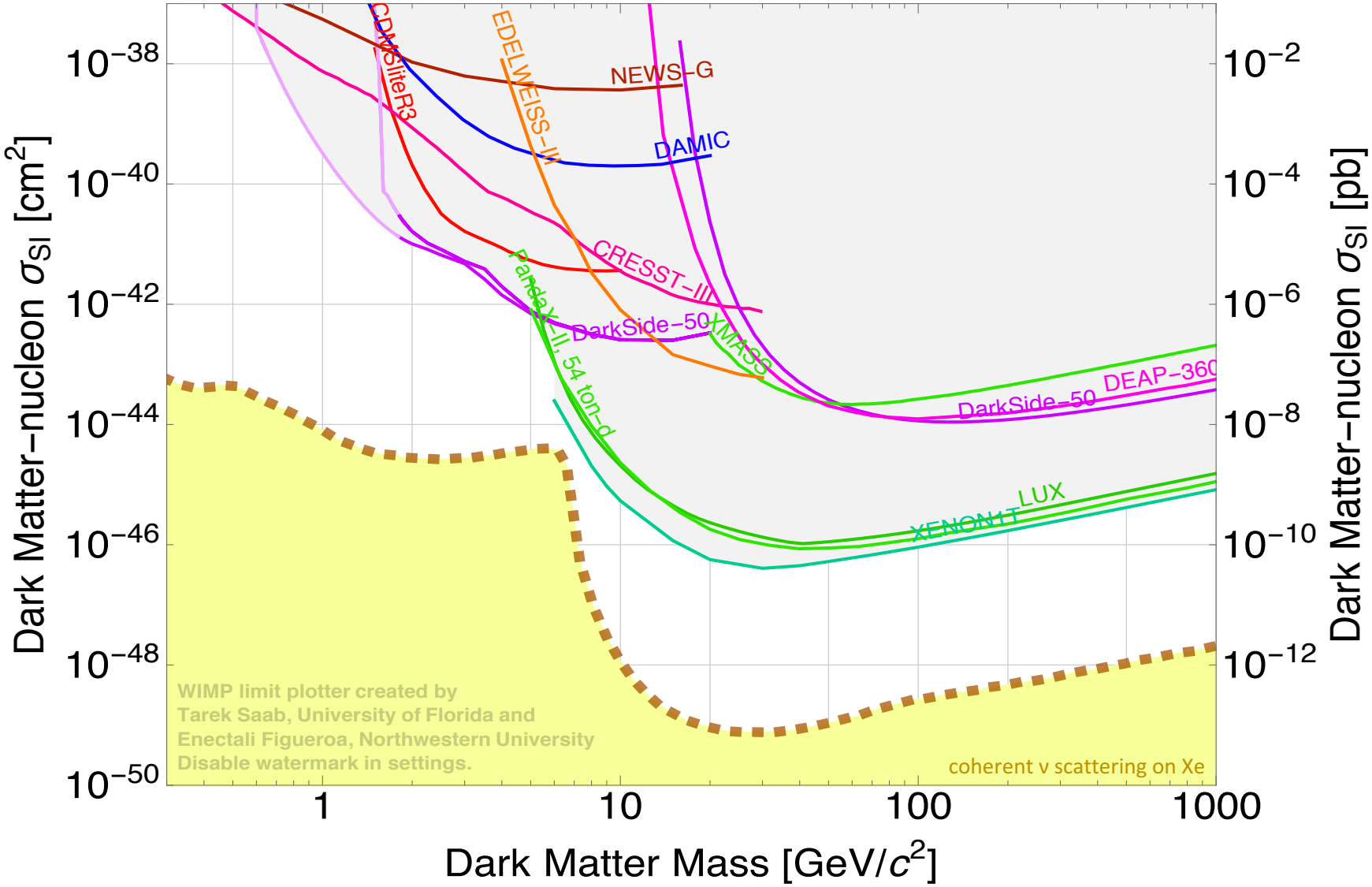
Conseil Scientifique de l'IN2P3, 25-26 octobre 2018

Direct Dark Matter searches: the experimental context

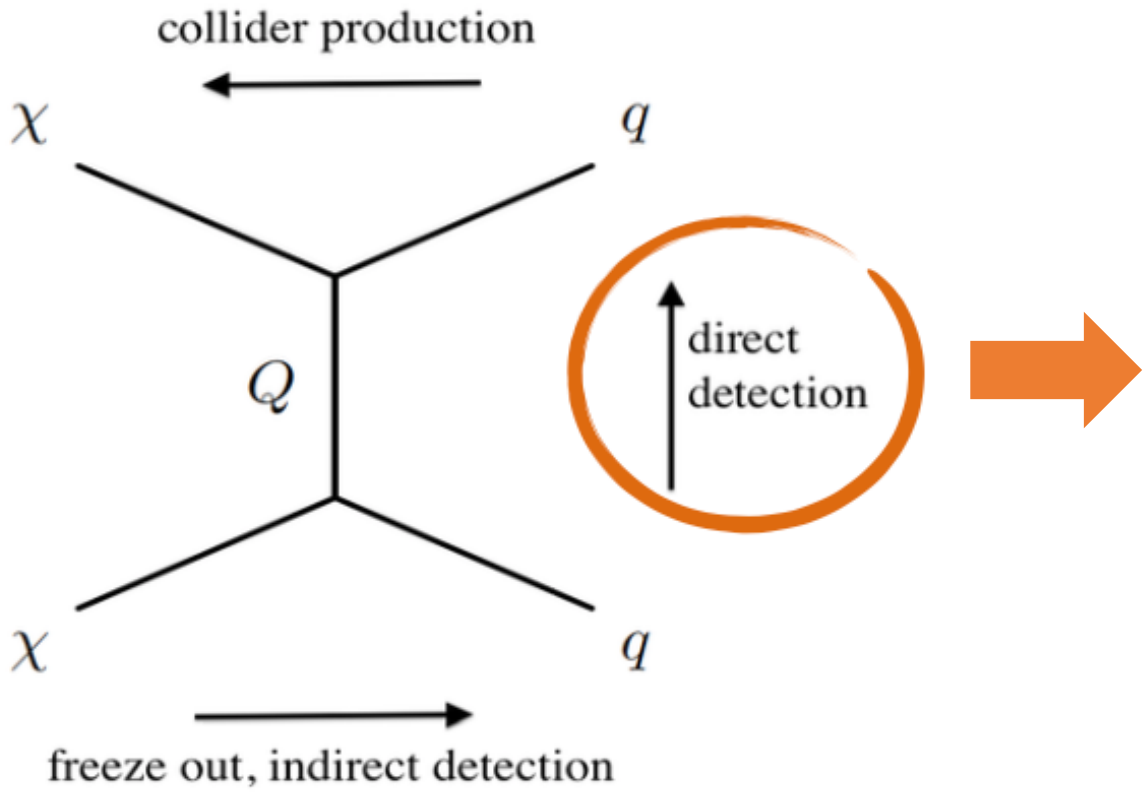
Alessandra Tonazzo (APC, Université Paris-Diderot)

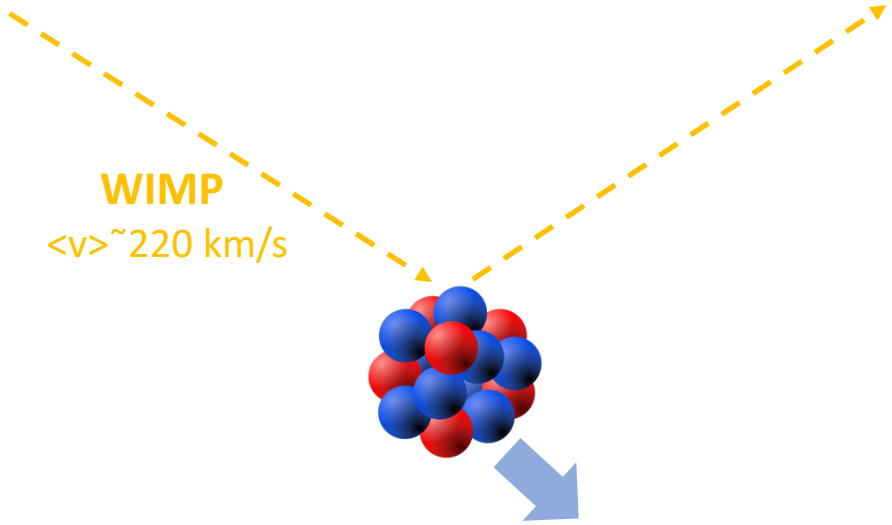
Direct search for WIMPs : current status



A personal selection

Direct detection of WIMPs



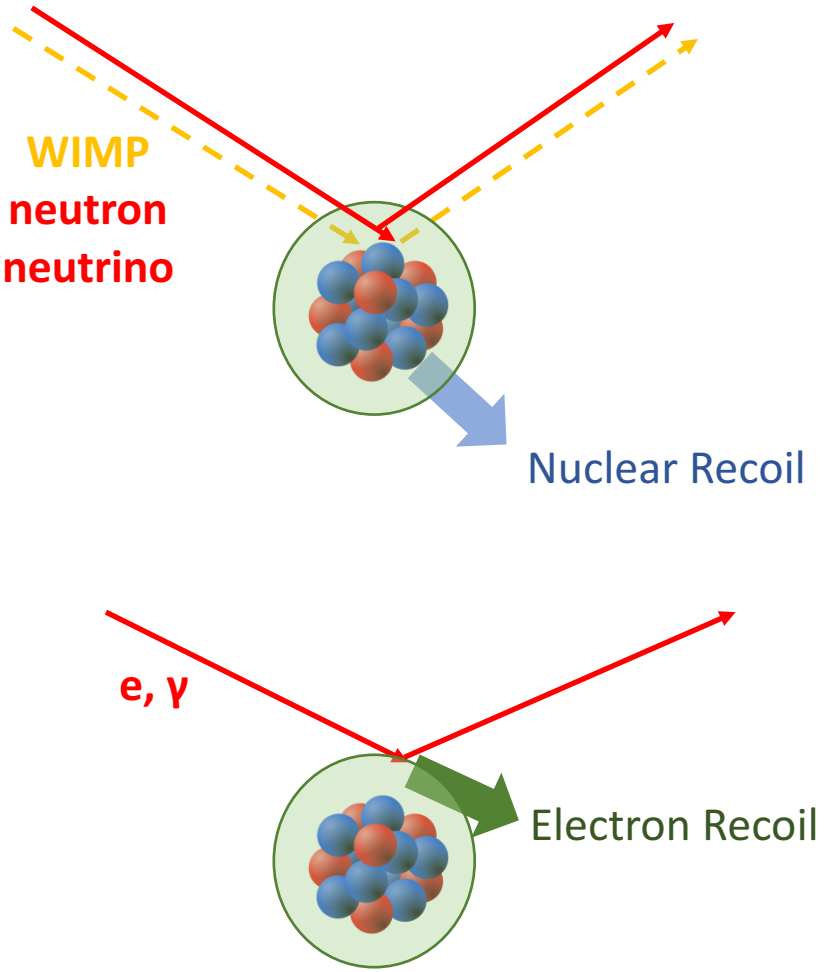


Nuclear Recoil
detectable signal
$E_R <$ 100 keV

Rate: ~1 evt/(ton*year)
for $\sigma \sim 10^{-47} cm^2$ in noble liquids

Backgrounds

- Cosmic rays and cosmogenic neutrons/isotopes
- Radioactivity, natural (^{238}U,^{232}Th,^{235}U,^{222}Rn,...) or anthropogenic (^{85}Kr,^{137}Cs,...), from detector elements
- Neutrinos (solar, atmospheric, diffuse SN) scattering coherently off nuclei
  ("neutrino floor")

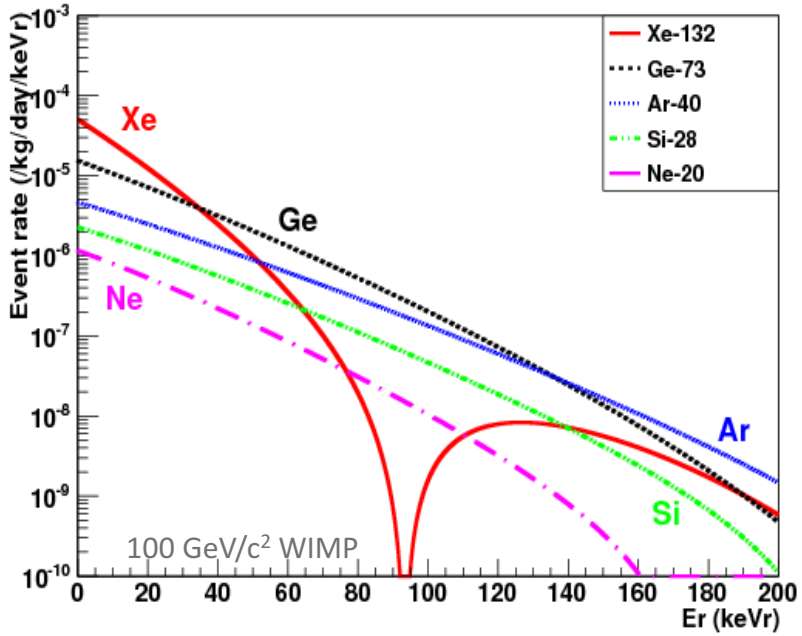


Possibility for background discrimination

Direct detection of WIMPs : signatures

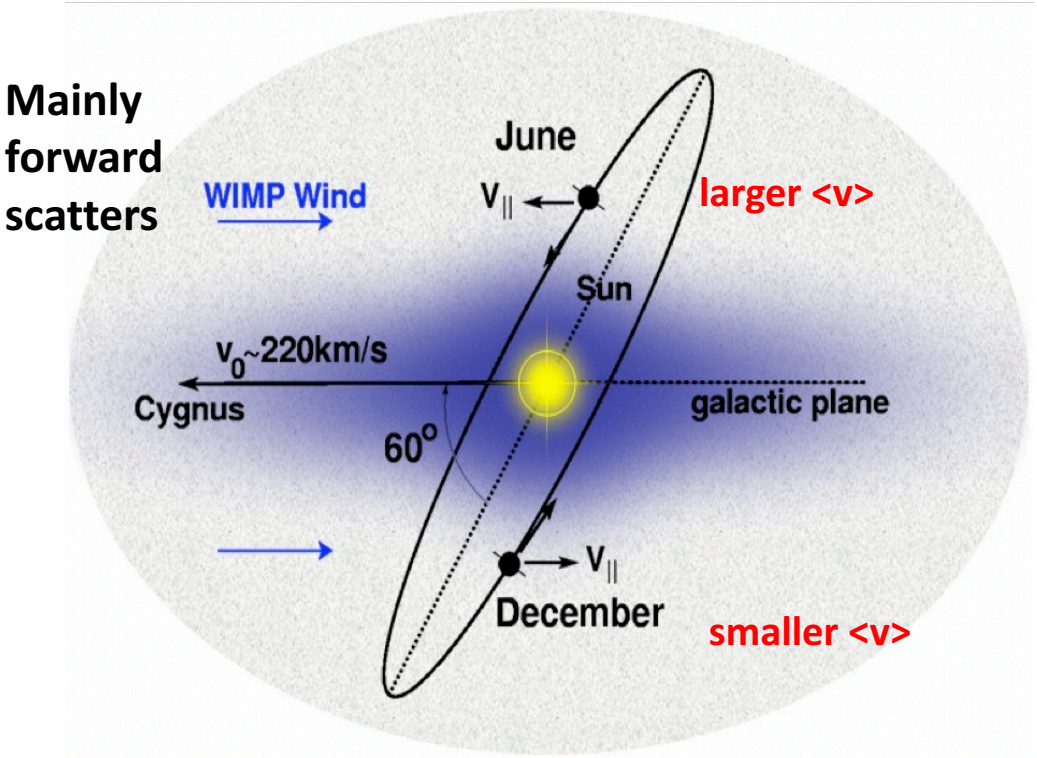
- Anomalous **rate** of low-energy nuclear recoils
- In case of positive signature, **additional evidence** of its nature is needed

Rate and spectra in different target materials



Directionality

Annual modulation

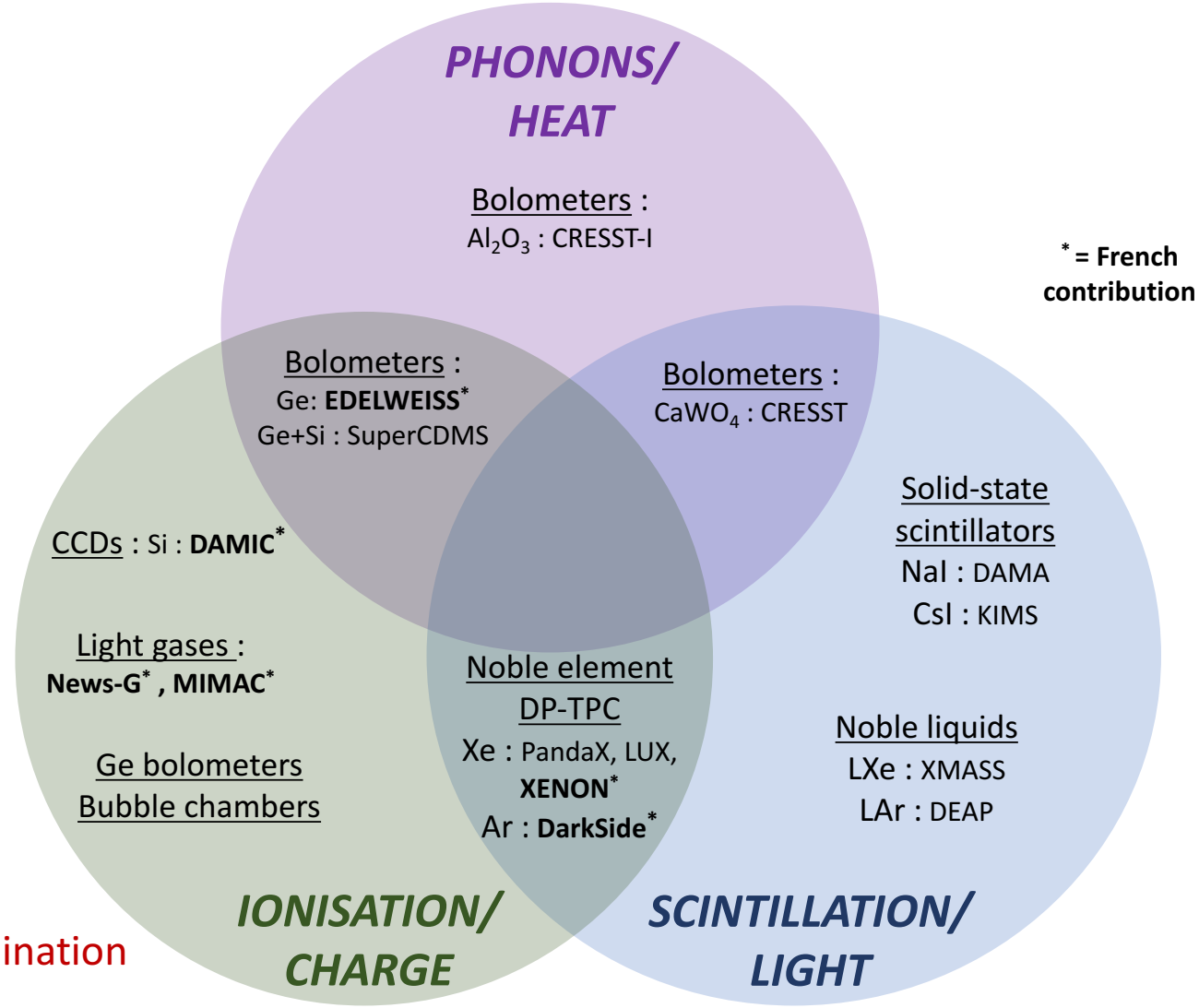


Detectors for direct WIMP search

Detector requirements :

- Large mass
- Low energy threshold
- Background suppression
  - ✓ deep underground
  - ✓ passive/active shielding
  - ✓ low intrinsic radioactivity
  - ✓ ER/NR discrimination
  - ✓ or specific signature (directionality, annual mod.)

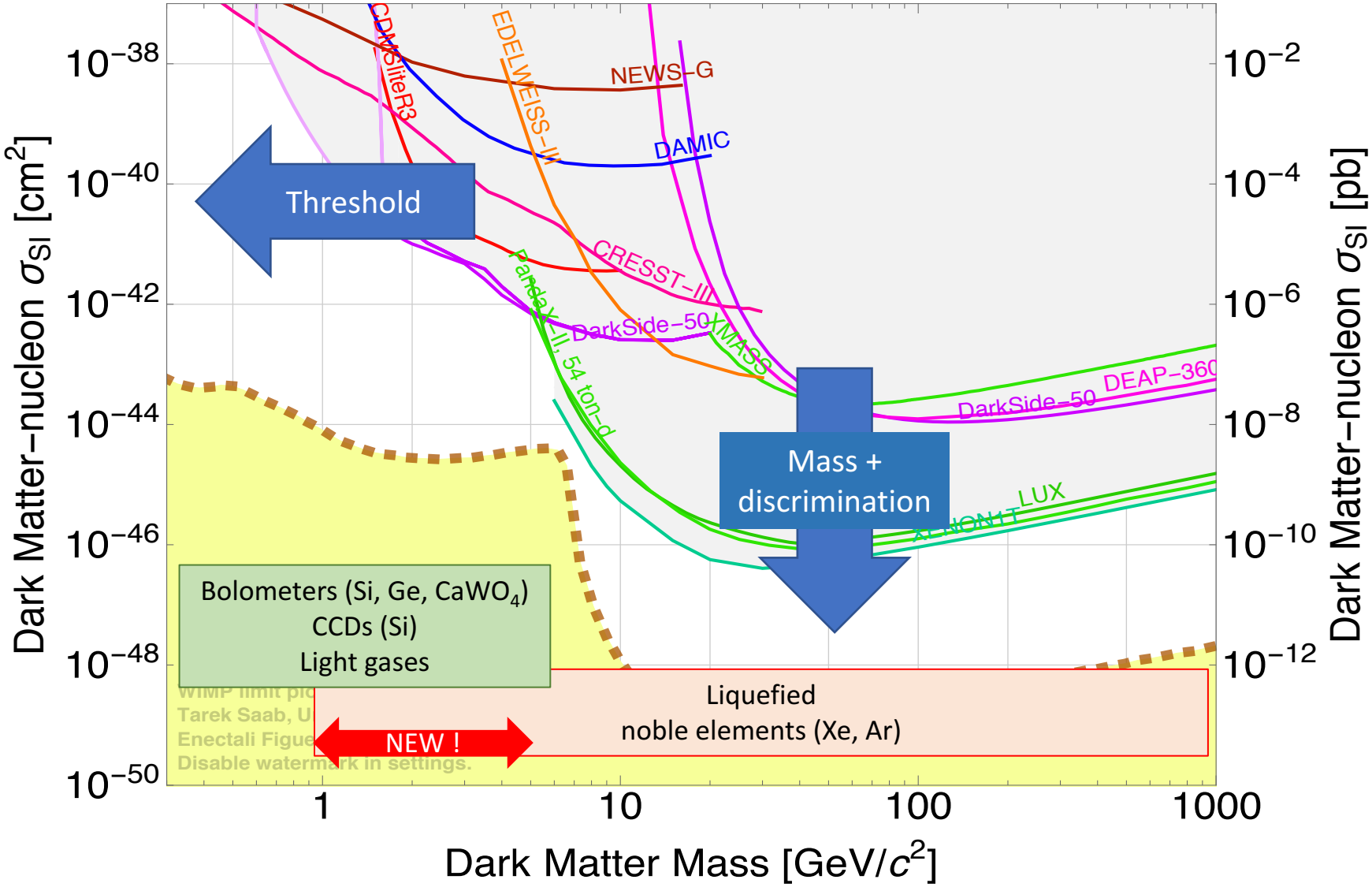
Direct detection techniques



* = French contribution

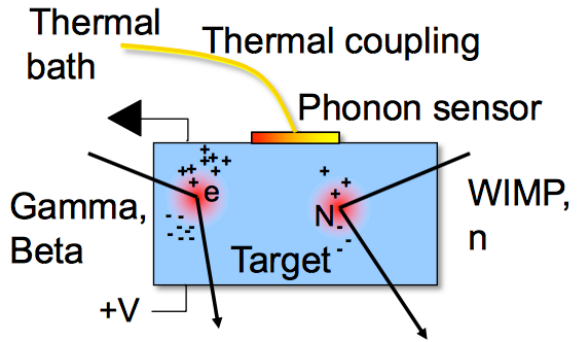
multiple signals → ER/NR discrimination

Direct search for WIMPs : status and strategies



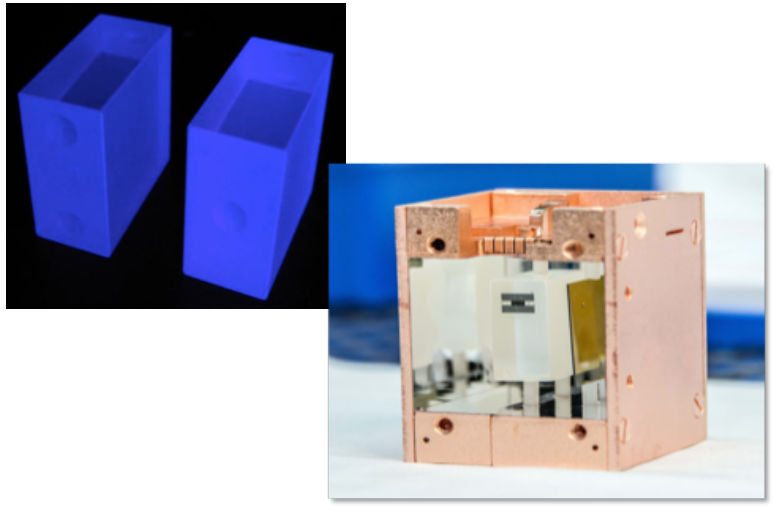
Cryogenic bolometers

+ low E threshold, excellent E resolution
+ good ER/NR discrimination from light or ionization yield
- need to operate in a cryostat
- limited crystal mass



HEAT + LIGHT

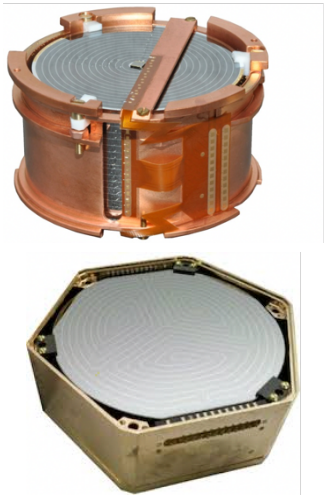
CRESST ($CaWO_4$ @LNGS)



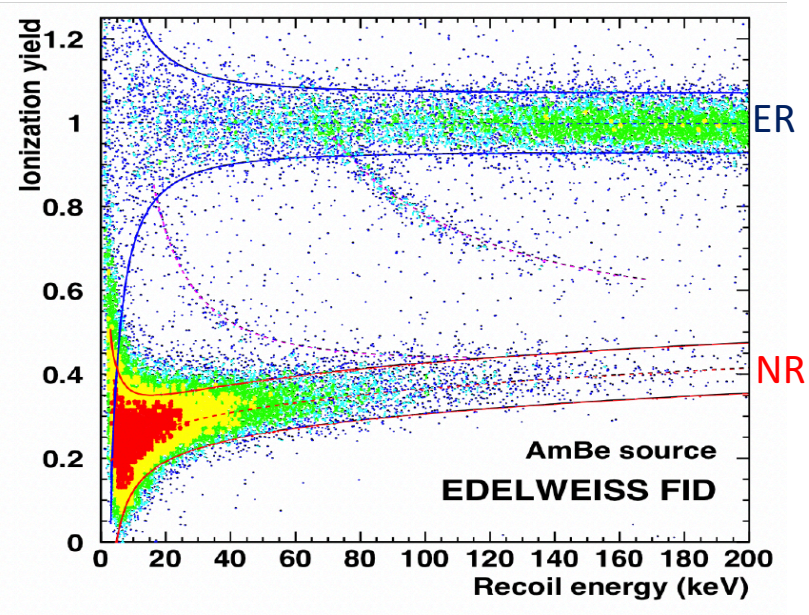
HEAT + CHARGE

EDELWEISS (Ge @LSM)

SuperCDMS (Ge/Si @Soudan)



→ *talk by J. Gascon*



Cryogenic bolometers : recent results

small size ➔ lower threshold

CRESST-III (2018,prel.)
- m_{det}~ 24 g x5
- exposure = 5.7 kg*day
- **threshold = 30 eV**

fiducialisation➔ surface bkg suppression

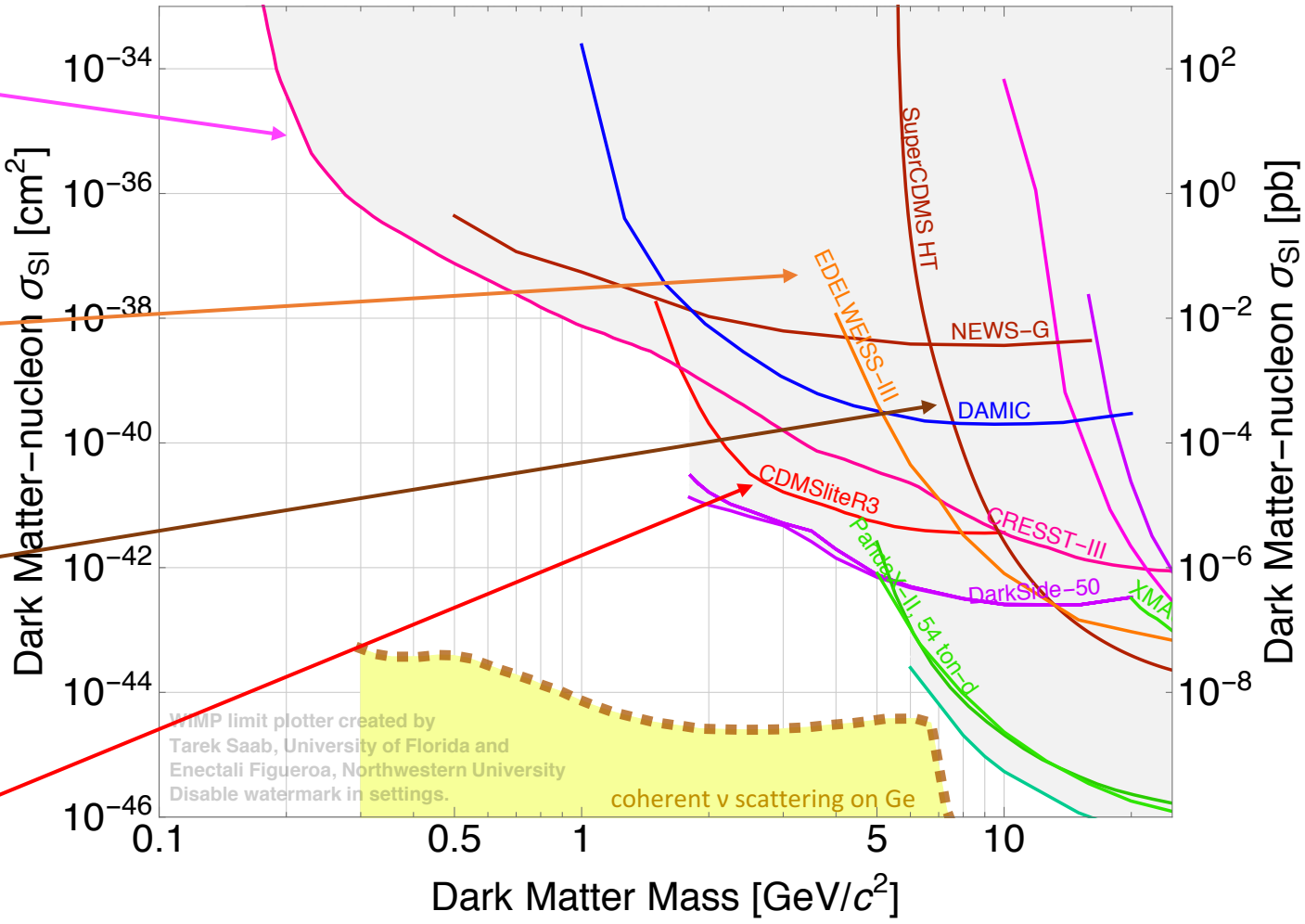
EDELWEISS-III (2016)
- m_{det}~ 870 g x24
- FID detectors
- exposure = 582 kg*day
- threshold = 900 eV

➔ *talk by J. Gascon*

SuperCDMS (2017)
- m_{det}~ 600 g x15
- exposure = 1690 kg*day
- threshold = 8 keV

high bias-V ➔ lower threshold (degraded PID)

CDMSlite-Run3 (2018)
- m_{det}~ 600 g
- large bias V (Luke-Neganov boost)
- exposure = 36(60) kg*day
- **threshold = 70 eV**



Cryogenic bolometers : future strategies

Lower E threshold

1-5 GeV/c² → Higher bias-voltage
(Luke-Neganov boost)

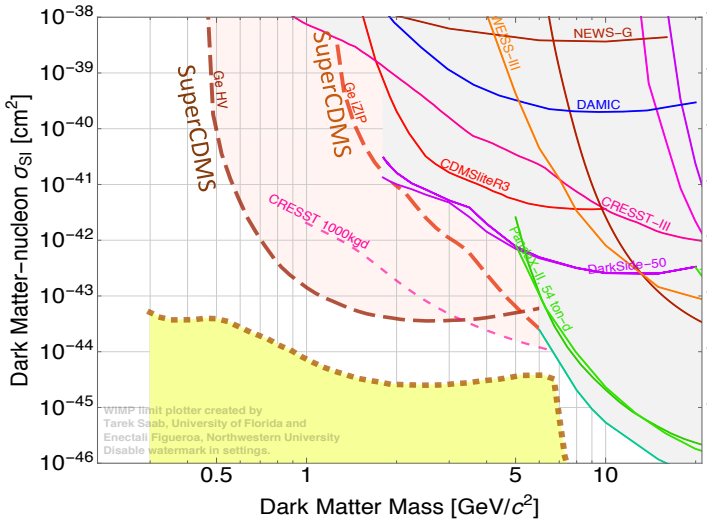
SuperCDMS-HV @SNOLAB

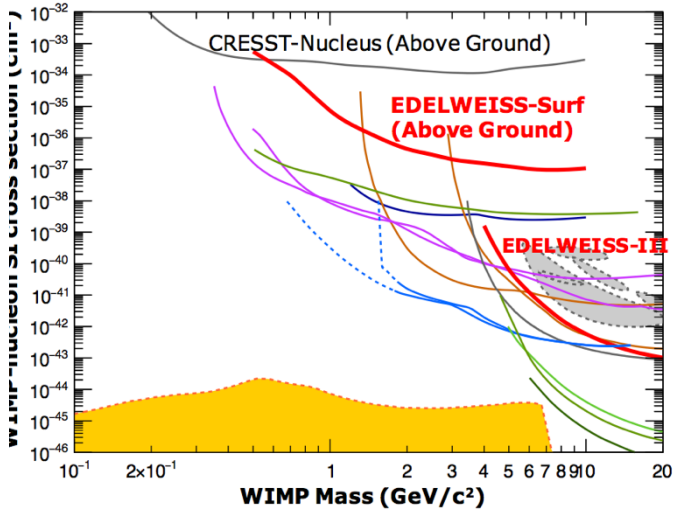
EDELWEISS-LT 500/100 kg*d

0.1-1 GeV/c² **[NEW!]** → Smaller-mass crystals
(above-ground operation so far)

CRESST-above ground 0.5g Al_2O_3

EDELWEISS-Surf 32g Ge





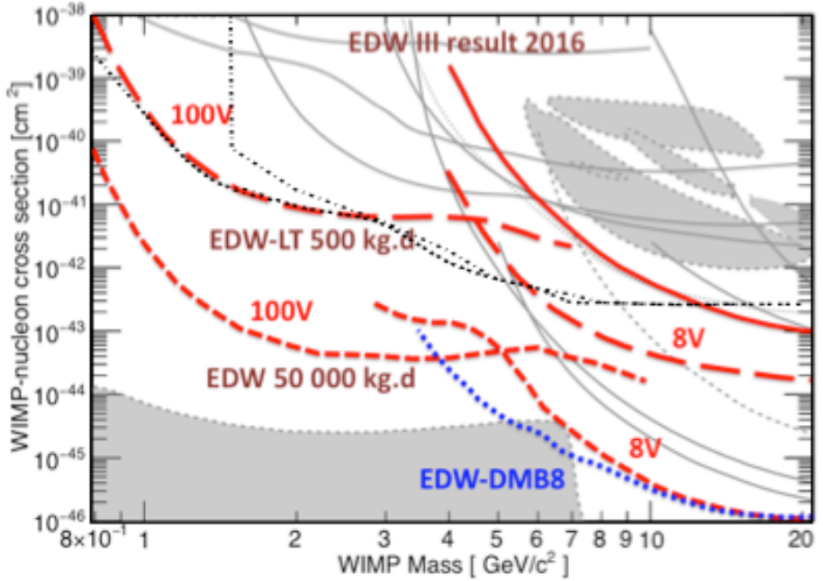
Improved background discrimination

→ better ionization resolution

EDELWEISS-DMB8, 200 kg @SNOLAB

→ surface background rejection

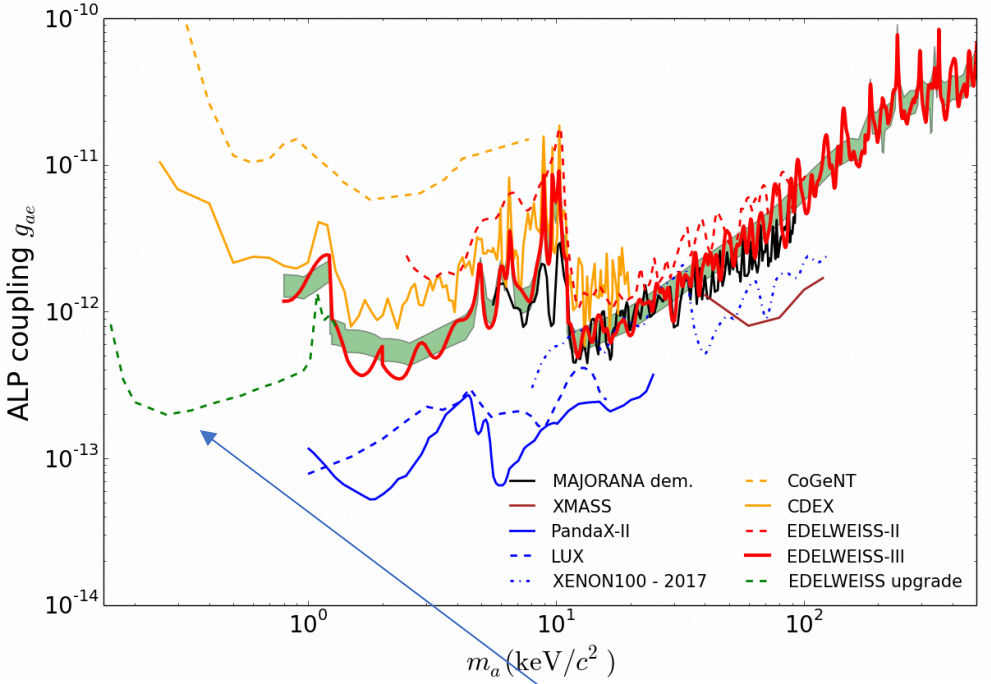
SuperCDMS-iZIP @SNOLAB

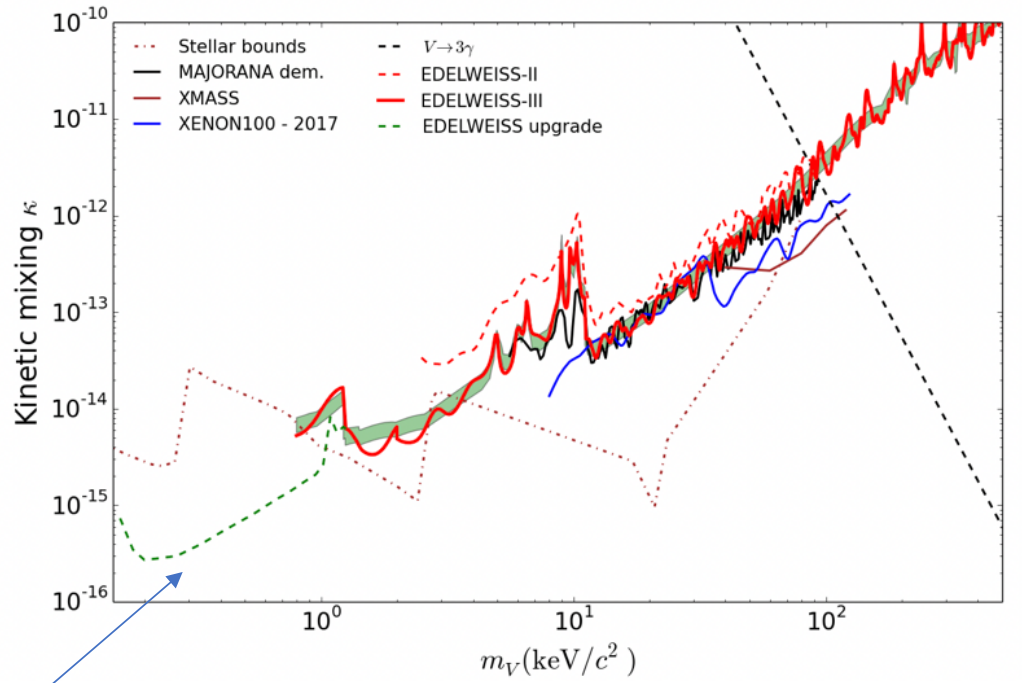


→ *talk by J. Gascon*

Other DM candidates

Electron recoil signal from scattering of very low-mass DM (Axions or Axion-Like Particles)
or from absorption of Dark Photons





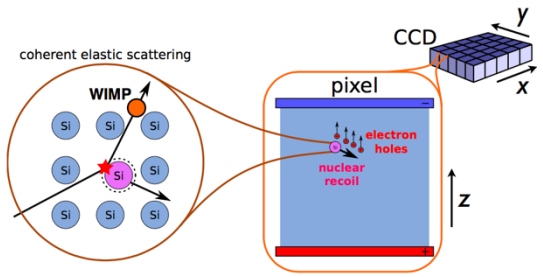
EDELWEISS with improved ionisation will extend reach to lower masses

→ *talk by J. Gascon*

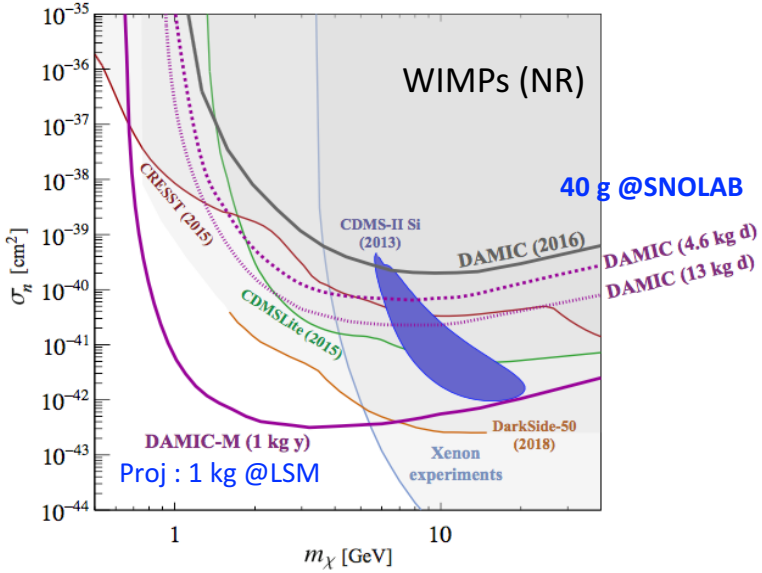
Silicon detectors

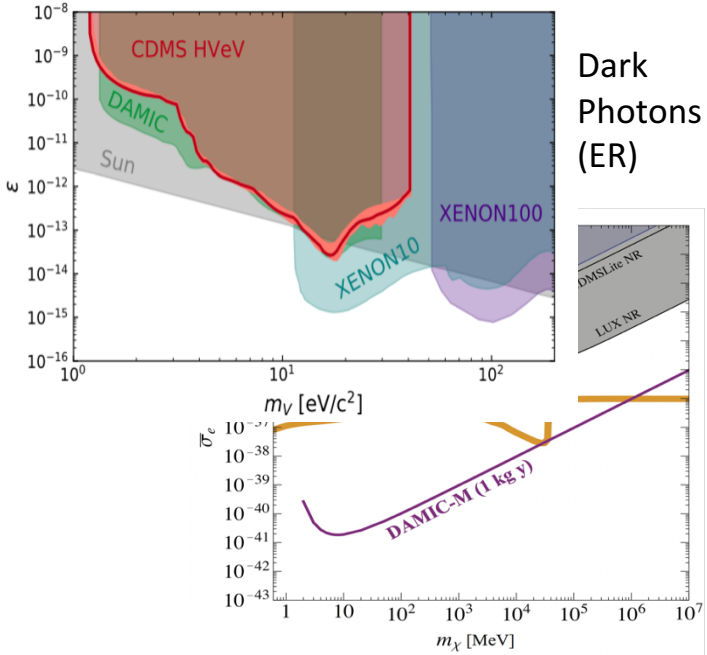
Si-CCDs **DAMIC**

→ *talk by A. Letessier-Selvon*



3D position reco
PID from cluster pattern



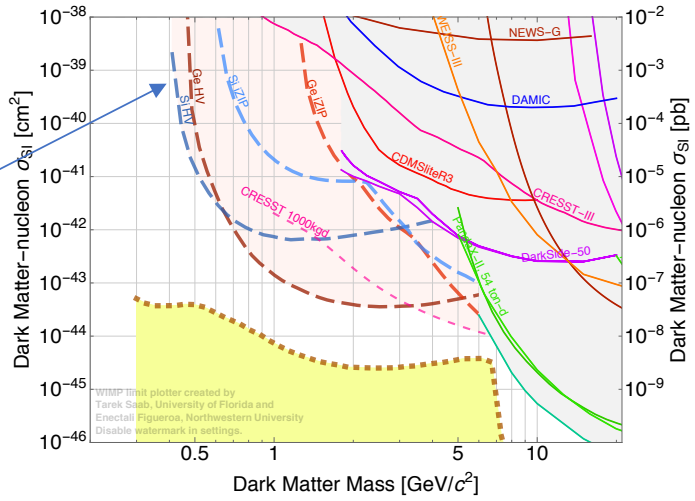


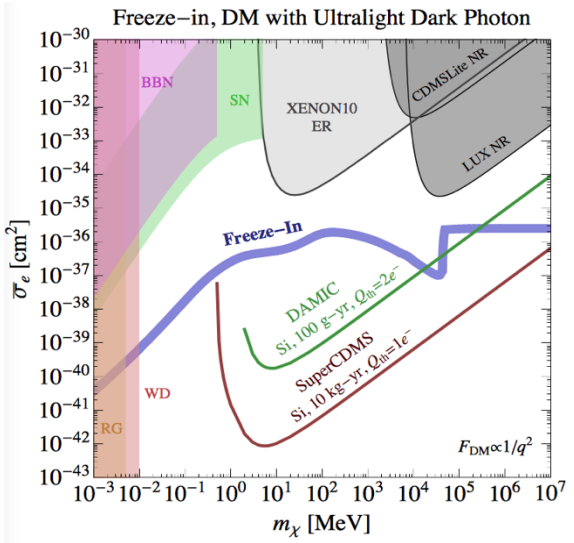
Dark Photons (ER)

Si-bolometers **SuperCDMS**

+ Lower energy threshold for WIMP searches
+ Single-charge resolution achieved in HV mode (ER)

CDMS-HVeV, 0.49 g*day (2018)
Projection 50 kg*y

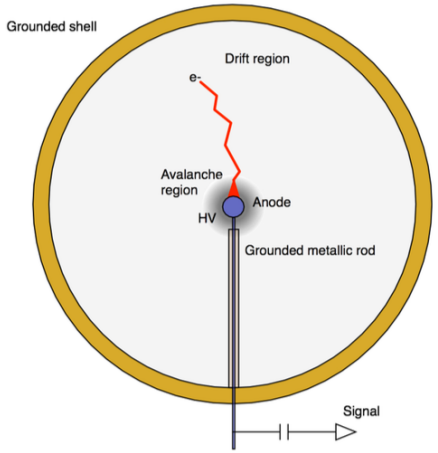




Gaseous detectors

NEWS-G

→ *talk by P. Lautridou*

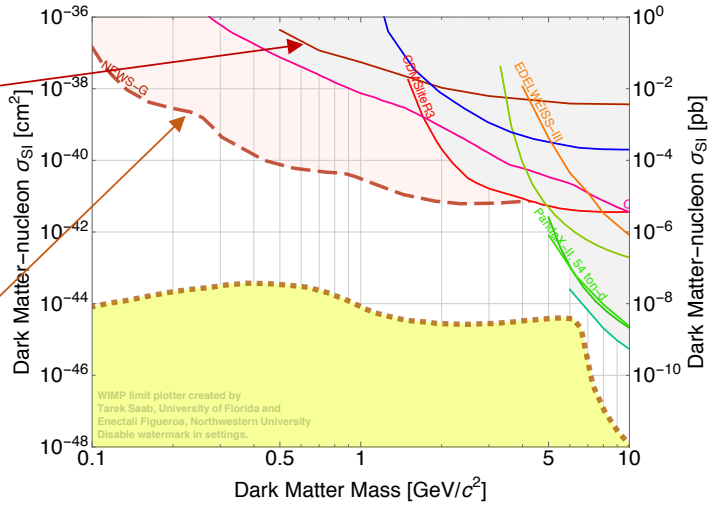


Light gases ➔
low mas WIMPs

Results (@LSM) :
- 60cm diam
- Ne-CH_4mix
- exp. 9,7 kg*d

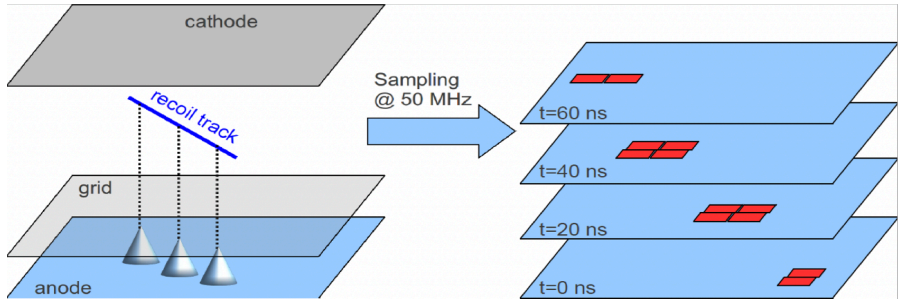
Prospects (@SNOLAB):
- 140cm diam
- H / He

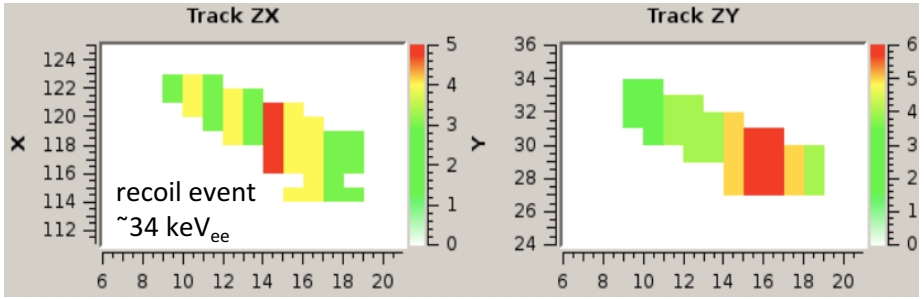
→ down to 0.1 GeV/c^2



MIMAC ➔ DIRECTIONAL DETECTION

→ *talk by D. Santos*





Other techniques for directional detection :
emulsions, anisotropic crystals, LAr

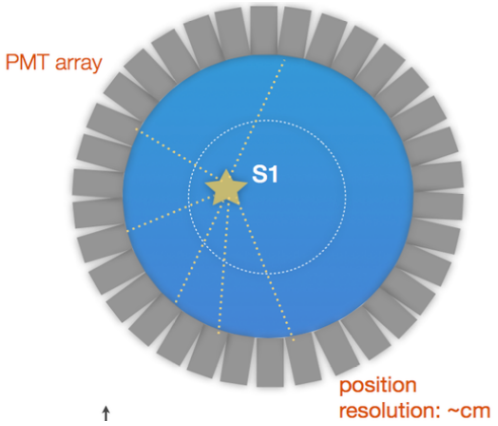
Noble liquid detectors (LXe, LAr)

- Non segmented, homogeneous, compact detectors
- Easily scalable to very large masses
- accurate position reconstruction -> background rejection
- ER/NR discrimination from light + charge
- in LAr, ER/NR discrimination also from scintillation pulse shape (PSD)
- in LAr, intrinsic contamination from ^{39}Ar → Underground Ar, Depleted Ar

Single-phase LIGHT ONLY

LXe : **XMASS** (832 kg @ Kamioka)

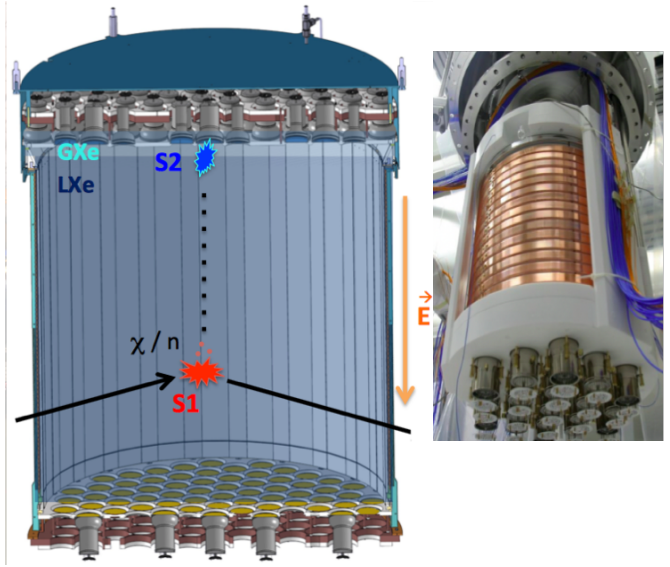
LAr : **DEAP-3600** (3600 kg @SNOLab)

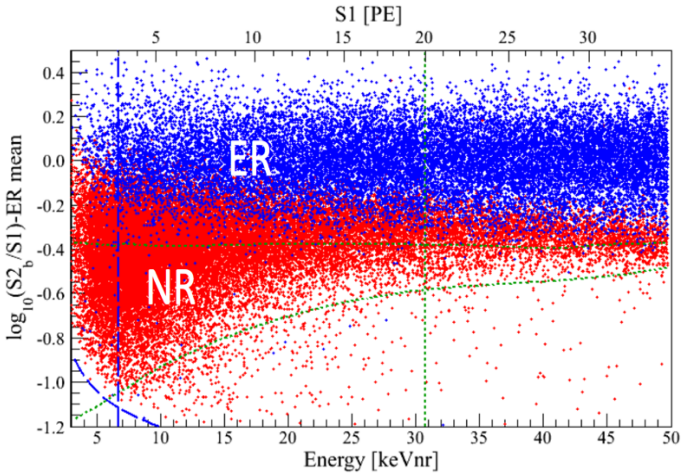


Dual-phase LIGHT(S1) + CHARGE(S2)

LXe : **XENON-1t** (1.3t @LNGS), **LUX** (118 kg@SURF), **Panda-X** (500kg @CJPL)

LAr : **DarkSide-50** (38kg @LNGS), **ArDM** (800 kg @CANFRANC)



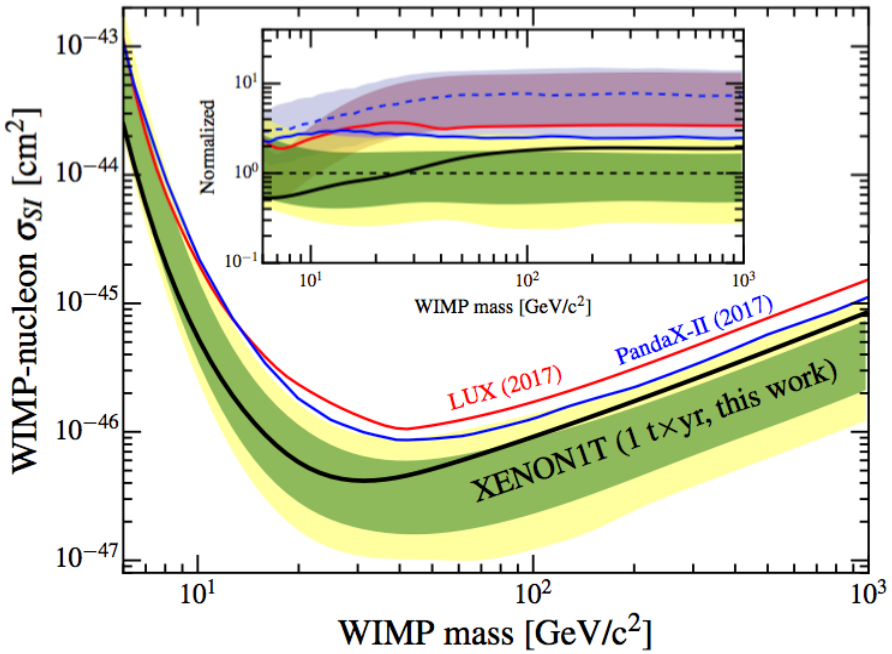


Noble liquid detectors : recent results

Xe

XENON-1t (2018) 1 t*y

current best limit
in high-mass region



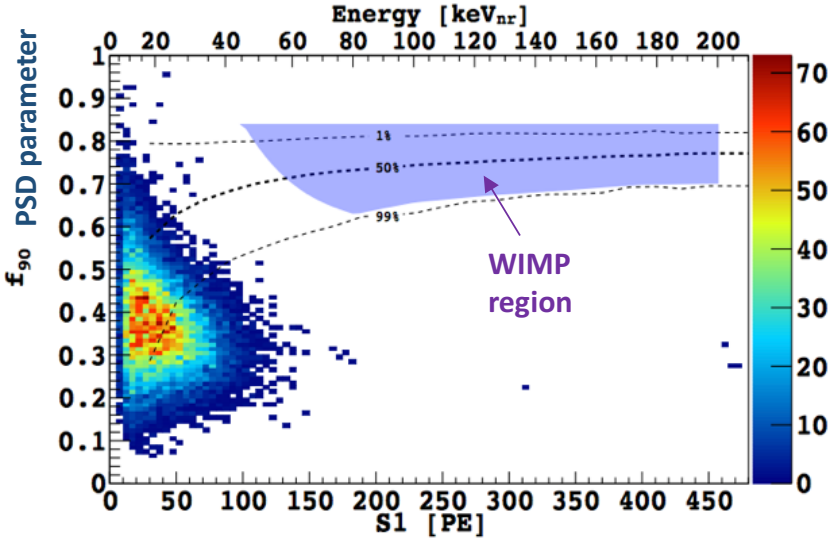
→ *talk by D. Thers*

Ar

DakSide-50 (2018)

16660 kg*d UAr

background-free result
(using PSD)



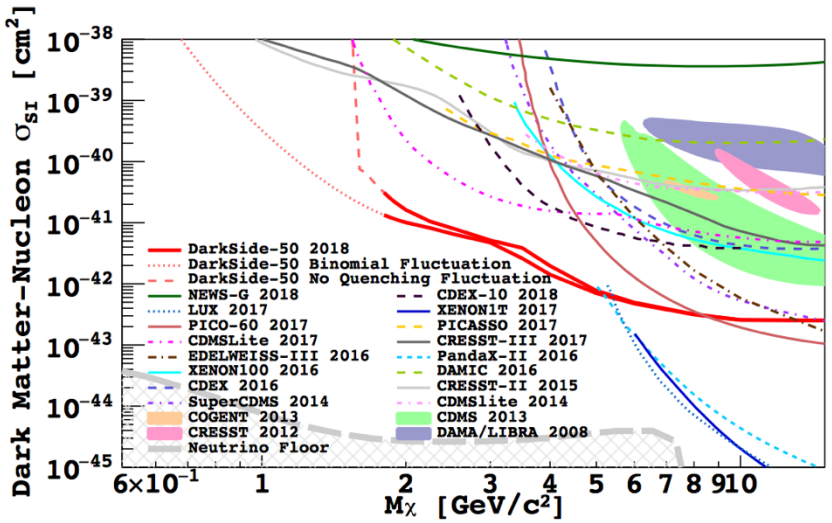
Ar

DakSide-50 (2018)

6786 kg*d UAr

current best limit
1.8-6 GeV/c^2
(ionisation only)

→ *talk by D. Franco*



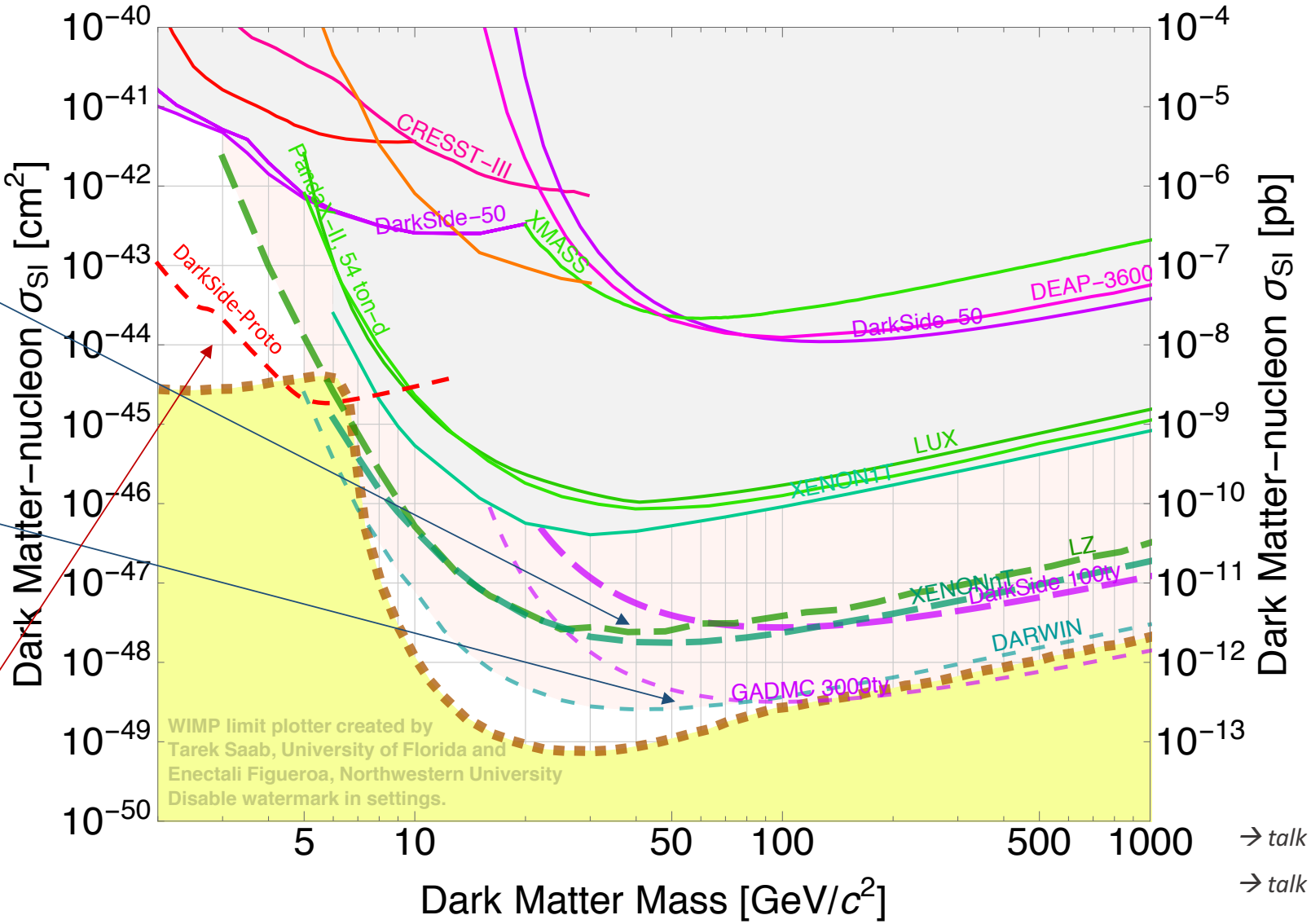
Noble liquid detectors : future perspectives

High-mass WIMPs

Muli-ton (2020-2025)
- **Lux-Zeplin (LZ)**
  10t LXe @SURF
- **XENON-nT**
  8t LXe @LNGS
- **DarkSide-20k**
  20t DAr @LNGS

global efforts (>2025)
- **DARWIN** 50t LXe
- **GADMC** 300t DAr

Low-mass WIMPs
- **DarkSide-Proto**
  1t UAr @LNGS



→ *talk by D. Thers*

→ *talk by D. Franco*

Summary and outlook

- A wide range of WIMP parameter space is being explored, with a variety of complementary techniques
- Next generation detectors will extend the sensitivity
  - lower threshold
  - better background rejection
  - larger masses
- In case of a positive signal, its nature must be probed
  - different target materials
  - directionality
- Searches for other types of DM candidates (Axions-ALPs, Dark Photons) offer interesting perspectives