2nd Brainstorming meeting

DARK MATTER @ LPNHE

Monday November 3rd 2014

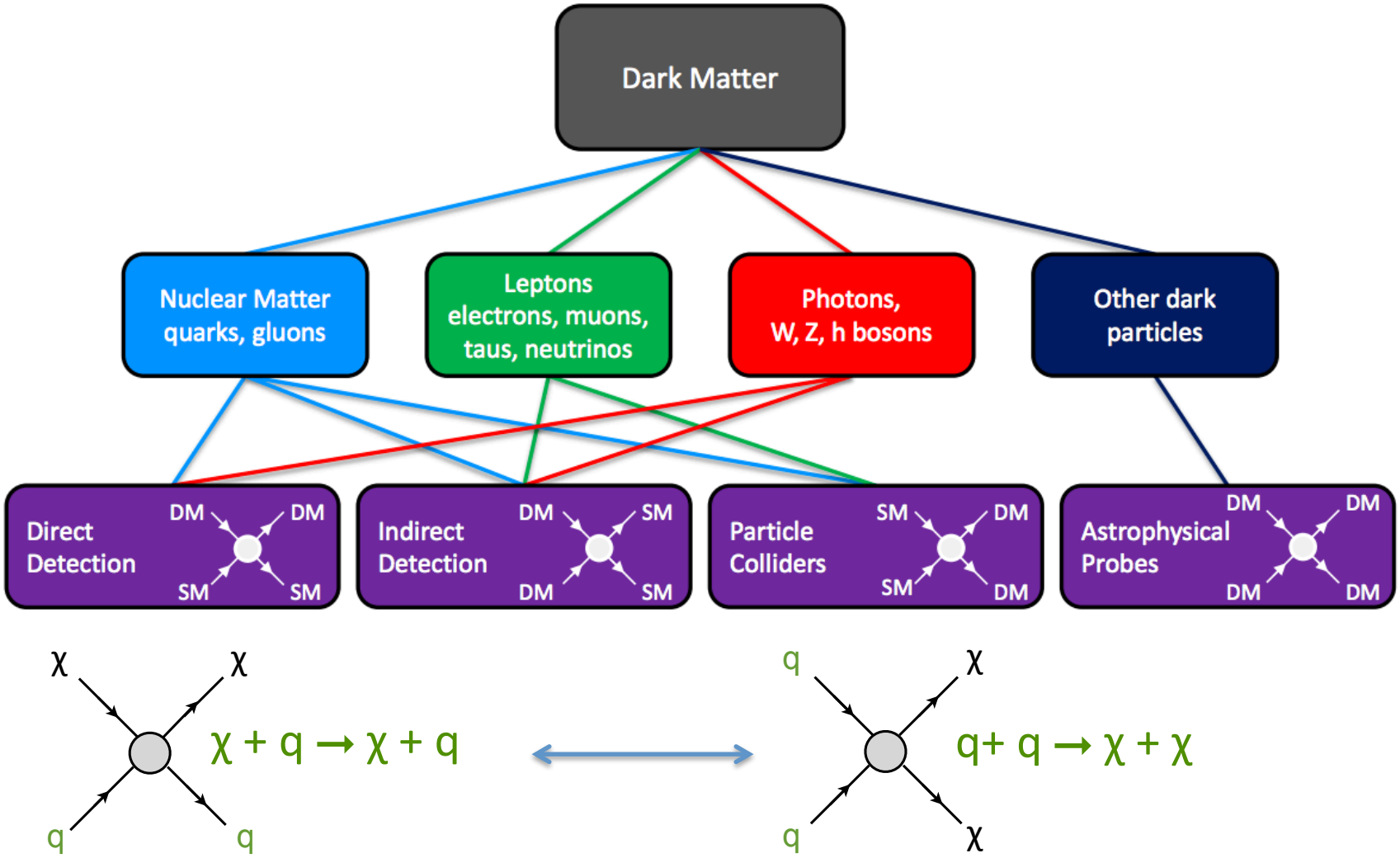
Sandro De Cecco

Goals of this brainstorming

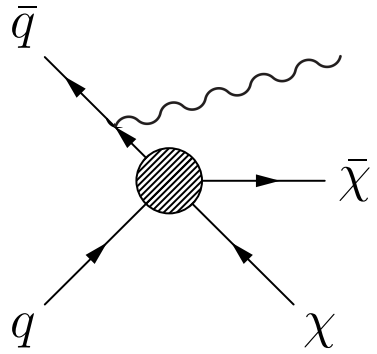
- LPNHE is not (yet) involved in direct search for dark matter but we feel it is important to understand if we have the will/forces to enter in this relevant domain for HEP physics in the next decade.
- DM direct search fits well between current projects (**LHC, Auger, T2K**, …) and (very) future ones like : **HL-LHC – LSST – ILC – LBNF** …

- We started an overview of the current/future projects which could match our lab skills and expertise in detector R&D.
- We feel constructive/stimulating to discuss this lab wide.
- This first meeting was not a comprehensive panorama but a good starting point to keep going in our collective reflection.
- A good timeline would be to produce roadmap for the end of the year.
- **@ today's meeting :** updated reviews and ongoing discussions on the options already discussed :
  - Ship : Heavy Neutral Lepton search at SPS
  - HPS : Heavy Photon searches at beam dumps
  - CCD : Low mass Wimp & axionic DM search
  - Noble gas TPC :

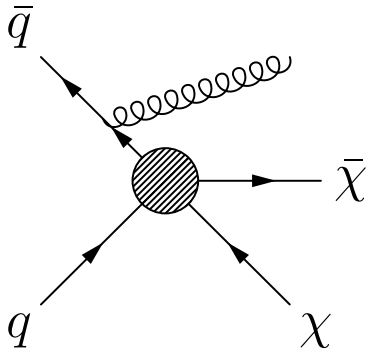
DM searches complementarities



Dark Matter searches at LHC



Monophoton + MET



Monojet + MET

→ Missing Transverse Energy
+ mono-everything (W,Z, …)

→ translate search limit into x-sec with Effective Field Theory

→ assume mediator mass M large (contact interaction)

$$\sigma(pp \to \bar{\chi}\chi + X) \sim \frac{g_q^2 g_\chi^2}{(q^2 - M^2)^2 + \Gamma^2/4} E^2 \approx \Lambda^{-4} E^2 \qquad \Lambda = M/\sqrt{g_\chi g_q} \qquad \mu = \frac{m_\chi m_p}{m_\chi + m_p}$$

develop in terms of operator expansion

$$\mathcal{O}_V = \frac{(\bar{\chi}\gamma_\mu \chi)(\bar{q}\gamma^\mu q)}{\Lambda^2}$$

vector --> spin independent (SI)

$$\mathcal{O}_{AV} = \frac{(\bar{\chi}\gamma_\mu \gamma_5 \chi)(\bar{q}\gamma^\mu \gamma_5 q)}{\Lambda^2}$$

axial-vector --> spin-dependent (SD)

$$\mathcal{L} = \mathcal{L}_{SM} + i\bar{X}\gamma^\mu \partial_\mu X - M_X \bar{X} X + \sum_q \sum_{i,j} \frac{G_{qij}}{\sqrt{2}} \left[\bar{X}\Gamma_i^X X\right]\left[\bar{q}\Gamma_q^j q\right]$$

Dark Matter searches at LHC

Name	Type	G_χ	Γ^χ	Γ^q
M1	qq	$m_q/2M_*^3$	1	1
M2	qq	$im_q/2M_*^3$	γ_5	1
M3	qq	$im_q/2M_*^3$	1	γ_5
M4	qq	$m_q/2M_*^3$	γ_5	γ_5
M5	qq	$1/2M_*^2$	$\gamma_5\gamma_\mu$	γ^μ
M6	qq	$1/2M_*^2$	$\gamma_5\gamma_\mu$	$\gamma_5\gamma^\mu$
M7	GG	$\alpha_s/8M_*^3$	1	-
M8	GG	$i\alpha_s/8M_*^3$	γ_5	-
M9	$G\tilde{G}$	$\alpha_s/8M_*^3$	1	-
M10	$G\tilde{G}$	$i\alpha_s/8M_*^3$	γ_5	-

Majorana WIMP

R1	$\chi^2\bar{q}q$	$m_q/2M_*^2$
R2	$\chi^2\bar{q}\gamma^5 q$	$im_q/2M_*^2$
R3	$\chi^2 G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/8M_*^2$
R4	$\chi^2 G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/8M_*^2$

C1	$\chi^\dagger\chi\bar{q}q$	m_q/M_*^2
C2	$\chi^\dagger\chi\bar{q}\gamma^5 q$	im_q/M_*^2
C3	$\chi^\dagger\partial_\mu\chi\bar{q}\gamma^\mu q$	$1/M_*^2$
C4	$\chi^\dagger\partial_\mu\chi\bar{q}\gamma^\mu\gamma^5 q$	$1/M_*^2$
C5	$\chi^\dagger\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^2$
C6	$\chi^\dagger\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^2$

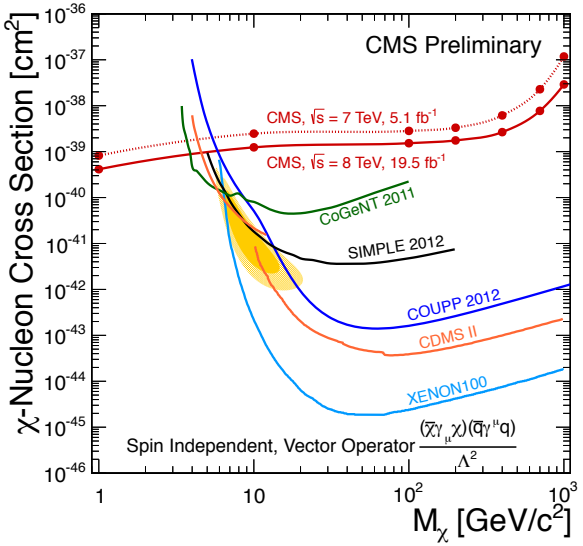
Spin zero WIMPs

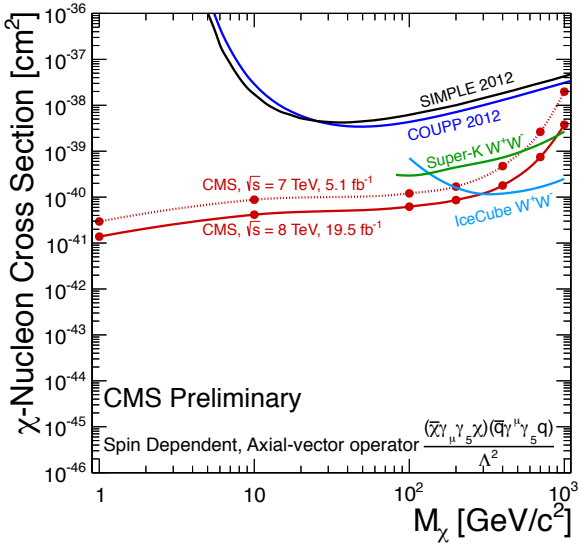
Name	Operator	Coefficient
D1	$\bar{\chi}\chi\bar{q}q$	m_q/M_*^3
D2	$\bar{\chi}\gamma^5\chi\bar{q}q$	im_q/M_*^3
D3	$\bar{\chi}\chi\bar{q}\gamma^5 q$	im_q/M_*^3
D4	$\bar{\chi}\gamma^5\chi\bar{q}\gamma^5 q$	m_q/M_*^3
D5	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D6	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D7	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D8	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D9	$\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$	$1/M_*^2$
D10	$\bar{\chi}\sigma_{\mu\nu}\gamma^5\chi\bar{q}\sigma_{\mu\nu}q$	i/M_*^2
D11	$\bar{\chi}\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^3$
D12	$\bar{\chi}\gamma^5\chi G_{\mu\nu}G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D13	$\bar{\chi}\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^3$
D14	$\bar{\chi}\gamma^5\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$\alpha_s/4M_*^3$
D15	$\bar{\chi}\sigma^{\mu\nu}\chi F_{\mu\nu}$	M
D16	$\bar{\chi}\sigma_{\mu\nu}\gamma^5\chi F_{\mu\nu}$	D

Dirac WIMPs

- model independent approach but validity limitations
- test only one interaction at a time (D5, D8 …)

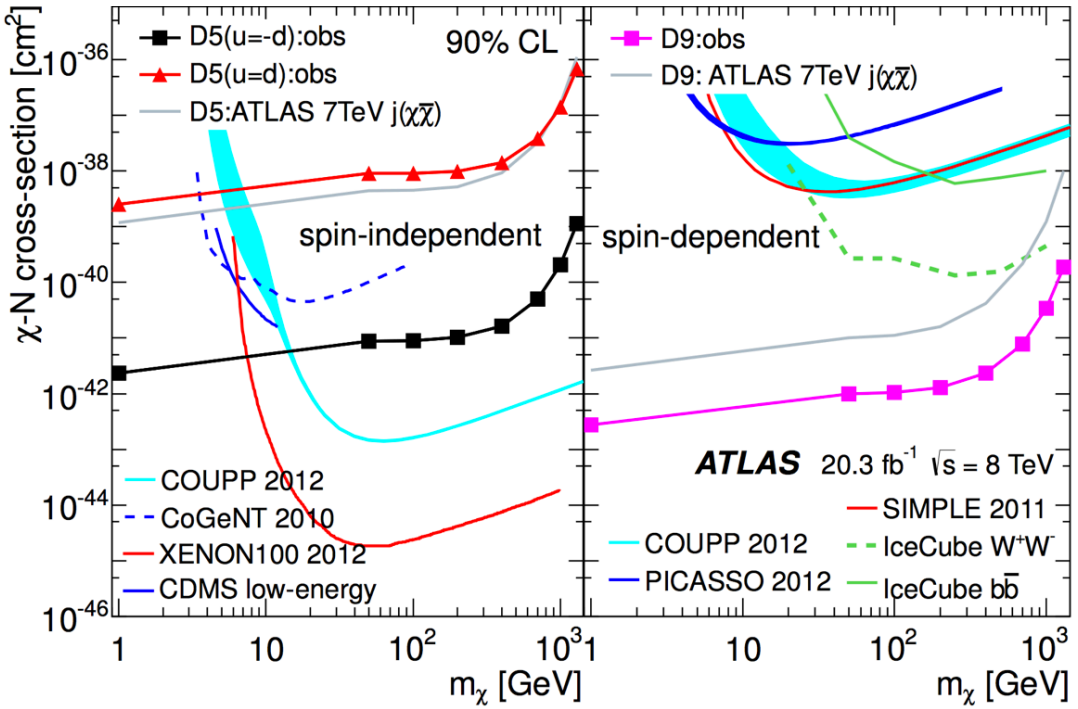
Dark Matter searches at LHC





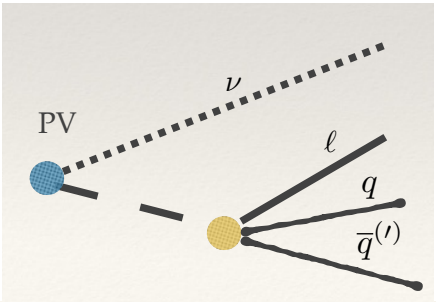
mono-jets

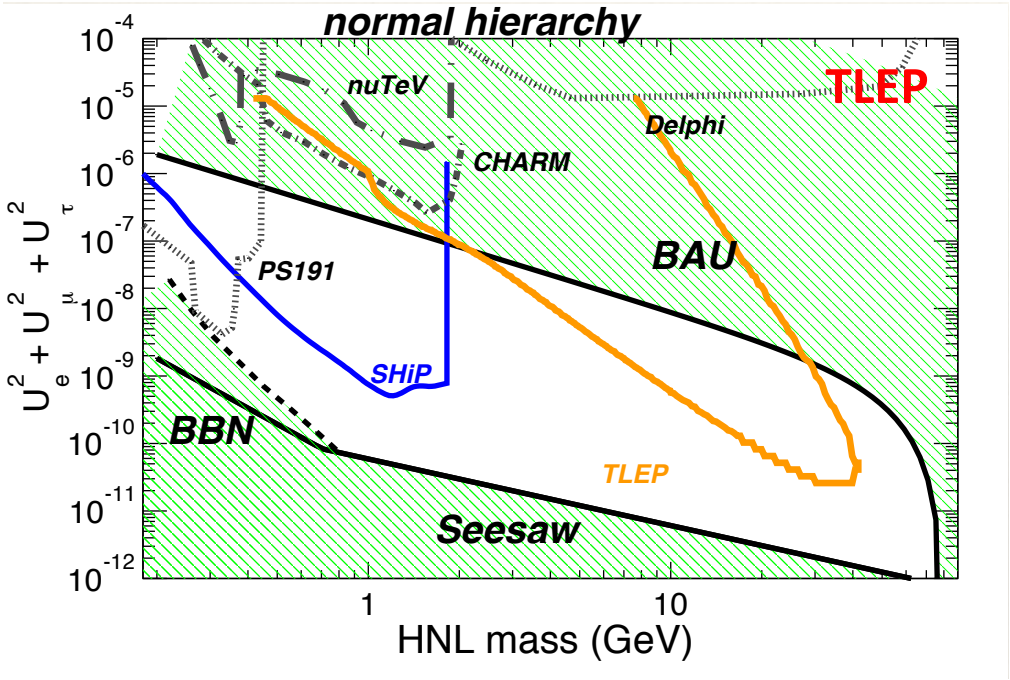
mono-W and
mono-Z
with W/Z → jj

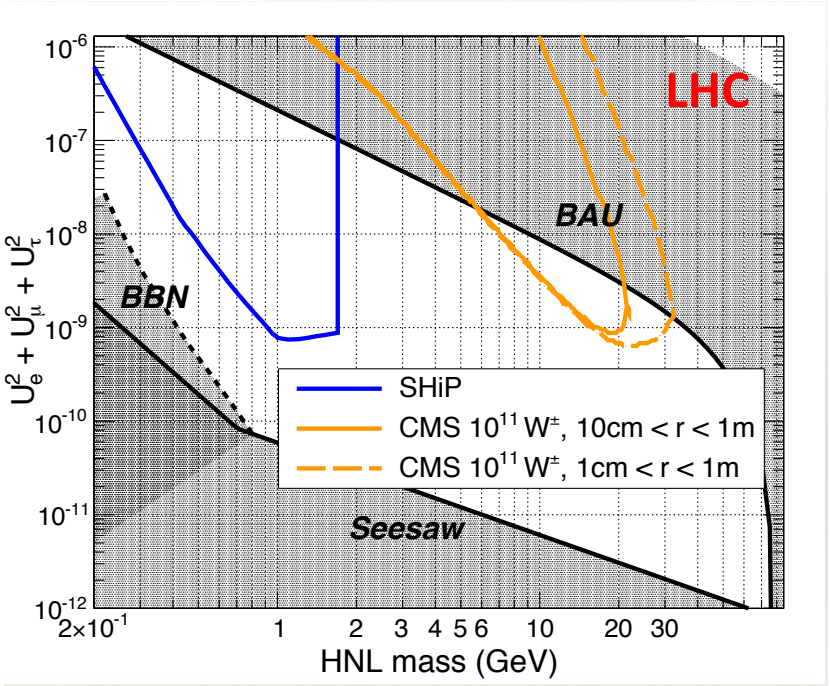


complementarities, another example : Heavy Leptons at LHC and e^+e^- colliders

N produced through Z→νν with a ν mixing with the sterile







Assuming zero background in the region 10cm and 1m with 10^{12} Z^0

from N. Serra talk at TLEP workshop last week at LPNHE

DM @ LPNHE brainstorming 03/11 agenda

Dark Matter @ LPNHE - 2nd brainstorming meeting

chaired by Sandro De Cecco (University of Paris VI and VII - LPNHE)

Monday, 3 November 2014 from **09:30** to **13:30** (Europe/Paris)
at **LPNHE (Salle des Séminaires (1222-RC/SB-08))**

Description Second brainstorming meeting at LPNHE on Dark Matter direct detection experiments.
Review of the current and future projects. Discussion on plans and next steps in view of LPNHE involvement.

Monday, 3 November 2014

10:00 - 10:15	Introduction *15'*	Speaker: Sandro De Cecco (University of Paris VI and VII - LPNHE)
10:15 - 10:55	Update on SHIP experiment *40'*	Speaker: Prof. Jacques Chauveau (LPNHE Paris 6-7)
10:55 - 11:25	Heavy photons search experiments *30'*	Speaker: Giovanni Marchiori (LPNHE Paris)
11:25 - 12:05	Update on CCD based experiments *40'*	Speaker: Dr. antoine letessier-selvon (LPNHE)
12:05 - 12:45	Update on noble gas experiments *40'*	Speaker: Dr. Claudio Giganti (LPNHE IN2P3/CNRS)
12:45 - 13:15	Wrap-up and discussion *30'*	Speaker: All

Backup

DM @ LPNHE brainstorming agenda

Monday, 22 September 2014

11:00 - 12:45 Review of DM direct detection experiments - part I

- 11:00 **Introduction** *10'*
  Speaker: Sandro De Cecco (University of Paris VI and VII - LPNHE)
- 11:10 **Search for WIMPs with Liquid Argon: the Darkside experiment** *35'*
  Speaker: Dr. Claudio Giganti (LPNHE IN2P3/CNRS)
- 11:45 **The Ship experiment** *35'*
  Speaker: Prof. Jacques Chauveau (LPNHE Paris 6-7)

12:45 - 14:00 Déjeuner

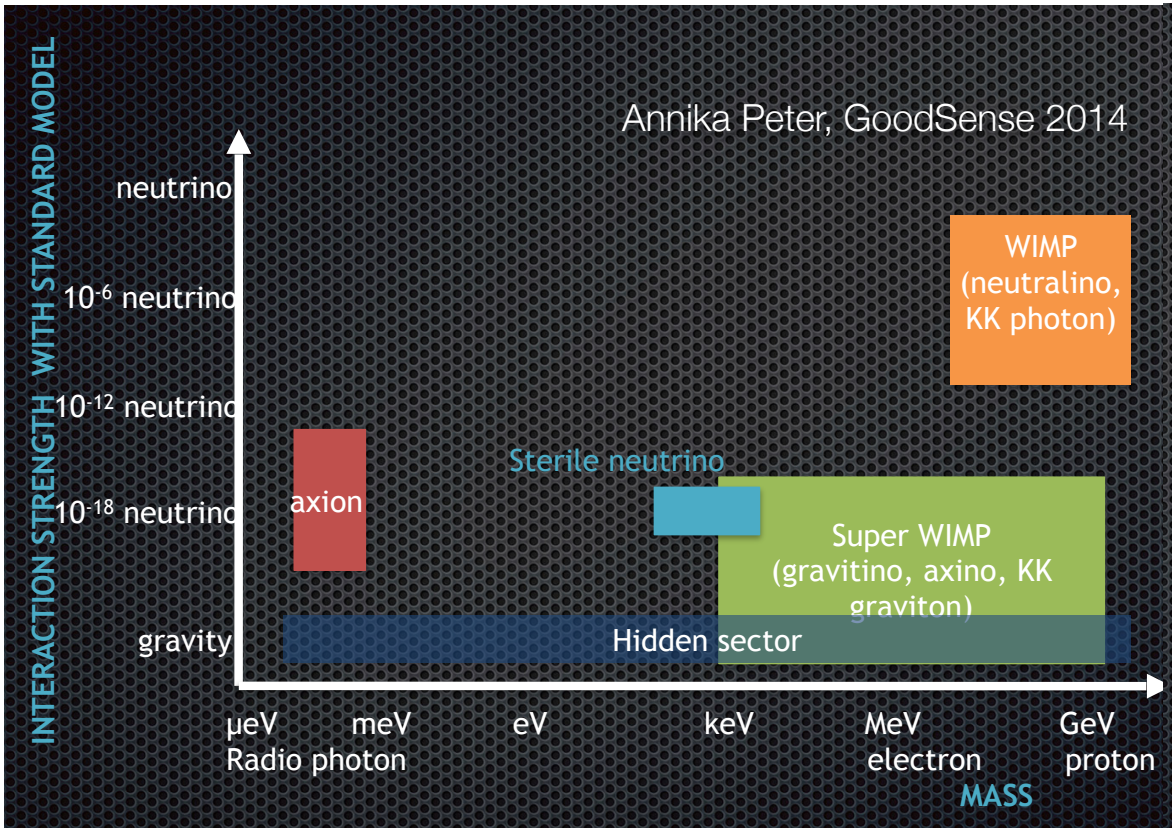
13:55 - 15:30 Review of DM direct detection experiments - part II

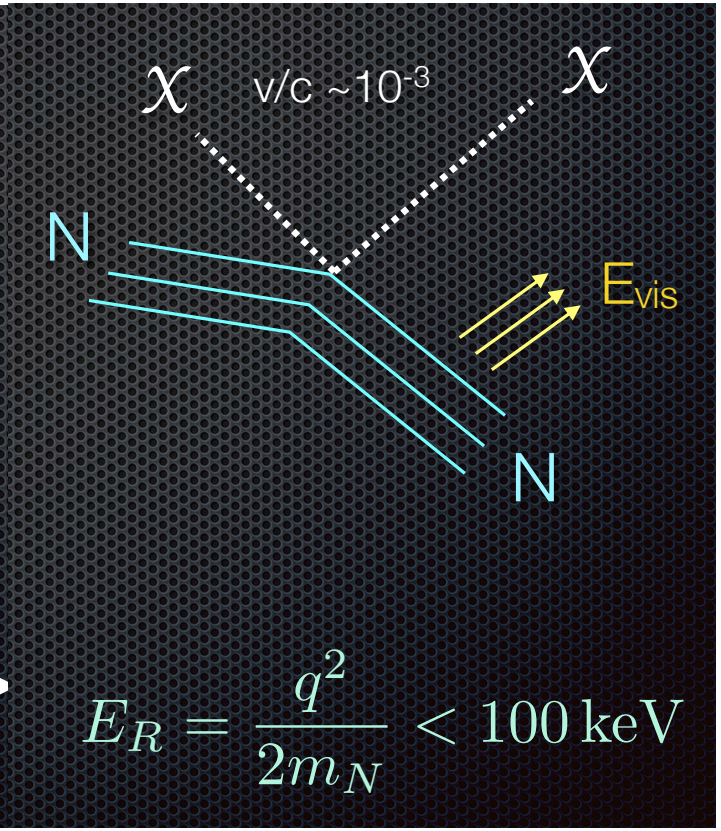
- 14:00 **The dark side messengers** *20'*
  Speaker: Witek Krasny (LPNHE)
- 14:20 **PQ axions searches** *20'*
  Speaker: Dr. antoine letessier-selvon (LPNHE)
- 14:40 **CCD based DM direct detection experiments** *35'*
  Speaker: Xavier Bertou (Centro Atomico Bariloche)

15:30 - 16:00 Final discussion and future plans @ LPNHE

- 15:30 **Discussion and plans** *30'*

not only WIMPs DM candidates

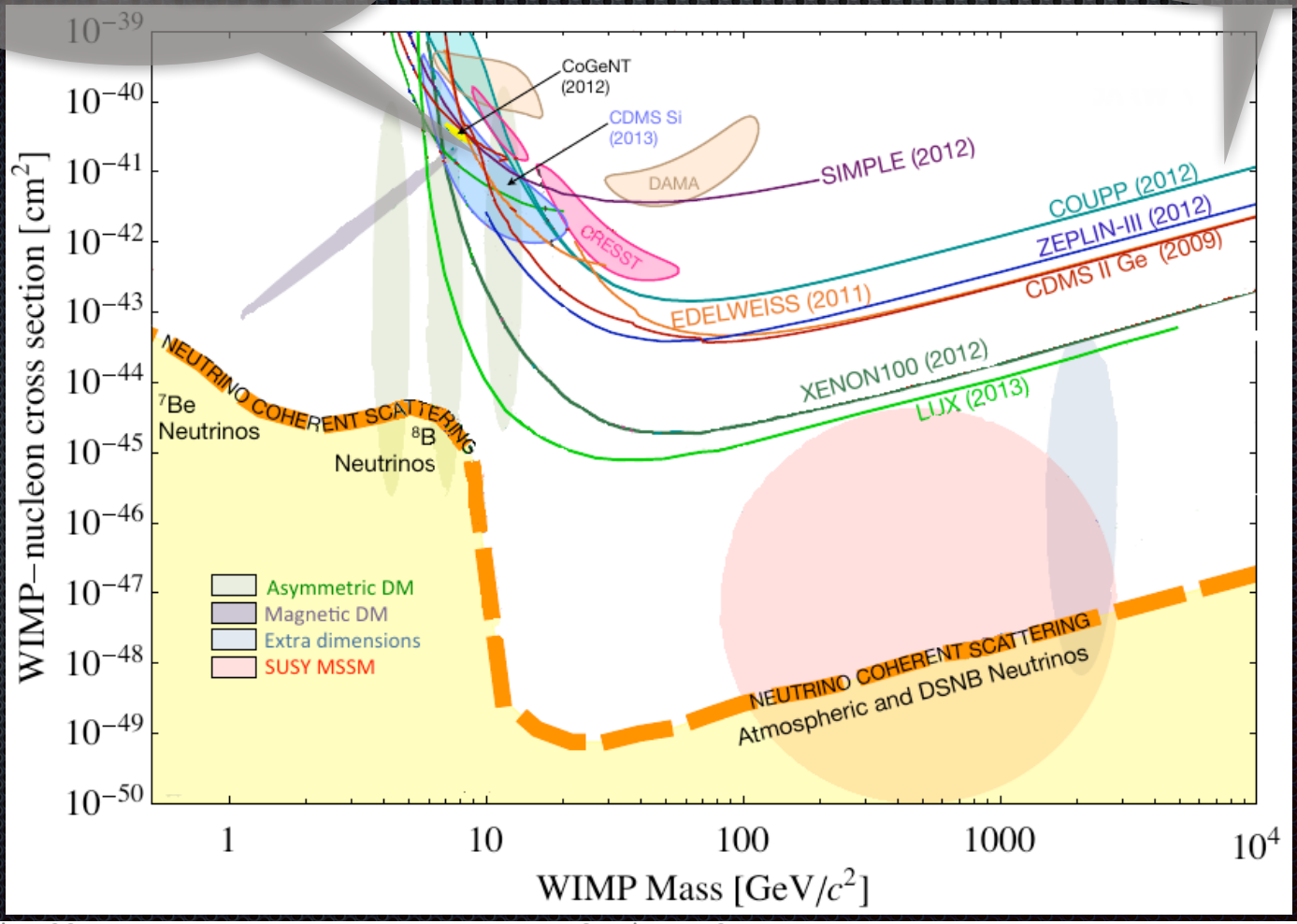




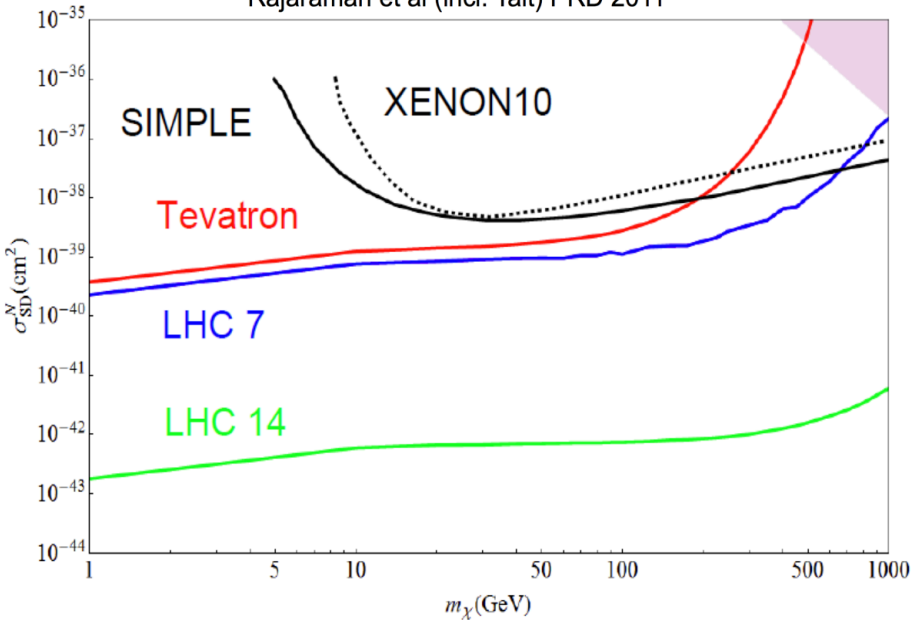
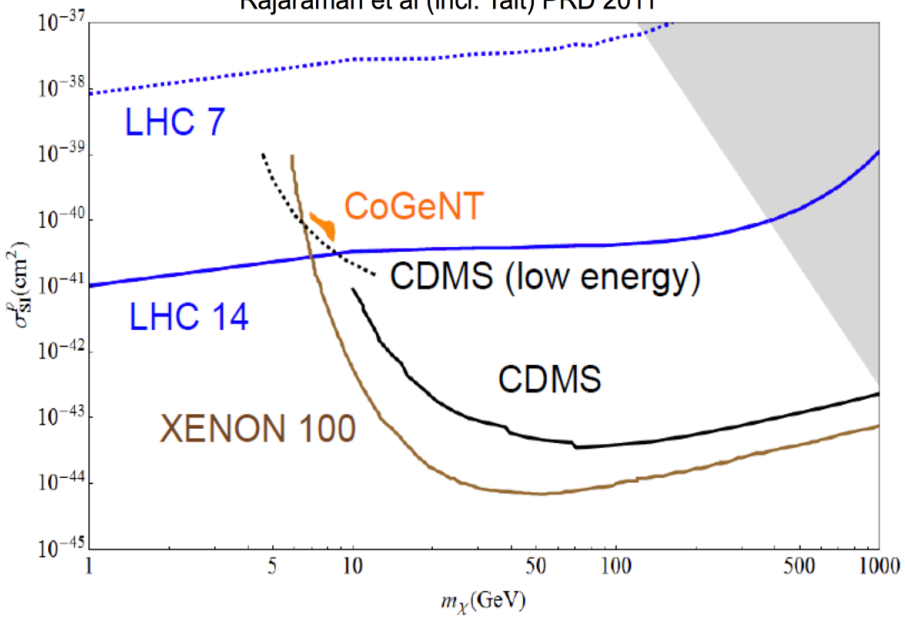
The WIMP landscape in 2014

"Anomalies" at low WIMP masses

Sensitivity to masses up to 10 TeV and above!



Rajaraman et al (incl. Tait) PRD 2011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