Fermion Portal Dark Matter
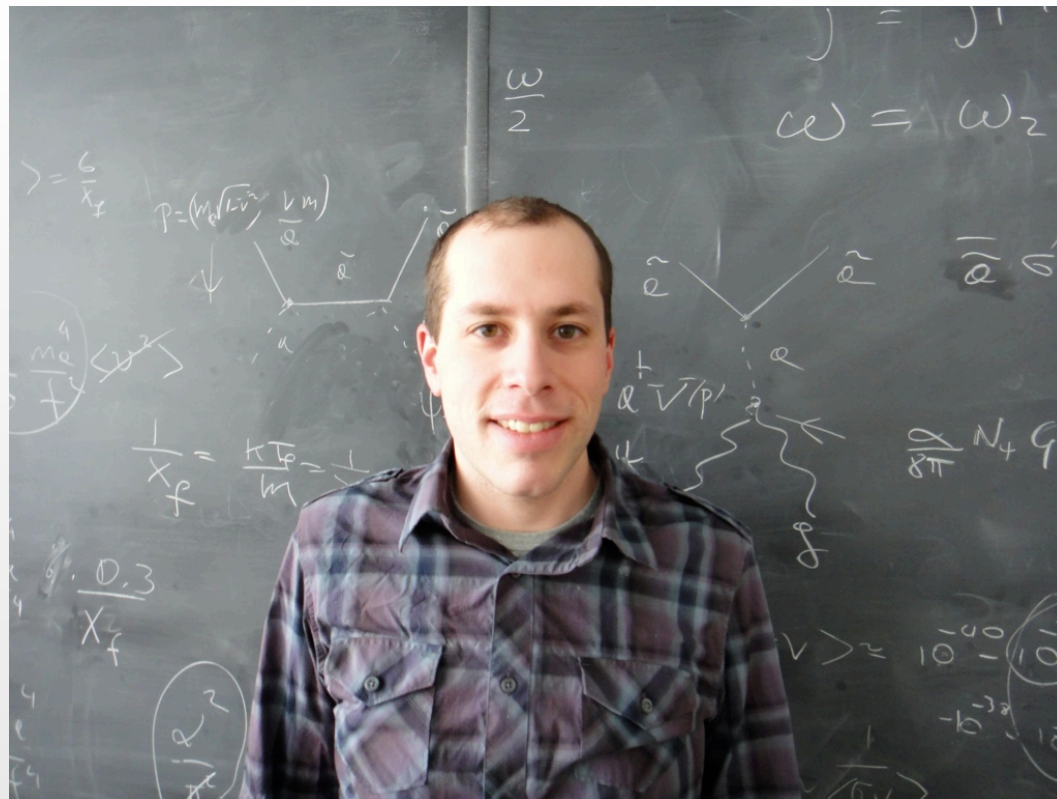
Yang Bai

University of Wisconsin-Madison

Dark Matter at the LHC @ KICP

Sept. 20, 2013

Joshua Berger

at SLAC

"quark portal dark matter"   "lepton portal dark matter"

1308.0612   1310.xxxx

Motivation I
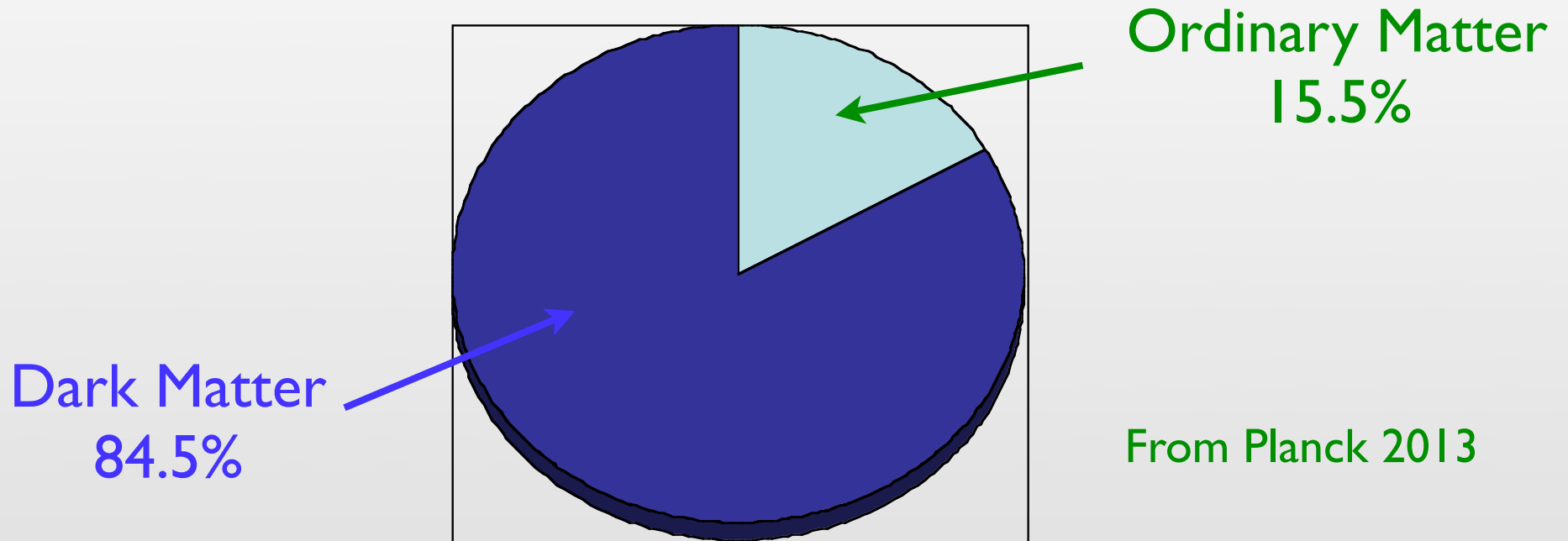
Standard Model

Dark Matter Sector

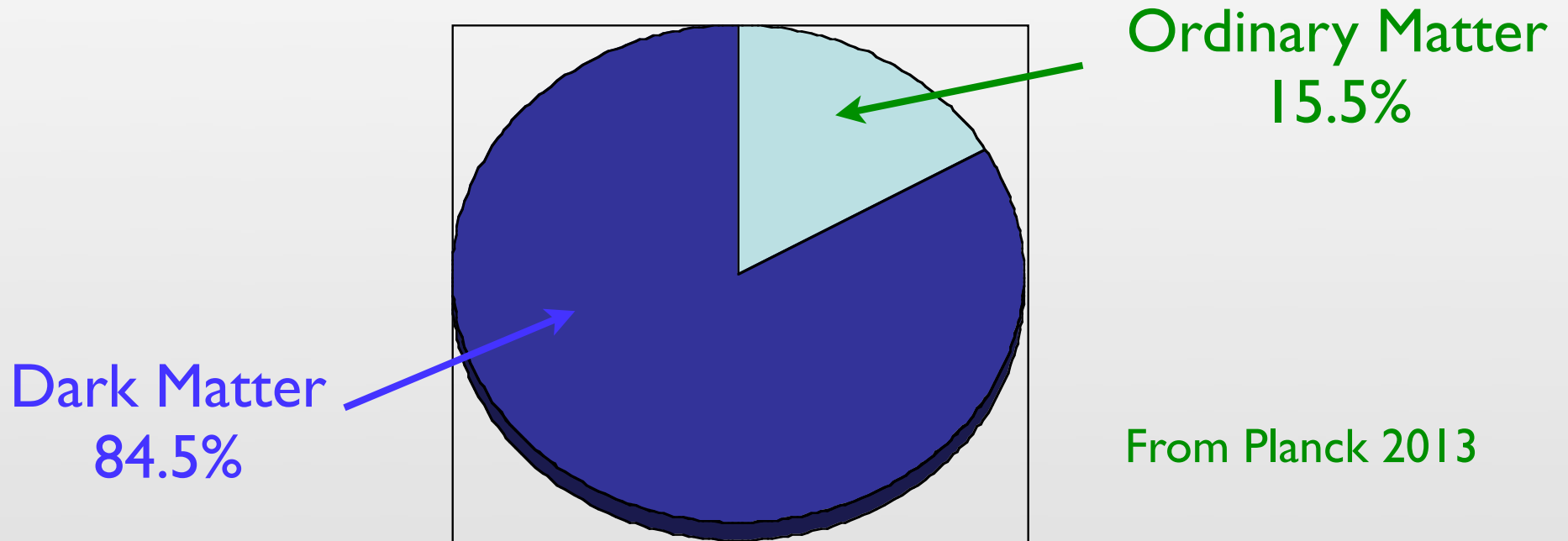★ Graviton
★ Z boson
★ Higgs boson
★ Z', dilaton, radion ...

Motivation II

Dark Matter is important by itself and should deserve attention as much as SUSY.

Ordinary Matter
15.5%

Dark Matter
84.5%

From Planck 2013

Motivation II

Dark Matter is important by itself and should deserve attention as much as SUSY.

Ordinary Matter
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Dark Matter
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From Planck 2013

Dark Matter@LHC ≠ SUSY@LHC

Motivation III

Weakly-interaction massive particle provides an excellent motivation

But, we should not be limited by WIMP's

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Weakly-interaction massive particle provides an excellent motivation

But, we should not be limited by WIMP's

WIMPZILLAS

hep-ph/9810361
Kolb, Chung, Riotto

Figure 7. Dark matter may be much more massive than usually assumed, much more massive than wimpy WIMPS, perhaps in the WIMPZILLA class.

Motivation IV

Validity of EFT

talks at this workshop:

Andrea De Simone, CERN & SISSA
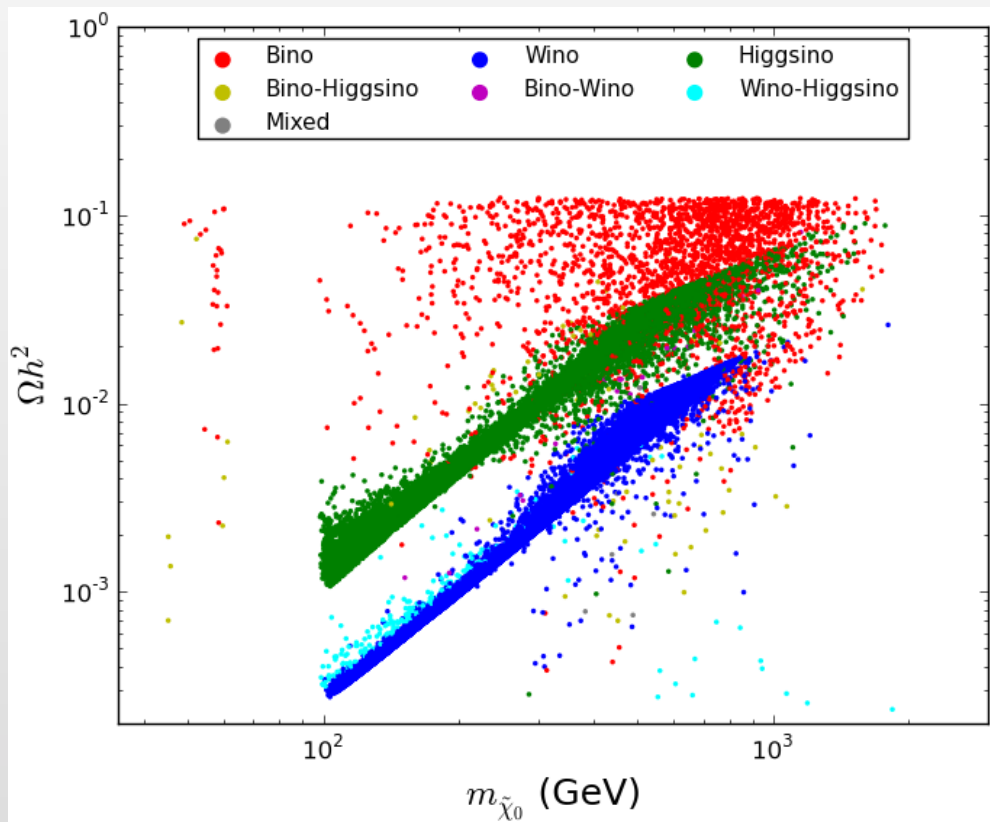[On the validity of the EFT for DM searches at the LHC](#)

Johanna Gramling, University of Geneva
[Validity of EFT interpretation of LHC Monojet results](#)

Felix Kahlhoefer, University of Oxford
[Theoretical uncertainties in mono-jet searches](#)

Motivation V

The SUSY searches are still relevant for many DM models

1305.6921, Cahill-Rowley, Cotta, Drlica-Wagner, Funk, Hewett, Ismail, Rizzo, Wood

Motivation V

The SUSY searches are still relevant for many DM models

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The SUSY searches are still relevant for many DM models
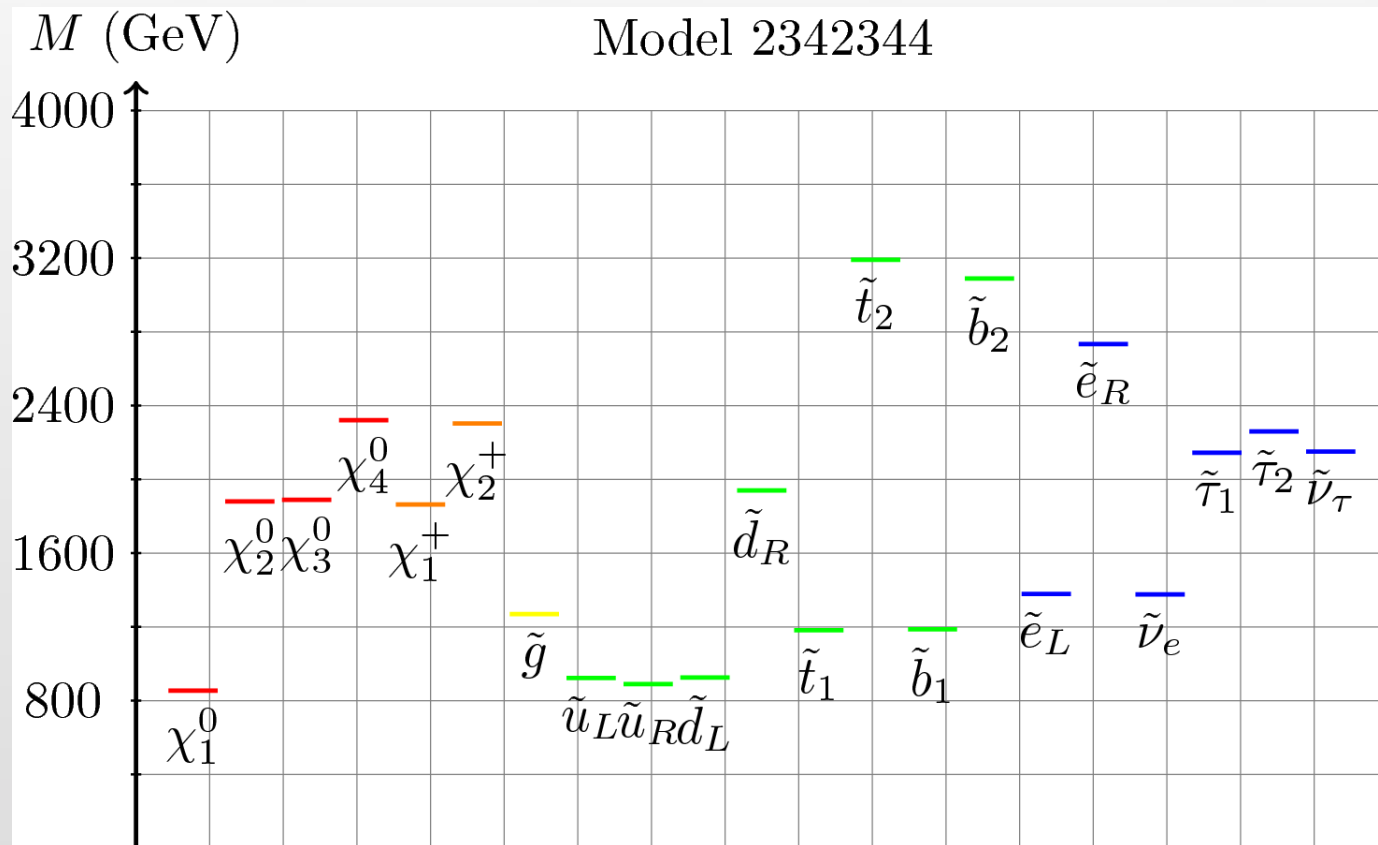
Figure 3: Bino-squark coannihilation benchmark sparticle spectrum.

Simplified Dark Matter Models

★ Boson portal: Higgs portal
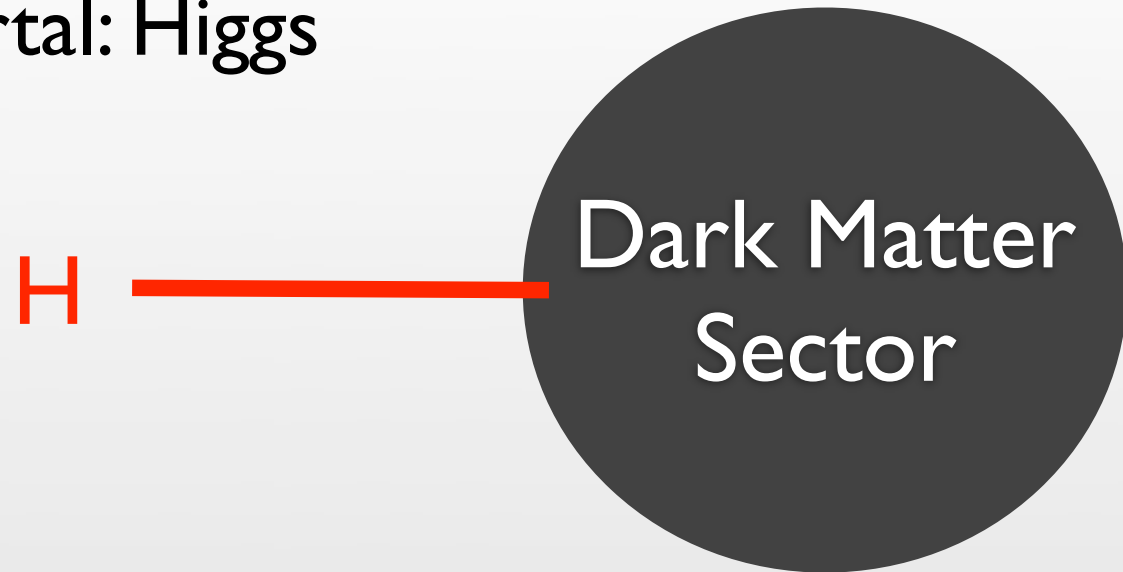
$$H$$ ———— **Dark Matter Sector**

★ Fermion portal

u, d, s, c, b, t

e, μ, τ ———— **Dark Matter Sector**

Fermion Portal Dark Matter

Conserving the Lorentz symmetry, at least two particles in the dark matter sector are required

one boson and one fermion

m

ϕ ⎯⎯⎯⎯⎯

ψ ⎯⎯⎯⎯⎯

χ ⎯⎯⎯⎯⎯

X ⎯⎯⎯⎯⎯

a Majorana or Dirac Fermion or a scalar dark matter

Fermion Portal Dark Matter

Conserving the Lorentz symmetry, at least two
particles in the dark matter sector are required

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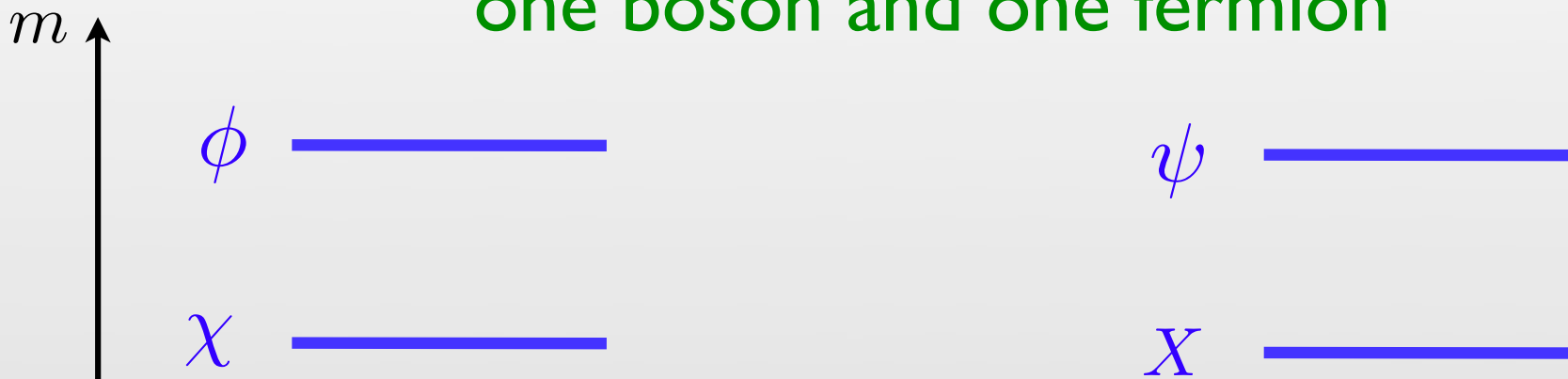
a Majorana or Dirac Fermion or a scalar dark matter

Fermion Portal DM at the LHC has "signatures"
beyond the simplified SUSY DM

Quark Portal Dark Matter

$$\mathcal{L}_{\text{fermion}} \supset \lambda_{u_i} \phi_{u_i} \overline{\chi}_L u_R^i + \lambda_{d_i} \phi_{d_i} \overline{\chi}_L d_R^i + \text{h.c.}$$
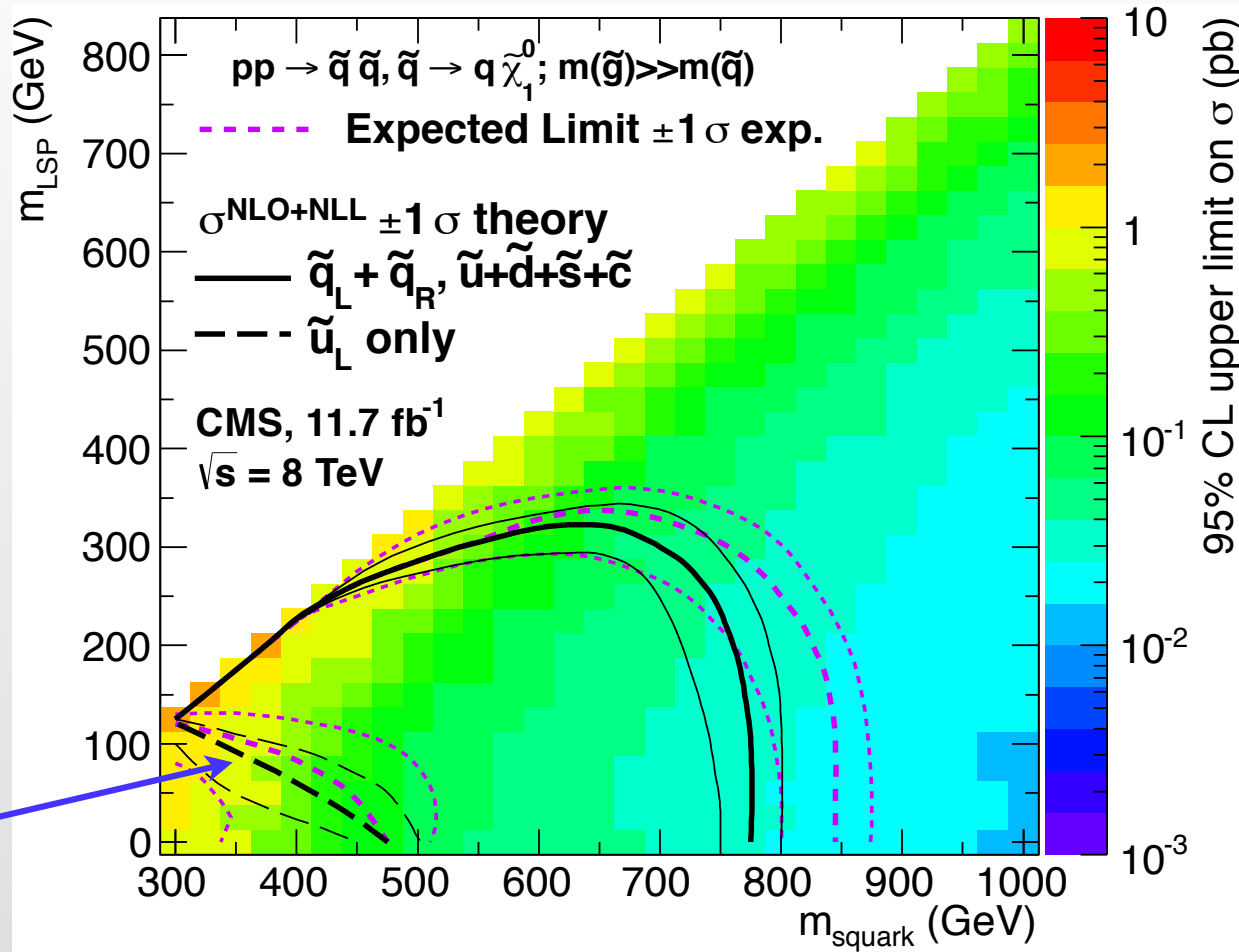

QCD triplet

Quark Portal Dark Matter

$$\mathcal{L}_{\text{fermion}} \supset \lambda_{u_i} \phi_{u_i} \overline{\chi}_L u_R^i + \lambda_{d_i} \phi_{d_i} \overline{\chi}_L d_R^i + \text{h.c.}$$

QCD triplet
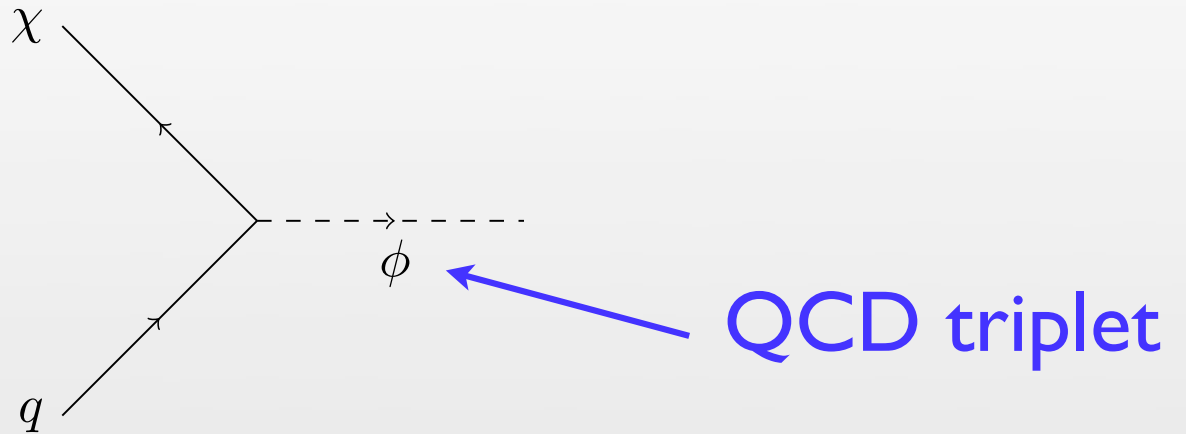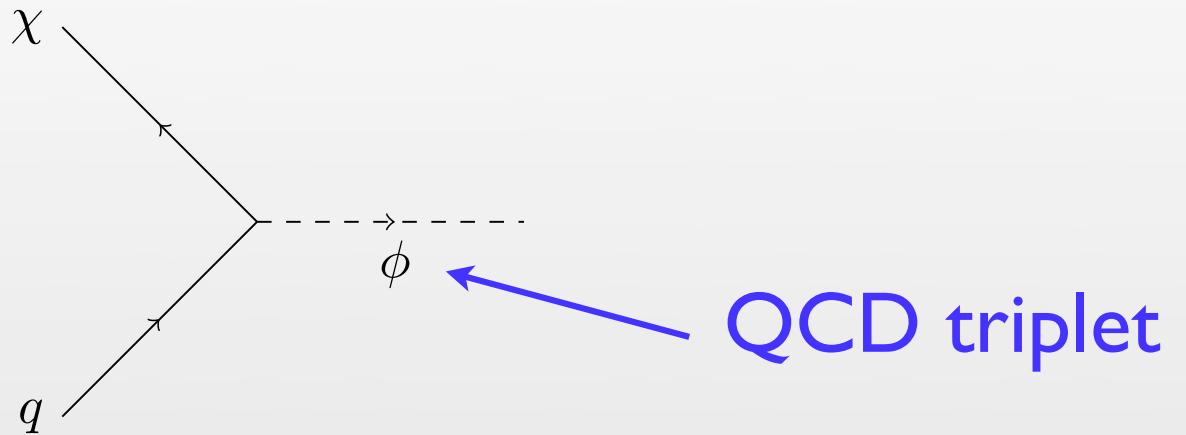
at the LHC
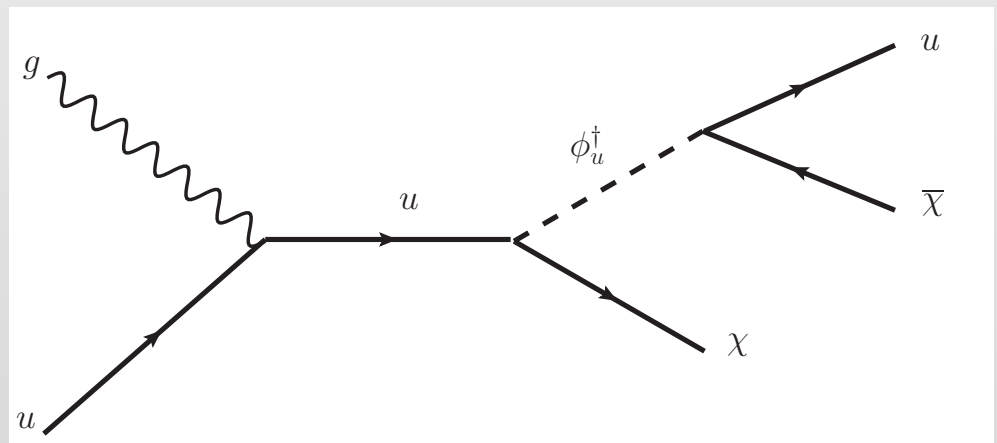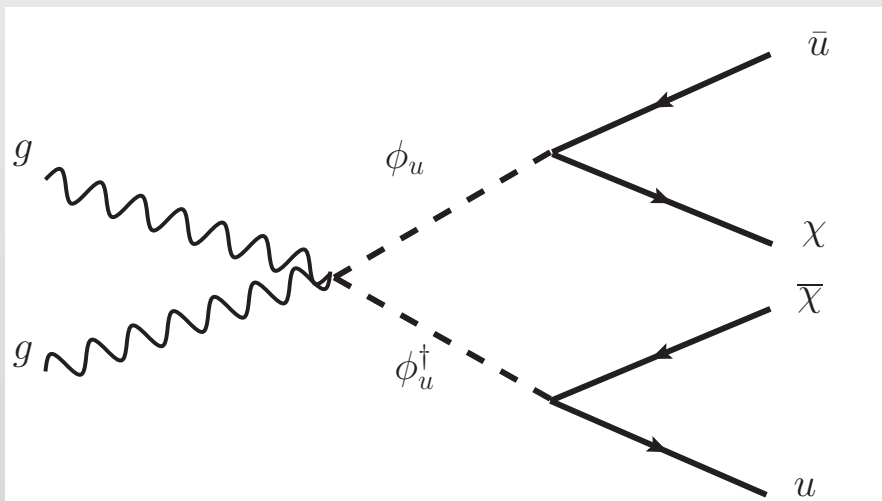
Quark Portal Dark Matter
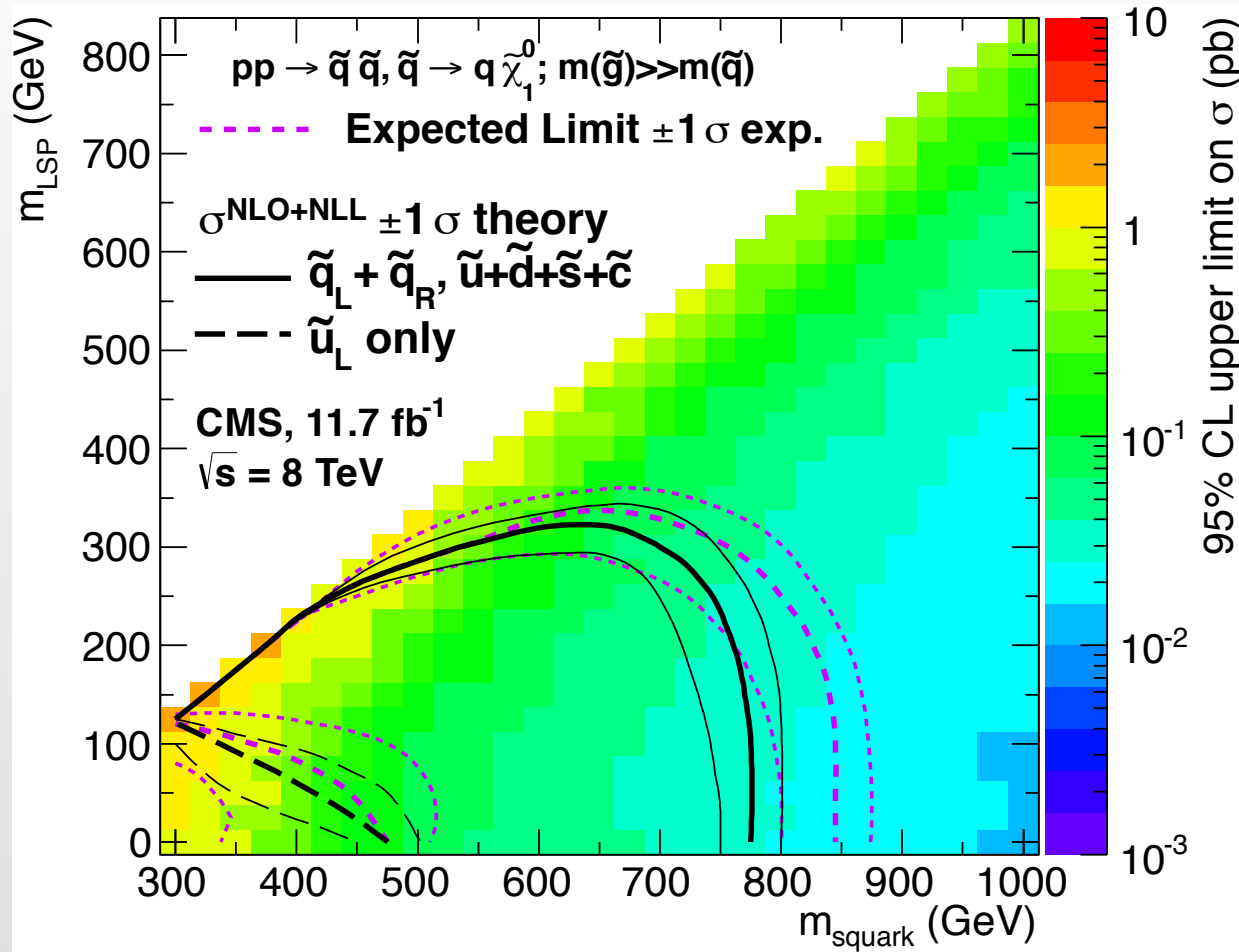
two jets + MET

Quark Portal Dark Matter

two jets + MET

QCD and Yukawa Interference
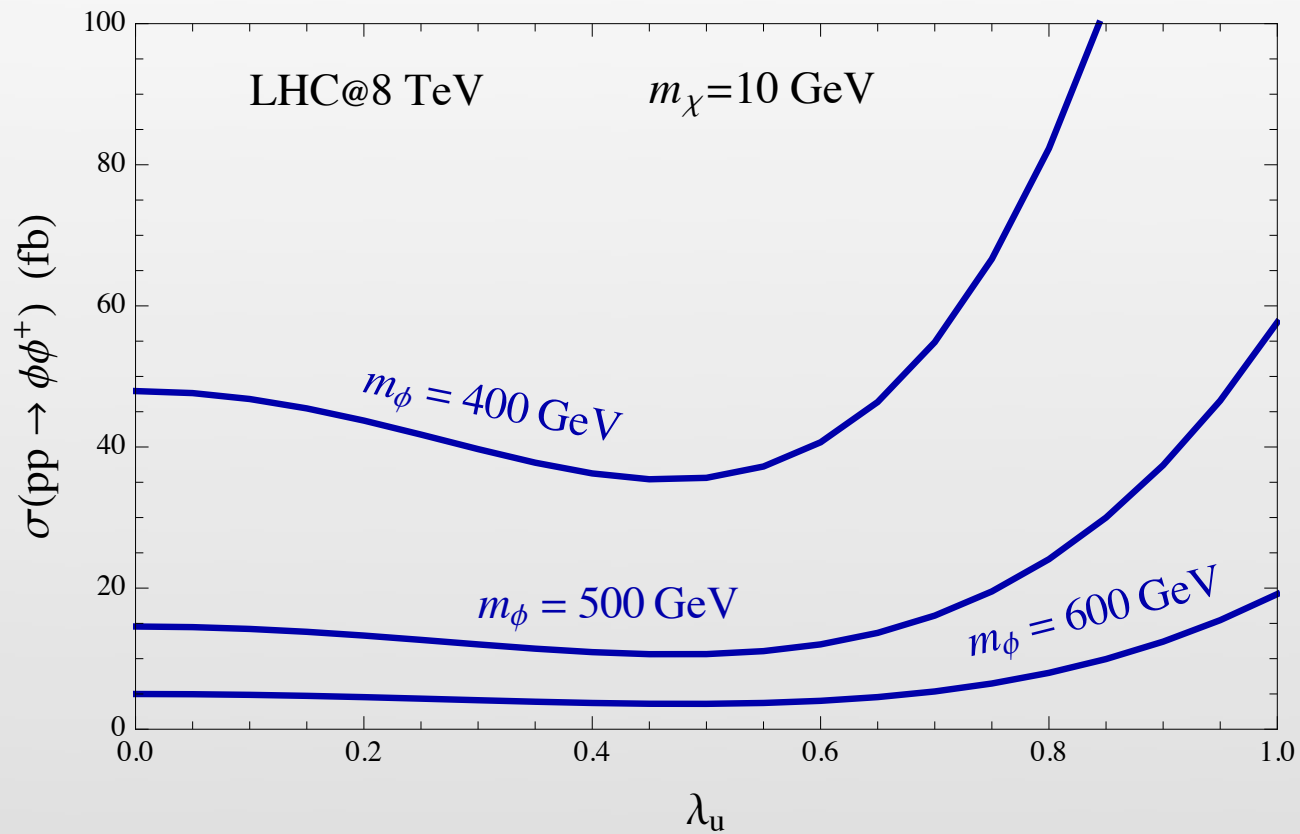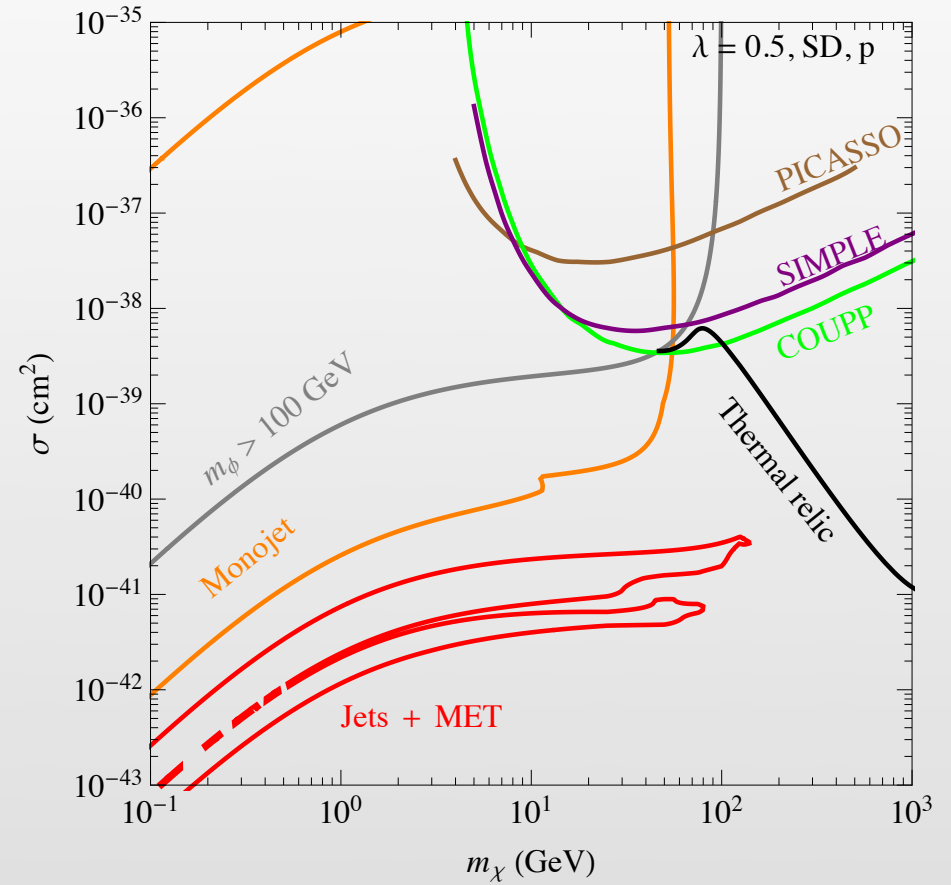

interesting deconstructive interference region

Current Allowed Parameter Space

Majorana fermion dark matter   up-quark
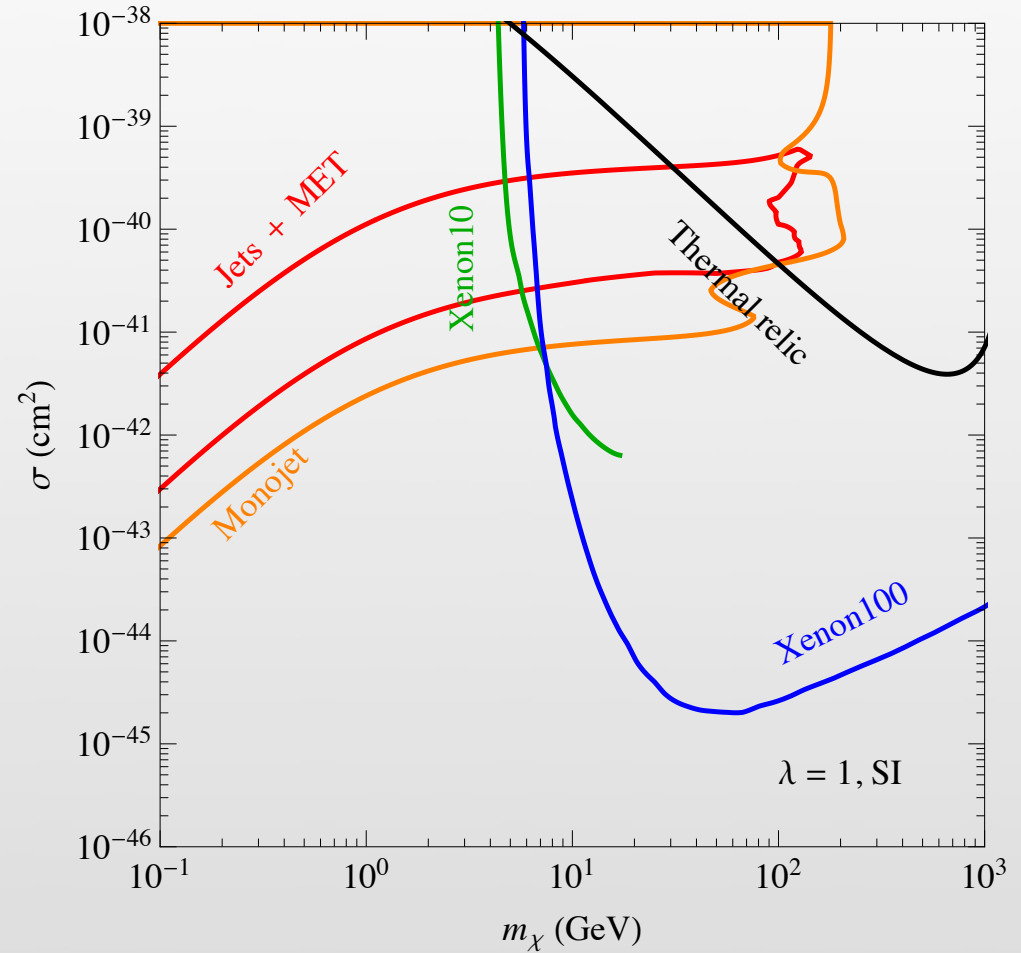
13
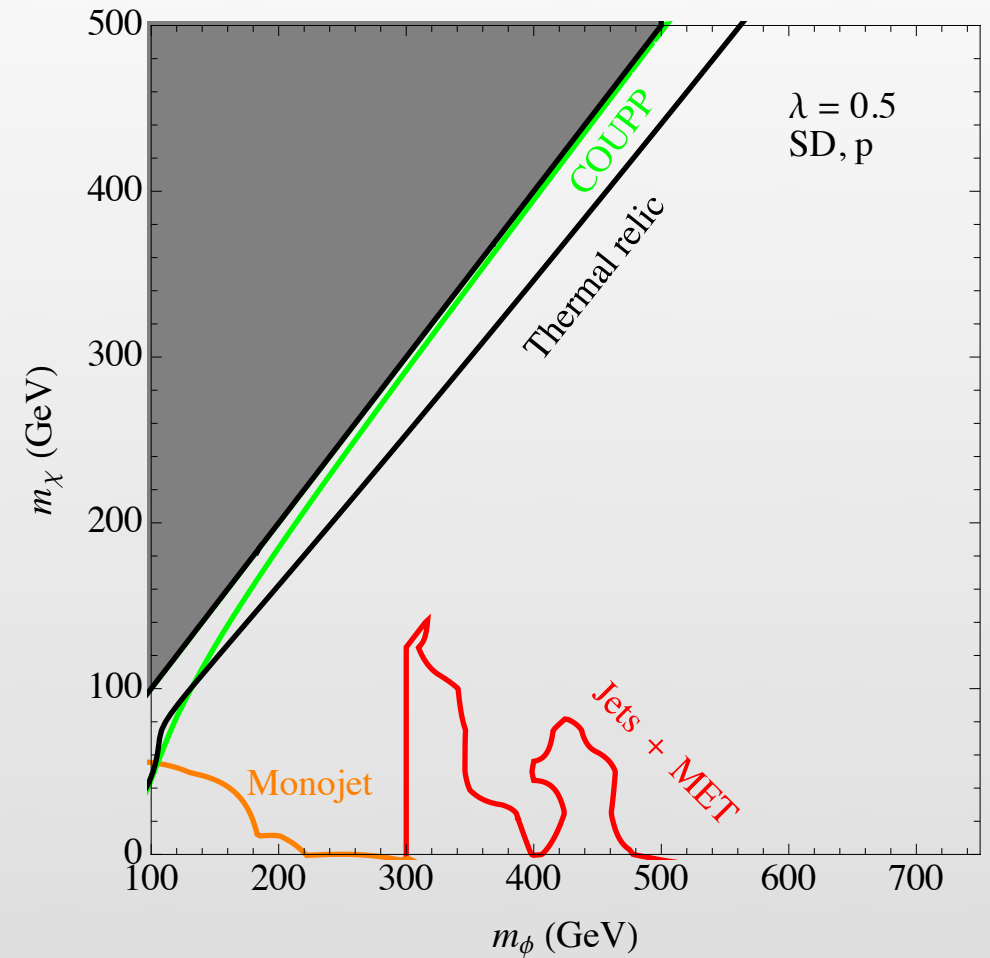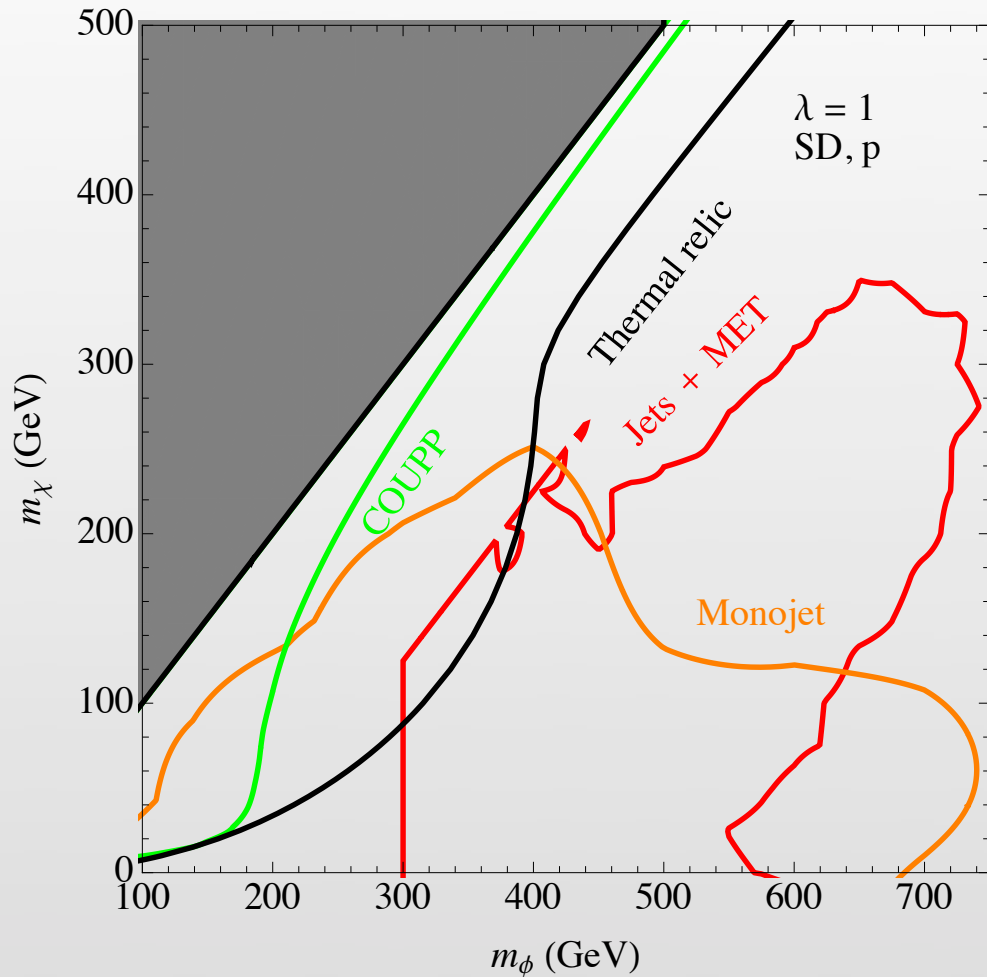
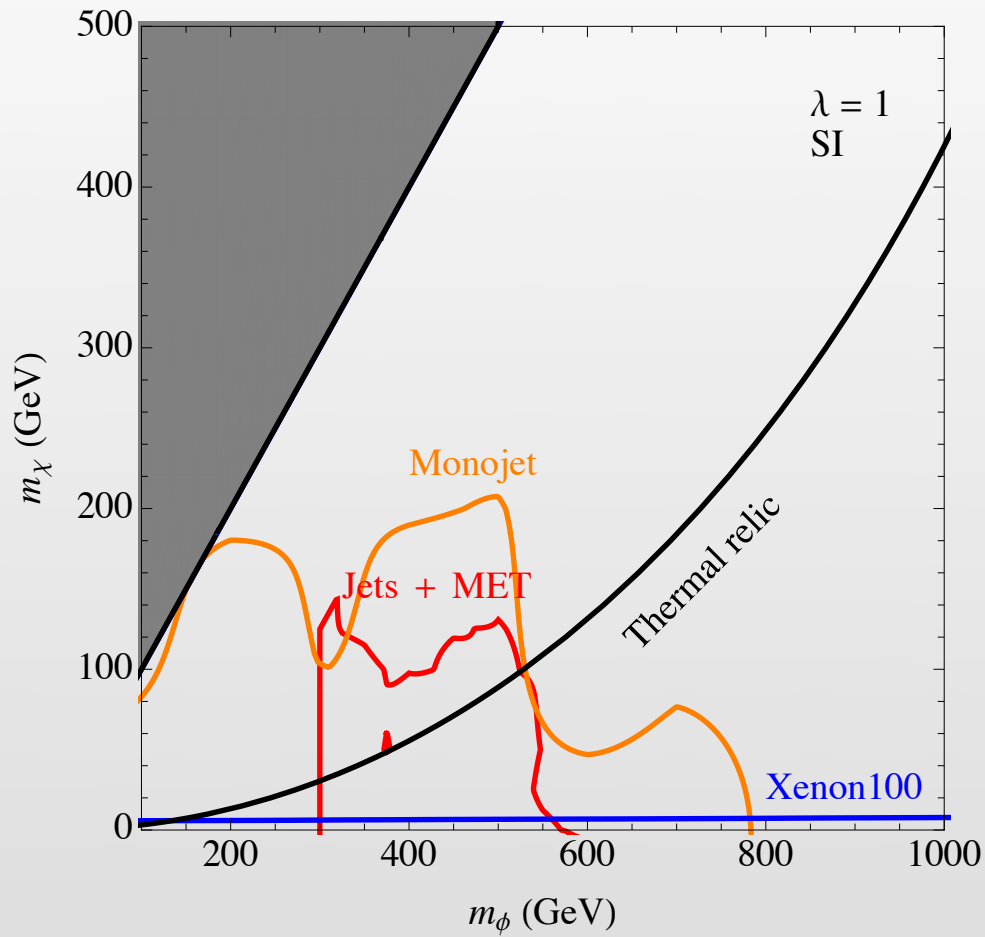# Compare to Direct Detection
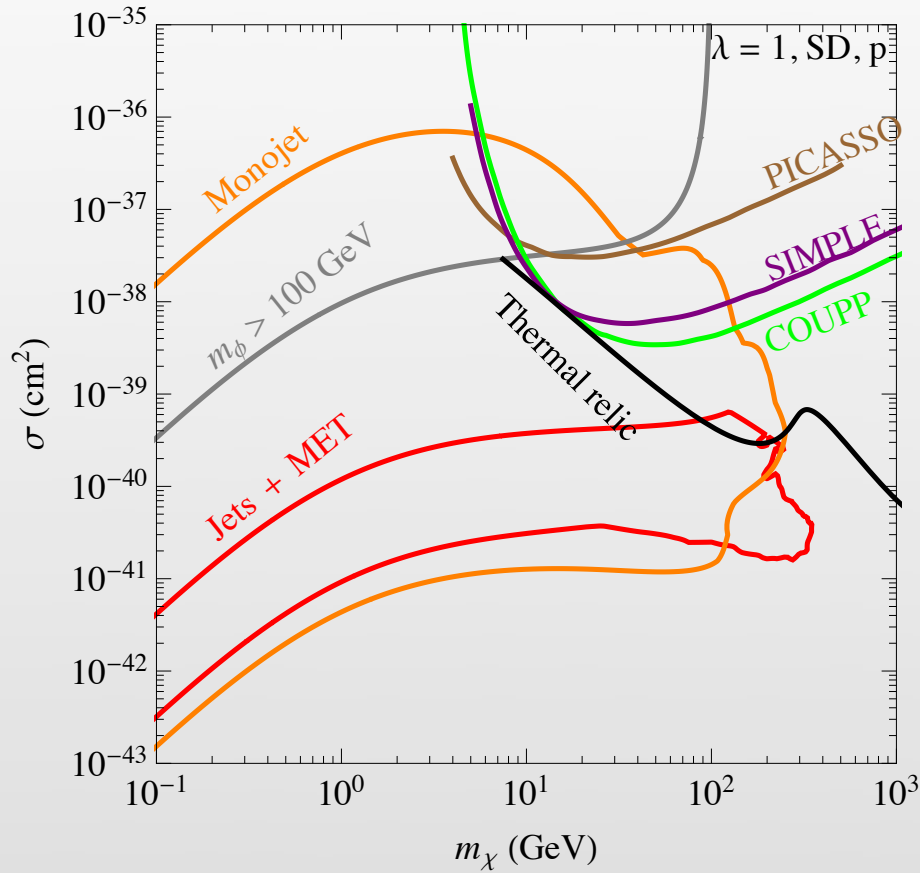
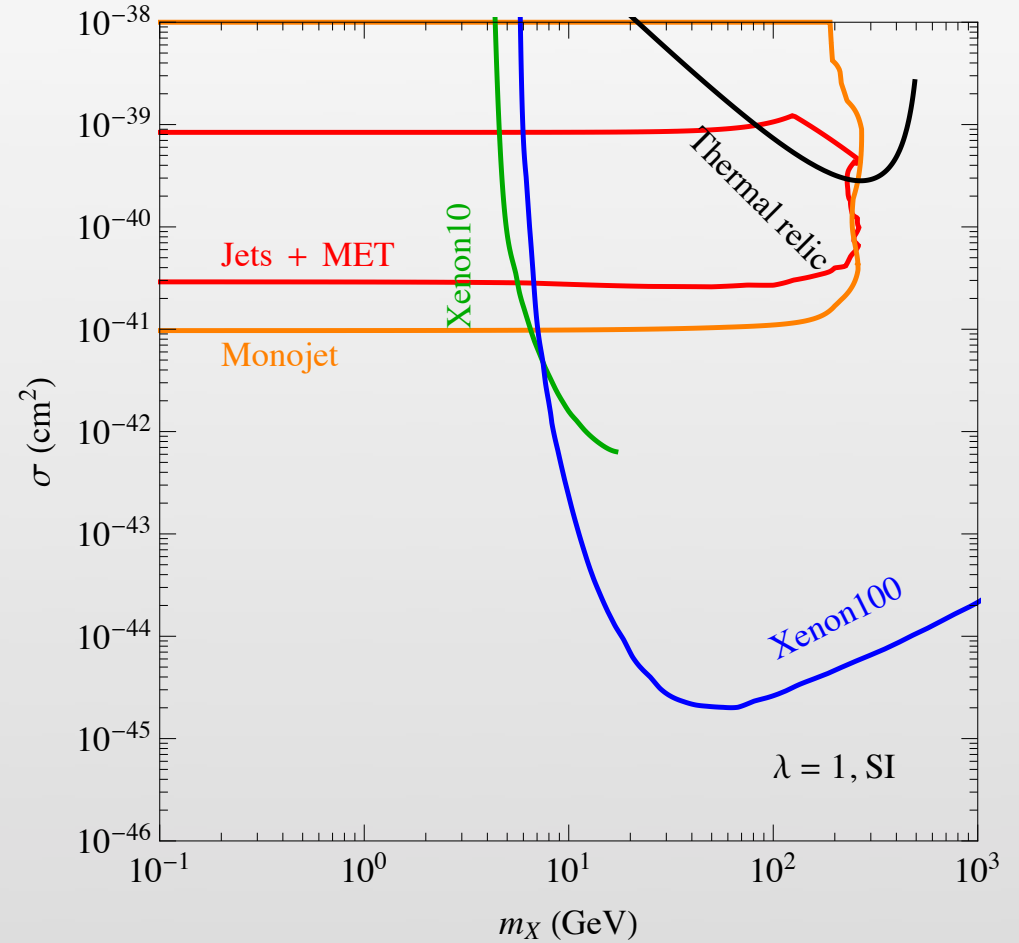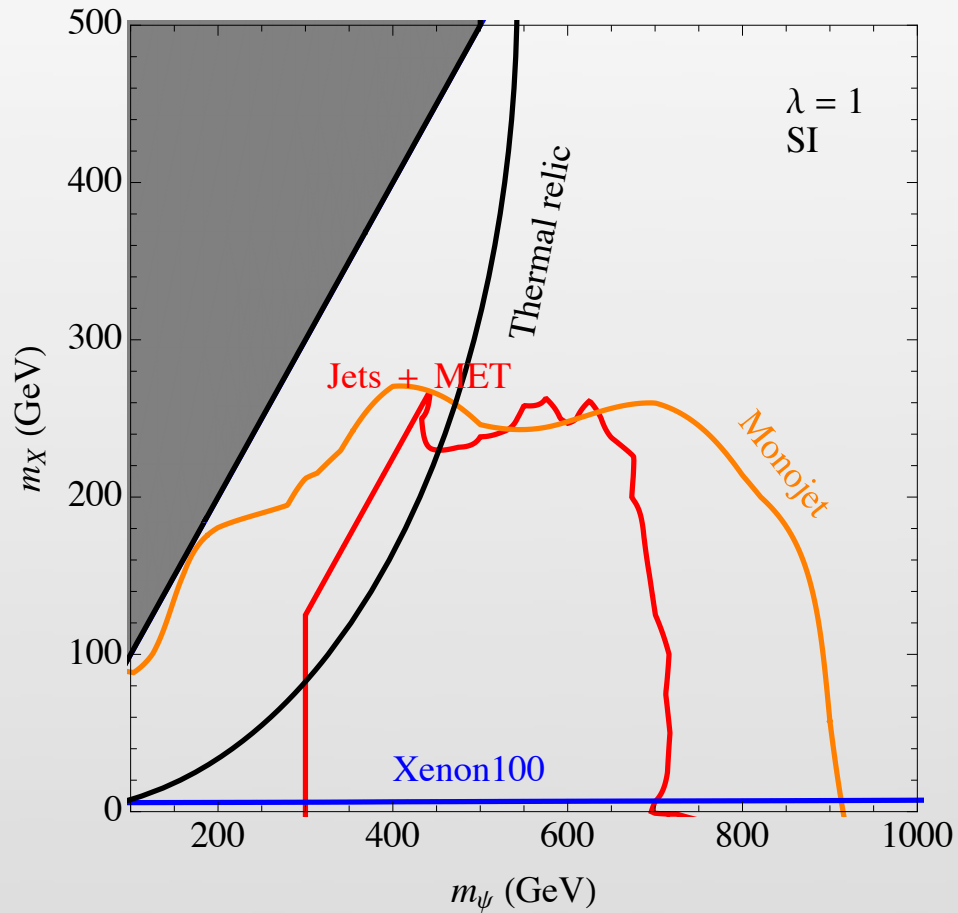Majorana fermion dark matter   up-quark

[more in talks by Chang, Zhang and Tait at this workshop]
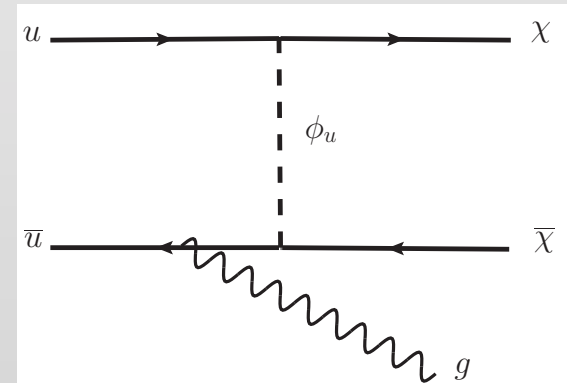
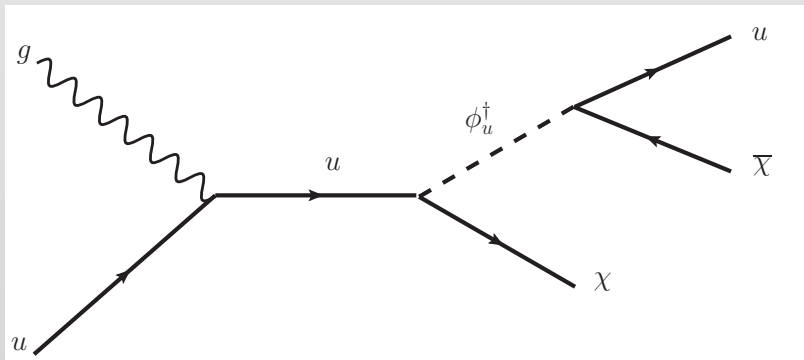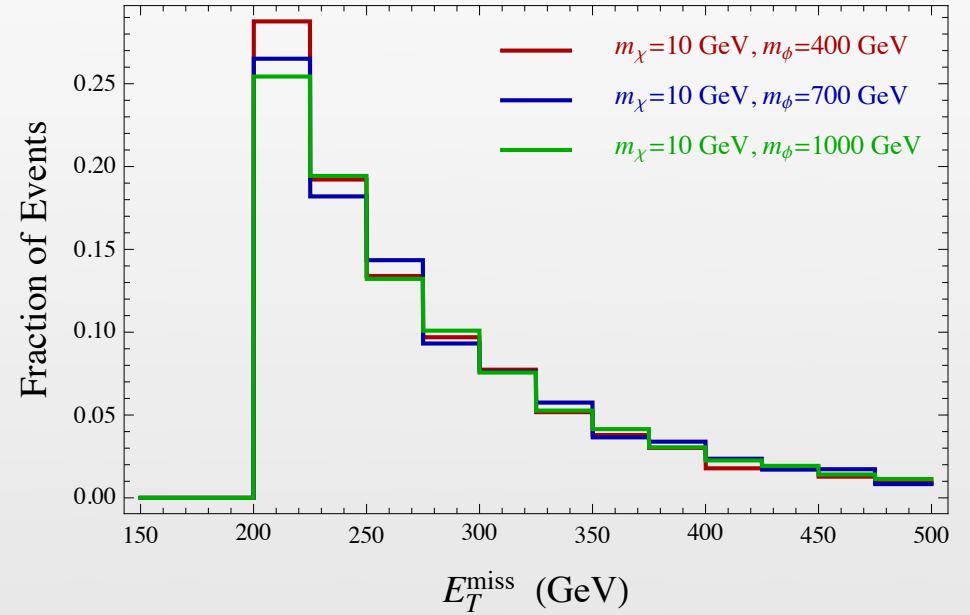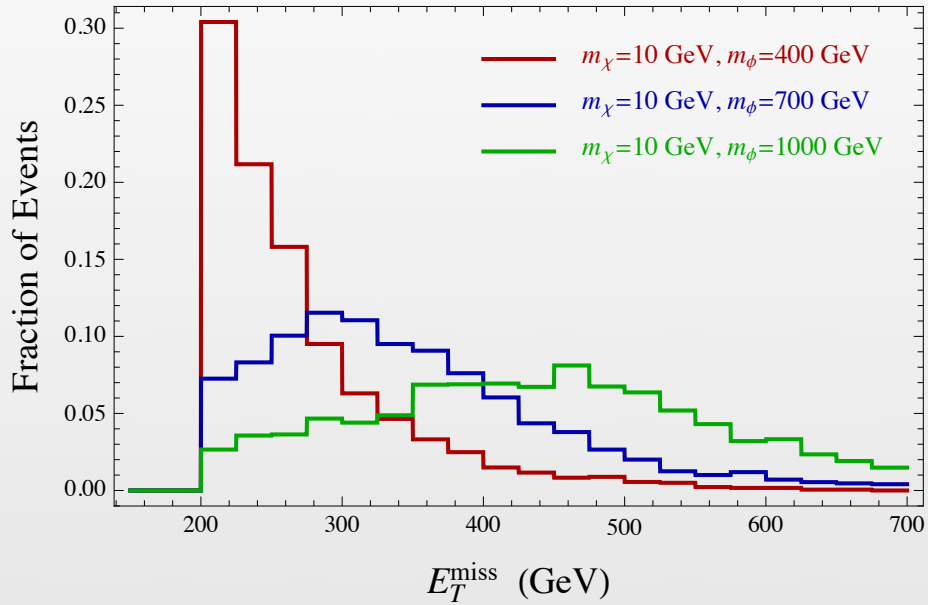# Dirac Fermion Dark Matter

up-quark

Complex Scalar Dark Matter

up-quark

MET Distribution in mono-jet

17

Lepton Portal Dark Matter

Lepton Portal Dark Matter

$$\mathcal{L}_{\text{fermion}} \supset \lambda_i \phi_i \overline{\chi}_L e_R^i \qquad\qquad \mathcal{L}_{\text{scalar}} \supset \lambda_i X \overline{\psi}_L^i e_R^i$$

Lepton Portal Dark Matter

$$\mathcal{L}_{\text{fermion}} \supset \lambda_i \phi_i \overline{\chi}_L e_R^i \qquad\qquad \mathcal{L}_{\text{scalar}} \supset \lambda_i X \overline{\psi}_L^i e_R^i$$

Lepton anomalous magnetic moment:

$$a_\mu \equiv (g-2)_\mu / 2$$
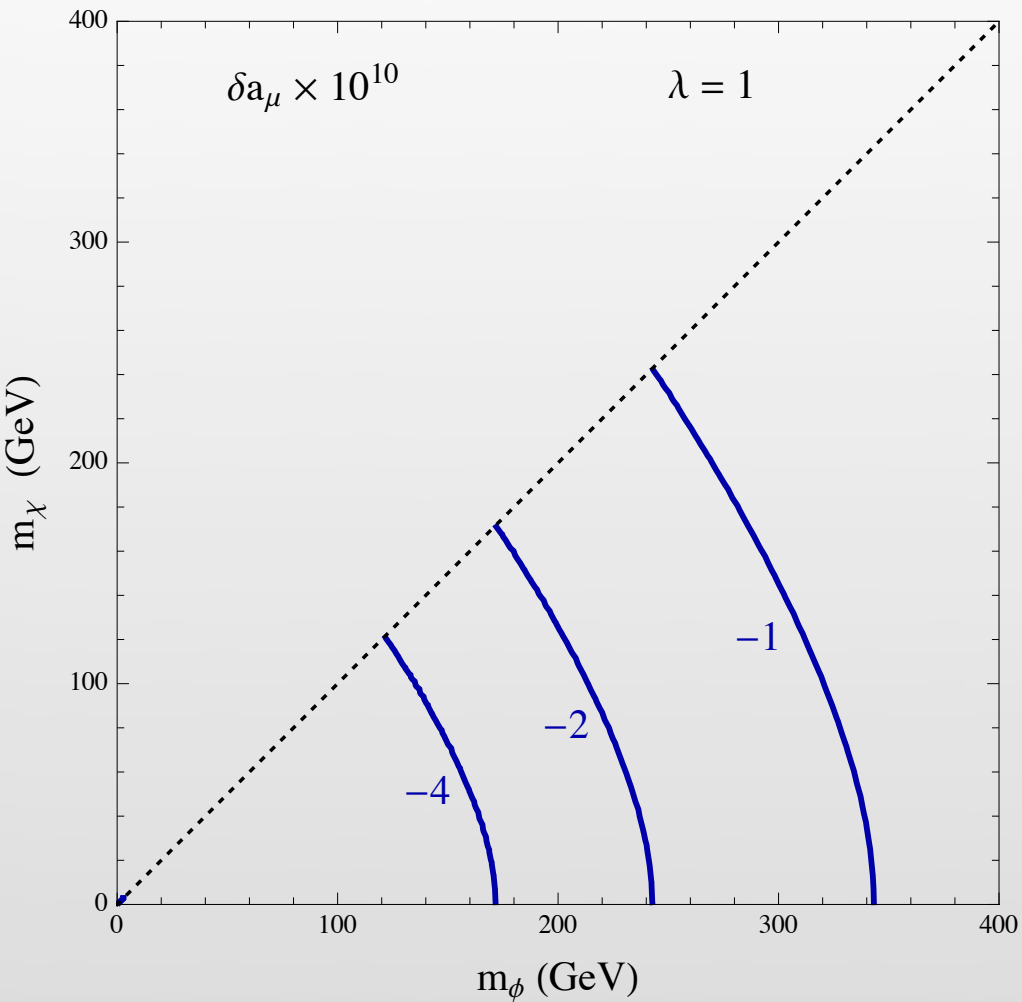
$$a_\mu^{\text{EXP}} = (11659208.9 \pm 6.3) \times 10^{-10}$$ hep-ex/0602035, Muon G-2 Collab.

$$a_\mu^{\text{SM}} = (11659182.8 \pm 4.9) \times 10^{-10}$$ 1105.3149, Hagiwara et. al.
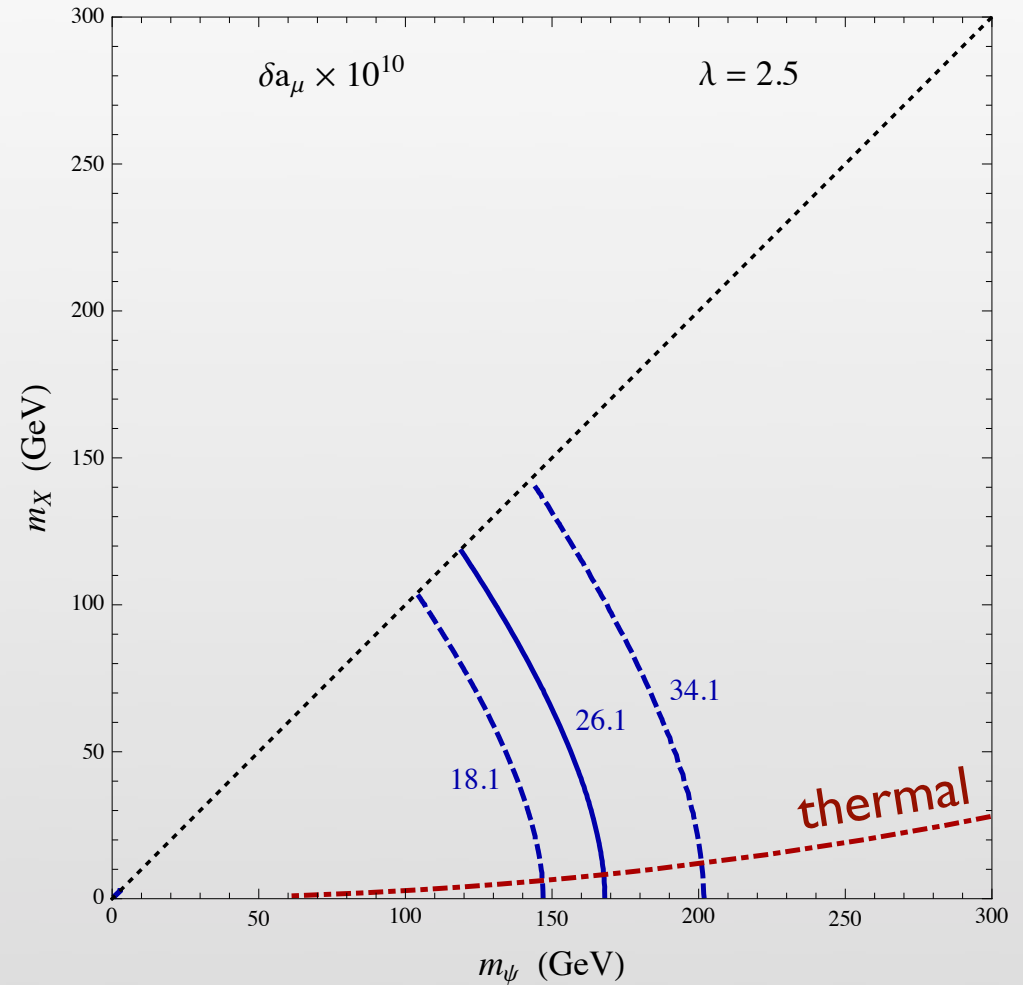
$$a_\mu^{\text{EXP}} - a_\mu^{\text{SM}} = (26.1 \pm 8.0) \times 10^{-10}$$

may need a positive contribution from new physics

Muon g-2
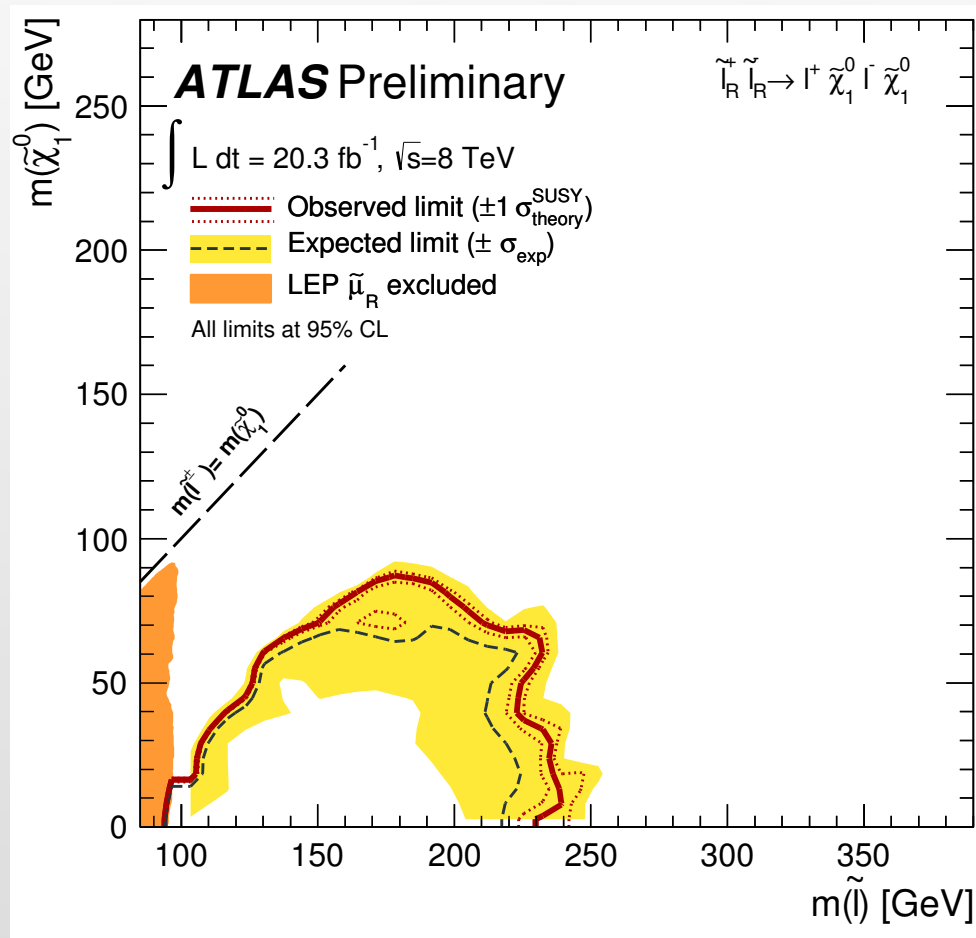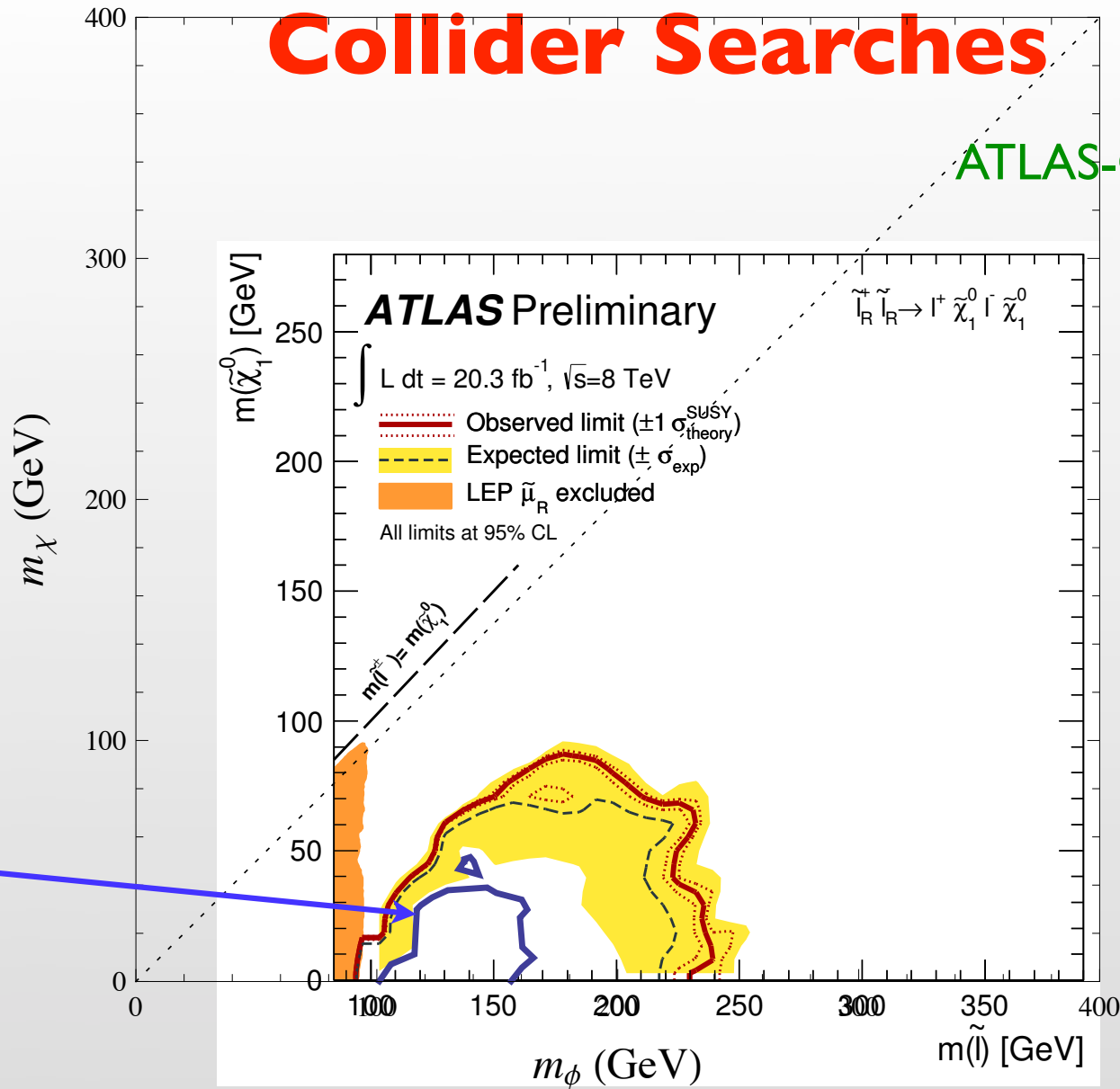
fermion dark matter

scalar dark matter

Collider Searches

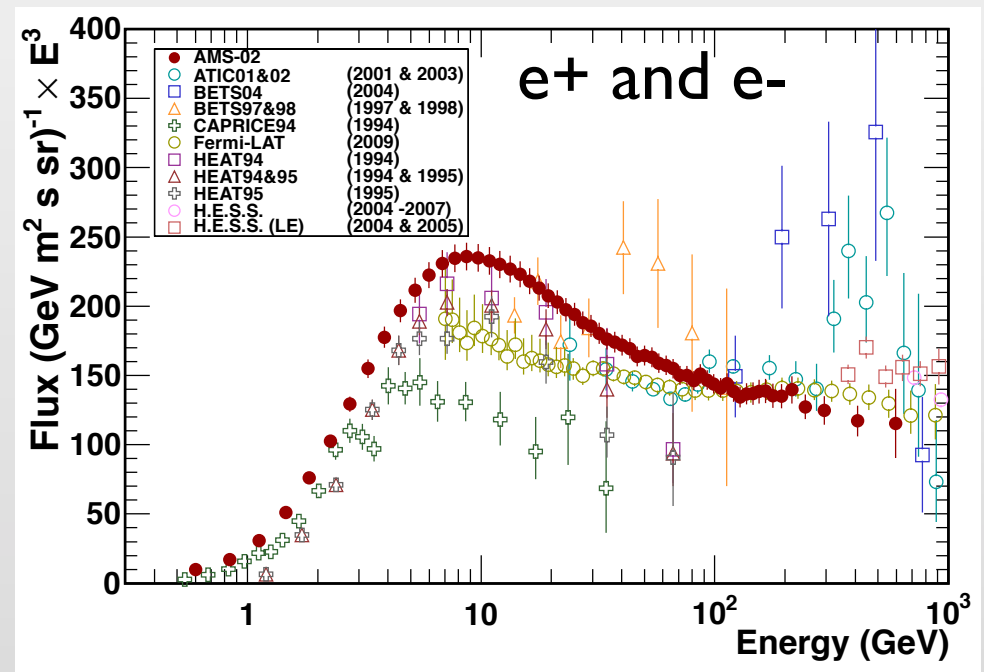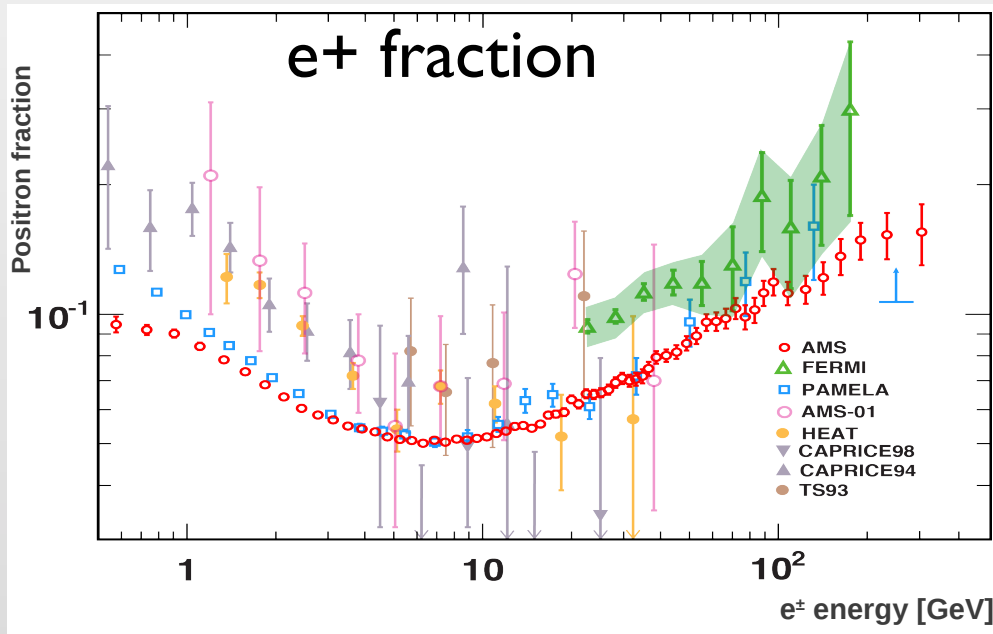ATLAS kept both selectron and smuon and used MT2

Collider Searches
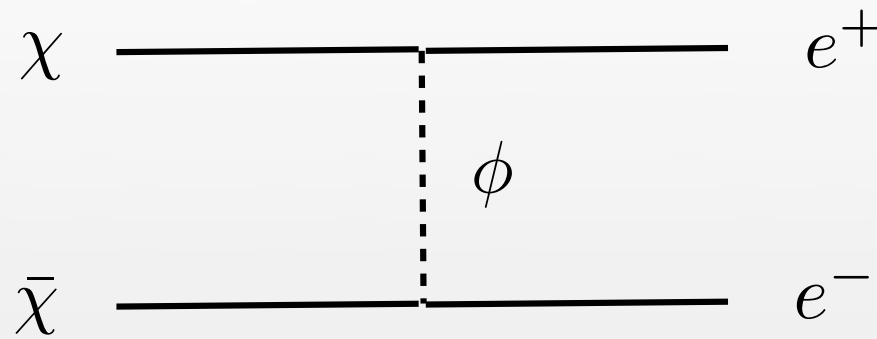
for one
flavor
(approx.)

ATLAS kept both selectron and smuon and used MT2

Indirect Detection

from AMS-02

22

Indirect Detection Constraints
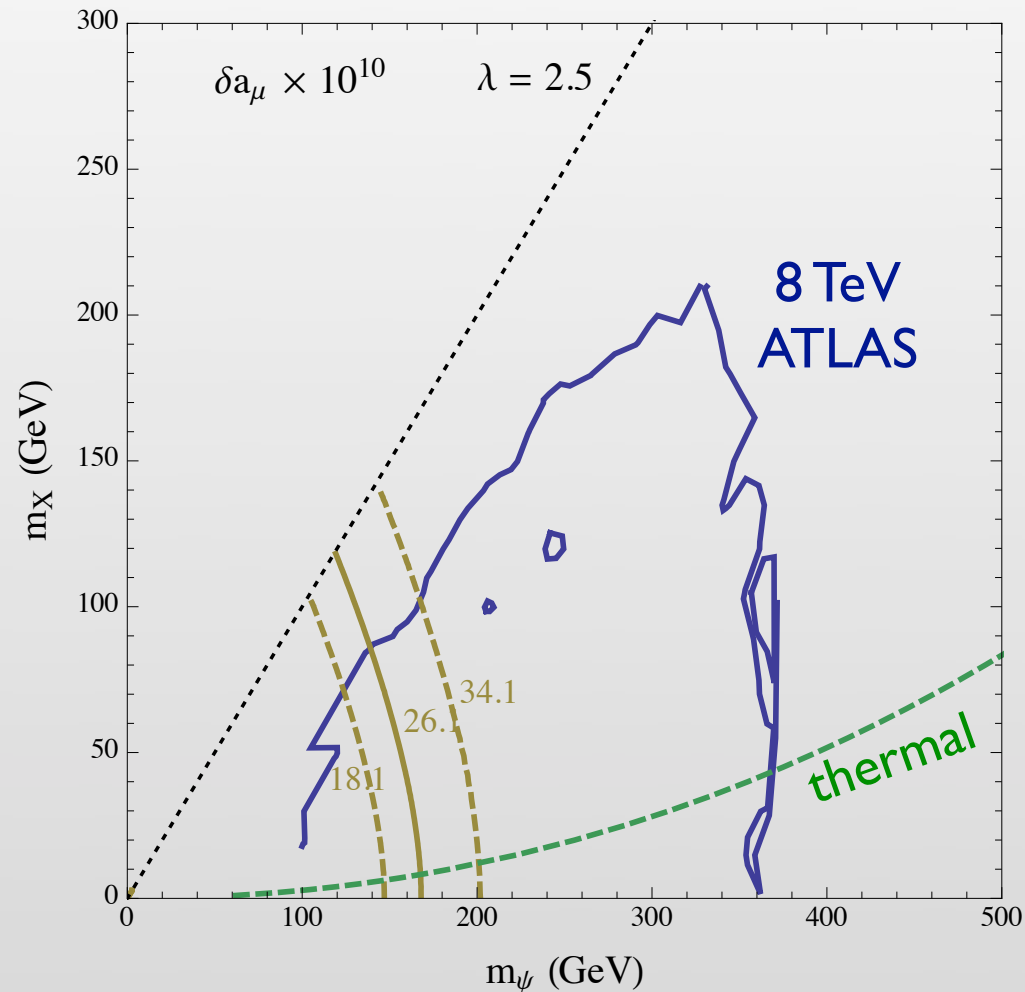

Dirac fermion DM
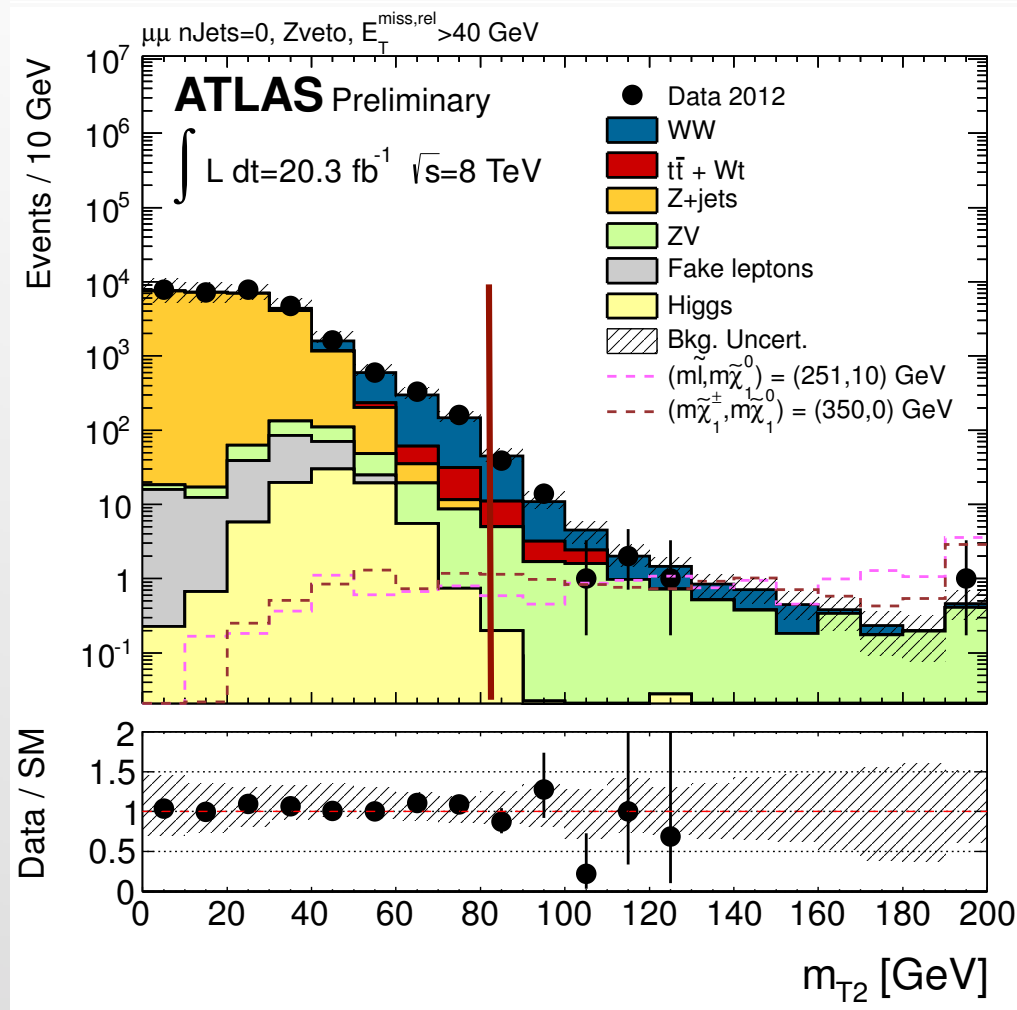
NFW profile, different propagation models

8 TeV ATLAS
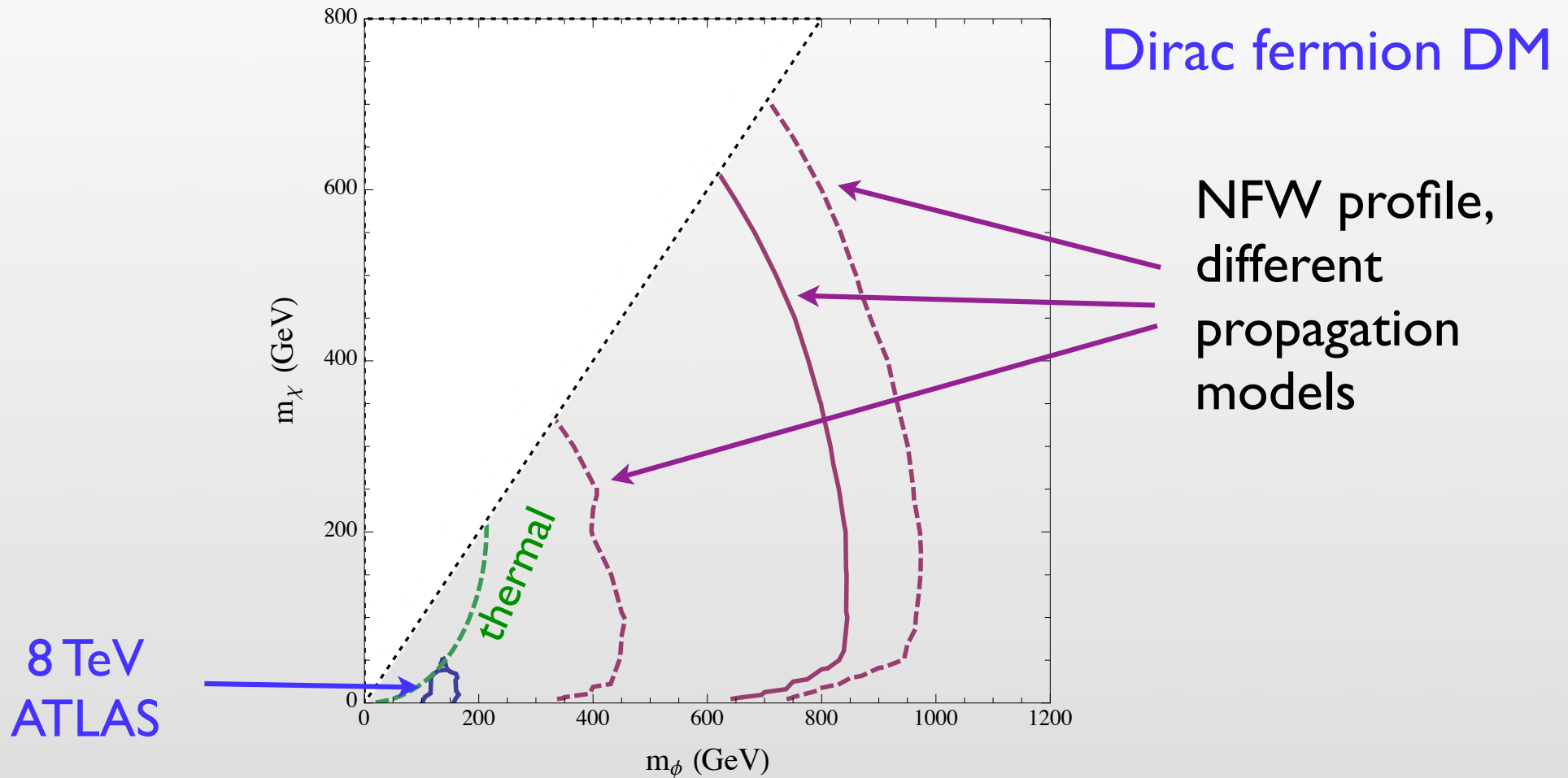
[see also model-independent constraints: 1306.3983 by Bergstrom, Bringmann, Cholis, Hooper, Weniger; 1309.2570 by Ibarra, Lamperstorfer, Silk]

23

Complex Scalar DM

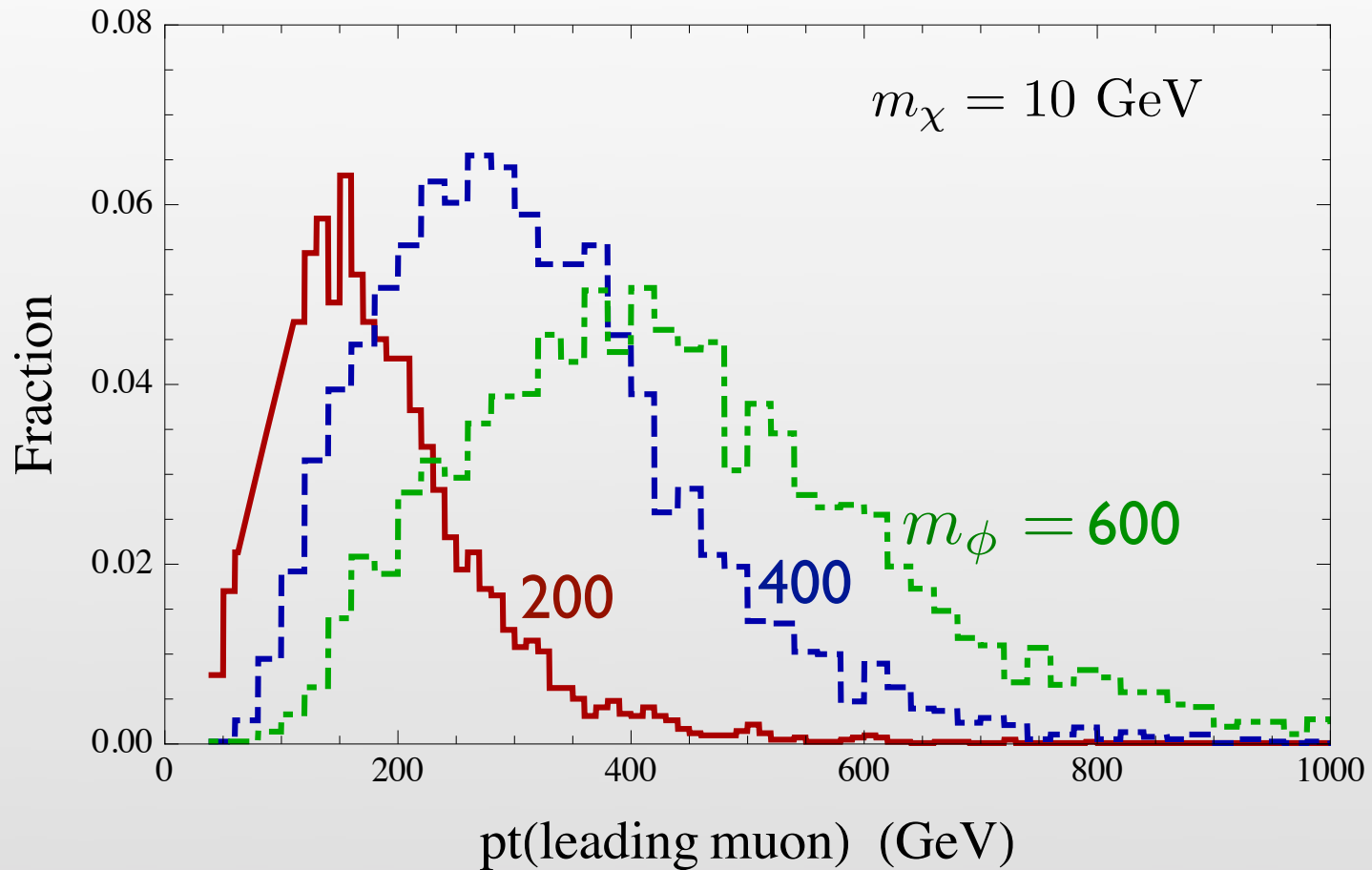The annihilation is p-wave suppressed; the indirect detection limits are irrelevant

pt(j) > 20 GeV
jet veto

Can we define MET just based on leptons?

Another comment: lepton pt

could have a large correlation with MT2
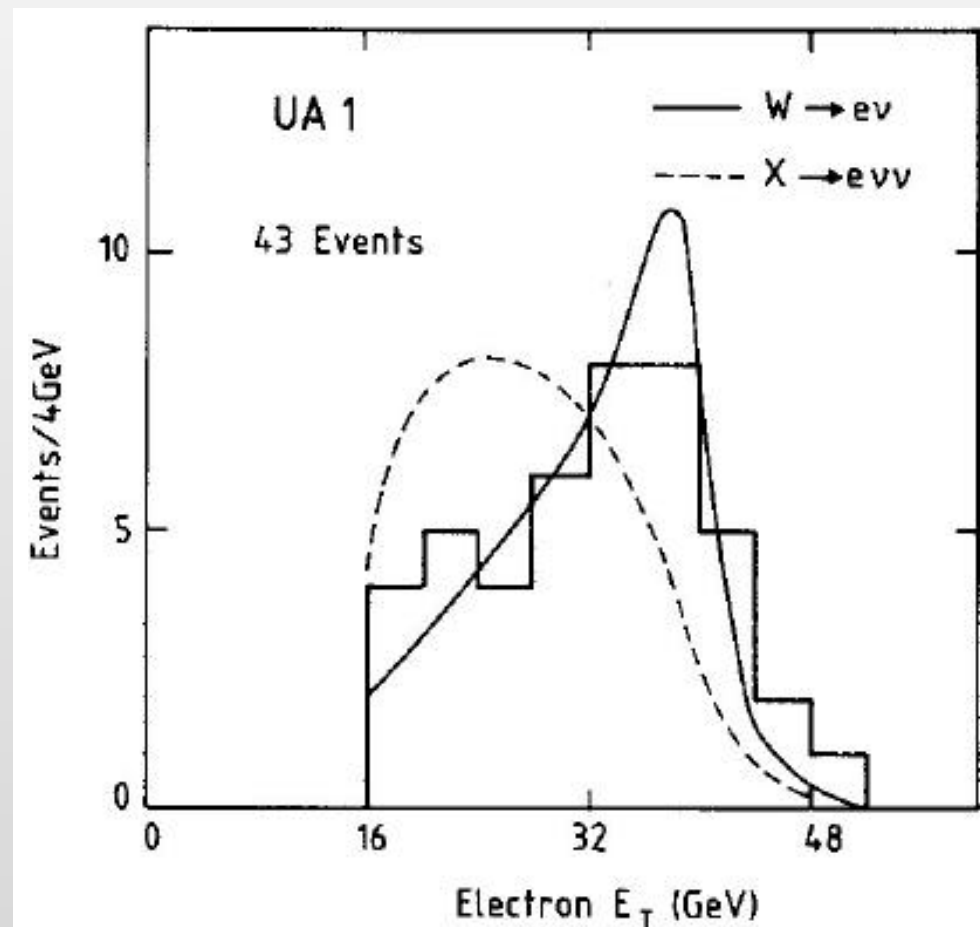
Can we repeat the W discovery?

EXPERIMENTAL OBSERVATION OF ISOLATED LARGE TRANSVERSE ENERGY ELECTRONS WITH ASSOCIATED MISSING ENERGY AT $\sqrt{s}$ = 540 GeV

UA1 Collaboration, CERN, Geneva, Switzerland

Conclusions

★ More searches for simplified SUSY or non-SUSY dark matter models should be performed at the LHC

★ Dedicated searches in the two jets + MET and two leptons + MET channels have chances to discover the Fermion Portal Dark Matter

Thanks