Implications of CMS searches for the Constrained MSSM - A Bayesian approach

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Outline

- Introduction of the **BayesFITS** group
- **Part 1 (MK)**
  - Experimental introduction
    CMS SUSY searches at $\sqrt{s}$ = 7TeV
    - In all-hadronic events with α_T with 1.1/fb [PRL 107, 221804]
- **Part 2 (Sming Tsai)**
  - **Bayesian Implications** of Current LHC and XENON100 (and Dark Matter) Searches **for SUSY (CMSSM)**
    - [ArXiv:1111.6098] Nov 2011 cited by 11 records
    - [ArXiv:1202.1503] Feb 2012 cited by 2 records

BayesFITS group

WELCOME FNP PROJECT: http://welcome.ncbj.gov.pl

Bayesian approach to multi-parameter problems in physics and beyond involving parallel computing and large data-sets

Based on:

- **NCBJ:** National Centre for Nuclear Research
- **CIŚ:** Świerk Computing Centre
- **MANHAZ:** The Centre of Excellence MANHAZ
  Management of Health and Environmental Hazards
- **UW:** University of Warsaw

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BayesFITS group

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BayesFITS activity

Development of **algorithms and procedures** to address **problems**

- in **high energy physics** and
- in practical applications to issues related to **safe operation of nuclear and chemical plants** with potentially big consequences for accident risks

HEP: Bayesian Fits for SUSY

The aim of the current analysis is to:

- Compare theory with experiment

  a comparison of SUSY model's predictions

  for various observables with experimental data from:
  - SM precision measurements, direct limits, flavour physics, …
  - Dark Matter searches
  - CMS SUSY searches

- Answer statistical question: **Which ranges of model's parameters fit the data well or poorly ?**
  - draw probability maps in SUSY model's parameter space
  - calculate expected ranges of e.g. masses of SUSY or Higgs particles

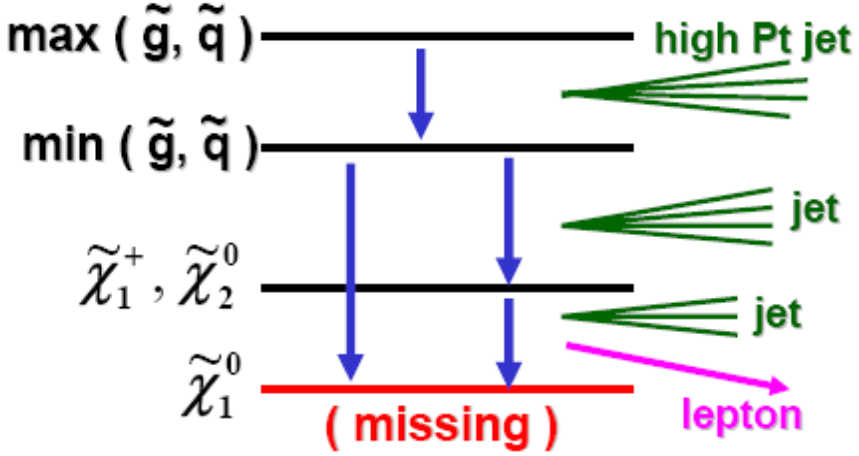
Part 1

Experimental introduction

CMS SUSY searches at $\sqrt{s}$ = 7TeV

Signatures of SUSY

Production of SUSY event at the LHC:



MAIN SIGNATURE:

large MET + multi-jets (+ multi-leptons)

MAIN BACKGROUND:

QCD, ttbar/W/Z associated with jets

SUperSYmmetry

- **MSSM**: the most popular Minimal Supersymmetric extension of the Standard Model

  too many free parameters...

- assuming simple scenario of SUSY breaking:

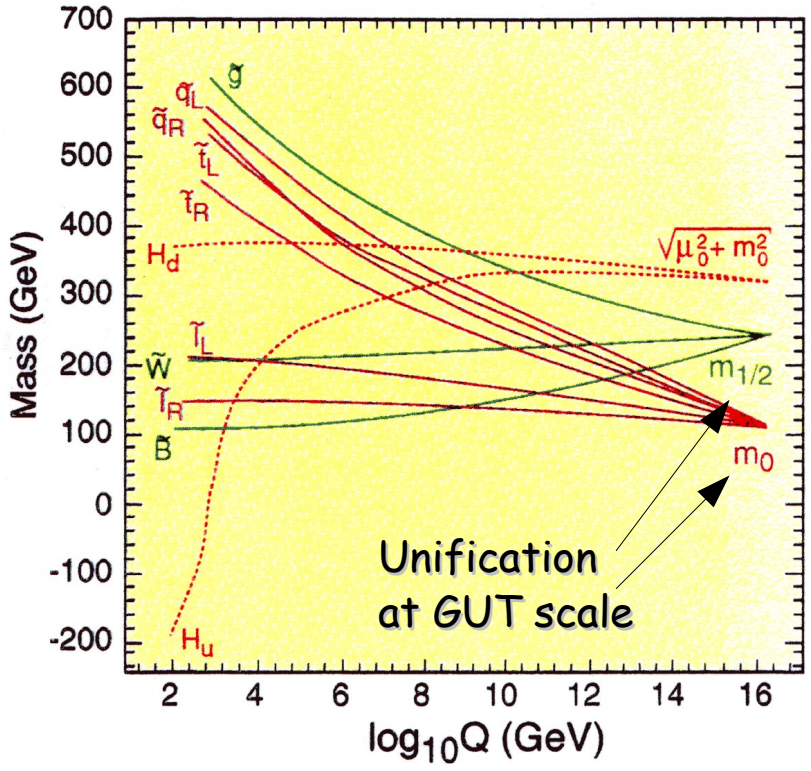
  Constrained MSSM

  [m_0 , $m_{1/2}$, A_0 , tan β , sign μ]

- Typically:

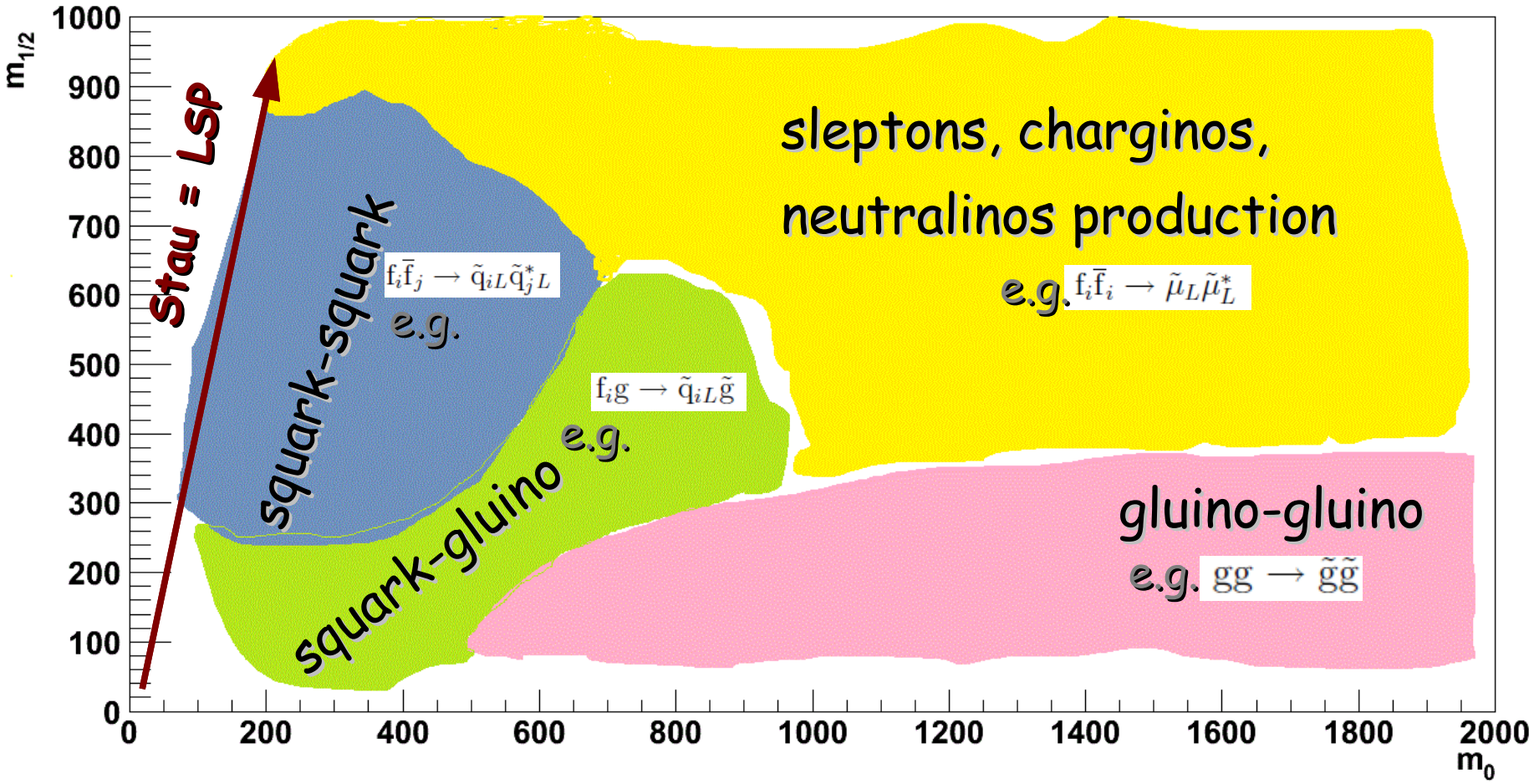
  $m_{gluino} = \sim 2.7\ m_{1/2}$

  $m_{squark} = \sqrt{(\sim 6\ m^2_{1/2} + m^2_0)}$



Anatomy of the CMSSM signal

- Dominant processes of SUSY events production at LHC



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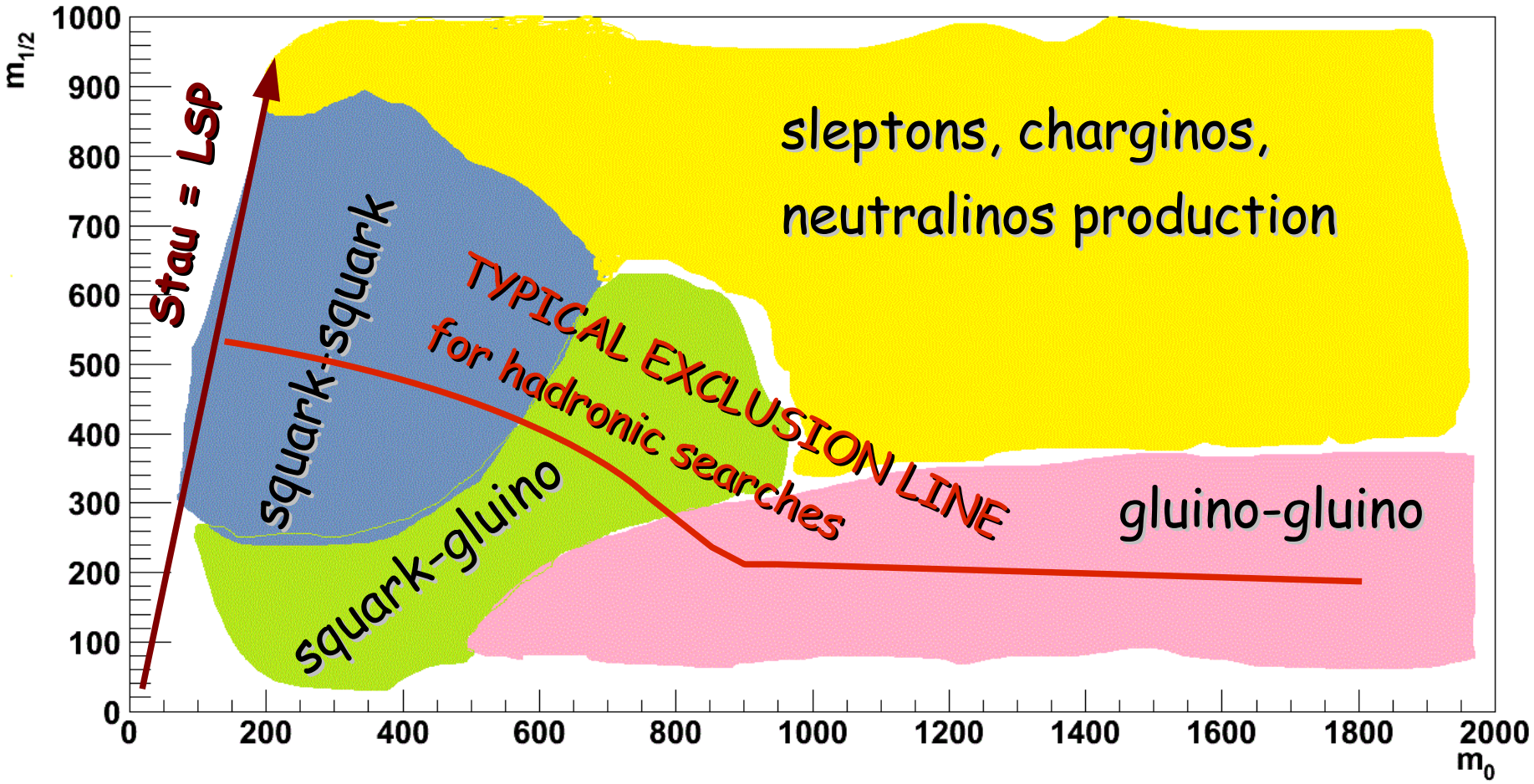
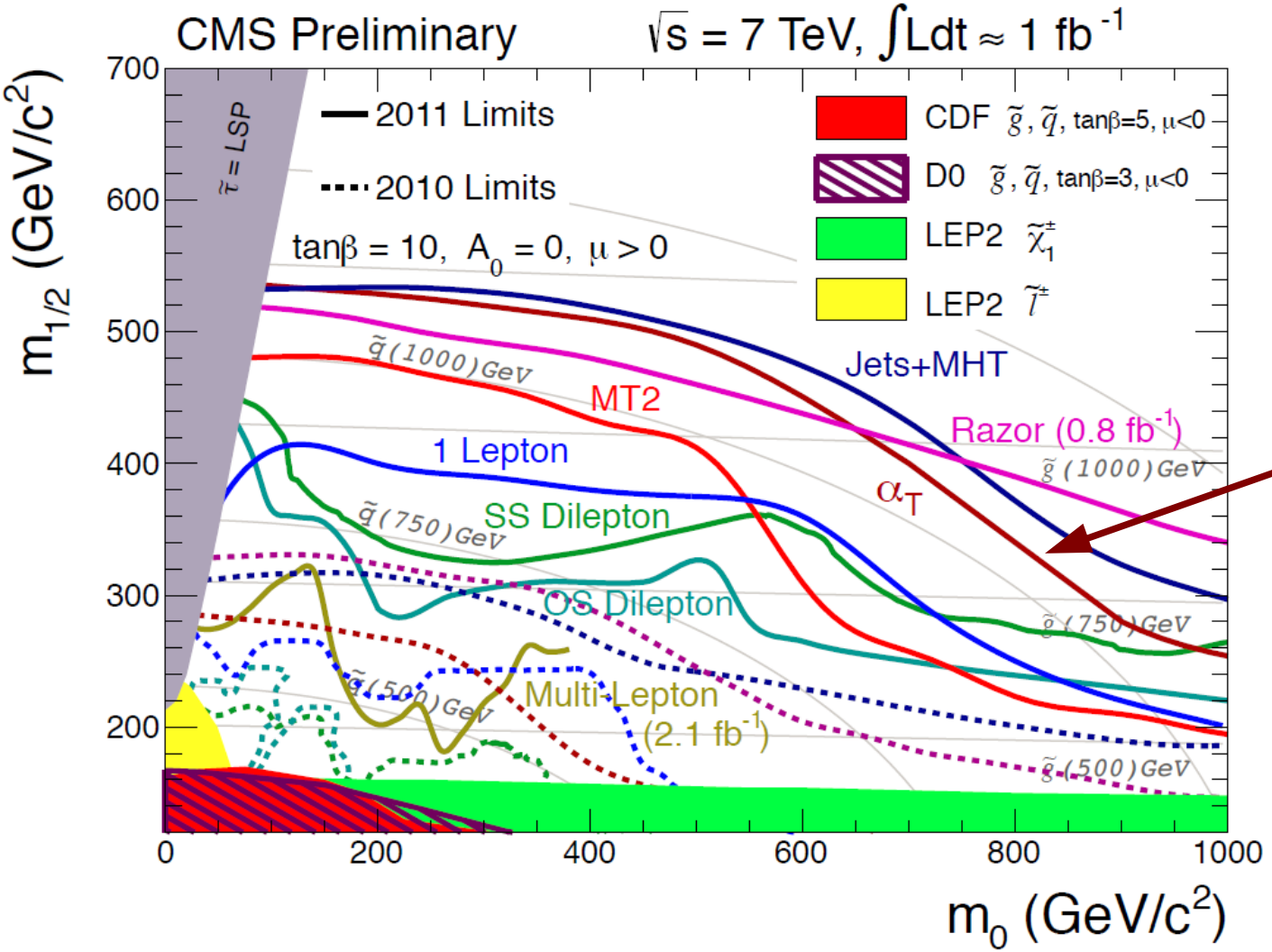


CMS Spaghetti

- 2011 Observed limits with ~1/fb



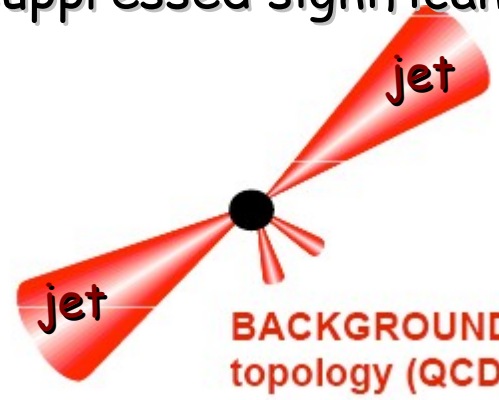
Selected analysis:

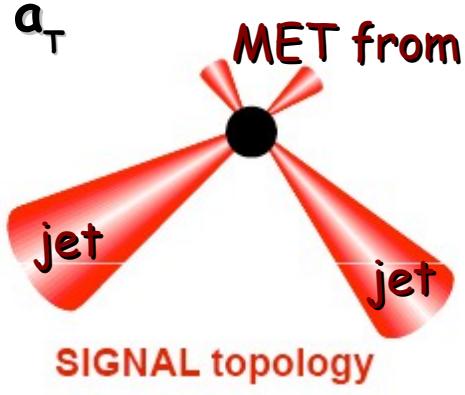
AlphaT

AlphaT analysis

[PRL 107, 221804]

- All-hadronig CMS SUSY search with 1.14/fb at $\sqrt{s}$ = 7 TeV
- Search using the **kinematic variable, a_T**
  - Originally proposed for di-jets [hep-ph 0806/1049]
  - Extended to multi-jets by merging jets in to two pseudo-jets defined by balance in "pseudo-jet" transverse energy
- a_T is used as the **main discriminator** between events with **genuine and misreconstructed MET** → QCD multi-jet background can be suppressed significantly with a cut on a_T





AlphaT variables

- **HT:** Scalar sum of the transverse energy of jets

$$H_{\mathrm{T}} = \sum_{i=1}^{N_{\mathrm{jet}}} E_{\mathrm{T}}$$

- **MHT:** Magnitude of the vector sum of the transverse momenta of jets

$$\not{H}_{\mathrm{T}} = \left| \sum_{i=1}^{N_{\mathrm{jet}}} \vec{p}_{\mathrm{T}} \right|$$

- **AlphaT:** For events with 2 (pseudo-)jets:

$$\alpha_{\mathrm{T}} = E_{\mathrm{T}}^{\mathrm{j2}} / M_{\mathrm{T}} = E_{\mathrm{T}}^{\mathrm{j2}} / \sqrt{H_{\mathrm{T}}^{2} - \not{H}_{\mathrm{T}}^{2}}$$

less energetic jet — transverse mass of di-jet system

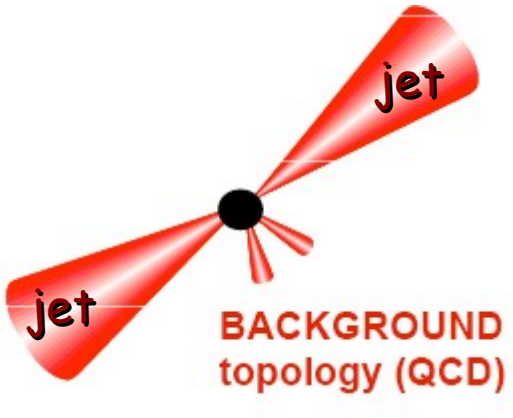
Event selection (pure multi-jet topology)

- Jet requirements:
  - Reconstructed with anti-kT algorithm for R=0.5
  - ET > 50 GeV and |η| < 3
  - At least 2 leading jets with ET> 100 GeV and |η| < 2.5
  - **HT > 275 GeV**
- Reject events with many low ET jets:
  - MHT/CaloMET < 1.25
- Veto of events with:
  - Isolated muons or electrons with pT > 10 GeV
  - Isolated photons with pT > 25 GeV
- Trigger
  - A dedicated HT trigger used to collect the signal and the control samples; High Level Trigger used energy corrected jets

AlphaT behaviour

- For a perfectly measured **dijet event** with $E_T j1 = E_T j2$

  jets are **back-to-back in φ**
  in the limit of large jet momenta
  compared to their masses
  → α_T is 0.5

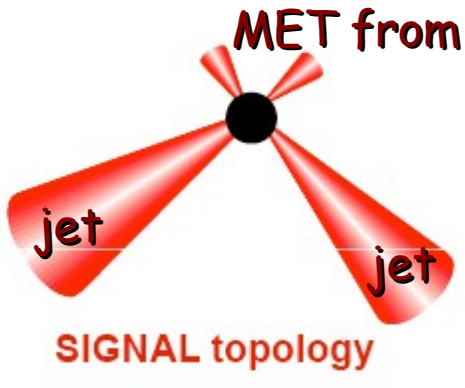


- α_T is smaller than 0.5

  in the case of **an imbalance in**
  the measured ETs of back-to-back jets

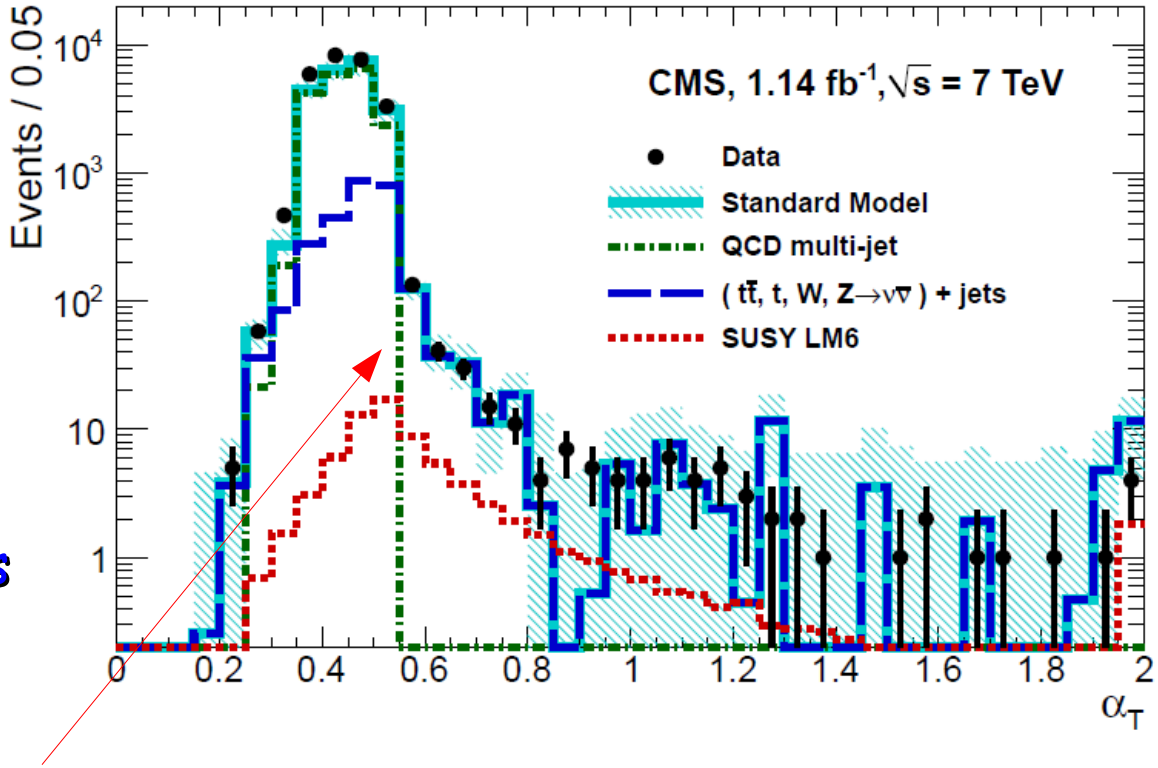
- α_T is greater than 0.5

  when the two **jets are not back-to-back**
  and balancing genuine MET



Final selection

- Distribution after all selection criteria except α_T for HT> 375 GeV
- SM from simulations
  for the illustration purpose only
  but total background is estimated from data



- Final selection: **aT > 0.55**
  - Makes background QCD free
  - Selects events with genuine MET: Top, EWK, SUSY

Background estimation

- Two control samples used for the background estimation:

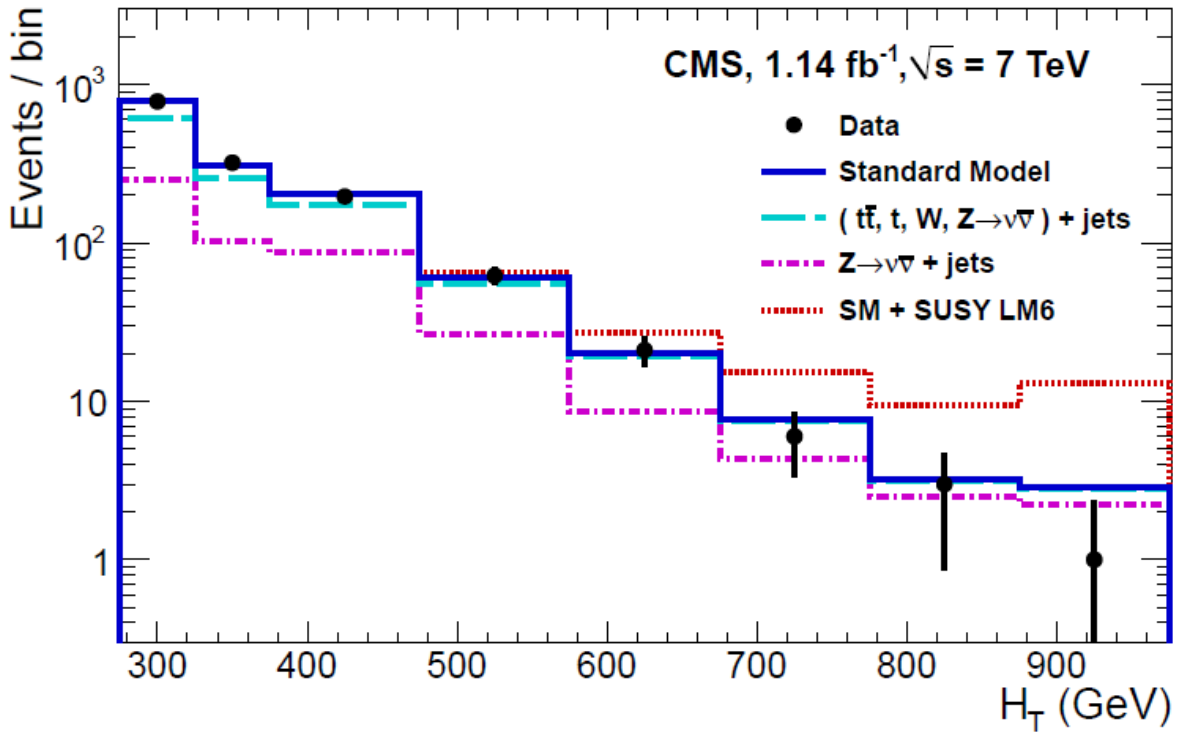
  μ + jets (ttbar,W) and **γ + jets (Z invisible)**

- **E.g. : μ + jets**
  - Use the same selection as for signal, with the requirement of an isolated pT > 10 GeV muon and calculate alphaT excluding the muon
    - Extra selection requirement of transverse mass of W candidate > 30 GeV to remove QCD
    - DR (jet, muon) > 0.5 and MHT/HT > 0.4
  - Use MC efficiencies and acceptances for the muon sample
  - Use this to estimate the number of hadronic final states

$$W^{\mathrm{had}}_{\mathrm{data}} = W^{\mu}_{\mathrm{data}} \times \frac{W^{\mathrm{had}}_{\mathrm{MC}}}{W^{\mu}_{\mathrm{MC}}}$$

SUSY search

- Analysis is performed in **8 bins** of the **HT variable**
  to increase the signal sensitivity in higher HT bins

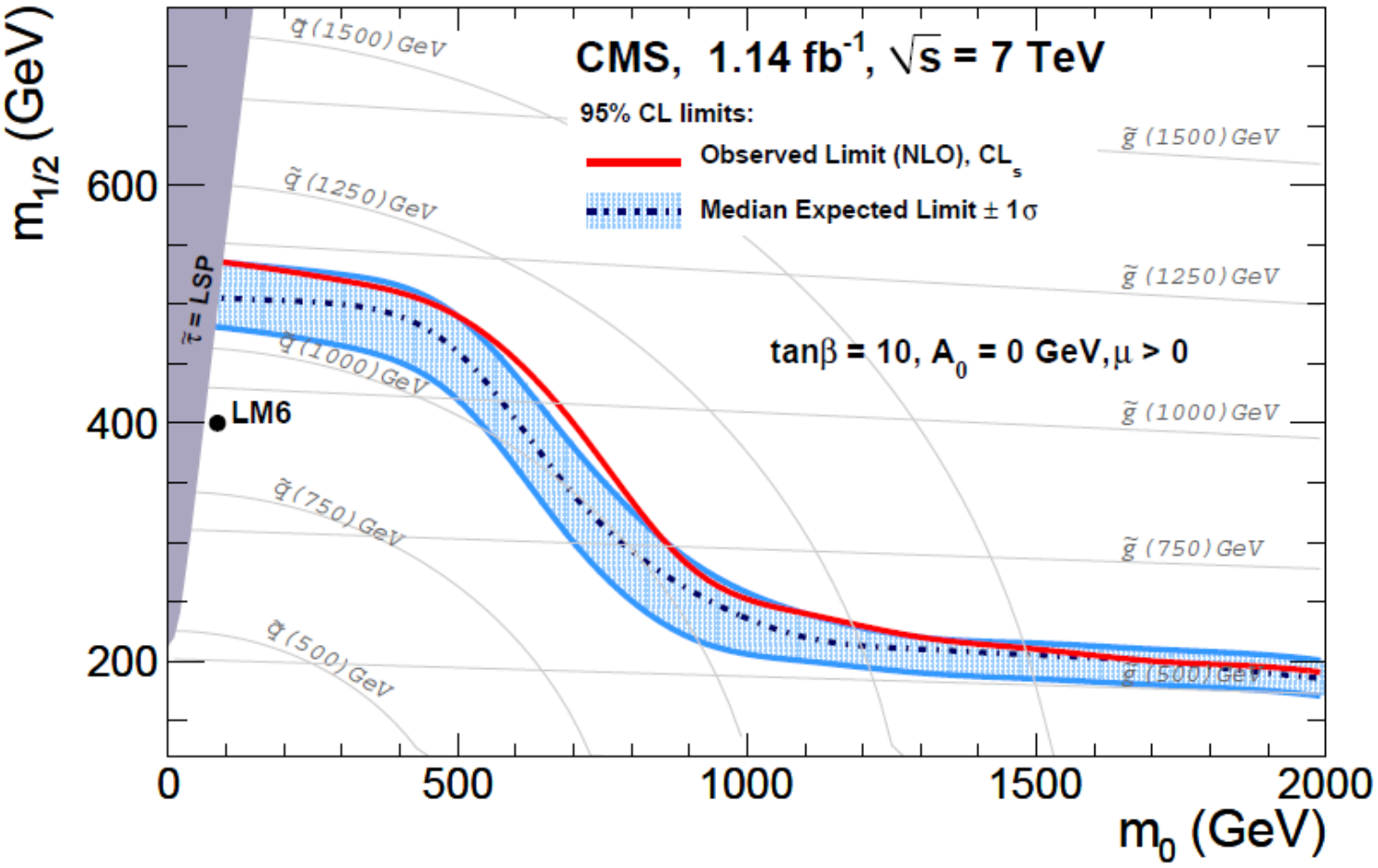


In an HT bin i:

signal yield
$= L \times \varepsilon_i \times \sigma$

- No excess has been found → limit SUSY parameter space

AlphaT lower limit



- For values of m0 < 500 GeV, squark and gluino masses up to 1.1 – 1.25 TeV can be excluded

Simulation of AlphaT analysis at GEN level

We (BayesFITS) need to re-derive the CMS result

- Observed and estimated background numbers are given
- We need an expected signal number of events for LUMI
- **Therefore we need to perform Monte Carlo simulations in the m_0-$m_{1/2}$ plane for each SUSY point**
- **For each SUSY point** we simulate:
  - Mass spectrum and decay table [SOFTSUSY, SUSY-HIT]
  - 10k events [Pythia] with reconstructed variables [jets, aT, HT,...]
  - Total cross-section [LO from Pythia]
- **We evaluate approximated efficiencies after all cuts for 8HT bins**

AlphaT efficiency maps

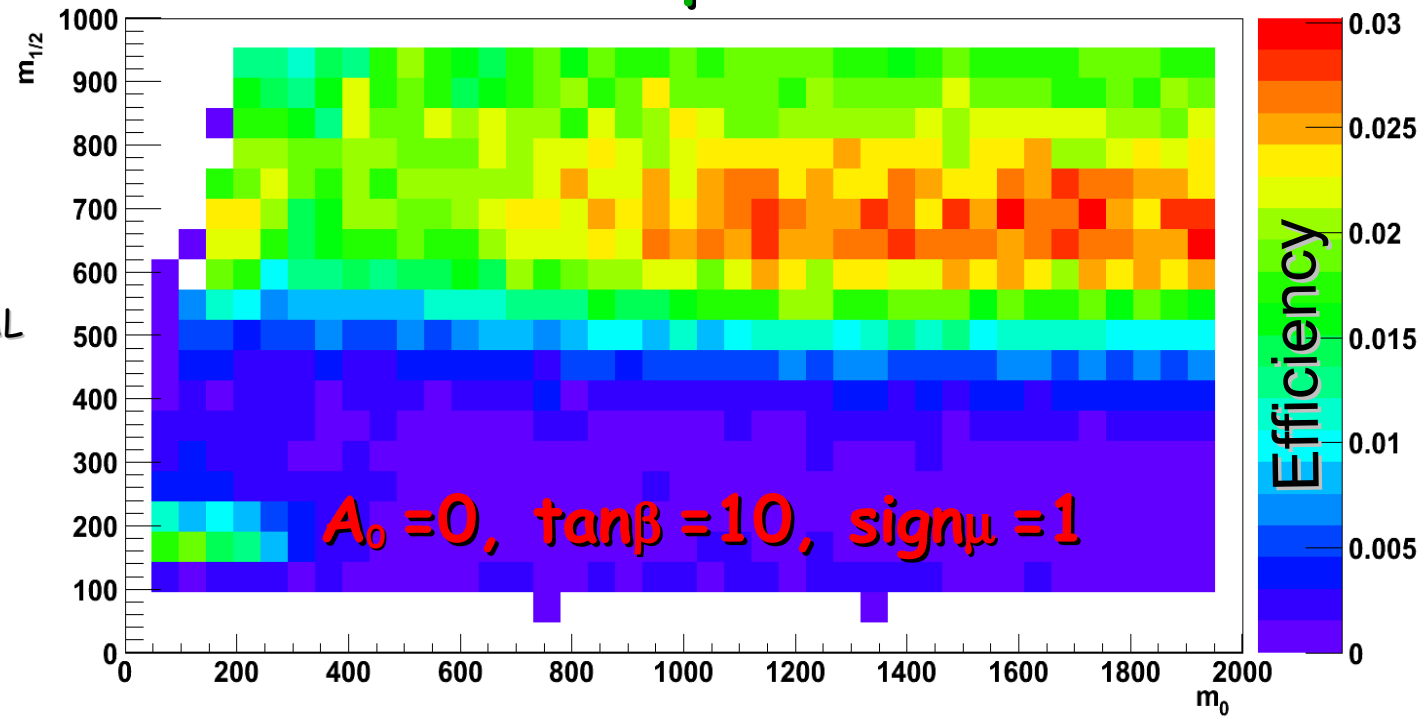
- Monte Carlo simulations in the m_0-$m_{1/2}$ plane

  with 50 GeV step

Efficiency

= N^{CUTS}/N^{TOTAL}

Our Eff map for 1st bin HT



- Maps are used to re-derive the alphaT limit

Conclusions

- We have developed a procedure to **approximately re-derive the alphaT limit at the MC level and obtain a realistic estimate of event yield**
  - Any SUSY analysis can be repeated (RAZOR)

- **Part 2:**

  The most favourite ranges of SUSY parameters can be evaluated with Bayesian approach