Introduction to Complementarity

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The Foundation for The Gator Nation

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Complementarity

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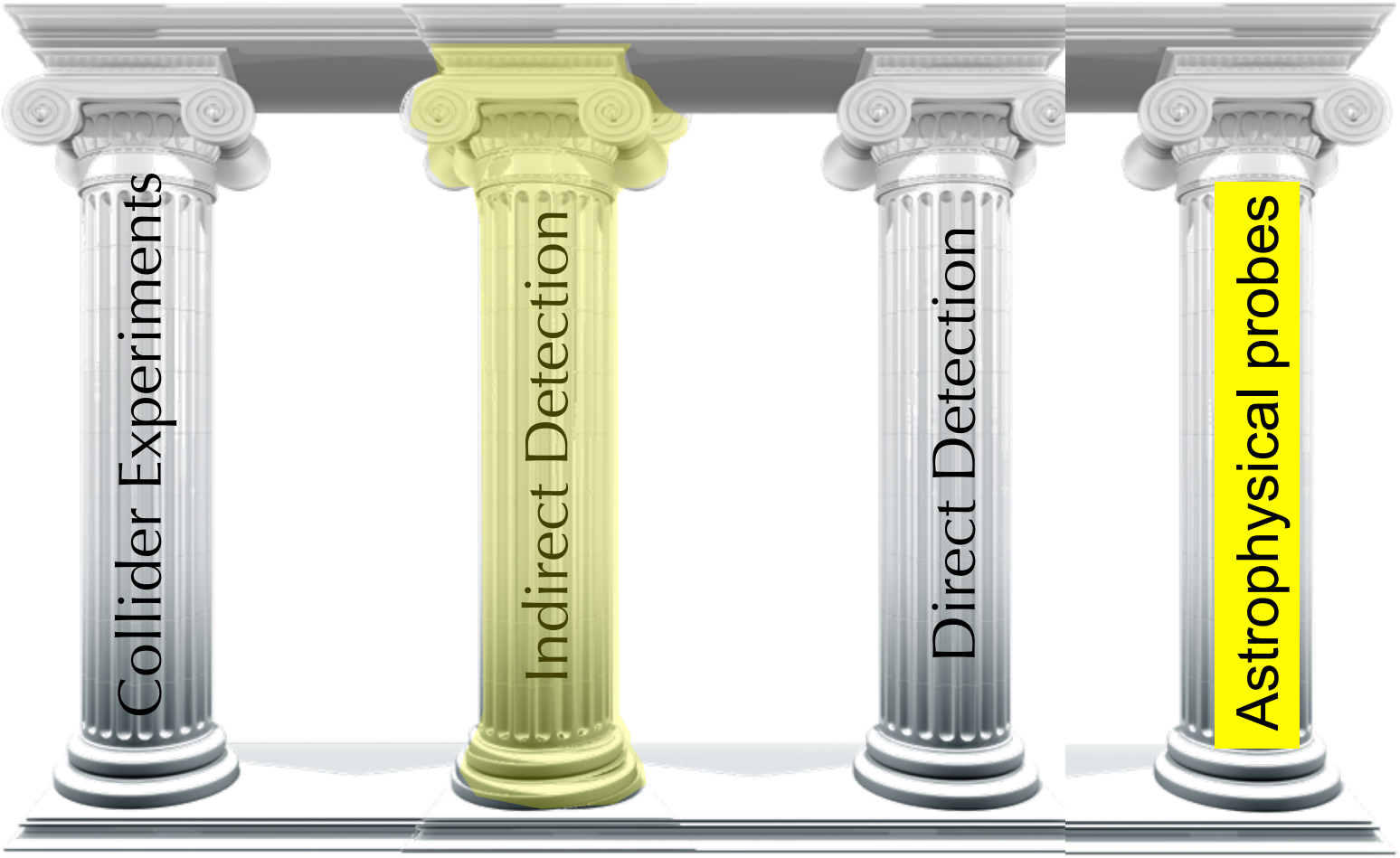
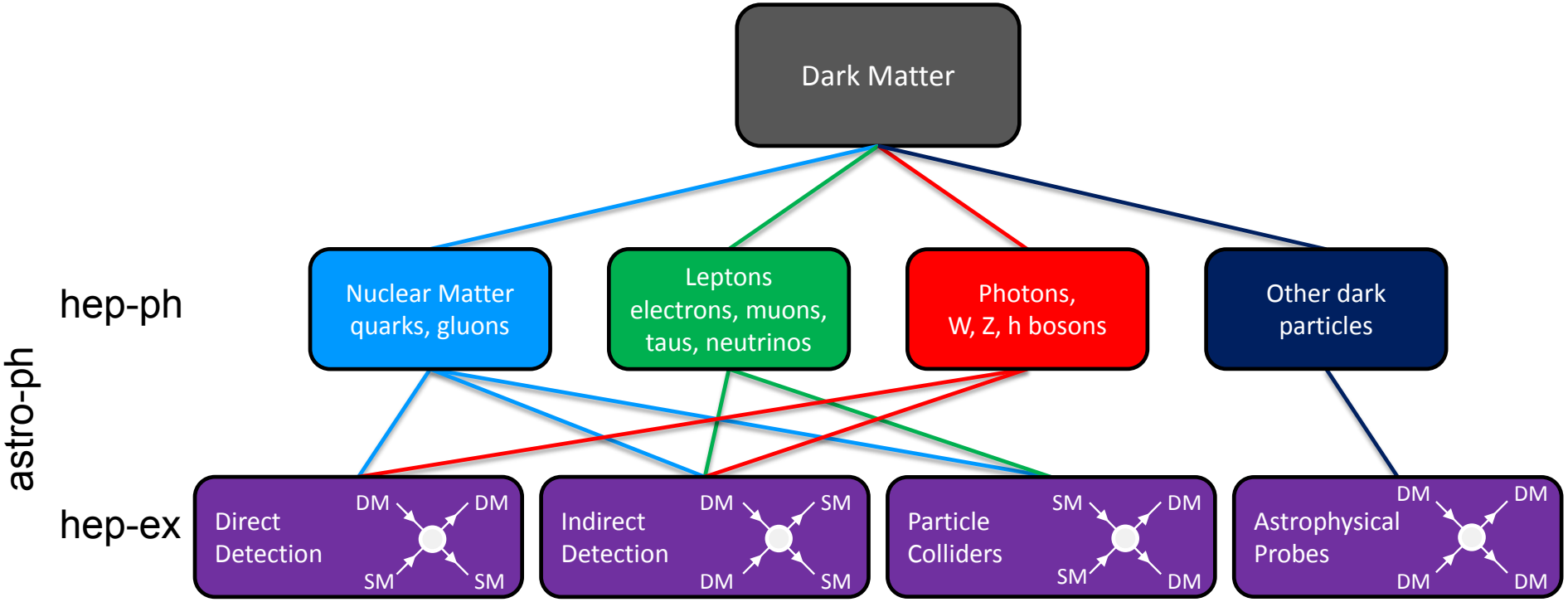
Dark Matter



What is dark matter?

- We are completely ignorant about its properties
  - mass, spin, lifetime, gauge quantum numbers
  - there could even be several DM species
- No single experiment will provide all this information
- In general, DM may couple to any of the following:

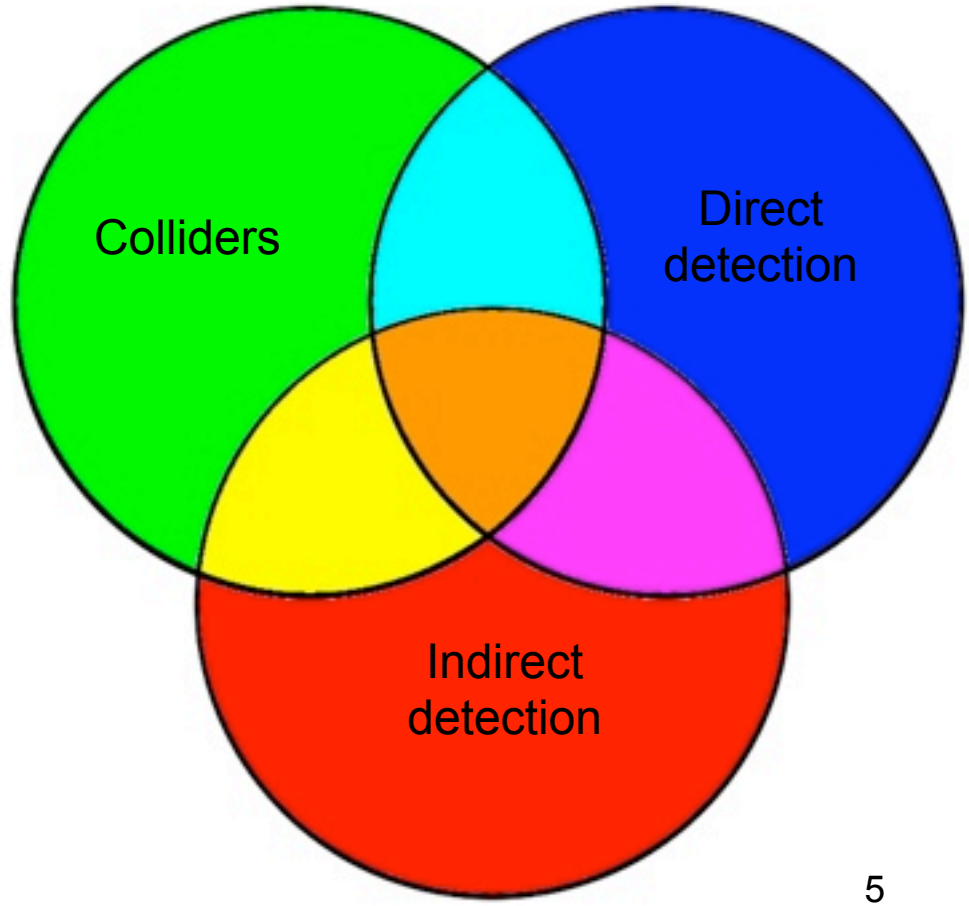


CF4 Subgroup and activities

- Who are we?
  - Conveners: D. Hooper, M. Kaplinghat, K. Matchev
  - Members: TBD... (please volunteer)
- What do we do?
  - Deliver deliverables
    - Short complementarity document in draft form (done!)
      - to be discussed tonight in EV1:CF4 session
    - Long Snowmass write-up to be completed in August
  - Talk to the other CF subgroups
    - joint sessions with CF1, CF2, CF3 at this meeting
  - Have the other CF subgroups talk to each other

How to illustrate complementarity?

- Qualitatively: the presence of a signal in:

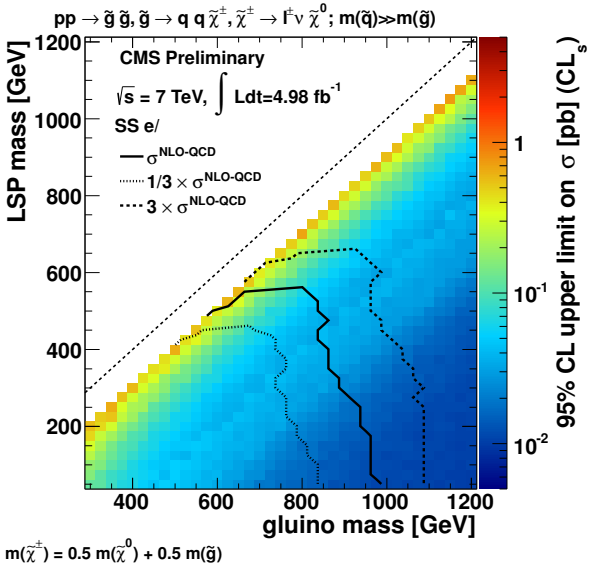


The point being this:

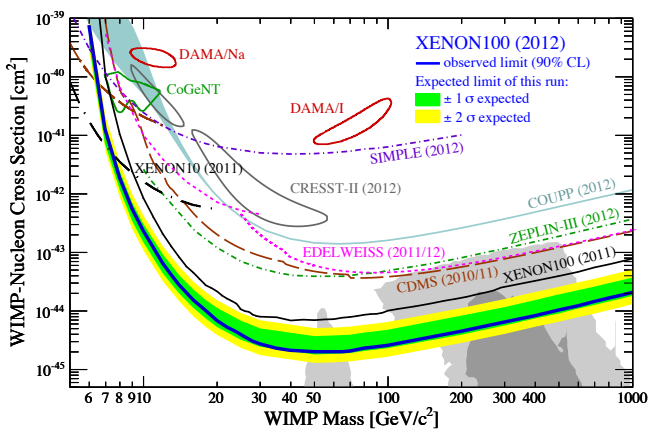
How to illustrate complementarity?

- Quantitatively: compare rates for the three probes
- Problem: different things are being plotted

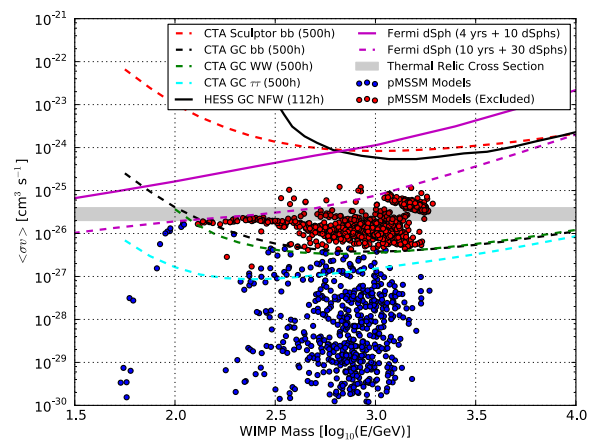
Colliders



Direct detection



Indirect detection



- How can we uniquely correlate those results?

I. Specific theory models

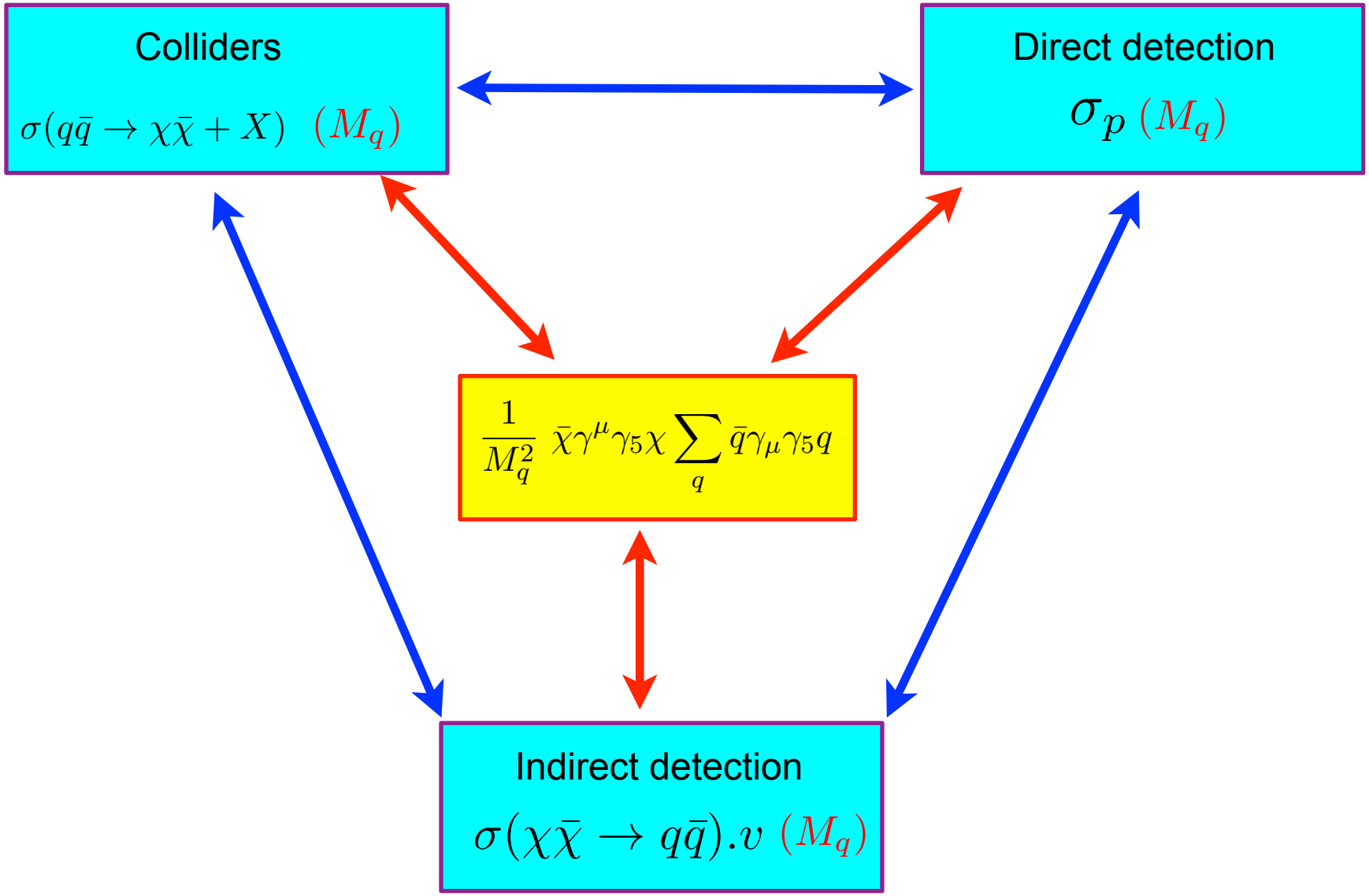
- Choose a complete new physics model with a dark matter candidate
  - See tomorrow afternoon's CF4 sessions for talks on
    - MSSM (Baer)
    - MSUGRA (Sanford)
    - NMSSM (McCaskey)
    - UED (Kong)
    - Hidden charged DM (Yu)
- Compute the three types of signals as a function of the model parameters. Impose constraints.
- Problem: too many free input parameters
  - fewer parameters come at the cost of introducing model dependent assumtions

II. Model-independent approaches

- Alternatively, be agnostic about the underlying theory model
- Parameterize our ignorance about
  - the origin of SUSY breaking
    - pMSSM talks (Ismail, Cotta, Cahill-Rowley, Drlica-Wagner)
  - the type of DM-SM interactions and their mediators
    - effective operators (Shepherd)
- Effective Lagrangian considered in the complementarity document:

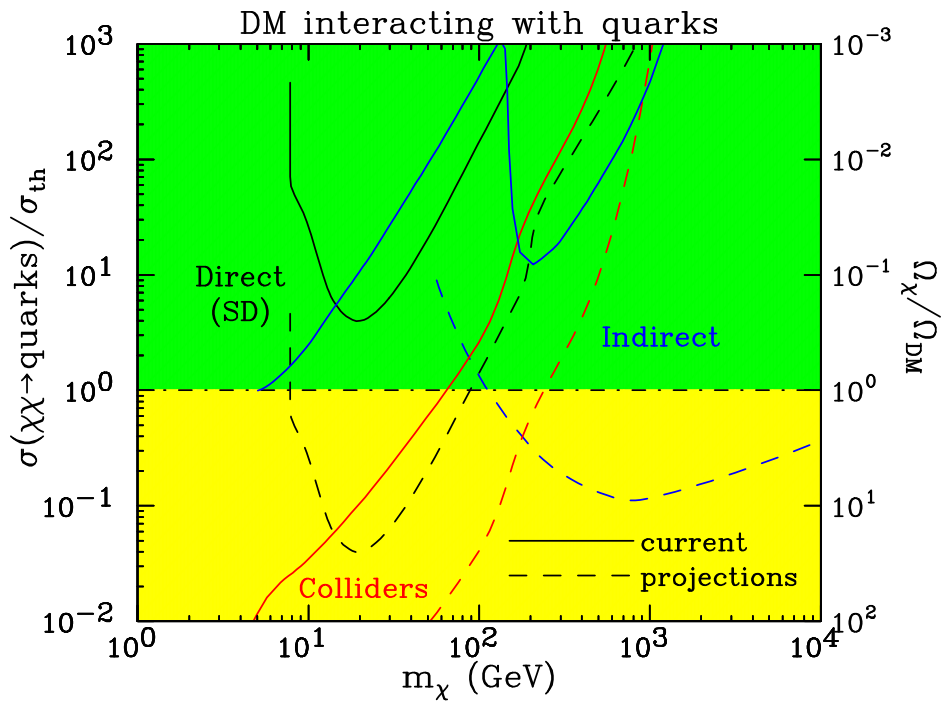
$$\frac{1}{M_q^2}\,\bar{\chi}\gamma^\mu\gamma_5\chi\sum_q \bar{q}\gamma_\mu\gamma_5 q + \frac{\alpha_S}{M_g^3}\,\bar{\chi}\chi G^{a\mu\nu}G^a_{\mu\nu} + \frac{1}{M_\ell^2}\,\bar{\chi}\gamma^\mu\chi\sum_\ell \bar{\ell}\gamma_\mu\ell$$

D8 D11 D5


Colliders
$\sigma(q\bar{q} \to \chi\bar{\chi} + X)$ (M_q)
Direct detection
σ_p (M_q)
$\frac{1}{M_q^2}\ \bar{\chi}\gamma^\mu\gamma_5\chi \sum_q \bar{q}\gamma_\mu\gamma_5 q$
Indirect detection
$\sigma(\chi\bar{\chi} \to q\bar{q}).v$ (M_q)

Comparing different DM signals

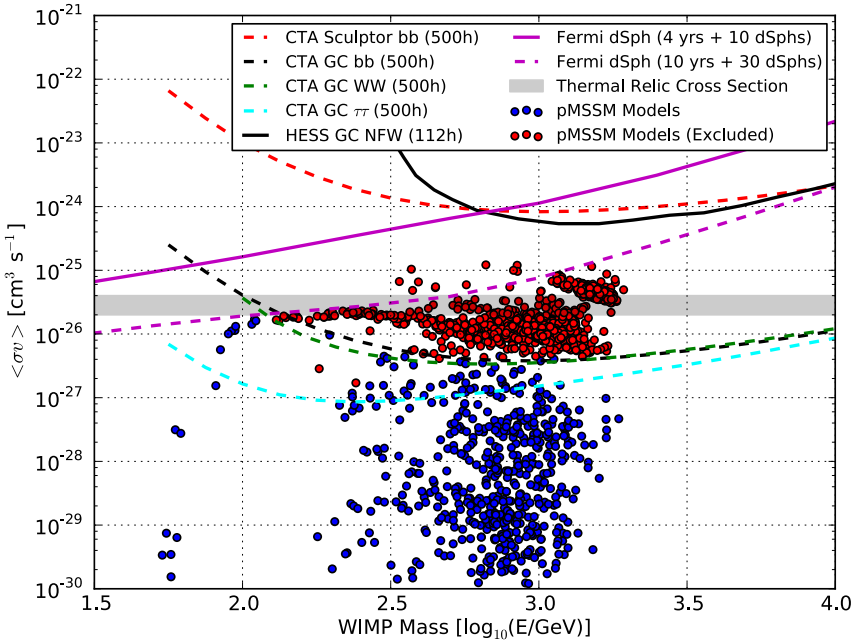
- Within this simplified model description, all DM signals can be parameterized in 4 equivalent ways
  - Production rate at colliders
  - Direct detection cross-section
  - Annihilation cross-section
  - New physics scale M_q
- Good news for CF2:
  - We chose annihilation xsec
  - but measured in funny units
- Relic density connection



$$\frac{\Omega_\chi}{\Omega_{DM}} \sim \frac{\sigma_{thermal}}{\sigma(\chi\bar{\chi}\to qq)+\sigma(\chi\bar{\chi}\to other)}$$

Summary

- What CF4 needs from CF2 - more plots like this one:
  - both current and projected experimental limits
  - extended to other channels: neutrinos, antimatter
  - adding other final states (WW,ZZ,hh)



- What does CF2 need from CF4?

BACKUPS

The importance of complementarity

com·ple·men·ta·ry (kmpl-mnt-r, -tr)
adj.
1. Forming or serving as a complement; completing.
2. Supplying mutual needs or offsetting mutual lacks.

- Observation of several signals will be needed to confirm a DM discovery
- All four probes are needed to get the full picture
- The limitations of one probe might be overcome by the strengths of the other probes
- A negative result from a given search also brings important complementary information
  - we need to find out not only what DM couples to, but also what it does <u>not</u> couple to.

Different levels of complementarity

- Between different types of probes
  - direct, indirect, colliders, astro

this document
+
Summer CF4 report

- Between different approaches within each probe
  - hadron colliders versus lepton colliders
  - indirect detection: neutrinos vs. gammas vs e^+
  - direct detection: techniques, targets, scale...

Summer
CF1, CF2, HE4
subgroup
reports

- Between different designs within each approach
  - e.g. D0 vs CDF, ATLAS vs CMS.
- Plots will be labelled simply as: “colliders”, “indirect detection”, direct detection”. The limit comes from the best experiment at that point.