Search for the Standard Model Higgs boson in $H \rightarrow WW \rightarrow \ell \nu q\bar{q}$

Kalanand Mishra

Fermilab

On behalf of the $H \rightarrow WW \rightarrow \ell \nu jj$ analysis team

Using 8 TeV 2012 data, and combined result of 7+8 TeV

Approval talk, June 22, 2012

The team

Nural Akchurin[1], Jake Anderson[2], Chayanit Asawatangtrakuldee[12], 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[13], Dan Green[2], Joey Goodell[4], Robert Harr[5], Pratima Jindal[8], Ajay Kumar[7], Gordon Kaussen[11], Kristina Krylova[5], Kevin Lannon[9], Sung-Won Lee[1], Quiang Li[12], Shuai Liu[12], Wuming Luo[9], Yajun Mao[12], 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[12], Weimin Wu[2], John Wood[4], Fan Yang[2], Francisco Yumiceva[2], and Wei Zou[12]

[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] University of Hamburg, Hamburg, Germany
[12] Peking University, China
[13] CERN

Acknowledgements

- **We sincerely thank our ARC members for their time and effort getting our analysis to this point.**
  - **Radia Redjimi Boulahouache**
  - **Vitaliano Ciulli**
  - **Marcello Maggi**
  - **Vivek Sharma (chair)**

- **We would also like to thank our conveners for their support.**

The analysis

- **Cadi/PAS**
  - http://cms.cern.ch/iCMS/analysisadmin/cadi?ancode=HIG-12-021

2011 analysis: HIG-12-003

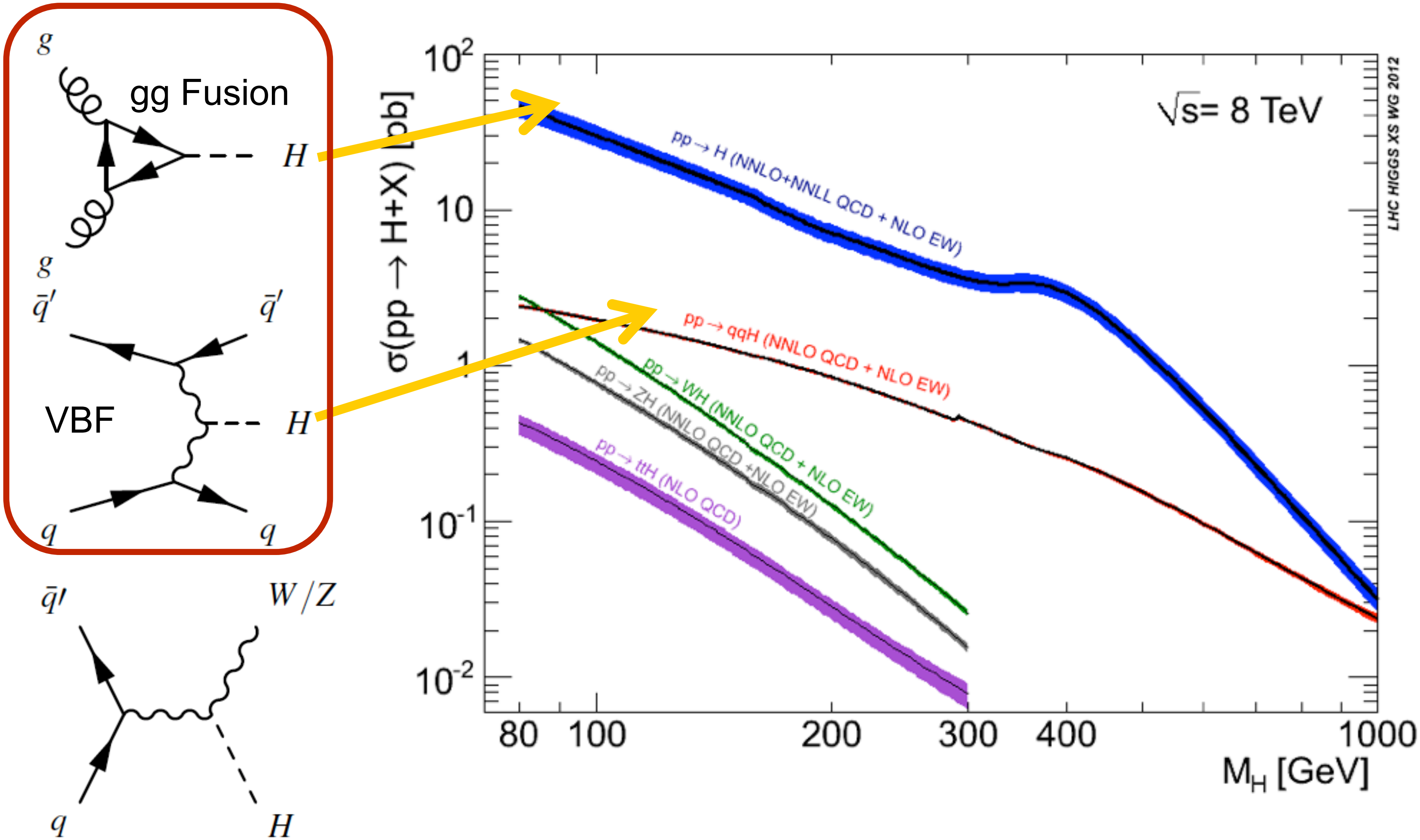
- **Hypernews**
  - https://hypernews.cern.ch/HyperNews/CMS/get/HIG-12-021.html
- **twiki**
  - https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig12021TWiki
- **Analysis note:**

  AN-2012/193
- **Review Q &A**
  - https://twiki.cern.ch/twiki/bin/viewauth/CMS/HIG-12-021-ARC

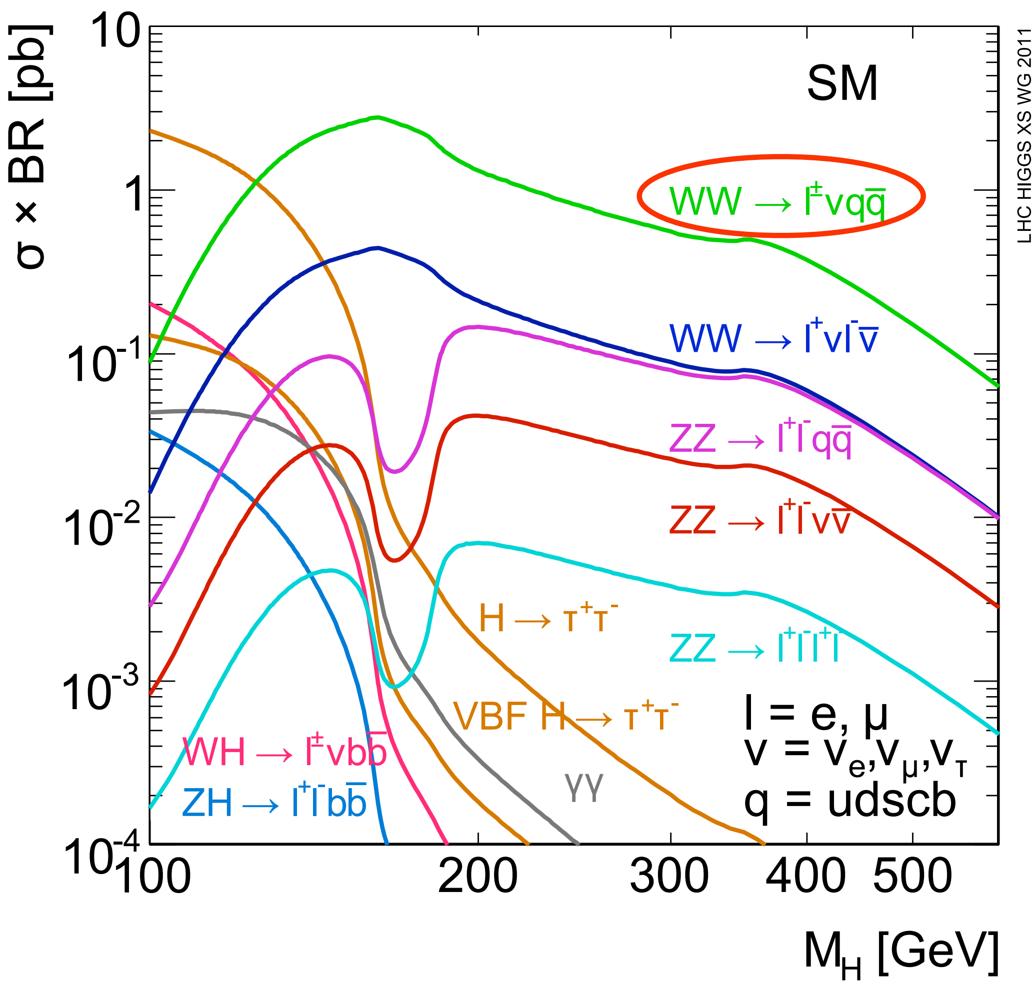
Outline

- **Motivation: signal production and decay**
- **Dataset and simulation, pre-selection**
- **Analysis flow**
  - **selection optimization**
  - **backgrounds**
  - **m_{jj} fit to extract background normalizations**
  - **data driven W+jets shape**
  - **systematic errors**
  - **limit**
- **Combined limit using 7 TeV and 8 TeV results**

Higgs production



Higgs decay



- H→WW→ℓvjj does a lot of heavy lifting.
  - largest BR × σ over most of the mass range.
  - Using a W mass constraint, the decay is sufficiently reconstructed to produce a mass peak.
- Principal drawback is the large W+jet background
  - We employ data-driven techniques to understand and control this process.

Data samples and trigger

dataset name
/SingleElectron/Run2012A-PromptReco-v1/AOD /SingleElectron/Run2012B-PromptReco-v1/AOD
/SingleMu/Run2012A-PromptReco-v1/AOD /SingleMu/Run2012B-PromptReco-v1/AOD

Certified "golden" JSON (June 12, **3.5 fb^{-1}**) used

electron trigger paths	run range
HLT_Ele27_WP80_v*	190456- June 12 cutoff

muon trigger paths	run range
HLT_IsoMu24_v*, HLT_IsoMu24_eta2p1_v*	190456- June 12 cutoff

- Lepton HLT efficiencies are corrected to account for data/MC differences by means of "Tag and Probe" with Z events
- Same technique is used to measure reconstruction/identification scale factors

MC samples

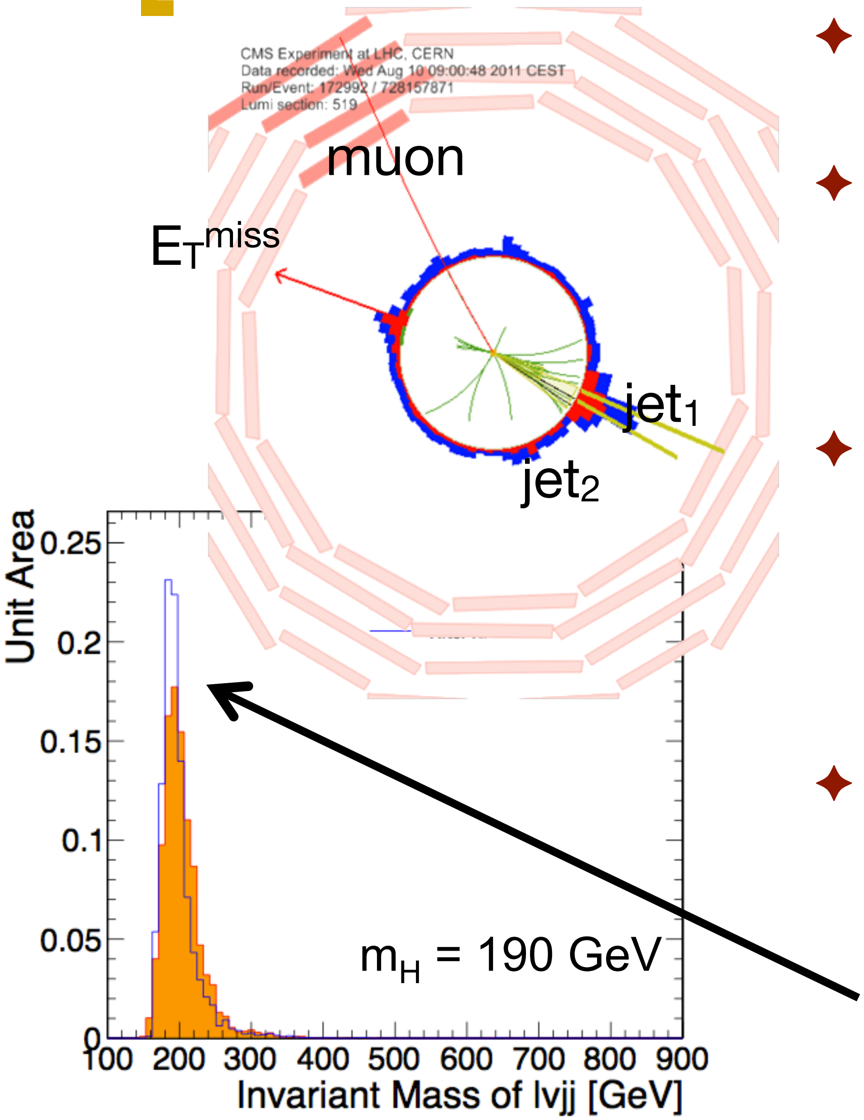
dataset name	x-sec (pb)	eq. lumi (fb^{-1})
/WJetsToLNu_TuneZ2Star_8TeV-madgraph-tarball/Summer12-PU_S7_START52_V9-v1/AODSIM	36257	0.5
/DYJetsToLL_M-50_TuneZ2Star_8TeV-madgraph-tarball/Summer12-PU_S7_START52_V9-v1/AODSIM	3503	4.1
/TTJets_TuneZ2star_8TeV-madgraph-tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	225	30
/WW_TuneZ2star_8TeV_pythia6_tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	57	170
/WZ_TuneZ2star_8TeV_pythia6_tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	32	300
/ZZ_TuneZ2star_8TeV_pythia6_tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	8	1000
/T_TuneZ2_*_TuneZ2star_8TeV-powheg-tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	10-50	~100
/Tbar_TuneZ2_*_TuneZ2star_8TeV-powheg-tauola/Summer12-PU_S7_START52_V9-v1/AODSIM	10-30	~100

8 signal mass points at 8 TeV: **180, 200, 300, 400, 450, 500, 550, 600 GeV.** Enough to plot limit curve with good granularity.

- **These signal samples have been produced by us using Summer12 conditions for pileup and underlying event.**

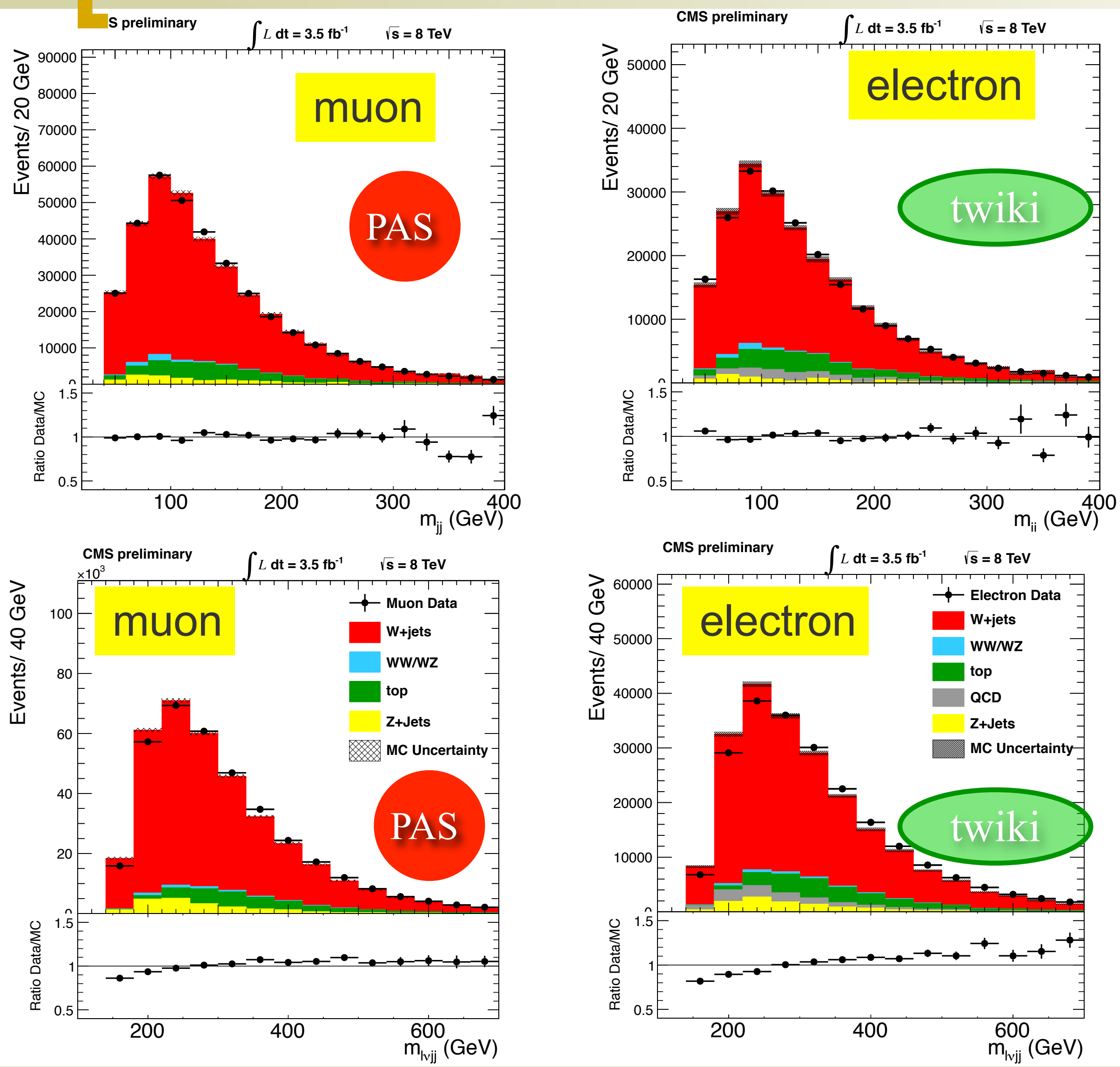
- **All MC samples corrected to account for different pile-up conditions in data**
  - -pile-up re-weighting applied

Event (pre-) selection



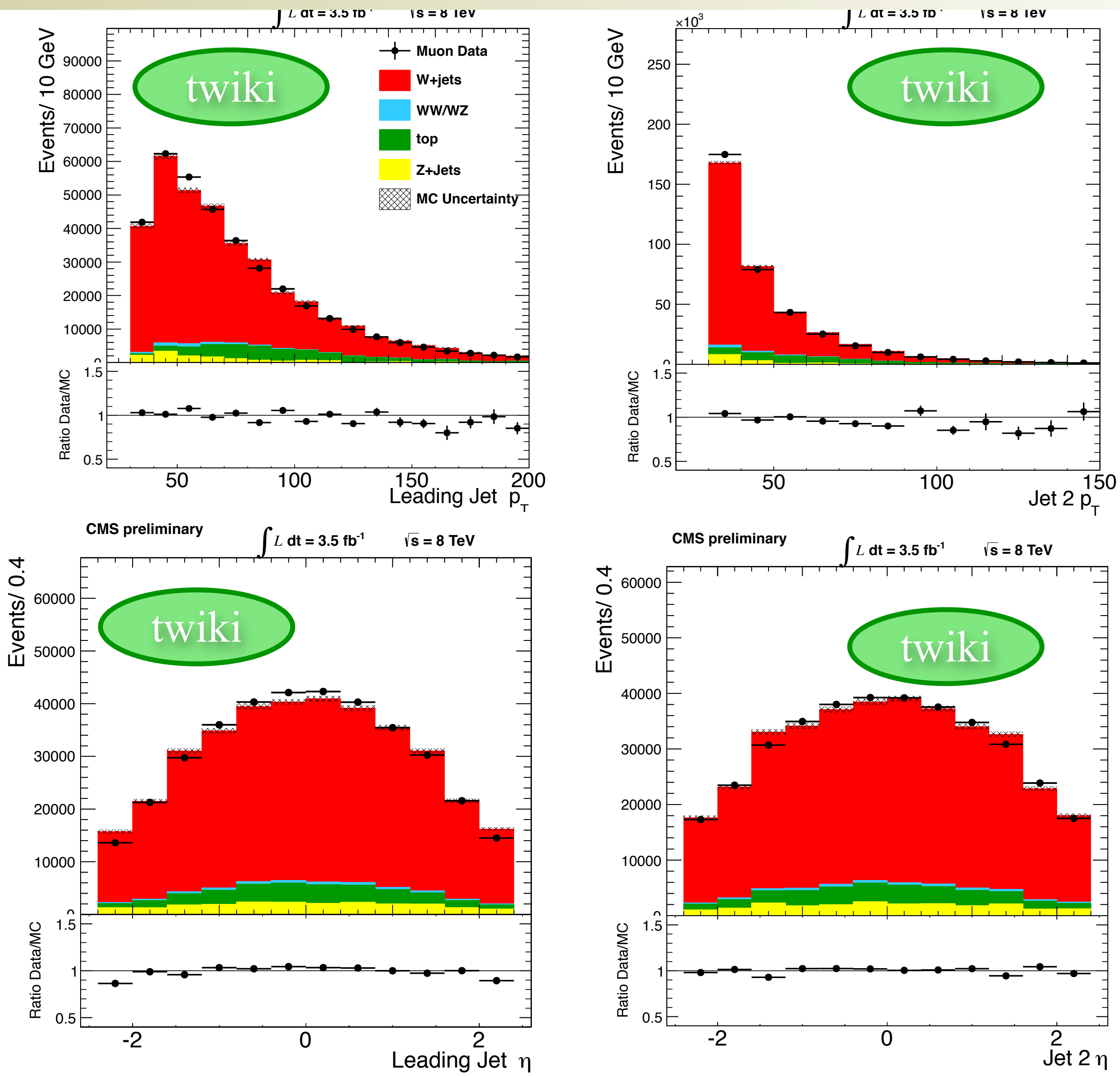
- One isolated, high-p_T lepton
  - p_T > 35 (25) GeV for electrons (muons)
- High E_T^{miss} from 1 neutrino
  - E_T^{miss} > 30 (25) GeV for electrons (muons)
  - m_T(lepton+E_T^{miss}) > 30 GeV
- Two high pT jets with m_{jj} ~ 80 GeV
  - Anti-Kt 0.5 particle flow jets
  - p_T > 30 GeV, $|\eta|$ < 2.4
  - ΔR(jet-lepton) > 0.3
  - $N_{extra\text{-}jets}$ = 0,1
- WW inv. mass ➔ reconstruct Higgs signal
  - neutrino p_Z from m_W constraint
  - We do a kinematic fit on lepton,E_T^{miss}, hadronic W to improve Higgs mass resolution and to remove the correlation between m_{WW} from m_{jj}.

Data/MC comparison @pre-sel level: m_{jj} , m_{lvjj}

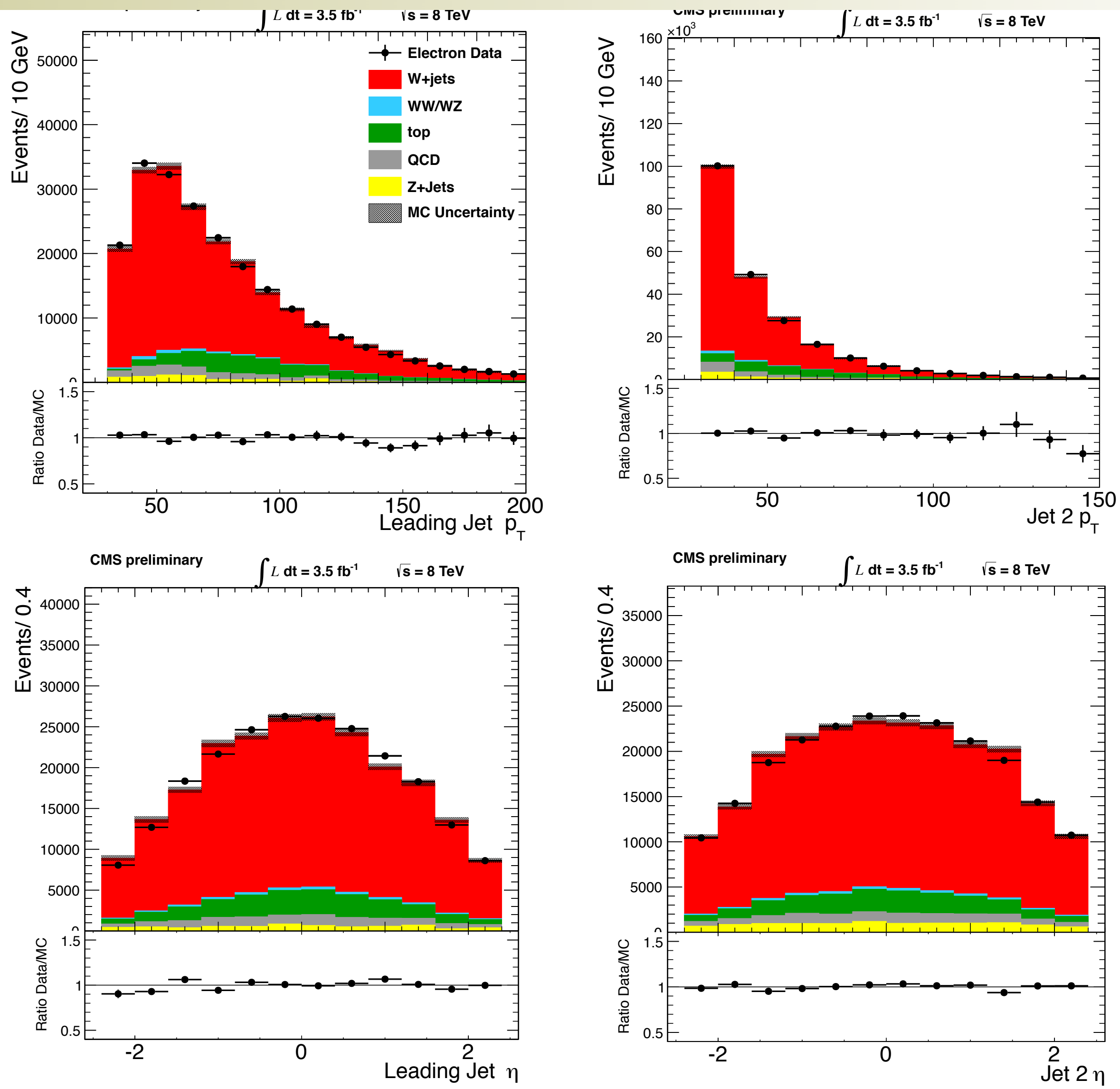


The disagreement seen here is understood. The LO MadGraph simulation doesn't get the m_{lvjj} spectrum right. Hence, we use data-driven technique for W+jets shape.

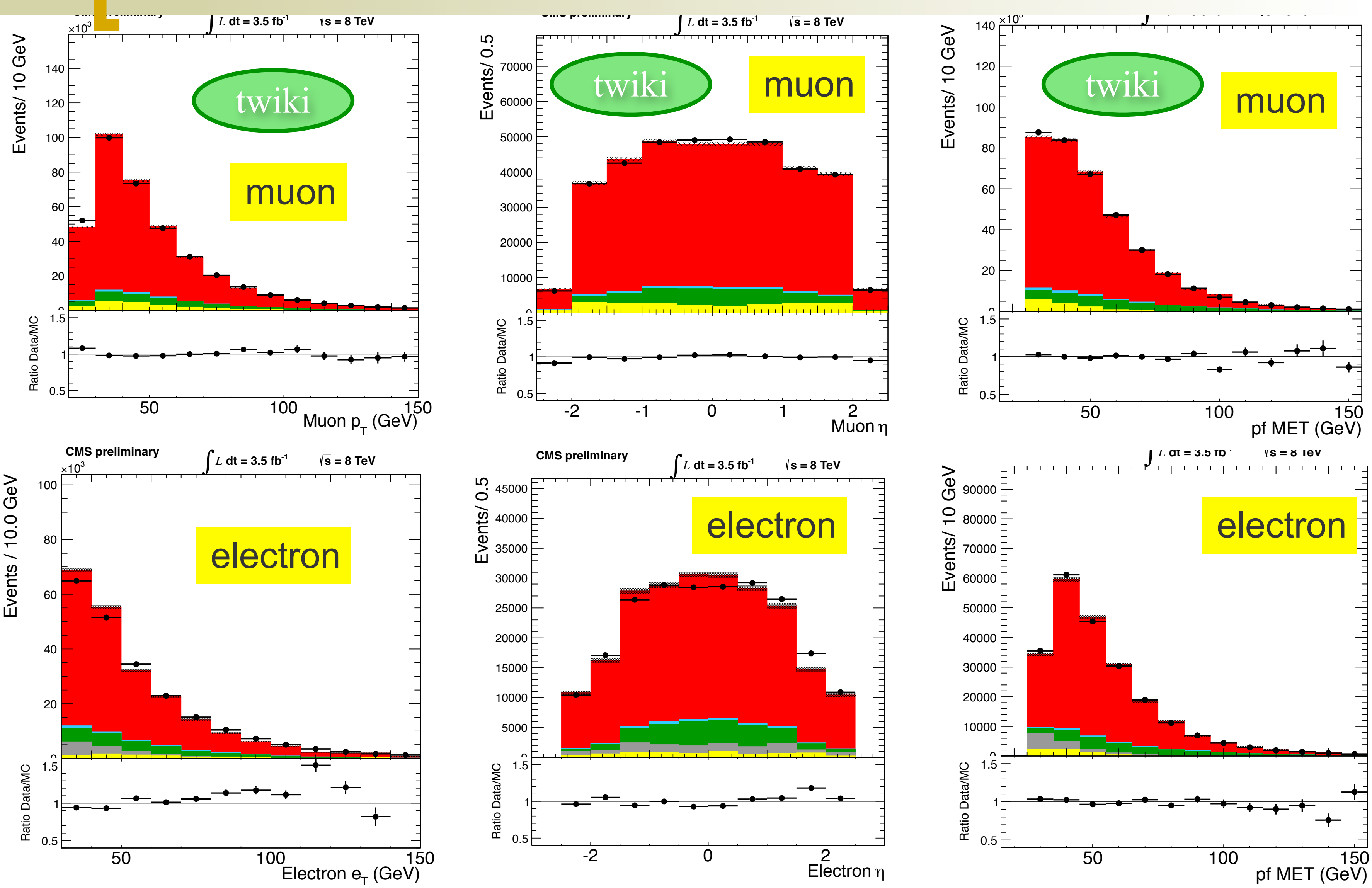
Comparison plots: jets (muon data)



Comparison plots: jets (electron data)



Comparison plots: leptons



Use optimized selection to improve sensitivity

- To **improve the limit** on SM Higgs cross-section and **reduce the systematics** on background evaluation:
  - ✓ drastically reduce the number of background events
  - ✓ preserve a reasonable efficiency on the signal

- Use event kinematics to build a simple **likelihood** discriminator:
  - a different likelihood is built for each operating point
    - 8 mass points × 2 flavors (e/μ) × 2 jet bins (2j/3j) = **32 different likelihoods**

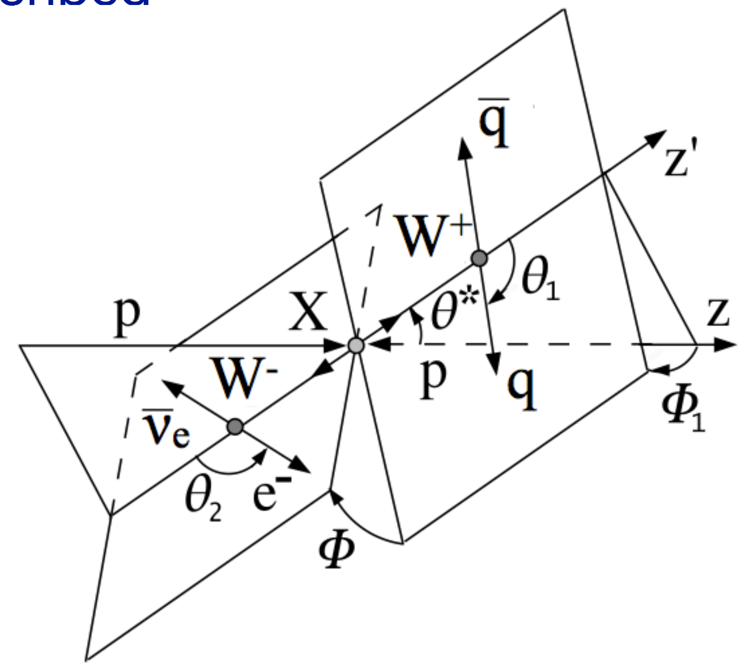
- Mostly sensitive at high mass, but have extended the analysis down to m_H = 180 GeV

Likelihood input variables

- Higgs boson decay kinematics is fully described by → $\{m_{WW}, m_{jj}, \boldsymbol{\theta_1}, \boldsymbol{\theta_2}, \boldsymbol{\theta^*}, \boldsymbol{\phi}, \boldsymbol{\phi_1}\}$

  - **m_{WW}** is the variable we use to extract limit, so it is not included

  - **m_{jj}** used to estimate background normalization, so it is not included



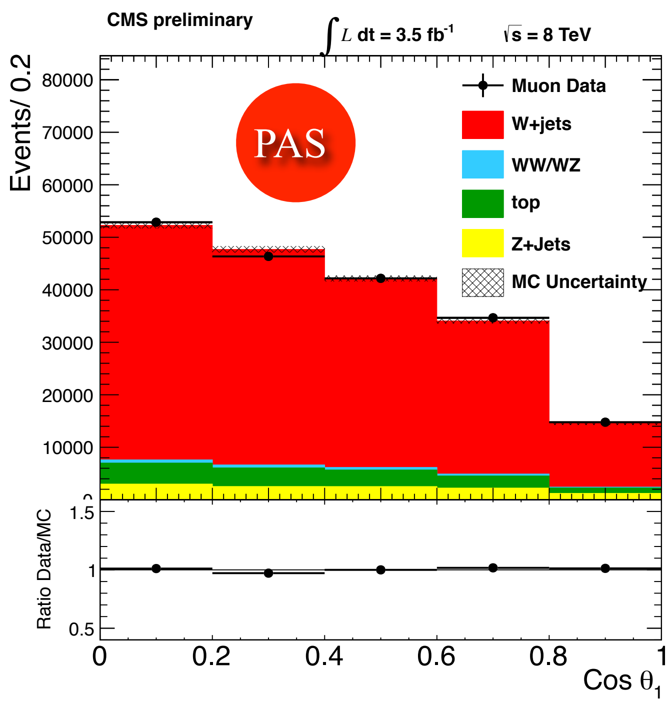
- the **five angular variables are included**

- **Lepton charge** is a good variable since signal is charge-symmetric, while W+jets is not

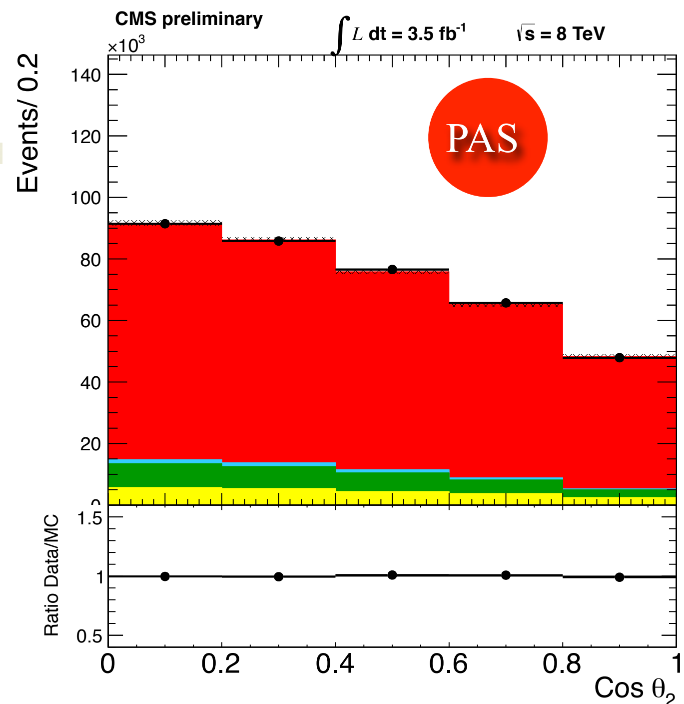
$\{\theta_1, \theta_2, \theta^*, \phi, \phi_1, (p_T)_{WW}, y_{WW}, \text{lepton charge}\}$

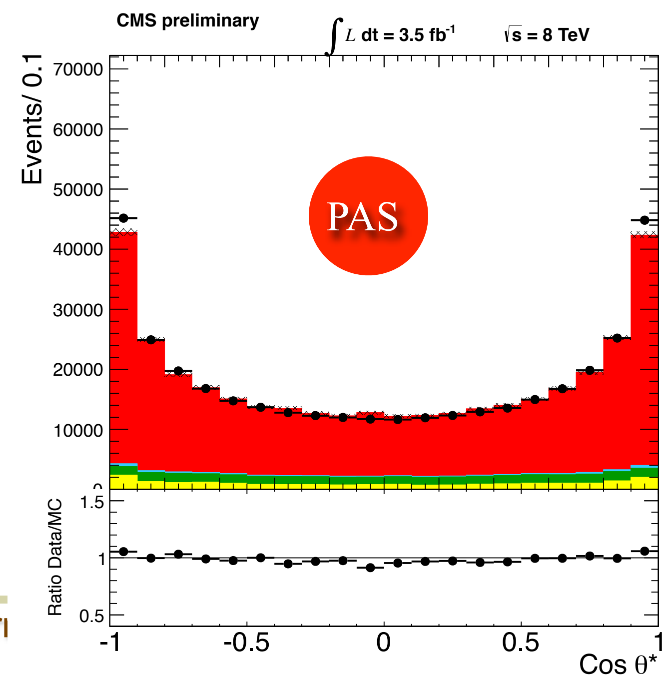
Input variables (I)

muon data



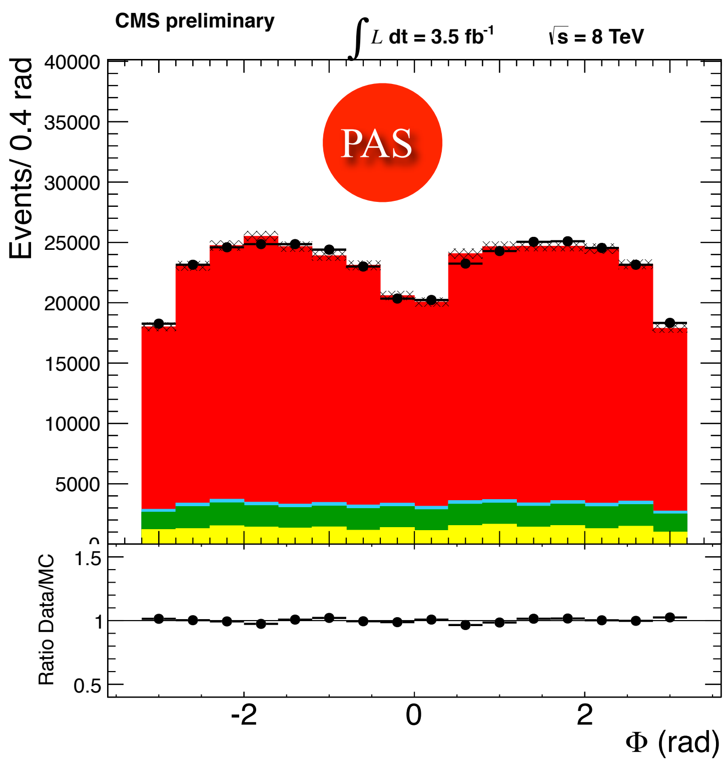
Reasonable modeling of kinematics in simulation.

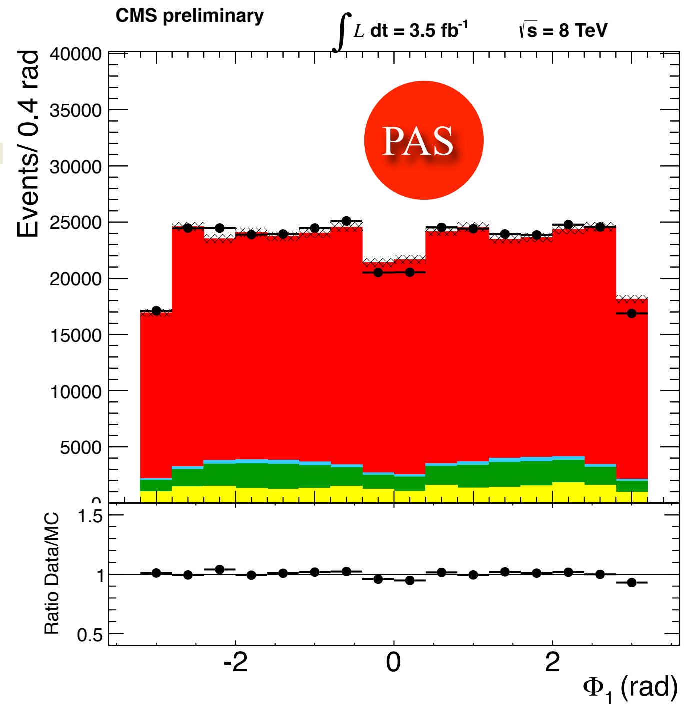


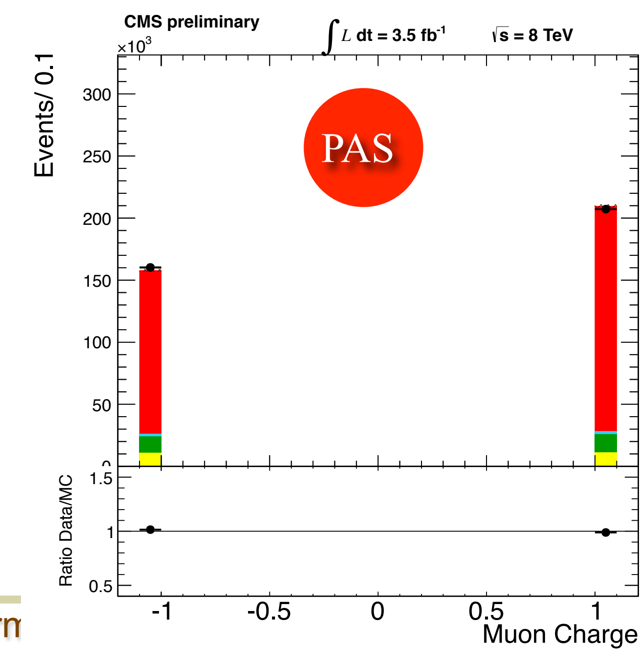


Input variables (II)

muon data

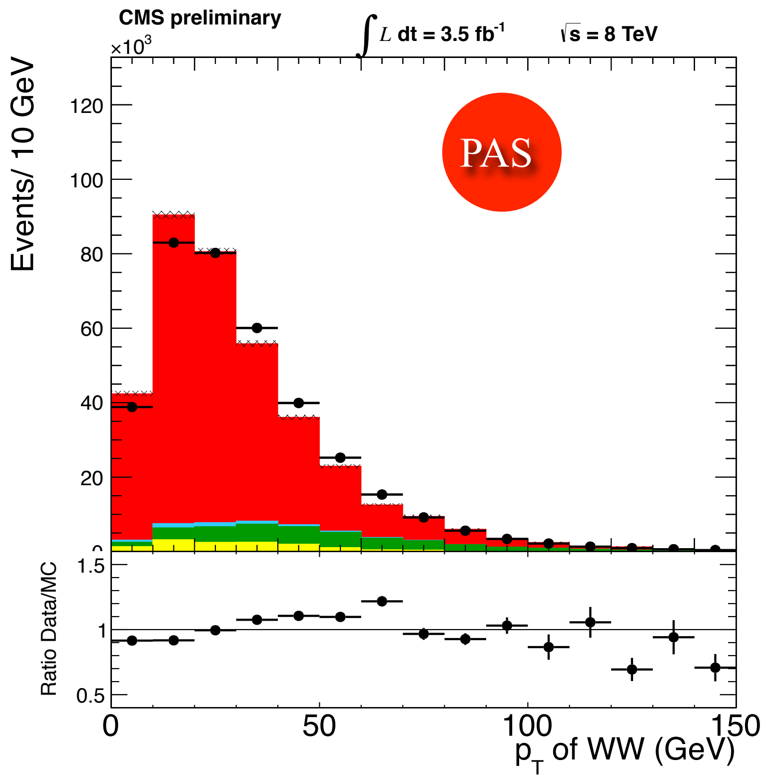


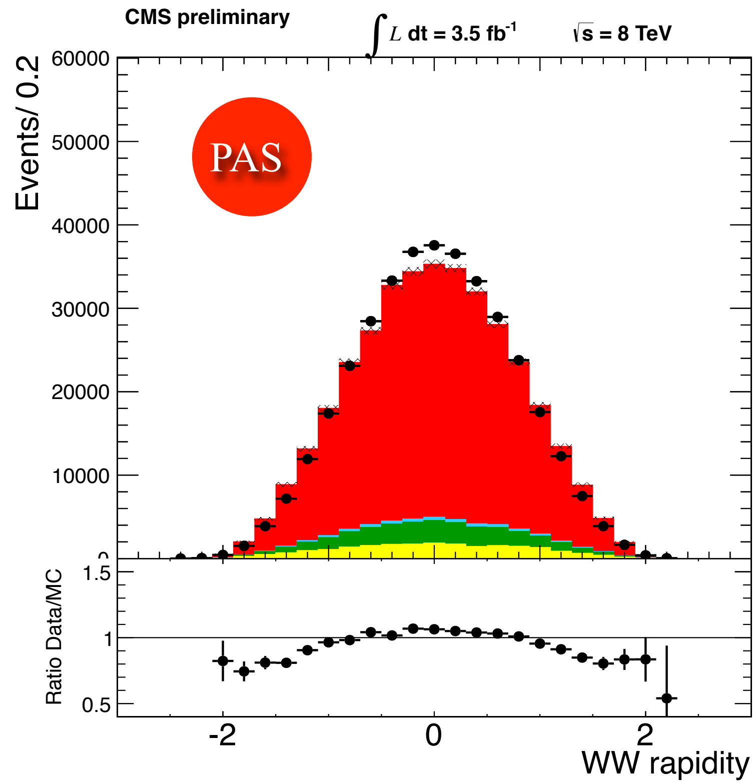




Reasonable modeling of kinematics in simulation.

Input variables (III)



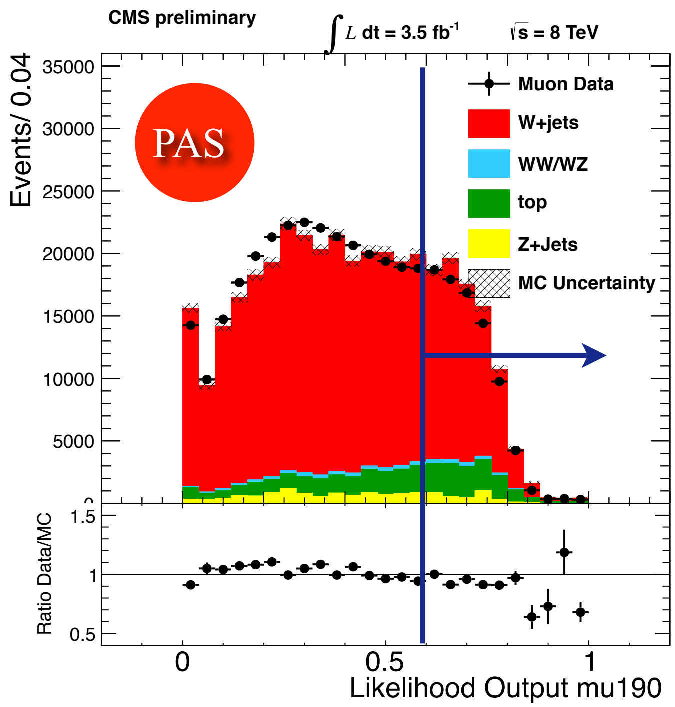


Agreement at the same level as in last year's data.

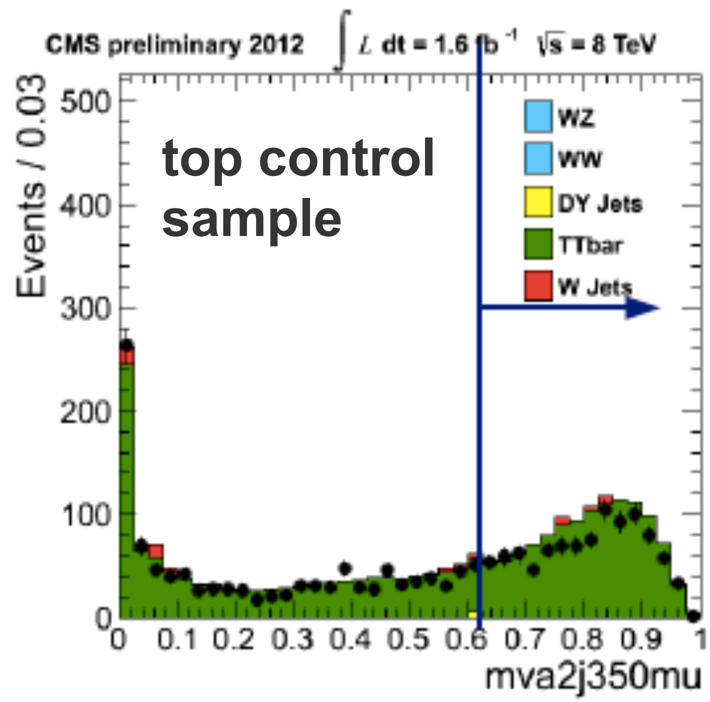
Example of likelihood output

- We look at data/MC comparison of the likelihood for the analysis final state, dominated by **W+jets** (left), and for a **tt-enriched** final state (right)

- Residual differences between tt-data and tt-MC taken as **systematic error on MVA-signal efficiency**



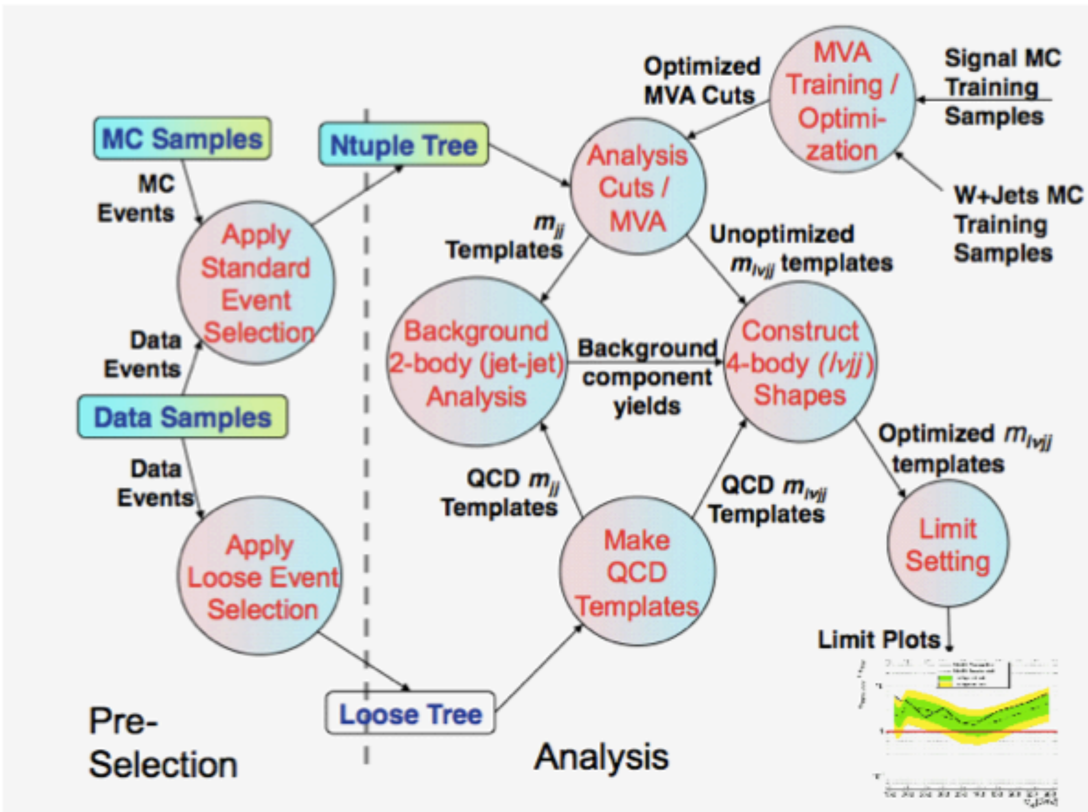
H190 - mu - 2j



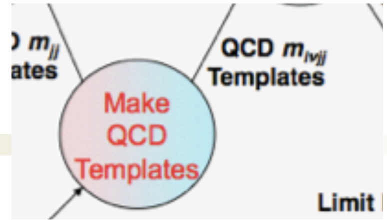
H350 - mu - 2j

Fitting and limit setting

- The analysis has two major parts
  - Fit to the m_{jj} spectrum to determine the backgrounds
  - limit setting from m_{WW} spectrum



QCD data driven

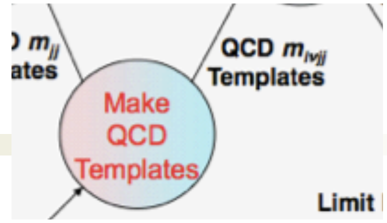


- To get the **QCD shape from data**: define a ~ pure QCD sample applying all standard cuts but
  - invert isolation cut: Icomb/pT > 0.3
  - for electrons, remove ID requirement
  - relax E_T^{miss} cut from >30 to >20 GeV

- Take the **signal W shape** from MC

- To get the **QCD fraction** in **data**
  - fit the leptonic W M_T distribution in data with the above described shapes
  - account for different acceptances between E_T^{miss} > 20 and E_T^{miss} > 30 GeV

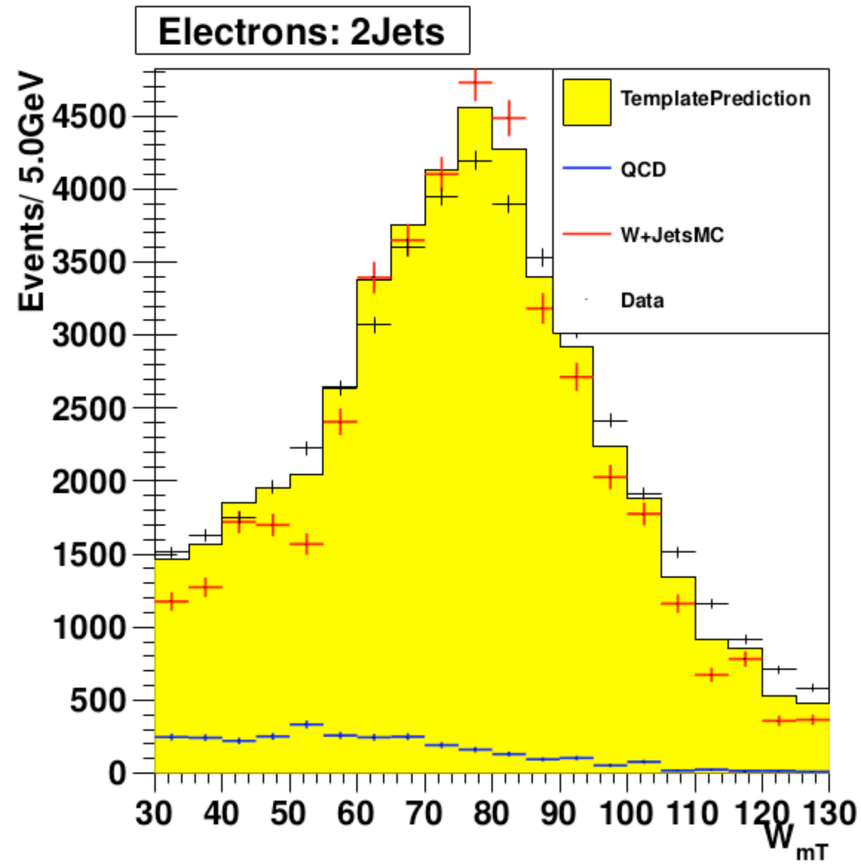
QCD fraction estimates



QCD fractions in data

	2 jets	3 jets
electron	6.4 ± 0.7%	2.1 ± 0.7%
muon	0.2 ± 0.4%	0.0 ± 0.4%

statistical fit errors only!



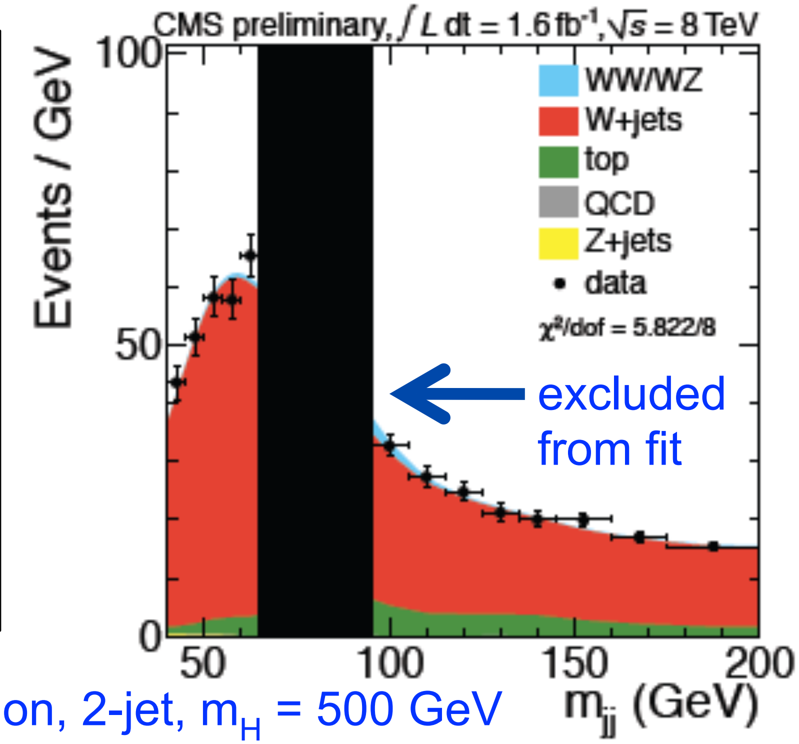
Uncertainty on QCD normalization

	2 jets	3 jets
electron	50%	50%
muon	100%	100%

Normalization from m_{jj} fit

Background 2-body (jet-jet) Analysis

- Determine backgrnd composition in a 1D, unbinned, max likelihood fit to the di-jet invariant mass spectrum.
- Background shapes are taken from:
  - MC for all minor backgrounds (not for W+jets and QCD)
  - data-driven approach for QCD
  - analytic description/ MC for W+jets



muon, 2-jet, m_H = 500 GeV

Process	Shape	External constraint on normalization
W+jets	data/MC	Unconstrained
Diboson	MC	Constrained: (NLO) 89.4 pb ± 10% [48]
$t\bar{t}$	MC	Constrained: (approx. NNLO) 225 pb ± 7% [49]
single top	MC	Constrained: (approx. NNLO) 113 pb ± 5% [50–52]
Drell-Yan+jets	MC	Constrained: (NNLO, $m_{\ell\ell} > 50\,\mathrm{GeV}$) 3504 pb ± 4.3% [53]
Multi-jet	data	Constrained: E_T^{miss} fit in data ± 50% (100%) for electrons (muons)

W+jets: the dominant background

- For $m_H \leq 180$ GeV, use MC shape template, because statistics are plentiful.
- For higher masses MC statistics are much lower so we take an analytic approach.
- The analytic shapes are chosen based on MC but the functional parameters are allowed to vary within constraints in the m_{jj} fit to the data.

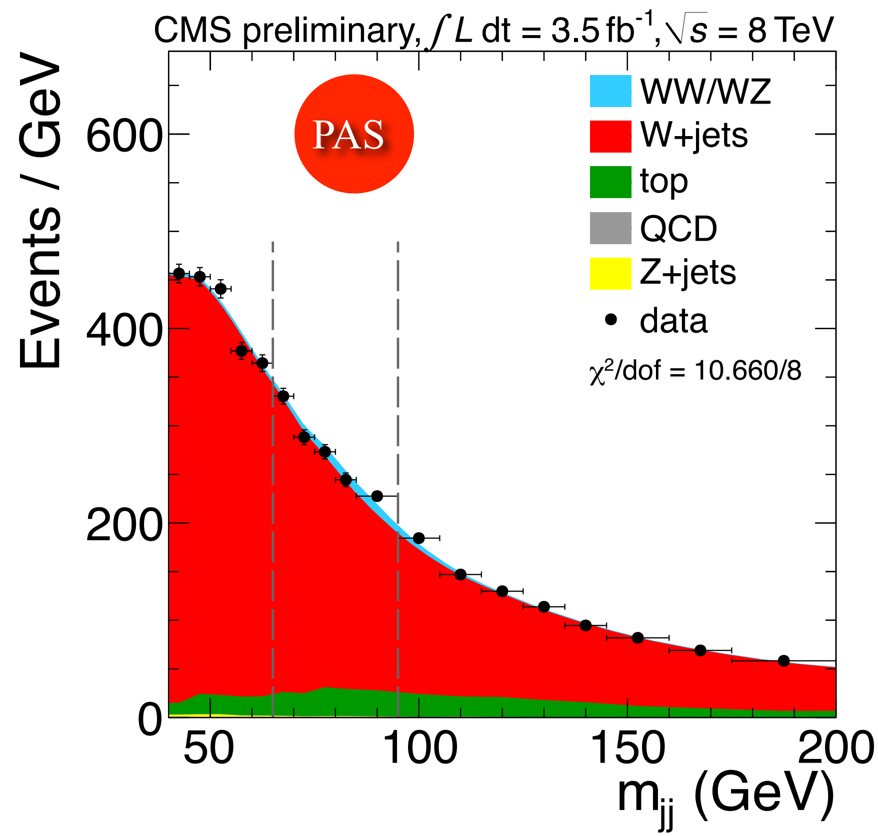
$$\mathcal{F}_{W+\mathrm{jets}} = \mathrm{erf}(m_{jj}; m_0, \sigma) \times \left[(m_{jj})^{-\alpha - \beta \ln(m_{jj}/\sqrt{s})} \right]$$

$$\mathcal{F}_{W+\mathrm{jets\ low\ mass,\ 2\ jets}} = \mathrm{erf}(m_{jj}; m_0, \sigma) \times (m_{jj})^{-\alpha} \times \exp(m_{jj}\tau)$$

$$\mathcal{F}_{W+\mathrm{jets\ low\ mass,\ 3\ jets}} = (m_{jj})^{-\alpha - \beta \ln(m_{jj}/\sqrt{(s)})} \times \exp(m_{jj}\tau)$$

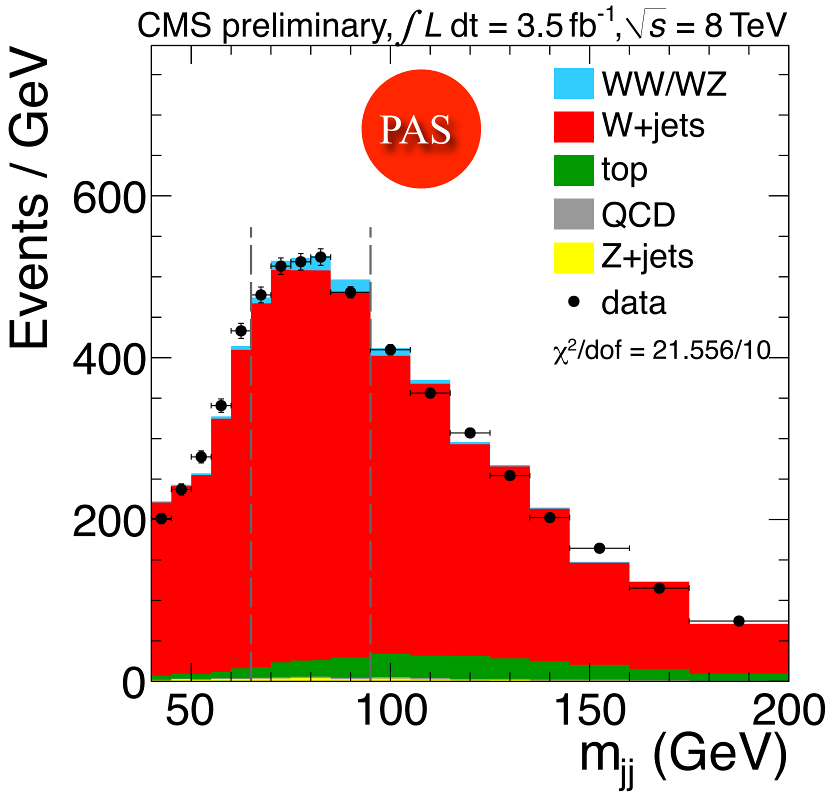
The background composition

- **We exclude the region from 65 – 95 GeV from the fit.**
- Good agreement between the fitted composition and data.
- The normalizations are extrapolated into the signal region and passed to the next stage, i.e., 4-body analysis.

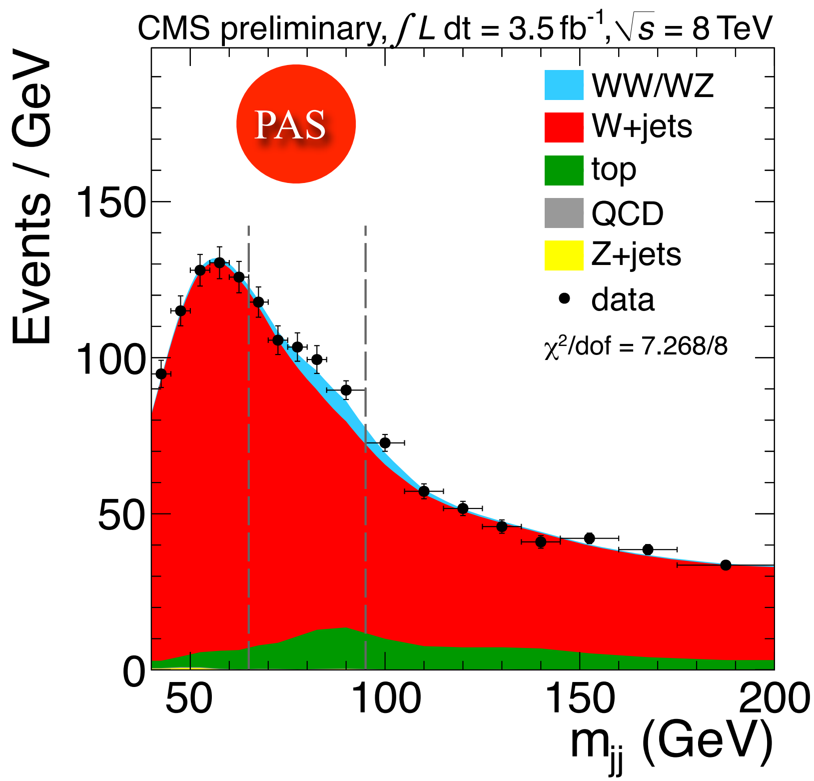


m_H = 300 GeV

Additional m_{jj} examples

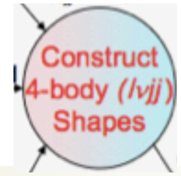


m_H = 200 GeV



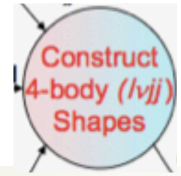
m_H = 500 GeV

Analysis of m_{WW} distribution



- The fit to the m_{jj} spectrum determines the relative normalization of the backgrounds.
- Then we plot the m_{WW} spectrum.
- The background components are stacked up and compared with the data with the additional selection $(65 < m_{jj} < 95)$ GeV.
- Shapes of the minor backgrounds are taken from MC.
  - Again, QCD is taken from the data-driven sample.
  - The W+jets shape is constructed from the m_{jj} sidebands (see next two slides).

W+jets shape (1/2)



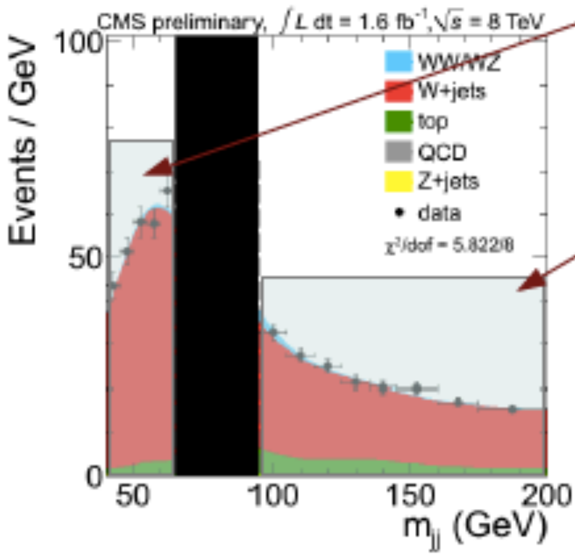
- Following the sideband method devised for **HIG-12-003**

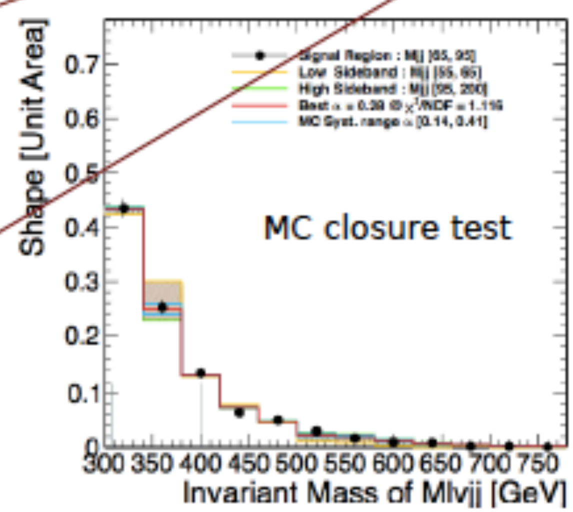
- For **each** of the **48 working points**, 3 regions are defined
  - $m_{jj} \in [65,95]$ GeV/c² (signal region)
  - $m_{jj} \in [55,65]$ GeV/c² (lower sideband, SBL)
  - $m_{jj} \in [95,115]$ or $[95,200]$ GeV/c² for $m_{H} <$ or ≥ 250 GeV/c² (higher sideband, SBH)

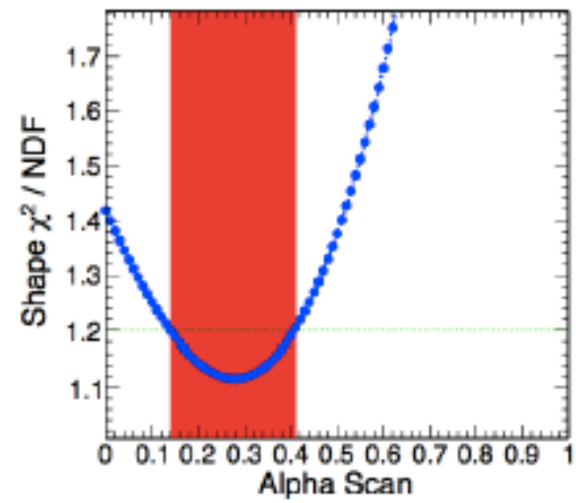
- The shape is extracted, in each bin *i*, as

$$m_{lvjj}^{i} = \alpha \cdot m_{SBL}^{i} + (1-\alpha) \cdot m_{SBH}^{i}$$

the **best α value**, as well as its **uncertainty**, are obtained on **MC**

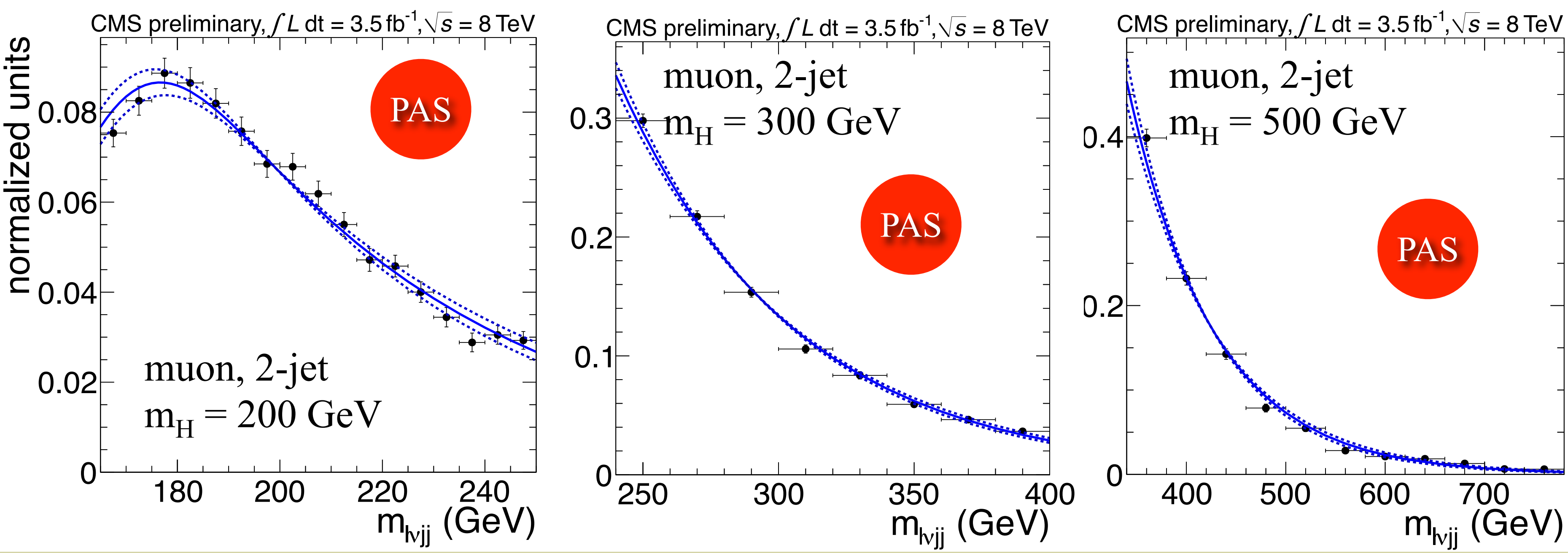




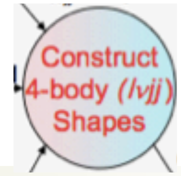


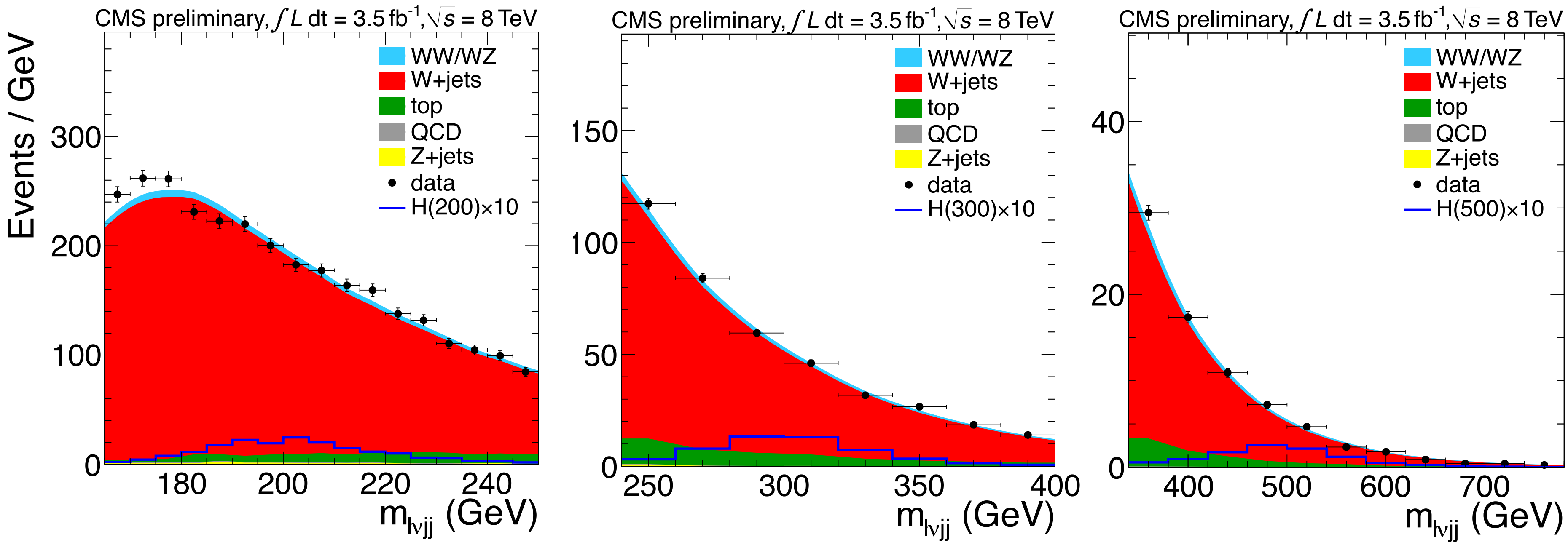
W+jets shape (2/2)

- The background-subtracted, alpha-combined sideband shape from data is smoothed using an exponential function.
  - Statistical uncertainty of the smoothing is combined with the uncertainty due to α and used as a systematic error.
  - The dotted lines are the total shape systematic envelope.



The m_{WW} spectrum





m_H = 200 GeV

m_H = 300 GeV

m_H = 500 GeV

Mass peak makes it straightforward to interpret any observed excess in data.

Systematic uncertainties

Source	uncertainty
Higgs line shape	0 – 30%
Signal cross-section	15 – 20%
Signal efficiency x acceptance	10%
Luminosity	5%
Jet energy scale, resolution and MET	< 1%
Theory (PDFs)	1 – 2%
Lepton trigger efficiency	1%
Lepton selection efficiency	1 – 2%
Pile-up	< 1%

Background systematics

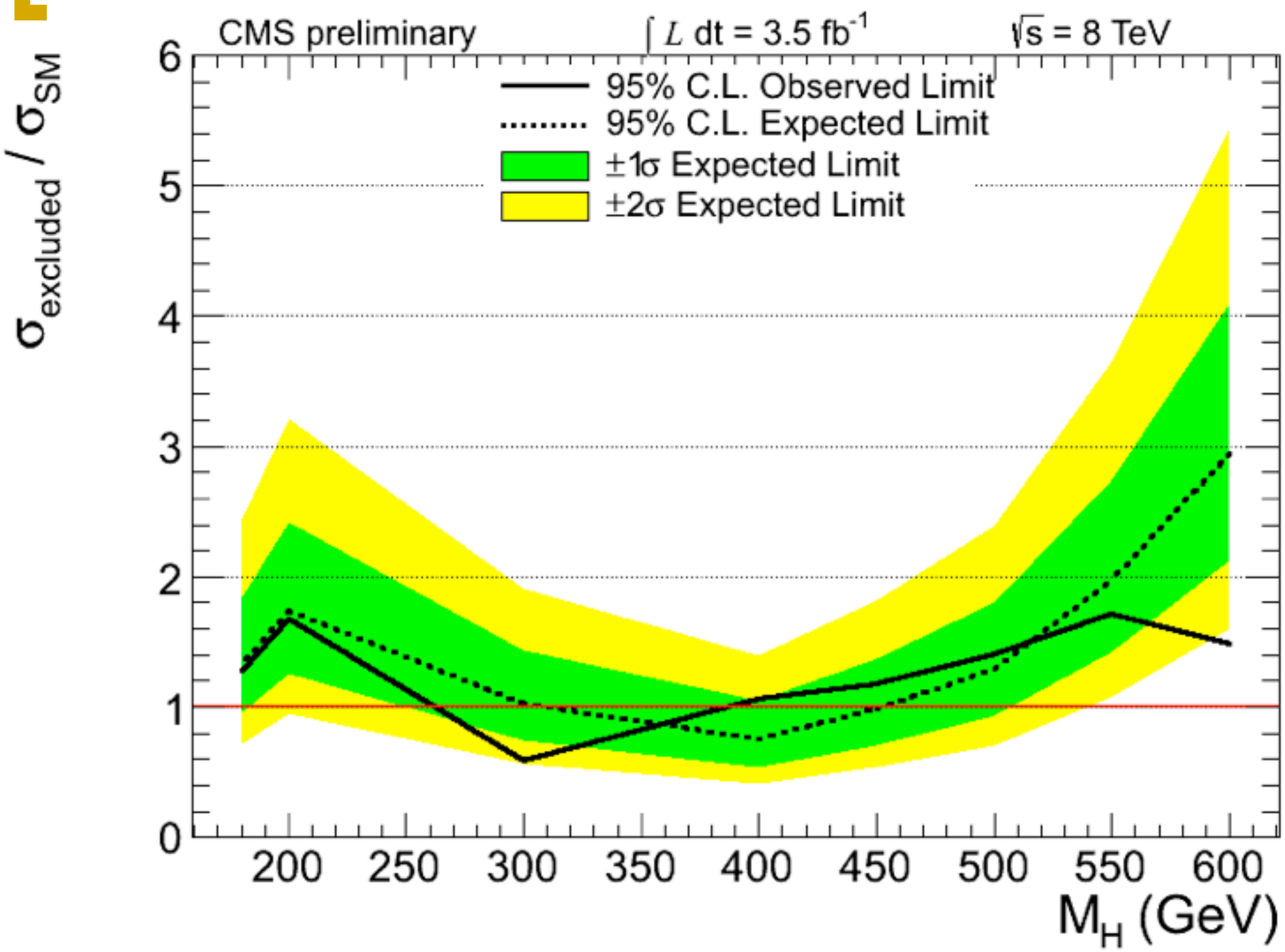
normalization uncertainty	<= 2 %
W+jets fit uncertainty	shape

already described previously

- Since background is ~100x signal, the background systematics is dominant.
- Signal efficiency x acceptance syst. is evaluated, using a pure ttbar control sample, as the difference between data and MC.

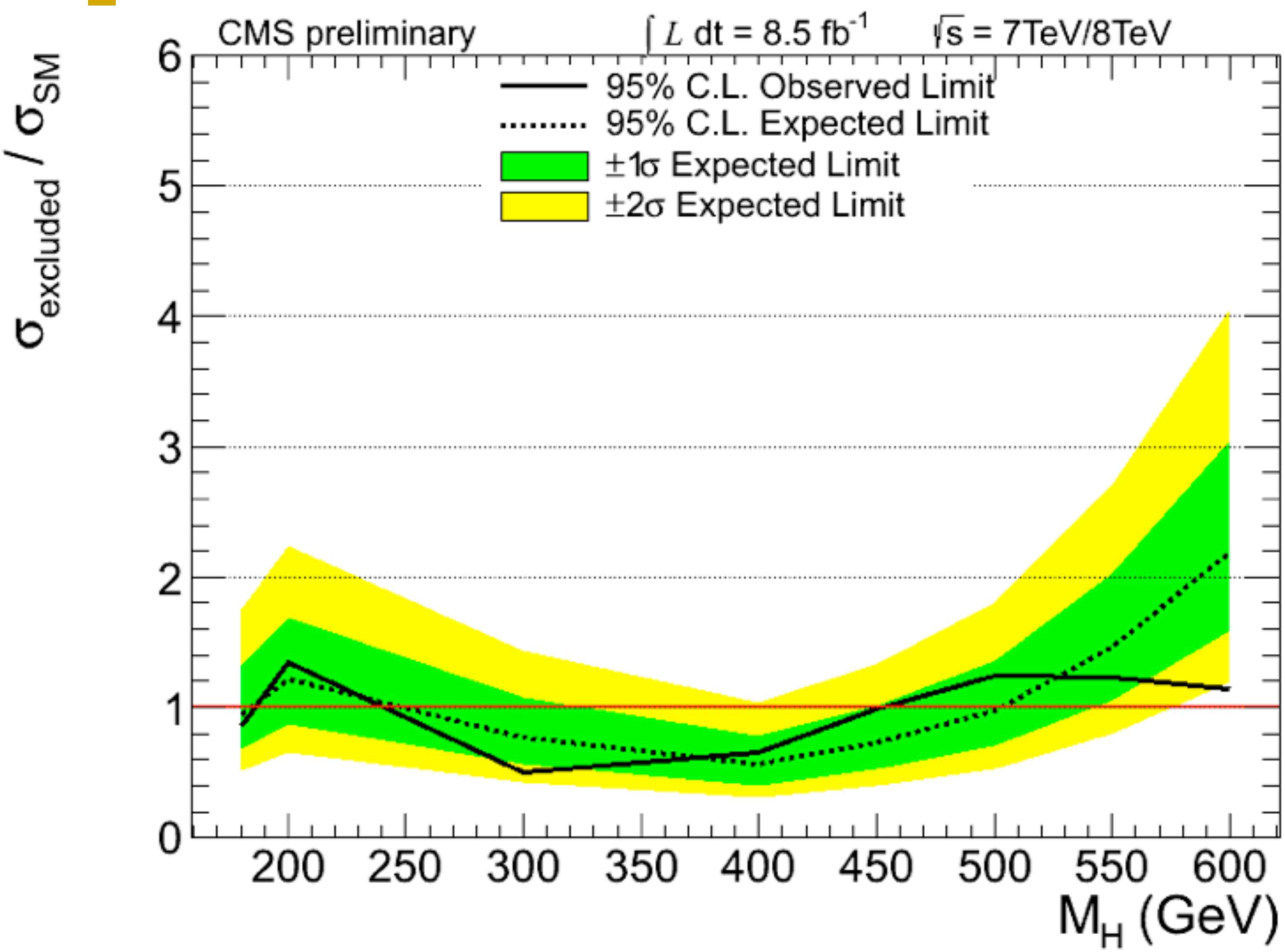
Added jet veto uncertainty which is in the range 4−28% (depending on m_H and nJets)

The 8 TeV limit



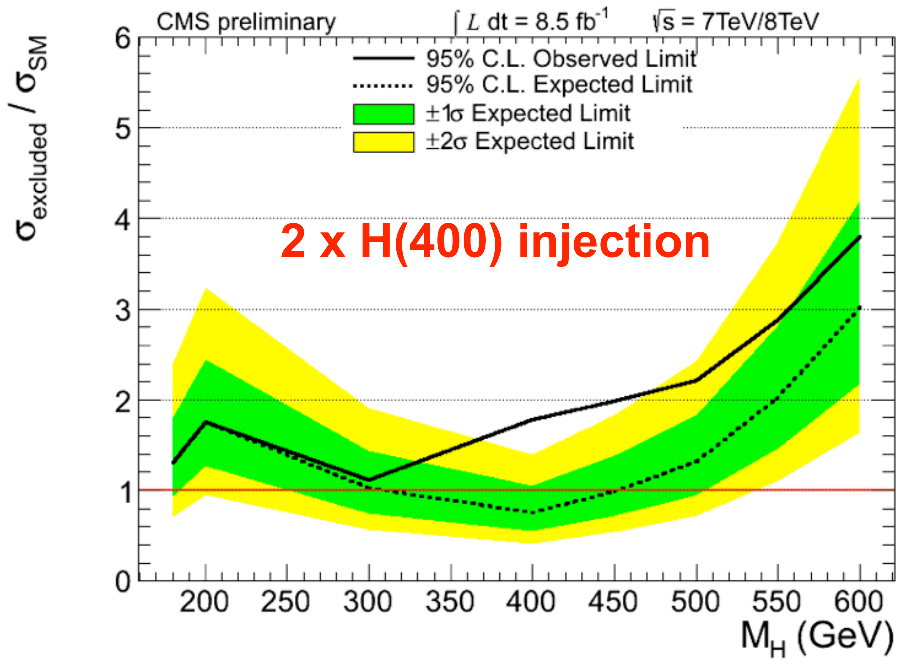
- ✦ About 30% improvement over 2011 sensitivity
  - higher Higgs xsection at 8 TeV, improved trigger

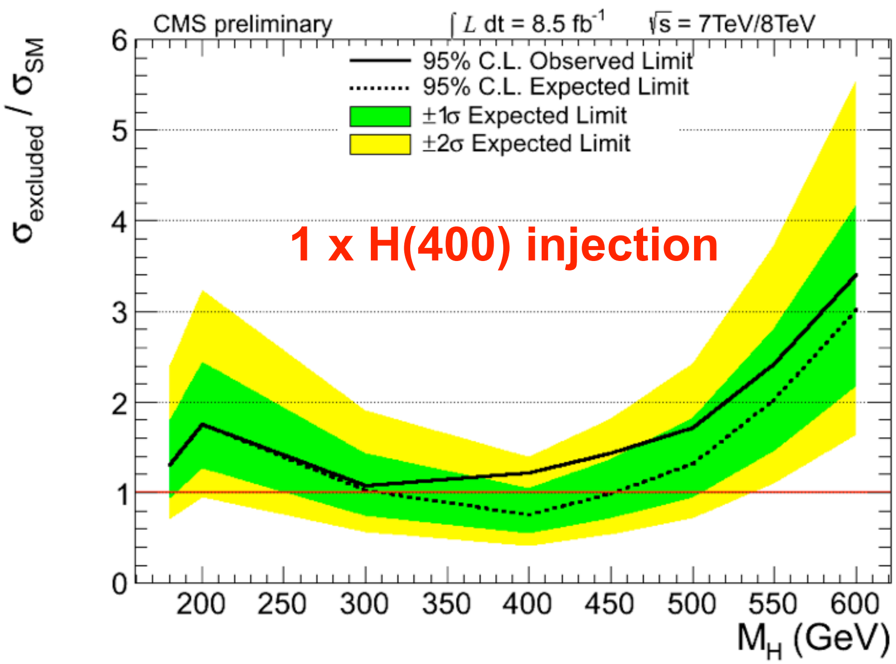
Combination of 7 TeV and 8 TeV results

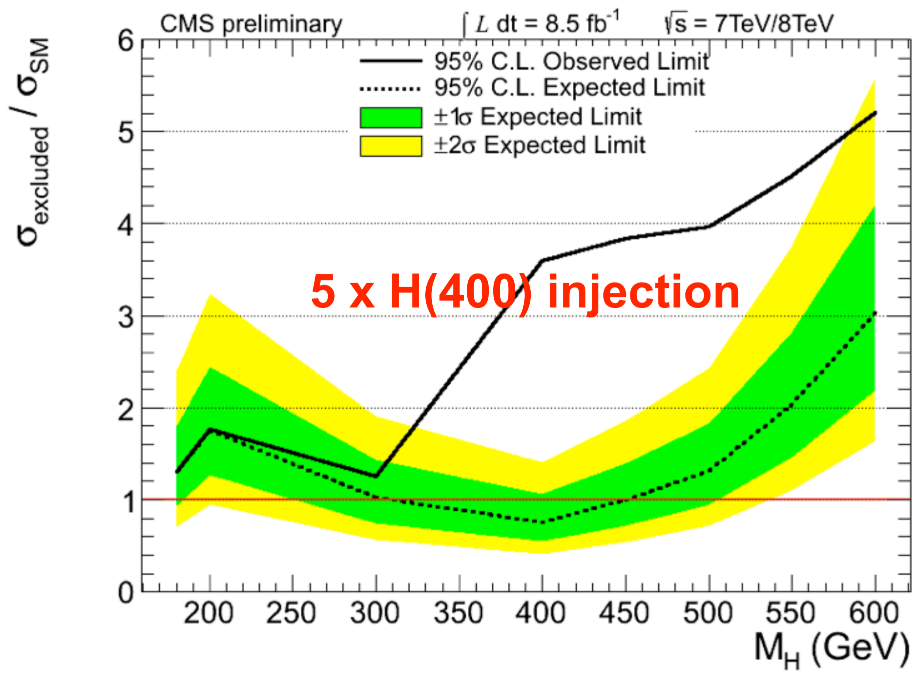


Signal injection test

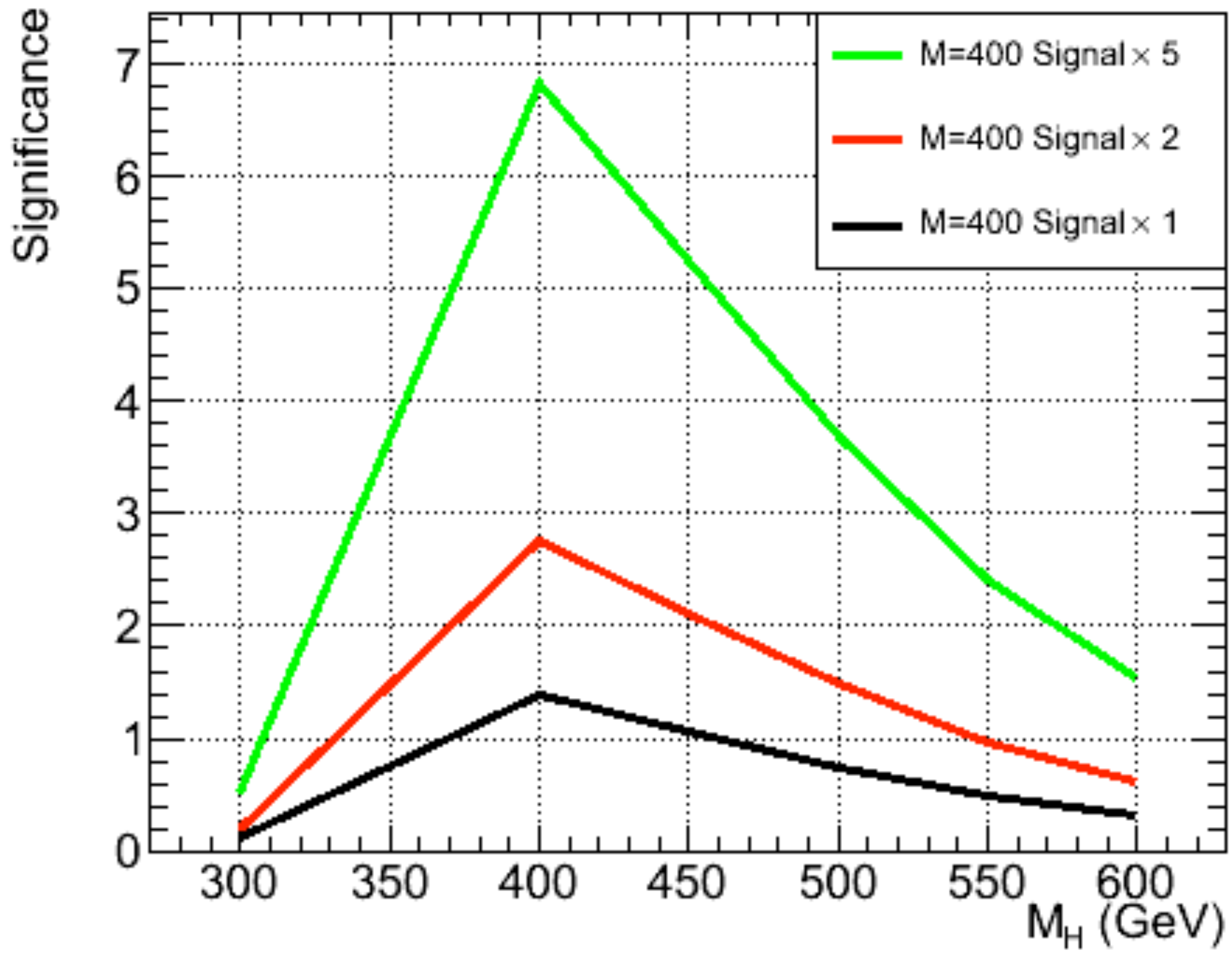
Inject Higgs signal and study its effect on observed limit (the expected limit doesn't change because background estimation comes from sideband data)







Signal injection test: significance



If there was a signal we would have found it !

Summary

- We have set a world leading limit in H→WW→$\ell\nu jj$ decays.
  - In 8 TeV data, we exclude the Standard Model Higgs boson in the mass range 260 – 390 GeV at 95% CL.
  - Combining 7 TeV and 8 TeV results, we exclude Higgs in the mass range **240 – 450 GeV** at 95% CL.
  - We employ data driven estimates for our principal background.
  - We have used a multivariate discriminator to control the backgrounds and improve sensitivity.

- Plan to top-up with additional data for ICHEP. Also, will try to include more Higgs mass points in limit setting.

backup slides

2012 physics objects

- Detailed summary in Sarah Boutle talk [*]:

[*]https://indico.cern.ch/getFile.py/access?contribId=45&sessionId=1&resId=0&materialId=slides&confId=188820

Short summary

- Use of PFBReco objects
  - PF isolation for electrons and muons
  - MVA Id for electrons (WP70) and cut based for muons (tight WP)
- AK5PFJets CHS Jets with JEC
  - Cut based JetId - loose WP
- PFMET with type 1 correction

Jet and MET

- Use PF2PAT jets (with CHS)
- PF MET with type 1 correction

- Jet energy corrections (standard):

The minimum correction levels to be applied on any CMS analysis using Monte Carlo and Data are:

Monte Carlo	L1(Pile Up)+L2(Relative)+L3(Absolute)
Data	L1(Pile Up)+L2(Relative)+L3(Absolute)+L2L3Residuals

- Jet ID: https://twiki.cern.ch/twiki/bin/viewauth/CMS/JetID:

PF Jet ID	Loose (Recommended)	Medium	Tight
Neutral Hadron Fraction	<0.99	<0.95	< 0.90
Neutral EM Fraction	<0.99	<0.95	< 0.90
Number of Constituents	>1	>1	> 1
And for η<2.4 , η>-2.4 in addition apply			
Charged Hadron Fraction	>0	>0	>0
Charged Multiplicity	>0	>0	>0
Charged EM Fraction	<0.99	<0.99	<0.99

- Will include the information for PU jet ID in our PATtuples: https://twiki.cern.ch/twiki/bin/view/CMS/PileupJetID

- Will also include information for computing mvaMET: https://twiki.cern.ch/twiki/bin/view/CMS/MVAMet

Muon

- **Muon ID:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId

Plain-text description	Technical description
The candidate is reconstructed as a Global Muon	`recoMu.isGlobalMuon()`
Particle-Flow muon id	`recoMu.isPFMuon()`
χ^2/ndof of the global-muon track fit < 10	`recoMu.globalTrack()->normalizedChi2() < 10.`
At least one muon chamber hit included in the global-muon track fit	`recoMu.globalTrack()->hitPattern().numberOfValidMuonHits() > 0`
Muon segments in at least two muon stations This implies that the muon is also an arbitrated tracker muon, see SWGuideTrackerMuons	`recoMu.numberOfMatchedStations() > 1`
Its tracker track has transverse impact parameter d_{xy} < 2 mm w.r.t. the primary vertex	`fabs(recoMu.innerTrack()->dxy(vertex->position())) < 0.2` Or `dB() < 0.2` on `pat::Muon` [1]
The longitudinal distance of the tracker track wrt. the primary vertex is d_z < 5 mm	`fabs(recoMu.innerTrack()->dz(vertex->position())) < 0.5`
Number of pixel hits > 0	`recoMu.innerTrack()->hitPattern().numberOfValidPixelHits() > 0`
Cut on number of tracker layers with hits >5	`track()->hitPattern().trackerLayersWithMeasurement() > 5`

Use tighter cut of 0.02 here

- **Isolation:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId

Algorithm	Type	Expression	PU correction	Cone size (ΔR)	Tight cut	Loose cut
Subdetector based	Tracker relative	$(\sum p_T(\text{TRK}))/p_T$	none	0.3	0.05	0.10
PF based	Combined relative	$(\sum E_T(\text{chHad from PV})+\sum E_T(\text{neutHad})+\sum E_T(\text{photons}))/p_T$	Reference correction using DeltaB corrections	0.4	0.12	0.20

Loose muon for veto and jet cleaning

- **Muon ID:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId

Plain-text description	Technical description	Comments
Particle-Flow muon id	`recoMu.isPFMuon()`	Can be complemented by muon quality cuts similar to those used in the Tight Muon selection.
Is Global OR Tracker Muon	`recoMu.isGlobalMuon() || recoMu.isTrackerMuon()`	Avoid using muons which are only Standalone Muons

- **Isolation:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/view/CMSPublic/SWGuideMuonId

Algorithm	Type	Expression	PU correction	Cone size (ΔR)	Tight cut	Loose cut
Subdetector based	Tracker relative	$(\sum p_T(TRK))/p_T$	none	0.3	0.05	0.10
PF based	Combined relative	$(\sum E_T(chHad\ from\ PV) + \sum E_T(neutHad) + \sum E_T(photons))/p_T$	Reference correction using DeltaB corrections	0.4	0.12	0.20

Not used in first round of 2012 data processing

Electrons

- **Electron ID:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/viewauth/CMS/Electrons4Higgs

- Retain possibility to do MVA ID
- But start with cut-based ID:

Barrel Cuts

	Veto	Loose	Medium	Tight
dEtaIn	0.007	0.007	0.004	0.004
dPhiIn	0.8	0.15	0.06	0.03
sigmaIEtaIEta	0.01	0.01	0.01	0.01
H/E	0.15	0.12	0.12	0.12
d0 (vtx)	0.04	0.02	0.02	0.02
dZ (vtx)	0.2	0.2	0.1	0.1
fabs(1/E - 1/p)	N/A	0.05	0.05	0.05
PF isolation / pT	0.15	0.15	0.15	0.10
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

Endcap Cuts

pT > 20 (pT < 20)	Veto	Loose	Medium	Tight
dEtaIn	0.01	0.009	0.007	0.005
dPhiIn	0.7	0.10	0.06	0.02
sigmaIEtaIEta	0.03	0.03	0.03	0.03
H/E	N/A	0.10	0.10	0.10
d0 (vtx)	0.04	0.02	0.02	0.02
dZ (vtx)	0.2	0.2	0.1	0.1
fabs(1/E - 1/p)	N/A	0.05	0.05	0.05
PF isolation / pT	0.15	0.15(0.10)	0.15(0.10)	0.10(0.07)
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

- **Isolation:** Use PF isolation (cone 0.3) with EA rho correction

Loose electron for veto and jet cleaning

- **Electron ID:** Use POG recommendations: https://twiki.cern.ch/twiki/bin/viewauth/CMS/Electrons4Higgs

- Retain possibility to do MVA ID
- But start with cut-based ID:

Barrel Cuts

	Veto	Loose	Medium	Tight
dEtaIn	0.007	0.007	0.004	0.004
dPhiIn	0.8	0.15	0.06	0.03
sigmaIEtaIEta	0.01	0.01	0.01	0.01
H/E	0.15	0.12	0.12	0.12
d0 (vtx)	0.04	0.02	0.02	0.02
dZ (vtx)	0.2	0.2	0.1	0.1
fabs(1/E - 1/p)	N/A	0.05	0.05	0.05
PF isolation / pT	0.15	0.15	0.15	0.10
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

Endcap Cuts

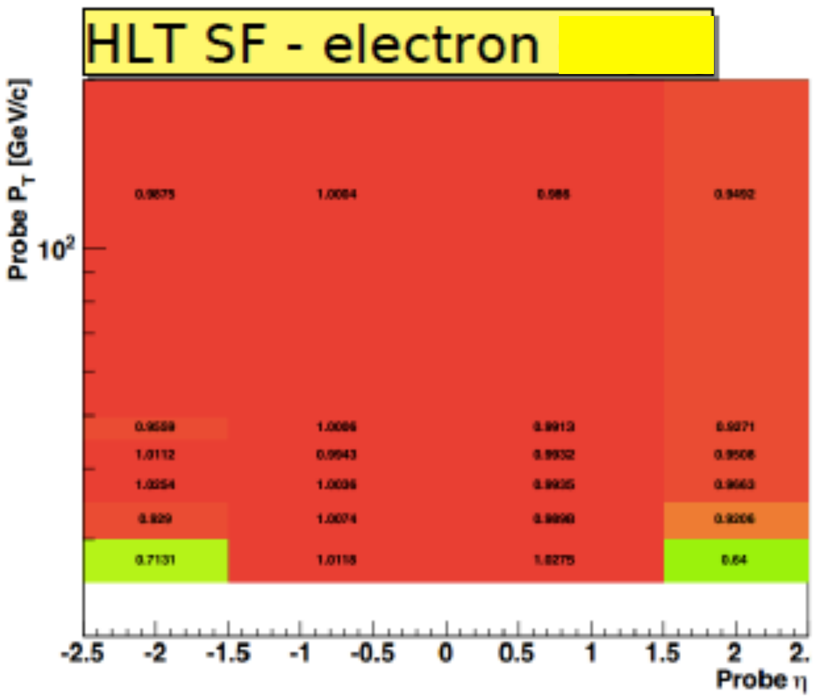
pT > 20 (pT < 20)	Veto	Loose	Medium	Tight
dEtaIn	0.01	0.009	0.007	0.005
dPhiIn	0.7	0.10	0.06	0.02
sigmaIEtaIEta	0.03	0.03	0.03	0.03
H/E	N/A	0.10	0.10	0.10
d0 (vtx)	0.04	0.02	0.02	0.02
dZ (vtx)	0.2	0.2	0.1	0.1
fabs(1/E - 1/p)	N/A	0.05	0.05	0.05
PF isolation / pT	0.15	0.15(0.10)	0.15(0.10)	0.10(0.07)
Conversion rejection: vertex fit probability	N/A	1e-6	1e-6	1e-6
Conversion rejection: missing hits	N/A	1	1	0

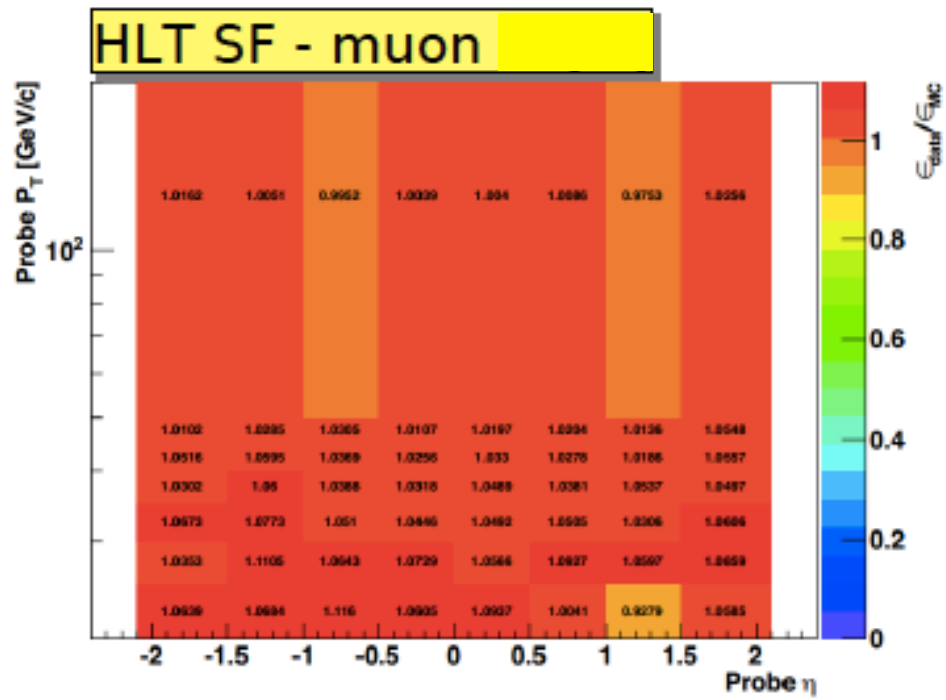
- **Isolation:** Use PF isolation (cone 0.3) with EA rho correction

Efficiency corrections

- MC lepton efficiencies corrected with **“Tag and Probe”** on Z events
  - **HLT efficiency** and **reconstruction/identification** scale factors
  - Detailed description in Gordon Kaussen talk [*]

[*]https://indico.cern.ch/getFile.py/access?contribId=23&sessionId=10&resId=0&materialId=slides&confId=193619

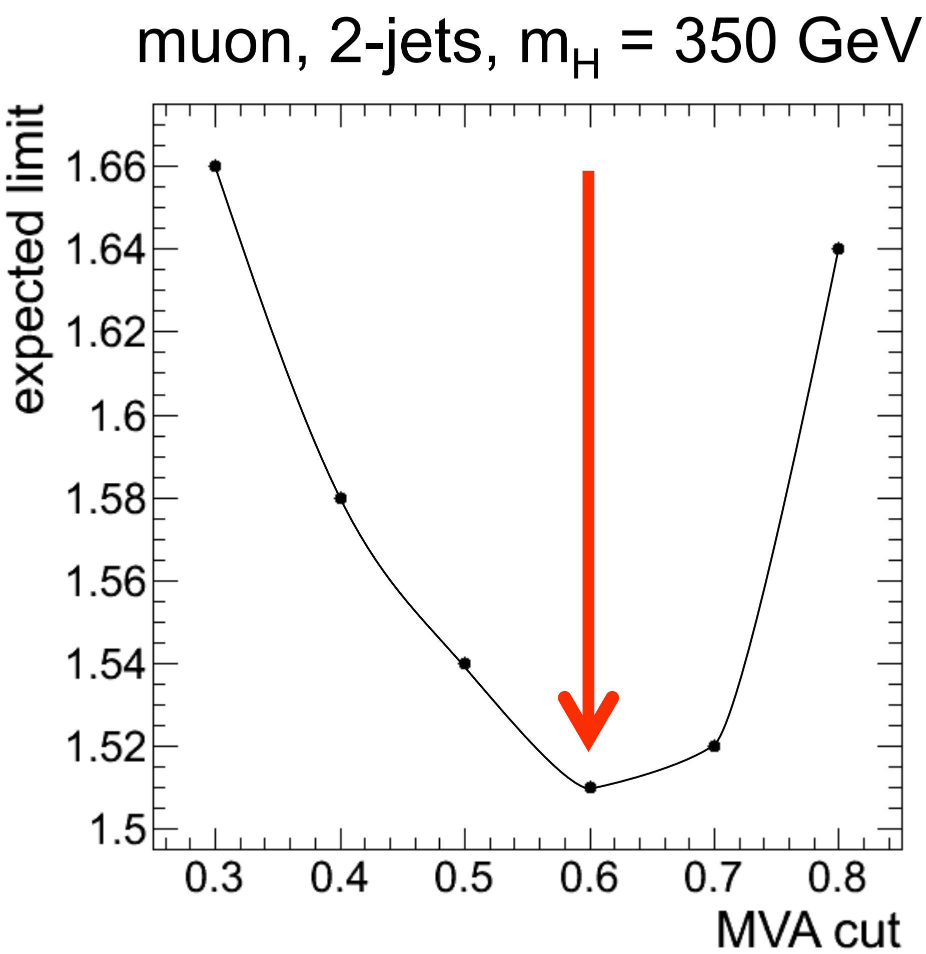




Apply similar scale factor for lepton reconstruction and ID efficiencies.

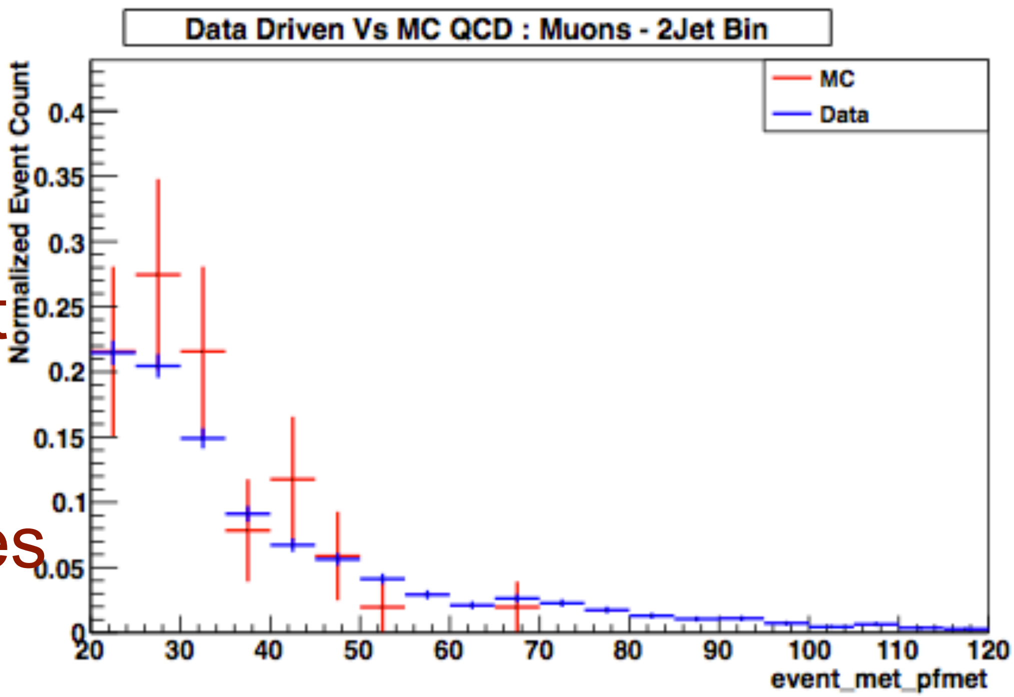
MVA cut optimization

- We select the MVA cut value based on running the full asymptotic limit setting machinery and using the expected limit.
- Once the optimal cut is selected for each of the 48 analysis points they can be combined using the standard Higgs combination package.

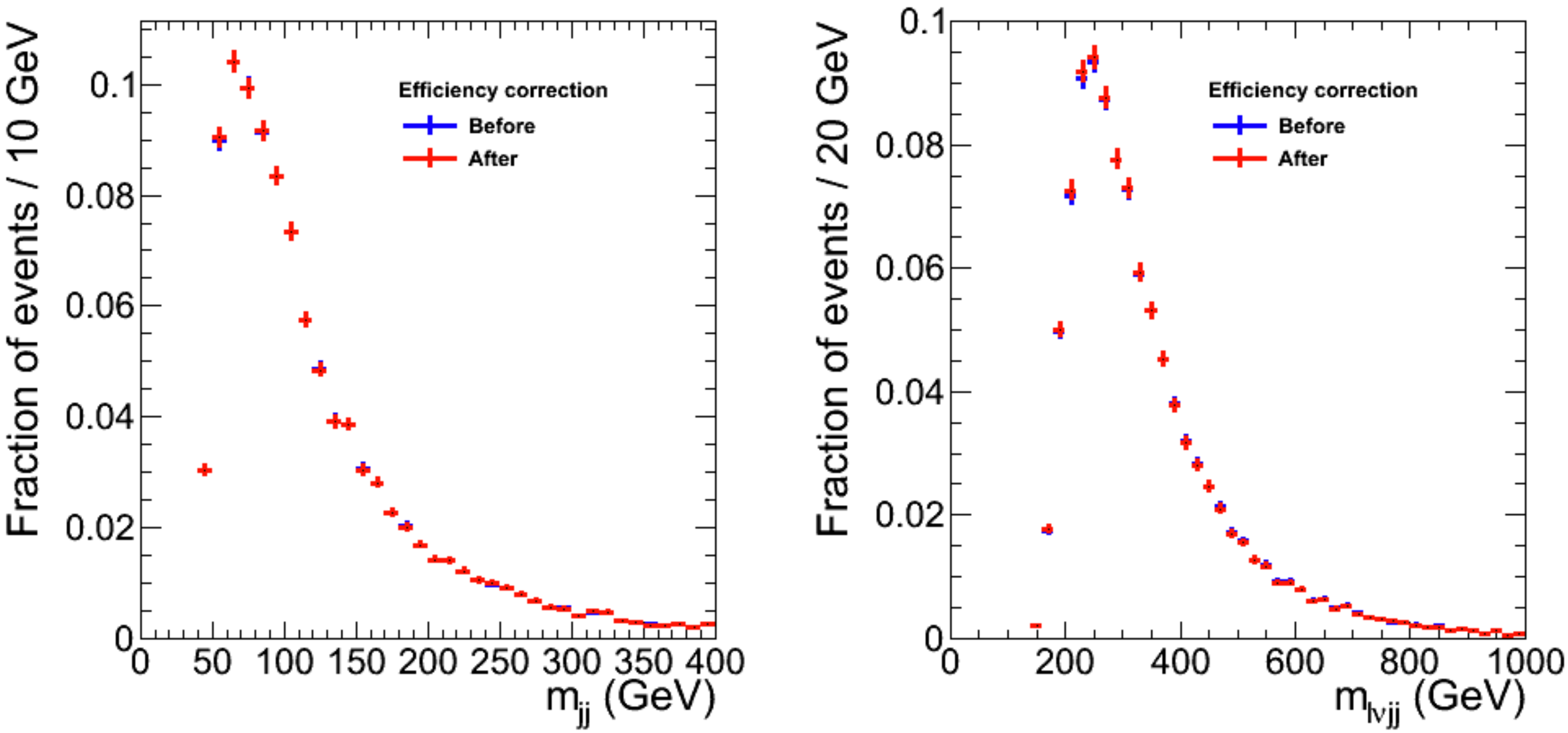


Data driven QCD estimation

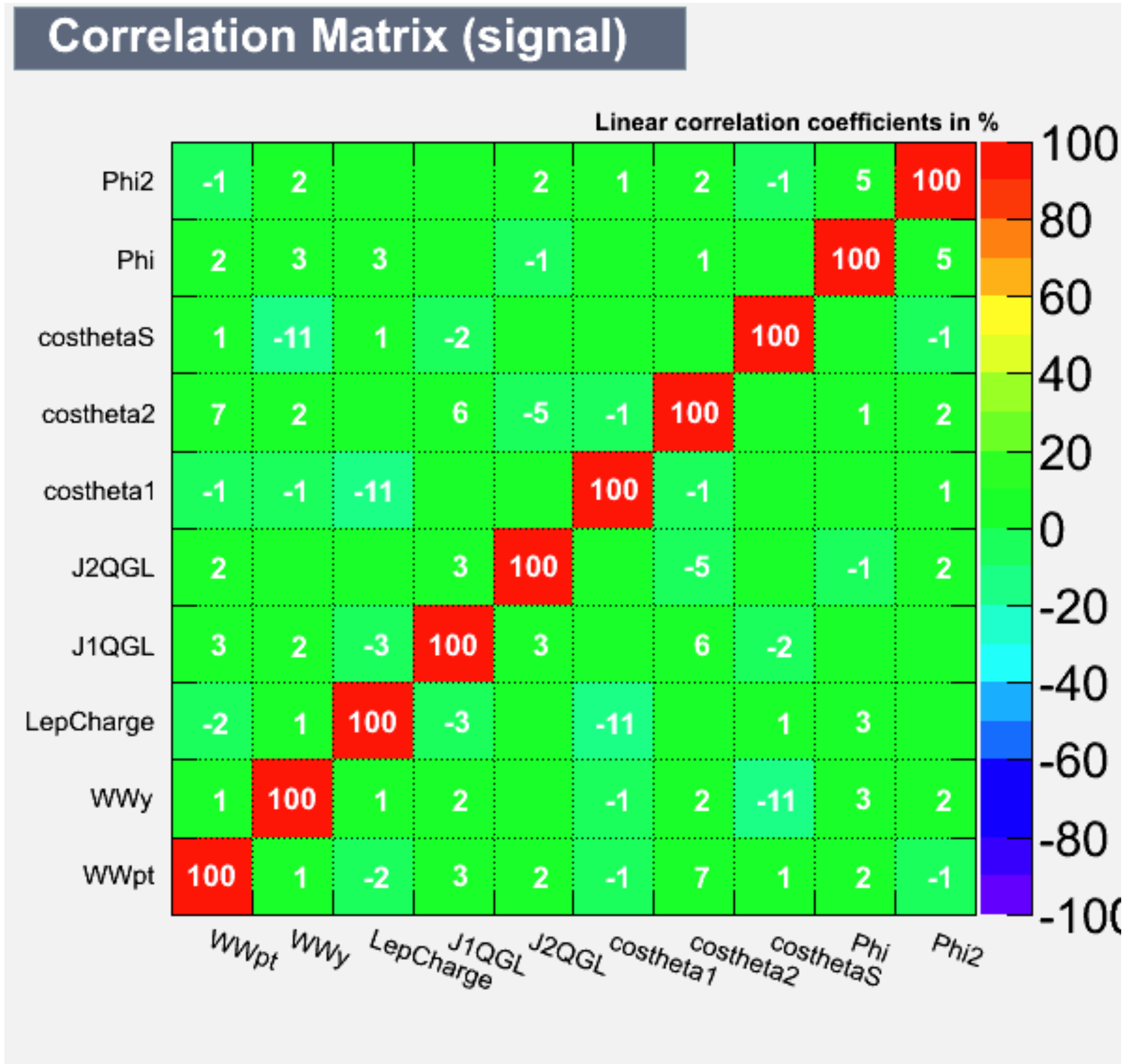
- We derive the QCD shape and normalization from the data.
  - invert the isolation requirements
  - relax ID requirements
  - relax the MET cut
- We can fit the MET distribution in data to get the normalization of the QCD contribution after accounting for differences due to the MET cut.
- The shape is also taken from this data as the MC is statistics starved.



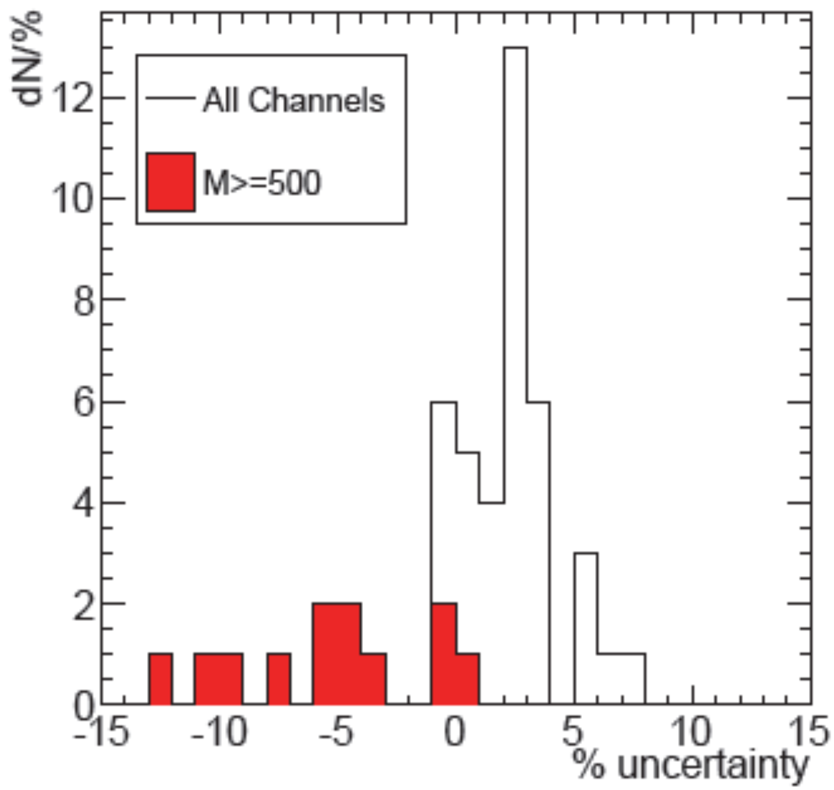
Trigger effect on key distributions

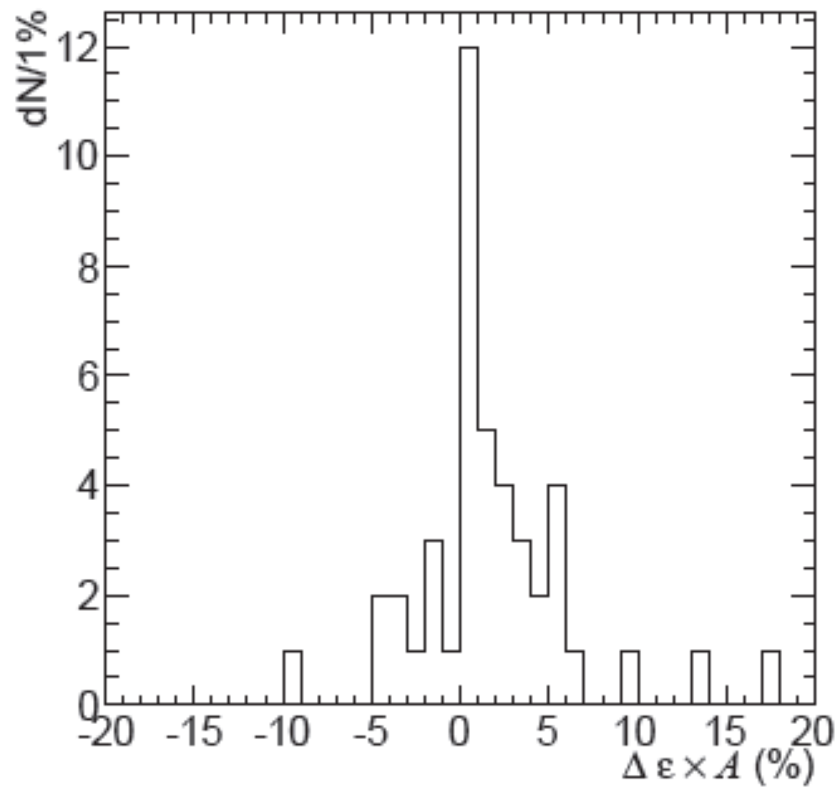


MVA correlations



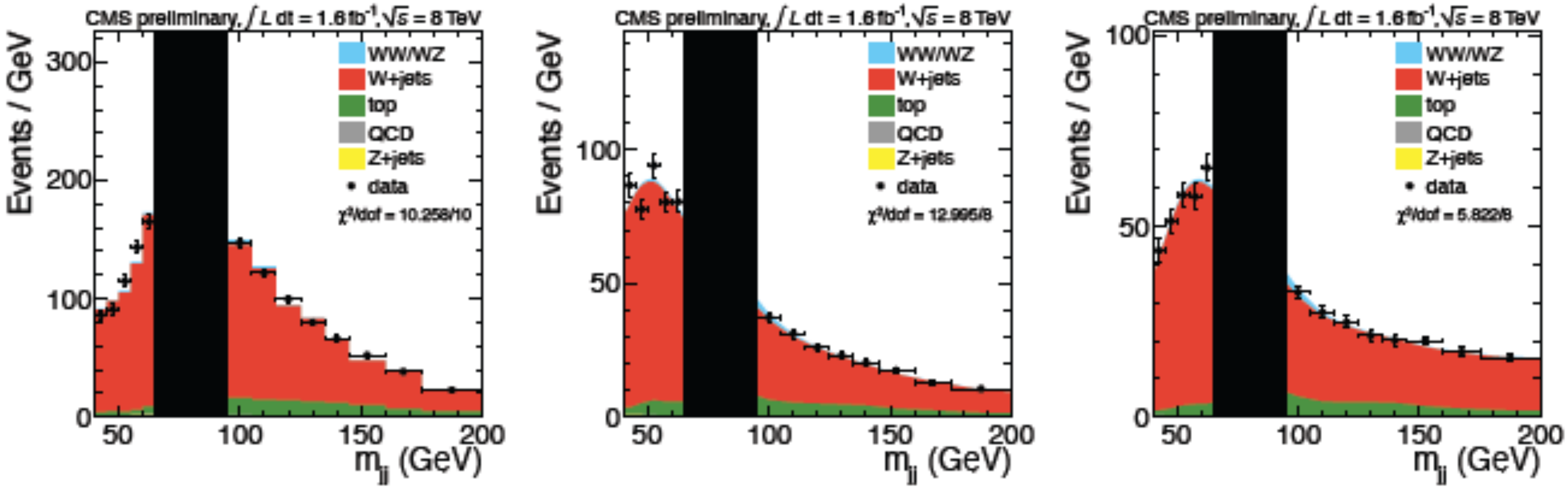
Likelihood selection efficiency

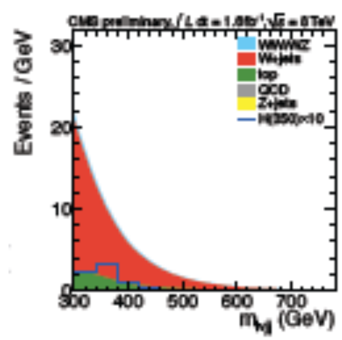




Unblinding procedure

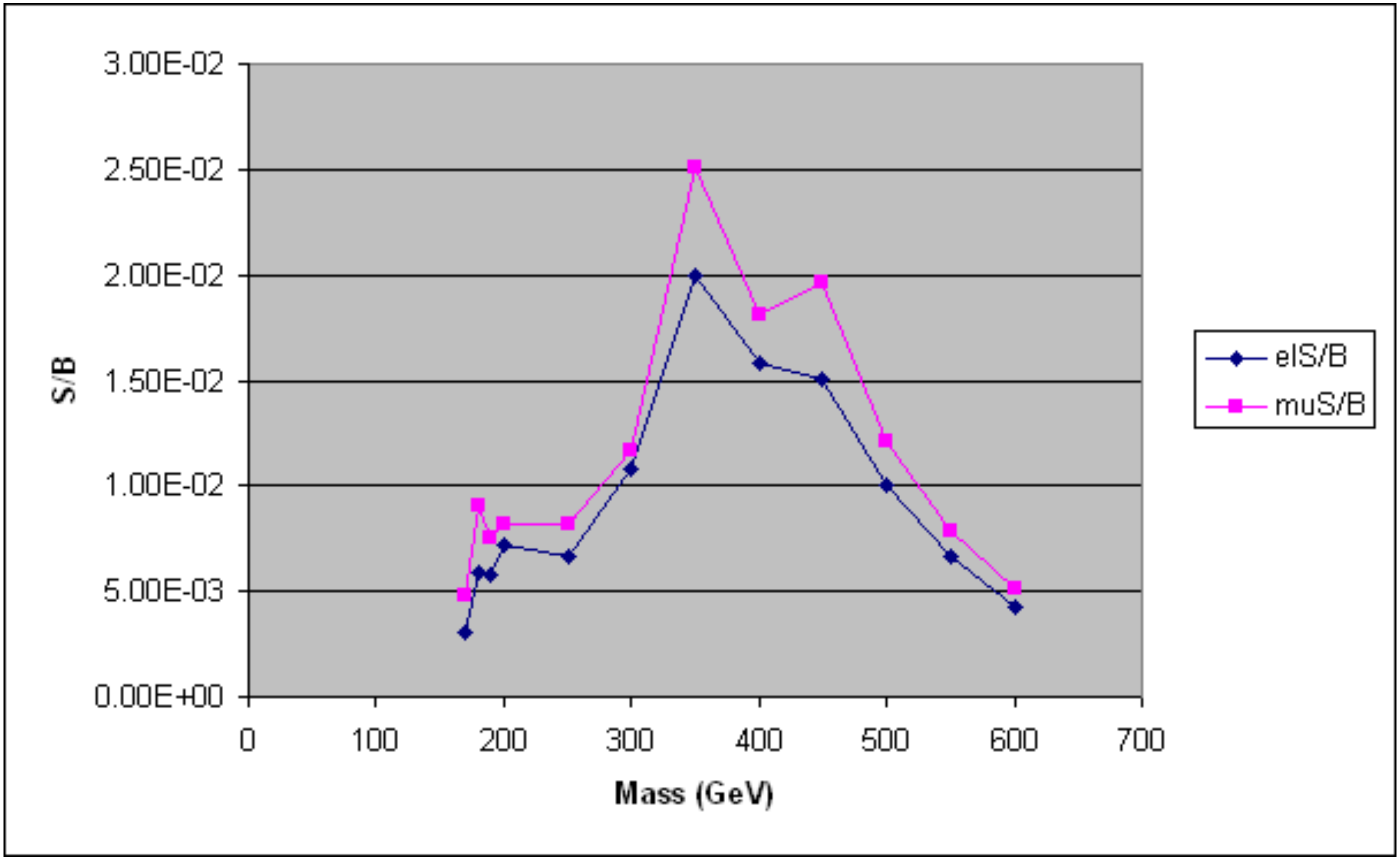
Open the box in the signal window (i.e., remove the cover) and derive observed limits



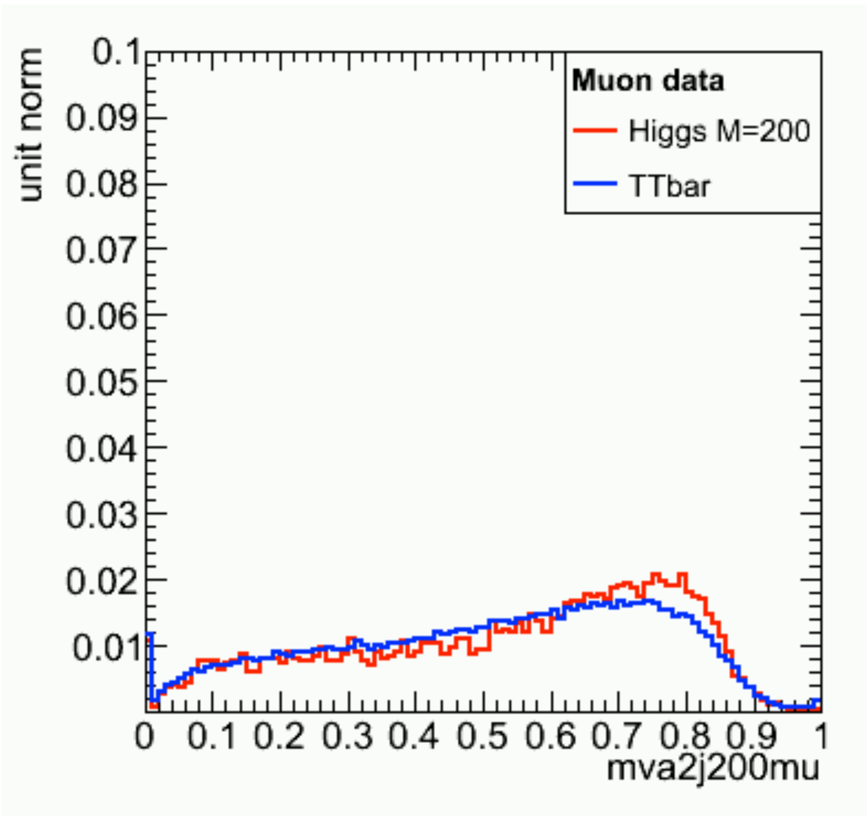


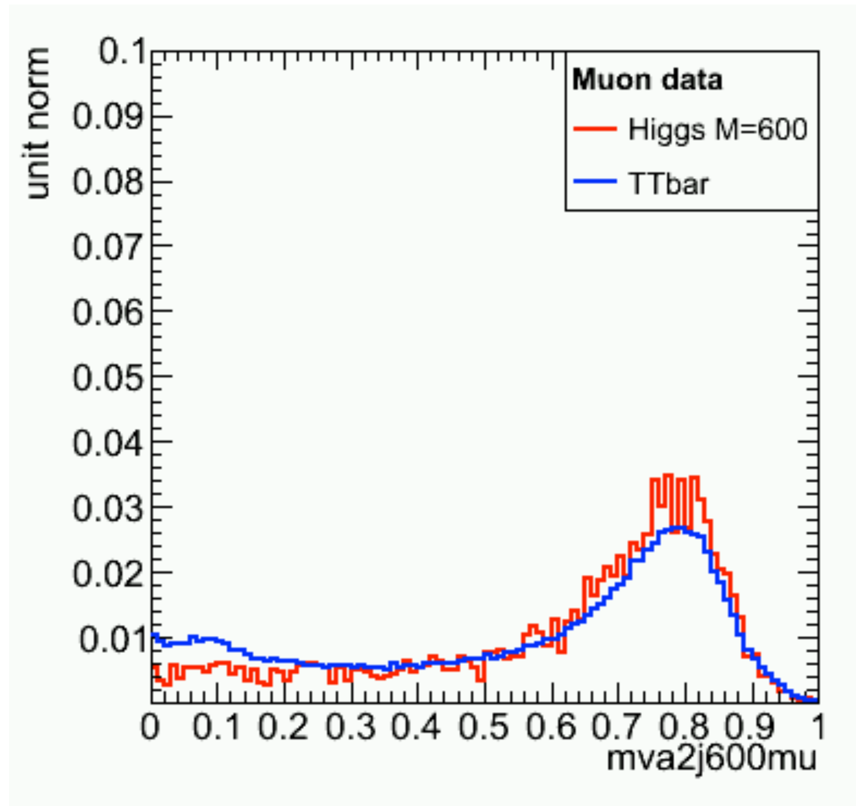
Plot the data points from the blackened signal region. Then set limit.

S/B comparison between muon and electron



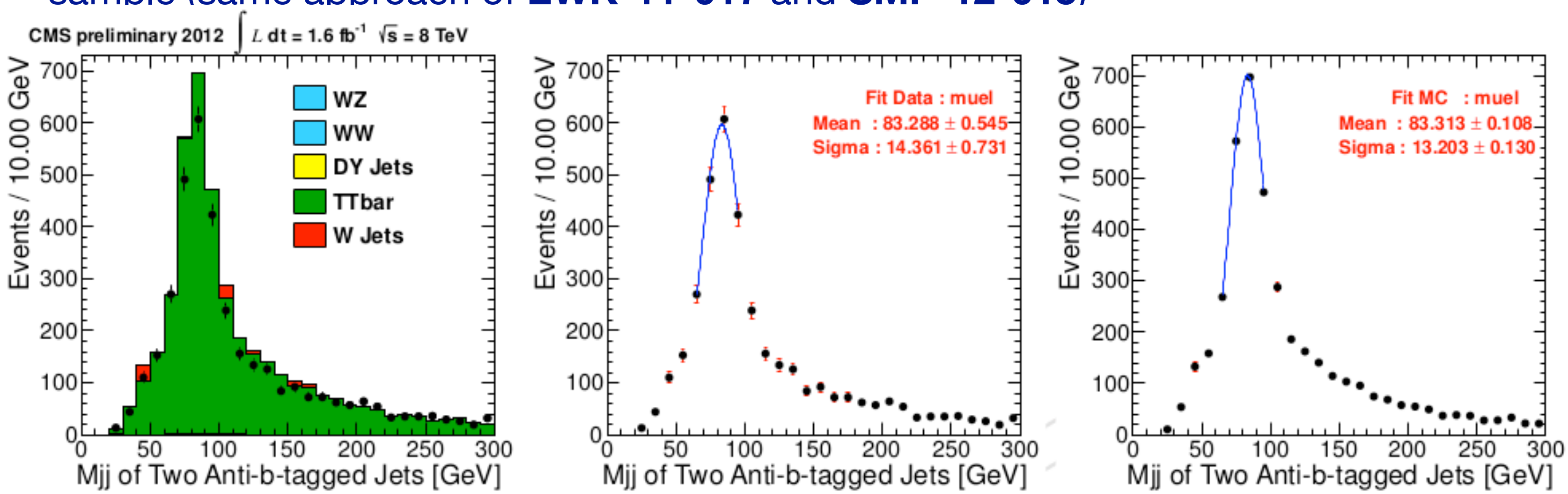
Comparison of MVA output for tt and Higgs

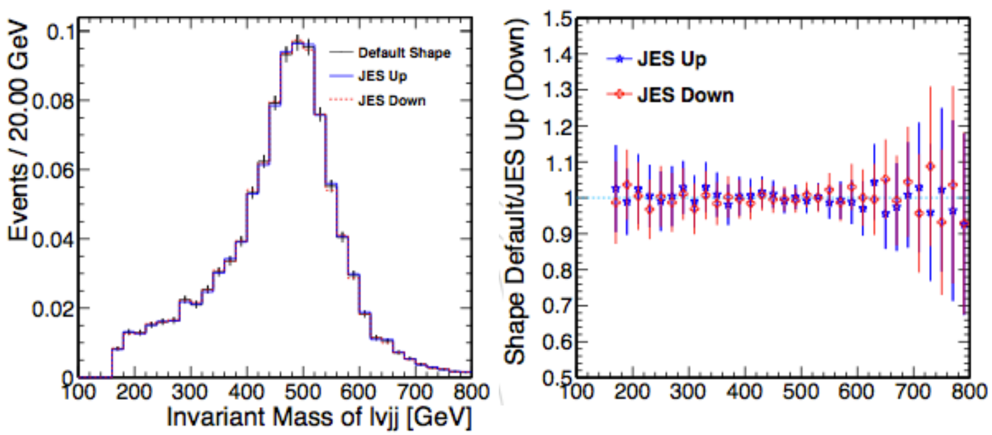




JES/JER

- The uncertainty on JES is evaluated from a fit to a had. W mass in a top-enriched sample (same approach of **EWK-11-017** and **SMP-12-015**)





- no impact on the Higgs mass is observed
- overall effect is negligible

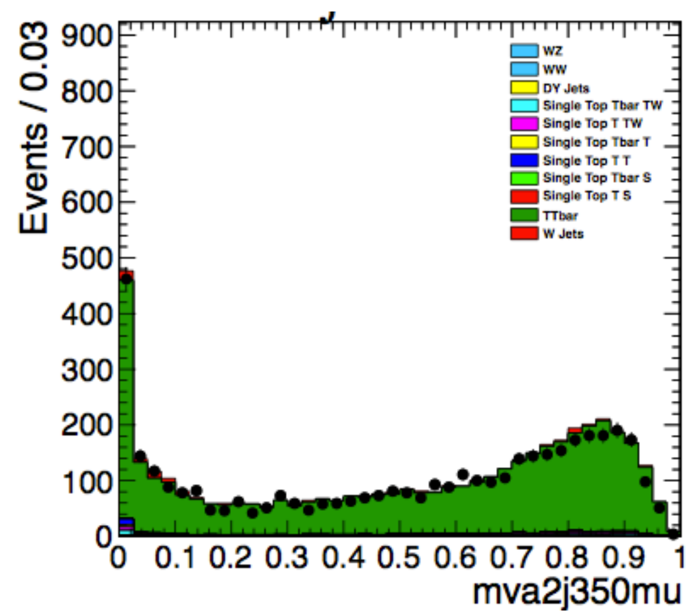
Systematic uncertainties

Source	uncertainty
Higgs line shape	0 – 30%
Signal cross-section	15 – 20%
Signal efficiency x acceptance	10%
Luminosity	5%
Jet energy scale, resolution and MET	< 1%
Theory (PDFs)	1 – 2%
Lepton trigger efficiency	1%
Lepton selection efficiency	1 – 2%
Pile-up	< 1%

Background systematics

normalization uncertainty	<= 2 %
W+jets fit uncertainty	shape

- Efficiency x acceptance syst. is evaluated, using a pure top sample, as the difference between data and MC.



Limit using 1.6 fb^{-1} 8 TeV data