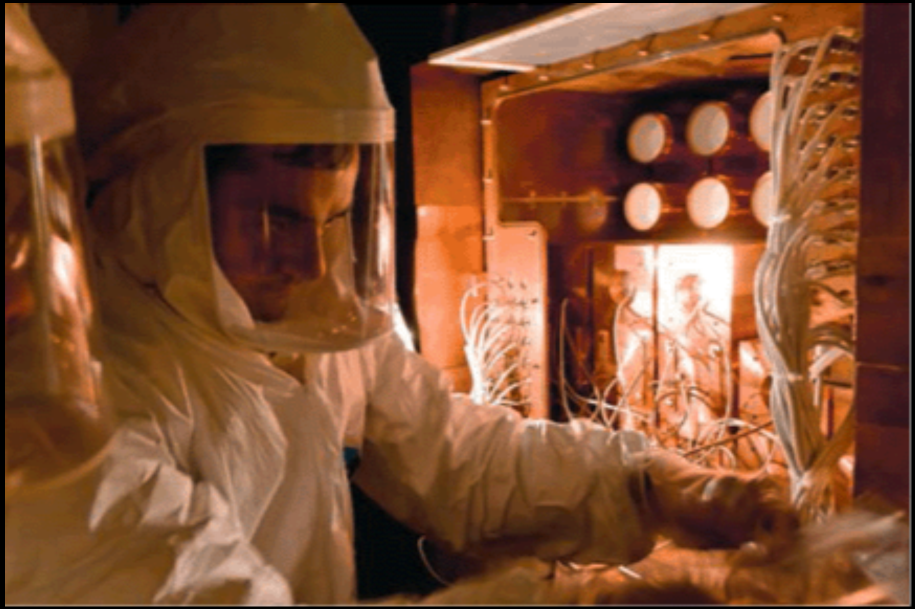
DAMA/LIBRA

1. DAMA/NaI (100kg): 1996-2002
2. DAMA/LIBRA (250kg) Phase I : 2003-2010
   – Mass upgrade
3. DAMA/LIBRA (250kg) Phase II: 2011-2016
   – New PMTs (low radioactivity, low noise)
4. DAMA/LIBRA (250kg) Phase III: 2017-…
   1. No light guides

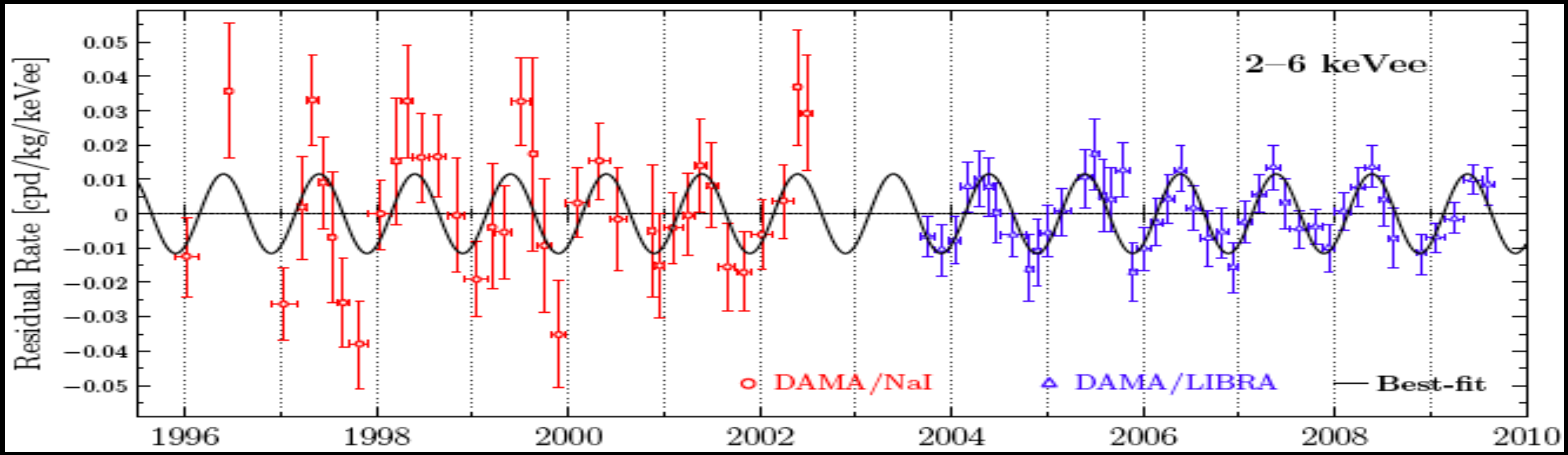
R. Bernabei et al. (DAMA coll.), EPJ C (2013) 73:2648.

Results announced for 2017





The DAMA/LIBRA modulation



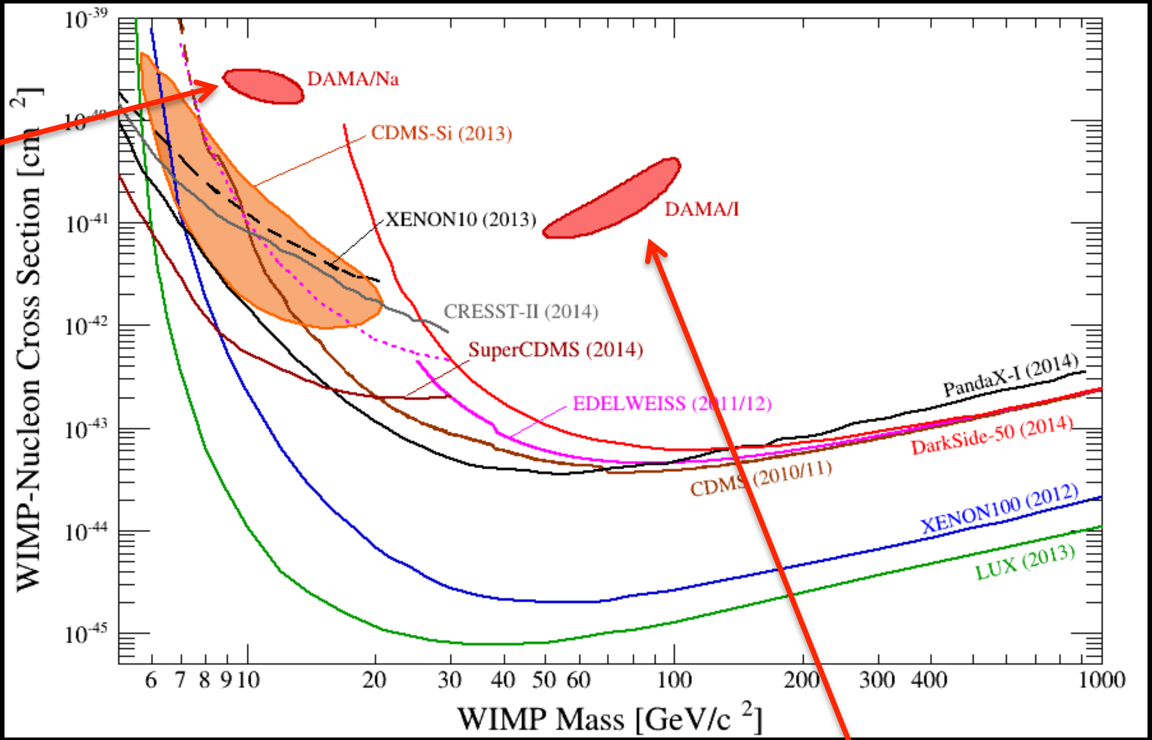
- 13 annual cycles (Dama/NaI + Dama/Libra)
- χ^2/ndf = 70.4/86
- 9.3σ significance
- (0.998±0.002) year period
- Phase is (144±7) days vs. Exp. DM phase 152.5 days
- Amplitude (0.0112±0.0012) cdp/kg/keV (~ 1.2% of signal)

Interpretation of DAMA/LIBRA results

Interaction on Na nuclei

M_{wimp} ~ 10 GeV

σ ~ 10^{-40} cm^2



In the simplest interpretation of SI WIMP-nucleus interaction there are two allowed regions with very similar χ^2

Interaction on I nuclei

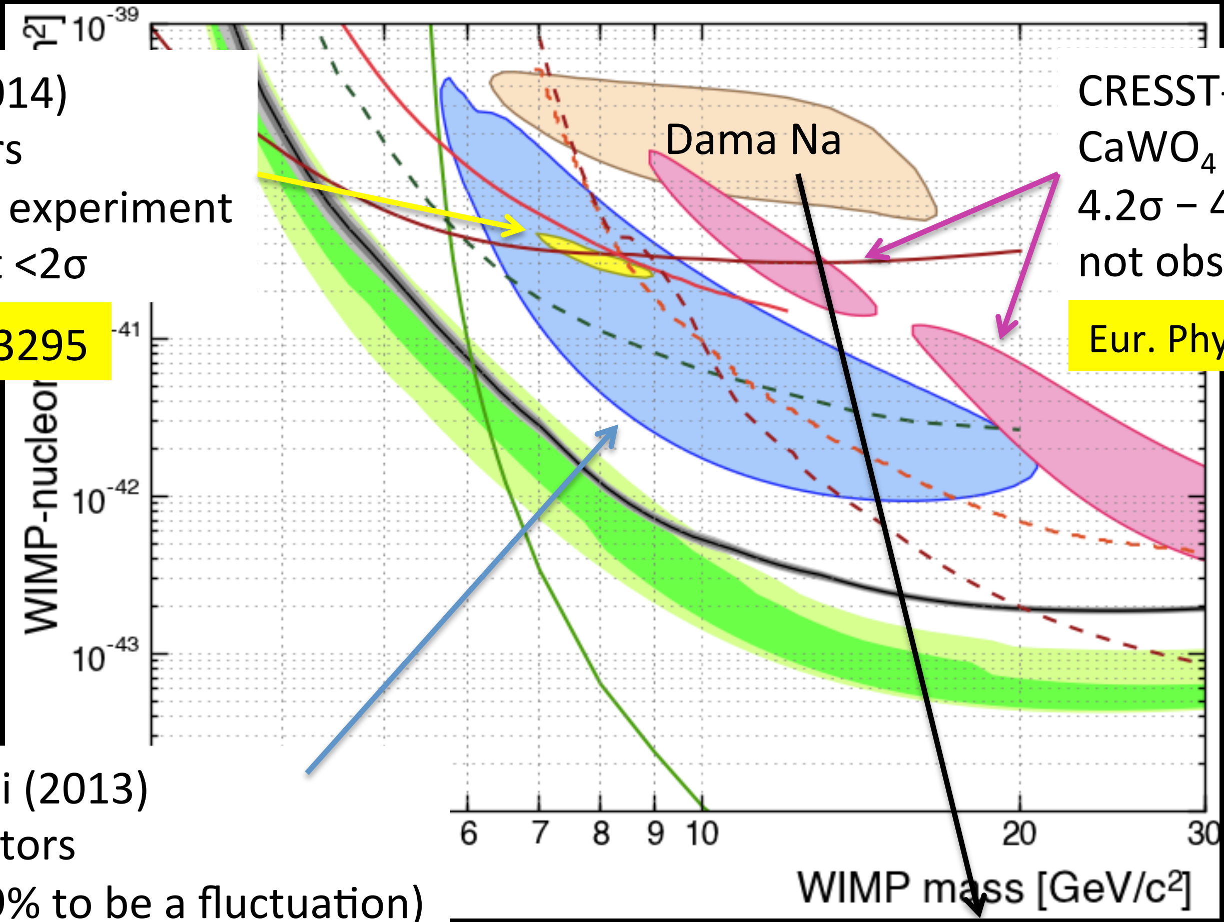
M_{wimp} ~ 80 GeV

σ ~ 10^{-41} cm^2

However there are several assumptions here:

- ✓ Astrophysics: DM halo
- ✓ Dark matter candidate: WIMP
- ✓ Nature of interaction: elastic and Spin Independent
- ✓ Target of Interaction: nuclei

What about other positive results?



CoGeNT (2014)
Ge detectors
modulation experiment
latest result <2σ

arXiv:1401.3295

CRESST-II (2011)
$CaWO_4$ bolometers
4.2σ – 4.7σ
not observed in new setup

Eur. Phys. J. C (2012) 72:1971

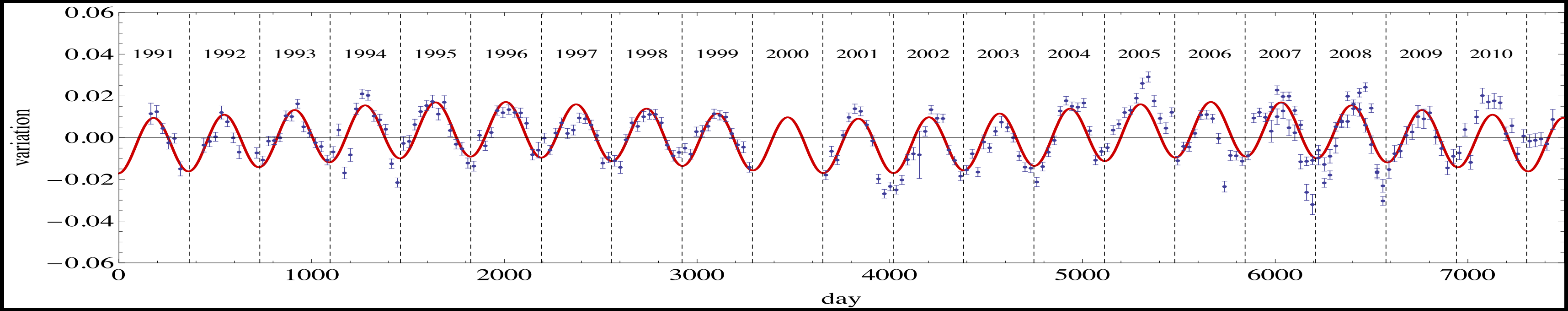
CDMS-Si (2013)
Si detectors
3σ (0.19% to be a fluctuation)
not observed in Ge

PRL 111 (2013) 251301

DAMA is the only one truly significant

DAMA alternative explanations?

- The rate of cosmogenic muons is known to modulate due to seasonal expansion/contraction of the troposphere which changes the pion/kaon mean free path.
- Could muon-induced background such as nuetrons explain D/L modulation?
- Could there be other explanations of terrestrial origin? (e.g. radon emanation)
- Long standing questions: tens of papers written on the subject.
- **No clear conclusion**



Combined MACRO+LVD+Borexino muon flux modulation

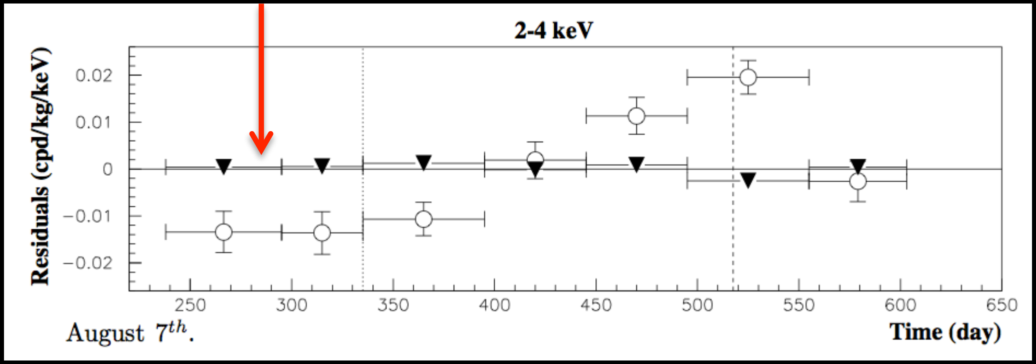
Why is DAMA/LIBRA robust?

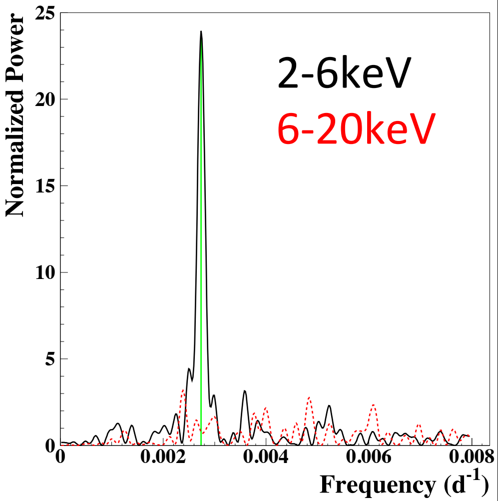
1) All instrumental sources of modulations have been investigated and excluded:

- ✓ radon
- ✓ temperature
- ✓ gas pressure
- ✓ noise
- ✓ energy scale
- ✓ efficiencies
- ✓ environmental neutrons

2) Phase: (144±7)d
cmp. muon: (182±6)d

3) No modulation in multi-hit events





4) No modulation > 6keV

A complex scenario

- DAMA/LIBRA (D/L) results (and other positive low mass results) are *in tension* with several other experiments
  - but only assuming basic SI WIMP-nucleus interaction and standard DM halo.
- D/L (and CoGeNT) observes DM annual modulation, while all others are counting experiments.
- No other experiments is using NaI as target material.
- Theoretical attempts to let D/L coexist with other results:

  NO clear conclusion.
- Attempts to explain D/L in terms of background have been made
  - ^{40}K
  - cosmogenic (and environmental) background

  NO clear conclusion
- D/L has done an excellent job. Strong arguments to sustain the result.

  NO trivial mistake

A complex scenario

- DAMA/LIBRA (D/L) results (and other positive low mass results) are *in*

Low-mas compatibility

H. Hooper, J. Collar, J. Hall, D. McKinsey, C. Kelso, PR D 82 (2010) 123509.

C. Savage et al., JCAP 04 (2009) 010.

P.W. Graham et al., PR D 82 (2010) 063512.

D. Hooper, Phys. Dark Univ. 1 (2012) 1.

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Instrumental backgrounds (^{40}K)

J. Pradler, B. Singh and I. Yavin, PL B 720 (2013) 399-404

R. Bernabei et al. (DAMA coll.), (2012) arXiv:1210.6199 and arXiv:1211.6346;

J. Pradler and I. Yavin, (2012) arXiv:1210.7548.

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A complex scenario

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Environmental backgrounds (Cosmic muons)

J. P. Ralston, (2010) arXiv:1006.5255

K. Blum, (2011) arXiv:1110.0857

E. Fernandez-Martinez and R. Mahbubani, JCAP 07 (2012) 029

S. Chang, J. Pradler and I. Yavin, PR D 85 063505 (2012)

J. Pradler, (2012) arXiv:1205.3675

R. Bernabei et al. (DAMA coll.), IJMP A 28 (2013) 1330022

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<u>NO trivial mistake</u>

Another NaI measurement is needed!

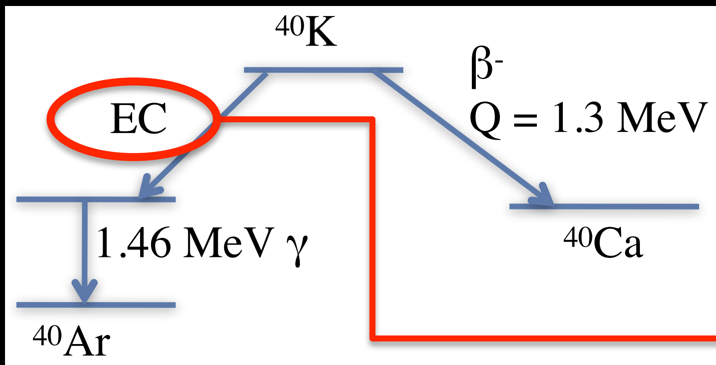
SABRE's four pillars

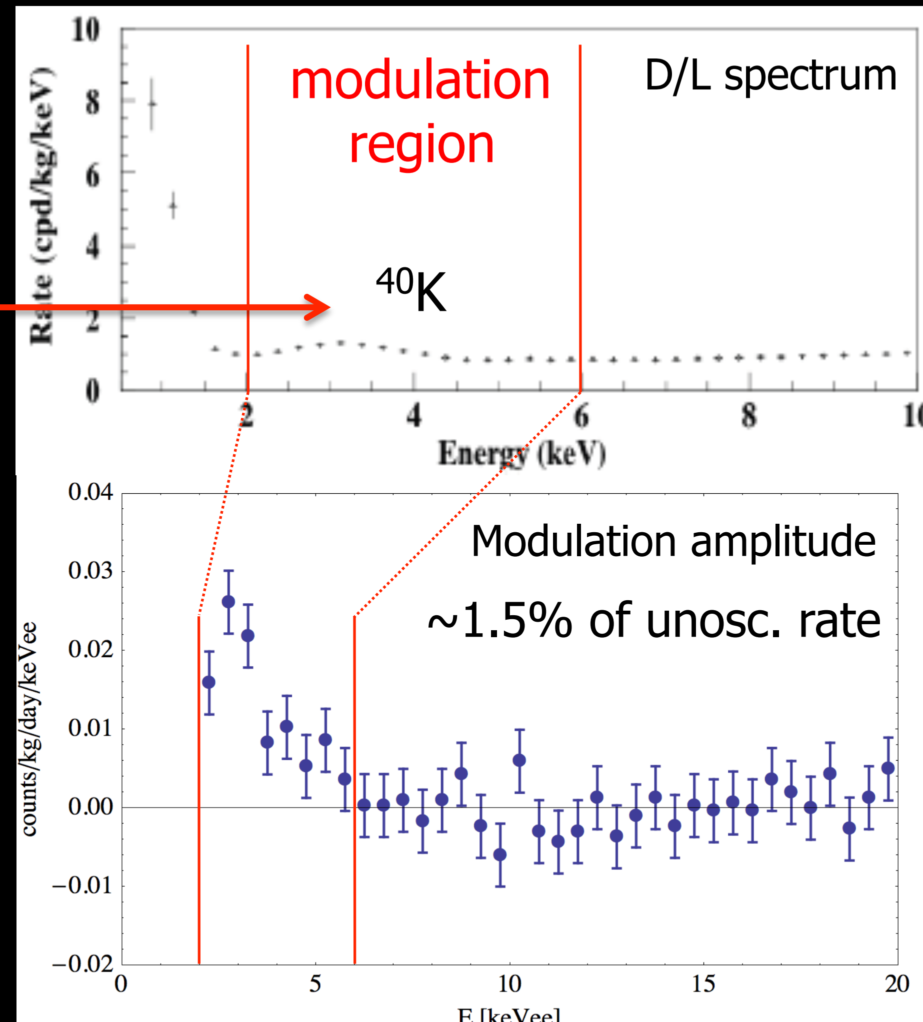
Model Independent Test

1. **Higher purity crystals**
2. **Active back-ground rejection**
3. **Better PMTs**
4. **Double location**

<u>Not just a test but a higher sensitivity stand-alone experiment</u>

Overcoming DAMA/LIBRA: background





^{40}K 3keV EC (10% BR) lies where the modulation amplitude is maximal

Pillar 1

Reduce K content in NaI

High Purity NaI powder

- Princeton University and industrial partners (now Sigma-Aldrich) have yielded Astro-Grade powder with higher purity then D/L crystals
- Large effort in Spectrometry (ICP-MS, ICP-OES, AMS) in several labs to measure such low concentrations

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	$0.5 – 7.5 \times 10^{-3}$
Th	< 0.5 ($< 10^{-3}$)**	~ 0.02	$0.7 – 10 \times 10^{-3}$

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

New batch is 9ppb!

High Purity Crystals

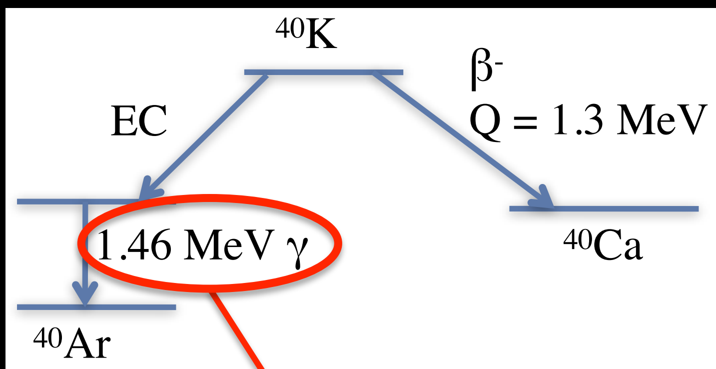
3.5’ -- 2kg test crystal
from Astro-Grade powder

^{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

^{87}Rb < 0.1ppb (<0.35ppb in D/L)

Breakthrough! → Full size 5kg crystal under production

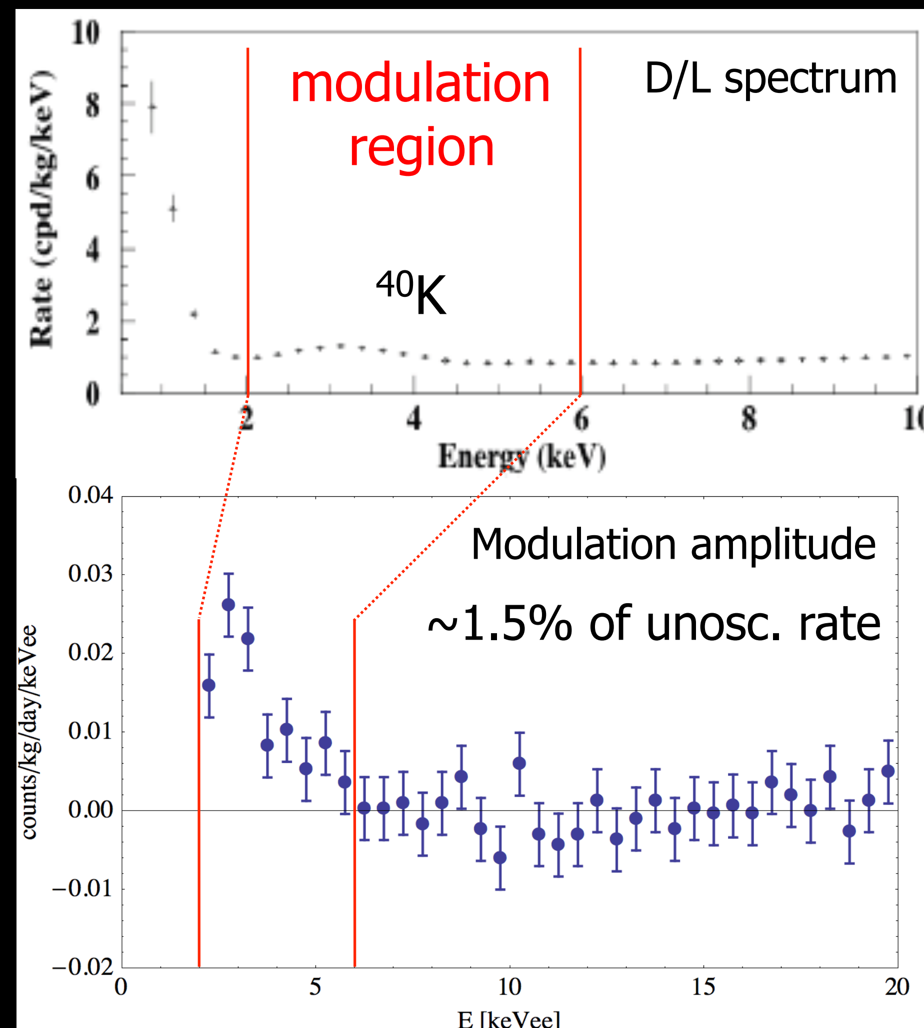
Overcoming DAMA/LIBRA: background



detect the gamma

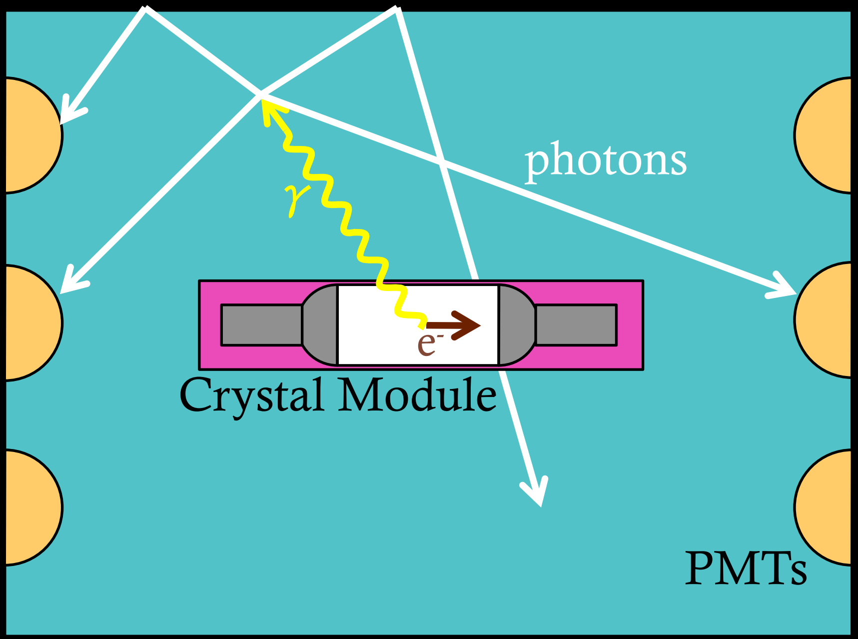
Tag K

Pillar 2



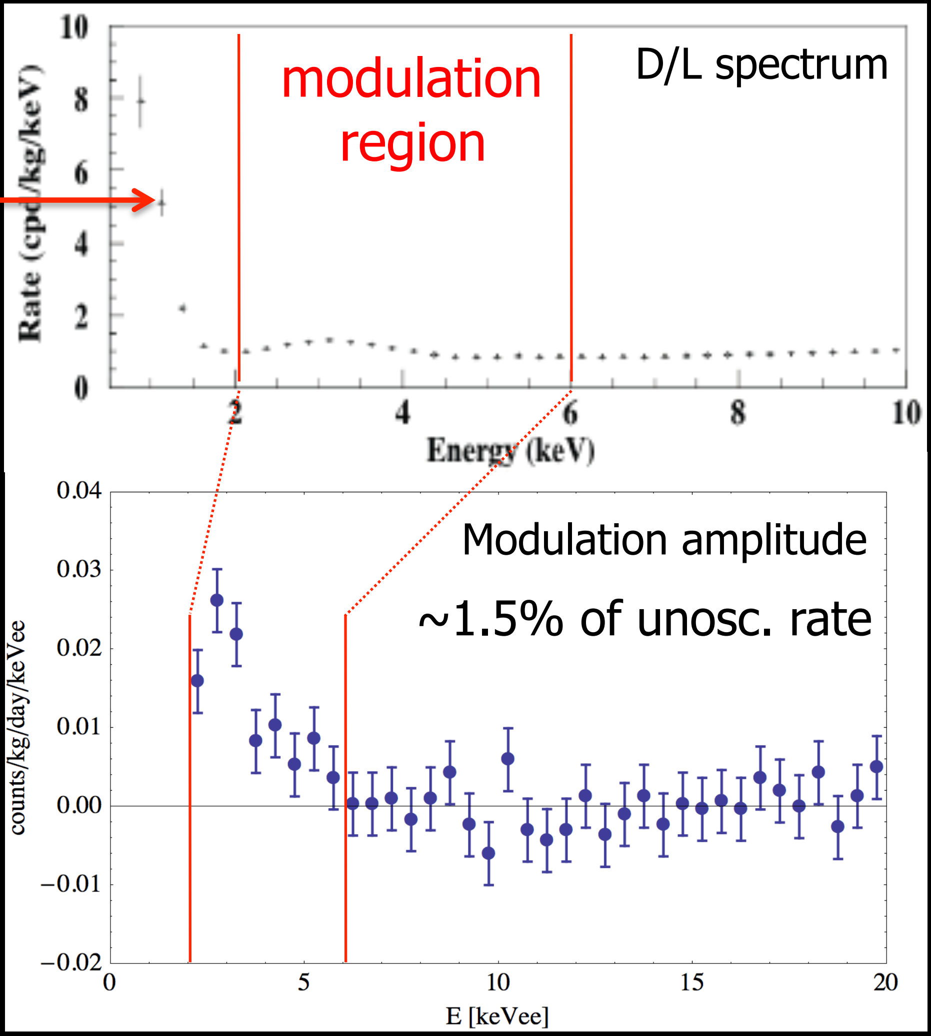
Pillar 2: Active Background Rejection

- Surround crystals with liquid scintillator
- 4π gamma detection
- high efficiency on ^{40}K suppression: >80%



Overcoming DAMA/LIBRA: threshold

DAMA/LIBRA energy threshold
is set to 2keV
due to high PMT noise



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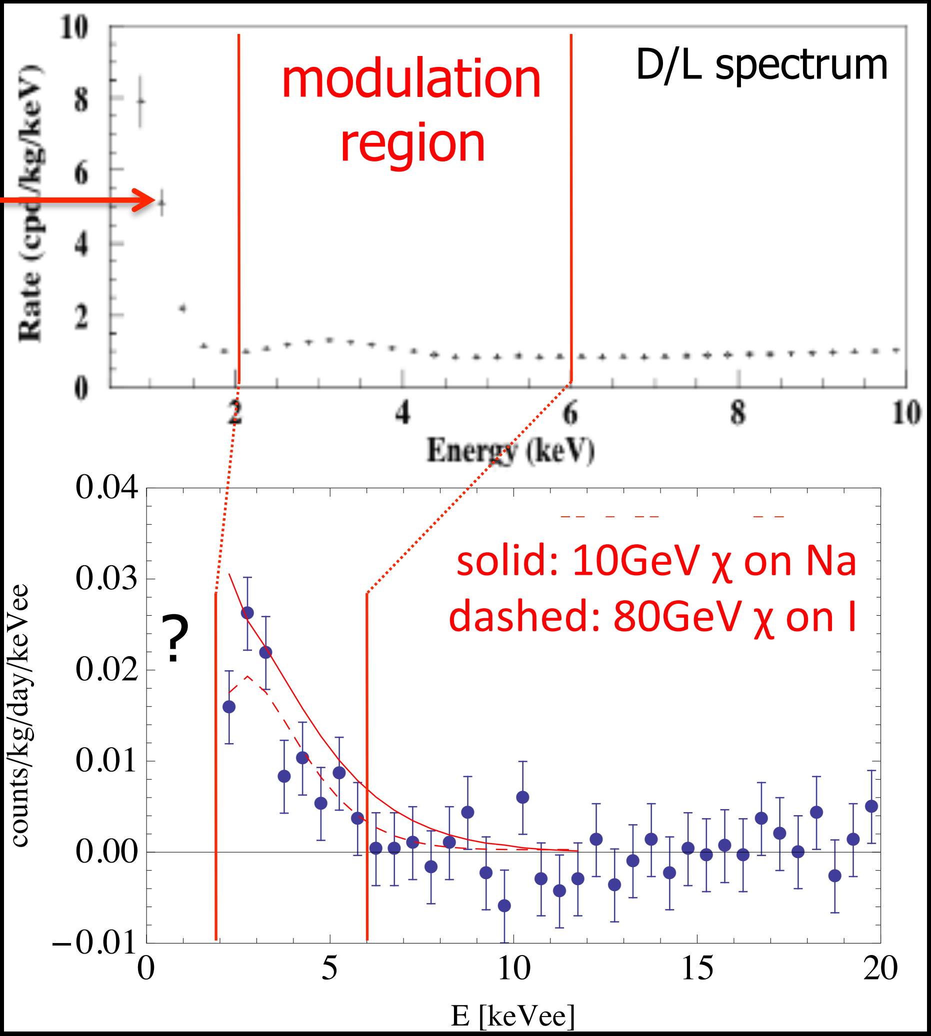


<u>Important to uncover the 1-2keV region</u>

Pillar 3

Next-generation
Photomultiplier Tubes

Pillar 3: PhotoMultiplier Tubes (PMTs)

Baseline: R11065 3" PMTs

5.5mBq → Less background

– no light guides → More light

custom pre-amplifiers

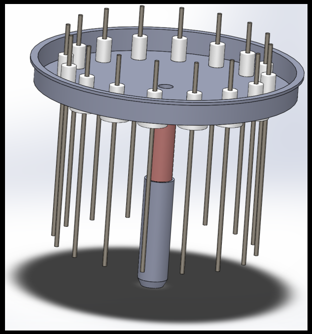
– reduced after-glow → Less noise

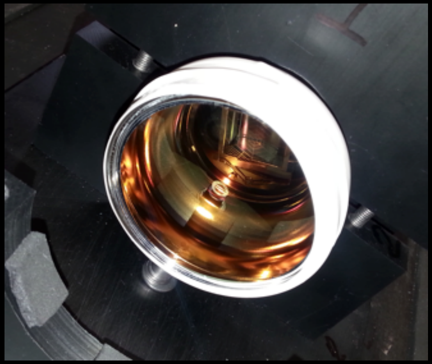
A 14pe/keV light collection is possible

Pillar 3: PhotoMultiplier Tubes (PMTs)

R&D trying to improve R11065-20:

1. Replace ceramic stem with individual ceramic pin feedthroughs
    - Improved stability
    - Lower light emission
    - Less background



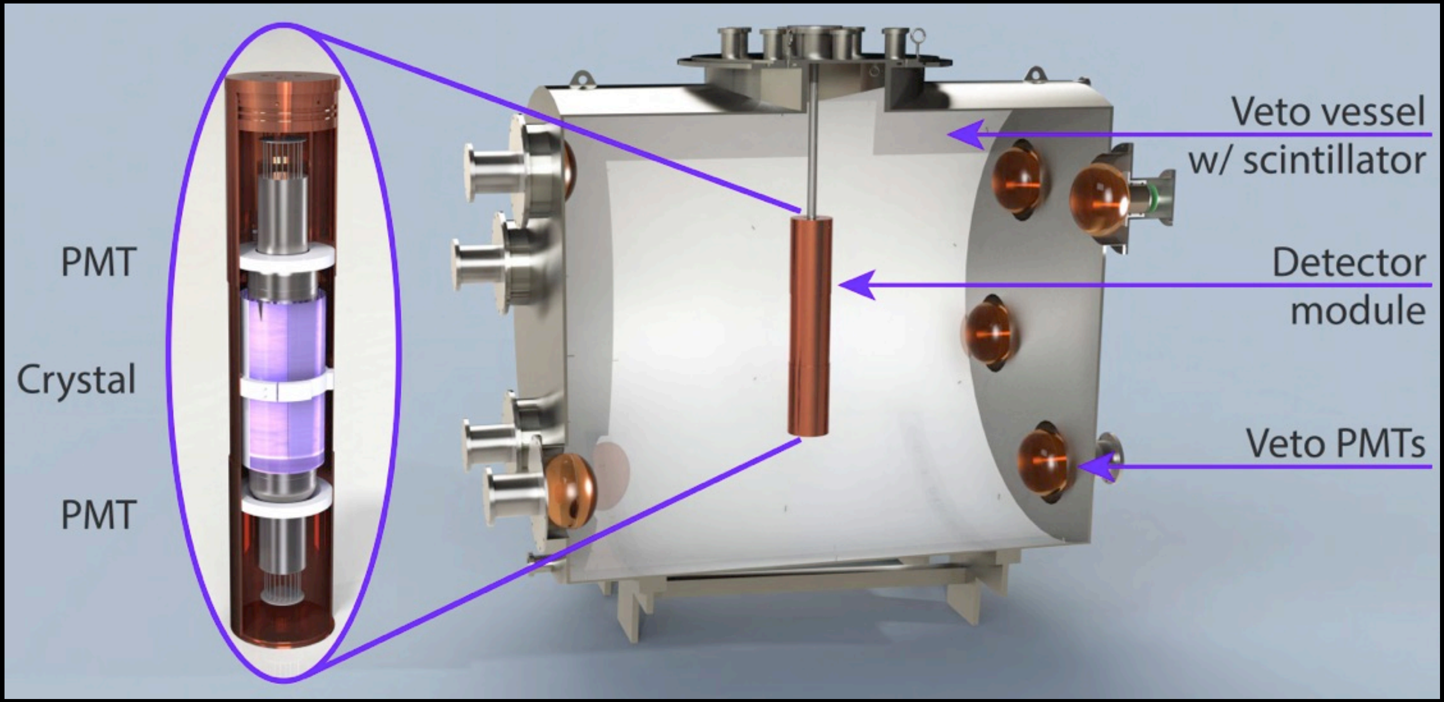


2. Use Super BiAlkali photocathodes:
    - higher Quantum Efficiency
    - Lower Dark Noise

SABRE Proof-of-Principle (PoP)

- Prototype phase @LNGS with single crystal
- Goal: fully characterize crystal background, detector design, and performance.
- Crystal Trigger: coincidence of opposing PMTs
- Liquid Scintillator trigger: coincidence of N PMTs

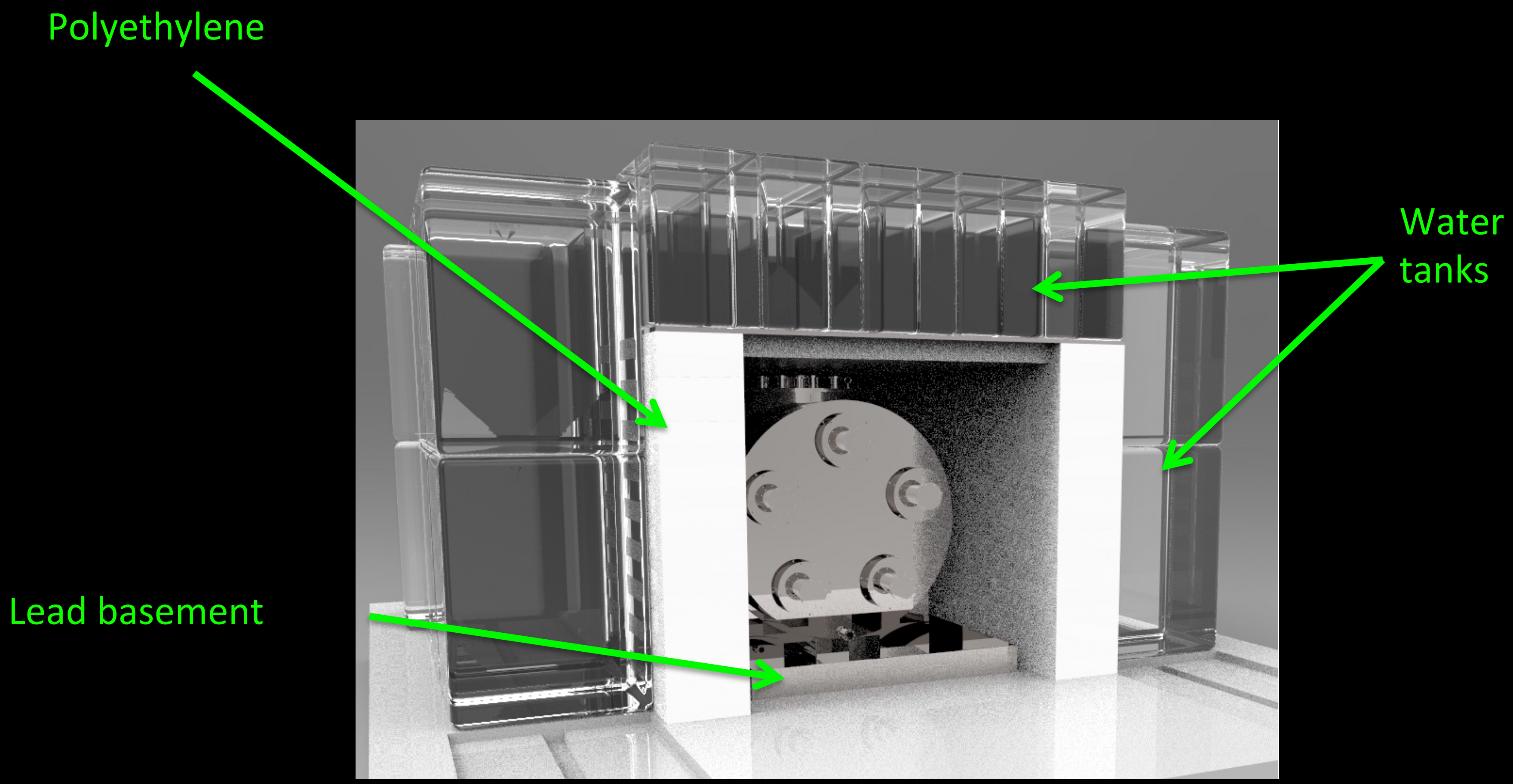
} { ORed Dark Matter mode
ANDed K measuring mode



PoP vessel

- 1.4x1.5m stainless steel vessel
- ~2ton of liquid scintillator (PC+ppo)
- 10 x 8" PMTs
- In a temporary location in Hall B at LNGS

PoP shielding



Space in Hall-C expected June 2017

Expected backgrounds

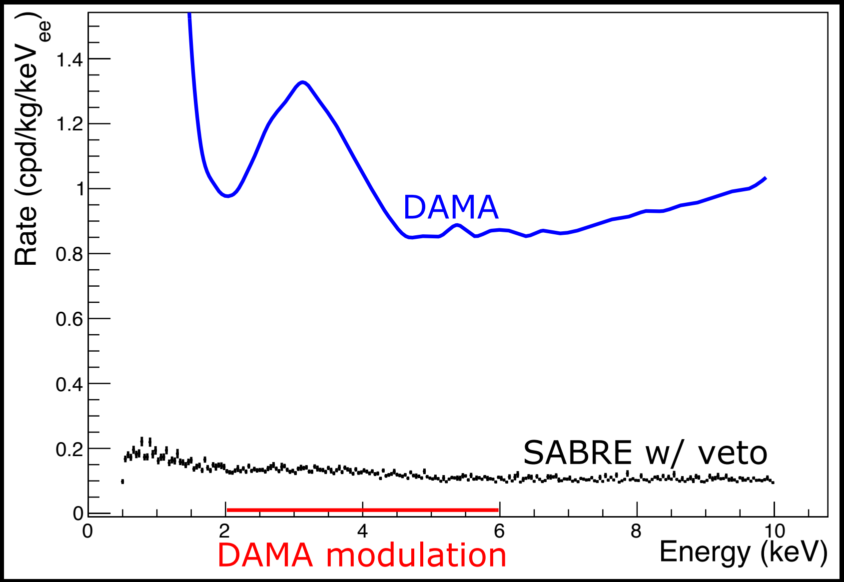
MonteCarlo simulations

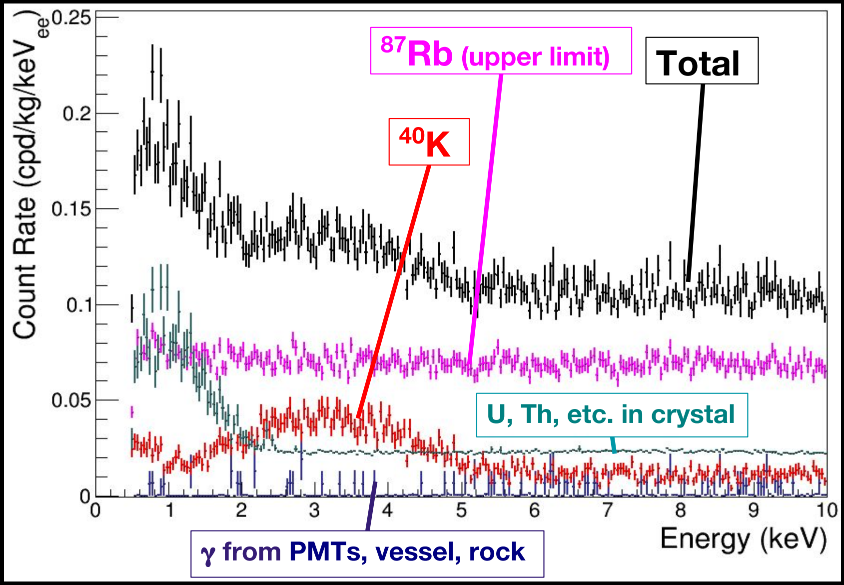
1. from crystals:

- ^{40}K: 0.03 cpd/kg/keV$_{ee}$
- ^{87}Rb: <0.07 cpd/kg/keV$_{ee}$ (upper limit)
- ^{238}U, ^{232}Th: ~0.02cpd/kg/keV$_{ee}$
- ^{3}H, ^{210}Pb to be determined

2. external:

γ from PMTs, enclosure, vessel, rocks are negligible

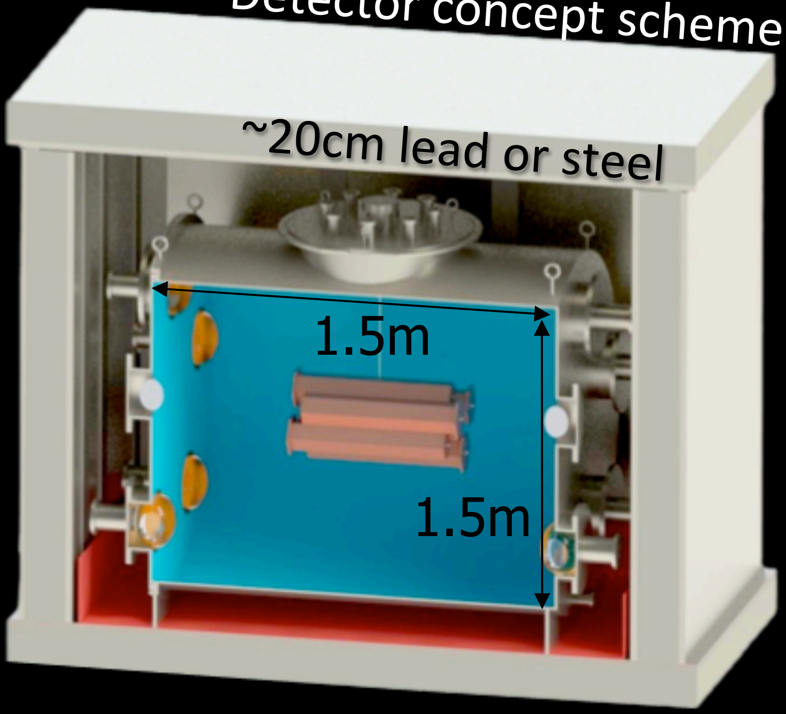




Total: 0.13cpd/kg/keV$_{ee}$ – DAMA/LIBRA: ~1cpd/kg/keV$_{ee}$

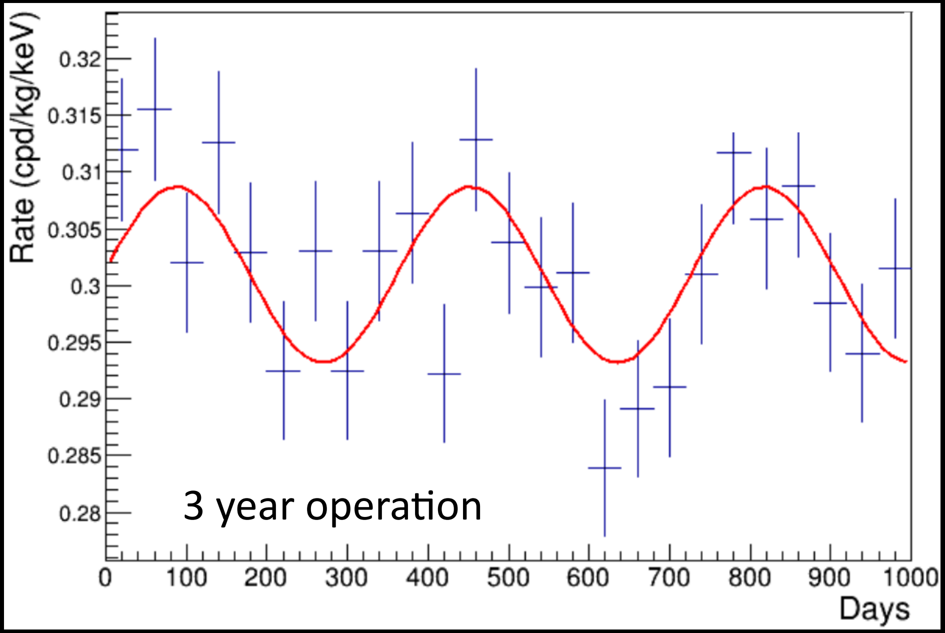
SABRE: Full Scale Experiment

- Final mass to be determined according to background
- Steel vessel could host up to 7 modules = 35kg
- Eventually design larger vessel



Sensitivity

Exposure:
50kg x 3y



Background:
0.13
$cpd/kg/keV_{ee}$

4σ power to verify DAMA/LIBRA

[or 6σ to refute]

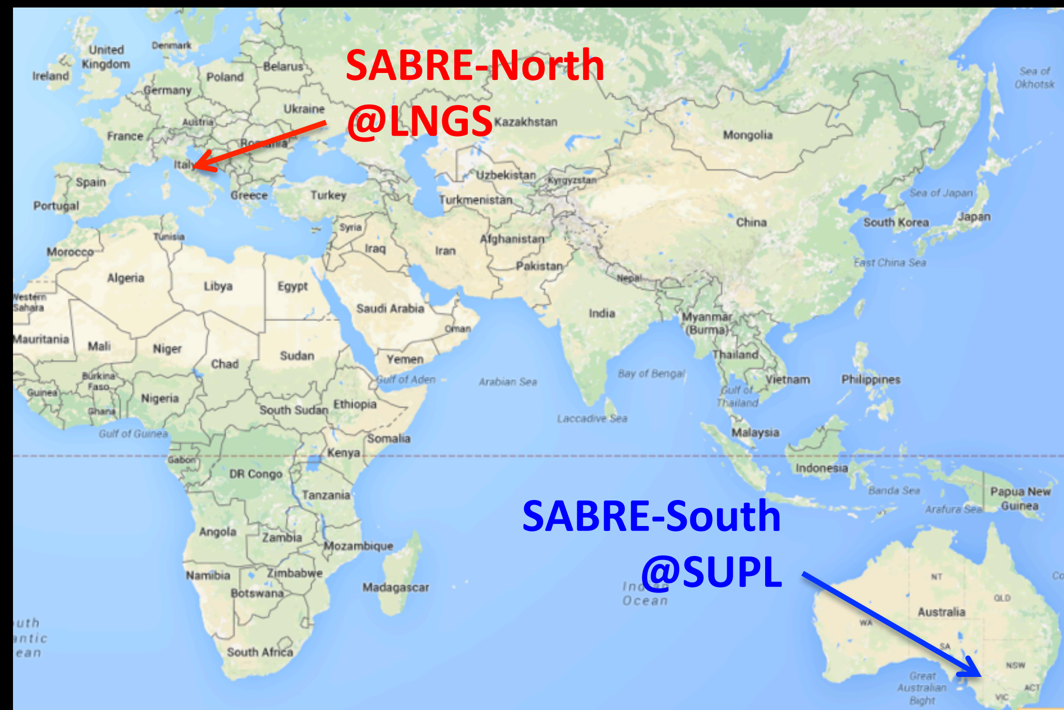
Pillar 4: Double location

Pillar 4

- SABRE Full scale experiment in two different laboratories

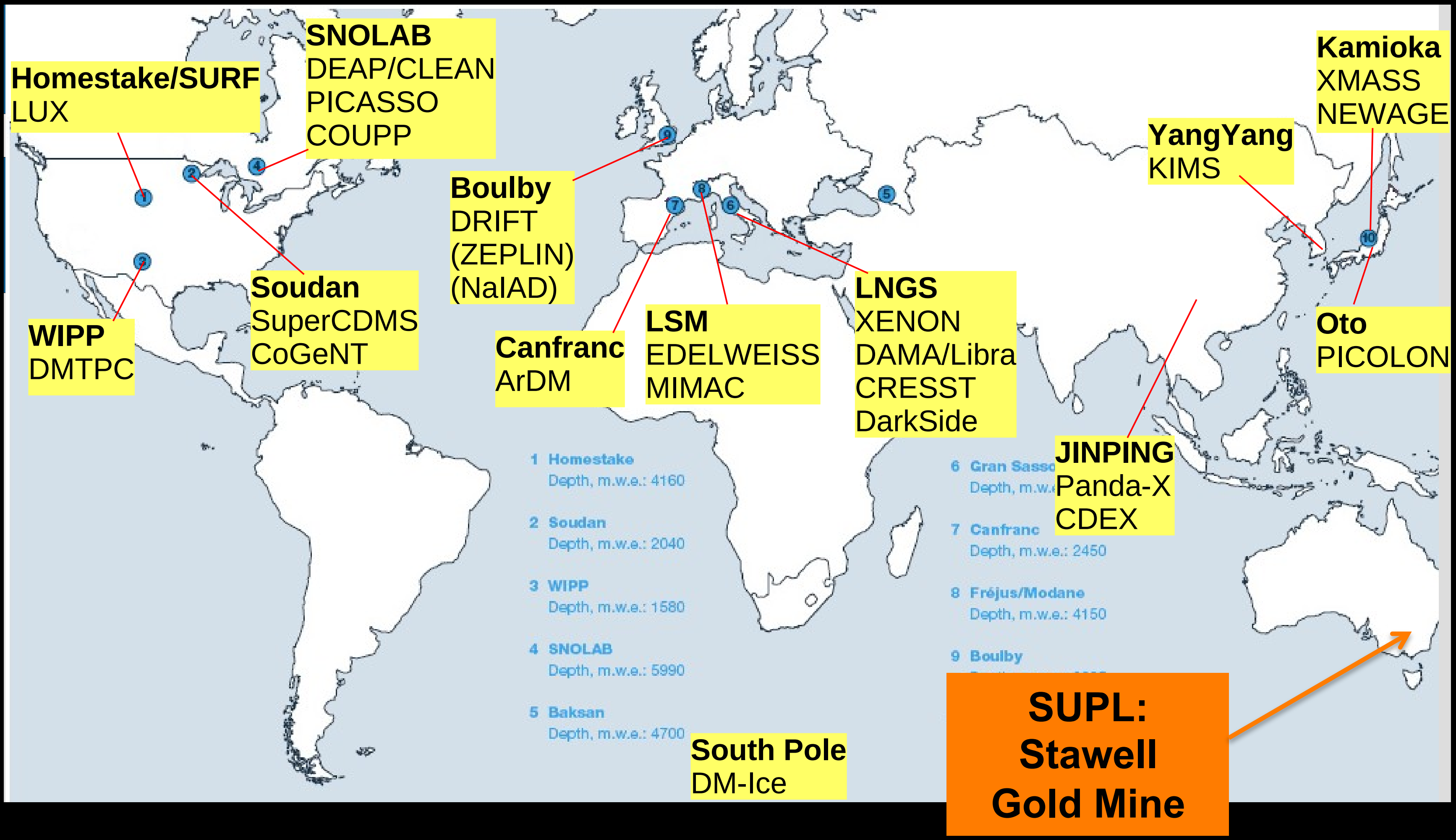
→ on opposite hemispheres

- Twin detectors for reduced systematics

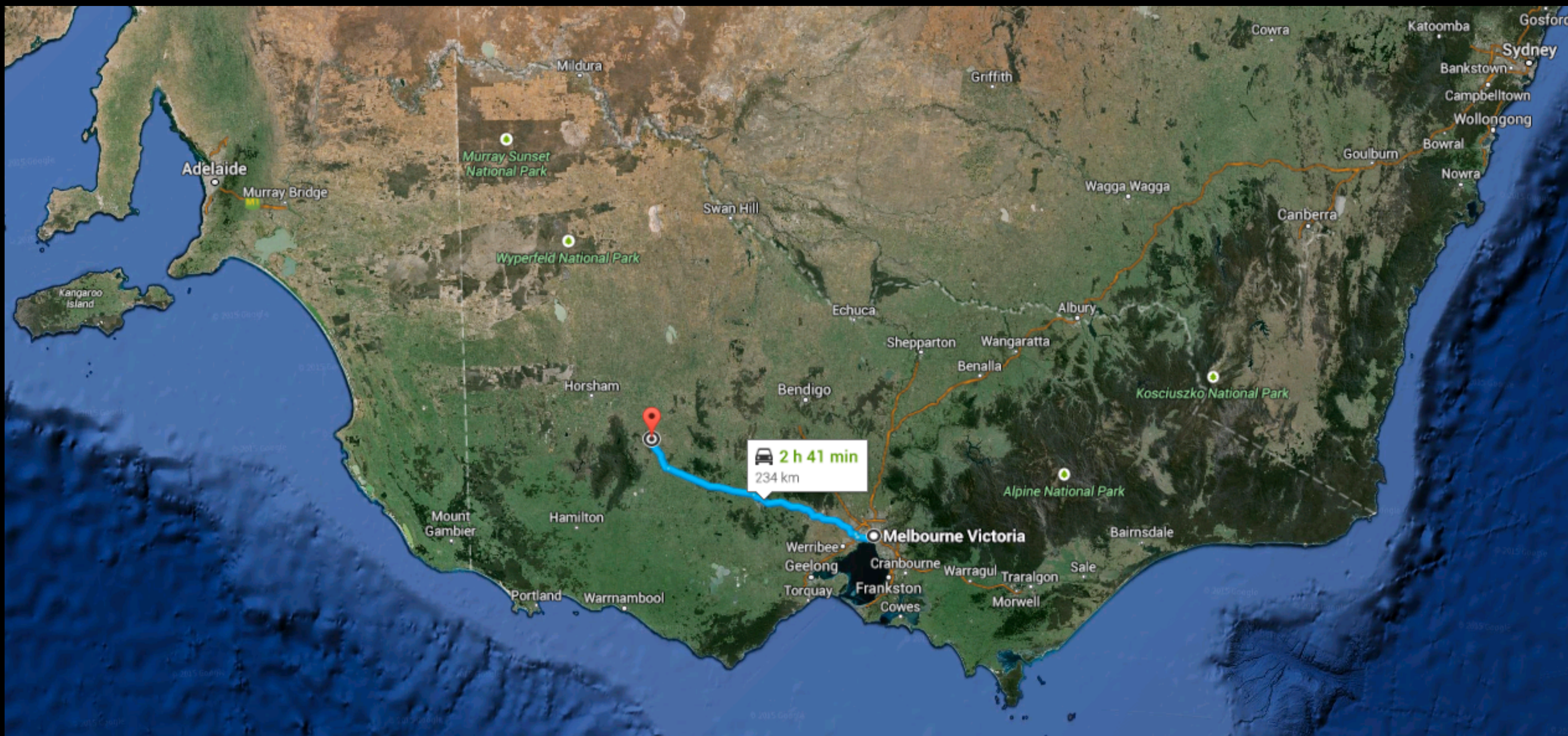


Any season-related contribution to the modulation would reverse phase

Underground labs

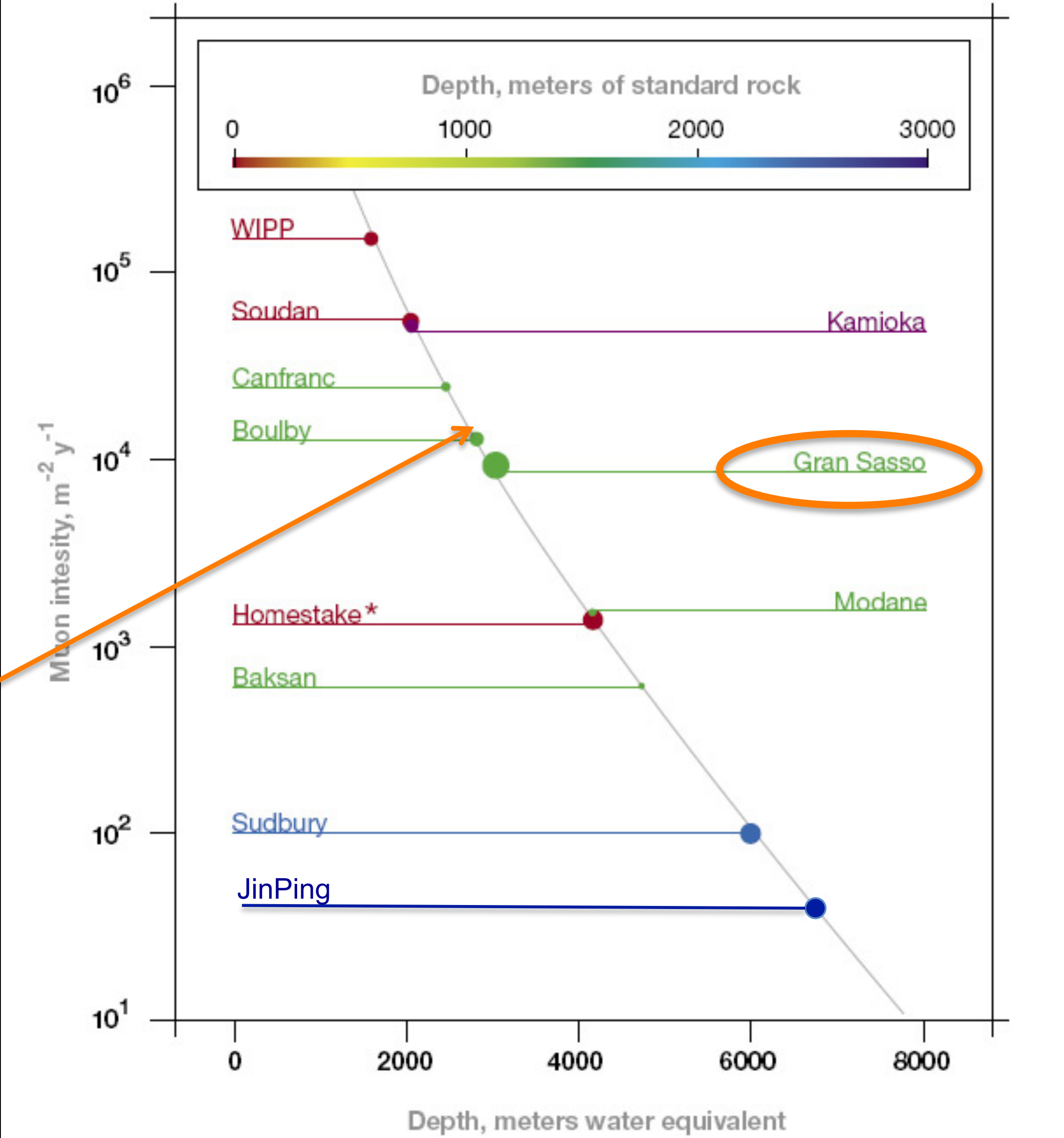


Stawell gold mine



State of Victoria, ~ 300km west of Melbourne, ~3h drive.

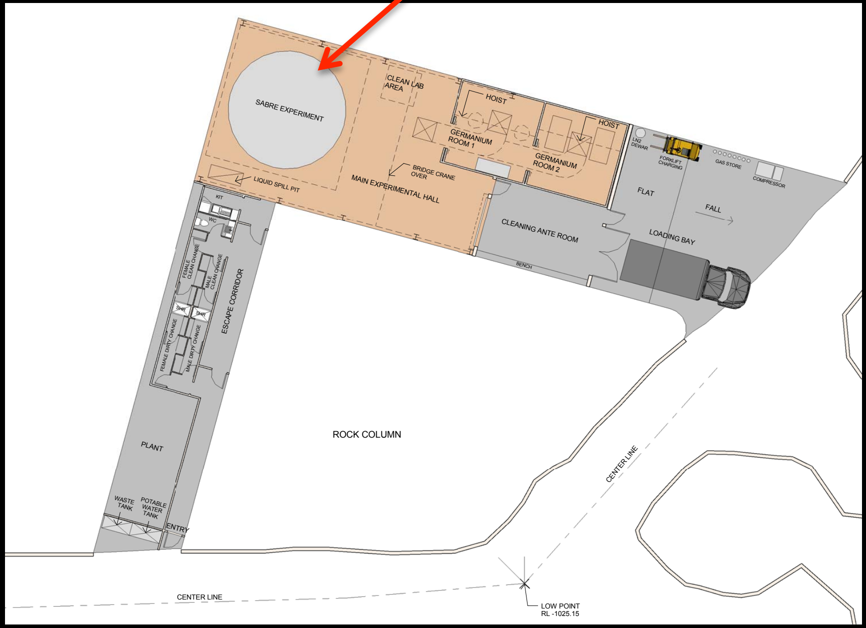
Underground Labs

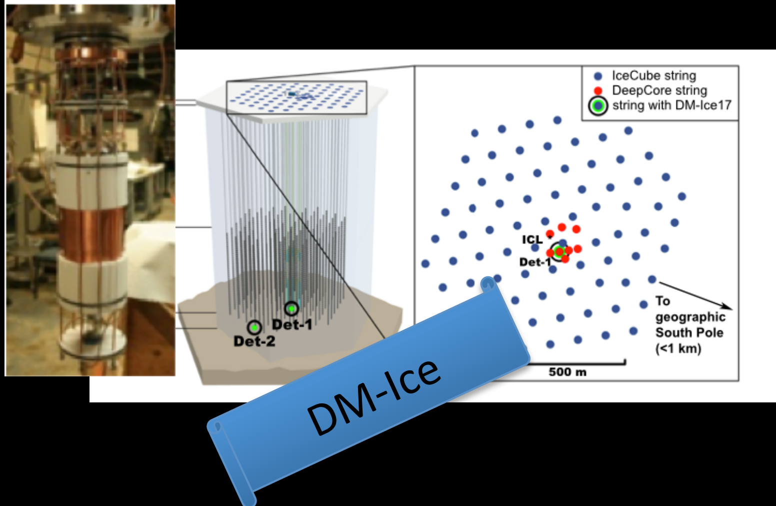


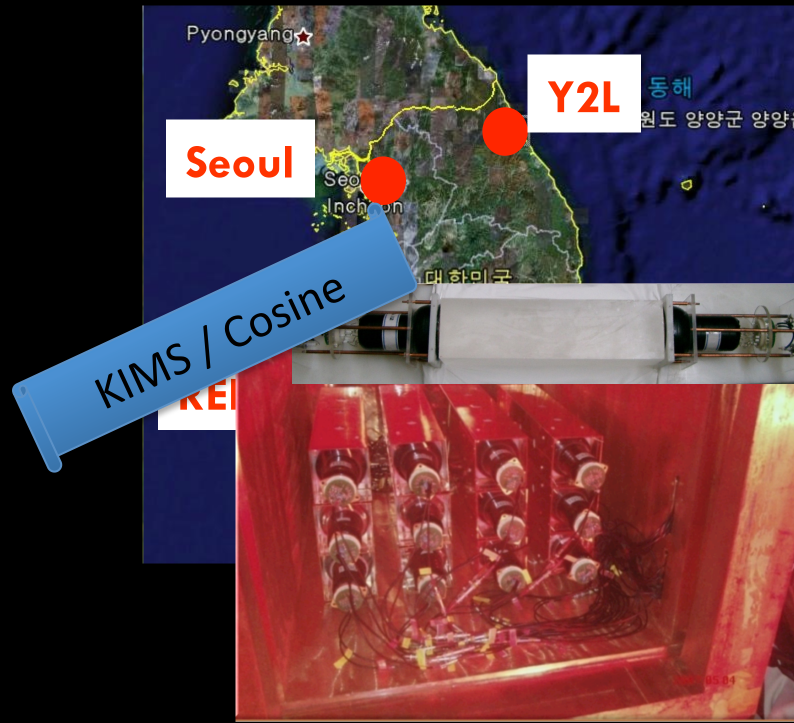
SUPL: Stawell Gold Mine

Stawell Underground Physics Laboratory (SUPL)

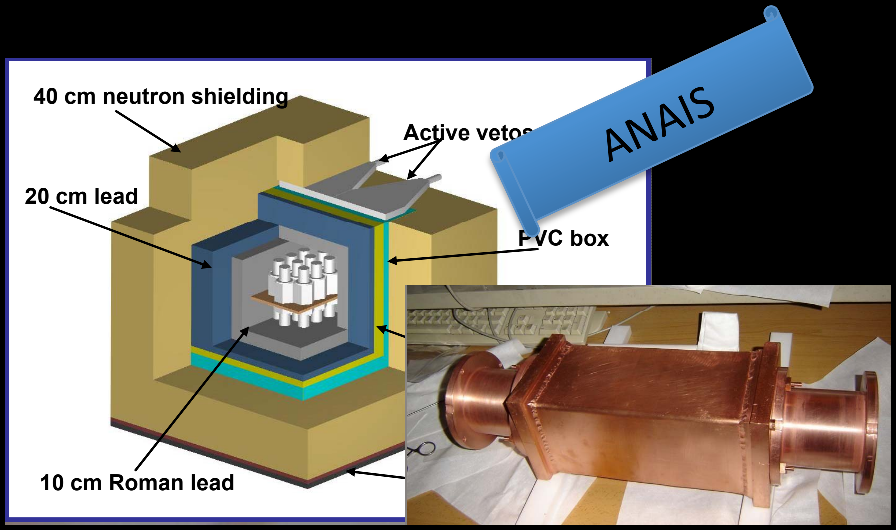
- Only underground lab in southern hemisphere
- Rock coverage: ~3100m w.e.
- ~ 240 km west of Melbourne
- Decline gold mine (road entrance)
- Background conditions measured (rocks, cosmogenics): similar to LNGS.
- Radon free air from surface
- Construction started in July 2016
- Expected completion: end 2017

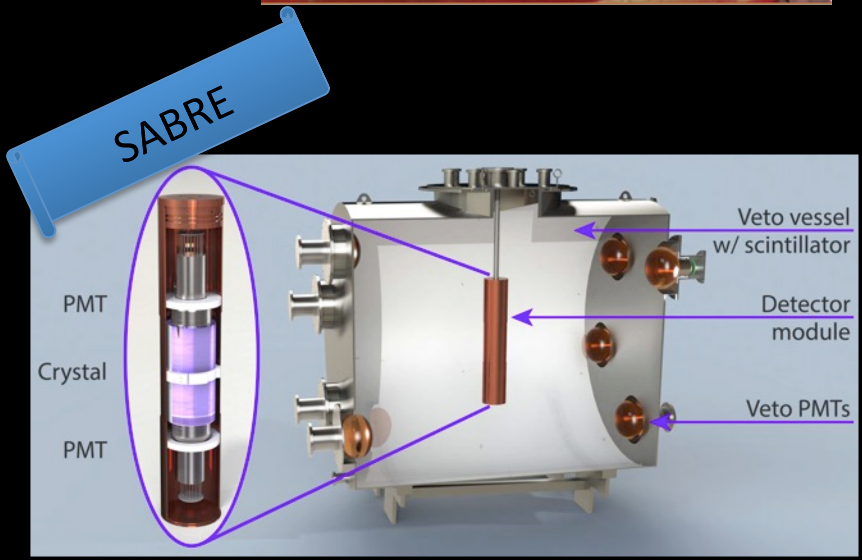






A world wide effort





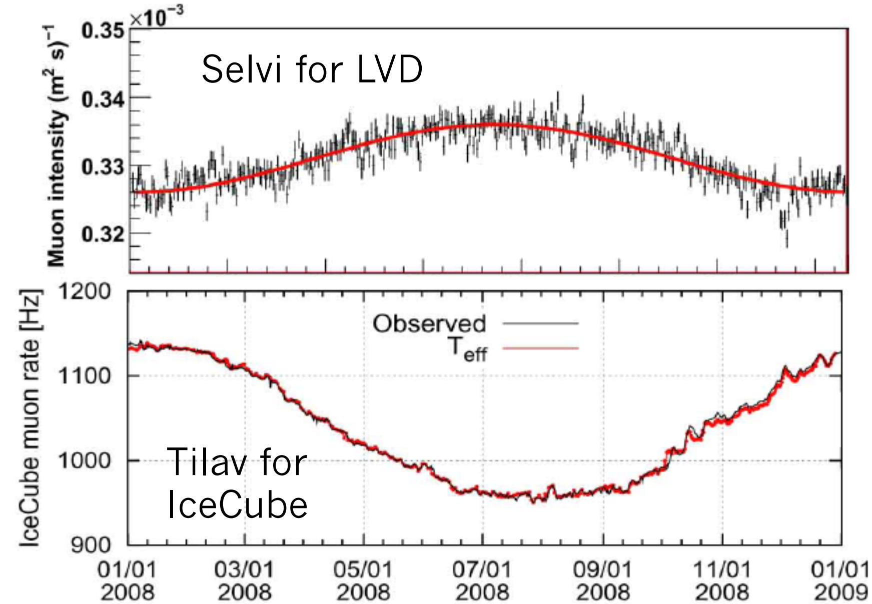
DM-Ice

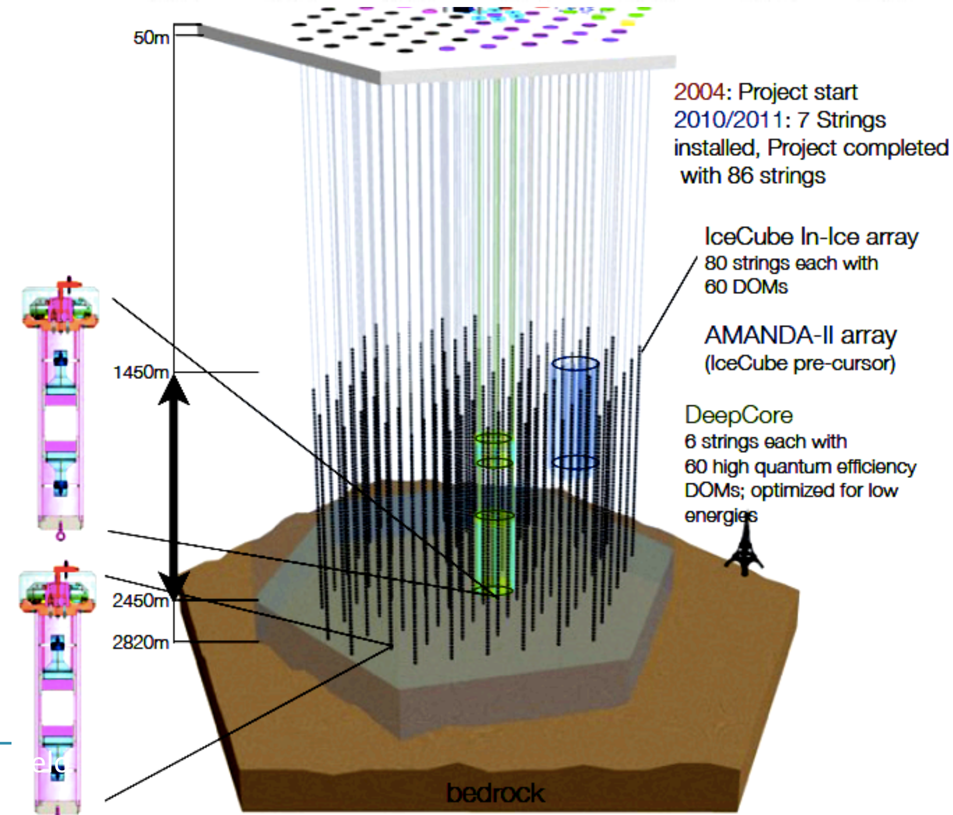
Ann Mod: Same phase if WIMPs,
Opposite phase for most
seasonal backgrounds
No radon or water table fluctuations

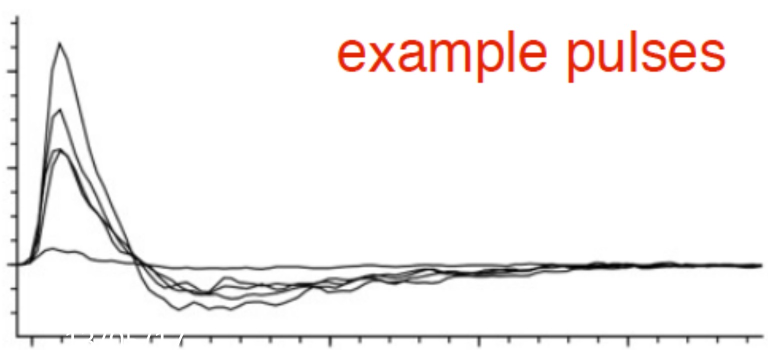
At 2450 m depth, constant T= −20° C
(warmer than a Minnesota winter)

IceCube provides a muon veto,
radiopure shielding
lab infrastructure

Prototype: 8.5 kg NAIAD crystals
(~8 cts/keV/d) at the bottom
of two IceCube strings (Dec 2010)

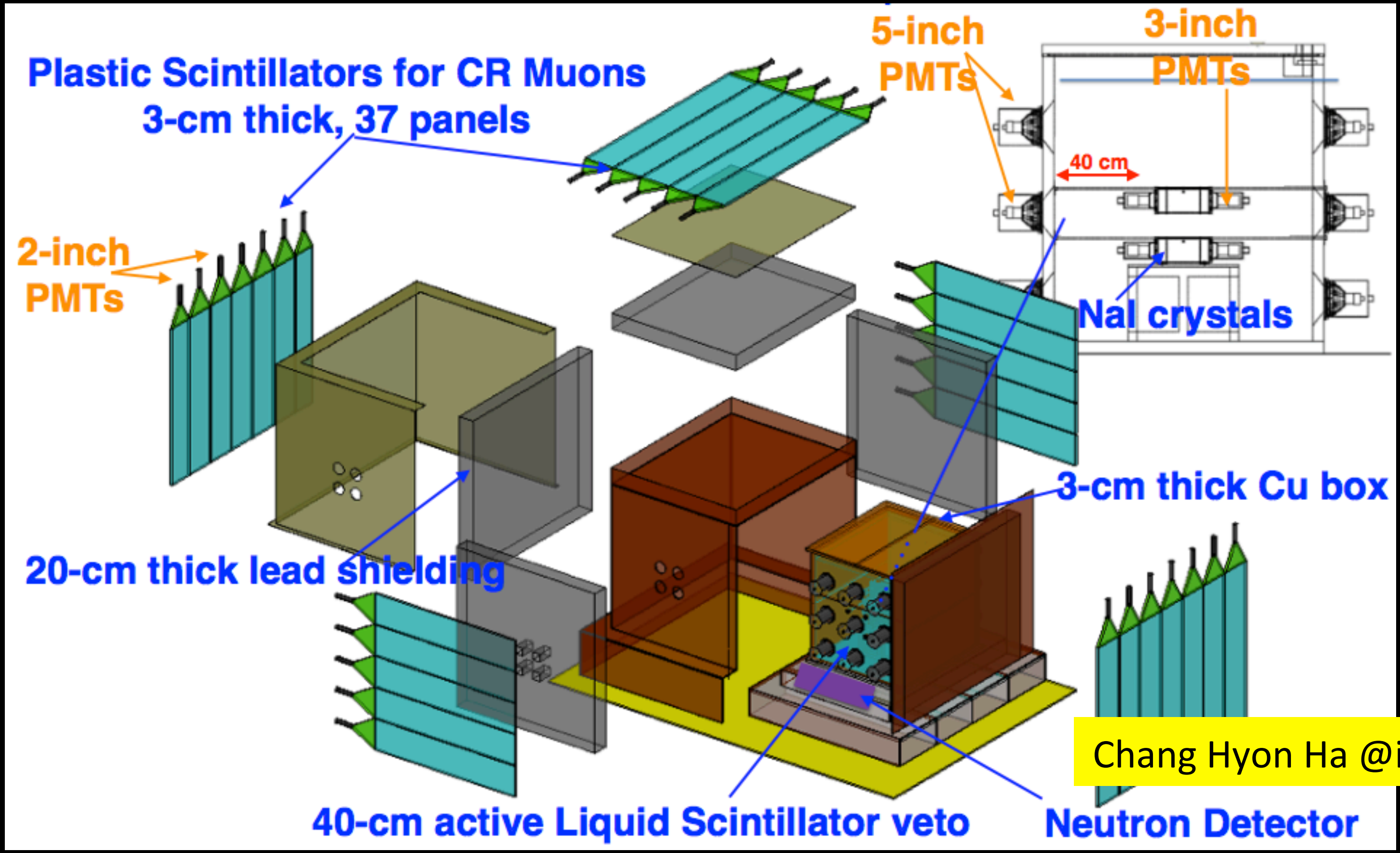






Cosine-100

Merging of DM-ICE and KIMS collaborations
Starting data taking now at YangYang (S. Korea)
Also implementing liquid scint. veto but only 40cm.
Background suppression on ^{40}K: ~50%
Not a deep location: need active muon tagging



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Cosine-100 backgrounds

- Crystal producer: Alpha Spectra
- 8 crystal of different sizes and production batches
- Total mass: ~106kg
- Background levels: x1.5 to x4 DAMA levels
- Designed for a quick verification

Crystals	Powder	Mass (kg)	^{nat}K(^{40}K) (ppb)	^{238}U (ppt)	^{232}Th (ppt)	α rate (mBq/kg)	Light Yield (pe/keV)
NaI-001 (C1)	AS B	8.3	40.4 ± 2.9	< 0.02	< 3.2	3.29 ± 0.02	15.6 ± 1.4
NaI-002 (C2)	AS C	9.2	48.2 ± 2.3	< 0.12	0.5 ± 0.3	1.77 ± 0.01	15.5 ± 1.4
NaI-007 (C3)	AS WimpScint II	9.3	38.1 ± 5.5	< 0.04	0.20 ± 0.01	0.85 ± 0.06	15.2 ± 1.4
AS3 (C4)	AS WimpScint II	18.0					
AS1 (C5)	AS C	18.3					
NaI-011 (C6)	AS WimpScint III	12.5	18.5 ± 3.2	< 0.018	< 0.079	1.03 ± 0.13	16.8 ± 1.2
NaI-012 (C7)	AS WimpScint III	12.5					
AS2 (C8)	AS C	18.3					
DAMA			< 20	0.7 - 10	0.5 - 7.5		

~106 kg in total

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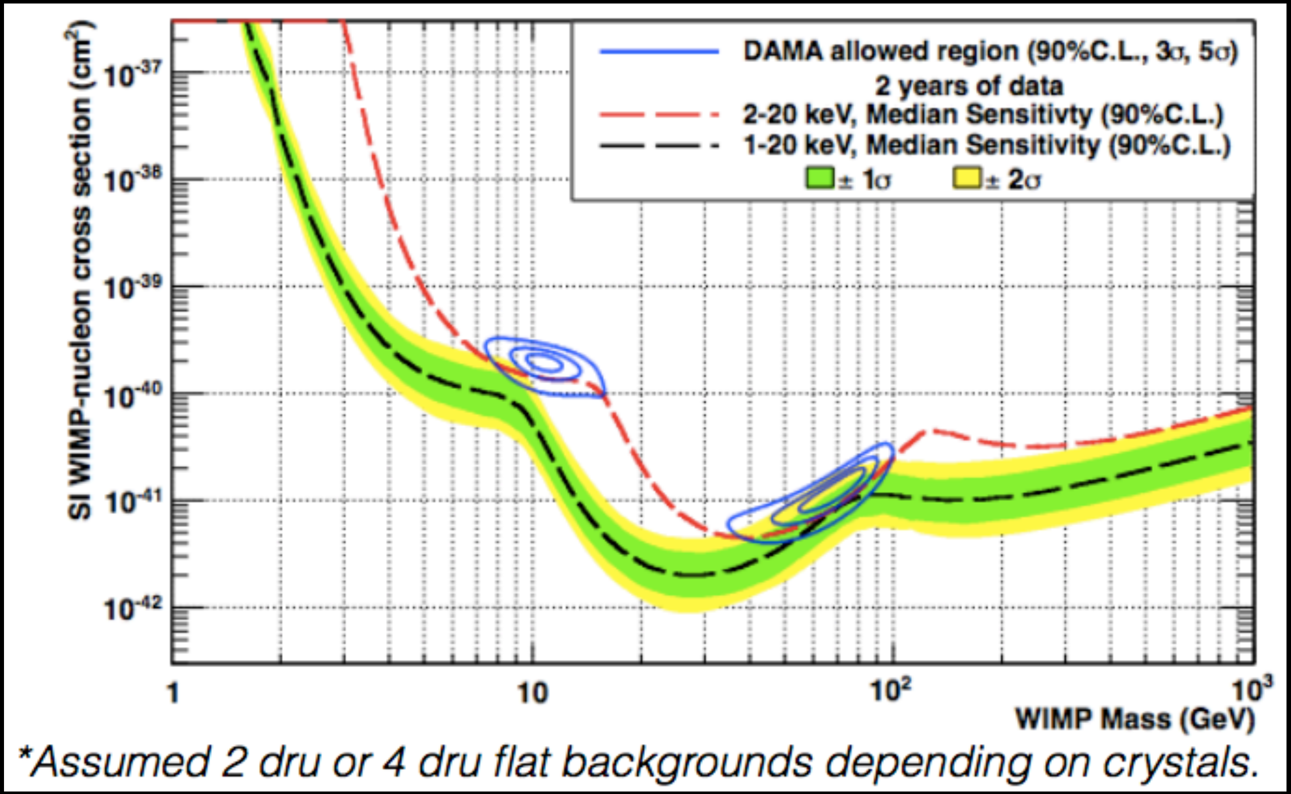
Cosine-100 sensitivity



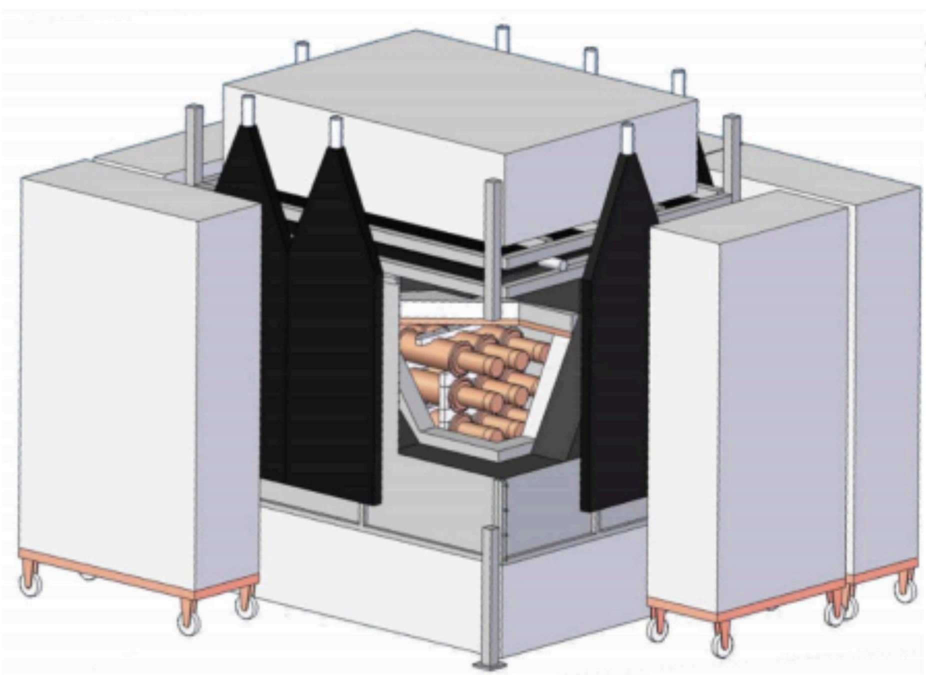
Chang Hyon Ha @ichep2016

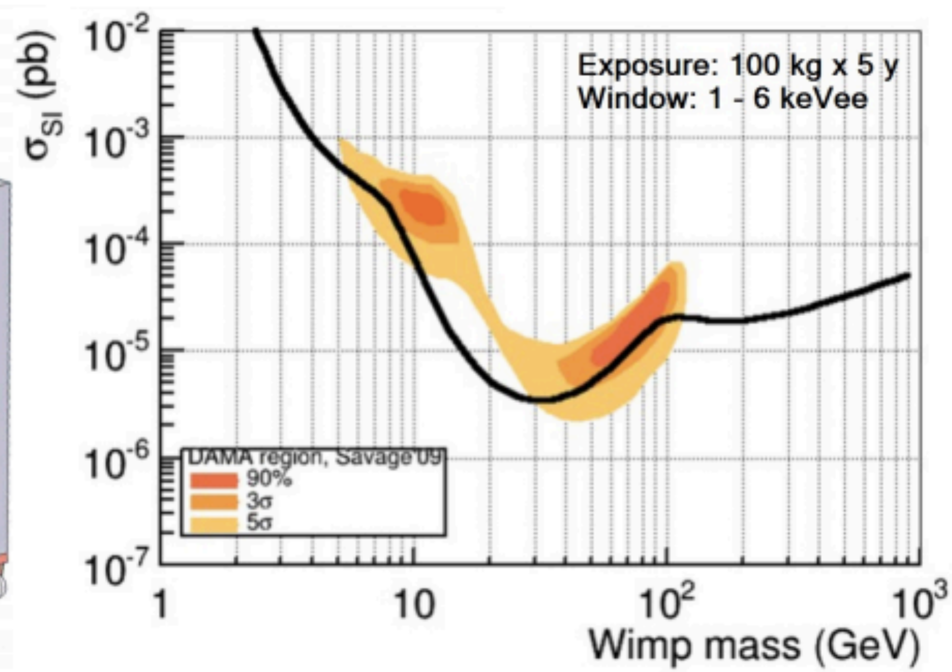
- No confirmation plot provided
- Very unlikely to reach Energy threshold <2keV
- A conclusive test may need to wait a further (planned) experiment with 250kg at new Laboratory (to be built)

ANAIS-112

- Laboratorio Subterraneo de Canfranc (LSC) in Spain (Universidad de Zaragoza)
- Experiment under construction: 3x3 crystal matrix for 112kg total mass
- Present background levels (measured in ANAIS-37 prototype):
  ~30ppb ^{40}K and 0.7-3mBq/kg in ^{210}Pb
- Crystal producer: Alpha Spectra

arXiv:1704.06861





Conclusions

- First point of the roadmap of direct Dark Matter searches: verify the D/L result
  - in tension with other results only under certain assumptions
- A model independent verification requires a new NaI(Tl) experiment
- Several players around the world aim at this.
- SABRE aims to deploy two twin detectors at LNGS and SUPL (different emispheres)
  - also able to investigate the Dark Matter modulation with enhanced sensitivity

Thank you for your attention !

BACKUP SLIDES

SABRE Collaboration

Australian National University
Swinburne University
University of Adelaide
University of Melbourne

LNGS & GSSI
INFN Rome
University of Milano & INFN

Imperial College London

LLNL
PNNL
Princeton University

Possible additional Backgrounds

Isotope	production	half-life	Energy	decay
^{22}Na	cosmogenic attivation	2.6y	2.8MeV	$\beta^+ + \gamma$
^{3}H	intrinsic or neutron attivation	12.3y	18.6keV	β^-
^{125}I	cosmogenic attivation	59.4d	67keV	EC-γ, ^{125}Te X-ray
^{129}I	cosmogenic attivation	10^7 y	peak at 40keV; up to 194keV	β^-, ^{129}Xe γ
^{210}Pb	Radon	22.3y	16+46keV	$\beta^- + \gamma$

→ Radon control

→ Ground transportation and underground storage

SUPL Background measurements summary

	LNGS	Stawell
Neutron Flux (n/s/cm^2)	4 x 10^{-6}	7 x 10^{-6}
Gamma-rayflux <3MeV (γ/s/cm^2)	0.73	~1
Rock Hall ^{238}U (ppm)	6.8-0.42-0.66	0.64
Rock Hall ^{232}Th (ppm)	2.2-0.06-0.06	1.63
Concrete ^{238}U (ppm)	1.05	<1.86 (wall) <2.18 (floor)
Concrete ^{232}Th (ppm)	0.66	3.84 (wall) 3.49 (floor)
Radon Bq/m^3 (12 day accumulation)	~50	408±40 (free air) 36±5 (comp. air)
Muon Flux (μ/h/m^2)	~1.2	**to be measured**

KIMS (Yangyang Lab, Korea - 2400 mwe)

H.S. Lee,[1,*] H. Bhang,[2] J.H. Choi,[2] S. Choi,[2] I.S. Hahn,[3] E.J. Jeon,[4] H.W. Joo,[2] W.G. Kang,[4] B.H. Kim,[2] G.B. Kim,[2] H.J. Kim,[5] J.H. Kim,[2] K.W. Kim,[2] S.C. Kim,[2] S.K. Kim,[2] Y.D. Kim,[4,6] Y.H. Kim,[4,7] J.H. Lee,[2] J.K. Lee,[2] S.J. Lee,[2] D.S. Leonard,[8] J. Li,[4] J. Li,[9] Y.J. Li,[9] X.R. Li,[10] S.S. Myung,[2] S.L. Olsen,[2] J.W. Park,[2] I.S. Seong,[2] J.H. So,[4] and Q. Yue[9]

CsI vs NaI

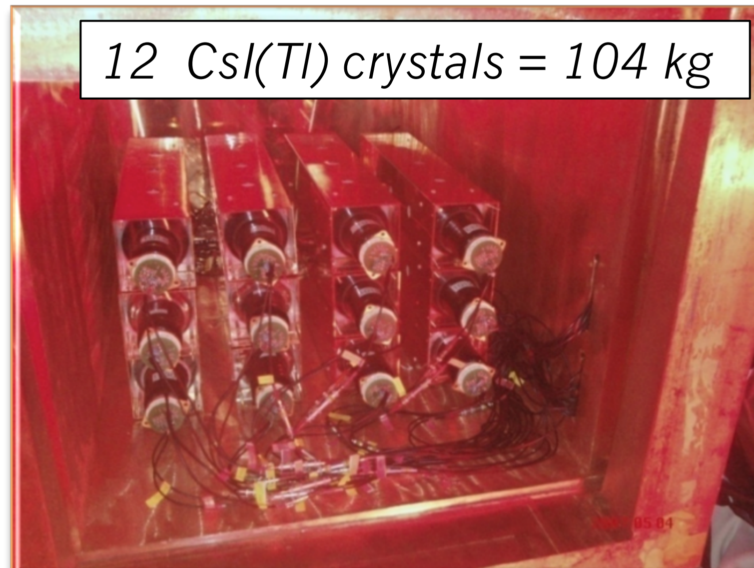
- \+ **Better PSD than NaI(Tl)**
- \+ **Less Hygroscopic**
- − **High cesium radioisotopes**

Reduce ^{137}Cs in processing (water)

^{134}Cs ($\tau_{1/2}$ = 2 y) cosmogenic activation

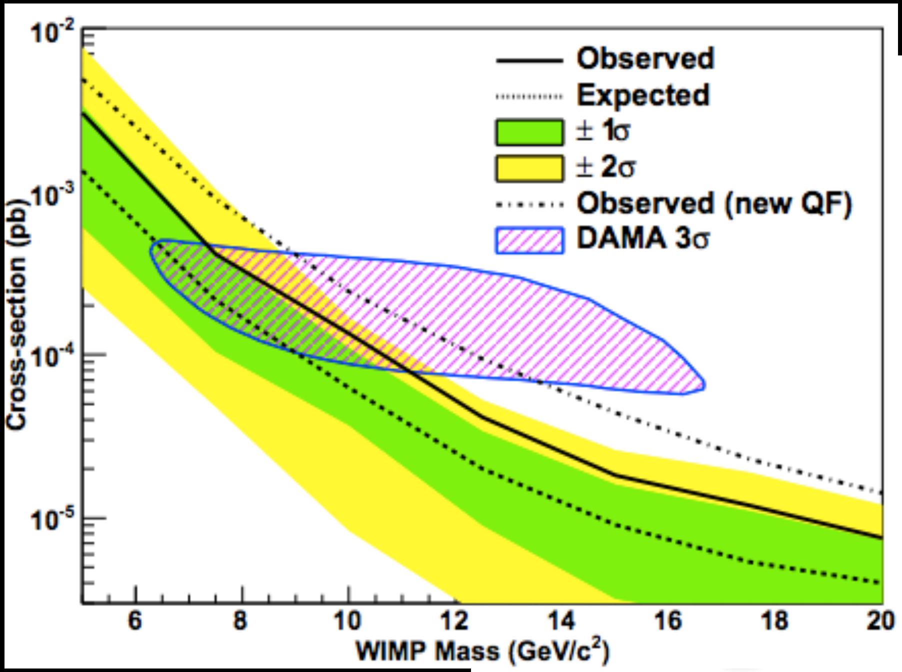
Reduce ^{87}Rb (in Cs ore)

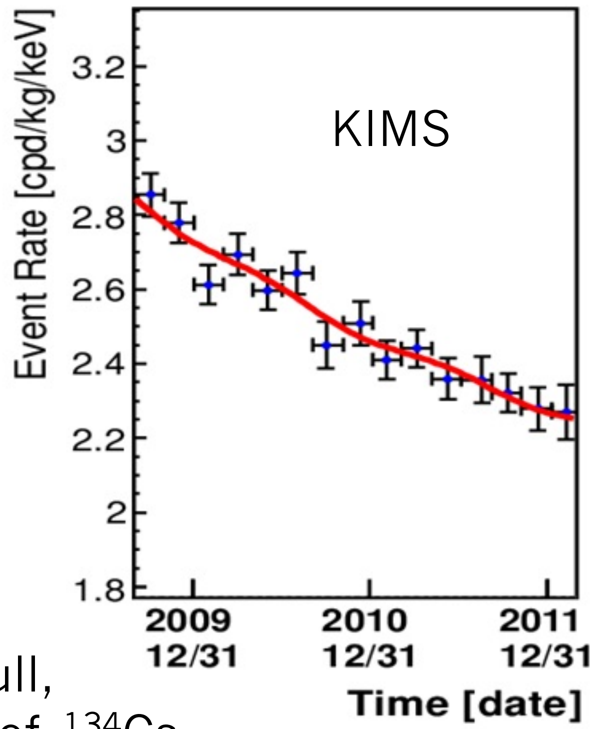
via repeated recrystallization



Bkd achieved: **2~3 cpd/kg/keV**

KIMS CsI



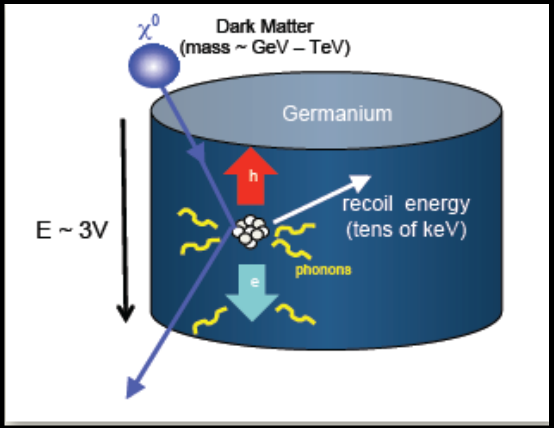


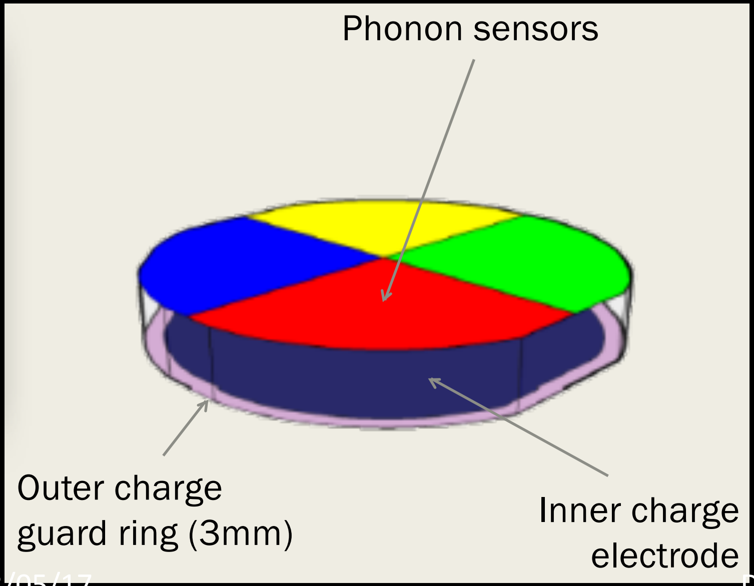
KIMS Ann Mod amp is consistent with null, incl. the exp. decay of ^{134}Cs.

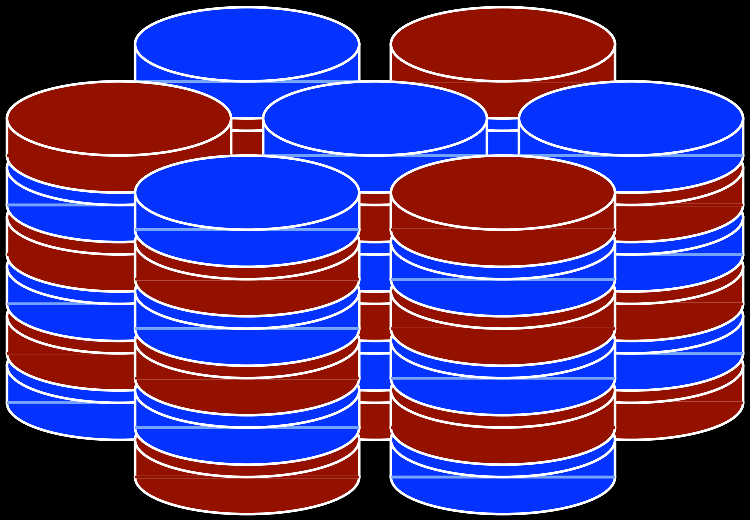
The 90% upper limit of KIMS amplitude is comparable to DAMA's ann mod (0.0189 cpd/kg/keV)

CDMS

- Location: Soudan Mine in Minnesota, 780m deep
- Detectors: towers of Ge and Si detectors
- Hybrid detectors: bolometers and solid state
- Operating temperature: ~50mK
- CDMS-II mass: M_{Si} ~ 1.5 Kg + M_{Ge} ~ 3.8Kg
- SuperCDMS mass: M_{Si} ~ 1.8 Kg + M_{Ge} ~ 5Kg



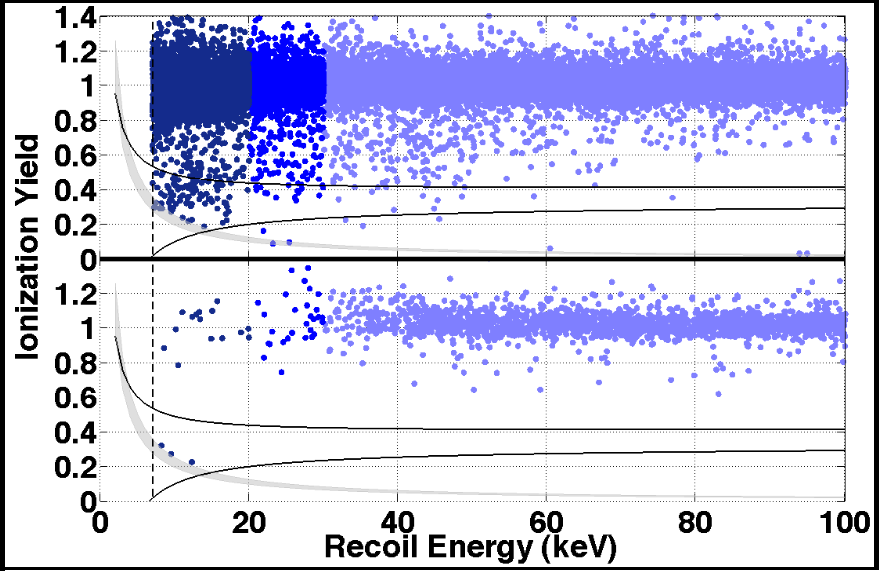


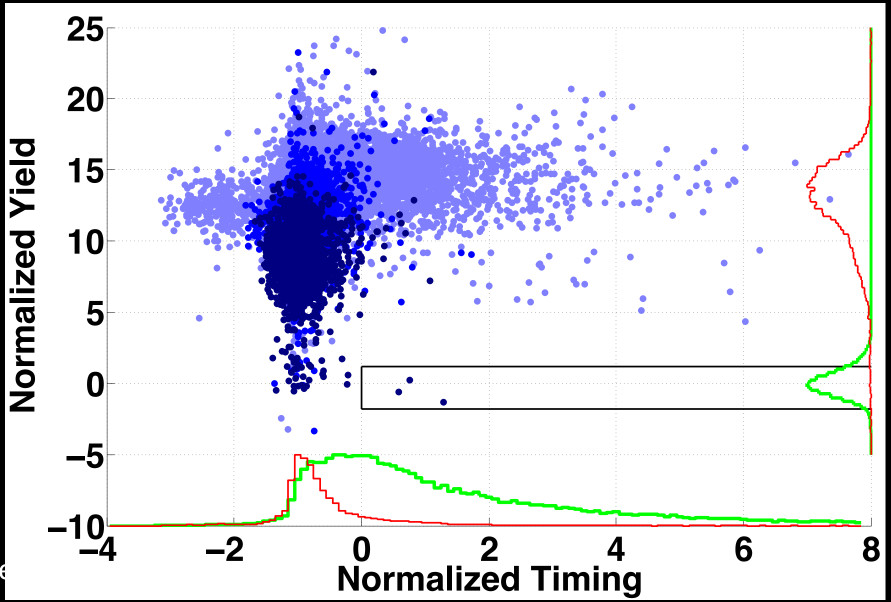


PRL 111 (2013) 251301

The CDMS-II Si result

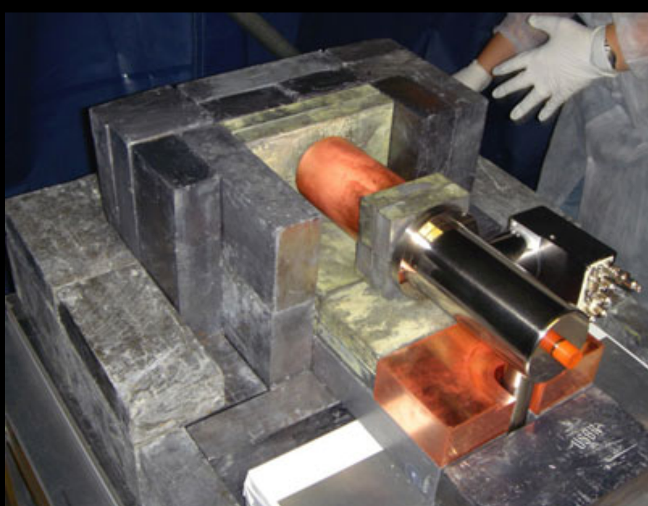
- Efficiency of electron and gamma background rejection: 99.9%
- WIMP search energy reagion: 10-150 keV
- 3 events pass the event selection criteria
- Expected background: ~0.7 events. Probability to be explained as background-only: 0.19%
- Spin-Independent WIMP-nucleon elastic scattering: ~9GeV WIMP mass
  – Not in agreement with DAMA/ LIBRA result
  – In agreement with COGENT result

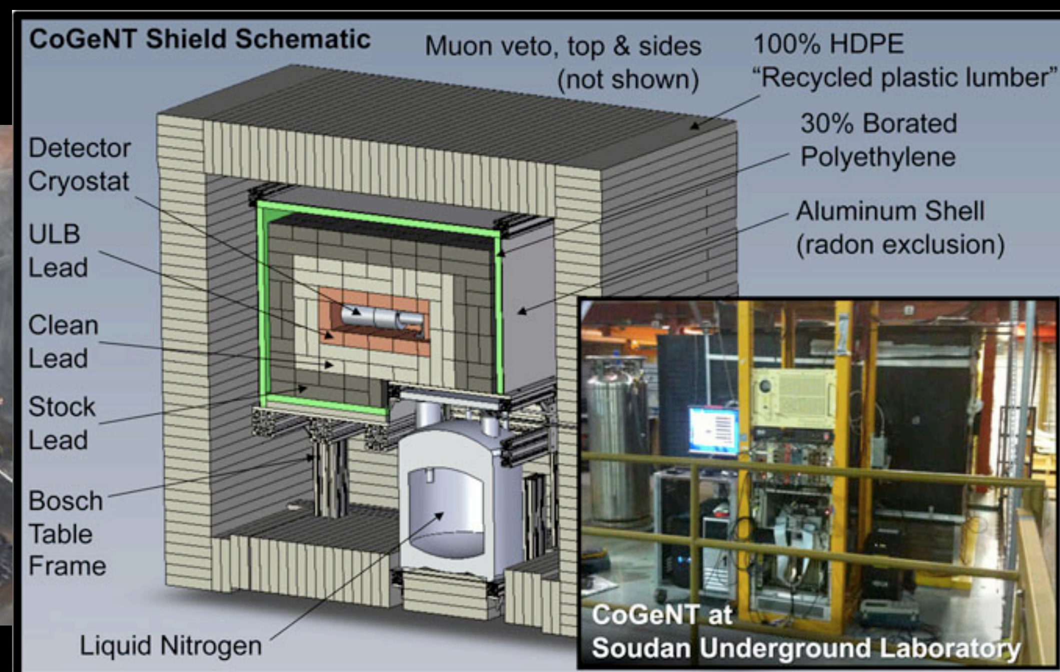




CoGeNT

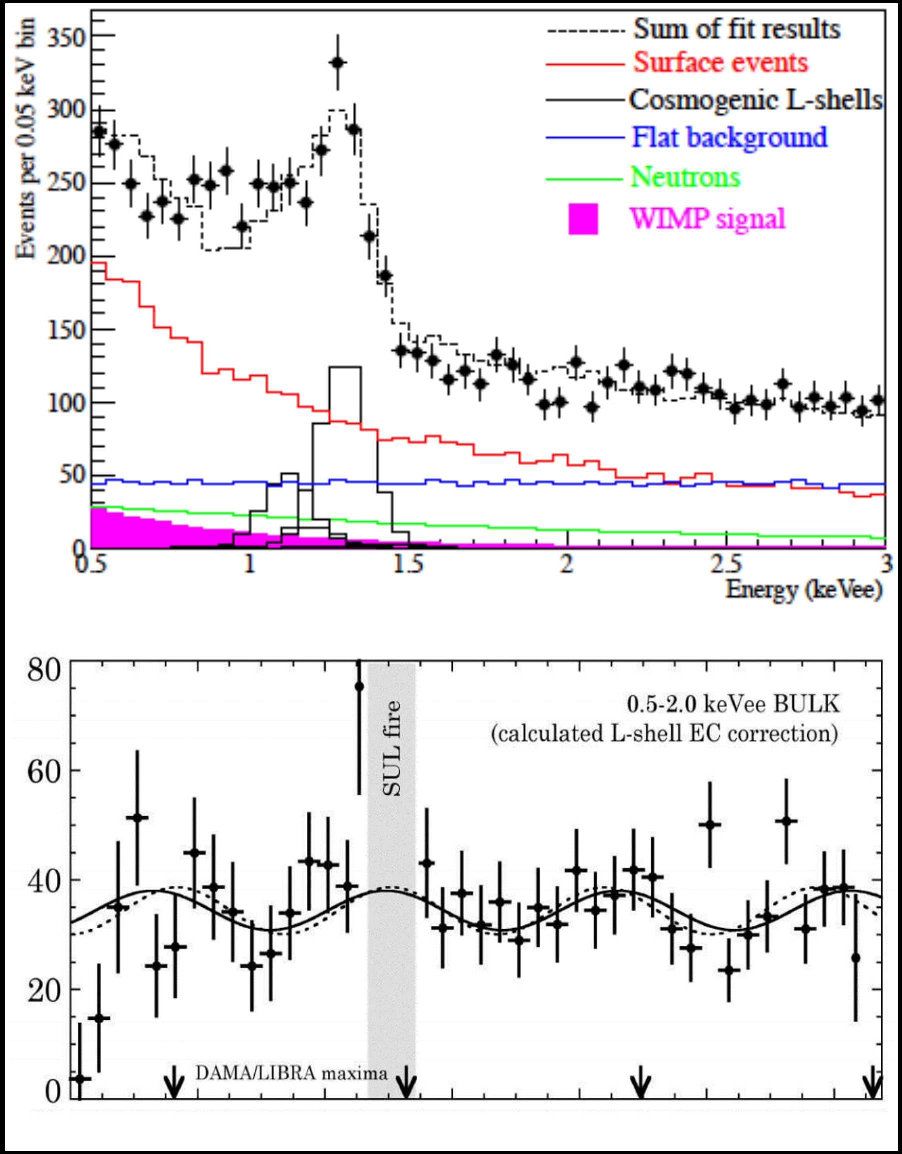
- CoGeNT (Coherent Germanium Neutrino Technology)
  - Originally thought for neutrino coherent scattering, now fully a DM project.
- Location: Soudan mine in Minnesota, 780m deep
- Operation years: Dec 2009 – May 2013
- Single 440 g PPC (p-Type Point Contact) Germanium detector





The CoGeNT result

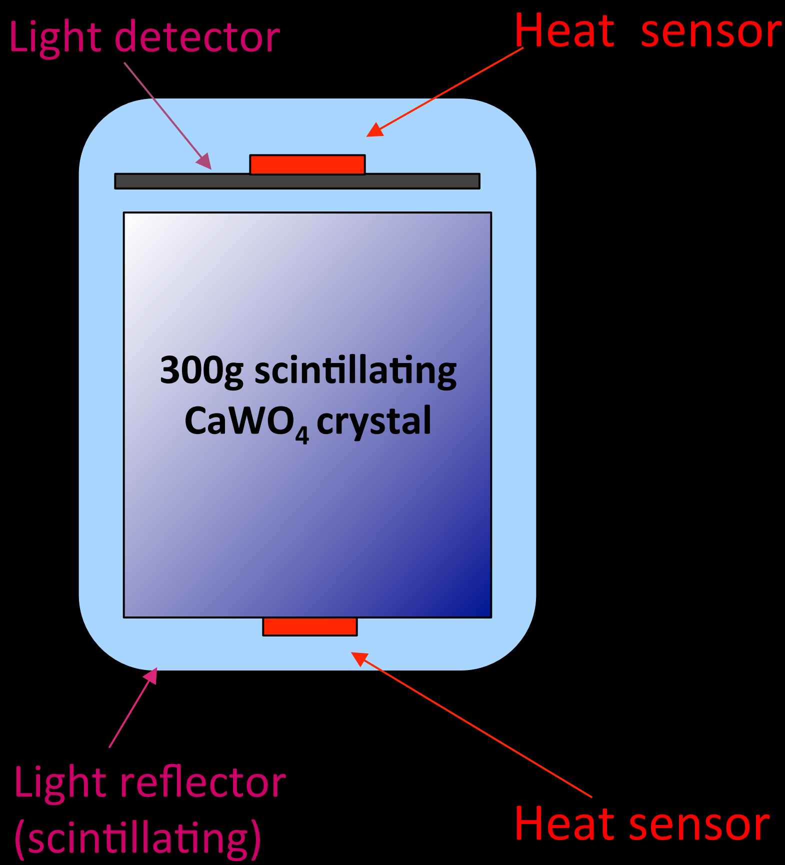
- 3.4y data
- Excellent background fit
- Excess of events
  - but background-only hypothesis is only excluded at 1.9σ
- Modulation observed
  - 2011: 2.8σ
  - 2014: 2.2σ
- Problem: it implies a WIMP signal modulation as large as 35-65%
  - requires a non-maxwellian velocity distributions in the halo



PRL 107 (2011) 141301

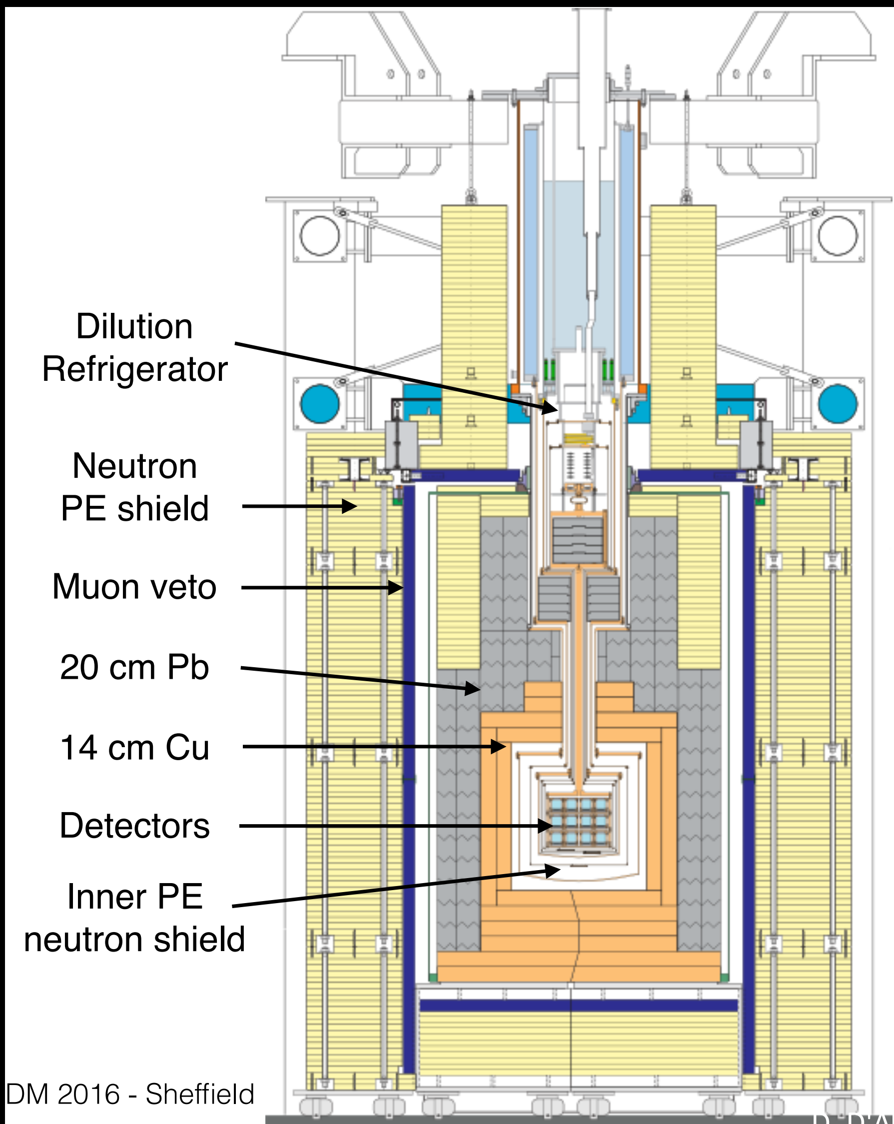
arXiv:1401.3295

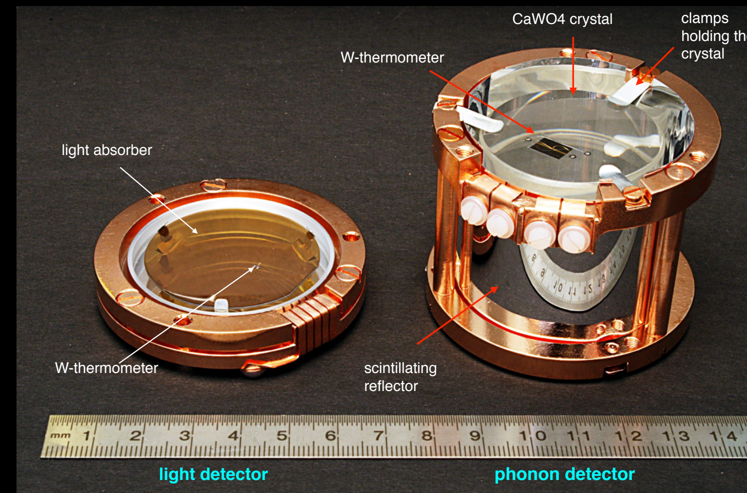
CRESST-II Detectors

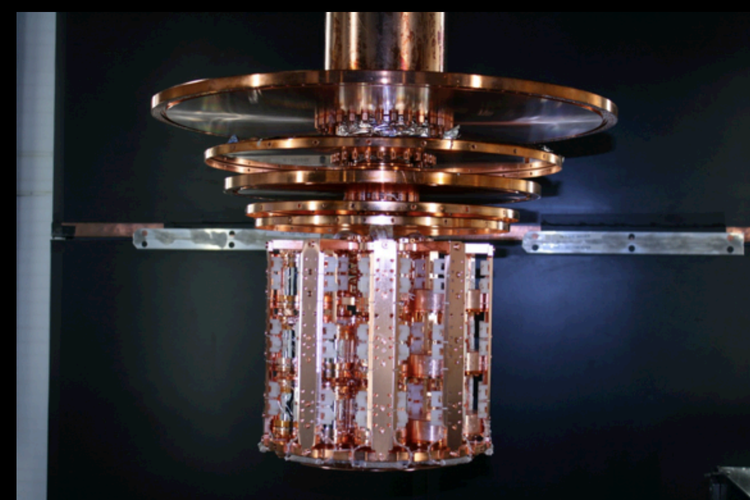


- Location: LNGS
- CaWO4 scintillating bolometers
- Hybrid detectors: phonons and light
- Operating temperature: 14mK
- 18x 300g detectors: ~6kg total mass

CRESST


Dilution Refrigerator
Neutron PE shield
Muon veto
20 cm Pb
14 cm Cu
Detectors
Inner PE neutron shield


CaWO4 crystal
clamps holding the crystal
W-thermometer
light absorber
W-thermometer
scintillating reflector
light detector
phonon detector

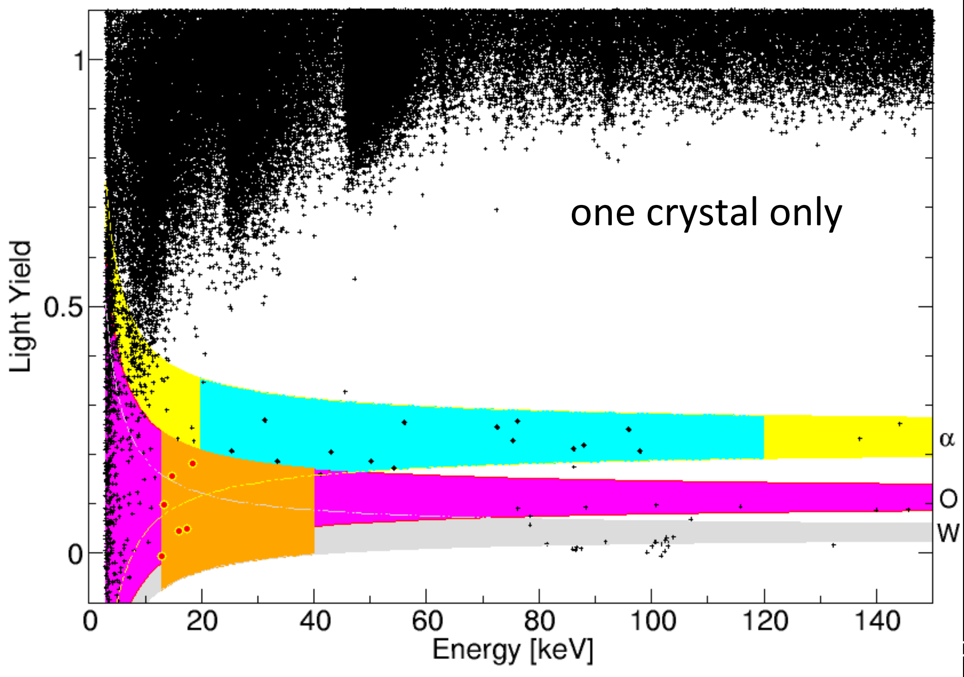


CRESST-II Phase-1 2011

- Exposure: 730 kg day
- Signal region: 10-40keV
- Counts: 67 events
- Expected background:

	M1	M2
e/γ-events	8.00 ± 0.05	8.00 ± 0.05
α-events	$11.5^{+2.6}_{-2.3}$	$11.2^{+2.5}_{-2.3}$
Neutron events	$7.5^{+6.3}_{-5.5}$	$9.7^{+6.1}_{-5.1}$
Pb recoils	$15.0^{+5.2}_{-5.1}$	$18.7^{+4.9}_{-4.7}$
Signal events	$29.4^{+8.6}_{-7.7}$	$24.2^{+8.1}_{-7.2}$
m_χ [GeV]	25.3	11.6
σ_{WN} [pb]	$1.6 \cdot 10^{-6}$	$3.7 \cdot 10^{-5}$

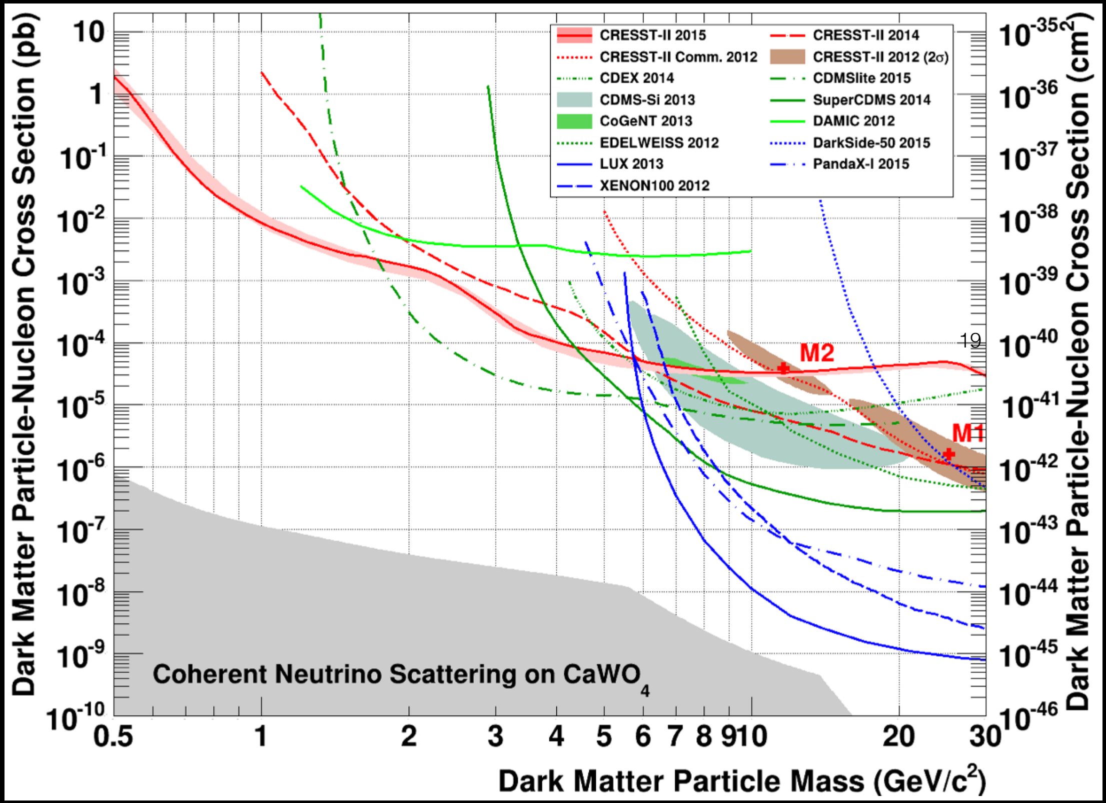
↑ 4.7σ ↑ 4.2σ



Eur. Phys. J. C (2012) 72:1971

CRESST-II Phase-2 Results

Best limit below ~2GeV



Eur.Phys.J. C76 (2016)25

CRESST-III
24g crystals
100eV threshold
Status: commissioning