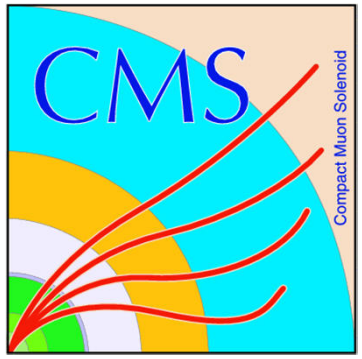
LHC Physics Discussions: W/Z+jets

W/Z+jets in CMS



Johannes Hauk
DESY

LHC Physics Discussions, 05.12.2011

HELMHOLTZ ASSOCIATION

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Overview

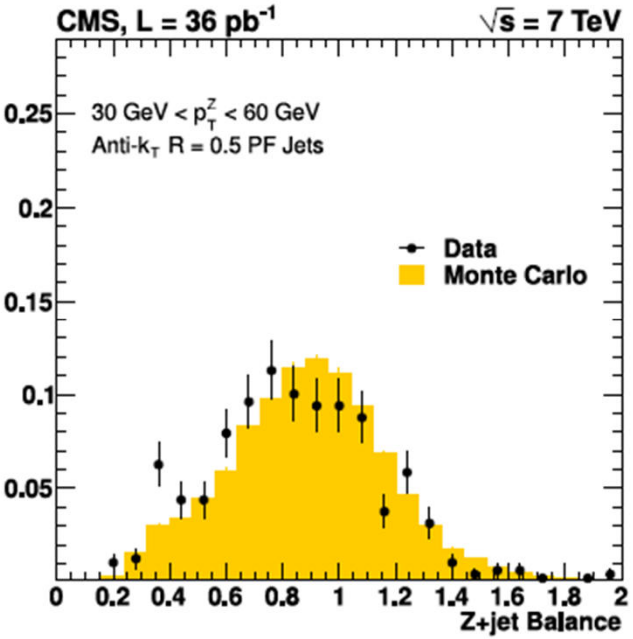
- Example: Usage of V+jets in detector calibration
- Overview of public electroweak results
  - Usage of jets
- Results in V+jets
- Jets with heavy flavours

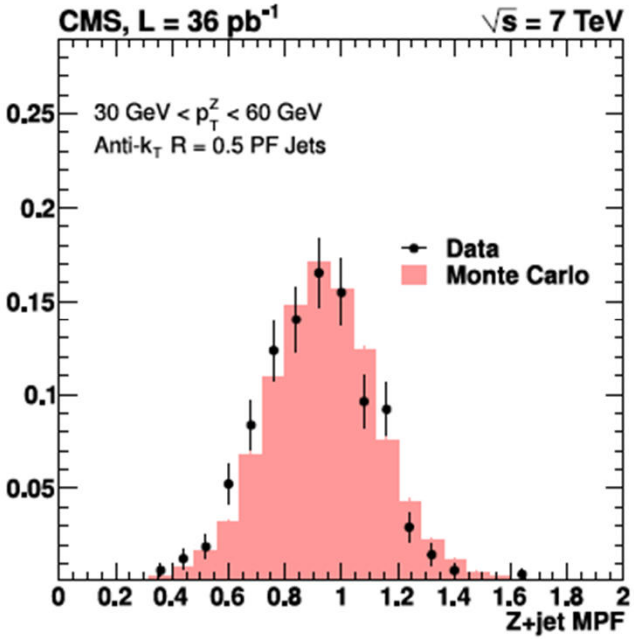
Calibration of Jet Energy Scale (JES) and Jet Transverse Momentum Resolution

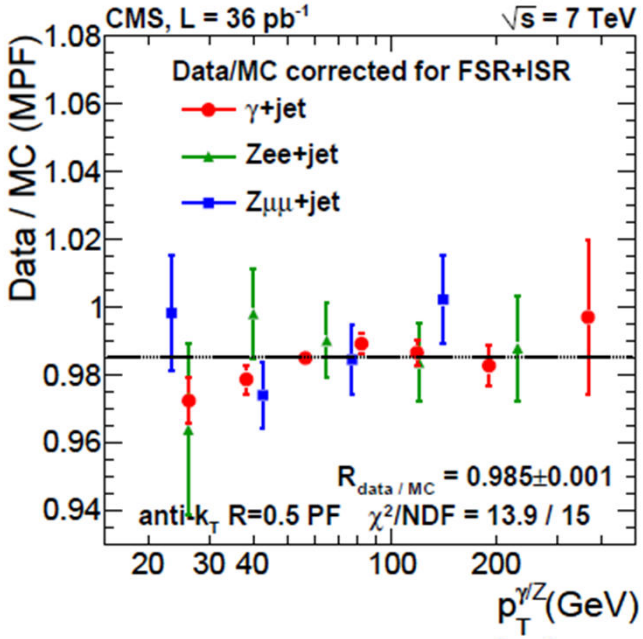
- Balance in p_T
  - (exactly 2 objects with nameable p_T, or events without missing E_T)
  - Dijet events → relative JES in η, p_T resolution
  - γ+jets (background: dijet) → absolute JES, p_T resolution
  - Z+jets (clean sample) → absolute JES

CMS-JME-10-011 (2010 – 36 pb^{-1})

- Calibration on MC, then rel. & abs. JES for deviations data/MC







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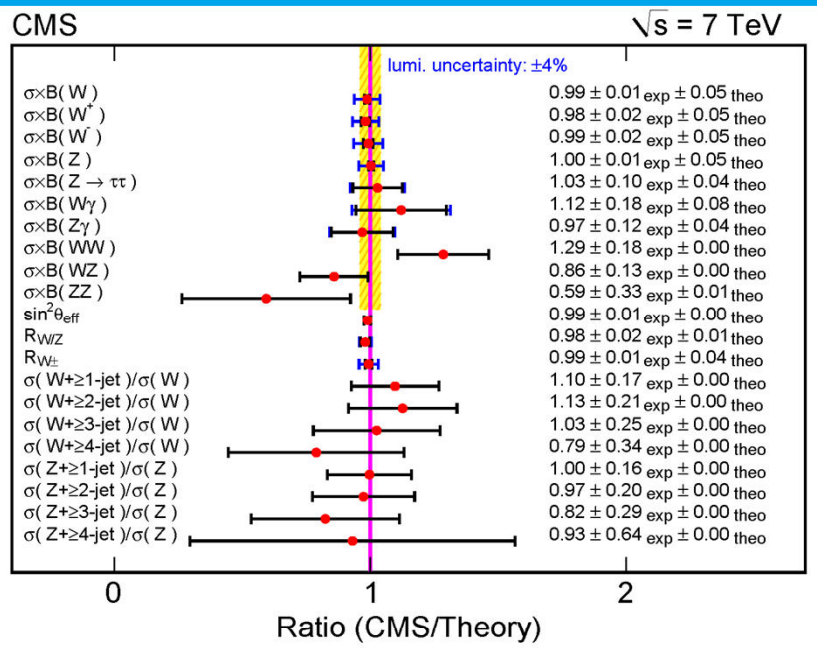
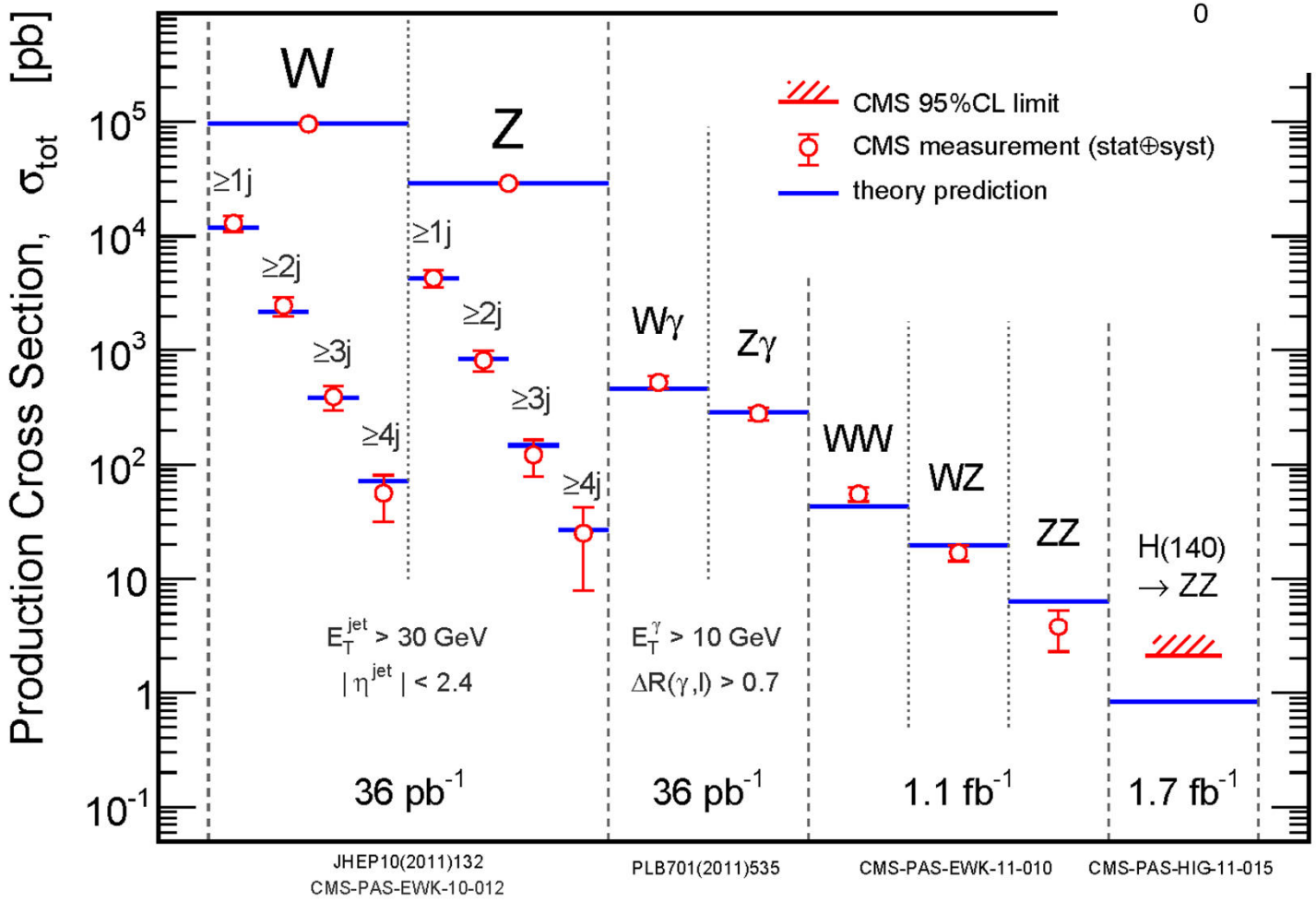
Public Electroweak Results

- Results at 7 TeV for first time
  - Good agreement with theory predicitions
  - Also ratios given to minimise uncertainties





Z mass window in CMS [60 GeV, 120 GeV]

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Electroweak Analyses using Jets

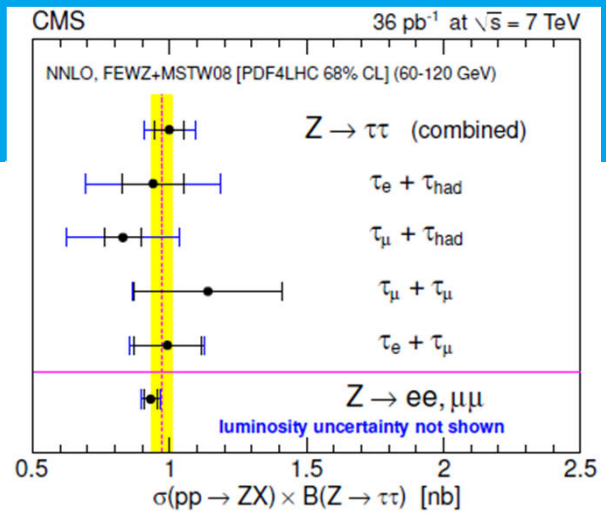
CMS-EWK-11-019 (in progress)

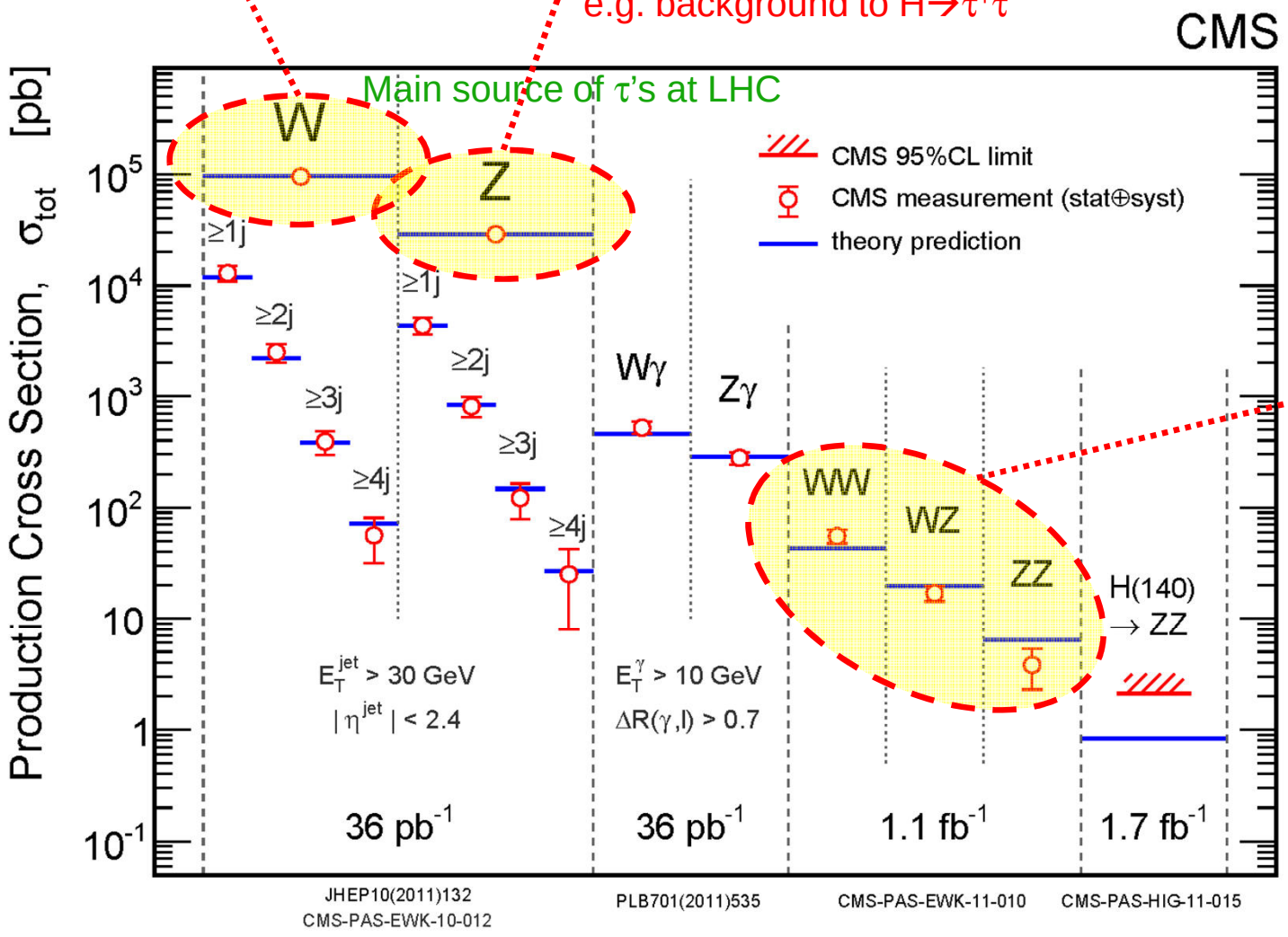
CMS-PAS-EWK-11-002
(2010 – 18.4 pb^{-1})

W→τν$_\tau$ with hadronic τ decays,
e.g. background to charged H

CMS-EWK-10-013
(2010 – 36 pb^{-1})

Z→τ$^+$τ$^-$ with hadronic τ decays,
e.g. background to H→τ$^+$τ$^-$





CMS-EWK-11-011 (in progress)

VV: one V with leptonic decay,
other hadronic,
e.g. background to heavy H

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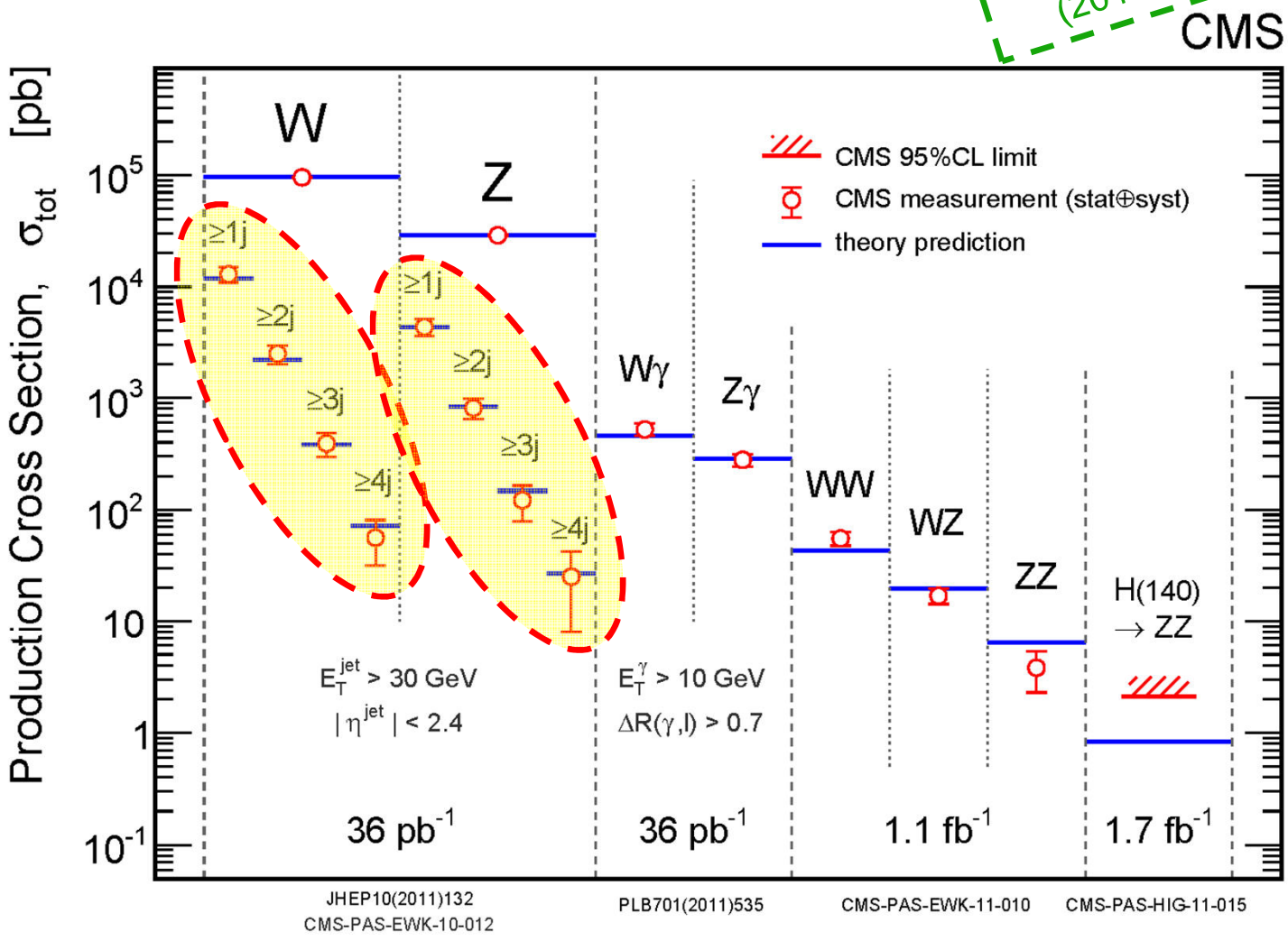
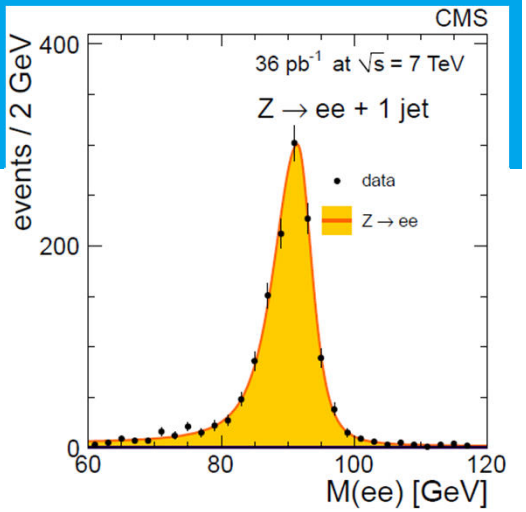
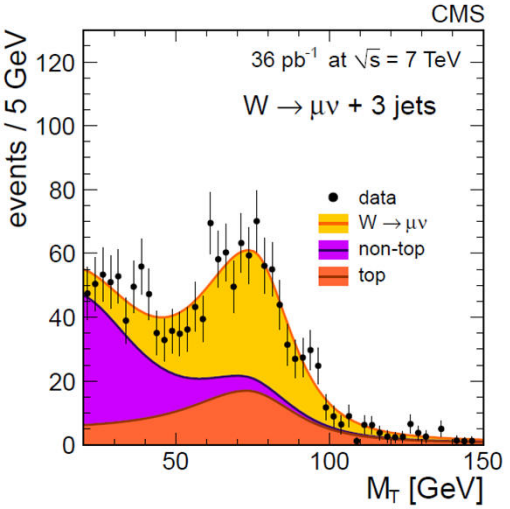
V+Jets Analyses

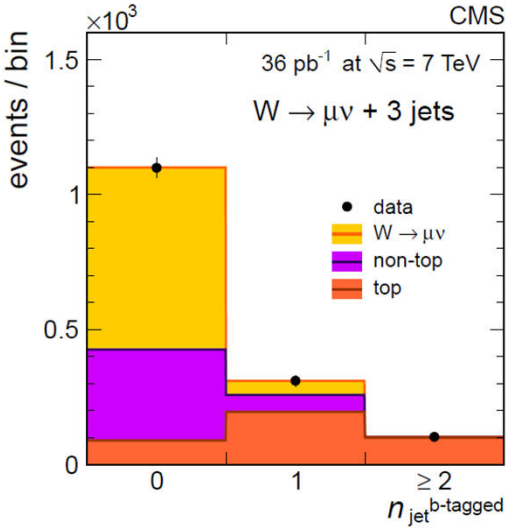
- W/Z production differential in number of jets
- W(+jets) with higher statistics than Z(+jets), faced by bigger background

CMS-EWK-10-012 (2010 – 36 pb^{-1})



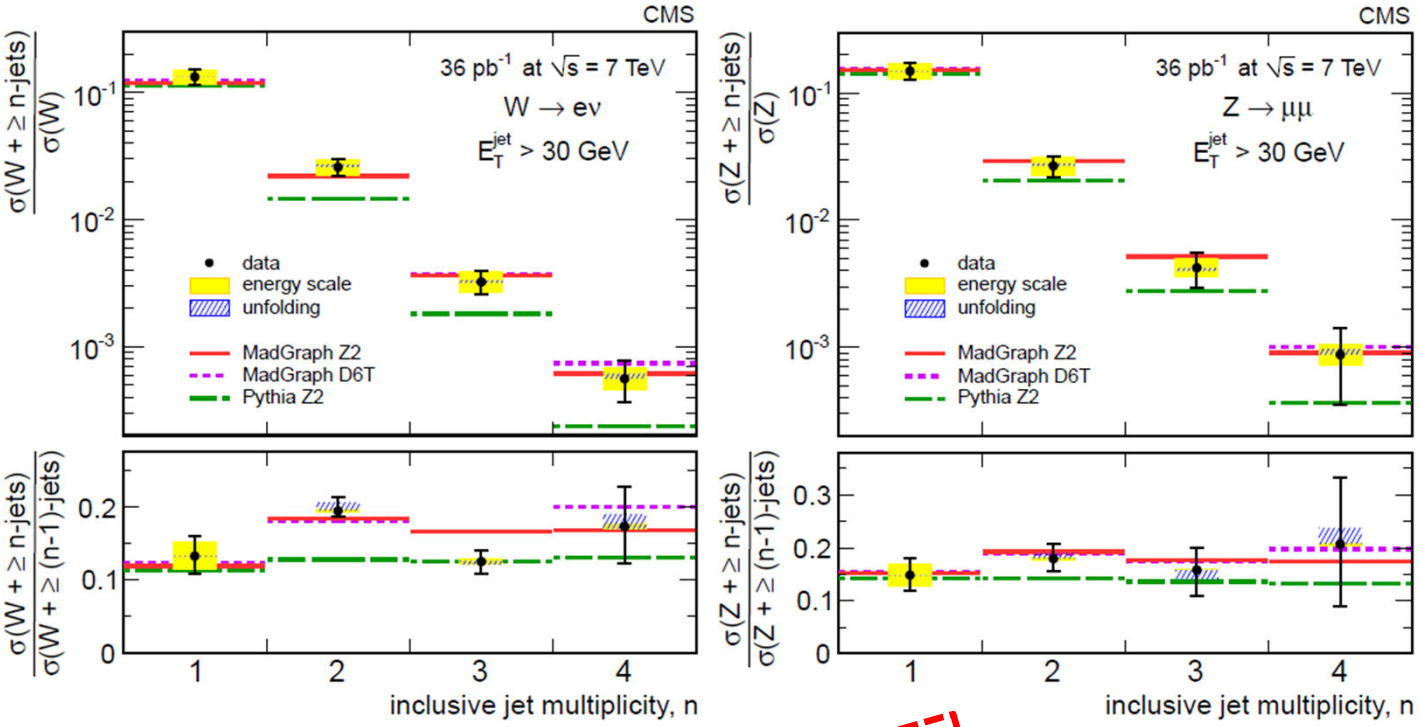




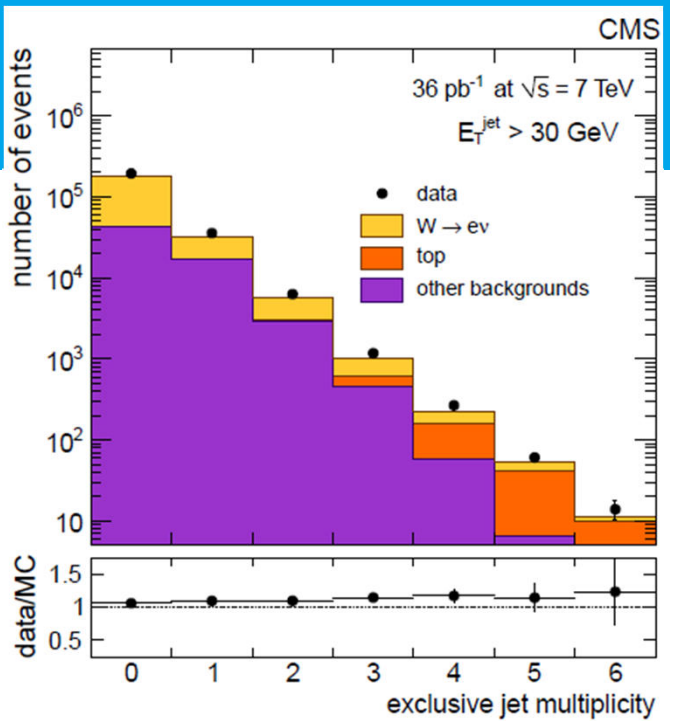


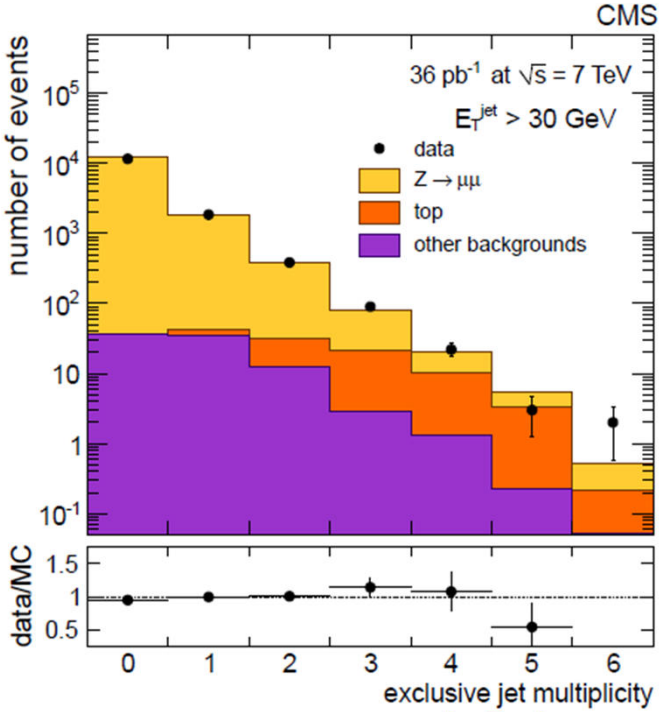
Results in V+Jets

- Test perturbative QCD calculations
  - Good agreement with ME+PS simulation
- Background for top and new physics



Visible cross sections





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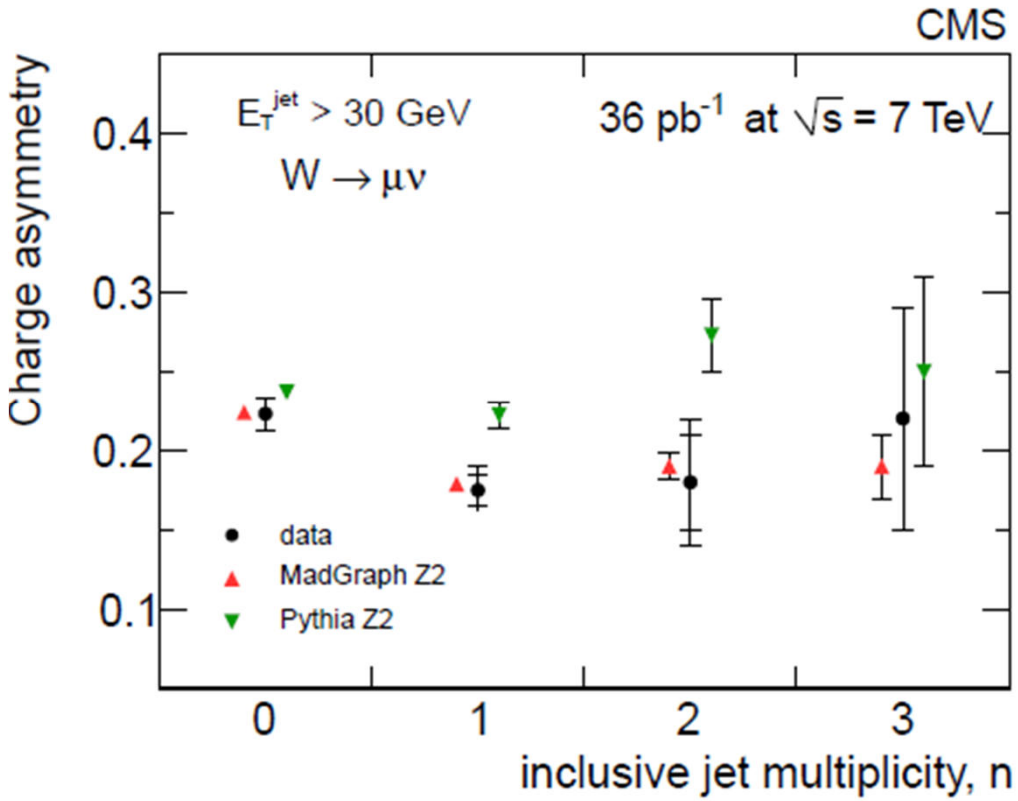
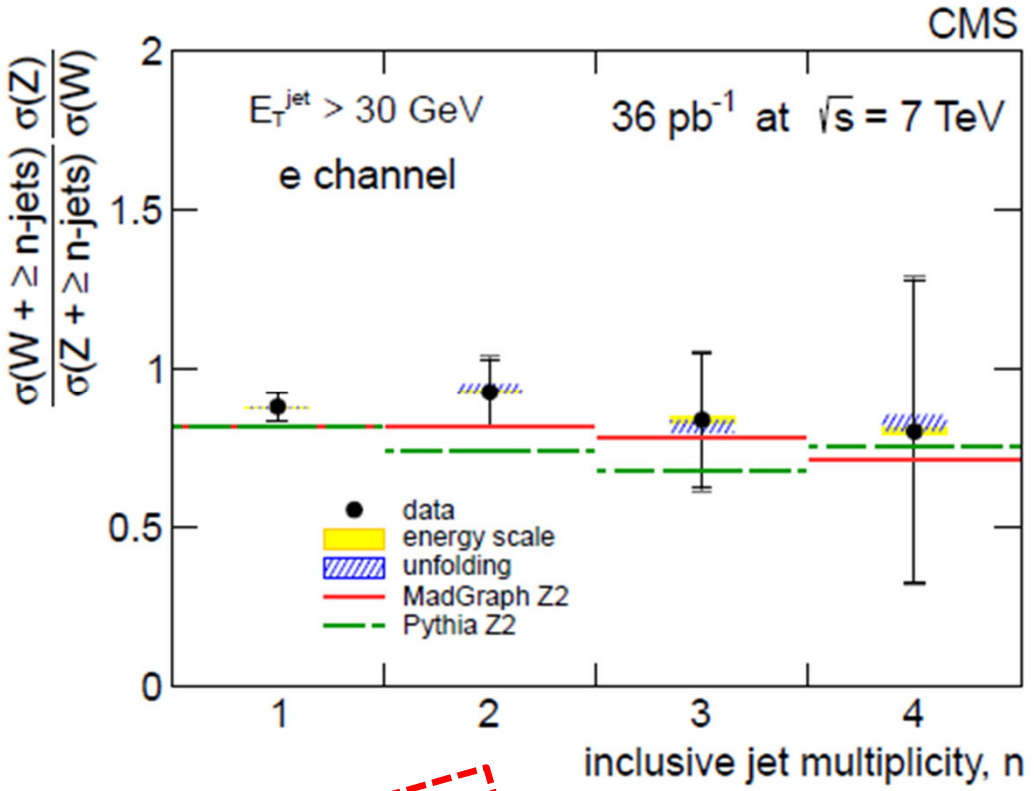
W/Z Ratio and W Charge Asymmetry

- Sensitive to new physics
  - Also good agreement with ME+PS simulation

$$A_W = \frac{\sigma(W^+) - \sigma(W^-)}{\sigma(W^+) + \sigma(W^-)}$$





Visible cross sections

Berends-Giele Scaling

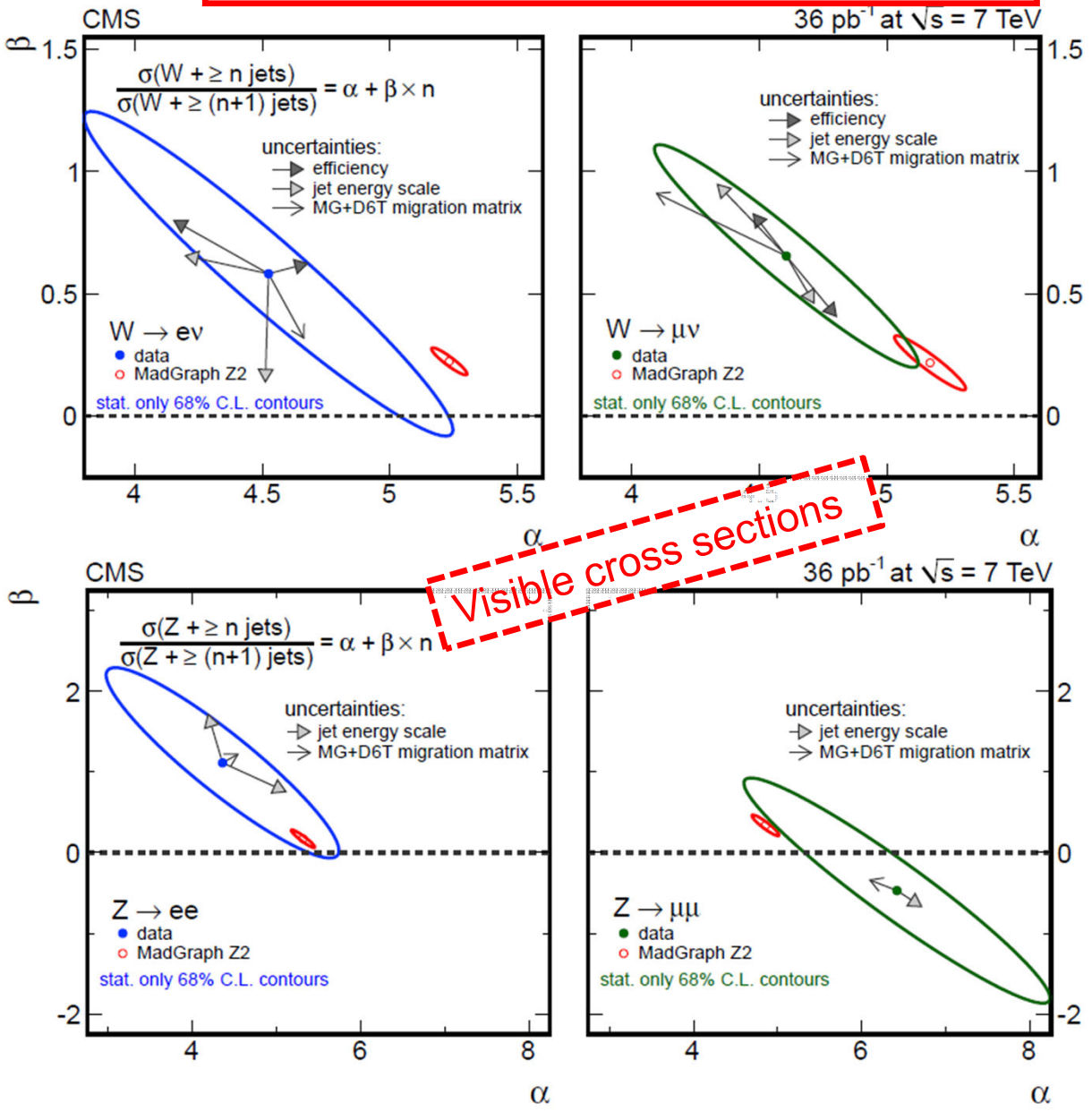
- Approximately constant ratio for n≥1

$$C_n = \frac{\sigma_n}{\sigma_{n+1}} = \alpha \quad \text{with} \quad \sigma_n = \sigma(\mathrm{V}+\geq n \text{ jets})$$

  - Even at NLO predicted, although not following from first principles
- Phase-space effects
  - Violation of proportionality
  - Fit function (second parameter)

$$C_n = \alpha + \beta \cdot n$$

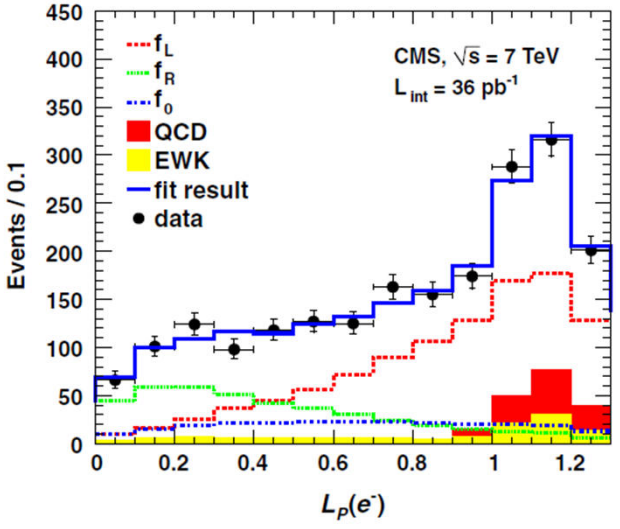
- Scaling works well
  - β compatible with 0

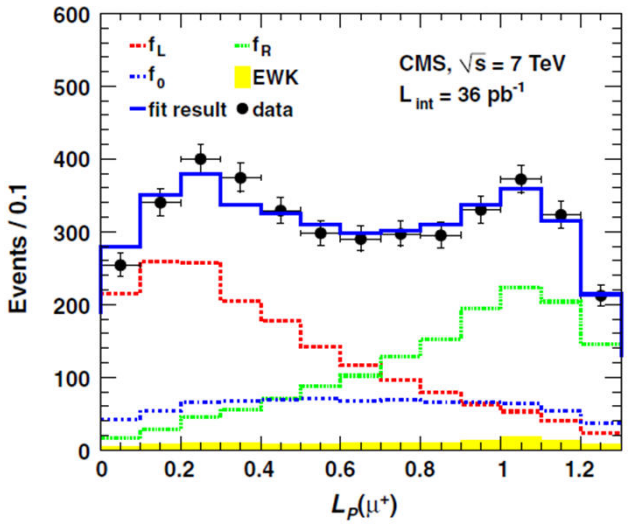


Polarisation of Boosted W

- Production of high-p_T W's (p_T>50 GeV)
- Left-handed, right-handed and longitudinal polarisation fractions (f_L, f_R, f_0)
  - Enhanced in pp collisions, since dominant production is valence quark + gluon
  - Left-handiness of valence quark transported to boosted W
  - Asymmetry in transverse momentum spectrum of decay neutrino and charged lepton
- Test perturbative QCD calculations, search for new physics
  - SM: predominantly left-handed (W^+ and W^-)
- Neutrino measured as missing E_T only in transverse plane
  - Use lepton projection in transverse plane L_P

CMS-EWK-10-014 (2010 – 36 pb^{-1})





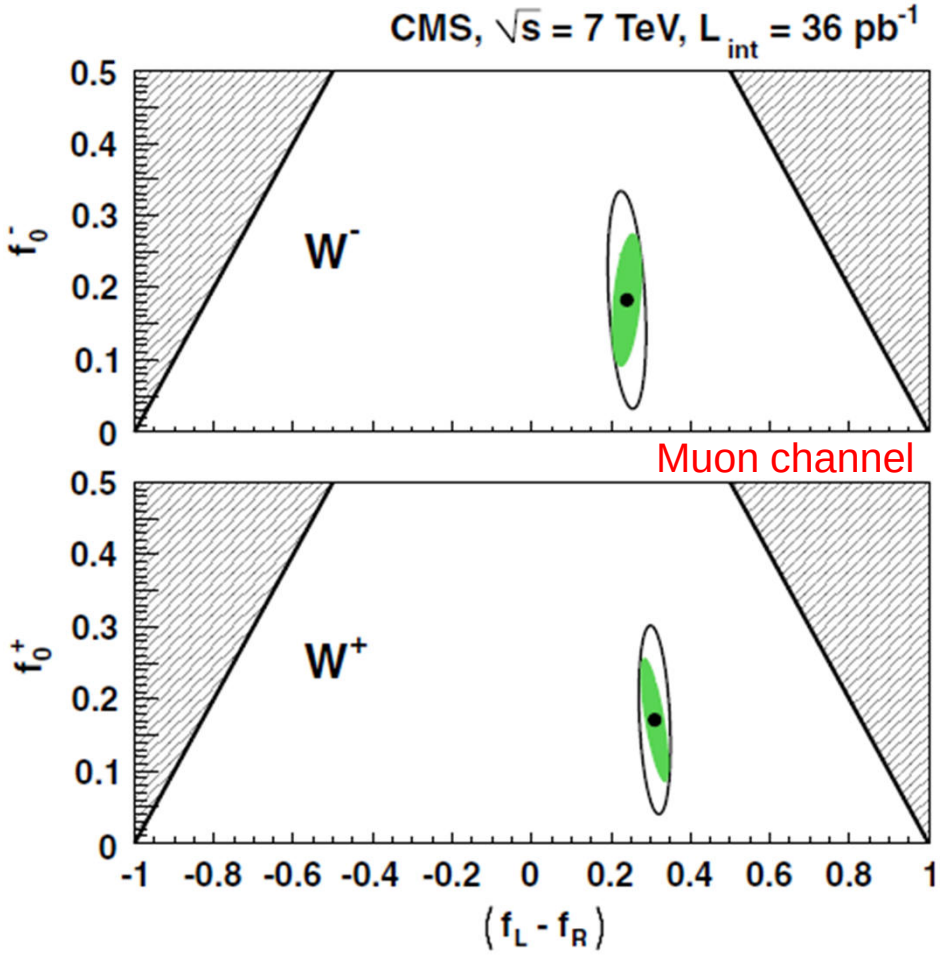
$$L_P = \frac{\vec{p}_T(l^{\pm}) \cdot \vec{p}_T(W)}{|\vec{p}_T(W)|^2}$$

Results of W Polarisation

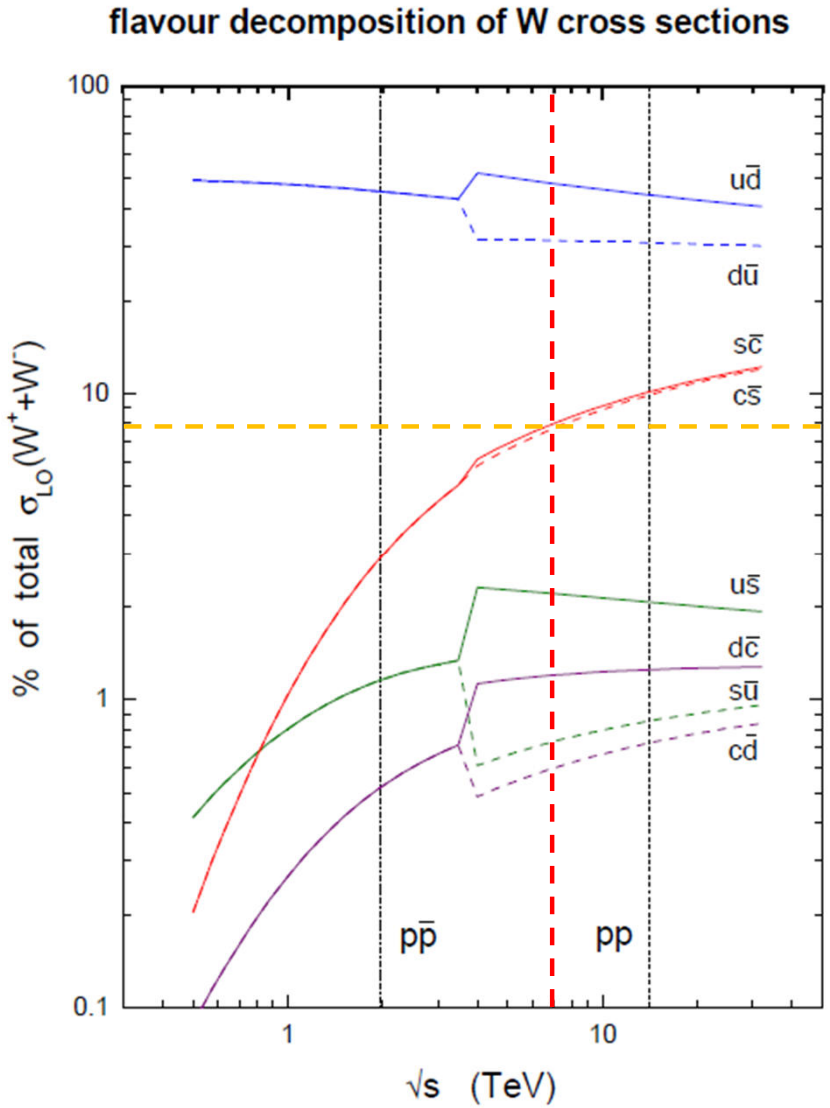
- First observation of predominant left-handed boosted W's in pp collisions

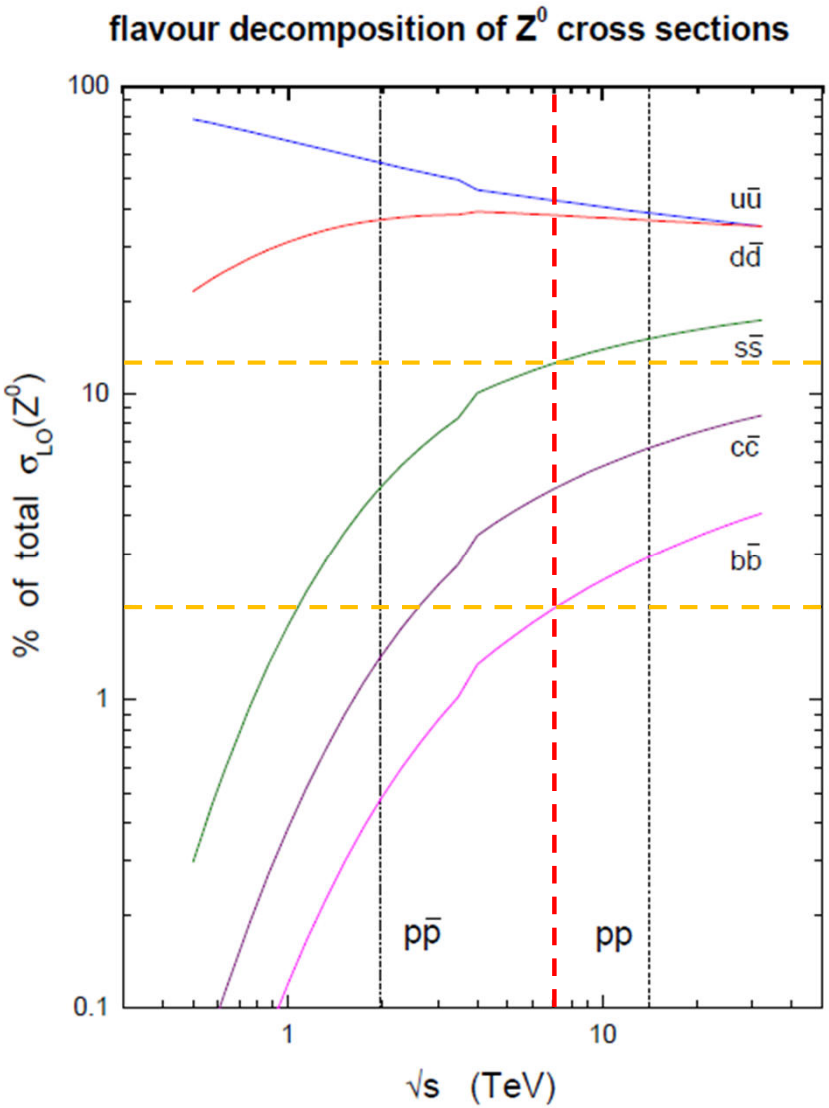
- Results in good agreement with SM calculations

	CMS	NLO	ME+PS	LO
W^+ $(f_L - f_R)$	$0.300 \pm 0.031 \pm 0.034$	0.308	0.283	0.309
W^- $(f_L - f_R)$	$0.226 \pm 0.031 \pm 0.050$	0.248	0.222	0.235
W^+ f_0	$0.192 \pm 0.075 \pm 0.089$	0.200	0.187	0.198
W^- f_0	$0.162 \pm 0.078 \pm 0.136$	0.193	0.179	0.190



Flavour Composition of W/Z Production

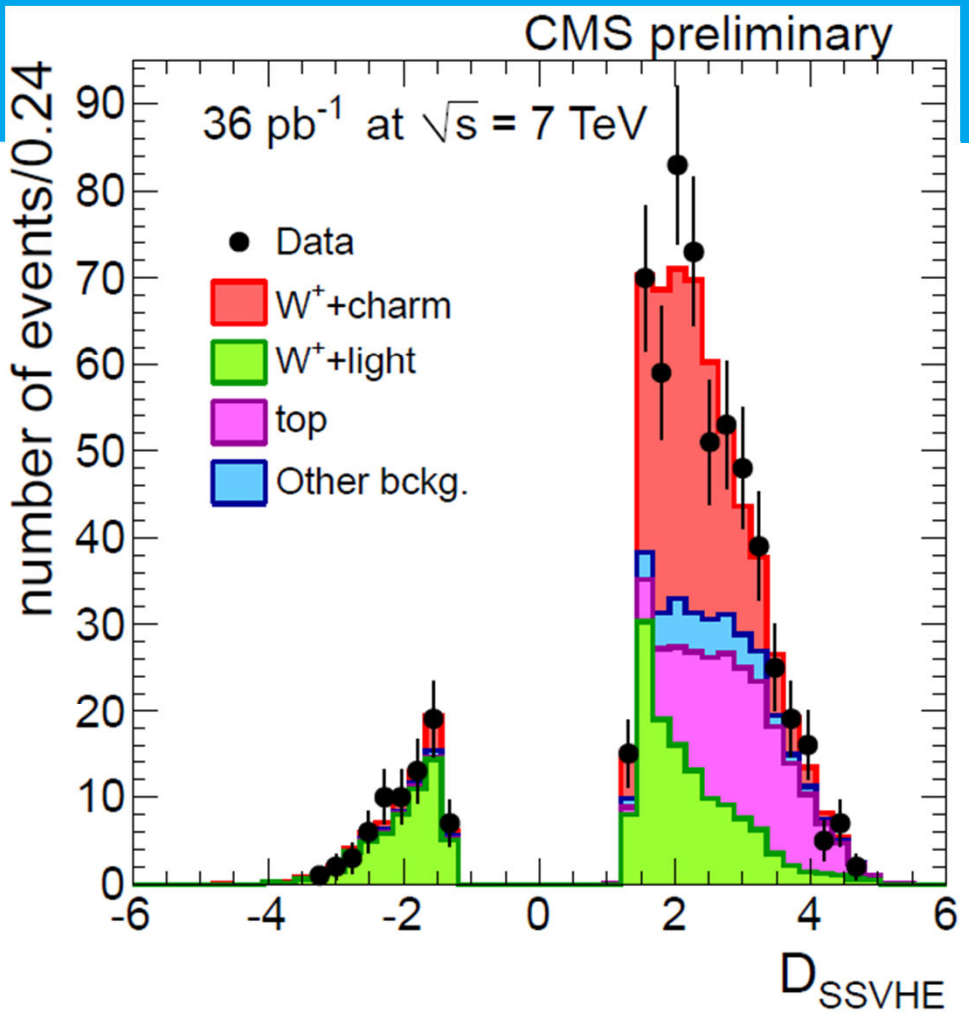


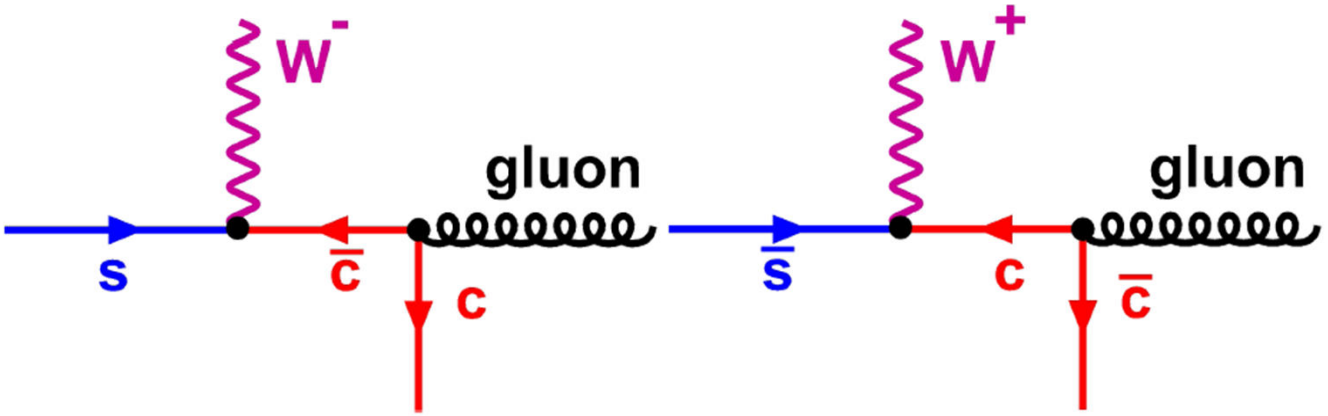


- u and d still dominant at LHC – but PDFs well known
- Significant contributions from s, c, b – PDFs with big uncertainties

W+c

- Sensitive to s-PDF
  - Possible constraint with 2011 dataset
- Dominant process s+g
  - Processes with b supressed
- Require secondary vertex (b-tagging)
  - Template fit





CMS-PAS-EWK-11-013
(2010 – 36 pb-1)

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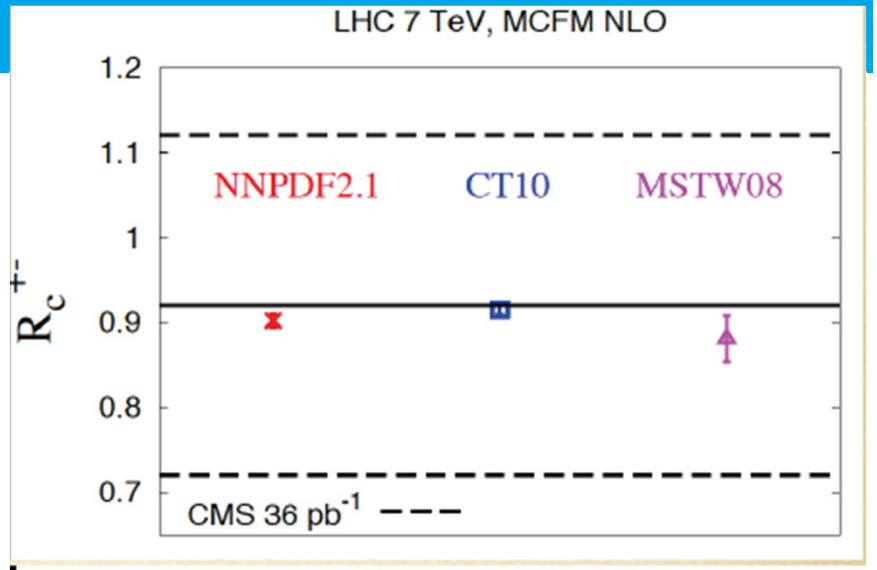
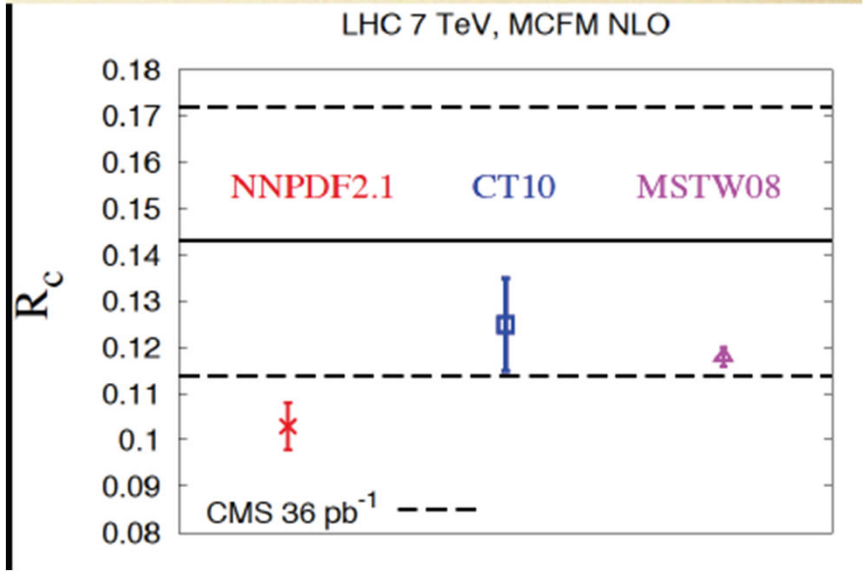
Results of W+c

- Measurements in agreement with theory for different PDF sets

$$R_c^{\pm} = \frac{\sigma(W^+ + \bar{c})}{\sigma(W^- + c)} = 0.92 \pm 0.19(\text{stat.}) \pm 0.04(\text{syst.})$$

$$R_c = \frac{\sigma(W + c)}{\sigma(W + \text{jets})} = 0.143 \pm 0.015(\text{stat.}) \pm 0.024(\text{syst.})$$





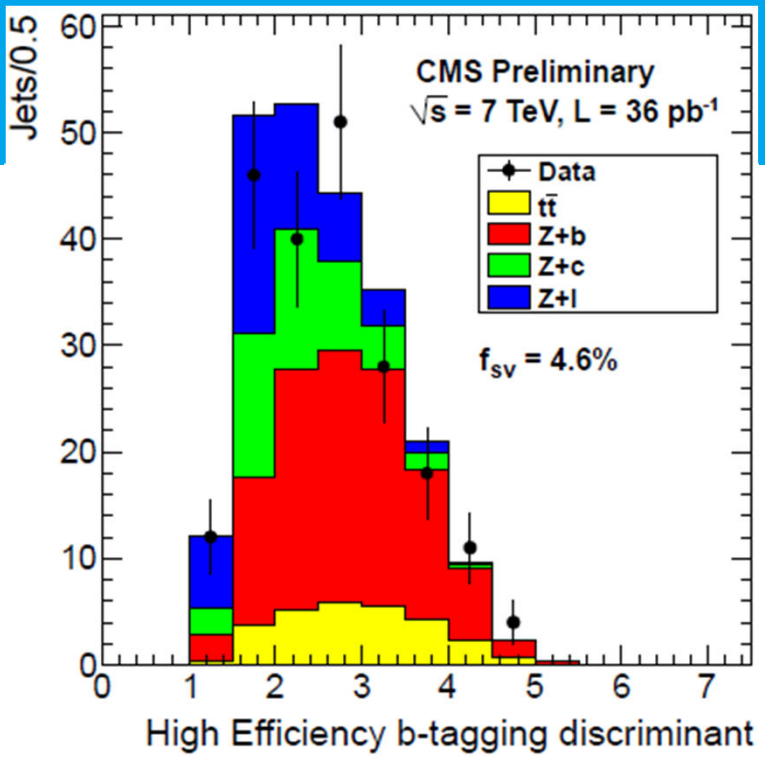
Visible cross sections

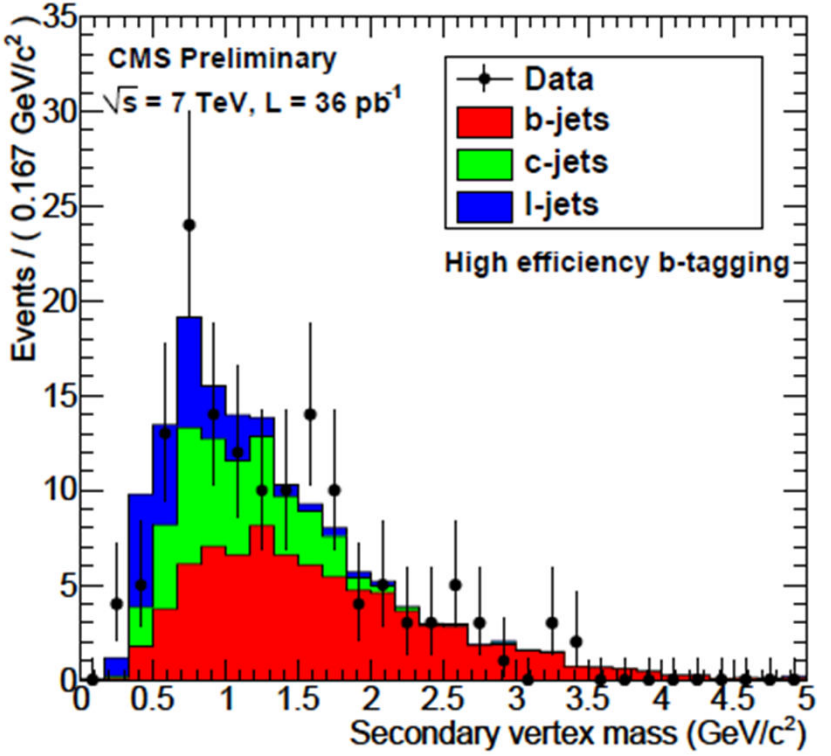
Ratio	MCFM (CT10)	MCFM (MSTW08)	MCFM (NNPDF21)
$R_c^{\pm}$	$0.915^{+0.006}_{-0.006}$	$0.881^{+0.022}_{-0.032}$	0.902 ± 0.008
R_c	$0.125^{+0.013}_{-0.007}$	$0.118^{+0.002}_{-0.002}$	0.103 ± 0.005

DESY

Z+b(b)

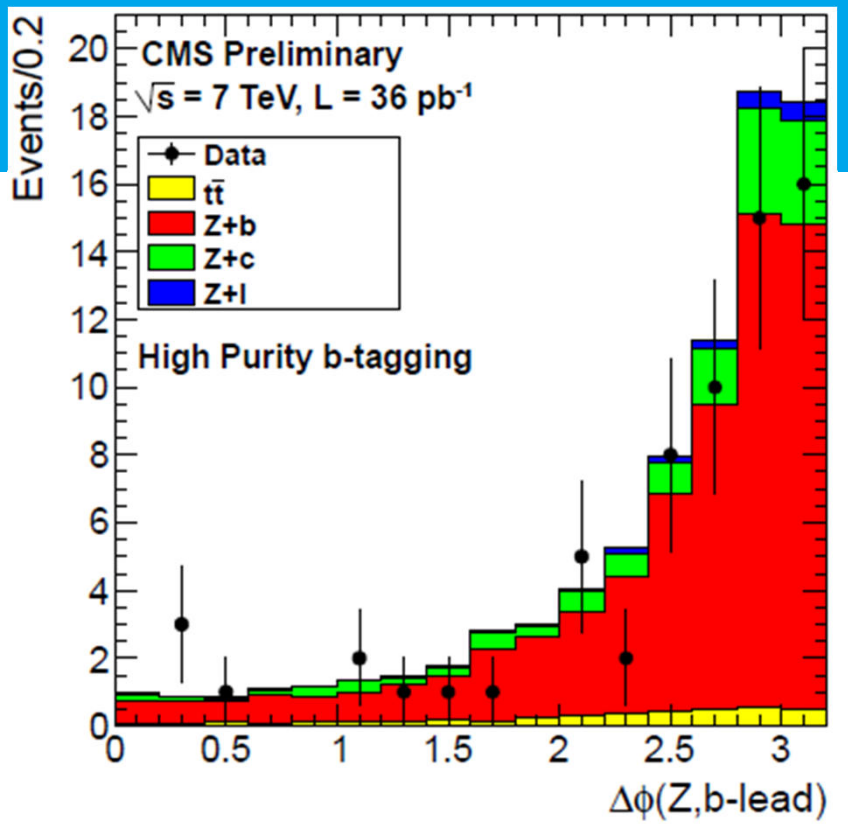
- Benchmark for other processes
  - Test of QCD calculations
  - b-PDF not well known (potentially constraining power)
  - associated b-jet and (SUSY) higgs production bbΦ
- Direct background
  - Top-pair in dilepton decay channel
  - Different channels of SM and SUSY higgs
- At least one b-jet
  - Secondary vertex b-tag
  - Purity from template fit of secondary vertex mass





CMS-PAS-EWK-10-015
(2010 – 36 pb^{-1})

Results in Z+b(b)



- Observation of Z+b in first data
  - Good description in control distributions
- Cross-section ratio
  - Good agreement with predictions

$$R_b = \frac{\sigma(Z^0 + b)}{\sigma(Z^0 + \text{jets})}$$

Sample	$\mathcal{R}(Z \to ee)$ (%), $p_T^e > 25$ GeV, $\lvert\eta^e\rvert < 2.5$	$\mathcal{R}(Z \to \mu\mu)$ (%), $p_T^\mu > 20$ GeV, $\lvert\eta^\mu\rvert < 2.1$
Data HE	$4.3 \pm 0.6(stat) \pm 1.1(syst)$	$5.1 \pm 0.6(stat) \pm 1.3(syst)$
Data HP	$5.4 \pm 1.0(stat) \pm 1.2(syst)$	$4.6 \pm 0.8(stat) \pm 1.1(syst)$
MADGRAPH	$5.1 \pm 0.2(stat) \pm 0.2(syst) \pm 0.6(theory)$	$5.3 \pm 0.1(stat) \pm 0.2(syst) \pm 0.6(theory)$
MCFM	$4.3 \pm 0.5(theory)$	$4.7 \pm 0.5(theory)$

- Cross-section measurement coming soon
- Potentially useful for flavour-dependent JES calibration of b-jets
  - Dominant uncertainty in top analyses

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Summary

- Many CMS electroweak analyses using jets
  - JES calibration
  - Exploit complementary decay channels (e.g. V→τ(τ), VV→llqq)
  - Associated V and jet production
- Test of SM in multiple observables
  - All results in agreement with SM predictions
- Important background for other processes (top, higgs, new physics)
- Associated production with heavy flavour
  - First results available
  - Possible constraining power for less known s-, c-, b-PDF
- Further analyses in progress (see backup)

Backup

Further Analyses in Progress

- Z+b — cross section — CMS-EWK-11-012 (in progress)
- Z+bb — angular correlations of both b — CMS-EWK-11-015 (in progress)
- W+jj — dijet mass (CDF anomaly) — CMS-EWK-11-017 (in progress)
- V+jets — differential distributions — CMS-EWK-11-008 (in progress)

- W+b — missing this year

- Updates of recent analyses with more statistics

Reconstructed Object Selection (V+jets and V+HF)

- Common electroweak identification and isolation criteria for leptons
- Particle flow jets (common identification criteria) and particle flow missing E_T
- Muons
  - $|\eta|<2.1$ (efficient muon trigger region)
  - second (veto) muon sometimes with $|\eta|<2.4$ (muon system acceptance)
  - $p_T>20$ GeV or >25 GeV , second (veto) muon sometimes with $p_T>10$ GeV
- Electrons
  - $|\eta|<2.5$ (tracker acceptance)
  - Exclude $1.4442<|\eta|<1.566$ (barrel/endcap transition)
  - $p_T>20$ GeV or >25 GeV , second (veto) electron sometimes with $p_T>10$ GeV
- Jets (anti-kt with $\Delta R=0.5$)
  - $|\eta|<2.4$, for HF $|\eta|<2.1$ (jets fully in tracker acceptance)
  - $p_T>20$ GeV or >25 GeV or >30 GeV

W/Z Selection

- Analyses on 2010 data with single lepton (electron or muon) trigger
- W definition
  - One charged lepton
  - M_T>50 GeV (W+c)
  - M_T>20 GeV and veto on second lepton with loose cuts (V+jets)
- Z definition
  - Two leptons of opposite charge with identical selection (Z+b)
  - One tight lepton and one loose lepton of opposite charge