Progress Report & Plans

Kalanand Mishra, Fermilab

Supervisor: Jeffrey Berryhill

CMS Center RA Meeting
(February 13, 2013)

Brief introduction

- Currently:

  -RA at Fermilab CMS Center since 2008
  -LPC Fellow for 2013

- Past:

  -Ph.D. (2008), Univ. Cincinnati, BaBar experiment at SLAC

  -Measured quark mixing (CKM) phase γ using $B \rightarrow D^{(*)}K^{(*)}$ decay, set limits on CP violation in charm decays

  -Cherenkov detector operations, hardware upgrade

  -Developed particle identification

Contribution to CMS detector calibration, upgrade

☑ Jet commissioning (JES, jet ID) with early data in 2008–10

- JES absolute calibration using Z+jet balance (included in the JINST paper on jet commissioning in CMS)

☑ Commissioning of electron with early data ➜ calibration using Z peak

- Led Egamma electron reco, ID & trigger efficiency subgroup in 2008–10

☑ Led development of CMS Tag&Probe tool for lepton efficiency measurements

Calibration works for POGs resulted in ≥ 5 ANs + 1 PAS + 1 publication

New

Currently contributing to CMS Level-1 trigger upgrade project

- improvements in L1 calorimeter triggers
- muon isolation in L1

Past physics analyses w/ significant involvement

2010 **36 pb^{-1}**	Inclusive W,Z cross section and properties	2 papers, published in JHEP
2011 **5 fb^{-1}**	M_{jj} in W+2-jet events	Published in PRL
New since last update	WW+WZ semi-leptonic: xsection & anomalous gauge couplings	Published in EJPC
New since last update	H→WW semi-leptonic: excl. limit in $2M_W$−600 GeV	To be submitted to EJPC, use data up to ICHEP12
2011 **5 fb^{-1}**	Jet substructure in dijet and W/Z+jet events	To be submitted to JHEP
2012 **5−19 fb^{-1}**	H→WW semi-leptonic	Approved public results for ICHEP12, HCP12, Moriond13

Physics contributions & accomplishments

Inclusive W,Z analysis: Co-led the Z analysis team, delivered the first cross section results for ICHEP 2010, and two papers with 3 pb^{-1} & 36 pb^{-1}. A high visibility analysis.

M_{jj} in W+jj analysis: Co-led the analysis team; edited the paper. Exclude CDF bump & several models to explain the effect (technicolor, leptophobic Z'). A high visibility analysis.

New

Diboson WW/WZ→$\ell\nu$jj: Led the analysis effort, edited the paper. The most stringent limits on anomalous triple gauge couplings at a hadron collider, in some cases improving upon the LEP results.

H→WW→$\ell\nu$jj: Led the analysis effort. Exclude SM Higgs in mass range 170–600 GeV. Part of high mass Higgs paper. Important channel for 2012 analysis of VBF/ WW scattering.

Jet substructure: First comprehensive study of boosted jets in dijet and W/Z+jet events in CMS. Part of the 4-member of analysis team.

People I work with: the lνjj team

Nural Akchurin[1], Jake Anderson[2], Chayanit Asawatangtrakuldee[11], Andrea Benaglia[3], Andrew Beretvas[2], Jeffrey Berryhill[2], Pushpa Bhat[2], Sarah Boutle[4], Chris Clarke[5], Fabio Colombo[3], Analu Custodio[10], Jordan Damgov[1], Leonardo Di Matteo[3], Phil Dudero[1], Ricardo Eusebi[6], Pietro Govoni[12], Dan Green[2], Joey Goodell[4], Robert Harr[5], Pratima Jindal[13], Ajay Kumar[7], Kristina Krylova[5], Kevin Lannon[9], Sung-Won Lee[1], Qiang Li[11], Shuai Liu[11], Wuming Luo[9], Yajun Mao[11], Kellen McGee[5], Kalanand Mishra[2], Md. Naimuddin[7], Chris Neu[4], Ilya Osipenkov[6], Alexx Perloff[6], Kirti Ranjan[7], Sasha Sakharov[5], Ram K Shivpuri[7], Kevin Siehl[5], Andre Sznajder[10], Nhan V. Tran[2], Zijun Xu[11], Weimin Wu[2], John Wood[4], Fan Yang[2], Francisco Yumiceva[2], and Wei Zou[11]

[1] Texas Tech University, Lubbock, Texas, USA
[2] Fermi National Accelerator Laboratory, Batavia, Illinois, USA
[3] Milano-Bicocca University and INFN, Milan, Italy
[4] University of Virginia, Charlottesville, Virginia, USA
[5] Wayne State University, Detroit, Michigan, USA
[6] Texas A&M University, College Station, Texas, USA
[7] Delhi University, Delhi, India
[8] University of Nebraska at Lincoln, Nebraska, USA
[9] University of Notre Dame, Notre Dame, Indiana, USA
[10] Universidade do Estado do Rio de Janeiro (UERJ), Brazil
[11] Peking University, China
[12] CERN
[13] Princeton Unversity, New Jersey, USA

Well established team, well oiled machinery

Supervisor at FNAL: Jeffrey Berryhill

Talks in the period since last progress report

Jan 2013	Invited talk at *Snowmass 2013: Energy Frontier Workshop on QCD Physics*, Fermilab. Title: "*Scale choices for complex processes*".
Jan 2013	HEP seminar at Iowa State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Dec 2012	Invited talk at US ATLAS Hadronic Final State Forum workshop, University of Chicago. Title: "*CMS measurements of jet structure and properties*".
Nov 2012	HEP seminar at Michigan State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Nov 2012	HEP seminar at Wayne State University. Title: "*Pursuing Electroweak Symmetry Breaking at CMS using WW semi-leptonic final state*".
Oct 2012	Physics colloquium, Florida Tech. Title: "*Discovery or Illusion: The Tale of a Tantalizing Bump*".
Sept 2012	Invited talk at *Workshop on electroweak corrections for LHC physics*, IPPP Durham (UK). Title: "*Electroweak measurements at CMS*".
Sept 2012	Joint Experimental-Theoretical (Wine & Cheese) Seminar at Fermilab, Title: "*Search for New Physics in Diboson Events at CMS*".
Aug 2012	Invited talk, *QCD@LHC 2012*, MSU. Title: "*W/Z+jets (incl. heavy flavor) at LHC*".
July 2012	BOOST 2012, Valencia, Spain. Title: "*Performance of jet substructure with pileup*".
July 2012	ICHEP 2012, Melbourne, Australia. Title: "*WW, WZ and ZZ production at CMS*".

Topical

Topical

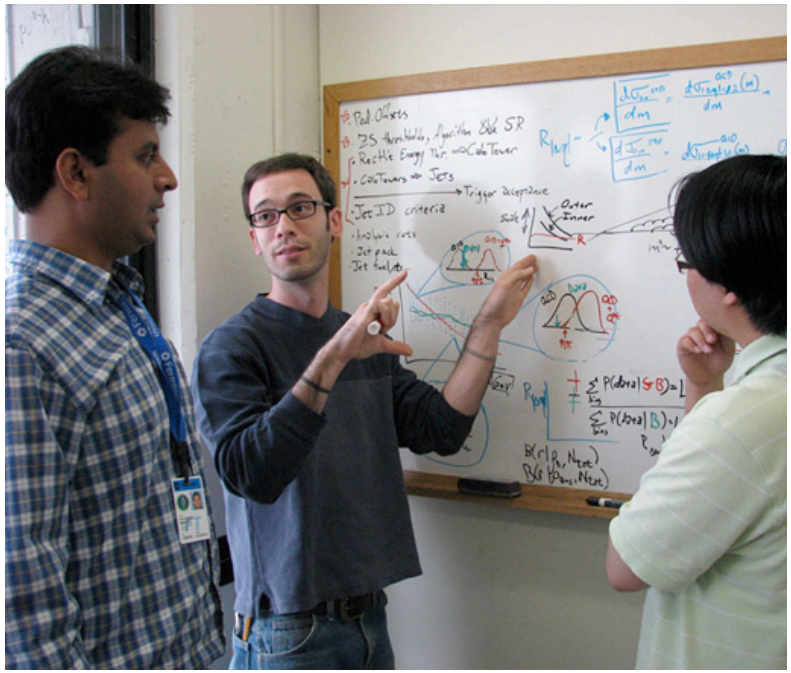
Topical

conference

Activities at LPC

1) Taught/facilitated CMSDAS jet short & long exercises in 2010, 2011, 2012, and 2013 including the ones at Pisa and Taipei

2) Regularly help LPC-based students with physics & data analysis



http://lpc.fnal.gov/

3) Mentored a number of undergrad and graduate students at LPC

2013: Kevin Siehl (Wayne State), Cristian Vega (Universidad San Francisco de Quito, UG)

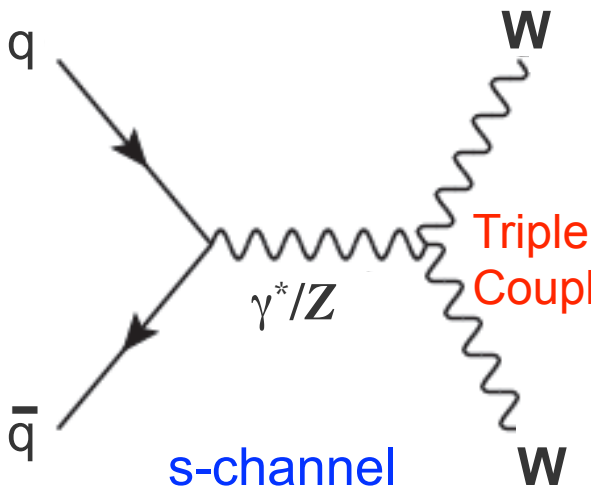
2012: Wei Zou (Beijing), Ajay Kumar (Delhi), Kevin Siehl (Wayne State), Geoffrey Fatin (Buffalo, UG), Joseph Flanigan (Wayne State,UG)

2011: Kristina Krylova (Buffalo, UG), Kellen McGee (Johns Hopkins, UG)

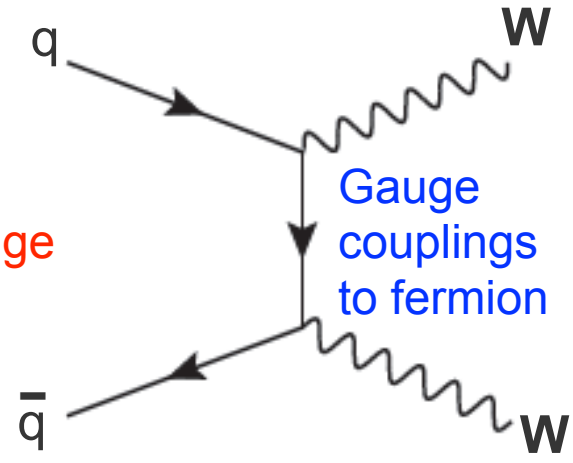
2008–10: Mikhail Makouski (Kansas State), Sunil Bansal (Panjab,India), Mehmet Deliomeroglu (Bogazici,Turkey), Kittikul Kovitanggoon (Texas Tech), David Bjergaard (Johns Hopkins, UG)

Physics analysis: my research focus

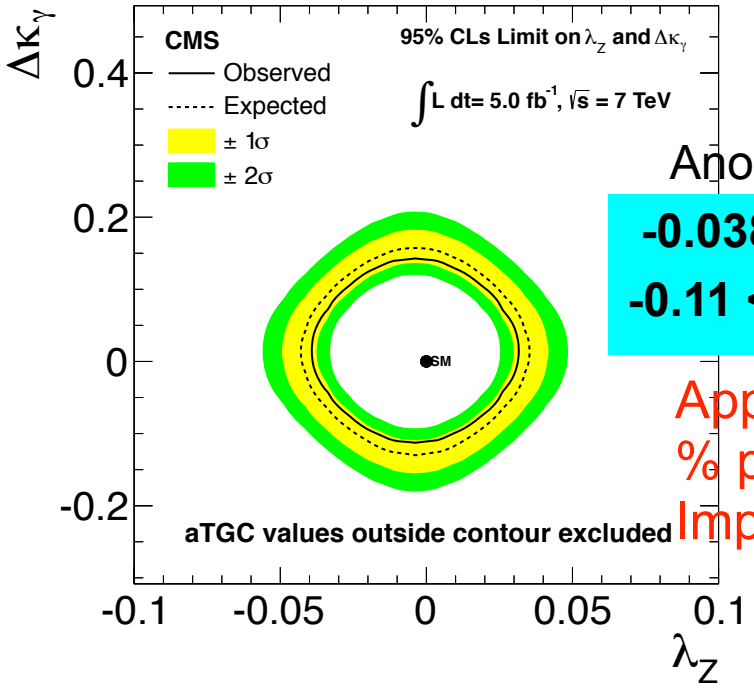
Semi-leptonic WW channel is most sensitive to anomalous TGC and high mass WW resonances



s-channel



t-channel

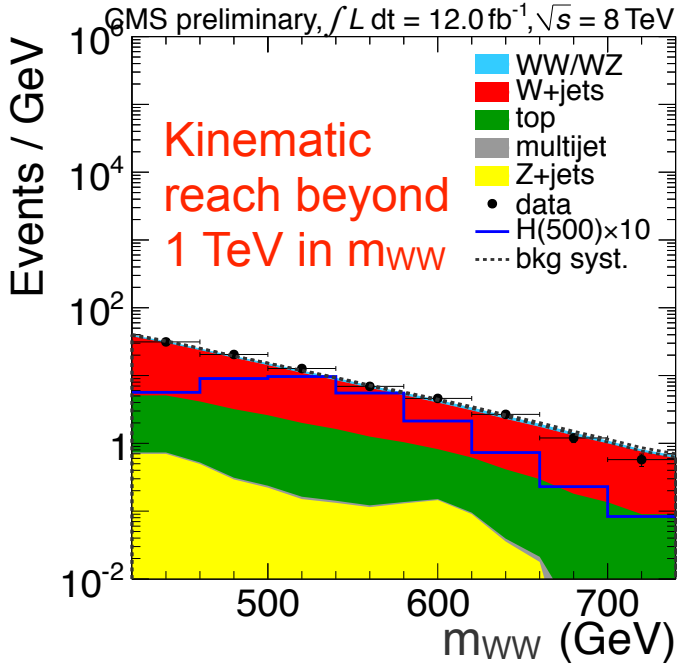


Anomalous TGC

$-0.038 < \lambda_Z < 0.030$

$-0.11 < \Delta\kappa_\gamma < 0.14$

Approaching a few % precision.
Improved over LEP.



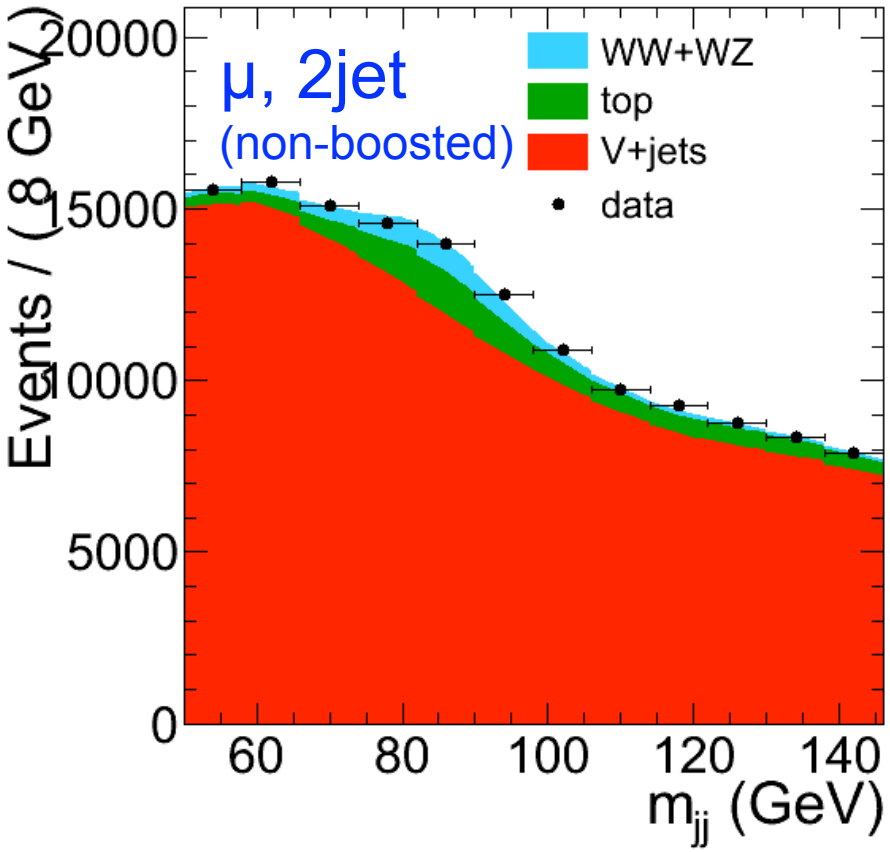
Plans for the next 6–12 months

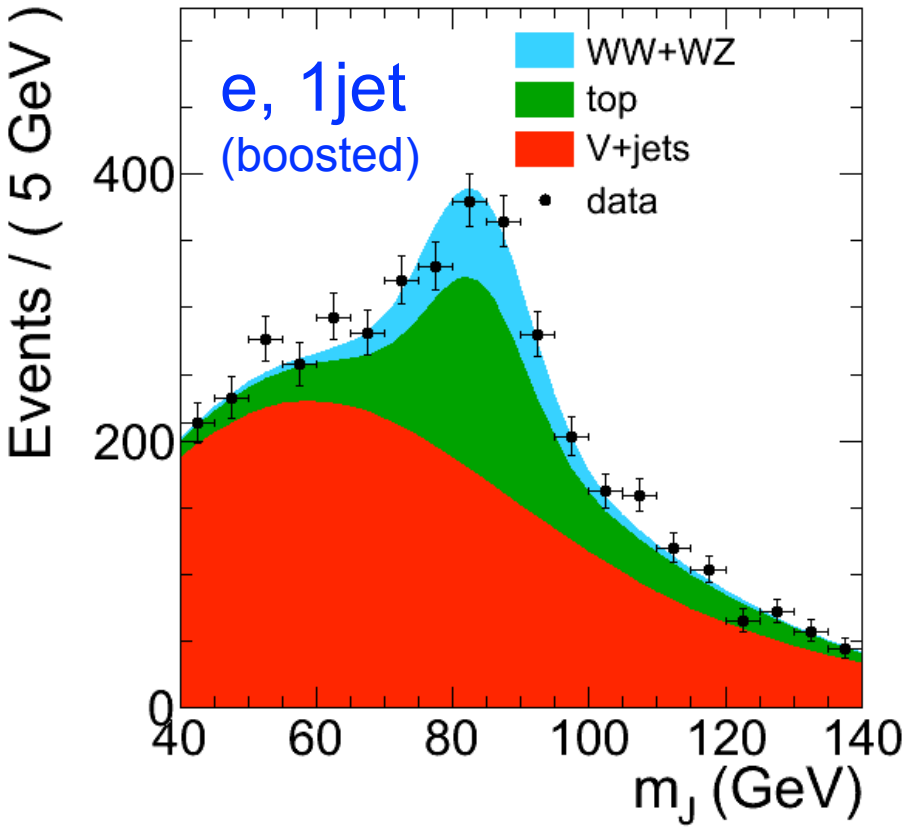
- Push the current 8 TeV analysis to publication
  - extend m_{WW} mass range >1 TeV for Higgs/BSM analysis
  - probe triple gauge couplings at the percent level
- Focus now on a deeper probe of EWSB using WW+ 2 tag jets events in VBF topology
  - First establish VBF production of WW
  - Check if data consistent with H(125) unitarized WW→WW scattering, probe quartic gauge couplings
- Continue ramping up on CMS Level-1 trigger upgrade

I elaborate on each of these topics in the following slides

Glimpse of currently ongoing 8 TeV analysis

WW production in semi-leptonic final state

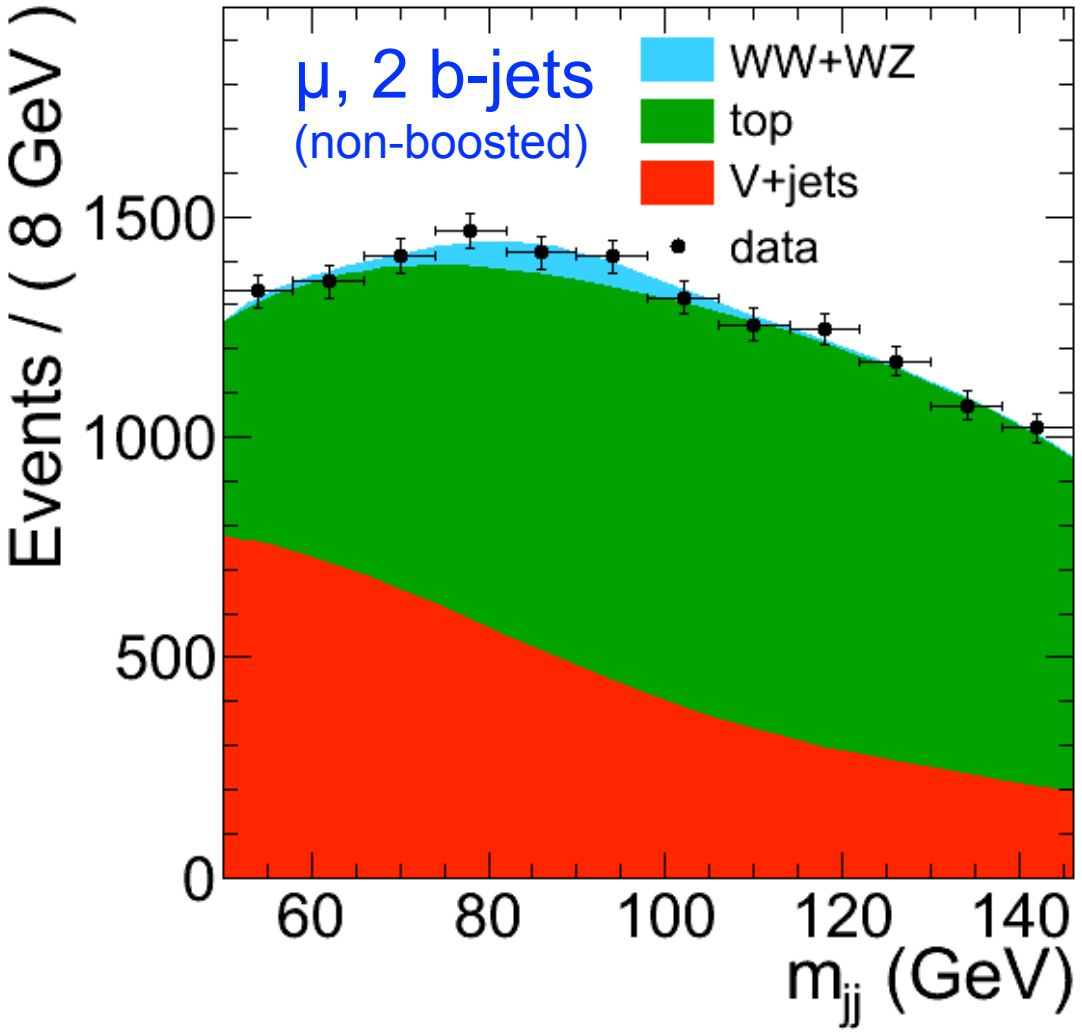




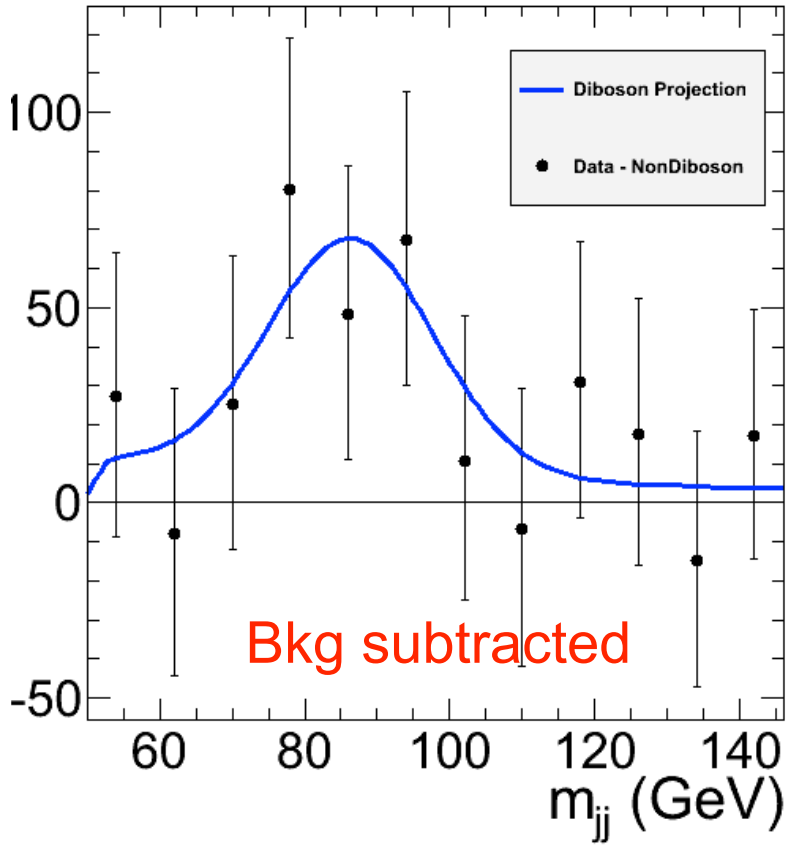
Found 9000 diboson events in 8 TeV data, with purity 5−15%

Glimpse of current analysis II

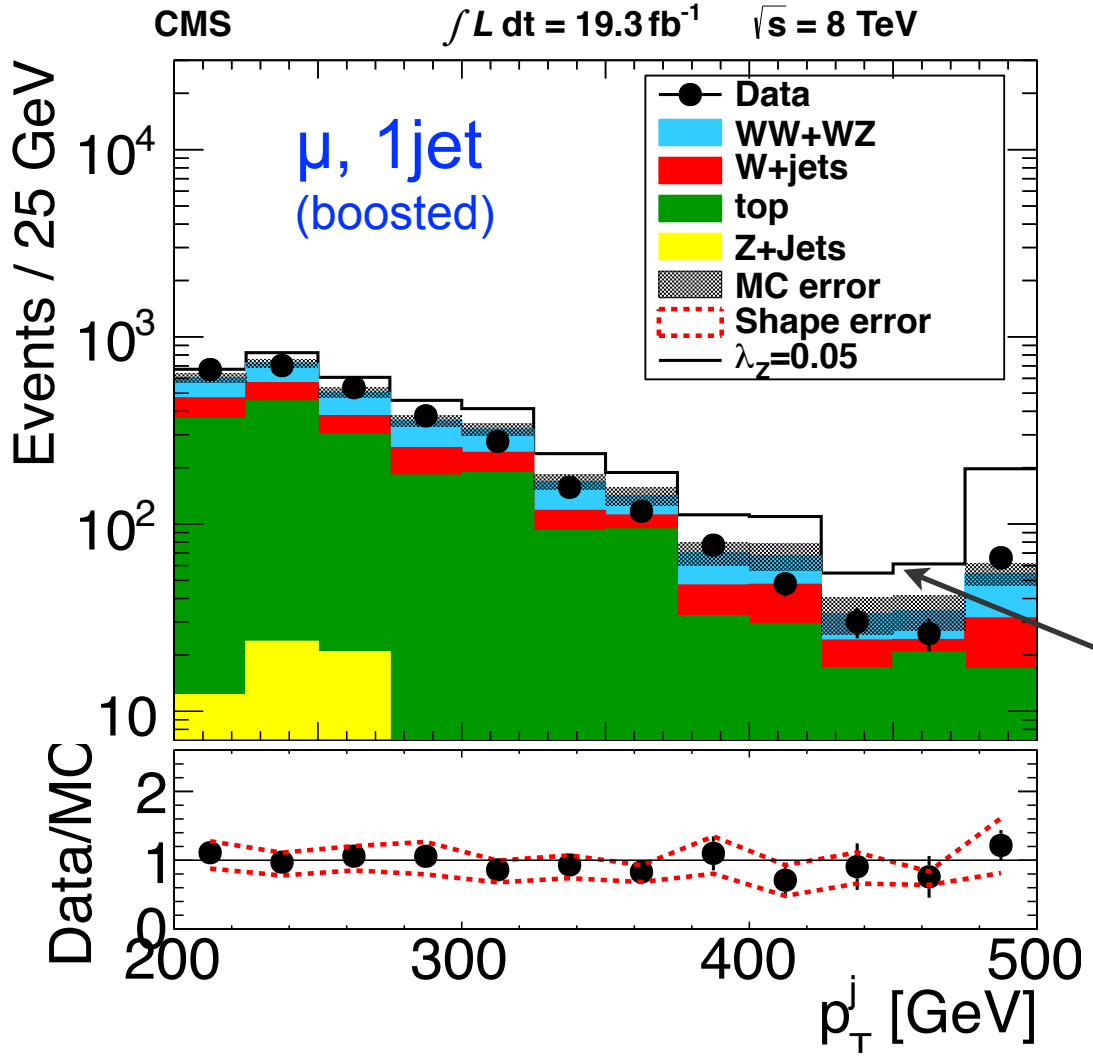
Hints of WZ(→bb) production.



Good proxy for WH(→bb).



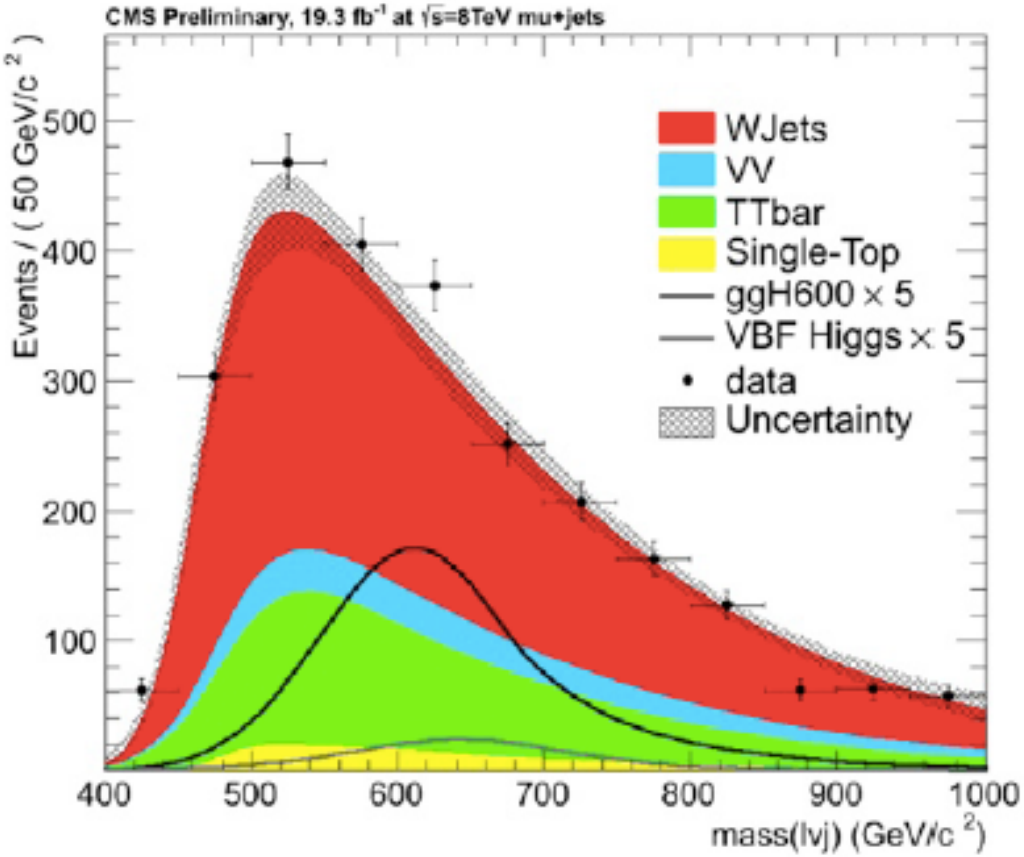
Glimpse of current analysis III



Limits on anomalous gauge couplings

Expect to constrain triple gauge coupling measurements to the % level. Already have world's best limit/ measurement.

Glimpse of current analysis IV



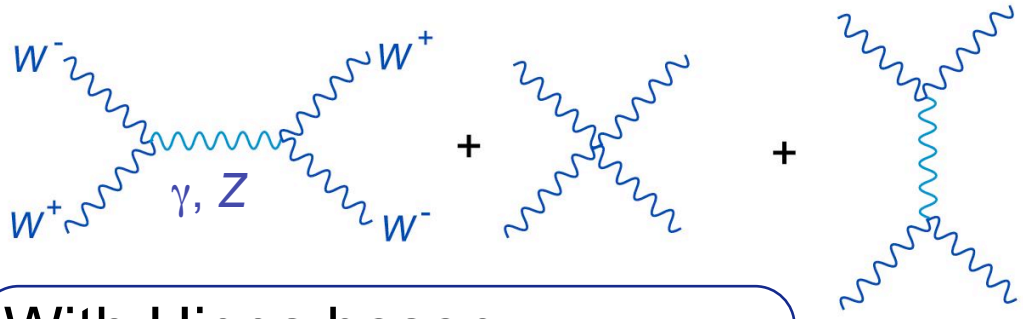
Probe WW invariant mass up to 1 TeV and beyond in the boosted regime (i.e., a single merged fat jet from W)

More details in Nhan's pre-approval presentation in Higgs PAG last week

https://indico.cern.ch/getFile.py/access?contribId=2&sessionId=6&resId=0&materialId=slides&confId=227892

Thinking of future: weak interaction @ high E

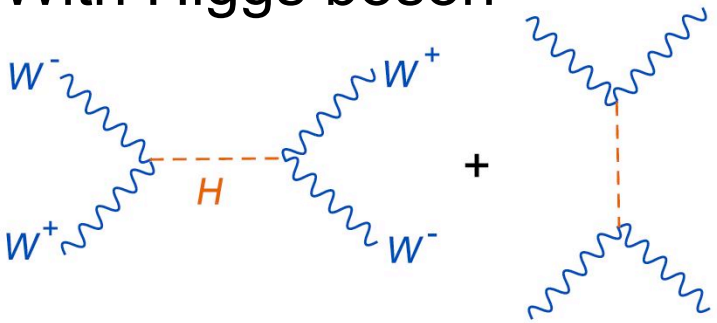
Without Higgs boson, WW scattering becomes divergent



$$= \frac{g^2 E^2}{2m_W^2}(1+\cos\theta)$$

unitarity violated: grows as E^2

With Higgs boson



$$= -\frac{g^2 E^2}{2m_W^2}(1+\cos\theta)$$

no problem now!

Higgs exchange needed to prevent unitarity violation in WW scattering at high energies or New Phenomena possible. With 20/fb, lvjj sensitive to weakly produced NP at 1 TeV.

Ballestrero et al, JHEP 1205, 083 (2012) [arXiv:1203.2771]

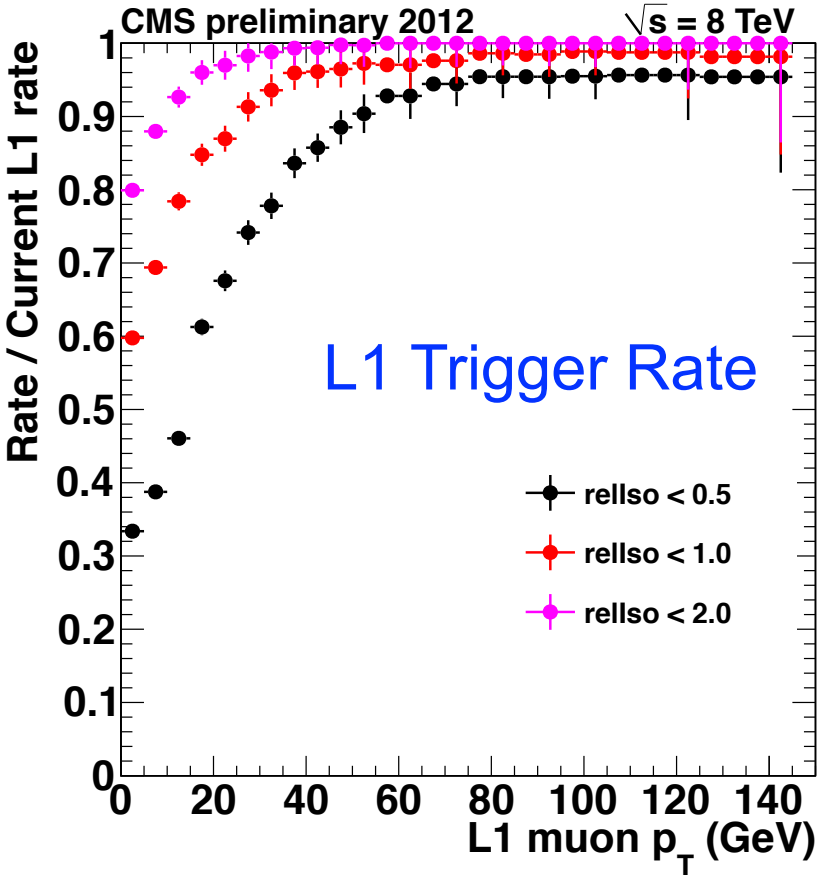
Upgrade activities

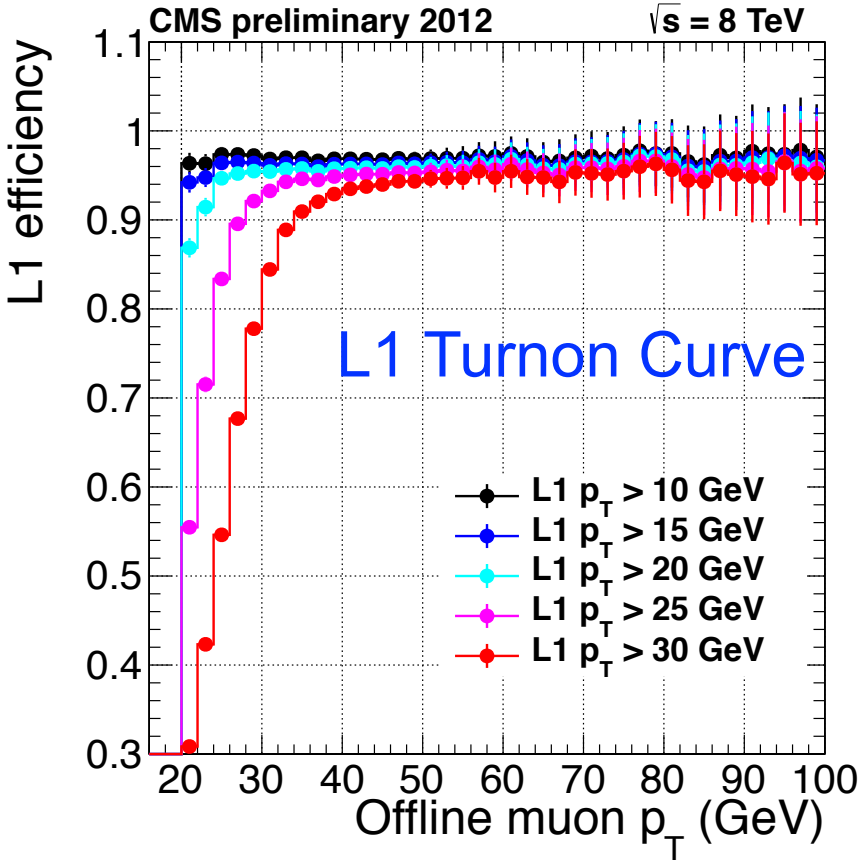
- The current Level-1 triggers will severely compromise CMS physics capability at 14 TeV, 50−100 pileup
  - E.g., single lepton threshold at HLT to go up to ~50 GeV
  - Will lose most of W,Z,top, Higgs events
  - Similar issues with jet, MET, tau, b-tag, cross triggers

- Having painfully dealt with the HLT rate increase of ℓ+jj triggers, I decided to invest my effort on L1 upgrade
  - Working closely w/ Andres Osorio (FIT & LPC) and Sergo
  - I focus on improvement from applying calorimeter isolation to L1 muons
  - Goal is to improve L1 objects in calorimeter by doing pileup subtraction and better algorithms
  - We started with performance studies, rate and efficiency computation etc, provided feedback for L1 upgrade TDR

Example: L1 muon isolation

Performance for “non-isolated” muons





Actual rate reduction is only 10−20% because significant fraction of L1 muons are already pretty isolated in calorimeter.

Career plans

- Got selected as LPC fellow for 2013
  - I am very excited
  - plan to take advantage of this opportunity to travel to more conferences and work with more collaborators
- Looking for next job as a tenure-track position
  - in the current academic year (2013) and the next (2014)

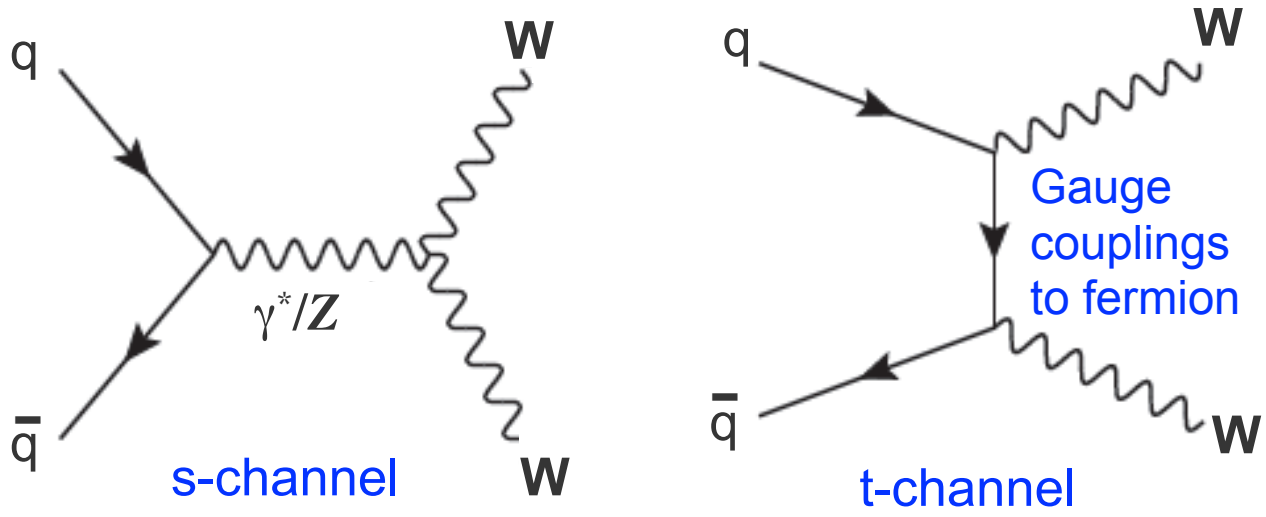
End of Report ! Thank You for Pizza !!!

BACKUP SLIDES

WW production and TGC

Need to measure WW production rate first !

WW production at Leading Order:



- Each diagram is divergent but the sum is finite !!!
- Higher order contribution is large: ~60% of the LO !
  (see backup for details, if interested)

Anomalous couplings in WW/WZ production

5 independent couplings remain after assuming basic symmetry

$$\mathcal{L}_{anom} = ig_{WWZ}\left[\Delta g_1^Z\left(W^*_{\mu\nu}W^\mu Z^\nu - W_{\mu\nu}W^{*\mu}Z^\nu\right) + \Delta\kappa^Z W^*_\mu W_\nu Z^{\mu\nu} + \frac{\lambda^Z}{M_W^2}W^*_{\rho\mu}W^\mu_\nu Z^{\nu\rho}\right] + ig_{WW\gamma}\left[\Delta\kappa^\gamma W^*_\mu W_\nu \gamma^{\mu\nu} + \frac{\lambda^\gamma}{M_W^2}W^*_{\rho\mu}W^\mu_\nu\gamma^{\nu\rho}\right],$$

Equal coupling (HISZ) parametrization

$$\Delta\kappa_Z = \Delta g_1^Z - \Delta\kappa_\gamma \cdot \tan^2\theta_W \qquad \lambda_Z = \lambda_\gamma = \lambda$$

Further assume that $\Delta g_1^Z = 0$ (SM), leaves two parameters: λ_Z , $\Delta\kappa_\gamma$

Coupling	Particle Data Group Fit
Λ_γ	$0.028^{+0.020}_{-0.021}$
Λ_Z	$0.088^{+0.060}_{-0.057}$
Δg_1^Z	$0.016^{+0.022}_{-0.019}$
$\Delta\kappa_\gamma$	$0.027^{+0.044}_{-0.045}$
$\Delta\kappa_Z$	$0.026^{+0.059}_{-0.056}$

LEP combination @ 95% CL

[-0.026, 0.208]

[-0.063, 0.115]

Tevatron (DØ) arXiv:1208.5458

λ_Z: [-0.039, 0.042]

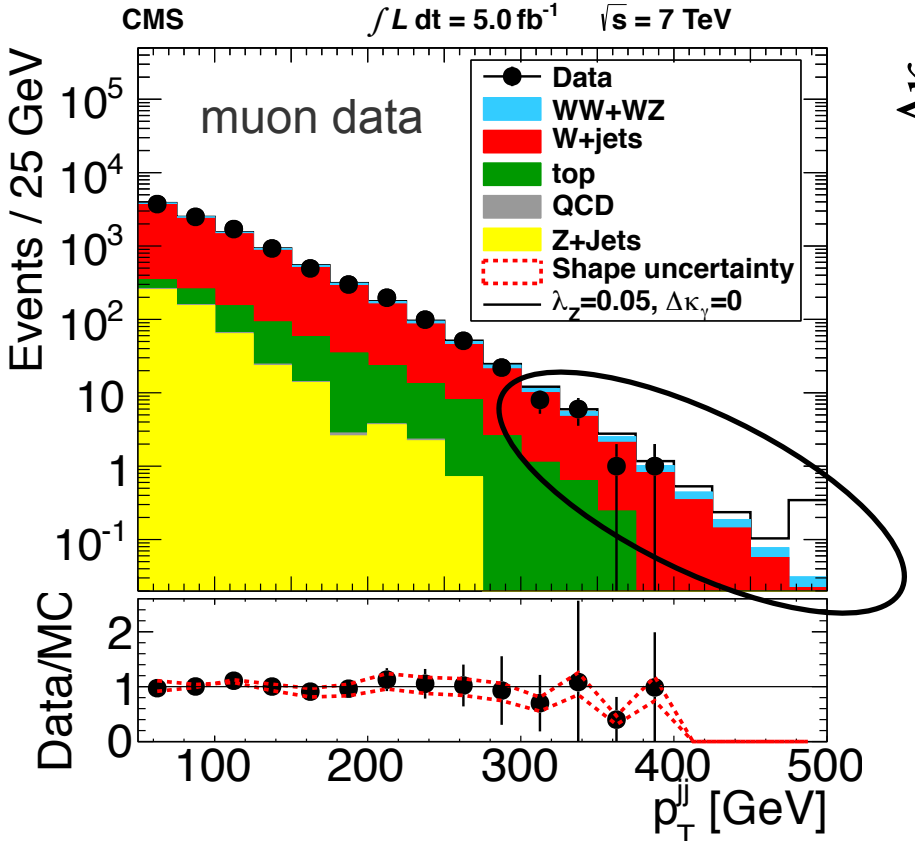
$\Delta\kappa_\gamma$: [-0.049, 0.124]

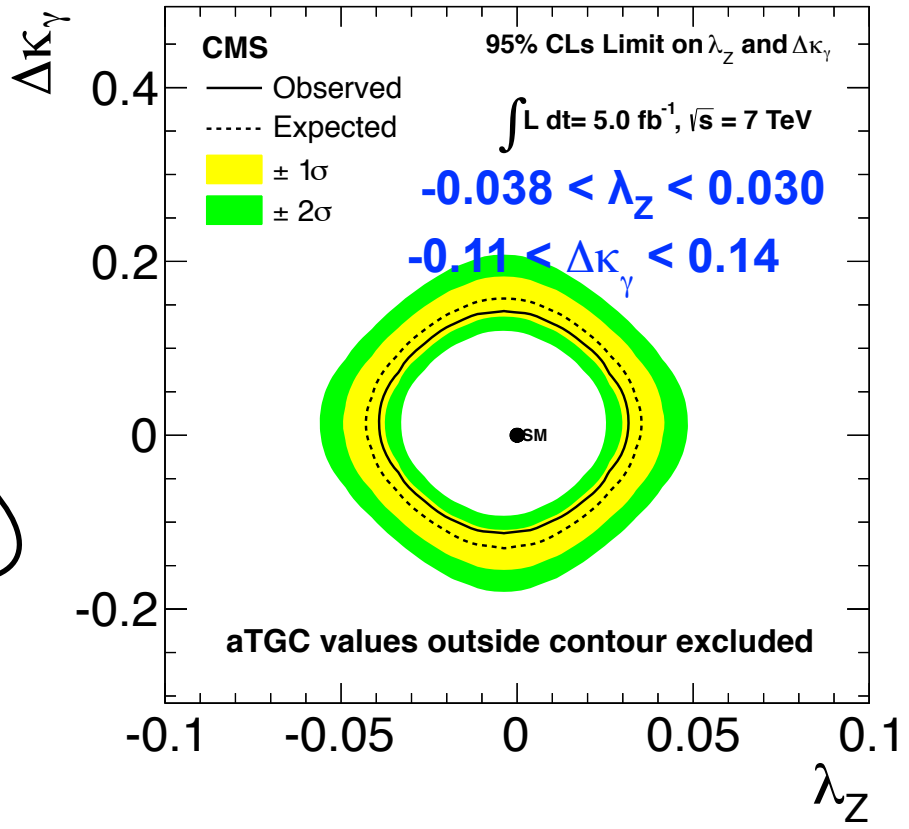
Note: assumes form factor of 2 TeV

ATLAS (arXiv:1208.1390) λ_Z: [-0.057, 0.093], $\Delta\kappa_\gamma$: [-0.37, 0.57]

Limits from WW/WZ→ℓνqq measurement

Use hadronic W p_T as the observable





Anomalous couplings show up in high p_T tails. Model using MCFM.

☑ Improve upon the LEP limit in some cases.

Shape of dijet mass in WW and WZ events

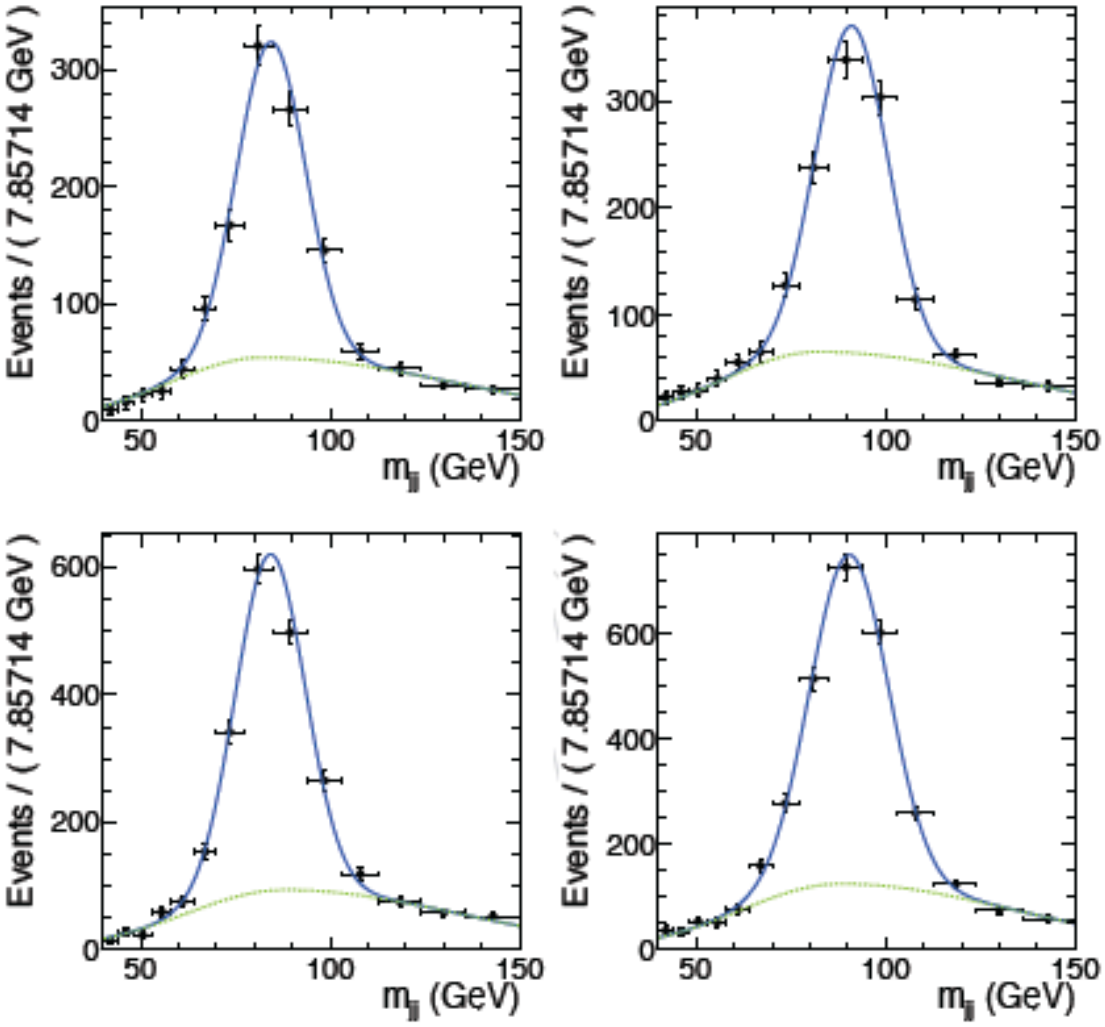


Figure 28: Diboson shape in the b-tagged sample: Projections of the fit to the diboson MC samples using the selected parameterization. Left is WW; right is WZ; top is electrons; bottom is muons.

AN-12-224 v8
pp 37