

Direct Search for Dark Matter

Direct
Dark Matter Search

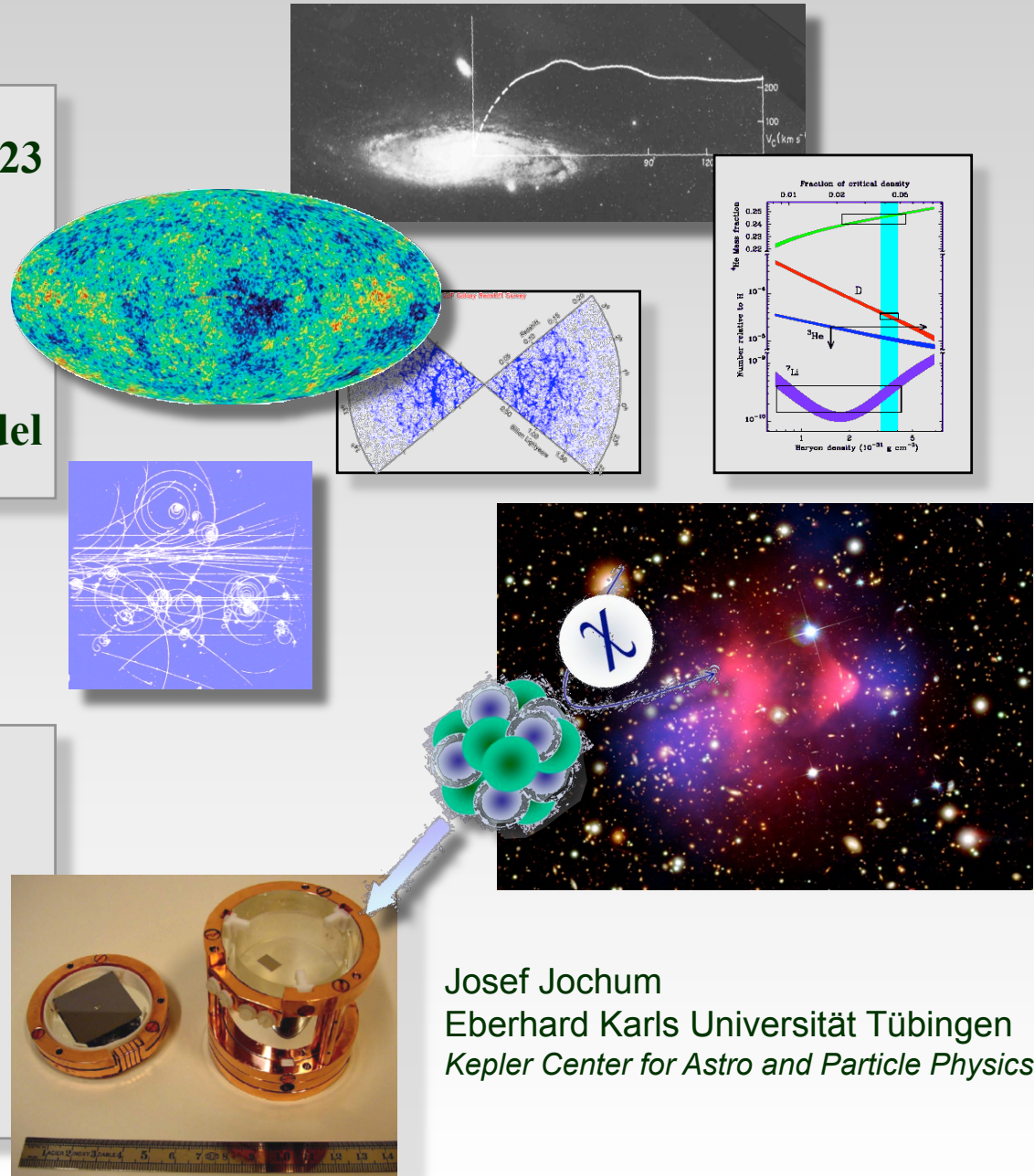
Dark Matter in the Universe $\Omega = 0.23$

- non-baryonic
- not neutrinos

⇒ physics beyond the standard model

thermal relics from Big Bang
weakly interacting
in the mass range $\sim (10 - 1000)$ GeV
could nicely explain Dark Matter

⇒ can be detected by direct detection
elastic scattering off nuclei
⇒ could be supersymmetry



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

WIMP – Direct Detection

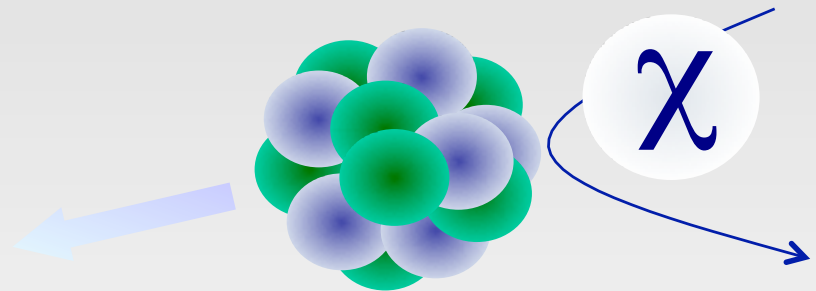
*Weakly Interacting Massive Particles = **WIMPs***

Elastic Scattering off Nuclei

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

- Mass GeV - $\sim 1000 GeV$
- relative speed $270 km/s$
($\sim$ orbital speed in Milky Way)

$\Rightarrow$ only a few keV of energy



- cross section

$$\sigma_{\chi} < 10^{-36} cm^2$$

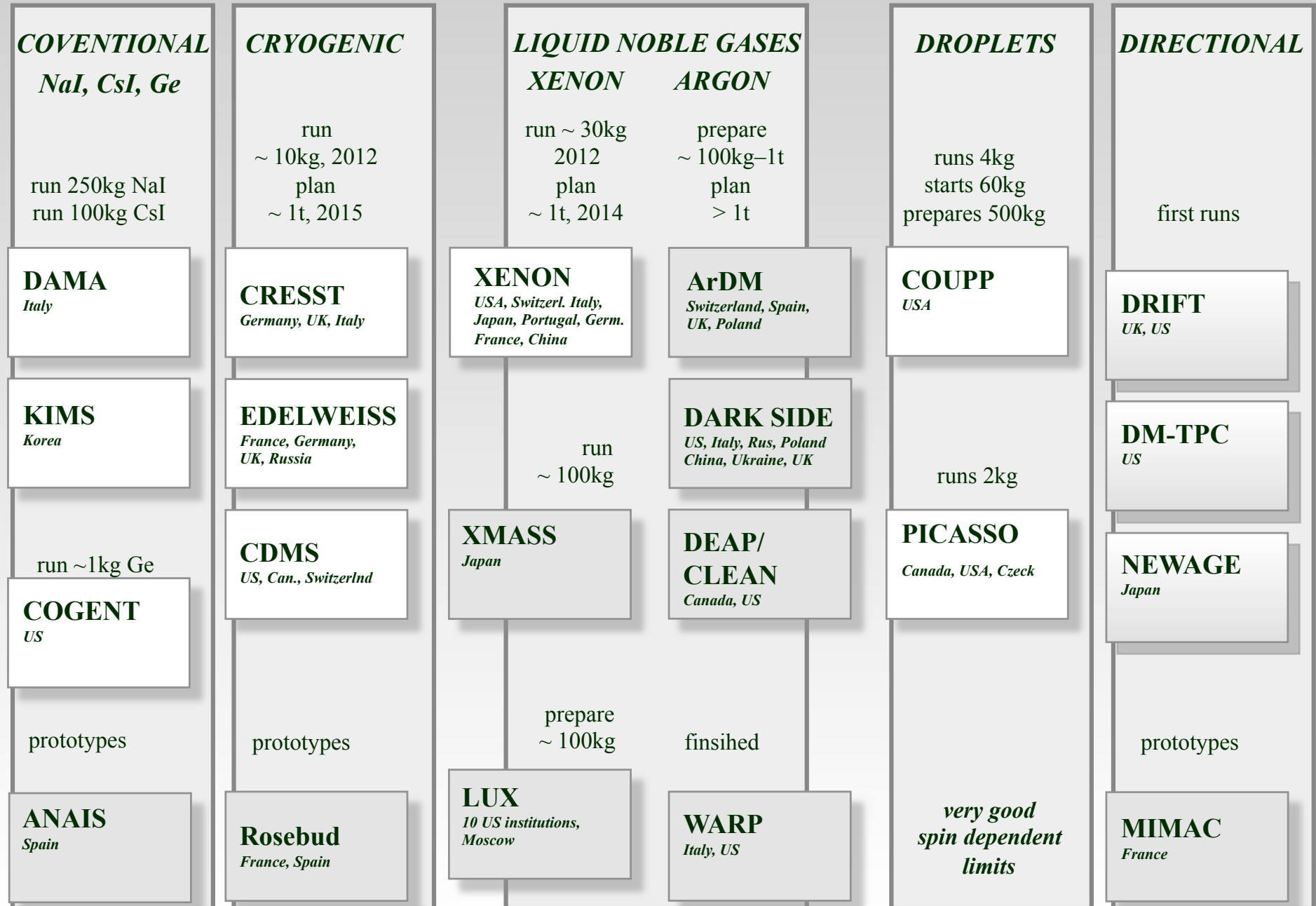
- local WIMP-Density

$$\rho_{\chi} = 0.3 GeV / cm^3 \quad - \text{corresp. } 3 WIMPs^{(100 GeV)} / Liter$$
$$- 75000 /s /cm^2$$

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

Today's sensitivity $< 1 / \text{year} / kg$

Direct DM Searches - Worldwide



Direct DM Searches

remarkable progress

x 100 improvement in
sensitivity
in 10 yrs

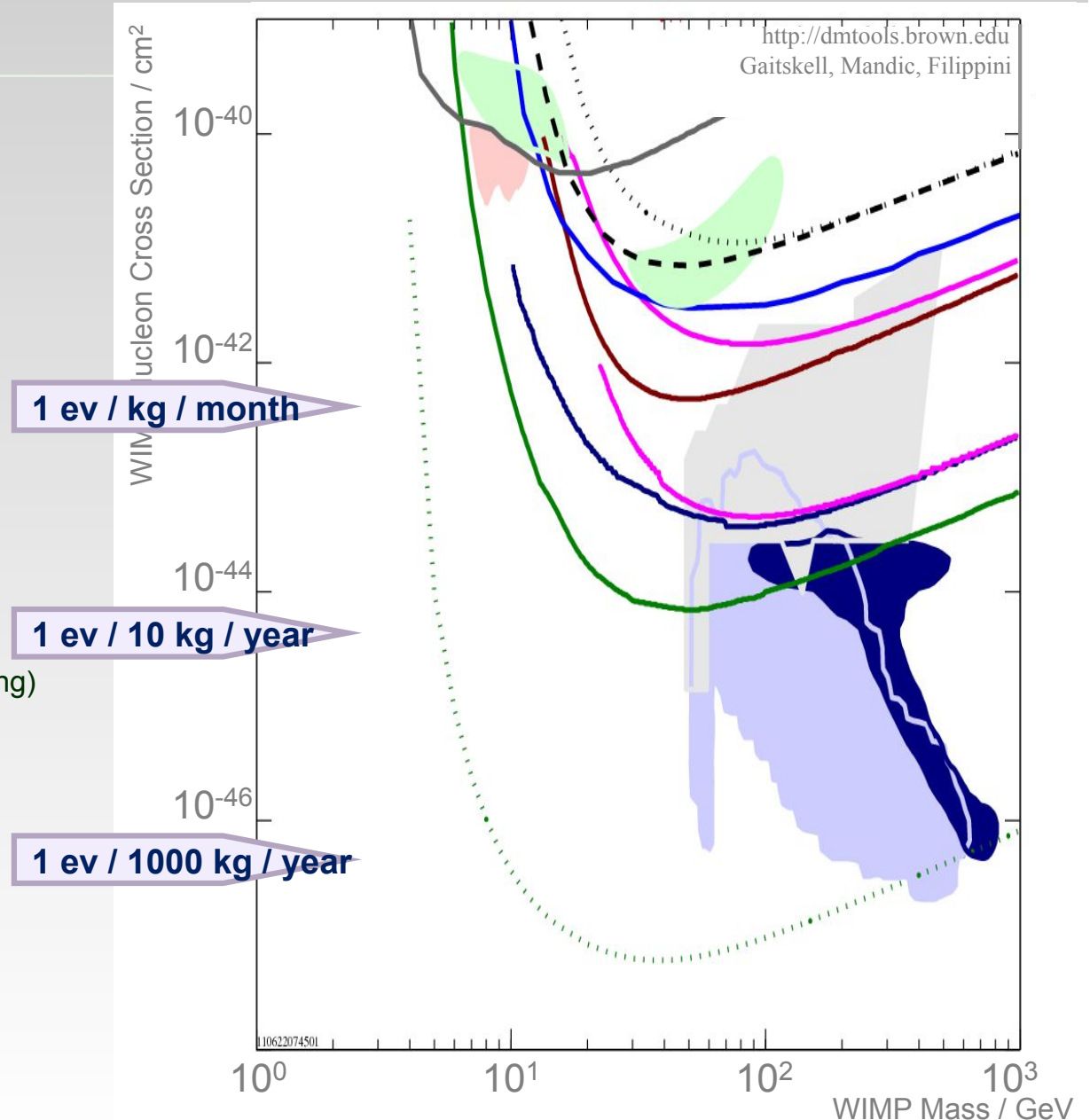
present best sensitivities
(for spin independent WIMP scattering)

- cryogenic
- liquid Xenon

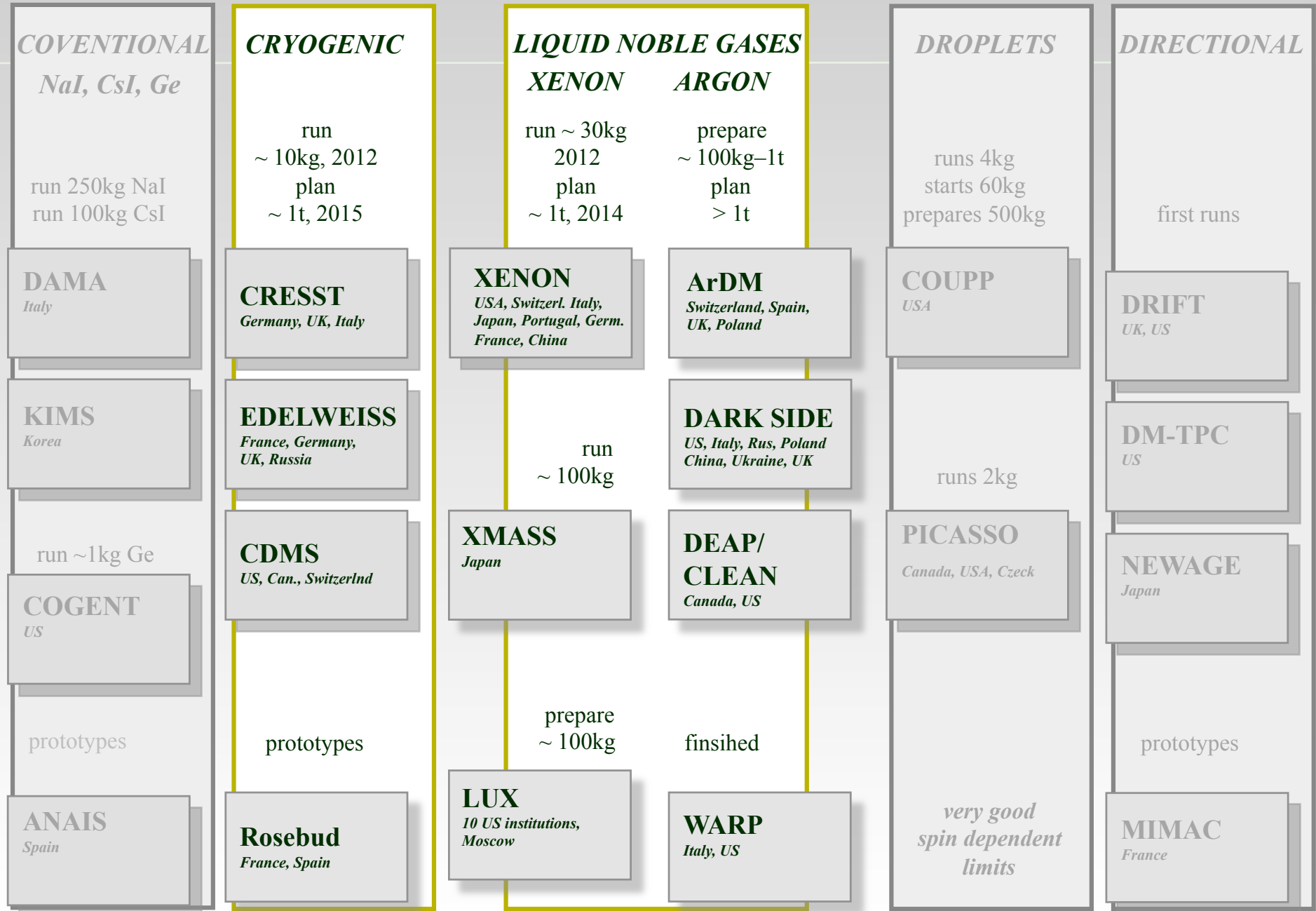
+ other techniques
(doing better for spin dependent WIMP scattering)

we have different techniques
with promising sensitivity

simultaneously
LHC is running
and will march upward in mass



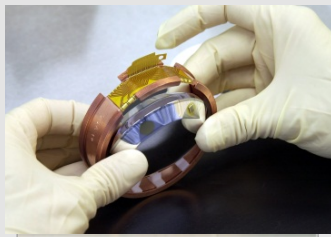
distinguish nuclear recoils / electron recoils



Particle Identification by Combination of Channels

cryogenic charge / phonon

EDELWEISS
CDMS,
EURECA



Phonons

cryogenic light / phonon

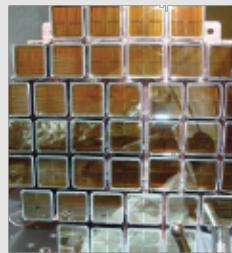
CRESST
EURECA



radioactive
background can be rejected
=> highly improved
sensitivity

Charge

Light

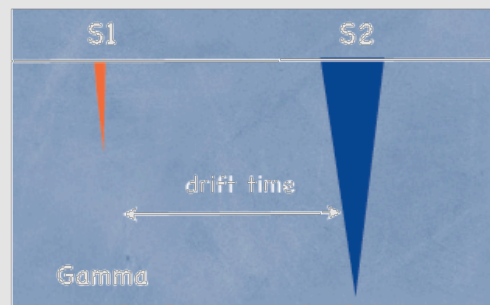
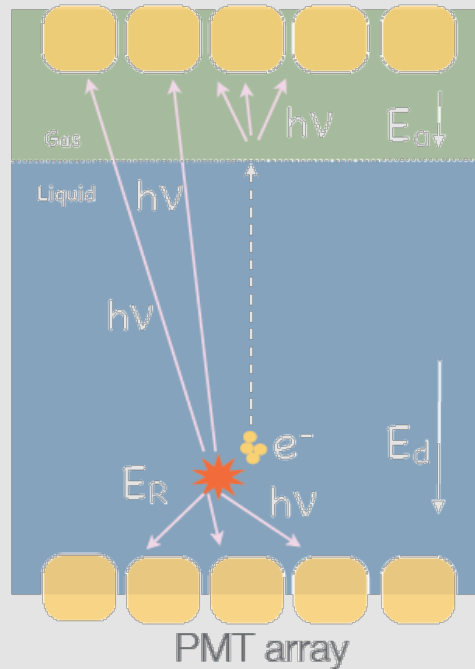


liquid noble gas light / charge

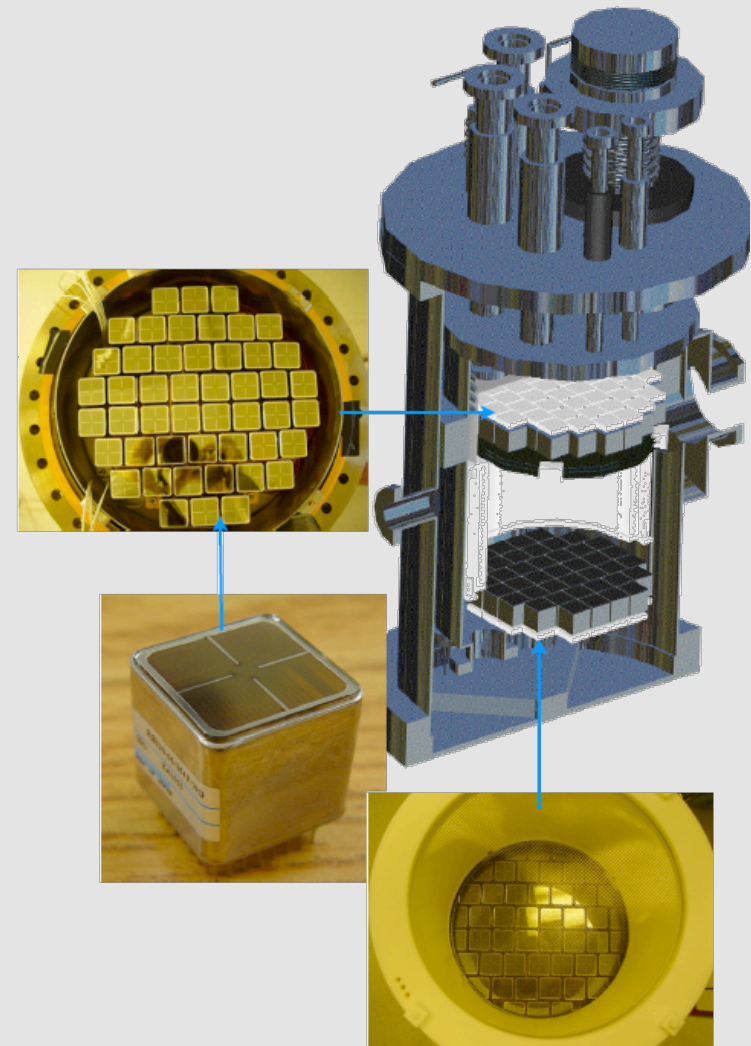
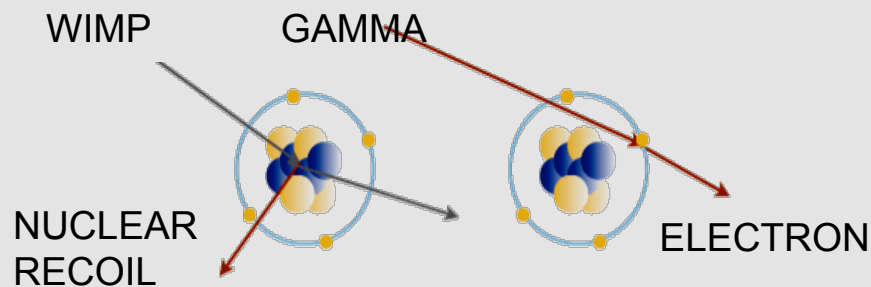
XENON
WARP, ArDM,
LUX, ZEPLIN

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

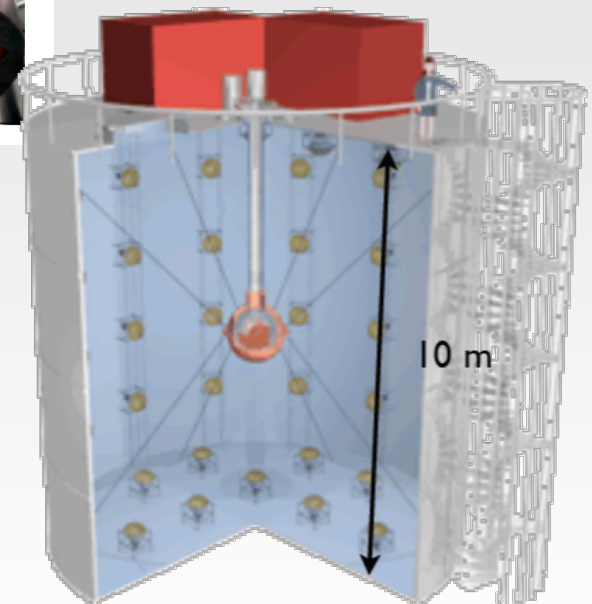
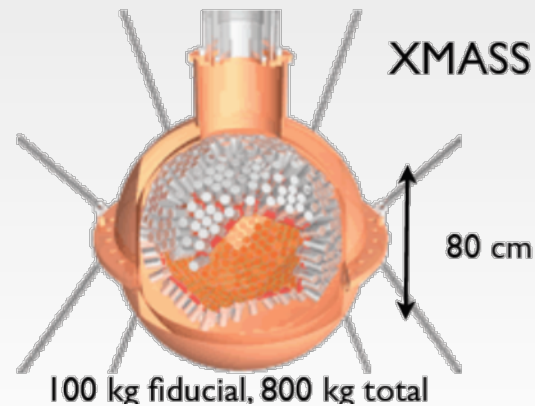
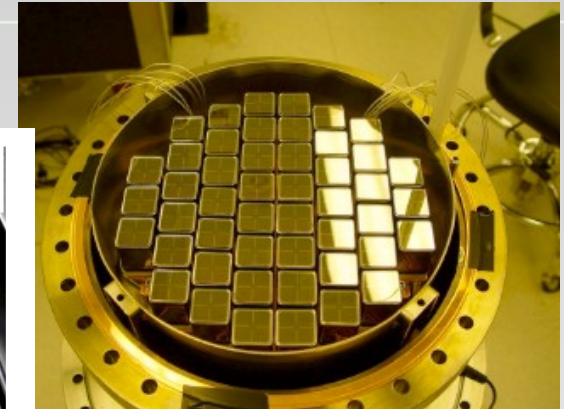
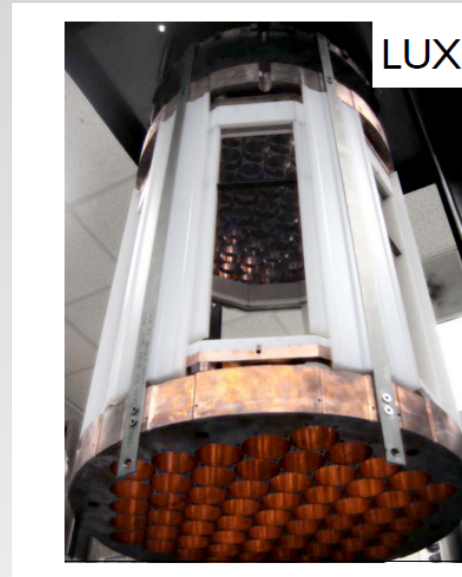
10 US institutions, Moscow

- planned 100 kg fiducial
- prototype tested
- July 2012 moved to Sanford Lab

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:

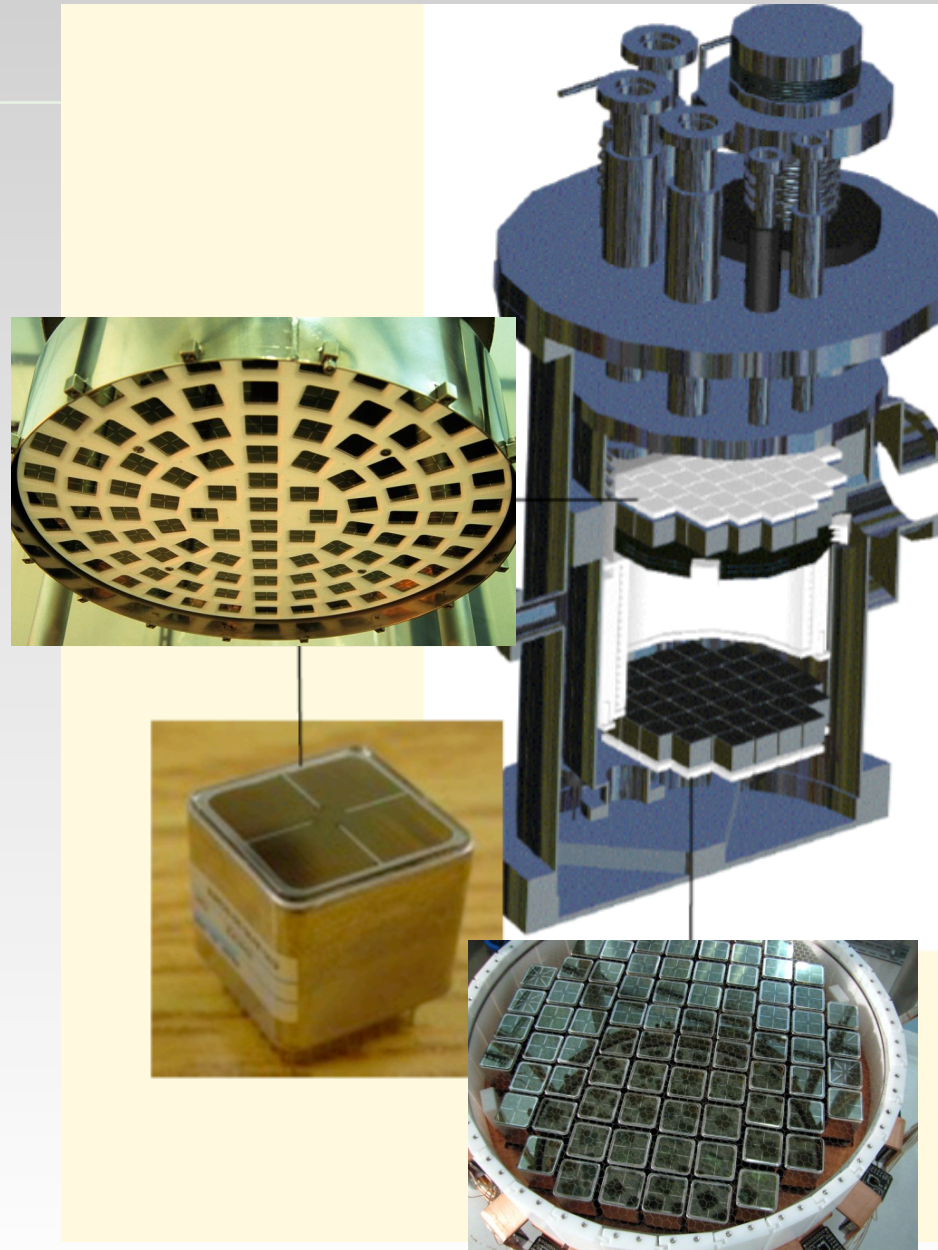
$$\sim 7 \times 10^{-45} \text{ cm}^2$$

- **achieved 2012:**

$$\sim 2 \times 10^{-45} \text{ cm}^2$$

⇒ self shielding 100 kg tid.

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



XENON Charge + Light

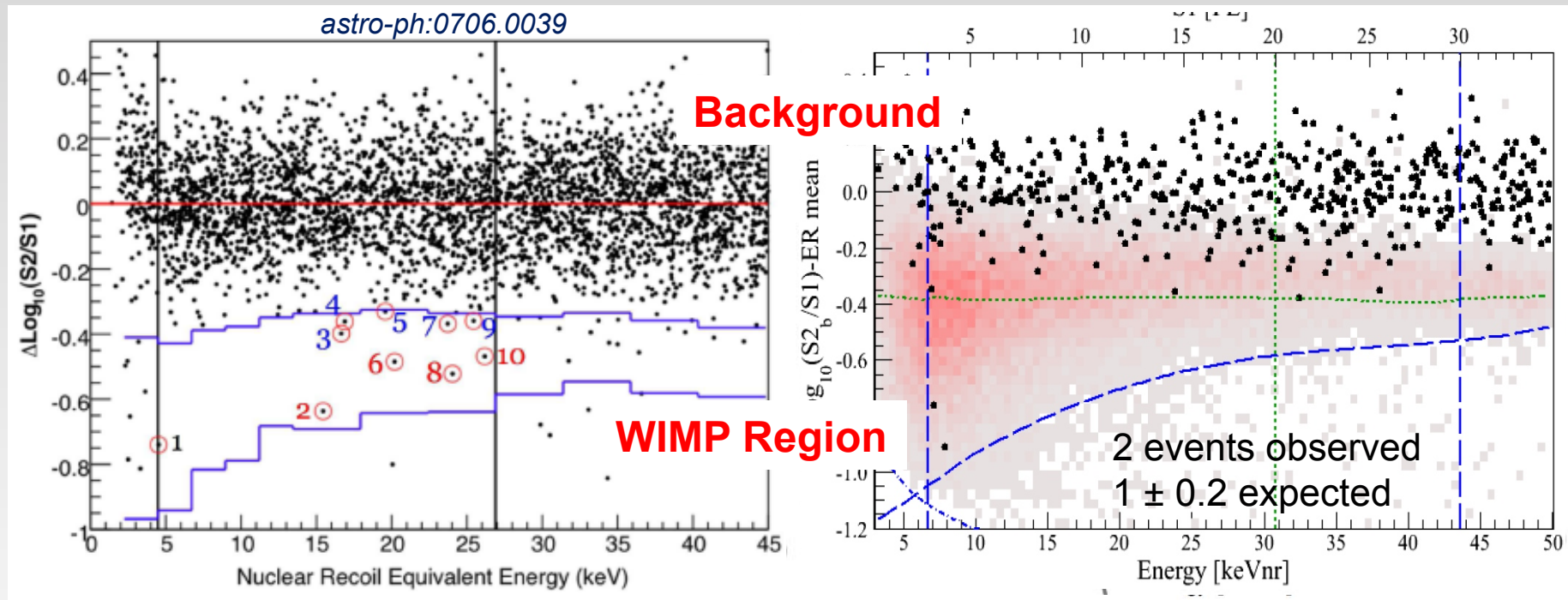
July 2012

XENON10
2007

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

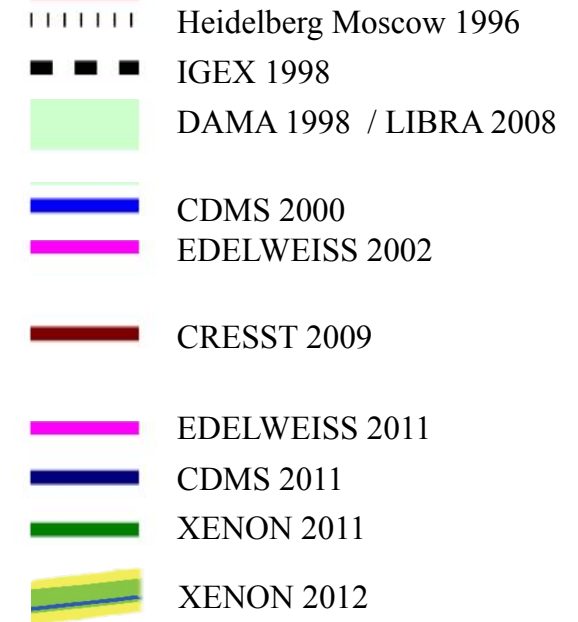
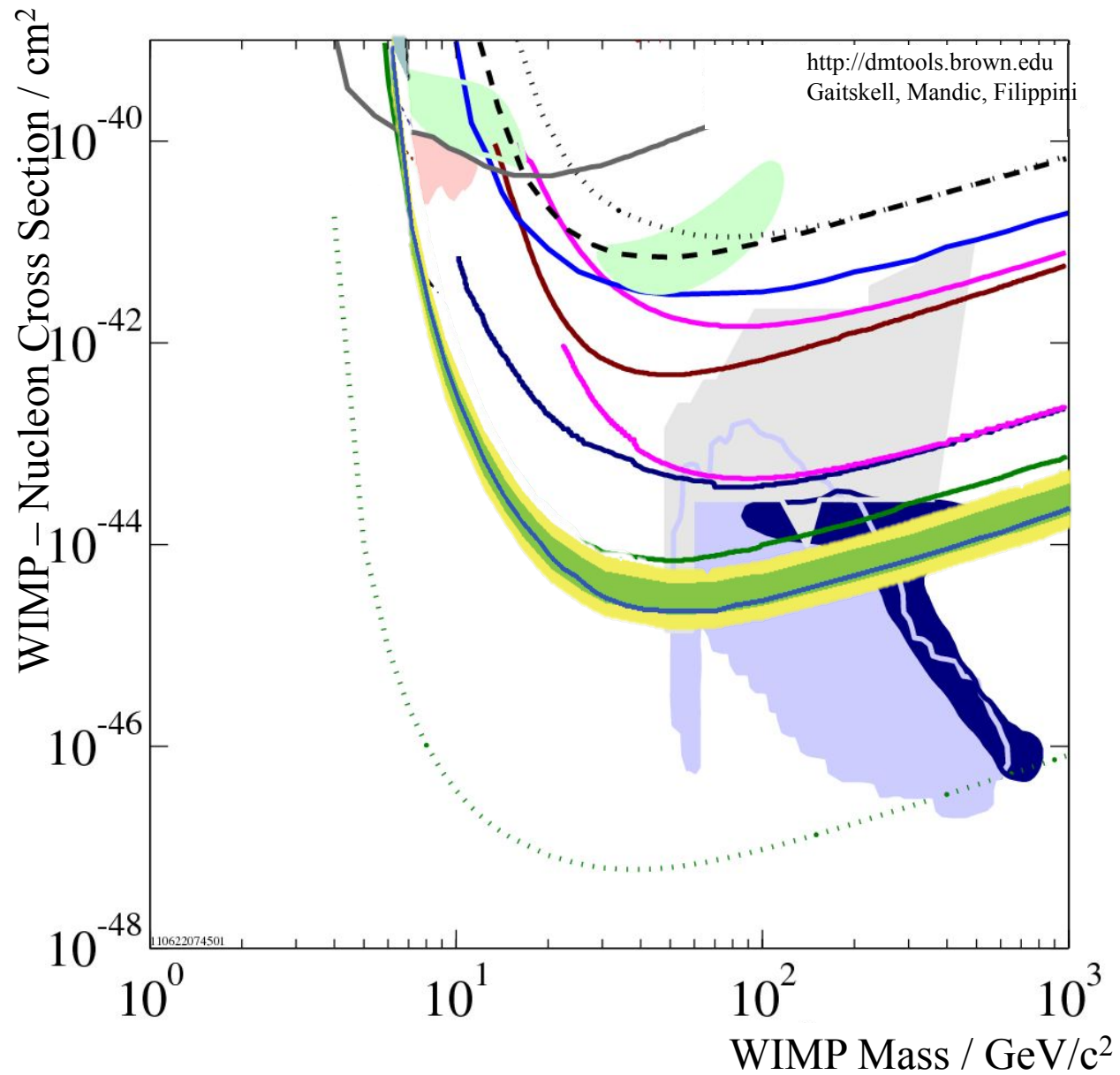
XENON100

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

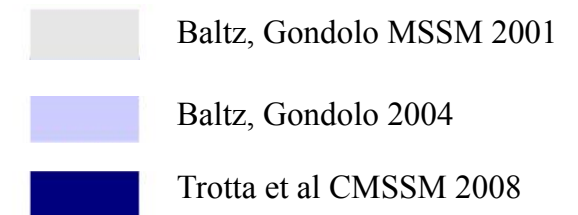


no indication for WIMP signal

Large improvement on background



$\sim 0.00003 \text{ cts / kg / d / keV}$



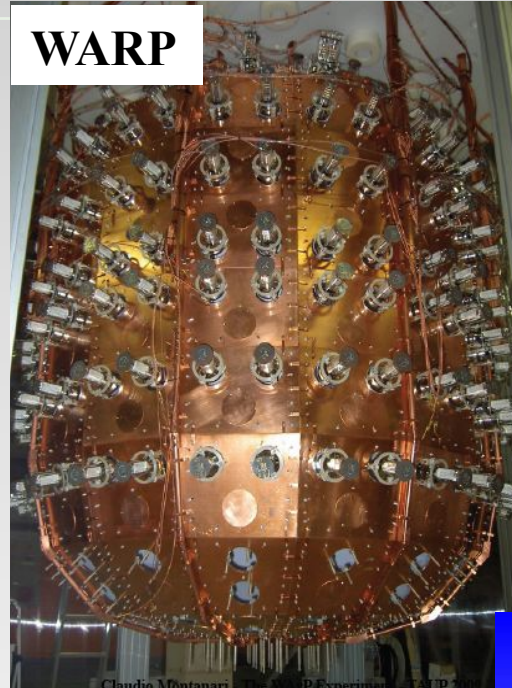
Liquid Argon Charge + Light

WARP

Italy, US

- at Gran Sasso
- stopped (technical problems)

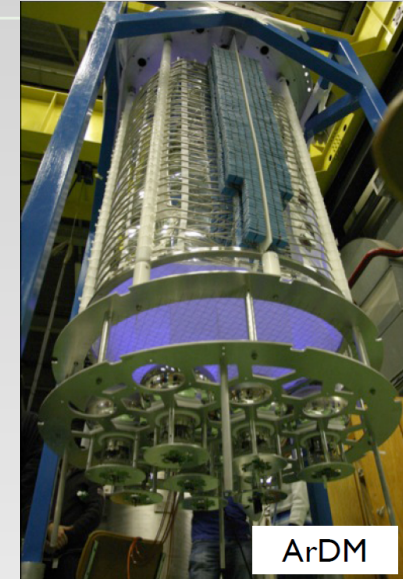
WARP



ArDM

Switzerland, Spain, UK, Poland

- 1000 kg R & D, prototype
- set up at Canfranc start 2012



ArDM

DarkSide

US, Rus, I, P, China, Ukr., UK

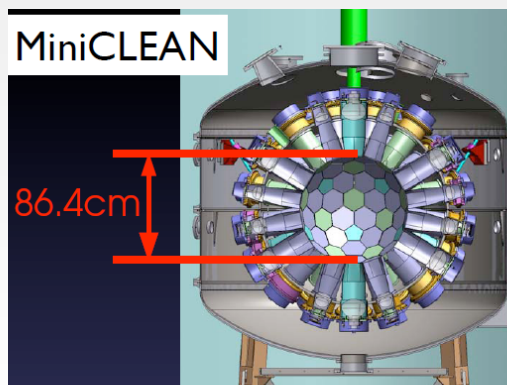
- proposed, depleted Ar

DEAP / CLEAN

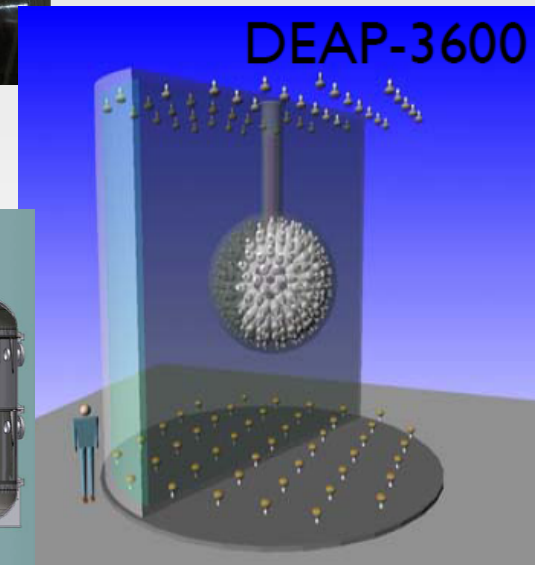
Canada, US

- 1-phase, SNOLAB
- 1000 kg fid. start set up 2012

MiniCLEAN



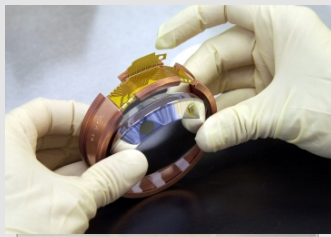
DEAP-3600



Particle Identification by Combination of Channels

cryogenic charge / phonon

EDELWEISS
CDMS,
EURECA



Phonons

cryogenic light / phonon

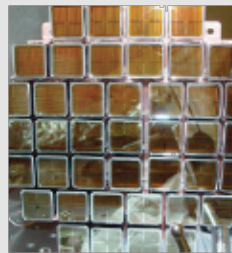
CRESST
EURECA



radioactive
background can be rejected
=> highly improved
sensitivity

Charge

Light



liquid noble gas light / charge

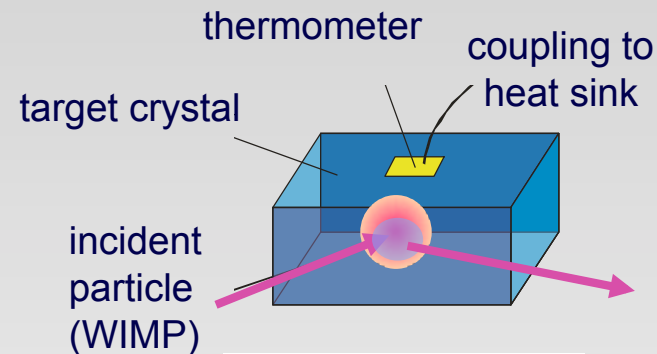
XENON
WARP, ArDM,
LUX, ZEPLIN

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

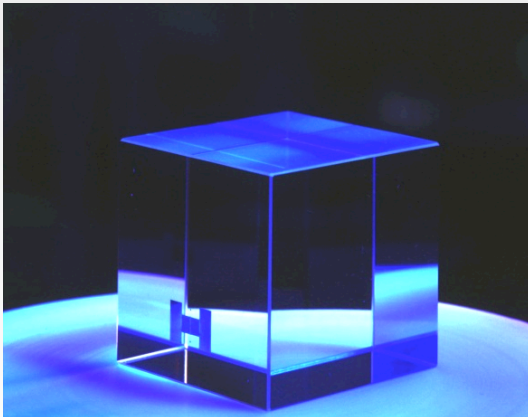
Energy deposition
by scattering

=> temperature rise

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



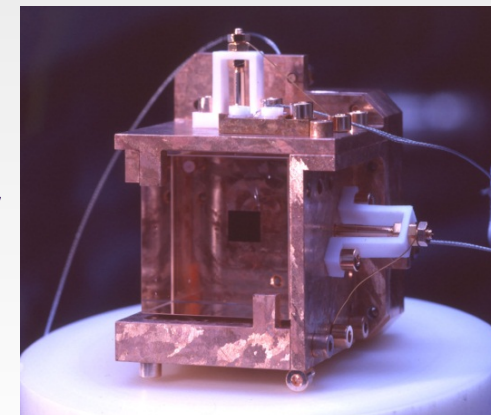
$$\Delta T \propto E/C$$



thermometer:

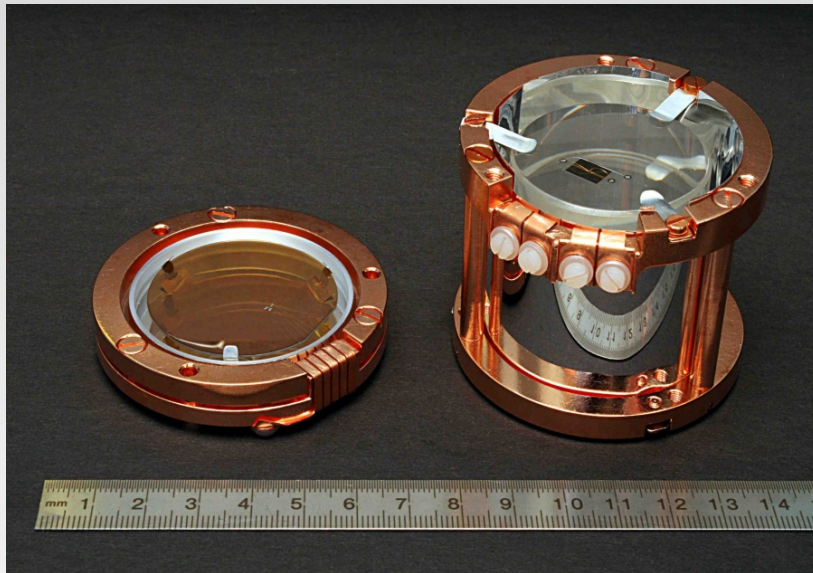
superconducting
phase-transition-thermometer

NTD semiconductors



Calorimeter for Dark Matter Search

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



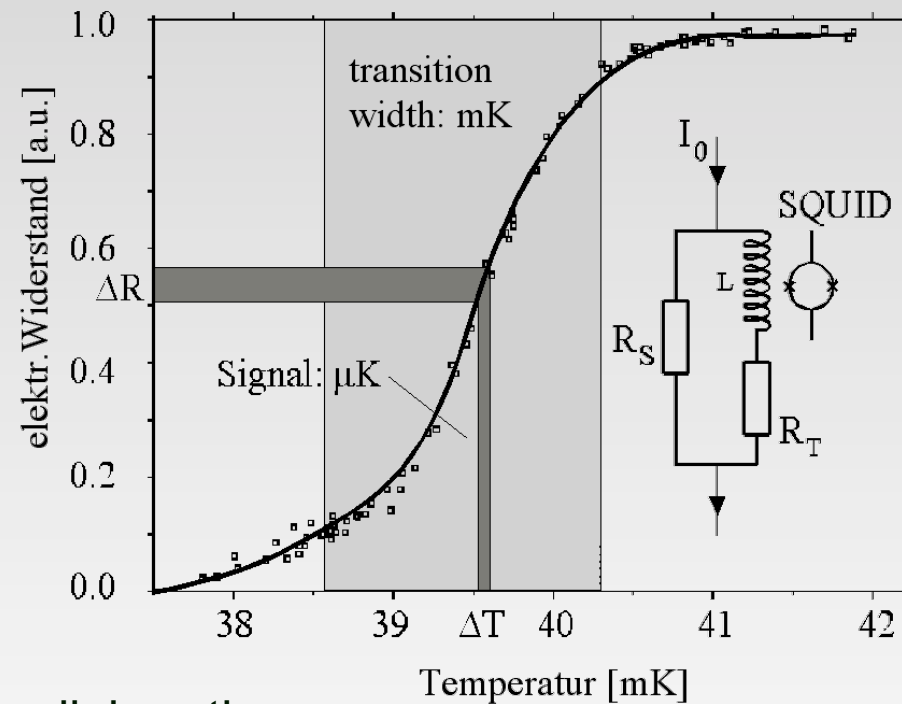
z.B. CaWO_4 -Absorber

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)

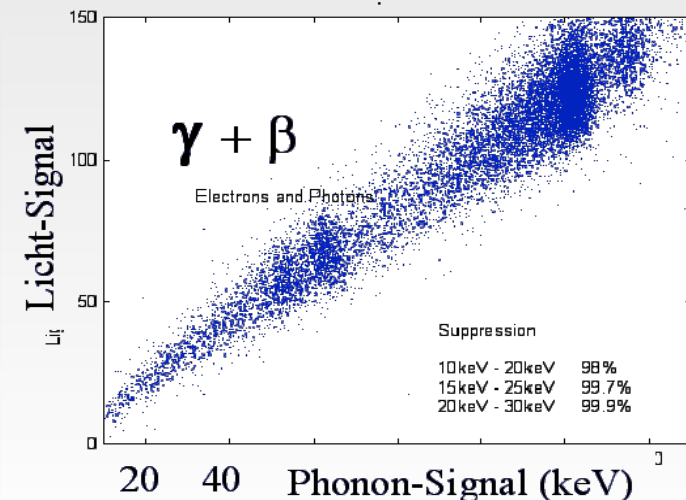
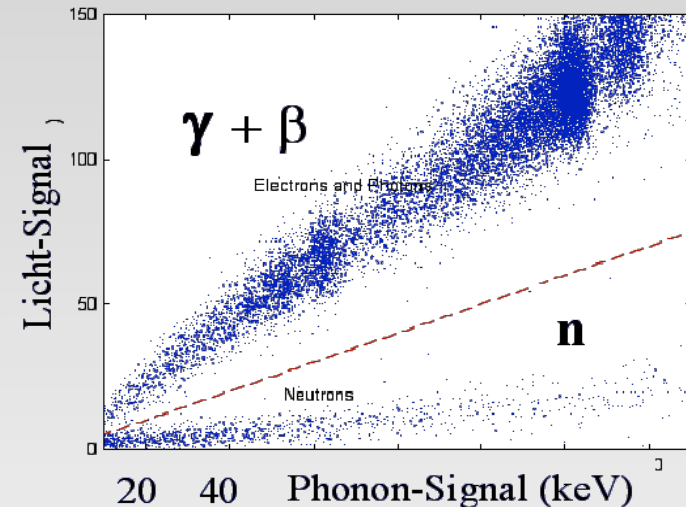
CRESST

Cryogenic Rare Event Search with
Superconducting Thermometers

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

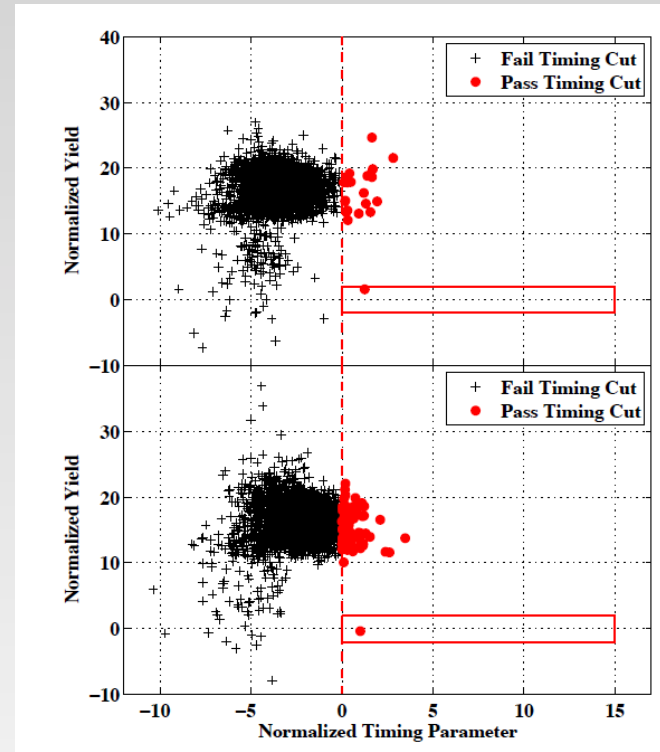
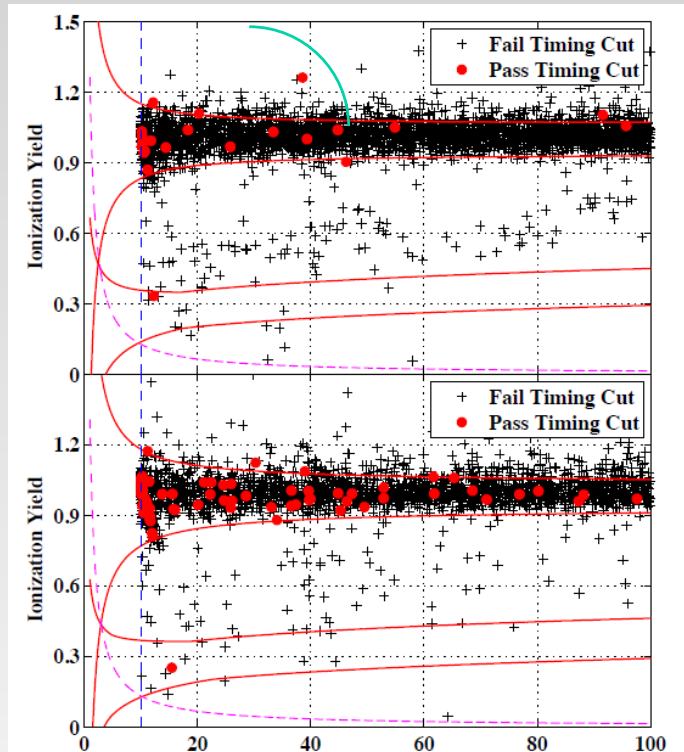
ROSEBUD

Cryogenic Rare Event Search with Superconducting Thermometers
Zaragoza, Paris



CDMS results

no indication for WIMP signal

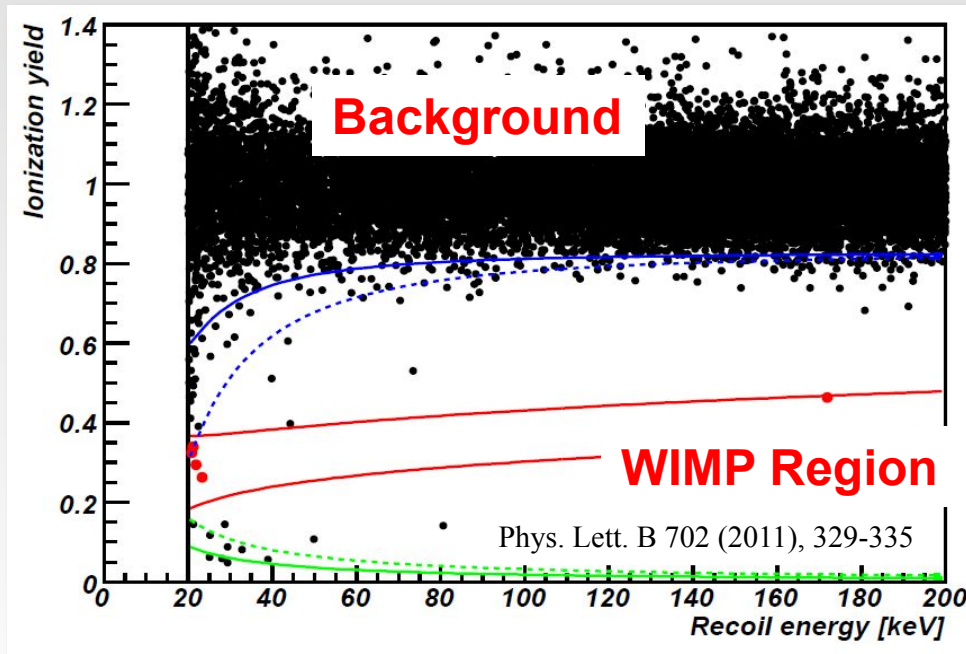
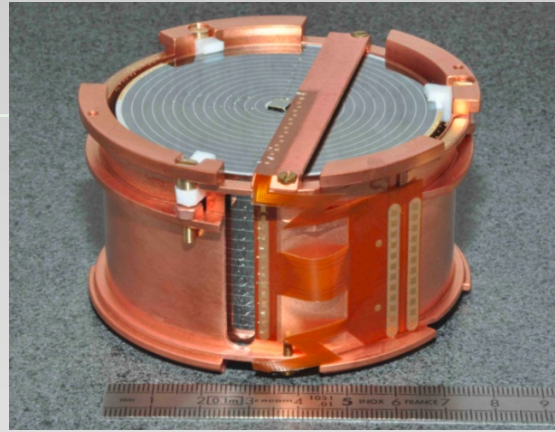


612 kg-days raw exposure
194.1 kg-days spectrum-averaged equivalent exposure @ 60 GeV
23% probability of observing two or more background events

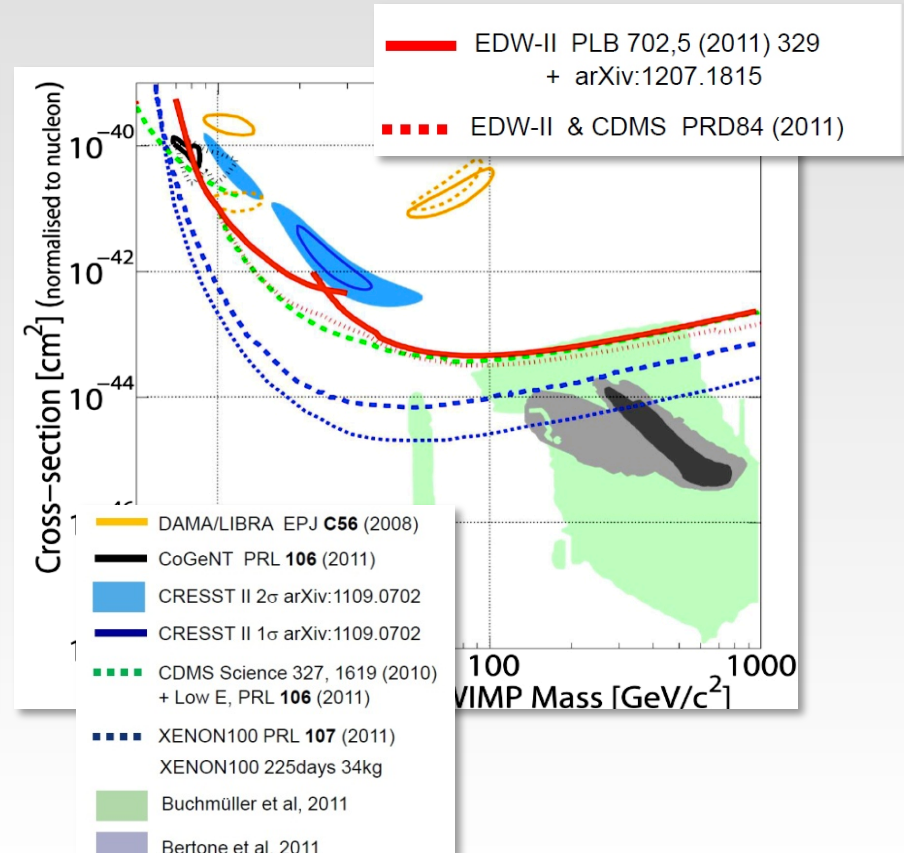
$3.8 \times 10^{-44} \text{ cm}^2$ upper limit on spin-independent cross-section @ 70 GeV, 90% CL
+ improved limits for low WIMP masses

EDELWEISS – Charge / Phonon

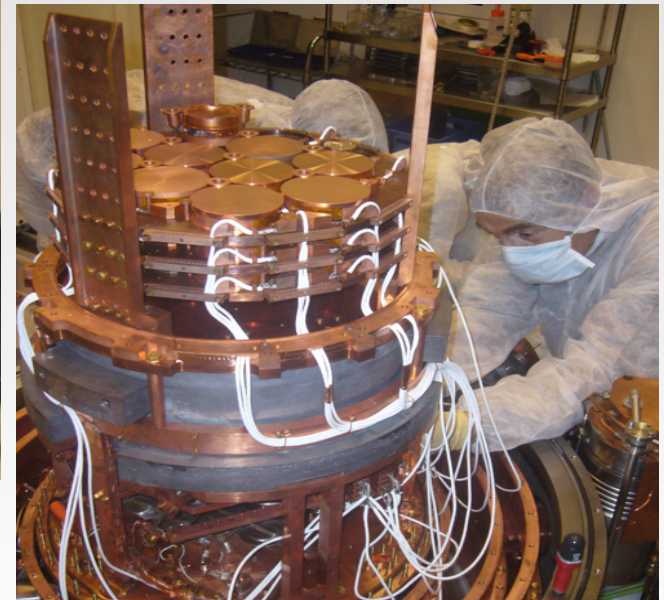
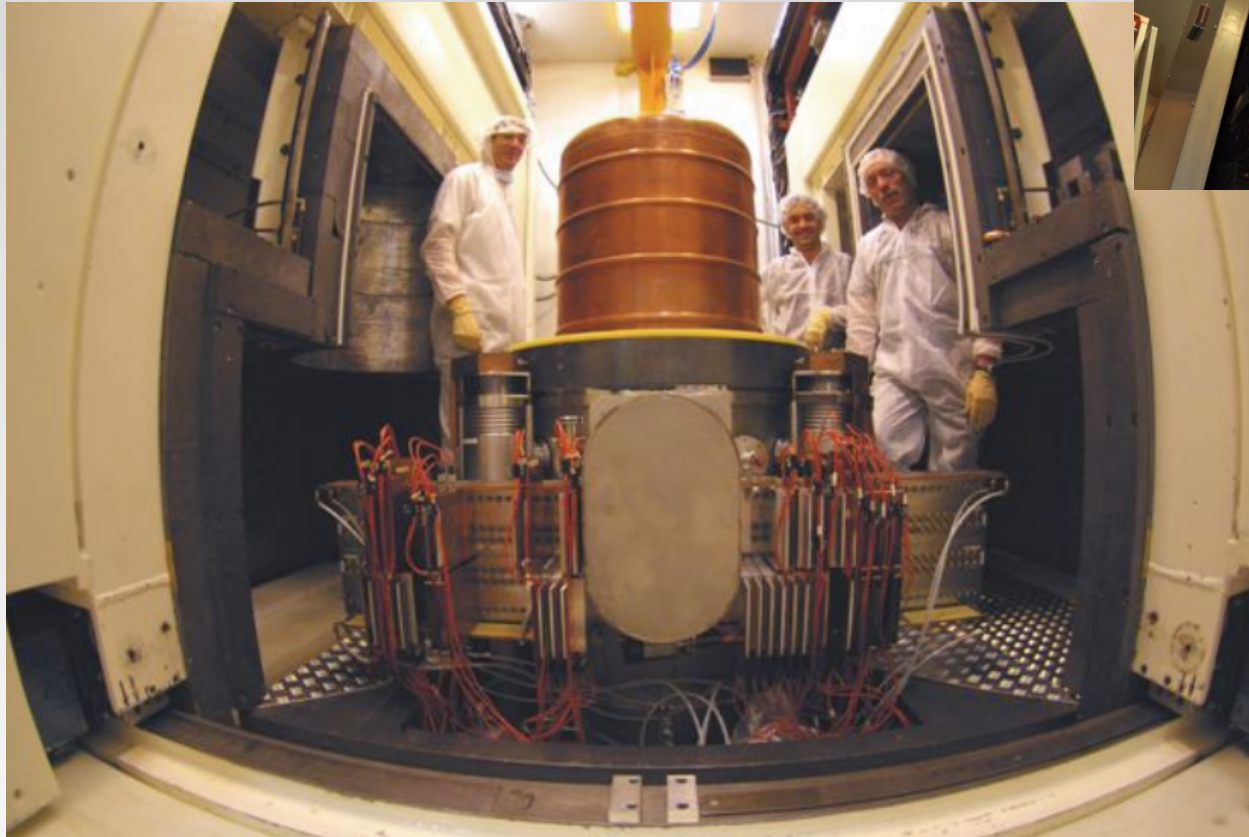
- continuous data taking
- 384 kg d published
- one of the best limits
- 3000 kg d expected 2013
- *1 cts / 80 kg day*



no indication for WIMP signal



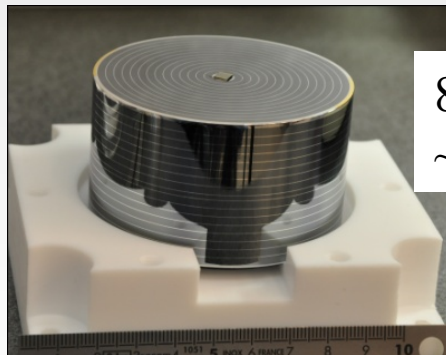
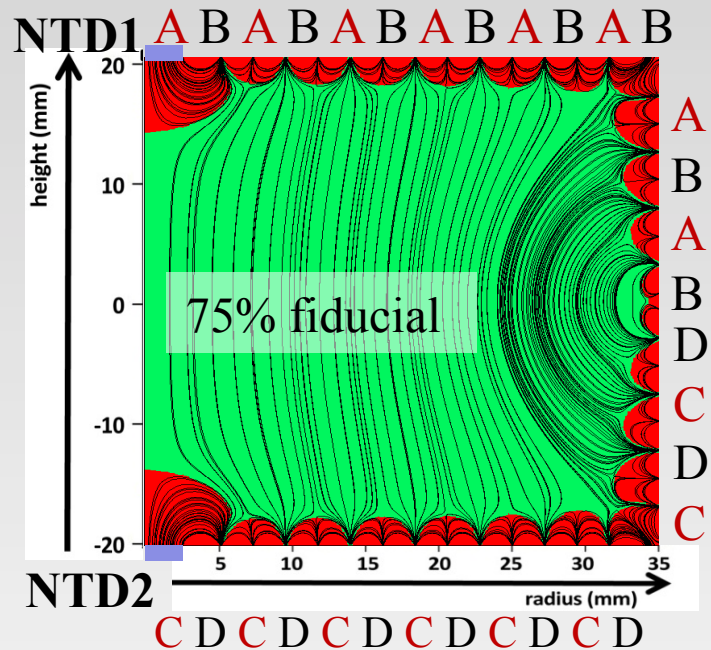
EDELWEISS-II experimental setup



(Courtesy K. Eitel)

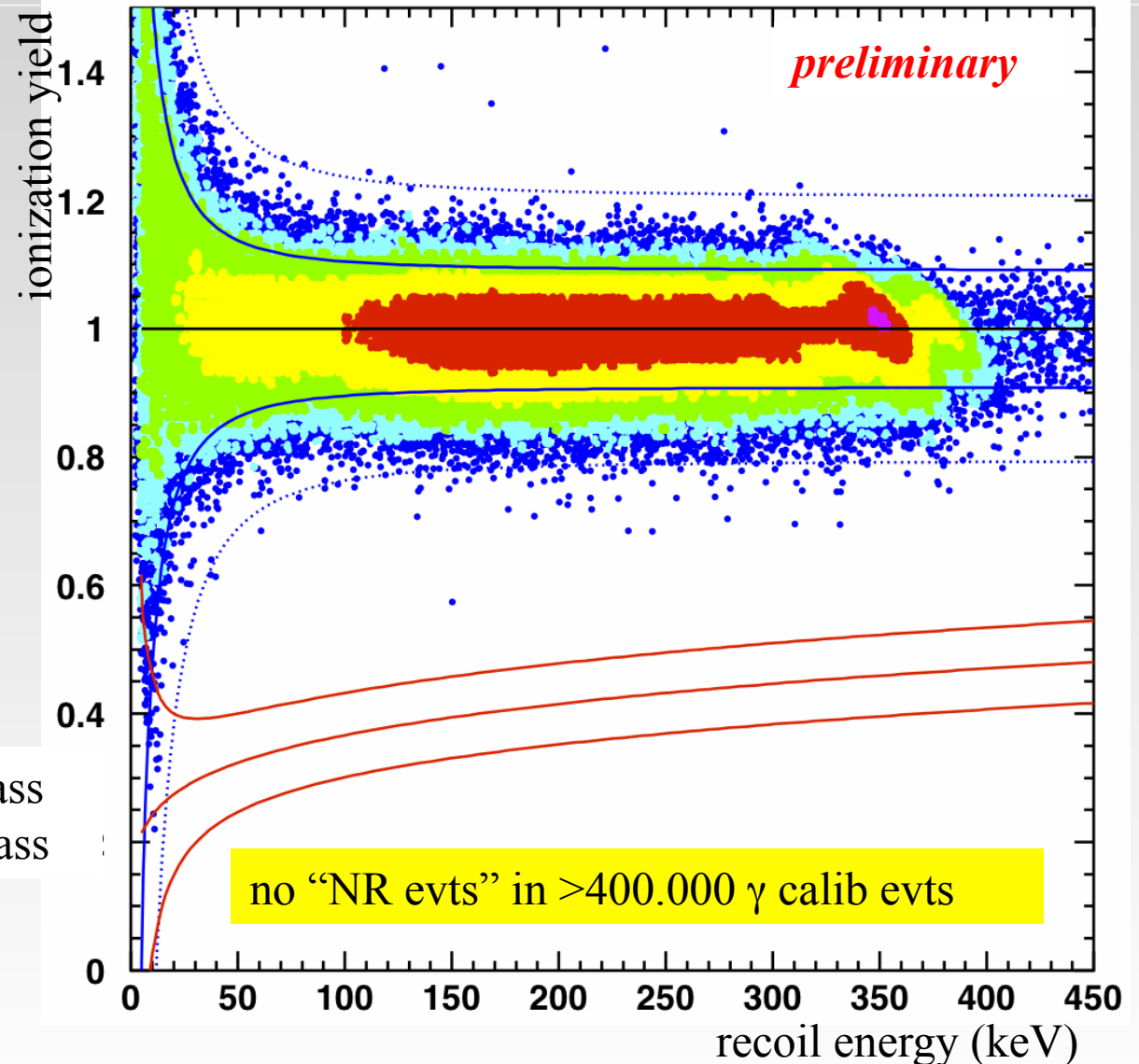
EDW-III: next generation of detectors

3. generation: FID detectors
with rings on all surfaces



800g total mass
~600g fid. mass

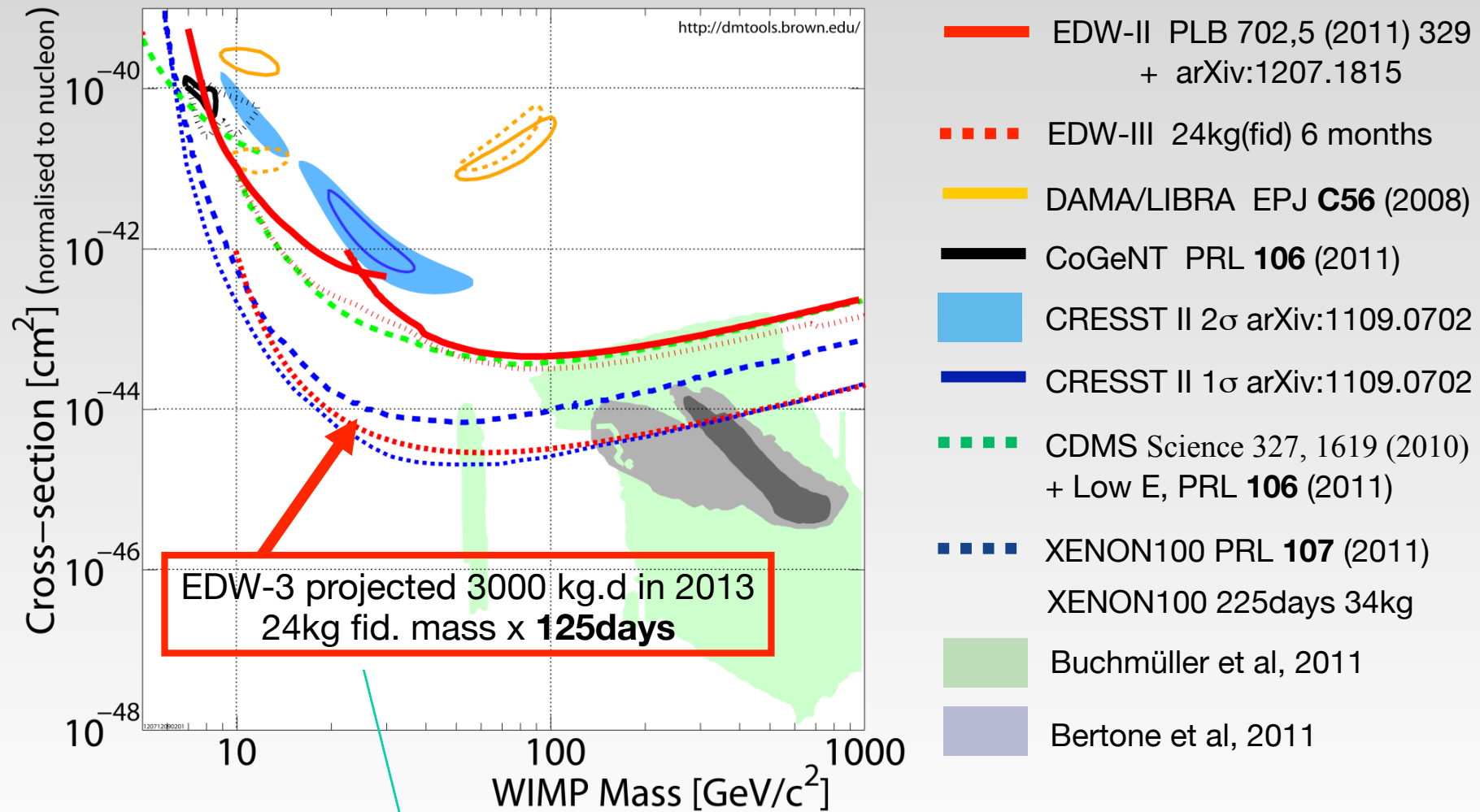
γ -calibration with ^{133}Ba (411663 γ 's)



(Courtesy K. Eitel)

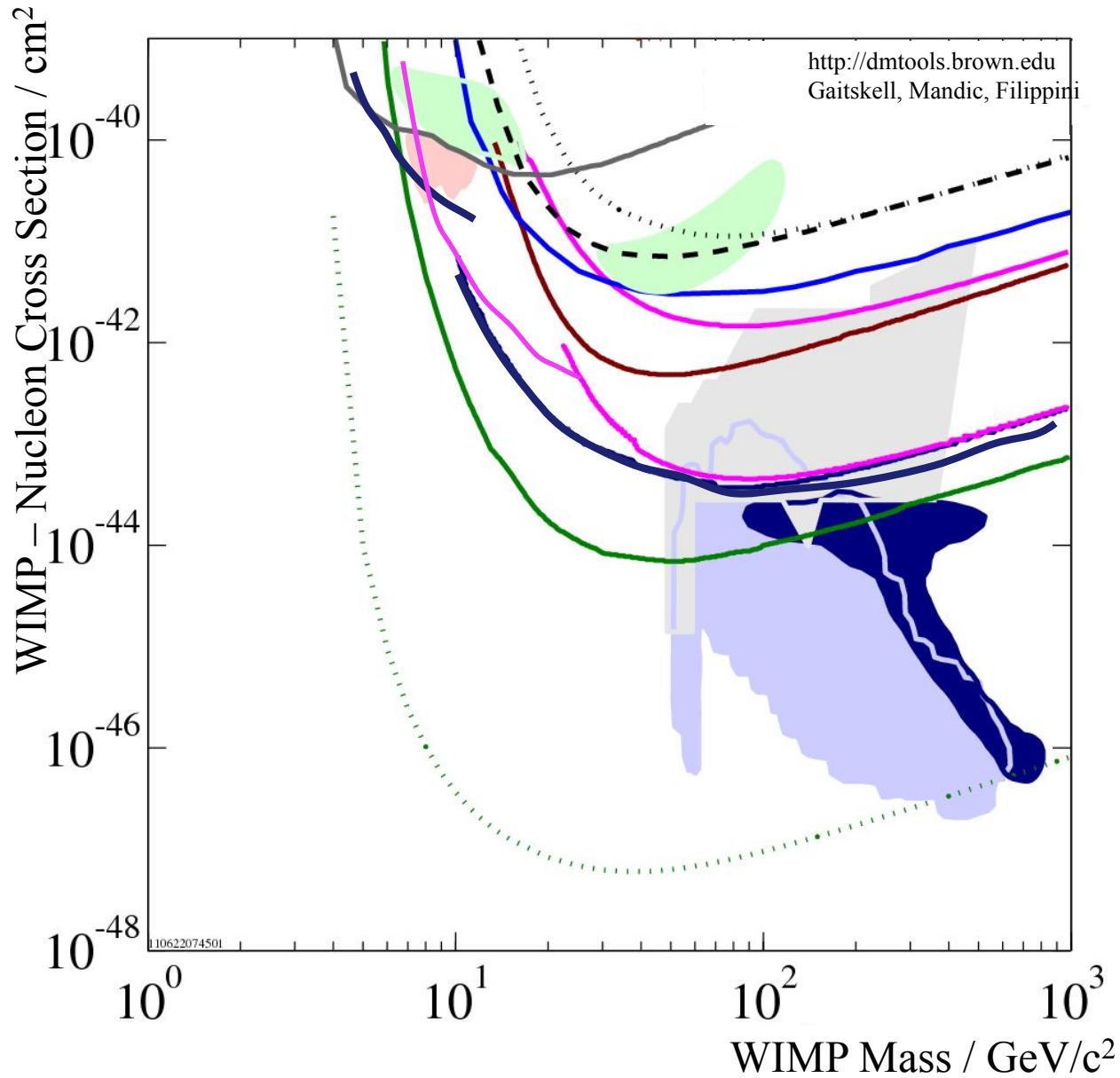
EDELWEISS-III goal for 2013

<1 evt total background estimated for 3000kg.d eff. exposure



EDW 3000 kgd in ~ 140 days => 21 kg eff
XENON100 2324 kgd in 395 days => 6 kg eff

(Courtesy K. Eitel)

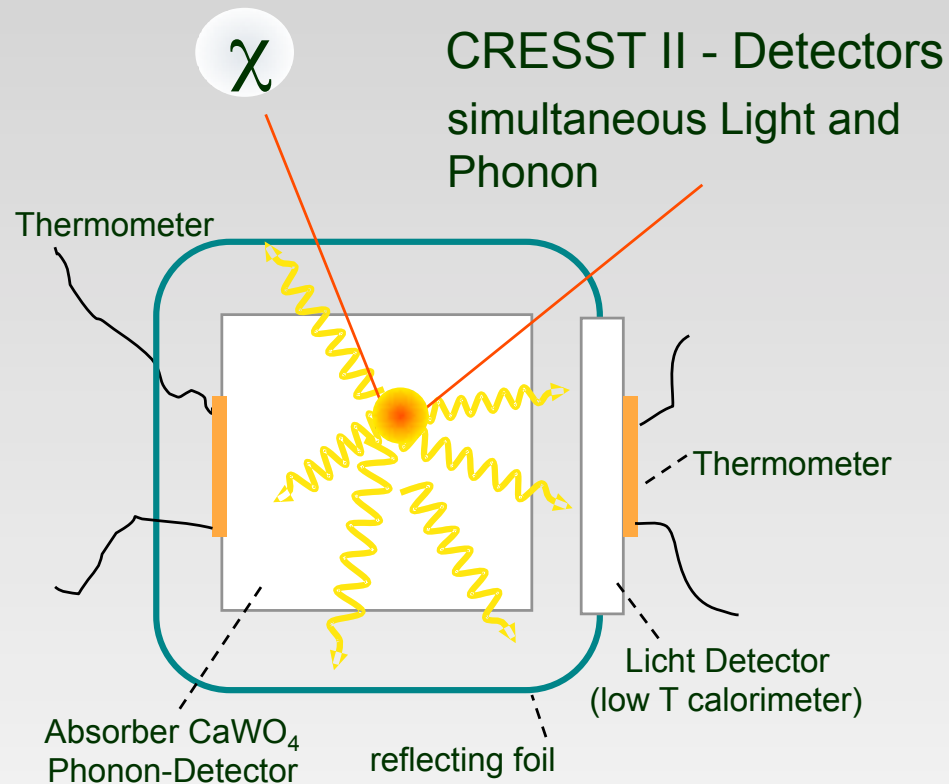


- Heidelberg Moscow 1996
- IGEX 1998
- DAMA 1998 / LIBRA 2008
- CDMS 2000
- EDELWEISS 2002
- CRESST 2009
- EDELWEISS 2011
- CDMS 2011
- XENON 2011

$\sim 0.0001 \text{ cts / kg / d / keV}$

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

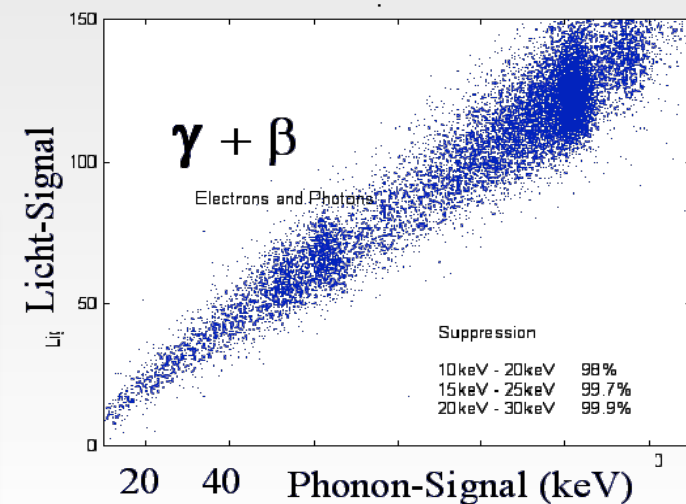
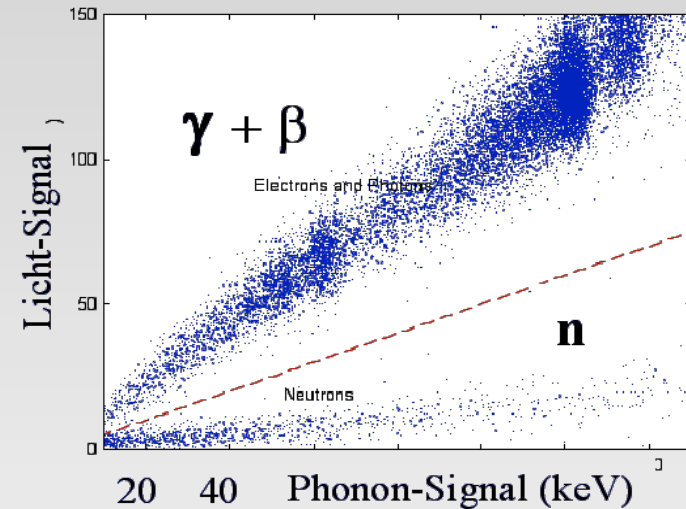
CRESST: Phonon + Light



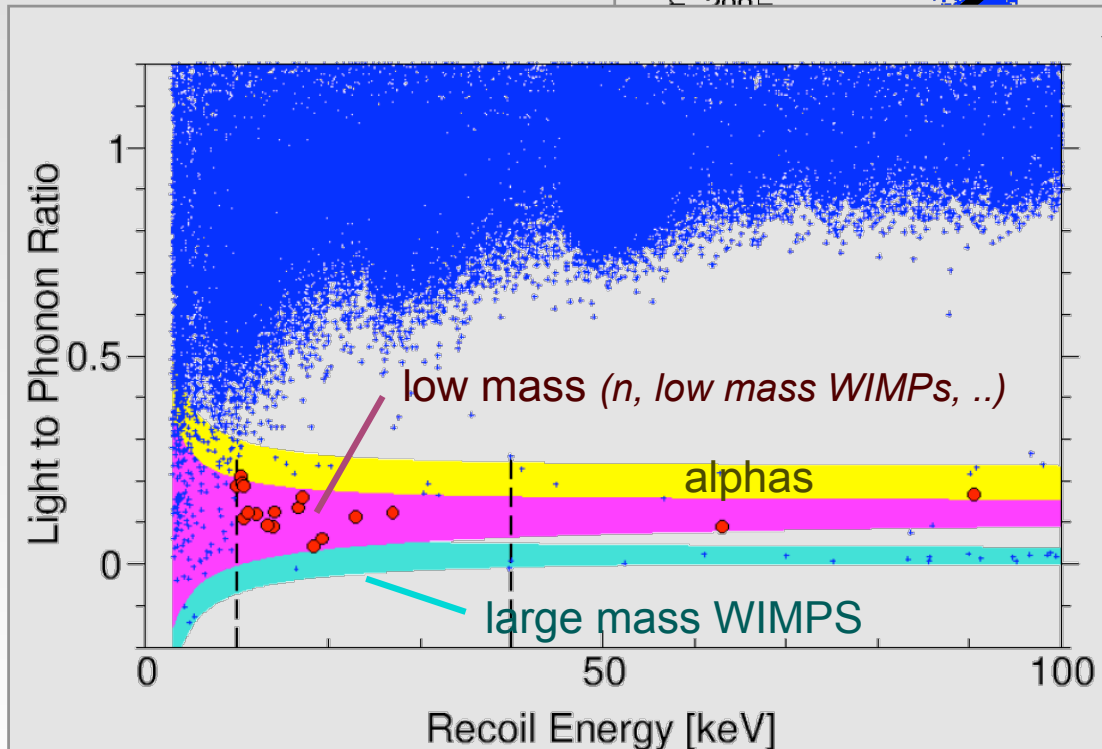
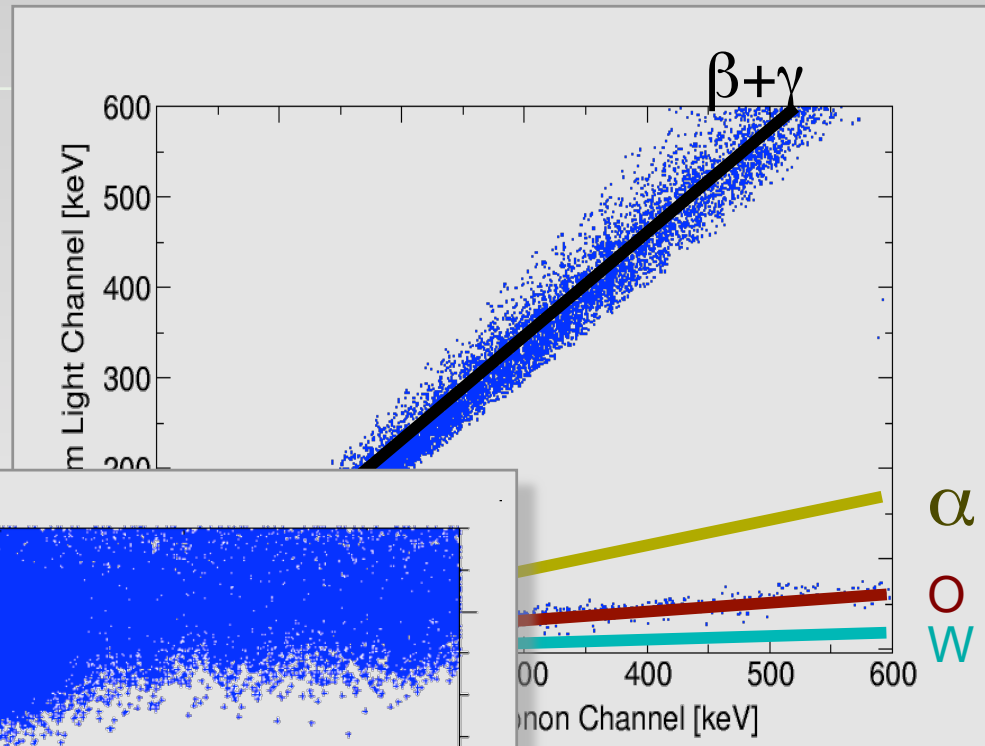
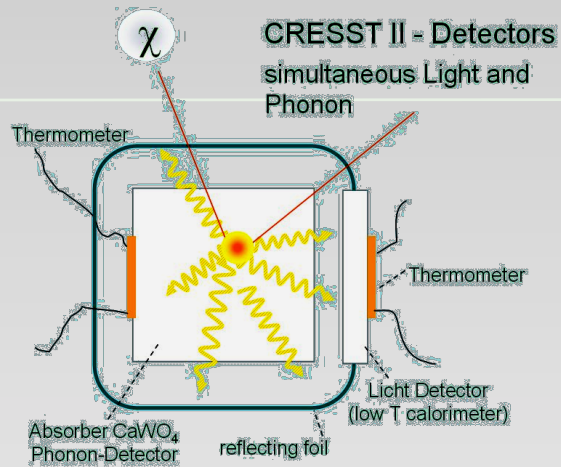
CRESST

*Cryogenic Rare Event Search with
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*Max-Planck-Institut München, TU München
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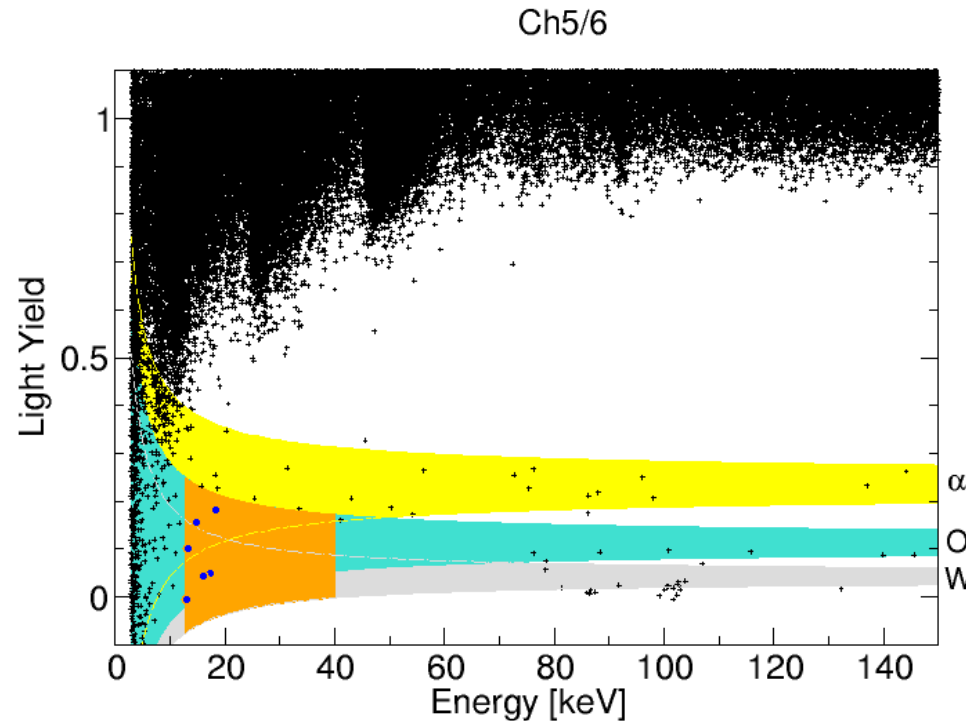


CRESST – Light / Phonon – CaWO_4 Target



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 :

α leakage or Pb-recoils:

Neutrons:

1 event per detector expected by threshold definition
very unlikely, overlap to acceptance region too small
very unlikely, rate too high, multiplicities wrong

+ energy spectrum, + light-yield spectrum

low mass WIMPs : who knows?

CRESST Run 2009 – 2011: Likelihood Analysis

Contributions from all backgrounds
+ possible WIMP signal

uses full information of
distribution in energy and
light-yield

takes into account different
resolutions and thresholds

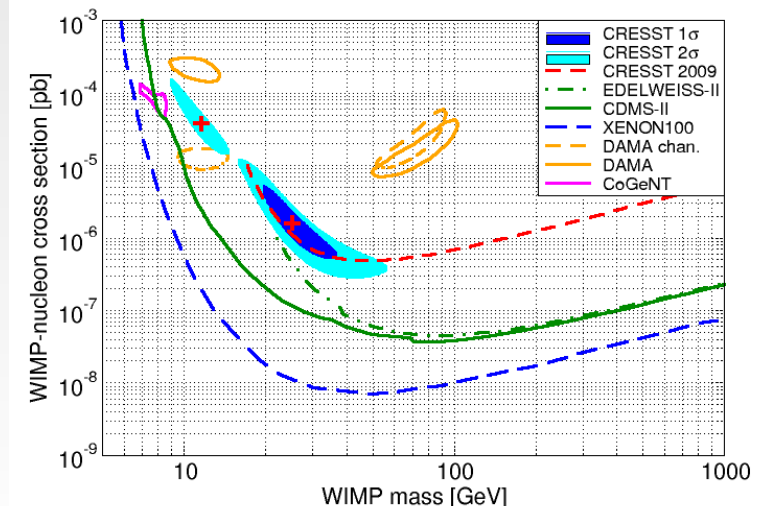
takes into account
statistical uncertainties

**Considered backgrounds not sufficient
to explain the data**

⇒ additional source needed

Likelihood function shows two maxima

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



CRESST Run 2009 – 2011

**Considered backgrounds
not sufficient
to explain the data**

⇒ additional source needed

background contributions
still large

next run:

*reduction of
 α - and Pb-background
by new clamps*

more detectors

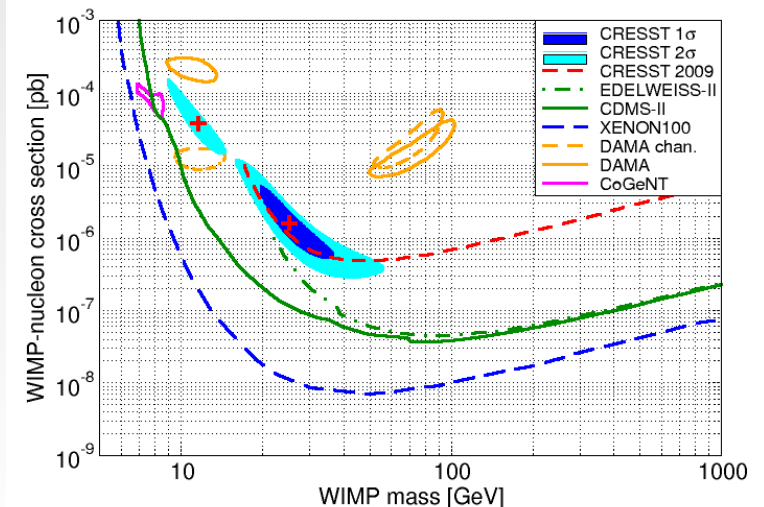
internal neutron shield

starting spring next year

Clarification if excess persists or not

Likelihood function shows two maxima

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m_χ [GeV]	25.3	11.6
σ_{WN} [pb]	$1.6 \cdot 10^{-6}$	$3.7 \cdot 10^{-5}$



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 ARGON

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*

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

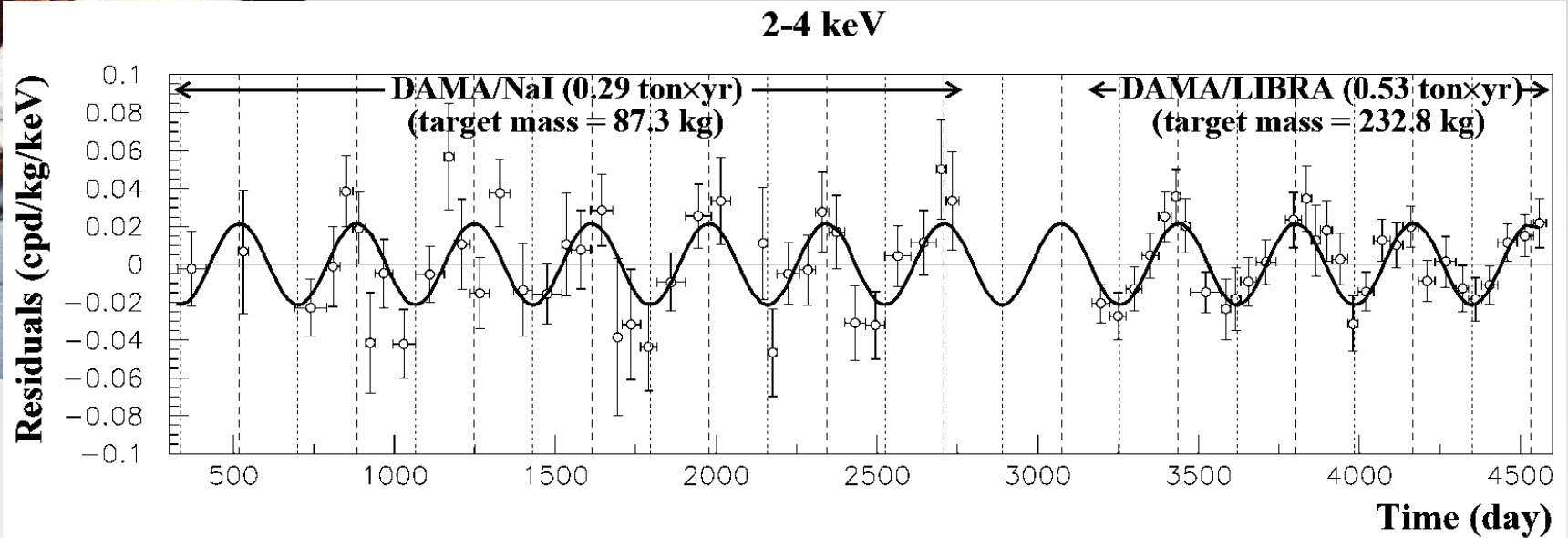
prototypes

MIMAC
France

Annual Modulation

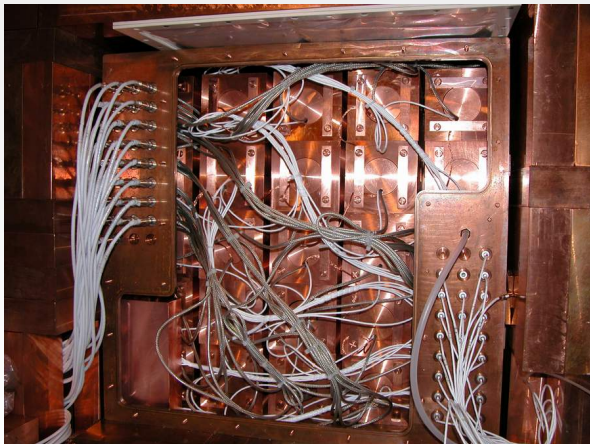
DAMA Exp. – Gran Sasso – Ital.Collab.

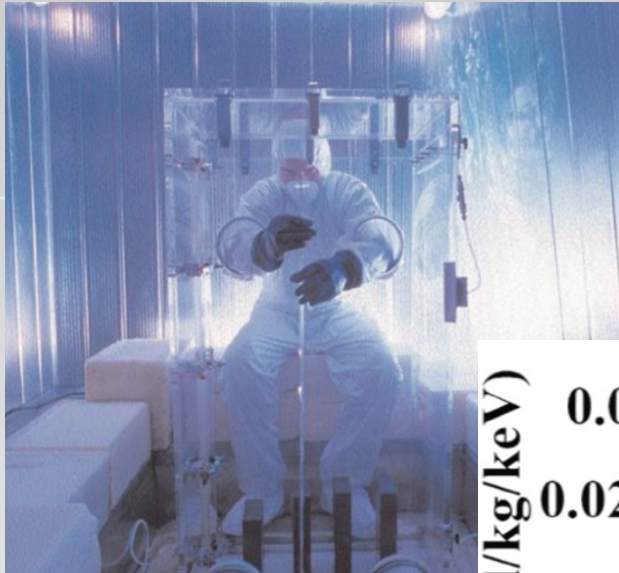
DAMA - Experiment:
first hint to WIMPs ?



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

Modulation with 8σ Confidence
Riv.N.Cim. 26/1 (2003), 1-73

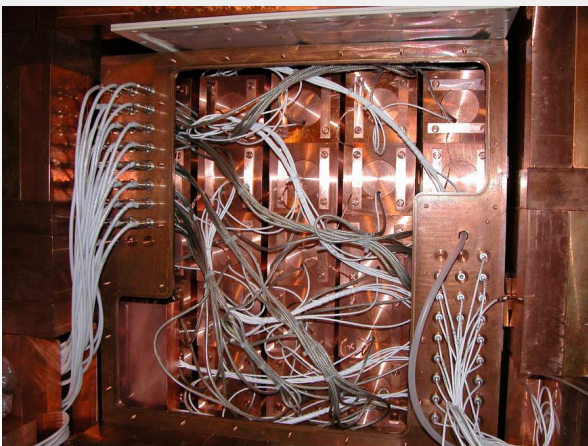
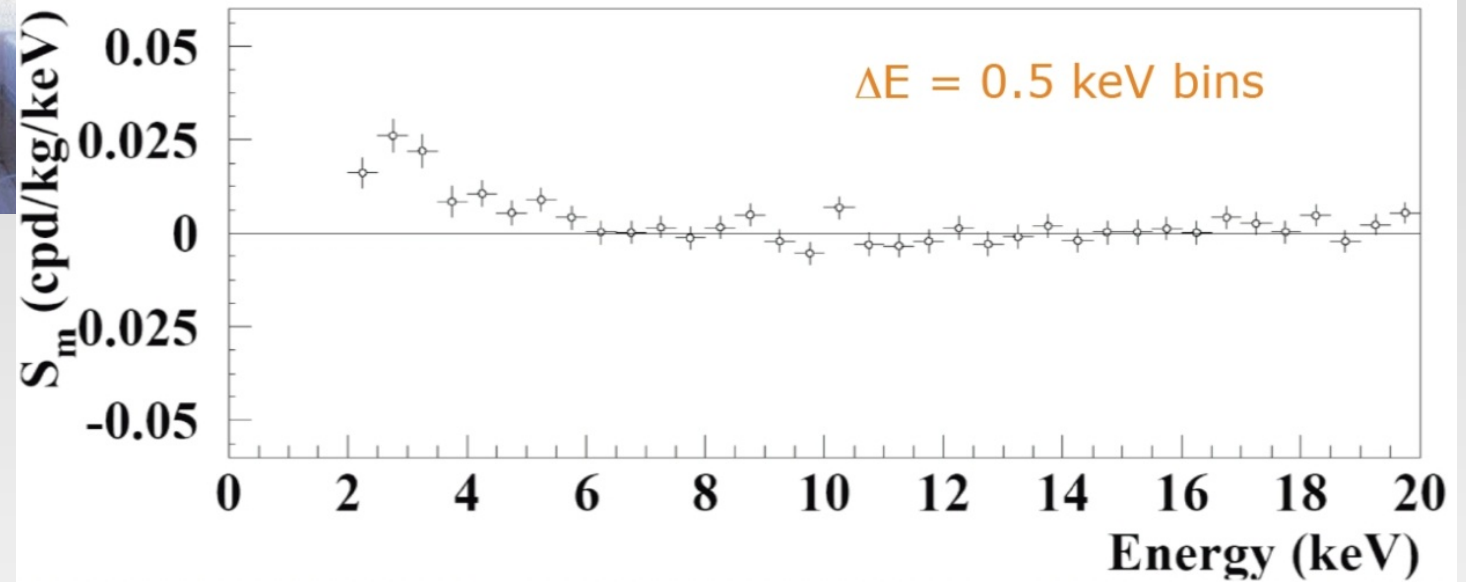




Annual Modulation

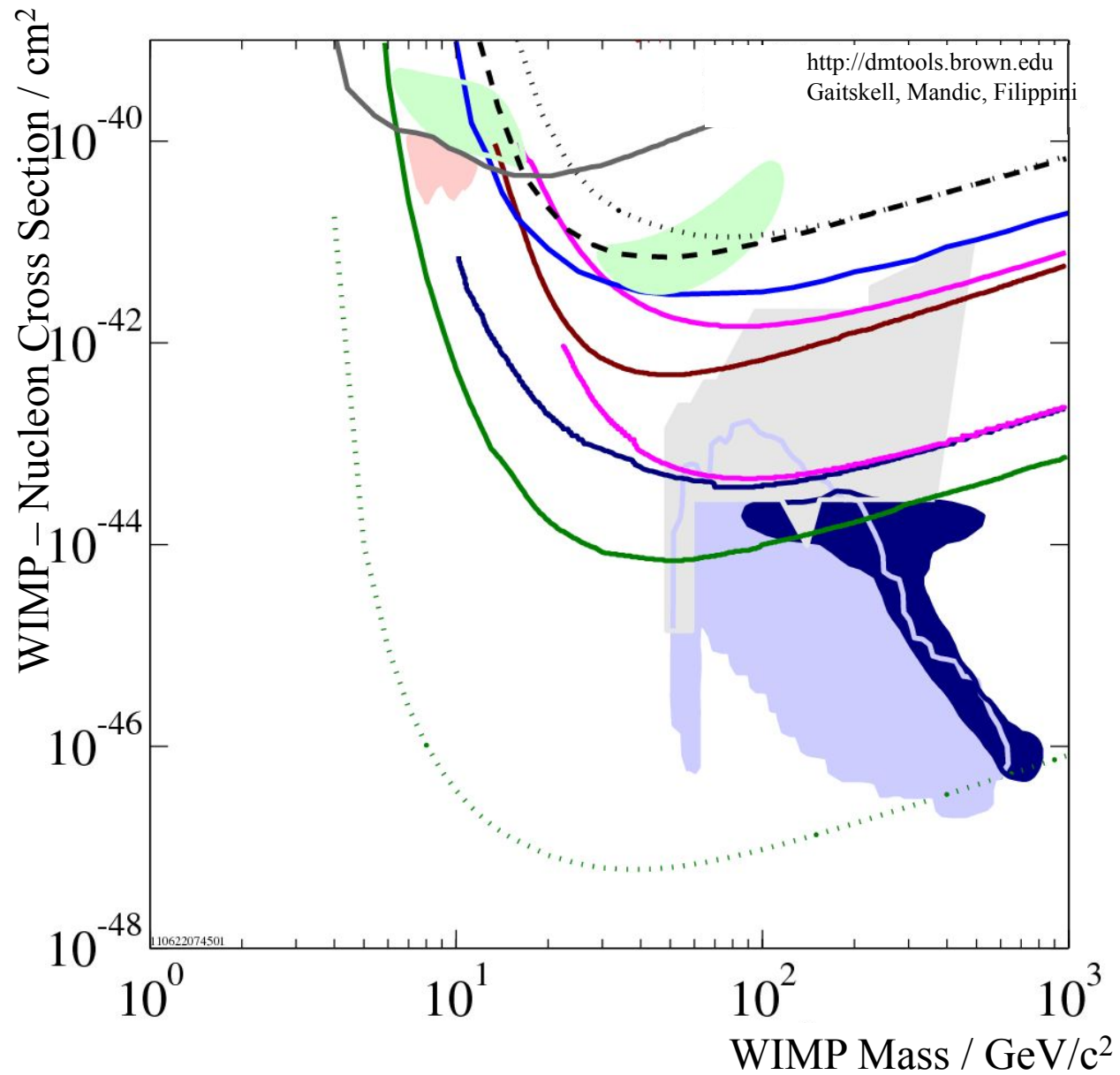
DAMA Exp. – Gran Sasso – Ital.Collab.

DAMA - Experiment:
first hint to WIMPs ?



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



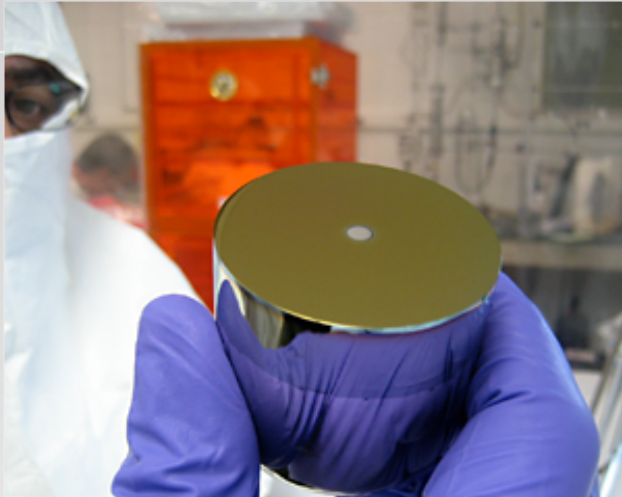


..... Heidelberg Moscow 1996
 - - - - - IGEX 1998
 DAMA 1998 / LIBRA 2008

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

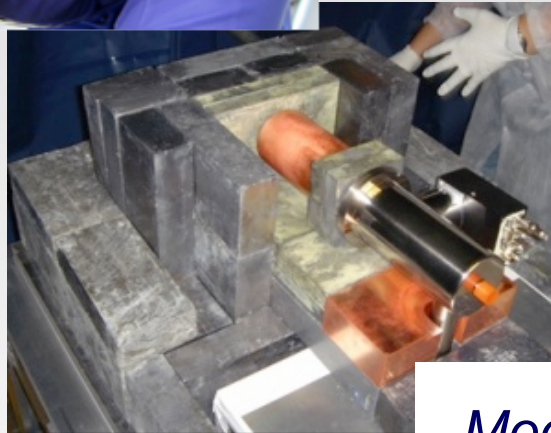
COGENT

Soudan Mine
US Collaboration



low energy
excess

low mass WIMPs?



Ge detectors

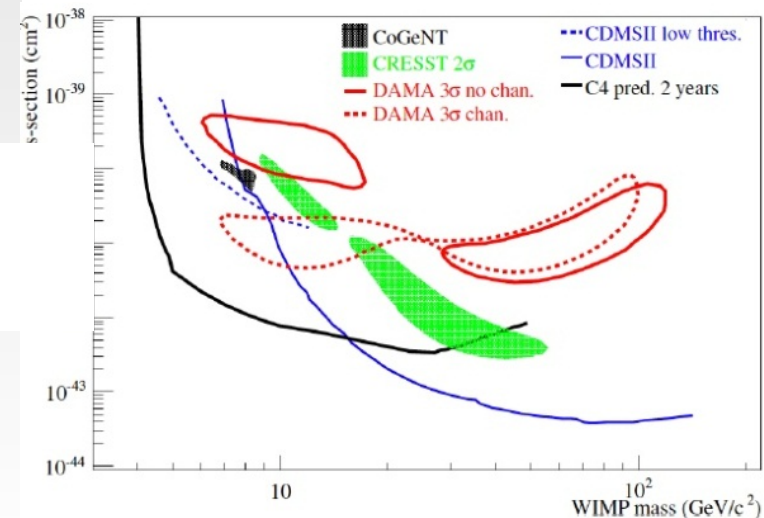
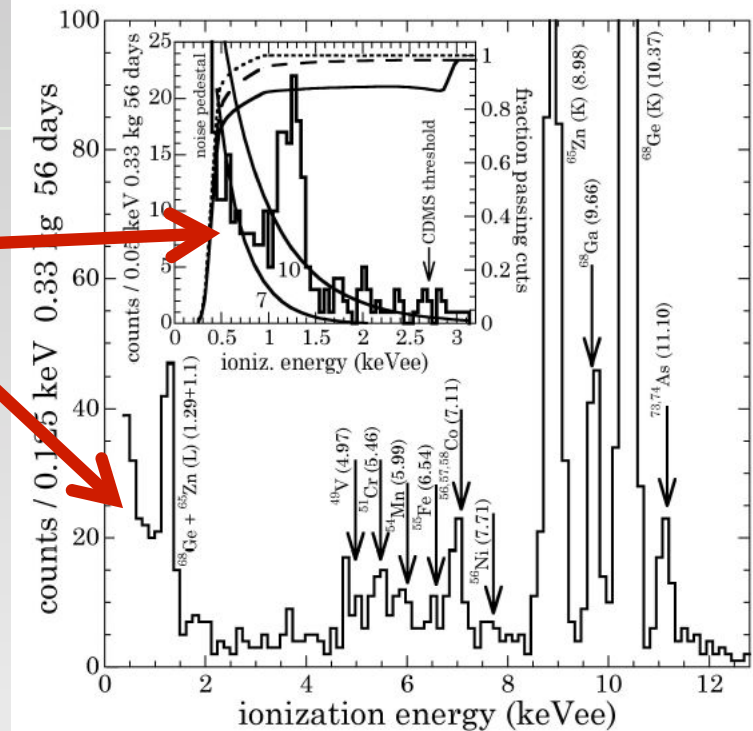
Ionisation only

Point contact detectors

⇒ Very low threshold

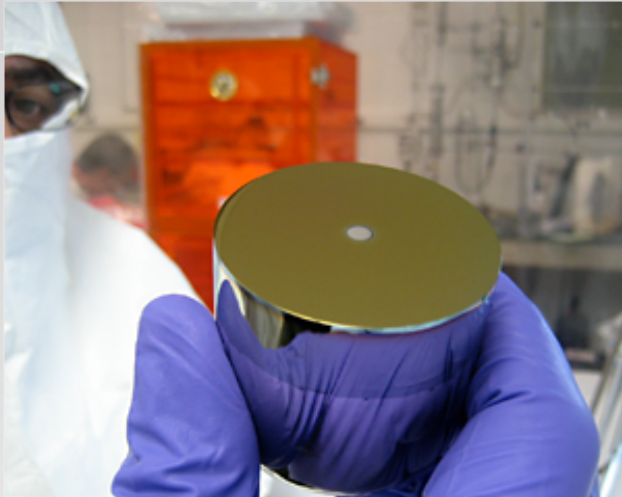
⇒ Good to look for light WIMPs

*Modulates ?
(2.8 sigma)*



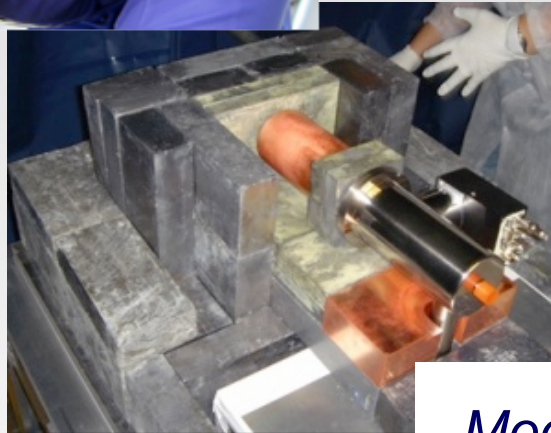
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low mass WIMPs?



Ge detectors

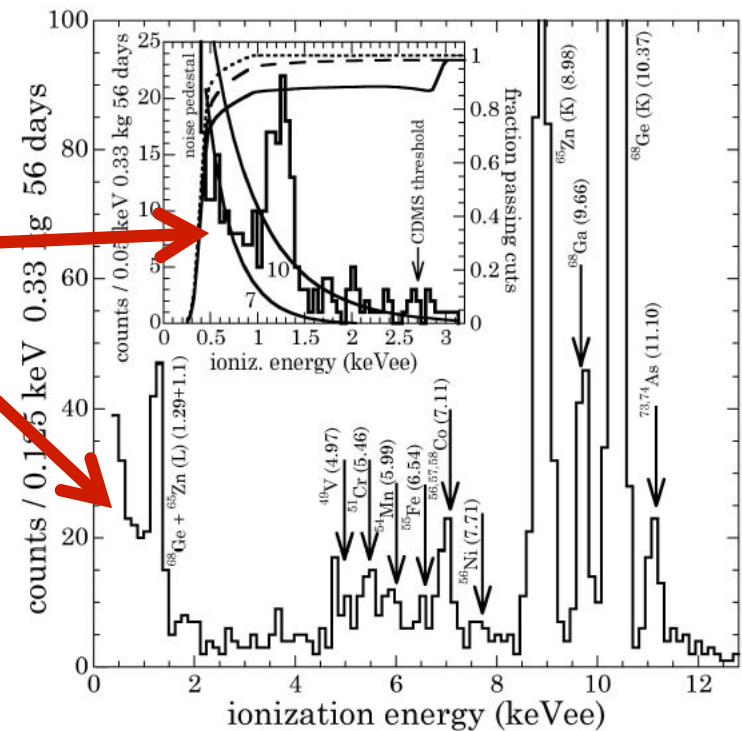
Ionisation only

Point contact detectors

⇒ Very low threshold

⇒ Good to look for light WIMPs

*Modulates ?
(2.8 sigma)*



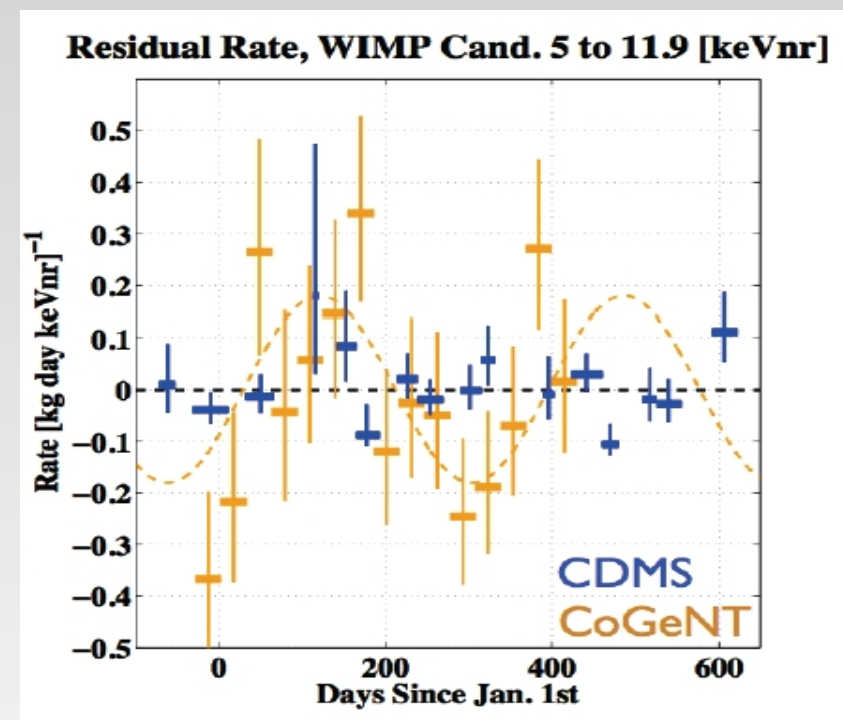
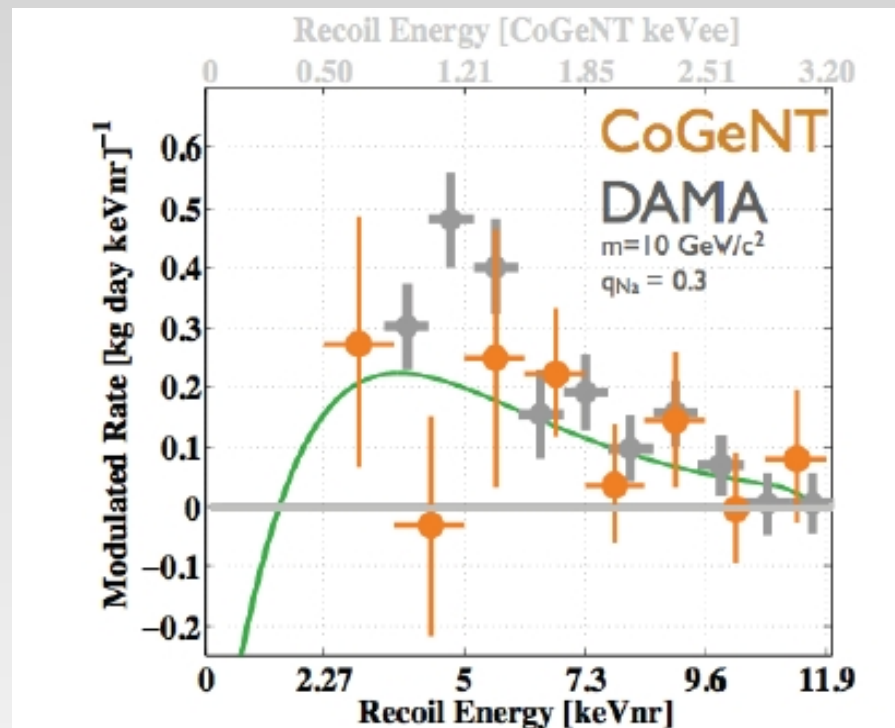
**July 2012
IDM Conference**

”

- Low-energy excess still there.
- Rates look flatter on second year.
Optimist: to be expected, the modulation was too large.
Pessimist: to be expected, the modulation was a fluke.

”

Modulation Signals DAMA - COGENT - CDMS



5.0-11.9 keVnr

CDMS
Modulation Analysis

$R_{\text{mod}} < 0.06 \text{ [keVnr kg day]}^{-1}$ (99% CL)

inconsistent with CoGeNT (>98% CL)

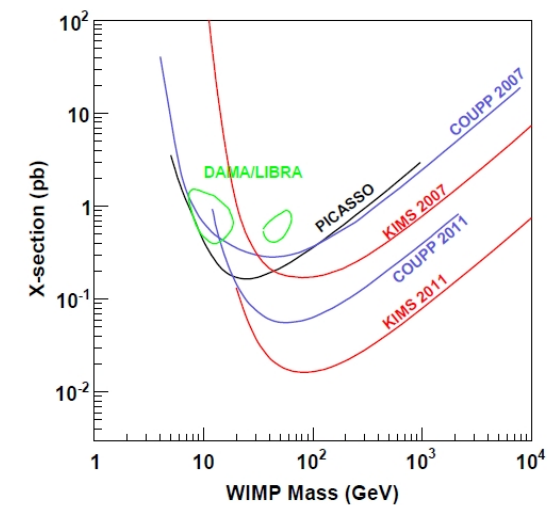
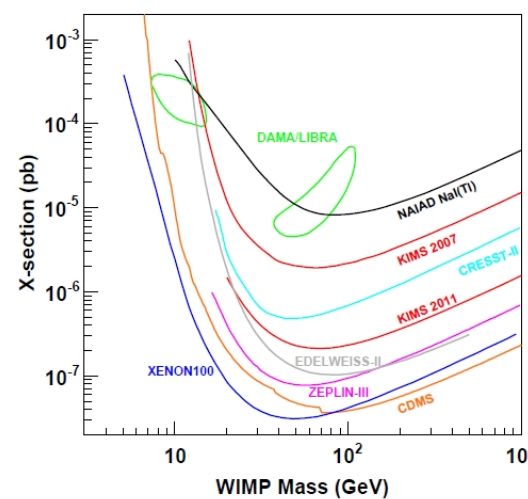
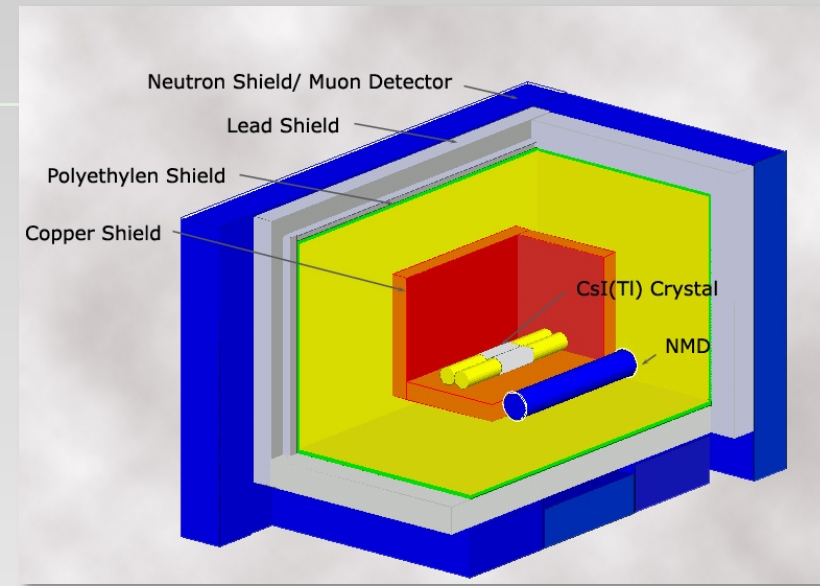
KIMS

Korea

CsI(Tl) detectors, $\sim 100\text{kg}$
scintillation only
exposure $\sim 25000\text{ kg days}$
continues

competitive SD and SI limits
nuclear recoil rate
smaller than
DAMA Modulation amplitude !!!

the same for
CDMS, EDELWEISS, CRESST, XENON
but
KIMS most similar to DAMA



Modulation Signals

*assume most extreme case,
signal fully modulates, no bulk rate
in any model, modulation is the
minimum you must see*

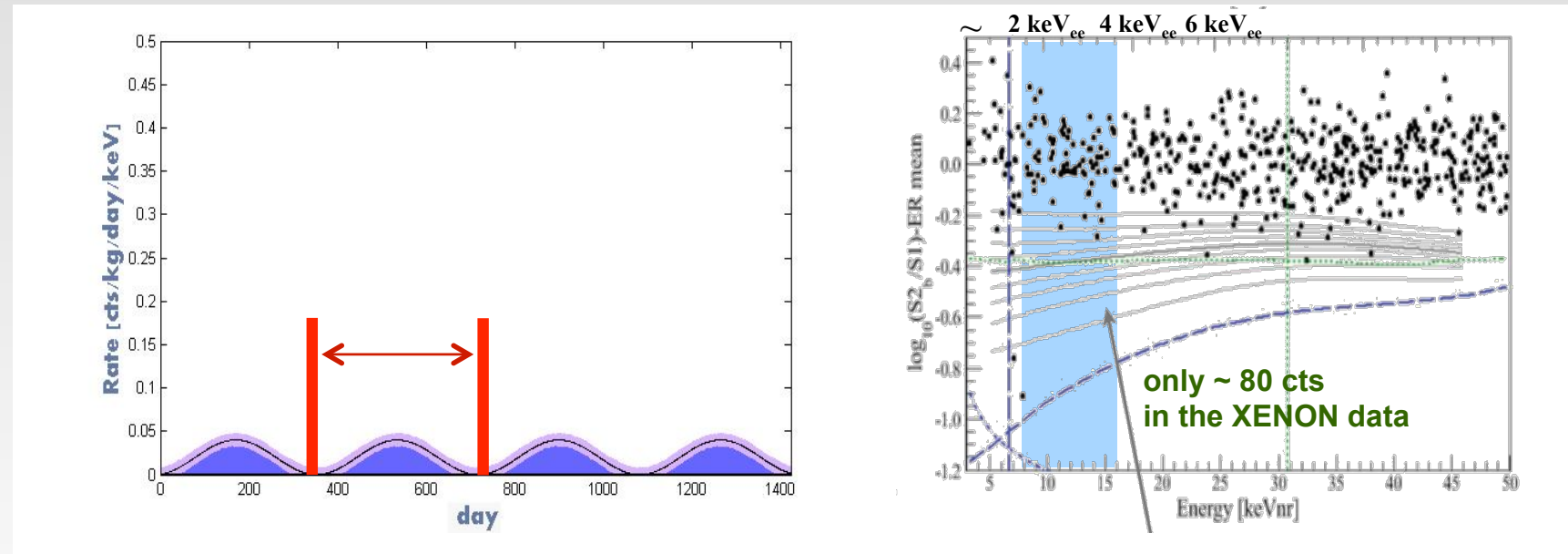
expected rate from DAMA signal in (2-4) keV:

if nuclear recoils:

1500 cts/year in KIMS (most similar to DAMA in mass and material), **but measured < 800 cts/year**

if electron recoils:

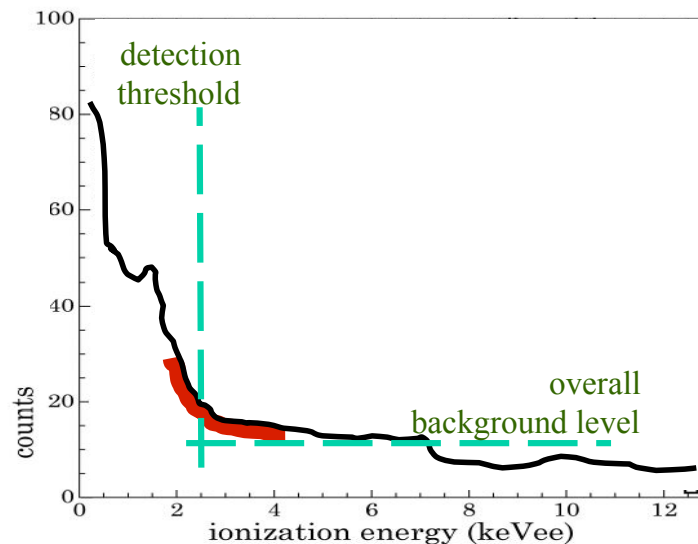
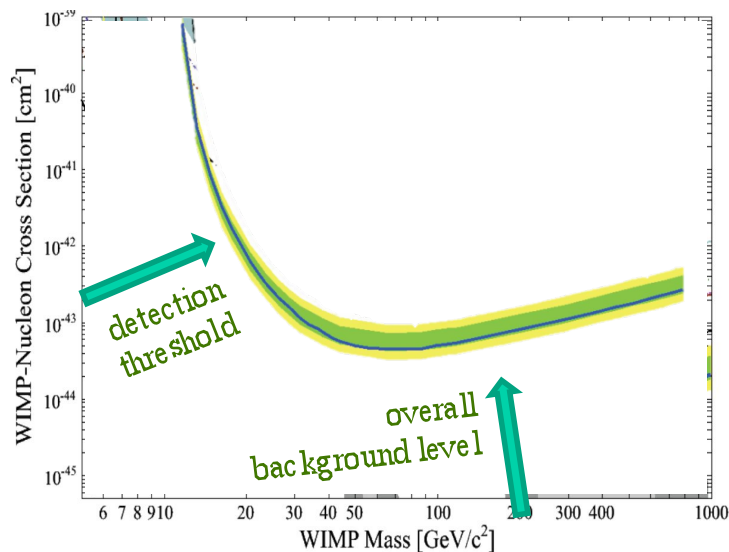
500 cts/year in XENON, but measured **~ 80 cts/year**



this conflict is model independent (halo: $v_{\text{galaxy}} - v_{\text{earth}}$; WIMP: electronic-nuclear recoils)

caveat left: XENON-keV_{ee} energy scale, so far calibrated only above 40keV ! needs to be done down to keV range !

Low Mass WIMPs ?



limit curves
= limit of detector sensitivity

*where statistics is too low
and
background comes in*

**any background or other technical problem
interpreted as WIMP**

shows up along this line

background usually rises towards lower energy
⇒ first background to sneak in
is background at threshold

⇒ low mass limit is the most difficult to control
+ low mass WIMP the most likely to get by background

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 ARGON

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*

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

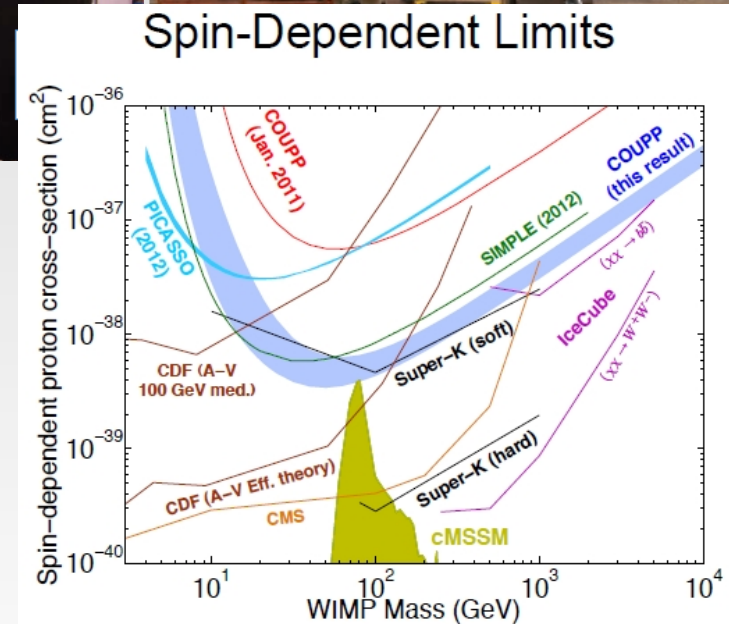
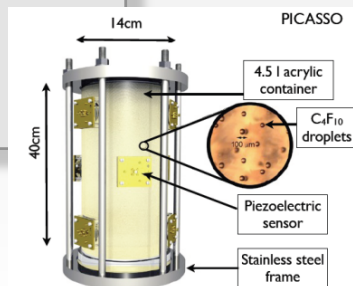
USA

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



PICASSO

- Canada, USA, Czech
- 1.9 kg running since 2009
- new SD constraints from
- moved to larger lab
within SNOLAB



COUPP 4kg

best direct detection
spin dependent limit

SD

Neutralino-proton SD cross-section (cm^2)

ction (cm^2)

Superheated Droplets PICASSO

similar to bubble chamber

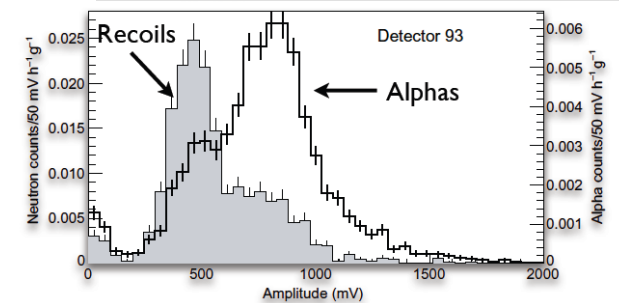
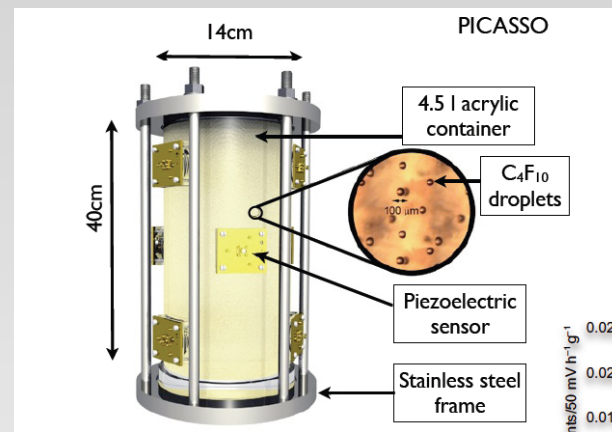
P and T set to be sensitive only to nuclear recoils and alphas

recognize alphas by pulse shape

COUPP

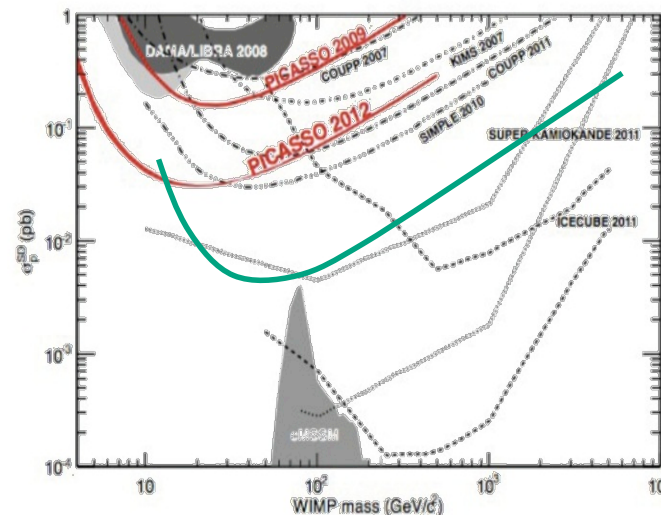
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PICASSO

- *Canada, USA, Czech*
- 1.9 kg running since 2009
- new SD constraints
- moved to larger lab
within SNOLAB



Directional

WIMPs come from certain direction (Cygnus)

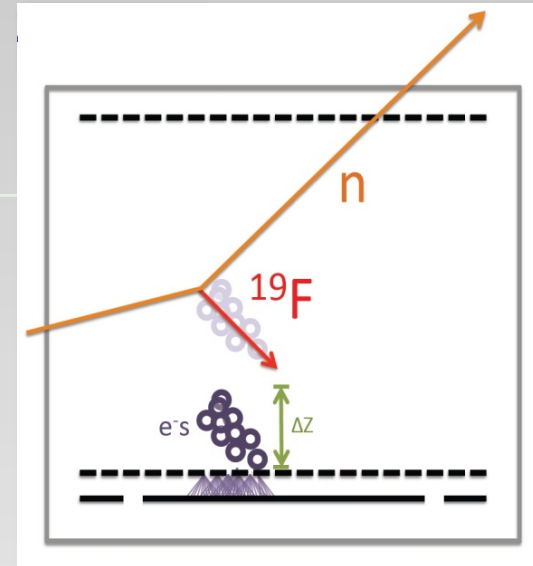
=> measure direction of recoil

needs gas target

thin => low mass,

CF good for spin dependent

and track read out

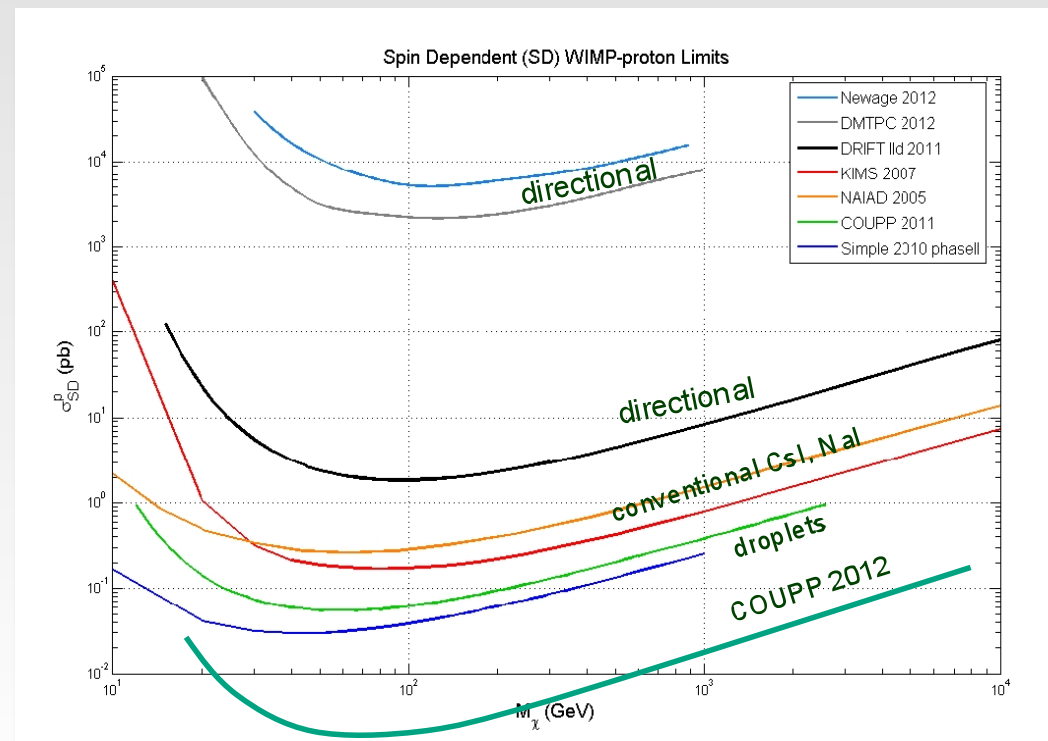


DMTPC – US

MIMAC – France

DRIFT – UK, US

NEWAGE - Japan



COVENTIONAL
NaI, CsI, Ge

run 250kg NaI
run 100kg CsI

DAMA
Italy

KIMS
Korea

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COGENT
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prototypes

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

CRESST
EURECA
Germany, UK, Italy

EDELWEISS
EURECA
*France, Germany,
UK, Russia*

CDMS
Super CDMS
US, Can., Switzerland

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
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XMASS
Japan

**DEAP/
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Canada, US

prepare
~ 100kg

finsihed

LUX
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WARP
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runs 4kg
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PICASSO
Canada, USA, Czeck

*very good
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DIRECTIONAL

first runs

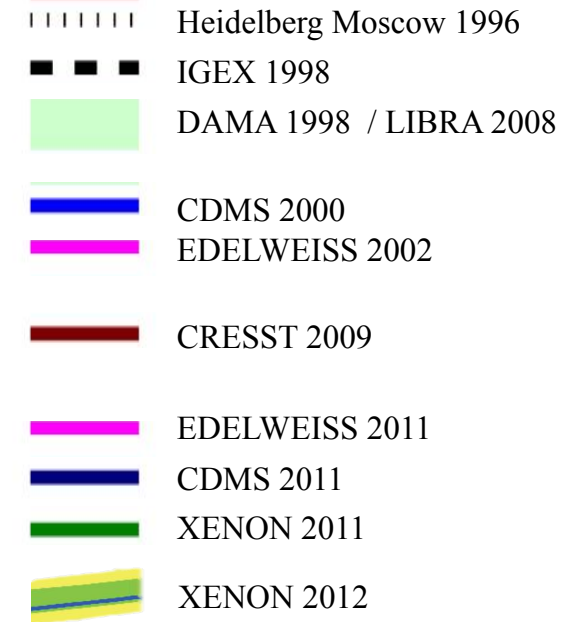
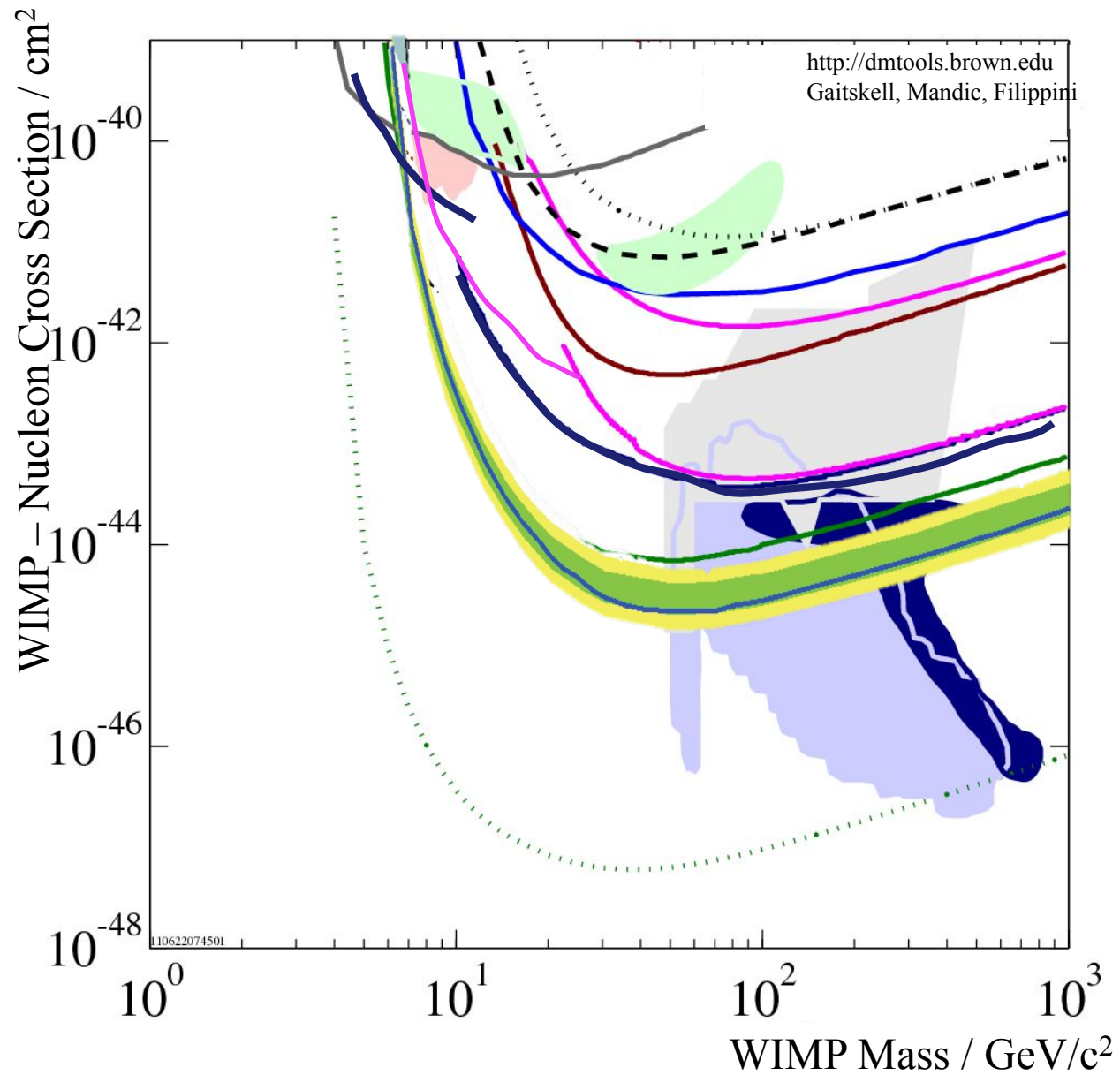
DRIFT
UK, US

DM-TPC
US

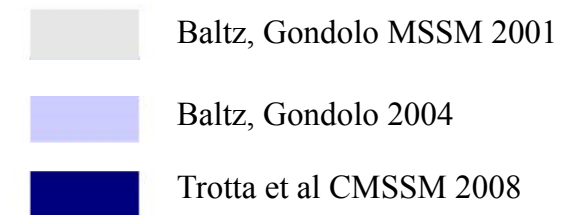
NEWAGE
Japan

prototypes

MIMAC
France



$\sim 0.00003 \text{ cts / kg / d / keV}$



Direct DM Searches

Nothing found yet => keep going on!

x 100 improvement in
sensitivity
in 10 yrs

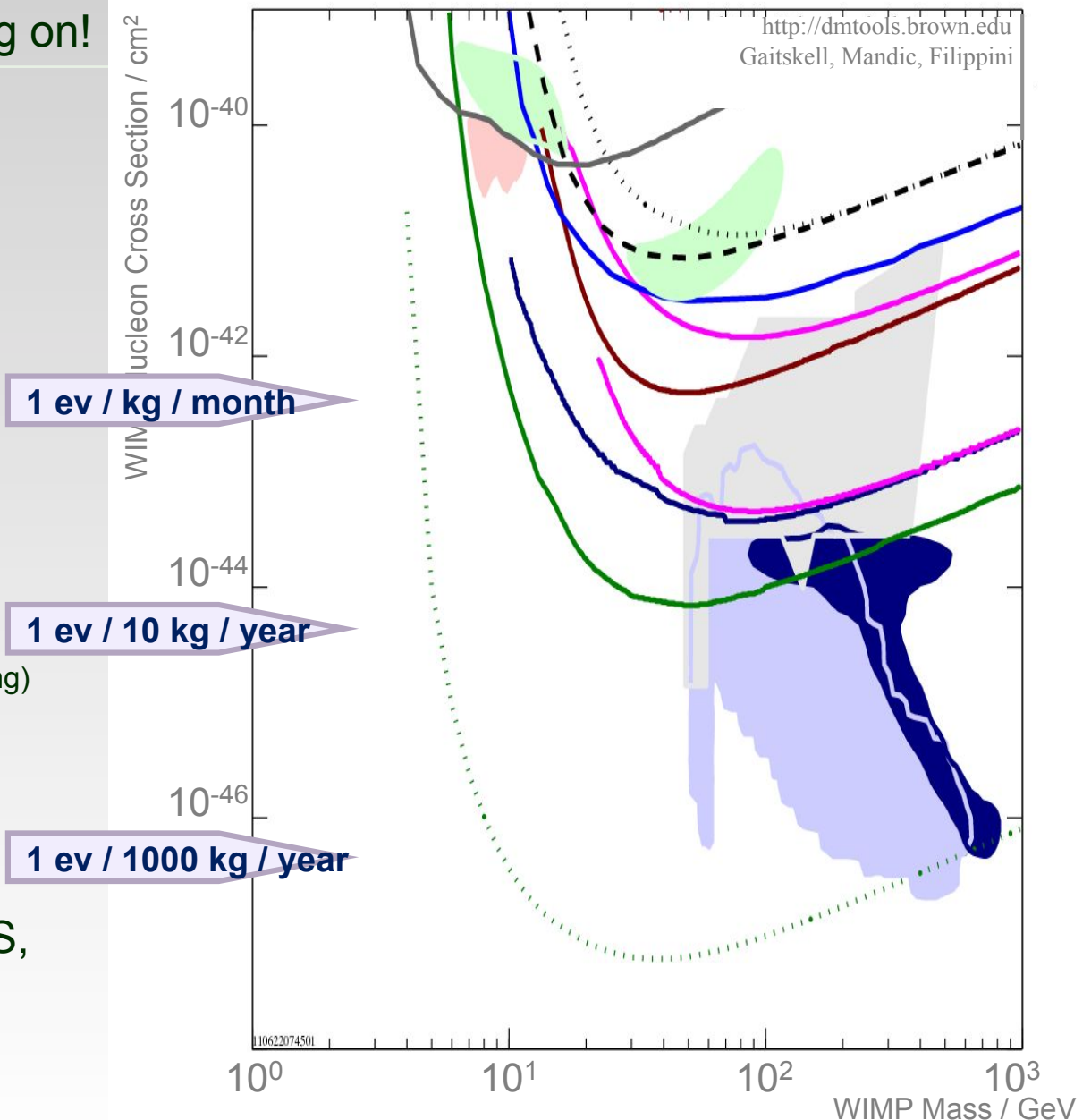
present best sensitivities
(for spin independent WIMP scattering)

- cryogenic
- liquid Xenon

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

we have different techniques
with promising sensitivity

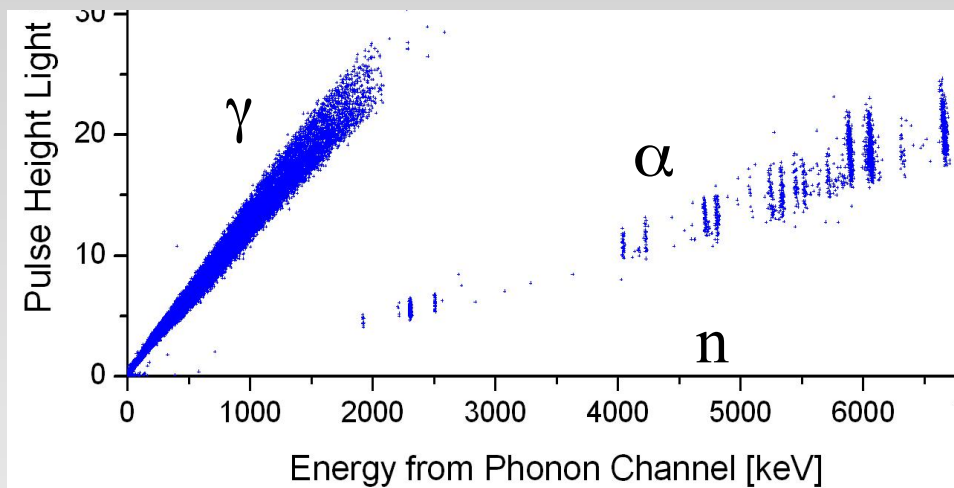
XENON, EURECA, SuperCDMS,
DARK Side, ArDM, DEAP, ...



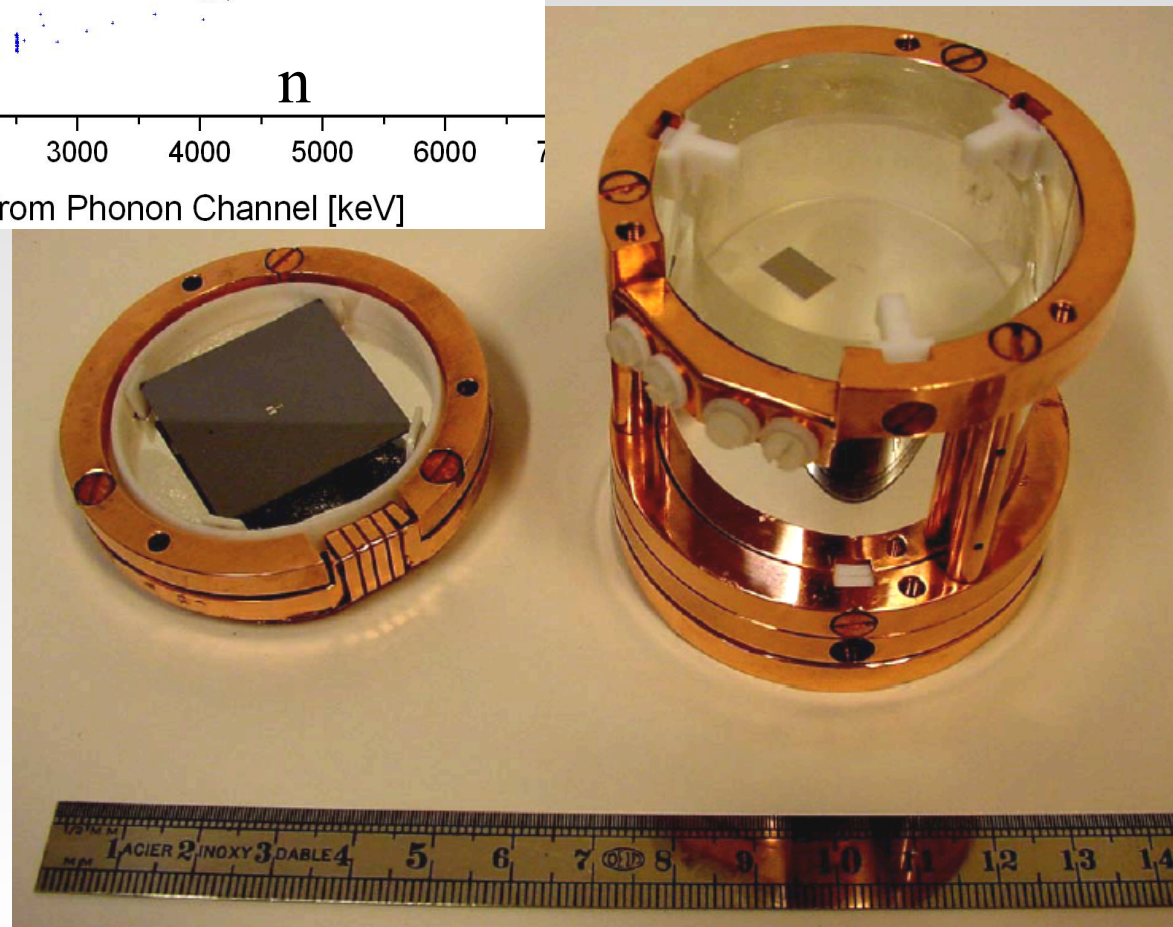
BACKUP SLIDES

CRESST

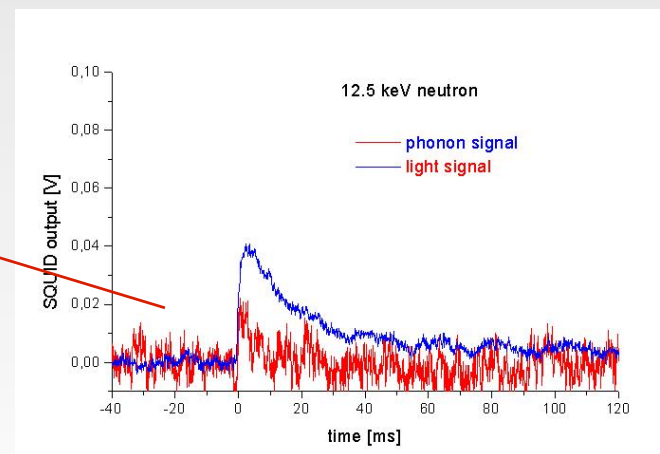
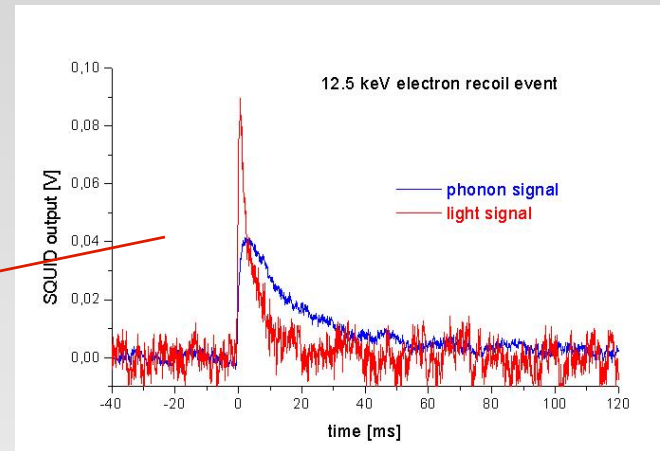
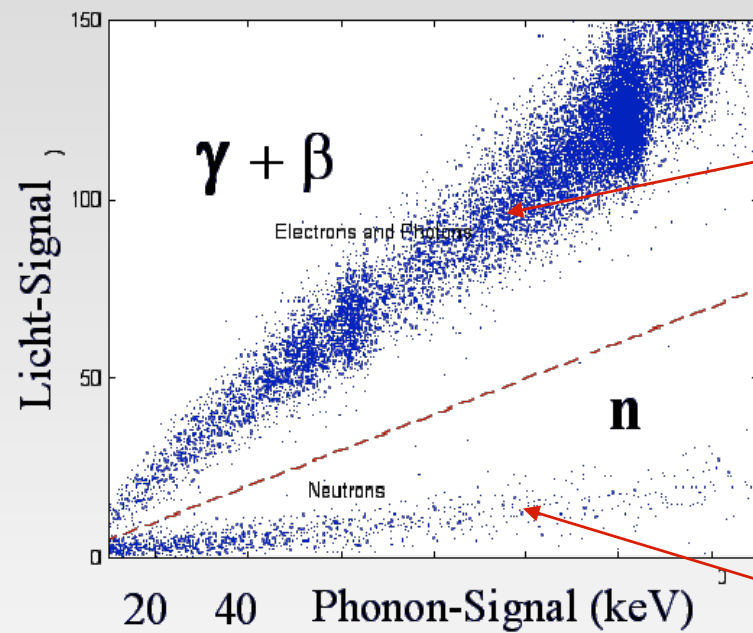
Cryo Detectors - CRESST - Phonon + Light



CaWO_4



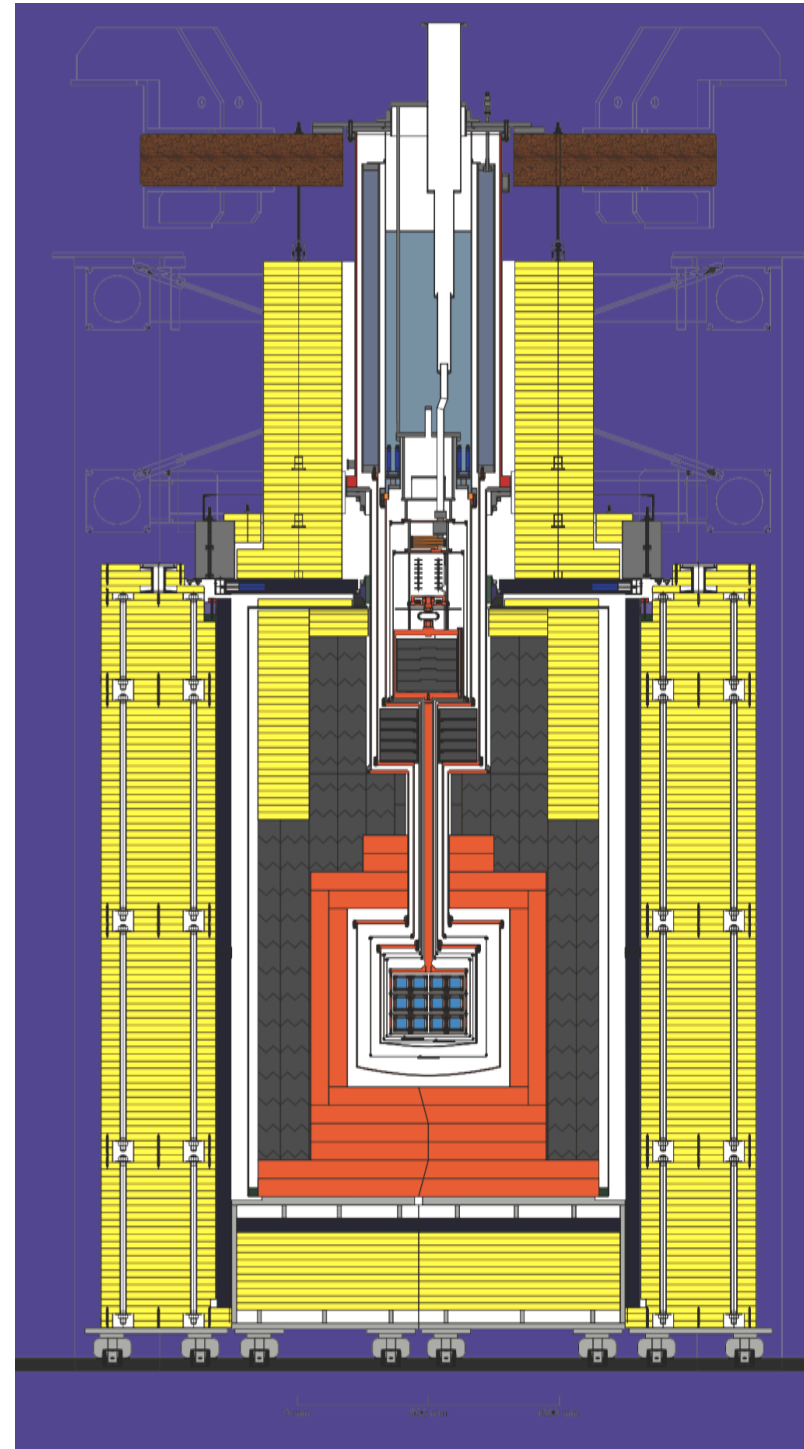
CRESST Phonons + Light



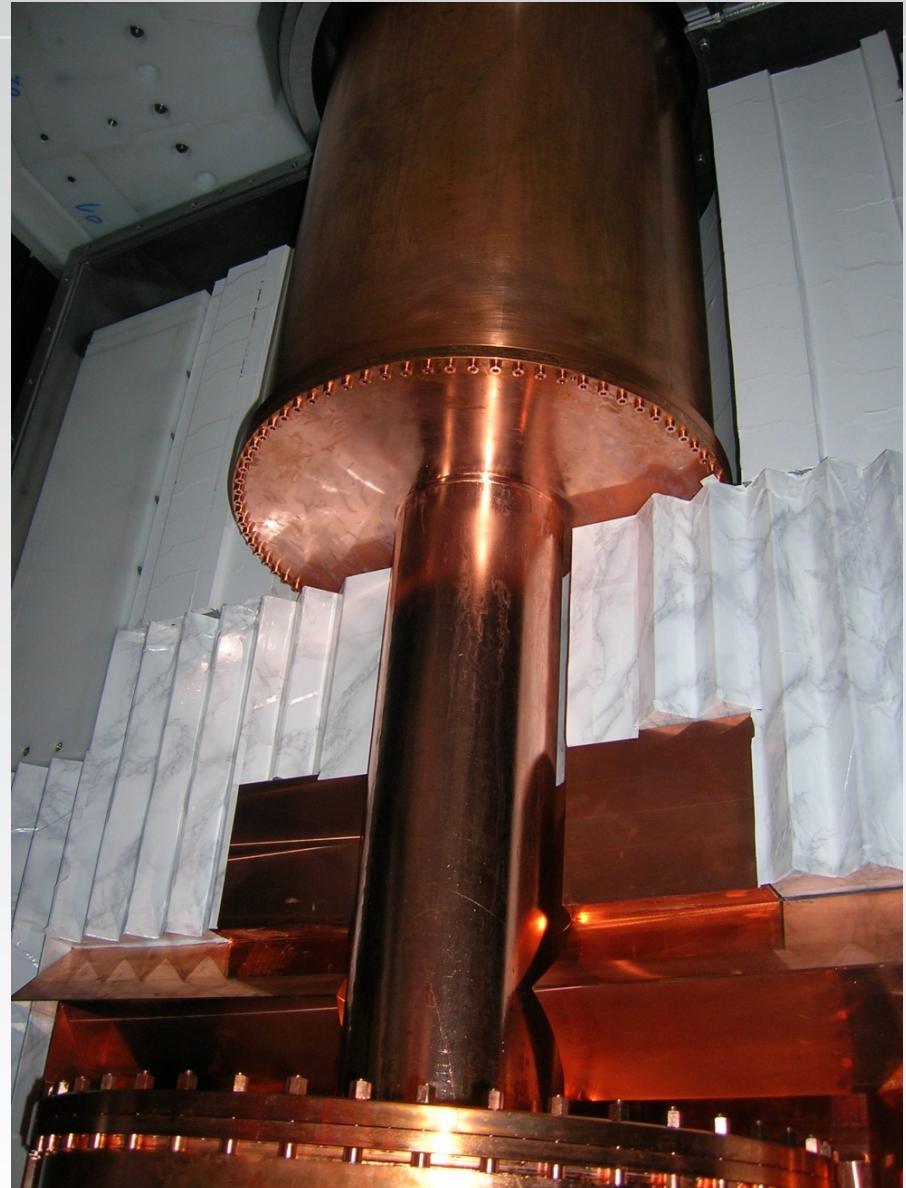
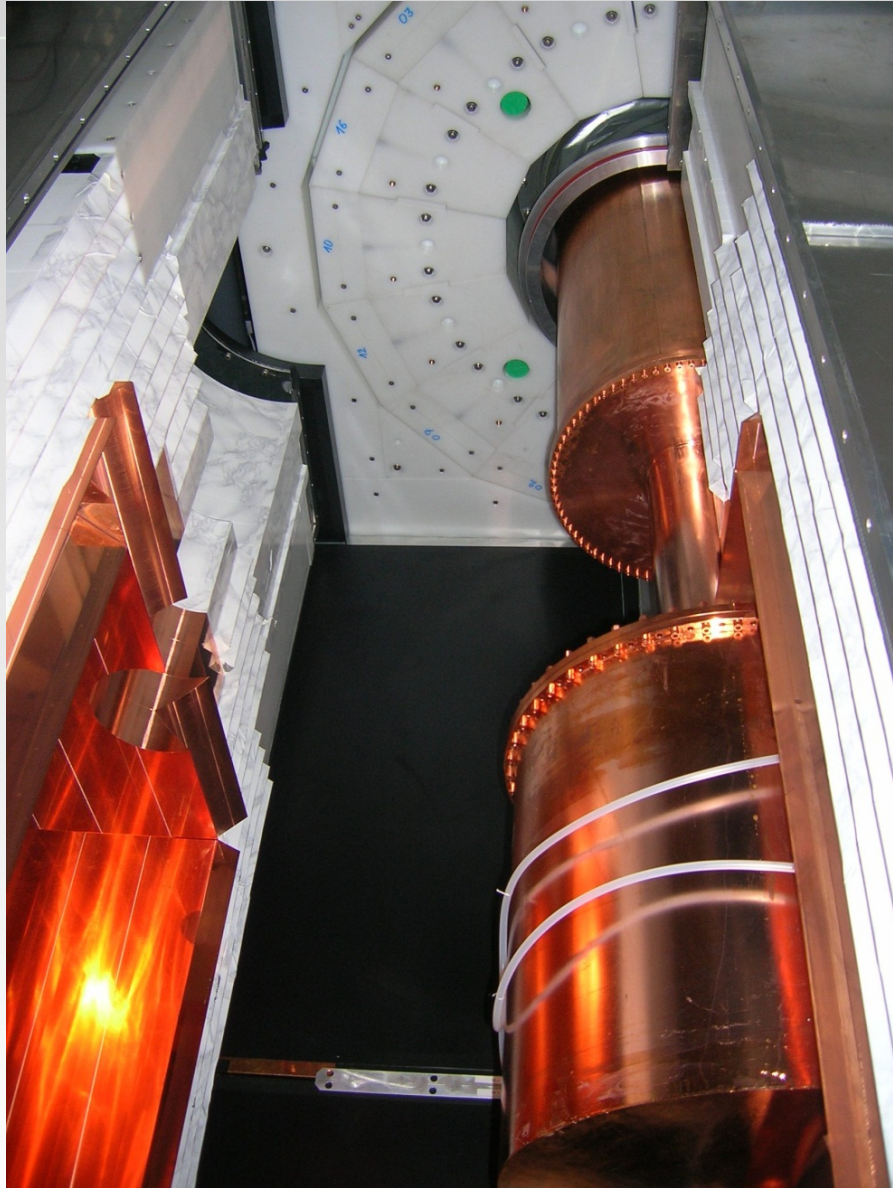
CRESST Set up at LNGS

Shielding

- Underground 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

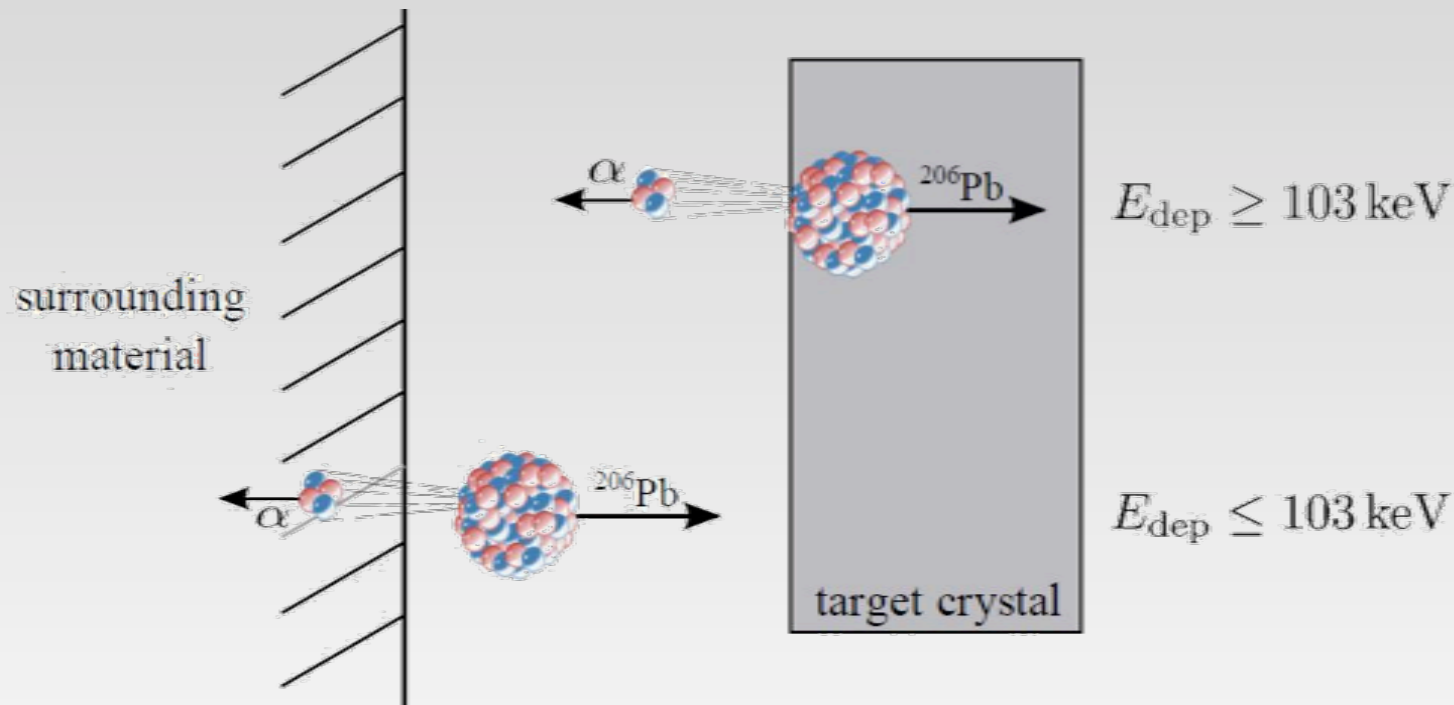


Coldbox closed – Pb shielding open



CRESST Alphas and Recoils

Surface contamination: $^{210}\text{Po} \rightarrow ^{206}\text{Pb} (103 \text{ keV}) + \alpha (5.3 \text{ MeV})$



Pb hits crystal

=> α deposits energy in crystal and/or hits surrounding veto-scintillator

α hits crystal

=> all energy lost before hitting goes into veto-scintillator

Only problem: clamps holding the crystal not covered by scintillator

=> low energy α 's (most energy lost in clamps)

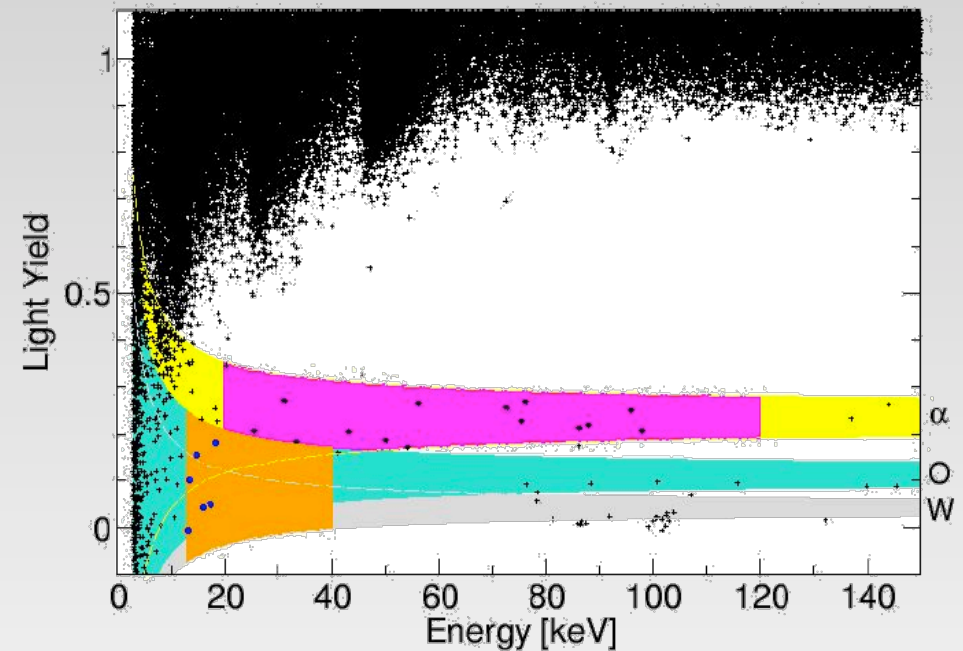
=> unvetoes Pb recoils

CRESST Run 2009 – 2011: Alphas

low energy α 's due to
contamination in clamps

flat spectrum

define overlap-free
reference region to
estimate α intensity



=> simple estimate: total of ~9.2 α -events leak into acceptance region

*similar result from full likelihood analysis
taking into account statistical uncertainties
allowing for a linear term in spectrum*

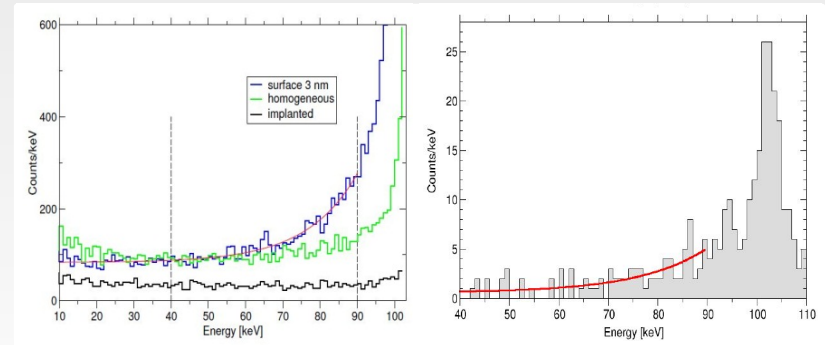
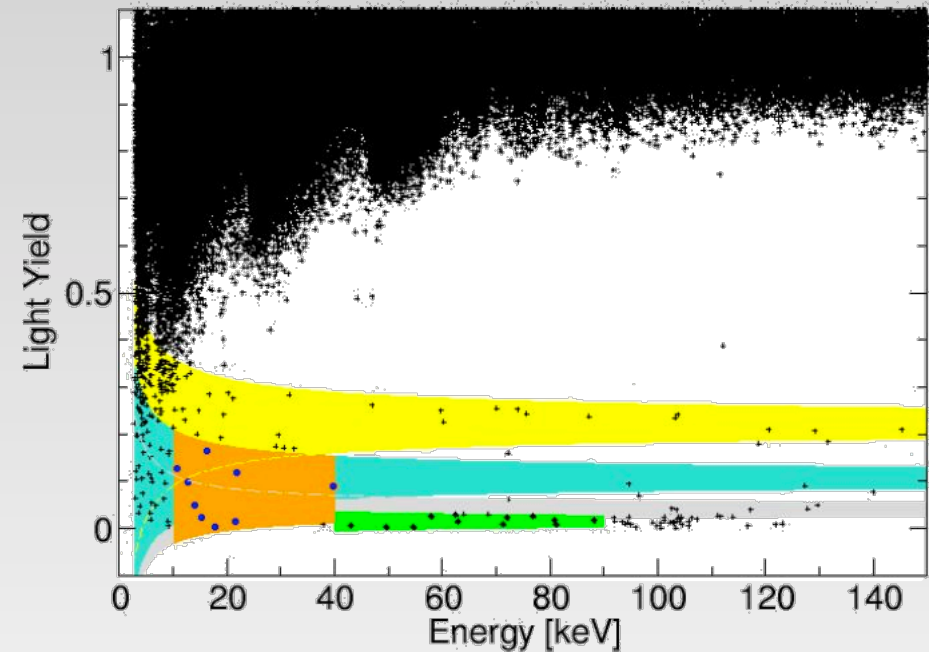
CRESST Run 2009 – 2011: Pb recoils

Pb recoils tail to low energies

overlap-free reference region,
to model spectral shape

SRIM simulation for different
depth profiles of implanted
 ^{210}Po to fit spectrum

Extrapolation into acceptance region



=> simple estimate: total of ~17 events of background

similar result from full likelihood analysis

CRESST Run 2009 – 2011: Neutrons

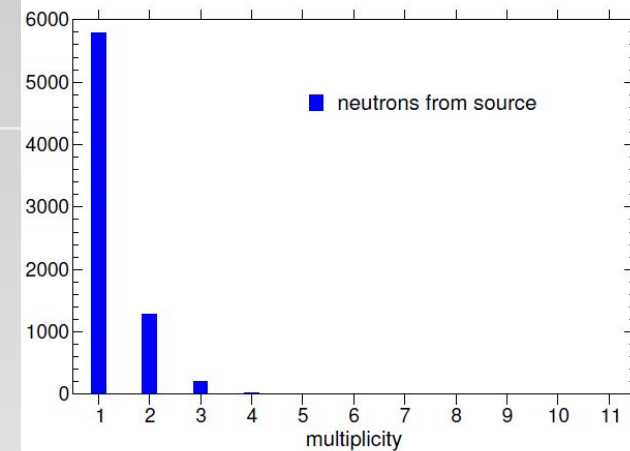
neutron sources
muon induced
 sf or (α, n) in surrounding
multiple scatters

3 coincidences
in acceptance region
two 3-fold
one 5-fold

compare with n-calibration
and observed muon coincidences

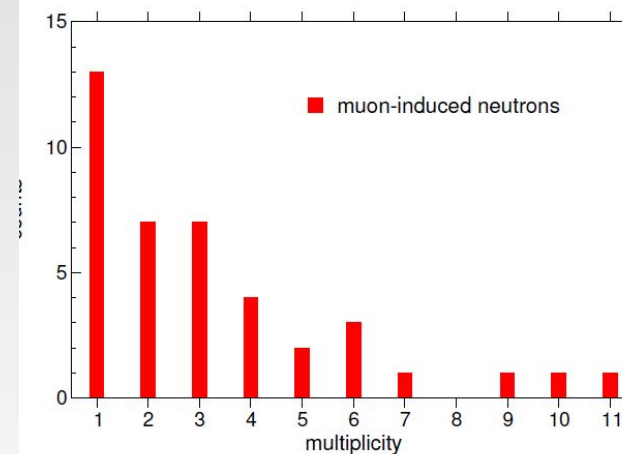
⇒ **simple estimate:**
total of ~11.4 events if caused by n-source
~ 1.5 events if caused by muon leakage
similar result from full likelihood analysis

→ study with AmBe source



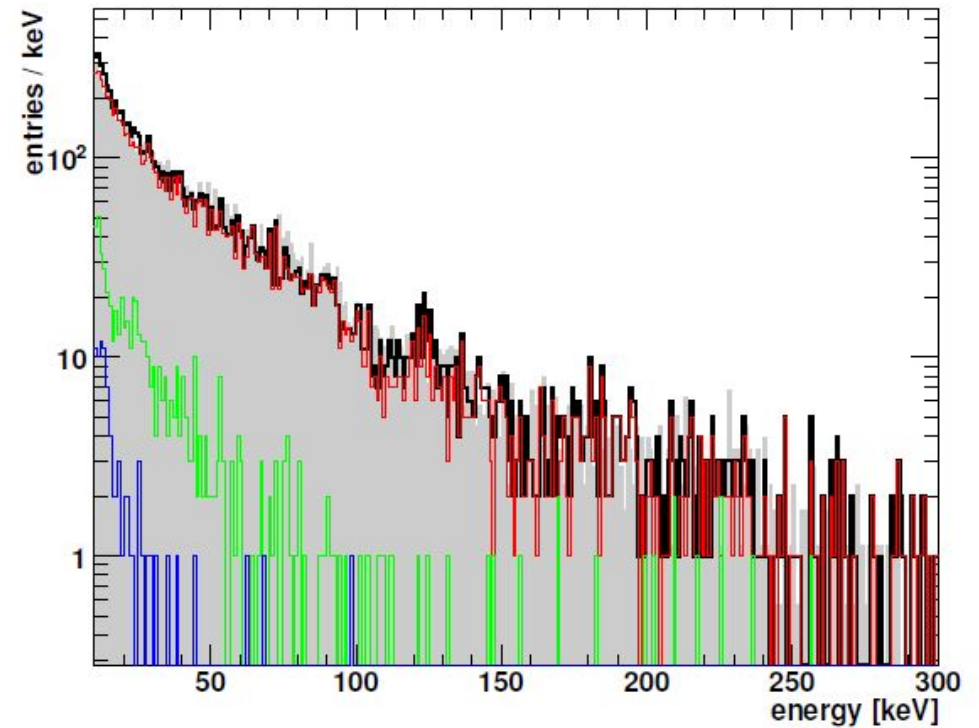
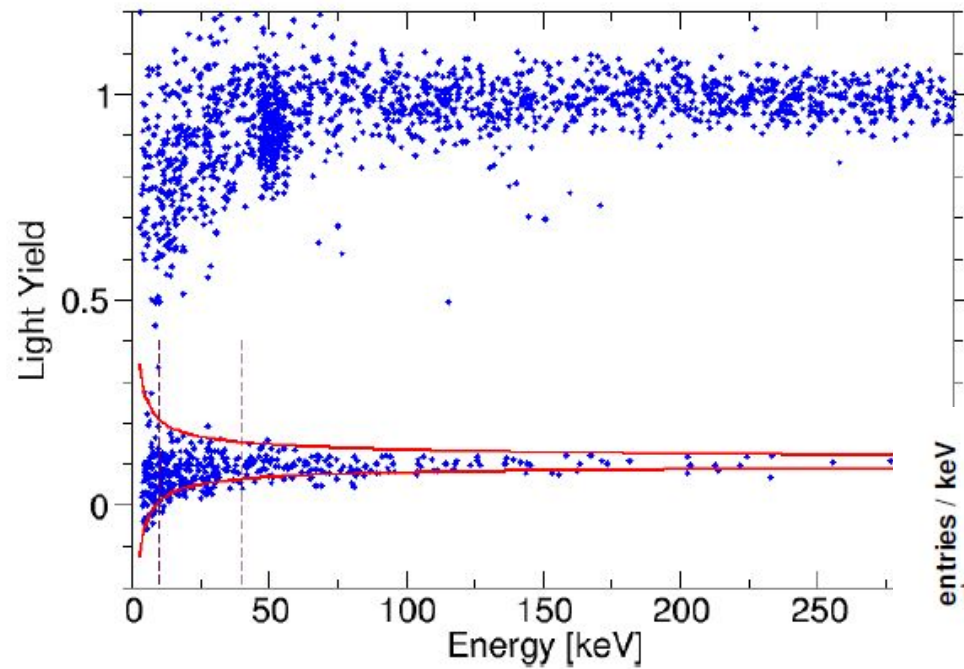
single/coincident: ~3.8

→ study with muon-coincident events



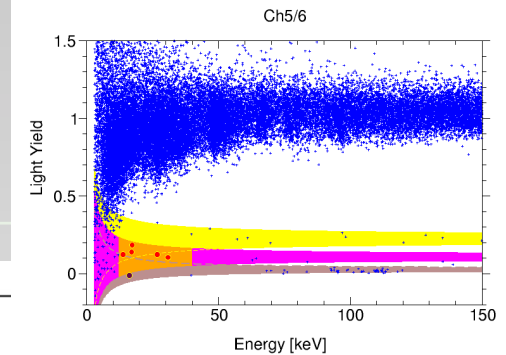
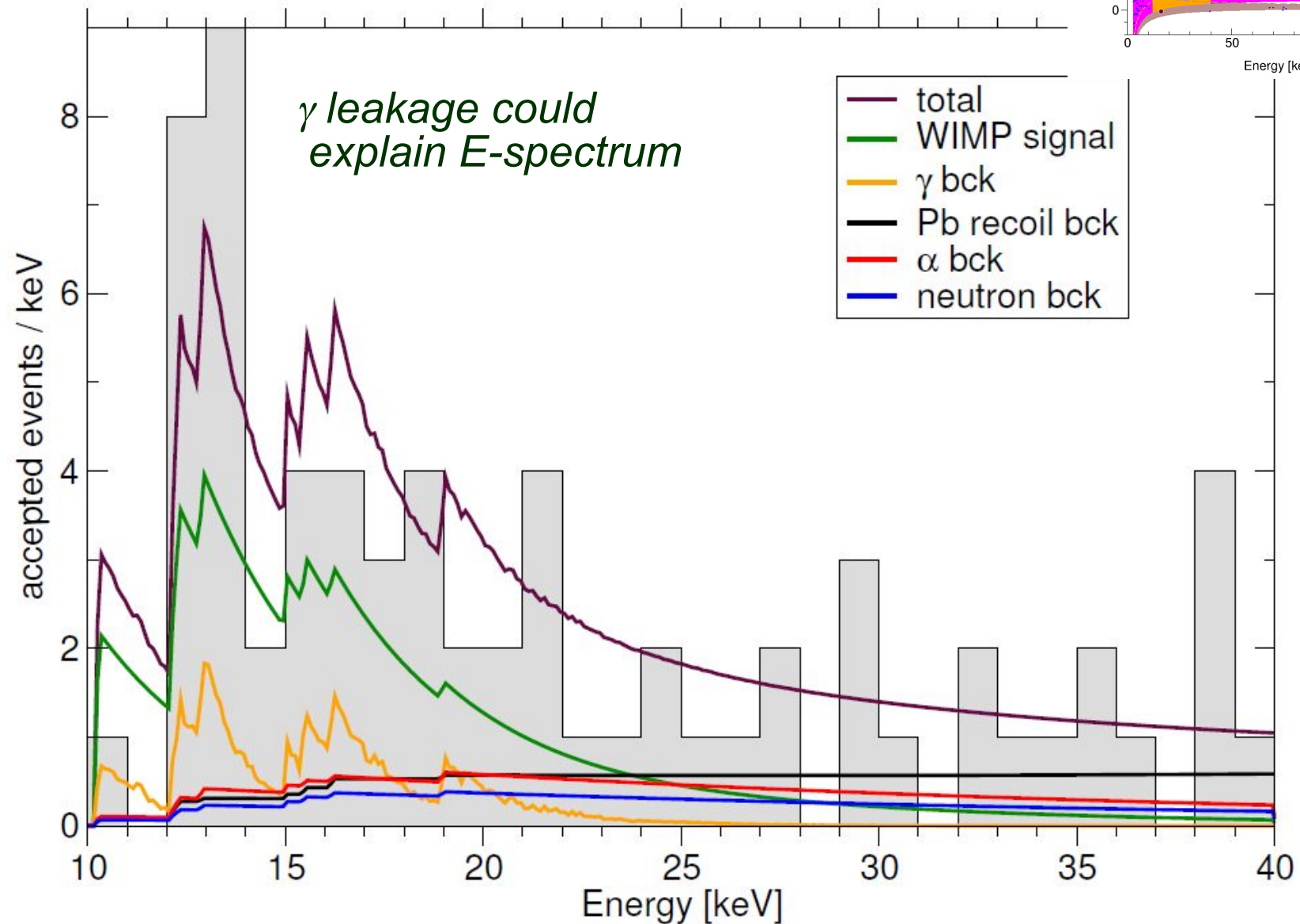
single/coincident: ~0.5

CRESST Run 2009 - 2011



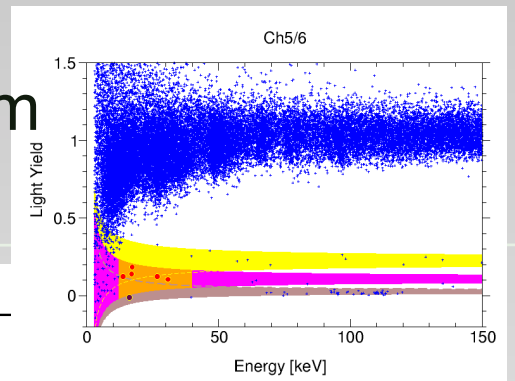
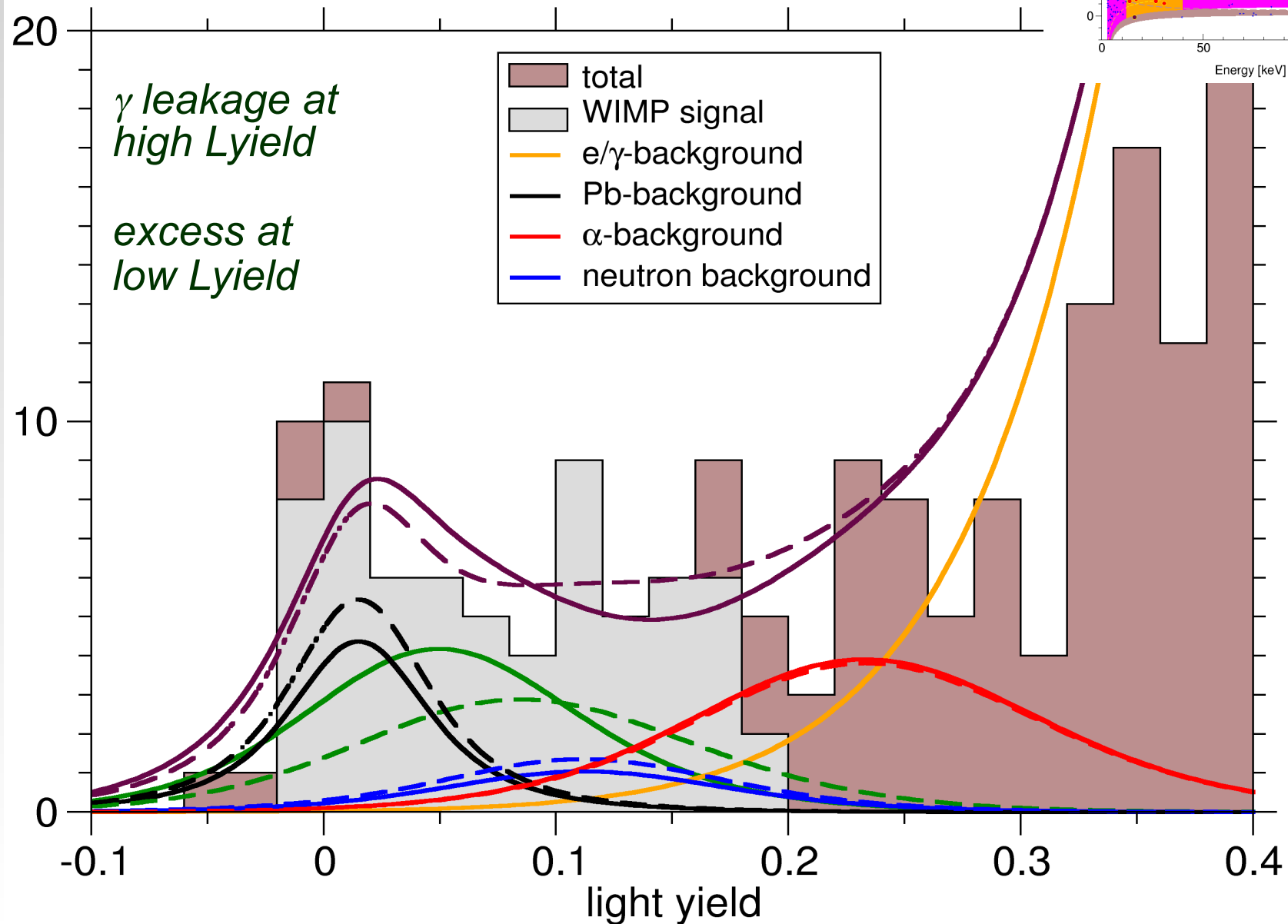
CRESST Run 2009 – 2011: Energy Spectrum

all events in acceptance region

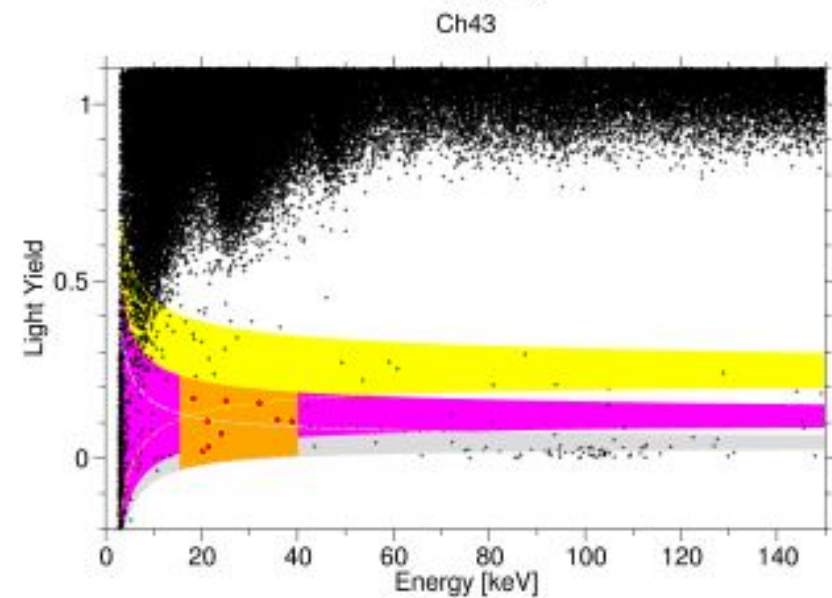
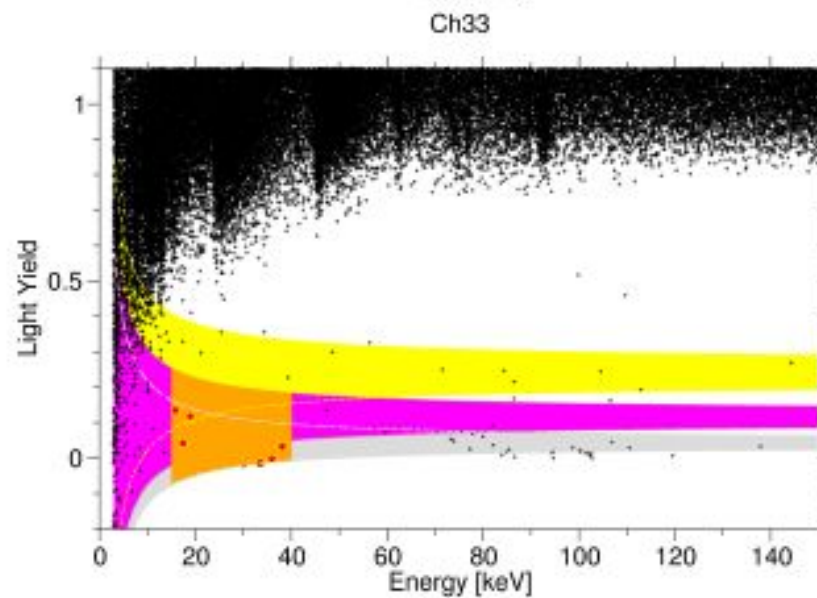
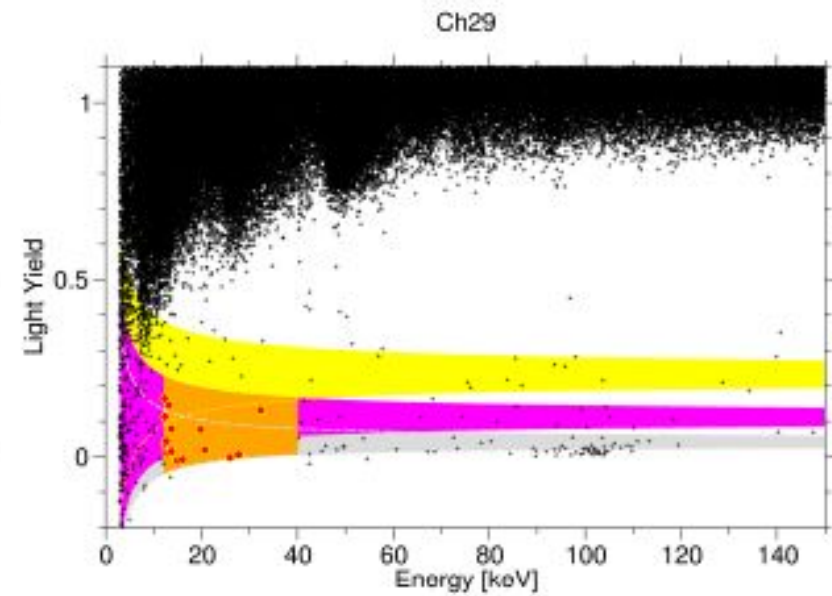
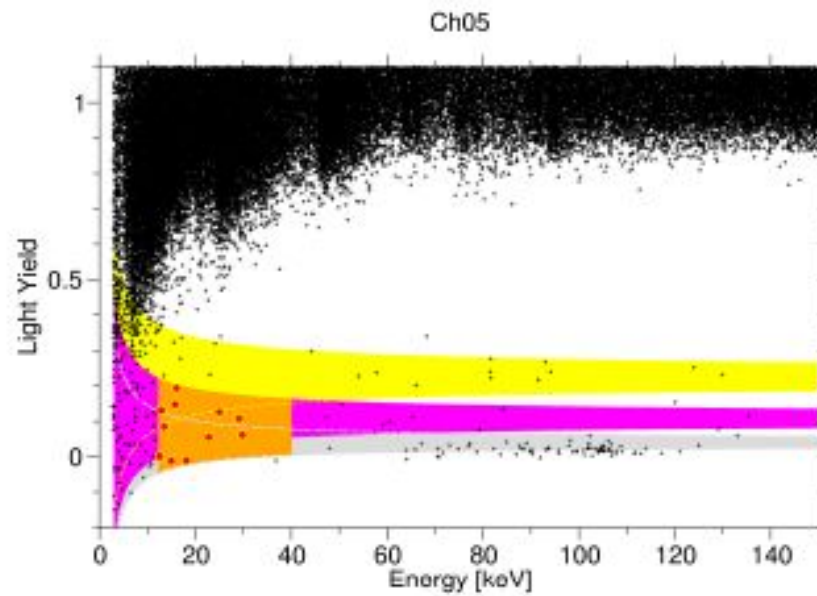


CRESST Run 2009 – 2011: Light-Yield Spectrum

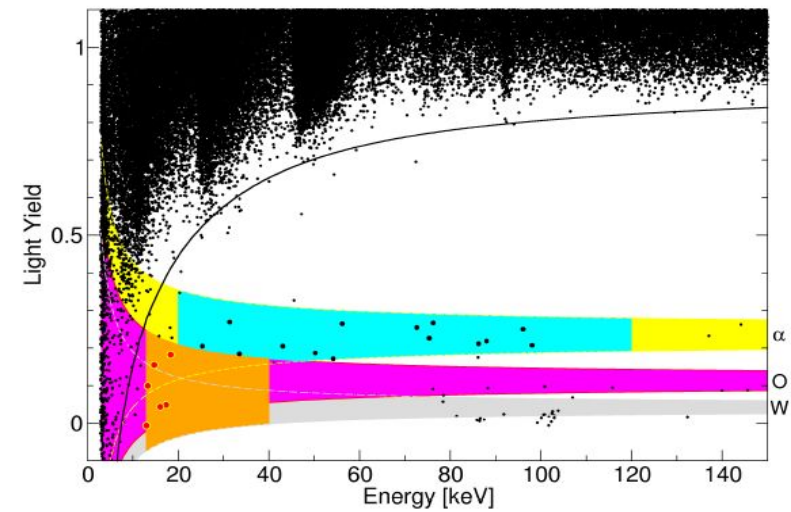
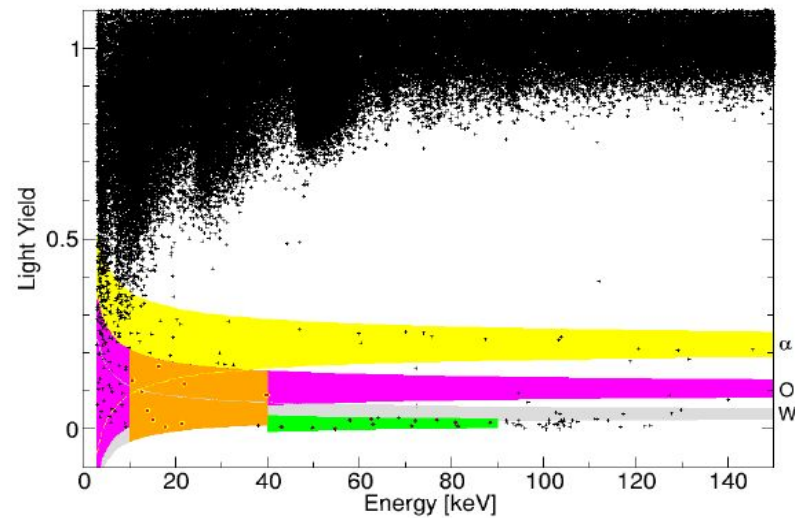
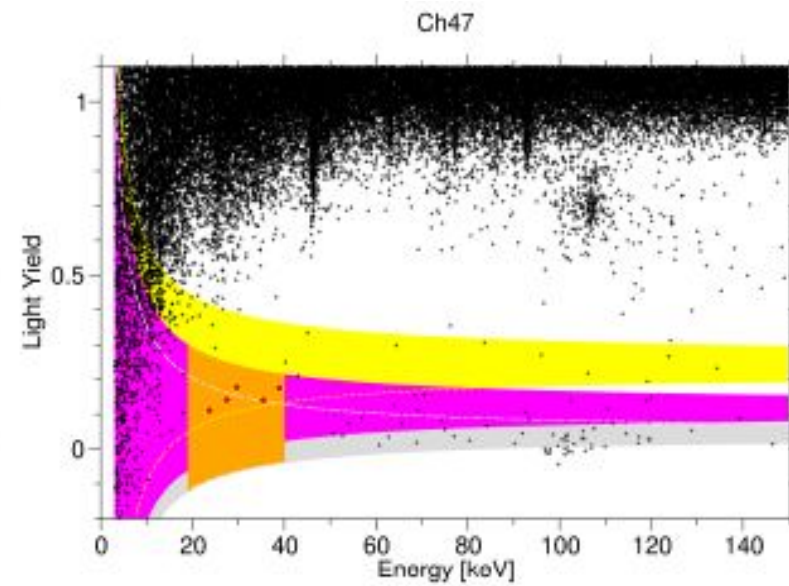
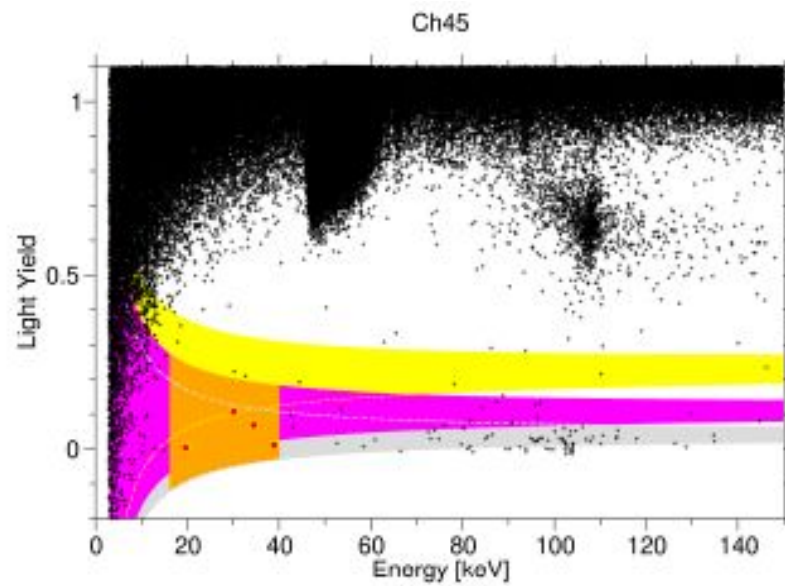
all events above (individual) threshold and below 40keV



CRESST Run 2009 - 2011



CRESST Run 2009 - 2011



EDELWEISS

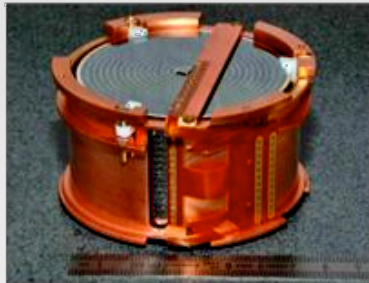
EDELWEISS – immediate future 2012

increase target mass

→ 40 detectors à 800g

800 g detector, 2 NTD,
4 electrodes

218 ultrasonic bondings
per detector



reduce neutron background

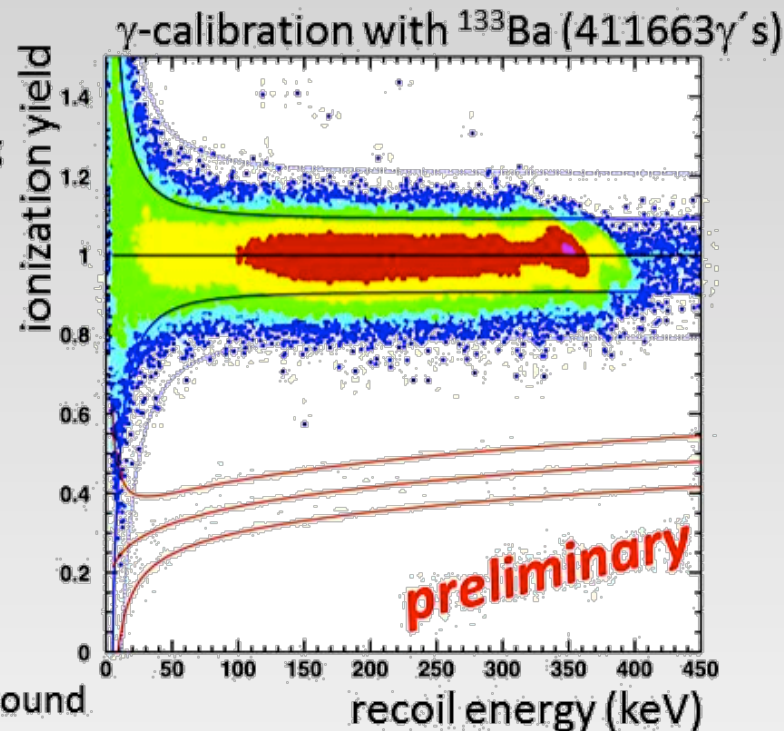
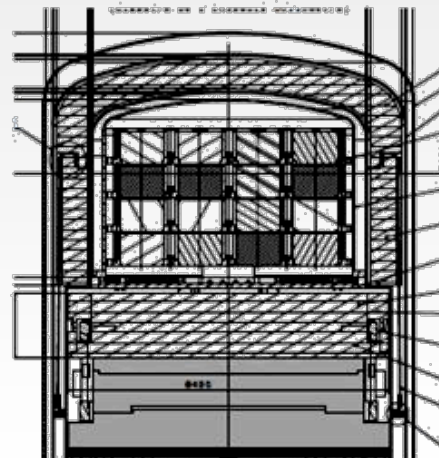
→ new cryostat design

new arrangement of Ge

new Cu mounting layers

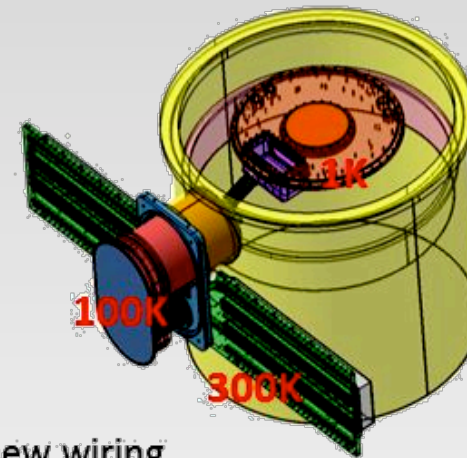
new internal PE shield

modified cryogenics



modify electronics & DAQ

→ 240 channels + auxiliary det.'s



new wiring

new ADC in-house electronics



new event-based readout scheme

EURECA

EURECA

Germany, France, UK, Spain, Russia, Ukraine

combines all European cryogenic DM efforts:

R&D 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

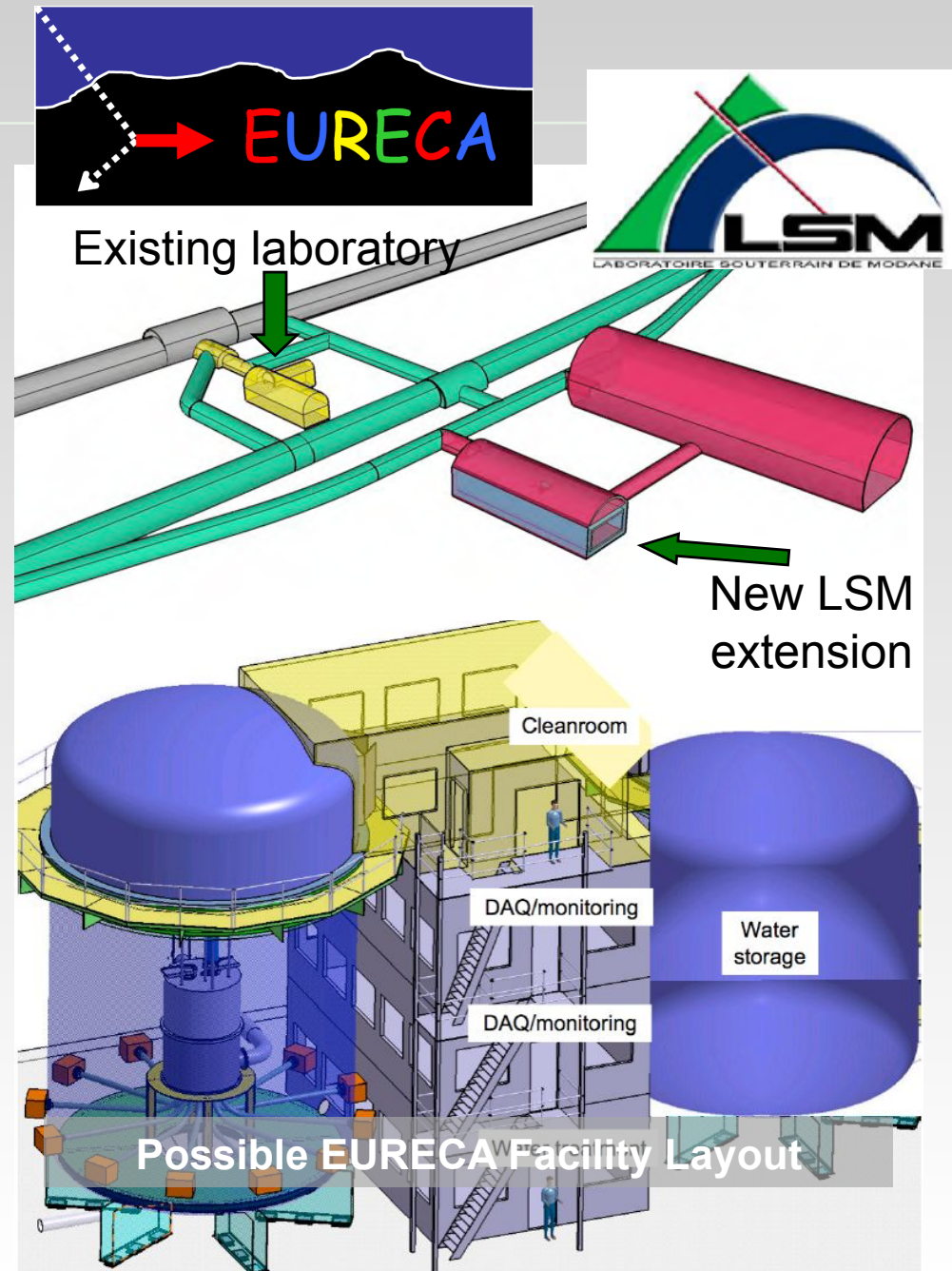
2013-2014 : TDR, construction of components

2015: construction at LSM or X site

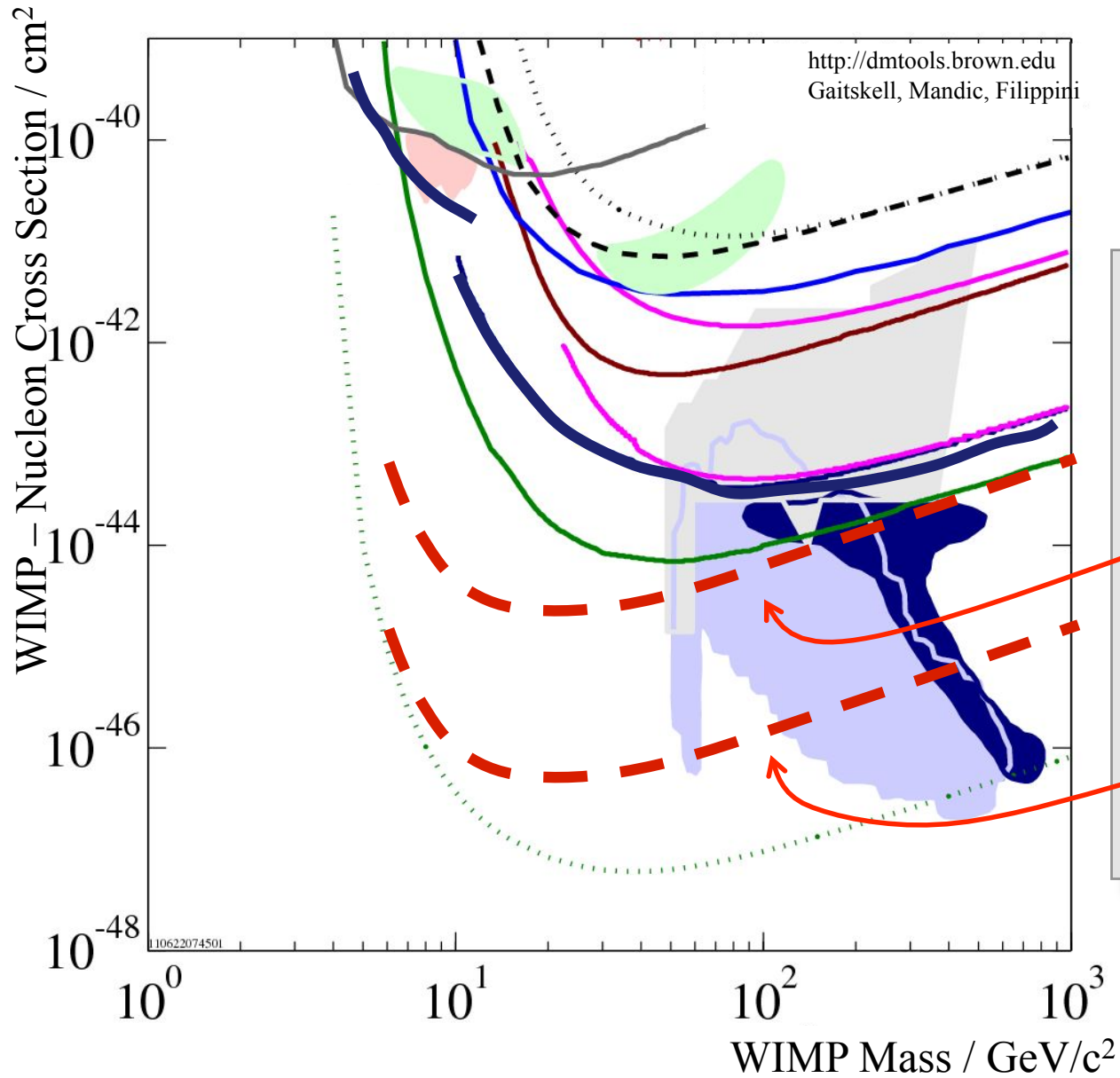
2016: begin phase 1 data taking

2016 – 2019: continuous upgrade to 1t target

=> from 10^{-45} to few 10^{-47} cm²



SuperCDMS



XENON 1t

XENON

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

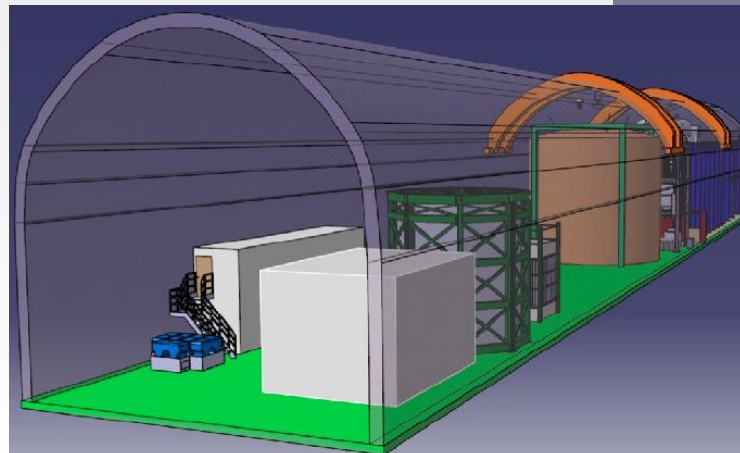
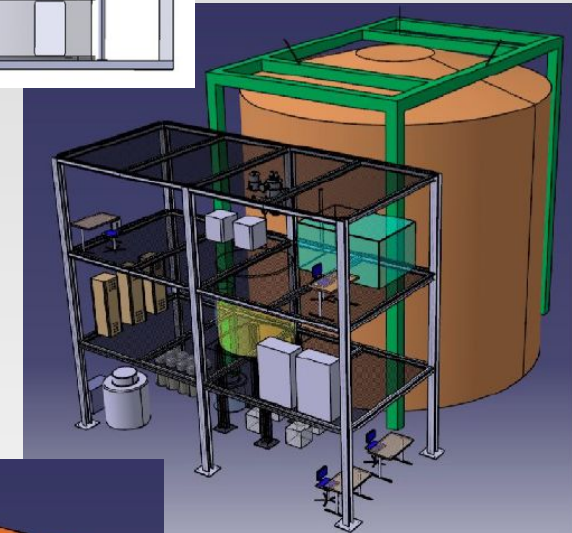
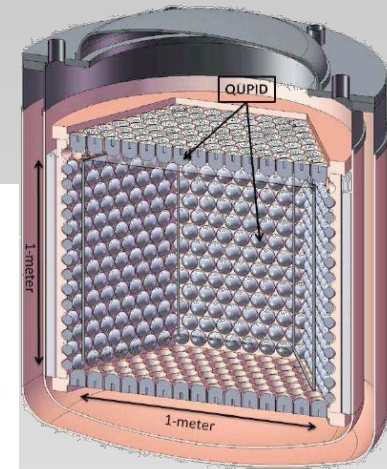
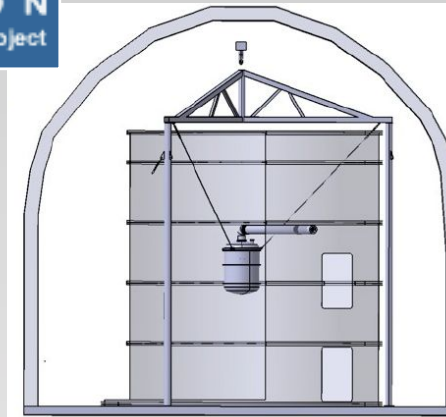


XENON 100 +

- at Gran Sasso
- 50 kg fiducial / 170 kg total funded
- starting end of 2009
- achieved 2011: $\sim 7 \times 10^{-45} \text{ cm}^2$
- achieved 2012: $\sim 2 \times 10^{-45} \text{ cm}^2$

XENON 1t

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

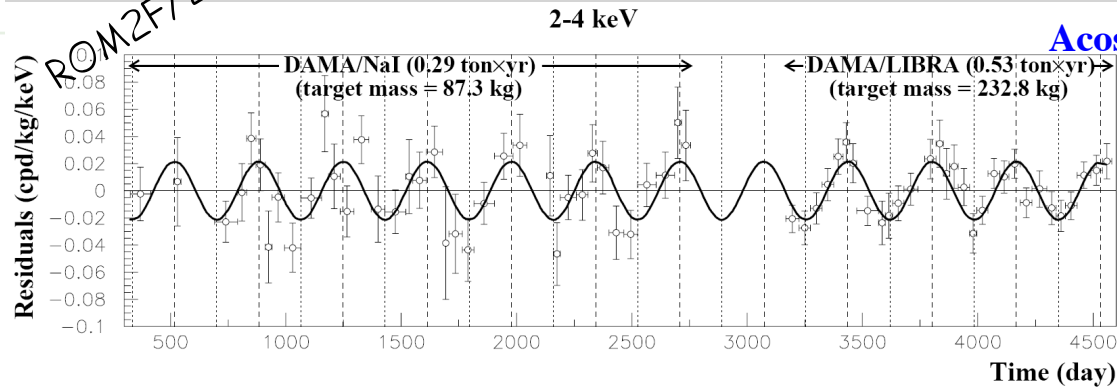


DAMA

Model Independent Annual Modulation Result

DAMA/NaI (7 years) + DAMA/LIBRA (4 years) Total exposure: 300555 kg×day = 0.82 ton×yr
experimental single-hit residuals rate vs time and energy

$\text{Acos}[\omega(t-t_0)]$; continuous lines: $t_0 = 152.5$ d, $T = 1.00$ y



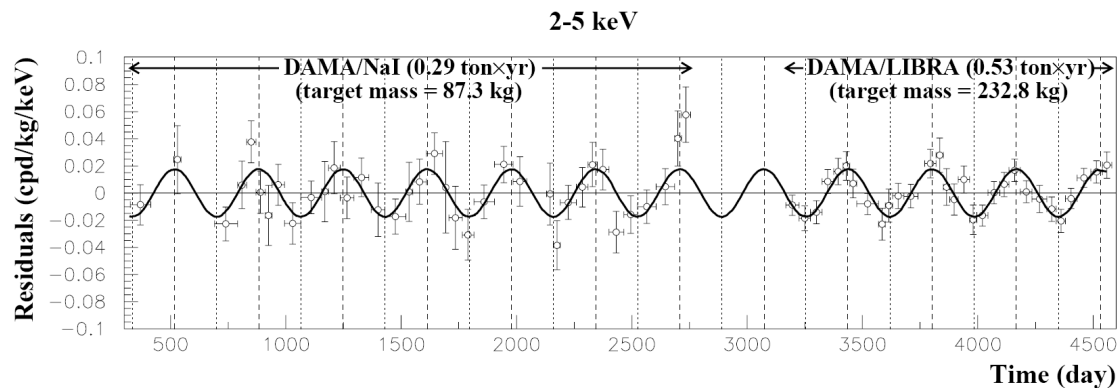
2-4 keV

$A = (0.0215 \pm 0.0026)$ cpd/kg/keV

$\chi^2/\text{dof} = 51.9/66$ **8.3 σ C.L.**

Absence of modulation? No

$\chi^2/\text{dof} = 117.7/67 \Rightarrow P(A=0) = 1.3 \times 10^{-4}$



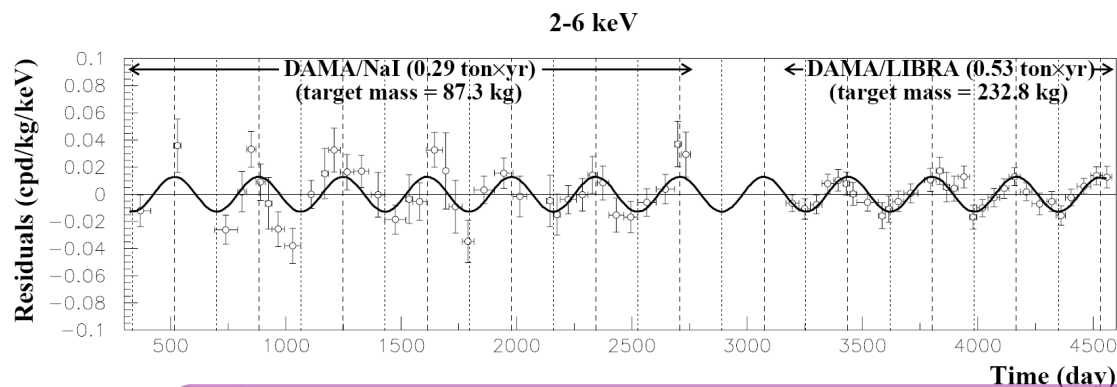
2-5 keV

$A = (0.0176 \pm 0.0020)$ cpd/kg/keV

$\chi^2/\text{dof} = 39.6/66$ **8.8 σ C.L.**

Absence of modulation? No

$\chi^2/\text{dof} = 116.1/67 \Rightarrow P(A=0) = 1.9 \times 10^{-4}$



2-6 keV

$A = (0.0129 \pm 0.0016)$ cpd/kg/keV

$\chi^2/\text{dof} = 54.3/66$ **8.2 σ C.L.**

Absence of modulation? No

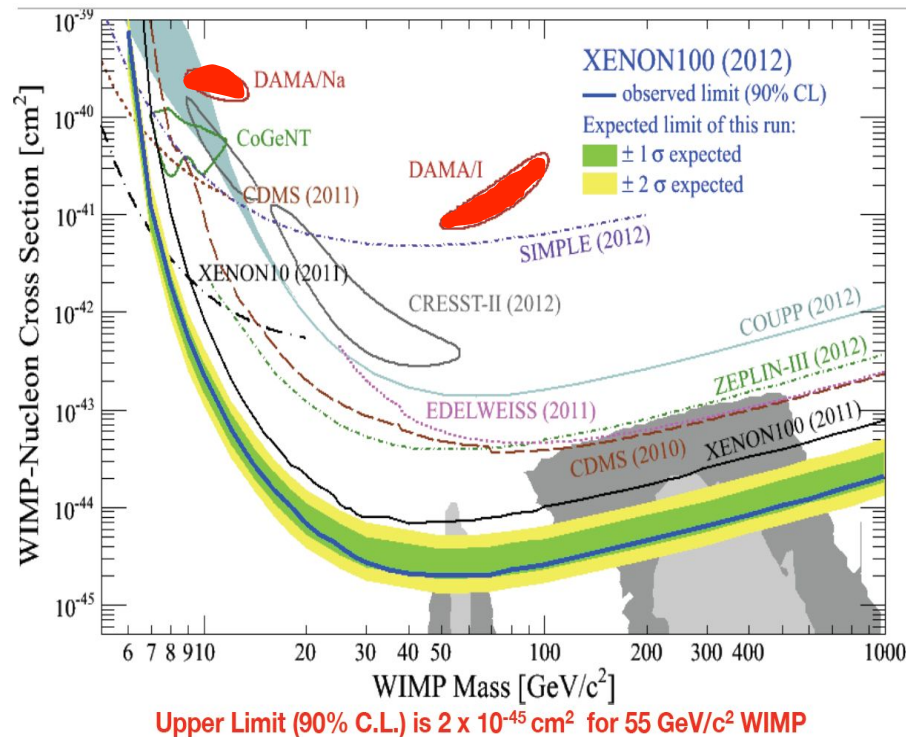
$\chi^2/\text{dof} = 116.4/67 \Rightarrow P(A=0) = 1.8 \times 10^{-4}$

The data favor the presence of a modulated behavior with proper features at 8.2 σ C.L.

Modulation

Modulation Signals

XENON100: New Spin-Independent Results



DAMA:

„ Others are insensitive to Modulation“

NO

meanwhile the DAMA-modulation alone would be visible to XENON

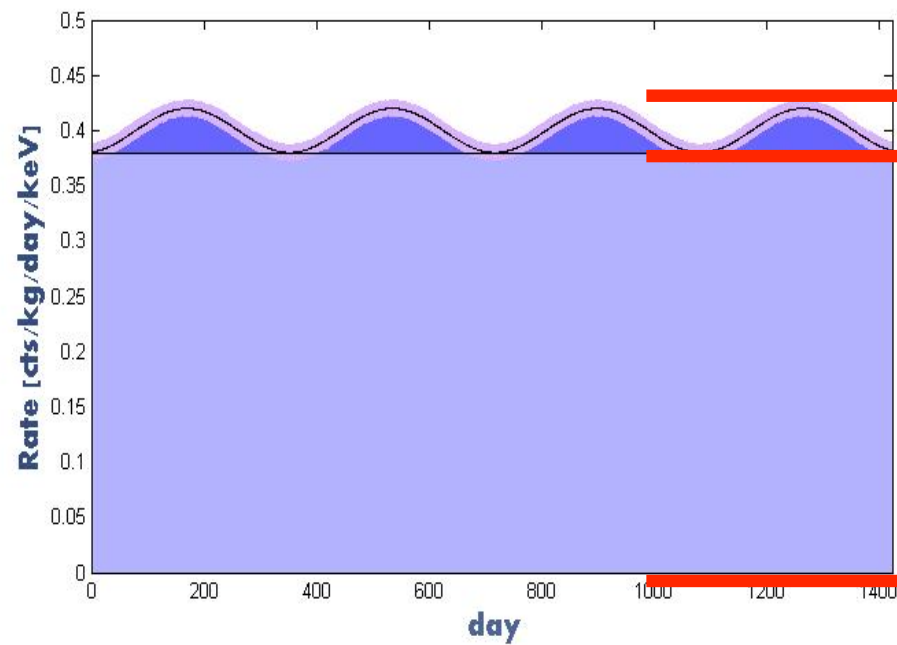
DAMA:

„ Others are only sensitive to Nuclear Recoils, what if Dark Matter scatters on electrons“

NO

meanwhile the DAMA-modulation alone would be visible to KIMS, XENON EVEN BEFORE NUCLEAR RECOIL CUT

Modulation Signals

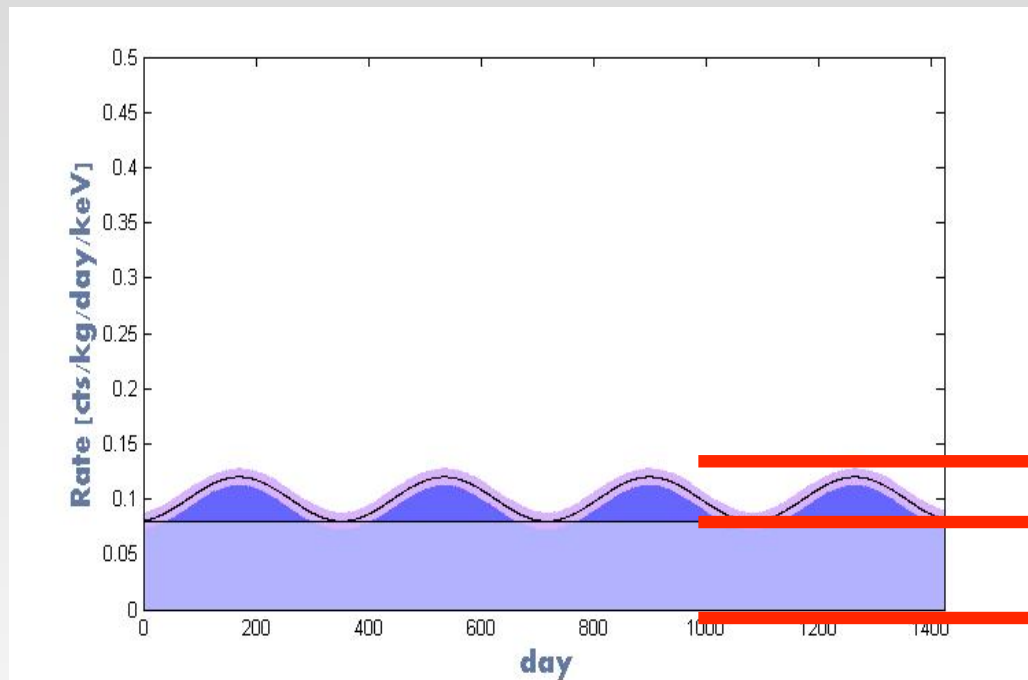


$\sim V_{Earth}$

$\sim V_{Sun-Halo}$

Modulation Signals

to avoid conflict between DAMA and Others



DAMA Signal
signals
for other
experiments

model dependence

modify

$V_{\text{Sun-Halo}}$

modify

halo structure

modify

WIMP structure
(inelastic)

=> mostly reduces bulk signal *(to make invisible to others)*

Liquid Argon

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

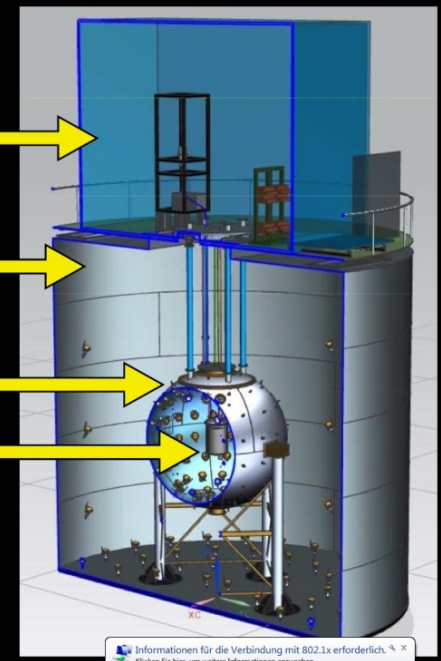
DarkSide 50

Radon-free clean room

Instrumented water tank

Liquid scintillator

Inner detector TPC
(Underground argon)



DarkSide

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

Liquid Argon *Charge + Light*

WARP

Italy, US

- at Gran Sasso
- stopped (technical problems)

ArDM

Switzerland, Spain, UK, Poland

- 1000 kg R & D, prototype
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DarkSide

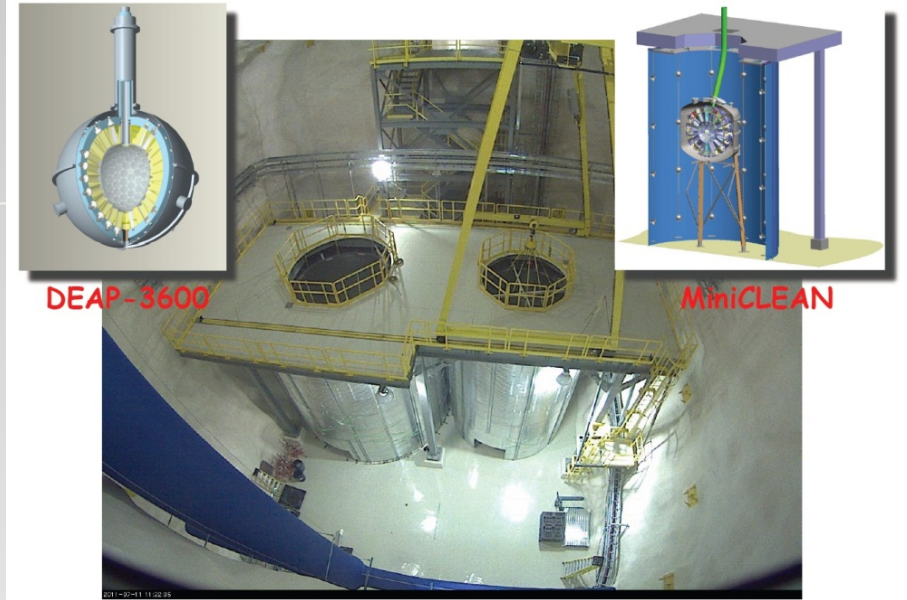
US, Italy at Gran Sasso

- proposed, depleted Ar

DEAP / CLEAN

Canada, US

- 1-phase, SNOLAB
- 1000 kg fid. start set up 2012



DEAP / CLEAN

- DEAP 3600 goal $\sim 10^{-47} \text{ cm}^2$

• Sep. 2012
most components
at SNOLAB

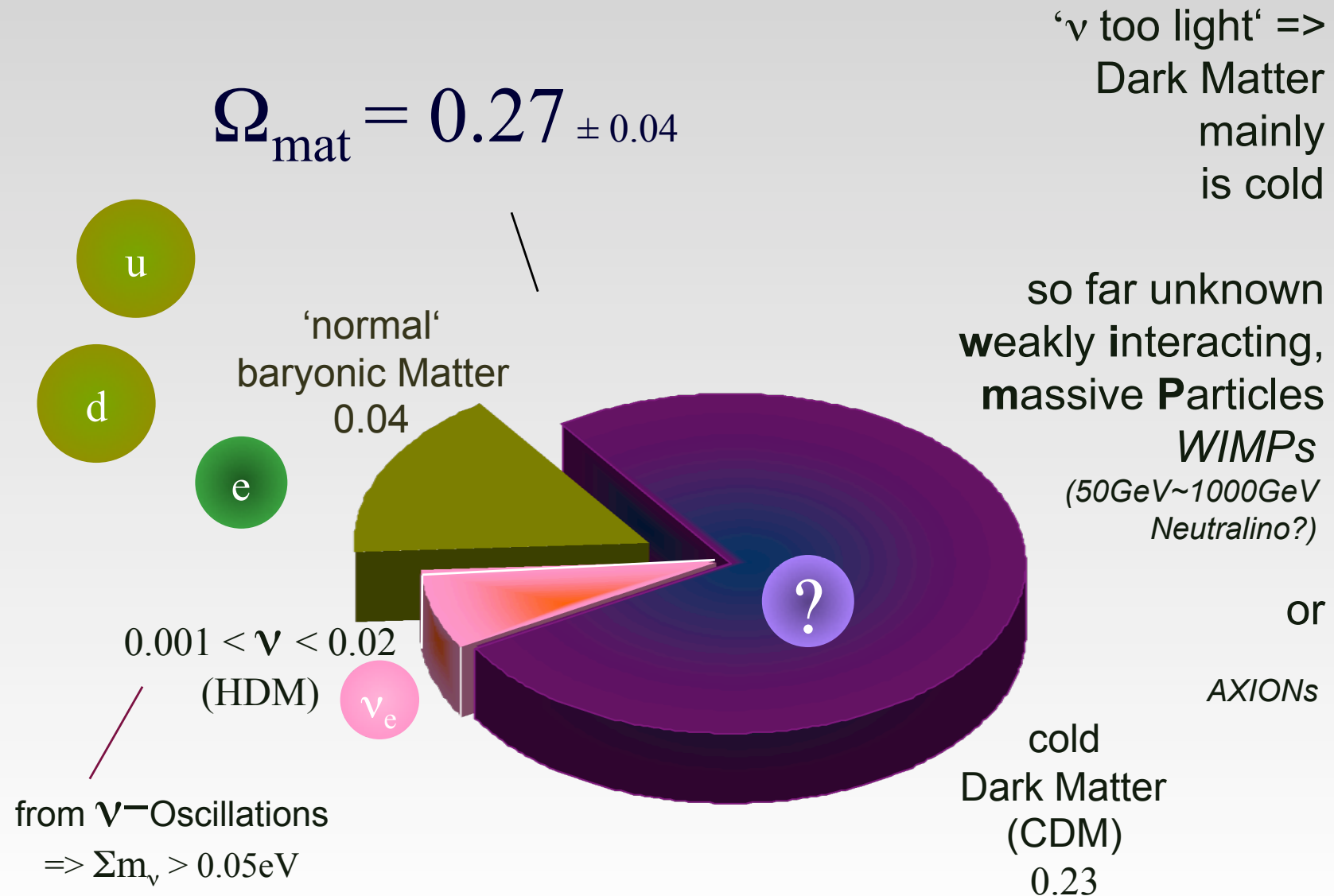
- commissioning
late 2013

DEAP Acrylic Vessel with Light Guide "Stubs" July 2012

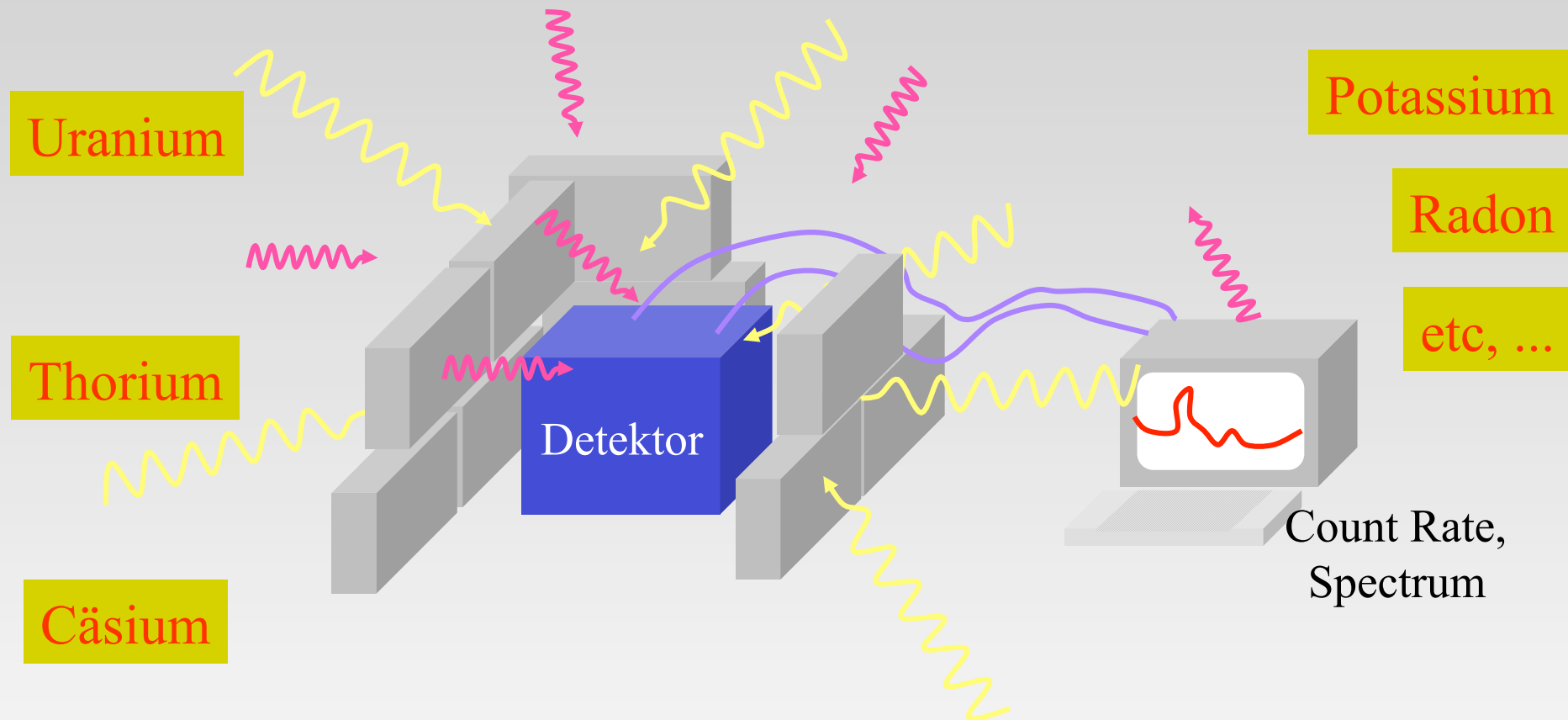


general

Matter in the Universe - Composition



Radioactivity in Environment

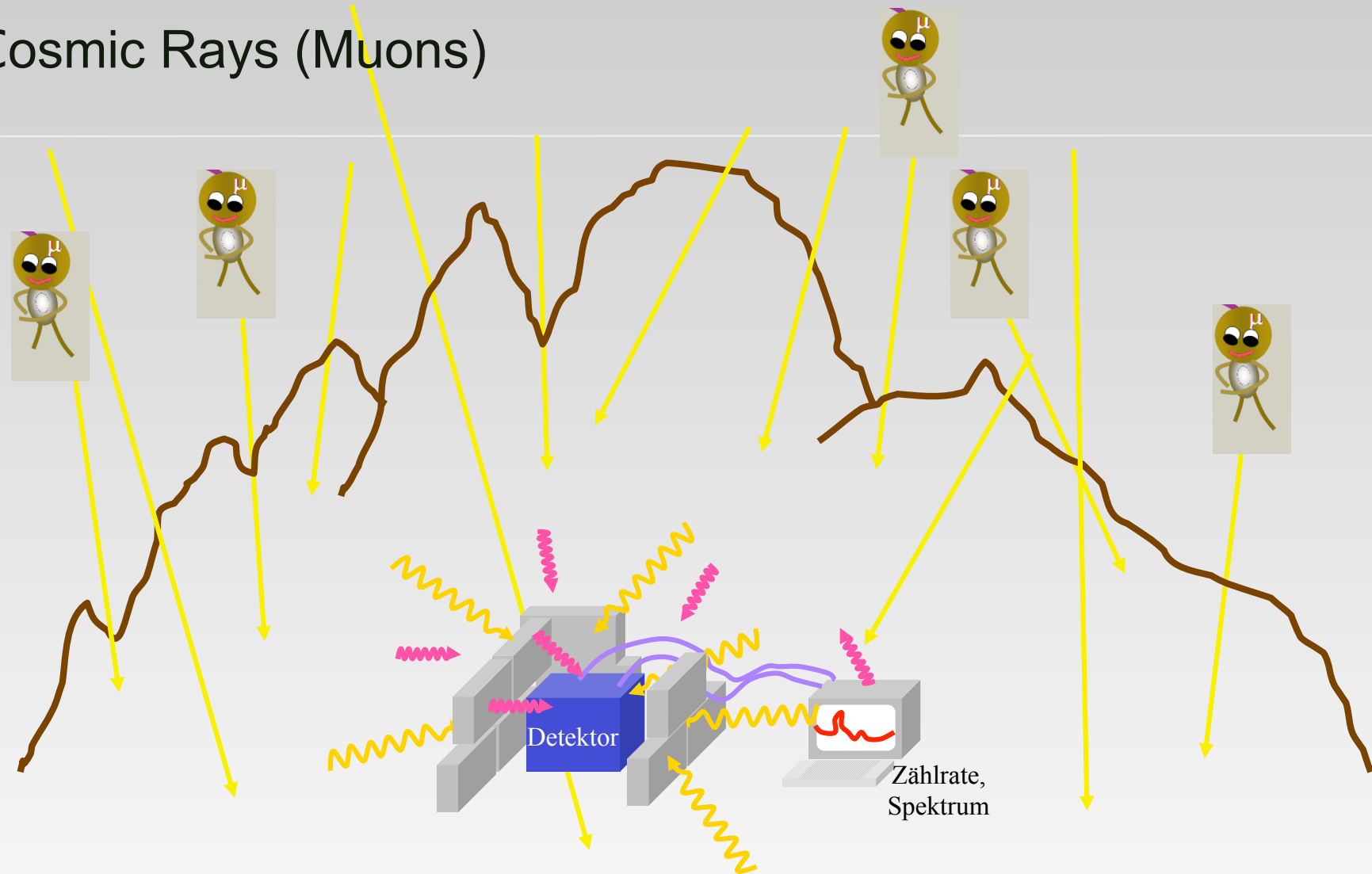


required Sensitivity~ 1 event / kg /year)

environmental Radioactivity: $> 1\text{ Hz/kg}$ $\sim 10^7$ 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**