Higgsino DM

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- Introduction: Problems with “standard" DM
- Solutions: Pure Higgsino
- Conclusion

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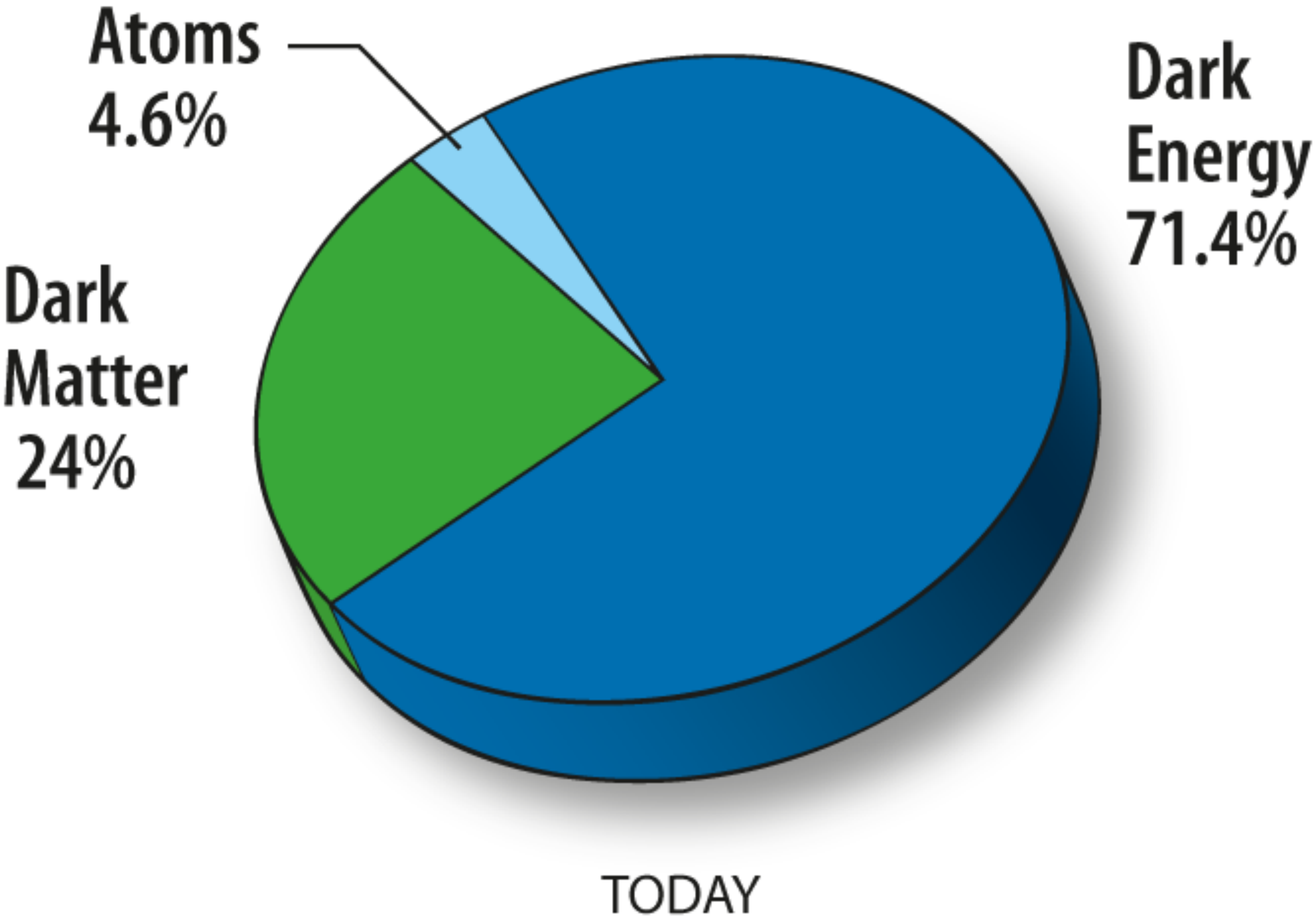
Introduction

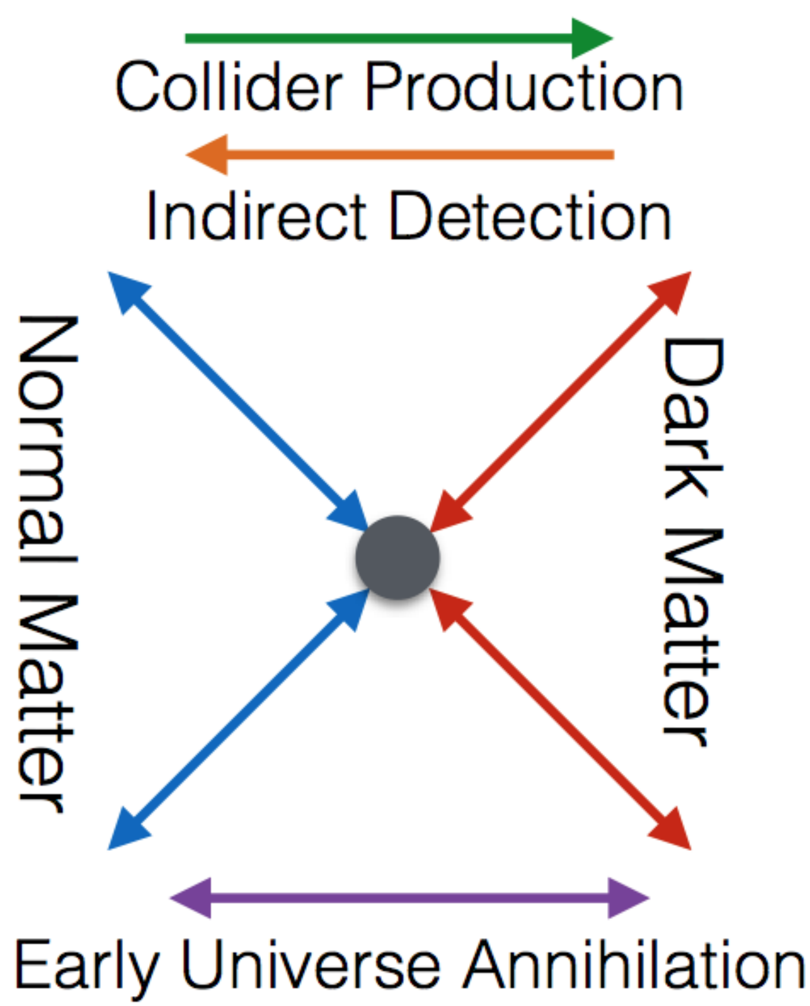


- DM may be the most stablished reason for physics BSM

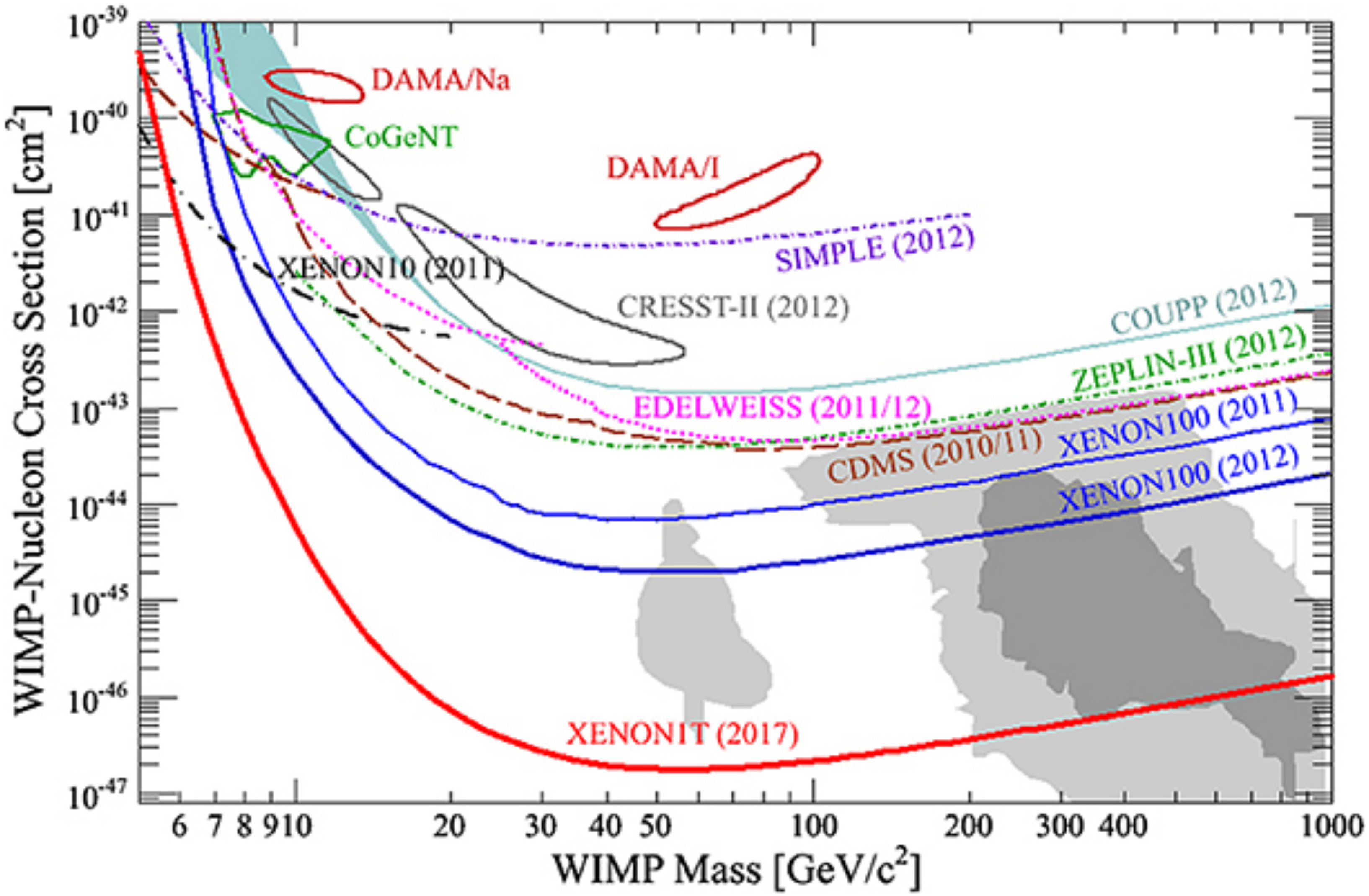
- It turns out that a WIMP: a stable massive object with weak interactions and a mass around the EW scale reproduces the observed relic abundance.

$$\Omega h^2 \simeq 0.118$$

- It has interesting experimental consequences.



- But:



DAMA/Na
CoGeNT
DAMA/I
SIMPLE (2012)
XENON10 (2011)
CRESST-II (2012)
COUPP (2012)
ZEPLIN-III (2012)
EDELWEISS (2011/12)
XENON100 (2011)
CDMS (2010/11)
XENON100 (2012)
XENON1T (2017)
WIMP-Nucleon Cross Section [cm^2]
WIMP Mass [GeV/c^2]

- Most models (well-tempered, higgs portals,….) are excluded by DD bounds.

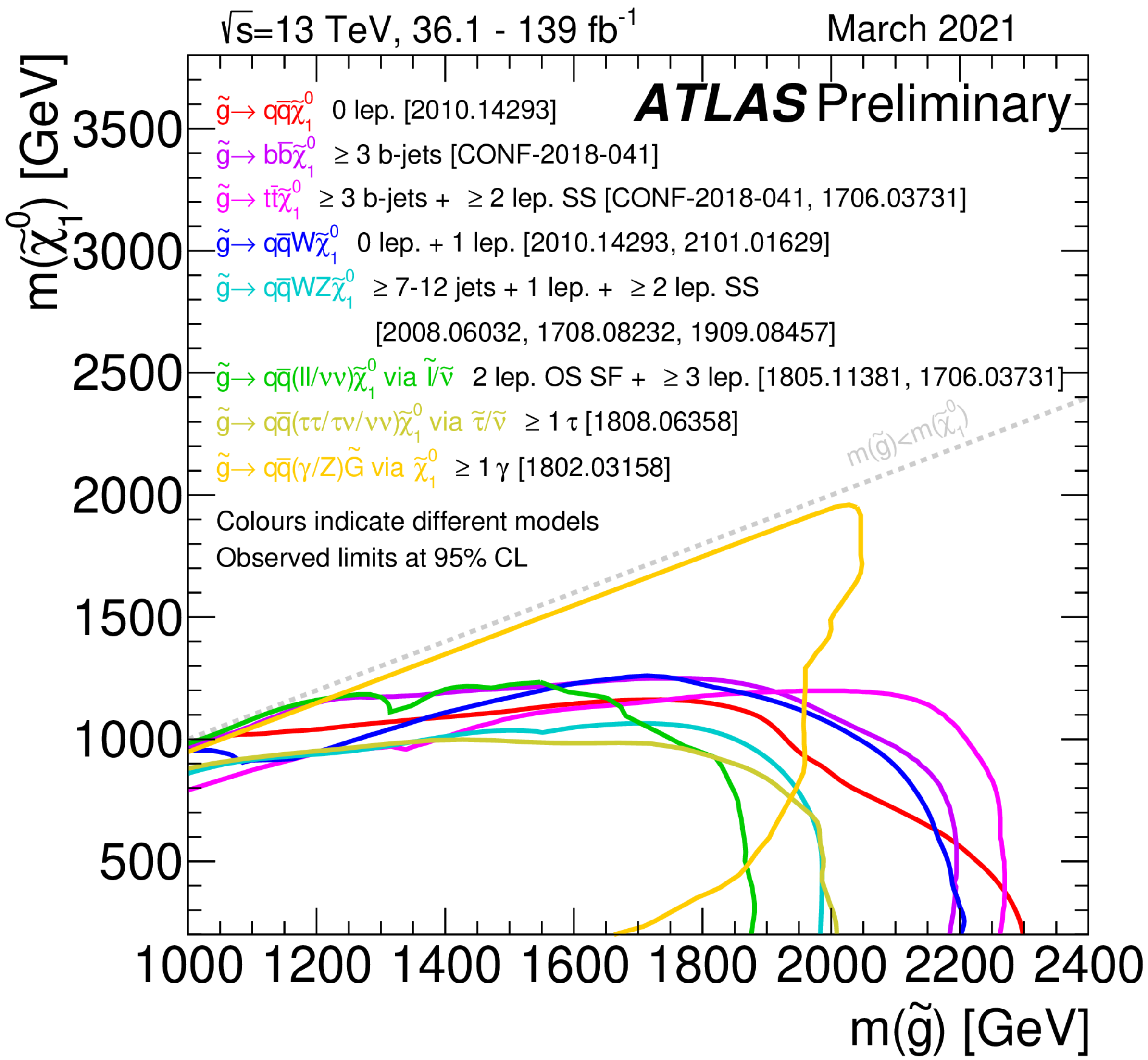
- Among the usual candidates for DM in the MSSM (neutralinos) the ones with less constrains (specially from direct detections):

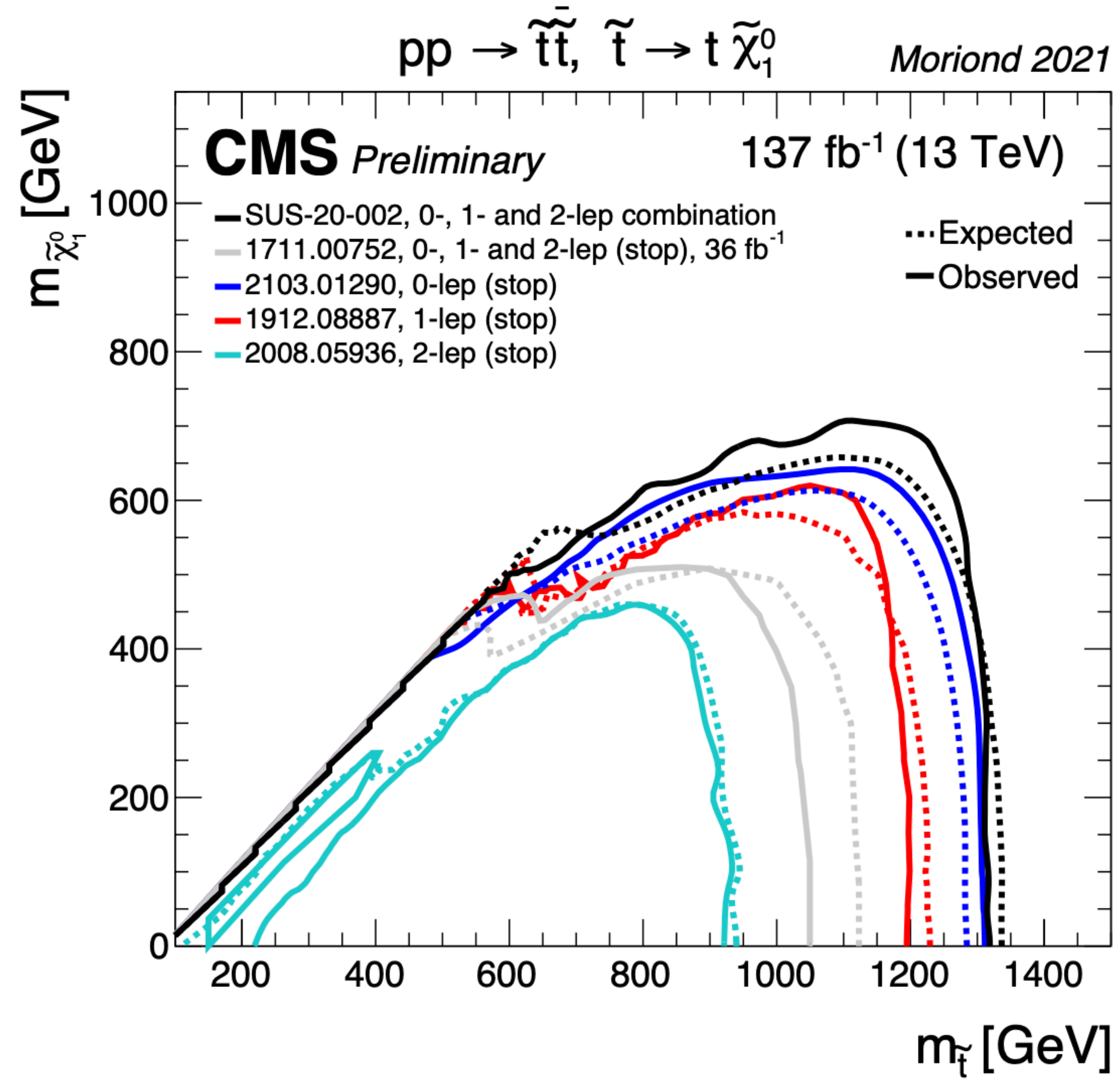
  - Pure Higgsino with mass ~1.1-1.2 TeV.

Searching for a LSP Higgsino

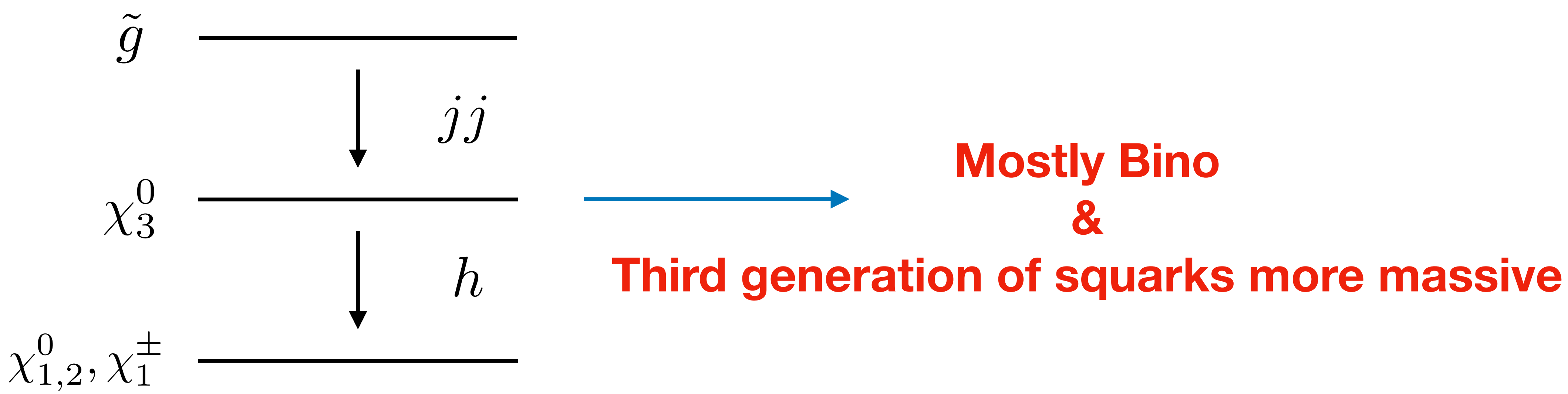
arXiv: 2104.13827, 2107.06034, 2112.09198

- The Higgsino as the LSP can be challenging at the LHC
- Even though there are several states quasi degenerated the fact that the mass splitting is small makes it very challenging to detect the ‘intra-higgsino’ decays
- Direct decays from strongly produced particles are already covered by the existing searches.


√s=13 TeV, 36.1 - 139 fb-1
March 2021
ATLAS Preliminary
g̃→ qq̄χ̃10 0 lep. [2010.14293]
g̃→ bb̄χ̃10 ≥ 3 b-jets [CONF-2018-041]
g̃→ tt̄χ̃10 ≥ 3 b-jets + ≥ 2 lep. SS [CONF-2018-041, 1706.03731]
g̃→ qq̄Wχ̃10 0 lep. + 1 lep. [2010.14293, 2101.01629]
g̃→ qq̄WZχ̃10 ≥ 7-12 jets + 1 lep. + ≥ 2 lep. SS [2008.06032, 1708.08232, 1909.08457]
g̃→ qq̄(ll/νν)χ̃10 via l̃/ν̃ 2 lep. OS SF + ≥ 3 lep. [1805.11381, 1706.03731]
g̃→ qq̄(ττ/τν/νν)χ̃10 via τ̃/ν̃ ≥ 1 τ [1808.06358]
g̃→ qq̄(γ/Z)G̃ via χ̃10 ≥ 1 γ [1802.03158]
Colours indicate different models
Observed limits at 95% CL
m(g̃)<m(χ̃10)
m(χ̃10) [GeV]
m(g̃) [GeV]


pp → t̃t̃̄, t̃ → t χ̃10
Moriond 2021
CMS Preliminary
137 fb-1 (13 TeV)
SUS-20-002, 0-, 1- and 2-lep combination
1711.00752, 0-, 1- and 2-lep (stop), 36 fb-1
2103.01290, 0-lep (stop)
1912.08887, 1-lep (stop)
2008.05936, 2-lep (stop)
Expected
Observed
m χ̃10 [GeV]
m t̃ [GeV]

- A more interesting possibility arises in a situation when you have the following cascade decay:



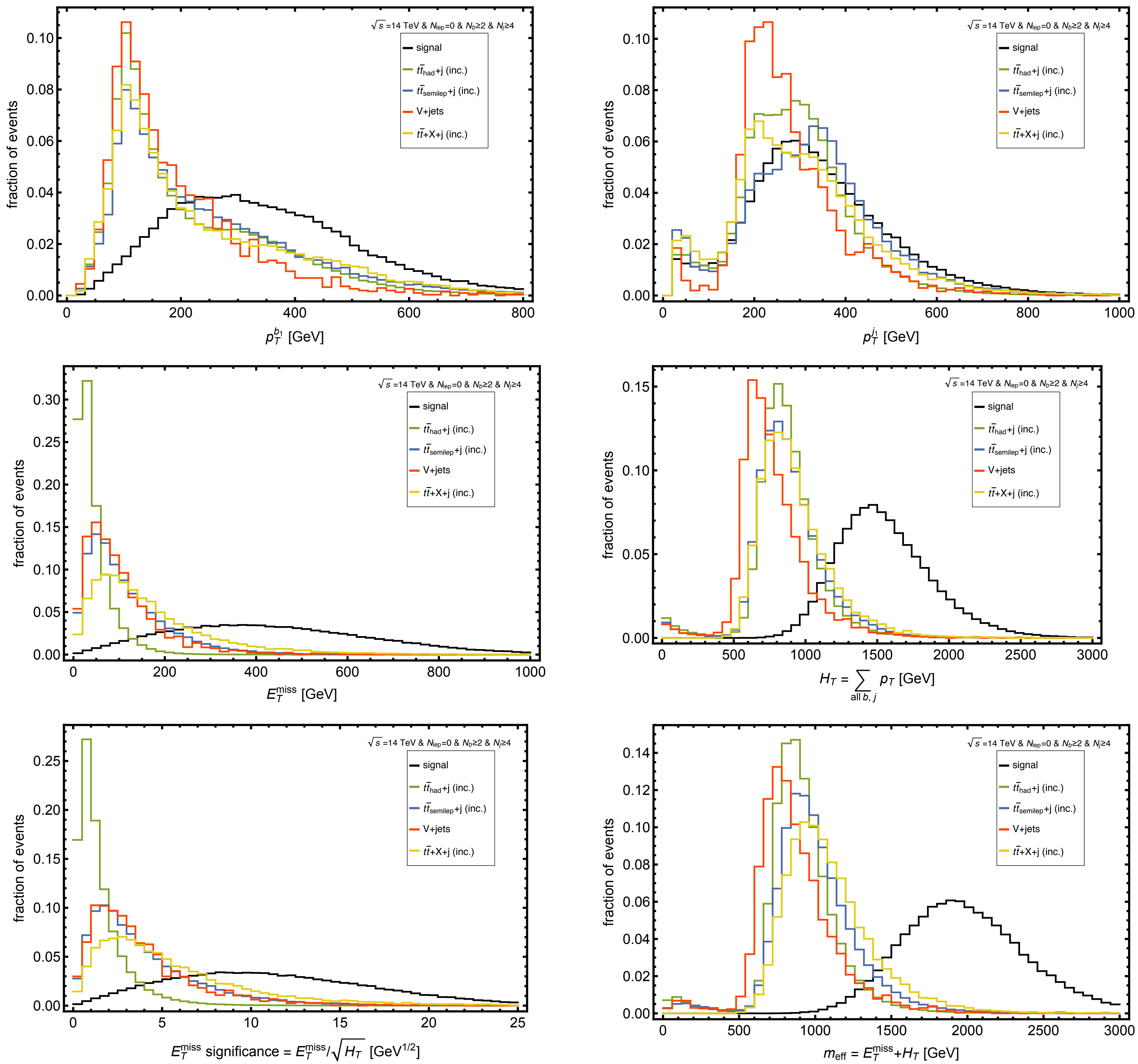
- We are going to design an strategy for discovery of a pair production of gluinos that decay to χ_3^0 and two light jets, that then decay to χ_1^0 plus a higgs decaying to b's.

signal **4j+4b+Emiss**

backgrounds:
- **QCD**
- **Z+jets**
- **W+jets**
- **t t-bar**
- **t t-bar + X**
- **diboson+jets**

- QCD will be handled with a large Emiss cut
- Diboson is negligible compare to single boson
- V+jets and events with tops are the most dangerous.
- Cuts at generator level:

$$p_T^{j_1} > 180\,\mathrm{GeV}\,, \quad p_T^{j_2} > 140\,\mathrm{GeV}\,, \quad p_T^{j_3} > 70\,\mathrm{GeV}\,, \quad p_T^{j_4} > 35\,\mathrm{GeV}\,;$$
$$p_T^{b_1} > 90\,\mathrm{GeV}\,, \quad p_T^{b_2} > 20\,\mathrm{GeV}\,, \quad p_T^{b_3} > 20\,\mathrm{GeV}\,, \quad p_T^{b_4} > 20\,\mathrm{GeV}$$



√s =14 TeV & N_lep=0 & N_b≥2 & N_j≥4
signal
tt̄_had+j (inc.)
tt̄_semilep+j (inc.)
V+jets
tt̄+X+j (inc.)
fraction of events
p_T^{b_1} [GeV]
p_T^{j_1} [GeV]
E_T^miss [GeV]
H_T = Σ_{all b, j} p_T [GeV]
E_T^miss significance = E_T^miss/√H_T [GeV^{1/2}]
m_eff = E_T^miss+H_T [GeV]

SR1-two b-jets

SR2-three b-jets

$$p_T^{j_1} > 200\,\mathrm{GeV}\,, \quad p_T^{j_2} > 150\,\mathrm{GeV}\,, \quad p_T^{j_3} > 80\,\mathrm{GeV}\,, \quad p_T^{j_4} > 40\,\mathrm{GeV}$$
$$loose: \quad p_T^{b_1} > 100\,\mathrm{GeV}\,, \quad p_T^{b_2} > 60\,\mathrm{GeV}\,,$$
$$tight: \quad p_T^{b_1} > 100\,\mathrm{GeV}\,, \quad p_T^{b_2} > 60\,\mathrm{GeV}\,, \quad p_T^{b_3} > 35\,\mathrm{GeV}\,.$$

$$loose: \quad N_b \geq 2\,, \quad N_j \geq 4\,, \quad N_\ell = 0$$
$$tight: \quad N_b \geq 3\,, \quad N_j \geq 4\,, \quad N_\ell = 0$$

Loose selections
Emiss > 150 GeV
meff> 1300 GeV

Tight selections
Emiss > 150 GeV
meff> 1800 GeV

SR1

Process	signal	$t\bar{t}_{\text{had}}+j$ (inc.)	$t\bar{t}_{\text{semilep}}+j$ (inc.)	V+jets	$t\bar{t}X+j$ (inc.)	$\mathcal{S}_{\text{sta}}$	$\mathcal{S}_{\text{sys}}$
Expected	20	2.19×10^{6}	0.67×10^{6}	3.56×10^{5}	2.9×10^{3}	0.01	2×10^{-5}
selection cut	15.7	2.98×10^{5}	2.6×10^{4}	4435	505.5	0.03	1.5×10^{-4}
loose p_T cuts	7.7	7341	259.3	12.7	14.3	0.09	3.3×10^{-3}
$E_T^{\text{miss}}>150$ GeV	7.1	60.9	37.8	0	5.1	0.68	0.21
$m_{\text{eff}}>1800$ GeV	5.5	1.0	1.5	0	0.2	2.69	2.30

SR2

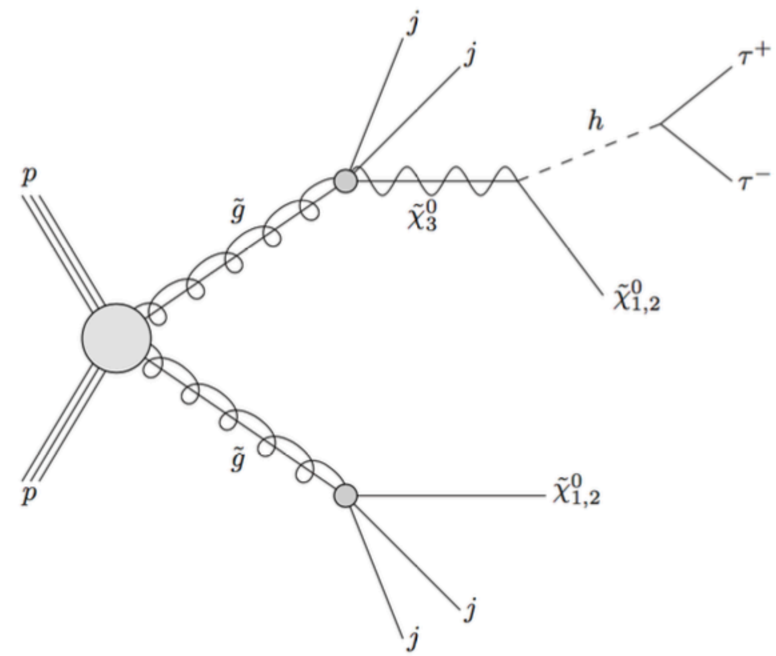
Process	signal	$t\bar{t}_{\text{had}}+j$ (inc.)	$t\bar{t}_{\text{semilep}}+j$ (inc.)	V+jets	$t\bar{t}X+j$ (inc.)	$\mathcal{S}_{\text{sta}}$	$\mathcal{S}_{\text{sys}}$
Expected	20	2.19×10^{6}	0.67×10^{6}	3.56×10^{5}	2.9×10^{3}	0.01	2×10^{-5}
selection cut	9.8	2.78×10^{4}	1841	145.7	94.1	0.06	1.1×10^{-3}
tight p_T cuts	4.4	197.1	3.7	0	2.1	0.31	0.07
$E_T^{\text{miss}}>150$ GeV	4	1.9	0.7	0	0.4	1.95	1.66
$m_{\text{eff}}>1300$ GeV	3.9	0	0.4	0	0	3.51	3.34

$$\mathcal{S}_{\mathrm{sta}} = \sqrt{-2\left((B+S)\log\left(\frac{B}{B+S}\right)+S\right)}$$

$$\mathcal{S}_{\mathrm{sys}} = \sqrt{2\left((B+S)\log\left(\frac{(S+B)(B+\sigma_B^2)}{B^2+(S+B)\sigma_B^2}\right)-\frac{B^2}{\sigma_B^2}\log\left(1+\frac{\sigma_B^2 S}{B(B+\sigma_B^2)}\right)\right)}$$

- We obtained significances around 2.5 for SR1 and around 3.5 for SR2.

- Extrapolating for 3 ab^{-1} one gets significances above 5.



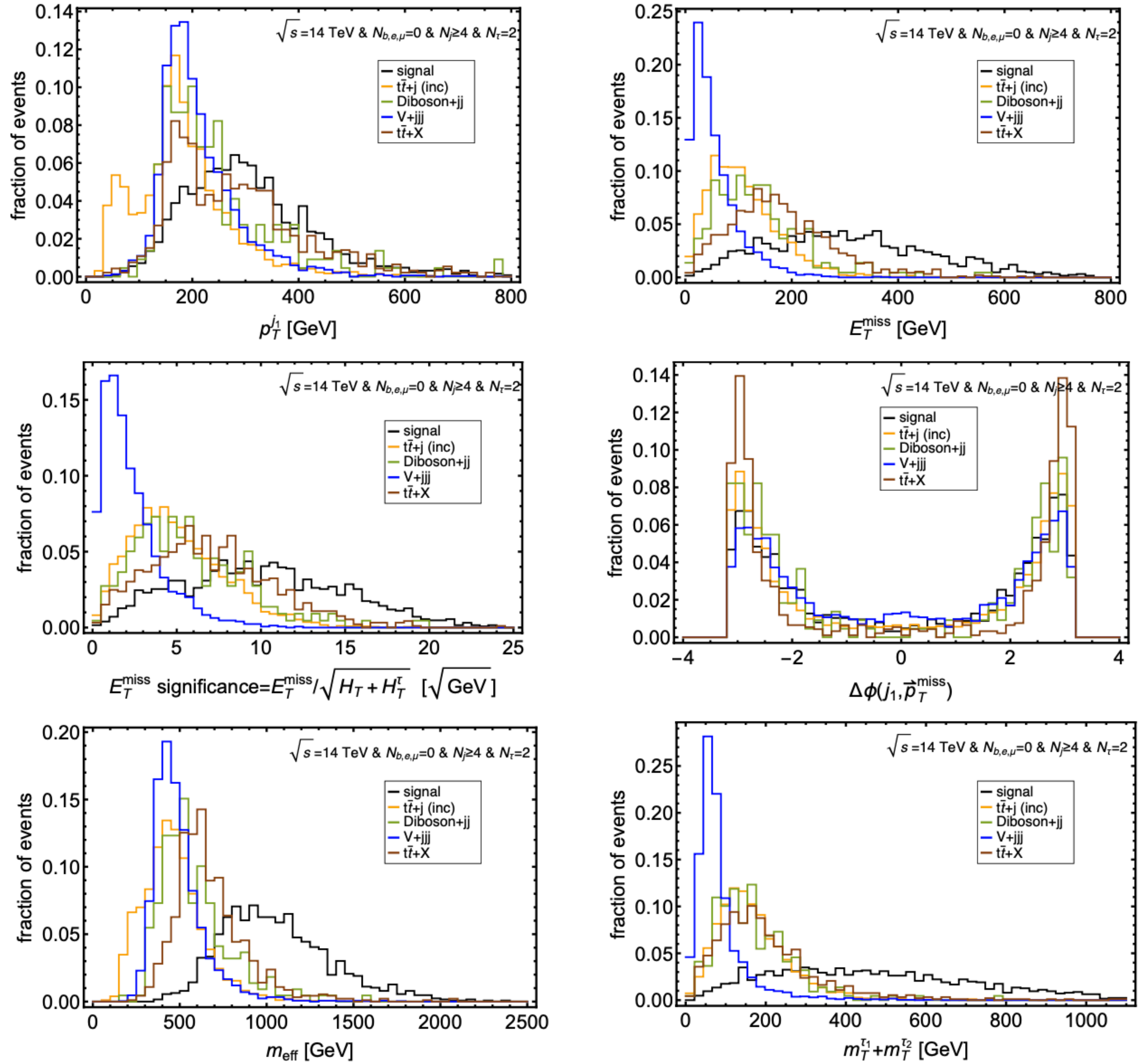
- An alternative signal could be when the Higgs decays to tau’s.

- Generator level cuts:

$$p_T^{j_1} > 150\,\mathrm{GeV}\,, \quad p_T^{j_2} > 80\,\mathrm{GeV}\,, \quad p_T^{j_3} > 20\,\mathrm{GeV}\,, \quad p_T^{j_4} > 20\,\mathrm{GeV}\,,$$
$$p_T^{\tau_1} > 20\,\mathrm{GeV}\,, \quad p_T^{\tau_2} > 20\,\mathrm{GeV}$$

- Signal selection:

$$N_\tau = 2\,, \quad N_j \geq 4\,, \quad N_{b,e,\mu} = 0$$



√s =14 TeV & N_{b,e,μ}=0 & N_j≥4 & N_τ=2
signal
tt̄+j (inc)
Diboson+jj
V+jjj
tt̄+X
fraction of events
p_T^{j_1} [GeV]
E_T^miss [GeV]
E_T^miss significance=E_T^miss/√(H_T+H_T^τ) [√GeV]
Δφ(j_1,p⃗_T^miss)
m_eff [GeV]
m_T^{τ_1}+m_T^{τ_2} [GeV]

Cuts

$$p_T^{j_1} > 170\,\text{GeV}\,, \quad p_T^{j_2} > 90\,\text{GeV}\,,$$
$$E_T^{\text{miss}} > 150\,\text{GeV}\,, \quad |\Delta\phi(j_1, \vec{p}_T^{\text{miss}})| > 0.4$$

- $m_{\text{eff}} > 1000$ GeV,
- and $m_T^{\tau_1} + m_T^{\tau_2} > 450$ GeV.

tau tagging 90%

Process	Signal	$t\bar{t}+2j$ (inc.)	$t\bar{t}+X$	Diboson	V+jets	$\mathcal{S}_{\text{sta}}$	$\mathcal{S}_{\text{sys}}$
Expected	19.6	1.47×10^{6}	1.1×10^{3}	1.12×10^{4}	3.56×10^{5}	0.01	4×10^{-5}
Selection cuts	5.6	3283.7	9.9	167.5	9952.4	0.05	1.4×10^{-3}
'MET cuts'	3.82	772.3	2.31	44.3	262.7	0.12	1.2×10^{-2}
$m_{\text{eff}} > 1000$ GeV	2.6	9.8	0.4	7.9	43.8	0.33	0.13
$m_T^{\tau_1}+m_T^{\tau_2} > 450$ GeV	2.4	0.4	0	0	0	2.10	1.99
Projections $\mathcal{L}=3$ ab^{-1}	7.2	1.2	0	0	0	3.64	3.15

- The significance is not very high so….
- We find this as a complementary search to discover gluinos with higgses final states.

Conclusions

- In this talk I have shown three different scenarios of DM that scape DD detection:
  - Pure Higgisino (~1.1 TeV) scape current bounds
    - For this case I have shown different signals to discover a gluino that decays to a Bino which subsequently decay to the Higgsino plus higgses (there are other possible signals one can analyze)