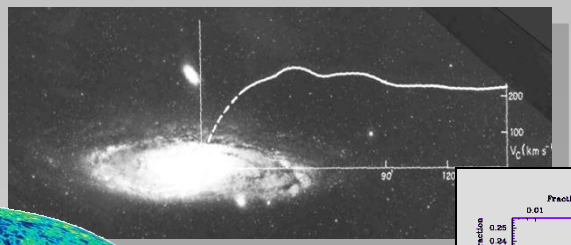
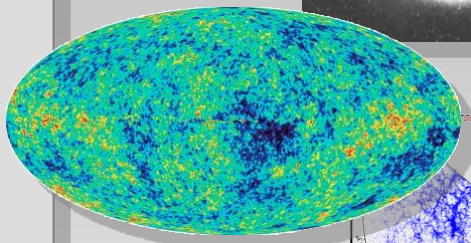
Direct Search for Dark Matter

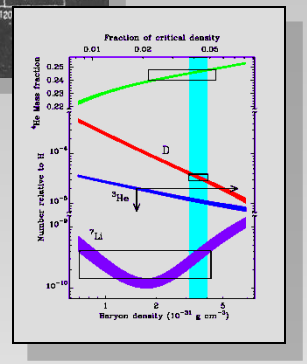
Dark Matter in the Universe $\Omega = 0.23$

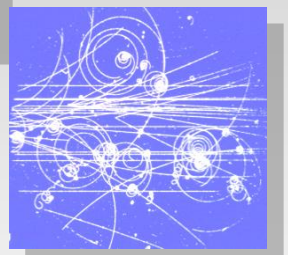
- non-baryonic
- not neutrinos

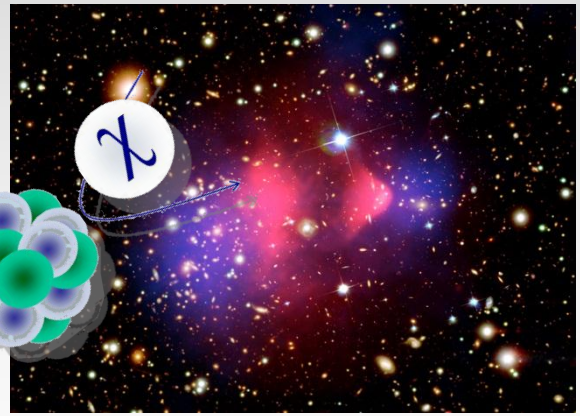
$\Rightarrow$ **physics beyond the standard model**











thermal relics from Big Bang
weakly interacting
in the mass range ~(10 – 1000) GeV
could nicely explain Dark Matter

$\Rightarrow$ can be detected by direct detection
elastic scattering off nuclei
$\Rightarrow$ could be supersymmetry

Josef Jochum
Eberhard Karls Universität Tübingen
Kepler Center for Astro and Particle Physics

WIMP – Direct Detection

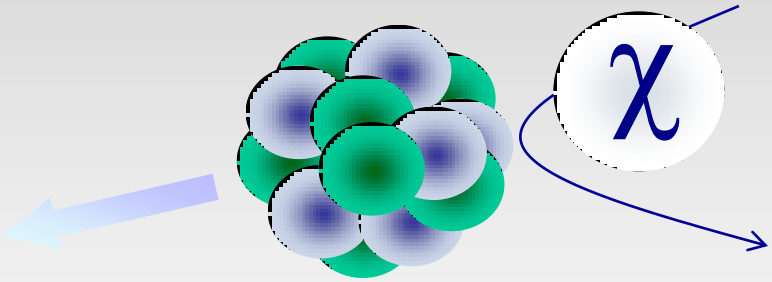
W**eakly **I**nteracting **M**assive **P**articles = **WIMPs

Elastic Scattering off Nuclei

- **Nuclear Recoils:** reduced efficiency for charge- or light-production

  - Mass GeV - ~ $1000\ GeV$
  - relative speed $270\ km/s$

    (~ oprbital speed in Milky Way)



$\Rightarrow$ only a few keV of energy

- cross section $\sigma_\chi < 10^{-36} cm^2$
- local WIMP-Density $\rho_\chi = 0.3\ GeV / cm^3$
  - *corresp. 3 WIMPs$^{(100GeV)}$ / Liter*
  - *75000 /s /cm^2*

$\Rightarrow$ very very rare scattering events(< 1 / Week / kg)

Today's sensitivity < 1 / year / kg

Direct DM Searches

remarkable progress

x 1000 improvement in sensitivity
in 10 yrs

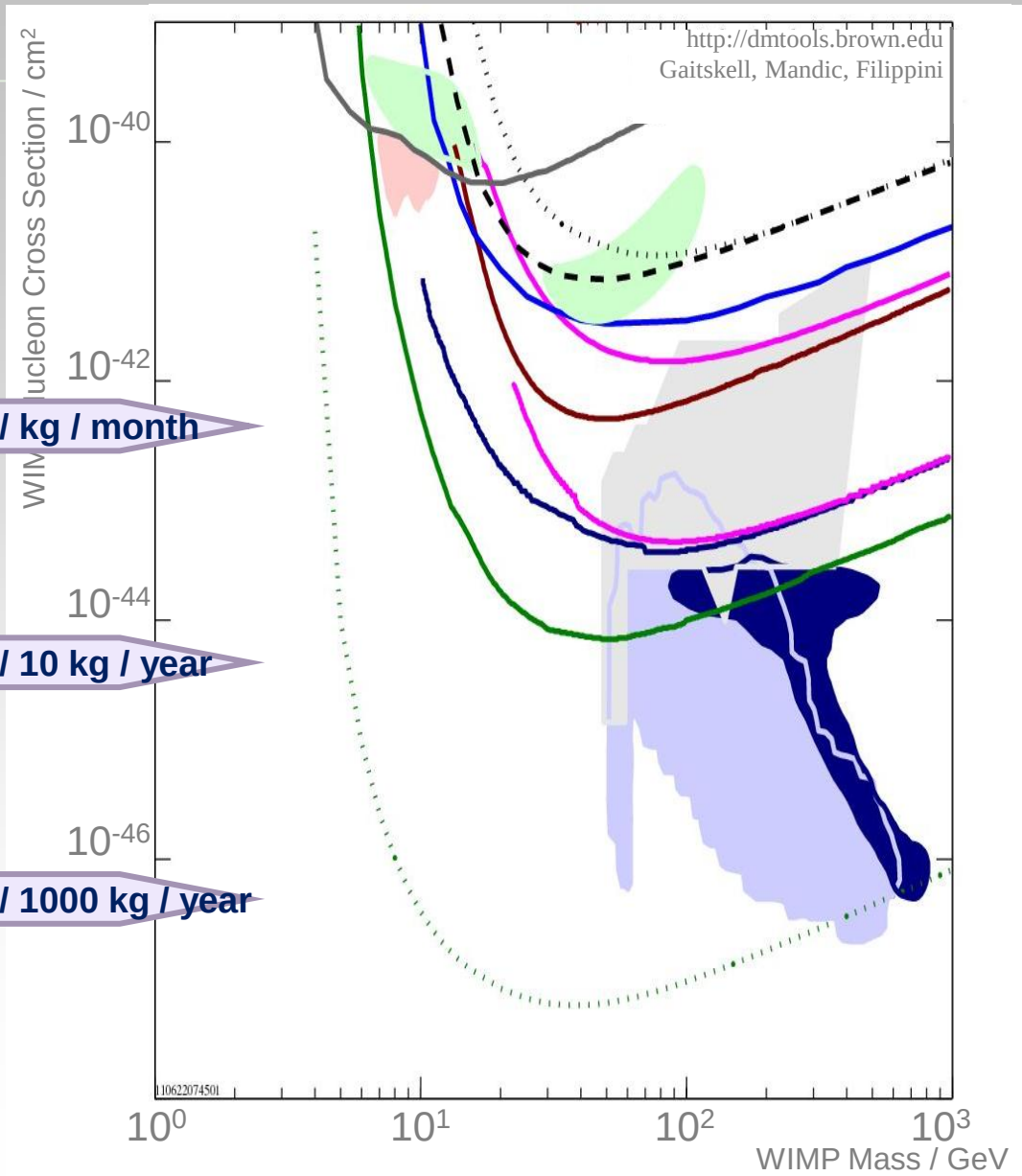
present best sensitivities
(for spin independent WIMP scattering)

- cryogenic
- liquid Xenon

+ other techniques
(doing better for spin dependent WIMP scattering)

we have different techniques with promising sensitivity

simultaneously
LHC is running
and will march upward in mass



Direct DM Searches - Worldwide

Direct
Dark Matter Search

COVENTIONAL
NaI, CsI, Ge

run 250kg NaI
run 100kg CsI

DAMA
Italy

KIMS
Korea

run ~1kg Ge

COGENT
US

prototypes

ANAIS
Spain

CRYOGENIC

run
~ 10kg, 2012
plan
~ 1t, 2015

CRESST
Germany, UK, Italy

EDELWEISS
France, Germany, UK, Russia

CDMS
US, Can., Switzerlnd

prototypes

Rosebud
France, Spain

LIQUID NOBLE GASES

XENON

run ~ 30kg
2012
plan
~ 1t, 2014

XENON
USA, Switzerl. Italy, Japan, Portugal, Germ. France, China

run
~ 100kg

XMASS
Japan

prepare
~ 100kg

LUX
10 US institutions, Moscow

ARGON

prepare
~ 100kg–1t
plan
> 1t

ArDM
Switzerland, Spain, UK, Poland

DARK SIDE
US, Italy, Rus, Poland China, Ukraine, UK

DEAP/ CLEAN
Canada, US

finsihed

WARP
Italy, US

DROPLETS

runs 4kg
starts 60kg
prepares 500kg

COUPP
USA

runs 2kg

PICASSO
Canada, USA, Czeck

very good spin dependent limits

DIRECTIONAL

first runs

DRIFT
UK, US

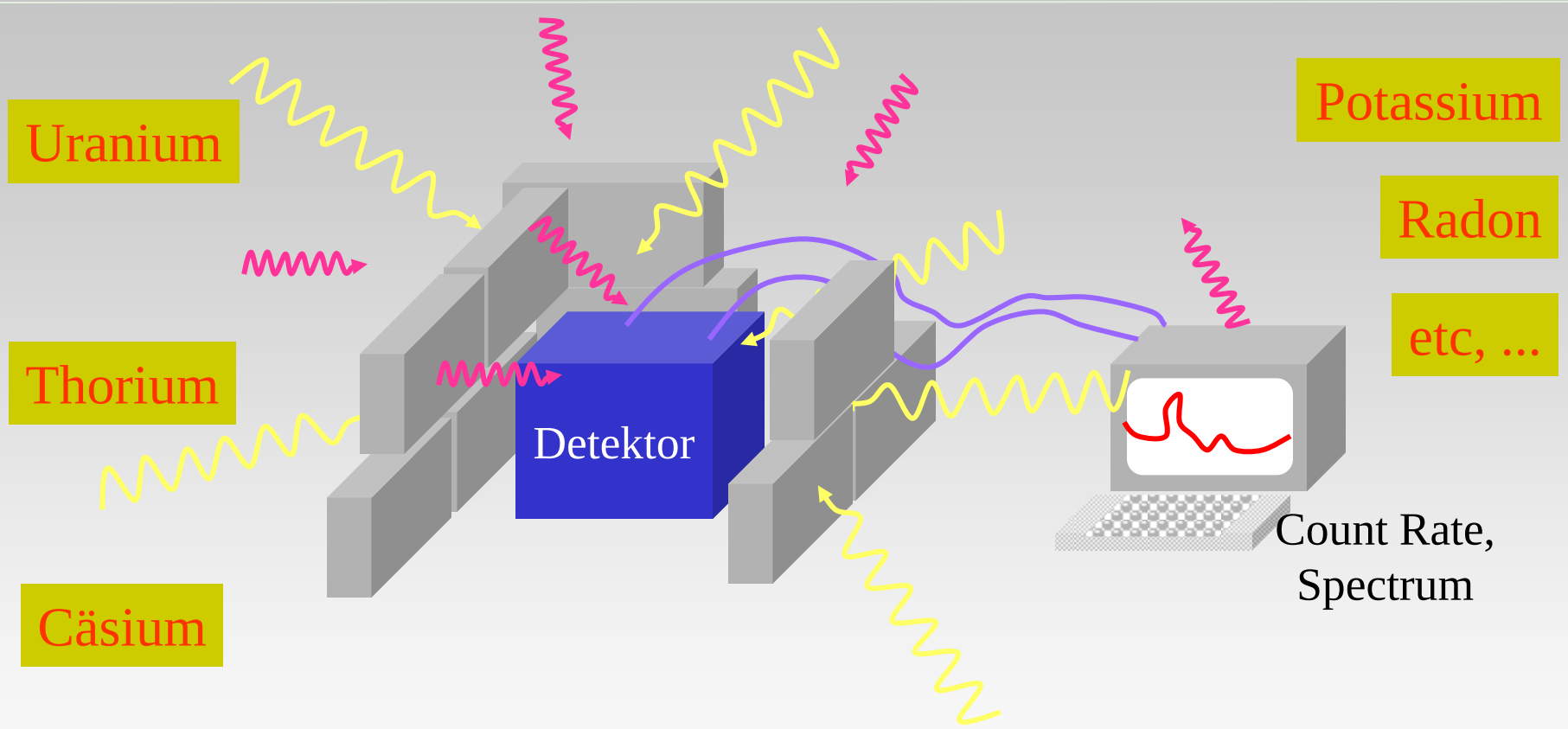
DM-TPC
US

NEWAGE
Japan

prototypes

MIMAC
France

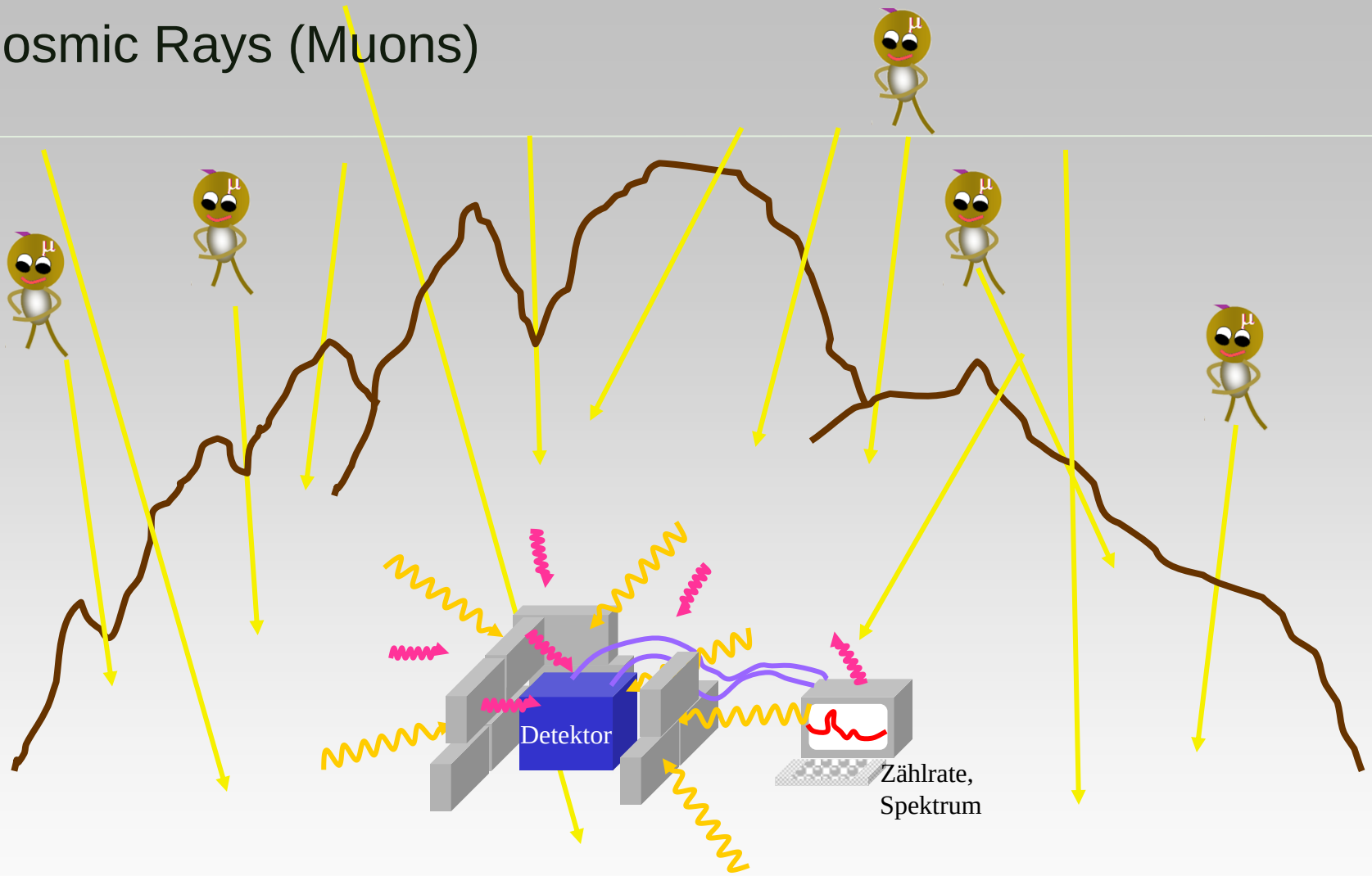
Radioactivity in Environment



required Sensitivity~ 1 event / kg /year)

environmental Radioactivity: > 1Hz/kg ~ 10^7 Events /kg /Week
=> ‘clean‘ Shielding: (old) Pb, Cu

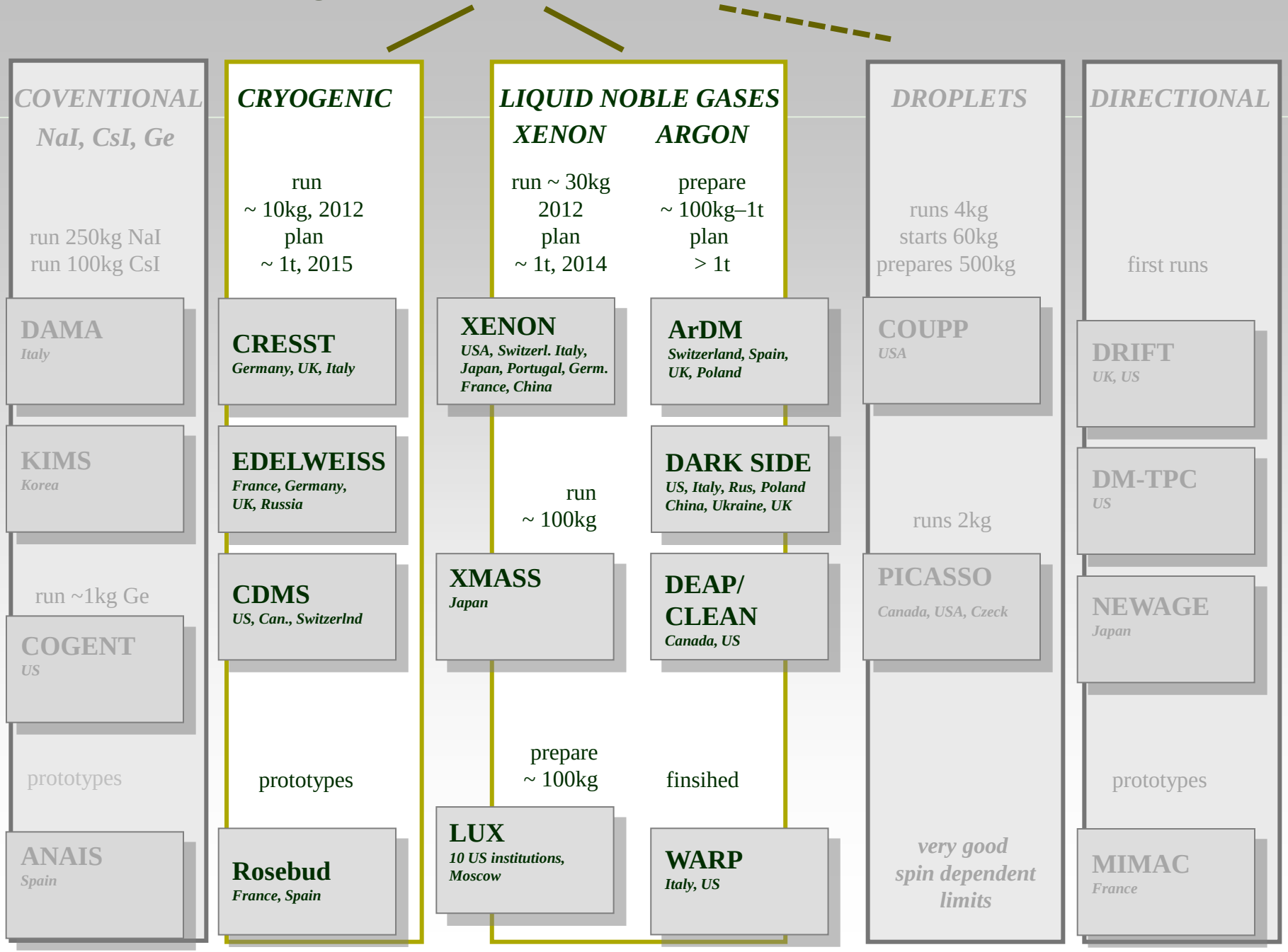
Cosmic Rays (Muons)



required Sensitivity~ 1 event / kg /year)

Muons ~ 0.1Hz/kg: ~ 10^6 Events /kg /Week

~ 1.5 km rock needed => Underground-Laboratory


distinguish nuclear recoils / electron recoils
COVENTIONAL
NaI, CsI, Ge
run 250kg NaI
run 100kg CsI
DAMA
Italy
KIMS
Korea
run ~1kg Ge
COGENT
US
prototypes
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run
~ 10kg, 2012
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France, Germany,
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US, Can., Switzerlnd
prototypes
Rosebud
France, Spain
LIQUID NOBLE GASES
XENON
ARGON
run ~ 30kg
2012
plan
~ 1t, 2014
prepare
~ 100kg–1t
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> 1t
XENON
USA, Switzerl. Italy,
Japan, Portugal, Germ.
France, China
ArDM
Switzerland, Spain,
UK, Poland
run
~ 100kg
XMASS
Japan
DARK SIDE
US, Italy, Rus, Poland
China, Ukraine, UK
DEAP/
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Canada, US
prepare
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finsihed
LUX
10 US institutions,
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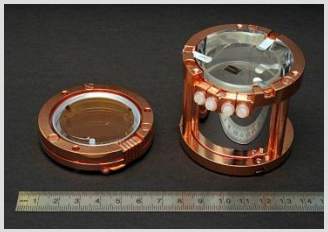
WARP
Italy, US
DROPLETS
runs 4kg
starts 60kg
prepares 500kg
COUPP
USA
runs 2kg
PICASSO
Canada, USA, Czeck
very good
spin dependent
limits
DIRECTIONAL
first runs
DRIFT
UK, US
DM-TPC
US
NEWAGE
Japan
prototypes
MIMAC
France

Particle Identification by Combination of Channels

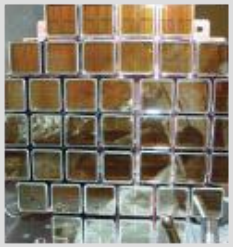
cryogenic charge / phonon

EDELWEISS
CDMS,
EURECA

cryogenic light / phonon



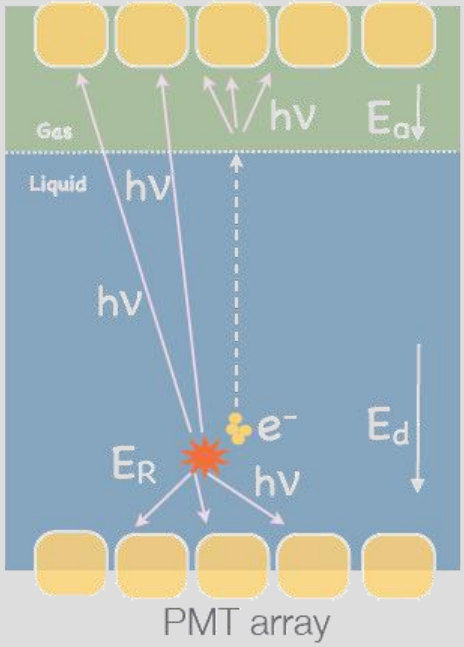
CRESST
EURECA

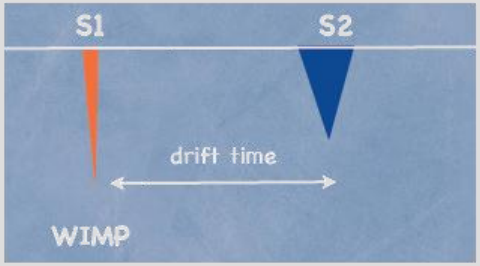


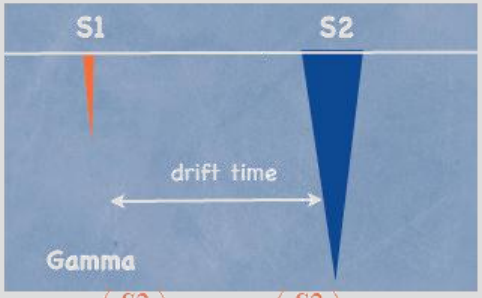
liquid noble gas light / charge

XENON
WARP, ArDM,
LUX, ZEPLIN

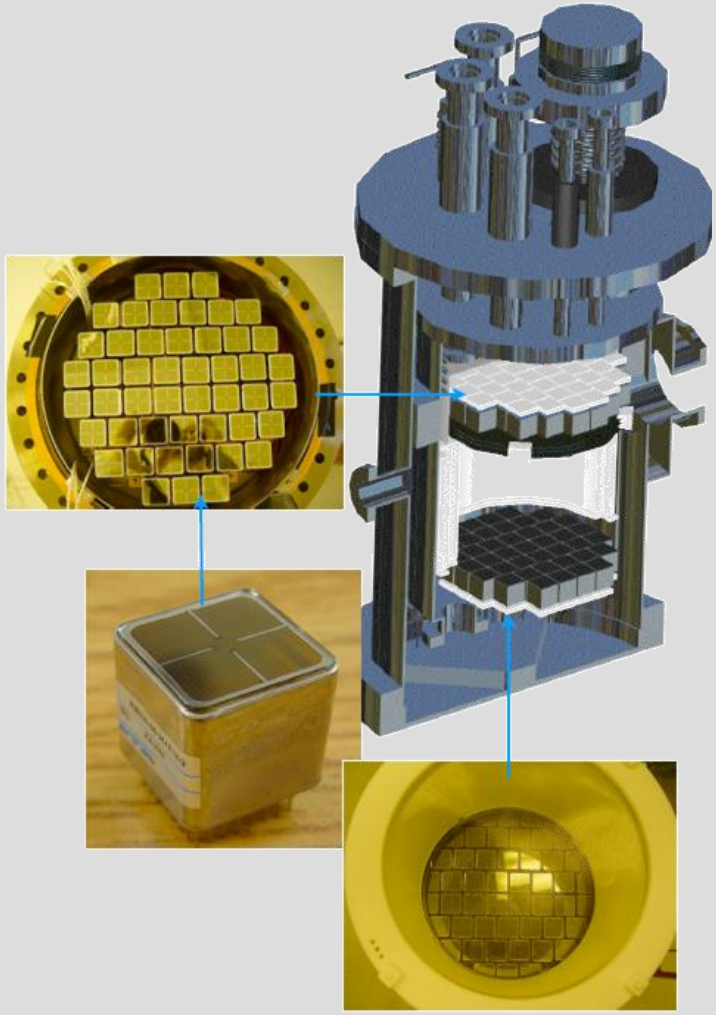
Liquid Noble Gases
Background Rejection by Light vs. Charge

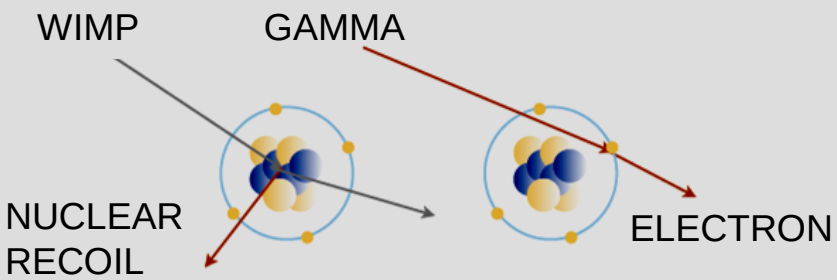






$$\left(\frac{S2}{S1}\right)_{WIMP} \ll \left(\frac{S2}{S1}\right)_{gamma}$$





Liquid Xenon *Charge + Light*

XENON
USA, Switzerland, Italy, Portugal, Germany, France, Japan, China

LUX
10 US institutions, Moscow

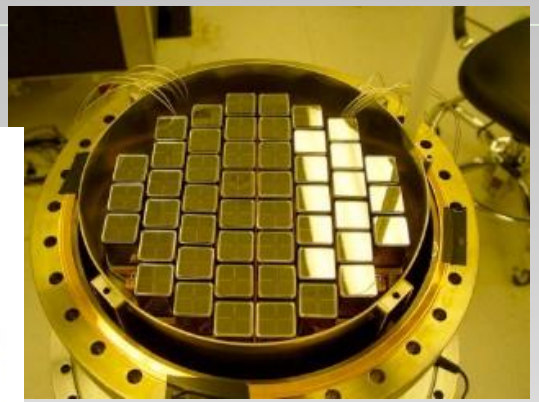
- at Sanford Lab
- running 100kg fiducial

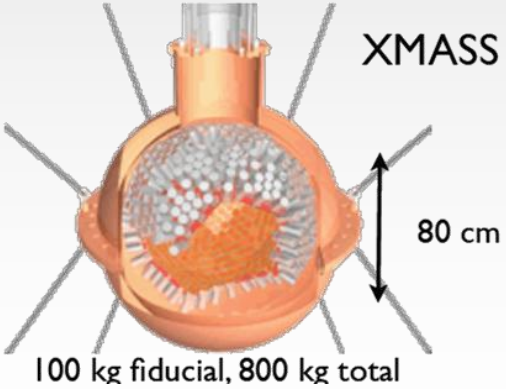
XMASS
10 institutions from Japan

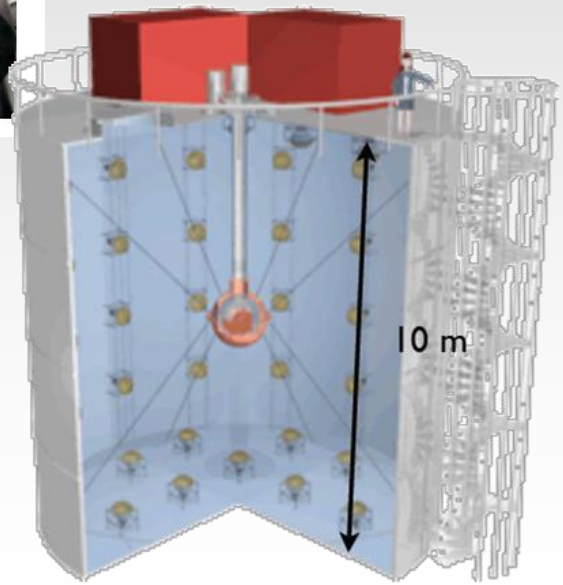
- at Kamioka
- 1 phase, 850 kg total

⇒self shielding 100 kg fid.

- larger bckgr. than expected
- new physics run in 2013







Liquid Xenon *Charge + Light*

XENON
USA, Switzerland, Italy, Portugal, Germany, France, Japan, China

Charge + Light, FV

at Gran Sasso
- 34 / 48 kg fiducial / 62 kg total
- starting end of 2009

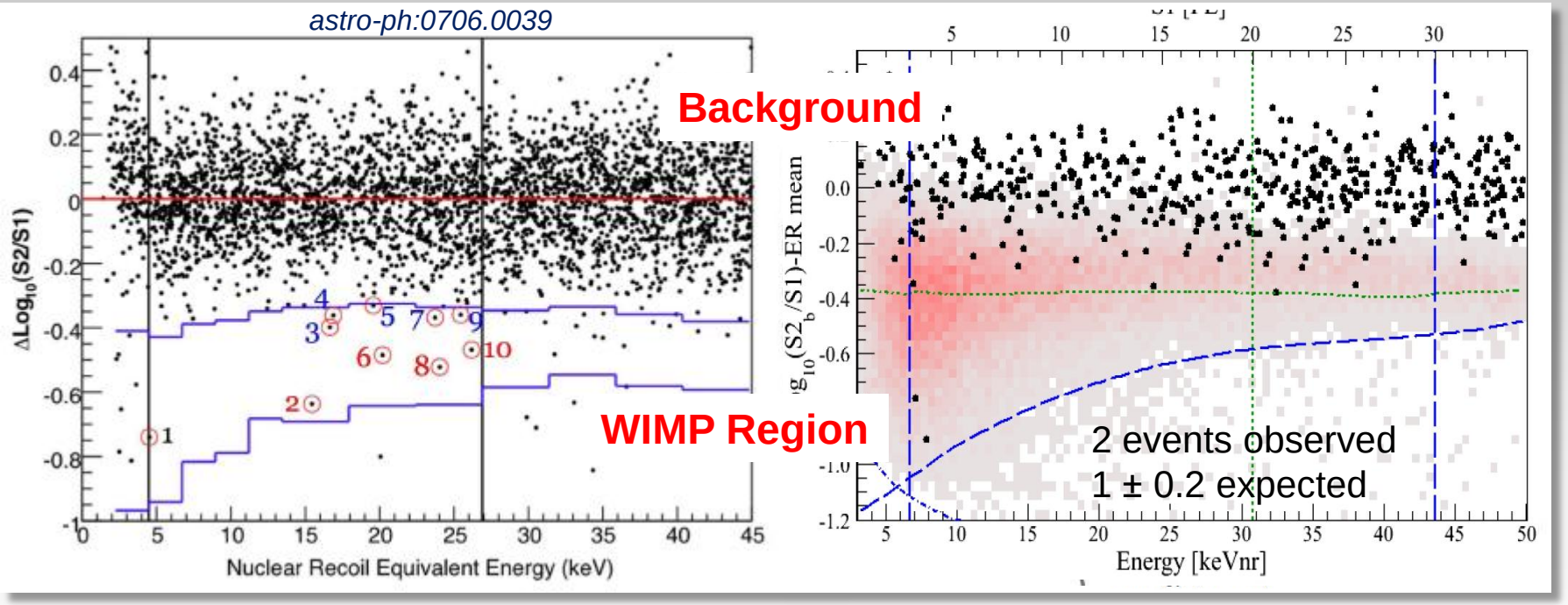
- achieved 2010:
  ~ 7 x 10^{-45} cm^2
- **achieved 2012:**
  ~ 2 x 10^{-45} cm^2

XENON *Charge + Light*

XENON10 *2007*
5.5 kg target,
58.6 kgd exposure
10 background events
~1 cts / 6 kgd

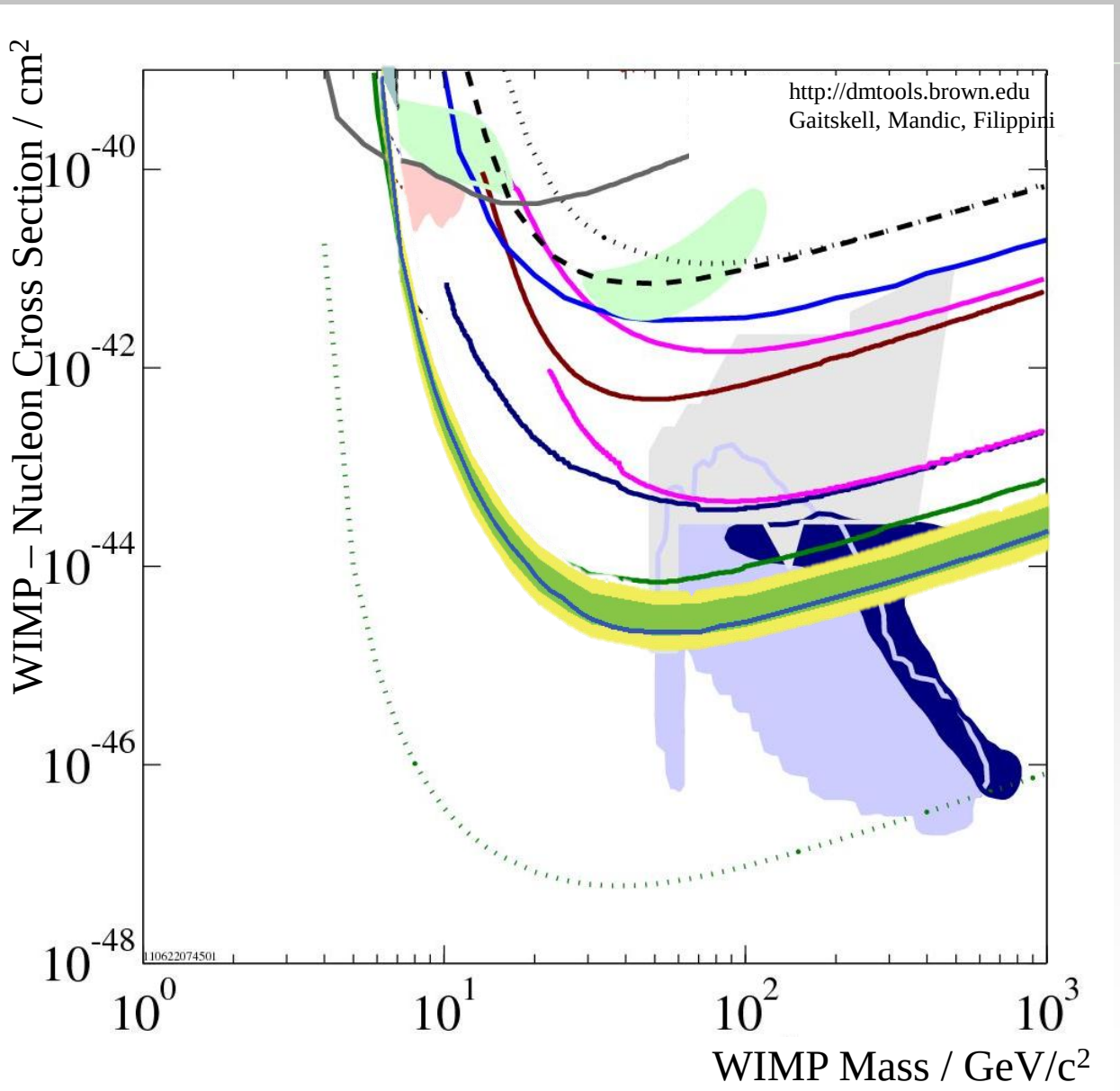
XENON100 *2012*
34 kg target,
~2500 kgd exposure
2 background events
~ 1 cts / 1500 kgd , ~ 1 cts/ 4 kg years
γ bckgrnd ~ 250 x lower

astro-ph:0706.0039



no indication for WIMP signal

Large improvement on background



Heidelberg Moscow 1996
IGEX 1998
DAMA 1998 / LIBRA 2008
CDMS 2000
EDELWEISS 2002
CRESST 2009
EDELWEISS 2011
CDMS 2011
XENON 2011
XENON 2012

~ 0.00003 cts / kg / d / keV

Baltz, Gondolo MSSM 2001
Baltz, Gondolo 2004
Trotta et al CMSSM 2008

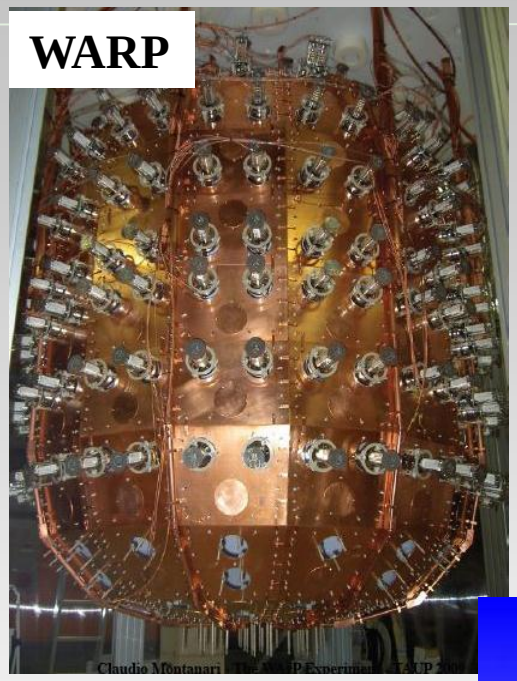
Liquid Argon *Charge + Light*

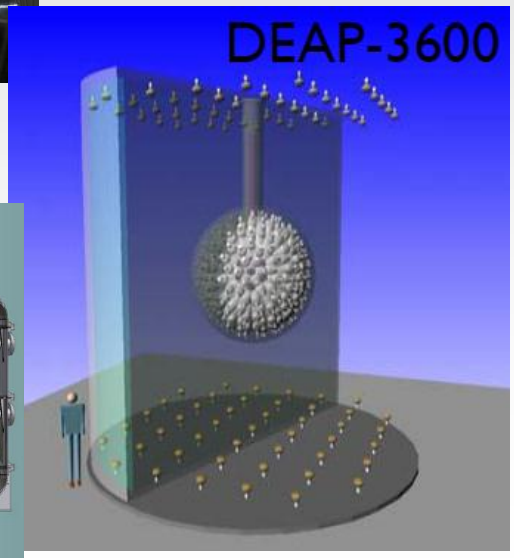
WARP
Italy, US
• at Gran Sasso
• stopped (technical problems)

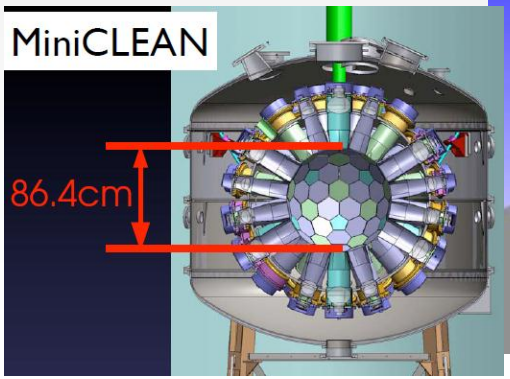
ArDM
Switzerland, Spain, UK, Poland
•1000 kg R & D, prototype
• set up at Canfranc start 2012

DarkSide
US, Rus, I, P, China, Ukr., UK
• proposed, depleted Ar

DEAP / CLEAN
Canada, US
• 1-phase, SNOLAB
•1000 kg fid. start set up 2012





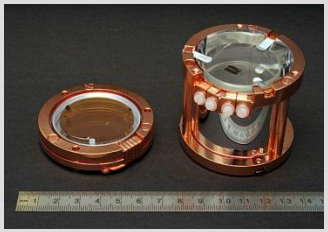


Particle Identification by Combination of Channels

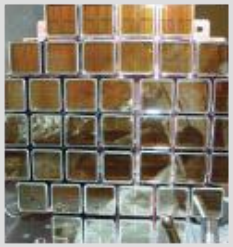
cryogenic charge / phonon

EDELWEISS
CDMS,
EURECA

cryogenic light / phonon



CRESST
EURECA



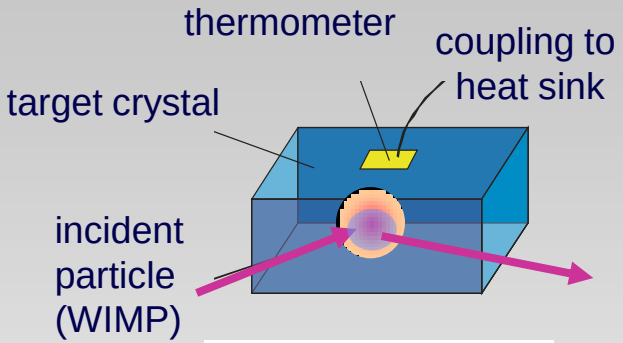
liquid noble gas light / charge

XENON
WARP, ArDM,
LUX, ZEPLIN

Calorimetry – measure total energy *(heat- or phonon- signal)*

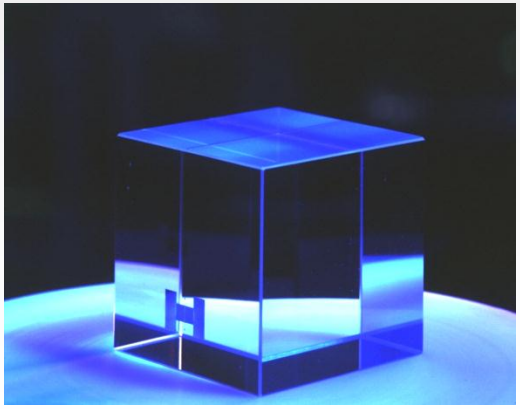
Energy deposition
by scattering

=> temperature rise



$$\Delta T \propto E/C$$

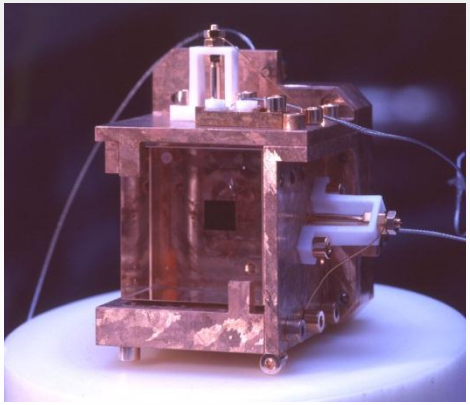
at very low temperature (~20mK)
=> high sensitivity, small C



thermometer:

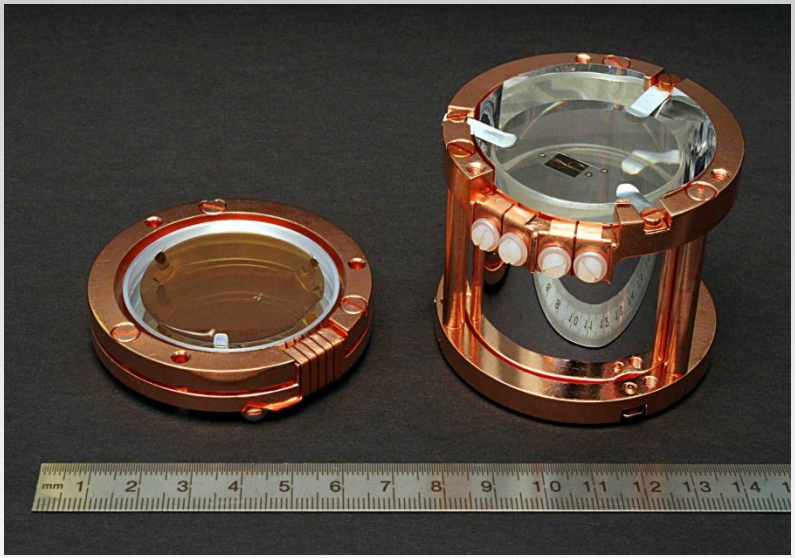
superconducting
phase-transition-thermometer

NTD semicondutors



Calorimeter for Dark Matter Search

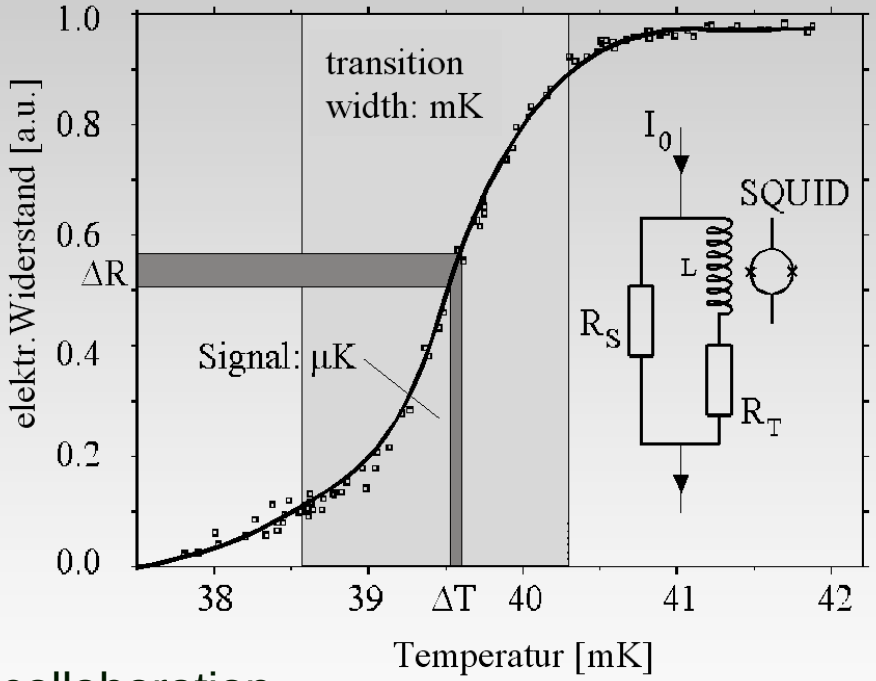
Superconducting Phase-Transition-Thermometer (SPT)
e.g. Wolfram $T_c \approx 15mK$



z.B. $CaWO_4$ -Absorber

300gr, 4cm x 4cm

Heat Capacity Sapphire 250gr
3.4 MeV / K @ 25mK
220 GeV / K @ 1K



CRESST-collaboration

(Cryogenic Rare Event Search with Superconducting Thermometers)

Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso Labor

Phonon + Light or Phonon + Charge

CDMS
Cryogenic Dark Matter Search
US Kollaboration

Charge+ Phonon
(semiconductor Ge, Si)

EDELWEISS
Experience pour DEtecter Les Wimps En SIte Souterrain
France and Germany

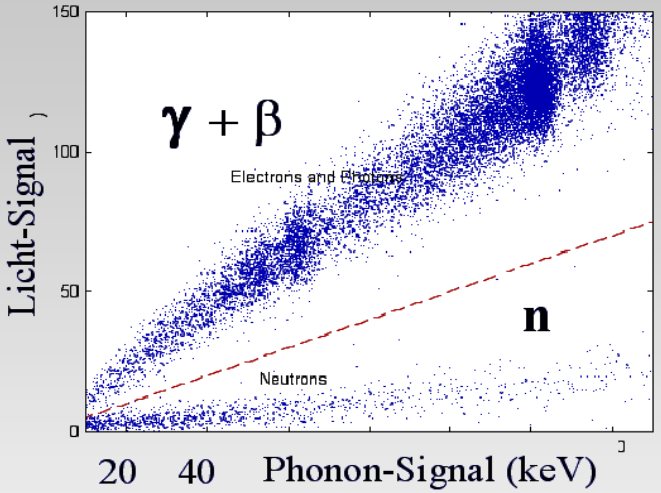
Charge + Phonon
(semiconductor Ge, Si)

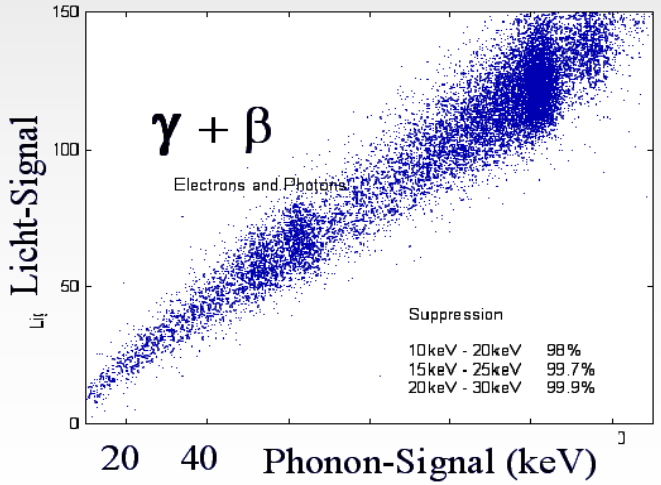
CRESST
Cryogenic Rare Event Search with Superconducting Thermometers

Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso

ROSEBUD
Cryogenic Rare Event Search with Superconducting Thermometers

Zaragoza, Paris

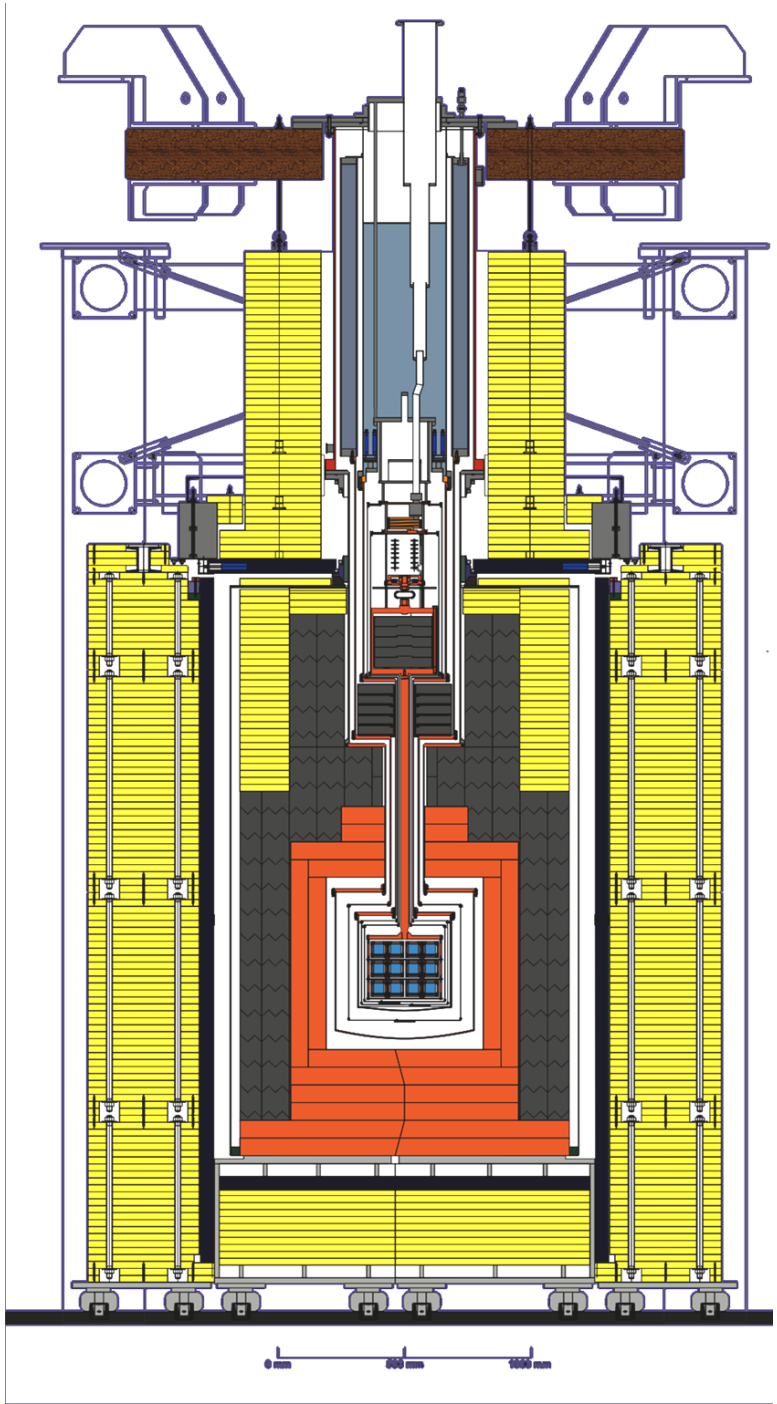




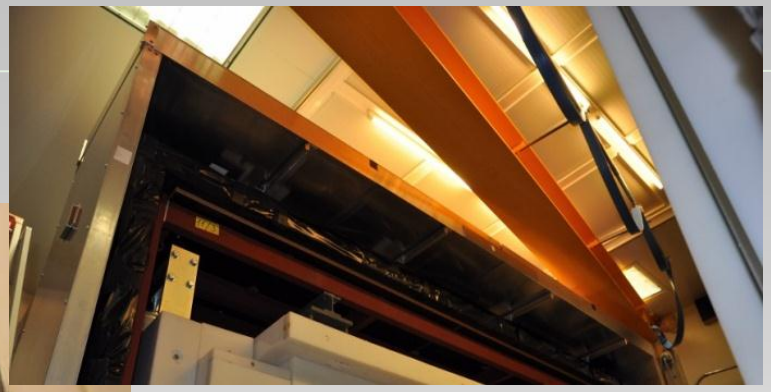
CRESST Set up at LNGS

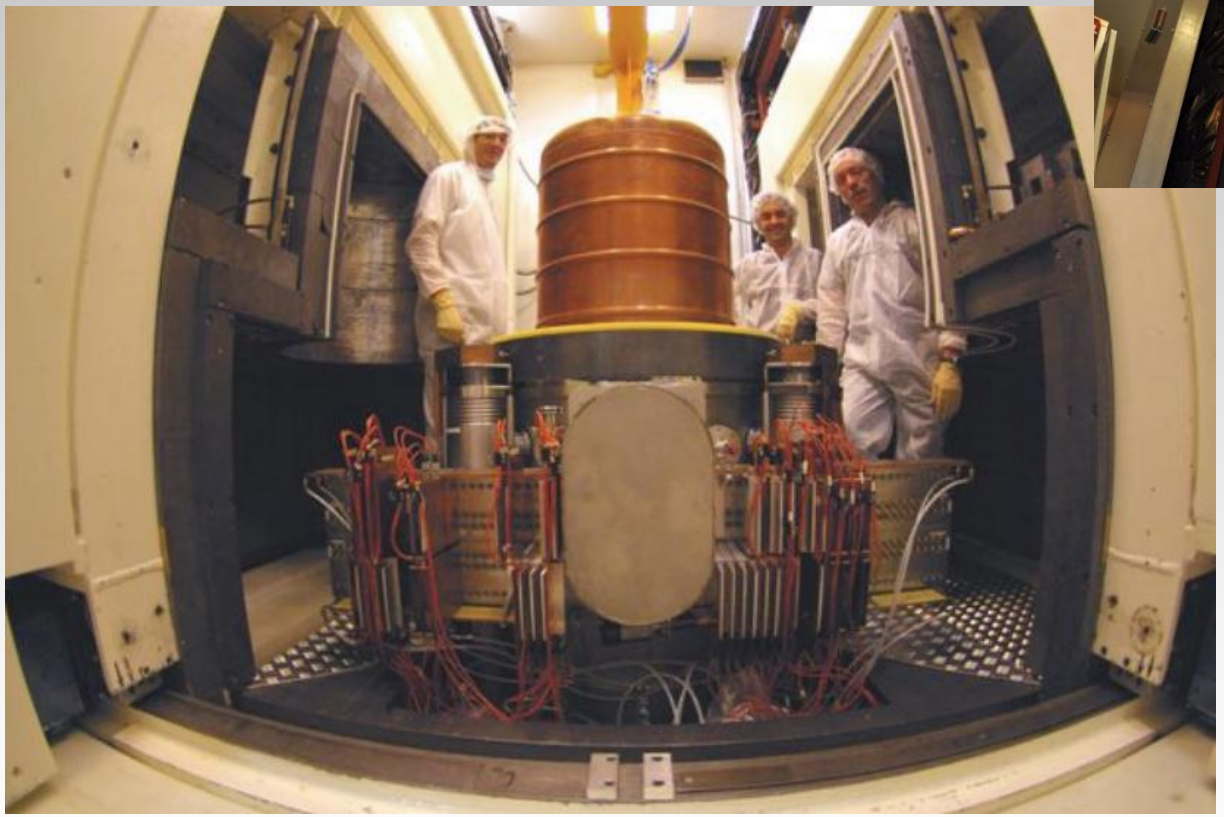
Shielding

- Unterground Lab
- 45 cm PE (12 t)
- Muon-Veto
- Radon Box
- 20 cm Pb (24 t)
- 14 cm Cu (10 t)
- carefully selected materials, as free from radioactivity as possible



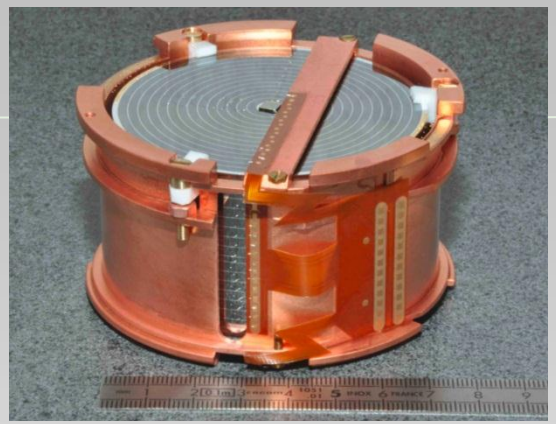
EDELWEISS-II experimental setup





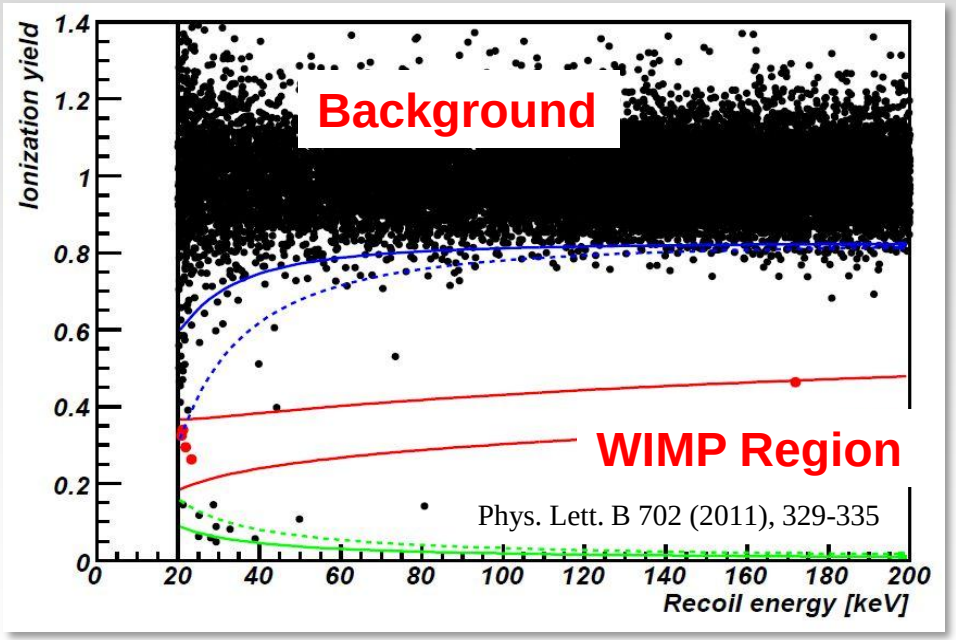
(Courtesy K. Eitel)

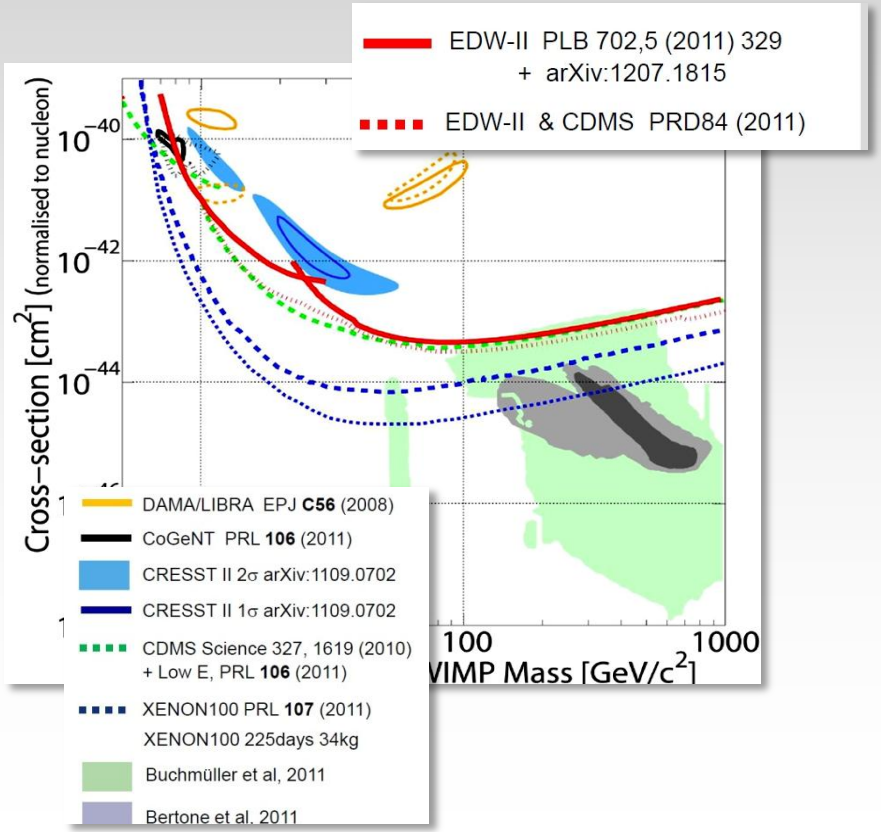
EDELWEISS – Charge / Phonon



- continous data taking
- 384 kg d published
- one of the best limits
- 3000 kg d expected 2013

- *1 cts / 80 kg day*

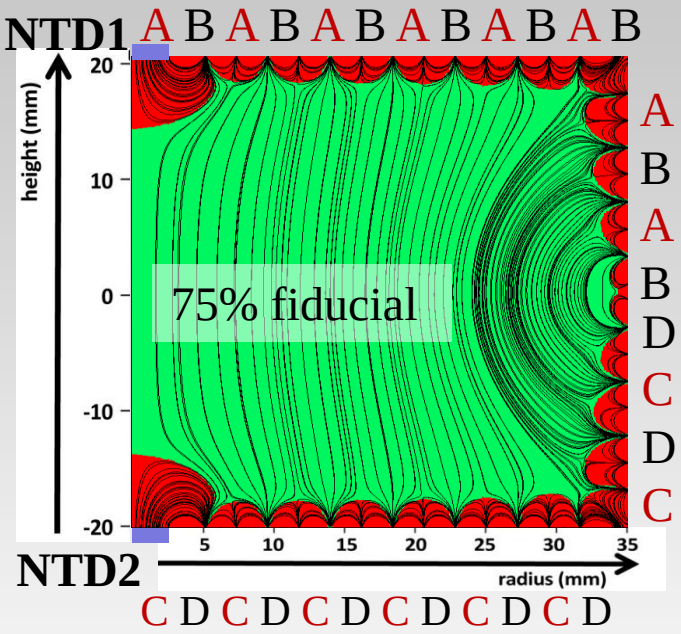


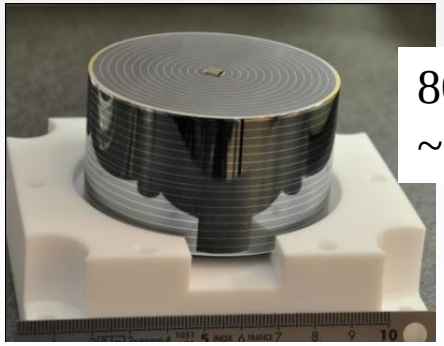


no indication for WIMP signal

EDW-III: next generation of detectors

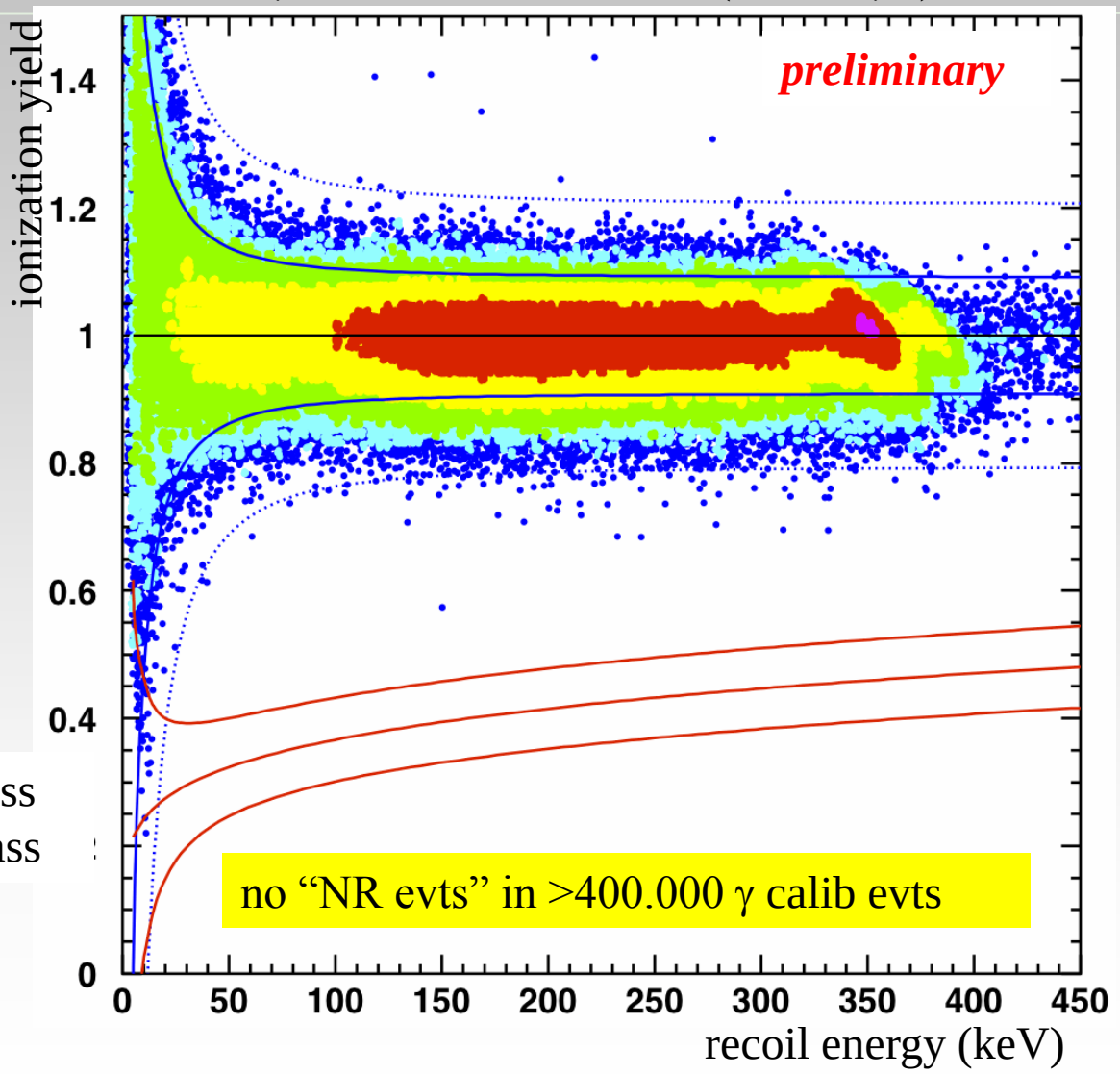
3. generation: FID detectors with rings on all surfaces





800g total mass
~600g fid. mass

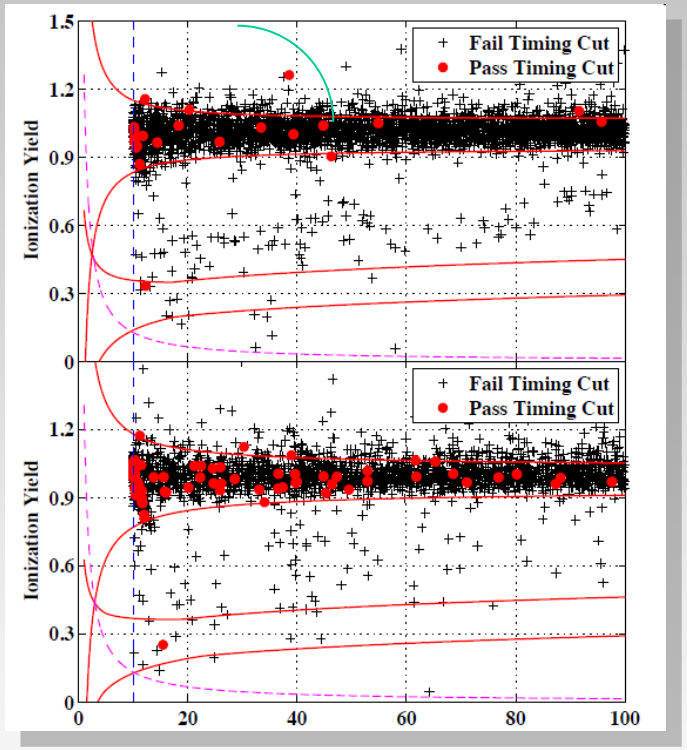
γ-calibration with ^{133}Ba (411663γ´s)

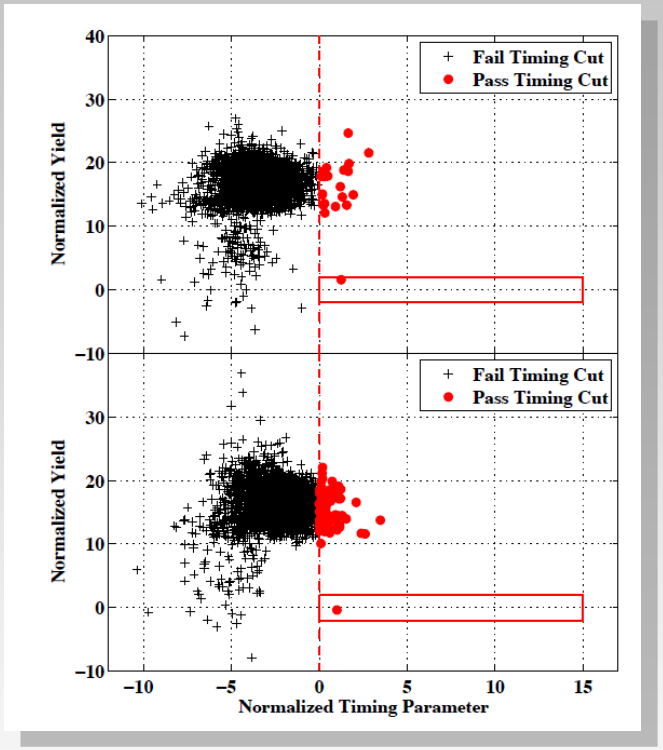


(Courtesy K. Eitel)

CDMS results

no indication for WIMP signal



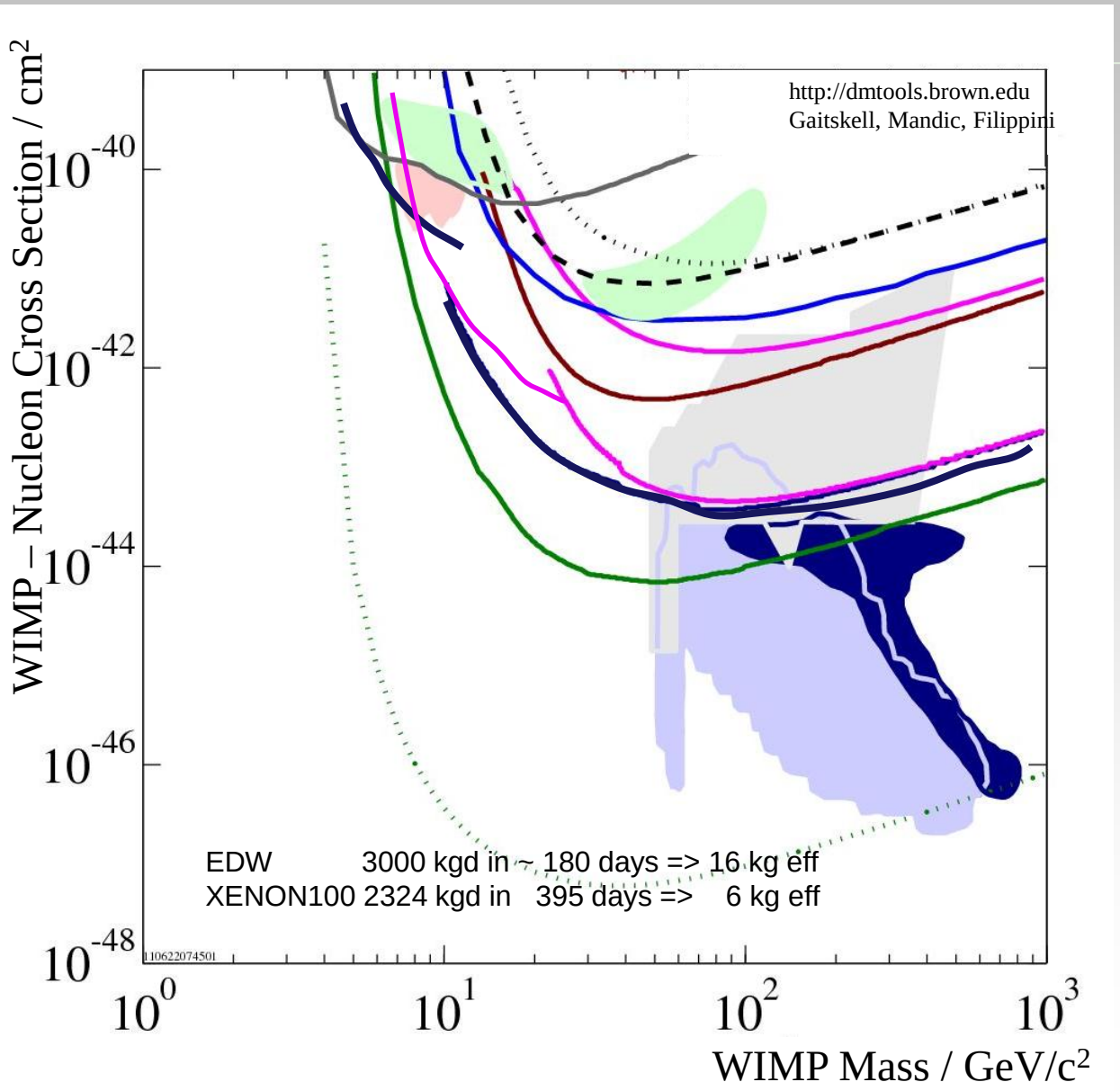


612 kg-days raw exposure

194.1 kg-days spectrum-averaged equivalent exposure @ 60 GeV

23% probability of observing two or more background events

$3{,}8 \times 10^{-44}$ cm^2 upper limit on spin-independent cross-section @ 70 GeV, 90% CL
+ improved limits for low WIMP masses

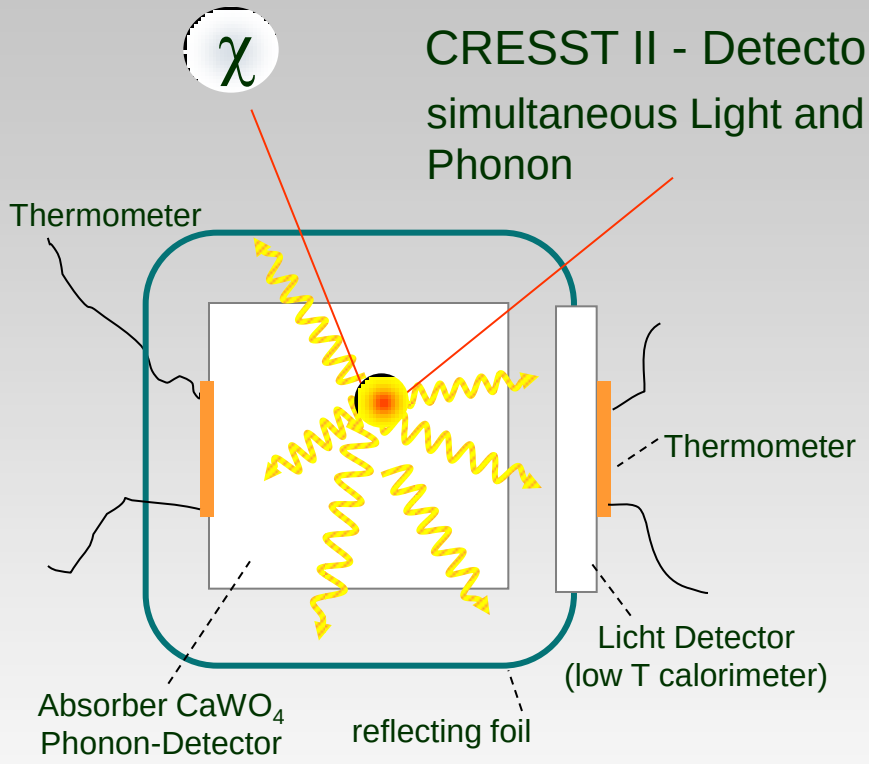


Heidelberg Moscow 1996
IGEX 1998
DAMA 1998 / LIBRA 2008
CDMS 2000
EDELWEISS 2002
CRESST 2009
EDELWEISS 2011
CDMS 2011
XENON 2011

~ 0.0001 cts / kg / d / keV

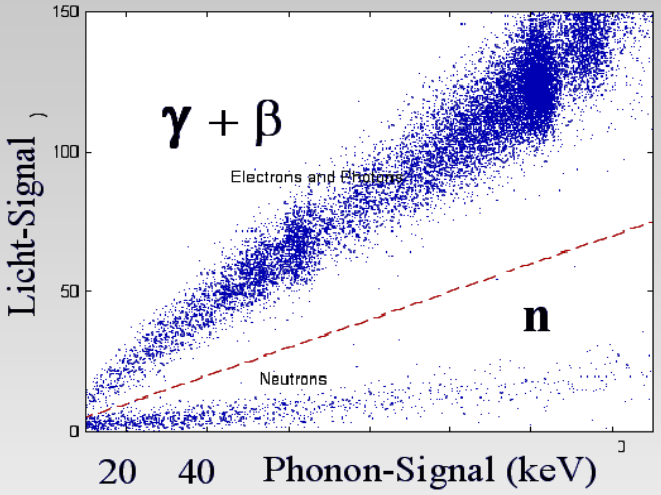
Baltz, Gondolo MSSM 2001
Baltz, Gondolo 2004
Trotta et al CMSSM 2008

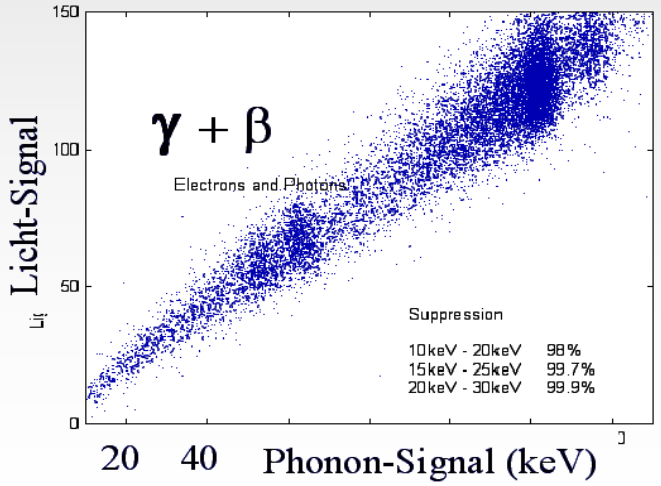
CRESST: Phonon + Light



CRESST II - Detectors

simultaneous Light and Phonon



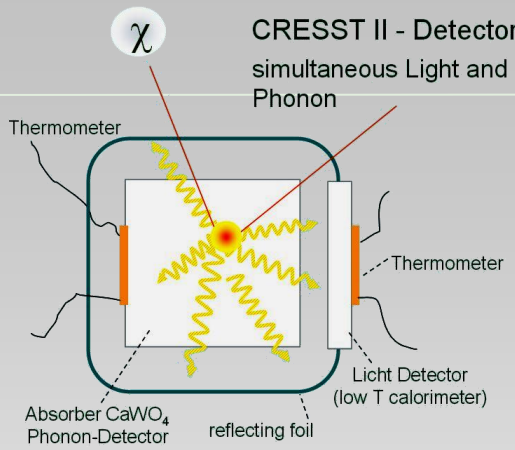


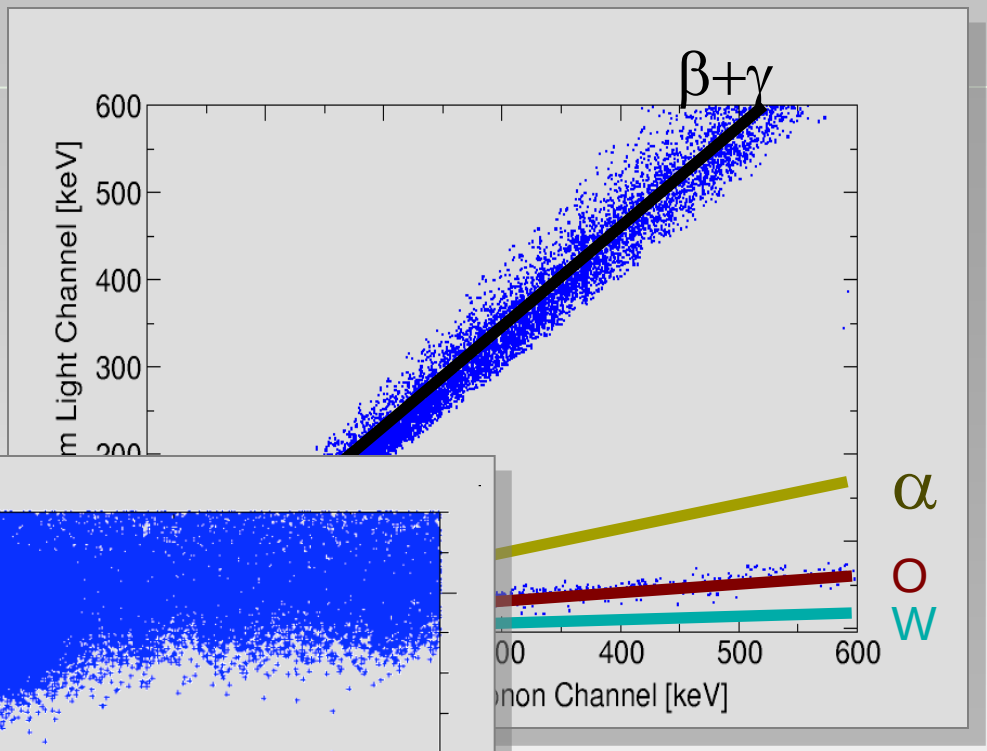
CRESST

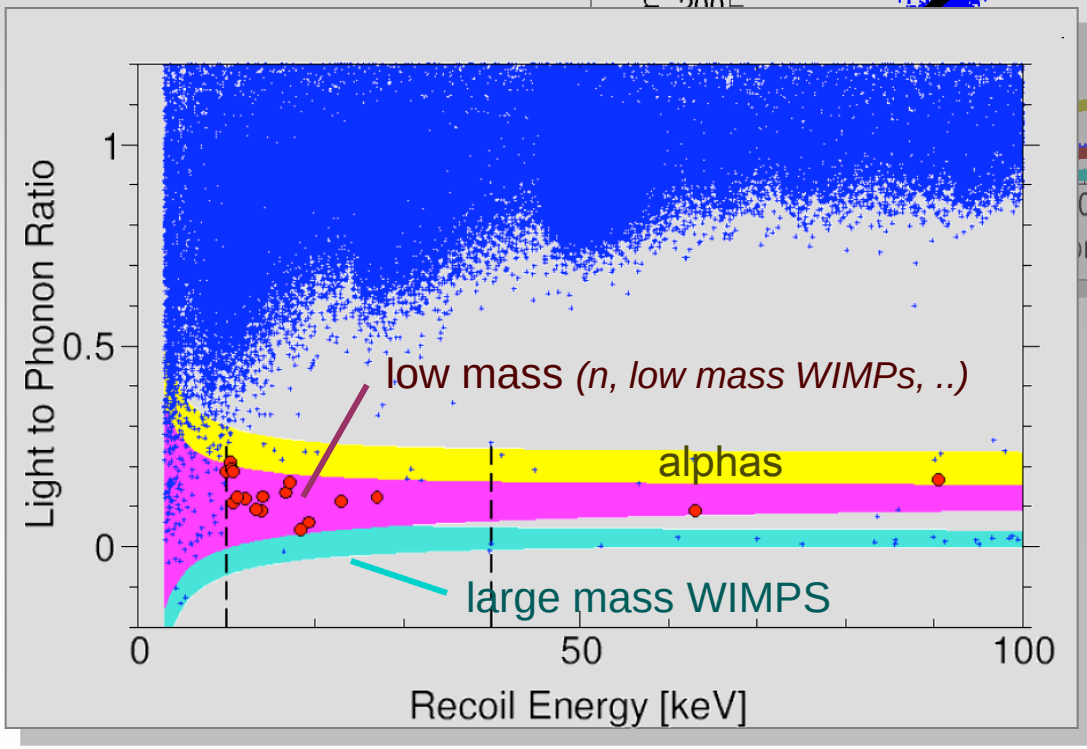
Cryogenic Rare Event Search with Superconducting Thermometers

Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso

CRESST – Light / Phonon – $CaWO_4$ Target

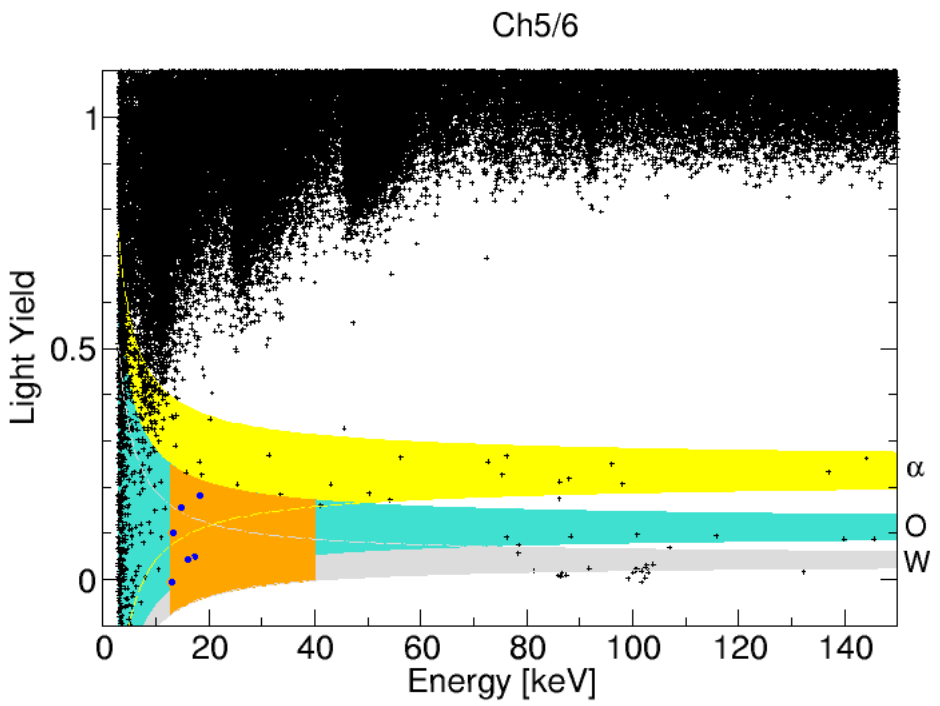






several target nuclei 'special feature' of CRESST

CRESST Data



- **Measurement 2009 - 2011**
- **8 detectors**
- results from 730 kgd exposure

⇒ **67 events in nuclear recoil acceptance region**

too many to be explained by known backgrounds

e / γ : 1 event per detector expected by threshold definition
α leakage or Pb-recoils: very unlikely, overlap to acceptance region too small
Neutrons: very unlikely, rate too high, multiplicities wrong

+ energy spectrum, + light-yield spectrum

low mass WIMPs : who knows?

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NaI, CsI, Ge

run 250kg NaI
run 100kg CsI

DAMA
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KIMS
Korea

run ~1kg Ge

COGENT
US

prototypes

ANAIS
Spain

CRYOGENIC

run
~ 10kg, 2012
plan
~ 1t, 2015

CRESST
Germany, UK, Italy

EDELWEISS
France, Germany, UK, Russia

CDMS
US, Can., Switzerlnd

prototypes

Rosebud
France, Spain

LIQUID NOBLE GASES

XENON

run ~ 30kg
2012
plan
~ 1t, 2014

XENON
USA, Switzerl. Italy, Japan, Portugal, Germ. France, China

run
~ 100kg

XMASS
Japan

prepare
~ 100kg

LUX
10 US institutions, Moscow

ARGON

prepare
~ 100kg–1t
plan
> 1t

ArDM
Switzerland, Spain, UK, Poland

DARK SIDE
US, Italy, Rus, Poland China, Ukraine, UK

DEAP/ CLEAN
Canada, US

finsihed

WARP
Italy, US

DROPLETS

runs 4kg
starts 60kg
prepares 500kg

COUPP
USA

runs 2kg

PICASSO
Canada, USA, Czeck

very good spin dependent limits

DIRECTIONAL

first runs

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DM-TPC
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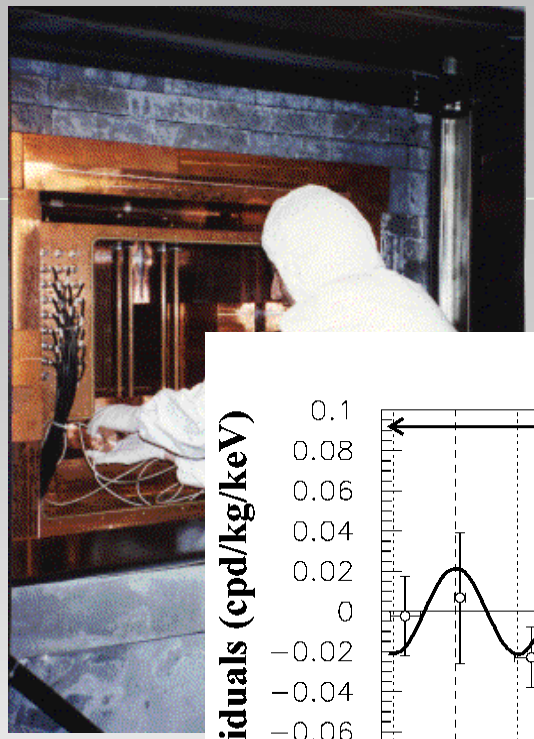
prototypes

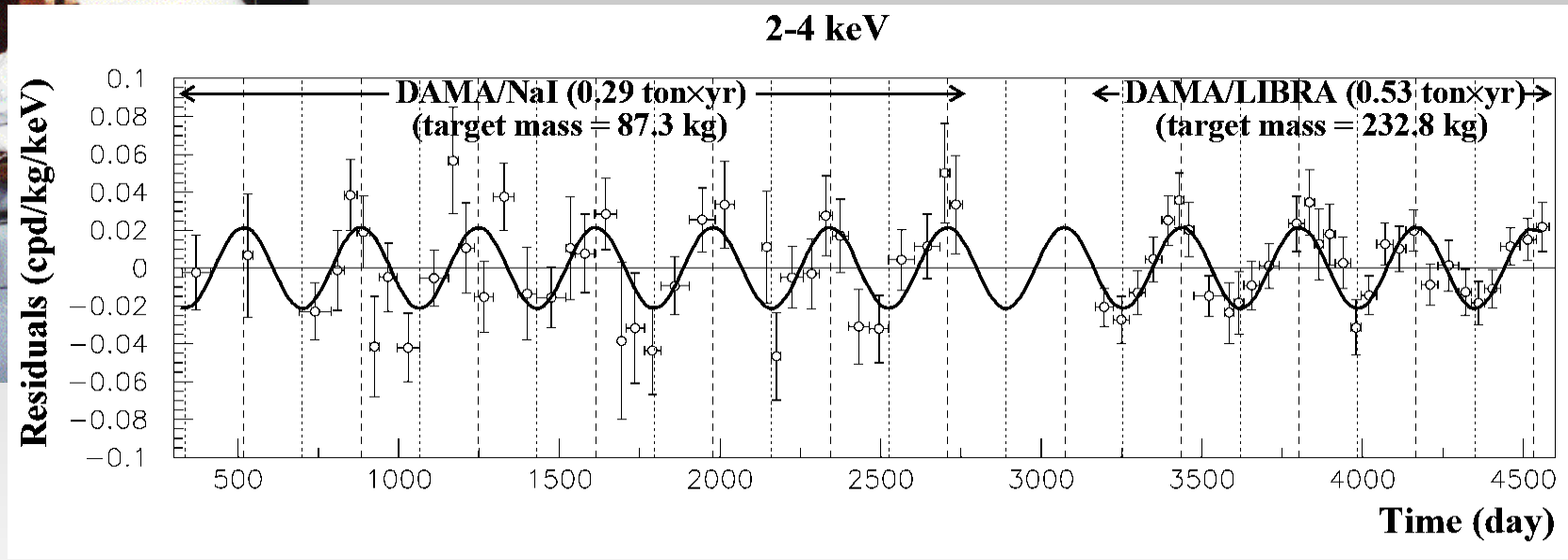
MIMAC
France

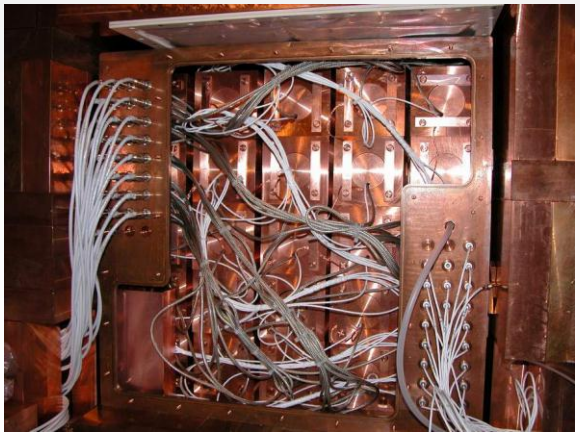


Annual Modulation

DAMA Exp. – Gran Sasso – Ital.Collab.

DAMA - Experiment:
first hint to WIMPs ?

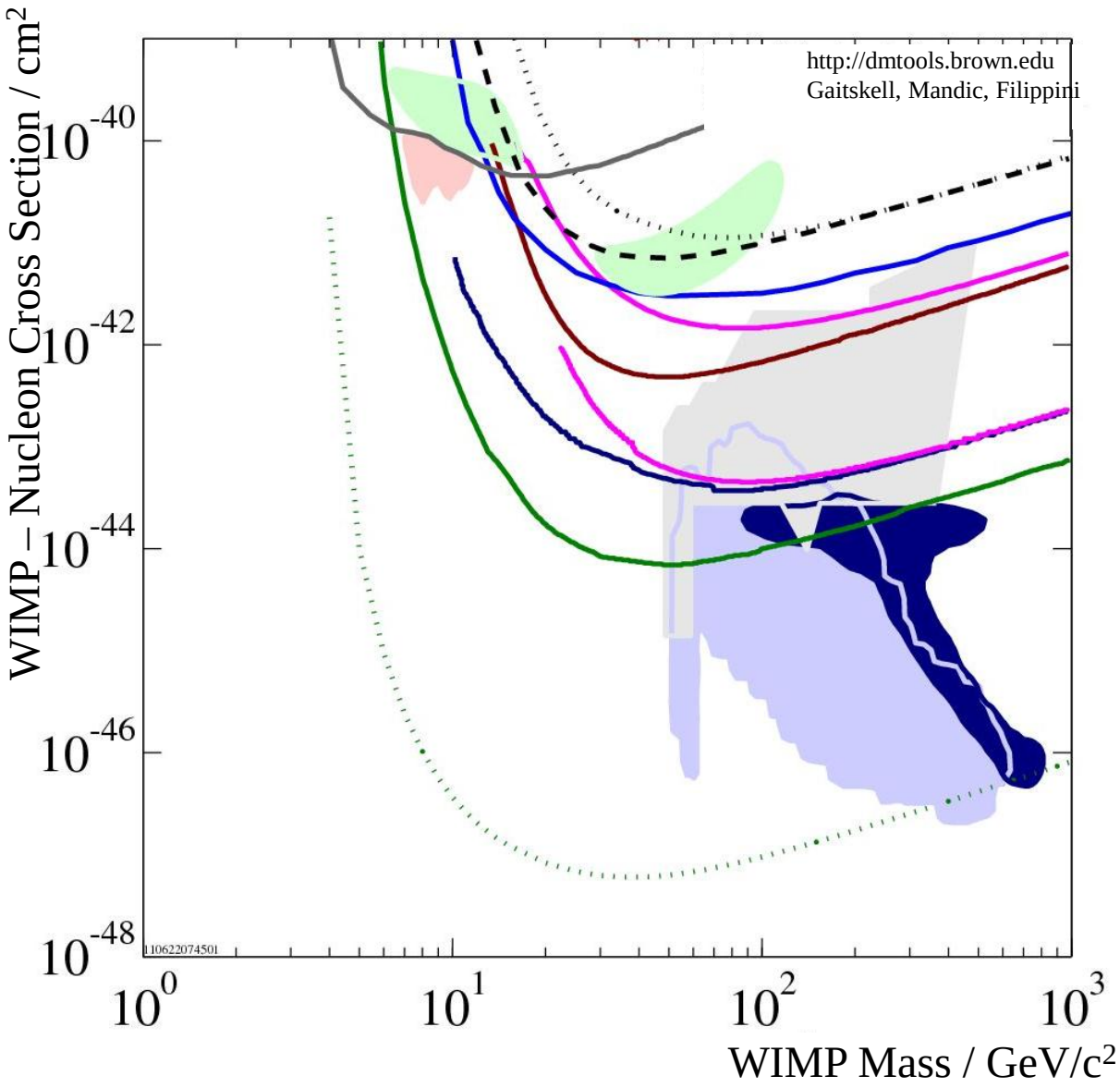




up to today 11 years of data taking
(~ 300.000 kg x days, 0.8 ton x year)

Modulation eith 8σ Confidence

Riv.N.Cim. 26/1 (2003), 1-73



Heidelberg Moscow 1996

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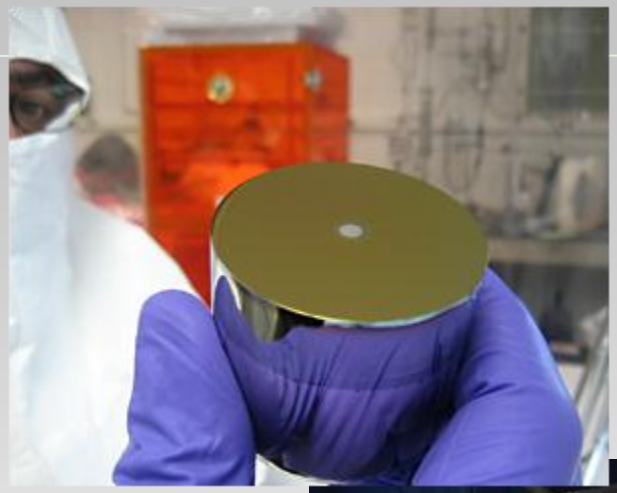
Baltz, Gondolo 2004

Trotta et al CMSSM 2008

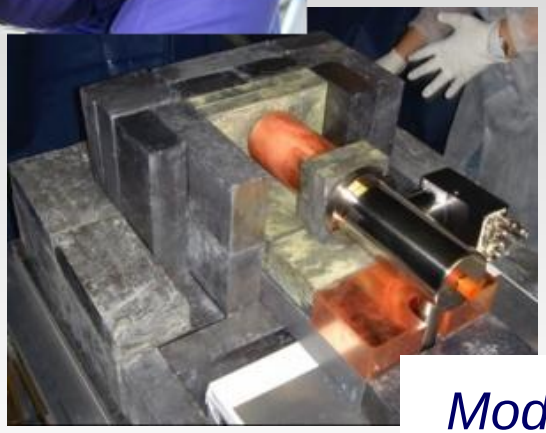
COGENT

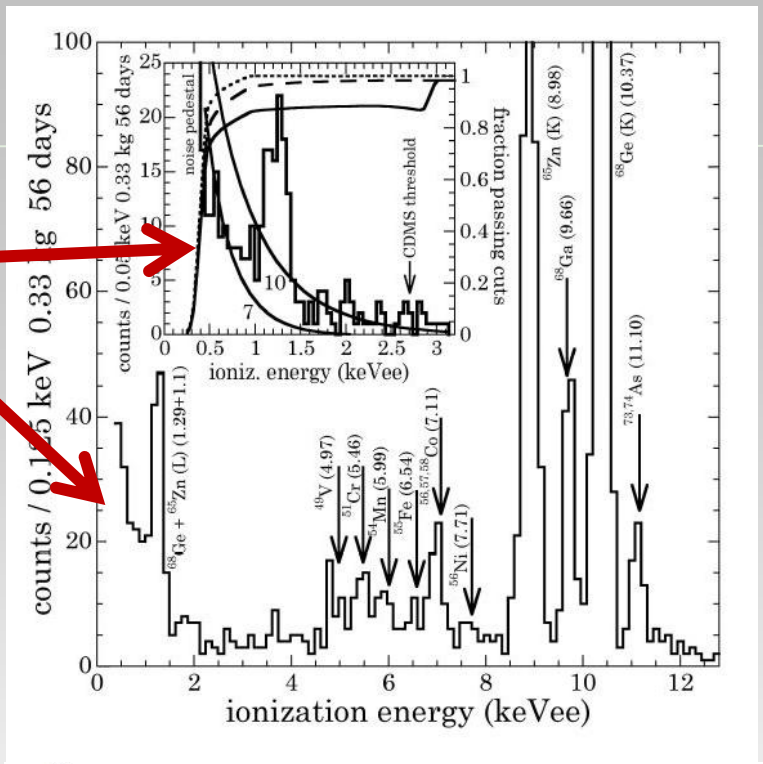
Soudan Mine
US Collaboration



low energy excess

low mass WIMPs?

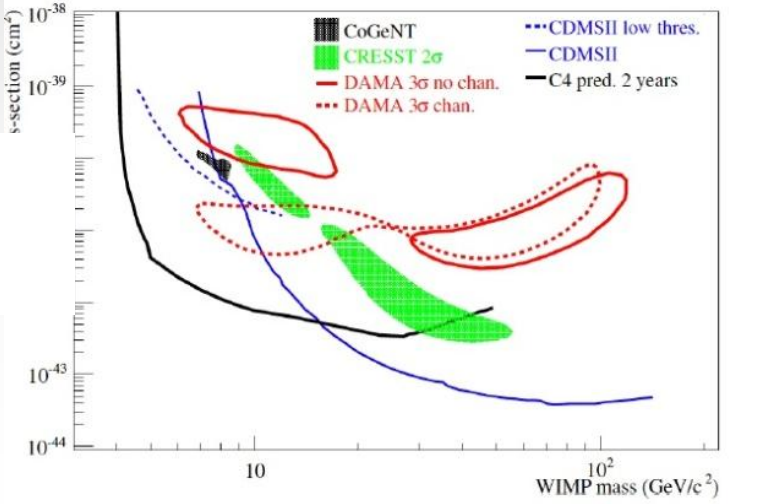




Ge detectors

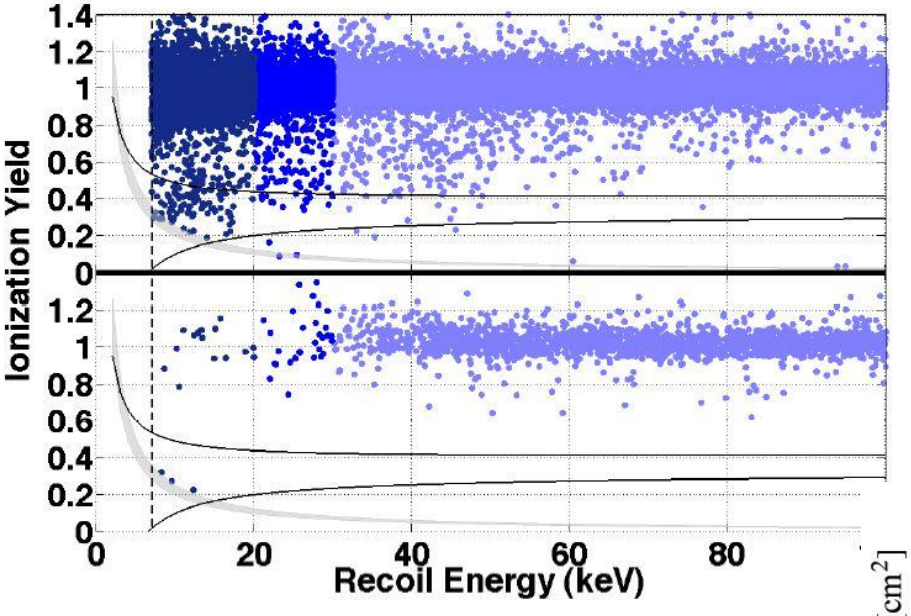
Ionisation only

Modulates ?
(2.8 sigma)



Point contact detectors
⇒ Very low threshold
⇒ Good to look for light WIMPs

CDMS *Si-Data light WIMPs ?*



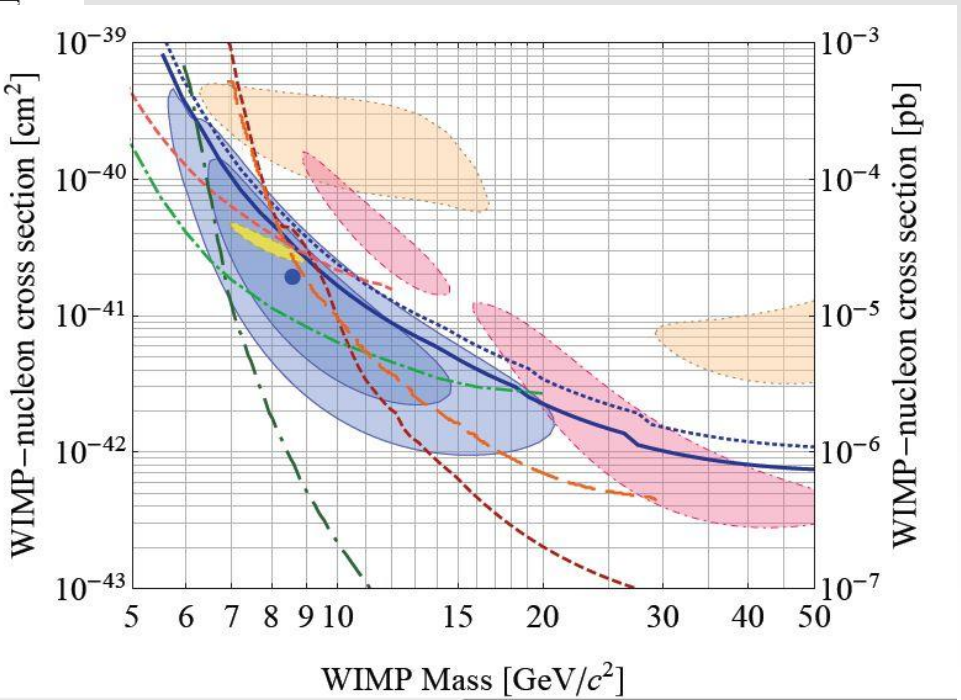


FIG. 4. Experimental upper limits (90% confidence level) for the WIMP-nucleon spin-independent cross section as a function of WIMP mass. We show the limit obtained from the exposure analyzed in this work alone (*blue dotted line*), and combined with the CDMS II Si data set reported in [23, 28] (*blue solid line*). Also shown are limits from the CDMS II Ge standard [17] and low-threshold [29] analysis (*dark and light dashed red*), EDELWEISS low-threshold [30] (*long-dashed orange*), XENON10 S2-only [31] (*dash-dotted green*), and XENON100 [32] (*long-dash-dotted green*). The filled regions identify possible signal regions associated with data from CoGeNT [33] (*dashed yellow*, 90% C.L.), DAMA/LIBRA [10, 34] (*dotted tan*, 99.7% C.L.), and CRESST [12, 35] (*dash-dotted pink*, 95.45% C.L.) experiments. 68% and 90% C.L. contours for a possible signal from these data are shown in light blue. The blue dot shows the maximum likelihood point at (8.6 GeV/c^2, 1.9×10^{-41} cm^2).

CDMSLite

low energy, no discriminiation, Negaov-Luke

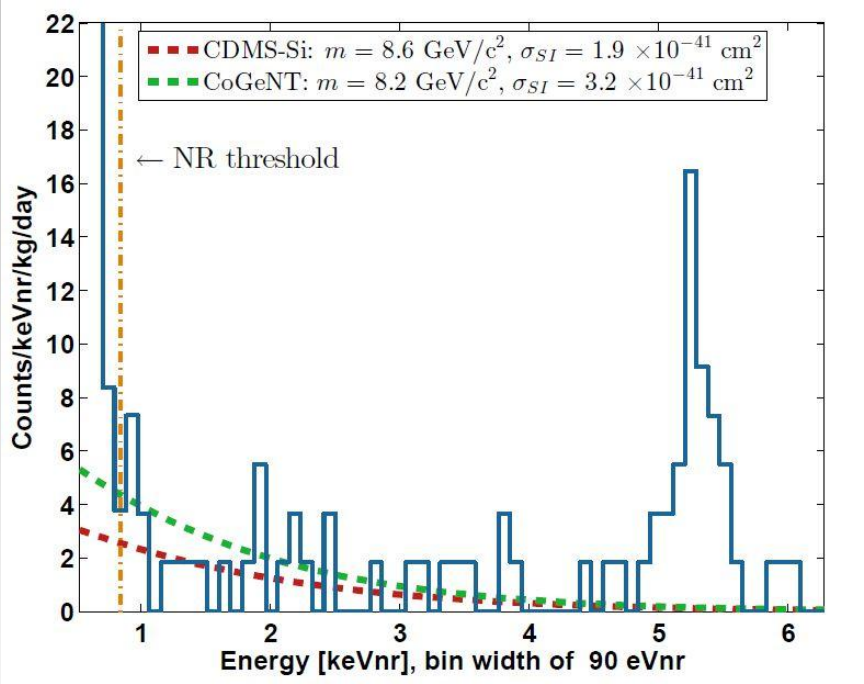


FIG. 2. The efficiency-corrected WIMP-search energy spectrum is shown in keV$_{nr}$, and compared with expected rates for WIMPs with the most likely masses and cross sections suggested by the analysis of CoGeNT [8] and CDMS II Si [10] data (dashed curves). Note that the $k = 0.157$ Lindhard yield model was used to convert from an electron-equivalent to a nuclear-recoil-equivalent energy scale. The 170 eV$_{ee}$ ionization threshold translates to 841 eV$_{nr}$ (amber dot-dashed line). The 1.3 keV$_{ee}$ activation line appears at ~ 5.3 keV$_{nr}$.

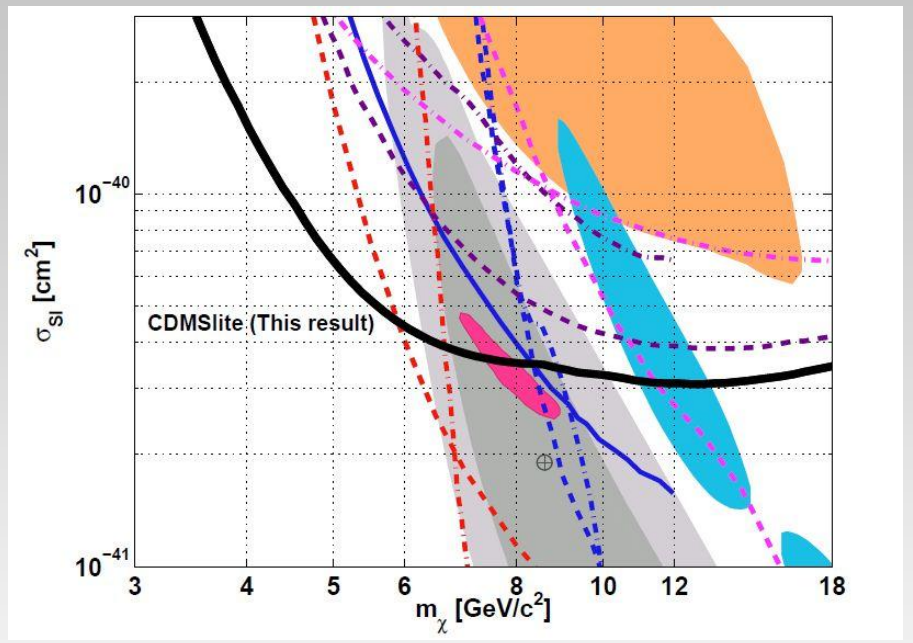


FIG. 3. The 90% upper confidence limit from the data presented here are shown with exclusion limits from other experiments. These are grouped as Ge bolometers in blue: CDMS II Ge regular (dot-dash) [39], CDMS II Ge low threshold (solid) [40], EDELWEISS II low threshold (dash) [37]; point-contact Ge detectors in purple: TEXONO (dash) [41], CDEX (dot-dash) [42]; liquid Xenon in red: XENON100 (dot-dash) [43], XENON10 S2 only (dash) [44]; and other technologies in magenta: Low threshold reanalysis of CRESST II data (dot-dash) [45], PICASSO (dash) [46]. The contours are from CDMS II Si (light and dark gray correspond to 68% and 90% CL regions respectively) [10], CRESST II (blue) [9], DAMA (orange) [6, 7], CoGeNT (pink) [8].

MALBEK *point contact Ge dtectors, low threshold*

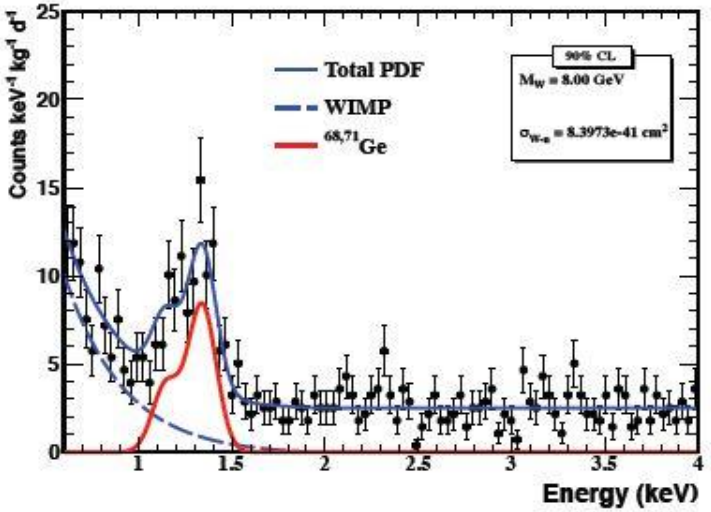
90% exclusions from 221 day dataset

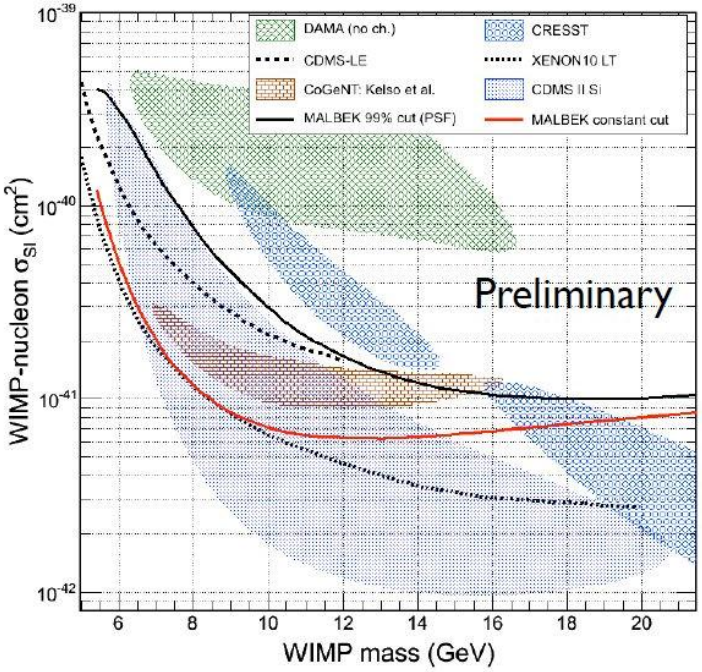
fit components:

- flat background
- ^{65}Zn L-capture line
- ^{68,71}Ge L-capture line
- *exponential background**
- WIMP signal

*the exponential is only included in fits of the spectrum generated with the 99% cut

8.0 GeV WIMP best fit for 99% cut spectrum





COVENTIONAL
NaI, CsI, Ge

run 250kg NaI
run 100kg CsI

DAMA
Italy

KIMS
Korea

run ~1kg Ge

COGENT
US

prototypes

ANAIS
Spain

CRYOGENIC

run
~ 10kg, 2012
plan
~ 1t, 2015

CRESST
Germany, UK, Italy

EDELWEISS
France, Germany, UK, Russia

CDMS
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prototypes

Rosebud
France, Spain

LIQUID NOBLE GASES

XENON

run ~ 30kg
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~ 1t, 2014

XENON
USA, Switzerl. Italy, Japan, Portugal, Germ. France, China

run
~ 100kg

XMASS
Japan

prepare
~ 100kg

LUX
10 US institutions, Moscow

ARGON

prepare
~ 100kg–1t
plan
> 1t

ArDM
Switzerland, Spain, UK, Poland

DARK SIDE
US, Italy, Rus, Poland China, Ukraine, UK

DEAP/ CLEAN
Canada, US

finsihed

WARP
Italy, US

DROPLETS

runs 4kg
starts 60kg
prepares 500kg

COUPP
USA

runs 2kg

PICASSO
Canada, USA, Czeck

very good spin dependent limits

DIRECTIONAL

first runs

DRIFT
UK, US

DM-TPC
US

NEWAGE
Japan

prototypes

MIMAC
France

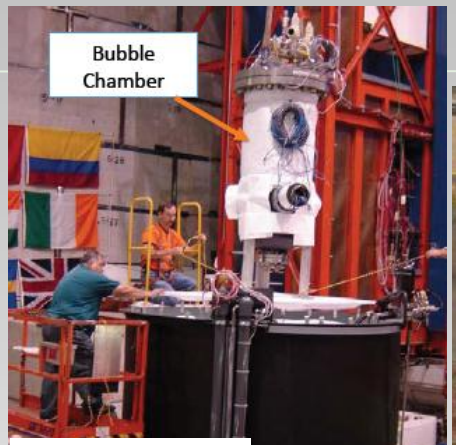
Superheated Droplets COUPP

similar to bubble chamber

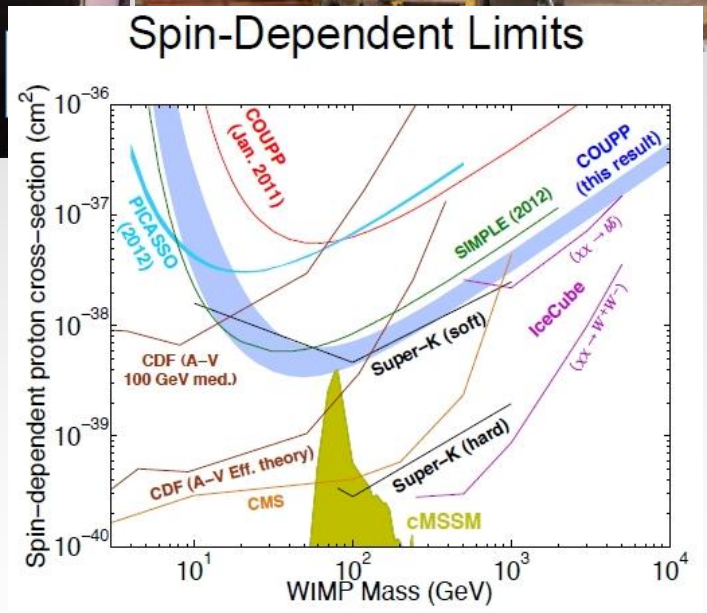
P and T set to be sensitive only to nuclear recoils and alphas

recognize alphas by pulse shape

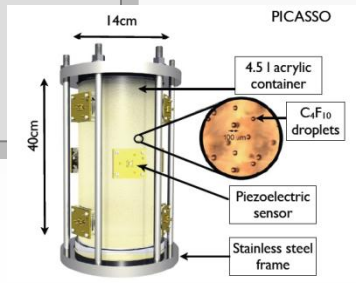
COUPP
USA
- 4kg running at SNOLAB
- 60kg running at Fermilab
  moving to SNOLAB
  physics run start 2012
- 500kg in preparation



COUPP
60-kg detector
surface test



PICASSO
•***Canada, USA, Czeck***
1.9 kg running since 2009
• new SD constraints from
• moved to larger lab
within SNOLAB



COUPP 4kg
best direct detection
spin dependent limit

Superheated Droplets PICASSO

similar to bubble chamber

P and T set to be sensitive only to nuclear recoils and alphas

recognize alphas by pulse shape

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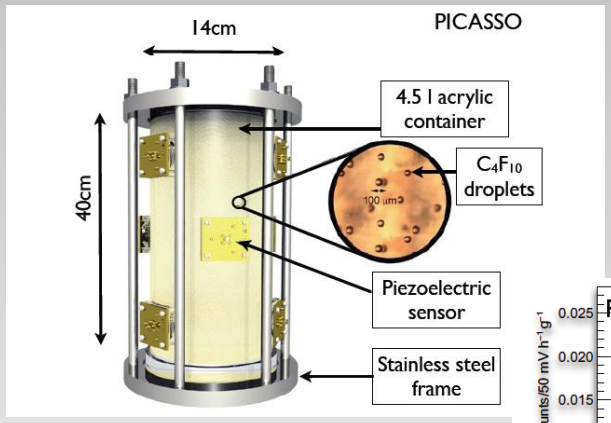

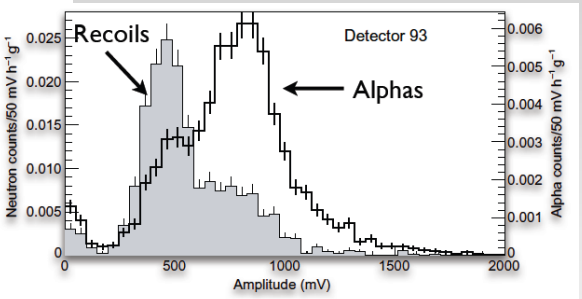

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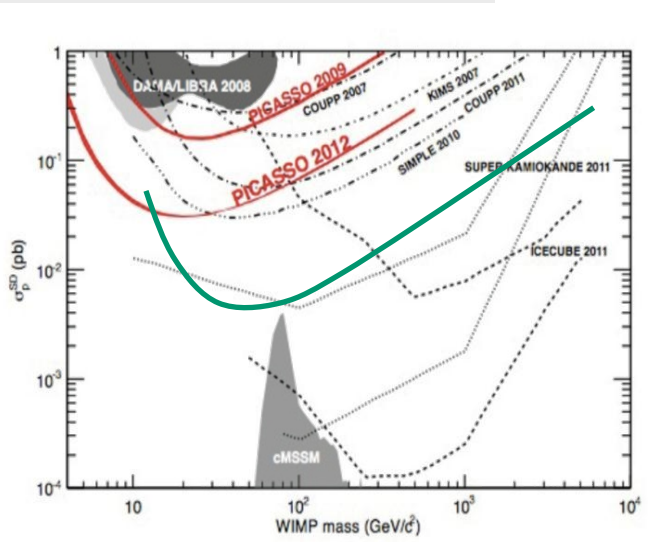
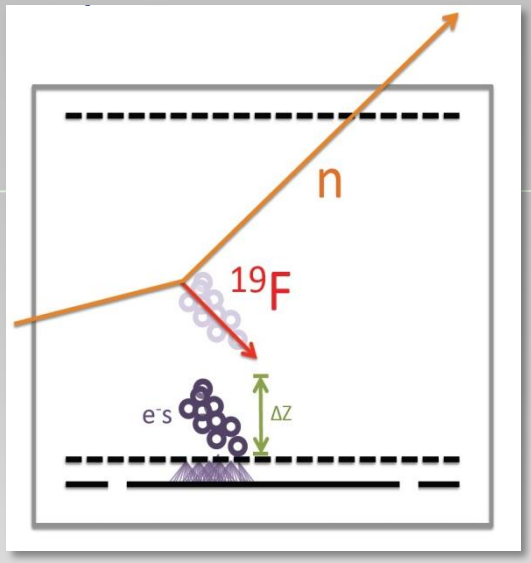


Directional



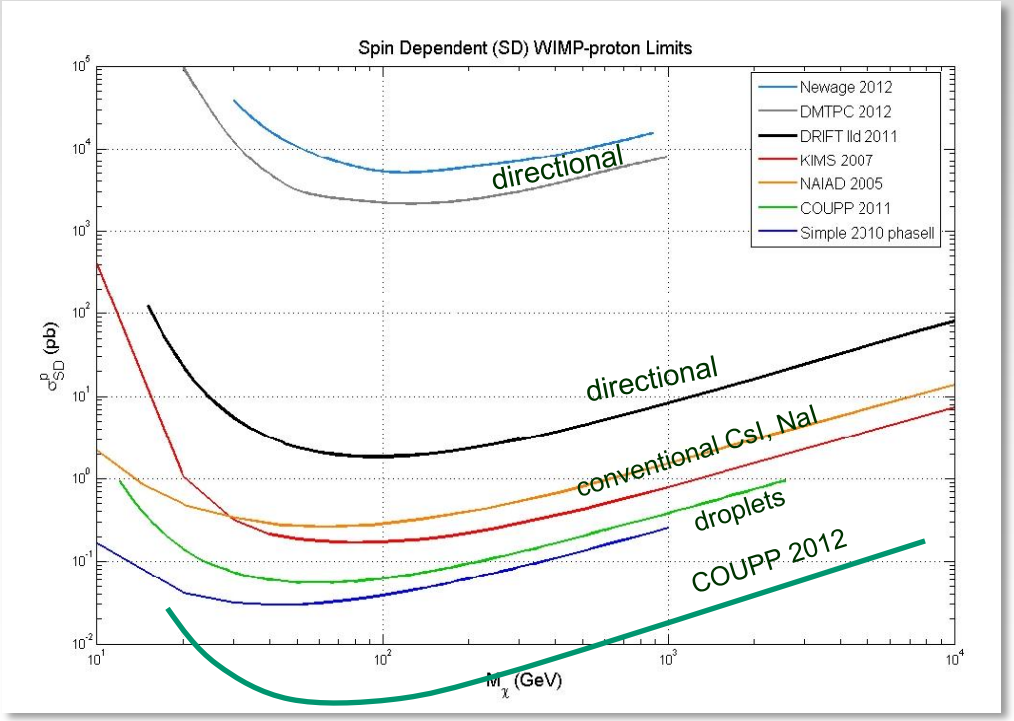
WIMPs come from certain direction (Cygnus)

=> measure direction of recoil

needs gas target
thin => low mass,
CF good for spin dependent

and track read out

DMTPC – *US*
MIMAC – *France*
DRIFT – *UK, US*
NEWAGE - *Japan*



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run ~1kg Ge

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prototypes

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run
~ 10kg, 2012
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Germany, UK, Italy

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EURECA
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CDMS
Super CDMS
US, Can., Switzerlnd

prototypes

Rosebud
France, Spain

LIQUID NOBLE GASES

XENON	*ARGON*
run ~ 30kg 2012 plan ~ 1t, 2014	prepare ~ 100kg–1t plan > 1t
XENON *USA, Switzerl. Italy, Japan, Portugal, Germ. France, China*	**ArDM** *Switzerland, Spain, UK, Poland*
run ~ 100kg	**DARK SIDE** *US, Italy, Rus, Poland China, Ukraine, UK*
XMASS *Japan*	**DEAP/** **CLEAN** *Canada, US*
prepare ~ 100kg	finsihed
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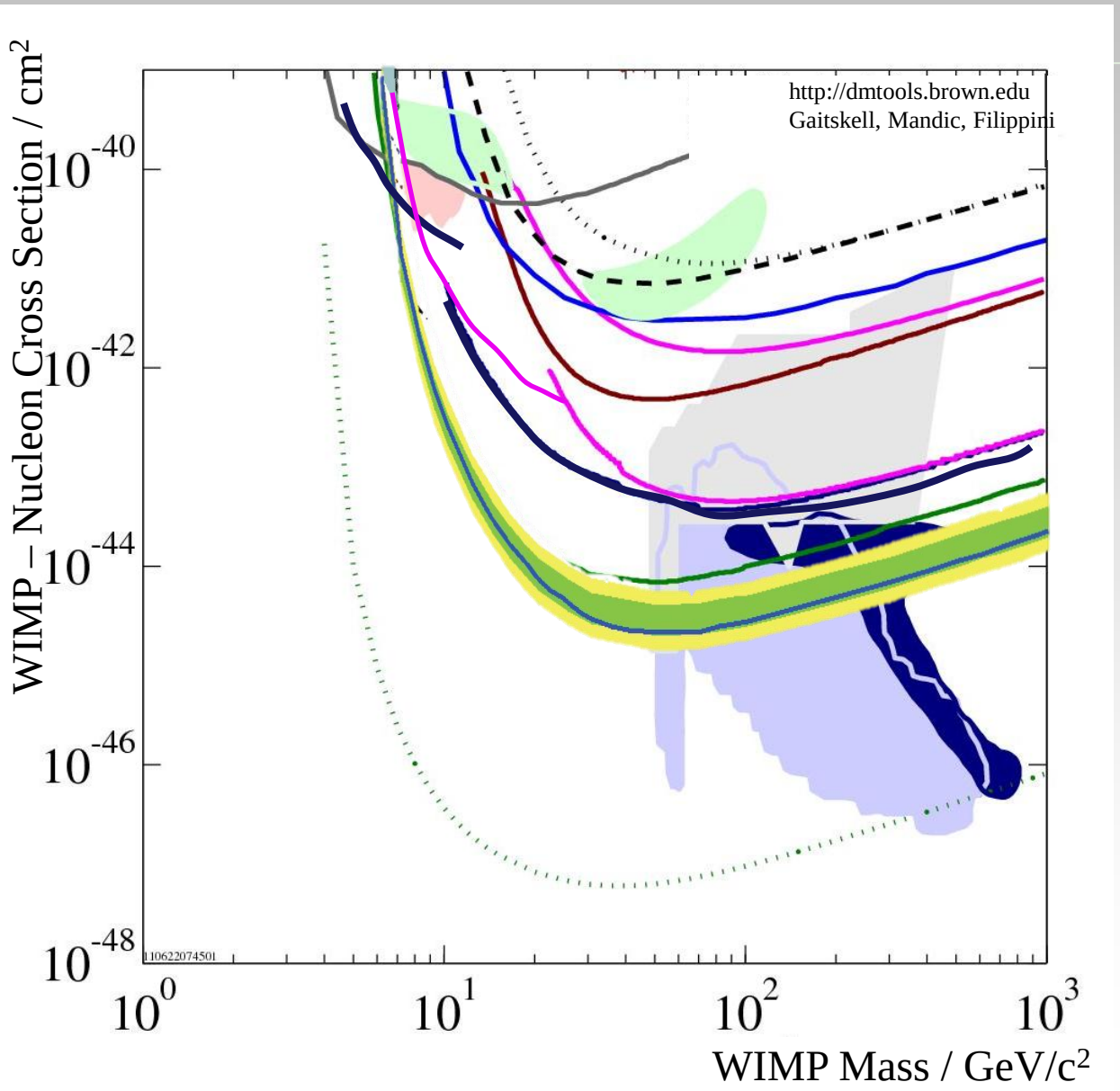

Heidelberg Moscow 1996
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CDMS 2000
EDELWEISS 2002
CRESST 2009
EDELWEISS 2011
CDMS 2011
XENON 2011
XENON 2012

~ 0.00003 cts / kg / d / keV

Baltz, Gondolo MSSM 2001
Baltz, Gondolo 2004
Trotta et al CMSSM 2008

Direct DM Searches

Nothing found yet => keep going on!

x 1000 improvement in sensitivity
in 10 yrs

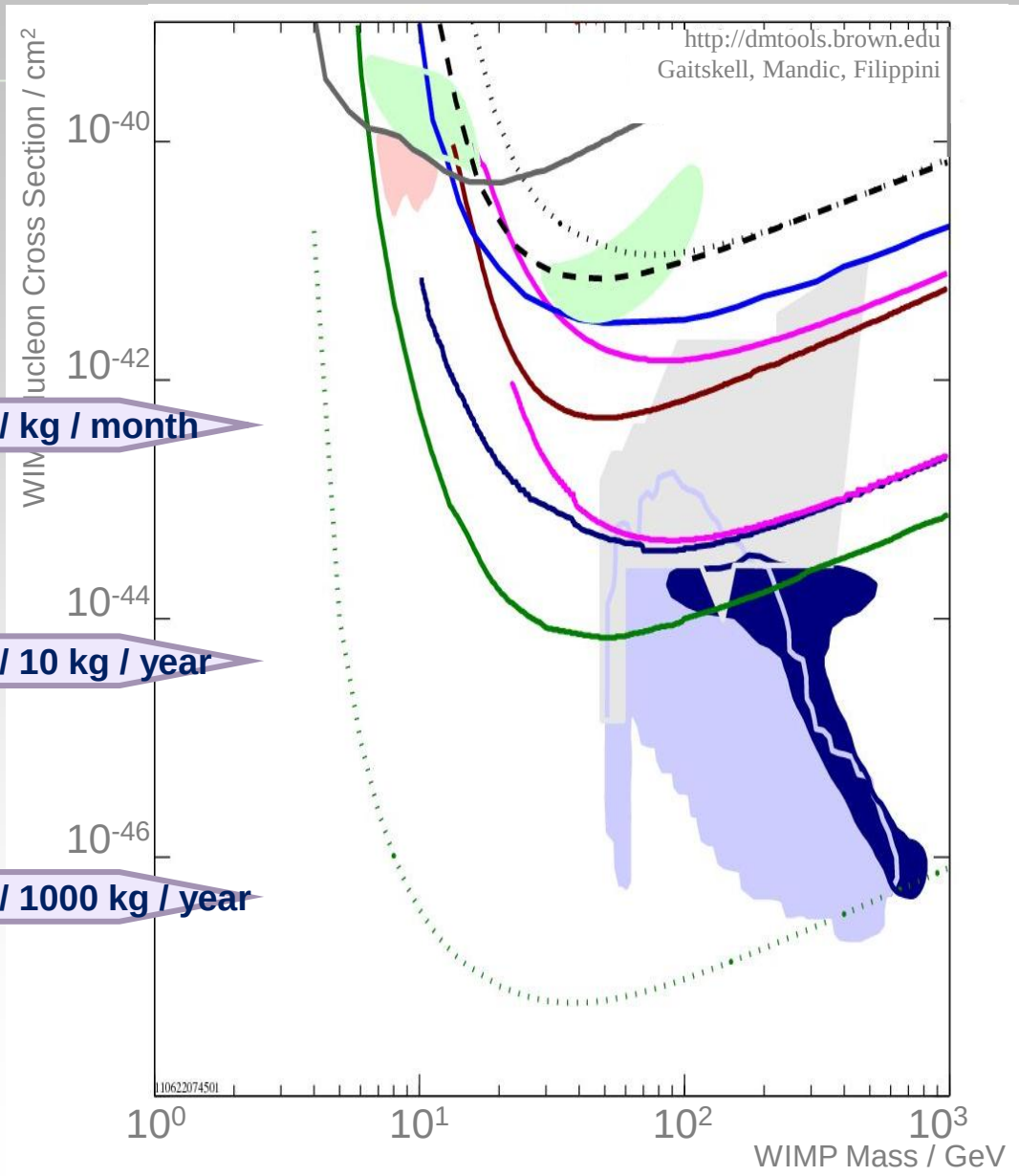
present best sensitivities
(for spin independent WIMP scattering)

- cryogenic
- liquid Xenon

+ other techniques
(doing better for spin dependent WIMP scattering)

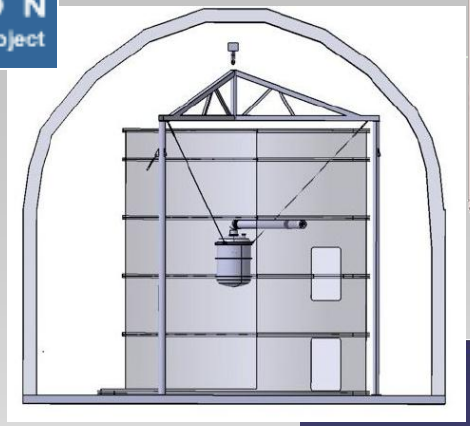
we have different techniques with promising sensitivity

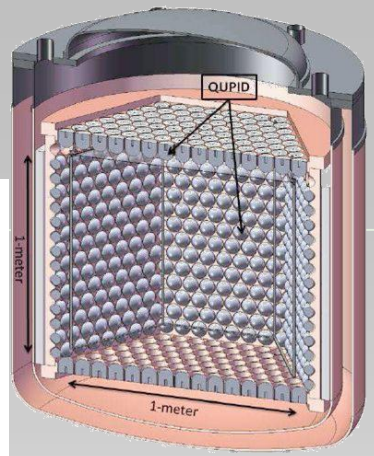
XENON, EURECA, SuperCDMS, DARK Side, ArDM, DEAP, …



XENON

USA, Switzerland, Italy, Portugal, Germany, France, Japan, China



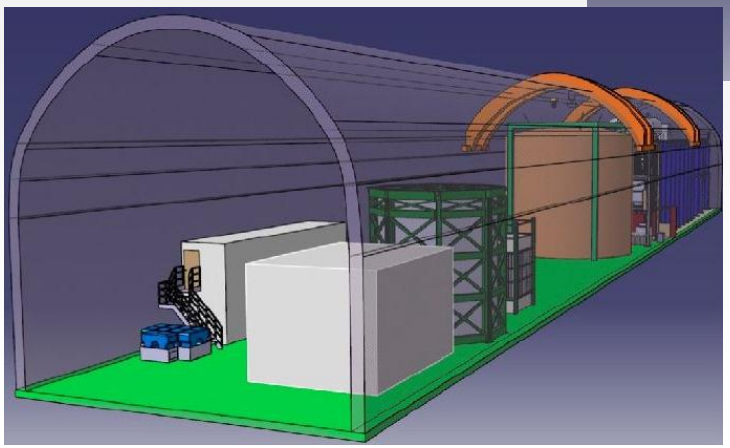


XENON 100 +

- at Gran Sasso
- 50 kg fiducial / 170 kg total funded
- starting end of 2009
- achieved 2011: ~ 7 x 10^{-45} cm^2
- achieved 2012: ~ 2 x 10^{-45} cm^2

XENON 1t

- TDR submitted 1t Xe fiducial
- approveds for hall B LNGS
- completion until 2014
- start data taking 2015
- goal < 10^{-47} cm^2



EURECA

Germany, France, UK, Spain, Russia, Ukraine

combines all European cryogenic DM efforts:

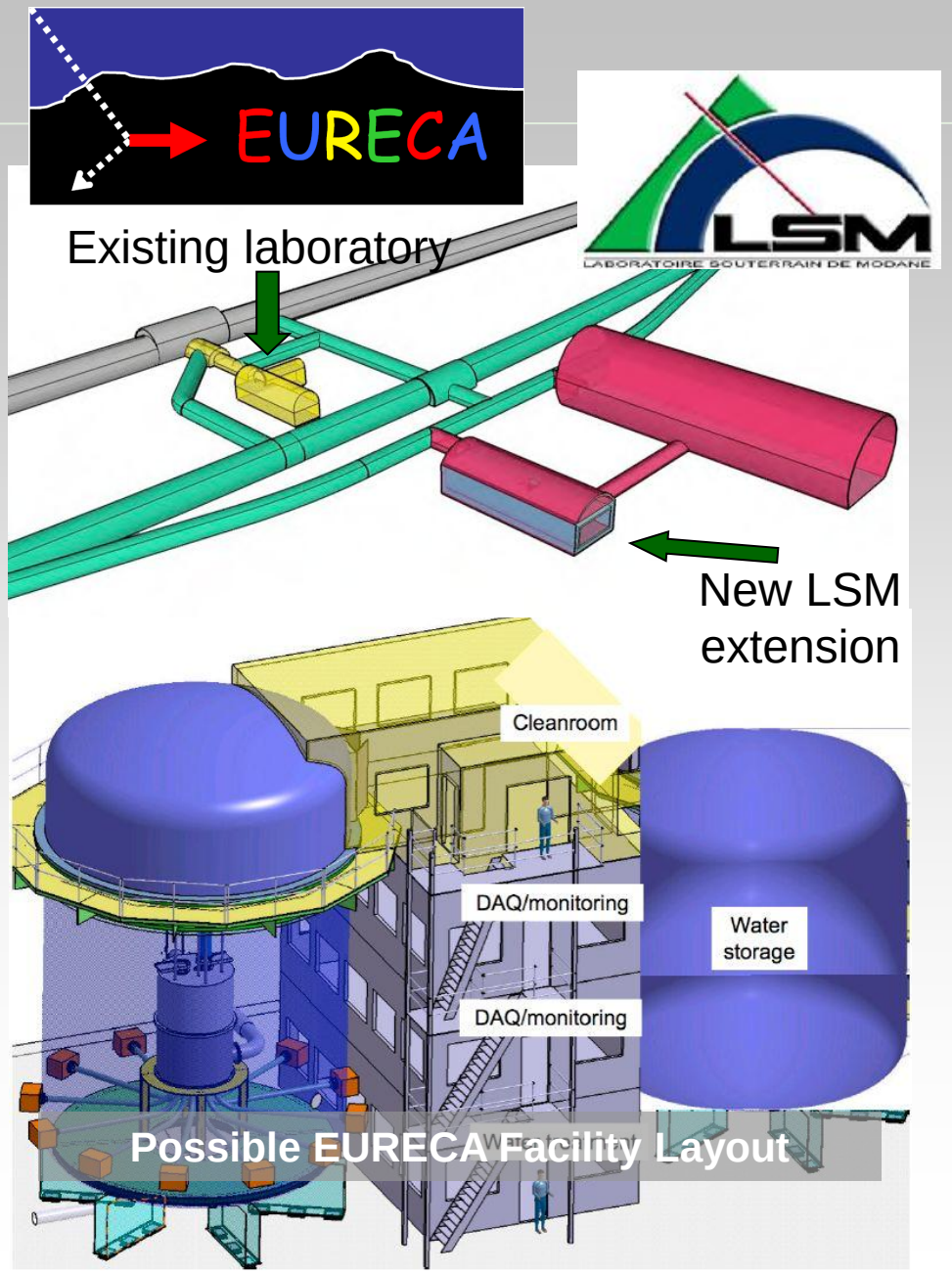
cooperation with CDMS/GeoDM !!??

Targets : Ge and CaW04

2012: CDR ready, “site independent”
1 cryostat for 1000 kg
2 steps: phase 1 = 150 kg;
phase 2 = 1000 kg

2013 : decision, site choice
2013-2014 : possible LSM excavation
2013-2014 : TDR, construction of components

2015: construction at LSM or X site
2016: begin phase 1 data taking
2016 – 2019: continuous upgrade to 1t target
=> from 10^{-45} to few 10^{-47} cm^2



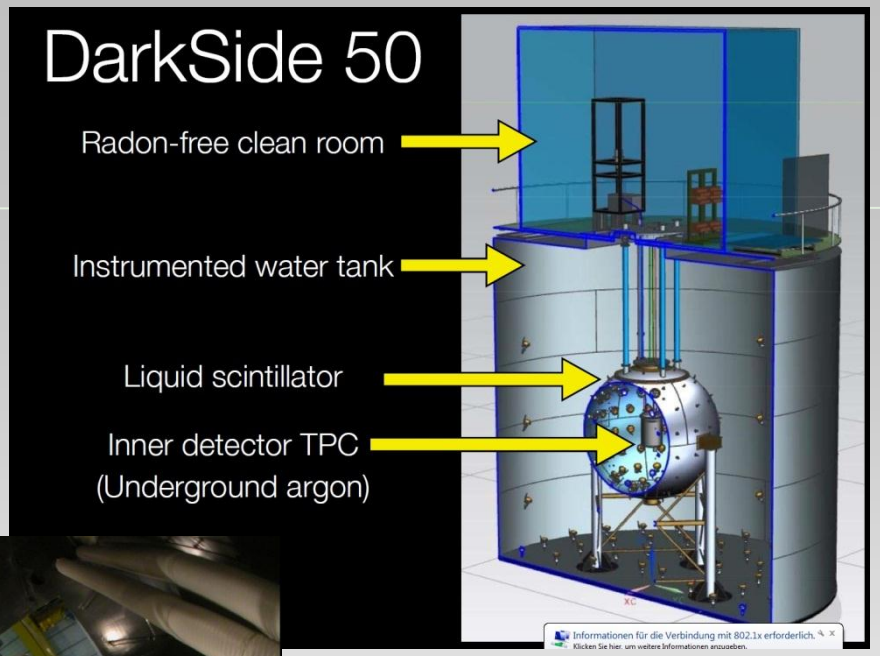
Liquid Argon *Charge + Light*

WARP
Italy, US
• at Gran Sasso
• stopped (technical problems)

ArDM
Switzerland, Spain, UK, Poland
•1000 kg R & D, prototype
• set up at Canfranc start 2012

DarkSide
US, Italy at Gran Sasso
• proposed, depleted Ar

DEAP / CLEAN
Canada, US
• 1-phase, SNOLAB
•1000 kg fid. start set up 2012



DarkSide

- geological Ar
  free of ^{39}Ar
- prototype running
- DarkSide 50 ~ 10^{-45} cm^2
  presently set up
  in Borexino-CTF
- multi ton ~ 10^{-47} cm^2

Liquid Argon *Charge + Light*

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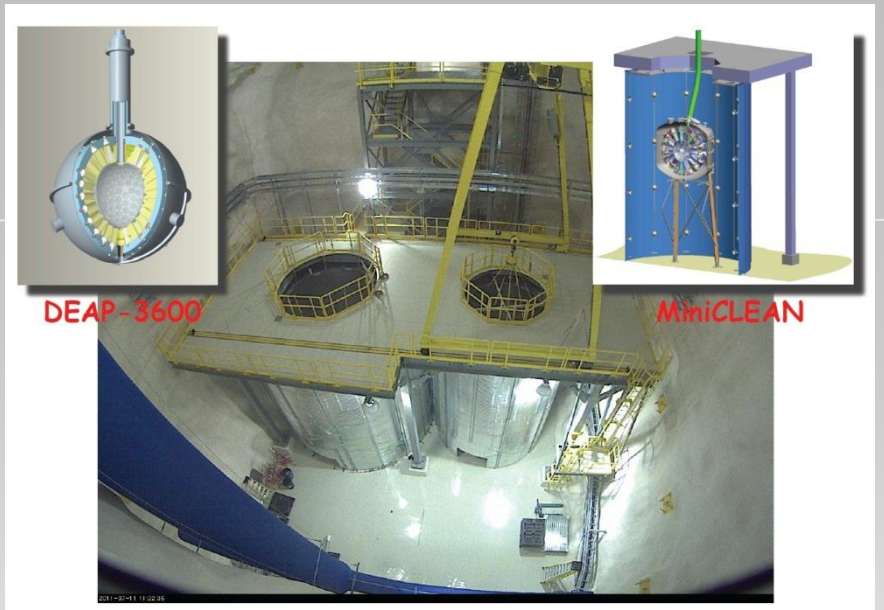
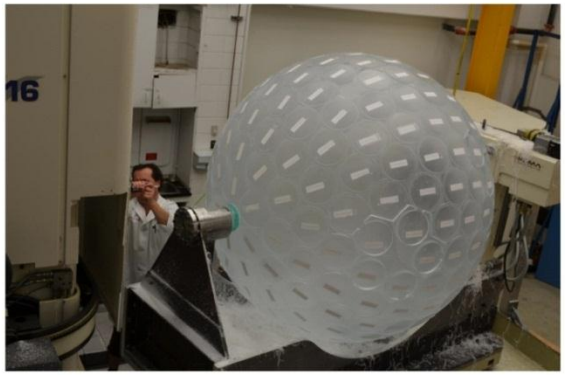


DEAP / CLEAN

- DEAP 3600 goal ~ 10^{-47} cm^2
- Sep.2012
  most componments
  at SNOLAB
- commissioning
  late 2013

DEAP Acrylic Vessel with Light Guide "Stubs" July 2012



Strategy: Next Years

US Roadmap Process:

- more than one large scale experiment

$\Rightarrow$ liquid noble gas + cryogenic ??

European Roadmaps:

- support now installation liquid Xenon,
  Cryo R&D and preparation => installation later

Cryo-Strategy:

- better on low mass WIMPs

- multi target (strong point for CRESST)

(liquid noble gases are not as large as name might suggest
1 t noble gas ~ 200 kg cryo)