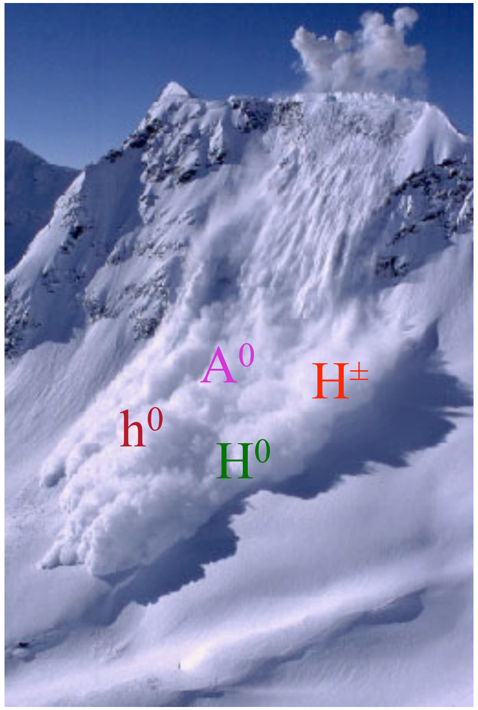
Split 06

Higgs searches in SUSY cascade decays



Filip Moortgat, ETH Zurich

- Motivation
- Analysis method
  (including the Hemisphere Separation Algorithm)
- New CMS Physics TDR full simulation results
- mSUGRA Reach (fast simulation)

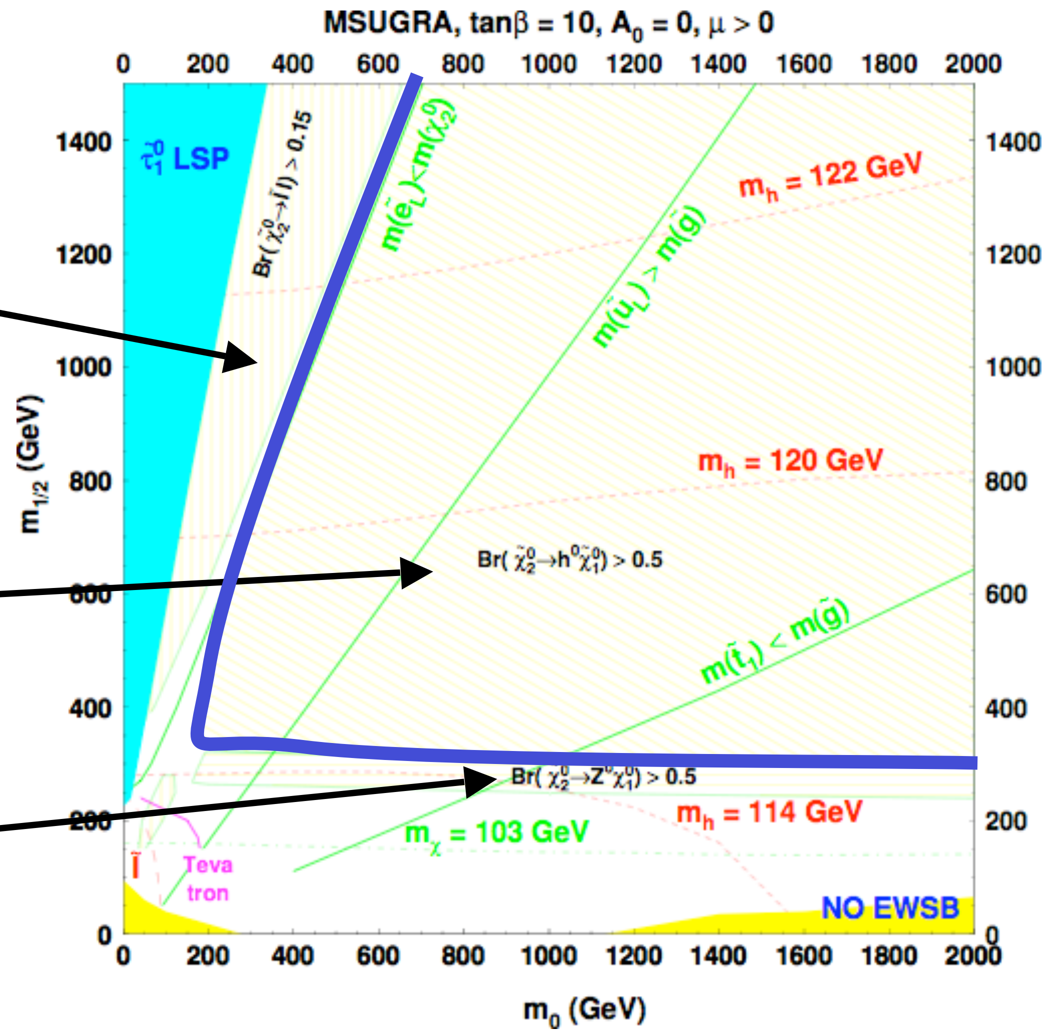
Neutralino decays in mSUGRA

Neutralino 2 decays in mSUGRA:

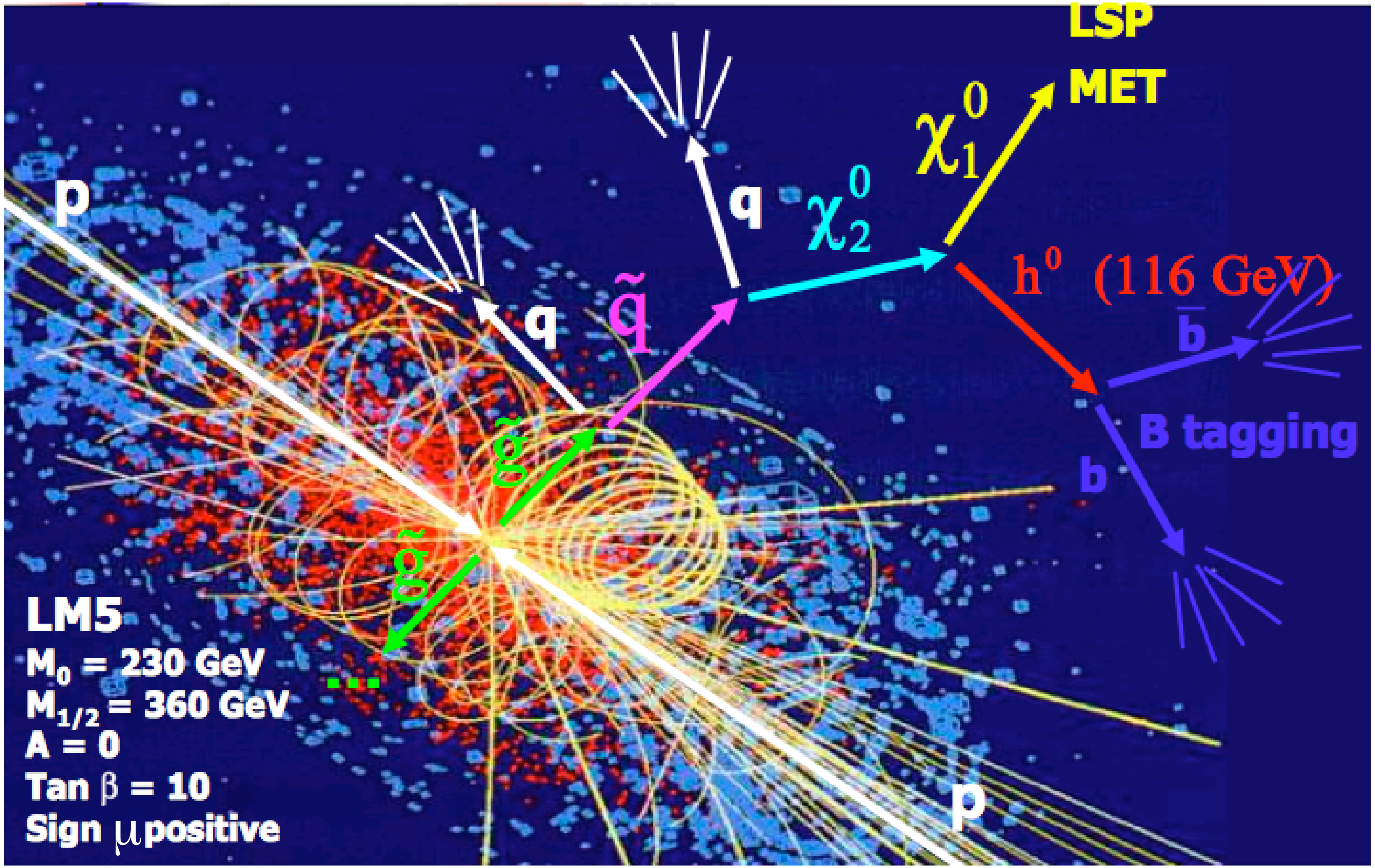
- dilepton final state
(e, μ, τ) through slepton
intermediate state
Larger tan β -> more taus

- higgs final state
Dominant h^0 decay to bb
Large area in parameter space

- dilepton final state
through Z^0



Higgs final state



Selection

for SUSY → Higgs final states:

Trigger stream = Jet + MET (L1 & HLT) : ~80% efficient

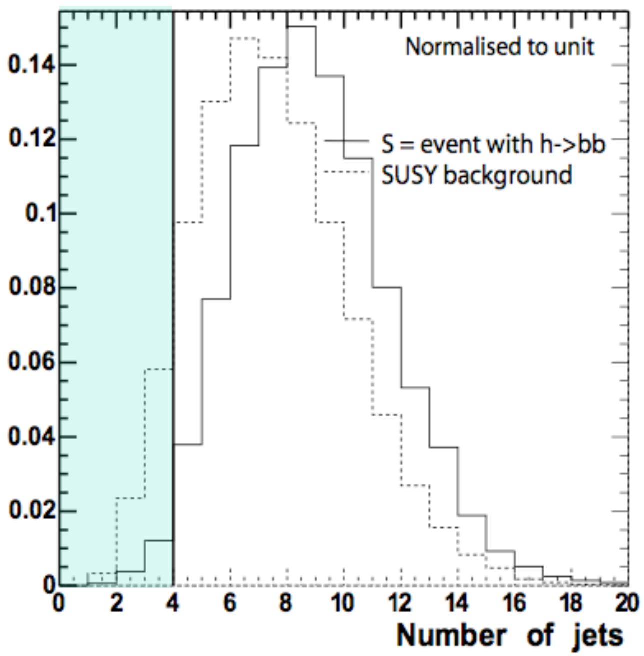
HLT thresholds: 180 + 123 GeV

basic SUSY →	• At least 4 jets with Et > 30 GeV
Higgs → bb →	• of which at least 2 b-tagged jets (discriminator > 1.5)
basic SUSY →	• MET > 200 GeV
optimizing S/B for SUSY	• Highest jet Pt > 200 GeV • Second highest jet Pt > 150 GeV • Third highest jet Pt > 50 GeV
optimizing S/B for Higgs	• B-jets in the same hemisphere • Smallest DR of b-jet pair (among DR < 1.5)

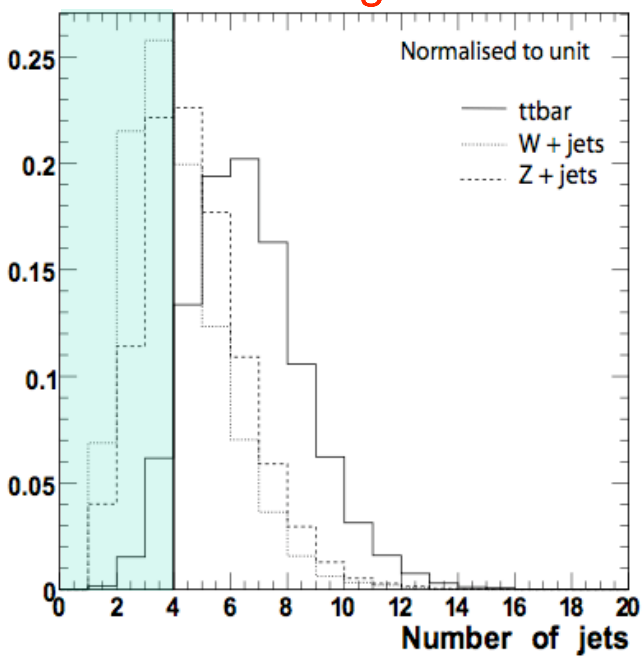
Kinematics : jets

Jets with Et > 30 GeV, GammaJet calibration

SUSY



SM backgrounds

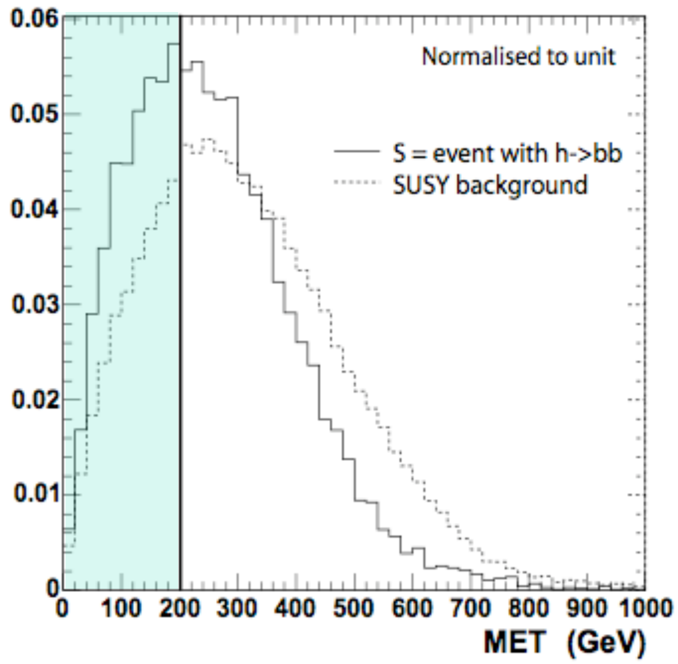


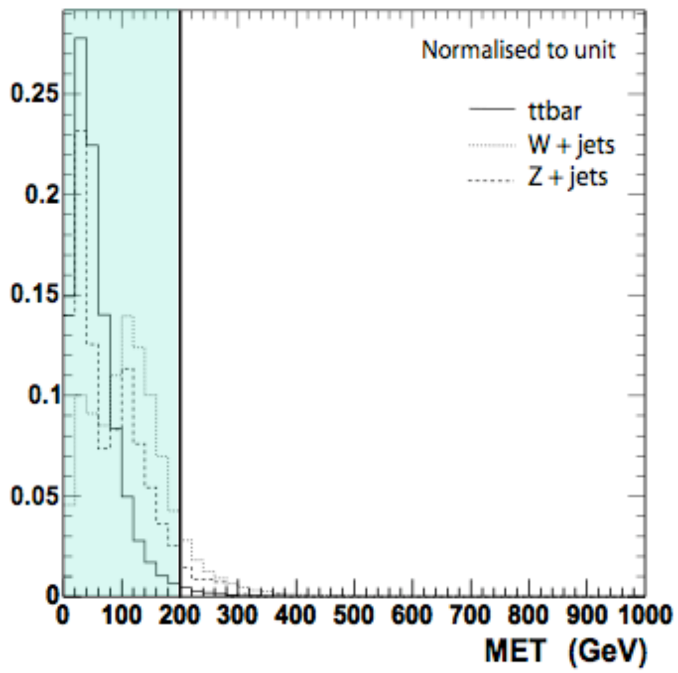
→

- at least 4 jets with Et > 30 GeV
- hard jets …

Kinematics: MET

Missing transverse energy (calculated from the jets):





→ MET > 200 GeV

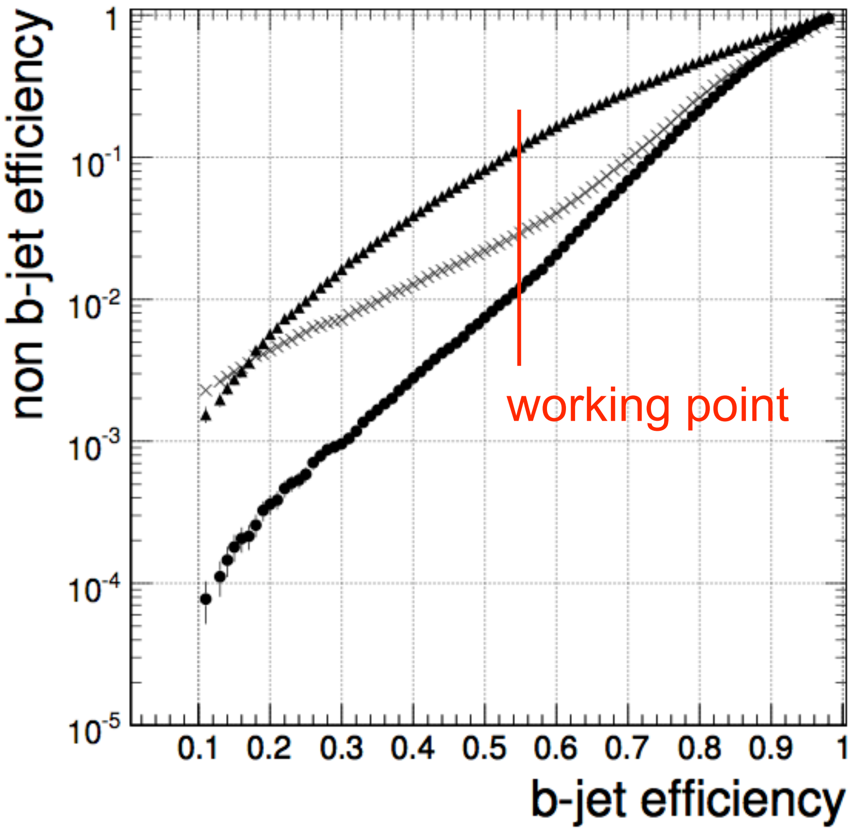
B-tagging

• using Combined Secondary Vertex Algorithm, which combines track and secondary vertex properties into one discriminator :

vertex mass, flight path, narrowness, track multiplicity, energy fraction, track impact parameters, …

• performance in multi-jet environment @ chosen working point:

b-tagging: 55%
c-jets: 12%
udsg-jets: 1.6%

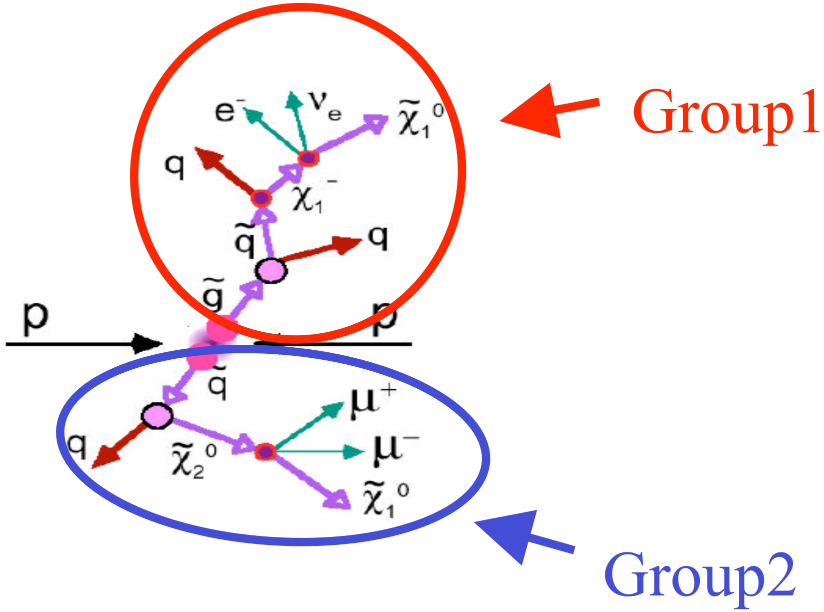


"Hemisphere" separation

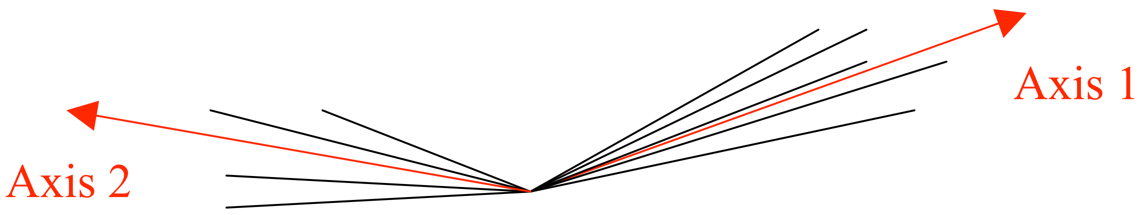
- 2 primary sparticles in event
- they both decay into a cascade

↓

separate both cascades will reduce pairing combinatorics!



Inspired by "thrust/sphericity" methods, but now 2 axes per event due to LSP's

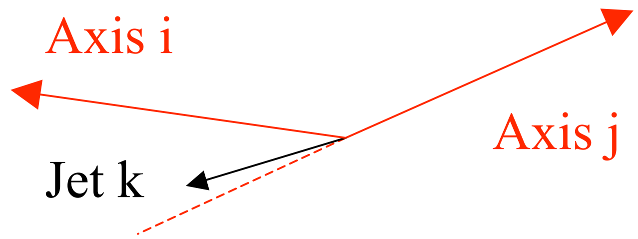


Collect objects in 2 groups with their axis (iterative procedure)

Hemisphere association

- 2 seeding methods:

1. 1^{st} axis: highest momentum object
   2^{nd} axis: object with largest P x ΔR (wrt A1)
2. pair of objects with maximal invariant mass



- 3 association methods: assign object to the axis for which

1. the scalar product $\vec{P} \bullet \vec{A}$ is maximal (|A| = 1)
   = pure angular test: $\cos\theta_{ik} \geq \cos\theta_{jk}$
2. the hemisphere masses are minimal: $m_{ik}^2 + m_j^2 \leq m_i^2 + m_{jk}^2$

   => $(E_i - p_i \cos\theta_{ik}) \leq (E_j - p_j \cos\theta_{jk})$

3. the minimal Lund distance:

$$(E_i - p_i \cos\theta_{ik}) \frac{E_i}{(E_i + E_k)^2} \leq (E_j - p_j \cos\theta_{jk}) \frac{E_j}{(E_j + E_k)^2}$$

- recalculate the axes as sum of objects; iterate till no object changes group

Hemisphere efficiencies

For jets, the probability that the jet is assigned to the "correct" hemisphere =

	All jets	quark jets	gluon jets	q from squark	q from gluino
LM1	81%	81%	79%	87%	73%
LM5	77%	77%	74%	87%	70%
LM9	74%	75%	69%	---	76%

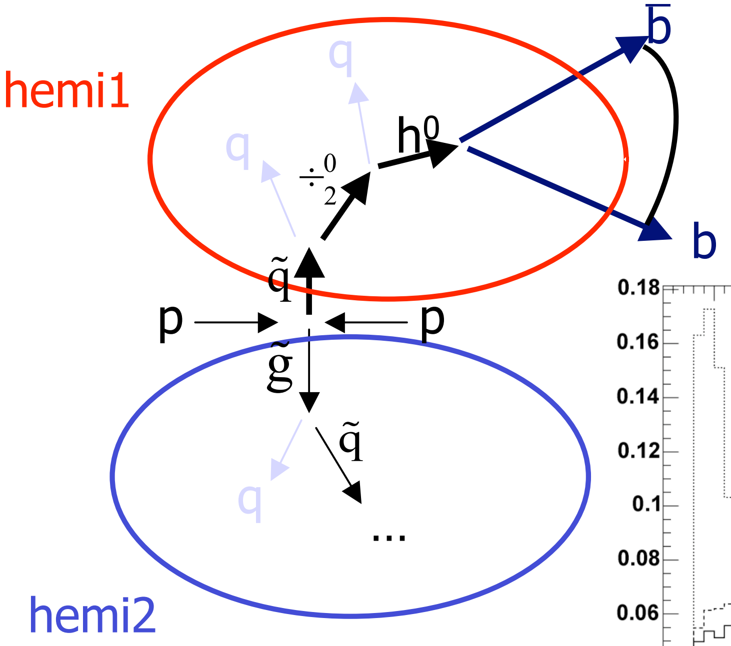
(using seeding method 2, association method 3)

different CMS study points

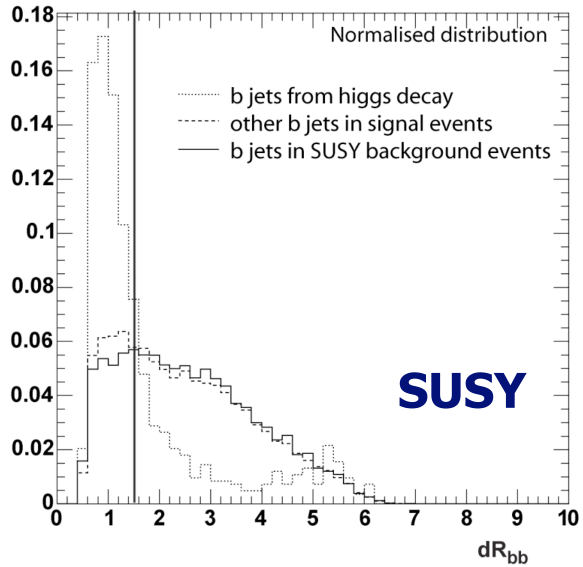
Cleans up invariant mass plots (hq, hqq, lqq, …) significantly
Does not work well for leptons (~massless) but there are tricks …

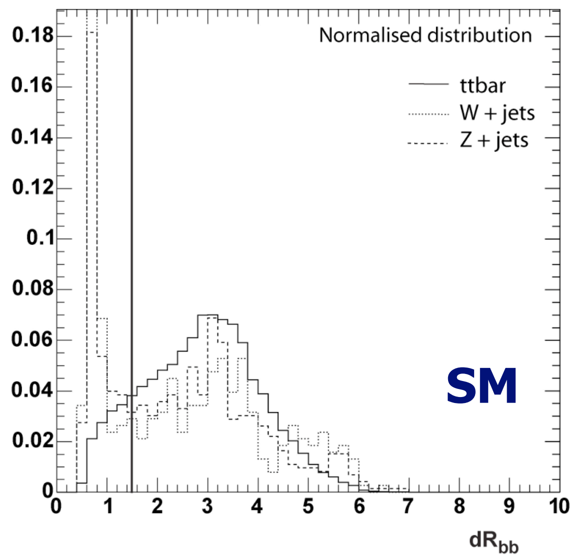
Angular separation of b-jets

within one hemisphere, take only that combination of reconstructed b tagged jets for which the space angle ΔR is smallest (among those with $\Delta R < 1.5$)



$$\Delta R = \sqrt{|\varphi_1 - \varphi_2|^2 + |\eta_1 - \eta_2|^2}$$





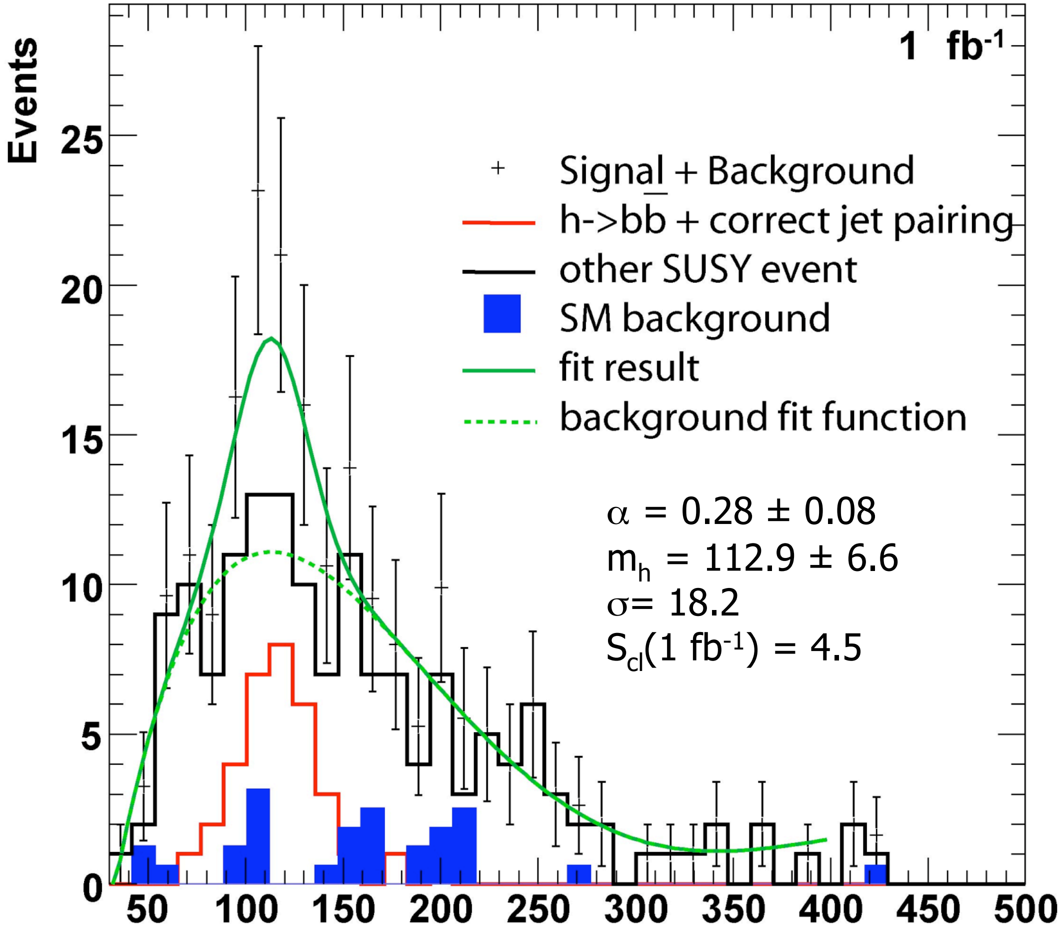
Cut flow

Selection efficiency for signal and main backgrounds (in percent), starting after the trigger (L1 + HLT Jet+MET).

DATA	TRIGGER	NJET+NBJET	MET	PTJETCUTS	DR+JET PAIRING
SIGNAL	100	43.0	30.7	24.7	8.1
SUSYBG	100	89.8	11.9	9.1	1.4
TTBAR	100	19.0	3.6	1.1	0.1
Z+JET	100	0.7	0.1	0.02	$< 10^{-4}$
W+JET	100	0.004	0.001	0.004	$< 10^{-4}$

Trigger efficiency: SUSY : 79%
ttbar : 4%

Mass reconstruction



M_h^{MC} = 116 GeV/c²

Mass fit:

Signal → gaussian G(m_h, 18.2)

extract bb width from other measurements (top, ZZ, …)

Background → 5th order polynomial (with fixed parameters from off peak fit)

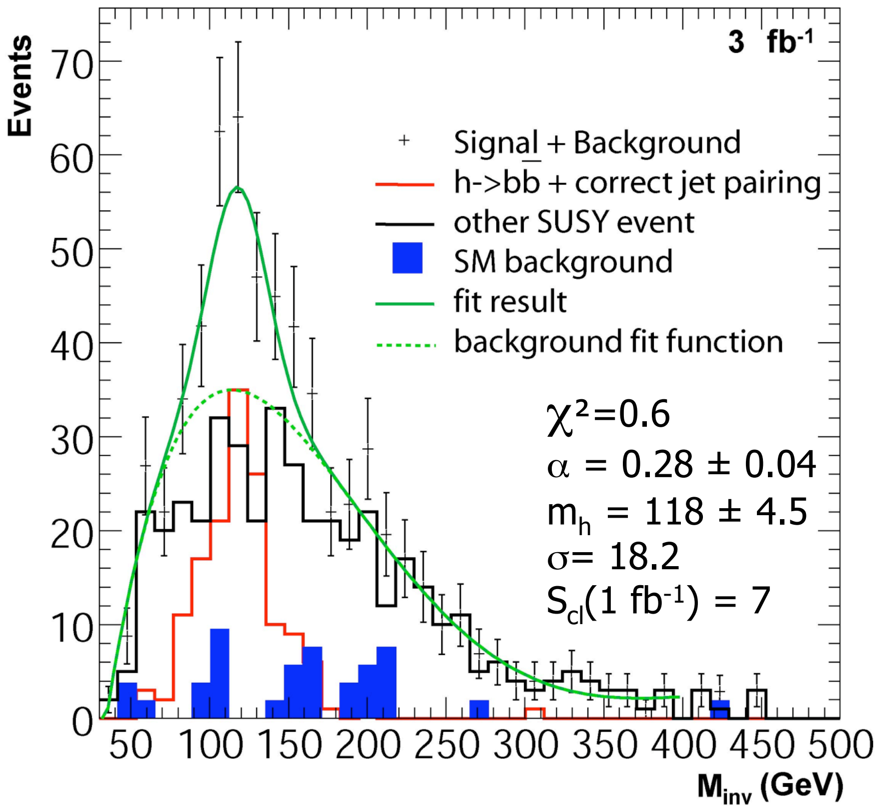
α = fraction of signal in the plot

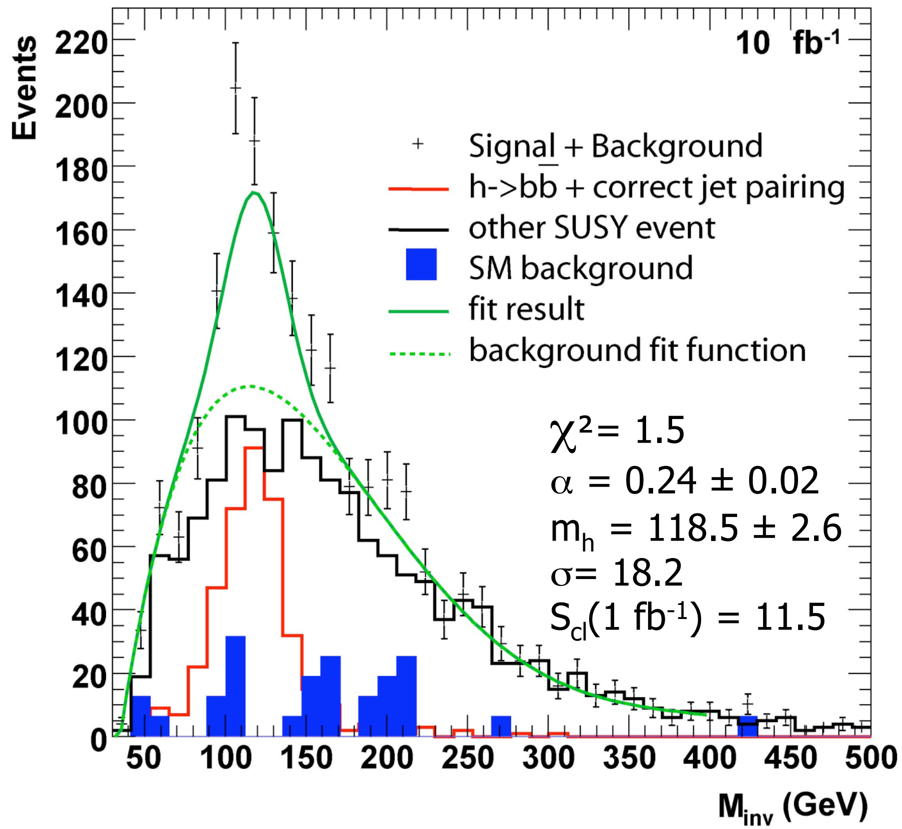
$$S_{cl} = \sqrt{2\left[(NS + NB)\log\left(1 + \frac{NS}{NB}\right) - NS\right]}$$

S_{cl}(1 fb^{-1}) = 4.5

Scl = 5 for 1.5 fb^{-1}

Mass reconstruction(2)





M_h^{MC} = 116 GeV/c²

Systematics

- Main systematic: Jet energy scale + MET scale (recomputed from corrected Jets):

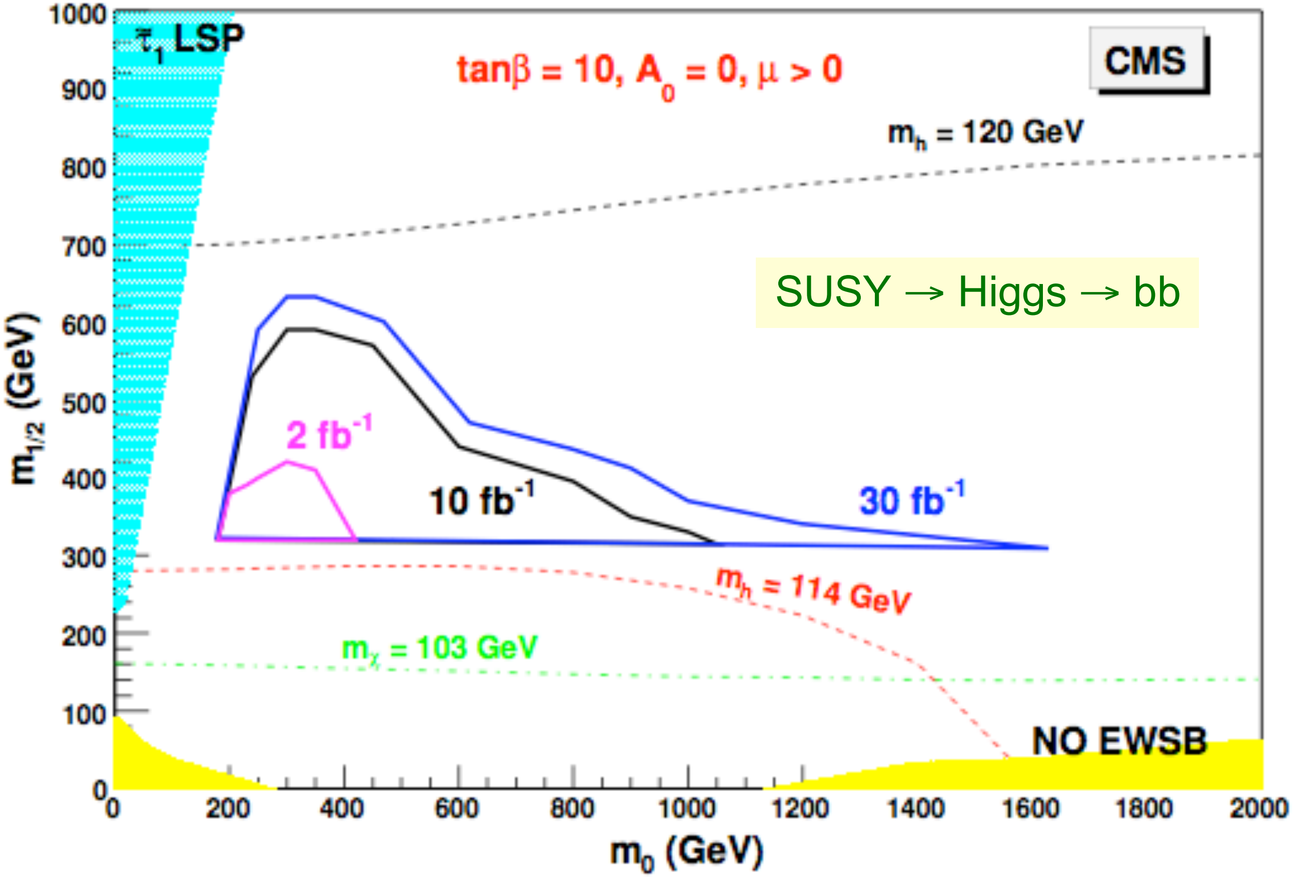
  - for 1 fb^{-1} (10 fb^{-1}), JES uncertainty
    goes linear from 15%(10%) at 20 GeV to 5%(3%) at 50 GeV;
    flat 5 %(3%) above 50 GeV;
  - leads to the following systematic uncertainties:
    15 % (7 %) on SUSY event selection ;
    17 % (10 %) on $t\bar{t}$ background rejection ;
  - Effect on fitted parameters estimated to be :
    ± 7.5 (5) GeV/c² on m_h (and ± 0.04 (0.01) on α).

- Tracker misalignment : applying the "short term" misalignment scenario (misalignment of about 100 μm on strips, 20 μm on pixels)

  => no effect on the position of the invariant mass distribution ;

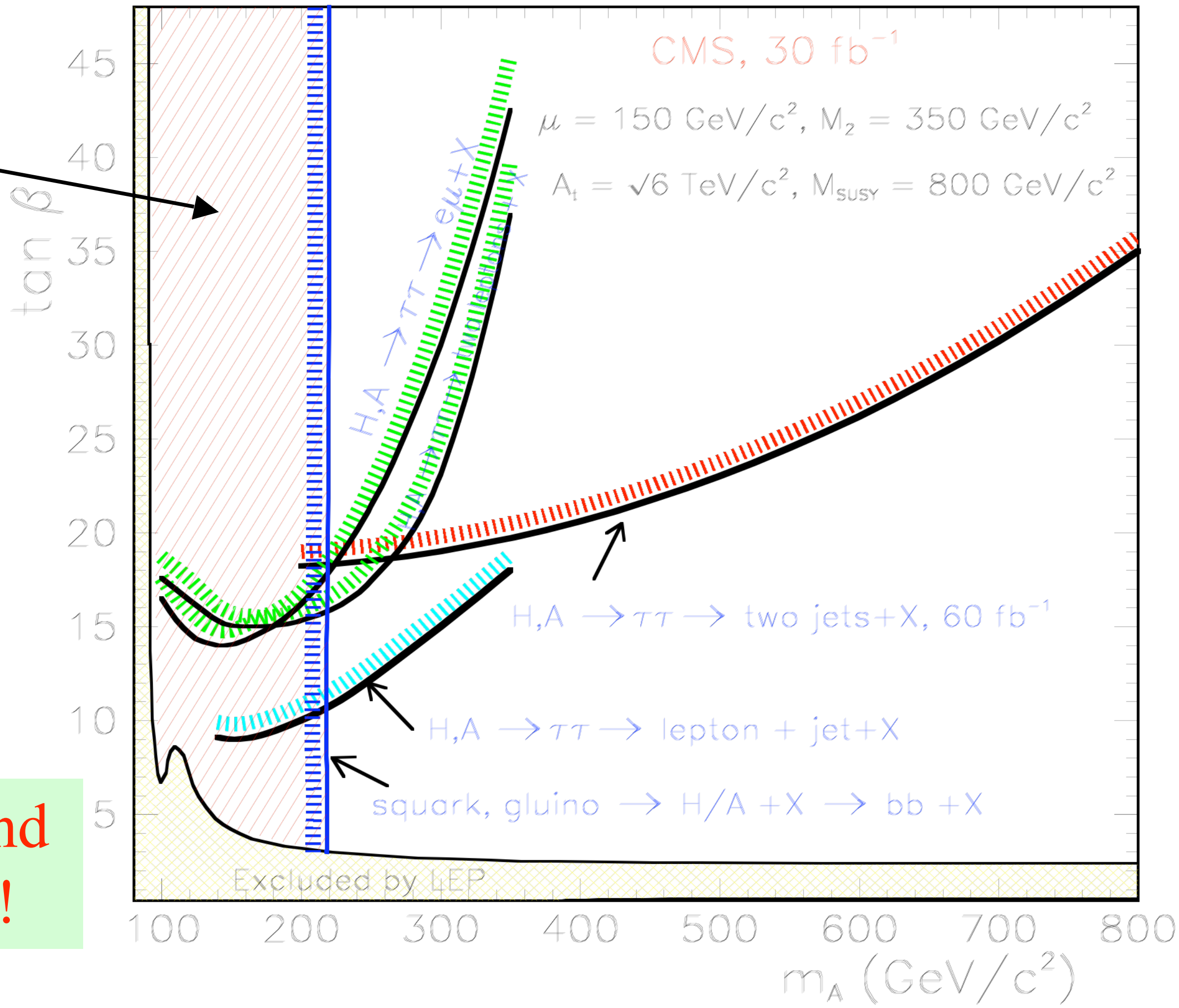
  => observed a small drop in number of selected signal events due to the reduced b-tagging efficiency

Reach in mSUGRA



Other MSSM Higgs bosons

region where H^0 and A^0 can be found in SUSY cascade decays



h^0 can be found in full plane!!

Conclusions

• A full simulation study of Higgs to bb decays has been completed in the framework of the CMS Physics TDR

• including trigger efficiencies, optimized b-tagging & systematics treatment

• developed a “hemisphere separation” algorithm for the separation of the 2 initial susy cascades to suppress combinatorics

• for LM5 point: 5σ significant Higgs evidence for 1.5 fb^{-1}

• significant mSUGRA reach for 10 fb^{-1} (could be Higgs discovery channel)

References/Acknowledgements

- h → bb in SUSY: S. Abdullin, D. Denegri (CMS Note 1997/070)
- Detection of MSSM Higgs bosons in SUSY cascades at the LHC :
  A. Datta, A. Djouadi, M. Guchait, F. M. (*Nucl. Phys.* B 631 (2004) 31)
- SUSY with h → bb final states: F.M., A. Romeyer, P. Olbrechts, L. Pape
  (CMS Note 2006/090)
- Hemisphere separation algorithm: F.M., L. Pape

Inclusive reach for 10 fb^{-1}