# SUSY/BSM Fit Working Group of the Helmholtz Alliance "Physics at the Terascale"

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PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Workshop "Global BSM fits and LHC data"
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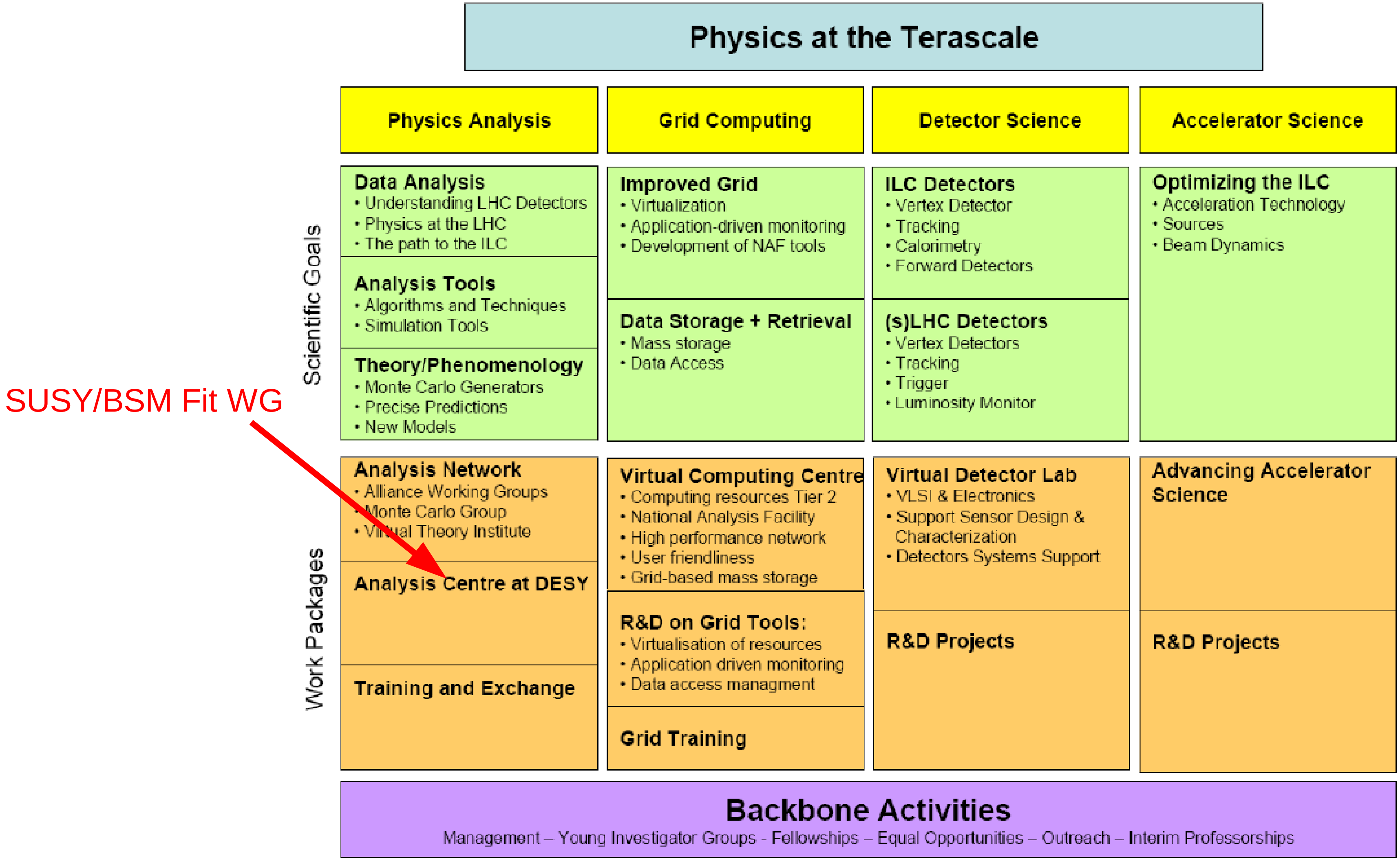
# Alliance “Physics at the Terascale”

Goal: Braid a structured network between universities, Helmholtz and Max Planck institutes to optimally place German particle physics in global HEP environment



# SUSY/BSM fit working group

Objective: Provide optimal means to fully exploit available and future data with respect to supersymmetry and other BSM models, i. e. either constrain new models and their parameters or translate search limits into excluded regions in theory parameter space

- Joint effort by experimentalists and theorist
- Involves members of various international BSM fitting groups:

  but not focused on a particular fitting package (anybody welcome!)
- Regular workshops (~every 6 months) with 20-30 participants
- More information available here
- Subscription to mailing list is possible here (presently 73 subscribers)

# Topics being worked on

Present work mainly focussed on improving “fit ingredients”:

- Uncertainties of calculations
- Including constraints from past search experiments
- Fast way of including LHC cross-section information
- Handling LHC decay chain ambiguities in fits
- Interpolation tools (morphing)
- Discussions on optimal way to incorporate LHC results
- ...

Actual fit work mostly takes place in the individual fitting groups

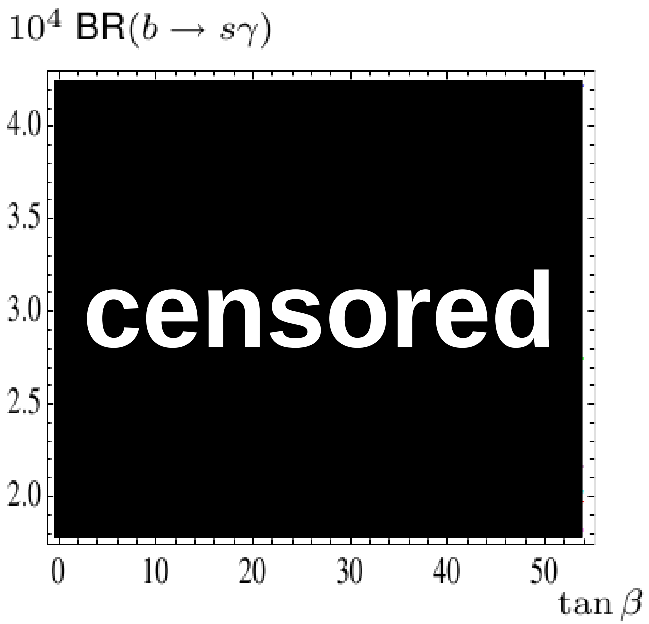
→ fit results not covered in this talk

# Comparison of theory codes

Mathias Hamer, Sabine Kraml, Werner Porod

One indicator of the precision of calculations is the agreement between different calculators:

## Low energy observables:

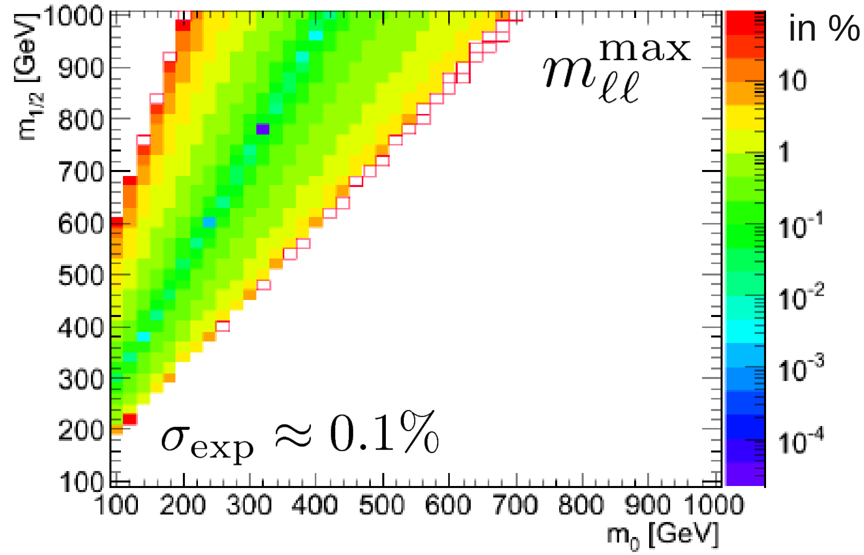



MasterCode , SUSY_FLAVOUR , SPheno , SusyBSG , SuperIso , Micromegas

Partly large differences

## LHC observables:

SoftSUSY vs. SPheno




Precision on masses: O(1 %)

Precision on LHC observables:
in rare cases much larger → O(30 %)

Probably huge differences only for cases where measurements are difficult/impossible

# Towards parameter dependent theory uncert.

Sven Heinemeyer

Two different types of theory uncertainties
(relevant if not much smaller than experimental uncertainty):

- Parametric uncertainty
  Parameter dependent uncertainty due to uncertainty on (SM) input parameters
  → calculable
  → automatically included if SM parameters are included in fit

- Intrinsic uncertainty
  Parameter dependent uncertainty due to missing higher order corrections
  → only estimates possible

It is important for reliable fit results that authors of calculators provide uncertainties

# Towards parameter dependent theory uncert.

Sven Heinemeyer

Example: $M_h$ (based on FeynHiggs)

Calculation includes:

– full one-loop
– leading two-loop: $\mathcal{O}(\alpha_t \alpha_s)$, $\mathcal{O}(\alpha_b \alpha_s)$, $\mathcal{O}\left(\alpha_t^2, \alpha_b^2, \alpha_t \alpha_b\right)$
– some very leading three-loop: $\mathcal{O}\left(\alpha_s^2 \alpha_t\right)$

Estimate of missing higher-order corrections:

– missing two-loop: scale variation of $\overline{\text{DR}}$ one-loop result
– missing three-loop corrections from $t/\tilde{t}$ sector: variation of $m_t$ at the two-loop level
– missing three-loop corrections from $b/\tilde{b}$ sector: variation of $\Delta_b$ inclusion (resummed vs. iteratively resummed)

⇒ FeynHiggs output contains intrinsic error for Higgs masses and mixings

⇒ strong variation from "usual 3 GeV" possible!

This is only a first step:
In principle a complete covariance matrix should be provided

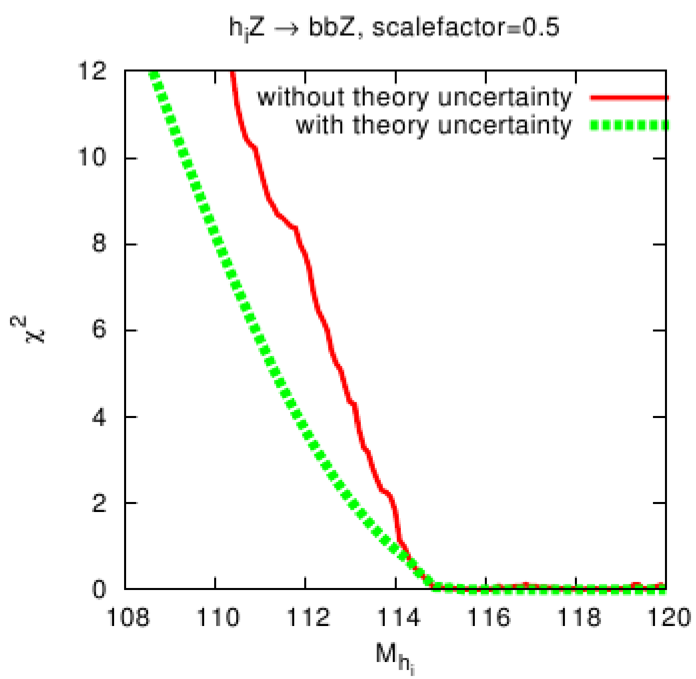
# HiggsBounds

P. Bechtle, O. Brein, S. Heinemyer, G. Weiglein, K. Williams

Program to check compatibility of the Higgs sector of a given model with Higgs search results from LEP and Tevatron

Formerly: simple binary answer

Soon: can return a $\chi^2$ contribution (currently only for LEP search channels)




Transfer (single-sided) $CL_{s+b}$ into (double-sided) $\chi^2$:

$$\chi^2_H = 2\,\mathrm{InvErf}^2(1 - 2\,CL_{s+b})$$

Would be nice to have something similar for other exclusions

# LHC FASER

M. Krämer, J. Lindert, B. O'Leary, C. Robens

In the past, LHC event rates very rarely included in fits due to CPU time constraints (cf. Lester, Parker, White, hep-ph/0508143)

FASER = Fast Approximation for Supersymmetric Event Rates

provides fast and precise (NLO) estimate of σ x BR x acceptance by combining parametrisations and analytical calculations

Implemented signatures to date:

- ≥ 2 jets + MET → determined by squark, gluino and LSP masses
- ≥ 2 jets + MET + 2 OSSF leptons → more relevant SUSY parameters

In progress:

- ≥ 3,4 jets + MET (+ leptons) → even more involved (other jet sources become important, e. g. QCD radiation, W decays, etc.)

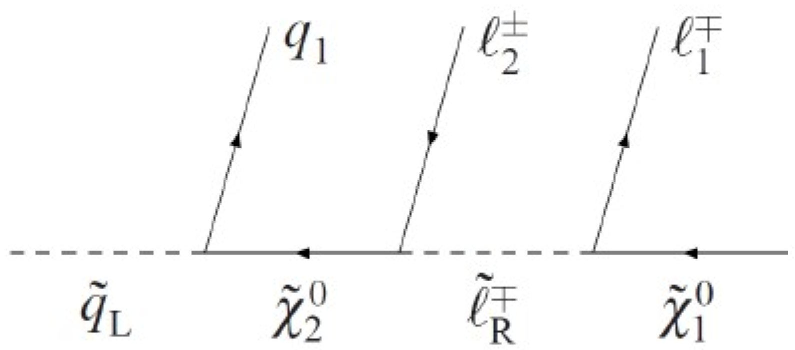
→ very nice for fast sensitivity studies

(see e. g. Dreiner, Krämer, Lindert, O'Leary, arXiv:1003.2648)

# Decay chain ambiguities at the LHC

Philip Bechtle, Takanori Kono

Example: "Favourite" LHC decay chain




$$\tilde{\chi}_2^0 \leftrightarrow \tilde{\chi}_i^0, i = 1,2,3,4$$
$$\tilde{\chi}_1^0 \leftrightarrow \tilde{\chi}_j^0, j = 1,2,3\,(\mathrm{i} > \mathrm{j})$$
$$\tilde{l}_R^\pm \leftrightarrow \tilde{l}_L^\pm$$
$$\tilde{\tau}_R^\pm \leftrightarrow \tilde{\tau}_L^\pm$$

Many different decay chains lead to same observable final state

→ let the fit rank the possible hierarchies, but again costly in terms of CPU (cf. Lester, Parker, White, hep-ph/0508143)

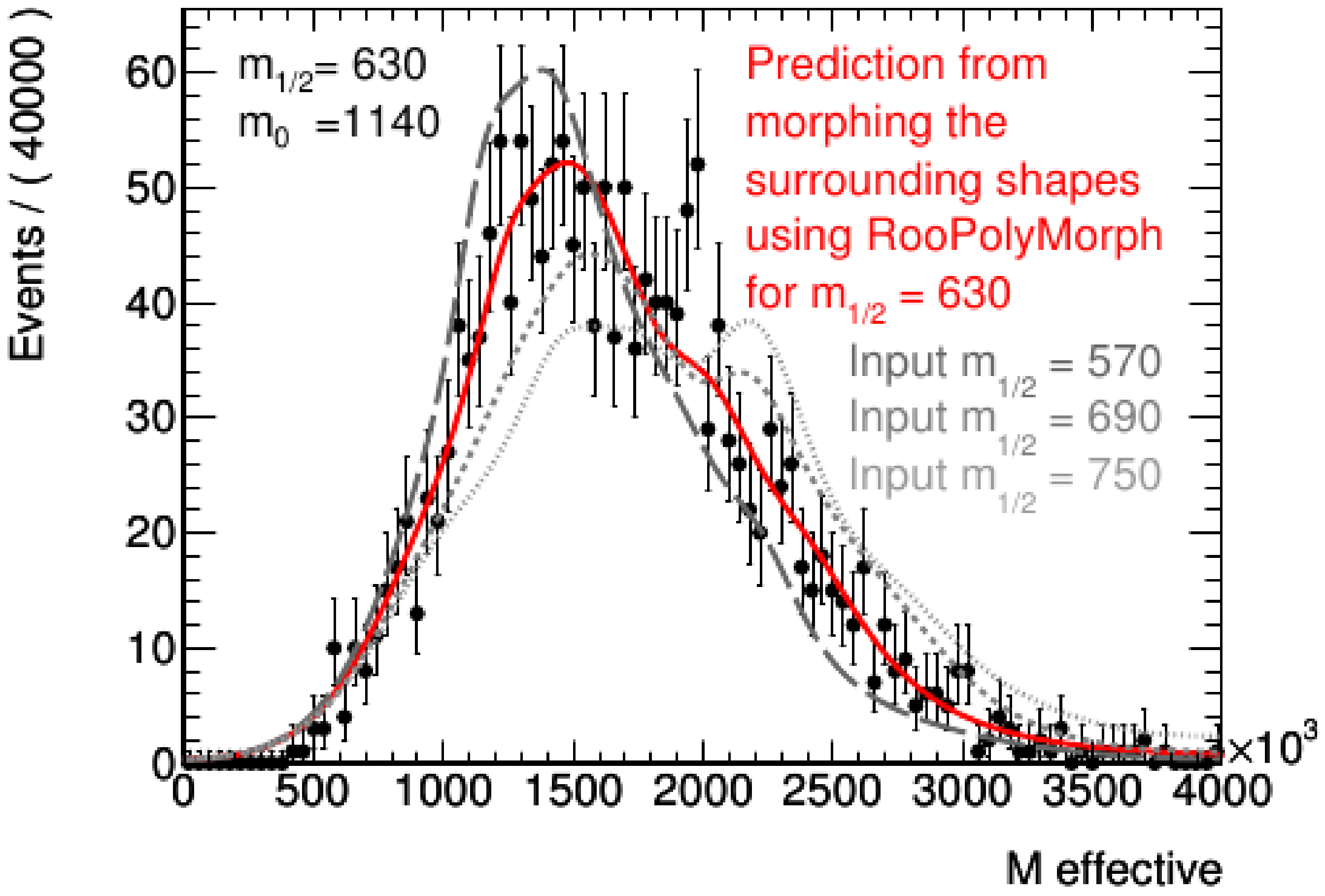
| Particle assignment | Fraction (%) |
|---|---|
| Correct interpretation | 69 |
| $\chi^2_0 \leftrightarrow \chi^3_0$ (e,μ-channel) | 16 |
| $l_R \leftrightarrow l_L$ (e,μ-channel) | 12 |
| $\chi^2_0 \leftrightarrow \chi^3_0$, $l_R \leftrightarrow l_L$ (e,μ-channel)<br>$\chi^2_0 \leftrightarrow \chi^4_0$, $l_R \leftrightarrow l_L$ (τ-channel) | 3 |
| $\chi^2_0 \leftrightarrow \chi^3_0$ (e,μ-channel)<br>$\chi^2_0 \leftrightarrow \chi^3_0$ (τ-channel) | <0.1 |

In practice number of "interesting" hierarchies typically small
→ focus CPU time on those

# Morphing

Max Baak

Experiments would provide signal expectations on discrete grids in parameter space → Need to interpolate shapes → Morphing



# Discussion: Incorporating LHC results

(Mutually related) questions:

- In what form should experimental results be made available?
  → talks by Kyle Cranmer and Max Baak

- How can one test models that have not been specifically analysed by the experimental collaborations?

Possible strategies:

- Publication of detector unfolded fiducial cross-sections
  Cons: model-dependence of unfolding, analysis optimisation model specific

- Publication of measurements without detector unfolding
  Cons: test of alternative models requires detector simulation, analysis optimisation model spec.

- Publication in terms of simplified models
  Cons: mapping of specific model onto simplified models only approximate