



Black Holes and SUSY

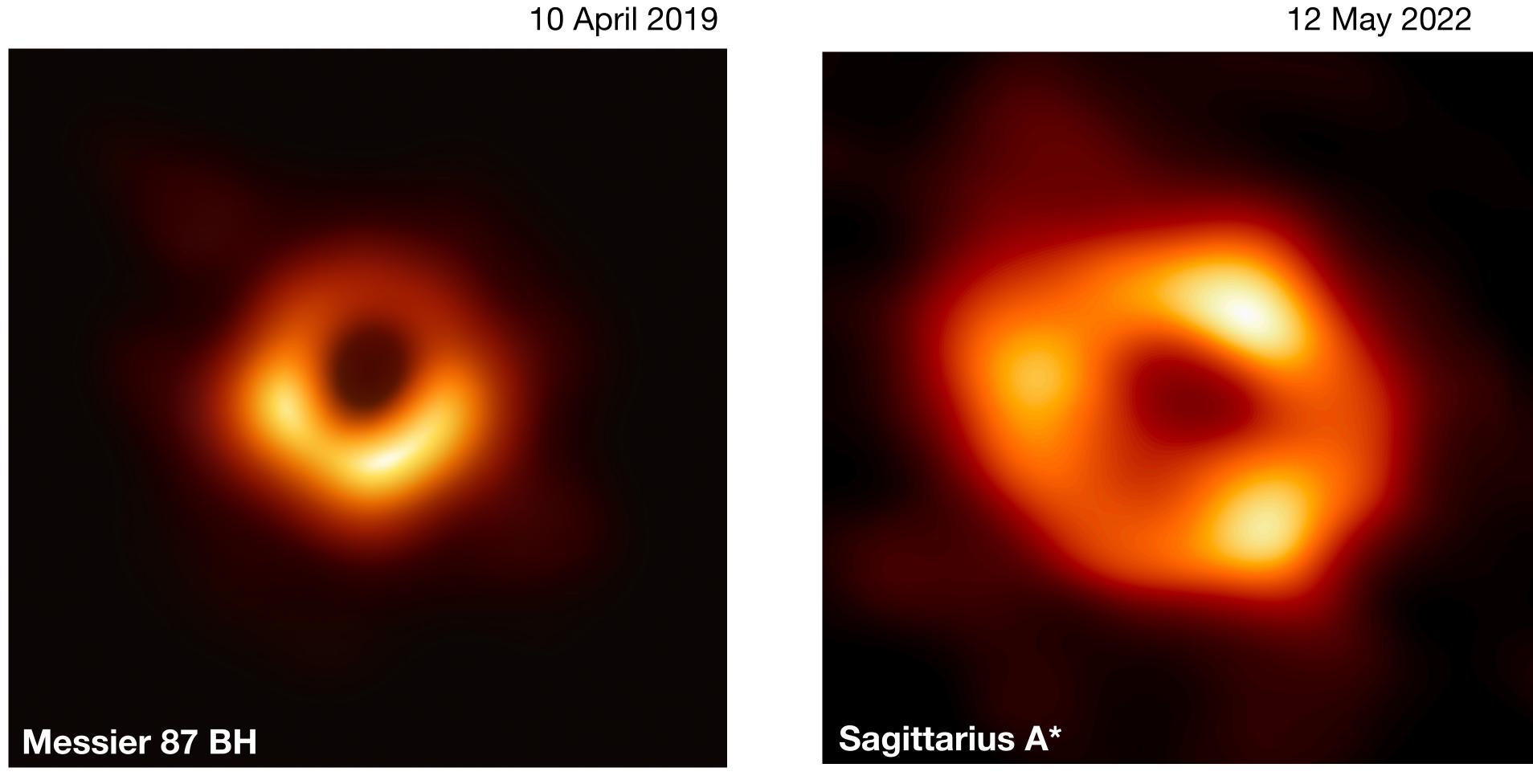
BND School 2025

Flavia de Almeida Dias

10 September 2025



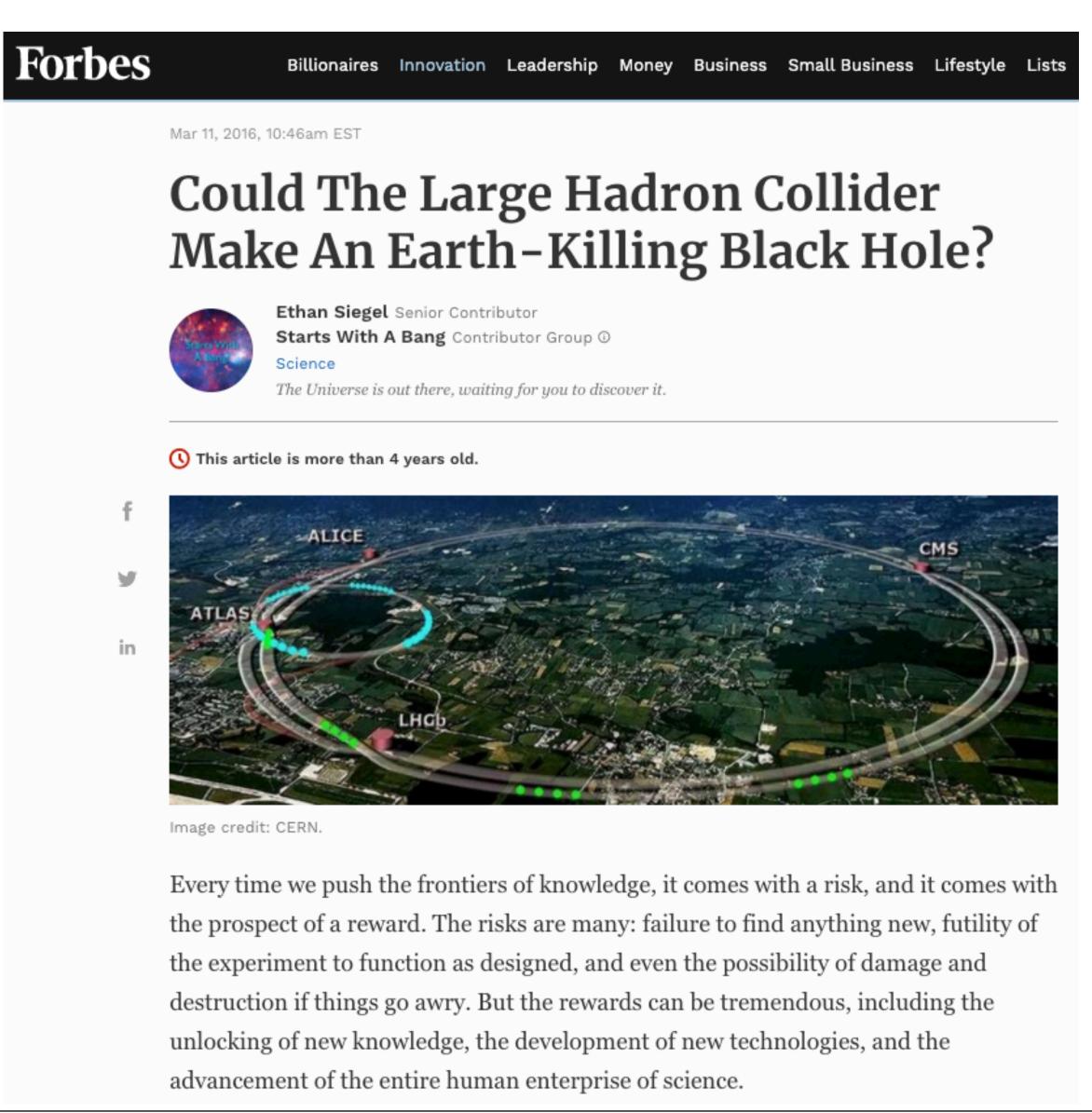
Black Holes







Black Holes?



Black-hole themed
Spotify playlist: https://
open.spotify.com/playlist/
6JXkGkPwiBOksHnbYGE
vvS?
si=cba2e97e1d704639



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In General Relativity

• A black hole (BH) can be formed when a large mass M is confined within a radius smaller than the Schwarzschild radius R_S :

$$R_S = \frac{2MG_N}{c^2}$$

• Naively, a BH would only grow, by attracting more mass. However, taking quantum effects into account, a BH behaves like a thermal blackbody with the Hawking temperature:

$$k_B T_H = \frac{1}{4\pi R_S} \hbar c$$

where k_B is the Boltzmann constant. In natural units, $G_N = c = \hbar = k_B = 1$ and $R_S T_H = (4\pi)^{-1}$

 \rightarrow BH evaporate and emit photons, or massive particles if T_H is high



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• Conversely, two energetic particles collide with impact parameter smaller than R_S , a BH can be formed with subsequent decay to particles

- \rightarrow $\sigma(E) \sim \pi R_S^2$
- In LED scenarios, the Schwarzschild radius could be large. Let's estimate it using classical mechanics:
 - \Rightarrow Equate the kinetic energy of a particle travelling at the speed of light with gravitational potential energy in 4+δ dimensions:

$$rac{mc^2}{2} \sim rac{G_D \ m \ M_{BH}}{R_S^{(1+\delta)}}$$

Using the relation (from previous module):

$$G_N = 1/M_{Pl}^2$$
 and $G_D = 1/M_D^{(2+\delta)}$





$$R_S^{(1+d)} \sim G_D \ M_{BH} \sim \frac{M_{BH}}{M_D^{2+\delta}}$$

$$R_S \sim \left(\frac{M_{BH}}{M_D \cdot M_D^{1+\delta}}\right)^{\frac{1}{1+\delta}} \Rightarrow R_S \sim \frac{1}{M_D} \left(\frac{M_{BH}}{M_D}\right)^{\frac{1}{1+\delta}}$$

• Now let's compare this to the exact solution solving the General Relativity equations for a flat spacetime in $4+\delta$ dimensions:

$$R_{\rm S} = \frac{k(\delta)}{M_{\rm D}} \left[\frac{M_{\rm BH}}{M_{\rm D}} \right]^{\frac{1}{(\delta+1)}}, \qquad k(\delta) = \left(2^{\delta} \pi^{\frac{\delta-3}{2}} \frac{\Gamma\left(\frac{\delta+3}{2}\right)}{\delta+2} \right)^{\frac{1}{(\delta+1)}}$$

The mass M_{BH} would roughly correspond to the total energy in a collision. If $M_D = 1$ TeV, where σ is the BH production cross section per partons and s the total energy of the partons participating in the collision. This would mean one BH per second of the LHC.



Nik hef & X

• A BH at ~TeV scale will also have ~TeV temperature, and it's lifetime will be 10-27 - 10-25 s.

• If decay is approximately that of a classical black hole, it will thermally radiate with Hawking temperature of:

$$T_H = \frac{(\delta + 1)}{4\pi R_S}$$

Evaporating isotropically and democratically into SM particles. The multiplicity of particles emitted by the BH evaporation is given by:

$$< N_{BH} > = \left\langle \frac{M_{BH}}{2E_{\text{particle}}} \right\rangle \sim \left\langle \frac{M_{BH}}{2T_H} \right\rangle$$

• The most stringent limits on microscopic black holes arise from LHC searches in high-multiplicity final states.





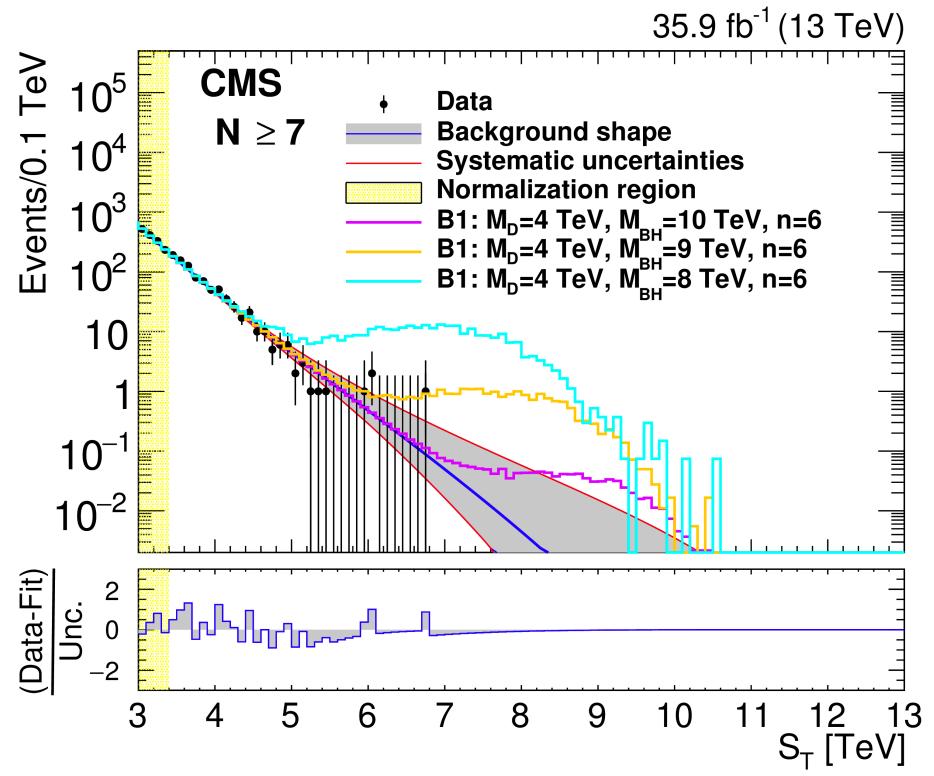
High Multiplicity Searches

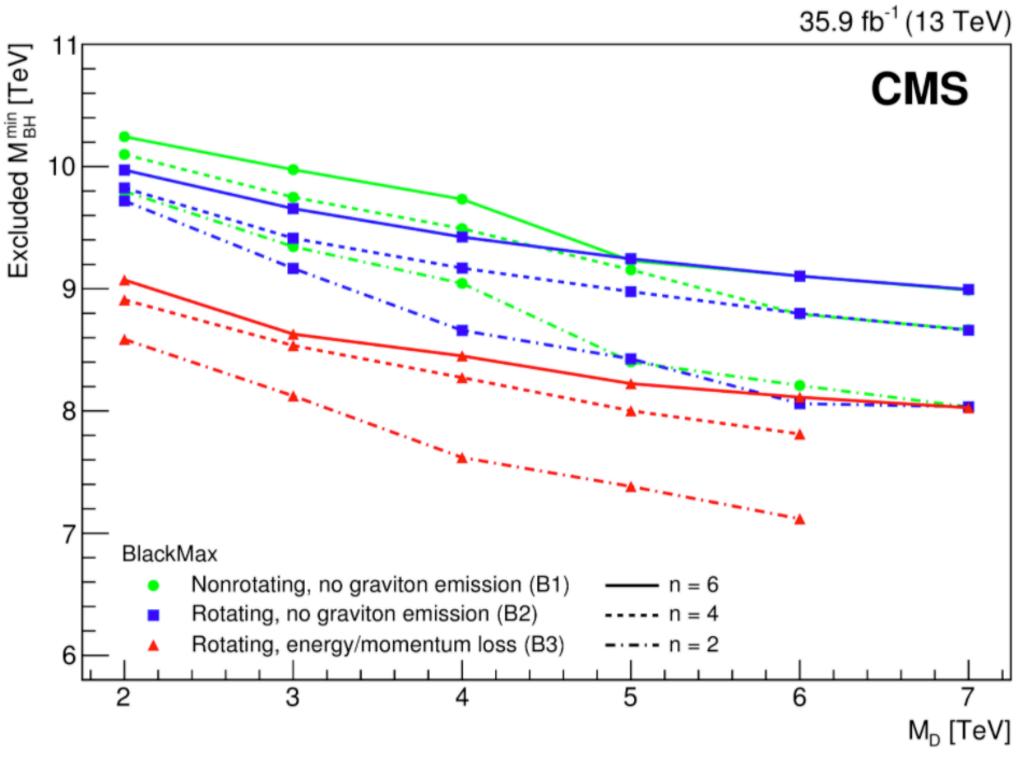
- Simulated samples of semi-classical black holes in different scenarios:
 - → Non-rotating BHs
 - → Rotating BHs
 - → Rotating BHs with mass loss
- For each model, investigate M_D 2-9 TeV, δ =2,4,6
- M_D +1 TeV < M_{BH} < 11 TeV
- Discriminant variable: $S_{\rm T} = p_{\rm T}^{\rm miss} + \sum_{i=1}^{N} p_{\rm T}^{i}$
 - Scalar sum of p_T of all N energetic objects in an event (jets, electrons, muons, and photons with p_T above a given threshold), plus p_T^{miss} in the event, if it exceeds the same threshold
- Look into object multiplicities between ≥3 and ≥11





- No excess above the SM expectation found
 - \rightarrow Excludes MBH < 10.1 TeV (MD = 2, δ = 6)
 - Similar ATLAS analysis with multi-jets excludes between MBH < 9.0 9.7 TeV depending on MD, for $\delta = 6$

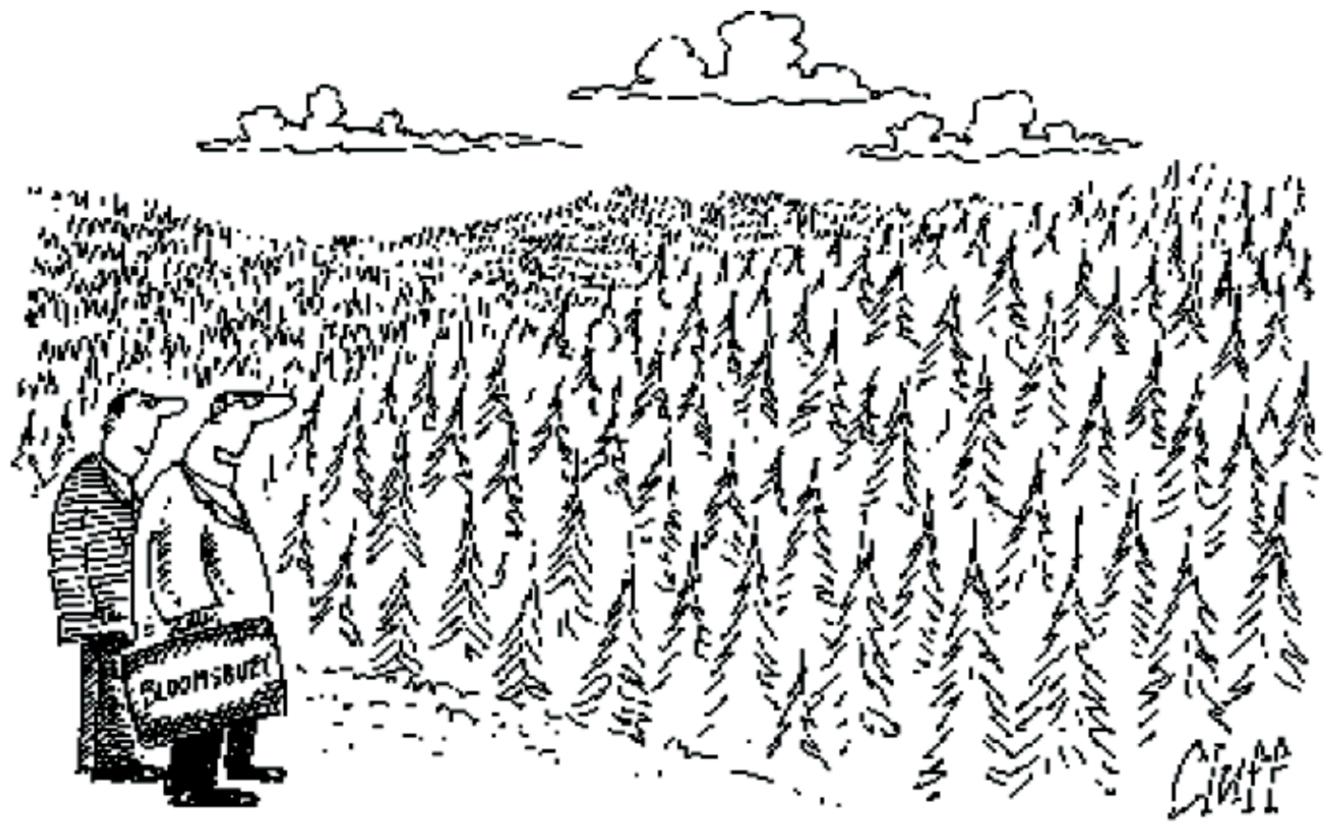








Supersymmetry



"One day, all of these will be supersymmetric phenomenology papers."

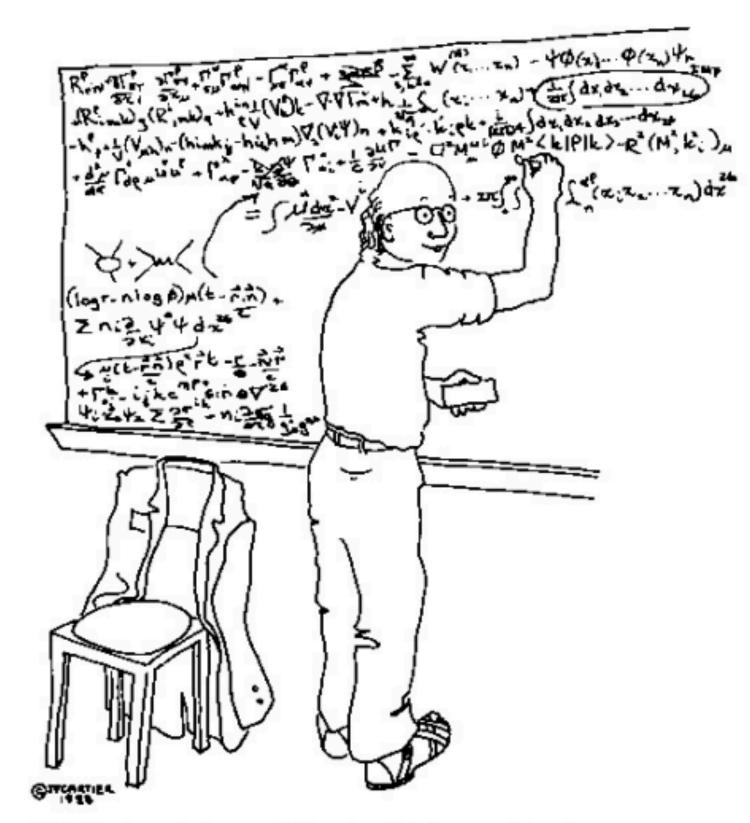


Nik hef &

~10.000 papers since 1990

What is SUSY?

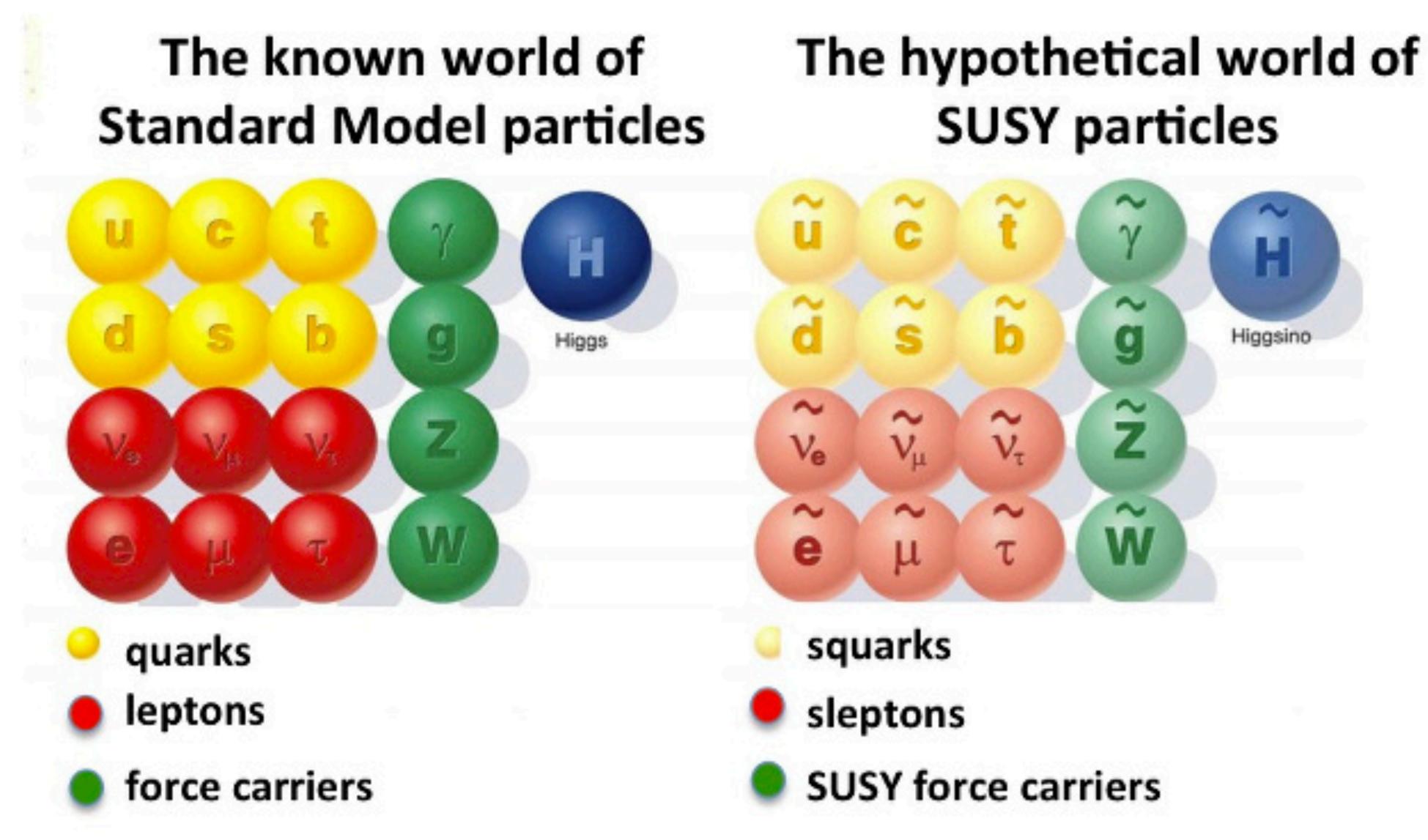
- Spacetime symmetry between bosons-fermions
 - → Make equations of force and matter similar
 - → Each particles gets a *superpartner* same mass/quantum numbers
 - Electron —> selectron (scalar electron)
 - Gluon —> gluino



"At this point we notice that this equation is beautifully simplified if we assume that space-time has 92 dimensions."



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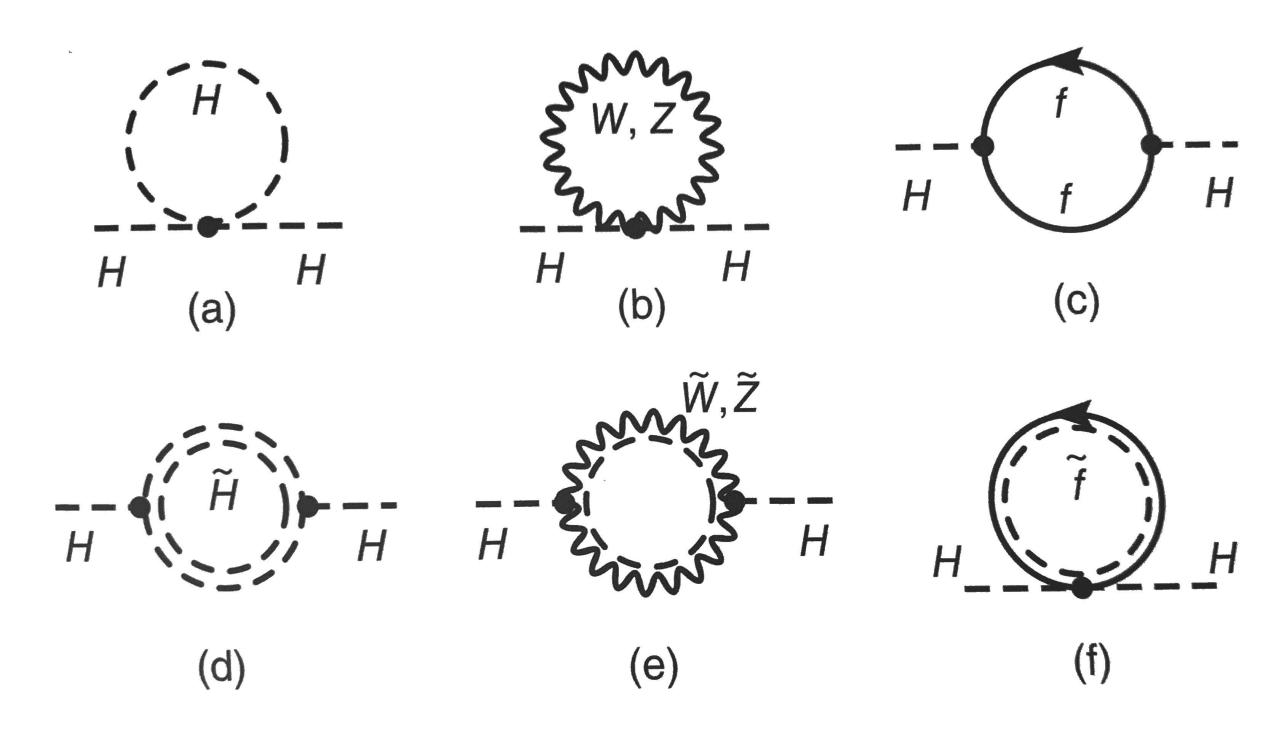




Why is SUSY?

Naturalness

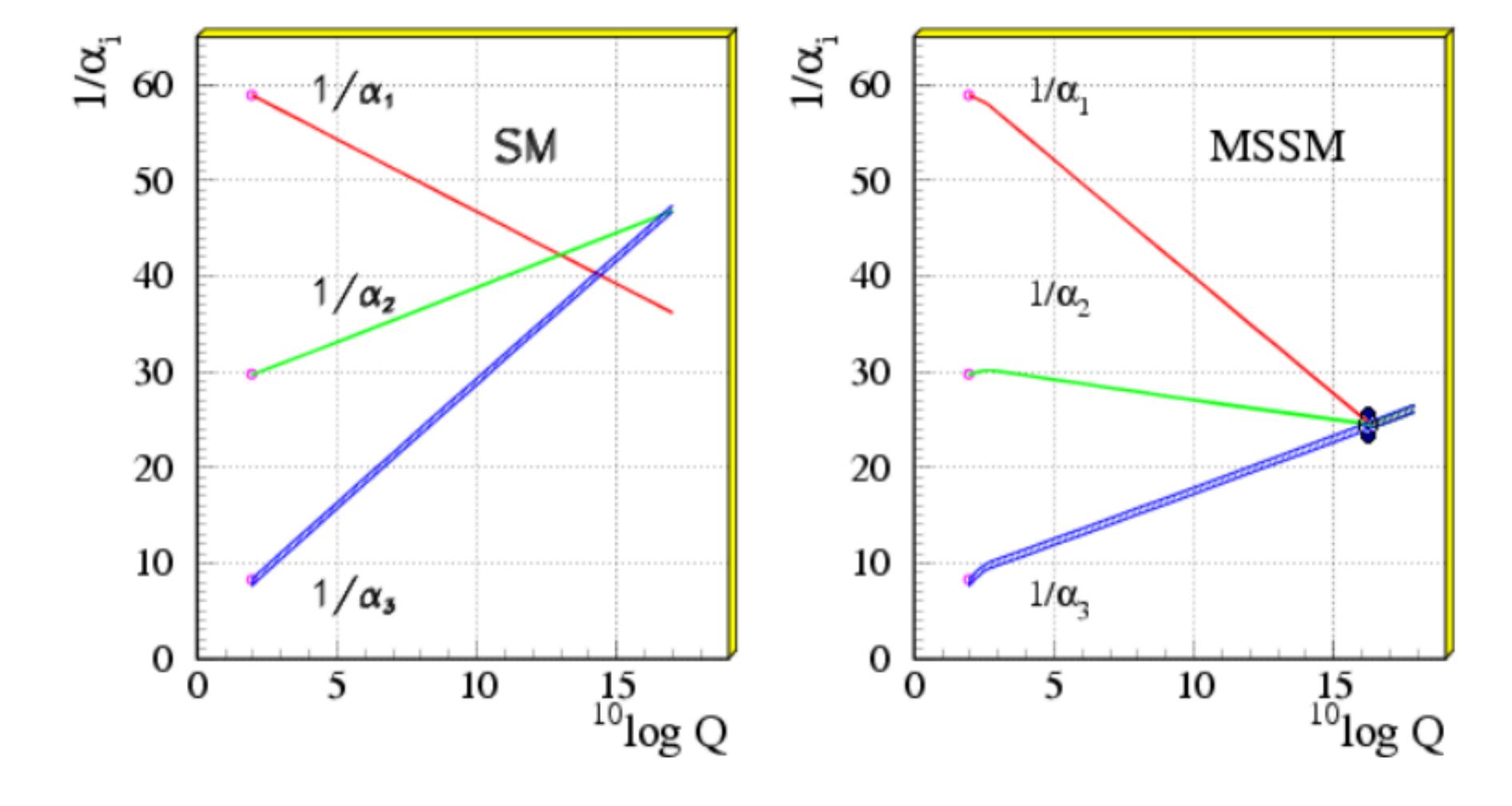
- → Radiative corrections by fermion loops have opposite signs to those by boson (Fermi-Dirac statistics)
 - New fermions corresponding to known bosons with same mass and same coupling could cancel exactly the boson loop
 - SM fermion loop compensated by a corresponding scalar boson
 - If supersymmetry is broken (not exactly the same mass), can still solve fine tuning provided that mass difference of partners remain ≤1 TeV







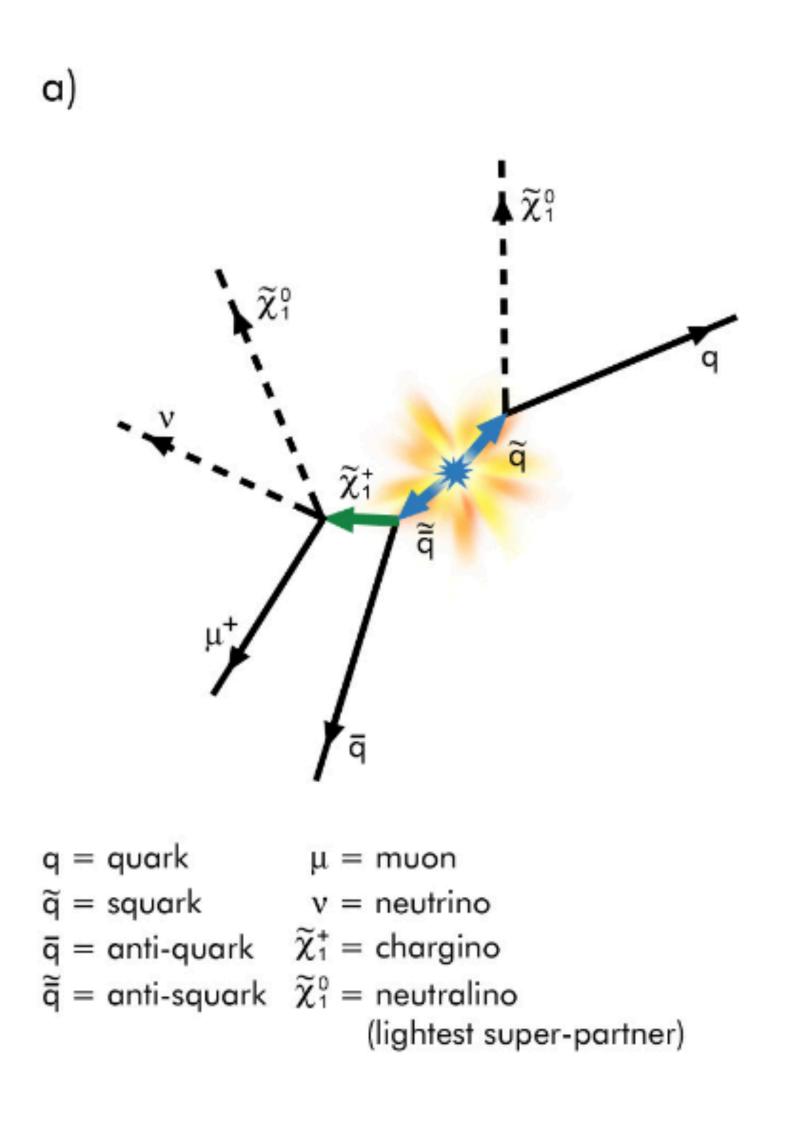
• Gauge-coupling unification

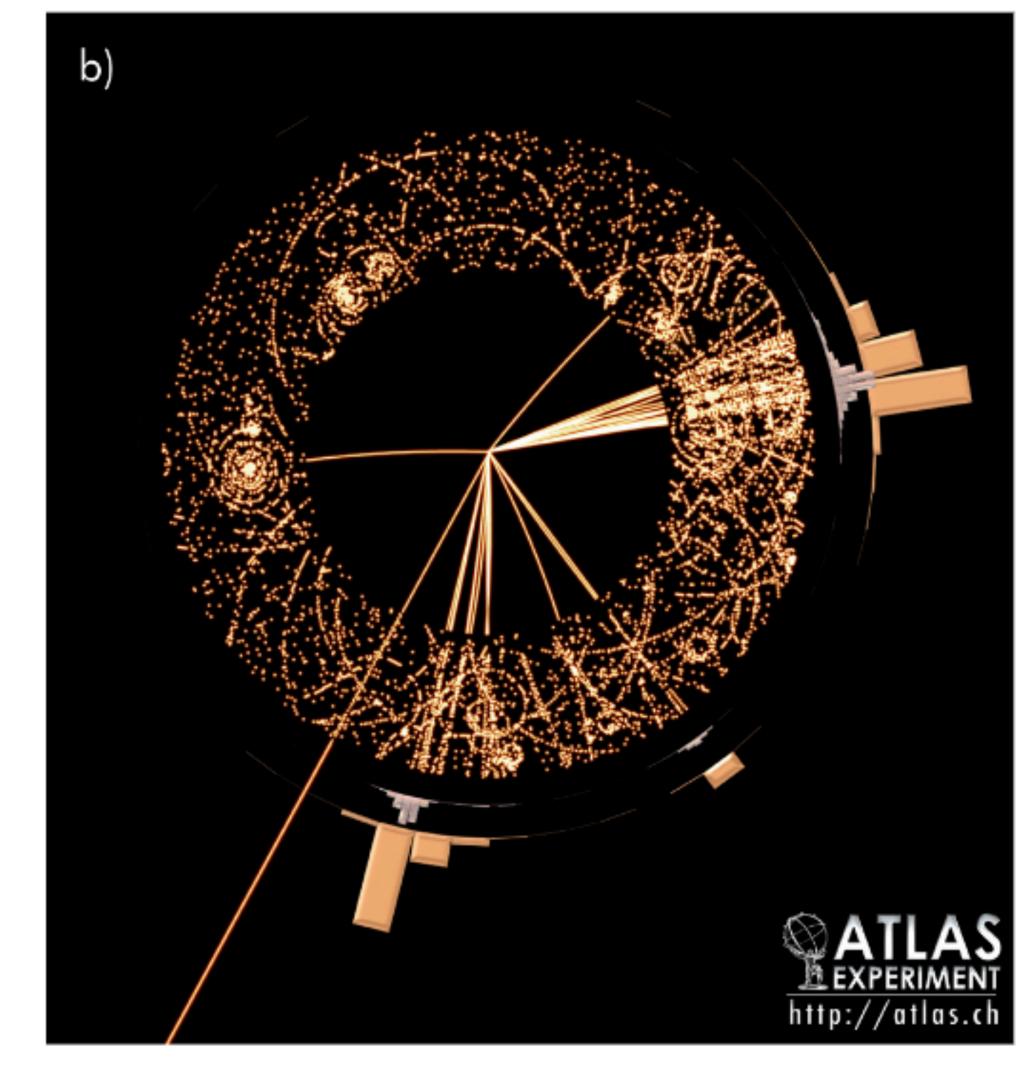






Dark matter candidate









Not everything is shiny though...

- Large number of new, free parameters (and particles!)
- Too heavy SUSY does not solve hierarchy!
 - → Ad-hoc SUSY breaking mechanisms
- Lack of experimental evidence
 - → Effects on precision observables
 - On-shell SUSY particle production
 - Cosmological implications



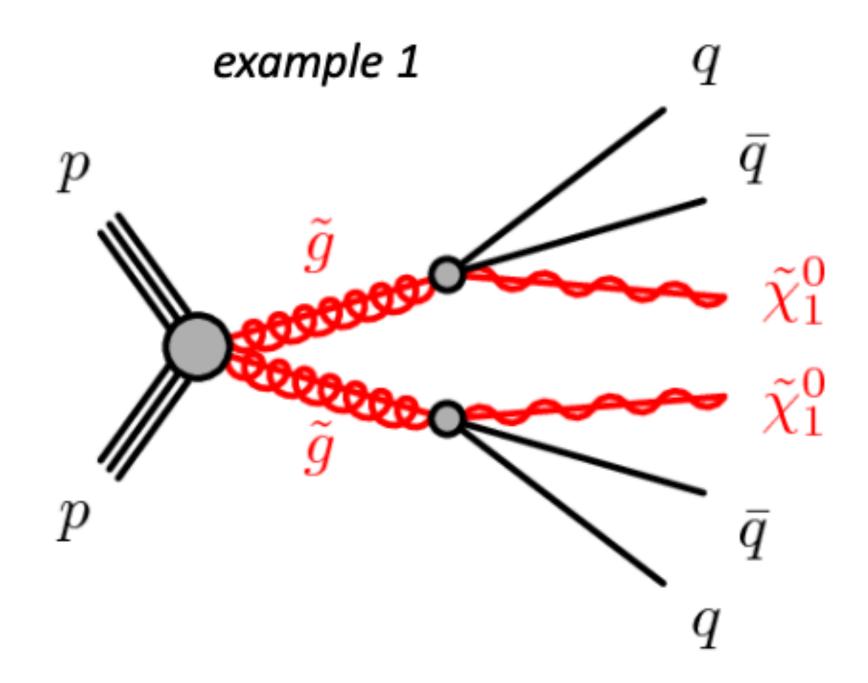


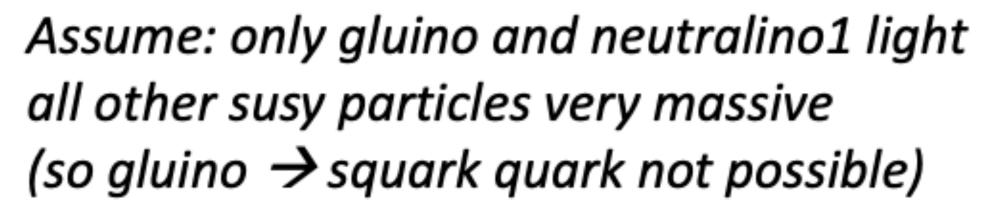


SUSY Phenomenology

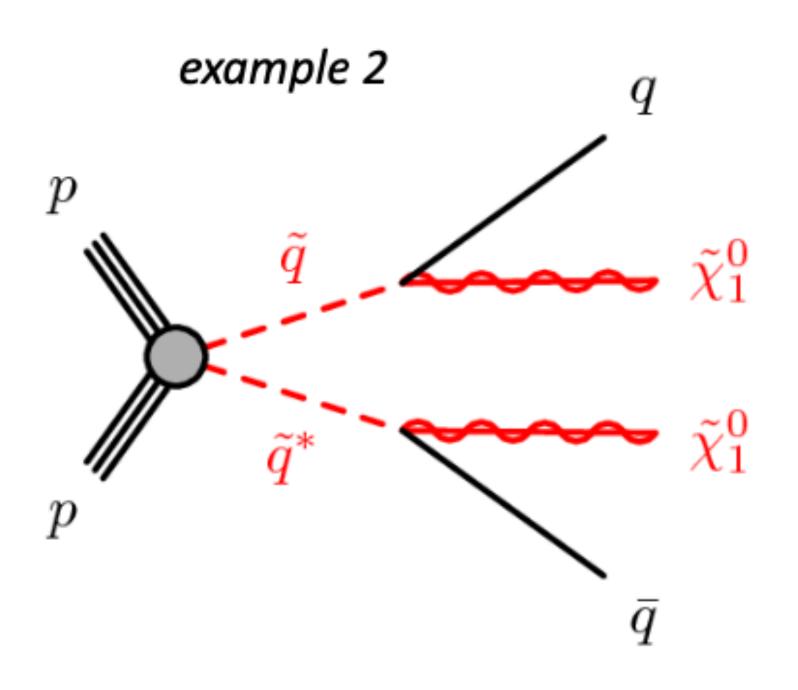
- MSSM: Minimal Supersymmetric Standard Model
 - → LHC: squarks and gluinos (strongly interacting); lightest SUSY particle (neutralinos);
- Too many free parameters in MSSM
 - Simplified models:
 - Set of basis: complicated SUSY spectrum can be decomposed in a set of simplified models
 - Scan of masses, to exclude cross sections
 - Combined results to draw conclusion about a more complicated model







Scan all gluino and neutralino1 masses
Assume 100% branching fraction



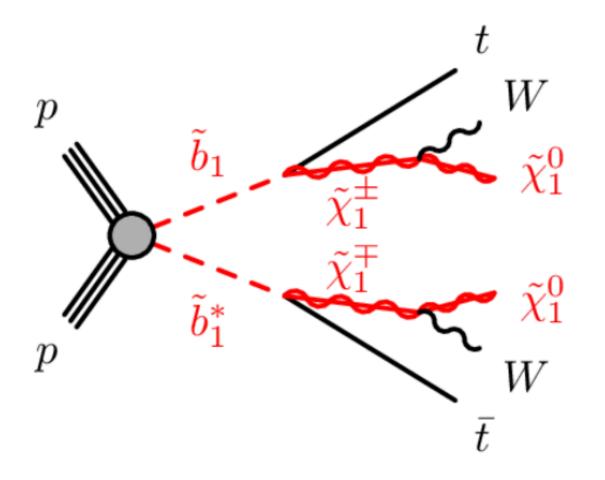
Assume: only squark and neutralino1 light all other susy particles very massive (so squark \rightarrow gluino quark not possible)

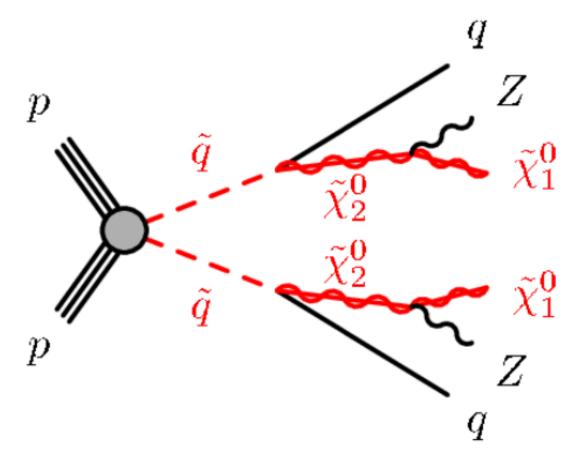
Scan all squark and neutralino1 masses
Assume 100% branching fraction

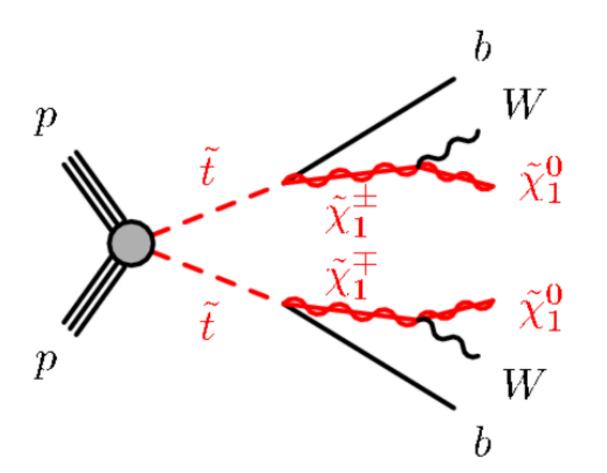


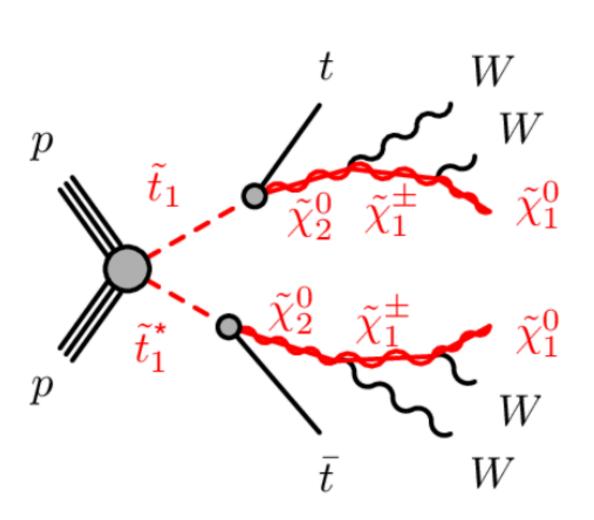


More complicated simplified models









 $2 \rightarrow 3$ or 4 free masses





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SUSY searches: Still not there...

ATLAS SUSY Searches* - 95% CL Lower Limits

March 2022

ATLAS Preliminary

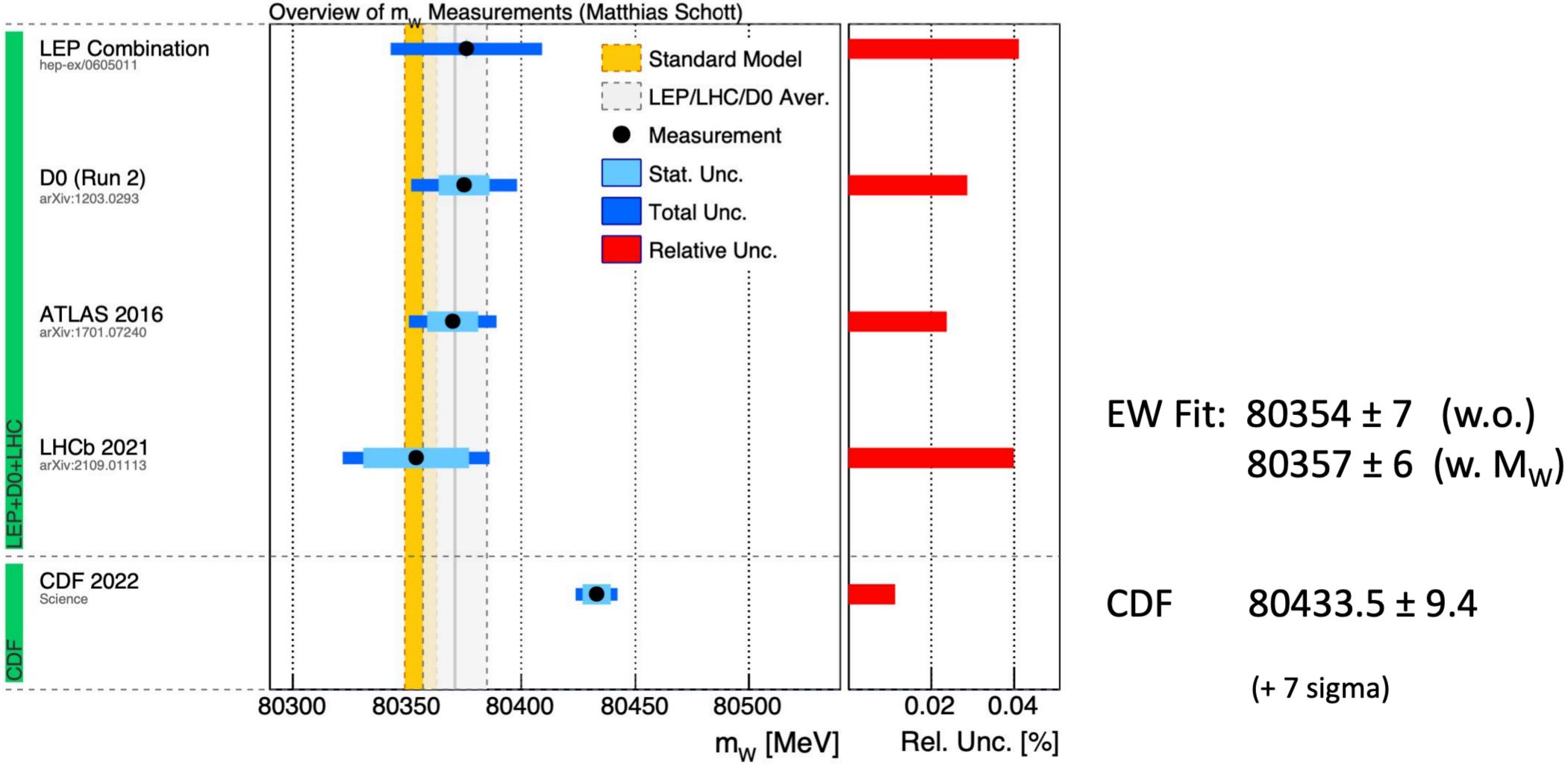
 $\sqrt{s} = 13 \text{ TeV}$

Model	Signature	$\int \mathcal{L} dt [fb^-]$	Mass limit		Reference
$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_1^0$	$\begin{array}{ccc} ext{0} \ e, \mu & ext{2-6 jets} & E_T^{ ext{miss}} \ ext{mono-jet} & ext{1-3 jets} & E_T^{ ext{miss}} \end{array}$	139 139	$ ilde{q}$ [1x, 8x Degen.] 1.0 $ ilde{q}$ [8x Degen.] 0.9	1.85	2010.14293 2102.10874
$\tilde{g}\tilde{g}, \; \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_{1}^{0}$ $\tilde{g}\tilde{g}, \; \tilde{g} \rightarrow q\bar{q}W\tilde{\chi}_{1}^{0}$	0 e,μ 2-6 jets $E_T^{ m miss}$		$ ilde{ ilde{g}}$ Forbidden	2.3 $m(\tilde{\chi}_1^0)=0 \text{ GeV}$ 1.15-1.95 $m(\tilde{\chi}_1^0)=1000 \text{ GeV}$	2010.14293 2010.14293
$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}W\tilde{\chi}_1^0$	1 e, μ 2-6 jets	139	$ ilde{g}$	2.2 $m(\tilde{\chi}_1^0)$ <600 GeV	2101.01629
$ ilde{g} ilde{g}, ilde{g}{ ightarrow}qar{q}(\ell\ell) ilde{\chi}_{1}^{0}$	$ee, \mu\mu$ 2 jets $E_T^{ m miss}$	139	$ ilde{g}$	2.2 $m(\tilde{\chi}_1^0)$ <700 GeV	CERN-EP-2022-014
$ \tilde{g}\tilde{g}, \tilde{g} \to q\bar{q}(\ell\ell)\tilde{\chi}_{1}^{0} \tilde{g}\tilde{g}, \tilde{g} \to qqWZ\tilde{\chi}_{1}^{0} $ $ \tilde{g}\tilde{g}, \tilde{g} \to t\tilde{t}\tilde{\chi}_{1}^{0} $	$egin{array}{lll} \hbox{0 } e,\mu & \hbox{7-11 jets} & E_T^{ m miss} \ \hbox{SS } e,\mu & \hbox{6 jets} \end{array}$	139 139	$\frac{\tilde{g}}{\tilde{g}}$ 1.15	$\begin{array}{ccc} \textbf{1.97} & & \text{m}(\widetilde{\chi}_1^0) < 600 \text{GeV} \\ & \text{m}(\widetilde{g})\text{-m}(\widetilde{\chi}_1^0) = 200 \text{GeV} \end{array}$	2008.06032 1909.08457
$\tilde{g}\tilde{g}, \; \tilde{g} \rightarrow t\bar{t}\tilde{\chi}^0_1$	$\begin{array}{ccc} \text{0-1 } e, \mu & \text{3 } b & E_T^{\text{miss}} \\ \text{SS } e, \mu & \text{6 jets} \end{array}$	79.8 139	$rac{ ilde{g}}{ ilde{g}}$	2.25 $m(\tilde{\chi}_1^0)$ <200 GeV $m(\tilde{g})$ - $m(\tilde{\chi}_1^0)$ =300 GeV	ATLAS-CONF-2018-041 1909.08457
$\tilde{b}_1 \tilde{b}_1$	0 e,μ 2 b $E_T^{ m miss}$	139	$egin{array}{cccc} ilde{b}_1 & & & & & & & & & & & & & & & & & & &$	m($ ilde{\chi}_1^0$)<400 GeV 10 GeV< Δ m($ ilde{b}_1, ilde{\chi}_1^0$)<20 GeV	2101.12527 2101.12527
$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}_2^0 \rightarrow b h \tilde{\chi}_1^0$ $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$ $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	$egin{array}{cccc} 0 \ e, \mu & 6 \ b & E_T^{ m miss} \ 2 \ t & E_T^{ m miss} \end{array}$	139 139	$egin{array}{cccc} ilde{b}_1 & Forbidden & 0.23 \ ilde{b}_1 & 0.13-0.85 \end{array}$	$\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130 \text{ GeV, } m(\tilde{\chi}_1^0) = 100 \text{ GeV}$ $\Delta m(\tilde{\chi}_2^0, \tilde{\chi}_1^0) = 130 \text{ GeV, } m(\tilde{\chi}_1^0) = 0 \text{ GeV}$	1908.03122 2103.08189
$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$	$0-1 \ e, \mu \ge 1 \ \text{jet} \qquad E_T^{\text{miss}}$	139	$ ilde{t}_1$.25 $m(\tilde{\chi}_1^0)=1 \text{ GeV}$	2004.14060,2012.03799
$\begin{cases} \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow \mathcal{U}_1 \\ \tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow W b \tilde{\chi}_1^0 \end{cases}$	1 e,μ 3 jets/1 b E_T^{miss}	139	\tilde{t}_1 Forbidden 0.65	$m(\widetilde{\chi}_1^0)$ =500 GeV	2012.03799
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 b \nu, \tilde{\tau}_1 \rightarrow \tau \tilde{G}$	1-2 $ au$ 2 jets/1 b $E_T^{ m miss}$	139	\tilde{t}_1 Forbidden	1.4 m(τ)=800 GeV	2108.07665
$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0 / \tilde{c} \tilde{c}, \tilde{c} \rightarrow c \tilde{\chi}_1^0$	$egin{array}{lll} ext{0} & e, \mu & ext{2} & c & E_T^{ ext{miss}} \ ext{0} & e, \mu & ext{mono-jet} & E_T^{ ext{miss}} \end{array}$	36.1 139	$ ilde{c} ilde{t}_1 ext{ 0.85}$	$egin{aligned} & m(\tilde{\chi}_1^0) = 0 \ GeV \\ & m(\tilde{t}_1, \tilde{c}) - m(\tilde{\chi}_1^0) = 5 \ GeV \end{aligned}$	1805.01649 2102.10874
$\tilde{t}_1\tilde{t}_1, \tilde{t}_1 {\rightarrow} t\tilde{\chi}_2^0, \tilde{\chi}_2^0 {\rightarrow} Z/h\tilde{\chi}_1^0$	1-2 e, μ 1-4 b E_T^{miss}	139	\tilde{t}_1 0.067-1.1	$m(\tilde{\chi}_2^0) = 500GeV$	2006.05880
$\tilde{t}_2\tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z$	$3 e, \mu$ $1 b$ E_T^{miss}		\tilde{t}_2 Forbidden 0.86	$m(\tilde{\chi}_1^0) = 360 GeV, m(\tilde{\iota}_1) - m(\tilde{\chi}_1^0) = 40 GeV$	2006.05880
$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via WZ	$\begin{array}{ccc} \text{Multiple } \ell/\text{jets} & & E_T^{\text{miss}} \\ ee, \mu\mu & \geq 1 \text{ jet} & E_T^{\text{miss}} \end{array}$	139 139	$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{0}^{0}$ 0.96 $\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ 0.205	$m(ilde{\chi}_1^0) = 0$, wino-bino $m(ilde{\chi}_1^\pm) - m(ilde{\chi}_1^0) = 5$ GeV, wino-bino	2106.01676, 2108.07586 1911.12606
$ ilde{\chi}_1^{\pm} ilde{\chi}_1^{\mp}$ via WW	2 e, μ $E_T^{ m miss}$	139	$\tilde{\chi}_1^{\pm}$ 0.42	$m(ilde{\chi}_1^0)$ =0, wino-bino	1908.08215
$ ilde{\chi}_1^{\pm} ilde{\chi}_2^0$ via Wh	$\begin{array}{ccc} 2 \ e, \mu & E_T^{ m miss} \\ m Multiple \ \ell/jets & E_T^{ m miss} \end{array}$	139	$\tilde{\chi}_1^{\pm}/\tilde{\chi}_2^0$ Forbidden 1.06	m $(\widetilde{\chi}_1^0)$ =70 GeV, wino-bino	2004.10894, 2108.07586
$ ilde{\mathcal{X}}_1^{\pm} ilde{\mathcal{X}}_1^{\mp}$ via $ ilde{\ell}_L/ ilde{v}$	e, μ $E_{T}^{ ext{miss}}$	139	\tilde{X}_1^{\pm} 1.0	$m(\tilde{\ell},\tilde{v}) = 0.5(m(\tilde{\mathcal{X}}_1^{\pm}) + m(\tilde{\mathcal{X}}_1^{0}))$	1908.08215
$ ilde{\mathcal{X}}_{1}^{\pm} ilde{\mathcal{X}}_{1}^{+} ext{ via } ilde{\ell}_{L}/ ilde{\nu}$ $ ilde{\tau}_{1}^{\tau} ilde{\tau}_{1}^{\tau} ilde{\tau}_{2}^{\tau} ilde{\chi}_{1}^{0}$ $ ilde{\ell}_{1}^{\tau} ilde{\ell}_{1}^{\tau} ilde{\nu}_{1}^{0} ilde{\ell}_{2}^{0}$	$2 au$ $E_T^{ m miss}$	139	$\tilde{\tau} = [\tilde{\tau}_{L}, \tilde{\tau}_{R,L}]$ 0.16-0.3 0.12-0.39	$m(\widetilde{\chi}_1^0) = 0$	1911.06660
$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	$\begin{array}{cccc} 2~e,\mu & E_T^{\rm miss} \\ 2~\tau & E_T^{\rm miss} \\ 2~e,\mu & {\rm 0~jets} & E_T^{\rm miss} \\ ee,\mu\mu & {\rm \geq 1~jet} & E_T^{\rm miss} \end{array}$		$ ilde{ ilde{\ell}}$ 0.256	$\begin{array}{c} m(\widetilde{\chi}_1^0) {=} 0 \\ m(\widetilde{\ell}) {-} m(\widetilde{\chi}_1^0) {=} 10 \; GeV \end{array}$	1908.08215 1911.12606
$\tilde{H}\tilde{H},\tilde{H}{ ightarrow}h\tilde{G}/Z\tilde{G}$	$0 e, \mu \geq 3 b$ $E_{T_{\text{niss}}}^{\text{miss}}$	36.1	<i>H</i> 0.13-0.23 0.29-0.88	$BR(ilde{\chi}^0_1 o h ilde{G})$ =1	1806.04030
	$\begin{array}{lll} \text{0 } e, \mu & \geq 3 \ b & E_{T}^{\text{miss}} \\ \text{4 } e, \mu & \text{0 jets} & E_{T}^{\text{miss}} \\ \text{0 } e, \mu & \geq 2 \ \text{large jets} & E_{T}^{\text{miss}} \end{array}$	139 139	${\tilde H} = 0.55 \ {\tilde H} = 0.45-0.93$	$BR(\widetilde{\chi}_1^0 o Z\widetilde{G})$ =1 $BR(\widetilde{\chi}_1^0 o Z\widetilde{G})$ =1	2103.11684 2108.07586
Direct $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk 1 jet $E_T^{ m miss}$	139	$ ilde{\chi}_1^{\pm}$ 0.66	Pure Wino Pure higgsino	2201.02472 2201.02472
Stable \tilde{g} R-hadron	pixel dE/dx $E_T^{ m miss}$	139	$ ilde{g}$	2.05	CERN-EP-2022-029
Stable \tilde{g} R-hadron Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq\tilde{\chi}_1^0$ $\tilde{\ell}\tilde{\ell}, \tilde{\ell} \rightarrow \ell\tilde{G}$	pixel dE/dx $E_T^{ m miss}$ Displ. lep $E_T^{ m miss}$	139	\tilde{g} [$\tau(\tilde{g})$ =10 ns]	2.2 $m(\tilde{\chi}_1^0)$ =100 GeV	CERN-EP-2022-029
$\tilde{\ell}\tilde{\ell},\tilde{\ell}{ ightarrow}\ell ilde{G}$	Displ. lep $E_T^{ m miss}$	139	$ ilde{e}, ilde{\mu}$	$ au(ilde{\ell})=0.1$ ns	2011.07812
	pixel dE/dx $E_T^{ m miss}$	139	$ ilde{ au}$ 0.34 $ ilde{ au}$ 0.36	$ au(ilde{\ell}) = exttt{0.1 ns} \ au(ilde{\ell}) = exttt{10 ns}$	2011.07812 CERN-EP-2022-029
$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}/\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{\pm} \rightarrow Z\ell \rightarrow \ell\ell\ell$	3 e, µ	139	$\tilde{\chi}_{1}^{\mp}/\tilde{\chi}_{1}^{0}$ [BR($Z\tau$)=1, BR(Ze)=1] 0.625	Pure Wino	2011.10543
$\tilde{\chi}_1^{\pm} \tilde{\chi}_1^{\mp} / \tilde{\chi}_2^0 \rightarrow WW/Z\ell\ell\ell\ell\nu\nu$	4 e,μ 0 jets $E_T^{ m miss}$		$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0} [\lambda_{i33} \neq 0, \lambda_{12k} \neq 0]$ 0.95	1.55 $m(\tilde{\chi}_1^0) = 200 \text{ GeV}$	2103.11684
$ \tilde{g}\tilde{g}, \tilde{g} \to qq\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \to qqq \tilde{t}\tilde{t}, \tilde{t} \to t\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \to tbs $	4-5 large jets	36.1	$\tilde{g} = [m(\tilde{X}_1^0) = 200 \text{ GeV}, 1100 \text{ GeV}]$	1.3 1.9 Large λ''_{112}	1804.03568
$t\widetilde{t}, \widetilde{t} \rightarrow t\mathcal{X}_{1}^{\circ}, \mathcal{X}_{1}^{\circ} \rightarrow tbs$	Multiple	36.1	\tilde{t} [l''_{323} =2e-4, 1e-2] 0.55 1.05	$m(\tilde{\chi}_1^0)$ =200 GeV, bino-like	ATLAS-CONF-2018-003
$ \begin{array}{ccc} \widetilde{tt}, \ \widetilde{t} \rightarrow tX_{1}^{\circ}, X_{1}^{\circ} \rightarrow tbs \\ \widetilde{tt}, \ \widetilde{t} \rightarrow b\widetilde{X}_{1}^{\pm}, \widetilde{X}_{1}^{\pm} \rightarrow bbs \\ \widetilde{t}_{1}\widetilde{t}_{1}, \ \widetilde{t}_{1} \rightarrow bs \end{array} $	$\geq 4b$ 2 jets + 2 b	139 36.7	$egin{array}{cccc} ar{t} & Forbidden & \textbf{0.95} \\ ar{t}_1 & [qq,bs] & \textbf{0.42} & \textbf{0.61} \\ \end{array}$	$m(\widetilde{\chi}_1^\pm)$ =500 GeV	2010.01015 1710.07171
$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow 0 s$ $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow q \ell$	$2e,\mu$ $2b$	36.1		D.4-1.45 BR($\tilde{t}_1 \rightarrow be/b\mu$)>20%	1710.05544
-1-17-11 - 140	1μ DV	136	\tilde{t}_1 [1e-10< λ'_{23k} <1e-8, 3e-10< λ'_{23k} <3e-9] 1.0	1.6 BR($\tilde{t}_1 \rightarrow q\mu$)=100%, $\cos \theta_t$ =1	2003.11956
$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}/\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1,2}^{0} \rightarrow tbs, \tilde{\chi}_{1}^{+} \rightarrow bbs$	1-2 $e, \mu \ge 6$ jets	139	$\tilde{\chi}_{1}^{0}$ 0.2-0.32	Pure higgsino	2106.09609



Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

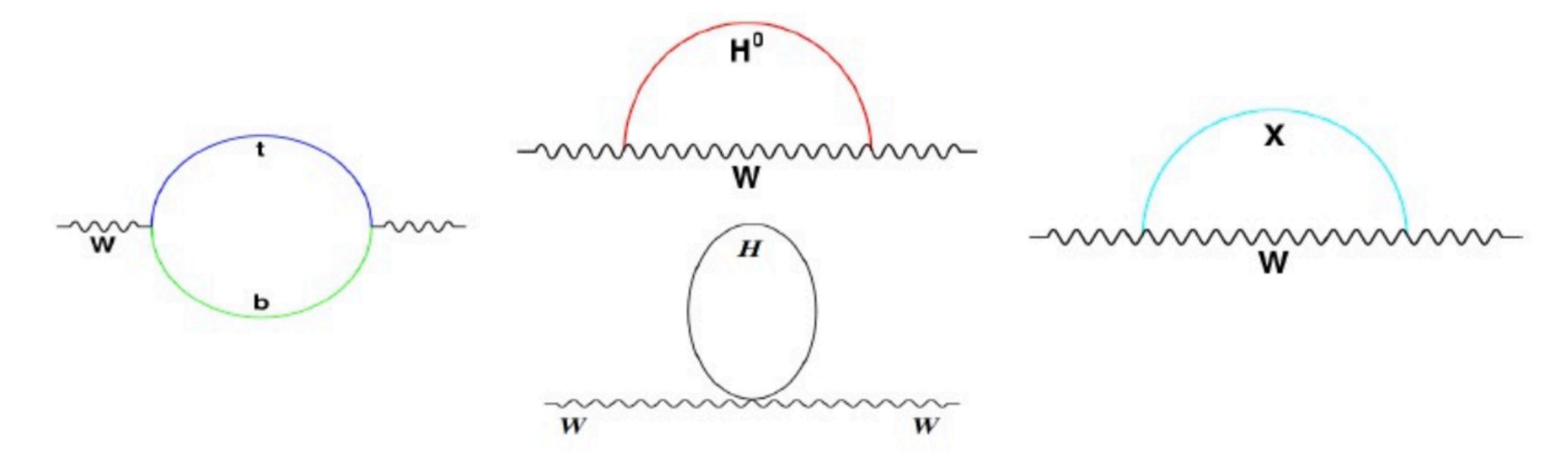
W Mass





INSTITUTE OF PHYSICS

• Affected by radiative corrections due to heavy quarks, Higgs, potentially undiscovered particles



 SUSY particles could run in the loop and change the value of W mass (or new Higgs bosons, new strong interactions, ...)



Summary

- (microscopic) Black Holes could potentially be created in colliders if we have extra spatial dimensions
 - ➡ Searches for semi-classical (high multiplicity) and quantum (2->2) black holes part of LHC programme
- Supersymmetry could lead to interesting solutions to some of the open questions in physics
 - → But unfortunately, it has not yet been seen by the LHC

