CMS searches in perspective

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Global BSM fits and LHC data – February 10, 2011

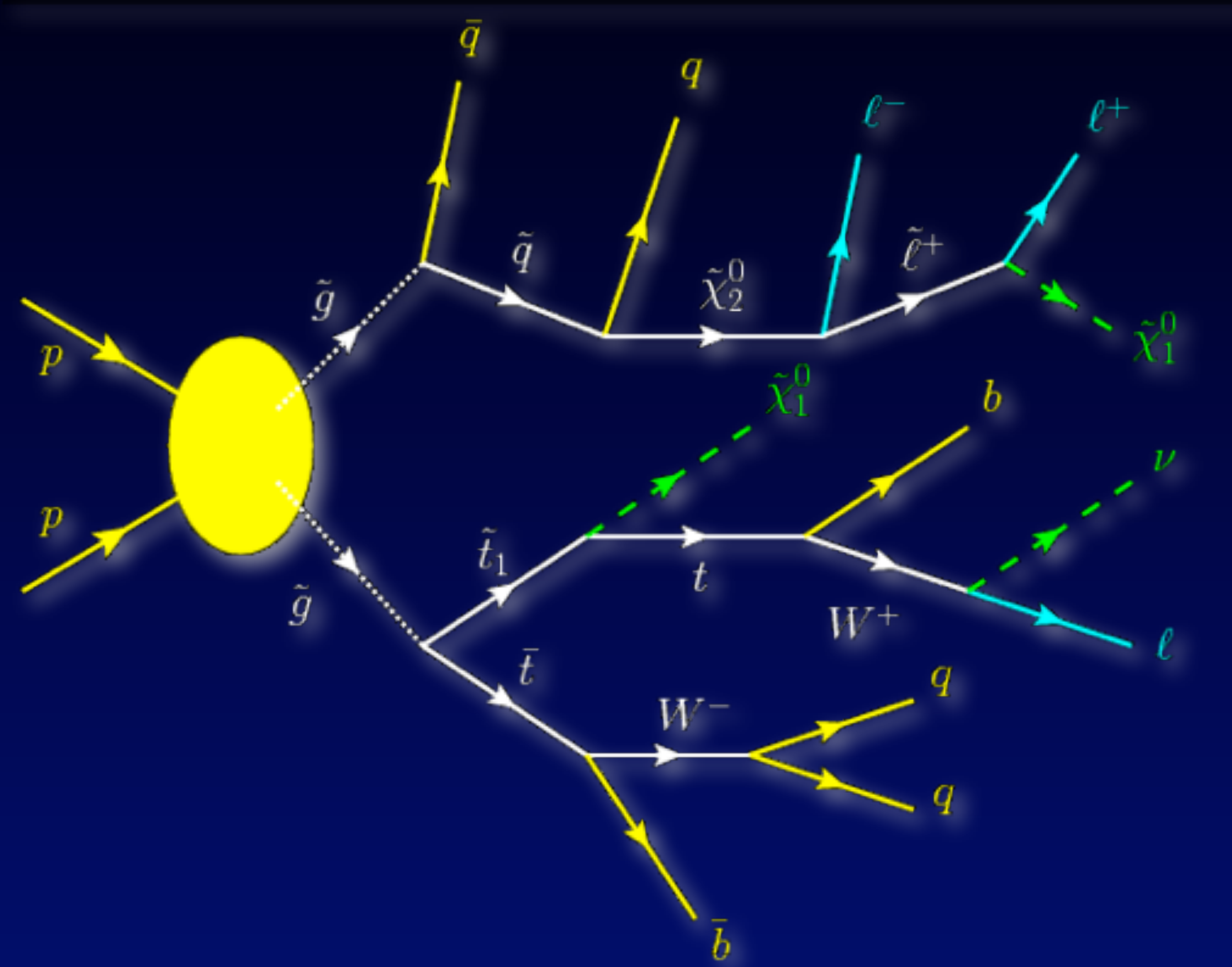
Outline

- SUSY searches at CMS: what we are after
- A selection of results
- Presenting the results
- Discussion

Searching for SUSY at the LHC

- Topology of a SUSY event
  - **large energy release**
  - **large number of jets**
  - **low-p_T leptons**
  - **missing energy (MET)**

- Searches are topology-based
  - **as model-independent as possible**
    - not even necessarily SUSY...
  - **trying to cover all topologies**



A "typical" SUSY event
many jets, leptons and missing energy

Searching for SUSY at CMS

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	Hadronic searches	*Leptonic searches*			
# leptons	**0**	**1**	**2 SS**	**2 OS**	**3**
Dominant back-grounds	QCD ttbar W+jets	ttbar W+jets QCD	*fakes* (ttbar)	ttbar Z+jets	*fake* (ttbar)

➠ different strategies depending on final state (different bkgds)

- Strategy
  - **suppress Standard Model processes ("background")**
  - **estimate remainder**
    - *data-driven techniques* developed
  - **New Physics will manifest itself as an "excess"**

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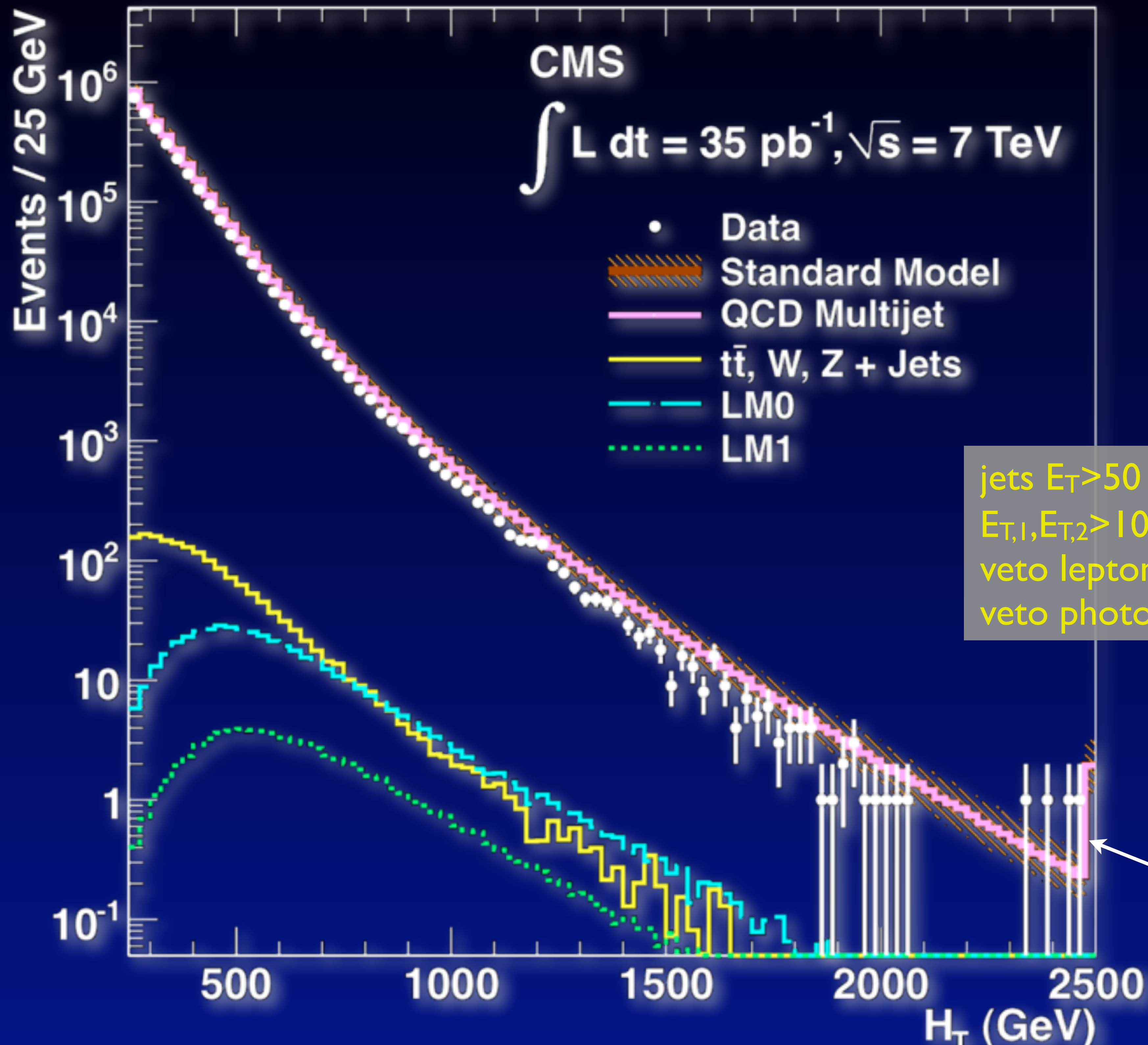
Jets + MET

Hadronic search: the problem



jets E_T>50 GeV/c, |η|<3.0
$E_{T,1}$,$E_{T,2}$>100 GeV, $|\eta_1|$<2.5
veto leptons p_T > 10 GeV/c
veto photons p_T > 25 GeV/c

Last bin contains overflow

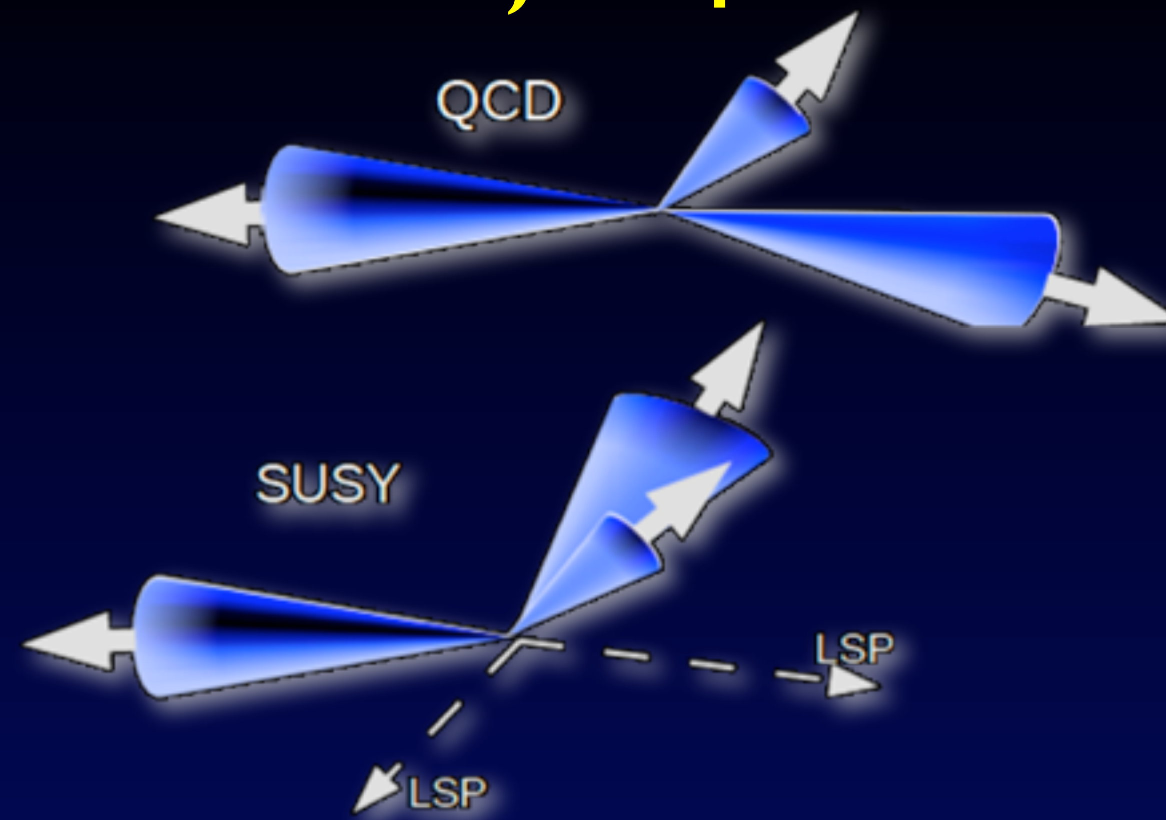
Distribution of total hadronic energy in data and MC simulation

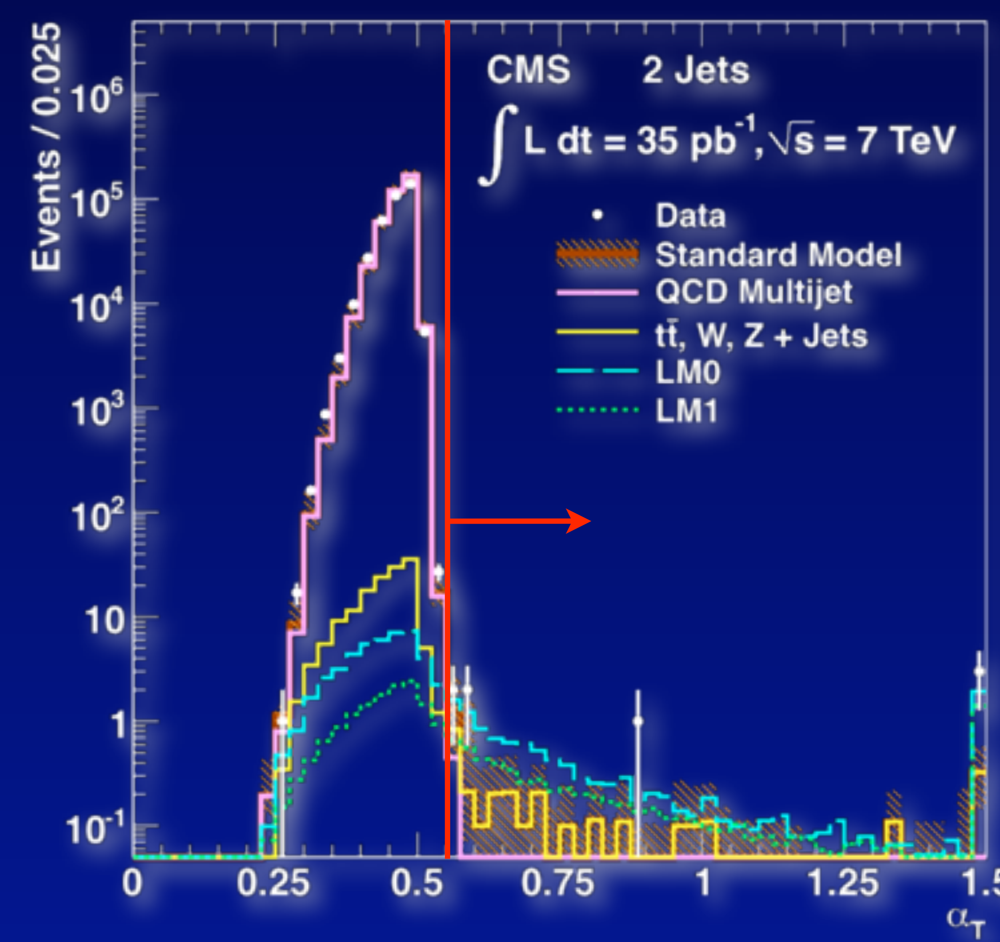
Hadronic search: a solution, α_T

- Construct distribution of

$$\alpha_T \equiv \frac{p_{T,2}}{M_T} = \frac{\sqrt{p_{T,2}/p_{T,1}}}{\sqrt{2(1-\cos\Delta\phi)}}$$

  - α_T=0.5 for perfectly balanced di-jet event
    α_T<0.5 if one jet **mis-measured**
  - **Multi-jet extension**
    - bring back to (pseudo) di-jet system by grouping jets together
  - **α_T>0.5 if**
    - real MET (top, W, SUSY)
    - lost jet
      - below threshold or dead zone

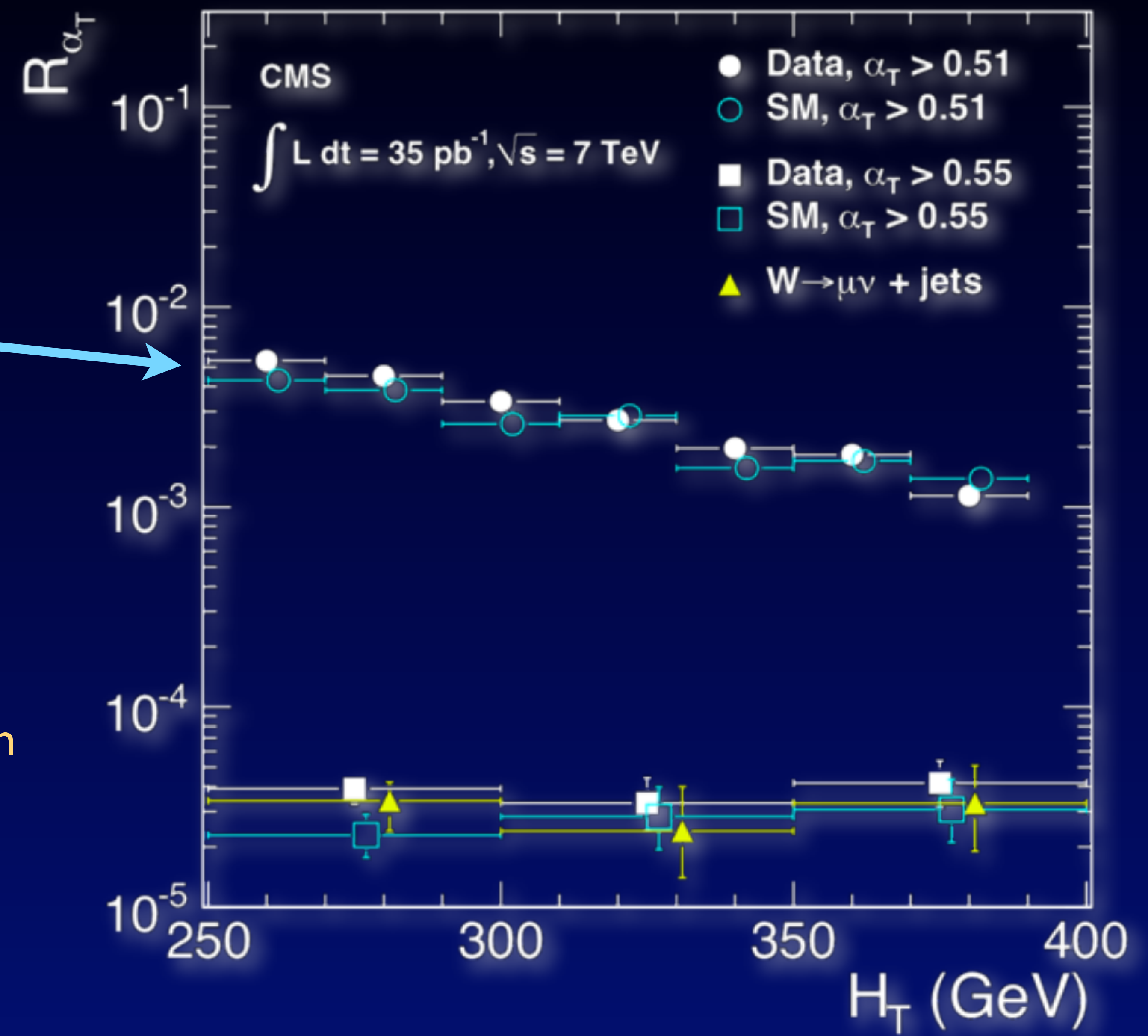




- QCD suppression: α_T>0.55

Remaining background estimate

- Study fraction of events failing $\alpha_T > 0.55$, $R_{\alpha T}$
  - independent of H_T for SM
  - increases with H_T in SUSY
  - estimate $R_{\alpha T}$ in first bins of H_T (250 and 300 GeV)
    - assuming constant $R_{\alpha T}$, gives value in region H_T>350 GeV
- W+jets and top estimate
  - also estimated from $W \rightarrow \mu\nu$
- $Z \rightarrow \nu\nu$ estimate
  - also estimated from γ+jets



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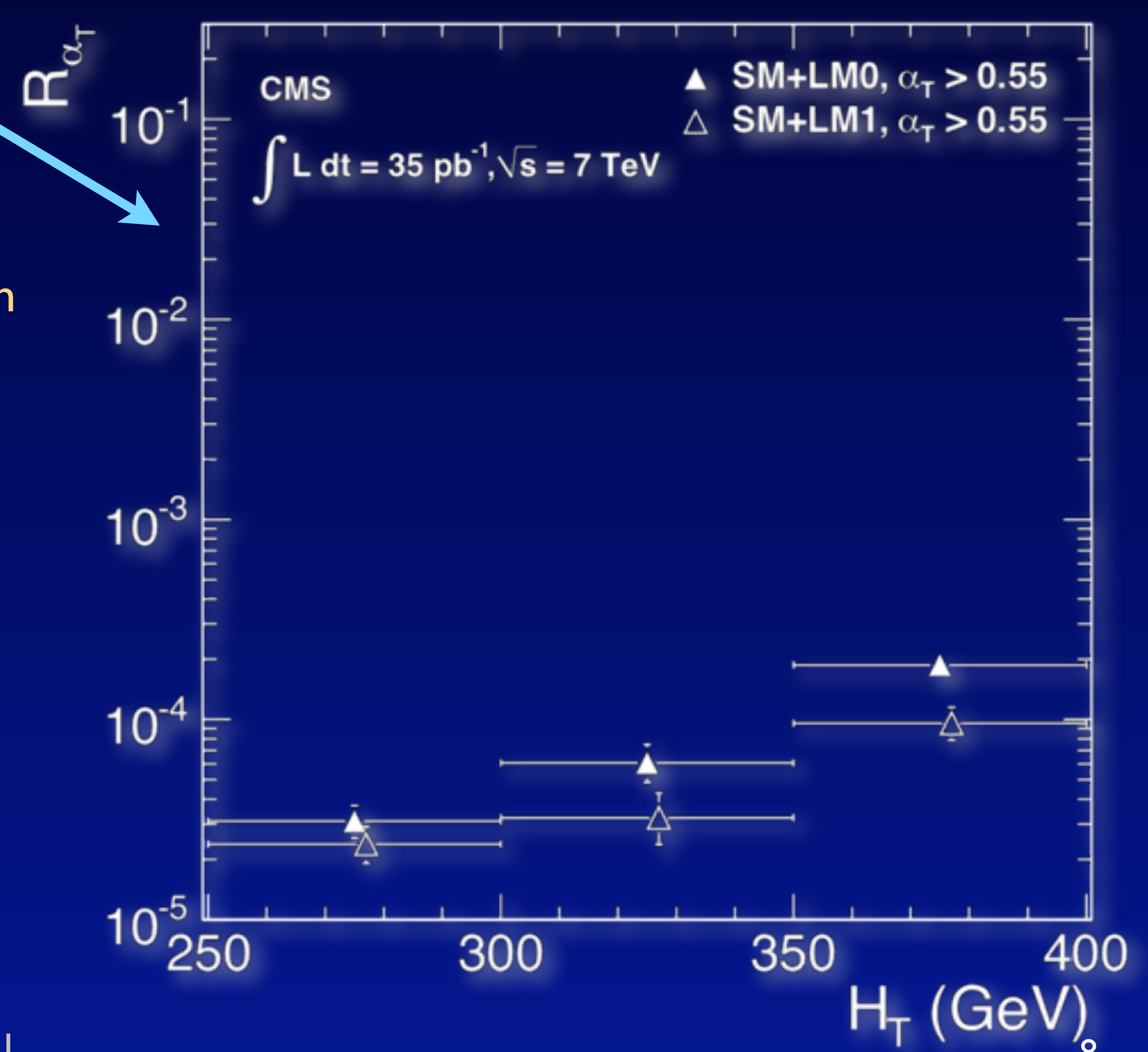

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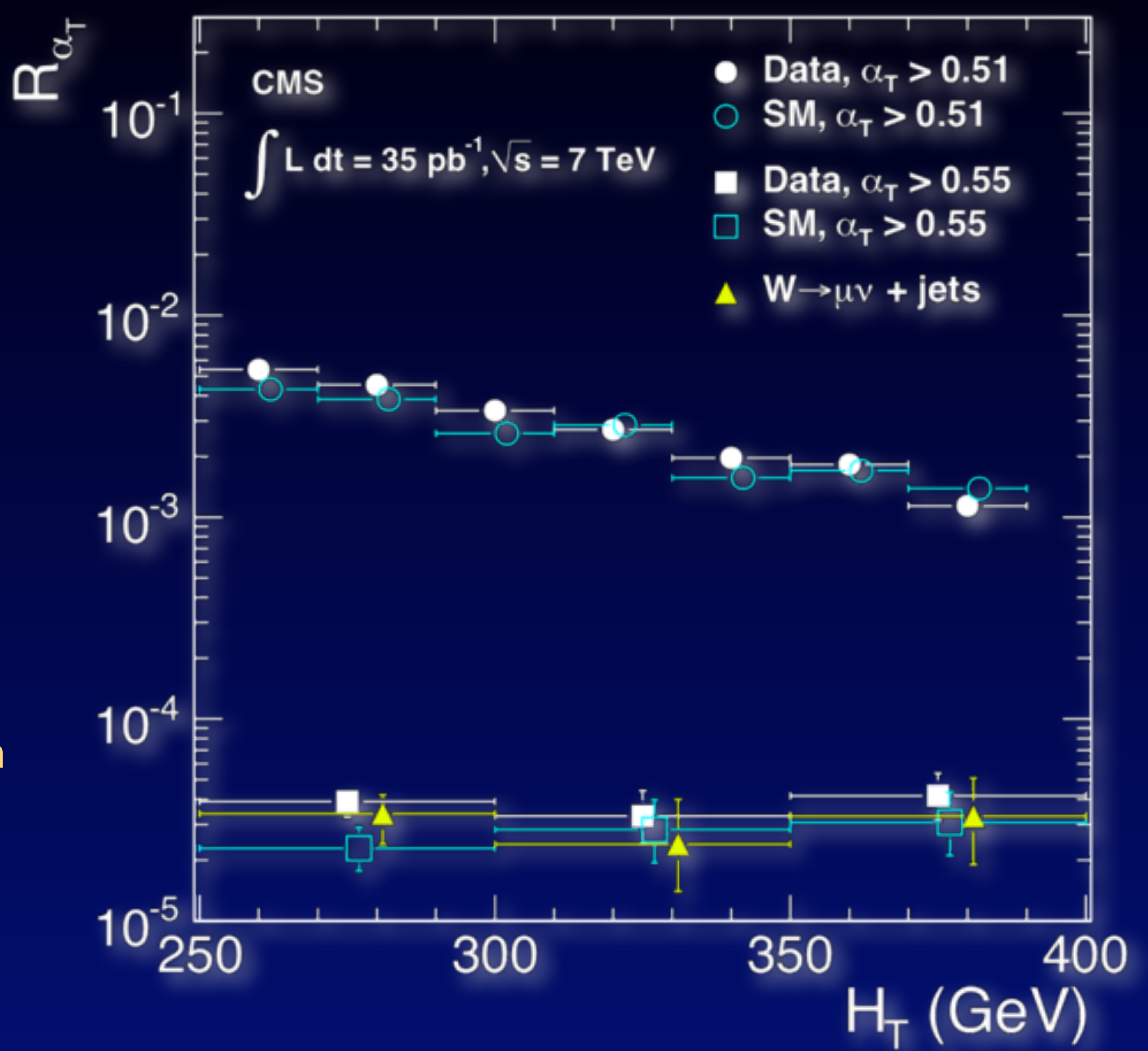
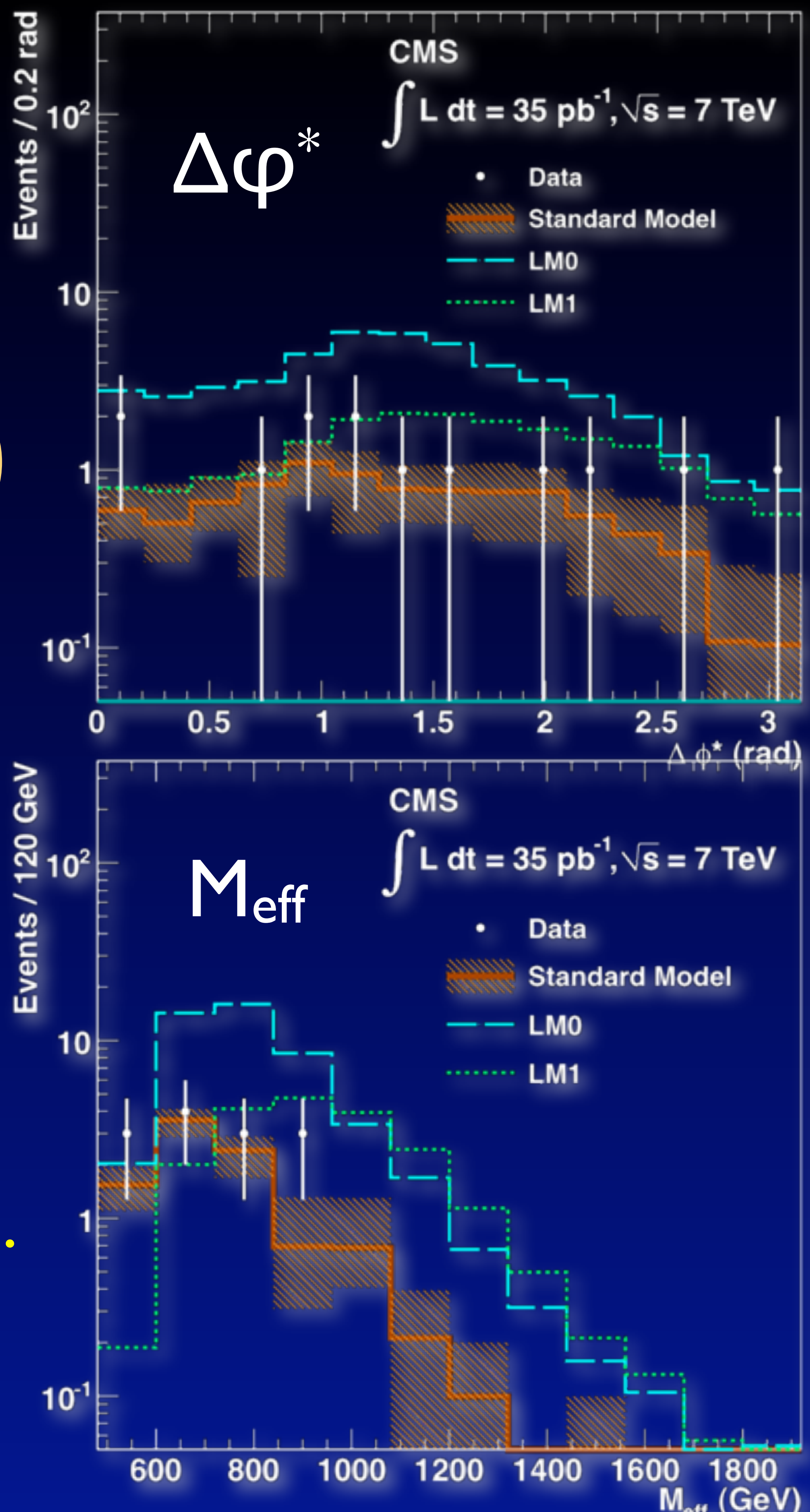


Results

- 13 events observed
  - **compatible with SM**
    - $\Delta\phi^* = \min_{i,j\in\text{jets}} \angle\left(\vec{p}_T^{\,i}, -\sum_{j\neq i} \vec{p}_T^{\,j}\right)$
    - $M_{eff} = MHT + H_T$
- Prediction
  - **inclusive :** $9.4^{+4.8}_{-4.0}(\text{stat}) \pm 1.0(\text{syst})$
  - **W+jets (tt) :** $6.4^{+2.8}_{-1.9}(\text{stat}) \pm 1.8(\text{syst})$
  - **Z→νν :** $4.4^{+2.3}_{-1.6}(\text{stat}) \pm 1.8(\text{syst})$
- The model independence stops here...



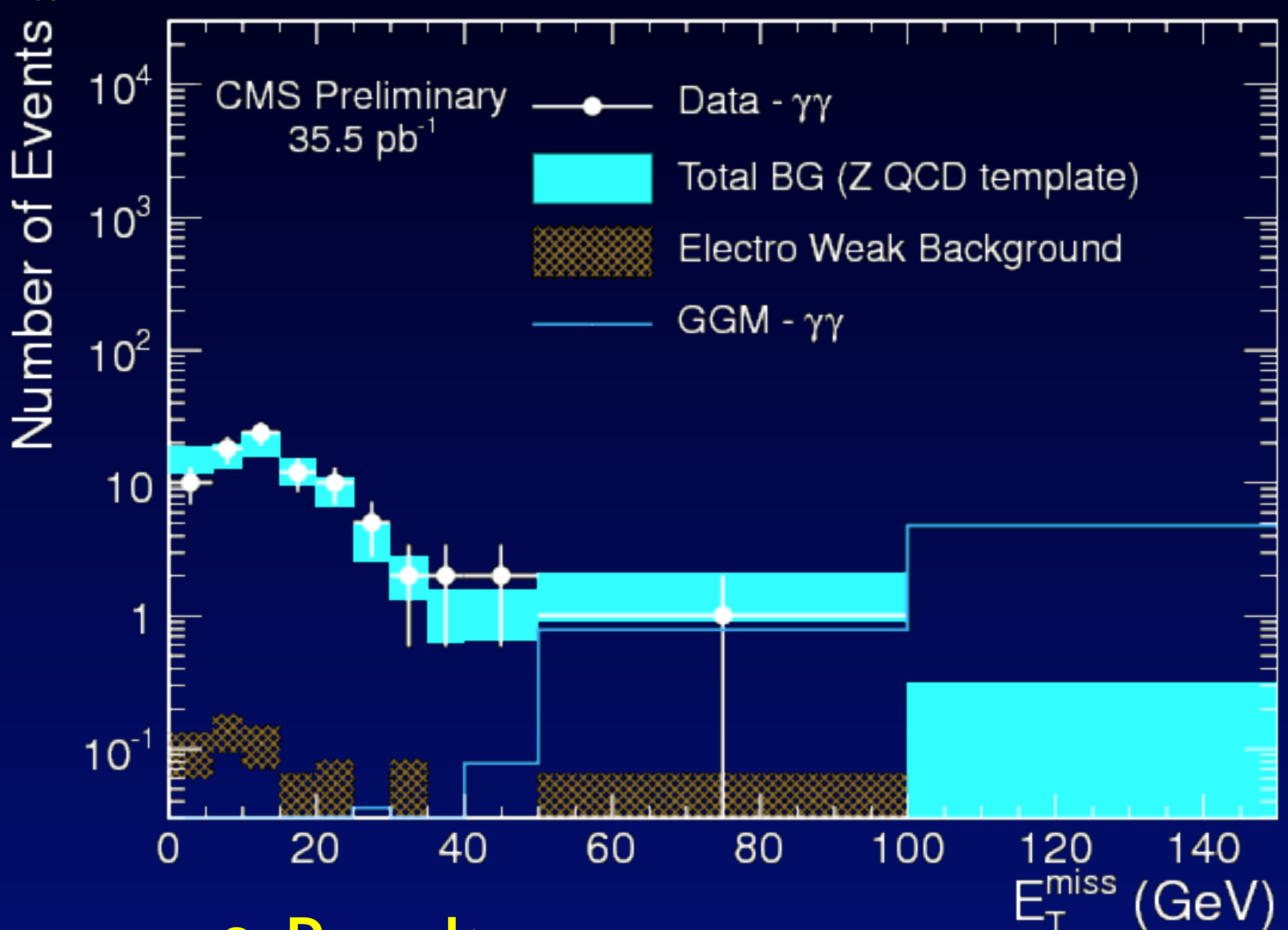
Jets + MET + γγ

Di-photon search

- Search in framework of General Gauge Mediation
  - **LSP is the gravitino:**

$$\tilde{g} \rightarrow \tilde{q}q \rightarrow qq\chi_1^0 \rightarrow qq\gamma\,\tilde{G}$$

- Selection
  - **2 photons (p_T > 30 GeV/*c*)**
  - **at least 1 jet (p_T > 30 GeV/*c*)**
  - **MET > 50 GeV**
- Backgrounds
  - **Electro-weak (electron mis-id'ed as γ)**
  - **QCD (instrumental MET)**

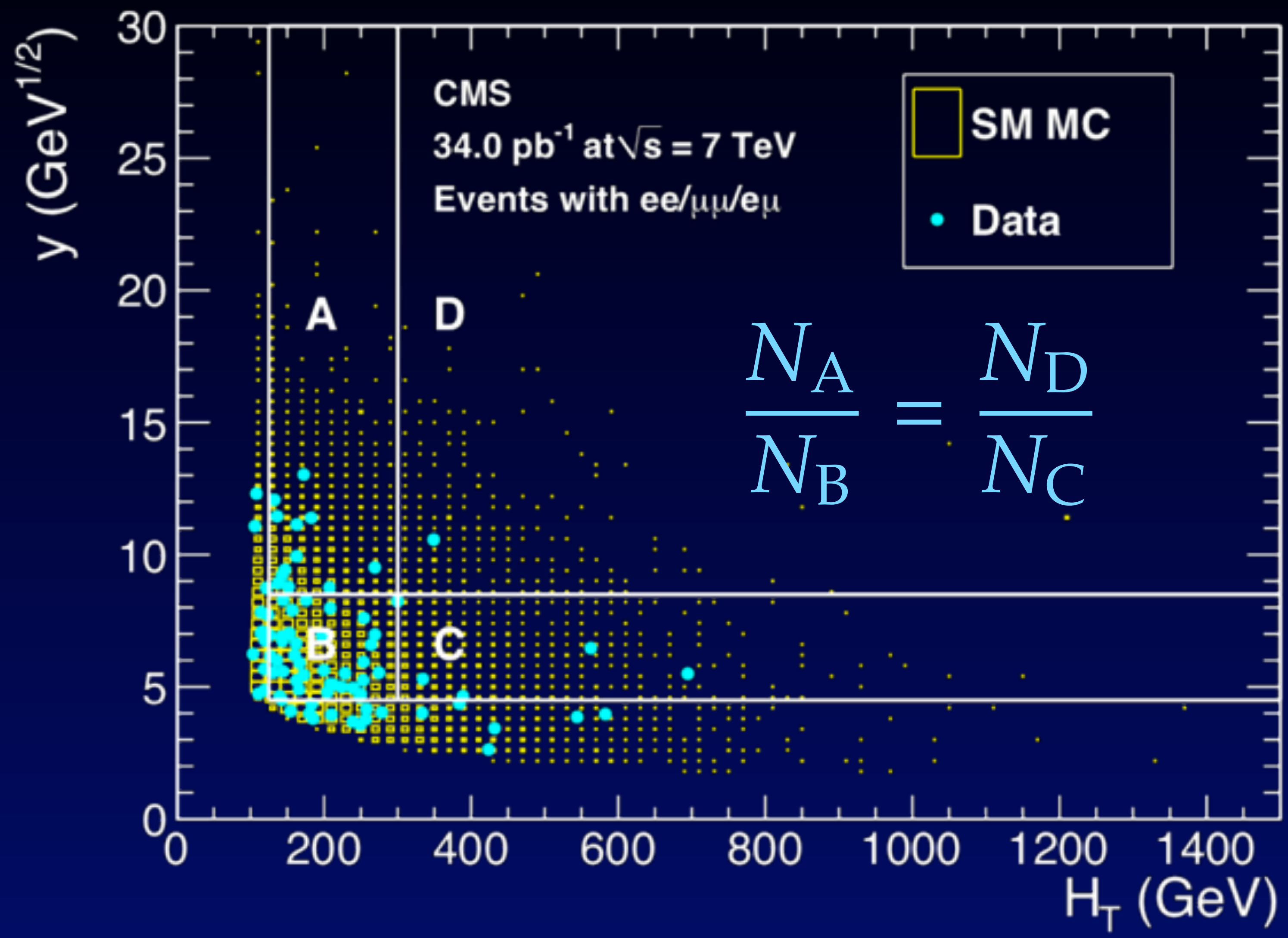


- Results
  - **1 event observed**
  - **1.2±0.8 predicted**

Jets + MET + l^+l^-

Di-lepton search

- Generic signature
  - 2 OS leptons (ee, μμ, eμ)
  - ≥2 jets, HT > 300 GeV
  - $y = MET/\sqrt{H_T} > 8.5\ \sqrt{GeV}$
- Main backgrounds:
  - Z+jets: use Z mass veto
  - top-antitop
    - "ABCD" method to estimate contribution in signal region
      - $N_D = N_C \times N_A / N_B$ if variables uncorrelated
    - use dilepton p_T distribution to model MET from di-neutrino



$$\frac{N_A}{N_B} = \frac{N_D}{N_C}$$

- Results
  - 1 event observed
  - 1.3±0.8±0.3 predicted

Presenting the result

Approaches in CMS

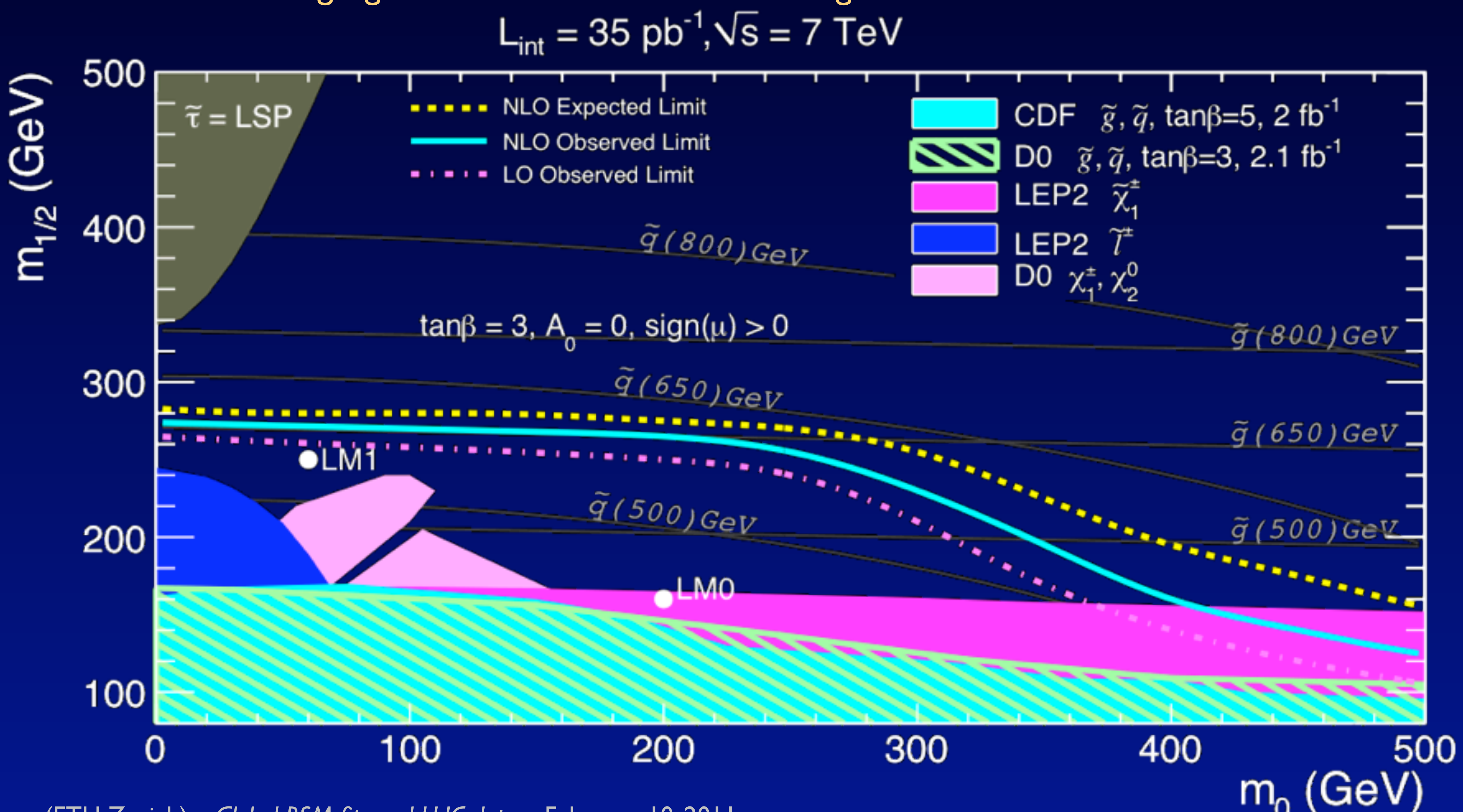
- *Project* the result on a particular model
  - **95% exclusion in the $(m_0,m_{1/2})$ plane in the CMSSM**
    - comparison with previous searches
- *Map* the result on a particular model
  - **cross-section upper limits in the (gluino,squark) plane of GGM**
  - **efficiency x acceptance upper limits**
- Provide information required for model testing
  - **acceptance, efficiency, detector response**

➠ **Discuss and illustrate these approaches in turn**

- *Simplified models: see W. Waltenberger's talk tomorrow!*

CMSSM scans

- In the CMSSM plane, check compatibility with result in each point
  - folds in efficiency + PDF uncertainty, NLO corrections (“k-factors”)
    - also considering signal contamination in control regions

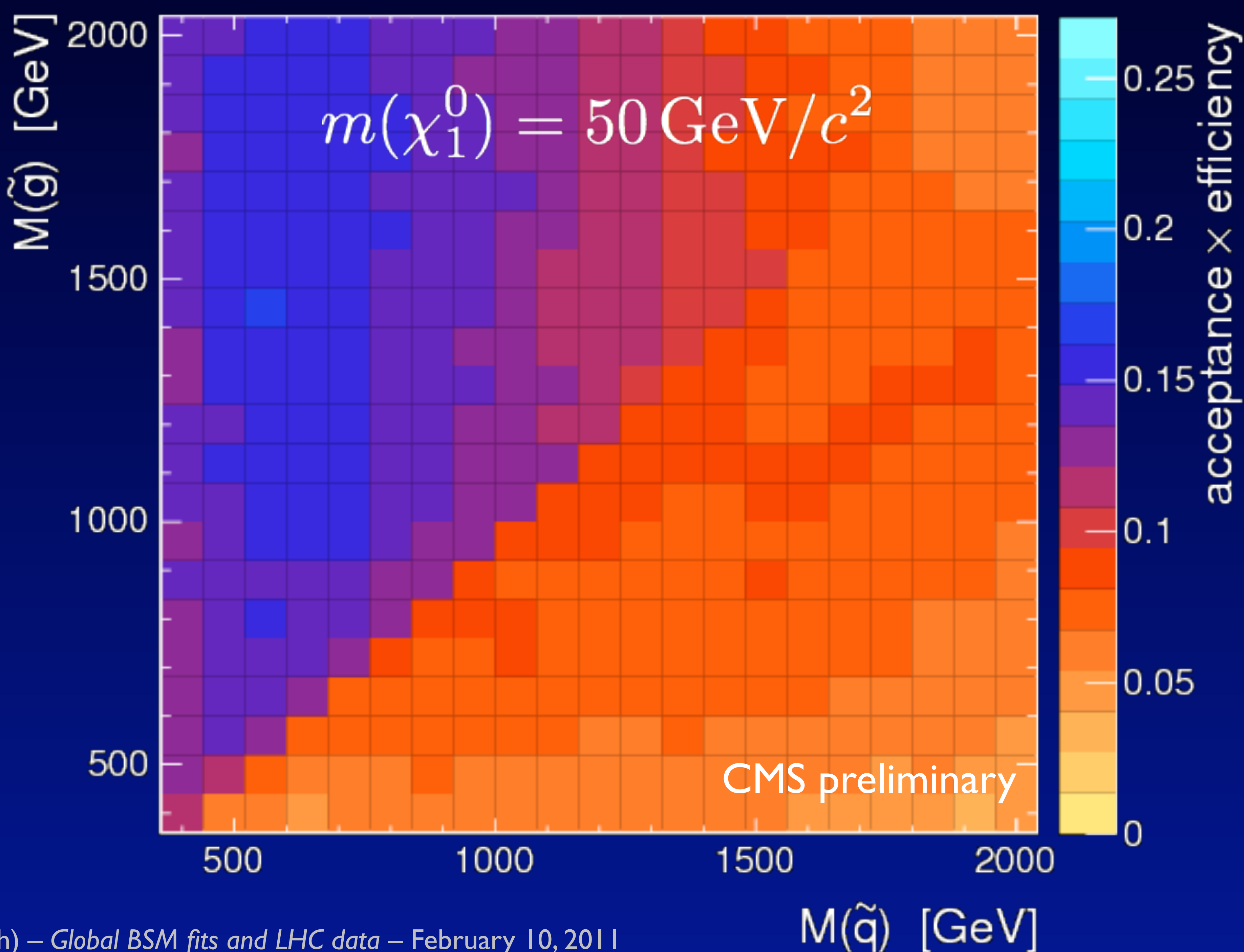


CMSSM scans: discussion

- Good benchmark to show sensitivity, compare with other experiment(s)
- Difficult to interpret, very model-dependent (!)
  - **How (much) does the limit depend on tanβ? (and sign(μ), A_0?)**
    - same question for other limits on the plot...
  - **Provide several plots for different values of tanβ?**
- How dependent is it on the systematic uncertainties used for PDF and NLO?
    - here: CTEQ6.6 error function envelope and factor 2 on scale, resp.
  - **Showing also LO limit helps?**
  - **Does it cover differences between spectrum generators**
    - e.g., SOFTSUSY vs. ISAJET/ISASUSY?

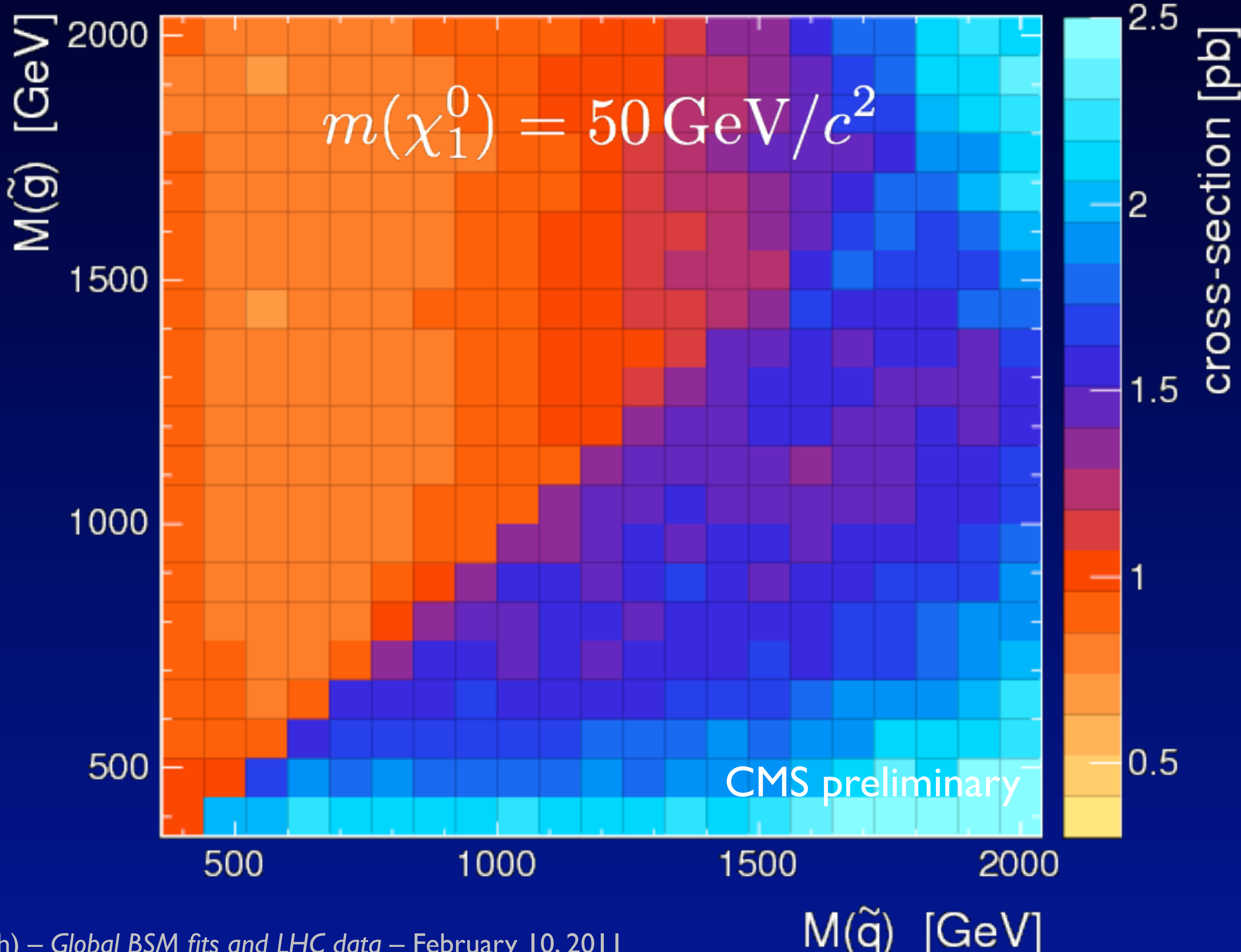
Upper limits in the GGM plane

- One step further:
  - **provide acceptance x efficiency information in the plane**



Upper limits in the GGM plane

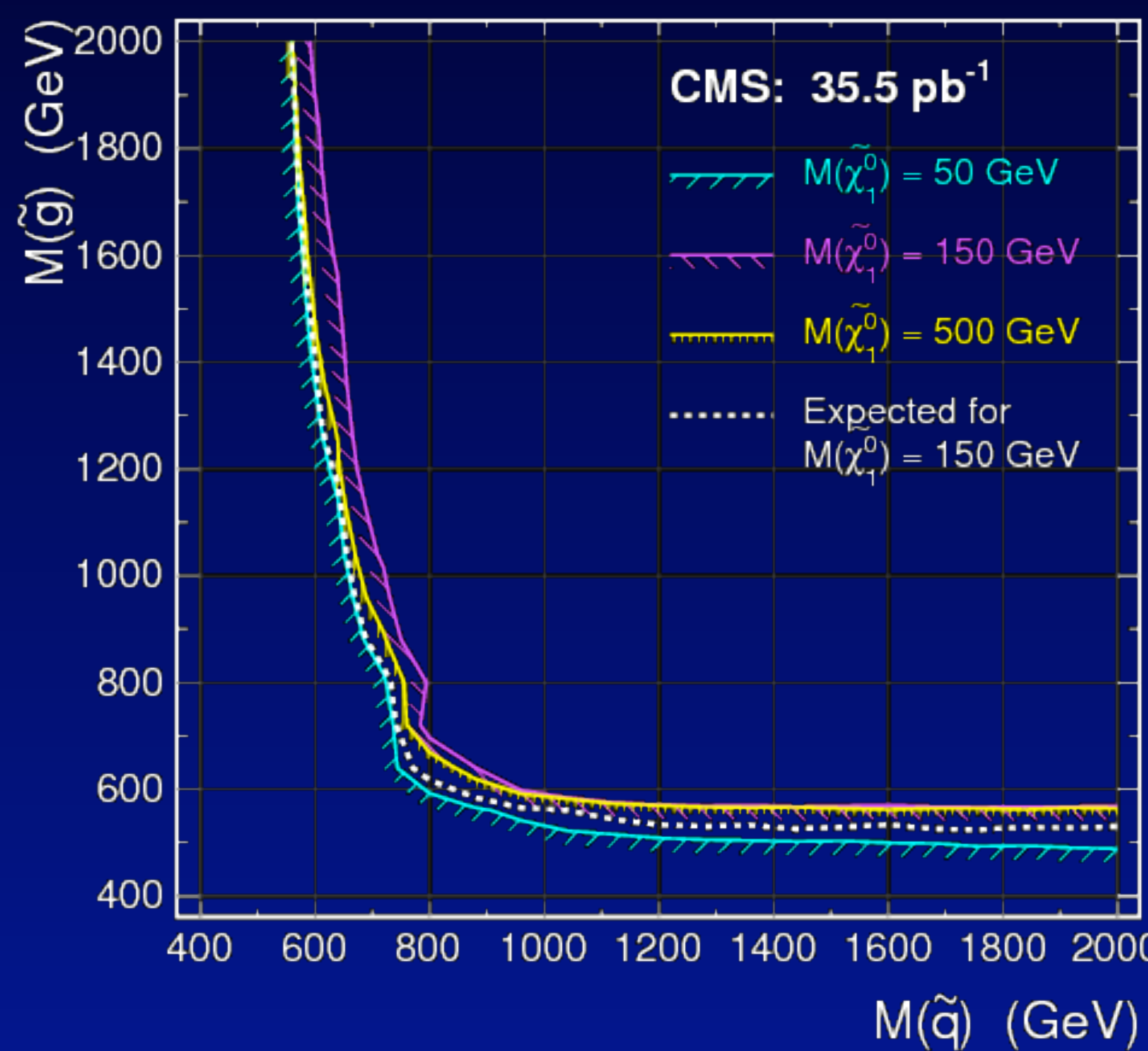
- One step further:
  - **provide cross-section upper-limit in the plane**



Upper limits: discussion

- Provides full information *within a certain model*
  - **in terms of sparticle masses: more universal?**
  - **can(will) this information be used to confront similar models?**

- Some parameters still fixed
  - e.g., neutralino mass
  - **provide set of plots?**
  - **provide exclusion limits?**



“Outreach” information

- Last alternative: provide full information
  - **~universal, or for several models**
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- Example: OS dilepton search
  - **definition of analysis acceptance (2 OS leptons p_T>20,10 GeV/c, etc.)**
  - **information on detector response (corrections to acceptance)**
  - **reconstruction and isolation efficiencies (model-dependent!)**
    - for different benchmark points, with different hadronic activity
    - quote both full-sim./generator and data/full-sim. corrections

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    - for different benchmark points, with different hadronic activity
    - quote both full-sim./generator and data/full-sim. corrections
- Discussion
  - is that useful? will/can it be used to confront other models?

Summary: points for discussion

- Three (preliminary) approaches presented
- Exclusion limits (in CMSSM plane)
  - **model dependence, interpretation: set of plots?**
  - **systematic uncertainties on PDF and NLO corrections?**
- Upper limits map (in GGM plane)
  - **efficiency, upper limits in sparticle mass plane: more universal?**
  - **still parameter-dependent**
- "Outreach" information
  - **will/can it be used?**
- Also considering to provide "likelihoods"

Additional material

Statistical methods

- Feldman-Cousins method for upper limits
  - **using profile likelihood ratio (Poisson)**
  - **includes nuisance parameters**
- Bayesian upper limit (Poisson) FERMILAB-TM-2104
  - **various models of nuisance parameters compared**
    - Gaussian, log-normal, gamma