

Lighting up Collider Searches for Electroweak States

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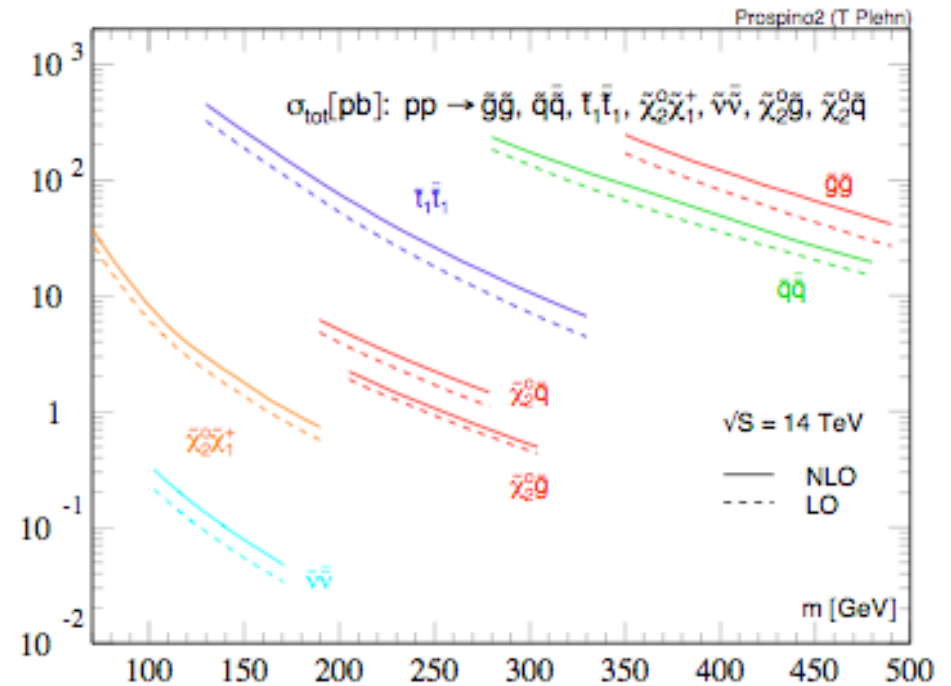
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New electroweak states

Generic in SM extensions, e.g.
WIMPs for dark matter,
gauginos in SUSY, ...

Low production cross sections
at colliders, but often low
backgrounds as well

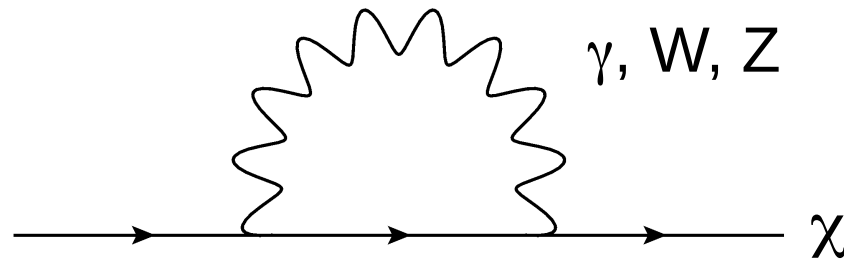
Often, symmetry protects
decay of the lightest
component of an EW multiplet,
cf. R-parity and the neutralino
LSP



New electroweak states

Any non-trivial $SU(2)_L$ multiplet χ contains at least one charged particle, which may decay to its neutral partner

Mass splitting from radiative corrections



$$\begin{aligned} M(\chi^+) - M(\chi^0) &= \left(1 + \frac{2Y}{c_w}\right) \frac{\alpha_2}{2} M_W (1 - c_w) \\ &\approx 166 + 189(2Y) \text{ MeV} \end{aligned}$$

Large extra splittings constrained by EW precision

χ^+ in the detector

< 200 MeV splitting: $\chi^+ \rightarrow \chi^0 + \pi^+$ gives disappearing tracks

> several GeV splitting: soft leptons from $\chi^+ \rightarrow \chi^0 + W^*$
Schwaller and Zurita, 1312.7350; Han, Kribs, Martin, Menon 1401.1235; ...

In between, limited to mono-X searches, e.g. monojet and mono-Z

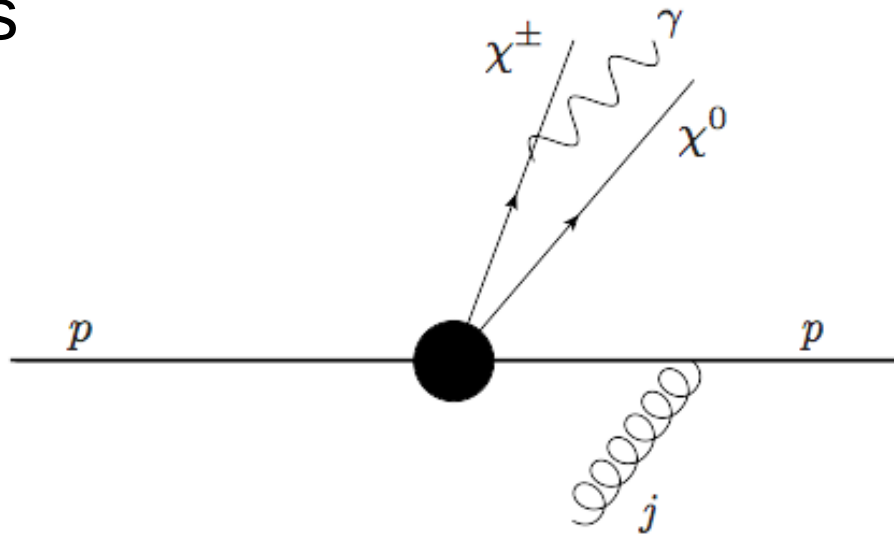
Baer, Mustafayev, Tata 1401.1162; Anandakrishnan, Carpenter, Raby 1407.1833; ...

Eventual sensitivity of monojet searches limited by background uncertainties, such as extrapolation from $Z \rightarrow \mu\mu$ to $Z \rightarrow \nu\nu$

Photon final-state radiation

Even if χ^+ decays promptly and invisibly, it can still produce electroweak radiation

Radiation tends to be emitted in direction of χ^+ , i.e. can look for photon aligned with missing energy in monojet events



Al, Izaguirre, Shuve
1605.00658

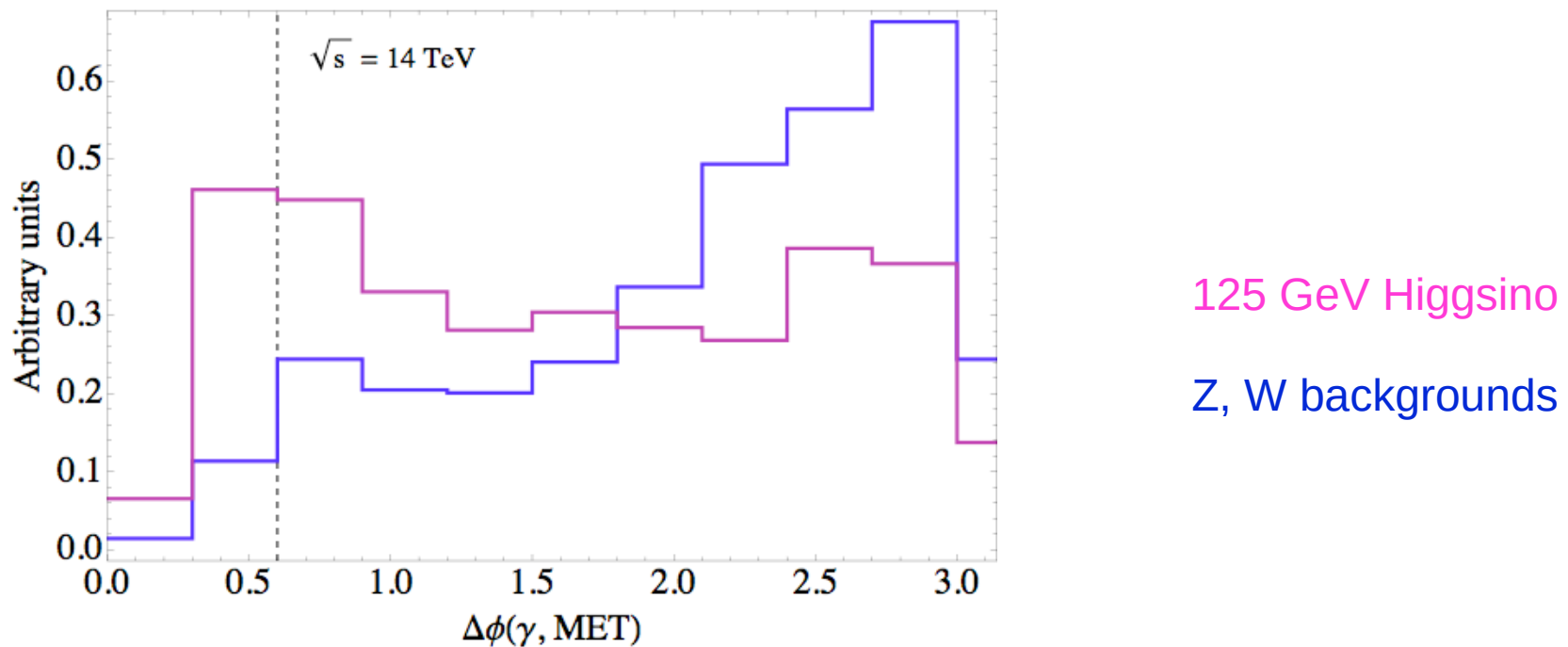
Pay statistical price of α but benefit from low backgrounds and extra kinematic handle

Photon + jet + MET search

Trigger on hard jet and missing energy, then look for soft photon (15 GeV) with small angular separation from MET

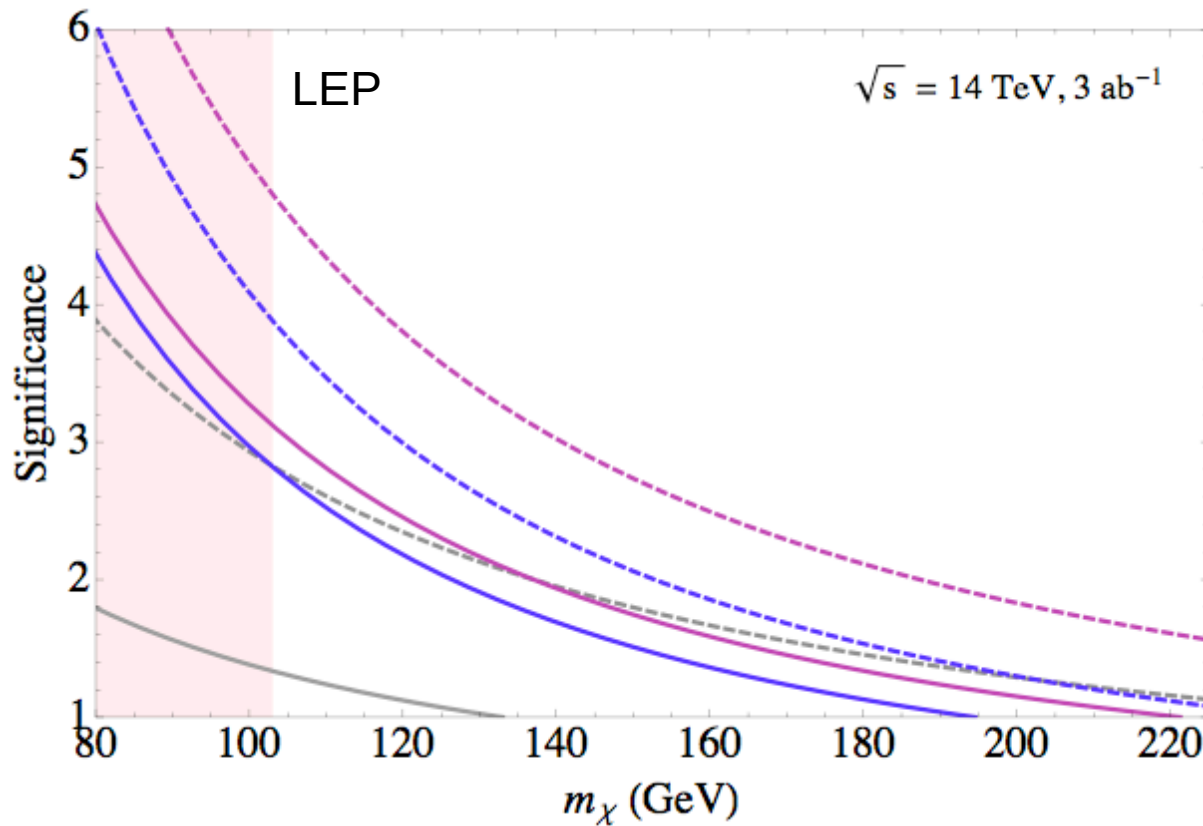
Backgrounds: $Z + \gamma$, $W + \gamma$, tops, QCD fakes

Optimize other cuts on jet p_T , MET, $\eta(\gamma)$



Results - Higgsinos

Light in natural SUSY, and $\chi^+ - \chi^0$ splitting of 340 MeV leads to prompt χ^+ decay even without additional splitting through dimension-5 operator



Photon + jet + MET

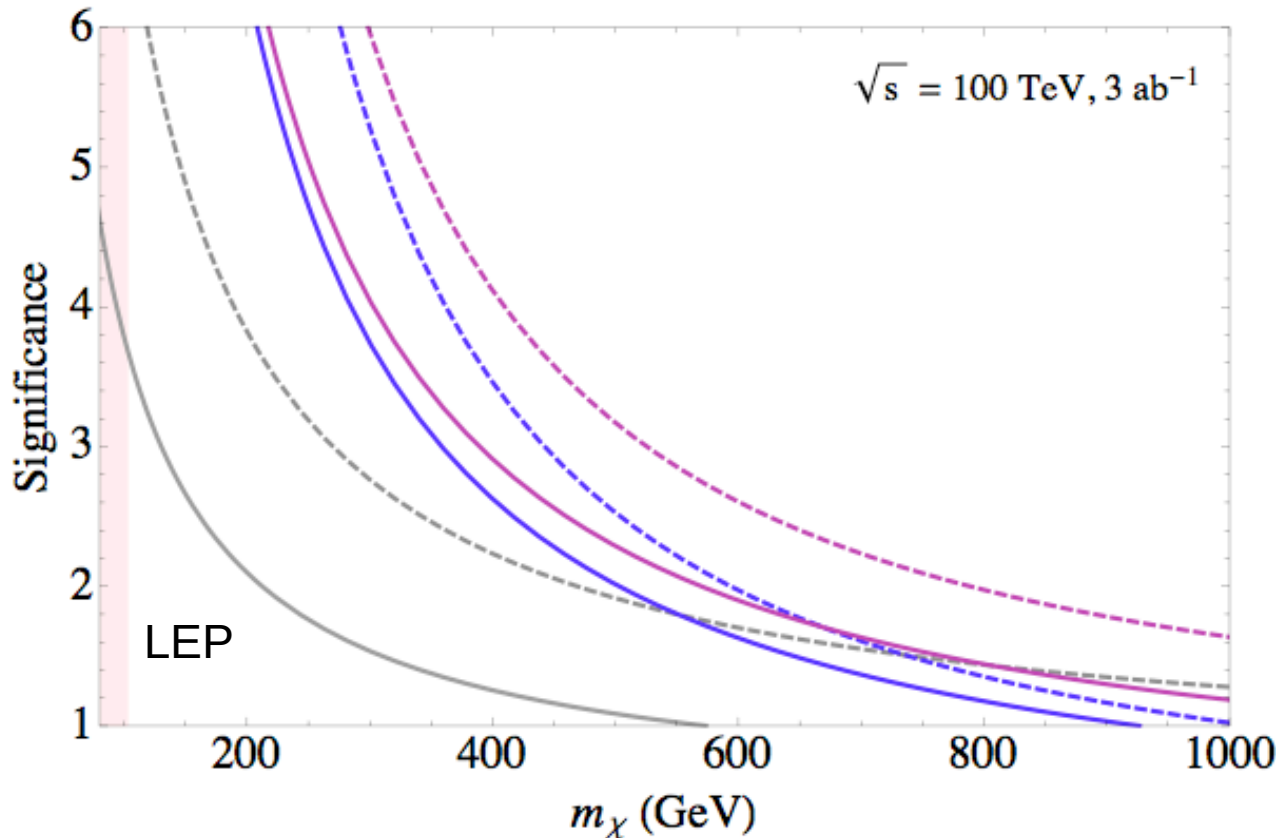
Monojet

Combination

Solid: 5% systematics
Dashed: 2% systematics

Results - Higgsinos

Light in natural SUSY, and $\chi^+ - \chi^0$ splitting of 340 MeV leads to prompt χ^+ decay even without additional splitting through dimension-5 operator



Photon + jet + MET

Monojet

Combination

Solid: 5% systematics
Dashed: 2% systematics

Results - Quintuplet

Fermionic 5 of $SU(2)_L$ cannot decay to SM by symmetry,
and is a standard minimal DM candidate

Cirelli, Fornengo, Strumia, hep-ph/0512090

Disappearing track search works if $\chi^+ - \chi^0$ mass difference
comes purely from radiative corrections

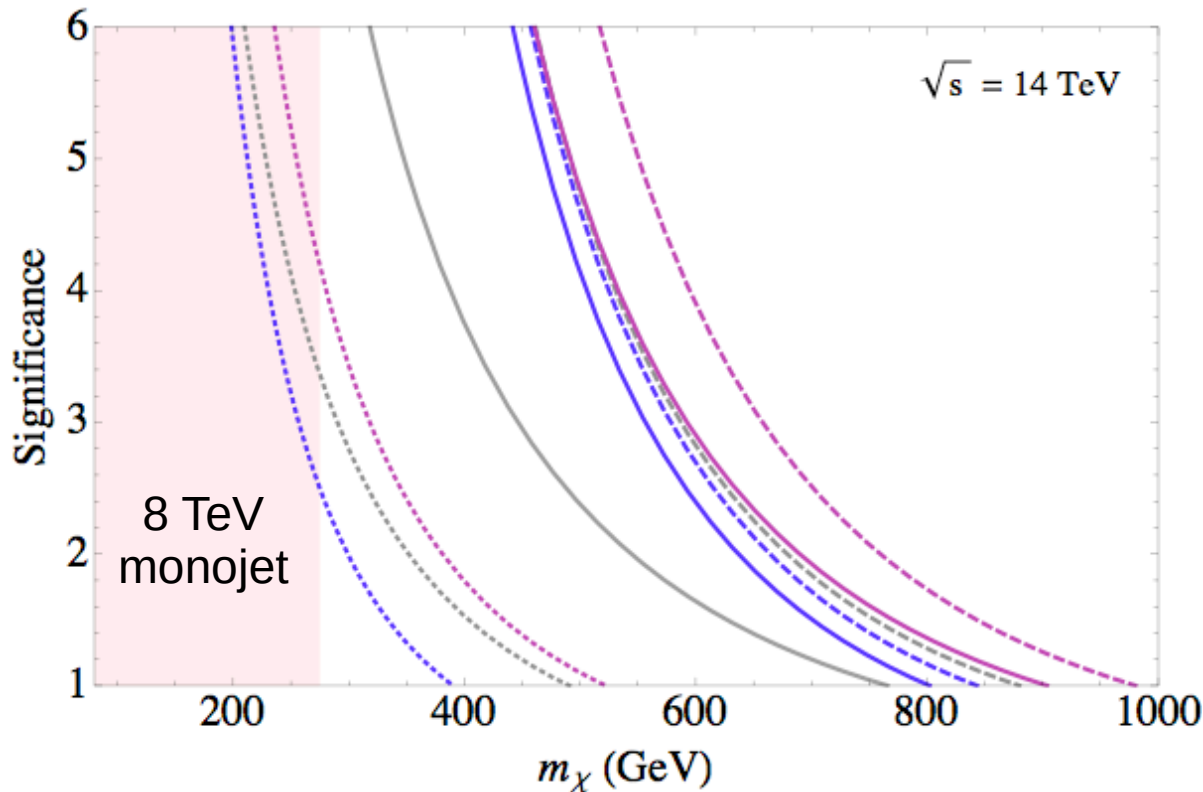
Ostdiek, 1506.03445

Direct coupling to Higgs field can increase splitting after
electroweak symmetry breaking

$$\mathcal{L} \supset \frac{i}{\Lambda} (\bar{\chi} \sigma_5^a \chi) (H^\dagger \sigma^a H)$$

Results - Quintuplet

Increased radiation from χ^{++} improves photon + jet + MET



Photon + jet + MET

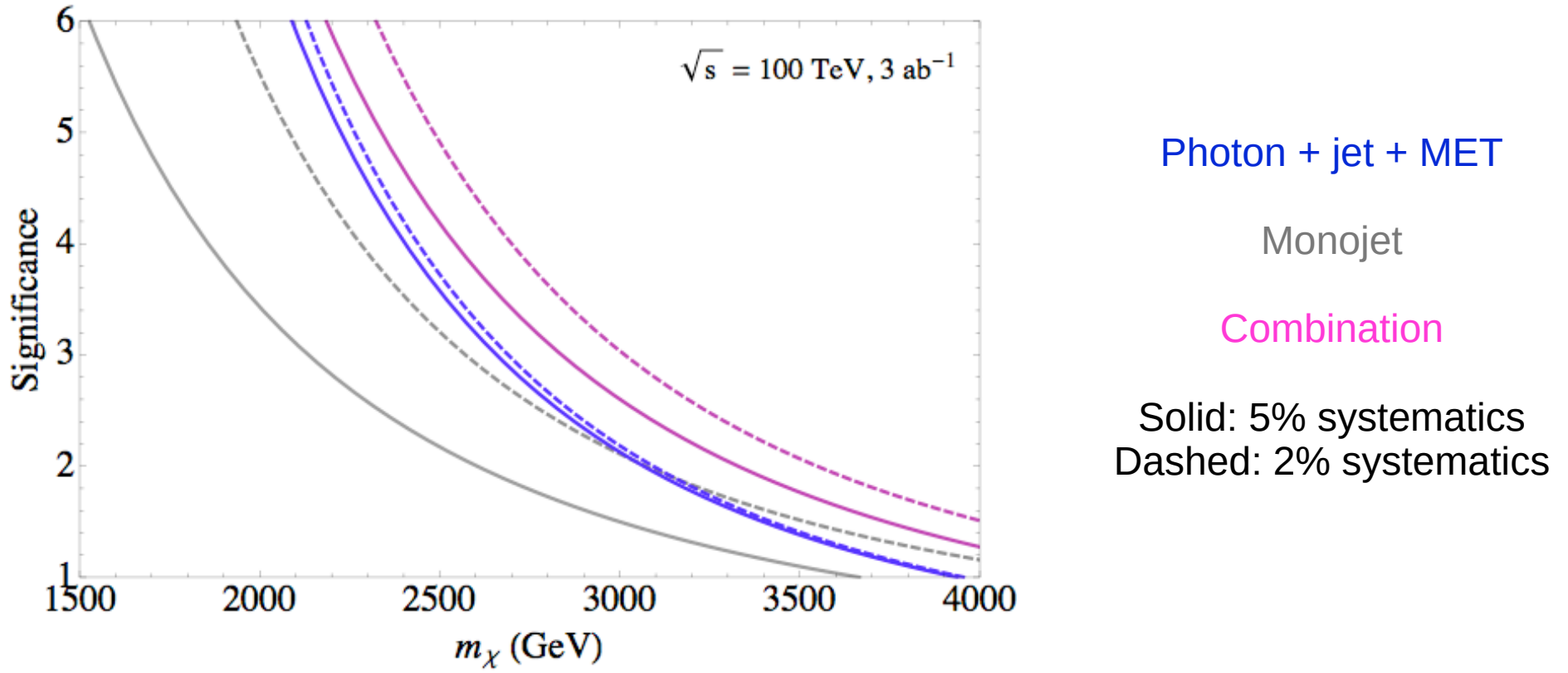
Monojet

Combination

Dotted: 20 fb⁻¹, 5% systematics
Solid: 3 ab⁻¹, 5% systematics
Dashed: 3 ab⁻¹, 2% systematics

Results - Quintuplet

Correct thermal relic density achieved for quintuplet mass of 4.4 TeV



Summary

Charged states in an $SU(2)_L$ multiplet may decay invisibly, but still leave photon final state radiation

Can look for photon in events with a hard ISR jet and missing energy, using kinematics to discriminate against backgrounds

Photon + jet can provide equal or better sensitivity than monojets to new electroweak states, depending on systematics that will be achievable

Experimental considerations

Don't expect many fakes from photon mismeasurement

Can estimate main backgrounds from data as for monojet search: $Z + \gamma + j$ from (hard) $\gamma + j$, and $W + \gamma + j$ from control region with isolated hard leptons

Cuts on extra jets, leading jet p_T / MET ratio reduce backgrounds from tops, QCD