‘Charged 2008’, Uppsala, 19 Sep 2008

Phenomenology & MC Summary

Stefano Moretti (NExT Institute)

Charged MSSM Higgs Bosons:
LHC Reach and Parameter Dependence

Sven Heinemeyer, IFCA (Santander)

$H^\pm$: $\dfrac{\tan^2\beta}{(1+\Delta_b)^2} \times \text{BR}(H^\pm \to \tau\nu_\tau)$

$$\Delta_b = \frac{2\alpha_s}{3\pi} m_{\tilde g}\, \mu \tan\beta \times I(m_{\tilde b_1}, m_{\tilde b_2}, m_{\tilde g}) + \frac{\alpha_t}{4\pi} A_t\, \mu \tan\beta \times I(m_{\tilde t_1}, m_{\tilde t_2}, \mu)$$

$\Rightarrow$ Δ_b effects so far neglected by ATLAS/CMS

Theory evaluation:

$\sigma(pp \to t\bar t) = 840\,\text{pb}$

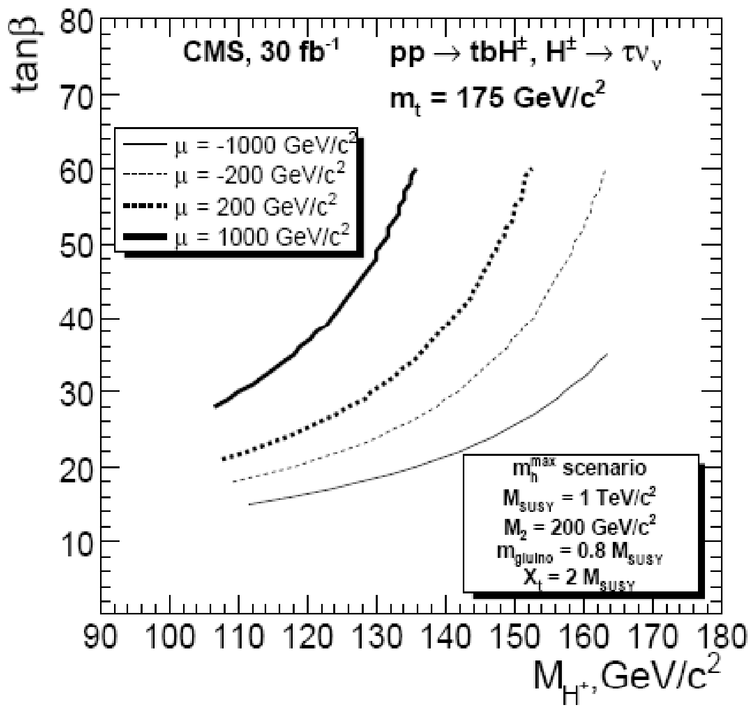
$\sigma(gb \to H^\pm t)$: state-of-the-art
[*T. Plehn '02*] [*E. Berger, T. Han, J. Jiang and T. Plehn '03*]
$+\ \Delta_b$ corrections

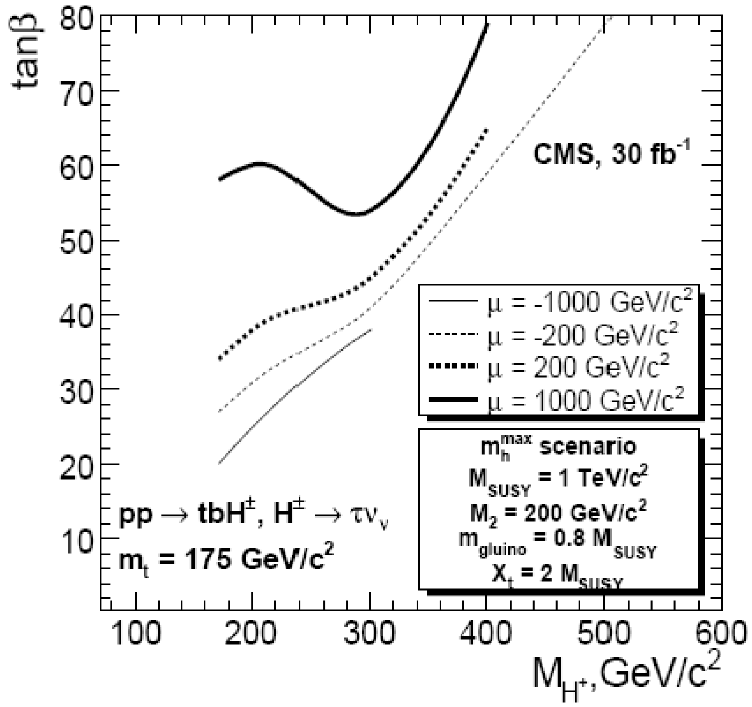
BR($t \to H^\pm b$): Δ_b corrections included

BR($H^\pm \to \tau\nu_\tau, tb, W^{\pm(*)}h, \ldots$): Δ_b corrections included

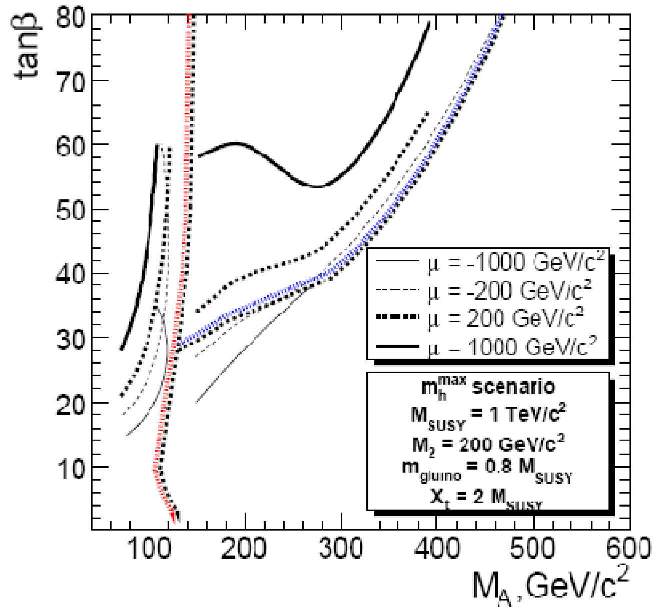
Fixed values for all other BRs

`FeynHiggs (www.feynhiggs.de)`





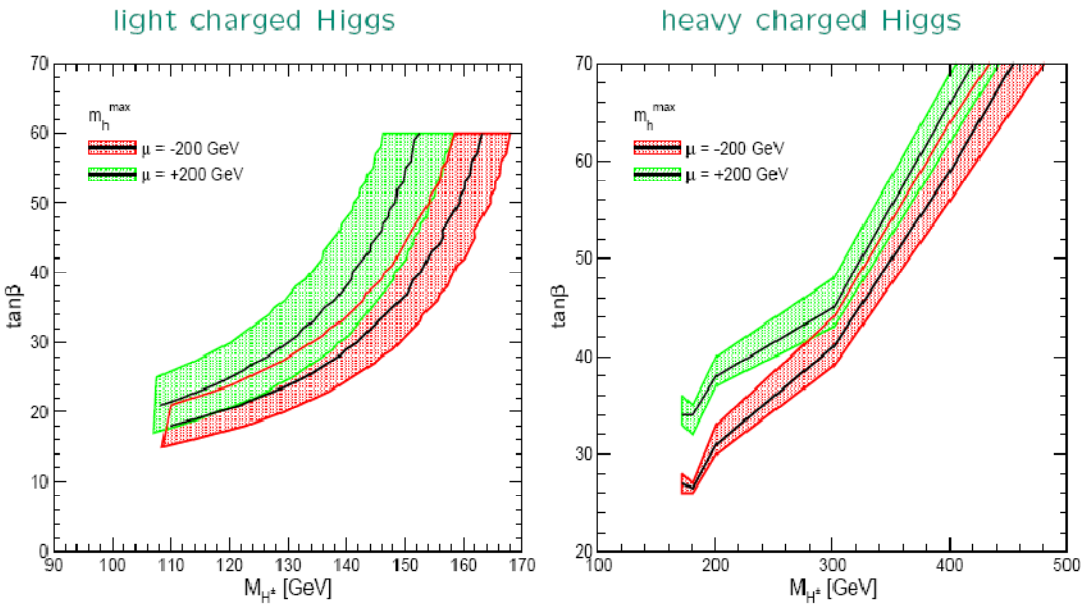
- light charged Higgs ($M_{H^\pm} < m_t$):
  strong variation with μ: $\Delta \tan\beta \sim 15$
- heavy charged Higgs ($M_{H^\pm} > m_t$):
  strong variation with μ: $\Delta \tan\beta \lesssim 40$



Results for the $m_h^{\max}$ scenario:

- Comparison with CMS PTDR:
  - light charged Higgs always worse (mostly due to $M_{H^\pm}$, Δ_b)
  - heavy charged Higgs: new results vary around PTDR (Δ_b)

Theory uncertainties



1. Uncertainties on $\sigma(pp \to t\bar{t})$ (for $M_{H^\pm} < m_t$)
   $\to \sim 5\%$ (now, or in the near future)

2. experimental uncertainties on m_t, affecting $\sigma(pp \to t\bar{t})$
   $\to \Delta\sigma/\sigma \approx 5\Delta m_t^{\rm exp}/m_t$
   combined error on σ: $\sim 6.5\%$

3. SM Uncertainties on $\sigma(pp \to H^\pm + X)$ (for $M_{H^\pm} > m_t$)
   comparison of 4 and 5 flavor scheme: $\lesssim 20\%$

4. Uncertainties beyond $\Delta_b(\sim \alpha_s \ldots + \alpha_t \ldots)$
   $\Rightarrow$ scale variation of $\alpha_s(Q) \Rightarrow$ effect on Δ_b $\lesssim 20\%$
   ($\Rightarrow$ smaller effects for $\mu \propto \Delta_b > 0$, larger effects for $\mu \propto \Delta_b < 0$)

Constraints on charged Higgs bosons in the CMSSM and NUHM models

Oscar Stål
Uppsala universitet

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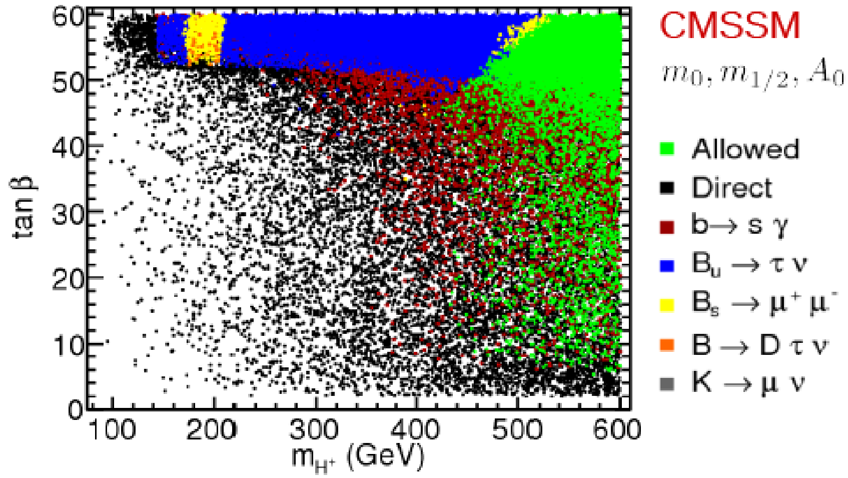
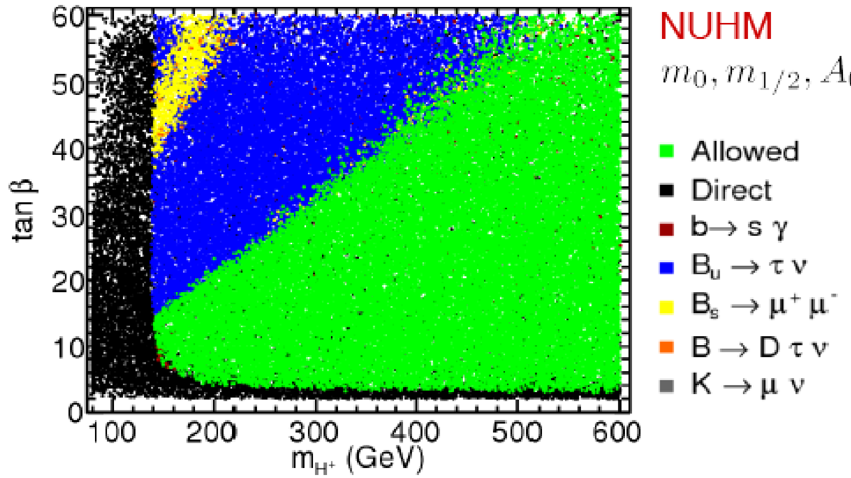


CMSSM

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

- High tan β tail excluded by combined flavor constraints

$m_{H^+} \gtrsim 400\ \text{GeV}$



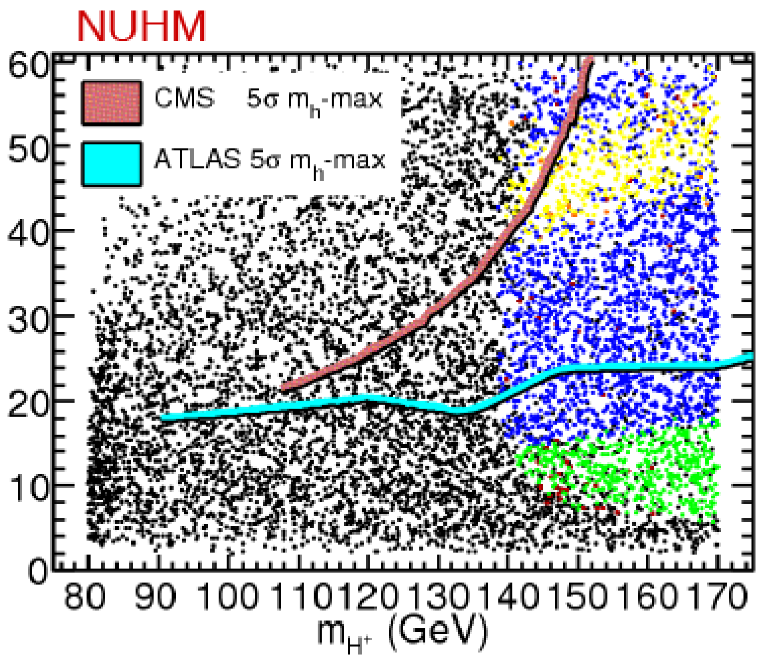
NUHM

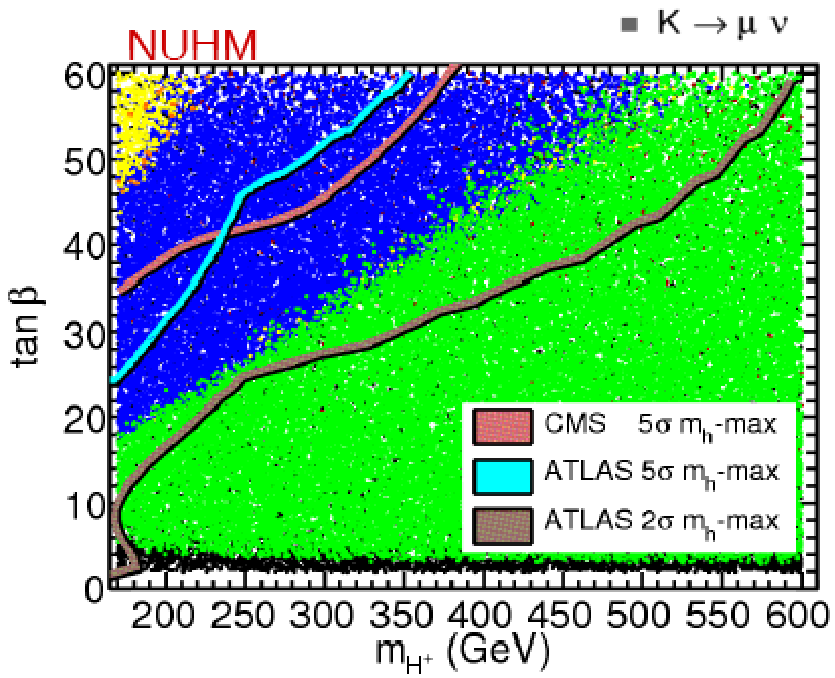
$m_0, m_{1/2}, A_0, \mu, m_A, \tan\beta$

- Large exclusion by flavor constraints. Low mass only allowed for intermediate tan β.

$m_{H^+} \gtrsim 135\ \text{GeV}$

Neutral LSP, μ>0





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- Restrictive constraints already exist on charged Higgs bosons in the CMSSM and NUHM models.
- In particular B-physics observables yield powerful constraints, although the uncertainties from theory and experiment are still rather large.
- The region where indirect searches obtains the highest exclusion power is where the largest cross sections are obtained for H^+ production at the LHC.
- Finding a charged Higgs early at the LHC points to non-minimal models.

Extensions, improvements:

- Alternative production of charged Higgs bosons in SUSY decay chains

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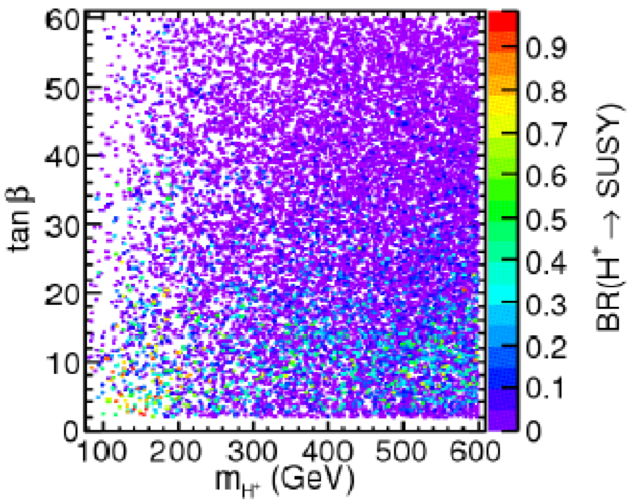
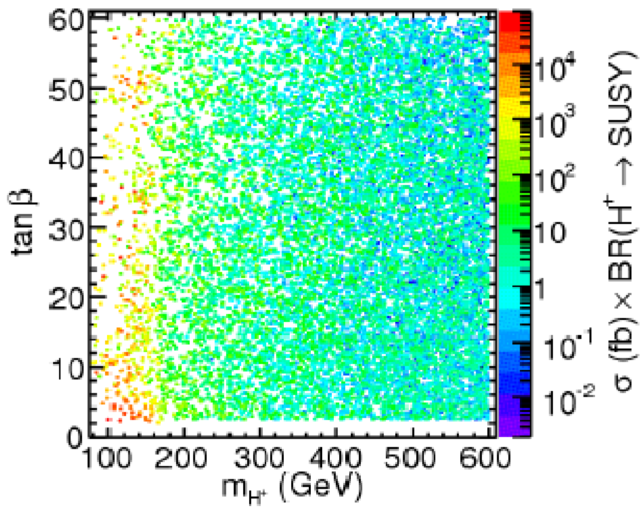
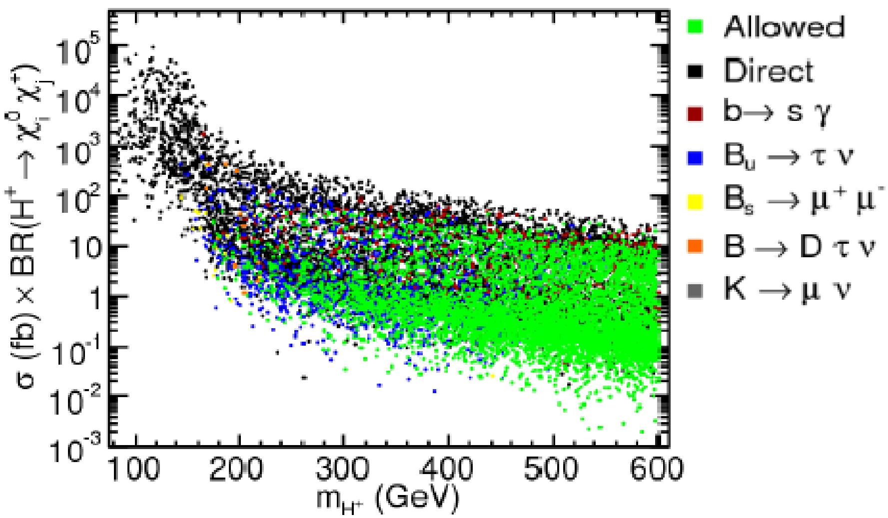






- Points with highest $\sigma \times \mathrm{BR}$ to SUSY already excluded by direct constraints

Cross-sections and Branching Ratios for H^+ Searches

André Sopczak

- For LHC startup H^+ cross-section and branching ratios determined for specific ATLAS scenarios (→talk by M.Flechl)
- Two MSSM benchmark scenarios (→talk by S.Heinemeyer).
- Investigated mass points 90, 110, 120, 130, 150, 170, 200, 250, 400 and 600 GeV.
- BR($t \to H^+ b$) similar for scenarios A and B.
- Cross-sections differ slightly in the low-mass region between scenarios A and B. For high-mass region: same values in NLO $gb \to tH^+$ calc. (Higher order corr.→talk by N.Kidonakis).
- MSSM dependences on cross-sections included.
- BR($H^+ \to \ldots$) differences for large H^+ masses.

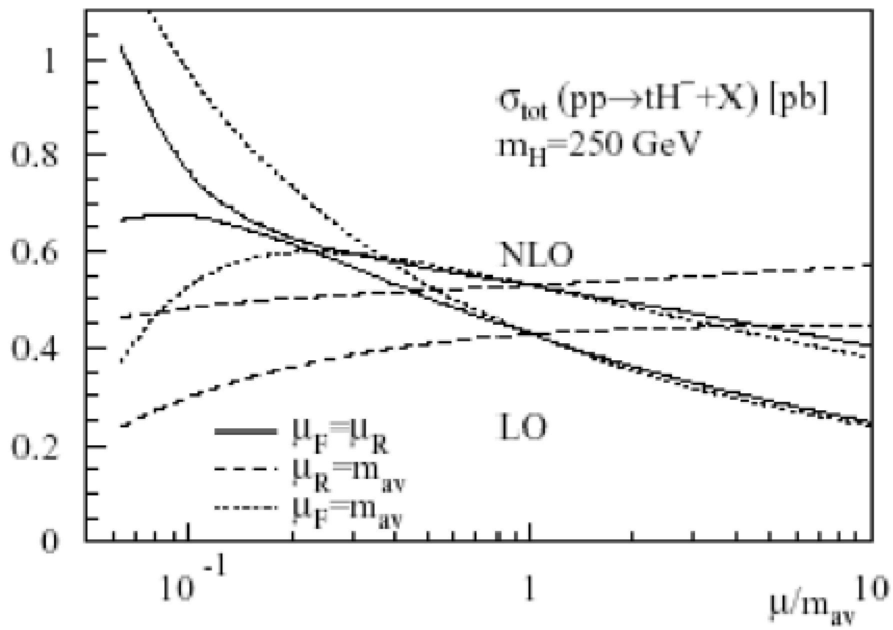
Their effect on the total cross-section in a simple mSUGRA model is estimated to stay below±5% for $\tan\beta=30$ and below ±20% for $\tan\beta=50$. In the MSSM the cross-section can be reduced by a factor 2.

Systematic Uncertainties
related to NLO $gb \to tH^+$ cross-section

[Berger, Han, Jiang, Plehn PRev D67 (2003) 014018]:

1. one-loop contributions largely improve the theoretical uncertainty of the leading order (LO) cross-section.
2. NLO: determine cross-section uncertainty from the dependence on the renormalization and the factorization scale: 20%

$$\mu_F \sim C\, m_{\rm av} = C\, \frac{m_t + m_H}{2}$$



BR Systematic Uncertainties

FeynHiggs v2.6.2:

BR($H^+ \to \tau\nu$,cs,tb) and BR($t \to H^+ b$):

a) non-calculated loop corrections to tbH^+ vertex

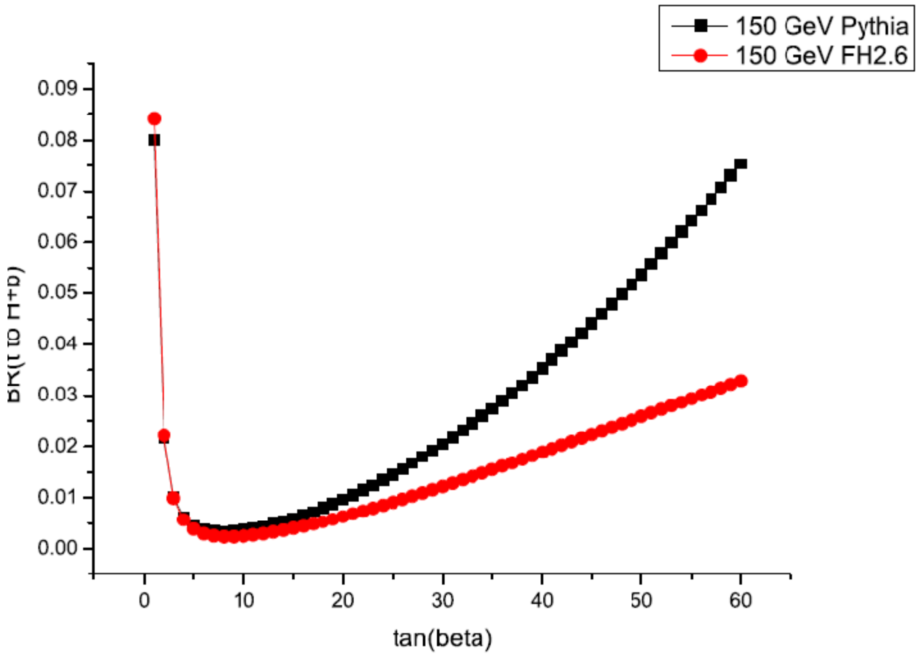
b) running masses of c and s quarks

Estimates:

ΔBR($H^+ \to \tau\nu$)<5%

ΔBR($H^+ \to$ cs,tb)<10%

ΔBR($t \to H^+ b$)<10%



Charged Higgs effects on top spin correlations

David Eriksson

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Parton level correlations

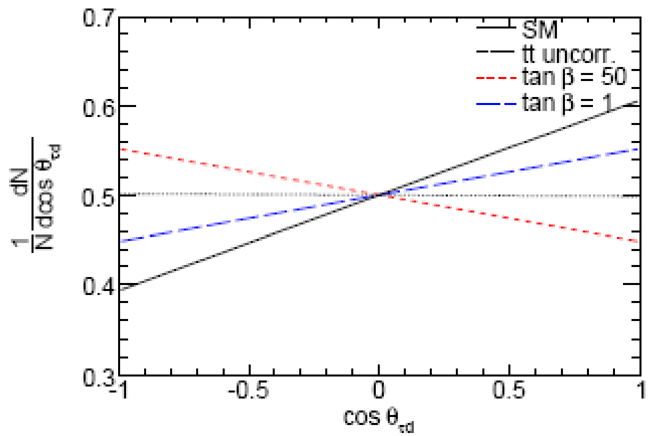
Best case

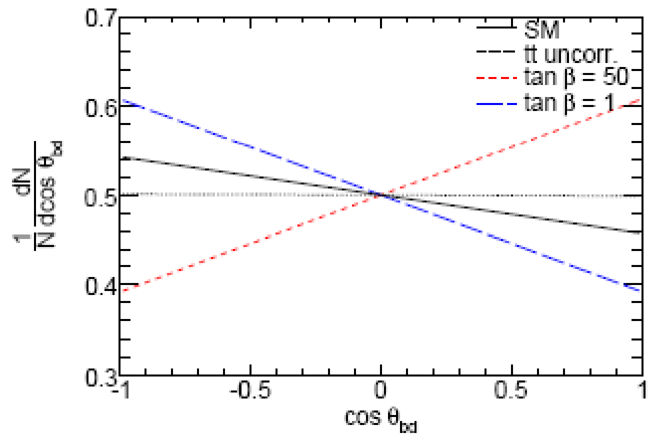
- $\begin{matrix} t \to b & H^+/W^+ \to b\,\tau^+\,\nu_\tau \\ \bar{t} \to \bar{b} & W^- \to \bar{b}\,\bar{u}\,d \end{matrix}$ + c.c. and α_i corresponding to $m_{H^+} = 80$ GeV
- $\mathcal{D}$-type correlations, $\mathcal{D} = -0.216$ at LHC

- $\cos\theta_{ij} = \hat{p}_i \cdot \hat{p}_j$ is "opening angle"

$$\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}\cos\theta_{ij}} = \frac{1}{2}(1 + \mathcal{D}\alpha_i\alpha_j\cos\theta_{ij})$$

→ Analyzing coefficients





- Stable τ^+, fully know final state and CM frame

Parton level correlations
Azimuthal correlations

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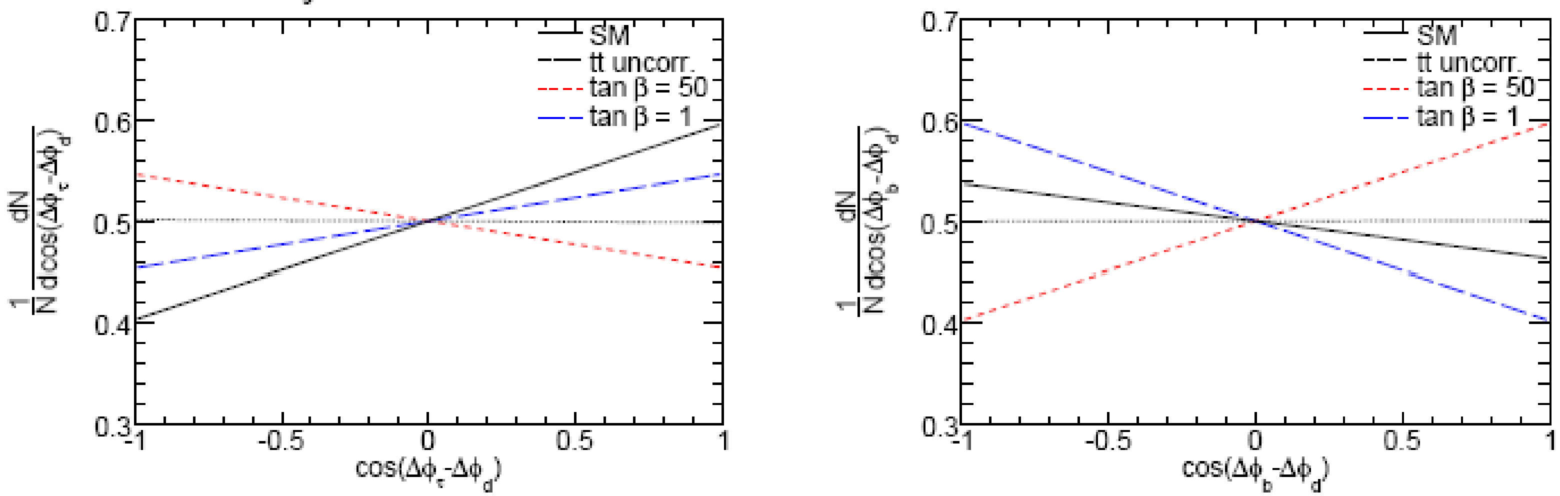
- Charged Higgs decays to $\tau^+ \nu_\tau$ and τ^+ to $X + \bar{\nu}_\tau$
- Center of mass frame not know
- Use hadronic W^+ and τ^+ to get transverse rest frame
- Use azimuthal angles and the correlation

$$\frac{1}{N}\frac{\mathrm{d}N}{\mathrm{d}\cos(\Delta\phi_i - \Delta\phi_j)} = \frac{1}{2}\Big[1 + \mathcal{D}'\alpha_i\alpha_j \cos(\Delta\phi_i - \Delta\phi_j)\Big].$$

- Numerically $\mathcal{D}' = 0.9\mathcal{D}$ at LHC



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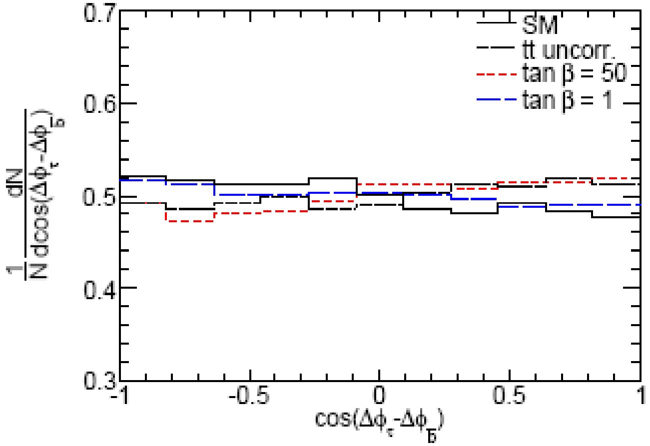
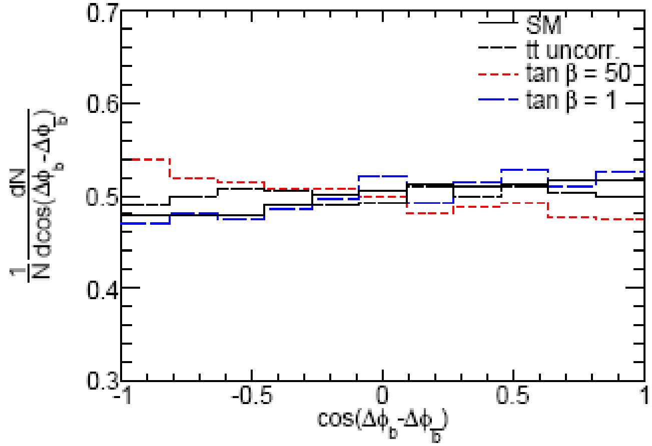
Hadron level correlations

- l^+ most efficient particle in SM
- b and H^+ most efficient particles in 2HDM (II)
- Strong dependence on $\tan\beta$
- l^+ also depend on m_{H^+}

- Full $2 \to 6$ ME with MadGraph/MadEvent
  $p\,p \to (t\,\bar{t}) \to (b\,H^+/W^+\,\bar{b}\,W^-) \to b\,\tau^+\,\nu_\tau\,\bar{b}\,\bar{u}\,d$
- τ^+ decay with Tauola
- Parton shower, hadronization and underlying event with Pythia
- $k_\perp$ jet finding in $|\eta| < 5$ with $d_{cut} = 20$ GeV
- "Flavor tag" $\Delta R(jet, truth) < 0.4$ in $|\eta| < 2.5$
- W^+ candidate $|m_{jj} - m_{W^+}| < 10$ GeV, t candidate $|m_{jjb} - m_t| < 15$ GeV
- No background or detector effects





- Charged Higgs in top decays alter angular distributions
- In 2HDM(II) b quark is the most efficient analyzer
- Charged Higgs decays to τ^+ and neutrinos so full reconstruction not possible
- Correlations with azimuthal angles can be constructed, $\mathcal{D}'$
- Realistic hadron-level correlations are small in both SM and 2HDM(II)

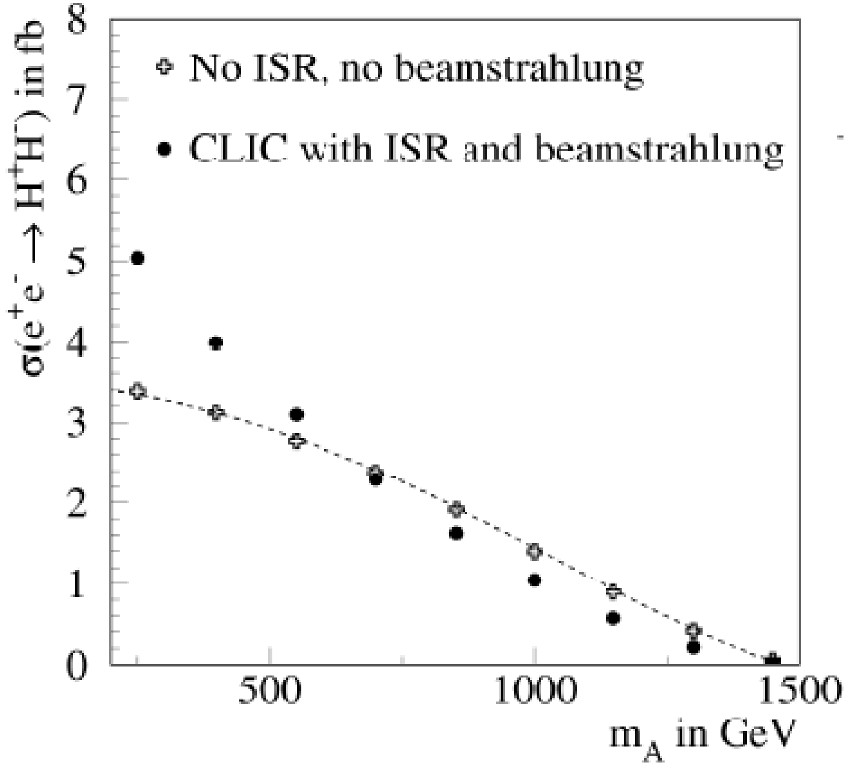
Elias Coniavitis

Charged Higgs Bosons at the Compact Linear Collider (CLIC)

- More precise knowledge of collision energy
- Cleaner environment
- Fewer backgrounds

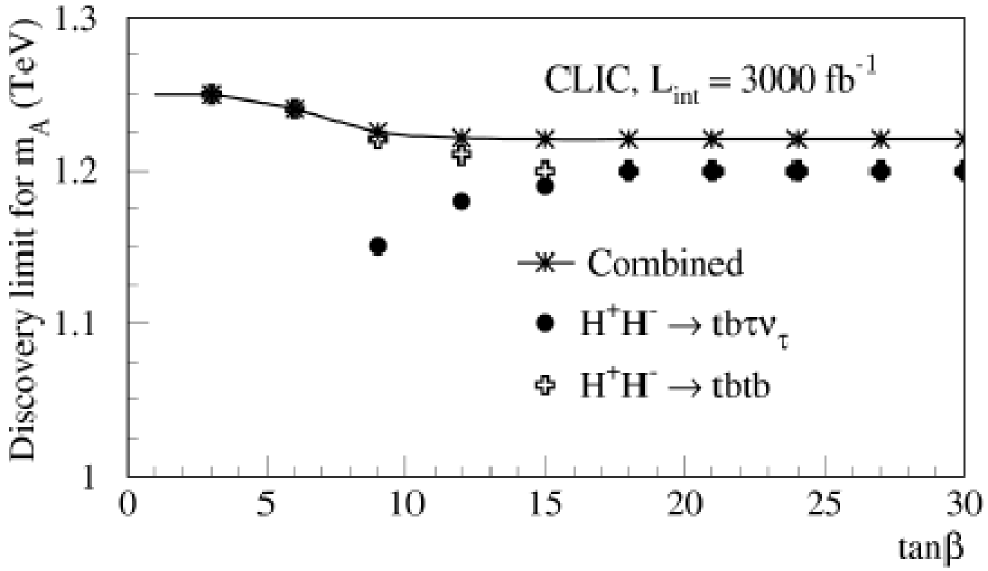
- Focus on very high H+ masses
- Examine potential for parameter determination

- MSSM
  - H^+ only decays to SM particles
  - No SUSY backgrounds considered
- Both dominant decay modes studied
  - $H^+ \to tb$ & $H^+ \to \tau\nu$
- Two channels:
  - $e^+e^- \to H^+H^- \to tbtb$
  - $e^+e^- \to H^+H^- \to tb\tau\nu$
- All results for integrated luminosity of 3000 fb^{-1} (~4 years)



Discovery Potential

- For discovery, require $S/\sqrt{B}>5$ and $S\geq10$
  - No systematics included



- Discovery contour only slightly tanβ-dependent.
- Reaching masses above 1 TeV

Mass Measurement

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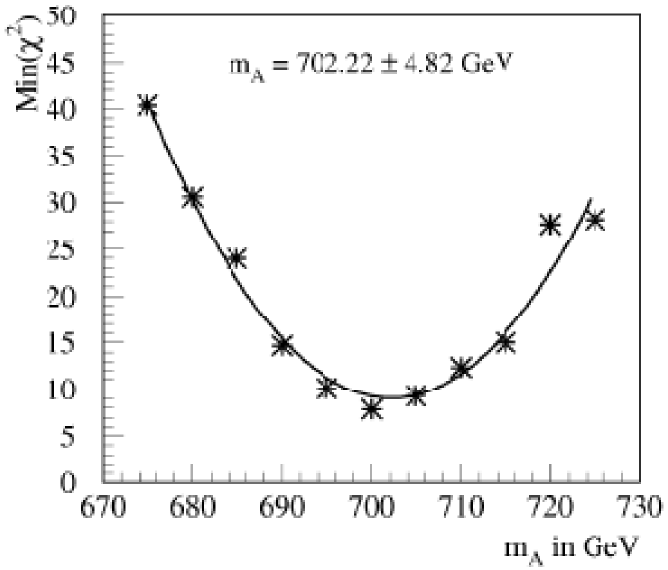
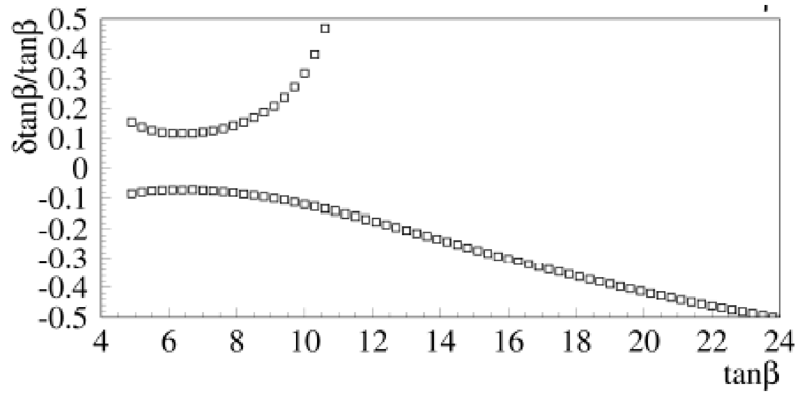
- χ^2 fit on $H^+H^- \to$ tbtb (+ background) sample to determine $H^\pm$ mass (and thereby m_A)
- Obtained relative uncertainties for m_{H+} typically <1%



	m_A (GeV)	δm_A (GeV)
Small $\tan\beta$	697.4	3.7
Large $\tan\beta$	702.2	4.8

The real mass m_A is 700 GeV and $\mathcal{L} = 3000\ \text{fb}^{-1}$

tanβ Determination →



Nazila Mahmoudi

SuperIso program and flavor data constraints

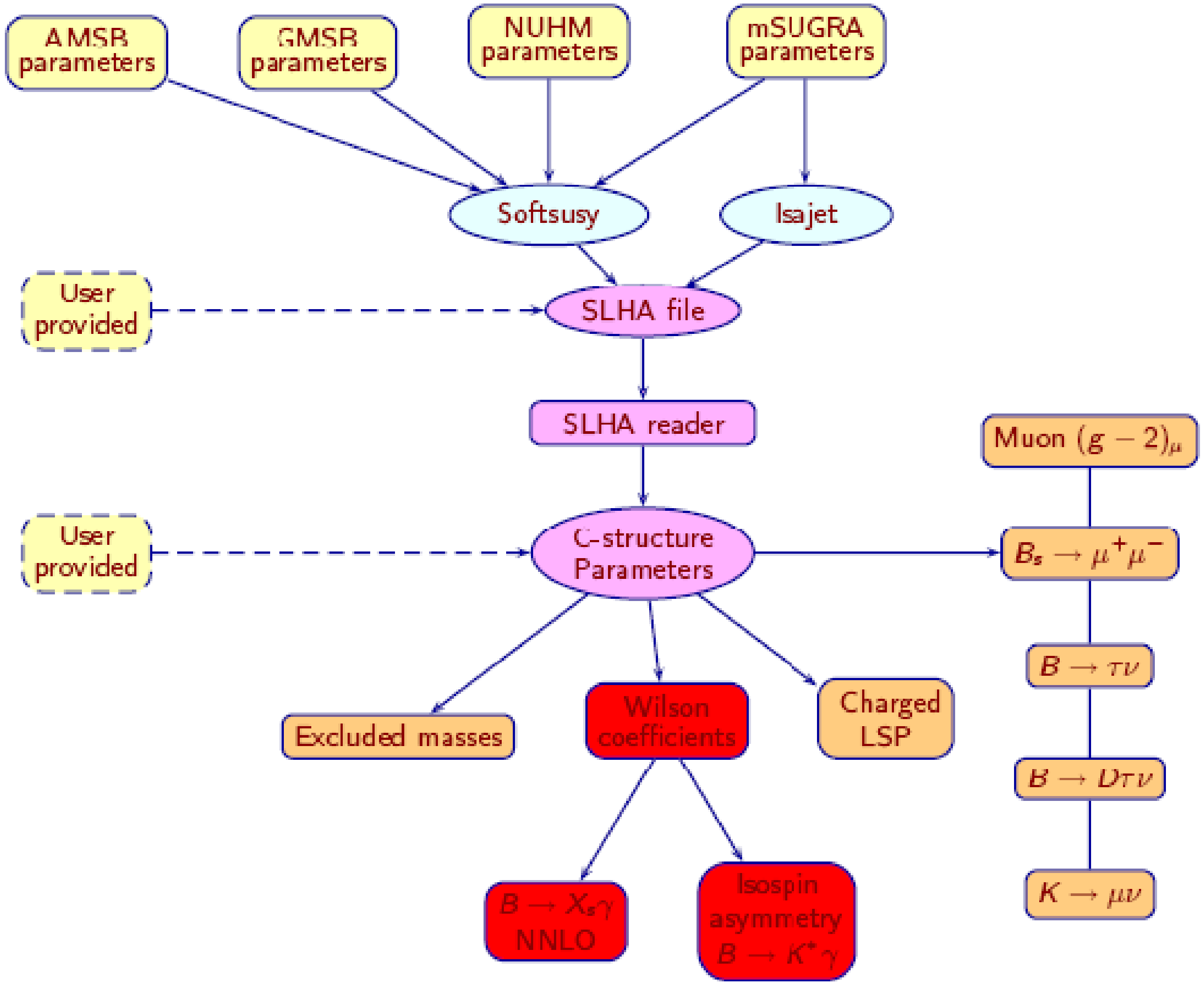
A public C–program for calculating different observables in supersymmetry

- Automatic calculation in mSUGRA, NUHM, AMSB and GMSB scenarios
- Compatible with the SUSY Les Houches Accord Format (SLHA2)
- Interfaced with Softsusy and Isajet for automatic spectrum calculation
- Modular program, with a well-defined structure
- Complete updated reference manual available

Observables:

1. Isospin asymmetry of $B \to K^* \gamma$ at NLO
2. Inclusive branching ratio of $B \to X_s \gamma$ at NNLO
3. Branching ratio of $B_s \to \mu^+ \mu^-$
4. Branching ratio of $B \to \tau \nu$
5. Branching ratio of $B \to D \tau \nu$
6. Branching ratio of $K \to \mu \nu$
7. Anomalous magnetic moment of muon $a_\mu = (g-2)/2$

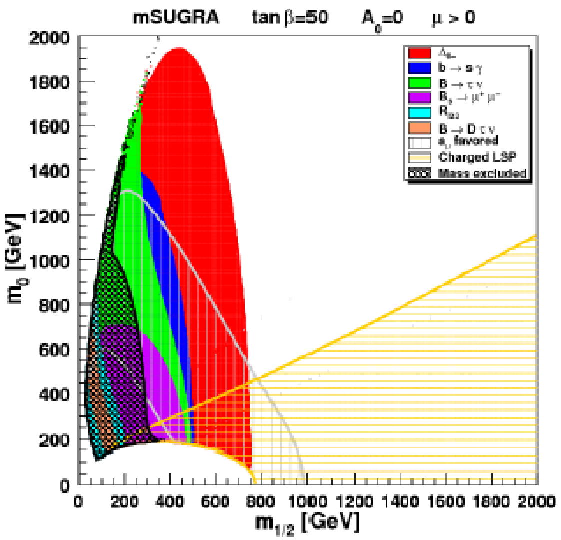
SuperIso v2.3



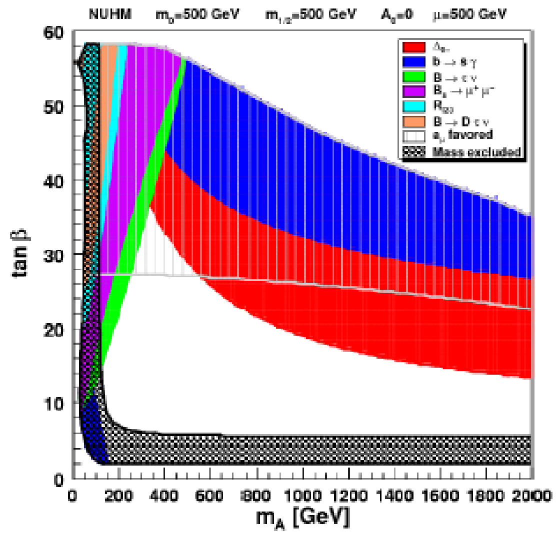
Can be downloaded from:

http://www3.tsl.uu.se/~nazila/superiso/

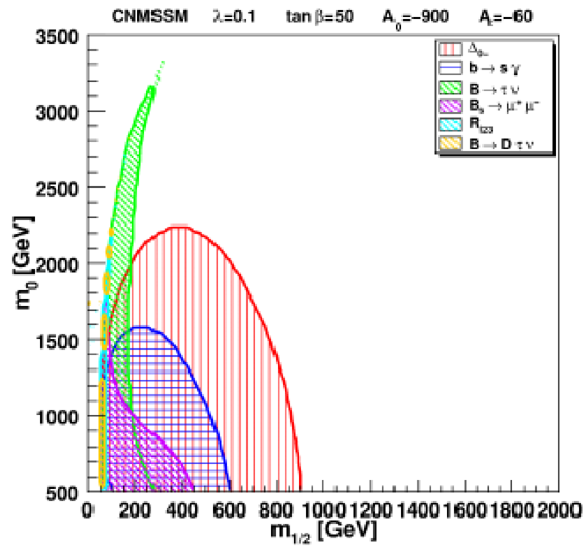
mSUGRA



NUHM



CNMSSM



Ongoing Developments

- Extension to NMSSM ✓
- Implementation of the relic density calculation (with A. Arbey) ✓
- Extension to NMFV
- Implementation of other observables

MadWeight

automatic event reweighting with matrix elements

Olivier Mattelaer

Université Catholique de Louvain

- motivation : method to maximize the information that you can extract from a sample of events : matrix element method
  - test theoretical hypothesis
  - need a good understanding of the detector
  - we can extract mass, spin, cross section,...
- plan
  - weighting experimental events
  - MadWeight : automatic computation of the weights

How to evaluate the weight ?

- $|M_\alpha|^2$ is the squared matrix element
- $W(\boldsymbol{x},\boldsymbol{y})$ is the resolution function
  - $\boldsymbol{x}$: experimental measurements
  - $\boldsymbol{y}$: partonic momenta
- $d\phi(\boldsymbol{y})$ is the partonic phase-space measure
- $f_1(w_1), f_2(w_2)$ are the Parton Distribution Functions

- matrix element method : weighting events

$$P(\boldsymbol{x},\alpha) = \frac{1}{\sigma}\int d\phi(\boldsymbol{y})dw_1dw_2f_1(w_1)f_2(w_2)|M_\alpha|^2(\boldsymbol{y})W(\boldsymbol{x},\boldsymbol{y})$$

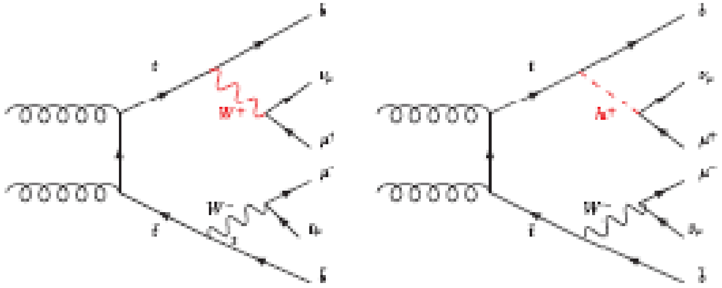
- transfer functions : experimental extraction

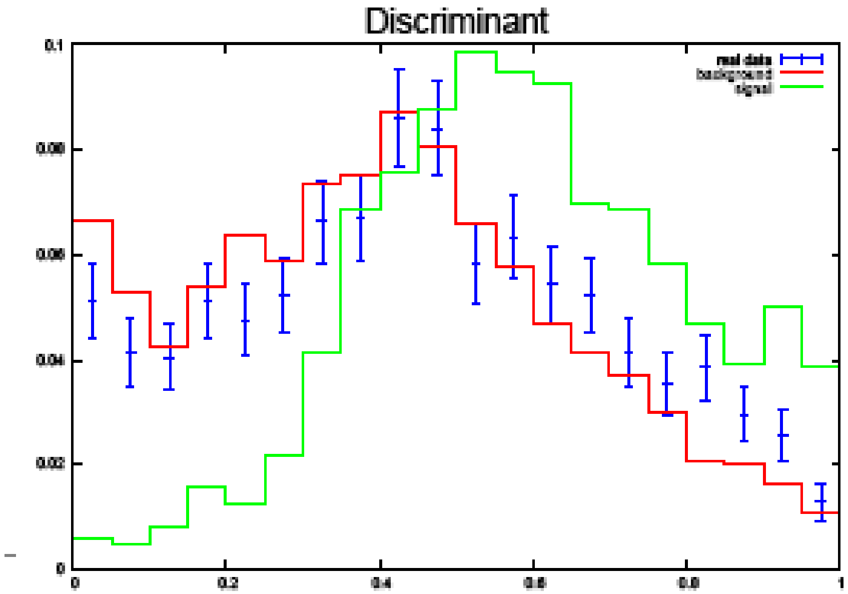
- numerical integration : very difficult due to the *structure in peaks* of the integrand

$|M_\alpha(\boldsymbol{y})|^2$: propagators

$$W(\boldsymbol{x},\boldsymbol{y}) \approx \prod_i \frac{1}{\sqrt{2\pi}\sigma_i} e^{-\frac{(x_i-y_i)^2}{2\sigma_i^2}}$$

Charged Higgs : Discriminant





- $M_{H^+} = 100\text{GeV}$

- 750 background events
- 262 signal events

- the Matrix Element method provides the best discriminator on an event-by-event basis
- both theoritical ($|M|^2$) and experimental ($\boldsymbol{x}$, $W(\boldsymbol{x}, \boldsymbol{y})$) information is used
- the computation of the weights requires a specific phase space generator : MadWeight