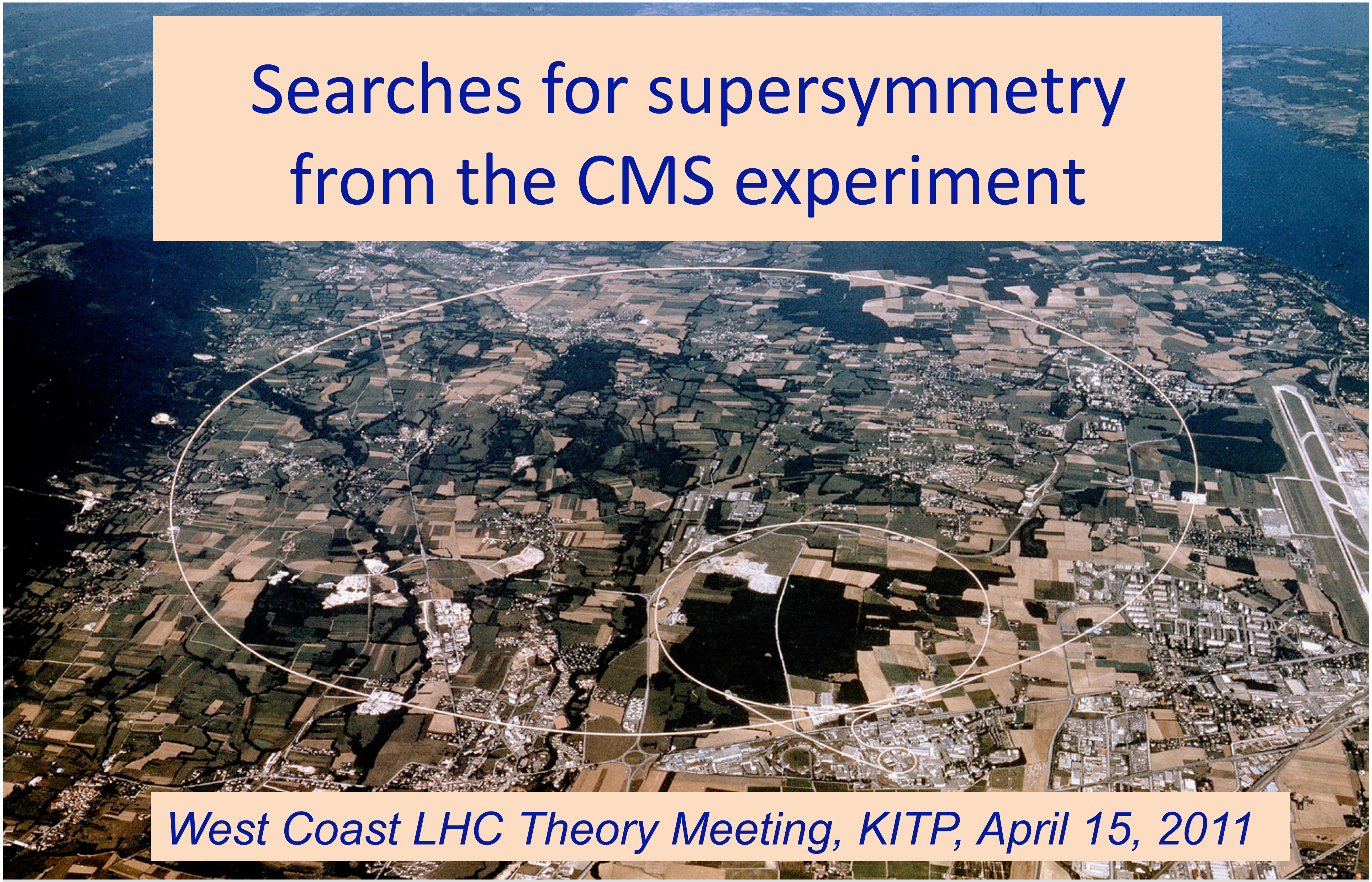
Searches for supersymmetry from the CMS experiment



West Coast LHC Theory Meeting, KITP, April 15, 2011

Jeffrey D. Richman
Department of Physics
University of California, Santa Barbara

Outline

- Perspective, Strategy, and Signatures
- Overview of SM backgrounds; comments on methods
- Hadronic searches: Jets + MET
- Leptonic searches: Jets + MET + lepton(s)
- Searches with photons
- Conclusions

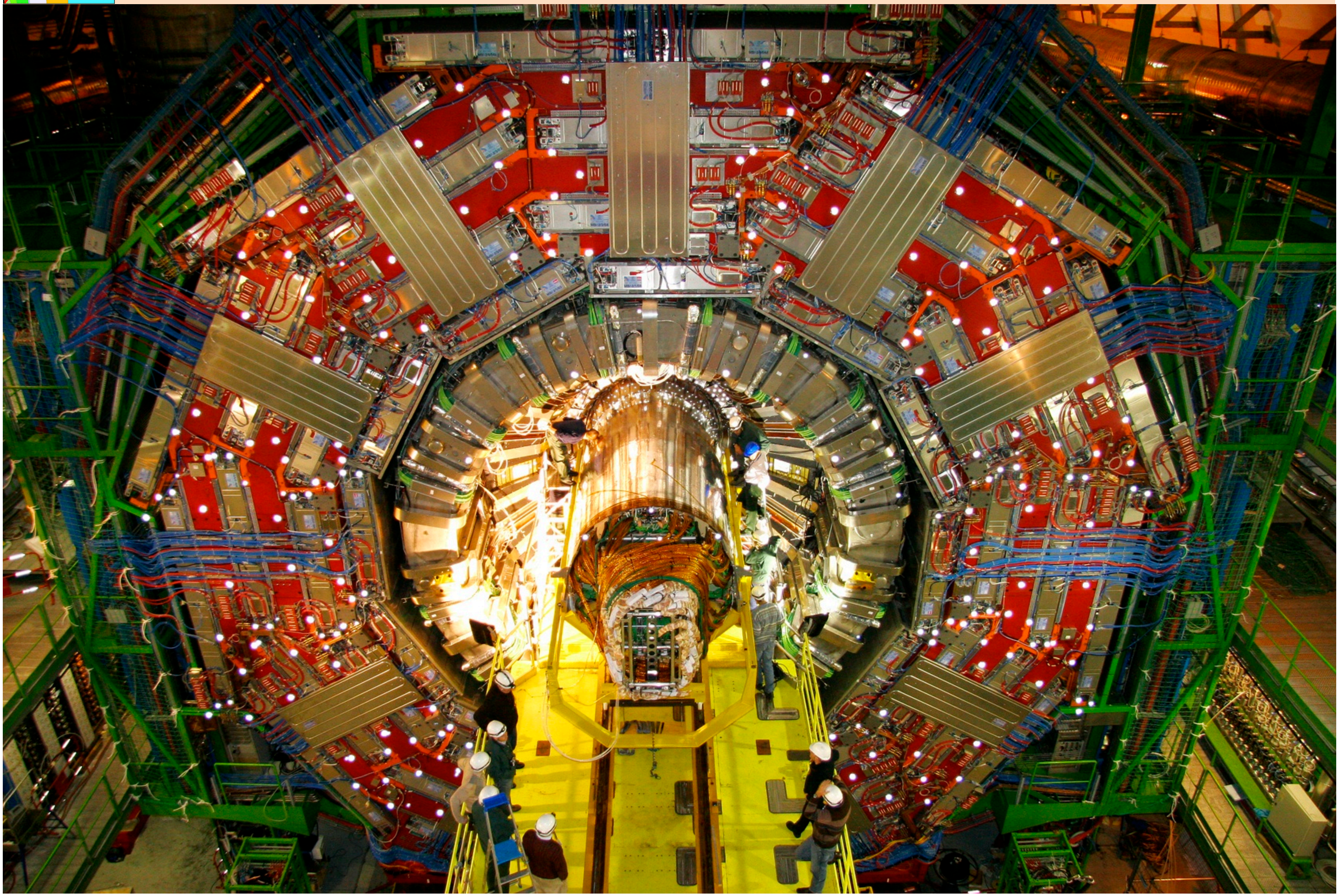
Not covering “exotic” models, e.g., stopped-gluino search:
http://arxiv.org/abs/1011.5861 PRL 106, 011801 (2011)

All public CMS physics results available from
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

Experimentalists vs. Theorists

- Theorists ask…
  - How will we know if the New Physics is SUSY?
  - How will we determine the mass scale…and then the full spectrum?
  - How will we determine the underlying Lagrangian?
- Experimentalists think about the truly fundamental questions.
  - Is there a leak? Will the trigger really work?
  - How much calorimeter noise is there?
  - How can we be sure that an excess of events is not just due to tails of distributions from SM processes?

CMS Silicon Tracker Installation: Dec 2007



Collisions at 7 TeV

http://cdsweb.cern.ch/journal/CERNBulletin/2010/14/News%20Articles/1246424?ln=fr

http://press.web.cern.ch/press/PressReleases/Releases2010/PR07.10E.html

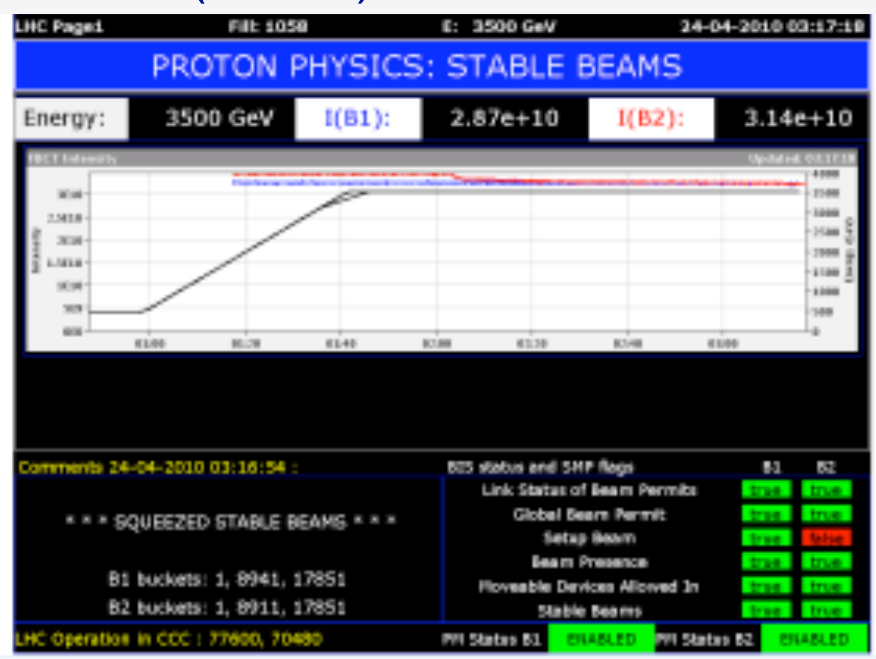
Nous avons réussi !

Presque 20 années de travail acharné accompli par des centaines de personnes ont permis au Grand collisionneur de hadrons (LHC) de passer du rêve à la réalité. Le LHC a livré aujourd'hui

March 30, 2010: 1st 7 TeV Collisions

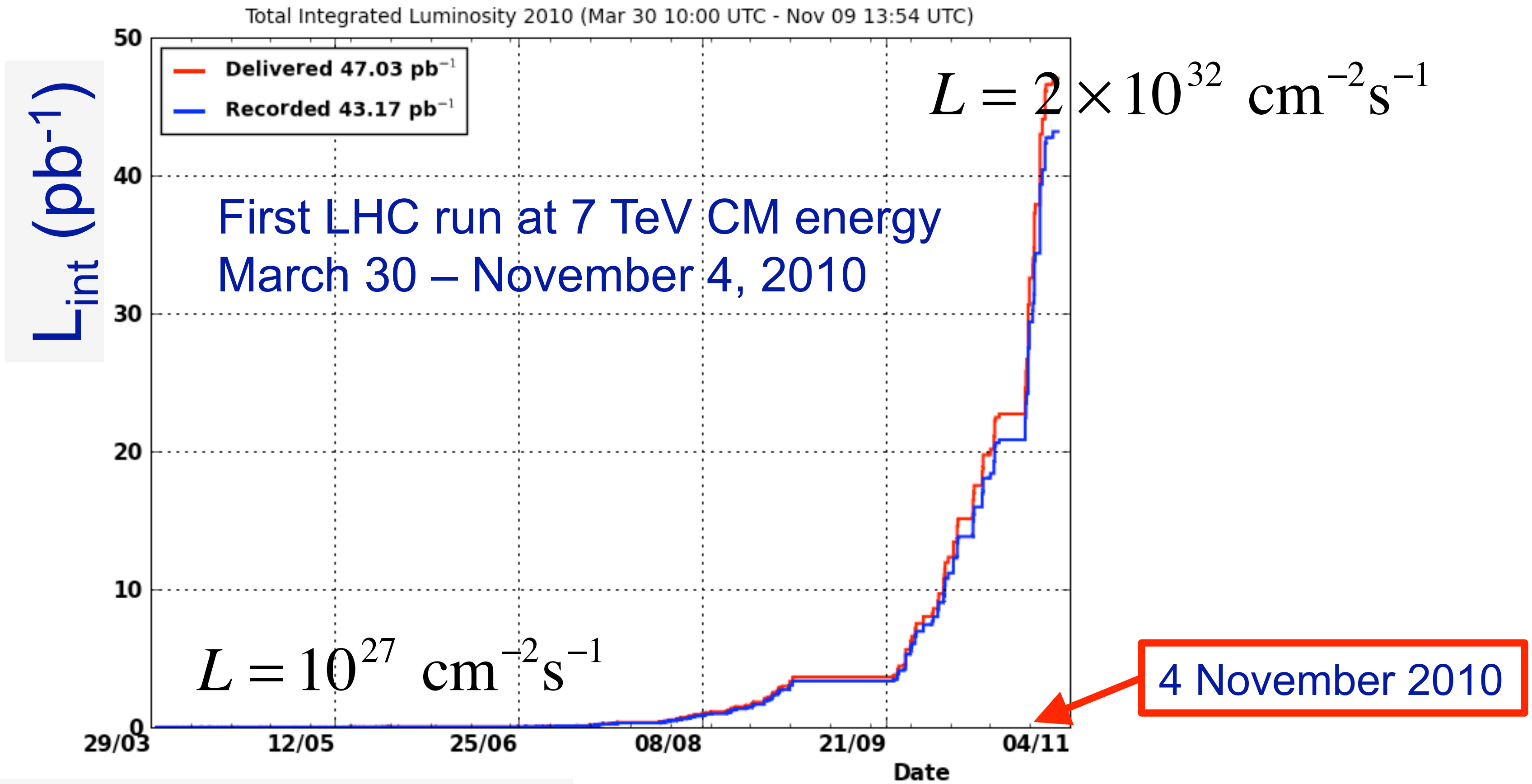
Il y a quelques instants à la CCC

May 1-2, 2010, squeezed, stable beams (30 hrs), $L>1.1\times 10^{28}\ cm^{-2}s^{-1}$



http://cdsweb.cern.ch/journal/CERNBulletin/2010/18/News%20Articles/1262593?ln=en

CMS Integrated Luminosity vs. Time

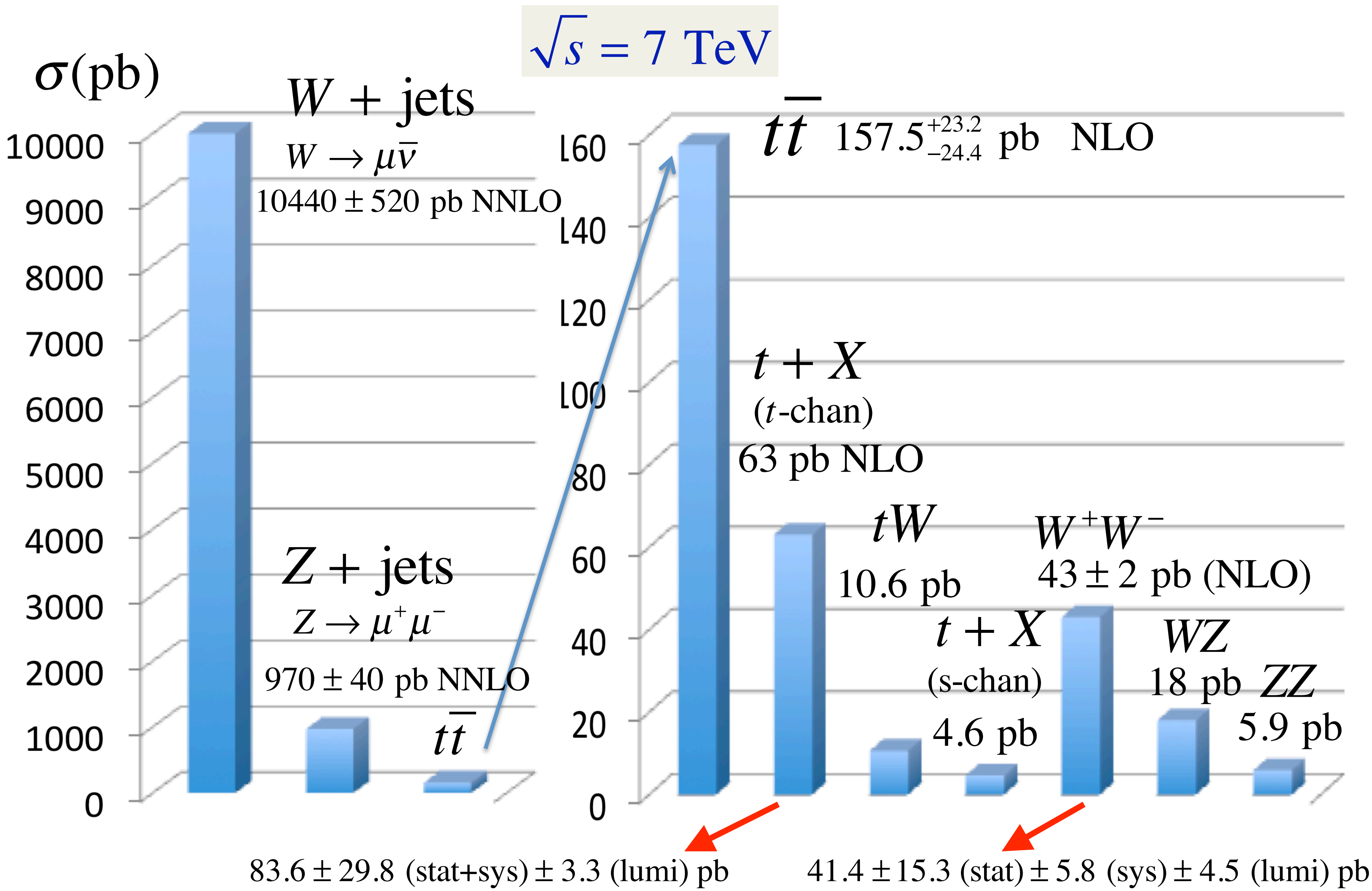


36 pb^{-1} validated high quality

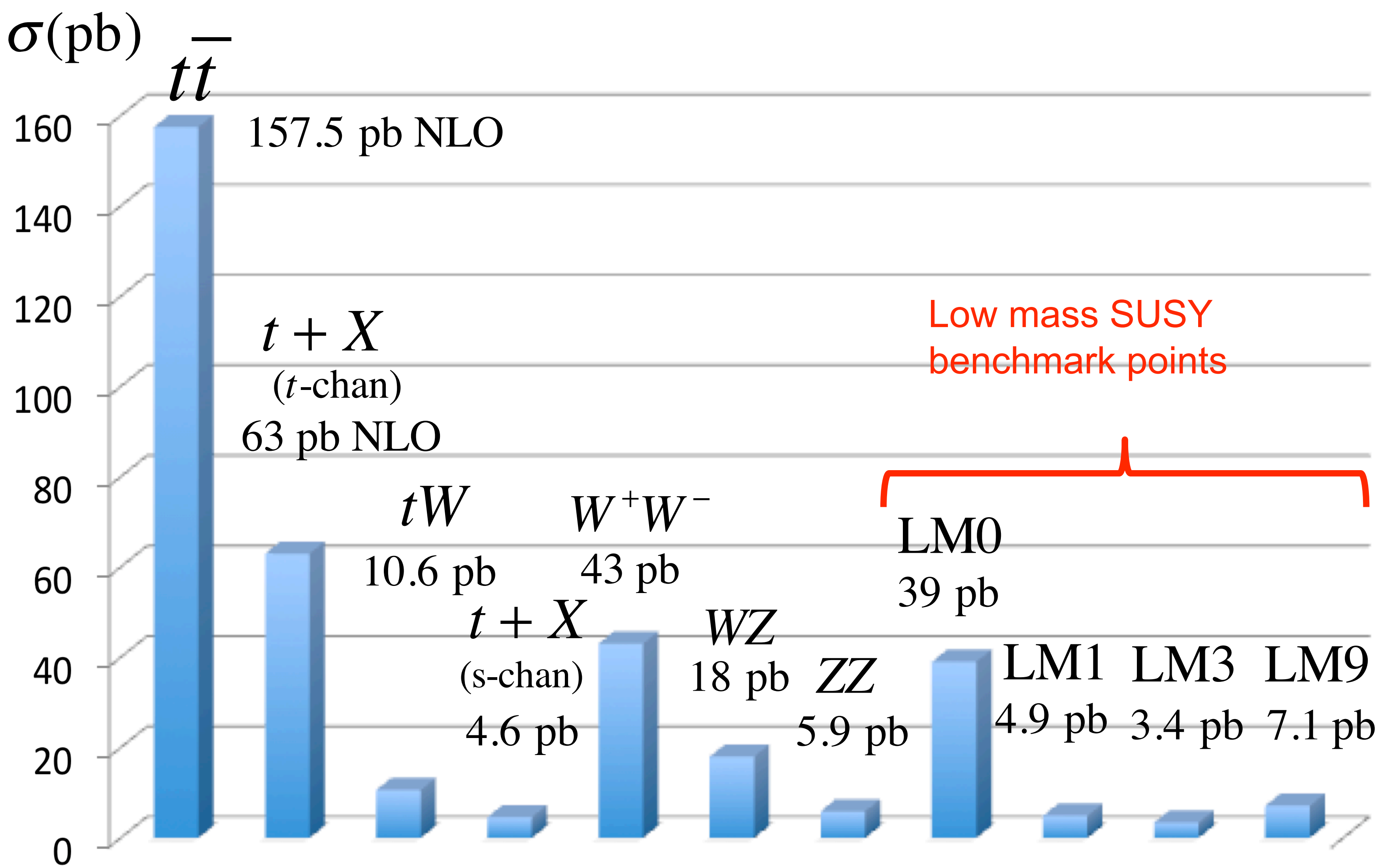
In some low mass SUSY model, the cross section is 40 pb; we would then have

$$N_{events} = 36\ \text{pb}^{-1} \cdot 40\ \text{pb} \simeq\ 1400 \quad \text{(produced)}$$

Cross Sections for Key SM Processes



Cross Sections for SM vs. low-mass SUSY benchmark points



CMS SUSY signatures & searches

Jets + MET	1 lepton + jets + MET	2 leptons: opp. sign + MET	2 leptons same sign	≥3 leptons	2 photons + MET	1 photon + 1 lepton+ MET

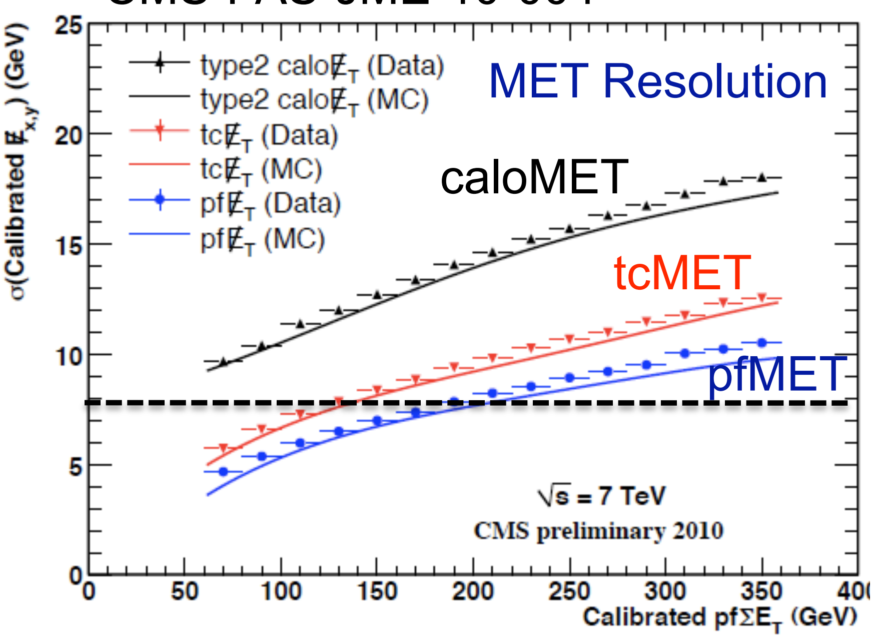
- Strong emphasis on data-driven background determination.
  - No narrow peaks: extreme tails of kinematic distribs.
  - Control samples in data → background
  - Is the control sample (SM + X) understood?
- Not simple; may rely on assumptions.
  - test extensively with MC samples
  - use multiple data-driven methods as crosschecks
  - critical for discovery

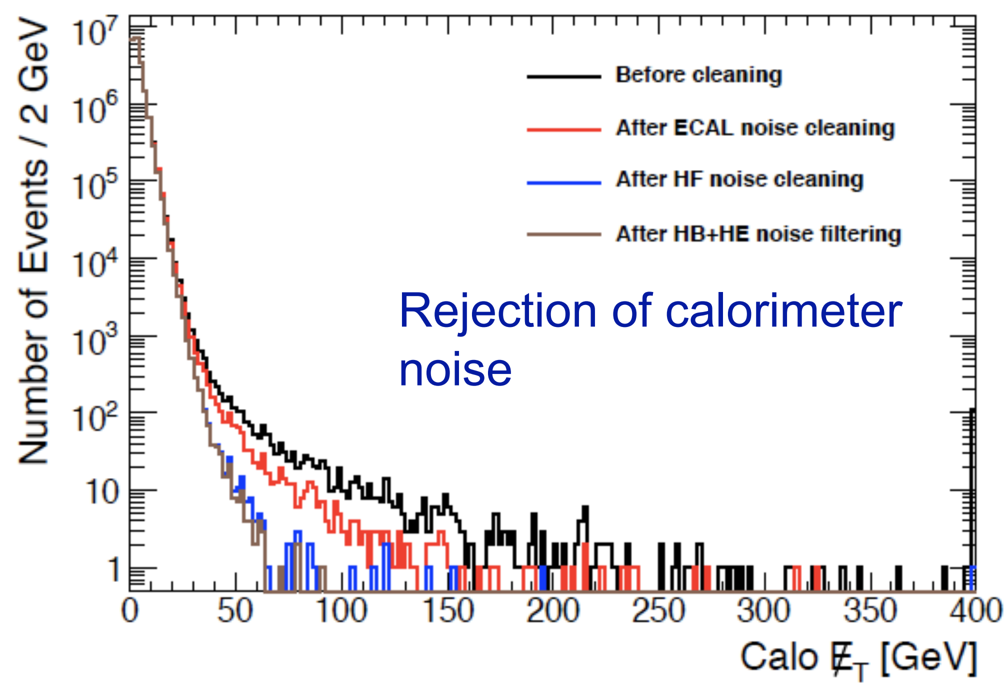
MET, MHT, and HT

- MET: reconstructed from calorimeter towers (ECAL+HCAL)
- MHT: reconstructed from jets above a threshold
- Jet threshold: 20 GeV – 50 GeV

$$\text{caloMET} = -\sum_{\text{CALO towers } i} \vec{\boldsymbol{p}}_T^{\,i} \qquad \text{MHT} = -\sum_{\text{jets } j} \vec{\boldsymbol{p}}_T^{\,j} \qquad \text{HT} = \sum_{\text{jets } j} \left| \vec{\boldsymbol{p}}_T^{\,j} \right|$$

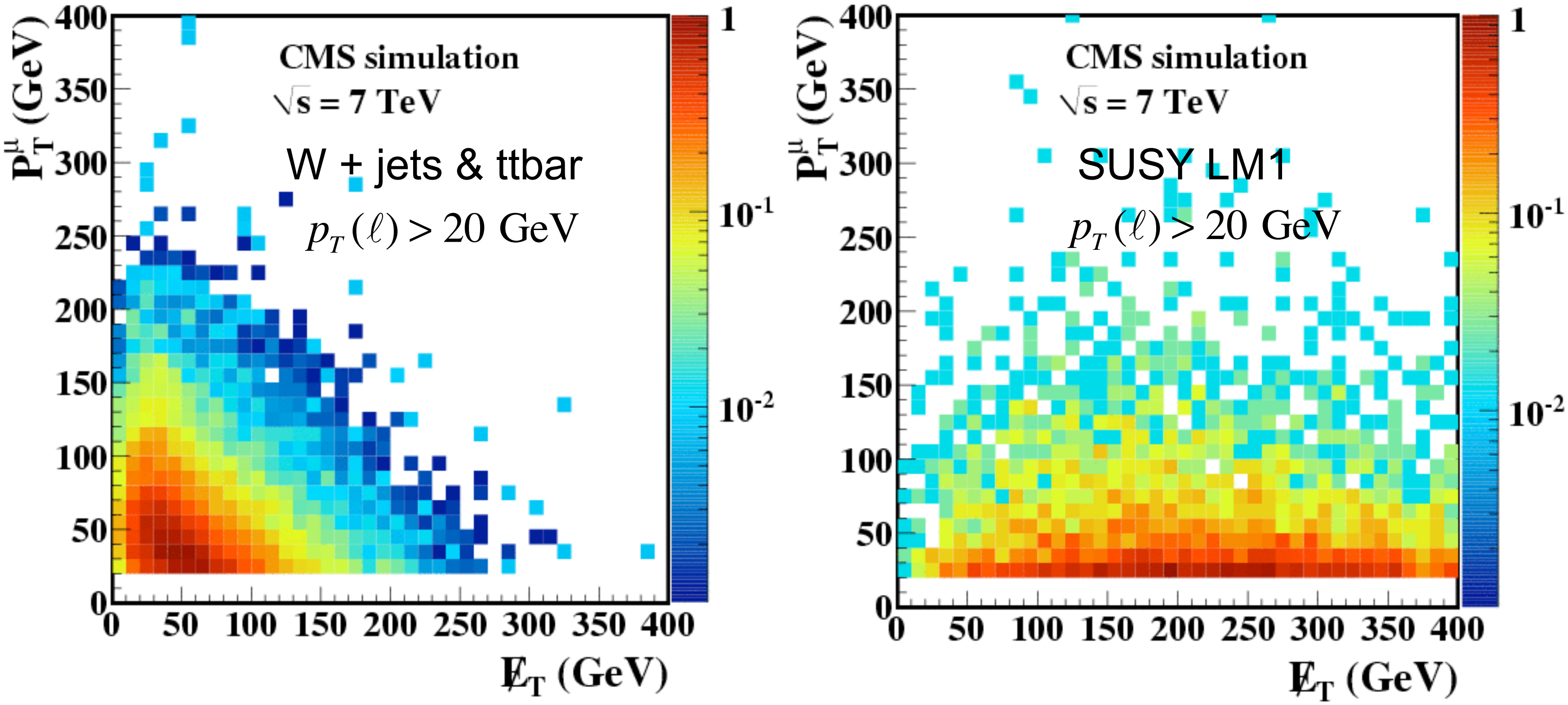
CMS-PAS-JME-10-004





MET ($\not{E}_T$) in the SM and SUSY

- Real MET: LSP, W + jets, ttbar events with high pT neutrino
- MET can also arise from jet mismeas., heavy-quark decay
- Large MET in W + jets, ttbar events is usually real
- Typical: MET>100 GeV ("loose") or MET>200 GeV ("tight")



Overview of SM backgrounds

Background	Comments	Hadronic searches	Leptonic searches
QCD multijets	• Largest cross section • Kinematics not well understood • Data-driven methods required. • Reduced by Njets>2,>3, HT, MET, jet threshold cut, Δϕ(MET,jet)	After cuts, usually not the largest background, but it's the one that keeps you awake at night. Data-driven methods challenging but essential to quantify jet-mismeas.	Lepton isolation provides powerful rejection and effective way to estimate background from b →lepton or "jets faking leptons"
W + jets, Z/Drell Yan +jets	• Large cross sections; can produce real MET • High pT W with W→τυ	Background from τ, lost leptons, or leptons below veto threshold $Z \to \nu\bar{\nu}$ + jets (irreducible)	• W+jets impt in 1 lep • Z+ jets impt in Z +MET • Fall rapidly w/ n jets
ttbar ↑ Data driven	Almost like SUSY	Lost lepton backgrounds	Dominant background
Other electroweak: single top, WW, ZZ,...	So far not a problem; sub-sub dominant Rely on MC to show is (usually) negligible.	not a problem for now	not a problem for now

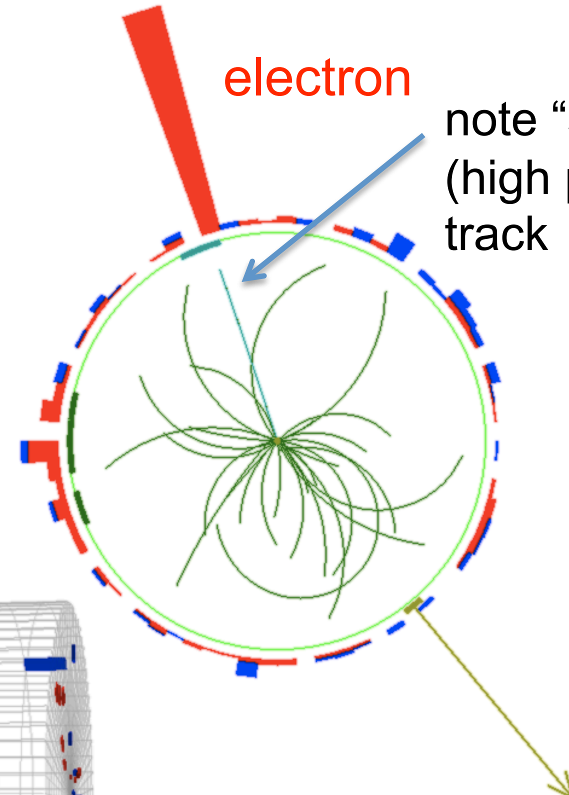
W boson decaying to electron + neutrino

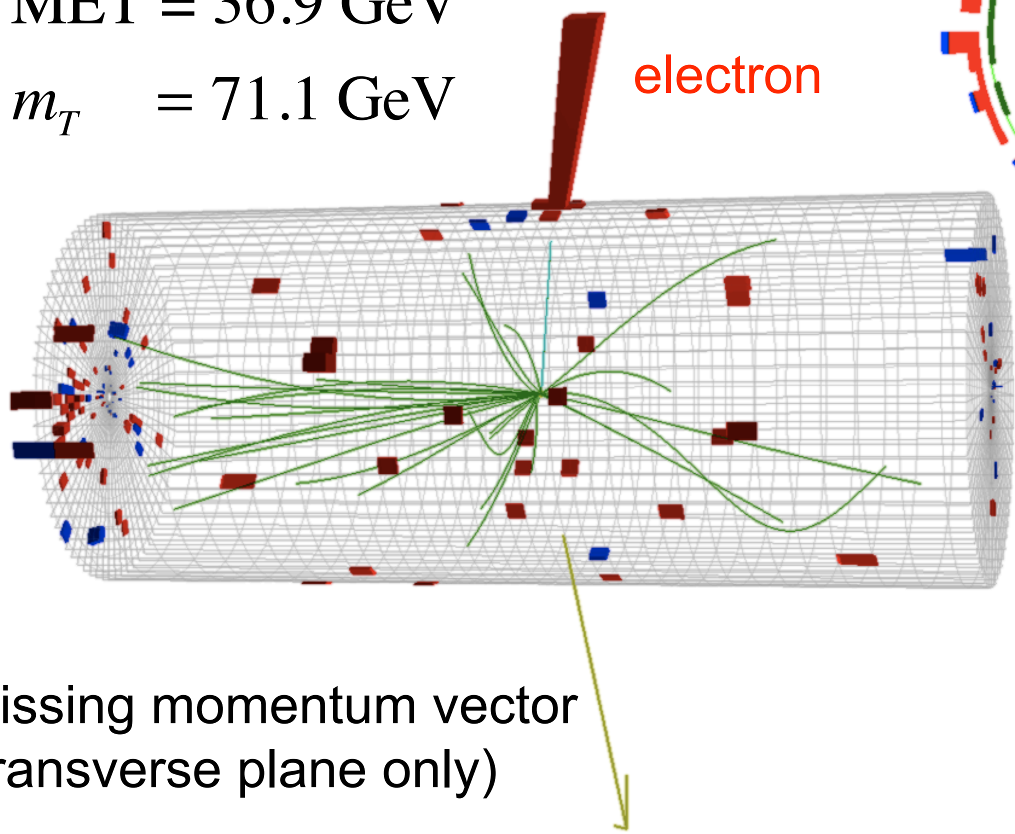
CMS Experiment at LHC, CERN
Run 133874, Event 21466935
Lumi section: 301
Sat Apr 24 2010, 05:19:21 CEST

$p_T(e) = 35.6$ GeV

MET = 36.9 GeV

$m_T \quad = 71.1$ GeV

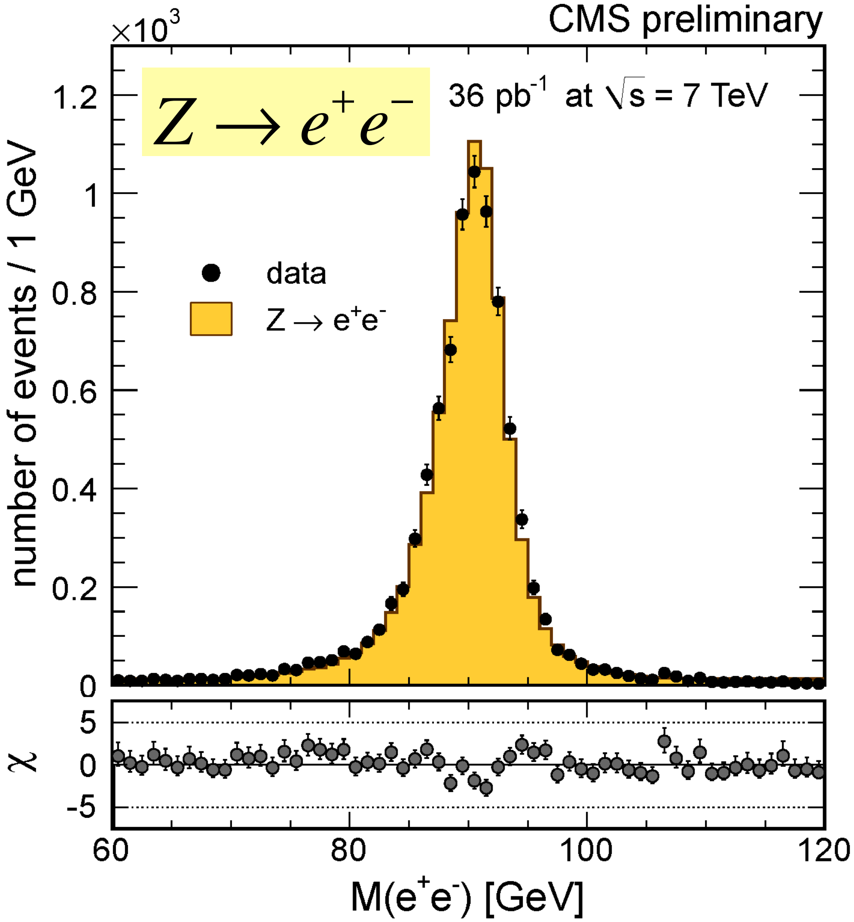


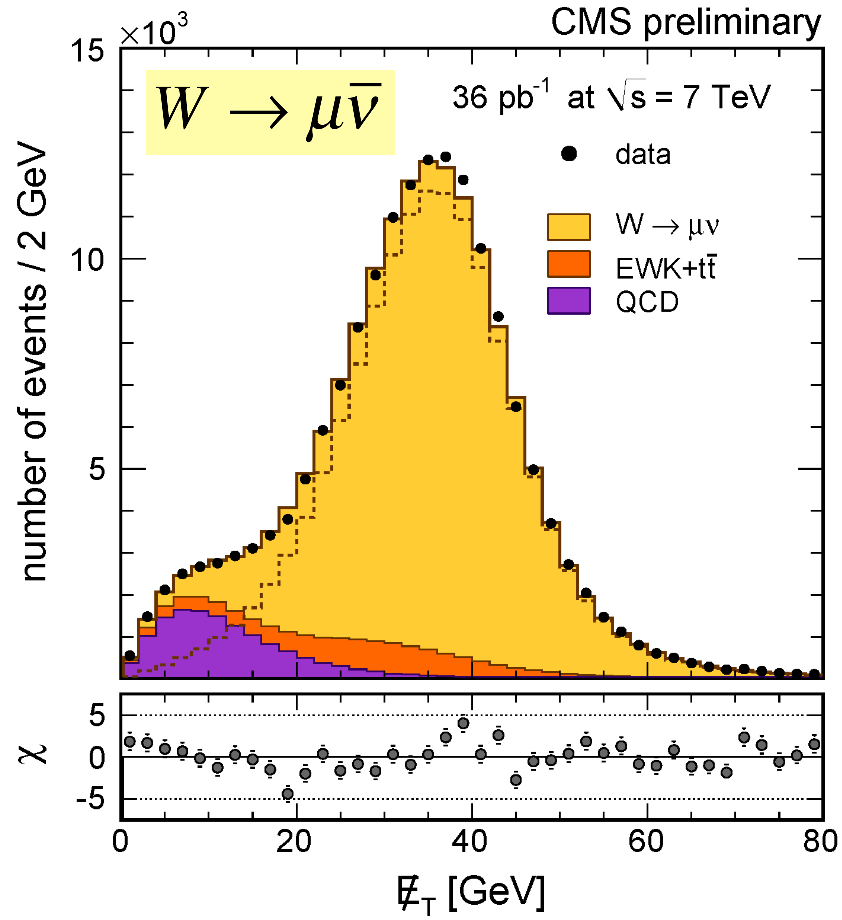


Missing momentum vector
(transverse plane only)

Measurement of the W, Z cross sections

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults



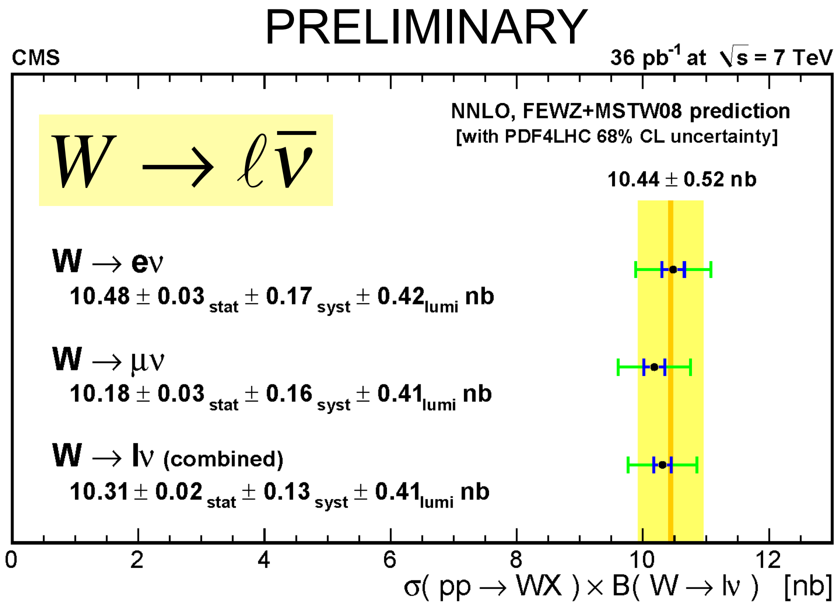


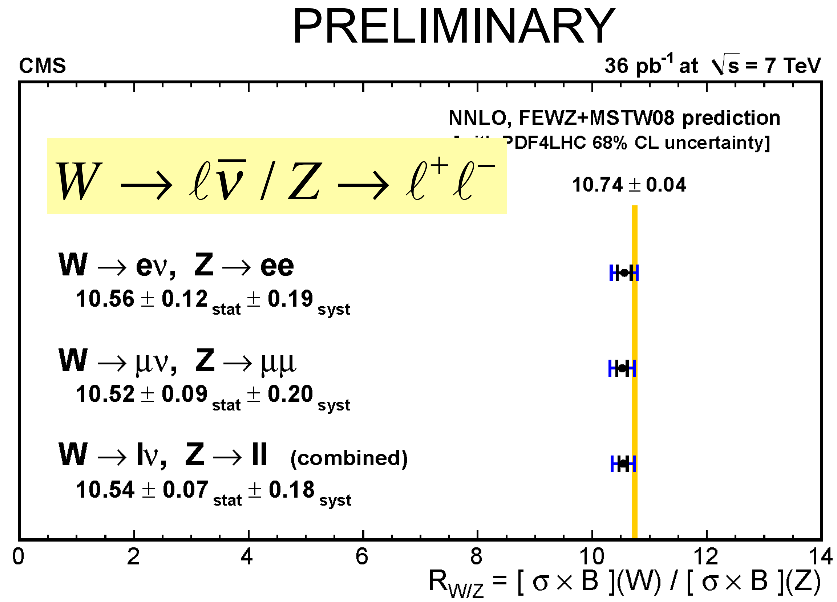
$$N_{tot}(e^+e^-) = 8442; \quad N_{back}(e^+e^-) = 36 \pm 12$$

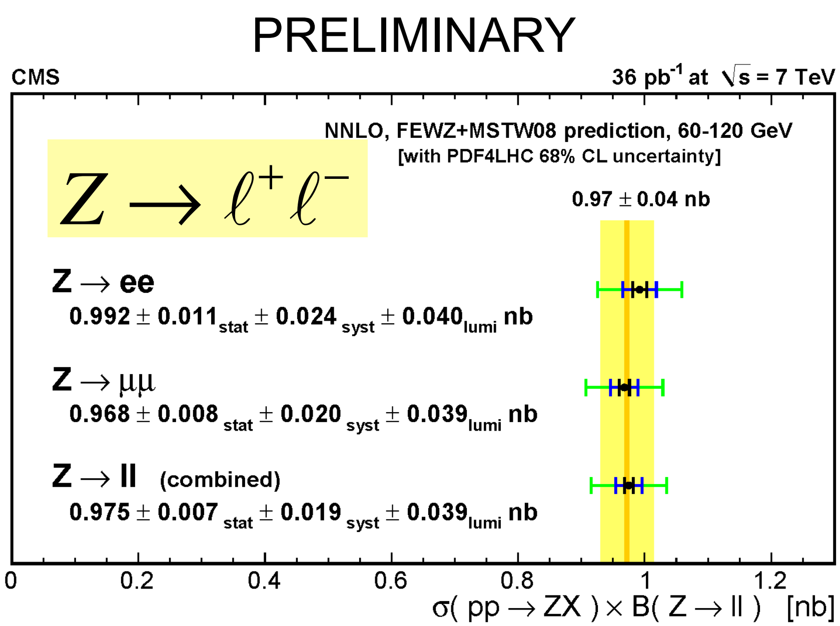
$$N_{tot}(W^+ \to \mu^+\nu_\mu) = 84,292 \pm 292$$

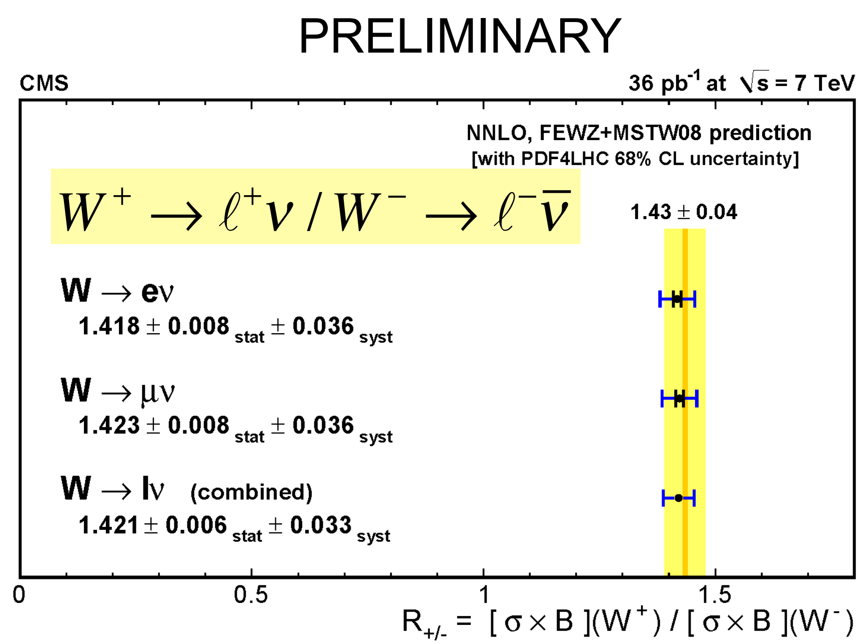
$$N_{tot}(W^- \to \mu^-\bar{\nu}_\mu) = 56,818 \pm 240$$

Measurement of W, Z boson cross sections in CMS

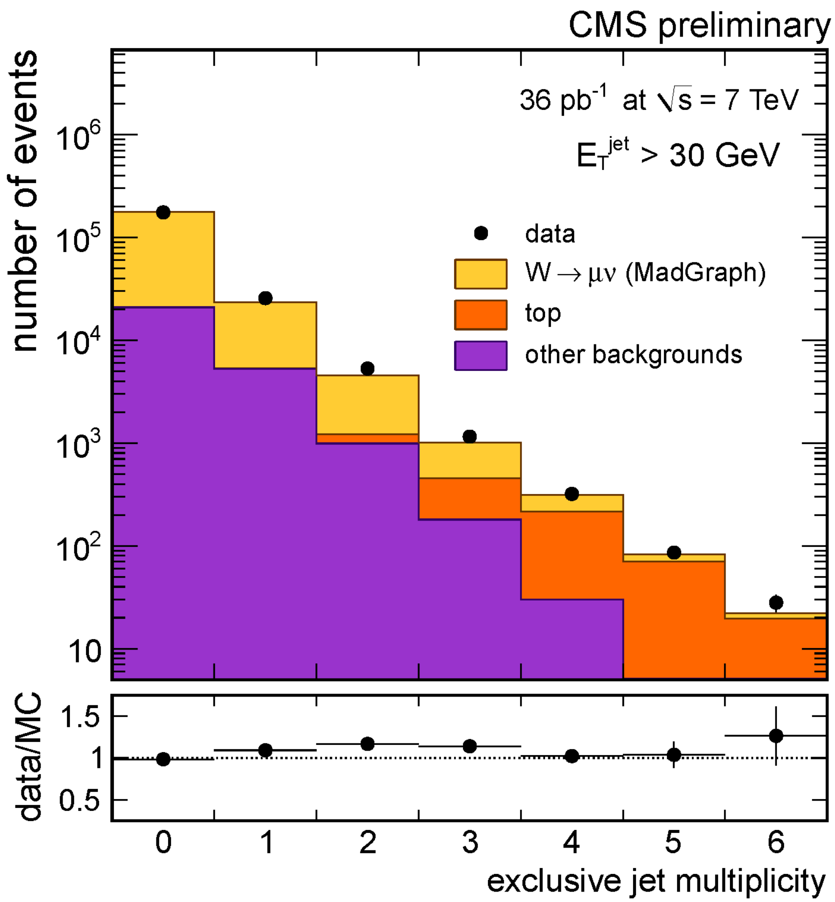


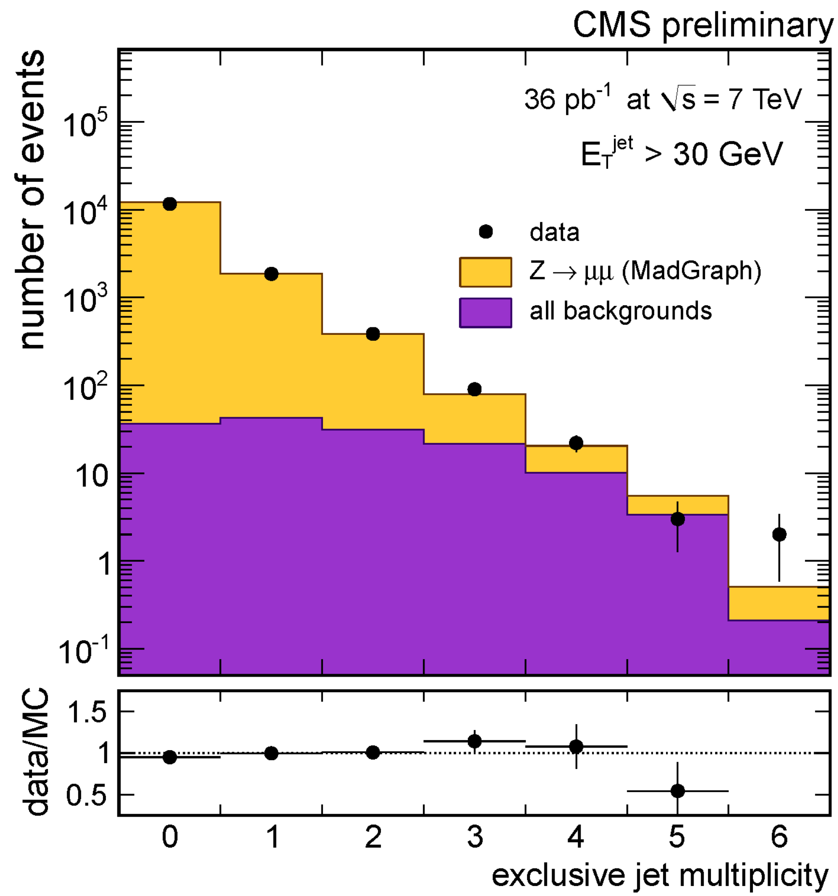




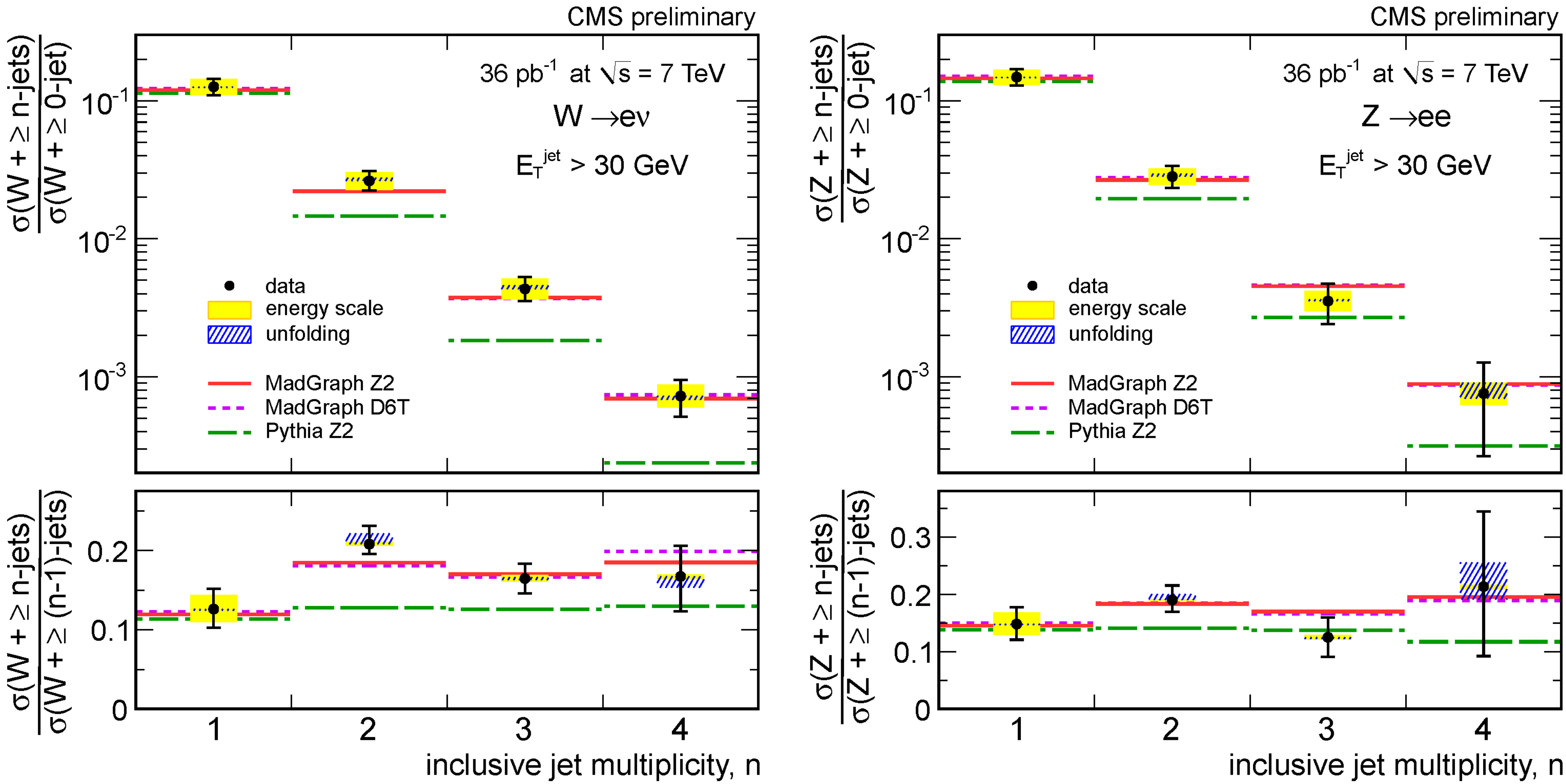


N(jets) in W + jets, Z + jets (E_T>30 GeV)

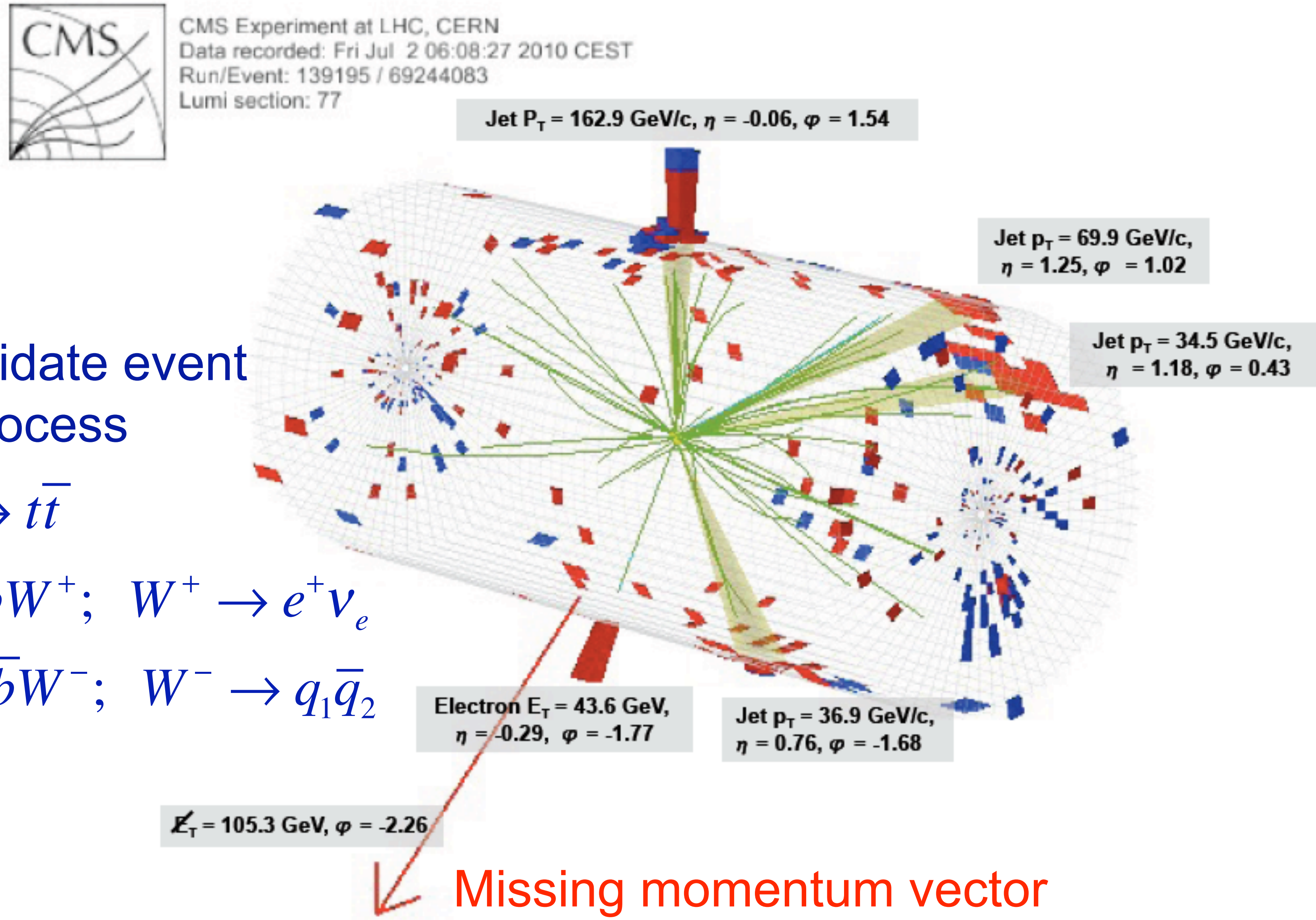




W, Z: number of jets (E_T>30 GeV)



Observation of $pp \rightarrow t\bar{t}$



Candidate event for process

$$pp \rightarrow t\bar{t}$$

$$t \rightarrow bW^+; \;\; W^+ \rightarrow e^+\nu_e$$

$$\bar{t} \rightarrow \bar{b}W^-; \;\; W^- \rightarrow q_1\bar{q}_2$$

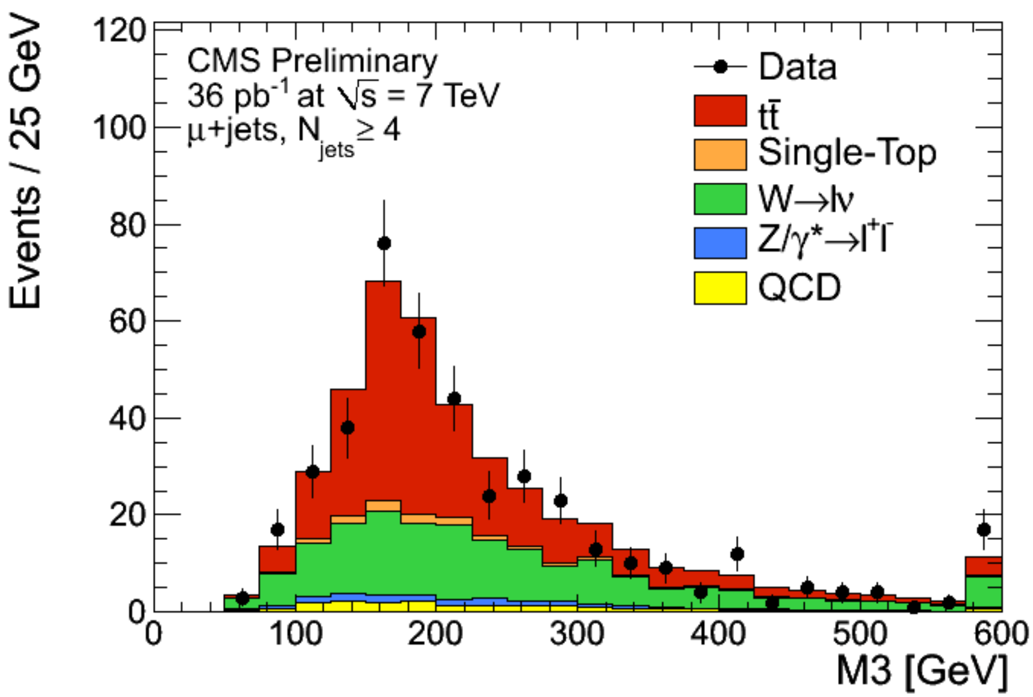
Missing momentum vector from neutrino

Signals for $t\bar{t}$ production

Single-lepton channel

$$t \to bW^+;\quad W^+ \to \mu^+\nu_\mu$$

$$\bar{t} \to \bar{b}W^-;\quad W^- \to q_1\bar{q}_2$$

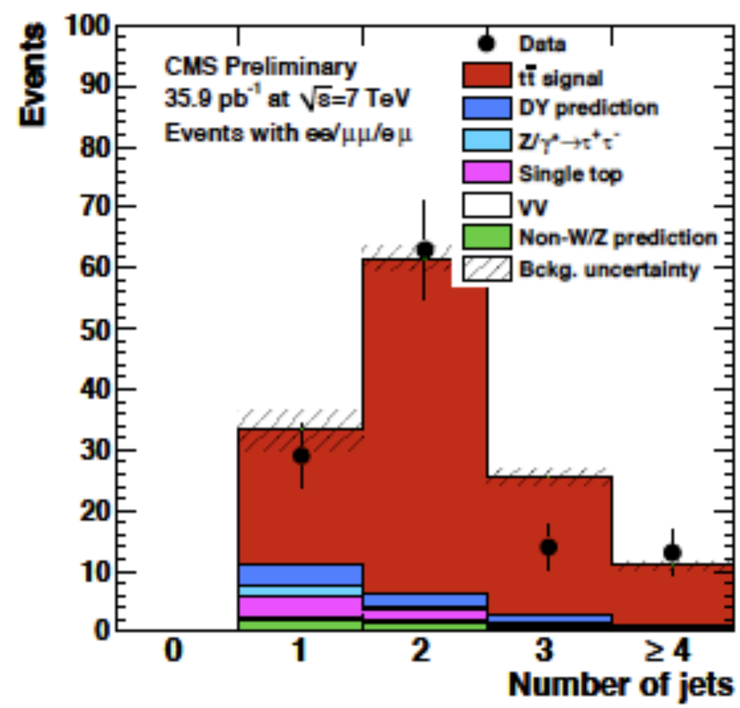


Di-lepton channel

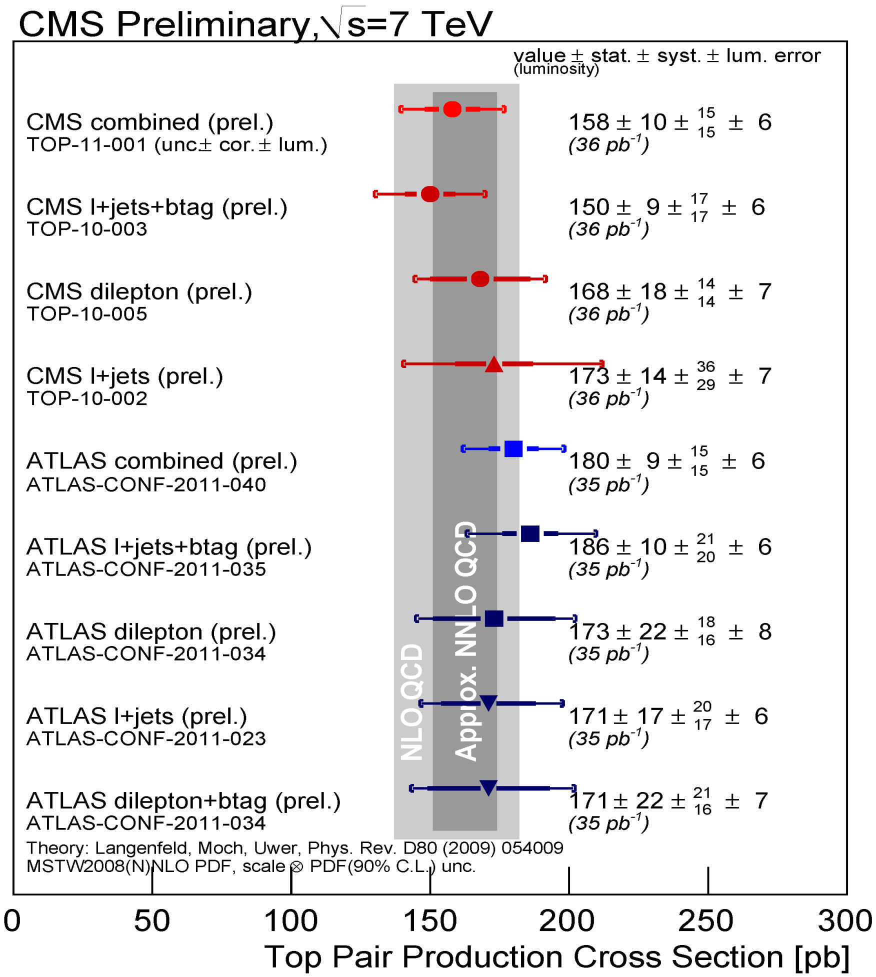
$$t \to bW^+;\quad W^+ \to \ell^+\nu_\ell$$

$$\bar{t} \to \bar{b}W^-;\quad W^- \to \ell^-\bar{\nu}_\ell$$

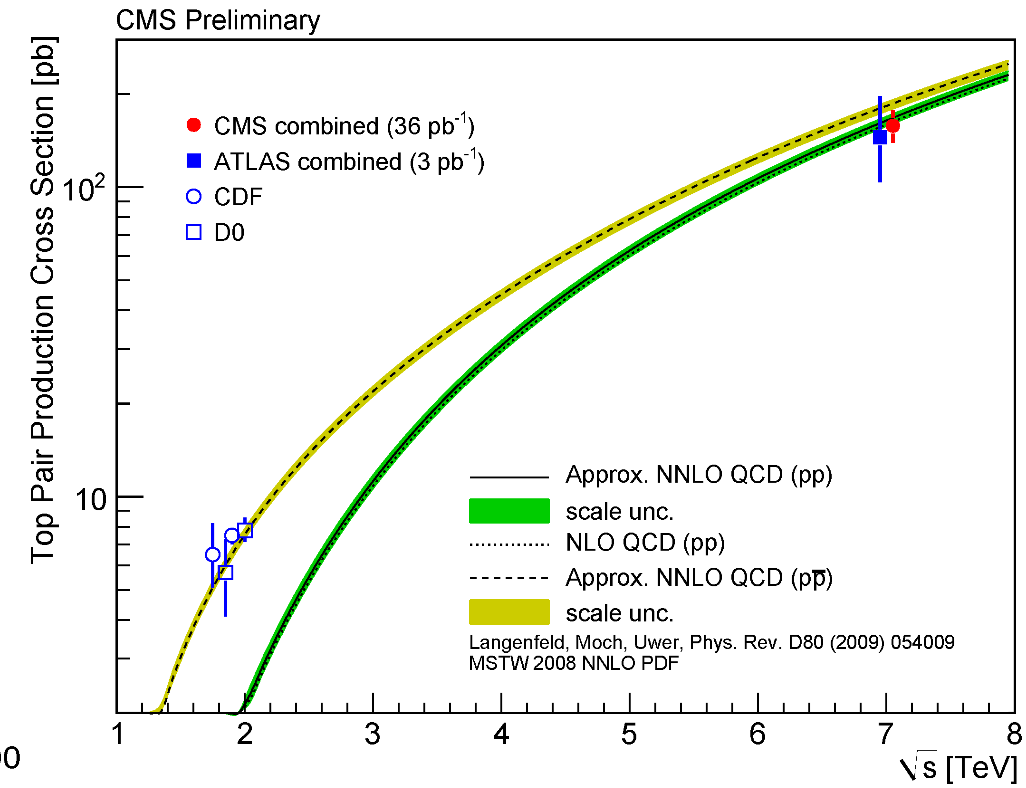
at least 1 b-tagged jet required



Summary of $t\bar{t}$ cross section results



LHC (pp) vs. Tevatron ($p\bar{p}$)



$t\bar{t}$ cross section results are in good agreement with Standard Model prediction.

Tradeoffs in background determinations

- A difficulty with data-driven methods: how well is composition of control sample understood?
- Tradeoff with tighter selection cuts:
  - search becomes less general
  - background methods become more reliable
- Sometimes need dedicated method for a distinct part of phase space, e.g., dijets + MET.
- Theoretical understanding of SM processes is extremely valuable and could play a key part in a discovery.

Understanding W polarization in ttbar

Helicity fractions of W bosons from top quark decays at NNLO in QCD

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(Dated: May 18, 2010)

Decay rates of unpolarized top quarks into longitudinally and transversally polarized W bosons are calculated to second order in the strong coupling constant α_s. Including the finite bottom quark mass and electroweak effects, the Standard Model predictions for the W boson helicity fractions are $\mathcal{F}_L = 0.687(5)$, $\mathcal{F}_+ = 0.0017(1)$, and $\mathcal{F}_- = 0.311(5)$.

The uncertainties associated with this aspect of ttbar are essentially negligible. This is extremely helpful.

Issues with uncertainties

- Quantifying the uncertainties is the foundation of the measurement.
- If the systematic uncertainties are comparable to the statistical uncertainties, it can be very difficult to understand the meaning of "5σ", which corresponds to a probability of $\approx 10^{-7}$.
- Many systematic errors are rough estimates and do not have a well-defined probability content.
- If a relative systematic error is large (e.g., on QCD), it is often best to cut tightly so impact is small.
- Sometimes a data-driven method allows one to convert a systematic error into a statistical error. This is good!

Hadronic Searches (Jets + MET)

Jets + MET	1 lepton + jets + MET	2 leptons: opp. sign + MET	2 leptons same sign	≥3 leptons	2 photons + MET	1 photon + 1 lepton+ MET

Jets + MET

α_T Method
includes dijet seach

Generic
search (MHT)

Razor variable
analysis

α_T + b-tags

Hadronic search with α_T

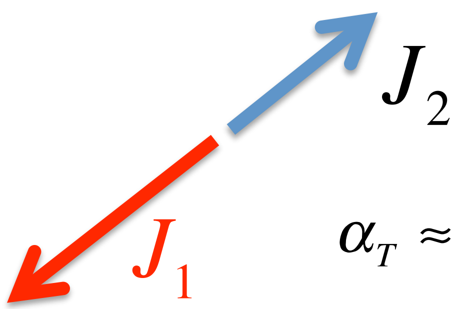
http://arxiv.org/abs/1101.1628

Trigger	Indiv. jet req.	Jets	Leading jet	Vetos (event vetoed if...)	HT & MHT	α_T
$HT^{trigger}$>150 GeV at HLT	ET>50, |η|<3	≥2 jets, ET>100 GeV	|η| <2.5, ET>100	isolated photon (pT>25) isolated leptons (pT>10), jets ET>50, |η|>3	HT >350 GeV MHT/MET >1.25	0.55

Di-jet case

http://arxiv.org/pdf/0806.1049
Randall and Tucker-Smith

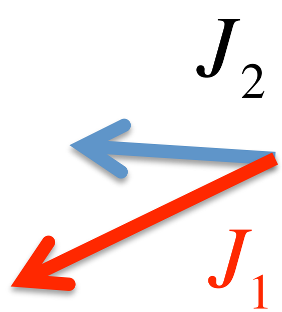
$$\alpha_T \equiv E_T^{J_2} / M_T(J_1 J_2) = \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{\sqrt{2(1-\cos\Delta\varphi_{J_1 J_2})}}$$



$$\alpha_T \approx \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{2} \leq \frac{1}{2}$$

example

$$\tilde{q}\tilde{q} \to (q\tilde{\chi}_1^0)(q\tilde{\chi}_1^0)$$

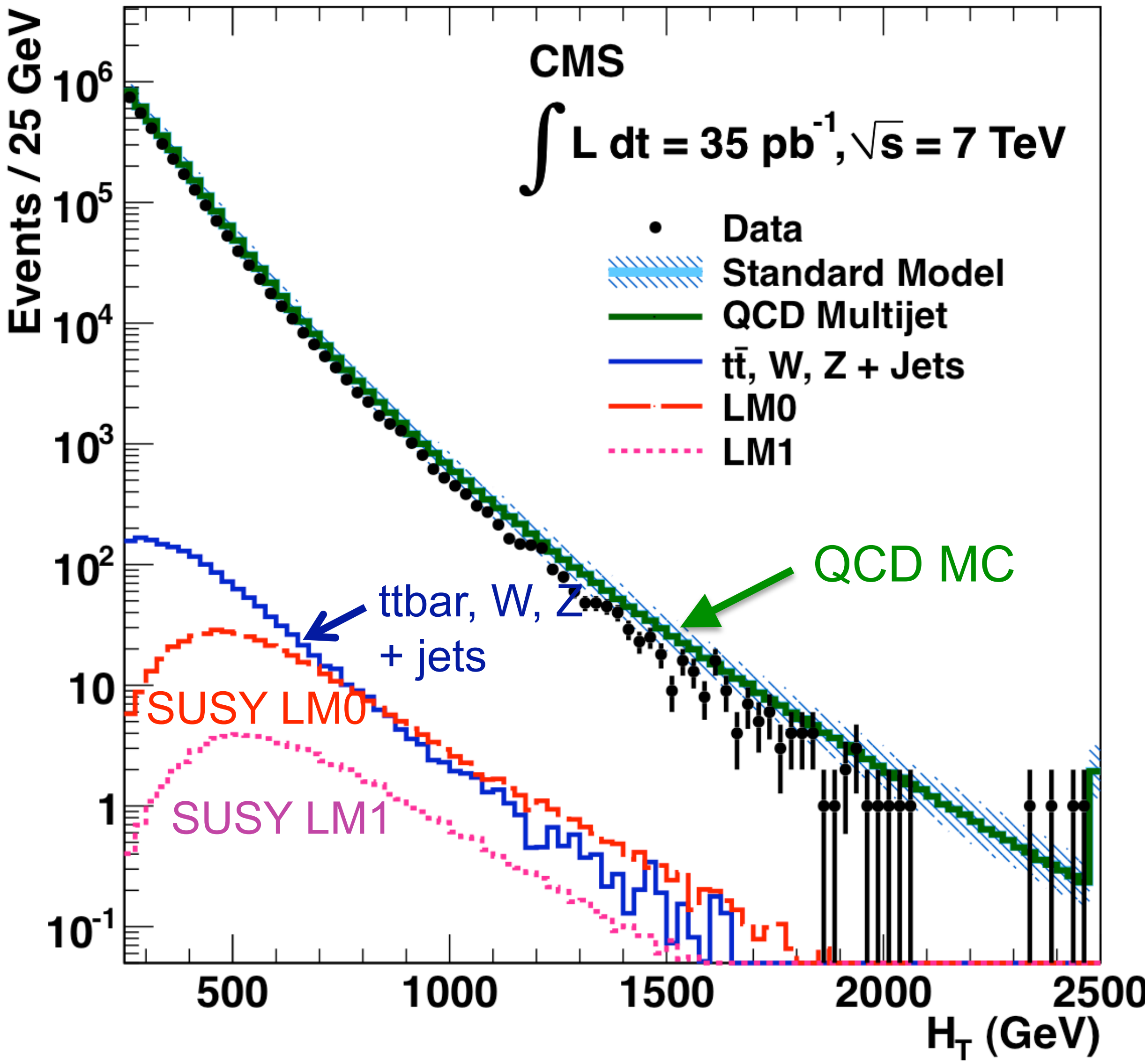


$$\alpha_T \approx \frac{\sqrt{E_T^{J_2} / E_T^{J_1}}}{\Delta\varphi_{J_1 J_2}}$$

Generalize to multi-jet case by forming 2 pseudo-jets.

Hadronic search with α_T

H_T distribution after pre-selection cuts.



QCD multijets from Pythia6.4 (tune Z2).

W,Z + jets, ttbar from MADGRAPH.

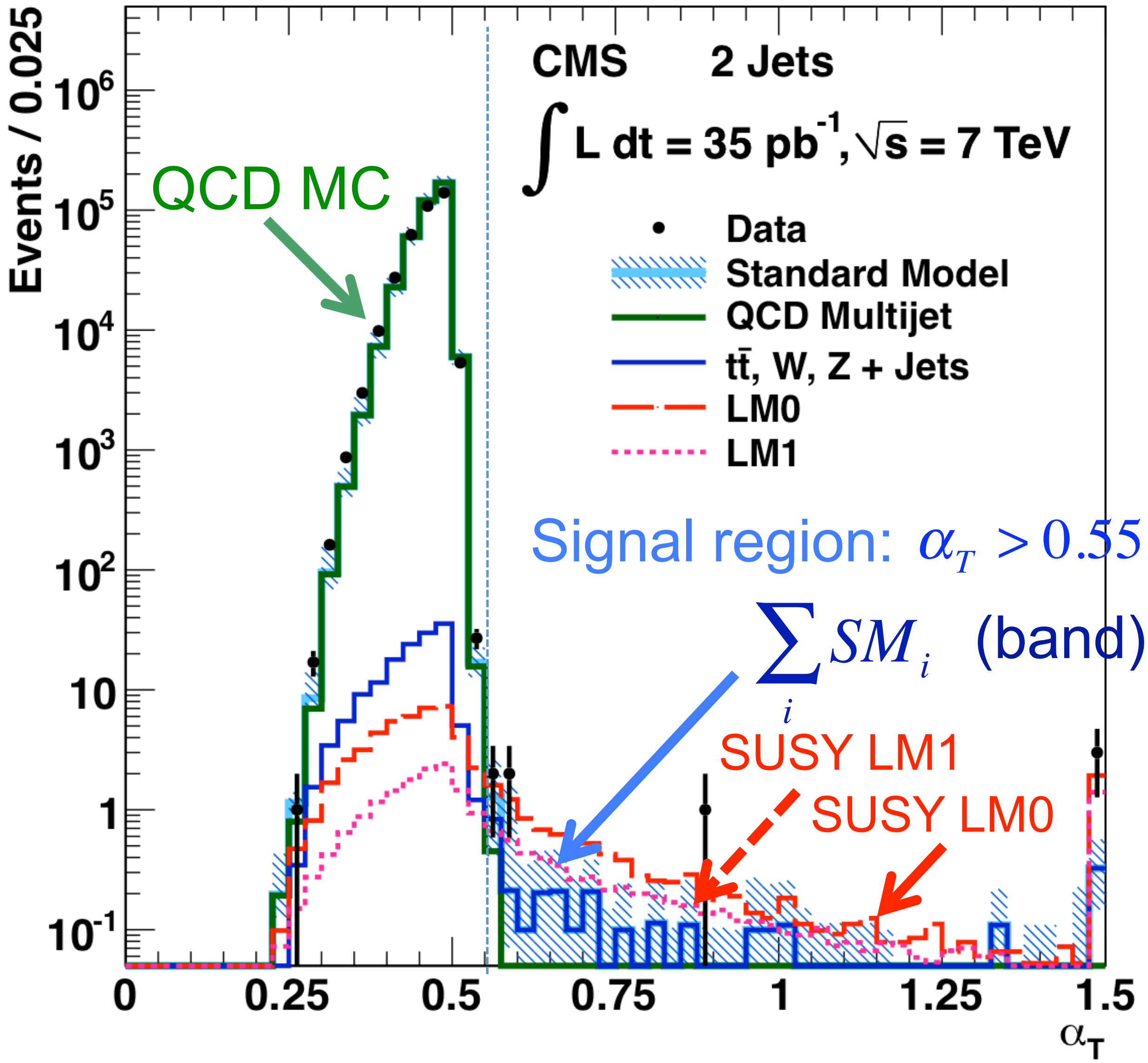
Overall exponential falloff except for ttbar.

Require HT> 350 GeV.

Data and MC in rough agreement over 6 orders of magnitude.

Don't use MC for background predictions...

Hadronic search: α_T for 2-jet sample



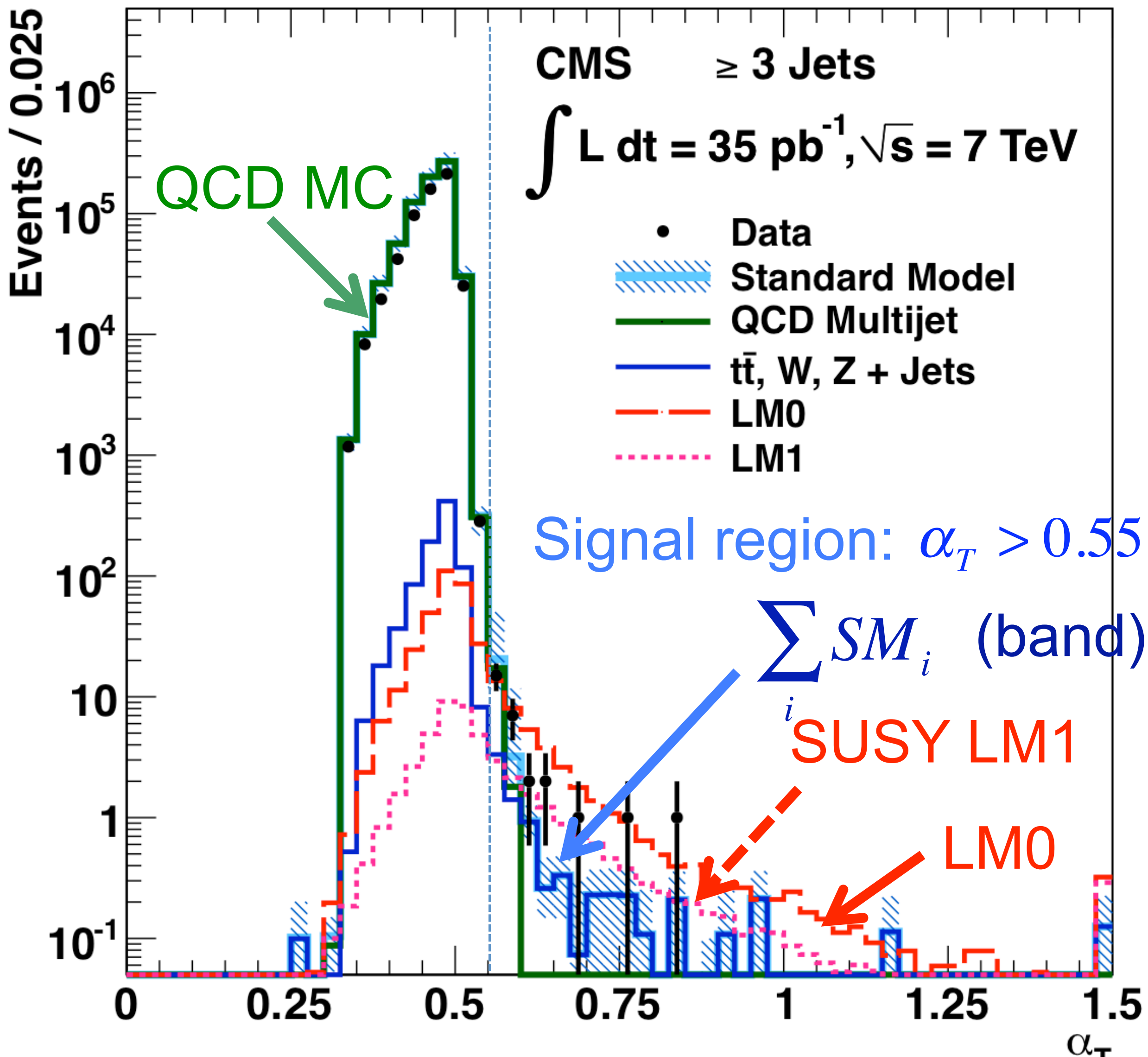
Rapid fall-off of QCD background for αT>0.5.

Tradeoff: loss of signal efficiency.

α_T

Given HT>350 GeV, αT>0.55 ➔ MHT>140 GeV.

Hadronic search: α_T for ≥3 jet sample



Rapid fall-off of QCD background for αT>0.5.

Tradeoff: loss of signal efficiency.

for later:

$$R_{\alpha_T} \equiv \frac{N(\alpha_T > \alpha_T^{cut})}{N(\alpha_T < \alpha_T^{cut})}$$

α_T

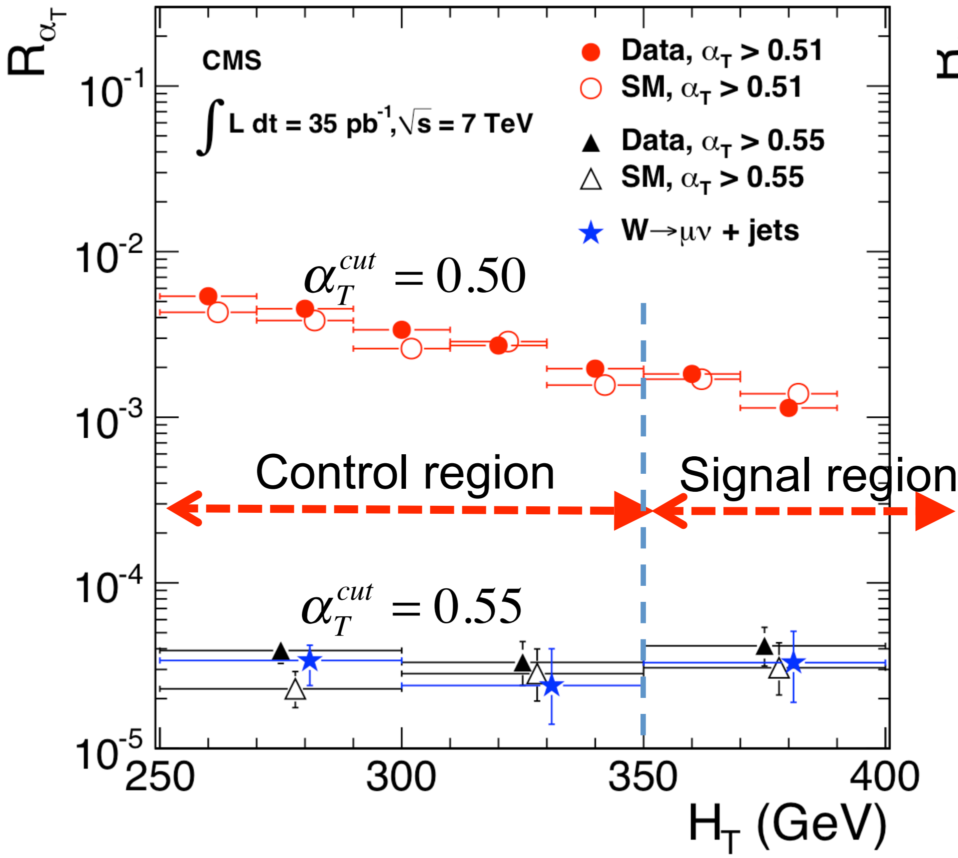
Given HT>350 GeV, αT>0.55 ➔ MHT>140 GeV.

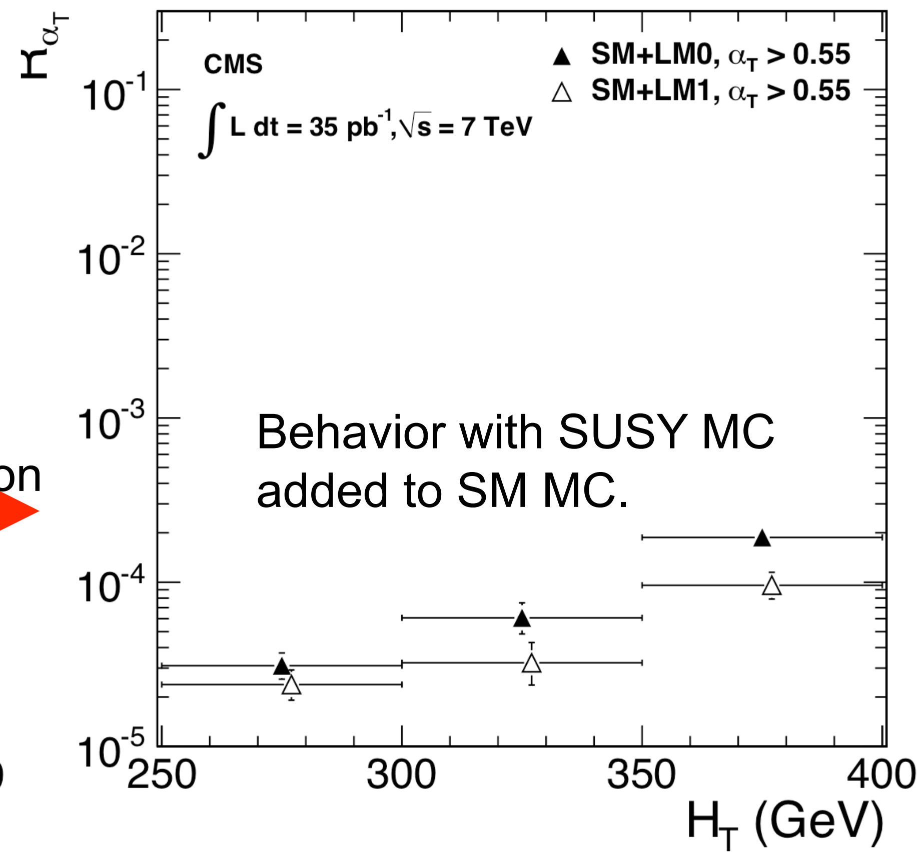
α_T method: background from HT extrap.

$$R_{\alpha_T} \equiv \frac{N(\alpha_T > \alpha_T^{cut})}{N(\alpha_T < \alpha_T^{cut})}$$

$N(\alpha_T) > 0.50$ (QCD dominated) $\Rightarrow R_{\alpha_T}$ decreases with H_T

$N(\alpha_T) > 0.55$ (EWK dominated) $\Rightarrow R_{\alpha_T}$ uniform with H_T





Behavior: for QCD events, the relative MET measurement improves with increasing HT. Note jet thresholds for lower HT bins are lowered to equalize phase space.

α_T method: background from HT extrap.

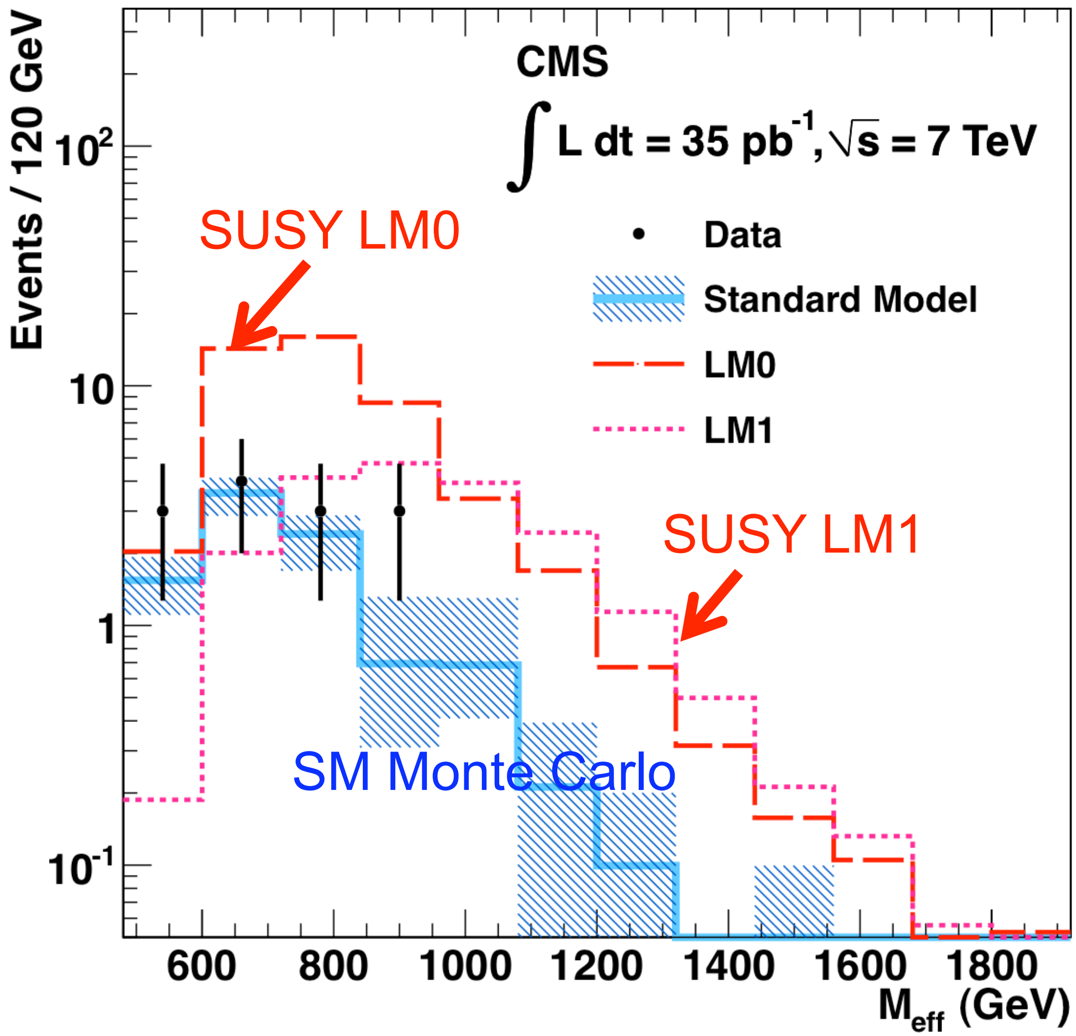
Method	Yield (events)	Comments
R(αT) extrap in HT; multiply by N(αT<0.55) in HT>350 GeV bin	$9.4^{+4.8}_{-4.0}$ (stat) ± 1.0 (sys)	Sum over all backgrounds
W + jets control sample to estimate W, ttbar	$6.1^{+2.8}_{-1.9}$ (stat) ± 1.8 (sys)	
Gamma + jets control sample to determine Z→νν + jets	$4.4^{+2.3}_{-1.6}$ (stat) ± 1.8 (sys)	
Sum of W + jets, ttbar, and Z→νν + jets	$10.5^{+3.6}_{-2.5}$	consistent with HT extrap method
Observed number of events in signal region	13	Observed yield consistent with backgnd predictions.

LM1 channel	Yield for 35 pb^{-1}	Total Efficiency (%)	Eff. for signature (%)
$\tilde{q}\tilde{q}$	9.7 ± 0.1	16.0 ± 0.1	22.2 ± 0.4
$\tilde{q}\tilde{g}$	8.8 ± 0.1	14.4 ± 0.1	23.0 ± 0.5
$\tilde{g}\tilde{g}$	0.71 ± 0.02	12.0 ± 0.4	22.5 ± 2.0

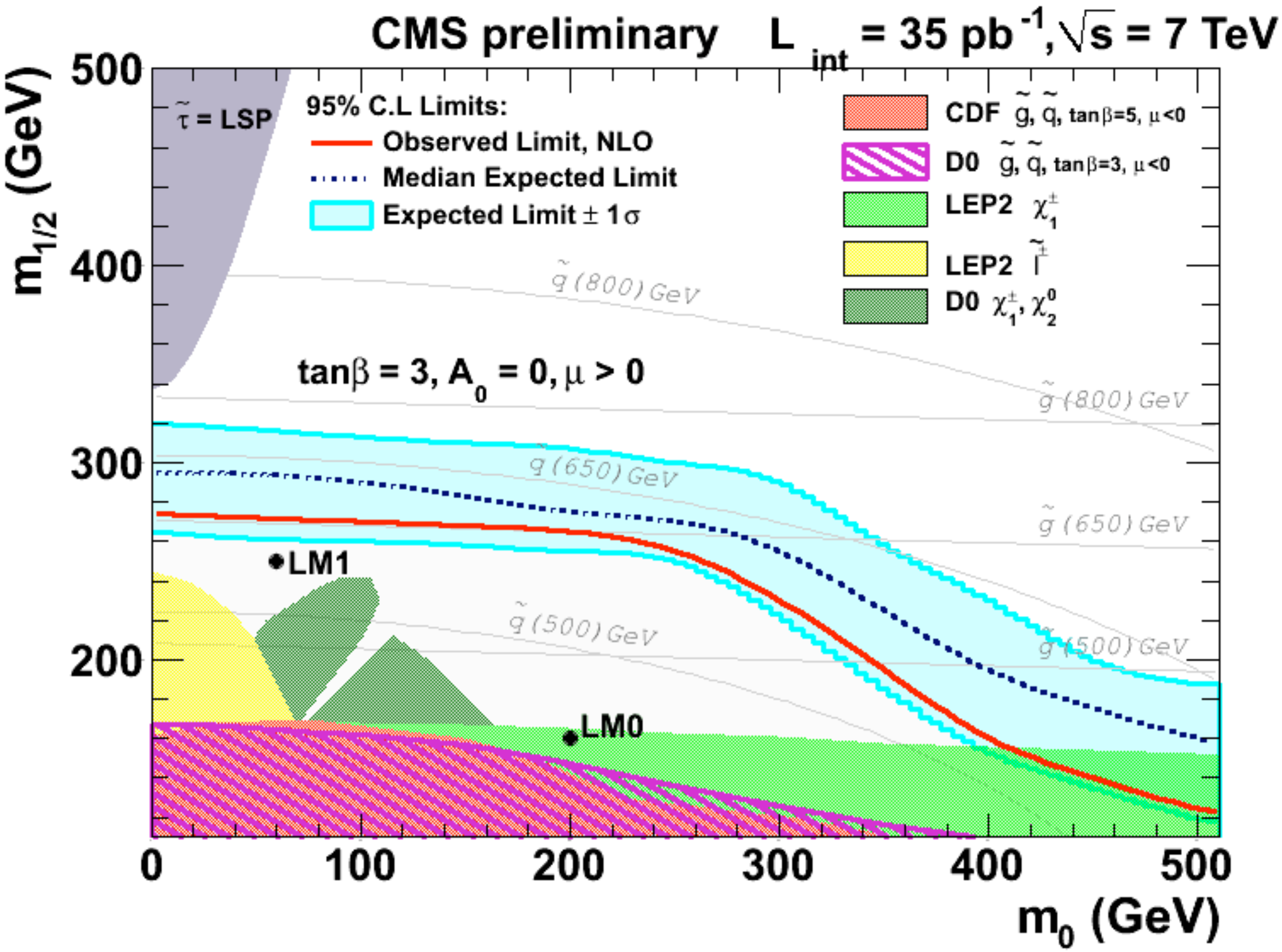
α_T method: M_{eff} distribution

$$M_{eff} = H_T + MHT$$

All selection cuts applied



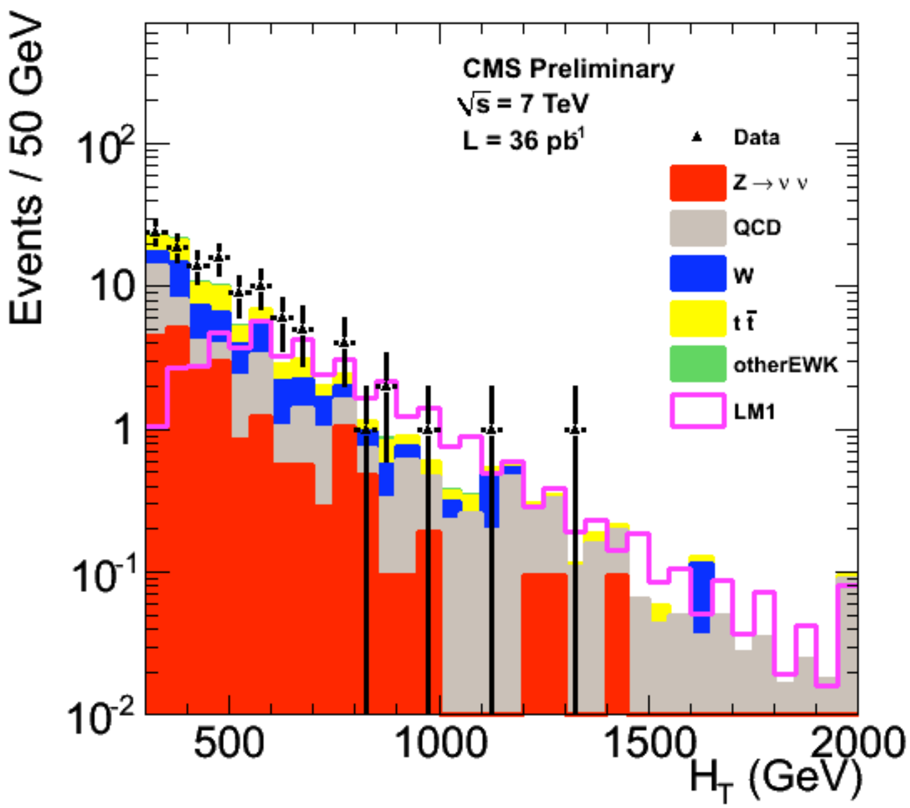
α_T method: CMSSM exclusion (95% C.L.)

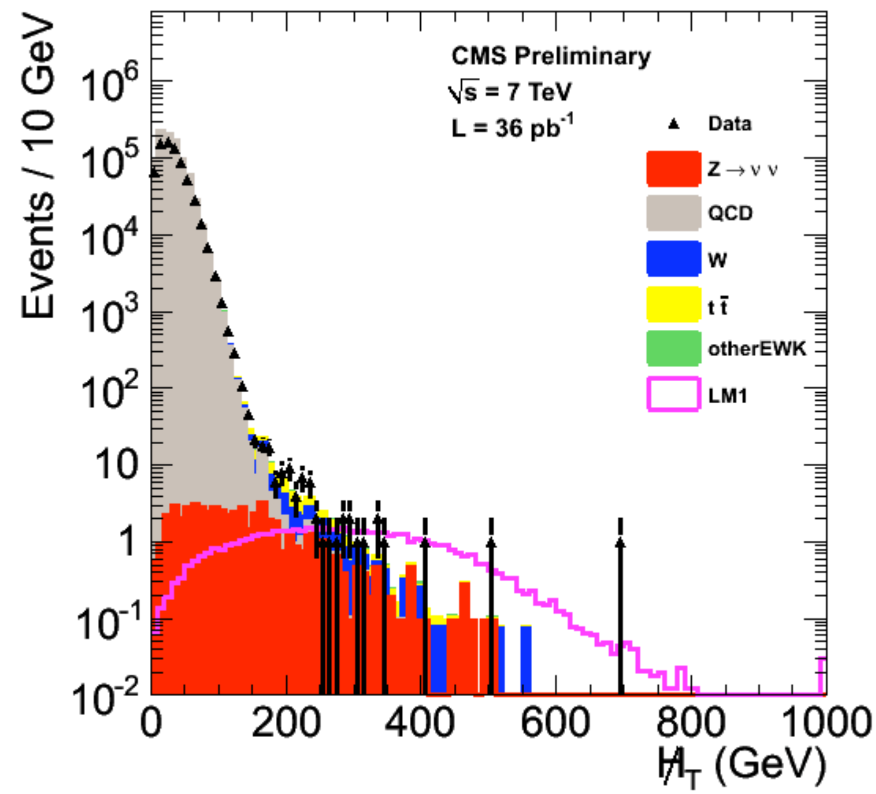


Hadronic SUSY Search: jets + MHT

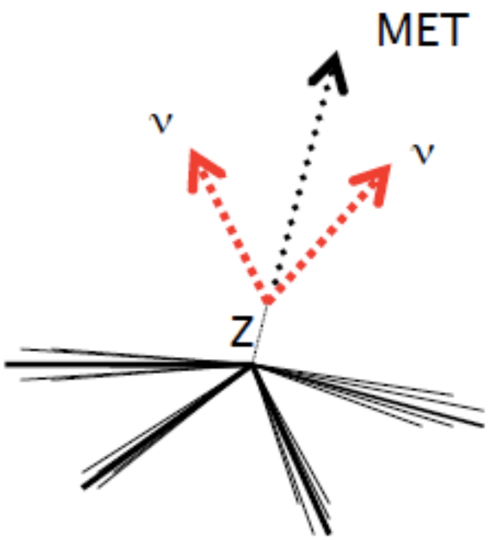
Baseline selection http://cdsweb.cern.ch/record/1343076?ln=en

Trigger	Jets	Vetos (event vetoed if)	HT	MHT
$HT^{trigger}$>150 GeV at HLT	≥3 jets, ET>50 |η|<2.5	isolated leptons (pT>10), jets ET>50, |η|>3	HT>300 using jets with pT>50, |η<2.5	MHT >150 GeV using jets with pT>30, |η|<5

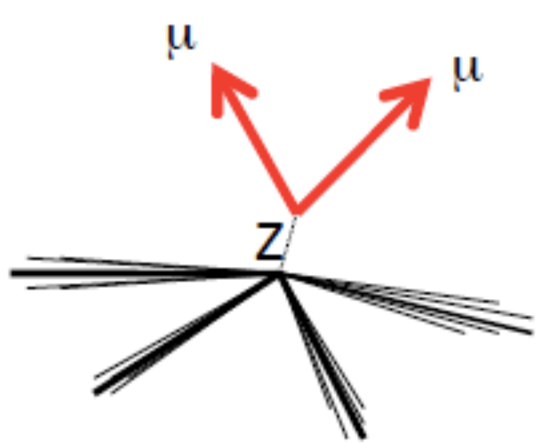




Jets + MHT search: $Z \rightarrow \nu\bar{\nu}$



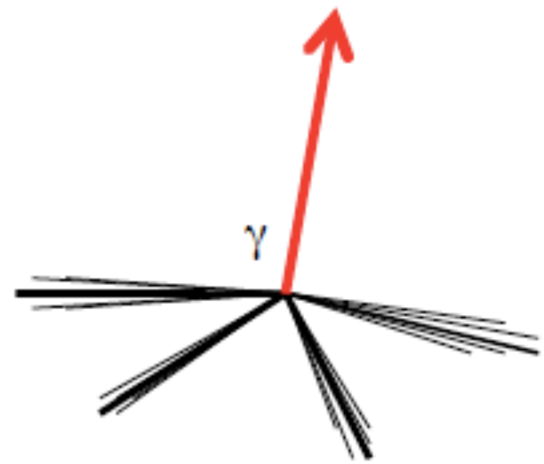
Irreducible background



Obvious control sample:
replace leptons by missing momentum

Baseline selection:
2 Z→ee evts,
1 Z→μμ evts
Scale for BF(νν)/(BF(ll)=6, effic, accept

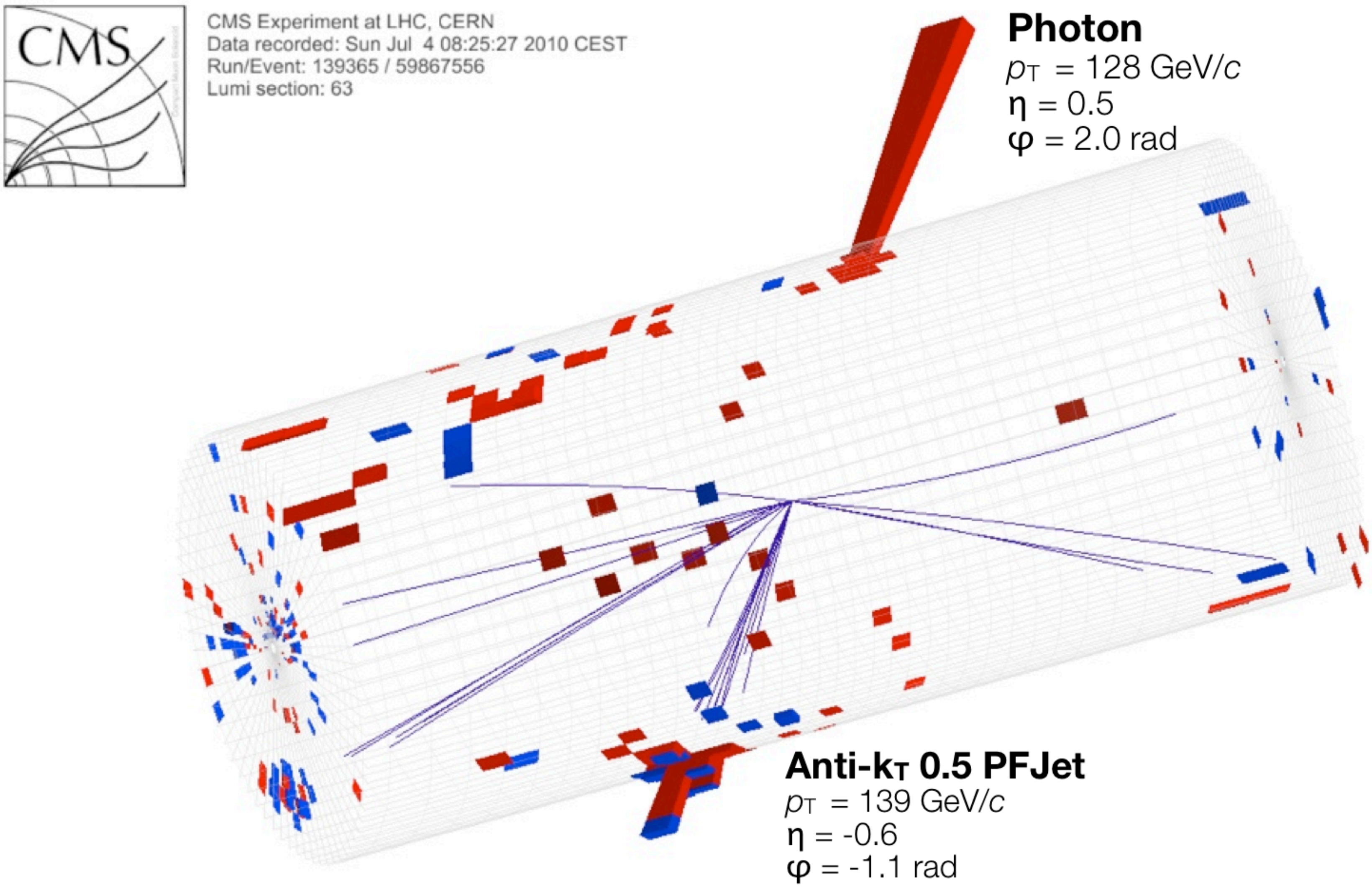
$$N(Z \rightarrow \nu\bar{\nu}) = 17^{+13}_{-10}$$



Non-obvious control sample:
replace Z by high pT, isolated photon

a major measurement in itself...

Photon + jet event



QCD background prediction

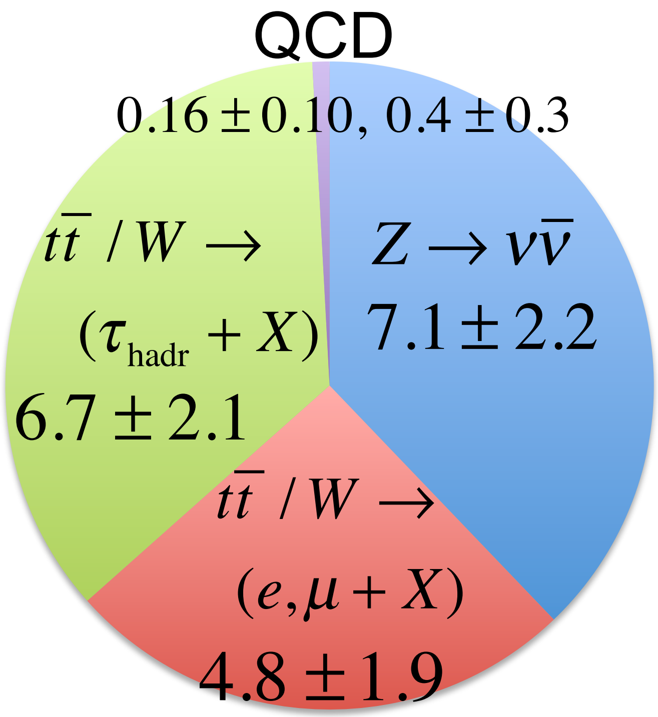
- Use control samples in data to measure jet resolution functions
  - photon + jets
  - dijets

$$\text{MHT} = -\sum_{\text{jets } j} \vec{p}_T^{\,j}$$

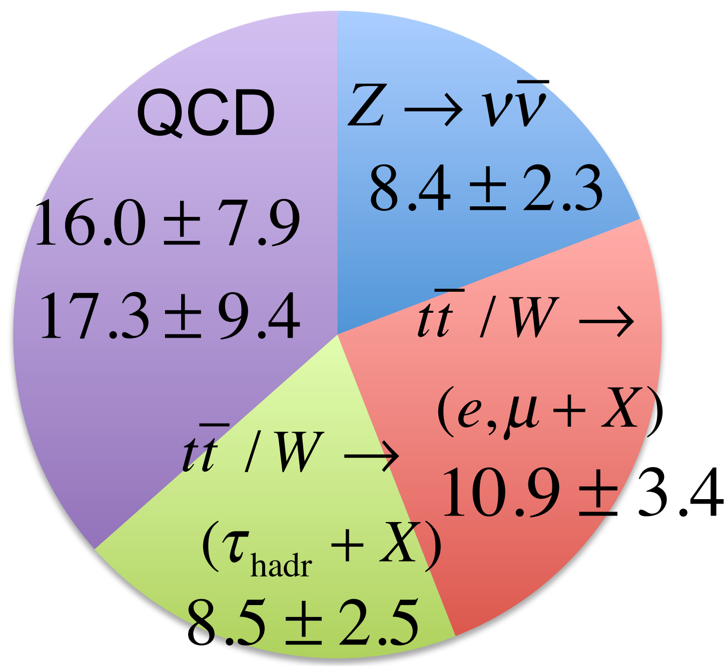
- Apply re-balancing procedure to data
  - adjust jet Et values to obtain overall zero MHT.
  - events with real MHT (ttbar, W, BSM) are included.
- Data events are then re-smeared using resolution function.
- Method is jet-based, so predicts MHT, not MET.

Jets + MHT search: results

High MHT selection:
Baseline + MHT>250 GeV

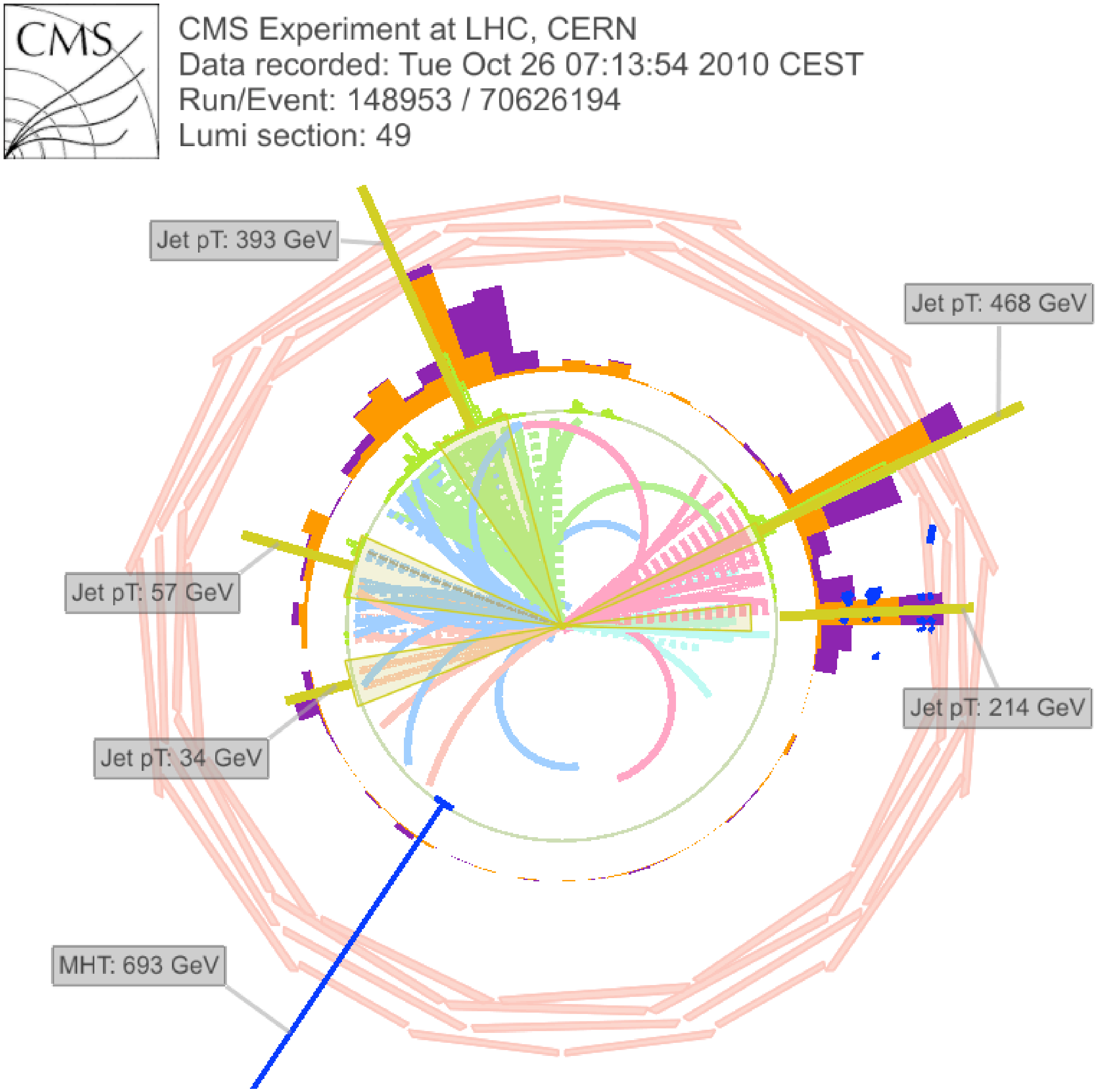


High HT selection:
Baseline + HT>500 GeV



	High MHT Selection	High HT Selection
Total predicted	18.8 ± 3.5	43.8 ± 9.2
Observed	15	40

Jets + MHT search: an interesting event

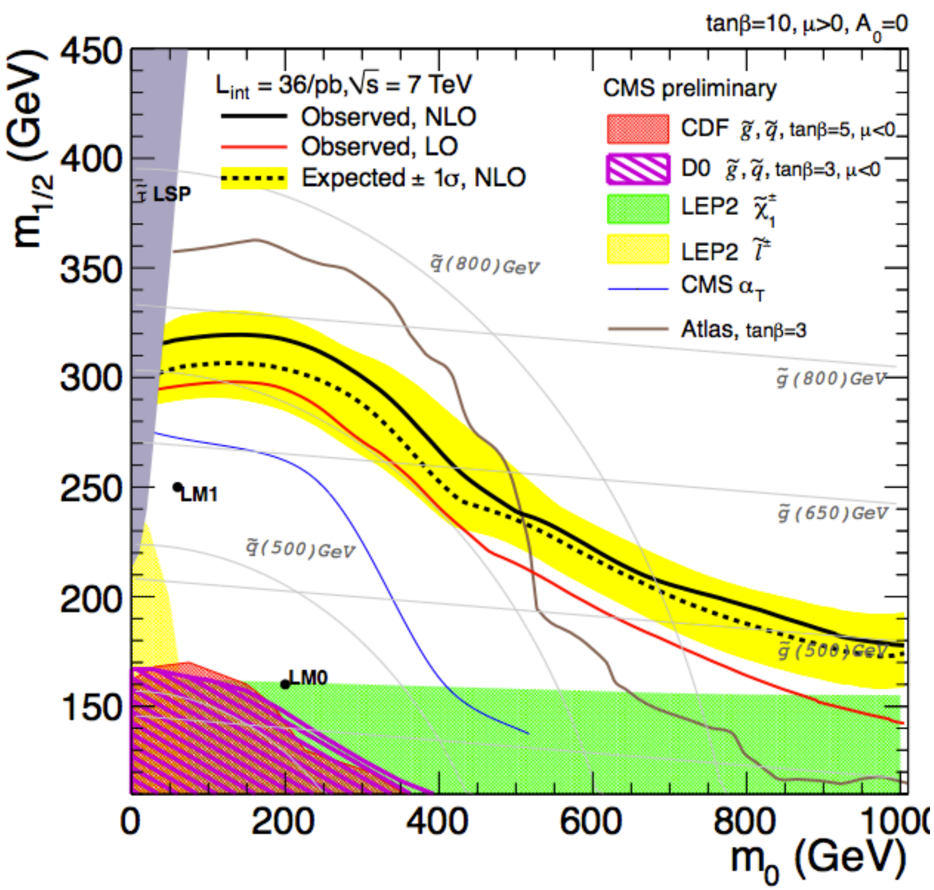


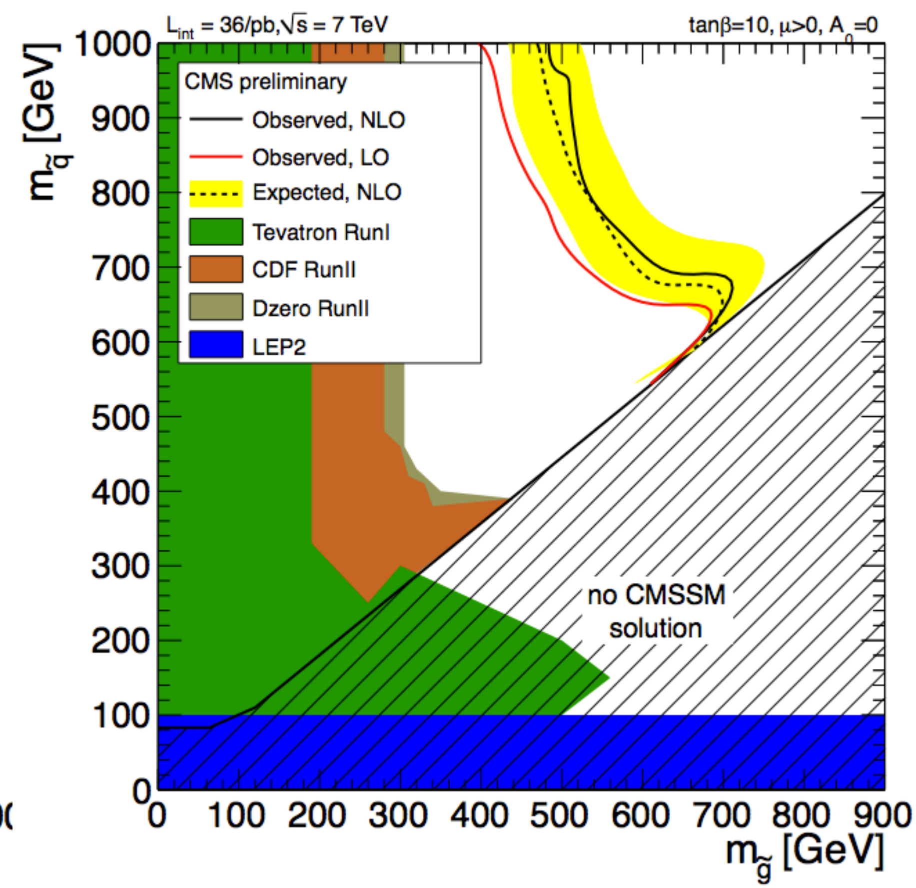
MHT = 693 GeV
HT = 1132 GeV
Meff = 1.83 TeV

No jet invariant mass combinations match W, t masses

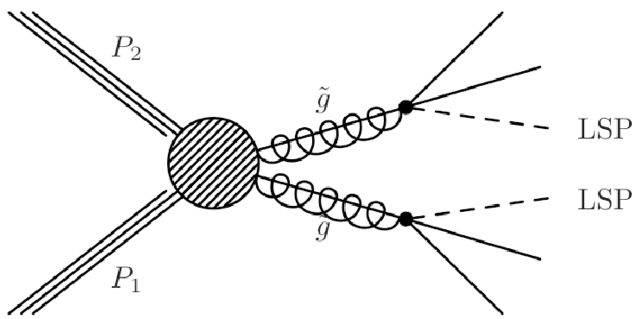
Jets + MHT search: CMSSM constraints

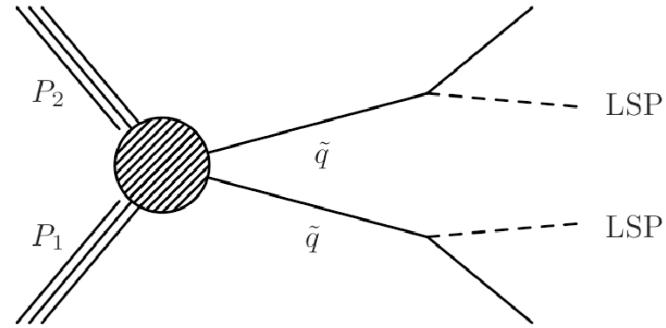
Signal acceptance: 10% – 20% for high MHT selection.
Contours: envelope of best sensitivity of both the HT and MHT selection. (Statistics: CLs method)



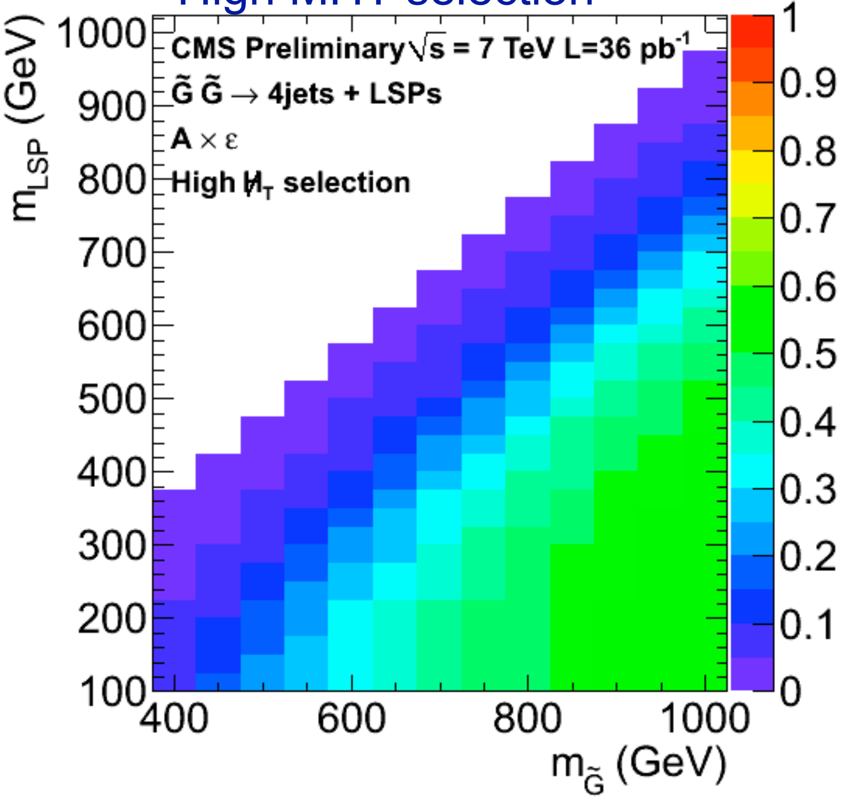


Simplified models: selection efficiency

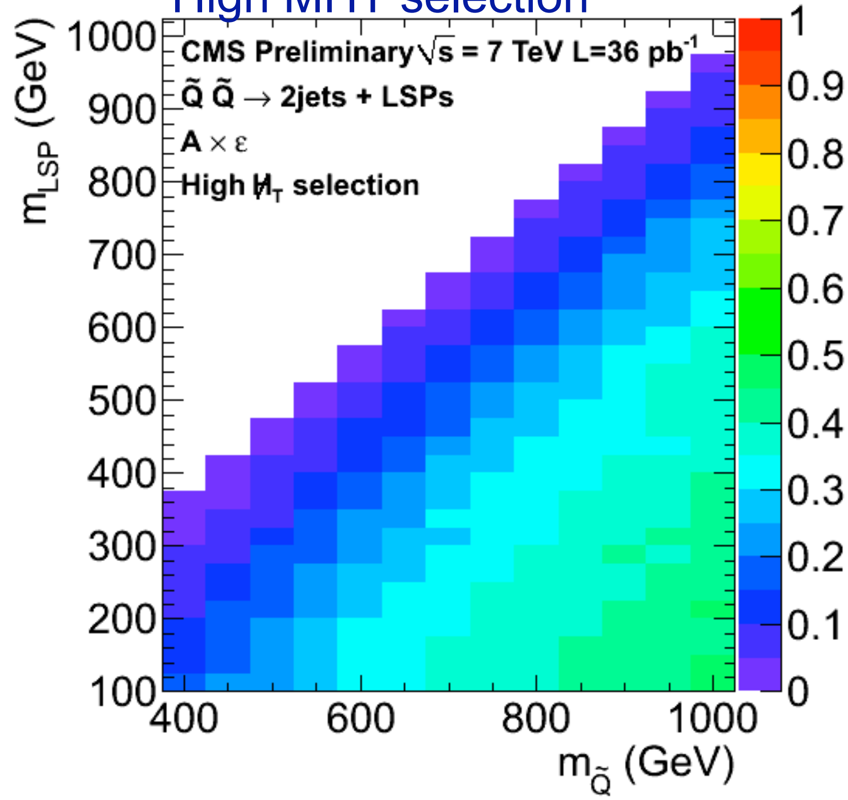




High MHT selection



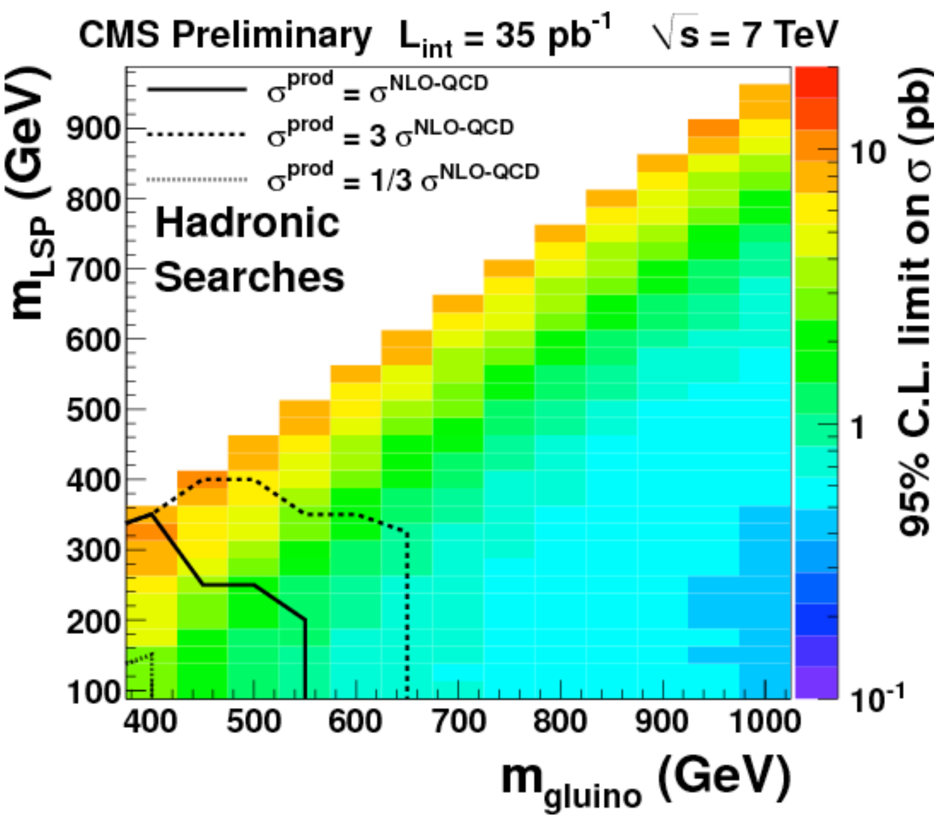
High MHT selection



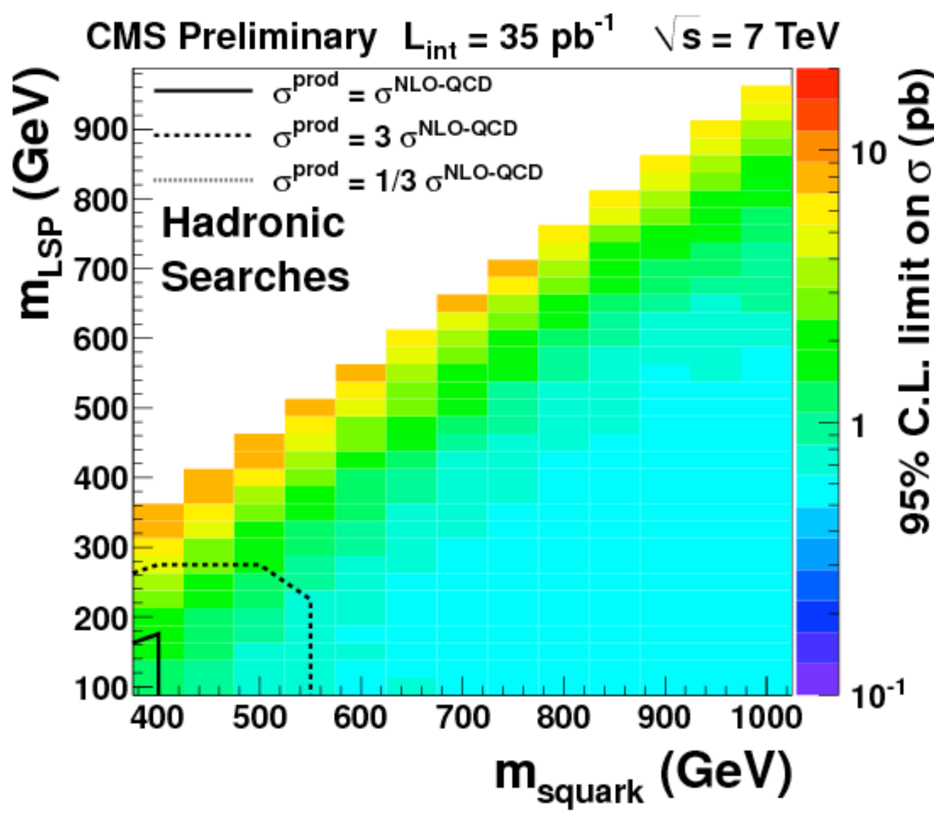
Simplified models: cross section limits on combined CMS hadronic searches

Minimum 95% C.L. upper limit on the production cross section from three hadronic analyses: αT, jets + MHT, razor.

Gluino pair production



Squark pair production



Hadronic search with "Razor" variables

C. Rogan http://arxiv.org/pdf/1006.2727v1

Main idea: search for pair production of heavy objects near threshold.
Arrange all reco'd objects into hemispheres, with 3 momenta $\vec{p}$ and $\vec{q}$

$$\mathbf{MET} = \vec{M}$$

Scale:

$$M_R = 2\sqrt{\frac{(|\vec{p}|q_z - |\vec{q}|p_z)^2}{(p_z - q_z)^2 - (|\vec{p}| - |\vec{q}|)^2}}$$

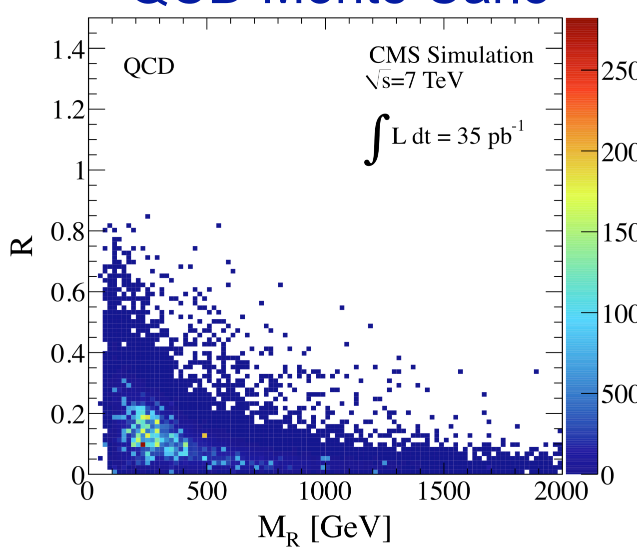
$$M_T^R = \sqrt{\frac{|\vec{M}|(|\vec{p}| + |\vec{q}|) - \vec{M} \cdot (\vec{p} + \vec{q})}{2}}$$

Angle:

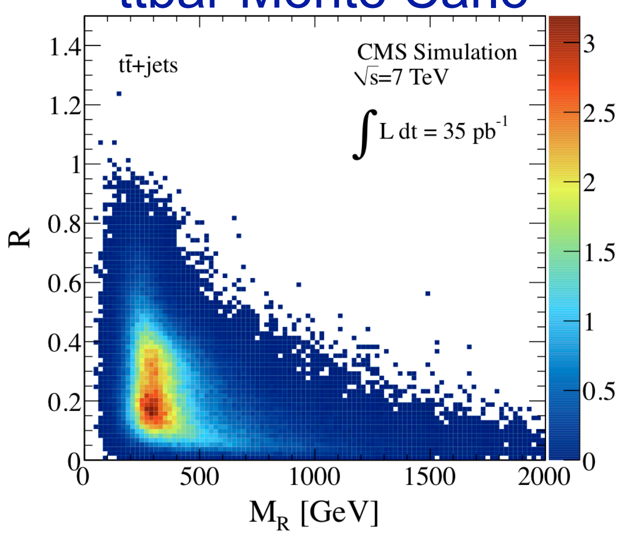
$$R = \frac{M_T^R}{M_R}$$

$$M_R \sim \sqrt{\hat{s}} \sim M_{eff} \qquad R \sim p_T^{miss} / \sqrt{\hat{s}}$$

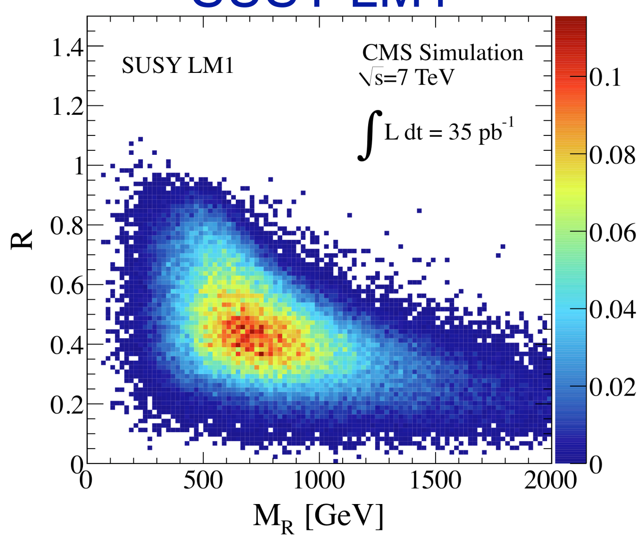
QCD Monte Carlo



ttbar Monte Carlo

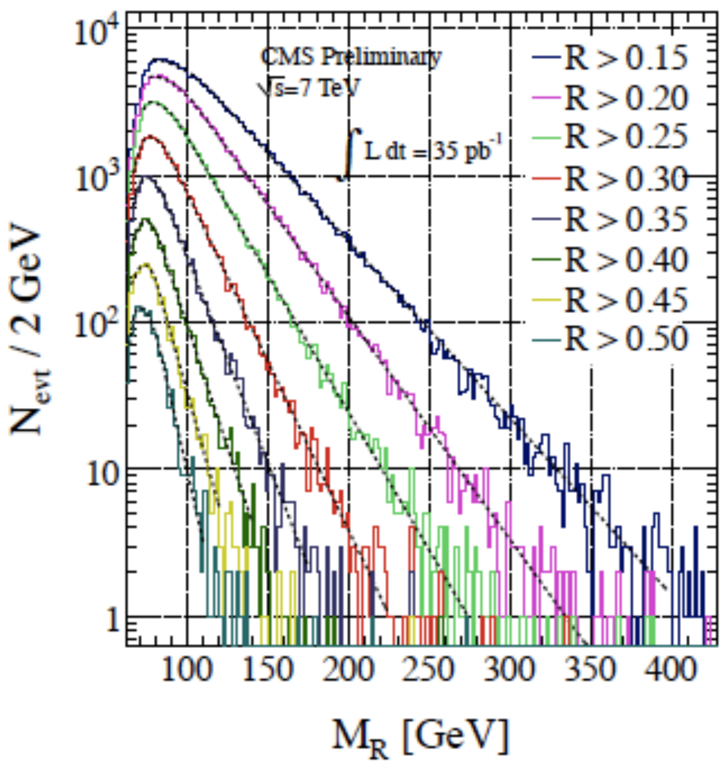


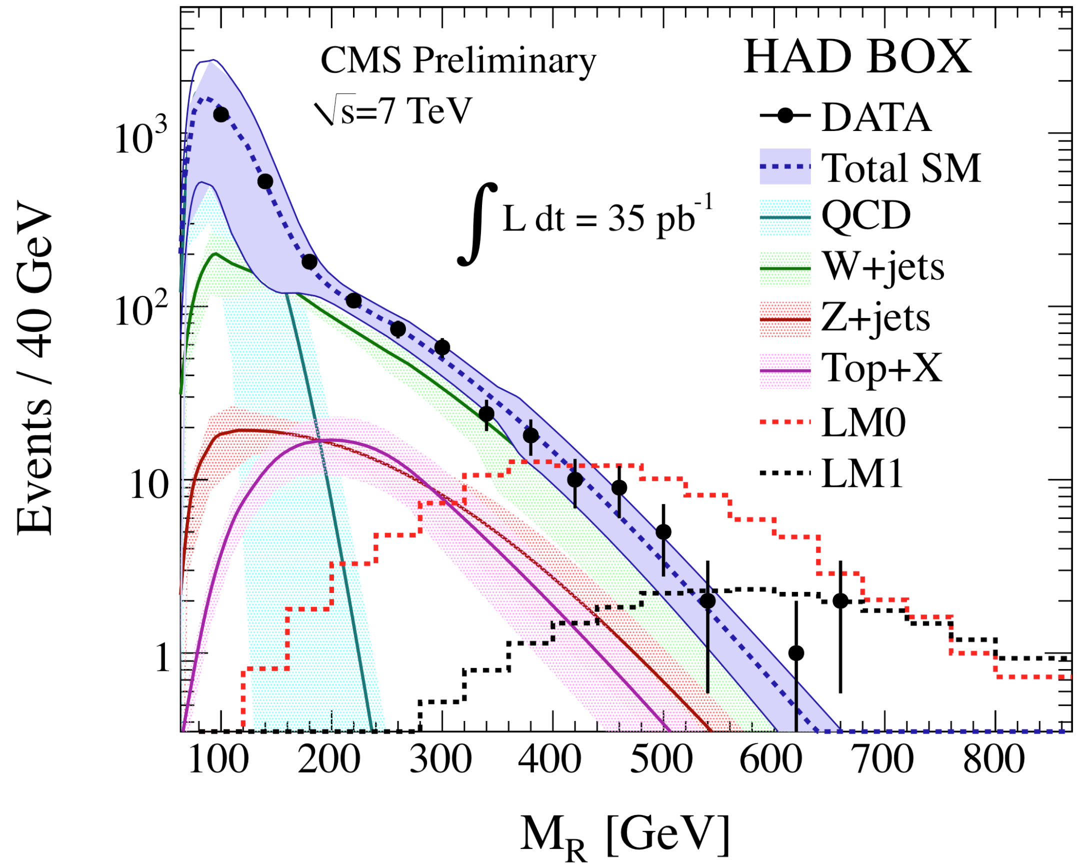
SUSY LM1



Razor analysis: results

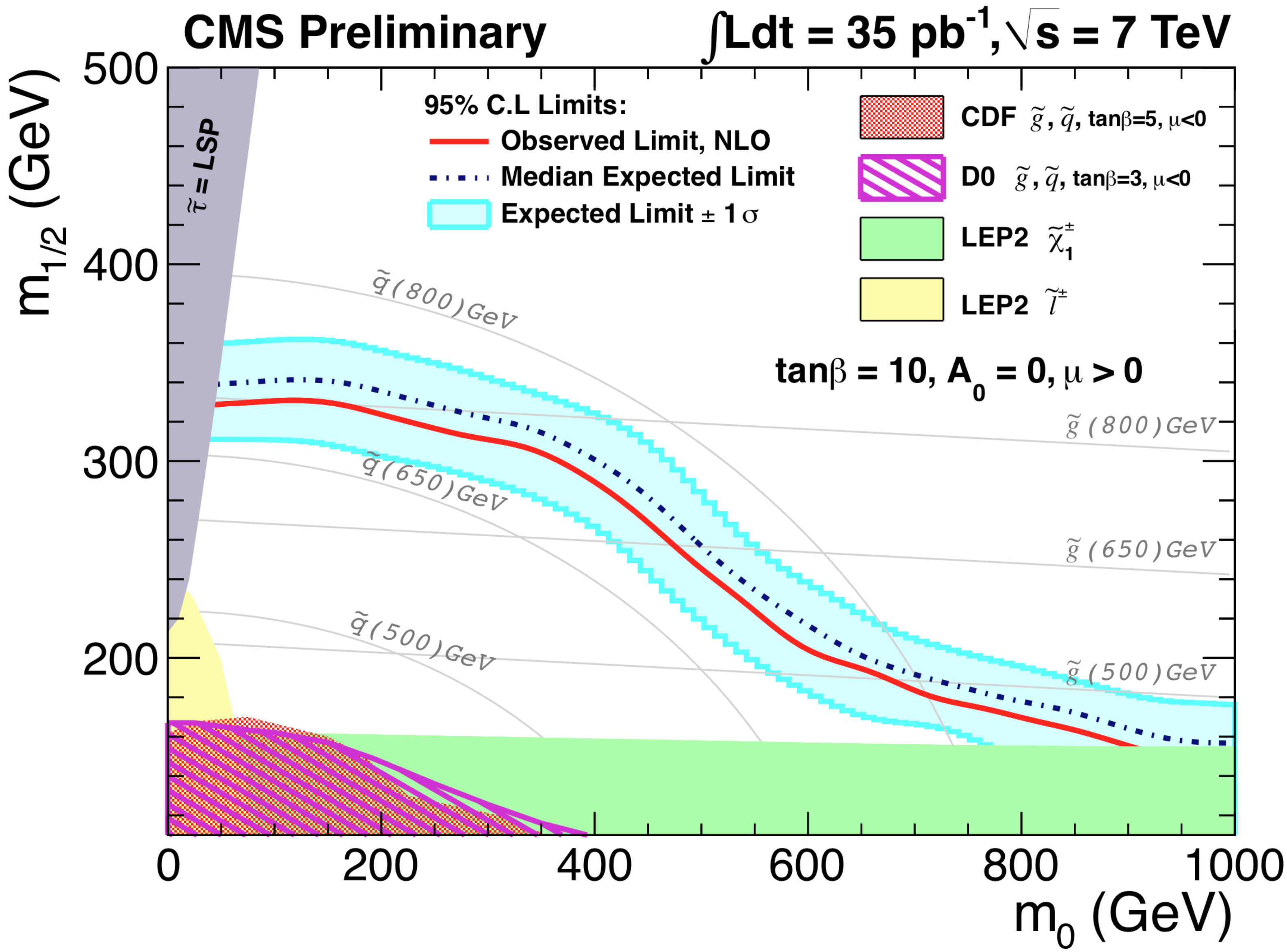
M_R distribution for QCD background falls exponentially, with slope determined by cut on R. Other backgrounds have similar behavior. Background shapes & norm from control samples.





R>0.5, M_R>500 GeV: predict 5.5 ±1.4 events, observe 7 events.

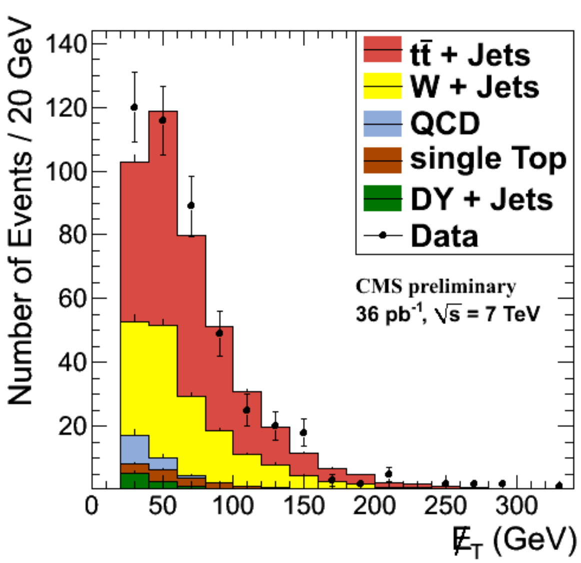
Razor analysis: CMSSM exclusion curves

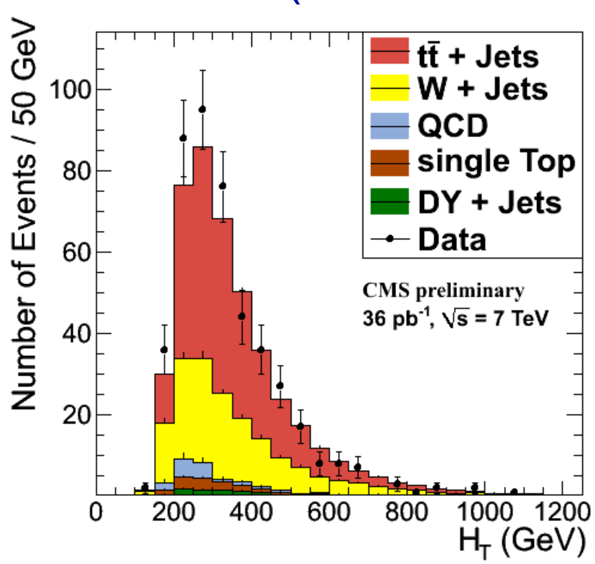


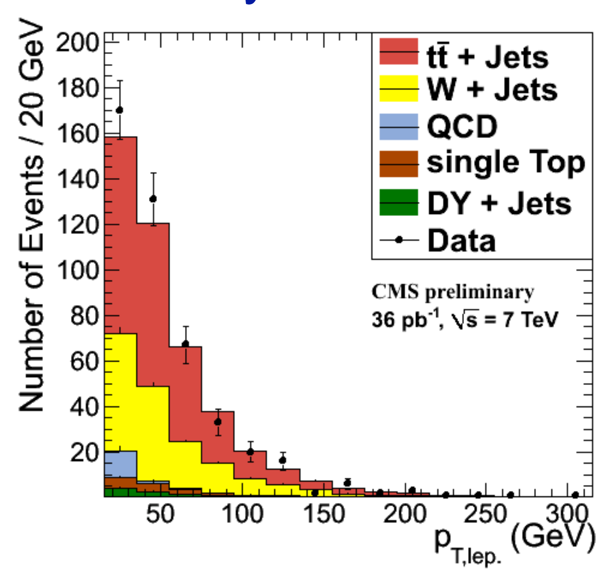
Single lepton + jets + MET search

Trigger	Jets	Leptons	HT	MET
Single mu (pT>5 GeV)+ HTtrig>70 GeV, pT(e)>17 GeV	≥4 jets, pT>30 |η|<2.4	pT(e)>20 GeV pT(mu)>20 GeV isolated, only 1 lepton/event	HT>300 GeV using jets with pT>20 GeV, |η|<2.4	MET >250 GeV

Distributions after baseline selection (no offline HT cut and only MET>25 GeV)

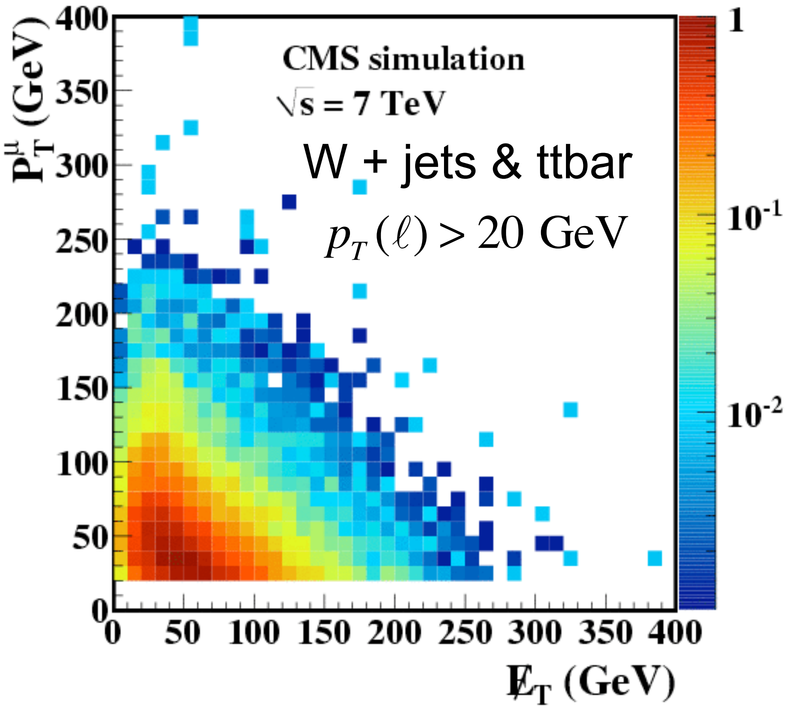


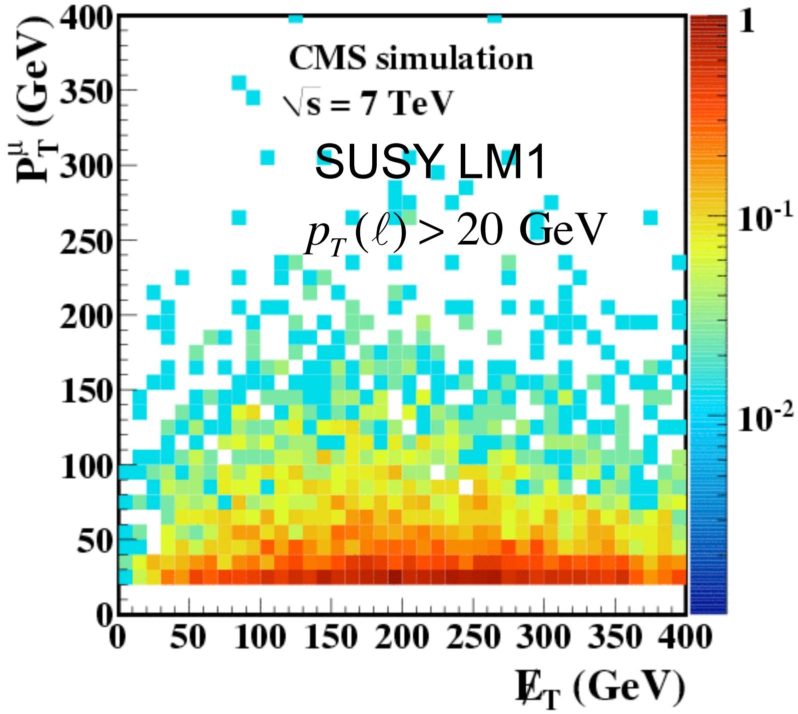




Lepton-spectrum method

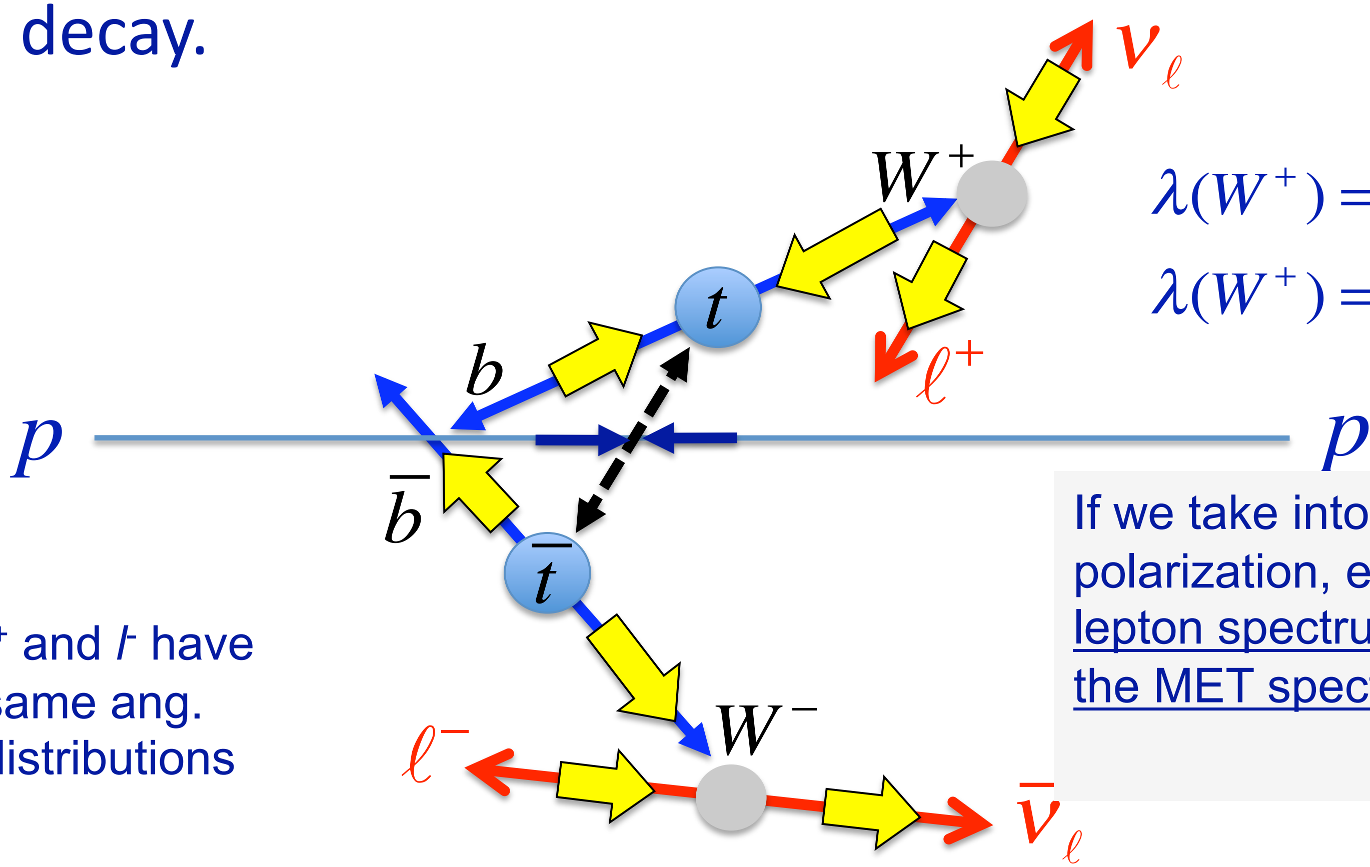
- For dominant backgrounds (ttbar & W + jets), the lepton and neutrino are produced together in W decay. (Identical boosts to lab frame.)
- If we control polarization effects, can use lepton spectrum to predict the MET spectrum for background.





W polarization in ttbar

- SM background is dominated by ttbar and W+jets events
- MET distribution is mostly due to real MET from neutrinos, which are produced together in two-body W decay.



$$\lambda(W^+) = \ 0 : \ f \ = 0.7$$

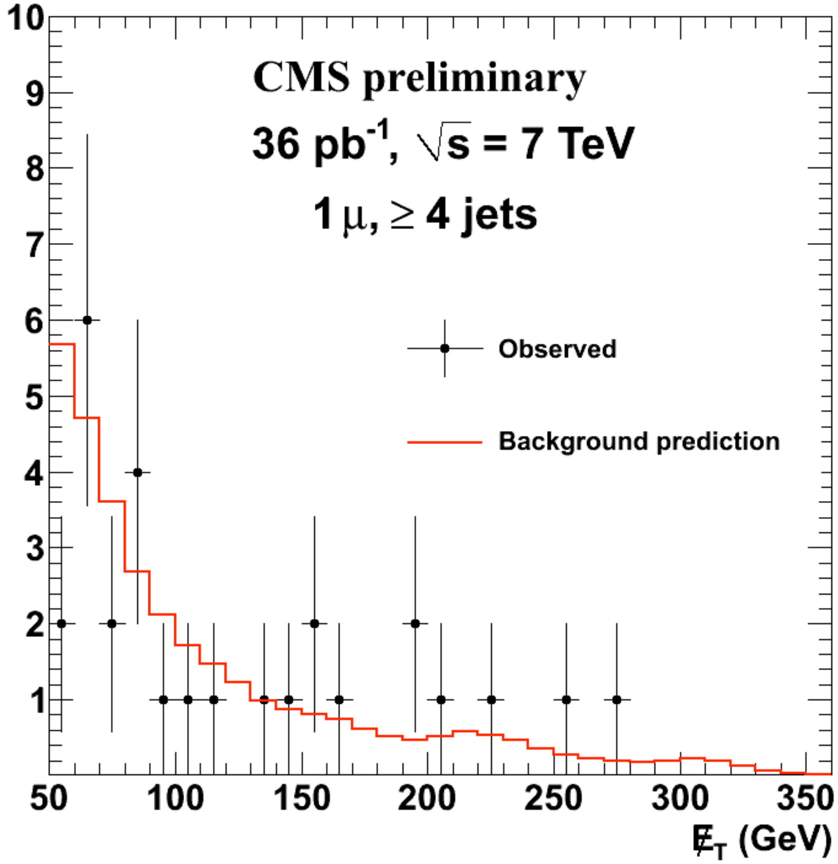
$$\lambda(W^+) = -1 : f \ = 0.3$$

l^+ and l^- have same ang. distributions

If we take into account polarization, etc., the lepton spectrum gives us the MET spectrum.

Single lepton + jets + MET: results

- Predicted single-lepton spectrum (with smearing using jet resolution templates from data).
- Also measure dilepton feed-down and ttbar →l +tau, W→tau→lep, and QCD from control samples.



Sample	μ	e
Predicted SM 1 lepton	1.7 ± 1.4	1.2 ± 1.0
Predicted SM dilepton	$0.0^{+0.8}_{-0.0}$	$0.0^{+0.6}_{-0.0}$
Predicted single tau	0.29 ± 0.22	$0.32^{+0.38}_{-0.32}$
Predicted QCD	0.09 ± 0.09	$0.0^{+0.16}_{-0.0}$
Total predicted SM	2.1 ± 1.5	1.5 ± 1.2
Observed signal region	2	0

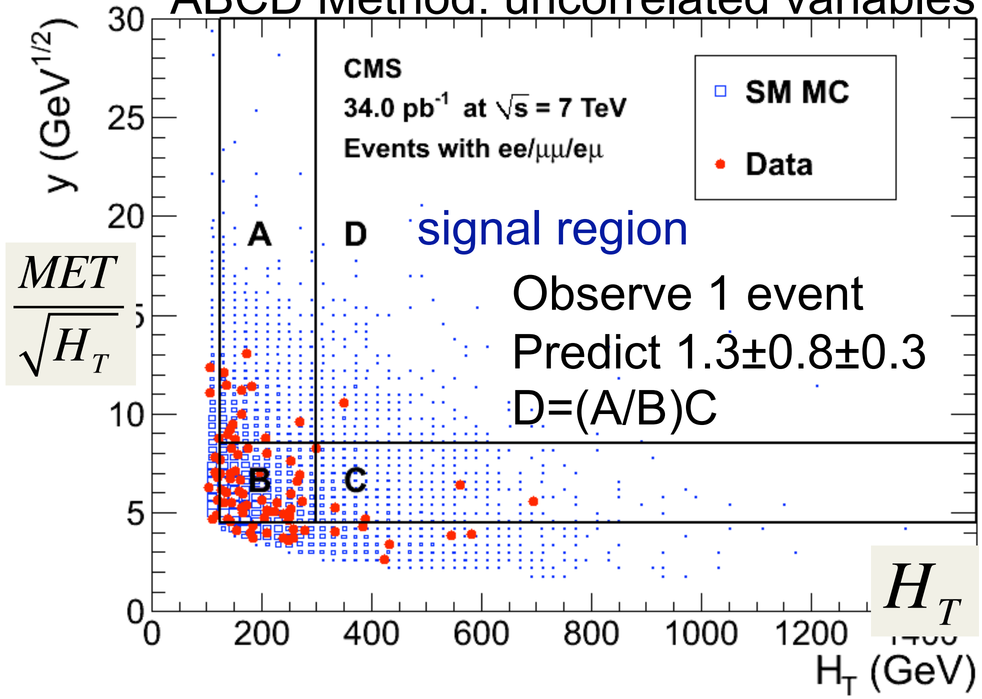
Dilepton search: opposite sign

http://arxiv.org/abs/1103.1348

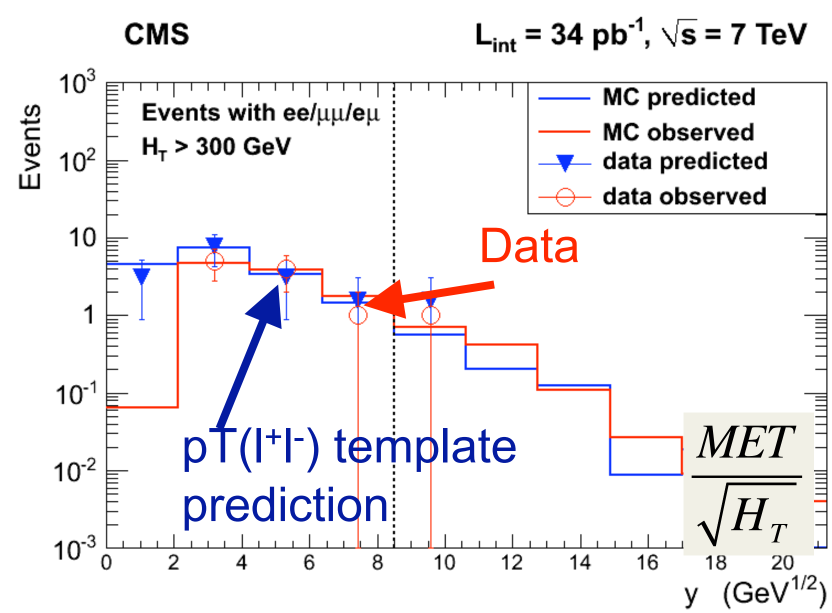
$$\tilde{\chi}_2^0 \rightarrow \ell^+\tilde{\ell}^-; \quad \tilde{\ell}^- \rightarrow \ell^-\tilde{\chi}_1^0$$

Trigger	Jets	Leptons	HT	MET
Single mu, and dilepton triggers	≥2 jets, pT>30 |η|<2.5	≥2 opp sign isolated leptons (e, μ): pT(lep 1)>20 GeV pT(lep 2)>10 GeV	HT>300 GeV using jets with pT>30 GeV, |η|<2.5	$y = MET/\sqrt{H_T}$ >8.5 √GeV

ABCD Method: uncorrelated variables



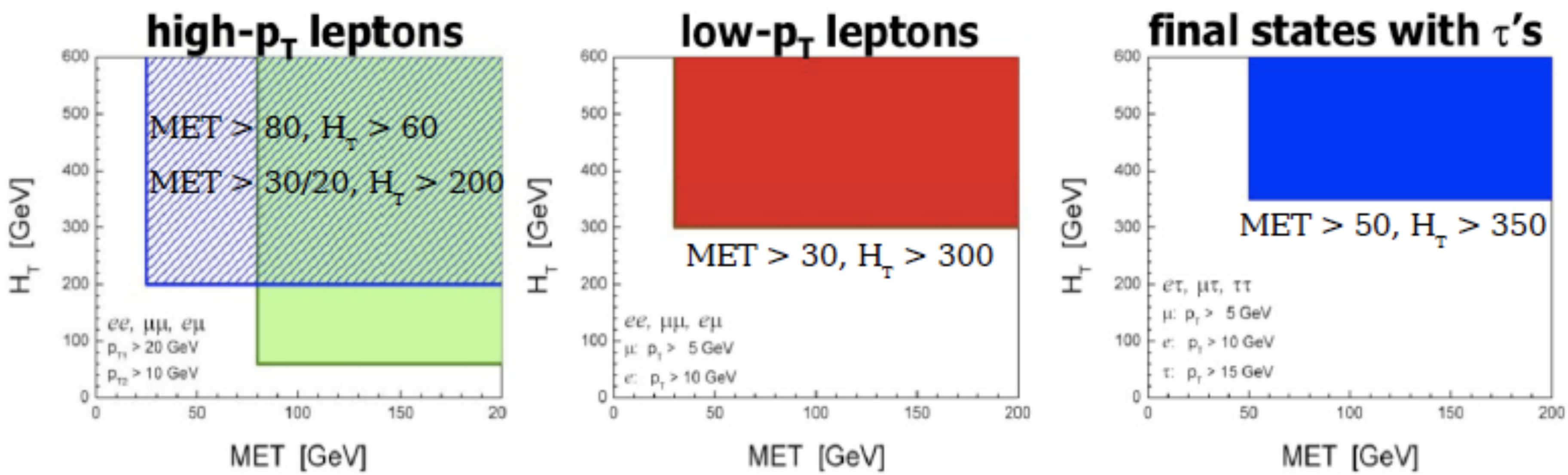
Lepton-spectrum method: use pT(l$^+$l$^-$)



Predicts 2.1±2.1±0.6 events

Dilepton search: same sign

- Classic SUSY signature: very low SM background due to suppression of dilepton ttbar with 2 primary leptons.
- Background from ttbar with 1 primary, 1 secondary lepton
- In electron channel, can also have charge misID resulting from hard bremsstrahlung + conversion in the detector.

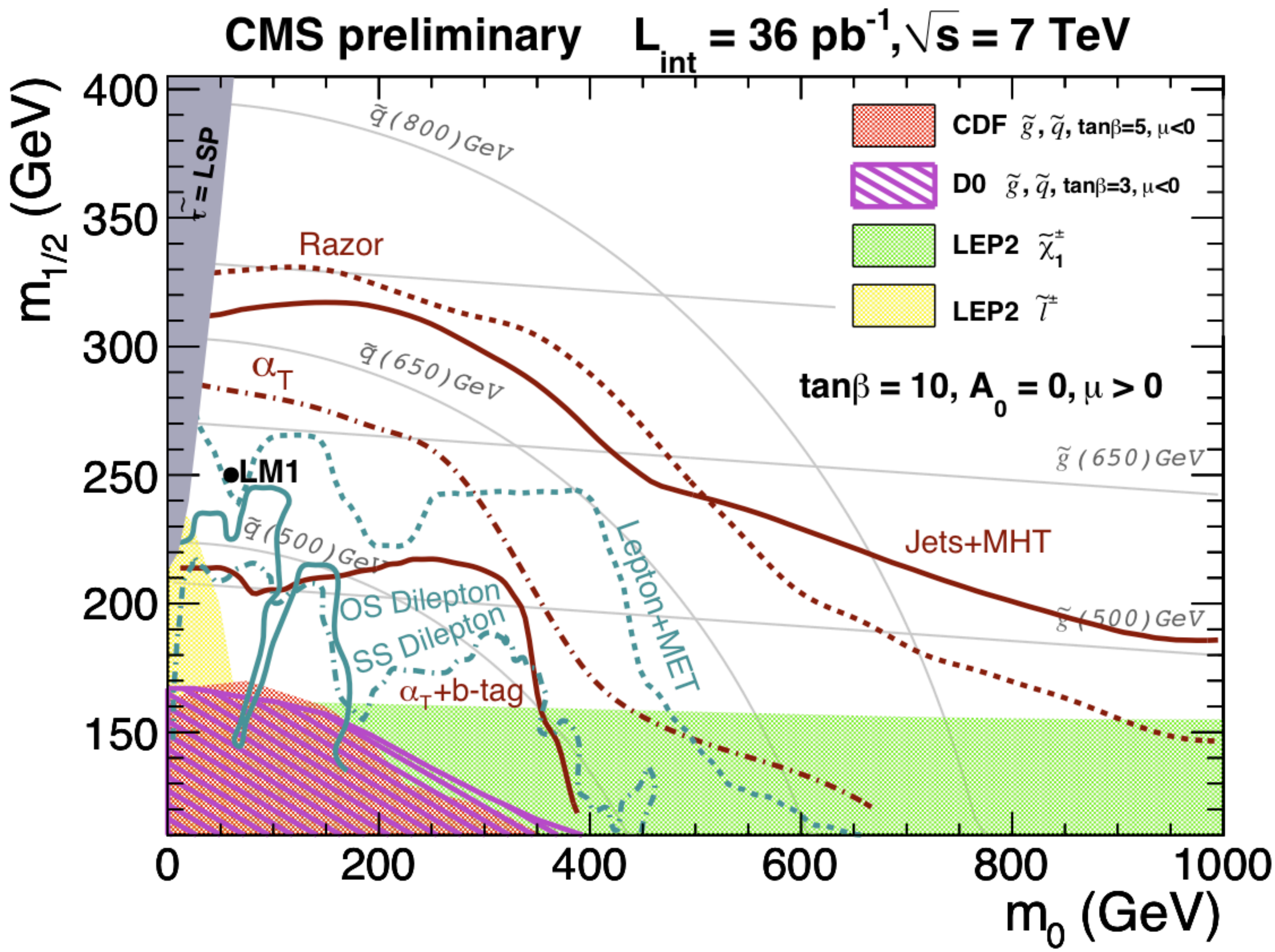


Can go to very low MET.
...no signal observed in any channel

Same-sign dilepton search: results

Search Region	ee	$\mu\mu$	$e\mu$	total	95% C.L. UL Yield
Lepton Trigger					
$E_T^{miss} > 80$ GeV					
MC	0.05	0.07	0.23	0.35	
BG predicted	$\mathbf{0.23^{+0.35}_{-0.23}}$	$\mathbf{0.23^{+0.26}_{-0.23}}$	$\mathbf{0.74 \pm 0.55}$	$\mathbf{1.2 \pm 0.8}$	
observed	**0**	**0**	**0**	**0**	**3.1**
$H_T > 200$ GeV					
MC	0.04	0.10	0.17	0.32	
BG predicted	$\mathbf{0.71 \pm 0.58}$	$\mathbf{0.01^{+0.24}_{-0.01}}$	$\mathbf{0.25^{+0.27}_{-0.25}}$	$\mathbf{0.97 \pm 0.74}$	
observed	**0**	**0**	**1**	**1**	**4.3**
H_T Trigger					
Low-p_T					
MC	0.05	0.16	0.21	0.41	
BG predicted	$\mathbf{0.10 \pm 0.07}$	$\mathbf{0.30 \pm 0.13}$	$\mathbf{0.40 \pm 0.18}$	$\mathbf{0.80 \pm 0.31}$	
observed	**1**	**0**	**0**	**1**	**4.4**
	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$	total	95% C.L. UL Yield
τ_h enriched					
MC	0.36	0.47	0.08	0.91	
BG predicted	$\mathbf{0.10 \pm 0.10}$	$\mathbf{0.17 \pm 0.14}$	$\mathbf{0.02 \pm 0.01}$	$\mathbf{0.29 \pm 0.17}$	
observed	**0**	**0**	**0**	**0**	**3.4**

Summary of CMSSM constraints



2 photons + MET + jet(s) search

http://arxiv.org/abs/1103.0953

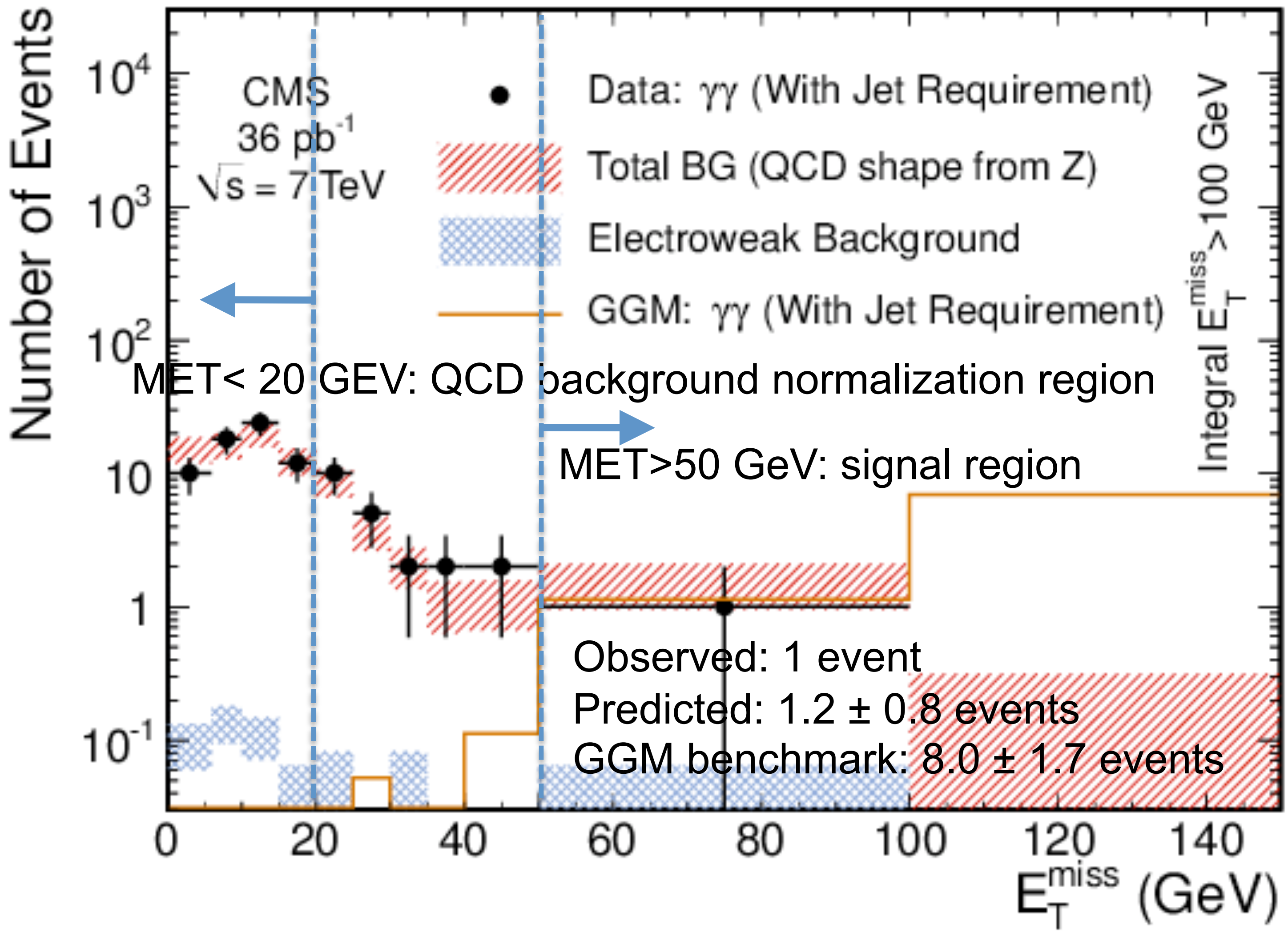
Trigger	Jets	Photons	MET
Single photon triggers (>99% efficient for signal)	≥1 jet pT>30, $\vert\eta\vert<2.6$, sep from both γ's with $\Delta R>0.9$	2 isolated γ's $\vert\eta\vert<1.4$, pT>30 GeV	MET >50 GeV

1. QCD (real or fake γ's) → Fake MET (dominant bkgrnd)
   - MET shape determined by resolution on jet recoil system
   - Measure MET shape using 2 control samples (Z→ee + jets & 2 Fake γ + jets)
   - Re-weight MET from control region according to pT (γγ)
   - Normalize to the low MET region in γγ sample.
2. EWK: W (e ν) + γ/fake γ ; e fakes γ → Real MET
   - Reweight eγ control sample using measured f(e→γ)

2 photon + MET + jet(s) search $\tilde{\chi}_1^0 \rightarrow \gamma + \tilde{G}$

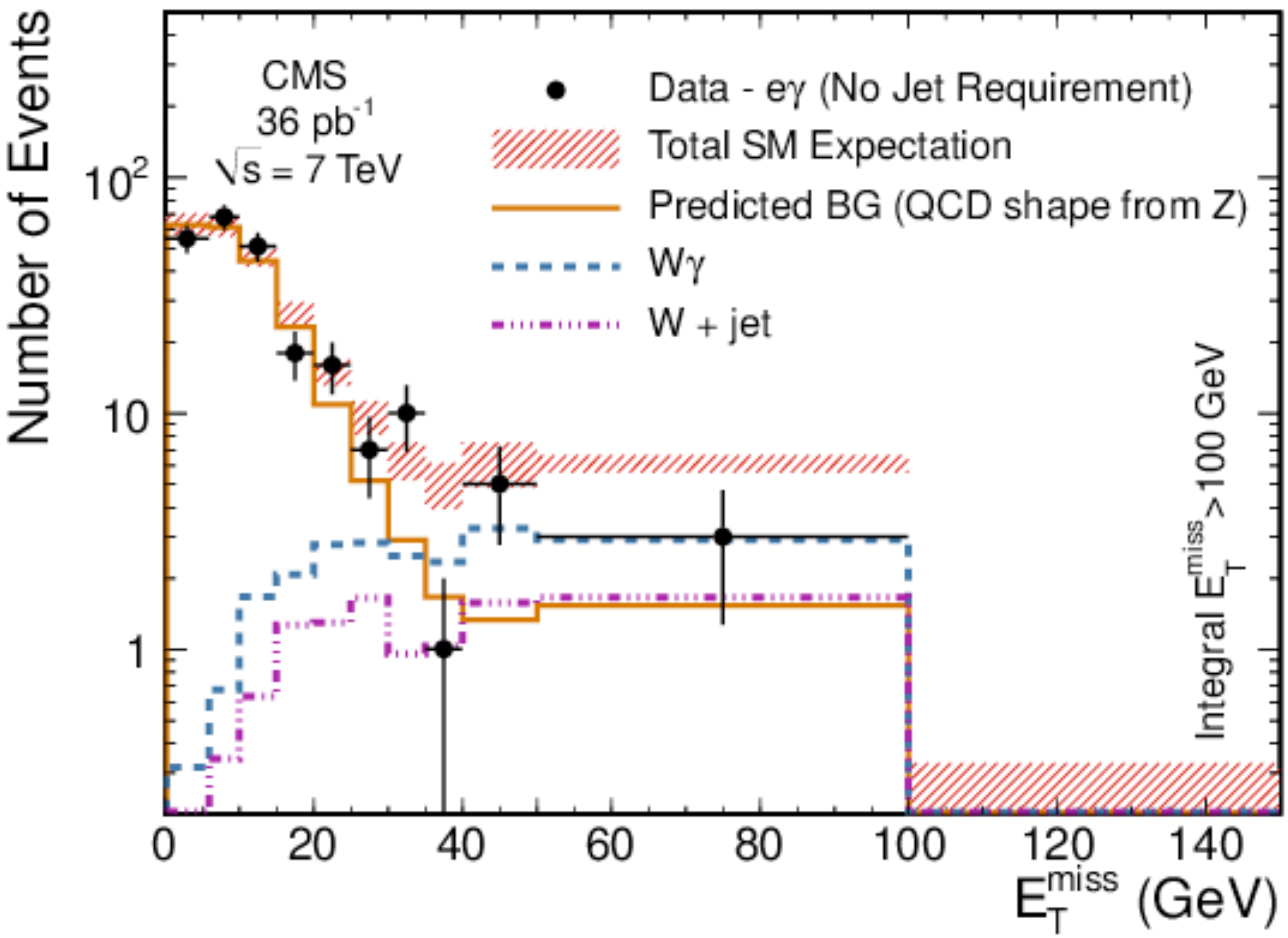
http://arxiv.org/abs/1103.0953

Oriented towards General Gauge Mediated (GGM) SUSY models.

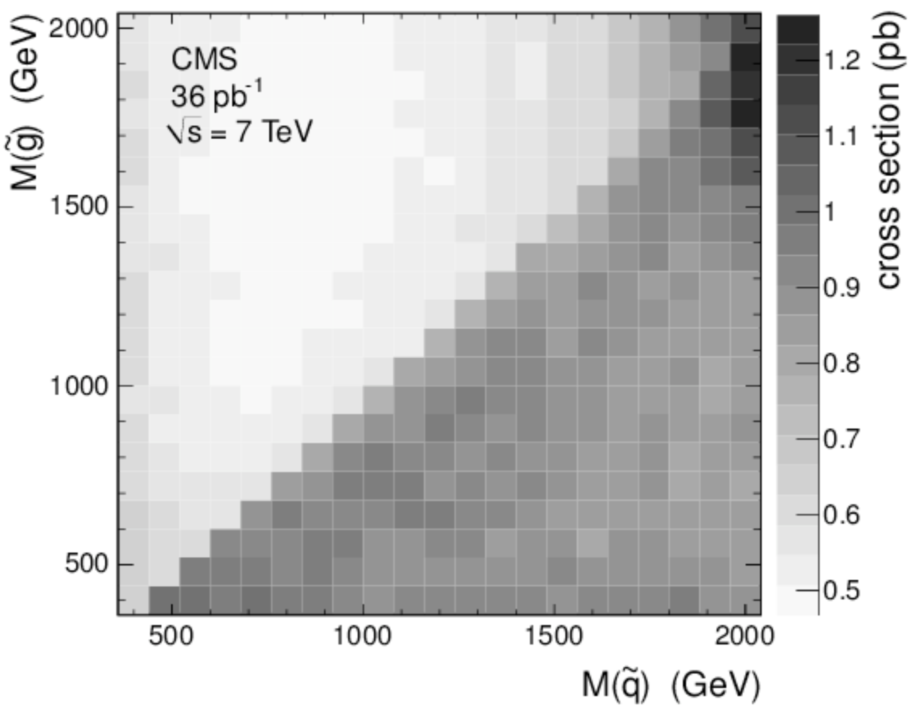


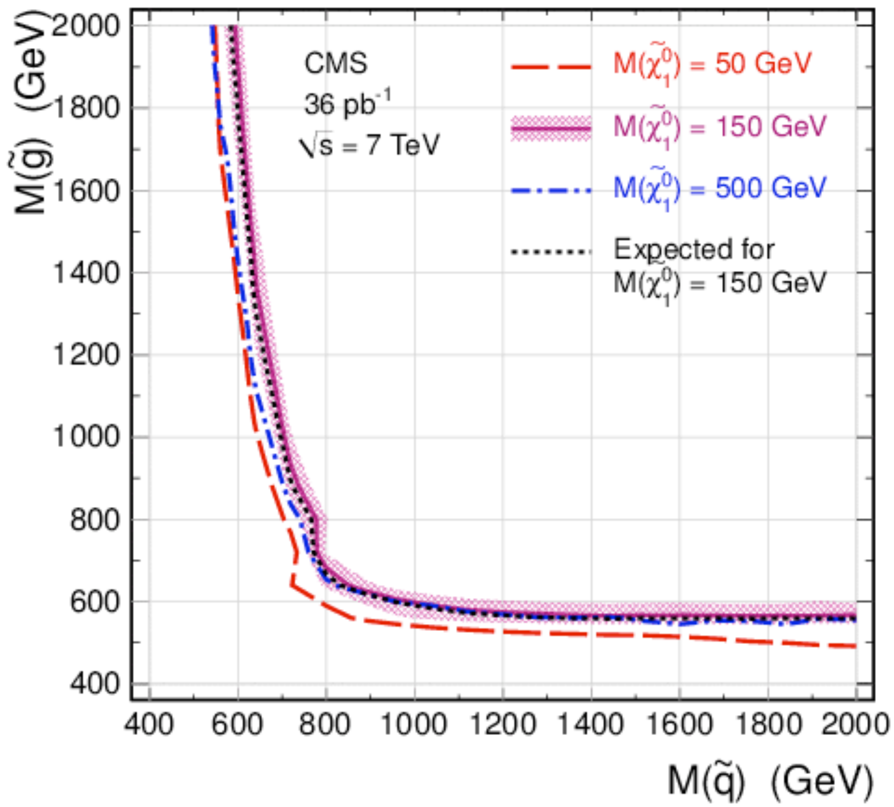
1 photon, 1 electron control sample

Observe excess over QCD background from SM processes with real MET.



2 photons + MET + jet(s) constraints



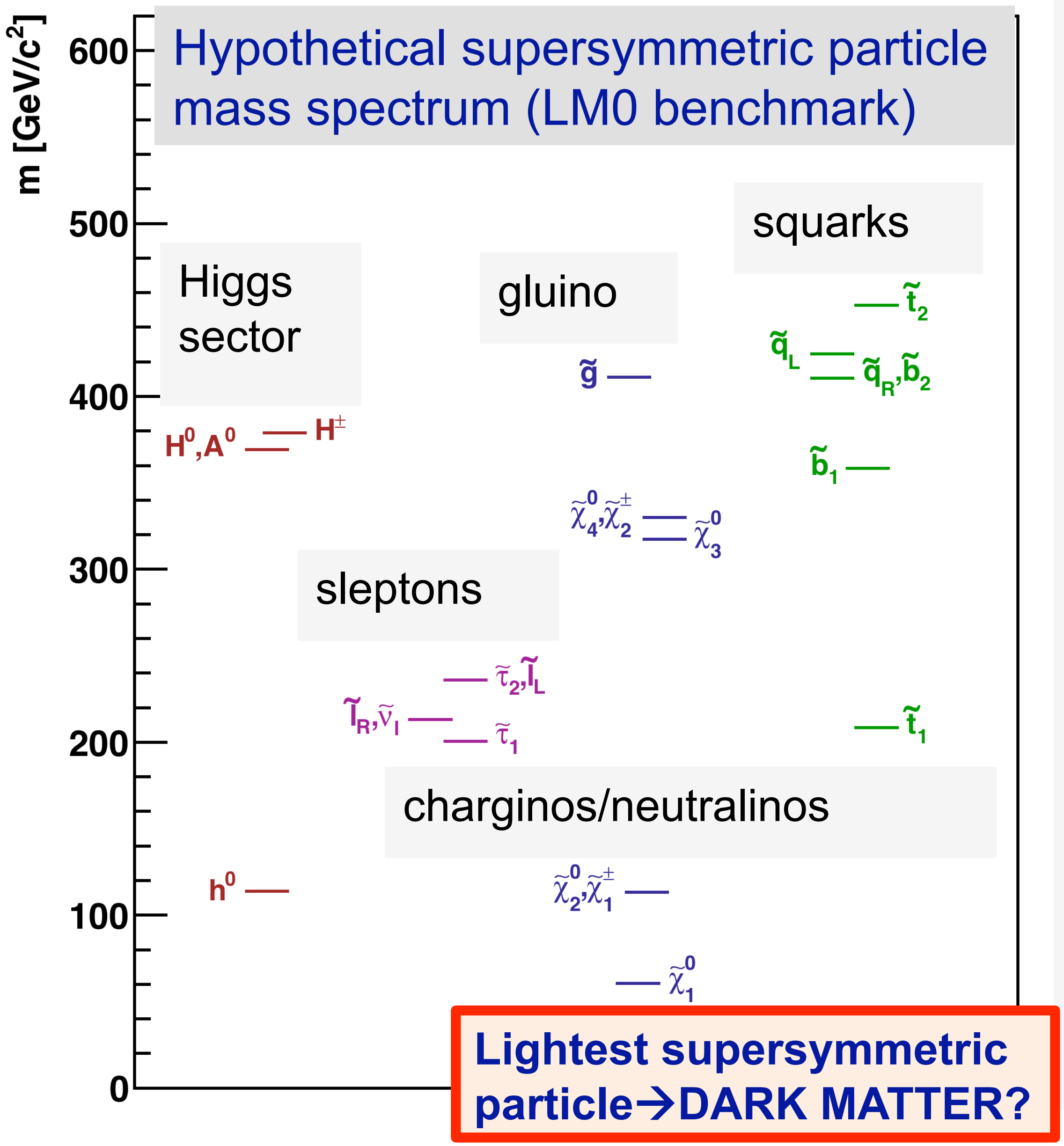


Conclusions/Prospects

- With 36 pb-1 at 7 TeV, we have surpassed the Tevatron sensitivity for SUSY searches.
- A broad range of SUSY analyses have been commissioned on 2010 data.
- Strategy is to use determine backgrounds using data-driven methods, with multiple methods for cross-checks.
- Explore as many distinct kinematic regions as possible.
- Hopes are high for 1 fb^{-1} by the summer. Should substantially extend our mass reach for SUSY.

Backup slides

A new spectroscopy?

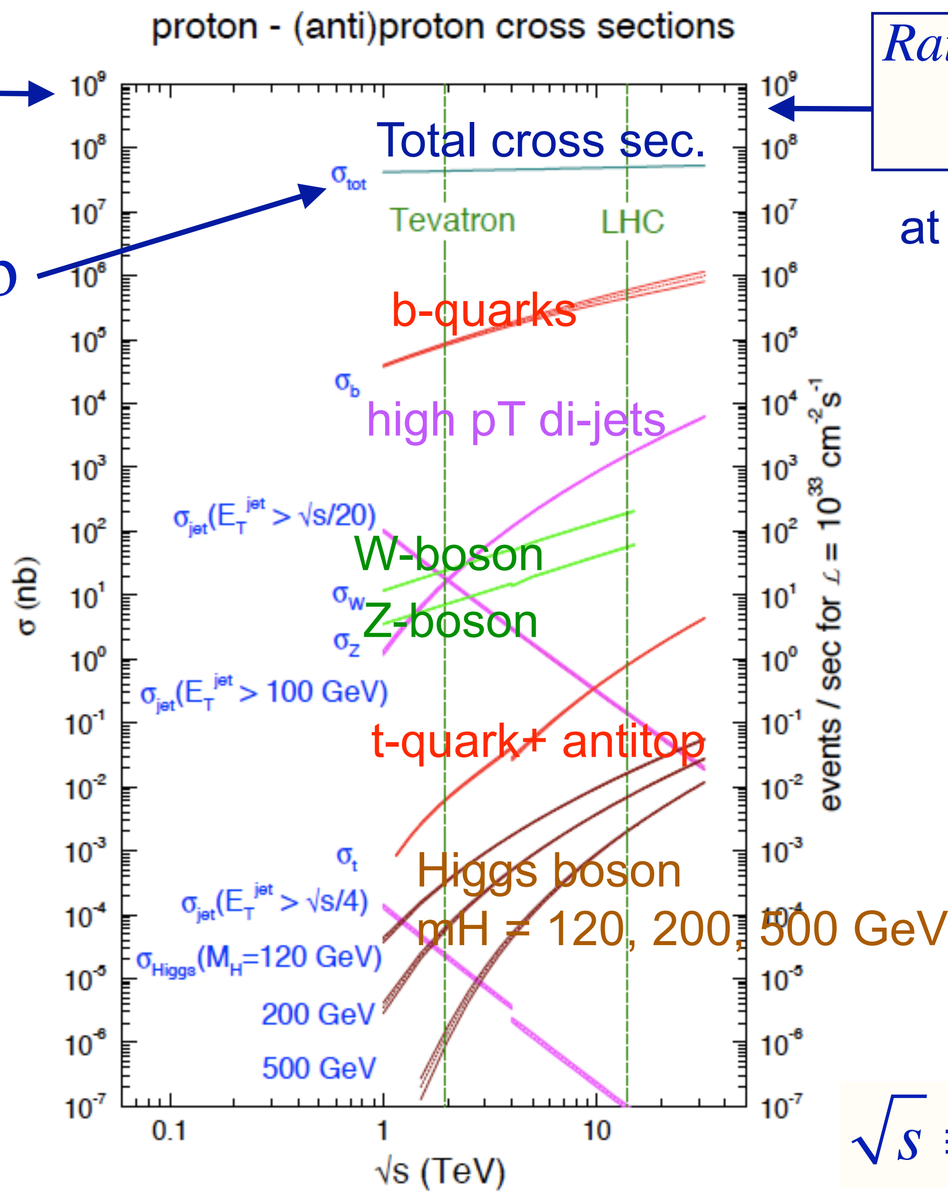


- Key element of SUSY searches: large (>200 GeV) missing momentum due to production of two LSPs.
- Broad range of signatures, with leptons, photons, b-quarks,...+ missing transerse momentum

Cross section vs. cm Energy in p + p

$\sigma(pp)$

$\sigma_{TOT} \sim 50$ mb



$$Rate(process\ i) = L_{accel} \cdot \sigma(process\ i)$$

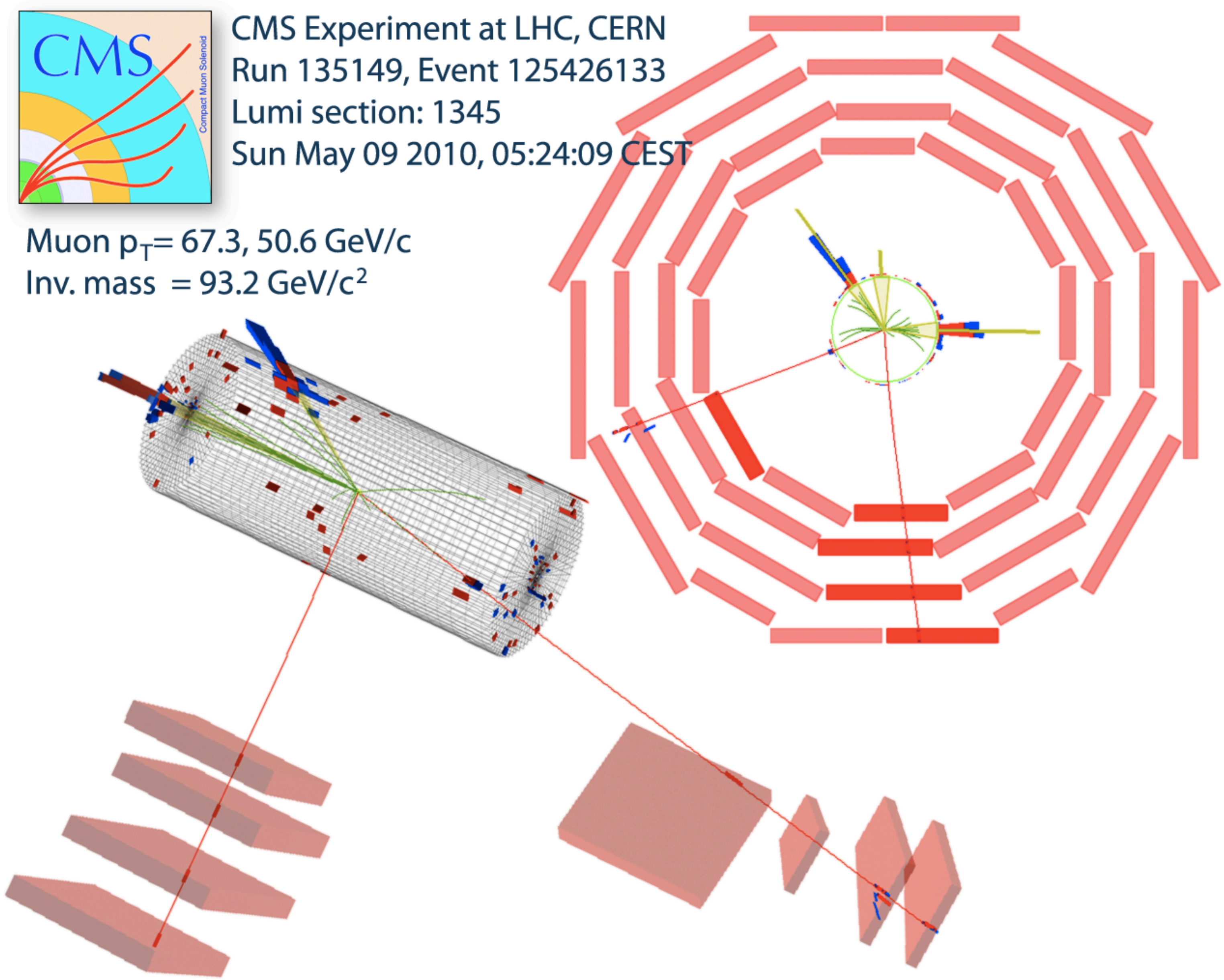
at $L_{accel} = 10^{33}$ cm^{-2} s^{-1}

In 2010, achieved
$L_{accel} = 2 \cdot 10^{32}$ cm^{-2} s^{-1}

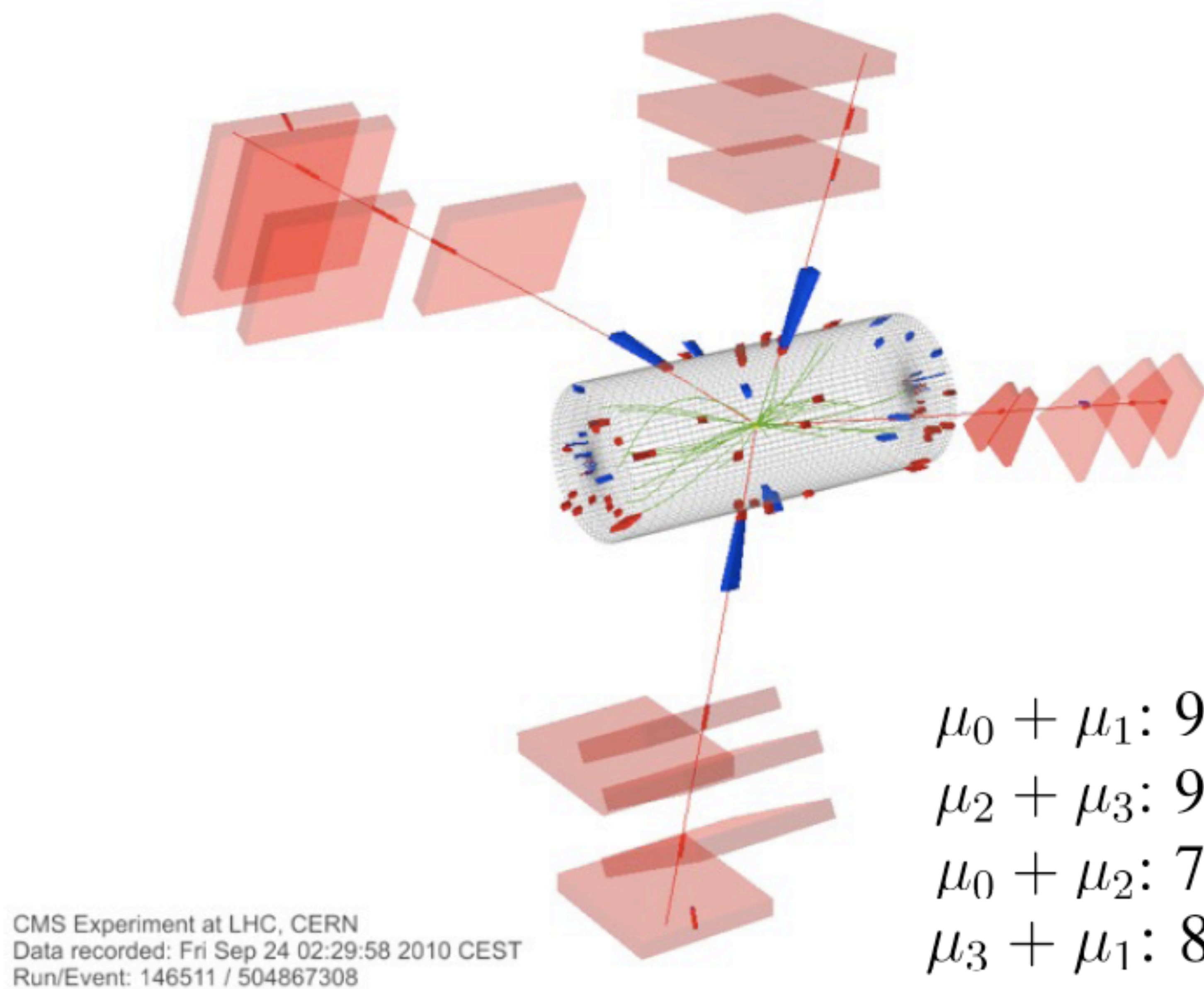
In 2011, may reach
$L_{accel} = 5 \cdot 10^{33}$ cm^{-2} s^{-1}

$\sqrt{s} \equiv CM$ energy

Z boson decaying to $\mu^+\mu^-$ in CMS



$pp \rightarrow Z\,(\rightarrow \mu^{+}\mu^{-}) + Z\,(\rightarrow \mu^{+}\mu^{-})$



$\mu_0 + \mu_1$: 92.15 GeV

$\mu_2 + \mu_3$: 92.24 GeV

$\mu_0 + \mu_2$: 70.12 GeV

$\mu_3 + \mu_1$: 83.1 GeV