Measurement of Z+c-jet Inclusive Cross-Section

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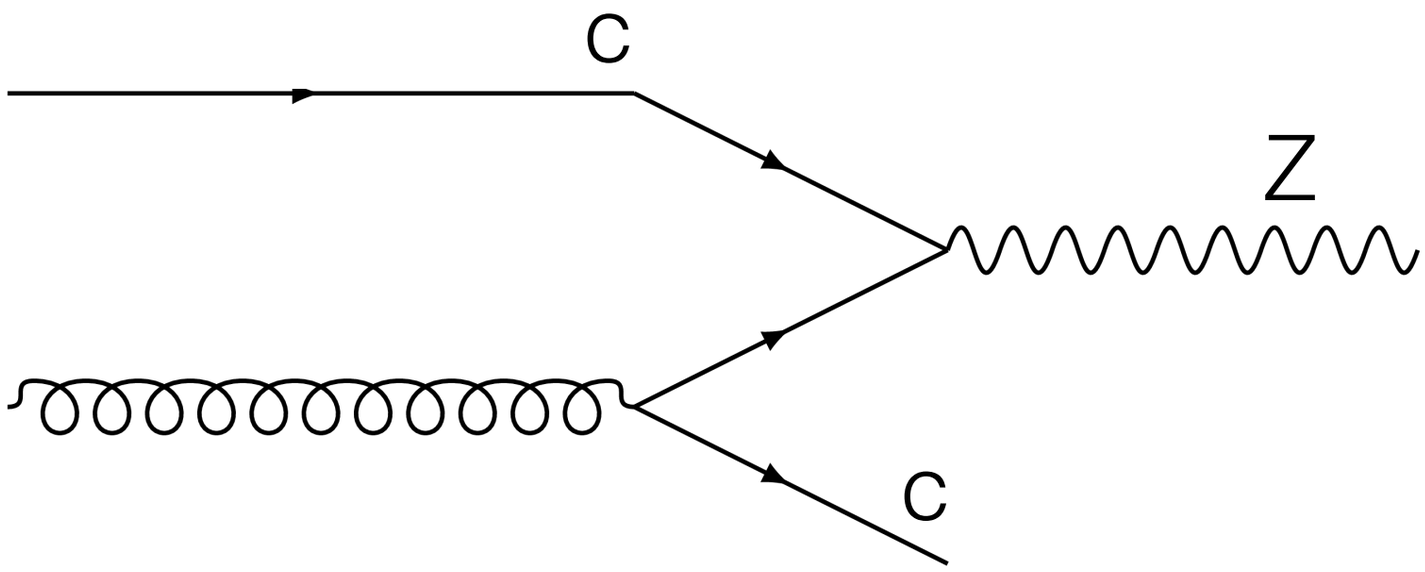
Motivation

- Tune existing Monte-Carlo models
- Extract pdf of c-quark



Z+c-jet process sensitive to pdf of c-quark

Events selections

2016 data ~ 35.6 fb-1

reco level, data and MC

muons

- HLT_IsoMu24/HLT_isoTkMu24
- 2 isolated muons, passing tight id
- $pt_{mu1} > 26$ GeV
- $pt_{mu2} > 10$ GeV
- $|eta| < 2.4$
- $|M_{ll} - 90| < 15$ GeV
- $pt_{\mu\mu} > 40$ GeV
- $|eta_{\mu\mu}| < 2.4$

jets

- ak4 PF CHS jets
- loose jet id
- loose puid
- pt > 40 GeV
- $|eta| < 2.4$
- C-tag

gen level, MC

gen objects selections

- 2 generator level muons
- generator level c-jet
- $|M_{\mu\mu} - 90| < 15$ GeV
- $Pt_{\mu\mu} > 40$ GeV
- $Pt_{gen\ c\text{-}jet} > 40$ GeV

matching criteria

- $dr(\mu\mu_{lhe} - \mu\mu_{reco}) < 0.3$
- $dr(c\text{-}jet_{reco} - c\text{-}jet_{gen}) < 0.3$
- same Ystar and Yb bins at GEN and reco levels

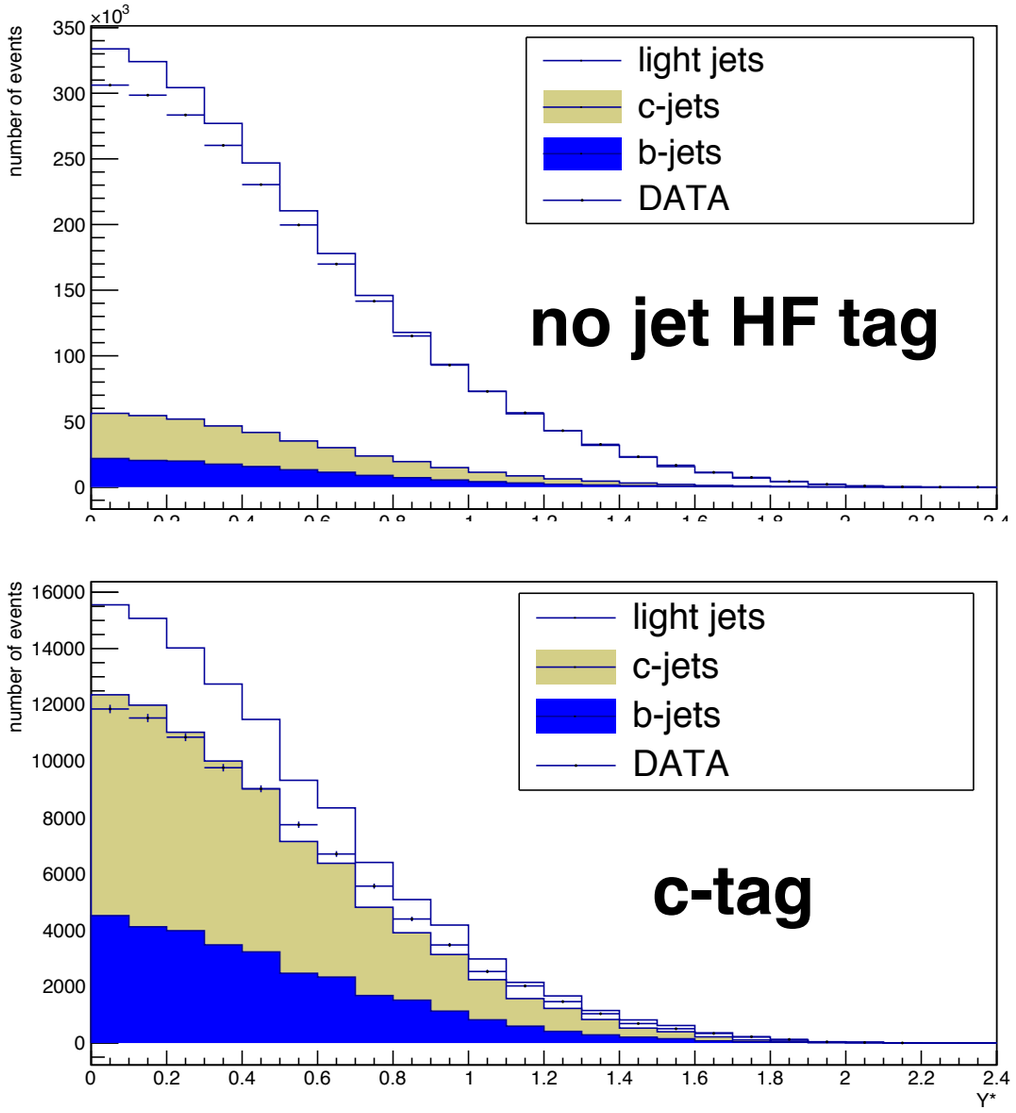
Events selections

Difference between data and MC DY predictions can be taken into account by multiplying light, bottom and charm components of DY by corresponding k_{MC}-factors. k_{MC}-factors can be found through solving 3 equations, corresponding to no jet tag, c-tag and b-tag. Number of events in DY is required to be equal to number of events in DATA - Top/VV:

K_c - factor = 0.77

K_b - factor = 0.70

K_{light} - factor = 0.99



Unfolding procedure

unfolding data

MC training

measured data - top - VV - DY (light + bottom)*

DY+c-jet: reco, gen, response matrix

DY with light and bottom jets multiplied by corresponding k-factors

(measured data - top - VV - DY (light + bottom))*(1-bkg)

unfolding with TUnfold, nScan = 10

unfolded (data - top - VV- DY (light + bottom))(1 - bkg)

acceptance = (matched* gen Z/c-j pt)/(gen Z/c-j pt)

background = 1 - (matched* reco Z/c-j pt)/(reco Z/c-j pt)

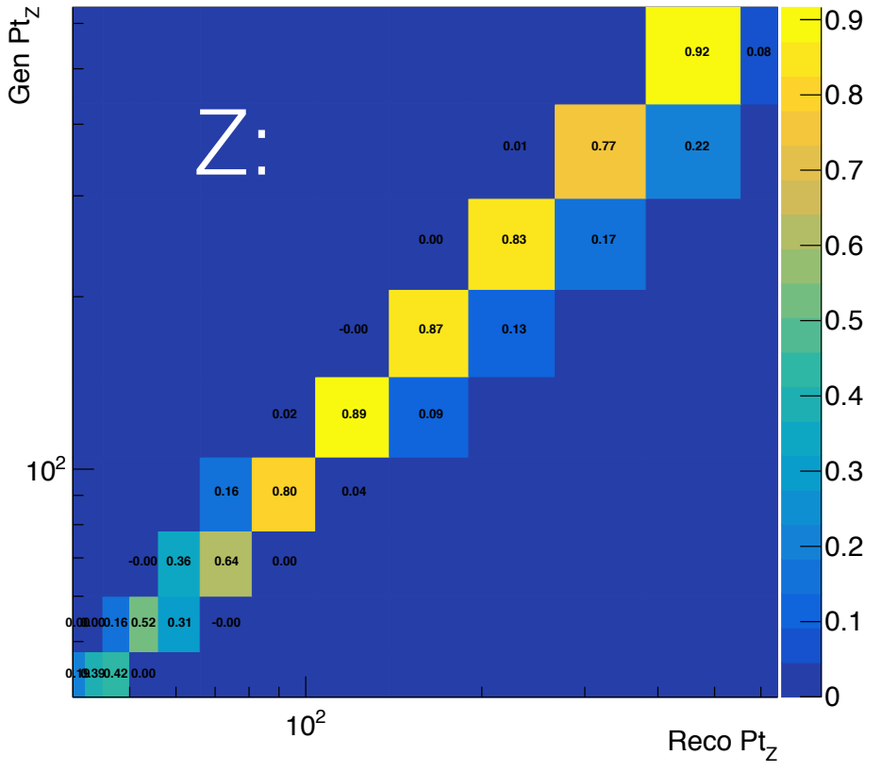
***matching criteria**

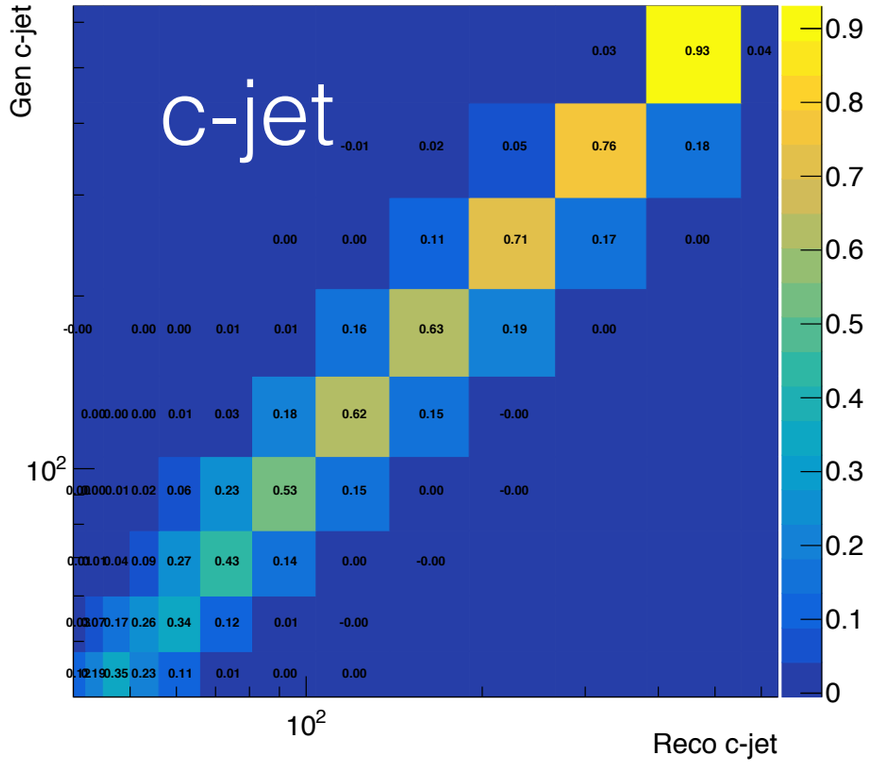
- both reco and gen level criteria fulfilled
- dr($\mu\mu_{lhe}$ - $\mu\mu_{reco}$) < 0.3 (Z pt unfolding)
- dr(c-jet_{reco} - c-jet_{gen}) < 0.3 (c-jet pt unfolding)
- same Ystar and Yb bins* at GEN and reco levels

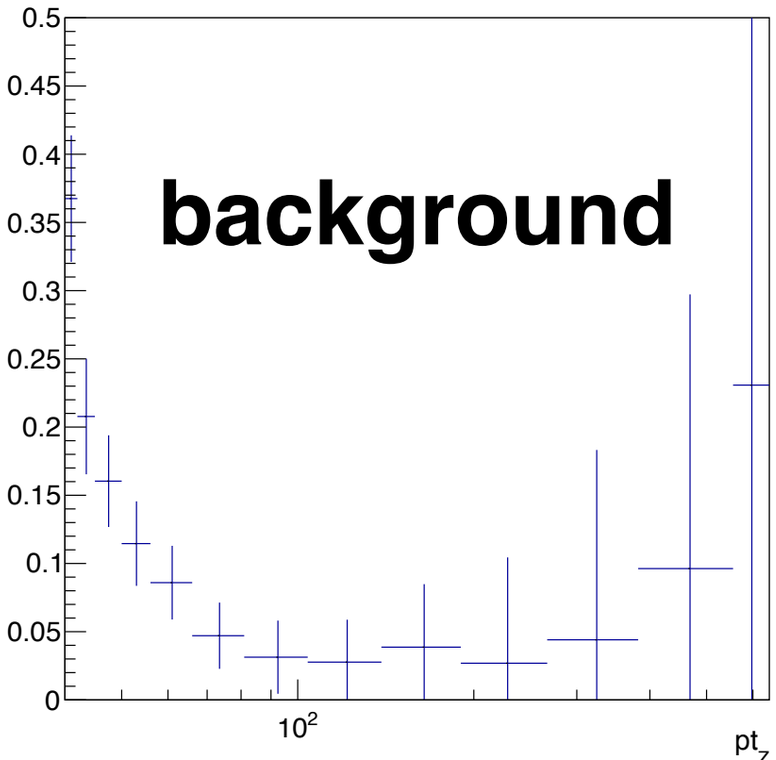
final result:

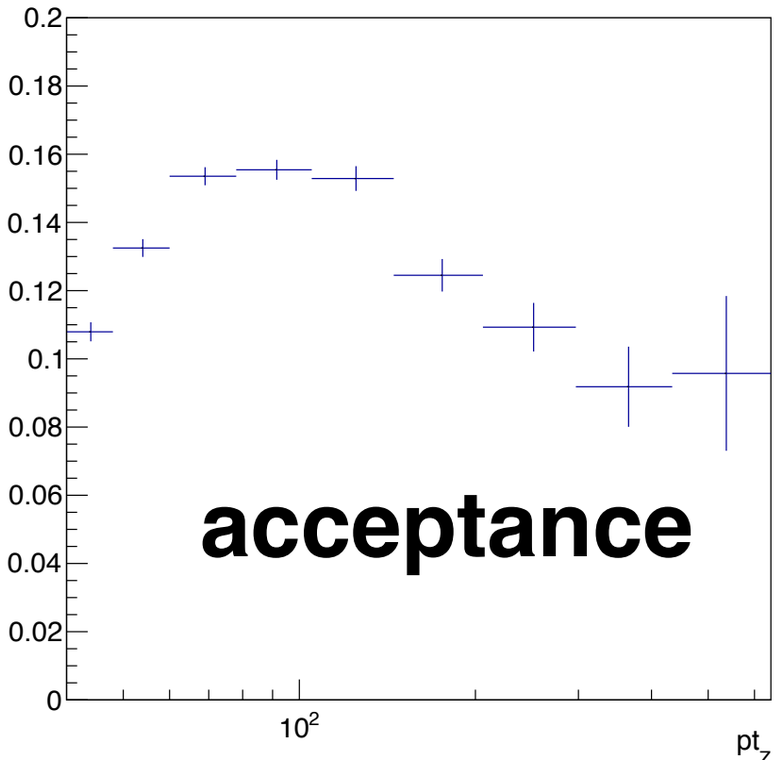
(unfolded (measured data - top - VV - DY (light + bottom))(1 - bkg))/acceptance

Unfolding procedure







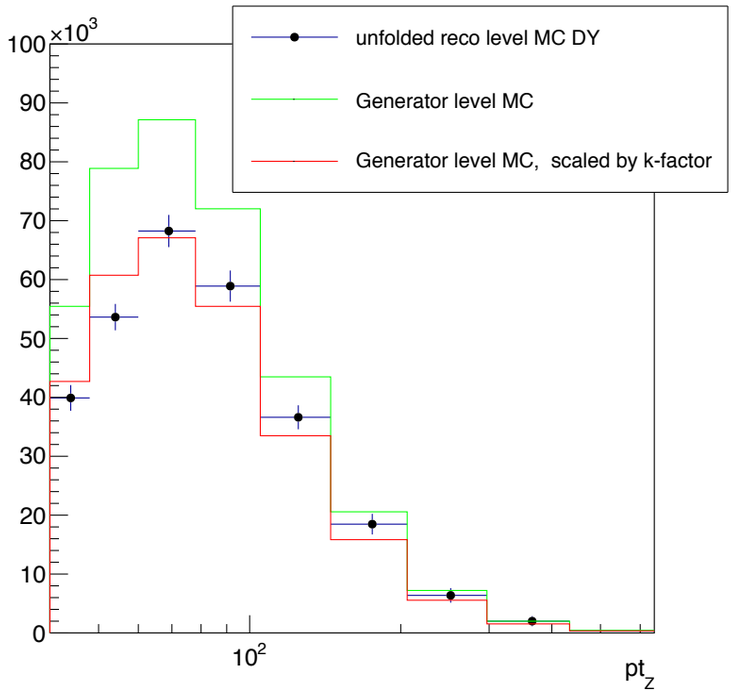


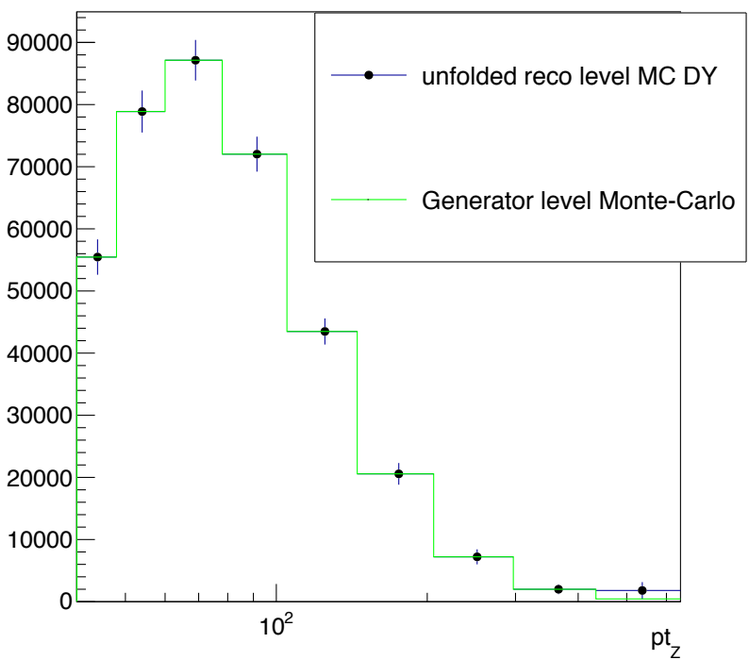
Unfolding procedure

data

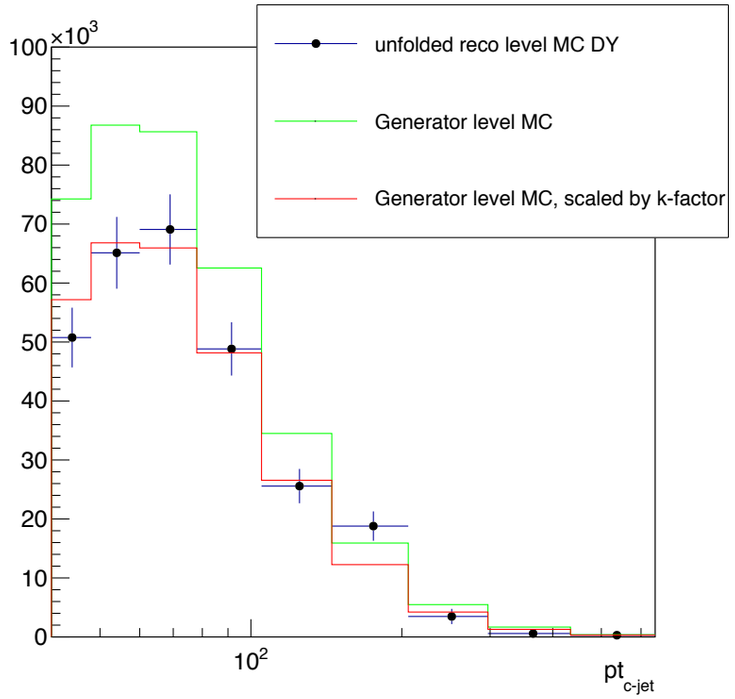
MC(closure)

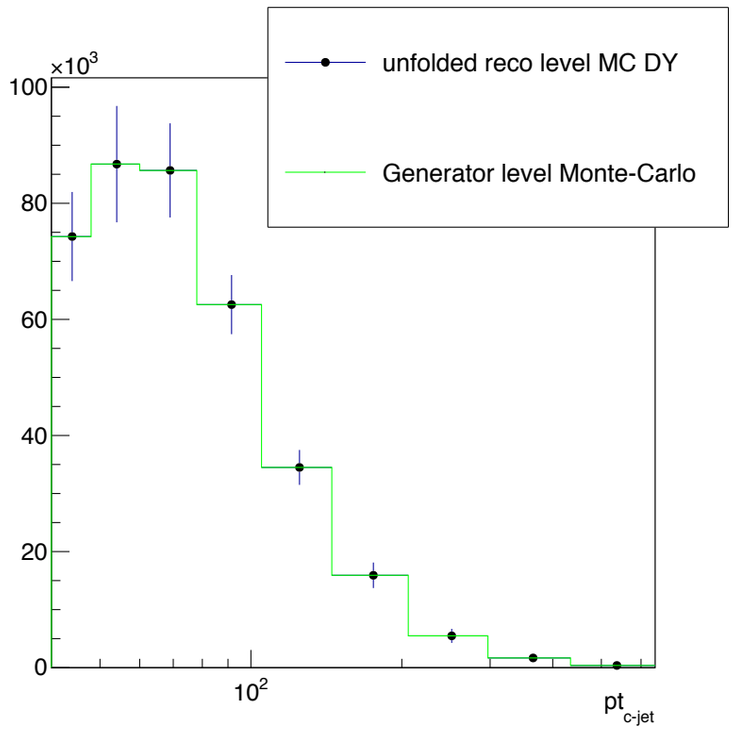
Z:





c-jet:





Systematic errors

Theoretical uncertainties

- pdf
- qcd

Experimental uncertainties

- c-tagging SFs
- jet energy resolution
- jet energy scale
- pileup
- luminosity

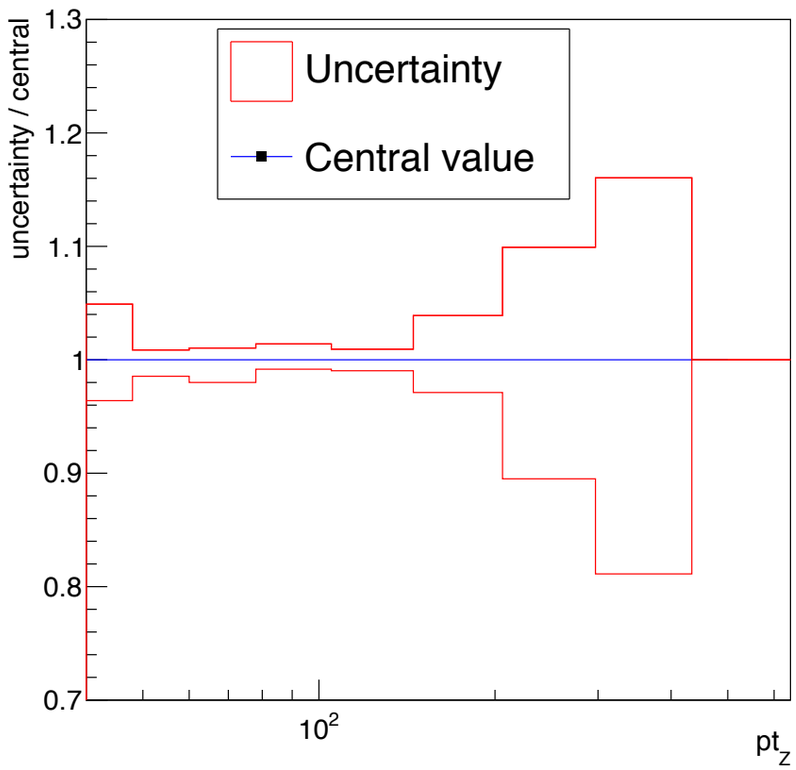
Uncertainties are taken into account by varying corresponding parameters and calculating new response matrix, acceptance, background and k-factors.
New unfolded distribution, obtained using these new objects, represents shape uncertainty of the result.

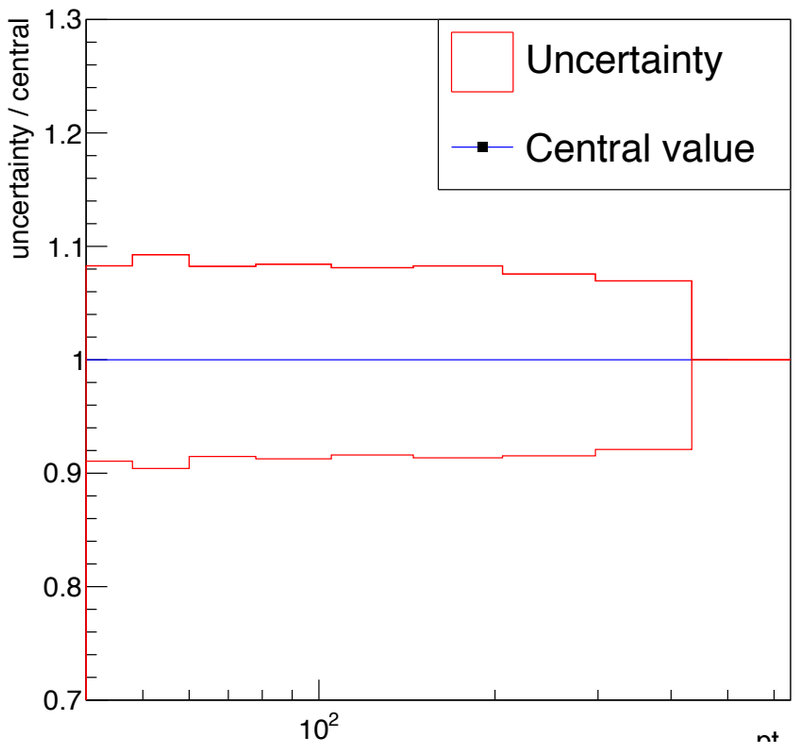
Systematic errors

QCD

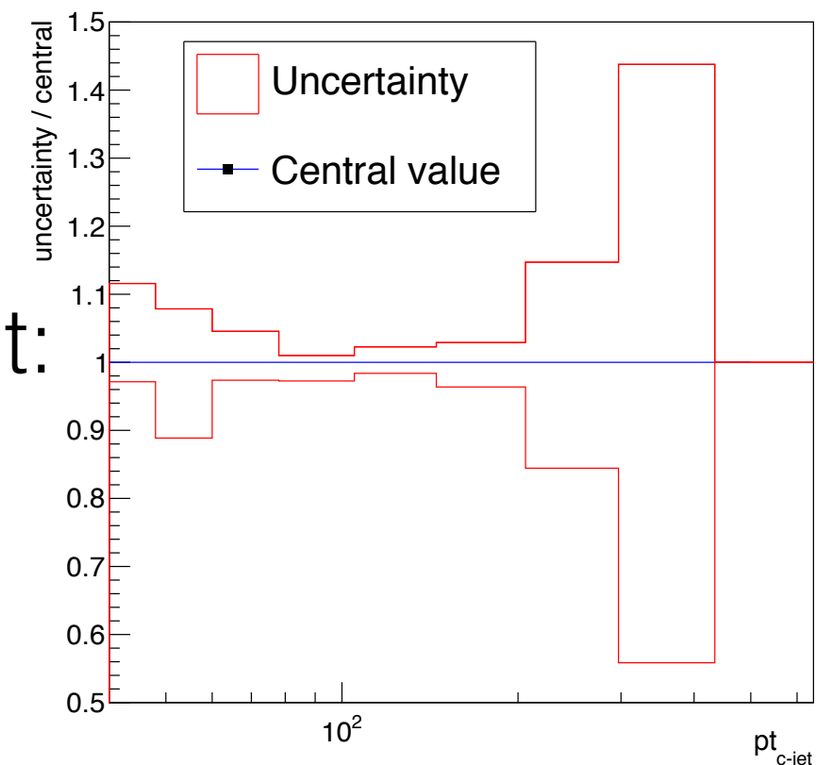
c-tag uncertainty

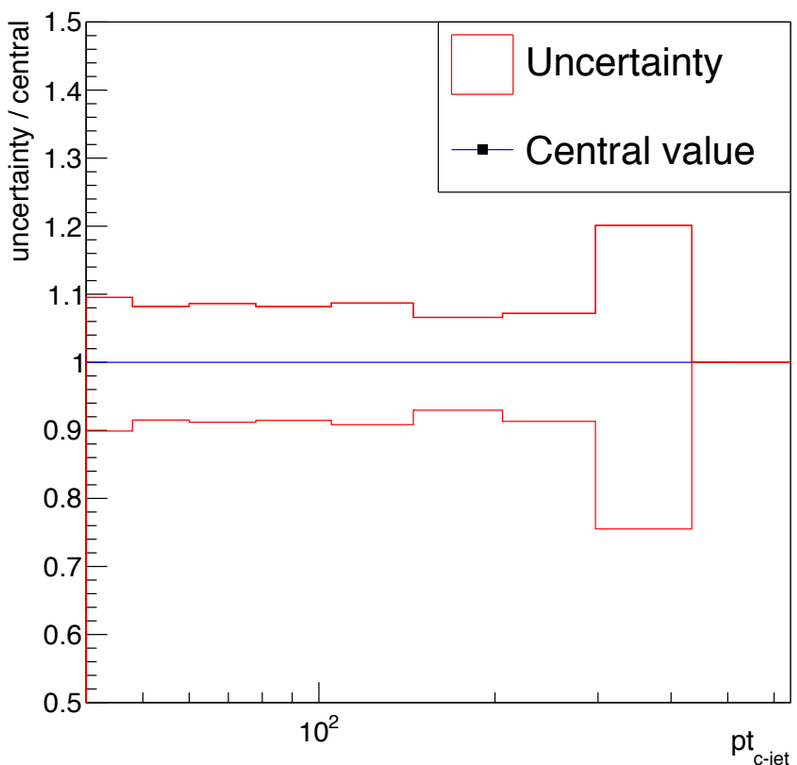
Z:





c-jet:

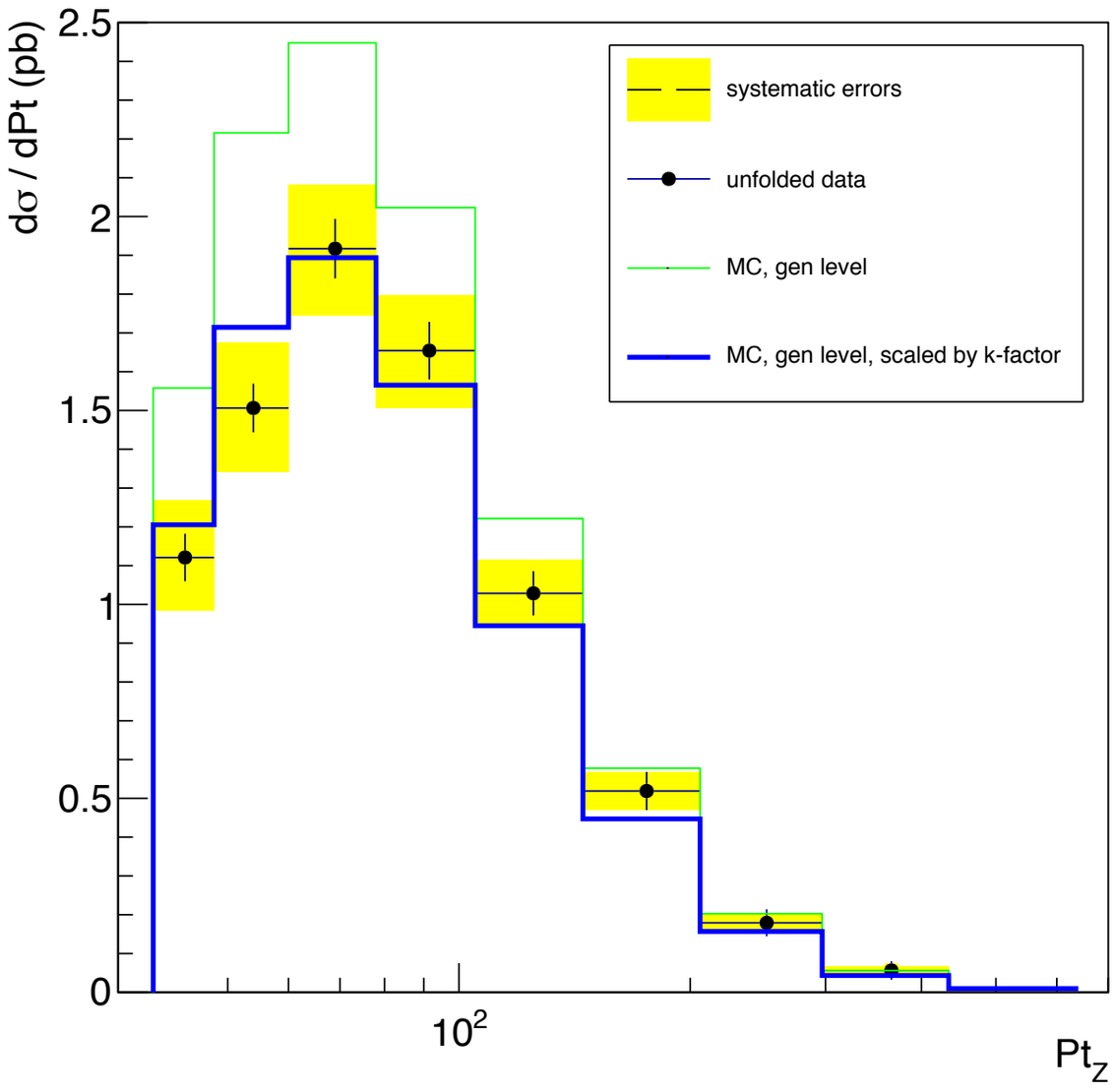




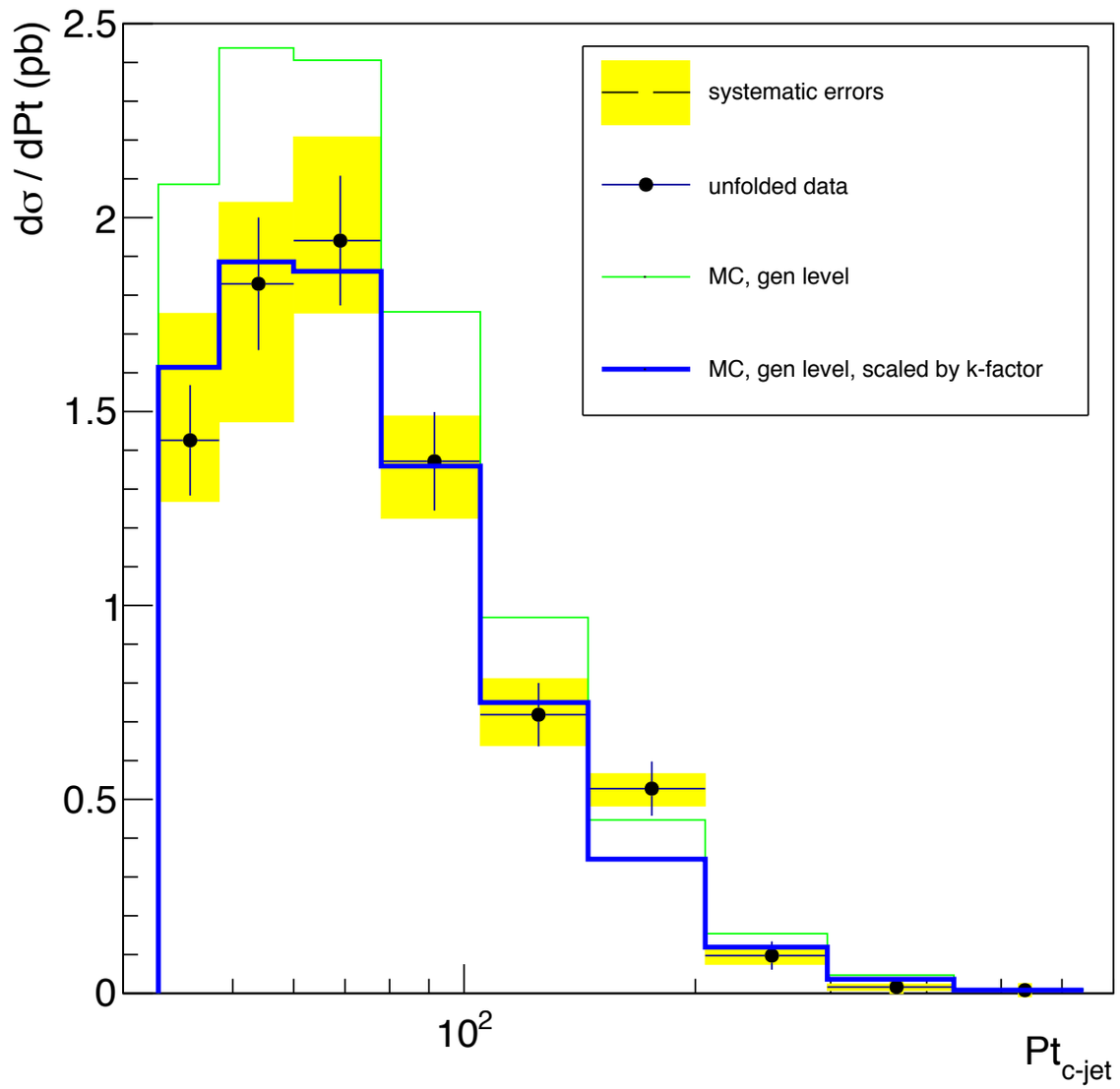
Results

unfolded Z and c-jet pt distributions with total uncertainties

Z pt

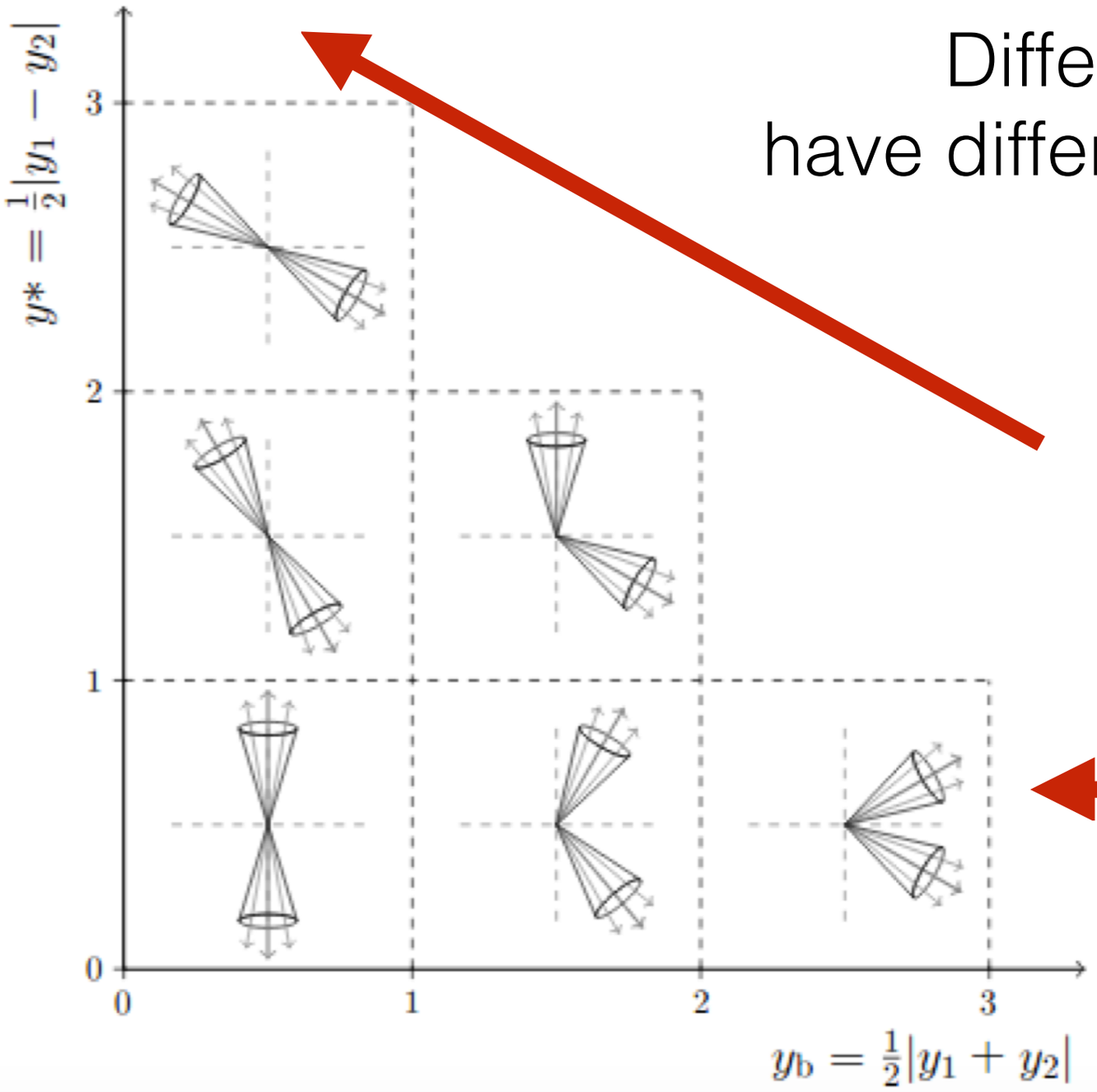


c-jet pt



Square of total uncertainty in each bin equals sum of squares of uncertainties, corresponding to different sources

Results (different Ystar and Yb bins)

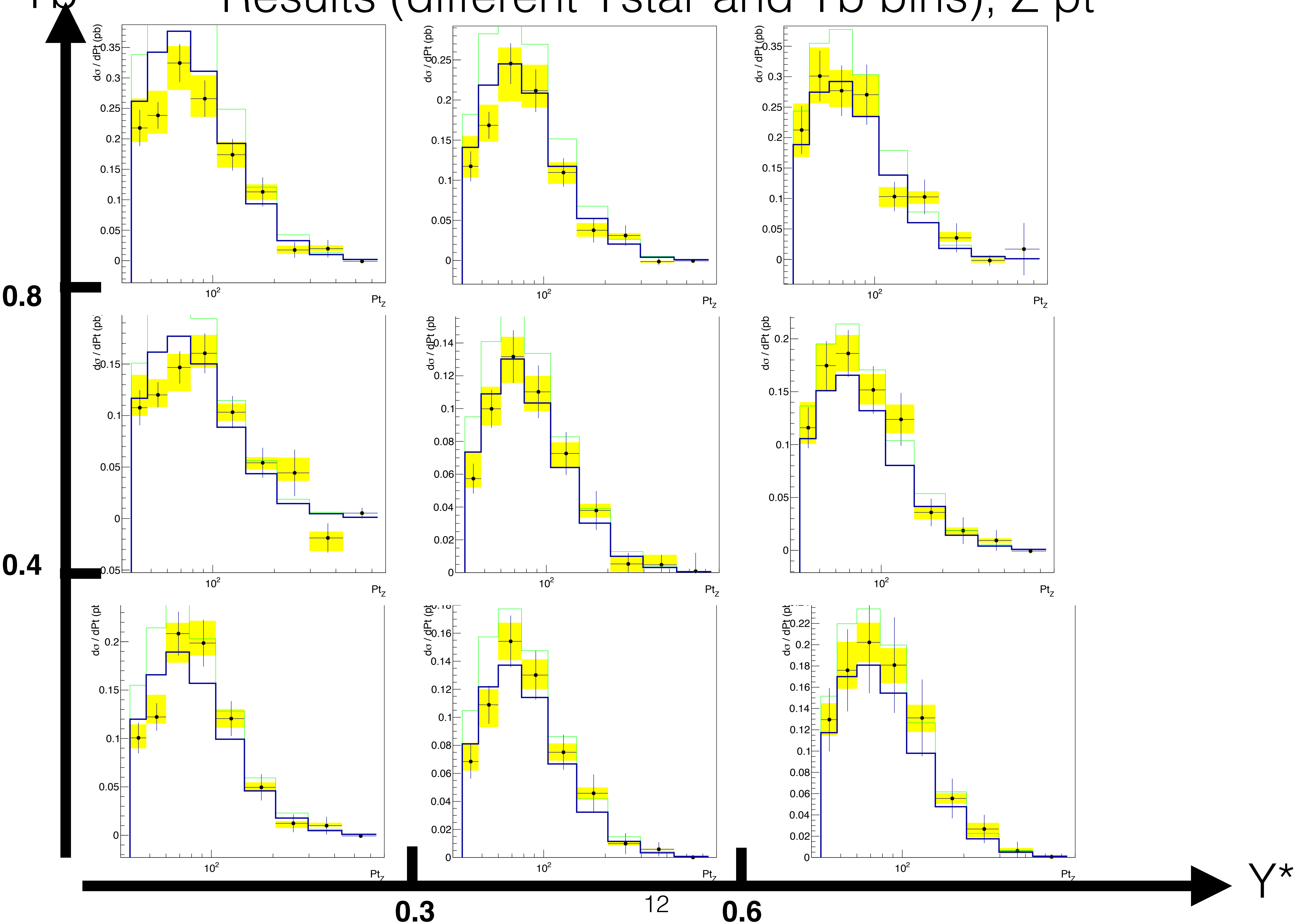


Different Y* and Yb regions
have different theoretical uncertainties

large NLO contribution

small NLO contribution

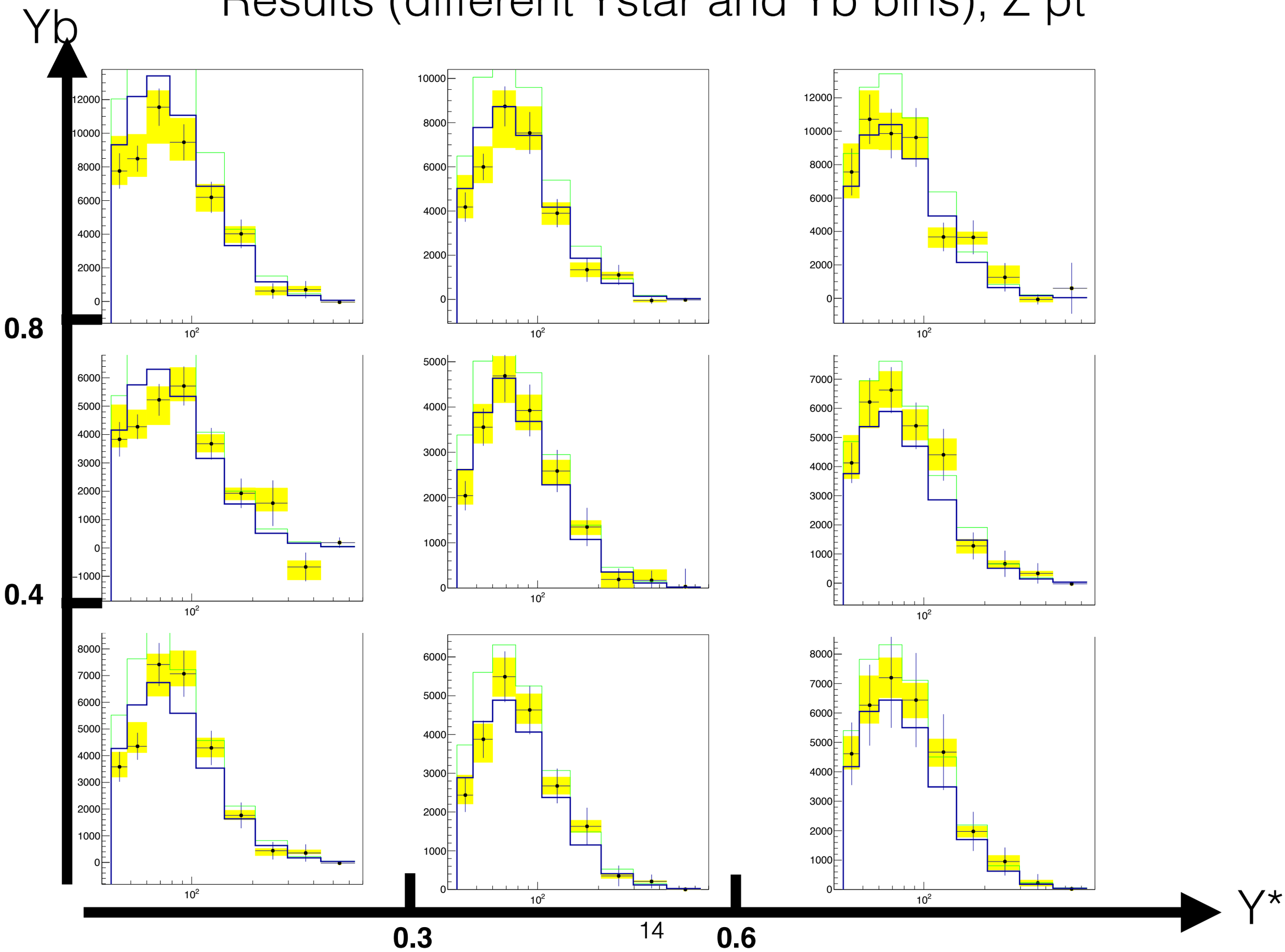
Results (different Ystar and Yb bins), Z pt



summary

- $d\sigma / dpt_Z$ and $d\sigma / dpt_{c\text{-}jet}$ measured
- dependence on Y* and Yb studied
- analysis finished - AN-2018/180
- to be done: check if c-quark pdf can be extracted with higher precision

Results (different Ystar and Yb bins), Z pt



Events selections

process	N of events data - Top/ VV bkg	N of events MC Z+light	N of events MC Z+c	N of events MC Z+b
Z+j	2.36915E+06	2.0863E+06	258051	154667
Z+cj	89992.5	25327.1	55941.8	31152.3
Z+bj	65181.8	2040.24	7710.92	82197.1
k_{MC}-factors*		0.99	0.77	0.70

* data - Top/VV bkg = $k_{MC\ light} * DY_{light} + k_{MC\ c} * DY_C + k_{MC\ b} * DY_b$

Data samples

Data:

/SingleMuon/Run2016B-23Sep2016-v3/AOD
/SingleMuon/Run2016C-23Sep2016-v1/AOD
/SingleMuon/Run2016D-23Sep2016-v1/AOD
/SingleMuon/Run2016E-23Sep2016-v1/AOD
/SingleMuon/Run2016F-23Sep2016-v1/AOD
/SingleMuon/Run2016G-23Sep2016-v1/AOD
/SingleMuon/Run2016H-PromptReco-v2/AOD
/SingleMuon/Run2016H-PromptReco-v3/AOD

35.6 fb-1

MC:

/DYToLL_0/1/2J_13TeV-amcatnloFXFX-pythia8/ **4754/888.9/348.8 pb**/
TTJets_TuneCUETP8M2T4_13TeV-amcatnloFXFX-pythia8/ **831.76 pb**
/ST_t-channel_top_4f_inclusiveDecays_13TeV-powhegV2-madspin-herwigpp/ **136*0.35**
/ST_t-channel_antitop_4f_inclusiveDecays_13TeV-powhegV2-madspin-herwigpp/ **81*0.35**
/ST_tW_antitop_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1 **35.6 pb**
/ST_tW_top_5f_inclusiveDecays_13TeV-powheg-pythia8_TuneCUETP8M1/ **35.6 pb**
/ST_s-channel_4f_leptonDecays_13TeV-amcatnlo-pythia8_TuneCUETP8M1 **96.74 pb**

/WWTo2L2Nu_13TeV-powheg/ **118.7 pb**
/WZ_TuneCUETP8M1_13TeV-pythia8/ **47.13 pb**
/ZZ_TuneCUETP8M1_13TeV-pythia8/ **16.5 pb**