Leptonic SUSY Analyses at DESY

5th Annual Helmholtz Alliance Workshop

A.Cakir, F. Costanza, D. Horton, D, Krücker, I. Melzer-Pellmann,
N. Pietsch, E. Ron, H. Schettler, M. Stein

Bonn, December 8th 2011

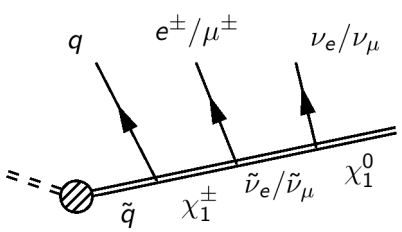
HELMHOLTZ | ASSOCIATION

DESY

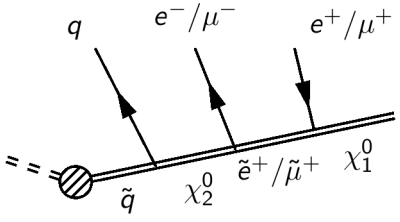
CMS

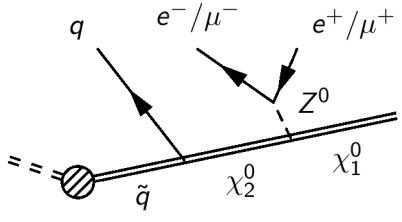
Introduction: Leptonic Analyses with CMS

- **Leptons:** Many SUSY models, including the cMSSM, predict a significant cross-section for events containing leptons, while the largest fraction of **SM background at LHC gets strongly reduced** by requiring isolated leptons**.**
- **Jets:** As in SM, SUSY cross-section in proton-proton collisions is **dominated by colored particle production**. These particles decay hadronically leading to events with many energetic jets.
- **Missing Transverse Energy (MET):** Assuming R-parity conservation → SUSY particles produced in pairs and decay chains end with the stable Lightest SUSY Particle (LSP).
  To explain Dark Matter → LSP interacts only weekly → escapes **unobserved** from the detector.



Single lepton



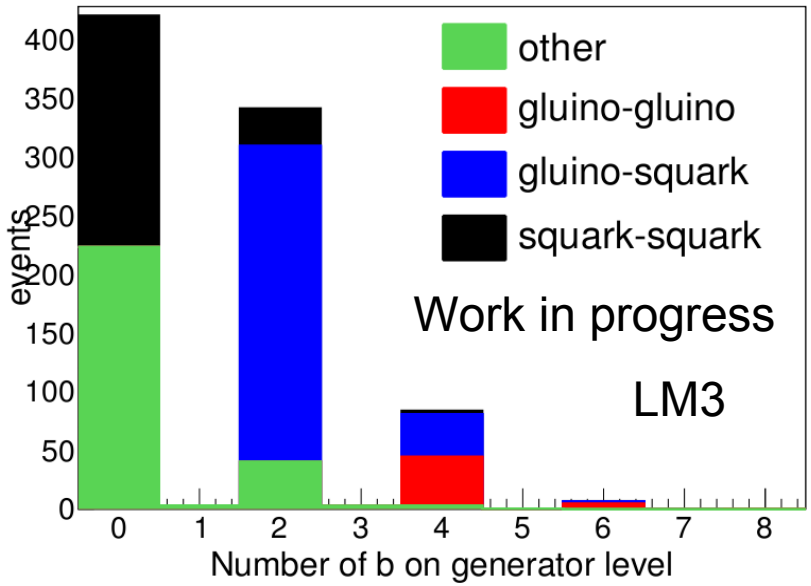


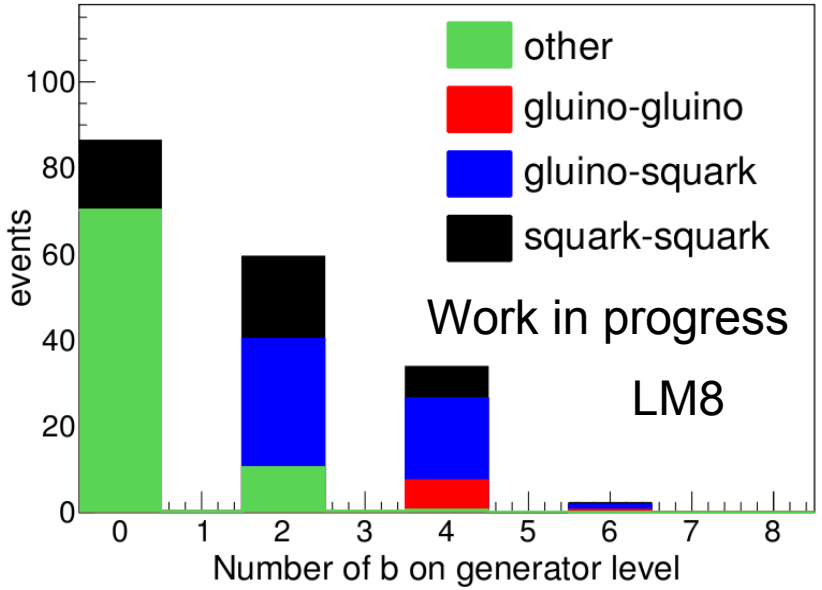
Two opposite-sign leptons

1 Lepton + b-tagging: Motivation

- There are good reasons to believe that (the lighter) **stop and sbottom squark** are significantly **lighter** than the 1st and 2nd generation squarks.
- In scenarios with **light gluinos*** $\left(m_{\tilde{t}}, m_{\tilde{b}} < m_{\tilde{g}} < m_{\tilde{q}}\right)$ the gluino predominantly decays into $t\,\bar{t}$ and/or $b\,\bar{b}$ pairs

  Assuming ***R-Parity conservation,*** the gluino decay chain is expected to end in **at least 2 *b-jets*** and **MET**.





* **G.L. Kane** et al. **Top Channel for Early SUSY Discovery at the LHC**. Jan. 2011
T. Gregoire et al. **Toptet**. 2011. (arXiv:1101.1294)
R. Essig et al. **Heavy Flavor Simplified Models at the LHC** (arXiv:1110.6443)

Analysis Strategy and Event Selection

- Event selection based on ***1 lepton + MET search*** with few changes to optimize for *b-rich* SUSY models.
  - **Hadronic activity**: $H_T = \sum_{jets} p_t > 350\,GeV$
  - ***Four jets*** (a*k5*) each with $E_T > 40$ *GeV*
  - **several *b-tags*: *# of b-jets = 0, 1, 2, 3 or more***
    - Currently using medium working point of Track Counting High Efficiency (TCHE) algorithm*.
  - **Exactly one isolated electron or muon** with $p_T > 20\,GeV$
  - ***MET > 60 GeV***

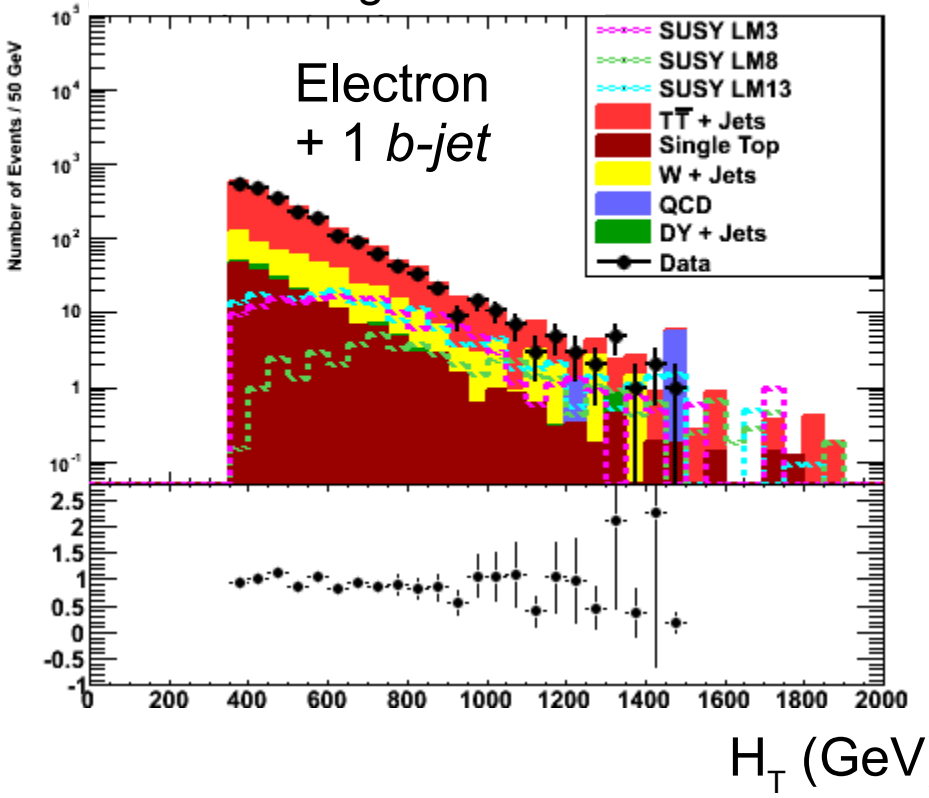
* **CMS Collaboration**, **"Performance of the b-jet identification in CMS"**, CMS-PAS-BTV-11-001

DESY

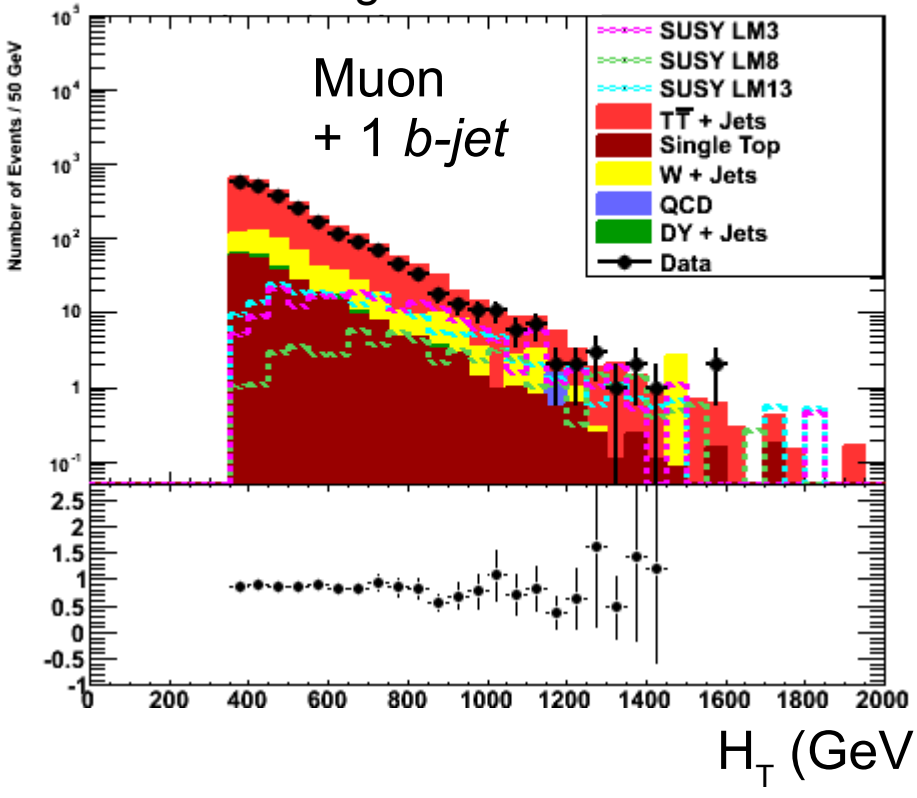
CMS

Results for 4.2 fb^{-1}: H_T

Work in Progress



Work in Progress

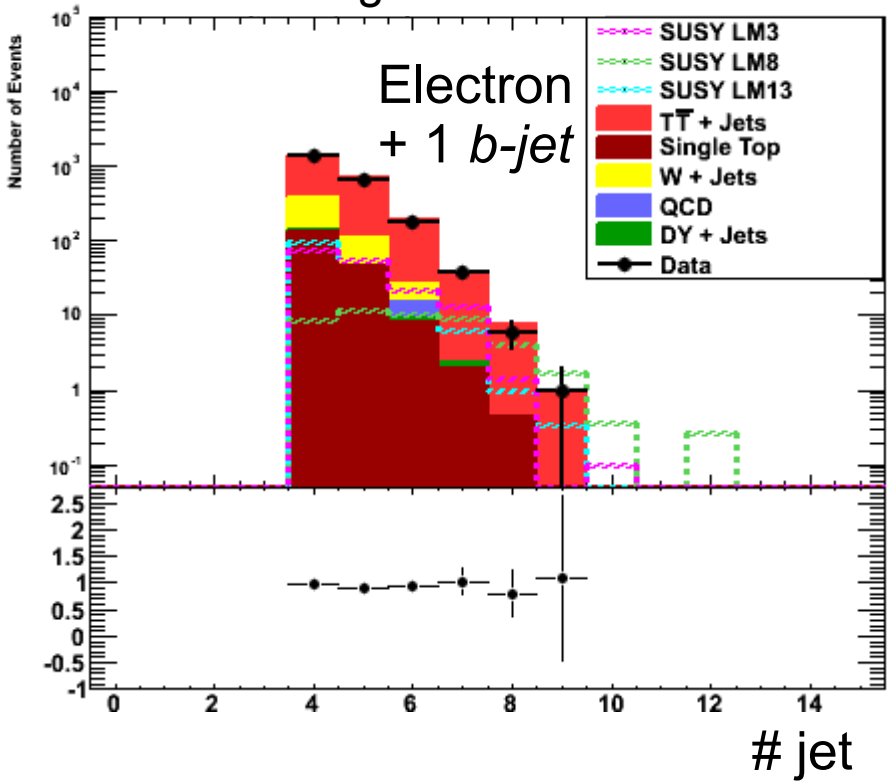


SUSY benchmark points in cMSSM →

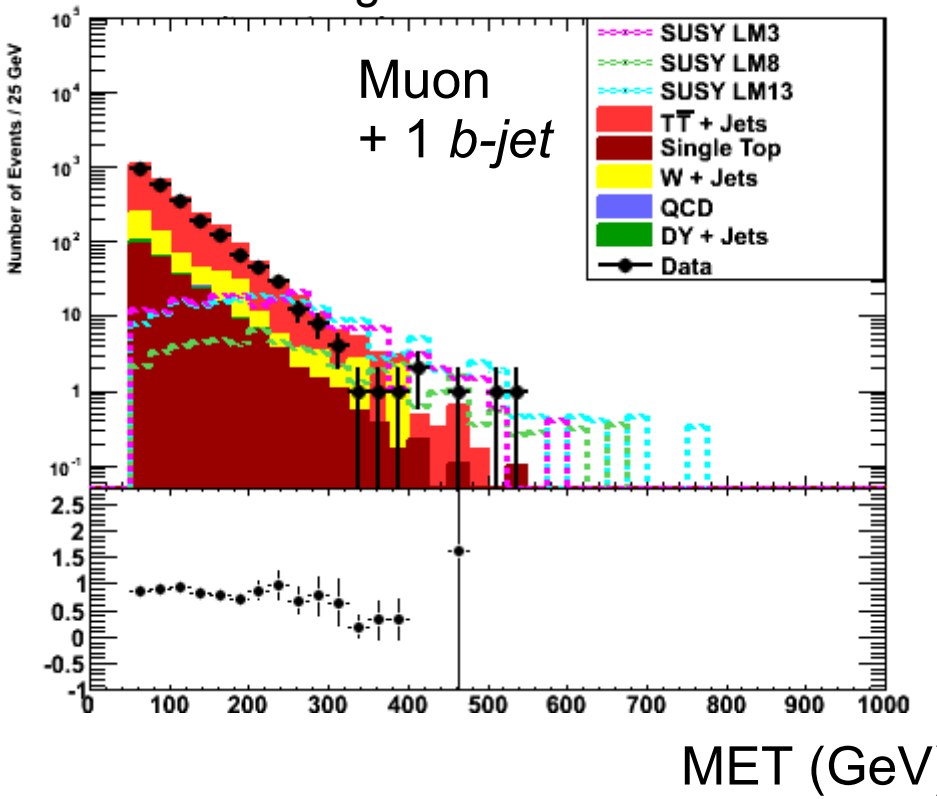
	m_0	$m_{1/2}$	A_0	tanβ	σ (LO *K factor)
LM3 →	330	240	0	20	3.438 * 1.4 pb
LM8 →	500	300	-300	10	0.73 * 1.41 pb
LM13 →	270	218	-553	40	6.899 * 1.42 pb

Results for 4.2 fb^{-1}: MET and Jet Multiplicity

Work in Progress



Work in Progress



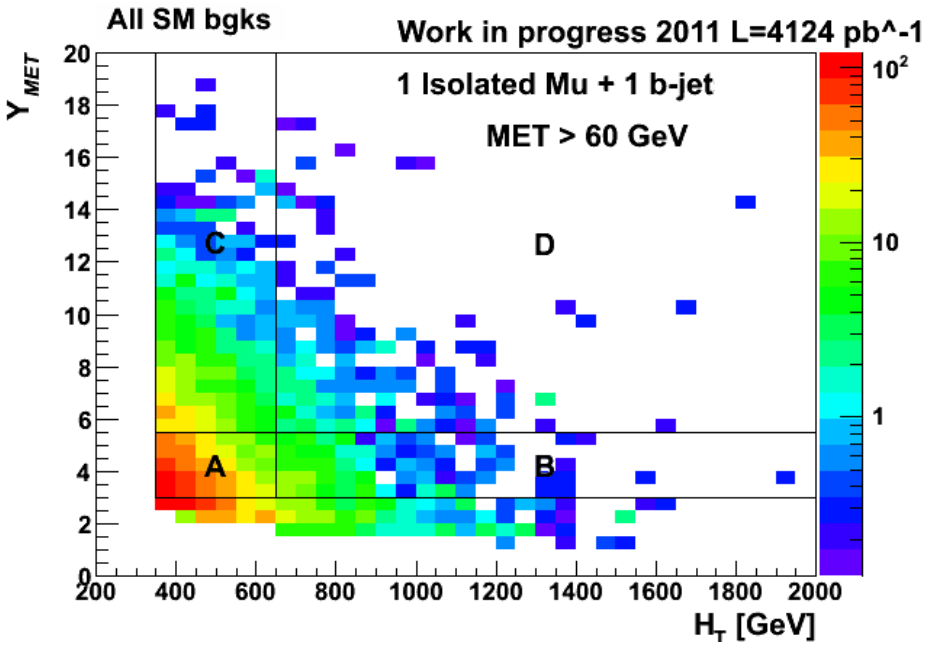
Very good agreement between data and MC !!
Main background is $t\,\bar{t}$

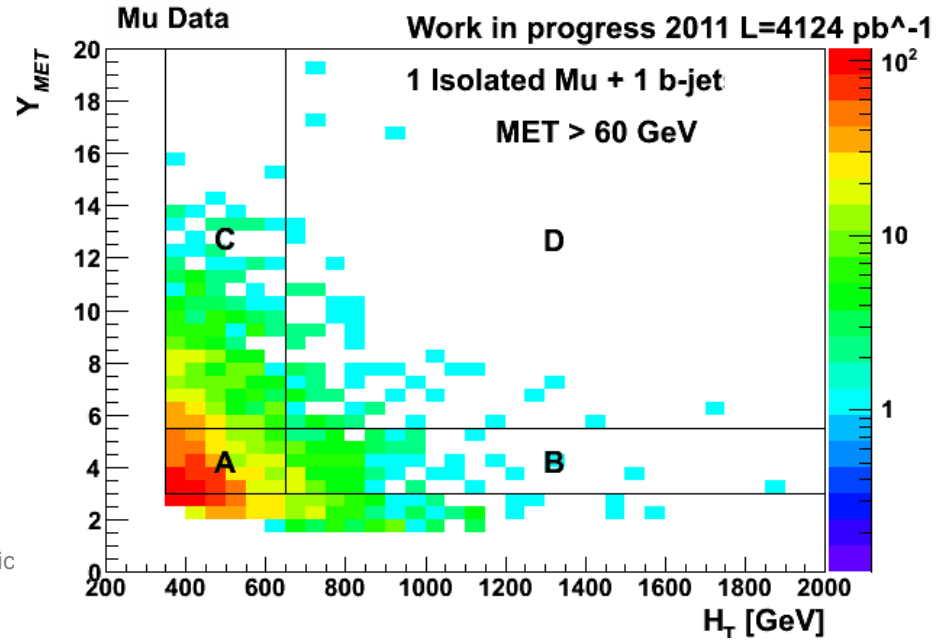
Background Estimation

- Factorization method (also called ABCD method) is used:
- Hypothesis: H_T and $Y_{MET} = MET/\sqrt{H_T}$ are not strongly correlated

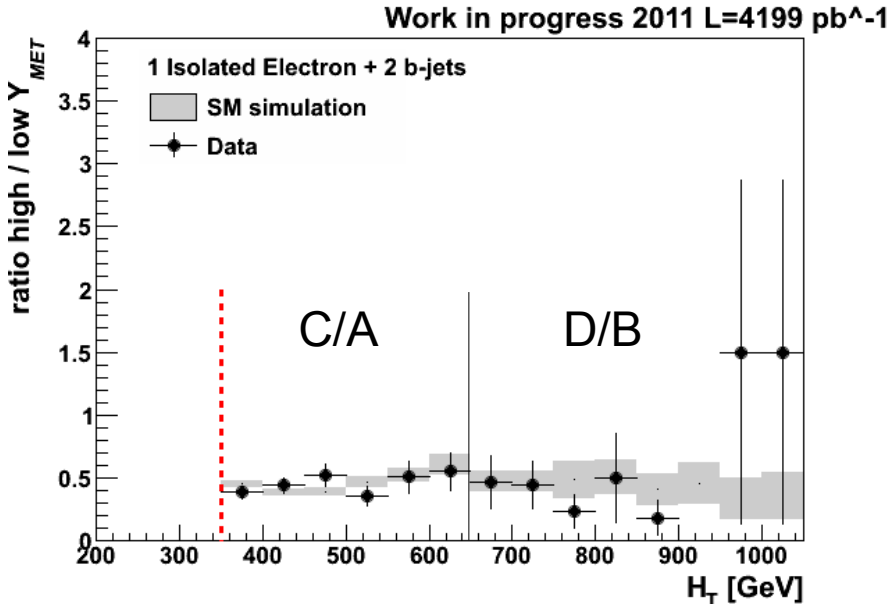
$$N(D) = \frac{N(B) * N(C)}{N(A)}$$

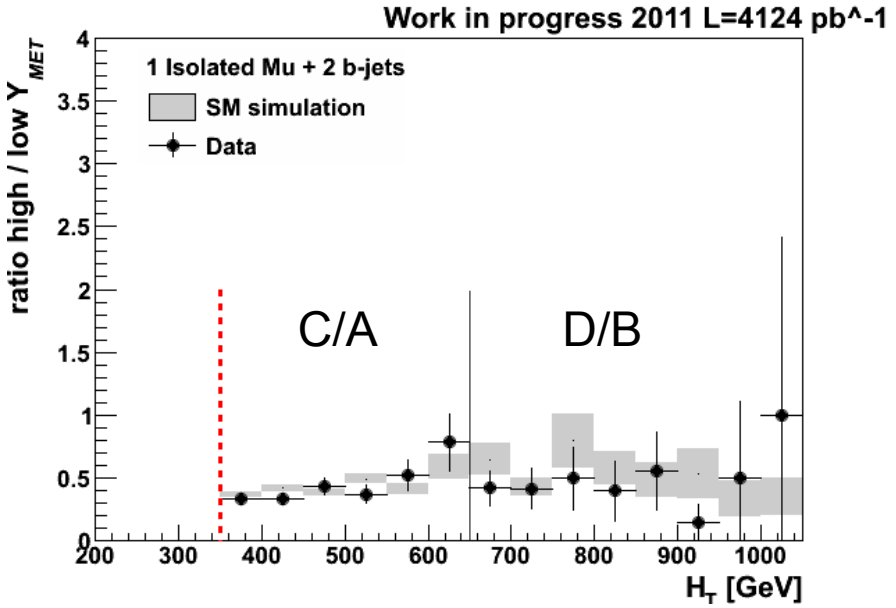
Regions Boundaries	
H_T	Y_{MET}
A: 350 < H_T < 650	3.0 < Y_{MET} < 5.5
B: 650 < H_T	3.0 < Y_{MET} < 5.5
C: 350 < H_T < 650	5.5 < Y_{MET}
D: 650 < H_T	5.5 < Y_{MET}

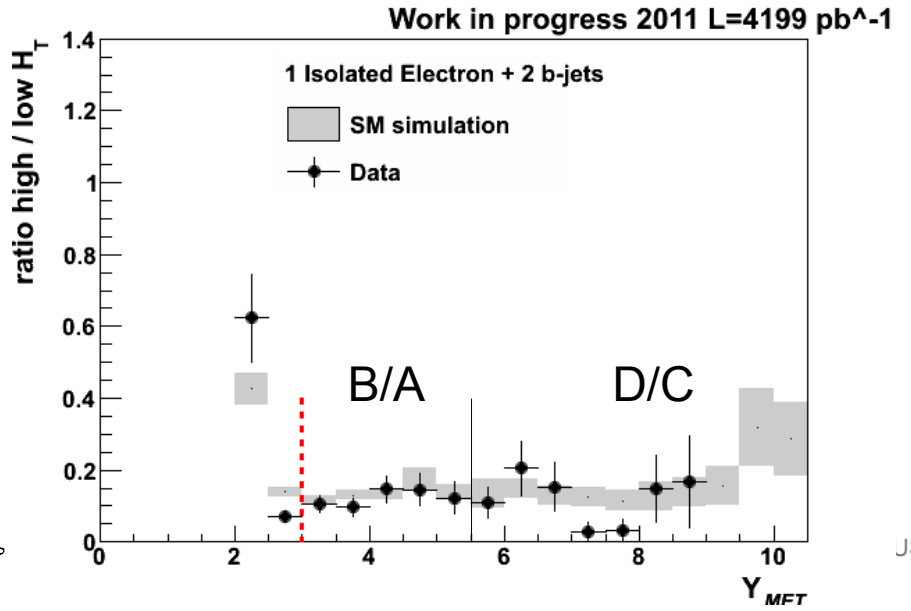


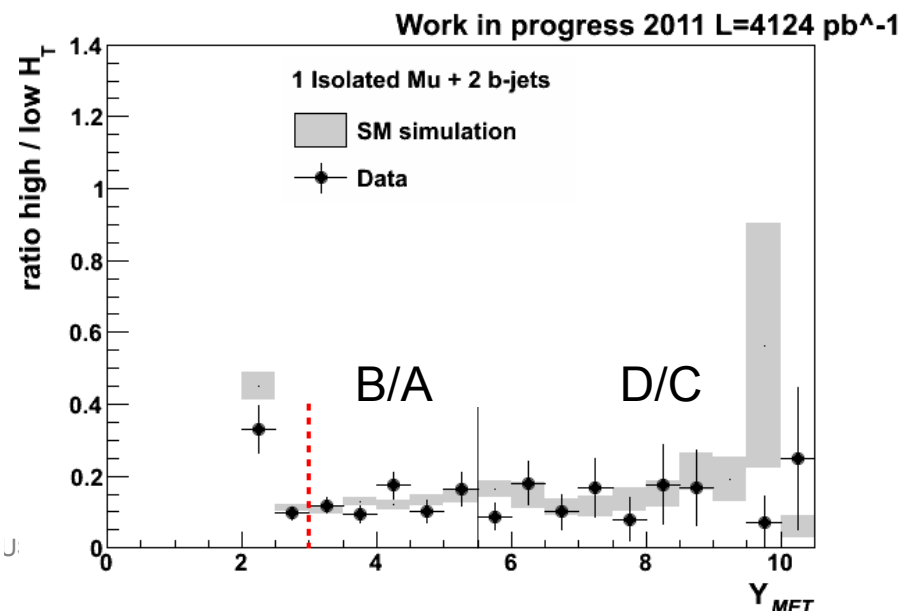


Factorization Method









Results:

1 Muon + *1 b-jet*

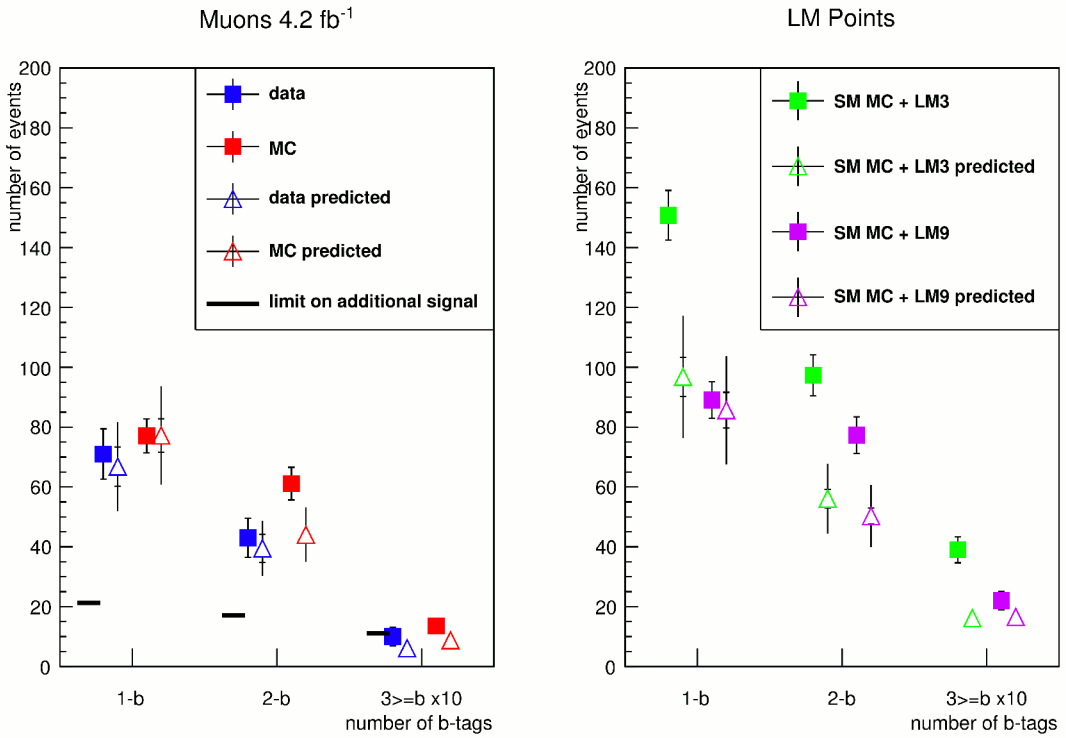
Background determination using HT and MET Significance 1b1m_AllCuts					
sample	$N(A)$	$N(B)$	$N(C)$	$N(D)$	$N(D)_{pred}$
Total SM MC	1129.93 ± 21.10	157.57 ± 10.05	553.70 ± 16.32	77.11 ± 5.69	77.21 ± 5.62
Data	1160.00 ± 34.06	144.00 ± 12.00	538.00 ± 23.19	71.00 ± 8.43	66.79 ± 6.57
LM3	18.61 ± 3.01	23.55 ± 3.37	60.05 ± 5.46	73.69 ± 6.04	75.98 ± 17.79
LM8	1.96 ± 0.87	10.13 ± 1.88	9.13 ± 1.72	26.87 ± 3.02	47.27 ± 24.44
LM9	15.62 ± 2.76	13.30 ± 2.50	20.67 ± 3.11	11.95 ± 2.37	17.60 ± 5.26
LM13	15.87 ± 2.73	20.51 ± 3.16	86.59 ± 6.37	60.57 ± 5.31	111.87 ± 27.14

1 Electron + *2 b-jets*

Background determination using HT and MET Significance 2b1e_AllCuts					
sample	$N(A)$	$N(B)$	$N(C)$	$N(D)$	$N(D)_{pred}$
Total SM MC	680.30 ± 12.69	91.01 ± 4.97	300.01 ± 8.06	45.75 ± 3.72	40.13 ± 2.55
Data	649.00 ± 25.48	77.00 ± 8.77	283.00 ± 16.82	32.00 ± 5.66	33.58 ± 4.51
LM3	11.65 ± 2.38	17.40 ± 2.92	44.18 ± 4.69	38.19 ± 4.37	66.01 ± 18.79
LM8	3.00 ± 0.99	5.77 ± 1.41	5.26 ± 1.35	22.56 ± 2.77	10.09 ± 4.89
LM9	14.46 ± 2.67	6.88 ± 1.77	13.26 ± 2.55	5.40 ± 1.54	6.31 ± 2.34
LM13	14.57 ± 2.61	15.24 ± 2.70	97.00 ± 6.82	51.42 ± 4.97	101.48 ± 26.56

Systematics Uncertainties and Limit Setting

- The sources of systematic uncertainties under study are:
  - Correlation between H_T and Y_{MET}:



For these plots, only 20% systematic on

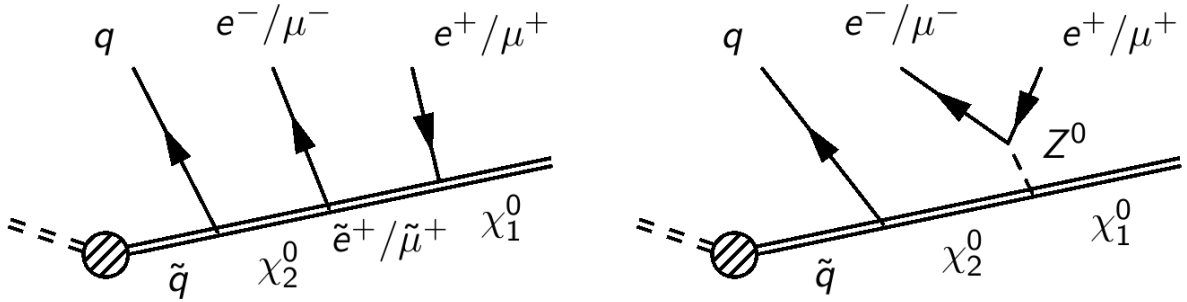
$$k = \frac{N(A)N(D)}{N(B)N(C)}$$

has been considered.

  - B-tagging efficiency (dominant one)
  - Jet Energy scale
  - PDF

Dilepton Opposite-Sign Same-Flavor: Motivation and Idea

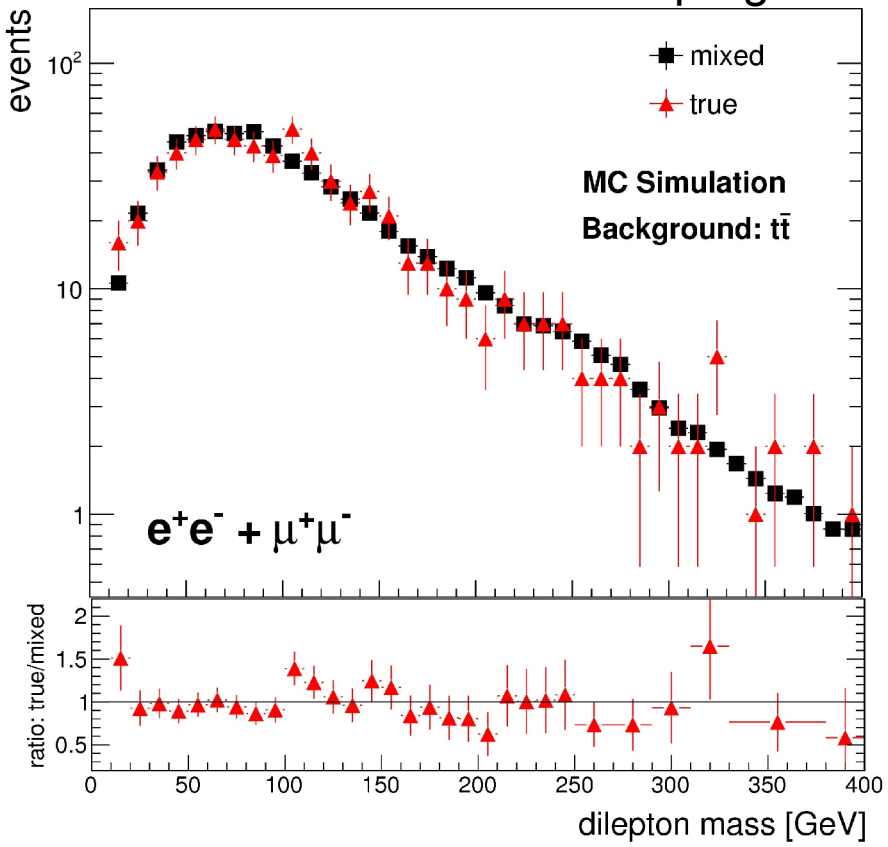
- In SUSY models, **opposite-sign lepton (OS)** pairs predominantly originate **from the same decay chain**.
- The invariant dilepton mass reflects the topology of the decay chain:
  - Two consecutive two-body decays lead to an edge in the mass spectrum;
  - Z^0 boson form a peak.
- The main background in this channel is leptonically decaying $t\,\bar{t}$, where no such structure appears in the di-lepton mass spectrum.
- Approximation: $M_{ll} \approx \sqrt{2|\vec{p}_1||\vec{p}_2|(1-\cos\theta_{ll})}$



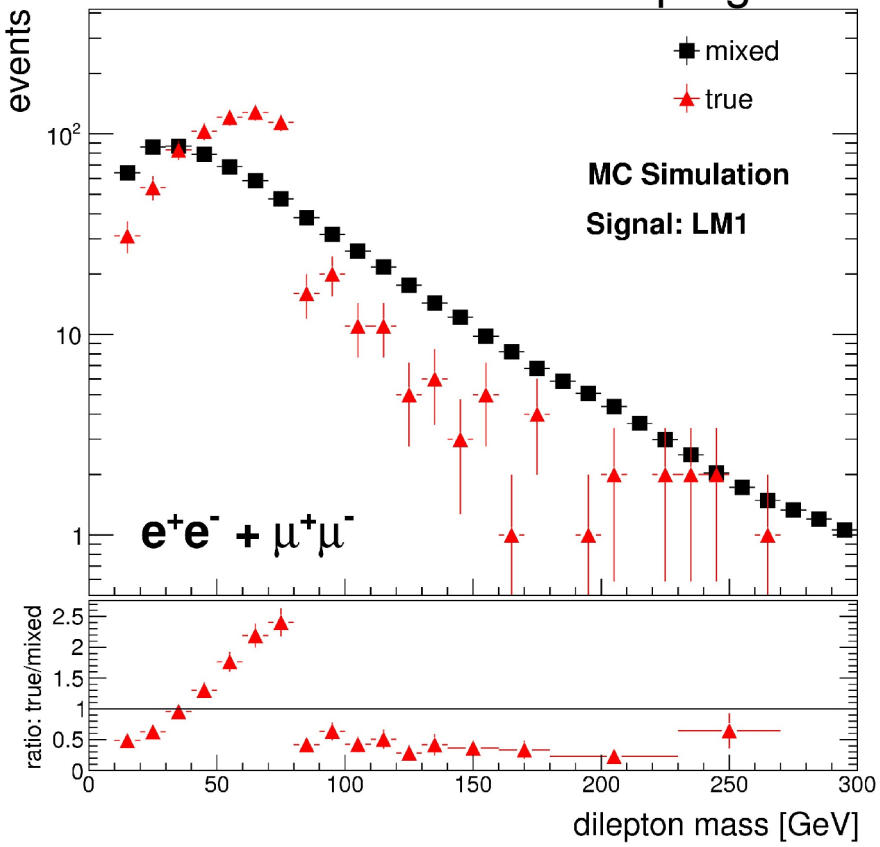
Dilepton OS SF: Motivation and Idea

- Assumption: in $t\bar{t}$ events $|\vec{p}_1||\vec{p}_2|$ and $(1-\cos\theta_{ll})$ are **uncorrelated**.
- **Template for the background** can be created by taking $|\vec{p}_1||\vec{p}_2|$ and $(1-\cos\theta_{ll})$ from two different events.

Work in progress



Work in progress



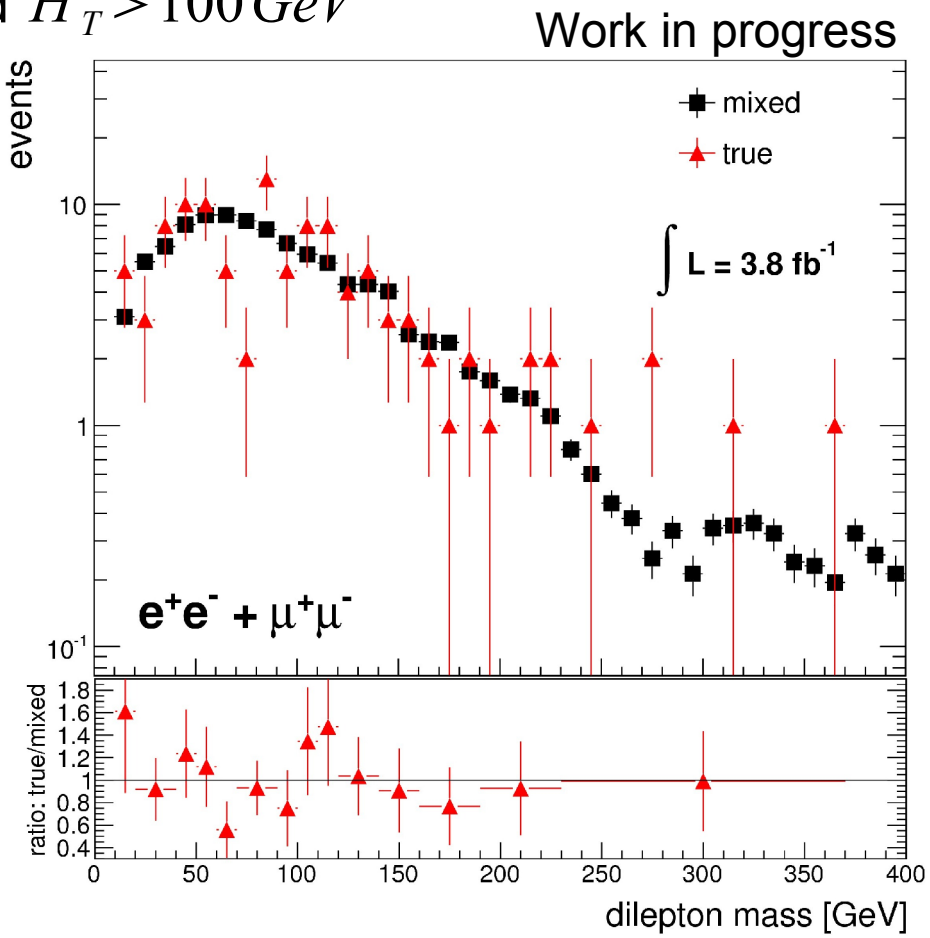
Dilepton OS SF: Event Selection

- At least two OS, isolated same flavor leptons
  $p_{T,1} > 20\,GeV$ and $p_{T,2} > 10\,GeV$
- Veto against low mass resonances: $M_{ee,\mu\mu} > 10\,GeV$
- At lest 2 *jets* with $p_T > 30\,GeV$ and $H_T > 100\,GeV$
- $MET > 180\,GeV$

Invariant di-lepton mass:
measured and mixed distribution.

The event mixing curve describes the true distribution **within statistical fluctuation** very well.

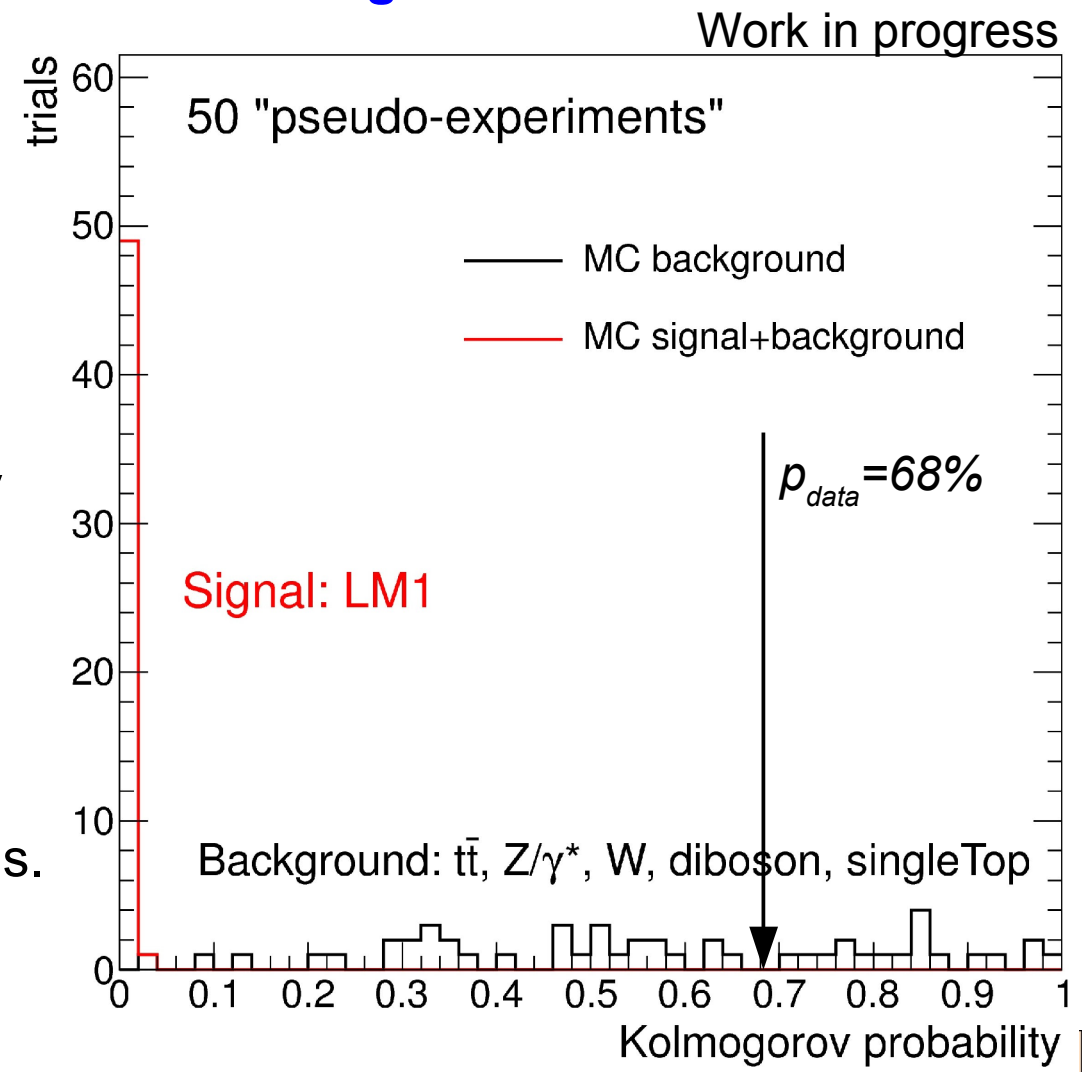
No evidence for signal visible.



Dilepton OS SF: Interpretation

- To compare the two distributions a **Kolmogorow-Smirnov-Test** is performed: $p_{data} = 68\,\%$
- To interpret this result, 50 pseudo-experiments were made randomly choosing events from MC sample in such a way that each pseudo-experiment has as much integrated luminosity as data.

The value determined from data is in **agreement with background** only hypothesis.



Summary

- Two different searches for SUSY with leptons in the final states were presented:
  - No deviation from the SM was found

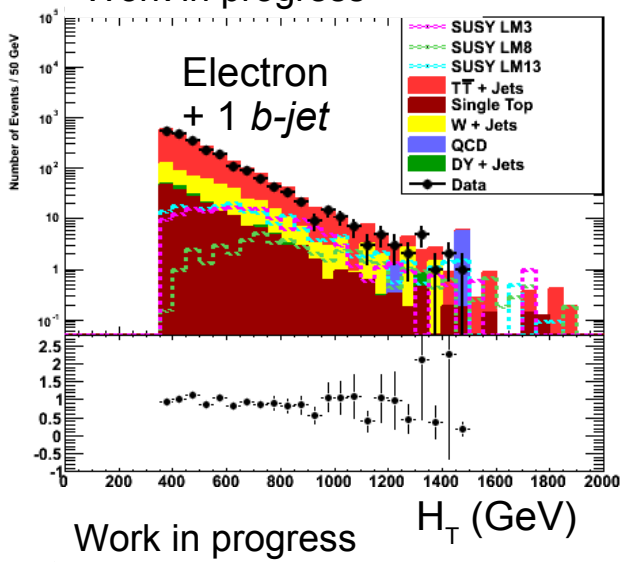
Outlook:

- Single lepton
  - Study of systematic uncertainties
  - Limit setting in cMSSM and for simplified models
- Di-lepton Opposite-Sign Same Flavor
  - Implement a likelihood ratio statistical tests to compare mixed and true distributions

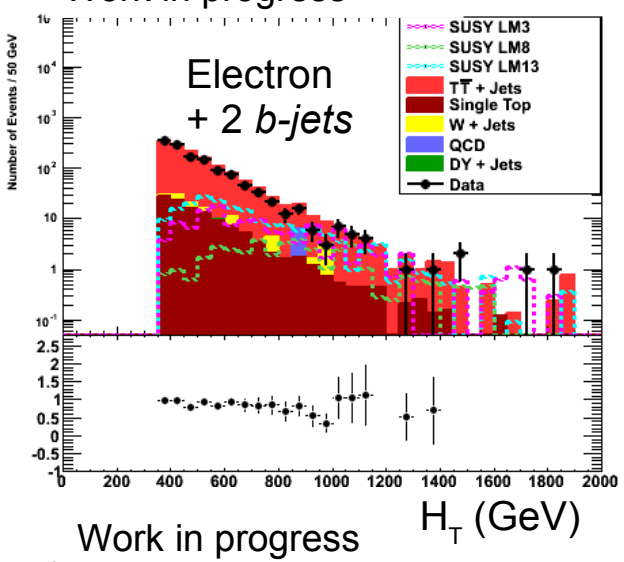
Backup

Results for 4.2 fb^{-1}: H_T

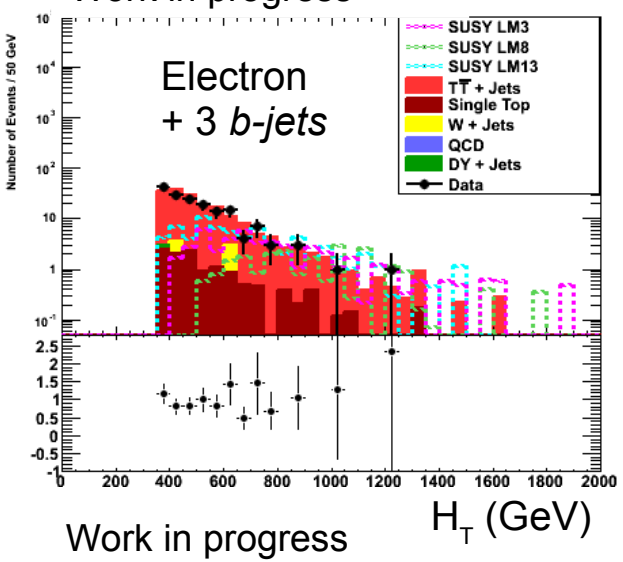
Work in progress



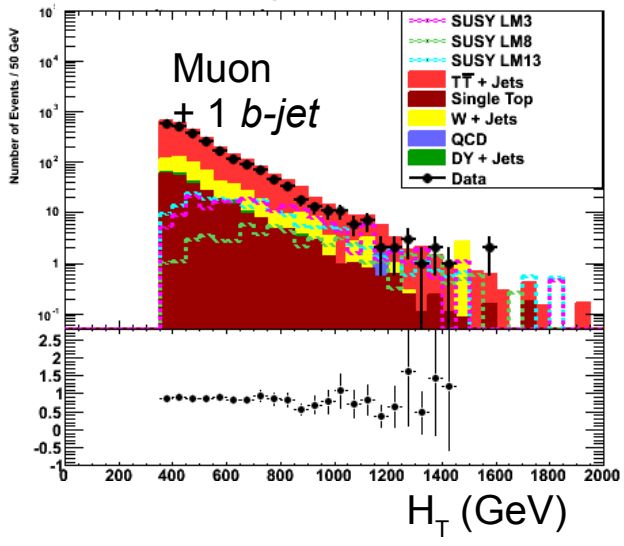
Work in progress



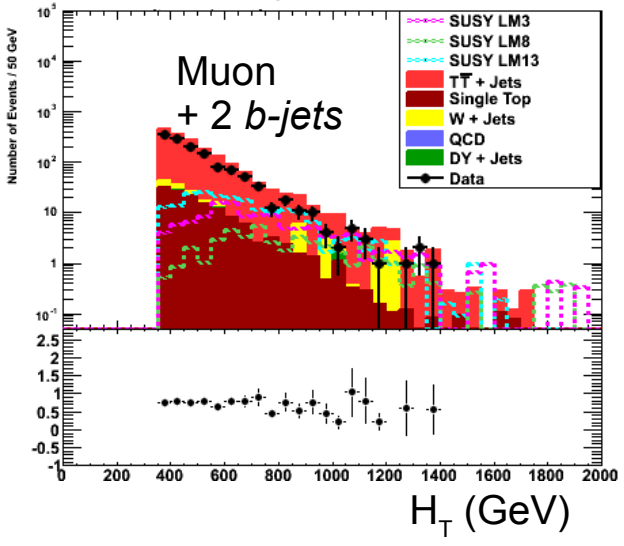
Work in progress



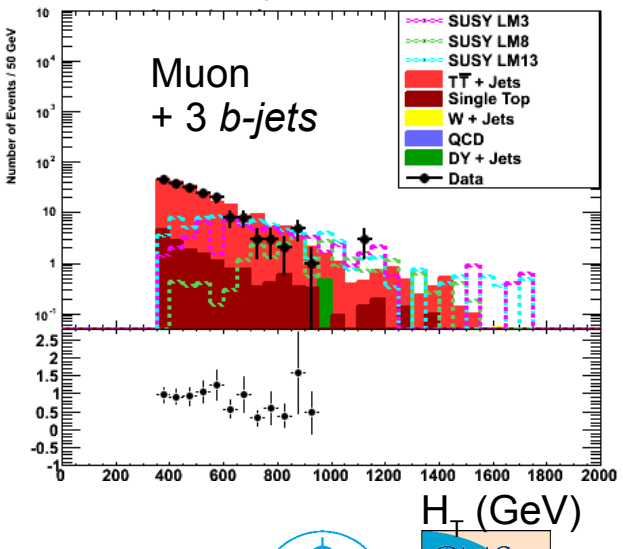
Work in progress



Work in progress

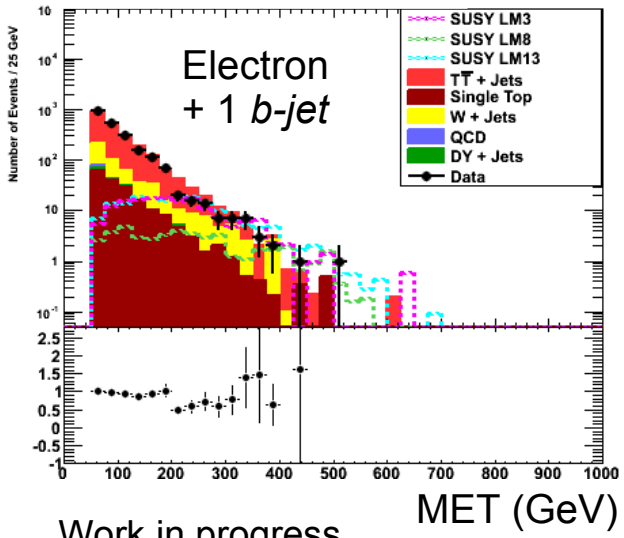


Work in progress

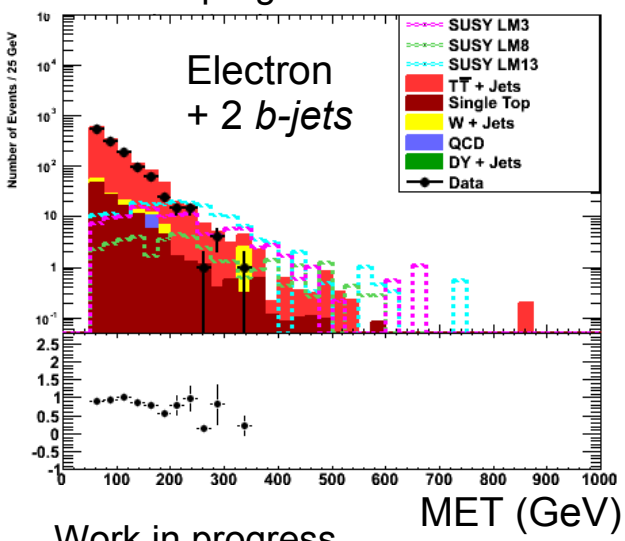


Results for 4.2 fb^{-1}: Missing Transverse Energy

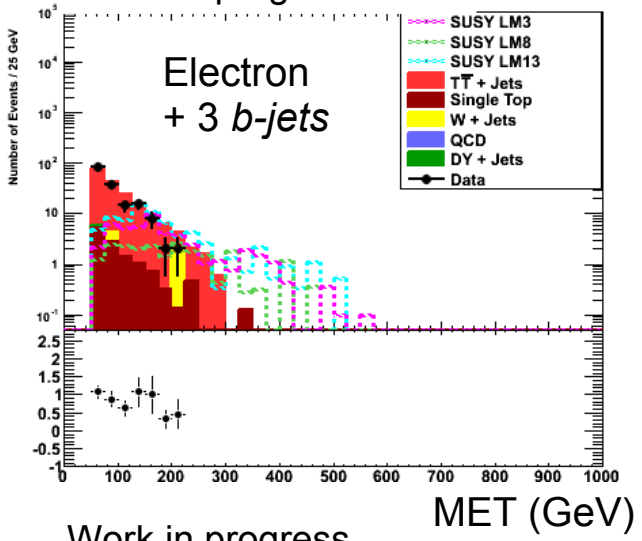
Work in progress



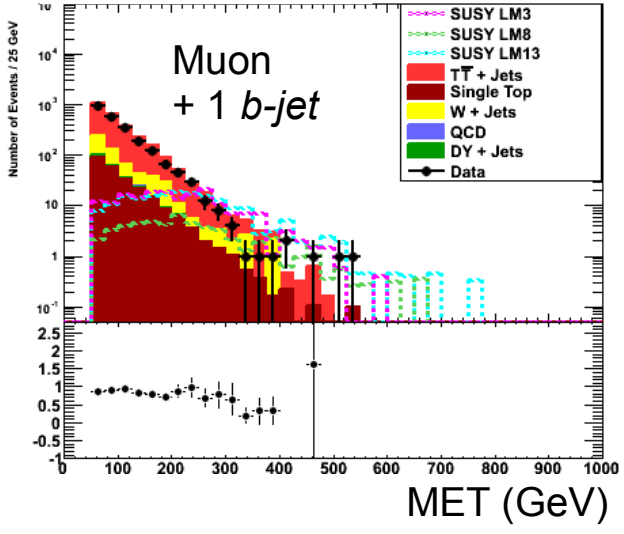
Work in progress



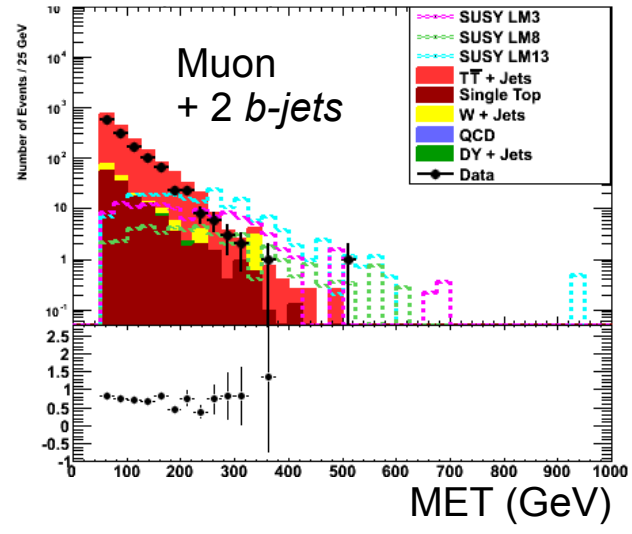
Work in progress



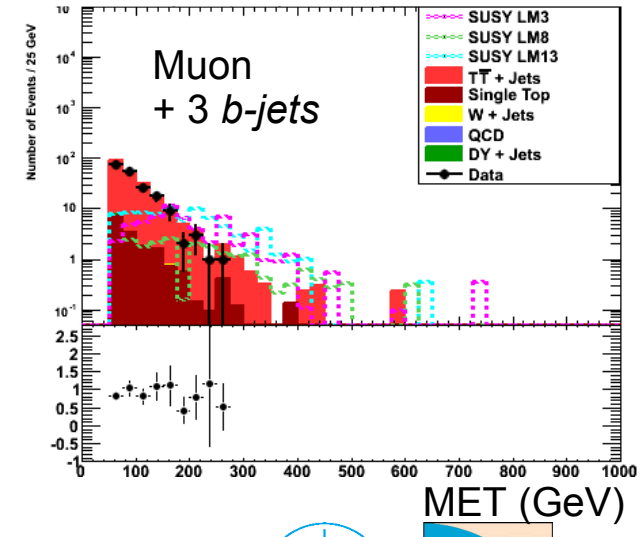
Work in progress



Work in progress

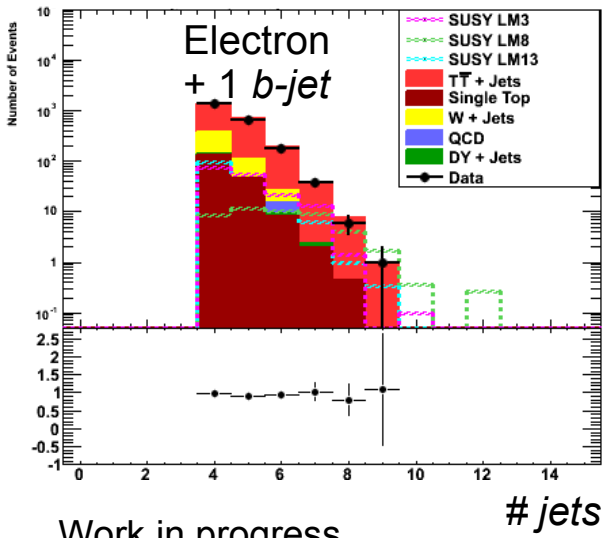


Work in progress

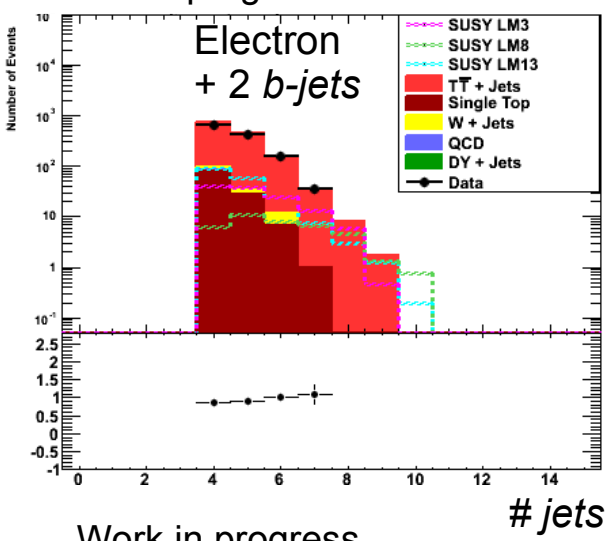


Results for 4.2 fb^{-1}: Jet Multiplicity

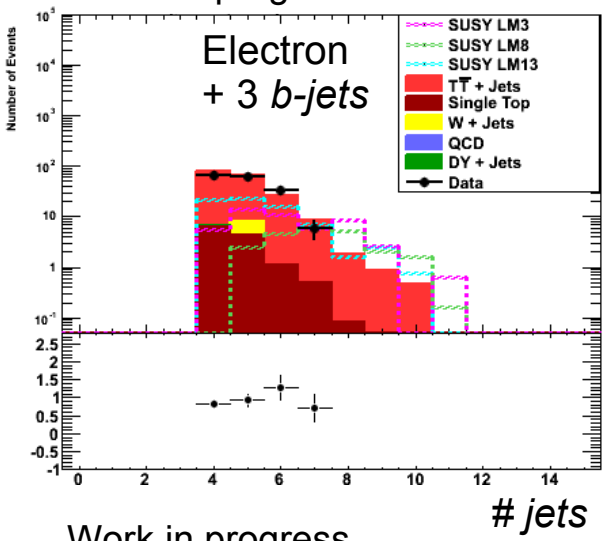
Work in progress



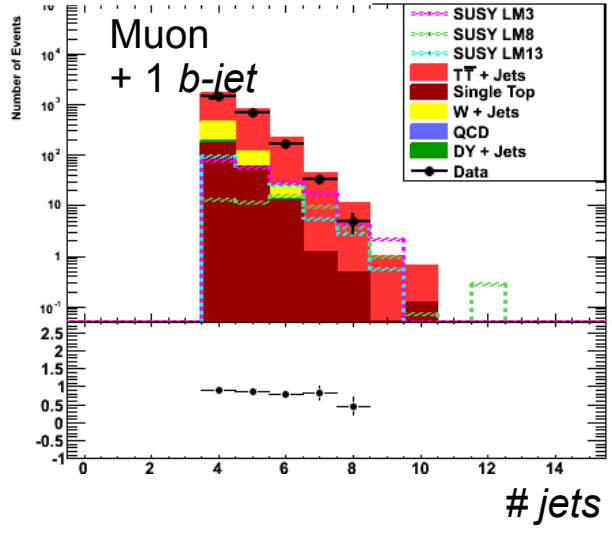
Work in progress



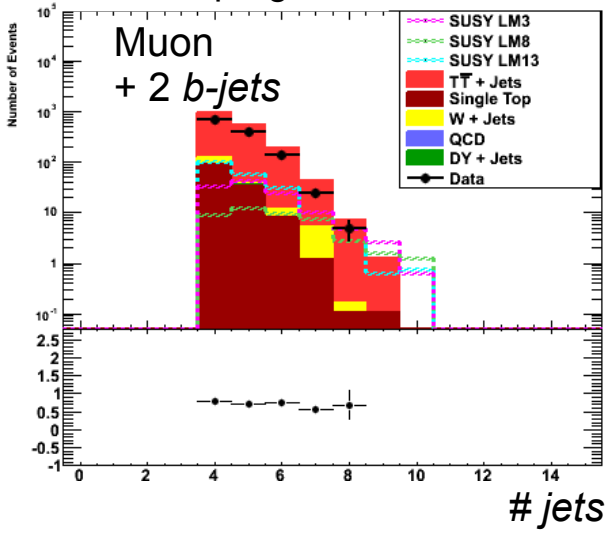
Work in progress



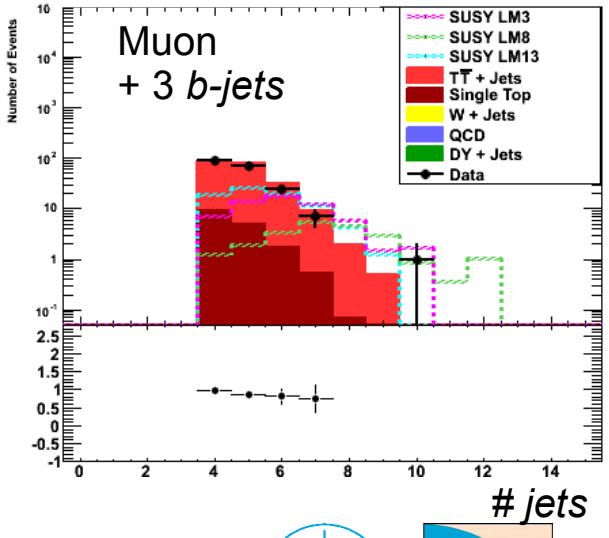
Work in progress



Work in progress



Work in progress



b-tagging Efficiency and Mistag Rate

CMS Collaboration, "Performance of the b-jet identification in CMS",
CMS-PAS-BTV-11-001