CERN + BSM

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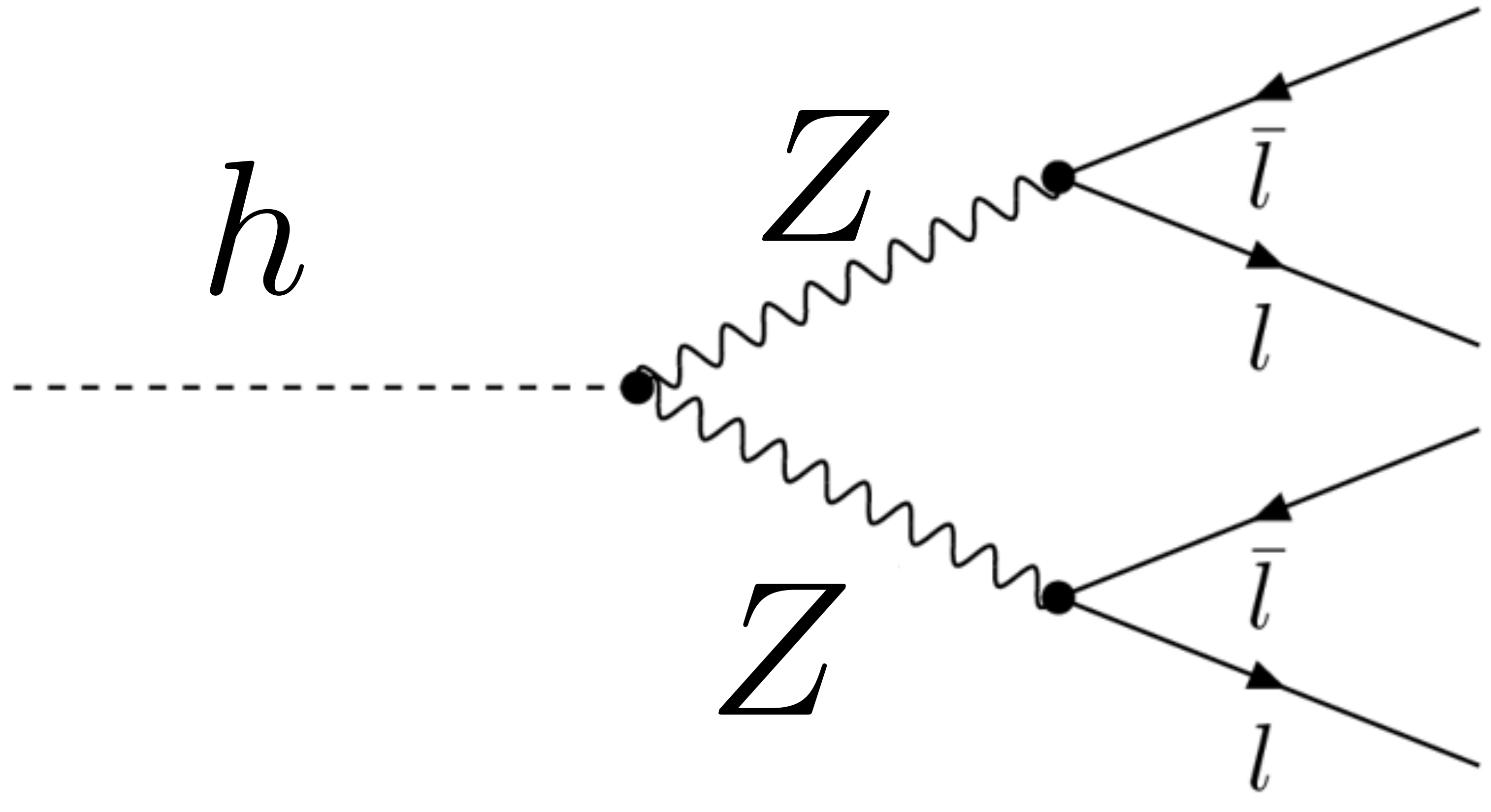
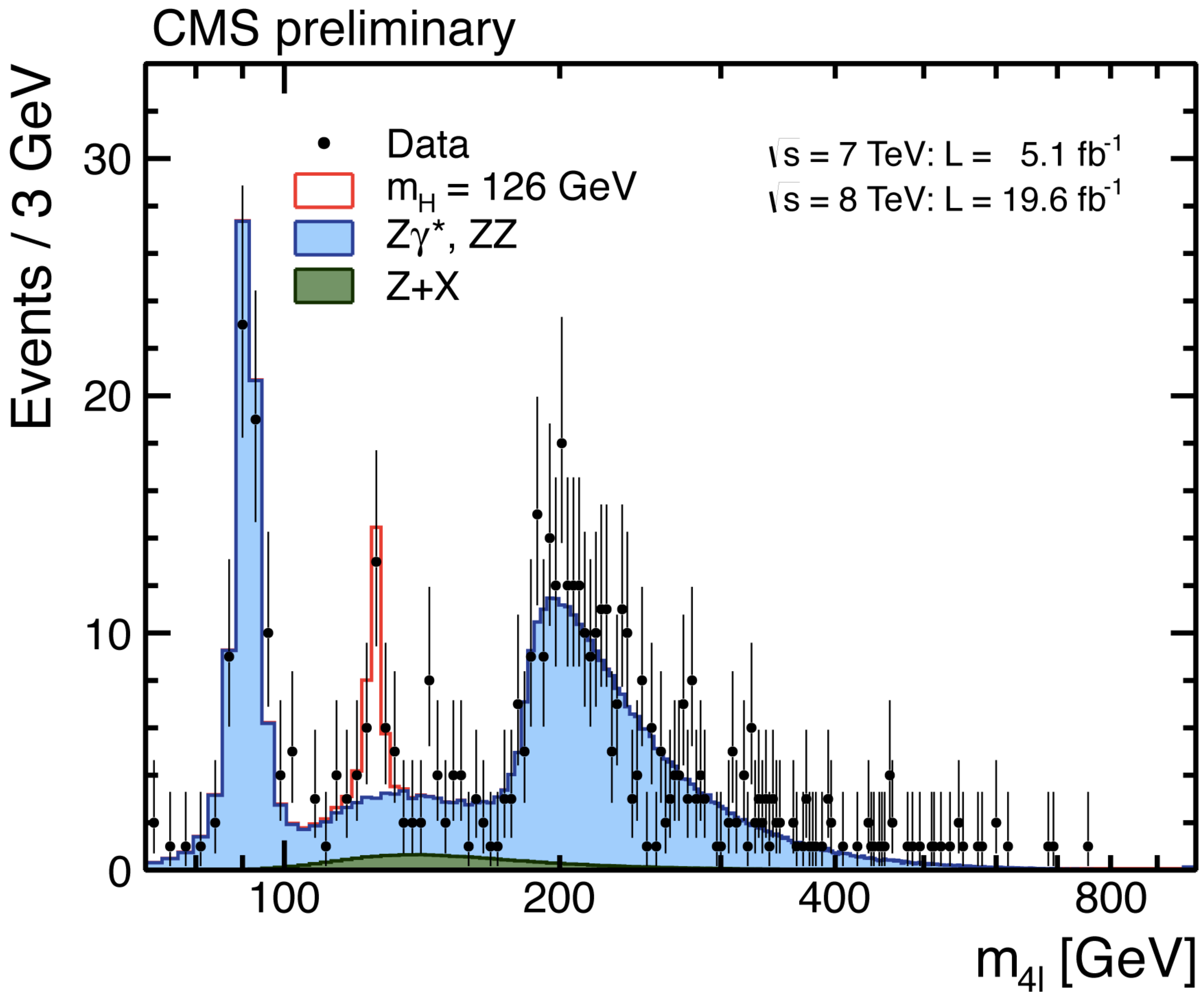
THE HIGGS

SPIN MEASUREMENT

Golden channel decay to 4 leptons.

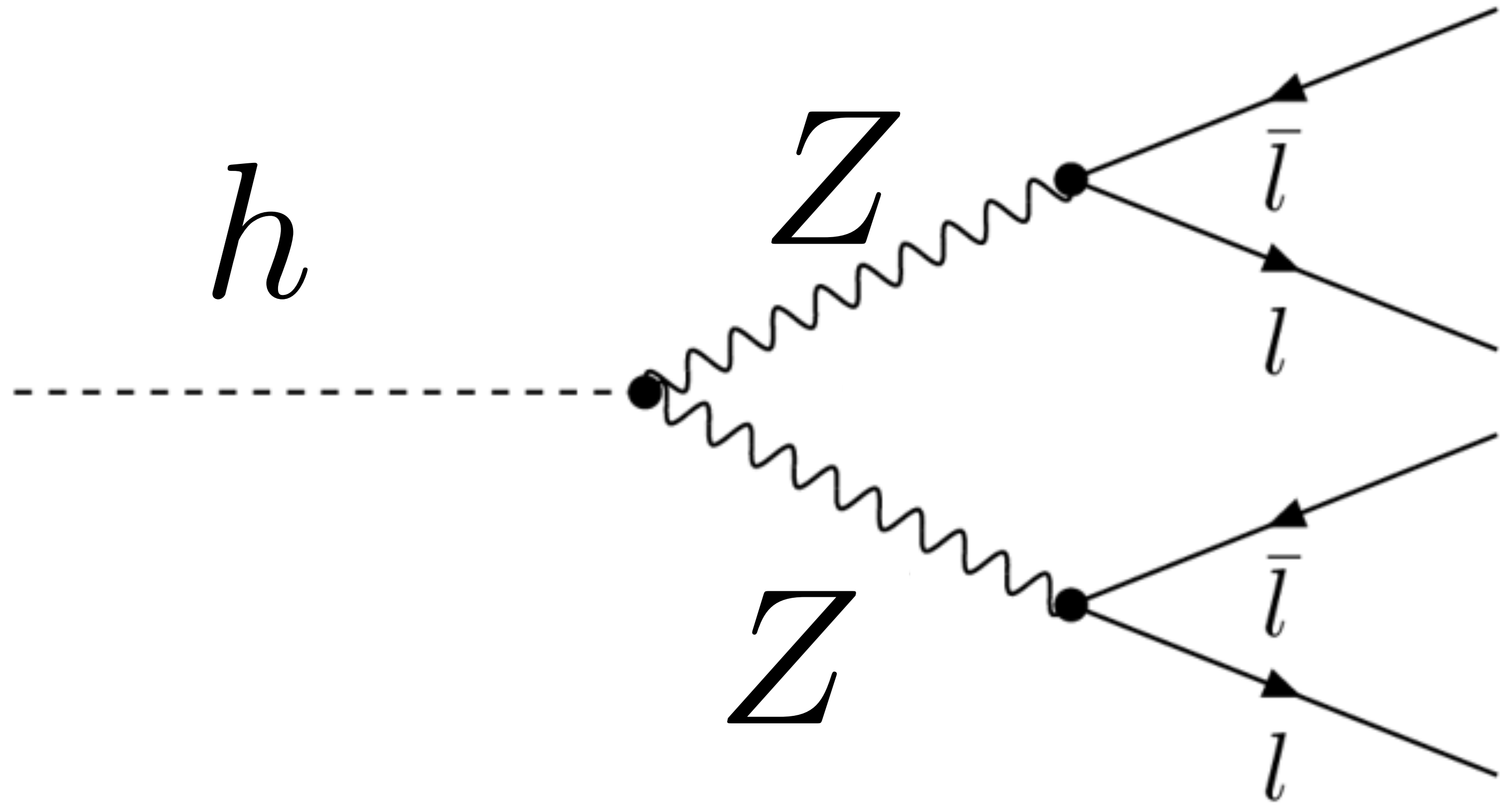


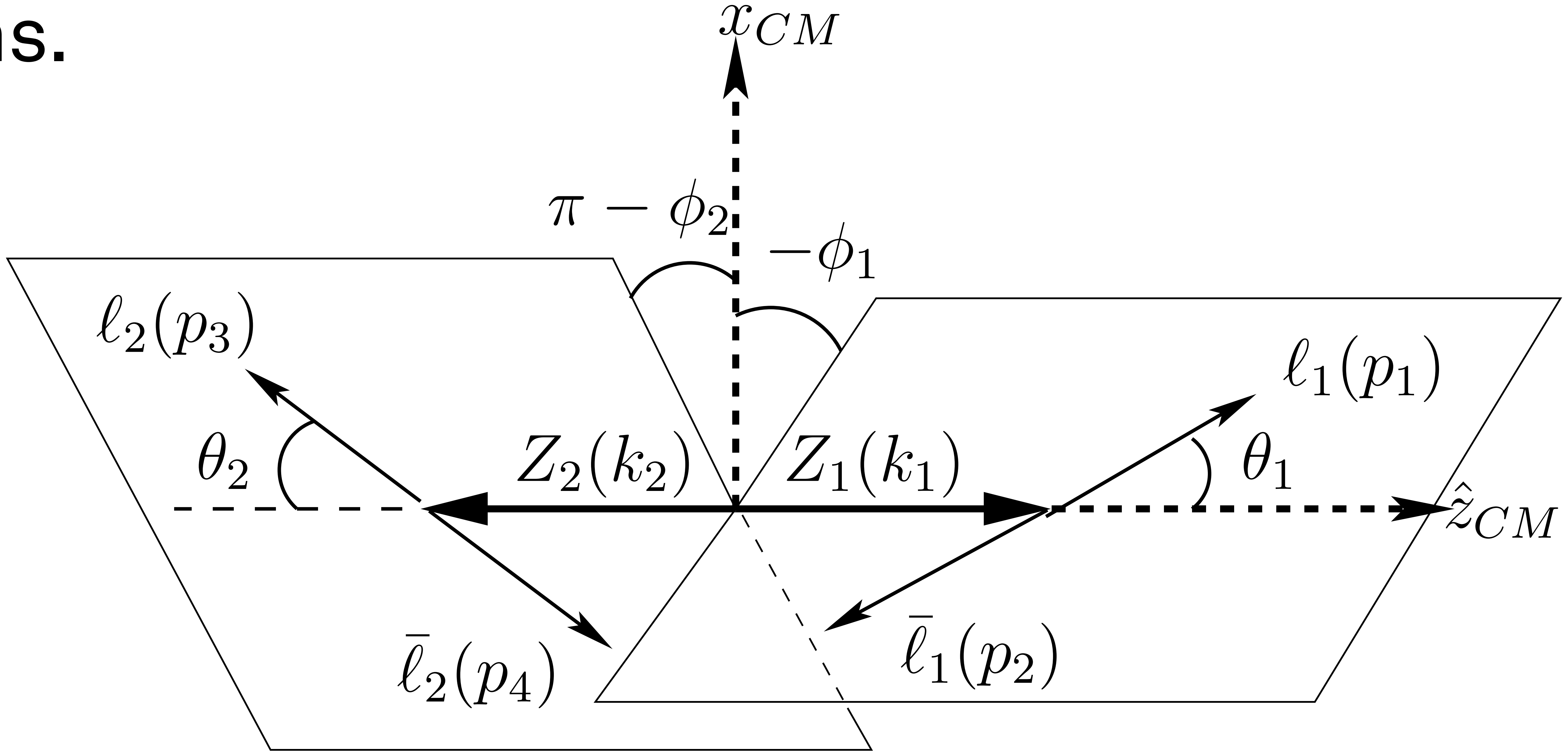
- Very low background
- Fully reconstructable final state



SPIN AND PARITY MEASUREMENT

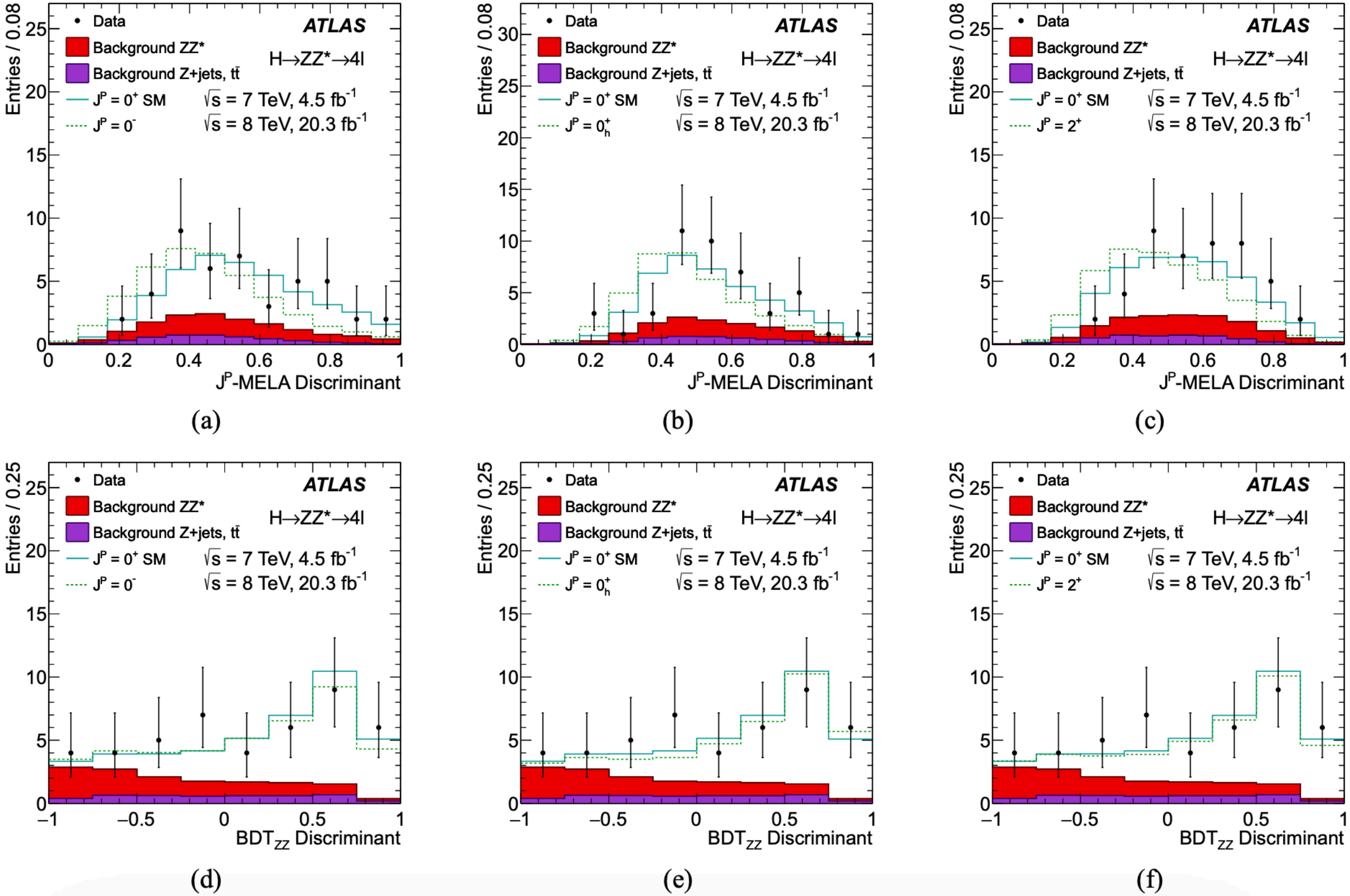
Golden channel decay to 4 leptons.





Each event described by 5 variables in Higgs rest frame.

SPIN AND PARITY MEASUREMENT



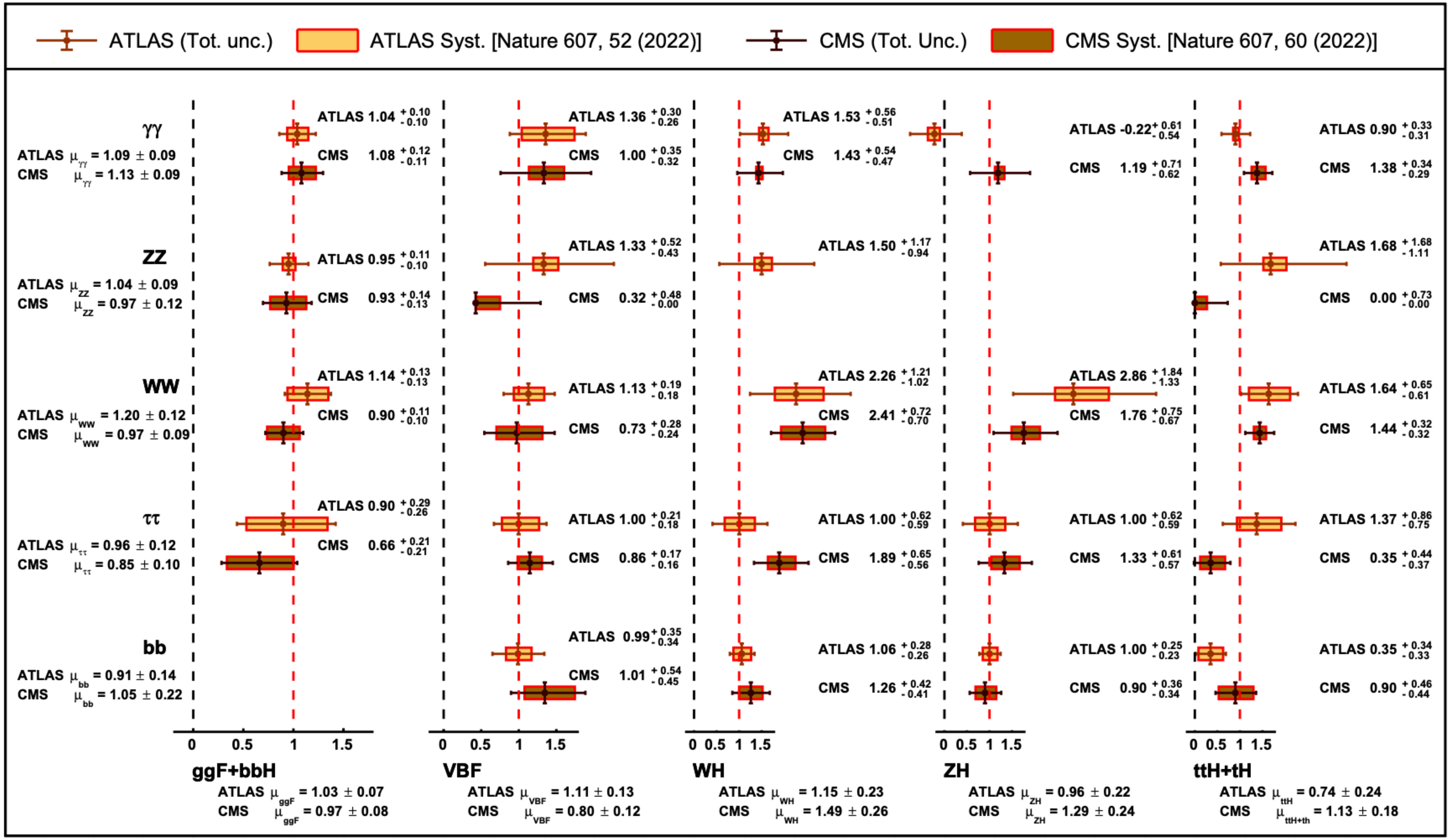
$$J^P = 0^+$$

is consistent with all data.

Agrees with SM prediction.

ATLAS, arXiv:1506.05669.

HIGGS RATE MEASUREMENTS



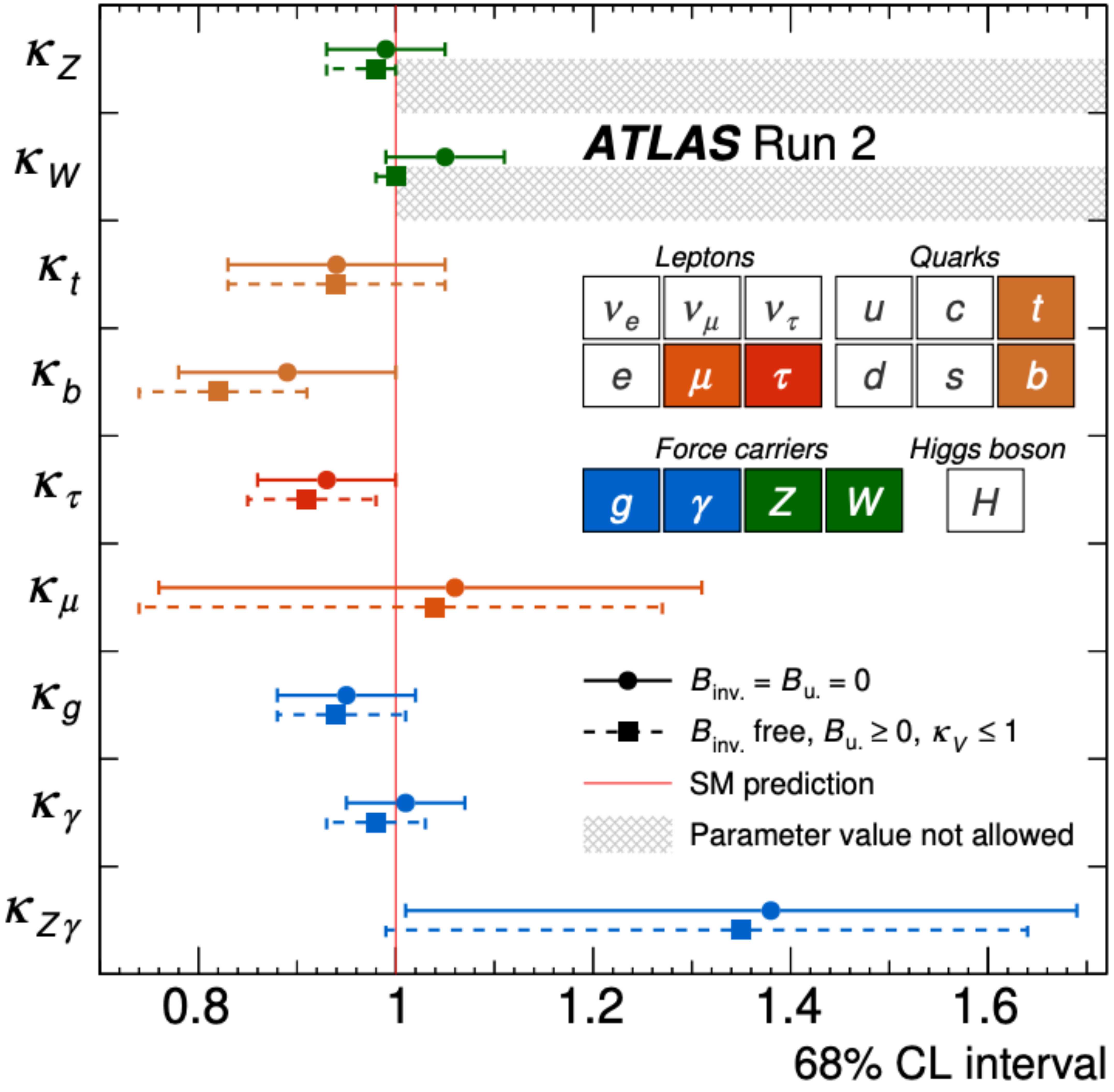
PDG

HIGGS COUPLING MEASUREMENTS

Convert rate measurement to coupling measurement.

Again normalize to SM ($\kappa_{SM} = 1$).

Precision ranges from 10 to 30%.



PDG

HIGGS COUPLING MEASUREMENTS

Convert rate measurement to coupling measurement.

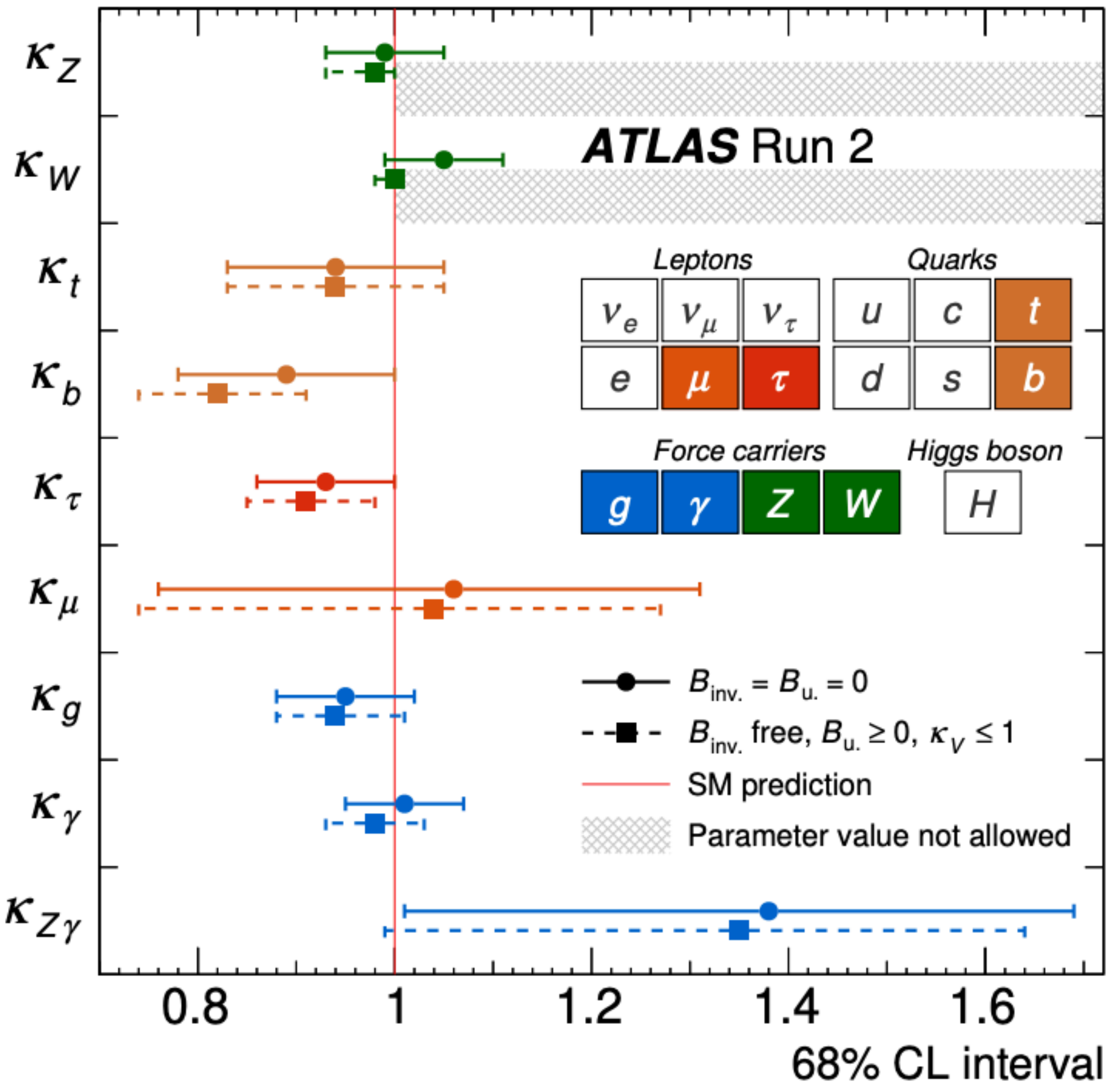
Again normalize to SM ($\kappa_{SM} = 1$).

Precision ranges from 10 to 30%.

Except Higgs self-coupling

$(\text{ATLAS})\ -0.6 < \kappa_\lambda < 6.6\ (\text{observed})$

$(\text{CMS})\ -1.2 < \kappa_\lambda < 6.5\ (\text{observed}),$



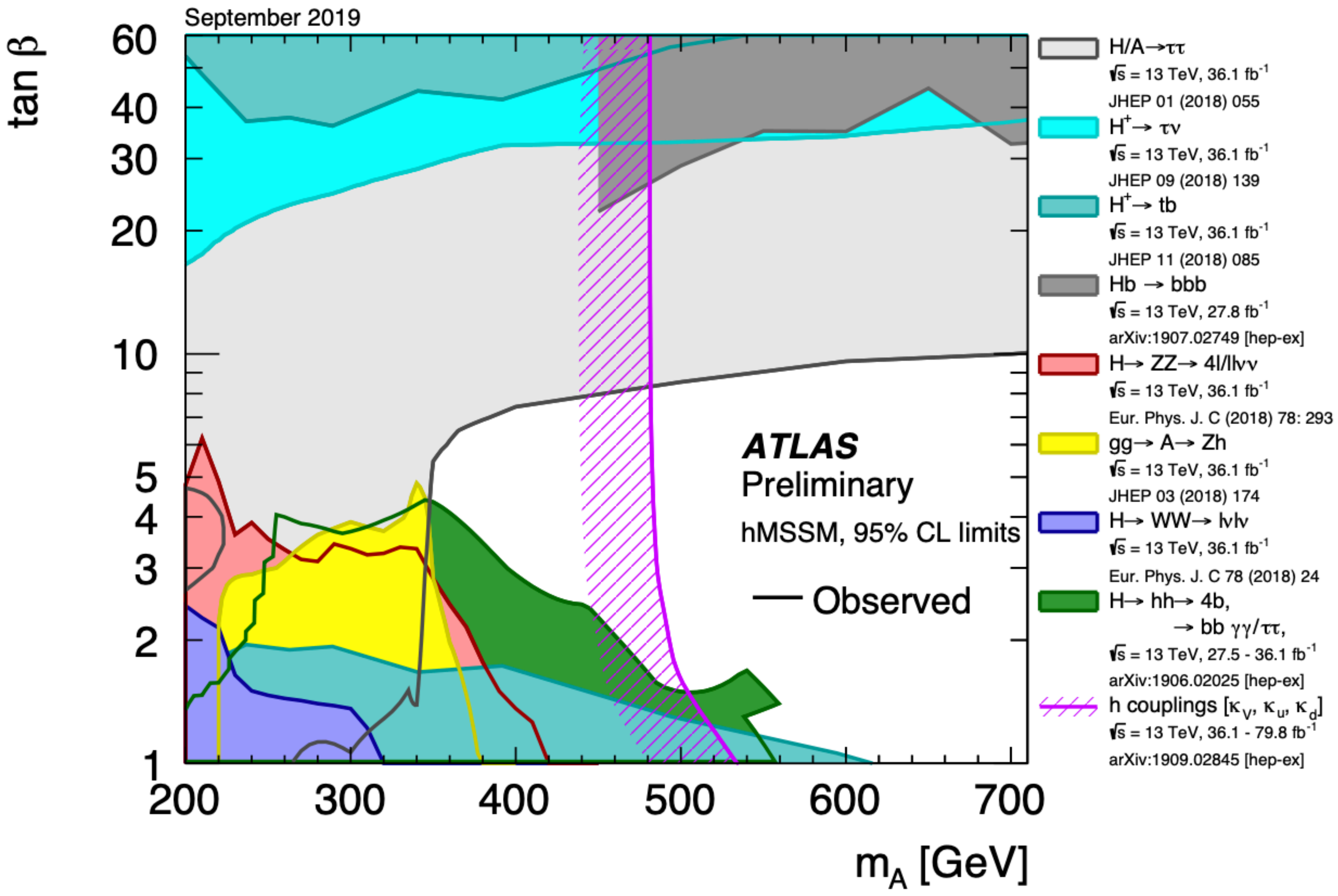
PDG

OTHER HIGGSES

SM has one Higgs because it is minimal.

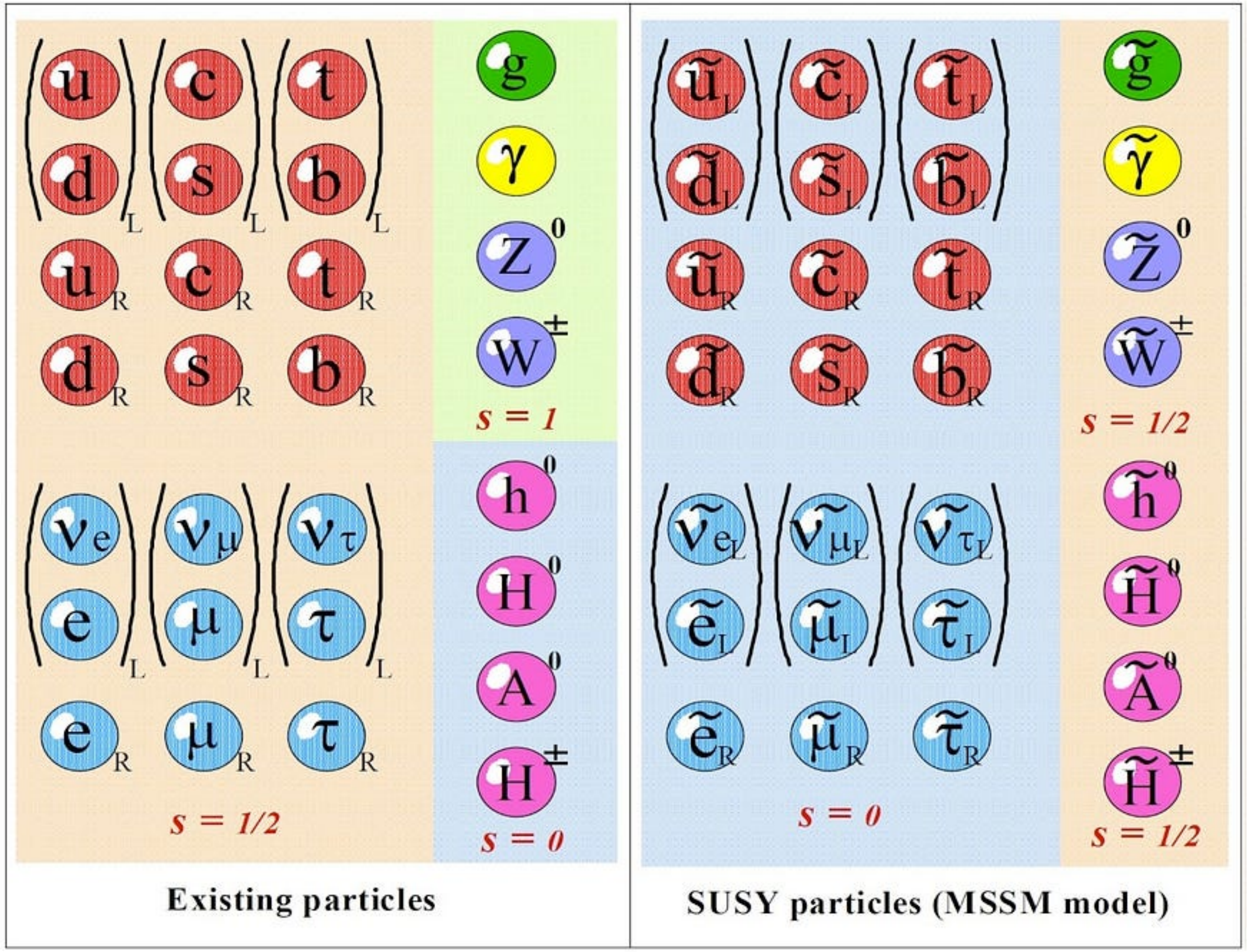
Can have additional Higgs states.

New Higgses can be charged (and doubly charged!).



SUPERSYMMETRY

MSSM



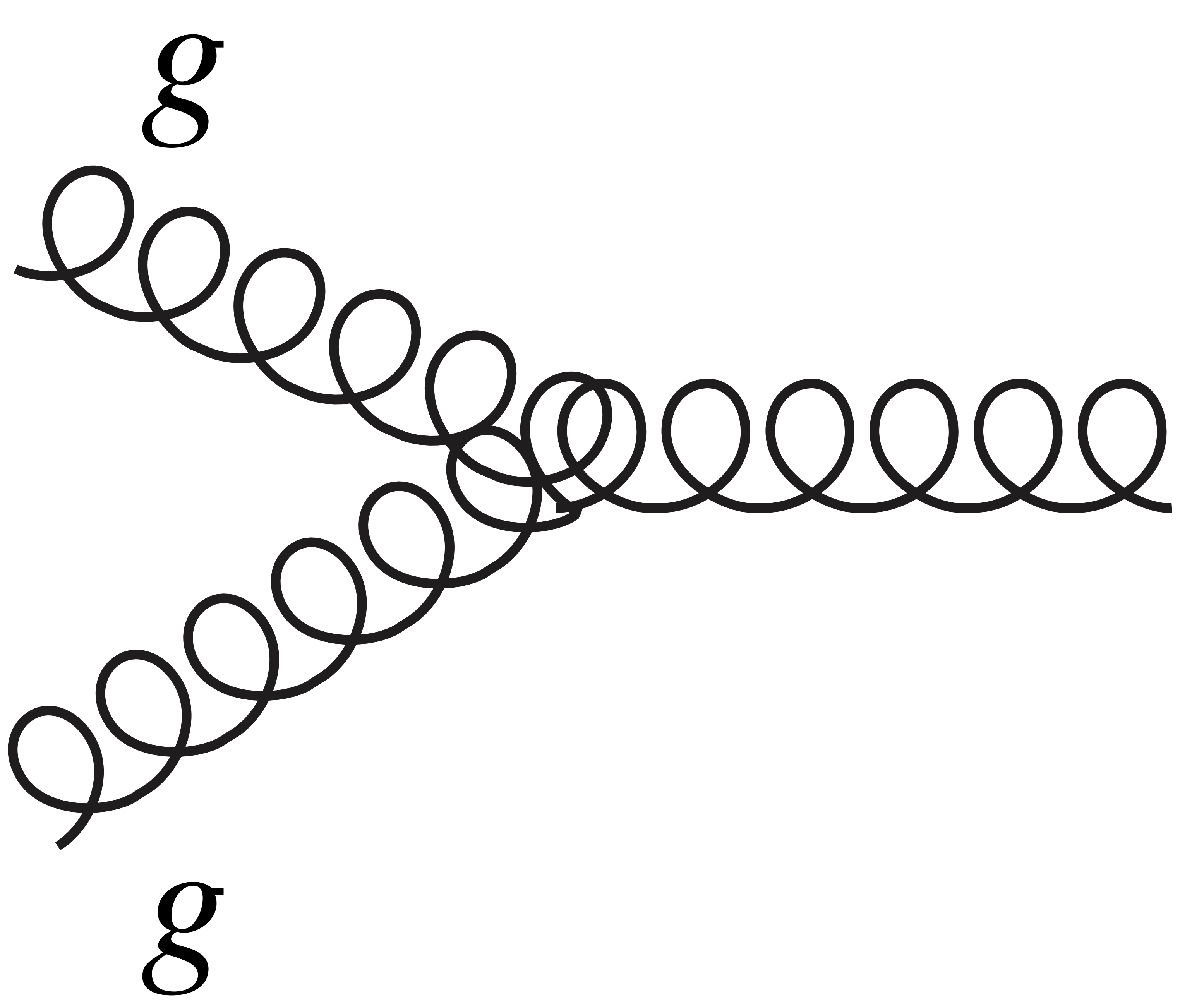
s = 1
s = 1/2
s = 0
Existing particles
s = 1/2
s = 0
s = 1/2
SUSY particles (MSSM model)

MSSM SIMPLIFICAITONS

Large number of parameters. Simplifying assumptions:

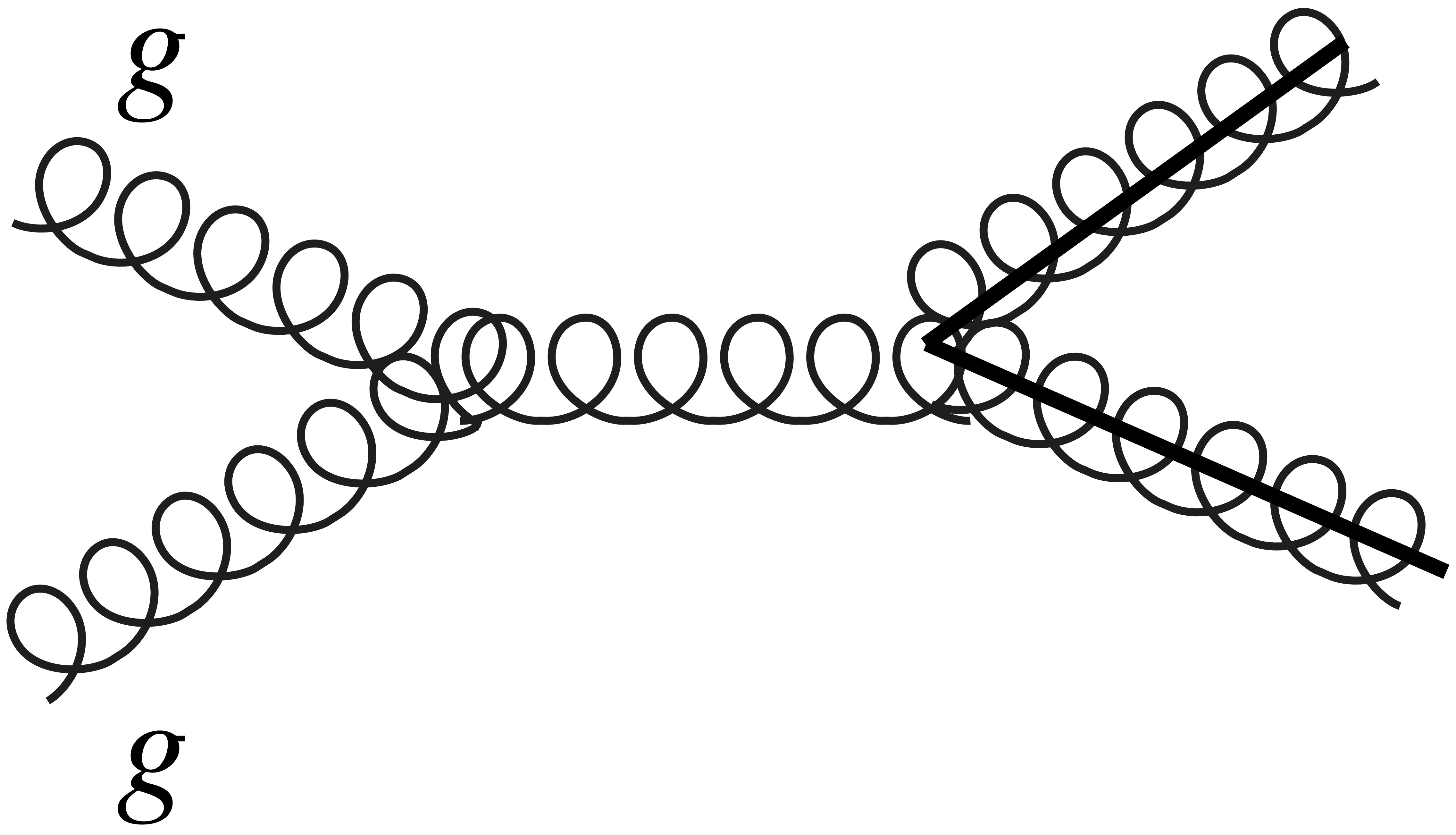
- R-parity conservation (save the proton)
- Neutralino LSP (WIMP miracle)

SEARCH FOR MSSM



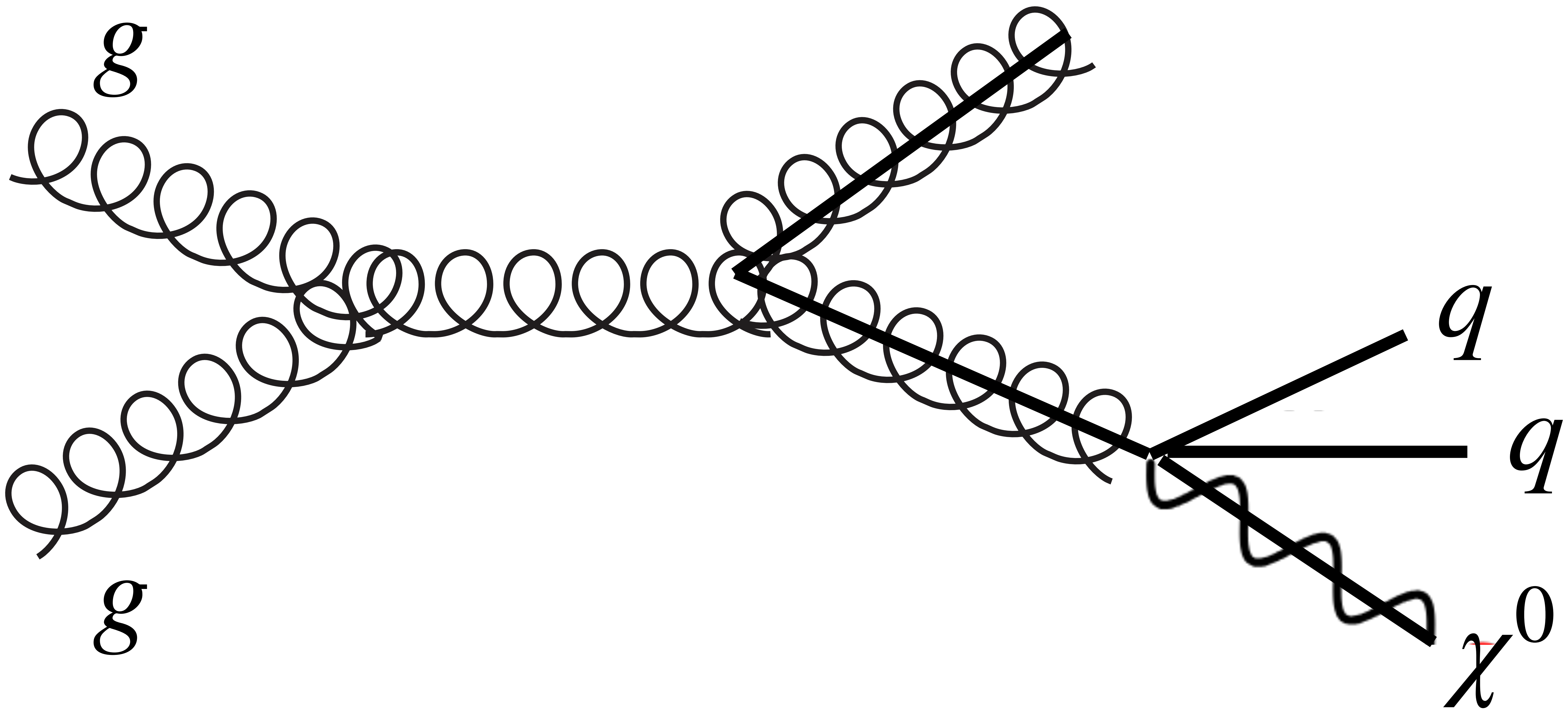
SEARCH FOR MSSM

Gluino pair production



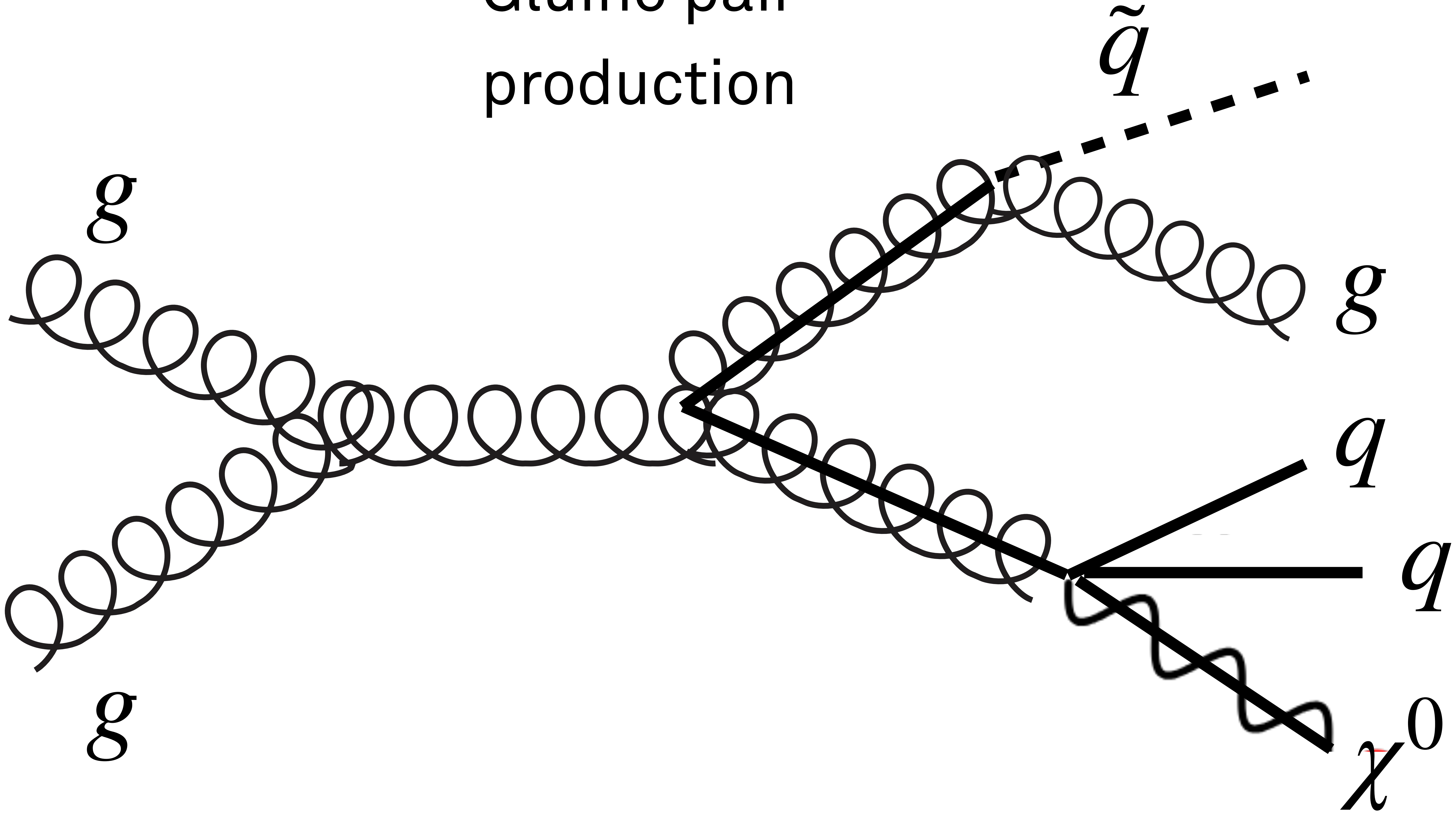
SEARCH FOR MSSM

Gluino pair production

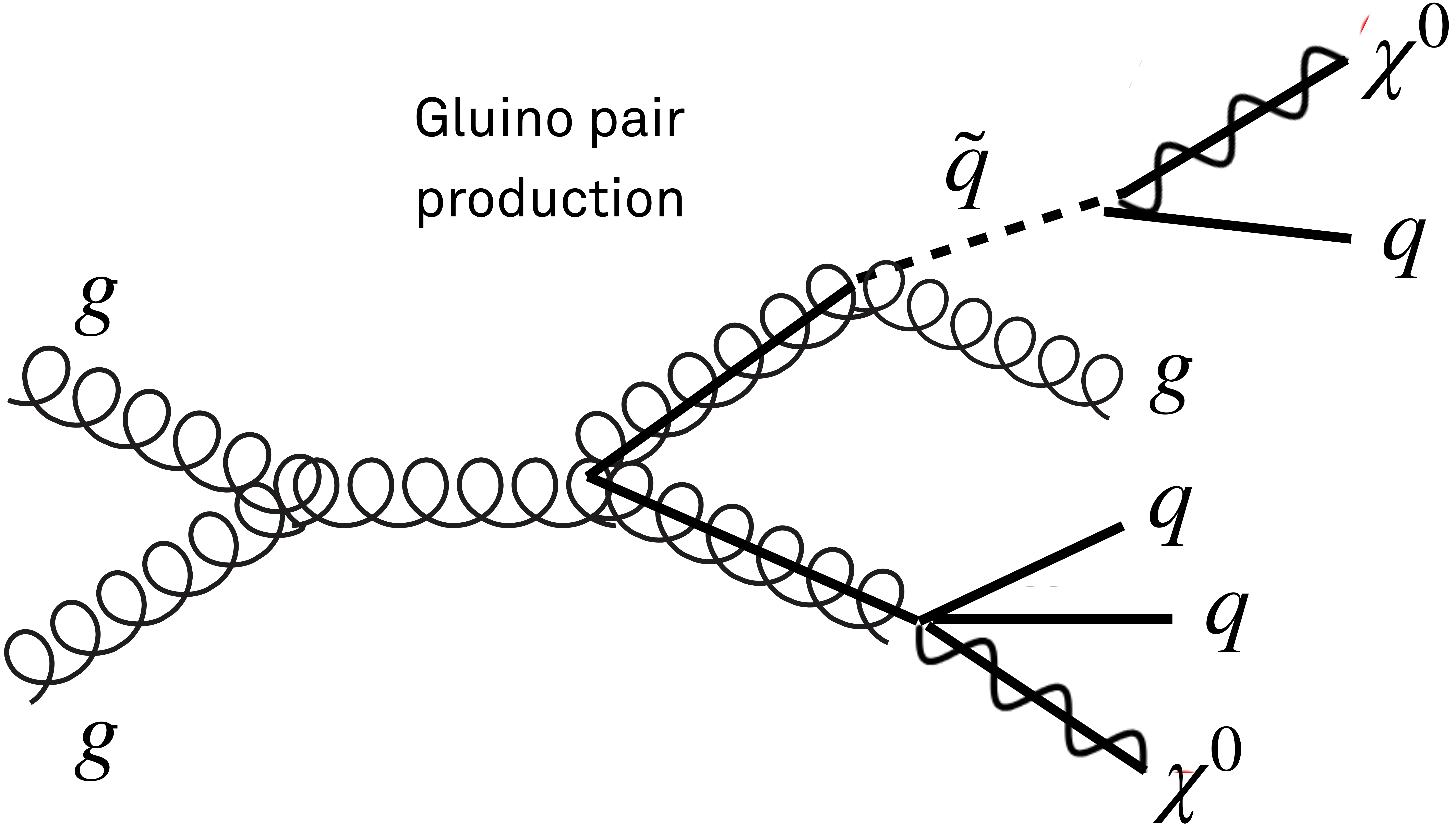


SEARCH FOR MSSM

Gluino pair production

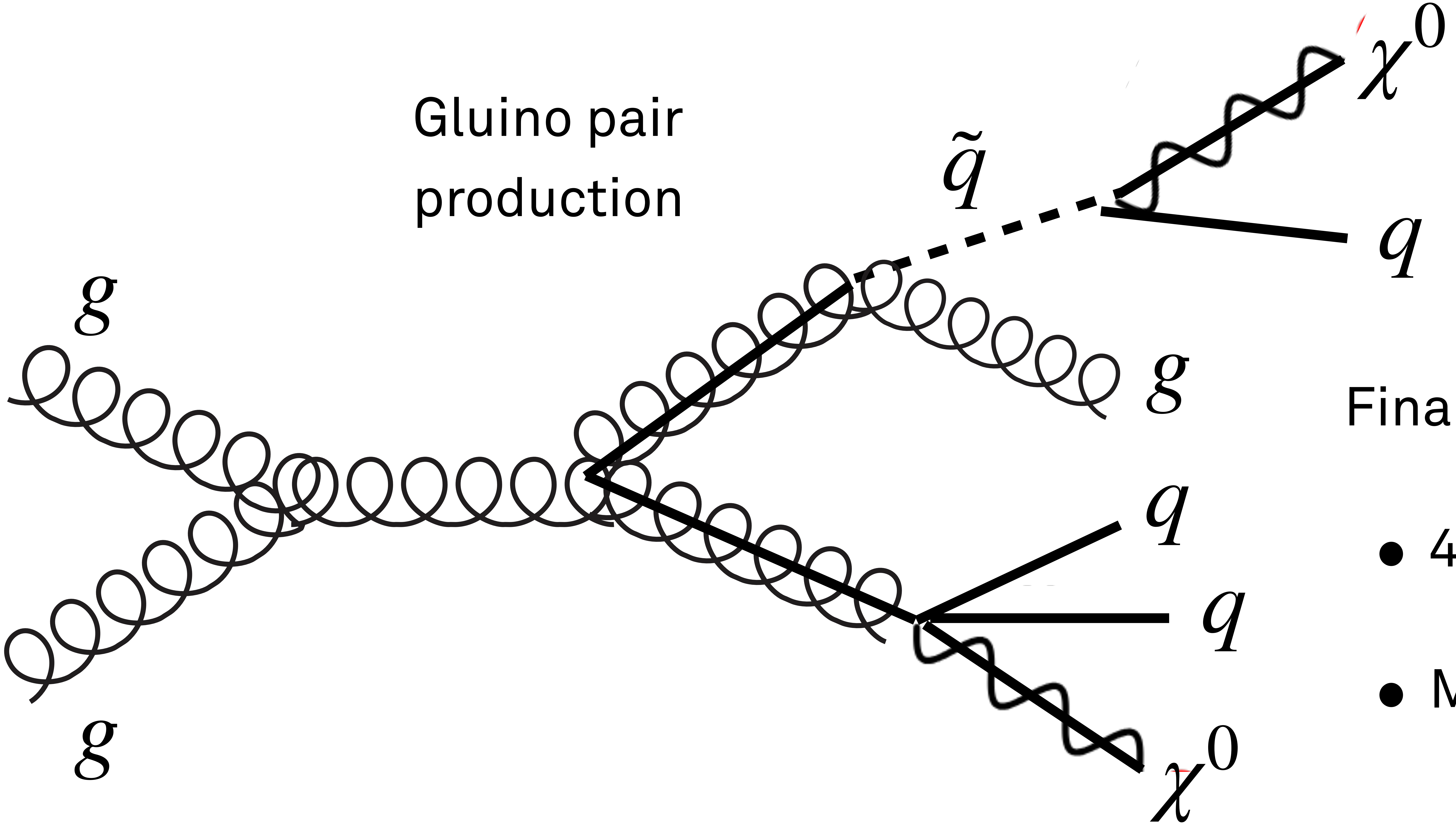


SEARCH FOR MSSM



SEARCH FOR MSSM

Gluino pair production



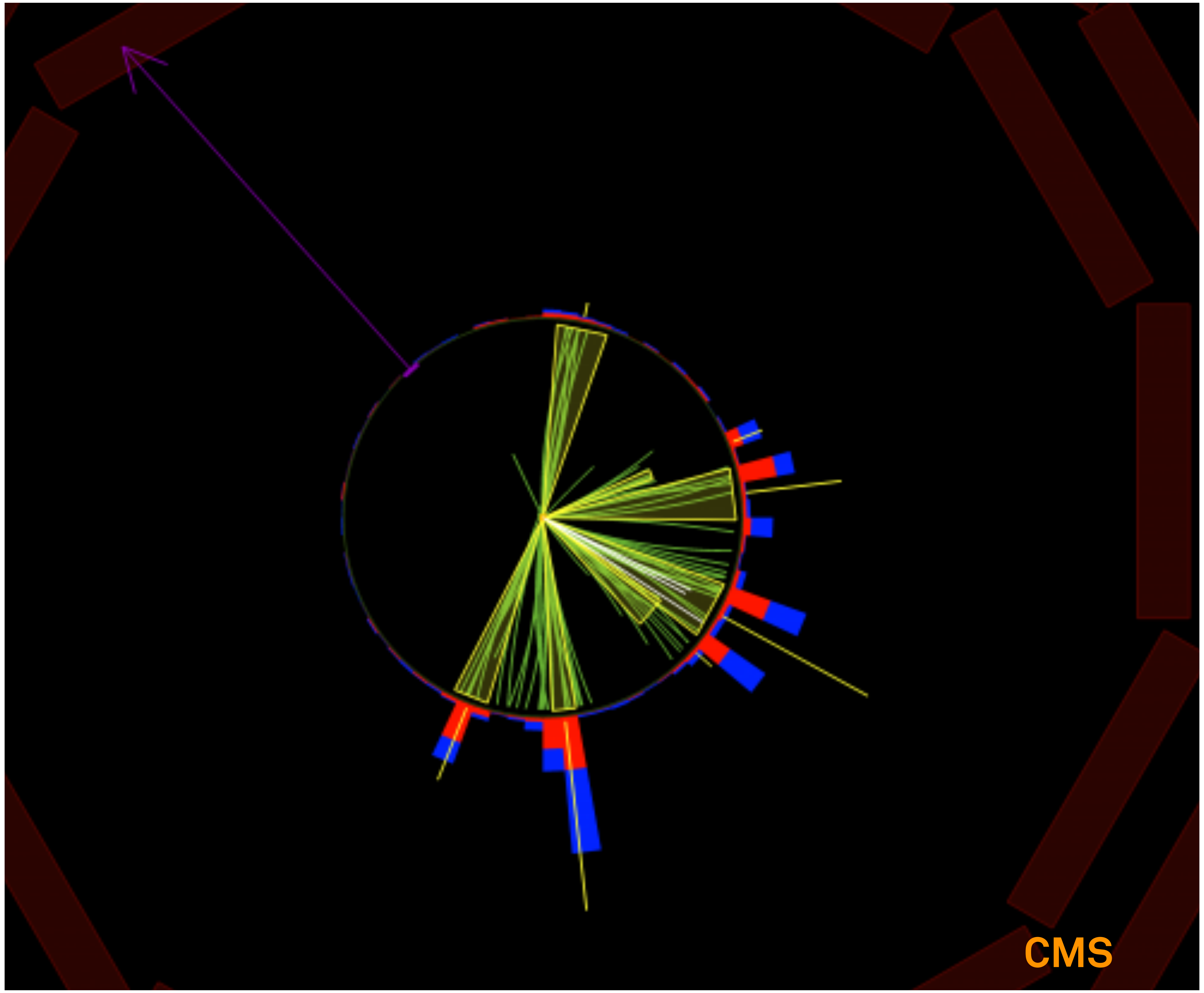
Final state:

- 4 jets
- Missing energy

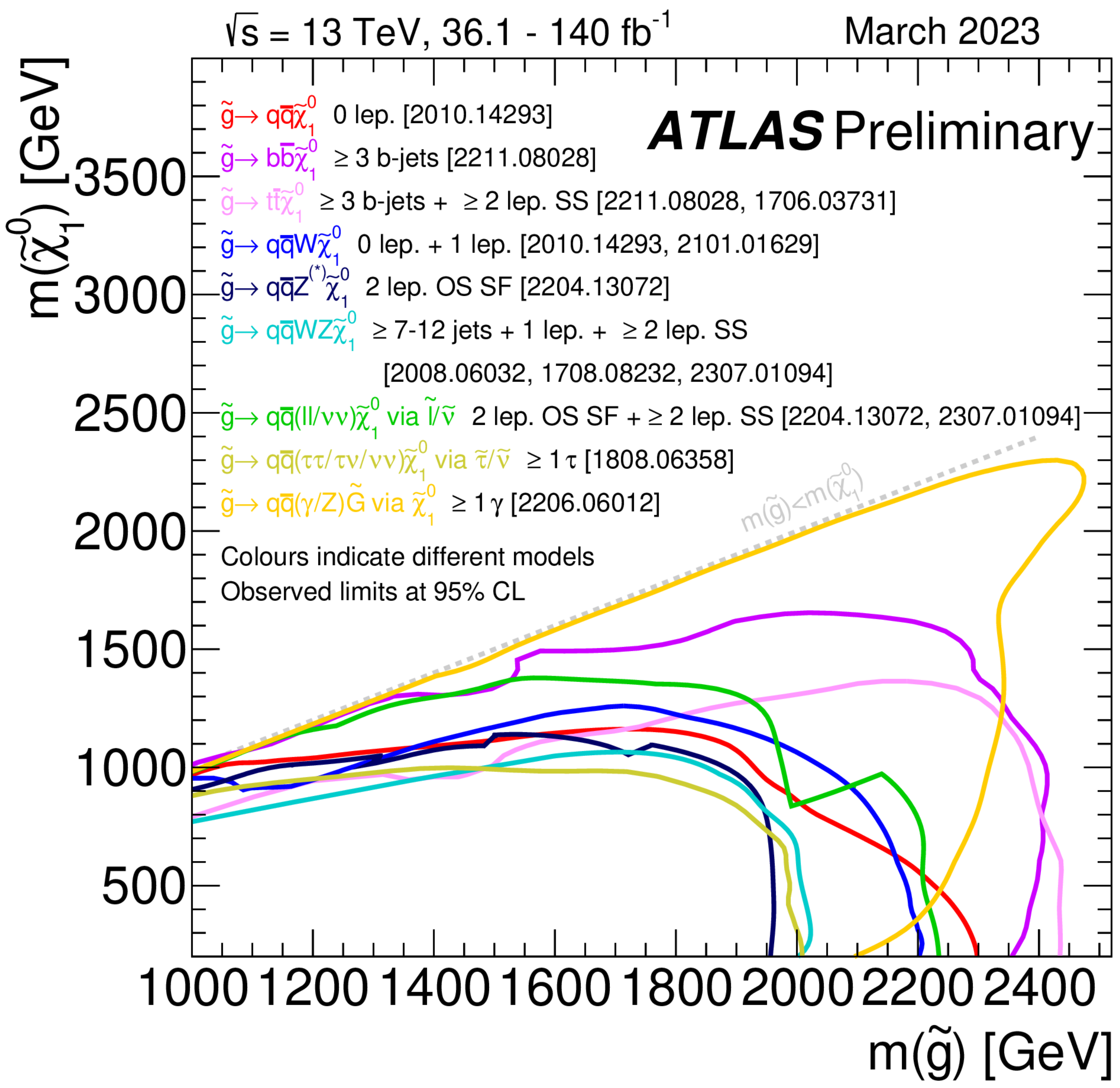
MISSING ENERGY

How do we detect something invisible?

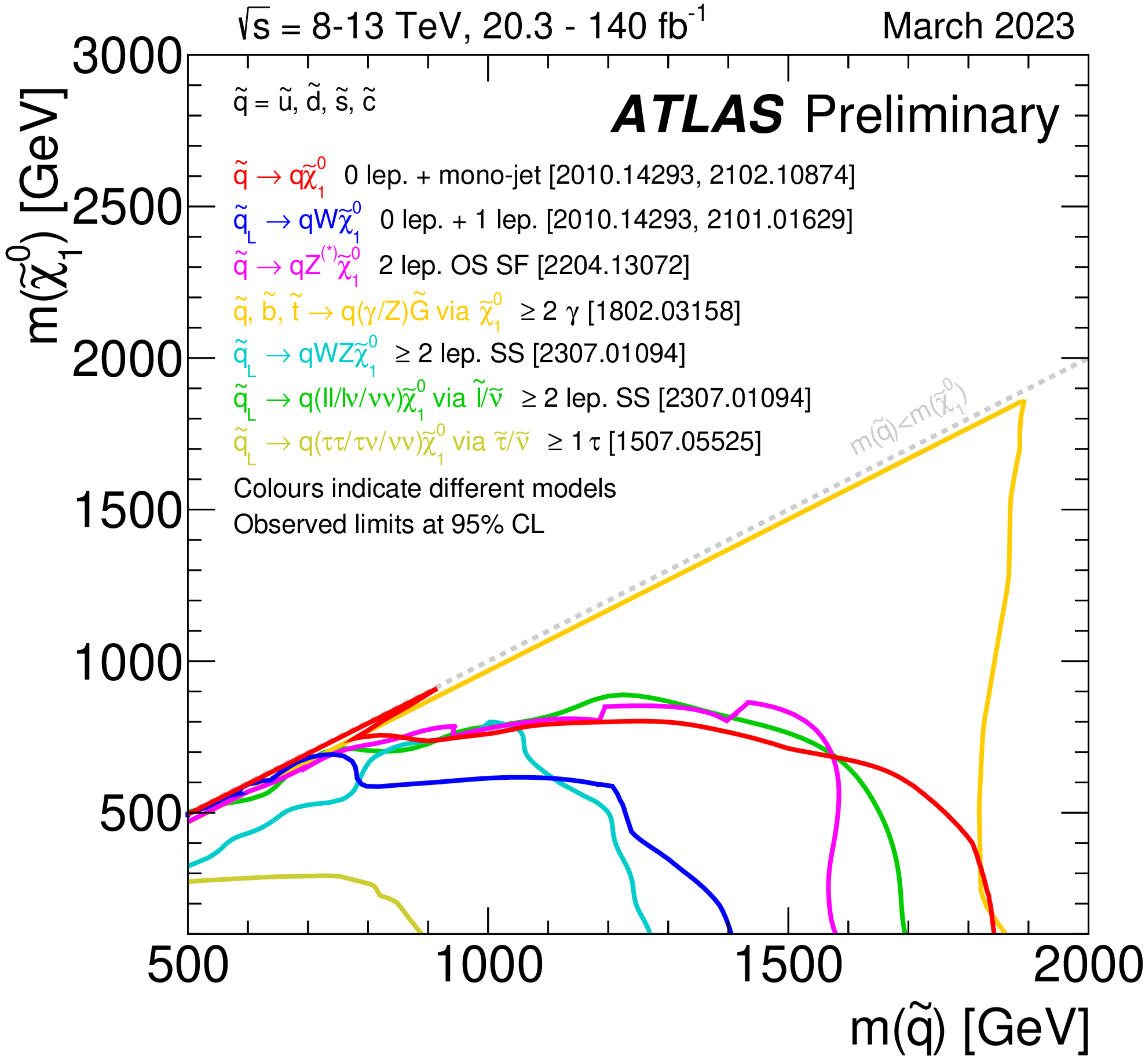
Conservation of (transverse) momentum.



LIMITS



√s = 13 TeV, 36.1 - 140 fb⁻¹
March 2023
ATLAS Preliminary
g̃→ qq̄χ̃⁰₁ 0 lep. [2010.14293]
g̃→ bb̄χ̃⁰₁ ≥ 3 b-jets [2211.08028]
g̃→ tt̄χ̃⁰₁ ≥ 3 b-jets + ≥ 2 lep. SS [2211.08028, 1706.03731]
g̃→ qq̄Wχ̃⁰₁ 0 lep. + 1 lep. [2010.14293, 2101.01629]
g̃→ qq̄Z(*)χ̃⁰₁ 2 lep. OS SF [2204.13072]
g̃→ qq̄WZχ̃⁰₁ ≥ 7-12 jets + 1 lep. + ≥ 2 lep. SS
[2008.06032, 1708.08232, 2307.01094]
g̃→ qq̄(ll/νν)χ̃⁰₁ via l̃/ν̃ 2 lep. OS SF + ≥ 2 lep. SS [2204.13072, 2307.01094]
g̃→ qq̄(ττ/τν/νν)χ̃⁰₁ via τ̃/ν̃ ≥ 1 τ [1808.06358]
g̃→ qq̄(γ/Z)G̃ via χ̃⁰₁ ≥ 1 γ [2206.06012]
Colours indicate different models
Observed limits at 95% CL
m(g̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]



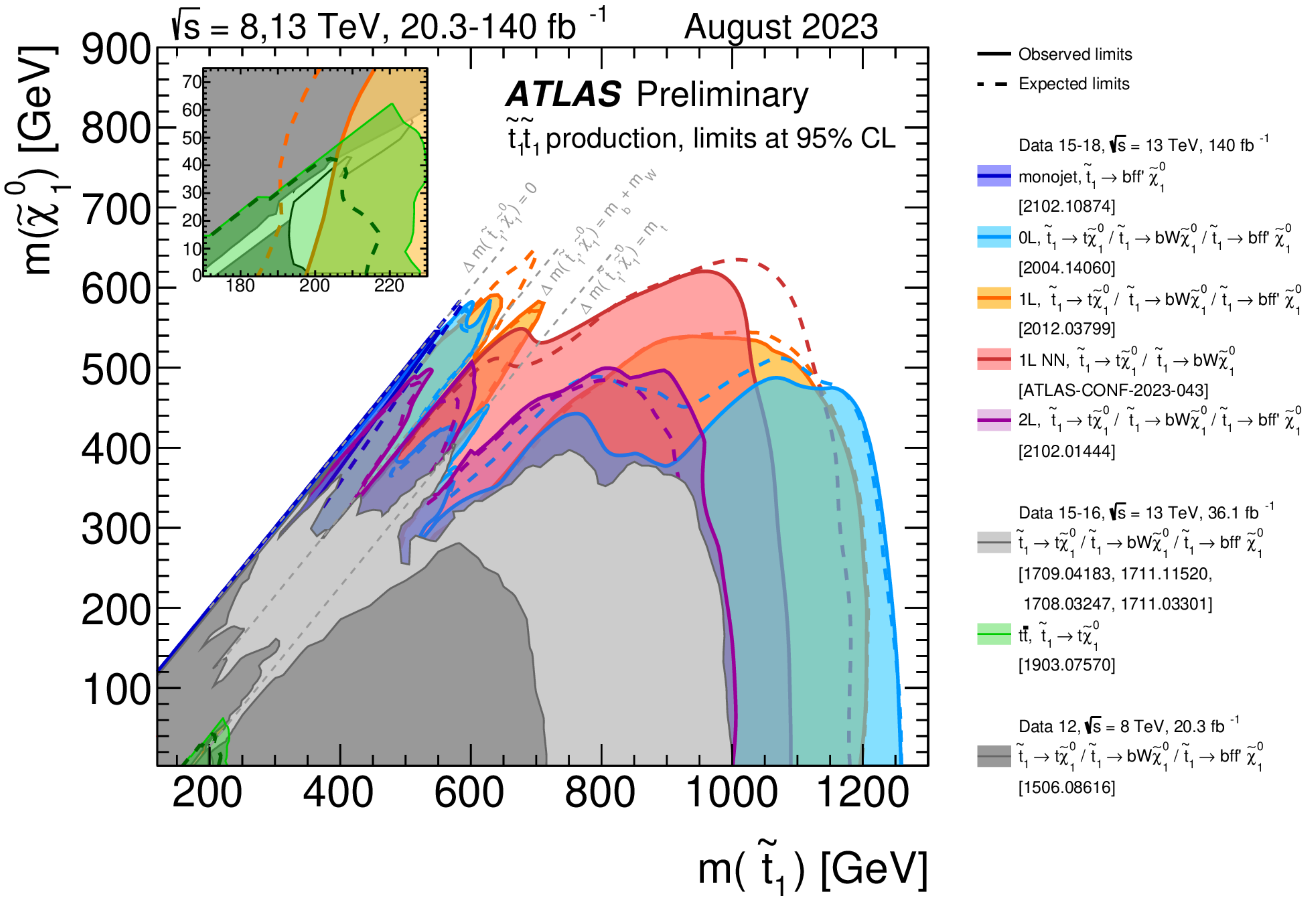
√s = 8-13 TeV, 20.3 - 140 fb⁻¹
March 2023
q̃ = ũ, d̃, s̃, c̃
ATLAS Preliminary
q̃ → qχ̃⁰₁ 0 lep. + mono-jet [2010.14293, 2102.10874]
q̃L → qWχ̃⁰₁ 0 lep. + 1 lep. [2010.14293, 2101.01629]
q̃ → qZ(*)χ̃⁰₁ 2 lep. OS SF [2204.13072]
q̃, b̃, t̃ → q(γ/Z)G̃ via χ̃⁰₁ ≥ 2 γ [1802.03158]
q̃L → qWZχ̃⁰₁ ≥ 2 lep. SS [2307.01094]
q̃L → q(ll/lν/νν)χ̃⁰₁ via l̃/ν̃ ≥ 2 lep. SS [2307.01094]
q̃L → q(ττ/τν/νν)χ̃⁰₁ via τ̃/ν̃ ≥ 1 τ [1507.05525]
Colours indicate different models
Observed limits at 95% CL
m(q̃)<m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(q̃) [GeV]

NATURAL SUSY

To solve hierarchy problem, mainly need top partner (stop) to be light.

Keep light WIMP for dark matter.

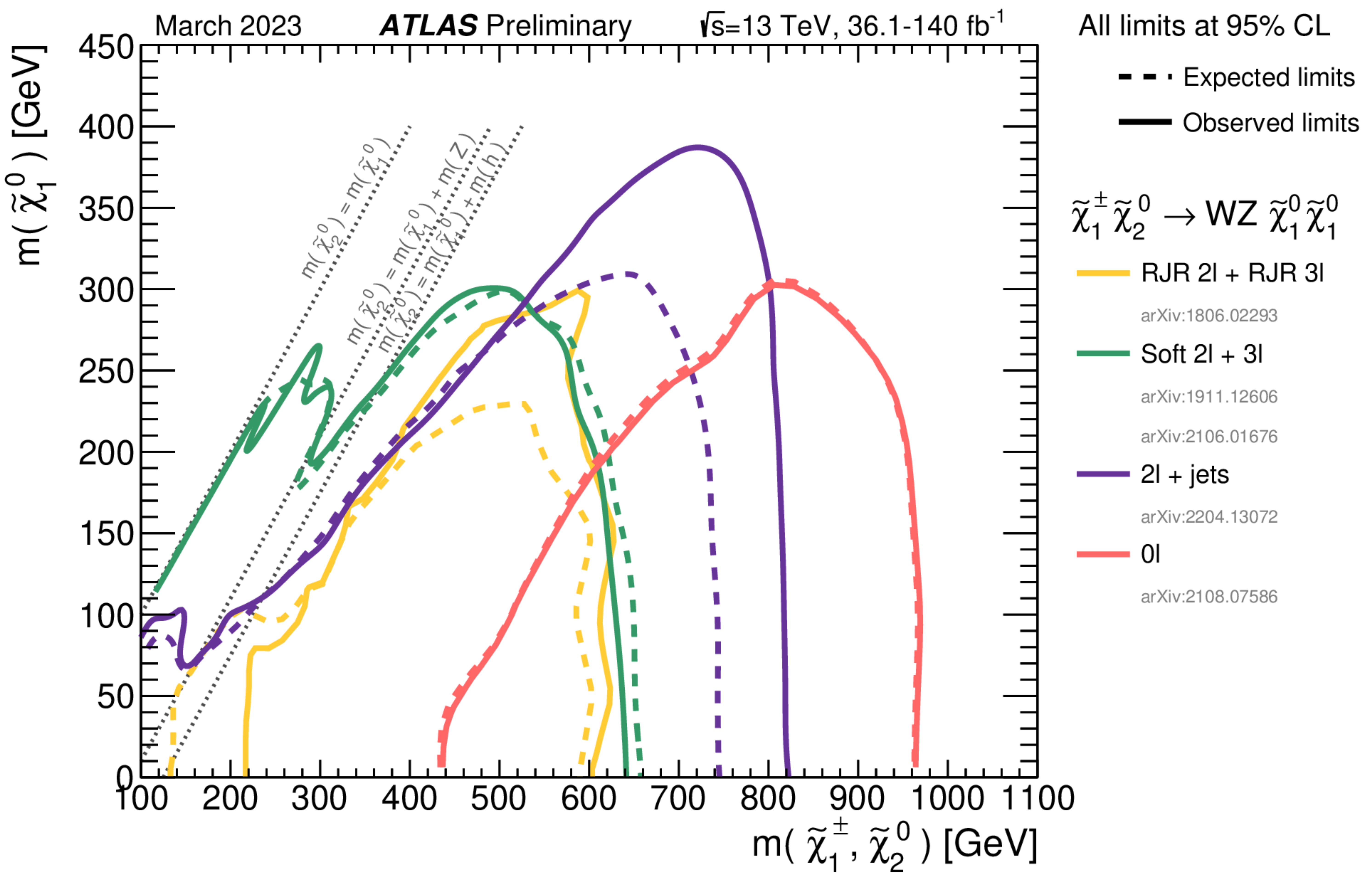
Final state is 2 tops + missing energy.



ELECTROWEAK SUSY

Forget naturalness, just dark matter.

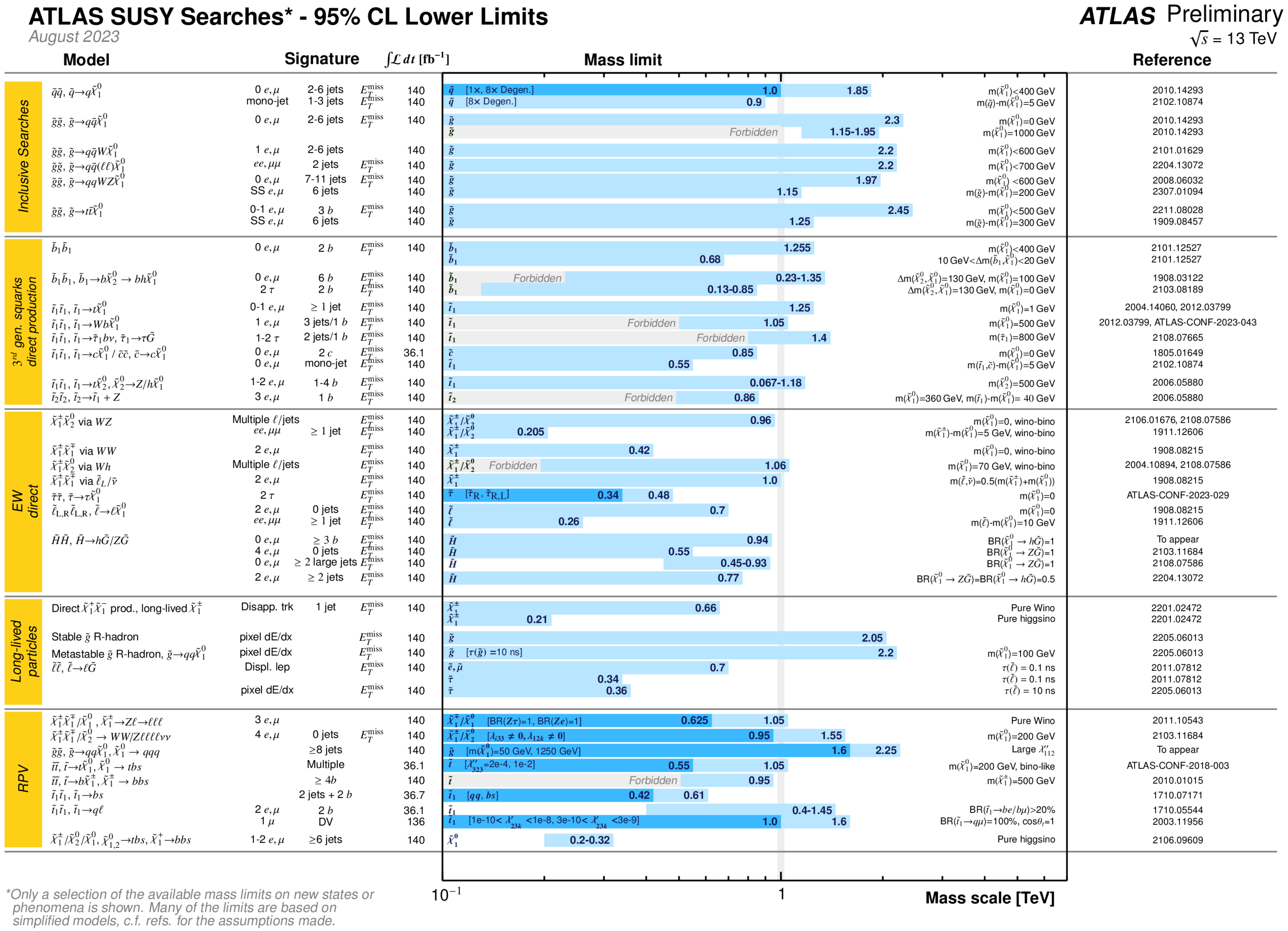
Look for leptons and missing energy.



LOTS OF LIMITS

Hundreds of experimental searches constrain an enormous variety of SUSY scenarios.

Folk Theorem: any BSM scenario has the same pheno as a SUSY model.



NON-SUSY (SORT OF)

Lots of other searches excluding things at the TeV scale.

Some searches sensitive to ~ 30 TeV.