WW Production at LHCb

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A Brief Introduction to LHCb

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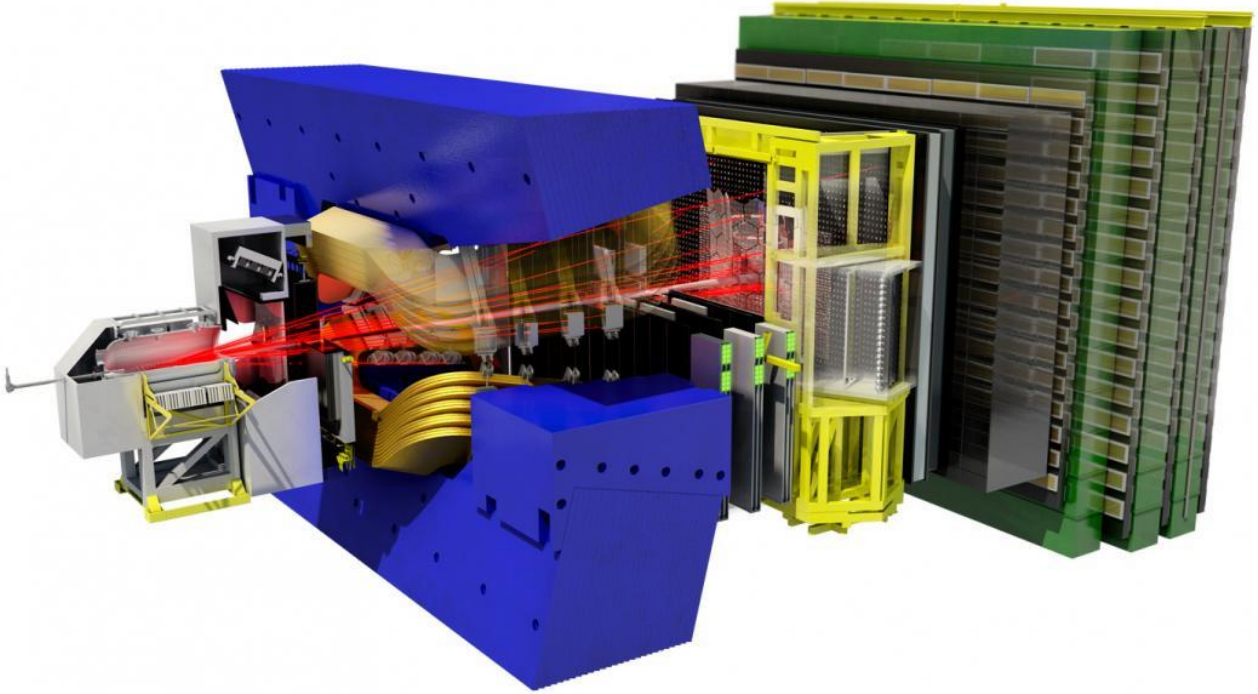
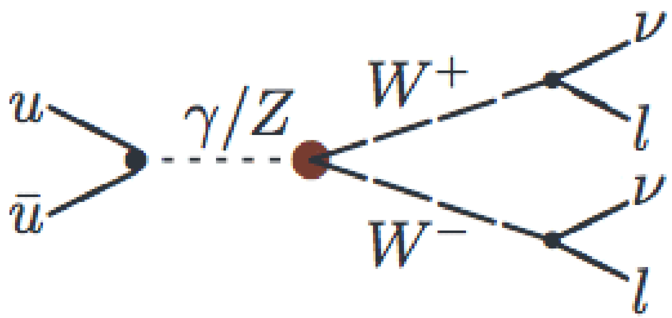
Summary and Next Steps



WW Production



NEW! measurement for LHCb in Run II

With focus on μe channel

Significantly improved cross-sections from Run I

Background to NEW! top physics investigations

arXiv:1803.05188

Results from ATLAS and CMS at 7, 8 and 13TeV

arXiv:1603.01702

A Brief Introduction to LHCb

Forward region general purpose detector at CERN

Heavy flavour physics from pp collisions

Designed to exploit cone of b-hadron production (pseudorapidity range: $2 \leq \eta \leq 4.5$)

Dipole magnet with about half of data taken at each polarity

Precise measurements of EW Physics are possible

LHCb Collaboration (cern.ch)

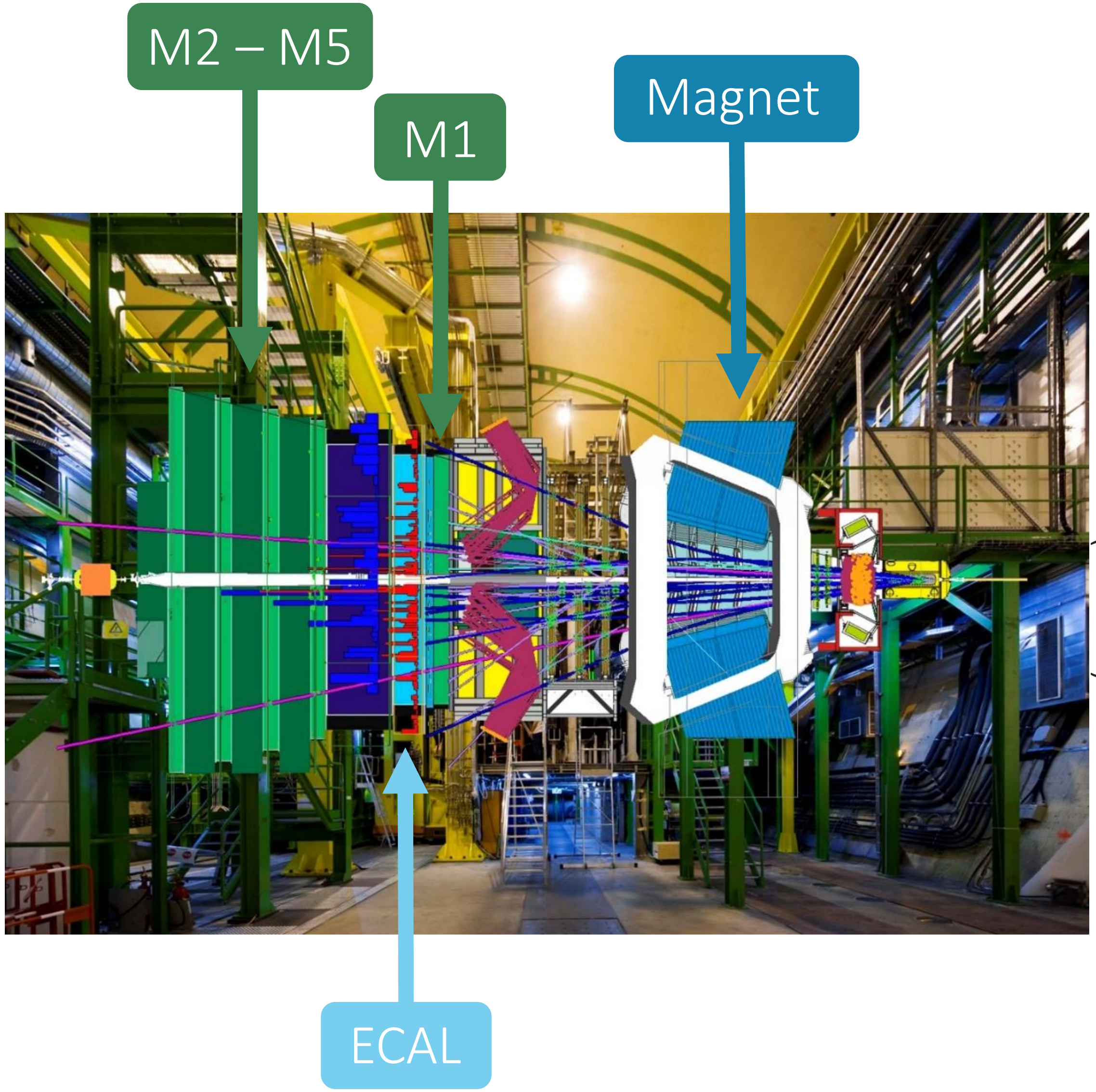
Particle Detection

Charged particles are detected by tracking stations before and after being deflected by the dipole magnet

Muons are identified by hits in the muon chambers

Electrons are identified using information from the calorimeter system

Particles that pass hard- and software triggers are reconstructed and candidates are selected during data stripping



LHCb Collaboration (cern.ch)

Signal and Background Processes

Major backgrounds are $t\bar{t}$, $Z \rightarrow \tau\tau$ and QCD

Also contributions from Wt and $Z \rightarrow ee$ & $Z \rightarrow \mu\mu$ mis-ID

Integrated luminosity in 2015 = 294pb^{-1} , 2016 = 1665pb^{-1}

Channel	2016 MC Events	Cross-section (pb)	Events @ 1.9fb^{-1} (2015 + 2016)	Events @ 5fb^{-1} (Run II: 2015 – 2018)	Generator
WW	58792	3.176	120	315	Pythia8*
$qq \rightarrow t\bar{t}$	41680	99	110	261	Pythia8*
$gg \rightarrow t\bar{t}$	15985	582	170	376	Pythia8*
$Z \rightarrow \tau\tau$	787	1689	800	2105	Pythia8▲

*Includes NLO correction from aMC@NLO

▲Includes correction from data

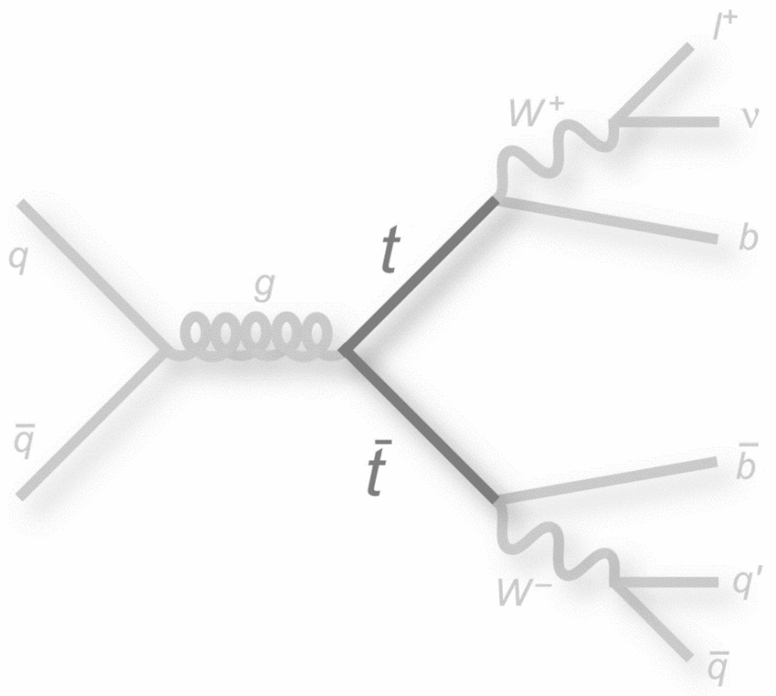
Reducing Top Background

Decays of top quarks characteristically include b-jets which are not usually seen in WW events

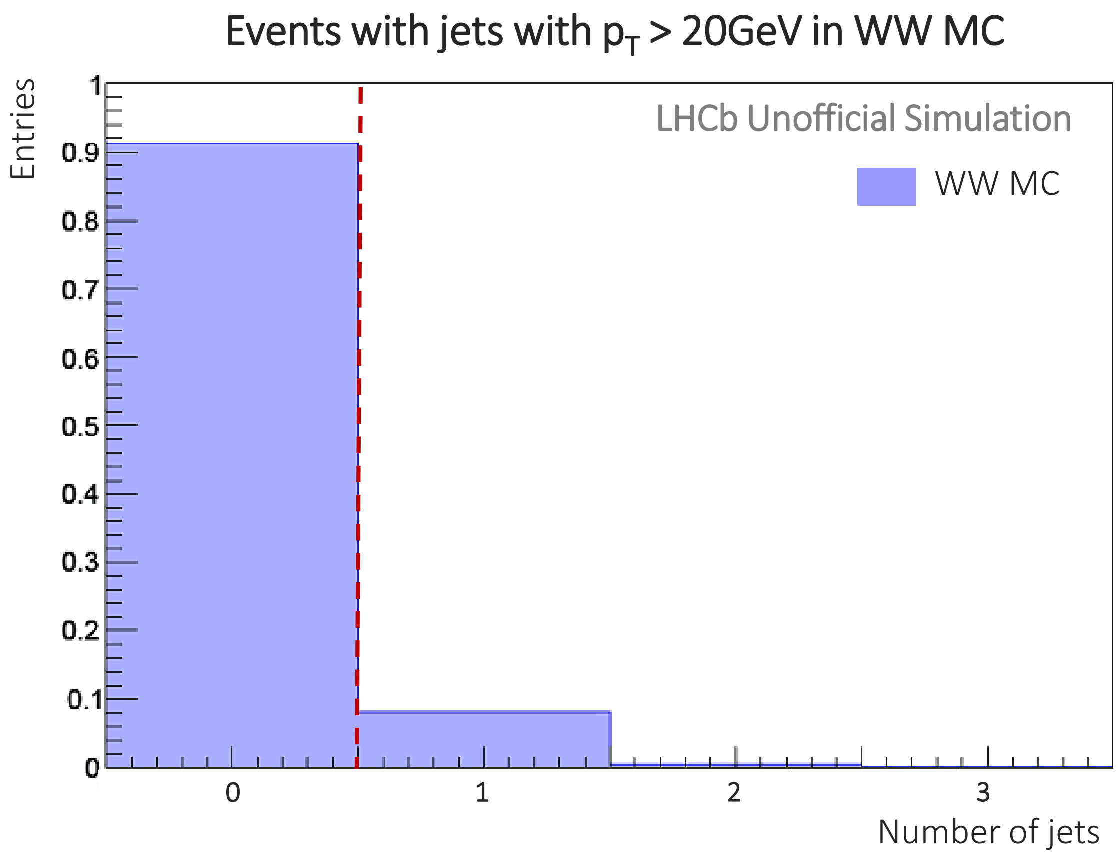
WW events are expected to have a lower jet multiplicity

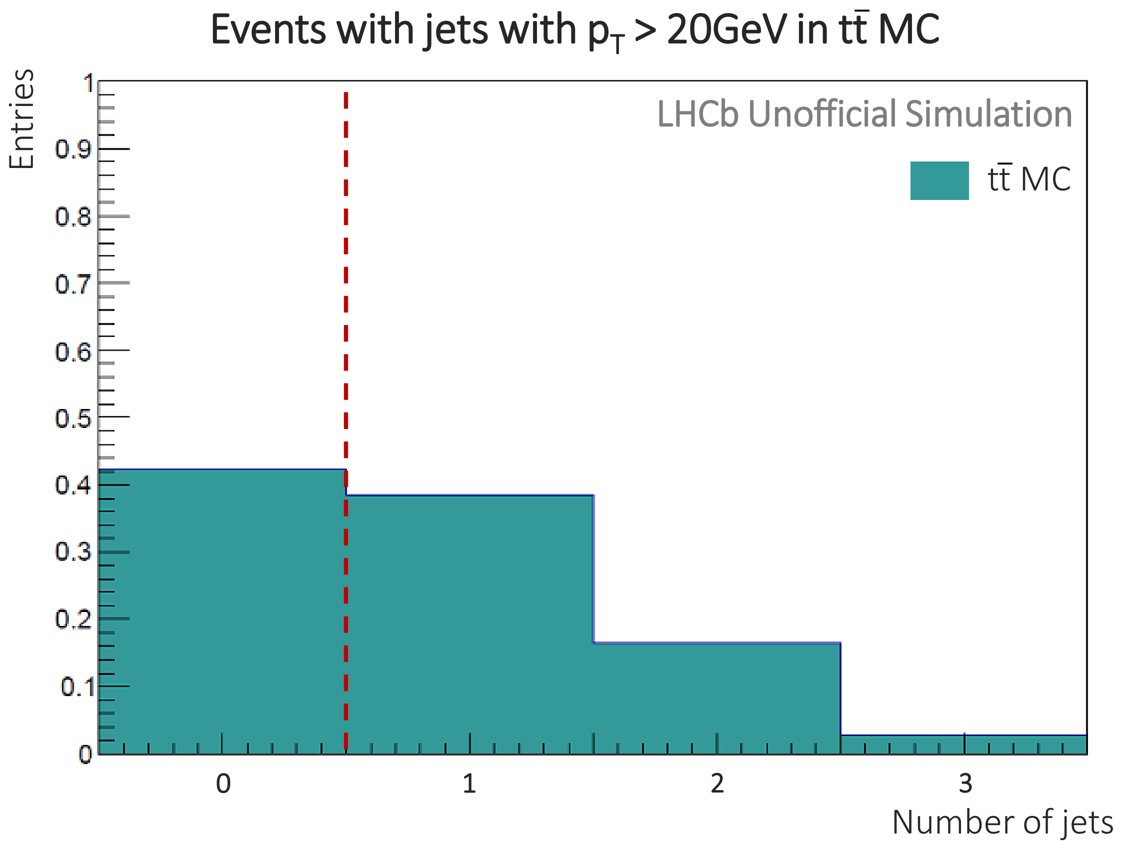
The number of jets identified in an event has been investigated as criteria for reducing this background

Compare distributions in Monte Carlo



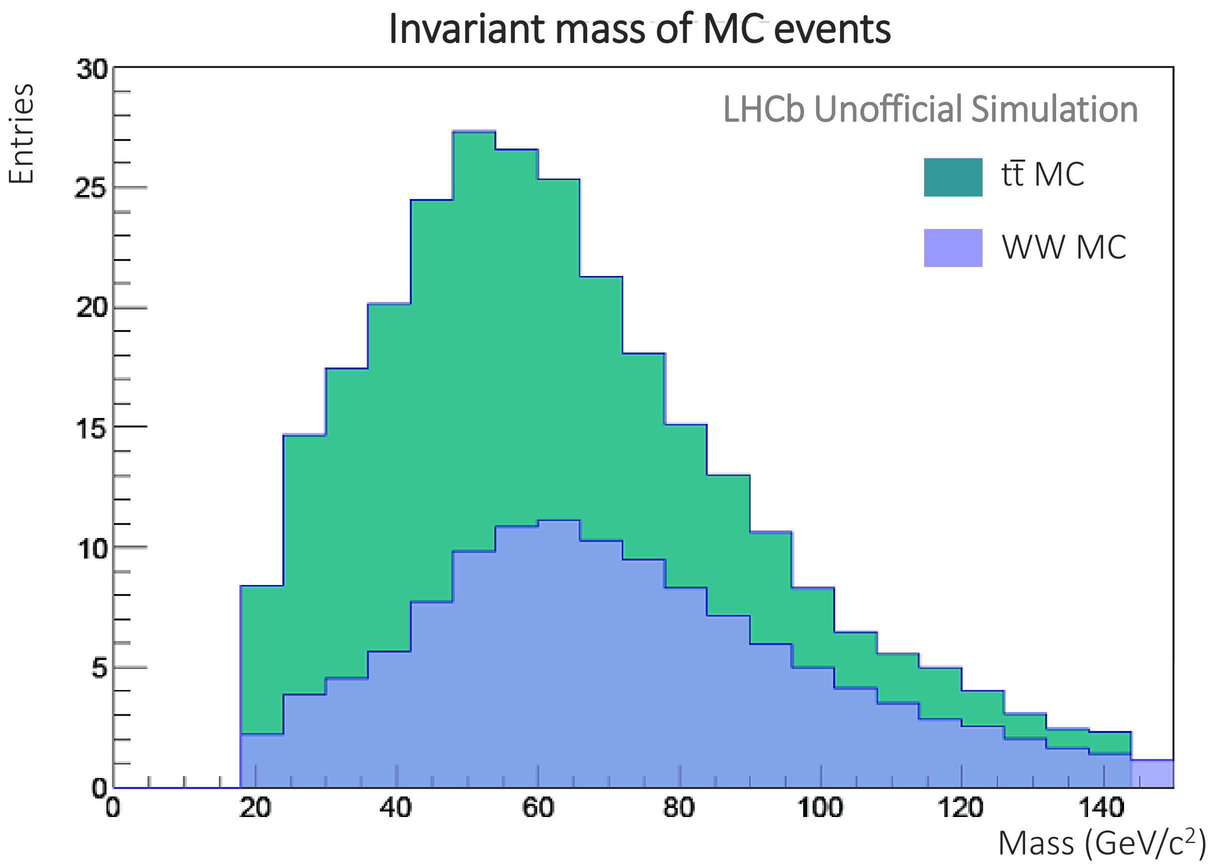
Reducing Top Background

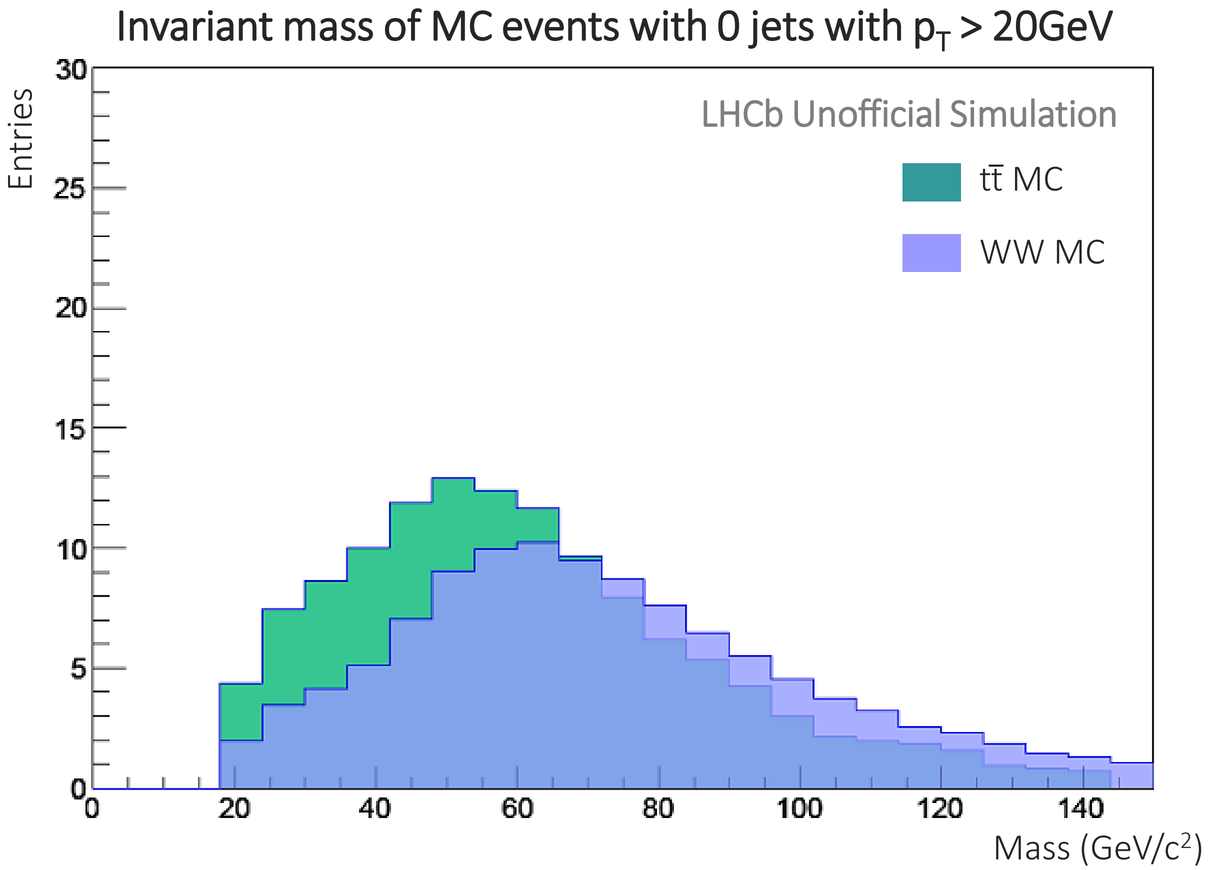




A veto on jets with p_T > 20GeV will remove $t\bar{t}$ events

Reducing Top Background





Samples normalised to 1.9 fb^{-1}

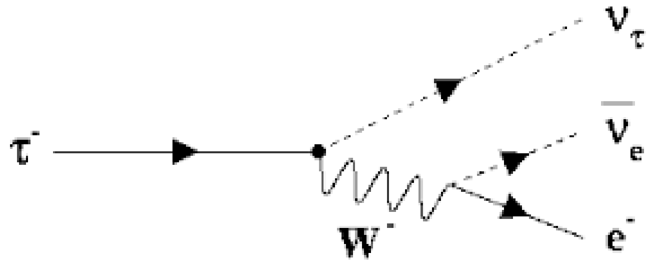
92% of WW events are retained, while 55% of $t\bar{t}$ events are removed

Reducing Z→ττ Background

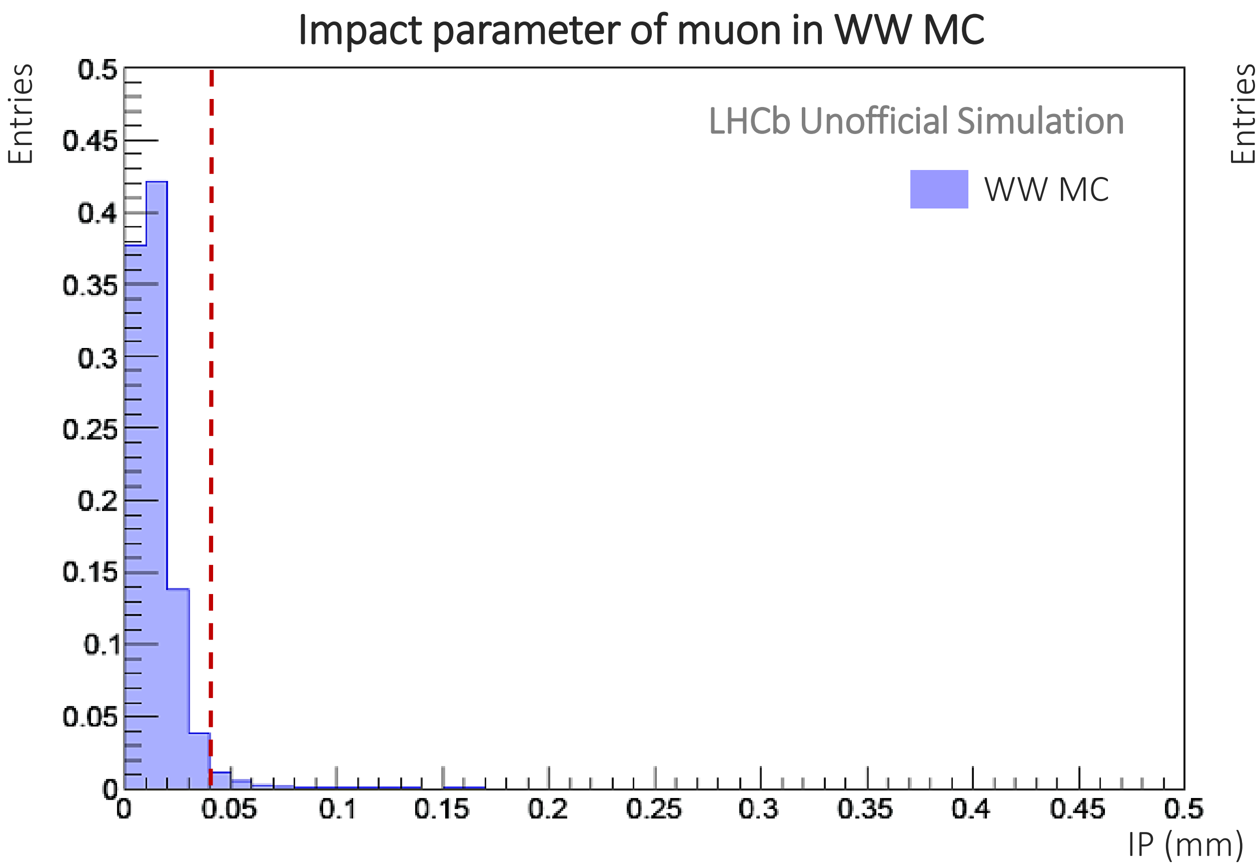
τ leptons have a finite lifetime and so travel within the detector before decaying to e/μ

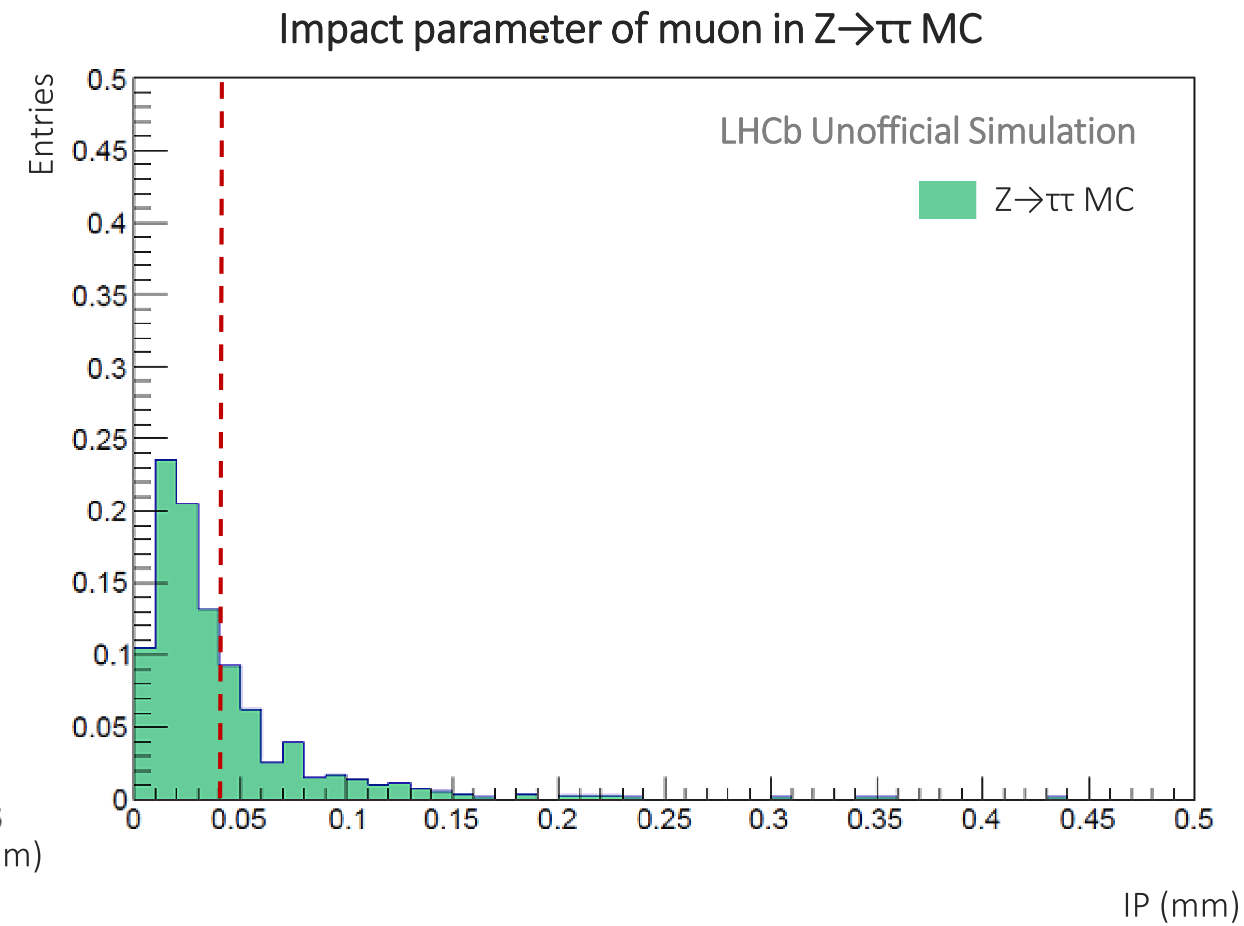
This produces events with a secondary vertex

One way to identify these events is by examining those with a high impact parameter



Reducing Z→ττ Background

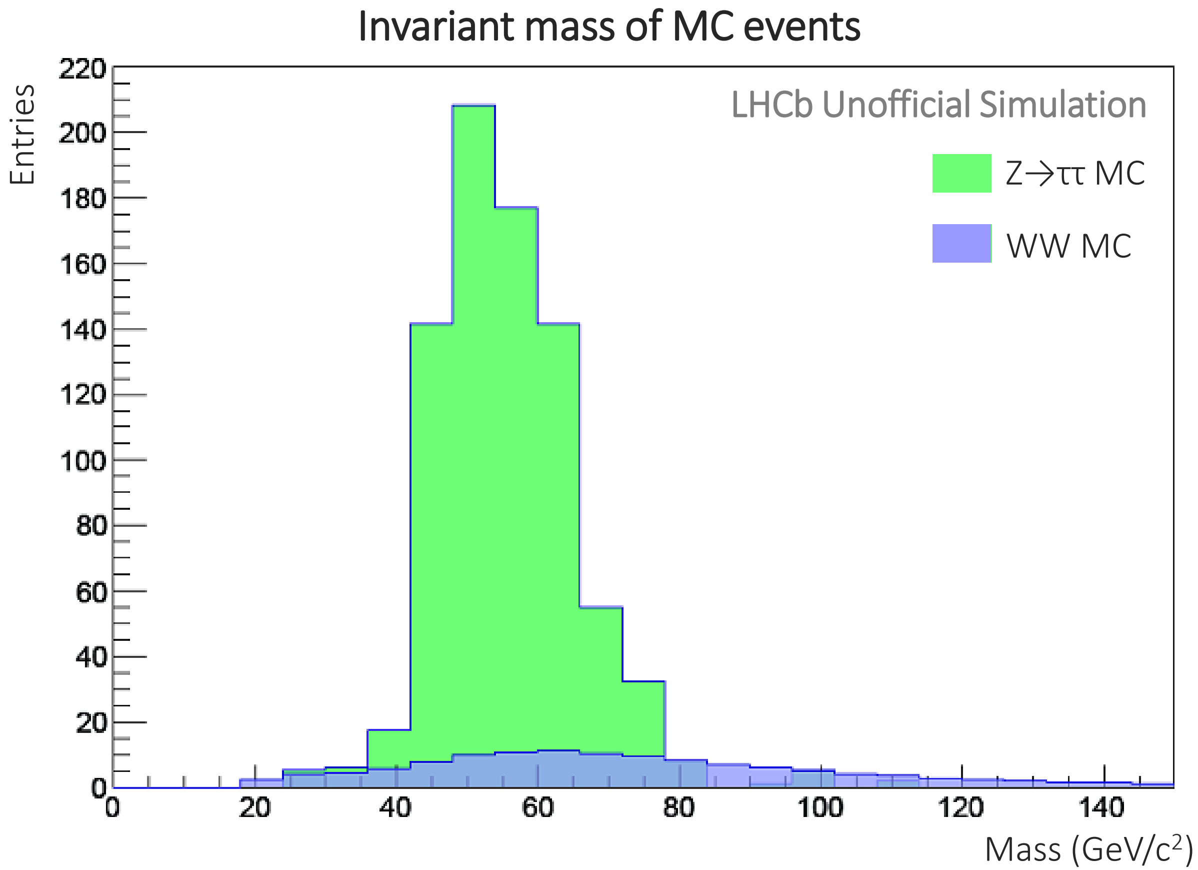


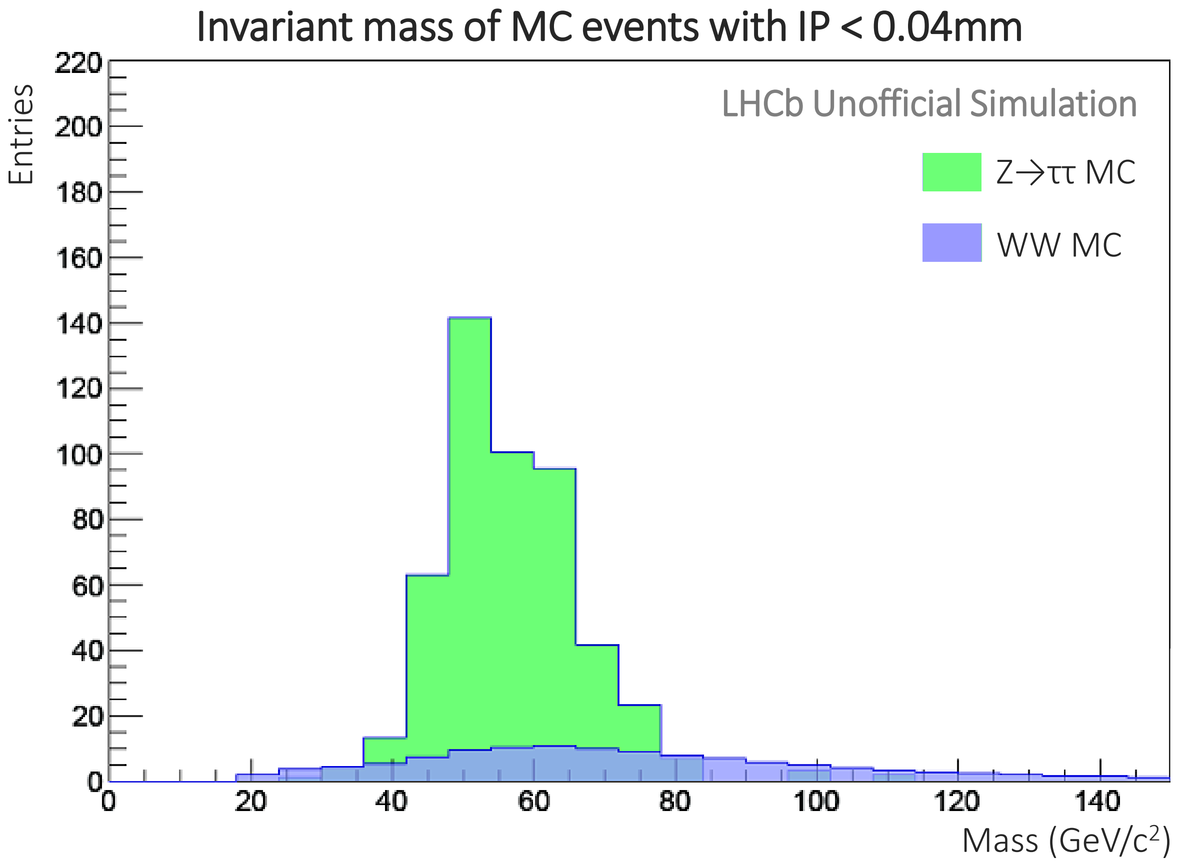


Distributions normalised to 1

Impact parameter cut around 0.04mm retains most WW events

Reducing Z→ττ Background





Samples normalised to 1.9 fb^{-1}

97% of WW events are retained, while 38% of Z→ττ events are removed

Reducing QCD Background

Same-sign data events can be used to estimate QCD background

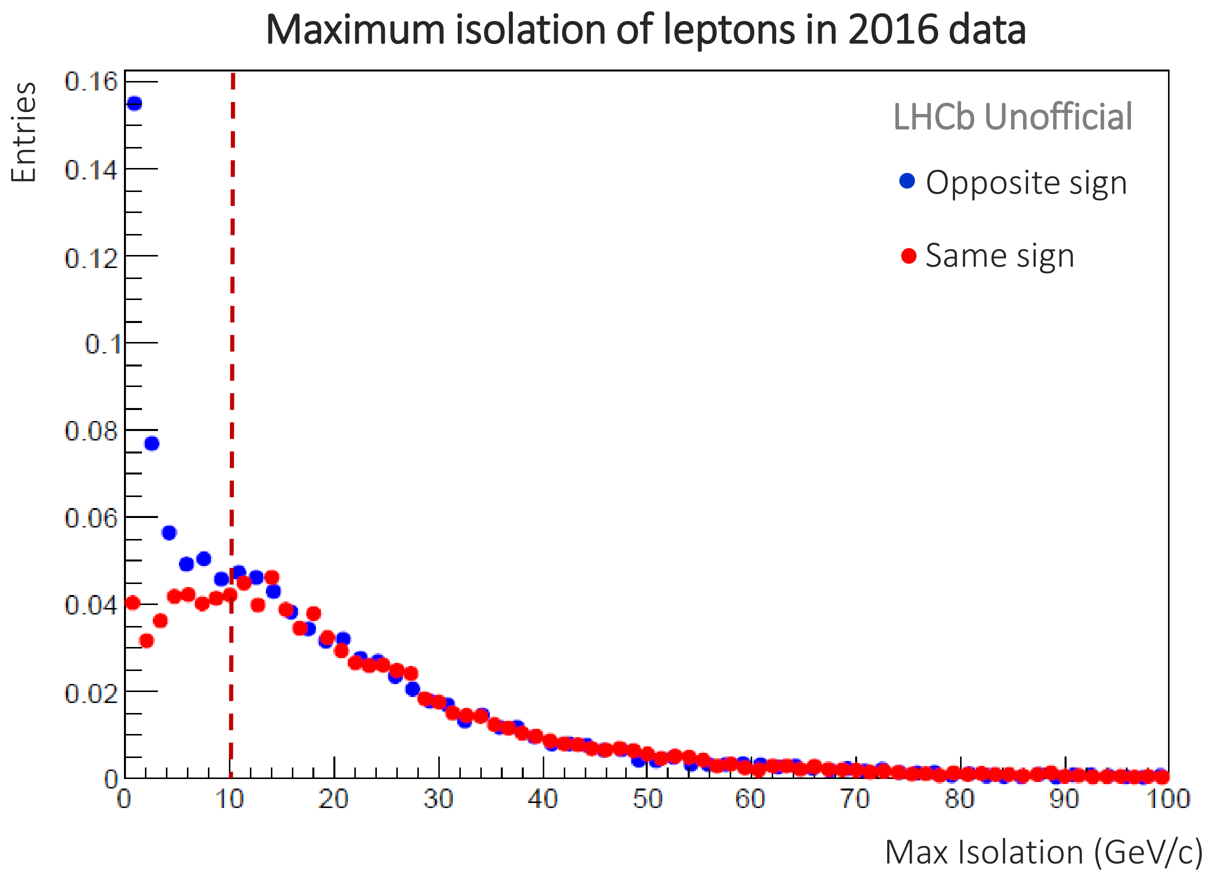
μ^+e^+ / μ^-e^- or 'wrong' sign

Isolation can be investigated as a discriminating variable

Vector sum of p_T in η-Φ cone of radius 0.5 around the lepton track (cpt)

Leptons from WW decays are isolated, not surrounded by other particles in jets

Around 85% of the data sample can be considered background



Finding QCD Correction Factor

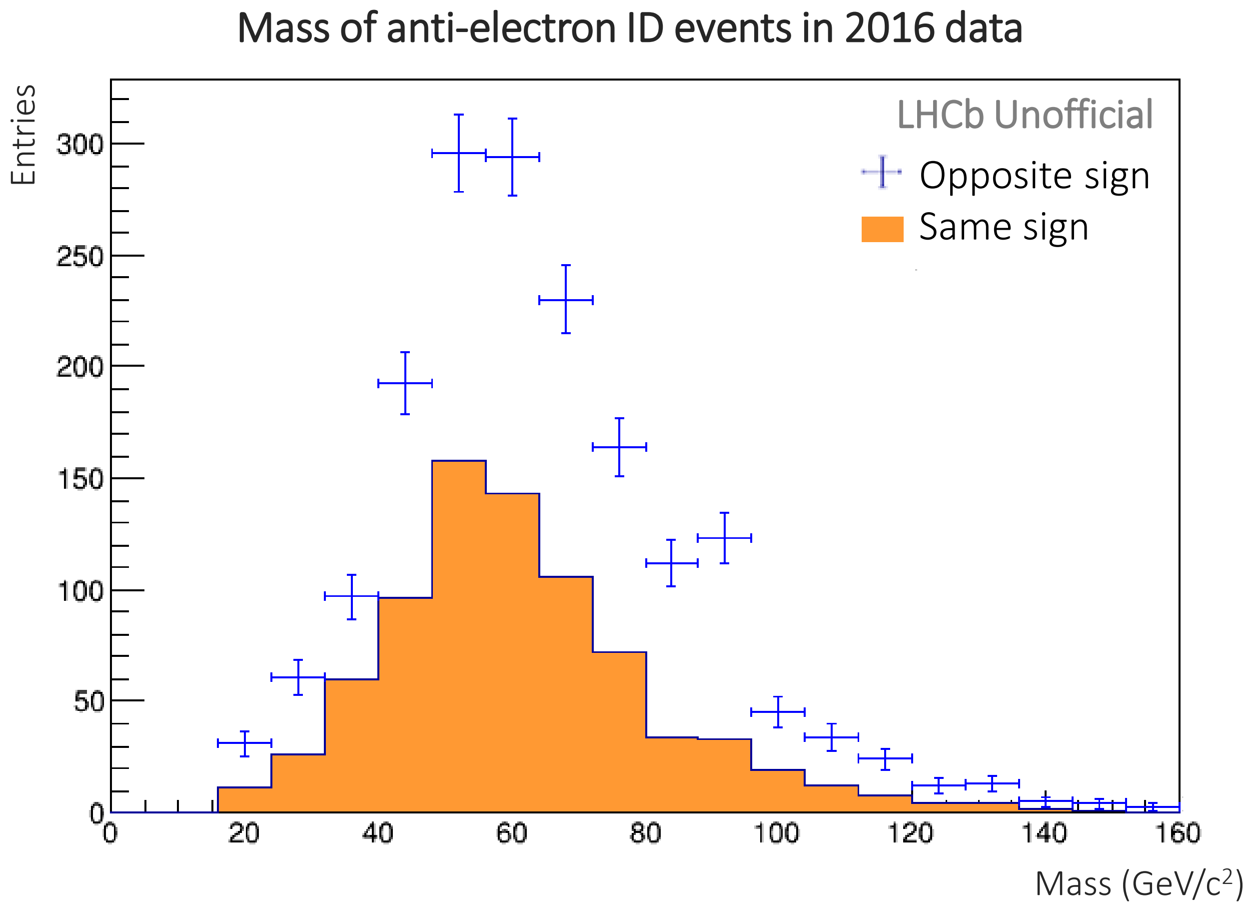
Ratio of same-sign and opposite-sign anti electron ID control sample

Some Z→μμ seen

These bins are removed when calculating correction factor

For the following selection criteria, correction factor is 2.08

Still working on the error associated with this number



Selection Applied to Data

$2 \leq \eta_{\mu/e} \leq 4.5$

$p_{T\ \mu/e} > 20$ GeV/c

Dilepton mass > 20 GeV/c^2

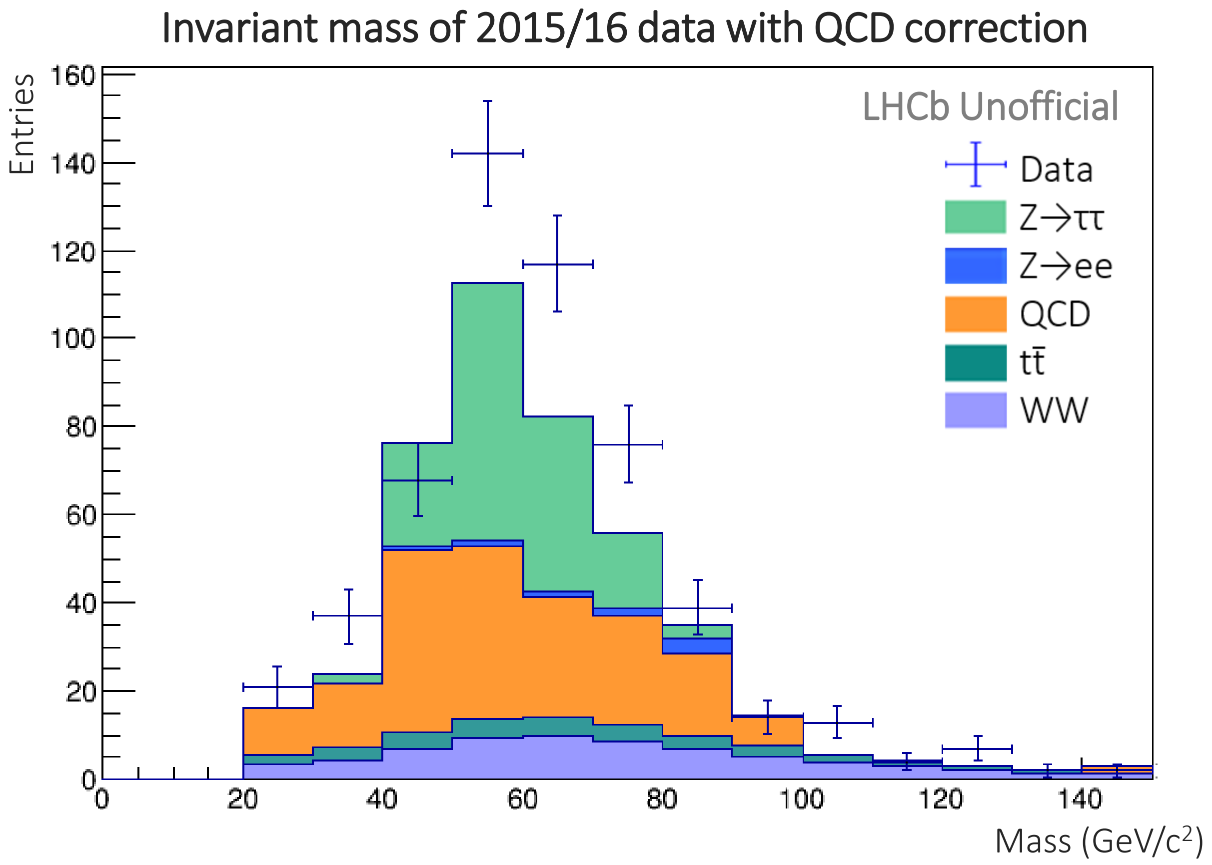
Impact parameter < 0.035 mm

Veto on jets with $p_T > 20$ GeV

Isolation: $cpt_{\mu/e} < 4$ GeV/c

Isolation: $\mu\ cpt_{\mu}/p_{T\ \mu} < 0.1$

Lepton ID requirements



WW = 66 events → Purity = 12% , Signal efficiency = 55%

185 QCD events → signal swamped by background

Including additional selection criteria may improve this

p_T Vector Sum

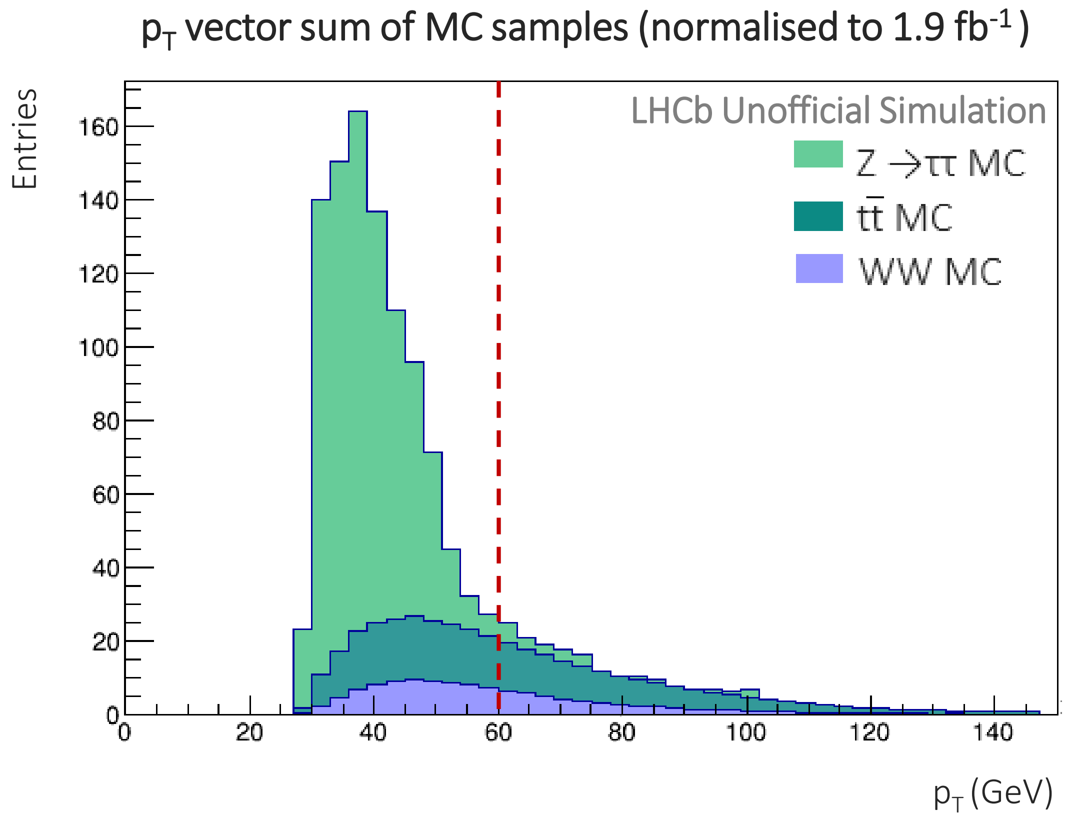
Vector sum of electron and muon p_T

Used as proxy for neutrino information to determine between WW and Z→ττ

Distribution shapes are different

Cut at 60GeV removes 95% of Z→ττ

However, including this cut in event selection greatly reduces signal efficiency as shown on the next slide



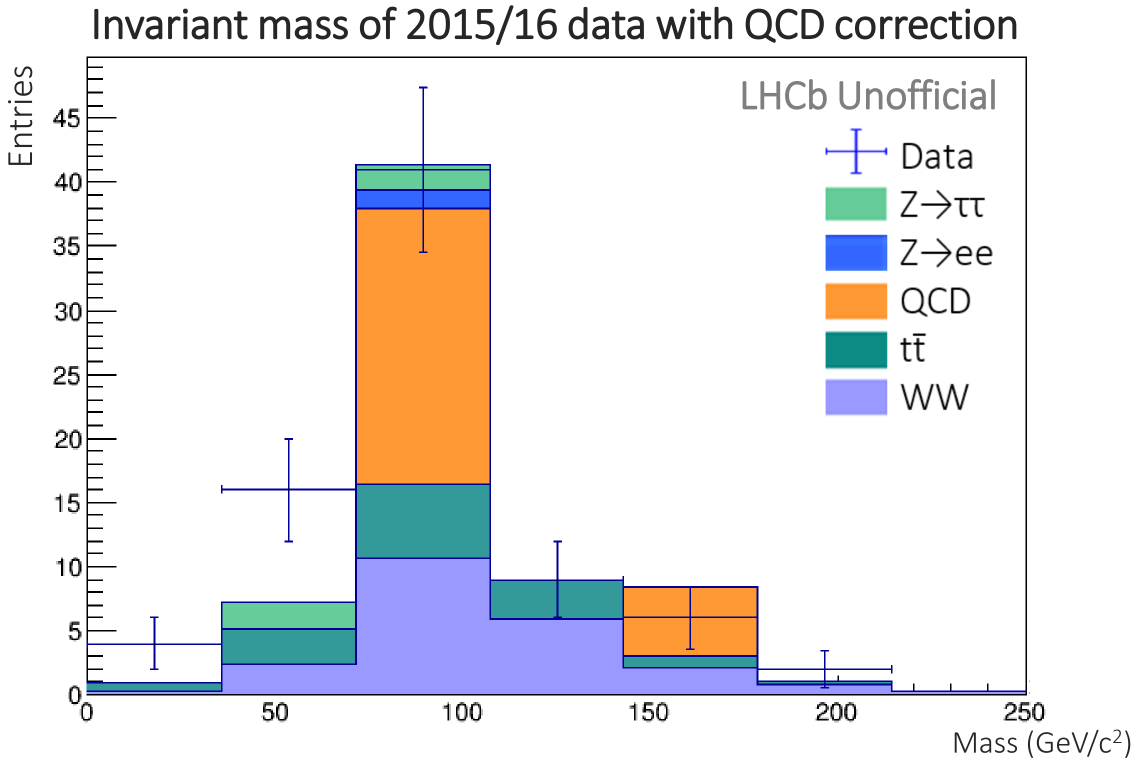
Applying Further Restrictions

Applying p_T vector sum cut and a tighter lepton isolation requirement (<1.5GeV) reduces number of selected events

WW contribution can be identified more clearly

Signal purity is greater (than 12%*), but signal efficiency is greatly reduced (from 55%*)

Statistics for same-sign background are low, a better model will be produced to smooth the distribution



WW = 22 events → Purity = 29% , Signal Efficiency = 18%

QCD = 27 events (correction = 2.7)

* in previous plot, slide 15

Summary and Next Steps

WW selection criteria has been developed using MC and data-driven methods

Currently working on efficiencies and uncertainties for a cross-section calculation

Next step is to determine whether a measurement is feasible with the Run II data set

→ Will a measurement be possible with 2017 and 2018 data included?

Looking forward: Make prediction for future of WW cross-section in Run III

→ Determine when a 5σ measurement will be possible

Back-up

LHC 13 TeV Kinematics