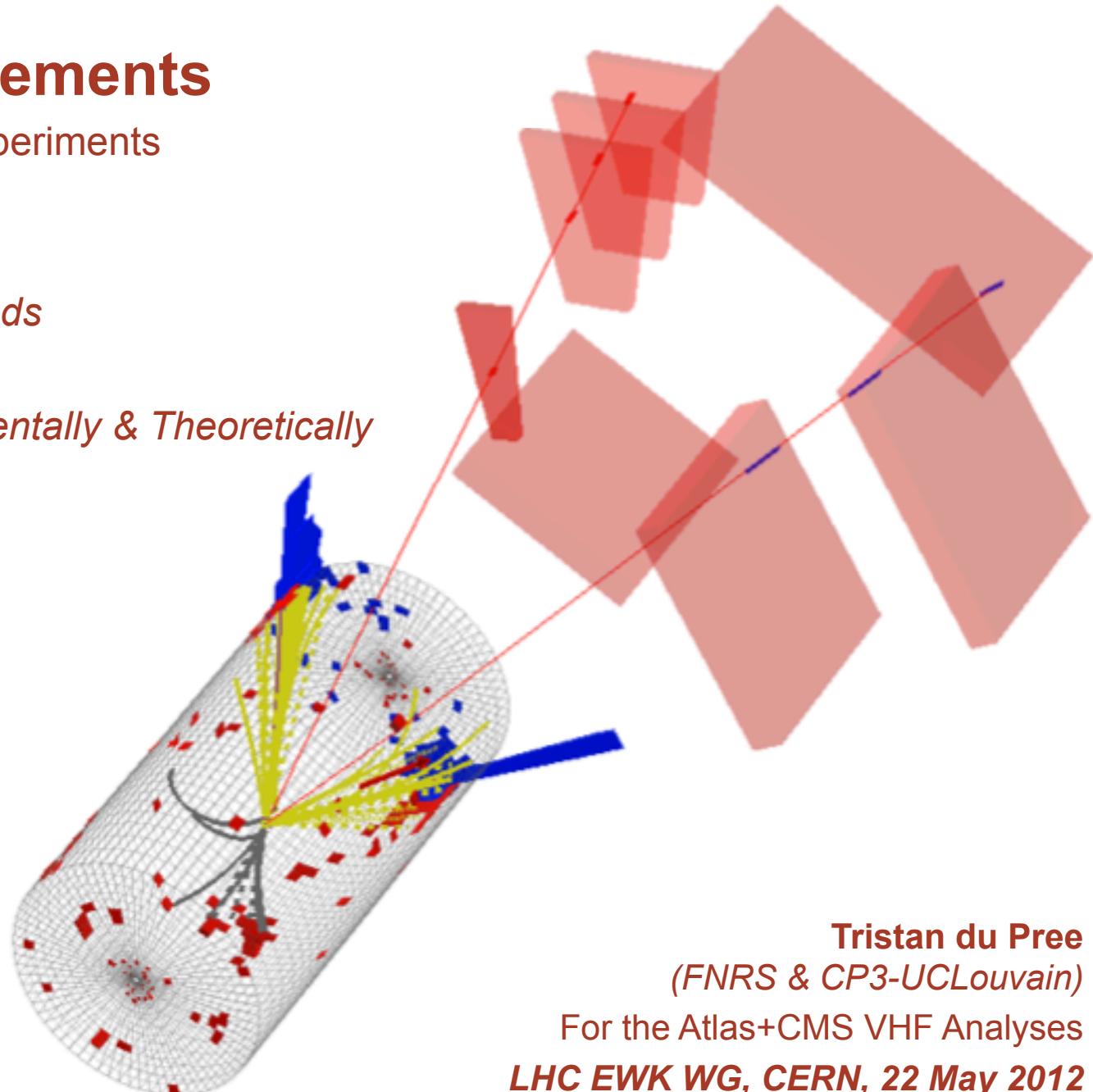


V+HF measurements

of the Atlas & CMS experiments

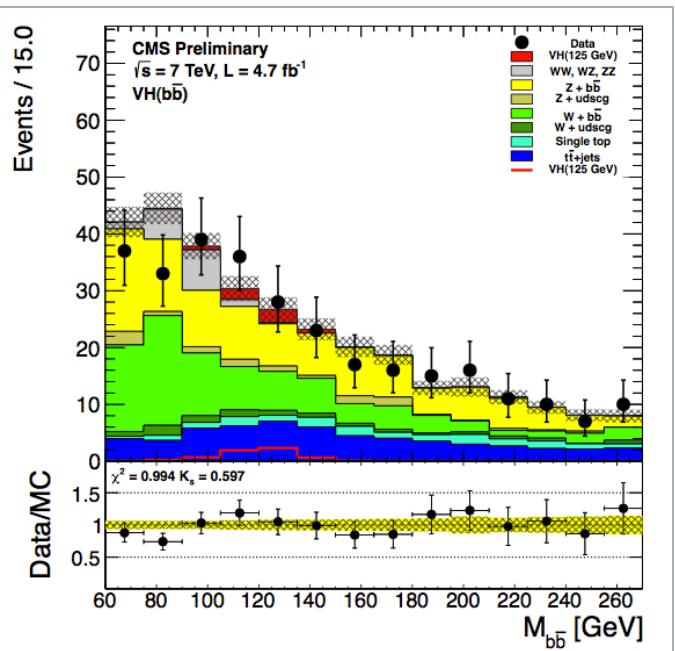
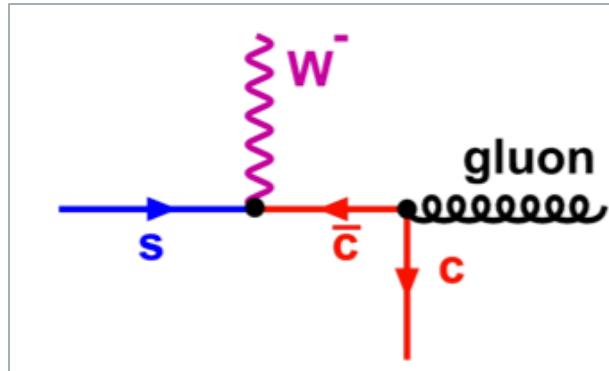
- *Introduction & Methods*
- *Results & Tensions*
- *Definitions: Experimentally & Theoretically*



Tristan du Pree
(FNRS & CP3-UCLouvain)
For the Atlas+CMS VHF Analyses
LHC EWK WG, CERN, 22 May 2012

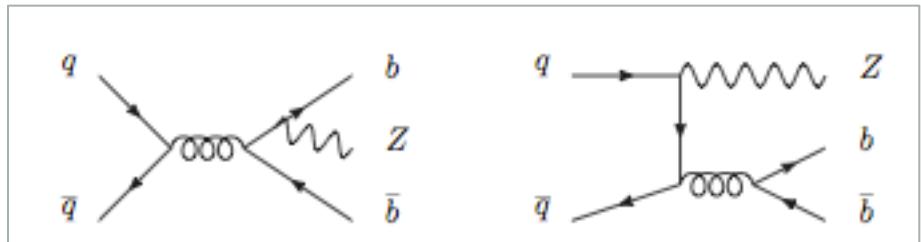
Motivation V+HF

- Background for **searches**
 - E.g. Higgs



- Gain understanding of **PDFs**
 - E.g. $W+c$

- **Test QCD theory**
 - Data/MC comparisons
 - Today's subject!



Measurements

- **Atlas & CMS**

- Cross-section measurements:

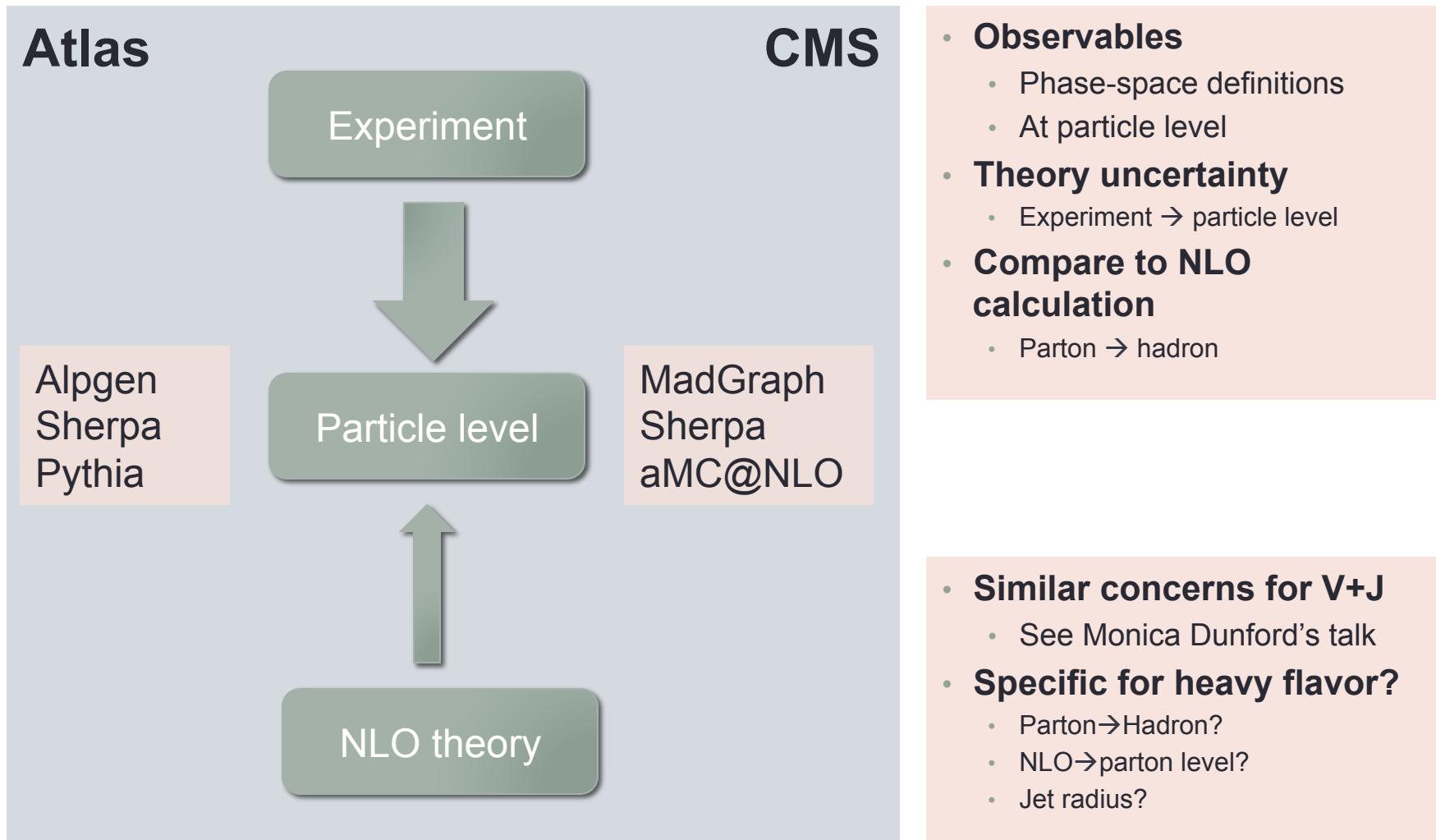
Table 4: V+hf cross sections measured by ATLAS and CMS on 2010/11 data.

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]	$\sigma(Z + 1b)$ $\sigma(Z + 2b)$ $\sigma(Z + b)$	exclusive in number of b-jets inclusive in number of events with ≥ 2 b jet inclusive in number of events with ≥ 1 b jet	$e, \mu, e + \mu$ $e, \mu, e + \mu$ $e, \mu, e + \mu$
CMS $W + c$ [10]	$\frac{\sigma(W^+\bar{c})}{\sigma(W^-)}$ $\frac{\sigma(W+c)}{\sigma(W+jets)}$	inclusive inclusive	μ μ

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

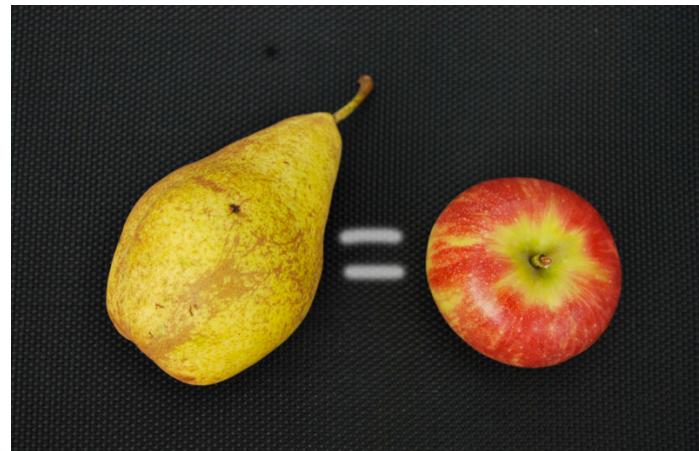
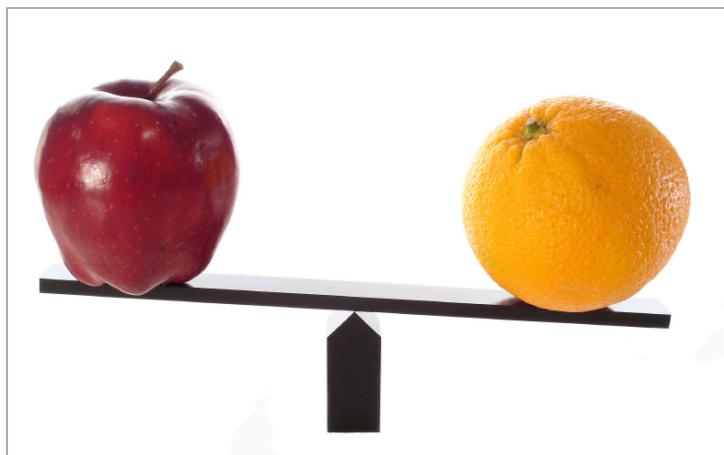
➤ **Data & MC: how to compare them best?**

Sketch of procedure



How to compare

...between the
different experiments...



... and between
experiment & theory

Phase space

Main differences,
full details in backup

Atlas

W/Z

- $E_T(l) \text{ or } p_T(l) > \mathbf{20} \text{ GeV}$
- $m_T(W) > \mathbf{40} \text{ GeV}$
- $60 < m(l\bar{l}) < 120$

B-jet:

- $R(\text{jet}) = \mathbf{0.4}$
 - Jet: $p_T > 25, |\eta| < 2.1$
- $\Delta R(B, \text{jet}) < \mathbf{0.3}$
- $p_T(B) > \mathbf{5 \text{ GeV}}$

CMS

W/Z

- $p_T(l) > \mathbf{25 \text{ GeV}}$
- $m_T(W) > \mathbf{50 \text{ GeV}}$
- $76 < m(l\bar{l}) < 106$

B-jet:

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

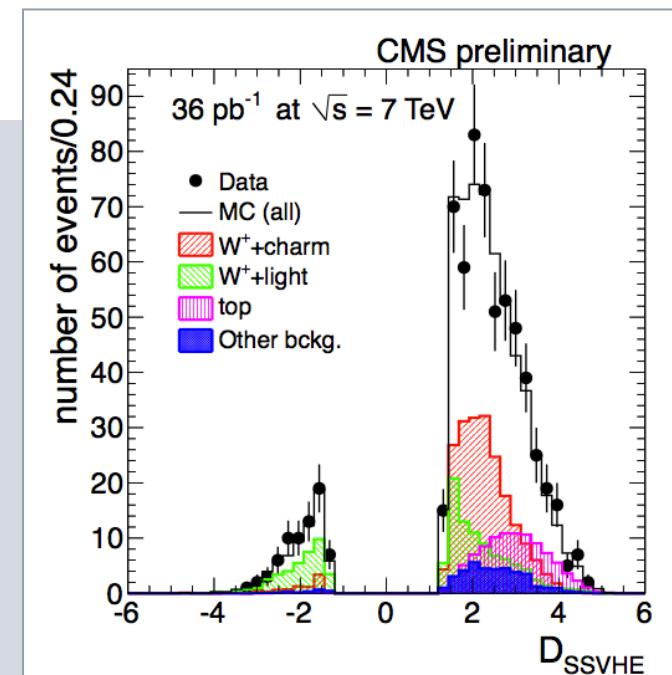
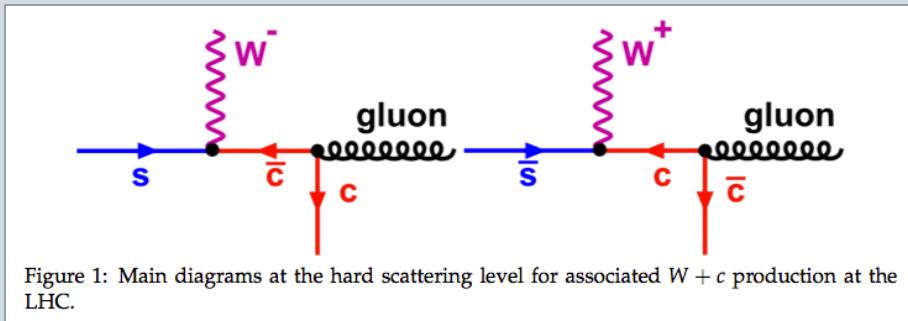
Differences in leptons and Z/W selections (FSR, lepton definition)

Already covered by V & VJ analysis

➤ This talk: compare V+HF

W+c

- CMS: W+c study
 - CMS-PAS-EWK-11-013



- $\sigma(W^+c\bar{c}+X)/\sigma(W^-c+\bar{c}+X) = 0.92 \pm 0.19 \text{ (stat.)} \pm 0.04 \text{ (syst.)}$
- $\sigma(W+c+\bar{c}+X)/\sigma(W+jet+X) = 0.143 \pm 0.015 \text{ (stat.)} \pm 0.024 \text{ (syst.)}$

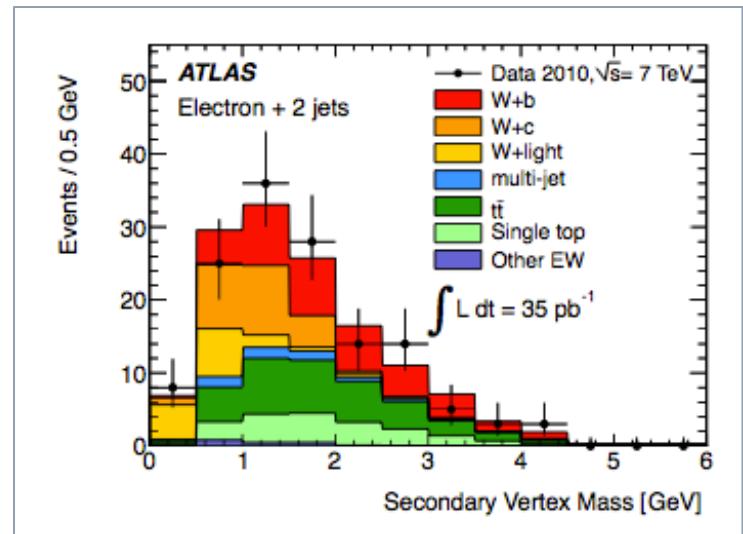
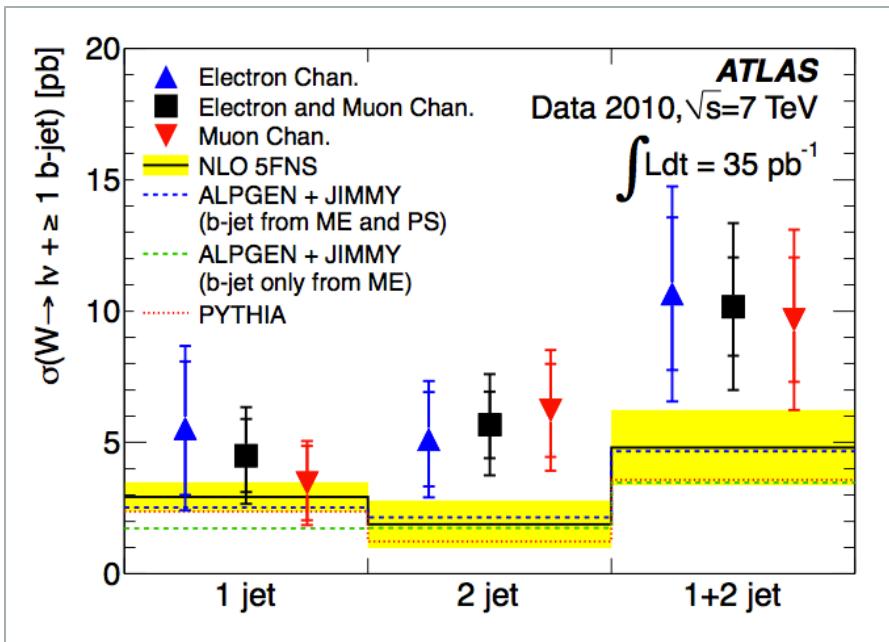
➤ In agreement with theoretical predictions at NLO

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 W+jets (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

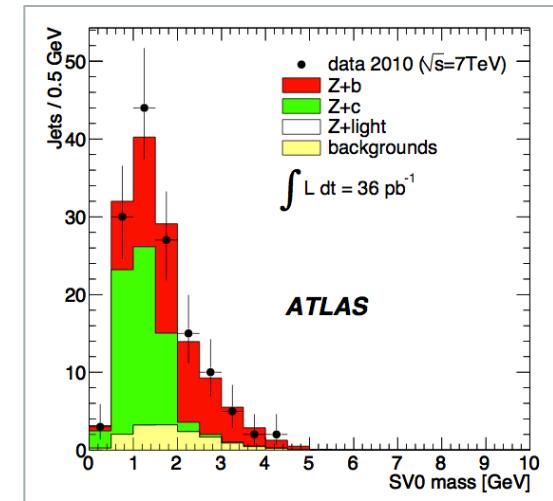
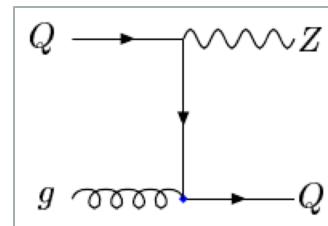
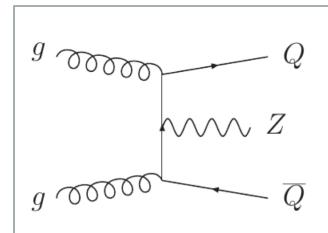
- “Per b-jet”
- Uncertainty ~20% stat, ~23% syst.
- Dominant systematics:
 - B-tag&m(SV) templates: ~10%
 - Z+b-jet modelling: ~10%
 - Jet + b-jet energy scale ~4%

Experiment $3.55^{+0.82}_{-0.74}(\text{stat})^{+0.73}_{-0.55}(\text{syst}) \pm 0.12(\text{lumi}) \text{ pb}$

MCFM $3.88 \pm 0.58 \text{ pb}$

ALPGEN	$2.23 \pm 0.01 \text{ (stat only) pb}$
SHERPA	$3.29 \pm 0.04 \text{ (stat only) pb}$

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**

Z+b(b) results

CMS: “per-event”

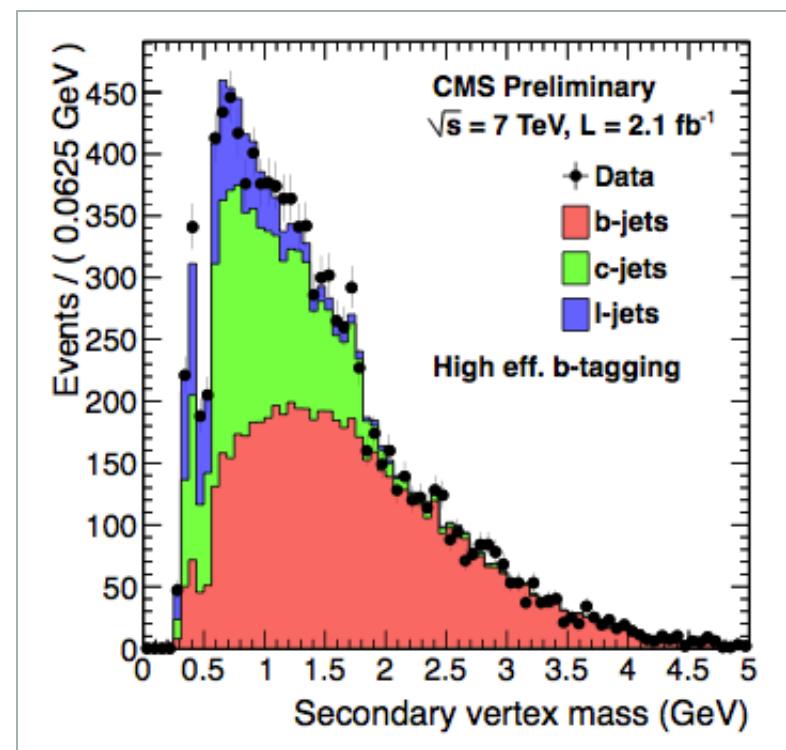
- Z+b(b) cross section

- Select events, subtract background
 - See backup
- Estimate efficiencies from MC
 - Scale to data expectations
- Unfold b-multiplicity

- MadGraph expectation

- Scaled to (DY+j) NLO

➤ $\sigma(Z(l)+2b) = 0.33 \pm 0.01_{\text{(stat.)}} \text{ pb}$



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

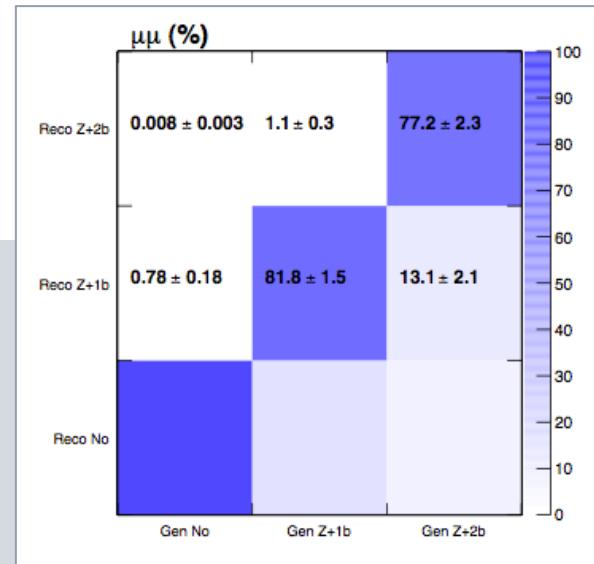
- Z+1b

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

Unfolding

Example: Z+b(b)

- **Z+1b and Z+2b yields at hadron level:**
unfold b-jet multiplicity
 - # b-tagged jets → # reconstructed b-jets → # hadron-level b-jets
- **Correct yields to acceptance**
 - Hadrons
 - Leptons
- Since the **acceptance is partly driven by the kinematics**
it is affected by potential difference between data and MC simulation



➤ Hadron correction

- Detector resolution and kinematics

➤ Lepton-acceptance uncertainty

- Acceptance and kinematics

Z+b unfolding

CMS

Atlas

Systematics of acceptance due to model dependence: **10%**

Source	SV0-mass Fit (%)	Acceptance (%)
Both Electron and Muon		
b-tagging efficiency	1.7	9.1
SV0-mass templates	3.5	-
Model dependence	2.7	10.0
Jet energy scale	0.7	4.0
t̄ cross-section	2.0	-
MPI model	negl.	1.0

- **Hadron correction**
 - Estimated from **MG+Pythia**
 - Systematics: (**+0.7, -6.9**)%
 - Comparison with **Sherpa** and **aMC@NLO**
- **Lepton-acceptance**
 - Systematics: (**+4.2, -6.5**)%
 - **Sherpa, aMC@NLO+herwig, MCFM**

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 ($\mu\mu+b$)
t̄t 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}_f)	$\begin{array}{c} +4.2 \\ -6.5 \end{array}$	
Theory (via \mathcal{C}_{hadron})	$\begin{array}{c} +0.7 \\ -6.9 \end{array}$	
Uncorrelated sources	ee+b	$\mu\mu+b$
Trigger and dilepton selection	4	2
t̄t contribution	1.9	2.2
Experimental systematic	13.0	12.3
Theoretical systematic	$\begin{array}{c} +4.2 \\ -9.5 \end{array}$	$\begin{array}{c} +4.2 \\ -9.5 \end{array}$
Statistical	2.2	1.7

➤ Follow same procedure?

Kinematics

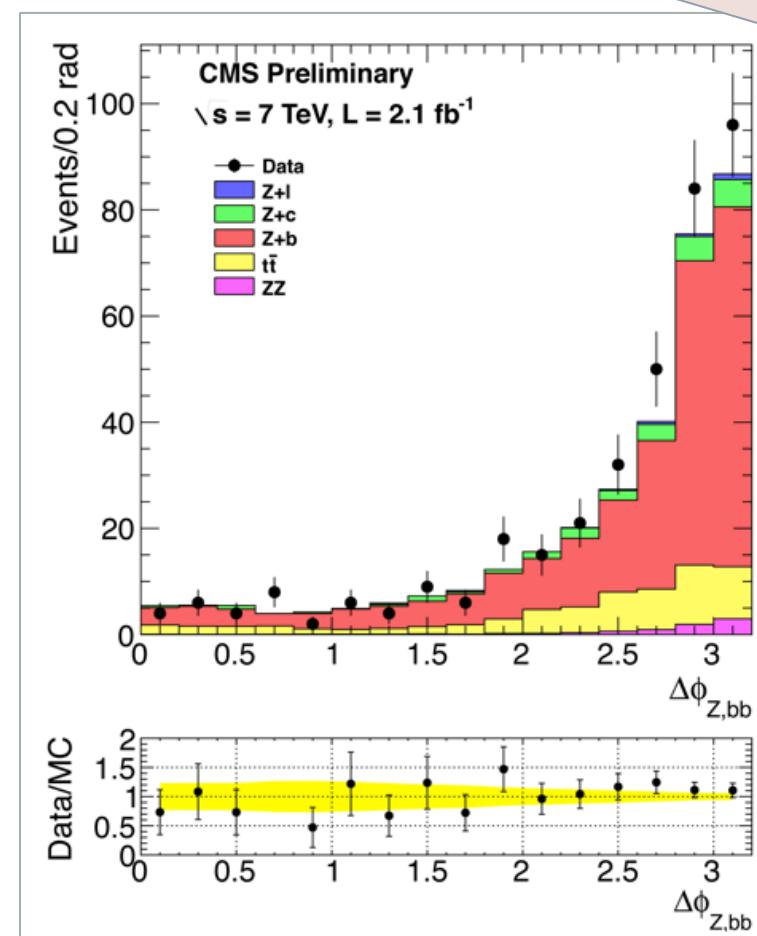
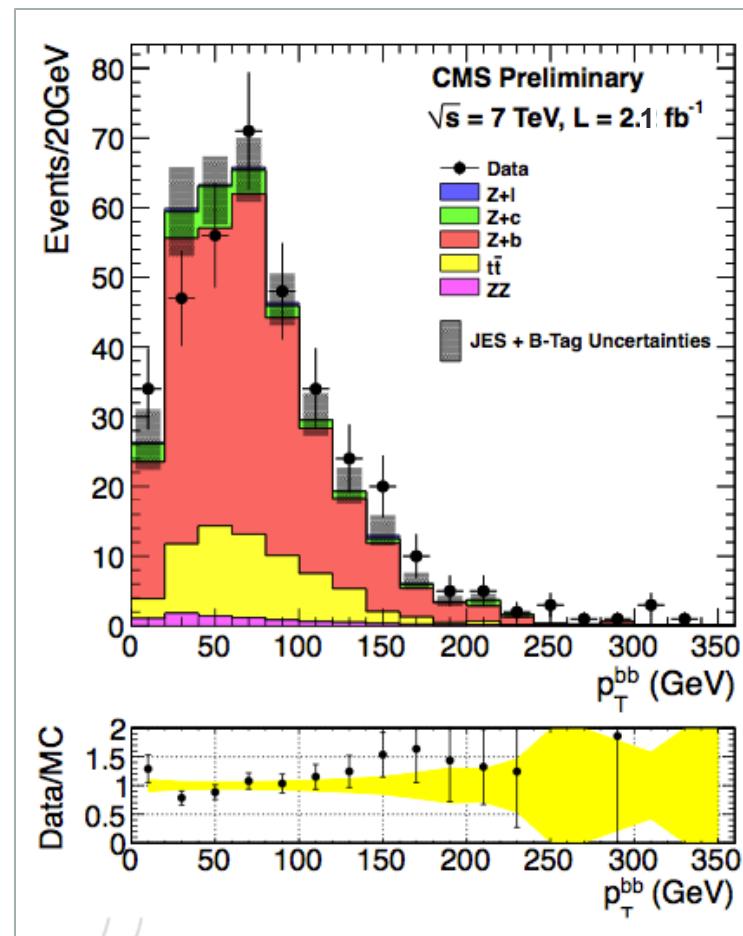
- **W+b**
 - [Atlas, arXiv:1109.1470, **35 pb⁻¹**]
- **W+c**
 - [CMS, EWK-11-013, **36 pb⁻¹**]
- **Z+b**
 - [Atlas, arXiv:1109.1403, **36 pb⁻¹**]
 - [CMS, arXiv:1204.1643, **2.1 fb⁻¹**]
 - **Z+b/Z+j**: [CMS, SMP-10-015, **36 pb⁻¹**]
- **Z+bb**
 - [CMS, SMP-12-003; **2.1 fb⁻¹**]
- **Z+2SV**
 - [CMS, EWK-11-015;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

➤ Many V+HF results...
let's now focus on **kinematic ‘tensions’**
➤ In the high-statistics measurements

“Tensions” in Z+bb

SMP-12-003

- $p_T(b\bar{b})$ harder in data than in MC
 - Consistent with angular distribution of bb wrt Z



MadGraph
generated in the 5-flavour scheme.
+ Pythia

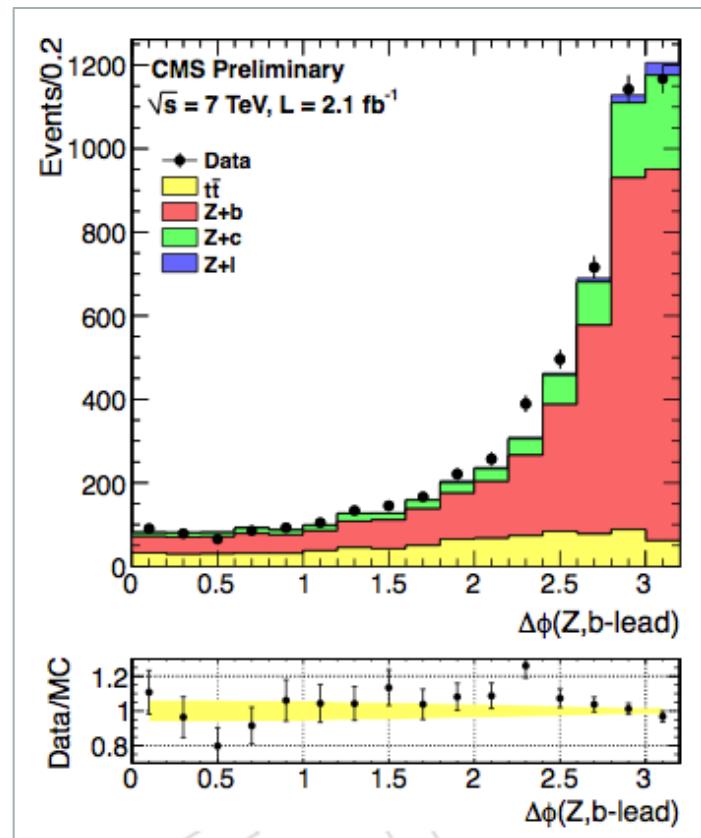
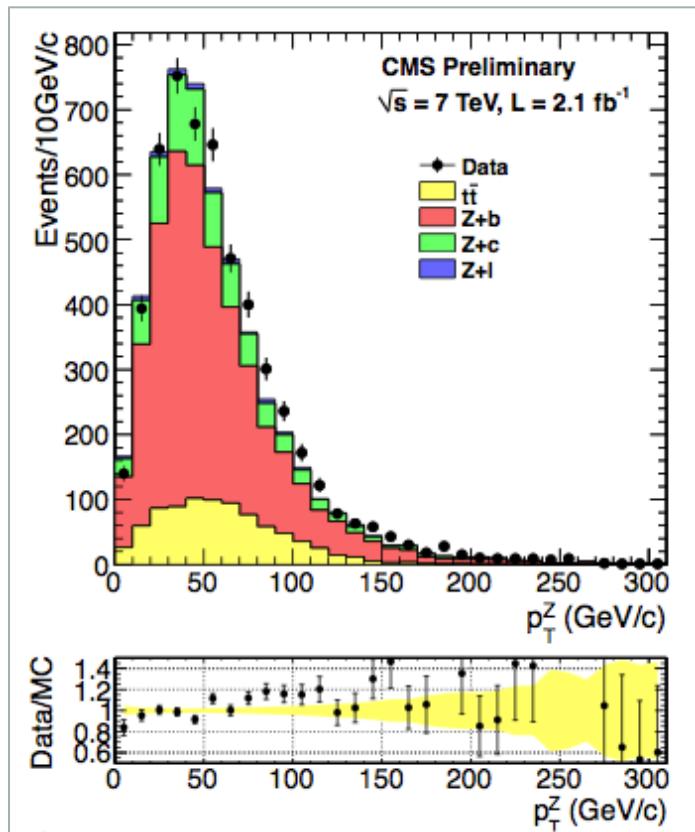
$p_T(Z) \& \Delta\Phi(Z,b)$

Z+1b

EWK-11-012

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

MadGraph
generated in the 5-flavour scheme.
+ Pythia

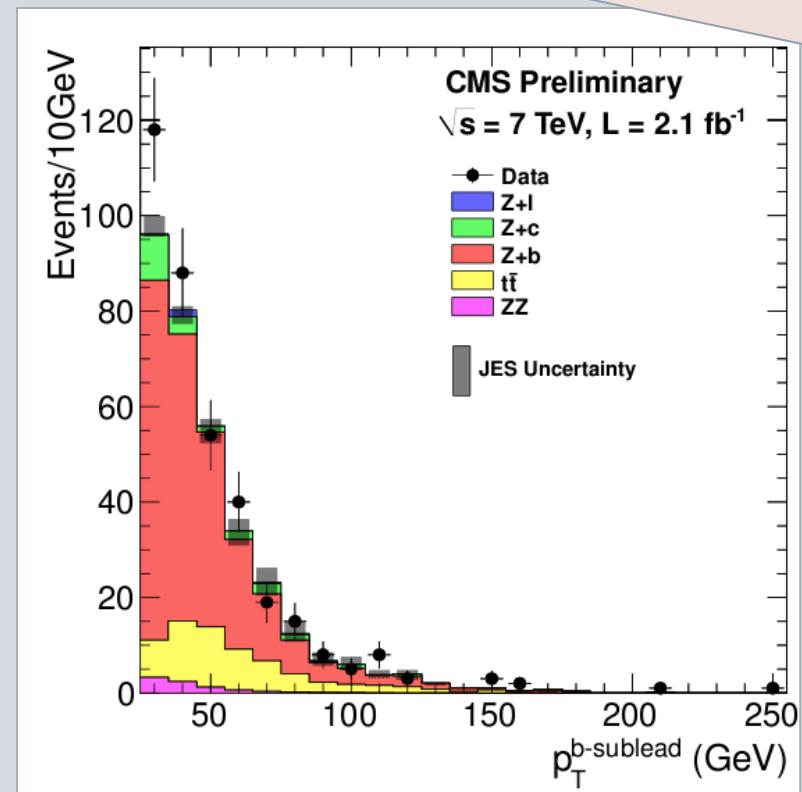
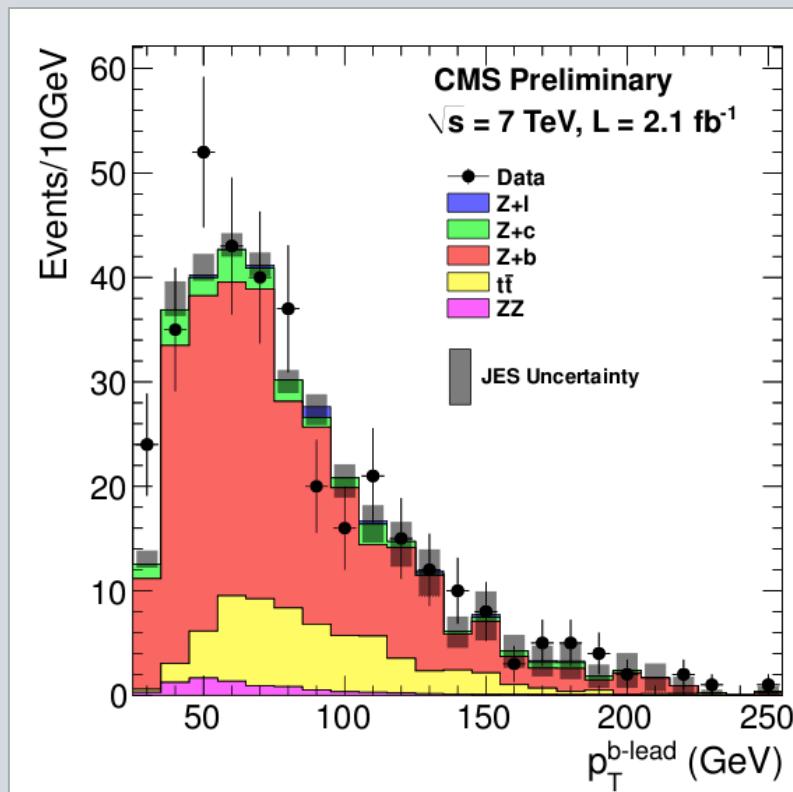


Kinematics comparison

Z+2b

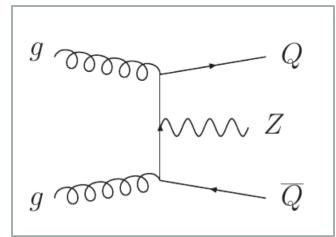
SMP-12-003

- Leading & sub-leading b- p_T



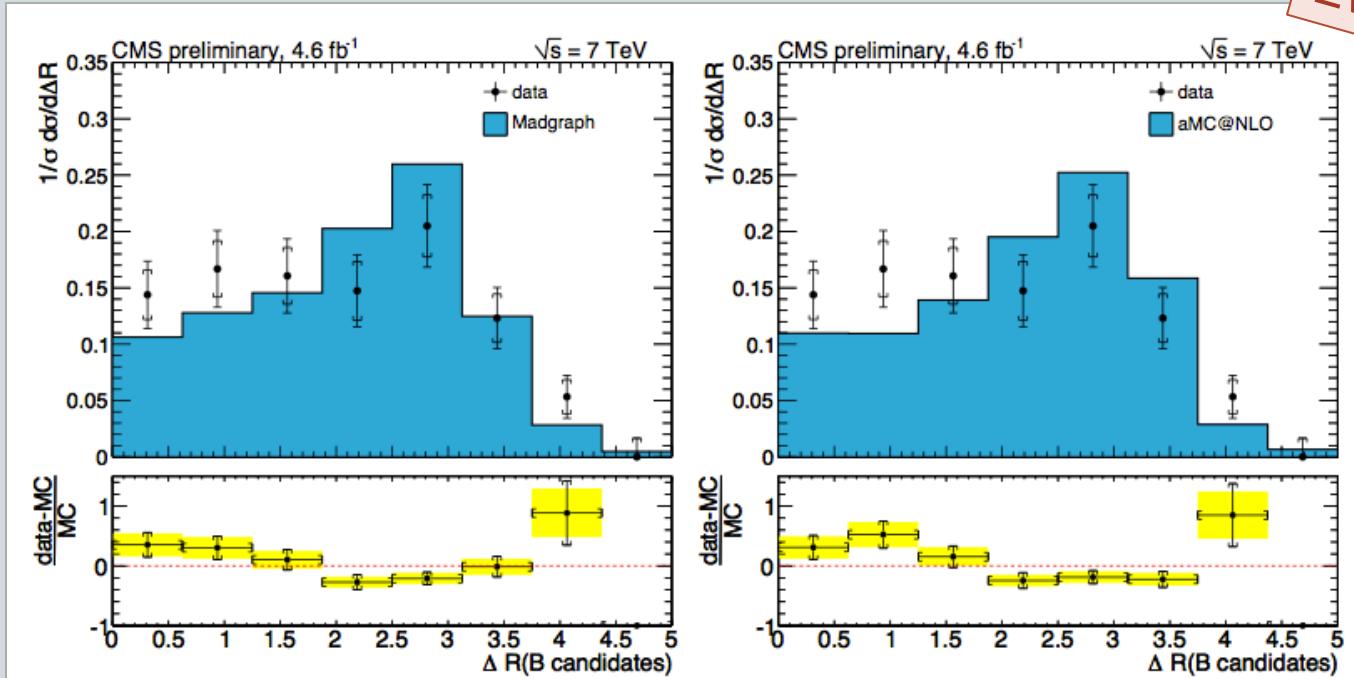
➤ More statistics needed before conclusions can be drawn

Z+2SV



- $\Delta R(b_1, b_2)$: 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

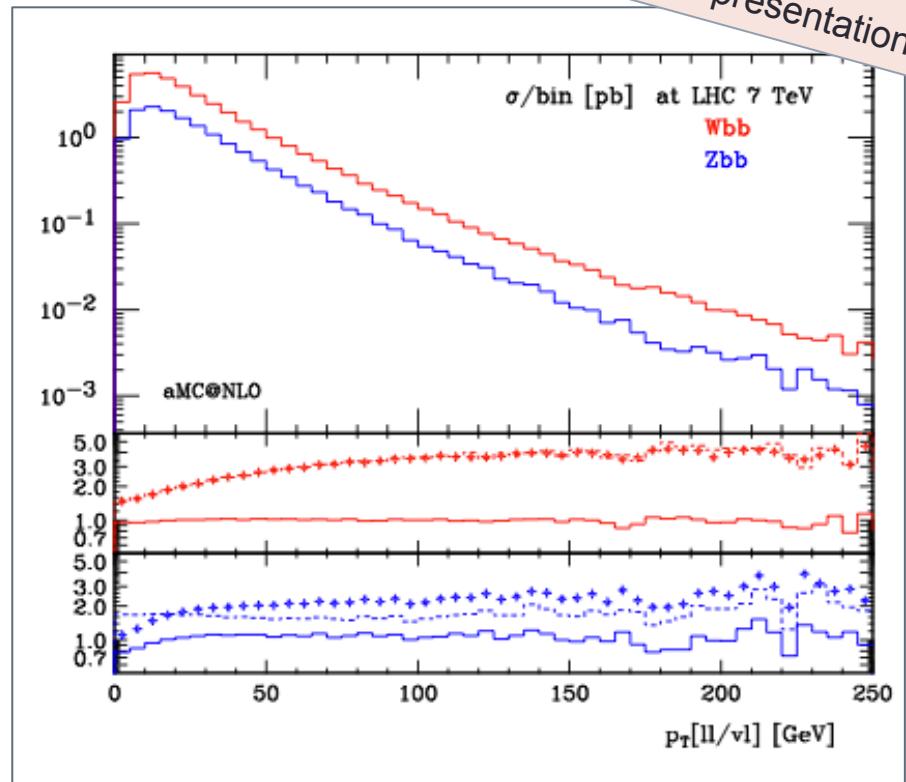
Plans

- **aMC@NLO**
- **MG4F**
- **Sherpa**
- ...?

Compare

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

NLO example
(more in Fabio Maltoni's presentation)



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

Points for discussion

Details in backup

- **Hadronization**

- Effect on purity estimate?

- **Definition of B-jet**

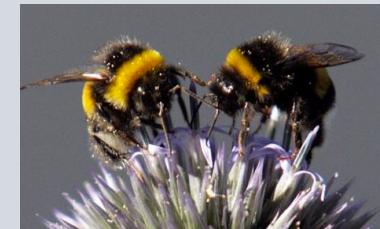
- Infrared-safe definition?
 - Cut on p_T of B-hadron?
 - Two b's in one jet?

- **Definition of Z+1b**

- Count number of b-jets...
 - ...or count the number of events containing at least one b?
 - And which systematics cancel in a $Z+b/Z+j$ measurement?

- **Definition of Z+bb**

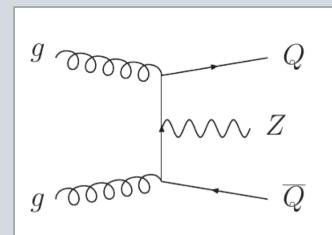
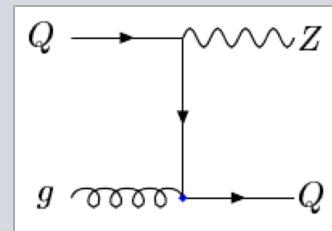
- Understand MPI



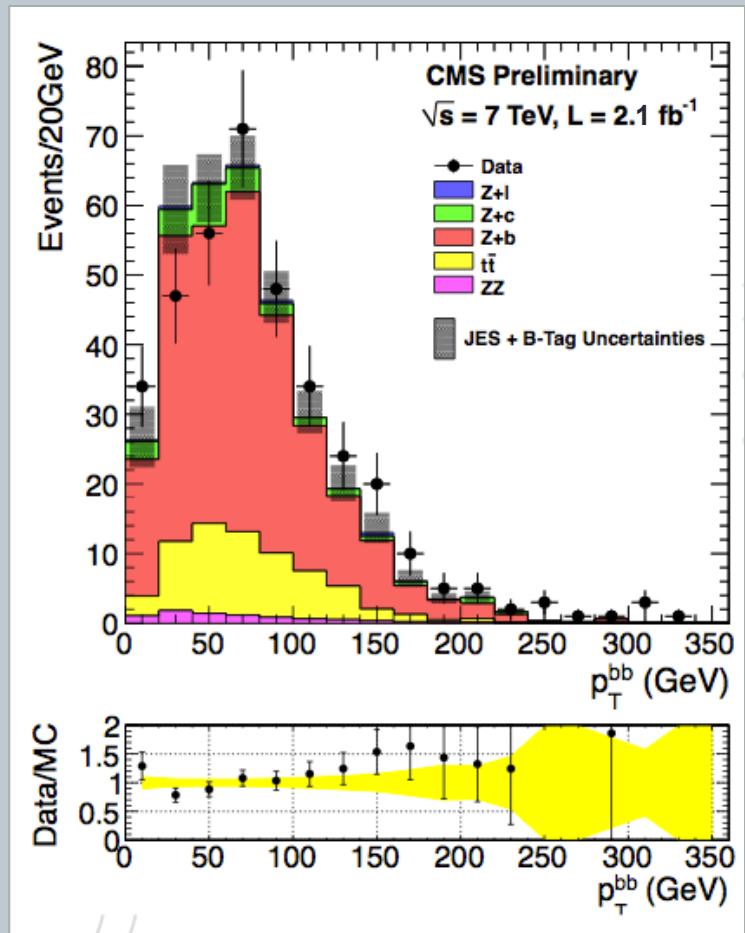
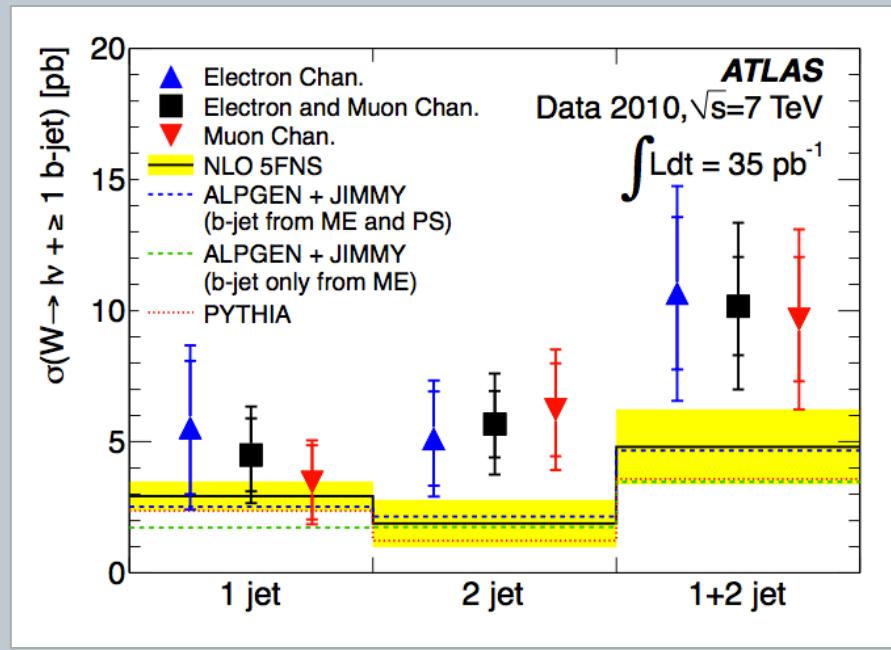
How do we treat it **experimentally**?
How does it affect the **theoretical** interpretation?

Conclusions

- **Atlas and CMS have multiple W/Z+b/c results**
 - Comparing data & MC
 - Some ‘tensions’ observed
 - Cross-sections and kinematics
- **Plans for new measurements**
 - Agree on definitions of observables/phasespace
 - Comparing with different MC
- **To improve comparison and understanding**



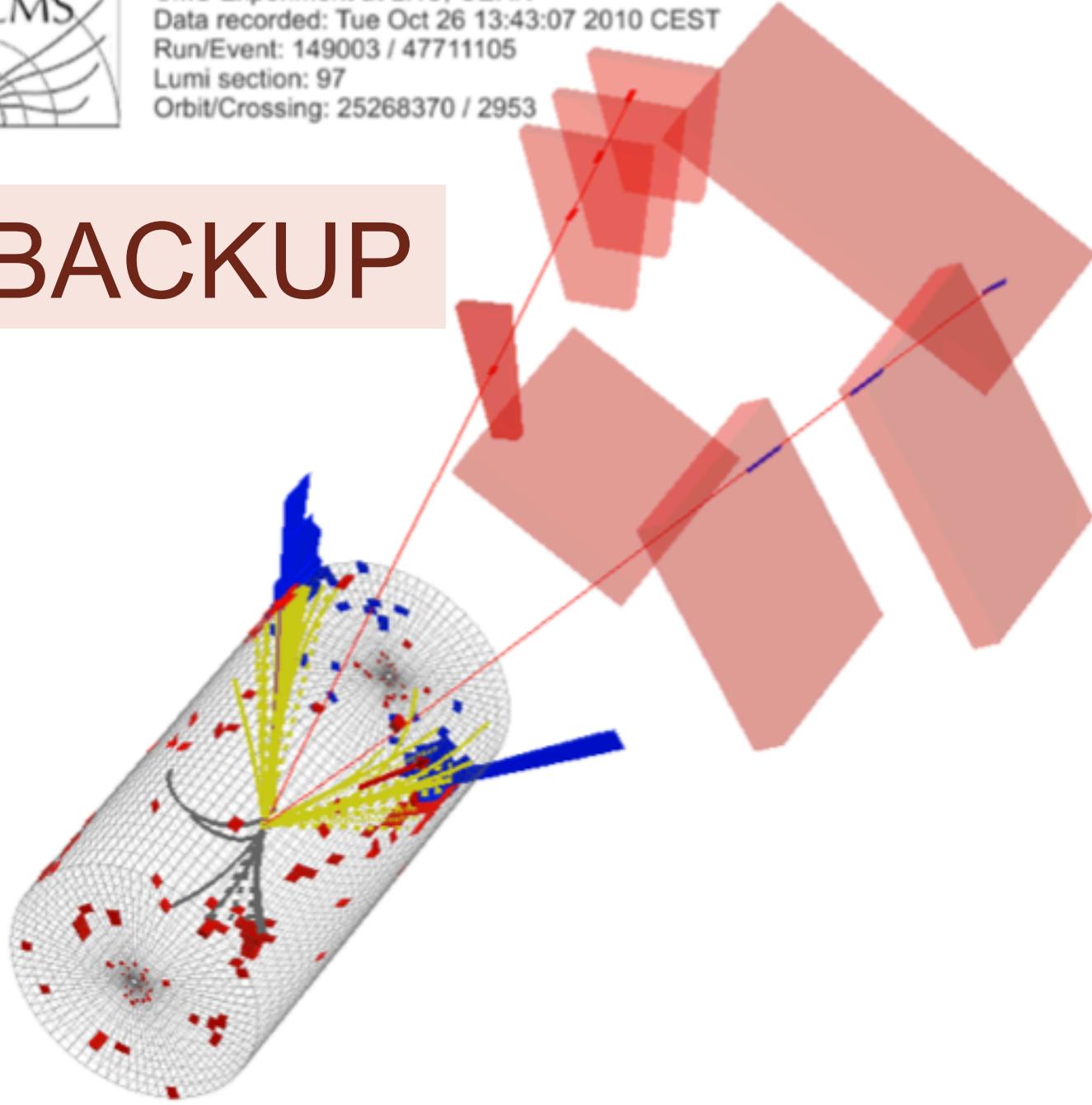
Thank you for your attention





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

BACKUP



Selection

- Two electrons

Trigger	DoubleEle_17_8 CaloIdL_CaloIsoVL
p_T	$> 25 \text{ GeV}$
$ \eta $	< 2.5
η_{SC}	$ \eta_{SC} < 1.4442$ or $ \eta_{SC} > 1.566$
ID	WP85
Isolation	WP85 relative
Non-prompt rejection	$dB < 200\mu\text{m}$
Trigger match	Two $\Delta R < 0.3$, $\Delta p_T / p_T < 0.5$
Pair	opposite signs
Invariant mass	$76 < M_{ll} < 106 \text{ GeV}$

- B-jet selection

p_T	$> 25 \text{ GeV}$
$ \eta $	< 2.1
id	loose PF ID
$\Delta R(\text{leptons})$	> 0.5
btag High Efficiency	$SSVHE > 1.74$
(btag High Purity)	$SSVHP > 2.0$)

- Vertex selection

$ z $	$< 24 \text{ cm}$
ρ	$< 2 \text{ cm}$
n_{dof}	> 4

Trigger	DoubleMu_7, DoubleMu_13_8
p_T	$> 20 \text{ GeV}$
$ \eta $	< 2.1
ID	$n_{trk} + n_{pix} > 10$, $\chi^2 < 10$
	$n_{trk} > 0$, $n_{pix} > 0$
	$> 1\mu\text{ seg matched}$
isolation	$\Sigma(I_{\text{combined}})/p_T < 0.15$
Non-prompt rejection	$dB < 200\mu\text{m}$
Trigger match	Two $\Delta R < 0.3$, $\Delta p_T / p_T < 0.5$
Pair	opposite signs
Invariant mass	$76 < M_{ll} < 106 \text{ GeV}$

Updating the measurements

When Atlas & CMS will update Z +bb, what should be compared?

➤ Z+2b

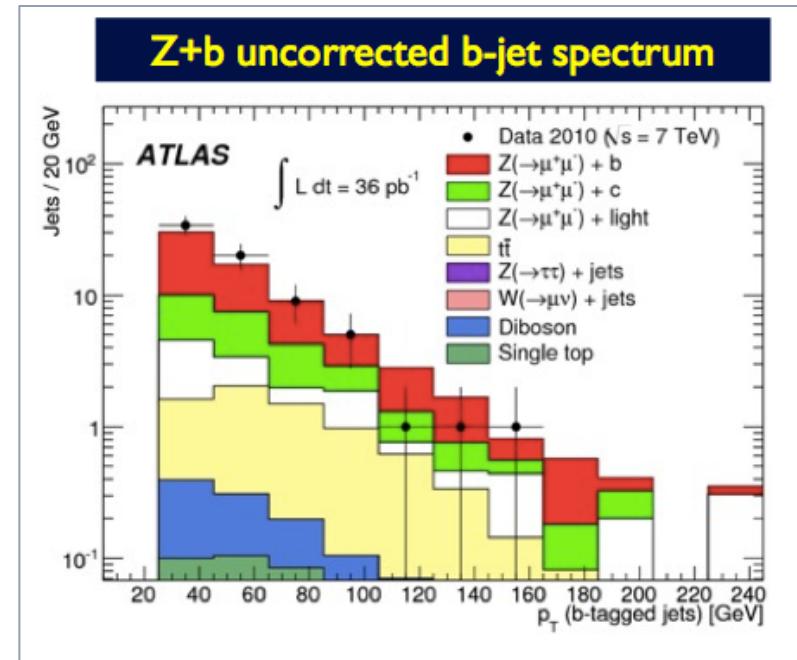
- Inclusive
 - Counting “per-jet” as opposed to “per-event” does not allow to study 2b-properties
- 2b in jet

• Z+1b exclusive

• Other suggestions?

➤ Furthermore: Z+b/Z+j

- [CMS, SMP-10-015, 36pb⁻¹]
 - Useful to measure Z+b/Z+j vs Z-rapidity?
 - Which systematics cancel? Theory, experiment?



Kinematic

- Observables/ phase space
 - Exact definitions

Table 3: Fiducial phase space definitions at particle level of the 2010/2011 LHC V+hf measurements. The $\Delta R(\ell, \text{jet})$ is applied to avoid mismeasured jets, *i.e.* as a *jet cleaning*, but the event is retained.

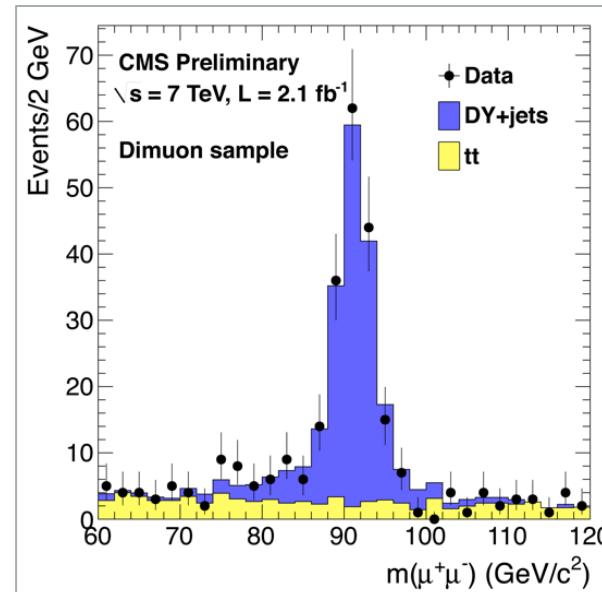
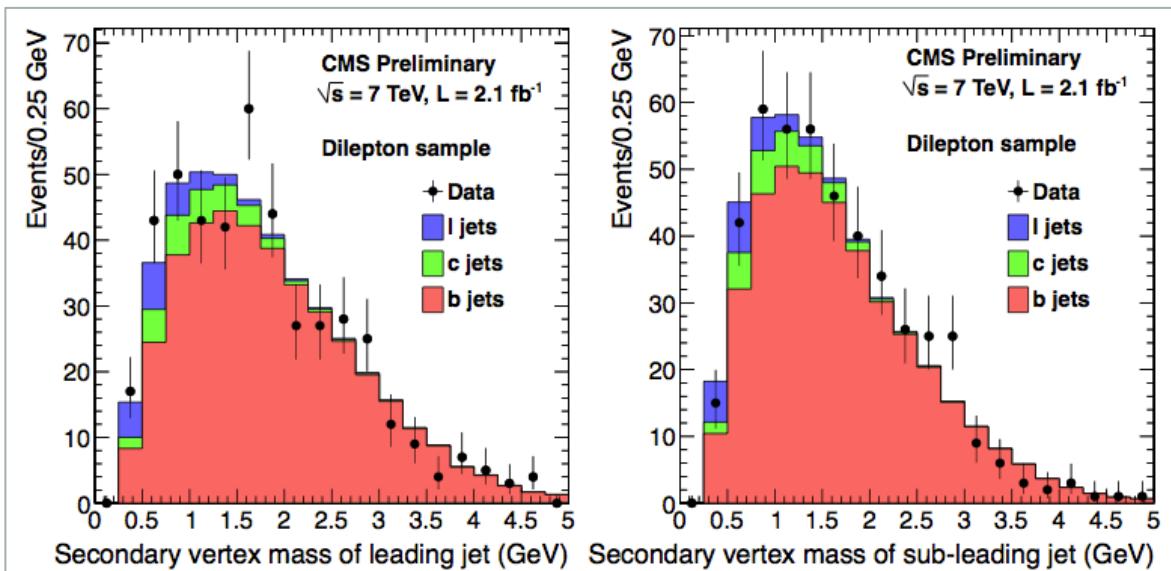
ATLAS $W + b$ [6]	
Leptons	$p_T^\ell > 20 \text{ GeV}, \eta^\ell < 2.5$
W	$E_T^{\text{miss}} > 25 \text{ GeV}, m_T > 40 \text{ GeV}$
Jets	anti- k_T $R = 0.4, p_T^{\text{jet}} > 25 \text{ GeV}, y^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5$
b -jets definition	at least one B-hadron with: $p_T > 5 \text{ GeV}, \Delta R(\text{B-hadron}, \text{jet}) < 0.3$
b -jets	anti- k_T $R = 0.4, p_T^{\text{jet}} > 25 \text{ GeV}, y^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5$
ATLAS $Z + b$ [7]	
Leptons	$E_T^\ell > 20 \text{ GeV}, \eta^e < 2.5$
Z	$76 < m_{\ell\ell} < 106 \text{ GeV}$
Jets	anti- k_T $R = 0.4, p_T^{\text{jet}} > 25 \text{ GeV}, y^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5$
b -jets definition	at least one B-hadron with: $p_T > 5 \text{ GeV}, \Delta R(\text{B-hadron}, \text{jet}) < 0.3$
b -jets	anti- k_T $R = 0.4, p_T^{\text{jet}} > 25 \text{ GeV}, y^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5$
CMS $Z + b$ [8]	
Leptons	$p_T^\ell > 25 \text{ GeV}, \eta^e < 2.5 \text{ or } p_T^\mu > 20 \text{ GeV}, \eta^\mu < 2.1$
Z	$60 < m_{\ell\ell} < 120 \text{ GeV}$
Jets	anti- k_T $R = 0.5, p_T^{\text{jet}} > 25 \text{ GeV}, \eta^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5$
b -jets	at least one B-hadron with $\Delta R(\text{B-hadron}, \text{jet}) < 0.5$
CMS $Z + 2b$ [9]	
Leptons	$p_T^\ell > 25 \text{ GeV}, \eta^e < 2.5 \text{ or } p_T^\mu > 20 \text{ GeV}, \eta^\mu < 2.1$
Z	$76 < m_{\ell\ell} < 106 \text{ GeV}$
Jets	anti- k_T $R = 0.5, p_T^{\text{jet}} > 25 \text{ GeV}, \eta^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.5, n_{\text{jet}} \geq 2$
b -jets	at least one B-hadron with $\Delta R(\text{B-hadron}, \text{jet}) < 0.5$
CMS $Z + 2SV$ [11]	
Leptons	$p_T^\ell > 25 \text{ GeV}, \eta^e < 2.5 \text{ or } p_T^\mu > 20 \text{ GeV}, \eta^\mu < 2.1$
Z	$60 < m_{\ell\ell} < 120 \text{ GeV}$
b hadrons	$p_T^{\text{hadron}} > 15 \text{ GeV}, \eta^{\text{hadron}} < 2.0$
CMS $W + c$ [10]	
Leptons	$p_T^\mu > 25 \text{ GeV}, \eta^\mu < 2.1$
W	$m_T > 50 \text{ GeV}$
Jets	anti- k_T $R = 0.5, p_T^{\text{jet}} > 20 \text{ GeV}, \eta^{\text{jet}} < 2.1, \Delta R(\ell, \text{jet}) > 0.3$

Z+bb Backgrounds

To convert yields into cross-section

- **Backgrounds** estimated from data

- **ttbar**: fit to $m(l\bar{l})$
- **ZZ**
 - From MC, scaled to CMS cross-section measurement
- **Z+ucdsg**: b-jet purity
 - Template fit to secondary vertex mass distributions



	$\mu\mu + bb$	$ee + bb$
Yields	219	148
bb-purity	$(83 \pm 6)\%$	$(83 \pm 6)\%$
ttbar frac.	$(20 \pm 5)\%$	$(17 \pm 5)\%$
$N_{Z(l\bar{l})Z(bb)}$	5.2 ± 0.2	3.0 ± 0.2

W+c

- C-estimate

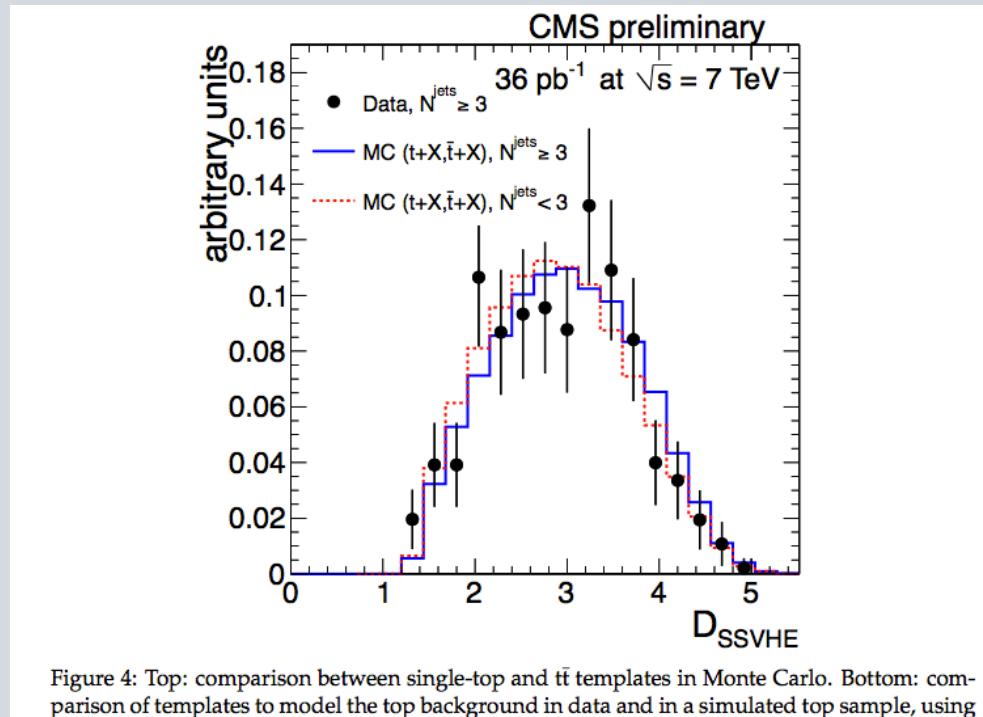


Figure 4: Top: comparison between single-top and $t\bar{t}$ templates in Monte Carlo. Bottom: comparison of templates to model the top background in data and in a simulated top sample, using an enriched-top selection. They are also compared with the expectation from the simulated sample using the final signal selection criteria. All templates are normalized to 1.

Selection

Just an example:
Z+bb at CMS

Reconstruct $Z \rightarrow l^+l^- \dots$

- $l = e/\mu$
 - $p_T(e/\mu) > 25/20$ GeV
 - $|\eta(e/\mu)| < 2.5/2.1$
- $76 < m(l\bar{l}) < 106$ (GeV)

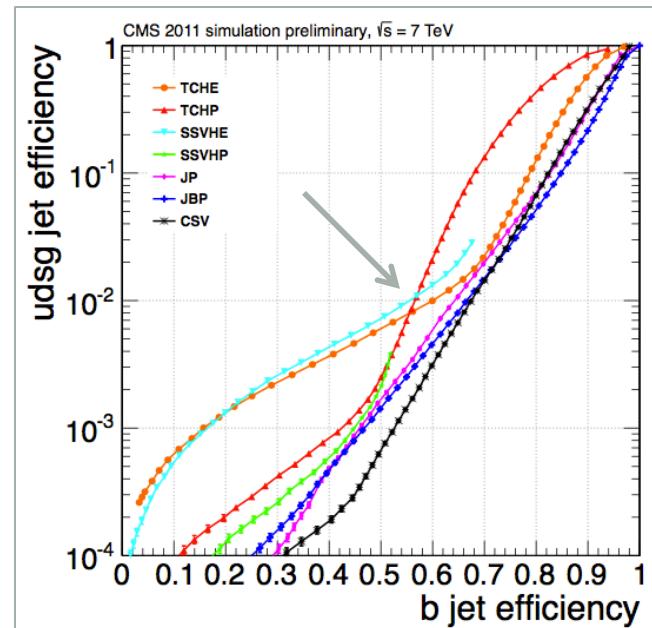
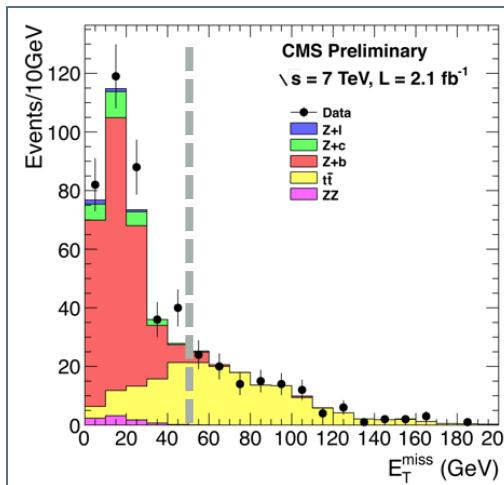
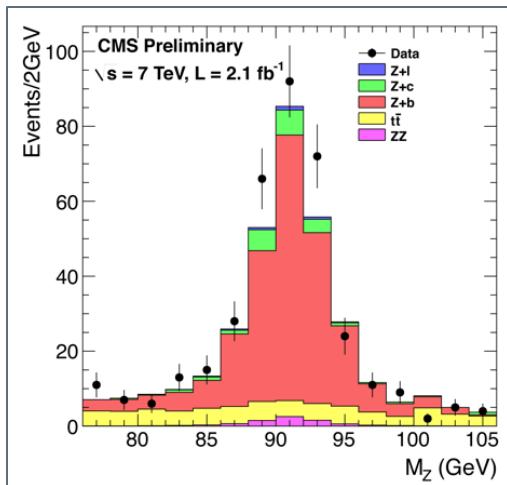
...and two jets...

- PF, anti- k_T , $\Delta R=0.5$
 - $p_T > 25$ GeV
 - $|\eta| < 2.1$
- Reduce $t\bar{t}$ with PFMet
 - $\text{ME}_T < 50$ GeV

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

- Detached secondary vertex
 - High efficiency selection
 - Efficiency $\sim 55\%$
 - udsg-mistag $\sim 1\%$

➤ Select $Z(l\bar{l}) + 2b$



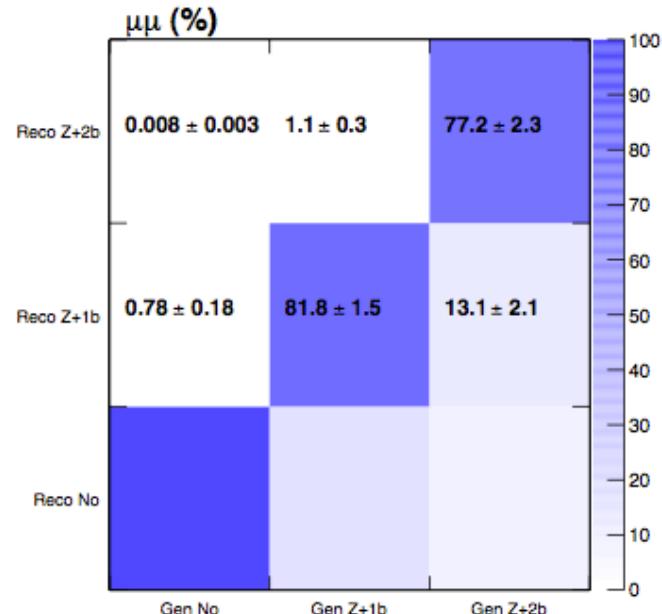
Efficiencies

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

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

- **ϵ_b : b-tagging efficiency**
 - Scale MC to data expectations, using a.o $p_{T\text{rel}}$
- **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

Just an example:
Z+bb at CMS



“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**

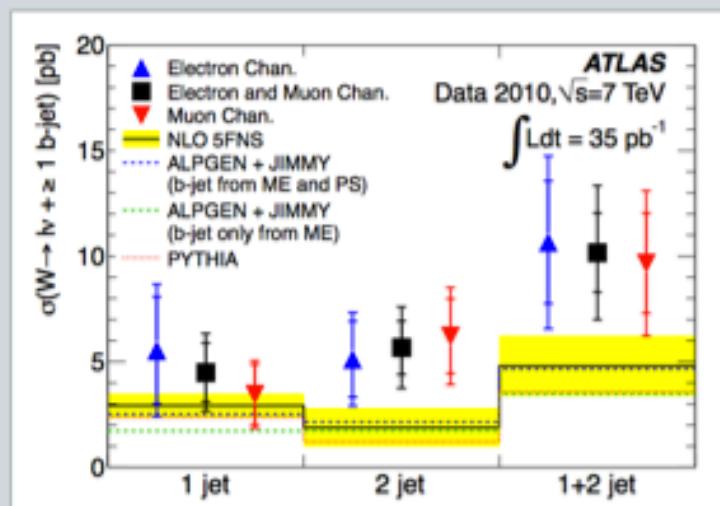
- CMS: **pT(Z)** and **DeltaPhi(Z,b)** distributions in the data suggests harder spectra than those predicted
 - by the LO MadGraph+Pythia MC generated in the 5-flavour scheme.

- **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.

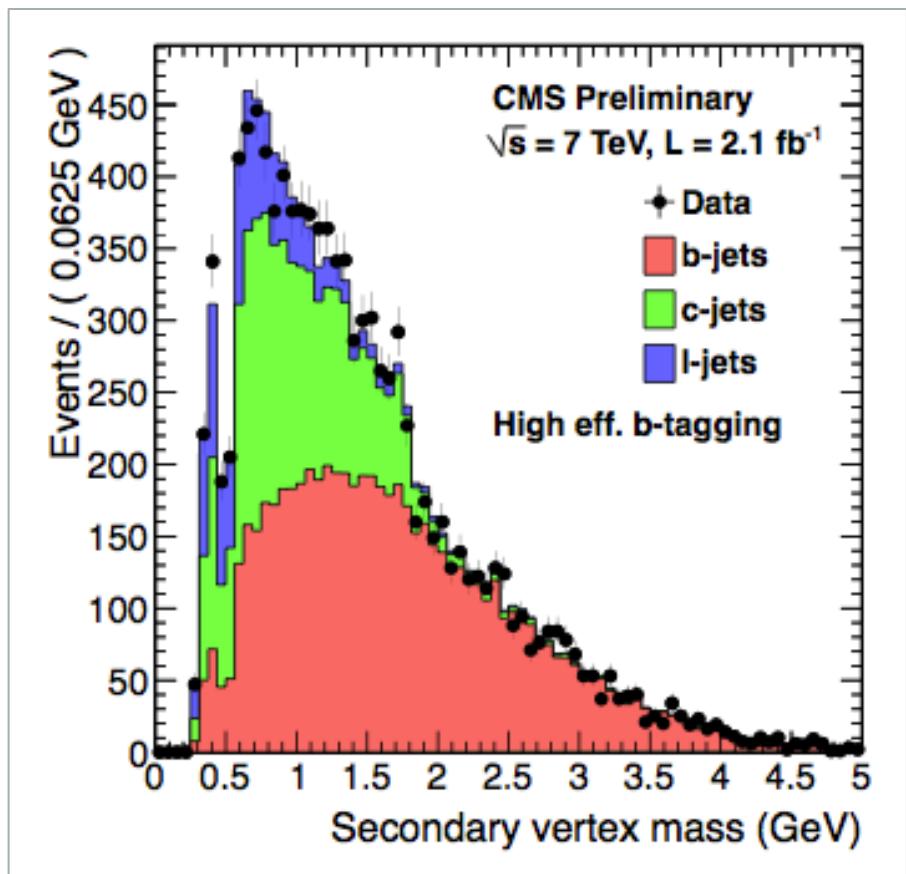
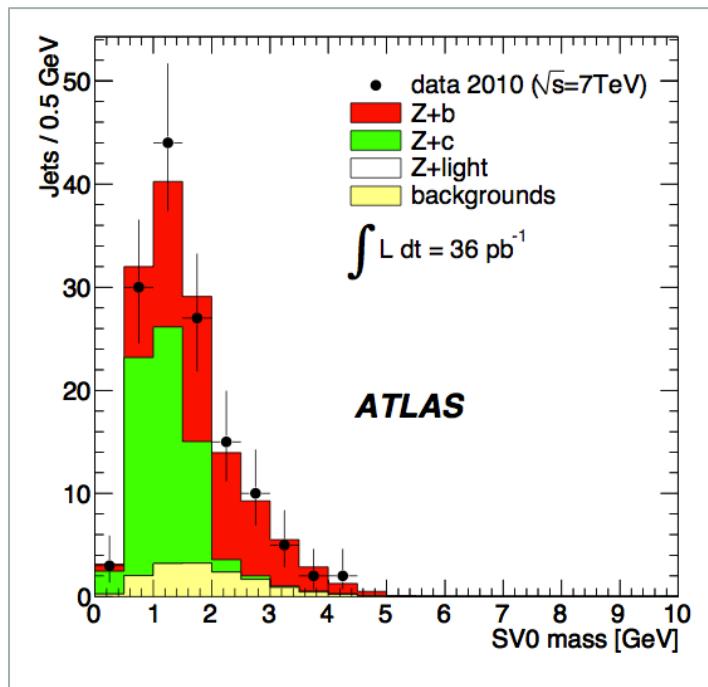
- **Z+2SV**

- CMS: data and MC disagree in the distribution of the angle between the two displaced vertices of the b-hadrons $\Delta R(b_1, b_2)$.



Hadronization

- Effect on purity estimate?



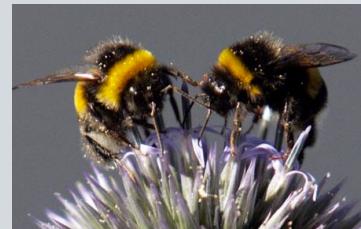
- Best way to estimate systematics?
 - Herwig?

“What is a B”?

Suppose: **2B hadrons 1 B-jet?**

- **Example**

- Reconstruct one jet
- With 2 b-hadrons in it
- Do we consider this experimentally as **two Bs or one B?**
- And if so, how does the cone definition affect the definition?



➤ Experimentally

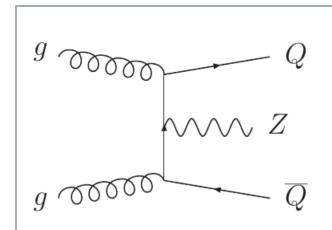
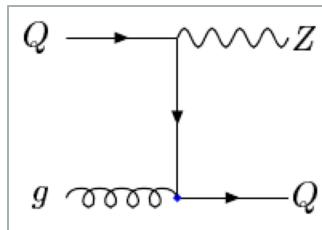
Study the feasibility to identify jets containing two b hadrons from the experimental point-of-view.

- “Infrared safety”? IVF?

➤ Theoretically

Does the meaning of the measurement change depending on such criteria?

“What is Z+1b”?



Select an event with a Z and...

1. **Atlas counts #b-jets**

- “Z with 2 b-jets in a single event counts as two Z+1b candidates”

2. **CMS counts events with at least one b-jets**

- “Z with two b-jets is a single Z+1b event”

Questions

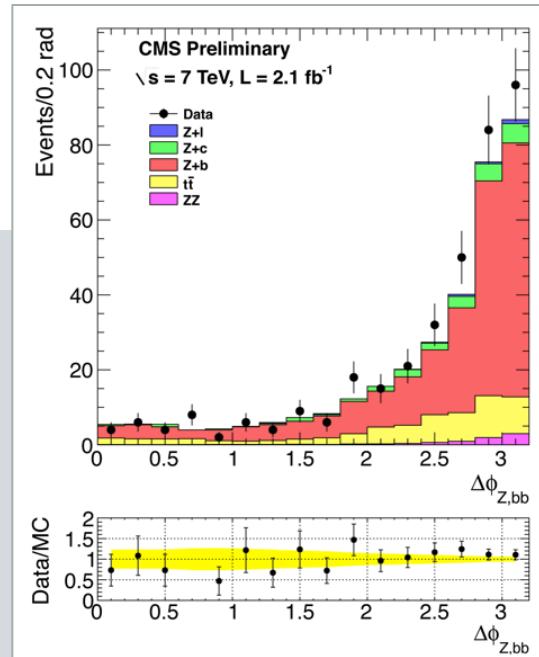
- How to define in 2012?
- What's best way to compare?
 - Between experiments?
 - Also affects event/jet purity
 - With theory?

“What is Z+bb”?

- **MPI = Multiple parton interactions**
 - Production of Z and bb from different parton interactions
 - Back o/t envelope estimate: ~15-20%
 - See backup
 - DeltaPhi(Z,bb) agrees in non-back-to-back region

Questions/concerns

- **How is MPI defined?**
 - Soft → underlying event?
 - Hard: “real MPI”?
- **4F approach:**
 - Need some generator to add some kind of MPI
 - Plan: use Pythia8 to add pure Z+bb MPI
- **Do we measure or remove?**



Can we reject fake Z+bb?

- Example: cut on pT hadron
- But this might affect the definition of
 - a B
 - a Z+bb
- Experimentally:
Study the importance of asking minimum requirements to the matched b hadron (e.g. $pT>5$ GeV)
- Theoretically
 - Does this affect the “meaning of a b”?
 - Does this change the meaning of a Z+b(b) measurement?