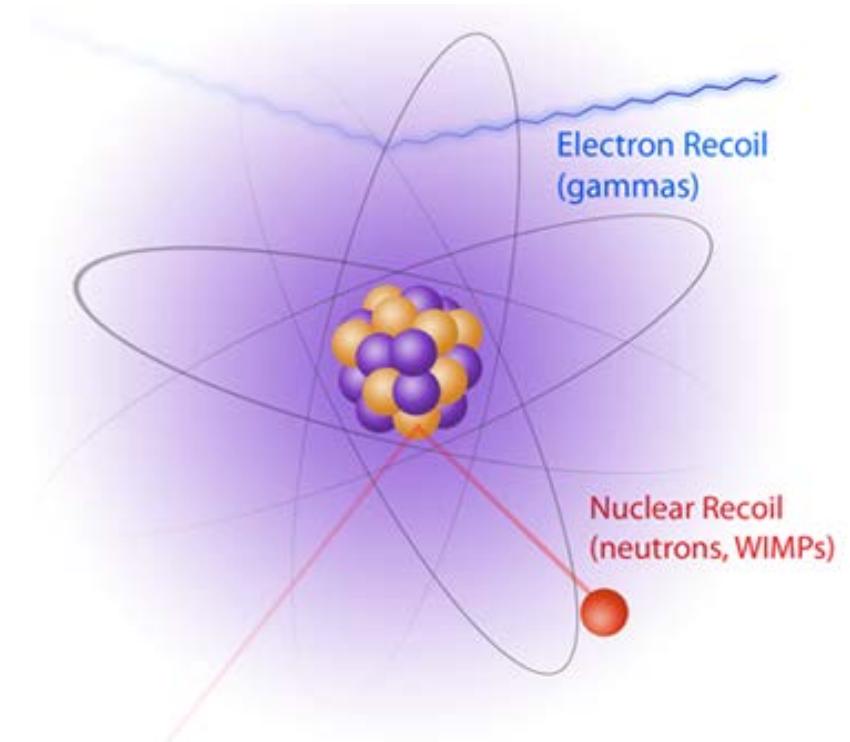


# Direct Dark Matter Search

Xiang Liu, MPI

Sino-German GDT  
Cooperation Symposium

2015.10.18-24



# Direct Dark Matter Search

**very personal**

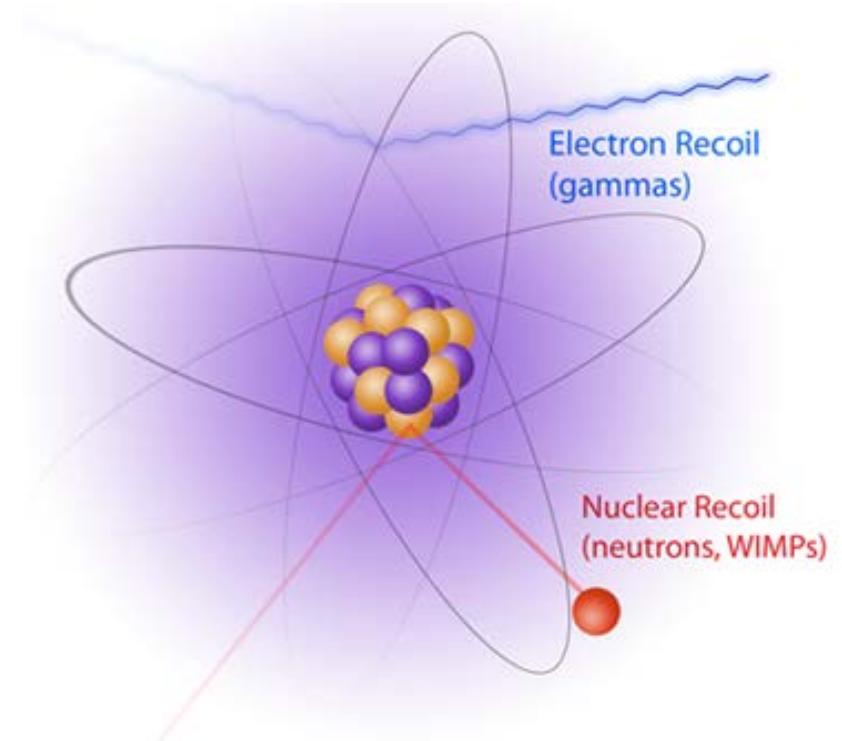
**& by no means complete nor all correct**

**& many stolen transparencies**

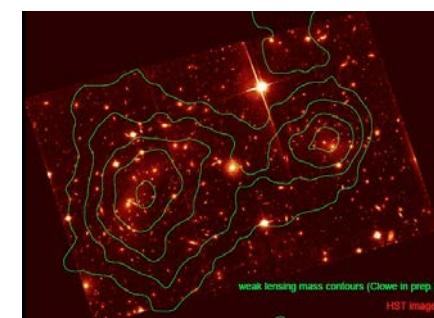
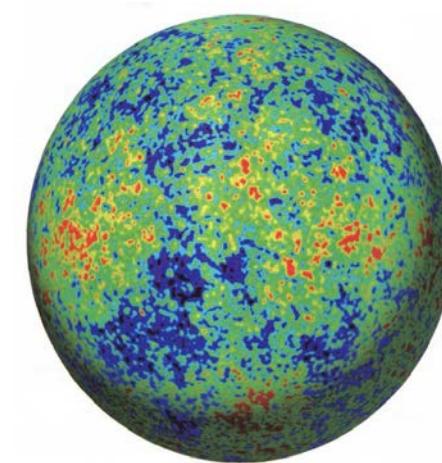
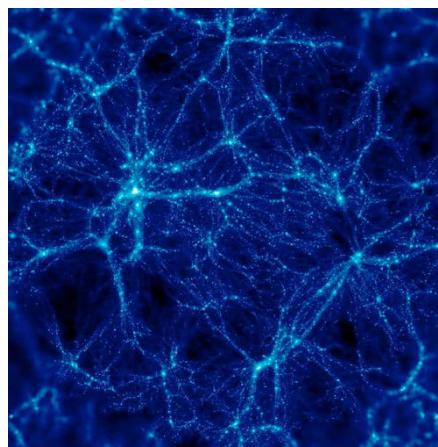
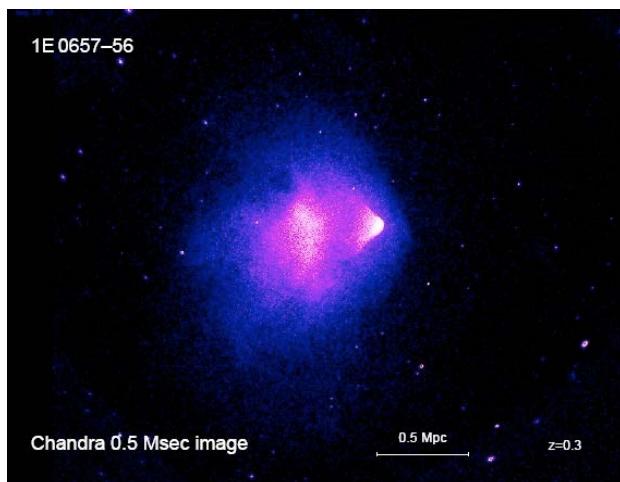
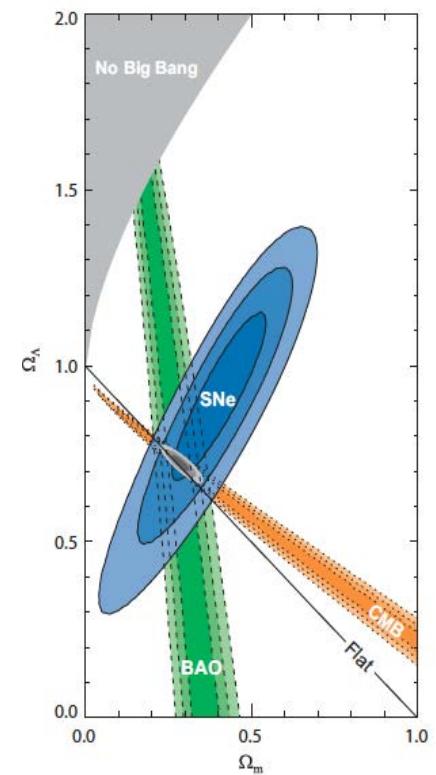
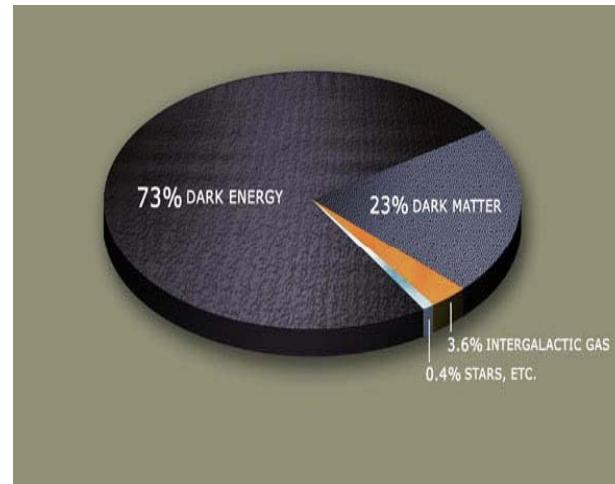
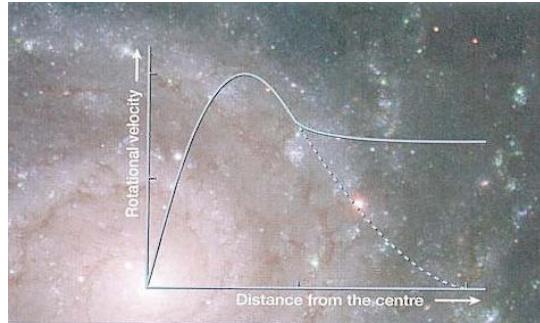
Xiang Liu, MPI

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Cooperation Symposium

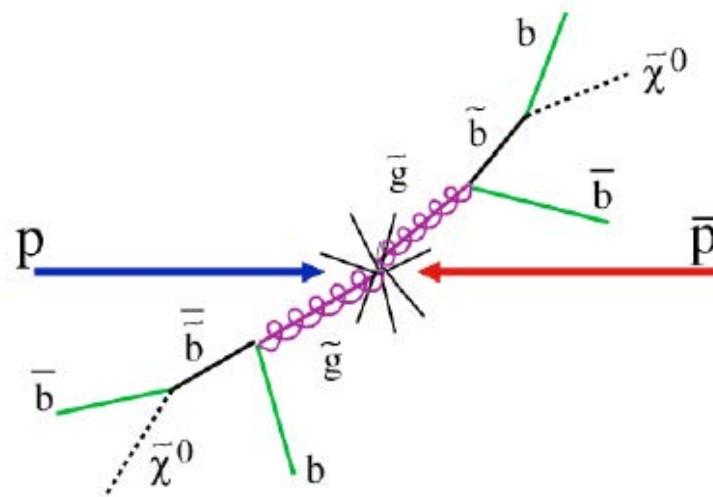
2015.10.18-24



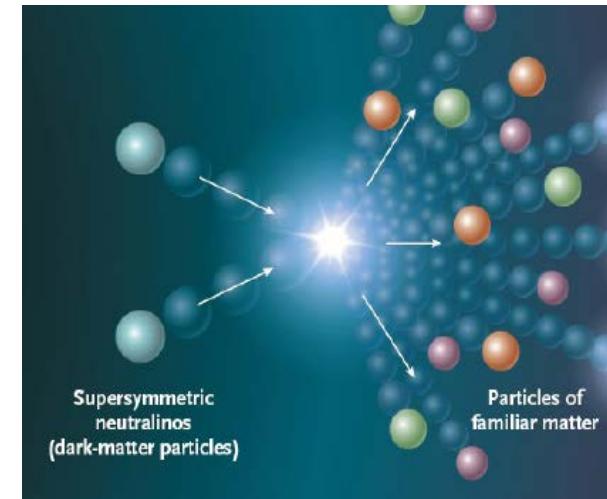
# Existing evidences of dark matter



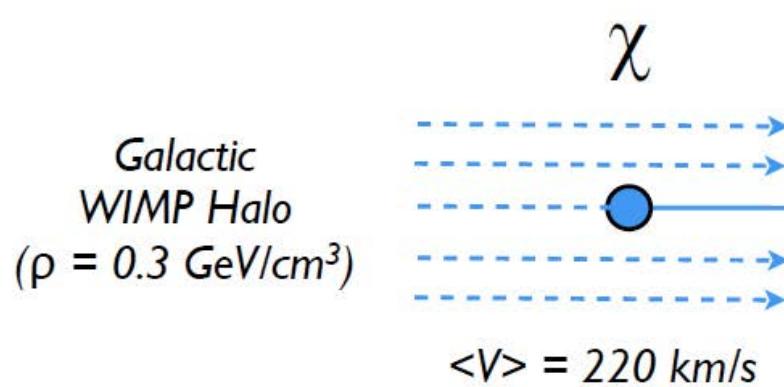
# Methods to search WIMP



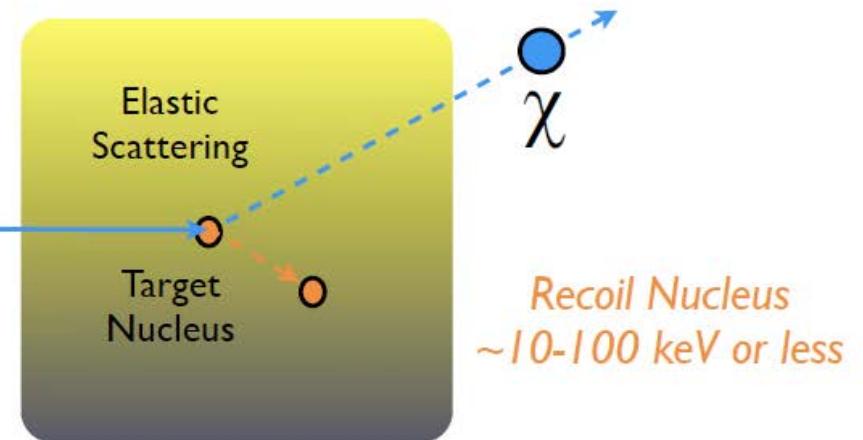
production at collider



annihilation particle detection (indirect)

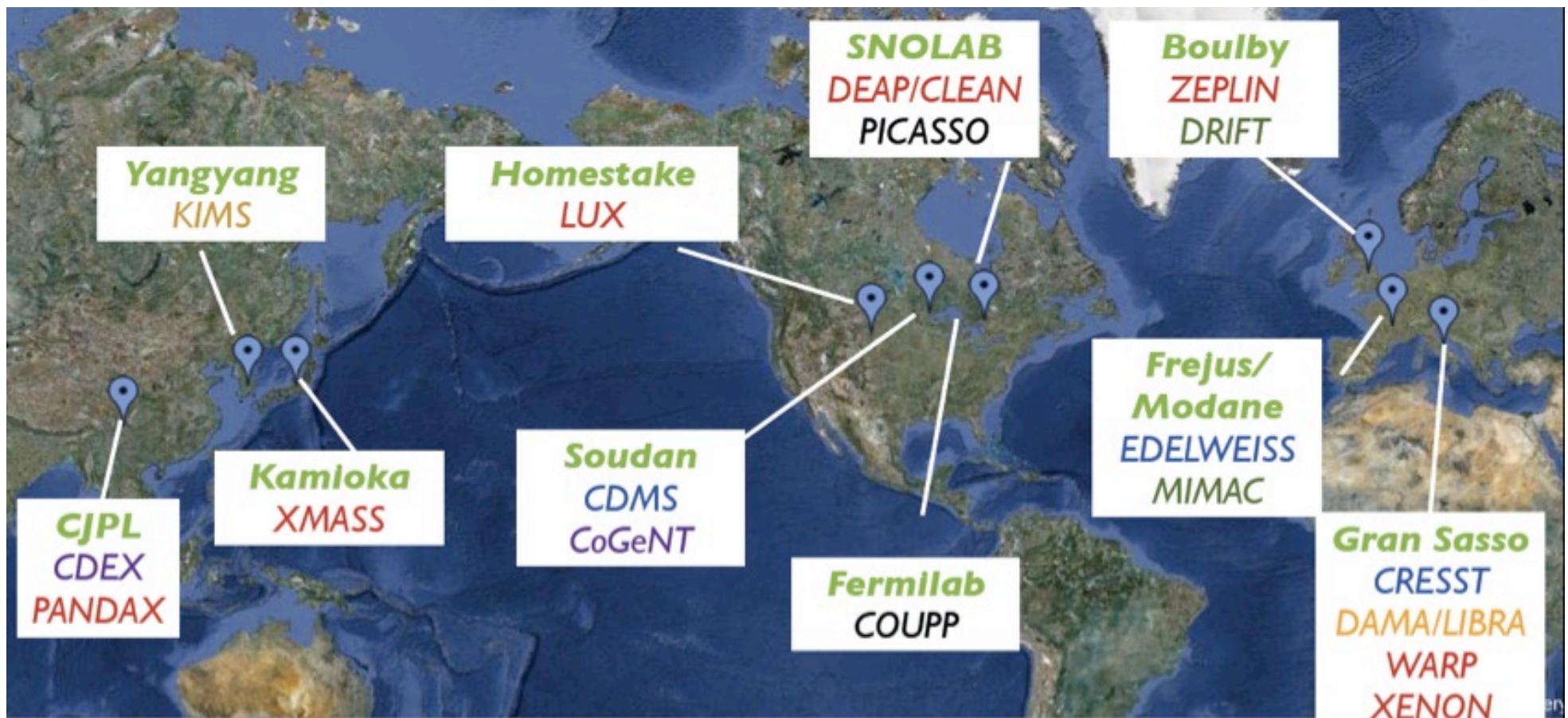


nuclear recoil (direct)

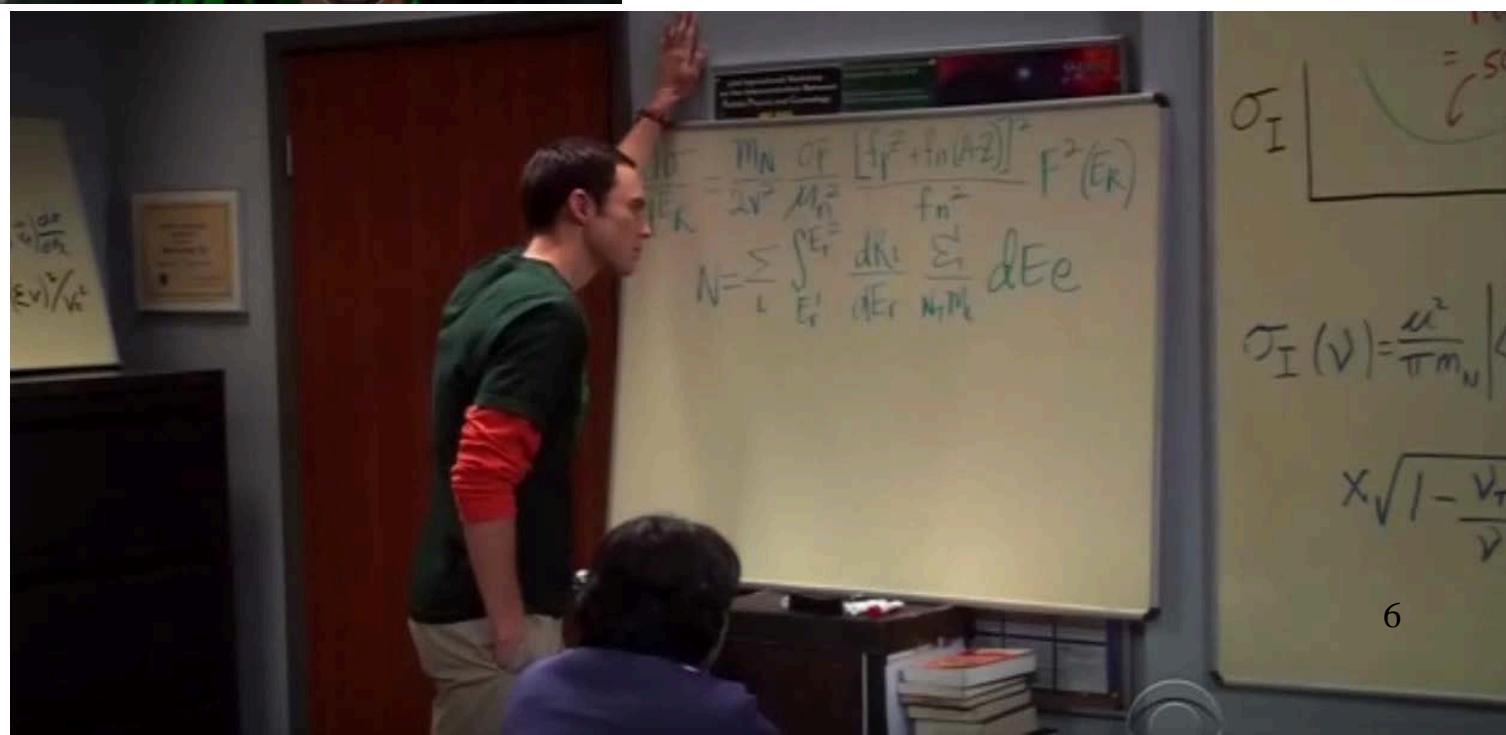
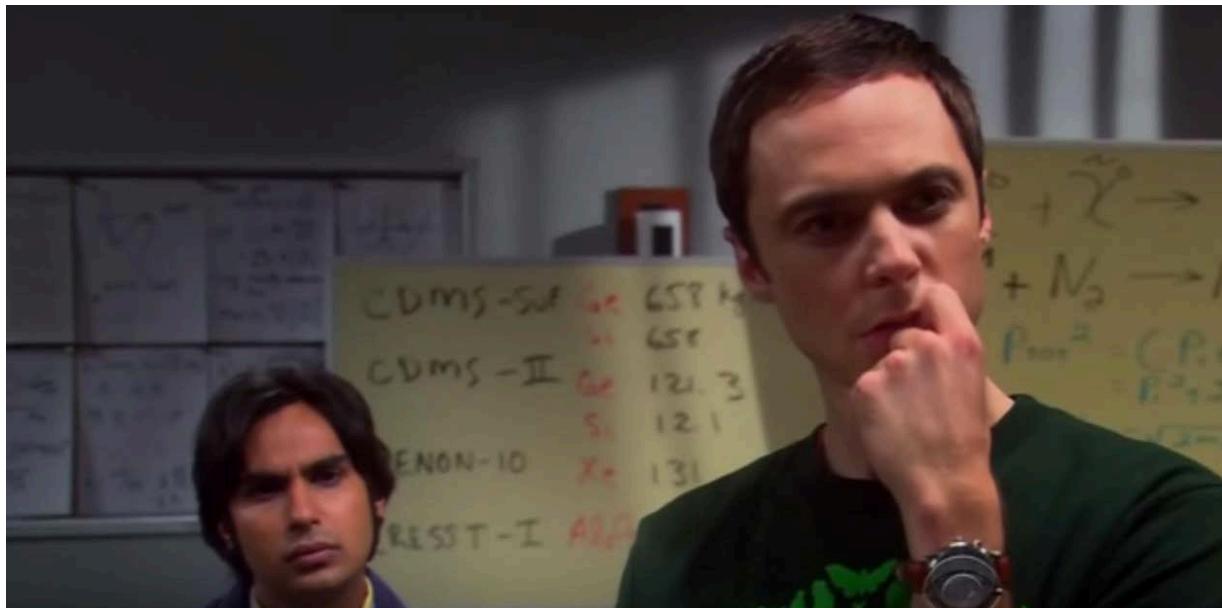


# Many Direct Search Experiments

in many underground labs



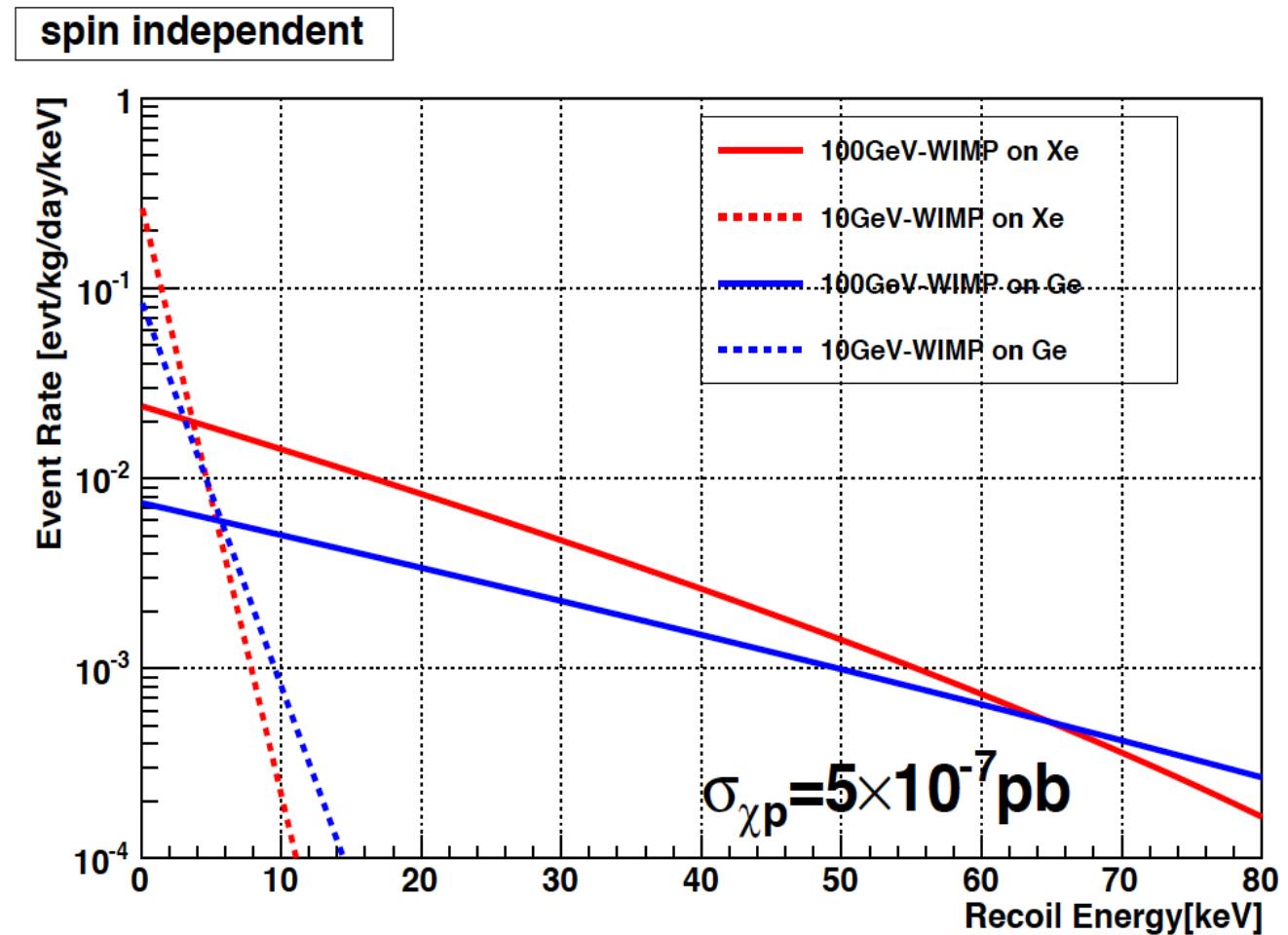
# We are not the only ones.....



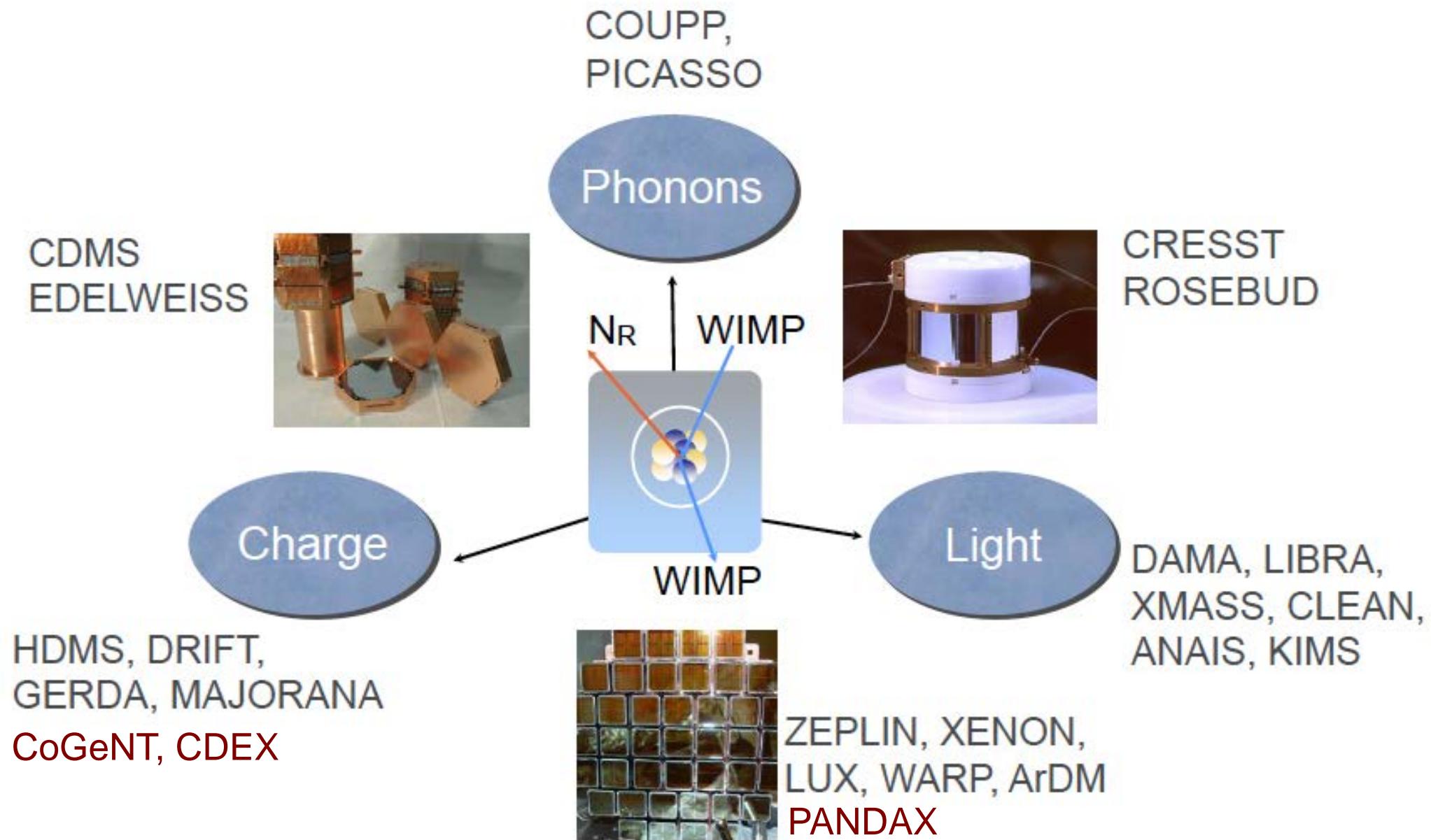
# Direct detection challenge

WIMP energy signal  
 $<0.1/\text{[kg day]},$   
 $<100\text{keV},$   
no feature.

- low E threshold,
- low bkg rate,
- large exposure.

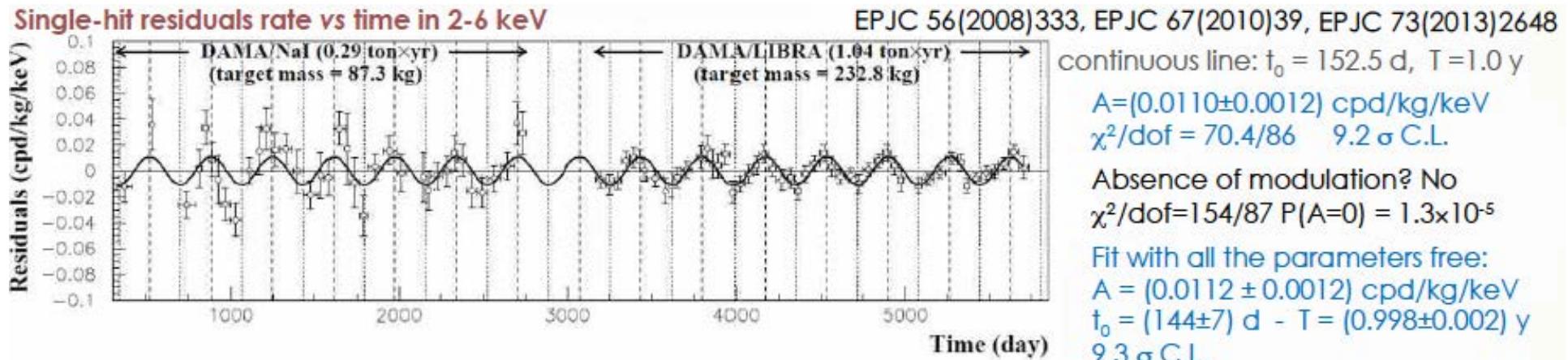


# Direct detection technique

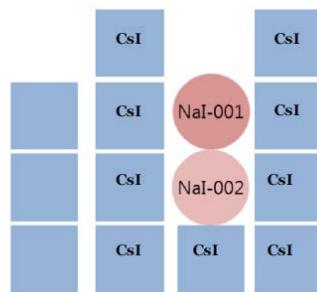


# Nal/CsI Crystal Single Channel

DAMA/Nal, DAMA/LIBRA, 230kg Nal



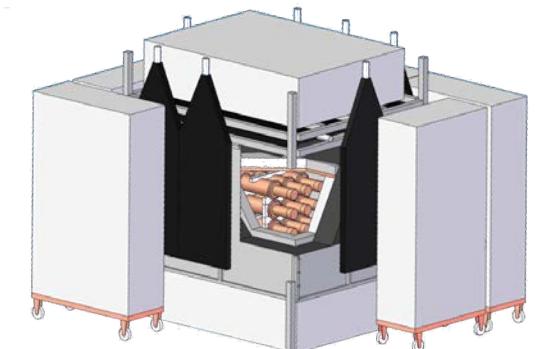
KIMS, ~200kg Nal, 103kg CsI



**2011 - Now**  
• mass: 17 kg of Nal(Tl)  
• location: South Pole

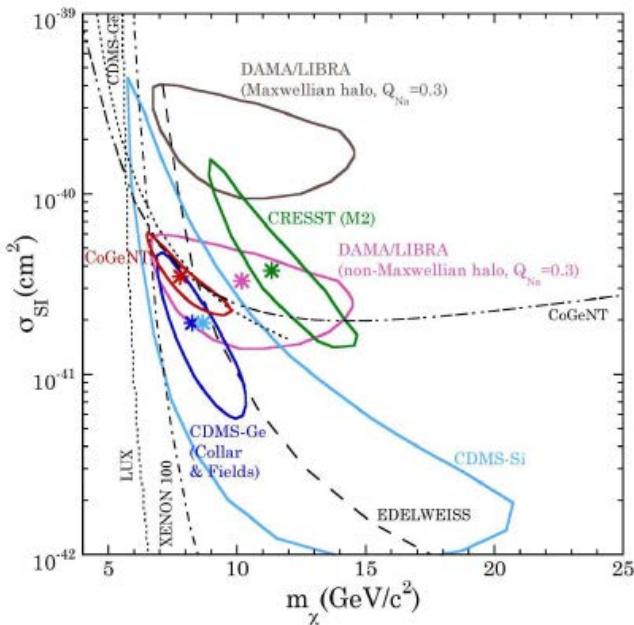
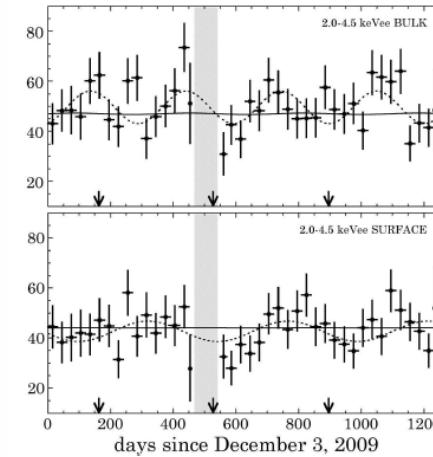
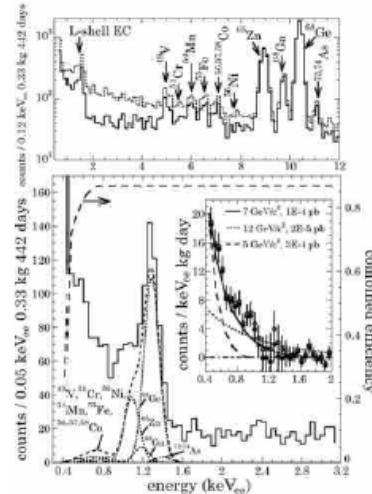
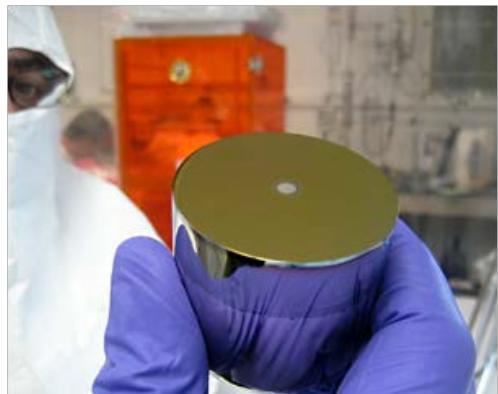


**Jan. 2015-now**  
• mass: 37 kg of Nal(Tl)  
• Add 18 kg (Fall 2015)  
• location: Boulby

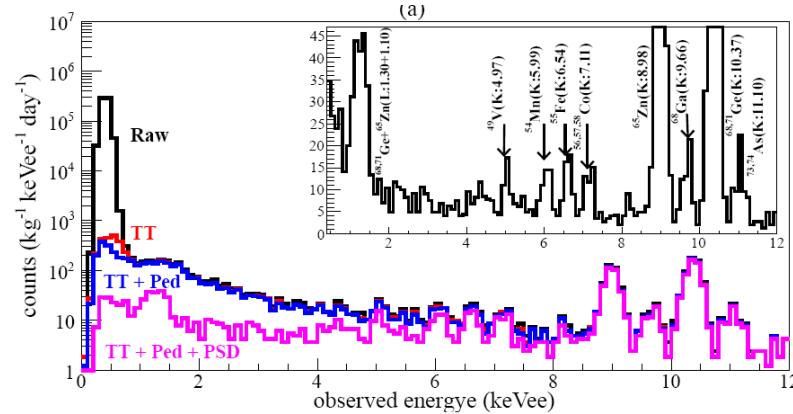


# Ge Crystal Single Channel

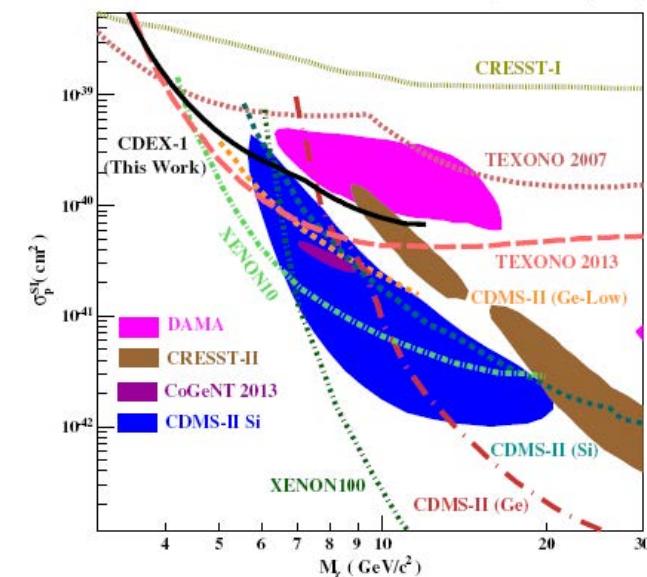
CoGeNT



CDEX-1, -10, -100,

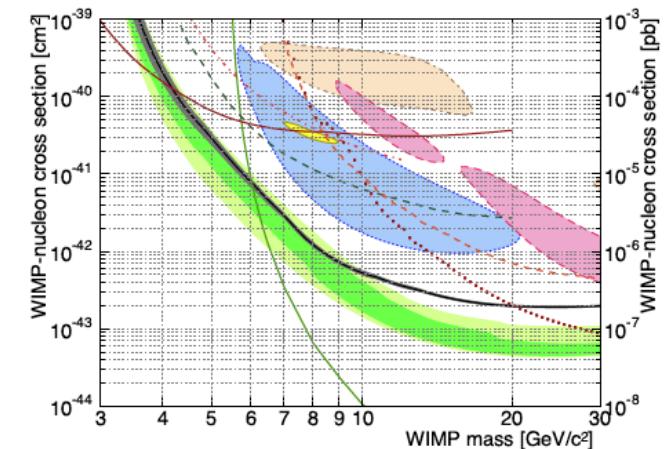
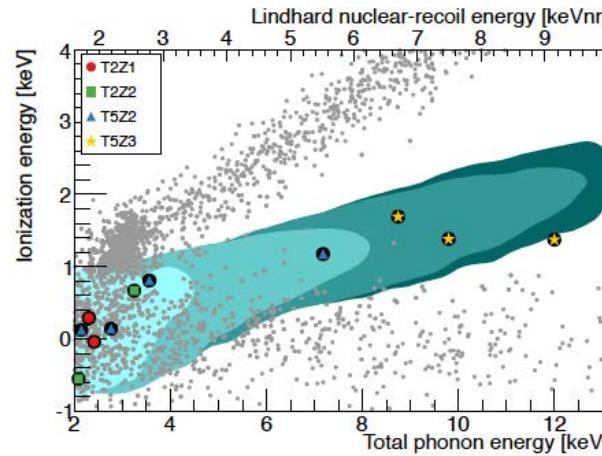
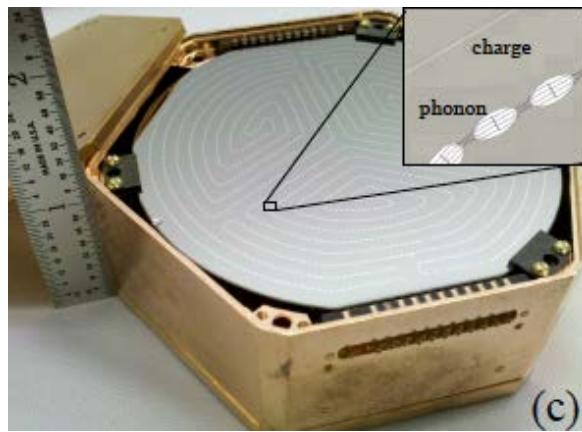


MELBEK



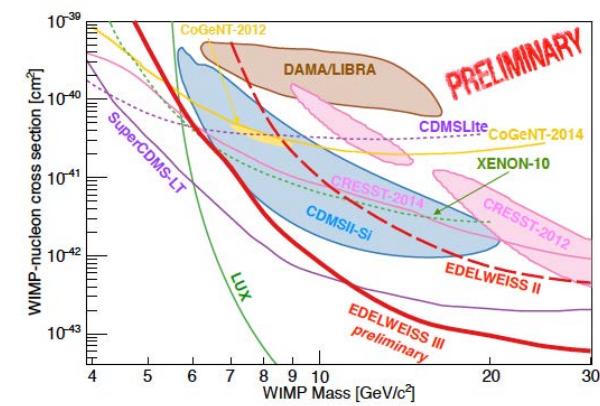
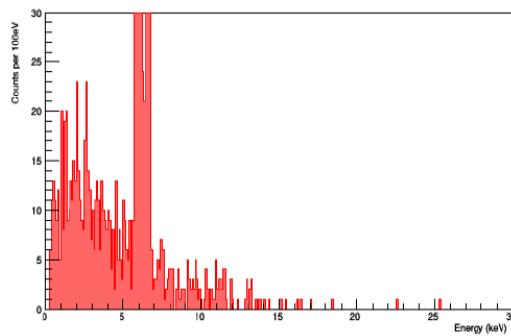
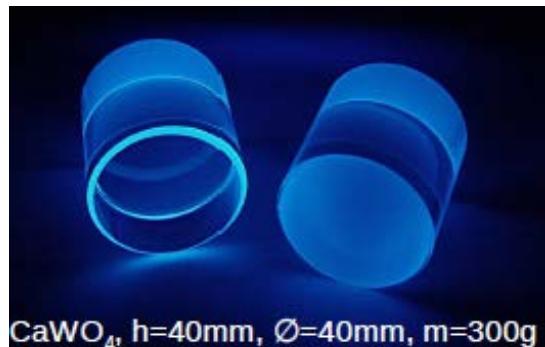
# Crystal Multi Channels

CDMS-Ge, CDMS-Si, CDMSlite, SuperCDMS (9kg Ge), **phonon+ionization**



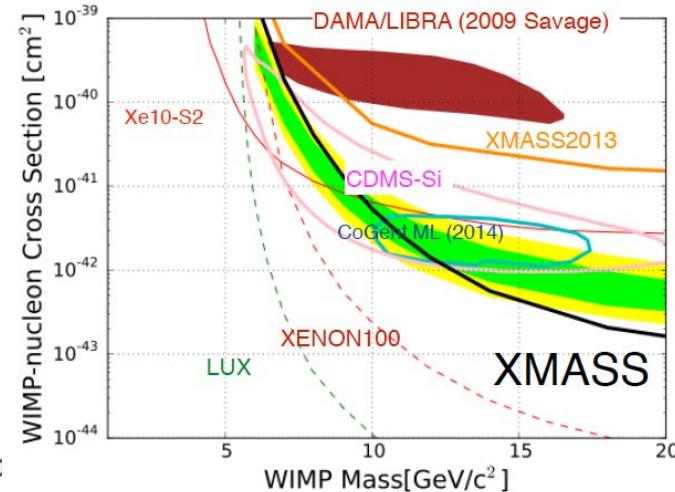
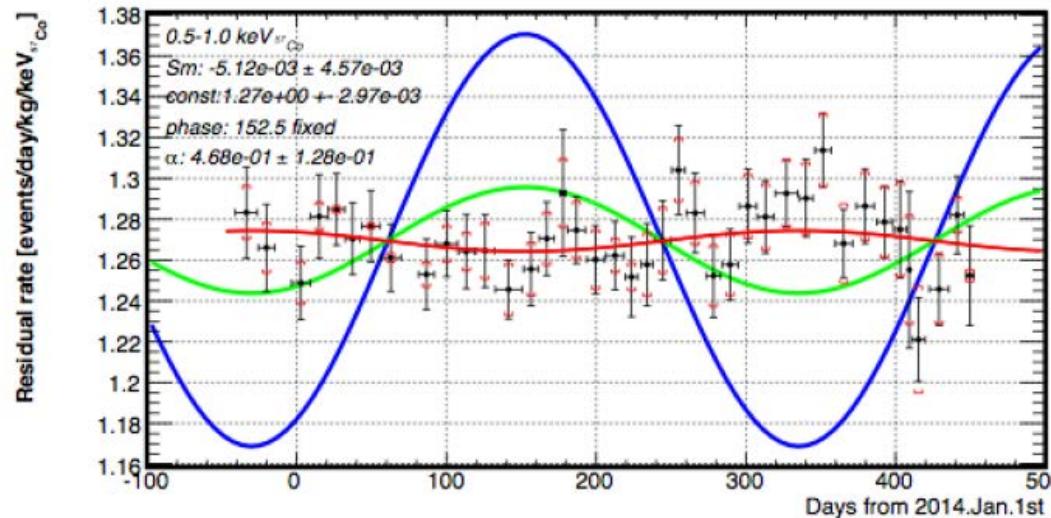
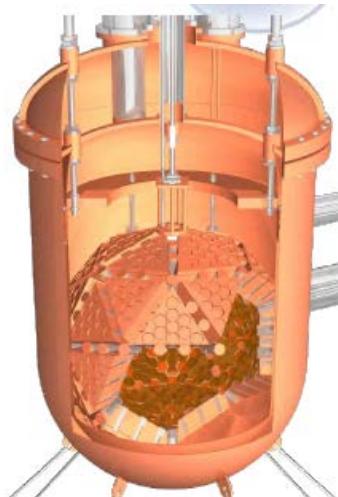
CRESST, **phonon+scintillation**

EDELWEISS, **photon+ionization**



# Liquid Xe/Ar single channel

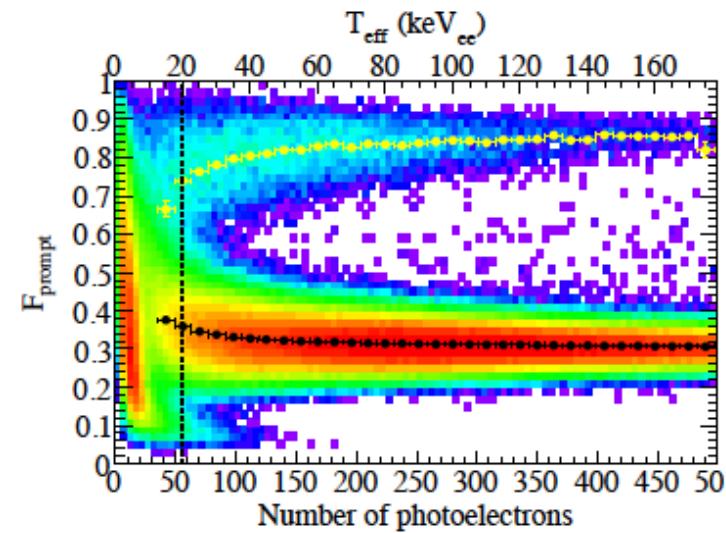
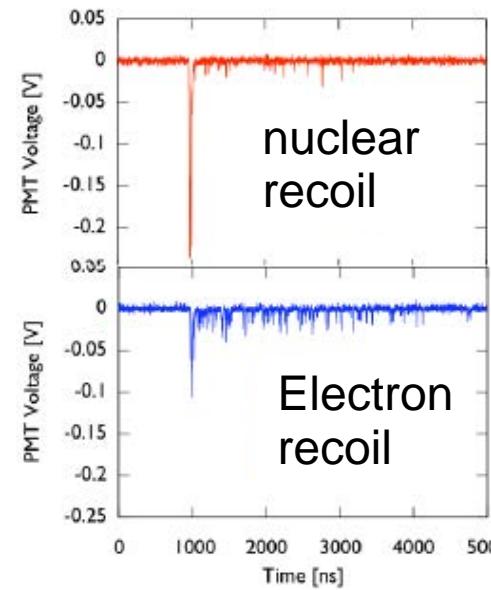
XMASS,  $4\pi$  scintillation, 0.7t (FV) LXe



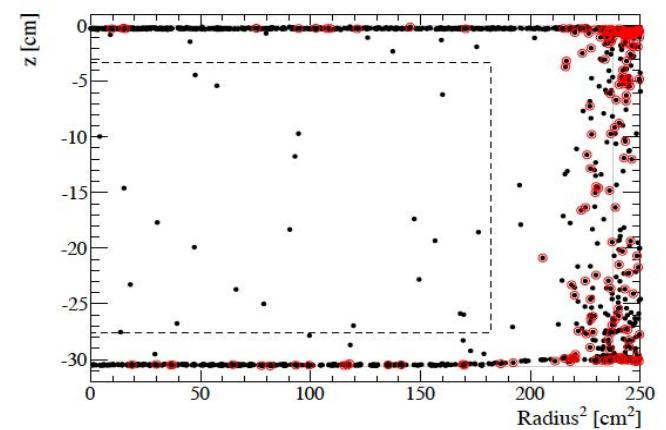
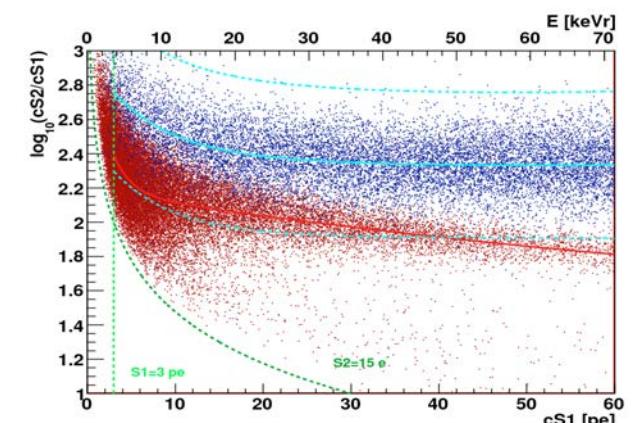
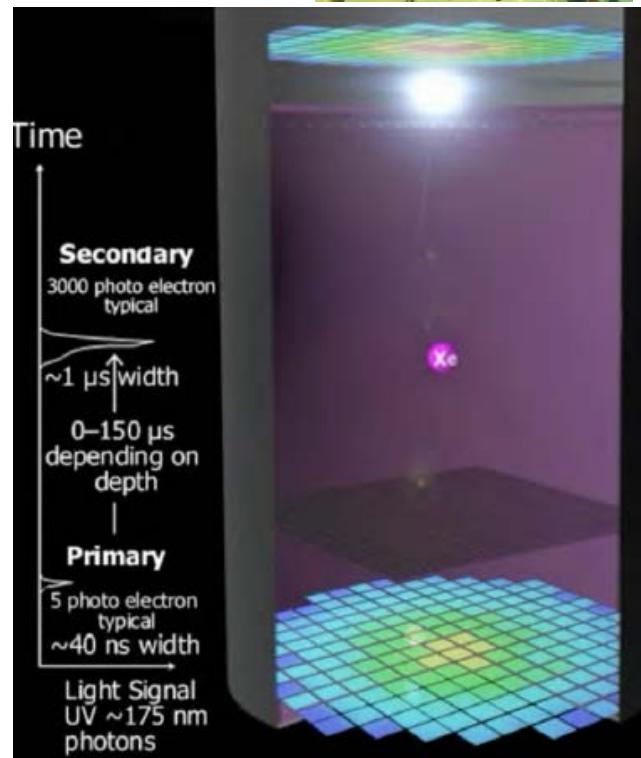
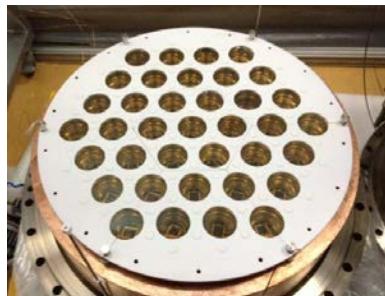
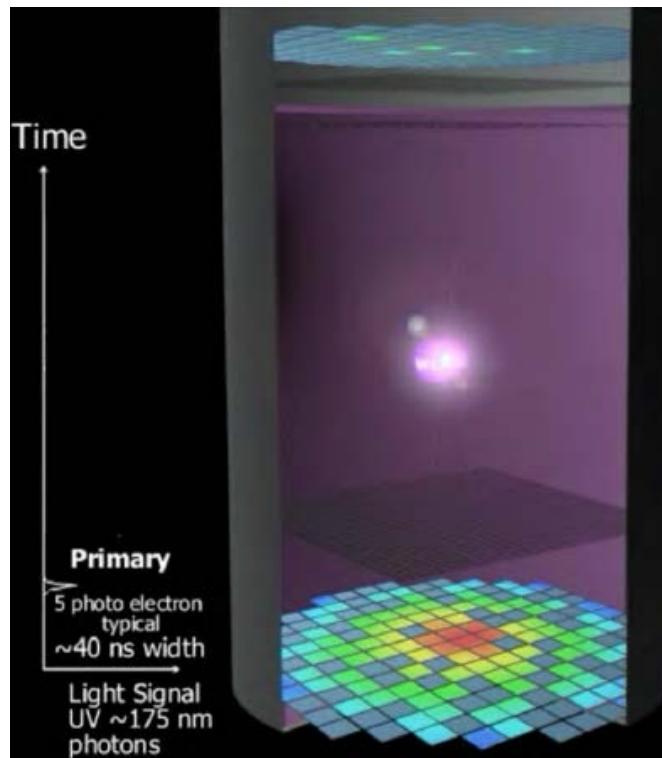
DEAP  
LAr 1T FV



MiniCLEAN  
LAr 150kg FV

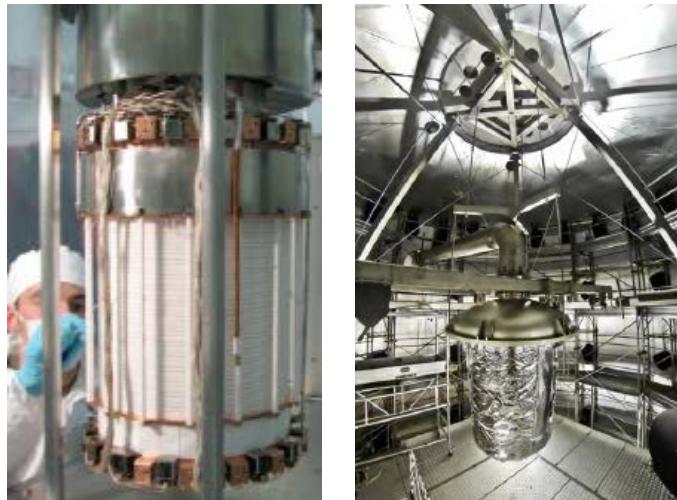


# Liquid Xe/Ar multi channels

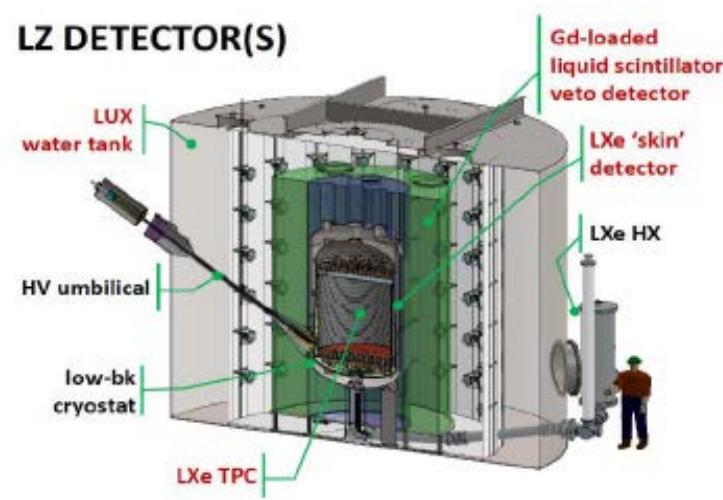


# Liquid Xe/Ar multi channels

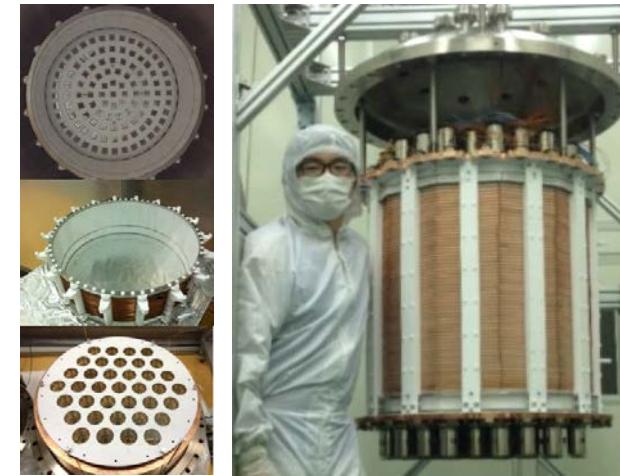
XENON-10, 100, 1T



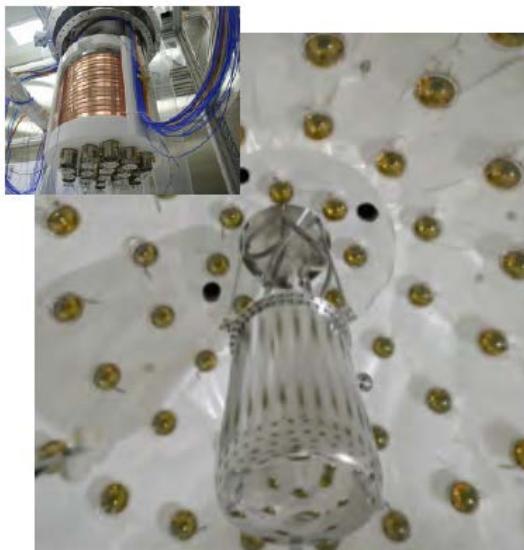
LUX, LZ



PANDAX-I II



DarkSide-50 LAr



ArDM-1t

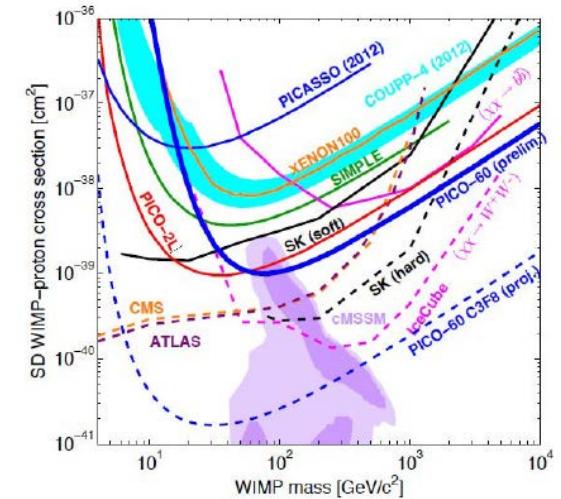
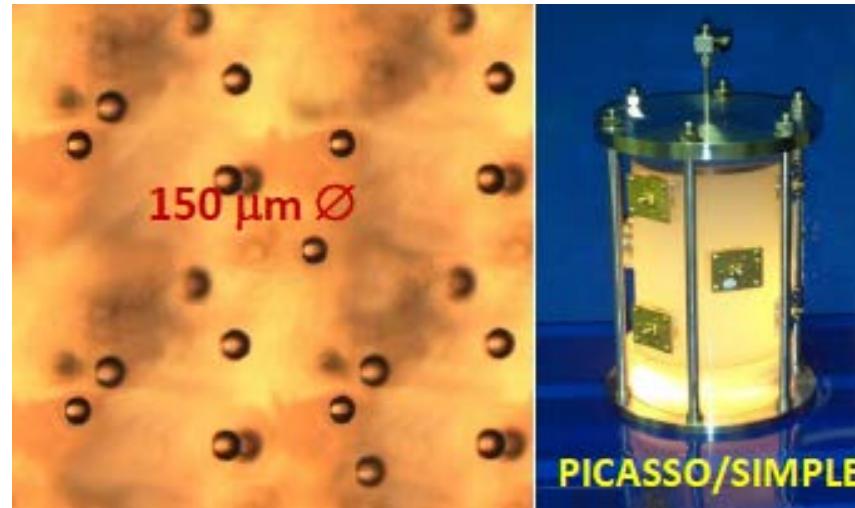
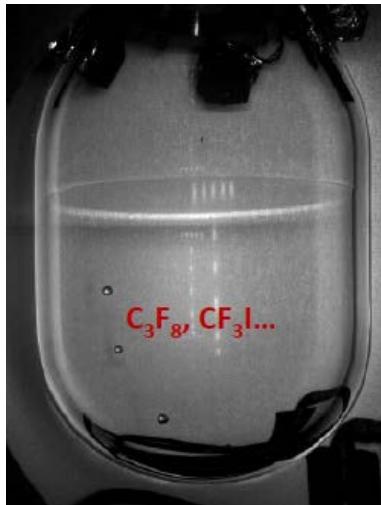


DARWIN



# New techniques

Bubble chamber coming back, CUPP, PICO, SIMPLE



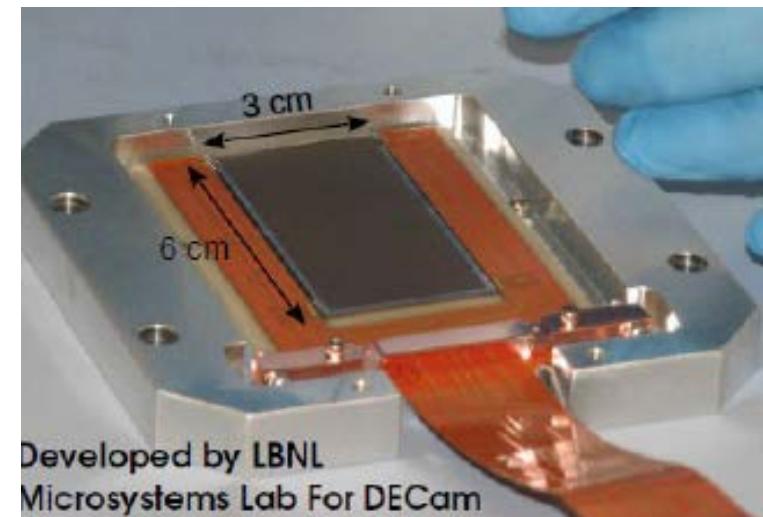
Even with LXe,



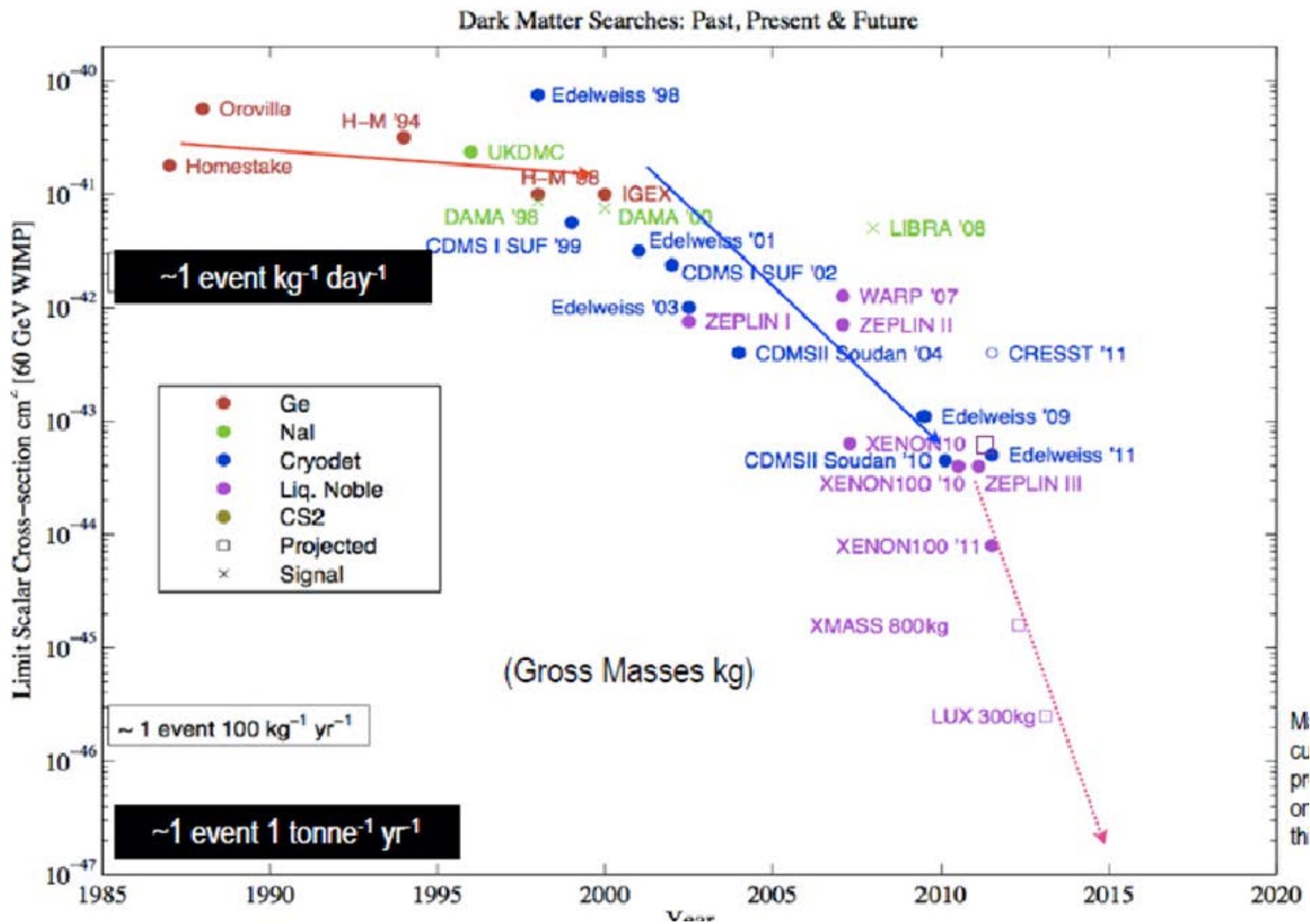
Gas chamber NEWS,



DM in CCD, DAMIC .....

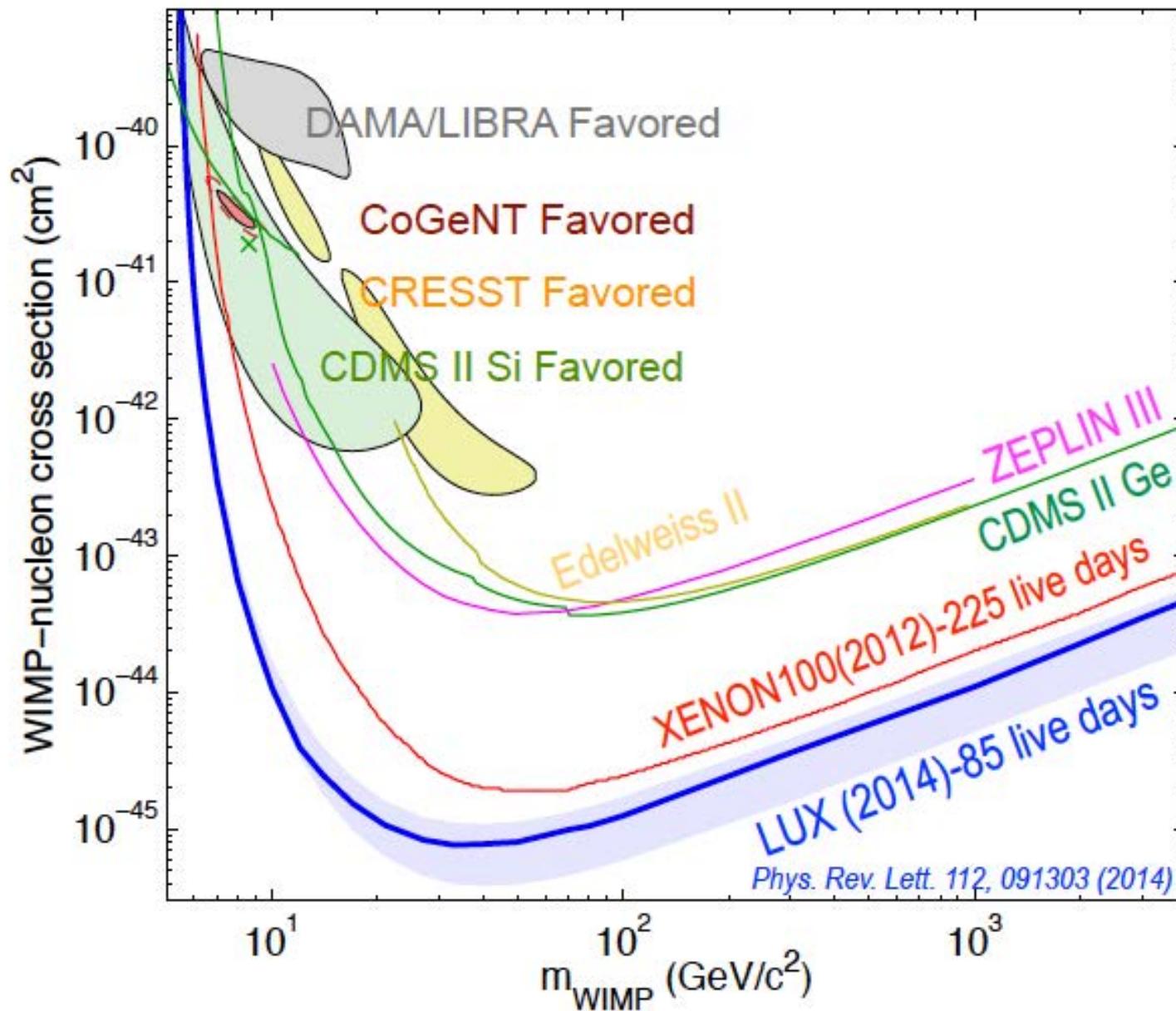


# Direct search history



# Present status

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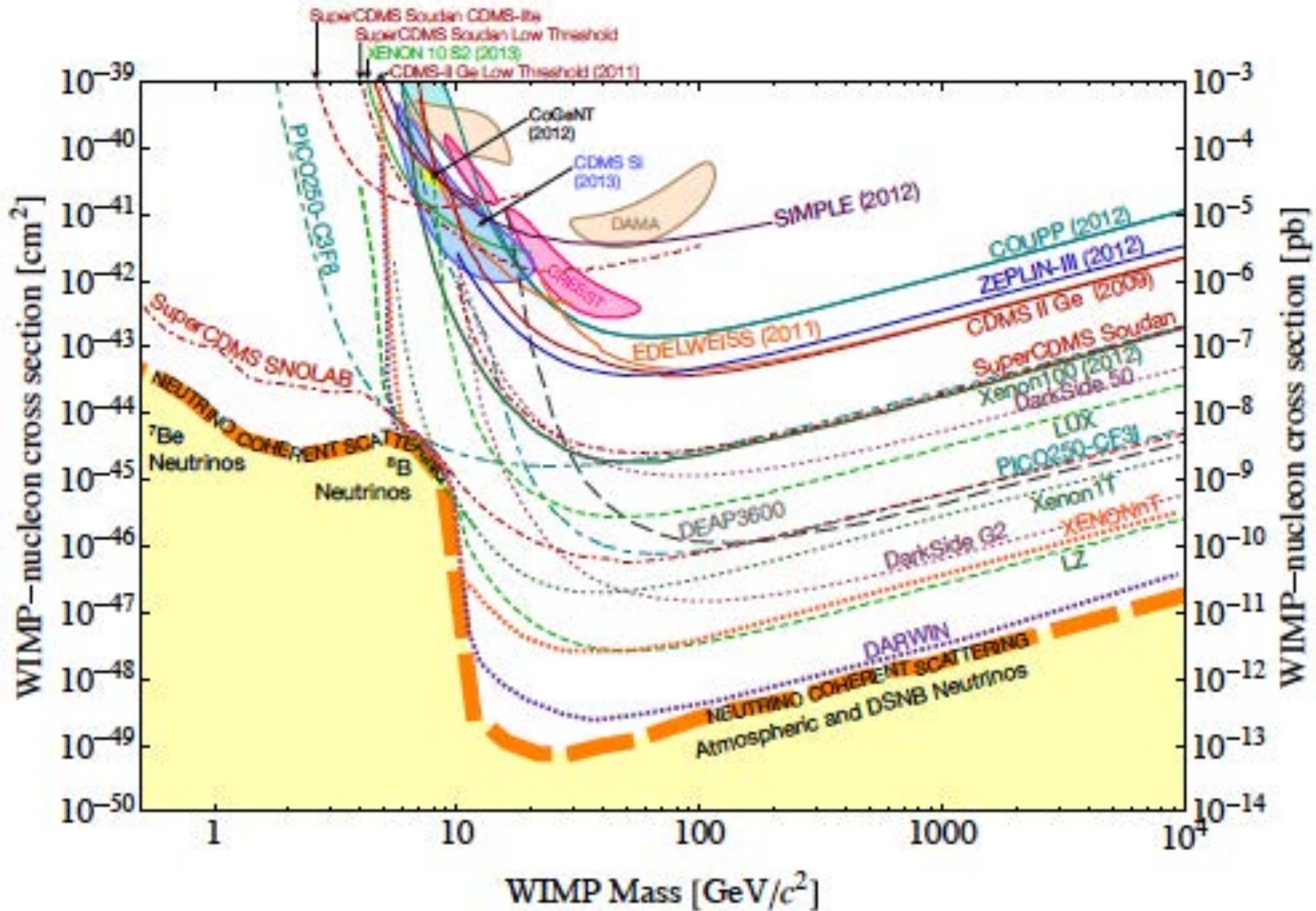


# Published results

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	target material	Ethreshold [keVnr]	mass [kg]	exposure [kg day]	Bkg. rate / [kgkeVday]	limit @ ~100GeV	limit @ 5GeV
DAMA	Nal	2/0.15=12	250	4.7E5	1		E-40*
DM-ICE	Nal	2/0.15=12	17	17 x 1300	7.9		~E-40*
SuperCDMS	Ge	1.6	9(4.2)	577	~11/(577*10)	E-43	~E-42
CRESST-II	CaWO4	0.6 0.307	2.5 0.3	29 52	8.5	~E-42	~E-40
CoGeNT	HPGe	0.5/0.2	0.33	~400	6 (C4 <1)		
CDEX-1	HPGe	0.48/0.2	1	54	4.1		~E-40
MALBEK	HPGe	0.6/0.2	0.465	90	3		~E-40
XMASS	LXe	0.3/0.1	851	851x6.1	~3		
XENON-100	LXe	6.6	34(FV)	34x225	5.3E-3 (no S2/S1)	E-44	
LUX	LXe	0.9/0.1	118(FV)	118x85.3	3.6E-3 (no S2/S1)	E-45	

# Expectation



# HPGe sensitivity

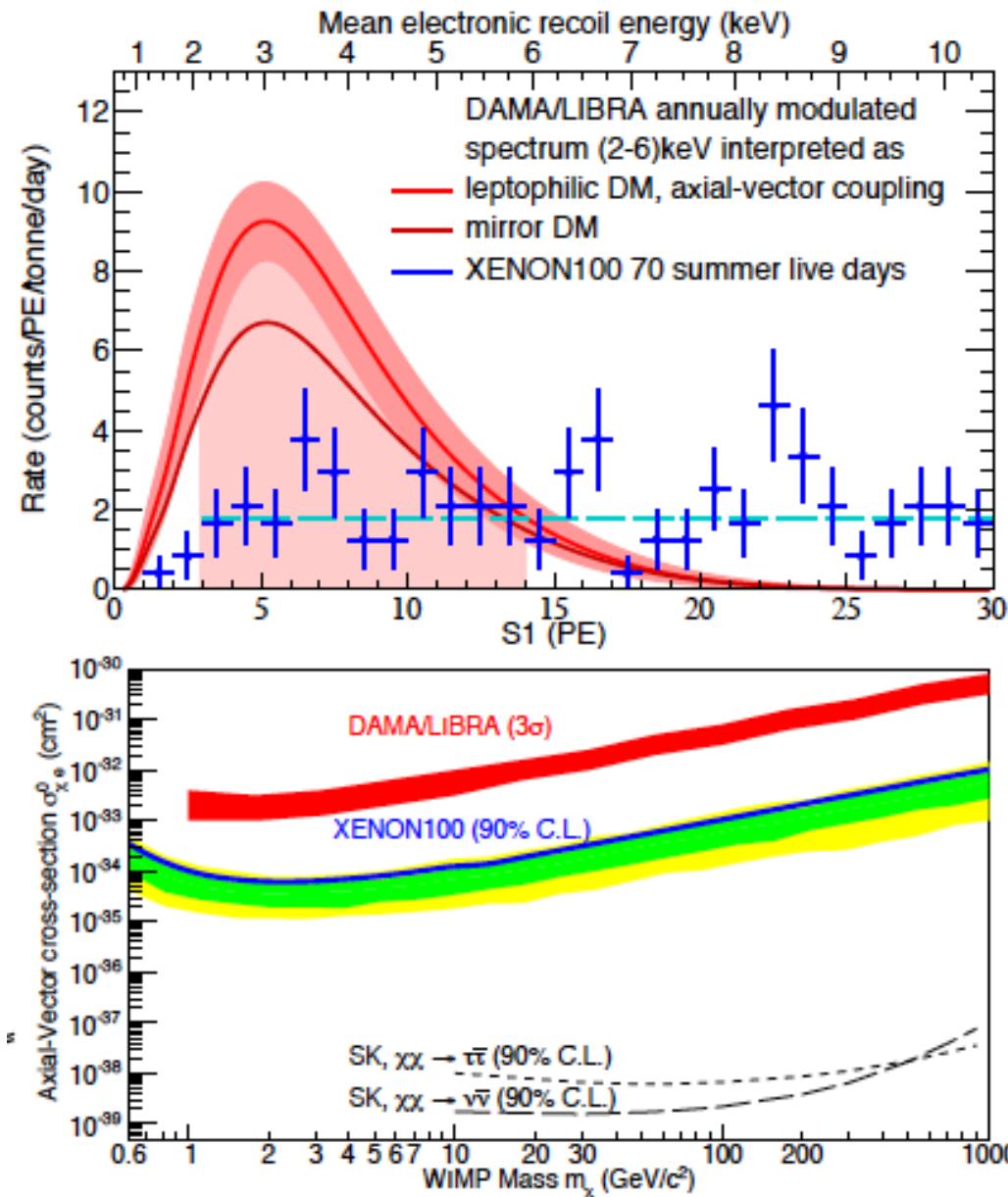
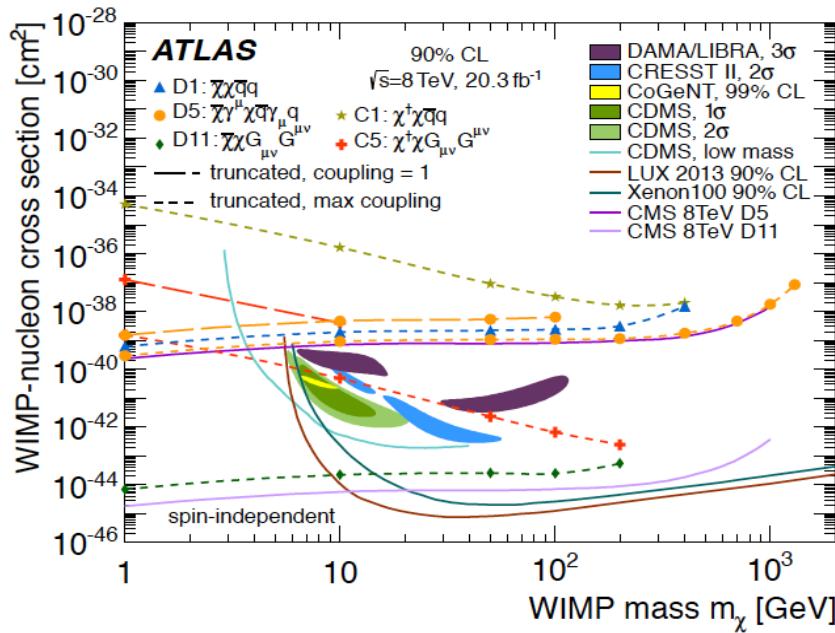
10GeV WIMP with  $\sigma_{SI} = 1E-40 \text{ cm}^{-2}$   $\rightarrow 0.16 \text{ evts}/[\text{kg}\cdot\text{day}]$

Assume ROI: 2-25keVnr (0.4-10keVee with Q=20%),  
bkg:  $0.1 / [\text{kg}\cdot\text{keV}\cdot\text{day}] = 1 / [\text{kg}\cdot\text{day}]$   
efficiency: 100%.

Exposure [kg•day]	#bkg	#WIMP	#WIMP /[kg•day]	$\sigma$ [cm <sup>-2</sup> ]
100	100	10	0.1	6E-41
70000	70000	260	3.7E-3	2E-42
365000	365000	600	1.6E-3	1E-42
 $\rightarrow$ bkg $0.1 / [\text{kg}\cdot\text{day}]$				
356000	36500	190	5E-4	3E-43
$\rightarrow$ Bkg $0.01 / [\text{kg}\cdot\text{day}]$				
3560000	3650	60	1.7E-5	1E-44

# summary

- Exciting results from many experiments, including CoGeNT and CDEX ...
- Low  $M_{\text{WIMP}}$  competition from LXe/LAr & LHC
- New types of HPGe? new methods for bkg. reduction? ...
- 上完甜点，进入正餐...



# backup

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# New challenge on DAMA signal

- keep BEGe core pulse properties,

