EF08: Model Specific Explorations

Elliot Lipeles (UPenn)
Nausheen Shah (Wayne State)
Jim Hirschauer (FNAL)

Model Specific Explorations

- Group's Focus and interactions with other groups
- Brief Review of European Strategy Report to motivate questions

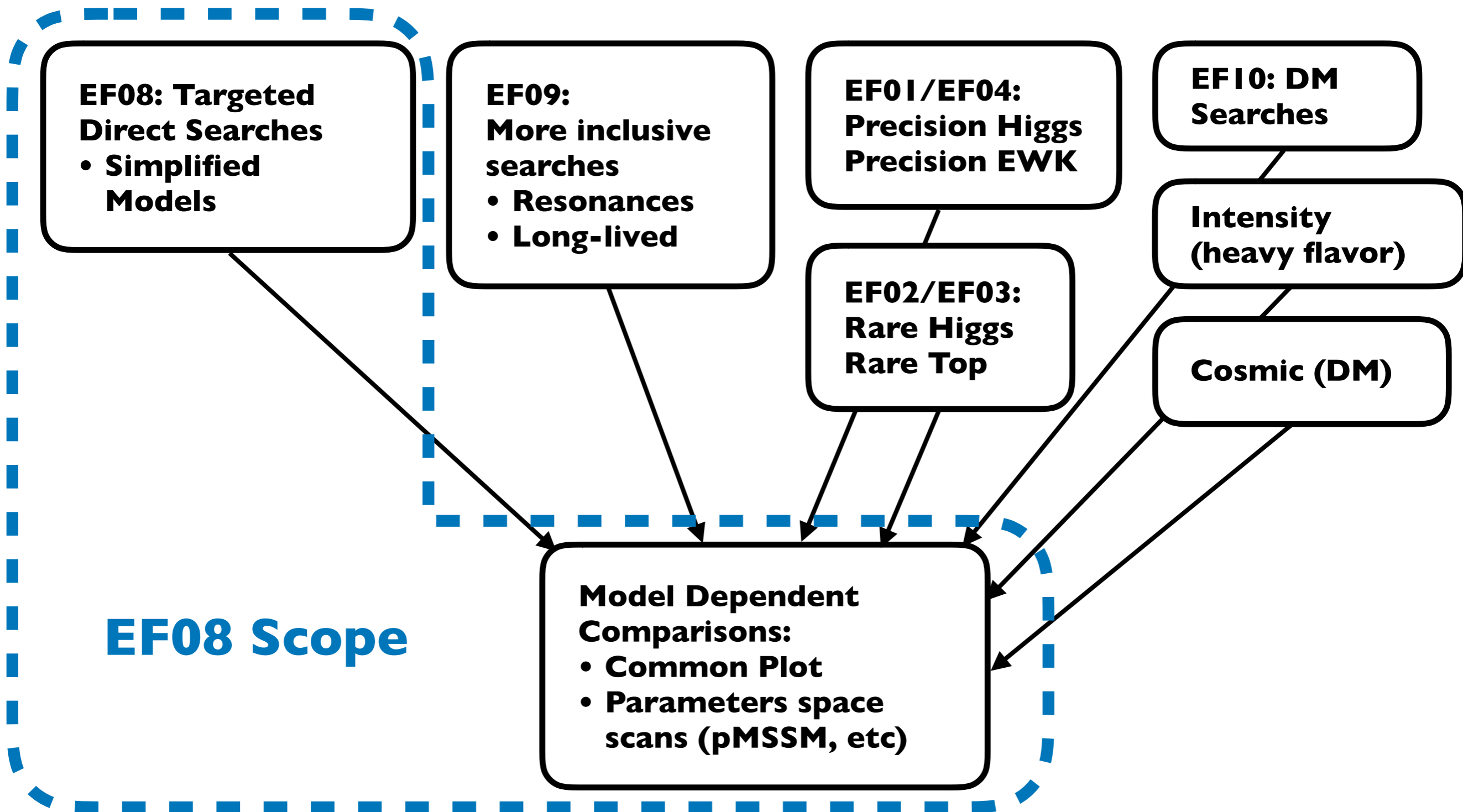Contact Info… (on wiki https://snowmass21.org/energy/bsm_models)

Conveners	Jim Hirschauer, Elliot Lipeles, Nausheen Shah (more contact info)
Mailing-list	SNOWMASS-EF-08-BSM_MODELS@FNAL.GOV (instructions)
Slack channel	ef08-bsm_models (instructions)
Next Event	May 28th 11am ET, general Energy Frontier Kick-off Meeting **(and biweekly there after)**
Contact Forms	In addition to direct emails, you can also use these forms to give us input (preferred method)
	If you'd like to add some input to the discussion in advance of the working group meetings, you can do so here https://forms.gle/FF55yn2aWHKQbgtc7
	To aid us in probing the interest of the community, steer future meetings, and facilitate connections between people interested in similar studies, we invite you to fill out a questionnaire at this link: https://forms.gle/1wSzdPNEqWVSeM1y9

Groups Focus

- Using models to quantify scenarios

- Models give concrete examples to compare scenarios
  - compare inclusivity of leptons colliders vs reach of hadron colliders
  - compare direct searches vs indirect constraints from precision measurements
- Limits on models are of intrinsic interest
  - What mass higgsino will still be allowed if we build XYZ
- In some cases top down motivations suggest viable parameter ranges
  - How will the relative fine-tuning change before and after project XYZ

Use European Strategy as a starting point to collect questions

Focus and Interaction with other groups…

EF08 Scope

EF08: Targeted Direct Searches
- Simplified Models

EF09: More inclusive searches
- Resonances
- Long-lived

EF01/EF04: Precision Higgs Precision EWK

EF02/EF03: Rare Higgs Rare Top

EF10: DM Searches

Intensity (heavy flavor)

Cosmic (DM)

Model Dependent Comparisons:
- Common Plot
- Parameters space scans (pMSSM, etc)

European Strategy Report

Some Leptoquarks

- SUSY is main model considered
- Other models are more like EFT
    - Composite Higgs (EF02)
    - Contact interactions (EF09)
- Dark Matter Simplified Models (EF10)
- Need to think broadly about **which models** to consider based on our goals
    - Intrinsic interest in sensitivity
        - E.g. what scale SUSY (RPC/RPV) or RS/Composite Higgs is probed,
    - Will have different comparison of methods
        - e.g. different signatures…

Want a broad but achievable set of models

European Strategy Example: SUSY (I)

All Colliders: Top squark projections
(R-parity conserving SUSY, prompt searches)
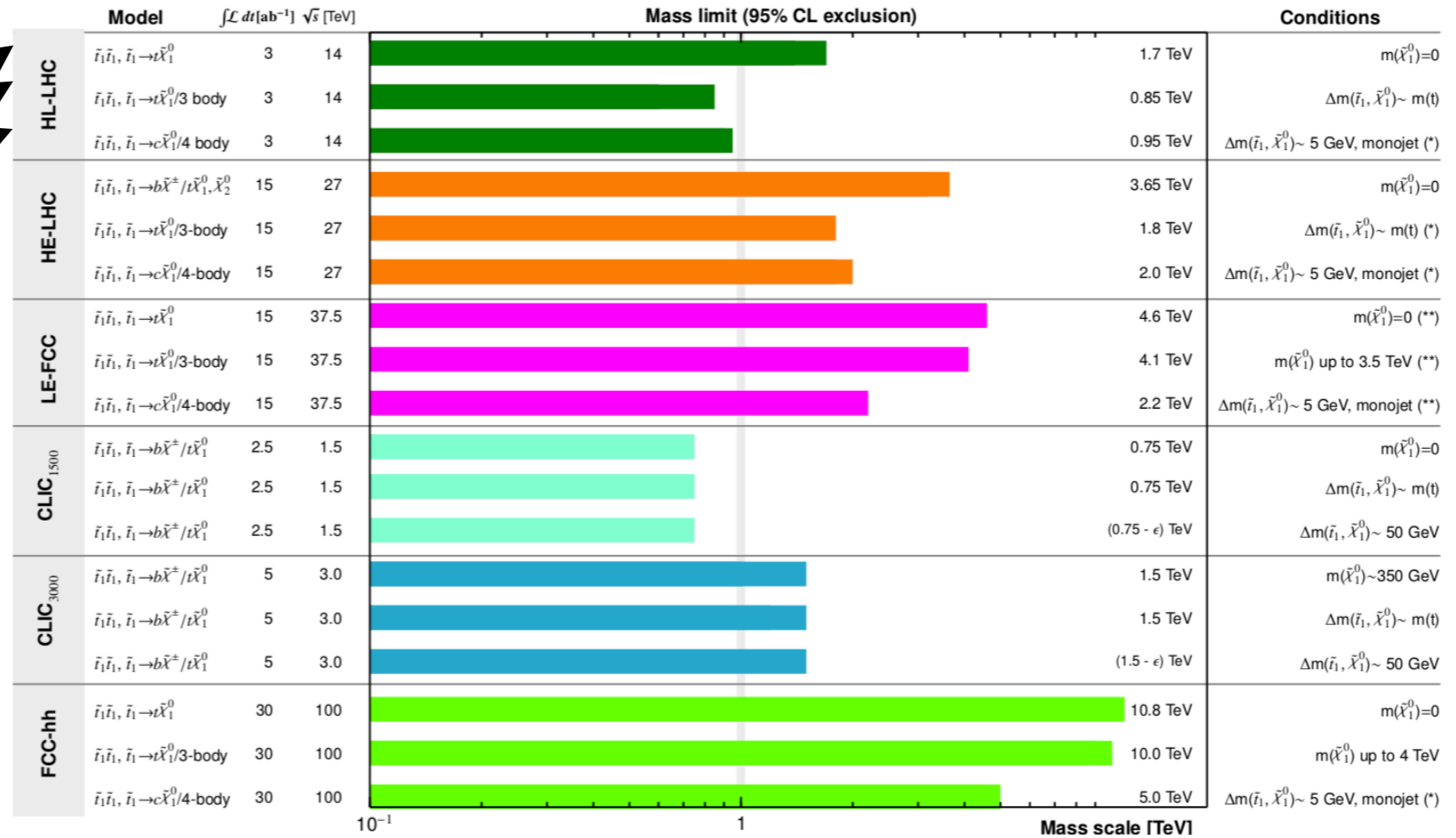
Consider several corners of stop phase space

Leptons less sensitive to corners

Measure of fine-tuning: Discussion needed: is it meaningful/interesting?

|	Model	$\int \mathcal{L}\, dt$ [ab^{-1}]	$\sqrt{s}$ [TeV]	Mass limit (95% CL exclusion)		Conditions
HL-LHC	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0$	3	14		1.7 TeV	$m(\tilde{\chi}_1^0)=0$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0/\text{3 body}$	3	14		0.85 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim m(t)$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0/\text{4 body}$	3	14		0.95 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 5$ GeV, monojet (*)
HE-LHC	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0,\tilde{\chi}_2^0$	15	27		3.65 TeV	$m(\tilde{\chi}_1^0)=0$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0/\text{3-body}$	15	27		1.8 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim m(t)$ (*)
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0/\text{4-body}$	15	27		2.0 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 5$ GeV, monojet (*)
LE-FCC	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0$	15	37.5		4.6 TeV	$m(\tilde{\chi}_1^0)=0$ (**)
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0/\text{3-body}$	15	37.5		4.1 TeV	$m(\tilde{\chi}_1^0)$ up to 3.5 TeV (**)
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0/\text{4-body}$	15	37.5		2.2 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 5$ GeV, monojet (**)
CLIC$_{1500}$	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	2.5	1.5		0.75 TeV	$m(\tilde{\chi}_1^0)=0$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	2.5	1.5		0.75 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim m(t)$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	2.5	1.5		$(0.75-\epsilon)$ TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 50$ GeV
CLIC$_{3000}$	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	5	3.0		1.5 TeV	$m(\tilde{\chi}_1^0)\sim 350$ GeV
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	5	3.0		1.5 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim m(t)$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to b\tilde{\chi}^\pm/t\tilde{\chi}_1^0$	5	3.0		$(1.5-\epsilon)$ TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 50$ GeV
FCC-hh	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0$	30	100		10.8 TeV	$m(\tilde{\chi}_1^0)=0$
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to t\tilde{\chi}_1^0/\text{3-body}$	30	100		10.0 TeV	$m(\tilde{\chi}_1^0)$ up to 4 TeV
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0/\text{4-body}$	30	100		5.0 TeV	$\Delta m(\tilde{t}_1,\tilde{\chi}_1^0)\sim 5$ GeV, monojet (*)

Mass scale [TeV]

ε	High-scale mediation	Low-scale mediation
stop	$5\times10^{-5}\left(\dfrac{10\text{ TeV}}{m_{\tilde{t}}}\right)^2$	$2\times10^{-3}\left(\dfrac{10\text{ TeV}}{m_{\tilde{t}}}\right)^2$
gluino	$7\times10^{-6}\left(\dfrac{17\text{ TeV}}{m_{\tilde{g}}}\right)^2$	$6\times10^{-3}\left(\dfrac{17\text{ TeV}}{m_{\tilde{g}}}\right)^2$

European Strategy Update
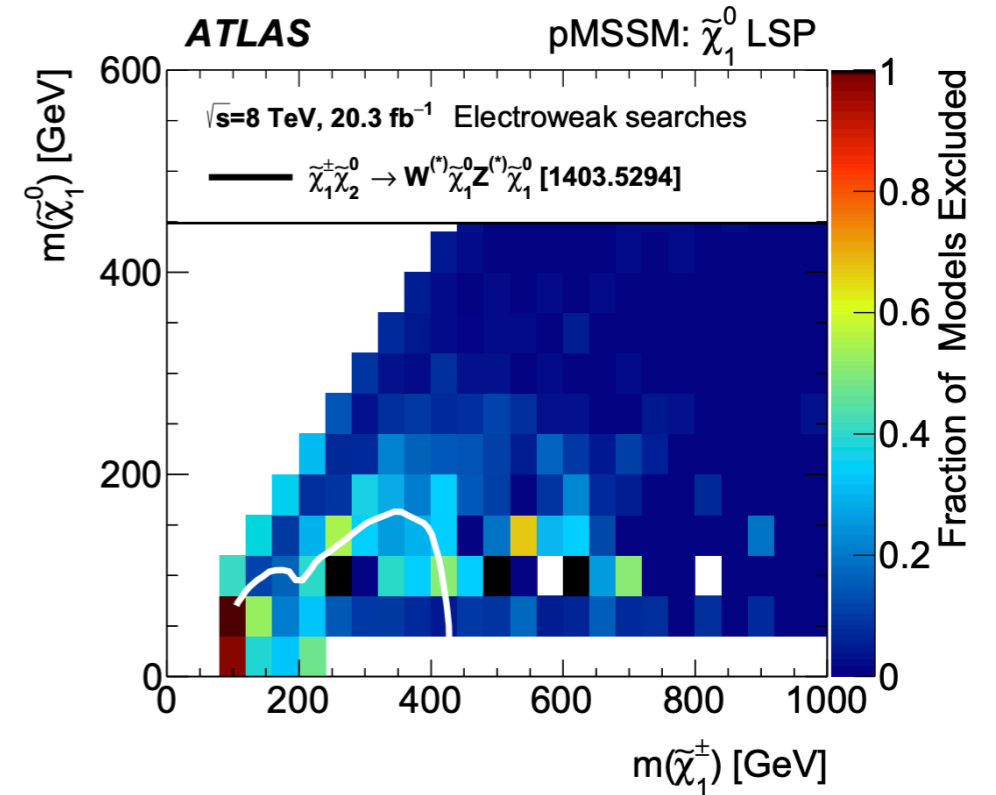
European Strategy Example: SUSY (II)
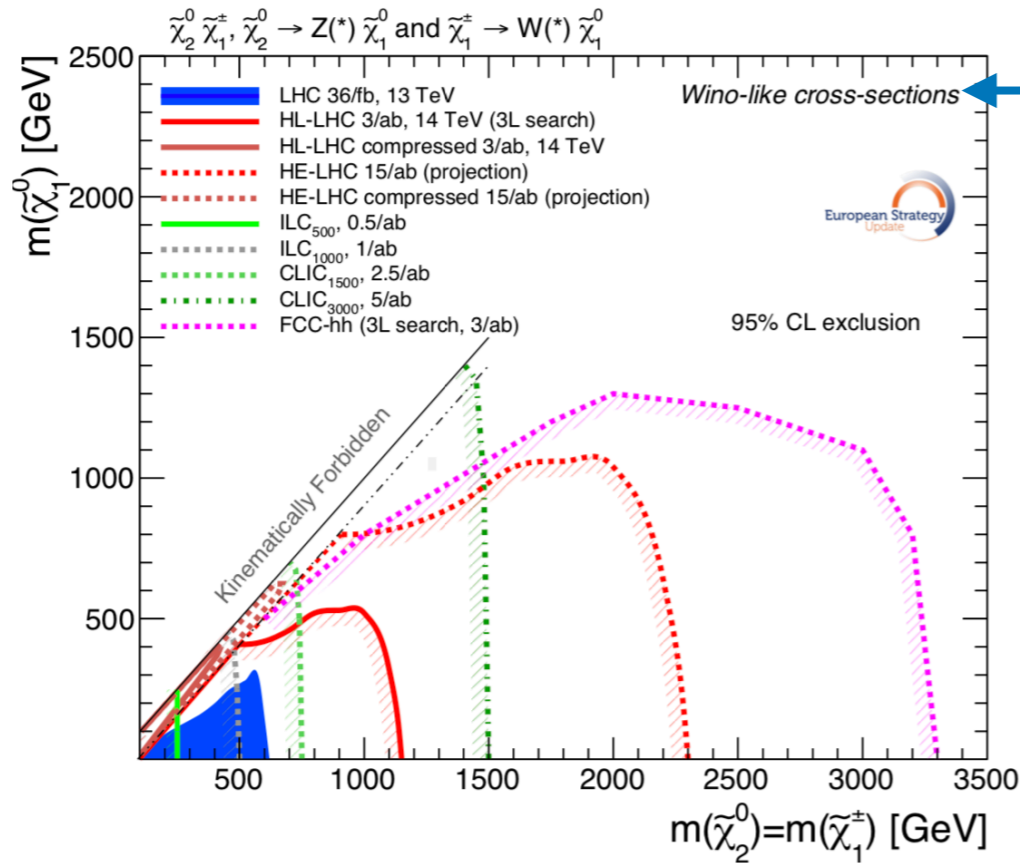
Assumptions are important. Simplified models plots have limitations

pMSSM scan → Very little of simplified model region actually excluded. How far should we go?
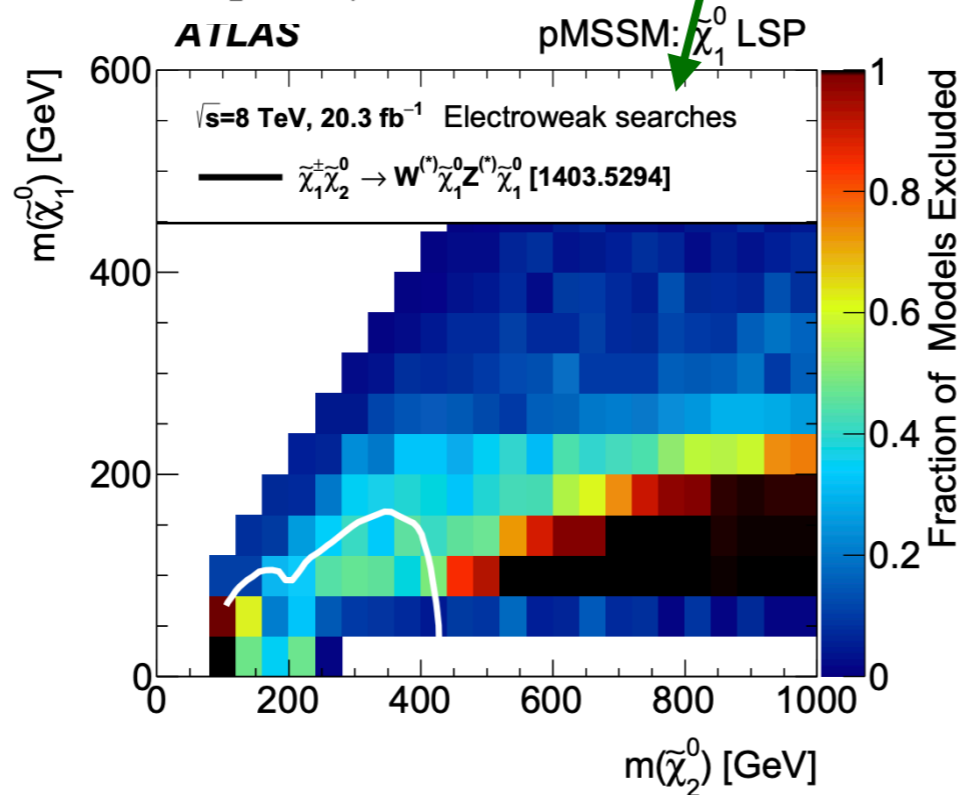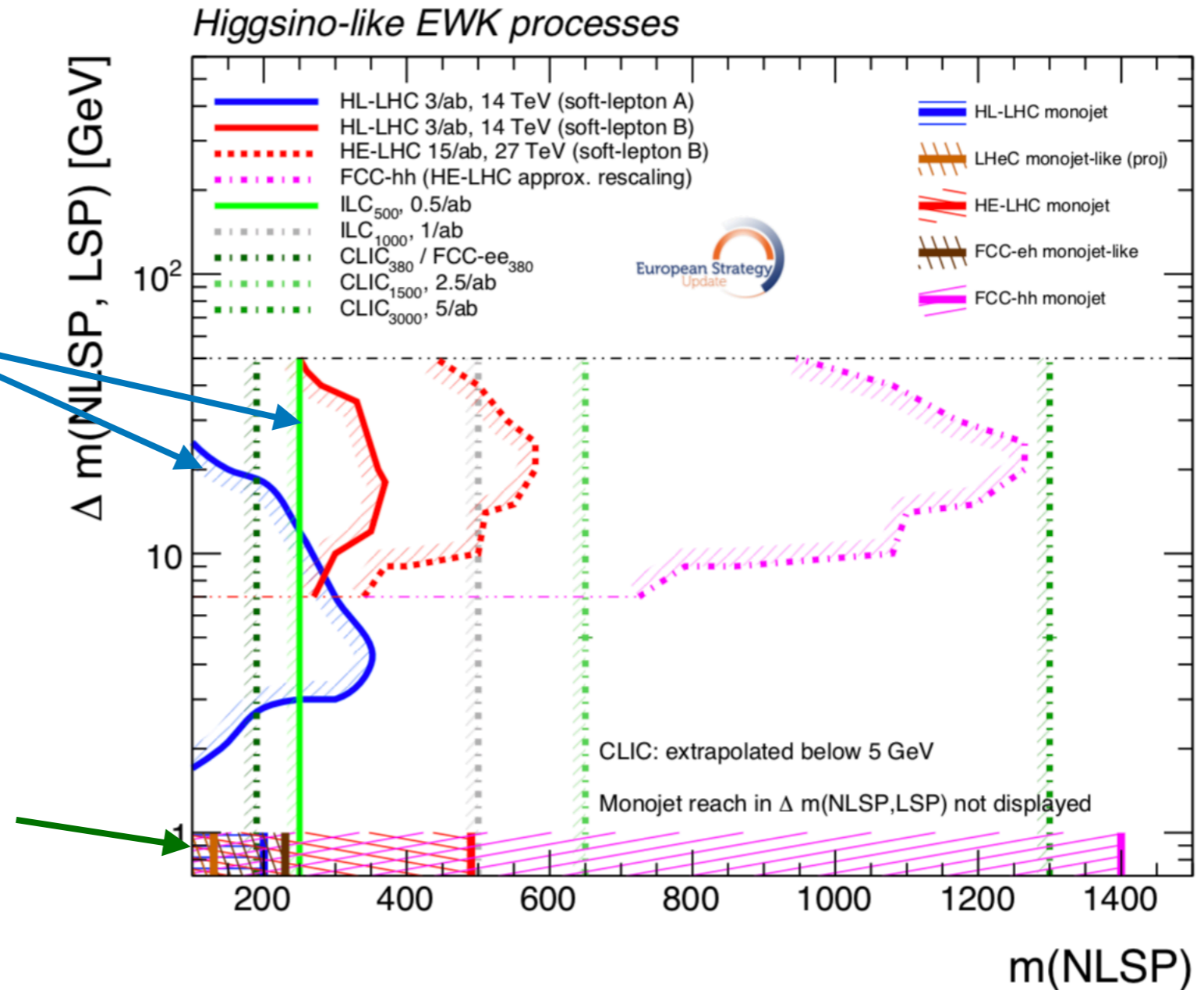
(a) Neutralinos

(b) Chargino–neutralino

European Strategy Example: Reinterpret LLP

Direct Searches

Reinterpretation of Long-live particle search: very sensitive to assumptions on detector reconstruction
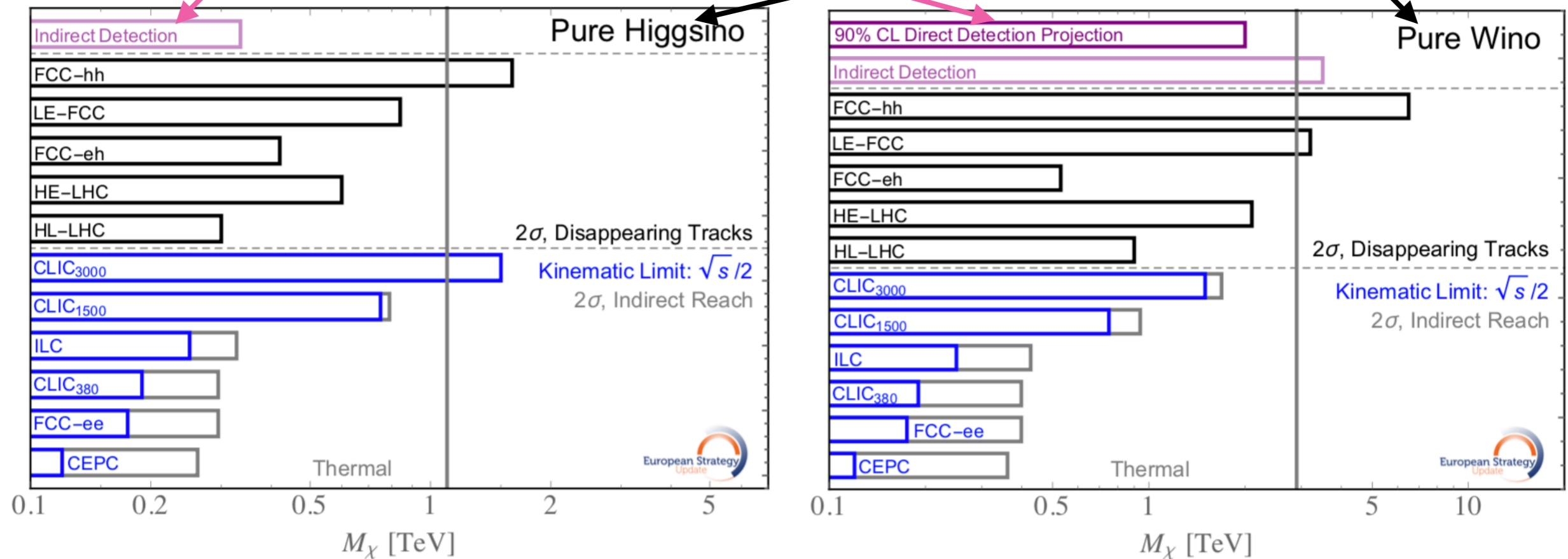
Need consistency on detector/reconstruction assumptions across EF
- E.g. lepton pT thresholds
- E.g. decay length of LLP sensitivity

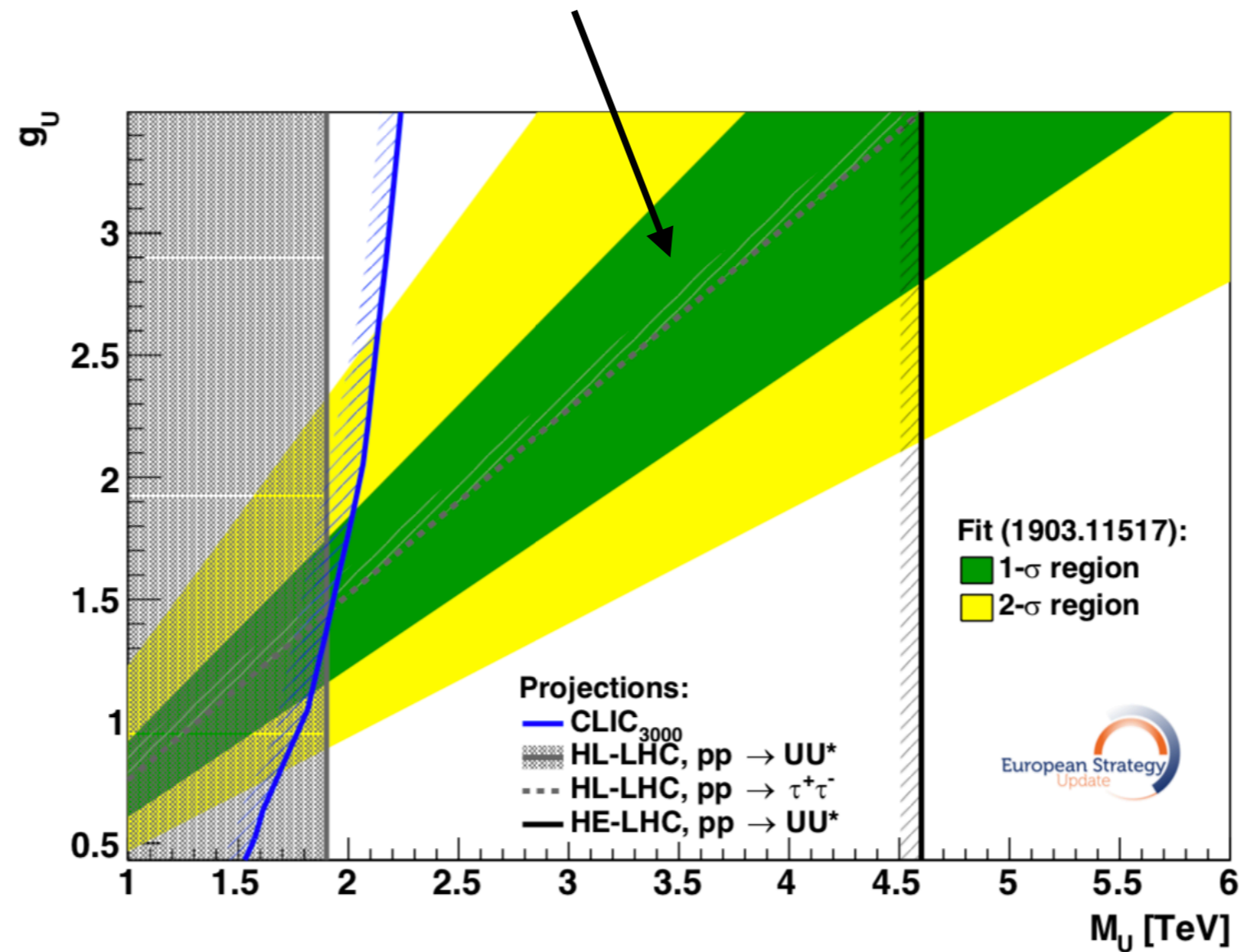# European Strategy Example: SUSY & DM

Comics Frontier projections

RPC SUSY still the target model

Need to coordinate with EF10 Dark Matter to not duplicate effort on this

European Strategy Example: Leptoquarks

Flavor physics anomalies can motivate model interest

Bibliography…

Need to build a bibliography for participants to review what has been done

Here is a very partial quick list (nothing has been excluded intentionally).

Please send us suggestions.

- European Strategy Briefing Book: http://cds.cern.ch/record/2691414
- Snowmass 2013 EF reports: https://www.slac.stanford.edu/econf/C1307292/docs/EnergyFrontier.html
- FCC physics opportunities: https://inspirehep.net/literature/1713706
- ILC physics report: https://arxiv.org/pdf/0709.1893.pdf
- CERN yellow book on HL-LHC and HE-LHC: https://cds.cern.ch/record/2703572?ln=en
- The CLIC Potential for New Physics: http://dx.doi.org/10.23731/CYRM-2018-003

Conclusions

- EF08 should focus on model specific signatures not covered in other groups and on model specific comparisons
- Should review European Strategy and other inputs
  - What can be used directly, what should be looked at in more depth
- Questions to address about our scope:
  - **Which Models**
    - Inclusive, but limited, adding models should motivate different signatures or sensitivity comparisons
    - Sensitivity to externally motivations: anomalies, fine-tuning, …
  - Need to consider how to approach **naturalness/fine-tuning**
  - Need to consider **applicability of simplified models**
  - Need to consider **detector constraints**, but also what might motivate detector choices
- Use forms to suggest more discussion questions or express interest in working on topics
  - Also can use for to suggest documents for a bibliography
  - Email is also always welcome