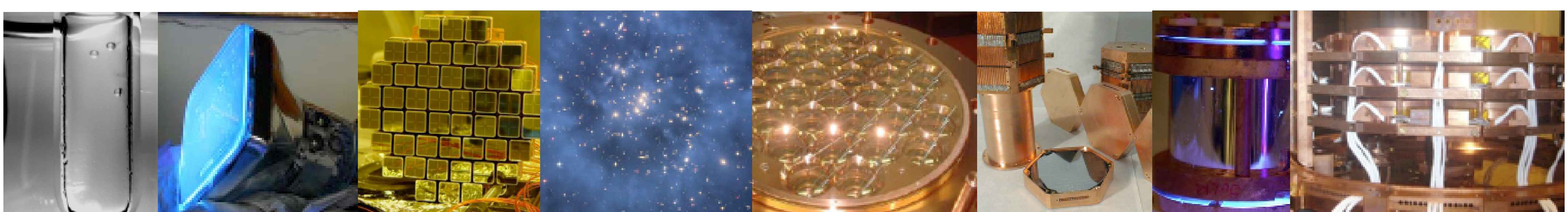
Status of direct experimental searches for dark matter

ENTApP Dark Matter Conference,

CERN, February 3, 2009

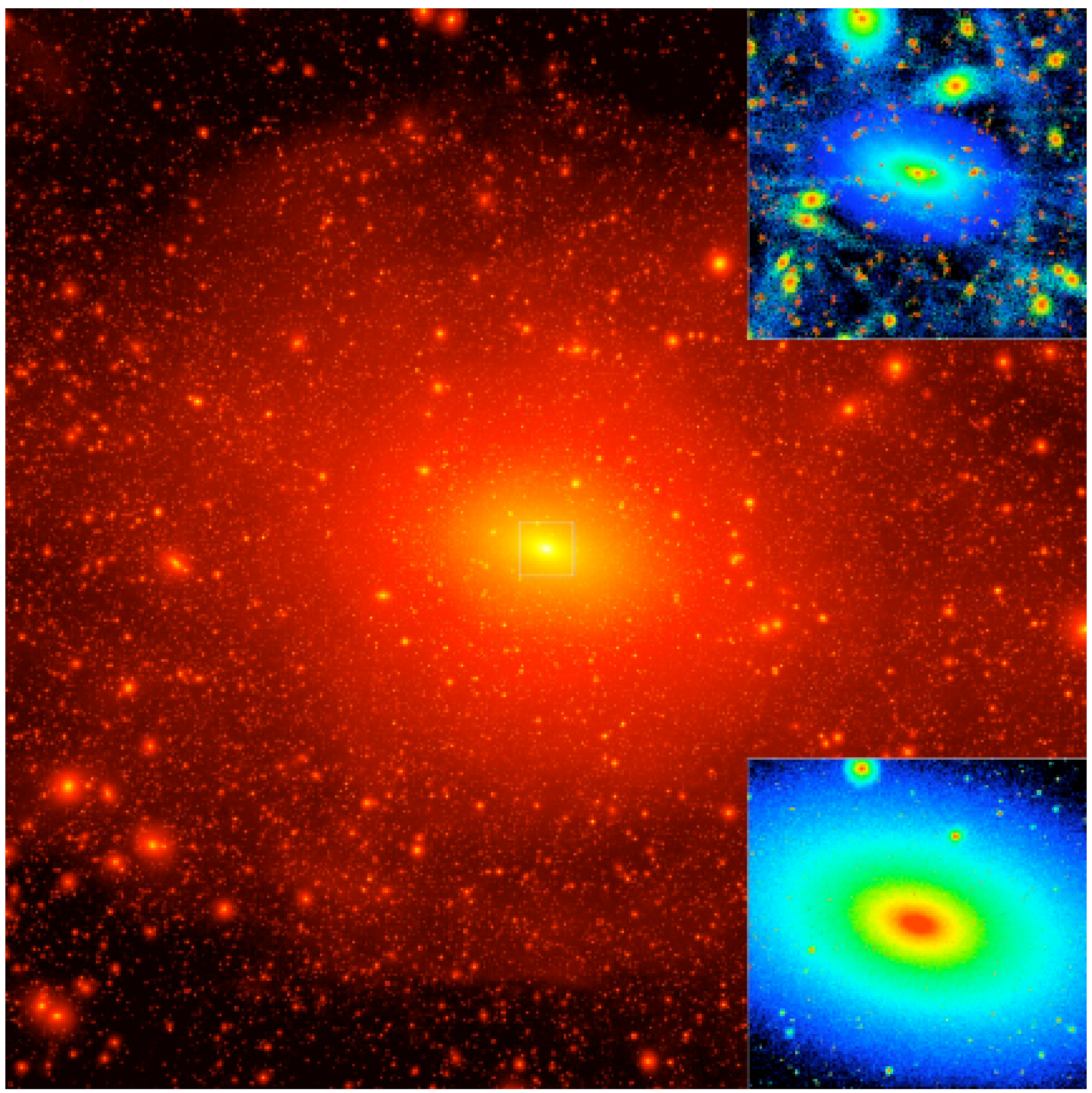
Laura Baudis

University of Zurich

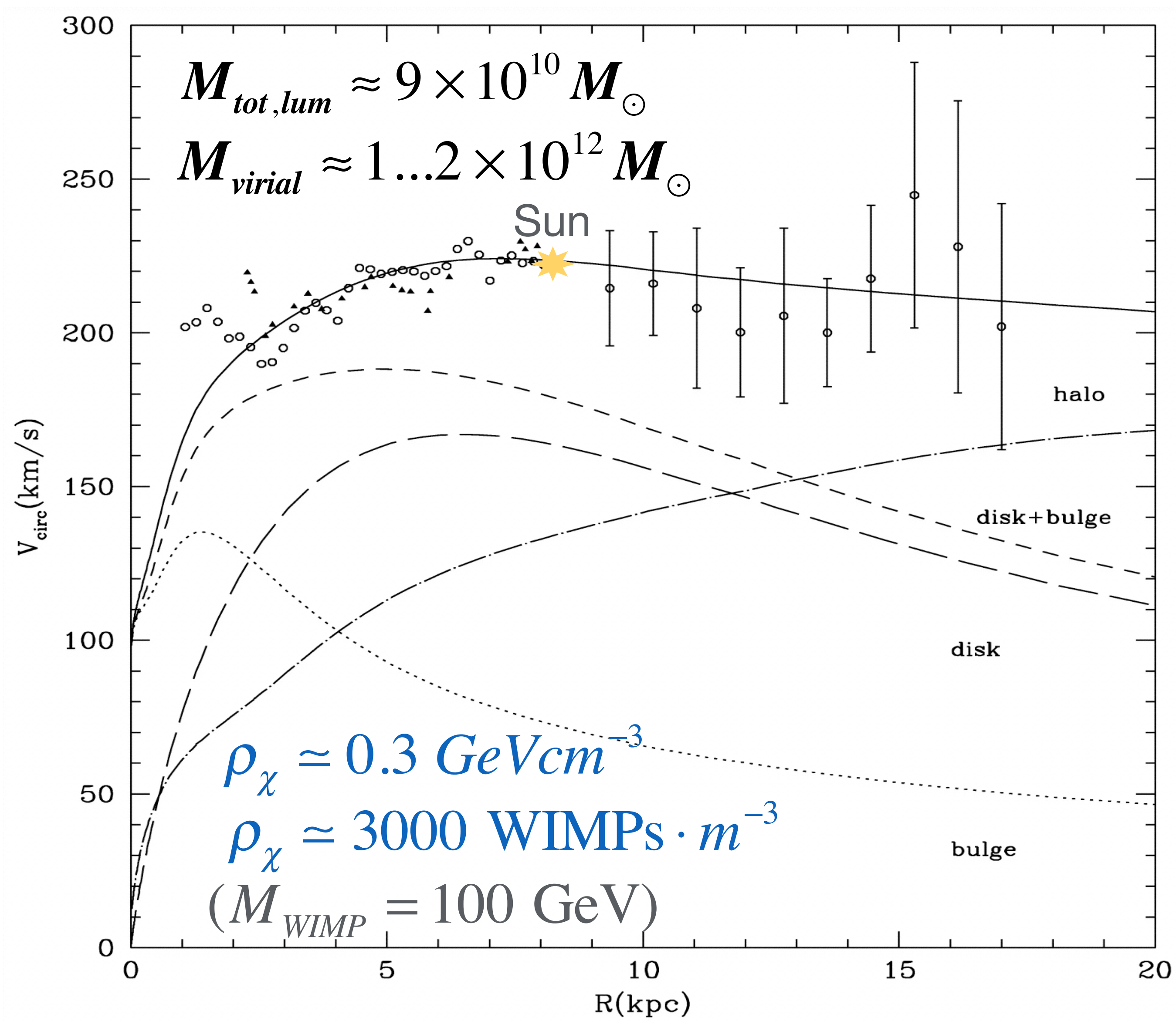


Goal of Direct Detection Experiments

- Detect new, yet undiscovered particles, which may be responsible for the dark matter in our galaxy. Example: WIMPs = heavy (few GeV - few TeV), color and electrically neutral; in thermal equilibrium with the rest of the particles in the early universe, freeze out when $M_W >> T_F$

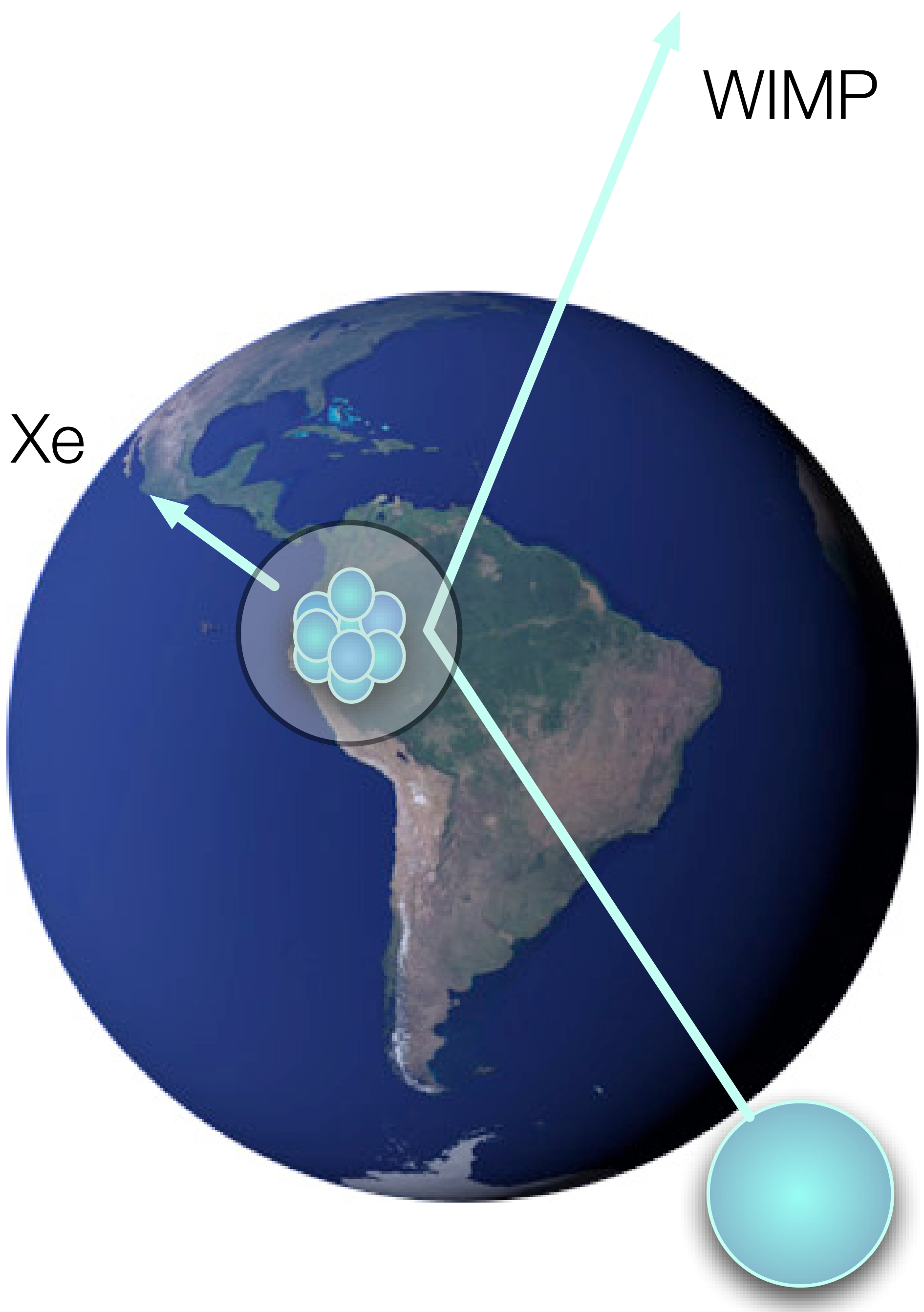


(J. Diemand et all, Nature 454, 2008, 735-738)



(Klypin, Zhao & Somerville 2002)

Strategy for WIMP Direct Detection



- Elastic collisions with atomic nuclei
- The recoil energy is:

$$E_R = \frac{|\vec{q}|^2}{2m_N} = \frac{\mu^2 v^2}{m_N}(1-\cos\theta) \leq 50\ keV$$

- and the expected rate:

$$R \propto N \frac{\rho_\chi}{m_\chi} \sigma_{\chi N} \cdot \langle v \rangle$$

Astrophysics: ρ_χ, $\langle v \rangle$

Detector: N

Particle physics: m_χ, $\sigma_{\chi N}$

Expected Scattering Cross Sections

- A general WIMP candidate: fermion (Dirac or Majorana), boson or scalar particle
- The most general, Lorentz invariant Lagrangian has 4 types of interactions (S, P, V, A)
- In the extreme NR limit relevant for galactic WIMPs ($v_{WIMP} \sim 10^{-3}c$), the interactions leading to WIMP-nuclei elastic scattering are classified as:

➡ **scalar interactions** (WIMPs couples to nuclear mass; from the scalar and vector part of L)

$$\sigma_{SI} = \frac{m_N^2}{4\pi(m_\chi + m_N)^2}\left[Zf_p + (A-Z)f_n\right]^2$$

$f_{p,n}$ = effective couplings to p, n

➡ **spin-spin interactions** (WIMPs couples to nuclear spin J_N, from the axial part of L)

$$\sigma_{SD} = \frac{32}{\pi} G_F^2 \frac{m_\chi^2 m_N^2}{(m_\chi + m_N)^2} \frac{J_N + 1}{J_N}\left(a_p \langle S_p \rangle + a_n \langle S_n \rangle\right)^2$$

$\langle S_{p,n} \rangle$ = expectation values of the spin content of the p, n in the target nucleus

$a_{p,n}$ = effective couplings to p, n

large hadronic uncertainties in the cross section
J. Ellis, K.A. Olive, C. Savage, arXiv:0801.3656v2

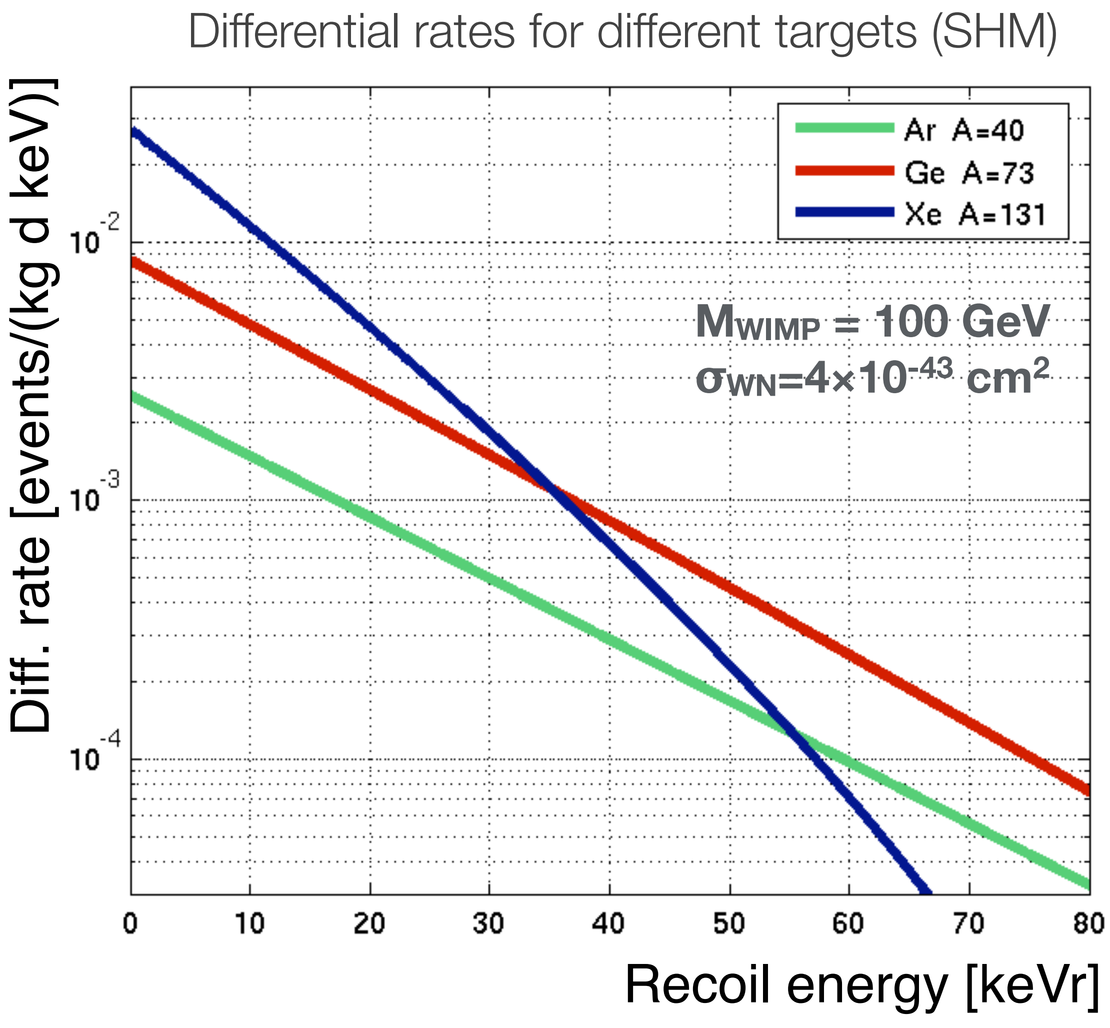
Expected Interaction Rates

- Integrate over WIMP velocity distribution; in general assumed to be a simple 1D Maxwellian (good approximation for isothermal halo with ideal WIMP gas):

$$\frac{dR}{dE_R} = \frac{\sigma_0 \rho_0}{2 m_\chi \mu^2} F^2(E_R) \int_{v > \sqrt{m_N E_R / 2\mu^2}}^{v_{max}} \frac{f(\vec{v},t)}{v} d^3 v$$

$$f(\vec{v},t) \propto \exp\left\{ \frac{-(\vec{v} + \vec{v}_E(t))^2}{2\sigma^2} \right\}$$

$$F^2(E_R) = \left[\frac{3 j_1(qR_1)}{qR_1} \right]^2 e^{-(qs)^2}$$

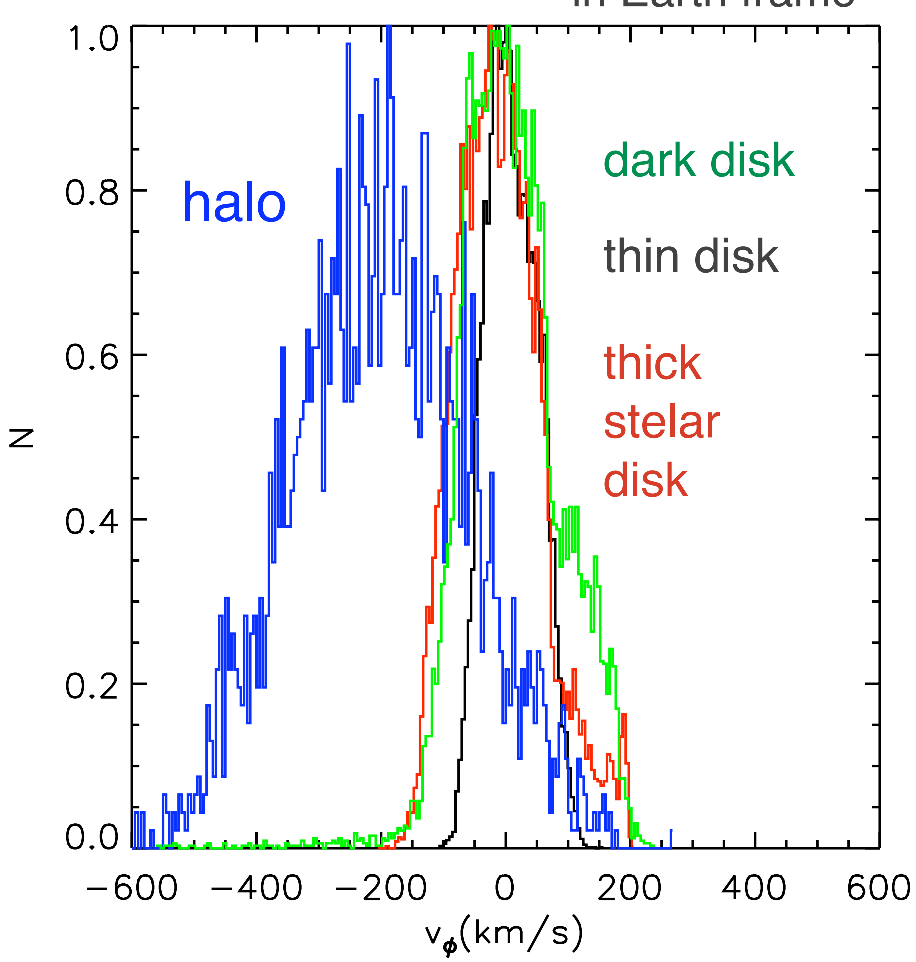


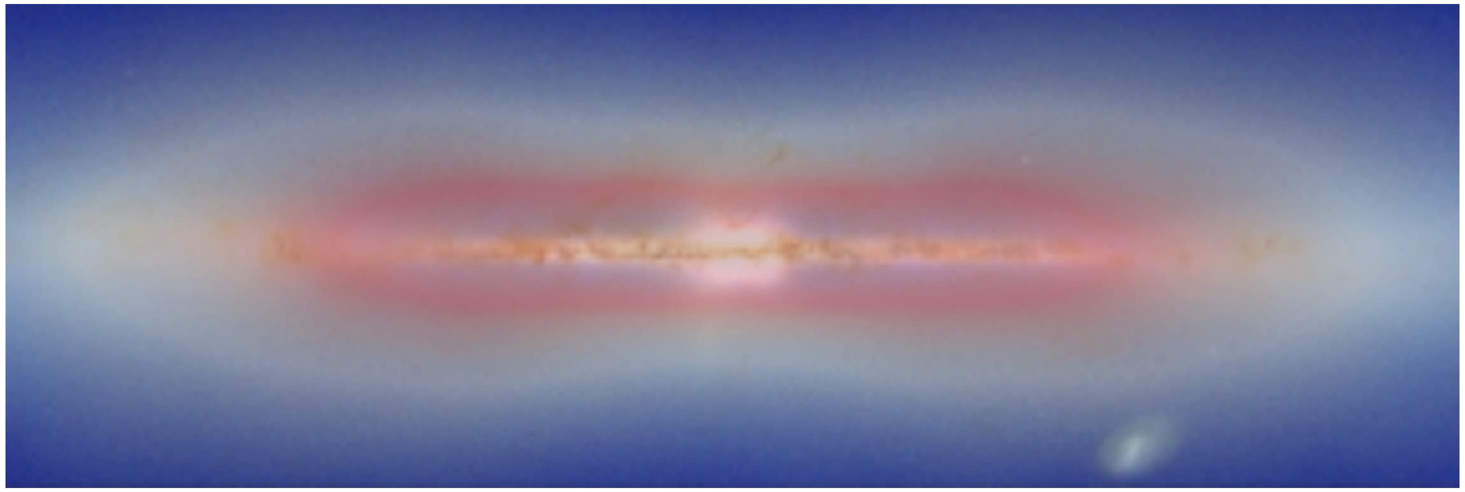
- with WIMP-nucleon cross sections $< 10^{-7}$ pb, the expected rates are

< 1 event/100kg/day

A Dark Matter Disk in The Milky Way

- **from ΛCDM numerical simulations which include the influence of baryons on the dark matter**
  [J. I. Read, G. Lake, O. Agertz, V. P. Debattista, MNRAS 389, 1041, 2008]
- **the stars and gas significantly alter the local phase space density of dark matter**
  - ➡ stars and gas settle onto the disk early on (z=1), affecting how smaller dark matter halos are accreted
  - ➡ the largest satellites are preferentially dragged towards the disk by dynamical friction, then torn apart
  - ➡ **the material from the satellites settles into a thick disk of stars, and dark matter**
  - ➡ the dark matter density in the disk is constrained to about 0.25 - 2 x halo density

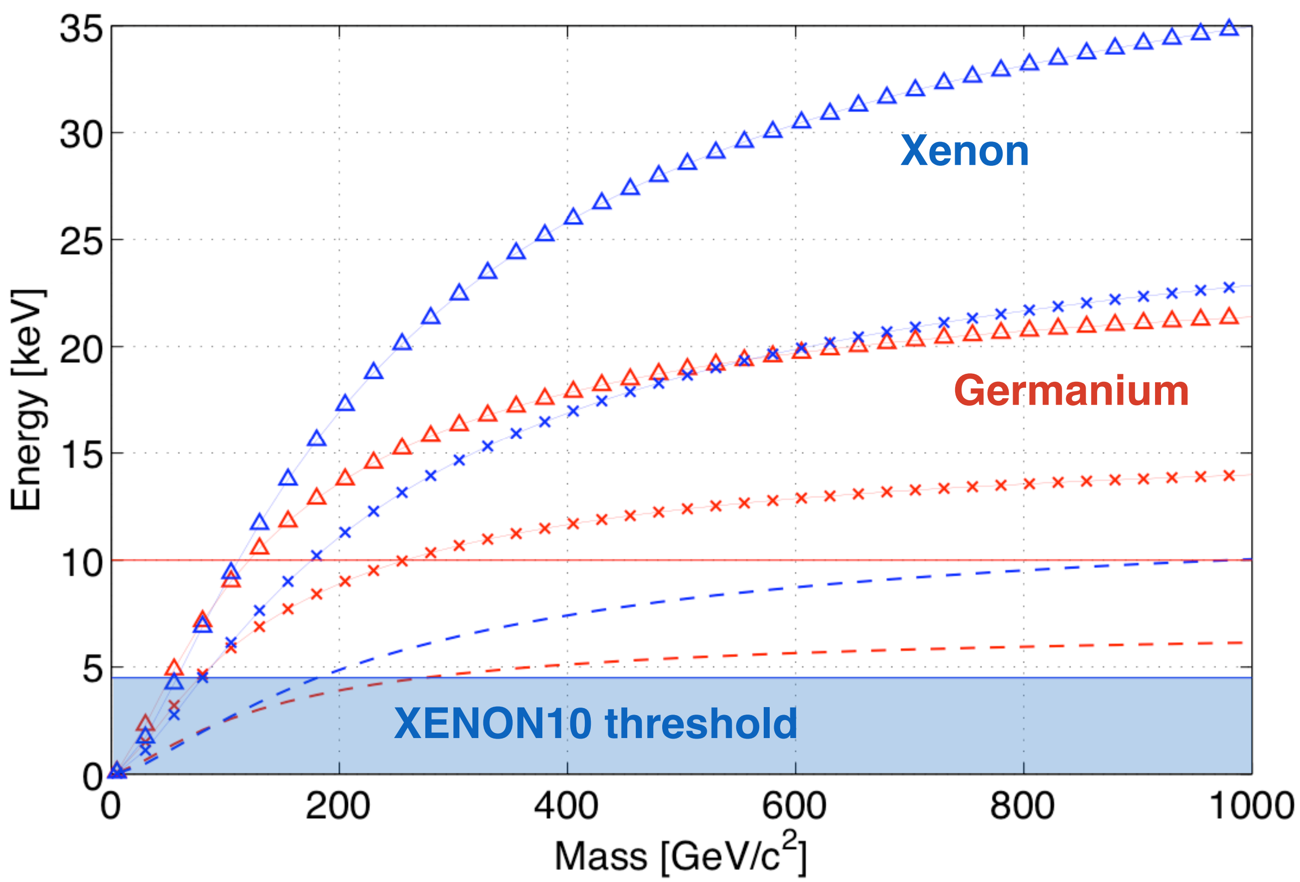


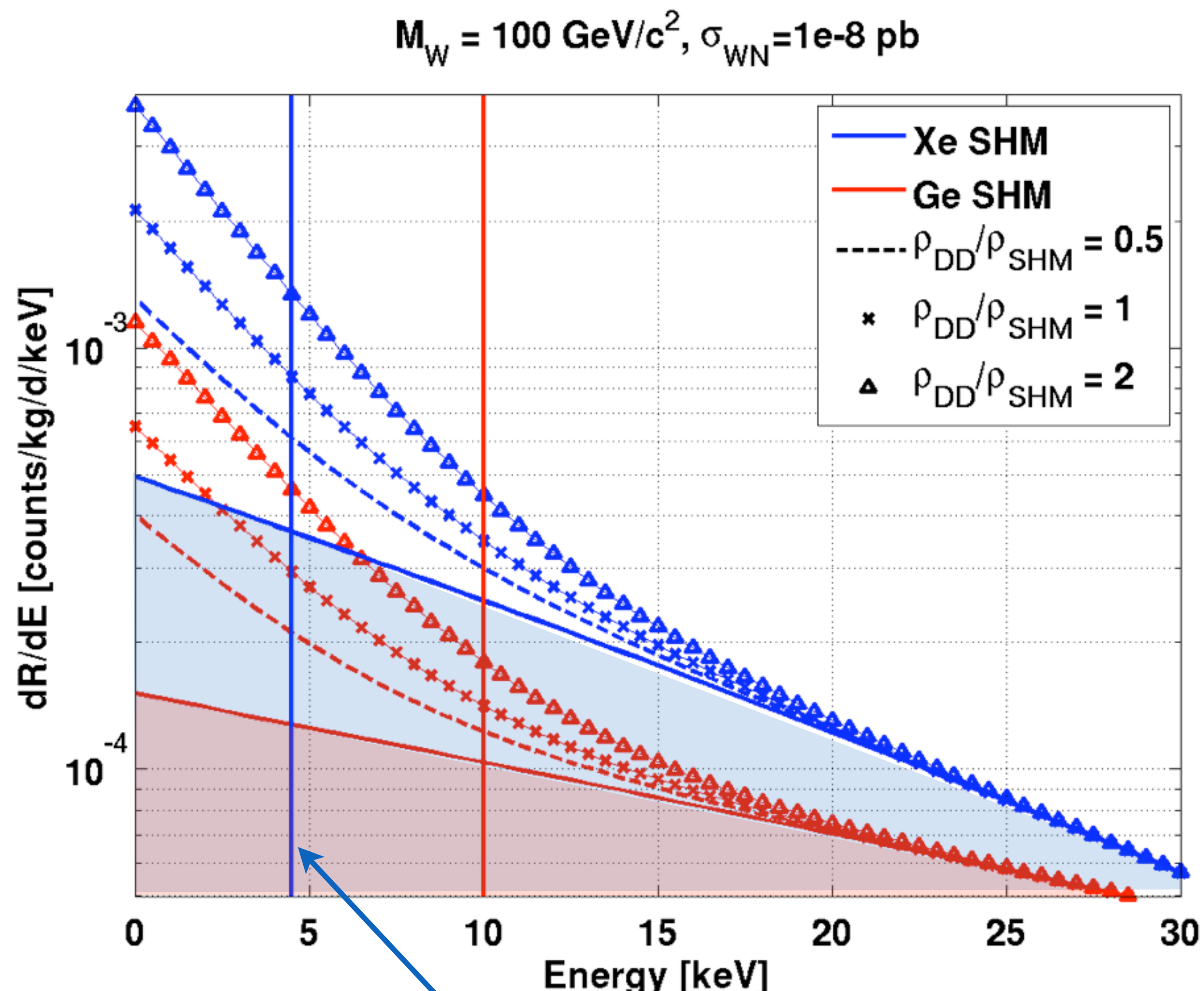


A Dark Matter Disk in The Milky Way

- **the solar system is embedded into the macroscopic structure of the dark disk**
- the local density is constrained by $\delta = \frac{\rho_{Disk}}{\rho_{SHM}} \leq 2$
- the velocities and dispersions are taken as $v_{disk} = [0,50,0]\ km \cdot s^{-1};\ \ \sigma_{disk} = 50\ km \cdot s^{-1}$
- the dark disk increases the rates at low recoil energies and provides and modifies the shape of the recoil spectrum, depending on the WIMP mass

Recoil energy below which the signal is dominated by the dark disk

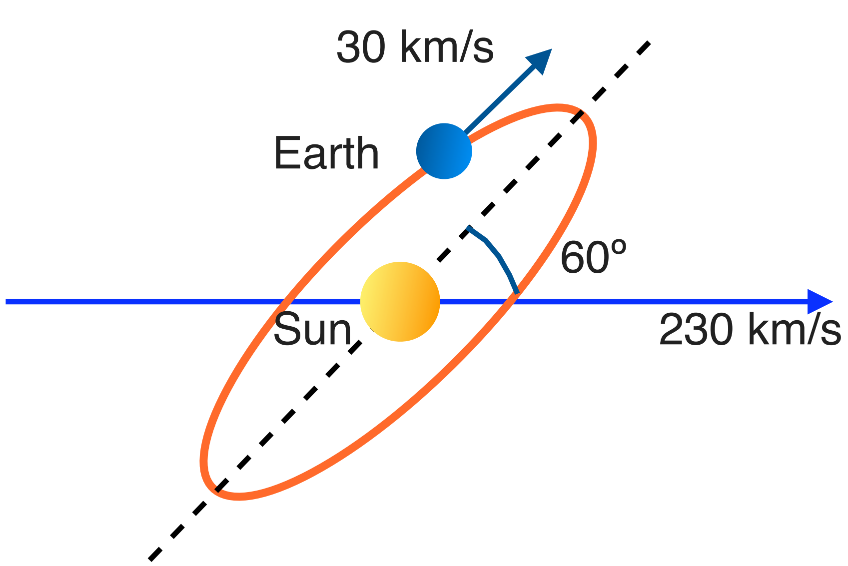


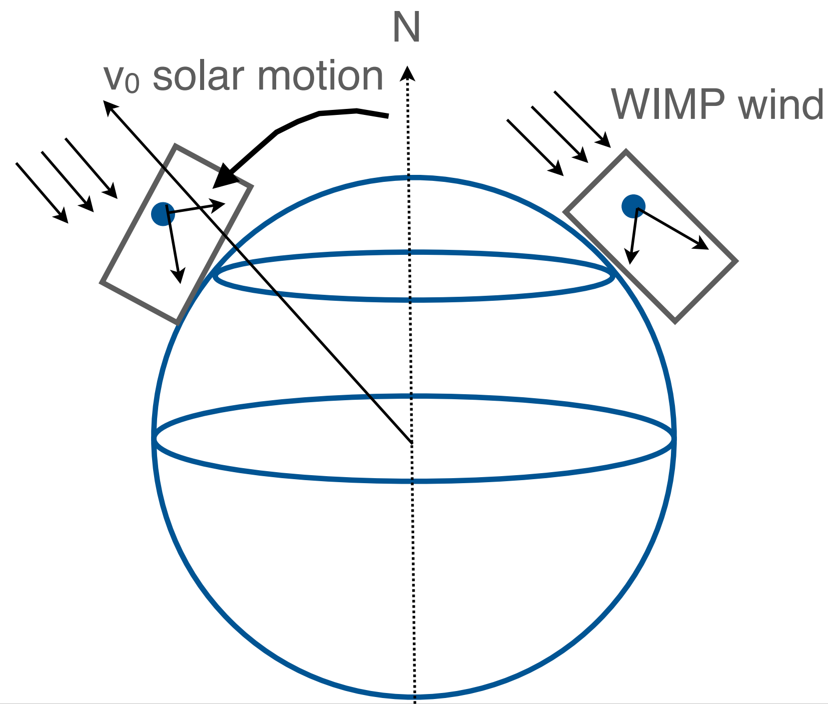


T. Bruch, J. Read, LB, G. Lake, APJ 2009

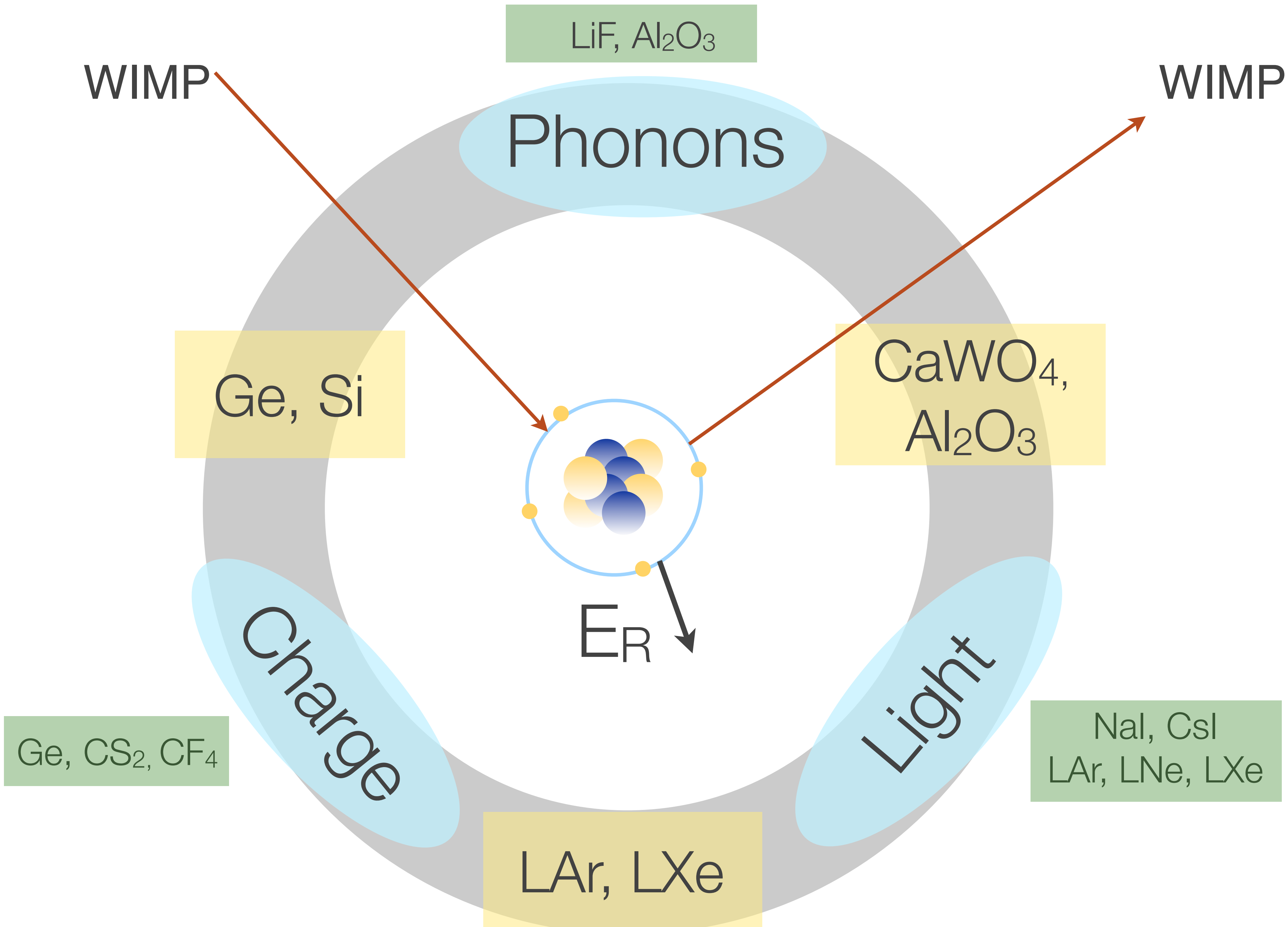
Expected WIMP Signatures

- **WIMP interactions in detector should be:**
  - nuclear recoils
  - single scatters, uniform throughout detector volume
- **Spectral shape** (exponential, however similar to background)
- **Dependance on material** (A^2, $F^2(Q)$, test consistency between different targets)
- **Annual flux modulation** (~ 3% effect, most events close to threshold)
- **Diurnal direction modulation** (larger effect, requires low-pressure gas target)

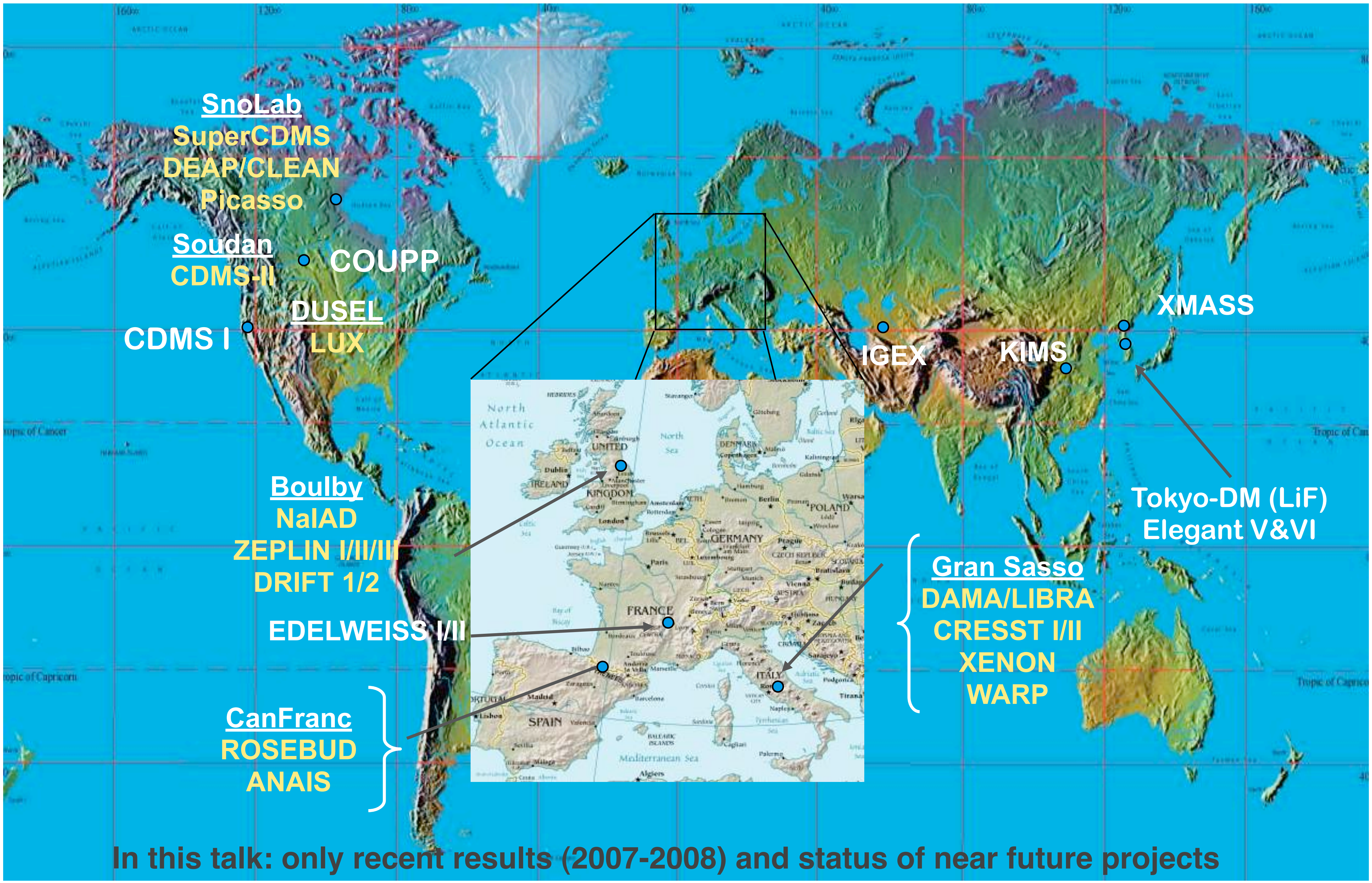




Direct Detection Techniques

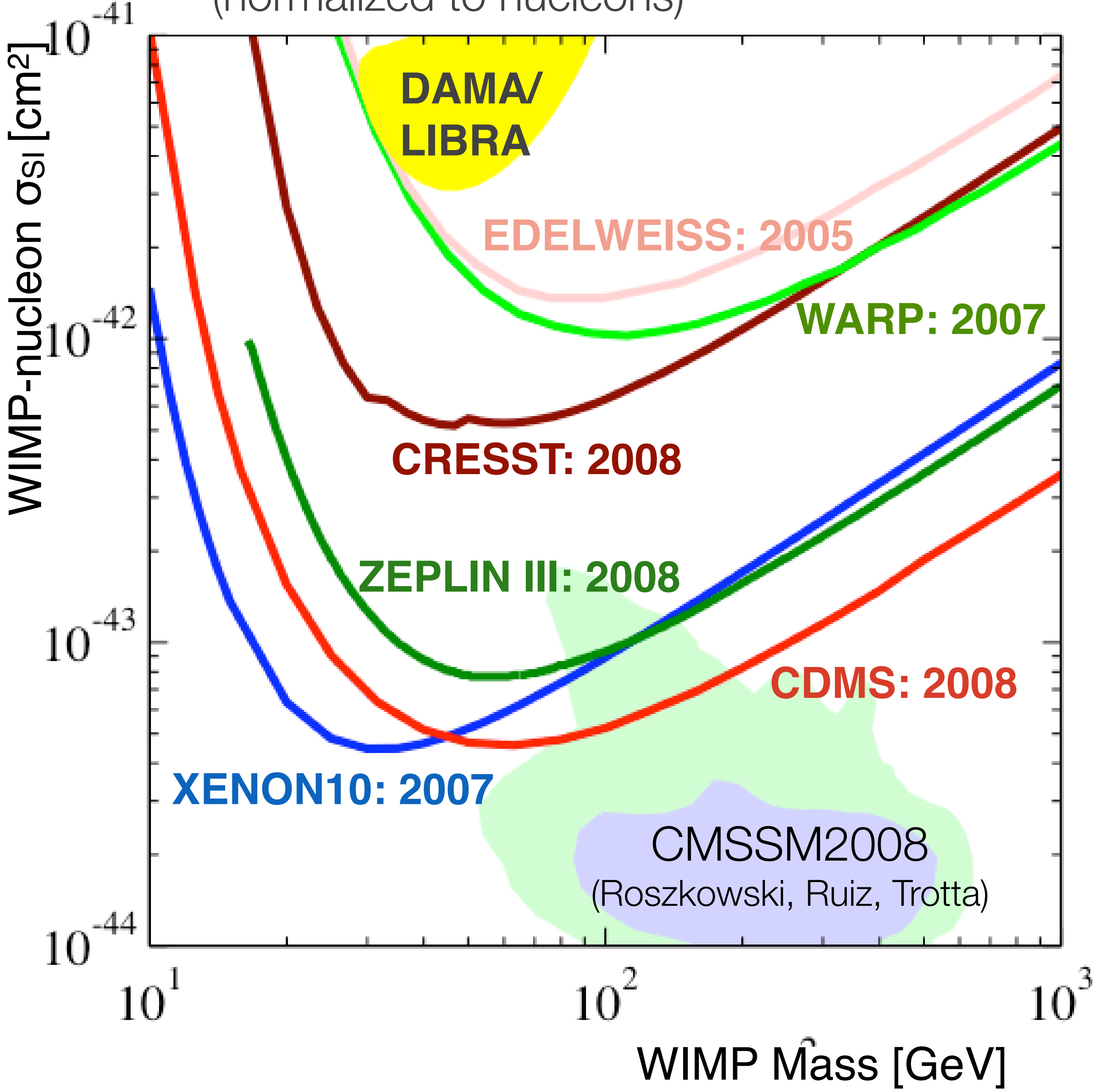


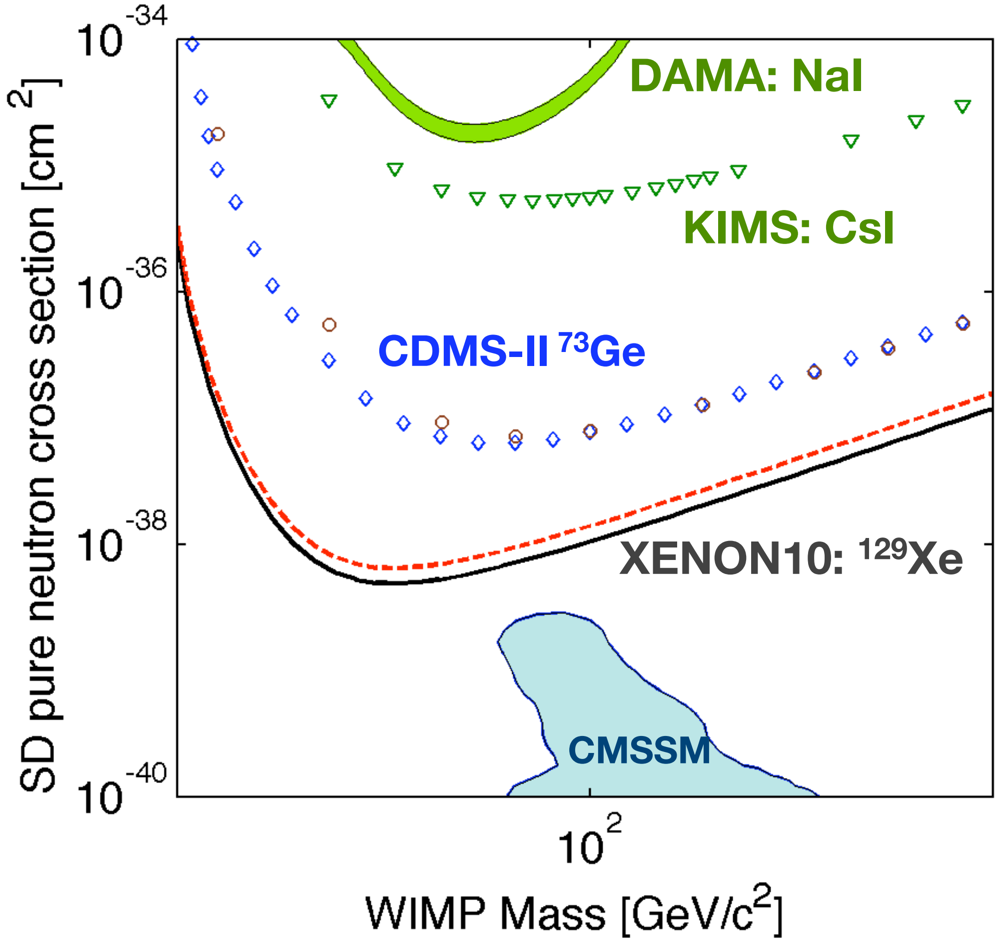
The World Wide WIMP Search

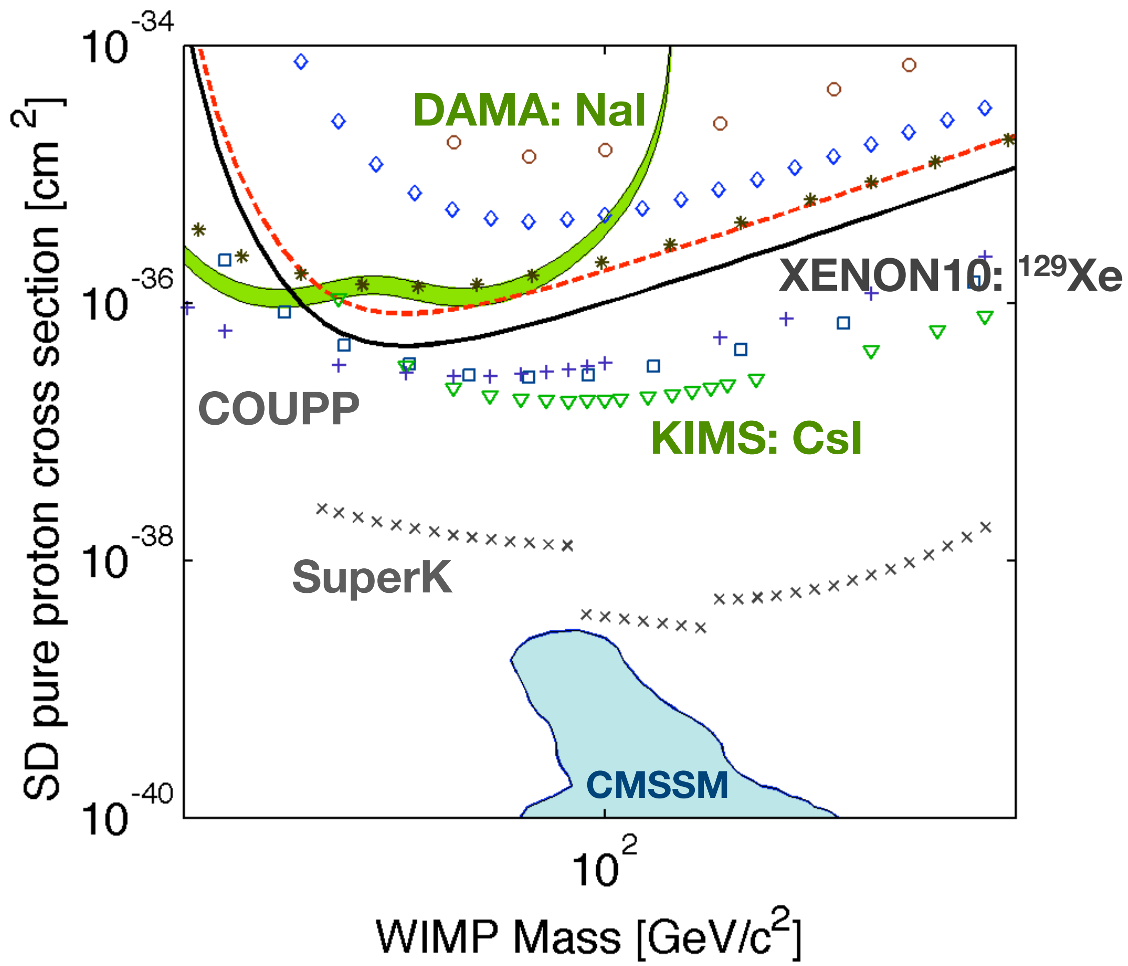


Experimental Results

Spin-independent cross section
(normalized to nucleons)





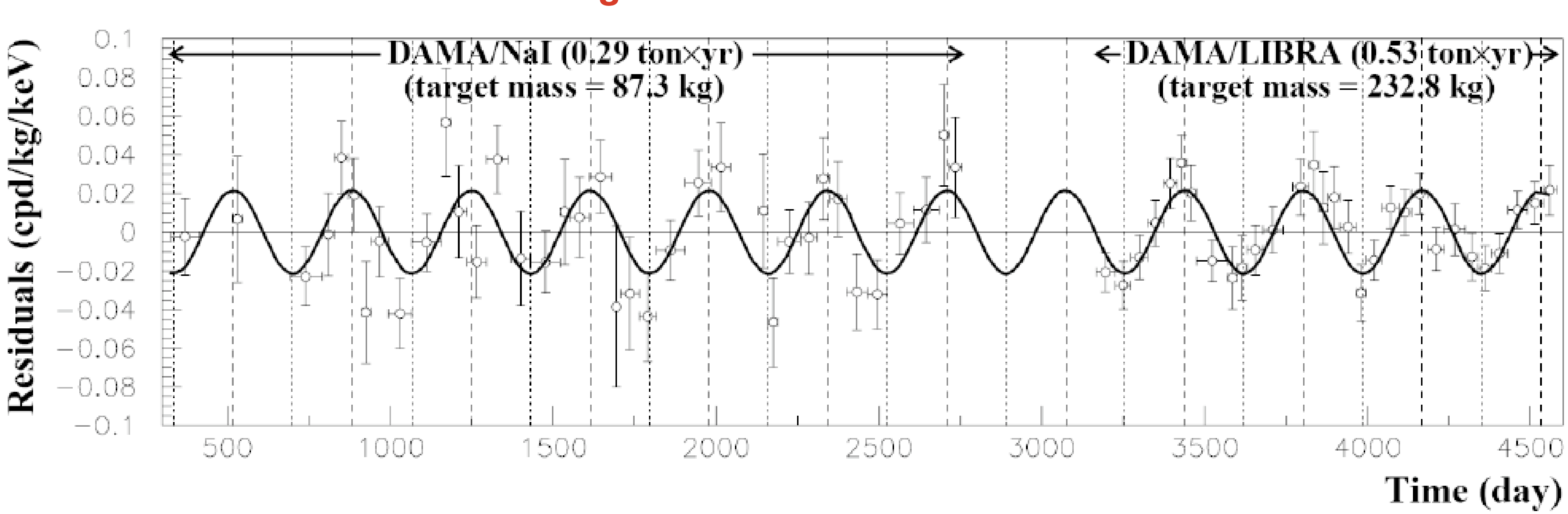


Spin-dependent

DAMA/LIBRA 2008

- **modulation of event rate confirmed in 2008**
- 25 NaI detectors a 9.7 kg; each viewed by 2 PMTs (5.5-7.5 p.e./keVee)
- 4 years of data taking: 192 x 10^3 kg days

residuals from average rate

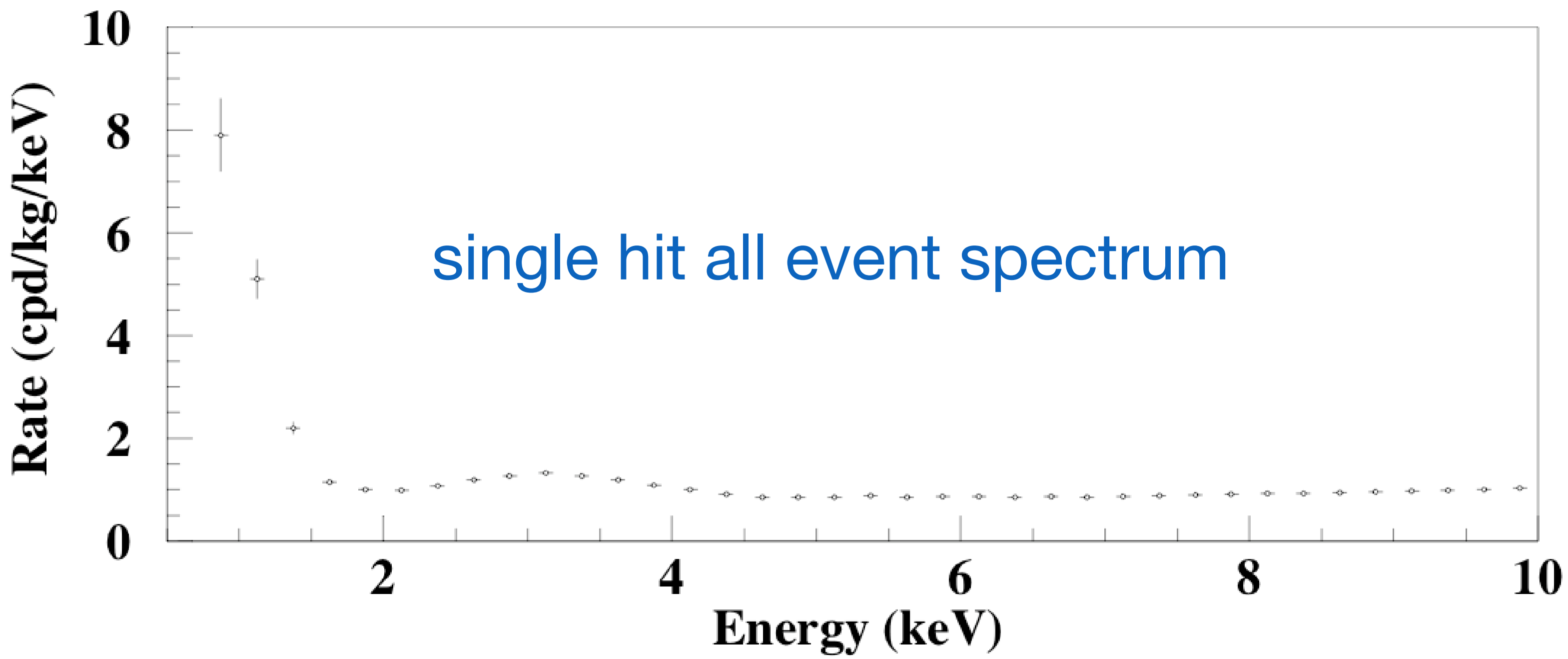


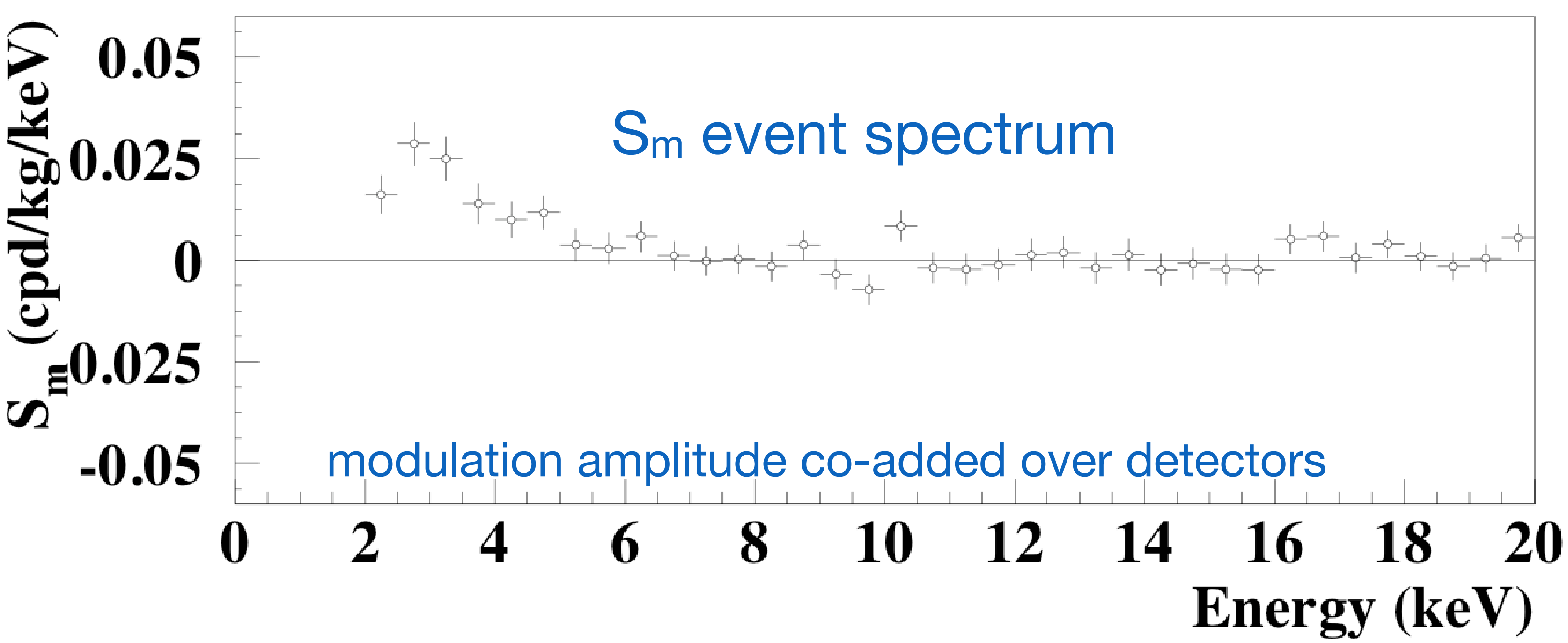
$$\frac{dR}{dE}(E,t) \approx S_0(E) + S_m(E)\cos\omega(t - t_0)$$

t_0 = 152.5 d
T = 1 year

S_m = (0.0215 ± 0.0026) counts/(day kg keV)

DAMA/LIBRA 2008



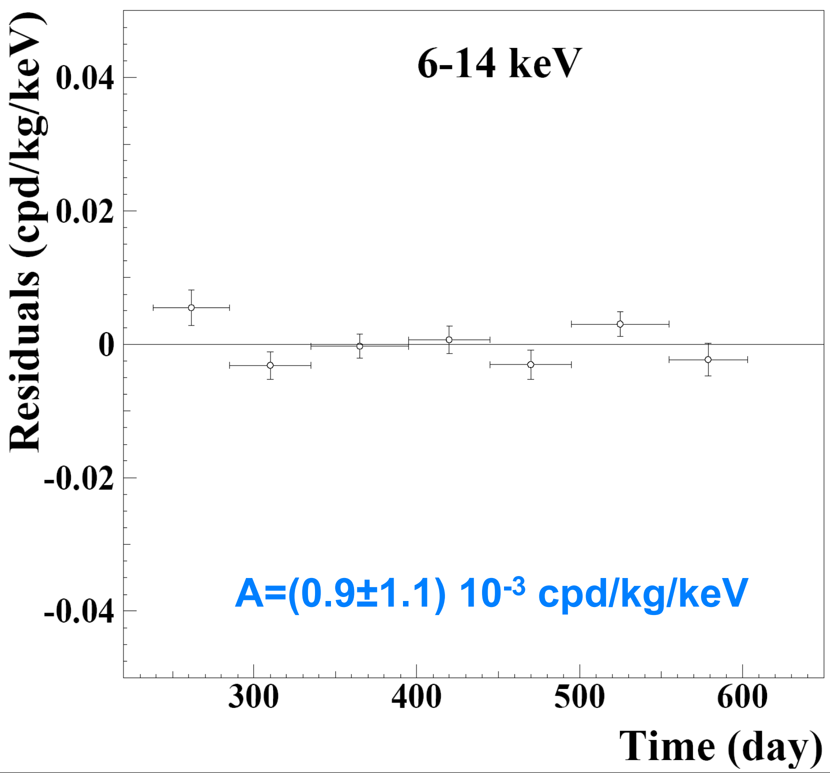


signal in region dominated by PMT noise (does the tail of the noise distribution modulate?)

signal very close to threshold

modulation of a peak around 3 keV?

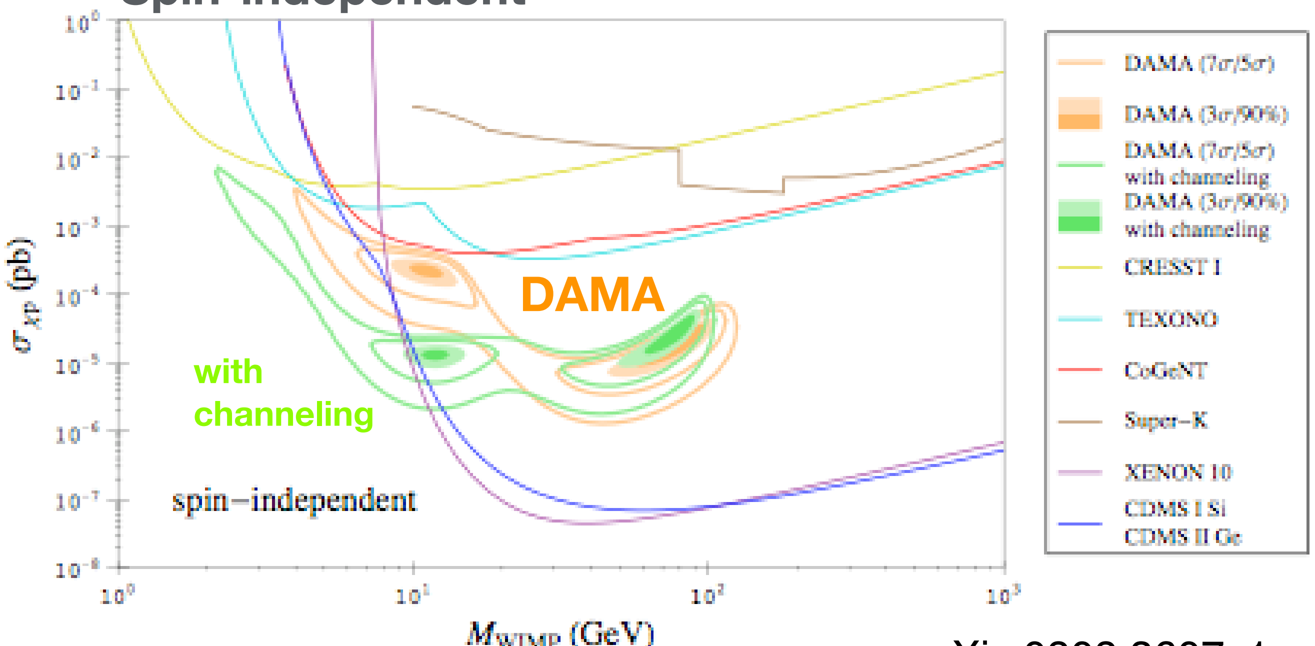
what is the contribution of the ^{40}K 3 keV X-ray in the singles spectrum?



DAMA Signal and Existing Experimental Limits at Low WIMP Masses

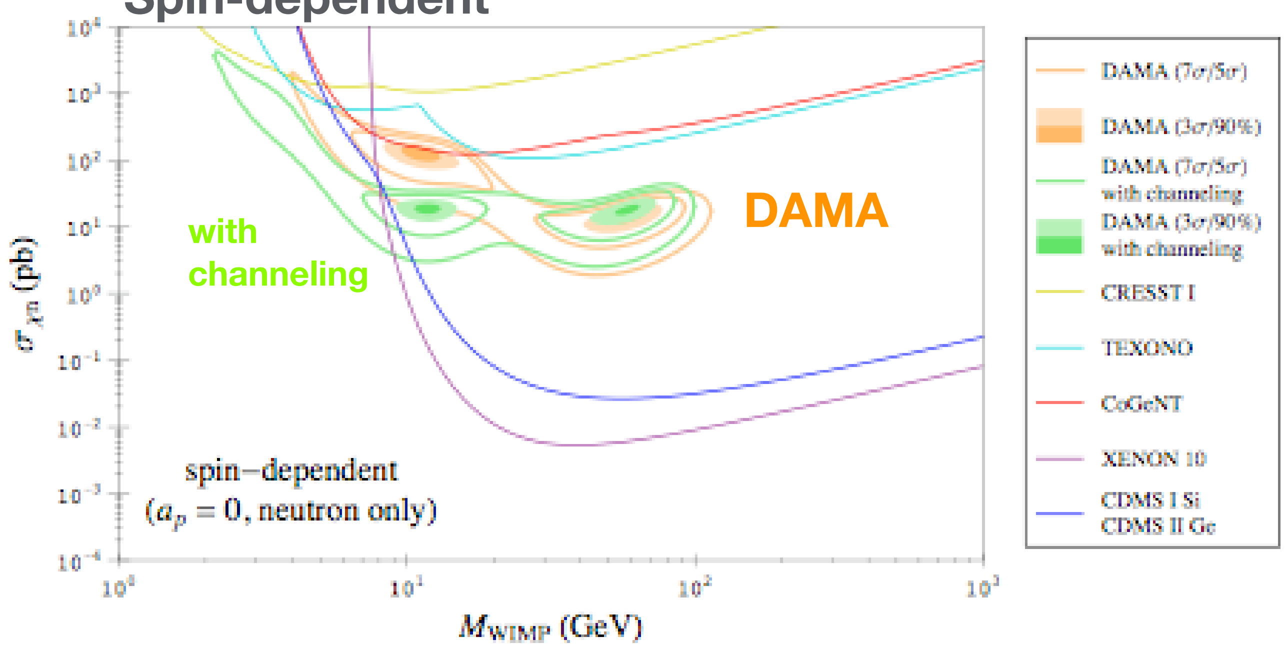
- WIMP hypothesis: severe tension with other experiments!

Spin-independent

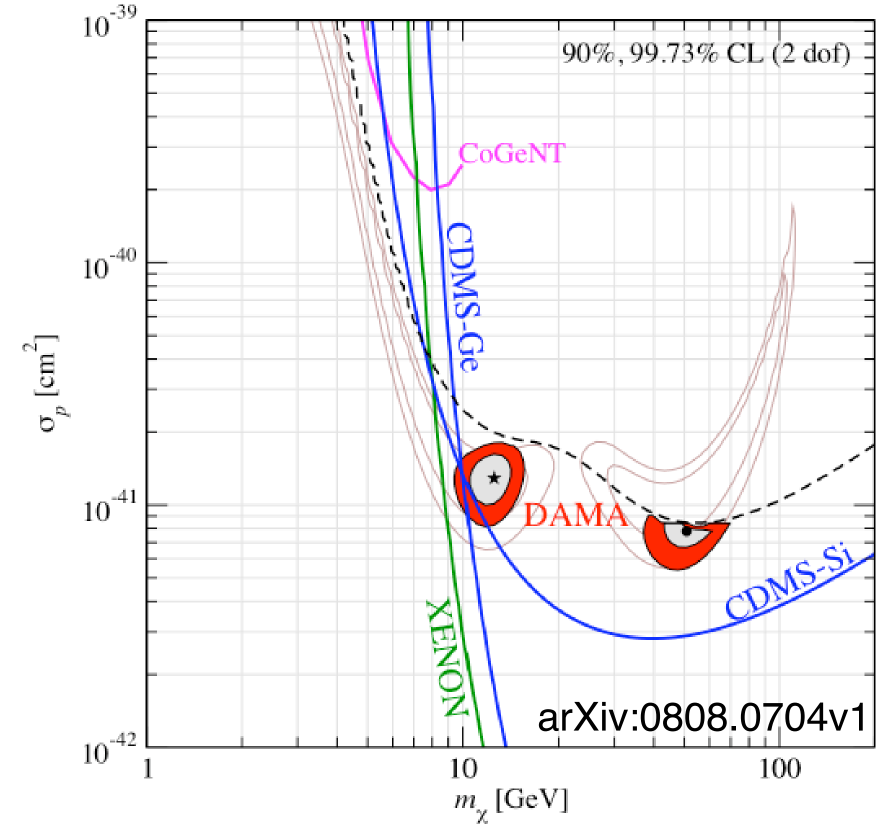


arXiv:0808.3607v1

Spin-dependent



M. Fairbairn, T. Schwetz

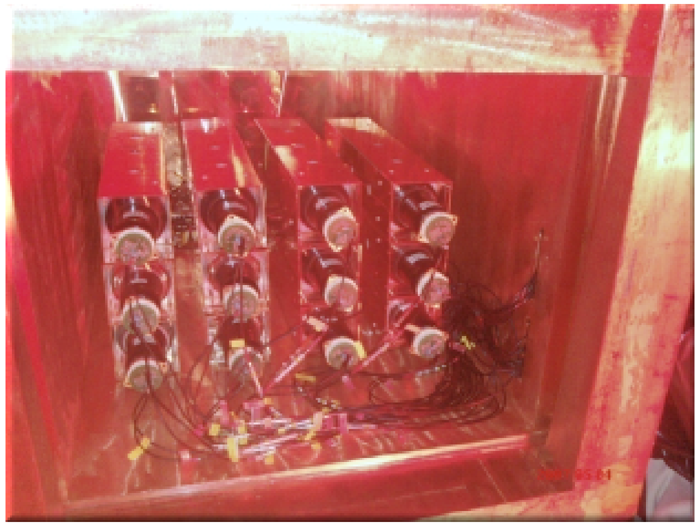


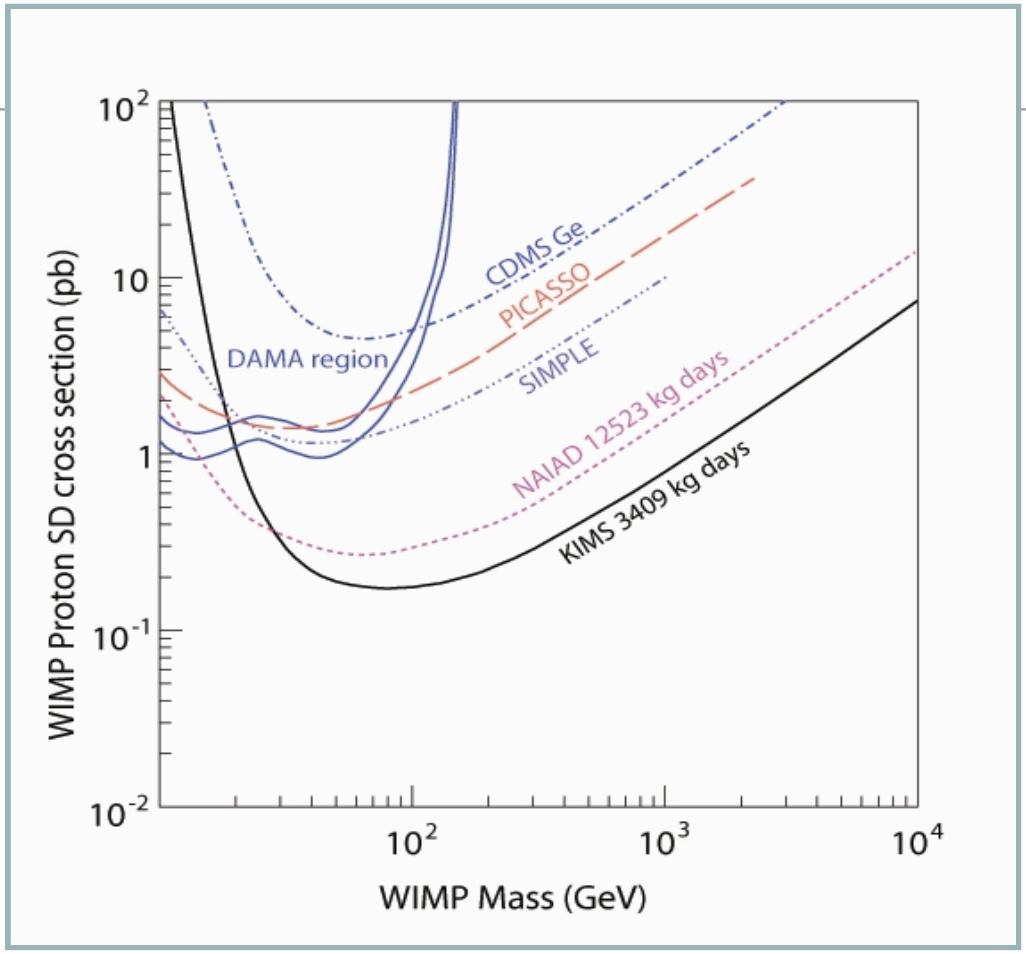
Ion channeling effect: scattered ion parallel to crystal axis will undergo small-angle scattering which will channel it along the gaps in the lattice; such an ion has lower dE/dx, yielding increased light , effectively reducing the energy threshold for low-energy nuclear recoils

Channeling: has not yet been demonstrated for nuclear recoils starting from a lattice site, only for incident ion beam; nor has the opposite effect, ion blocking, been considered

The KIMS Experiment

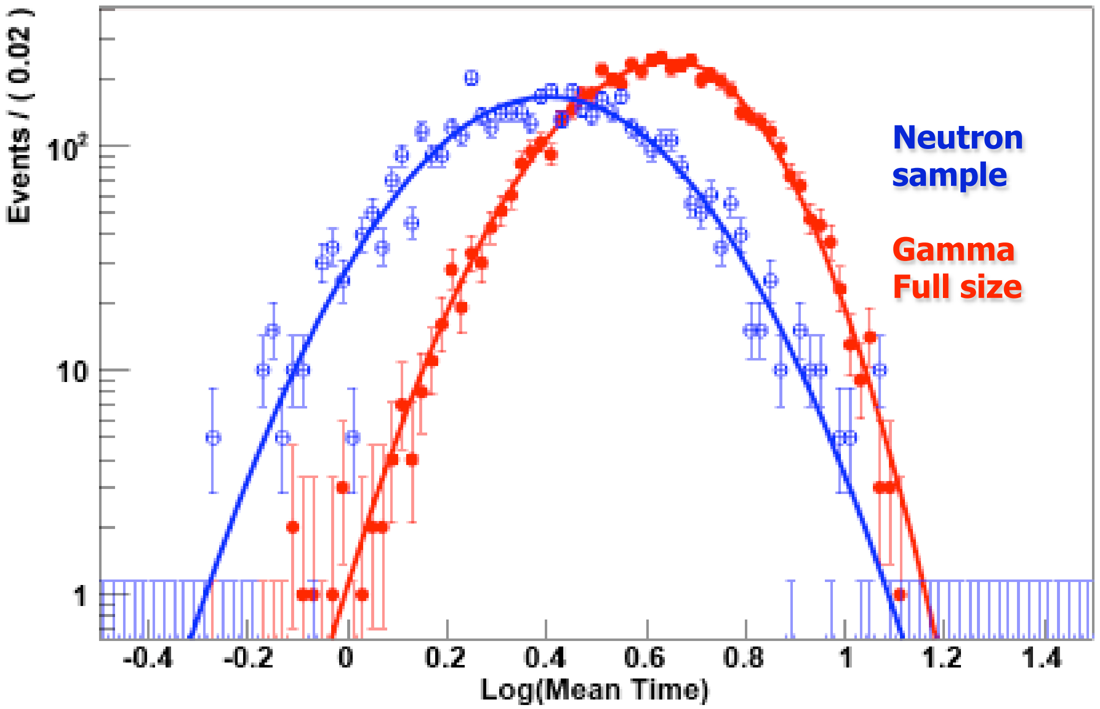
- at the Yangyang lab in Korea (200 mwe)
- results from 4 x 8.7 CsI(Tl) crystals (3407 kg yr)
- background reduction by PSD
- best SD limit for pure-p published in PRL99





Current status:
12 detectors (104.4 kg) installed
- muon veto (liquid scintillator+56 PMTs)
- optimization runs finished (BG ~ 1 dru)

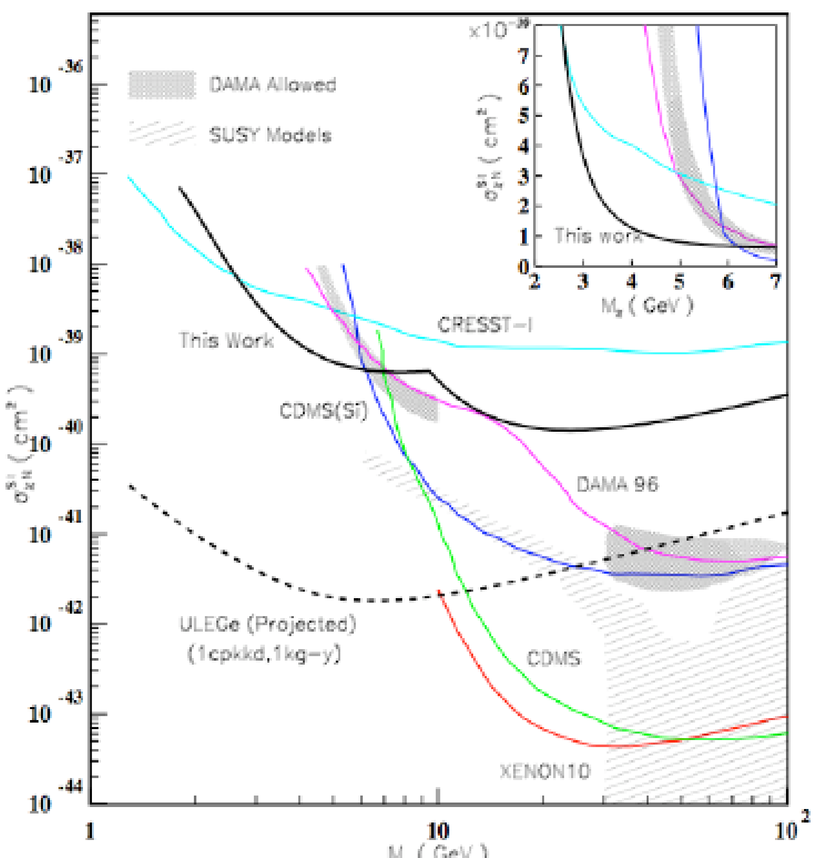
stable operation in progress
-> probe the DAMA modulation signal



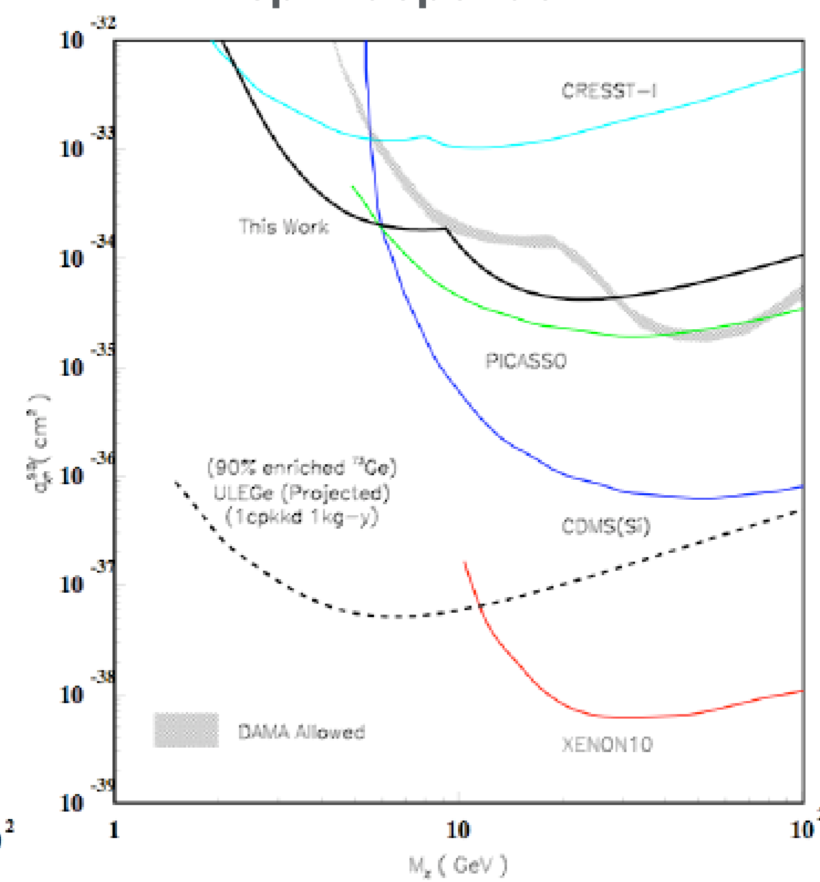
New Experimental Results at Low WIMP Masses

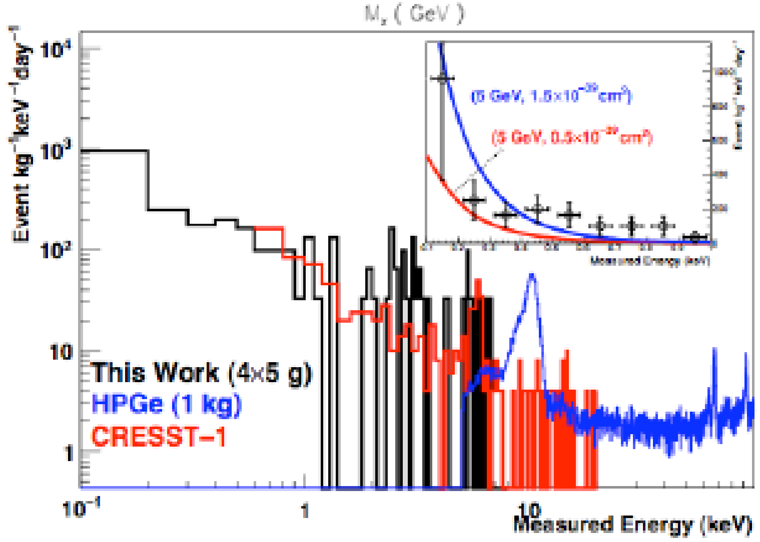
TEXONO: 4 x 5 g Ge

spin-independent



spin-dependent

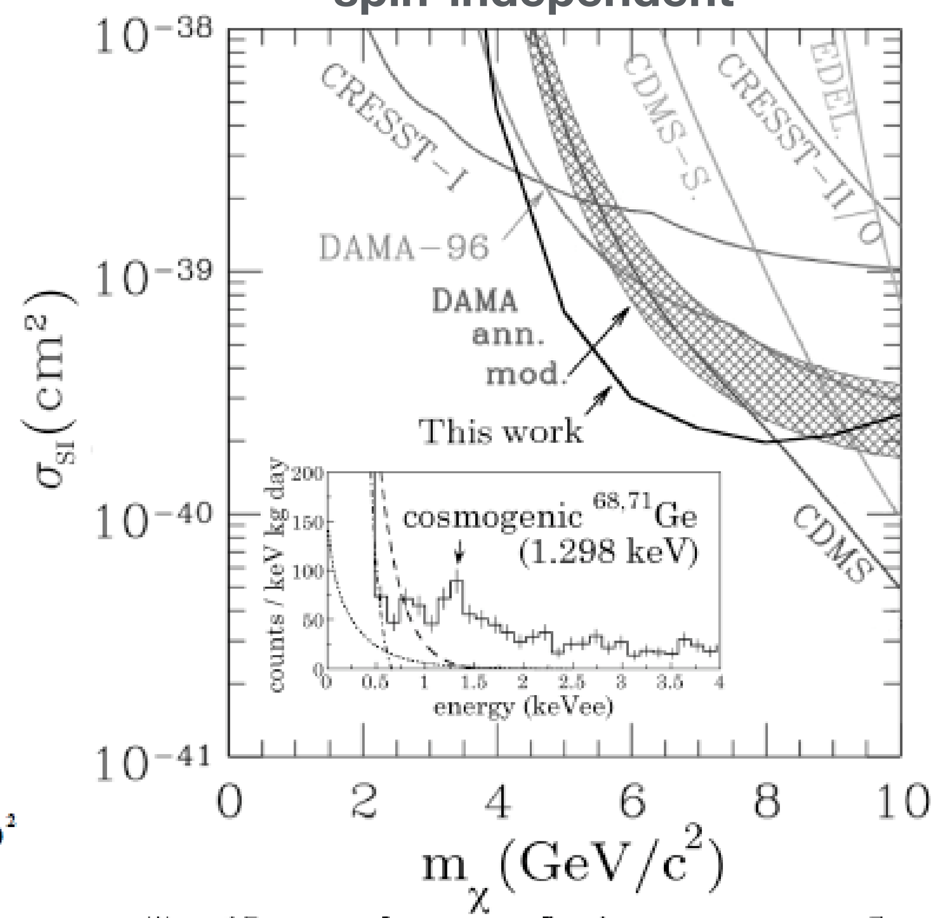


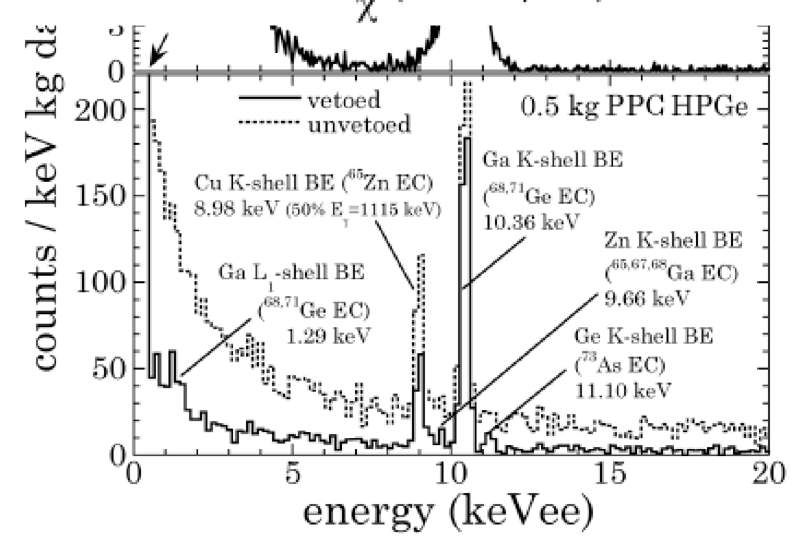


0712.1645v4

CoGeNT: 500 g PPC Ge

spin-independent

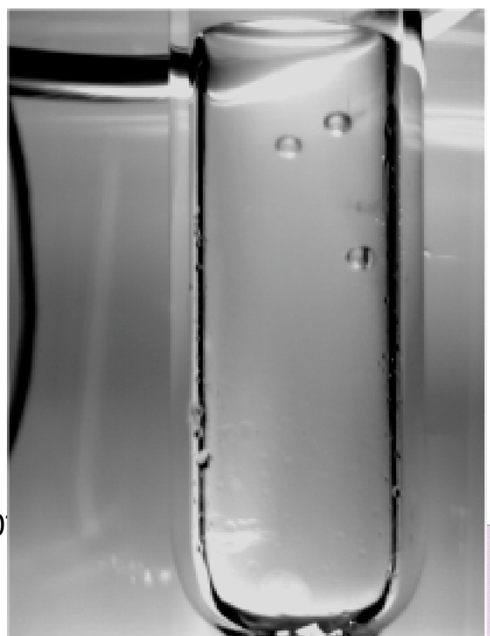




PRL 101 (2008)

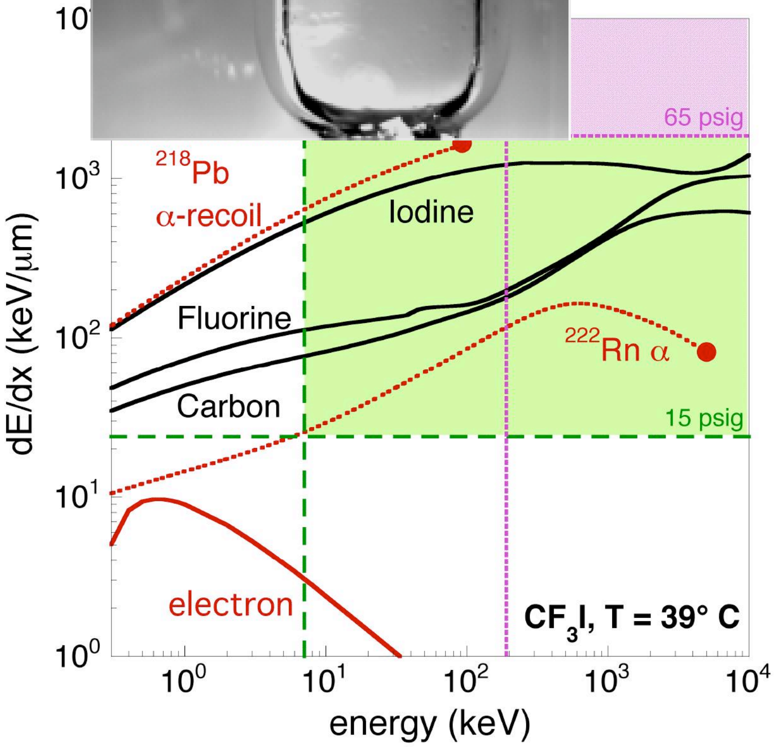
The COUPP Experiment

- superheated liquid -> detects single bubbles induced by high dE/dx nuclear recoils; **advantage:** large masses, low costs, SD, SI (I, Br, F, C), high spatial granularity, ‘rejection’ of ERs 10^{10} at 10keV$_r$; **challenge:** reduce alpha background

- 

n-induced event (multiple scatter)

WIMP: single scatter



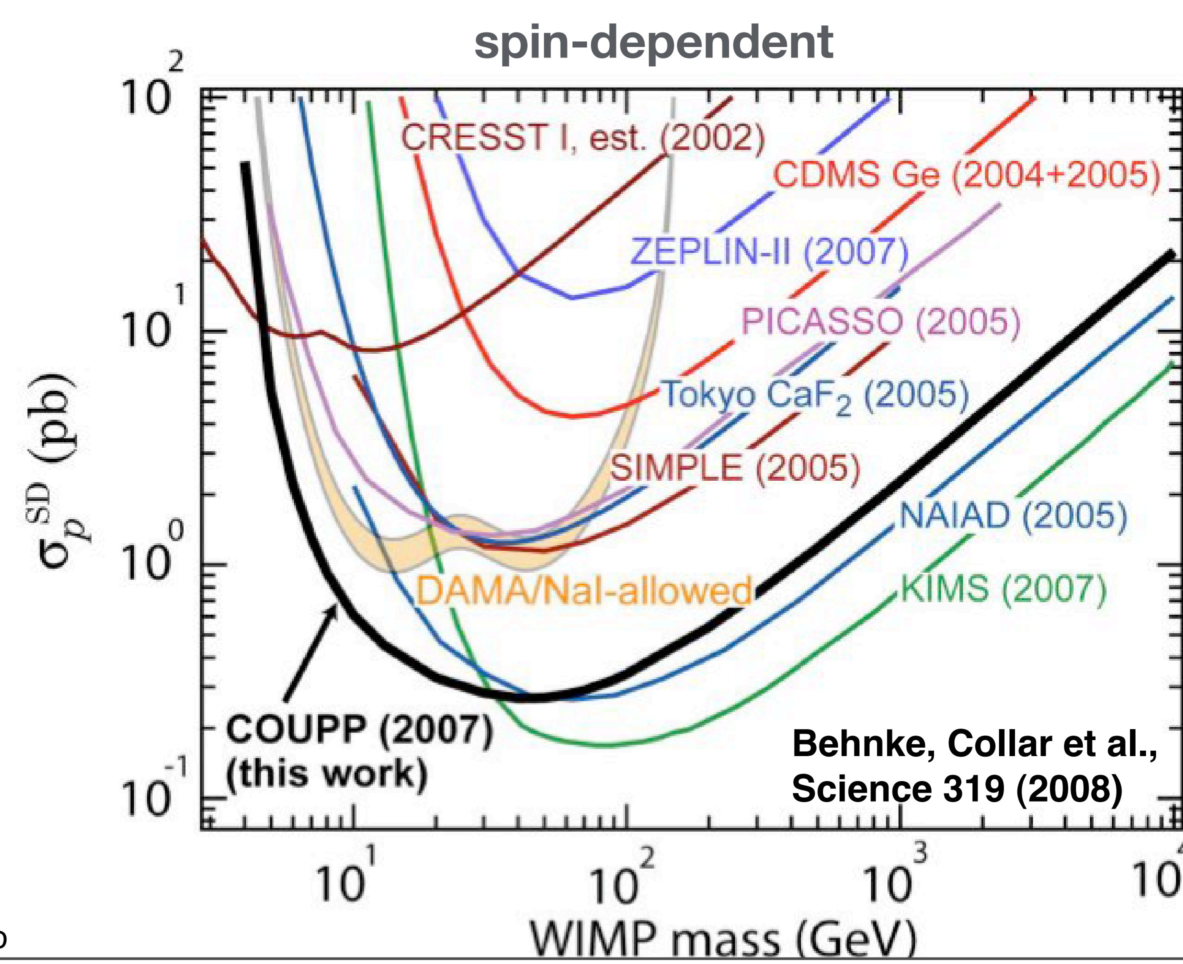
2 kg detector at 300 mwe in 2006: α BG from walls

^{222}Rn decays -> ^{210}Pb plate-out + ^{222}Rn emanation

run with 2 kg in 2007/2008 (reduced backgrounds)

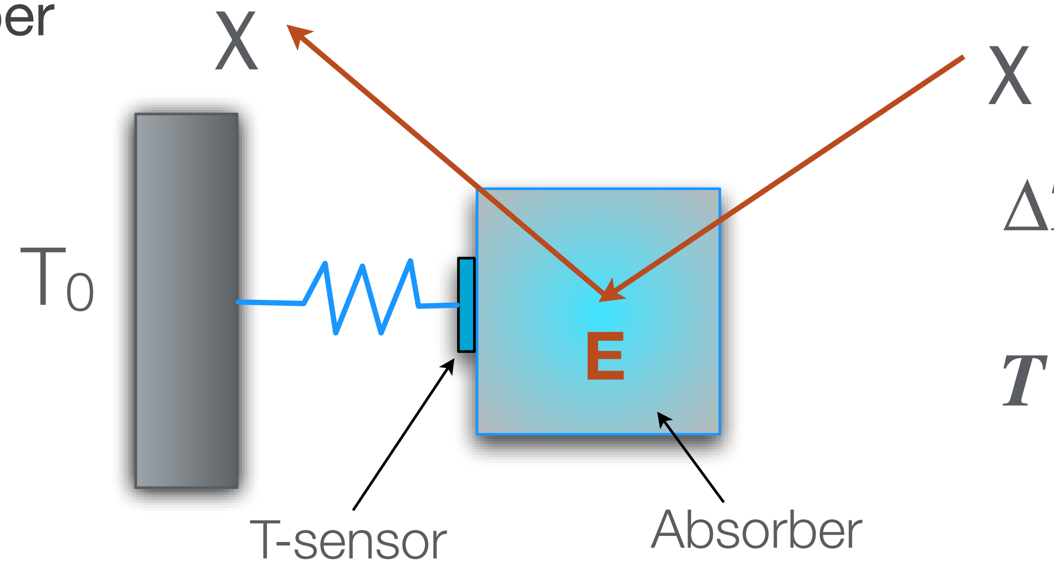
60 kg module under construction at FNAL -> 3 x 10^{-8}pb

spin-dependent



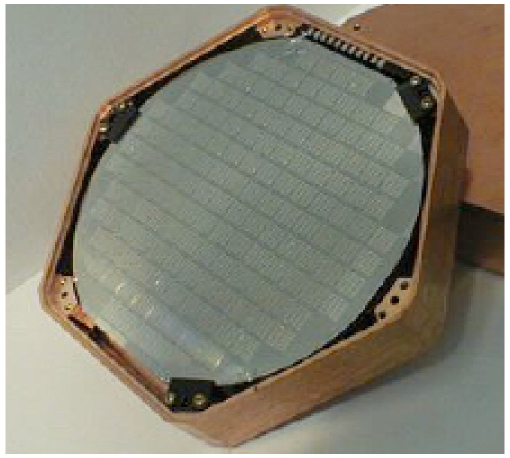
The CDMS Experiment at the Soudan Mine

- Measures the T-rise and the charge when a WIMP interacts with a nucleus of the Ge or Si absorber

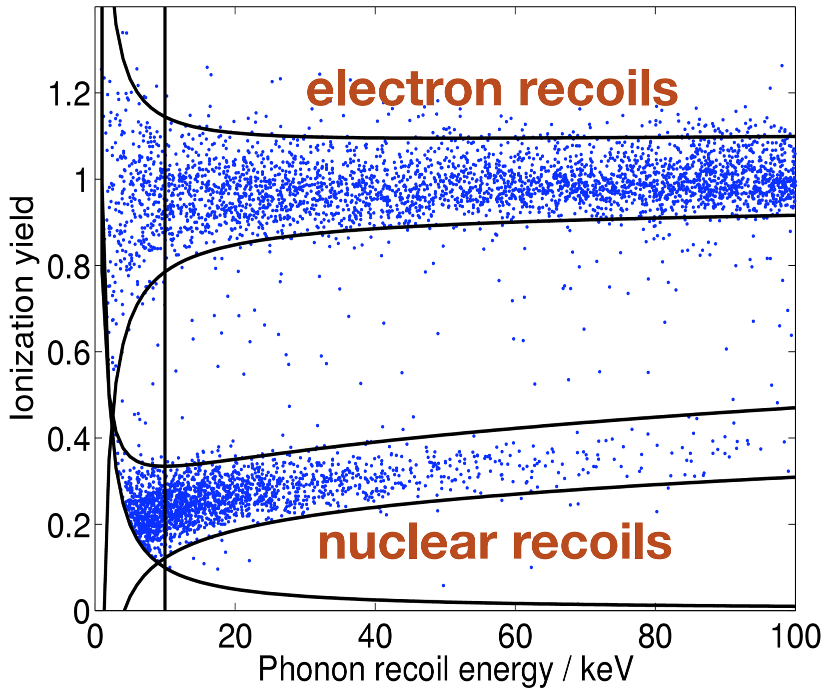


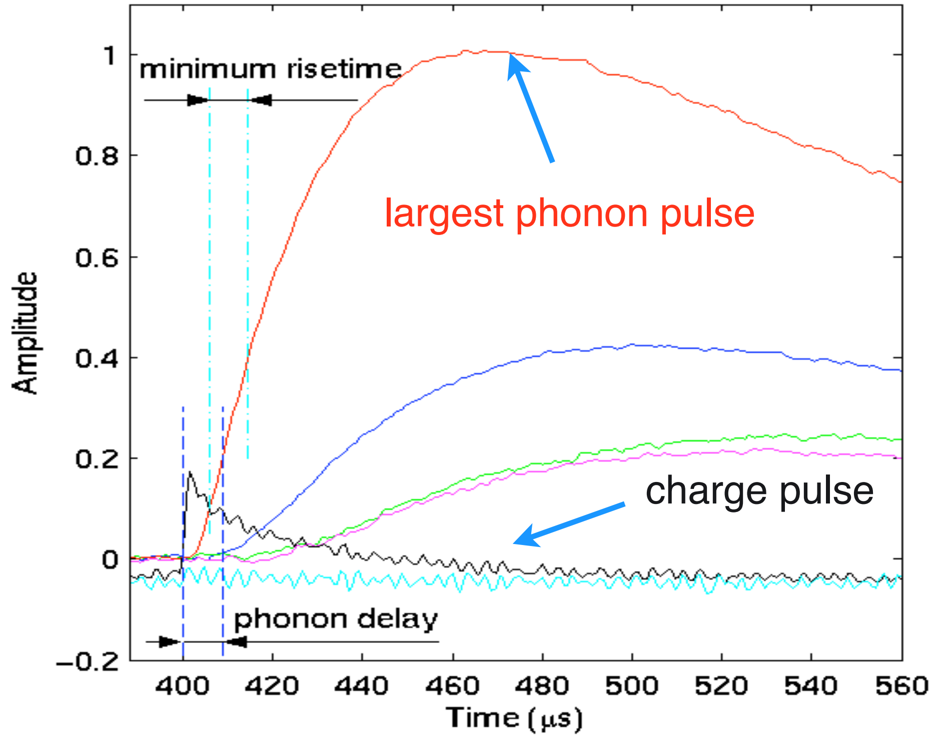
$$\Delta T \propto \frac{E}{C(T)}$$

$$T \ll T_c \Rightarrow C(T) \propto T^3$$



- The charge/phonon ratio: nuclear vs. electron recoil discrimination

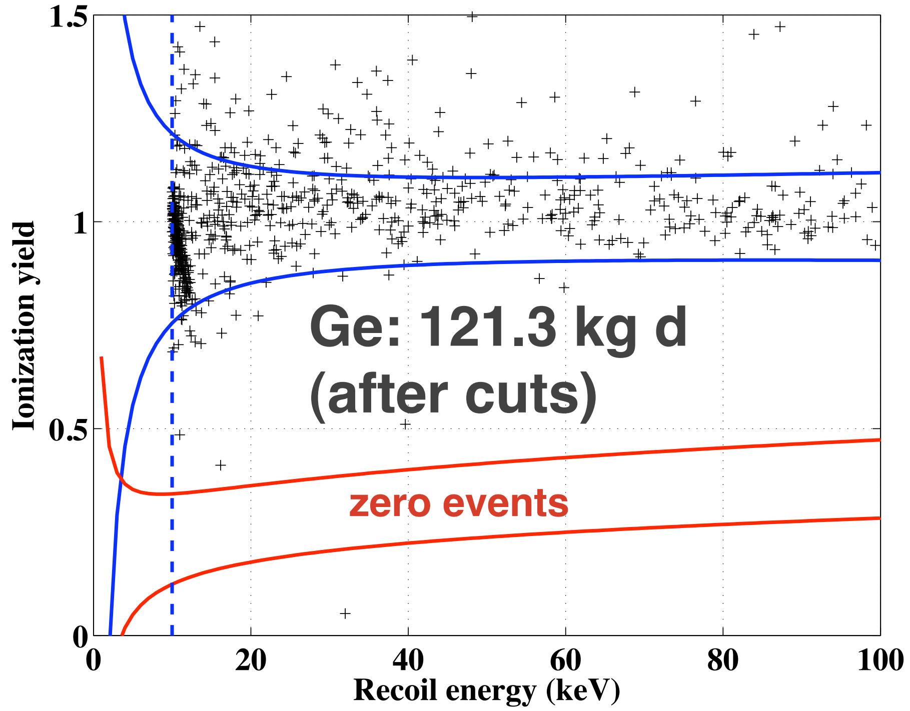


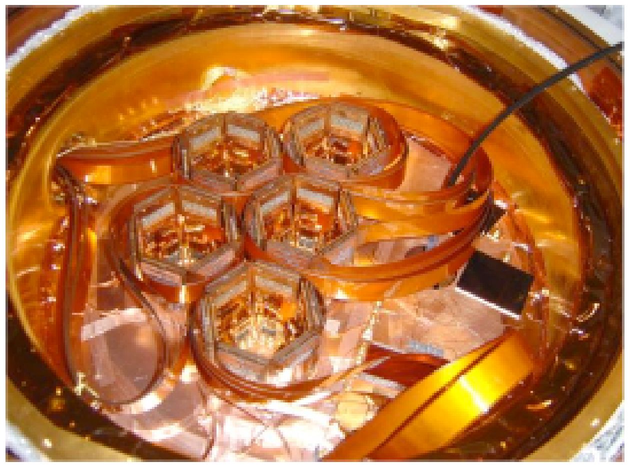


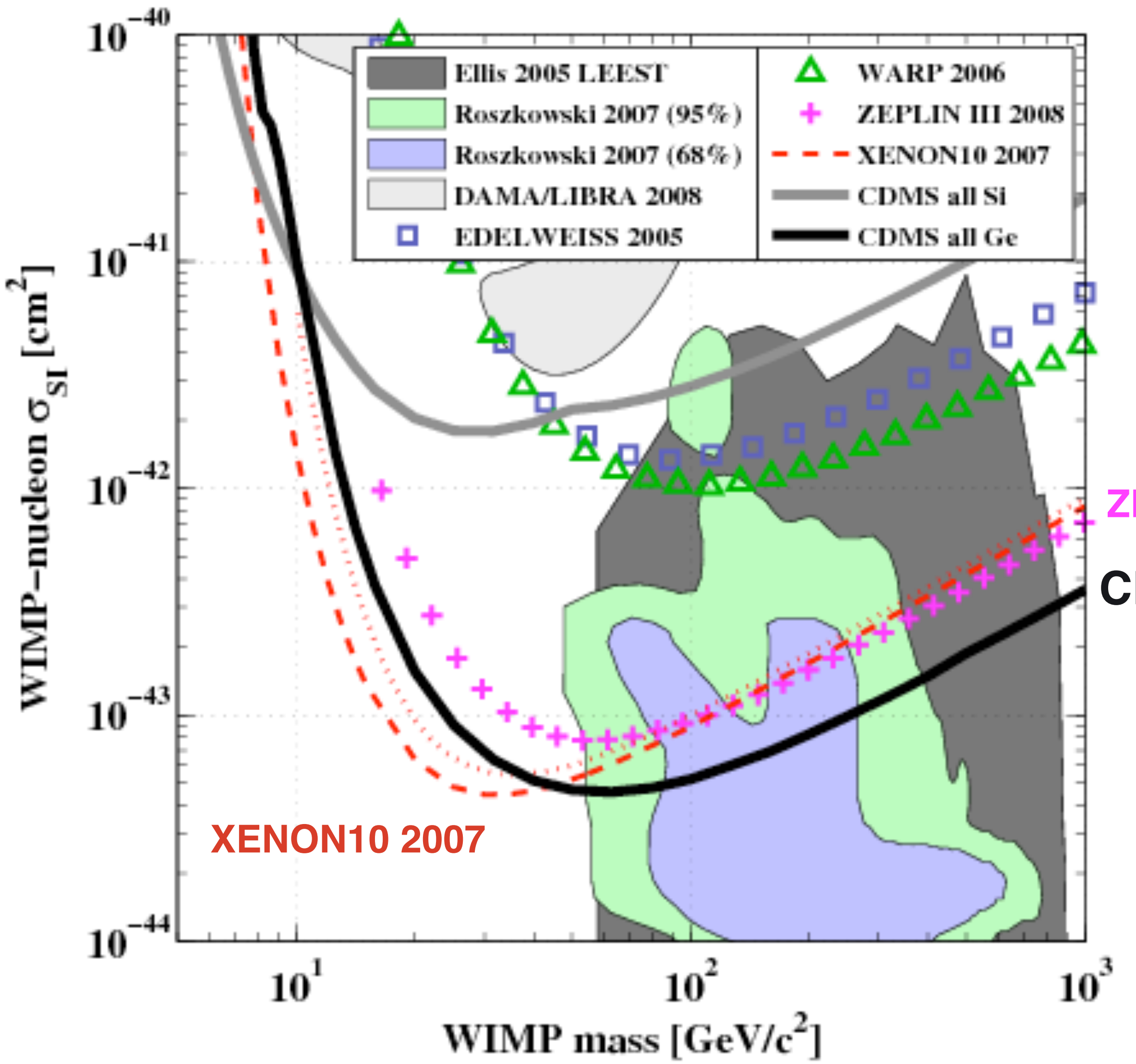
timing information: discrimination of surface vs. bulk events

CDMS Results

- **30 Ge (4.75 kg) and Si (1.1 kg) detectors in 5 towers**
- **Run 123+124:** 163 live days, results published in PRL102 (2009) 011301
- **Run 125-128:** 240 live days under analysis, first results in summer 09 (sensitivity reach ~ 1×10^{-44} cm^2)

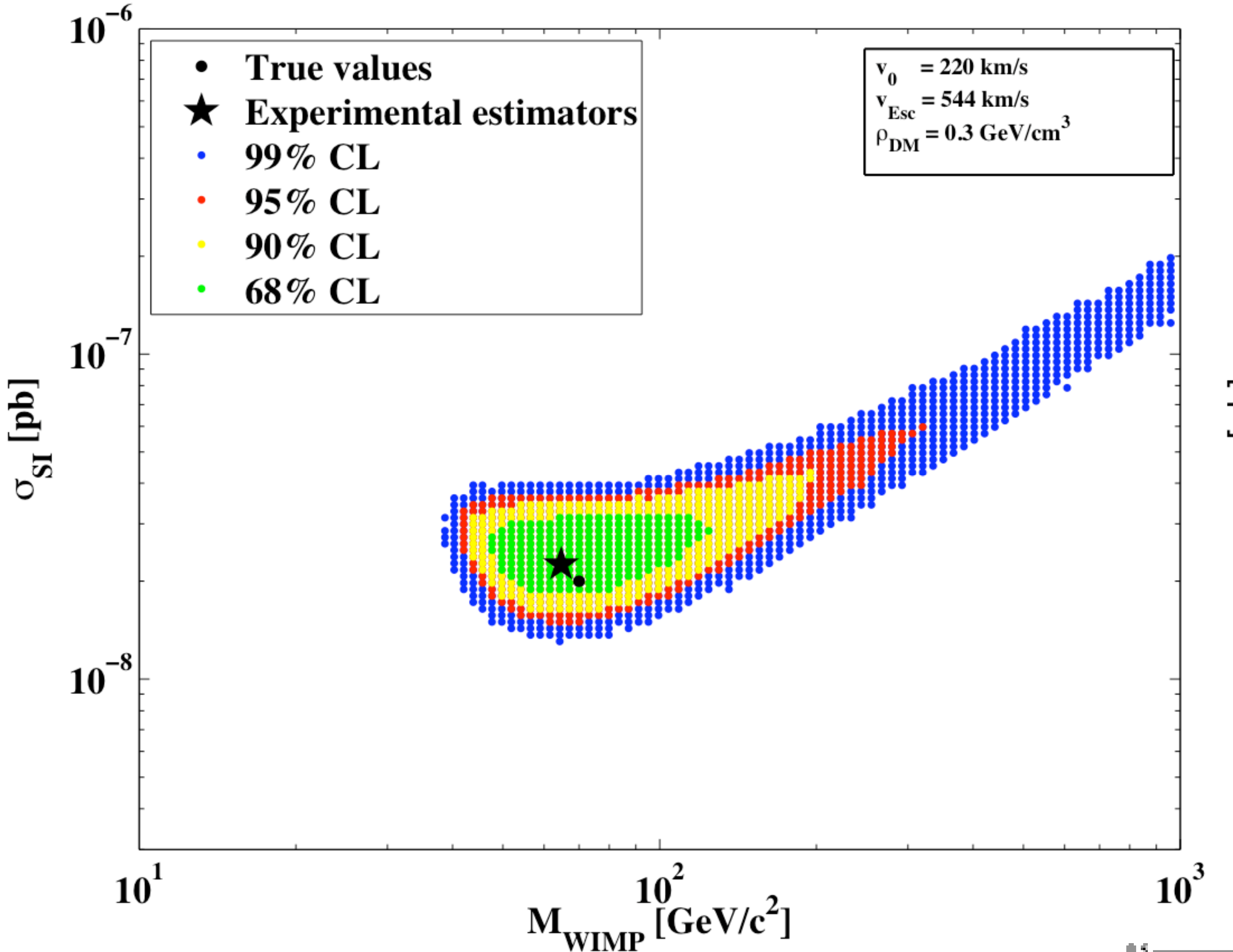




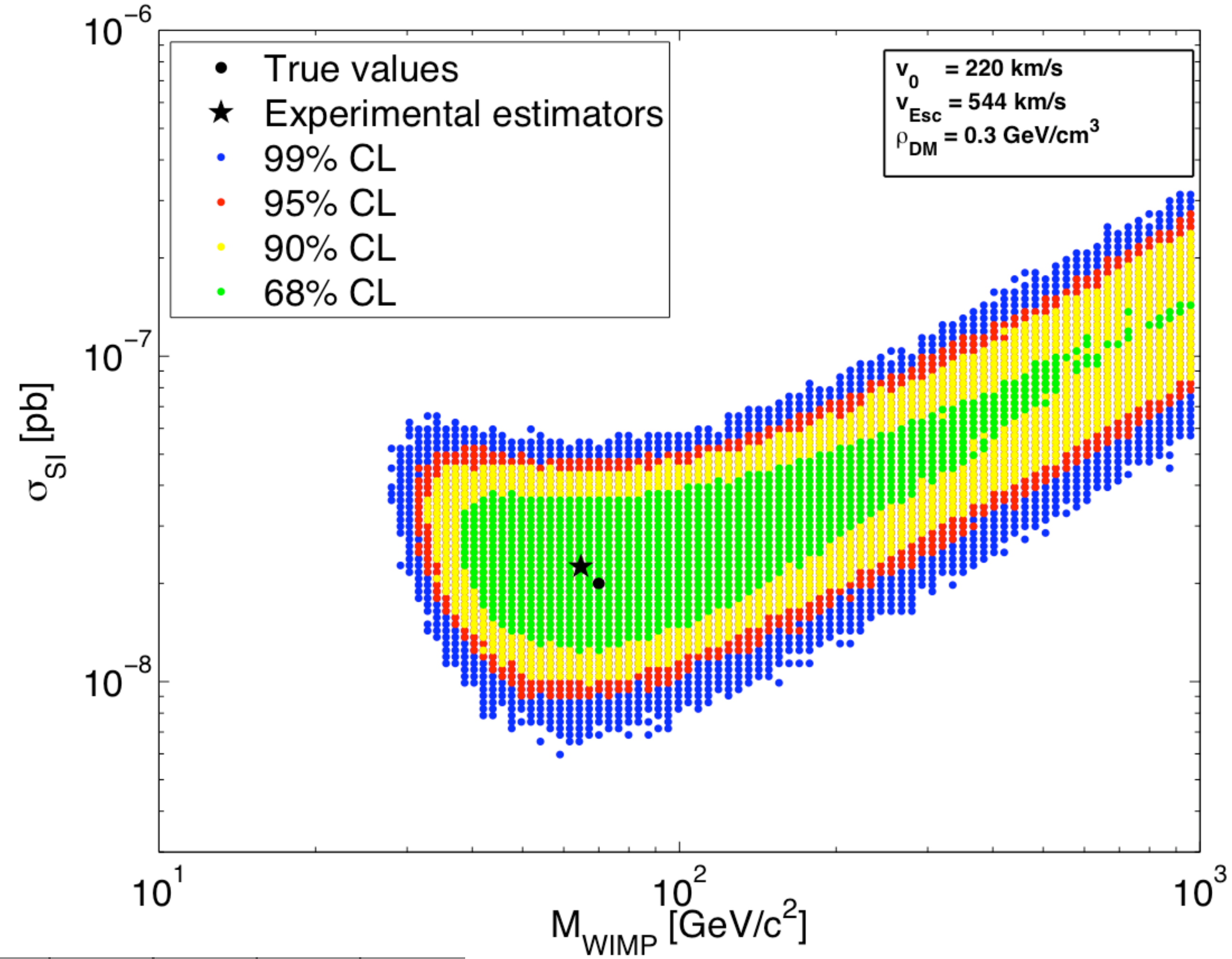


How well would we determine the WIMP mass?

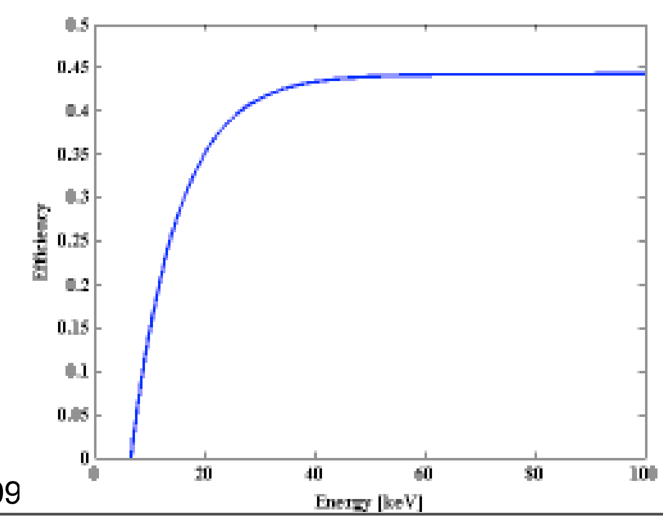
30 events in 12’250 (raw) kg days



8 events in 3’500 (raw) kg days



Preliminary study:
Tobias Bruch, Zurich

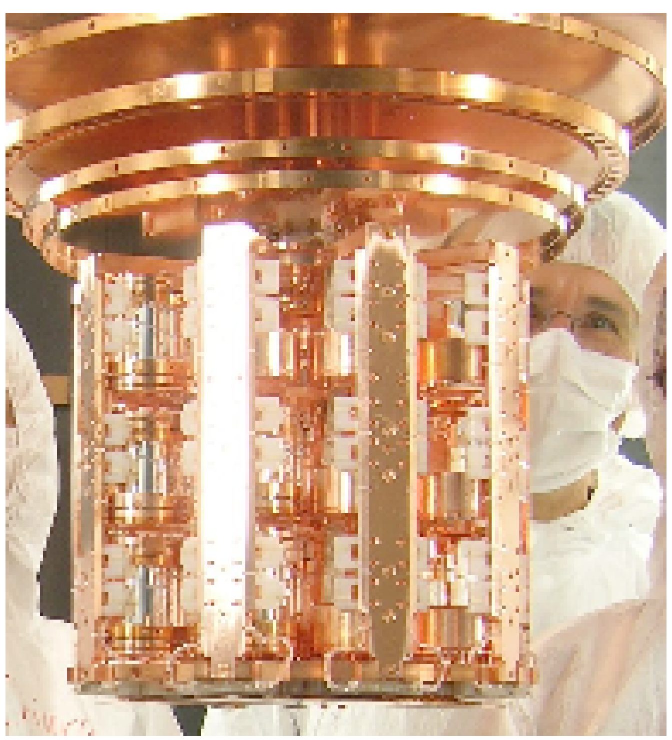


assumed detection efficiency

Cryogenic mK Experiments: Near Future

CRESST at LNGS

10 kg array of 33 $CaWO_4$ detectors
new 66 SQUID channel array
- **new limit from operating 2 detectors (48 kg d) published in 2008,** arXiv:0809.1829v1
- new run in progress



EDELWEISS at LSM

10 kg (30 modules) of NTD and NbSi Ge detectors in new cryostat
- new charge electrodes
- 100 kg d under analysis
- **data taking in progress**

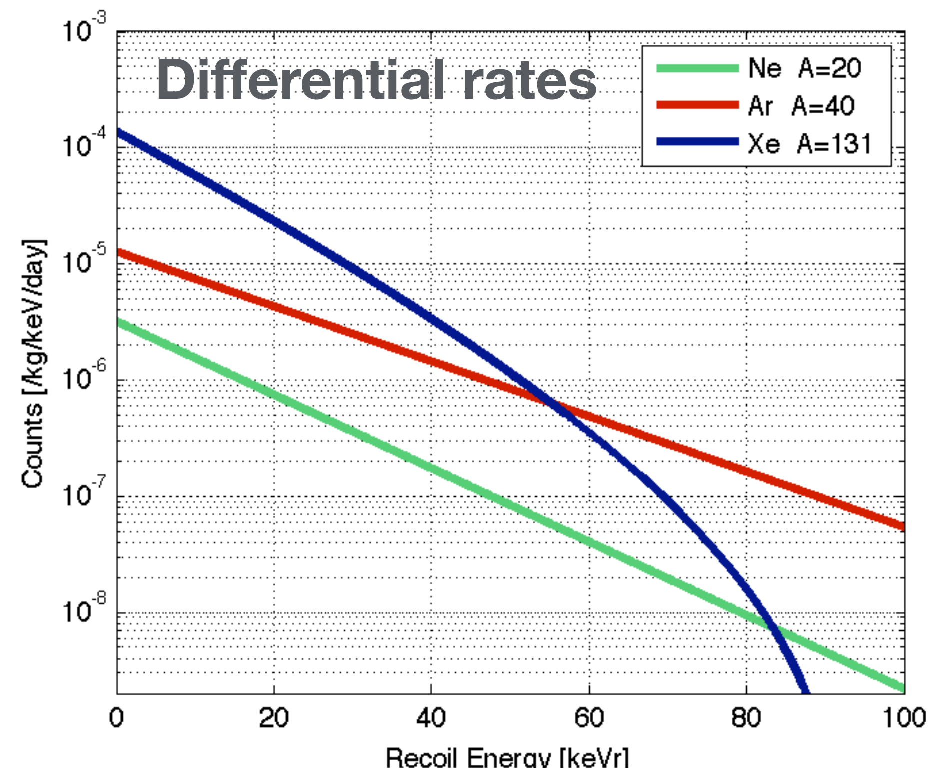
CDMS/SuperCDMS at Soudan

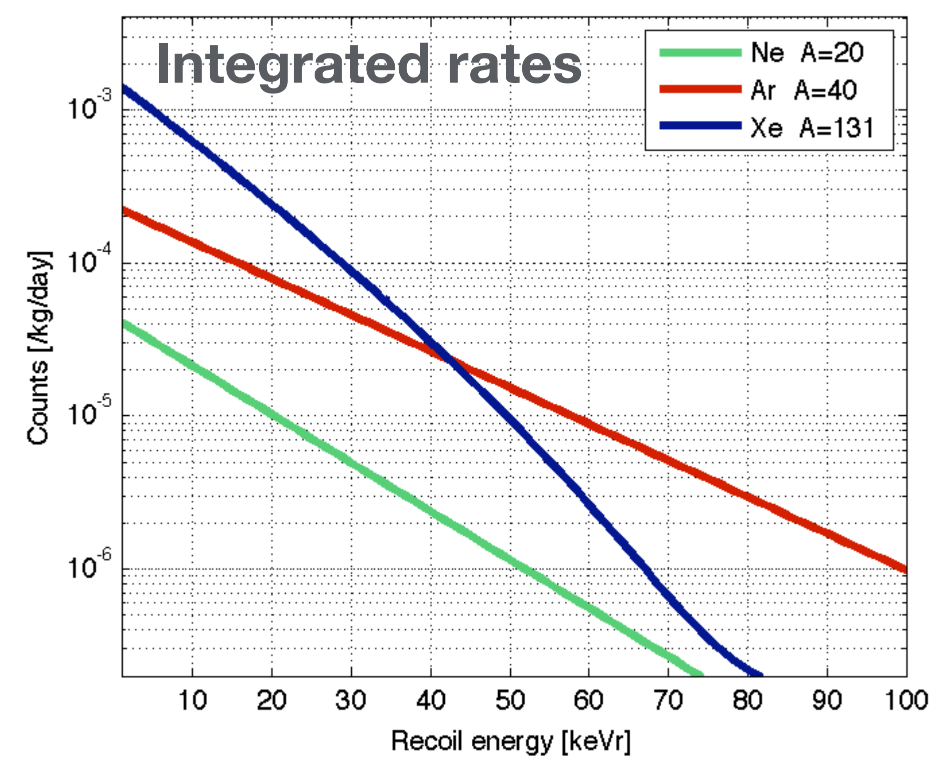
CDMS-II run 129 in progress
SuperCDMS detectors (1'' thick ZIPs, each 650 g of Ge) have been tested
Installation of first SuperTower at Soudan in spring 2009
Goal: 5 x 10^{-45} cm^2 with 16 kg Ge

Noble Liquids as Dark Matter Detectors

Dense, homogeneous targets/detectors
High scintillation/ionization yields
Commercially easy to obtain and purify

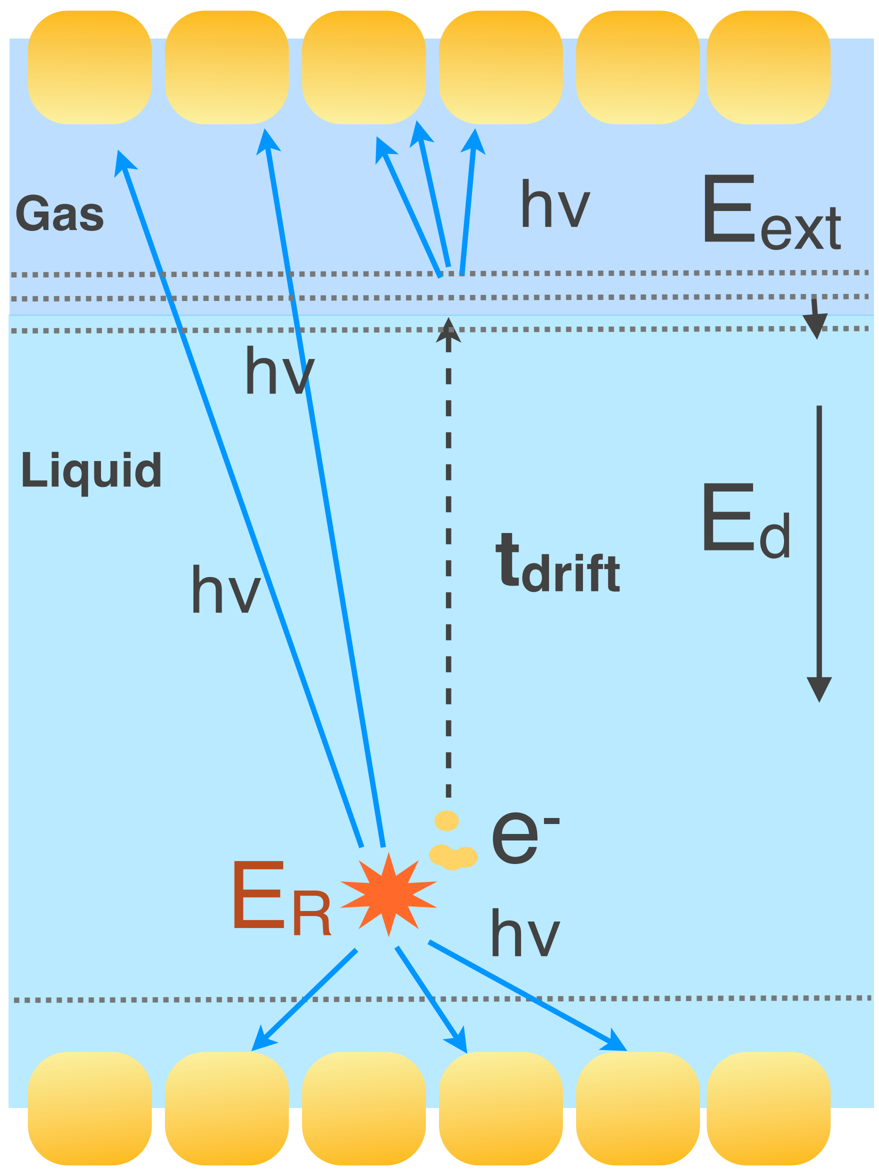
	Scintillation Light	**Intrinsic Backgrounds**
Ne (A=20) \$60/kg 100% even-even nucleus	**85 nm** requires wavelength shifter	Low BP (20 K), all impurities frozen out No radioactive isotopes
Ar (A=40) \$2/kg 100% even-even nucleus	**128 nm** requires wavelength shifter	Natural Ar contains ^{39}Ar at 1Bq/kg, corresp. to ~150 ev/kg/day/keV at low energies
Xe (A=131) \$800/kg 50% odd nuclei (^{129}Xe, ^{131}Xe)	**175 nm** UV quartz PMT window	No long lived isotopes ^{85}Kr can be removed by active charcoal filter or distillation

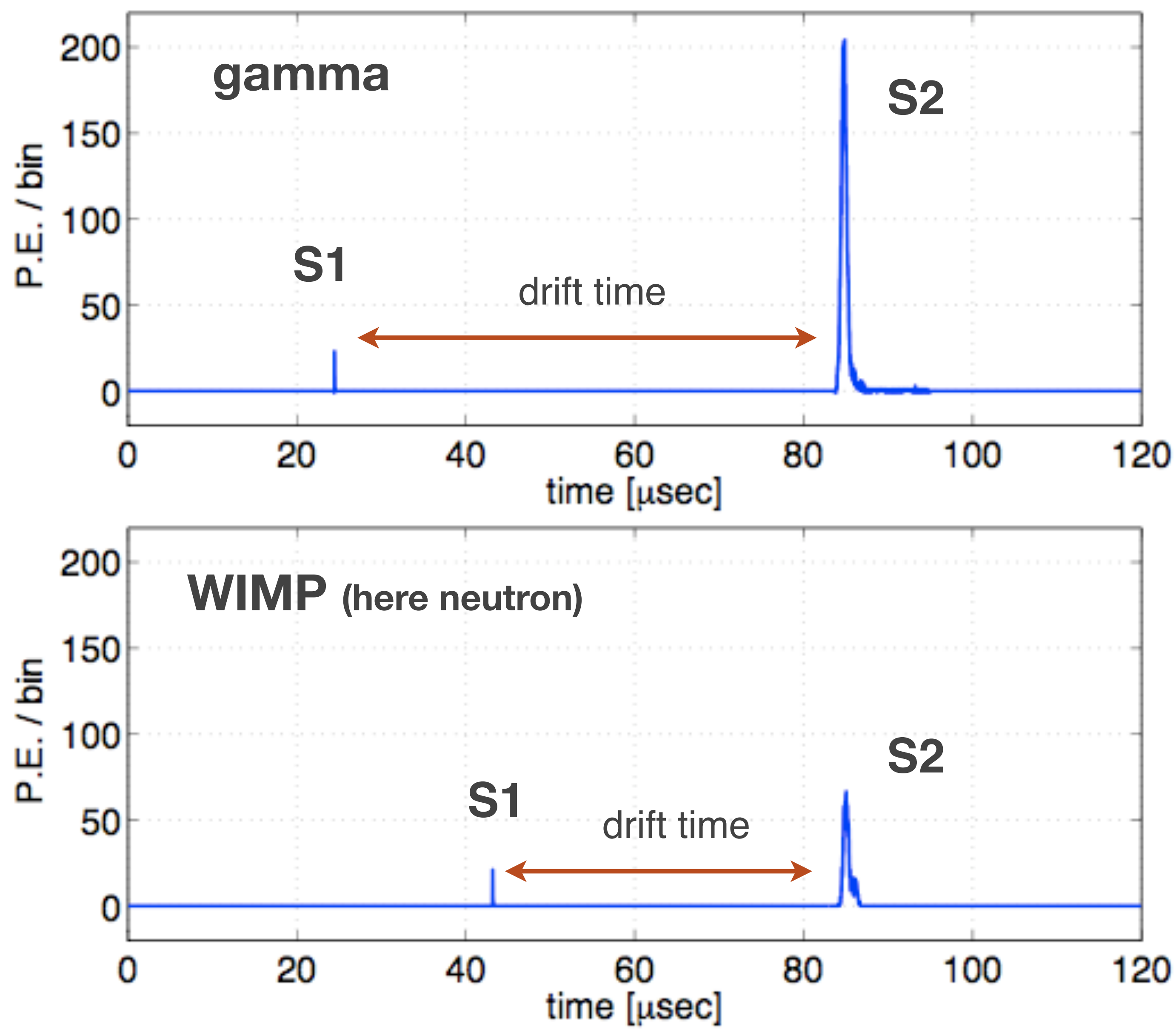




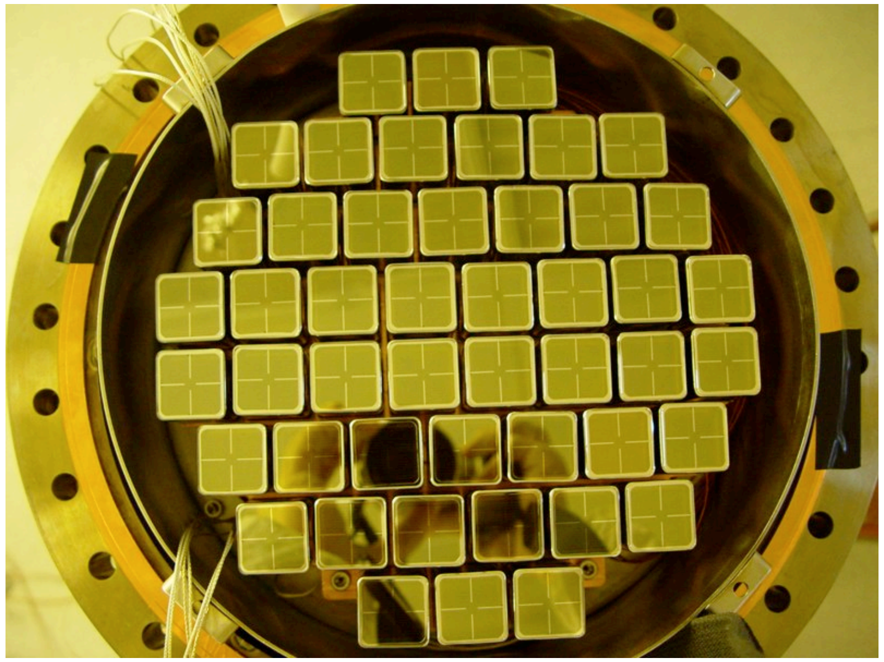
The Double-Phase Detector Concept

- **Prompt (S1) light signal** after interaction in active volume; charge is drifted, extracted into the gas phase and detected either **directly with LEMs**, or as **proportional light (S2)**
- **Challenge:** ultra-pure liquid + high drift field; efficient extraction + detection of e⁻





The XENON10 Experiment at LNGS

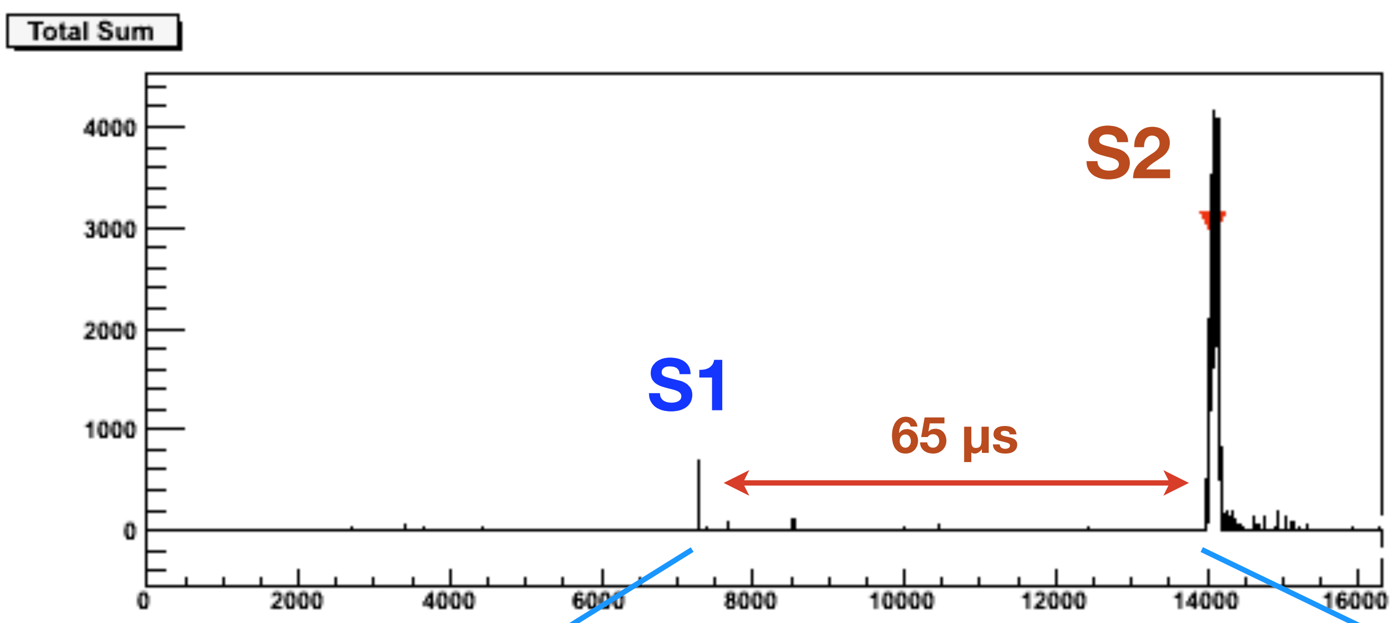


- **Operated at LNGS in 2006-2007**
- **22 kg of liquid xenon**
  - ➡ 15 kg active volume
  - ➡ 20 cm diameter, 15 cm drift
- **Hamamatsu R8520 1"× 3.5 cm PMTs**
  - ➡ bialkali-photocathode Rb-Cs-Sb, Quartz window; ok at -100ºC and 5 bar, QE > 20% @ 178 nm
- **48 PMTs top, 41 PMTs bottom array**
  - ➡ x-y position from PMT hit pattern; $\sigma_{x\text{-}y} \approx$ 1 mm
  - ➡ z-position from Δt_{drift} ($v_{d,e-} \approx$ 2mm/µs), $\sigma_Z \approx$0.3 mm
- **Cooling: Pulse Tube Refrigerator (PTR),**

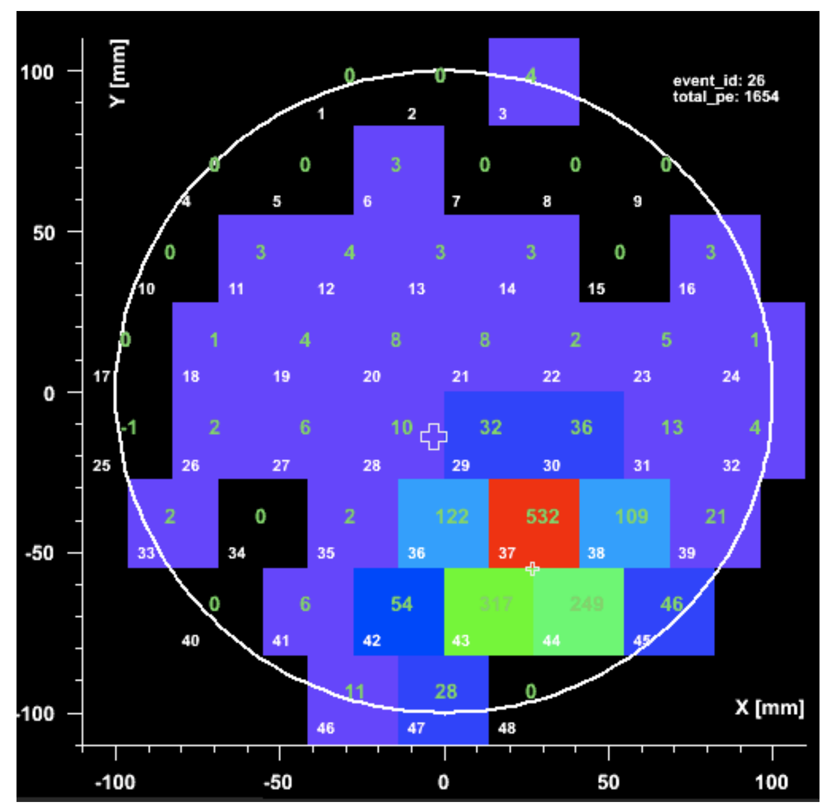
  90W, coupled via cold finger (LN_2 for emergency)
  - ➡ LXe maintained at T = 180 K and P=2.2 atm
- **12 kV cathode:** E_d=0.73 kV/cm (drift), E_{gas}=9kV/cm (S2)

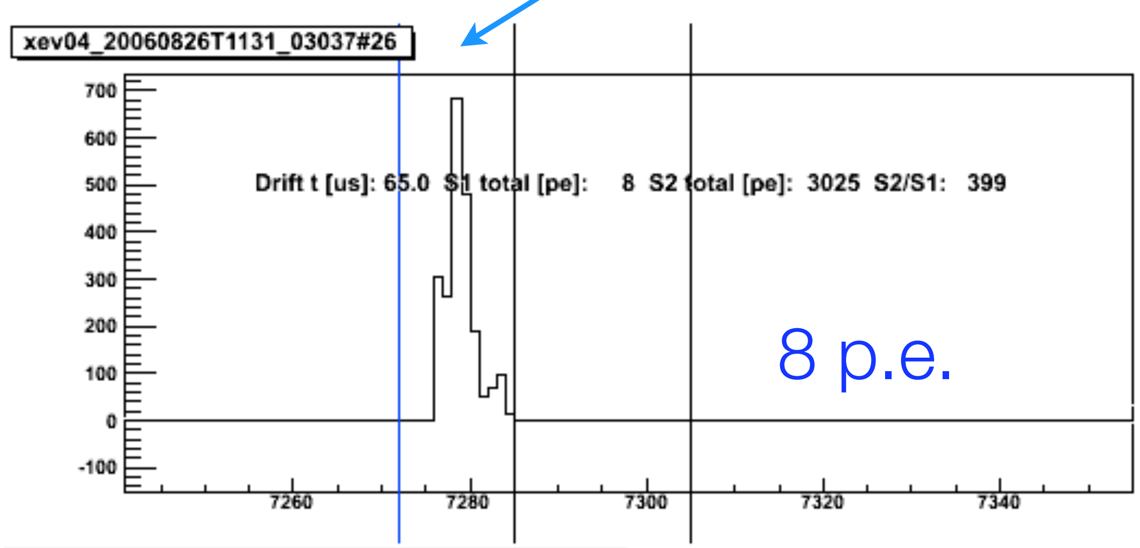
XENON10 Low-Energy Event

- 4 keV_{ee} event; **S1: 8 p.e => 2 p.e./keV**

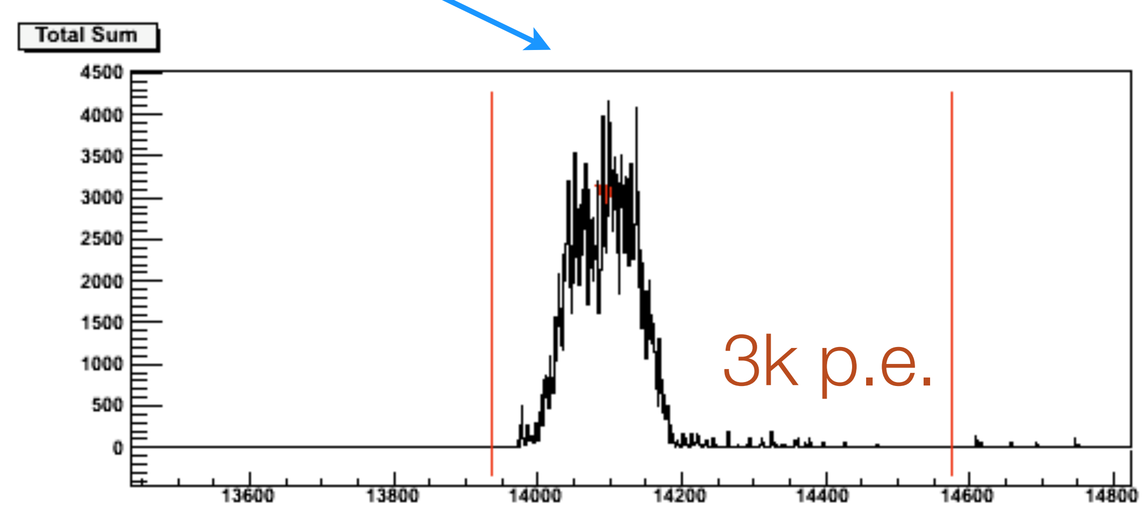


Hit pattern of top PMTs





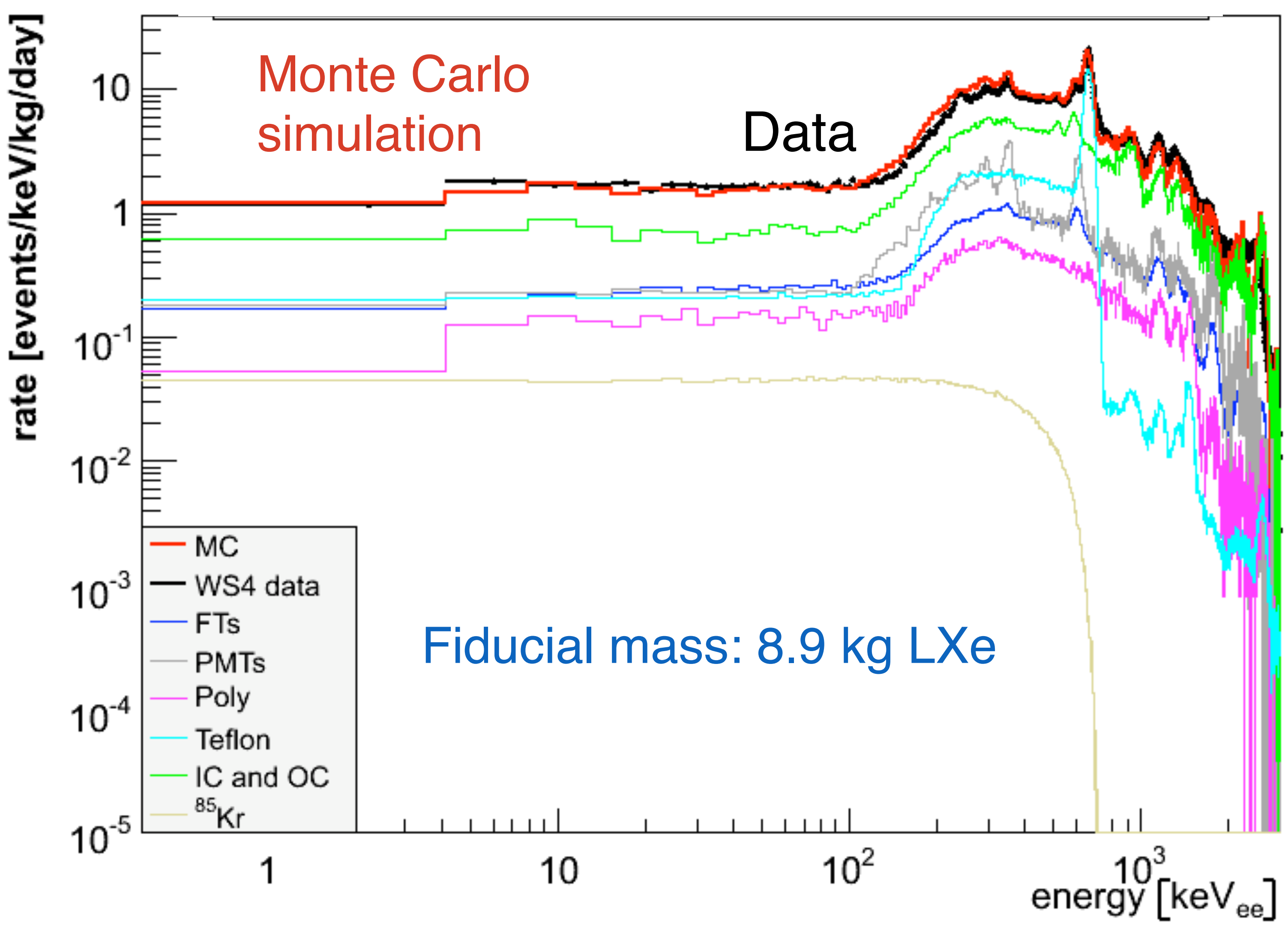
S1

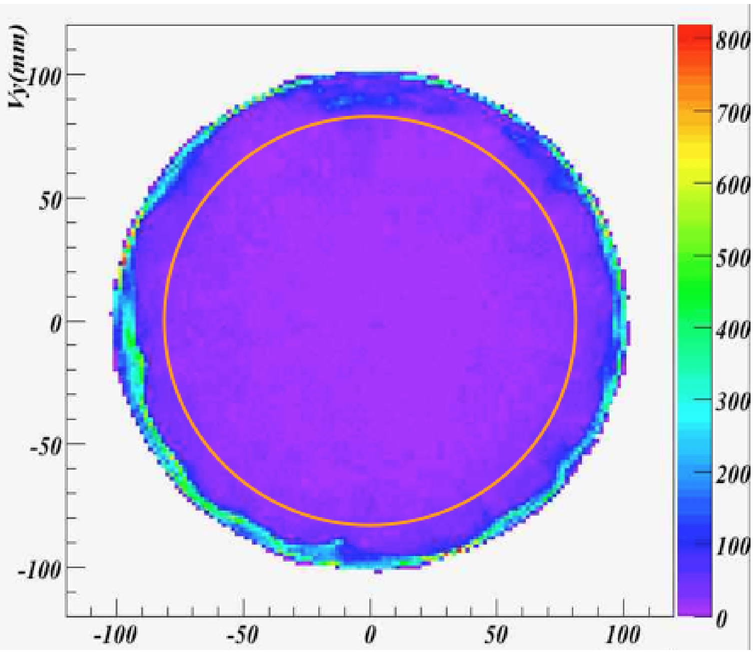


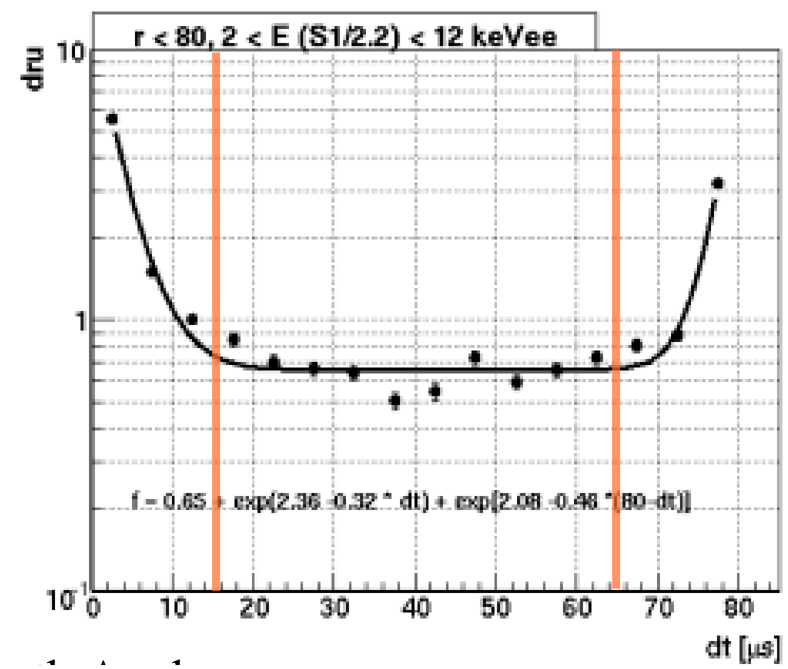
S2

XENON10 Backgrounds

- Dominated by contribution from detector materials:
  - ➡ steel (~ 180 kg, ^{60}Co), PMTs (89 R8520, U/Th/K/Co) and ceramic HV feed-throughs (U/Th/K)

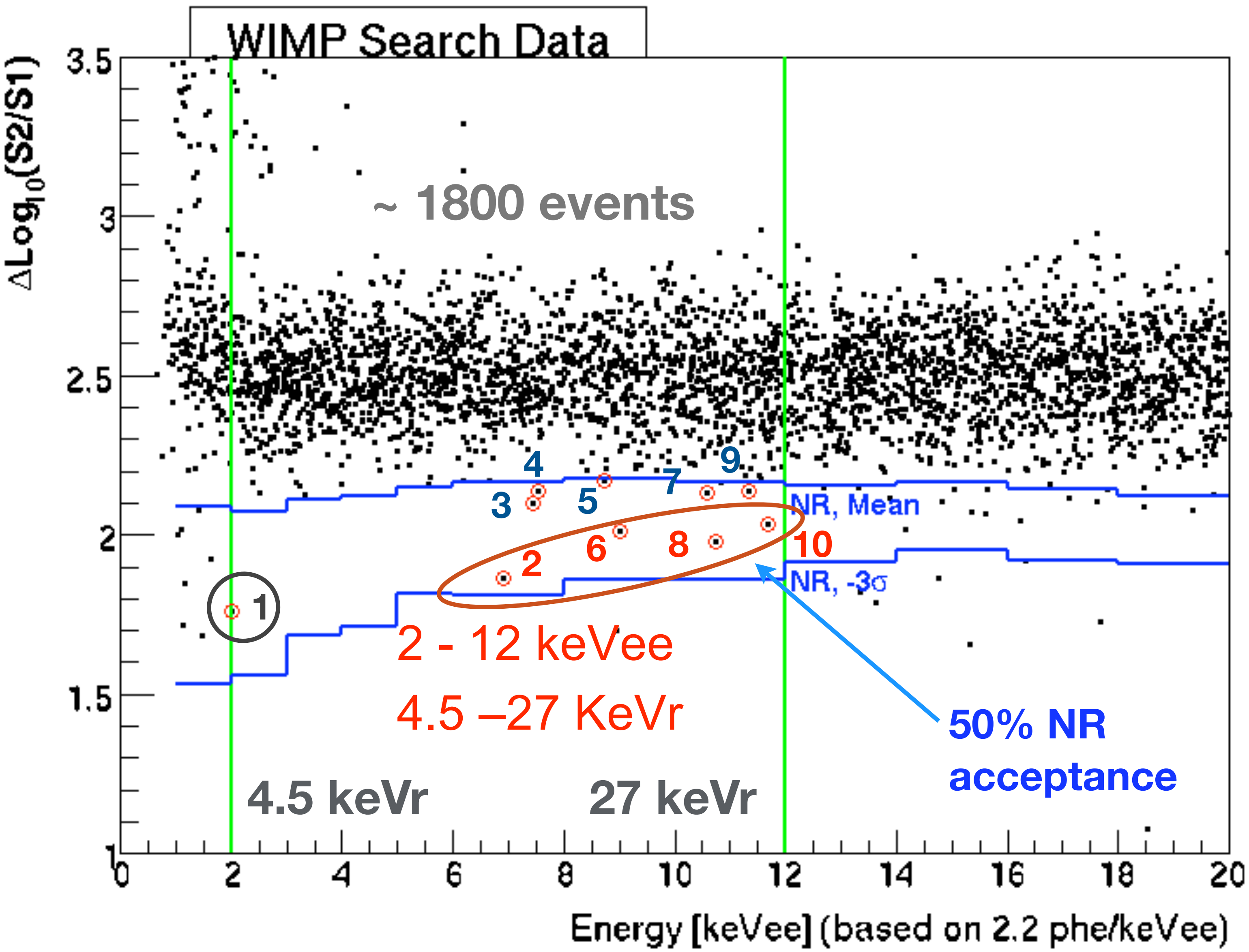






XENON10 WIMP Search Data

- WIMP search run Aug. 24. 2006 - Feb. 14, 2007: ~ **60 (blind) live days**
- **136 kg-days exposure** = 58.6 live days × 5.4 kg × 0.86 (ε) × 0.50 (50% NR acceptance)



WIMP 'Box' defined at

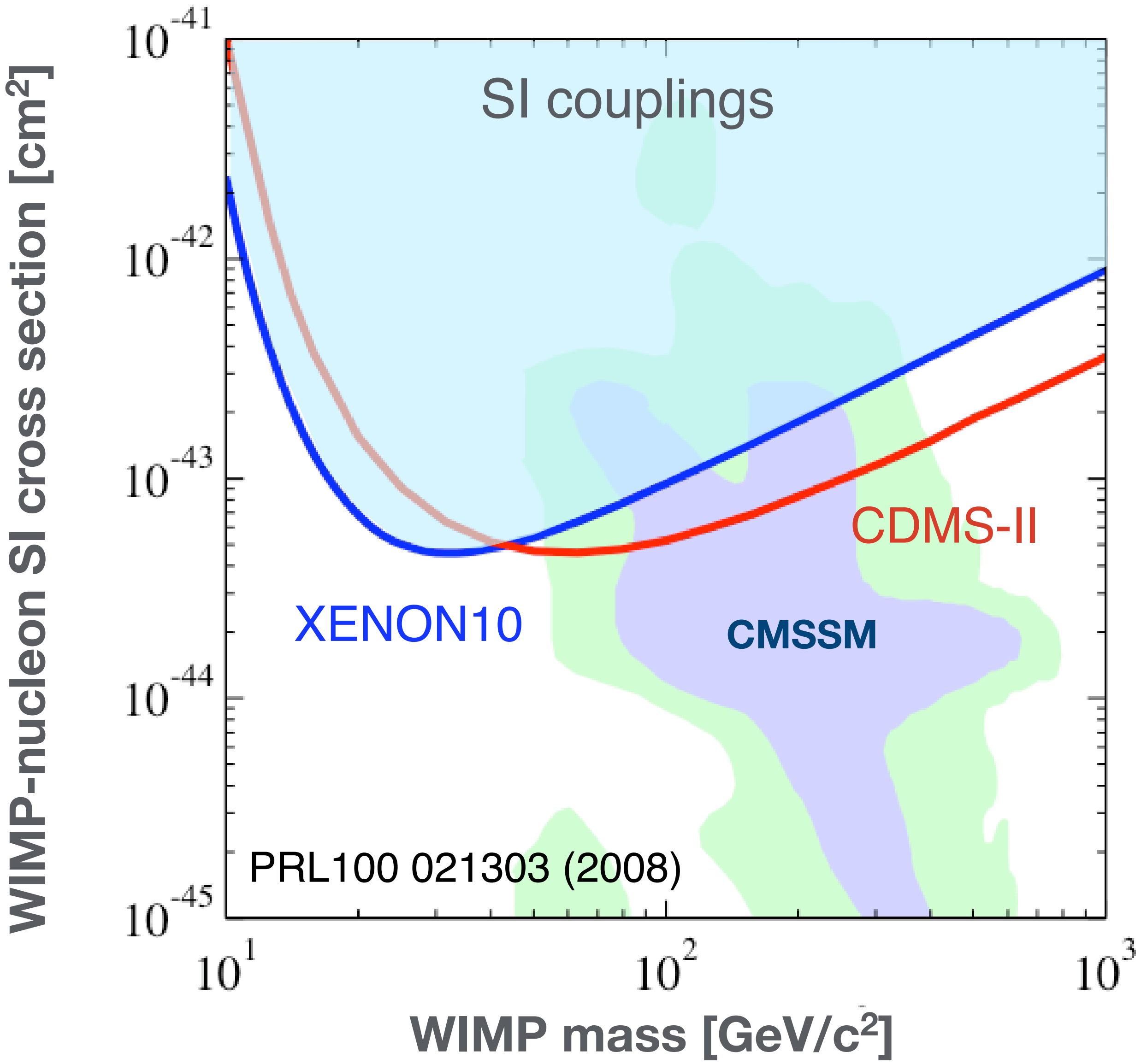
50% acceptance of NRs (blue lines): [Mean,-3σ]

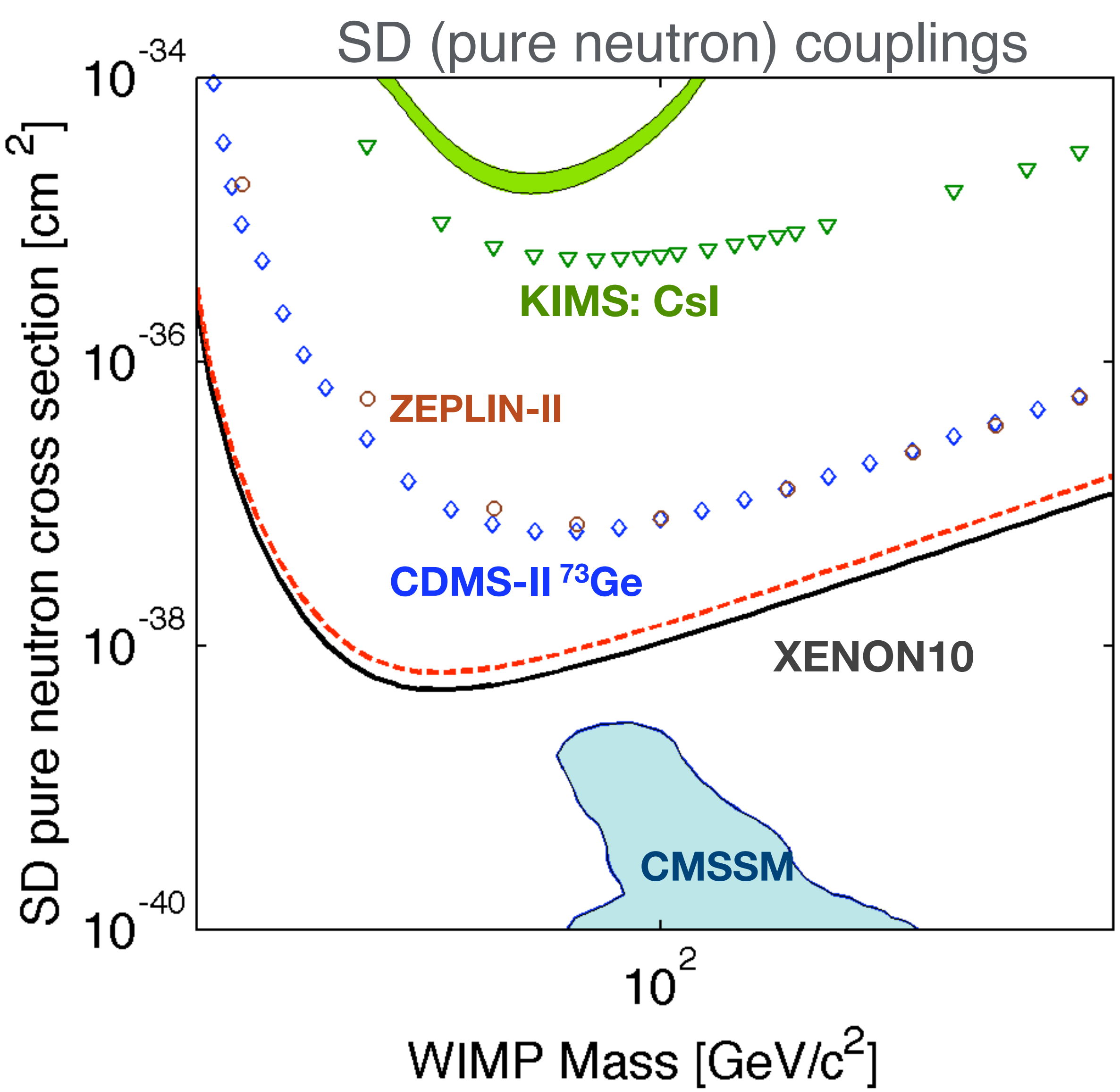
10 events in 'box' after all cuts
7.0 ($^{+1.4}_{-1.0}$) statistical leakage expected from the gamma (ER) band

NR energy scale based on constant 19% QF

XENON10 WIMP Search Results for SI and SD Interactions

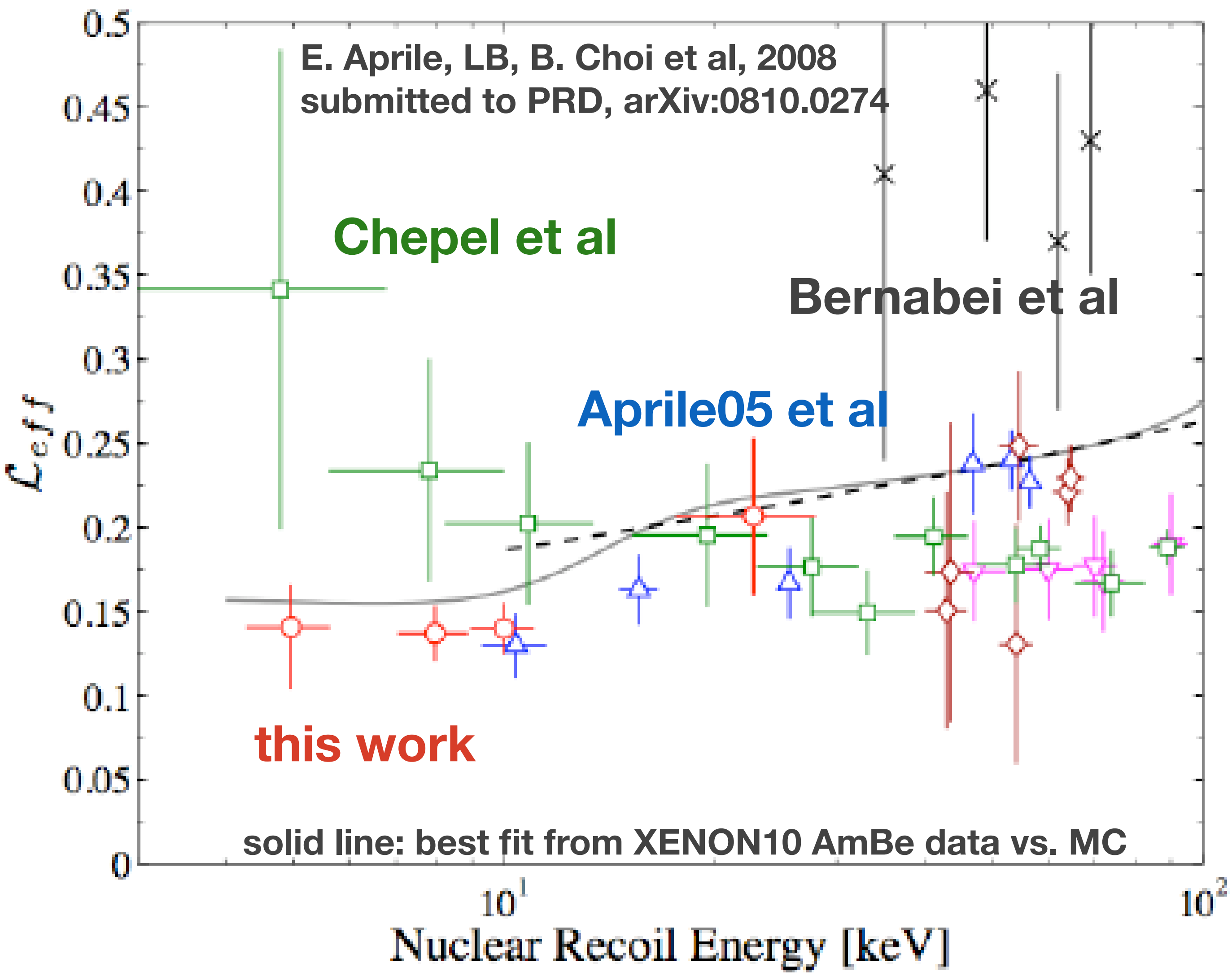
- To set limits: all 10 events considered, thus no background subtraction performed
  ➡ probed the elastic, SI WIMP-nucleon σ down to **≈ 4 × 10^{-44} cm^2** (at M_{WIMP} = 30 GeV)
- natural Xe: ^{129}Xe, 26.4 %, spin 1/2, ^{131}Xe, 21.2%, spin 3/2
- use shell-model calculations by Ressel and Dean [PRC 56, 1997] for <S_n>, <S_p>

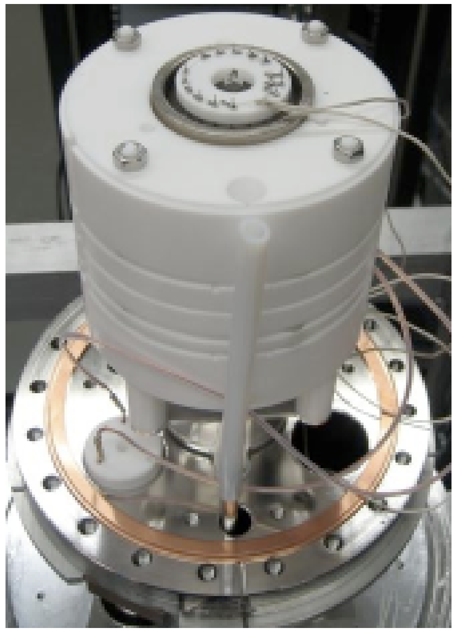


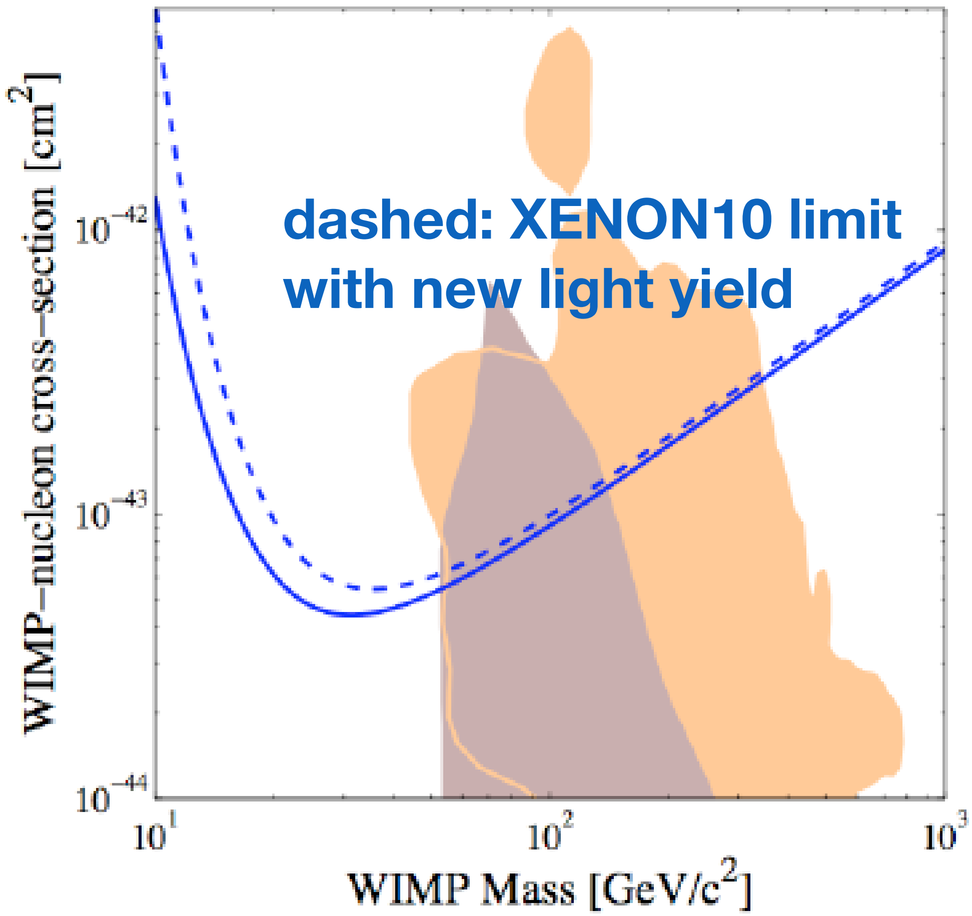


New measurements of the Light Yield in LXe

- Columbia + Zurich: at RaRAF (Nevis Labs), 1 MeV n-beam
- Detector: XeCube, 6 R8520 PMTs, 2.5 cm³ LXe, zero field
- New experiment for charge/light yield under preparation at UZH (using D-D neutron generator)

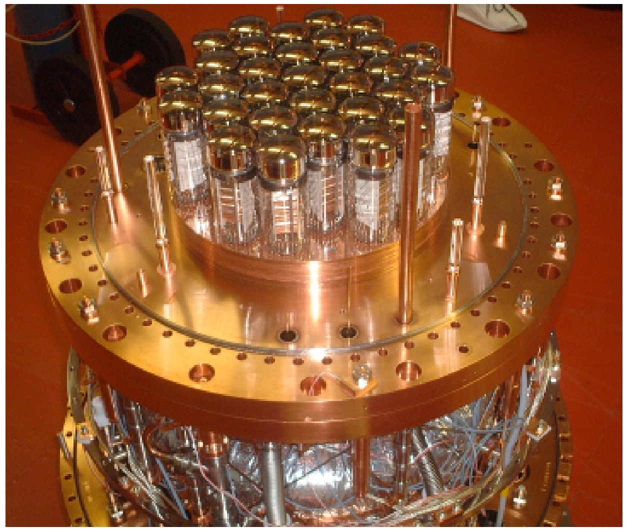


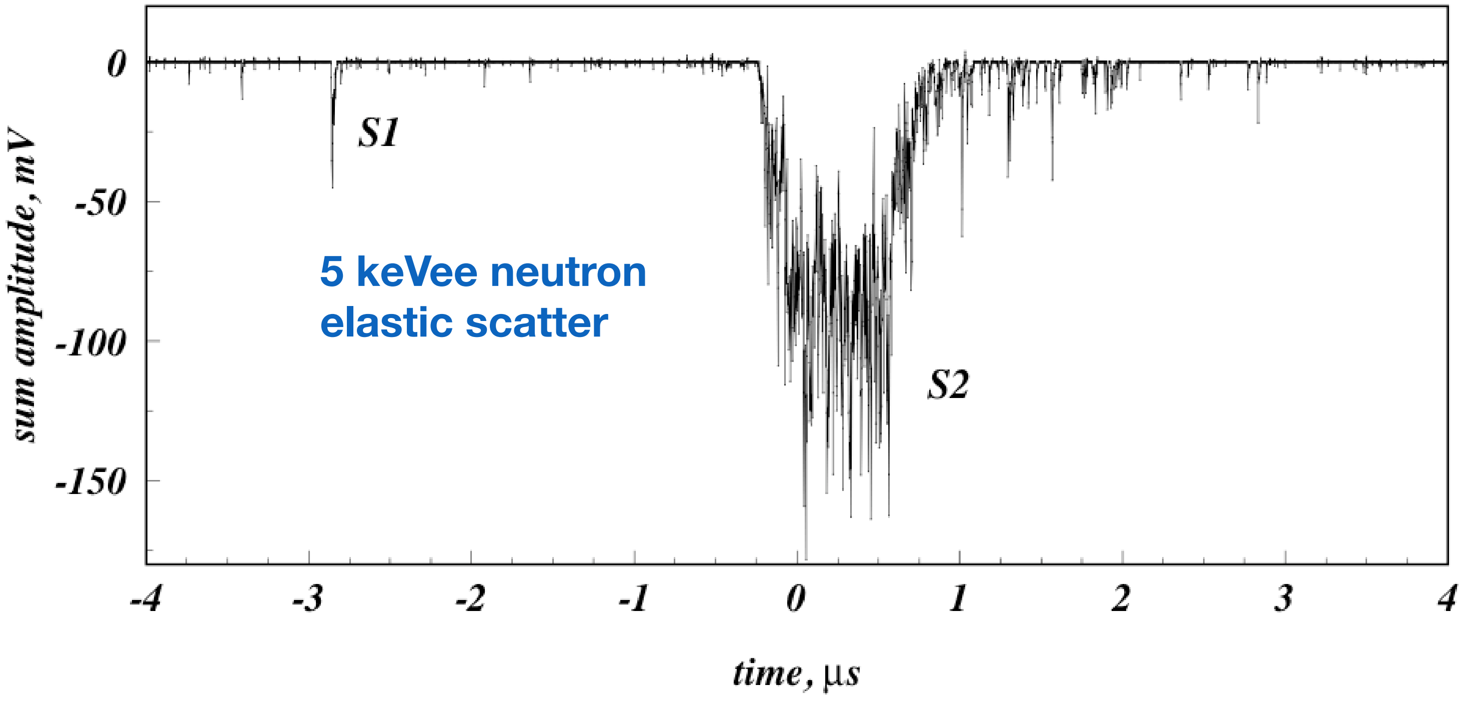


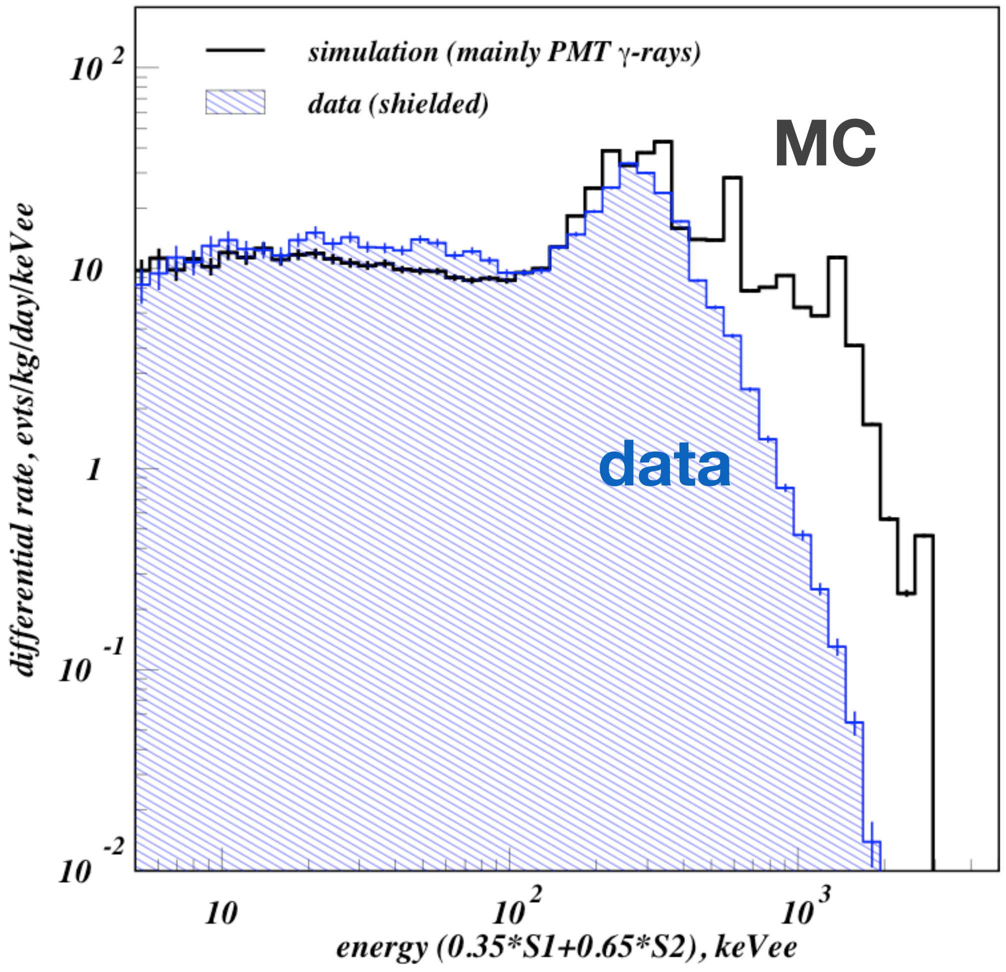


The ZEPLIN-III Experiment at the Boulby Mine

- Two-phase xenon TPC: 12 kg of LXe in active volume
- 31 x 2” PMTs detect both primary and proportional light signal
- field: 3.9 kV/cm in liquid, 7.8 kV/cm in gas
- backgrounds (about 10x higher than in XENON10):
  - ➡ dominated by radioactivity of PMTs



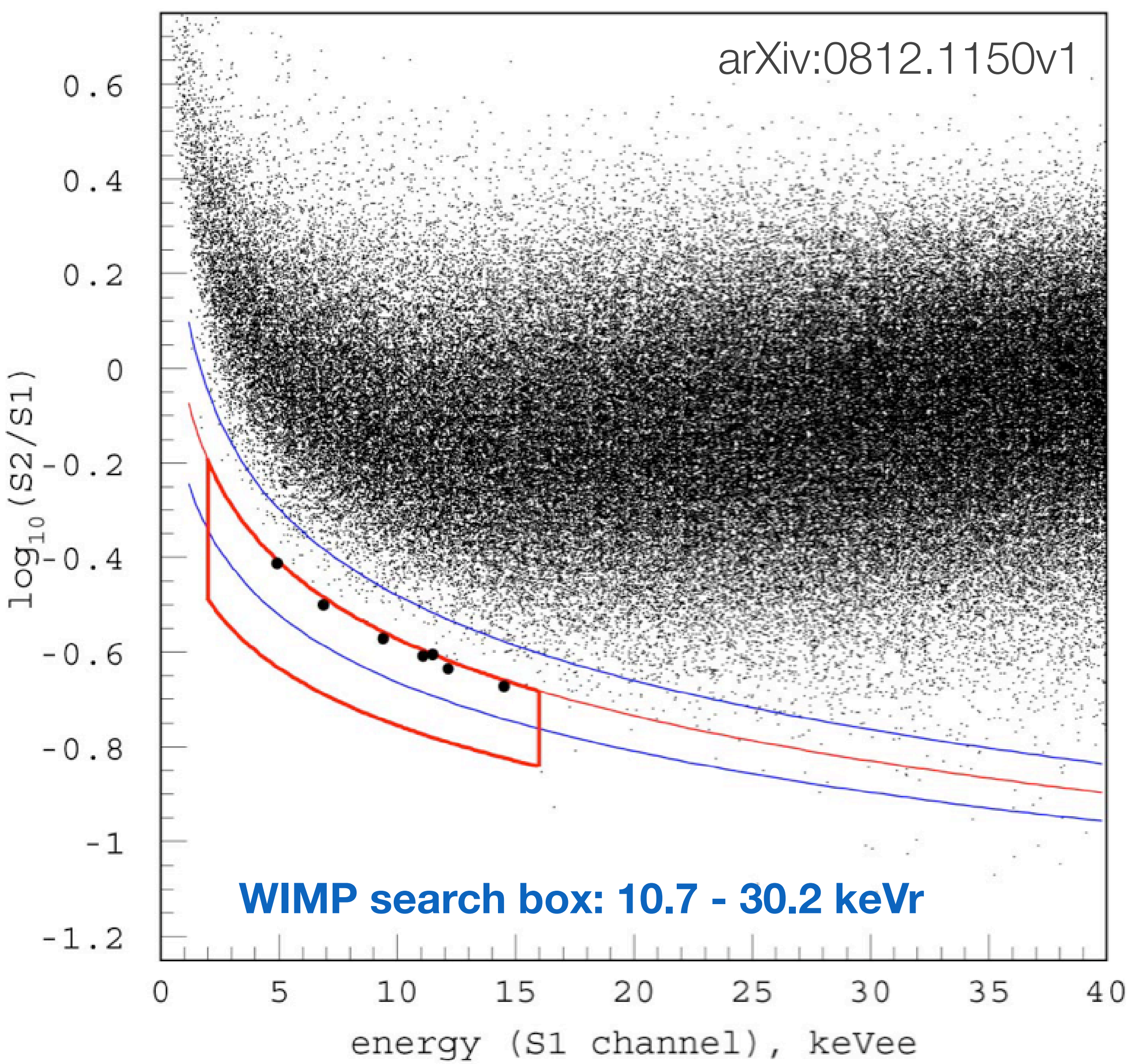


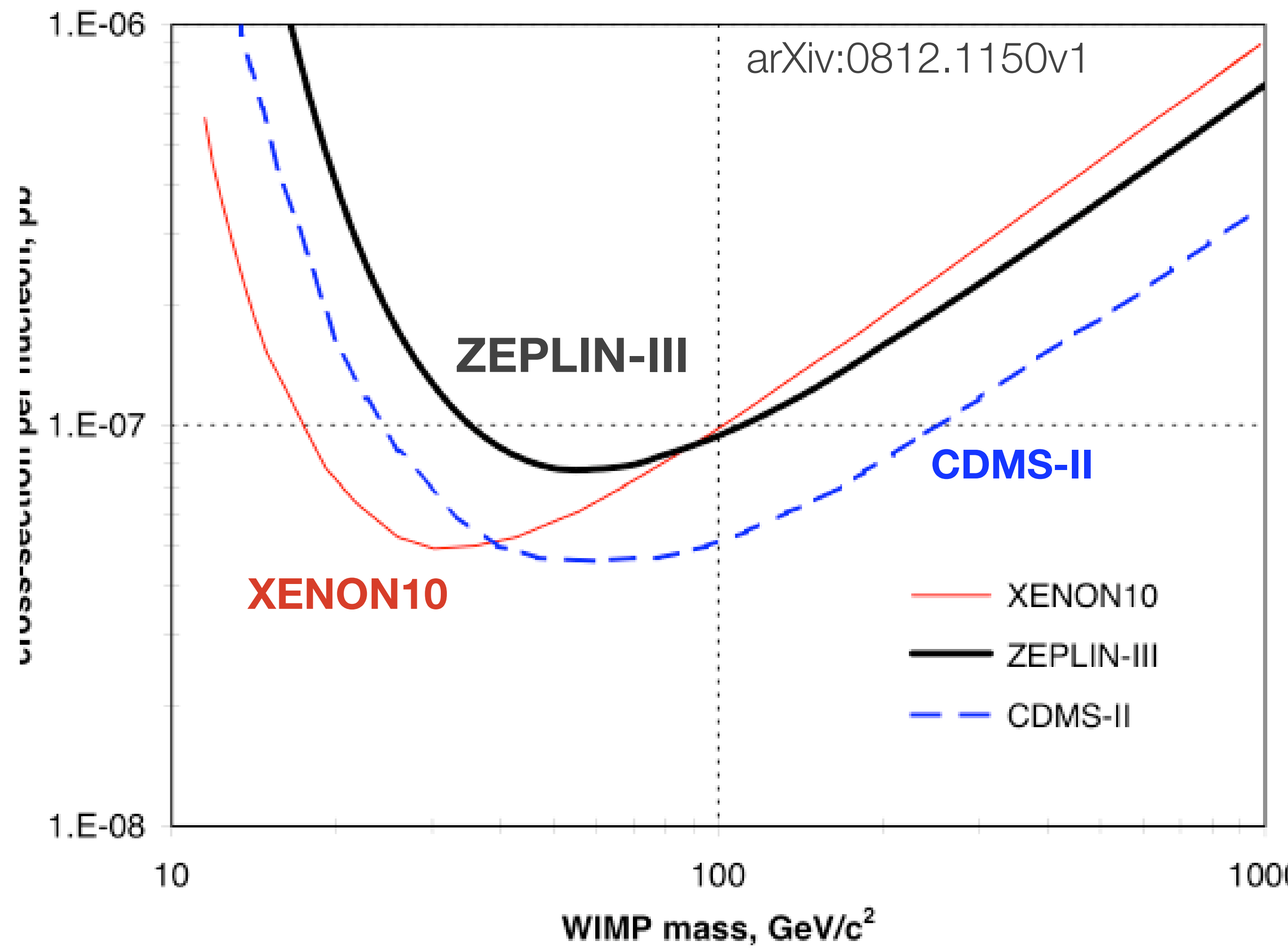


- new run, with low-BG PMTs is planned

ZEPLIN-III WIMP Search Data and Results

- **WIMP search data: 127 kg days (after cuts) in 6.7 kg fiducial**
- 7 events observed in the 'WIMP box', 11.6 ± 3.0 events expected (from non-blind WS data)
- Consistent with zero signal, 90% upper signal limit of 2.9 events

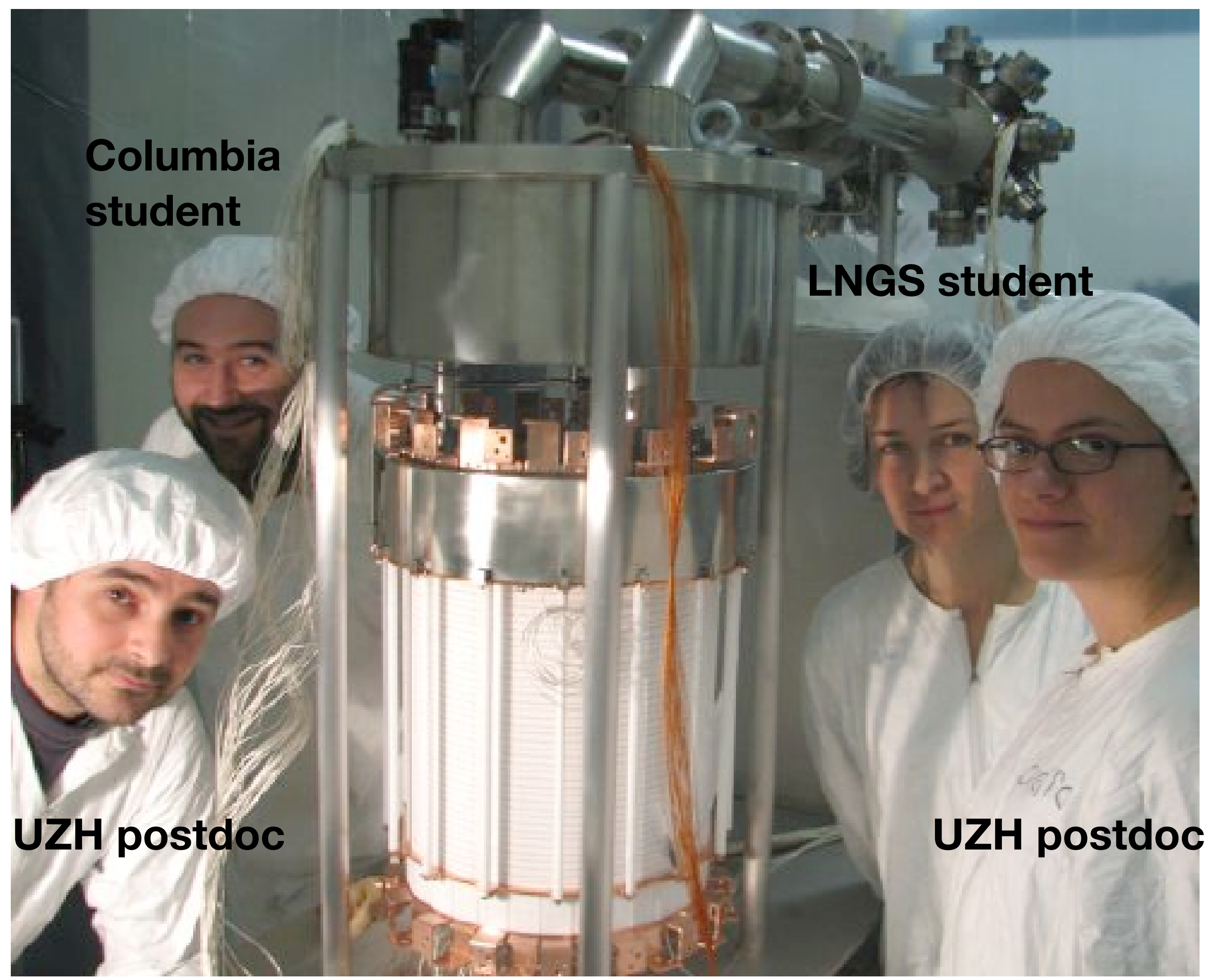




LXe TPCs: near future

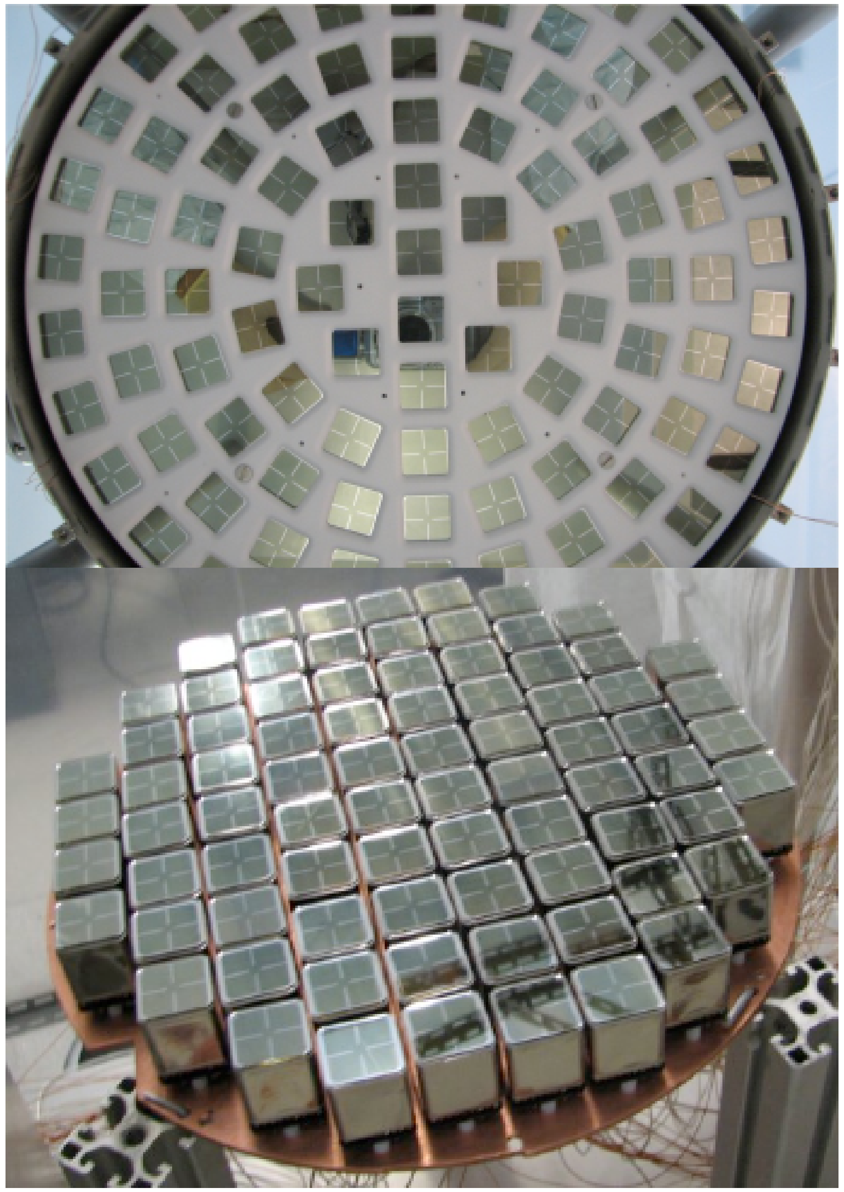
- **XENON100:** under commissioning at LNGS, expected to start WS run in spring 2009
- 170 kg (100 kg in active veto) LXe, viewed by 242 PMTs, 30 cm ∅, 30 cm drift
- **Goal: factor 100 lower background, factor 10 higher mass than XENON10**

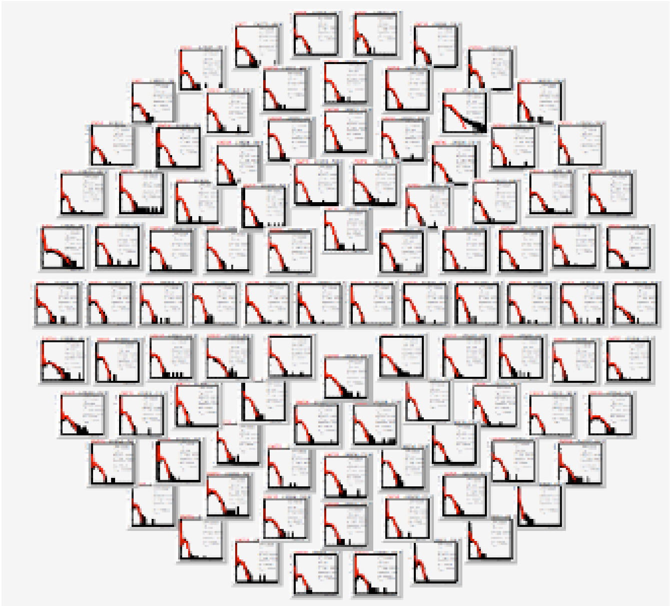

XENON100 in its shield



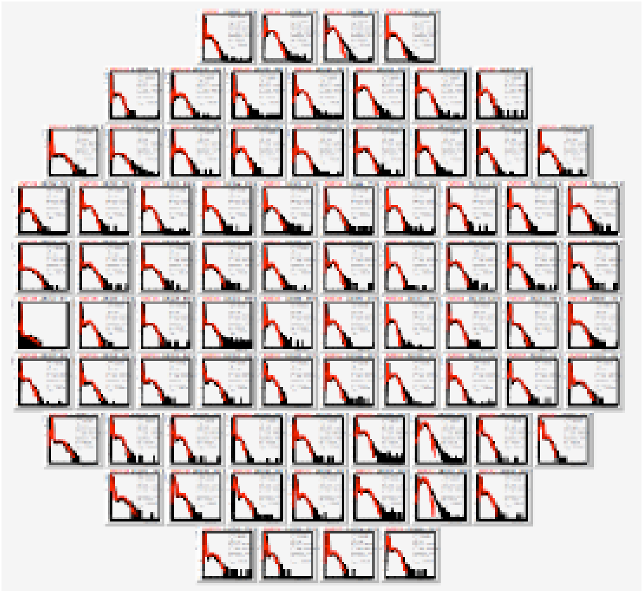
XENON100 Light Detectors

- **242 (Hamamatsu R8520) 1”x1”, low radioactivity PMTs; 80 with high QE of 33%**
  - ➡ 98 top: for good fiducial volume cut efficiency
  - ➡ 80 bottom: for optimal S1 collection efficiency (thus low threshold); 64 in active LXe shield
- PMT gain calibration with blue LEDs; the SPE response is measured





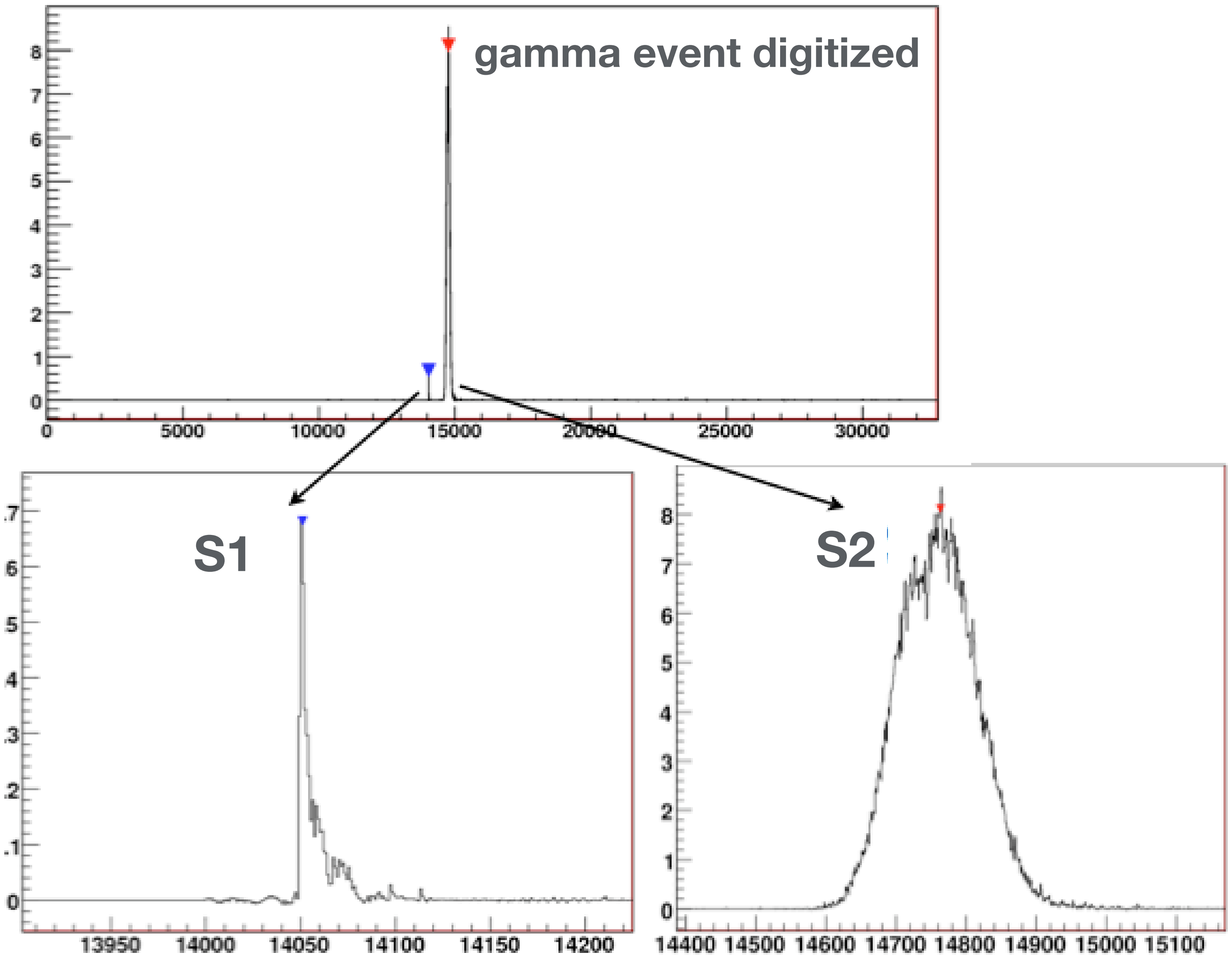
top PMT array
(gain equalized to $2x10^6$)



bottom PMT array
(gain equalized to $2x10^6$)

XENON100 Charge and Light Event

- data taken with ^{137}Cs calibration source; S1, S2: summed waveforms of all inner PMTs

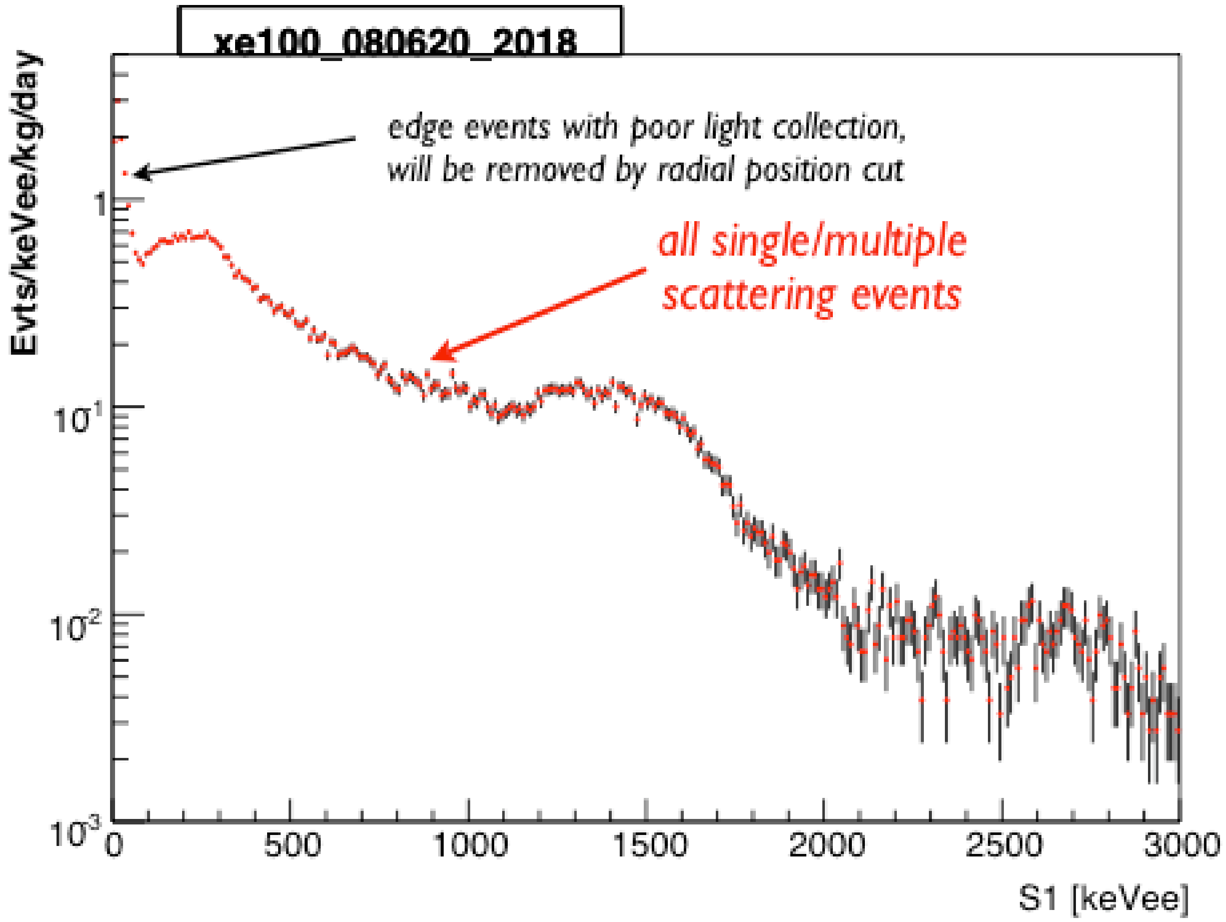


gamma event localized

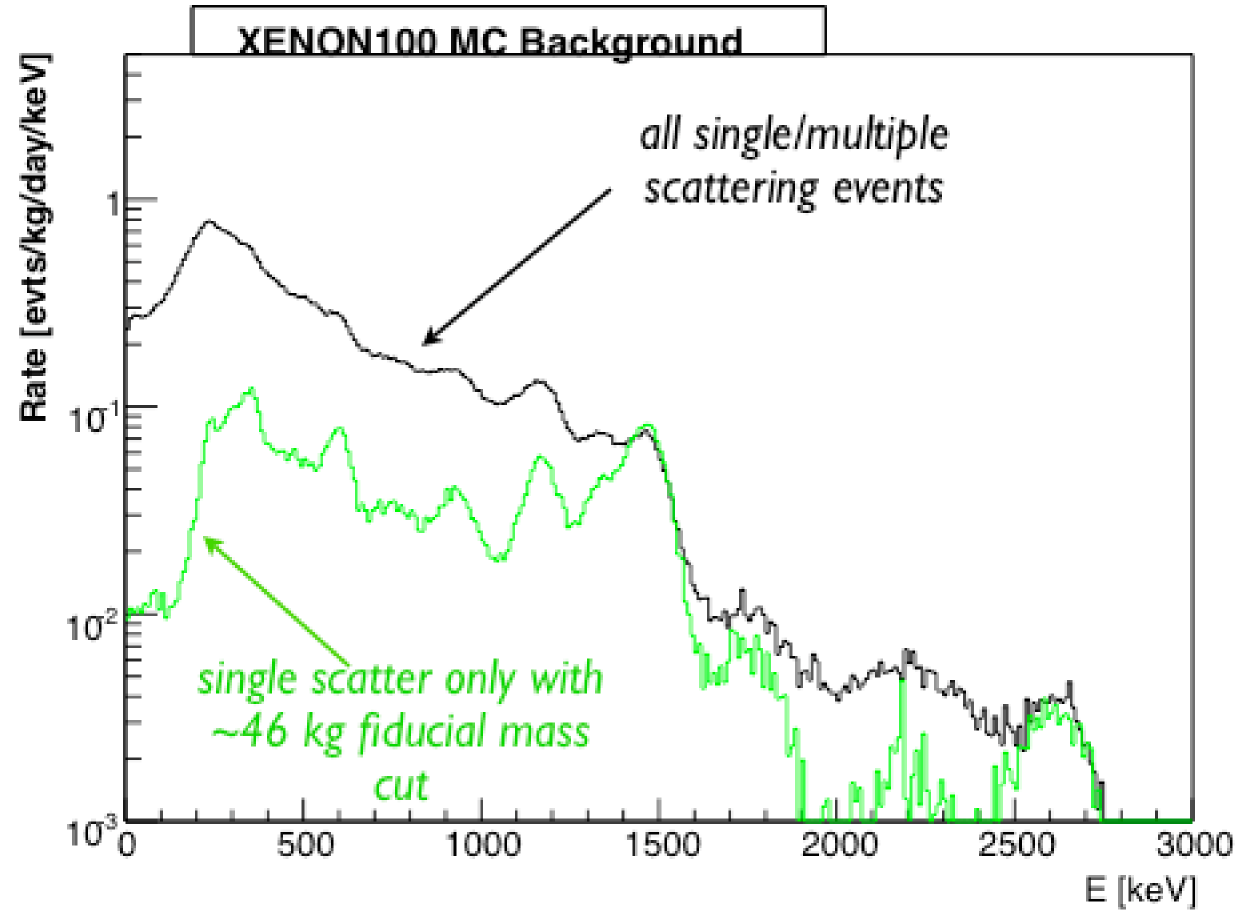
Top PMT array

Preliminary Background from XENON100 Data

data (S1 only)



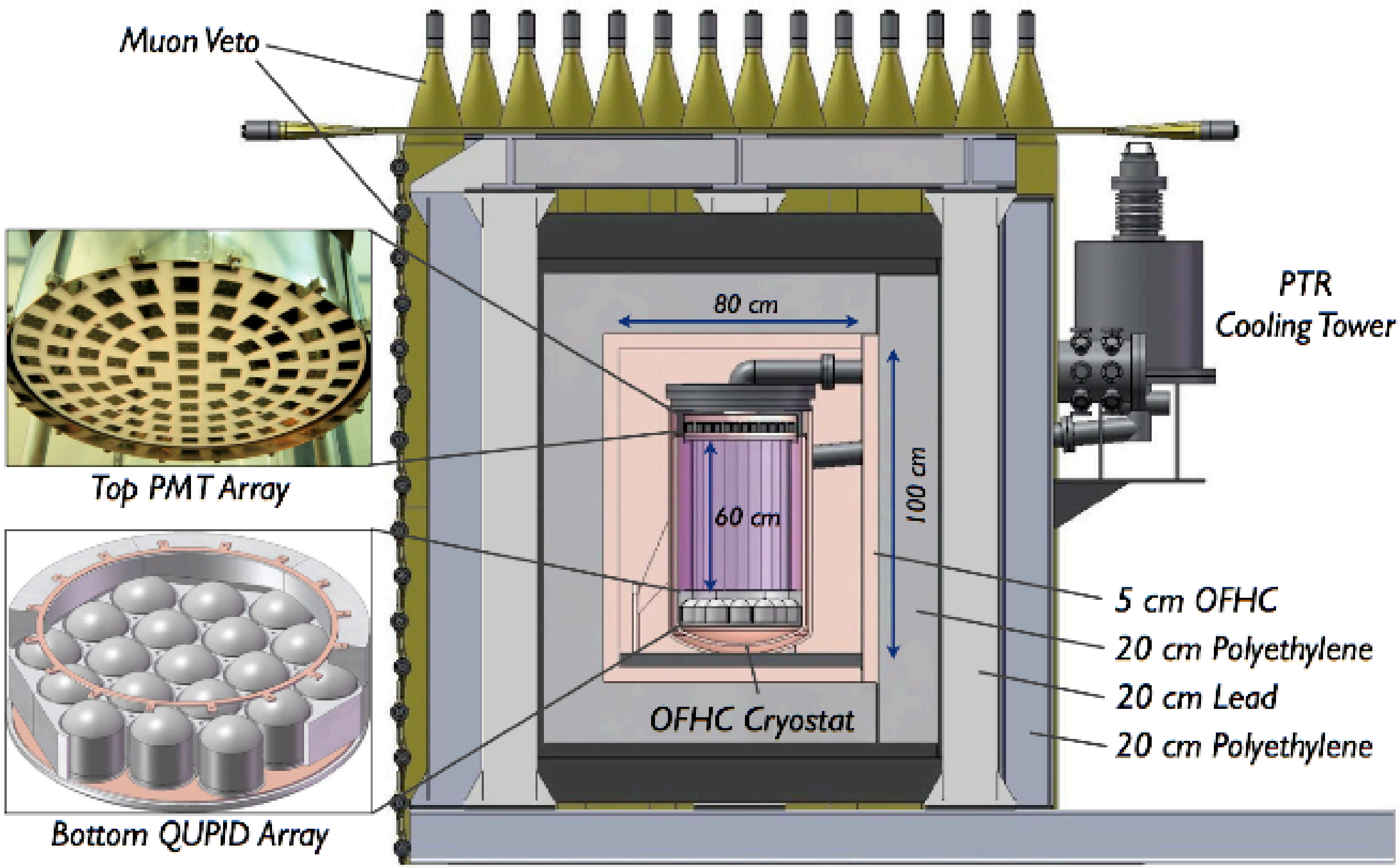
Monte Carlo simulations

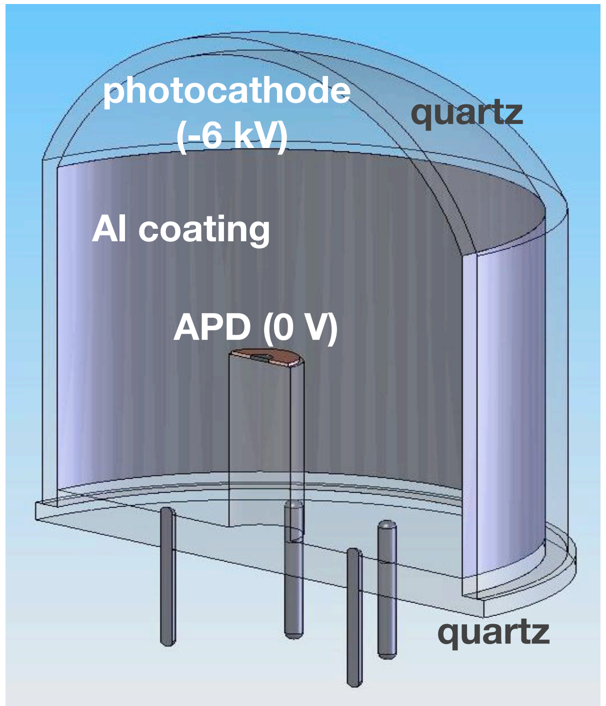


Data and Monte Carlo predictions are in good agreement for overall rate

Next Step: The Xenon100 Upgrade

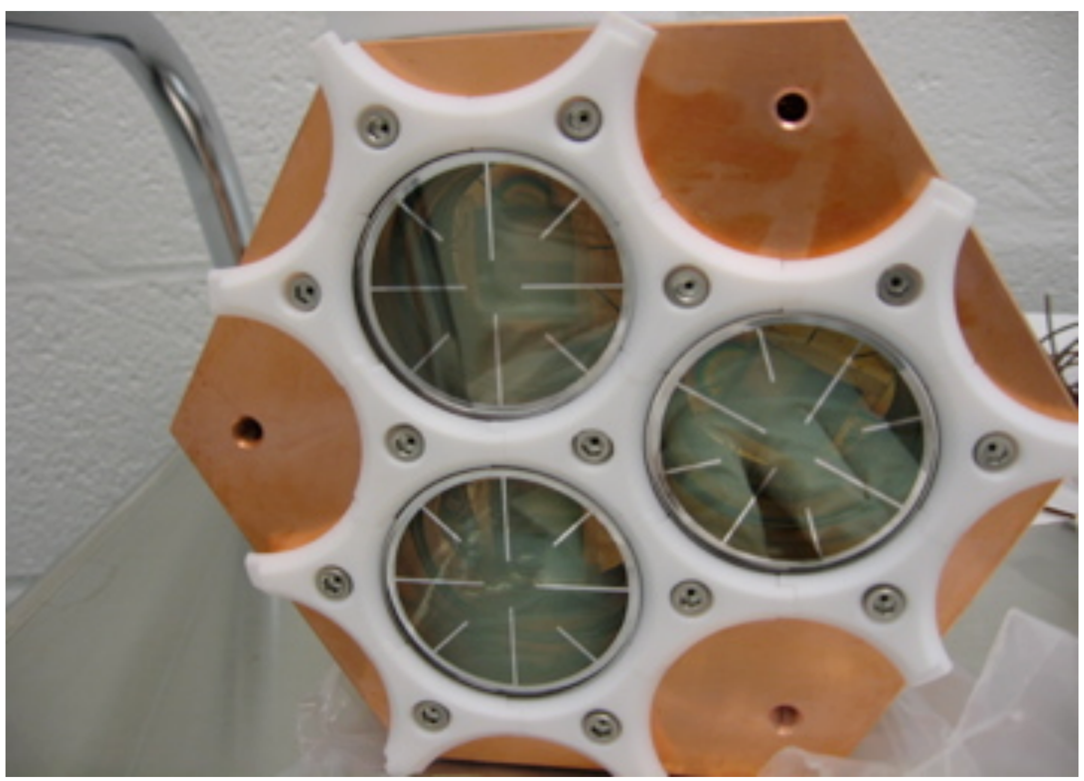
- **100 kg fiducial mass (total of 260 kg LXe), background $5x10^{-4}$ events/(kg day keV)**
- new photon detectors, QUPIDs; ultra-low BG Cu cryostat, new shield, including muon veto
- **construction 2010; WIMP search 2011-2012**





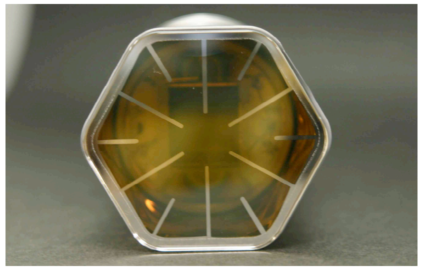
The LUX Experiment

- **300 kg dual phase LXe TPC (100 kg fiducial), with 122 PMTs in large water shield with muon veto**
- 50 kg LXe prototype with 4 R8778 PMTs being assembled and tested at CWRU
- full detector to be installed at Homestake Davis Cavern, 4850 ft in fall 2009 (in 8 m ∅ water tank)
- **WIMP sensitivity goal: 7 × 10^{-10} pb after 10 months**



R. Gaitskell, IDM08, Stockholm

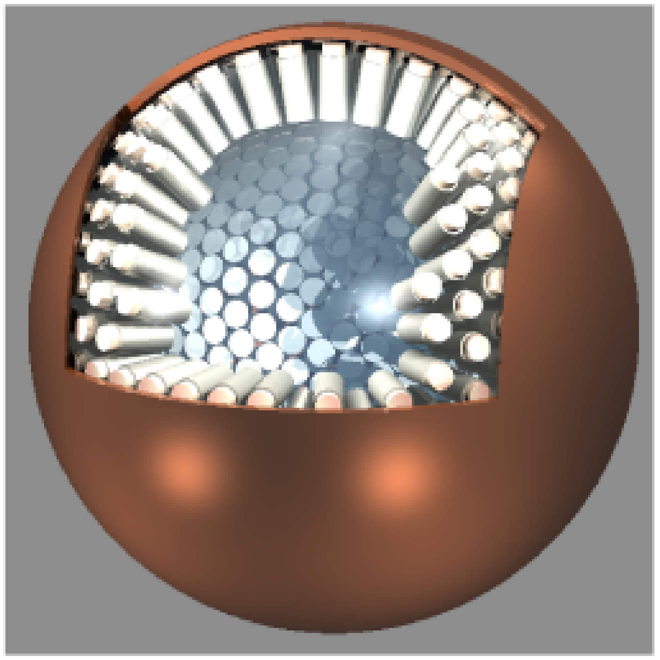
Single-Phase Xenon: XMASS



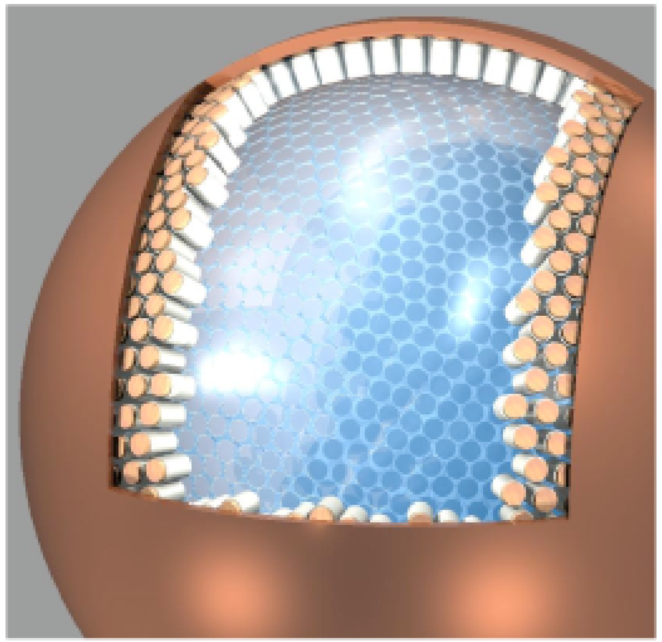
- 100 kg (3 kg fiducial mass) prototype operated (52 2” Hamamatsu R8778 PMTs)
  - the PMT coverage was limited, thus also the position reconstruction of edge events
- **next step:** 850 kg (100 kg fiducial mass) with 642 PMTs (64% photo coverage)
  - basic performance confirmed with prototype
  - vertex reconstruction, self-shielding, BG level are being studied with MCs
- detector is being designed, new hall in Kamioka is ready since February 08

Y. Suzuki, IDM08, Stockholm

100 kg (3 kg fiducial)



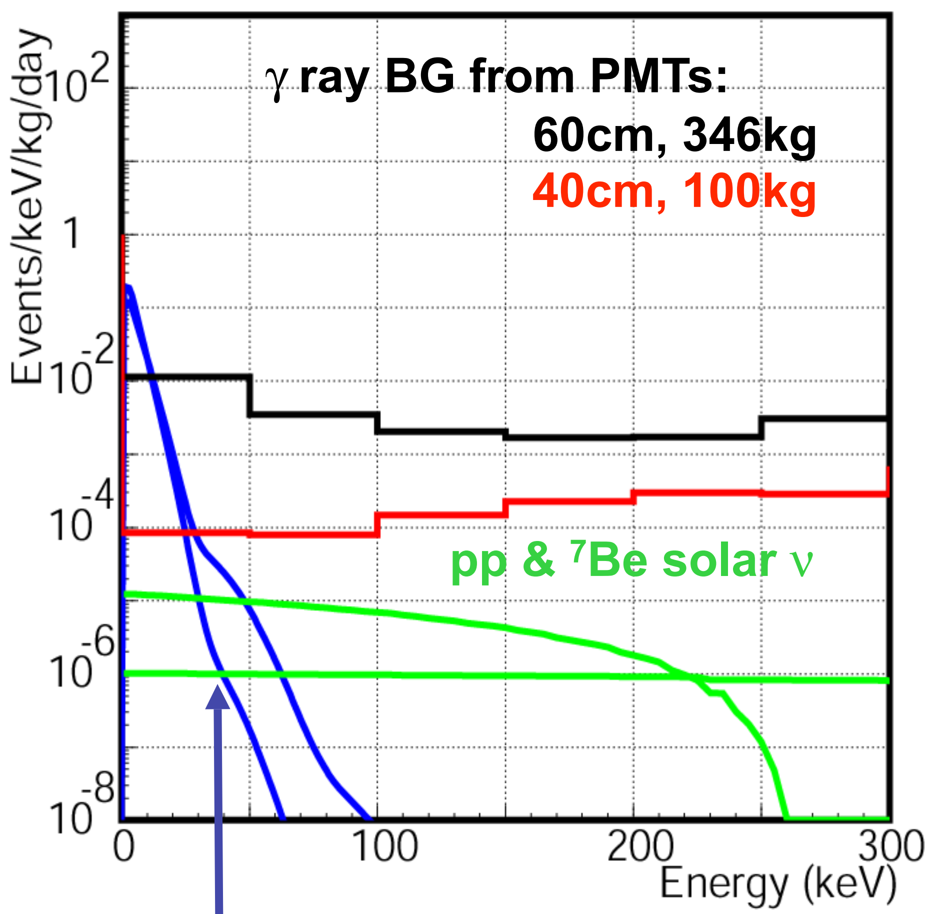
850 kg (100 kg fiducial)



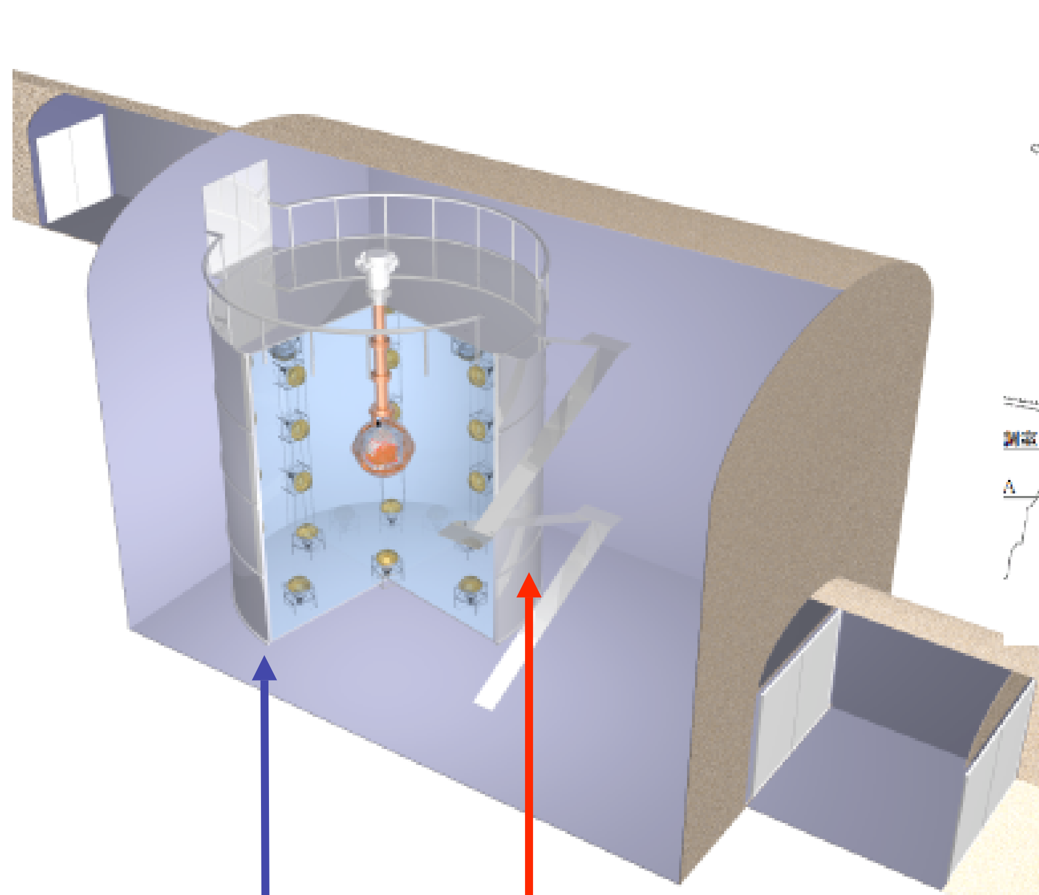
23 t (10 t fiducial)

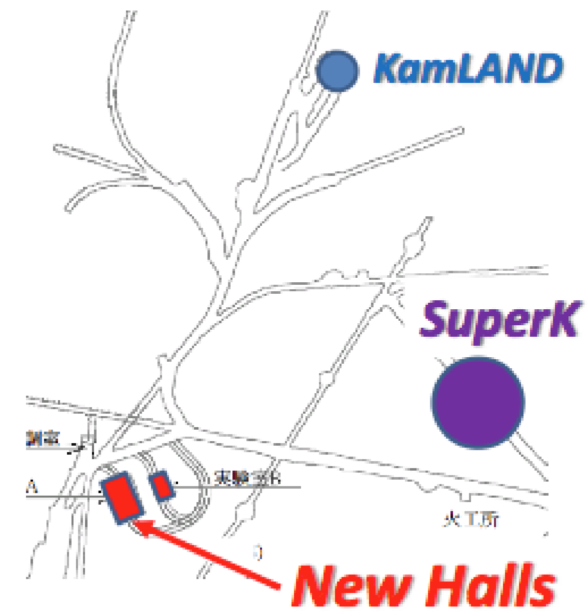
Single-Phase Xenon: XMASS

- Active and passive water shield in new experimental hall at KAMIOKA - almost ready
- Construction of 10 m x 10 m water tank by February 2009; BG aim: 10^{-4} dru
- Expected WIMP sensitivity: 1×10^{-45} cm^2 for 0.5 ton × year exposure (100 GeV WIMP)



Expected dark matter signal
(assuming 10^{-42} cm^2, Q.F.=0.2, $M\chi$=50,100GeV)





~10m diameter, ~10m high pure water tank.

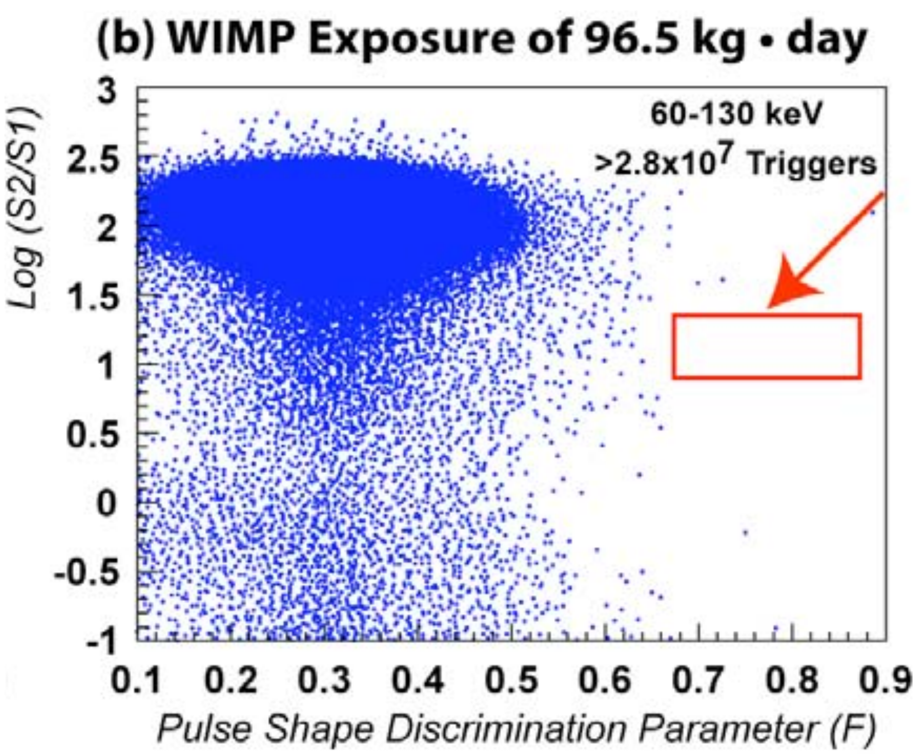
20-inch PMTs for veto counter.

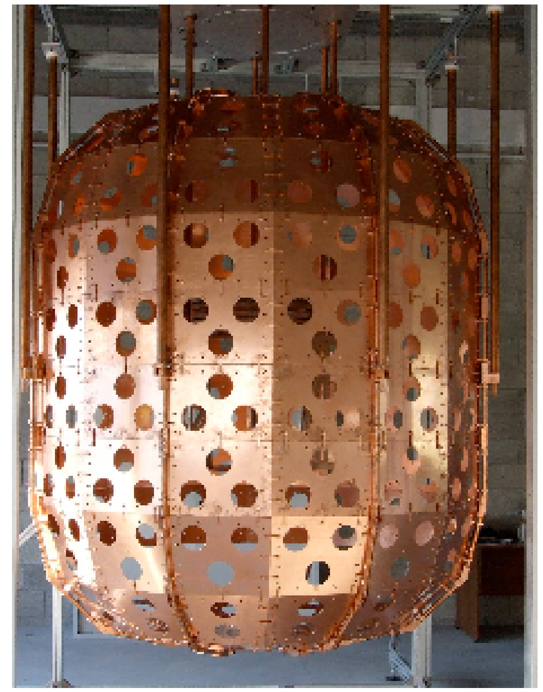
Y. Suzuki, IDM08, Stockholm

Two-phase Argon Detectors

WARP at LNGS

3.2 kg LAr operated at LNGS; results from zero events > 55 keVr

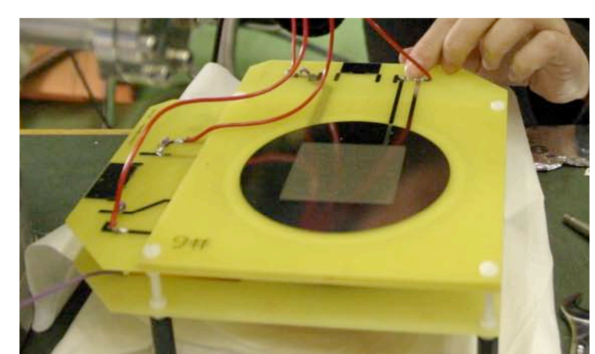




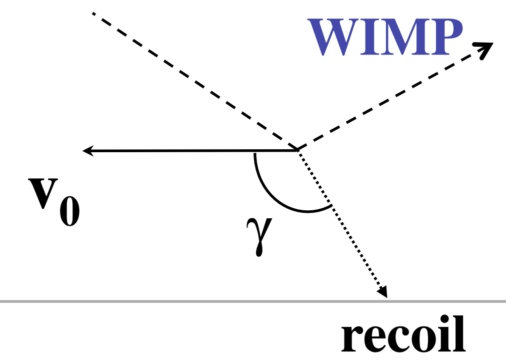
140 kg LAr, 41 3'' PMTs under construction
active LAr shield: ~ 8t, viewed by 300 PMTs

ArDM at CERN

1 t LAr prototype under construction
direct electron readout via LEMs (thick macroscopic GEM)
S1 with 14 x 8'' PMTs



Directional Detectors: gas TPCs

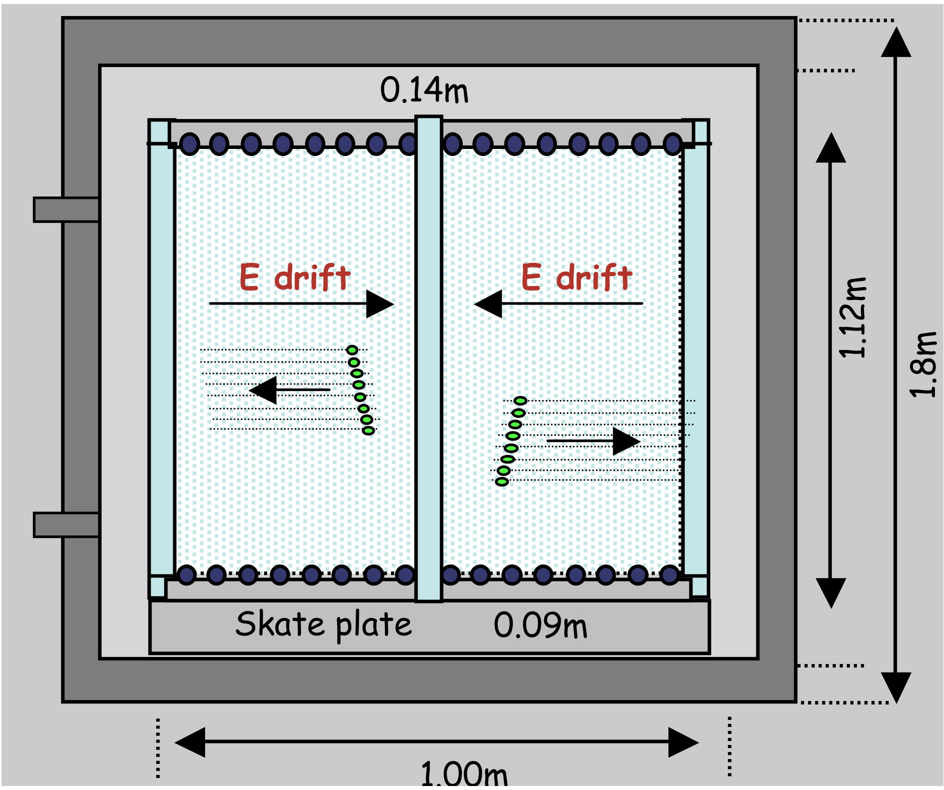


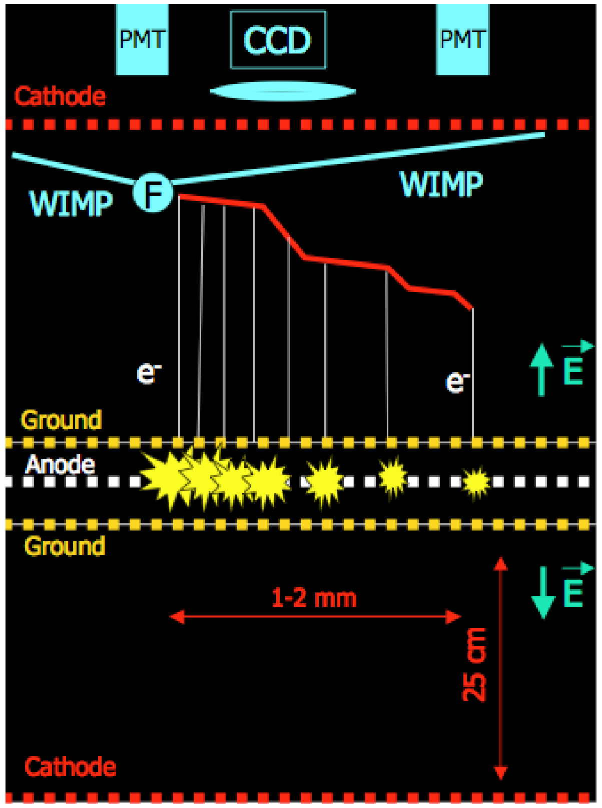
DRIFT at Boulby

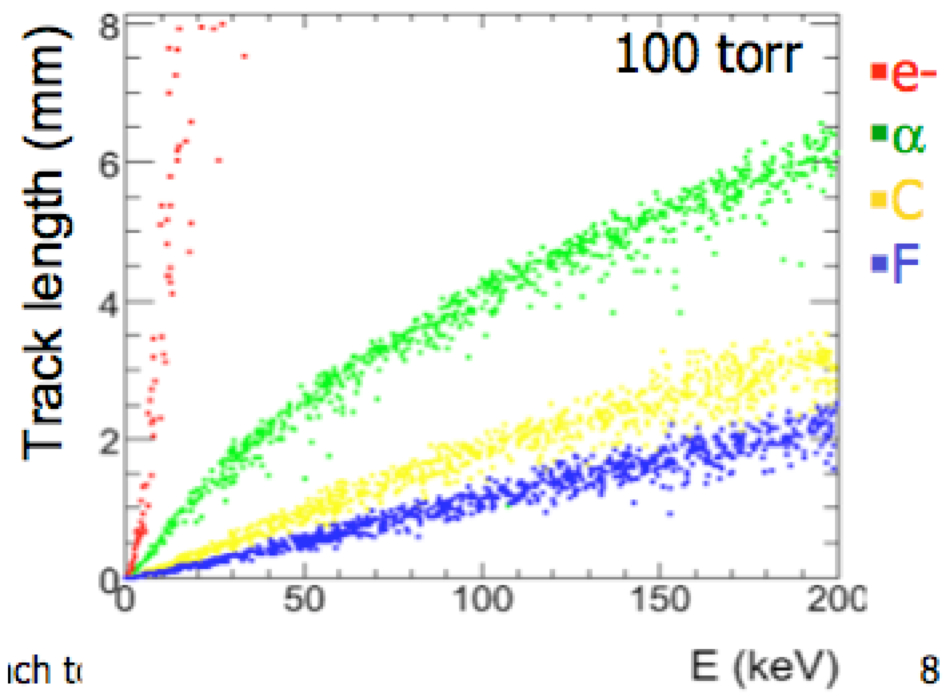
negative ion (CS_2) TPC: 1 m^3 40 Torr CS_2 gas (0.17 kg); 2 mm pitch anode + crossed MWPC
- NR discrimination via track morphology
- 3D track reconstruction for recoil direction: find head-tail of recoil based on dE/dx
- new run in 2007/08 at Boulby with strongly reduced Rn backgrounds

DM-TPC

low-pressure CF_4 gas TPC: 50 Torr
- 40 keV recoil ~ 1-2 mm track
- PMTs for trigger => z - information
- CCD images avalanche region => E and x-y
- head-tail of recoil based on dE/dx
- 2 x 10^{-2} m^3 modules under commissioning at MIT and ready for operation at WIPP in 2009
- 1 m^3 detector being designed (0.25 - 0.5 kg/m^3)

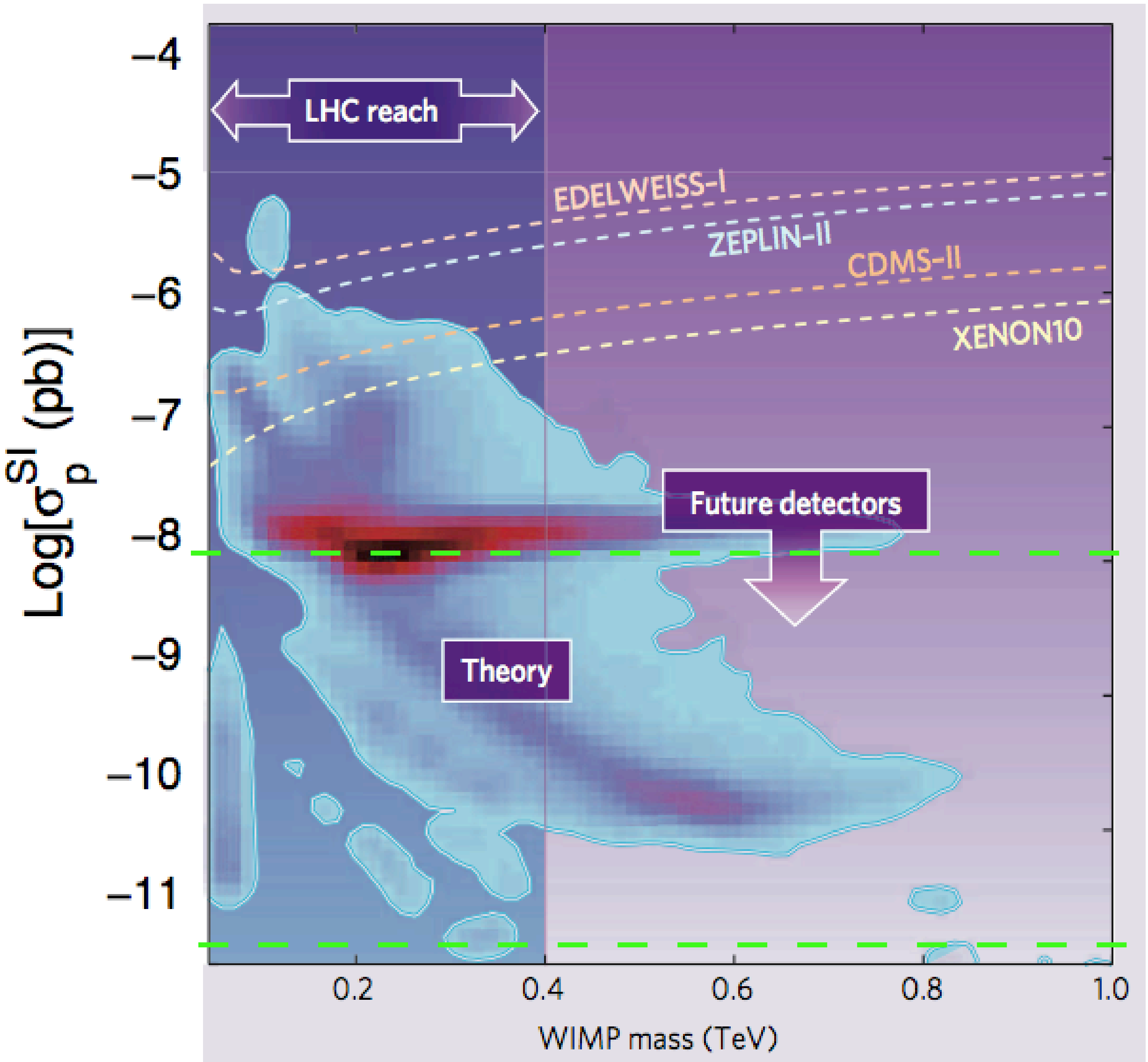






Conclusions

- Many different techniques/targets are being employed to search for dark matter particles
- Experiments are probing some of the theoretically interesting regions for WIMP candidates
- Next generation projects: should reach the ≲ 10^{-10} pb level => WIMP (astro)-physics



Theory example: CMSSM (Roszkowski, Ruiz, Trotta)
see also: Balz, Baer, Bednyakov, Bottino, Cirelli, Chattopadhyay, Ellis, Fornengo, Giudice, Gondolo, Massiero, Olive, Profumo, Santoso, Spanos, Strumia, Tata,...+ many others

1 event/kg/yr

sensitivity of existing experiments:
CDMS-II, XENON100, ArDM, COUPP, CRESST-II, EDELWEISS-II, ZEPLIN-III,...

1 event/t/yr

sensitivity of near-future projects
SuperCDMS1t, WARP1t, ArDM XENON1t, EURECA, XMASS, ...

End

Inelastic Dark Matter: an explanation for DAMA/LIBRA signal?

- **possible explanation for DAMA signal and null results for other experiments by:**
  - ➡ suppressing signals on lighter vs heavier target
  - ➡ enhancing the modulated vs unmodulated signal (20-30%), because the model is sensitive to the high velocity component of the halo
  - ➡ eliminating low energy events; signal peaks at higher energies (70 keV for Ge, 35 keV for I/Xe, 25 keV for W)

- **needed:**
  - ➡ 2 dark matter states with a mass splitting of about 100 keV (by "coincidence" equal to $m_\chi v^2$)
  - ➡ WIMP-nucleus scattering occurs through a transition to an WIMP excited state
  - ➡ elastic scattering ($\chi N \rightarrow \chi N$) must be forbidden, or highly suppressed
  - ➡ inelastic scattering ($\chi N \rightarrow \chi^* N$) is allowed

$$\delta = m_{\chi^*} - m_\chi \sim \beta^2 m_\chi \sim 100 \text{ keV}$$

$$\frac{v^2 \mu_{\chi N}}{2} > \delta$$

Tucker-Smith, Weiner, 2001
Neil Weiner, IDM08, Stockholm

Inelastic Dark Matter: an explanation for DAMA/ LIBRA signal?

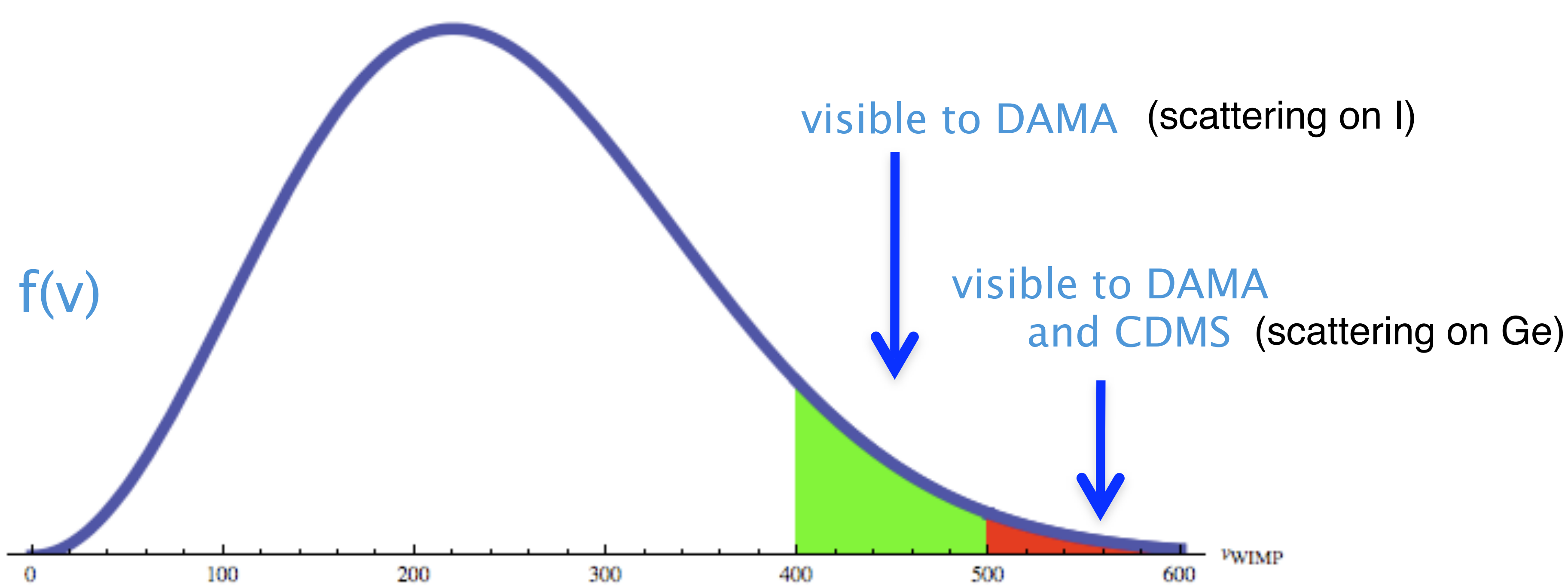
- The mass splitting is comparable to the kinetic energy of a WIMP in the halo
- Only WIMPs with sufficient kinetic energy to up-scatter into the heavier state will scatter off nuclei in a detector:

$$\frac{v^2 \mu_{\chi N}}{2} > \delta$$

➡ Minimum velocity requirement: experiments will probe the higher velocity region of the WIMP halo distribution

➡ Heavier targets will be favored over light targets

Neil Weiner, IDM08



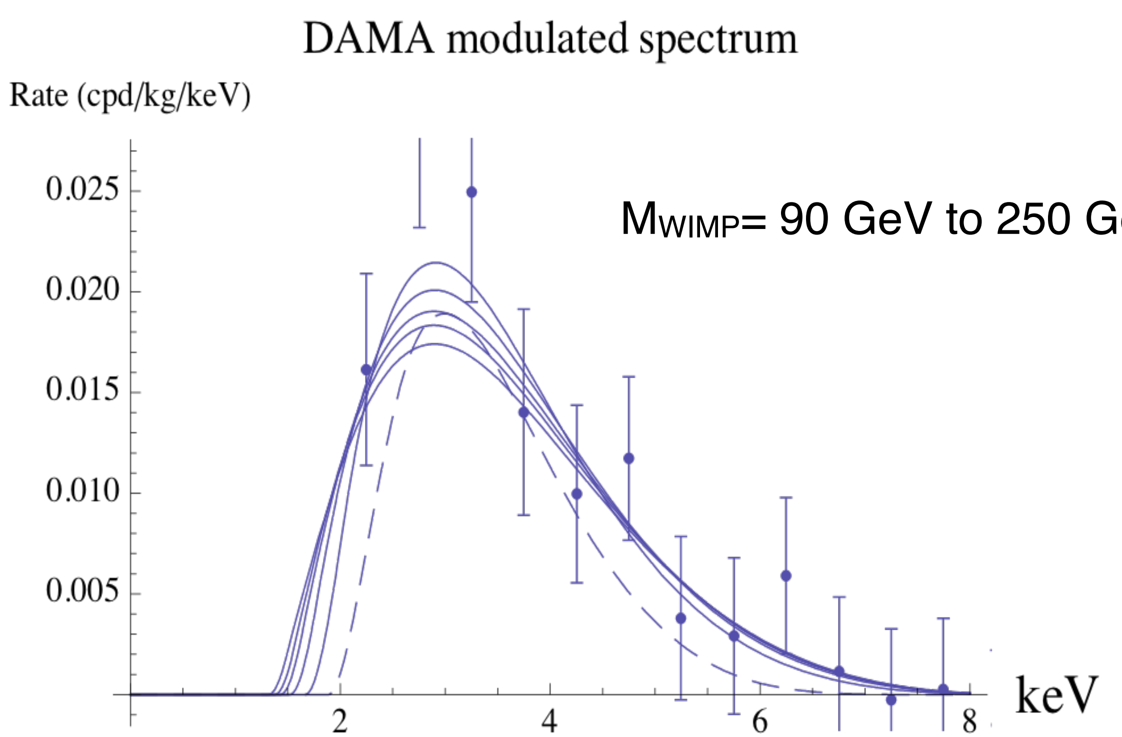
Inelastic Dark Matter: an explanation for DAMA/ LIBRA signal?

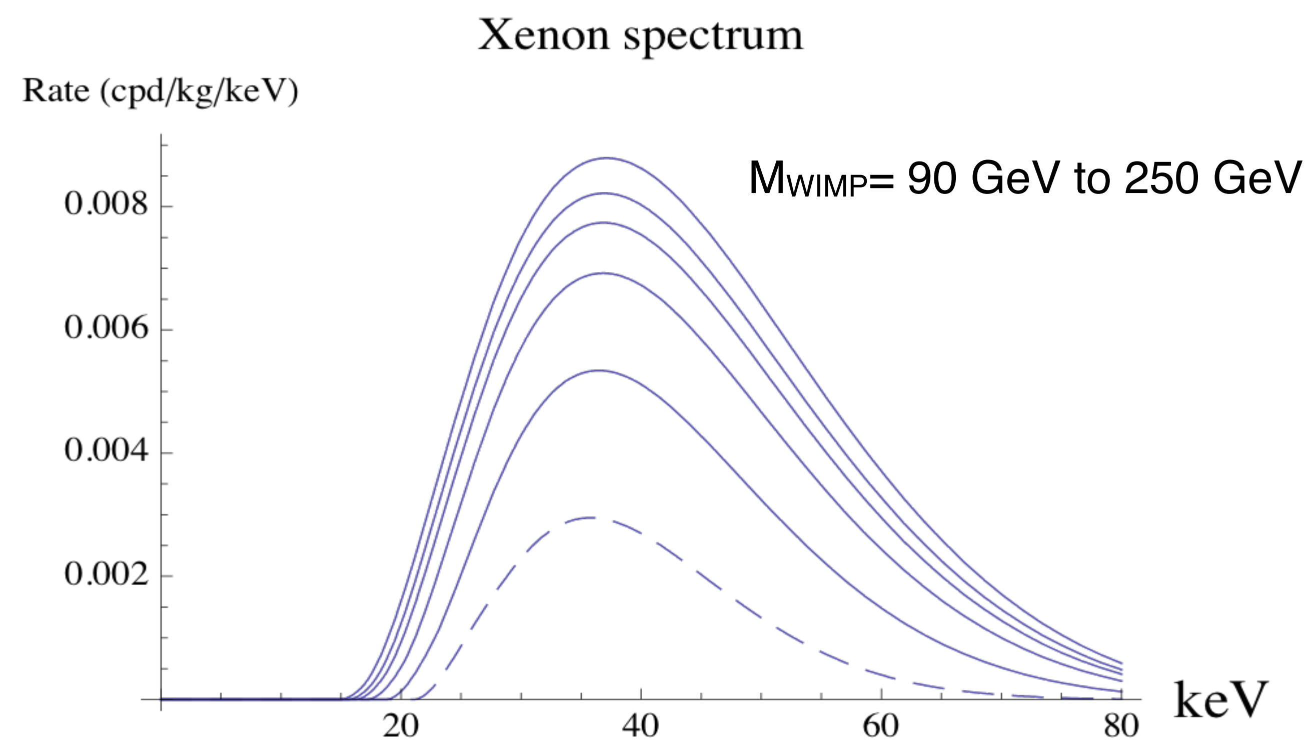
- Some benchmark points:

#	m_χ (GeV)	σ_n (10^{-40} cm^2)	δ (keV)	DAMA 2-6 keVee (10^{-2} dru)	XENON 4.5-45 keV (counts)	CDMS 10-100 keV (counts)	ZEPLIN 5-20 keVee (counts)	KIMS 3-8 keVee (10^{-2} dru)	CRESST 12-60 keV (counts)	
expt				1.31 ± 0.16	24 (31.6)	2 (5.3)	29 (37.2)	5.65 ± 3.27	6 (10.5)	obs. # events
1	70	11.85	119	0.93	1.39	0	8.81	0.77	8.92	pred. # events
2	90	5.75	123	1.25	5.52	0	14.87	1.62	9.38	
3	120	3.63	125	1.24	9.06	0.26	18.61	2.27	9.64	
4	150	2.92	126	1.21	11.17	1.19	20.55	2.63	9.82	
5	180	2.67	126	1.18	12.46	2.22	21.69	2.85	9.93	
6	250	2.62	127	1.14	14.01	3.95	23.03	3.12	10.02	

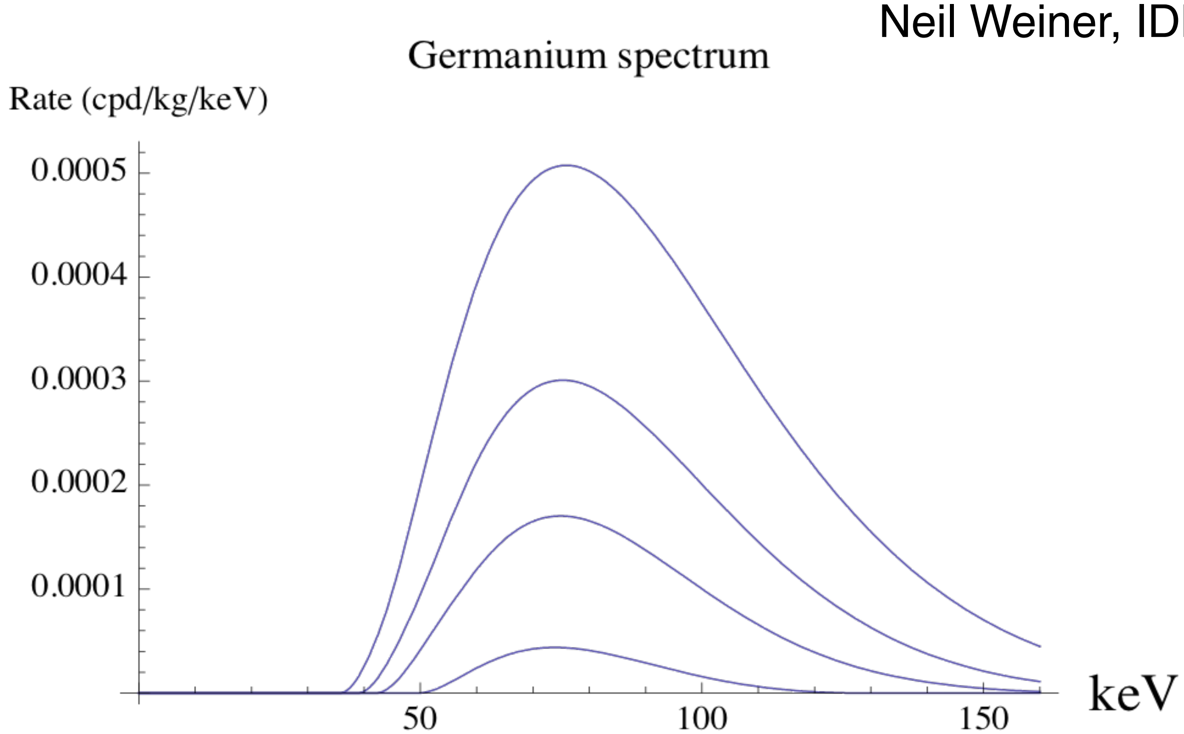
- Upcoming results from Ge (peak at ~70 keV), Xe (35 keV), I (35 keV) and W (25 keV) should test this explanation for the DAMA signal!

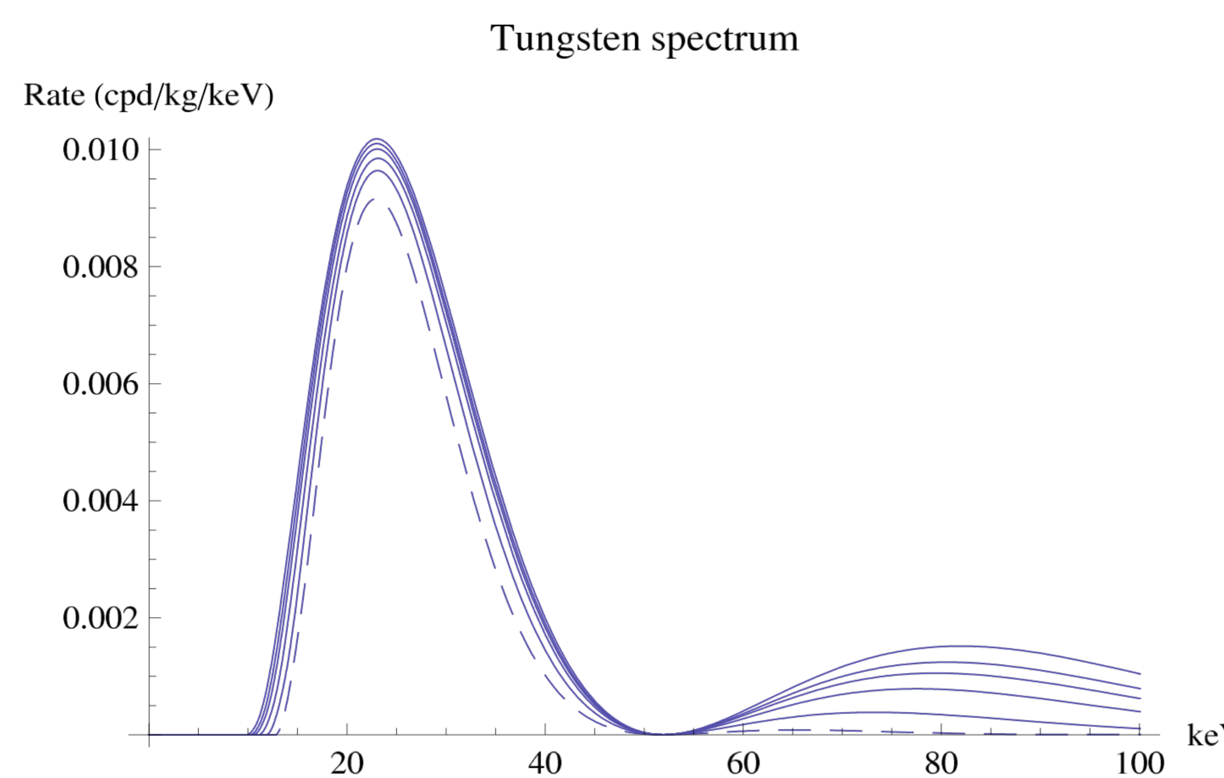
Inelastic Dark Matter: an explanation for DAMA/ LIBRA signal?





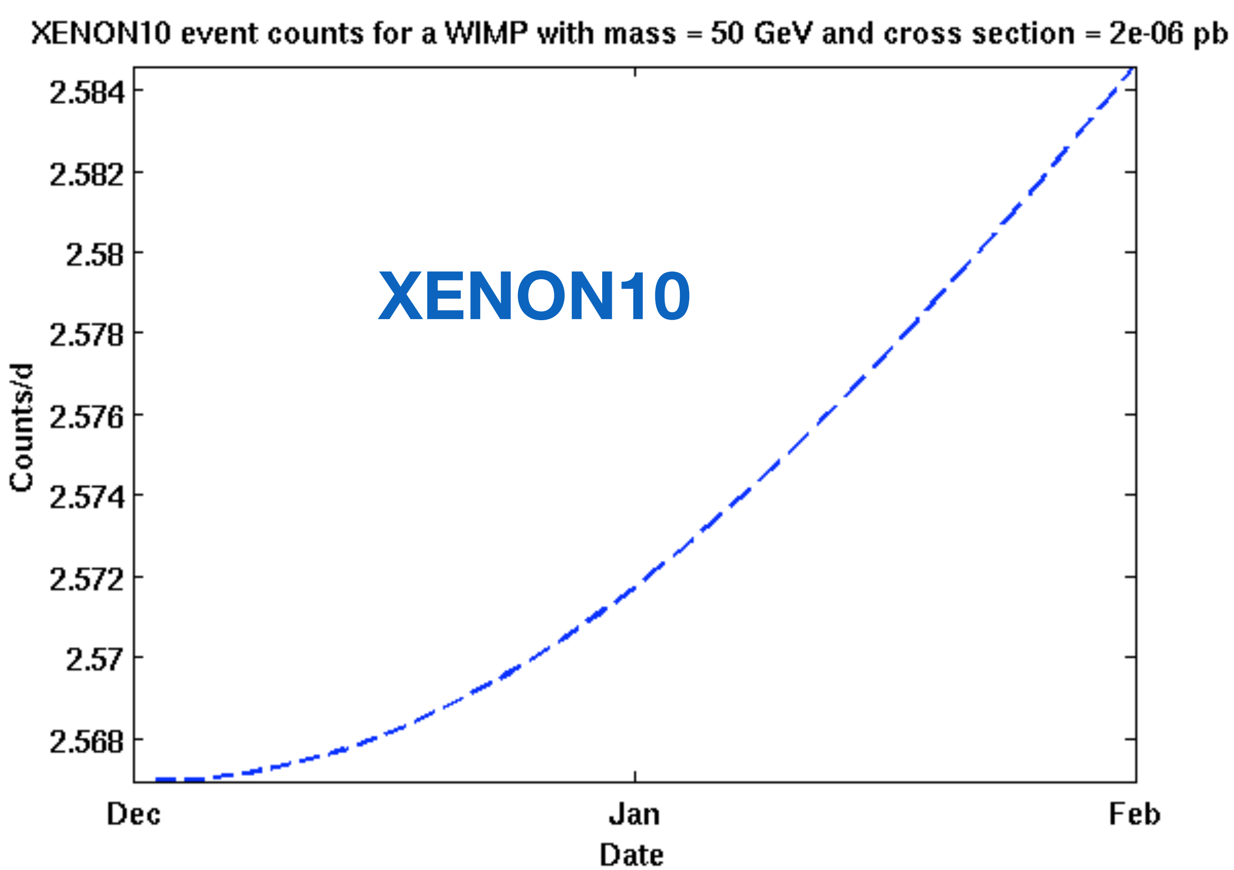
Neil Weiner, IDM08

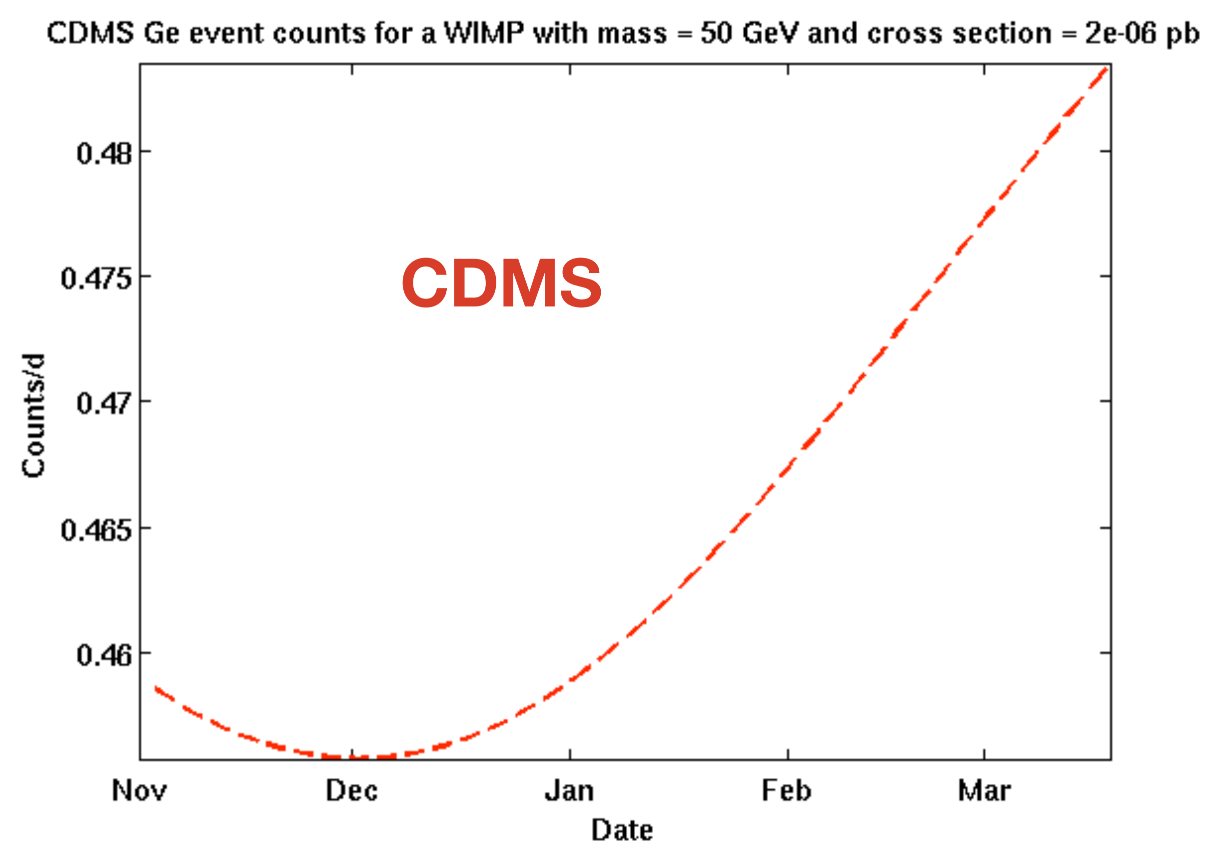




Predicted Rates in XENON10/CDMS if DAMA would see WIMPs

- **Assumption:** m_W = 50 GeV, $\sigma_{SI} = 2x10^{-6}$ pb
- **XENON10:** 136 kg day, 4.5-27 keVr => 162 events
- **CDMS R123/124:** 397.8 kg day in Ge, 10-100 keVr => 62 events

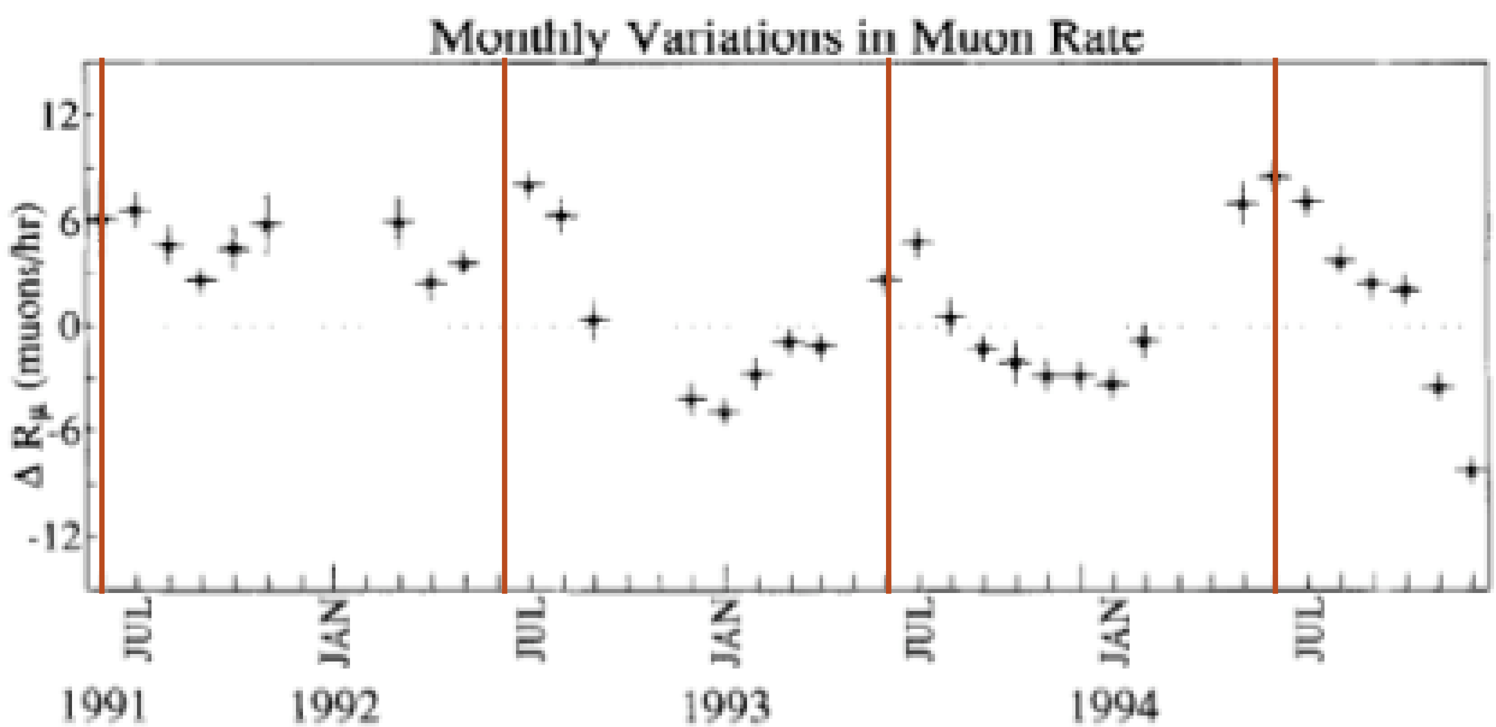




T. Bruch, UZH

Annual modulation of muons at LNGS

- measured by the MACRO experiment (phase ~ correct)

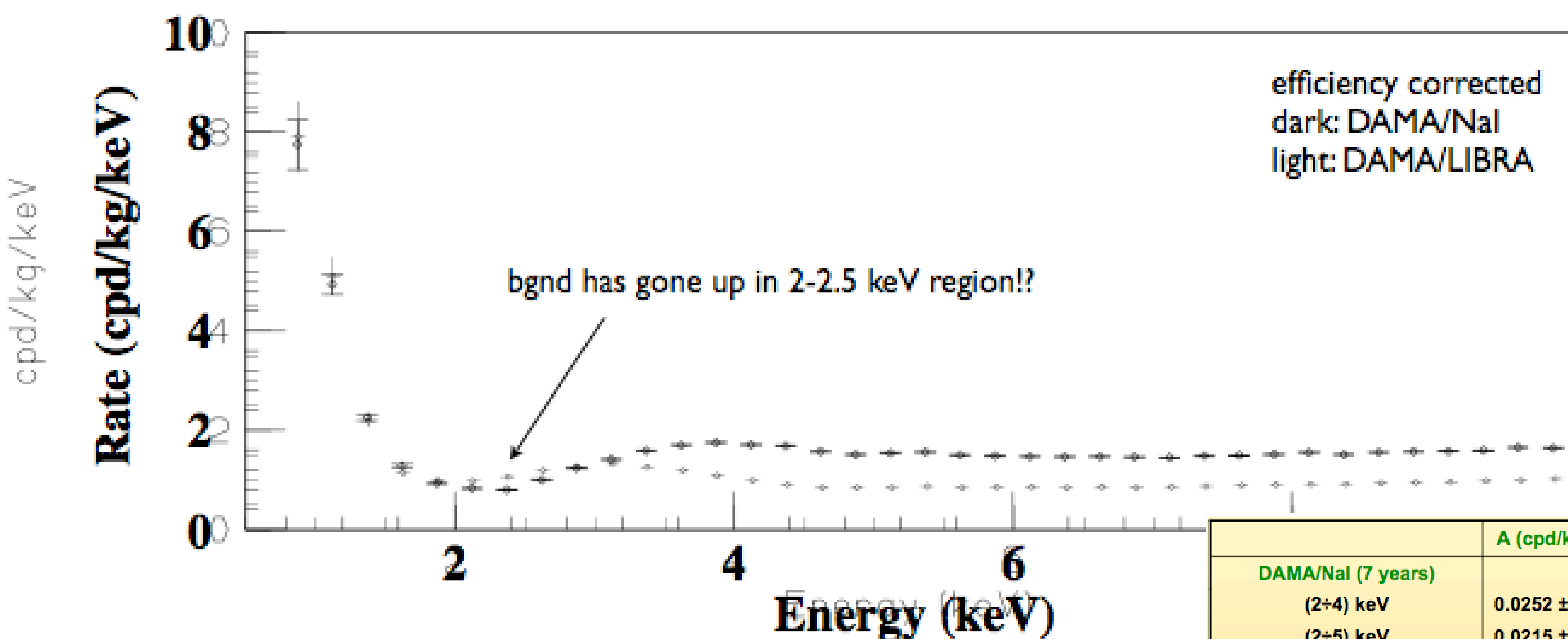


- DAMA: fast, μ-induced n-rate is not sufficiently high to produce observed rate modulation; good cross check: muon rate versus time! (no μ veto, but HE showers)

- How about metastable isotope production by μ- spallation reactions in NaI? (with $T_{1/2}$ > 500 μs trigger hold-off time, and ~ 3 keV emission)

Background spectra in DAMA and LIBRA

- compare DAMA/LIBRA DC spectrum:
- LIBRA: continuum background ~ 2 x lower than in DAMA
- LIBRA: slight increase in background in the 2-2.5 keV energy region
- the ‘peak’ around 3 keV seems to have slightly shifted to lower energies



	A (cpd/kg/keV)	T= 2π/ω (yr)	t_0 (day)	C.L.
DAMA/NaI (7 years)				
(2÷4) keV	0.0252 ± 0.0050	1.01 ± 0.02	125 ± 30	5.0σ
(2÷5) keV	0.0215 ± 0.0039	1.01 ± 0.02	140 ± 30	5.5σ
(2÷6) keV	0.0200 ± 0.0032	1.00 ± 0.01	140 ± 22	6.3σ
DAMA/LIBRA (4 years)				
(2÷4) keV	0.0213 ± 0.0032	0.997 ± 0.002	139 ± 10	6.7σ
(2÷5) keV	0.0165 ± 0.0024	0.998 ± 0.002	143 ± 9	6.9σ
(2÷6) keV	0.0107 ± 0.0019	0.998 ± 0.003	144 ± 11	5.6σ
DAMA/NaI + DAMA/LIBRA				
(2÷4) keV	0.0223 ± 0.0027	0.996 ± 0.002	138 ± 7	8.3σ
(2÷5) keV	0.0178 ± 0.0020	0.998 ± 0.002	145 ± 7	8.9σ
(2÷6) keV	0.0131 ± 0.0016	0.998 ± 0.003	144 ± 8	8.2σ