The pMSSM Interpretation of CMS 7 and 8 TeV Results

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SUS-15-010

Charge

make robust, comprehensive statements about SUSY

parameter estimation in case of discovery

guide the next generation of searches

CMS PAS SUS-13-020

Phenomenological MSSM interpretation of the CMS 7 and 8 TeV results

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The Phenomenological (p)MSSM

A realization of the R-parity conserving MSSM with

*no new sources of CP violation

*no flavor changing neutral currents

*1st and 2nd generation squarks are degenerate

*lightest SUSY particle is the neutralino

19 Parameters

Gaugino mass parameters M_1, M_2, and M_3

Higgs sector parameters $\tan(\beta)$, μ, and m_A

10 sfermion mass parameters m_i

Trilinear couplings A_t, A_b, and A_τ

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Strategy

- incorporate relevant prior information
(10 previous results)
- scan parameter space with
(20,000,000 points)
- generate events for
(7200 points)
- draw conclusions in a probabilistic framework

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Parameter Ranges

$$-3\,\mathrm{TeV} \leq M_1, M_2 \leq 3\,\mathrm{TeV}$$

$$0 \leq M_3 \leq 3\,\mathrm{TeV}$$

$$-3\,\mathrm{TeV} \leq \mu \leq 3\,\mathrm{TeV}$$

$$0 \leq m_A \leq 3\,\mathrm{TeV}$$

$$2 \leq \tan\beta \leq 60$$

$$0 \leq \tilde{Q}_{1,2}, \tilde{U}_{1,2}, \tilde{D}_{1,2}, \tilde{L}_{1,2}, \tilde{E}_{1,2}, \tilde{Q}_3, \tilde{U}_3, \tilde{D}_3, \tilde{L}_3, \tilde{E}_3 \leq 3\,\mathrm{TeV}$$
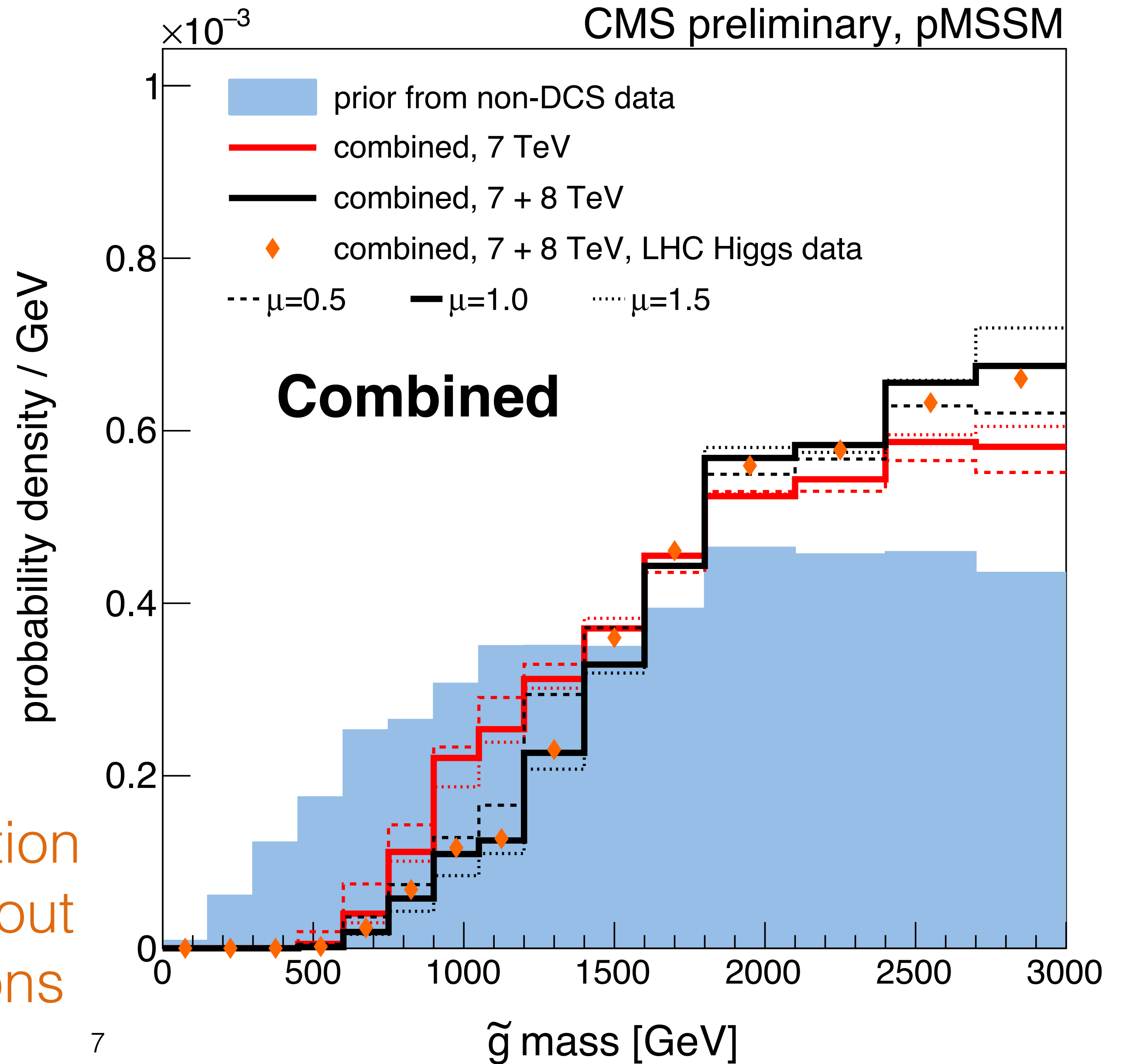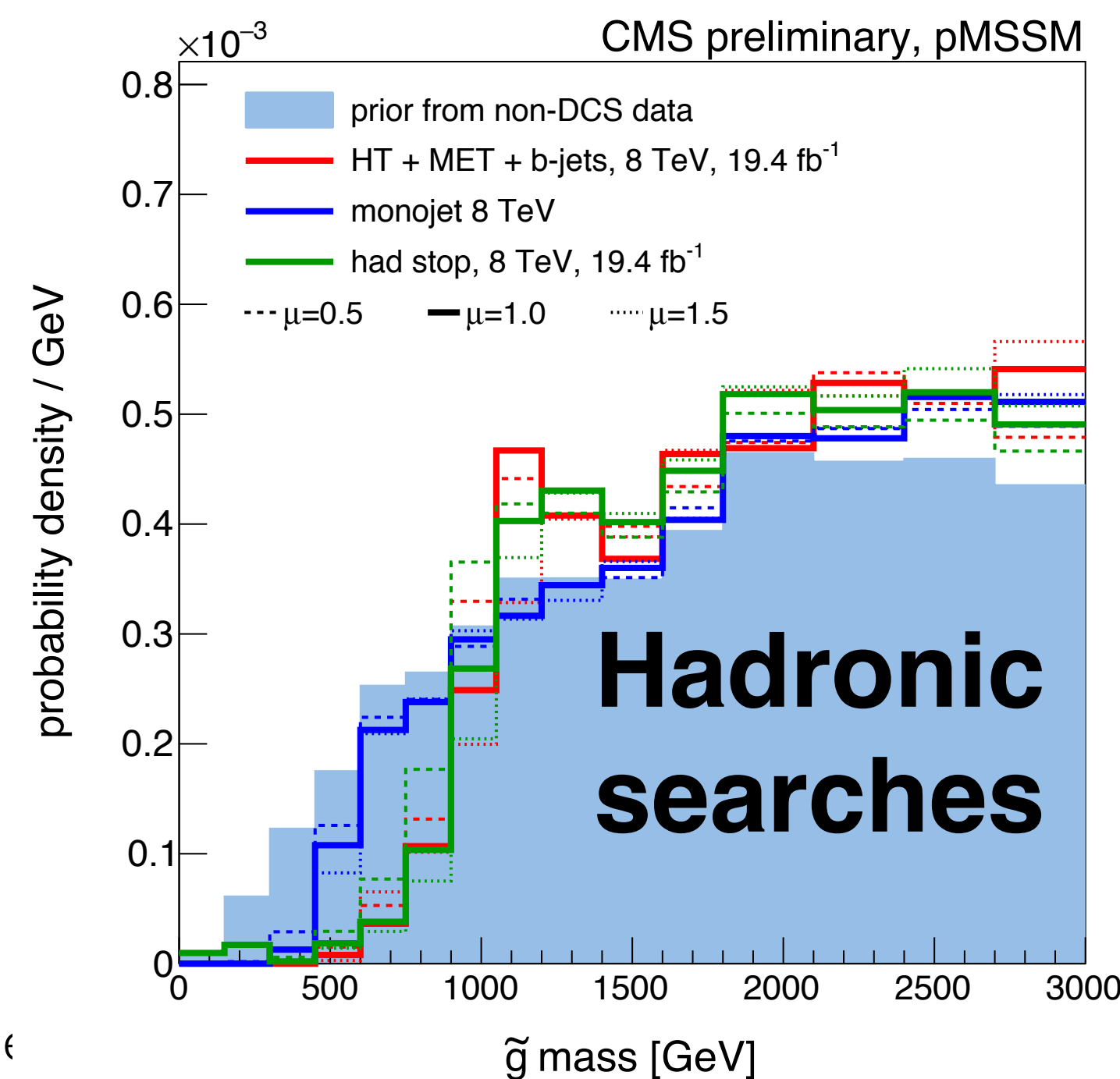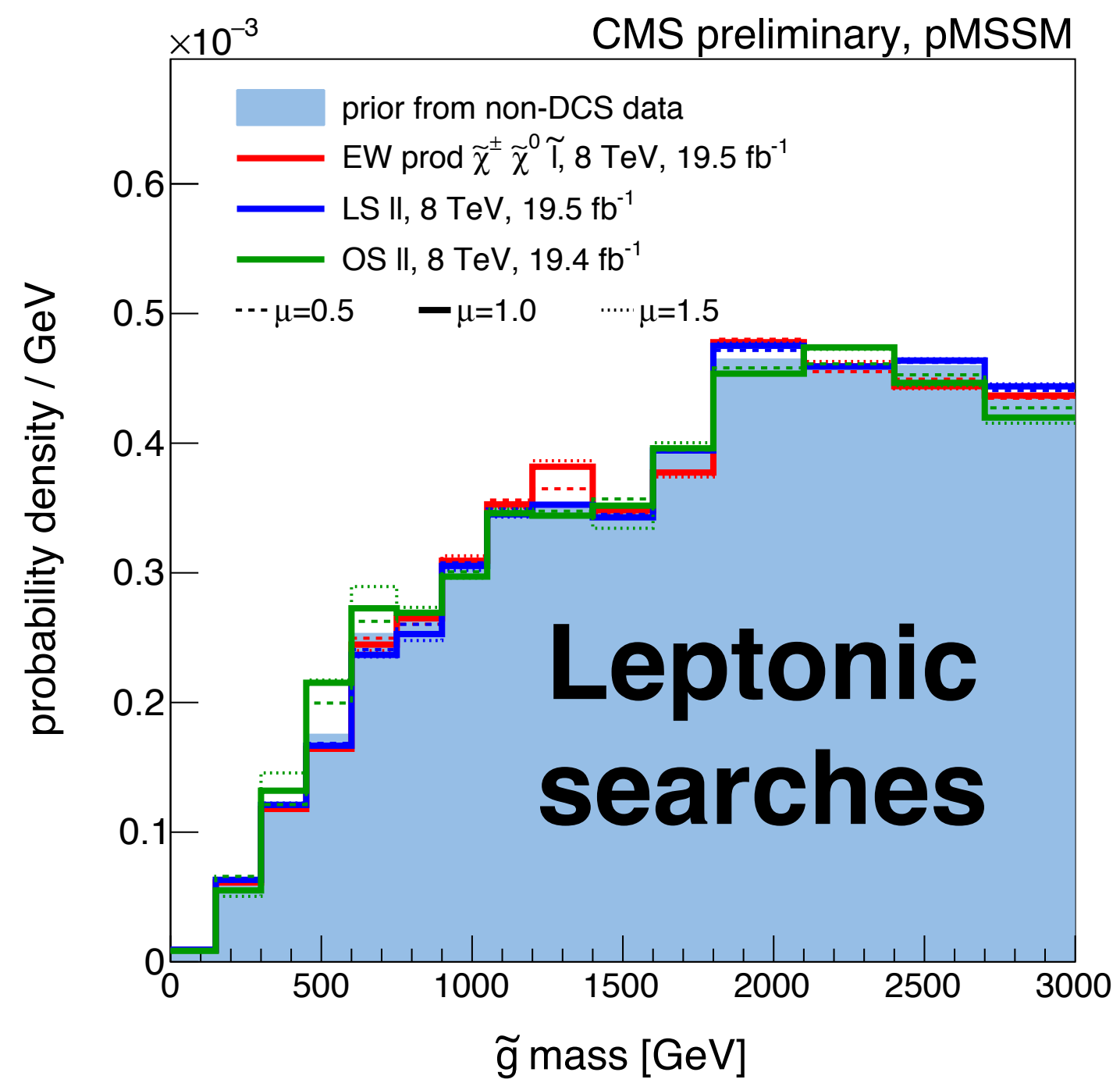
$$-7\,\mathrm{TeV} \leq A_t, A_b, A_\tau \leq 7\,\mathrm{TeV},$$

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CMS SUSY Analyses

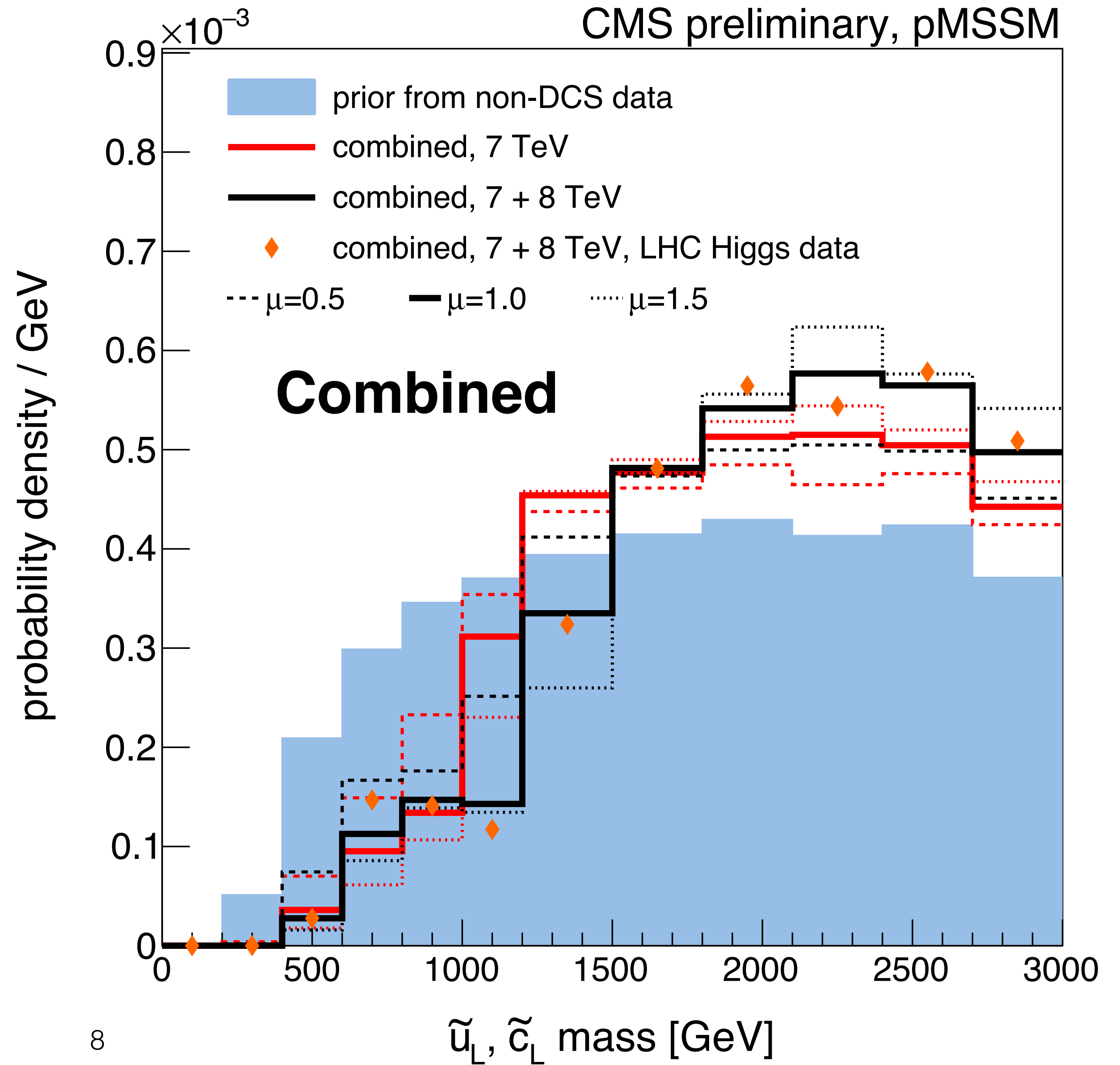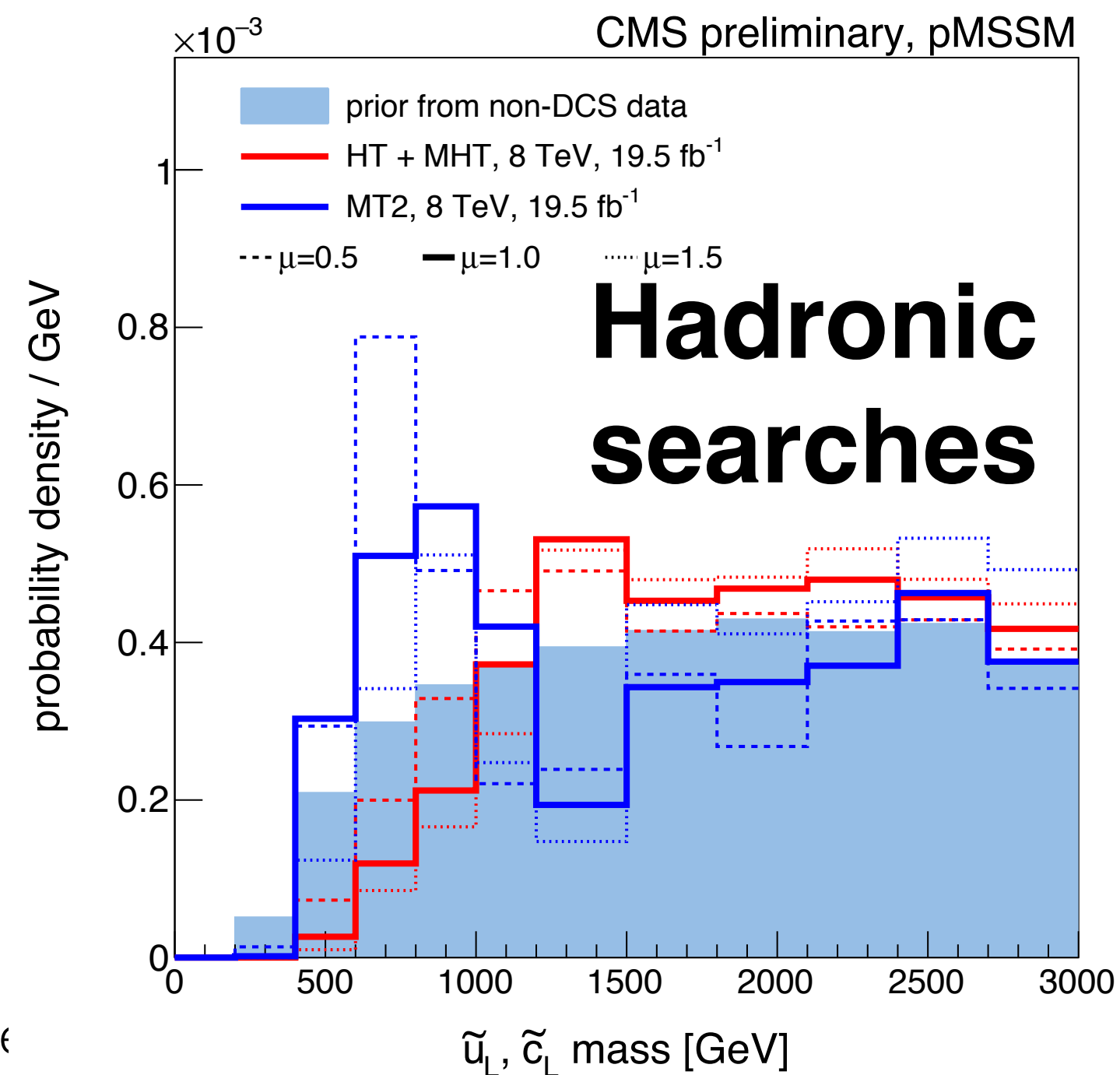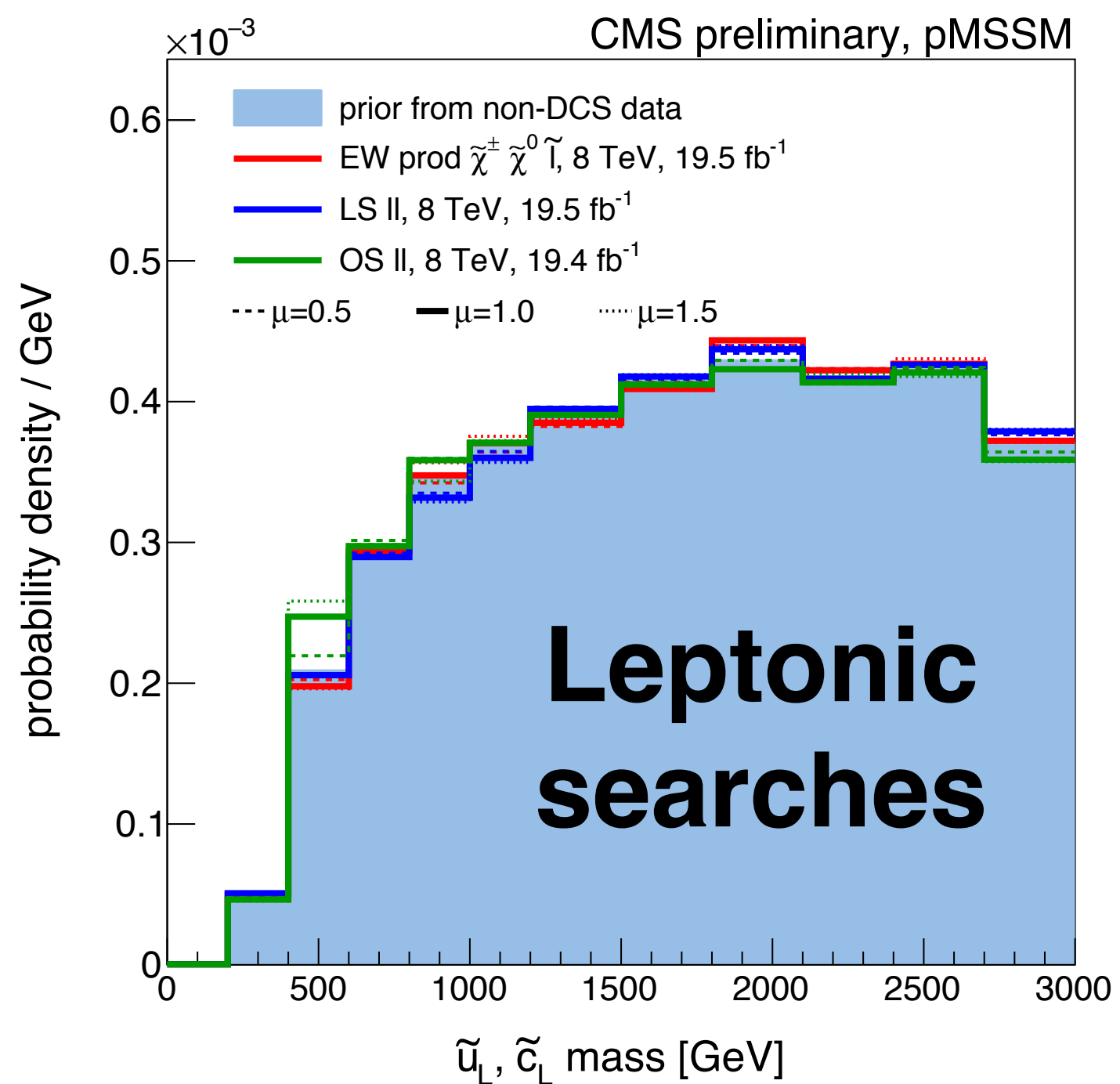| Analysis	$\sqrt{s}$ [TeV]	L [fb^{-1}]
Hadronic HT + MHT search	7	4.98
Hadronic HT + MET + b-jets search	7	4.98
Leptonic search for EW prod. of $\tilde{\chi}^0$, $\tilde{\chi}^\pm$, $\tilde{l}$	7	4.98
Hadronic HT + MHT search	8	19.5
Hadronic M_{T2} search	8	19.5
Hadronic HT + MET + b-jets search	8	19.4
Monojet searches	8	19.7
Hadronic stop search	8	19.4
Opposite sign di-lepton (OS ll) search (count experiment only)	8	19.4
Like-sign di-leptoin (LS ll) search (only channels w/o 3rd lepton veto)	8	19.5
Leptonic search for EW prod. of $\tilde{\chi}^0$, $\tilde{\chi}^\pm$, $\tilde{l}$ (only ss, 3l, and 4l channels)	8	19.5

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Gluino

$\tilde{g}$

Leptonic searches

Top-left plot: CMS preliminary, pMSSM. probability density / GeV vs $\tilde{g}$ mass [GeV]. Legend: prior from non-DCS data; EW prod $\tilde{\chi}^{\pm}\tilde{\chi}^{0}\tilde{l}$, 8 TeV, 19.5 fb^{-1}; LS ll, 8 TeV, 19.5 fb^{-1}; OS ll, 8 TeV, 19.4 fb^{-1}; $\mu=0.5$, $\mu=1.0$, $\mu=1.5$.

Hadronic searches

Bottom-left plot: CMS preliminary, pMSSM. probability density / GeV vs $\tilde{g}$ mass [GeV]. Legend: prior from non-DCS data; HT + MET + b-jets, 8 TeV, 19.4 fb^{-1}; monojet 8 TeV; had stop, 8 TeV, 19.4 fb^{-1}; $\mu=0.5$, $\mu=1.0$, $\mu=1.5$.

Combined

Right plot: CMS preliminary, pMSSM. probability density / GeV vs $\tilde{g}$ mass [GeV]. Legend: prior from non-DCS data; combined, 7 TeV; combined, 7 + 8 TeV; combined, 7 + 8 TeV, LHC Higgs data; $\mu=0.5$, $\mu=1.0$, $\mu=1.5$.

Combination smooths out fluctuations

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Squark

$\tilde{q}_{\mathsf{L}}$

Leptonic searches

Legend (top-left plot):
- prior from non-DCS data
- EW prod $\tilde{\chi}^{\pm}\tilde{\chi}^{0}\tilde{l}$, 8 TeV, 19.5 fb^{-1}
- LS ll, 8 TeV, 19.5 fb^{-1}
- OS ll, 8 TeV, 19.4 fb^{-1}
- μ=0.5 μ=1.0 μ=1.5

CMS preliminary, pMSSM

Hadronic searches

Legend (bottom-left plot):
- prior from non-DCS data
- HT + MHT, 8 TeV, 19.5 fb^{-1}
- MT2, 8 TeV, 19.5 fb^{-1}
- μ=0.5 μ=1.0 μ=1.5

CMS preliminary, pMSSM

Combined

Legend (right plot):
- prior from non-DCS data
- combined, 7 TeV
- combined, 7 + 8 TeV
- combined, 7 + 8 TeV, LHC Higgs data
- μ=0.5 μ=1.0 μ=1.5

probability density / GeV

$\tilde{u}_{L}$, $\tilde{c}_{L}$ mass [GeV]

LSP

$\tilde{\chi}_1^0$

Leptonic searches

Hadronic searches

Combined

Higgs to invisible suppresses mLSP<60GeV

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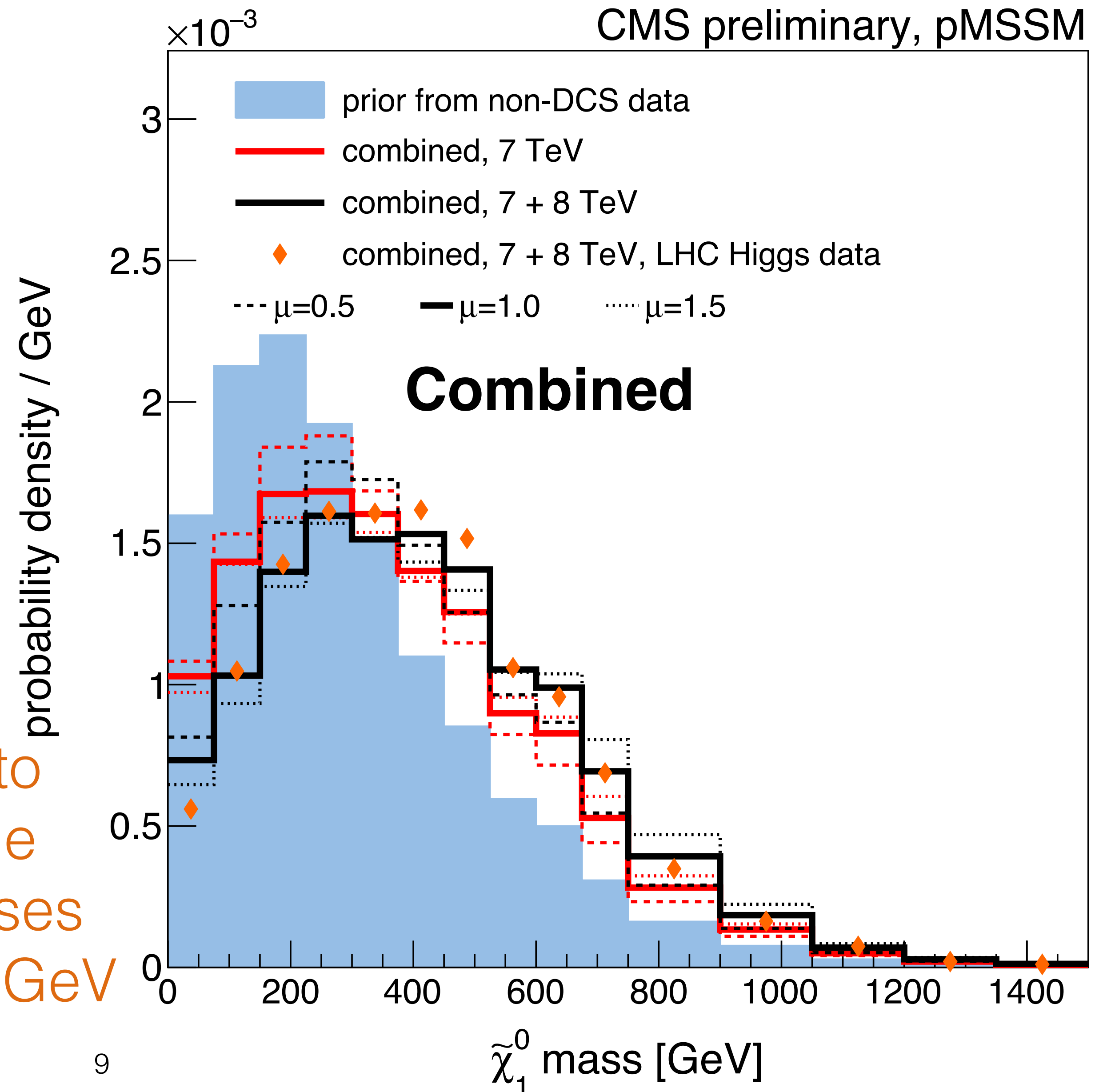
LSP vs Gluino

prior

posterior

posterior/prior

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Higgsino

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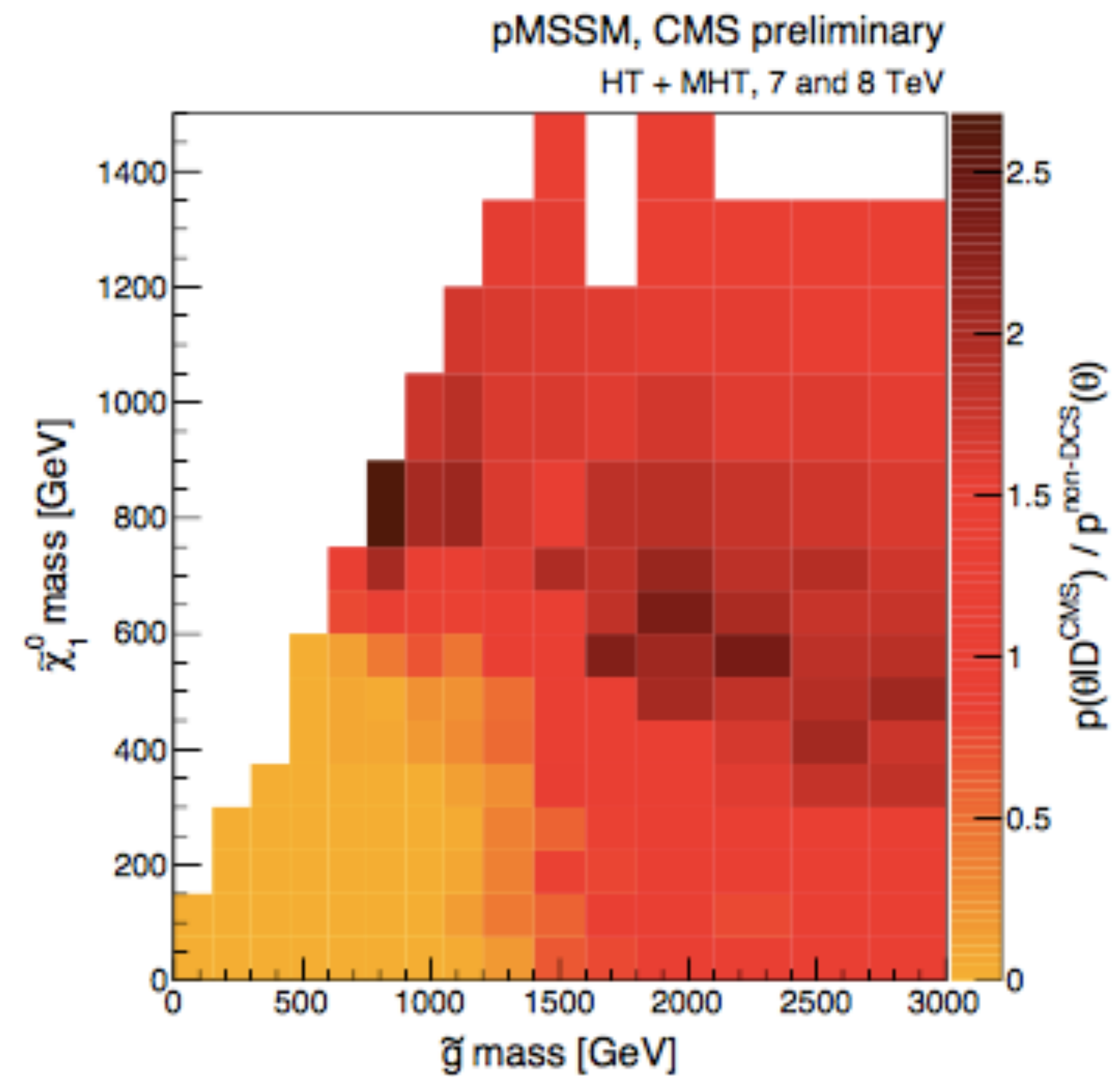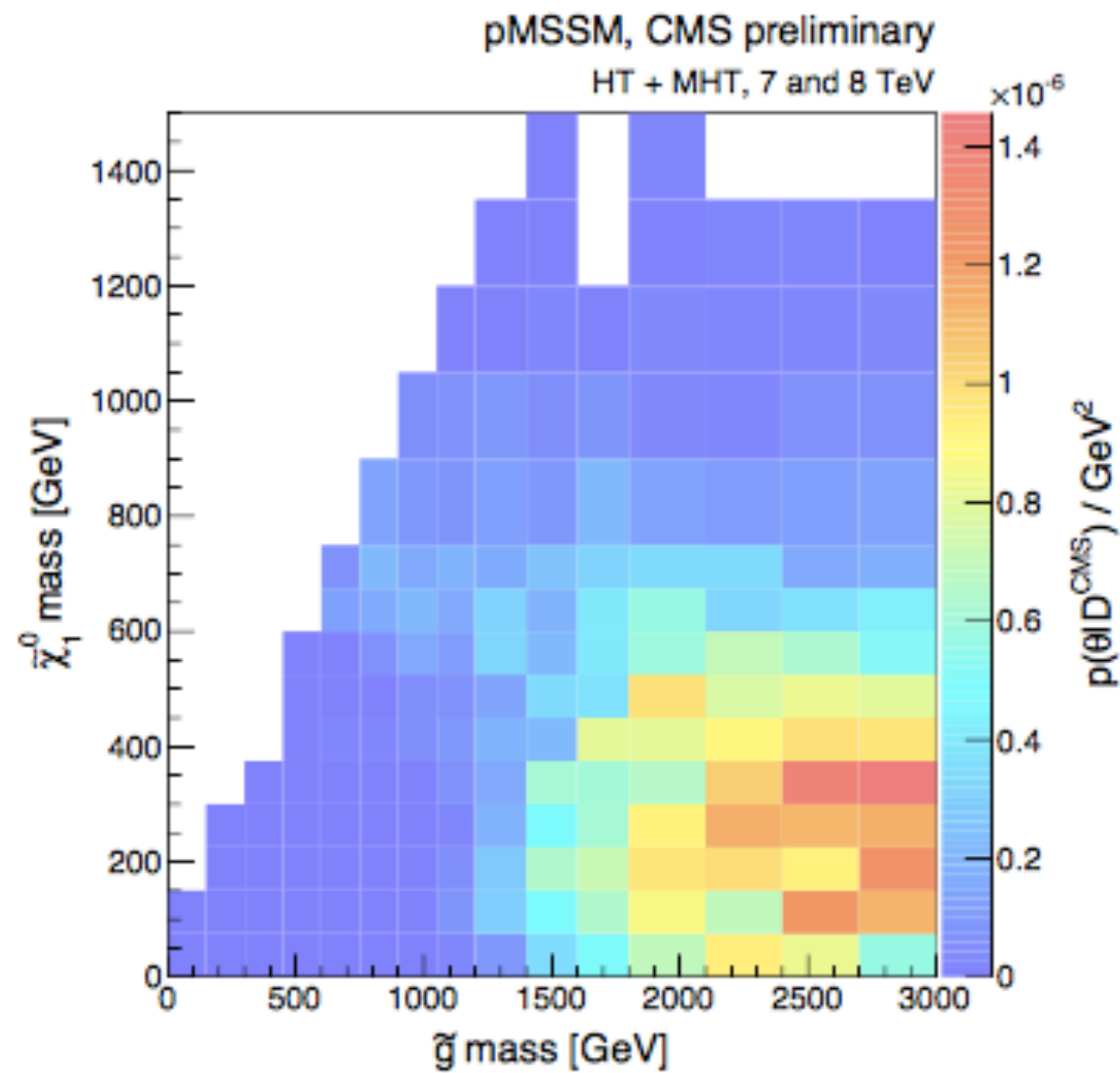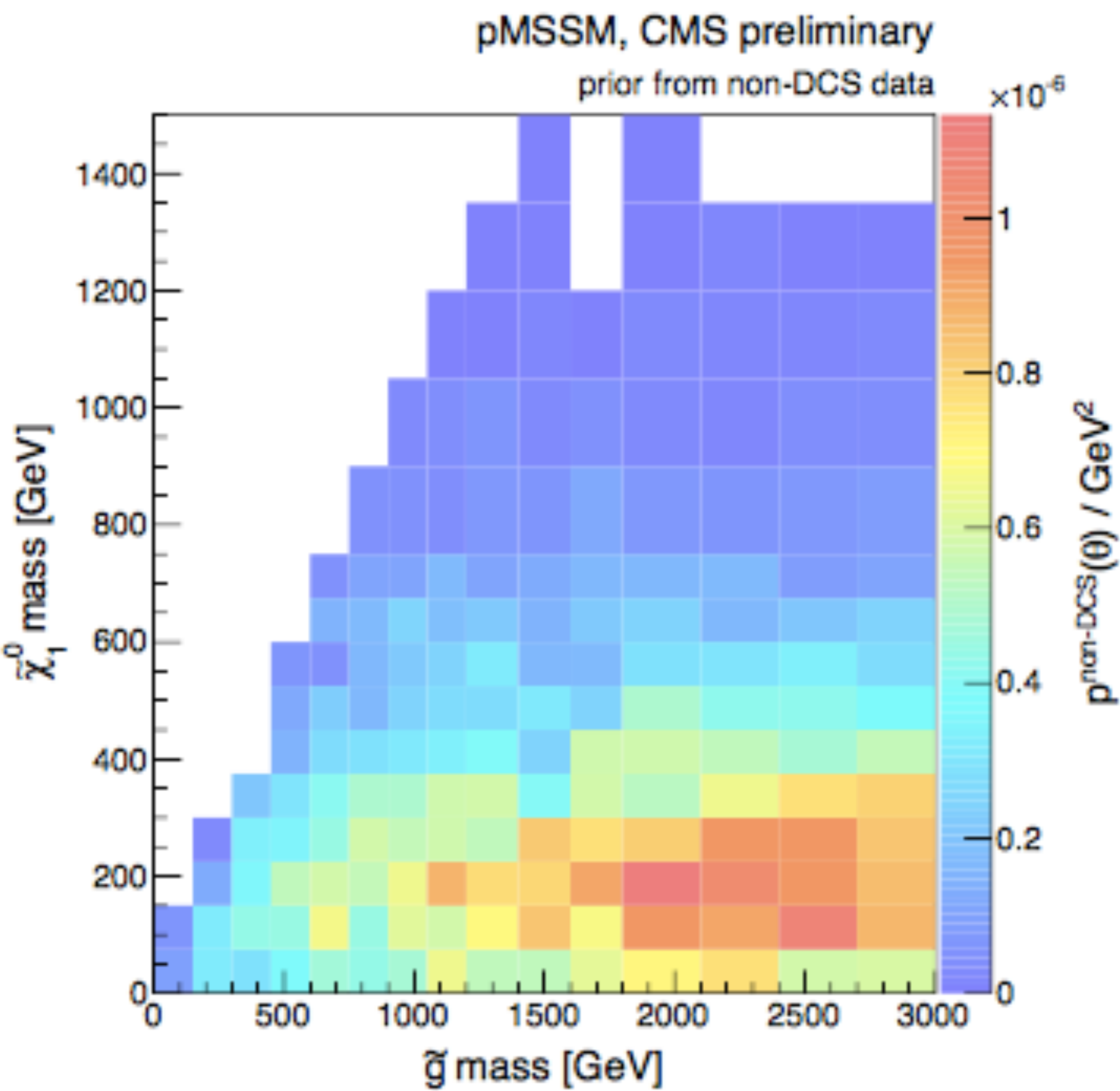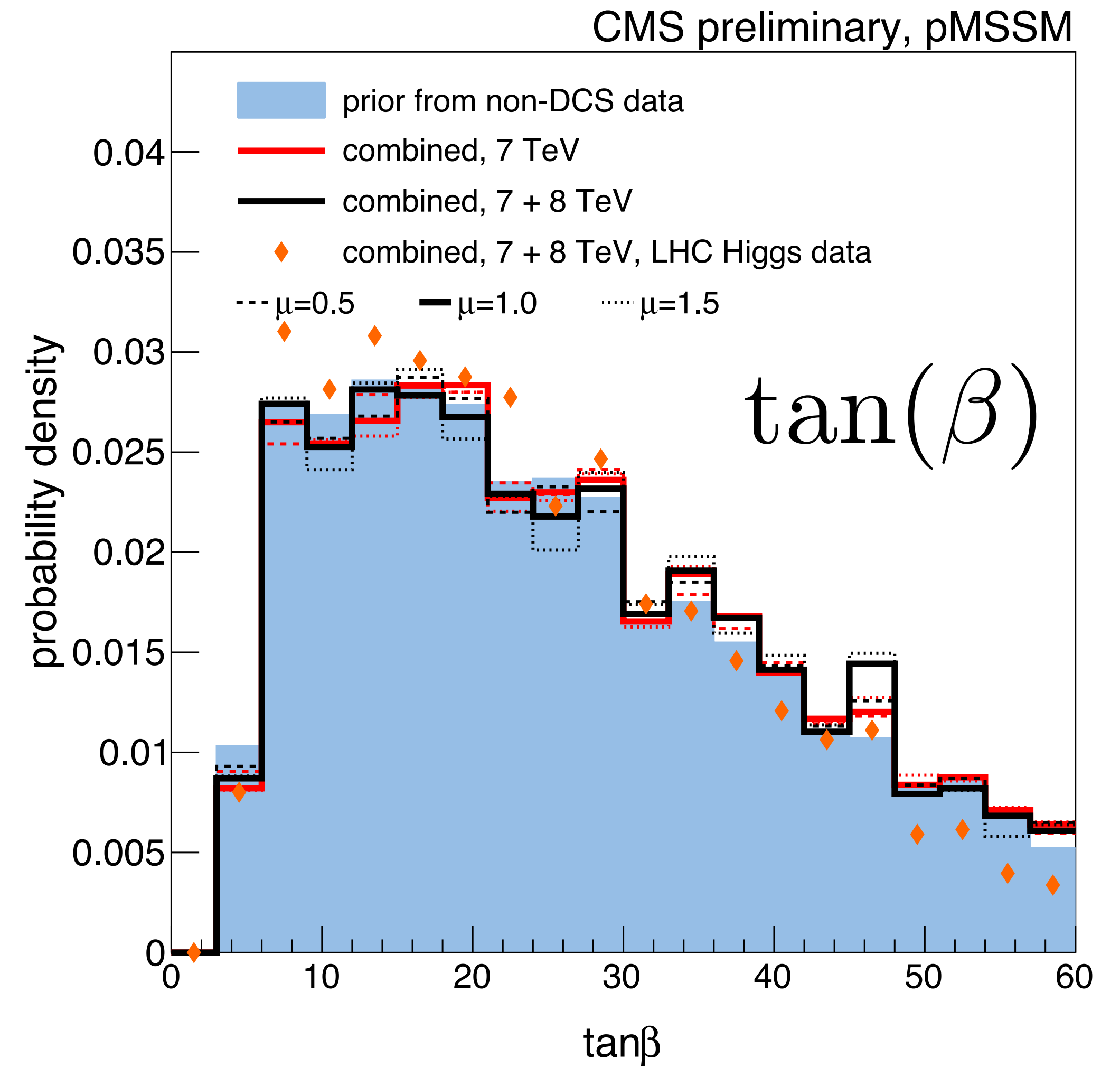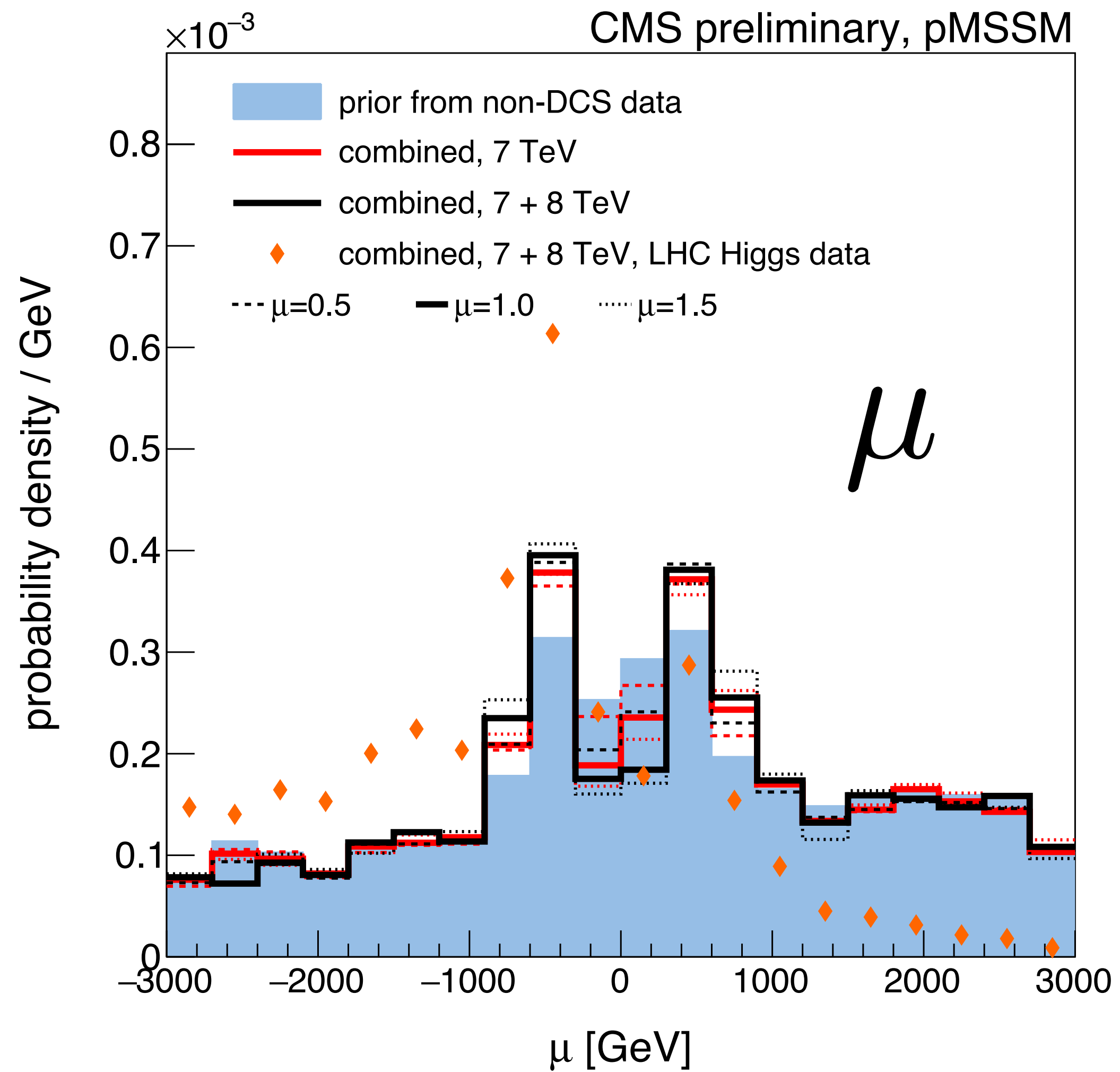
Dark Matter
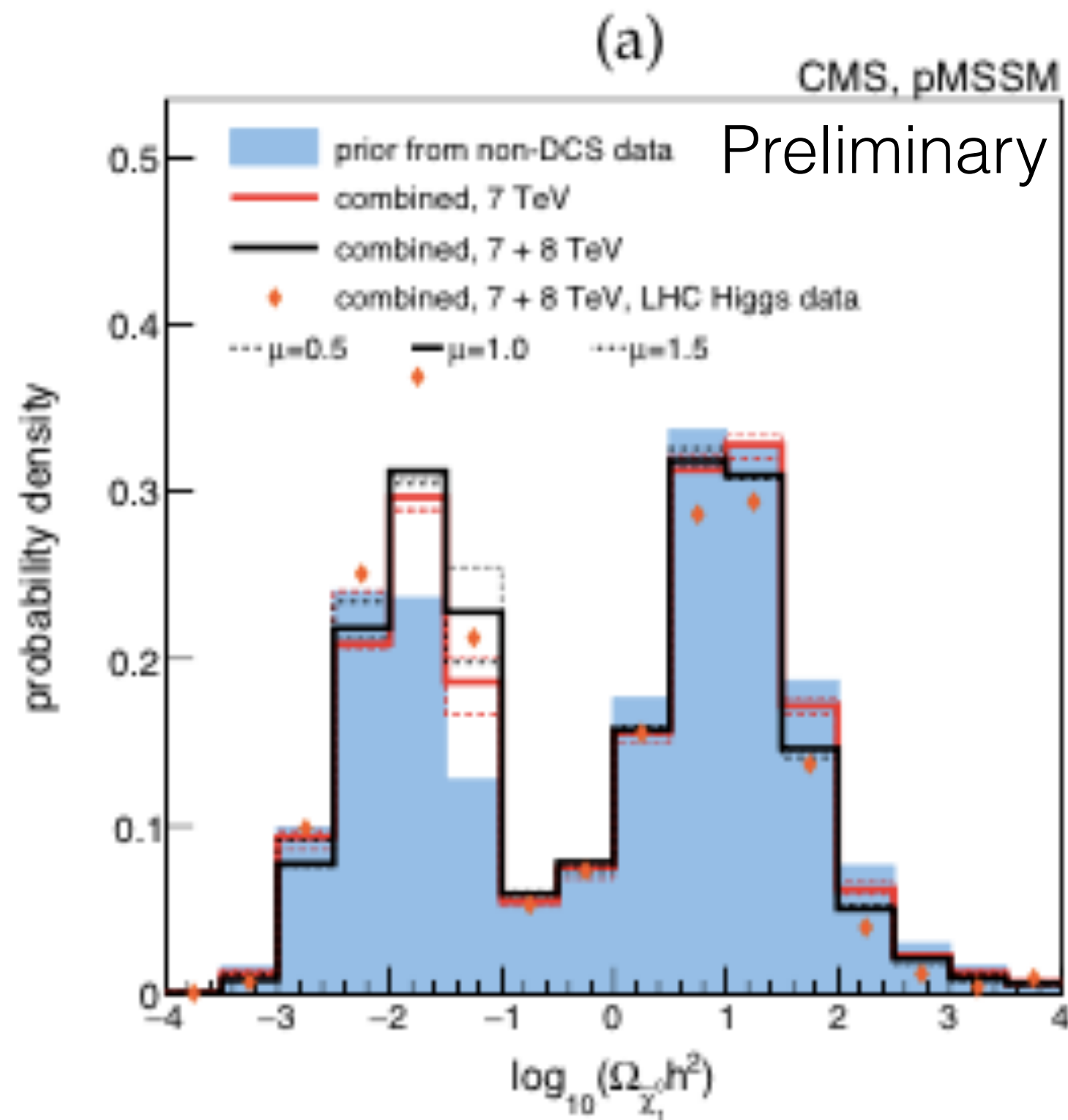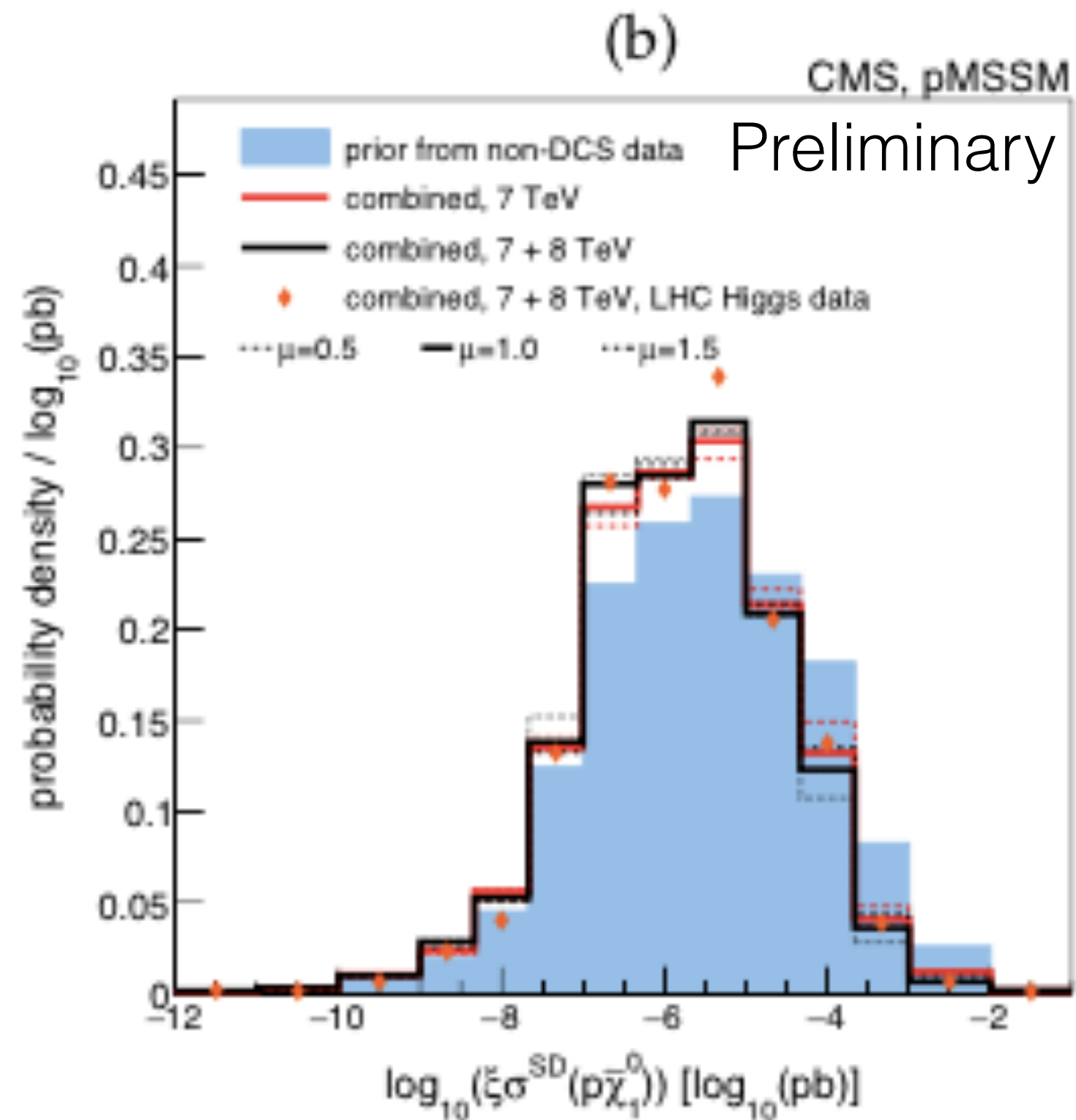
relic density   **spin-dependent**   **spin-independent**

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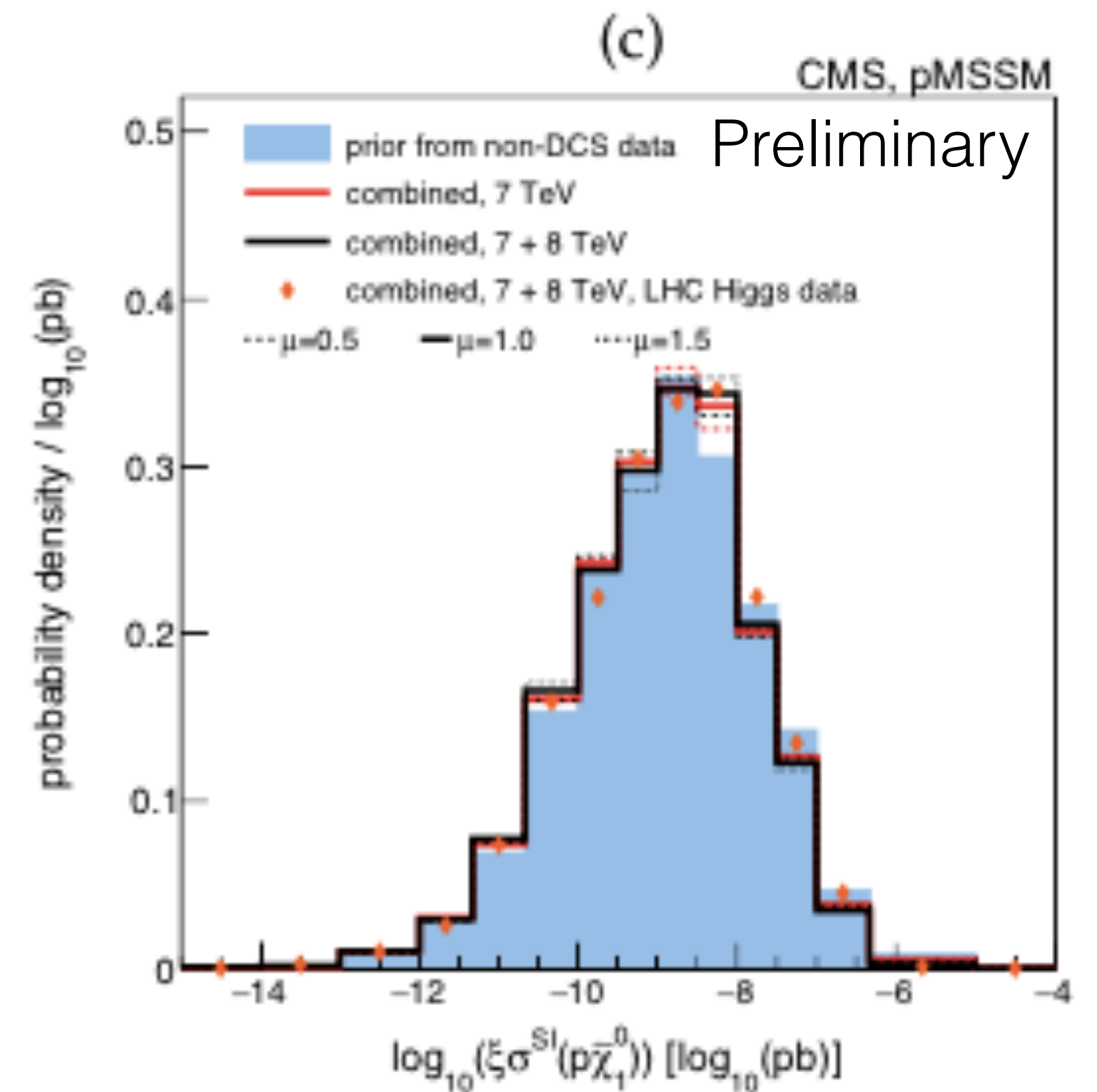
Non-excluded parameter space

Convenient re-mapping of the Bayes factor:

Bayes factor: $B_{10} = L(Data|H_1)/L(Data|H_0)$

Z-signficiance: $Z = \mathrm{sign}(\log(B_{10}))\sqrt{2|\log(B_{10})|}$

Z <= -1.64 (excluded)   **Z > -1.64 (non-excluded)**
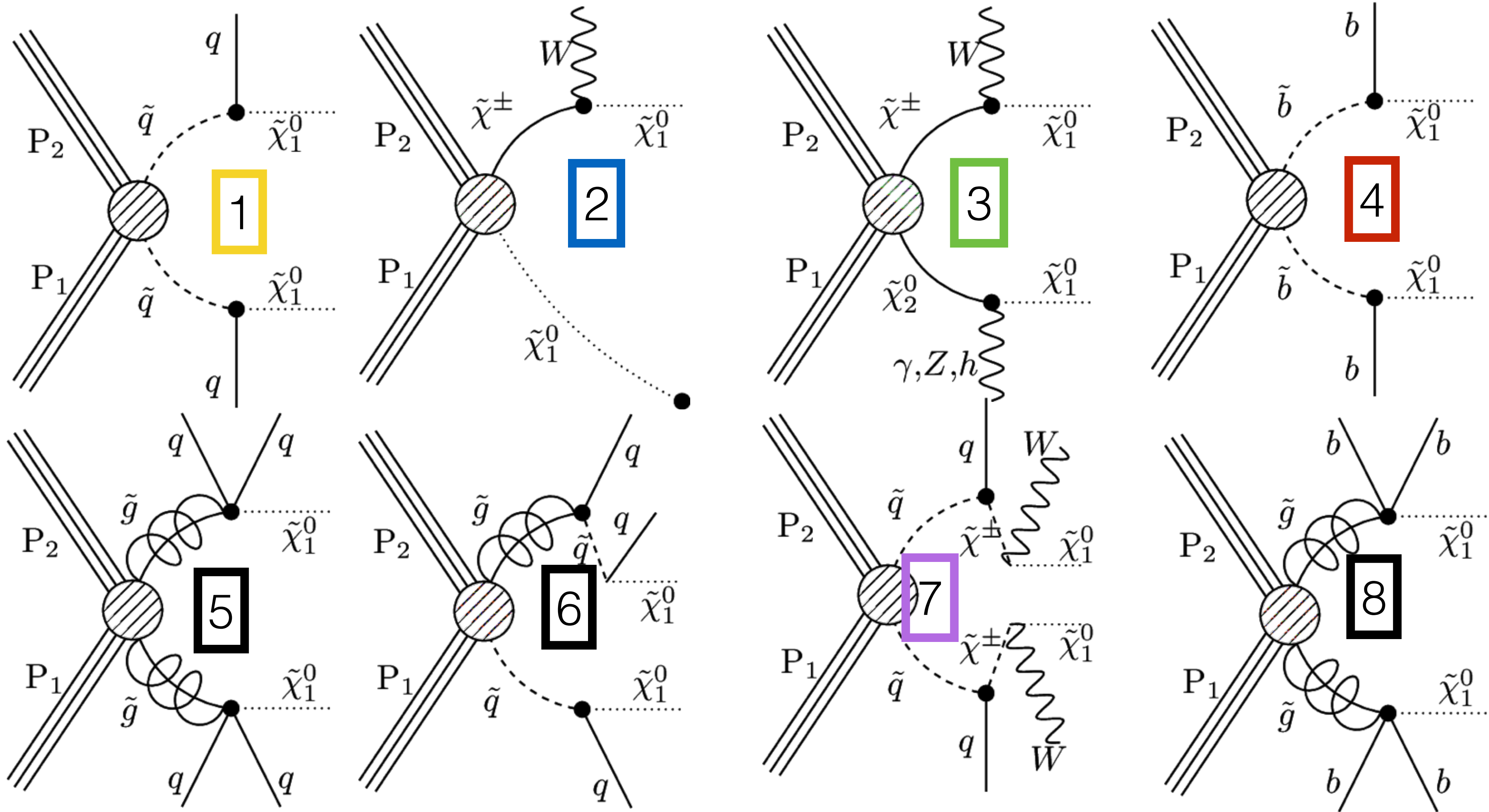
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Non-excluded parameter space

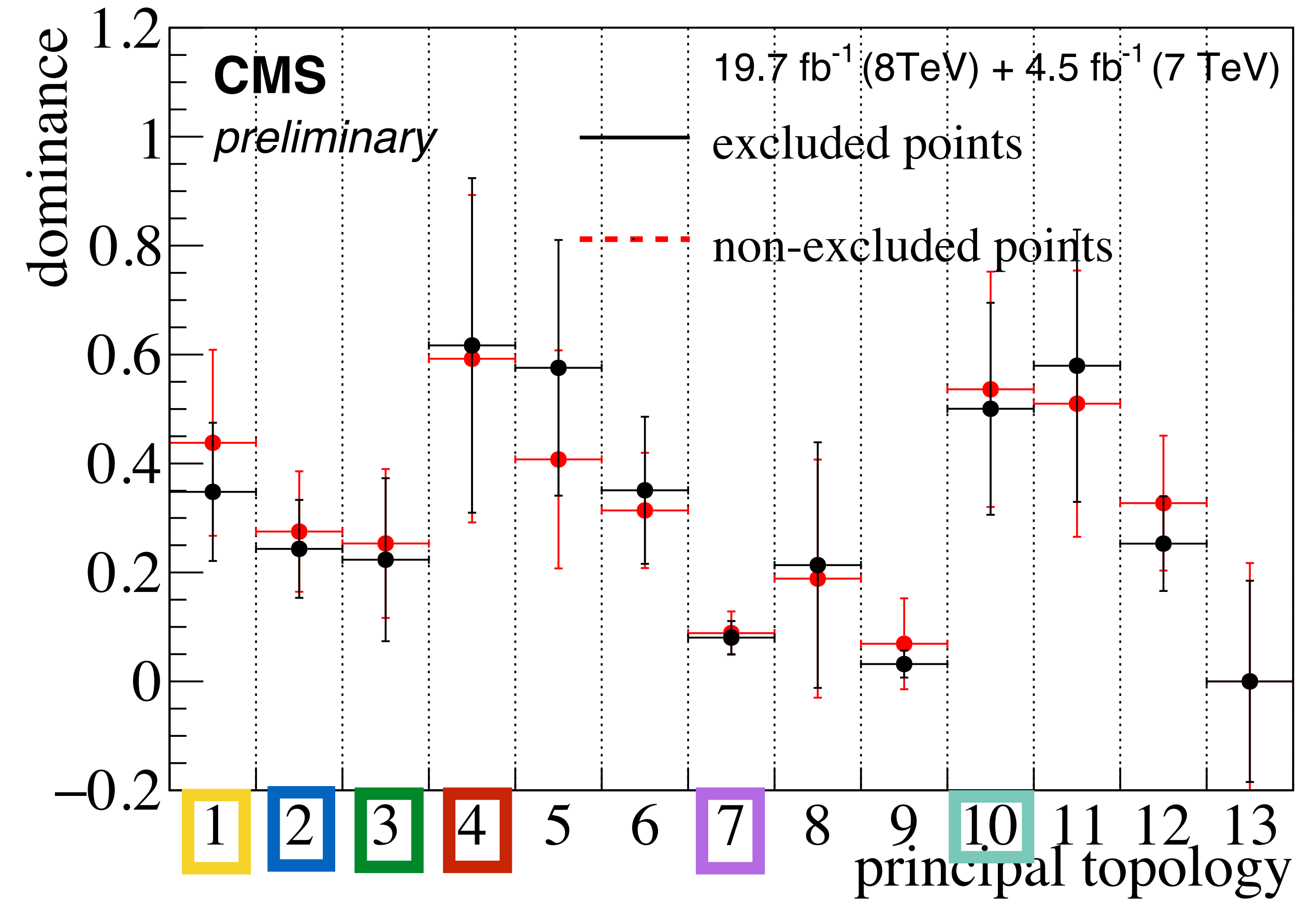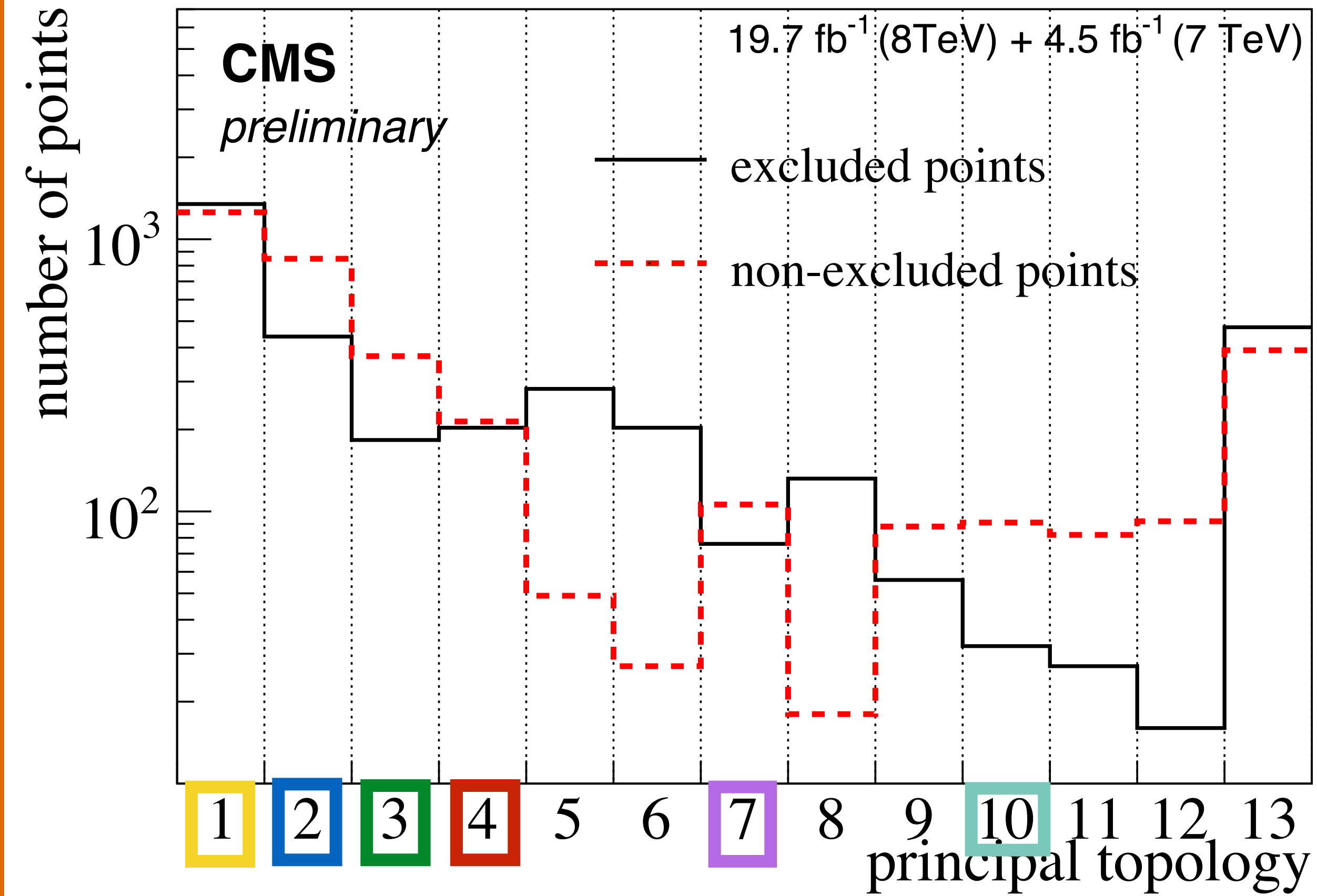Out of 7200 studied pMSSM points:

- ~3,500 points have been excluded by direct CMS SUSY searches

over 50% of the non-excluded points have a total production cross section greater than 10 fb.

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Principal topologies

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Principal topologies

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Idealized analysis

We establish a set of observables at the generator level:

jets: clustered ak5 gen particles

b-jets: jets associated to a b-hadron

leptons, photons: pT>5 GeV

HT: scalar sum of the hadronic activity

MET: magnitude of the vector sum of the visible particles

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Parallel Coordinates

CMS *preliminary*   19.7 fb⁻¹ (8TeV) + 4.5 fb⁻¹ (7 TeV)
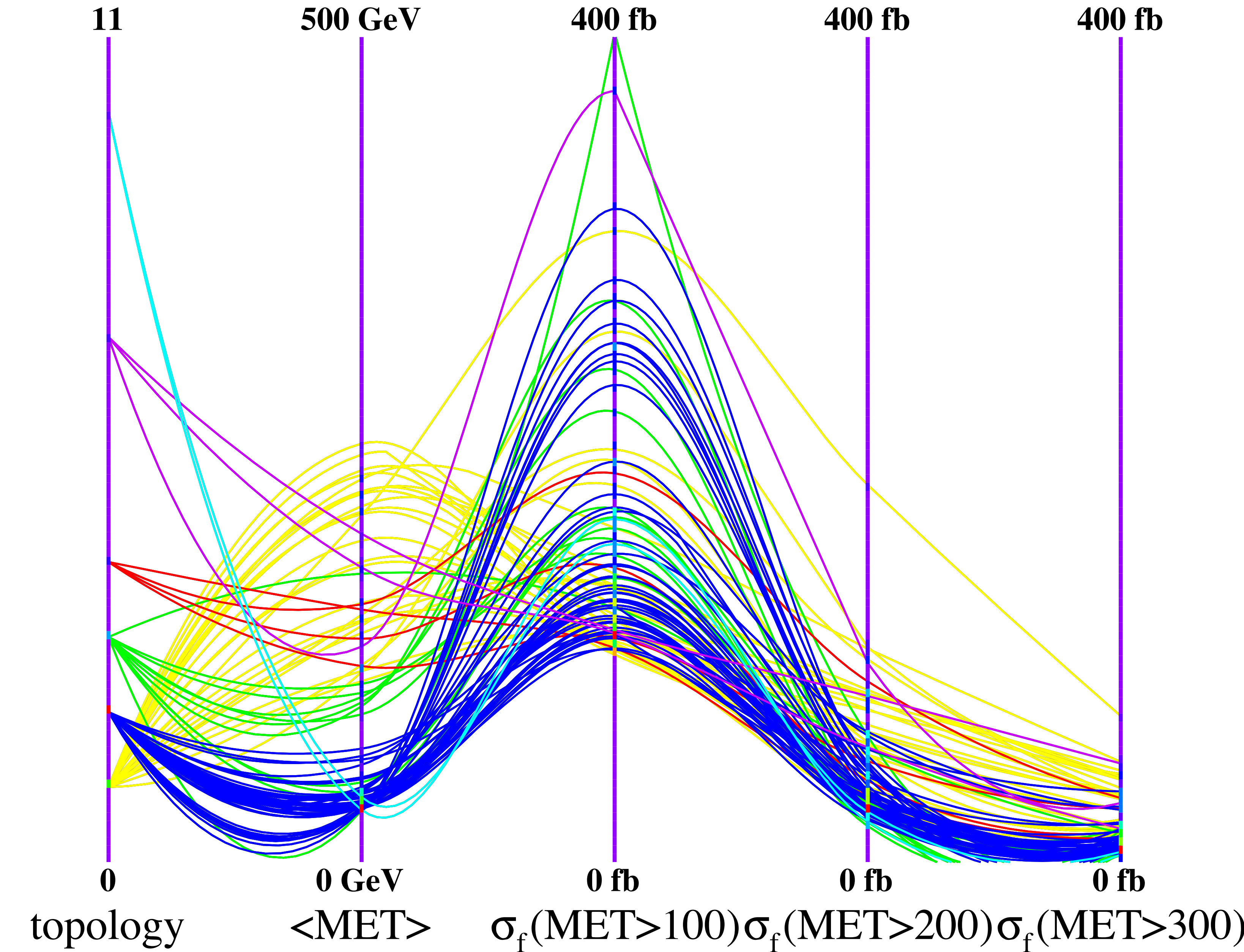
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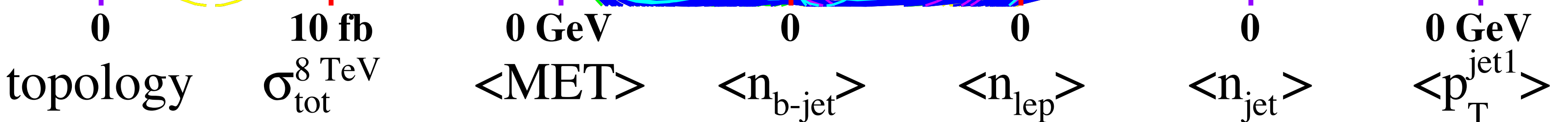
Fiducial cross section

$$\sigma_f^{SUSY} = \sigma_{tot}^{SUSY} A$$

fraction of events passing set of
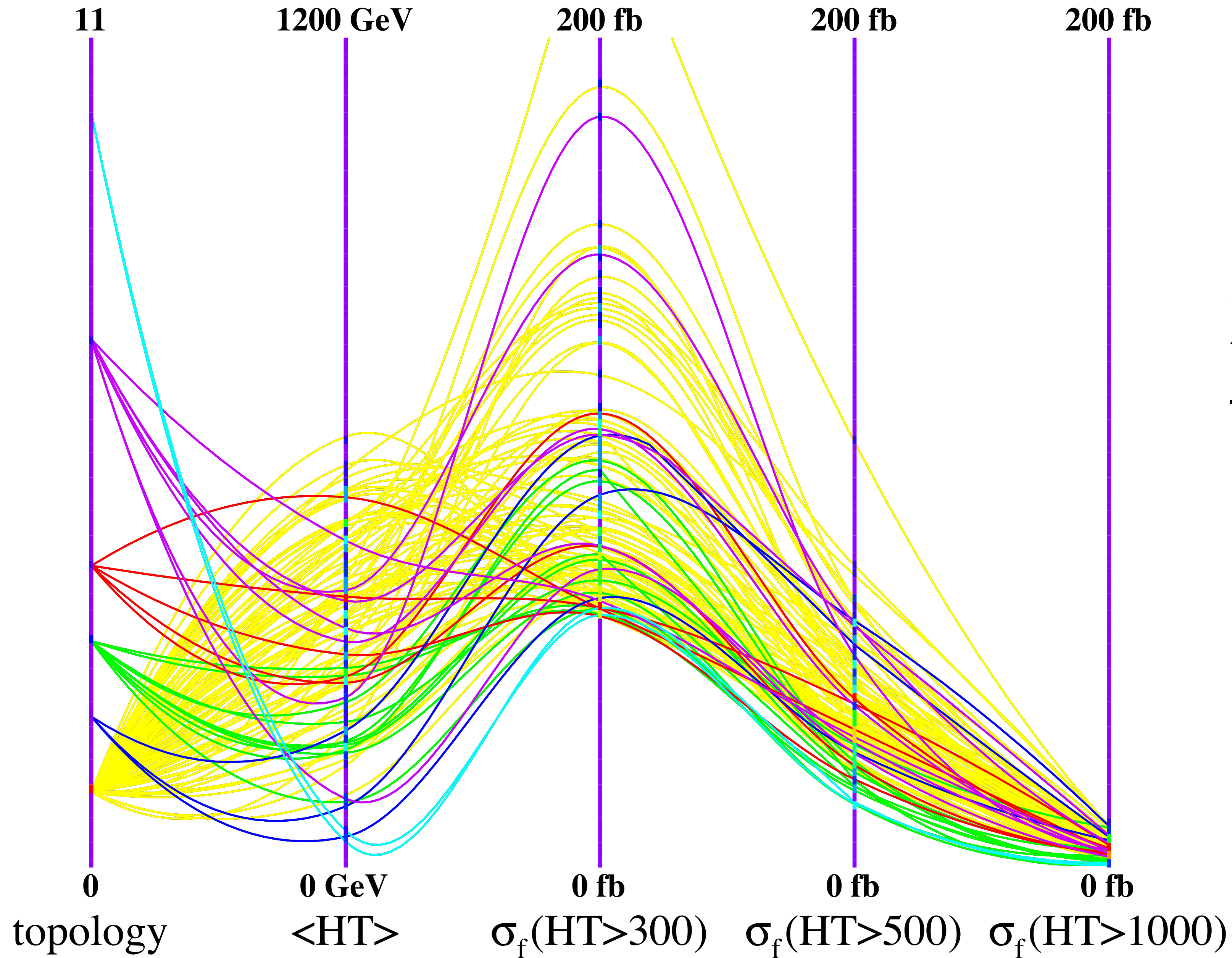event level criteria

Calculated once per model point

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CMS *preliminary*

MET

x10 increases in fiducial cross sections possible.

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Conclusion

- we have investigated the impact of a set of 7 and 8 TeV SUSY searches on the pMSSM

- gluino masses below 500 GeV are excluded

- low mass LSPs cannot be ruled out

- the topological composition of the non-excluded points has been evaluated

- fiducial cross section studies suggest new analysis strategies

CMS PAS SUS-13-020

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Backup

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Posterior Density

$$p(\theta|Data^{CMS}) \propto L(Data^{CMS}|\theta)\Pi(\theta)$$

- Expected signal counts estimated by simulation for each signal region

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Determinants of the Prior

i	Observable $\mu_j(\theta)$	Constraint D_j^{preCMS}	Likelihood function $L(D_j^{\text{preCMS}}|\mu_j(\theta))$
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
2a	$BR(B_s \to \mu\mu)$	observed CLs curve from	$d(1-CLs)/dx$
2b	$BR(B_s \to \mu\mu)$	$3.2^{+1.5}_{-1.2} \times 10^{-9}$	2-sided Gaussian
3	$R(B_u \to \tau\nu)$	1.63 ± 0.54	Gaussian
4	Δa_μ	$(26.1 \pm 8.0^{\text{exp}} \pm 10.0^{\text{th}}) \times 10^{-10}$	Gaussian
5	m_t	$173.3 \pm 0.5^{\text{stat}} \pm 1.3^{\text{sys}}$ GeV	Gaussian
6	$m_b(m_b)$	$4.19^{+0.18}_{-0.06}$ GeV	Two-sided Gaussian
7	$\alpha_s(M_Z)$	0.1184 ± 0.0007	Gaussian
8a	m_h	pre-LHC: $m_h^{low} = 112$	1 if $m_h \geq m_h^{low}$ 0 if $m_h < m_h^{low}$
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 $m_h > m_h^{up}$
9	sparticle masses	LEP via micrOMEGAs	1 if allowed 0 if excluded
10	prompt $\tilde{\chi}_1^\pm$	$c\tau(\tilde{\chi}_1^\pm) < 10$ mm	1 if allowed 0 if excluded

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