



# SUSY searches at CMS



CMS Experiment at LHC, CERN  
Data recorded: Mon Oct 25 12:47:22 2010 CEST  
Run/Event: 148864 / 592760996  
Lumi section: 520  
Orbit/Crossing: 136152948 / 1594

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GDR Terascale – IPN Lyon – April 18, 2011

# SUSY searches at the LHC

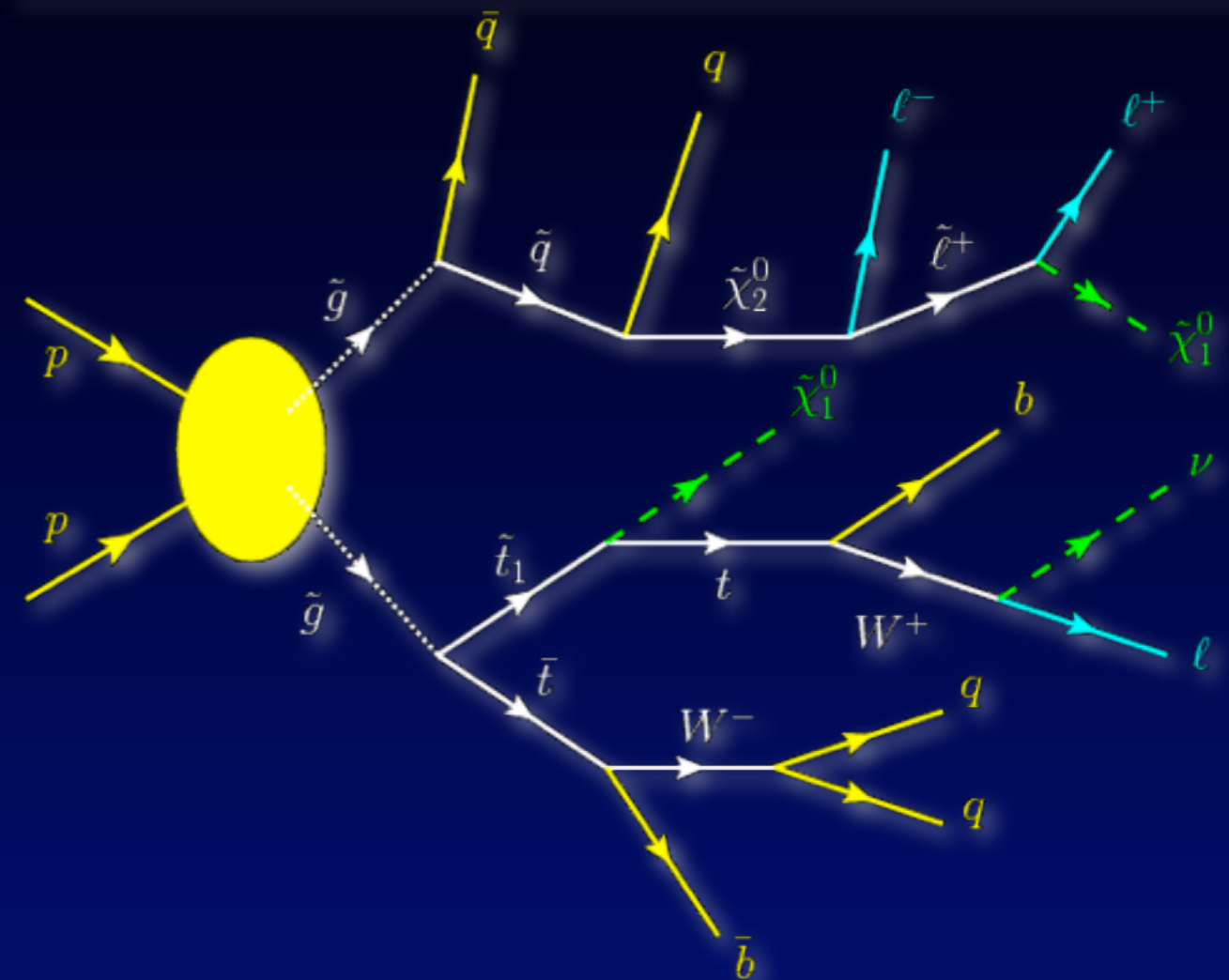
- Topology of a SUSY event

- ▶ large energy release
- ▶ large number of jets
- ▶ low- $p_T$  leptons
- ▶ missing energy (MET)

- Searches rely on all aspects of the reconstruction

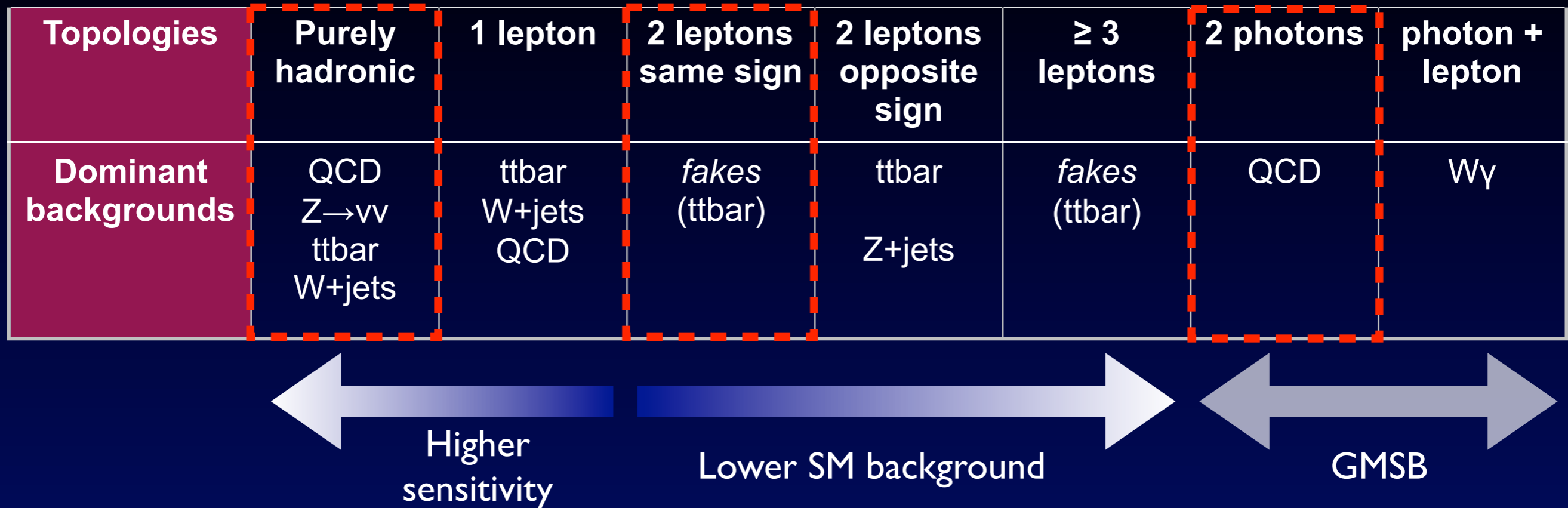
- ▶ electrons, photons and muons
- ▶ jets, total hadronic activity
- ▶ missing energy (especially tails)

**N.B. key is to try and stay as model-independent as possible**



A “typical” SUSY event  
many jets, leptons and missing energy

# SUSY searches at CMS



## ● Strategy

- ▶ suppress Standard Model processes (“background”)
  - ▶ estimate remainder
    - *data-driven* techniques developed
  - ▶ BSM physics will manifest itself as an “excess”
- ▶ different strategies depending on final state (different bkgds)

# Purely hadronic search

- Search for high  $H_T$  and high MHT

$$H_T = \sum_{\text{jets}} |\vec{p}_T| \quad MHT = \left| \sum_{\text{jets}} \vec{p}_T \right|$$

▶ strategy: modeling of the backgrounds

- Selection

▶  $\geq 3$  jets  $p_T > 50$  GeV,  $|\eta| < 2.5$

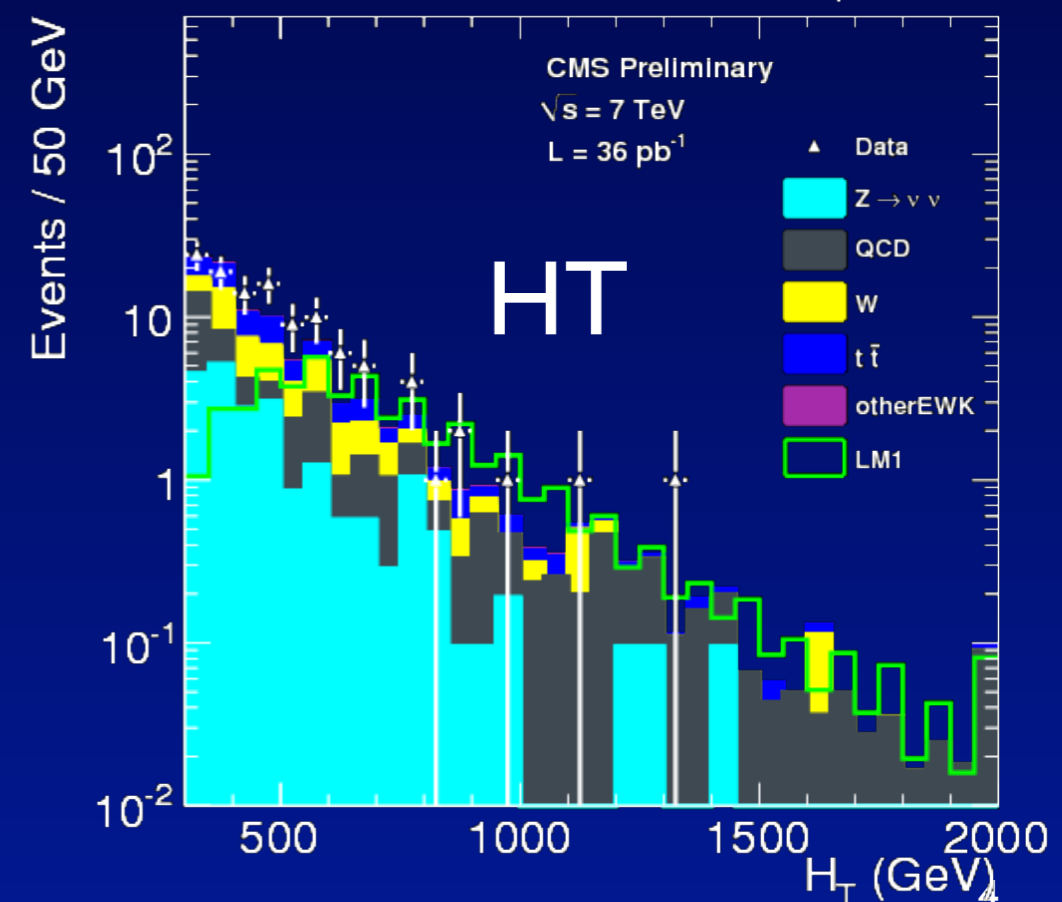
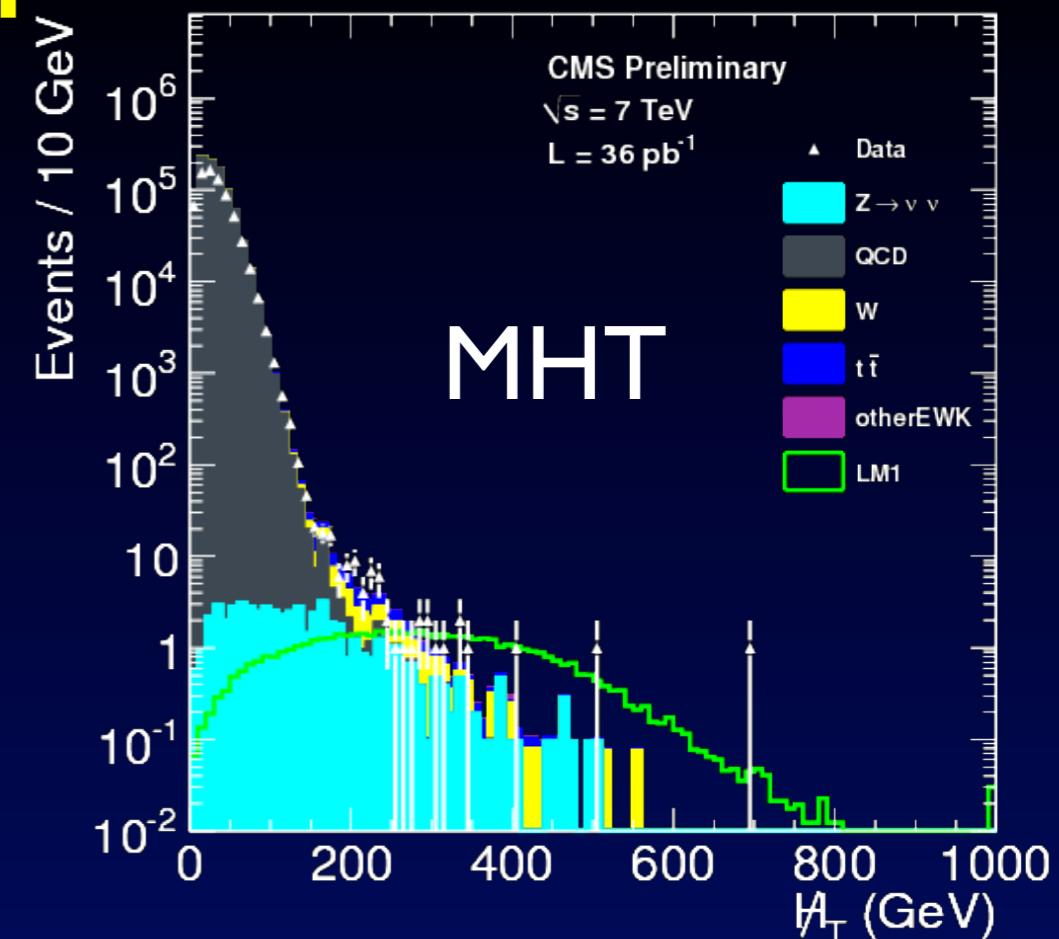
▶ veto isolated electrons and muons

▶  $H_T > 300$  GeV,  $MHT > 150$  GeV

- Backgrounds

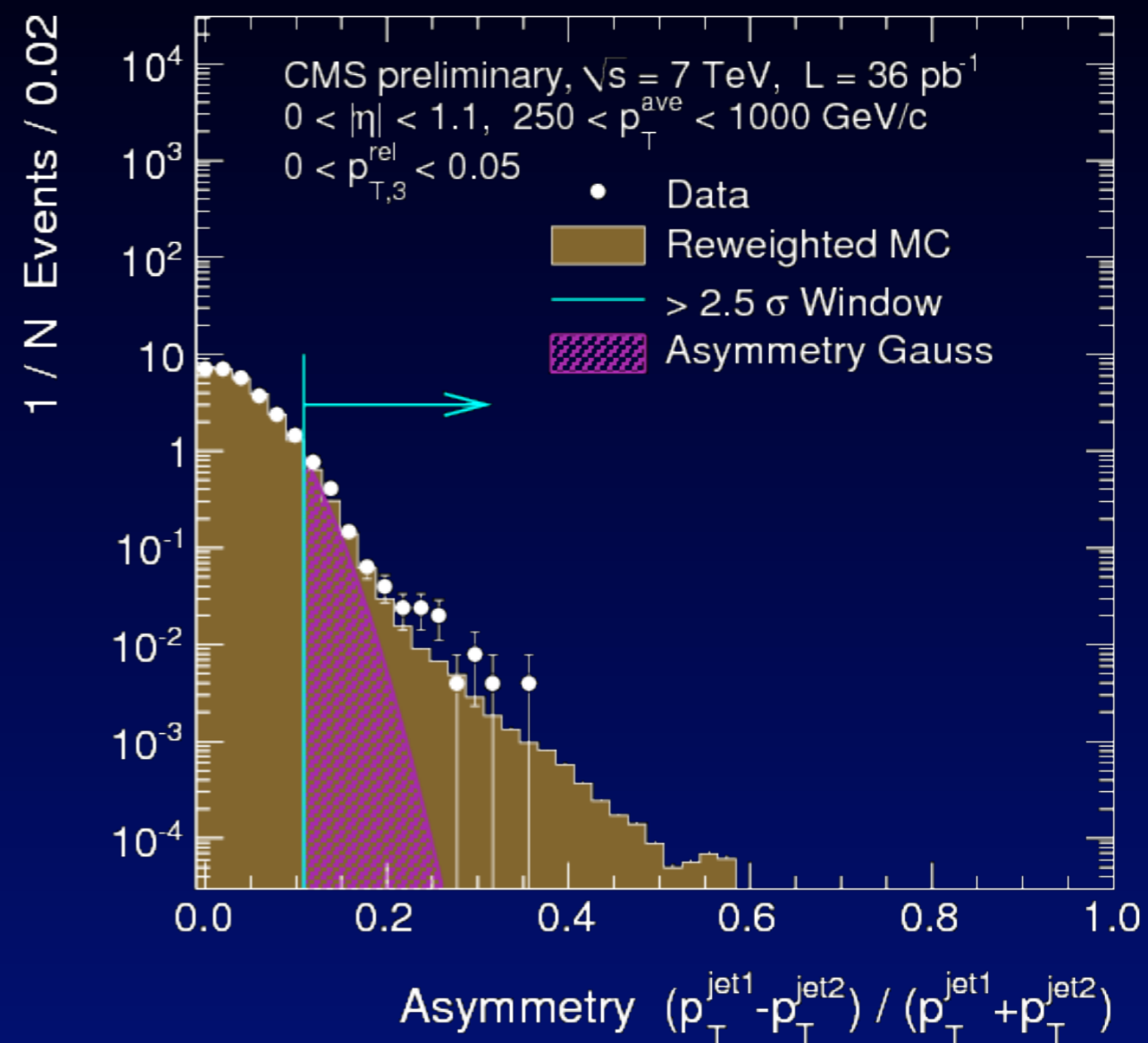
▶ QCD multijet,  $Z \rightarrow \nu\nu$ ,  $W$ +jets/ $t\bar{t}$

■ all determined (essentially) on data



# QCD multijet background

- High MHT background from jet *mismeasurement*
- “Rebalance and smear”
  - ▶ rebalance events to obtain “seed” sample of well-balanced jets
  - ▶ derive per-jet smearing function from data ( $\gamma$ +jets and di-jets)
    - from Monte Carlo corrected to describe data
  - ▶ apply smearing to seed sample to describe tail



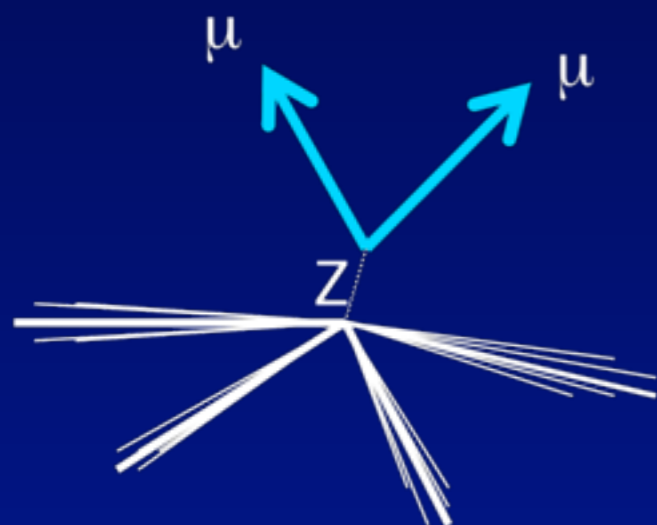
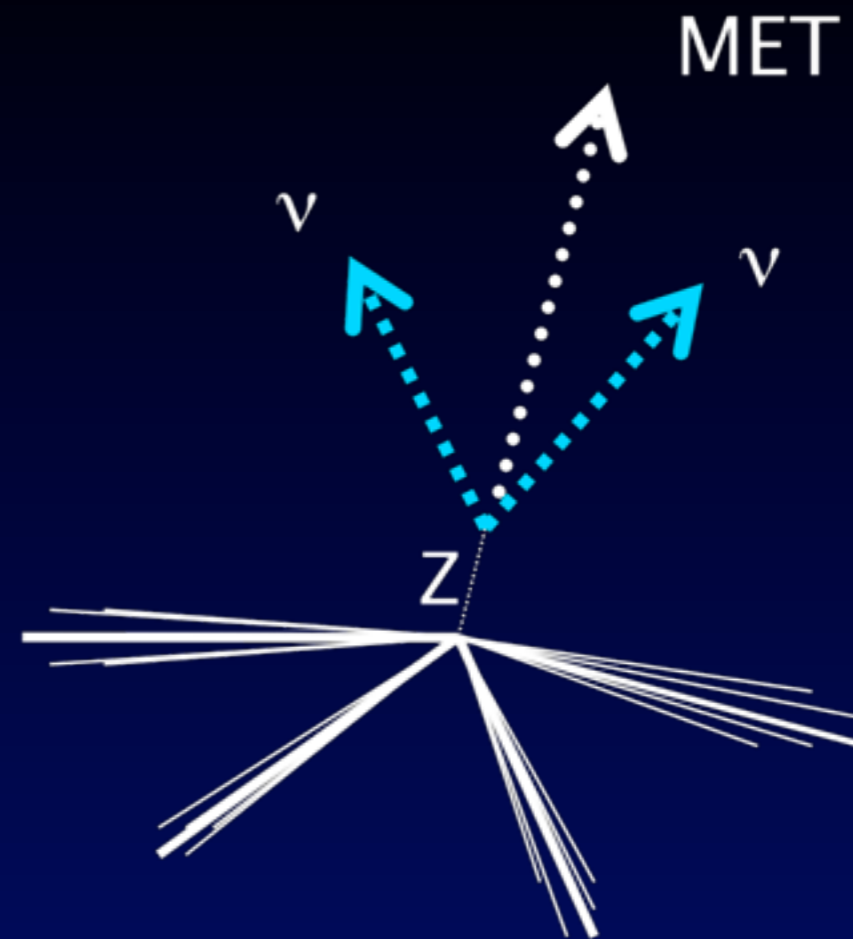
*Dijet asymmetry used to describe tail  
of jet resolution  
(extrapolation to exact 2-jet topology)*



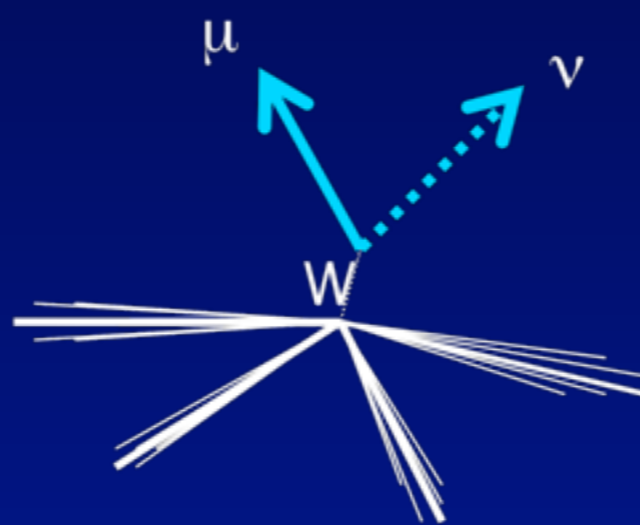
# Background from $Z \rightarrow \nu\nu$

- Irreducible background
- Three replacement methods:

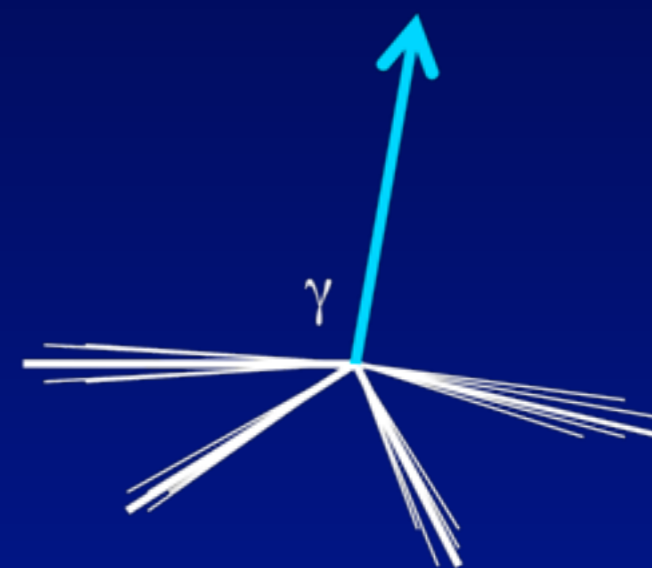
- ▶  $Z \rightarrow \mu\mu$  (cross-check)
- ▶  $W \rightarrow \mu\nu$  (not used here)
- ▶  $\gamma$ +jets (used in result)



Clean, but low statistics



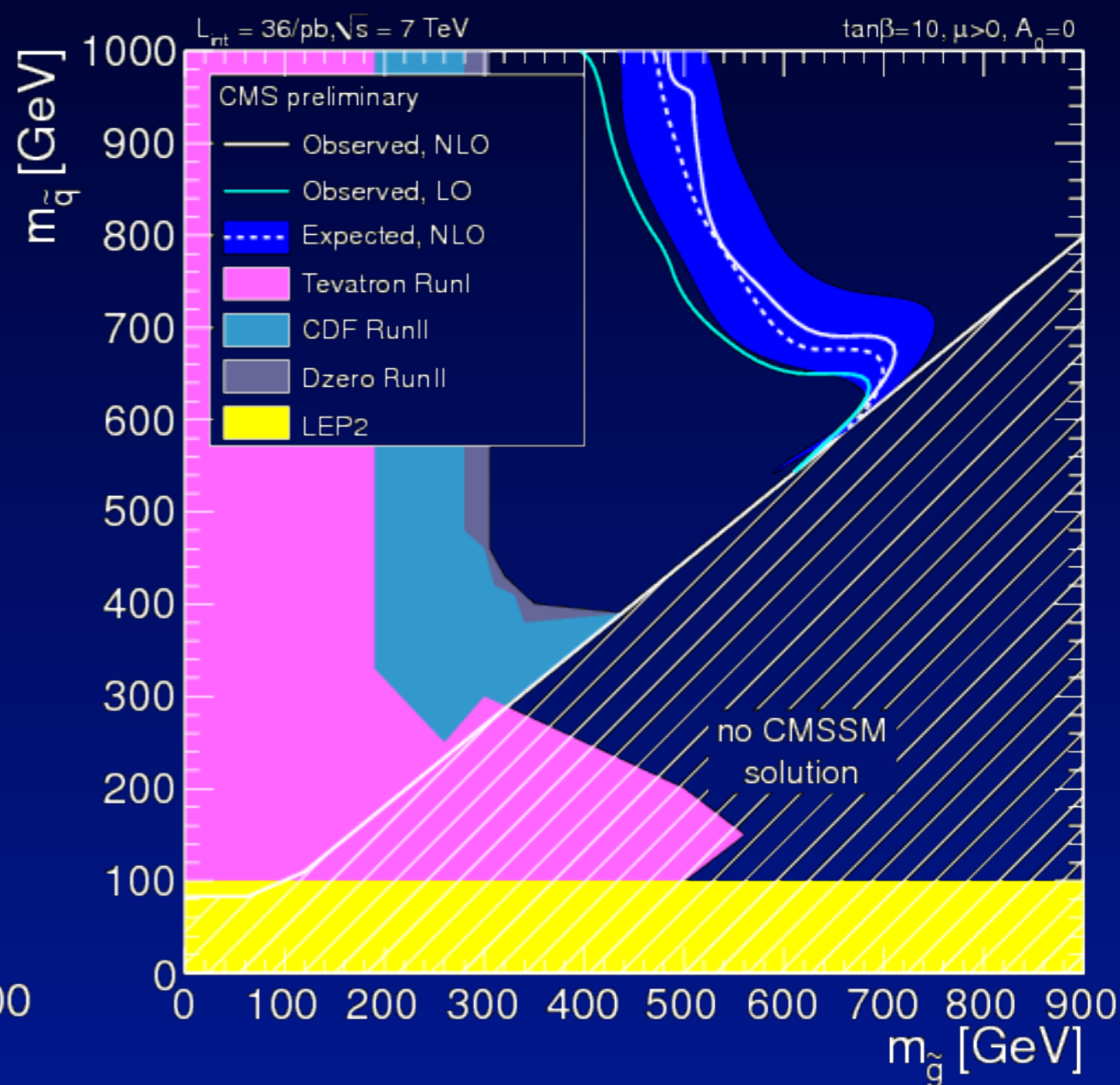
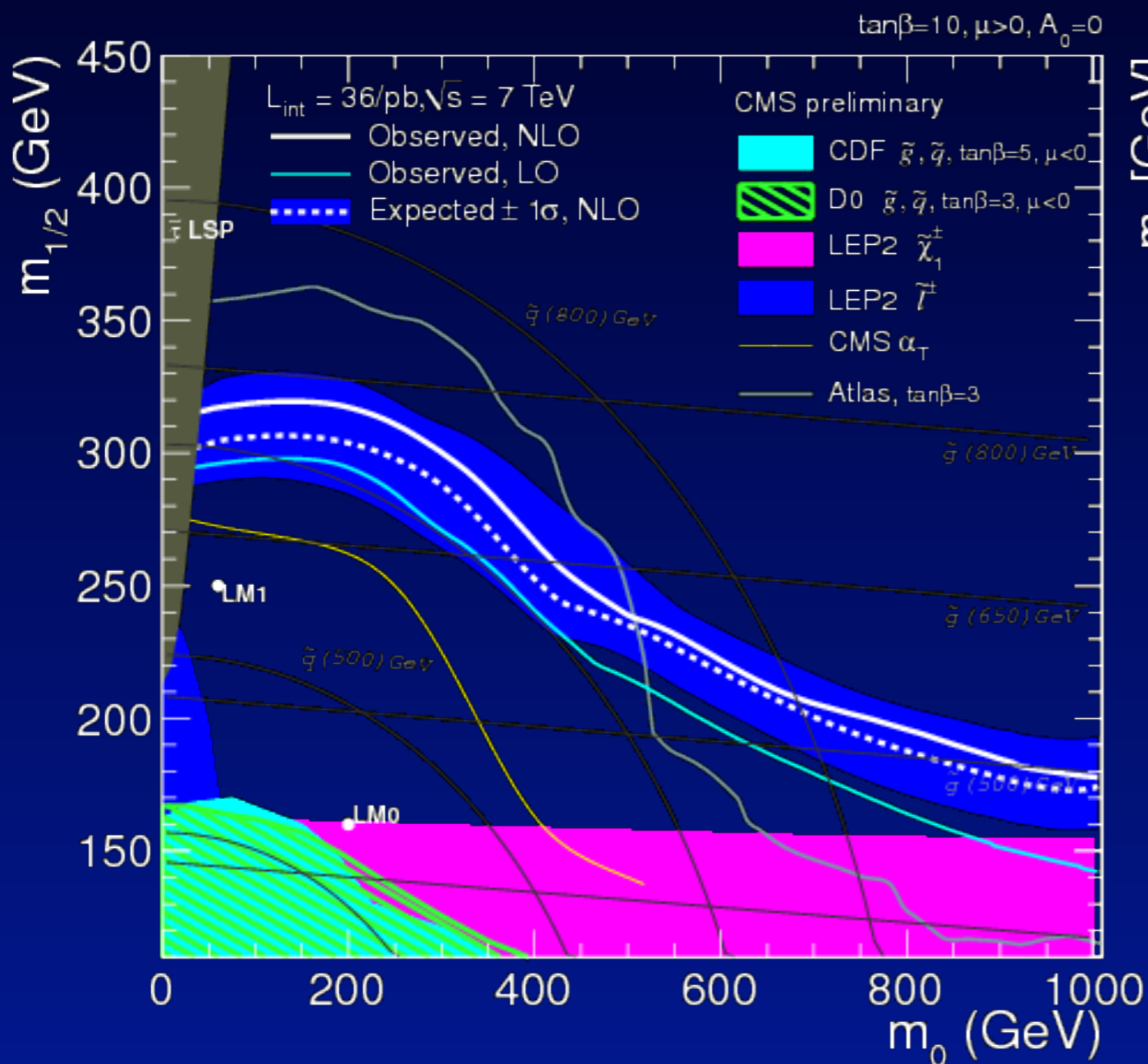
Higher statistics, but less pure



Clean at high MET, but syst. uncertainty

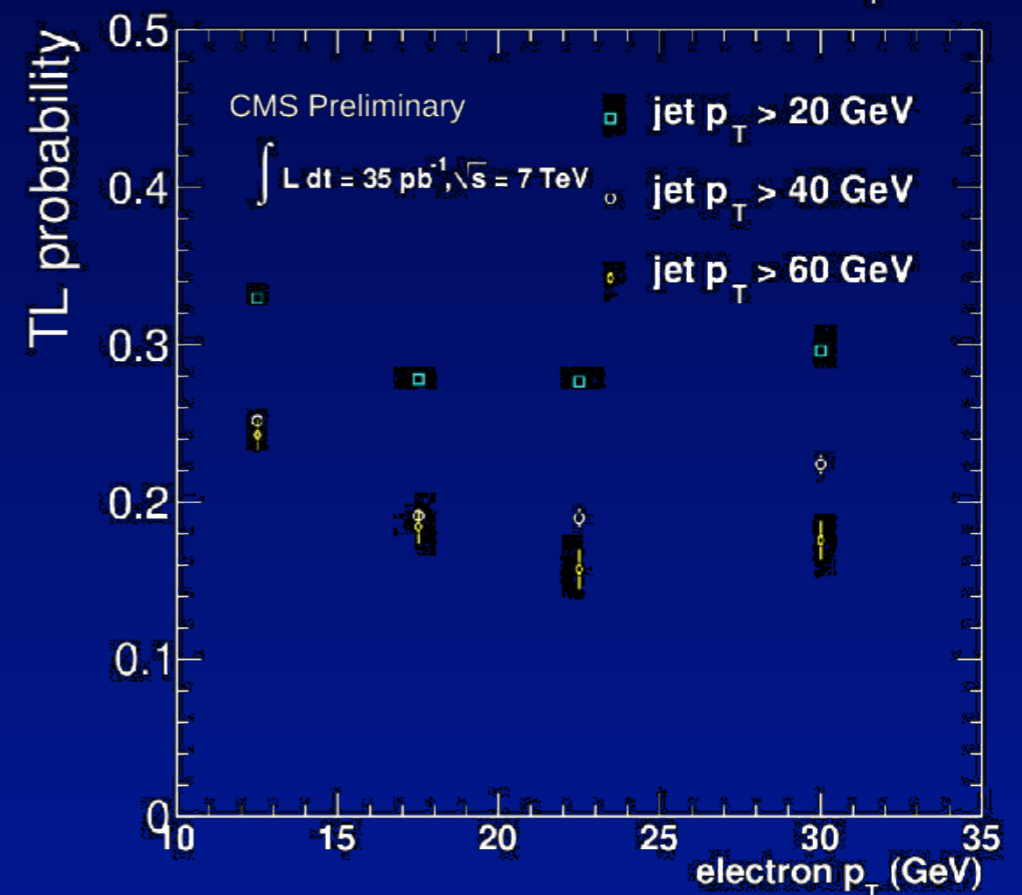
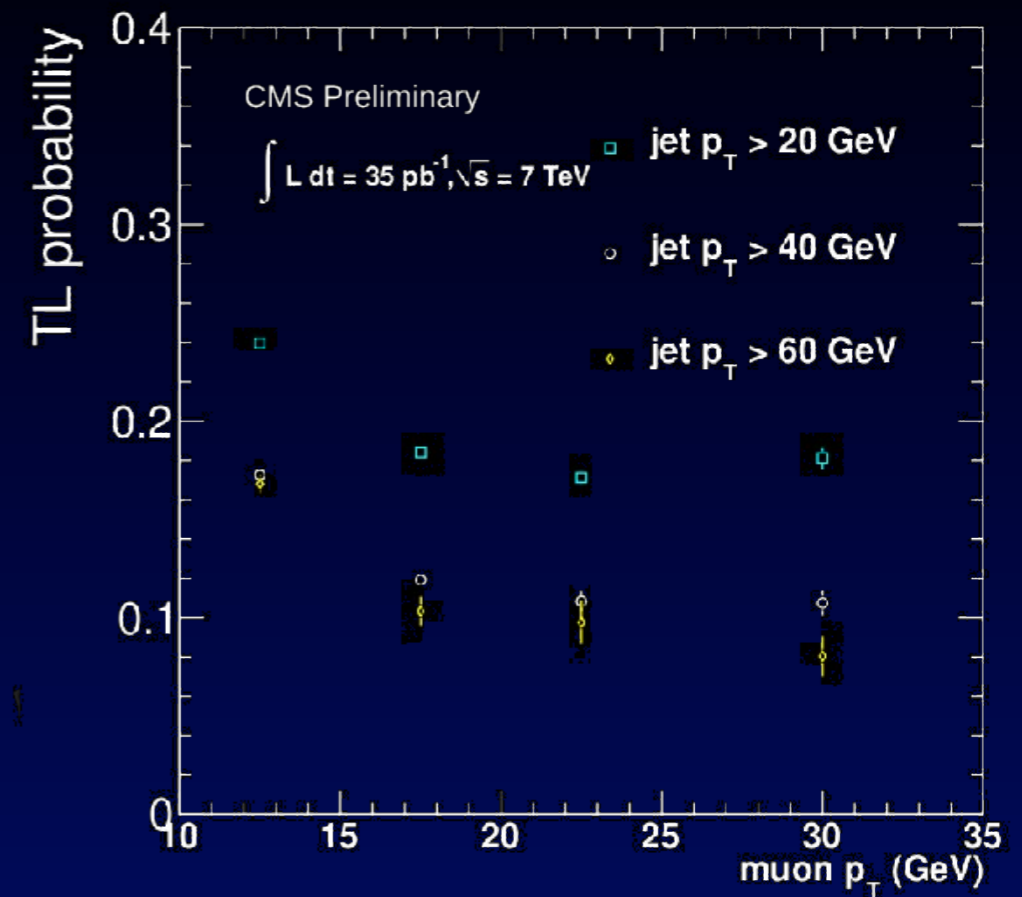
# Results

|                         |                                  |           |
|-------------------------|----------------------------------|-----------|
| <b>HT &gt; 500 GeV</b>  | <b><math>18.8 \pm 3.5</math></b> | <b>15</b> |
| <b>MHT &gt; 250 GeV</b> | <b><math>43.8 \pm 9.2</math></b> | <b>40</b> |



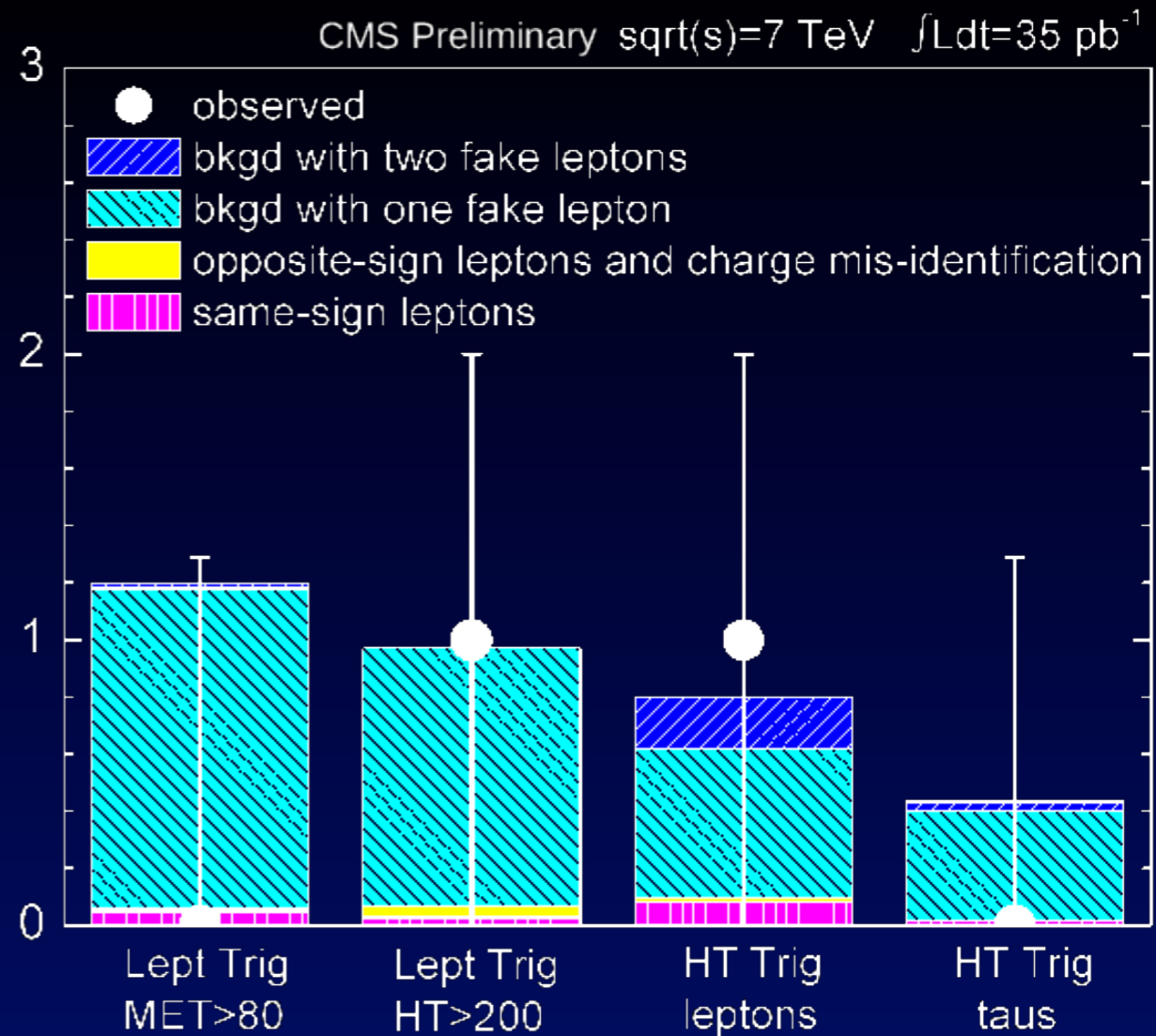
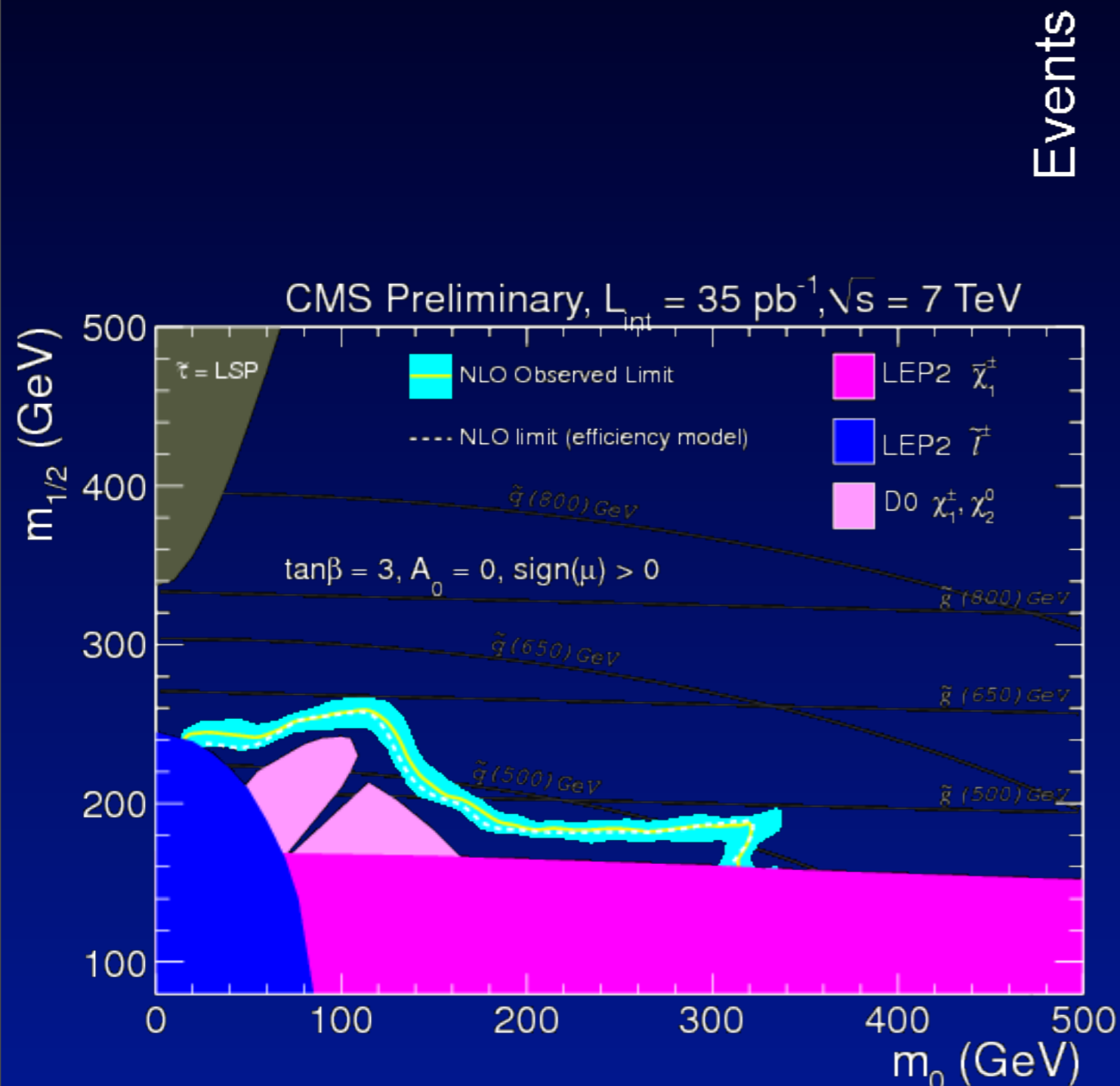
# Same-sign dileptons

- Search in all three lepton species and four search regions
- Essentially no “real” SM background
  - ▶ only fake/non-isolated leptons
  - ▶  $t\bar{t}$  (dominant),  $W$ +jets and QCD (esp. for taus)
- “Tight-to-loose” method used to estimate backgrounds
  - ▶ probability for fake lepton to pass tight selection, from control sample
  - ▶ also other methods for QCD and charge mis-ID





# Same-sign results



# Search in di-photon events

- 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 ( $p_T > 30 \text{ GeV}/c$ )**

- ▶ **at least 1 jet ( $p_T > 30 \text{ GeV}/c$ )**

- ▶ **MET > 50 GeV**

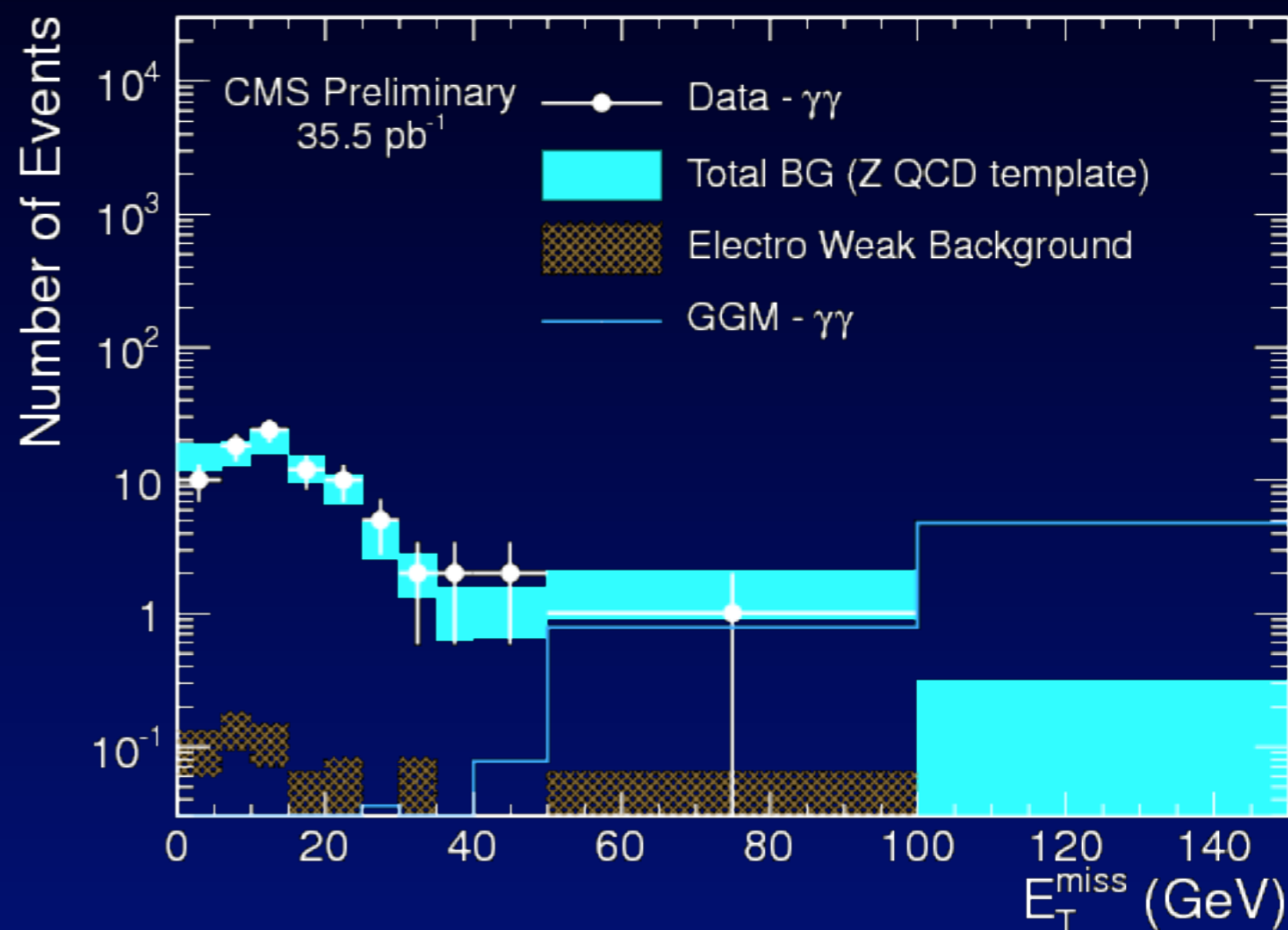
- Backgrounds

- ▶ **QCD (instrumental MET)**

- use control sample of di-EM objects

- ▶ **Electro-weak ( $e^-$  mis-id'ed as  $\gamma$ )**

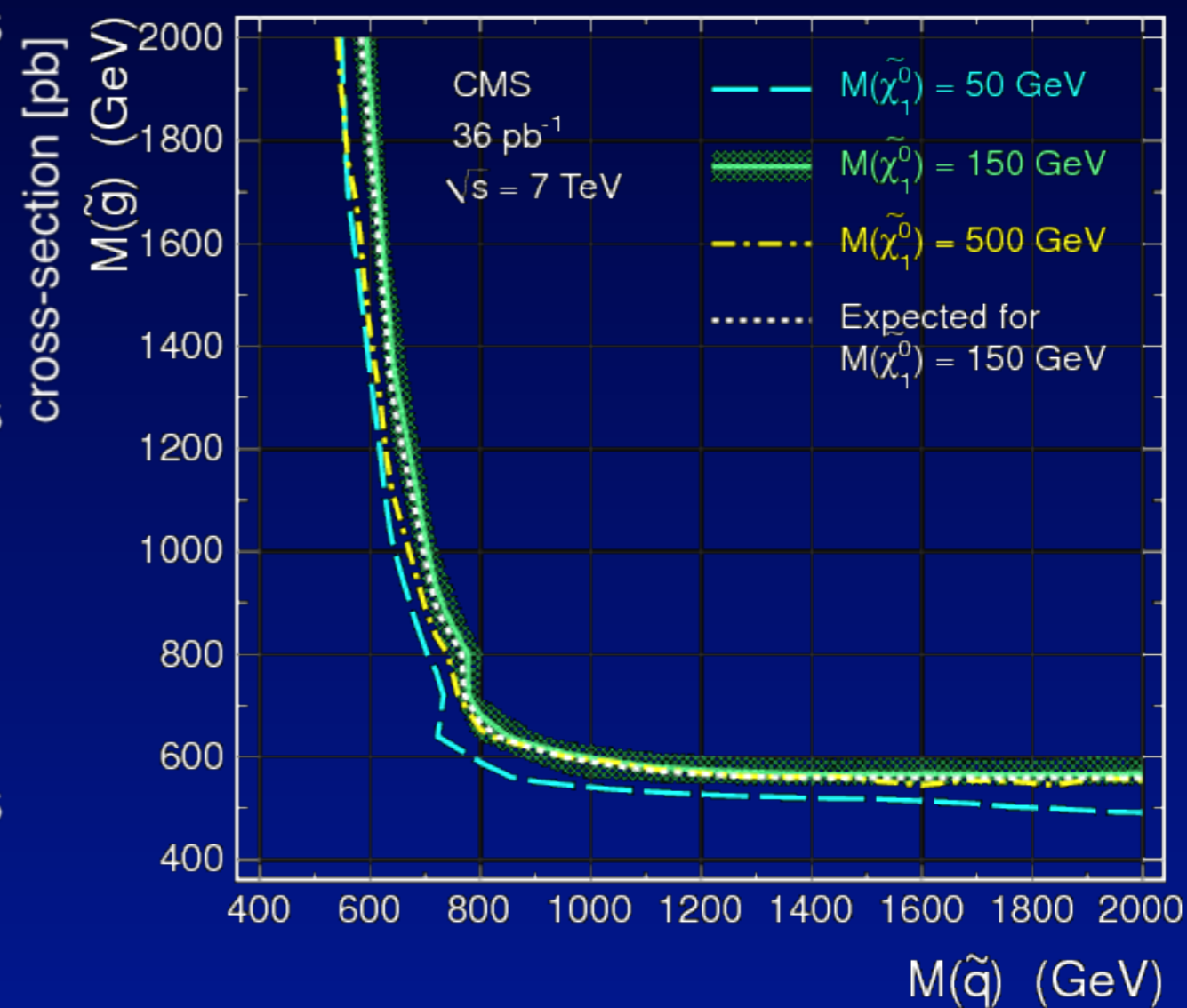
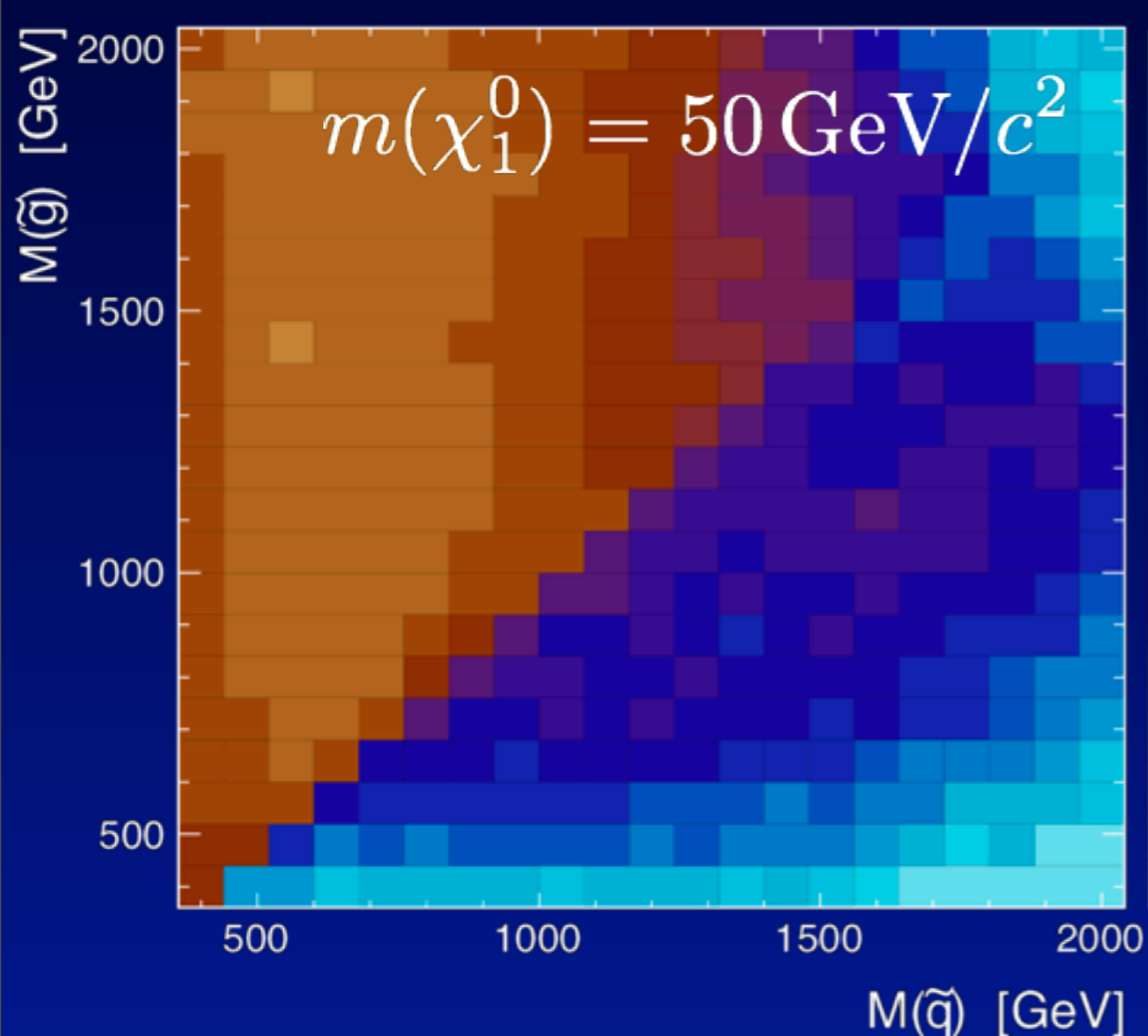
- use Z mass peak from  $e\gamma$  candidates



# Di-photon results

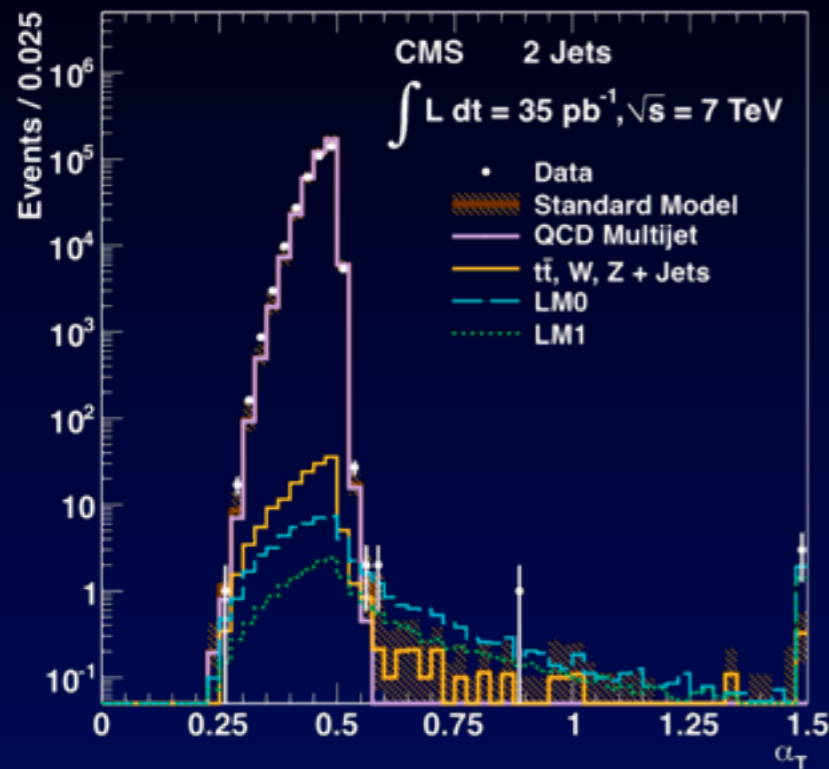
- 1 event observed —  $1.2 \pm 0.8$  predicted
  - ▶ Interpret in GGM model with gluino, squarks and neutralino decaying to jets +  $\gamma\gamma$  + 2 Gravitinos

95% upper limits on cross-section

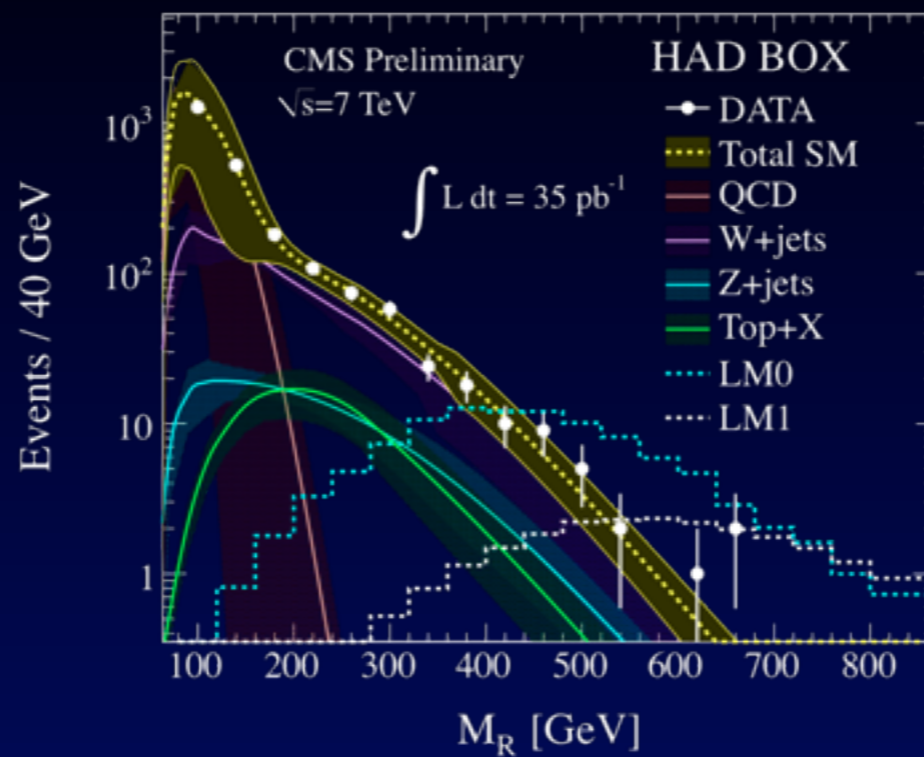


# There are more...

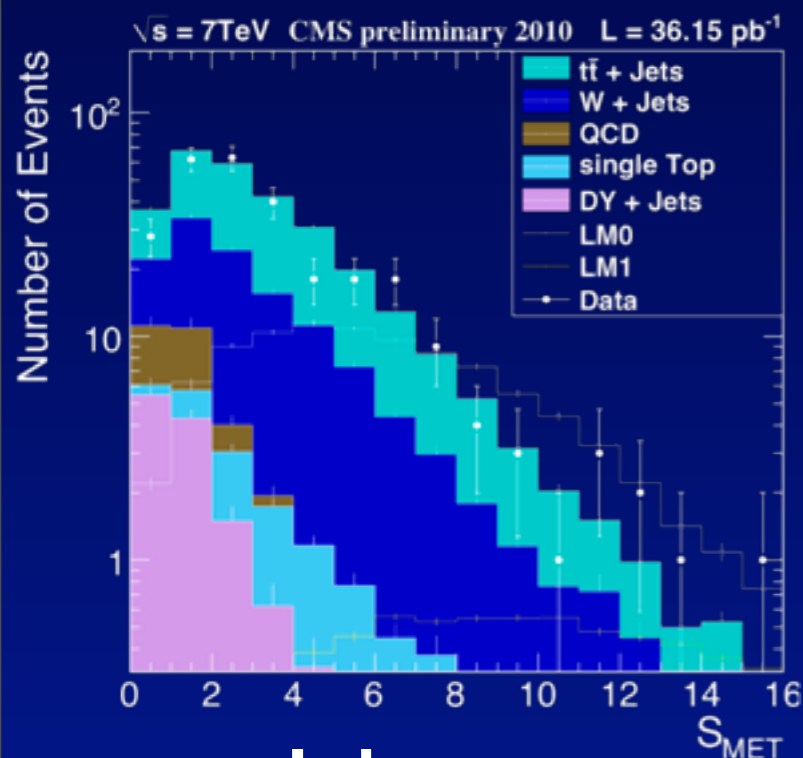
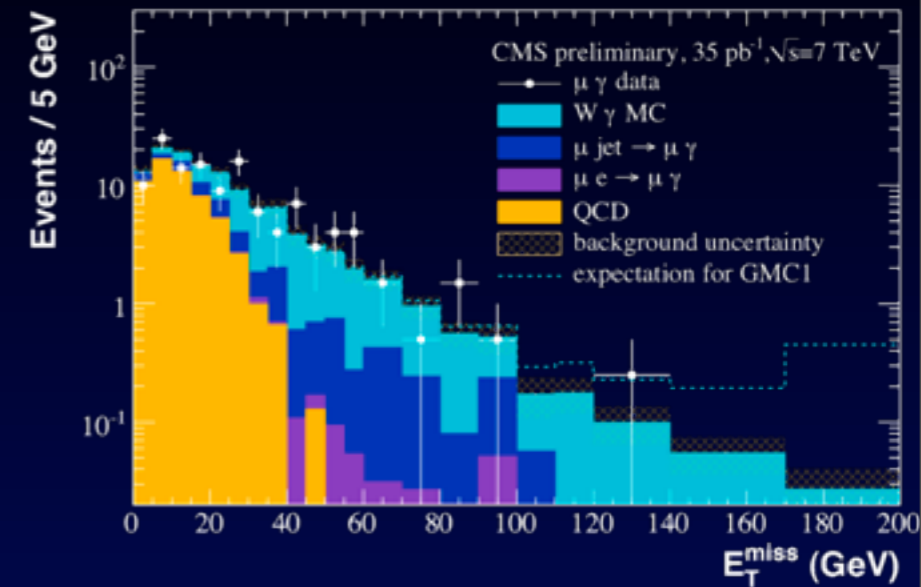
$\alpha_T$



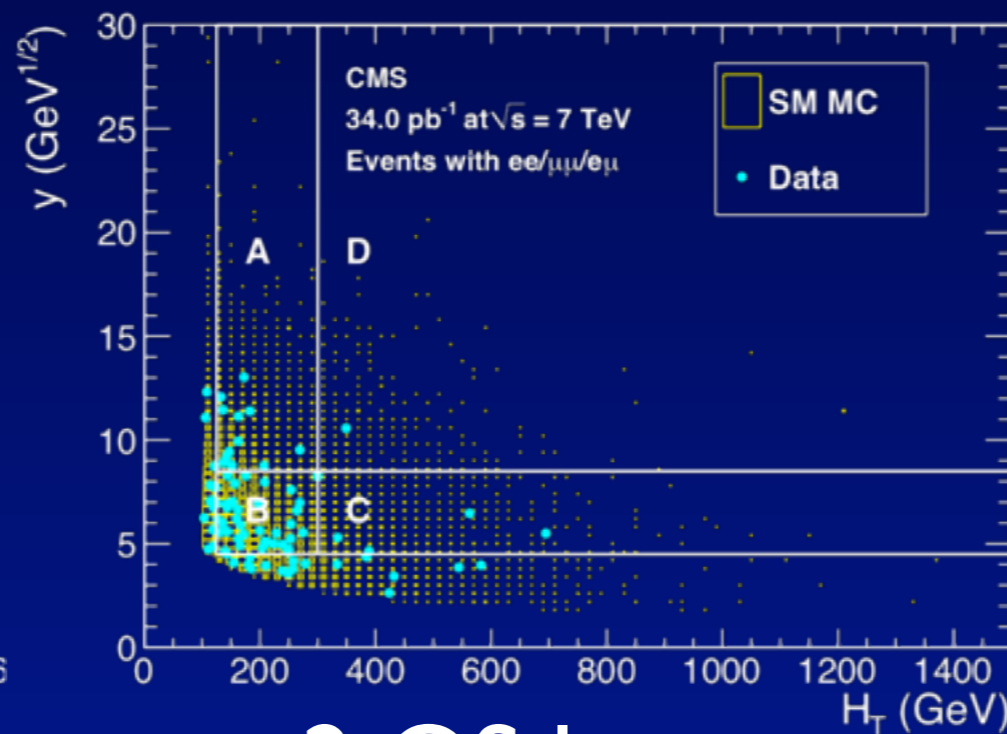
Razor



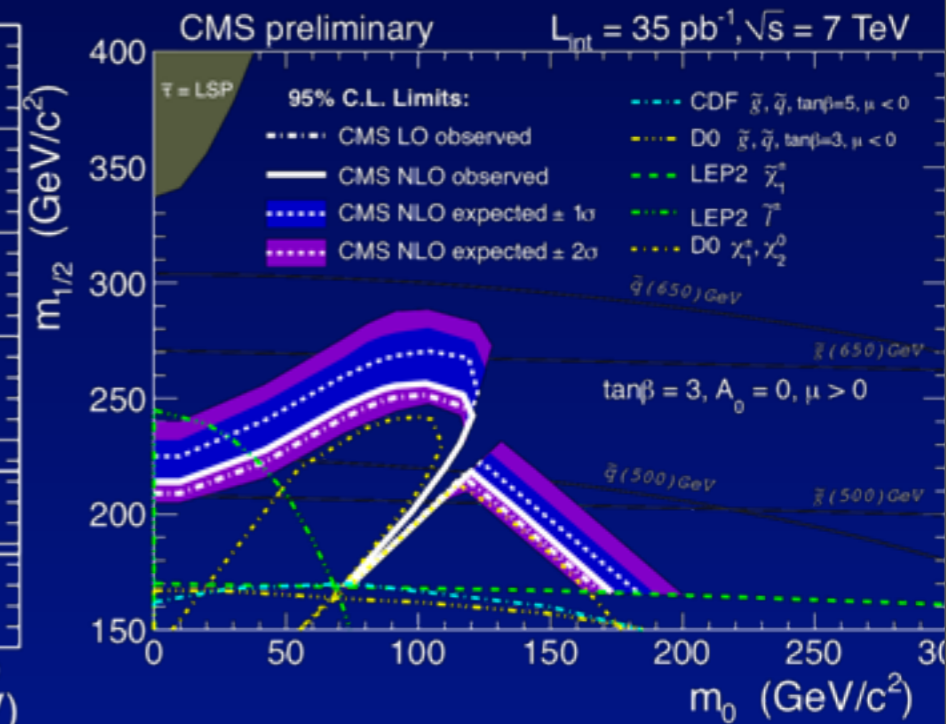
lepton +  $\gamma$



1 lepton



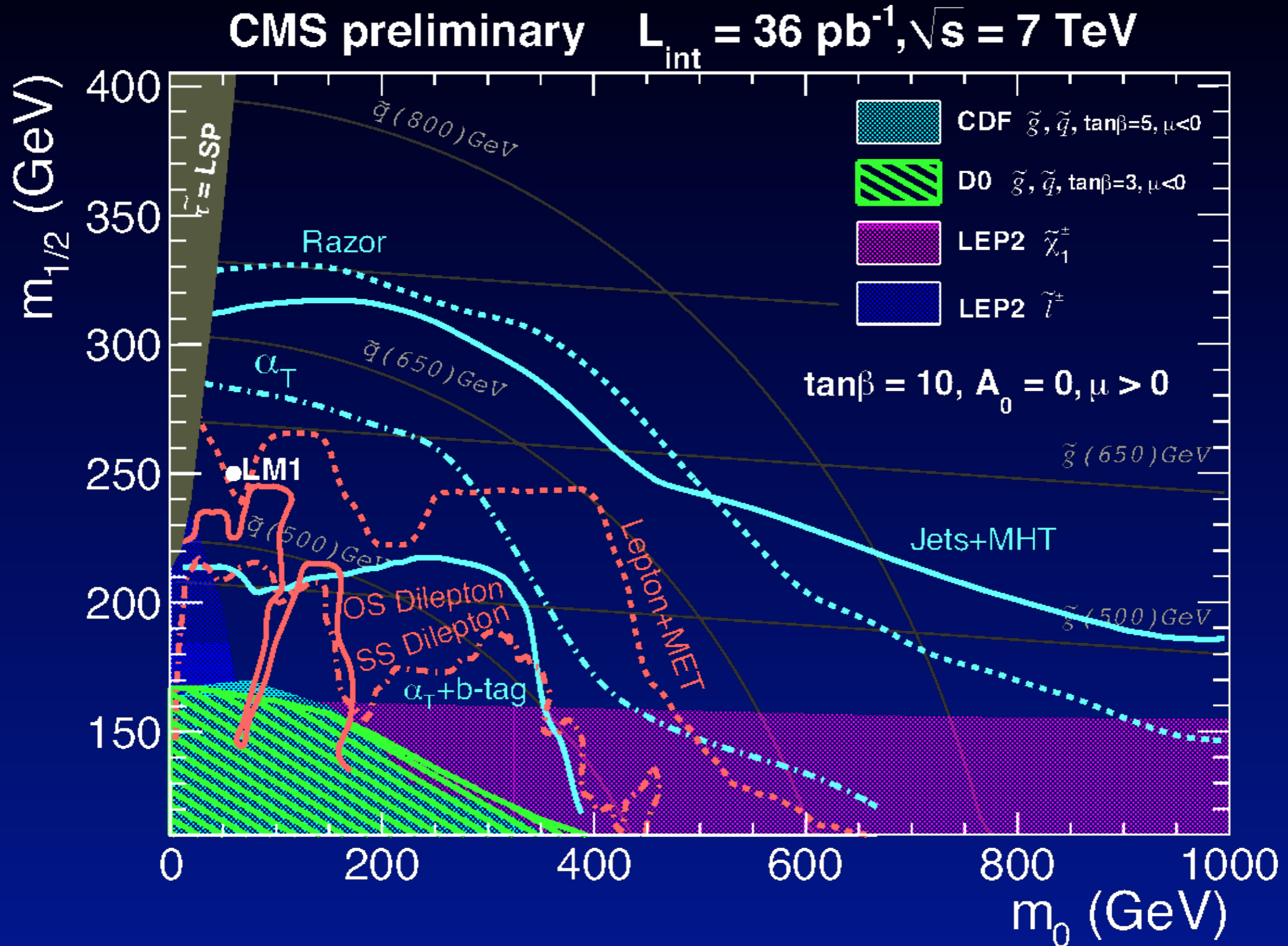
2 OS leptons



$\geq 3$  leptons



# Interpretation & Communication



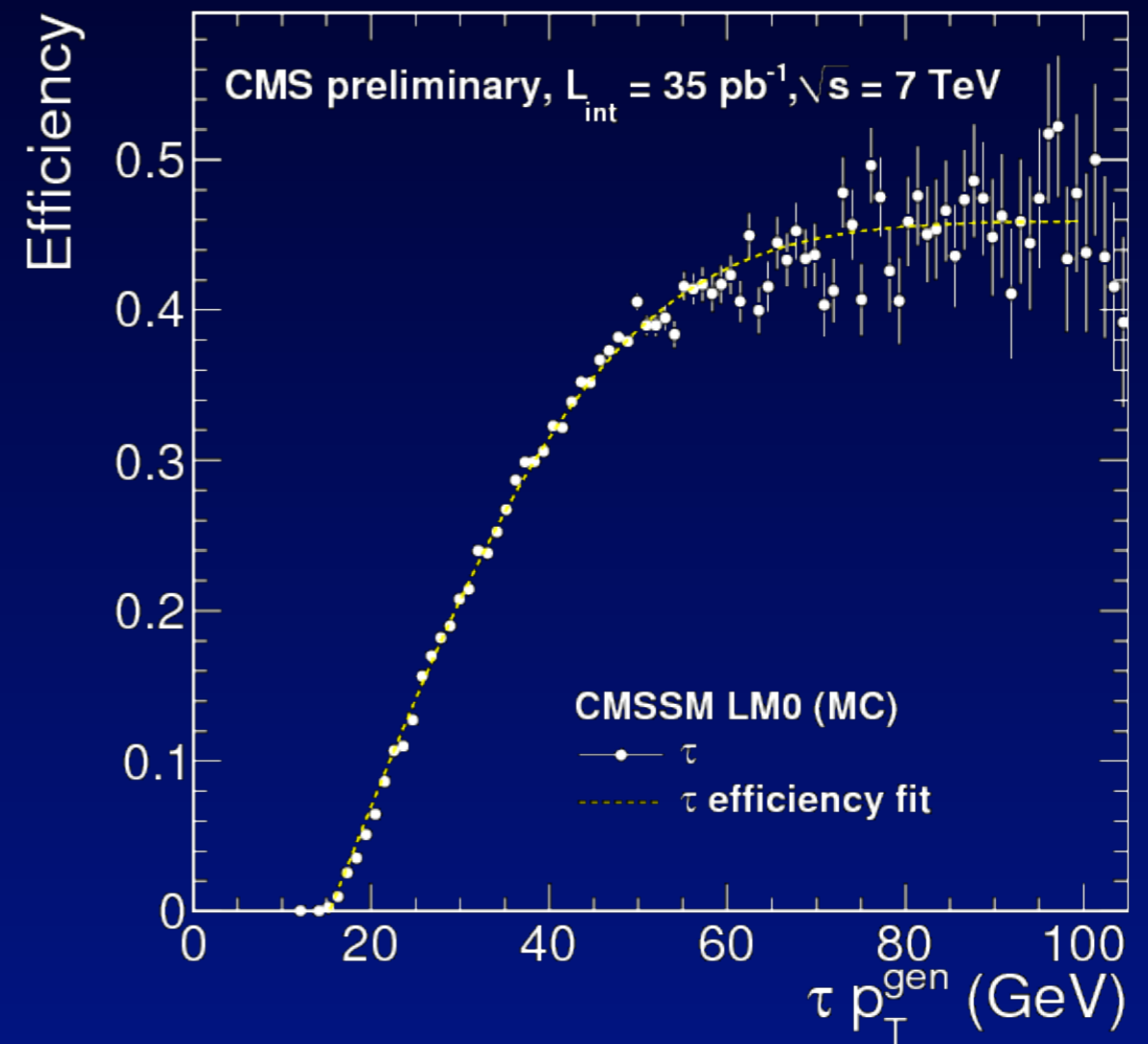
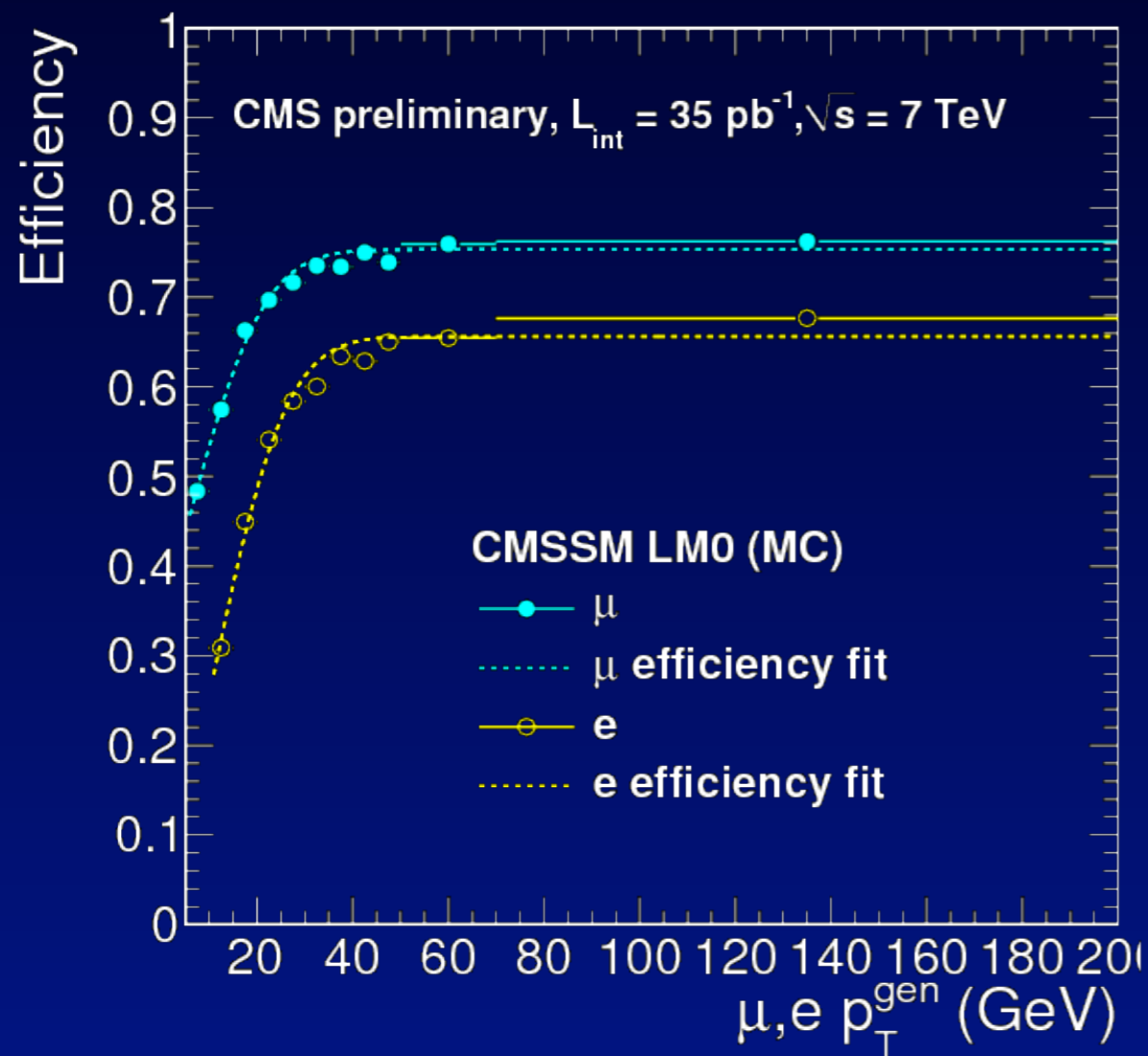


# Interpretation & Communication

- Project the result on a particular model
  - ▶ **95% exclusion in the  $(m_0, m_{1/2})$  plane in the CMSSM**
  - ▶ **comparison with previous searches**
- Provide “outreach” information required for model testing
  - ▶ **acceptance, efficiency, detector response**
- Simplified models
  - ▶ **“bottom-up” approach: adapt model to search**
- Global fits
  - ▶ **“top-down”: integrate results in global fit of parameter space**

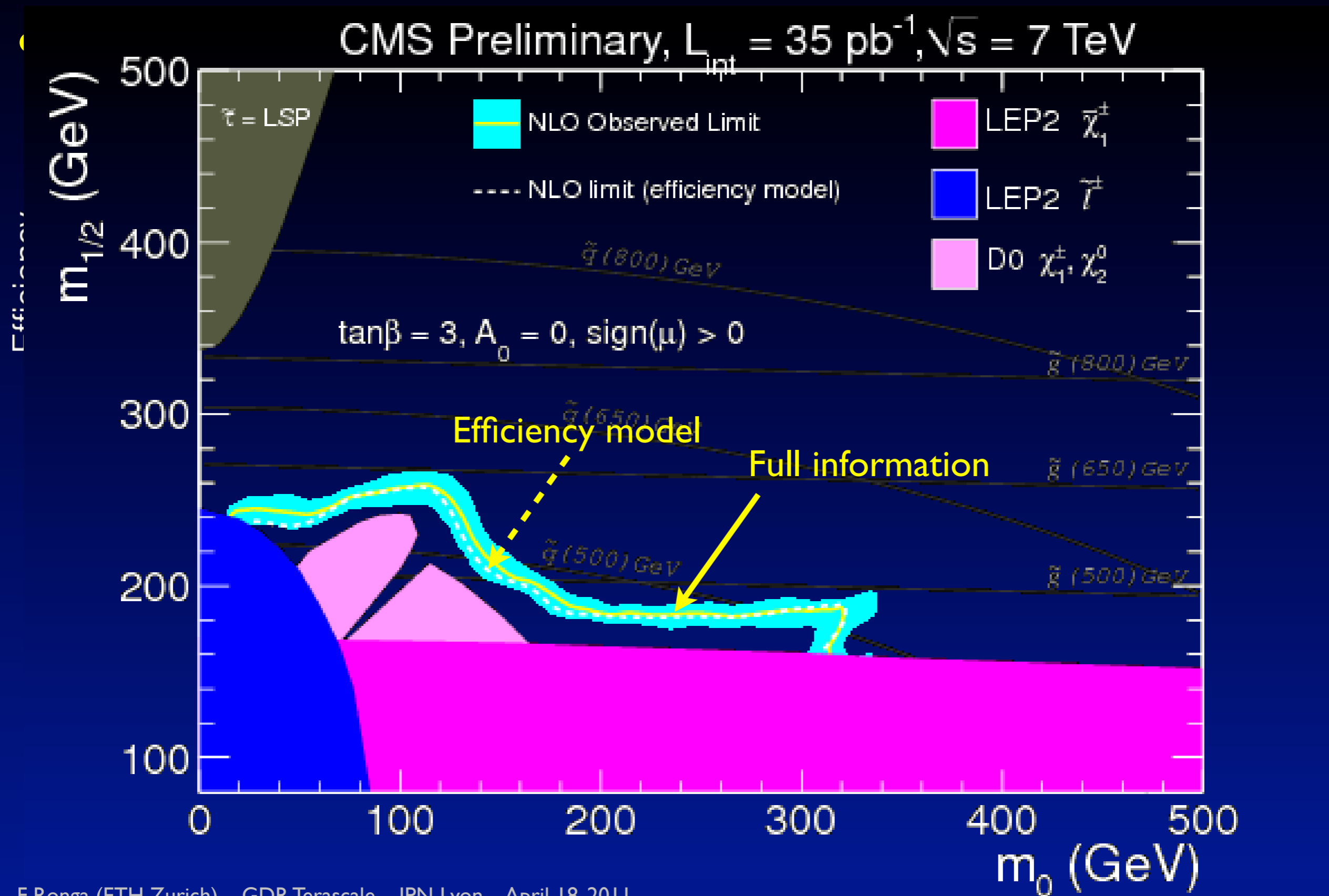
# “Outreach information”

- Provide information on efficiencies to test models
  - ▶ checked that the model gives identical **CMSSM** reach



*Same-sign dilepton search*

# “Outreach information”



# Simplified models

- Work done in contact with theorists (LPCC)

- ▶ See <http://www.lhcnewphysics.org/>

- ▶ Proposed simplified topologies for early searches

- ▶ another attempt at “model-independent” limits

- Hadronic models

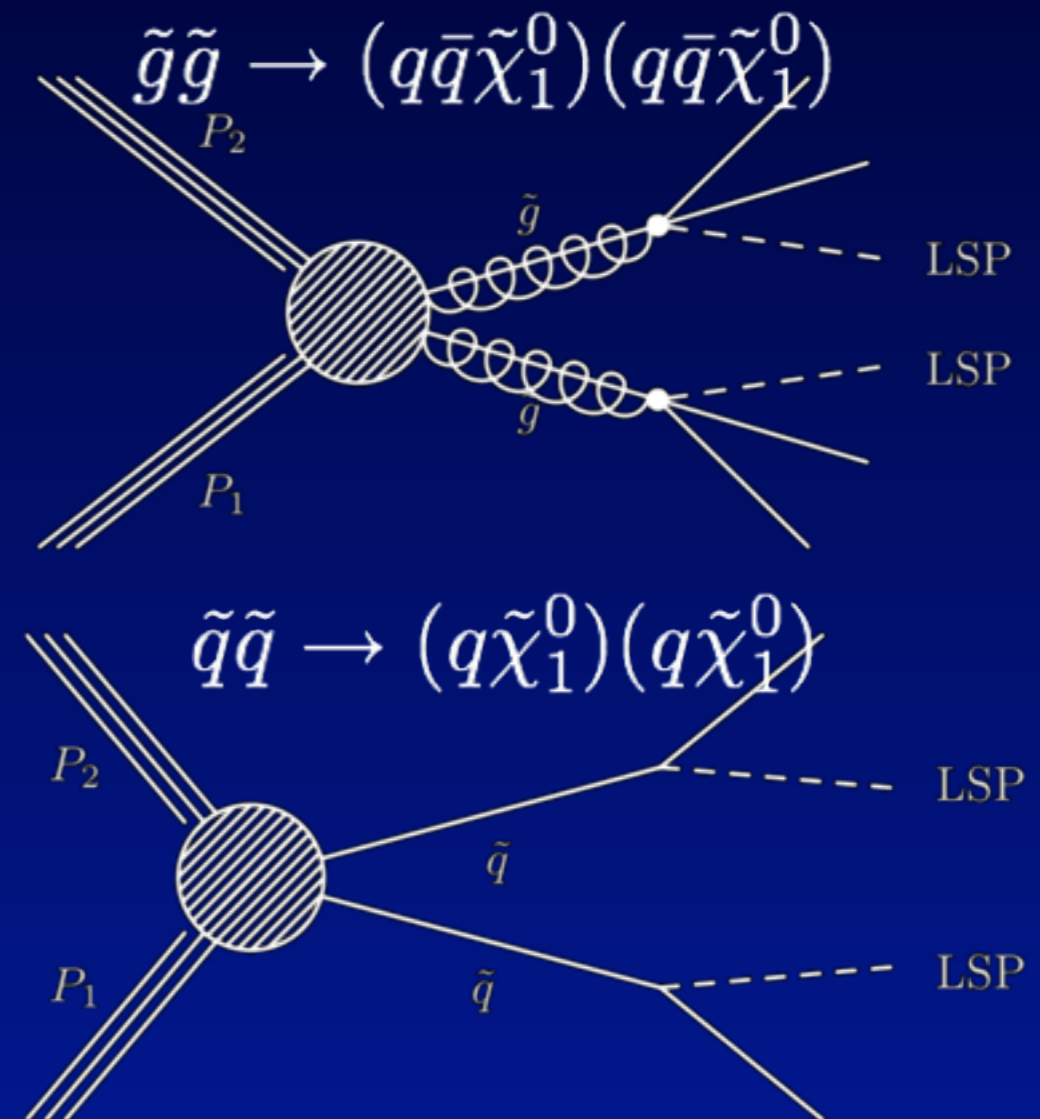
- ▶ gluino pair production with decay to quark-antiquark + LSP

- ▶ squark-antisquark with decay to quark + LSP

- ▶ kinematics specified by masses

- represent limits in 2D mass plot

- ▶ reference cross-section for comparison

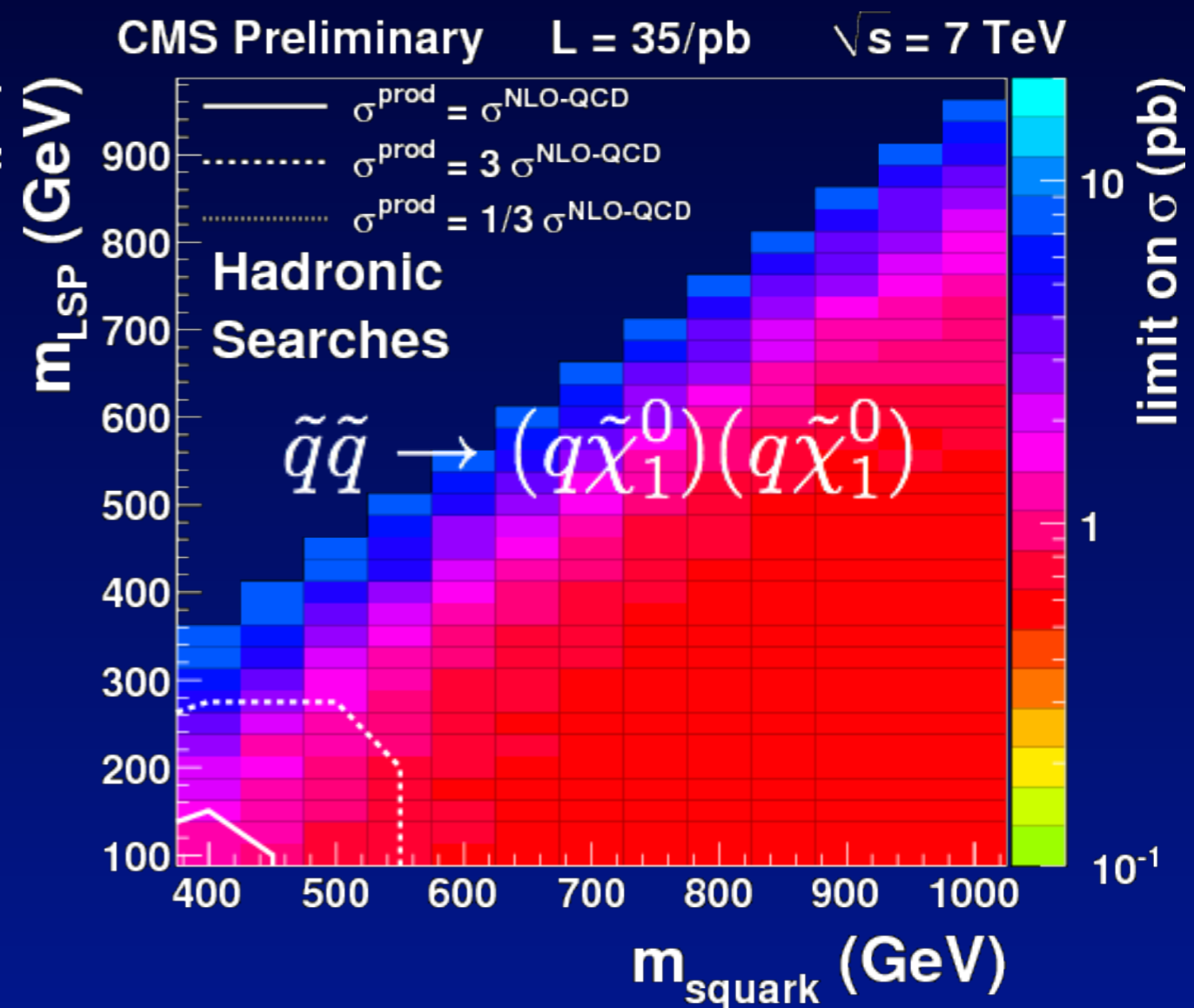
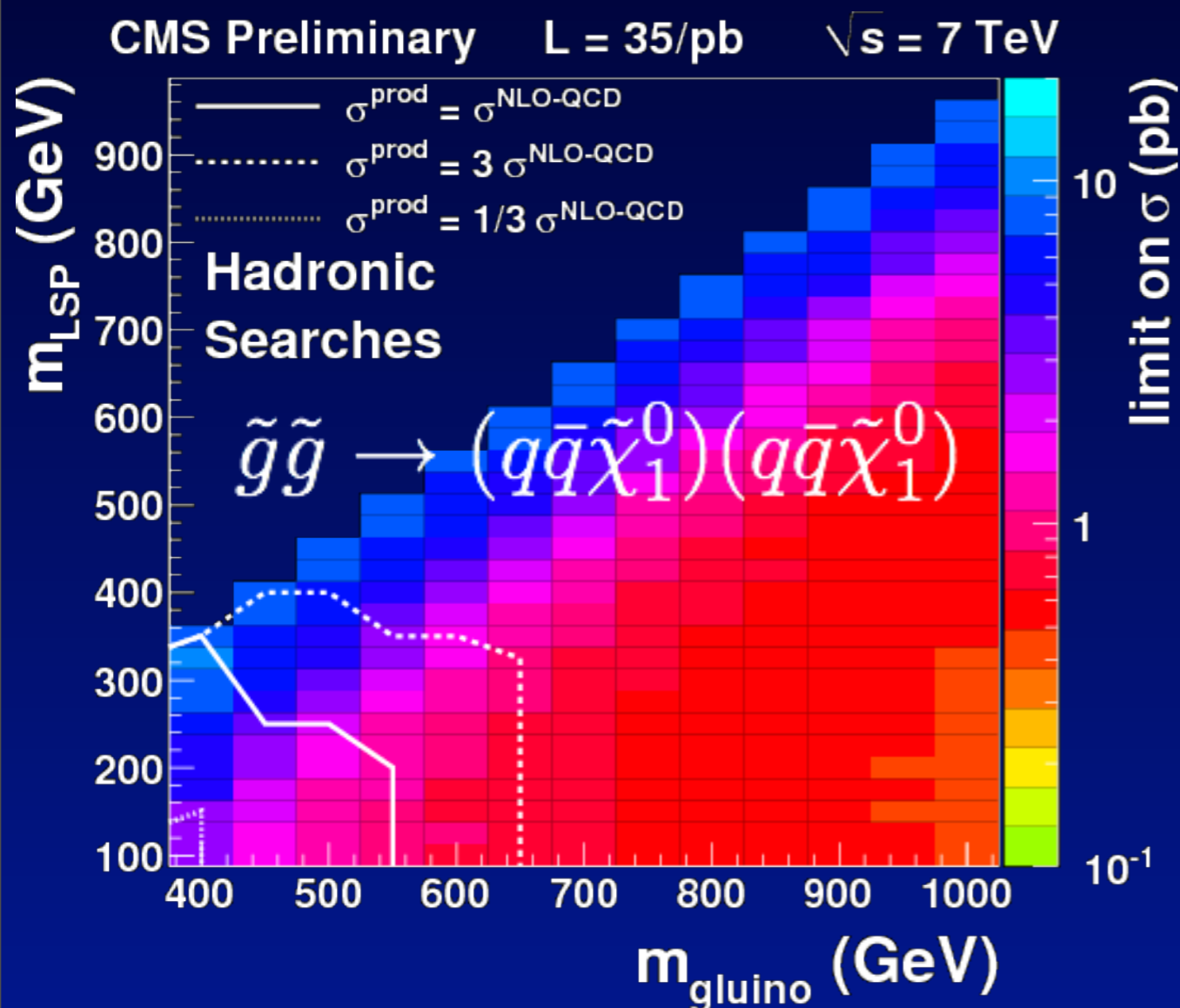


# Simplified models

- Combined limits from hadronic searches

▶ information also available in digital format

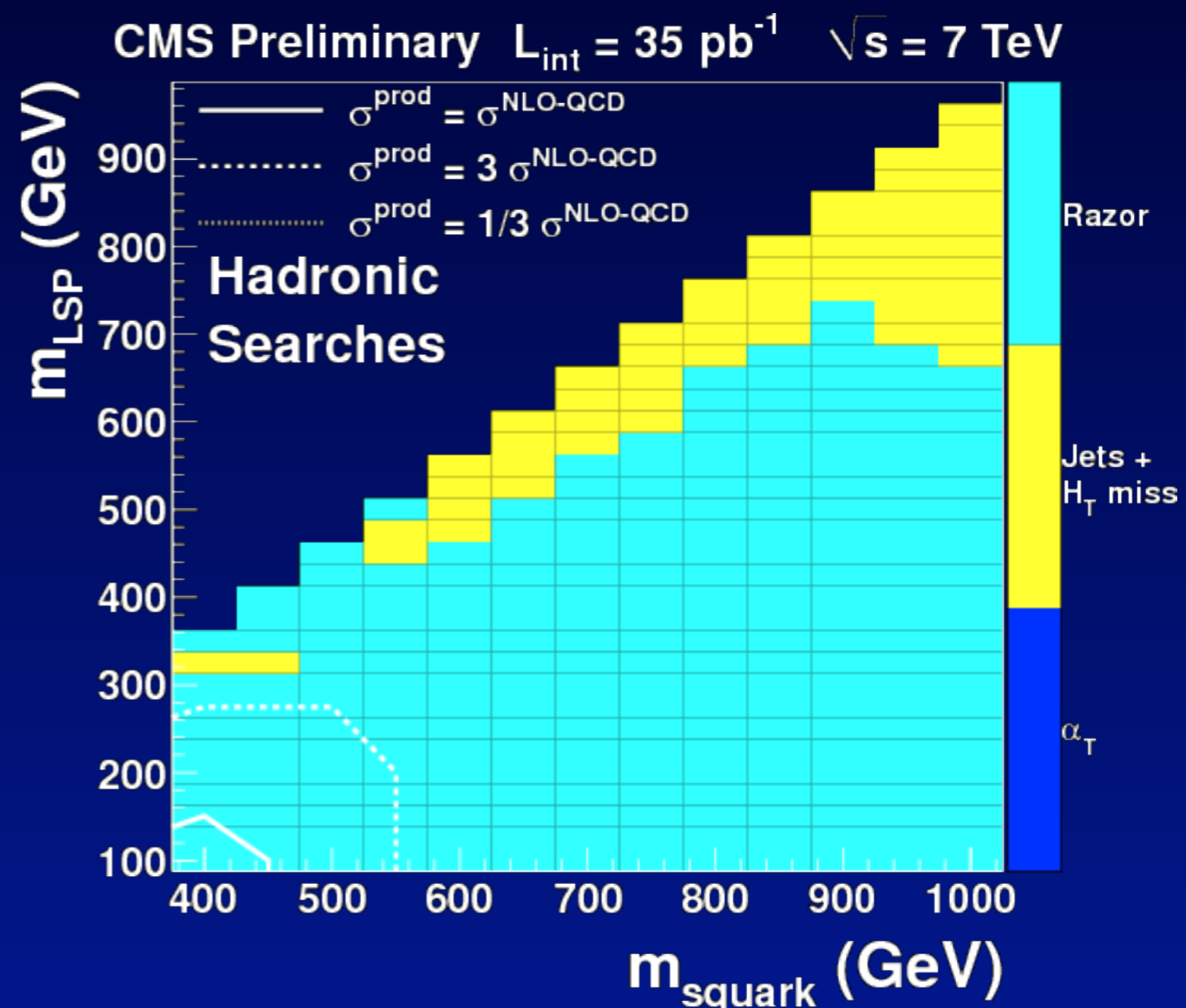
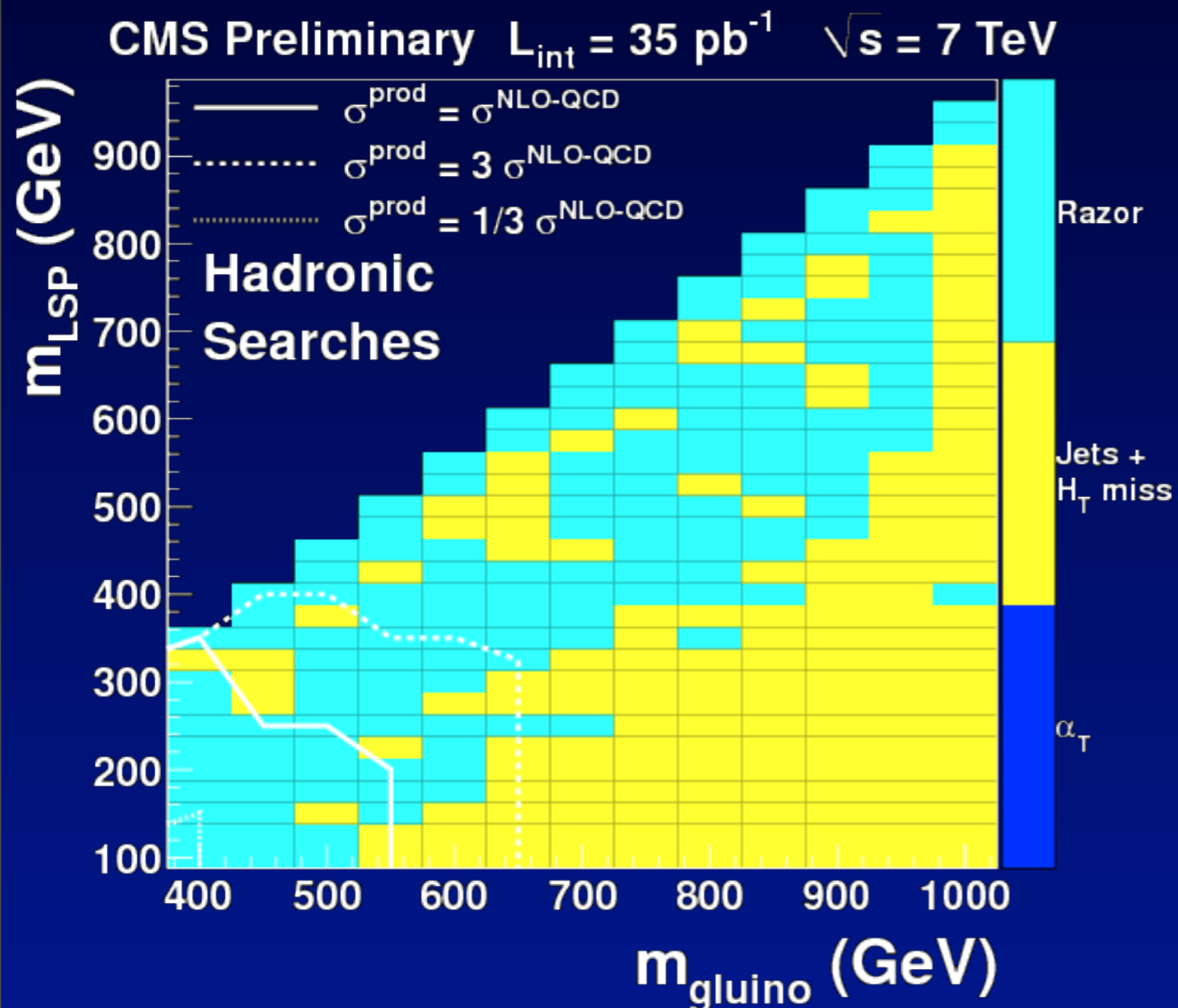
*Experimental uncertainties only  
(theo. unc. under study)*






# By-product: complementarity

- Analysis providing the best 95% upper limit



# Conclusion

- Excellent performance of LHC and CMS allowed launch of SUSY searches in all topologies
- Many different “data-driven” techniques commissioned
- In the absence of signal, limits set and various attempts to convey information
- Good prospects for 2011/2012!



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Luminosity: 520  
CDF Crossing: 156152948 / 1594



# More information

- <https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS>

| Analysis   | Approved Plots           | CDS Entry                           | Luminosity | Comment                         |
|--|--------------------------|-------------------------------------|------------|---------------------------------|
| Inclusive search for new physics at CMS with the jets and missing momentum signature   | <a href="#">SUS10005</a> |                                     | 36/pb      |                                 |
| Further interpretation of the search for SUSY based on $\alpha T$  | <a href="#">SUS11001</a> |                                     | 35/pb      |                                 |
| Inclusive search for squarks and gluinos at $\sqrt{s} = 7$ TeV   | <a href="#">SUS10009</a> |                                     | 35/pb      |                                 |
| Search for New Physics in pp Collisions at $\sqrt{s} = 7$ TeV in Events with a Single Lepton, Jets, and Missing Transverse Momentum            | <a href="#">SUS10006</a> |                                     | 36/pb      |                                 |
| Search for Supersymmetry in pp Collisions at $\sqrt{s} = 7$ TeV in Events with A Lepton, Photon, and Missing Transverse Energy                 | <a href="#">SUS11002</a> |                                     | 35/pb      |                                 |
| Search for Physics Beyond the Standard Model Using Multilepton Signatures in $\sqrt{s} = 7$ TeV pp Collisions with the CMS Detector at the LHC | <a href="#">SUS10008</a> |                                     | 35/pb      |                                 |
| Search for new physics with same-sign isolated di-lepton events with jets and missing transverse energy at the LHC                             | <a href="#">SUS10004</a> |                                     | 35/pb      |                                 |
| A Search for New Physics in b-tagged dijet and multi-jet events with Missing Energy in pp collisions at $\sqrt{s}=7$ TeV                       | <a href="#">SUS10011</a> |                                     | 35/pb      |                                 |
| Search for Physics Beyond the Standard Model in Opposite-Sign Dilepton Events in pp Collisions at $\sqrt{s} = 7$ TeV                           | <a href="#">SUS10007</a> | <a href="#">CERN-PH-EP-2011-016</a> | 34/pb      | <a href="#">arxiv:1103.1348</a> |
| A Search for Supersymmetry in pp Collisions at 7 TeV Using Events with Two Photons and Large Missing Transverse Energy                         | <a href="#">SUS10002</a> | <a href="#">CERN-PH-EP-2011-007</a> | 36/pb      | <a href="#">arxiv:1103.0953</a> |
| Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy   | <a href="#">SUS10003</a> | <a href="#">CERN-PH-EP-2010-084</a> | 35/pb      | <a href="#">arXiv:1101.1628</a> |