LPC CMSDAS'17 long exercise
$Z \rightarrow \tau\tau$ production cross section

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- Jan 11 2017 -

Goals

Physics (This is a full analysis!):

- Compute the cross section production of the Z → $\tau\tau$ in proton-proton collisions at 13 TeV centre-of-mass energy

Experience:

- learn the workflow of a CMS analysis, involving taus
- learn how to work in a team
- learn/improve how to summarize and present results
- learn to prioritize

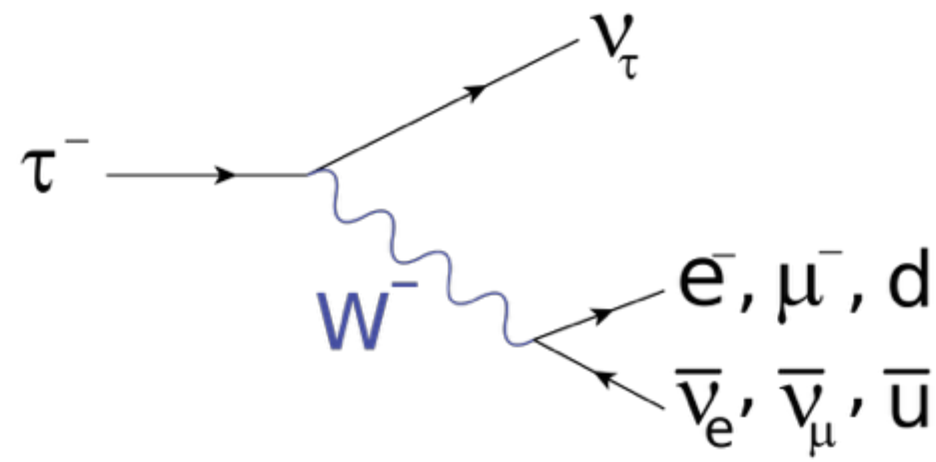
Core Steps

- Identify the signal signature
- Identify and estimate the backgrounds
- Find ways to reduce the backgrounds
- Interpret the results

Tau Leptons

Third generation lepton

* **charge**: +/-1
* **mass**: 1776.86 ± 0.12 MeV
* **spin**: 1/2 (fermion)
* **mean lifetime**: 2.9 × 10^{-13} s



Taus Decay Weakly

- Leptonic e/muon + 2ν
- Hadronic + ν

Decay Mode	Resonance	$\mathcal{B}$ [%]
$\tau^- \to e^- \bar{\nu}_e \nu_\tau$		17.8
$\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$		17.4
$\tau^- \to h^- \nu_\tau$		11.5
$\tau^- \to h^- \pi^0 \nu_\tau$	$\rho(770)$	26.0
$\tau^- \to h^- \pi^0 \pi^0 \nu_\tau$	$a_1(1260)$	10.8
$\tau^- \to h^- h^+ h^- \nu_\tau$	$a_1(1260)$	9.8
$\tau^- \to h^- h^+ h^- \pi^0 \nu_\tau$		4.8
Other hadronic modes		1.8
All hadronic modes		64.8

Remember: At CMS Taus are never Fully Reconstructed due to the presence of Neutrinos, instead studies of Tau Leptons make use of the **'visible decay products'**

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Tau ID: Hadron+Strips

1 prong

π^+

Single Hadron is assumed to have the mass of the pion

3 prong

π^+

π^-

π^+

Three charged hadrons are required to come from the same secondary vertex created using a kalman vertex fitter

The τ_h mass distribution is used to control the tau energy-scale within 3%

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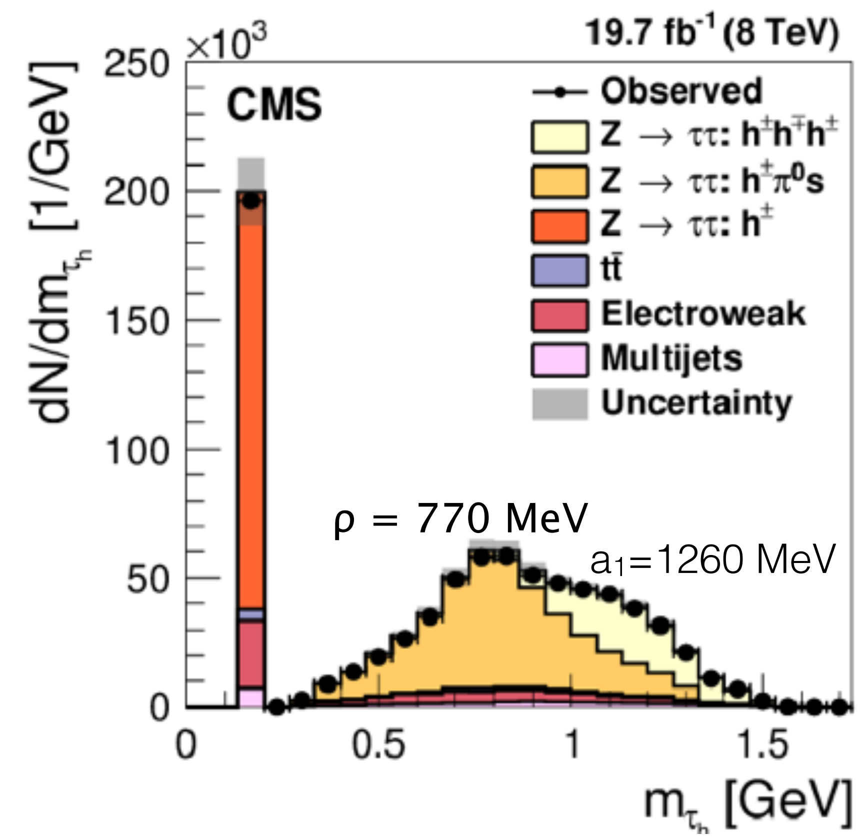

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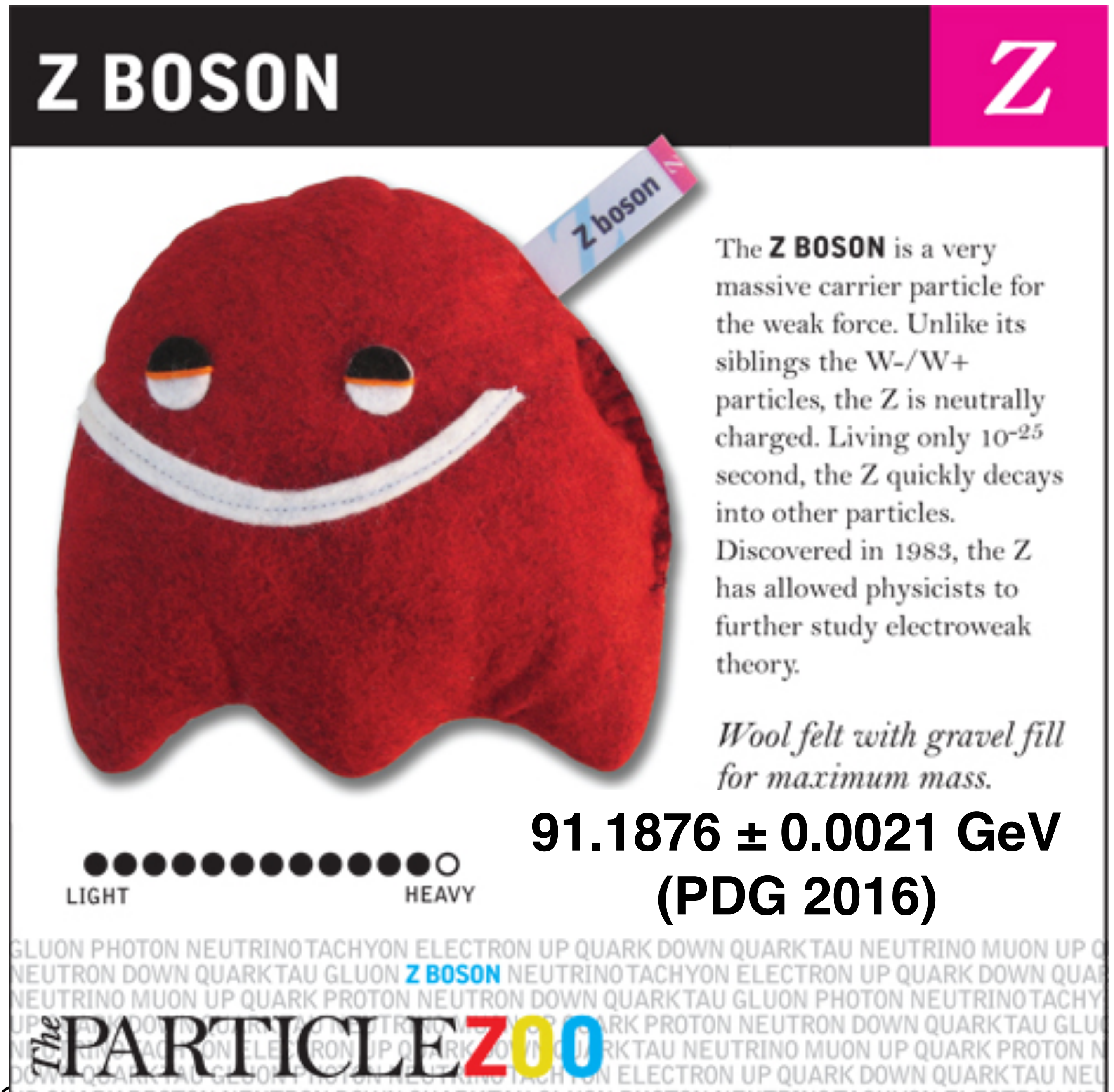
Z Boson Introduction

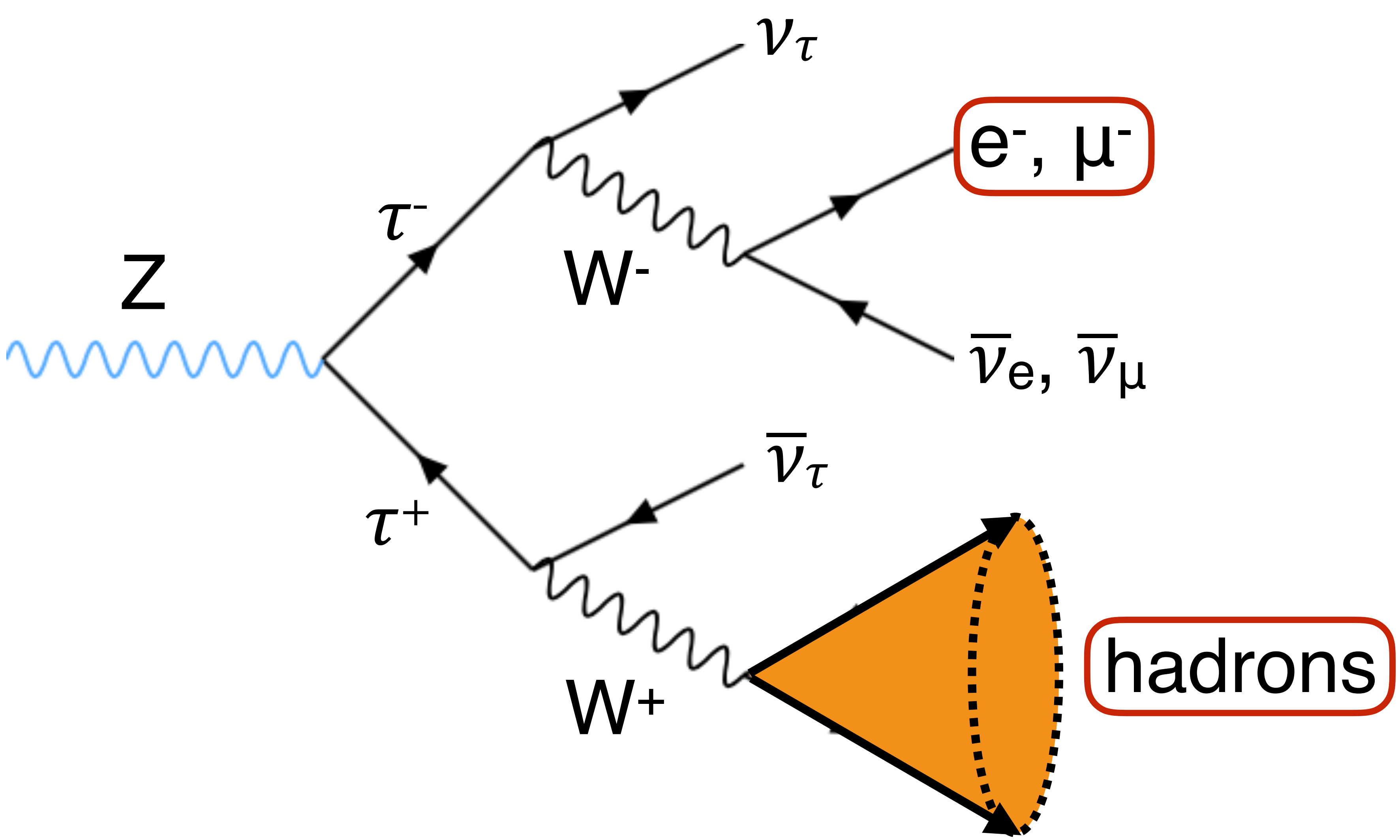


91.1876 ± 0.0021 GeV (PDG 2016)

Z dominant decay modes	
Mode	**Fraction (%)**
e^+e^-	3.363 ± 0.004
$\mu^+\mu^-$	3.366 ± 0.007
$\tau^+\tau^-$	3.370 ± 0.008
invisible	20.00 ± 0.06
hadrons	69.91 ± 0.06

$Z \rightarrow \tau\tau$ acts as a standard candle for BSM X-> $\tau\tau$ searches

Signal Topology



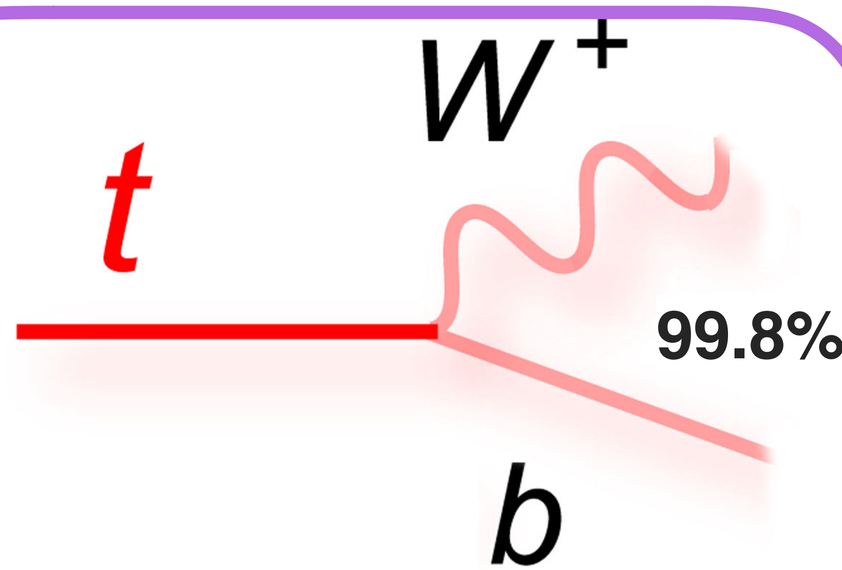
In the end, we look for a muon/electron + hadronic tau (τ_h).

Why not require both taus to decay hadronically ($\tau_h + \tau_h$)?

Main SM Backgrounds For Lepton Searches

W^+ DECAY MODES		Fraction (Γ_i/Γ)
$\ell^+\nu$	[b]	$(10.86\pm\ 0.09)$ %
$e^+\nu$		$(10.71\pm\ 0.16)$ %
$\mu^+\nu$		$(10.63\pm\ 0.15)$ %
$\tau^+\nu$		$(11.38\pm\ 0.21)$ %
hadrons		$(67.41\pm\ 0.27)$ %

leptons are produced through electroweak interactions



single top processes
top anti-top processes

Rare DiBoson processes

WW, WZ, ZZ

Muti-jet processes

QCD

Relevant Backgrounds

Backgrounds with $\ell + \tau_h$

$t\bar{t} \rightarrow e/\mu/\tau + \tau + \boxed{2b} + \text{neutrinos}$ — **reducible with b-jet veto**

$tW \rightarrow e/\mu/\tau + \tau + \boxed{b} + \text{neutrinos}$ — **reducible with b-jet veto**

rare diboson processes: WW, WZ, ZZ — **low production rate**

Backgrounds with fakes (jet faking ℓ, jet/e/μ faking τ_h)

$t\bar{t} \rightarrow e/\mu/\tau + \boxed{\text{jet}} + \boxed{2b} + \text{neutrinos}$ — **reducible with b-jet veto**

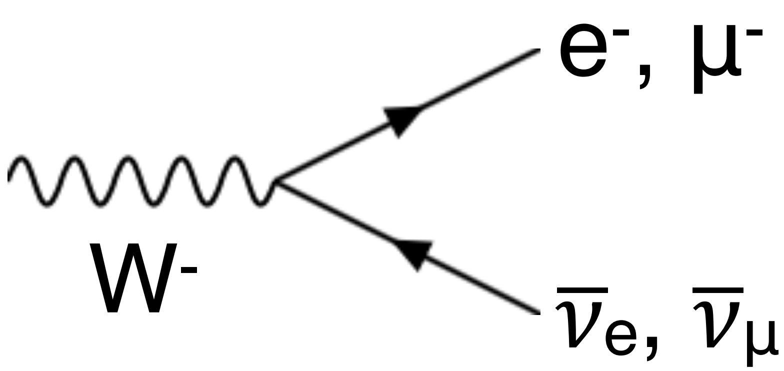
$Z + \text{jets} \rightarrow e\boxed{e/\mu}\mu + \text{jets}$ — **reducible with extra-lepton veto**

$W + \text{jets} \rightarrow e/\mu + \boxed{\text{jets}} + \text{neutrinos}$ — **reducible with m_T cut and τ requirements**

$t + \text{jets} \rightarrow e/\mu + \boxed{b} + \boxed{\text{jets}}$ — **reducible with b-jet veto**

QCD — **reducible with τ requirements and charge selections**

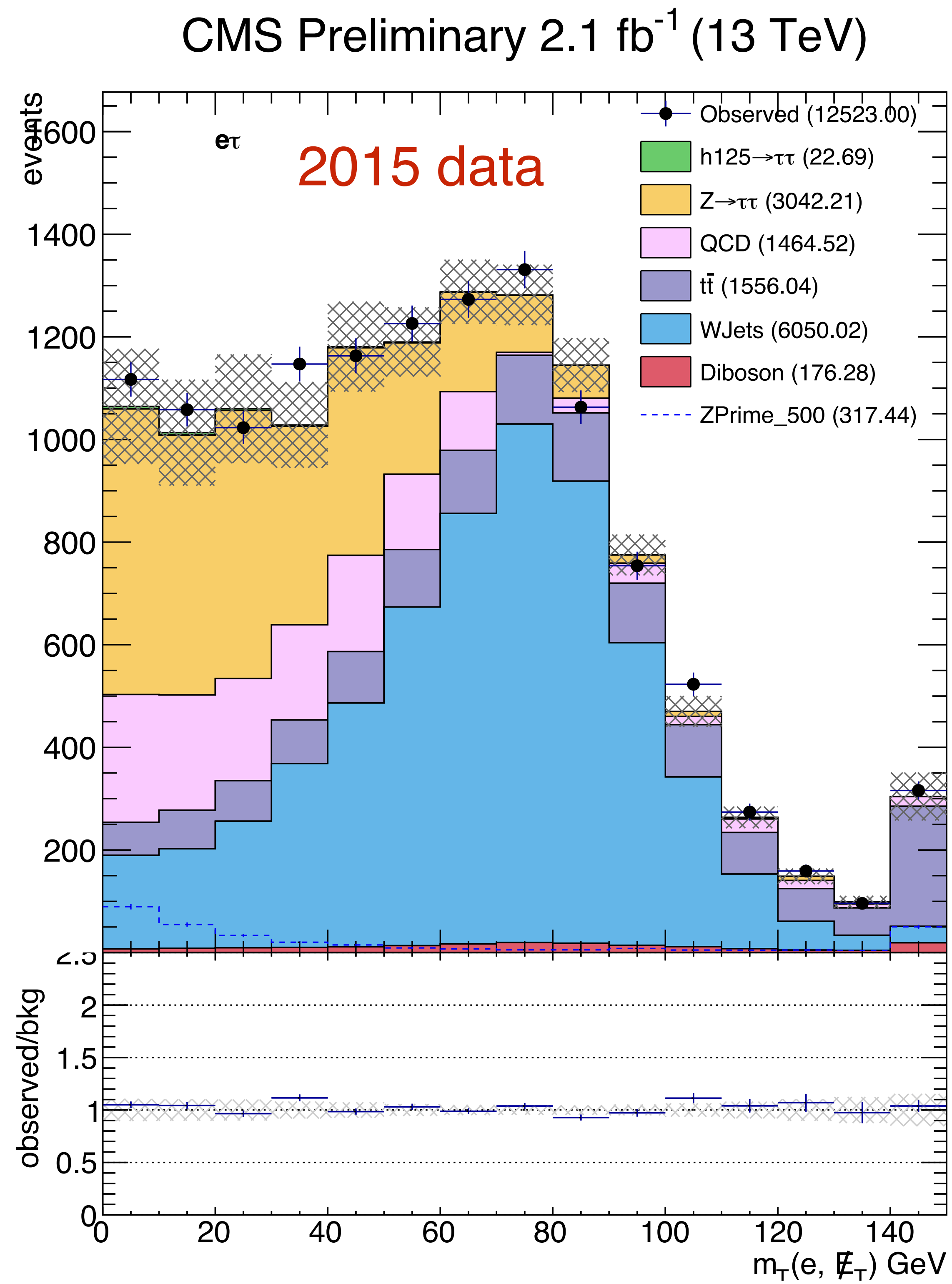
W + jets Background



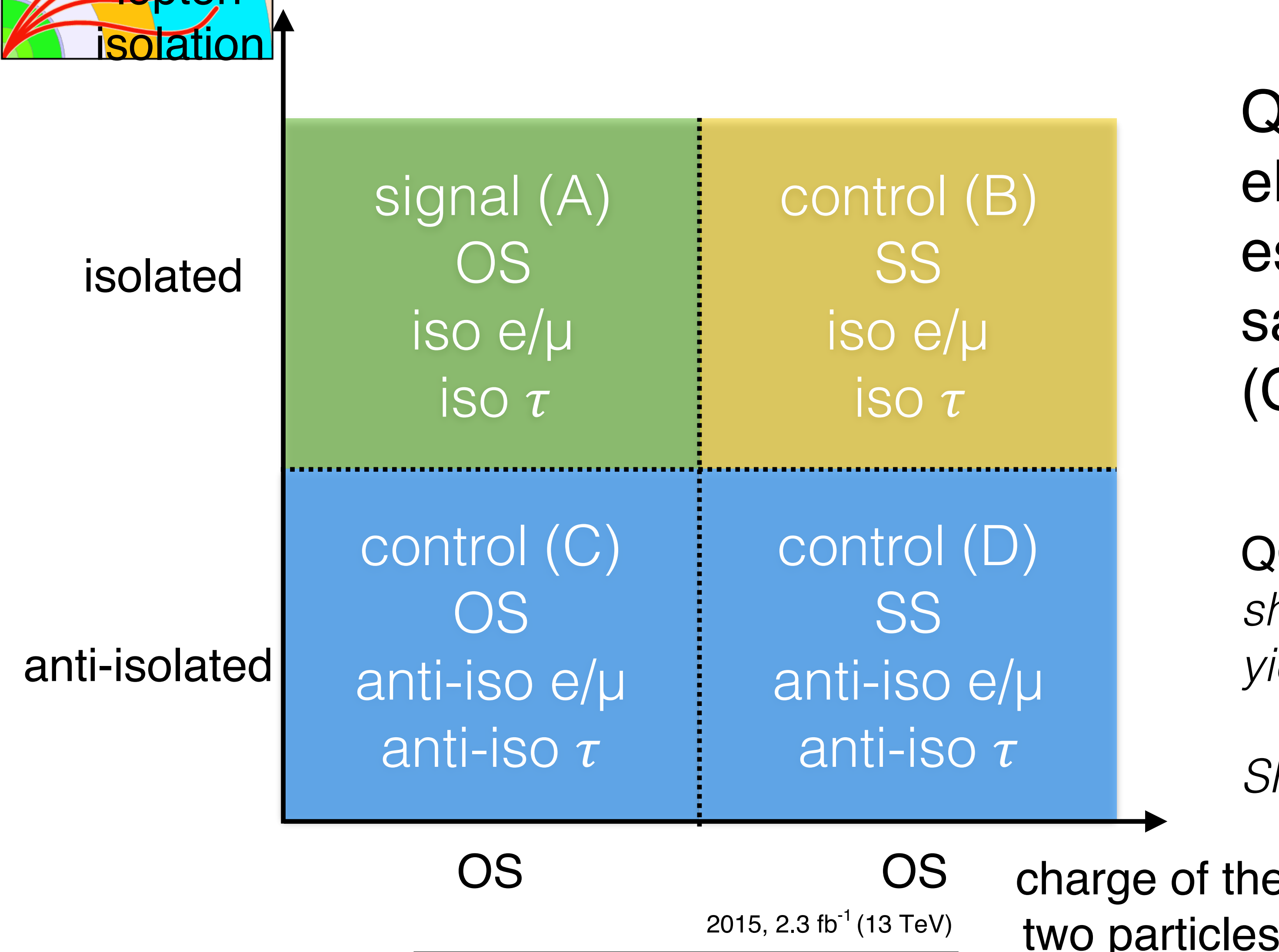
events with one genuine e/μ and a jet faking τ_h

$$m_T(l, \mathrm{E}_{\mathrm{T}}^{\mathrm{miss}}) = \sqrt{(E_l + \mathrm{E}_{\mathrm{T}}^{\mathrm{miss}})^2 + (\vec{p}_l + \vec{\mathrm{E}}_{\mathrm{T}}^{\mathrm{miss}})}$$

A cut on m_T ($m_T < 40$ GeV) would greatly reduce W+jets contamination



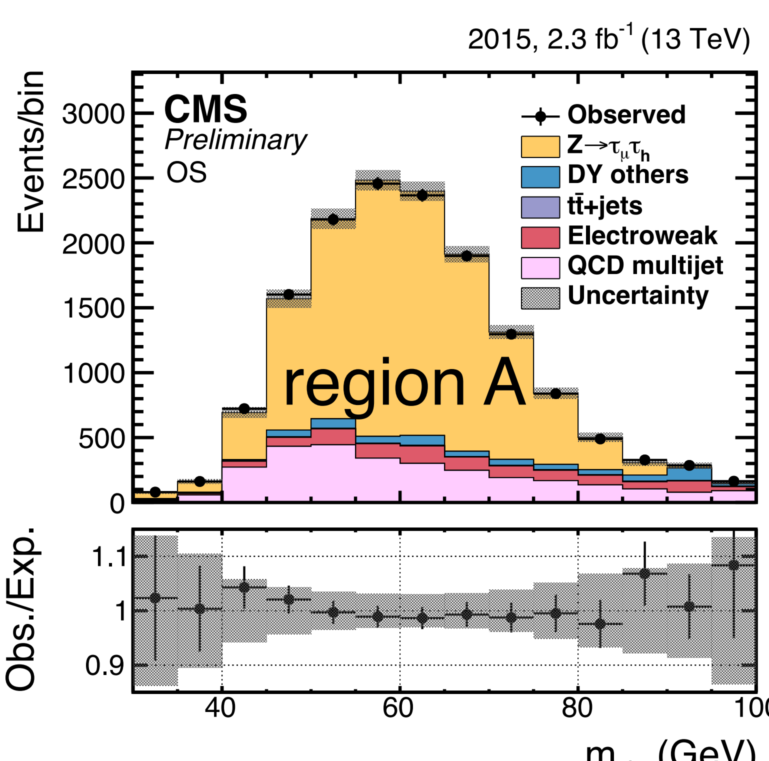
QCD Background

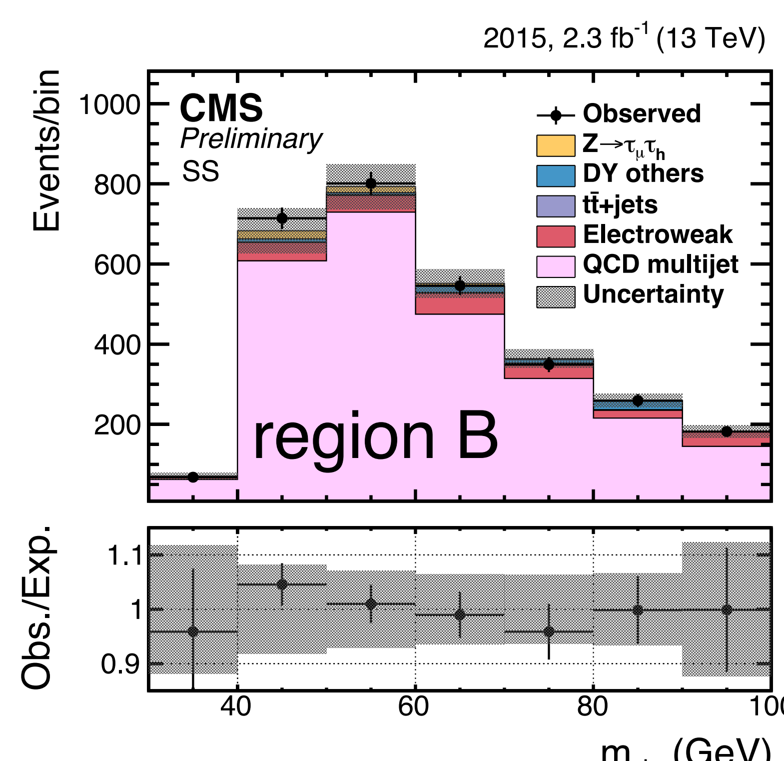


QCD dijets are expected to be electric-charge-blind. It is estimated from data using the same-signed controlled region (QCD rich).

QCD:
shape: $data_B - MC_B$
yield: $(data_B - MC_B) \times SF_{SStoOS}$

$SF_{SStoOS} = (data_C - MC_C)/(data_D - MC_D)$



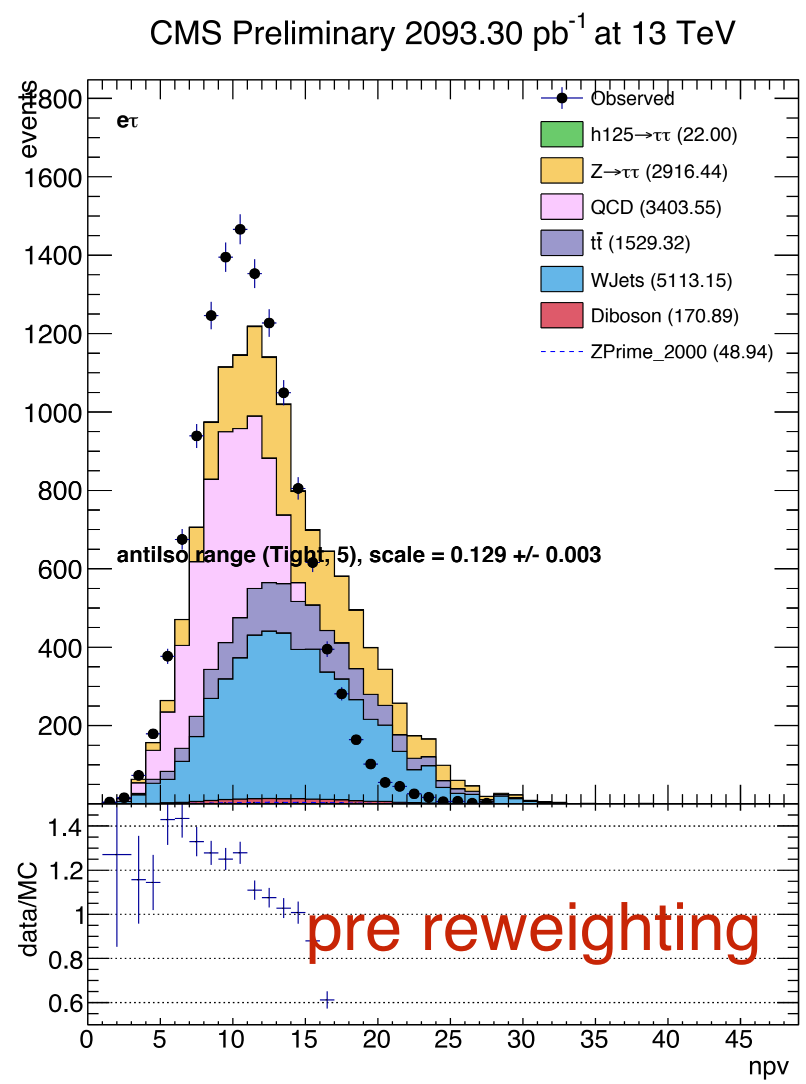


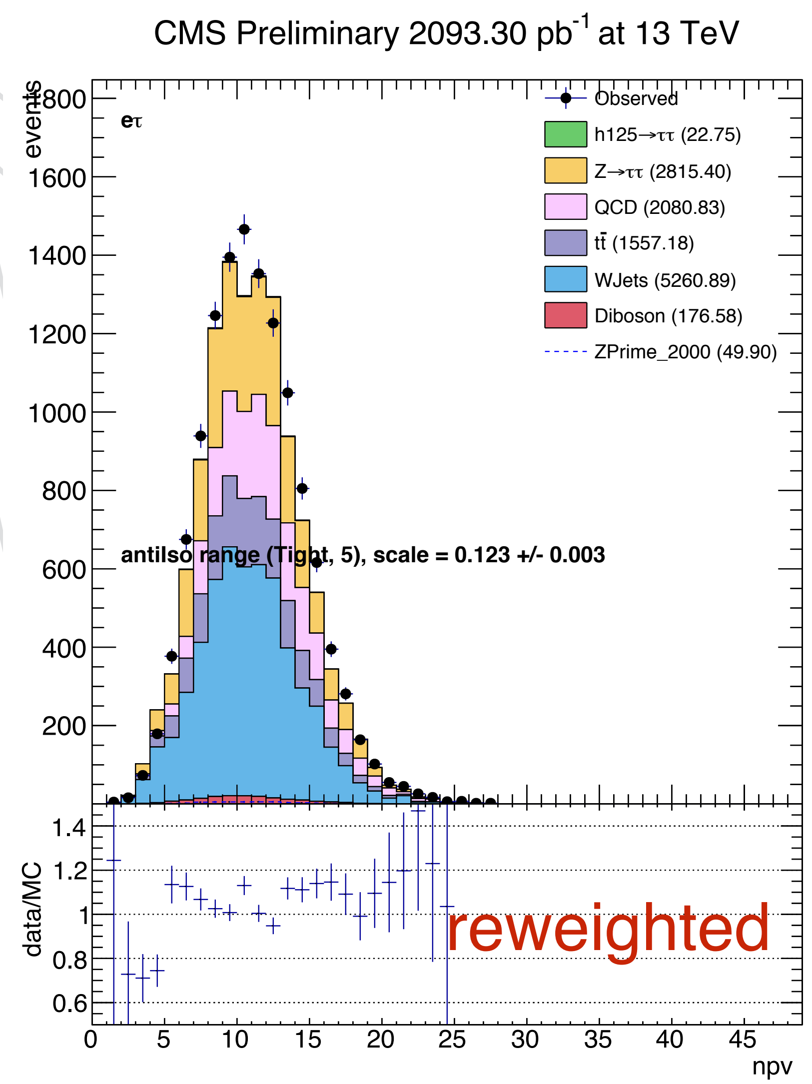
Corrections: PileUp re-weighting

Quantities such as and isolation, where energy depositions are summed up over some range of the detector, can suffer large inefficiencies or systematic effects due to particles from pile-up interactions.

The pile-up distributions in MC simulations may not correctly model the distributions from data. Thus, we need to apply some corrections.

2015 data





Hands-on: Tasks

https://twiki.cern.ch/twiki/bin/view/CMS/SWGuideCMSDataAnalysisSchoolLPC2017LongExerciseTau

Wed 8am

Discuss and work as a group :)

Preparations:
- setup CMSSW, download code etc

Event Selections:

similar to short exercise
- topology cuts
- vetos for background rejection

how?
- visible mass reconstruction

start with F_{SStoOS} = 1.06 then try to estimate your own
- data-driven QCD estimation
- compare data with background estimations!

Compute cross sections:
- based on normalization
- based on maximum likelihood fit
- compare to 8 TeV results

x2 for muon+tau and electron+tau in 3 person groups

Presentation

Team Reports Fri 10:30am

Enjoy and have fun!