$Z \rightarrow \tau\tau \rightarrow \mu\ \tau_h\ 3\nu$

Data driven background estimation method for QCD and W+jets

BMBF-Forschungsschwerpunkt
ATLAS Experiment
Physics on the TeV-scale at the Large Hadron Collider
FSP 101
ATLAS

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Introduction and cut flow

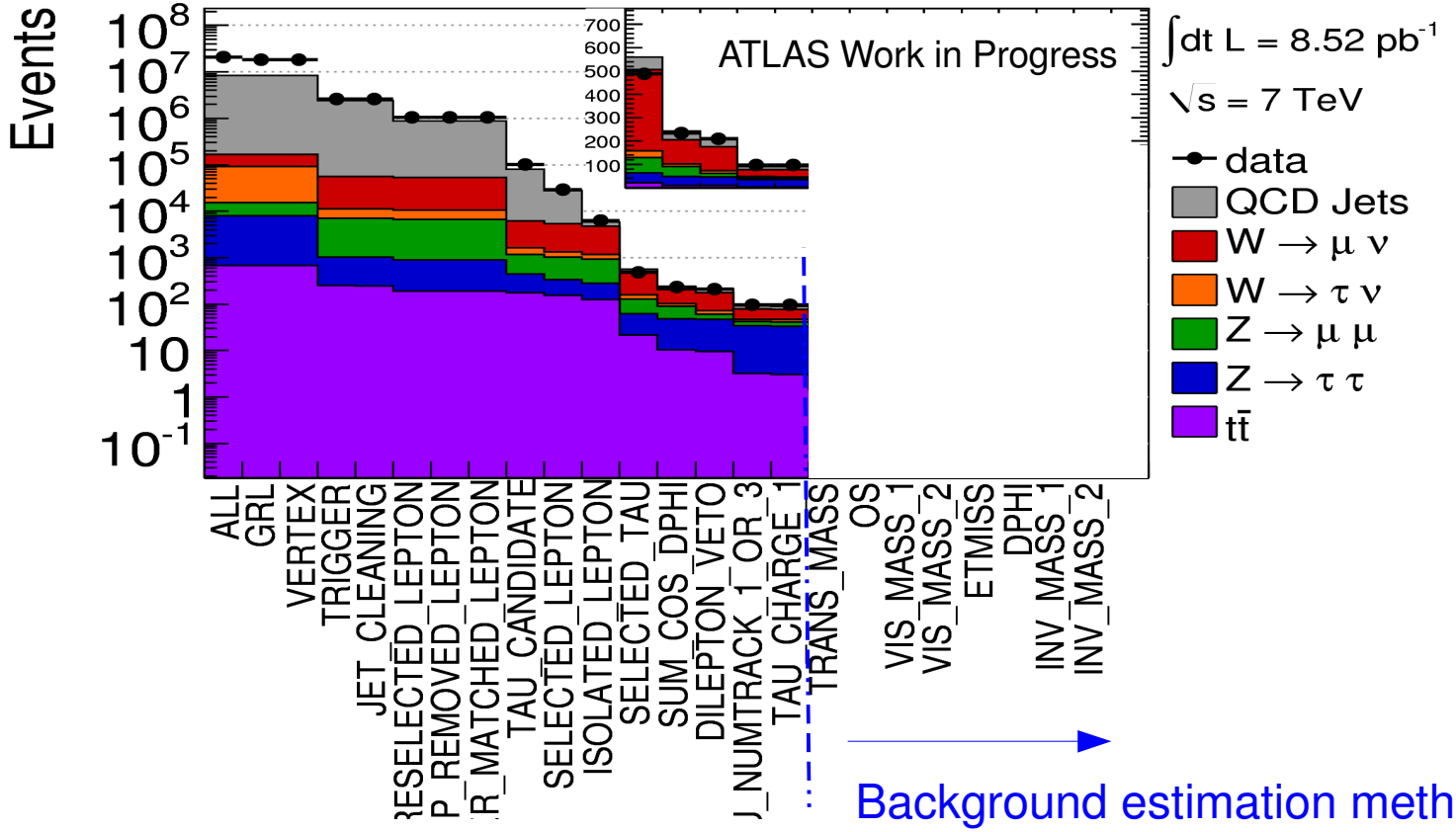
Background study is based on the $Z \rightarrow \tau\tau \rightarrow \mu\, \tau_h\, 3\nu$ analysis package of the ATLAS $Z \rightarrow \tau\tau$ working group.

Cut flow:

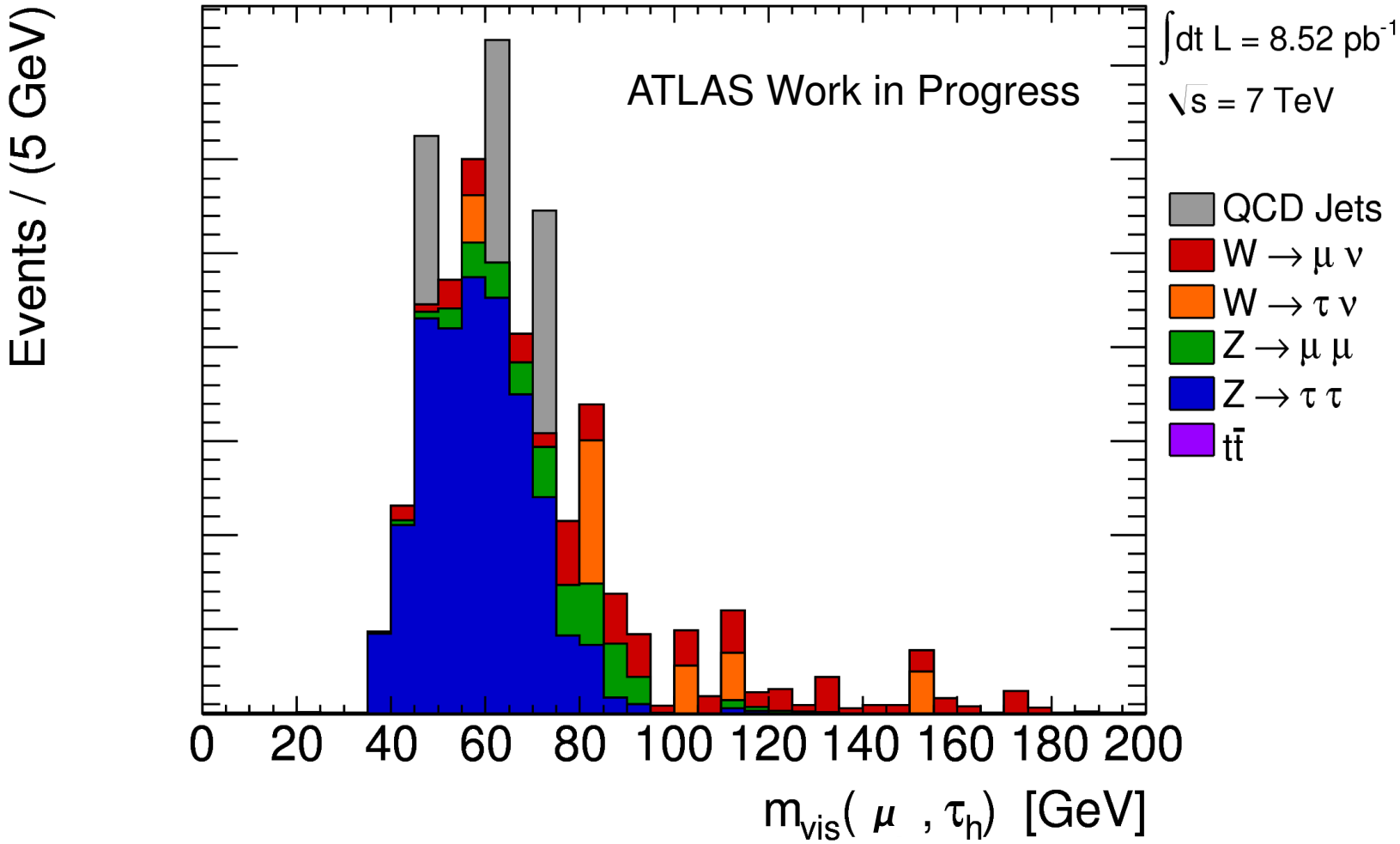
- ≥1 reconstructed tau candidate
- ≥1 muon (reconstructed in muon spectrometer matched to ID track), $p_T > 15$GeV
- Require muon isolation
- Identified tau passing strong quality criteria
- $\cos[\varphi(\mu)-\varphi(E_T^{miss})] + \cos[\varphi(\tau)-\varphi(E_T^{miss})] > -0.15$
- Dilepton veto
- τ_h : $N_{track} = 1$ or 3, $|charge| = 1$
- Transverse mass $M_T(\mu, E_T^{miss}) < 50$GeV
- Opposite charge of μ and tau
- $35\text{GeV} < M_{vis}(\mu, \tau_h) < 75\text{GeV}$
- $E_T^{miss} > 20$ GeV

Overview of event yields

- Data period D-G (8.52pb^{-1}) is used.
- Monte carlo (MC) with <$N_{\text{primary vertex}}$>=2 is used and a vertex reweighting method from data to MC is applied.



Visible mass distribution after M_T > 50GeV and OS cut



→ **Need to estimate QCD and W+jets background contribution from data**

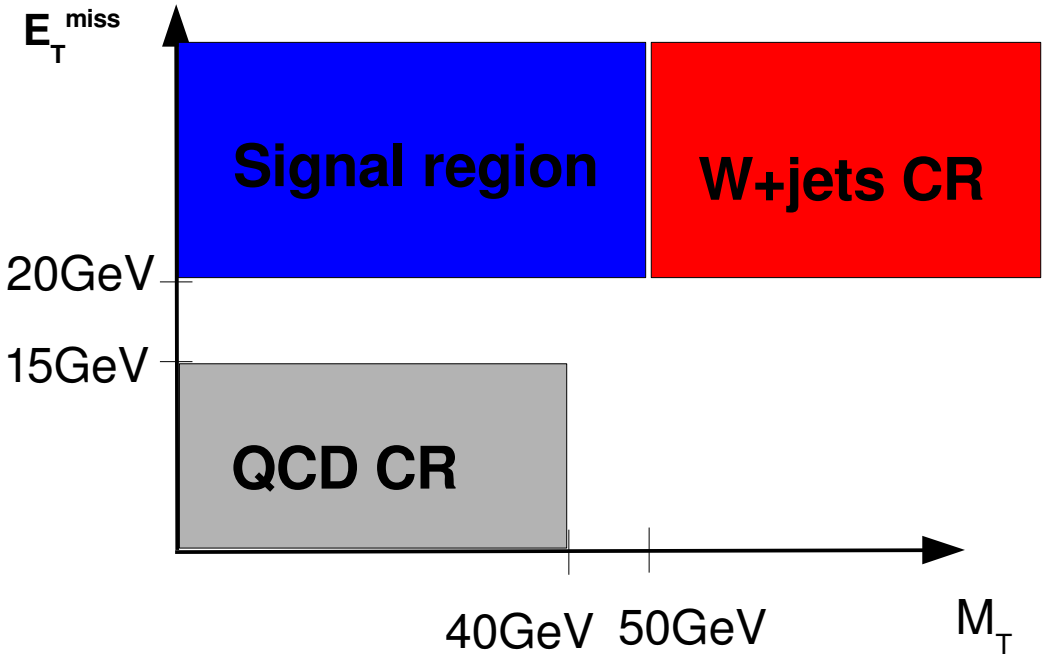
Background estimation method

➔ **Method should rely as much as possible on data**

• **Use control regions (CR) in Z → ττ → μ τ_h 3ν selection, where background is enriched → use OS/SS ratio of background contributions**

Signal region	QCD CR	W+jets CR
E_T^{miss} > 20GeV	E_T^{miss} < 15GeV	E_T^{miss} > 20GeV
M_T < 50GeV	M_T < 40GeV	M_T > 50GeV

+ Drop lepton isolation to increase statistics in the QCD control region!



Calculation of the background components

$$N_{OS,Bkg.}^{SigReg} = R_{OS/SS,QCD} * N_{SS,QCD}^{SigReg} + R_{OS/SS,W} * N_{SS,W}^{SigReg}$$

From Data QCD CR

$$= R_{SR/CR,SS,QCD} * N_{SS,QCD}^{CR}$$

From MC

From Data QCD CR

→ Trust only on MC E_T^{miss} shape of QCD

Assumptions to be proven:

- $R_{OS/SS}$ is the same in signal region (SR) and CR for each background component
- E_T^{miss} and M_T distributions are the same for OS and SS events

OS and SS events in the control regions with isolation

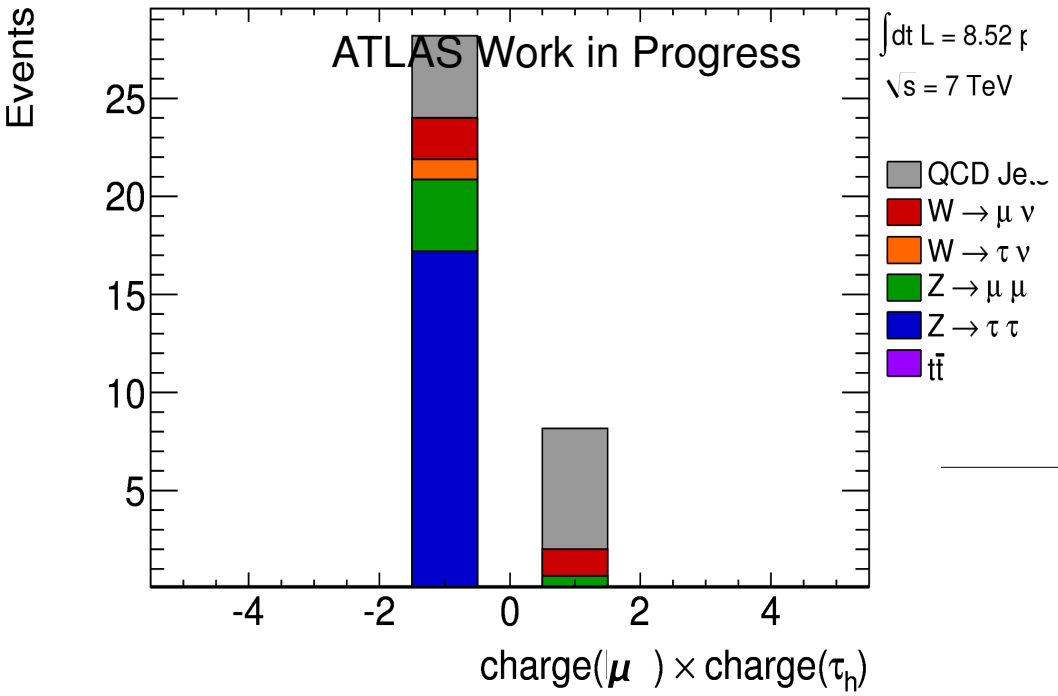
Number of events left in signal- and control regions.

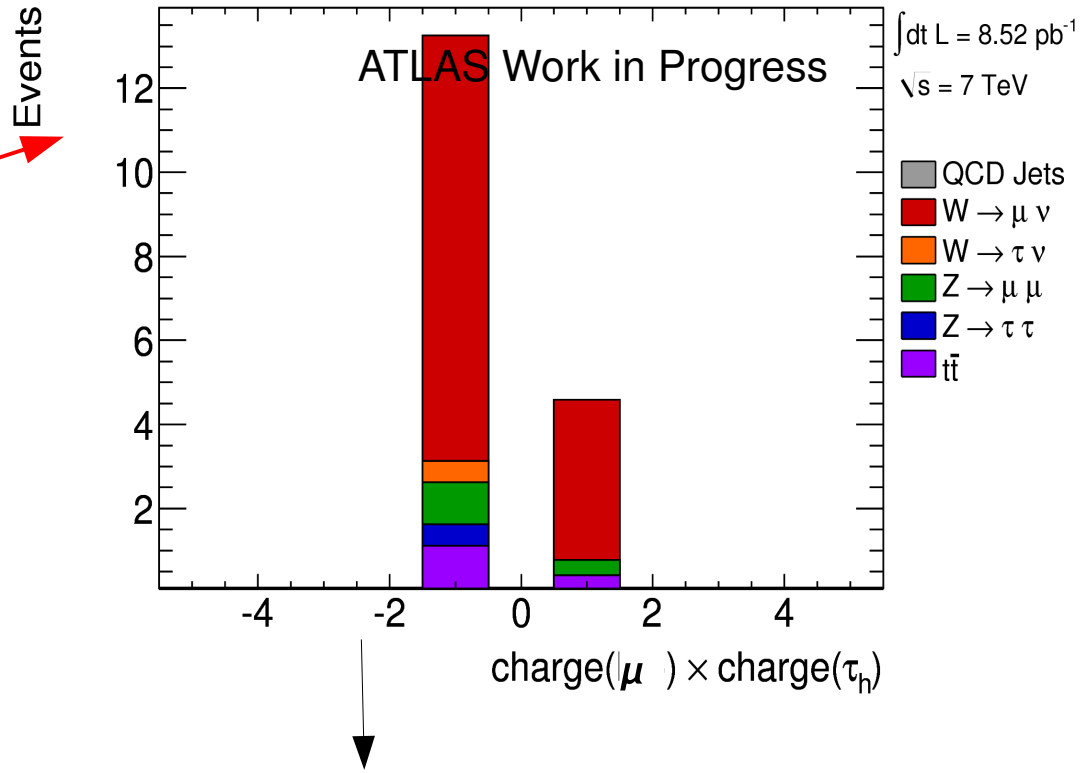
OS and SS

With muon isolation

QCD CR

W+jets CR





- W+jets CR dominated by W+jets events

- QCD CR dominated by signal events

➔ Drop isolation criteria on muons to increase QCD contribution

OS and SS events in the control regions without isolation

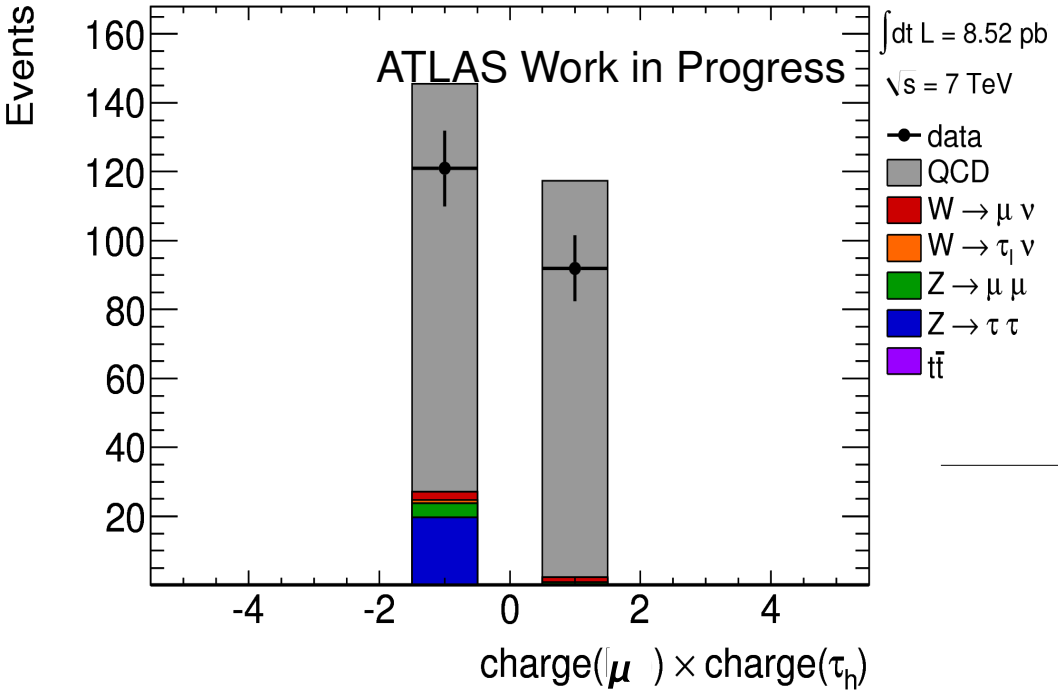
Number of events left in signal- and control regions.

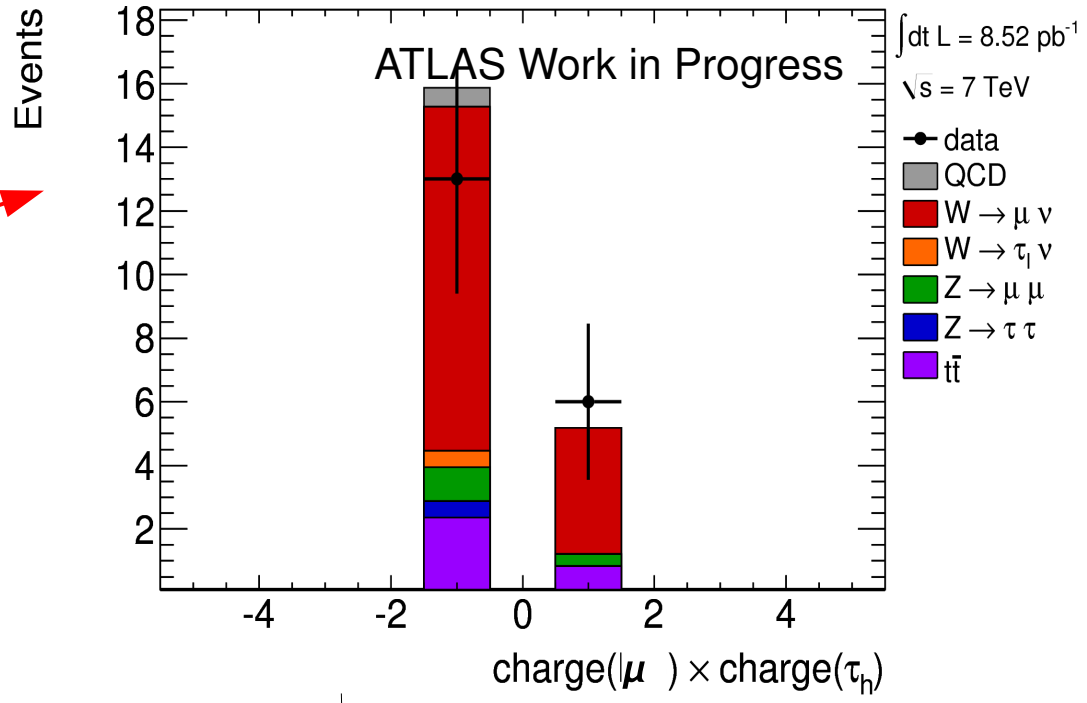
OS and SS

Without muon isolation

QCD CR

W+jets CR

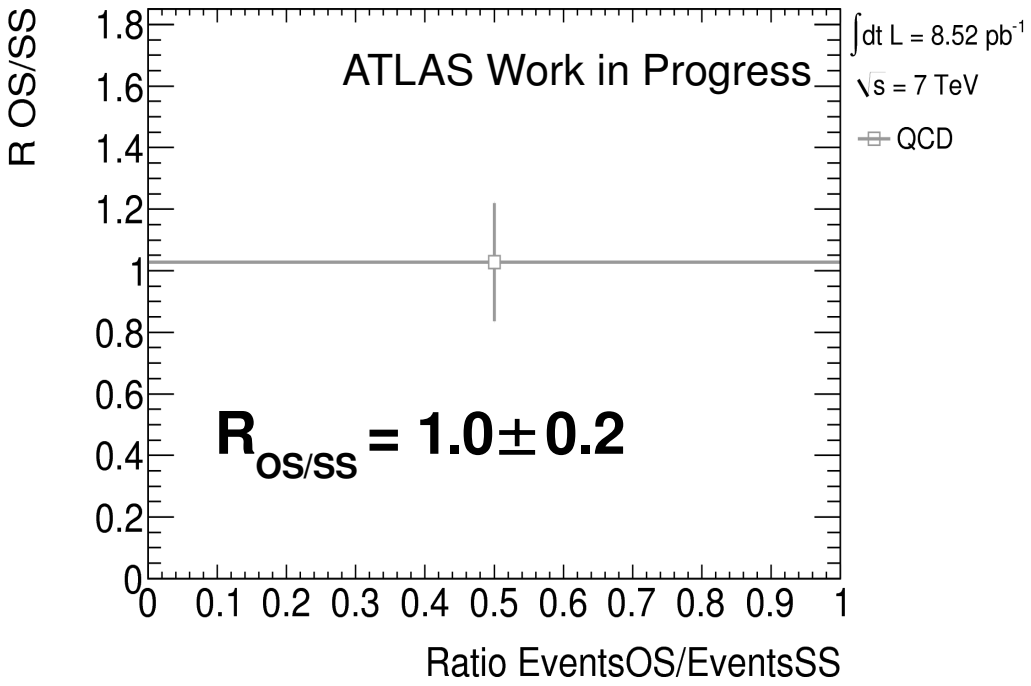




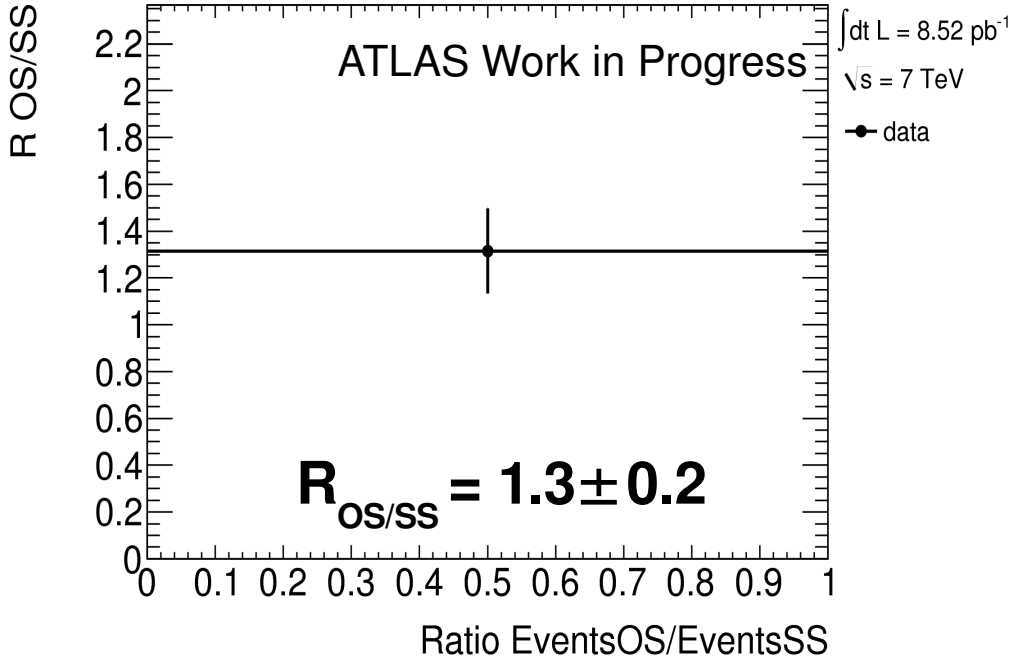
- W+jets CR dominated by W+jets events
- QCD CR now dominated by QCD events
- Normalization of QCD CR to be investigated

OS/SS ratio of QCD events from QCD CR

Events QCD MC (QCD CR)



Events Data (QCD CR)



→ **OS/SS ratio of Data and MC in QCD CR compatible, but big uncertainties**

→ **can be improved**

Preliminary Numbers for QCD

$N_{QCD,SS}^{SR} = 8.6 \pm 4.0$ → statistical uncertainty limits precision

$N_{QCD,SS}^{QCD\ CR} = 115 \pm 15$

$N_{Data,SS}^{QCD\ CR} = 92 \pm 10$

$$N_{OS,QCD}^{SigReg} = R_{OS/SS,QCD} * N_{SS,QCD}^{SigReg}$$

From Data QCD CR

$$= R_{sig/CR,SS,QCD} * N_{Data,SS}^{QCD\ CR}$$

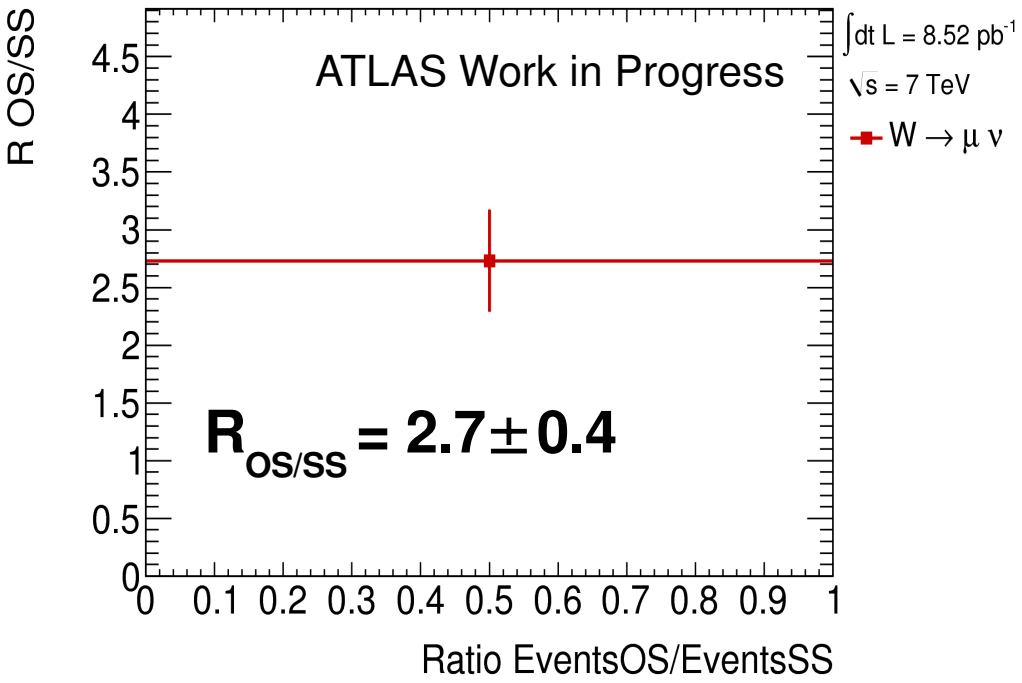
$$\text{QCD} = (1.3 \pm 0.2) * (0.075 \pm 0.036) * (92 \pm 10)$$

$$\text{Background:} = \underline{9.0 \pm 4.6}$$

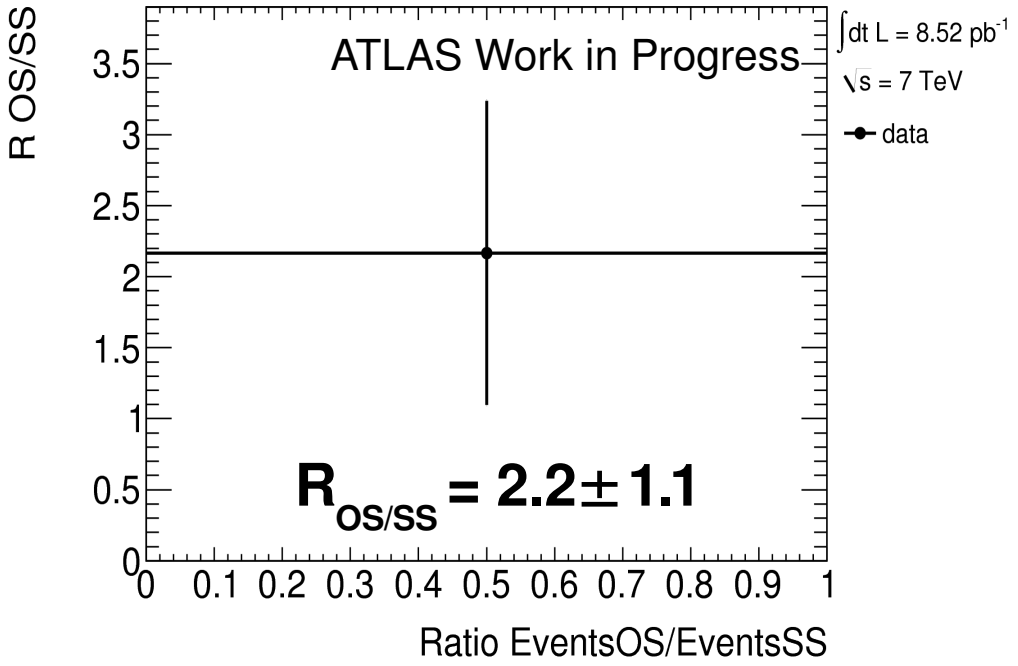
Numbers without lepton isolation criteria!

OS/SS ratio of W+jets events from W CR

Events MC W+jets (W CR)



Events Data (W CR)



→ **Low statistics in W control region**

→ **Could modify the W CR to get higher statistics**

Preliminary Numbers for W+jets

$N_{W,SS}^{SR} = 1.8 \pm 0.4$

$N_{W,SS}^{W\ CR} = 4.0 \pm 0.5$

$N_{Data,SS}^{W\ CR} = 6.0 \pm 2.5$ → statistical uncertainty limits precision

$$N_{OS,W}^{SigReg} = R_{OS/SS,W} * N_{SS,W.}^{SigReg}$$

From Data W CR

$$= R_{sig/CR,SS,W} * N_{Data,SS}^{W\ CR}$$

For W+jets:

$$= (2.2 \pm 1.1) * (0.45 \pm 0.11) * (6.0 \pm 2.5)$$

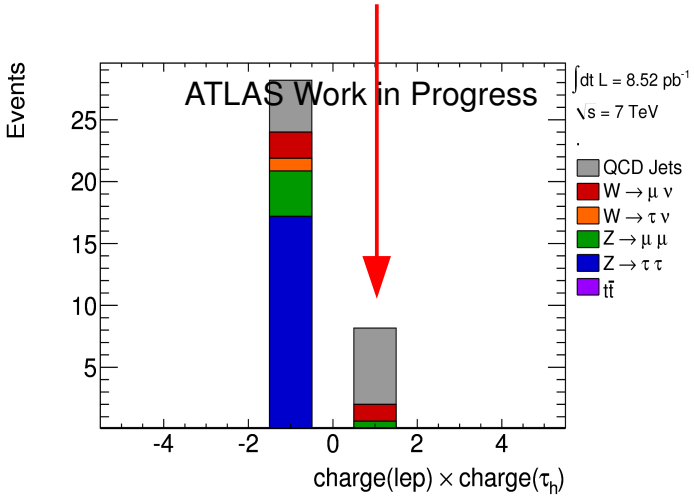
$$= \underline{5.9 \pm 3.4}$$

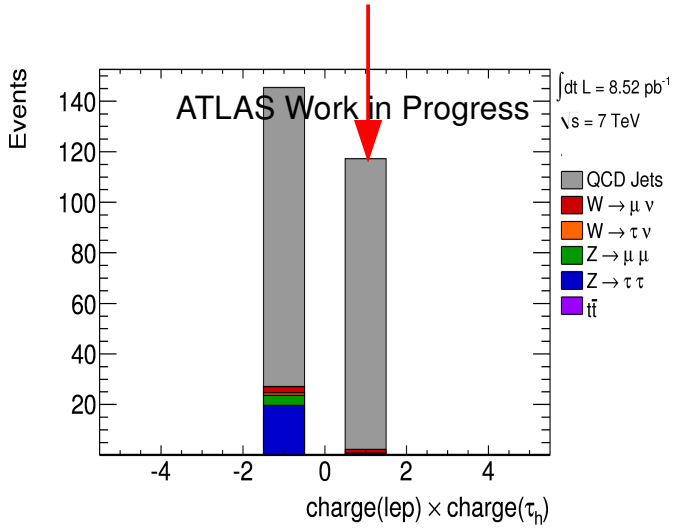
Application to Signal region <u>including</u> lepton isolation

- **Take the Number of SS events in the QCD CR with and without lepton isolation to get the difference of QCD events in the SR with and without isolation**

→ Take $R_{noIso/Iso}(N_{SS}^{QCD\ CR})=(9.0\pm2.9)$ from data to scale down to SR with isolation

QCD CR →





→ Divide the (9.0±4.6) events by (9.0±2.9) to get QCD estimate in SR <u>including</u> lepton isolation

Preliminary numbers including lepton isolation

Taking into account the efficiency of lepton isolation leads to the following number of QCD- and W+jets events in the signal region:

Estimated number of events:

- **1.0±0.6 QCD events in signal region**
- **5.9±3.4 W+jet events in signal region**

Crosscheck with Monte Carlo numbers:

- **0.0 QCD events in signal region**
  (uncertainty to be investigated)
- **4.5±1.1 W+jet events in signal segion**

Conclusion

- The estimated numbers for QCD and W+jets backgrounds match with the MC prediction
- → The method looks in principle promising

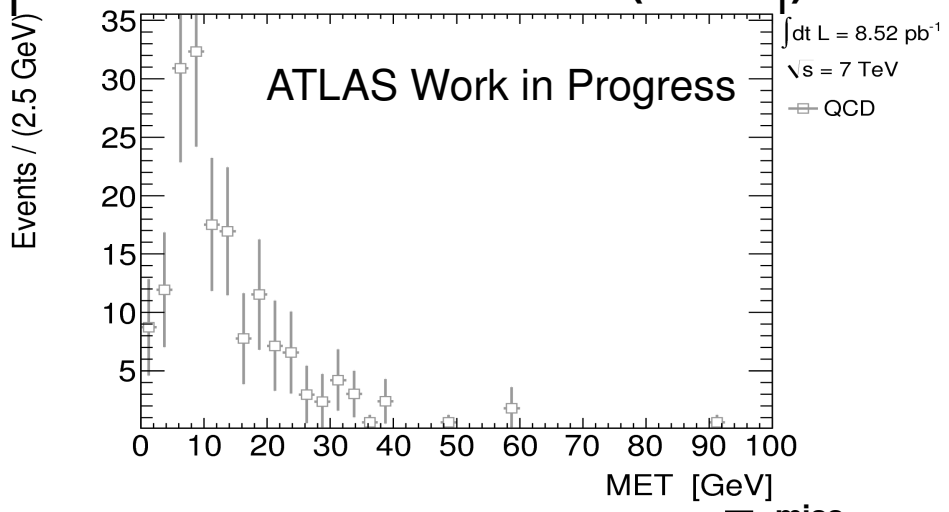
- Statistical uncertainties will become smaller with more data available
- → Could evaluate method to estimate cross-feed between signal and control regions ("tiles method", "ABCD method")

- QCD CR contains too much signal → drop cut on E_T^{miss} for signal selection → this method cannot be applied in the near future
- → Can be used at a later step, when selecting the signal for calculating the inv. $Z \rightarrow \tau\tau$ mass

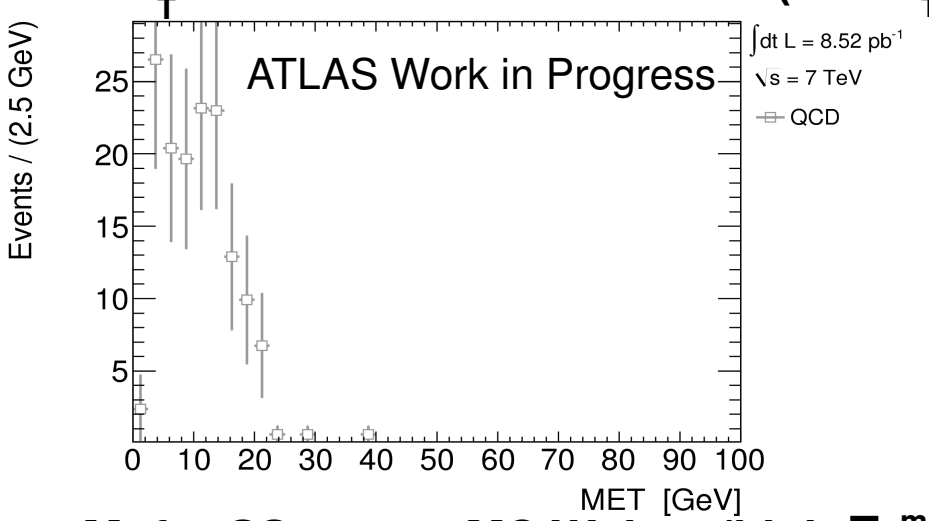
Backup

Monte carlo control histograms

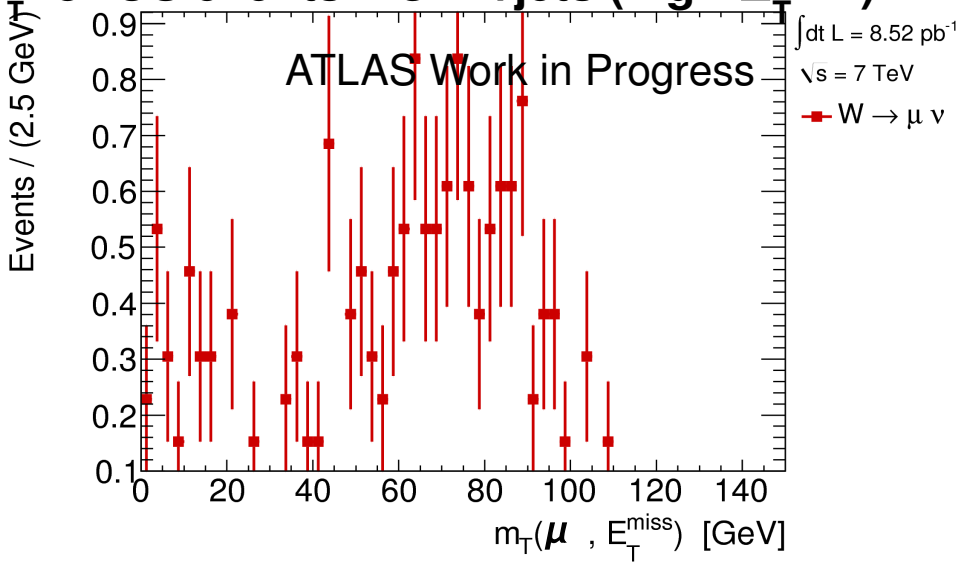
E_T^{miss} for OS events MC QCD (low M_T)



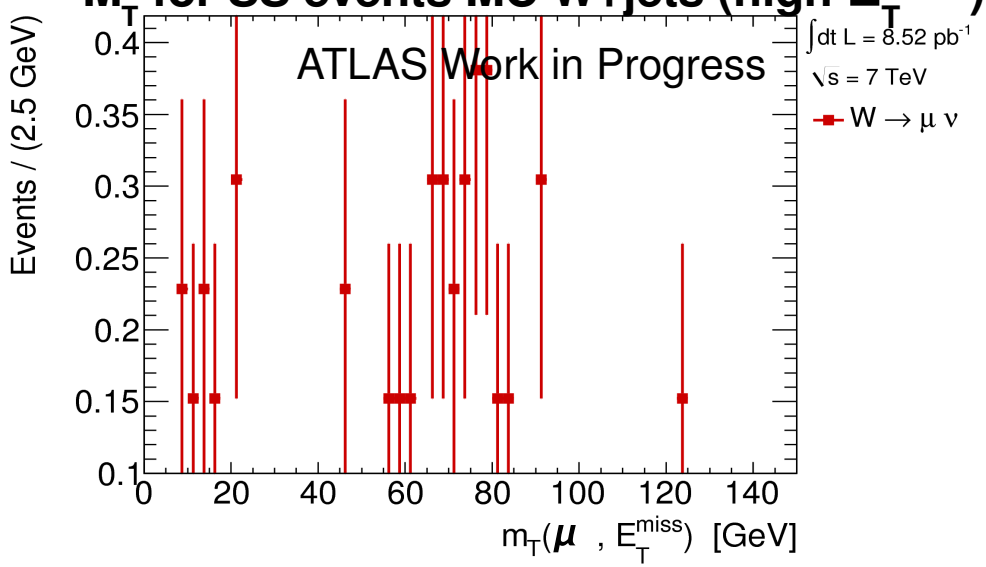
E_T^{miss} for SS events MC QCD (low M_T)



M_T for OS events MC W+jets (high E_T^{miss})



M_T for SS events MC W+jets (high E_T^{miss})



→ Too low MC statistic for good proof of assumptions