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Phenomenological MSSM interpretation of the 7 TeV CMS results

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on behalf of the CMS collaboration

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the phenomenological MSSM (pMSSM) is ...

the pMSSM is ...

- **a realization of the R-parity conserving MSSM**
  - no new sources of CP violation
  - no flavor changing neutral currents
  - 1st and 2nd generation sfermions degenerate in mass
- **19 SUSY parameters**
  - M_1, M_2, and M_3
  - $\tan\beta$, μ, m_A
  - 10 sfermion mass parameters
  - A_t, A_b and A_τ

captures most of the phenomenological features of the R-parity conserving MSSM

Analysis

preCMS prior for pMSSM parameters θ

preCMS prior

preCMS likelihood

initial prior (flat)

$$p^{\mathrm{preCMS}}(\theta) = L(D^{\mathrm{preCMS}}|\theta)\, p^0(\theta)$$

$$L(D^{\mathrm{preCMS}}|\theta) = \left\{ \prod_i L(D_i^{\mathrm{preCMS}} \mid \mu_i(\theta) \right\}$$

measurement of observable i

theory prediction for observable i

preCMS prior

preCMS observables

i	Observable $\mu_j(\theta)$	Constraint D_j^{preCMS}	Likelihood function $L(D_j^{\text{preCMS}} \| \mu_j(\theta))$	MCMC / post-MCMC
1	$BR(b \to s\gamma)$	$(3.55 \pm 0.23^{\text{stat}} \pm 0.24^{\text{th}} \pm 0.09^{\text{sys}}) \times 10^{-4}$	Gaussian	MCMC
2a	$BR(B_s \to \mu\mu)$	observed CLs curve from	$d(1 - CLs)/d(BR(B_s \to \mu\mu))$	MCMC
2b	$BR(B_s \to \mu\mu)$	$3.2^{+1.5}_{-1.2} \times 10^{-9}$	2-sided Gaussian	post-MCMC
3	$R(B_u \to \tau\nu)$	1.63 ± 0.54	Gaussian	MCMC
4	Δa_μ	$(26.1 \pm 8.0^{\text{exp}} \pm 10.0^{\text{th}}) \times 10^{-10}$	Gaussian	MCMC
5	m_t	$173.3 \pm 0.5^{\text{stat}} \pm 1.3^{\text{sys}}$ GeV	Gaussian	MCMC
6	$m_b(m_b)$	$4.19^{+0.18}_{-0.06}$ GeV	Two-sided Gaussian	MCMC
7	$\alpha_s(M_Z)$	0.1184 ± 0.0007	Gaussian	MCMC
8a	m_h	pre-LHC: $m_h^{low} = 112$	1 if $m_h \geq m_h^{low}$ 0 if $m_h < m_h^{low}$	MCMC
8b	m_h	LHC: $m_h^{low} = 120$, $m_h^{up} = 130$	1 if $m_h^{low} \leq m_h \leq m_h^{up}$ 0 if $m_h < m_h^{low}$ or $m_h > m_h^{up}$	post-MCMC
9	sparticle masses	LEP (via micrOMEGAs)	1 if allowed 0 if excluded	MCMC

preCMS prior

discrete representation with MCMC

- sample pMSSM parameters within a 19-D cube
  sparticle masses can go as high as $\sim$3 TeV
- sample m_t, $m_b(m_b)$ and $\alpha_s(M_Z)$, no hard limits
- χ_1^0 must be LSP, $\chi_1^\pm$ must be short-lived

$\sim$ **20 000 000 preCMS points sampled**

CMS posterior density

CMS posterior density

$$p(\theta|D^{\mathrm{CMS}}) = L(D^{\mathrm{CMS}}|\theta)\ p^{\mathrm{preCMS}}(\theta)$$

CMS likelihood

given a count experiment I

- N_I counts observed
- $B_I \pm \delta B_I$ bkg counts predicted

$$L\left(N_I|s_I(\theta)\right) = \int \mathrm{Poiss}(N_I|s_I(\theta) + b_I)\, p(b_I) db_I$$

$$p(b_I) = \mathrm{Gamma}(b_I; (B_I/\delta B_I)^2 + 1, B_I/\delta B_I^2)$$

for independent count experiments

$$L(D^{\mathrm{CMS}}|\theta) = \prod_I L(N_I|s_I(\theta))$$

signal prediction $s_I(\theta)$ from simulation

CMS posterior density

7 TeV CMS data

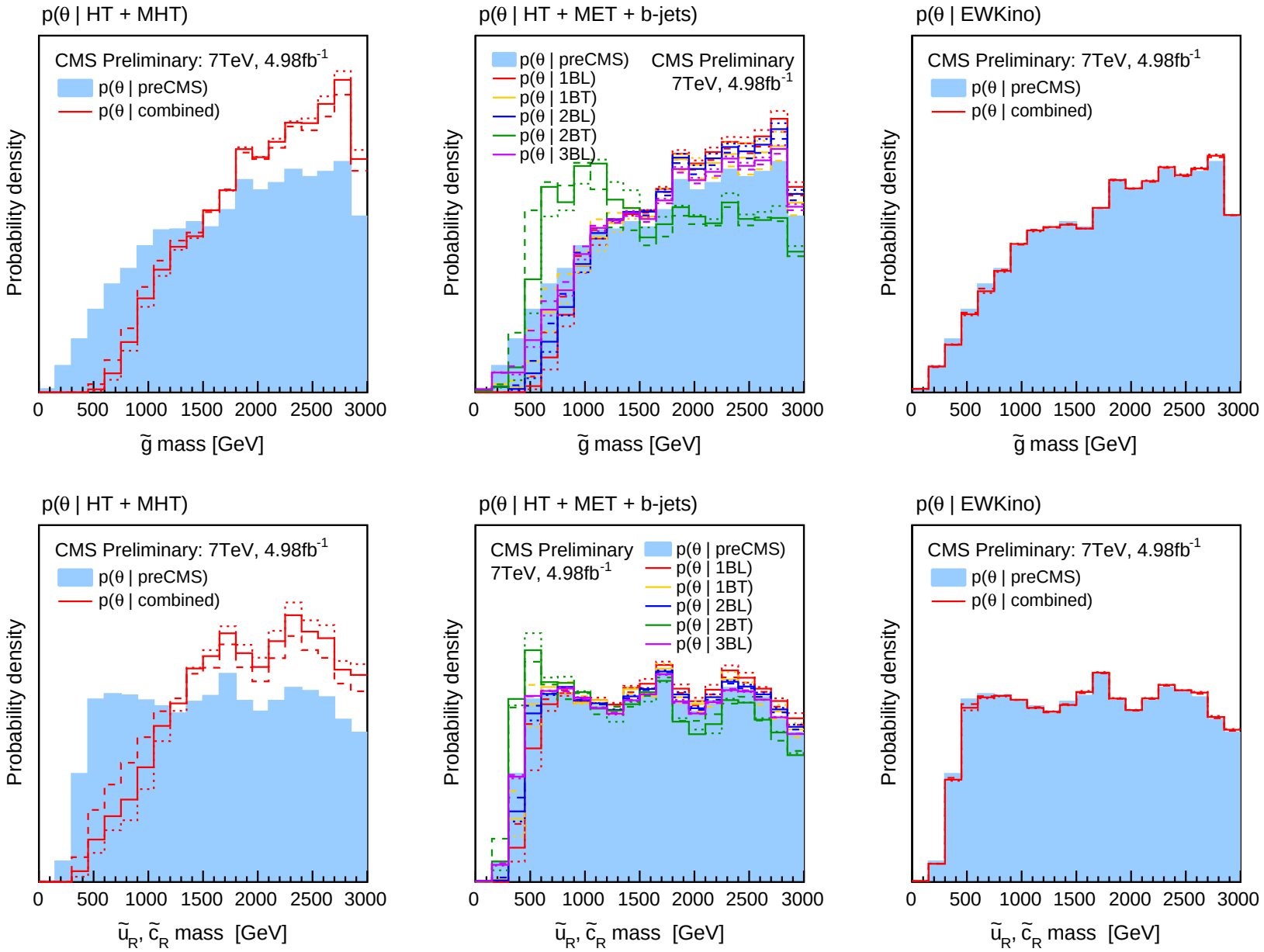
Hadronic $H_T + H_T^{miss}$ search:	arXiv:1207.1898
Hadronic jets + $E_T^{miss} + b$-jets search:	arXiv:1208.4859
Hadronic $H_T + E_T^{miss} + \tau$s search:	arXiv:1301.3792
Hadronic monojet $+E_T^{miss}$ search:	arXiv:1206.5663
Leptonic same sign 2ℓ search:	arXiv:1205.6615
Leptonic opposite sign 2ℓ search:	arXiv:1206.3949
Leptonic EWKino search:	arXiv:1209.6620

discrete representation

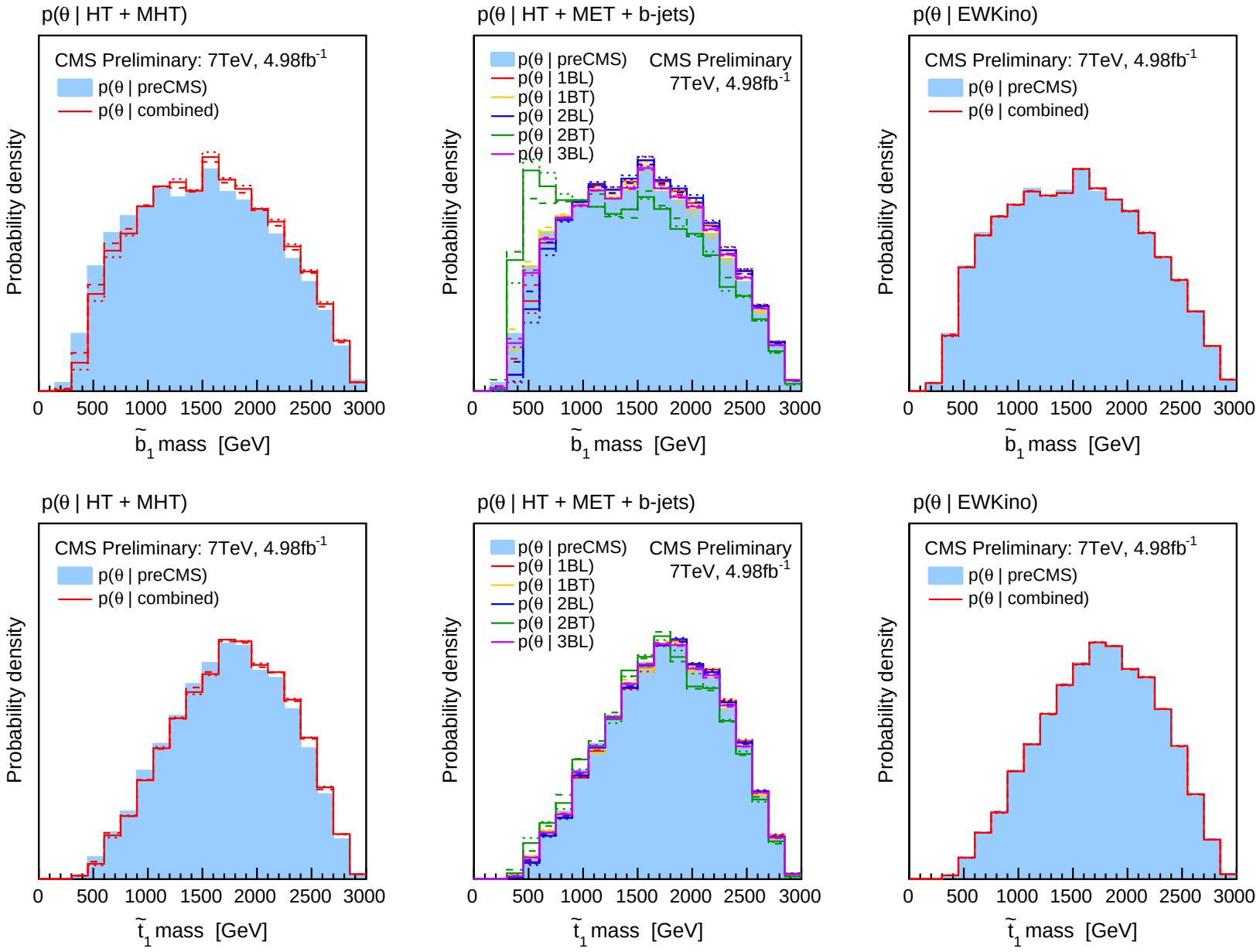
choose random 7300 out of 20 000 000 preCMS points
weight with $L(D^{\mathrm{CMS}}|\theta)$

Results

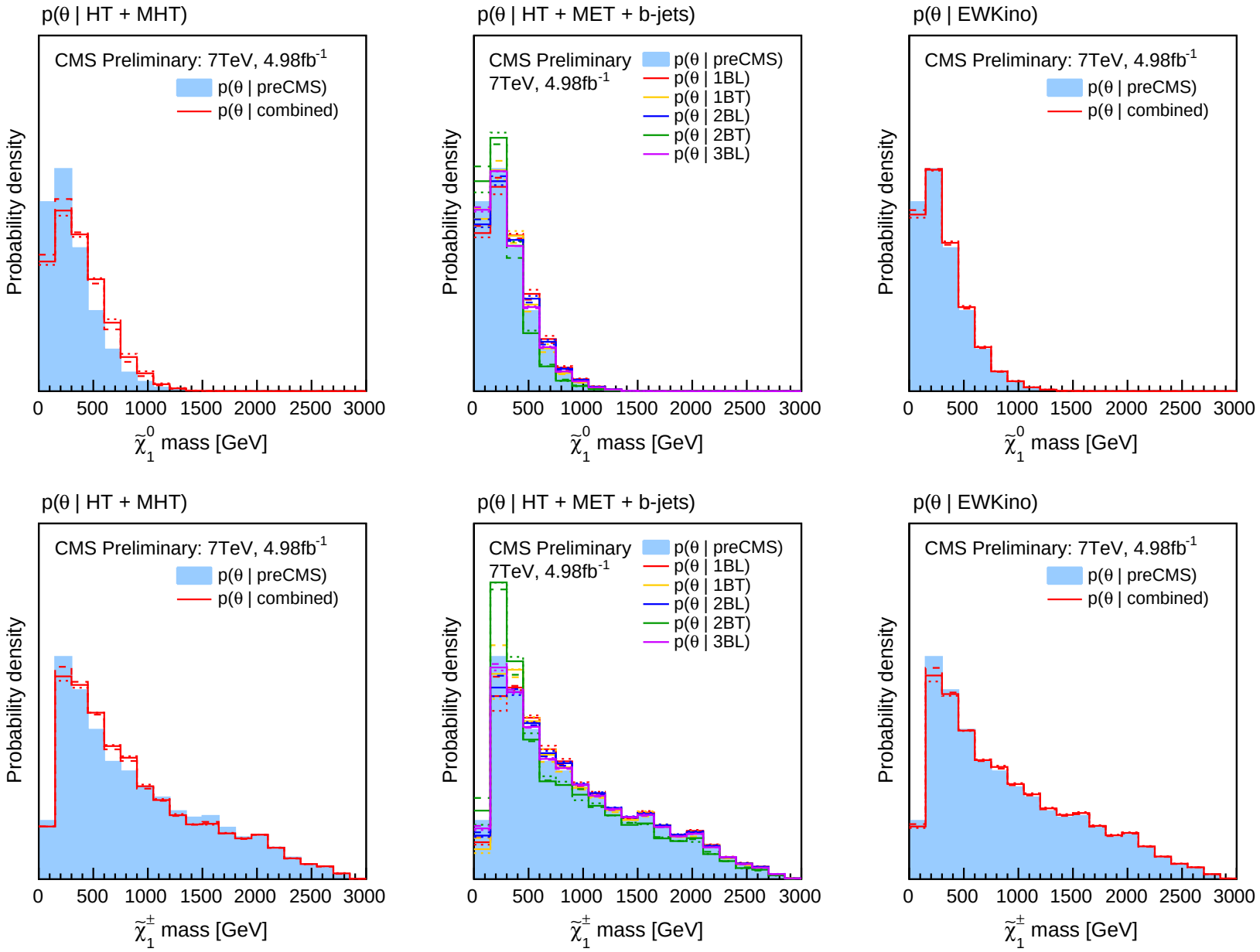
gluino, $\tilde{u}_R$, $\tilde{c}_R$ masses



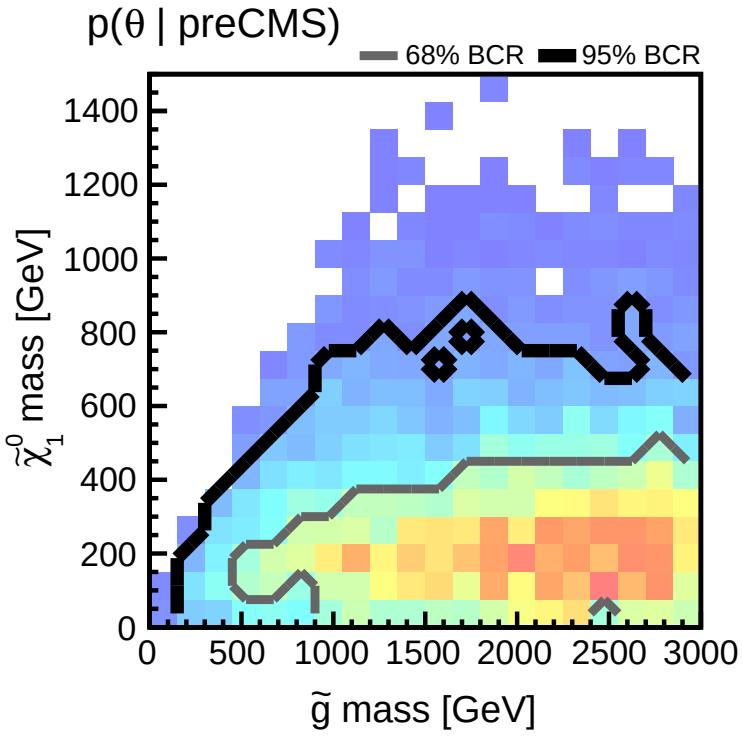
3rd generation squarks

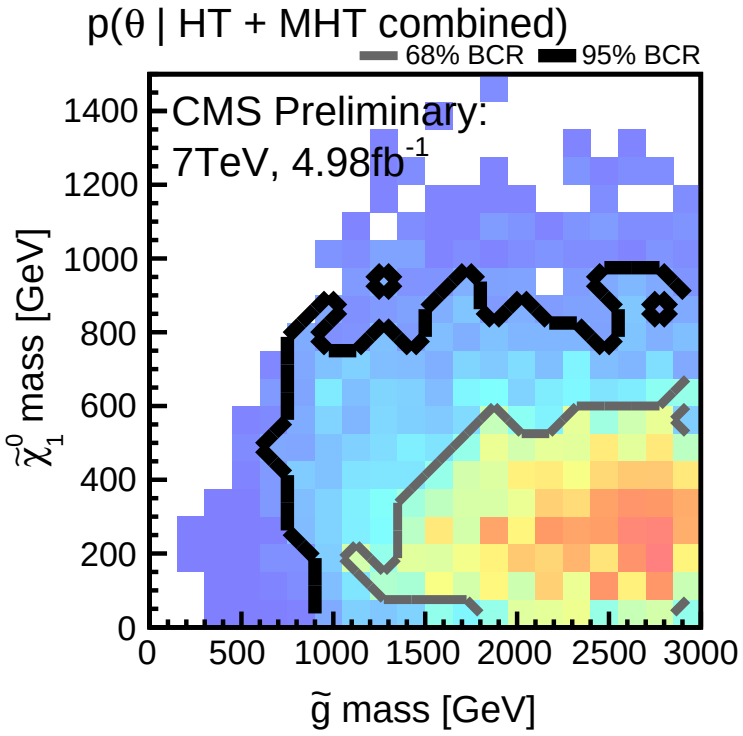


EW gauginos

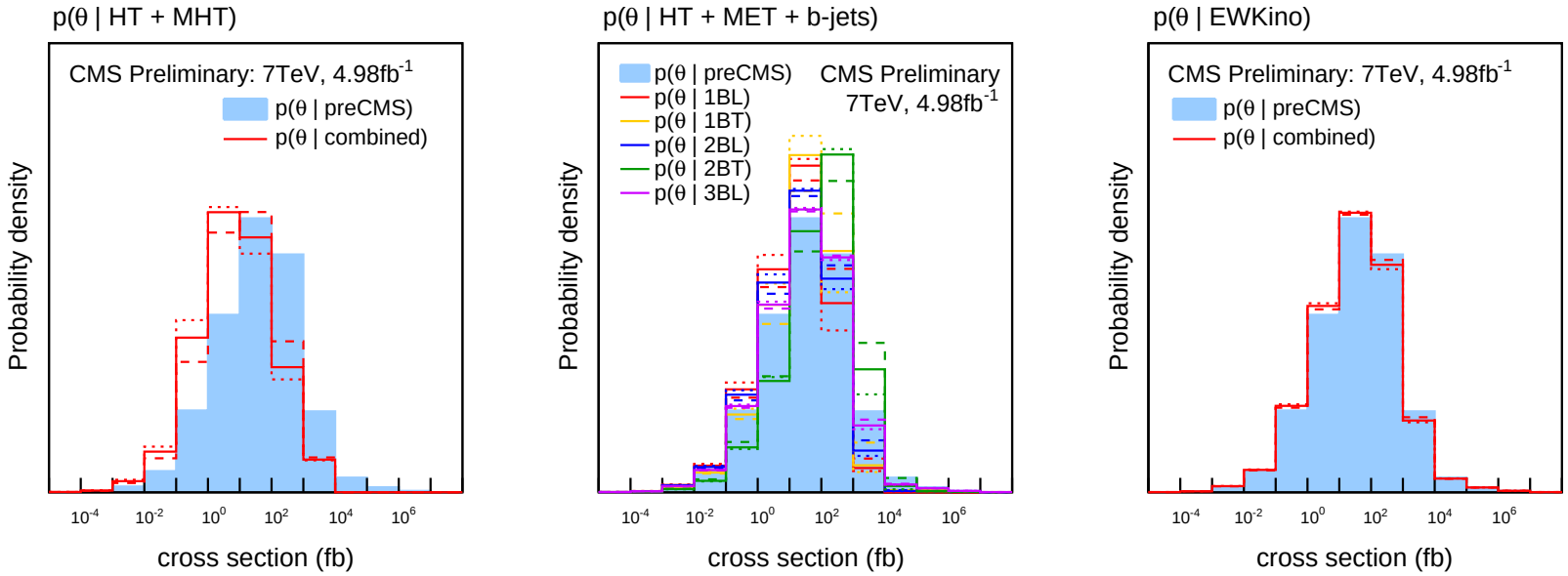

p(θ | HT + MHT)
p(θ | HT + MET + b-jets)
p(θ | EWKino)
CMS Preliminary: 7TeV, 4.98fb-1
CMS Preliminary 7TeV, 4.98fb-1
p(θ | preCMS)
p(θ | combined)
p(θ | 1BL)
p(θ | 1BT)
p(θ | 2BL)
p(θ | 2BT)
p(θ | 3BL)
Probability density
0 500 1000 1500 2000 2500 3000
$\tilde{\chi}_1^0$ mass [GeV]
$\tilde{\chi}_1^\pm$ mass [GeV]

gluino and LSP





SUSY cross section



unexplored regions

Z-significance:

$$Z = \mathrm{sign}(\ln \mathrm{B}_{10})\sqrt{2|\ln \mathrm{B}_{10}|}$$

$$B_{10}(\theta) = L(D^{\mathrm{CMS}}|\theta, H_1)/L(D^{\mathrm{CMS}}|H_0)$$

Bayesian analog of frequentist "n-sigma":

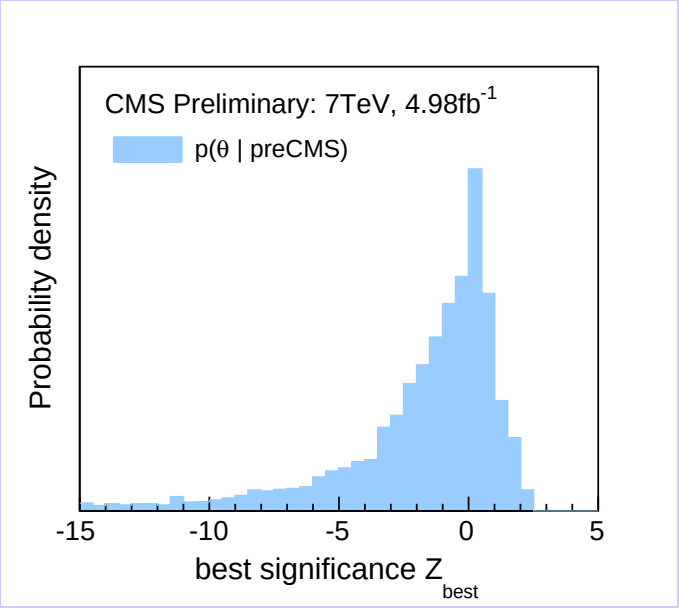
$Z < -1.64$ $\approx$ signal excluded, 95% CL

$Z > 5$ $\approx$ 5-σ discovery

Combination:

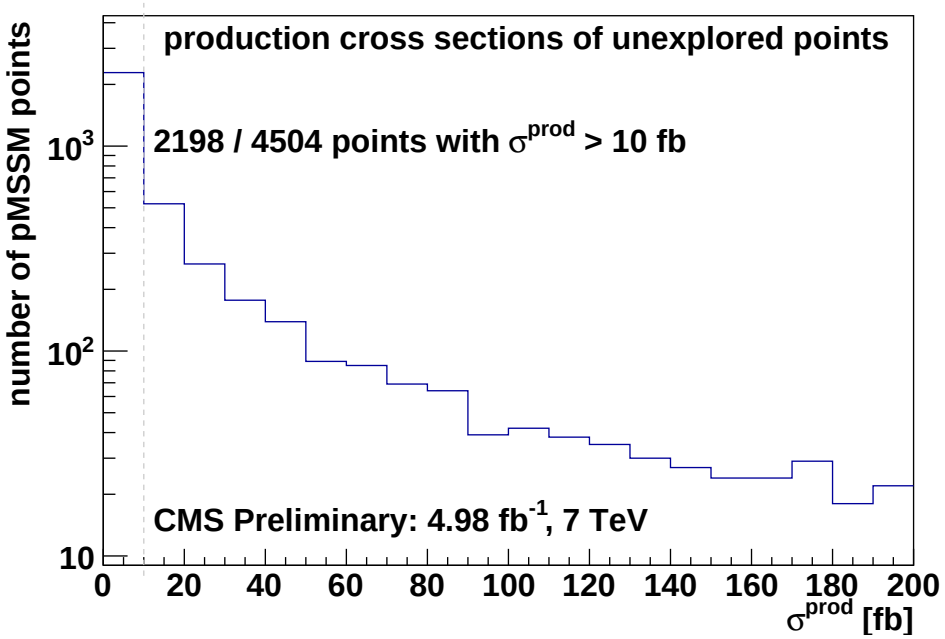
independent experiments:
$B_{10}(\theta) = \prod_l B^l_{10}(\theta)$

overlapping experiments:
Z_{best}: Z_l with max $|Z_l|$



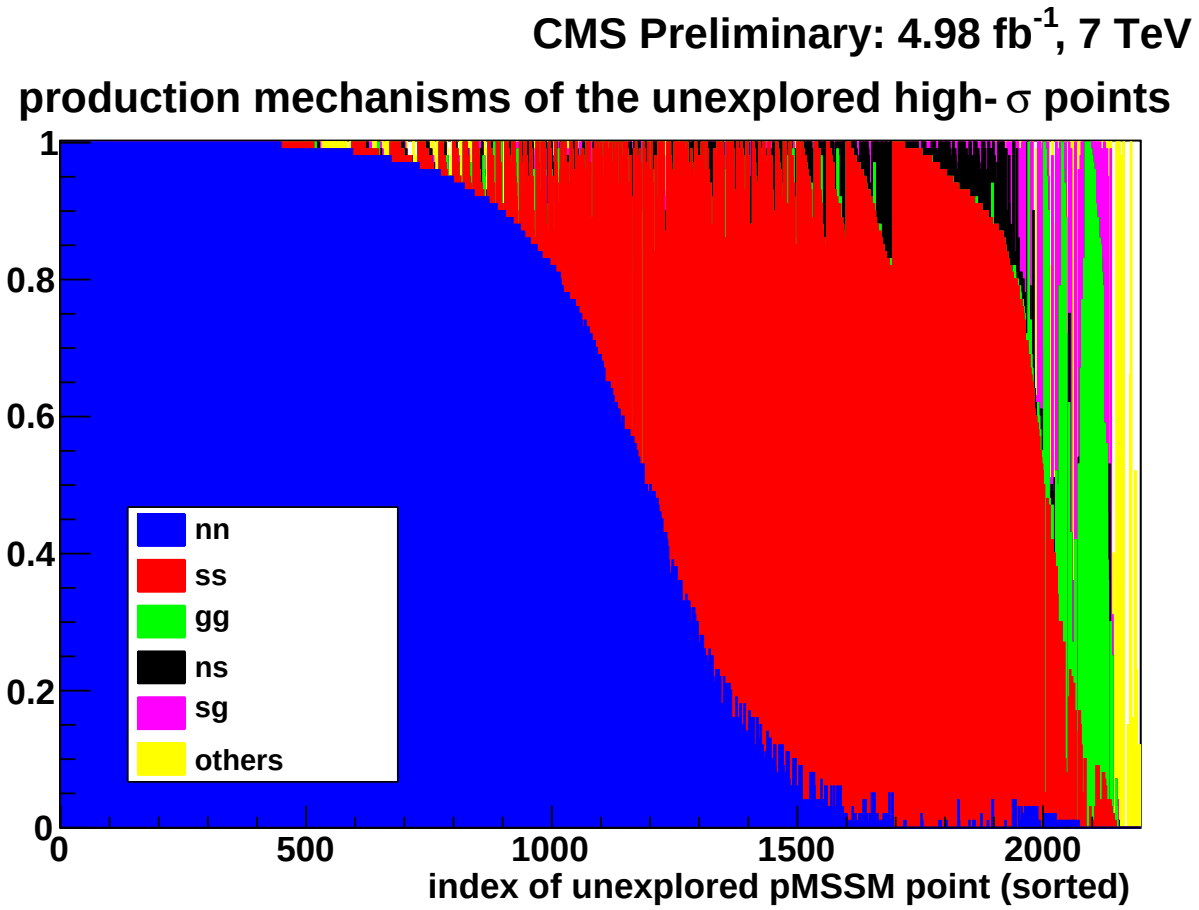
unexplored regions with high cross section

unexplored $:= |Z_{\text{best}}| < 2$ $\sim$ 4500/7300 points
high xsec $:= \sigma > 10\text{fb}^{-1}$ $\sim$ 2200/4500 points



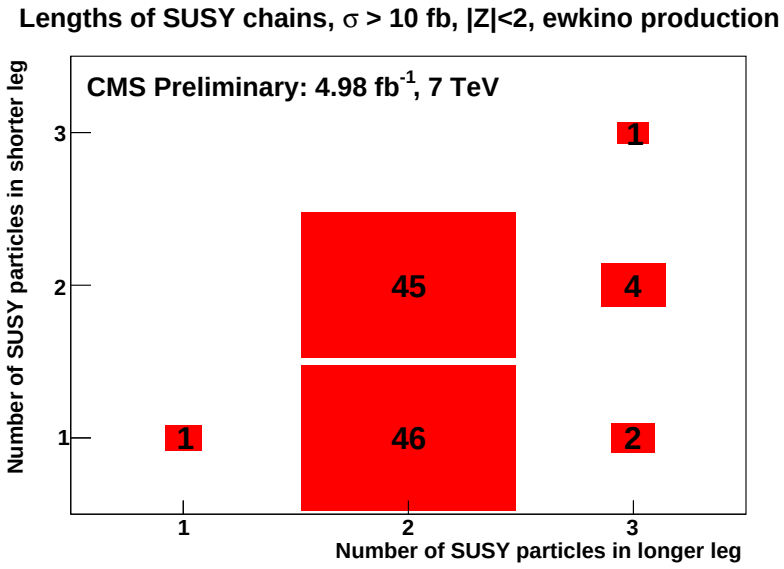
decompose these interesting points into Simplified Model Spectra

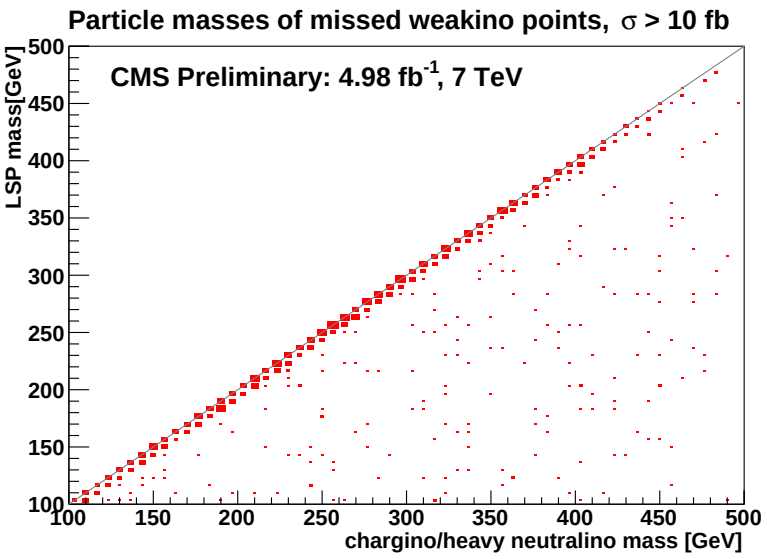
production mechanism

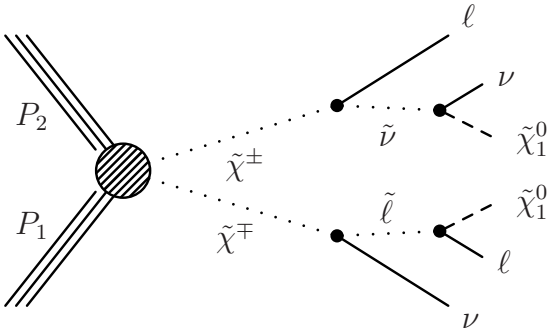


dominated by EW gaugino production
and by squark production

EWKino production

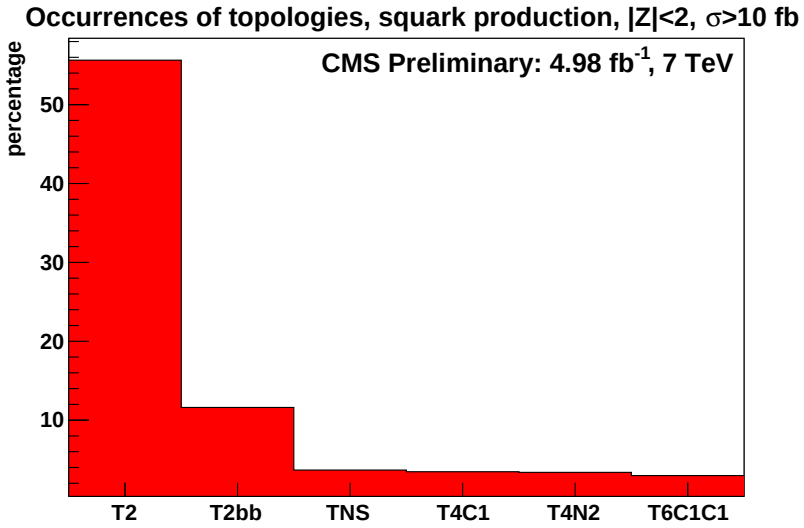


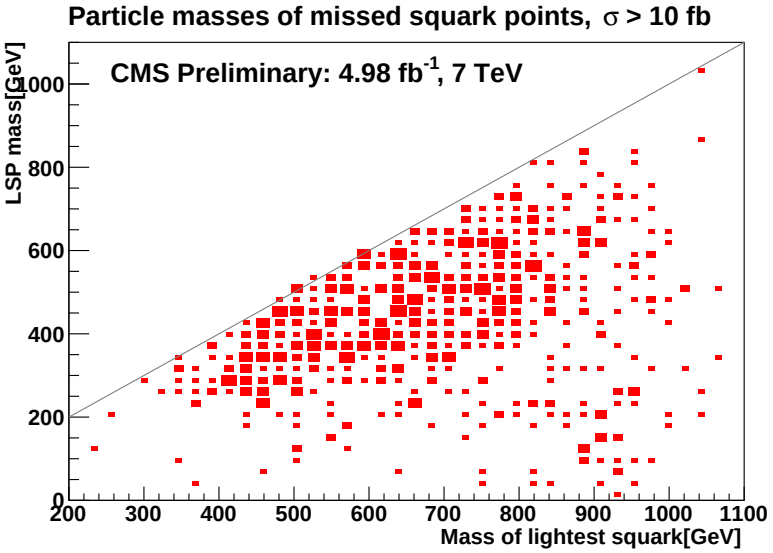




- typically, 1 or 2 legs with 2 sparticles
- typically, very small mass differences

squark production





- typically, 1st/2nd gen squark pair production
- typically, rather low mass differences

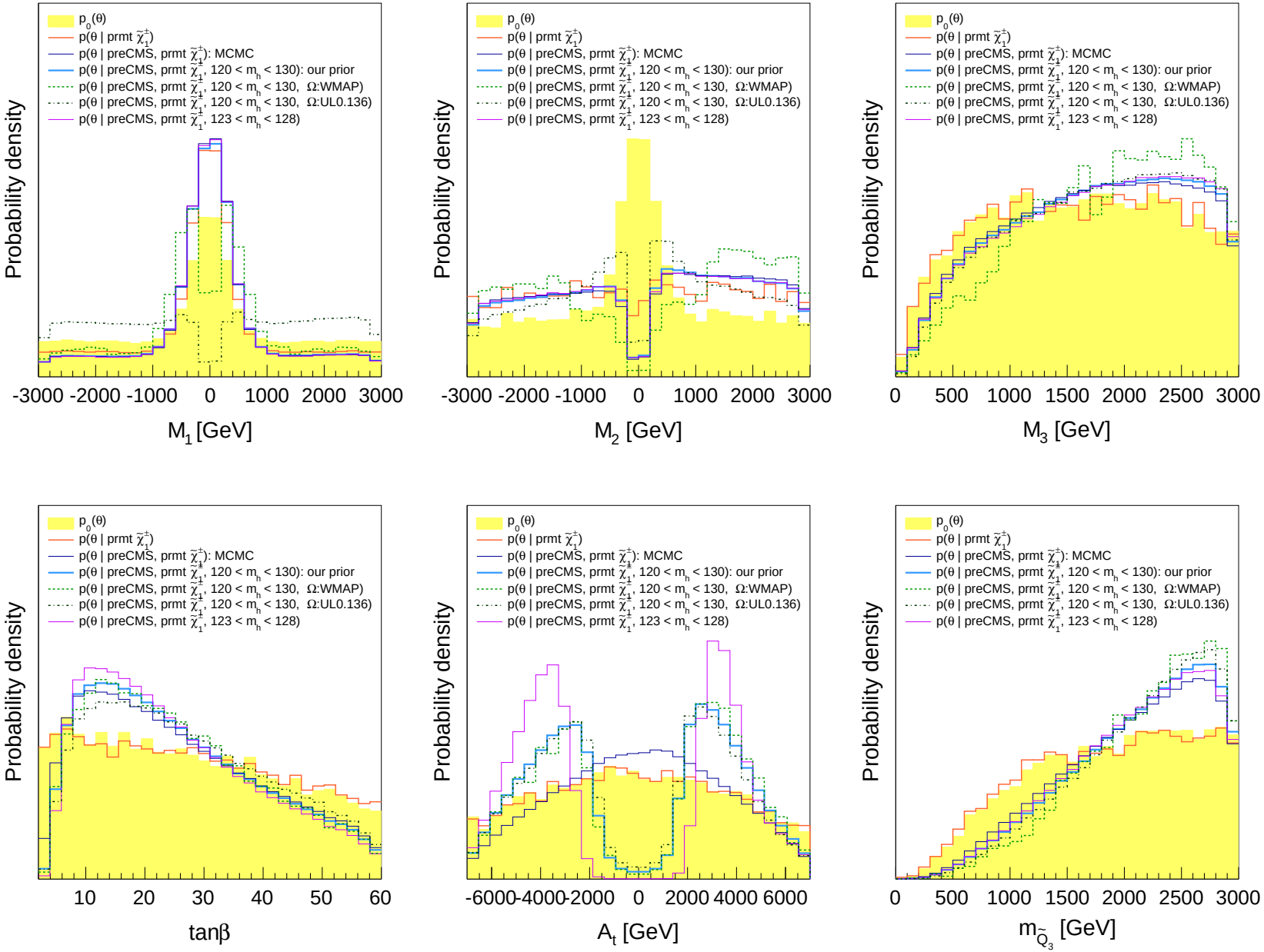
Summary

- **impact of considered 7 TeV CMS data**
  - disfavoring squarks, gluinos $<$ 1 TeV
    ... but many scenarios not probed
  - impact on 3rd gen very limited
  - impact on EWKinos, sleptons not visible
- **unexplored regions**
  - many “high cross section” scenarios not probed
  - mainly EWKino production (mass degeneracy)
  - and squark production (low mass splitting)
- **more in back-up**
  - consequences for dark matter and Higgs

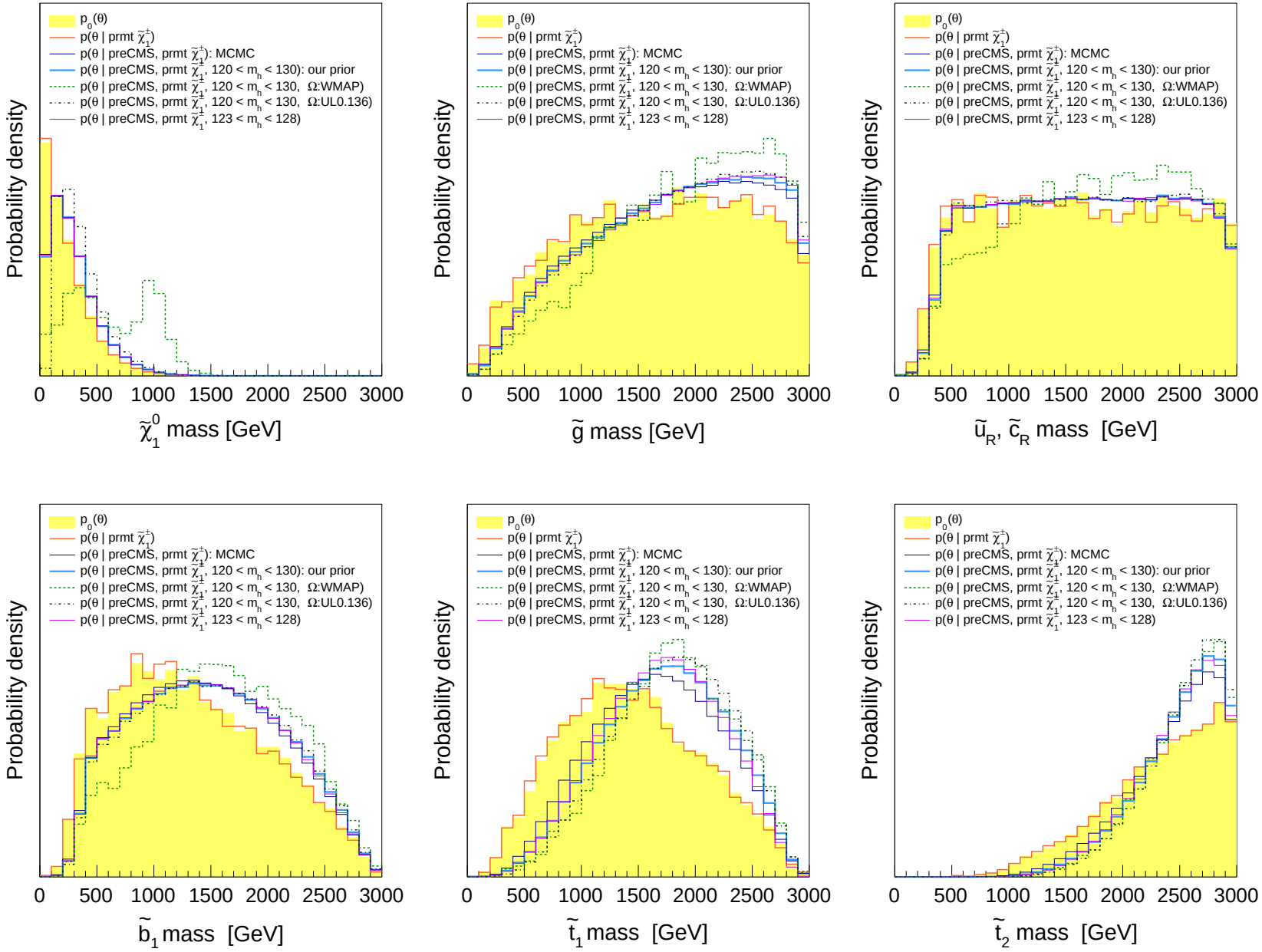
full documentation: SUS-12-030
coming soon: 8 TeV updates

Backup

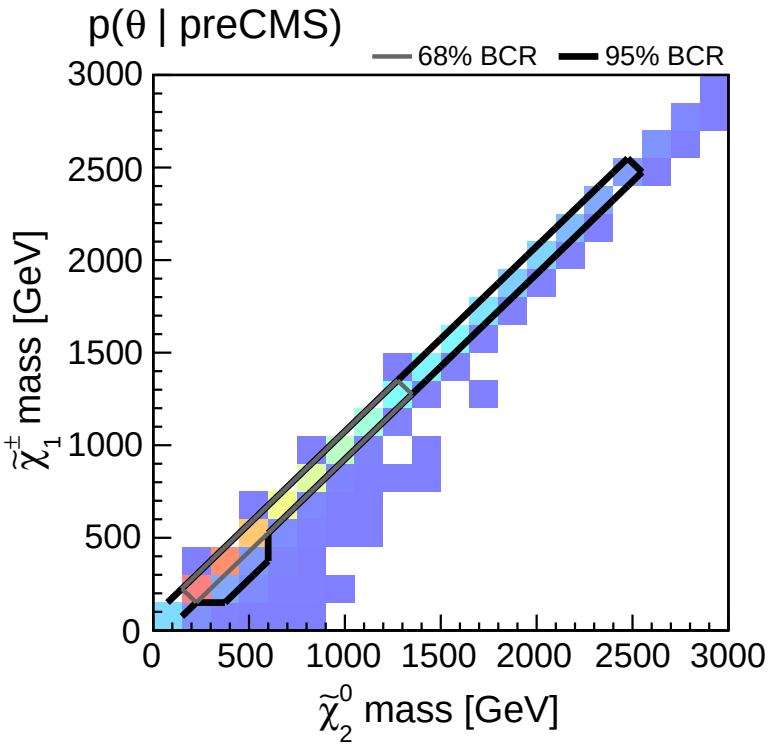
some preCMS distributions

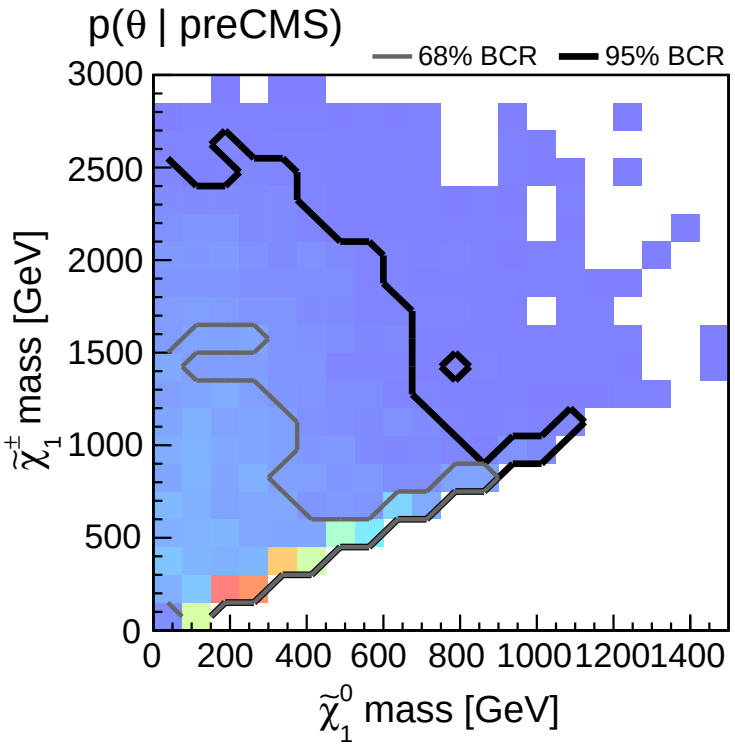


some preCMS distributions



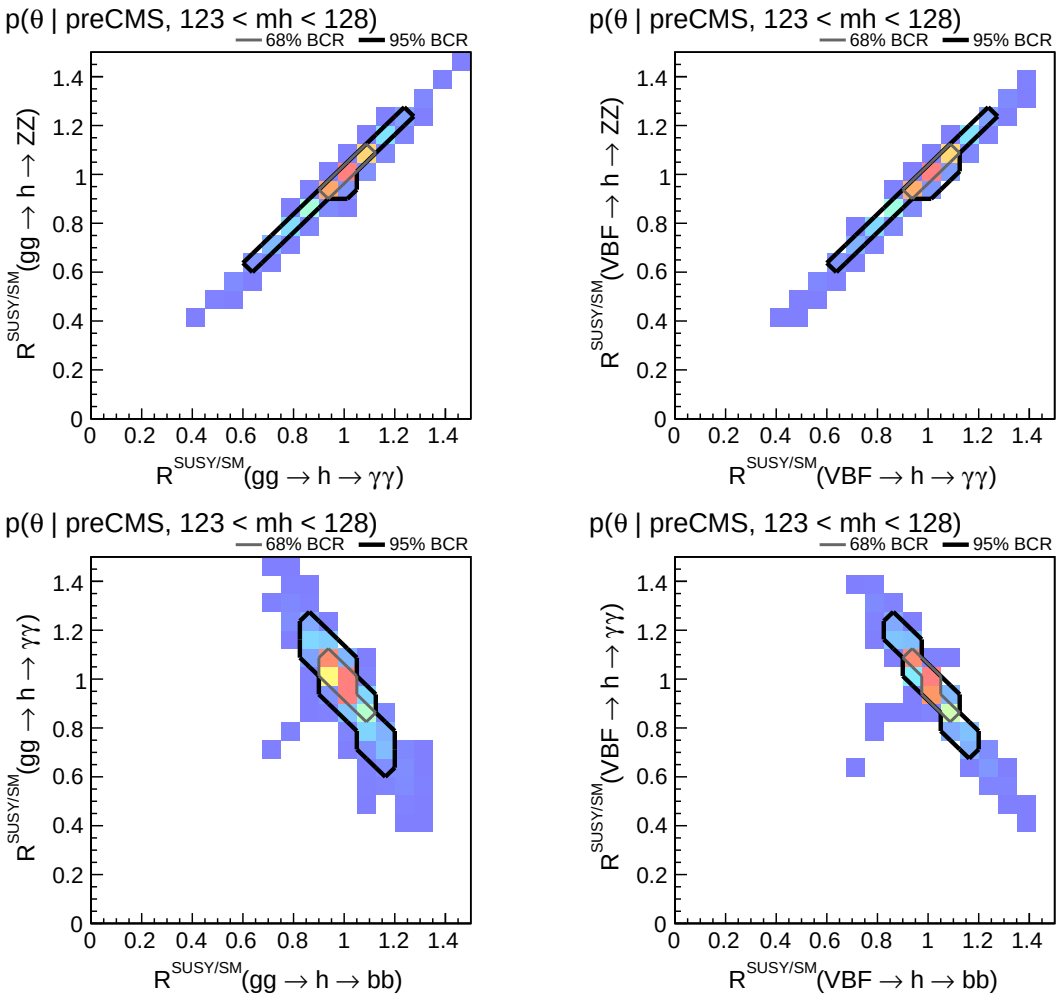
degeneracy of EW gauginos



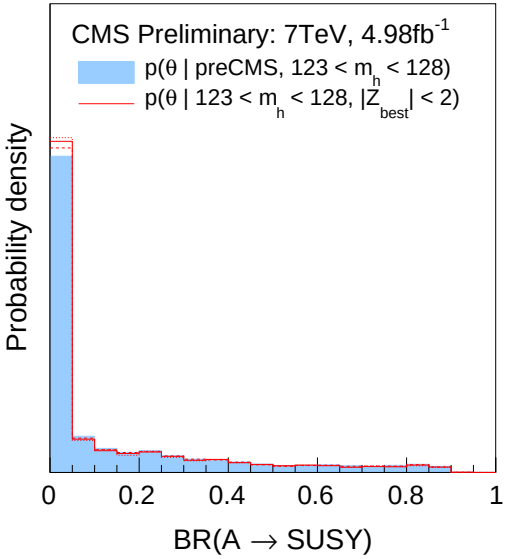


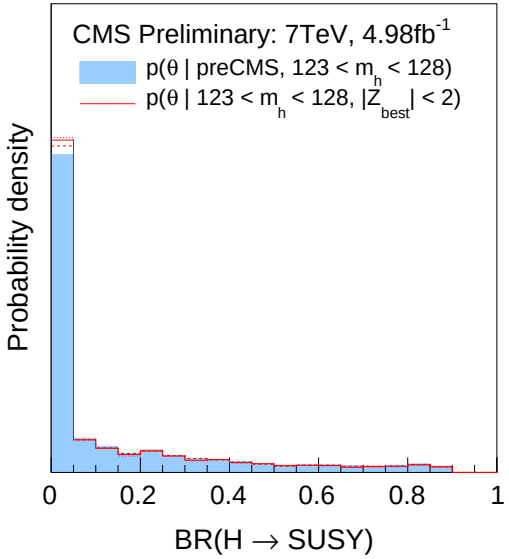
consequences for Higgs

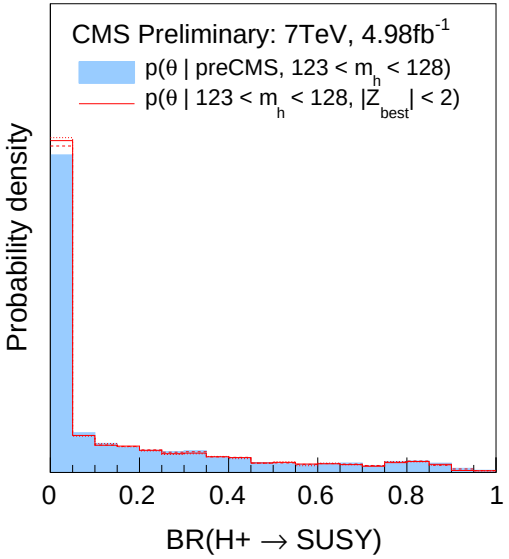
$$R_X(Y) = \frac{\sigma(X \to h)\mathrm{BR}(h \to Y)}{\sigma_{\mathrm{SM}}(X \to h_{\mathrm{SM}})\mathrm{BR}(h_{\mathrm{SM}} \to Y)}$$



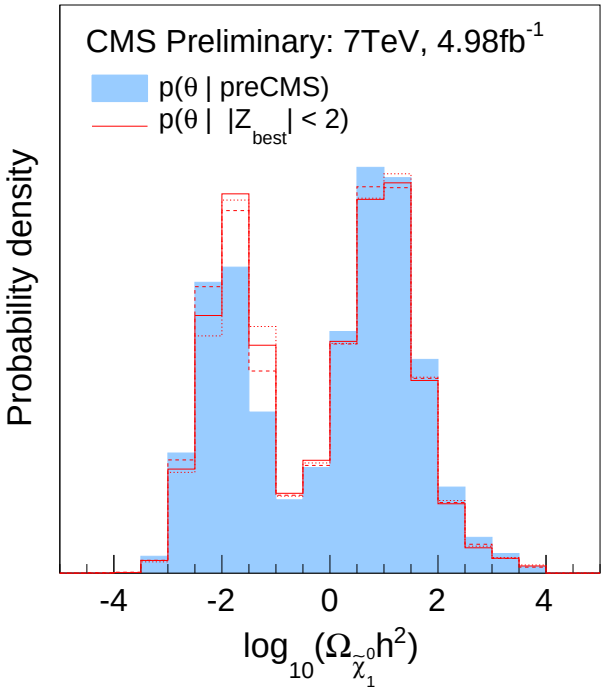
consequences for Higgs







consequences for dark matter



consequences for dark matter