

Pheno and Theory in Belgium

RECFA meeting 2017

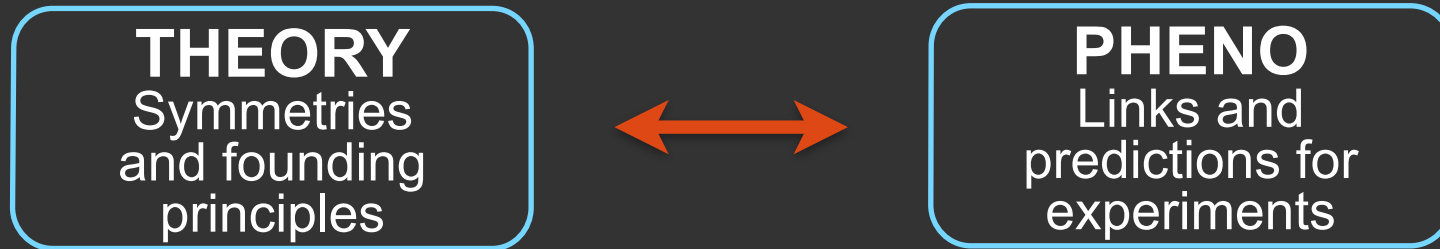
Laura Lopez Honorez - Alberto Mariotti

Brussels Universities

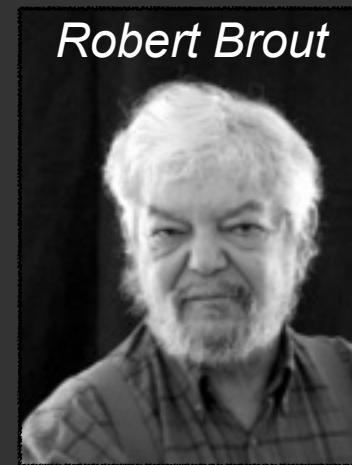
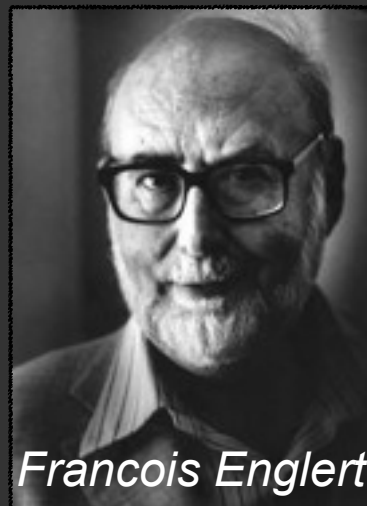
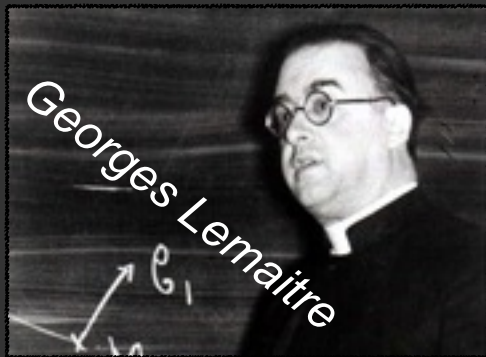
on behalf of the TH-PH Belgian groups

HEP: Theory and Pheno

Study of fundamental interactions
and constituents of matter



Precursors of HEP-TH and HEP-PH Belgian tradition



TH-PH.be Community

35 Staff Members

	TH	PH
ULB	7	5
VUB	2	1
KUL	4	-
UCL	2	5
UMons	2	-
ULG	-	3
UNamur	-	2
UGhent	2	-
Total	19	16



PostDocs: ~ 45
PhD students: ~ 50

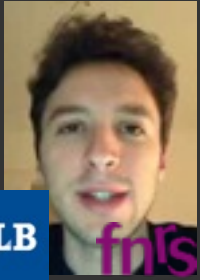
Hired Internationally with national and international fundings

New Generation

New Staff hired after 2010

THEORY

A. Collinucci



G. Compere



S. Detournay



PHENO

A. Mariotti



L. Lopez Honorez



T. Hertog



T. VanRiet



N. Bobev



C. Duhr



M. Drewes



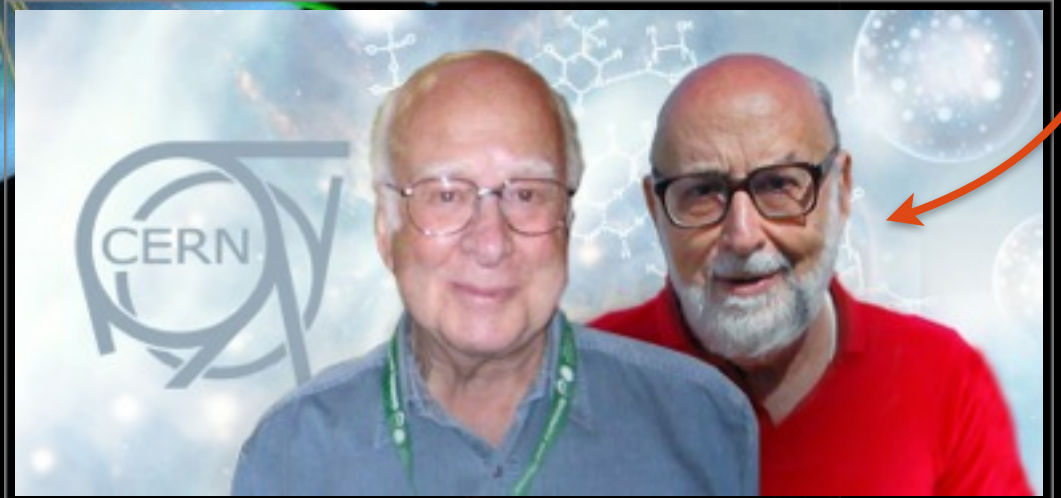
C. Arina

*Increase of ~15% of the staff member community
... but barely compensate retirements in near future!*

Nobel Prize 2013

2012: Discovery of the BEH boson at the Large Hadron Collider at CERN

*Englert Higgs
Nobel prize in
physics 2013*



Awards and fund raising

National and international successful fund raising



Solvay
Institutes



IAP NETWORK
...for last 15 years ...
Coordinator: J.M. Frere

JOINT
INITIATIVE!

fnrs

FREEDOM TO RESEARCH

- Research Associate
- IISN, CDR, PDR
- PostDoc Fellowship
- PhD (FRIA & Aspirant)

Crucial
support
to our
research in
Belgium



- Odysseus grant
- Research Projects
- PostDoc Mandate
- PhD Mandate



ARC Projects



M. Henneaux (2),
T. Hertog, C. Duhr
G. Compere

University fundings:
• KUL C1 project: e.g.
Horizons in HEP
• VUB SRP: e.g.
HEP@VUB

Interest and expertise

Theory

KU LEUVEN

KUL: holography, strong coupling, black holes, gravitational waves and LISA, supergravity, string theory, quantum cosmology, branes

UCL

Université
catholique
de Louvain

- **UCL:** scattering amplitudes, precision computations in QCD and SM, mathematical structure of gauge theory scattering amplitudes

ULB

- **ULB:** Gauge theories, Supersymmetric quantum field theory, Instantons, strong coupling, General relativity and supergravity, Black holes, Quantum gravity, QFT in curved spacetime, 3-D gravity, Conformal field theory, Entanglement entropy, Cosmology, String theory, D-branes, M-theory, F-theory, Dualities, Holography, Gauge/gravity duality



GHENT
UNIVERSITY

- **Ughent:** string theory, gauge/gravity duality, holography

UMONS

- **Umons:** Supergravity, string theory, higher-spin gauge theories, gravitation, gauge gravities and extensions in higher-dimensions, numerical solutions

VUB

- **VUB:** Geometric aspects of string theory, holography, supergravity, M-Theory, F-Theory, quantum cosmology, branes, gauge/gravity duality, cosmology, non-local gravity, inflation

Interest and expertise

Pheno (HEP-PH & ASTRO-PH)

- **UCL:** perturbative QCD, BEH and top-quark phenomenology, dark matter, BSM, Madgraph, LHC, precision computations in QCD and the Standard Model, cosmology, neutrino physics, early universe, inflation, CMB and Planck, 21cm, gravitational waves, cosmo data analysis, Large scale structures, topological defects, early universe
- **ULB:** Leptogenesis, dark matter, BSM, cosmology, neutrino masses and magnetic moment, symmetry breaking, baryonic asymmetry, High energy cosmic rays and Telescope array, 21 cm, gravitational waves, extra dimensions, glueballs, modified gravity.
- **Ulg:** axions, dark matter, large scale structures, quasars, neutrinos, leptogenesis, LHC cross-sections, QCD and diffractive physics, BSM and Multi-BEH models
- **VUB:** Flavour, inflation, dark matter, BSM, LHC, naturalness, supersymmetry, top physics, gauge mediation, symmetry breaking
- **UNamur:** cosmology, relativistic gravitation, dark energy, modified gravity, numerical relativity, EUCLID: modeling of observables beyond LCDM, test of gravity, large scale structures



Interest and expertise

Many thanks to M. Tytgat for inspiration

Pheno

Symmetry
Breaking,
SM & BSM,
Unification

Dark matter,
neutrinos,
Cosmology,
early Universe

High energy
cosmic rays

Theory

String, SUSY
Holography,
Higher spins
Amplitudes

Gravity,
Cosmology,
Inflation

Black Holes
Gravit. waves

Interest and expertise

Many thanks to M. Tytgat for inspiration

Pheno

Symmetry
Breaking,
SM & BSM,
Unification



String, SUSY
Holography,
Higher spins
Amplitudes

Symmetries

Dark matter,
neutrinos,
Cosmology,
early Universe



Gravity,
Cosmology,
Inflation

Dark sector

High energy
cosmic rays



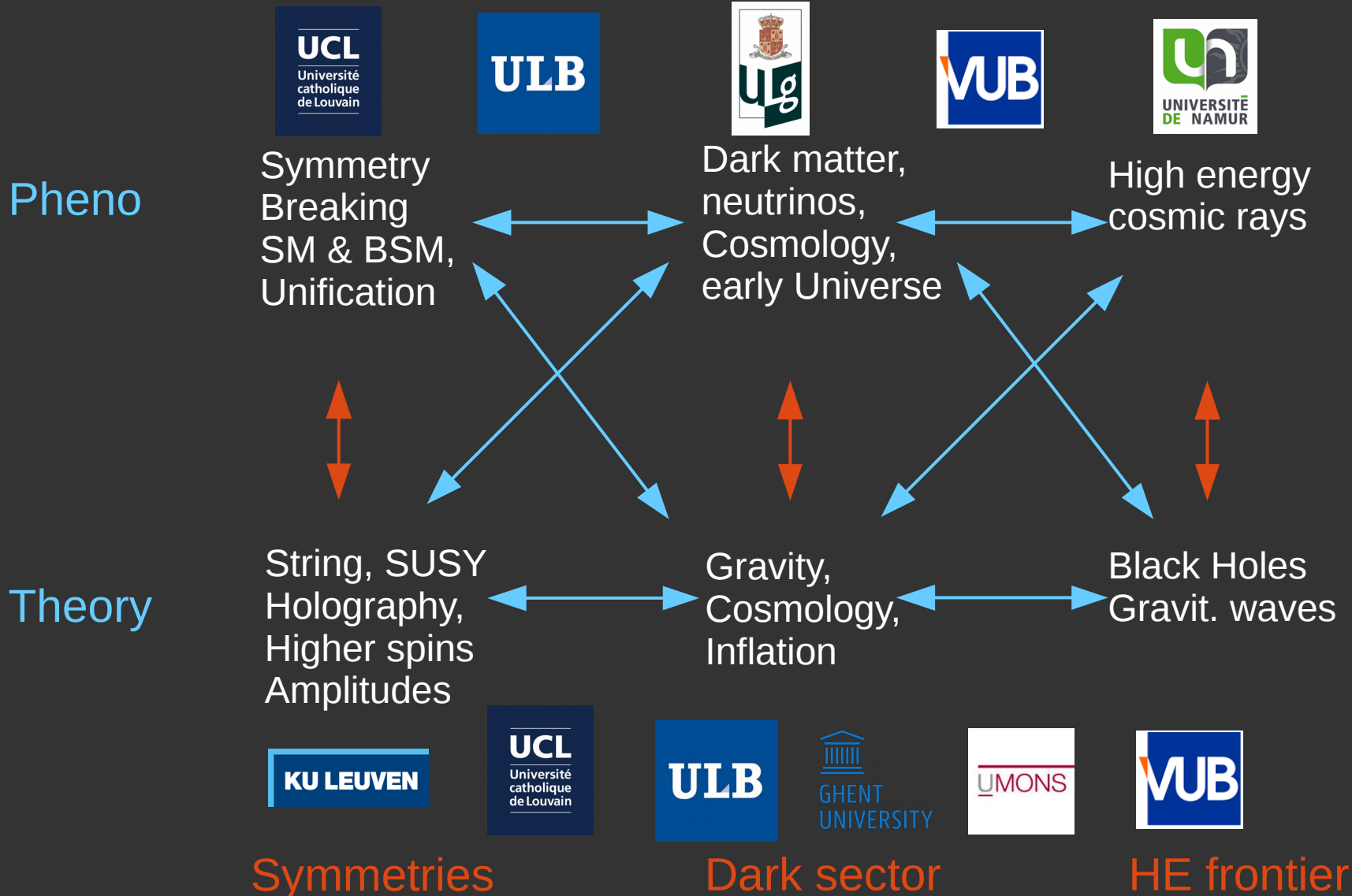
Black Holes
Gravit. waves

HE frontier

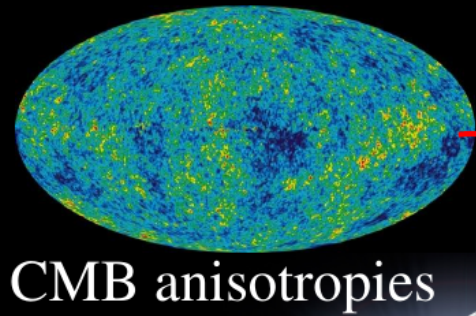
Theory

Interest and expertise

Many thanks to M. Tytgat for inspiration



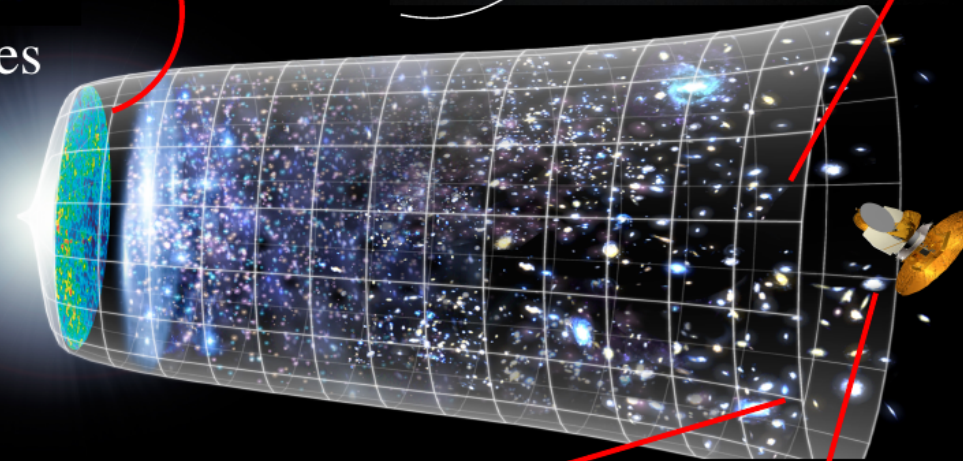
Example: Dark Sector



SNIa

Dark Energy

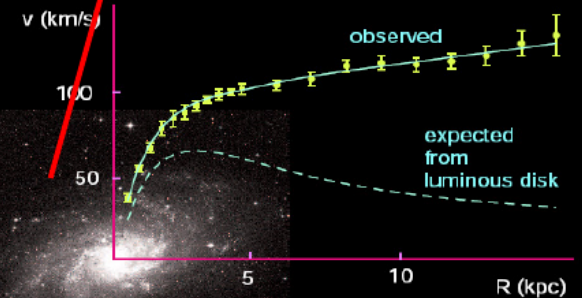
Accelerated expansion



Large Scale Structures (LSS)



Dark matter

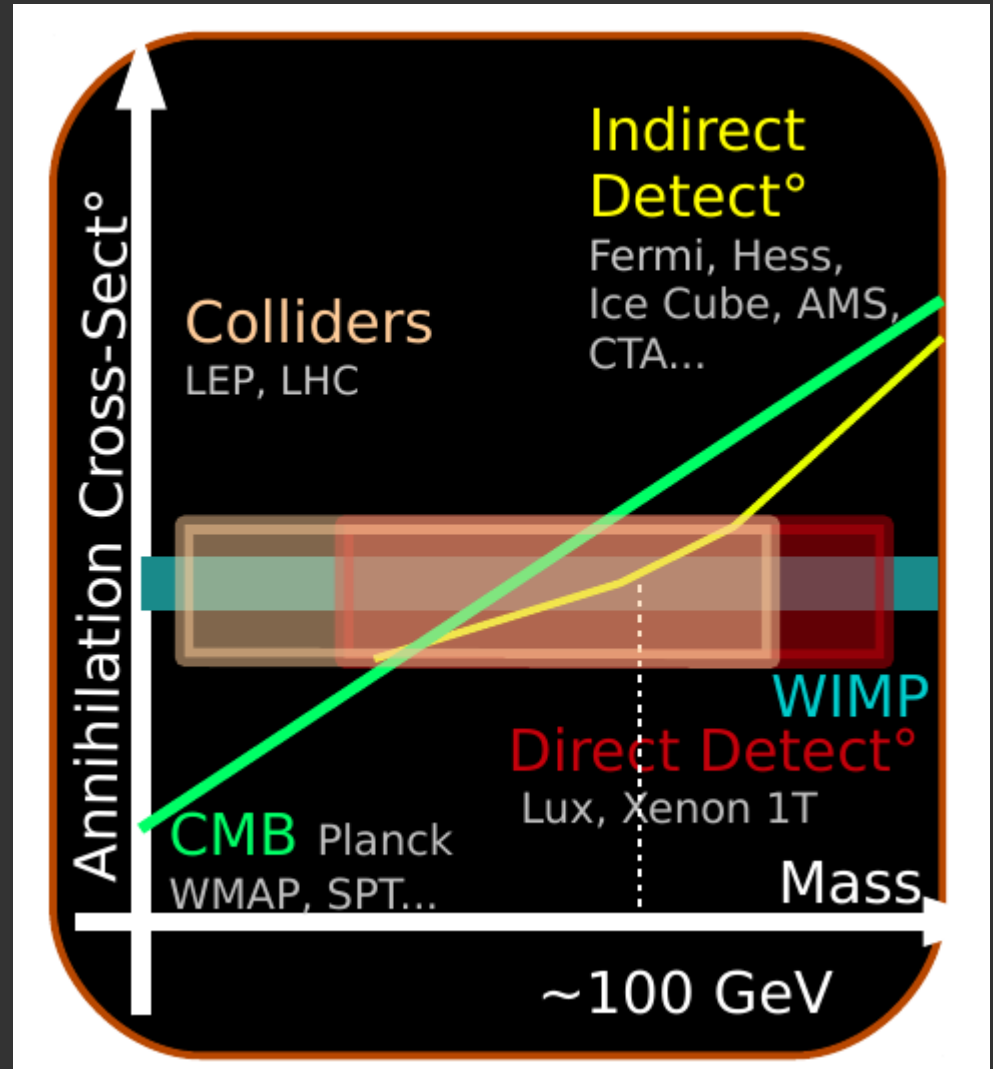
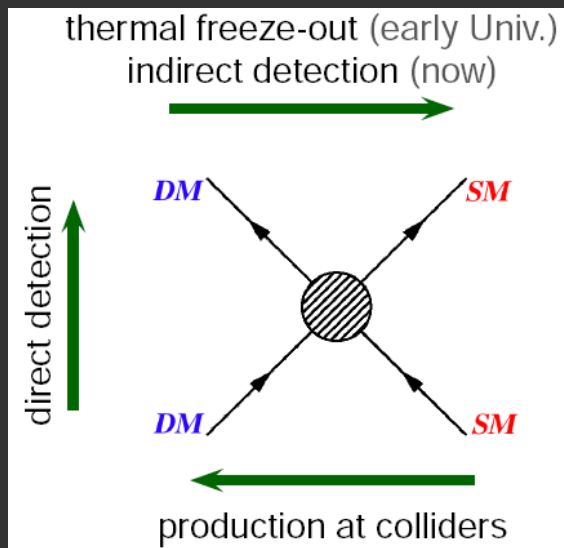


galaxy

M33 rotation curve
(fig. 1)

Dark Matter

Ordinary Matter

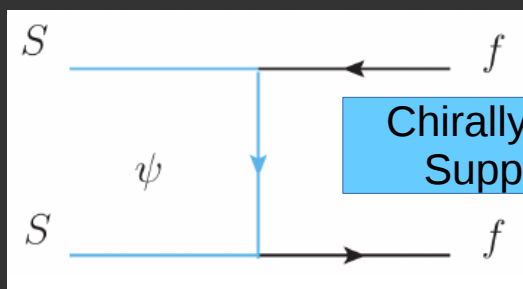


Scalar DM-light quarks interactions

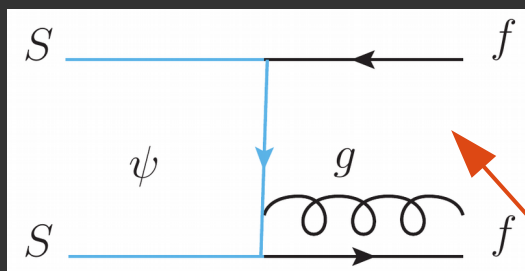
Giacchino, Ibarra, Lopez Honorez, Tytgat, Wild, JCAP 2016

DM = Real Scalar S

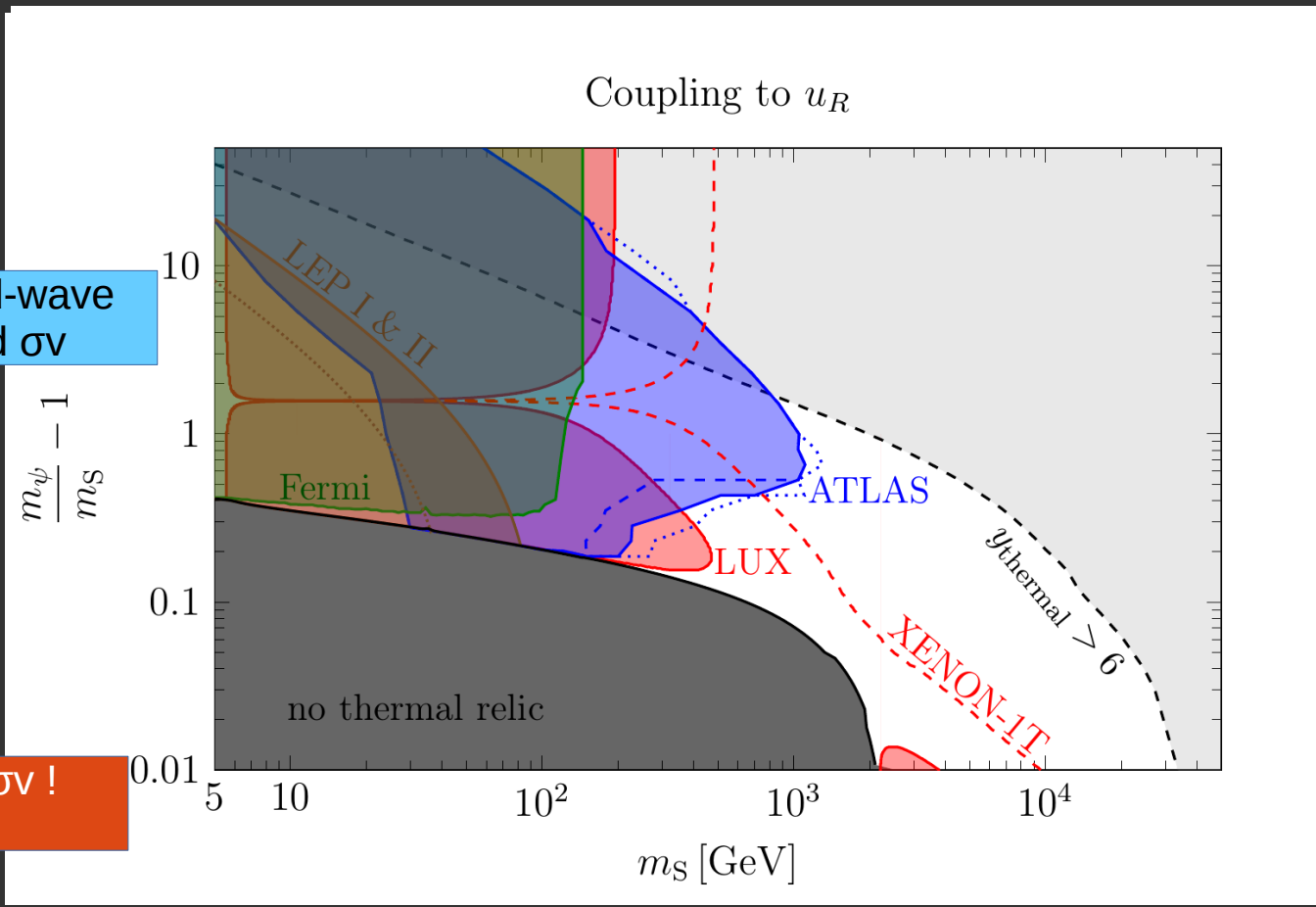
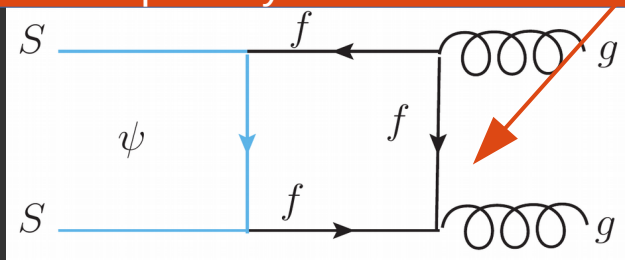
$$\mathcal{L} \supset y_l S \bar{\Psi} f_R + h.c..$$



Chirally and d-wave Suppressed σ



Can be the major contribs to total σ ! Especially for Indirect searches



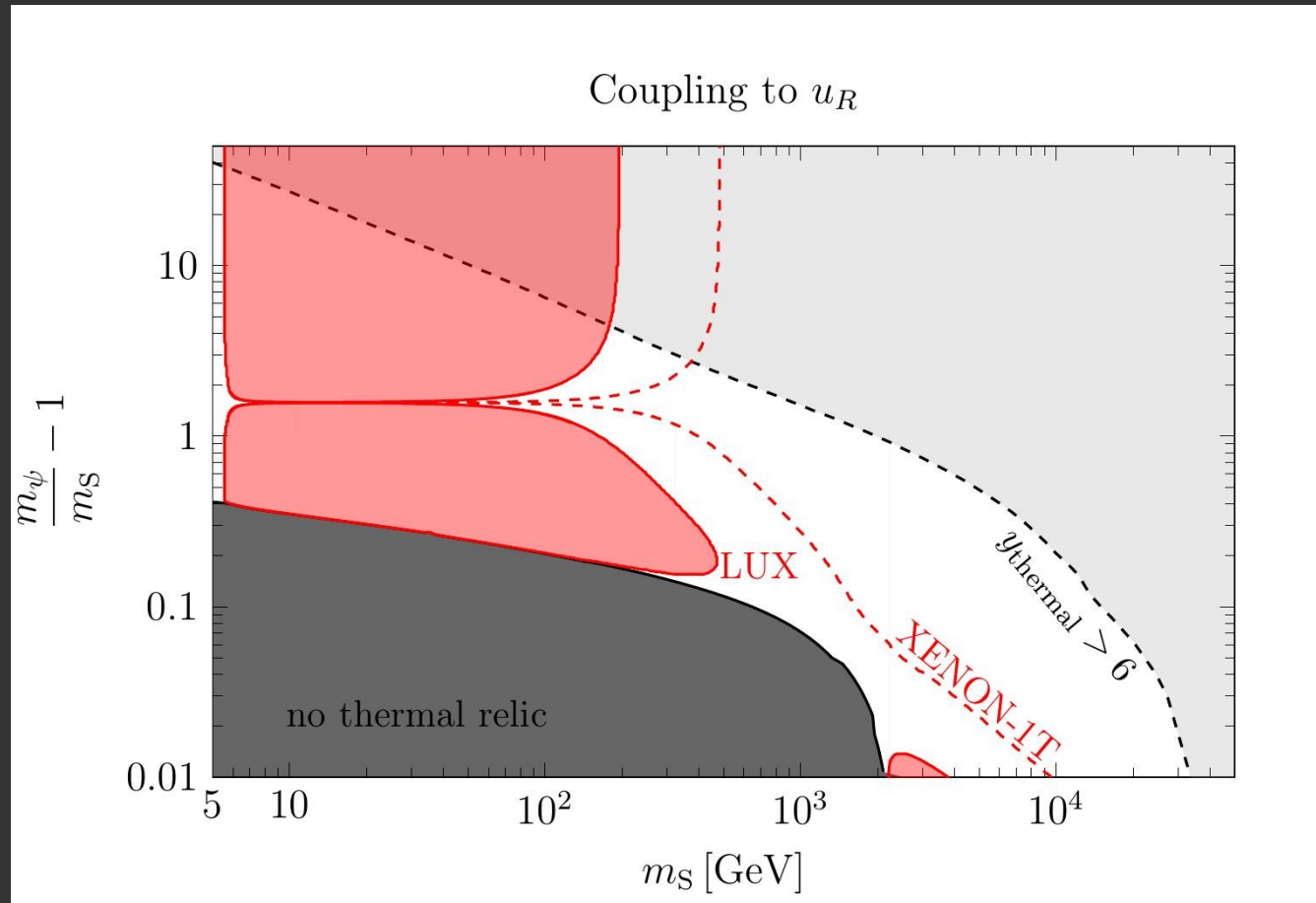
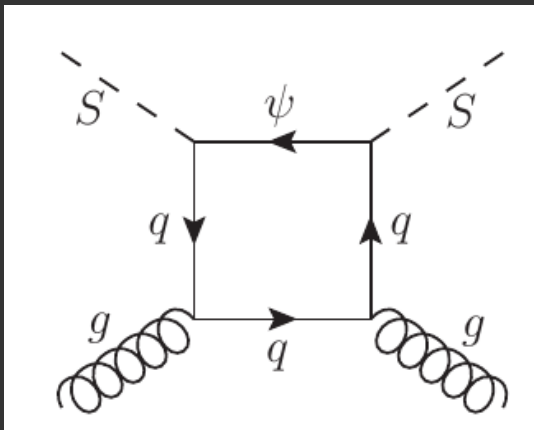
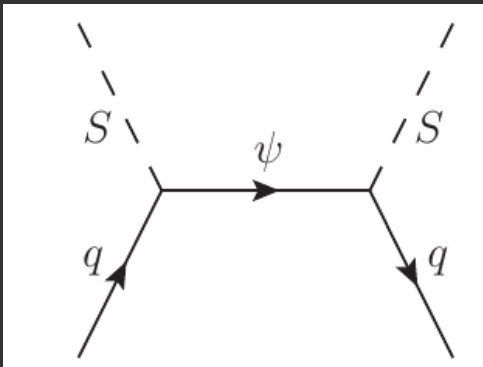
Scalar DM-light quarks interactions

Giacchino, Ibarra, Lopez Honorez, Tytgat, Wild, JCAP 2016

DM = Real Scalar S

$$\mathcal{L} \supset y_l S \bar{\Psi} f_R + h.c..$$

Direct detection



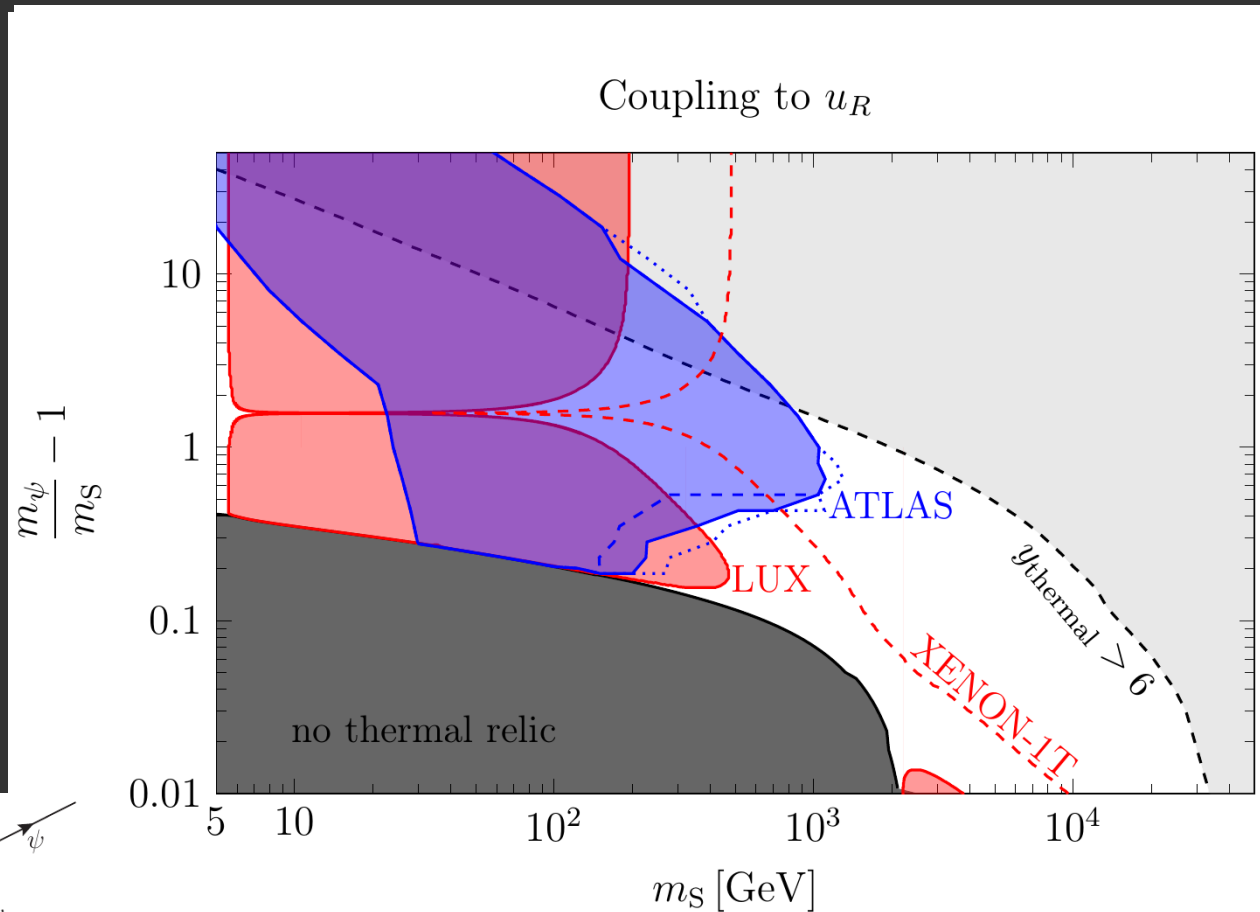
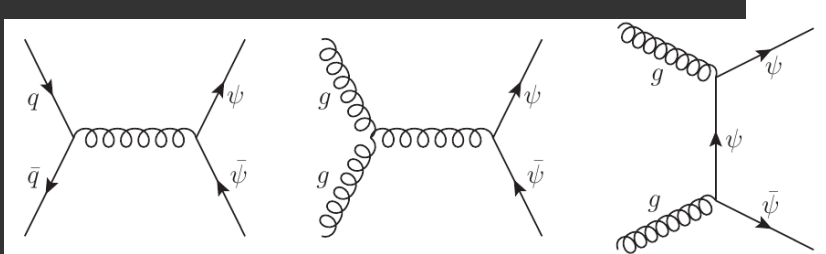
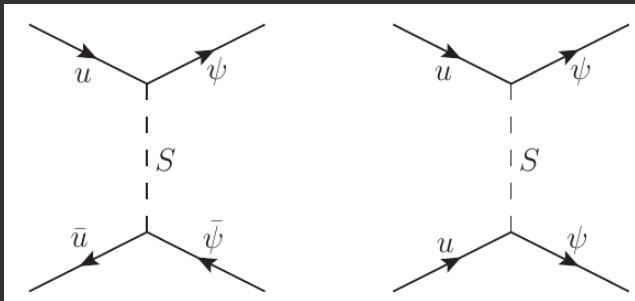
Scalar DM-light quarks interactions

Giacchino, Ibarra, Lopez Honorez, Tytgat, Wild, JCAP 2016

DM = Real Scalar S

$$\mathcal{L} \supset y_l S \bar{\Psi} f_R + h.c..$$

Collider Searches for mediator multi-j+ MET



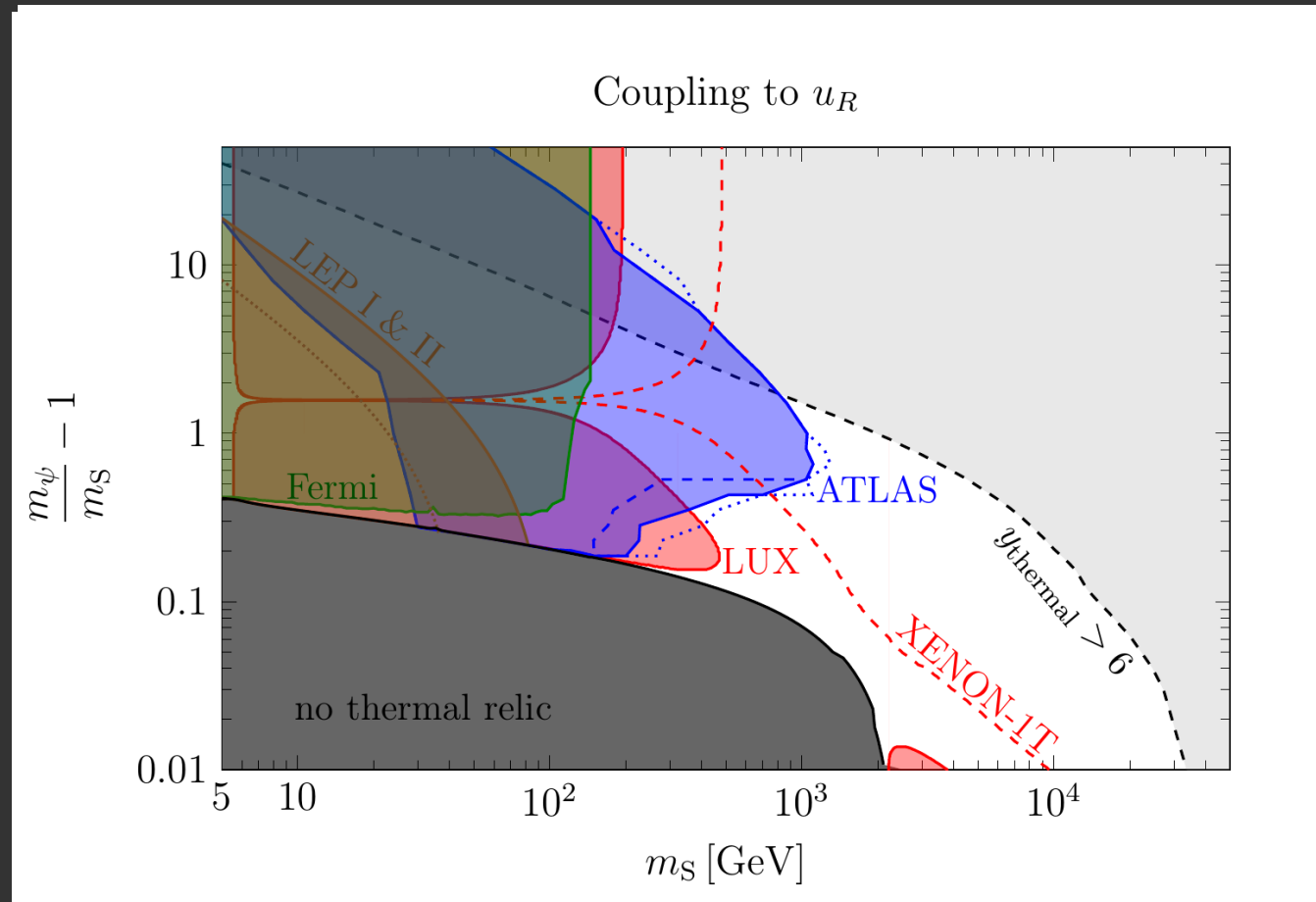
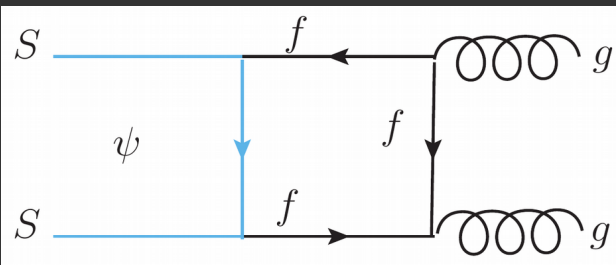
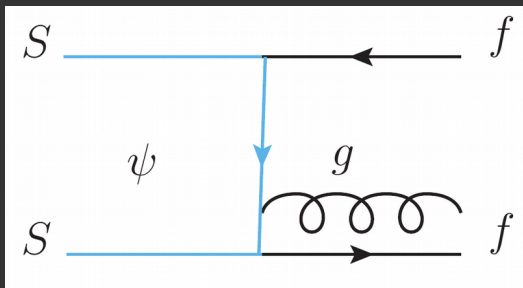
Scalar DM-light quarks interactions

Giacchino, Ibarra, Lopez Honorez, Tytgat, Wild, JCAP 2016

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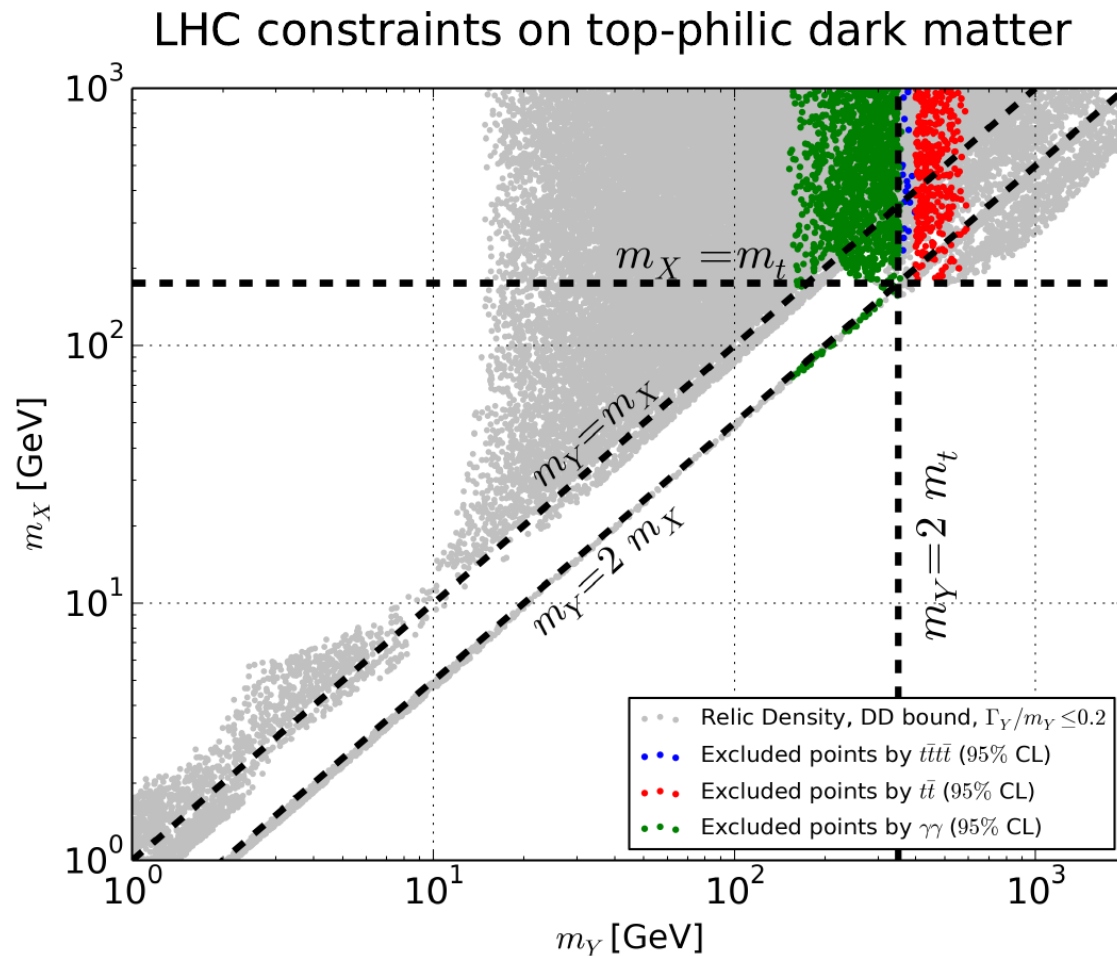
$$\mathcal{L} \supset y_l S \bar{\Psi} f_R + h.c..$$

Indirect detection



DM-top quarks interactions

Arina, Backović, Maltoni, Martini, Mawatari et al JHEP 2016



Simplified DM model
(assumed by LHC DM working group)

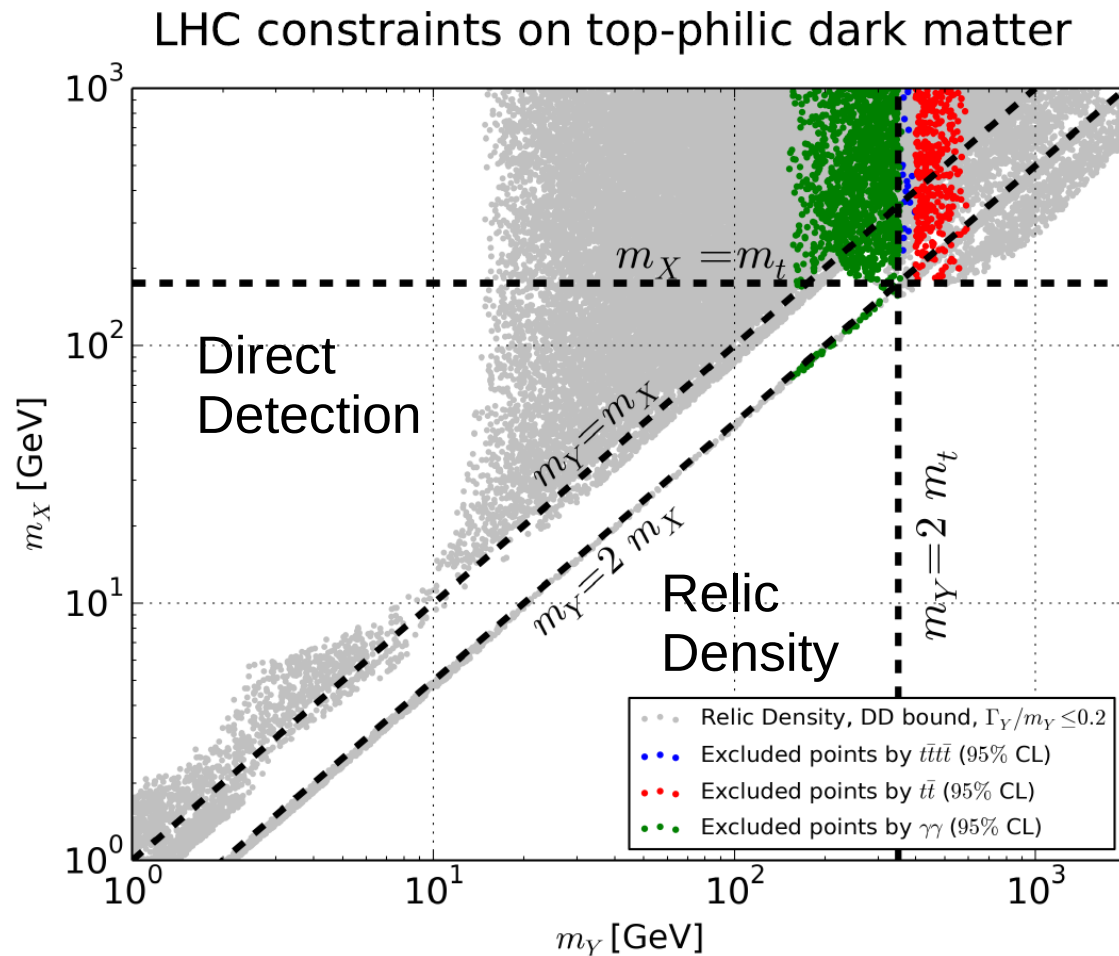
$$\mathcal{L} \propto \mathcal{L}_{\text{SM}} + g_X \bar{X} X Y + \frac{y^t}{\sqrt{2}} g_t \bar{t} t Y$$

$$y^t \sim 1$$

$$y^i \sim 0 \text{ for } i = u, d, s, c, b$$

DM-top quarks interactions

Arina, Backović, Maltoni, Martini, Mawatari et al JHEP 2016



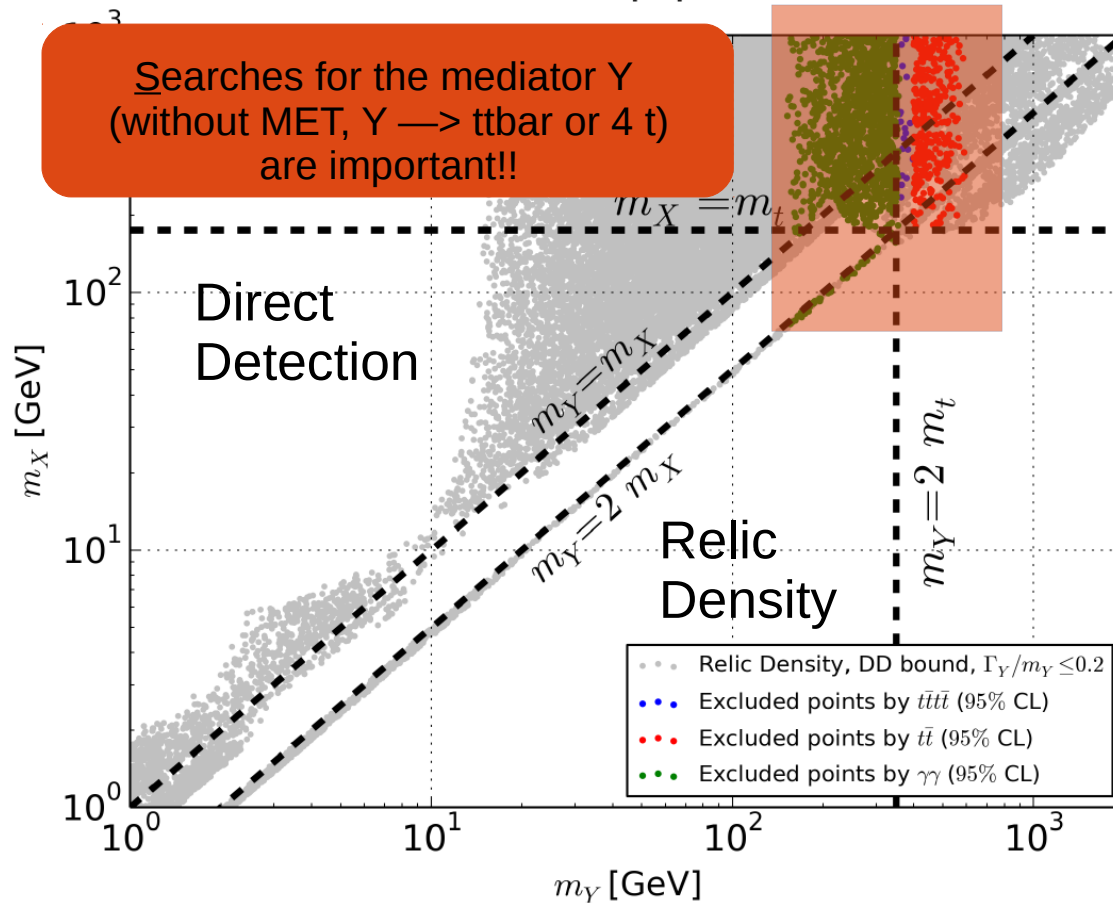
Cosmology	relic indirect		$m_X > m_t$	Planck, FermiLAT
			$m_X < m_t$	
Astrophysics			$m_X > m_Y$	
	direct		$m_X > 1 \text{ GeV}$	LUX, CDMSLite
Colliders	\cancel{E}_T		$m_Y > 2 m_X$	$+t\bar{t}$
			$m_Y > 2 m_X$	$+j, +Z, +h$
	no \cancel{E}_T		$m_Y > 2 m_t$	$4t$
			$m_Y > 2 m_t$	$t\bar{t}$
			$m_Y < 2 m_X, 2 m_t$	$jj, \gamma\gamma$

DM-top quarks interactions

Arina, Backović, Maltoni, Martini, Mawatari, Vryonidou et al JHEP 2016

LHC constraints on top-philic dark matter

Searches for the mediator Y
(without MET, $Y \rightarrow t\bar{t}$ or $4t$)
are important!!



Cosmology	relic indirect		$m_X > m_t$	Planck, FermiLAT
			$m_X < m_t$	
Astrophysics			$m_X > m_Y$	
	direct		$m_X > 1 \text{ GeV}$	LUX, CDMSLite
Colliders	\cancel{E}_T		$m_Y > 2m_X$	$+t\bar{t}$
			$m_Y > 2m_X$	$+j, +Z, +h$
	no \cancel{E}_T		$m_Y > 2m_t$	$4t$
			$m_Y > 2m_t$	$t\bar{t}$
			$m_Y < 2m_X, 2m_t$	$jj, \gamma\gamma$

DM and Flavour violating TOP

Simplified model

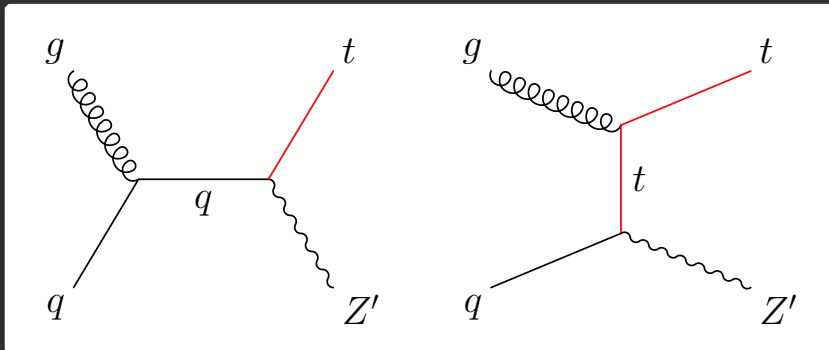
$$\mathcal{L}_{int} = g_\chi \bar{\chi} \gamma^\mu \chi Z'^\mu + (g_{13} \bar{u}_R \gamma_\mu t_R Z'^\mu + g_{23} \bar{c}_R \gamma_\mu t_R Z'^\mu + h.c.).$$

Top-Up DM

Top-Charm DM

Collider Signatures:
MONOTOP

Dark Matter
phenomenology:

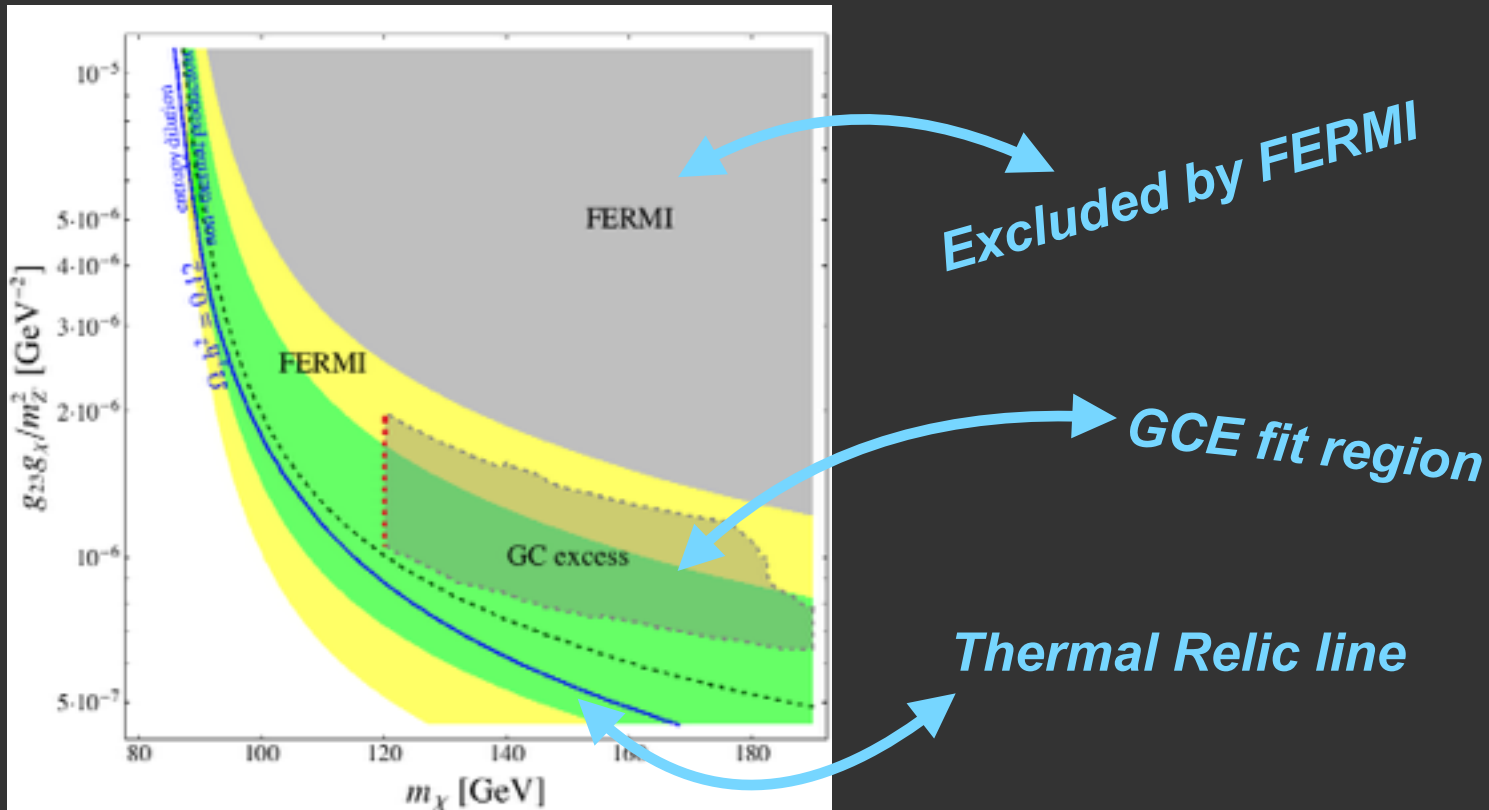


- ★ Relic Density (thermal WIMP)
- ★ Indirect Detection (can fit GCE)
- ★ Direct Detection (loop suppressed)

DM and Flavour violating TOP

$$\mathcal{L}_{int} = g_\chi \bar{\chi} \gamma^\mu \chi Z'^\mu + (g_{13} \bar{u}_R \gamma_\mu t_R Z'^\mu + g_{23} \bar{c}_R \gamma_\mu t_R Z'^\mu + h.c.).$$

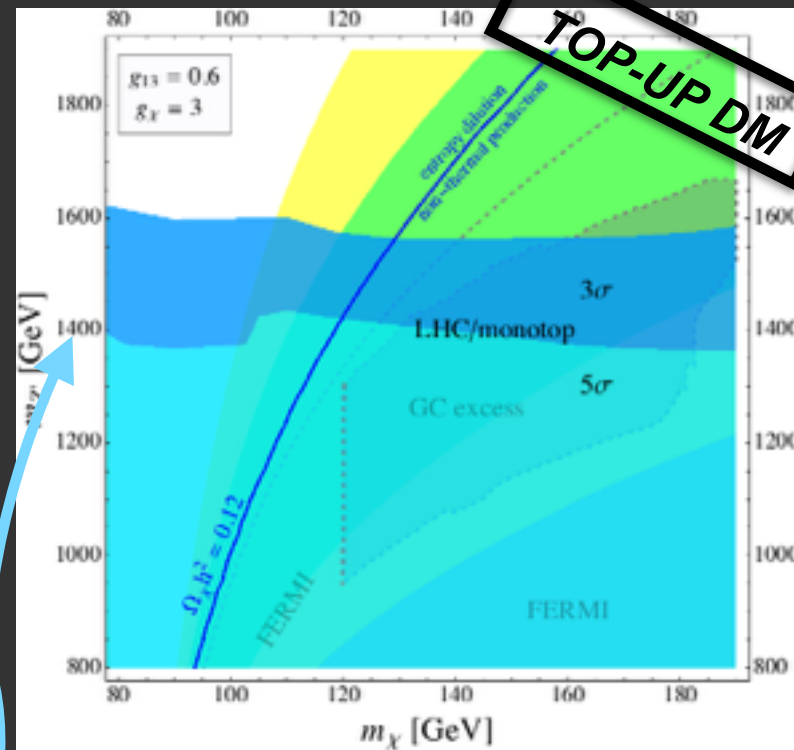
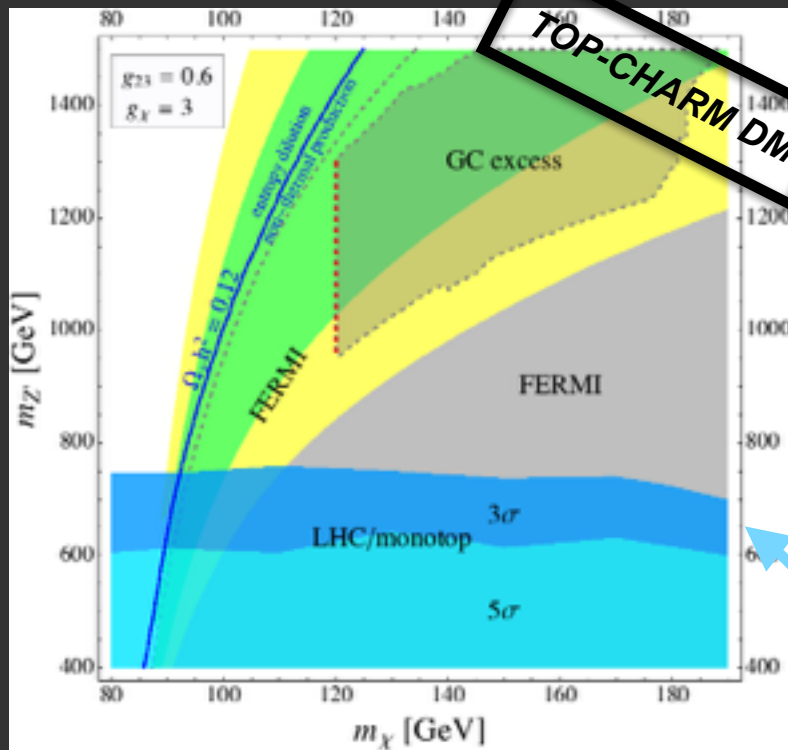
Relic Density and Indirect Detection constraints
Equivalent for Top-Up or Top-Charm DM Model



DM and Flavour violating TOP

$$\mathcal{L}_{int} = g_\chi \bar{\chi} \gamma^\mu \chi Z'^\mu + (g_{13} \bar{u}_R \gamma_\mu t_R Z'^\mu + g_{23} \bar{c}_R \gamma_\mu t_R Z'^\mu + h.c.).$$

DM plus LHC signatures



LHC13 100fb⁻¹

LHC discriminates top-charm and top-up DM models

Also using charm tagging or lepton charge final state

Summary: Dark Sector physics

- ★ Dark sectors/PH: strong **common interest** on Dark sectors and as illustrated on dark matter
- ★ **LHC** definitely offers the exciting **opportunity** to look for DM or its dark sector partners in complementary approach to astro-particle & cosmo experiments.
- ★ Offer occasions for transversal **collaborations** among groups
- ★ E.g.: new joint **initiative** on such topic (ULB-VUB & PH-EXP): FWO project submitted jointly: AM, LLH, S. Lowette

Sample of PH-TH initiatives

- ★ IAP meetings: Two gatherings every year
- ★ Th seminars: every Wednesday ULB-VUB-KUL-Mons
- ★ Cospa network - Cosmo-particle initiative (FWO& FNRS):
meetings twice per year (next meeting Nov. at ULB)
- ★ DM journal club: every week UCL-VUB-ULB
- ★ Solvay conference/workshops, shared PhD...
- ★ Applications to new fundings: e.g. recent EOS projects

Conclusions

- ★ Exciting moment for High Energy Physics, **discovery** can be around the corner in collider or DM experiments
- ★ **Diversity** and complementarity of TH and PH research activities in Belgium
- ★ Our research needs fund **support** from national and international agencies
- ★ New **funding** scheme (e.g. EOS) elemental to strengthen research activities in HEP
- ★ Important to boost **joint effort** between TH/PH/EXP in HEP

Thanks for the attention!

Thanks to all who helped with precious information and preventive apologies for omissions or (unwanted) mistakes