

News from the MasterCode

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CERN, 03/2009

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) ?

⇒ combination of EWPO, BPO, CDM ?

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⇒ 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 $\text{BR}(b \rightarrow s\gamma)$: 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 ...

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

⇒ combination makes only sense if all parameters are connected!

⇒ 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, Flücher, 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

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

m_0 : universal scalar mass parameter

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

A_0 : universal trilinear coupling

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

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

} at the GUT scale

⇒ 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
- combine with CDM and $(g - 2)_\mu$
- include SM parameters with their errors: $m_t, M_Z, \Delta\alpha_{\text{had}}$

→ T

⇒ χ^2 function

→ scan over the full CMSSM/NUHM1 parameter space

~ $2.5 \cdot 10^7$ points samples with MCMC

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

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

→ final minimum: Minuit

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

⇒ preferred CMSSM/NUHM1 parameters

⇒ LHC/ILC/Flavor exp. reach

B/K physics observables in the MasterCode

1. $\text{BR}(b \rightarrow s\gamma)$
2. $\text{BR}(B_s \rightarrow \mu^+\mu^-)$
3. ΔM_s
4. $R(\Delta M_s/\Delta M_d)$
5. $\text{BR}(B_u \rightarrow \tau\nu_\tau)$
6. $\text{BR}(B \rightarrow X_x\ell^+\ell^-)$
7. $R(K \rightarrow \ell\nu)$
8. $R(\Delta M_K)$

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

Best-fit points:

CMSSM:

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

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

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

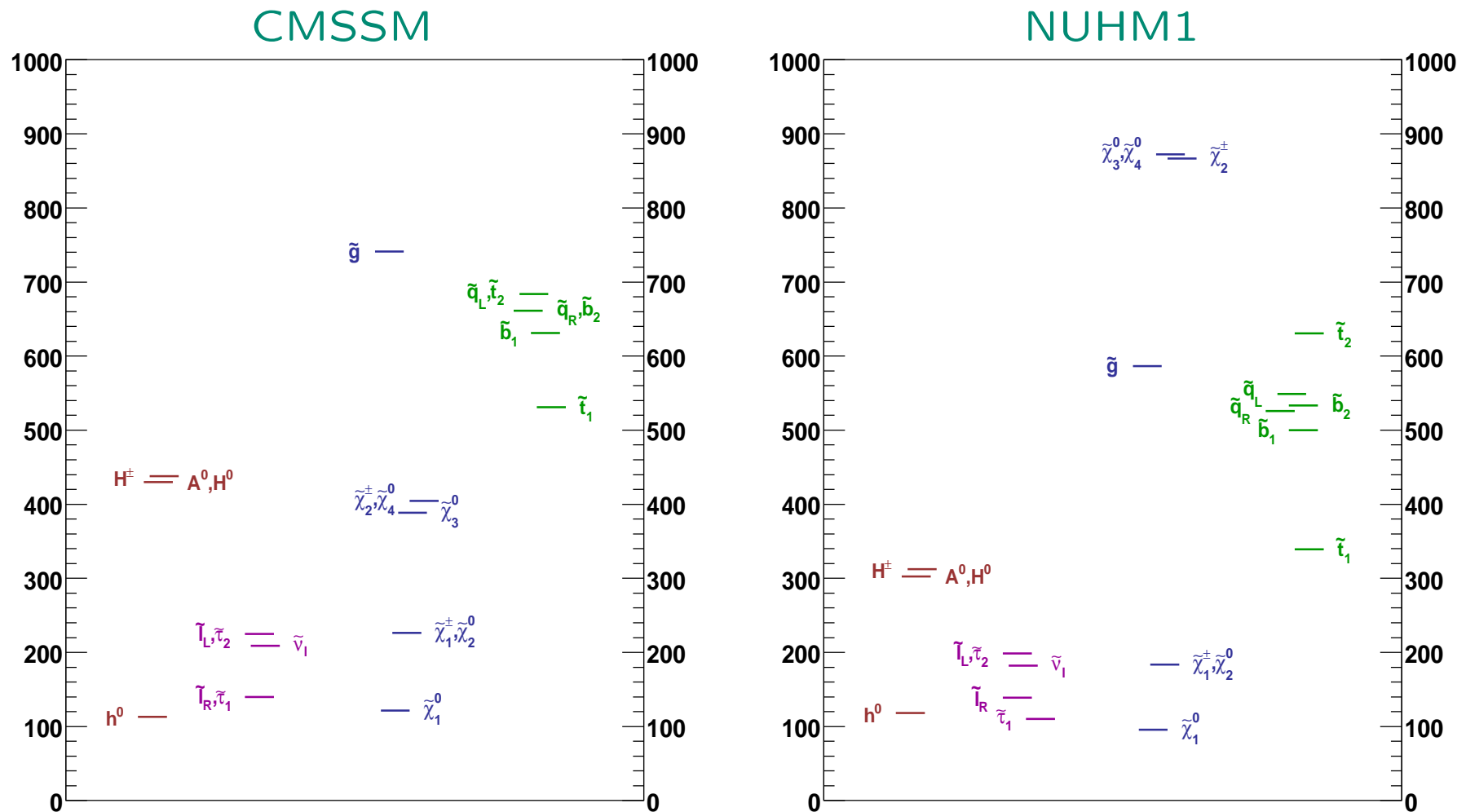
⇒ very similar to SPS 1a :-)

NUHM1:

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

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

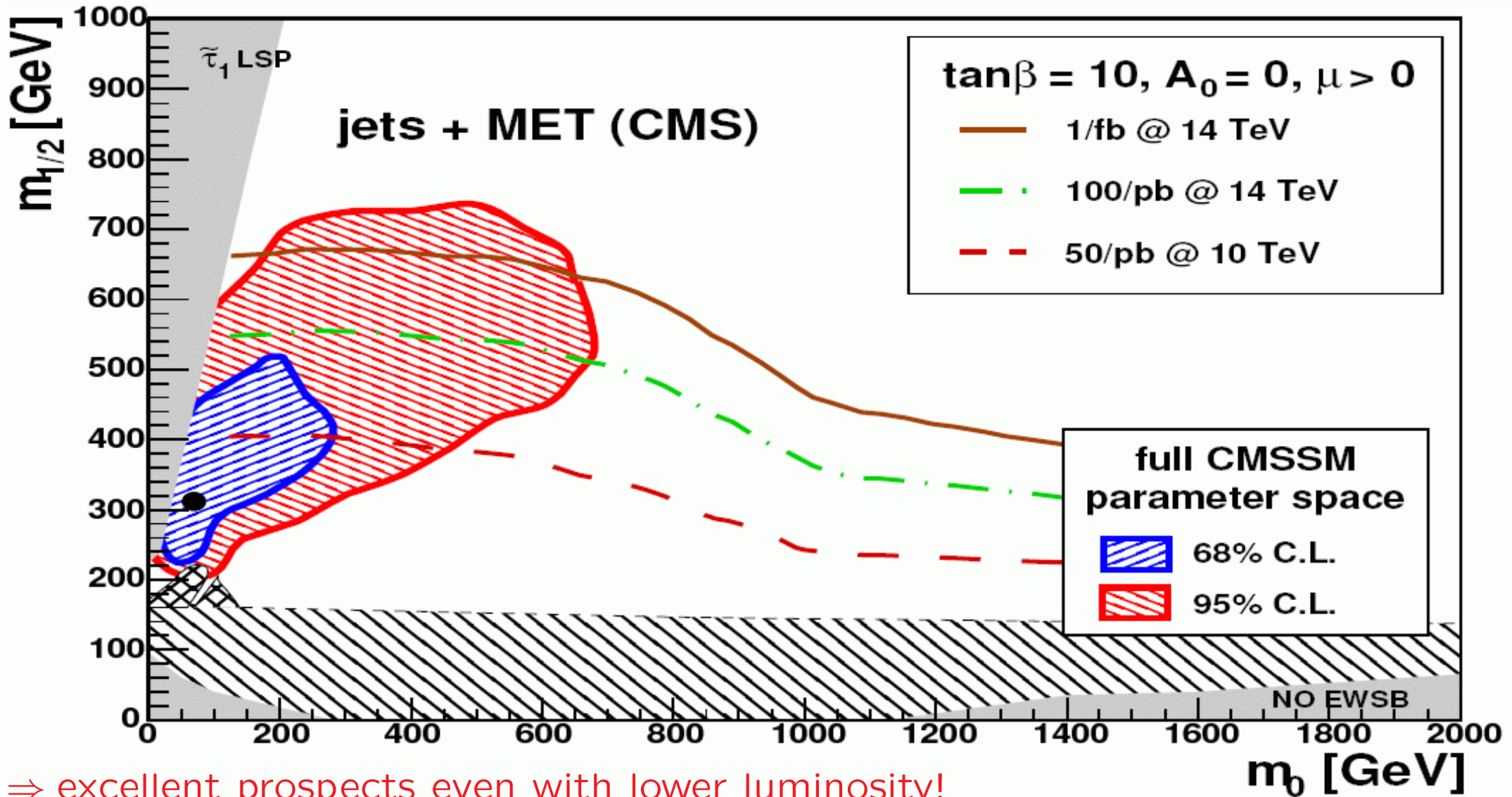
(39 % probability)



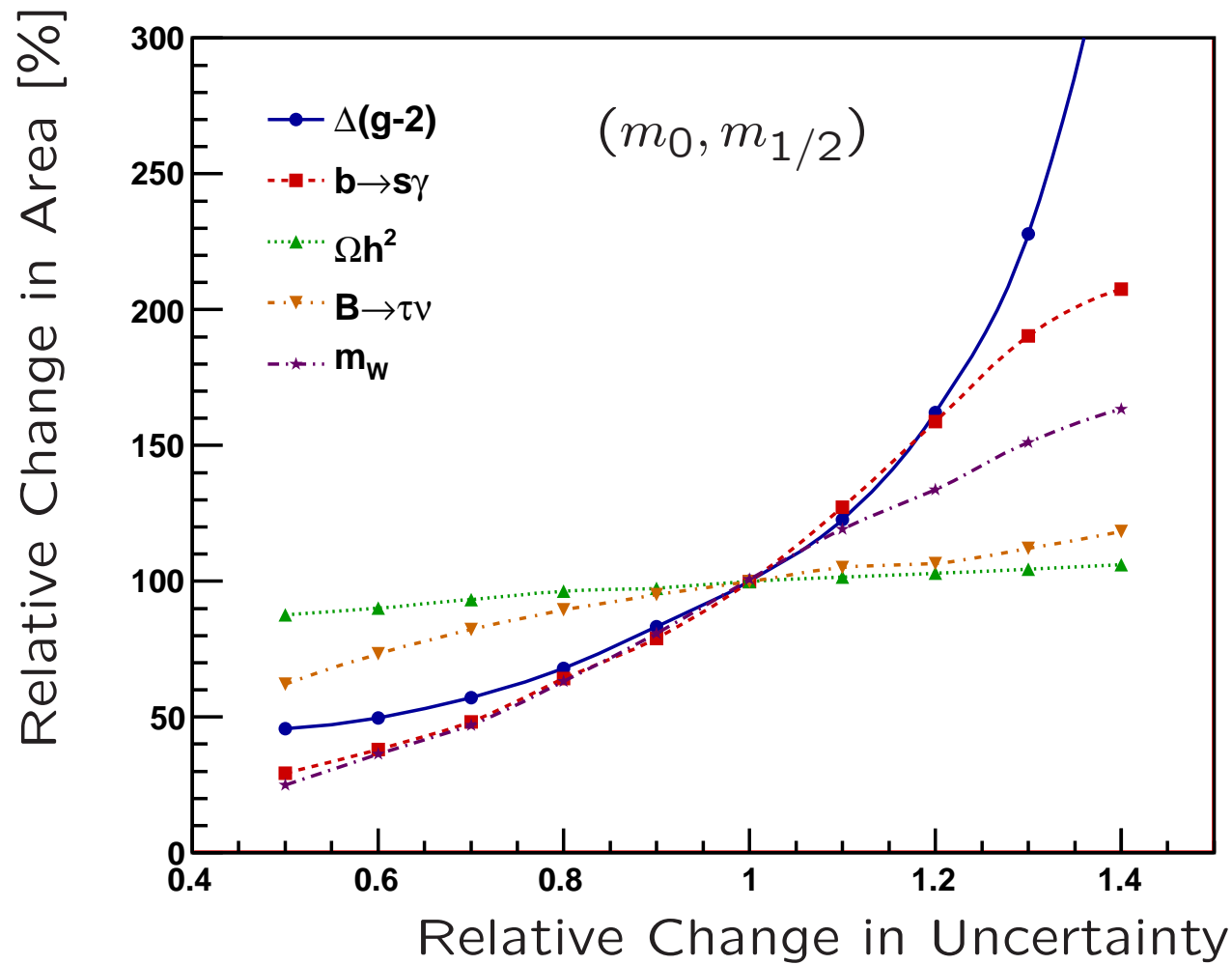
⇒ largely accessible spectrum for LHC and ILC

LHC (CMS):

[MasterCode '08] [CMS '07]



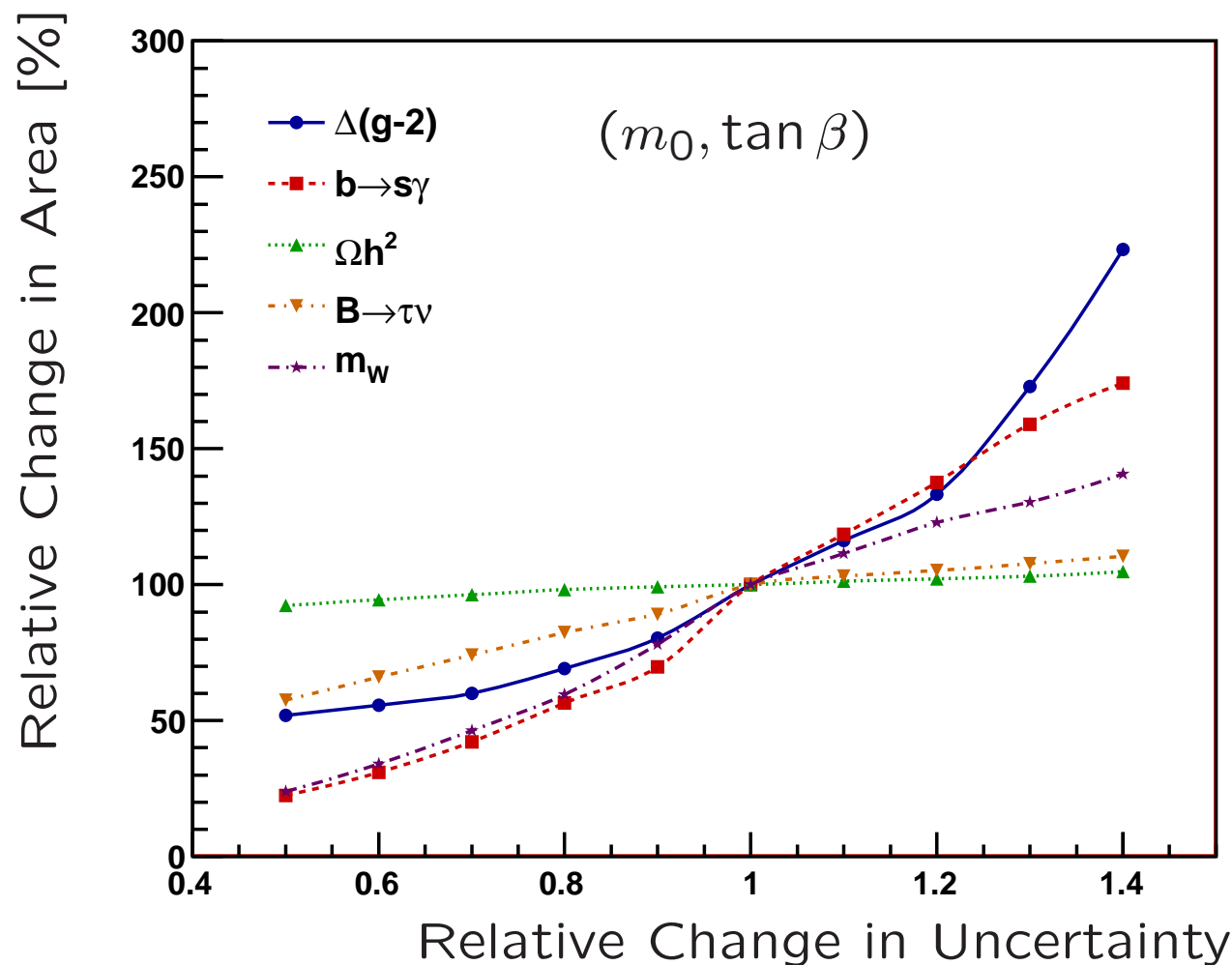
⇒ excellent prospects even with lower luminosity!



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

⇒ moderate impact of $BR(B_u \rightarrow \tau\nu_\tau)$

(but more potential for improvement?)

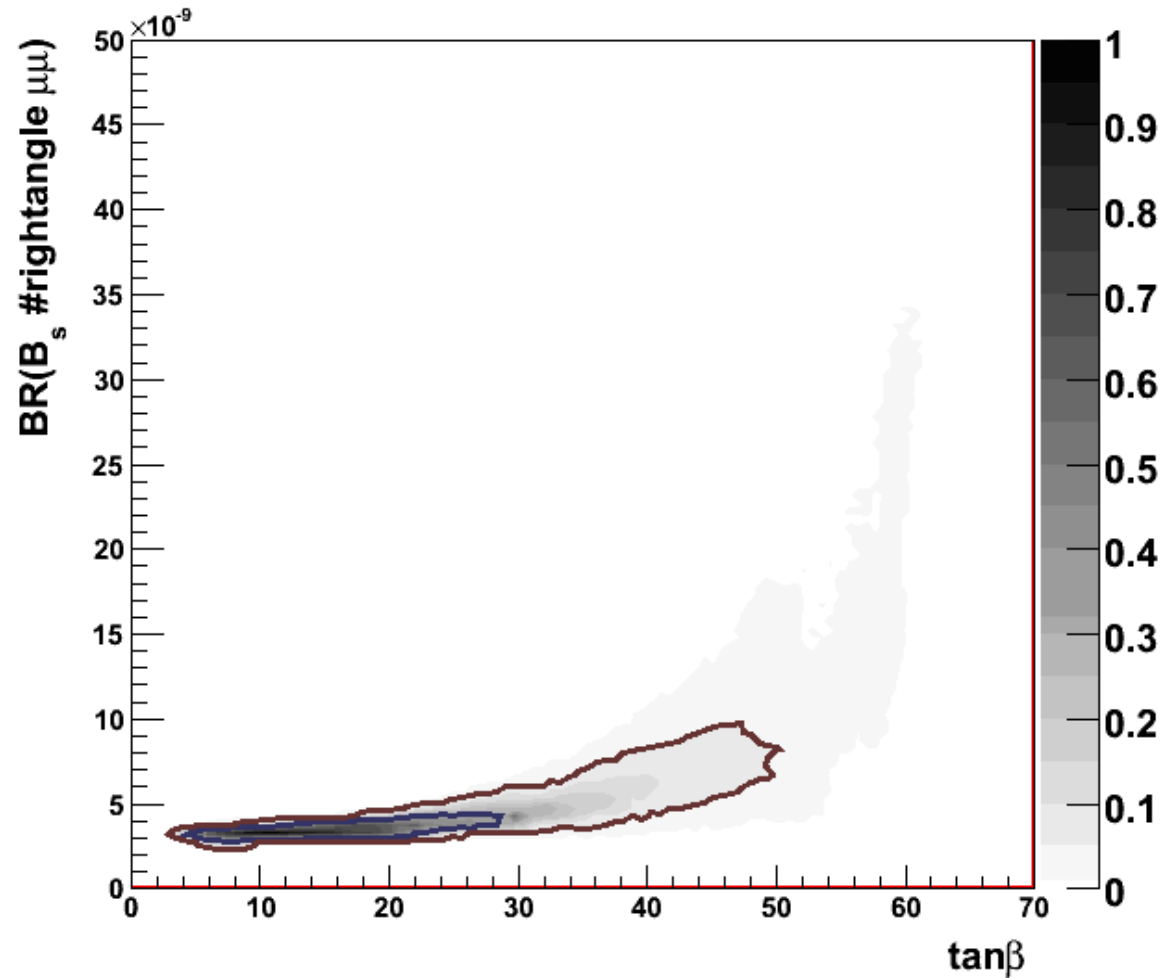


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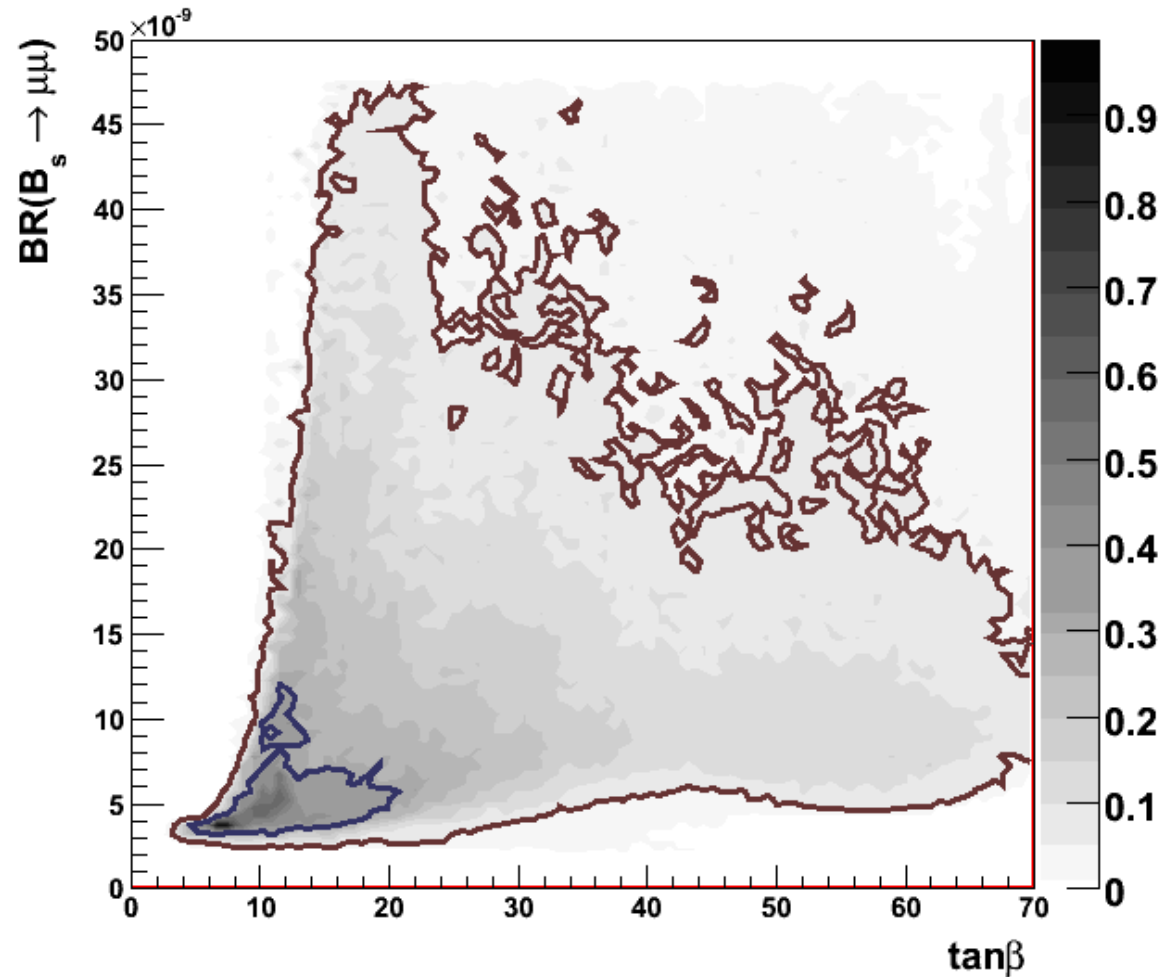
CMSSM:



⇒ similar to SM

⇒ accessible at LHCb

NUHM1:



⇒ much larger than in the CMSSM possible

⇒ accessible at the Tevatron(?)/LHCb

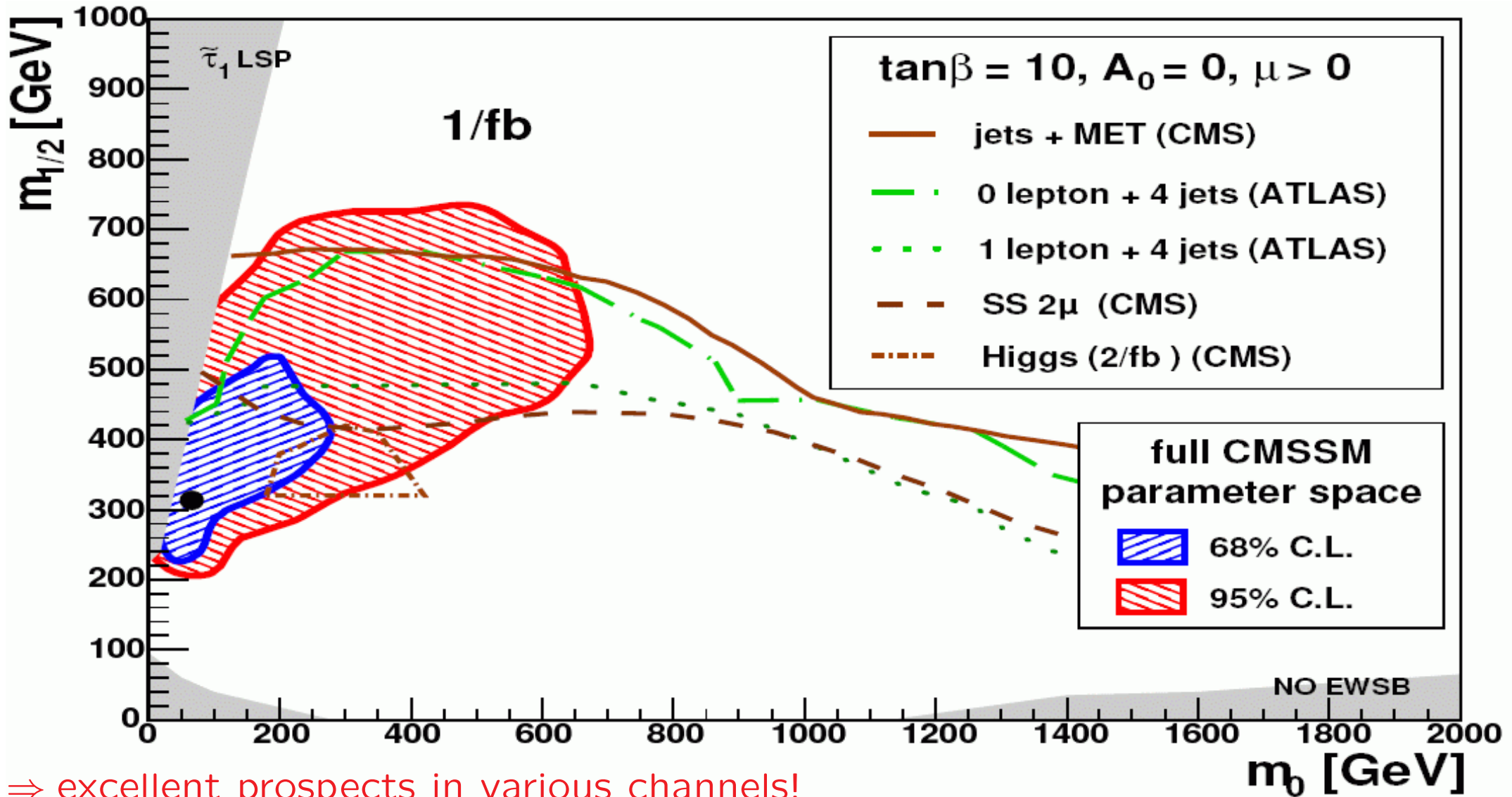
3. Conclusinos

- 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)
 $\sim 2.5 \cdot 10^7$ 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 $\text{BR}(b \rightarrow s\gamma)$
 \Rightarrow moderate impact of $\text{BR}(B_u \rightarrow \tau\nu_\tau)$
(but more potential for improvement?)
- Prediction for $\text{BR}(B_s \rightarrow \mu^+\mu^-)$:
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} :

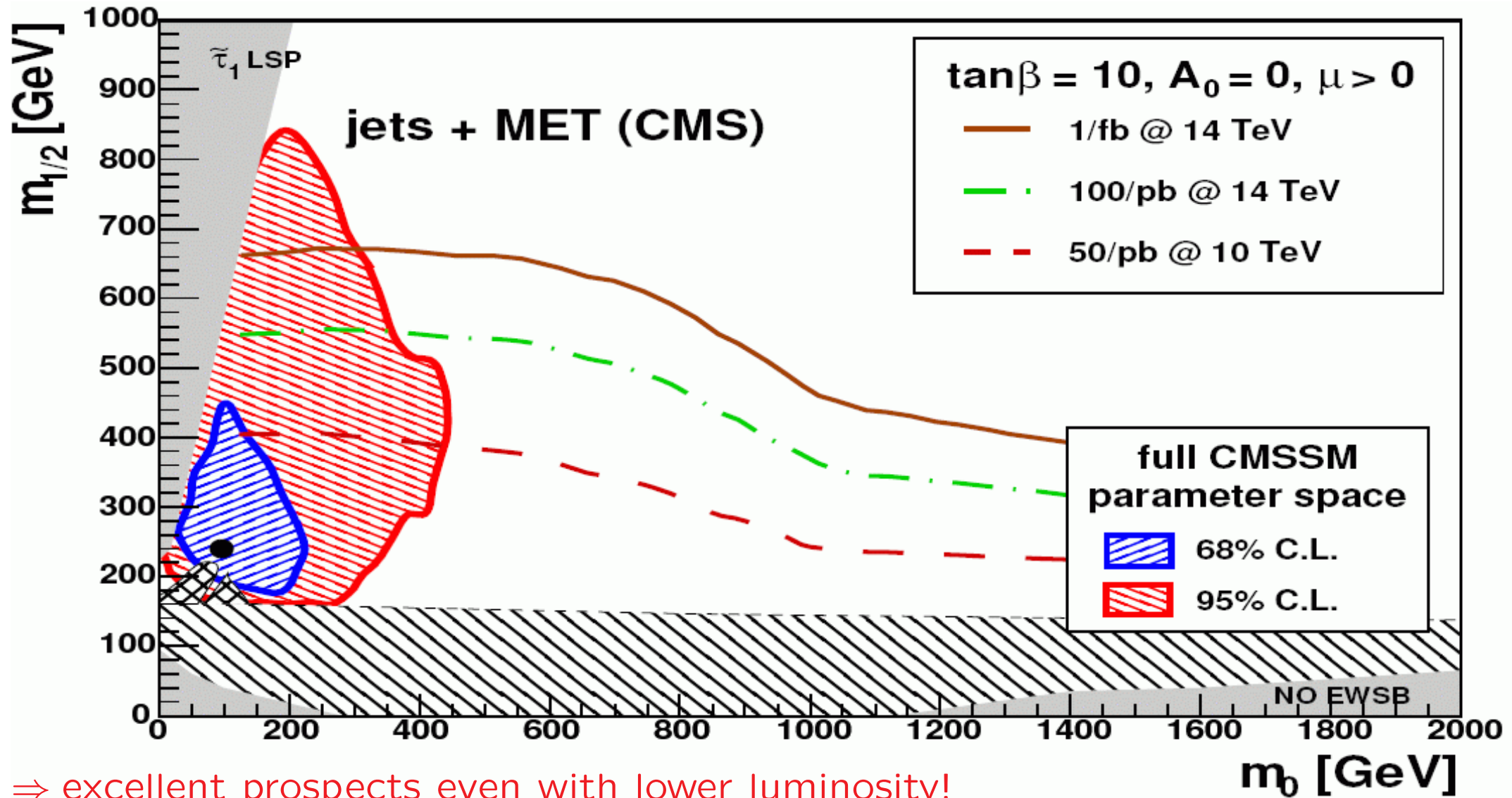
[CMS '07]



⇒ excellent prospects in various channels!

LHC (CMS): NUHM1 analysis

[MasterCode '08] [CMS '07]



LHC (CMS) reach with 1 fb^{-1} : NUHM1 analysis

[CMS '07]

