A Theorist's View on the Current Status of SUSY Searches

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Rutgers University

BNL Workshop on SUSY with 5/fb

May 3, 2012

SUSY at the LHC

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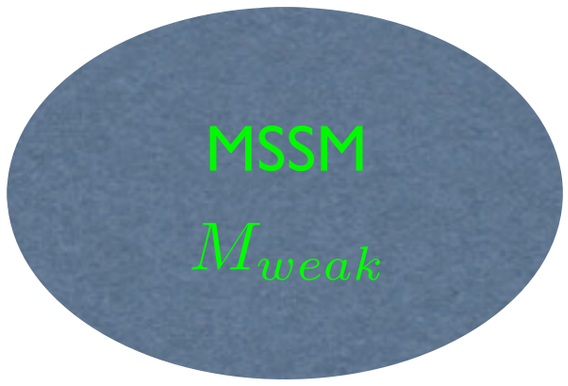
- While it is disappointing that SUSY was not "just around the corner," I hope you will agree that there is still much discovery potential remaining!

The SUSY Paradigm



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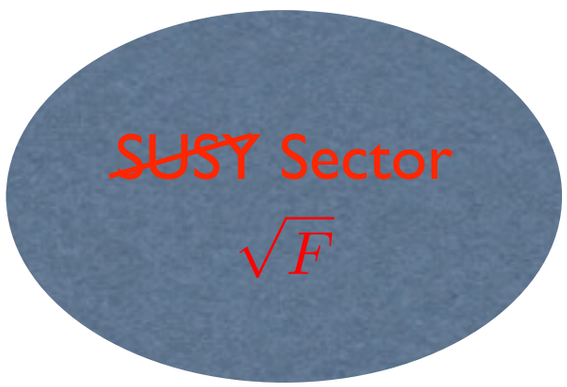

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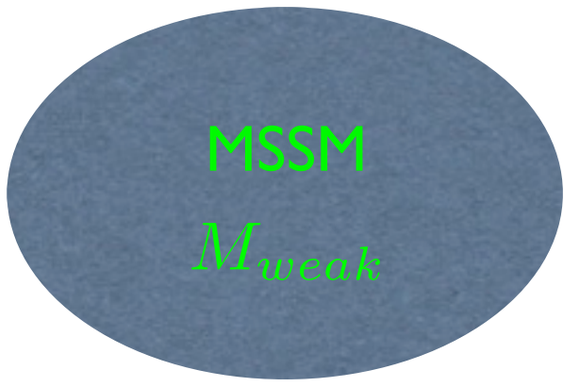

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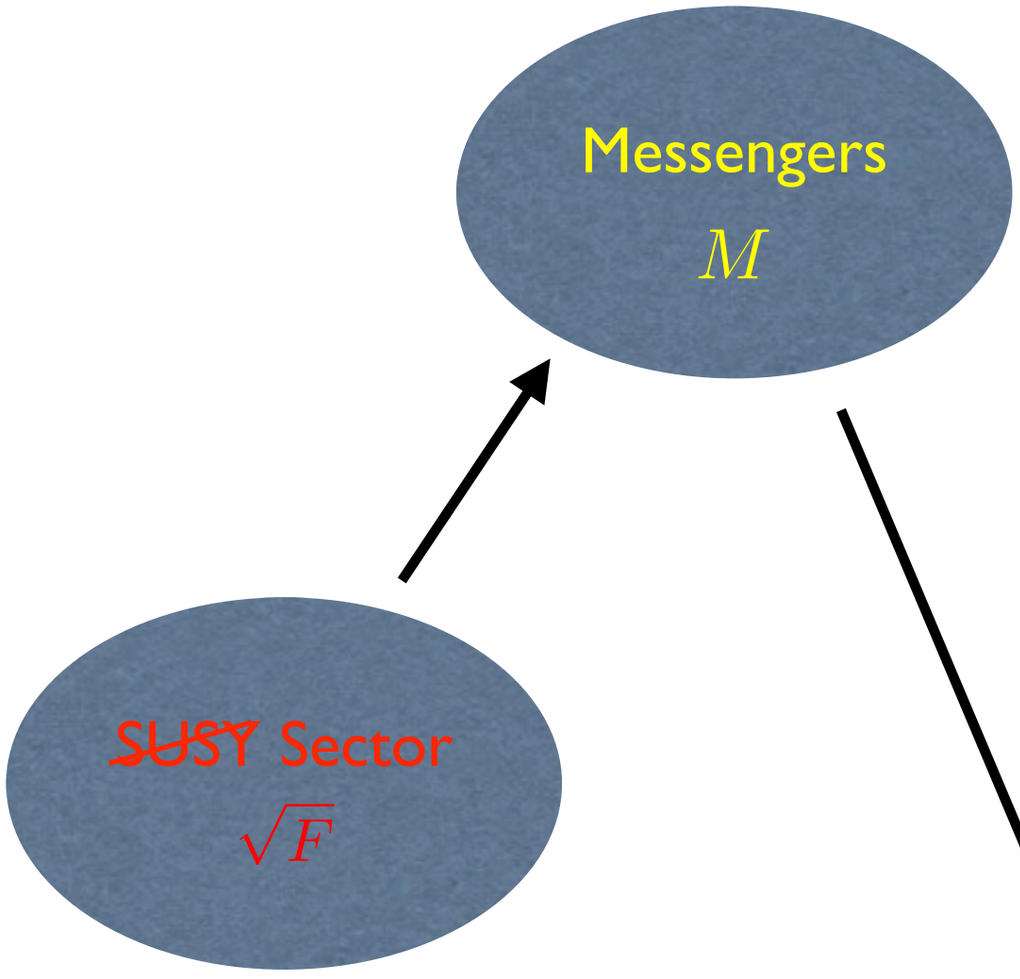

And then communicated through loops of "messengers."

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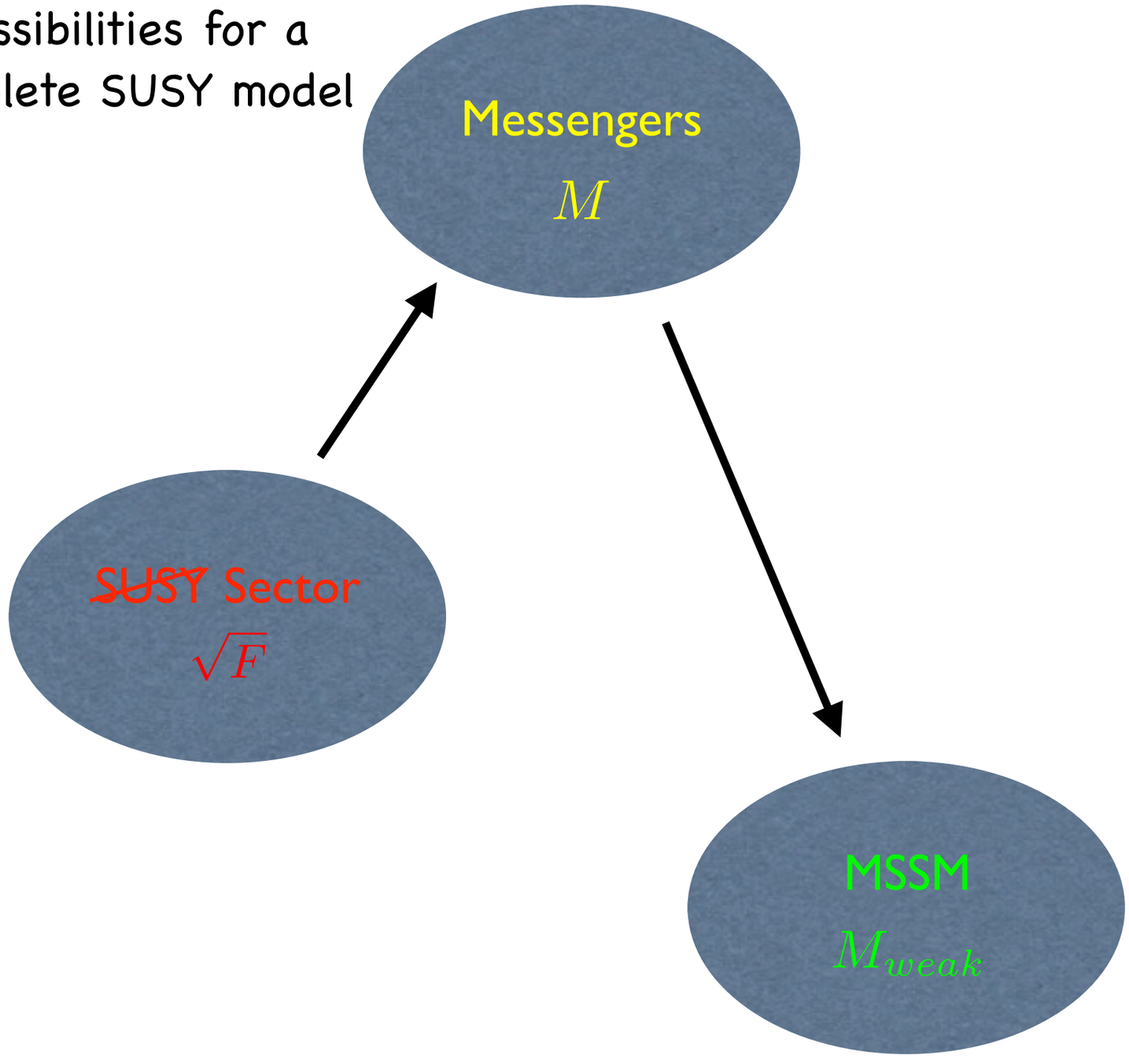

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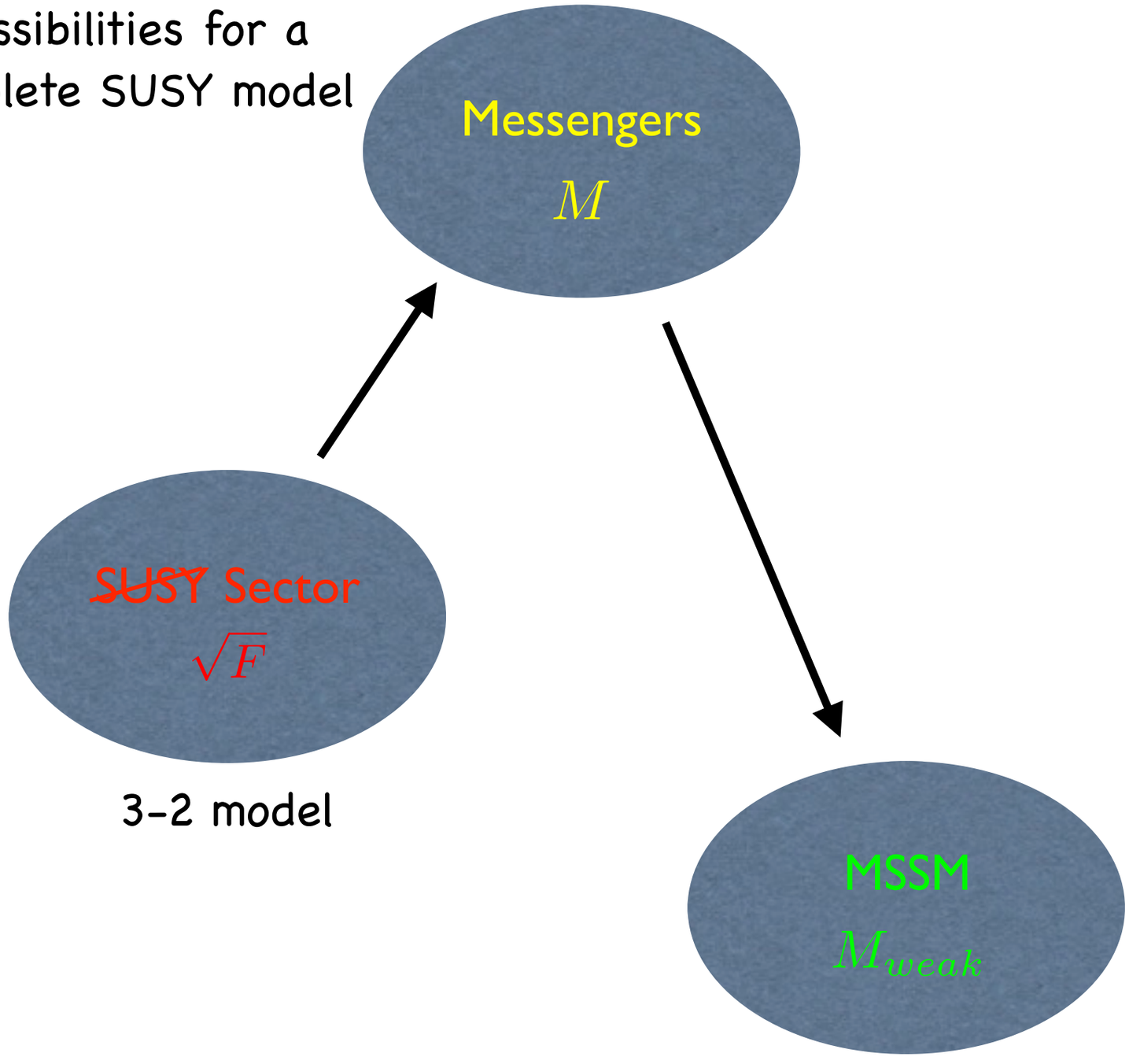

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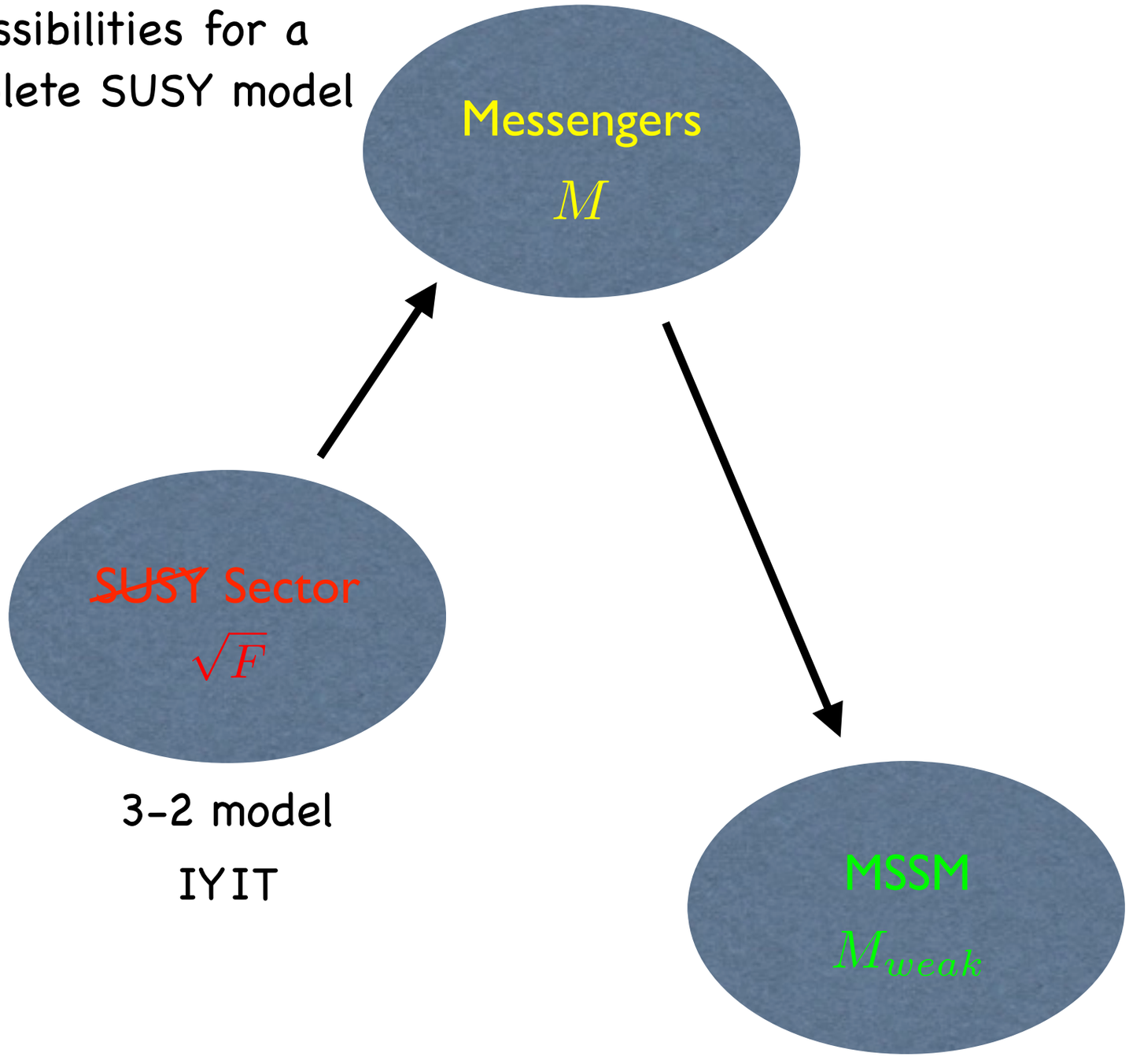

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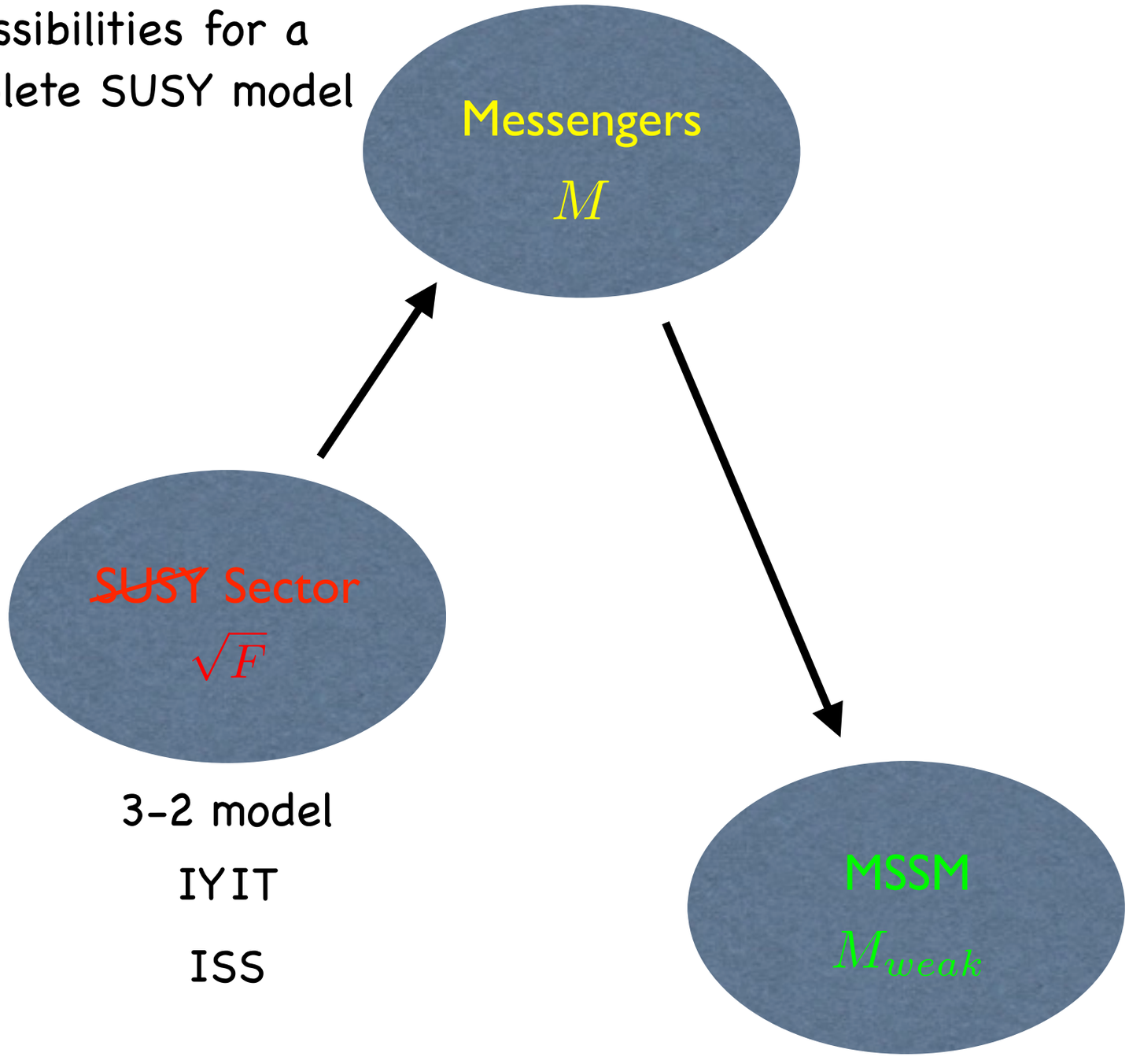

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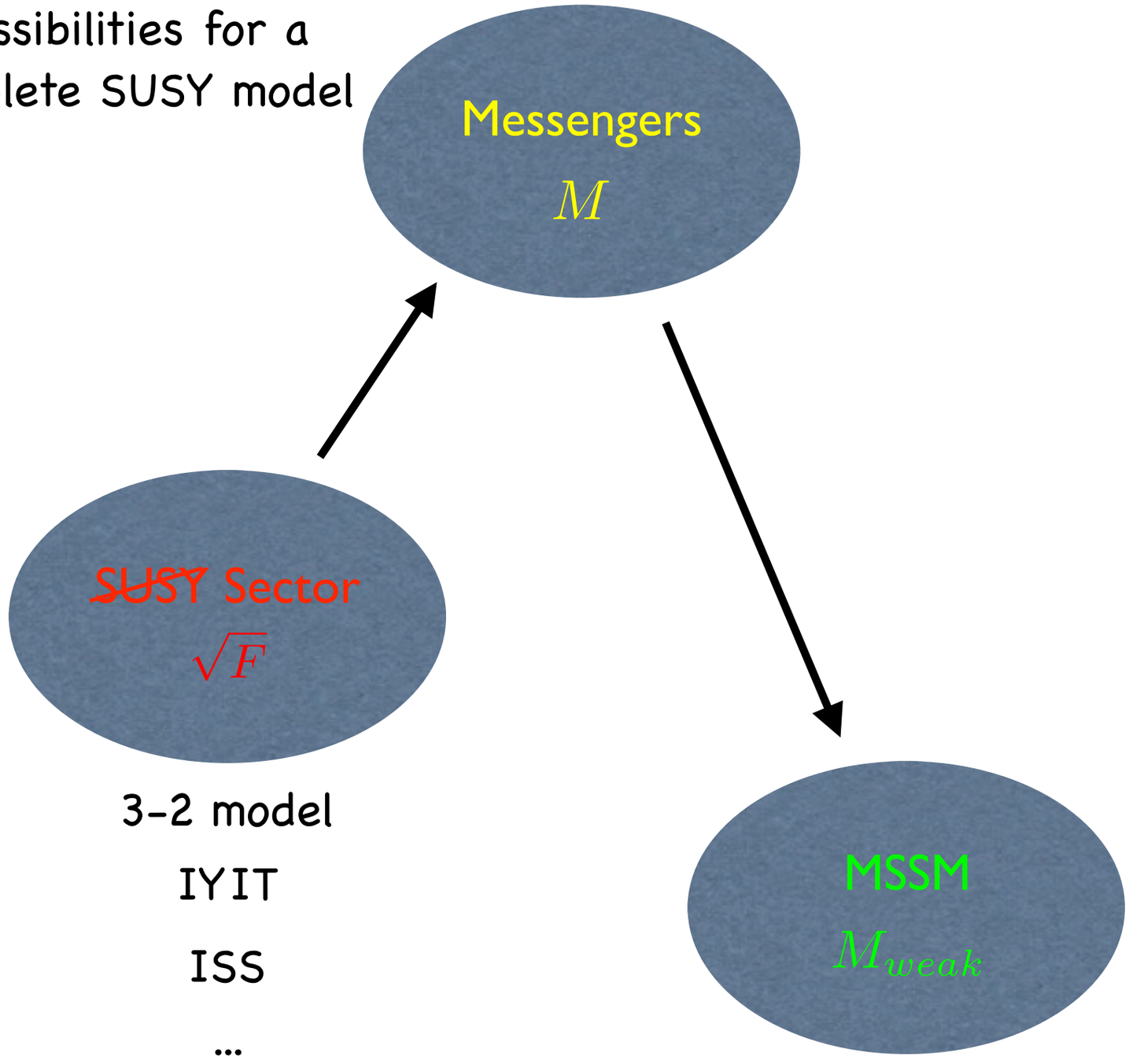

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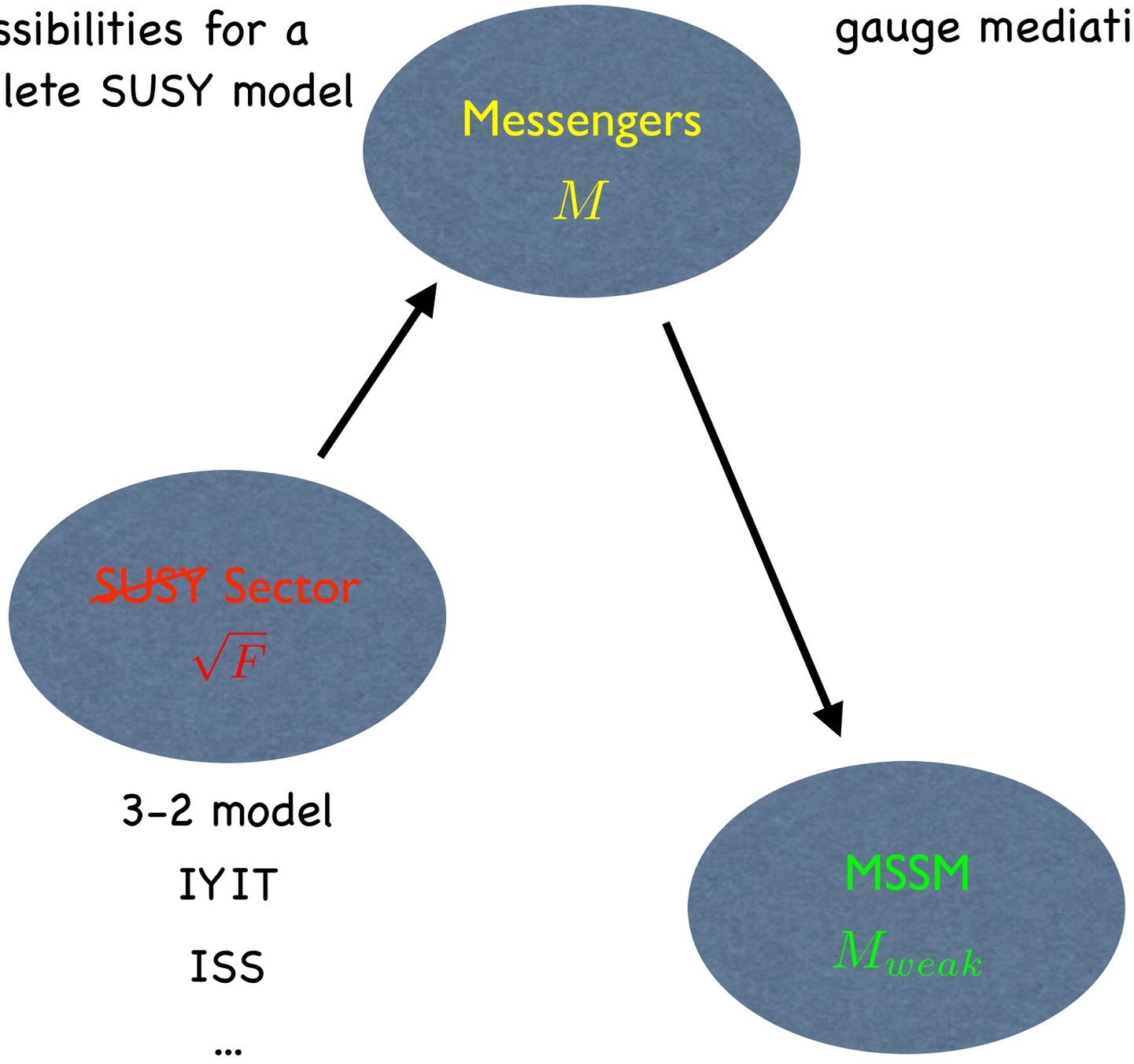

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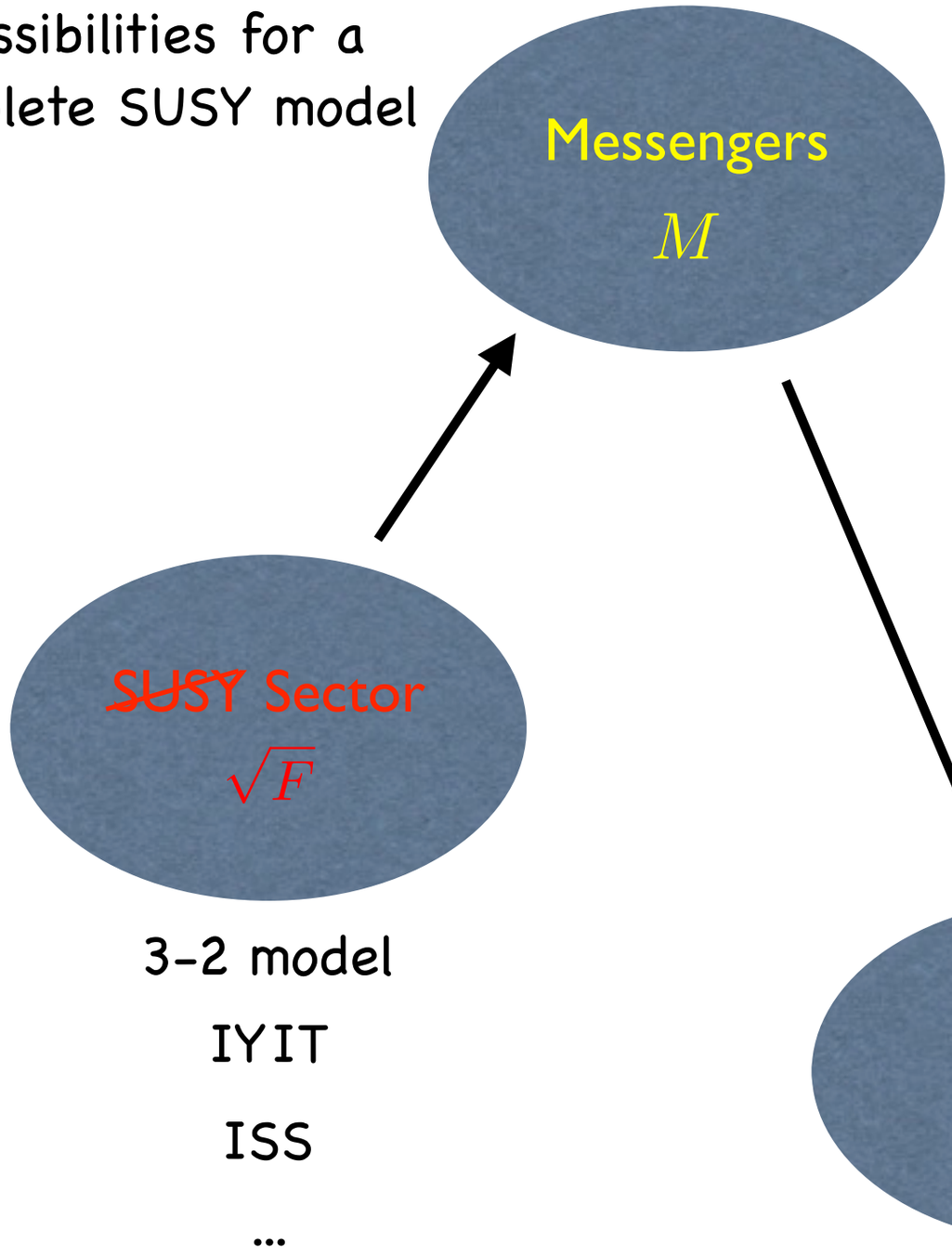

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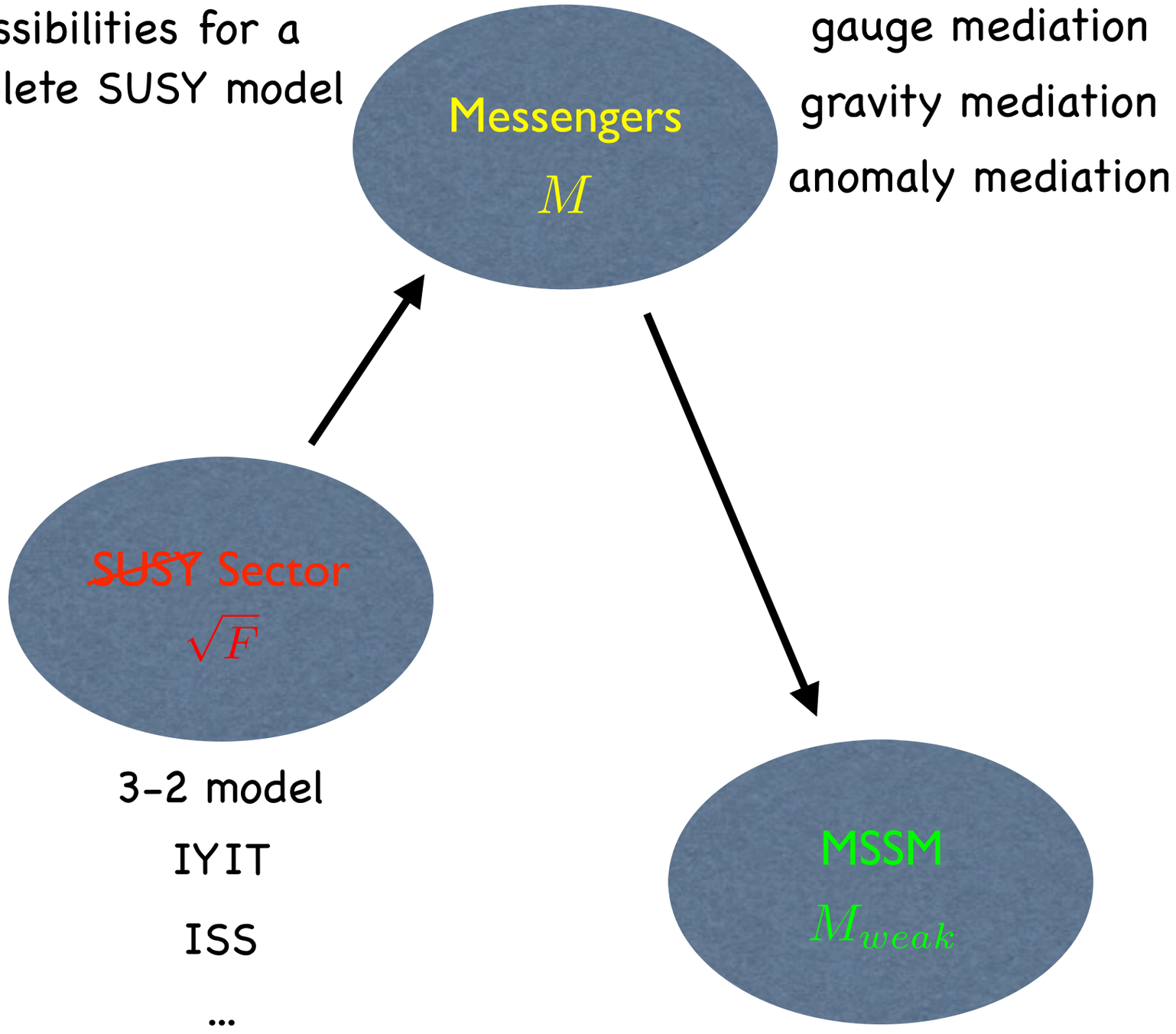

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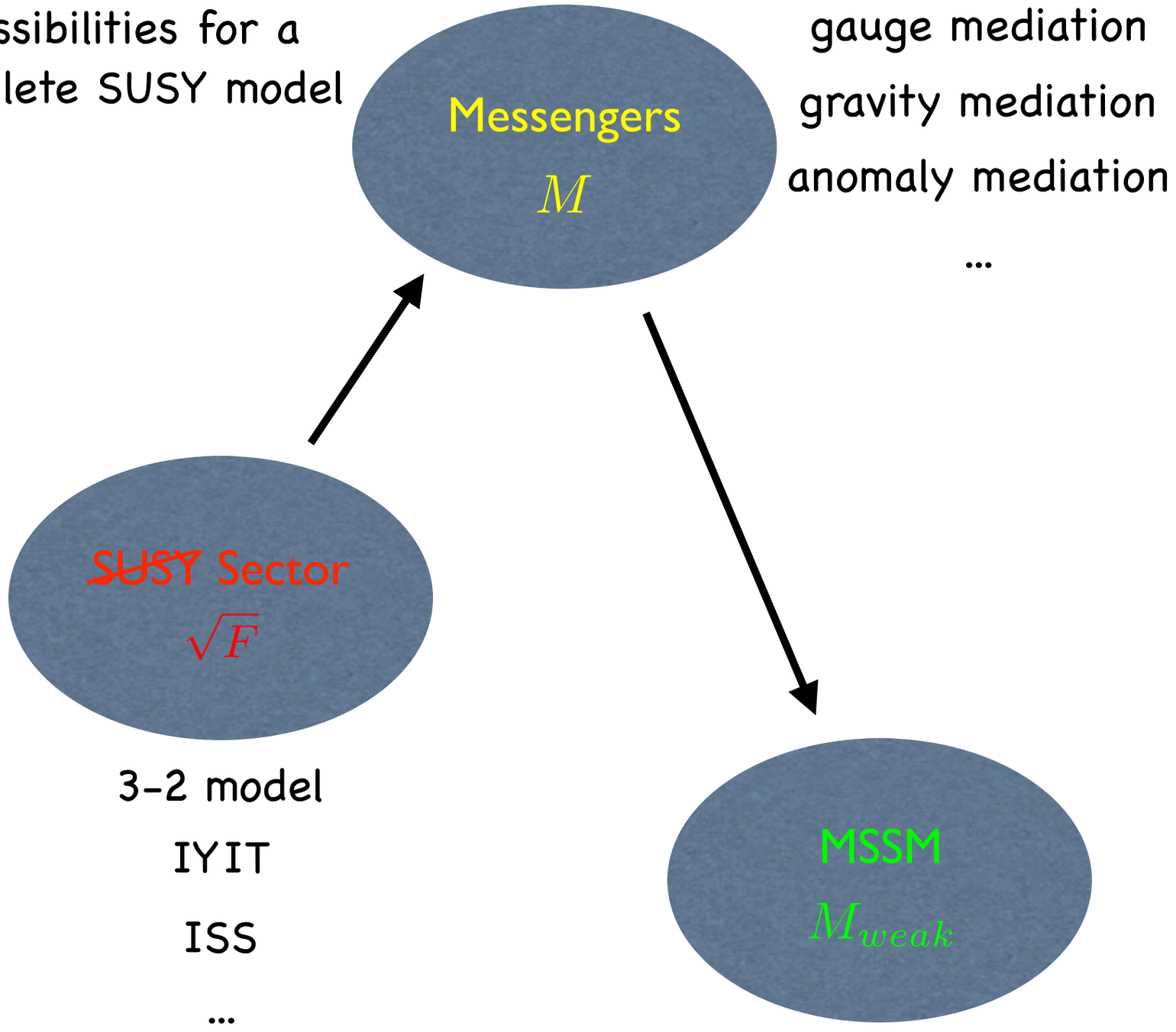

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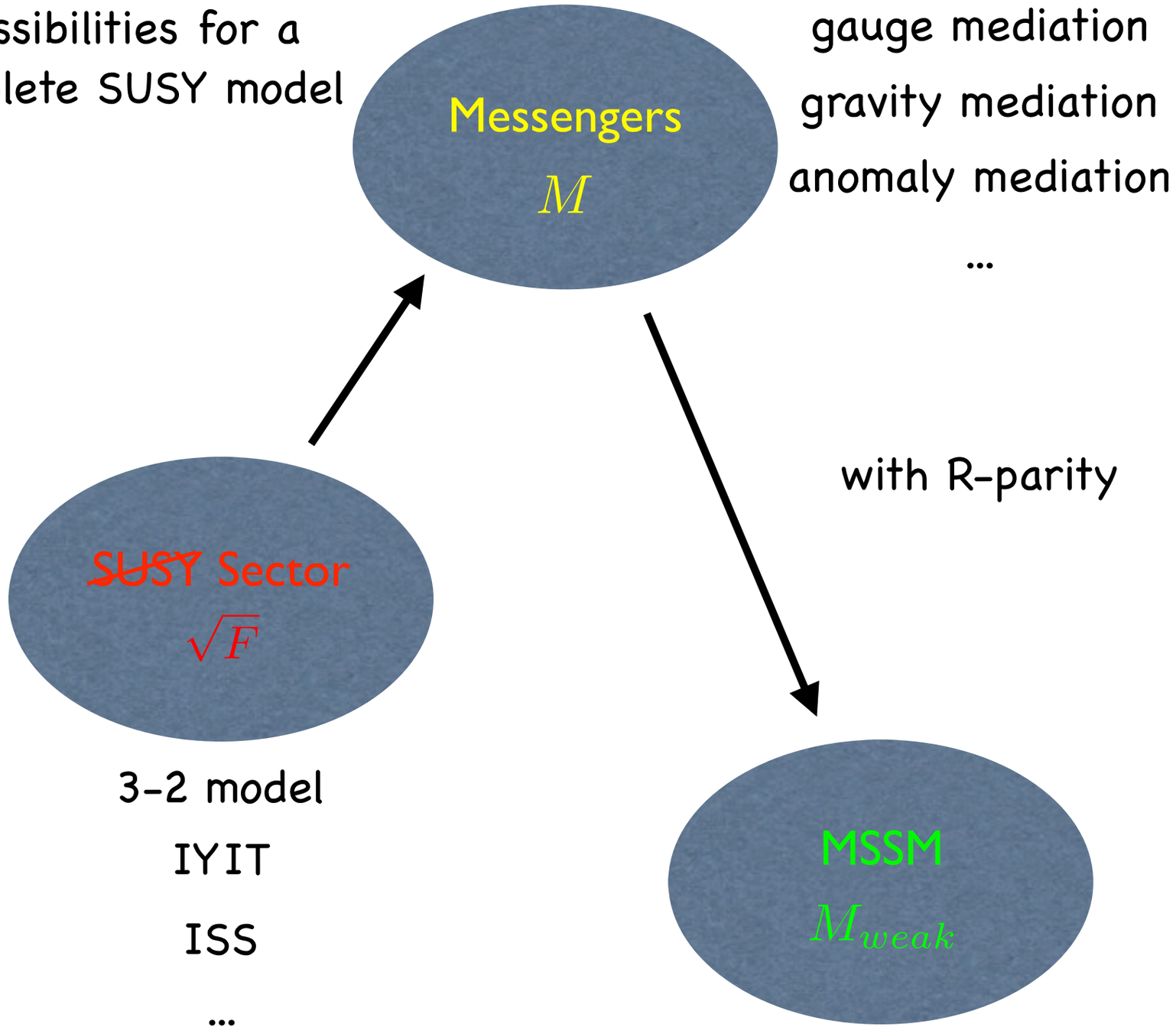

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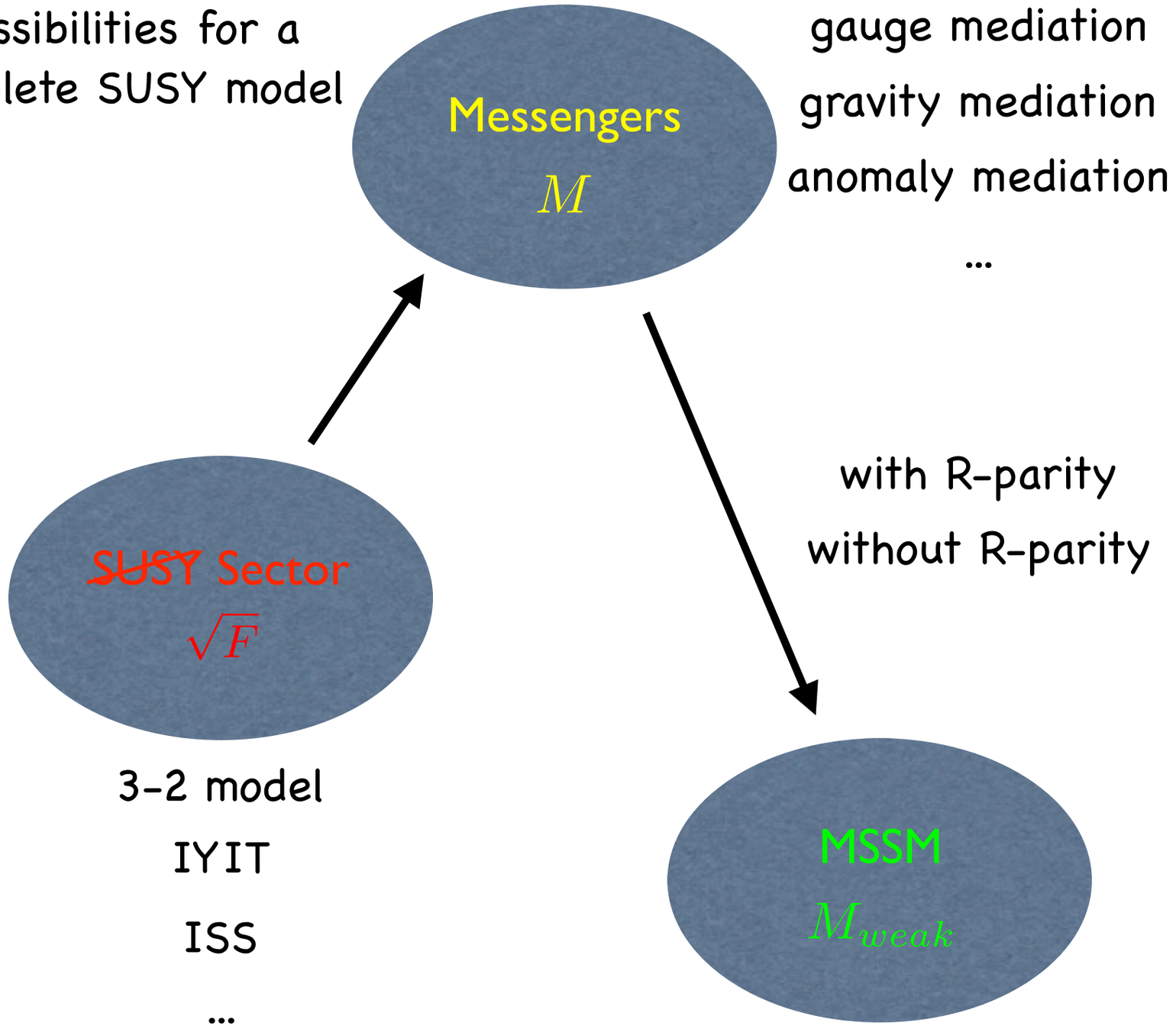

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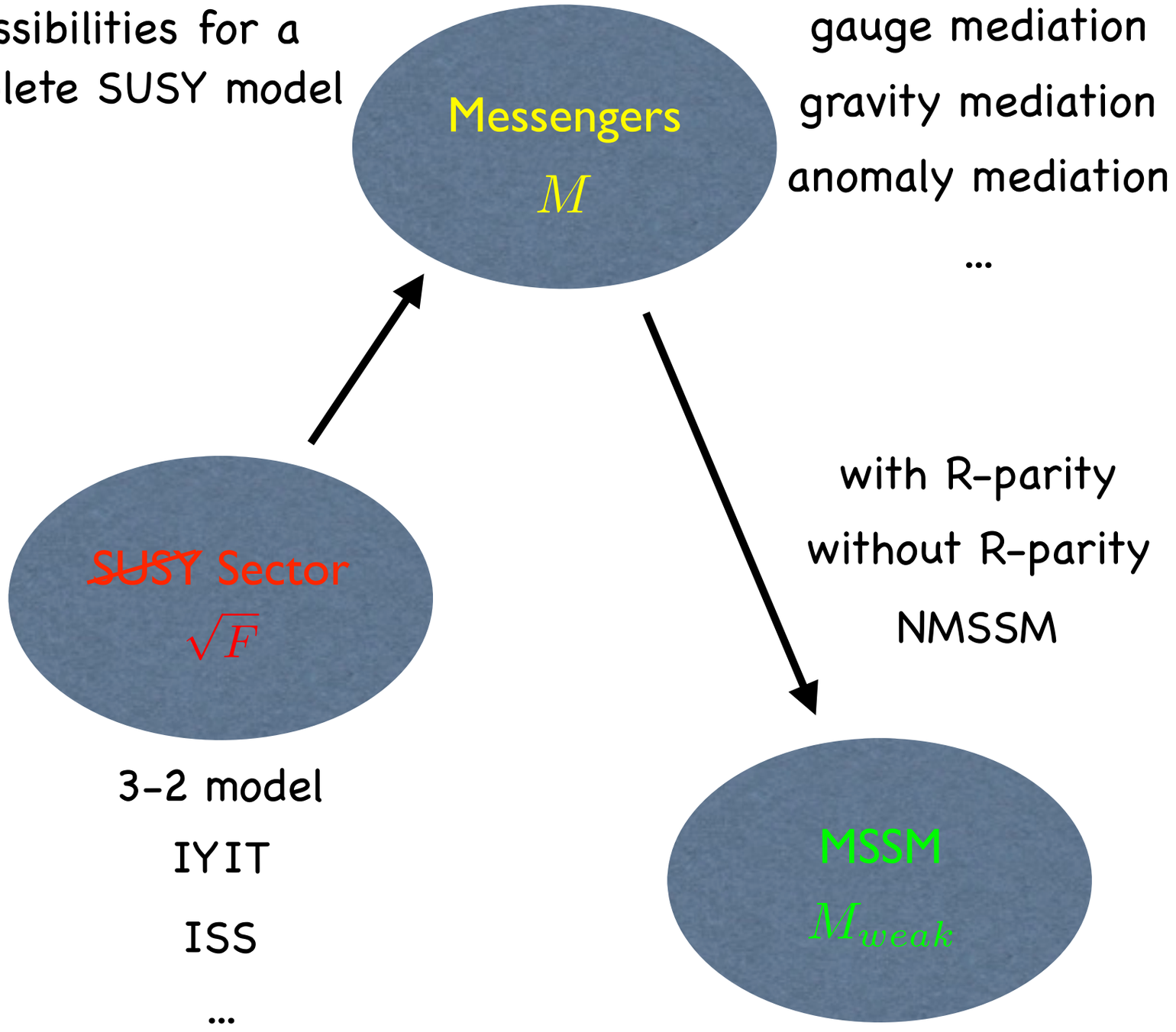

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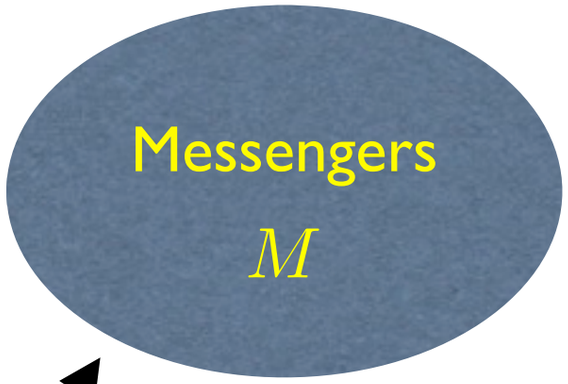

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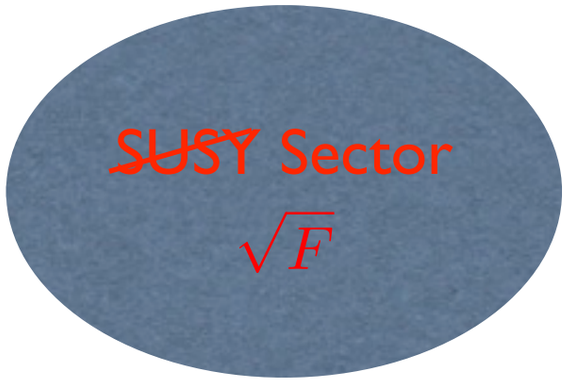

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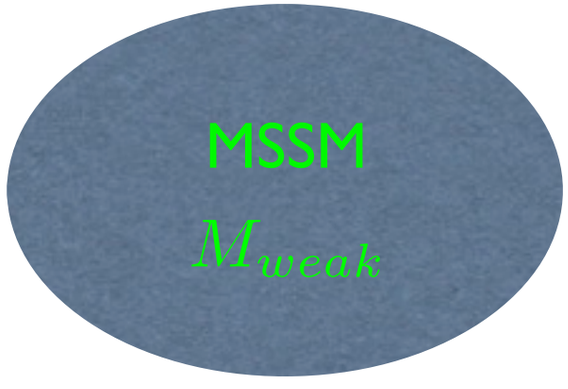

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Signatures

Most of these details are not immediately relevant for collider signatures!!!

SUSY Scenarios

Type	Mediation Scale	LSP	Pros	Cons
Gravity mediation	Planck-scale	Neutralino or sneutrino	WIMP DM candidate; automatic mu/Bmu	severe SUSY flavor problem; uncalculable framework
Anomaly mediation	super-Planck-scale	Neutralino (wino)	no SUSY flavor problem	tachyonic sleptons; requires "sequestering"
Gauge mediation	sub-Planck-scale	gravitino	no SUSY flavor problem; calculable framework; viable spectrum	no WIMP DM mu/Bmu problem

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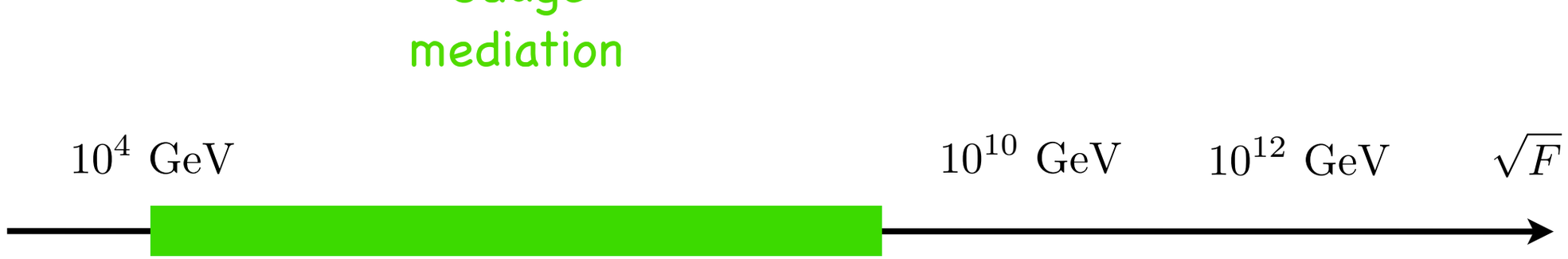

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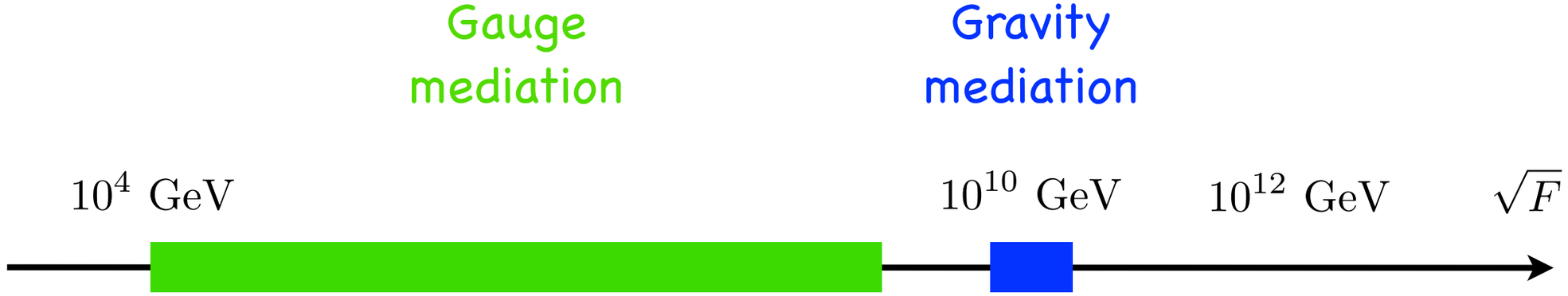

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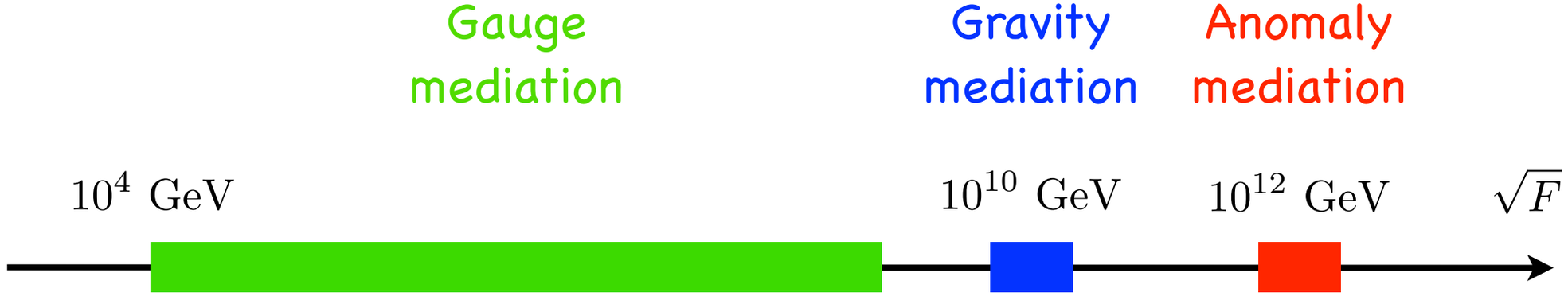

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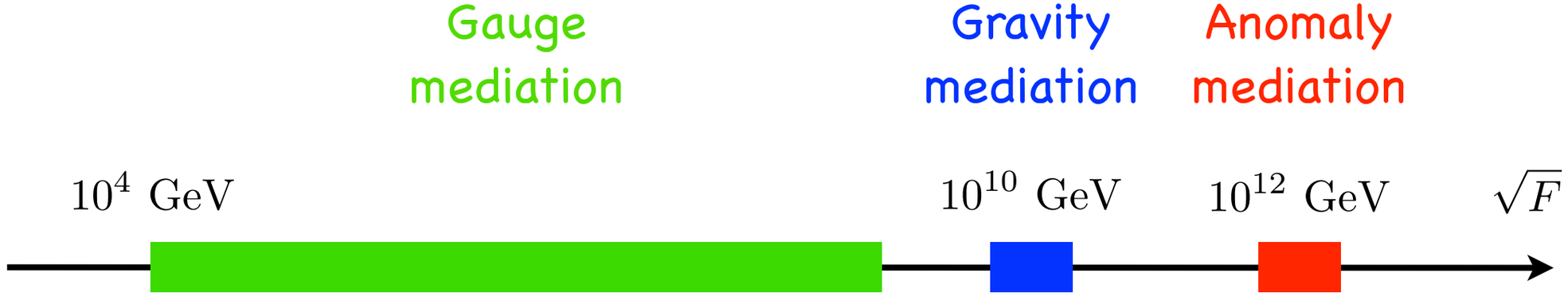

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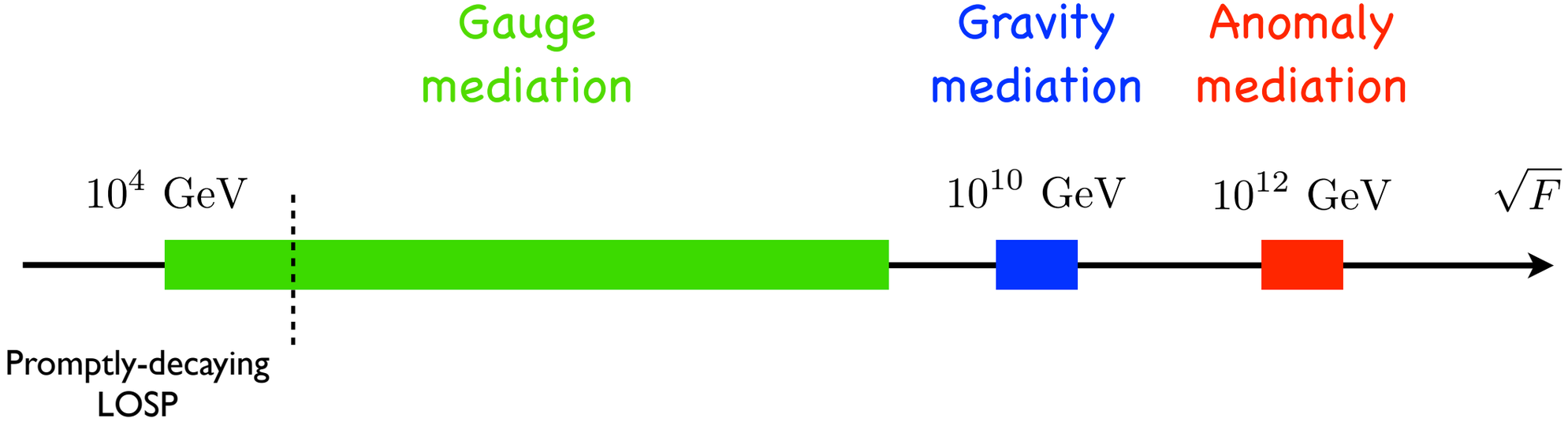

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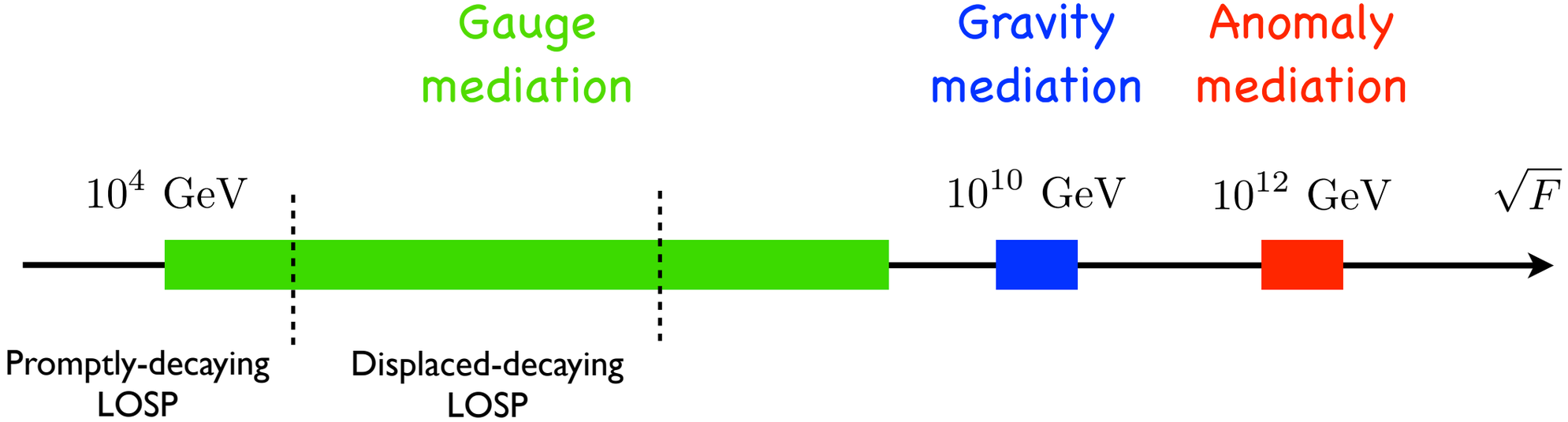

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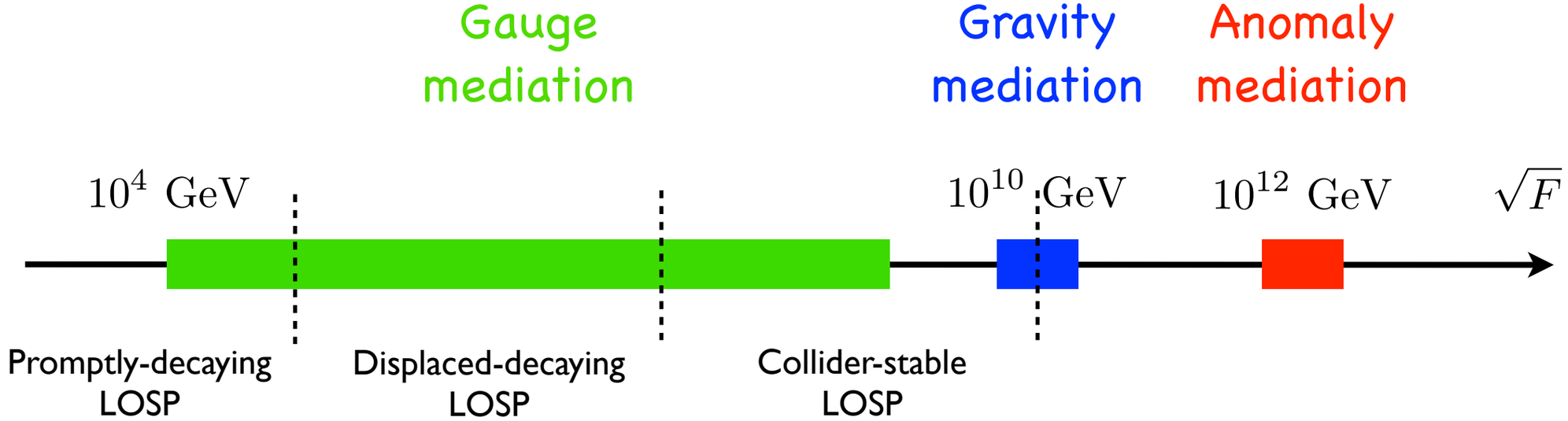

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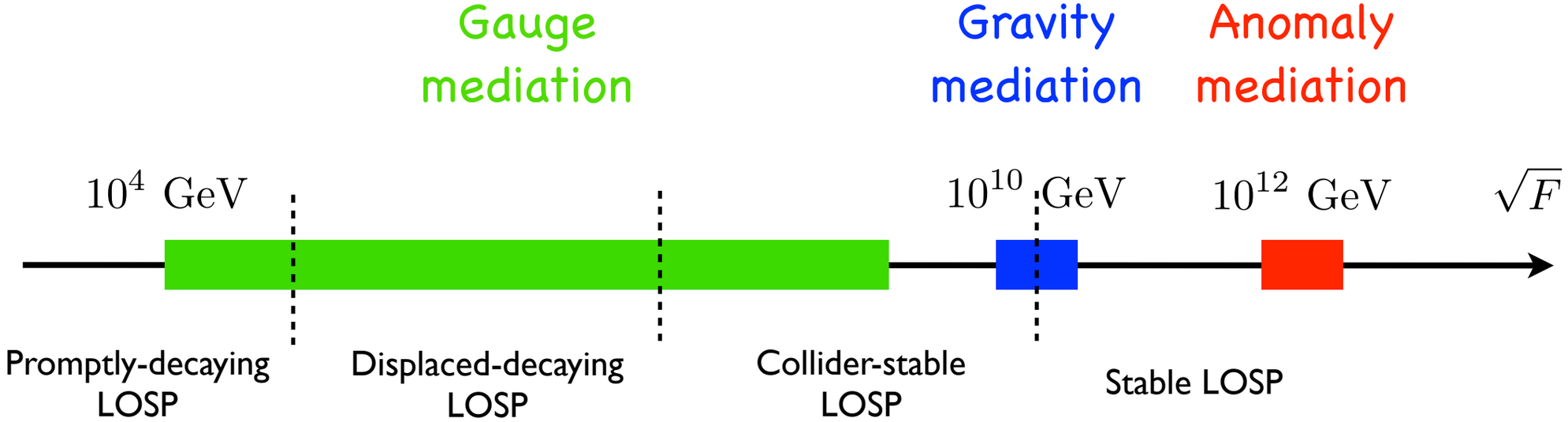

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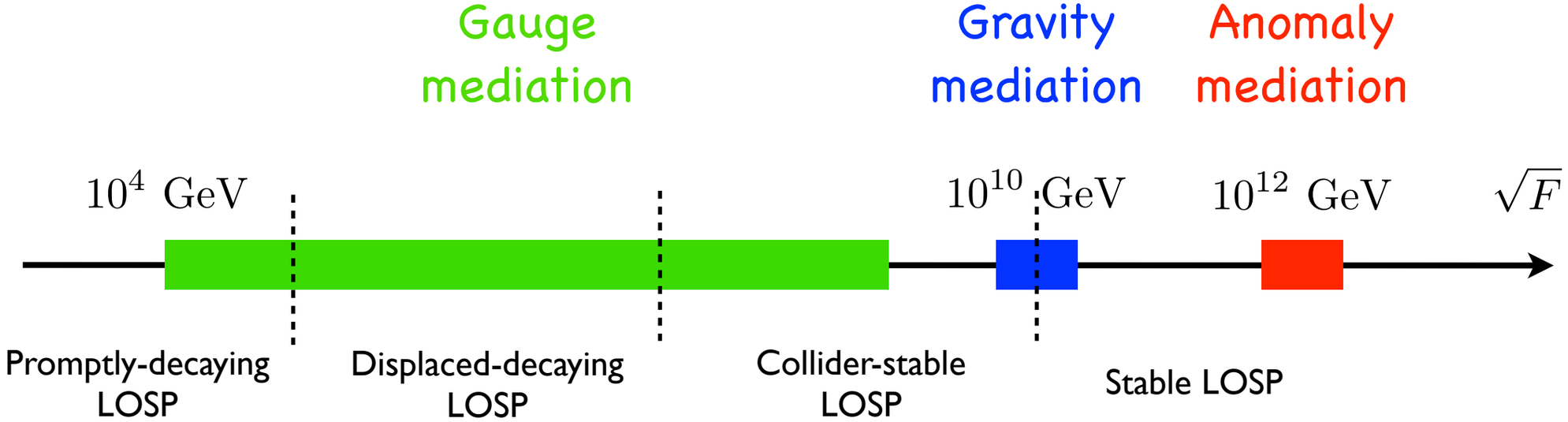

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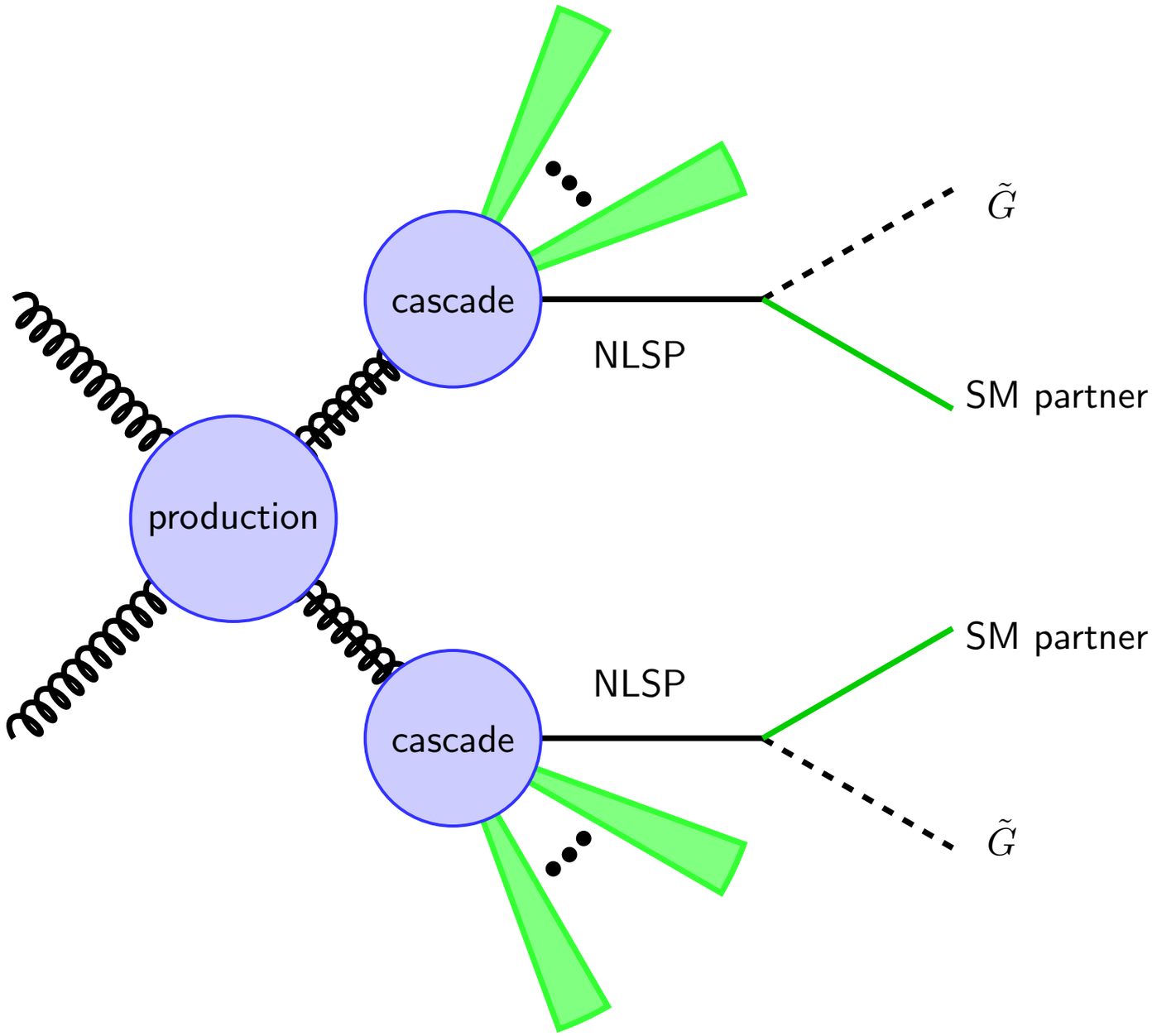
Viewed like this, there is no material difference between high-scale GMSB, gravity mediation, and anomaly mediation!!!



Inclusive SUSY collider signatures are mainly dictated by:

- Production mechanism (strong or EW superpartner)
- Identity of the LOSP
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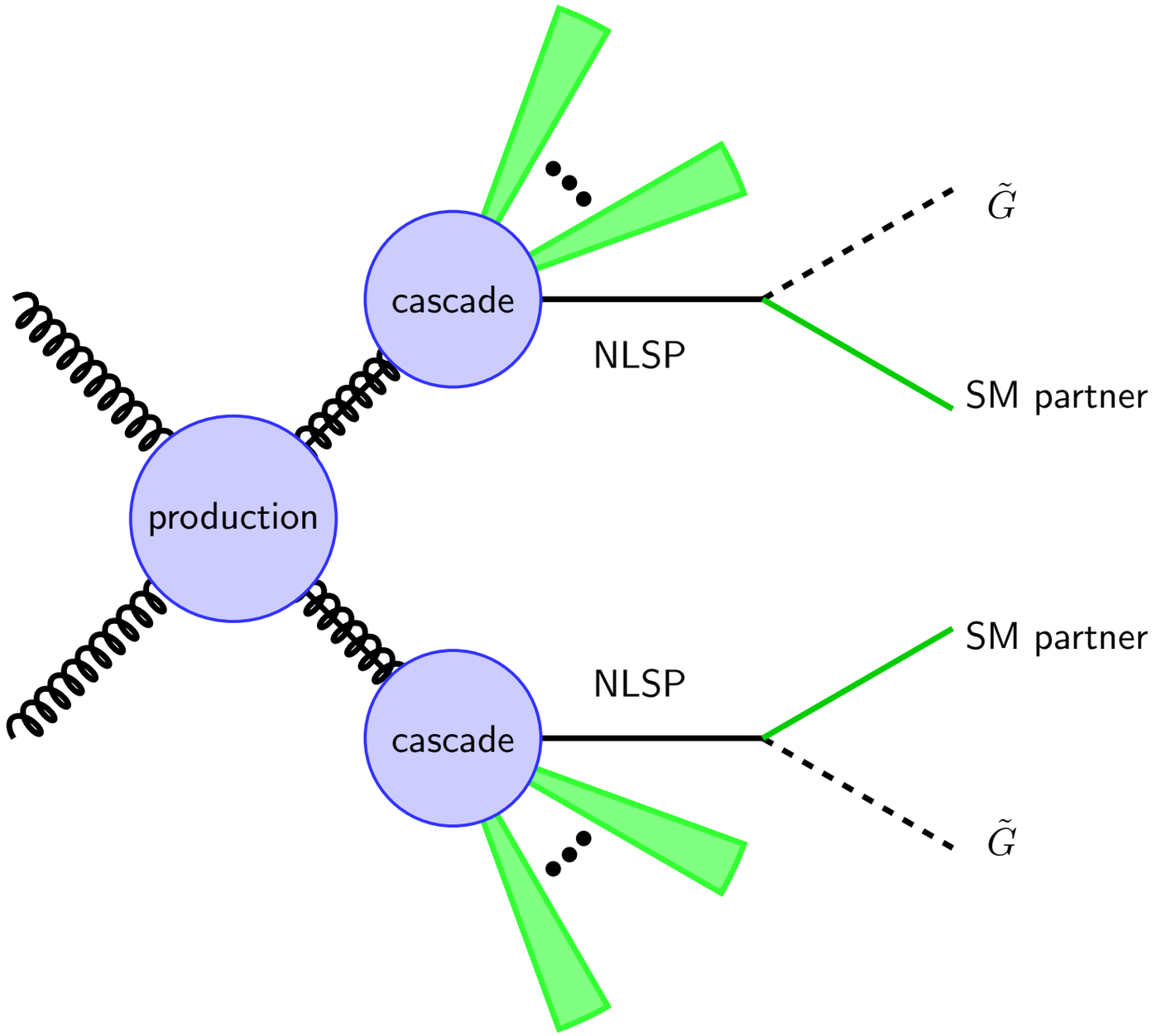

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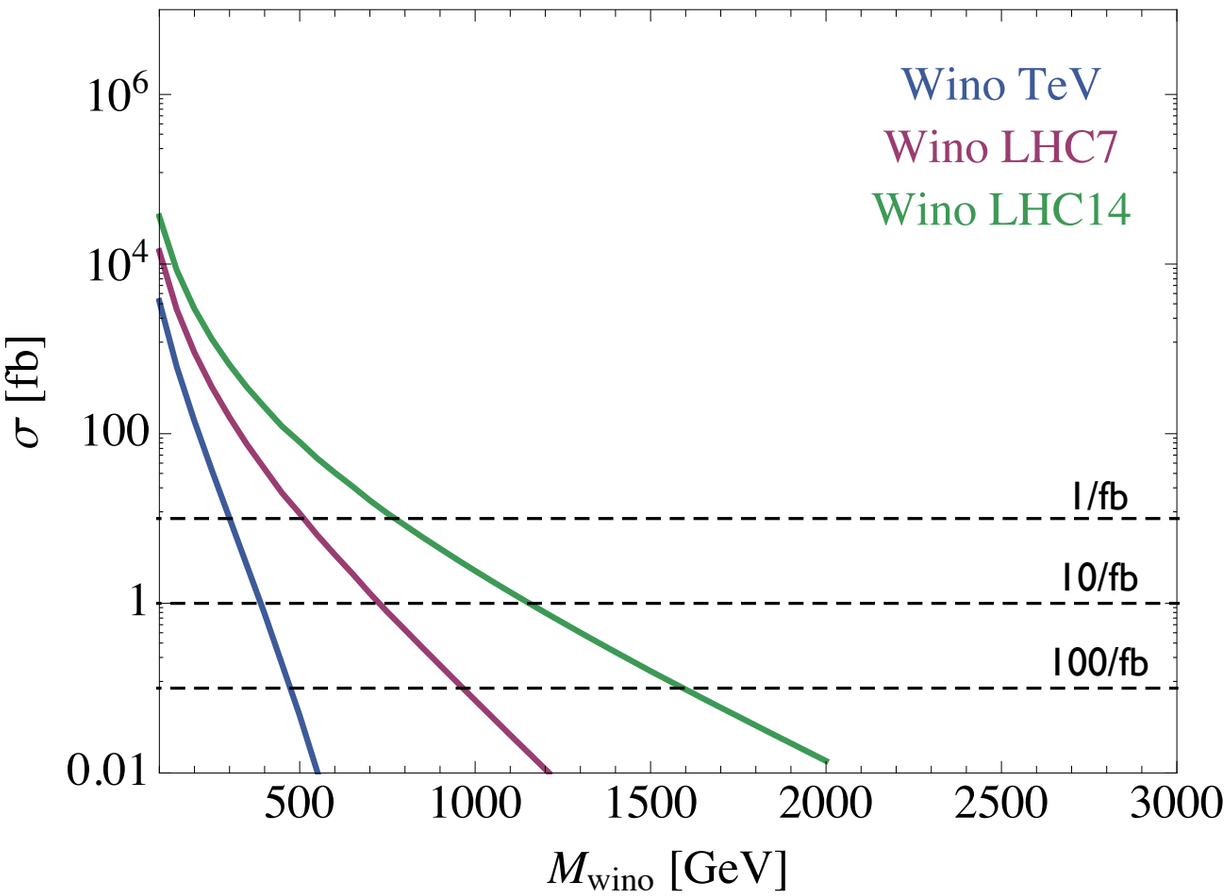
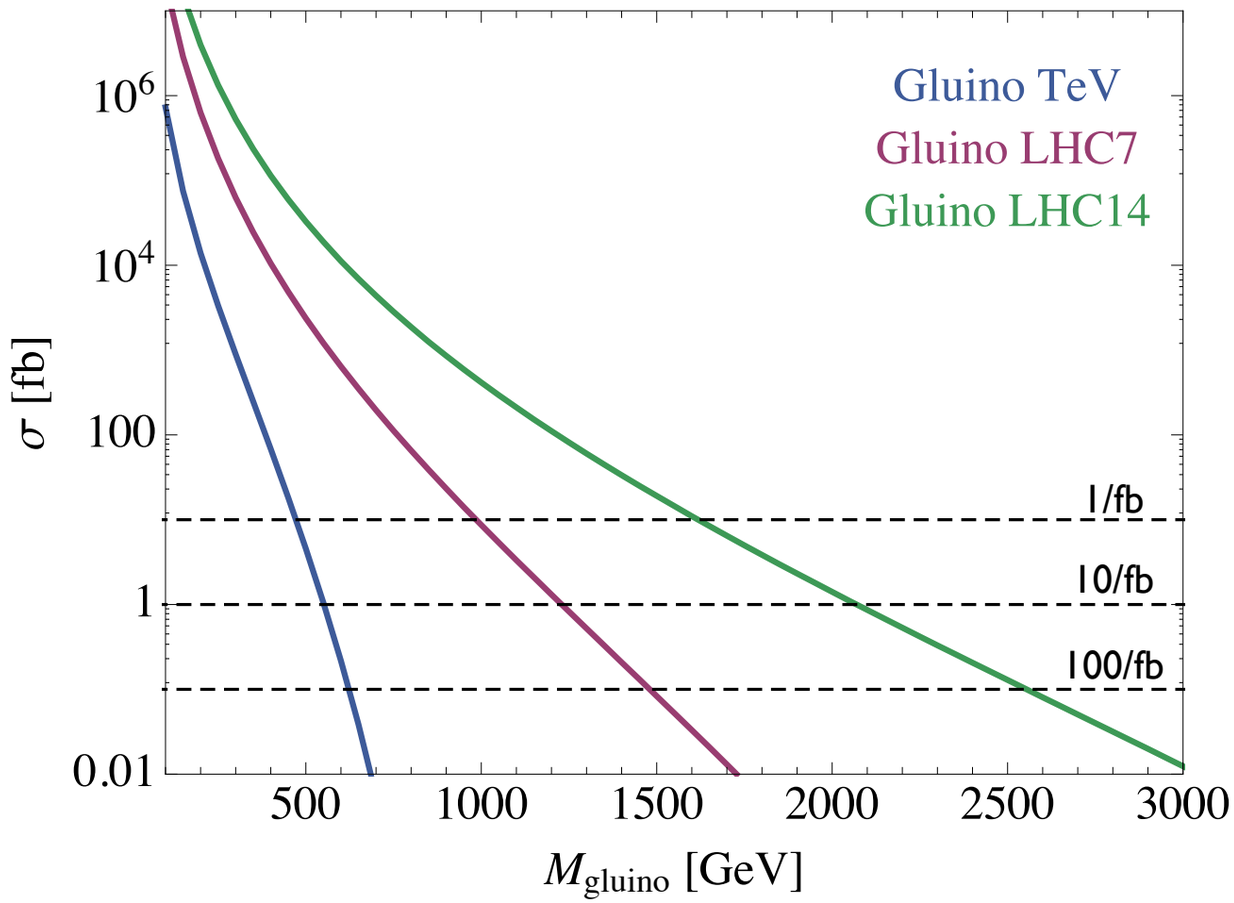
We will now survey some of the possibilities, keeping in mind the underlying mediation mechanism.

SUSY production at the LHC





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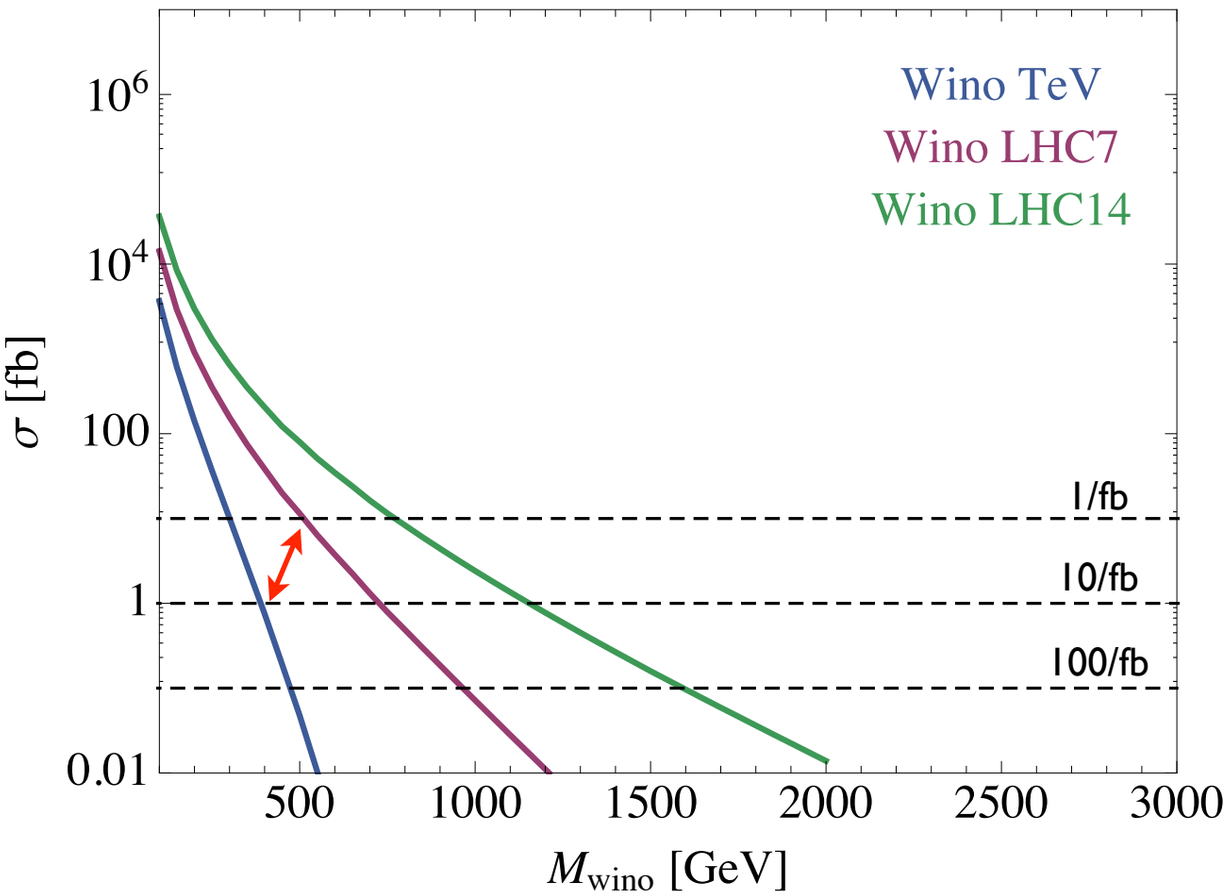

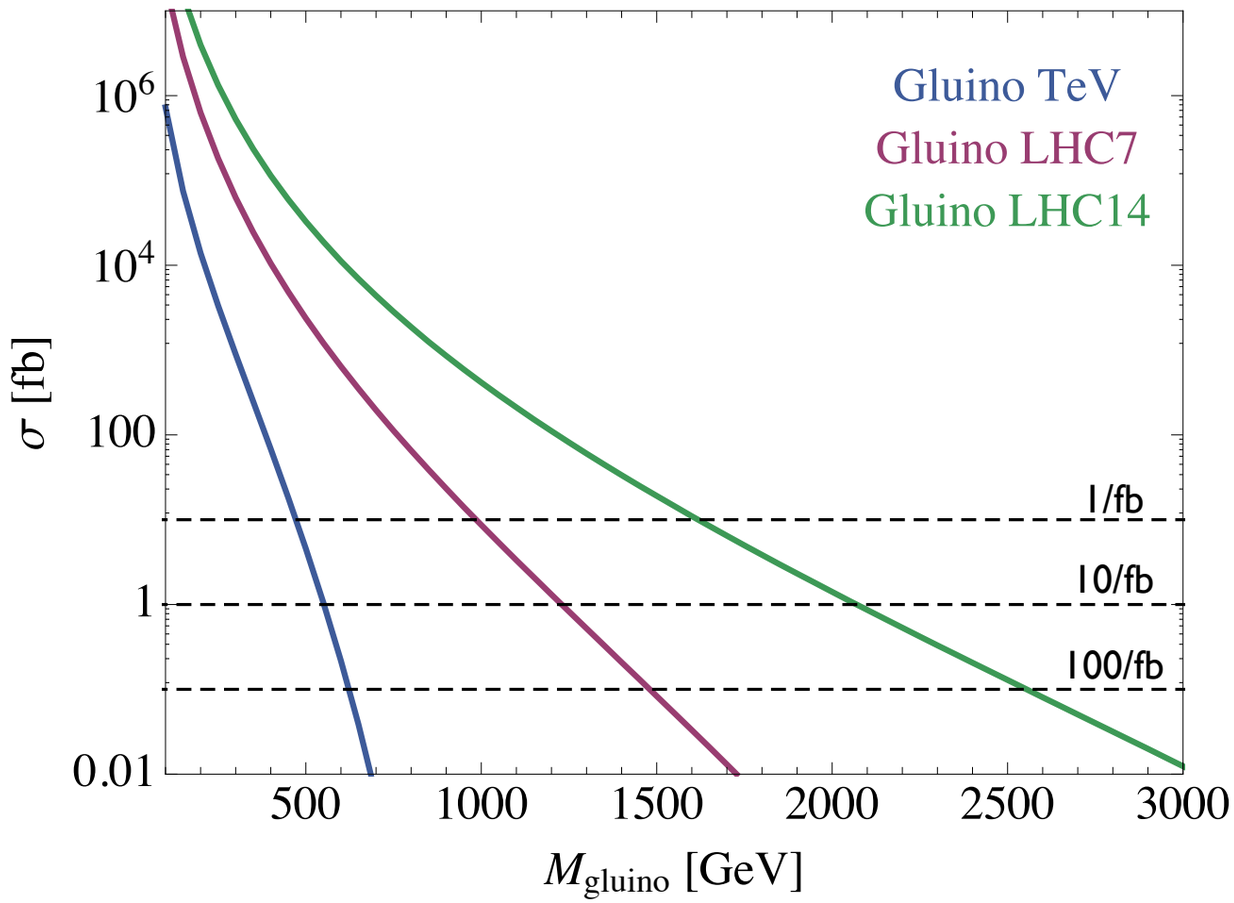

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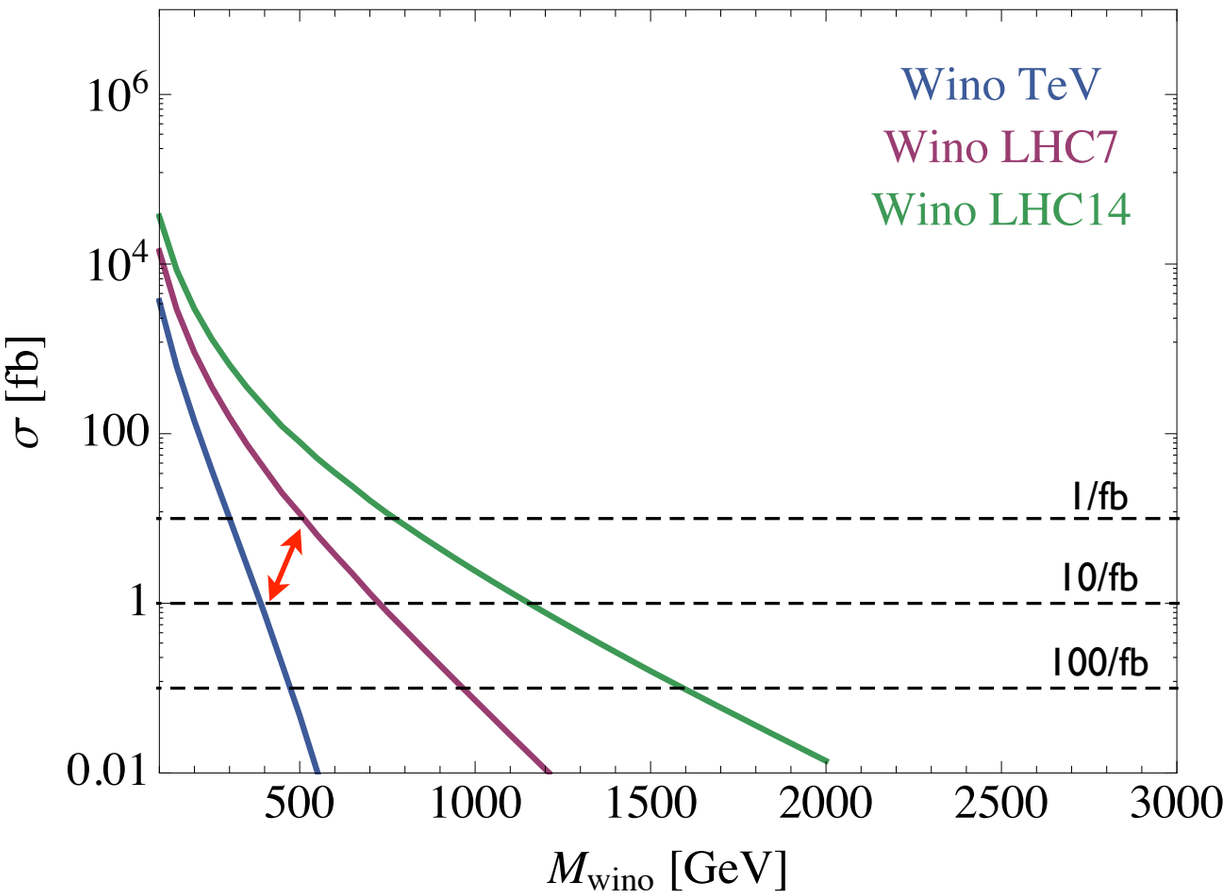

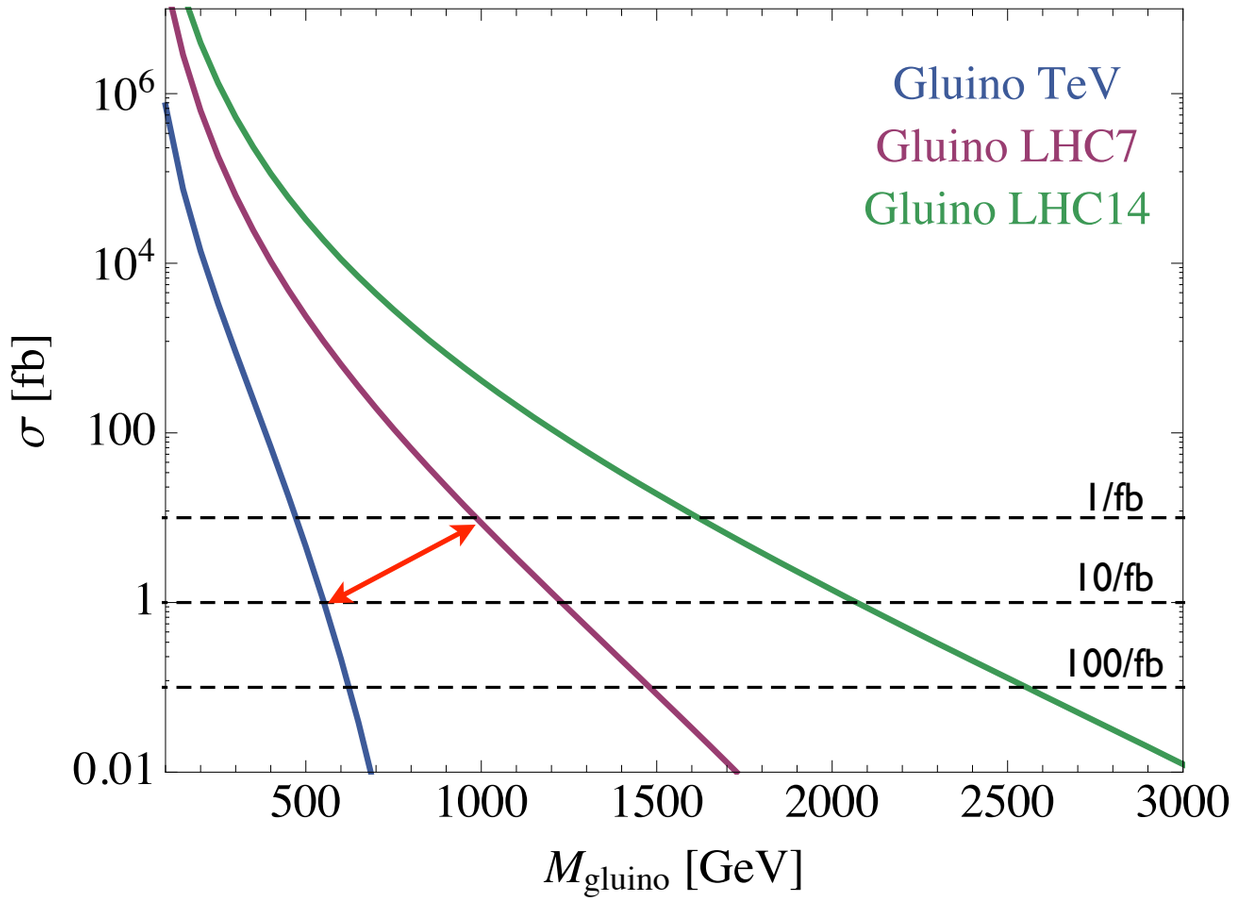

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- For strong production, LHC7 @ 1/fb >> Tevatron @ 10/fb

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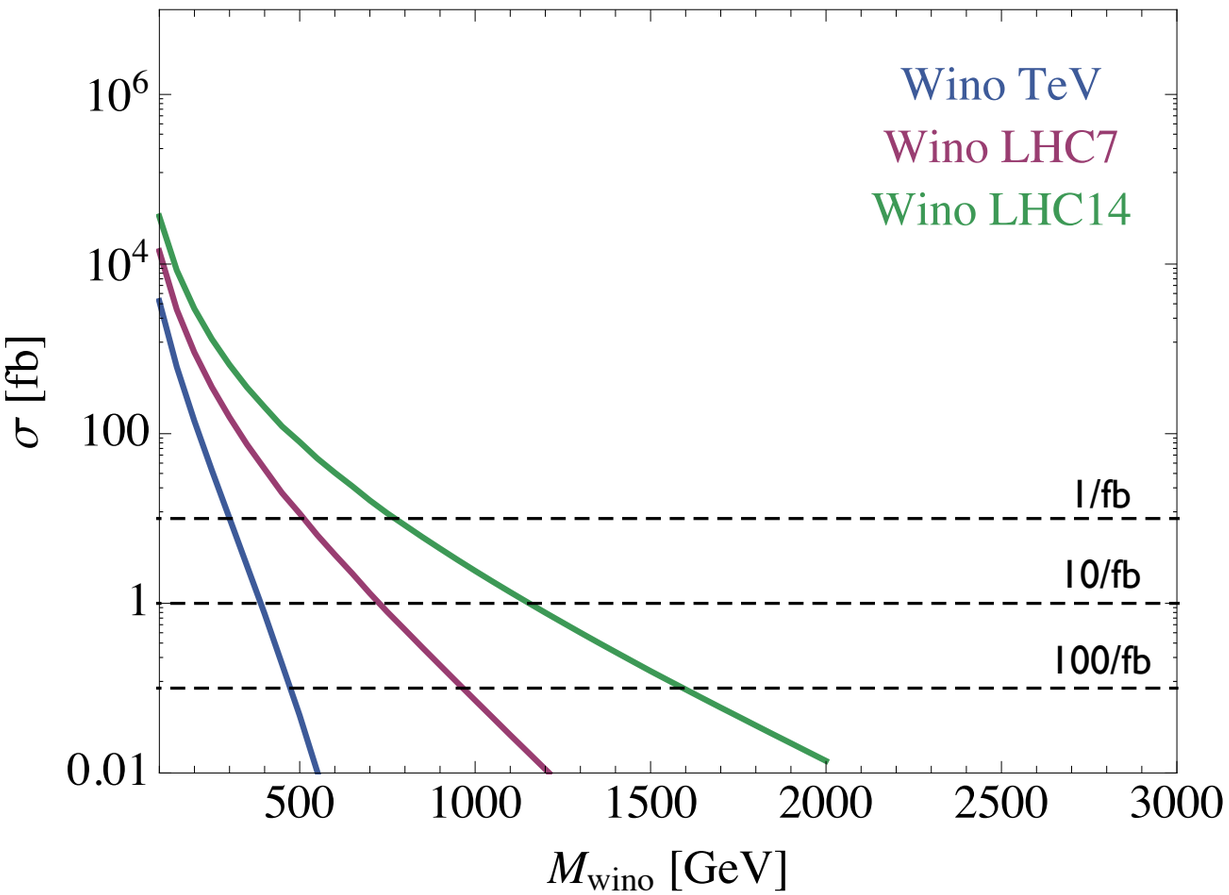

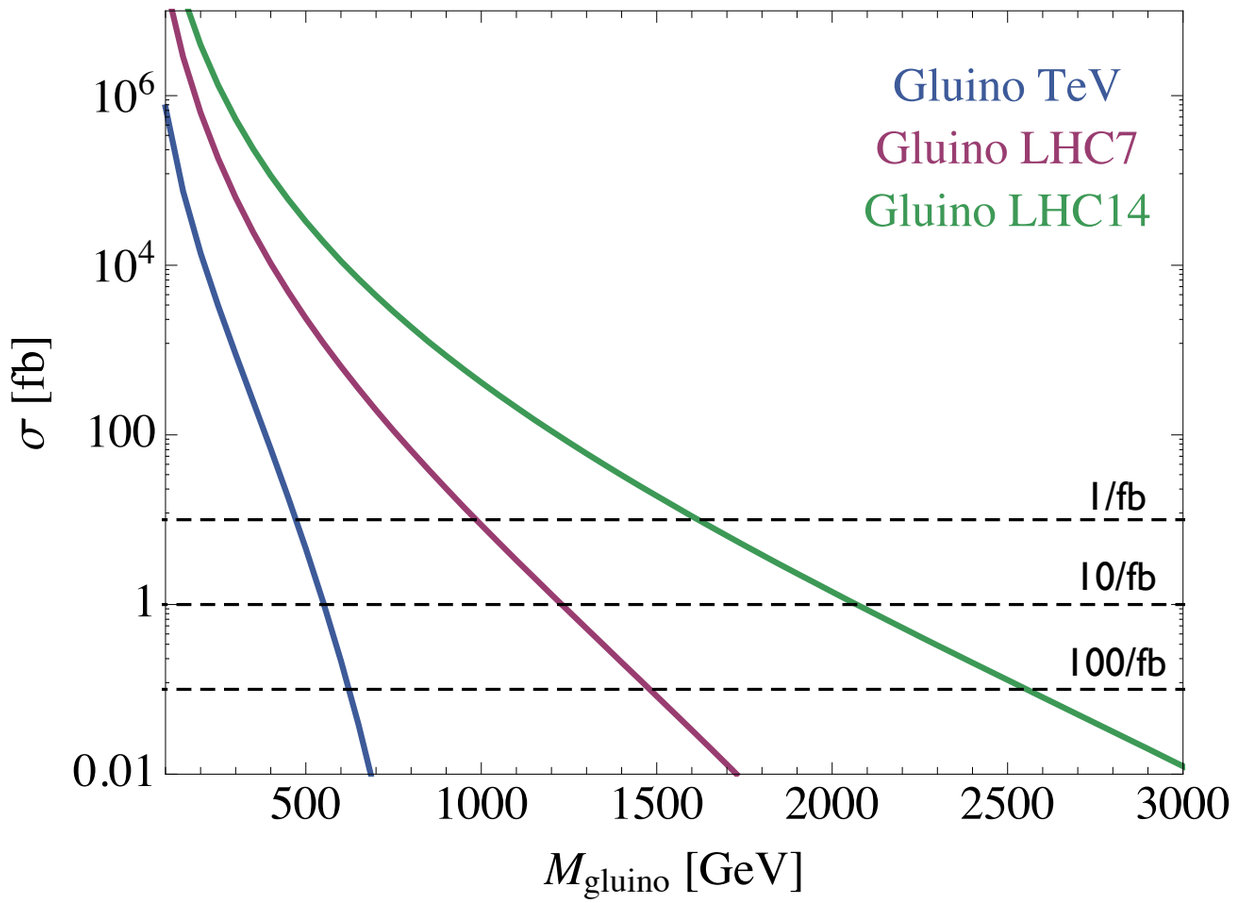

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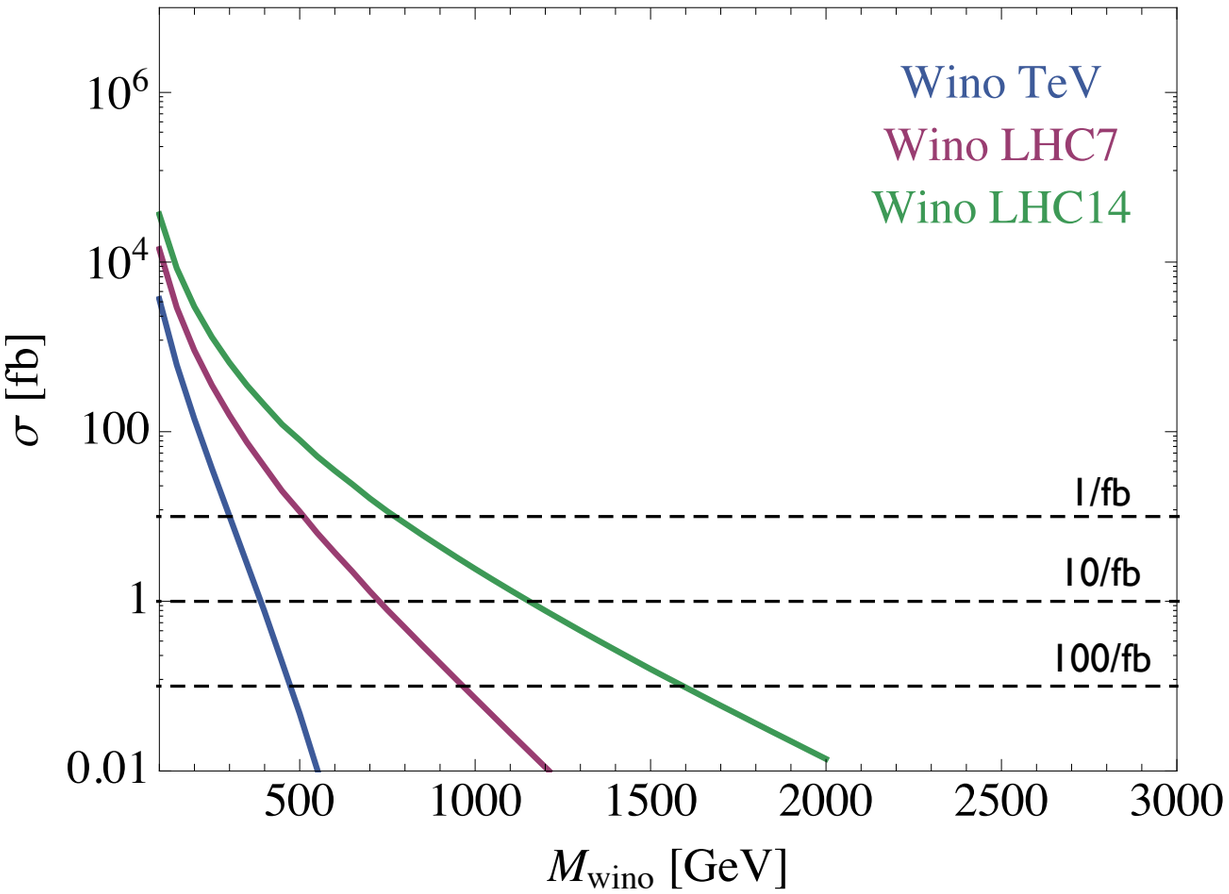
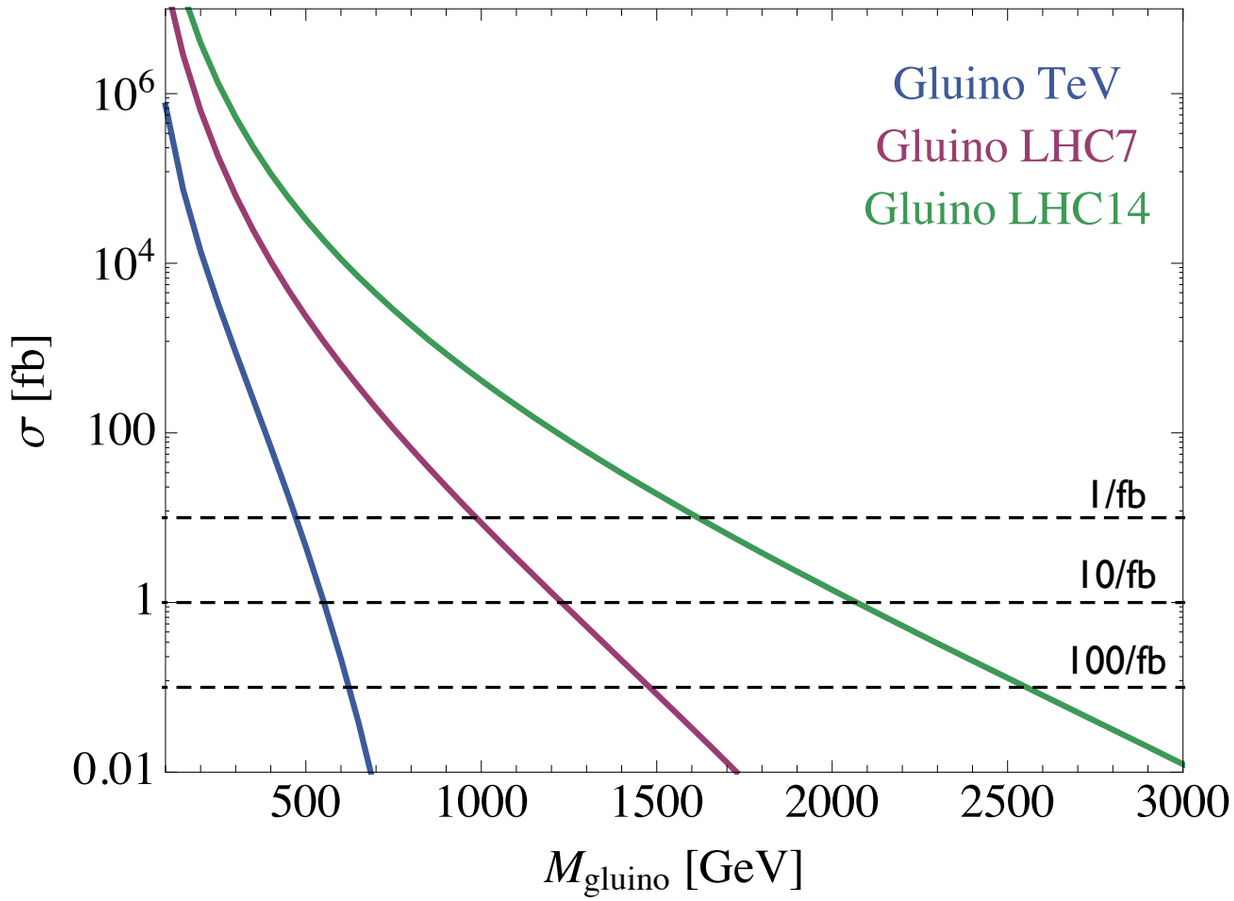
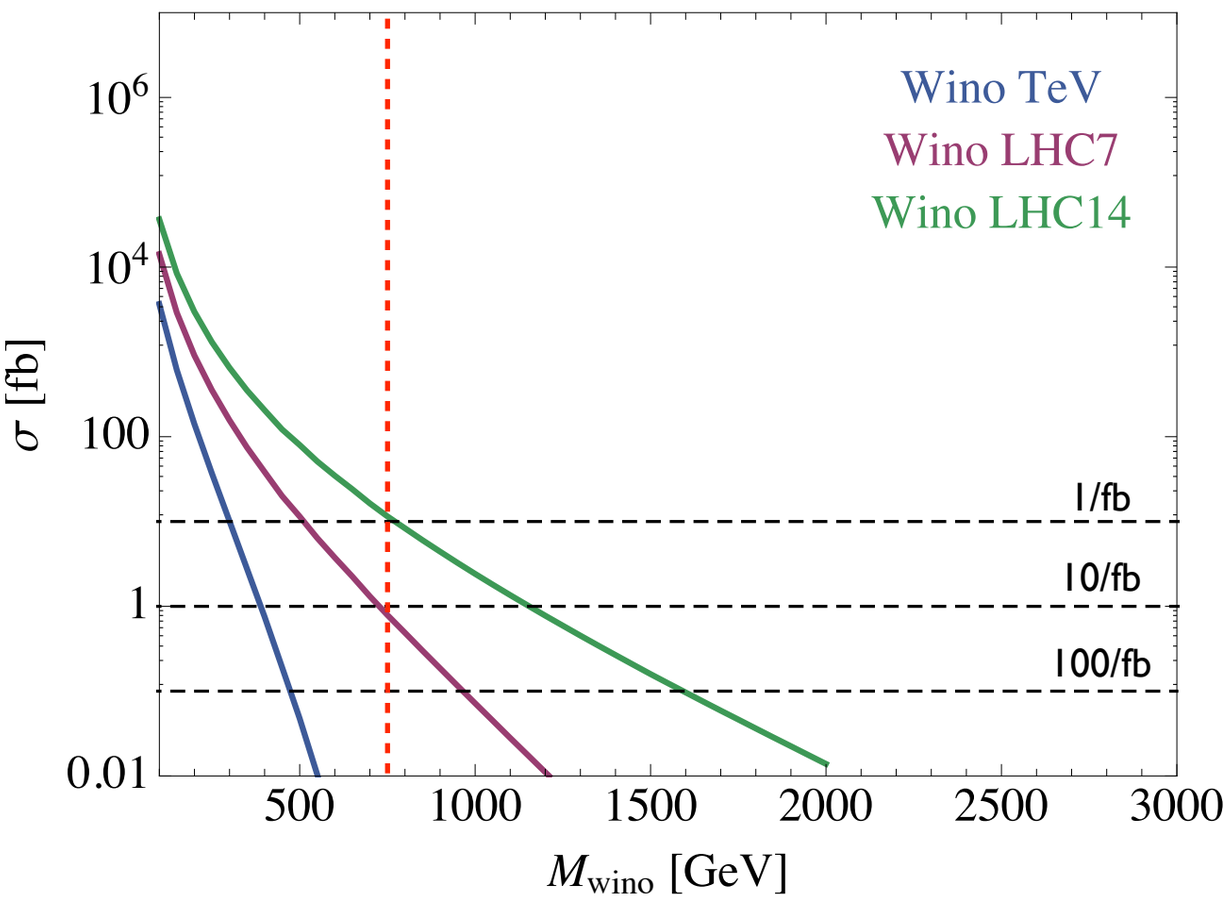
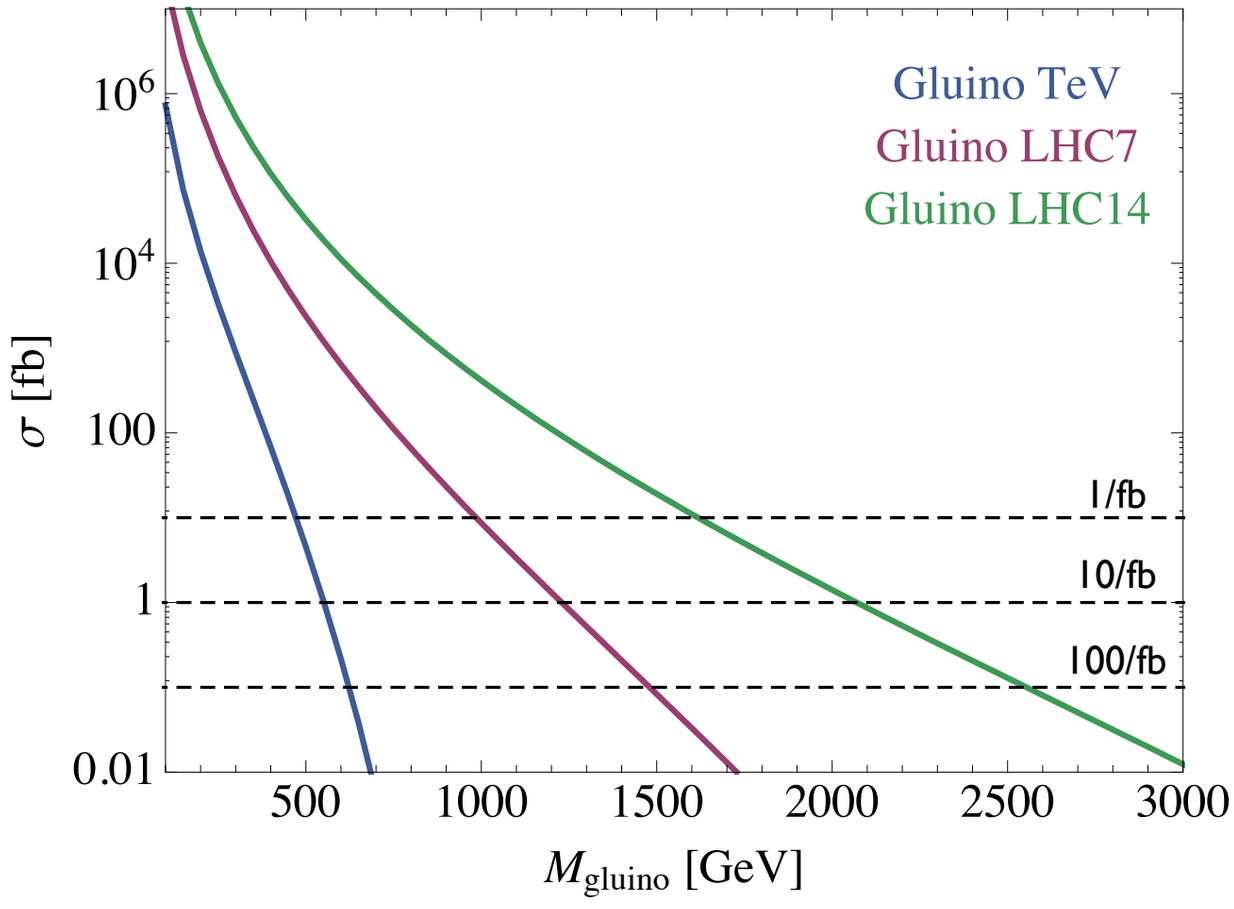




"Kinematic reach" of LHC7:

SUSY production at the LHC





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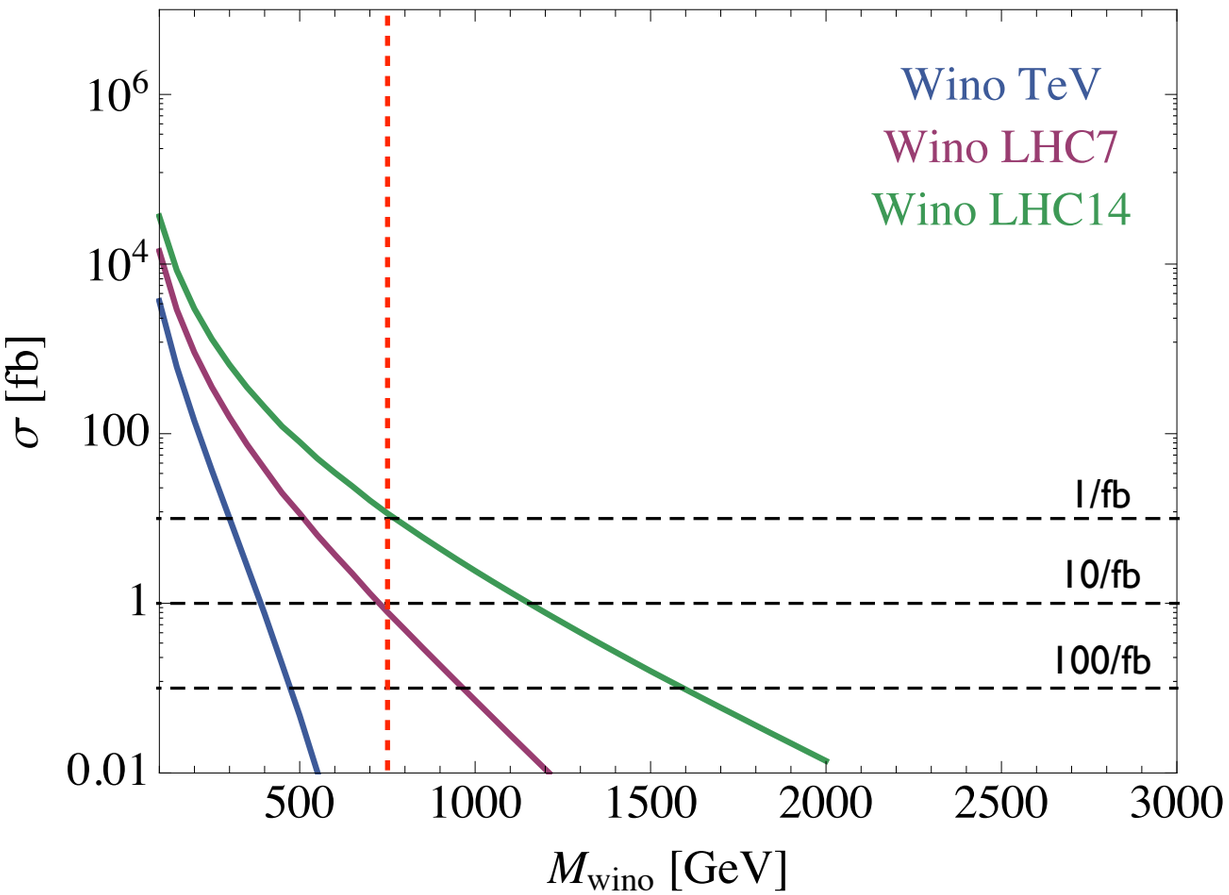

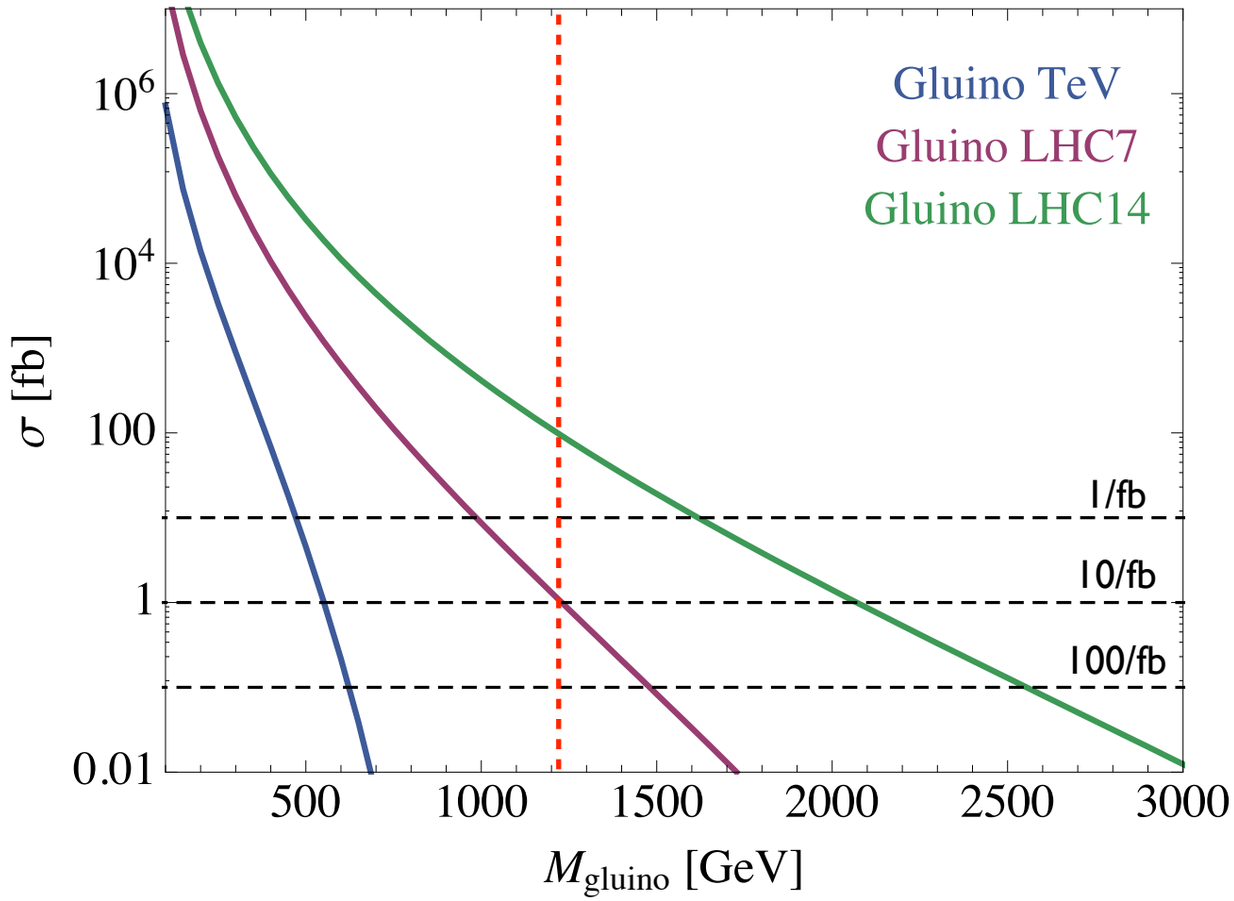

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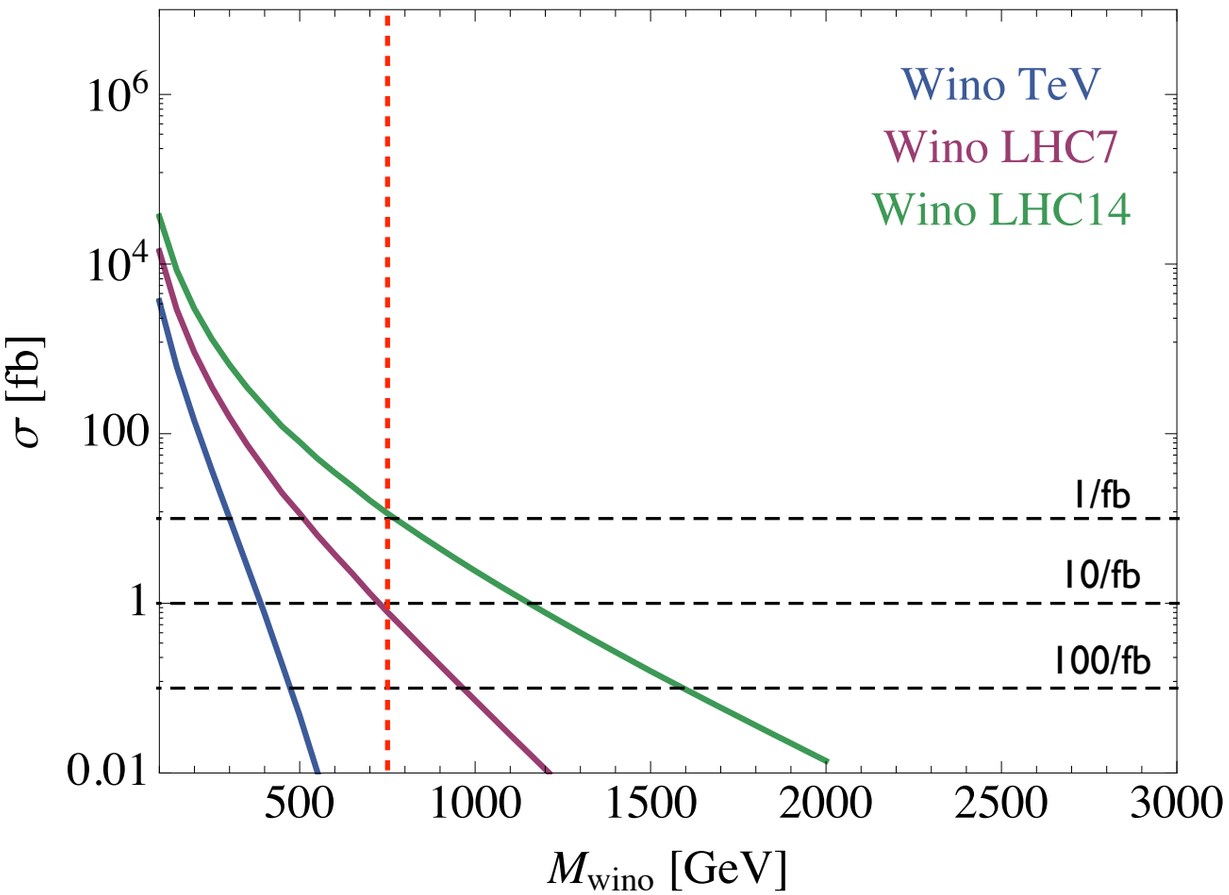
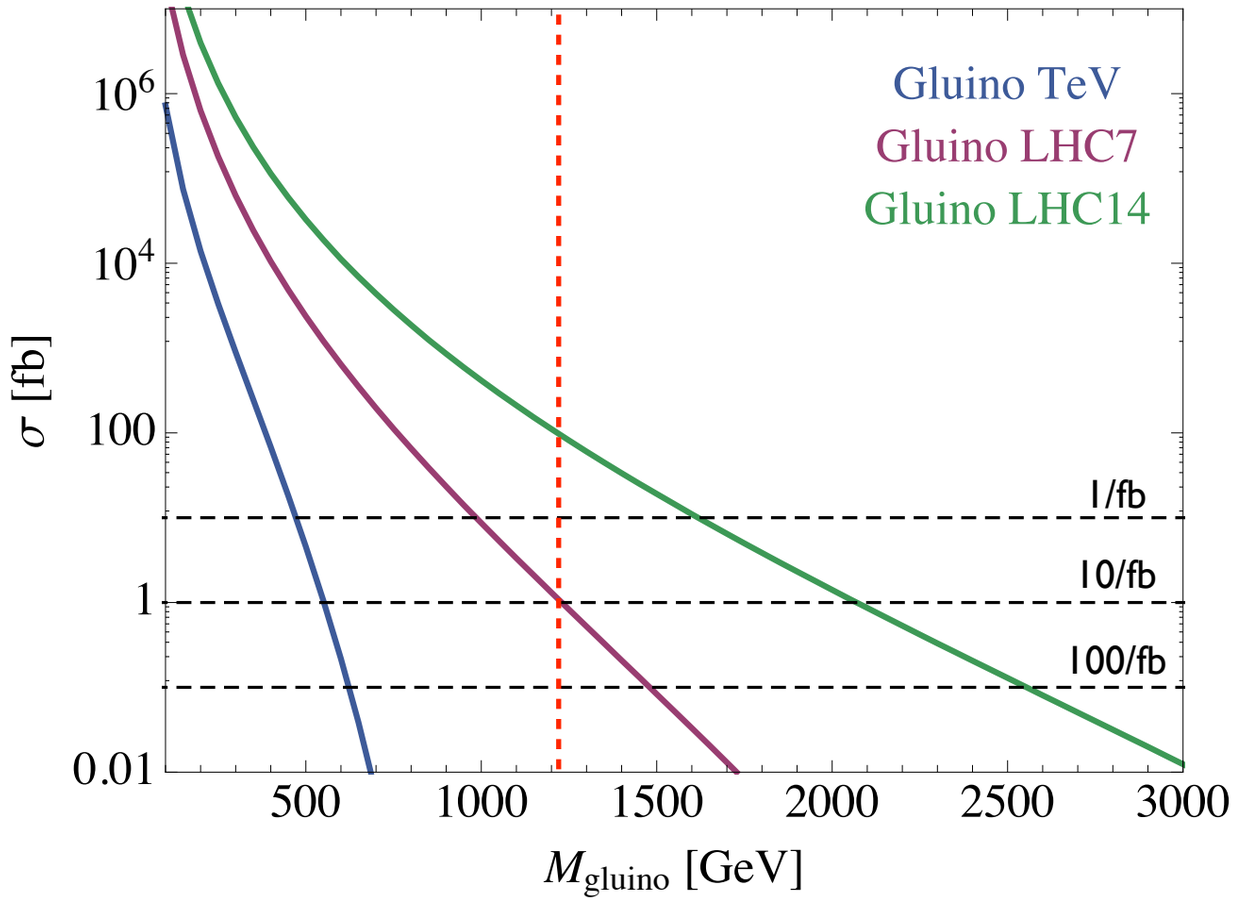
$M_{gluino} \sim 1200$ GeV

SUSY production at the LHC

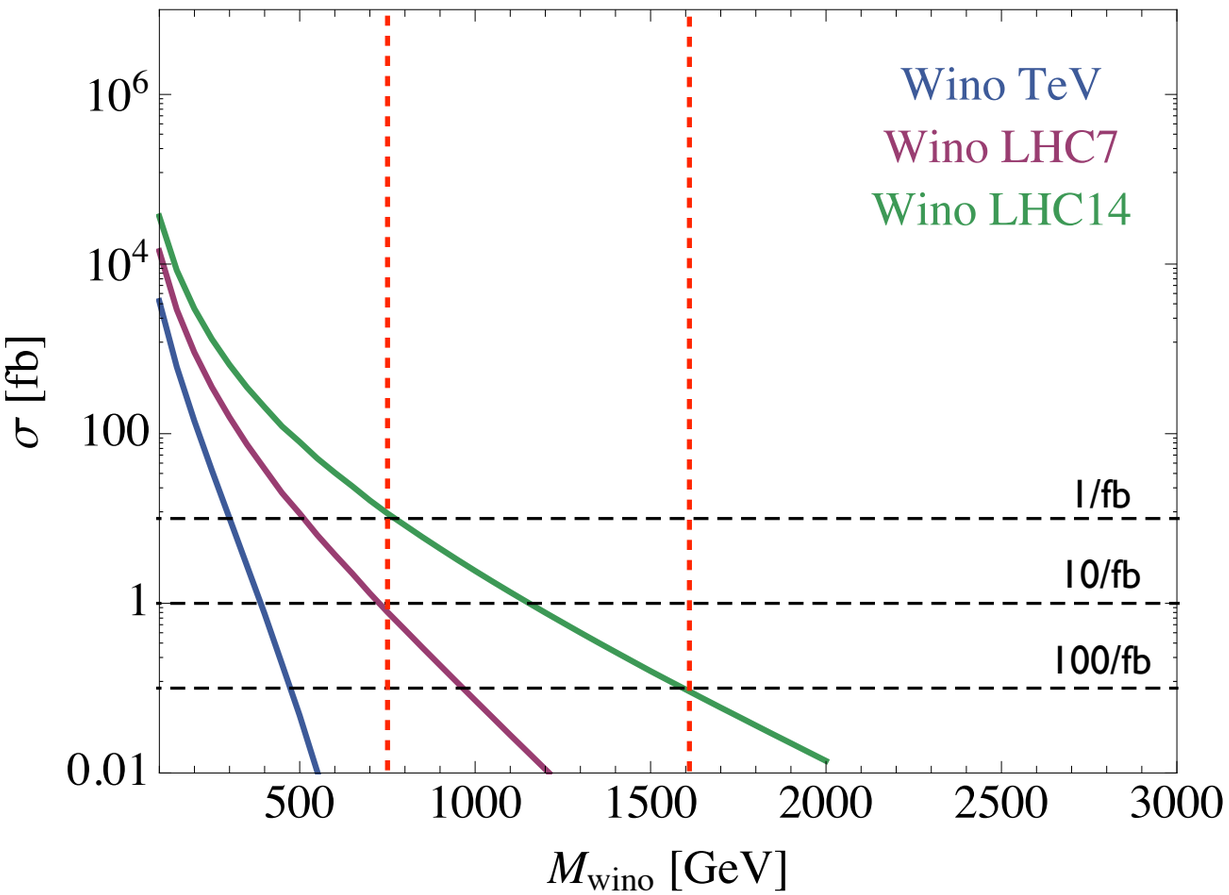


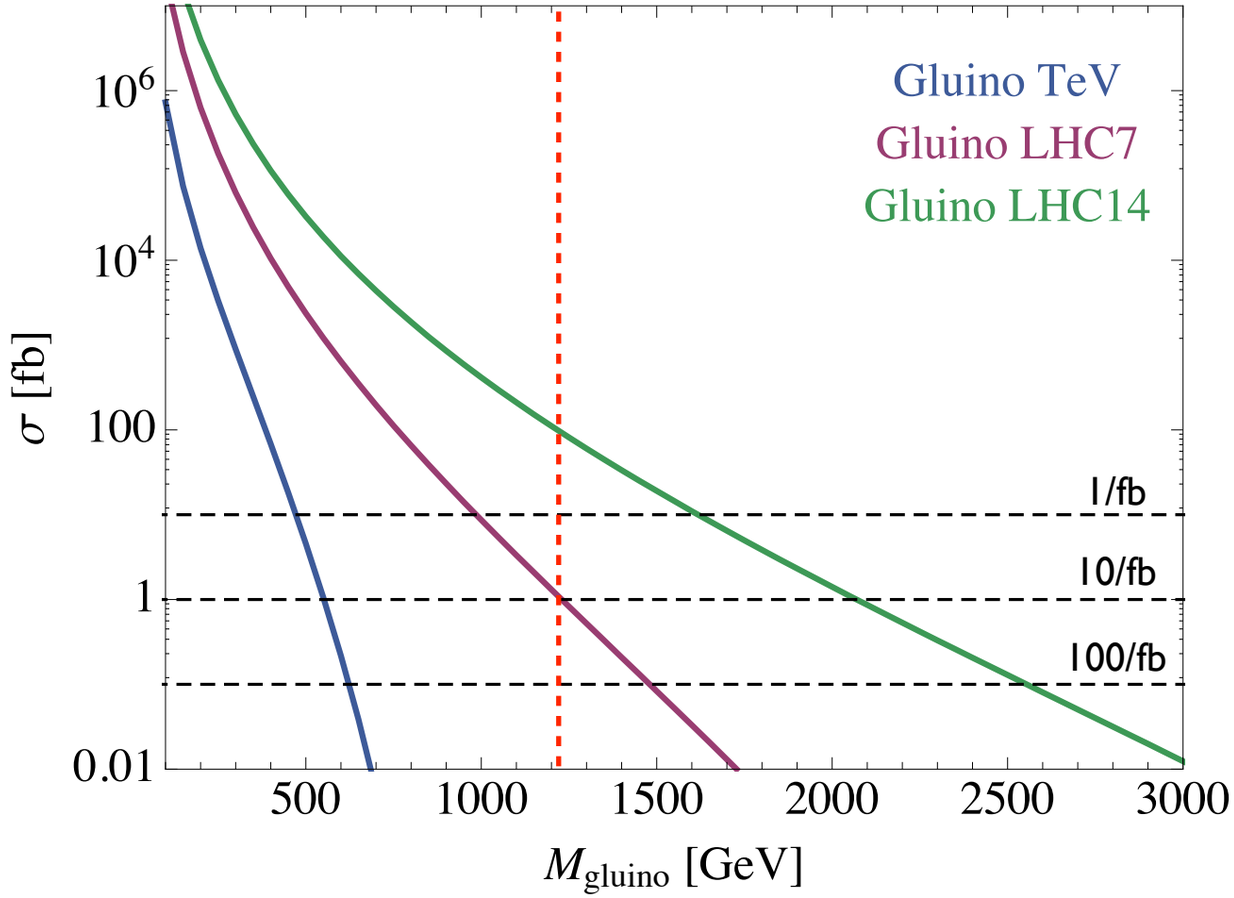


"Kinematic reach" of LHC7: $M_{wino} \sim 700$ GeV $M_{gluino} \sim 1200$ GeV

"Kinematic reach" of LHC14:

SUSY production at the LHC



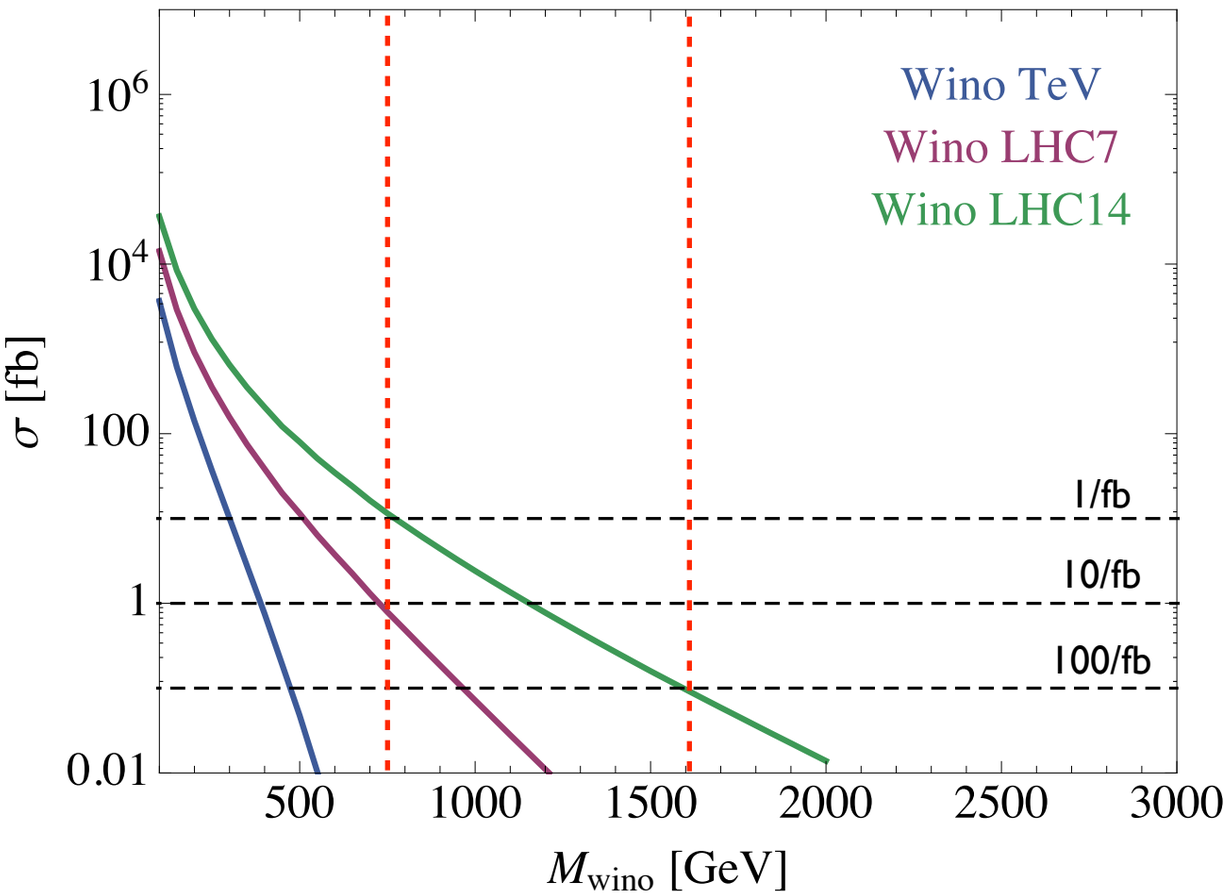


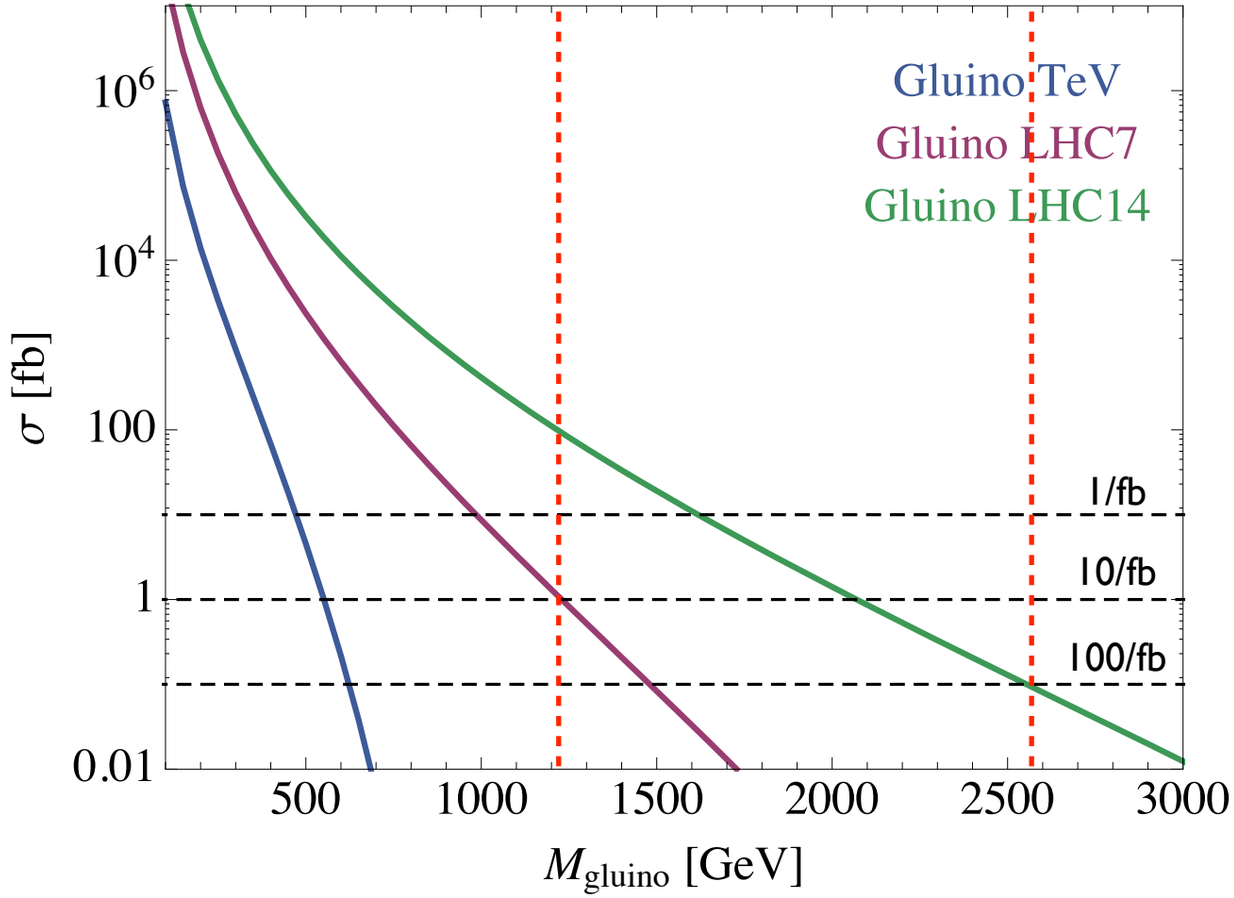
"Kinematic reach" of LHC7: $M_{wino} \sim 700$ GeV

"Kinematic reach" of LHC14: $M_{wino} \sim 1600$ GeV

$M_{gluino} \sim 1200$ GeV

SUSY production at the LHC

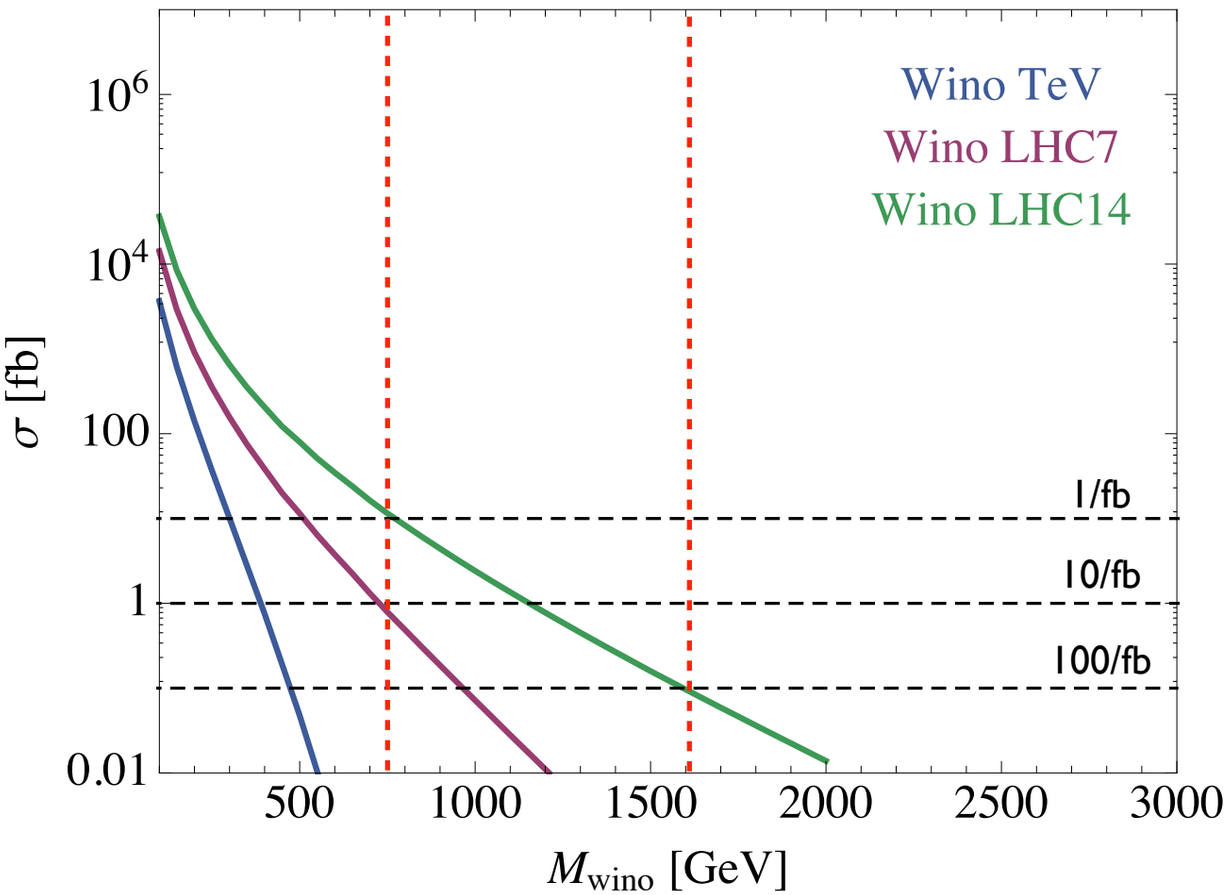


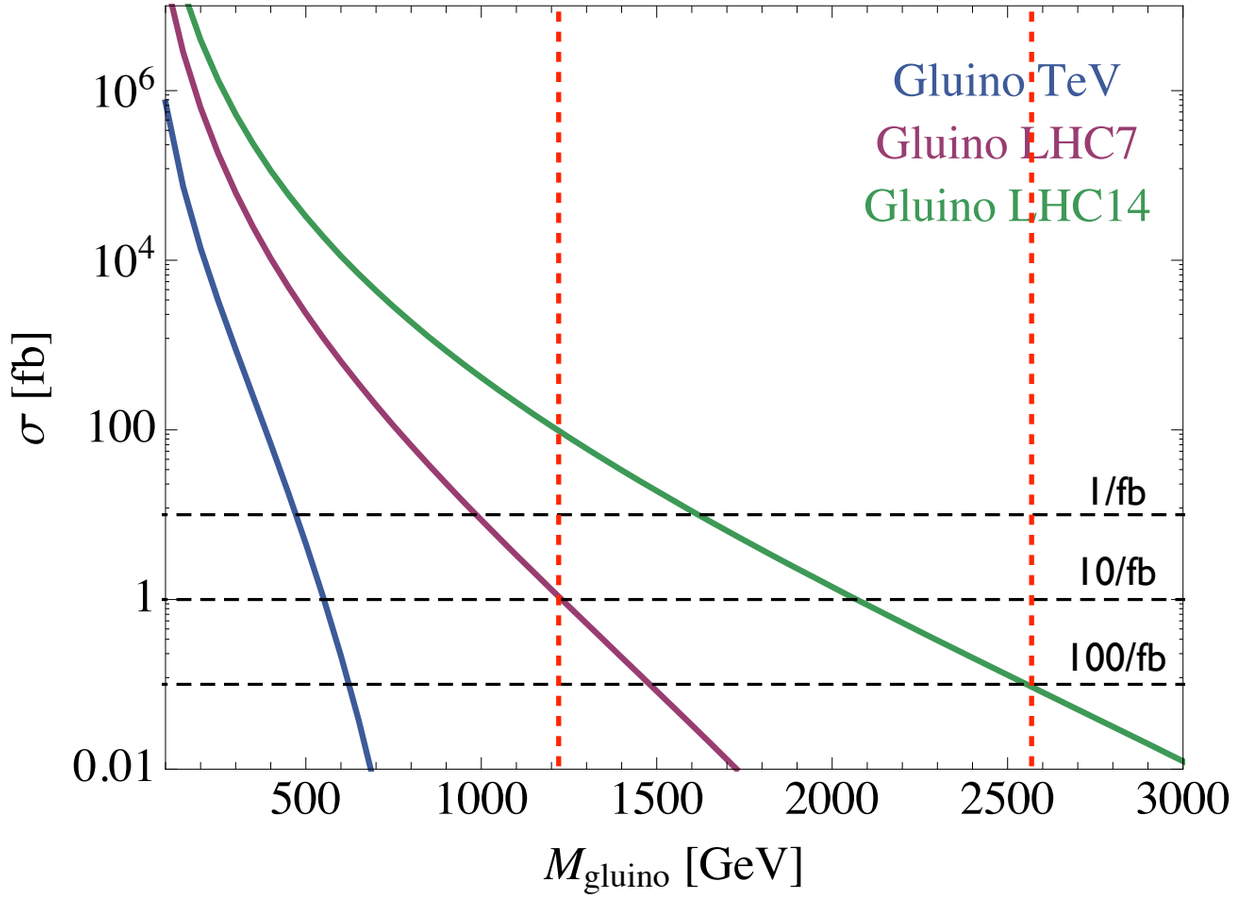


"Kinematic reach" of LHC7: $M_{wino} \sim 700$ GeV $M_{gluino} \sim 1200$ GeV

"Kinematic reach" of LHC14: $M_{wino} \sim 1600$ GeV $M_{gluino} \sim 2500$ GeV

SUSY production at the LHC





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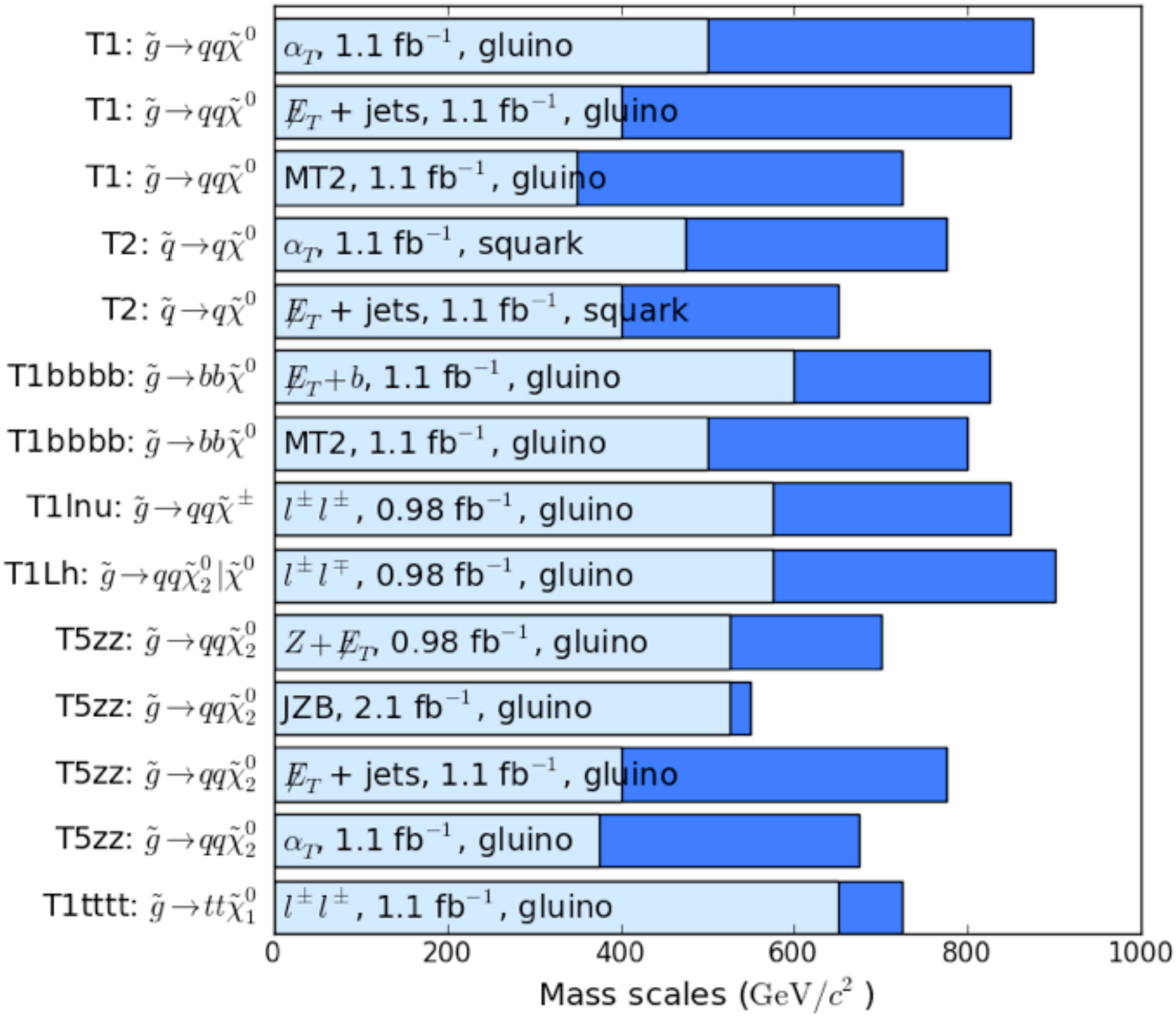
"Kinematic reach" of LHC14: $M_{wino} \sim 1600$ GeV $M_{gluino} \sim 2500$ GeV

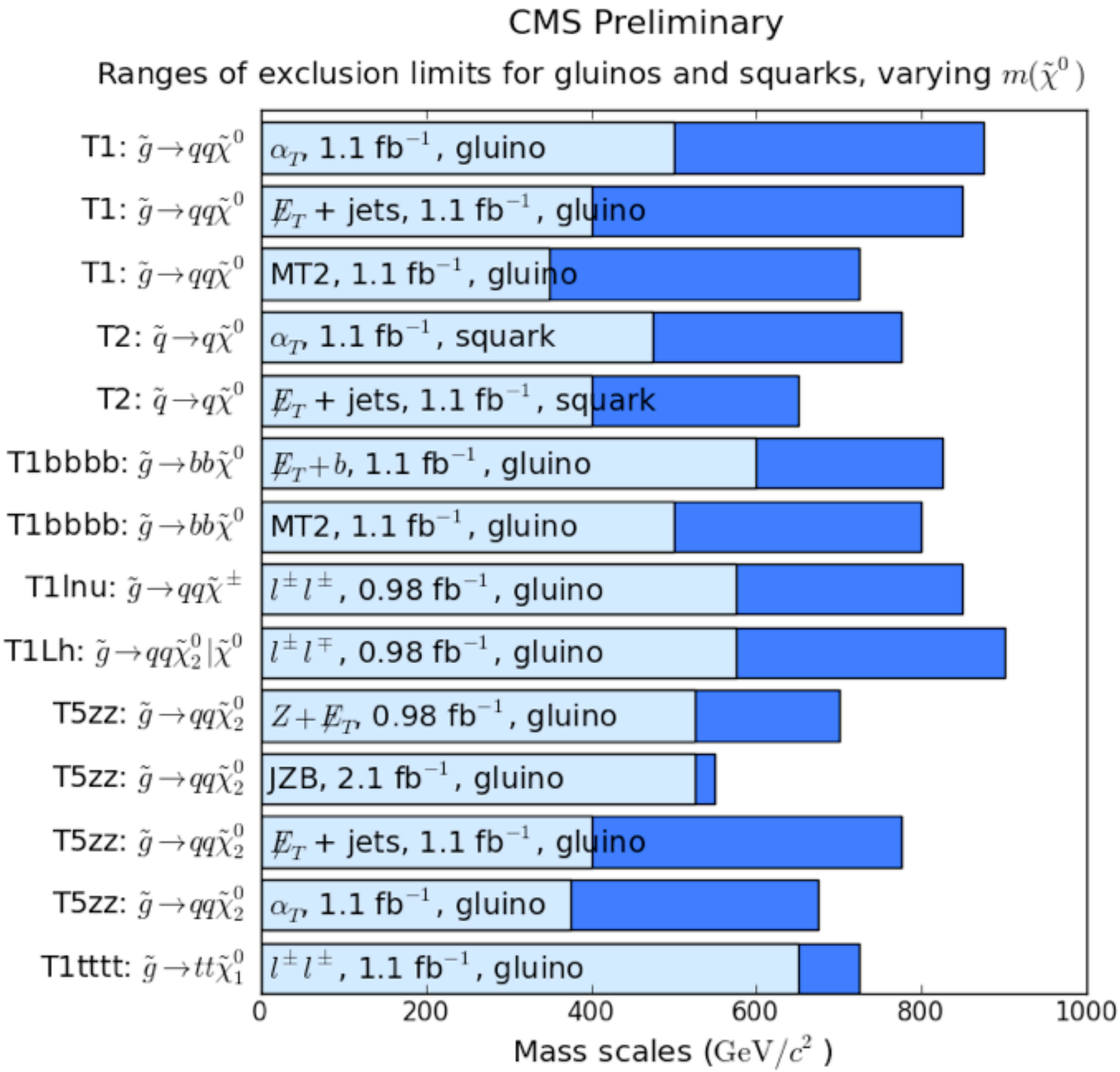
Yardsticks to measure the current progress

CMS Preliminary

Ranges of exclusion limits for gluinos and squarks, varying $m(\tilde{\chi}^0)$



For limits on $m(\tilde{g}),m(\tilde{q}) >> m(\tilde{g})$ (and vice versa). $\sigma^{\text{prod}} = \sigma^{\text{NLO-QCD}}$.
$m(\tilde{\chi}^{\pm}),m(\tilde{\chi}_2^0) = \frac{m(\tilde{g})+m(\tilde{\chi}^0)}{2}$.
$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (dark blue) to $m(\tilde{g})-200$ GeV/c^2 (light blue).



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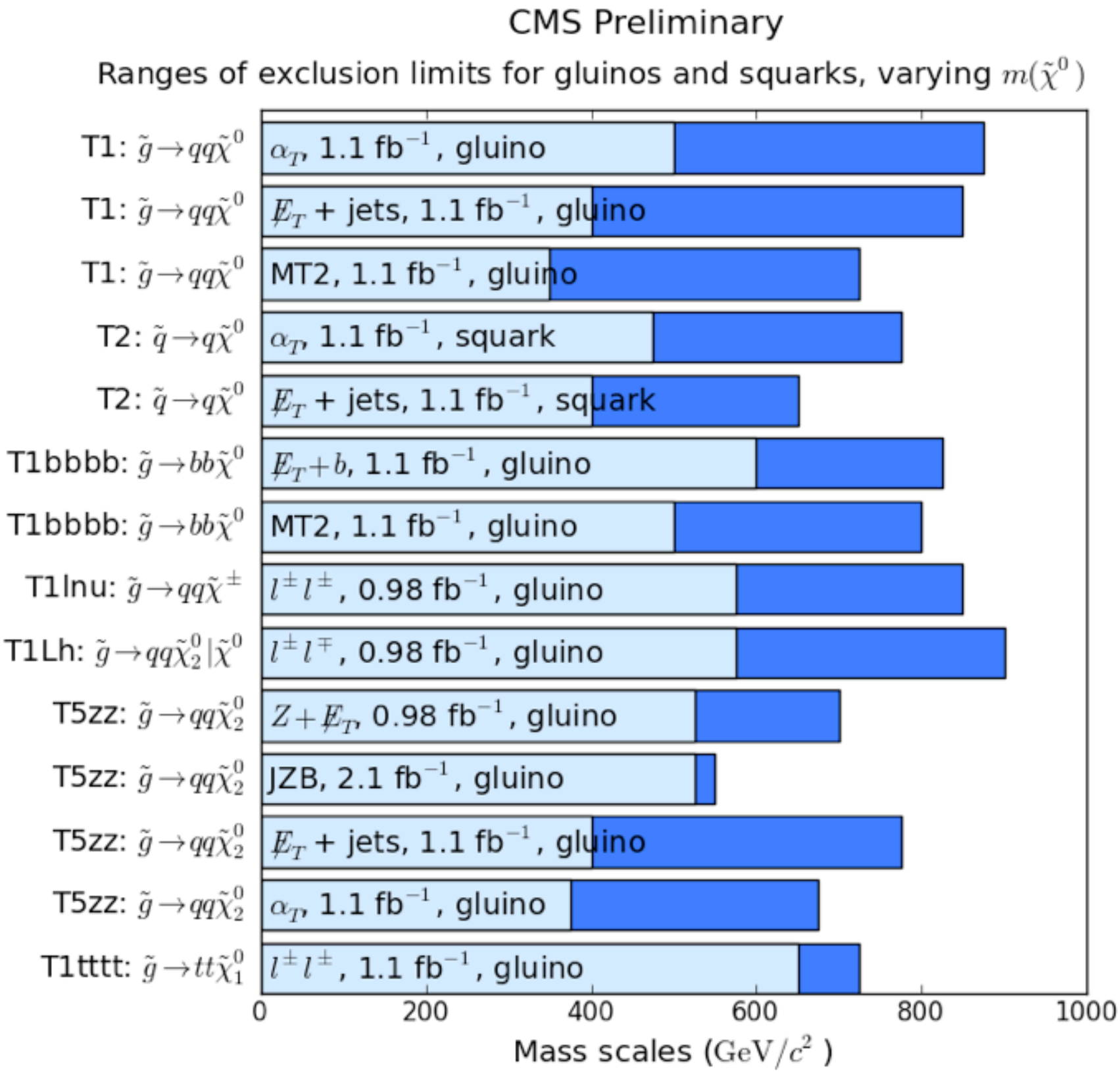
Limits on colored SUSY production are pretty much on track.



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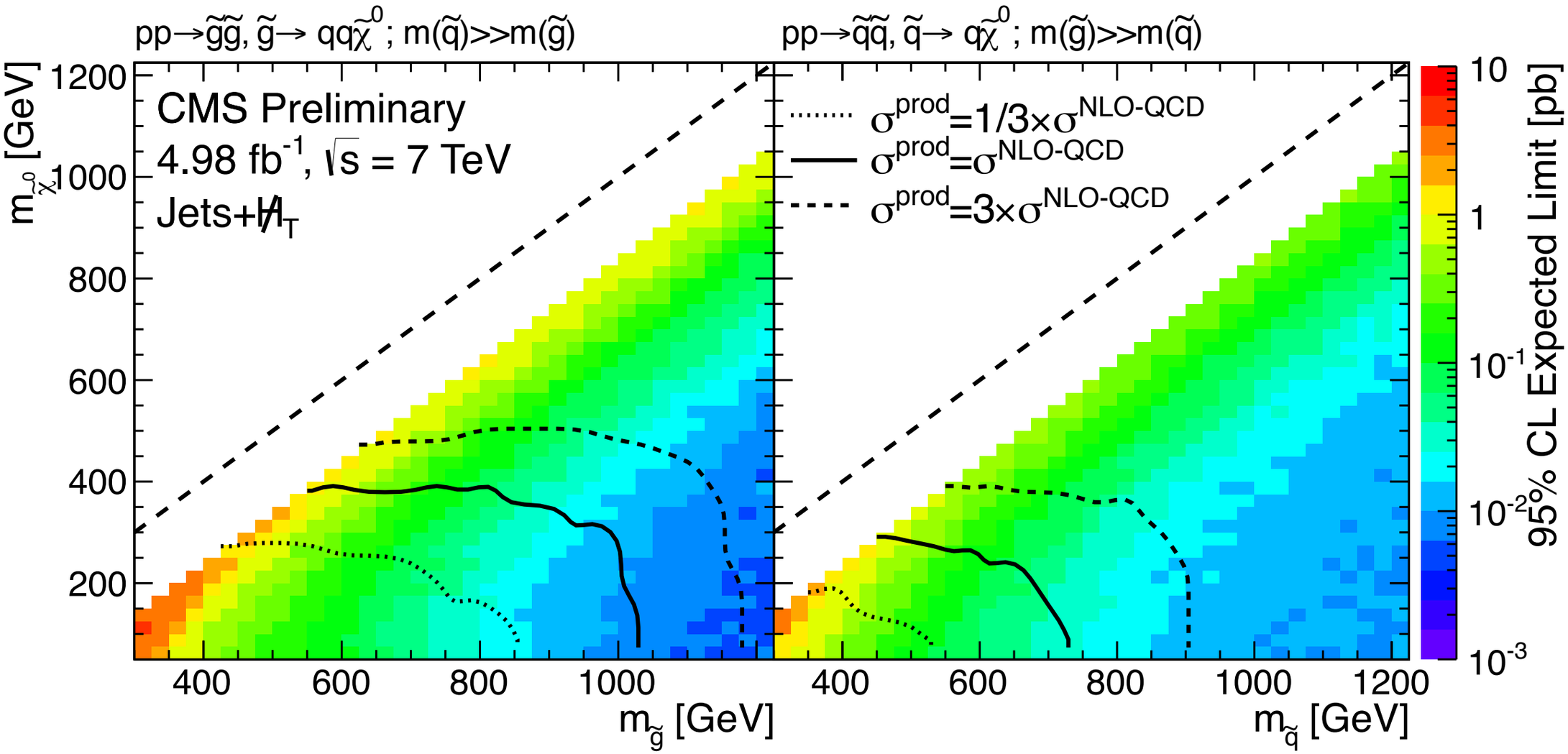
Limits on colored SUSY production are pretty much on track.

Squeezed spectra are currently one exception.

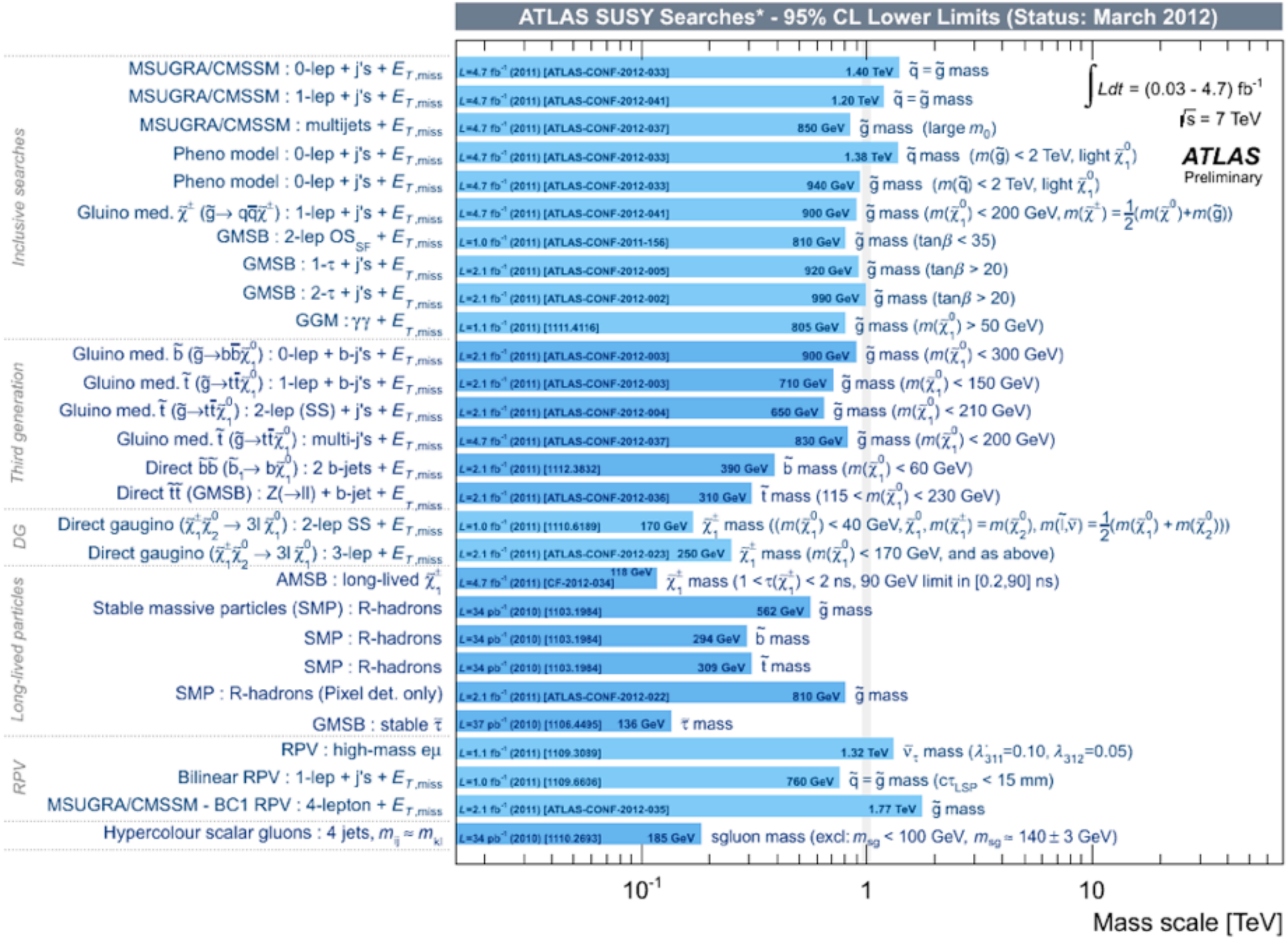
Squeezed Spectra

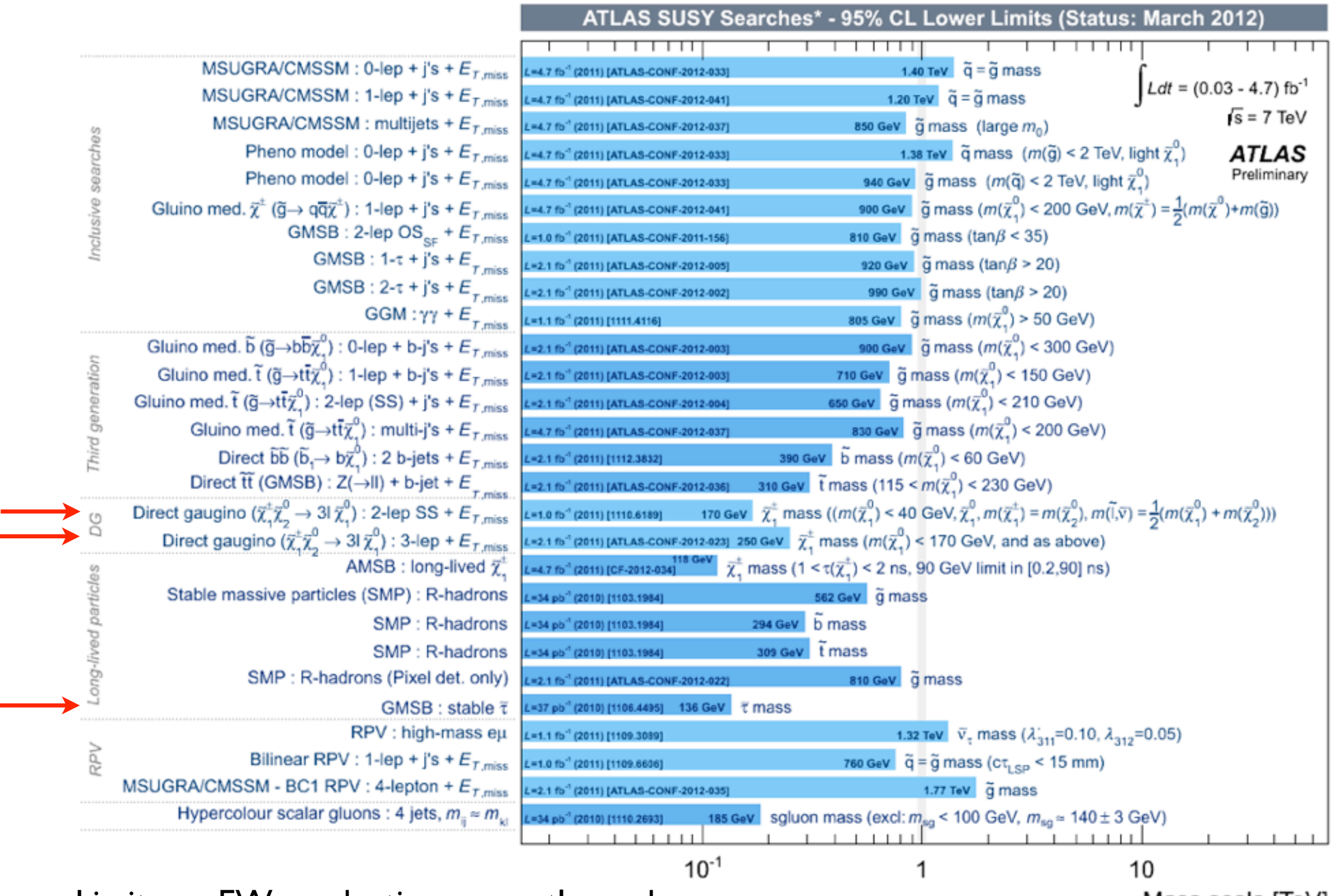


No limit on gluino mass for m_{LSP} > 400 GeV ??

Keep in mind, squeezed spectra are perfectly valid theoretically!! They only do not arise in straw-man models like the CMSSM.

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: March 2012)

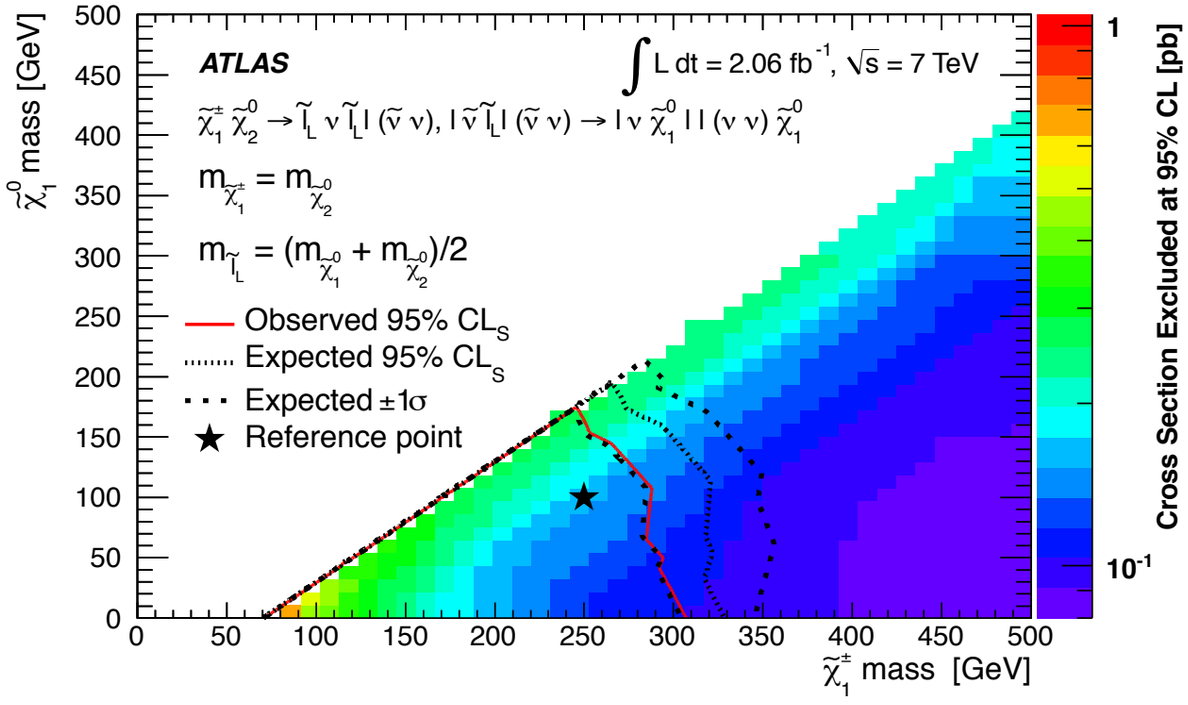




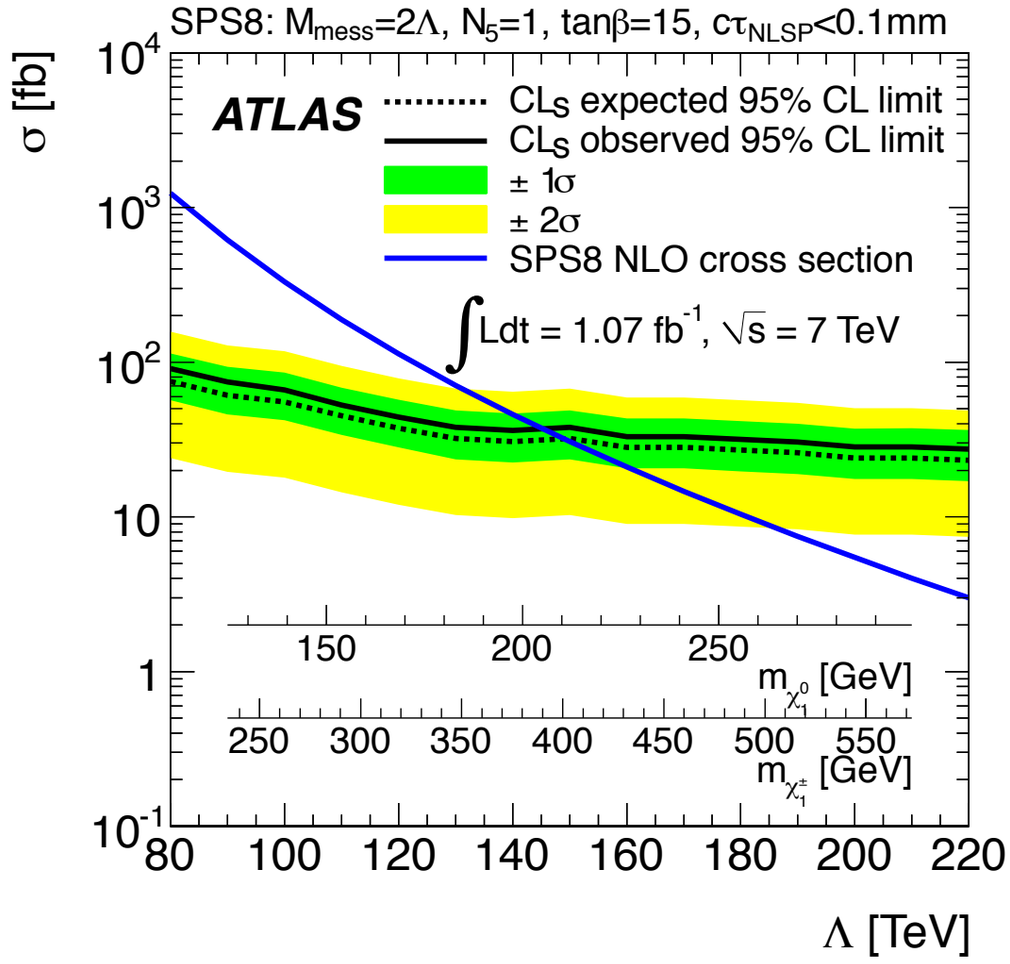
Limits on EW production currently weak, nearly non-existent.

LHC Limits on EW production

Currently need to assume best-case scenarios to get a limit:



neutralino LSP with 100% BR to leptons

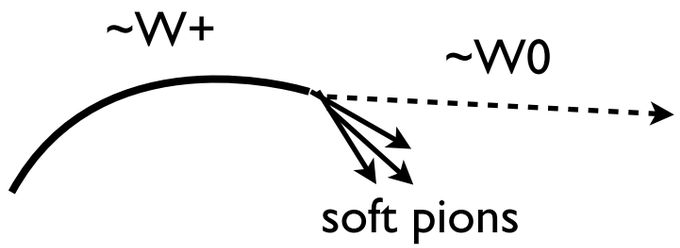


gravitino LSP with 100% BR to photons

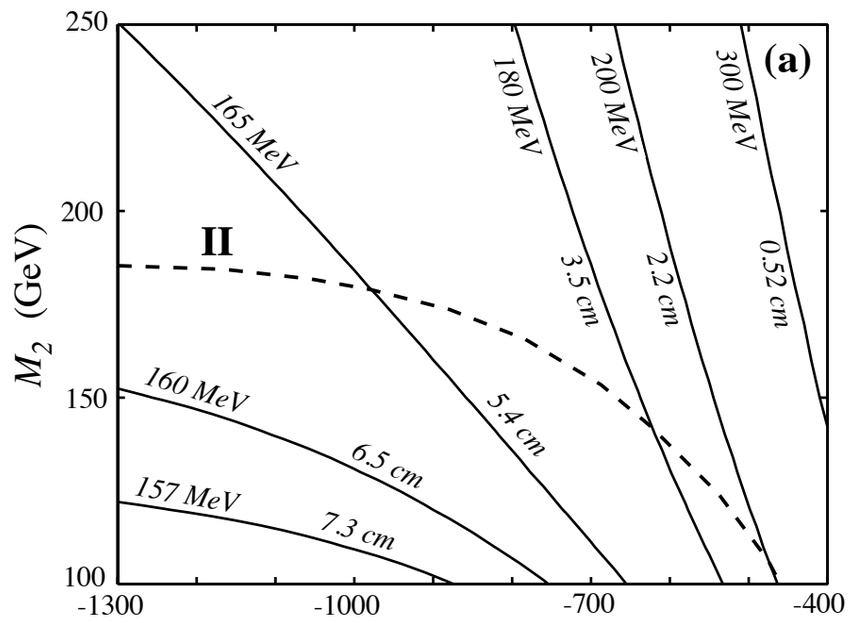
Identity of the LOSP: AMSB

- A general feature of anomaly mediation:
- M1:M2:M3 = 2.8 : 1 : 7
- Wino LSP!!
- In AMSB, squarks and sleptons either ~100 TeV (not sequestered), or weak scale (sequestered). Latter case leads to tachyonic slepton masses for pure AMSB.
- Version of "minimal AMSB" implemented in spectrum generators adds a universal scalar mass-squared to AMSB masses. THIS IS NOT A REAL MODEL. As problematic as the CMSSM.

Identity of the LOSP: AMSB

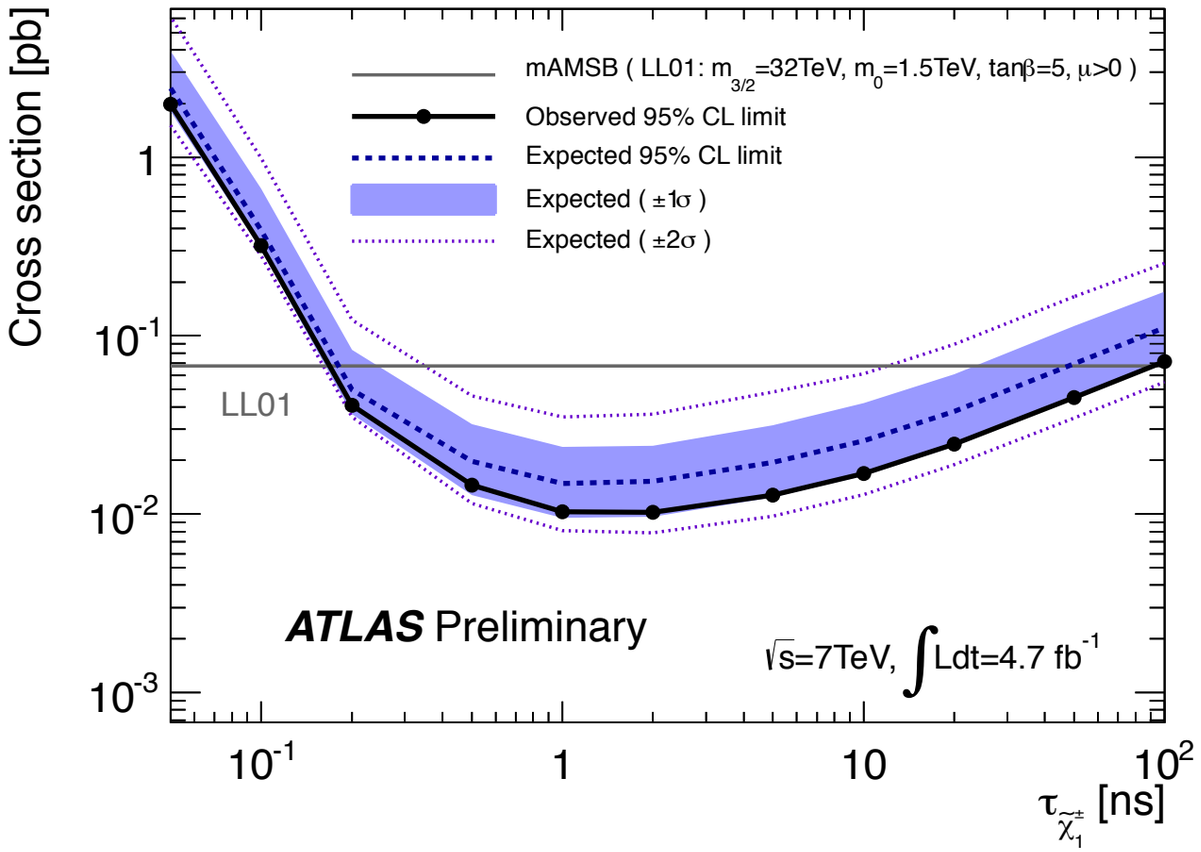


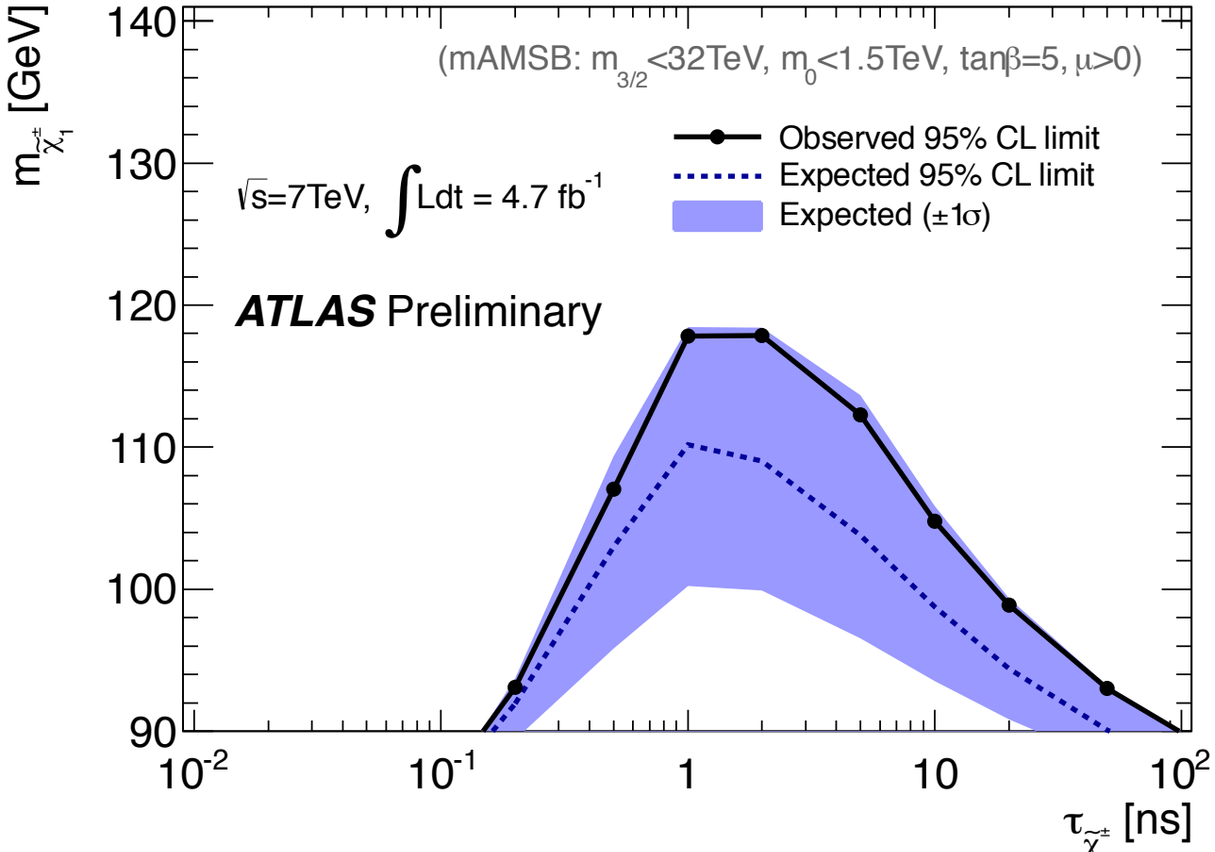
Randall & Sundrum;
Feng, Moroi, Randall, Strassler & Su



- Charged wino can have a macroscopic lifetime before decaying to the neutral wino -- disappearing track
- ATLAS has a recent search (ATLAS-CONF-2012-034).
- Final state: >=3 jets + lepton veto + MET + disappearing track
- It's a good start, but very non-inclusive!!! Highly tuned to specifics of minimal AMSB model.

ATLAS search for disappearing tracks + (....)

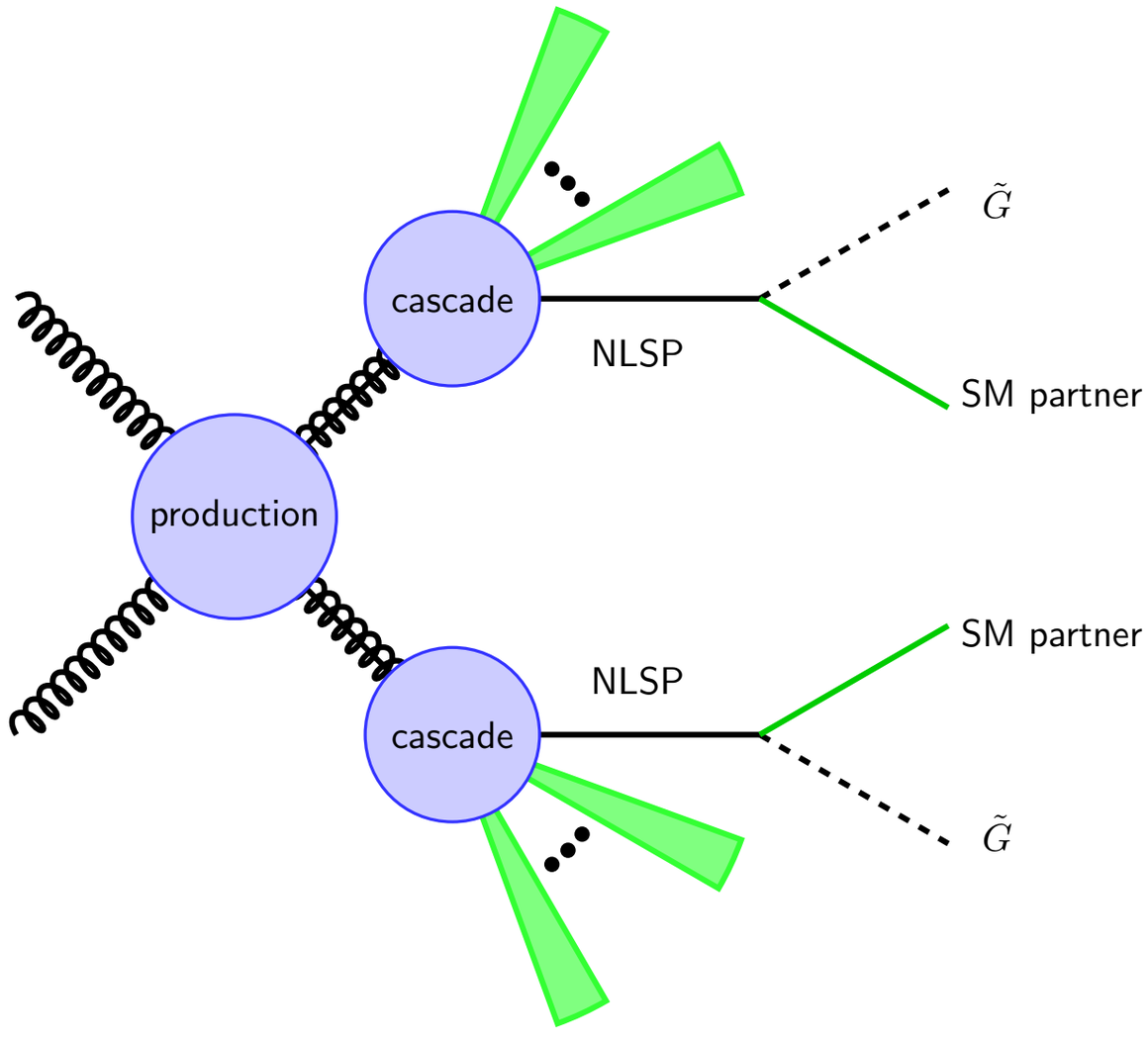




Misleading plot!
Search is actually looking for gluino and squark production...

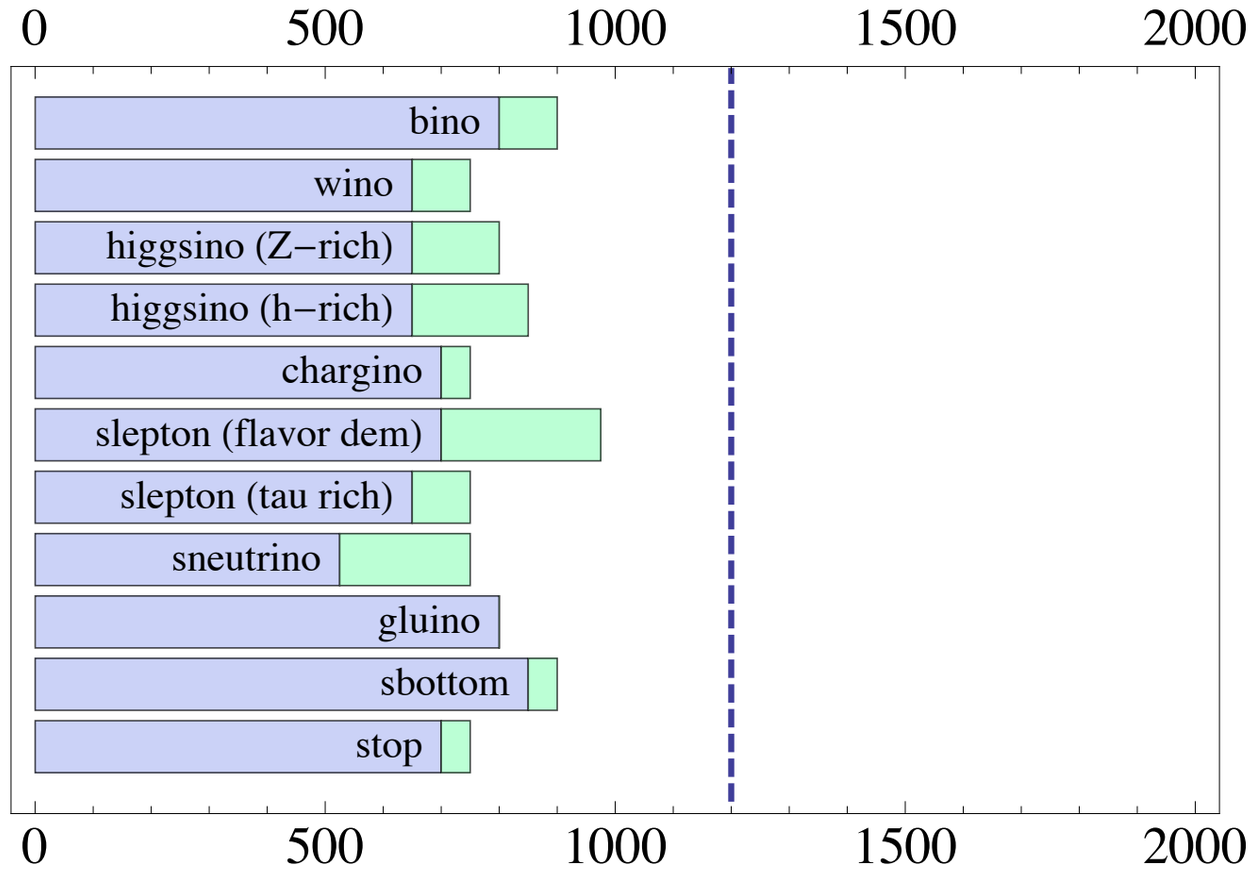
Identity of the LOSP: GMSB

- In GMSB, the LOSP (aka the NLSP) can be any superpartner in the MSSM. (Meade, Seiberg & DS; Buican, Meade, Seiberg, DS)



Identity of the LOSP: GMSB

Analysis	Collaboration	Luminosity (fb^{-1})	Ref
jets+MET	ATLAS	1	[2]
	CMS	1.1	[3]
with α_T	CMS	1.1	[4]
6-8 jets+MET	ATLAS	1.34	[5]
b-jets+MET	ATLAS	0.833	[6]
	CMS	1.1	[7]
SS dileptons+jets+MET	CMS	0.98	[8]
OS dileptons +jets+ MET	CMS	0.98	[9]
lepton+jets+MET	ATLAS	1.04	[10]
	CMS	1.1	[11]
lepton+b-jets+MET	ATLAS	1.03	[12]
$Z(\ell^+\ell^-)$+jets+MET	CMS	0.98	[13]
$t\bar{t}$+MET	ATLAS	1.04	[14]
$\gamma\gamma$+MET	ATLAS	1.07	[15]
$\gamma\gamma$+jet+MET	CMS	1.1	[16]
γ+jets+MET	CMS	1.1	[16]
$\gamma+\ell$+MET	CMS	0.035	[17]



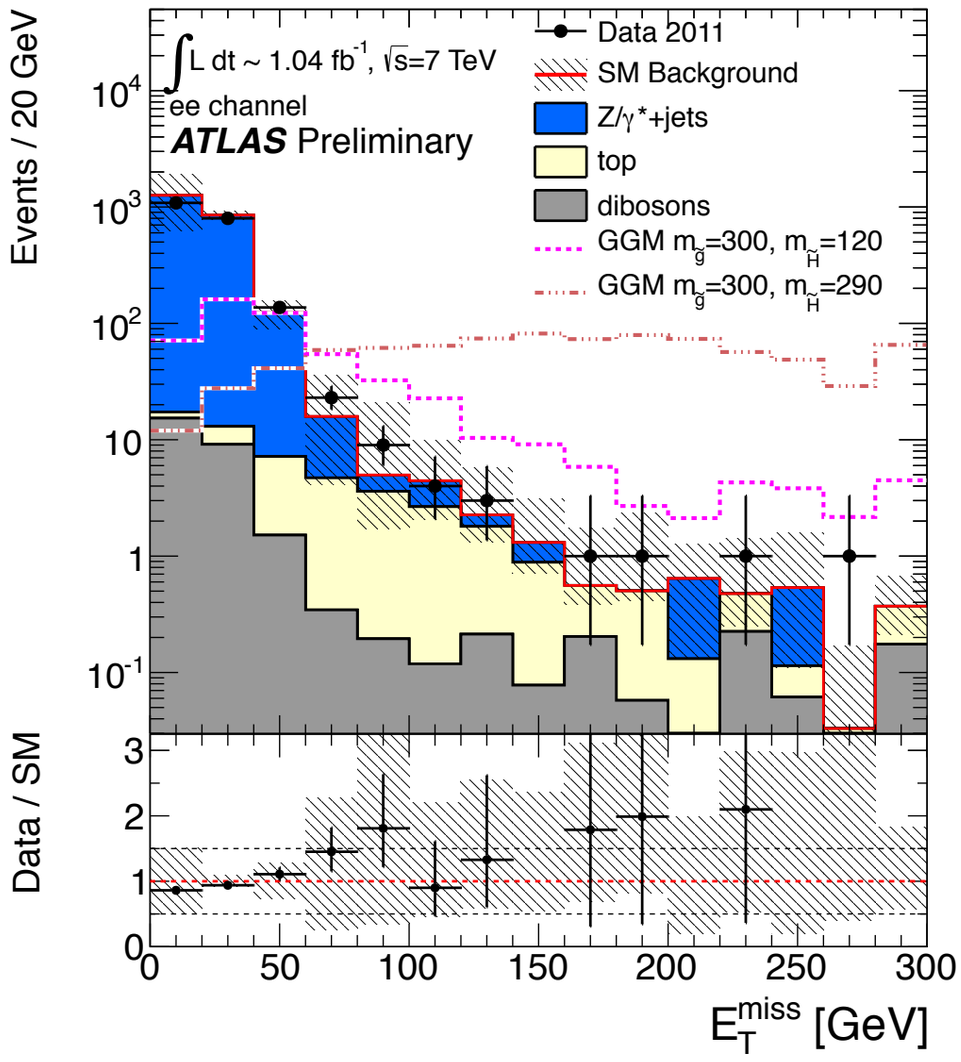
(from Kats, Meade, Reece, DS; "Status of GMSB after 1/fb at the LHC")

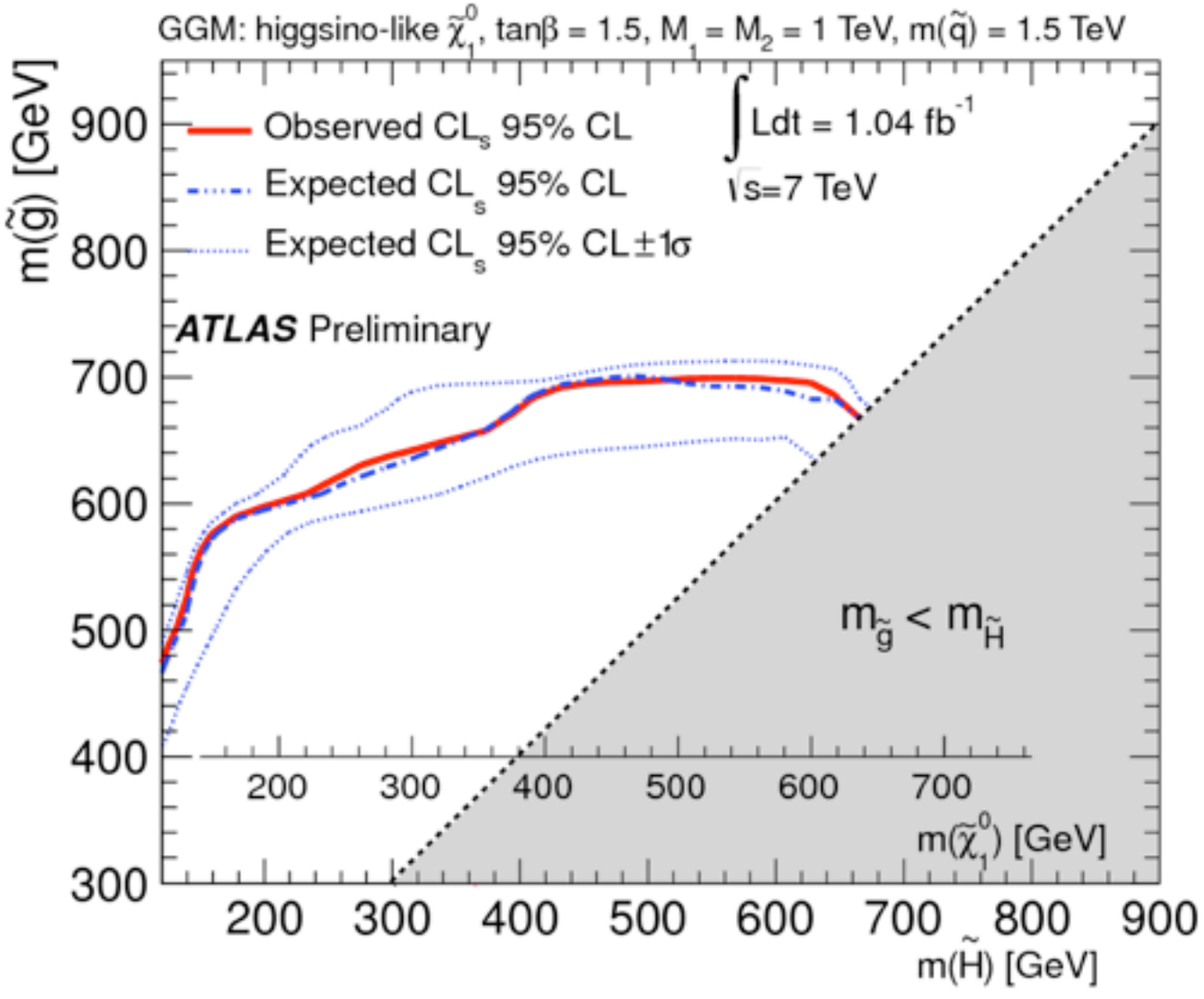
- Overall, the coverage of different NLSP types by non-dedicated searches has been pretty good.
- Indicates that the search for SUSY at the LHC is robust. Well done!
- Again, limits are for strong production; limits on EW production still lacking.

Identity of the LOSP: GMSB

- We're also starting to see more dedicated searches for general GMSB signatures.
- There's more to GMSB than photons and taus!!!
- For example, hot off the presses is an ATLAS search for higgsino-like NLSPs decaying to Z+MET (ATLAS-CONF-2012-047)
- First ever dedicated search for higgsino NLSPs!
- gluino → higgsino+jets; higgsino → Z+gravitino
- Final state: Z(ll) + MET + (>=3 jets or HT)

ATLAS Search for Higgsino NLSPs

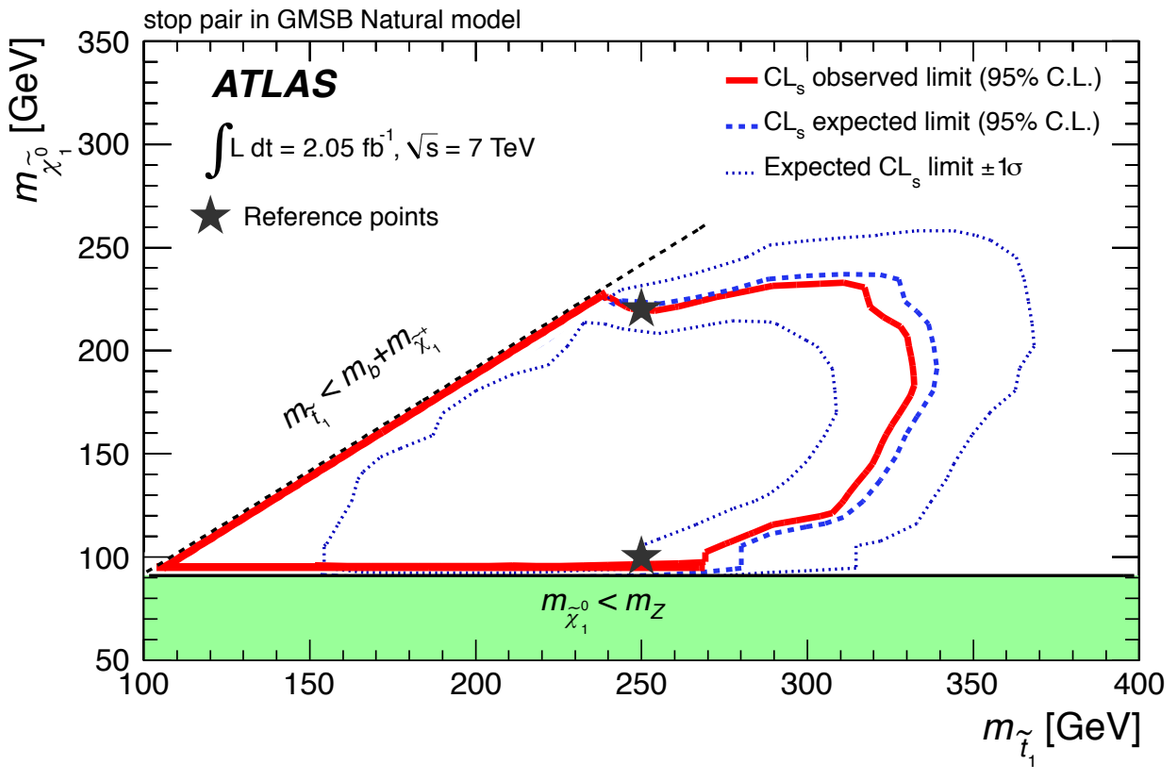




Interestingly, no limit yet on direct Higgsino production...

Higgsino NLSPs through Stop Production

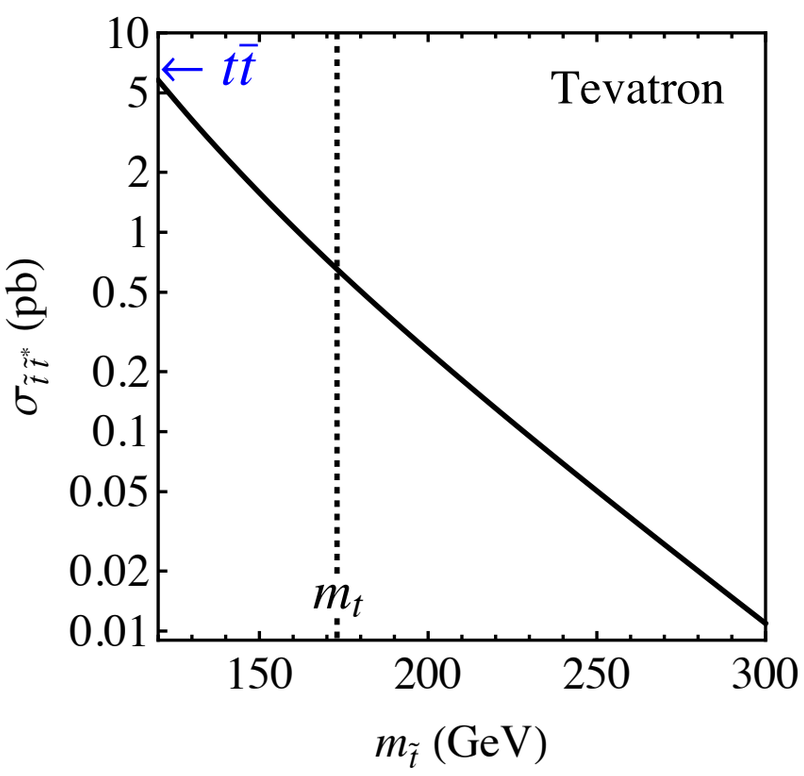
- Another recent, related search from ATLAS: Higgsino NLSPs through stop production -- "natural SUSY" (arXiv:1204.6736)
- Stop → b + Higgsino or t + Higgsino; Higgsino → Z+MET
- Final state: Z(ll) + MET + b jet+ jets

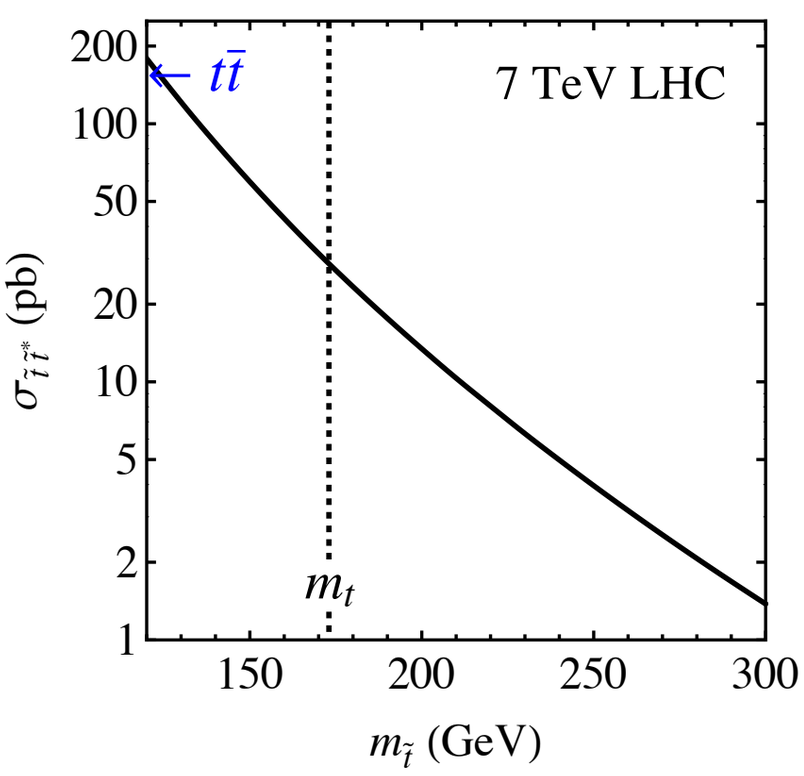


An Interesting Alternative: Stop NLSPs

- An even more minimal realization of "natural SUSY" is stop NLSP
  (Kats & DS "Light Stop NLSPs at the Tevatron and LHC")

- Direct production of stop; stop → top+MET

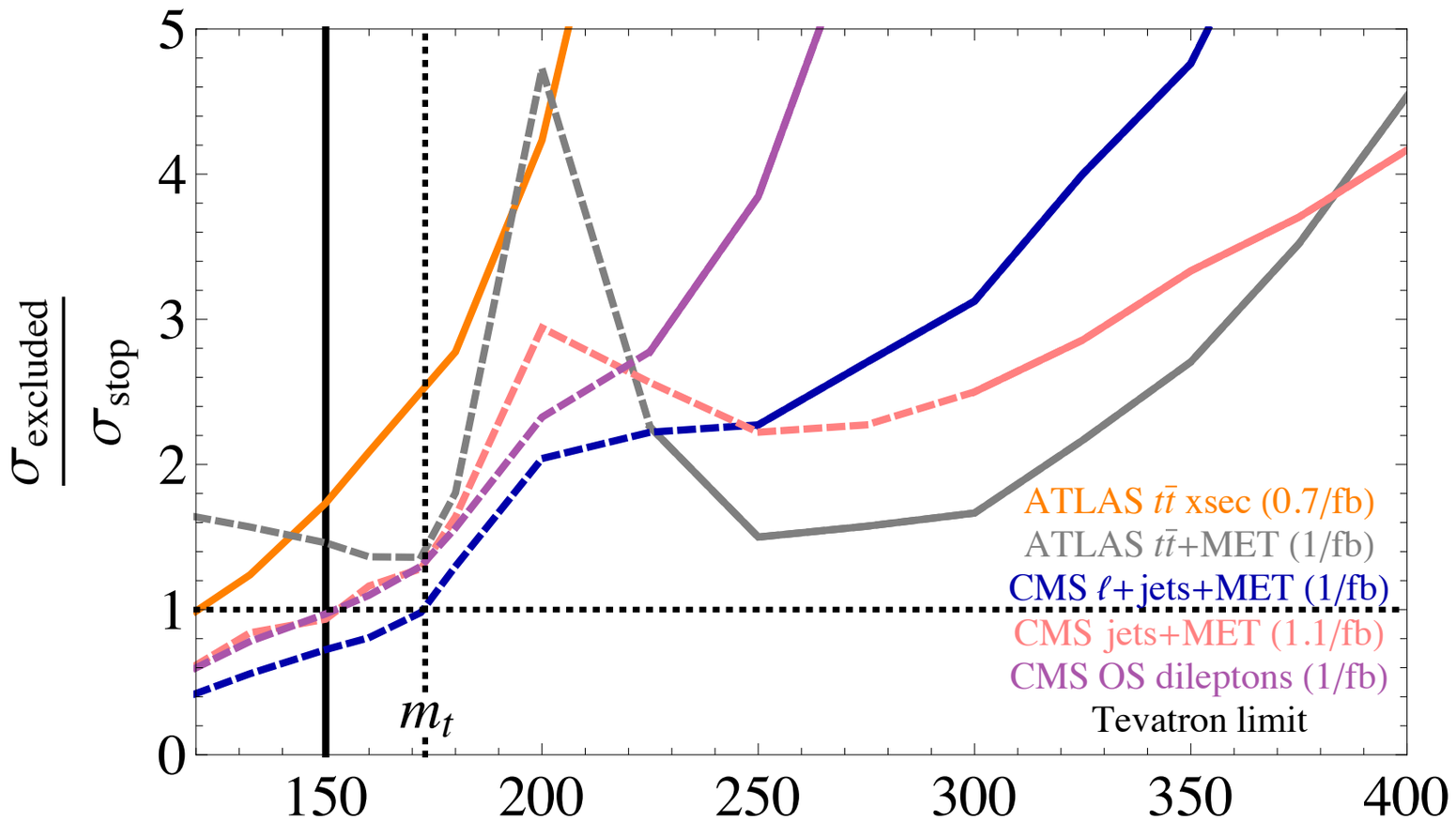




Very challenging to see under ttbar background!

An Interesting Alternative: Stop NLSPs

- Currently no dedicated searches for stop NLSPs, at either Tevatron or LHC. They could still be lighter than the top!!



(Kats & DS; Kats, Meade, Reece, DS)

Conclusions

- "The state of the SUSY search at the LHC is strong."
- Colored SUSY production has been well covered.
- Searches are mostly robust, not overly tuned to specific scenarios.
- The low hanging fruit has largely been picked.
- New, more challenging frontiers await:
  - EW production (winos, higgsinos, sleptons)
  - top-rich signatures (light stops)
  - Displaced vertices (intermediate SUSY-breaking scale)

The End