Update on Searches for New Physics in CMS

CERN PH-LHC Seminar
January 31, 2012

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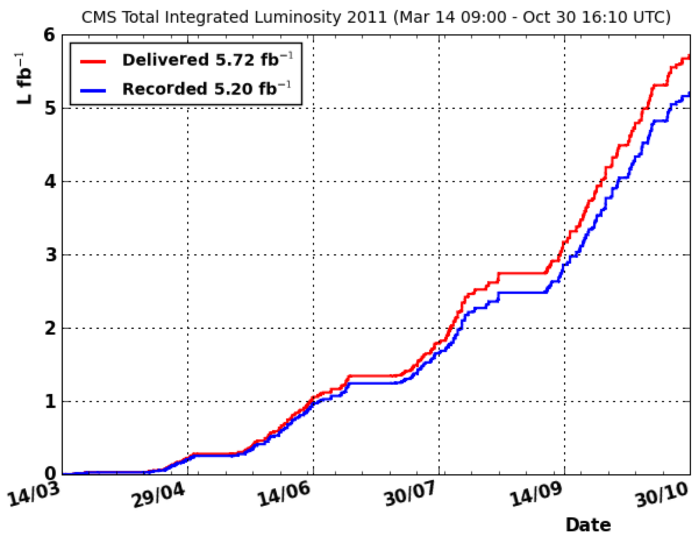
LHC and CMS Performances

Spectacular performance of the LHC in 2011

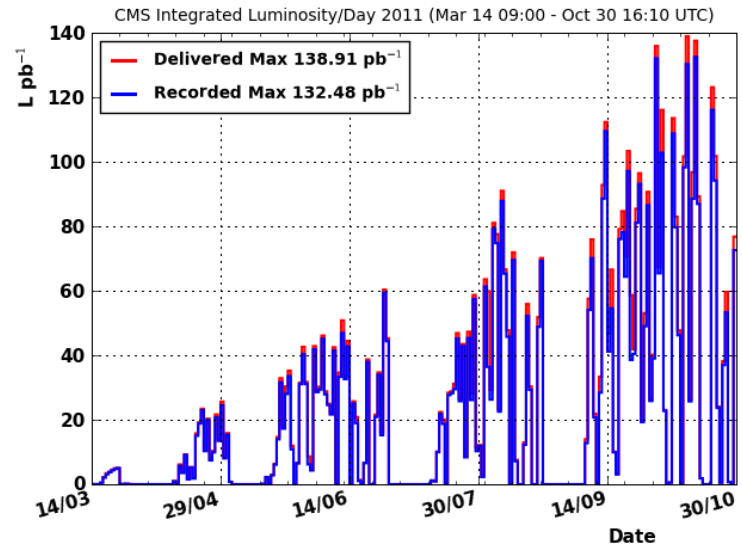
Thank you for delivering 5.7 fb^{-1}!

Eagerly awaiting this year's data

Total integrated luminosity



Integrated luminosity/day



Excellent performance of CMS experiment

→ 91% data-taking efficiency

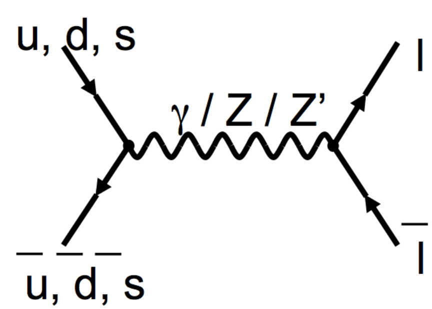
Outline

- I will cover "exotic" and SUSY searches:
  - Heavy Resonances and Extra Dimensions
    - → ordered in increasing complexity of final state
  - 4^{th} Generation Quarks
  - Leptoquarks
  - Long-lived Particles
  - SUSY and RPV SUSY
- Many new physics results with 2011 data
  - Analyses today done with ~1 - 4.7 fb^{-1}
    - → 5 new analyses with full dataset!
  - Impossible to cover everything
- **All CMS new physics results can be found at:**

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

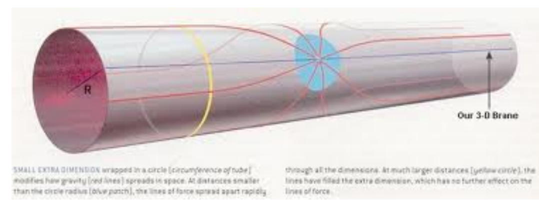
Searches for Heavy Resonances

- Search for excesses in invariant mass spectra
  - Bump hunt
  - Generic, powerful and track record for discovery in the past
  - Predicted by several BSM models with extended gauge symmetries
    - Z' and W' with SM-like couplings
    - Kaluza-Klein excitations from RS model of extra dimensions
    - E6 models
    - Technicolor
    - ….



Searches for Non-Resonant Signatures

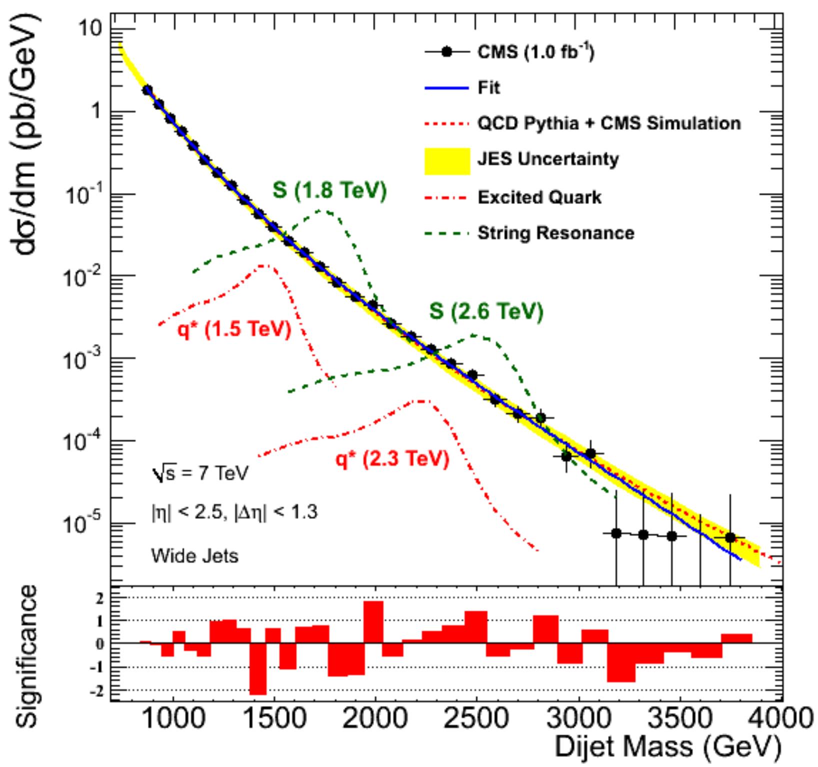
- Searches non-resonant excess in kinematic distributions and mass spectra
- Predicted by many Extra Dimension Models
  - Universal Extra Dimensions (UED)
    - All particles propagate the bulk
  - Large Extra Dimensions:
    e.g. ADD
    - Only Graviton propagates the bulk
  - Warped Extra Dimensions:
    e.g. Randall-Sundrum
    - Warped geometry



$$M_{Pl}^2 \sim M_D^{2+n} R^n$$

Dijet Resonances

High sensitivity to strongly produced new resonances decaying to pairs of jets predicted in numerous models: string phenomena, excited quarks, colorons, diquarks



Mass limits up to 4 TeV

Model	Excluded Mass (TeV)	
	Observed	Expected
String Resonances	4.00	3.90
E_6 Diquarks	3.52	3.28
Excited Quarks	2.49	2.68
Axigluons/Colorons	2.47	2.66
W′ Bosons	1.51	1.40

First search published with 1 fb^{-1}

[PLB 704, 123 (2011)]

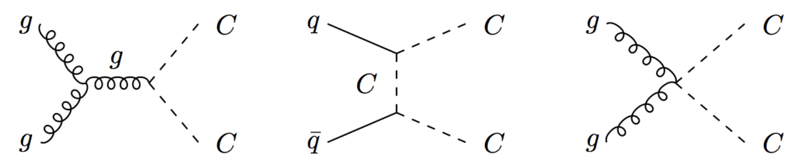
CMS PAS-EXO-11-016

Paired Dijet Resonances

$2.2\ fb^{-1}$

Extension of inclusive dijet resonance search

Paired dijet production predicted by several models: coloron, axigluon, hyperpions

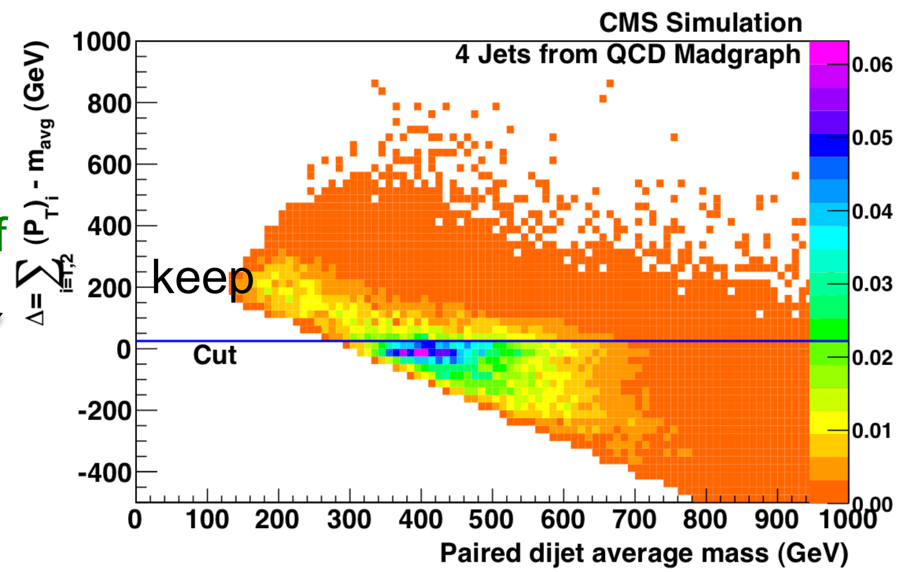


- Consider 4 leading jets with p_T > 150 GeV
  - Require dijet mass pairs to be equal, within resolution
  - Consider average dijet masses
- To further suppress QCD, cut in 2D plane of SumPt(jj) and Mjj(avg)

$$\Delta = \sum_{i=1,2} (P_T)_i - m_{avg}$$

  - Ensures a smoothly falling background
  - Enhances the resonant part of the signal

    → Would appear as a vertical stripe in plot on the right



QCD shaped by p_T thresholds

CMS PAS-EXO-11-016

Paired Dijet Resonances

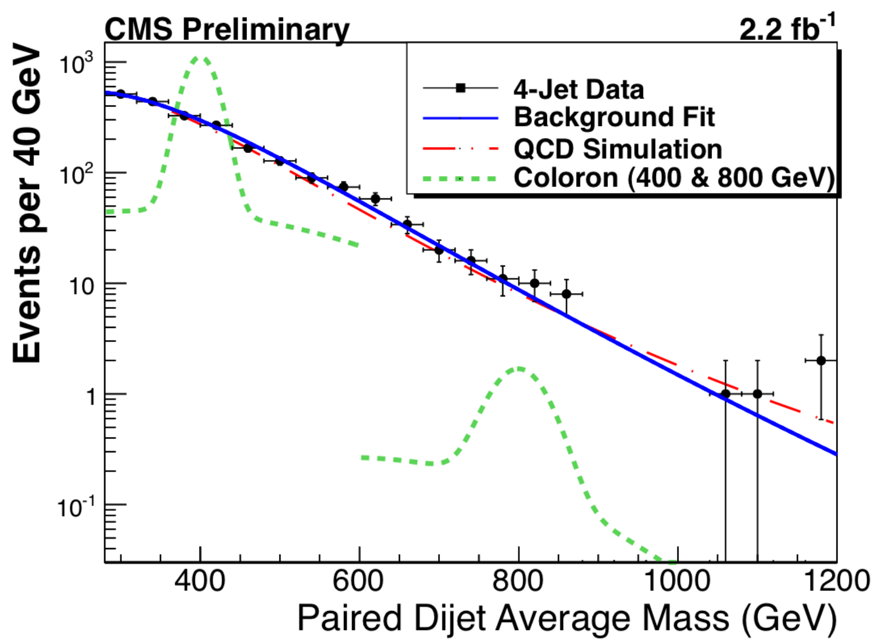
2.2 fb^{-1}

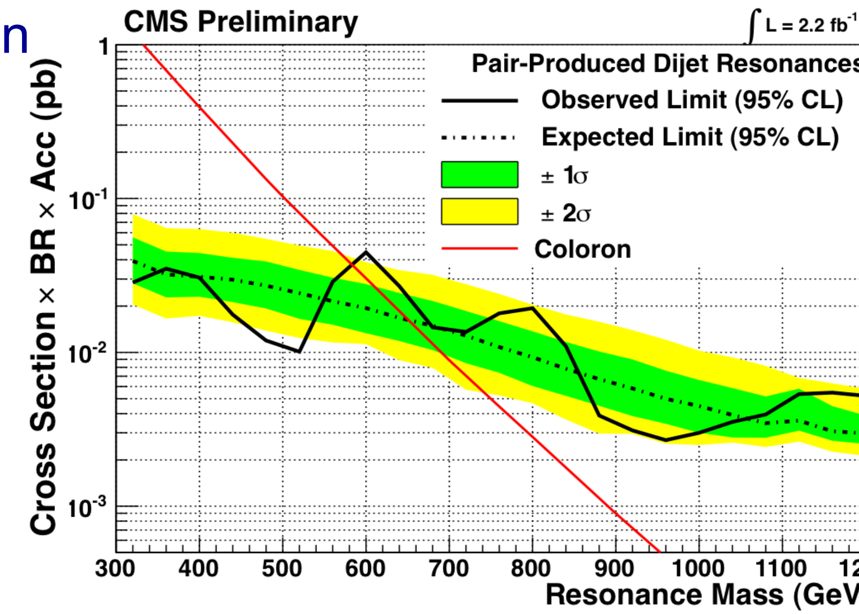
First such search from CMS

Use 4-parameter parameterization as in the inclusive Dijet Resonance search

Largest fluctuation ~615 GeV

2.7σ → 1.5σ after LEE

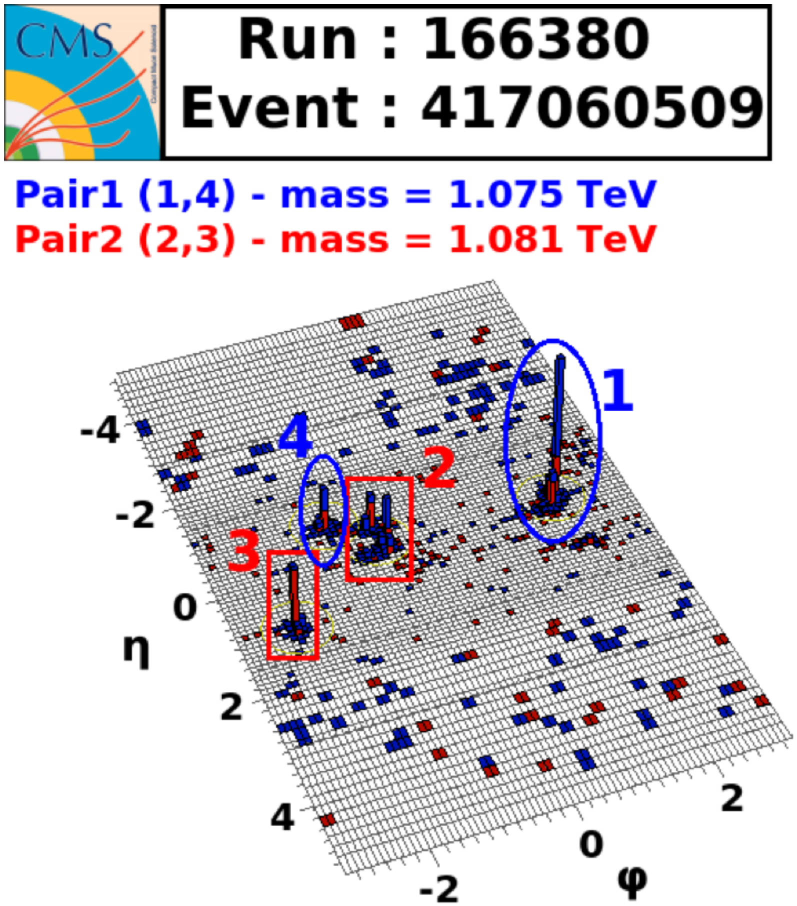


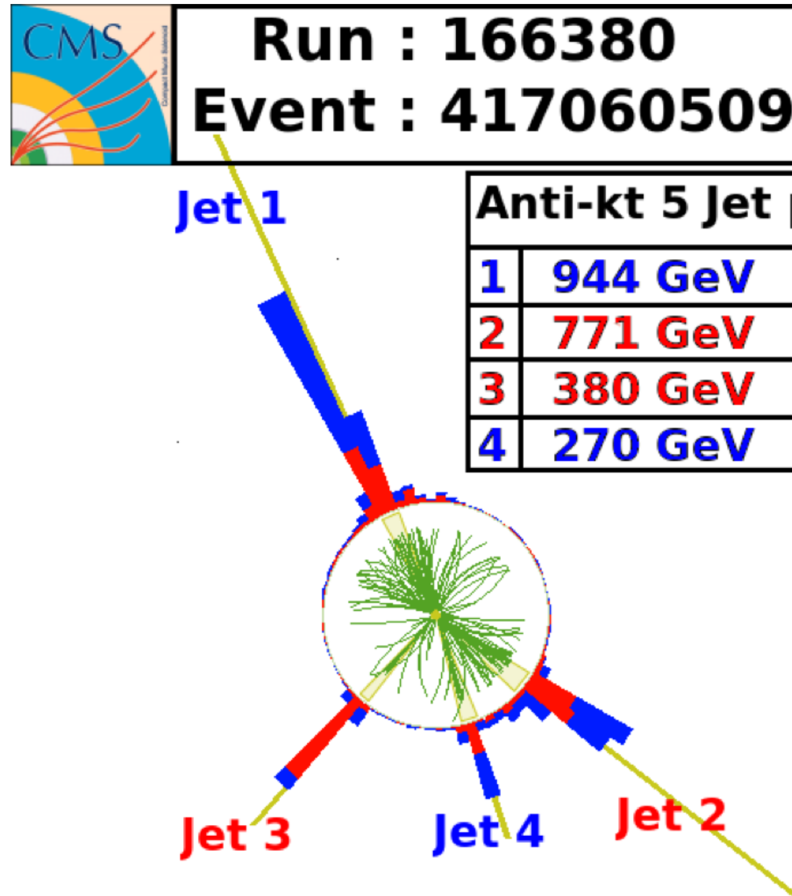


No evidence for new physics

Exclude pair production of colorons with mass between 320 – 580 GeV

High Paired Dijet Mass Event



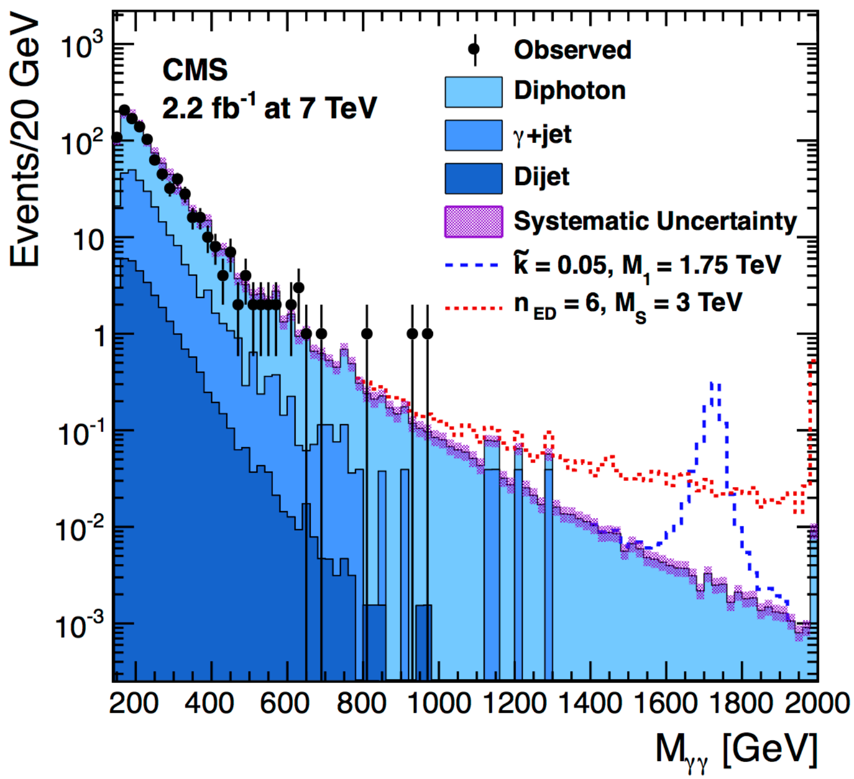


Anti-kt 5 Jet p_T	
1	944 GeV
2	771 GeV
3	380 GeV
4	270 GeV

Diphoton Mass Spectrum

2.2 fb^{-1}

Search for resonant and non-resonant diphoton production



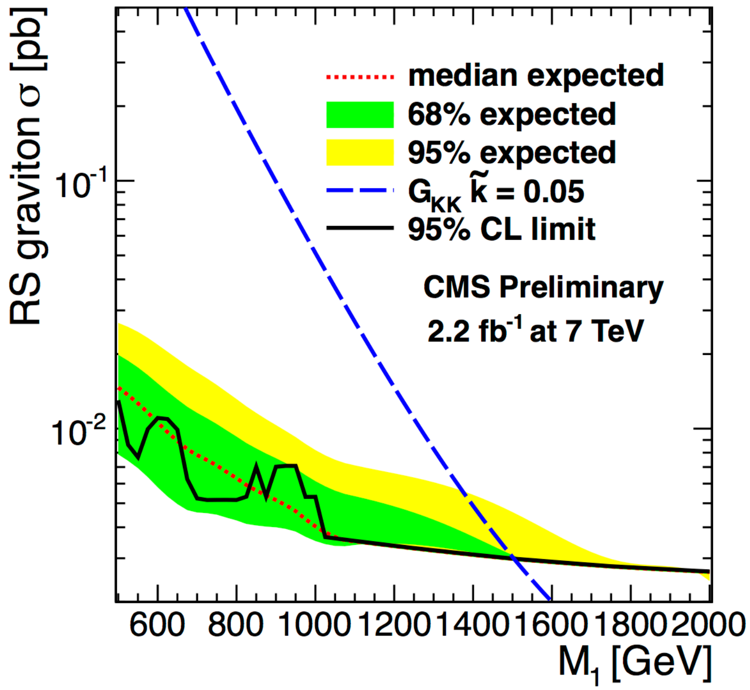
- Select two photons in barrel with E_T > 70 GeV and $M_{\gamma\gamma}$ > 140 GeV
- Optimal search region for ADD
  $M_{\gamma\gamma}$ > 0.9 TeV
  - Observed: 2 events
  - Background: 1.5 ± 0.3 events
    - Primarily SM diphoton production
      → Estimated with Pythia + NLO (DIPHOX+GAMMA2MC)

Accepted by PRL arXiv:1112.0688v1

Limits on Extra Dimensions and RS gravitons

Exclusion limits on RS gravitons (0.86-1.84 TeV) and several ADD models (2.3-3.8 TeV)

2.2 fb^{-1}



Effective Planck scale (TeV) in ADD

K factor	GRW	Hewett		HLZ (n_{ED})					
		pos.	neg.	2	3	4	5	6	7
1.0	2.94	2.63	2.28	3.29	3.50	2.94	2.66	2.47	2.34
1.6	3.18	2.84	2.41	3.68	3.79	3.18	2.88	2.68	2.53

RS gravitons: Mass (TeV)

$\tilde{k}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10	0.11
M_1 [TeV]	0.86	1.13	1.27	1.39	1.50	1.59	1.67	1.74	1.80	1.84	1.88

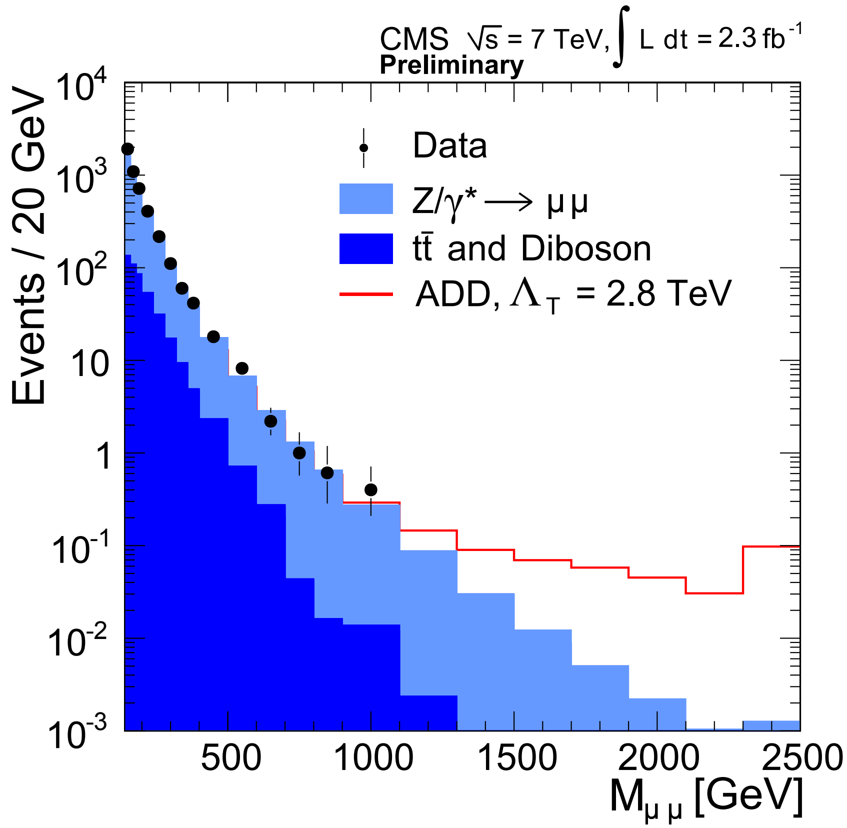
CMS PAS-EXO-11-087

Dilepton Mass Spectra

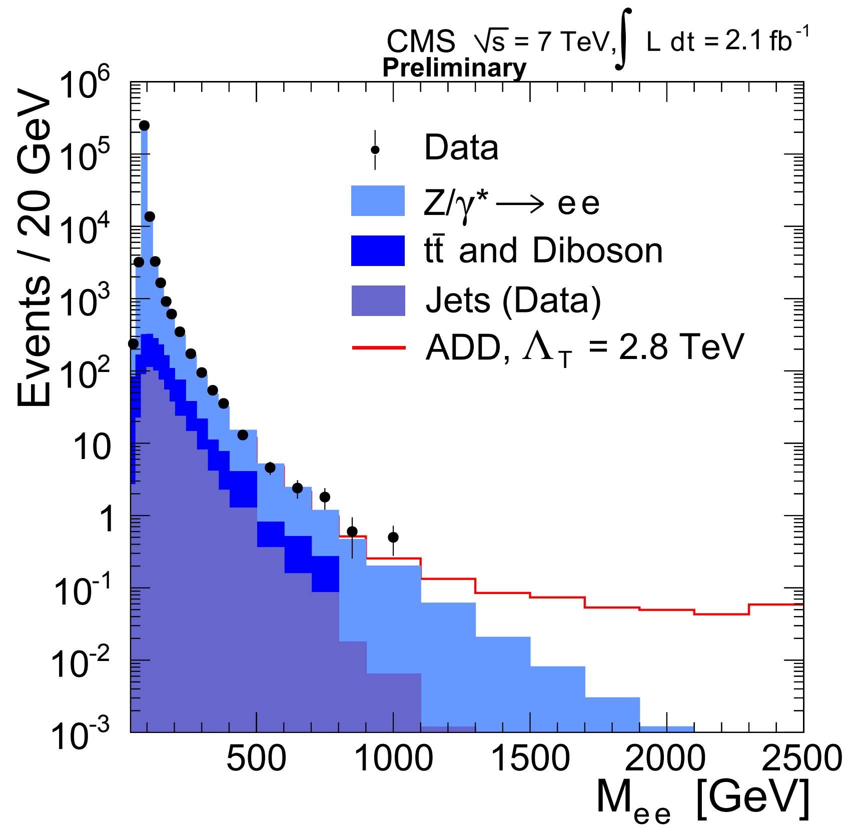
~2 fb^{-1}

Search for non-resonant excess in $M_{\ell\ell}$

di-muons



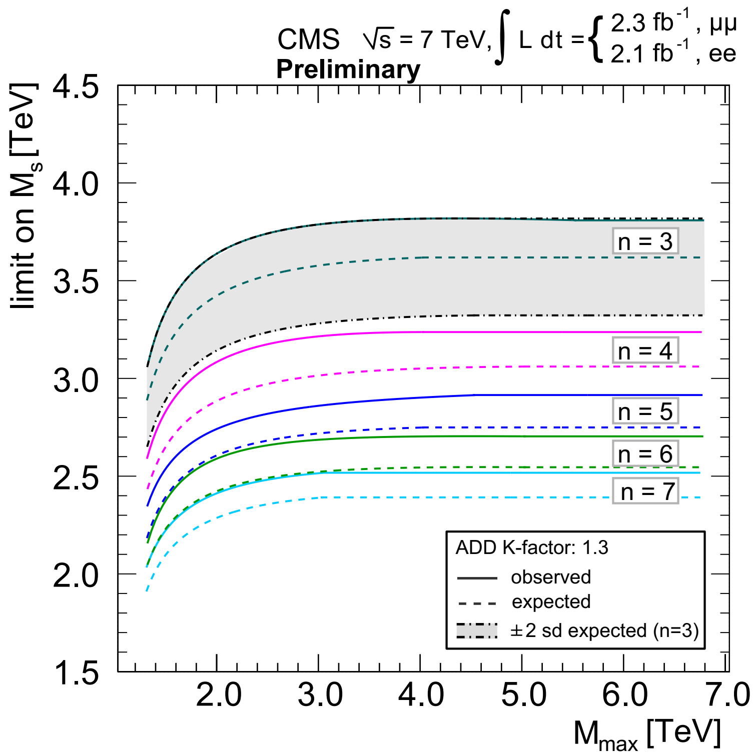
di-electrons



CMS PAS-EXO-11-087

Limits on Large Extra Dimensions

~2 fb^{-1}



Search for excess above 1.1 TeV

Combined ee and μμ exclusion limits for ADD models for several parameters (2.5-3.8 TeV)

Combined ee and μμ with γγ:

ADD K-factor	Λ_T [TeV] (GRW)	M_s [TeV] (HLZ) n = 2	n = 3	n = 4	n = 5	n = 6	n = 7
μμ, ee, and γγ							
1.3 (μμ and ee), 1.6 (γγ)	3.3	4.1	3.9	3.3	3.0	2.8	2.6

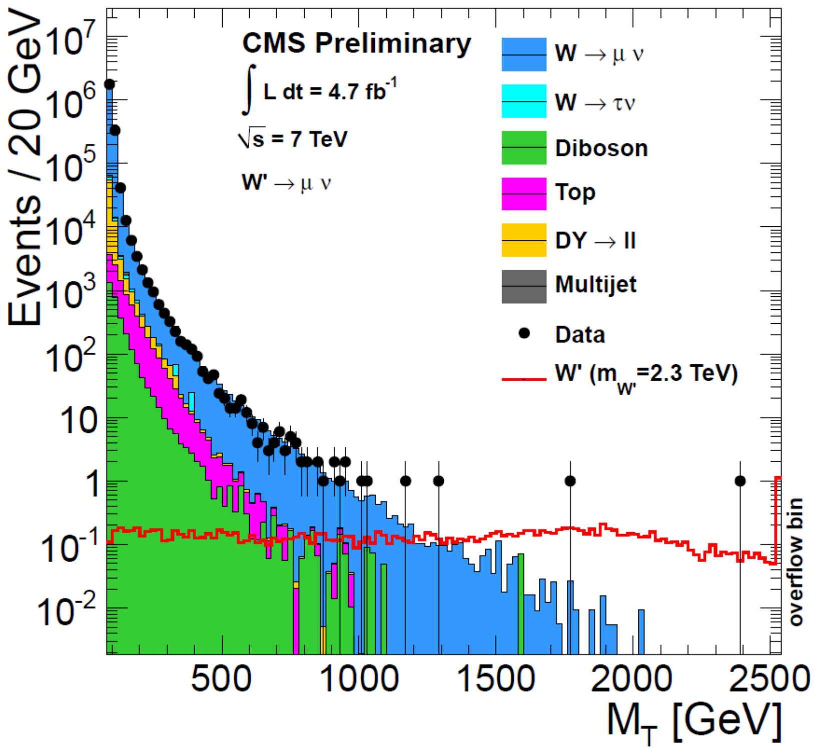
CMS PAS-EXO-11-024

Lepton+MET Channel

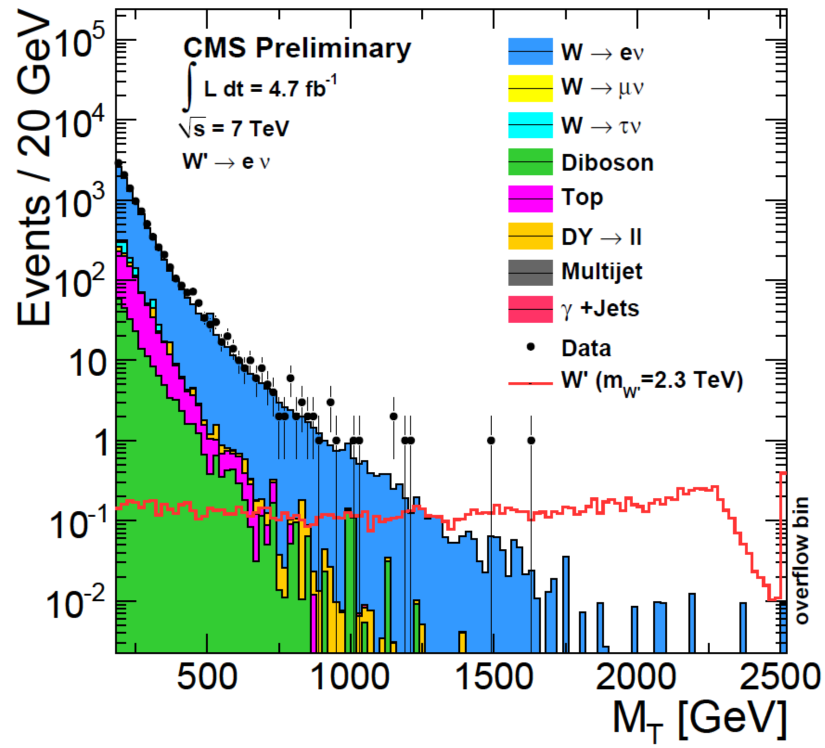
4.7 fb^{-1}

Look for an excess in the transverse mass spectrum

μ+MET



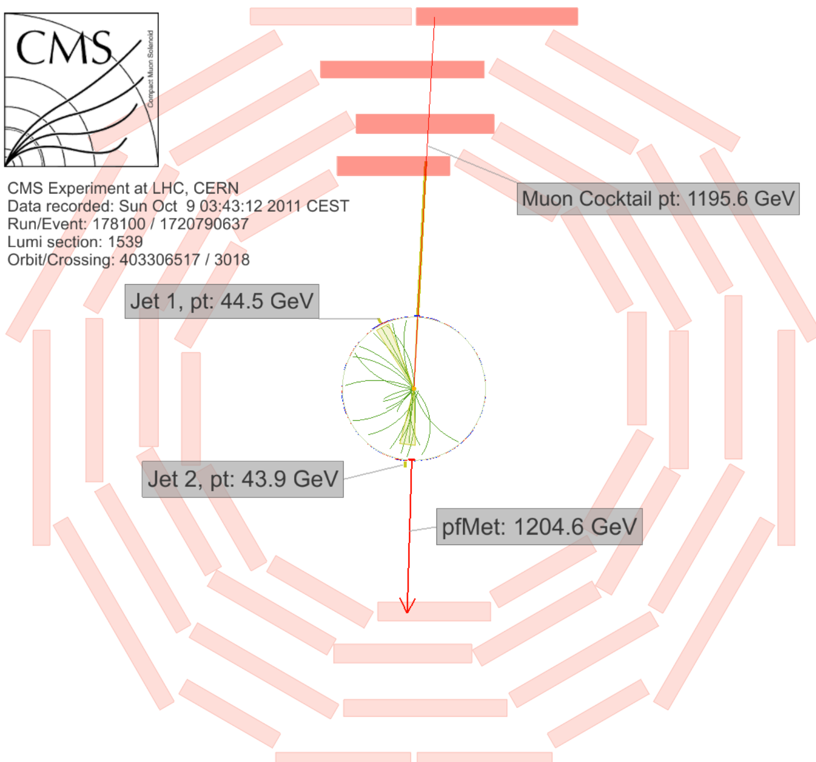
e+MET



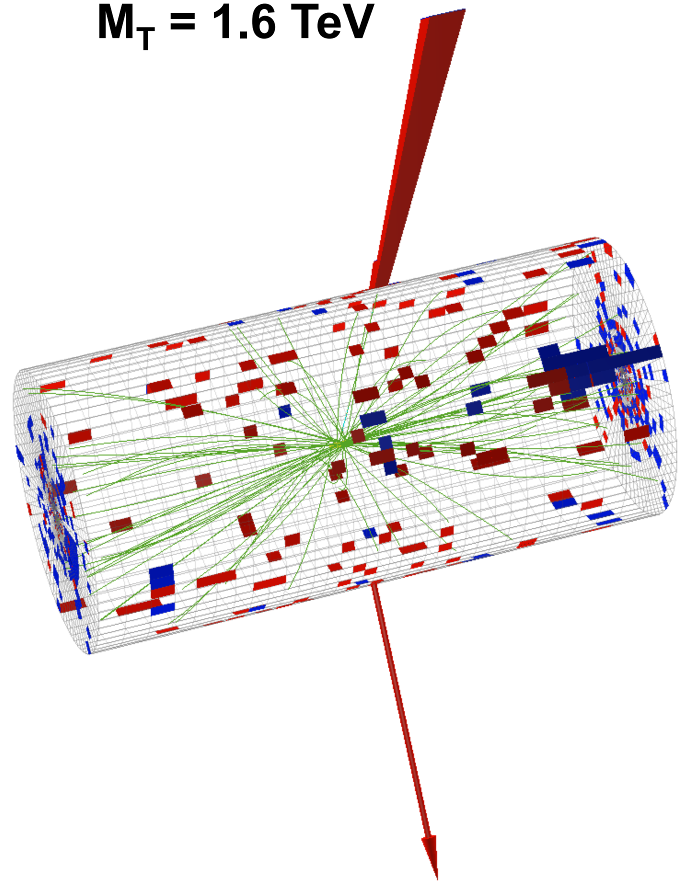
$$M_T = \sqrt{2 \cdot p_T^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos \Delta\phi_{\ell,\nu})}$$

Highest M_T Events

μ+MET
M_T = 2.4 TeV

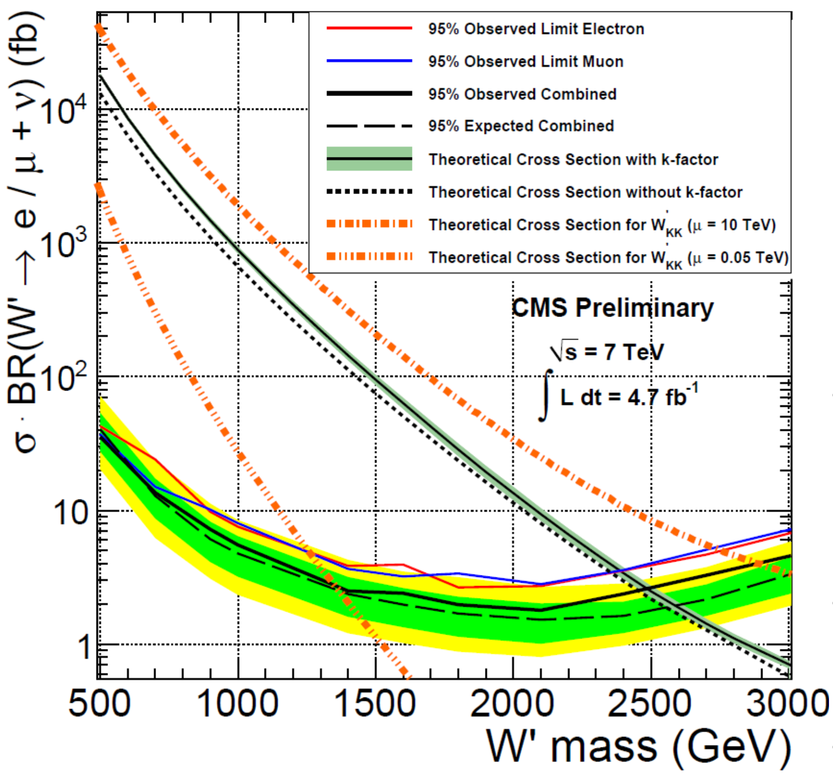


e+MET
M_T = 1.6 TeV



Limits on W’

4.7 fb^{-1}



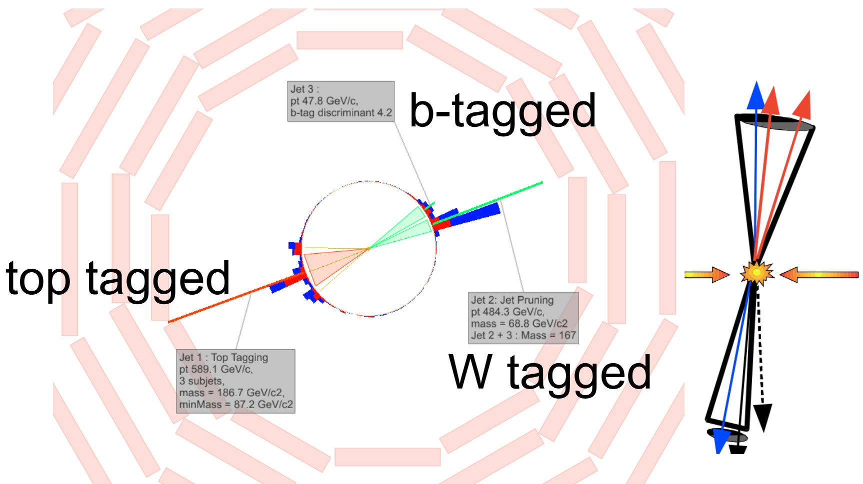
- Exclusion limits for different W′ models:
  - RH W′ with SM-like couplings
  - LH W′ including their interference with the SM W
  - Kaluza-Klein W'_{KK}-states in the framework of UED
- First exclusion limits where interference has been considered for the leptonic channels
- W’ with SM-like couplings is excluded below 2.5 TeV
- Including interference, we exclude below:
  - → 2.63 TeV (constructive)
  - → 2.43 TeV (destructive)

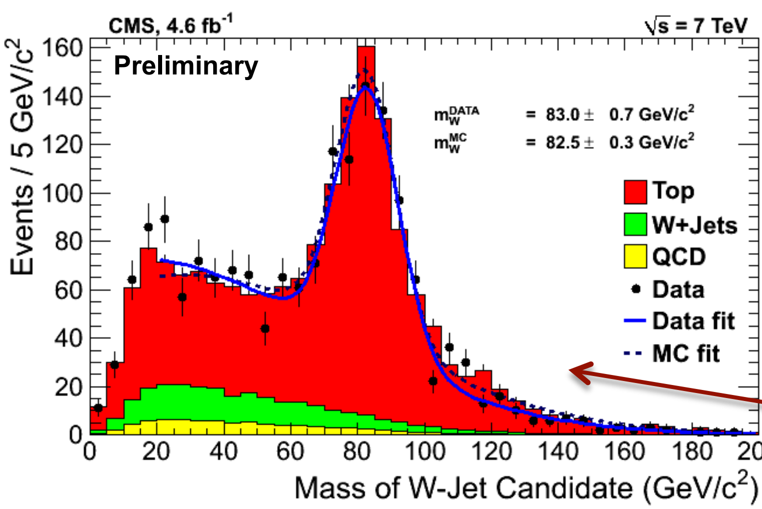
CMS PAS-EXO-11-006

ttbar Resonances

4.6 fb^{-1}

Boosted All-Hadronic State





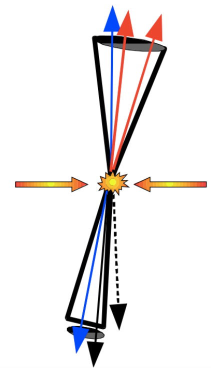
Top decay products either partially or fully merged into one jet.

Top-tagging tools using jet substructure with Cambridge-Aachen R=0.8 jets.

- 1+1 or Type 1
  - dijet event: two fully merged top candidates
- 1+2 or Type 2
  - trijet event: one fully merged top jet in one hemisphere, and two jets in the other (a b-jet and a merged W-jet)

W mass within jets in μ + boosted jet sample used to measure subjet energy scale

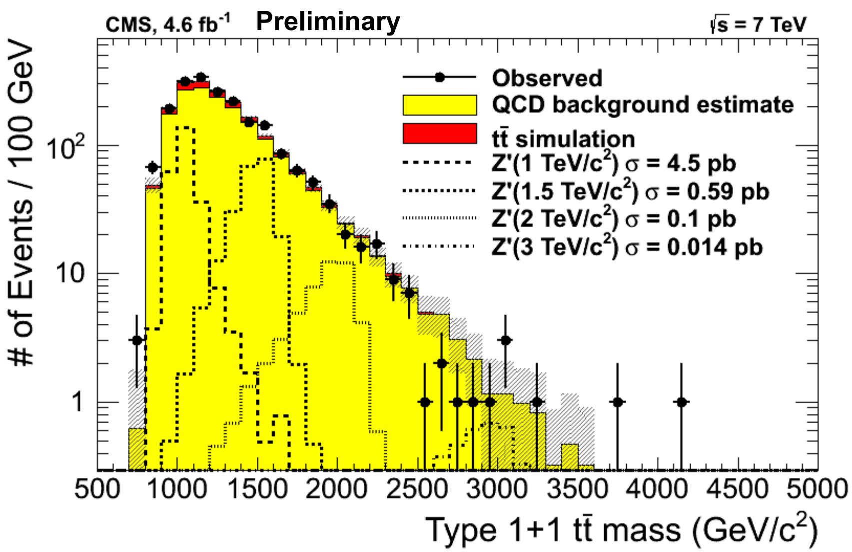
ttbar Resonances



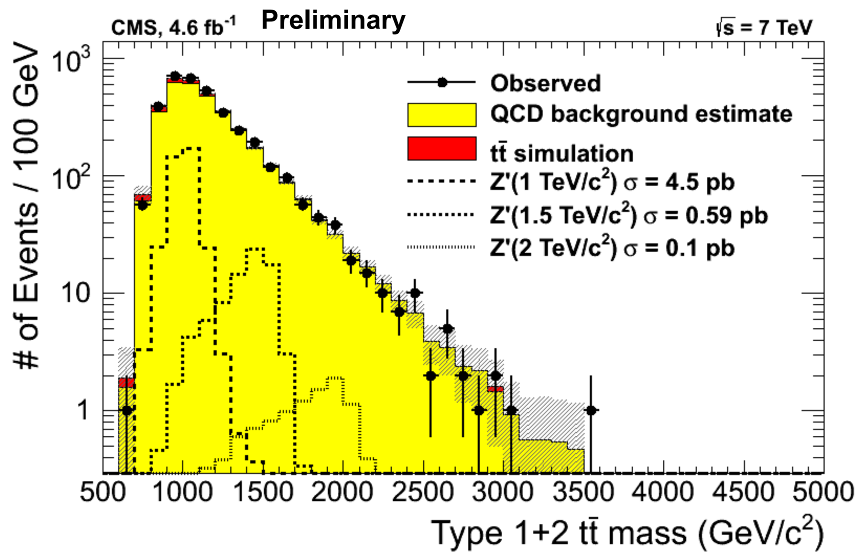
CMS PAS-EXO-11-006

4.6 fb^{-1}

Type 1+1 mass



Type 1+2 mass



- Type 1 jet p_T > 350 GeV
- W jet p_T > 200 GeV
- Other jet p_T > 30 GeV
- Plus jet mass and *mass drop* requirements consistent with top and W
- Data-driven techniques used in QCD background estimate

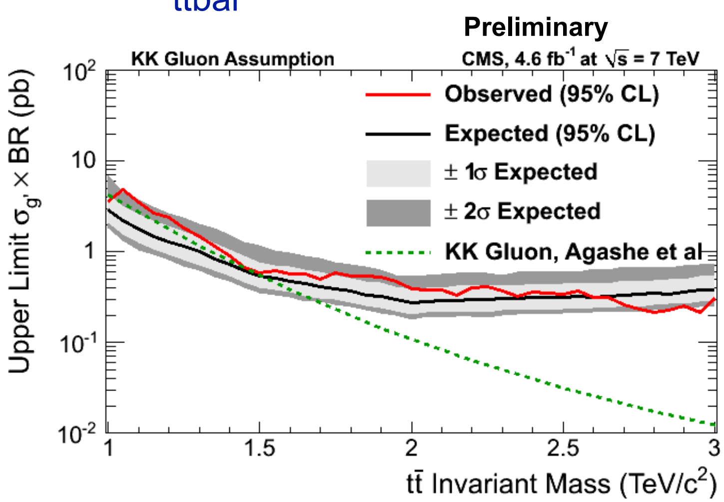
CMS PAS-EXO-11-006

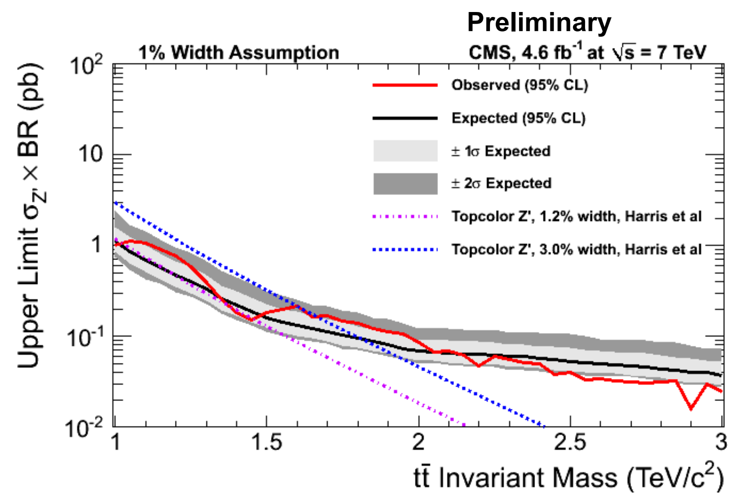
ttbar Resonances

4.6 fb^{-1}

Exclusion limits on Z' of varying widths with SM couplings and RS KK gluon models

New physics enhancements to σ_{ttbar} must be less than 2.8 times NLO for M_{ttbar} > 1 TeV





KK Gluon
1.0 < M < 1.4 TeV

Topcolor Z'
1.0 < $M_{Z'}$ < 1.4 TeV (1.2% width)
1.0 < $M_{Z'}$ < 1.7 TeV (3% width)
1.0 < $M_{Z'}$ < 1.9 TeV (10% width)

CMS PAS-EXO-11-071

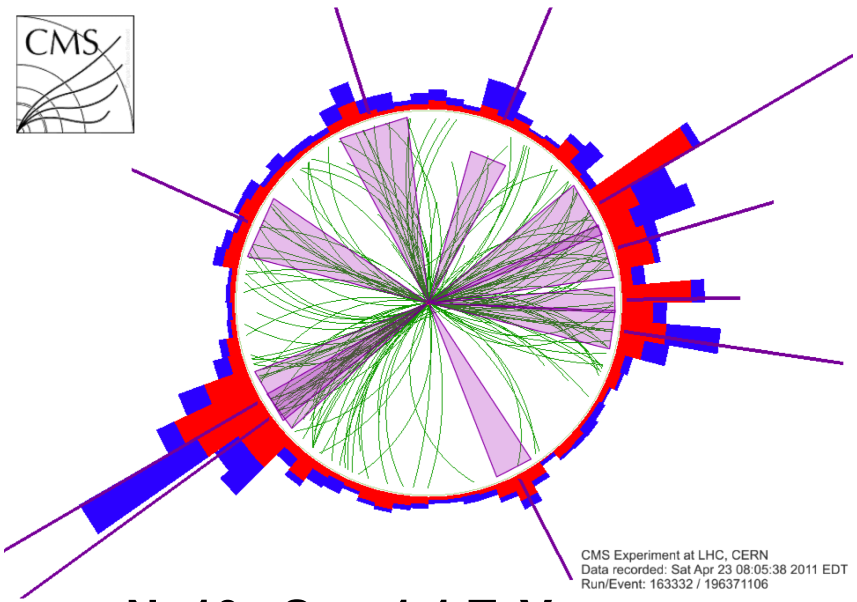
Black Holes

4.7 fb^{-1}

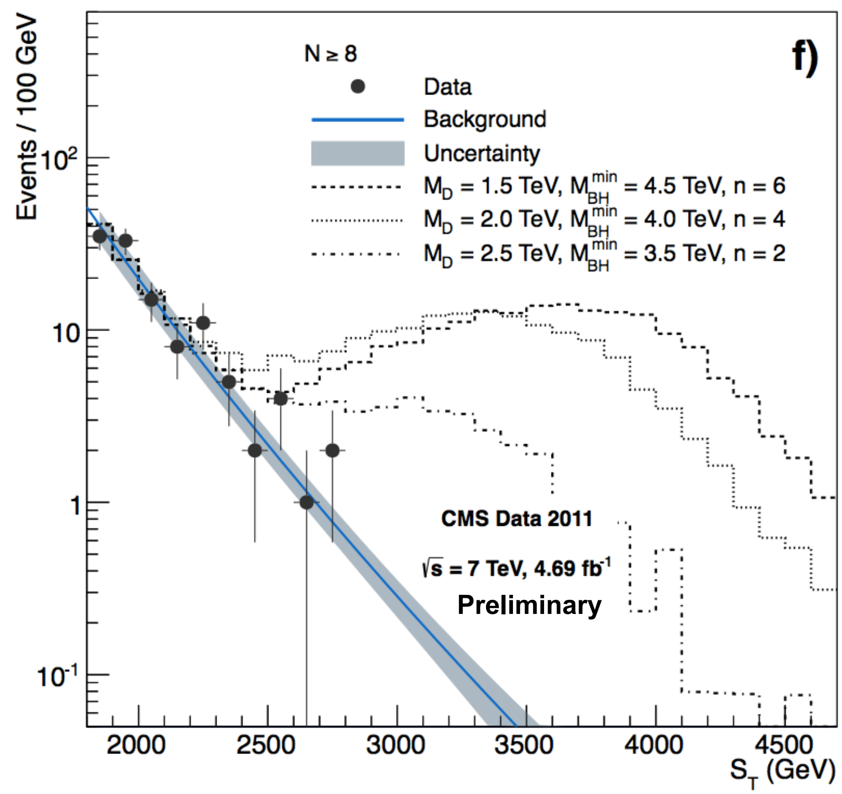
BH production in ADD model (large flat extra spatial dimensions)

- Democratic and isotropic decay
- High S_T events (total transverse energy)
- High total multiplicity (e.g. ≥4)

Use N=2, 3 for background model.



N=10 S_T = 1.1 TeV



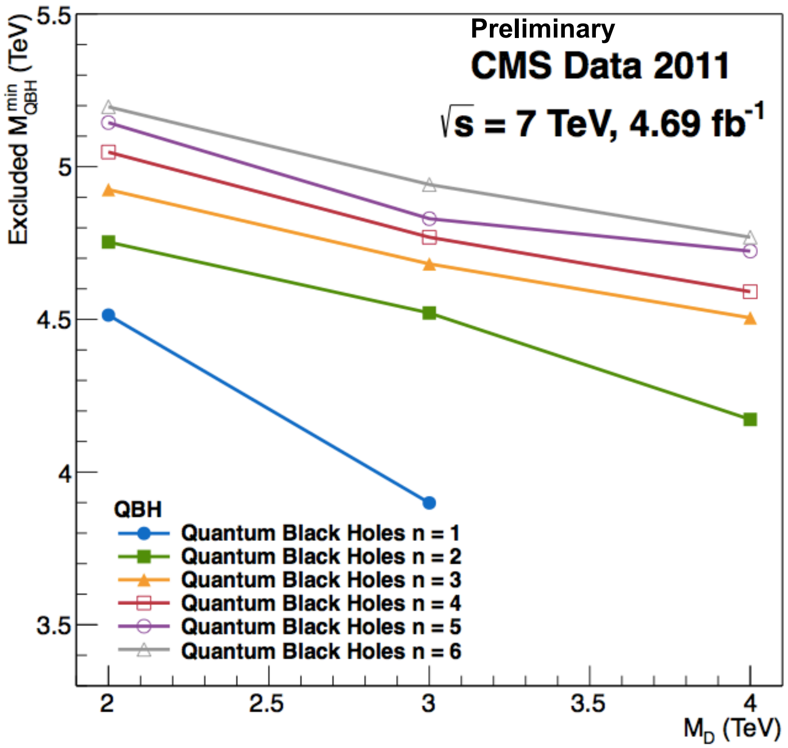
CMS PAS-EXO-11-071

Limits on Black Holes

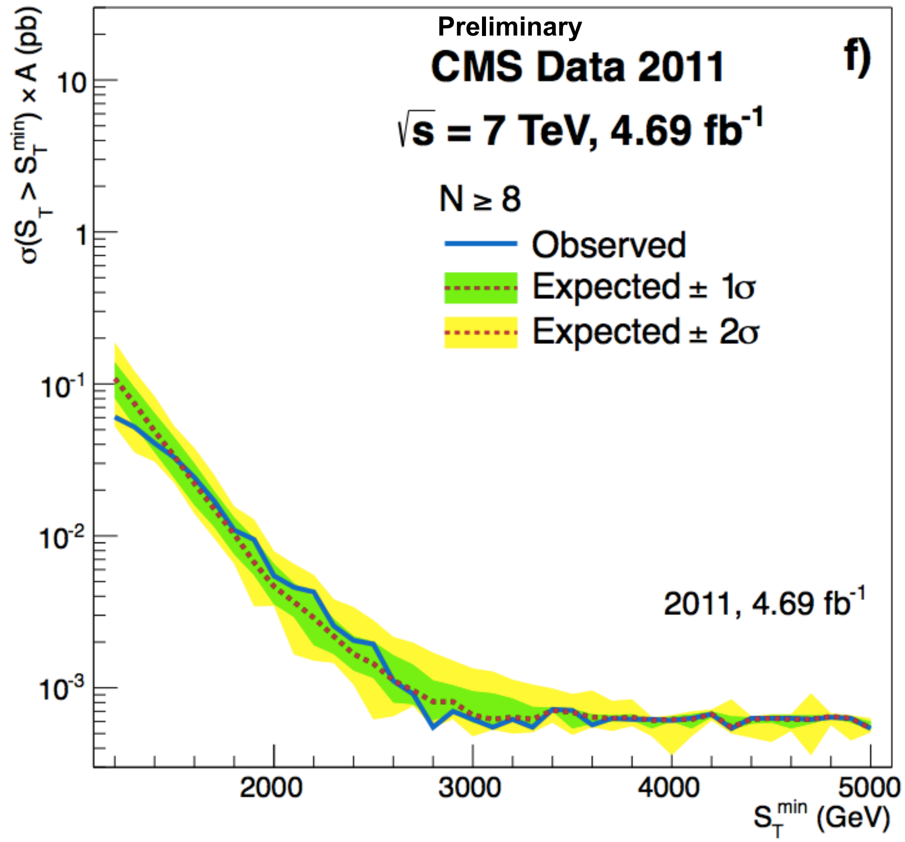
4.7 fb^{-1}

Model-specific limits on minimum black hole (ADD), string balls, and quantum black holes (→NEW)

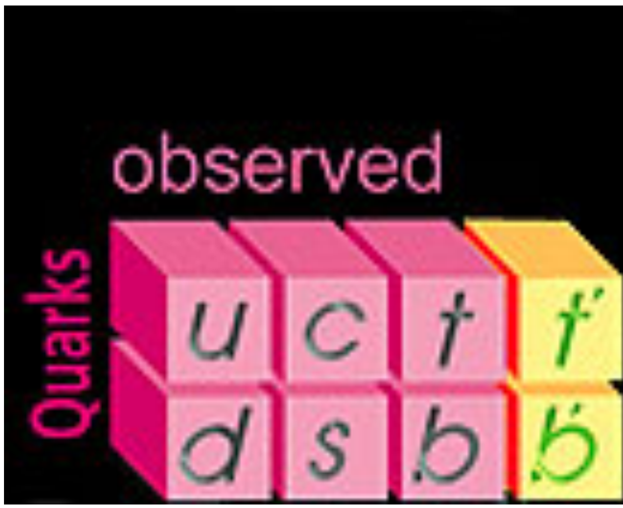
3.8 − 5.3 TeV range for large variety of model parameters



Also model-independent limits



Searches for 4th Generation Quarks



$t'\bar{t}' \to bW^+\bar{b}W^-$

Searches for the extension of the generations of fermions

CMS PAS-EXO-11-050

Heavy Top-like Quark

4.7 fb^{-1}

Search for production of: $t'\bar{t}' \rightarrow bW^+\bar{b}W^-$

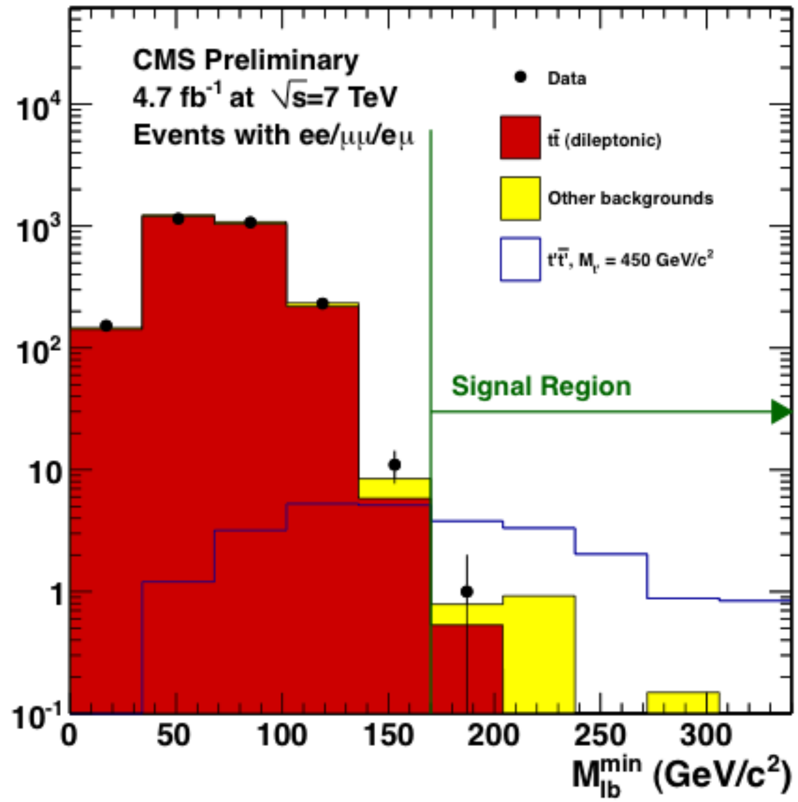
In dilepton channels: ee, eμ, μμ with opposite sign

Use M_{lb}(min): minimum value of four possible combinations

Select events with M_{lb}(min) > 170 GeV to reduce ttbar background

Backgrounds:

Sample	Yield
Category I (data-driven)	0.74 ± 0.79
Category II (data-driven)	$0^{+0.4}_{-0.0}$
Category III (simulated)	0.99 ± 0.69
Total prediction	1.73 ± 1.12
Data	1

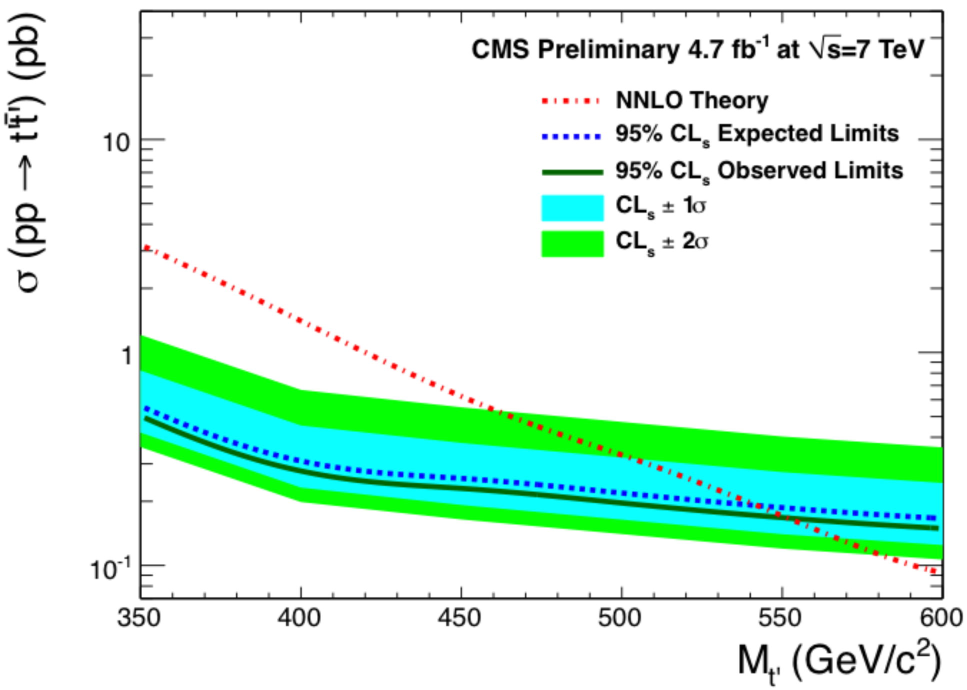


- Category I: events with mistagged b(s) and 2 real leptons
- Category II: events with misidentified lepton(s) and 2 real bs
- Category III: events with 2 real bs and 2 real leptons
- Category IV: events with mistagged b(s) and misidentified lepton(s). ← negligible

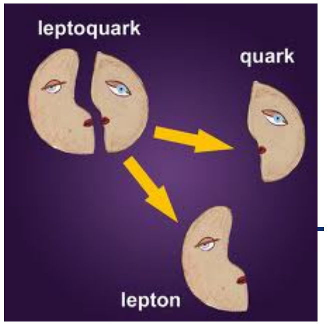
Limits on Heavy Top-like Quark Production

t' excluded below 552 GeV

4.7 fb^{-1}



$M_{t'}$	350 GeV/c^2	400 GeV/c^2	450 GeV/c^2	500 GeV/c^2	550 GeV/c^2	600 GeV/c^2
Theory (pb)	3.200	1.406	0.622	0.330	0.171	0.092
Expected (pb)	0.560	0.309	0.256	0.219	0.187	0.166
Observed (pb)	0.503	0.278	0.230	0.196	0.168	0.149



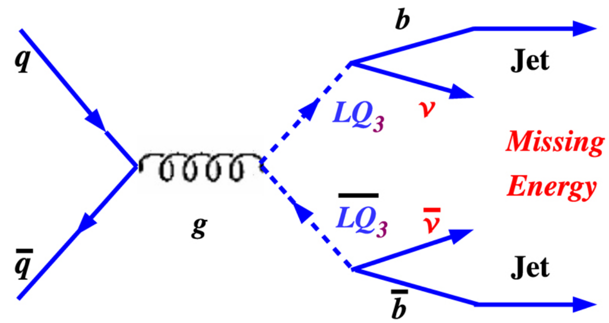
Searches for Leptoquarks

Fractionally charged colored boson

→ quark + charged lepton (BR=β)

OR

→ quark + neutrino (BR=1-β)



Coupling = λ
Pair Production

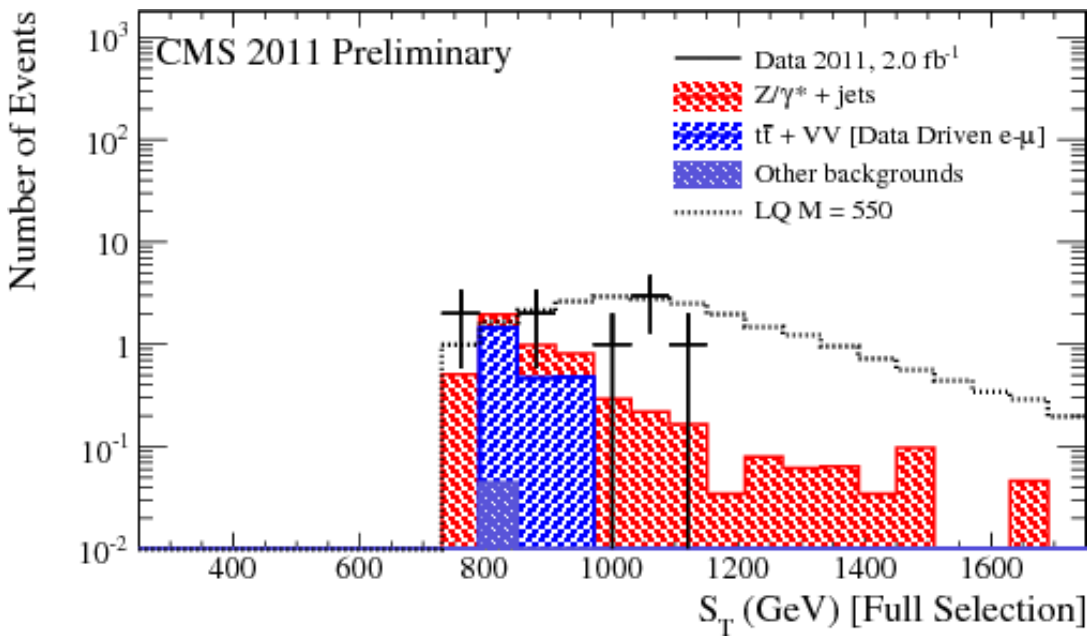
- 2nd generation decays and signatures: CMS PAS-EXO-11-028
  - μ-q-μ-q (2μ+2j) , μ-q-ν-q (1μ+MET) [also, ν-q-ν-q]
  - Analyze in $S_T = \Sigma$ muon p_T+ jet p_T (+MET)
- 3rd generation: CMS PAS-EXO-11-030
  - ν-b-ν-b (2b-jets+MET) [also, τ-b-τ-b & τ-b-ν-b]
  - Analyze with *razor* variable R (dimensionless, related to MET)

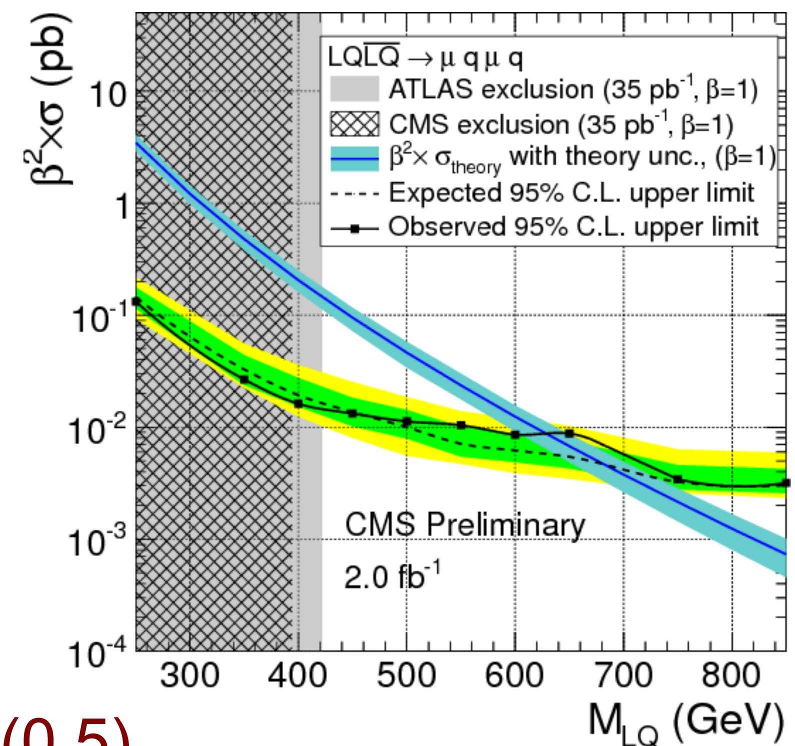
Leptoquarks (2^{nd} generation) 2.0 fb^{-1}

Cut thresholds on kinematic variables including S_T optimized for LQ mass

Example: S_T for 550 GeV LQ signal shown below in μq-μq channel (β=1)

Overall consistency with SM predictions





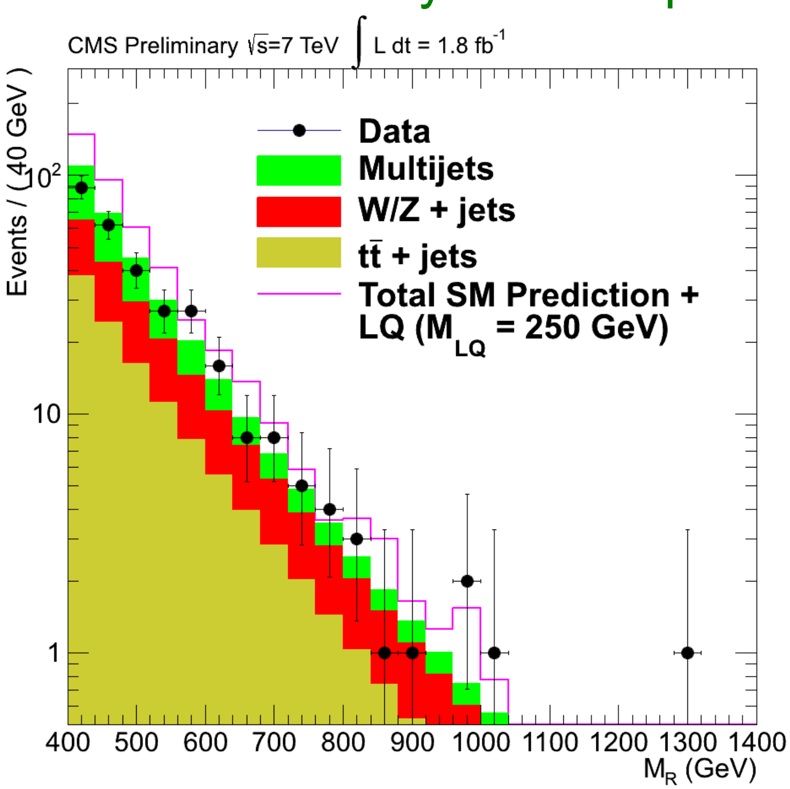
630 (523) GeV exclusion for β=1 (0.5)

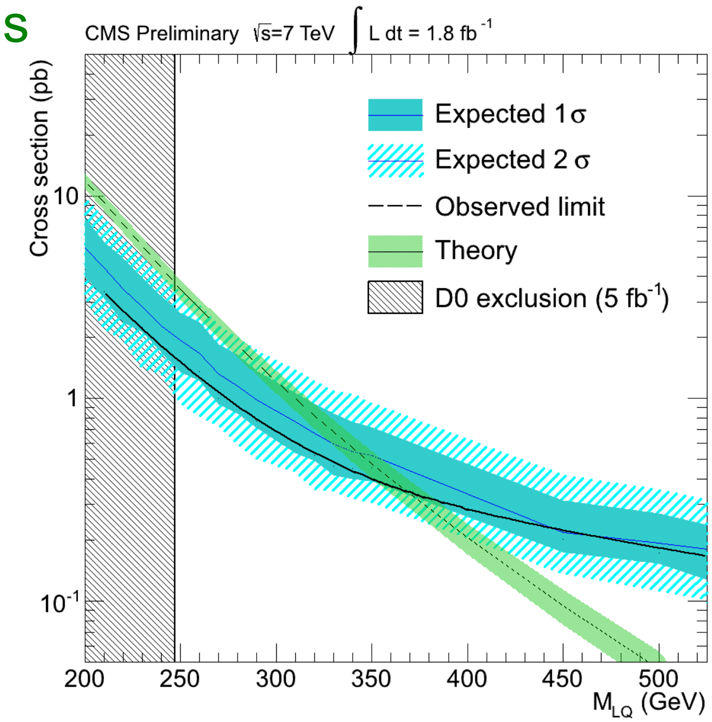
Leptoquarks (3rd generation) 1.8 fb^{-1}

Signal region optimized for *razor* variables: M_R> 400 GeV, and R^2 (varying with LQ mass)

Backgrounds: ttbar and multijet shapes data-driven

Overall consistency with SM predictions





350 GeV exclusion for β=1

Long lived particles

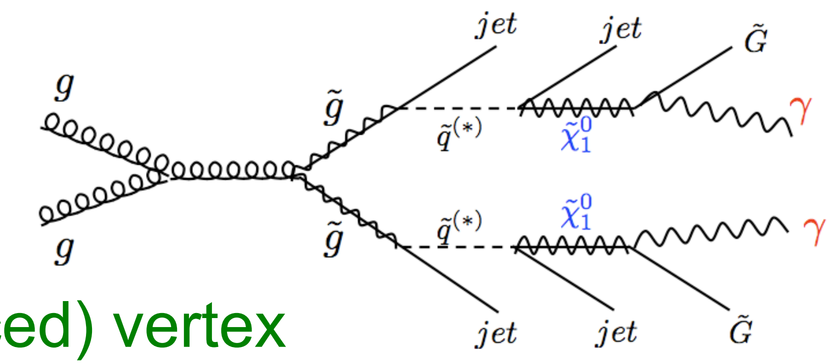
- Predicted in many extensions of the SM: SUSY, hidden valley, etc.
- Several ways to look for them
  - Displaced tracks
  - Highly ionizing tracks
  - Out-of-time particles
  - Non-pointing photons
  - …
- I will focus on two new results
  - Long lived particles decaying to photons
  - Heavy Stable Charged Particles (HSCP)

http://en.wikipedia.org/wiki/Jeanne_Calment

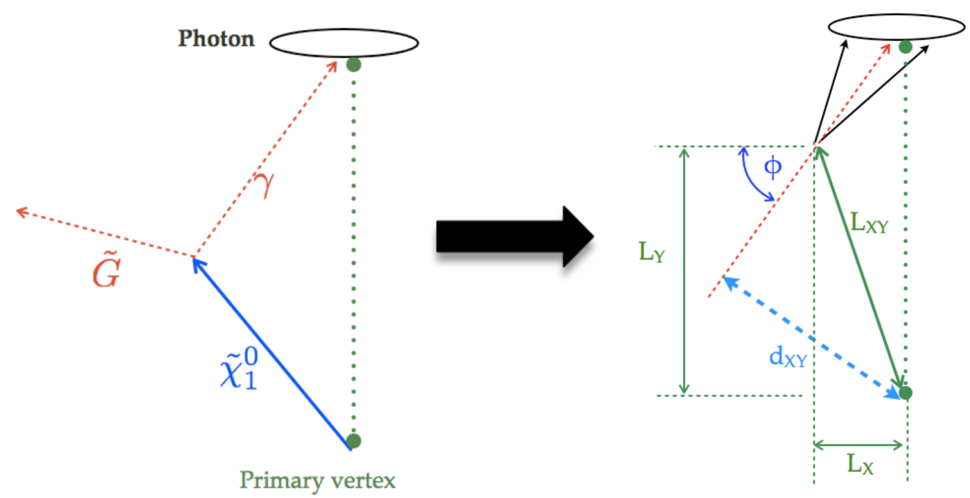
Somewhat Lazy Photons

2.1 fb^{-1}

- Long-lived neutral → Non-prompt Photon + invisibles (MET)
  - $c\tau$ not that large, ~2 to 20cm, e.g. GMSB neutralino below
  - Pair production (diphotons)
  - Accompanying jets
  - Converted photon → (displaced) vertex

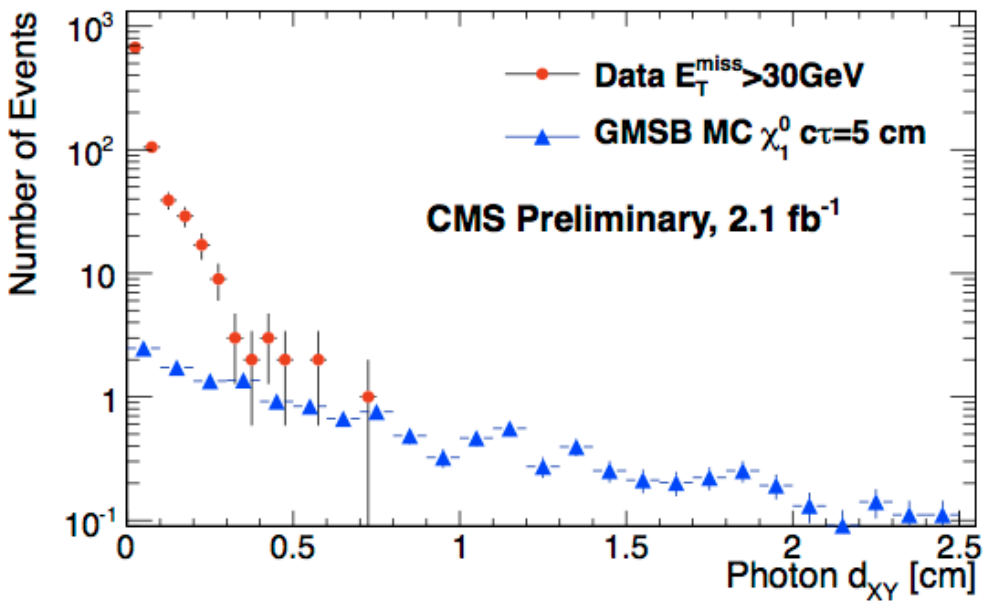


Technique:



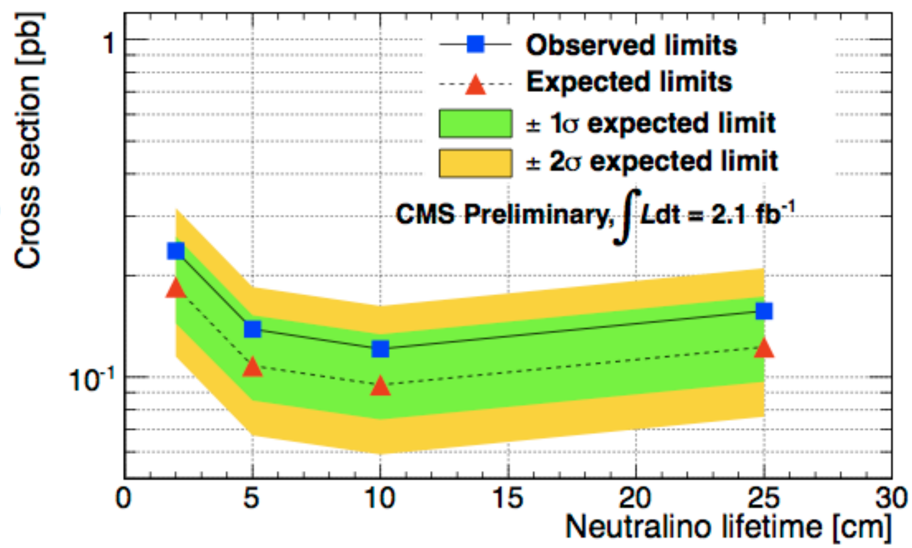
Sensitive to lifetimes $\mathcal{O}$(0.1ns)

Non-prompt (mildly displaced) photons 2.1 fb^{-1}



Select:
$E_T(\gamma)$ > 45 GeV
≥ 2 jets (80/50 GeV)
MET > 30 GeV

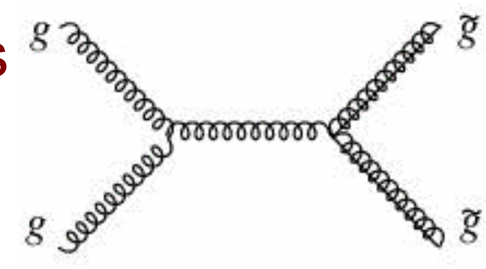
Backgrounds:
Photon + jets, Misid jets
Evaluated in MET<20 GeV region



Limits on neutralino cross section as a function of neutralino lifetime

4.7 fb^{-1} CMS PAS-EXO-11-022

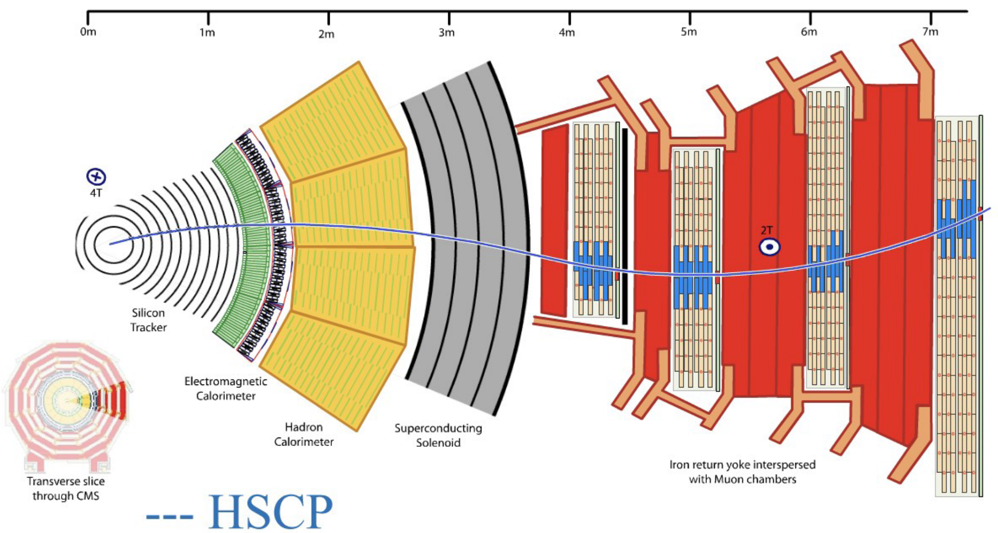
Searches for Heavy Stable Charged Particles



- R-hadron: Strongly interacting particle forms bound state in process of hadronization
  - squarks or gluinos hadronize with quarks/gluons
- Long-lived NLSP
  - Split-SUSY,GMSB,UED etc.
- Characteristic: High momentum, but slower than light
  - Tracker hits show high dE/dx (→ particle mass)
  - Late arrival : Long Time Of Flight (TOF) to the muon system
  - Charge exchange possible in material: live without muon hits
- Two approaches → model independent
  - Inner tracker only
  - Full tracking (reconstruct as a muon) and require TOF

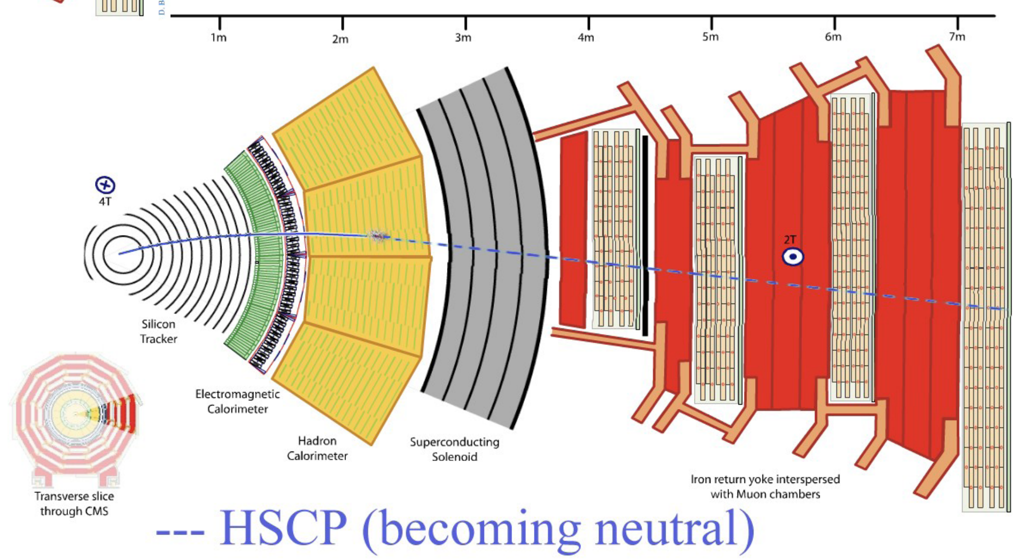
4.7 fb^{-1} CMS PAS-EXO-11-022

Searches for Heavy Stable Charged Particles



← HSCP makes it through CMS (looks like a muon)
Tracker + TOF analysis

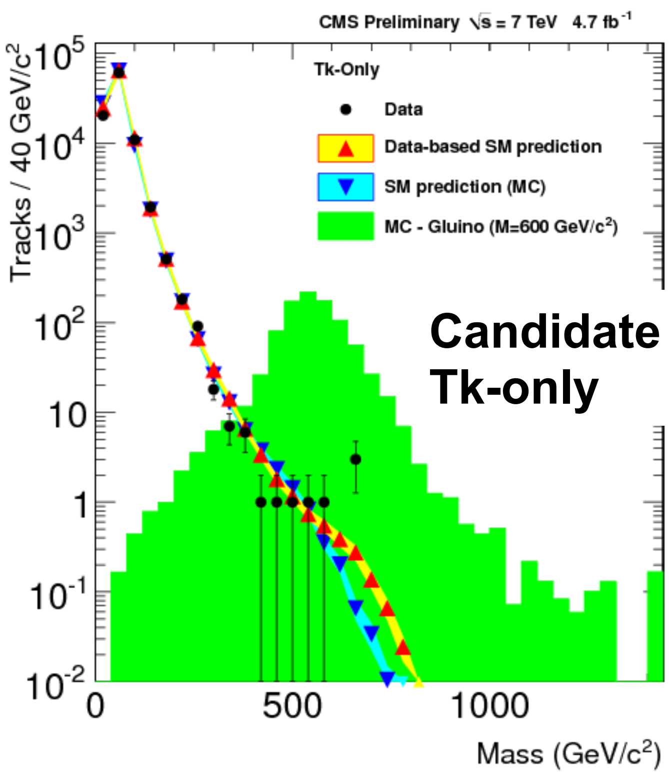
HSCP through CMS, suffering charge exchange in the hadron calorimeter
Inner tracker only analysis →



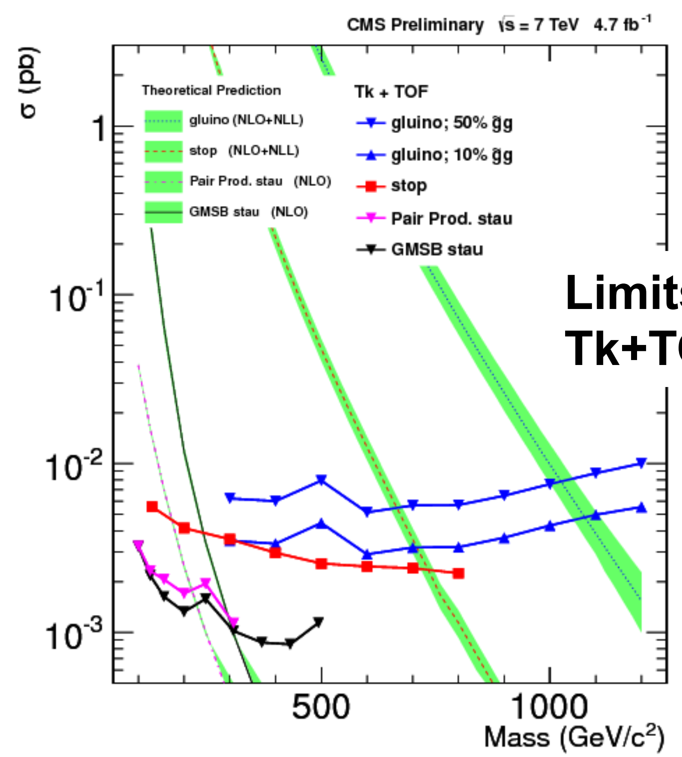
Searches for Heavy Stable Charged Particles

In both Tk-only and Tk+TOF analyses, data consistent with expected background, estimated with a data-driven technique

Limits on a variety of models: M(gluino)>1091 GeV, M(scalar top)>734 GeV, M(scalar tau) > 221 GeV, and on hyper-K and hyper-ρ

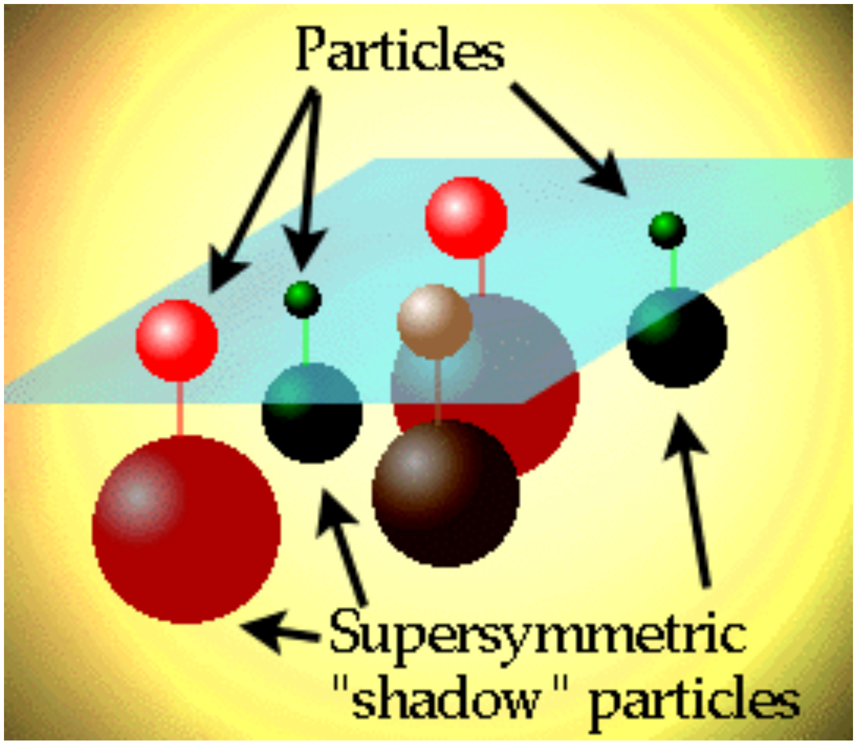


Candidate mass Tk-only



Limits for Tk+TOF

Supersymmetry



Why SUSY?

- Symmetry between bosons and fermions
- Unification of forces
- Provides a dark matter candidate
- No "fine-tuning"

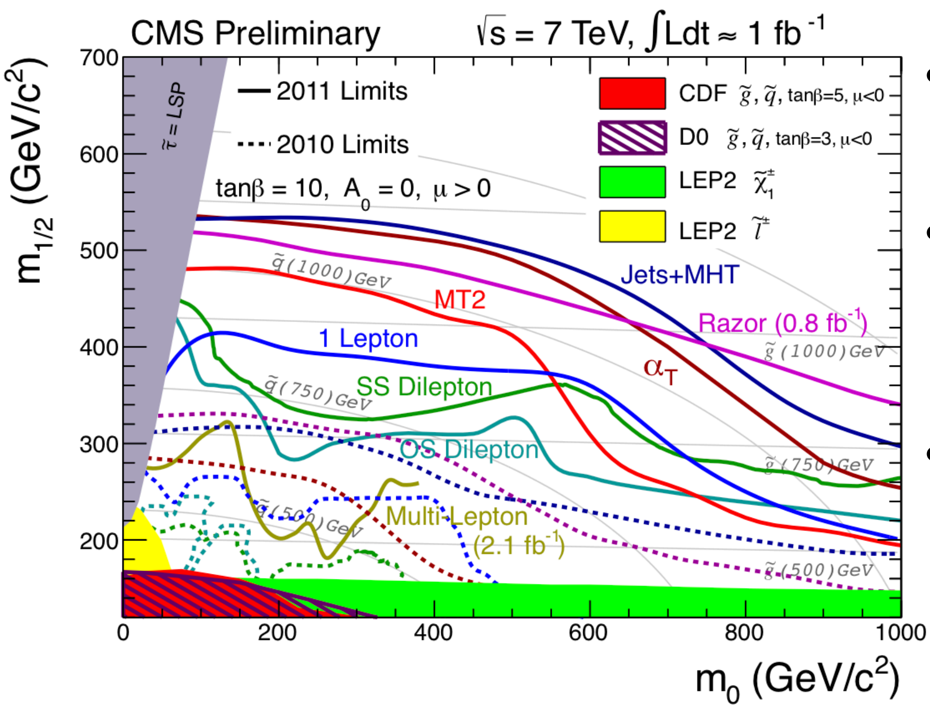
I will focus on these new results

- Razor analysis
- Multilepton final state
- Z+jets+MET final state

→ Two complementary analyses

→ First SUSY result with full dataset! (More coming soon….)

Searches for SUSY at CMS



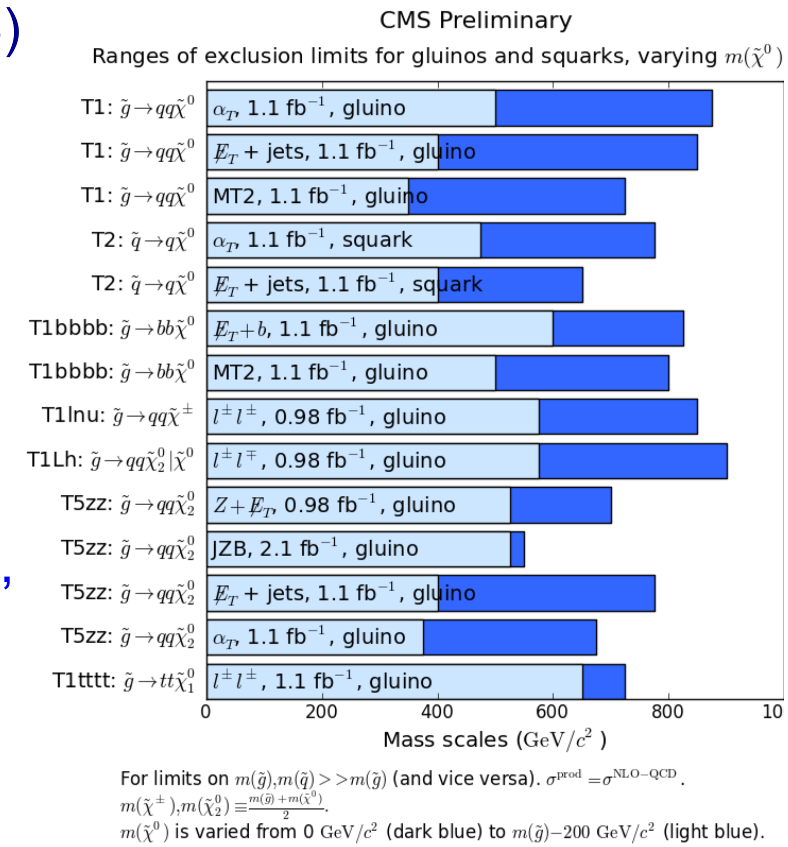
- A number of channels and methods pursued
- Focus has been on simple signatures
  - Common to wide variety of models
- Gearing toward dedicated sbottom and stop searches
  - **Stay tuned!**
- Our results have been most commonly presented in the CMSSM m_0 vs $m_{1/2}$ plane
  - Shows breadth of analyses and large gain in coverage

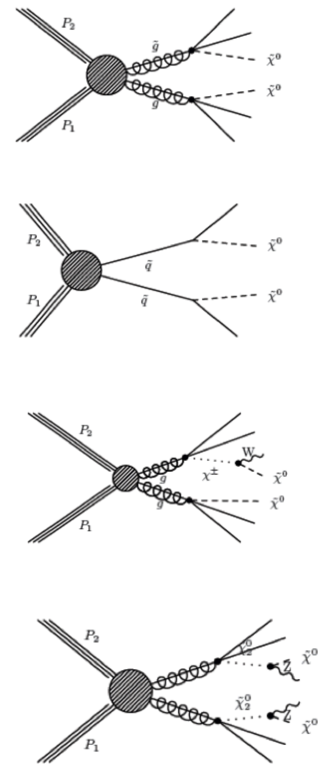
Interpretation of Limits

Results interpreted in terms of simplified model spectra (SMS)

- Use limited set of new hypothetical particles and decays to produce a given topological signature
- Excluded mass scales for gluinos and squarks, where large mass splittings between them are assumed, as well as for varying neutralino masses
- Limits are quite dependent on model assumptions.
  - But they are quantified

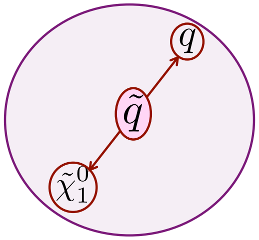
1 fb^{-1} summary





Search for SUSY using Razor variables ~1 fb^{-1}

- Search for pair production heavy particles
  - squarks and gluinos
- Objects grouped into two "megajets"
  - perform event-by-event test that they represent visible portion of decays
- Use two kinematic variables: M_R and R
  - Evaluated in *razor* frame:



$$M_\Delta \equiv \frac{M_{\tilde{q}}^2 - M_{\tilde{\chi}}^2}{M_{\tilde{q}}}$$

M_R is invariant under this longitudinal boost

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}\,.$$

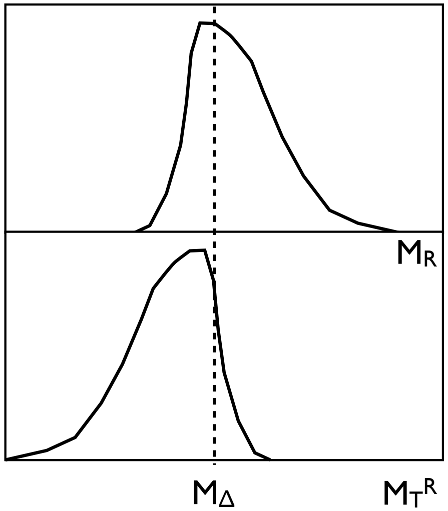
← M_R peaks at M_Δ

$$M_T^R \equiv \sqrt{\frac{\not{E}_T(p_T^{j1} + p_T^{j2}) - \vec{\not{E}}_T \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$

← M_Δ edge in $M_T{}^R$

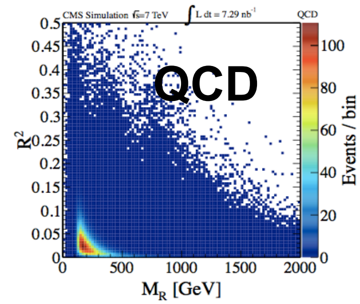
$$R \equiv \frac{M_T^R}{M_R}$$

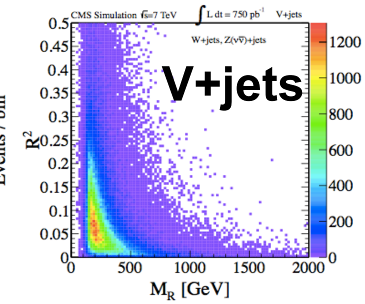
← R is ratio of the two and related to MET

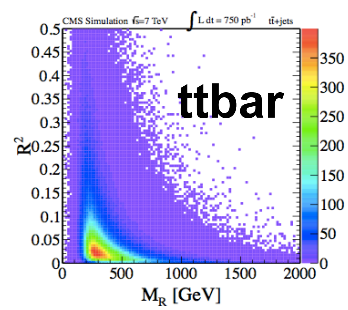


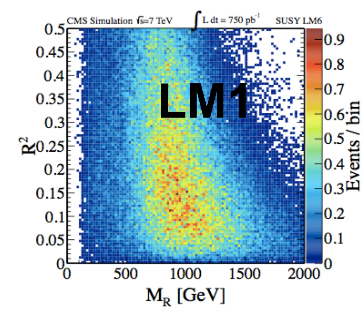
Search for SUSY using Razor variables ~1 fb^{-1}

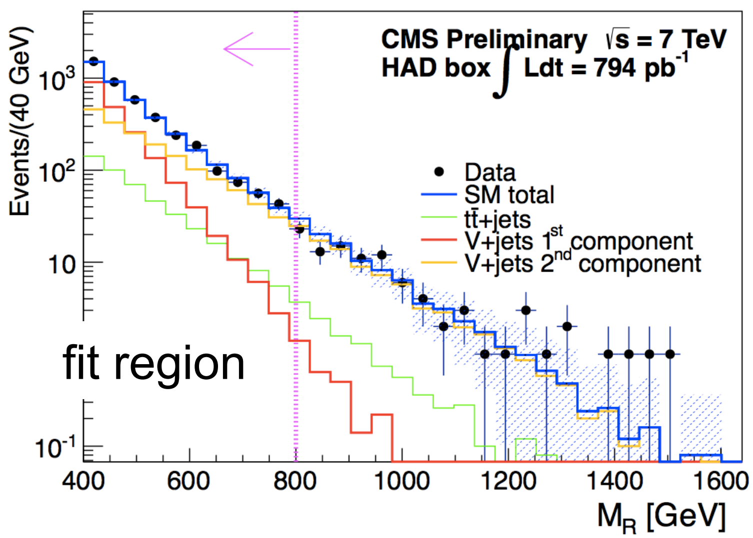
- Search is done in 2D: R^2 & M_R
  - Backgrounds expected to fall exponentially in both variables
  - Signal would ~ peak in M_R
- Background modeling based on data
- Shapes predicted from 2D fit to low (M_R,R^2) in multi-jet, lepton & dilepton control samples
  - Extrapolate to signal region



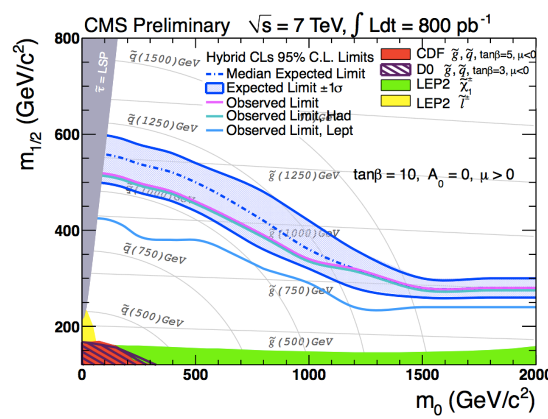








Limit in CMSSM plane →



CMS PAS-EXO-11-045

CMS PAS-SUS-11-013

Multileptons (e,μ,τ)

2.1 fb^{-1}

- A universal low-background signature (≥3 leptons)
  - R-Parity-conserving & RPV-SUSY
    - → GMSB, mSUGRA/EWK production
    - → high tanβ (with tau's)
  - (Fermiophobic) Higgs
  - 4^{th} generation (b') (with b tags), See-saw…
- Search: ≥3 e,μ,τ with or w/o H_T, MET & on-Z/off-Z, binned in S_T
- Backgrounds: Drell Yan, ttbar, Dibosons (irreducible)
  - With high statistics: ttW, ttZ, WH, ttH (!!)
- A broad model-independent multichannel search
- Exclusive channels ordered by SM background
  - Large background channels also control (validation) regions

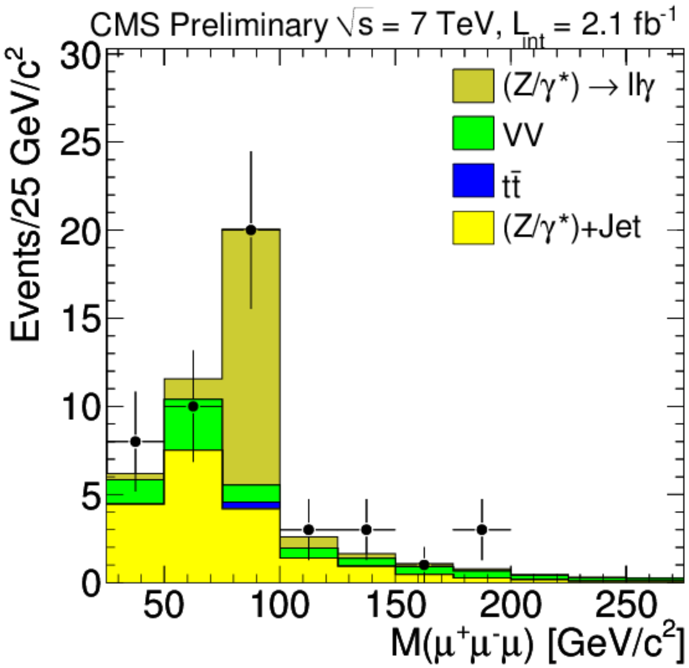
CMS PAS-EXO-11-045

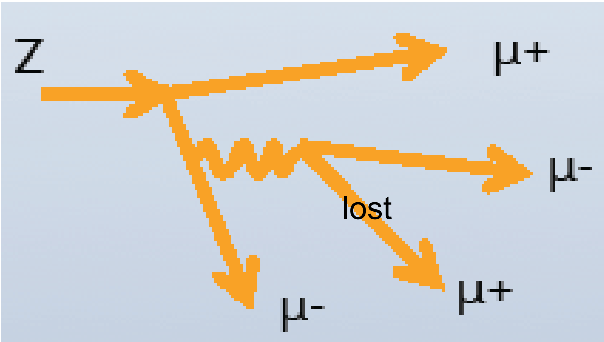
CMS PAS-SUS-11-013

Multileptons (e,μ,τ)

2.1 fb^{-1}

A surprise on the way to the result : Internal conversion background





Asymmetric internal (Dalitz) conversion of FSR from Z followed by the loss of soft lepton

Affects mostly an on-Z control channel for this analysis

But corresponding Wγ* internal conversion affects H to WW search
(Now being taken into account by CMS and ATLAS)

CMS PAS-EXO-11-045

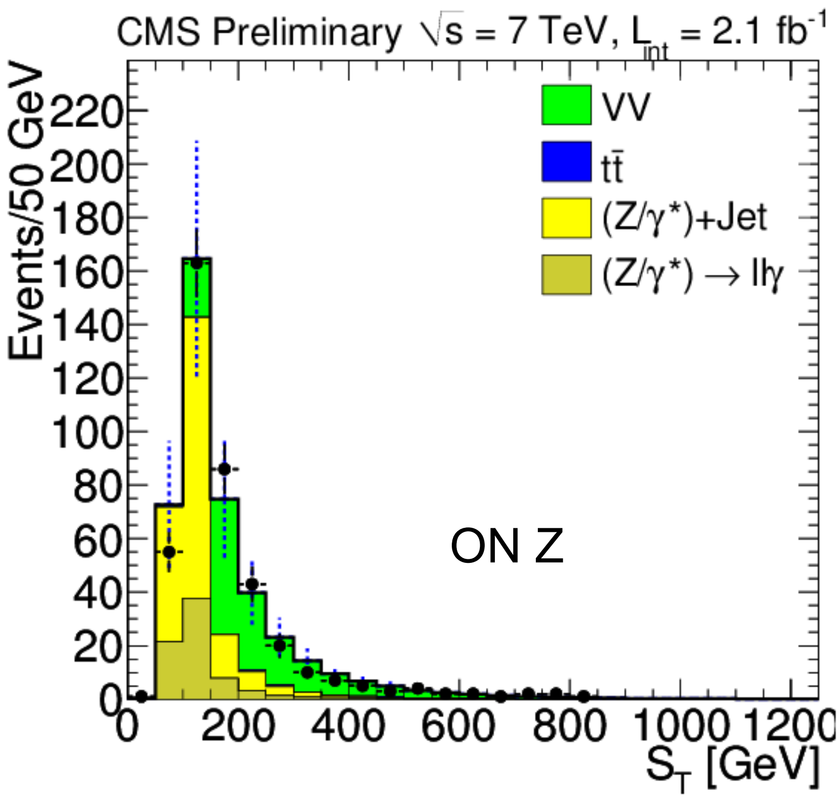
CMS PAS-SUS-11-013

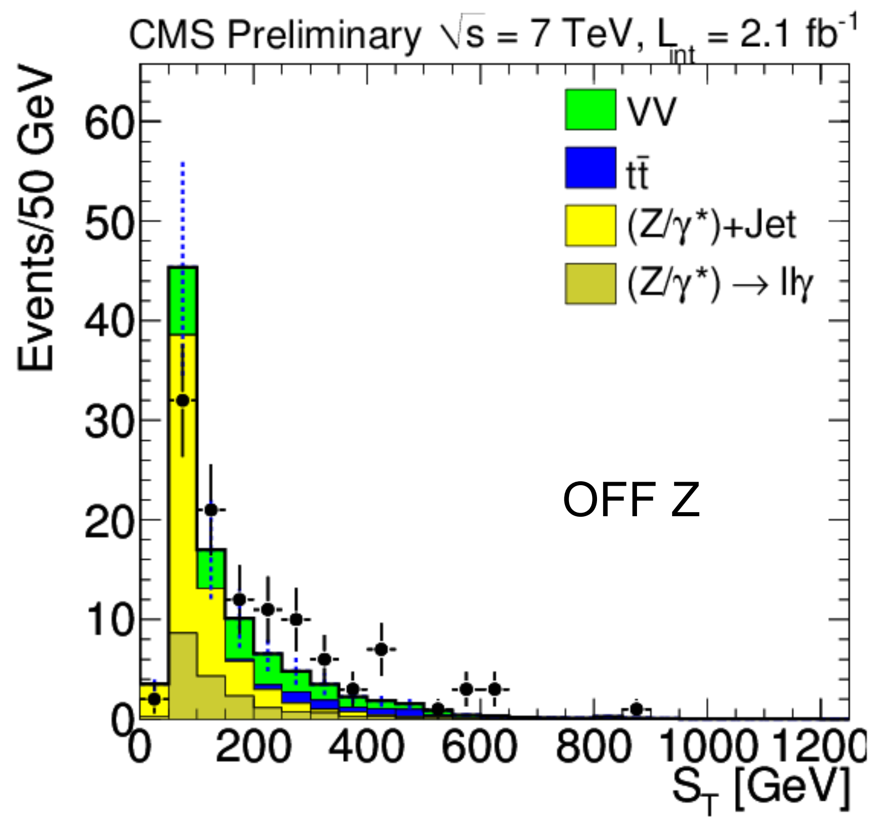
Multileptons (e,μ,τ)

2.1 fb^{-1}

Many channels explored – overall agreement with SM predictions.

Example bin: 3(e/μ) channel S_T distributions





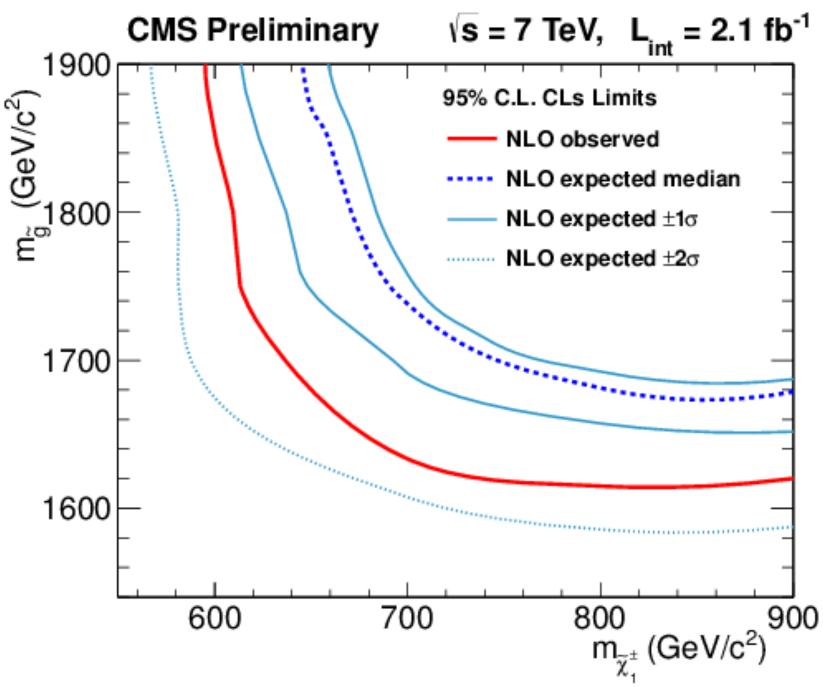
Interpretation of Multileptons

CMS PAS-EXO-11-045
CMS PAS-SUS-11-013
2.1 fb^{-1}

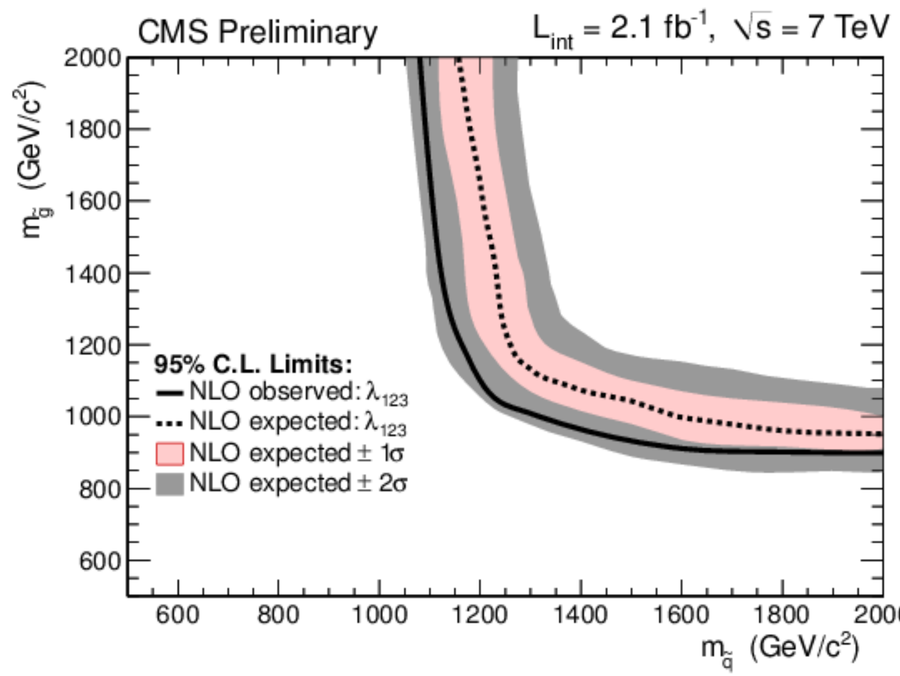
Sensitive to gluino-squark production via q-g and g-g interactions

RP conserving limit in gluino-wino-like chargino plane (left)

RPV limit in the squark-gluino plane (right)



slepton co-NLSP scenario



Leptonic RPV : $\lambda_{123} = \lambda_{e\mu\tau}$

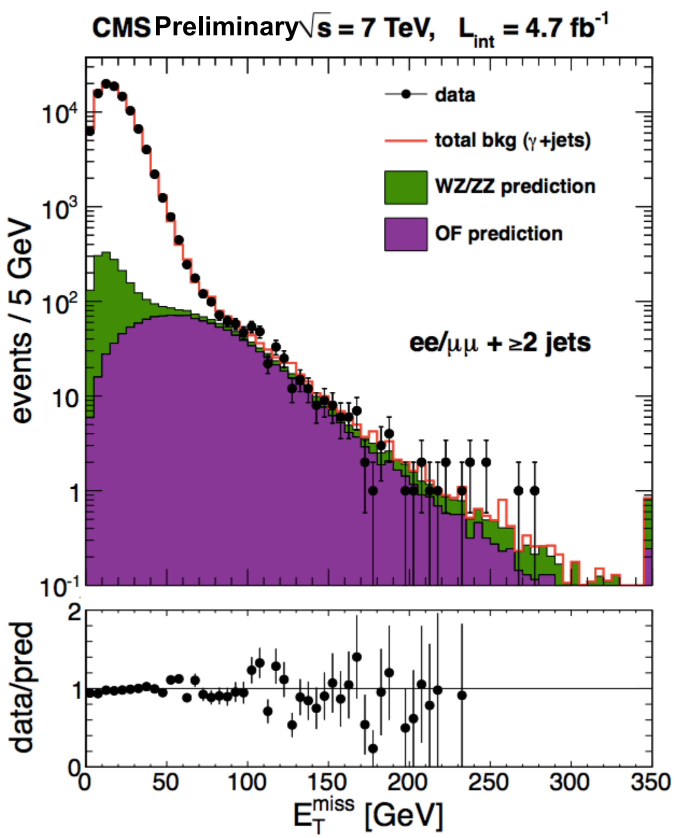
Search for SUSY in Z + jets + MET events

Two complementary searches: MET and **JetZBalance**

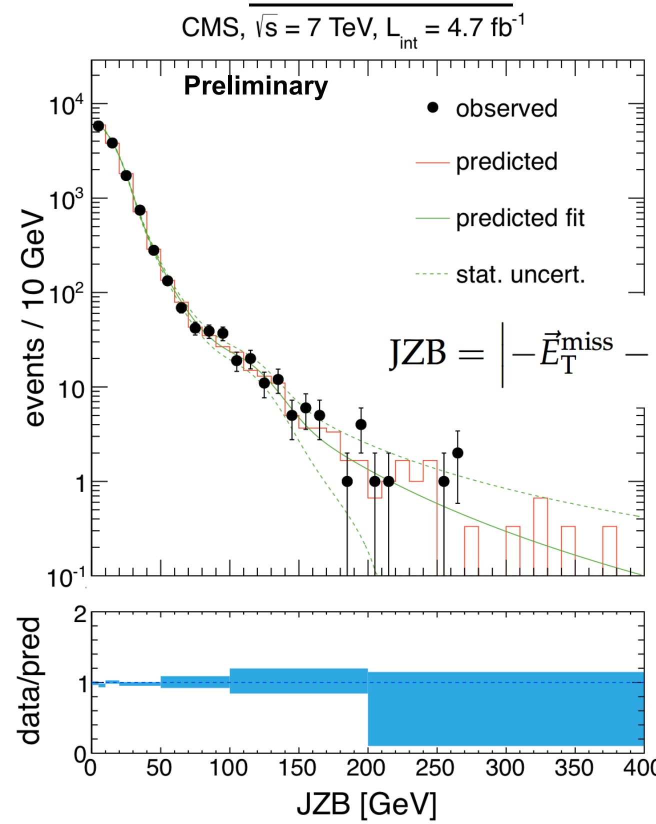
4.7 fb^{-1}

Backgrounds: dominantly top (predicted from eμ events) and Z+jets (use MET templates or JZB symmetry)

MET Search



JZB Search



$$\mathrm{JZB} = \left| -\vec{E}_{\mathrm{T}}^{\mathrm{miss}} - \vec{p}_T^{\,(\mathrm{Z})} \right| - \left| \vec{p}_T^{\,(\mathrm{Z})} \right|$$

CMS PAS-SUS-11-021

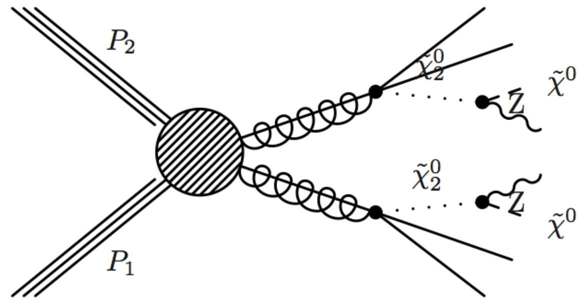
Interpretation of Results

4.7 fb^{-1}

- Good agreement with SM → set upper limits on SMS scenarios
- Scenario inspired by mSUGRA where the LSP is the lightest neutralino
  - Results are parameterized as a function of the gluino and the LSP masses
  - Mass of the intermediate neutralino is

    M(chi2) = M(LSP) + x (M(glu) – M(LSP))

    - x = 0.5 and x = 0.75

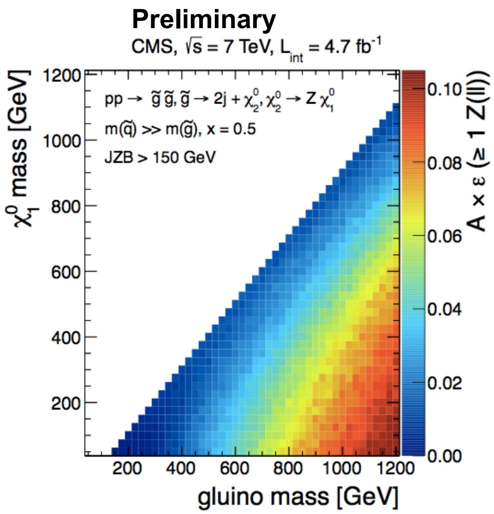


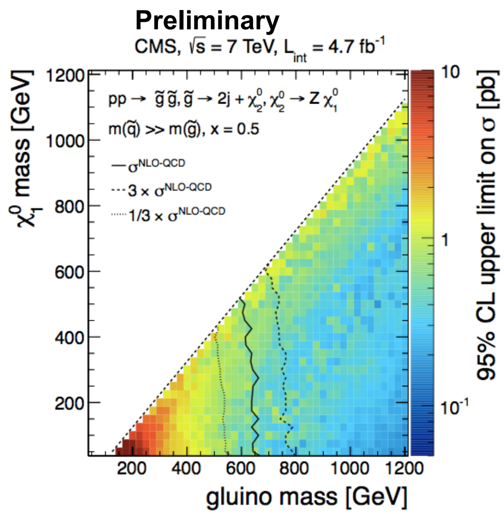
- Also consider scenario inspired by GMSB where the LSP is the gravitino
  - Results are parametrized as a function of the gluino and neutralino masses
- We also provide additional information for model testing
  - Generator level efficiencies as a function of JZB and MET

CMS PAS-SUS-11-021

Limits on Neutralino LSP Scenario

4.7 fb^{-1}



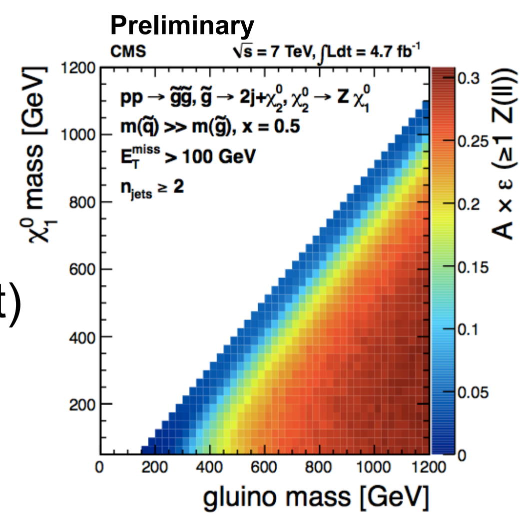


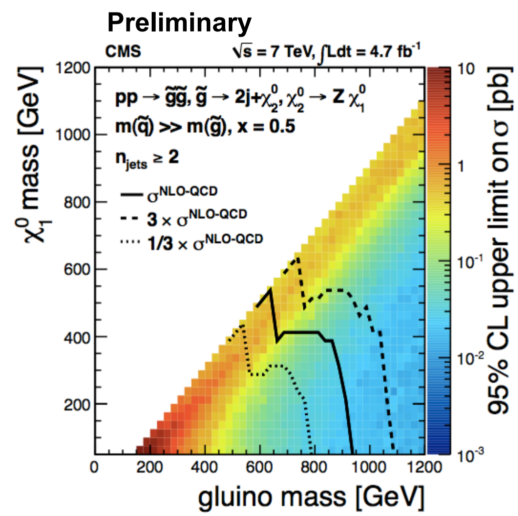
← **JZB Search**

Signal efficiency, including acceptance, for JZB>150GeV (left)
Cross section limit (right)

MET Search →

Signal efficiency, including acceptance, for MET>100GeV (left)
Cross section limit (right)





Conclusions

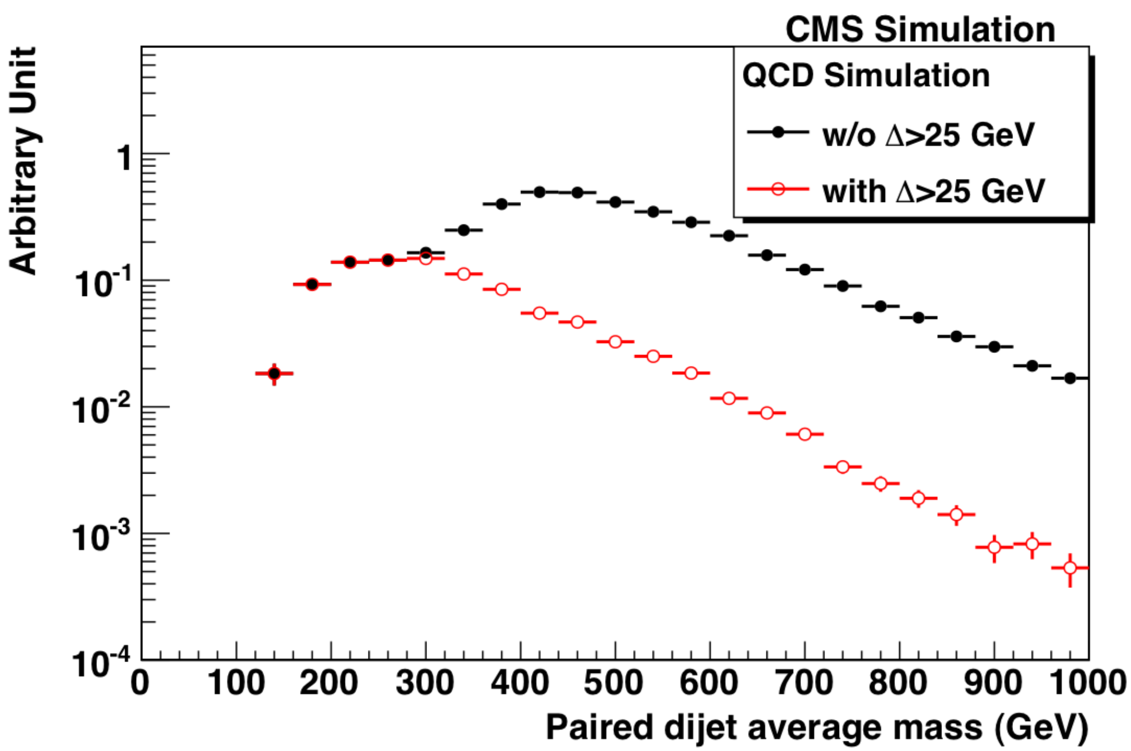
- Rich program of searches for physics beyond the SM
- Many analyses performed with ~1 - 4.7 fb^{-1}
    - Lots more analyses with full dataset coming for Moriond
    - Preparing for 2012 run
- Advanced analysis techniques
- Stringent limits on many benchmark models
- No evidence of new physics yet
  - Keep looking until either we find something
  - **The exploration of Terascale physics has only just started!**

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

Backup

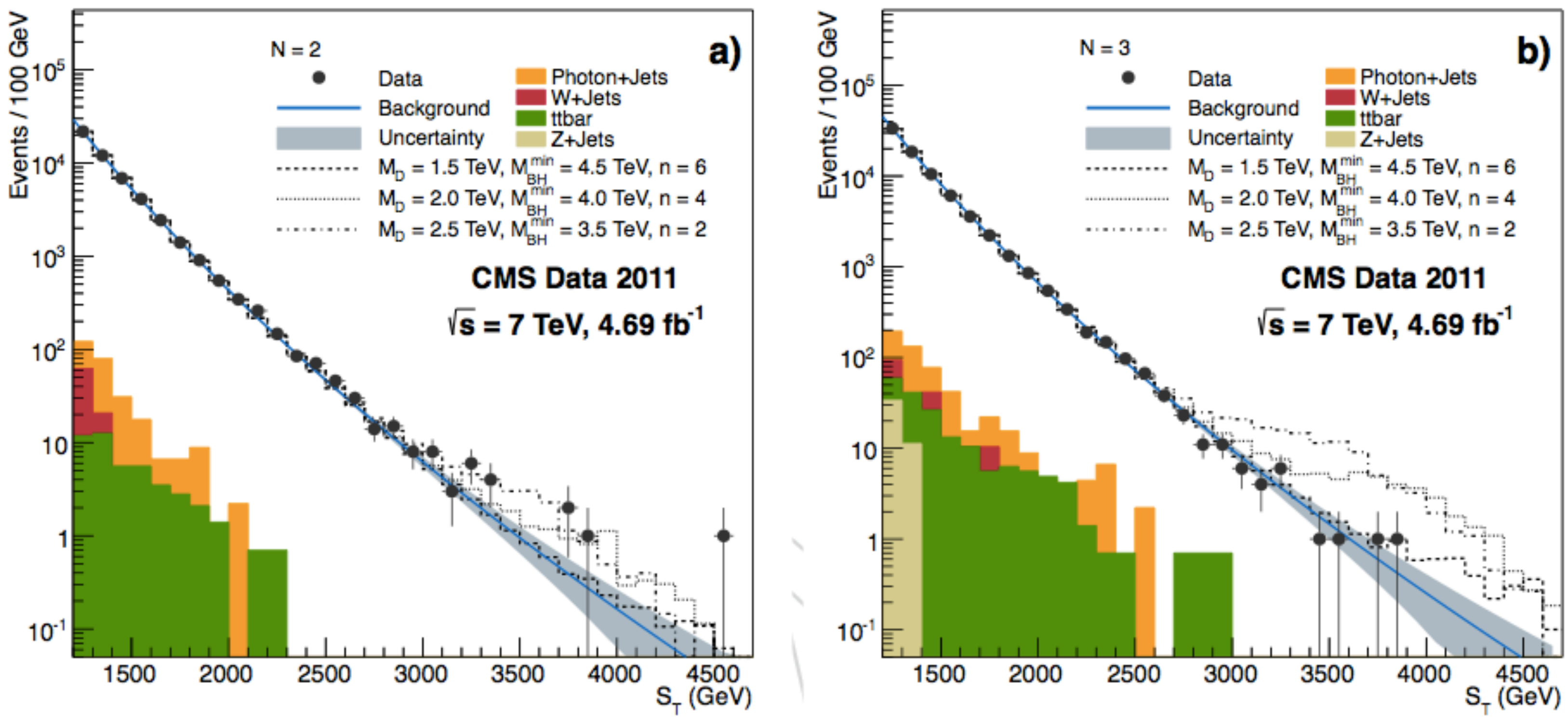
Paired Dijet Resonances

QCD with and without Δ cut

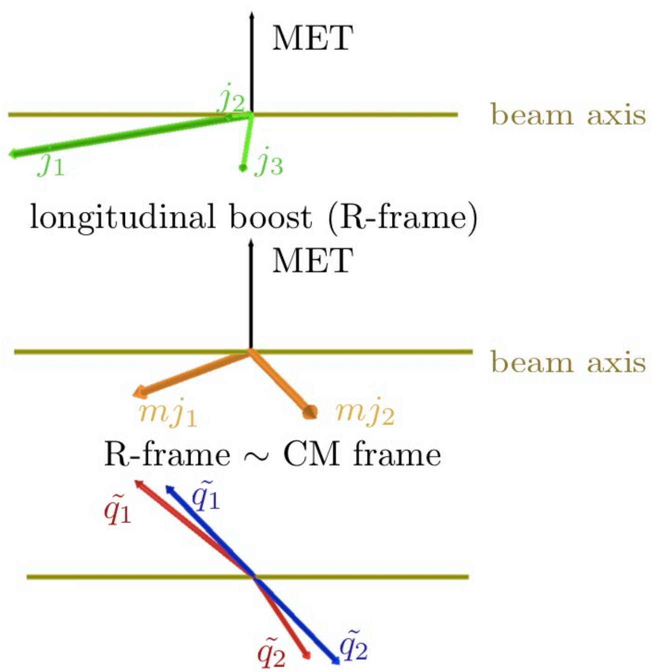


Black Holes

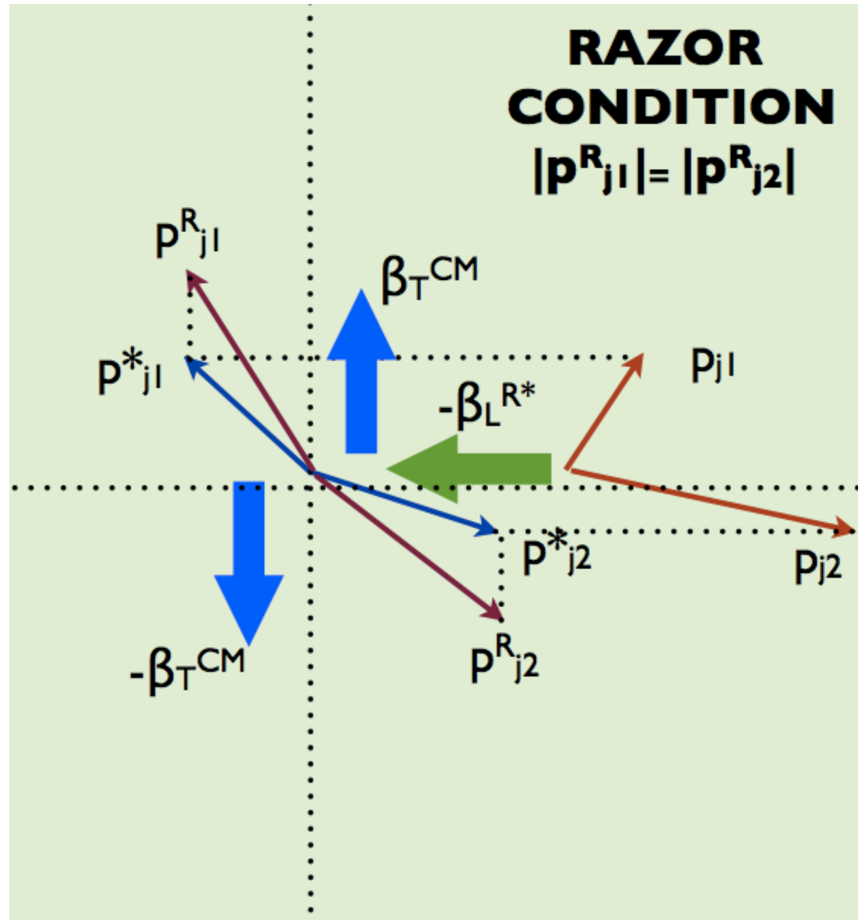
N = 2 and N = 3. Fit S_T between 1200 and 2800 GeV



Razor frame



MET
beam axis
j_2
j_1
j_3
longitudinal boost (R-frame)
MET
beam axis
mj_1
mj_2
R-frame ~ CM frame
$\tilde{q}_1$
$\tilde{q}_1$
$\tilde{q}_2$
$\tilde{q}_2$



RAZOR CONDITION
$|p^R_{j1}| = |p^R_{j2}|$
p^R_{j1}
β_T^{CM}
p^*_{j1}
p_{j1}
$-\beta_L^{R*}$
p^*_{j2}
p_{j2}
$-\beta_T^{CM}$
p^R_{j2}

Multileptons

Selection	N(τ)=0		N(τ)=1		N(τ)=2	
	obs	expected SM	obs	expected SM	obs	expected SM
≥FOUR Lepton Results						
MET>50,H_T >200,noZ	0	0.003 ± 0.002	0	0.01 ± 0.05	0	0.30 ± 0.22
MET>50,H_T >200, Z	0	0.06 ± 0.04	0	0.13 ± 0.10	0	0.15 ± 0.23
MET>50,H_T <200,noZ	1	0.014 ± 0.005	0	0.22 ± 0.10	0	0.59 ± 0.25
MET>50,H_T <200, Z	0	0.43 ± 0.15	2	0.91 ± 0.28	0	0.34 ± 0.15
MET<50,H_T >200,noZ	0	0.0013 ± 0.0008	0	0.01 ± 0.05	0	0.18 ± 0.07
MET<50,H_T >200, Z	1	0.28 ± 0.11	0	0.13 ± 0.10	0	0.52 ± 0.19
MET<50,H_T <200,noZ	0	0.08 ± 0.03	4	0.73 ± 0.20	6	6.9 ± 3.8
MET<50,H_T <200, Z	11	9.5 ± 3.8	14	5.7 ± 1.4	39	21 ± 11
THREE Lepton Results						
MET>50,H_T >200,no-OSSF	2	0.87 ± 0.33	21	14.3 ± 4.8	12	10.4 ± 2.2
MET>50,H_T <200,no-OSSF	4	3.7 ± 1.2	88	68 ± 17	76	100 ± 17
MET<50,H_T >200,no-OSSF	1	0.50 ± 0.33	12	7.7 ± 2.3	22	24.7 ± 4.0
MET<50,H_T <200,no-OSSF	7	5.0 ± 1.7	245	208 ± 39	976	1157 ± 323
MET>50,H_T >200,noZ	5	1.9 ± 0.5	7	10.8 ± 3.3	–	–
MET>50,H_T >200, Z	8	8.1 ± 2.7	10	11.2 ± 2.5	–	–
MET>50,H_T <200,noZ	19	11.6 ± 3.2	64	52 ± 13	–	–
MET<50,H_T >200,noZ	5	2.0 ± 0.7	24	26.6 ± 3.3	–	–
MET>50,H_T <200, Z	58	57 ± 21	47	44.1 ± 7.0	–	–
MET<50,H_T >200, Z	6	8.2 ± 2.0	90	119 ± 14	–	–
MET<50,H_T <200,noZ	86	82 ± 21	2566	1965 ± 438	–	–
MET<50,H_T <200, Z	335	359 ± 89	9720	7740 ± 1698	–	–
Totals 4L	13.0	10.4 ± 3.8	20.0	7.8 ± 1.5	45	30 ± 12
Totals 3L	536	539 ± 94	12894	10267 ± 1754	1086	1291 ± 324

Table 3: Results from 2.1 fb^{-1} of 2011 data summed over electron and muon flavors. The labels going down the side refer to whether or not there are OSSF pairs, whether or not $Z \to \ell^+\ell^-$ was excluded (noZ), and the H_T and MET requirements. Labels along the top of the table give the number of τ candidates, 0, 1, or 2. All channels are exclusive. The τ channels serve as "signal" channels for SUSY signals assuming high tan(β) values, for example.

Multileptons

Table 2: Number of events observed in 2.1 fb^{-1} data (obs), the SM expectation, and expected event counts from typical signals: The rows indicate the *total* number of isolated leptons in the event. The columns indicate the number of τ's among the isolated objects. The number of Drell-Yan pairs is specified by DYn; the S_T ranges in GeV are Low (< 300 GeV), Mid (300 < S_T < 600 GeV), and High (> 600 GeV); and ZV stands for Z-Veto, indicating there are no OSSF lepton pairs with invariant mass in the Z window. For example, the entry in row marked "3 (DY1)S_T(Mid)" and column marked "τ=1" would be the number of three lepton events which have one opposite-sign electron or muon (same flavor) pair in it, one tau candidate and the total event S_T in the 300 to 600 GeV range. The channel right above it requires a Z-veto in addition, and thus suffers from significantly less background. The channels are exclusive, i.e., non-overlapping. The column labeled sigA is for the L-RPV signal with λ_{122} coupling for squark and gluino masses of 1100 GeV/c^2 and 1000 GeV/c^2, while the column labled sigB is for λ_{123}, 1000 GeV/c^2 and 1100 GeV/c^2, respectively. Note the shift in signal between τ=0 and τ=1 channels because λ_{123} is tau rich. The totals at the bottom are for informational purposes.

# Bodies (Selection)	τ=0				τ=1				τ=2			
	obs	SM	sigA	sigB	obs	SM	sigA	sigB	obs	SM	sigA	sigB
$\geq$ FOUR Lepton Results												
4 (DY0) S_T(High)	0	0.0000 ± 0.0007	2.9	0.3	0	0.00 ± 0.09	2.0	2.5	0	0.09 ± 0.07	0.5	7.0
4 (DY0) S_T(Mid)	0	0.001 ± 0.002	0.0	0.0	0	0.11 ± 0.10	0.0	0.0	0	0.68 ± 0.30	0.0	0.0
4 (DY0) S_T(Low)	0	0.02 ± 0.02	0.0	0.0	0	1.69 ± 0.27	0.0	0.0	4	1.34 ± 0.41	0.0	0.0
4 (DY1,ZV) S_T(High)	1	0.002 ± 0.001	12.6	1.1	0	0.02 ± 0.07	6.1	5.5	0	0.10 ± 0.07	0.7	2.4
4 (DY1) S_T(High)	1	0.010 ± 0.004	2.9	0.4	0	0.22 ± 0.10	1.6	1.8	0	0.15 ± 0.07	0.0	0.3
4 (DY1,ZV) S_T(Mid)	0	0.008 ± 0.003	0.0	0.0	0	0.20 ± 0.09	0.0	0.0	0	0.45 ± 0.19	0.0	0.0
4 (DY1) S_T(Mid)	0	0.27 ± 0.11	0.0	0.0	2	1.38 ± 0.38	0.0	0.0	2	1.52 ± 0.44	0.0	0.0
4 (DY1,ZV) S_T(Low)	0	0.03 ± 0.01	0.0	0.0	4	2.2 ± 1.4	0.0	0.0	10	10.0 ± 7.8	0.0	0.0
4 (DY1) S_T(Low)	0	0.37 ± 0.13	0.0	0.0	14	6.6 ± 1.5	0.0	0.0	56	30 ± 22	0.0	0.0
4 (DY2,ZV) S_T(High)	0	0.005 ± 0.002	7.7	0.8	–	–	–	–	–	–	–	–
4 (DY2) S_T(High)	0	0.33 ± 0.13	3.9	0.5	–	–	–	–	–	–	–	–
4 (DY2,ZV) S_T(Mid)	0	0.022 ± 0.009	0.0	0.0	–	–	–	–	–	–	–	–
4 (DY2) S_T(Mid)	1	2.2 ± 0.9	0.0	0.0	–	–	–	–	–	–	–	–
4 (DY2,ZV) S_T(Low)	0	0.04 ± 0.02	0.0	0.0	–	–	–	–	–	–	–	–
4 (DY2) S_T(Low)	10	7.2 ± 2.9	0.0	0.0	–	–	–	–	–	–	–	–
THREE Lepton Results												
3 (DY0) S_T(High)	2	0.53 ± 0.25	6.3	3.2	10	5.5 ± 1.9	4.0	18.6	10	15.5 ± 3.6	0.5	6.6
3 (DY0) S_T(Mid)	3	3.8 ± 1.5	0.0	0.0	63	45 ± 15	0.0	0.0	106	114 ± 16	0.0	0.0
3 (DY0) S_T(Low)	9	6.4 ± 2.0	0.0	0.0	291	236 ± 42	0.0	0.0	1590	2054 ± 404	0.0	0.0
3 (DY1,ZV) S_T(High)	4	1.34 ± 0.40	19.9	8.4	5	8.8 ± 1.6	2.7	8.0	–	–	–	–
3 (DY1) S_T(High)	8	7.9 ± 2.6	3.2	2.4	21	18.5 ± 2.7	0.3	0.7	–	–	–	–
3 (DY1,ZV) S_T(Mid)	20	10.2 ± 2.8	0.0	0.0	71	64 ± 12	0.0	0.0	–	–	–	–
3 (DY1) S_T(Mid)	31	43 ± 13	0.0	0.0	216	222 ± 23	0.0	0.0	–	–	–	–
3 (DY1,ZV) S_T(Low)	88	85 ± 21	0.0	0.0	2579	2004 ± 441	0.0	0.0	–	–	–	–
3 (DY1) S_T(Low)	368	381 ± 92	0.0	0.0	9611	7839 ± 1725	0.0	0.0	–	–	–	–
Totals	546	549 ± 95	59.0	17.0	12887	10456 ± 1781	17.0	37.0	1778	2228 ± 405	2.0	16.0
Totals 4L	13	10.4 ± 3.1	29.9	3.1	20	12.4 ± 2.1	9.7	9.8	72	44 ± 23	1.0	10.0
Totals 3L	533	539 ± 95	29.0	14.0	12867	10443 ± 1781	7.0	27.0	1706	2184 ± 404	0.0	7.0