Monojets:
Faster, Higher, Stronger

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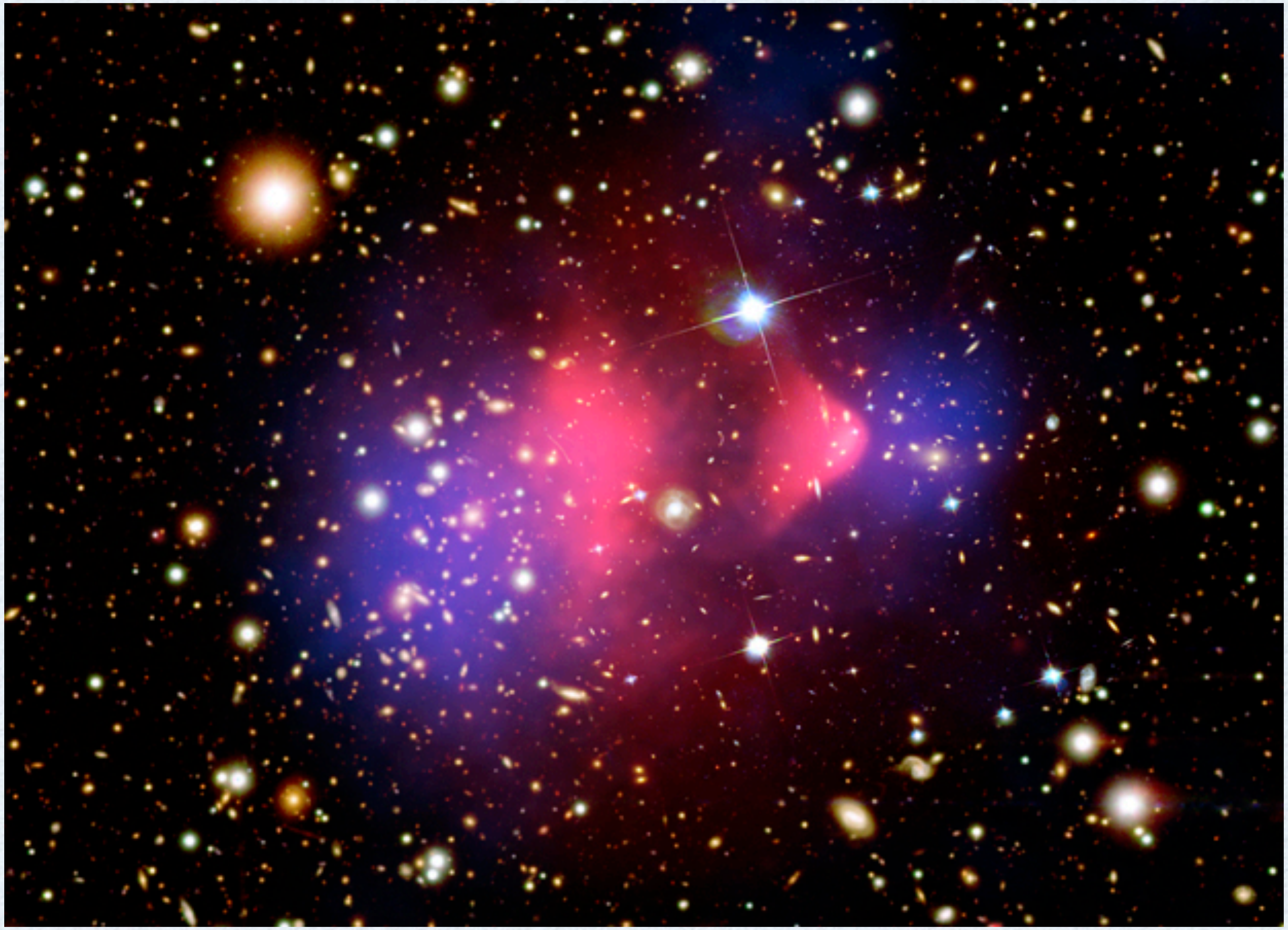
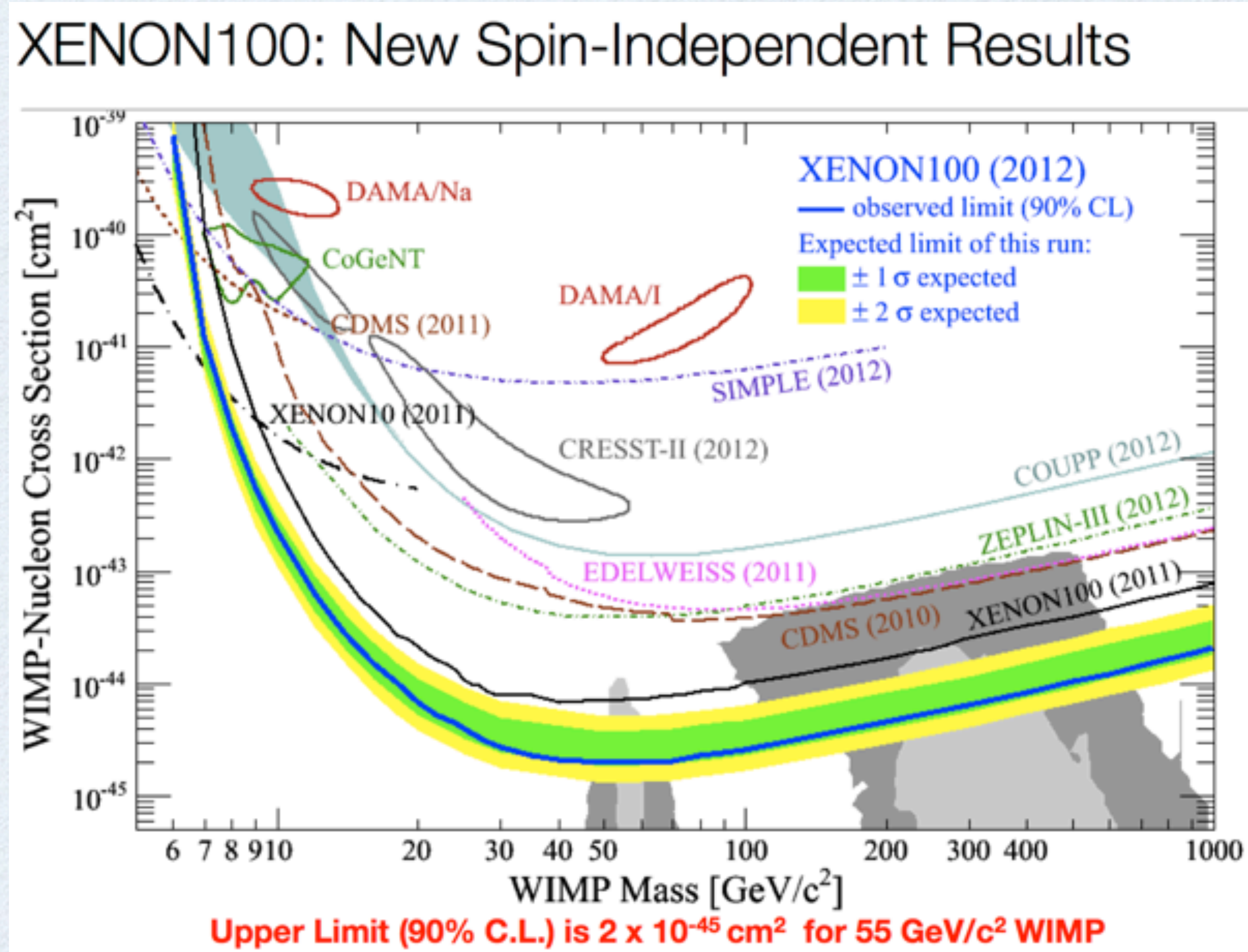
Work with K. Matchev and T. Tait
Snowmass Cosmic Frontier
and
arXiv:1305.SOON



We are confident in the existence of dark matter...

Where's
~~Waldo~~
WIMP-do?



But so far no convincing* signals for dark matter in the laboratory

Complementarity

- The LHC can be a powerful tool for studying dark matter
- Need to understand potential signals of dark matter production at the LHC and their correlation with
  - Relic Density
  - Direct Detection Signatures
  - Indirect Detection Signatures
- Important question in general-- dark matter is the best argument for new physics at LHC
- Focus of Cosmic Frontier Complementarity Document: on the arxiv tonight-ish

SNOWMASS 2013

Complementarity

- The complementarity document presents two frameworks for comparing dark matter signatures at colliders with other observations
  - pMSSM: scans over ~19 parameter MSSM parameter space
  - Effective Field Theories: describe physics in terms of operators with additional new physics states integrated out
- We'd like to think about monojet production relative to these approaches
  - **Faster**: Can we parametrize monojet cross sections in a simple way in terms e.g. of $\sigma_{LO}(p\ p \rightarrow \chi\ \chi)$? Practical use in **fast** scans of large sets of pMSSM points.
  - **Stronger**: Can we quantify the breakdown of the effective theory when additional states are lighter to strengthen sensitivity relative to EFT approaches?
  - **Higher**: **We hope to see higher rates in collider and direct detection experiments soon!!!**

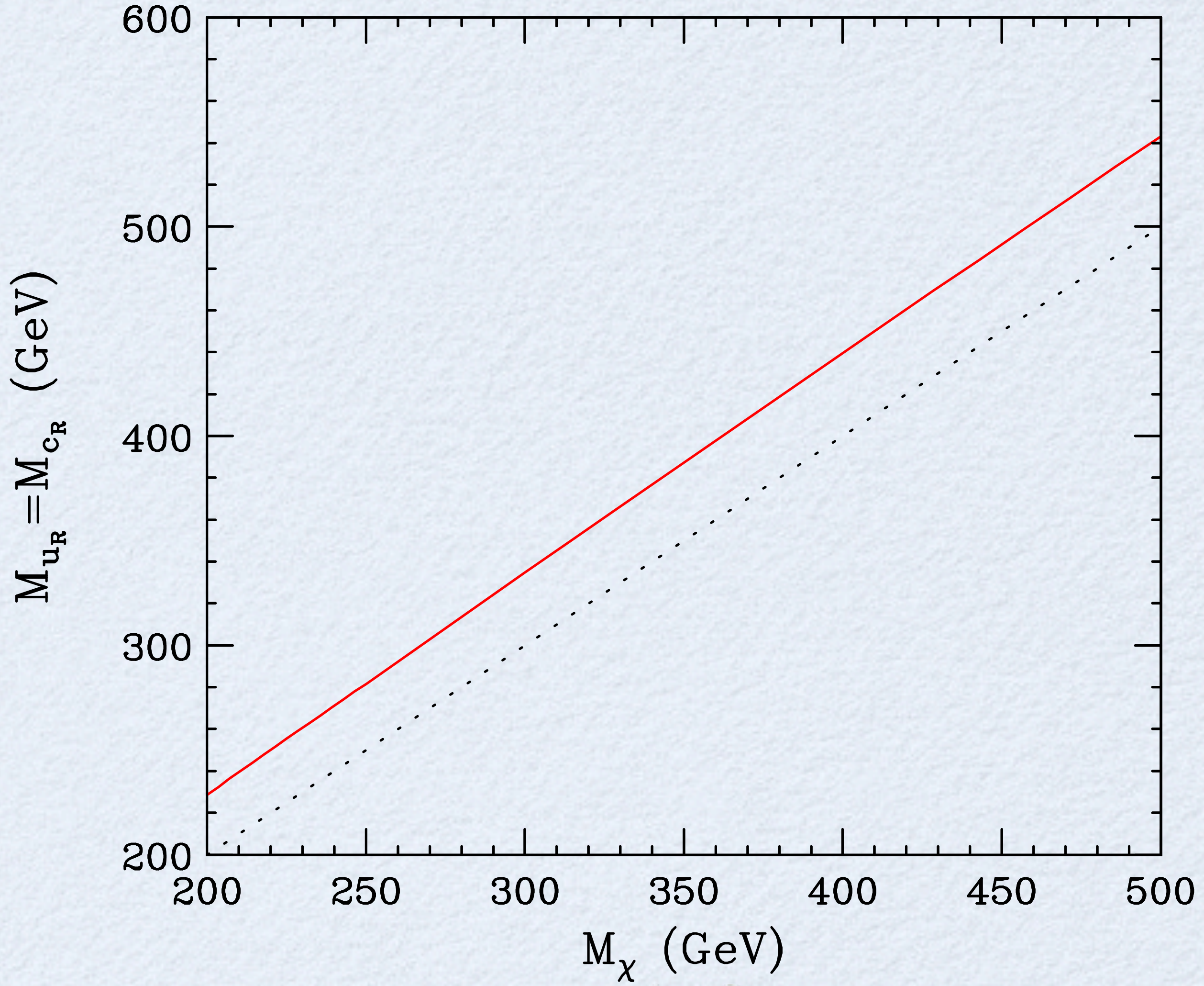
Fixing the squark mass

- We consider a pMSSM model with light ~u_R, ~c_R, bino LSP, other states heavy

- We can find the squark mass (red line) that gives the observed value of relic density for each choice of bino mass (x-axis and dotted line)

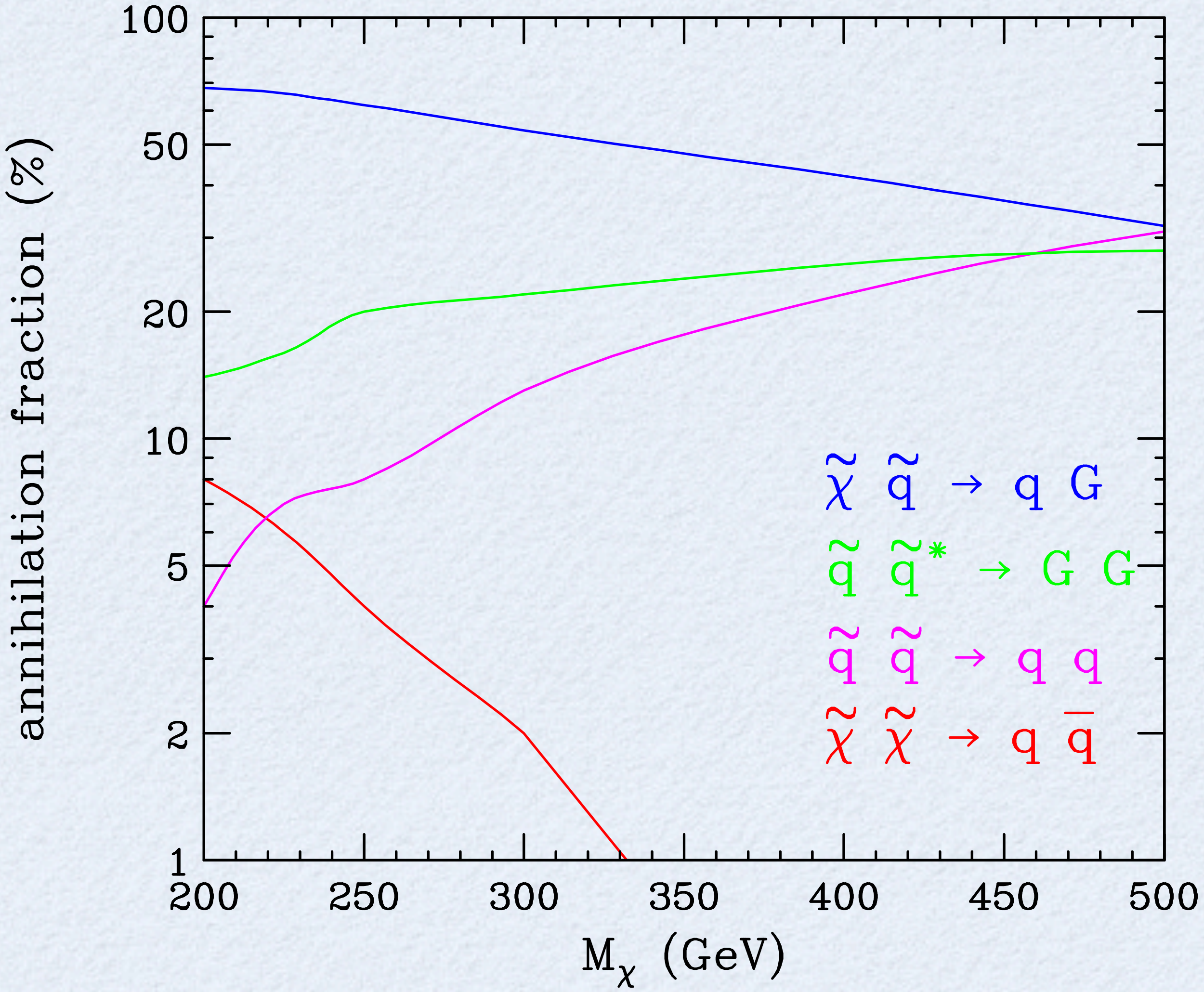
- We will look a bit at the phenomenology of this model, though monojet cross sections are suppressed in SUSY (due to Majorana fermion nature of LSP).

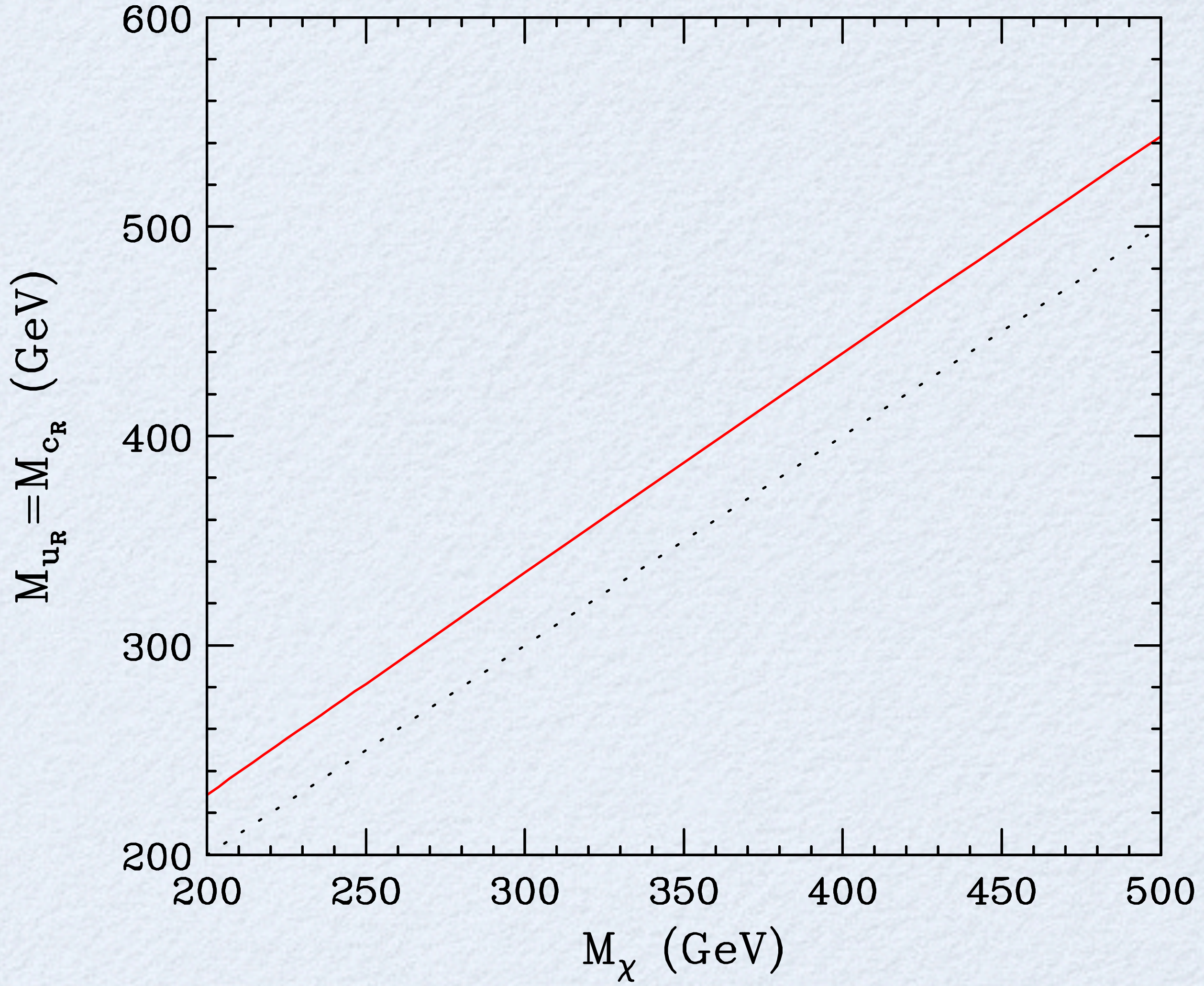
  (Though see e.g. Dreiner, Kramer, Tattersall, 2012.)



Theory hat

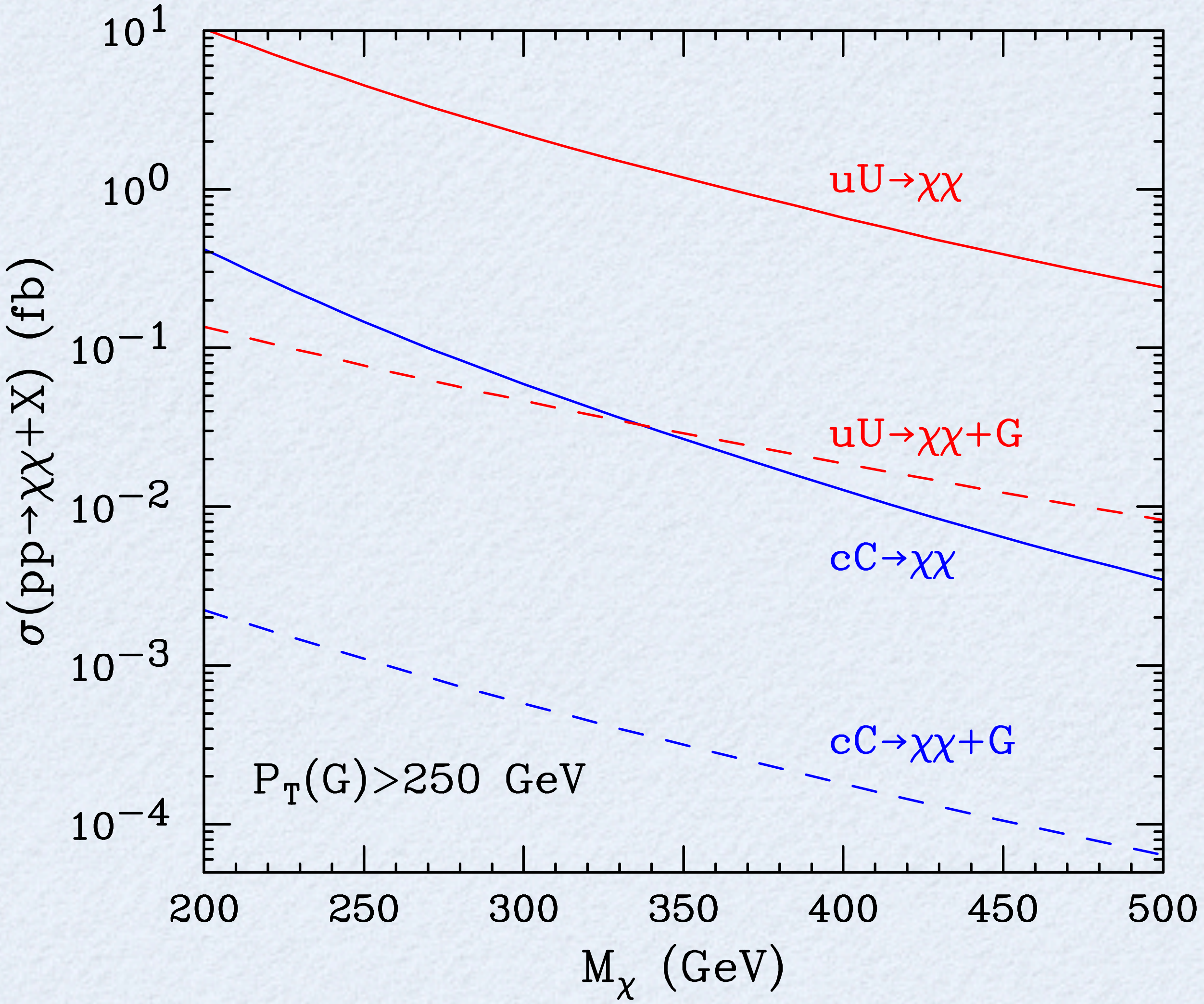
CO-ANNIHILATION





Role of various annihilation and co-annihilation channels

Monojet Cross Section



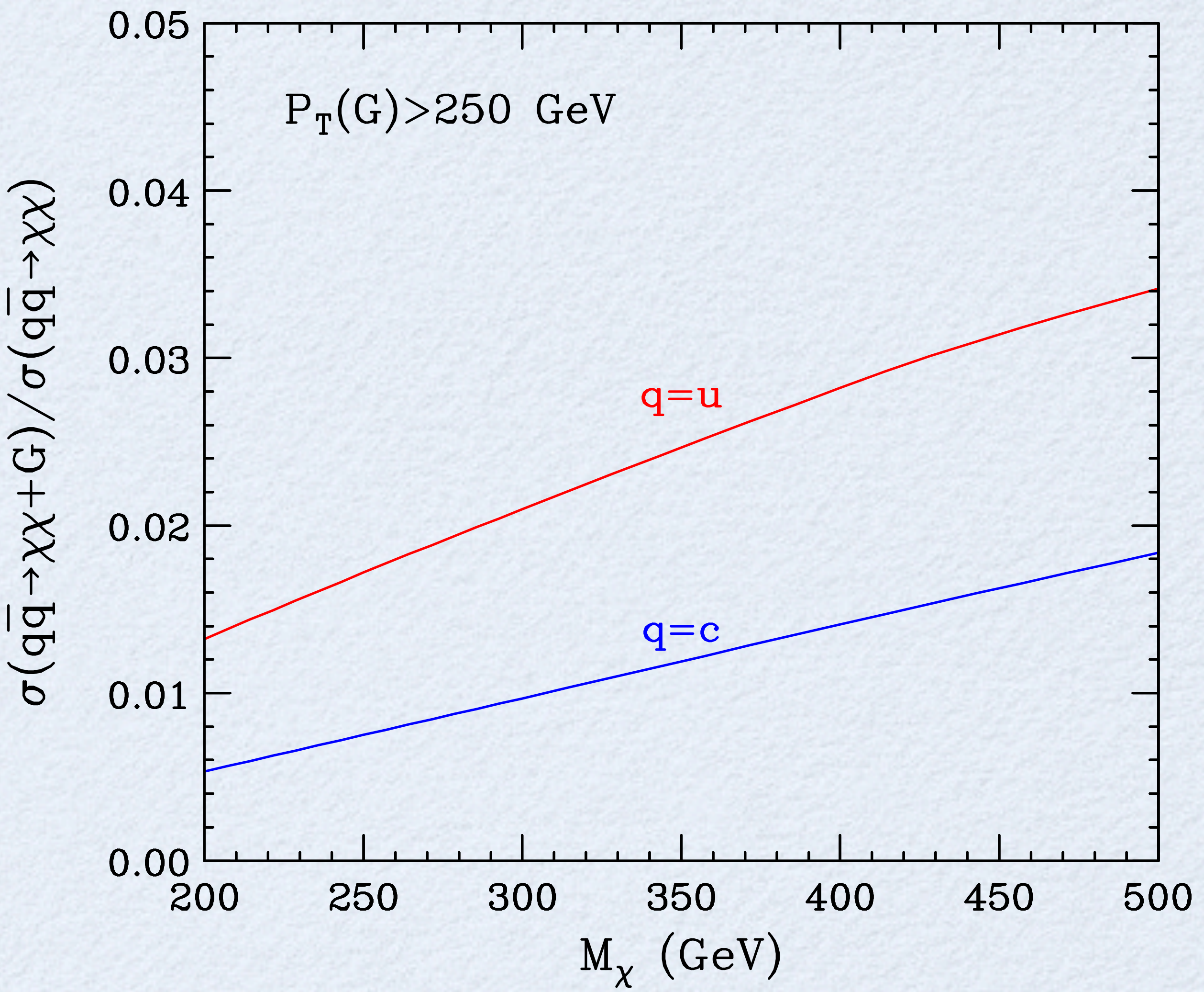
- Having fixed the squark mass, we can investigate σ(q q →χ χ) and σ(q q →χ χ g) as a function of the bino mass
- $p_{T,\,jet} > 250$, $|\eta_{jet}| < 2.5$
- (Lucky) 13 TeV LHC
- σ(q g → χ (~q → q χ)), which we are neglecting here (and later) is very significant.

  Obviously sensitive to squark mass-- so this is one way in which an EFT approach breaks down.

  We will focus for this talk on examining whether there are other ways in which the EFT approach breaks down.

Cross Section Ratio

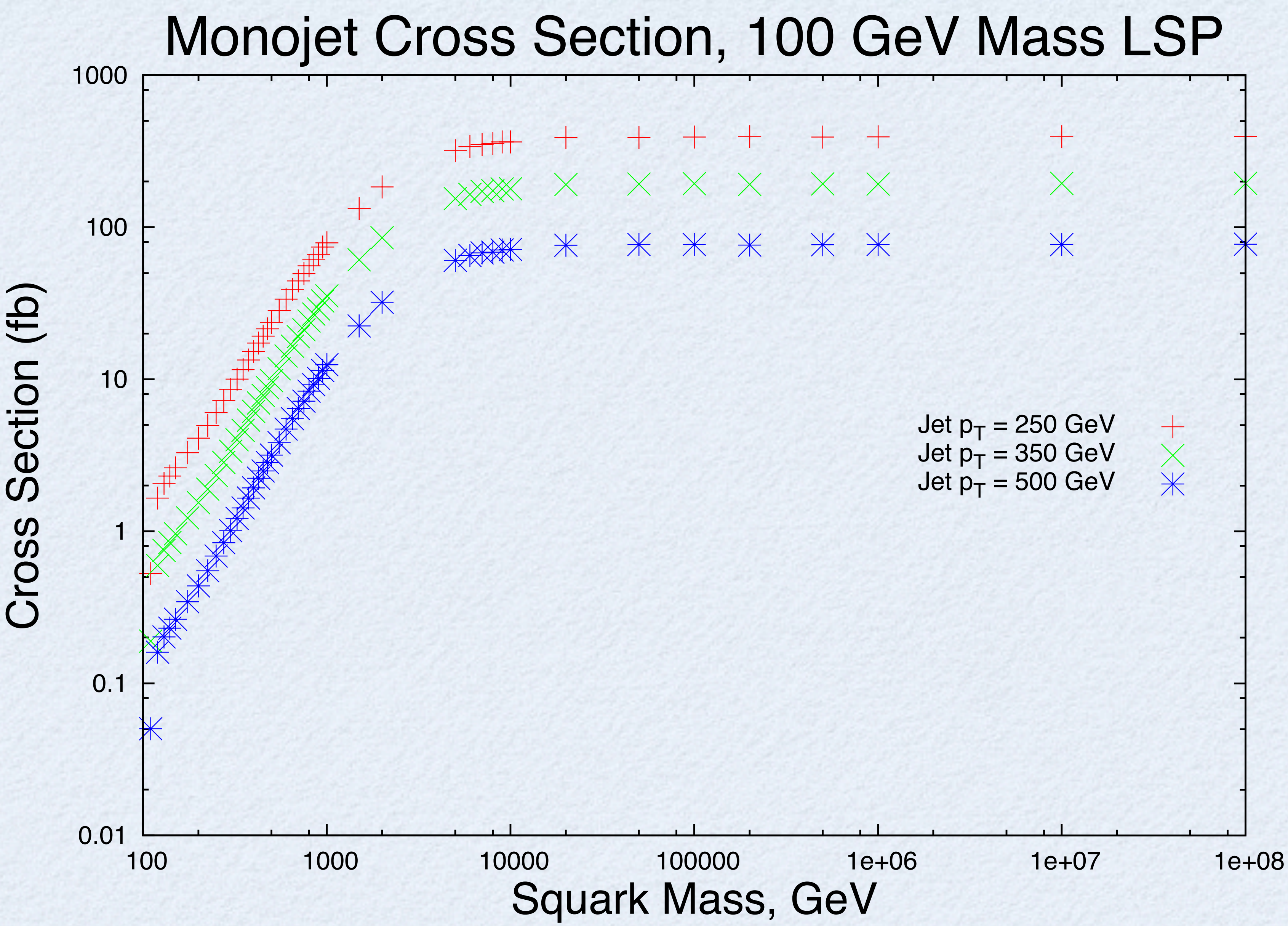
- We can use the data shown on the preceding slide to obtain the ratio of σ(q q →χ χ g) to σ(q q →χ χ) as a function of LSP mass
- Nearly (but not quite) linear
- Partial answer to "Faster" question about parameterizing monojet cross sections (but would like to know more about the dependence on collider energy, flavor of squarks, jet p_T cut, etc.)



Plus One Model

- Since couplings are specified in the MSSM, setting the squark mass to give the correct thermal relic density
- Might be interesting to create a simplified model with
  - arbitrary couplings
  - “squarks” and “binos”
  - So we still have the t- and u-channel diagrams present in the SUSY case
- **“Plus One” Model**
  - Possibly a useful extension to existing frameworks for collider/ cosmic complementarity in dark matter studies

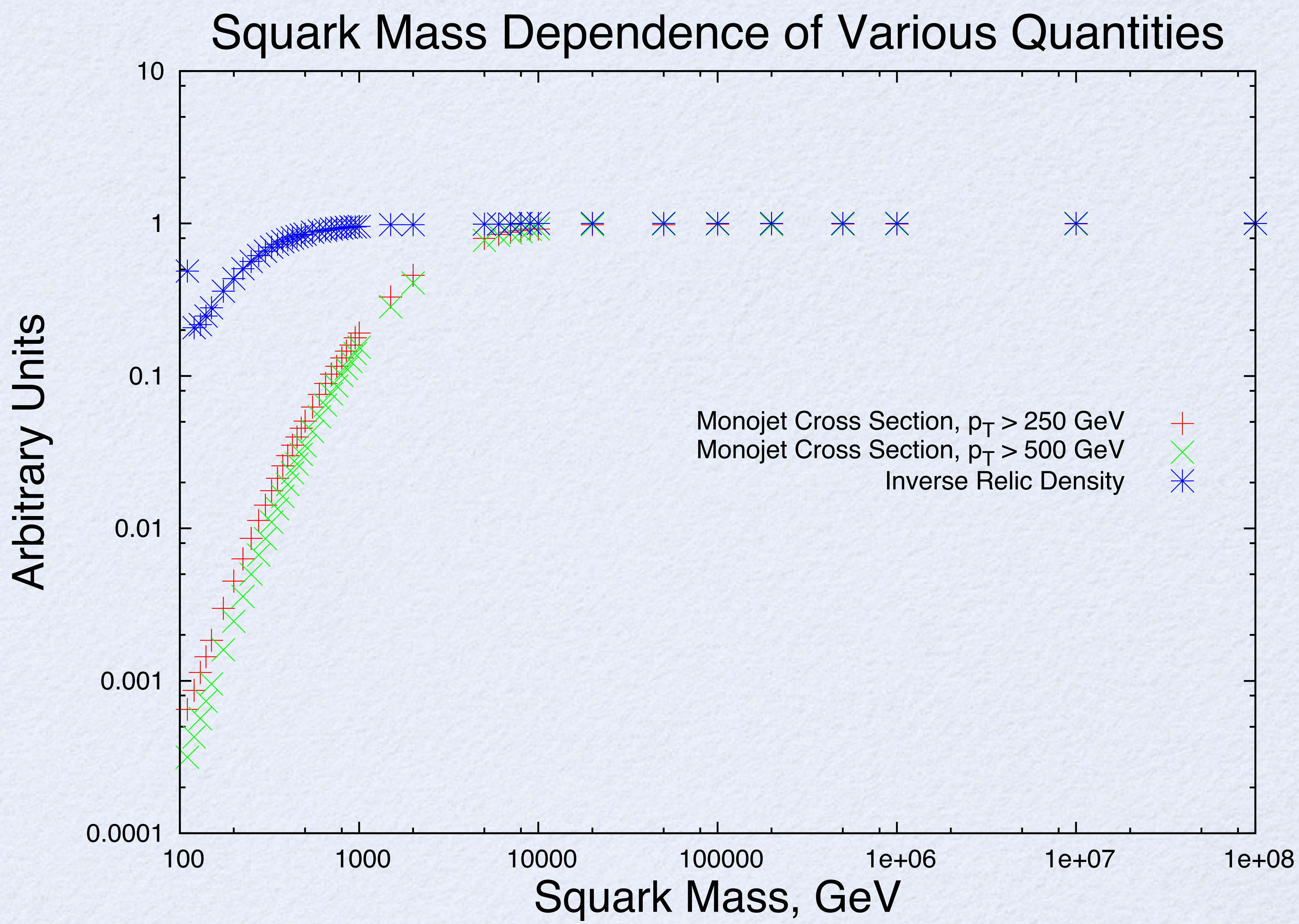
Plus one Monojet Cross Section



- Here we fix the LSP mass at 100 GeV
- Vary the squark mass
- Fix coupling to give $\Omega h^2 = 0.1199$
- $p_{T,\,jet} > 250$, $|\eta_{jet}| < 2.5$
- 13 TeV LHC
- Constant value at high squark mass corresponds to EFT value

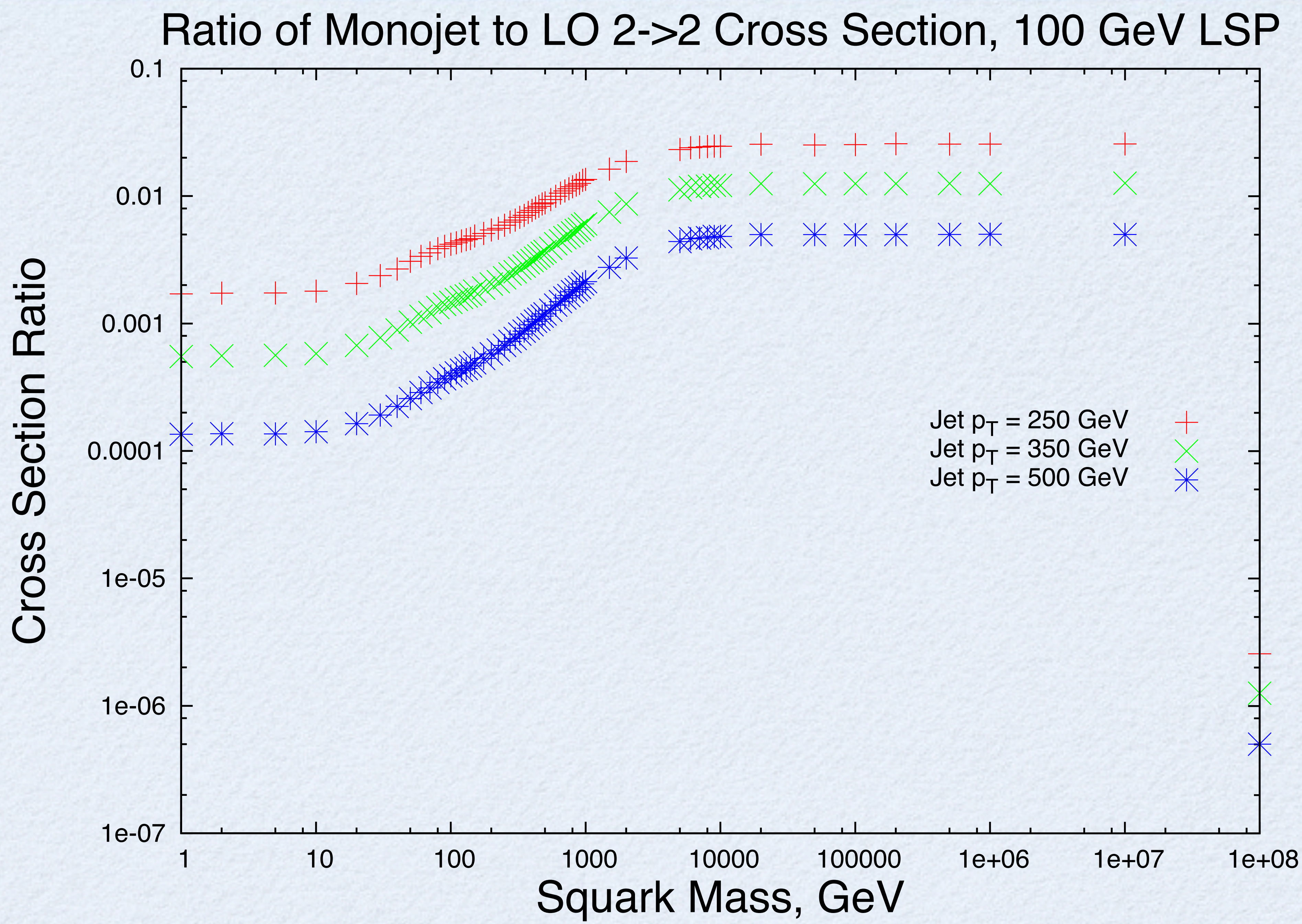
Ascending toward EFT

- Here we fix g/M
- So in region where EFT applies, constant value
- (Inverse) Relic density reaches asymptotic value at lower squark mass values
- All quantities go as ~g^4 when g is not fixed



- For low values of squark mass, t (u) dominates the t- (u-) channel propagator: suppresses dependence on M

Cross Section Ratio



- Ratio of monojet to LO 2->2 cross section for 100 GeV LSP mass at the 13 TeV LHC

Conclusions

- EFT approaches are useful for understanding collider/ cosmic complementarity
- However, we have shown a concrete example where the value of the monojet cross section predicted from the relic density is (for squark mass less than ~10 TeV)
  - strongly suppressed
  - squark mass dependent
- Monojet cross section as function of LO 2->2 cross section seems better behaved: constant high and low squark mass regimes
- Important to perform a similar analysis for models which give larger monojet cross sections
- **We look forward to the discovery and exploration of dark matter in complementary experiments!!!**