30/05/2012

SEARCH FOR $t\bar{t}$ RESONANCES

implications for new physics models

24th Rencontres de Blois

Samvel Khalatyan @ UIC University of Illinois at Chicago

*on behalf of **CMS** and **ATLAS** collaborations*

INTRODUCTION

- Many Beyond the Standard Model theories predict new heavy states (e.g. Z' bosons) decaying to $\mathrm{t\bar{t}}$:

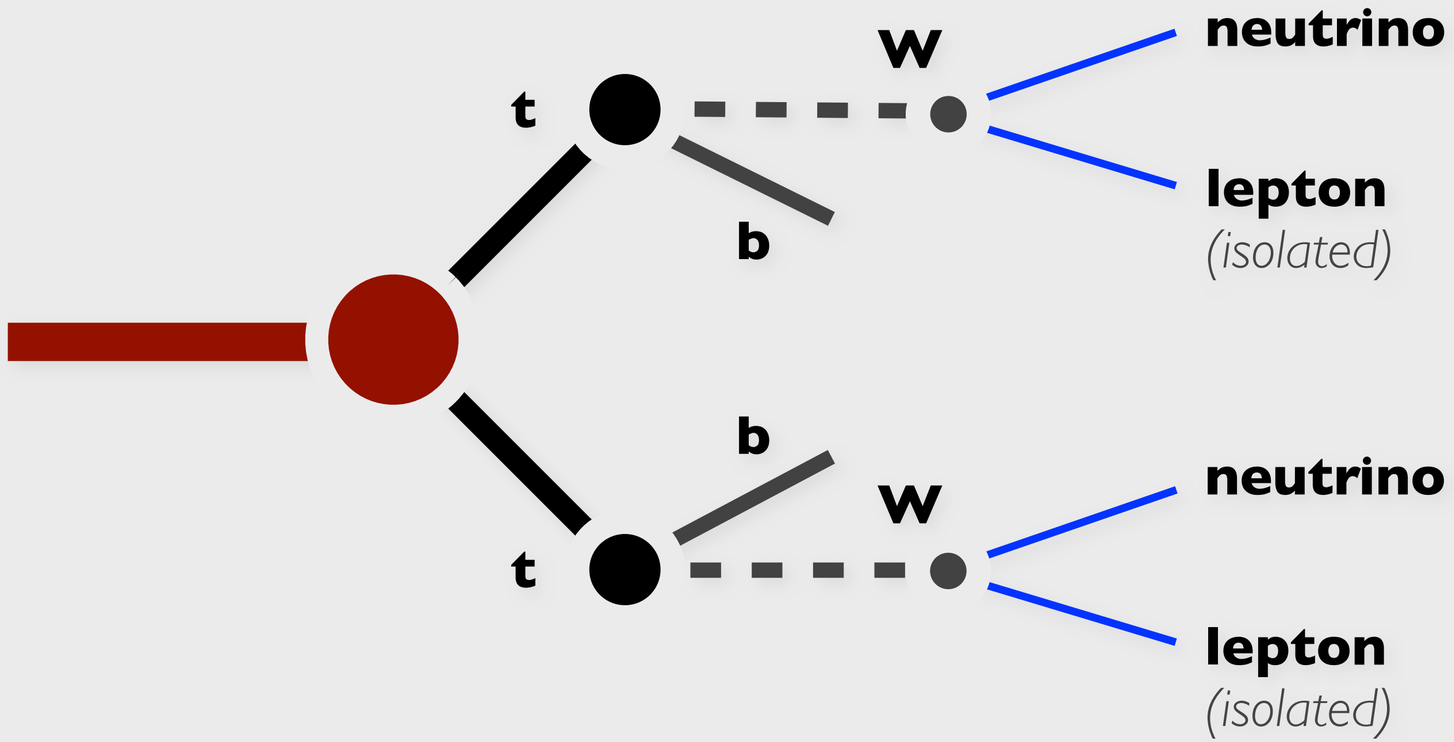
  topcolor Z', Randall-Sundrum Kaluza-Klein gluons

- Split searches into different channels based on $\mathrm{t\bar{t}}$ final state:

  dilepton, lepton+jets, all-hadronic

- Results on searches for new physics in CMS and ATLAS experiments are presented

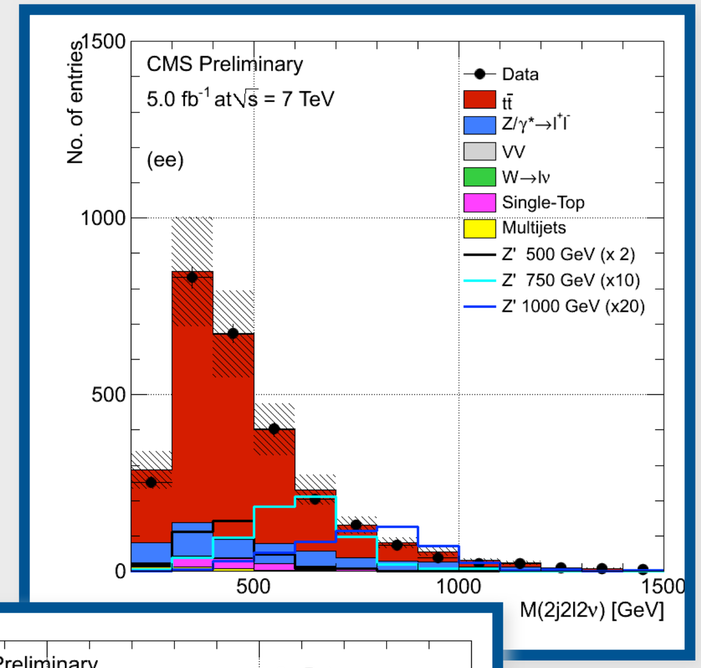
DILEPTON CHANNEL

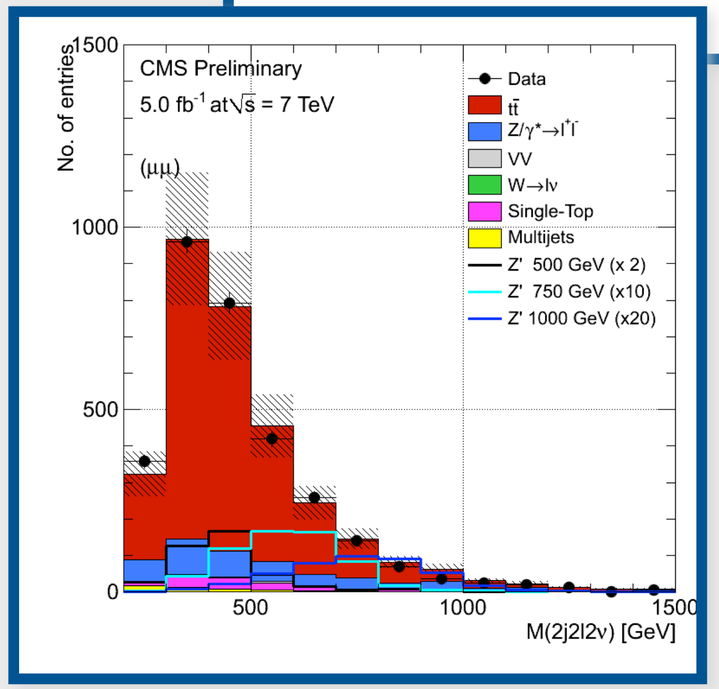


DILEPTON CHANNEL

CMS TOP-11-010 L = 5.0 fb^{-1}

- two **isolated** leptons
  - e: $P_T > 20$ GeV
  - **μ**: $P_T > 20$ GeV
- reject low mass resonances suppress Z-boson production
  - $M_{ll} > 10$ GeV
  - $|M_Z - M_{ll}| > 10$ GeV
- **two** or more anti-K_T (R=0.5) jets: $P_T > 30$ GeV
- large transverse missing energy: MET > 30 GeV
- secondary vertex b-tagged jet
  (60% b-tag and 2% mistag rate)
- Model QCD multijet from data by inverting the isolation requirement
- Correct Drell-Yan yield in the Z-boson production region



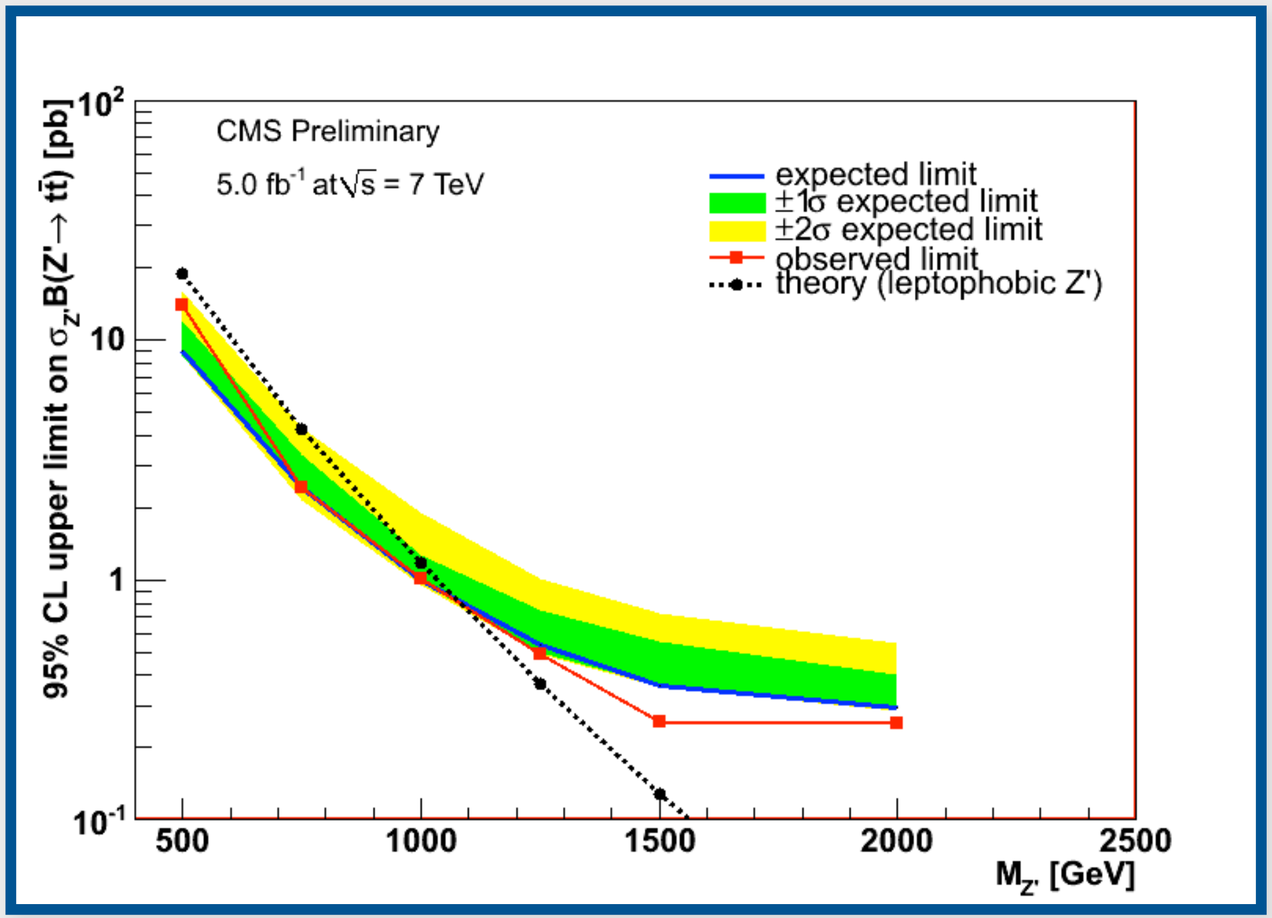


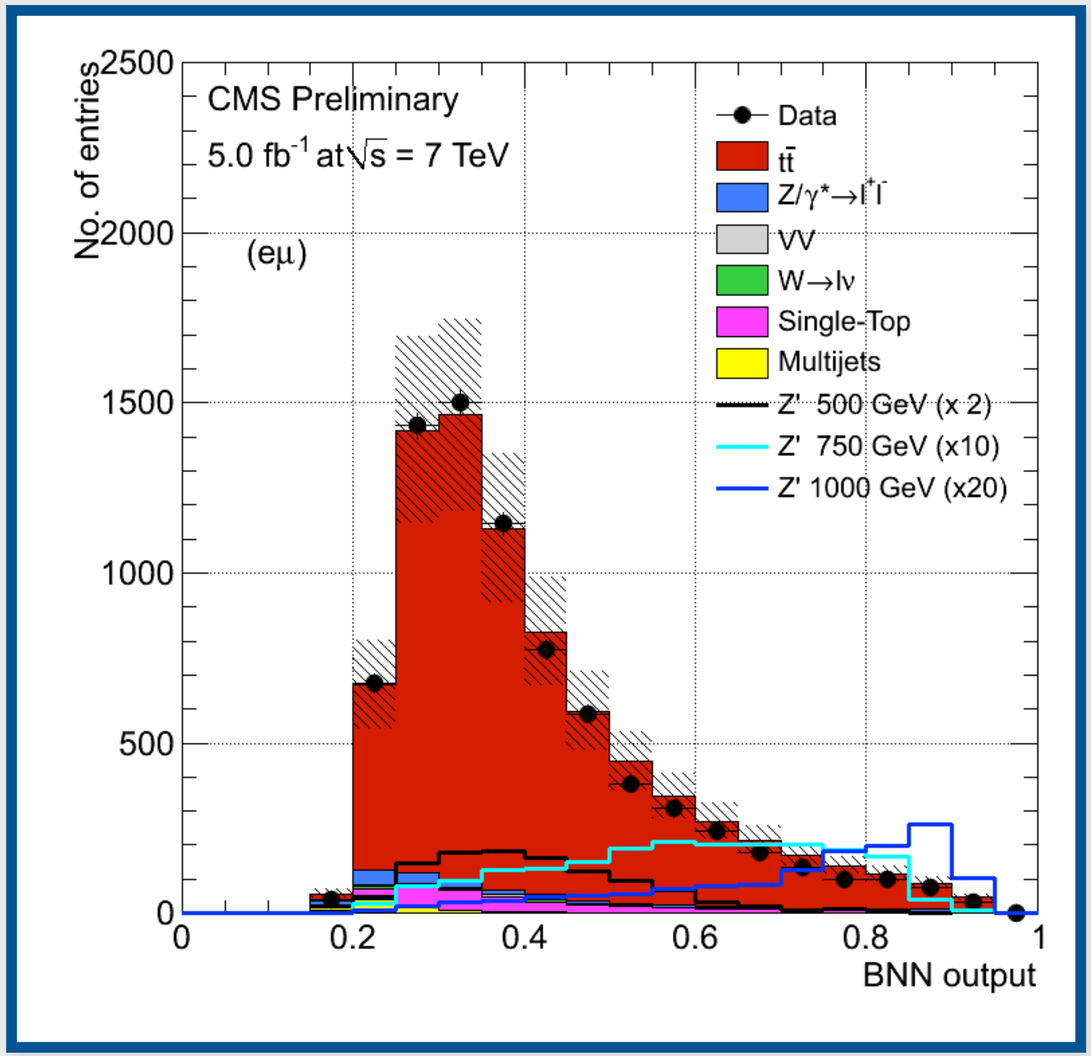
DILEPTON CHANNEL

CMS TOP-11-010 L = 5.0 fb^{-1}

Excluded mass region

narrow Z' mass < 1.1 TeV



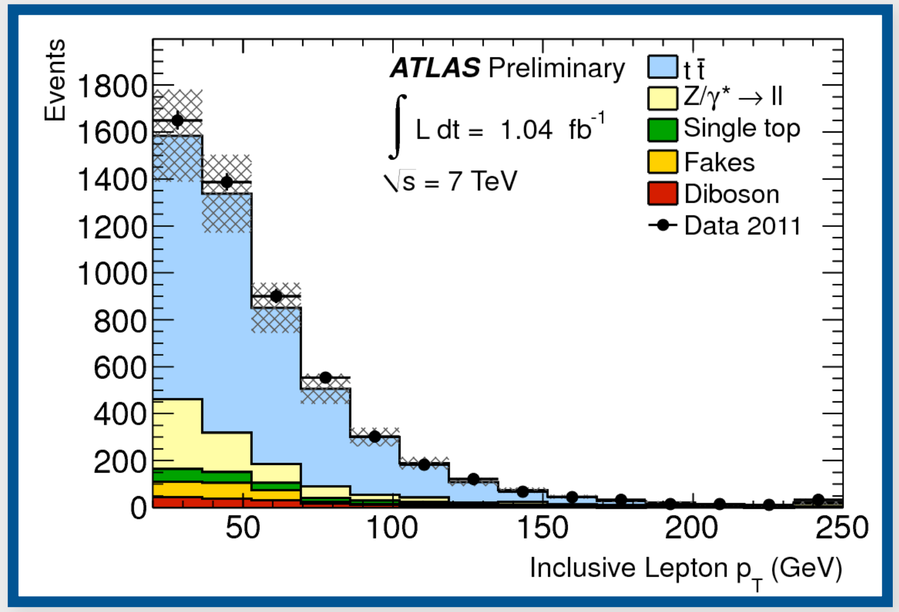


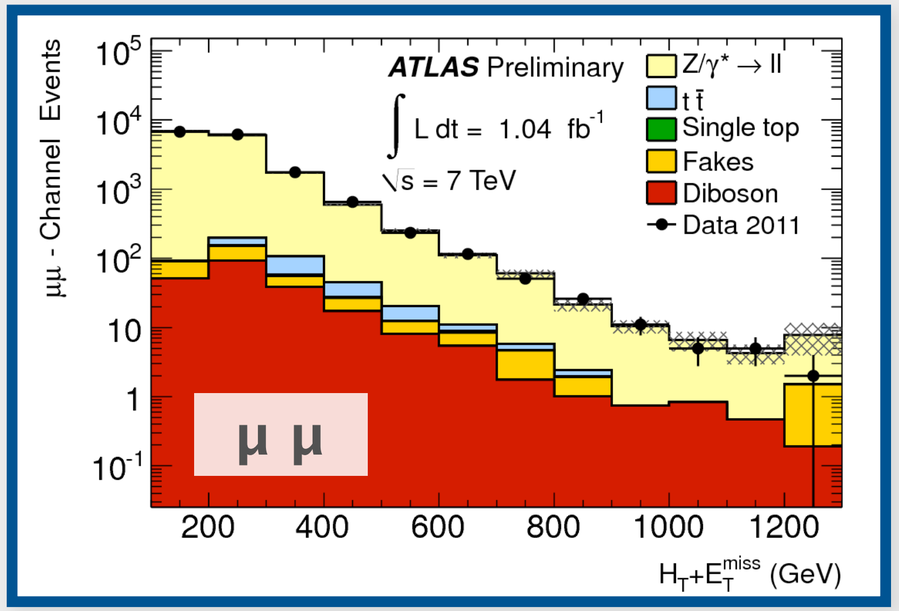
Bayesian **N**eural **N**etwork discriminant

DILEPTON CHANNEL

ATLAS-CONF-2011-123 L = 1.04 fb^{-1}

- two **isolated** leptons — e: $E_T > 25$ GeV; μ: $P_T > 20$ GeV
- reject low mass resonances suppress Z-boson production — $M_{ll} > 12$ GeV; $|M_Z - M_{ll}| > 15$ GeV
- **two** or more anti-K_T (R=0.4) jets — $P_T > 30$ GeV
  (remove jet if ΔR(electron,jet) < 0.2)
- large missing energy suppress non-$t\bar{t}$ events (eμ) — MET > 40 GeV; $H_T > 130$ GeV
- Contribution of W+jets and QCD multijet is estimated from data using the Matrix Method
- Extract Drell-Yan from data in the Z-boson production region





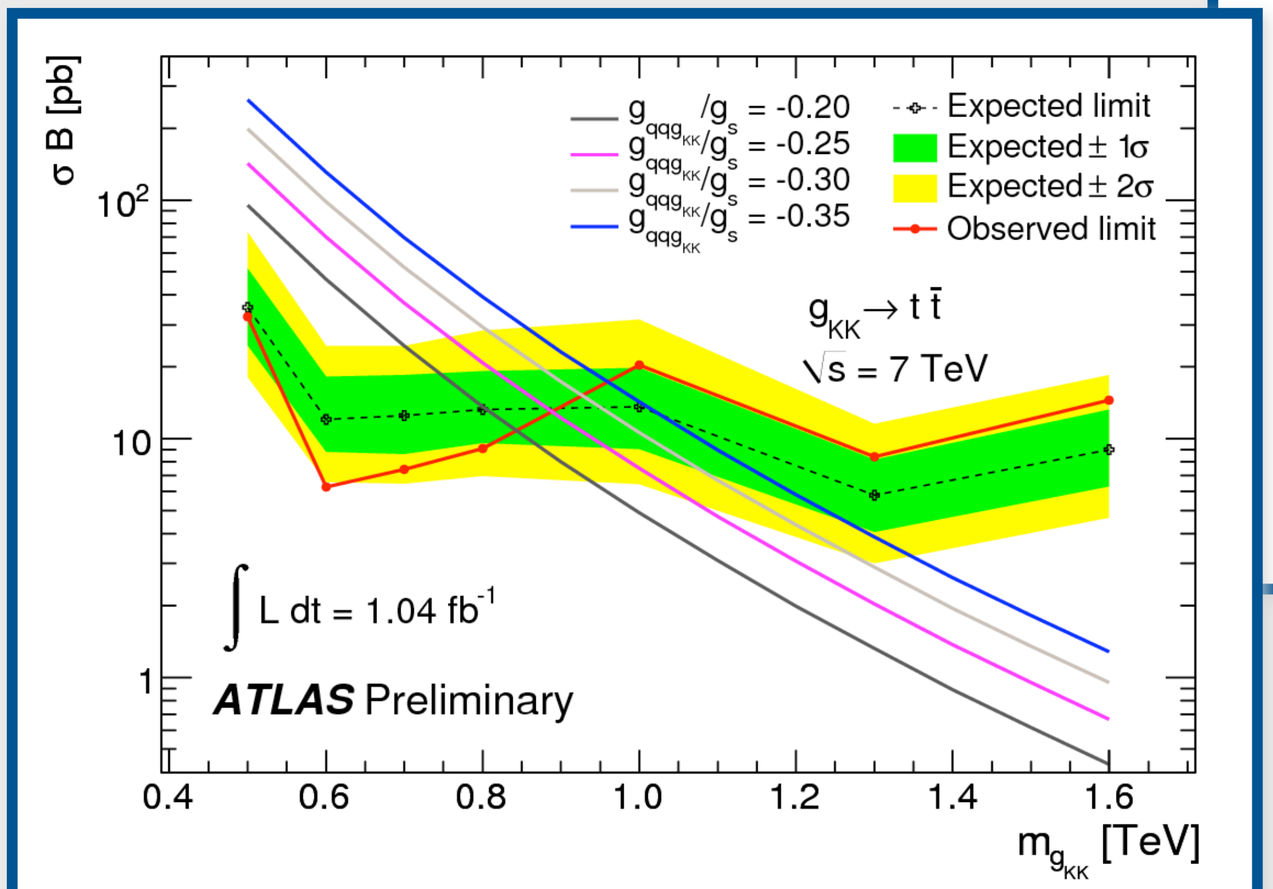
$$H_T = \sum_{lepton} P_T + \sum_{jet} P_T$$

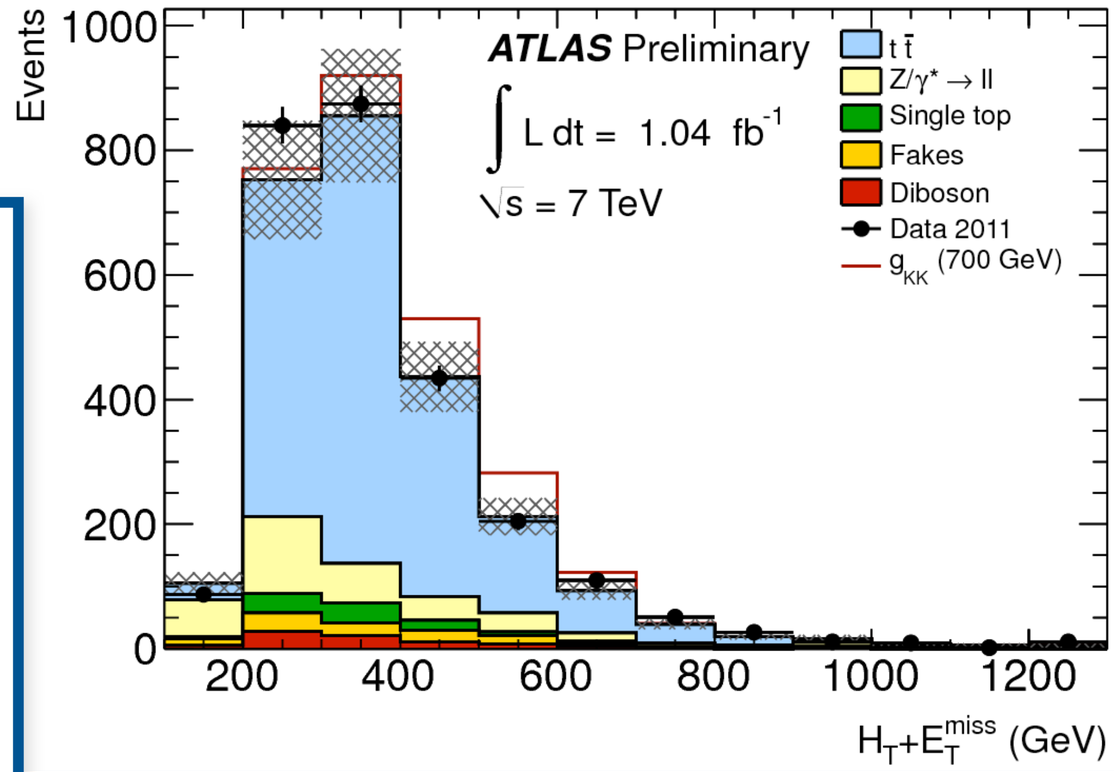
DILEPTON CHANNEL

ATLAS-CONF-2011-123 L = 1.04 fb^{-1}

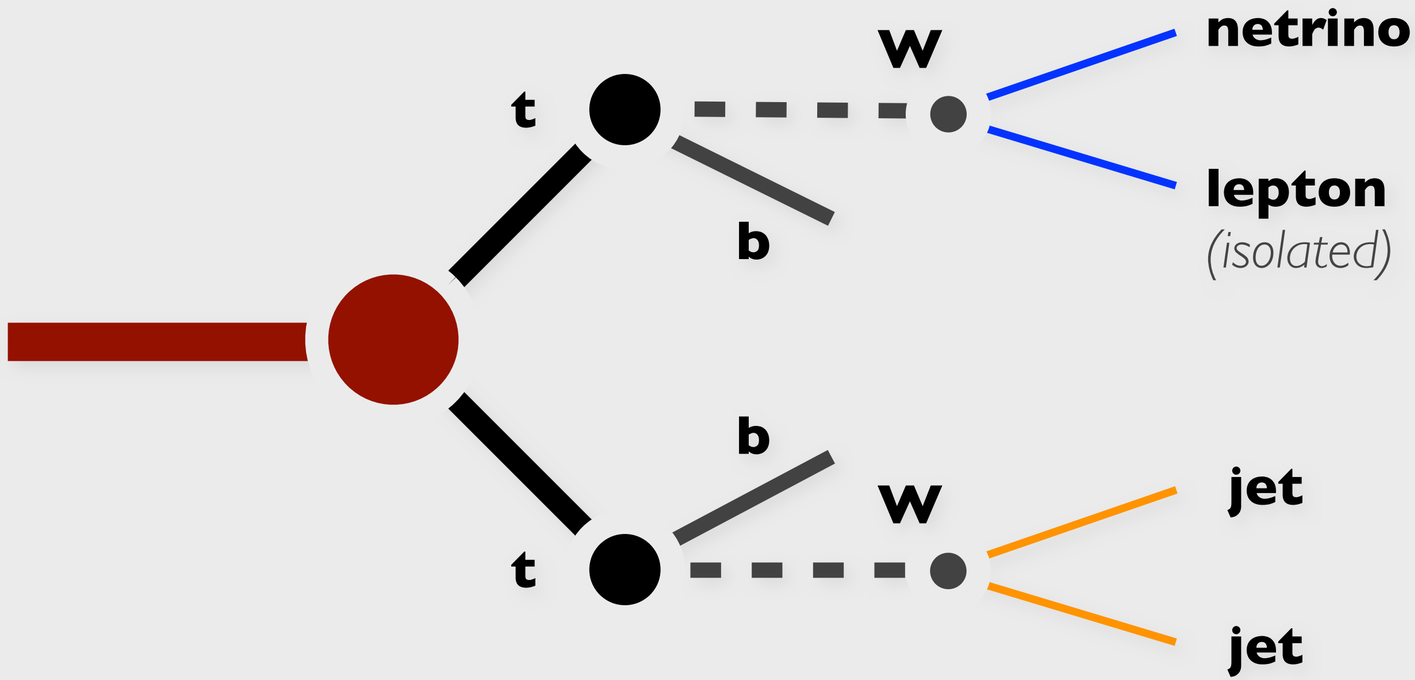
Excluded mass region

KK gluon mass < 0.84 TeV





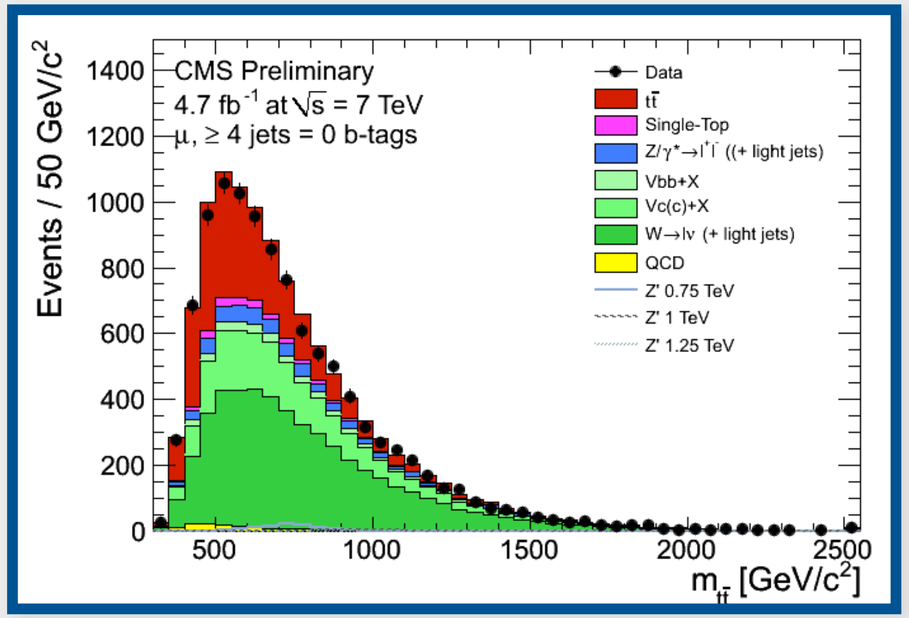
LEPTON+JETS CHANNEL
(AT THRESHOLD)

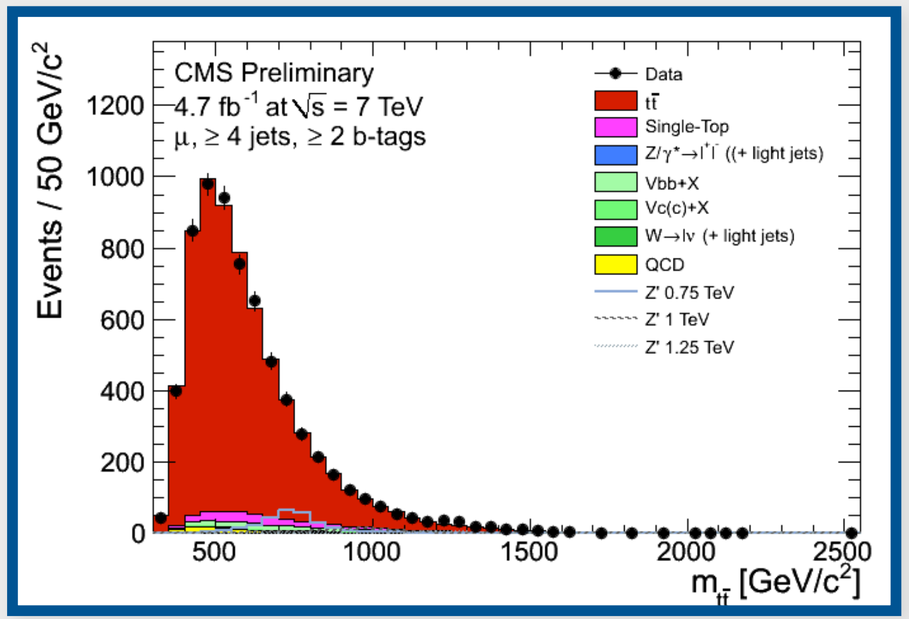


LEPTON+JETS CHANNEL (AT THRESHOLD)

CMS TOP-11-009 L = 4.7 fb^{-1}

- one **isolated** e $P_T > 30$ GeV
  μ $P_T > 20$ GeV
- veto second lepton
- **three** or more anti-K_T (R=0.5) jets $P_T > 50$ GeV
  leading jet $P_T > 70$ GeV
- missing energy *MET > 20 GeV*
- secondary vertex b-tagged jet
  (60% b-tag and 2% mistag rate)
- Model QCD multijet from data by inverting the isolation requirement
- W+jets yield is normalized to data yield in the control region: four jets, no b-tags



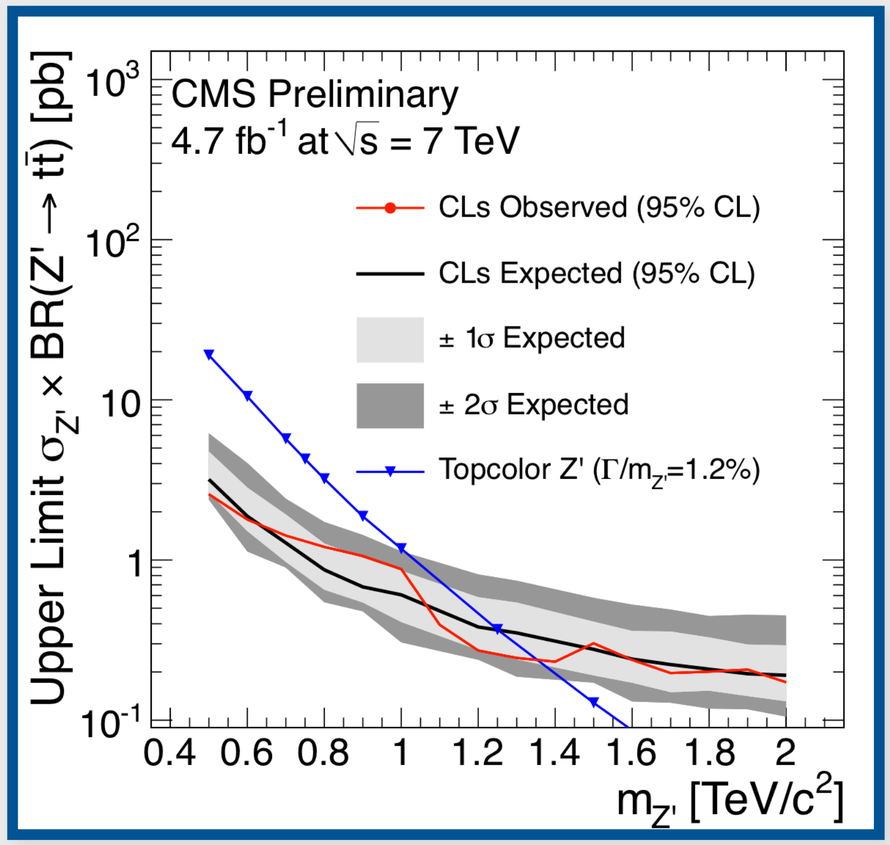


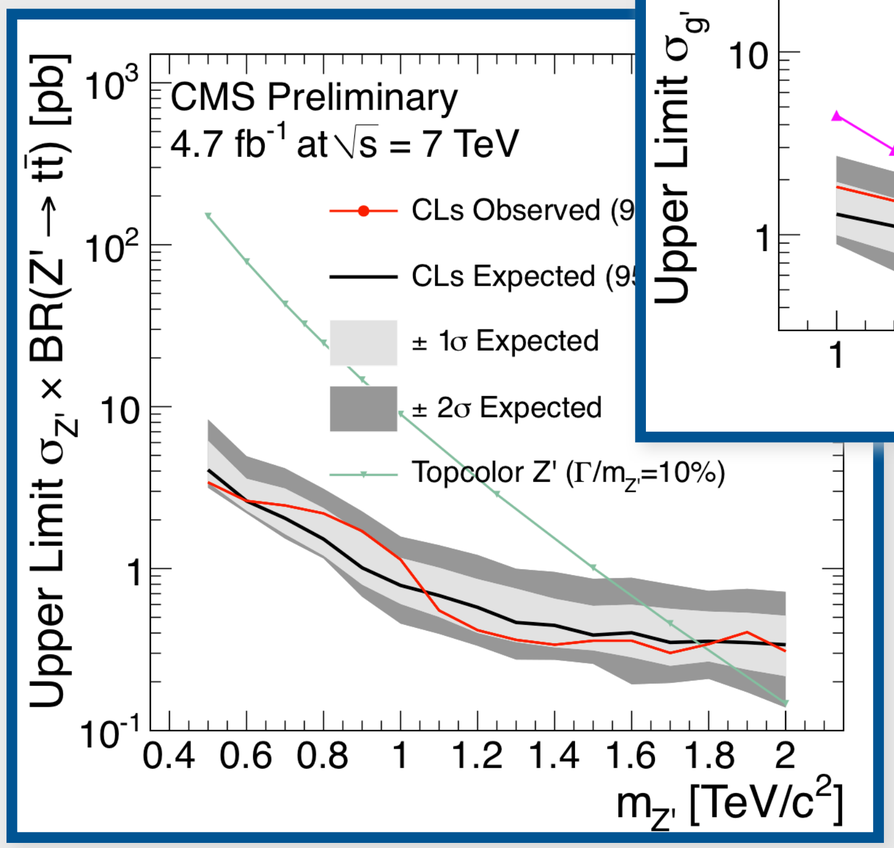
LEPTON+JETS CHANNEL (AT THRESHOLD)

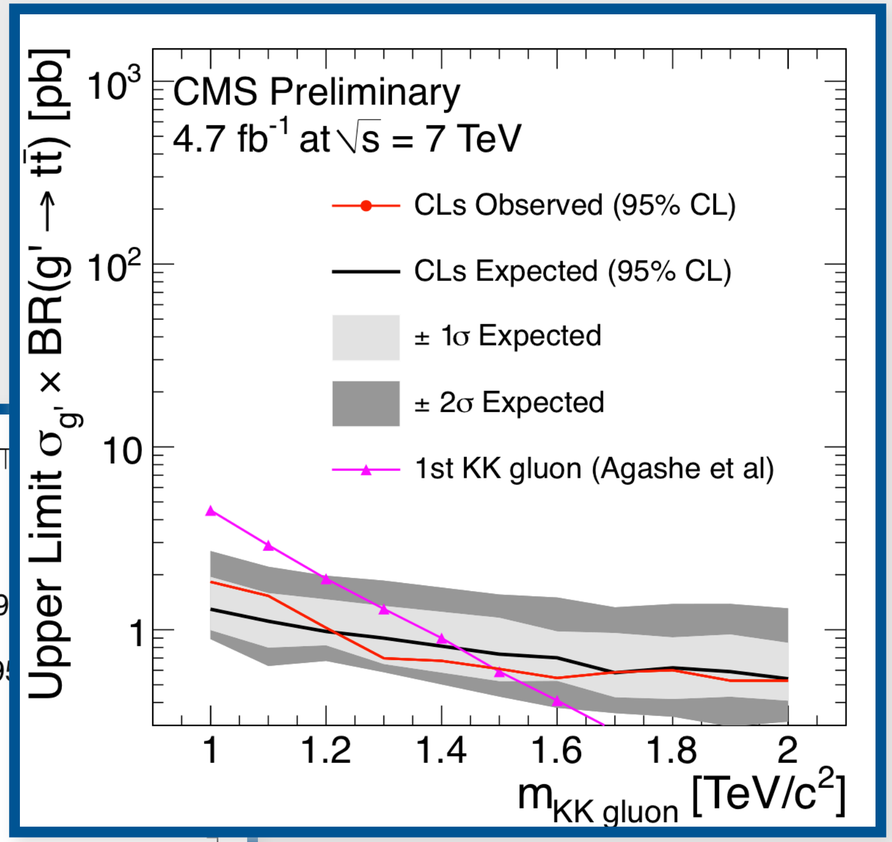
CMS TOP-11-009 L = 4.7 fb^{-1}

Excluded mass region

narrow Z' mass < 1.3 TeV
wide Z' mass < 1.7 TeV
KK gluon mass < 1.4 TeV



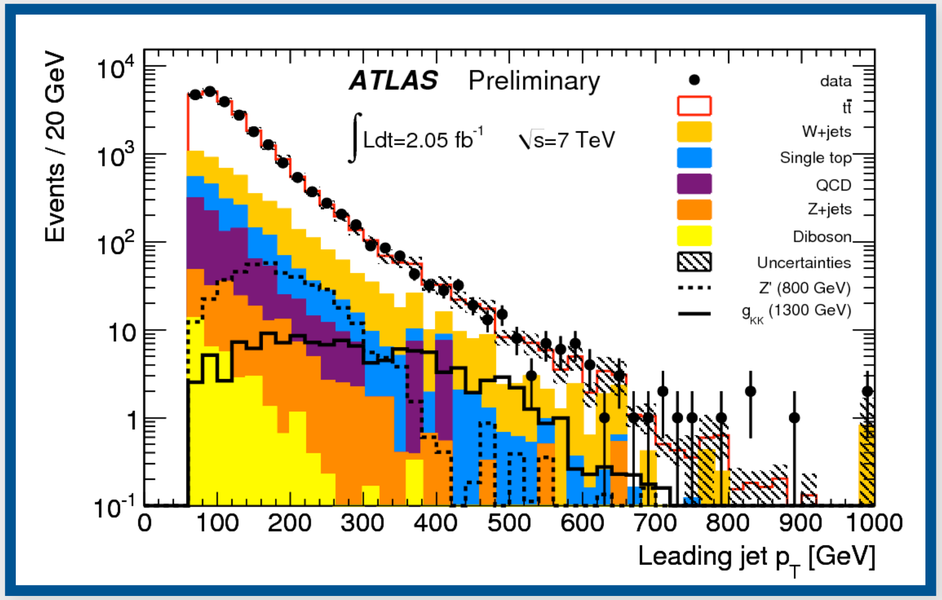


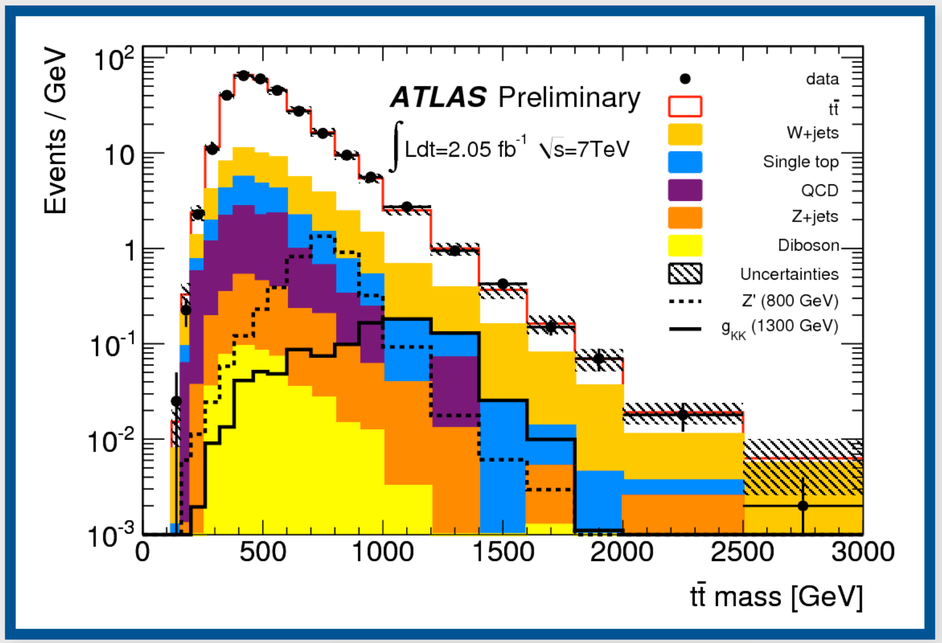


LEPTON+JETS CHANNEL (AT THRESHOLD)

ATLAS-CONF-2012-029 L = 2.05 fb^{-1}
arXiv:1205.5371

- one **isolated** e $E_T > 25$ GeV
  μ $P_T > 25$ GeV
- **four** or more anti-K_T (R=0.4) jets $P_T > 25$ GeV
  (three jets if found Mjet > 60 GeV) leading jet $P_T > 60$ GeV
- large missing energy e $MET > 35$ GeV
  μ $MET > 20$ GeV
- transverse mass e $M_T > 25$ GeV
  μ $MET+M_T > 60$ GeV
- (multiple) secondary vertices based b-tagged jet
  (60% b-tag)
- Model QCD multijet from data by faking lepton with jet
- Apply data driven correction due to charge asymmetry in W+jets production





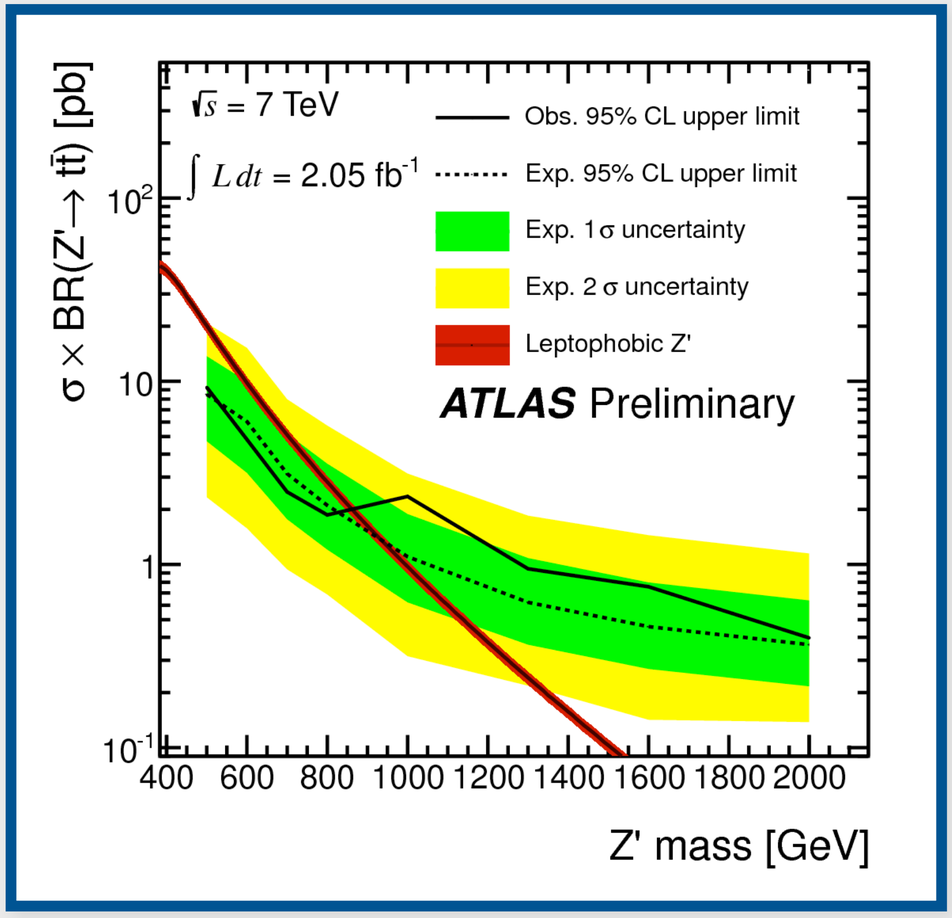
$$m_T = \sqrt{2p_T^l \not{E}_T (1 - \cos\Delta\phi)}$$

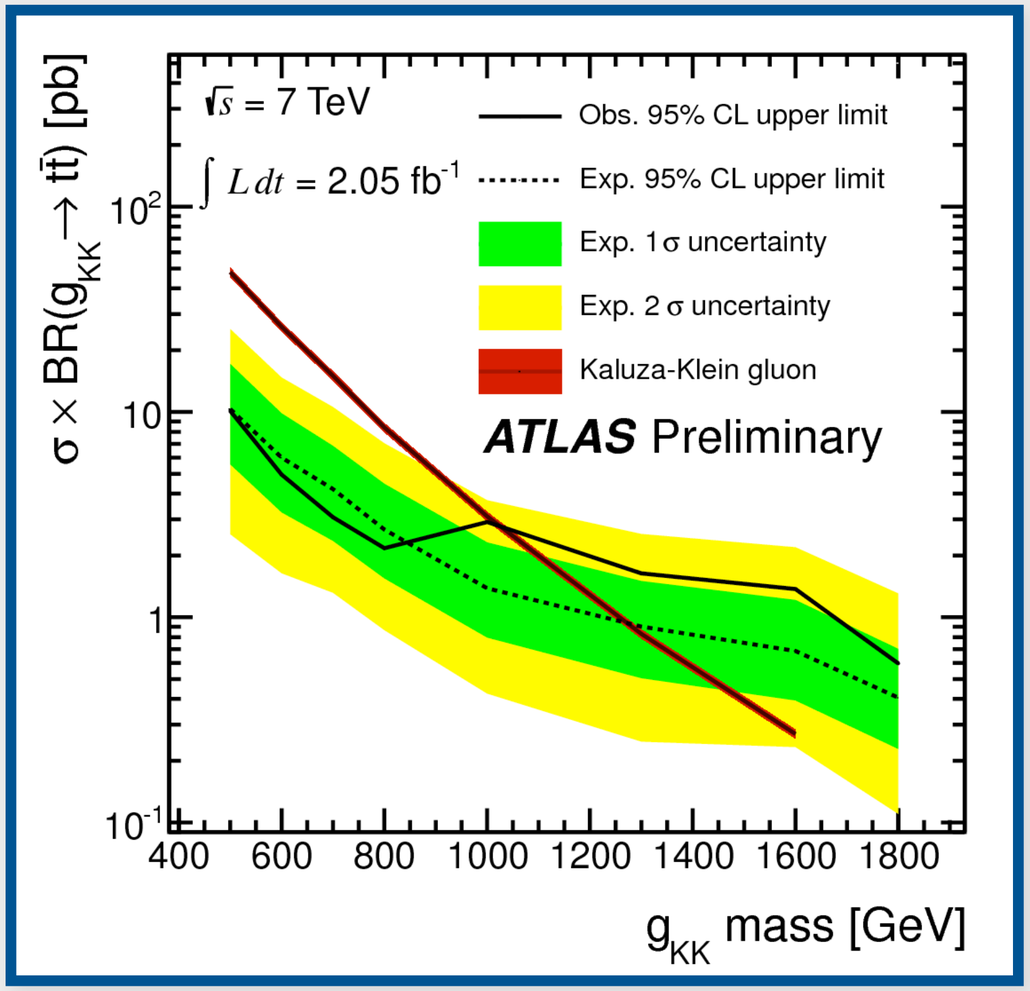
LEPTON+JETS CHANNEL (AT THRESHOLD)

ATLAS-CONF-2012-029 L = 2.05 fb^{-1}
arXiv:1205.5371

Excluded mass region

narrow Z' mass < 0.86 TeV
KK gluon mass < 1.03 TeV

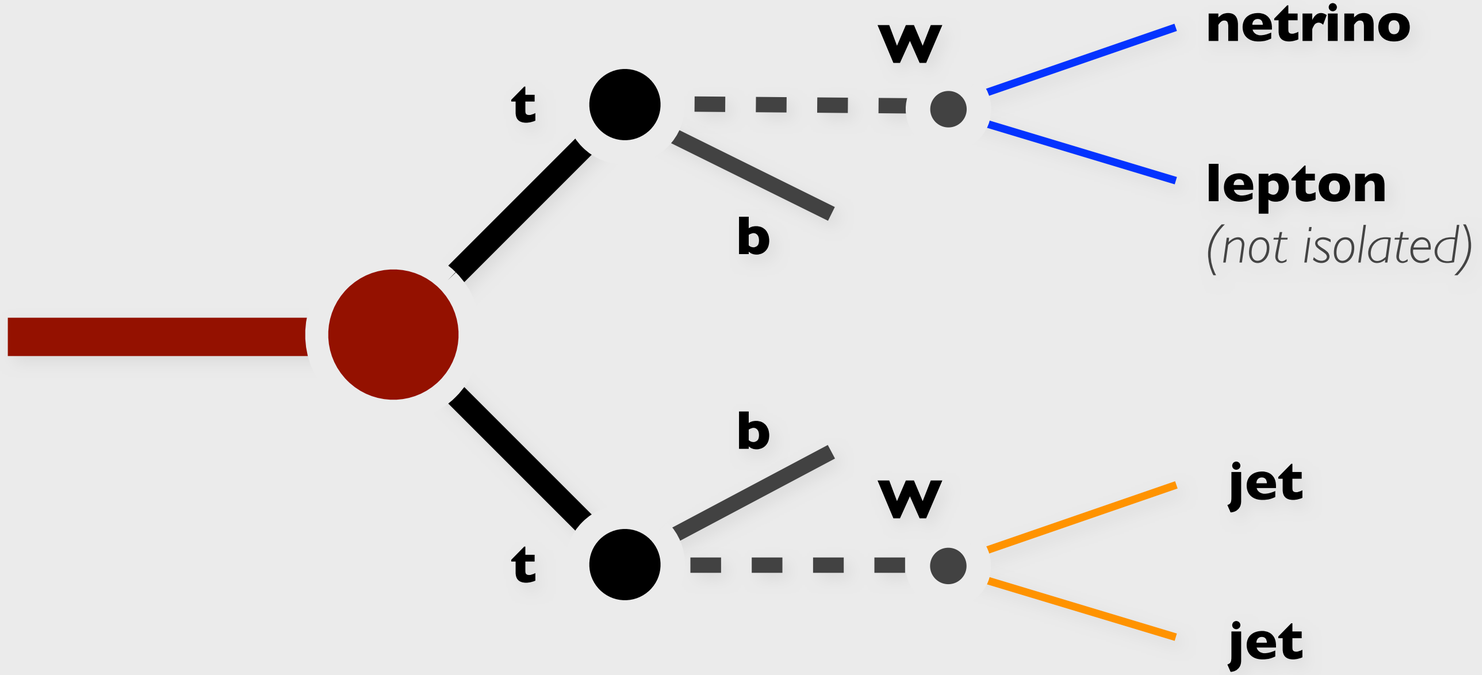




LEPTON+JETS CHANNEL

(BOOSTED)

new



LEPTON+JETS CHANNEL (BOOSTED)

new

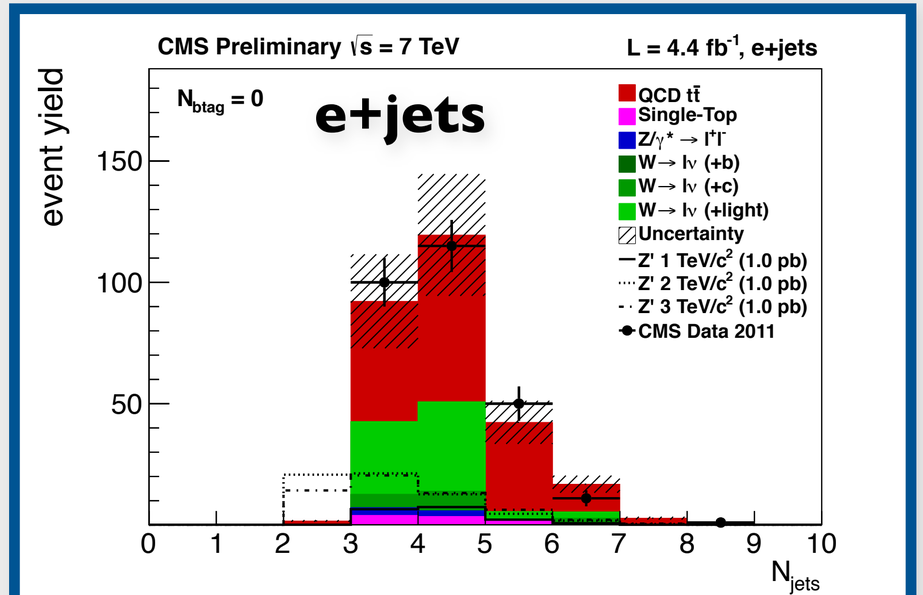
CMS EXO-11-093 L = 5.00 fb^{-1}

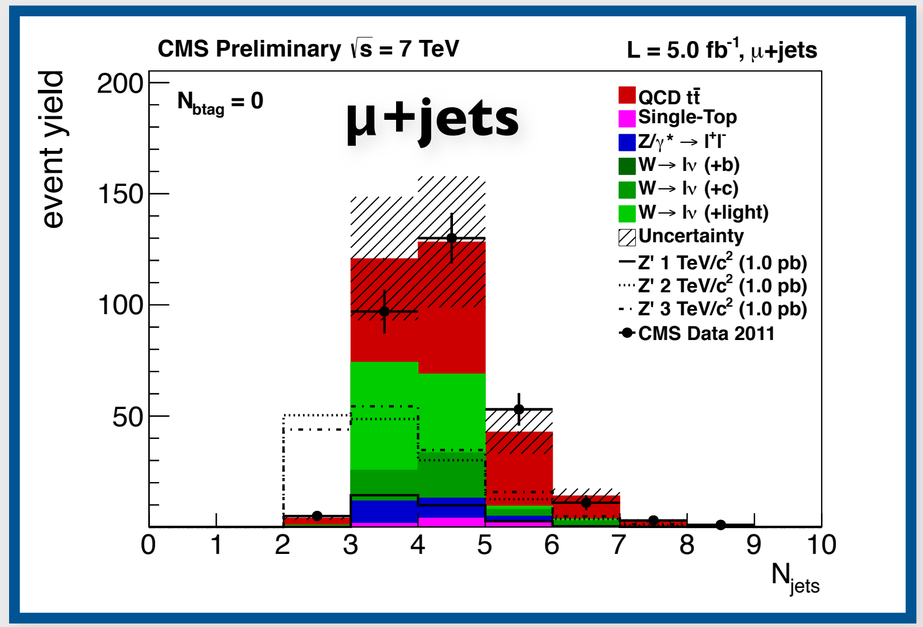
motivation

- the signal efficiency drops if isolated lepton is required:

Z' 1 TeV	*~ 8%*
Z' 1.5 TeV	*~ 28%*
Z' 2TeV	*~ 47%*
Z' 3TeV	*~ 54%*

- low mass search uses 3+ jets
- 2 jets bin is highly populated with signal and *almost no* background



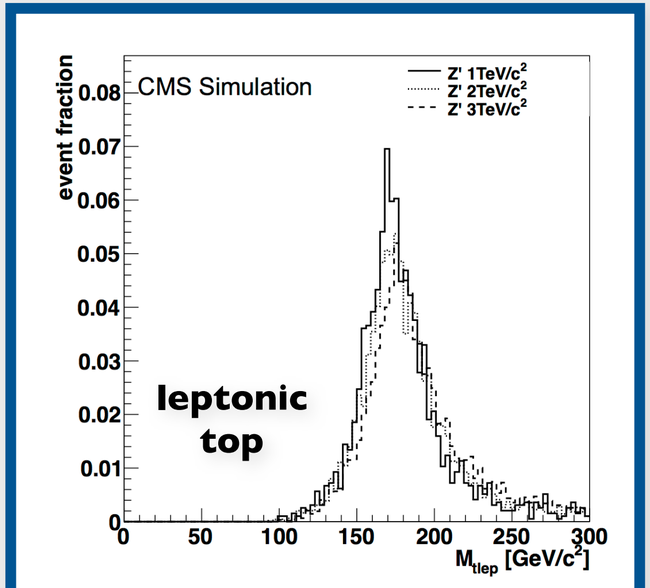


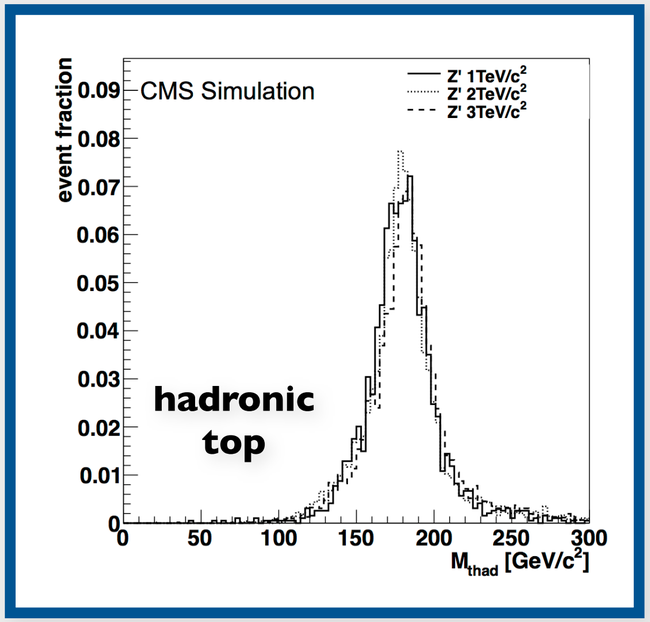
LEPTON+JETS CHANNEL (BOOSTED)

new

CMS EXO-11-093 L = 5.00 fb^{-1}

- one lepton (**no isolation** is applied)
  - **μ** $P_T > 35$ GeV
  - **e** $P_T > 70$ GeV
- drop event if second lepton is present
- **two** or more anti-K_T (R=0.5) jets $P_T > 50$ GeV
  - leading jet **μ** $P_T > 250$ GeV
  - **e** $P_T > 150$ GeV
- suppress QCD multijet
  - *2D cut* $\Delta R > 0.5$ or $P_T^{rel} > 25$ GeV
  - *and* $H_T^{lep} > 150$ GeV
- additional topological cuts in e+jets channel to reject QCD multijet
- reconstruct top quarks in simulation by matching reconstructed jets to partons





$$H_T^{lep} = \not{E}_T + p_T^{\mu}$$

LEPTON+JETS CHANNEL (BOOSTED)

new

CMS EXO-11-093 L = 5.00 fb^{-1}

- reconstruct resonance with Chi2

$$\chi^2 = \left[\frac{M_{lep} - \bar{M}_{lep}}{\sigma_{M_{lep}}}\right]^2 + \left[\frac{M_{had} - \bar{M}_{had}}{\sigma_{M_{had}}}\right]^2$$

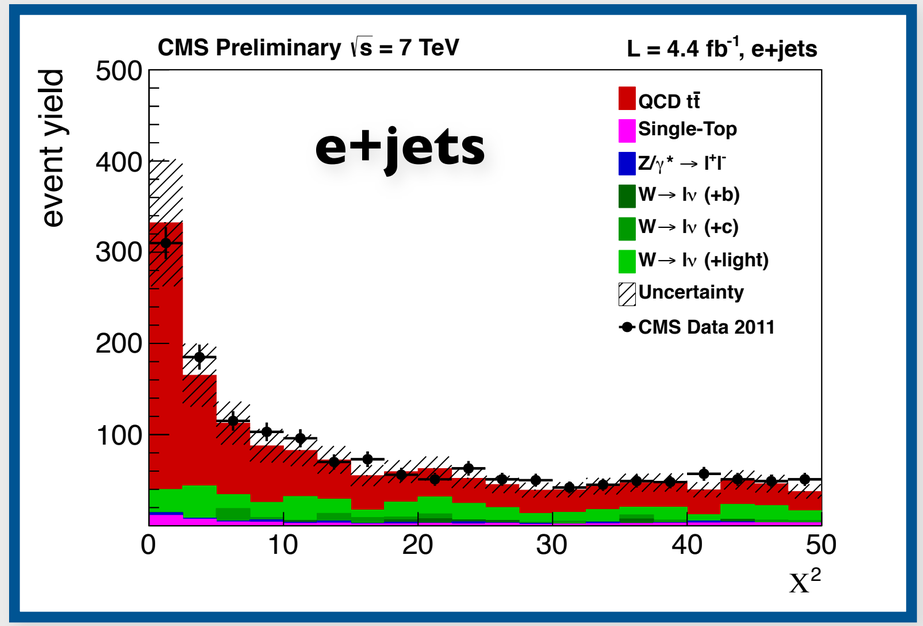
the Chi2 parameters are extracted from simulation by matching reconstructed jets to partons

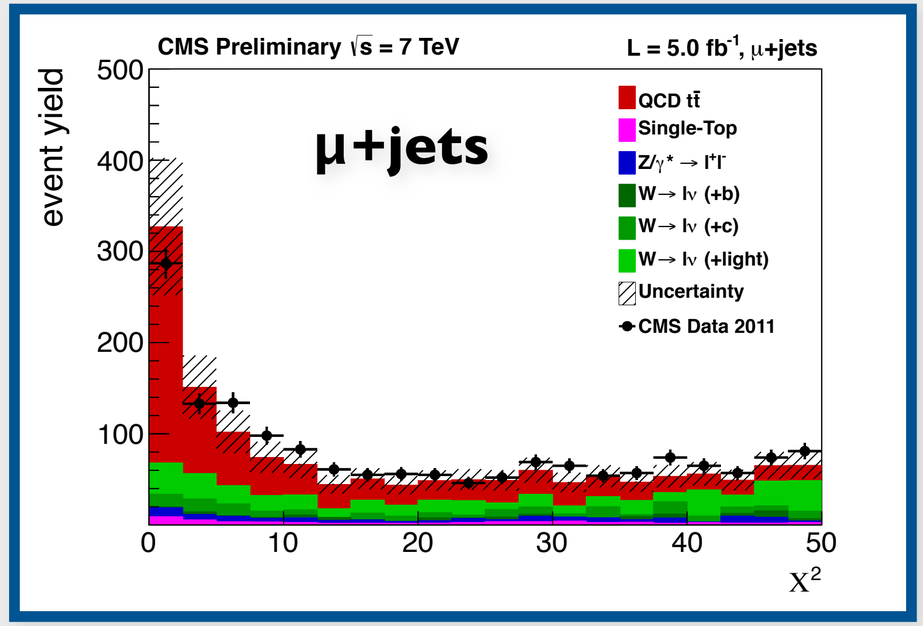
- cut on Chi2 to suppress W+jets and QCD contributions

(< 1% of QCD is left after all cuts)

- use secondary vertex b-tagged jet to split events into 0-btag and 1+btag channels

(60% b-tag and 2% mistag rate)

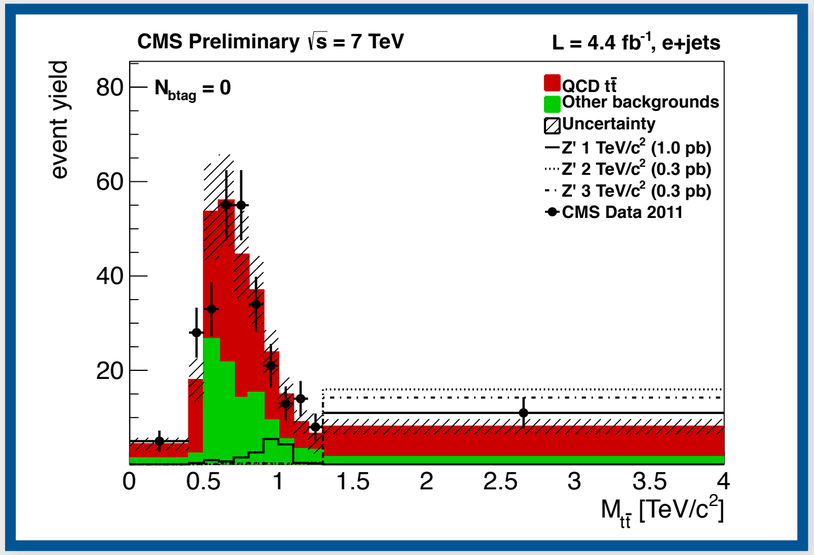


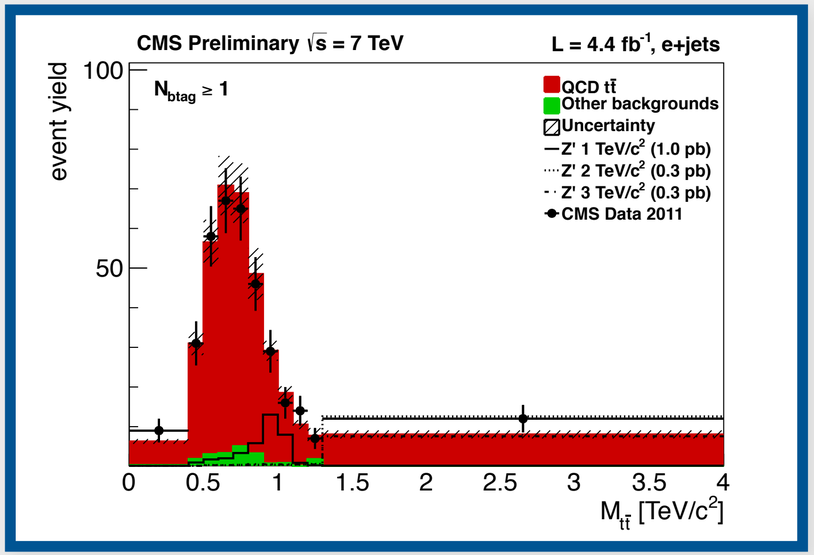


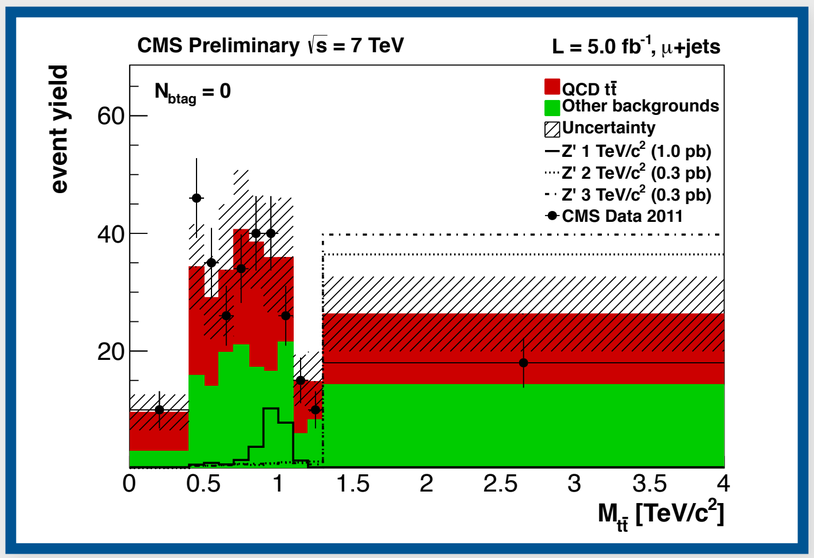
LEPTON+JETS CHANNEL (BOOSTED)

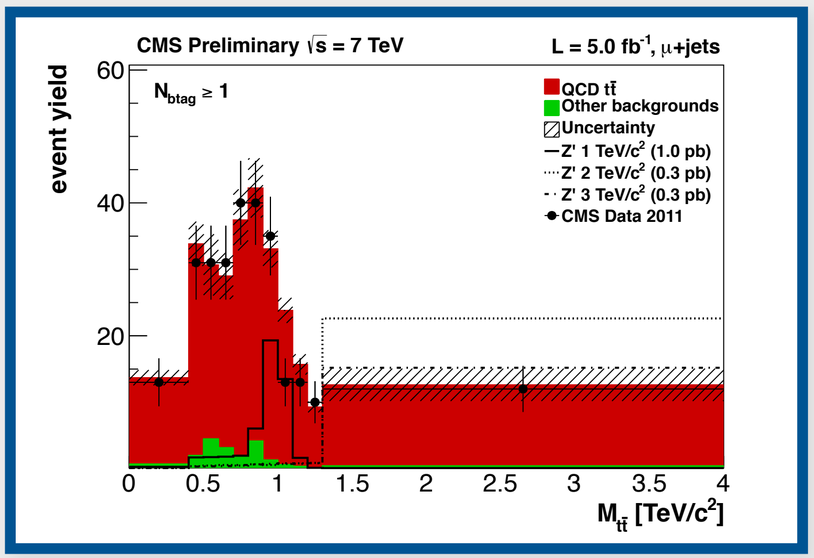
new

CMS EXO-11-093 L = 5.00 fb^{-1}









- reconstructed resonance mass is used as input for limit setting procedure
- re-binning is required to cover low-statistics in the tails
- use CLs method to set the limit

LEPTON+JETS CHANNEL (BOOSTED)

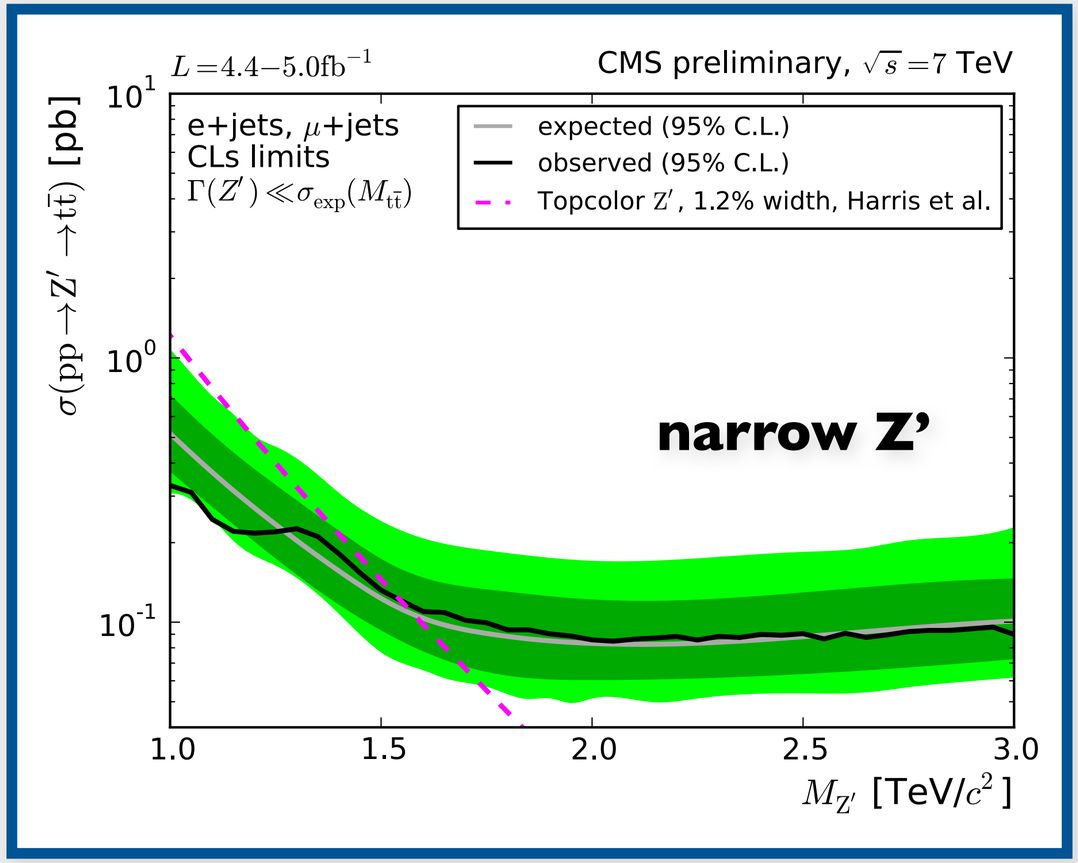
new

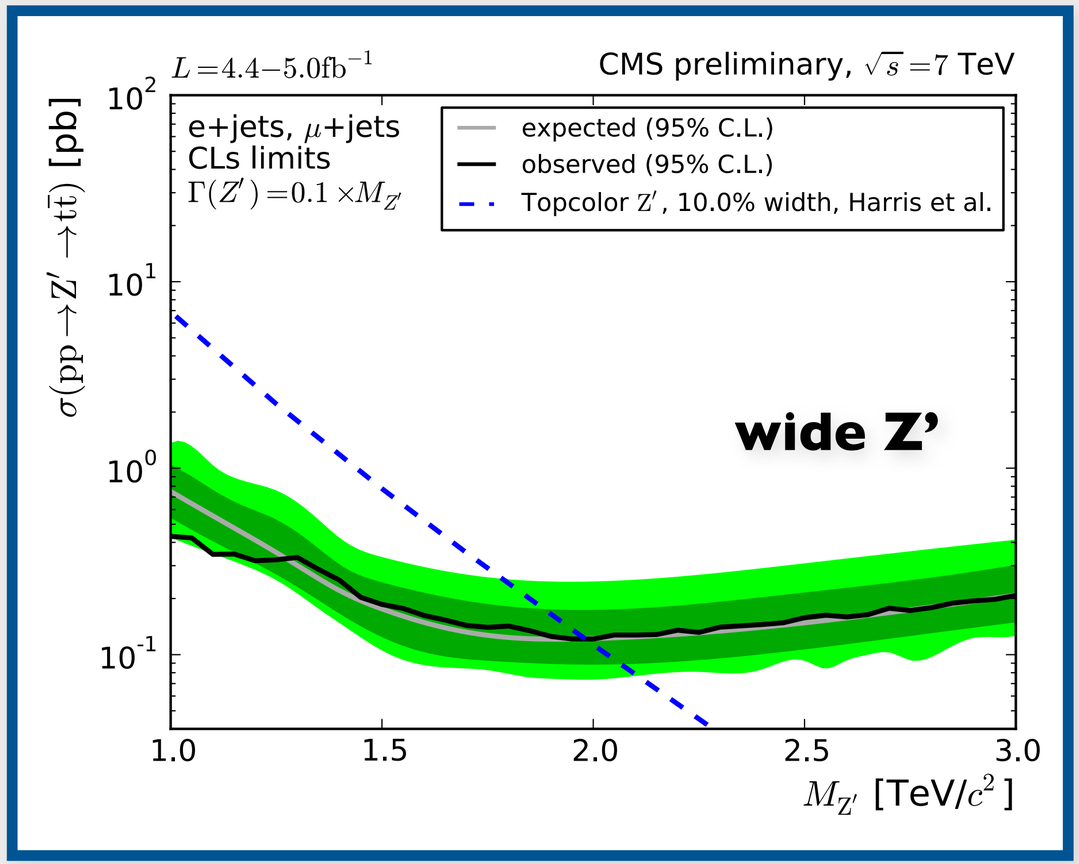
CMS EXO-11-093 L = 5.00 fb^{-1}

Excluded mass region

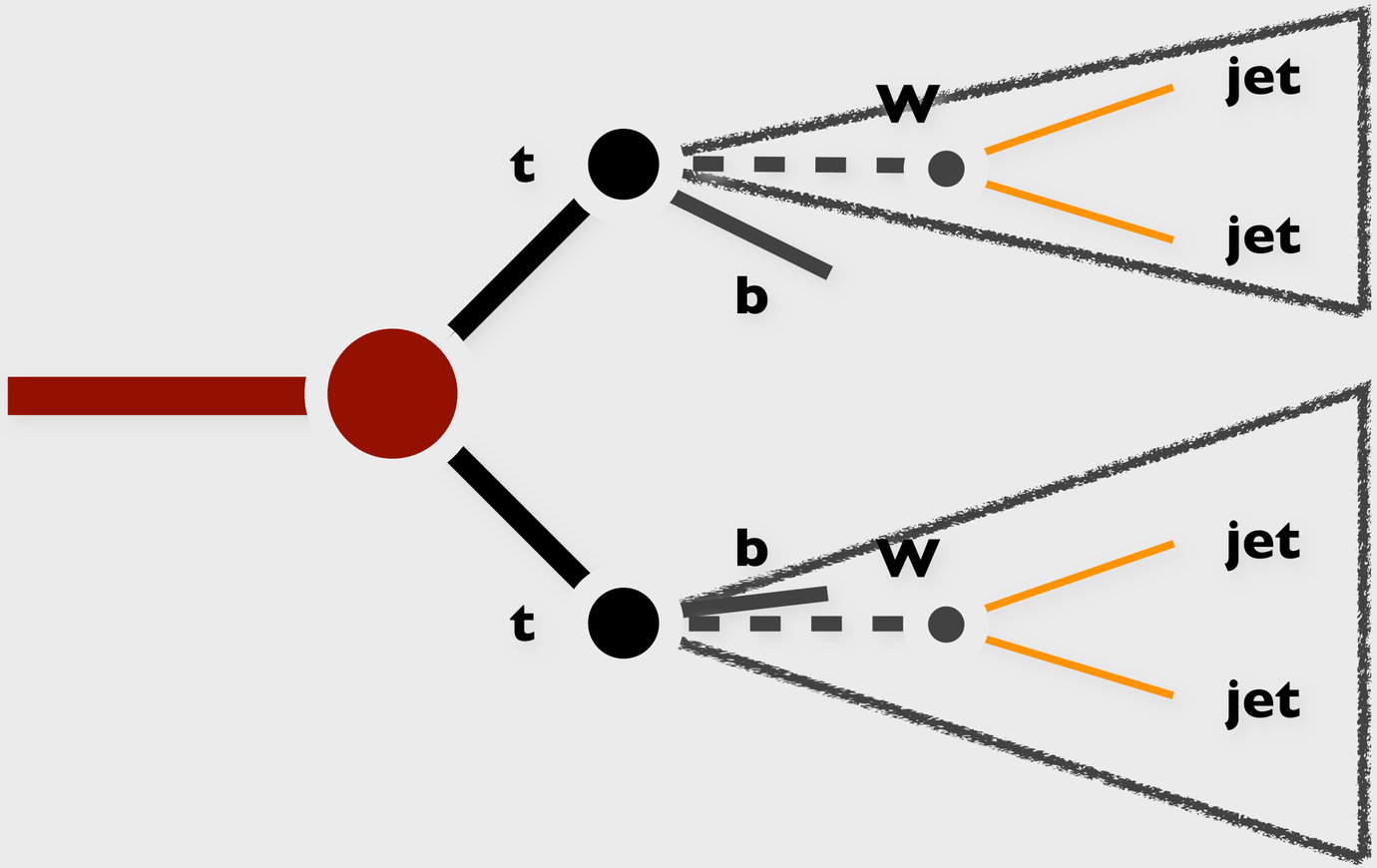
narrow Z' mass $<$ 1.55 TeV

wide Z' mass $<$ 1.98 TeV





ALL-HADRONIC CHANNEL
(BOOSTED)



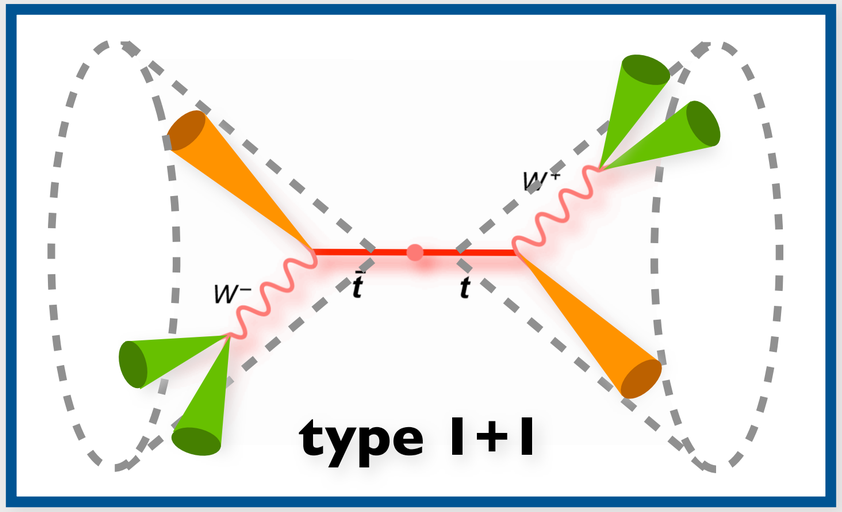
ALL-HADRONIC CHANNEL (BOOSTED)

CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488

- high-mass search - **type 1+1**:
  - two Cambridge-Aachen (R=0.8) jets $P_T > 350$ GeV
  - both jets are *top-tagged* and lie in opposite hemispheres

    $N_{sub\text{-}jets} \geq 3$ $140 < M_{jet} < 250$ GeV $M_{min}(jet1, jet2) > 50$ GeV

    (jet1, jet2 are any two sub-jets)

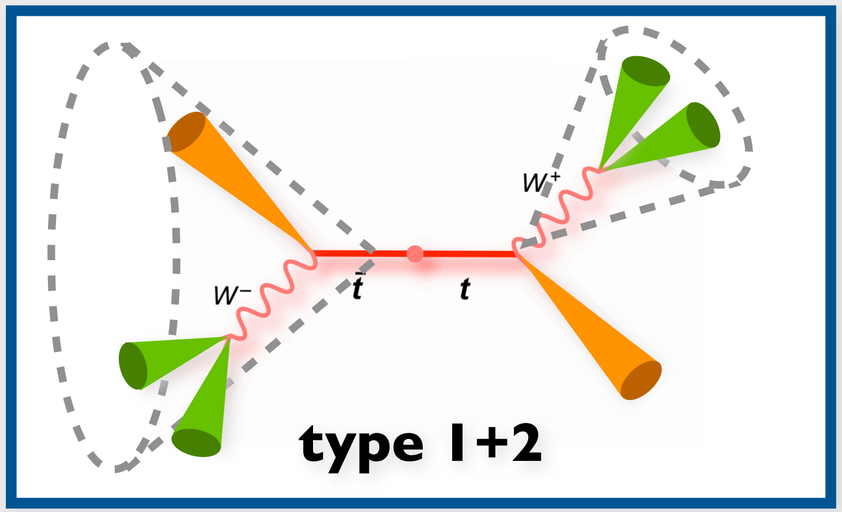


- medium-mass search - **type 1 + 2**:
  - three Cambridge-Aachen (R=0.8) jets:

    $P_T > 350, 200, 30$ GeV
  - reject type 1+1 events
  - one jet is *top-tagged* in one hemisphere
  - low-P_T and *W-tagged* jets are in the opposite hemisphere:

    $N_{sub\text{-}jets} = 2$ $60 < M_{jet} < 100$ GeV $\mu < 0.4$

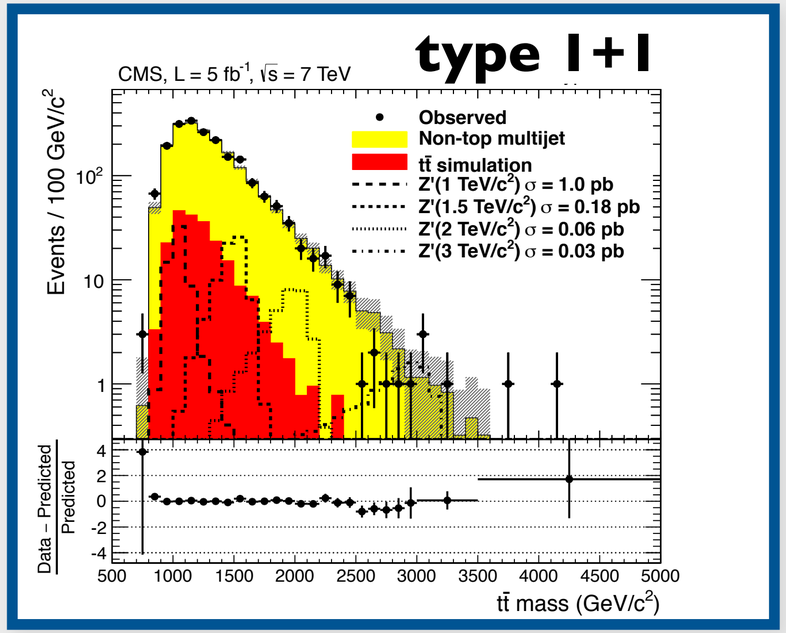
    (μ is a mass drop: mass of the heaviest sub-jet divided by W-tagged jet mass)

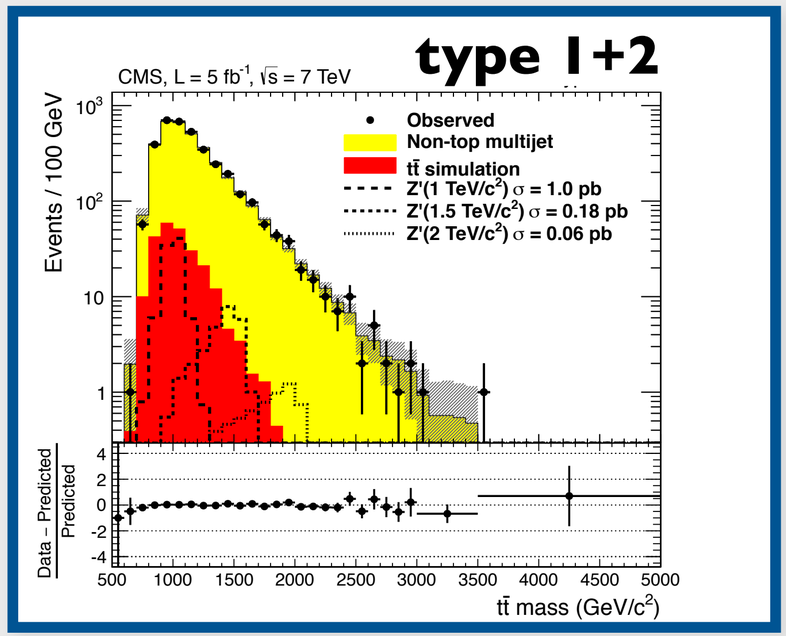


ALL-HADRONIC CHANNEL (BOOSTED)

CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488

- Study top-tagging efficiency in control sample: single muon and at least two jets
- Mistag rate is measured by inverting some of the top-tagging and W-tagging selections
- Extract QCD multijet from data by looking at:
  - type 1+1 events but require only one top-tagged jet
  - type 1+2 events with only W-tagged jet
  - weight events by top-tagging mistag rate efficiency



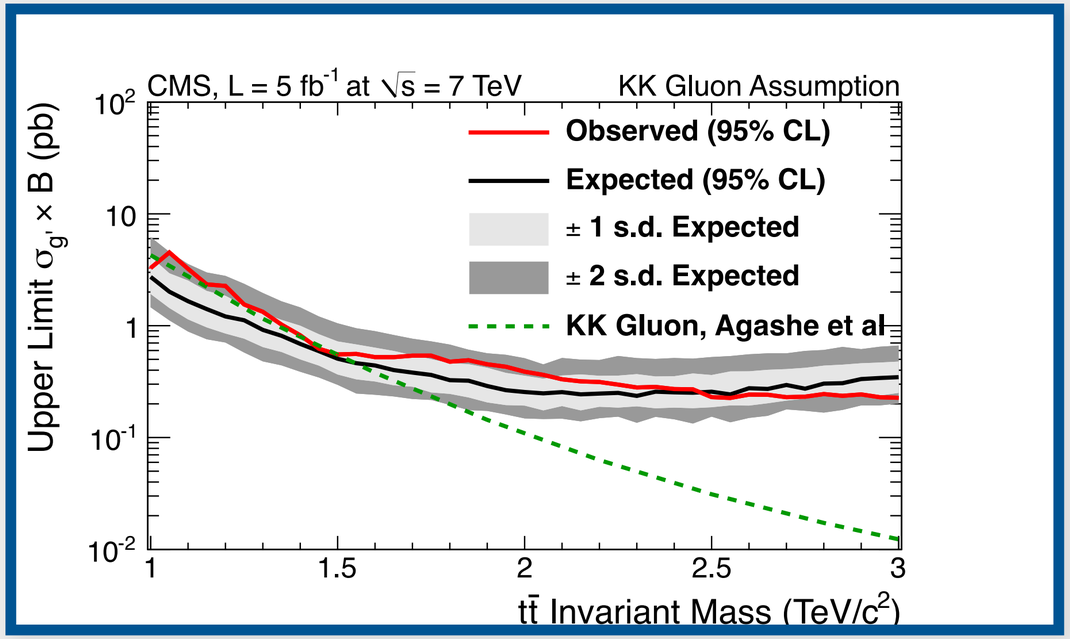


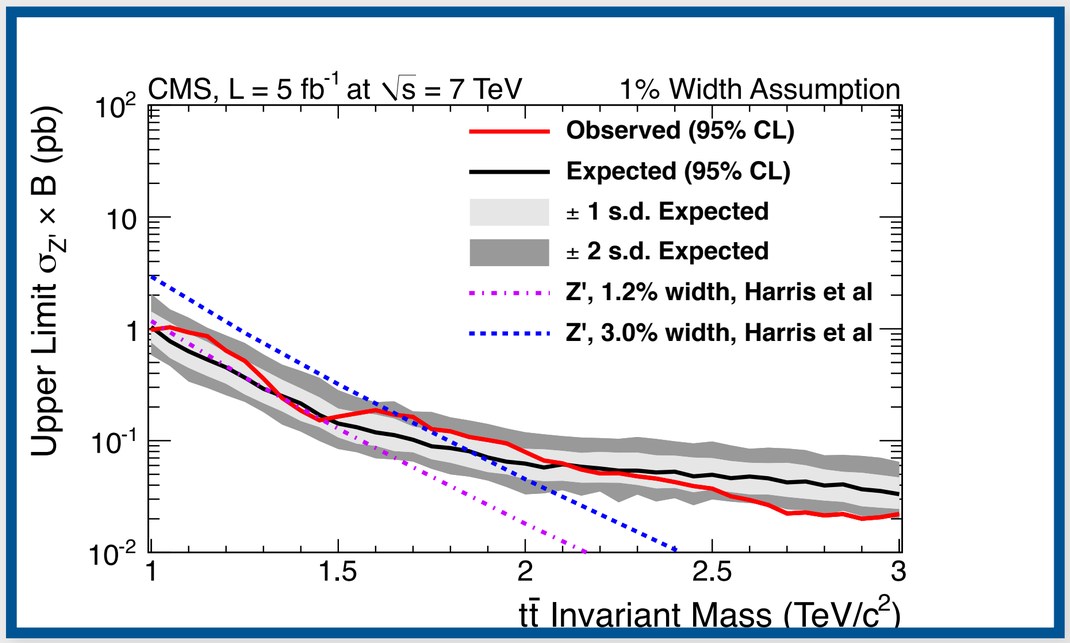
ALL-HADRONIC CHANNEL (BOOSTED)

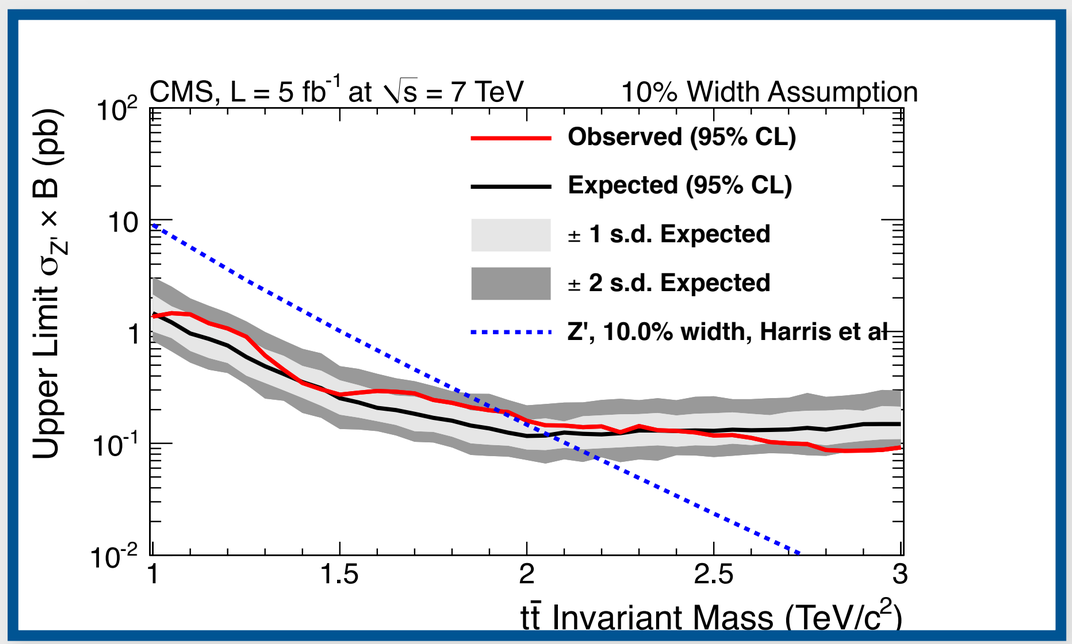
CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488

Excluded mass region

narrow Z' mass < 1.6 TeV
wide Z' mass < 2.0 TeV
KK gluon mass $1.4 < M_{KKg} < 1.5$ TeV







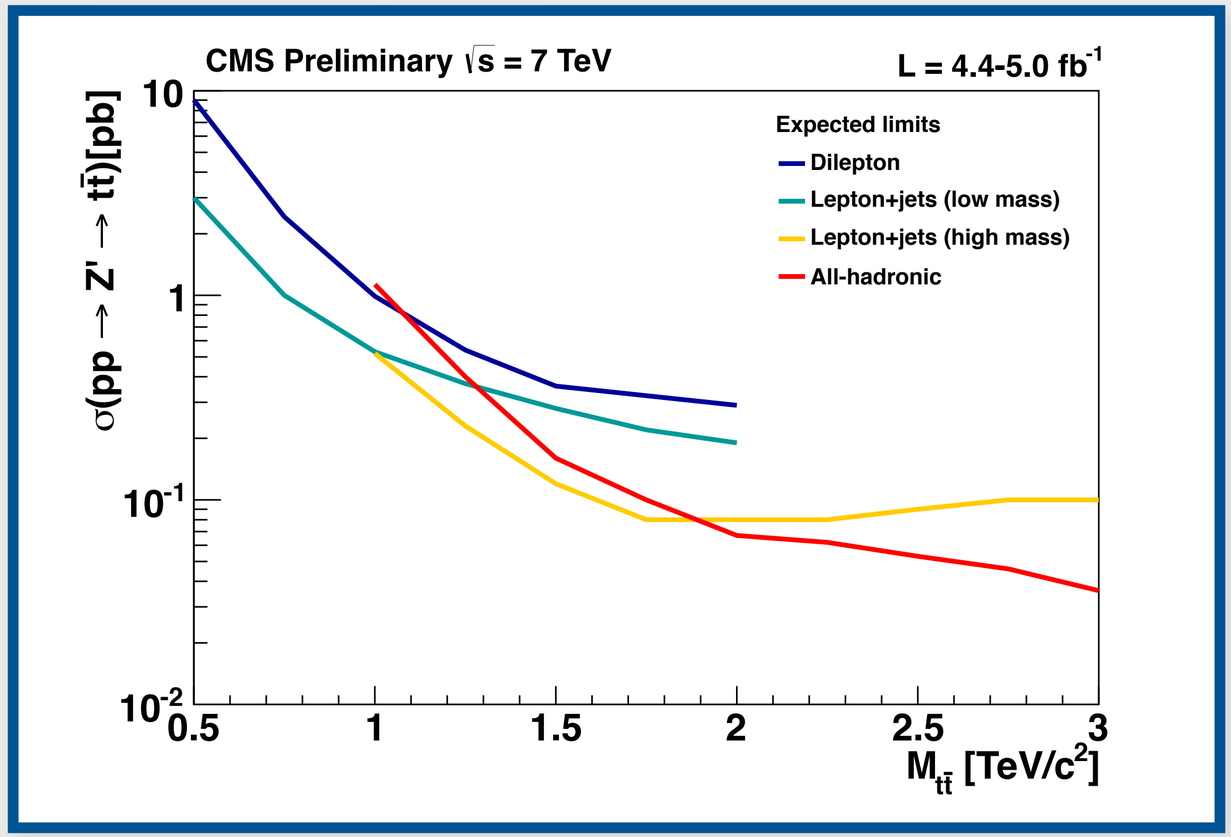
SUMMARY

Comparison of the expected limits between Z' resonances

	narrow Z' mass	wide Z' mass	KK gluon mass
CMS TOP-11-010	< 1.1 TeV		
ATLAS CONF-2011-123			< 0.8 TeV
CMS TOP-11-009	< 1.3 TeV	< 1.7 TeV	< 1.4 TeV
ATLAS CONF-2012-029	< 0.9 TeV		< 1.0 TeV
CMS EXO-11-093	< 1.6 Tev	< 2.0 TeV	
CMS EXO-11-006	< 1.6 TeV	< 2.0 TeV	1.4 < M_{KKg} < 1.5

the limits are rounded up to one decimal places

narrow Z' mass



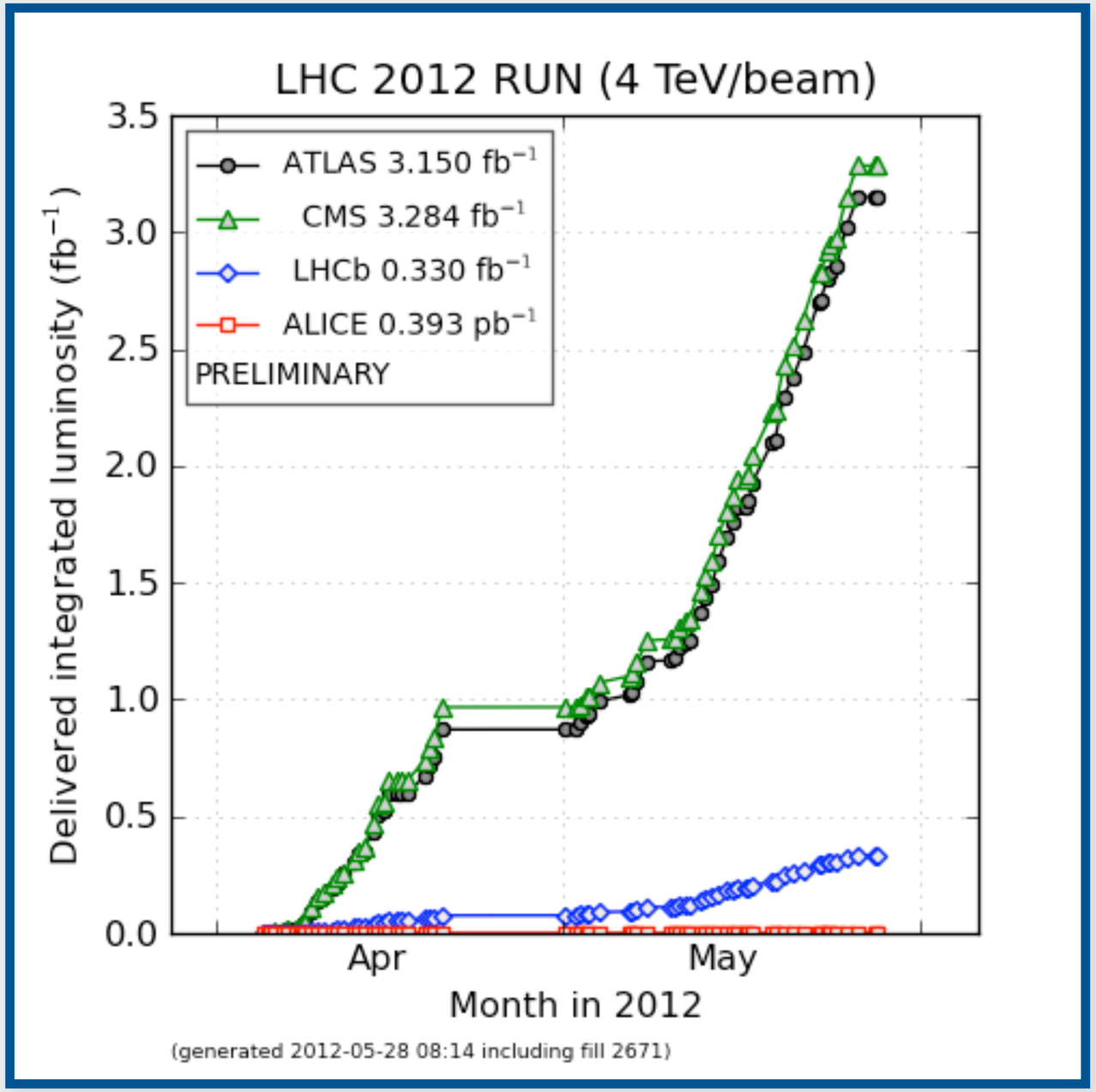
CONCLUSION

- Results on searches for resonances decaying to $\mathrm{t\bar{t}}$ were presented
- All main channels are covered: *dilepton, lepton+jets, all-hadronic*
- New analysis is presented based on non-isolated leptons (CMS EXO-11-093) and aimed at boosted resonances search
- top- and W-tagging based search is shown (CMS EXO-11-006)
- No signal peaks are observed in data
- Resonances are **excluded** in mass regions:

narrow Z' mass	*< 1.6 TeV*
wide Z' mass	*< 2.0 TeV*
KK gluon mass	*< 1.4 TeV*

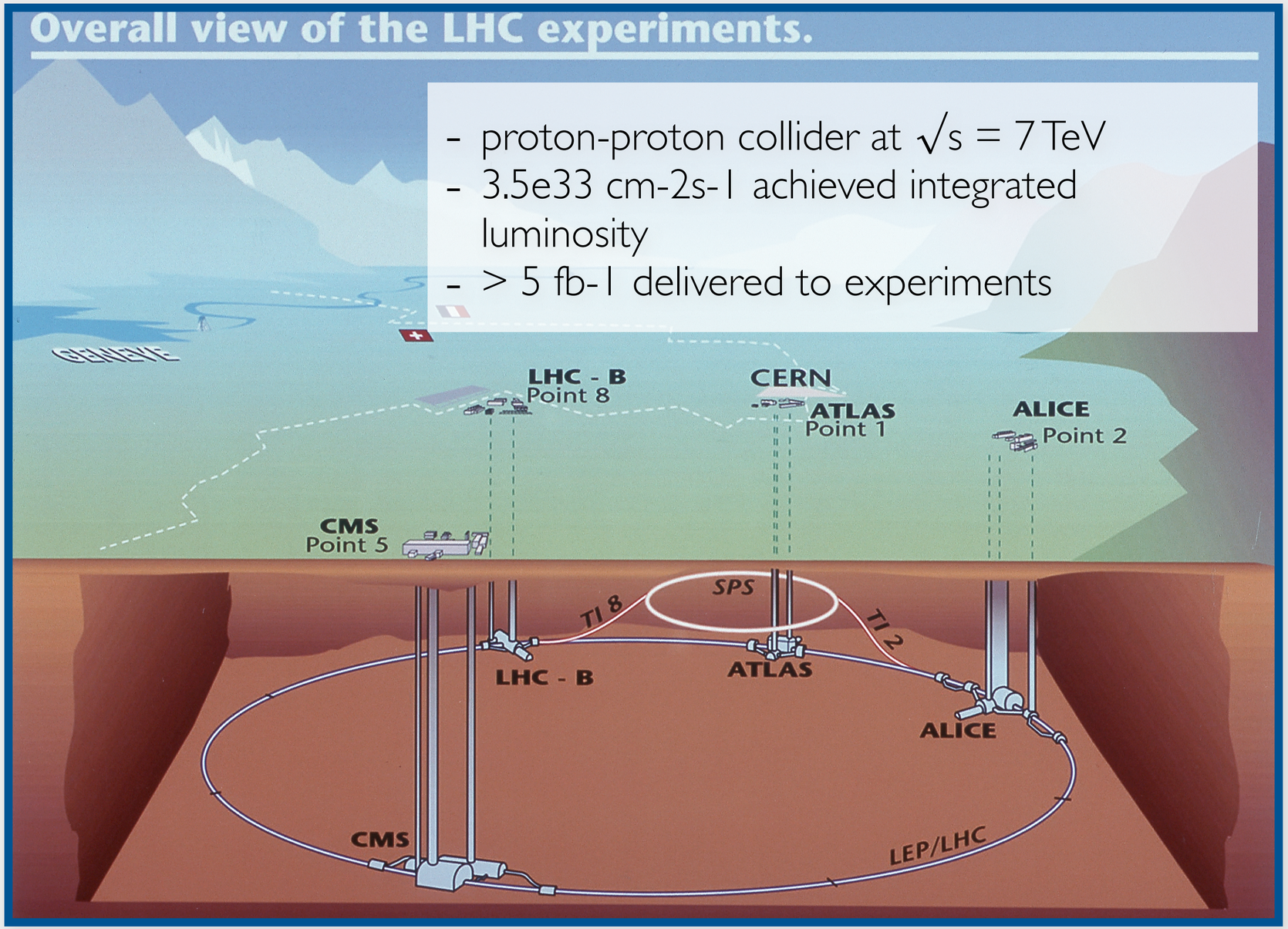
CONCLUSION

2012 Data are coming at high rate and ready for the analysis

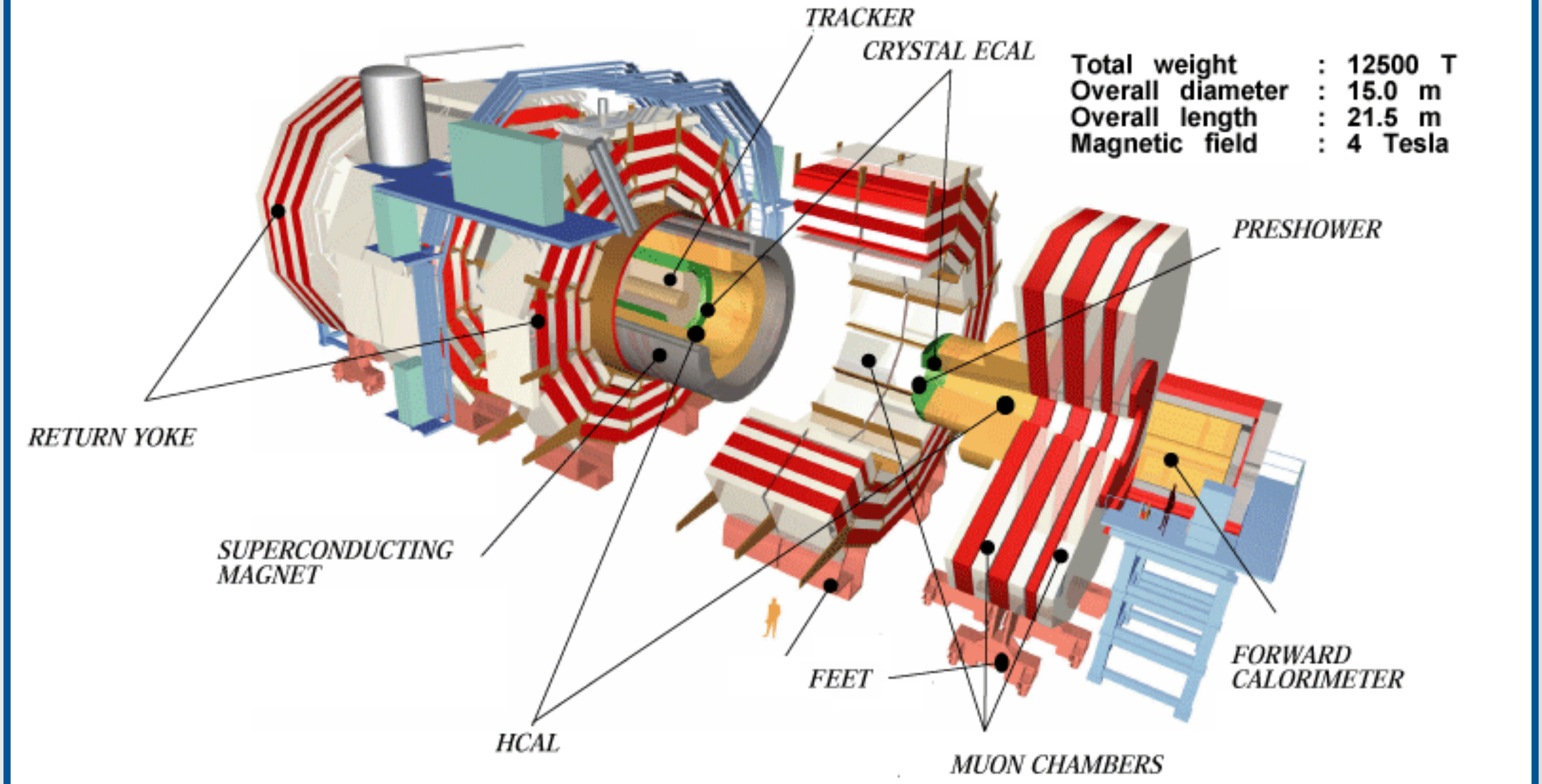


BACKUP

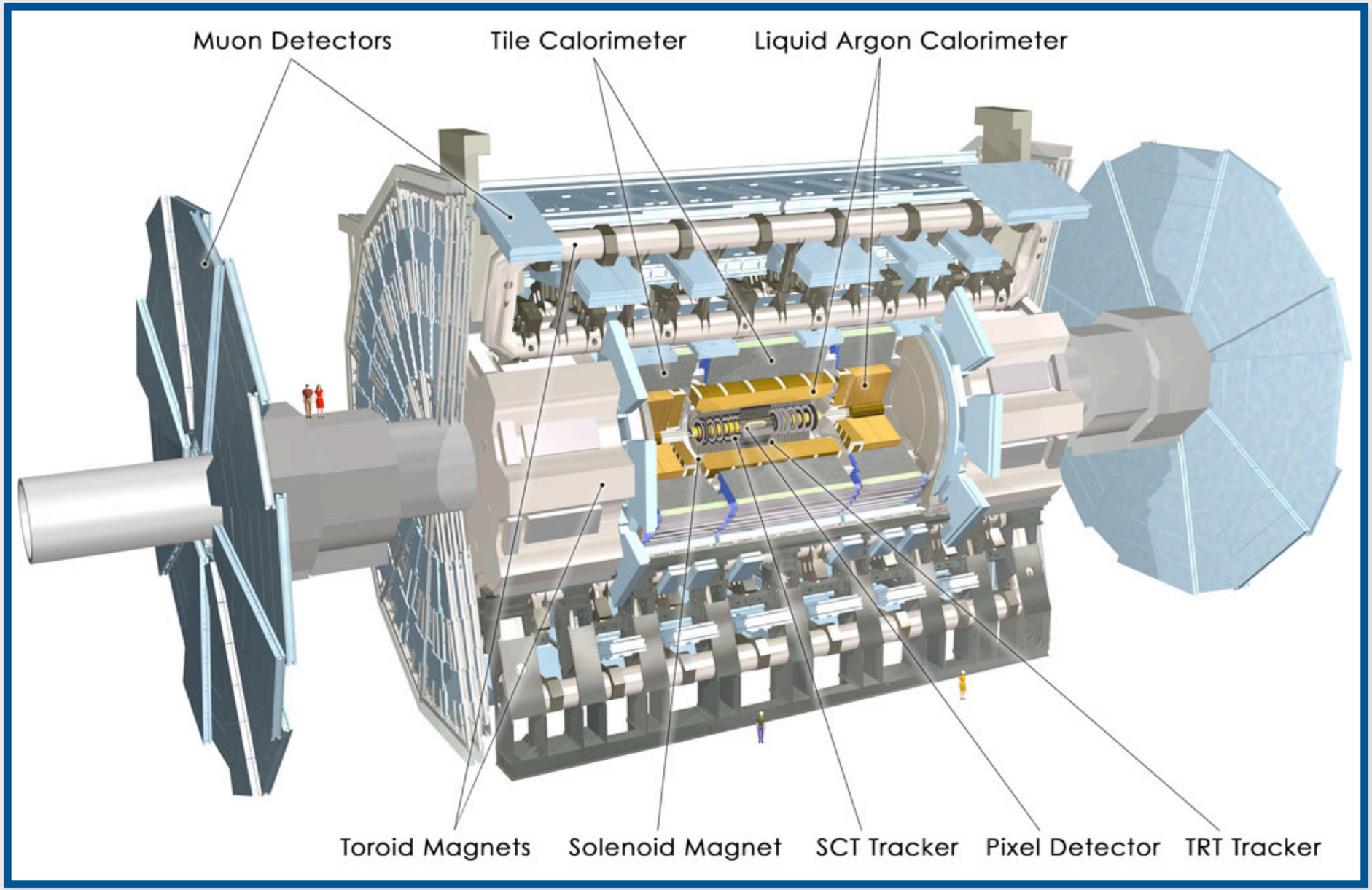
LARGE HADRON COLLIDER



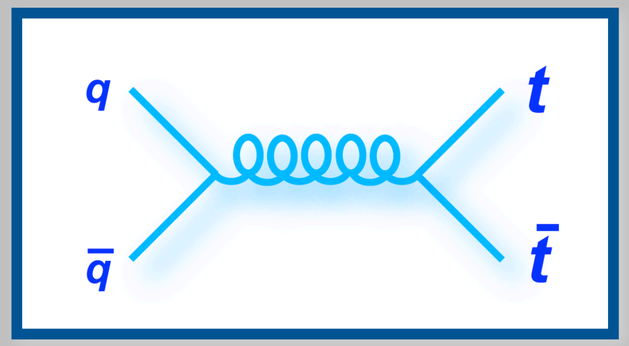
COMPACT MUON SOLENOID



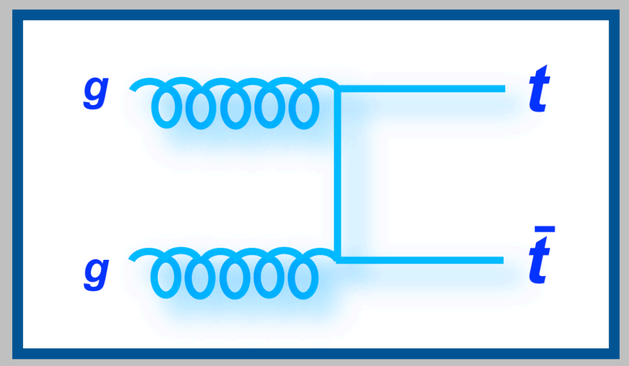
ATLAS


Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

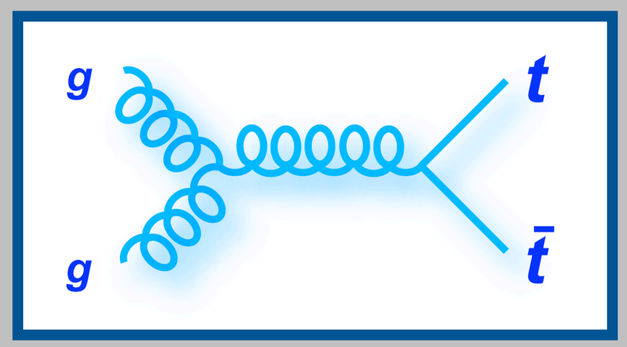
SM $t\bar{t}$ PRODUCTION AND DECAY

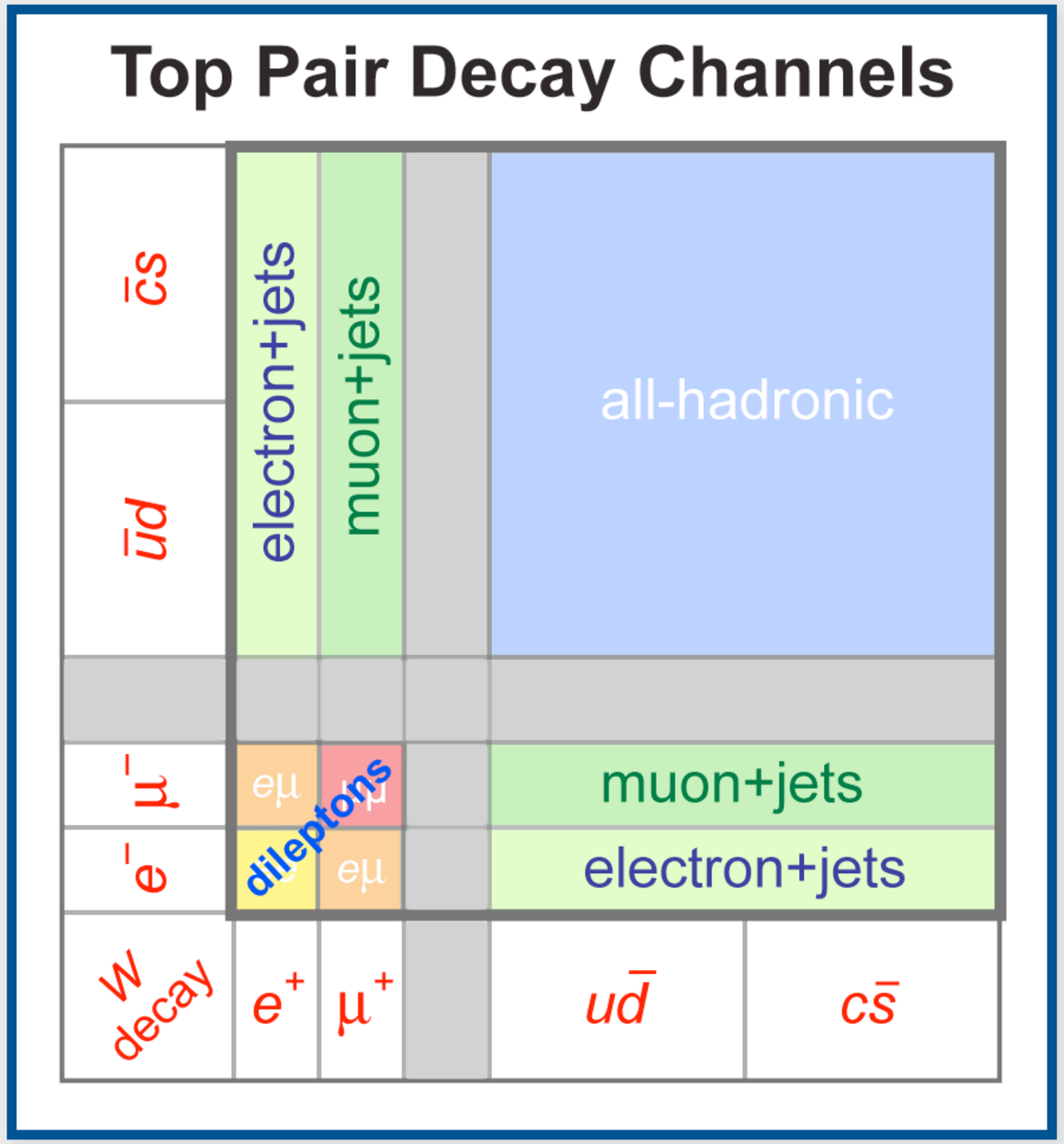


15%



85%





DILEPTON CHANNEL

CMS TOP-11-010 L = 5.0 fb^{-1}

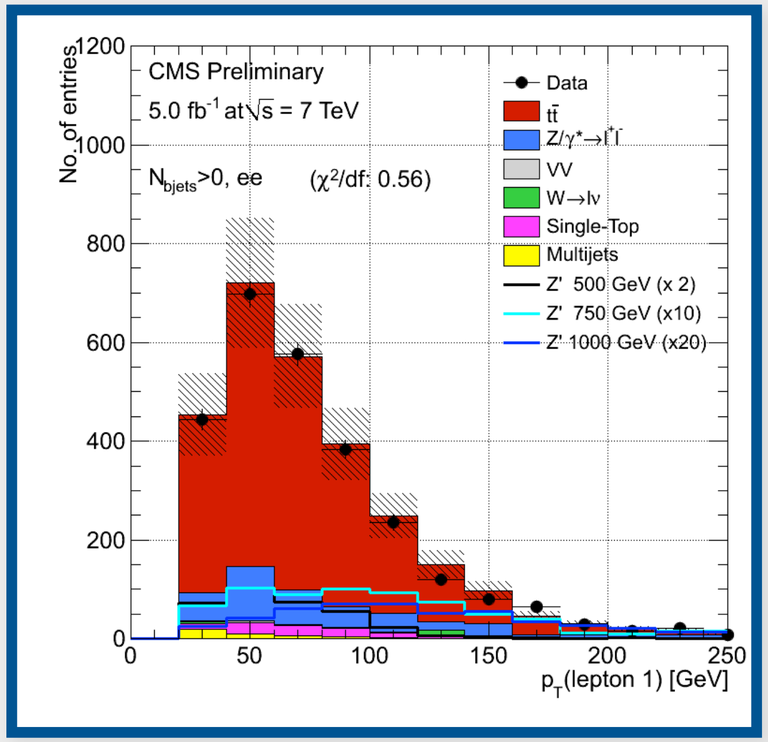
event yield

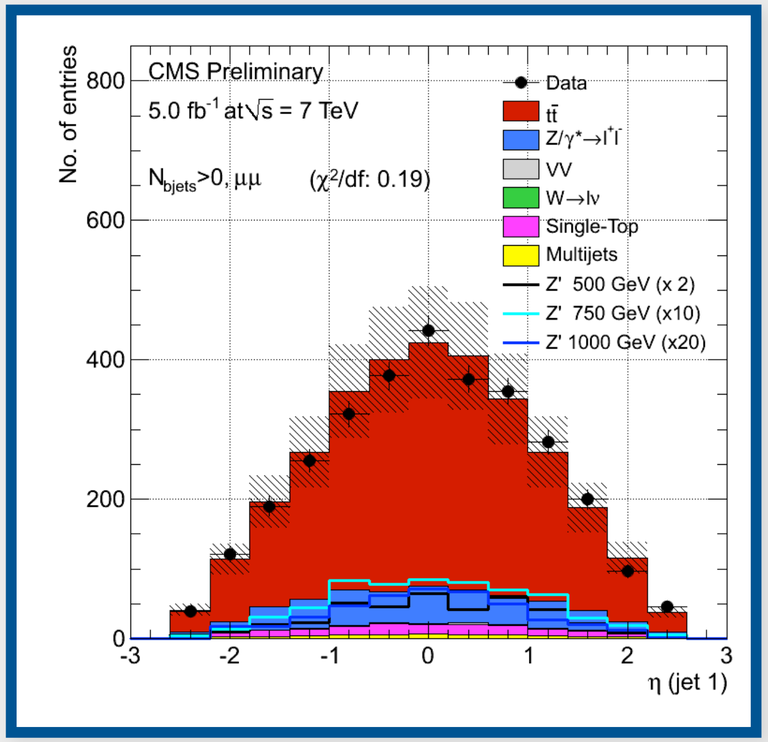
Sample	ee	$\mu\mu$	$e\mu$
$t\bar{t}$	2208.5 ± 461.1	2546.4 ± 548.4	7323.4 ± 1498.8
$Z/\gamma* \to l\bar{l}$	405.2 ± 128.1	422.1 ± 133.5	178.9 ± 56.6
VV	11.5 ± 1.5	15.4 ± 2.0	32.3 ± 4.2
$W \to l\nu$	16.7 ± 23.7	0.0 ± 0.0	26.2 ± 37.2
Single-top	105.6 ± 15.3	120.7 ± 17.5	343.4 ± 50.1
Multijets	41.8 ± 6.9	50.1 ± 10.4	102.9 ± 14.3
Total background	2789.4 ± 510.0	3154.7 ± 596.0	8007.0 ± 1545.6
Observed count	**2690**	**3098**	**7704**

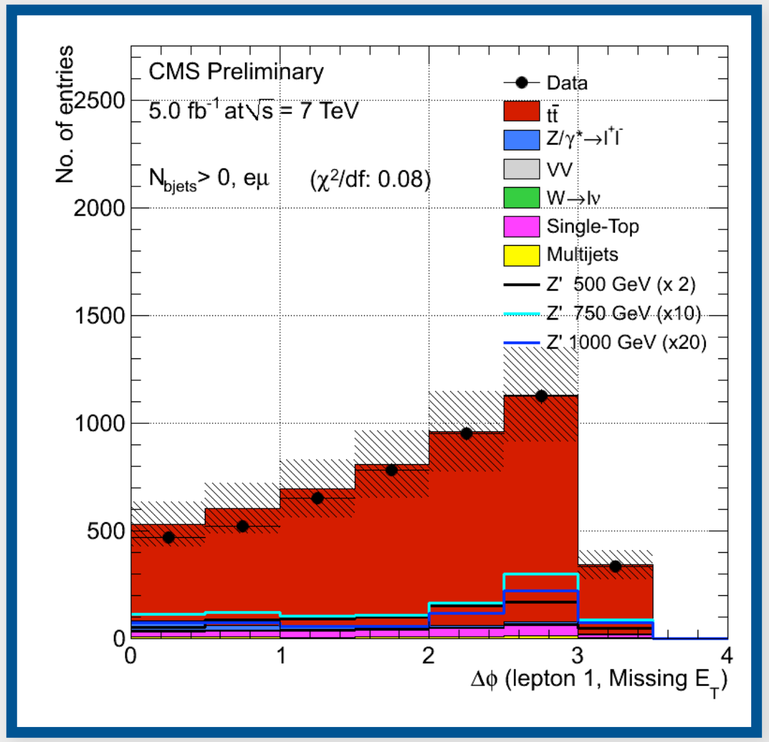
DILEPTON CHANNEL

CMS TOP-11-010 L = 5.0 fb^{-1}

control plots



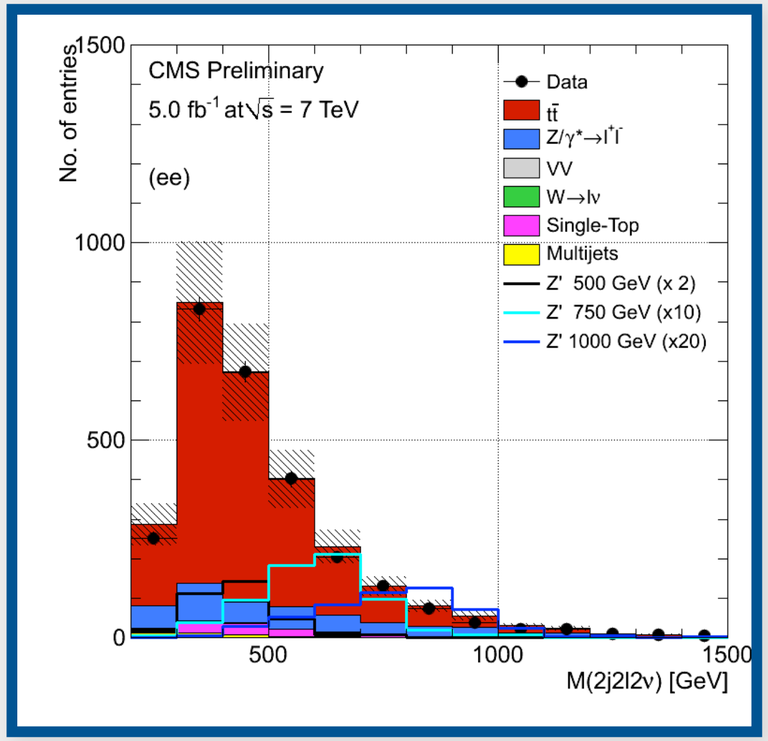


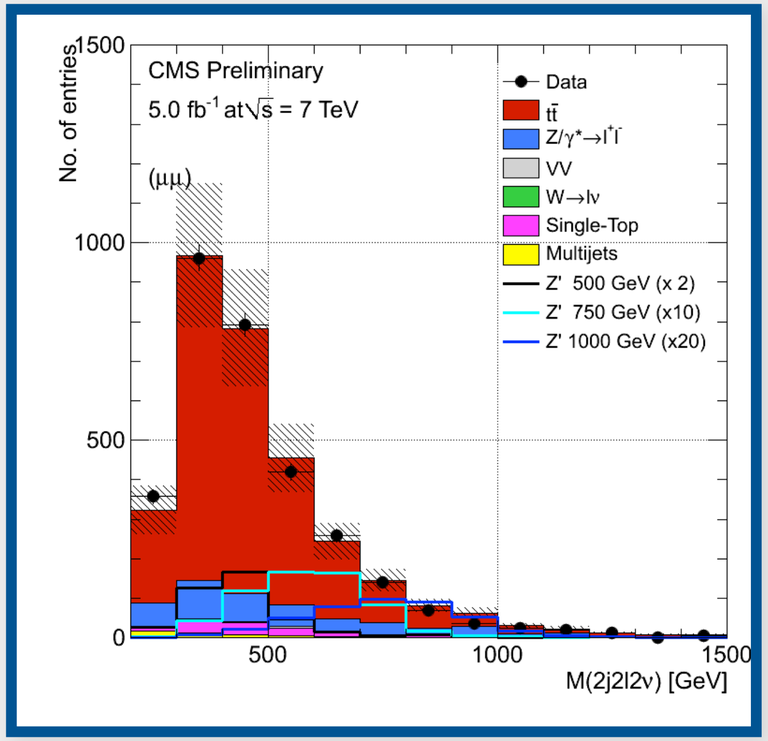


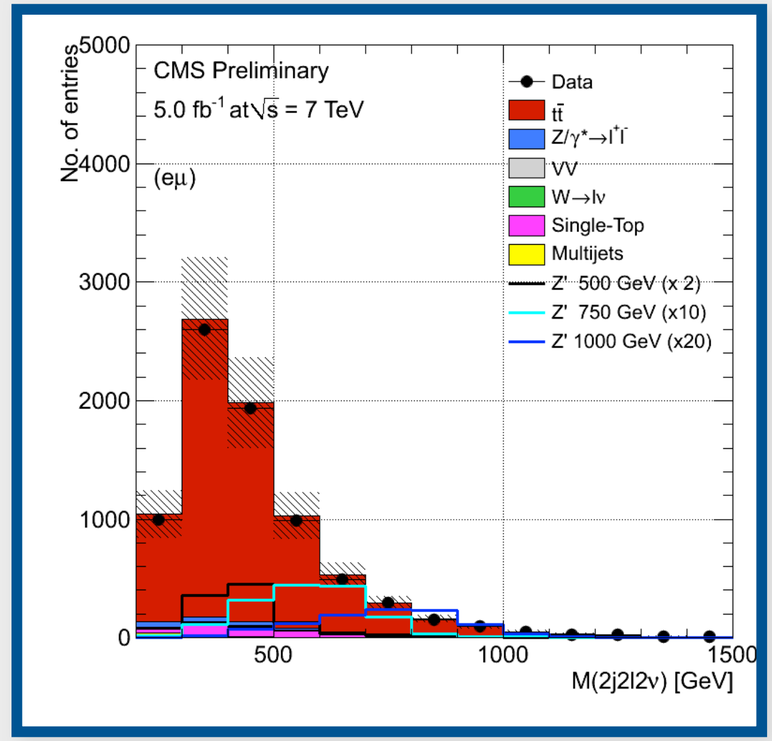
DILEPTON CHANNEL

CMS TOP-11-010 L = 5.0 fb^{-1}

reconstructed resonance mass

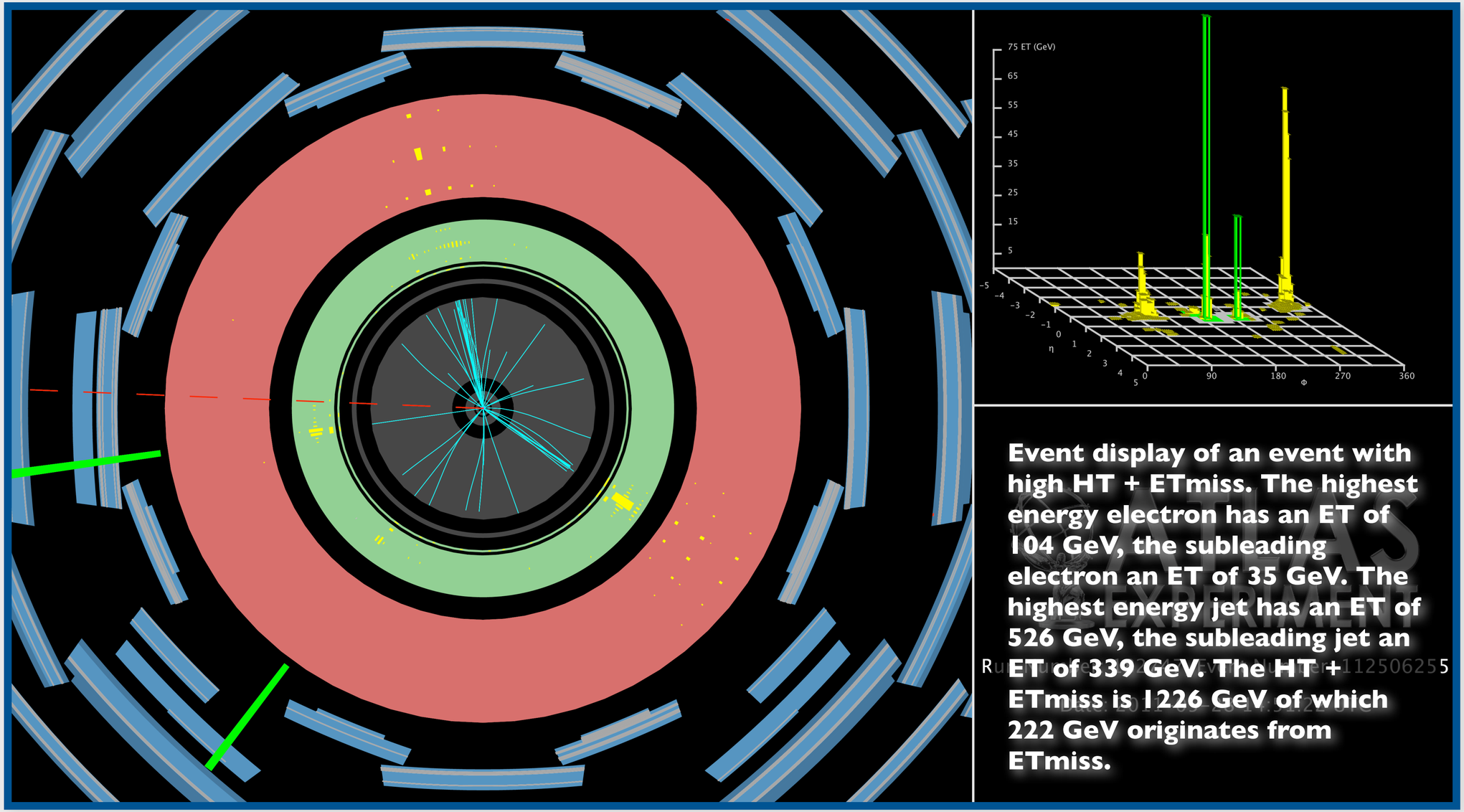






DILEPTON CHANNEL

ATLAS-CONF-2011-123 L = 1.04 fb^{-1}

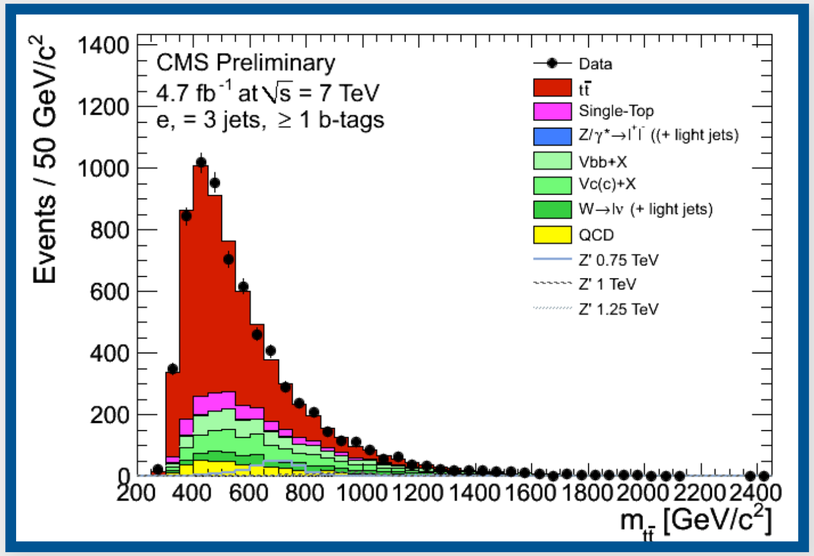


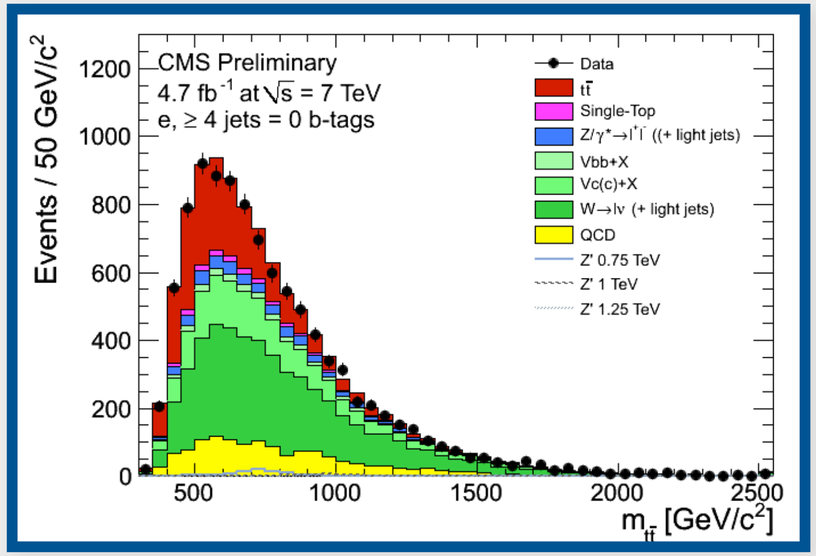
Event display of an event with high HT + ETmiss. The highest energy electron has an ET of 104 GeV, the subleading electron an ET of 35 GeV. The highest energy jet has an ET of 526 GeV, the subleading jet an ET of 339 GeV. The HT + ETmiss is 1226 GeV of which 222 GeV originates from ETmiss.

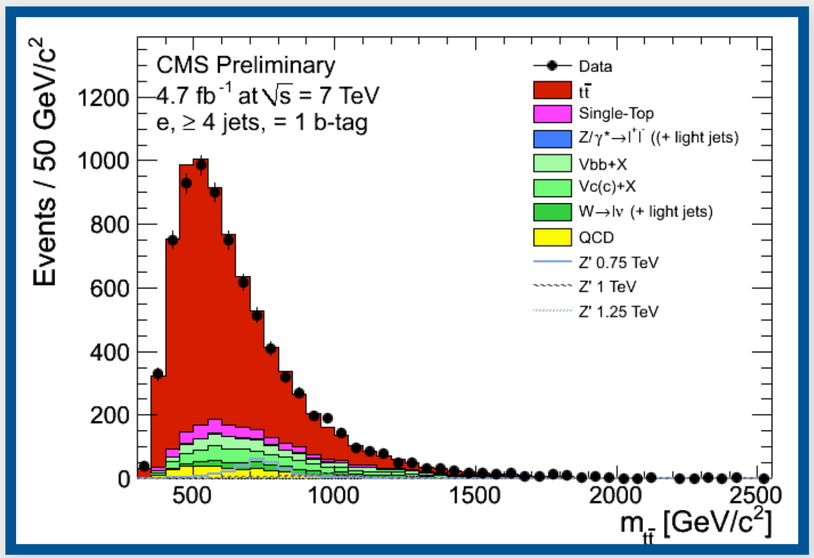
LEPTON+JETS CHANNEL (AT THRESHOLD)

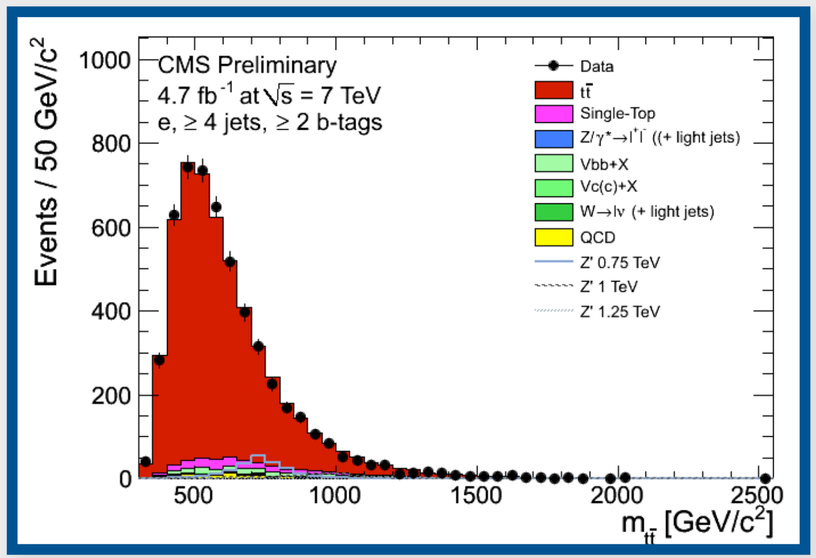
CMS TOP-11-009 **L = 4.7 fb^{-1}**

e+jets





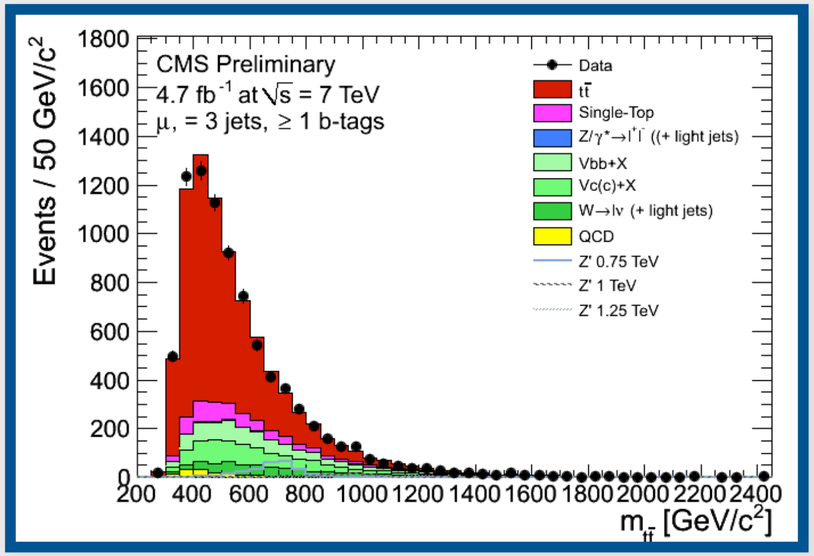


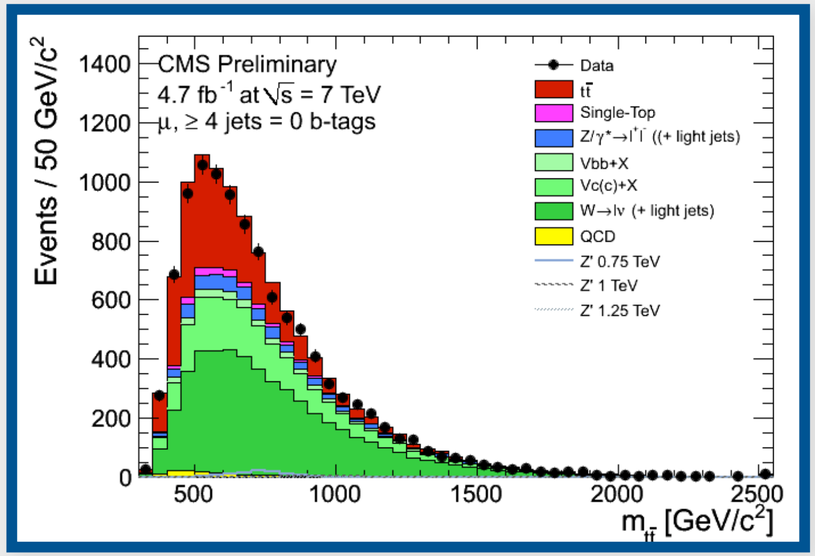


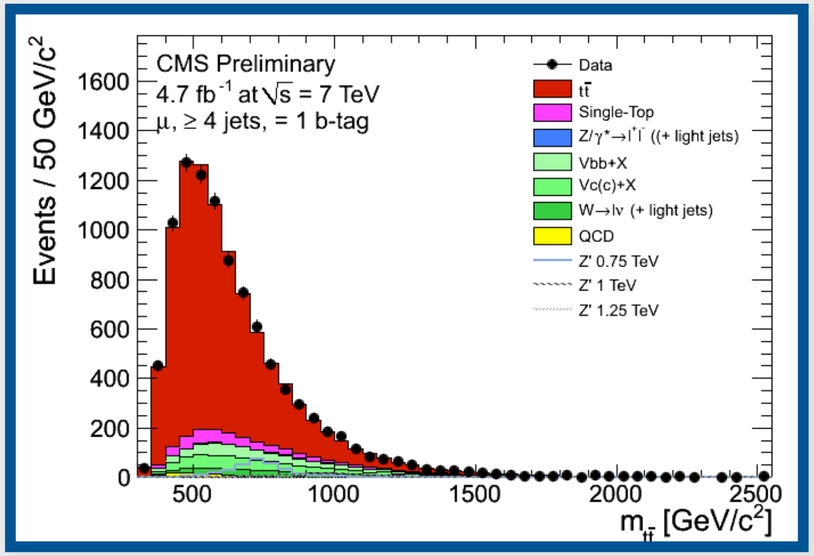
LEPTON+JETS CHANNEL (AT THRESHOLD)

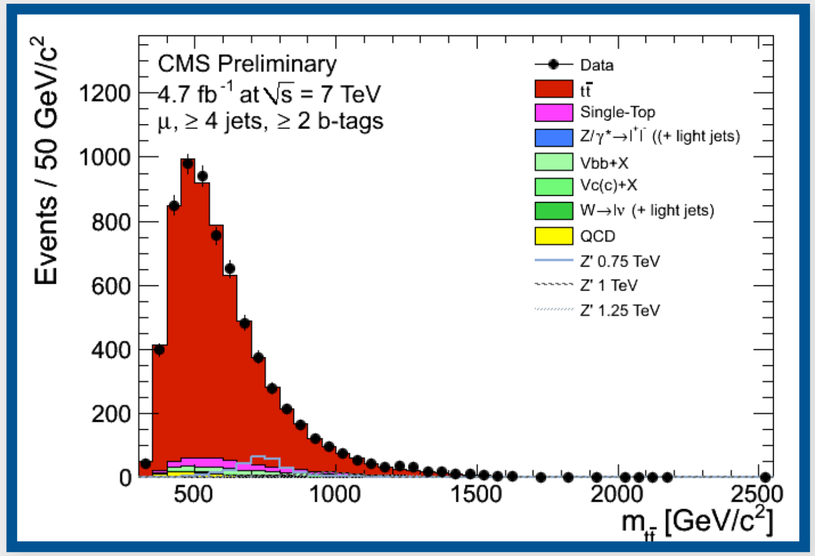
CMS TOP-11-009 L = 4.7 fb^{-1}

mu+jets





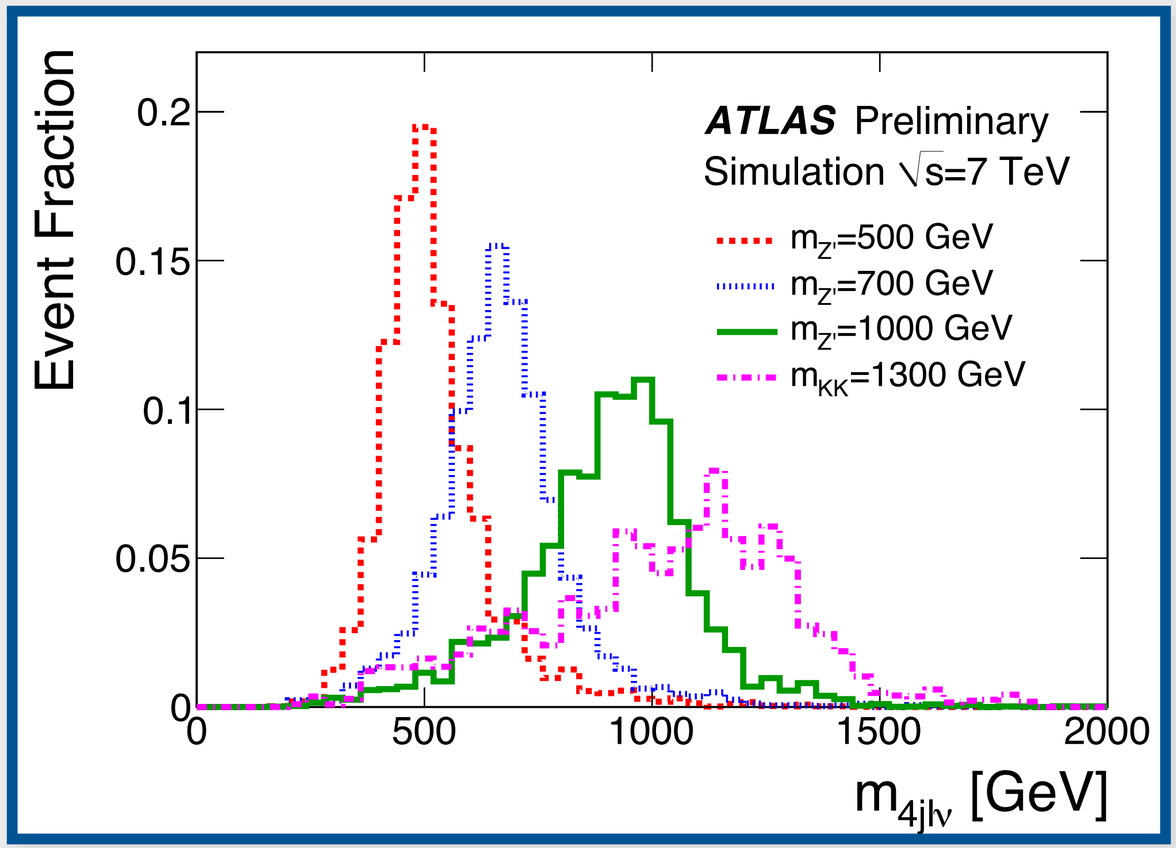


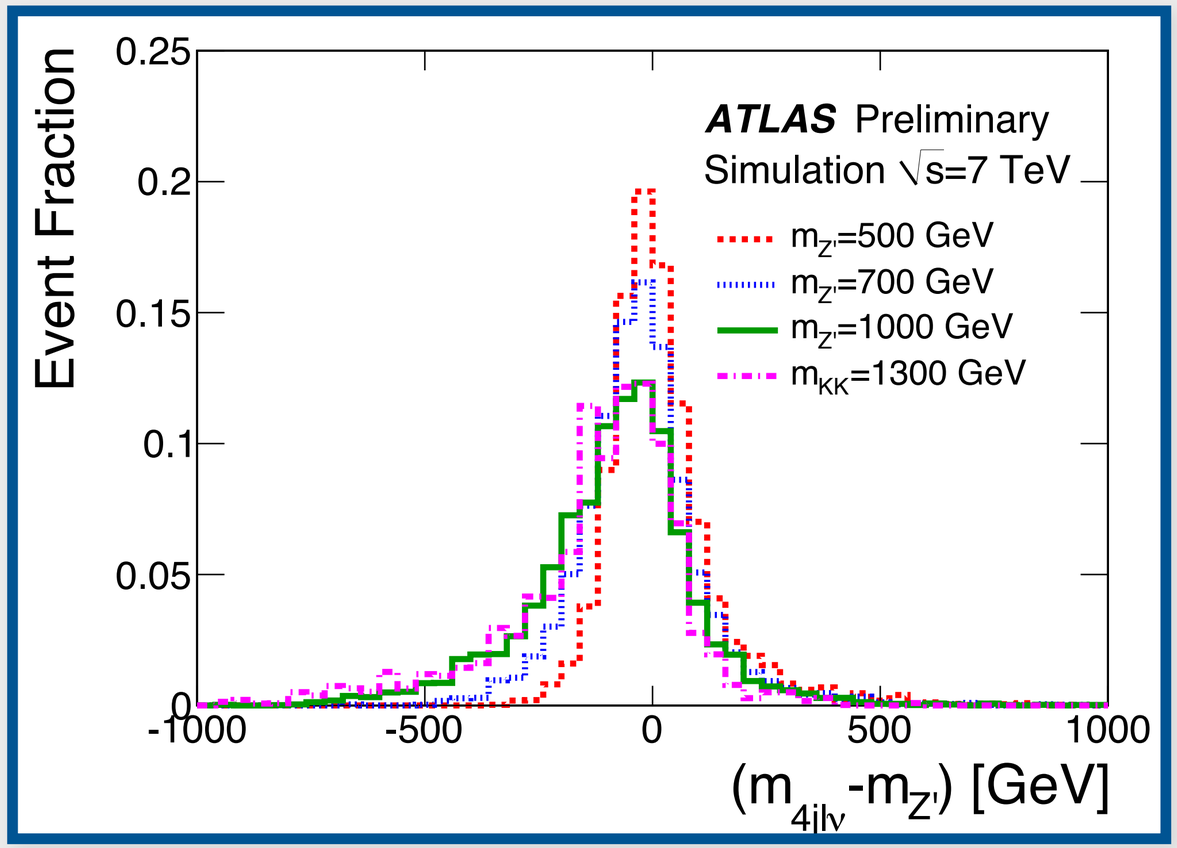


LEPTON+JETS CHANNEL (AT THRESHOLD)

ATLAS-CONF-2012-029 L = 2.05 fb^{-1}

Expected signal shapes

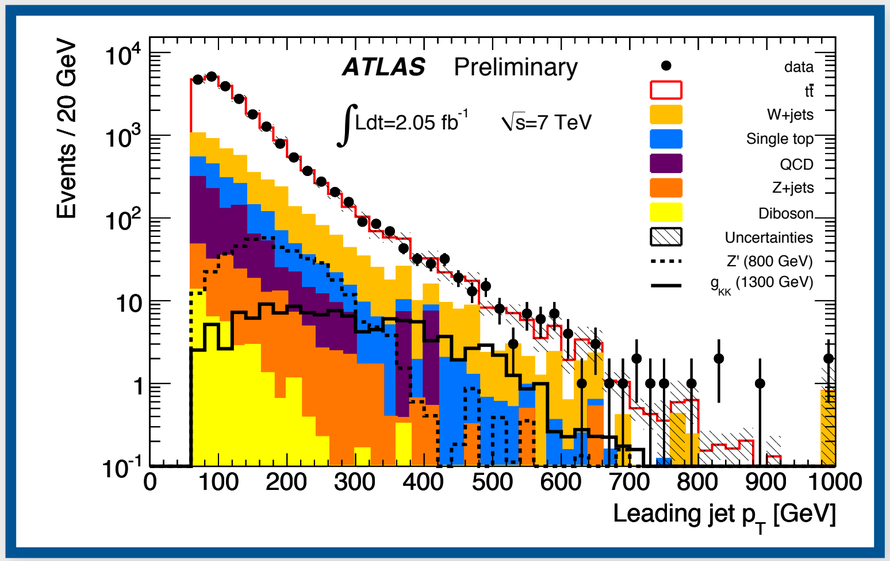


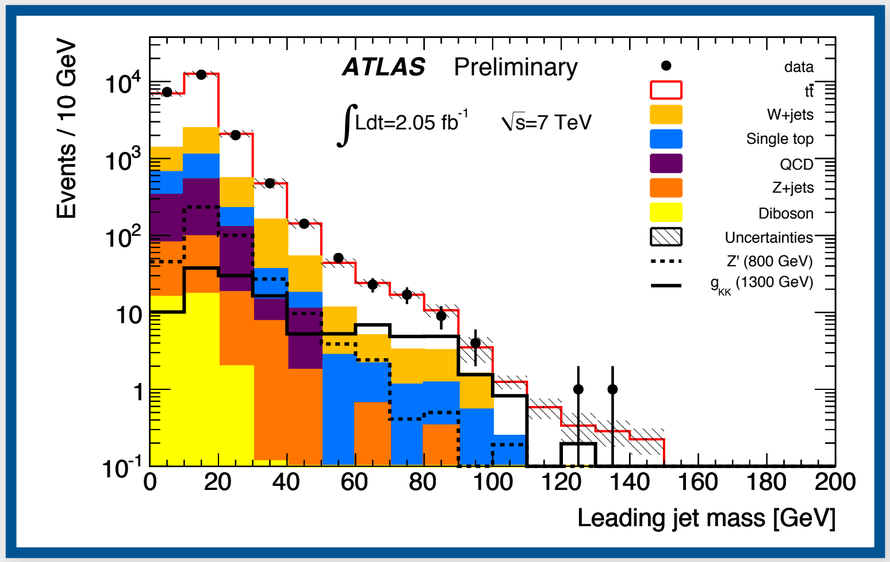


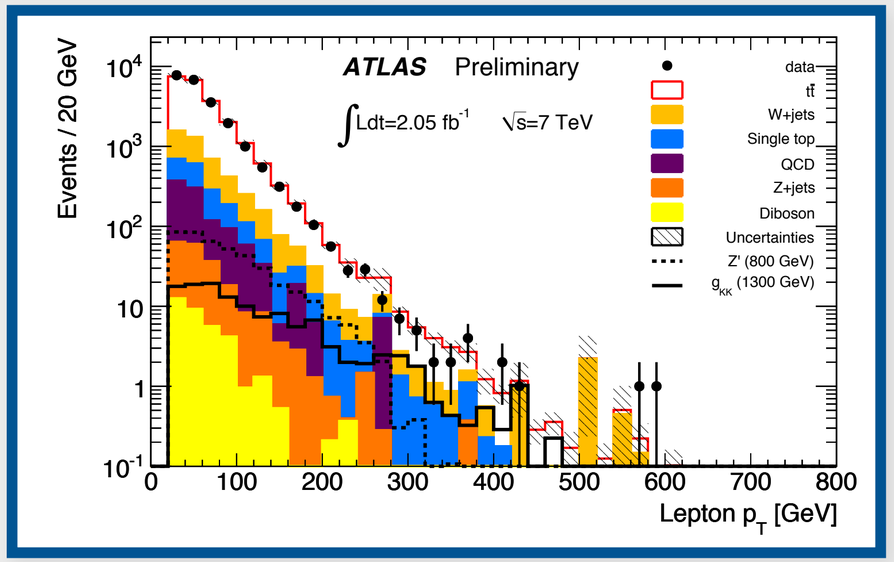
LEPTON+JETS CHANNEL (AT THRESHOLD)

ATLAS-CONF-2012-029 L = 2.05 fb^{-1}

control plots







LEPTON+JETS CHANNEL (BOOSTED)

CMS EXO-11-093 L = 5.00 fb^{-1}

event yield

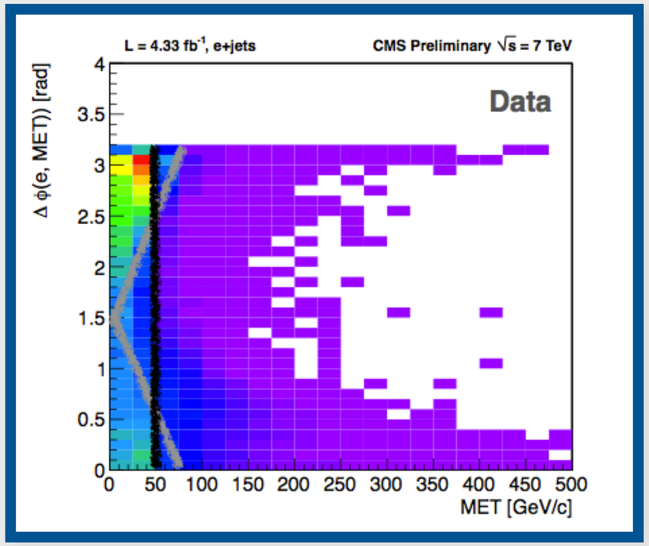
Sample	electron+jets channel $N_{\text{b-tag}} = 0$	electron+jets channel $N_{\text{b-tag}} \geq 1$	muon+jets channel $N_{\text{b-tag}} = 0$	muon+jets channel $N_{\text{b-tag}} \geq 1$
Z', $M = 1\,\text{TeV}/c^2$	17.1	36.5	27.8	48.3
Z', $M = 1.5\,\text{TeV}/c^2$	44.7	55.4	95.9	94.4
Z', $M = 2\,\text{TeV}/c^2$	62.1	52.8	146.3	94.1
Z', $M = 3\,\text{TeV}/c^2$	57.2	36.9	155.2	69.0
Single Top	9.3	14.6	8.1	11.0
W+jets	89.4	5.5	127.2	6.8
Z+jets	5.6	0.0	22.0	1.5
$t\bar{t}$	171.6	335.8	156.5	262.1
Total Background	276 ± 58	356 ± 50	314 ± 72	281.4 ± 34
Data 2011	277	354	300	269

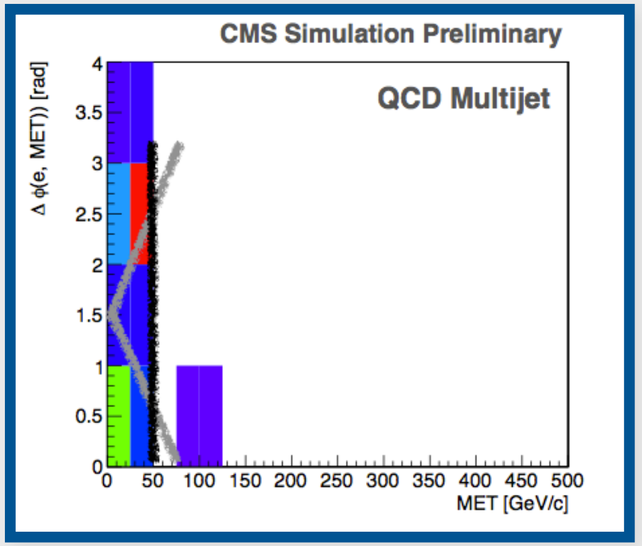
LEPTON+JETS CHANNEL (BOOSTED)

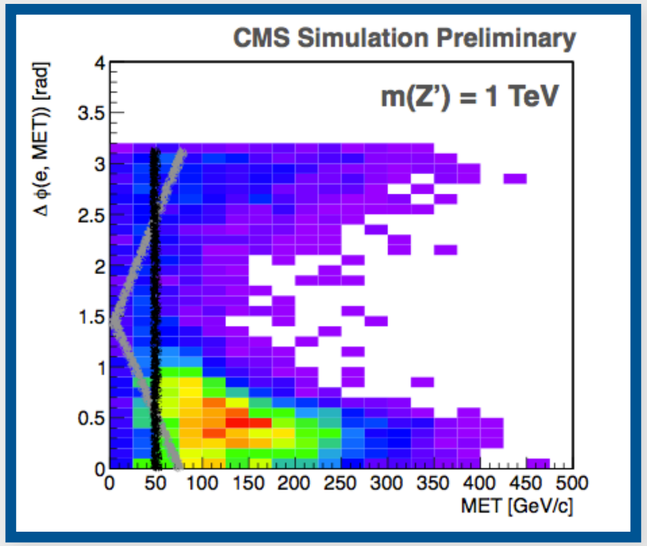
CMS EXO-11-093 L = 5.00 fb^{-1}

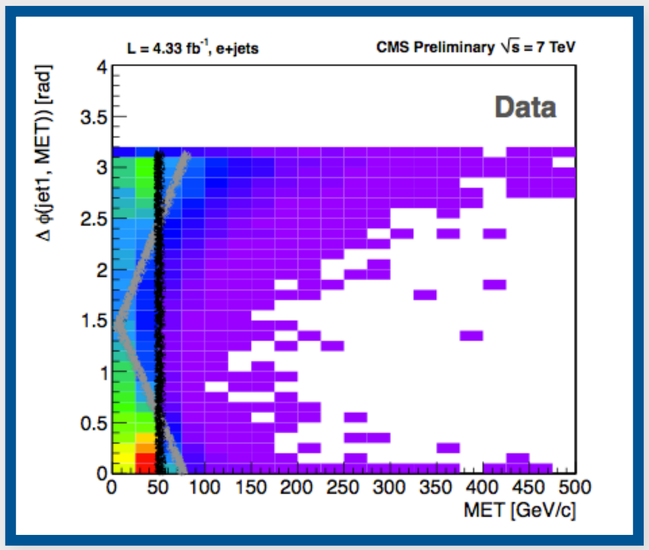
topological cuts in e+jets

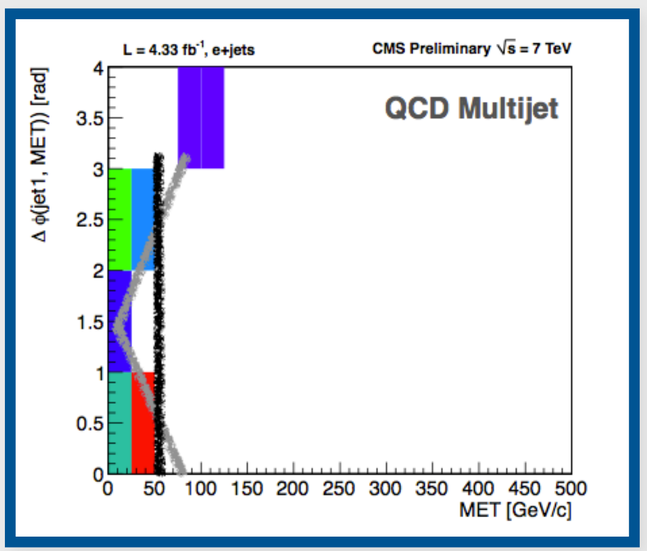
(plots are taken from CMS-EXO-11-092)

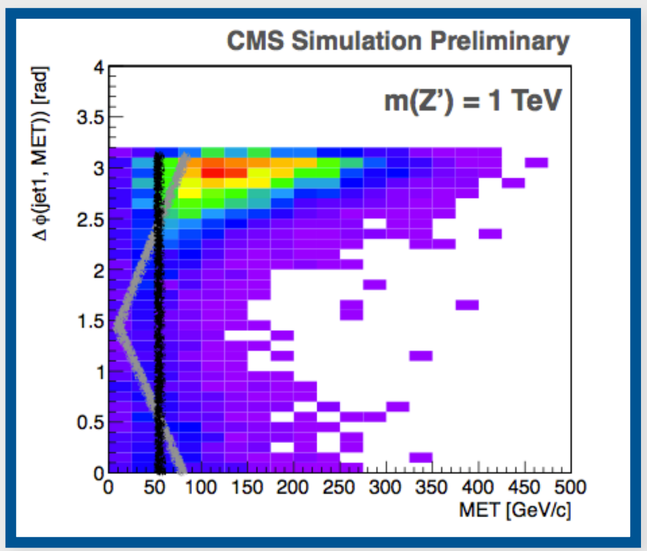










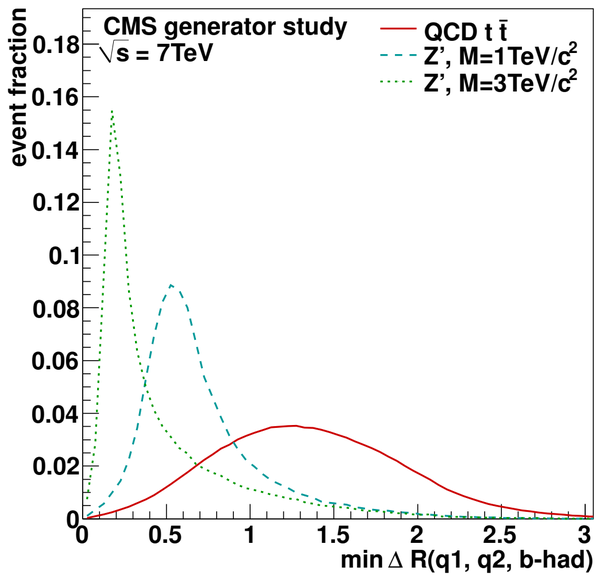


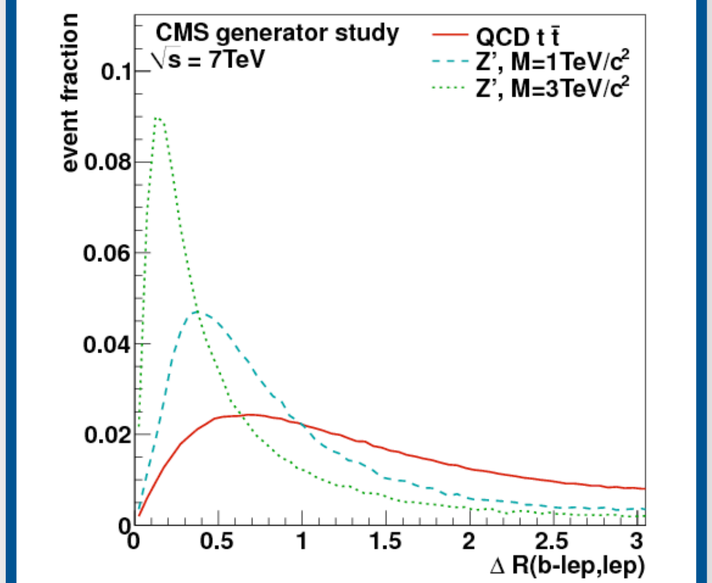
LEPTON+JETS CHANNEL (BOOSTED)

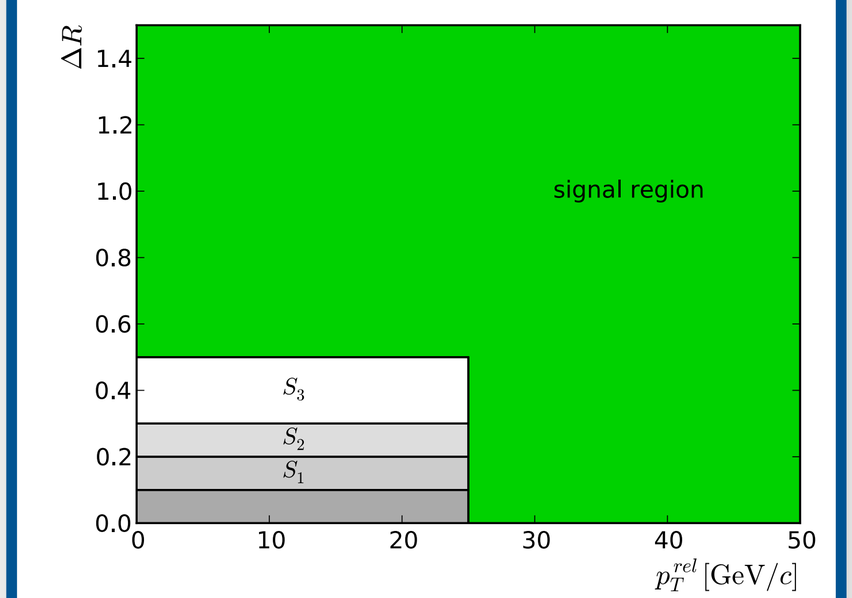
CMS EXO-11-093 L = 5.00 fb^{-1}

isolation

(plots are taken from CMS-EXO-11-055)

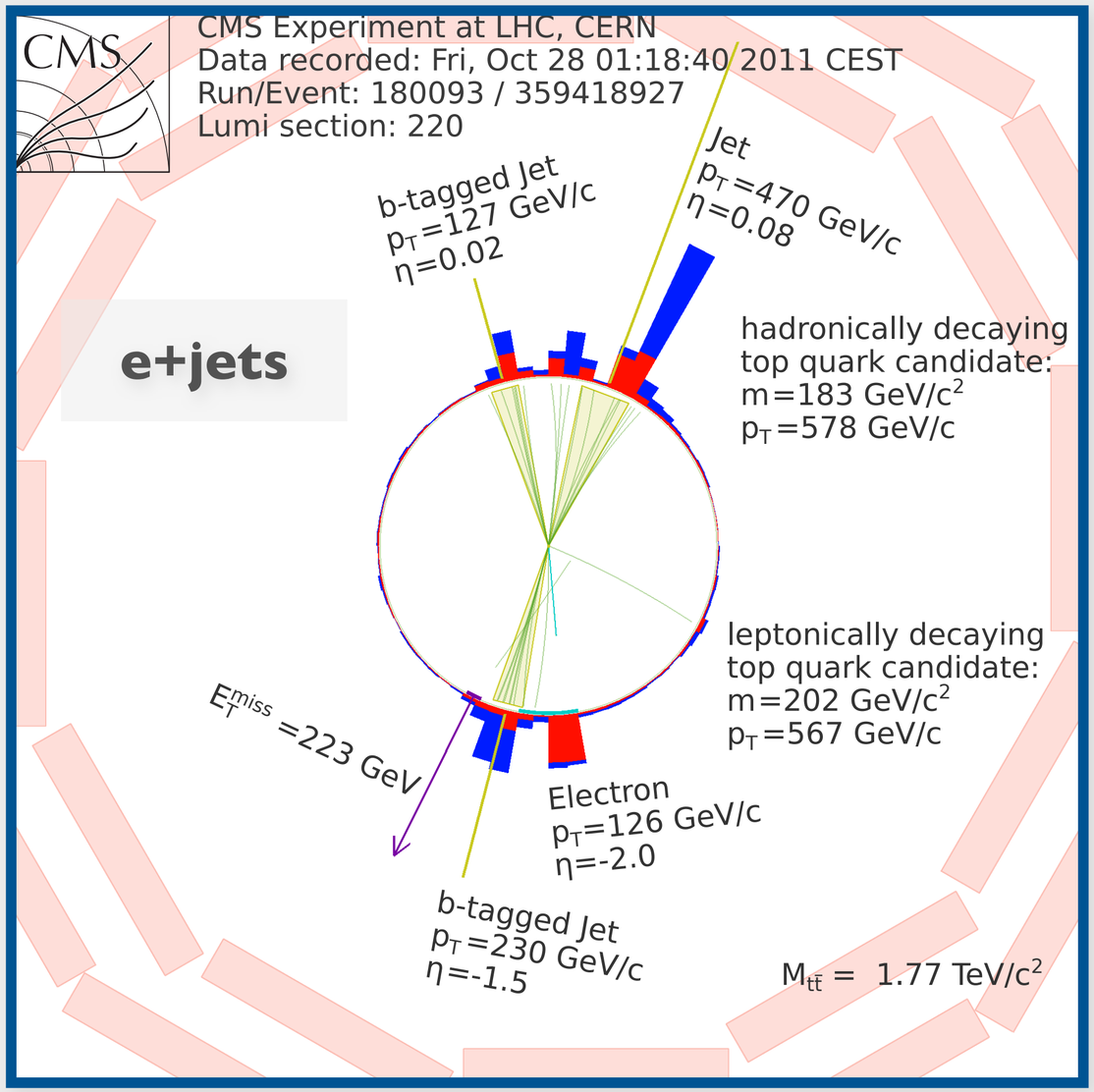


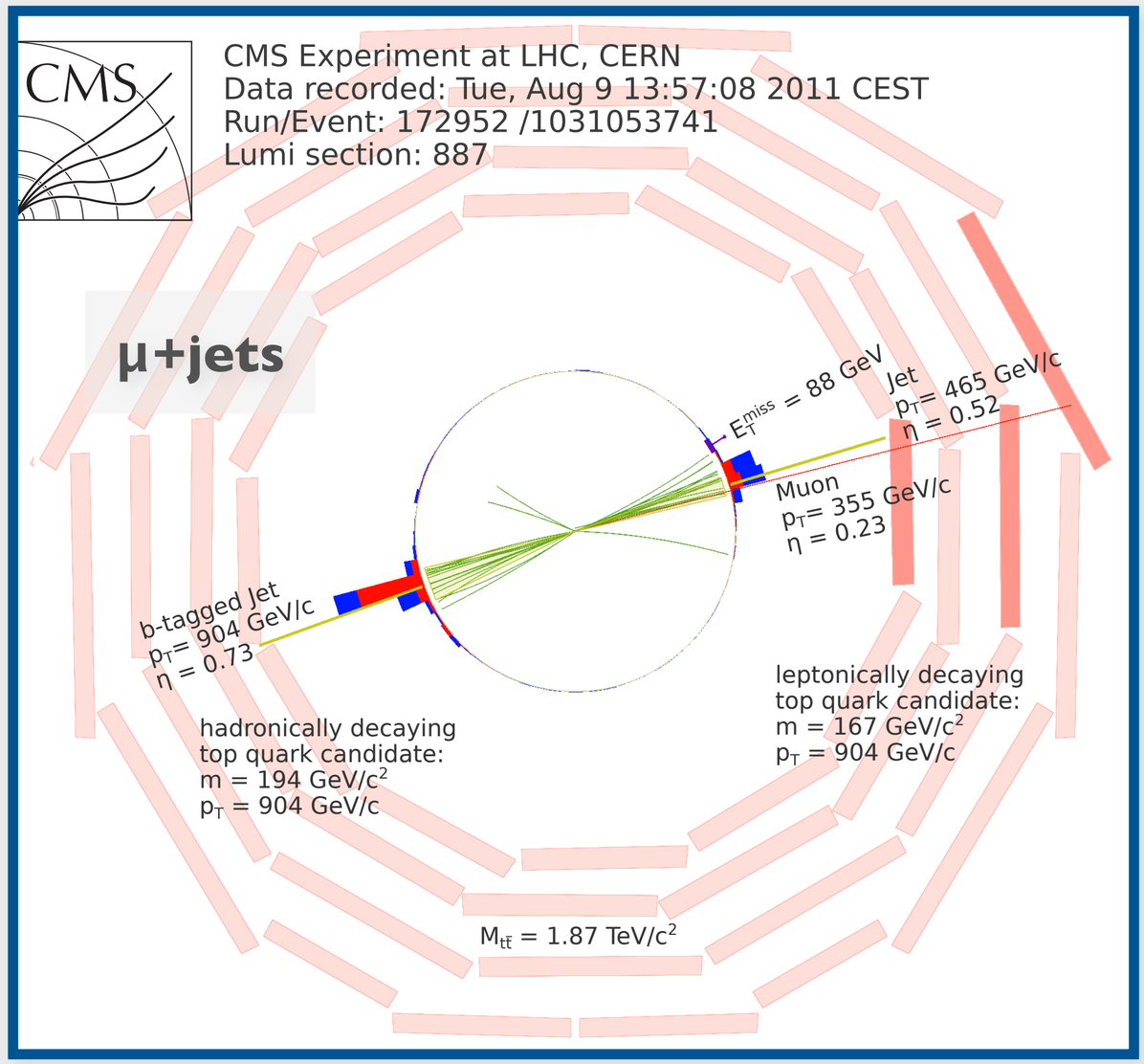




LEPTON+JETS CHANNEL (BOOSTED)

CMS EXO-11-093 L = 5.00 fb^{-1}

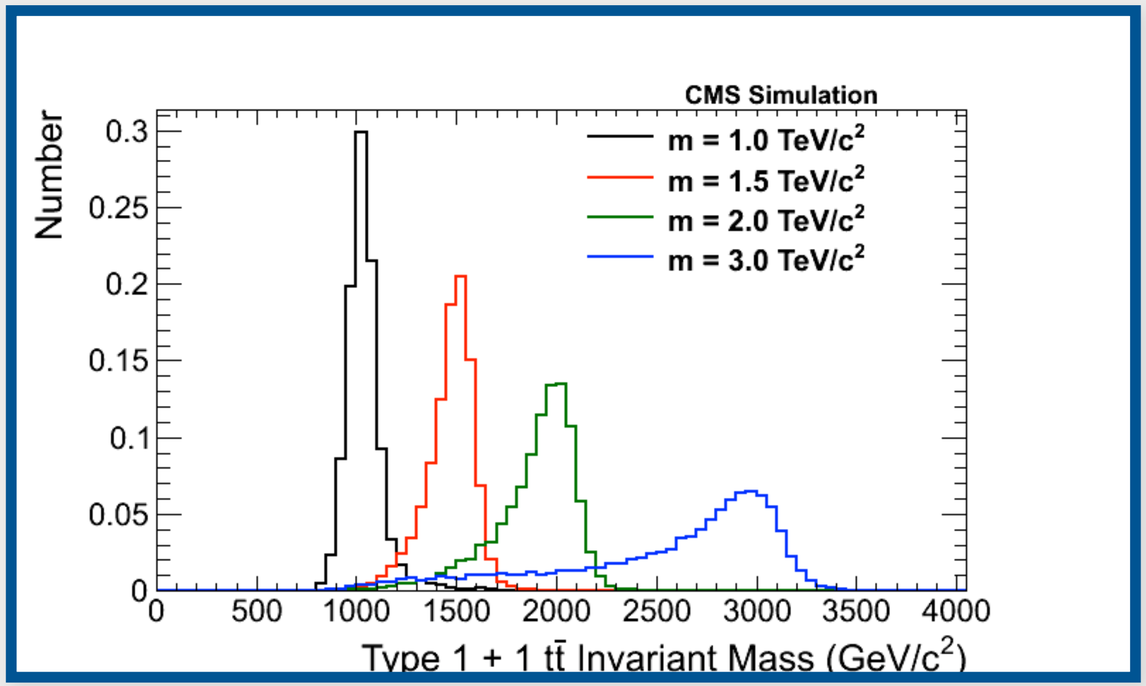


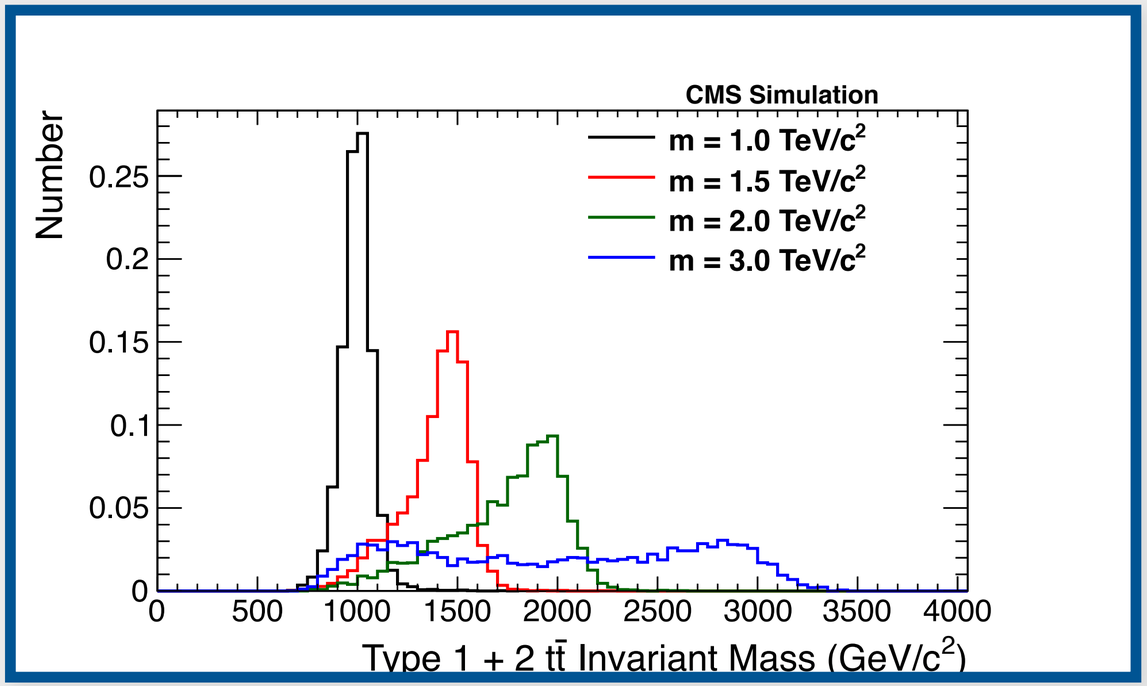


ALL-HADRONIC CHANNEL (BOOSTED)

CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488

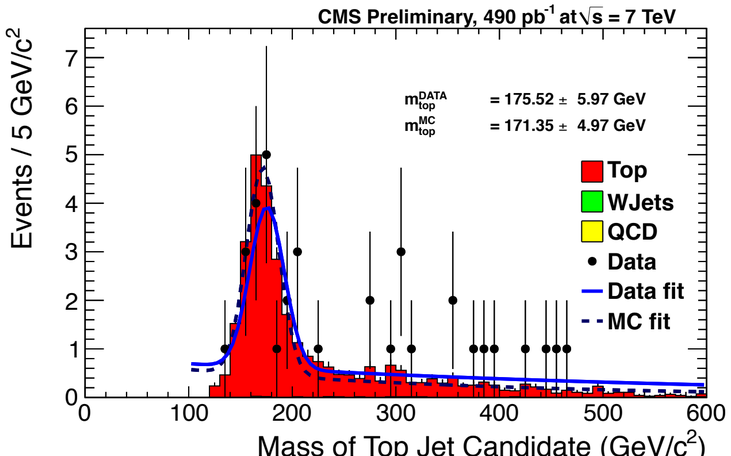
Expected signal shapes

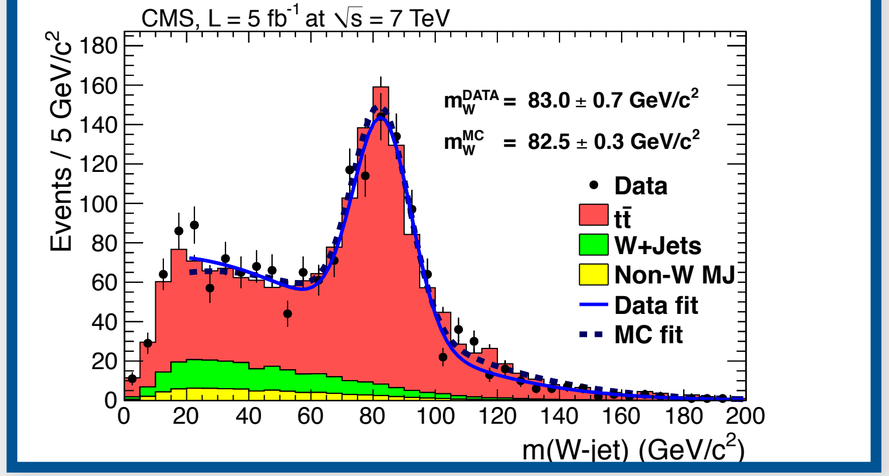


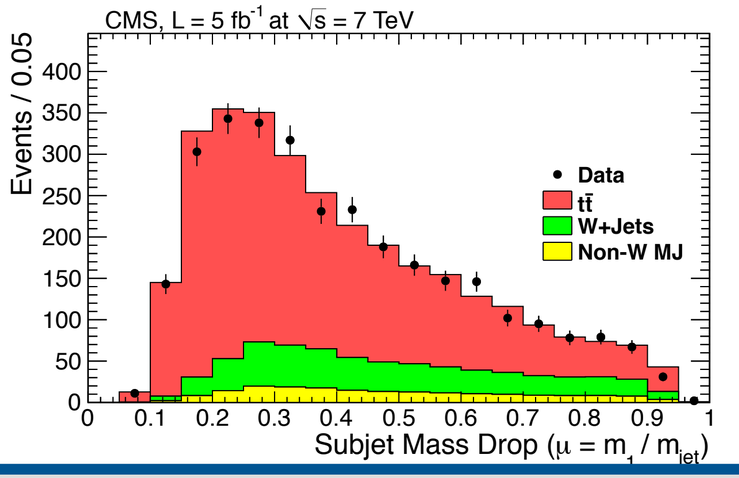


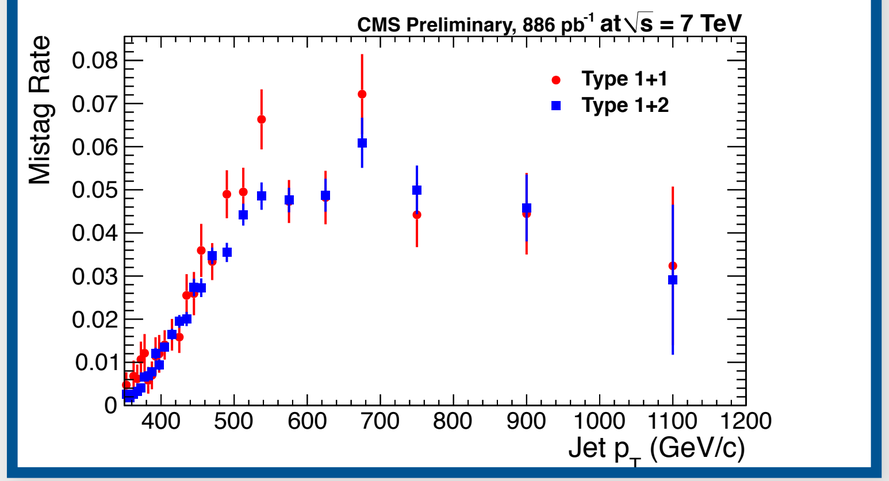
ALL-HADRONIC CHANNEL (BOOSTED)

CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488



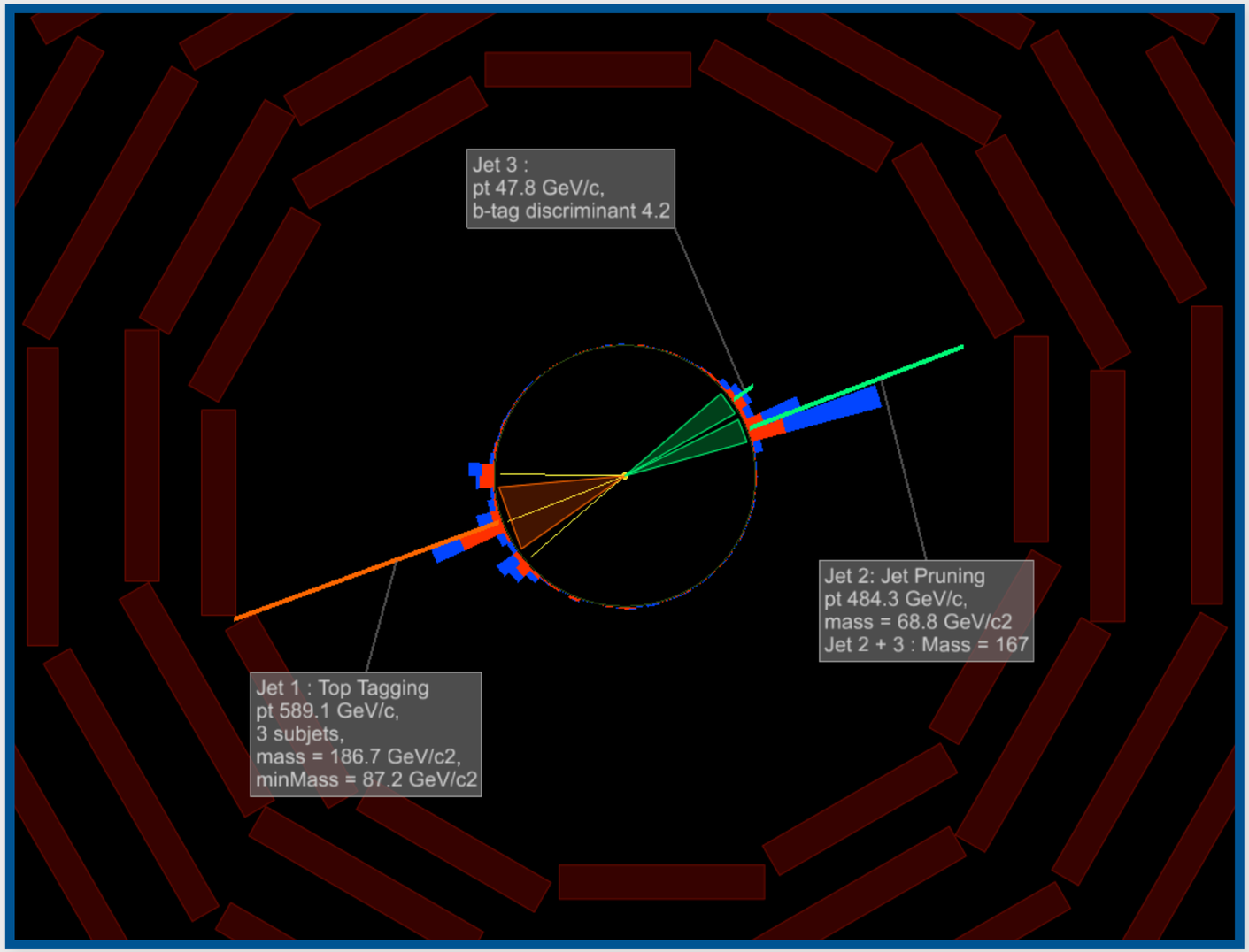






ALL-HADRONIC CHANNEL (BOOSTED)

CMS EXO-11-006 L = 5.0 fb^{-1}
arXiv:1204.2488



CONCLUSION

- Results on searches for resonances decaying to $t\bar{t}$ were presented
- All main channels are covered: *dilepton*, *lepton+jets*, *all-hadronic*
- Resonances are **excluded** in mass regions:

	dilepton		lepton+jets (at threshold)	lepton+jets (boosted)	allhadronic (boosted)
narrow Z' mass	< 1.1 TeV		< 1.3 TeV	< 0.9 TeV	< 1.6 TeV	< 1.6 TeV
wide Z' mass			< 1.7 TeV		< 2.1 TeV	< 2.0 TeV
KK Gluon mass		< 0.8 TeV	< 1.4 TeV	< 1.0 TeV		$1.4 < M_{KKg} < 1.5$
	CMS TOP-11-010	ATLAS CONF-11-123	CMS TOP-11-009	ATLAS CONF-12-029	CMS EXO-11-093	CMS EXO-11-006

the limits are rounded up to one decimal places

DILEPTON CHANNEL

LEPTON+JETS CHANNEL (AT THRESHOLD)

LEPTON+JETS CHANNEL (BOOSTED)

new

ALL-HADRONIC CHANNEL (BOOSTED)