# Recent results on direct Dark Matter searches

Marco Vignati INFN Sezione di Roma *Roma, 15/Nov/13* 

source: TAUP2013 conference when not specified

#### Dark Matter



Planck Satellite arXiv:1303.5076

Dark matter particles should have the following properties:

- 1) Stable or long-lived
- 2) Neutral
- 3) Density = 0.3 GeV/cm<sup>3</sup>
- 4) Maxwellian distribution (v₀ ~ 220 km/s)



WIMPs (Weakly interactive massive particles) of mass
~ 100 GeV, are the "miracle" candidates: Neutralinos (χ)?

## WIMP detection principle

Elastic scattering off nuclei, measure nuclear recoil energy  $E_{nr}$ :



Spin dependent (SD) or spin independent (SI) interaction:

For  $m_{\chi} = 100$  GeV and A = 100:

- $\sigma_{SI} = 10^{-42} 10^{-44} \text{ cm}^2$
- Rate =  $10^{-2} 1$  events / (kg day)
- E<sub>nr</sub> = 0 25 keV

# The WIMP signal (SI)

Exponential-like shape, increasing at low E (similar to many bkgs...)



Demands O(keV) thresholds and backgrounds close to zero.

All experiments operated in low radioactivity environments and deep underground.

## Counting rate annual modulation

Earth velocity combines to solar system velocity in the galaxy.

Dark matter "wind" in the heart rest frame is modulated:

$$v(t) = v_{\rm sun} + v_{\rm orb}^{||} \cos[\omega(t - t_0)]$$

and affects the counting rate:

$$S(E,t) = S_0(E) + S_m(E) \cos[\omega(t-t_0)]$$



Distinctive modulation signal features:

$$T = 1$$
 year  $t_0 = 2^{nd}$  June

Pro: model independent

Con: requires detector stability and bkg control.

#### **Detection channels**

The combination of different techniques allows one to discriminate between electron and nuclear recoils, and thus to reduce the  $\beta/\gamma$  background.



Energy calibrations are done with  $\gamma$  sources (electron recoils).

The relative calibration of nuclear recoils ( $keV_{ee} \Rightarrow keV_{nr}$ ), the quenching factor (QF), must be known with accuracy



#### DAMA/LIBRA

25 Nal crystals, 9.70 kg each

- QF: Na (30%), I (10%)
- High radiopurity: <sup>232</sup>Th and <sup>238</sup>U (ppt), <sup>40</sup>K (<20 ppb)</li>



#### DAMA/LIBRA - data analysis

#### Pulse shape cuts to reject PMT noise events:



Low energy calibration with <sup>241</sup>Am and <sup>133</sup>Ba, check with <sup>40</sup>K



#### **DAMA/LIBRA - result**



#### DAMA/LIBRA - checks

#### R. Cerulli at IDM2012

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Source	Main comment	Cautious upper limit (90%C.L.)	
RADON	Sealed Cu box in HP Nitrogen atmosphere,	<2.5×10 <sup>-6</sup> cpd/kg/keV	
TEMPERATURE	Installation is air conditioned+ detectors in Cu housings directly in contact with multi-ton shield→ huge heat capacity + T continuously recorded	<10 <sup>-4</sup> cpd/kg/keV	
NOISE	Effective full noise rejection near threshold	<10 <sup>-4</sup> cpd/kg/keV	
ENERGY SCALE	Routine + intrinsic calibrations	<1-2 ×10 <sup>-4</sup> cpd/kg/keV	
EFFICIENCIES	Regularly measured by dedicated calibrations	<10 <sup>-4</sup> cpd/kg/keV	
BACKGROUND	No modulation above 6 keV; no modulation in the (2-6) keV <i>multiple-hits</i> events; this limit includes all possible	<10 <sup>-4</sup> cpd/kg/keV	
SIDE REACTIONS	sources of background Muon flux variation measured at LNGS	<3×10 <sup>-5</sup> cpd/kg/keV	
+ they cannot satisfy all the requirements of annual modulation signature DAMA phase: May 26±7 μ phase @LNGS: July 6±6			

## CoGeNT

One 0.5 kg p-type point contact (PPC) HP-Germanium detector

Measure ionization only (QF: 20%):

No recoil identification.

Ultra low noise:

 $10^{-38}$ 

Threshold at 0.5 keVee!





#### CoGeNT - Surface events

Ionization at the surface experience a weaker electric field

• surface events exhibit slower rise time, and can be rejected (almost).



#### **CoGeNT - Results**

PRD 88, 012002 (2013)





#### CoGeNT check - Malbek

Majorana collaboration (Double beta decay) test of CoGeNT (spin-off of Majorana).

the same detector as CoGeNT but the same detector as CoGeNT bu



Preliminary results exclude CoGeNT, but no paper yet.

## CoGeNT, the WIMP and DAMA



J.I. Collar, PRC 88, 035806 (2013)

# CDMSII



The basic principle is essentially that of a standard Si particle tracker or high-purity Ge

#### **CDMSII-Si - final result**



#### **CDMSII-Si - final result**



Signal+bkg. favored against bkg. only hypothesis at 99.81% CL ( $3\sigma$ ).

Comment from the collaboration: "We do not believe this result rises to the level of a discovery, but does call for further investigation."

#### **CDMSII-Ge - Annual modulation**



#### <u>ODECCT</u>

bolometers (phonon detectors):

- 1) detect also scintillation light to discriminate nuclear recoils
- 2) Multi-target: sensitive to different WIMP masses:







#### **CRESST** - setup

- 10 mK operating temperature.
- 18 modules:
  - ▶ 8 active 330g CaWO<sub>4</sub> crystals
  - 1 CaWO<sub>4</sub> bad resolution
  - 1 ZnWO<sub>4</sub> not well working
  - ▶ 10 CaWO<sub>4</sub> with light detector not working.
- Other 12 modules used to reject multi-hit events
- γ-calibrations with <sup>57</sup>Co and <sup>232</sup>Th



## **CRESST - discrimination**



67 accepted events in the 8 modules (730 kg days)!

#### Source: daughter nuclei emitted after decay off source material

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4 0 0 10 110 23 Energy [keV]

100

120

140

## **CRESST - Sputtering?**

Astropart. Phys. 36 (2012) 77

Possible explanation of the CRESST excess: sputtering from the crystal supports.



New run with reduced background from supports already started.

#### Status in the low-mass region



#### Xenon-100

- 161 kg LXe (34 kg fiducial volume), 225 days published so far.
- Dual phase TPC, detect scintillation (S1) and ionization (S2)
  - x,y and z (via S2-S1 time difference), and recoil discrimination via S2/S1 ratio



#### Xenon-100 - Results

#### Phys.Rev.Lett 109 (2012) 181301

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#### Phys.Rev.Lett 109 (2012) 181301



## **XENON - quenching factor**

Phys.Rev.D 88 (2013) 012006

Uncertainty in the scintillation efficiency for nuclear recoils at low energy (Leff)

• affects the calibration (S1  $\Rightarrow$  E<sub>nr</sub>) of the detector.



## LUX

Same technique as Xenon-100: Dual phase LXe TPC



	Xenon-100	LUX
Total/Active Volume [kg]	161/62	370/250
Fiducial volume [kg]	34	118
S1 Light Yield [PhE/keVee]	2.3 (field on)	8.8 (field off)
WIMP search region [keVnr]	6.6 - 30.5	~ 3 - 18
Published live time [day]	225	85

## LUX - Results



## LUX - Results



#### LUX - WIMP space



#### Where are we going?

