SUSY neutralino WIMP and a 100 TeV Collider

M Battaglia
UCSC & CERN

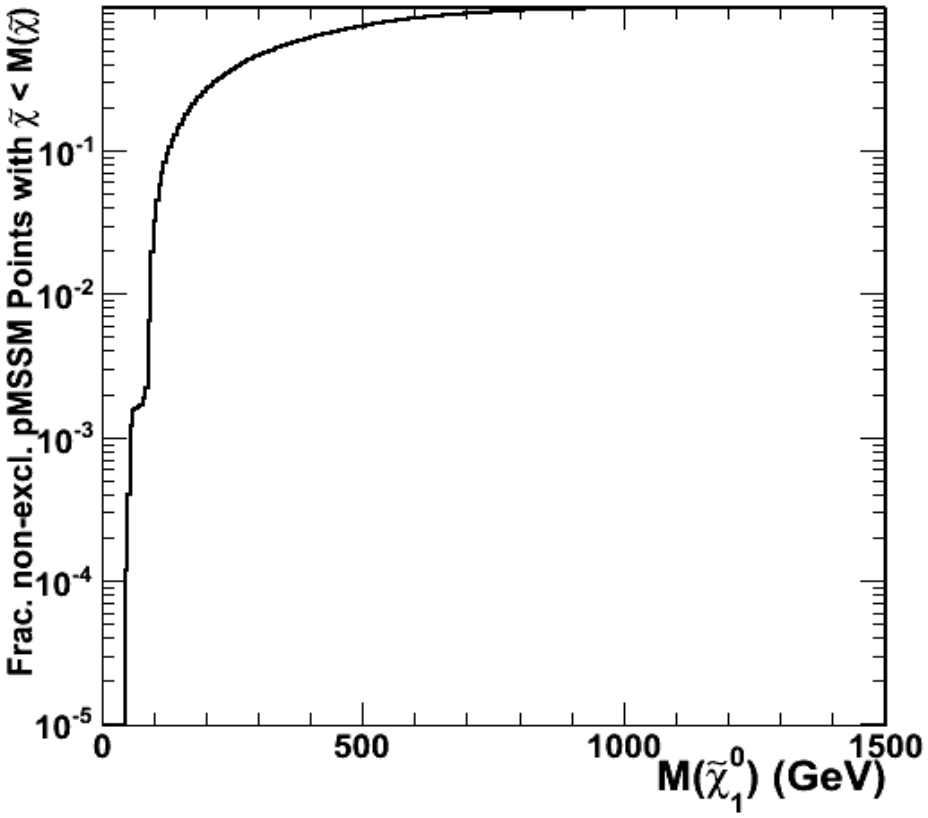
with A Arbey, N Mahmoudi

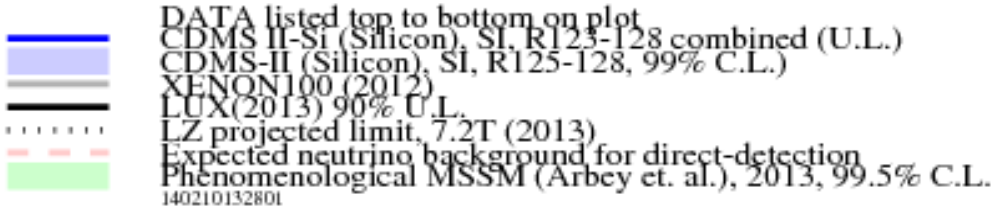
100 TeV Physics Workshop

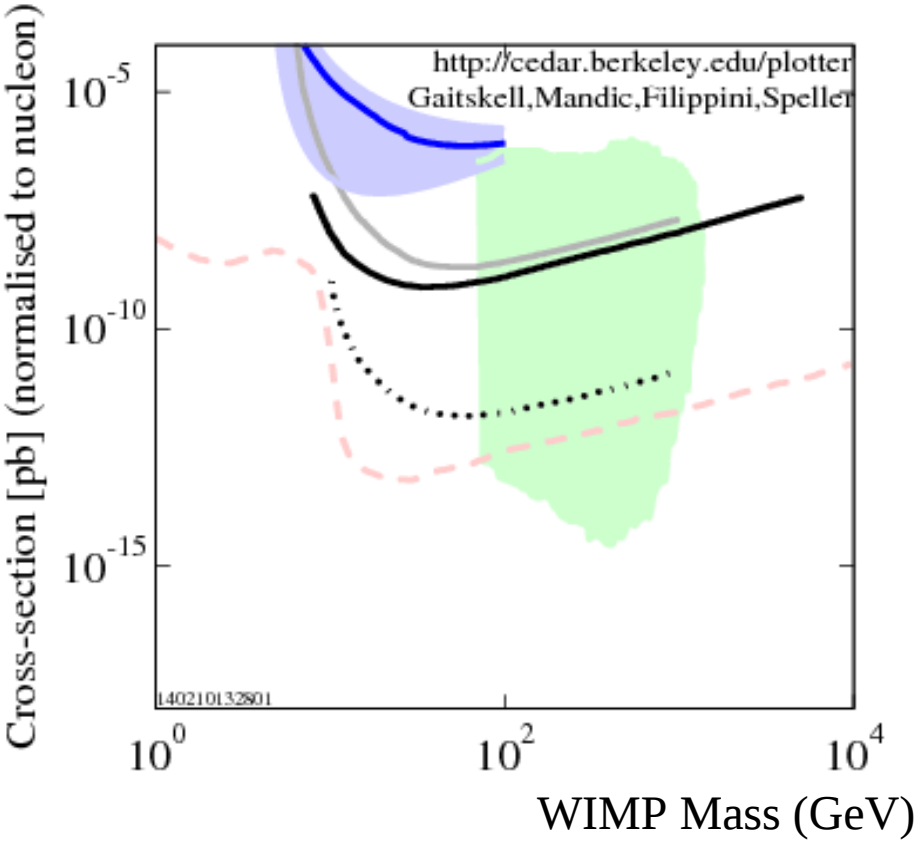
SLAC, 23-25 April 2014

This talk discusses a program of studies of physics opportunites for a 100 TeV collider in direct production of WIMPs, the complentarity with dark matter direct detection expts and its role in the study of their nature;

ATLAS+CMS jets/leptons+MET
Searches 7+8 TeV



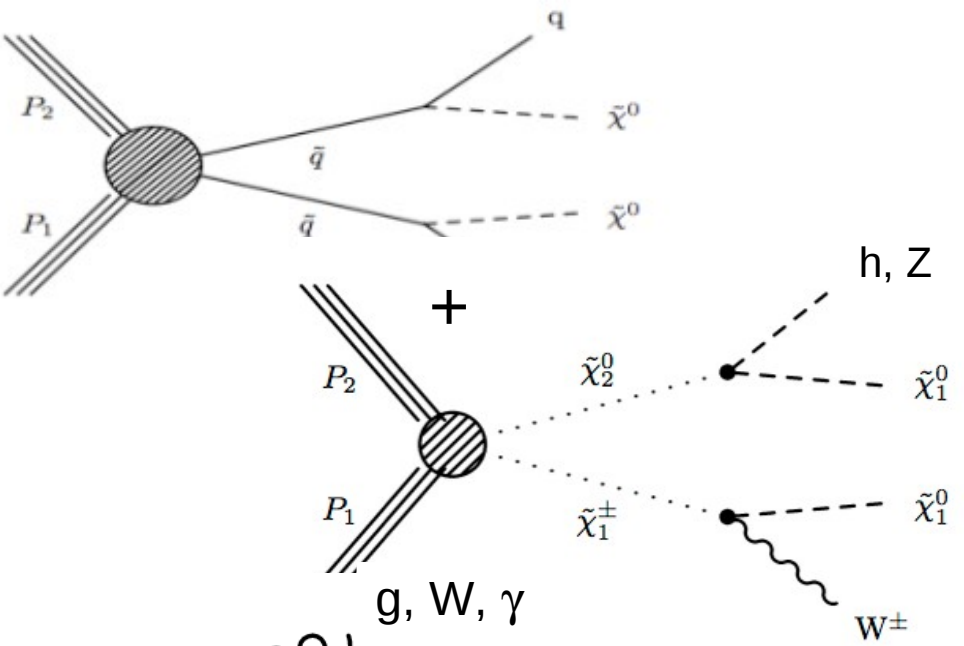




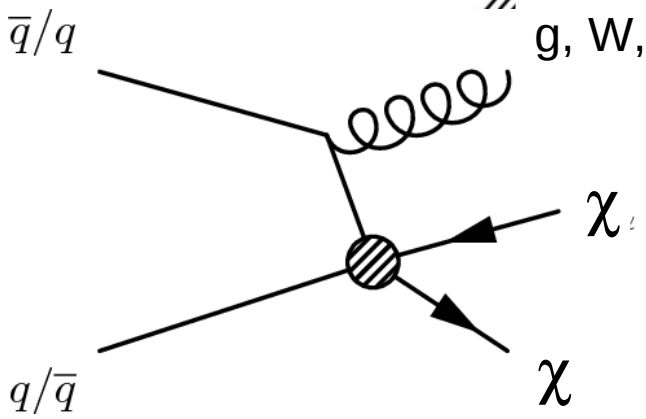
Can a 100 TeV collider say the definitive word on WIMPs at least in some well- defined models/theories (MSSM, …) ?

Combination of constraints from:

Jets/Leptons + MET Searches

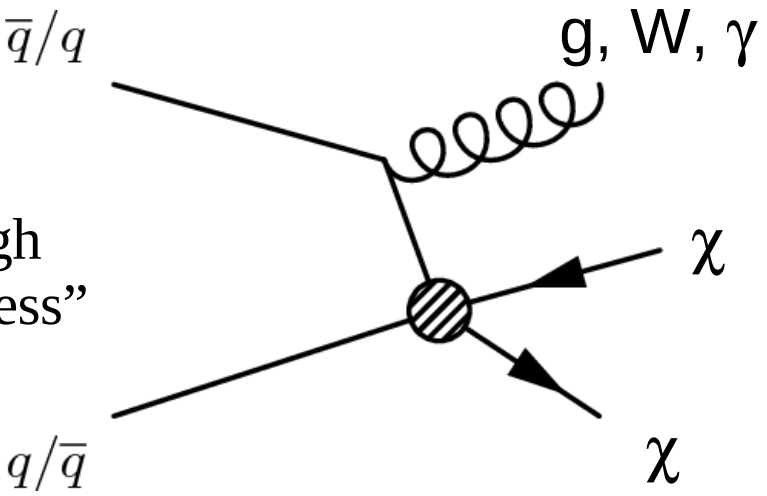


Mono-jet/W/Z/g/l Searches



Dark Matter Direct Detection Underground Experiments:
LUX+Xenon+CDMS, LZ, 3rd generation experiments

Mono-Jet (+ W/Z, γ, l) Signatures from 8 to 100 TeV



pp collider can search for WIMP production through processes with large MET and one parton as "witness" of interaction;

Sensitivity can be estimated using EFT or actual models (SUSY, …);

Results can be interpreted as limits on $\Lambda \equiv M/\sqrt{g_\chi g_q}$ related to limits on

WIMP scattering cross section on nucleons $\sigma_{\rm DD} \sim g_\chi^2\, g_q^2\, \frac{\mu^2}{M^4}$ to compare

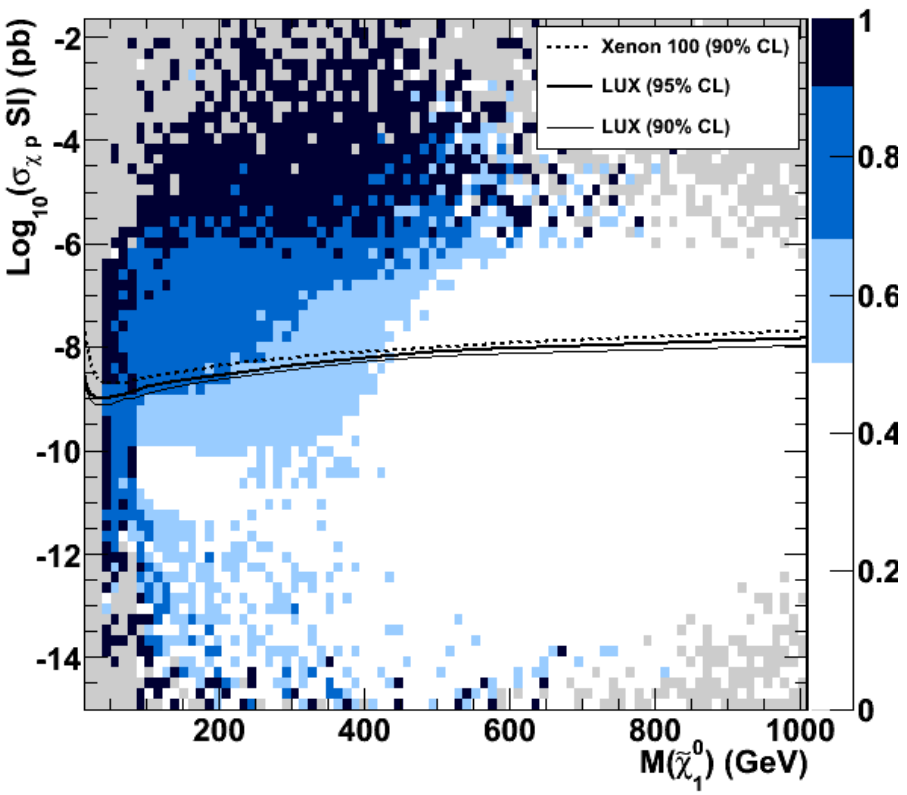
with results of DM direct detection experiments.

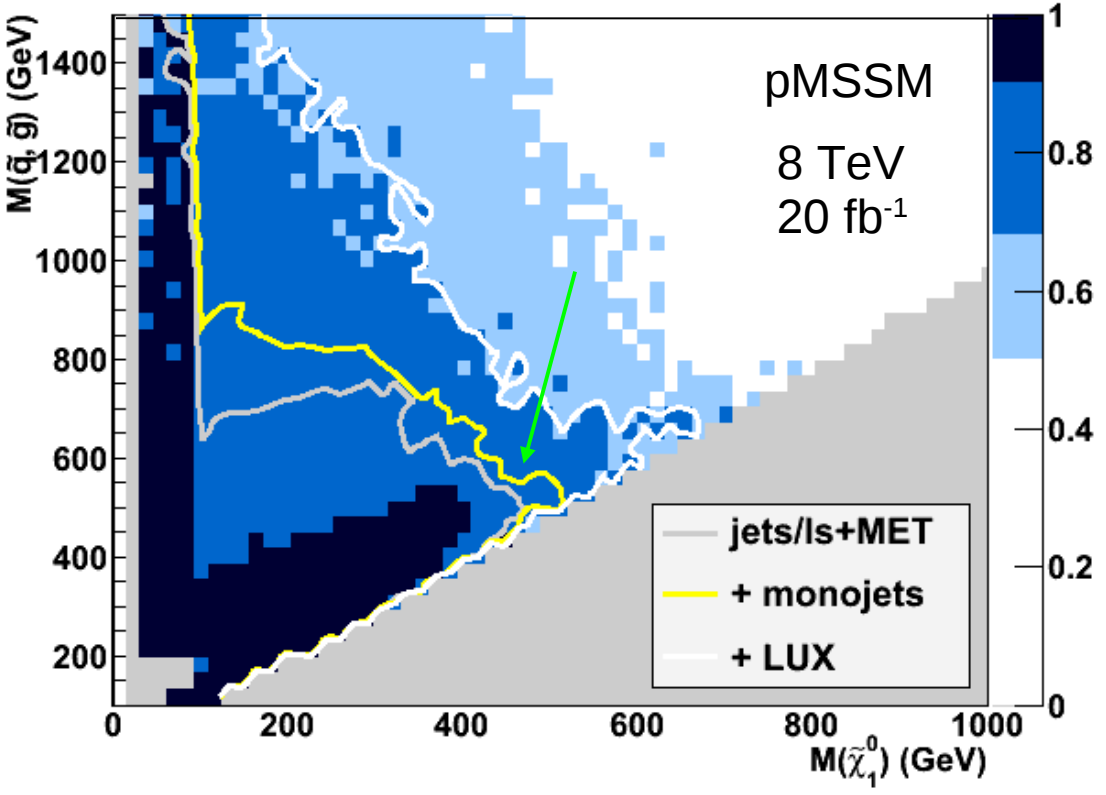
Bai, Fox, Harnik, JHEP 1012 (2010) 048
Goodman et al, PRD 82 (2010) 116010
Goodman et al, PLB 695 (2011) 185
...

Complementarity of Mono-jet and Jets/leptons +MET searches in MSSM

In the case of SUSY χ^0_1 WIMP, results are affected by the availability of multiple propagators and presence of other particles at small mass splitting, still mono-jets add to the LHC sensitivity, notably in the kinematically difficult small ΔM region;

An example at 8 TeV (pMSSM masses limited at 3 TeV):





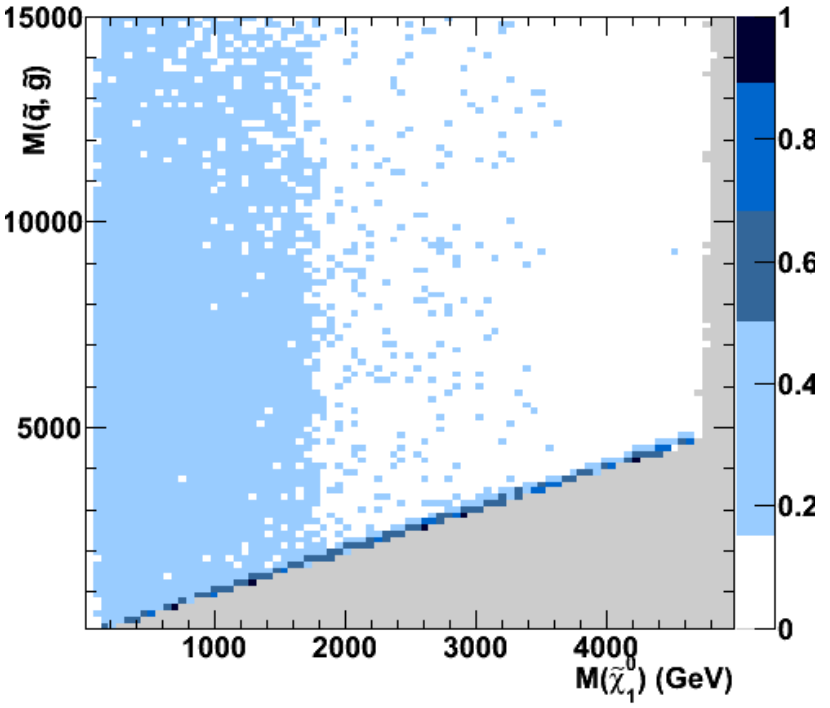
Arbey, MB, Mahmoudi, PRD 89 (2014) 077701

Main regions of interest for mono-jets et al.:

Large mass splitting scenarios where other particles are too heavy to be detected

$M_1 << M_2, M_3, \mu \rightarrow \chi$ WIMP must be bino-like, cross section drops but Ωh^2 is too large

Fraction of pMSSM points compatible with PLANCK $\Omega_\chi h^2$ upper limit (+syst)

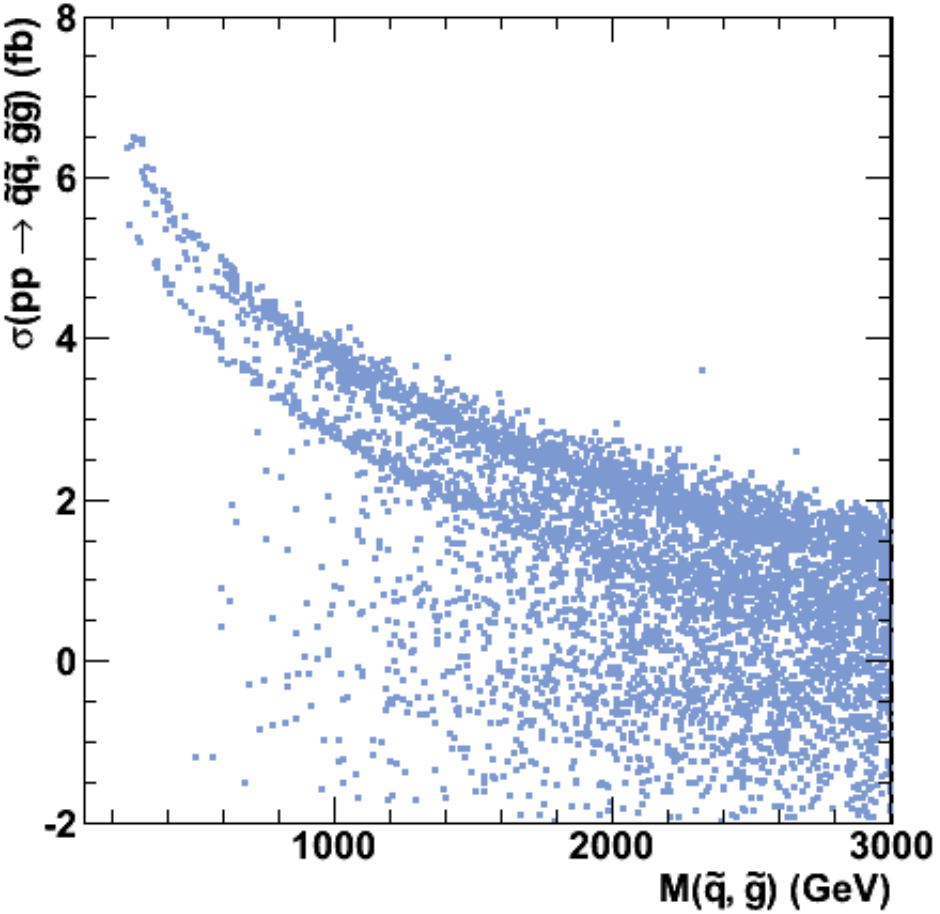


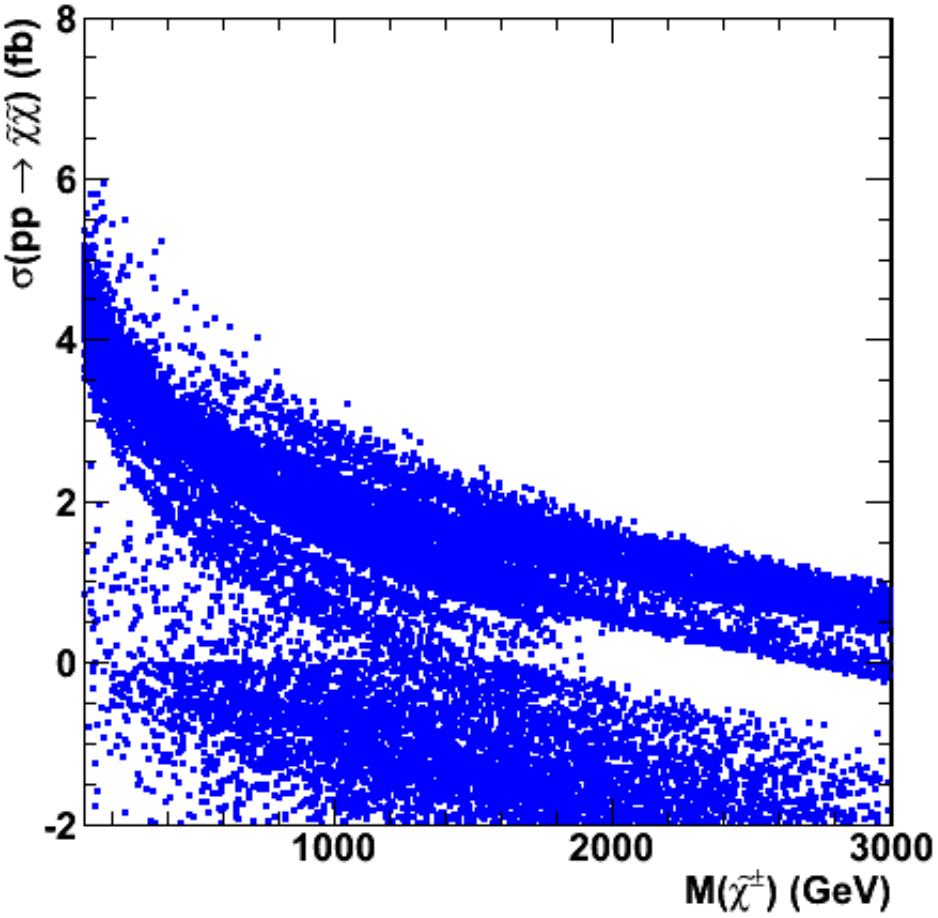
Small mass splitting scenarios where kinematics reduces efficiency of jets/leptions+MET searches

$M_1 \sim M_3$ (or M~q) $<< M_2, \mu$: Ωh^2 brought down by co-annihilation, mono-jet xsec boosted by production of strongly-interacting sparticles

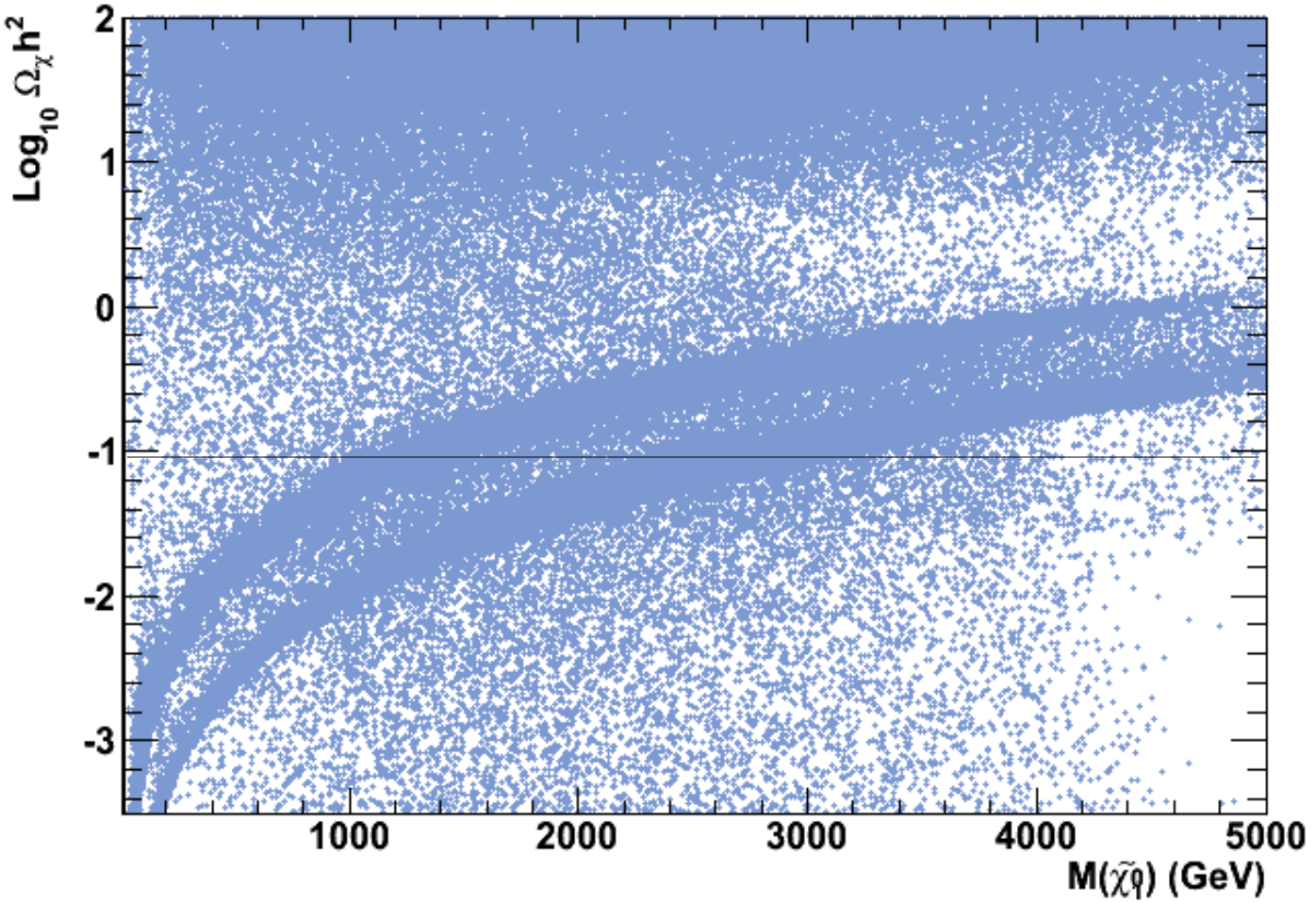
$M_1 \sim M_2$ or $\mu << M_3$ monoW/Z best suited for detection

EWK production at 100 TeV





Neutralino Mass and Relic Density



Neutralino WIMP in the pMSSM

Take analyses as performed at 8 TeV, no cut optimisation (yet), use SM bkg from ATLAS/CMS analyses and scale it up by appropriate factor to describe increase of rate in signal regions (MadGraph): 8 TeV 25 fb^{-1}, 14 TeV 0.3-3 ab^{-1}, 100 TeV 1-5 ab^{-1}

Study S/B in jet pT vs MET plane for points along small mass splitting region at 8, 14 and 100 TeV

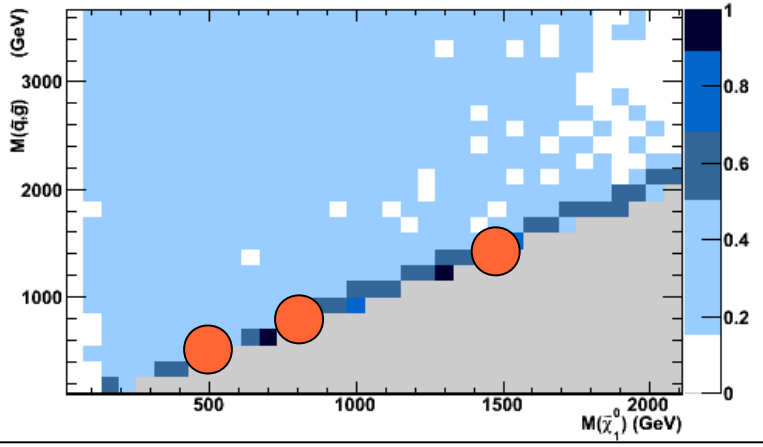
Broad pMSSM scan with sparticle masses up to 20 TeV, impose Ωh^2 flavour, Lep and LHC constraints

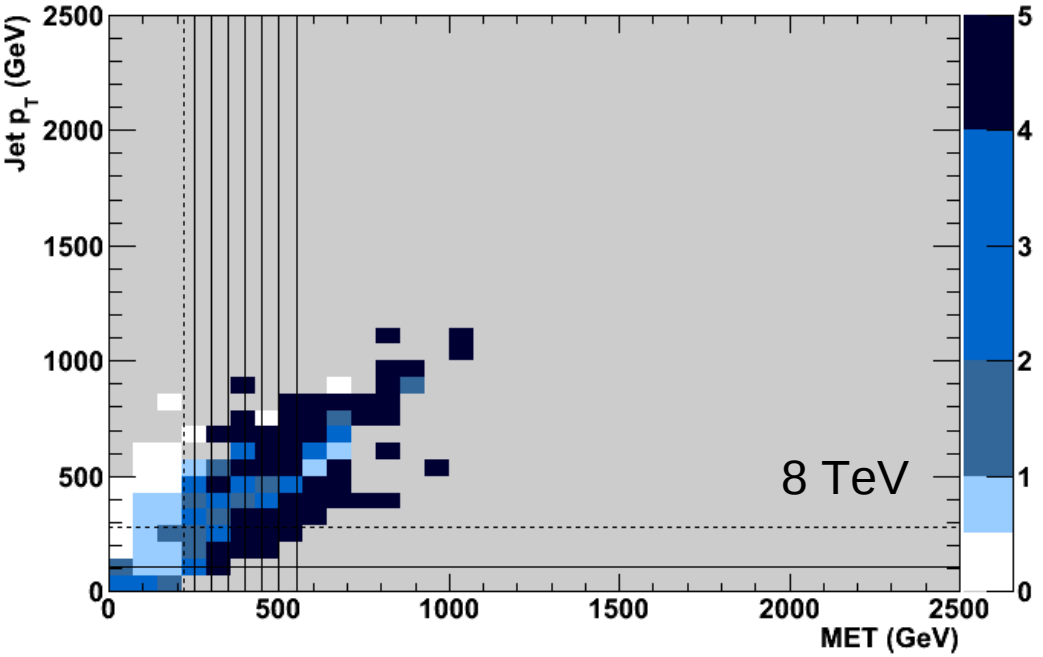
Study M(~q,~g) vs M(χ) and $\sigma(\chi p)$ SI vs M(χ)

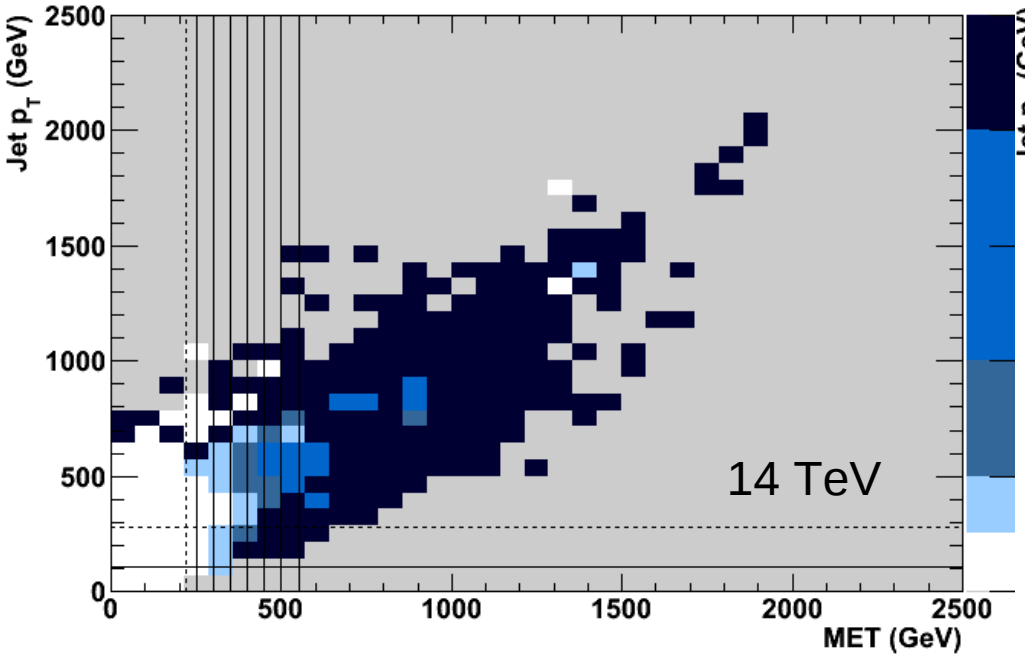
Towards a cut optimisation:

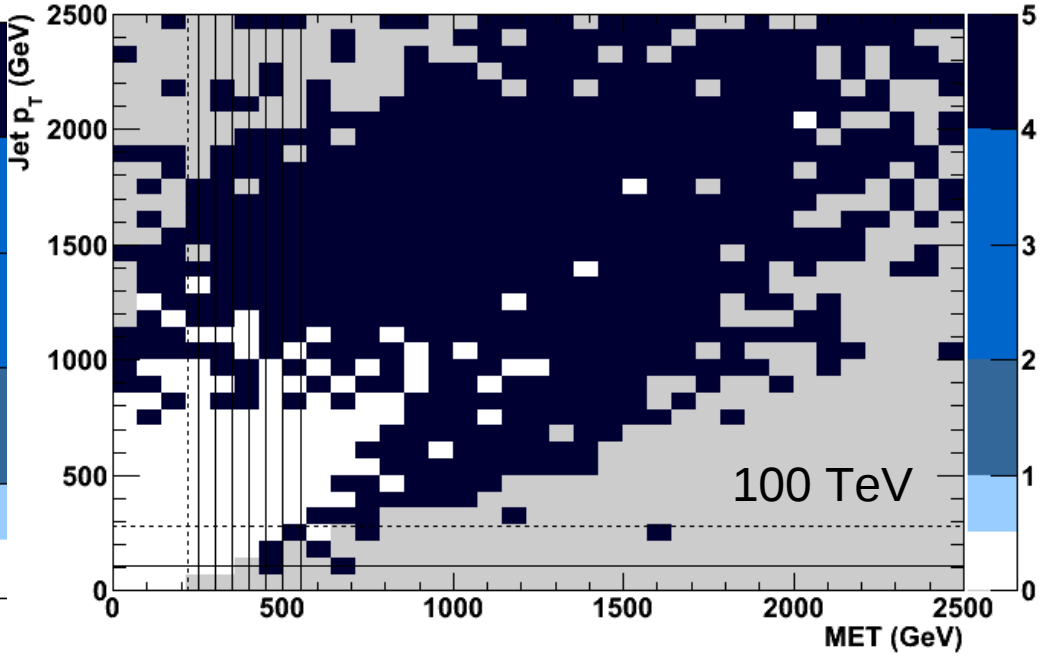
S/B

Study S/B in jet pT vs MET plane for points along the small mass splitting region at 8, 14 and 100 TeV



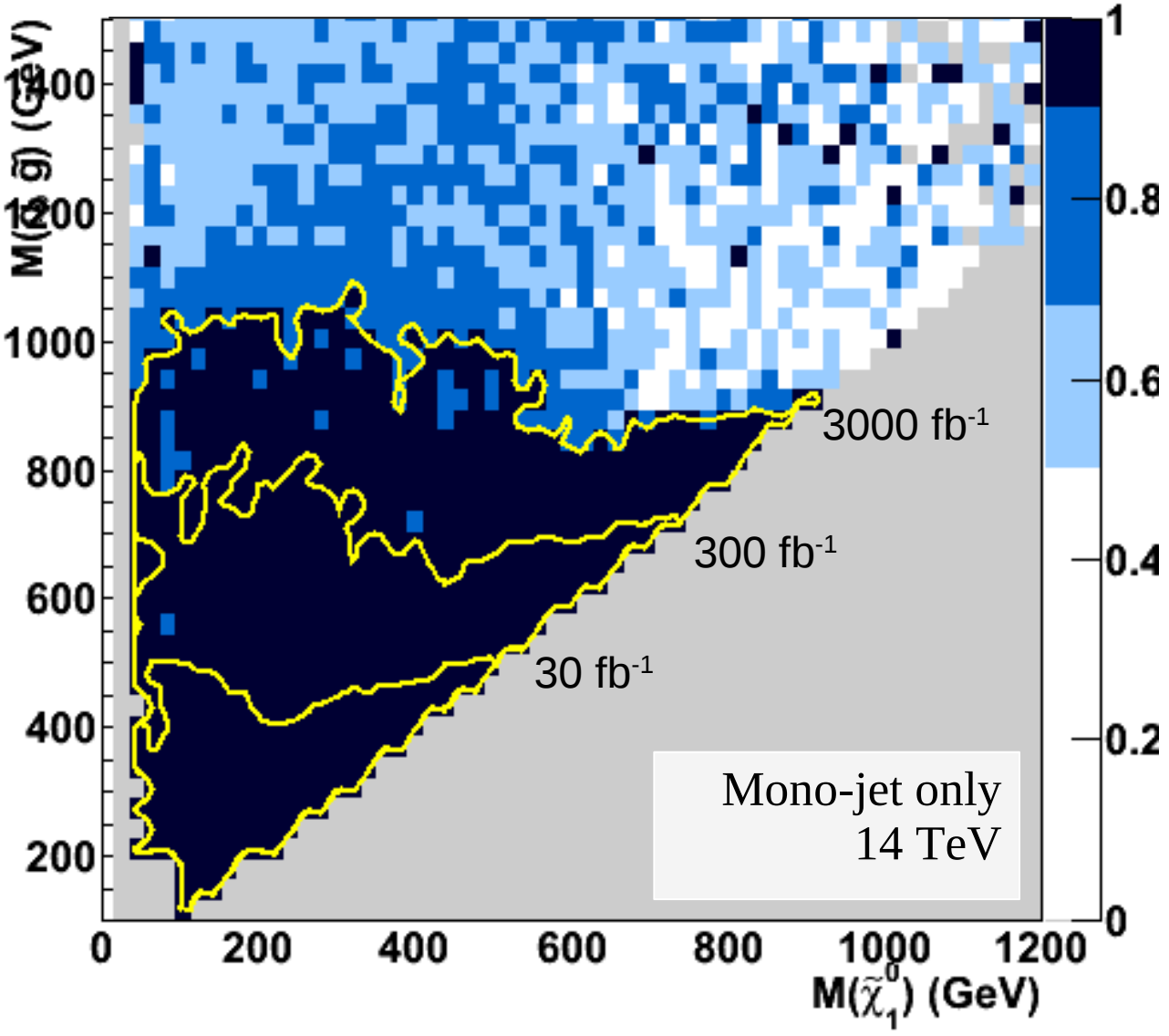






Lightest strongly-interacting SUSY particle mass vs M_{WIMP}

14 TeV



pp collider channels from LHC Run 1

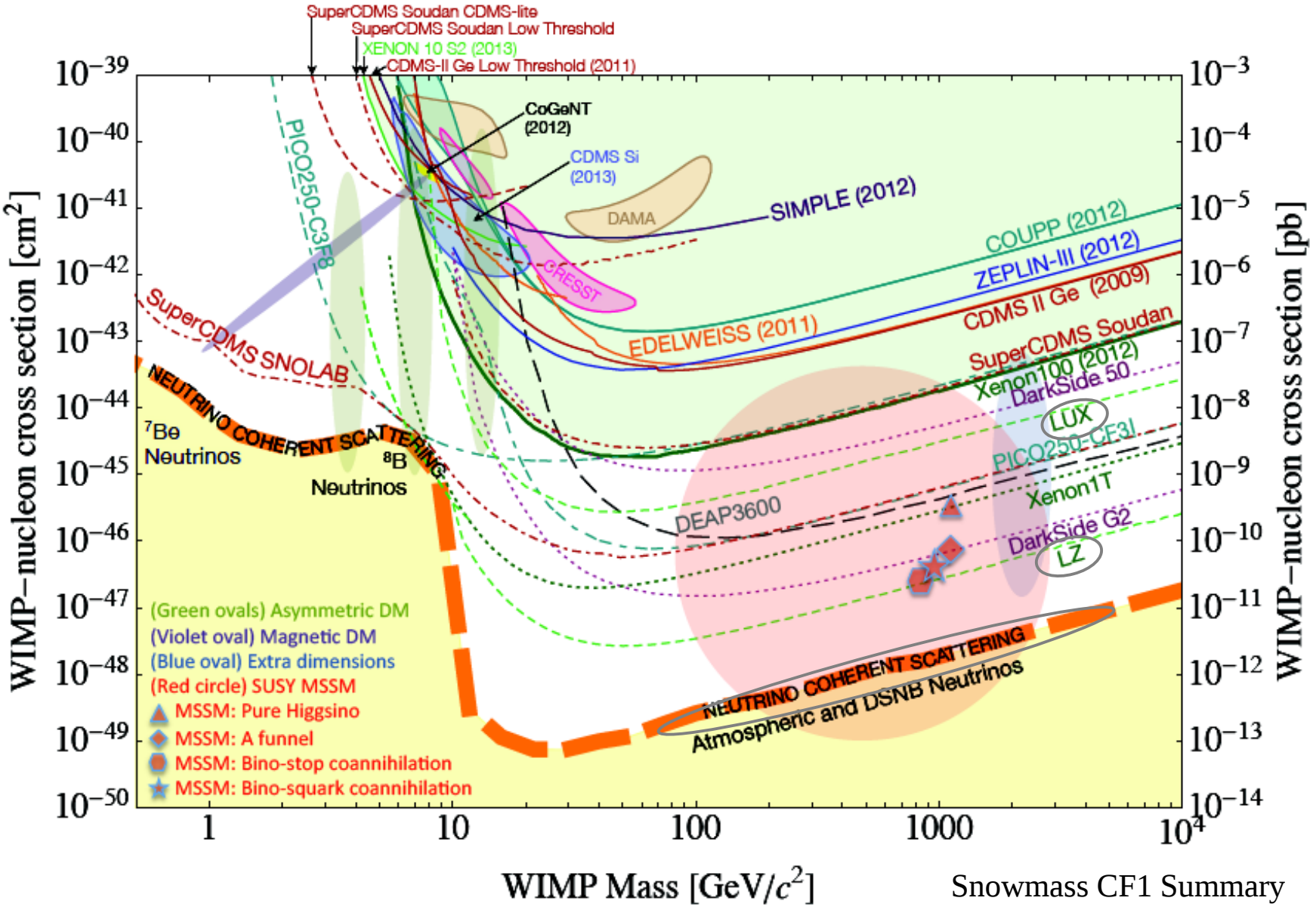
Signal event generation with Madgraph & Pythia from scan points;
Physics objects reconstruction with Delphes & FastJet;
Test exclusion against scaled bkg using CLs.

Jets+MET	EWK	mJ	mW/Z
j0l+MET bb0l+MET (ATLAS)	2l+MET 3l+MET bb(h)l+MET (ATLAS)	MonoJET+MET (ATLAS+CMS)	monoW/Z+MET (ATLAS)

Fraction of pMSSM points excluded at 95%CL

	Jets+MET	EWK	mJ	mW/Z
14 TeV 3 ab^{-1}	0.08	0.02	0.01	0.001
100 TeV 5 ab^{-1}	0.65	0.08	0.16	0.02

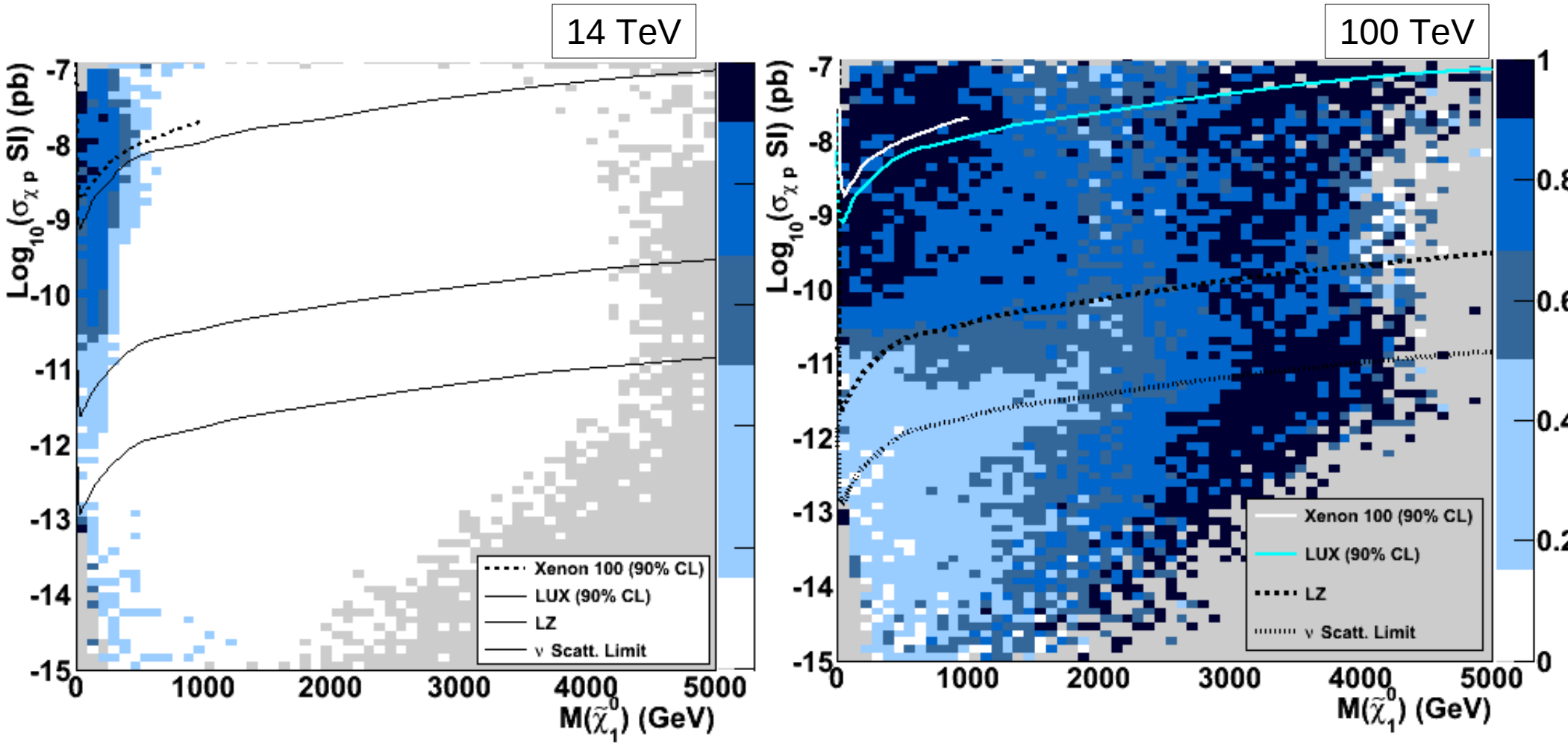
Dark Matter Direct Detection Experiments: Limits and Future Sensitivity



Snowmass CF1 Summary
arXiv:1310.8327

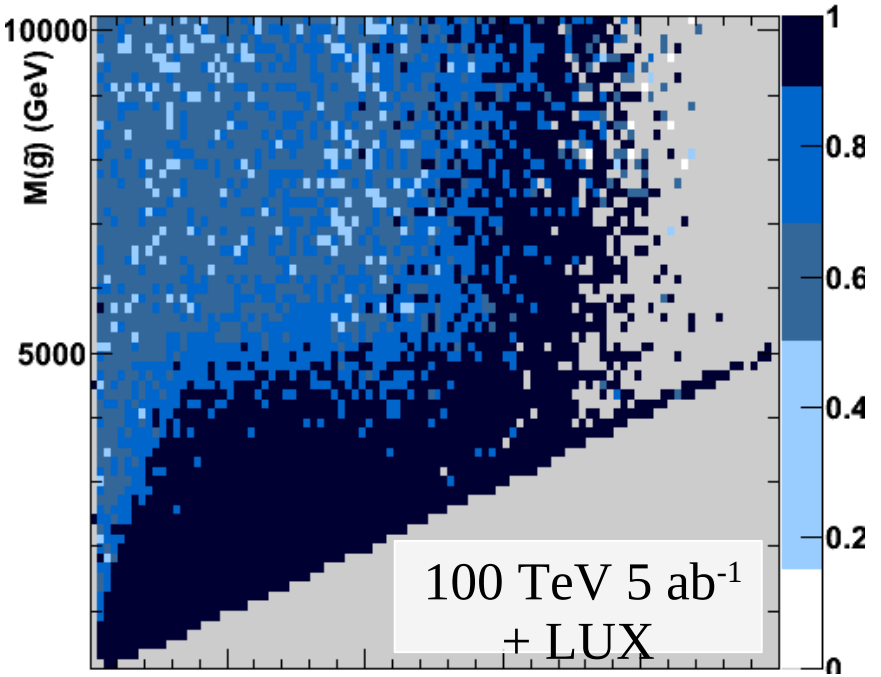
Spin-independent Scattering Cross Section vs M_{WIMP}: 14 vs 100 TeV

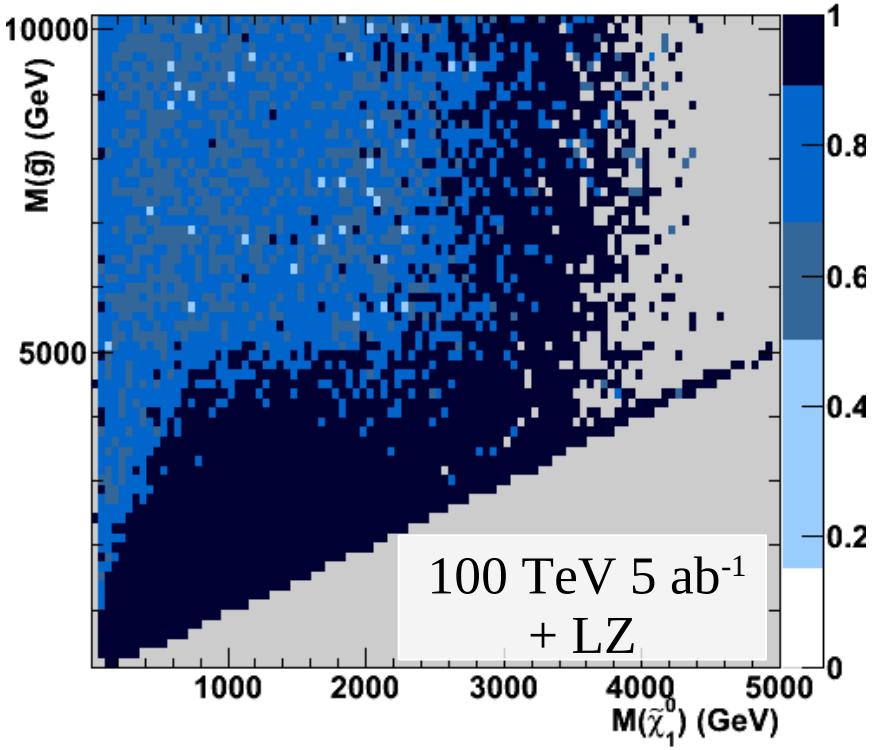
Fraction of pMSSM points excluded at 95%CL

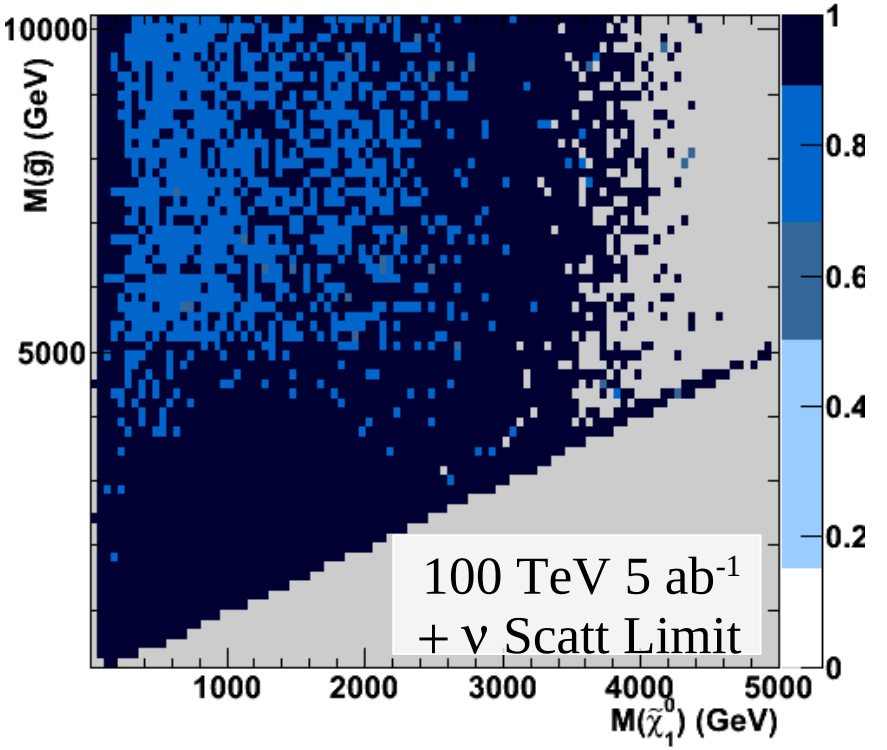


Combining Exclusions at 100 TeV with DM Direct Detection Limits

Fraction of pMSSM points excluded at 95%CL







Summary of fractions of excluded pMSSM points

(Preliminary)	Jets+MET+EWK +mJ +mW/Z	+LUX DM	+LZ DM	+3rd Gen. DM
14TeV 3 ab^{-1}	0.09	0.19	**0.50**	0.76
100 TeV 1 ab^{-1}	0.63	0.65	0.73	0.90
100 TeV 3 ab^{-1}	0.67	0.69	0.75	0.91
100 TeV 5 ab^{-1}	0.69	0.72	0.76	**0.92**