H → WW → 2l2ν in 0 and 1-jet Final States at CMS

Jae Hyeok Yoo (UC San Diego)
jaehyeokyoo@gmail.com
on behalf of CMS collaboration

DPF 2013, Santa Cruz, USA, Aug 13-17, 2013
Overview of talk

- The $H \rightarrow WW \rightarrow 2l2\nu$ : signal and background
- Signal extraction
- Background estimation
- Fit validation for shape analysis
- Search results
- Spin-parity hypothesis test
- Summary
The $H \rightarrow WW \rightarrow 2l2\nu$ channel

*What is different from other modes?*

- **No mass peak** due to neutrinos in the final state
  - measure overall excess on top of backgrounds
  - very important to understand backgrounds
  - measure signal strength at the measured $M_H$

- **Large signal yields**
  - good statistical power to measure signal strength
  - This channel measures the signal strength with the best precision with current data

from $ZZ \rightarrow 4l$ and $\gamma \gamma$
The $H \rightarrow WW \rightarrow 2l2\nu$ channel

*Signature and analysis strategy*

- **Signature**
  - **Two** energetic, identified/isolated, opposite-sign leptons (e or $\mu$)
  - large missing transverse energy (MET)

- **Background composition depends on**
  - number of jets: 0 and 1
  - lepton flavor: $ee/\mu\mu$ and $e\mu$

- **Analysis optimized in 4 categories**

<table>
<thead>
<tr>
<th></th>
<th>0-jet ee/\mu\mu</th>
<th>0-jet e\mu</th>
<th>1-jet ee/\mu\mu</th>
<th>1-jet e\mu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MET</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>$p_T$</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>56.0 GeV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>$p_T$</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>23.6 GeV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>38.7 GeV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The H→WW→2l2ν channel

Signature and analysis strategy

- **Signature**
  - **Two** energetic, identified/isolated, opposite-sign leptons (e or μ)
  - large missing transverse energy (MET)
- **Background composition** depends on
  - number of jets: 0 and 1
  - lepton flavor: ee/μμ and eμ
- **Analysis optimized in 4 categories**

<table>
<thead>
<tr>
<th>0-jet ee/μμ</th>
<th>0-jet eμ</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-jet ee/μμ</td>
<td>1-jet eμ</td>
</tr>
</tbody>
</table>

**MET**

56.0 GeV

**H→WW→2l2ν(0/1jet) at CMS - Jae Hyeok Yoo**
Backgrounds

How they fake signal and how to suppress them

Color code: two opposite-sign leptons MET handles for suppression

**WW**
- Irreducible
- Use difference in kinematics

**Top**
- B-tagging
- Soft-muon tagging
- Number of jets

**W+jets**
- Tight lepton ID & ISO
- Tight $p_T$ (ll) cut

**Drell-Yan**
- Z mass veto
- Tight MET cut
  (MVA technique)

**Wγ**
- Conversion rejection

**WZ/ZZ/Wγ***
- Extra lepton veto
Backgrounds
How they fake signal and how to suppress them

Color code: two opposite-sign leptons MET handles for suppression

**WW**
- Irreducible
- Use difference in kinematics

**Top**
- B-tagging
- Soft-muon tagging
- Number of jets

**W+jets**
- Tight lepton ID & ISO
- Tight $p_T$ cut

**Drell-Yan**
- $Z$ mass veto
- Tight MET cut

**Wγ**
- Conversion rejection

**WZ/ZZ/Wγ**
- Extra lepton veto

**WW selection**
**Signal Extraction**

*How to extract signal yields: cut-based*

- Baseline selection to reject backgrounds: WW selection
- Two approaches: cut-based (ee/μμ/eμ) and shape-based (eμ)

**Cut-based**

- $M_H$-dependent selection taking advantage of event kinematic difference due to helicity conservation

![Diagram of particle interactions](diagram.png)

- Low $M_H$ : small $\Delta \phi_{ll}$, small $M_{ll}$

---

**CMS preliminary, $\sqrt{s} = 8$ TeV, $L_{int} = 19.5$ fb$^{-1}$**

- **data**
  - $H(125) \rightarrow WW$
  - $W+\gamma$
  - $W+\gamma^{(*)}$
  - di-boson
  - top
  - Z+jets
  - WW

**$M_H$-dependent selection applied**

![Graph of event distribution](graph.png)

- $p_T$, $M_{ll}$, $M_T$, $\Delta \phi_{ll}$
Signal Extraction

How to extract signal yields: shape-based

- Use binned 2D templates of \([M_T, M_{ll}]\) and fit the full shape

\[ M_T = \sqrt{2p_T^{ll} \cdot \text{MET} \cdot (1 - \cos(\Delta\phi_{ll-MET}))} \]

- Applied to only \(e\mu\) channel

- Two templates: for low (<300 GeV) and high (\(\geq 300\) GeV) Higgs mass

- Large signal-free region to constrain backgrounds: especially WW in 0-jet

- More sensitive than cut-based

Low \(M_H\) templates zoomed in signal-populated region
full range : \(60 < M_T < 280\) GeV, \(12 < M_{ll} < 200\) GeV

\[ M_T = \sqrt{2p_T^{ll} \cdot \text{MET} \cdot (1 - \cos(\Delta\phi_{ll-MET}))} \]
Background Estimation

Overview of background estimation

<table>
<thead>
<tr>
<th>Background</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>WW</td>
<td>Data-driven</td>
</tr>
<tr>
<td>Top</td>
<td>Data-driven</td>
</tr>
<tr>
<td>Drell-Yan</td>
<td>Data-driven</td>
</tr>
<tr>
<td>W+jets</td>
<td>Data-driven</td>
</tr>
<tr>
<td>Wγ*</td>
<td>Data-driven</td>
</tr>
<tr>
<td>Wγ</td>
<td>from MC</td>
</tr>
<tr>
<td>WZ/ZZ</td>
<td>from MC</td>
</tr>
</tbody>
</table>

- WW selection applied
- Data-driven methods for dominant backgrounds
  - Measure the ratio ($\varepsilon$) of yields in signal region (SR) to control region (CR) in an independent sample (data or MC), and apply $\varepsilon$ to CR

\[
N_{SR} = N_{CR} \times \varepsilon
\]

- Others are taken from MC
**WW Estimation**

- Main background in the 0-jet category
- Cut-based analysis: extrapolation from high $M_{ll}$ to low $M_{ll}$ region

**WW MC**

Measure ratio of $M_{ll} < X$ GeV to $M_{ll} > 100$ GeV: $\varepsilon_{WW}$

**Data**

- control region: $M_{ll} > 100$ GeV
- signal region: $M_{ll} < X$ GeV

$X \cdot \varepsilon_{WW}$ $\Rightarrow$ $N_{WW}$ estimate in signal region

**Shape-based analysis**:

Data/MC in whole $M_{ll}$ region is taken $\rightarrow$ fit is able to constrain $WW$ using high $M_{ll}$, high $M_T$ regions
Fit Validation in Data

Is the WW fit model correct?

- Need to make sure fit model fits data correctly: WW, Top, W+jets, Wγ(∗), ...
- WW template is taken from MC normalized by data-driven estimation and shapes are allowed to move to match data in the fit
- Test WW fit model using WW sideband in eμ 0-jet
  - Divide signal-free region into two control regions (CR1 and CR2)
  - Predict CR1(2) from the fit result using only CR2(1)
  - All other backgrounds are fixed by nominal fit to test only WW

Fit Validation in Data

Is the WW fit model correct?

- Need to make sure fit model fits data correctly: WW, Top, W+jets, Wγ(∗), ...
- WW template is taken from MC normalized by data-driven estimation and shapes are allowed to move to match data in the fit
- Test WW fit model using WW sideband in eμ 0-jet
  - Divide signal-free region into two control regions (CR1 and CR2)
  - Predict CR1(2) from the fit result using only CR2(1)
  - All other backgrounds are fixed by nominal fit to test only WW
Fit Validation in Data

Is the WW fit model correct?

- Need to make sure fit model fits data correctly: WW, Top, W+jets, Wγ(*), ...
- WW template is taken from MC normalized by data-driven estimation and shapes are allowed to move to match data in the fit
- Test WW fit model using WW sideband in eμ 0-jet
  - Divide signal-free region into two control regions (CR1 and CR2)
  - Predict CR1(2) from the fit result using only CR2(1)
  - All other backgrounds are fixed by nominal fit to test only WW

Good agreement with data → WW fit model is correct
Fit Validation in Data

Are the Top and W+jets/WWγ(*) models correct?

- Fit two control regions populated by Top and W+jets/WWγ(*)
- Same selections as 2D analysis except for inverting top-veto and opposite-sign requirements
Fit Validation in Data

Are the Top and $W$+jets/$W\gamma(*)$ models correct?

- Fit two control regions populated by Top and $W$+jets/$W\gamma(*)$
- Same selections as 2D analysis except for inverting top-veto and opposite-sign requirements

Good agreement with data → Top and $W$+jets/$W\gamma(*)$ fit models are correct
Search Results

Exclusion : Compatible with SM Higgs hypothesis?

2D method is used in e\(\mu\) channel and cut-based method is used in ee/\(\mu\mu\) channel

SM Higgs exclusion

- Observed
- Median Expected
- Expected \(\pm 1\sigma\)
- Expected \(\pm 2\sigma\)
- Injection \(m_H = 125\) GeV \(\pm 1\sigma\)

expected : 115 - 575 GeV
observed : 128 - 600 GeV

Second SM-like Higgs exclusion

- observed
- median expected
- \(H \rightarrow WW \rightarrow 2l2\nu\) (shape-based)
- expected \(\pm 1\sigma\) \(L = 4.9\) fb\(^{-1}\) (7 TeV) + 19.5 fb\(^{-1}\) (8 TeV)
- expected \(\pm 2\sigma\)

expected : 118 - 600 GeV
observed : 115 - 600 GeV
Search Results

Significance: Compatible with bkgd-only hypothesis?

2D method is used in $e\mu$ channel and cut-based method is used in $ee/\mu\mu$ channel

![Graph showing significance and mass distribution](image)

- $\sqrt{s}=7$ TeV, $L = 4.9$ fb$^{-1}$
- $\sqrt{s}=8$ TeV, $L = 19.5$ fb$^{-1}$
- $H\rightarrow WW\rightarrow 2l2\nu$ 0/1-jet

CMS Preliminary

- Expected
- Observed
- Injection $m=125$ GeV
- Injection $\pm 1\sigma$
- Injection $\pm 2\sigma$

$4.0\sigma / 5.1\sigma$ (observed/expected)
Search Results
Is signal strength consistent with SM Higgs?

Confidence intervals in \((M_H, \mu)\) plane

<table>
<thead>
<tr>
<th>Channel</th>
<th>(M_H) (GeV)</th>
<th>(\mu/\sigma_{SM})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF 1jet 7TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>SF 0jet 7TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>DF 1jet 7TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>DF 0jet 7TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>SF 1jet 8TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>SF 0jet 8TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>DF 1jet 8TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
<tr>
<td>DF 0jet 8TeV</td>
<td>110-200</td>
<td>0-20</td>
</tr>
</tbody>
</table>

Signal strength\((\mu)\) in each channel

Confidence interval: \(\mu = 0.76 \pm 0.13\) (stat.) \(\pm 0.16\) (syst.)

\(\mu(H \rightarrow \gamma\gamma) = 0.78 \pm 0.27\) (stat.+syst.)

\(\mu(H \rightarrow ZZ \rightarrow 4l) = 0.91^{+0.30}_{-0.24}\) (stat.+syst.)
Search Results

Is “Data – background” consistent with SM Higgs?

- Data - background plots in 0/1-jets $e\mu$ with $S/(S+B)$ weighting
- $S/(S+B)$ weighting at each bin of 2D template
- Post-fit normalization and uncertainties

Important plots to show consistency of data with SM Higgs
Search Results

Is “Data – background” consistent with SM Higgs?

- Data - background plots in 0/1-jets eμ with S/(S+B) weighting
- S/(S+B) weighting at each bin of 2D template
- Post-fit normalization and uncertainties

Important plots to show consistency of data with SM Higgs

Clear excess over background uncertainty consistent with $M_H = 125$ GeV
Spin-parity Test

Model to test and method

- $H \rightarrow WW \rightarrow 2l2\nu$ has good sensitivity to distinguish SM Higgs ($J^P=0^+$) from a spin-2 resonance which couples to di-boson through minimal couplings ($J^P=2^+$)
- Use the same 2D templates and background estimation as the main analysis in 0/1-jets $e\mu$ categories

- Test $gg \rightarrow H/X$ ($gg \rightarrow X$ normalized to $gg \rightarrow H$)

CMS preliminary L = 19.5 fb$^{-1}$ (8TeV)

$M_H = 125$ GeV

$2^+_{\text{min}} (125$ GeV$)$

CMS preliminary L = 19.5 fb$^{-1}$ (8TeV)
Spin-parity Test
Is data consistent with $2^+$ model?

- Test statistic
  
  $$ q = -2 \ln \left( \frac{L_{2^+}}{L_{0^+}} \right) $$

- Result using the best fit values ($\mu^{0^+}=0.76$ and $\mu^{2^+}=0.83$)

<table>
<thead>
<tr>
<th>Assumed Model ($j^P$)</th>
<th>Separation of other model</th>
<th>Expected</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0^+$</td>
<td>1.5$\sigma$</td>
<td></td>
<td>0.5$\sigma$</td>
</tr>
<tr>
<td>$2^+$</td>
<td>1.8$\sigma$</td>
<td></td>
<td>1.3$\sigma$</td>
</tr>
</tbody>
</table>
Summary

• The whole Run1 LHC data of 4.9 + 19.5 fb\(^{-1}\) analyzed for SM Higgs boson search in \(H \rightarrow WW \rightarrow 2l2\nu\) 0/1-jet channel
  • Fit model validated using data
  • Significance : 4.0\(\sigma\) / 5.1\(\sigma\) (observed/expected)
  • Signal strength : \(\mu = 0.76 \pm 0.13\) (stat.) \(\pm 0.16\) (syst.)

• Spin-parity hypothesis test performed in 0/1-jet e\(\mu\) categories
  • Inconsistency with 2+ model : 1.3\(\sigma\)

• All results are consistent with SM Higgs at \(M_H = 125\) GeV

• Future plan
  • Publication in progress including VBF and other leptonic channels(WH/ZH)
Extra slides
Standard Model Higgs Boson

Production and decay

Production modes

- Standard Model Higgs: charge = 0 and spin = 0
- Mass is a free parameter → task for experimentalists
### WW selection

<table>
<thead>
<tr>
<th>Selection [units]</th>
<th>√s = 7 TeV</th>
<th>√s = 8 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ee,μμ</td>
<td>eμ</td>
</tr>
<tr>
<td>pTmax [GeV/c]</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>pTmin [GeV/c]</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>third lepton veto</td>
<td>applied</td>
<td>applied</td>
</tr>
<tr>
<td>opposite-sign requirement</td>
<td>applied</td>
<td>applied</td>
</tr>
<tr>
<td>mll [GeV/c^2]</td>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>projected MET [GeV]</td>
<td>37 + N_{vtx}/2</td>
<td>20</td>
</tr>
<tr>
<td>Drell-Yan MVA</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Z mass veto</td>
<td>applied</td>
<td>---</td>
</tr>
<tr>
<td>Δφ(ll-jetmax) [dg.]</td>
<td>165</td>
<td>---</td>
</tr>
<tr>
<td>top veto</td>
<td>applied</td>
<td>applied</td>
</tr>
<tr>
<td>pTll [GeV/c]</td>
<td>45</td>
<td>30 [*]</td>
</tr>
</tbody>
</table>

- To suppress WZ/ZZ
- To suppress low M_{ll} resonance
- To suppress DY, QCD
- To suppress DY
- To suppress Top
- To suppress W+jets

[*] For the cut and count analysis, pTll is required to be larger than 45 GeV.
M$_H$-dependent selection for cut-based analysis

<table>
<thead>
<tr>
<th>$m_H$ [GeV]</th>
<th>$p_T^{\ell,\text{max}}$ [GeV]</th>
<th>$p_T^{\ell,\text{min}}$ [GeV]</th>
<th>$m_{ll}$ [GeV]</th>
<th>$\Delta\phi_{ll}$ [$^\circ$]</th>
<th>$m_T$ [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>20</td>
<td>10</td>
<td>40</td>
<td>115</td>
<td>[80,120]</td>
</tr>
<tr>
<td>125</td>
<td>23</td>
<td>10</td>
<td>43</td>
<td>100</td>
<td>[80,123]</td>
</tr>
<tr>
<td>130</td>
<td>25</td>
<td>10</td>
<td>45</td>
<td>90</td>
<td>[80,125]</td>
</tr>
<tr>
<td>160</td>
<td>30</td>
<td>25</td>
<td>50</td>
<td>60</td>
<td>[90,160]</td>
</tr>
<tr>
<td>200</td>
<td>40</td>
<td>25</td>
<td>90</td>
<td>100</td>
<td>[120,200]</td>
</tr>
<tr>
<td>250</td>
<td>55</td>
<td>25</td>
<td>150</td>
<td>140</td>
<td>[120,250]</td>
</tr>
<tr>
<td>300</td>
<td>70</td>
<td>25</td>
<td>200</td>
<td>175</td>
<td>[120,300]</td>
</tr>
<tr>
<td>400</td>
<td>90</td>
<td>25</td>
<td>300</td>
<td>175</td>
<td>[120,400]</td>
</tr>
</tbody>
</table>

Figure 1: Distributions of the azimuthal angle difference between two selected leptons in the 0-jet (left) and 1-jet (right) categories in the different flavor final state, for data (points with error bars), for the main backgrounds (stacked histograms), and for a SM Higgs boson signal with $m_H = 125$ GeV (superimposed histogram). The standard W+W selection is applied.

Table 1: Final event selection requirements for the cut-based analysis in the 0-jet and 1-jet samples. Values for other mass hypotheses follow a smooth behavior with respect to the reported values.
Top Estimation

- Main background in 1-jet category
- Handle: presence of b-quarks → top tagging with b-tagged jets and soft muons
- Extrapolation from top-tagged region to top-vetoed region

![Diagram showing top tagging efficiency and control regions](image)

Measure Top tagging efficiency: $\varepsilon_{\text{tag}}$

control region
Top Tagged

signal region
Top Vetoed

$N_{\text{Top}}$ estimate in signal region

$\varepsilon_{\text{tag}} \times \frac{1 - \varepsilon_{\text{tag}}}$
W+jets Estimation

- Jets can be mis-identified as leptons
- Measure the rate (Fake Rate) for a lepton with loose selection to pass the full requirement in data events dominated by QCD
- Apply FR to the control region where one lepton passes the full selection and the other passes loose selection but not full selection

\[
\text{Measure fake rate: } \text{FR}(p_T, \eta)
\]

\[
\text{QCD data} \quad \text{Data}
\]

- CR: Full-Loose
- SR: Full-Tight

\[
N_{W+jets} \text{ estimate in signal region}
\]

- Systematics: \(\sim 40\%\)
Drell-Yan Estimation

- Main background in ee/μμ final states
- Handle: Z mass veto and MVA-based Drell-Yan suppression technique → worse sensitivity than eμ channel
- Extrapolation from inside to outside of Z peak

Data with loose MVA output

Measure $R_{\text{out/in}}$

Data control region
In Z-peak

$\nabla \times \ R_{\text{out/in}}$

N_{DY} estimate
in signal region

$R_{\text{out/in}}$ in Data and MC

$R_{\text{out/in}}$ in Data and MC

H → WW → 2l2ν(0/1jet) at CMS - Jae Hyeok Yoo
**WW Selection Results**

*Putting all these together*

---

**M_{ll}**

- 0-jet
  - Data
  - H125
  - W+jets
  - VV
  - Top
  - σ_{stat} + σ_{syst}

- CMS Preliminary
  - 8 TeV, L = 19.5 fb^{-1}
  - 7 TeV, L = 4.9 fb^{-1}

- Data / MC
  - 0
  - 0.5
  - 1
  - 1.5
  - 2
  - 2.5

---

**Δφ_{ll}**

- 0-jet
  - Data
  - H125
  - W+jets
  - VV
  - Top
  - σ_{stat} + σ_{syst}

- CMS Preliminary
  - 8 TeV, L = 19.5 fb^{-1}
  - 7 TeV, L = 4.9 fb^{-1}

- Data / MC
  - 0
  - 0.5
  - 1
  - 1.5
  - 2
  - 2.5

---

**WW selection eμ channel**

- Overall good agreement between Data and MC
Systematics

- Luminosity: 4.4% (8 TeV), 2.2% (7 TeV)
- Theoretical uncertainties on signal following LHC cross section recommendation
  - PDF + higher order effects + UEPS: 20 - 30%
- Background normalization
  - WW: 5/10% for cut-based, W+jets: 36%, Top: 20/5%, DY: 30 - 200%, Wγ(\*) : 30 - 40%
- Instrumental
  - Lepton identification and trigger efficiency: 3(4)% for muon(electron)
  - Lepton Energy/Momentum scale: 1.5% for muon, 2% (5%) for electron in barrel (endcap)
  - MET resolution: 2%, Jet energy scale: 2 - 10%
- Shape variations
  - Instrumental variation: list same as above
  - Backgrounds:
    - WW: QCD scale variation and different generators (Madgraph vs MC@NLO)
    - Top: different generators (Madgraph vs Powheg)
    - W+jets: difference away jet pT thresholds
More WW fit validation plots

$M_{ll}$ is shown here instead of $M_T$

CR1 using CR2 fit result

CR2 using CR1 fit result

Good agreement with data → WW fit model is correct
Stacked S/(S+B) weighted plots

used to make data - bkgd plots
Significance and signal strength

*Divided by energy and analysis method*

**cut-based**: cut-based $e\mu + $ cut-based $e\mu$

**shape-based**: cut-based $e\mu + $ shape-based $e\mu$

<table>
<thead>
<tr>
<th>Energy (TeV)</th>
<th>7 TeV</th>
<th>8 TeV</th>
<th>7+8 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>expected/observed significance</td>
<td>expected/observed significance</td>
<td>expected/observed significance</td>
</tr>
<tr>
<td>cut-based</td>
<td>1.7/0.8</td>
<td>2.6/2.1</td>
<td>2.7/2.0</td>
</tr>
<tr>
<td>shape-based</td>
<td>2.5/2.2</td>
<td>4.7/3.5</td>
<td>5.1/4.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy (TeV)</th>
<th>7 TeV</th>
<th>8 TeV</th>
<th>7+8 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>best fit value</td>
<td>best fit value</td>
<td>best fit value</td>
</tr>
<tr>
<td>cut-based</td>
<td>0.46 ± 0.57</td>
<td>0.79 ± 0.38</td>
<td>0.71 ± 0.37</td>
</tr>
<tr>
<td>shape-based</td>
<td>0.91 ± 0.44</td>
<td>0.71 ± 0.22</td>
<td>0.76 ± 0.21</td>
</tr>
</tbody>
</table>