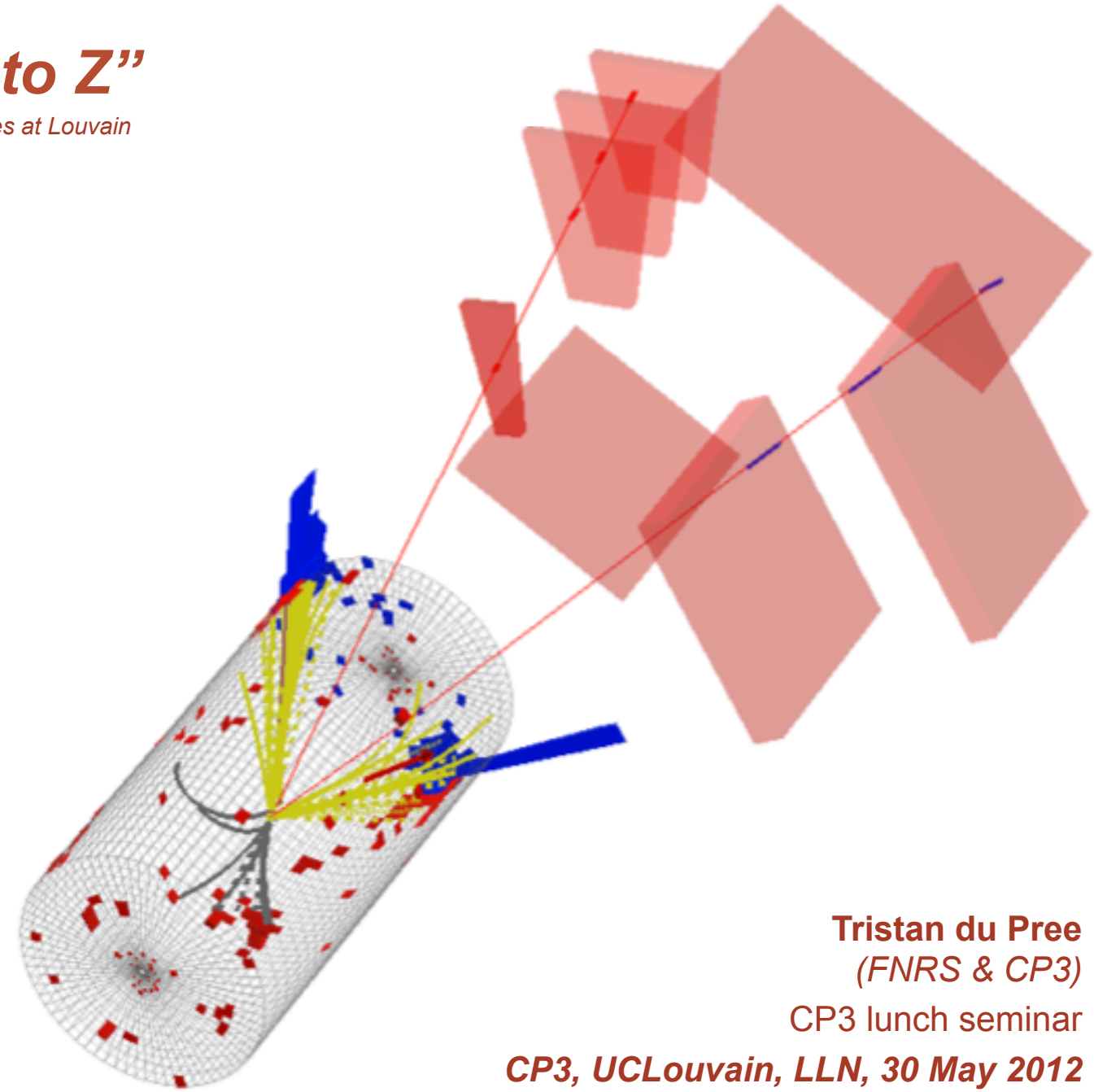
Z+b: *"from b to Z"*

1.5 years of experimental Z+b studies at Louvain

- *Introduction to V+J*
- *Z+b at CMS*
- *V+b/c at the LHC*
- *Higgs and beyond*



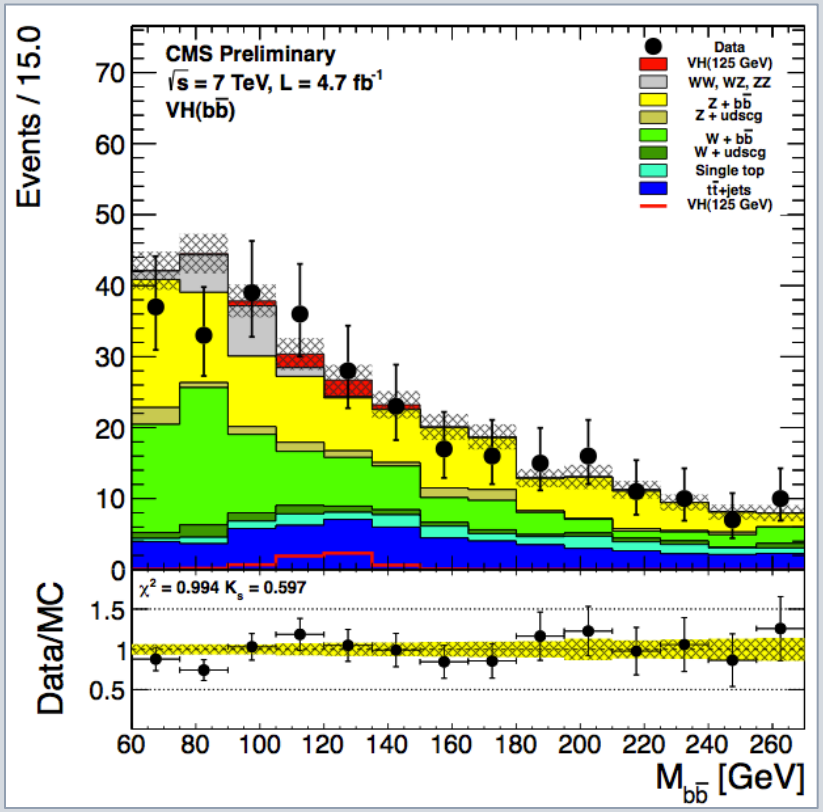
Tristan du Pree
(FNRS & CP3)

CP3 lunch seminar

CP3, UCLouvain, LLN, 30 May 2012

Why V+jets?

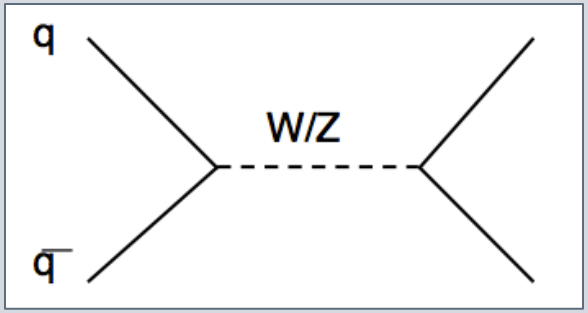
- **A simple answer:**



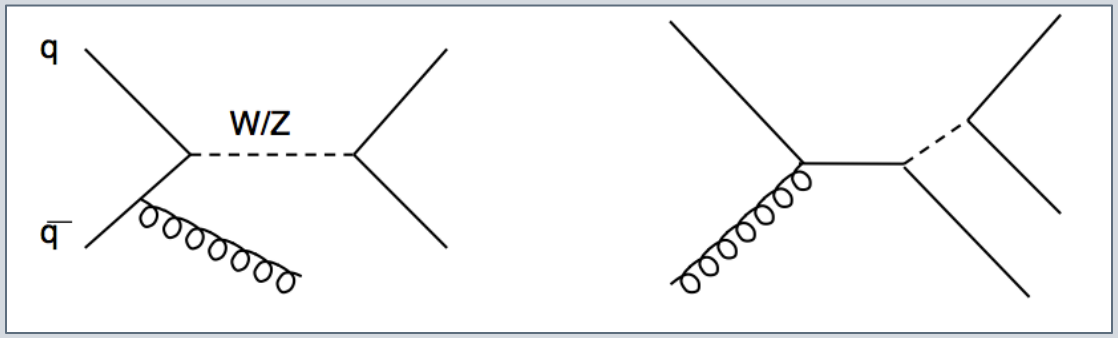
- **Background in many searches!**

W/Z+jets production

- **Vector boson** production in the s-channel:

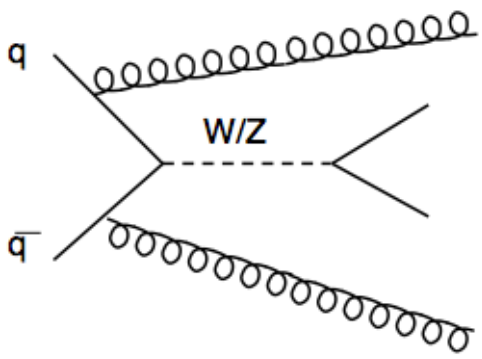


- **Extra jets** from QCD radiation
  - +crossed diagrams



W/Z+jets difficulties

- **Difficult to calculate with many jets**
  - Recently done at NLO with up to 4(3) jets for W(Z)
    - Uncertainties 10%-30% due to PDFs and perturbative nature of calculations
  - ME+PS Monte Carlo are the main tools for simulation

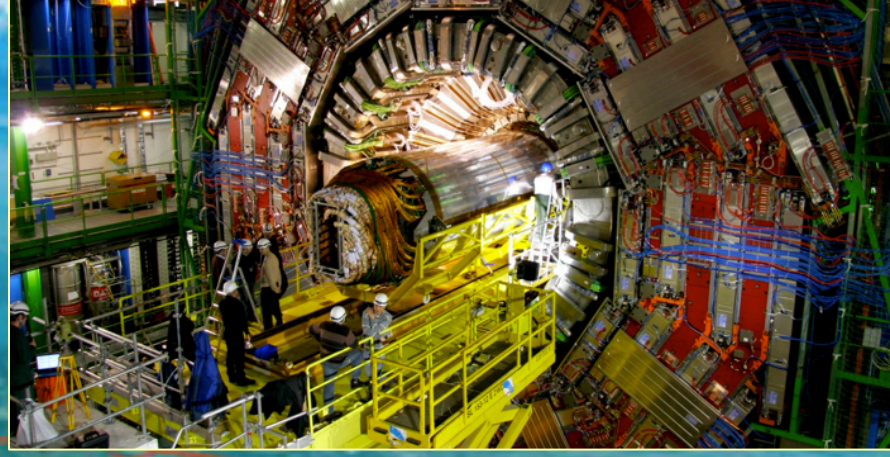


Final state:
Jets + leptons (+missing energy)
Like new physics!

- **EWK+QCD,** hard to calculate for large number of jets
  - Study backgrounds in data
  - Learn about QCD!

LHC in 2011

- **pp, 3.5x3.5 TeV**
- Peak luminosity: **3.5×10^{33} $cm^{-2}s^{-1}$**
- Recorded luminosity: **5.2 fb^{-1}**
- Studied luminosity in this talk:
  - **36 pb^{-1}** (2010) or
  - **2.1 fb^{-1}** (2011A)



CMS V+jets

Leptons:

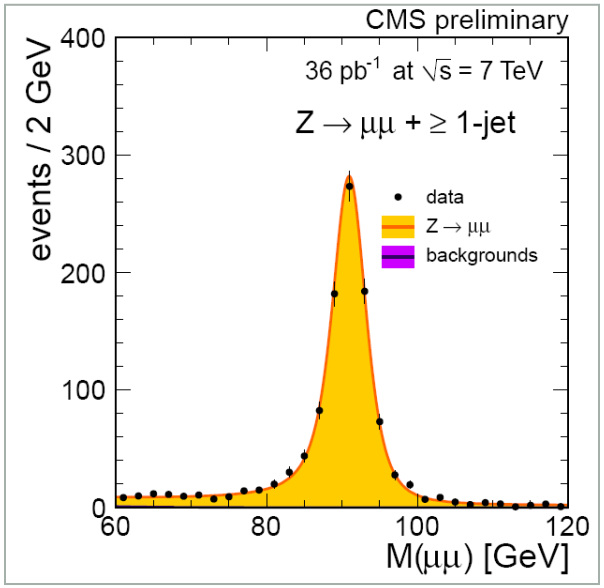
- **$p_T(l) > 20$** GeV/c
- **$\eta(e/\mu) < 2.5/2.1$**

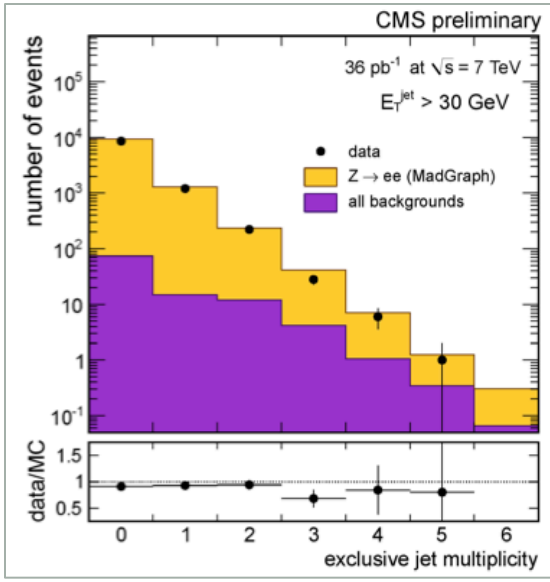
Jets (anti-k_T, PF)

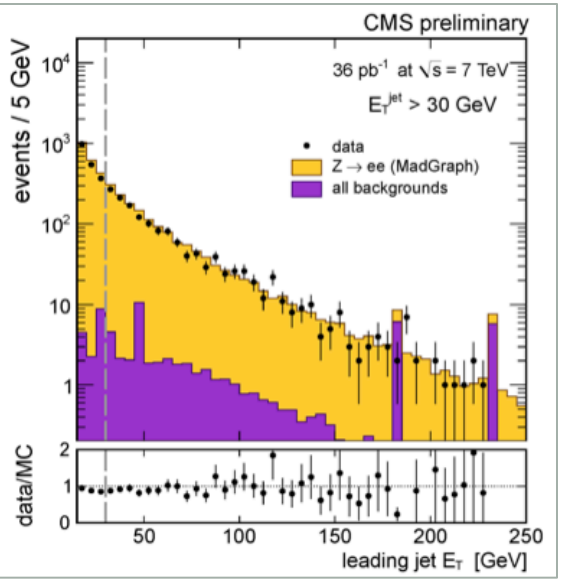
- **$p_T(j) > 25$** GeV/c
- **$\eta(j) < 2.4$**
- **R = 0.5**
- **$\Delta R(l,j) > 0.3$**

Z+jets

- Select leptons
  - 60 < M(ll) < 120
- ➢ Clean **Z peak**
- ➢ and **jets!**



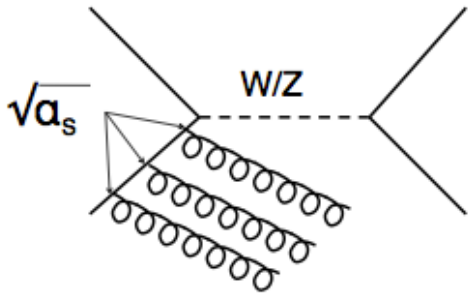




- **Compare**
  - Jet E_T
  - Jet multiplicity
- **With MadGraph predictions**

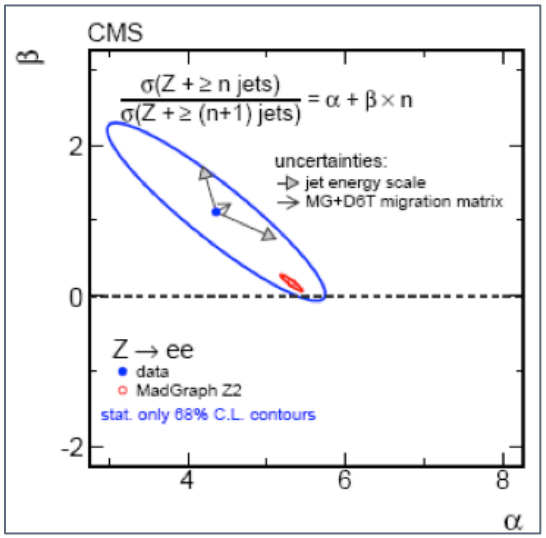
Jet multiplicity

- Example: test **Berends-Giele scaling**



Leading order: $\sigma(N_{jet}) \sim \exp(c^*\alpha_s N_{jet})$

- **Measure c**
  - Hard to compute in QCD
- **Best description?**
  - $\sigma(N_{jet}) \sim \sigma(N_{jet}\text{-}1)/\alpha$
    - Tevatron
  - $\sigma(N_{jet}) \sim \sigma(N_{jet}\text{-}1)/(\alpha + \beta N_{jet})$
    - Nonzero β?

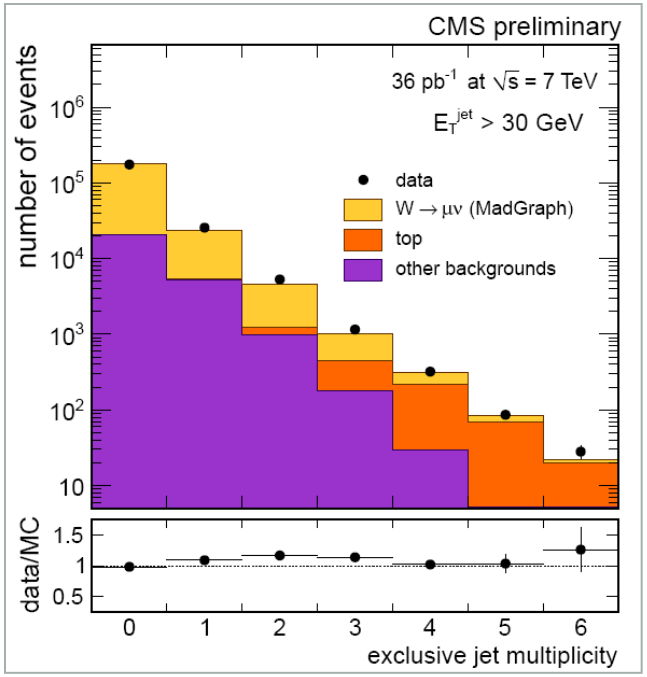


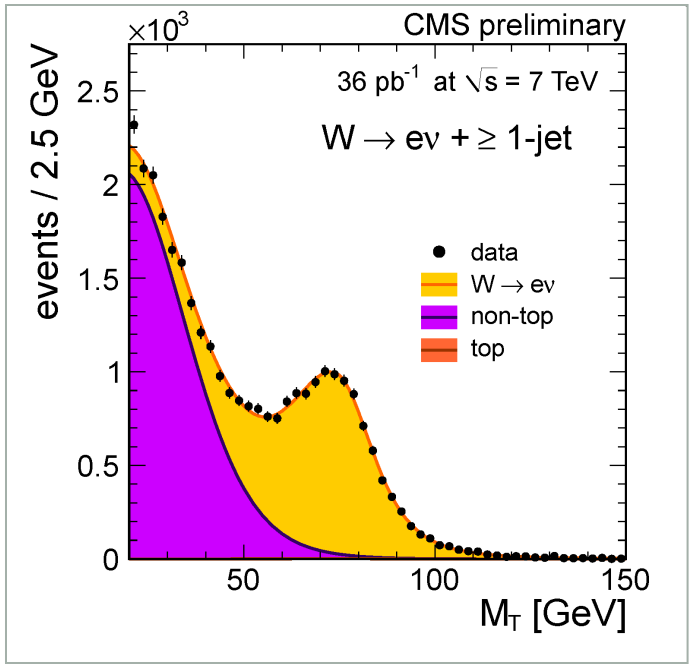
W+jets

W+jets wrt Z+jets:

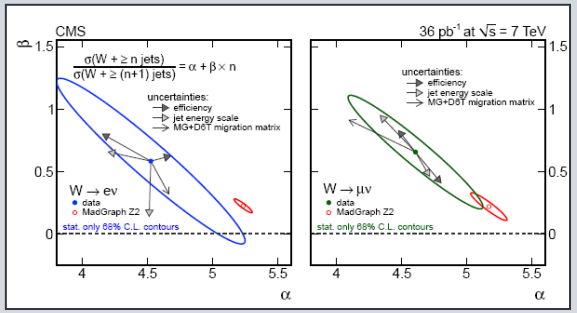
Two leptons ➔ one lepton + M_T

$$M_T = \sqrt{2 \times p_T^{lept} p_T^{\nu} \left(1 - \cos(\Delta\varphi)\right)} > 50 GeV$$





- **Global 3D fit**
  - M_T
  - jet-multiplicity
  - #b-jets
- **Scaling, like Z+j:**



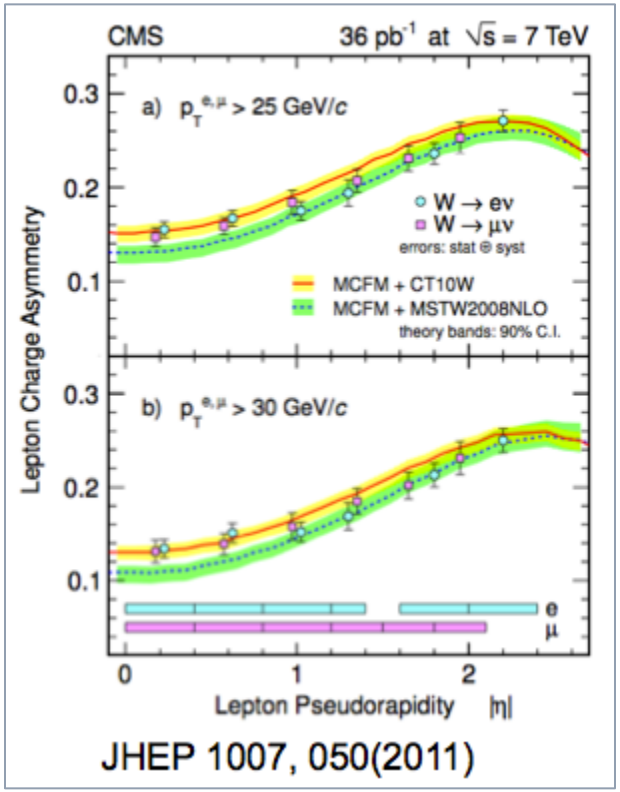
V+J results

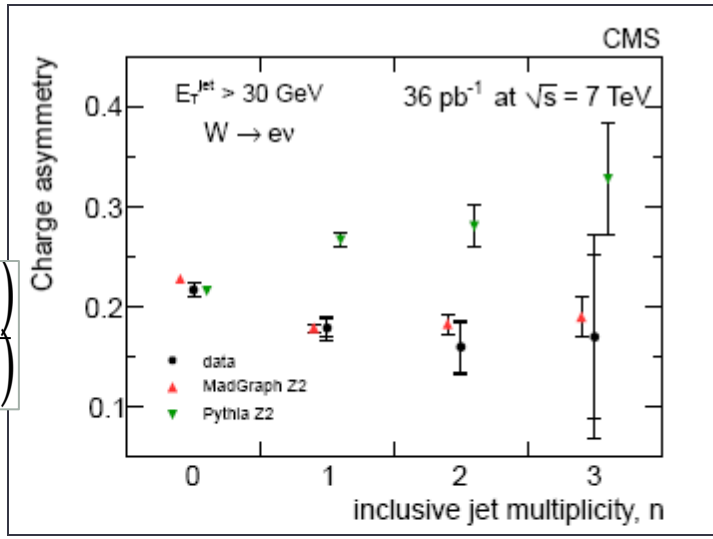
Some CMS highlights

- **W+J charge asymmetries**
  - PDFs

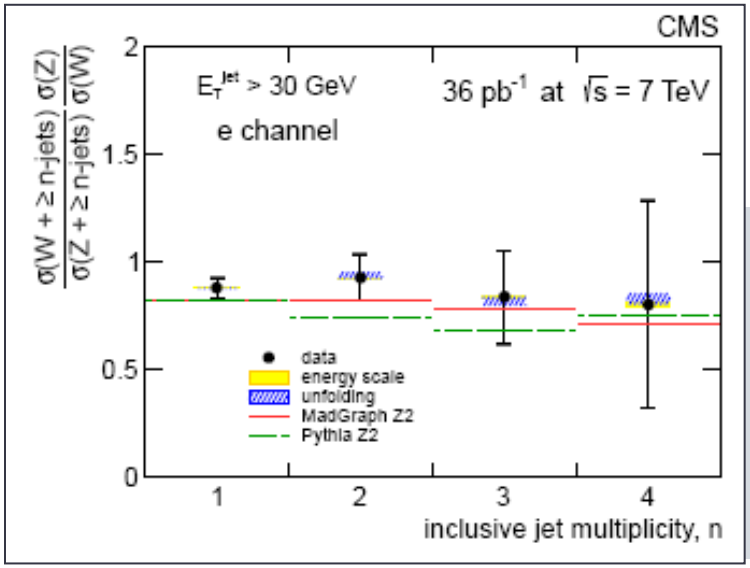
$$A_W = \frac{\sigma(W^+) - \sigma(W^-)}{\sigma(W^+) + \sigma(W^-)}$$

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})},$$



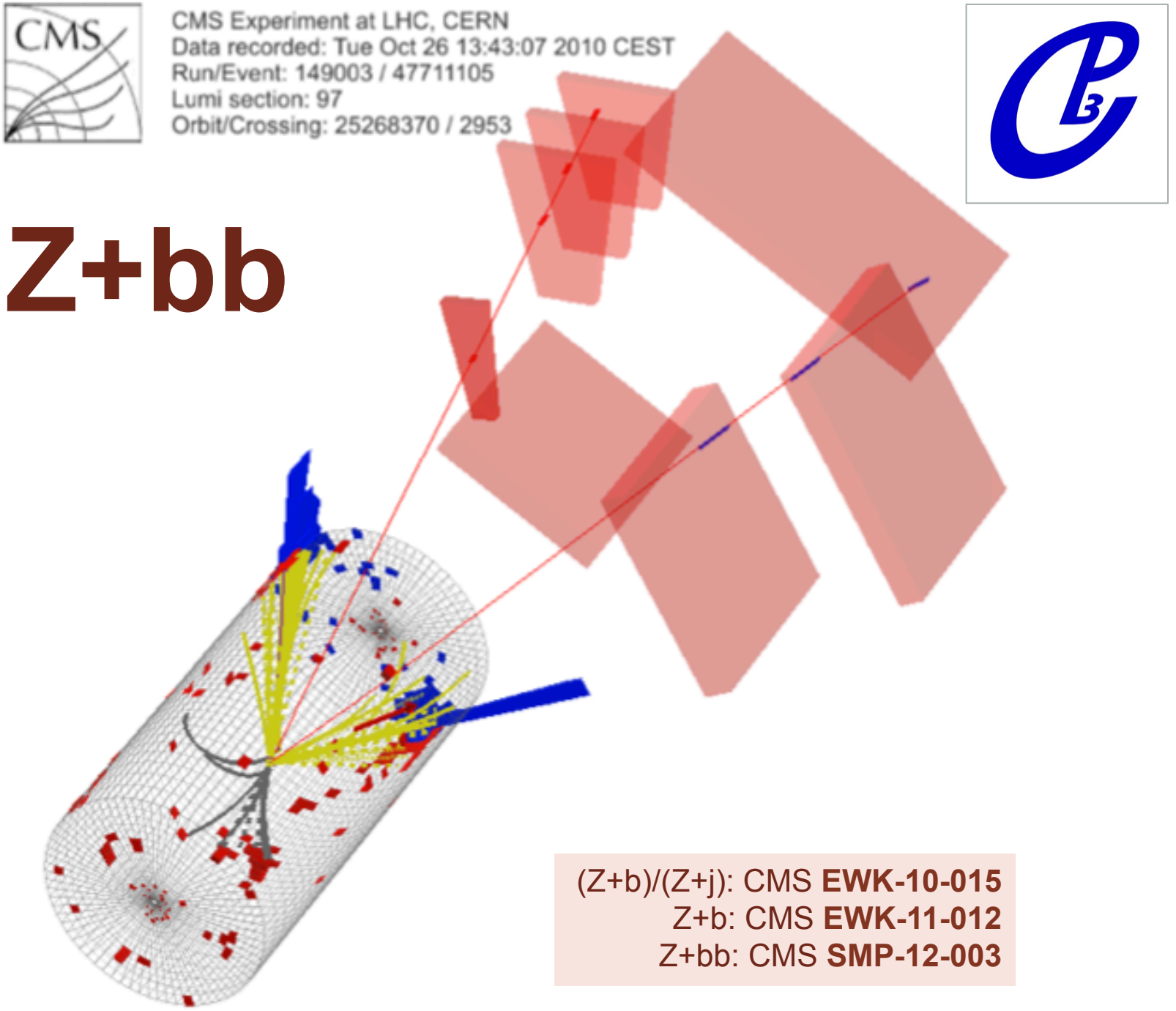


- Correct description by MadGraph
  - Not by Pythia!



Ratio (Z+j)/(W+j)

- **Reduce systematics**
  - Jet energy scale/ resolution, lepton efficiency, generator
  - **Well described by different generators**



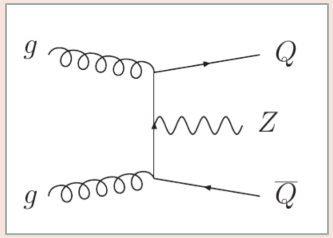
Z+bb

(Z+b)/(Z+j): CMS **EWK-10-015**
Z+b: CMS **EWK-11-012**
Z+bb: CMS **SMP-12-003**

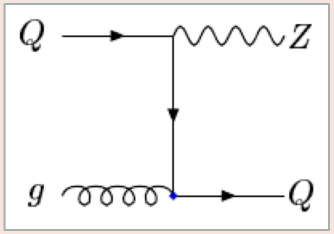
Z+b motivation

Z+1b: test QCD predictions

Fixed flavor scheme
(arXiv:hep-ph/1106.6019)
Massive b
Full event description
➢ aMC@NLO

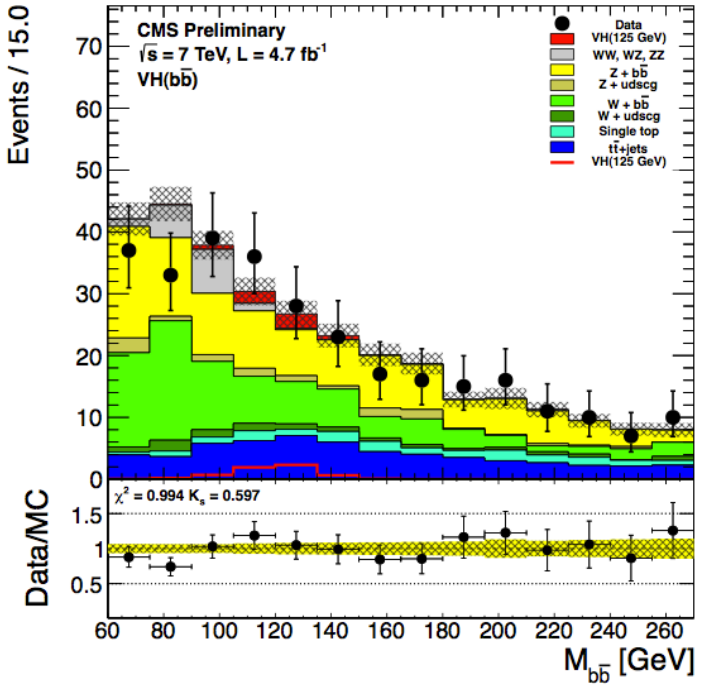


Variable flavor scheme
(arXiv:hep-ph/0312024)
Splitting inside PDF
Massless b
➢ Collinear approach



Z+2b: background and candle

- **Exotics**
  - *e.g.* 4th gen. b'→bZ search
- **MSSM** with large tanβ
  - bb+Φ(μμ,ττ,bb)
- **BSM Higgs**
  - *e.g.* H→Z+A(bb)
- **SM Higgs**
  - *e.g.* Z+H(bb)



Selection

Reconstruct **$Z \rightarrow l^+l^-$**…

- l = e/μ
  - p_T(e/μ) > 25/20 GeV
  - |η(e/μ)| < 2.5/2.1
- **76 < m(ll) < 106** (GeV)

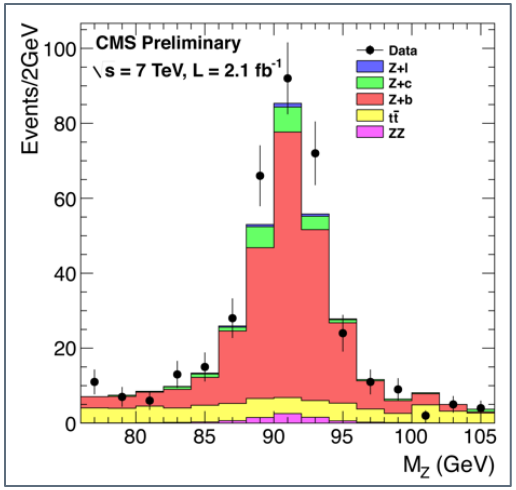
…and **two jets**…

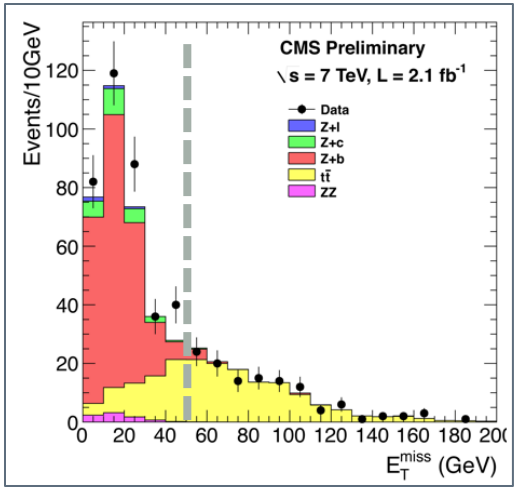
- PF, anti-k_T, ΔR=0.5
  - p_T > 25 GeV
  - |η| < 2.1
- Reduce tt with PFMet
  - **ME_T < 50** GeV

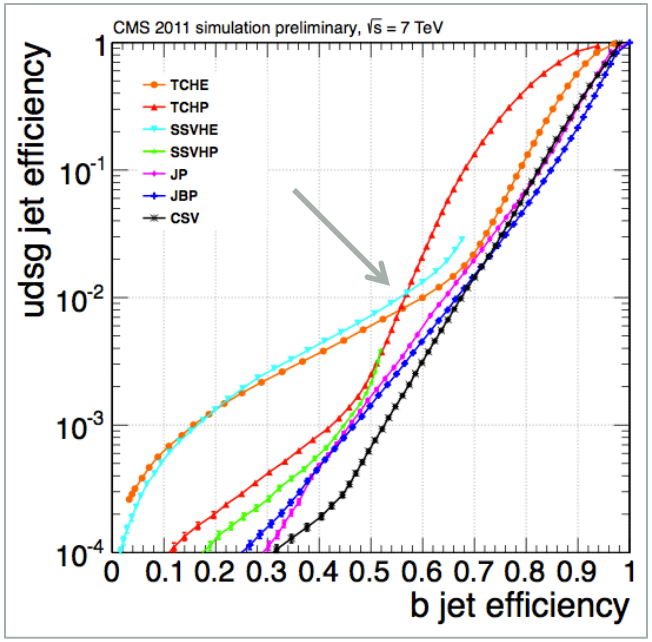
...with **b-tagging** ('SSVHE')

- Detached secondary vertex
  - High efficiency selection
    - Efficiency ~55%
    - udsg-mistag ~1%

➢ Select **Z(ll)+2b**

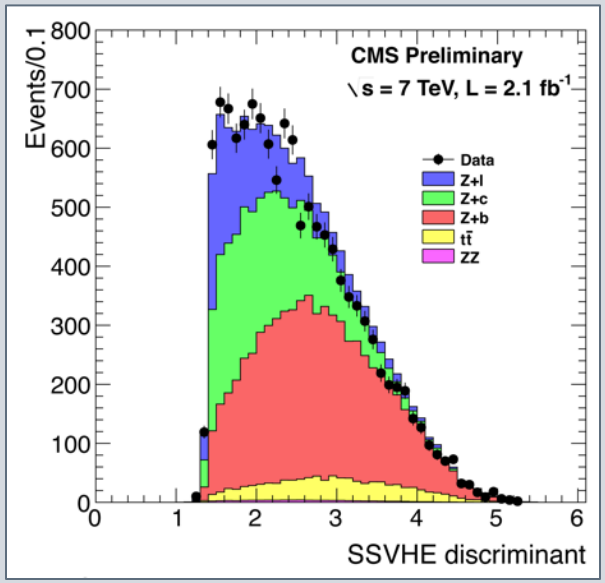






B-tagging

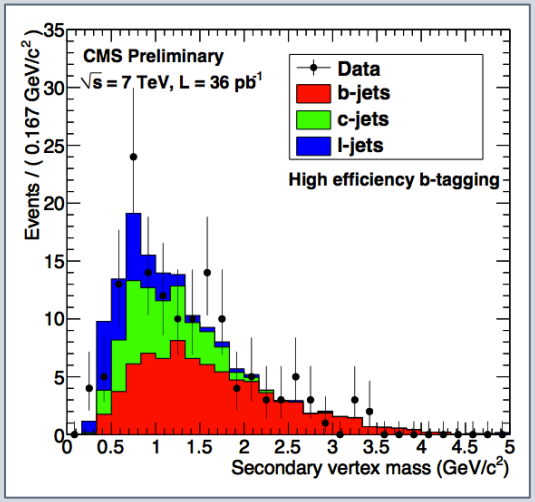
- **Require significantly displaced secondary vertex**
  - Exploit B lifetime
- **B-tag discriminator**
  - Plot: b/c/l fraction not fitted
  - Plot: b/c/l fractions and eff/mistag from MC



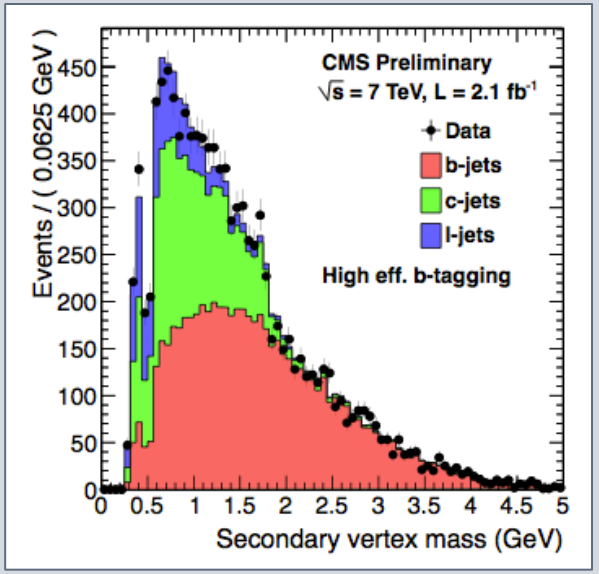
➢ **Estimate b-content from data!**

Z+b: b-purity

- **Invariant mass** of tracks from **secondary vertex**
  - Reconstruct charged tracks in detached jet



36 pb^{-1} ➔ 2.1 fb^{-1}

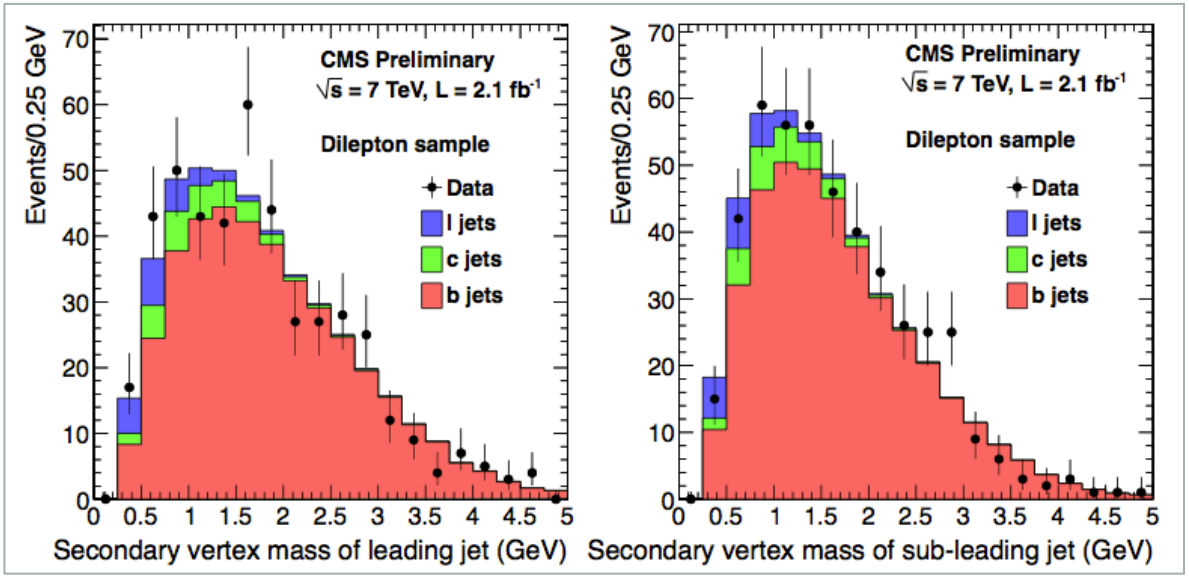


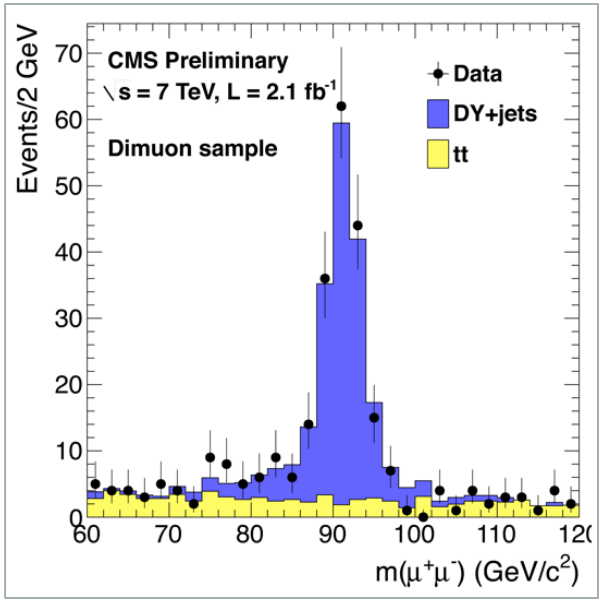
- Perform template **fit to extract purity**
  - Separate K/D/B meson contributions clearly visible!

Backgrounds

To convert yields into cross-section

- **Backgrounds** estimated from data
  - **ttbar**: fit to m(ll)
  - **ZZ**
    - From MC, scaled to CMS cross-section measurement
  - **Z+ucdsg**: b-jet purity
    - Template fit to secondary vertex mass distributions





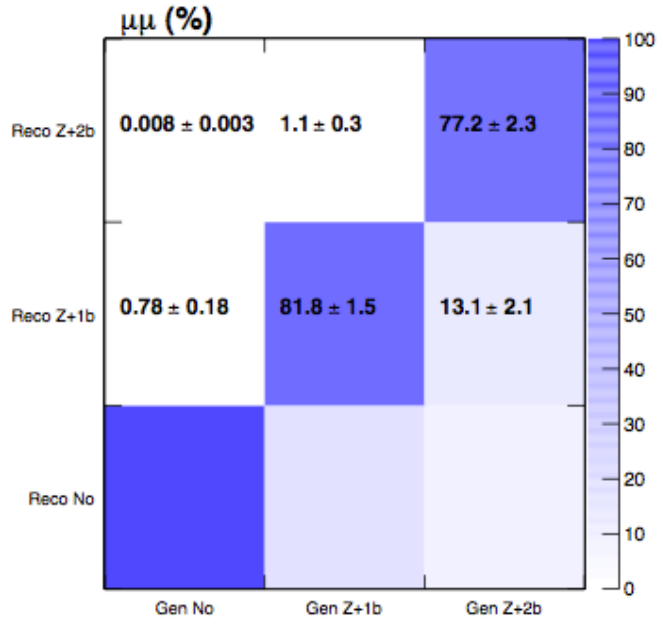
	μμ+bb	ee+bb
Yields	**219**	**148**
bb-purity	**(83 ± 6)%**	**(83 ± 6)%**
ttbar frac.	**(20 ± 5)%**	**(17 ± 5)%**
$N_{Z(ll)Z(bb)}$	**5.2 ± 0.2**	**3.0 ± 0.2**

Efficiencies

- **Z+1b and Z+2b** yields at hadron level: **unfold b-jet multiplicity**
- **# b-tagged** jets → **# reconstructed** b-jets → **# hadron-level** b-jets

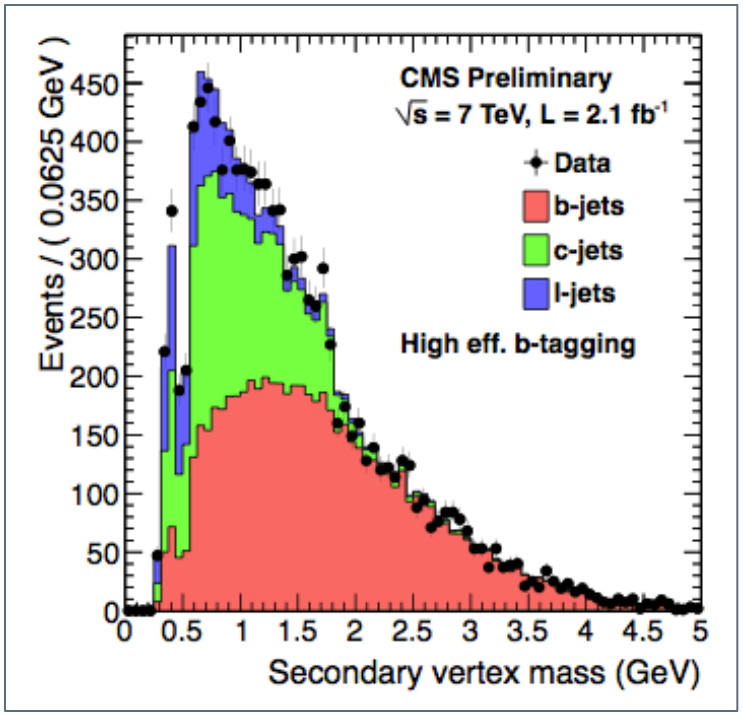
$$\begin{pmatrix} N^{gen}_{Z+1b} \\ N^{gen}_{Z+2b} \end{pmatrix} = \underset{A_l}{\begin{pmatrix} \frac{1}{A_l^1} & 0 \\ 0 & \frac{1}{A_l^2} \end{pmatrix}} \underset{\epsilon_r}{\begin{pmatrix} \epsilon_r^{11} + R\epsilon_r^{01} & \epsilon_r^{21} + R\epsilon_r^{01} \\ \epsilon_r^{12} + R\epsilon_r^{02} & \epsilon_r^{22} + R\epsilon_r^{02} \end{pmatrix}^{-1}} \underset{\epsilon_l}{\begin{pmatrix} \frac{1}{\epsilon_l^1} & 0 \\ 0 & \frac{1}{\epsilon_l^2} \end{pmatrix}} \underset{\epsilon_b}{\begin{pmatrix} \frac{1}{\epsilon_b^{11}} & -\frac{\epsilon_b^{21}}{\epsilon_b^{22}\epsilon_b^{11}} \\ 0 & \frac{1}{\epsilon_b^{22}} \end{pmatrix}} \begin{pmatrix} N^{tag}_{Z_{sel}+1b} \\ N^{tag}_{Z_{sel}+2b} \end{pmatrix}$$

- **ϵ_b: b-tagging efficiency**
  - Scale MC to data expectations, using a.o $p_T$rel
- **ϵ_l: lepton selection efficiency**
  - Scale MC to data expectations, using tag&probe
- **ϵ_r: detector resolution**
  - Correct yields to generator level in acceptance
- **A_l: lepton acceptance**
  - Correct to full lepton acceptance



Z+b analysis overview

- **Selection**
  - Reconstruct Z+jets
  - Require significantly detached secondary vertex



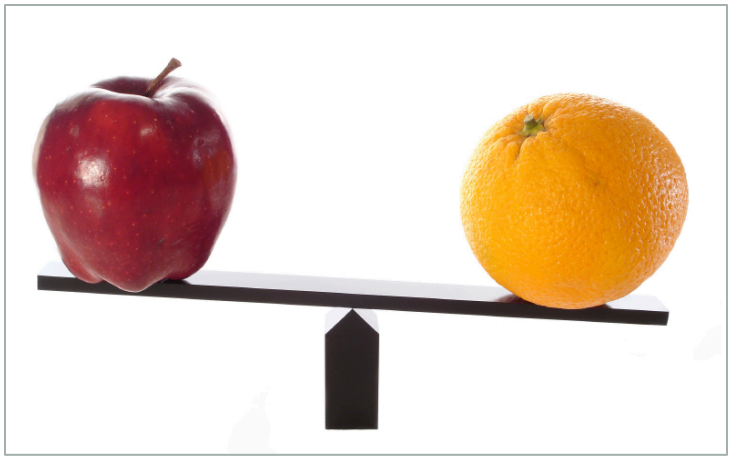
- **Take into account**
  - B-tag efficiency
  - B-purity
  - Ttbar
  - Lepton efficiencies
  - 'Unfolding'
    - ➢ to parton level

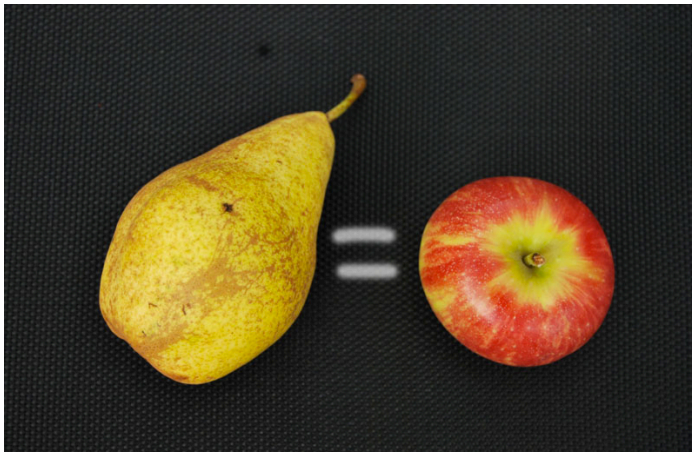
MC

- Corrections from detector effects using **MC Madgraph** signal sample.
- Comparison with **fixed order NLO** calculation
  - ➢ Correct MCFM for non-perturbative effects using MC Madgraph signal sample.
- Comparison with other generators
  - ➢ **Sherpa, aMC@NLO**

How to compare

…between the **different experiments**…





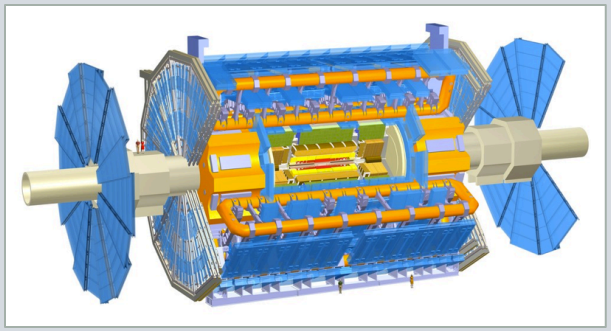
… and between **experiment & theory**

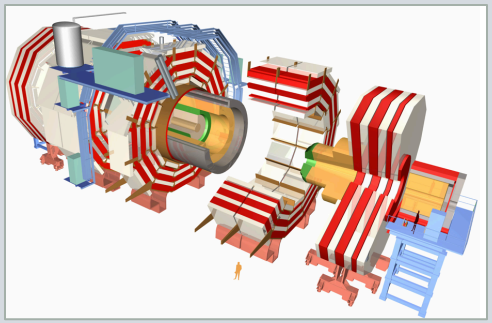
Sketch of procedure

Atlas

CMS

Experiment





Alpgen
Sherpa
Pythia

Particle level

MadGraph
Sherpa
aMC@NLO

NLO theory

- **Observables**
  - Phase-space definitions at particle level
- **Theory uncertainty**
  - Experiment → particle level
- **Compare to NLO calculation**
  - NLO→parton level?
  - Parton → hadron
  - E.g.: Jet radius

Systematics

Table 2: Fractional uncertainties on the cross section measurement from the different sources considered.

Correlated sources	Fractional uncertainty (%)	
b-tagging efficiency	10	
b-jet purity	5.6 (ee+b)	4.6 ($\mu\mu$+b)
$t\bar{t}$ contribution	2.9	
Jet energy scale	2.5	
Luminosity	2.2	
Jet energy resolution	0.5	
Pile-up	1.5 (ee+b)	0.5 ($\mu\mu$+b)
Mistagging rate	0.04	
Theory (via $\mathcal{A}_\ell$)	$^{+4.2}_{-6.5}$	
Theory (via $\mathcal{C}_{\text{hadron}}$)	$^{+0.7}_{-6.9}$	
Uncorrelated sources	**ee+b**	**$\mu\mu$+b**
Trigger and dilepton selection	4	2
$t\bar{t}$ contribution	1.9	2.2
Experimental systematic	13.0	12.3
Theoretical systematic	$^{+4.2}_{-9.5}$	$^{+4.2}_{-9.5}$
Statistical	2.2	1.7

- **Main uncertainties from**
  - B-tagging
    - Efficiency, purity
  - Theory uncertainties

Z+b results

Z+b/Z+j

Spring 2011

- Relative cross-section
  - Probe of b-pdf
- 2010 data: 36 pb^{-1}
- **$\sigma(Z+b)/\sigma(Z+j)$ = 5.4%** ± 1.6% ($\mu^+\mu^-$)
  - e^+e^-: 4.6% ± 1.4%

Z+1b

Winter 2011/2012

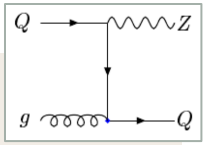
- Absolute cross-section
- 2011 data: 2.1 fb-1
- **$\sigma(Z+1b)$ =**
  3.41 ± 0.05 (stat.) ± 0.27 (syst.) ± 0.09 (theory) **pb**

Z+2b

Spring 2012

- Absolute cross-section, 2.1fb^{-1}
- **$\sigma(Z+2b)$ =**
  0.37 ± **0.02** (stat.) ± **0.07** (syst.) ± **0.02** (theory) **pb**
- **$\sigma(Z+b)$ =**
  3.78 ± 0.05 (stat.) ± 0.31 (syst.) ± 0.11 (theory) **pb**

In agreement



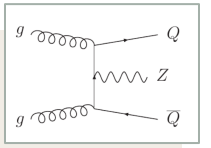
1. with MCFM (NLO) and MadGraph (LO fixed-flavour)
   - 4.3% ± 0.5% (4.7% ± 0.5%)
2. with MadGraph

‘Tension’

with MCFM (NLO) and MadGraph (LO fixed-flavour)

- 2-3 sigma

In agreement



with expectation

- $\sigma(Z+2b)$ = 0.33 ± 0.01(stat.) pb

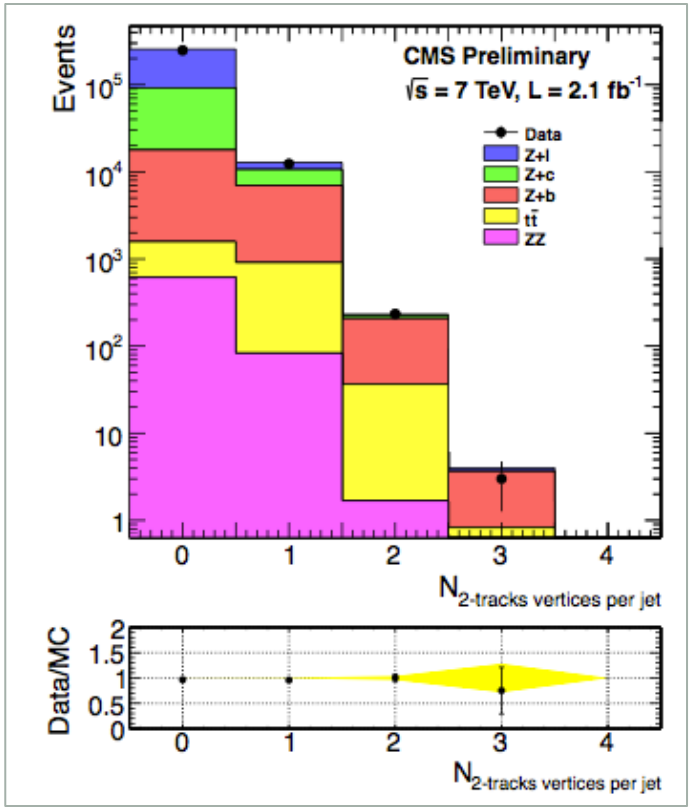
Z+bb

on a single slide

- CMS: Z+b(b) **cross section**
  - Select events, subtract background
  - Estimate efficiencies from MC
    - Scale to data expectations
  - Unfold b-multiplicity
- MadGraph expectation
  - Scaled to (DY+j) NLO

➢ **σ(Z(ll)+2b) = 0.33 ± 0.01**(stat.) **pb**

➢ **CMS results:**



Z(ll)+nb	Cross section σ_{hadron} $p_T(l)>20$ GeV and $\|\eta(l)\|<2.5$ (acc. = 84%(e)-89%(μ), full acc.: acc. = 56%(e)-59%(μ))
Z(ll)+2b	**0.37** ± **0.02** (stat.) ± **0.07** (syst.) ± **0.02** (theory) **pb**
Z(ll)+1b	3.41 ± 0.05 (stat.) ± 0.27 (syst.) ± 0.09 (theory) pb
Z(ll)+b	3.78 ± 0.05 (stat.) ± 0.31 (syst.) ± 0.11 (theory) pb

- **Z+1b**
  - CMS observe ‘larger though consistent’ cross-section in data than predicted.
    - 2-3 sigma
    - MCFM NLO (5FNS MadGraph)

Kinematics

- **W+b**
  - [Atlas, arXiv:1109.1470, 35 pb^{-1}]
- **W+c**
  - [CMS, EWK-11-013, 36 pb^{-1}]
- **Z+b**
  - [Atlas, arXiv:1109.1403, 36 pb^{-1}]
  - [CMS, arXiv:1204.1643, **2.1 fb^{-1}**]
  - **Z+b/Z+j**: [CMS, SMP-10-015, 36 pb^{-1}]
- **Z+bb**
  - [CMS, SMP-12-003; **2.1 fb^{-1}**]
- **Z+2SV**
  - [CMS, EWK-11-015; **4.6 fb^{-1}**]

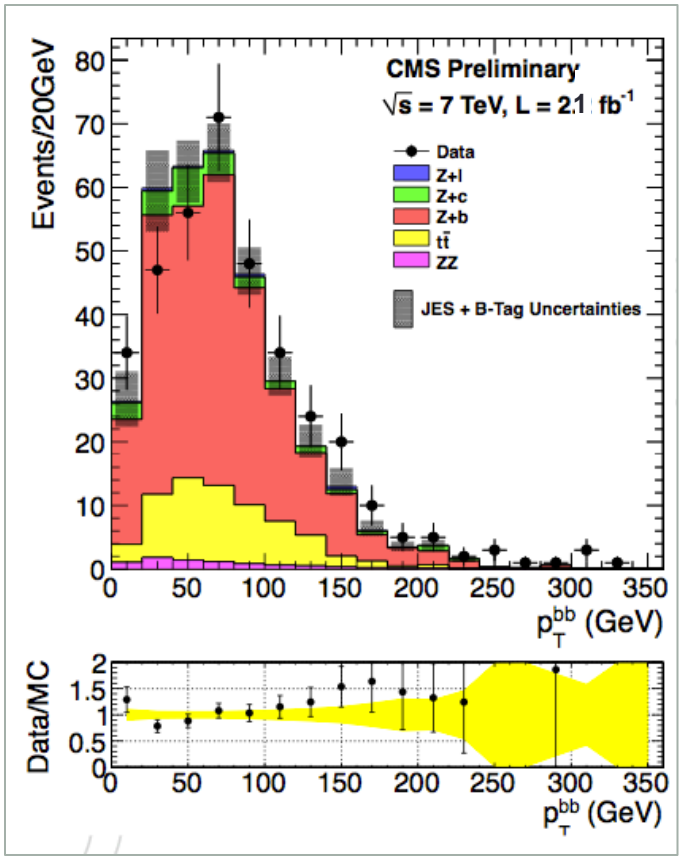
- Many V+HF results at the LHC…
  let's now focus on **kinematic 'tensions'**
  - In the high-statistics measurements

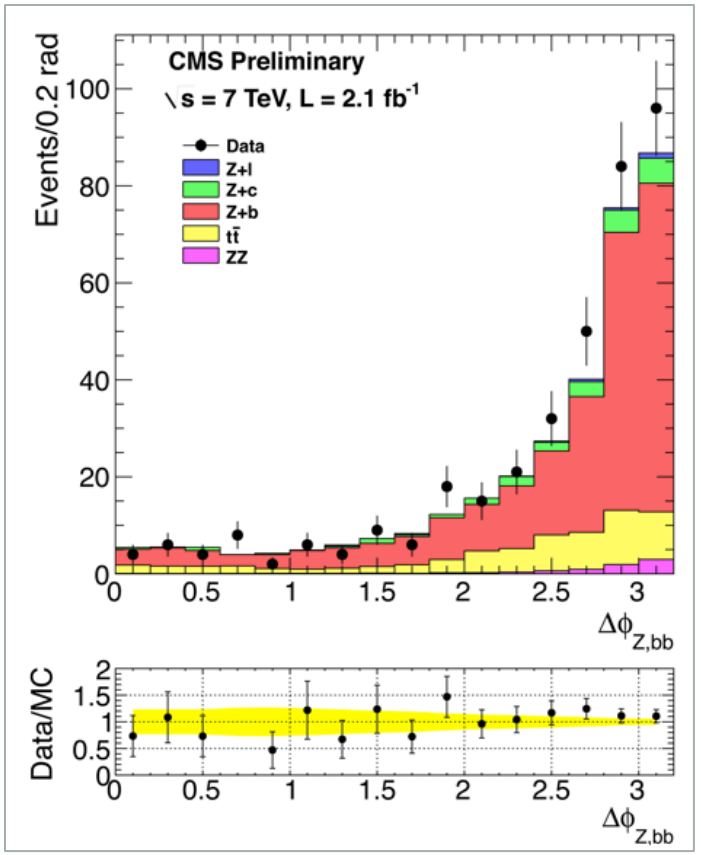
"Tensions" in Z+bb

SMP-12-003

MadGraph
generated in the 5-flavour scheme.
+ Pythia

- **p_T(bb)** harder in data than in MC
  - Consistent with angular distribution of bb wrt Z
    - NB: typical selection in search: p_T(jj),p_T(ll)>100



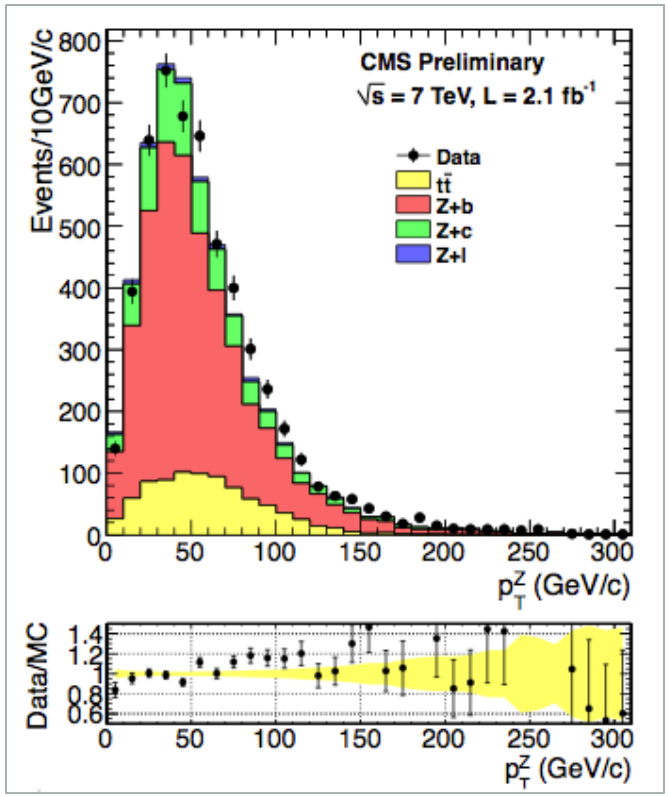


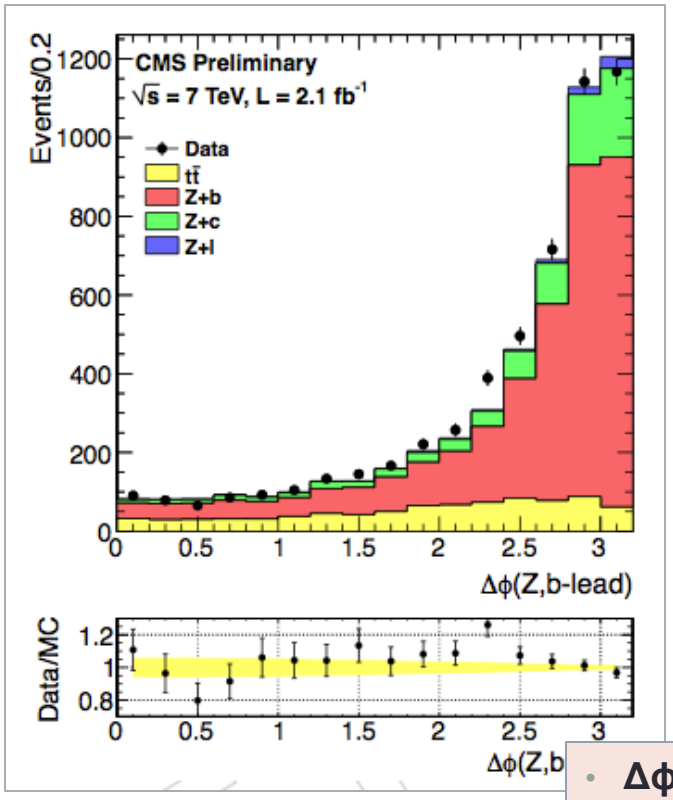
$p_T(Z)$ & $\Delta\Phi(Z,b)$
Z+1b

EWK-11-012 + JHEP

MadGraph generated in the 5-flavour scheme. + Pythia

- **$p_T(Z)$ harder**
  - Qualitatively like kinematics in Z+bb





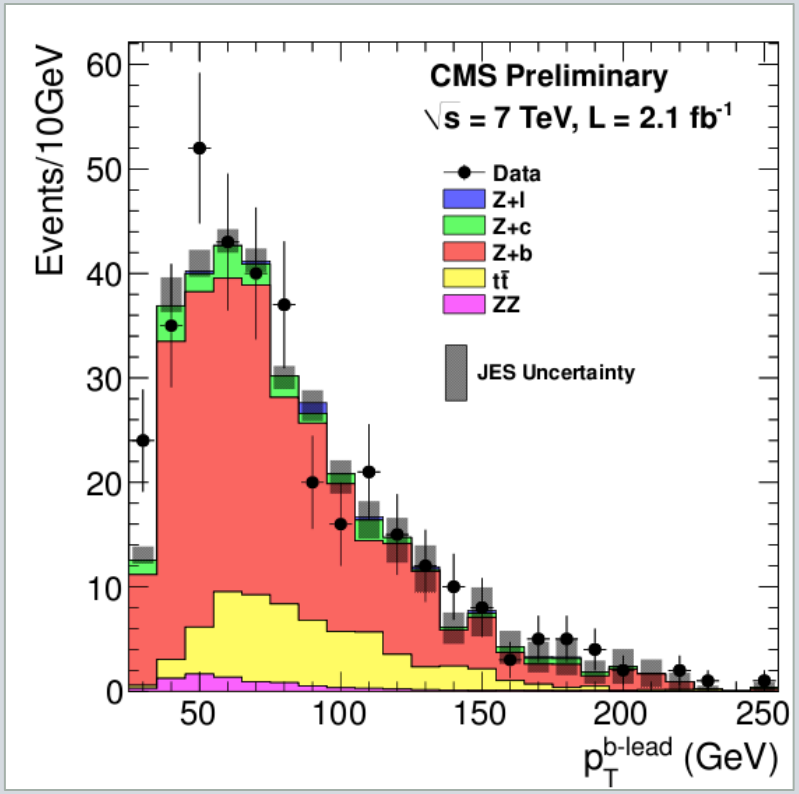
- **$\Delta\phi(Z,b)$ & $p_T(b)$**
  - Lack of hard radiations?
- **$p_T(Z)$: 4/5 flavour approach?**

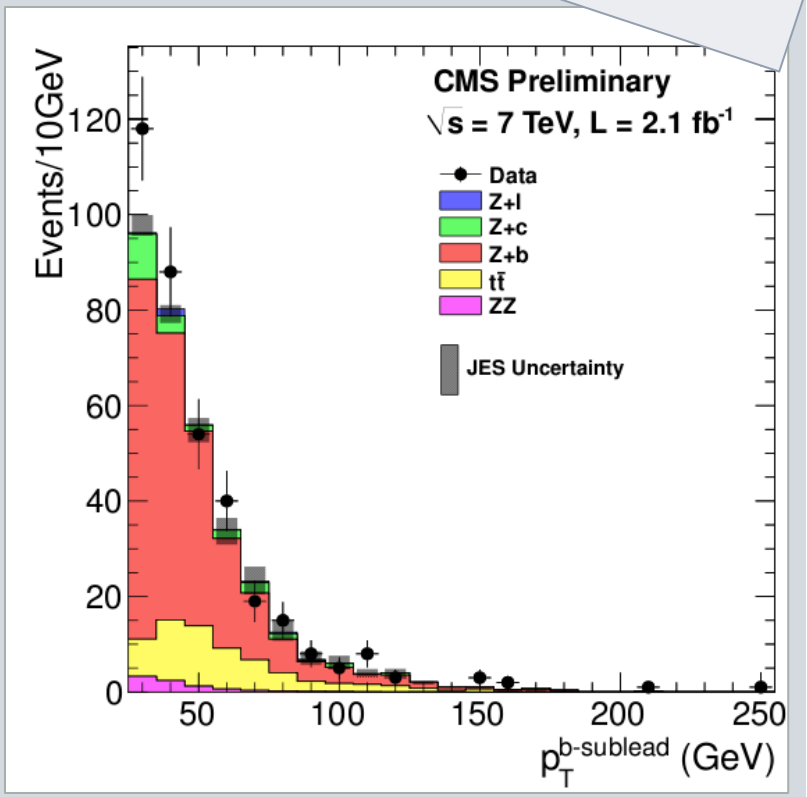
Kinematics comparison
Z+2b

SMP-12-003

MadGraph generated in the 5-flavour scheme. + Pythia

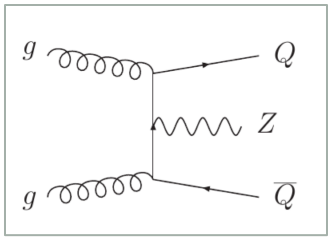
- **Leading & sub-leading b-p_T**





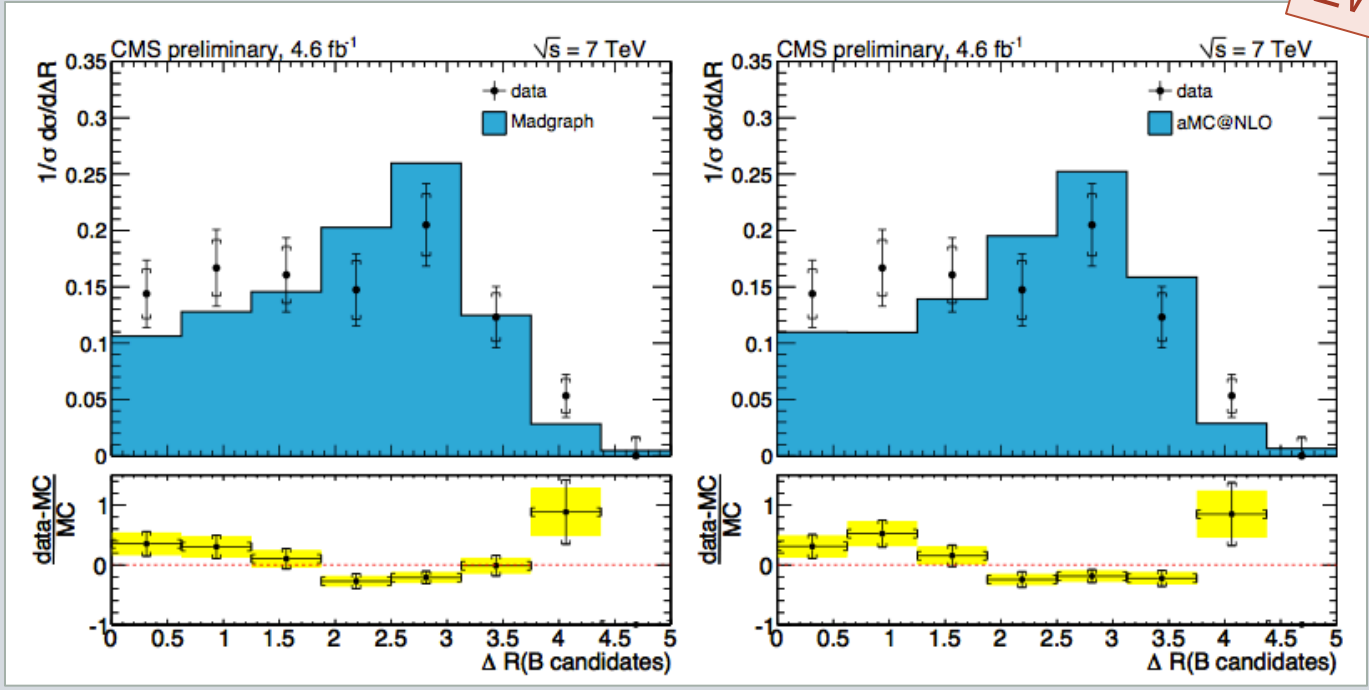
- **More statistics needed before conclusions can be drawn**

Z+2SV



- **ΔR(b1,b2): angle between the two displaced vertices of the b-hadrons**
  - Not using b-jets, but "Inclusive Vertex Finder" to find displaced vertex
    - Sensitivity at **small angles**

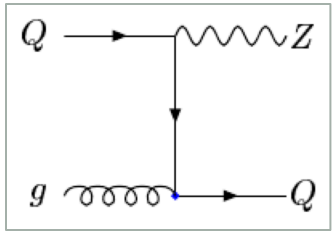
EWK-11-015



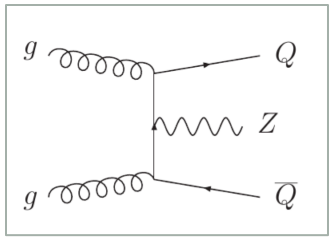
- **General shape disagreement**

Comparisons

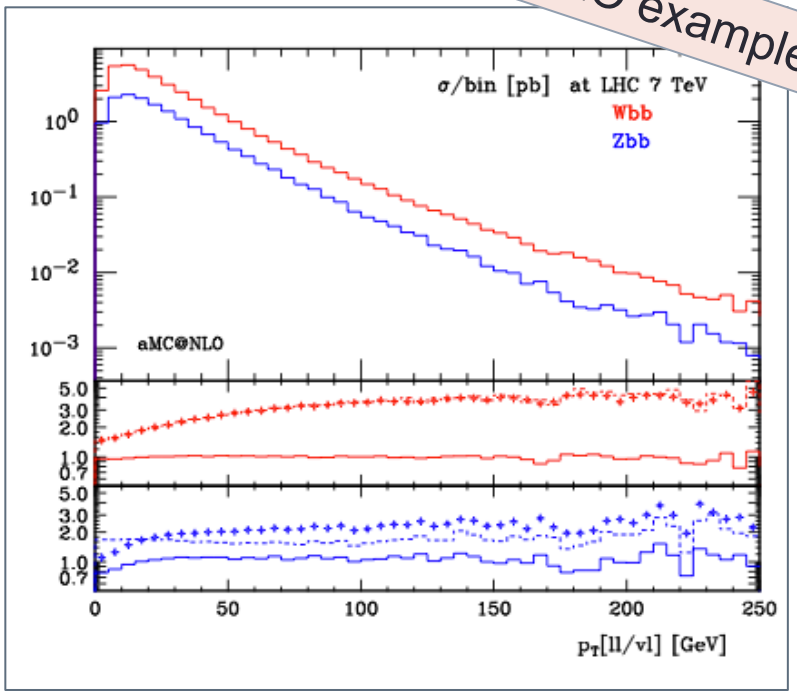
Currently
- **MadGraph 5F**
  - CMS
- **Alpgen**
  - Atlas



Plans
- **aMC@NLO**
- **MG 4F**
- **Sherpa**
- **…**
- **And more data!**
  - Full 2011 5fb^{-1} dataset



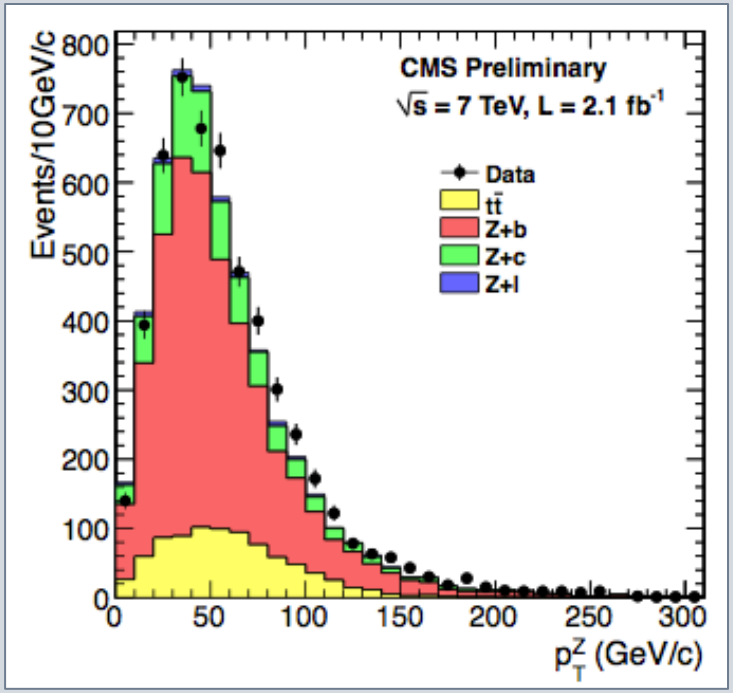
NLO example



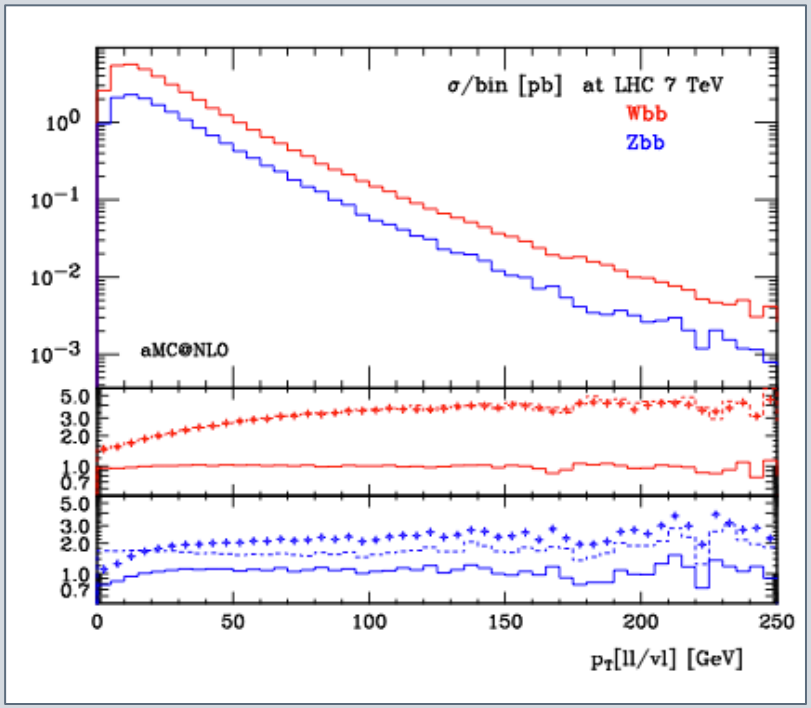
Compare
- LO vs NLO
- Massive b
- 4F vs 5F

Compare data & MC

- **CMS result**



- **aMC@NLO prediction**



- Distinguish LO/NLO
  - NLO results might impact 4/5 flavor approach
  - Of relevance for searches

V+HF at the LHC

(if time permits)

Measurements

- **Atlas & CMS**
  - Cross-section measurements:

Table 4: V+hf cross sections measured by ATLAS and CMS on 2010/11 data.

Publication	Distribution	Range	Channels
ATLAS $W+b$ [6]	$\frac{d\sigma(W+b)}{dn_{jet}}$	$n_{jet} = 1, 2, 1+2$	$e, \mu, e+\mu$
ATLAS $Z+b$ [7]	$\sigma(Z+b)$	inclusive in number of b jets	$e+\mu$
CMS $Z+b$ [8]	$\sigma(Z+b)$	inclusive in number of events with ≥ 1 b jet	$e, \mu, e+\mu$
CMS $Z+2b$ [9]	$\sigma(Z+1b)$	exclusive in number of b-jets	$e, \mu, e+\mu$
	$\sigma(Z+2b)$	inclusive in number of events with ≥ 2 b jet	$e, \mu, e+\mu$
	$\sigma(Z+b)$	inclusive in number of events with ≥ 1 b jet	$e, \mu, e+\mu$
CMS $W+c$ [10]	$\frac{\sigma(W^+\bar{c})}{\sigma(W^-)}$	inclusive	μ
	$\frac{\sigma(W+c)}{\sigma(W+jets)}$	inclusive	μ

  - And angular correlations:
    - CMS Z+2SV: study of the angle between two B-hadrons in association with a Z

W+c

- **CMS: W+c study**
  - CMS-PAS-EWK-11-013
    - Probe of strange content of proton

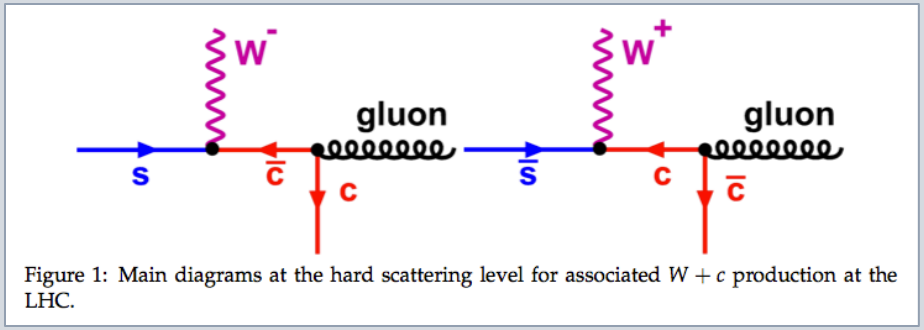
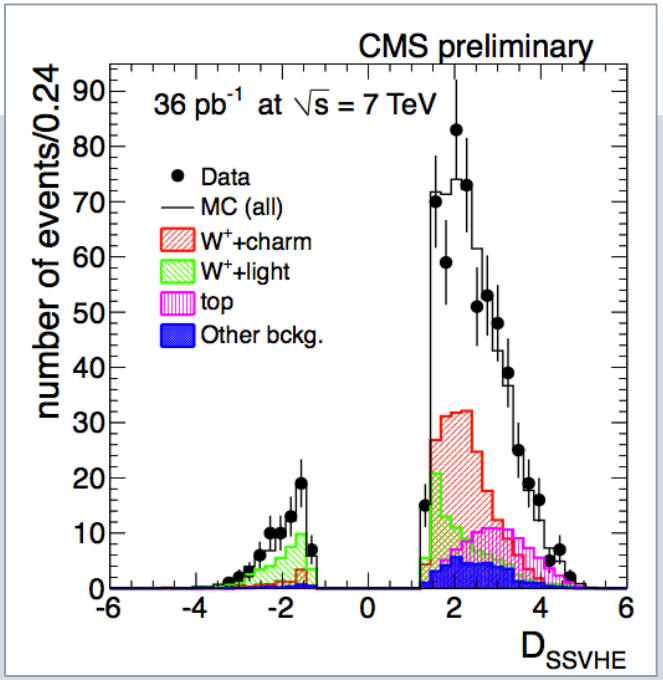


Figure 1: Main diagrams at the hard scattering level for associated $W + c$ production at the LHC.



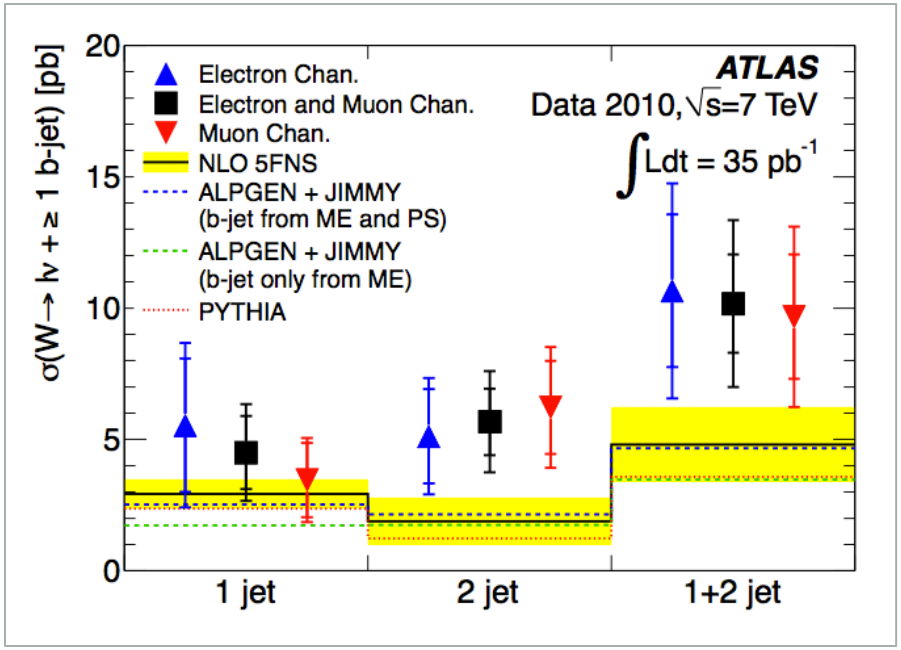
- **σ(W⁺cbar+X)/σ(W⁻c+X)** = 0.92 ± 0.19 (stat.) ± 0.04 (syst.)
- **σ(W+c+X)/σ(W+jet+X)** = 0.143 ± 0.015 (stat.) ± 0.024 (syst.)

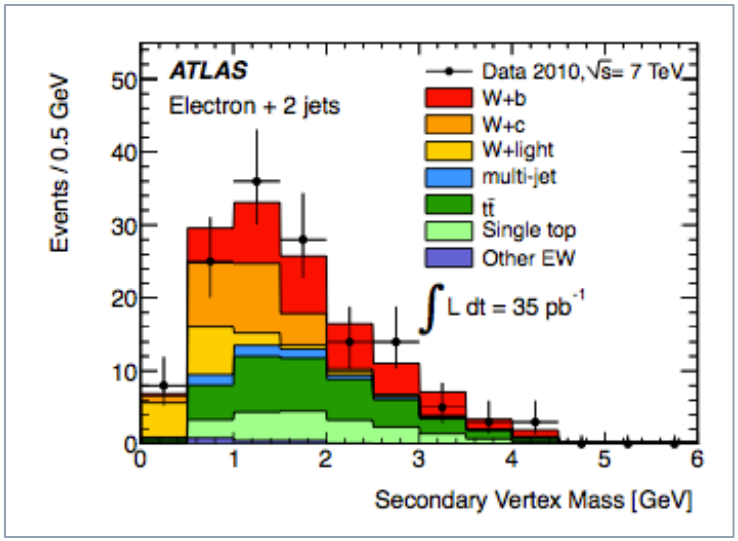
➢ **In agreement with theoretical predictions at NLO**

W+b

"Tension" in data/MC comparisons

- **W+b**
  - ATLAS observe 'tension' in cross-section
    - **~1.5 sigma**
    - NLO(5FNS) and LO (Alpgen+Jimmy)





Event fitted yield is corrected for detector effects with MC LO matched prediction for Wjets (including heavy flavour) from **ALPGEN**. Uncertainty ~20% stat and ~25% syst.

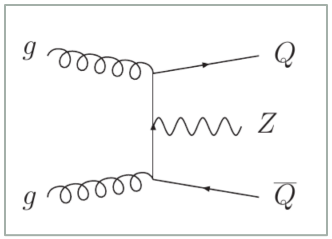
Dominant systematics

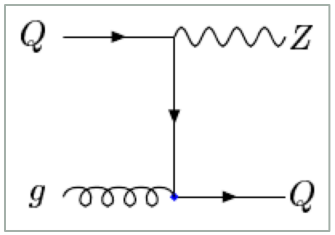
- B-tagging & m(SV) templates ~16%
- Top background ~12%
- QCD background ~7%
- W+b-jet modeling ~10%
- Jet+b-jet energy scale ~7%

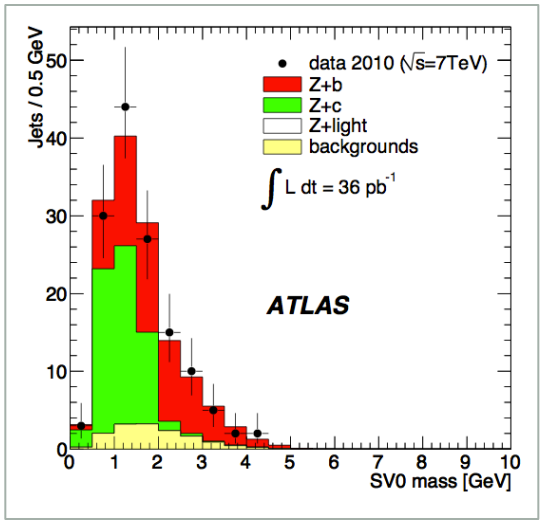
Non-perturbative correction 0.93±0.07

Z+b

ATLAS measurement
- **"Per b-jet"**
- Uncertainty ~20% stat, ~23% syst.
- Dominant systematics:
  - B-tag&m(SV) templates: ~10%
  - Z+b-jet modelling: ~10%
  - Jet + b-jet energy scale ~4%







Experiment	$3.55^{+0.82}_{-0.74}(\text{stat})^{+0.73}_{-0.55}(\text{syst}) \pm 0.12(\text{lumi})$ pb
MCFM	3.88 ± 0.58 pb
ALPGEN	2.23 ± 0.01 (stat only) pb
SHERPA	3.29 ± 0.04 (stat only) pb

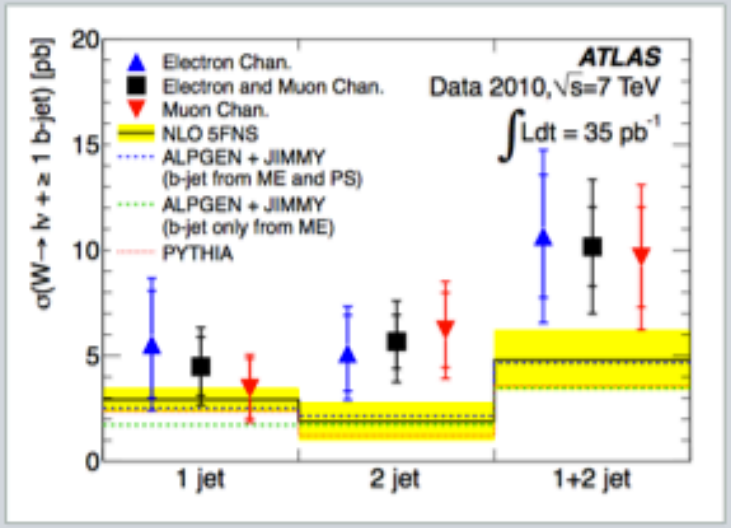
Table 4: Experimental measurement and predictions of σ_b, the cross-section for inclusive b-jet production in association with a Z boson, per lepton channel, as defined in the text.

- In agreement within uncertainty
- MCFM + **non-pert.corr. (0.89±0.07)**
  Non-perturbative hadronic effects:
  comparing particle-level results to parton-level,
  where parton-level jets are matched to *b* quarks.
  - Calculated using **SHERPA, PYTHIA and AcerMC**

"Tensions"

Cross-sections

- **W+b**
  - ATLAS observe larger cross-section in data than predicted
    - NLO(5FNS) and LO (Alpgen+Jimmy)
    - … sigma
- **Z + b**
  - CMS observe larger cross-section in data than predicted.
    - MCFM NLO (5FNS MadGraph)
  - 2-3 sigma



Kinematics

- **Z+b**
  - CMS: **pT(Z) and DeltaPhi(Z,b)** distributions in the data suggests harder spectra than those predicted
    - by the LO MadGraph+Pythia MC generated in the 5-flavour scheme.
- **Z+bb**
  - CMS: **pT(bb) & DeltaPhi(Z,bb)** also suggests harder spectra in the data than those predicted
    - by the LO MadGraph+Pythia MC generated in the 5-flavour scheme.
- **Z+2SV**
  - CMS: data and MC disagree in the distribution of the angle between the two displaced vertices of the b-hadrons ΔR(b1, b2).

Phase space

Main differences, full details in backup

Atlas

W/Z

- $E_T(l)$ or $p_T(l) >$ **20** GeV
- $m_T(W) >$ **40** GeV
- $60 < m(ll) < 120$

B-jet:

- R(jet) = **0.4**
  - Jet: $p_T > 25$, $|y|<2.1$
- $\Delta R(B,jet) <$ **0.3**
- **$p_T(B) > 5$ GeV**

CMS

W/Z

- $p_T(l) >$ **25** GeV
- $m_T(W) >$ **50** GeV
- $76 < m(ll) < 106$

B-jet:

- R(jet) = **0.5**
  - Jet: $p_T > 25$, $|\eta|<2.1$
- $\Delta R(B,jet) <$ **0.5**

Differences in leptons and Z/W selections (FSR, lepton definition)
Already covered by V & VJ analysis

➢ V+**HF**

Theory uncertainties

- Need to identify a **common approach** for both the prediction's central value and systematic uncertainties
  - Theory uncertainties like for V+jets, and those specific for V+HF.
  - Consistent between experiments

Points to consider:

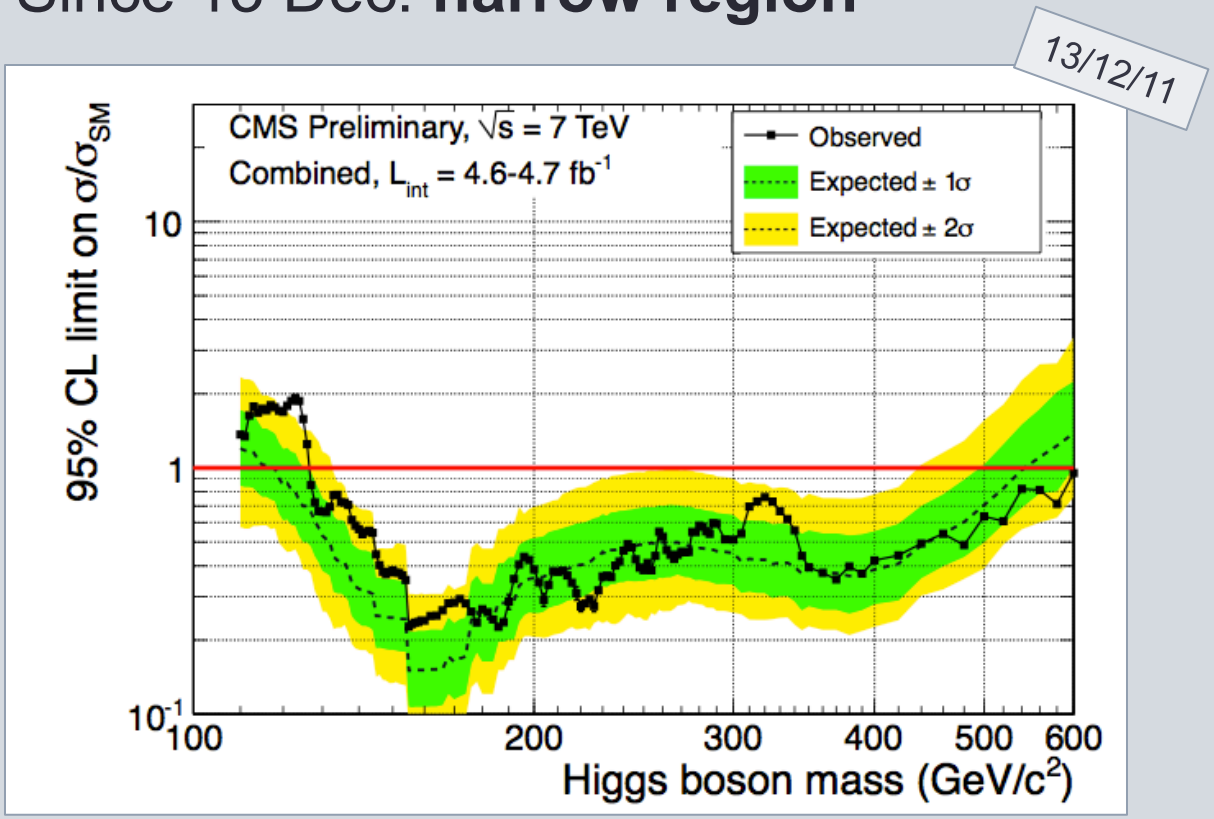
- **PDFs**
- **Renormalization/factorization scales**
- **Matching procedure and scale**
  - Different for heavy quarks?
- **Underlying event model**
  - MPI?
- **Fragmentation, hadronization, decay tables**
  - Effect on purity estimate

Taking the jet to discoveries

- **Start from the bottom!**

V+j ➔ Higgs?

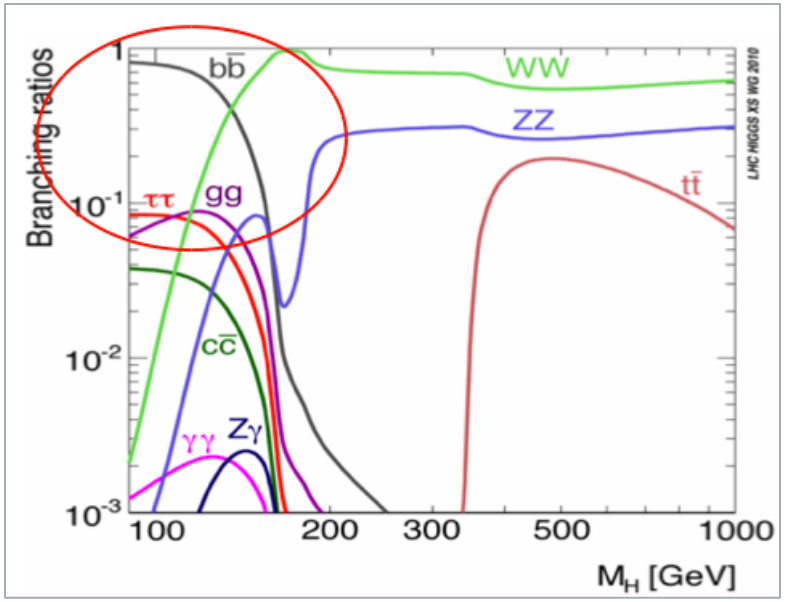
- Since 13 Dec: **narrow region**

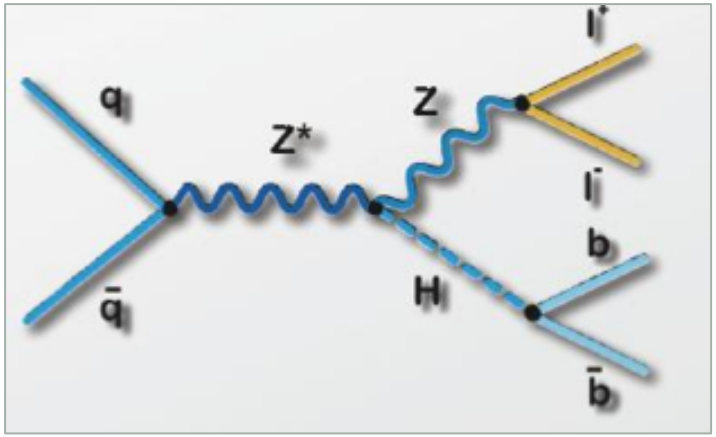


➢ Non-excluded (CMS+LEP, @95%CL): **114 - 127 GeV**

H→bb

- Low m_H: **H→bb high BR**
  - But dominated by QCD
- **'Higgs Strahlung'**
  - Higgs in association with V
    - Decreases production
  - Z+H(bb) final state
    - Boosted bb
    - To further suppress SM background

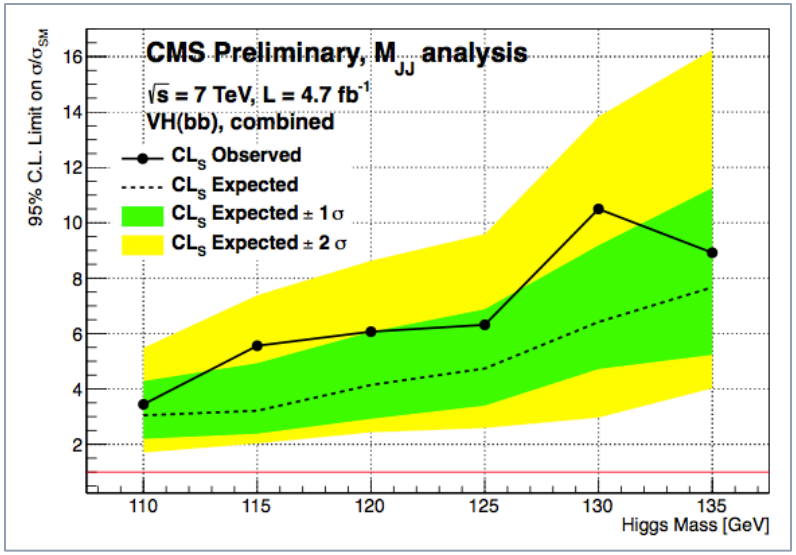


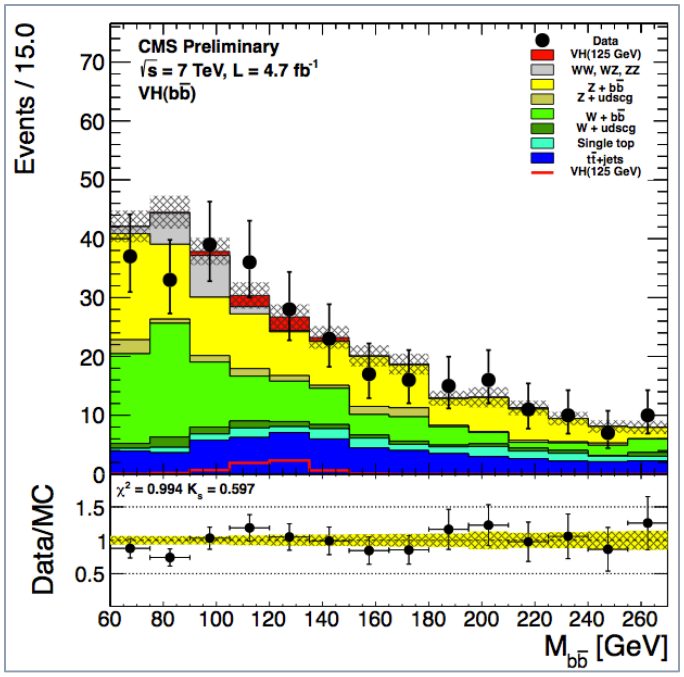


- **H→bb not dominating sensitivity**
  - But contributing to total search
    - If Higgs is found, needs to be tested
  - Potential to gain!
    - Understanding of SM Z+bb

Z(ll)+bb vs H

- **SM Z(ll)+(bb)**
  - Background for **Z+boosted H(bb)**
  - Also background for
    - **H→Z(ll)Z(ll)**,
    - **H→Z(ll)Z(bb)**, …





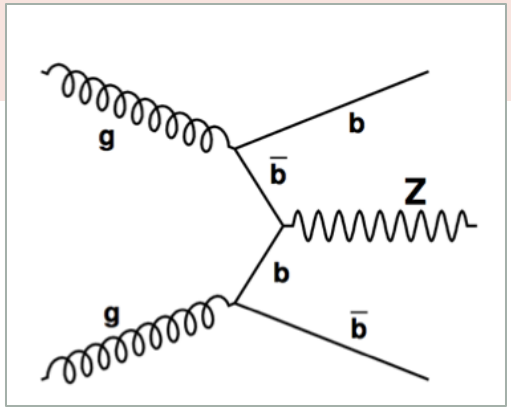
- **BSM**
  - E.g. 2HDM
    - H→Z(ll)A(bb)

➢ **Future plans**

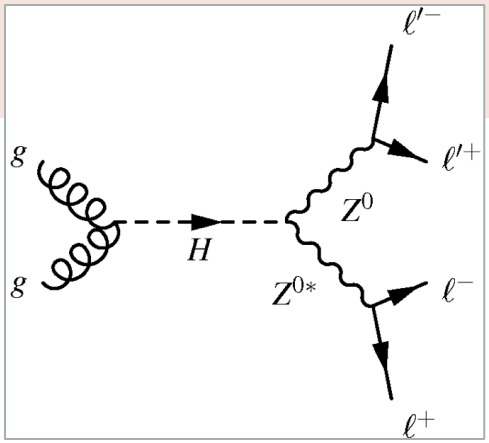
➢ Exploit SM Z+bb expertise in searches

Z+bb final states

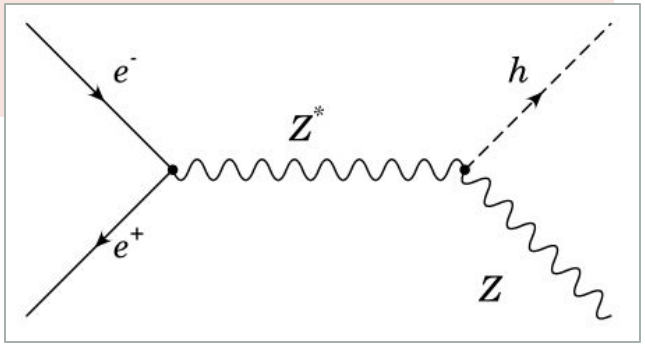
SM: Z+bb



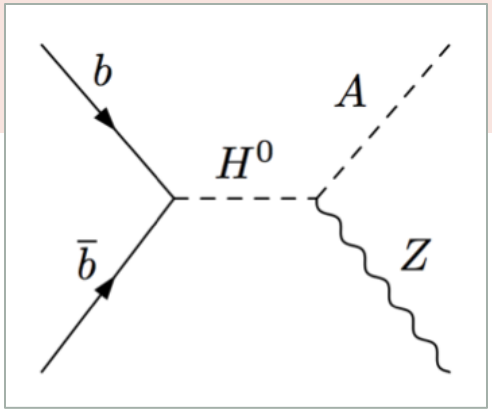
SM-H: gg→H→Z(ll)Z*(bb)



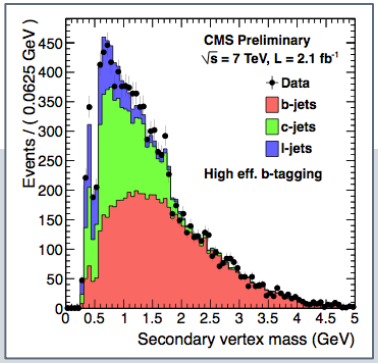
SM-H: qq→Z*→Z+H(bb)

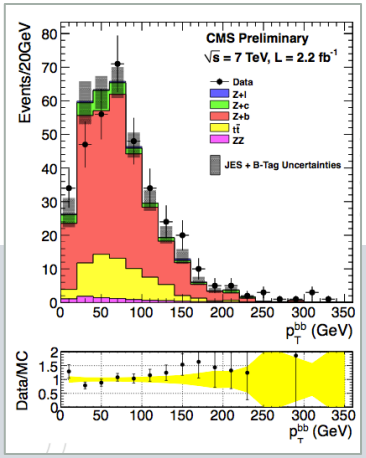


BSM: qq→H→Z(ll)A(bb)

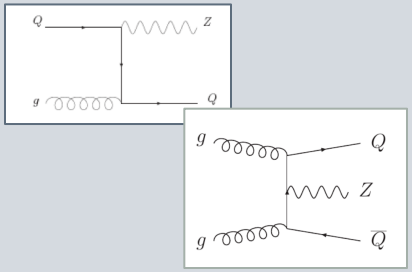


Conclusions

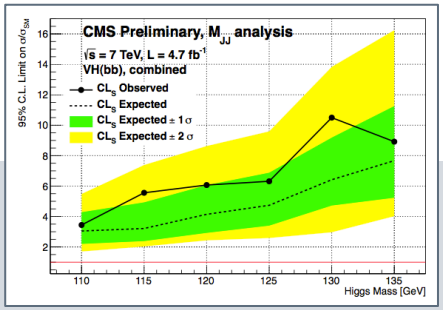




- **V+HF studies**
  - Understanding of MC (SM&BSM)
  - Detector & reconstruction
- **CMS Z+b(b) measurements**
  - Z+b/Z+j, Z+1b, Z+2b (& Z+2SV)
  - Comparing data & MC: cross-sections & kinematics
- **More tests foreseen**
  - Comparison of MCs
    - LO vs NLO, massive bs, 4/5 flavor…
  - Precision understanding of QCD



- **Getting ready for searches**
  - Backgrounds for hunts for Higgs, 2HDM, …



CMS Experiment at LHC, CERN
Data recorded: Tue Oct 26 13:43:07 2010 CEST
Run/Event: 149003 / 47711105
Lumi section: 97
Orbit/Crossing: 25268370 / 2953

Thank you for your attention

(Z+b)/(Z+j): CMS **EWK-10-015**
Z+b: CMS **EWK-11-012**
Z+bb: CMS **SMP-12-003**