News from the MasterCode

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based on collaboration with
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1. Introduction

2. Flavor in the MasterCode

3. Conclusions

1. Introduction

Indirect constraints on M_{SUSY} from existing data?

- Electroweak precision observables (EWPO) ?
- B physics observables (BPO) ?
- Cold dark matter (CDM) ?

$\Rightarrow$ combination of EWPO, BPO, CDM ?

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  $\Rightarrow$ combination of EWPO, BPO, CDM ?

EWPO M_W : information on $m_{\tilde{t}}$, $m_{\tilde{b}}$ or M_A, $\tan\beta$ or . . .

EWPO $(g-2)_\mu$: information on $\tan\beta$ and/or $m_{\tilde{\chi}^0}$, $m_{\tilde{\chi}^\pm}$ and/or $m_{\tilde{\mu}}$, $m_{\tilde{\nu}_\mu}$

BPO $\text{BR}(b \to s\gamma)$: information on $\tan\beta$ and/or $M_{H^\pm}$ and/or $m_{\tilde{t}}$, $m_{\tilde{\chi}^\pm}$

CDM (LSP gives CDM) : information on $m_{\tilde{\chi}^0_1}$ and $m_{\tilde{\tau}}$ or M_A or . . .

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BPO BR$(b \to s\gamma)$: information on $\tan\beta$ and/or $M_{H^\pm}$ and/or $m_{\tilde{t}}$, $m_{\tilde{\chi}^\pm}$

CDM (LSP gives CDM) : information on $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$ or M_A or ...

$\Rightarrow$ combination makes only sense if all parameters are connected!
$\Rightarrow$ GUT based models, ...

Existing analyses for GUT based models: (involving precision observables)

CMSSM/mSUGRA:

[*J. Ellis, S.H., K. Olive, G. Weiglein '04, '06, '07*] [*J. Ellis, S.H., K. Olive, A. Weber, G. Weiglein '07*]

[*E. Baltz, P. Gondolo '04*]

[*R. de Austri, R. Trotta and L. Roszkowski '06, '07*]

[*B. Allanach, C. Lester and A. Weber '06, '07*]

[*O. Buchmueller et al. '07*] [*O. Buchmueller et al. '08*]

NUHM (Non-Universal Higgs Mass model):

[*J. Ellis, S.H., K. Olive, G. Weiglein '06*] [*J. Ellis, S.H., K. Olive, A. Weber, G. Weiglein '07*]

[*J. Ellis, T. Hahn, S.H., K. Olive, G. Weiglein '07*]

[*L. Roszkowski, R. de Austri, R. Trotta, Y. Tsai, T. Varley '09*]

VCMSSM (Very Constrained MSSM):

[*J. Ellis, S.H., K. Olive, G. Weiglein '06*]

mSUGRA (GDM) (Gravitino Dark Matter):

[*J. Ellis, S.H., K. Olive, G. Weiglein '06*]

CMSSM, mGMSB, mAMSB:

[*S.H., X. Miao, S. Su, G. Weiglein '08*]

Finite Unified Theories:

[*S.H., M. Mondragón, G. Zoupanos '07*]

Different methods:

1.) Scanning:

– 3-dim scans (possibly with CDM fixing one dimension)

[J. Ellis, T. Hahn, SH, K. Olive, A. Weber, G. Weiglein '04, '06, '07]

– multi-dim scans

[O. Buchmueller et al. '07] [S.H., X. Miao, S. Su, G. Weiglein '08]

– multi-dim scans (with Markov Chain Monte Carlo technique)

[E. Baltz, P. Gondolo '04] [R. de Austri, R. Trotta and L. Roszkowski '06, '07]

[B. Allanach, C. Lester and A. Weber '06, '07] [O. Buchmueller et al. '08]

⇒ here: results using last two

2.) Fitting:

– Frequentist

[J. Ellis, T. Hahn, SH, K. Olive, A. Weber, G. Weiglein '04, '06, '07]

[O. Buchmueller et al. '07, '08] [S.H., X. Miao, S. Su, G. Weiglein '08]

– Bayesian

[R. de Austri, R. Trotta and L. Roszkowski '06, '07 . . . et al. '09]

[B. Allanach, C. Lester and A. Weber '06, '07]

⇒ focus on Frequentist here

3.) Priors . . . (flat)

The "MasterCode"

⇒ collaborative effort of theorists and experimentalists

[*Buchmüller, Cavanaugh, De Roeck, Ellis, Flächer, SH, Isidori, Olive, Paradisi, Ronga, Weiglein*]

Über-code for the combination of different tools:

– tools are included as subroutines

– compatibility ensured by collaboration of
authors of "MasterCode" and authors of "sub tools" /SLHA(2)

– one "MasterCode" for one model . . .

⇒ evaluate observables of one parameter point consistently
with various tools

Example: flavor observables and high p_T observables
can be combined

⇒ MAIN POINT of the 2. LHC/Flavor workshop!?

Status of the "MasterCode" :

- one model: (MFV) MSSM
- tools included:
  - B-physics observables [*Isidori, Paradisi*]
  - more B-physics observables [*SuperIso*]
  - Higgs related observables, $(g-2)_\mu$ [*FeynHiggs*]
  - Electroweak precision observables [*FeynWZ (SUSYPope)*]
  - Dark Matter observables [*MicrOMEGAs, DarkSUSY*]
  - for GUT scale models: RGE running [*SoftSusy*]
- added: χ^2 analysis code

  (→ similar directions as SFitter, Fittino)
- currently being implemented:
  - Higgs constraints (for χ^2 contributions . . .) [*HiggsBounds*]
- planned: inclusion of more tools

  inclusion of more models

The models: 1.) CMSSM (or mSUGRA):

⇒ Scenario characterized by

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \mathrm{sign}\,\mu$$

m_0 : universal scalar mass parameter

$m_{1/2}$: universal gaugino mass parameter

A_0 : universal trilinear coupling

} at the GUT scale

$\tan\beta$: ratio of Higgs vacuum expectation values

$\mathrm{sign}(\mu)$: sign of supersymmetric Higgs parameter

⇒ particle spectra from renormalization group running to weak scale

The models: 2.) NUHM1: (Non-universal Higgs mass model)

Assumption: no unification of scalar fermion and scalar Higgs parameter at the GUT scale

⇒ effectively M_A or μ as free parameters at the EW scale

> ⇒ besides the CMSSM parameters
>
> M_A or μ

Further extension: NUHM2:

Assumption: no unification of the Higgs parameters at the GUT scale

⇒ effectively M_A and μ as free parameters at the EW scale

> ⇒ besides the CMSSM parameters
>
> M_A and μ

2. Flavor in the MasterCode

– combine all electroweak precision data as in the SM
– combine with B/K physics observables → T
– combine with CDM and $(g-2)_\mu$
– include SM parameters with their errors: m_t, M_Z, $\Delta\alpha_{\rm had}$

$\Rightarrow \chi^2$ function

→ scan over the full CMSSM/NUHM1 parameter space

$\sim 2.5\ 10^7$ points samples with MCMC

(comparison: L.R. et al.: $0.04\ 10^7$ points)

statistical measure: χ^2 function (Frequentist, no priors)

→ final minimum: Minuit

$\Delta\chi^2$: 68, 95% C.L. contours

$\Rightarrow$ preferred CMSSM/NUHM1 parameters
$\Rightarrow$ LHC/ILC/Flavor exp. reach

B/K physics observables in the MasterCode

1. BR($b \to s\gamma$)

2. BR($B_s \to \mu^+\mu^-$)

3. ΔM_s

4. R($\Delta M_s/\Delta M_d$)

5. BR($B_u \to \tau\nu_\tau$)

6. BR($B \to X_x\ell^+\ell^-$)

7. R($K \to \ell\nu$)

8. R(ΔM_K)

$\Rightarrow$ largest impact: (1) and (2)

Best-fit points:

CMSSM:

$m_{1/2} = 310$ GeV, $m_0 = 60$ GeV, $A_0 = 240$ GeV,

$\tan\beta = 11$, $\mu = 380$ GeV, $M_A = 410$ GeV

$\chi^2/N_{\rm dof} = 20.4/19$ (37.3 % probability)

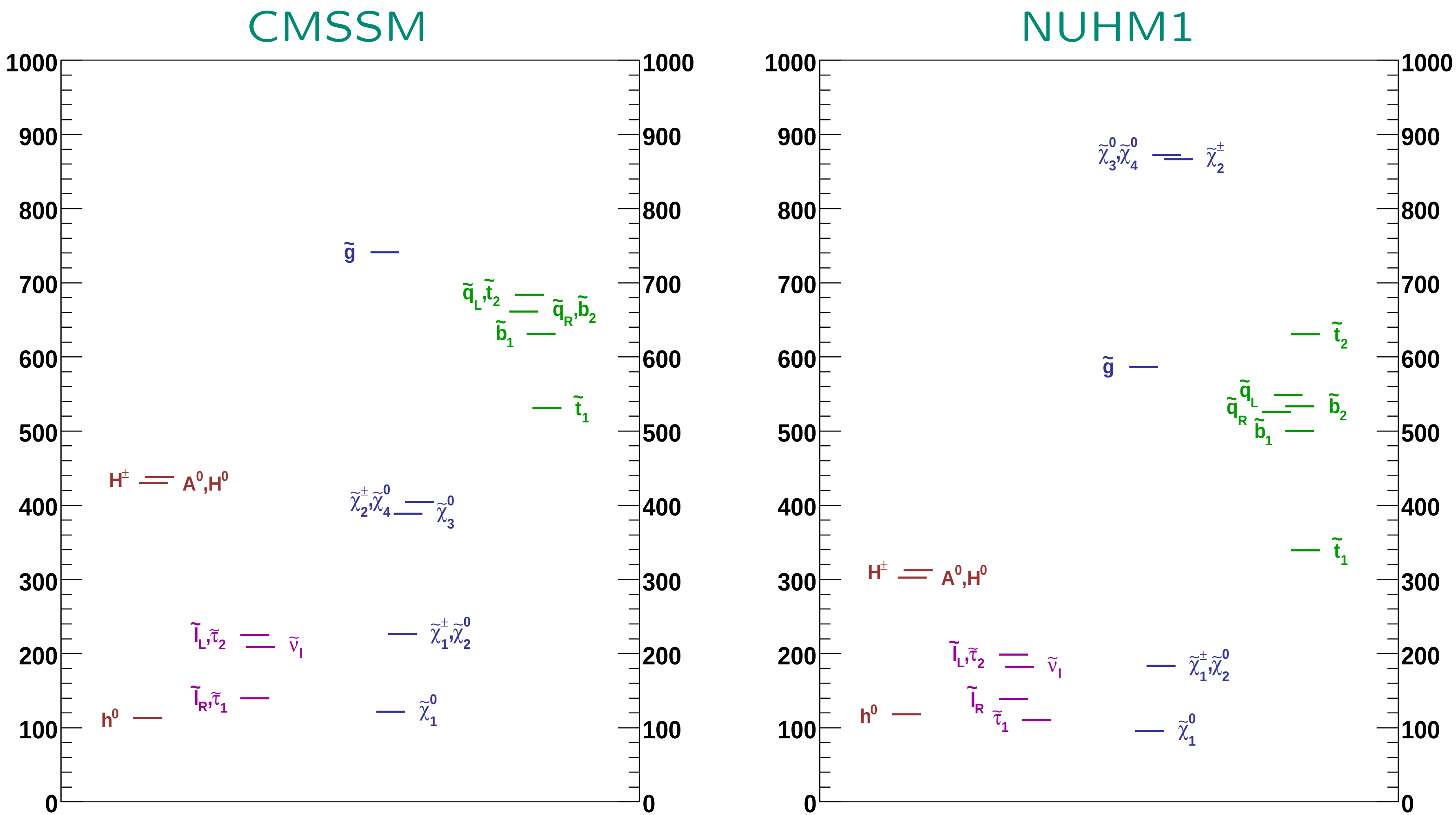
$\Rightarrow$ very similar to SPS 1a :-)

NUHM1:

$m_{1/2} = 240$ GeV, $m_0 = 100$ GeV, $A_0 = -930$ GeV,

$\tan\beta = 7$, $\mu = 870$ GeV, $M_A = 300$ GeV

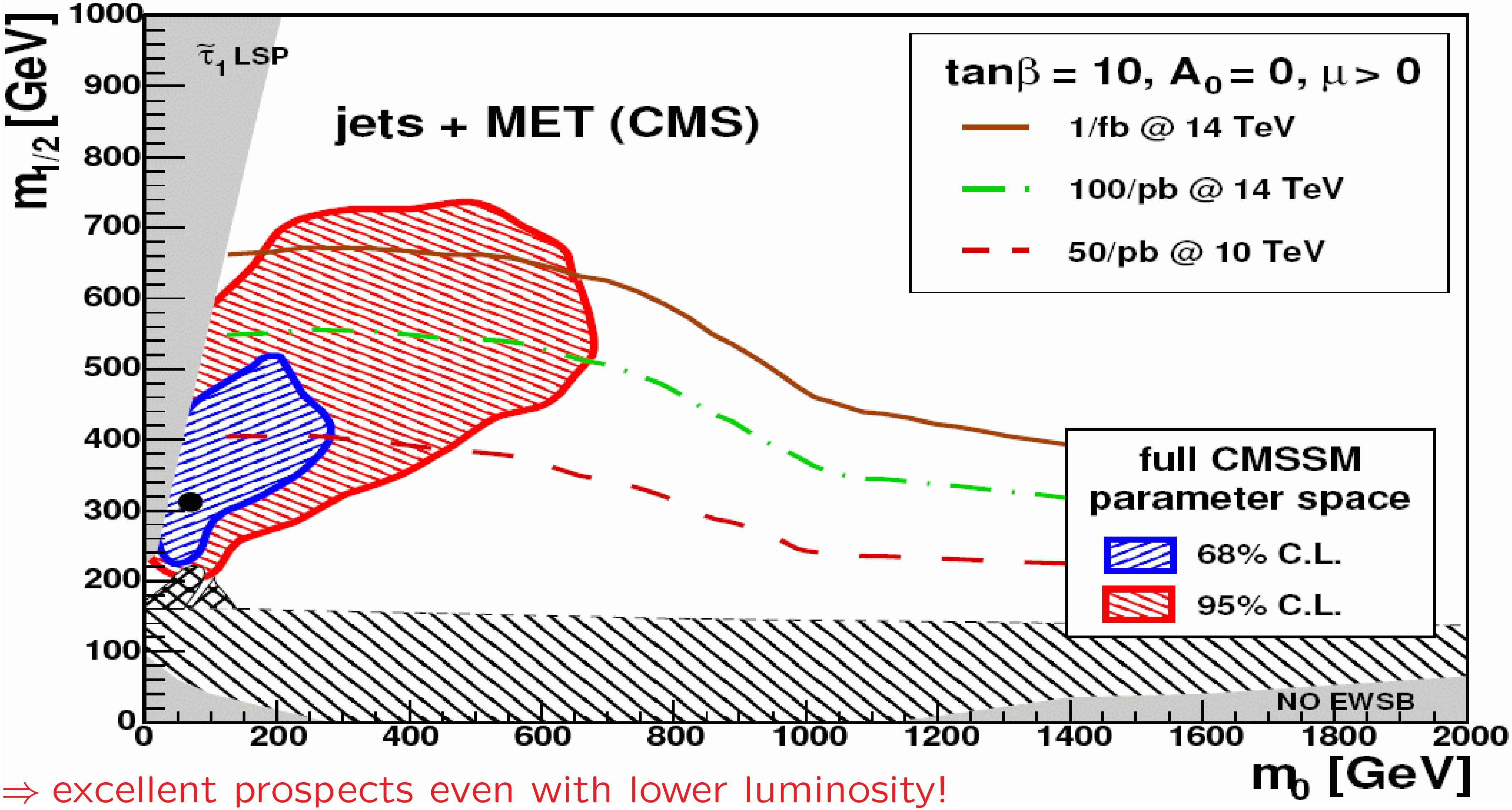
(39 % probability)



⇒ largely accessible spectrum for LHC and ILC

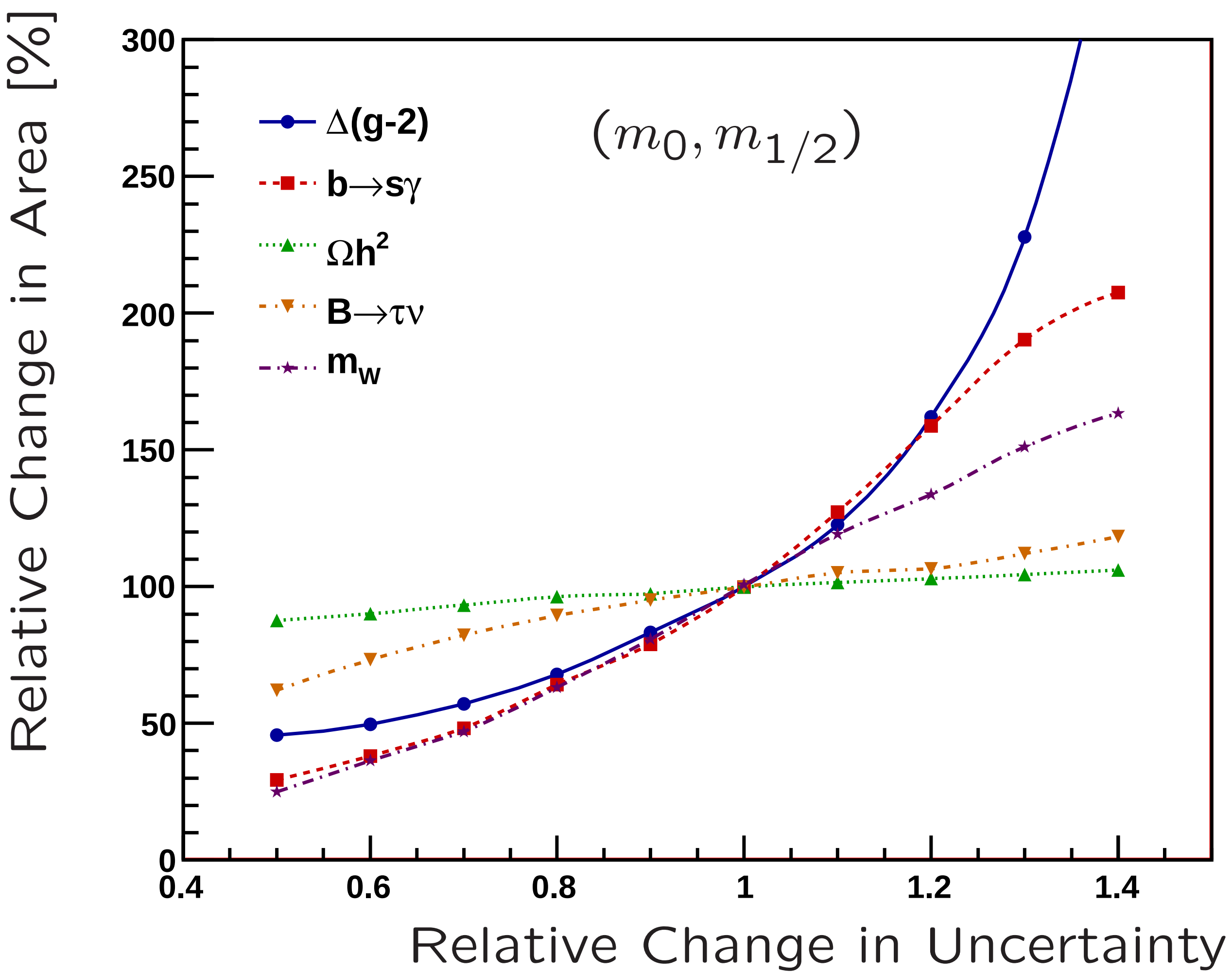
LHC (CMS):

[*MasterCode '08*] [*CMS '07*]



⇒ excellent prospects even with lower luminosity!

Impact of B physics observables (CMSSM): [*MasterCode '08*]



⇒ strong impact of BR($b \to s\gamma$)

⇒ moderate impact of BR($B_u \to \tau\nu_\tau$)
(but more potential for improvement?)

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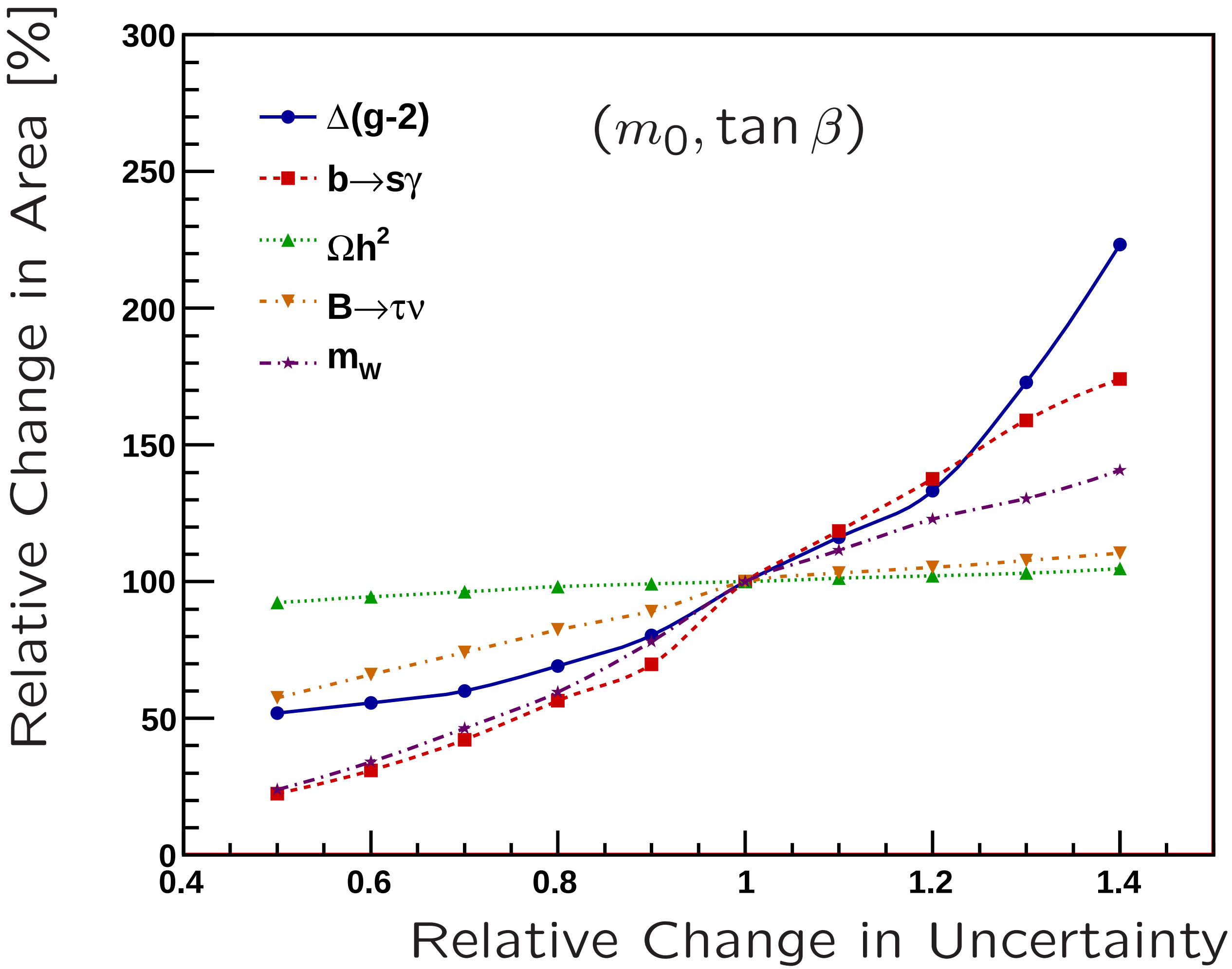

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Predictions for BR($B_s \to \mu^+\mu^-$):

[*MasterCode '09 PRELIMINARY*]

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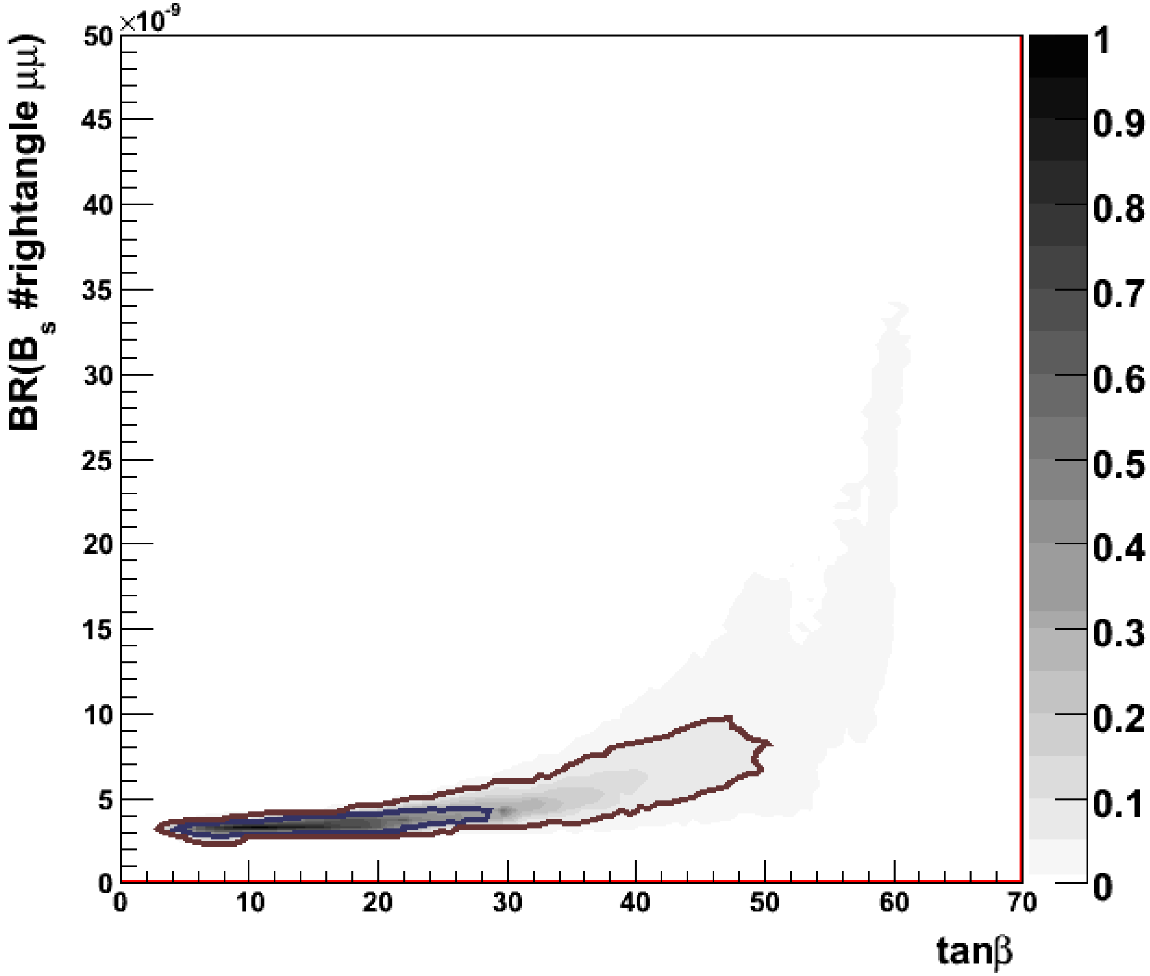
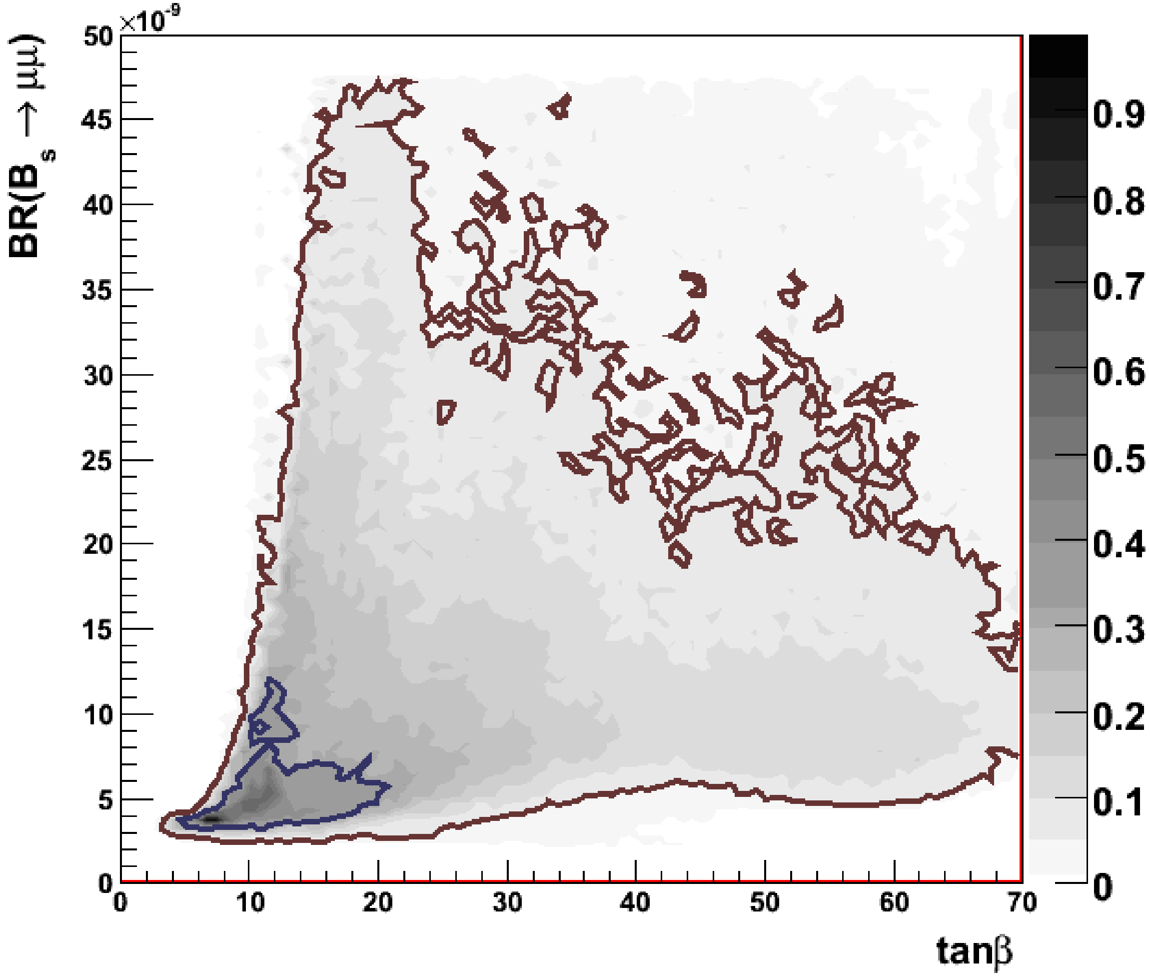


⇒ similar to SM

⇒ accessible at LHCb

Predictions for BR($B_s \to \mu^+\mu^-$): [MasterCode '09 PRELIMINARY]

NUHM1:



⇒ much larger than in the CMSSM possible

⇒ accessible at the Tevatron(?)/LHCb

3. Conclusinos

- Idea: Predict most probable MSSM parameter regions using existing data: EWPO, B/KPO, CDM, . . .

- Models: CMSSM, NUHM1

- statistical measure: χ^2 function (Frequentist, no priors)
  $\sim 2.5\ 10^7$ points samples with MCMC
  $\Delta\chi^2$: 68, 95% C.L. contours

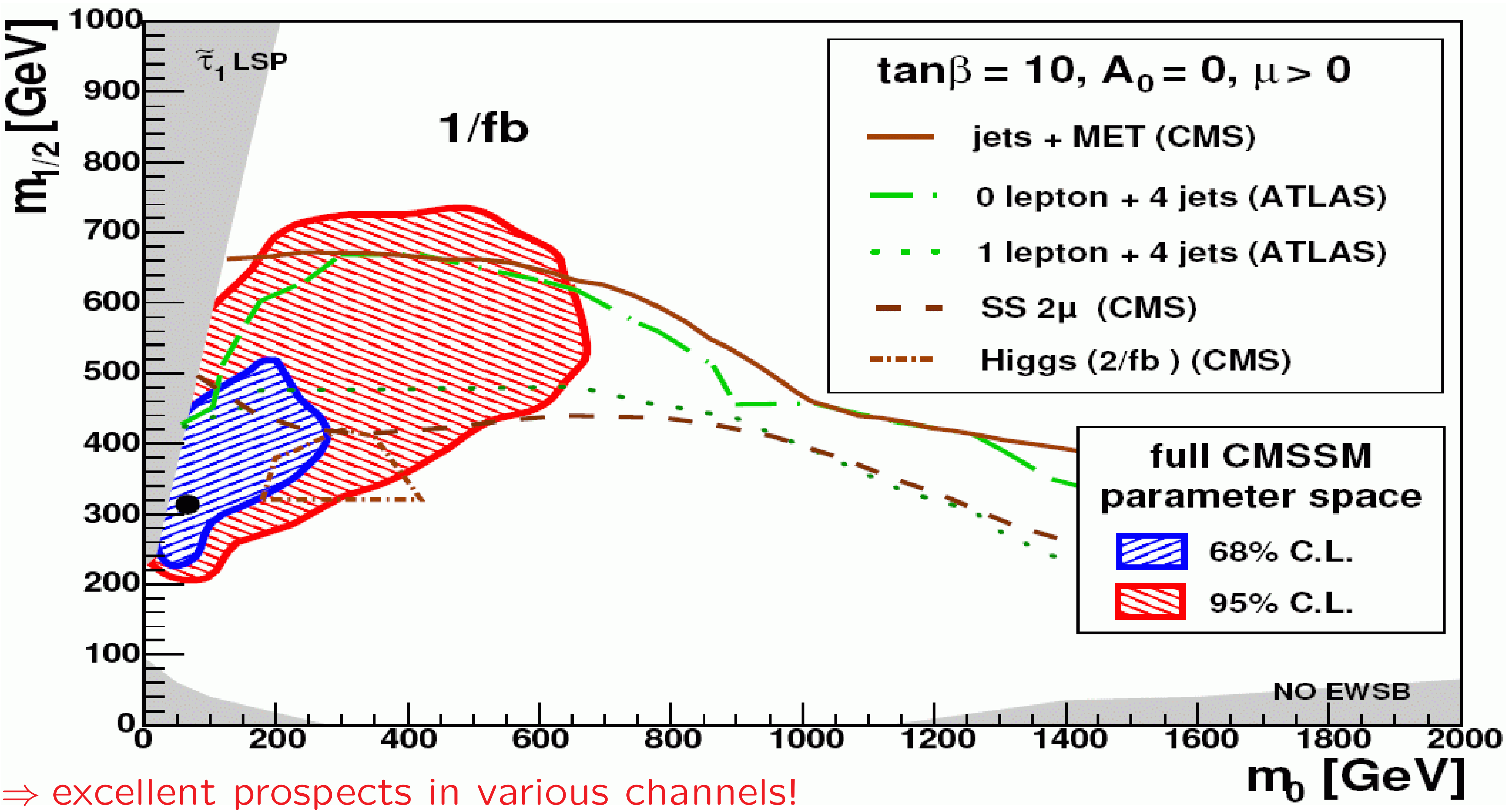
- Area in the $(m_0, m_{1/2})$ plane: (CMSSM)
  $\Rightarrow$ strong impact of BR$(b \to s\gamma)$
  $\Rightarrow$ moderate impact of BR$(B_u \to \tau\nu_\tau)$
  (but more potential for improvement?)

- Prediction for BR$(B_s \to \mu^+\mu^-)$:
  CMSSM: similar to SM $\Rightarrow$ accessible at LHCb
  NUHM1: much larger than CMSSM
  $\Rightarrow$ accessible at the Tevatron/LHCb

Back-up

LHC (CMS) reach with 1 fb^{-1}:

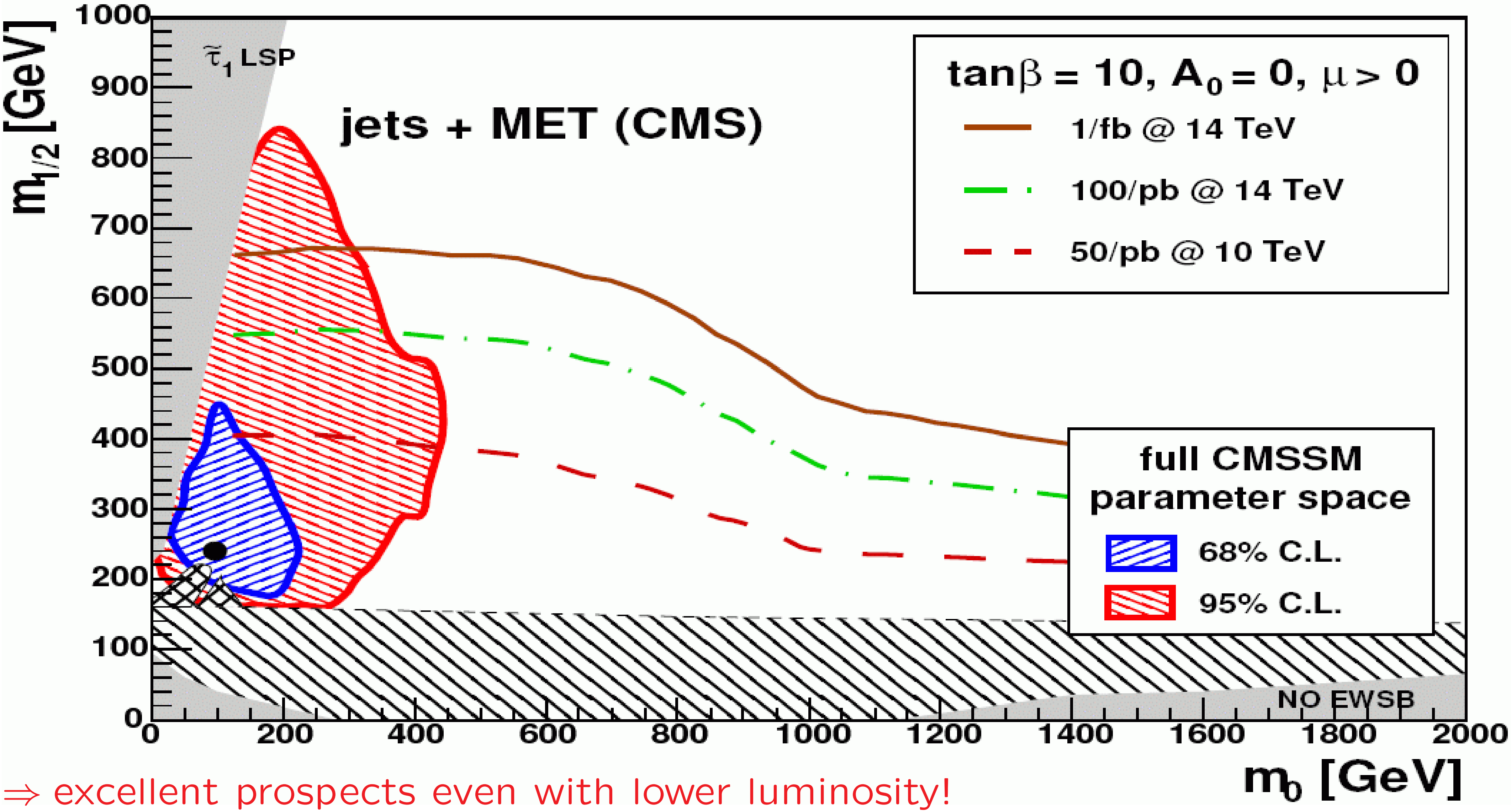
[*CMS '07*]



⇒ excellent prospects in various channels!

LHC (CMS): NUHM1 analysis

[*MasterCode '08*] [*CMS '07*]



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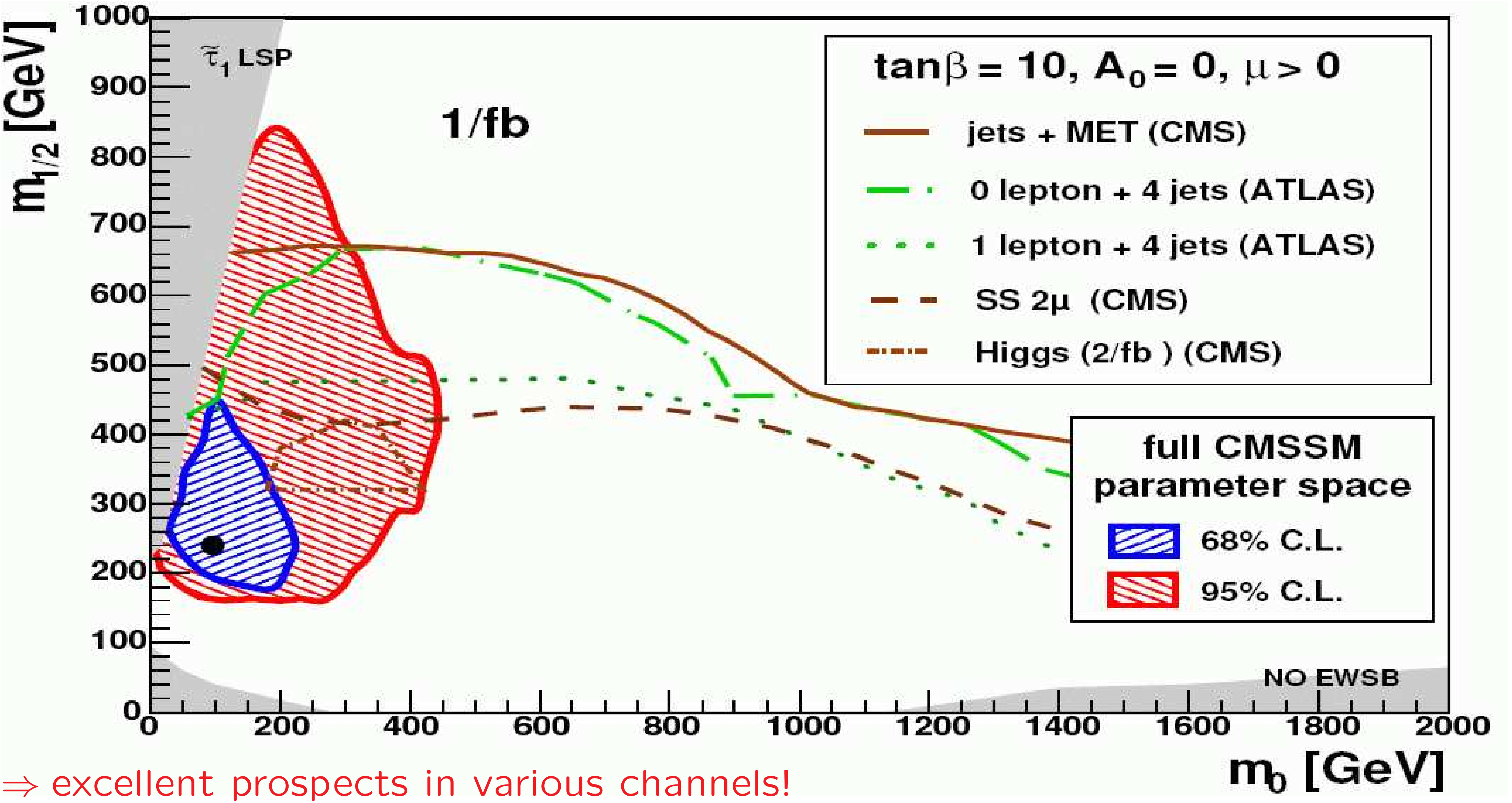

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