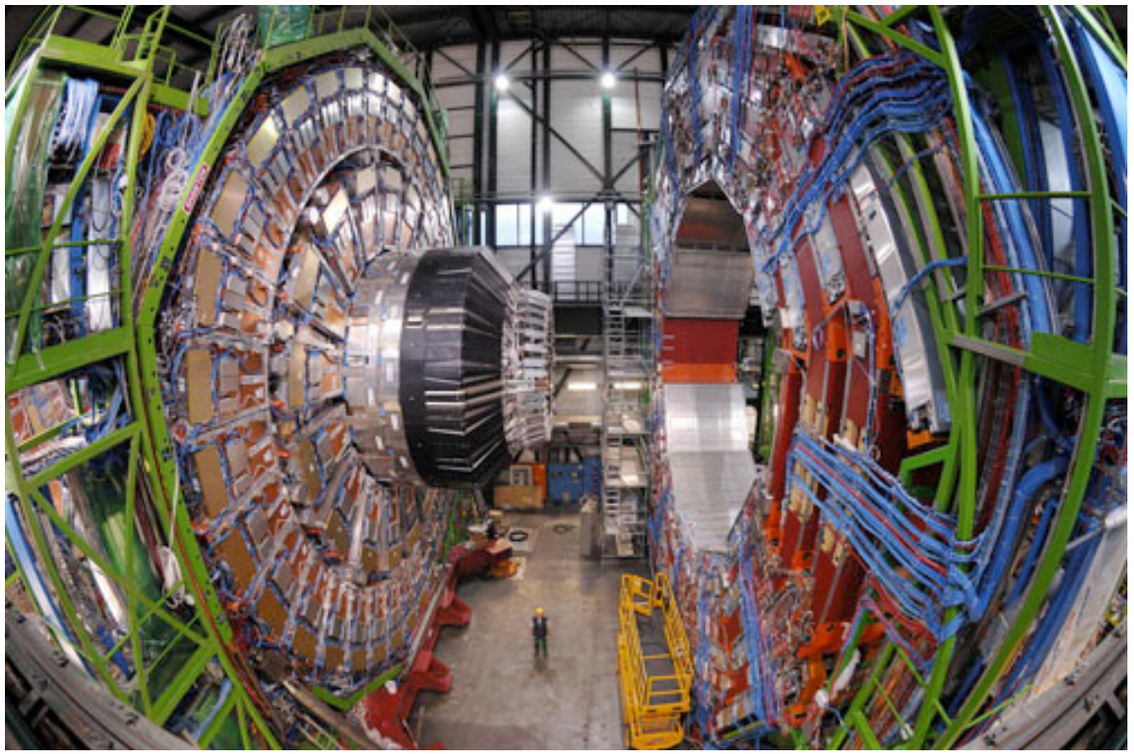
Production of jets accompanied by W/Z bosons at LHC



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On behalf of CMS the Collaboration

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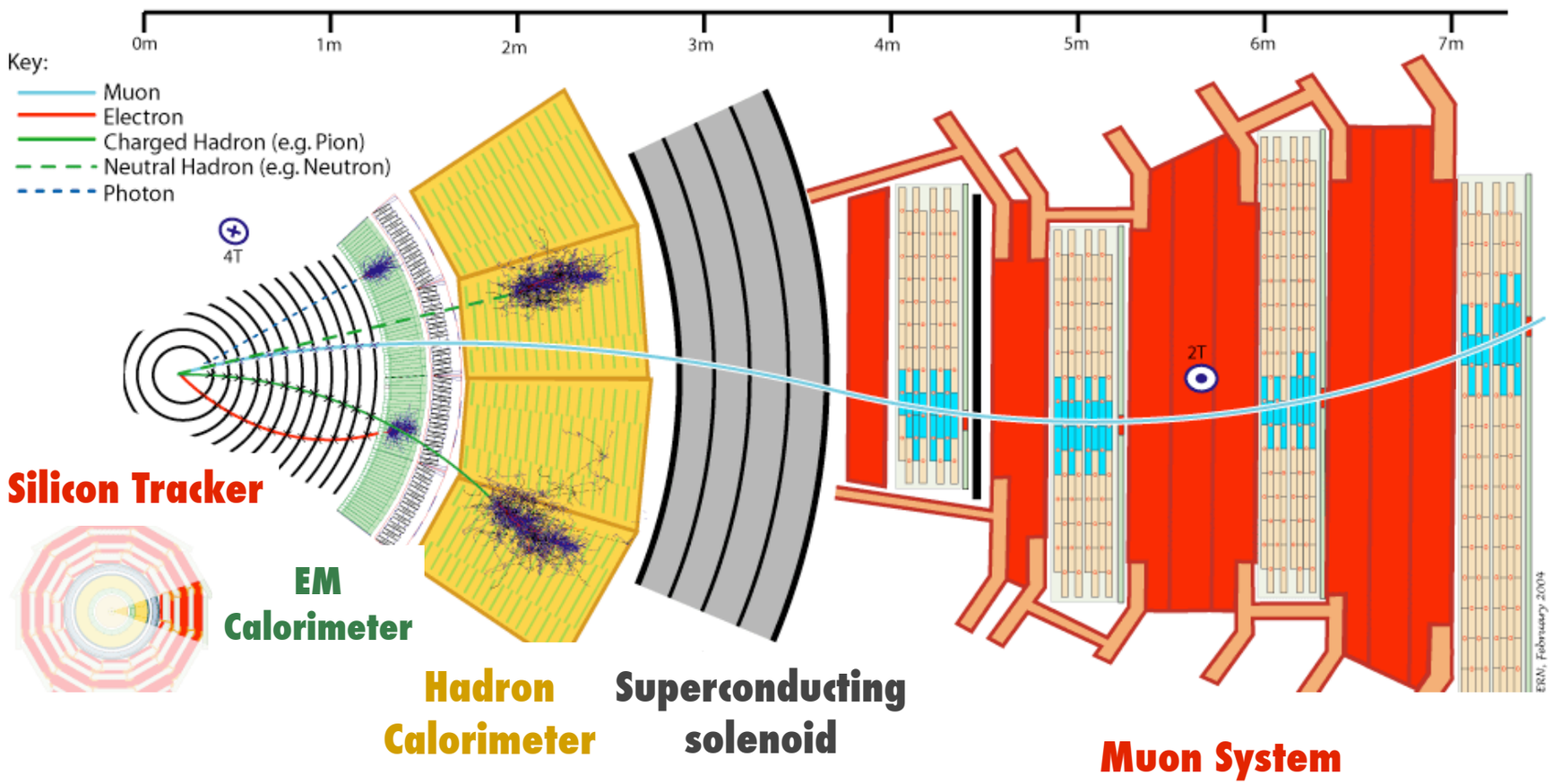
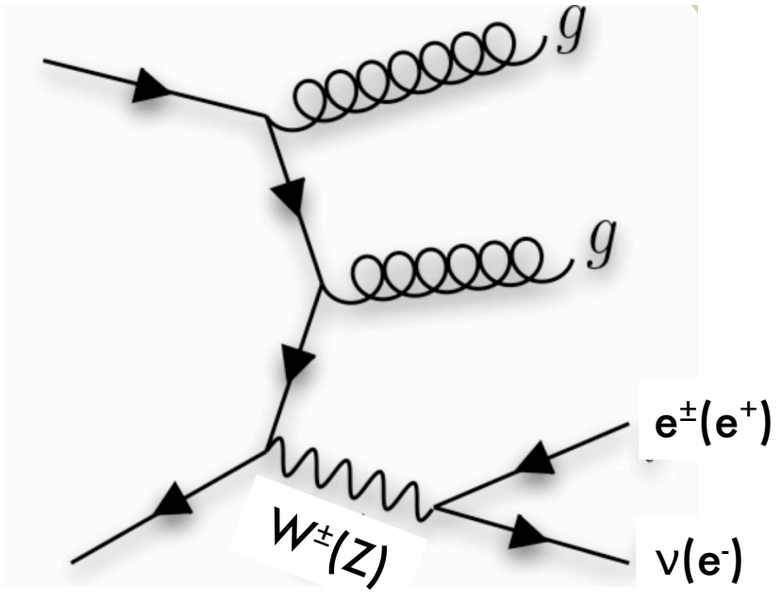
Outline

- Introduction
- W & Z selection (μ/e channel)
- W/Z+jets selection (μ/e channel)
- Using (Z→μμ)+jet for jet calibration
- Summary

CMS detector



Transverse slice through CMS detector



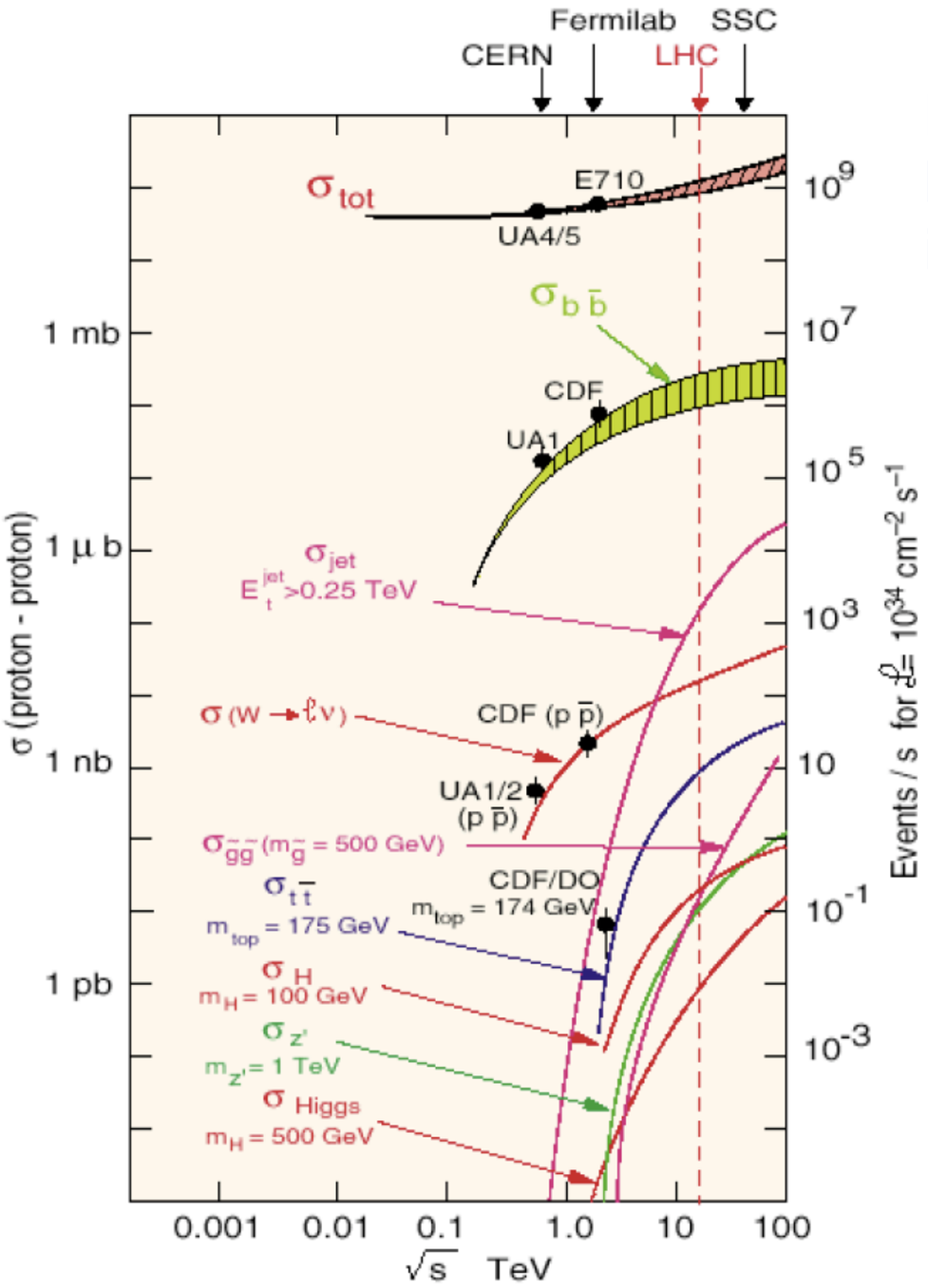
Muons: tracker + muon chambers

Electrons: Tracker + Electromagnetic Calorimeter

Missing Transverse Energy : EM+Hadronic Calorimeter + Tracker+Muon system

Jets: EM+Hadronic Calorimeter / Tracker only / Particle Flow Objects(Tracker+Calorimeter)

Physics potential with W/Z+jets



Direct production of W/Z in association with jets have large cross section at LHC and is relevant to many interesting topologies:

- Tests of perturbative QCD: calculations @ NLO available only up to W/Z+2jets. Predictions for the higher jet multiplicities accessible through ME+Parton Shower computations and can be considered as a prime testing ground for the accuracy of such predictions
- W/Z+NJets forms a relevant background to many interesting phenomena including new physics : decay of squarks and gluinos in SUSY have same signature as W/Z+Jets (e.g MET+Jets)
- Z + jet events can be used to calibrate jets measured in the calorimeter: pT balance between Z and jet

However the individual x-section measurements @ startup will be affected by large systematic uncertainties growing rapidly by jet multiplicity

Physics potential with W/Z+jets

- Measuring the x-sect ratio $R = \frac{\sigma(W + Njets)}{\sigma(Z + Njets)}$ allows to cancel out some of the most relevant sources of systematics:

  - Jet Energy Scale
  - Jet algorithm and algorithm parameters
  - Underlying event
  - ISR
  - Multiple Interactions
  - Luminosity
  - Detector acceptance and efficiency: partially
  - Q2, PDFs systematics also minimized

➠Studies on measurement of **Ratio** as a function of Jet multiplicity & boson p_T are not yet public but underway

- Precision Measurements of SM parameters

$$\frac{\sigma(W/Z + (N+1)Jets)}{\sigma(W/Z + NJets)} \sim \alpha_s$$

Direct measurement of α_S

$$\frac{\sigma(W/Z(\mu\nu) + Njets)}{\sigma(W/Z(\tau\nu) + Njets)} = 1$$

Lepton universality,
new physics evidence if deviations from 1

$\gamma^*/Z \rightarrow \mu^+\mu^-(e^+e^-)$ selection

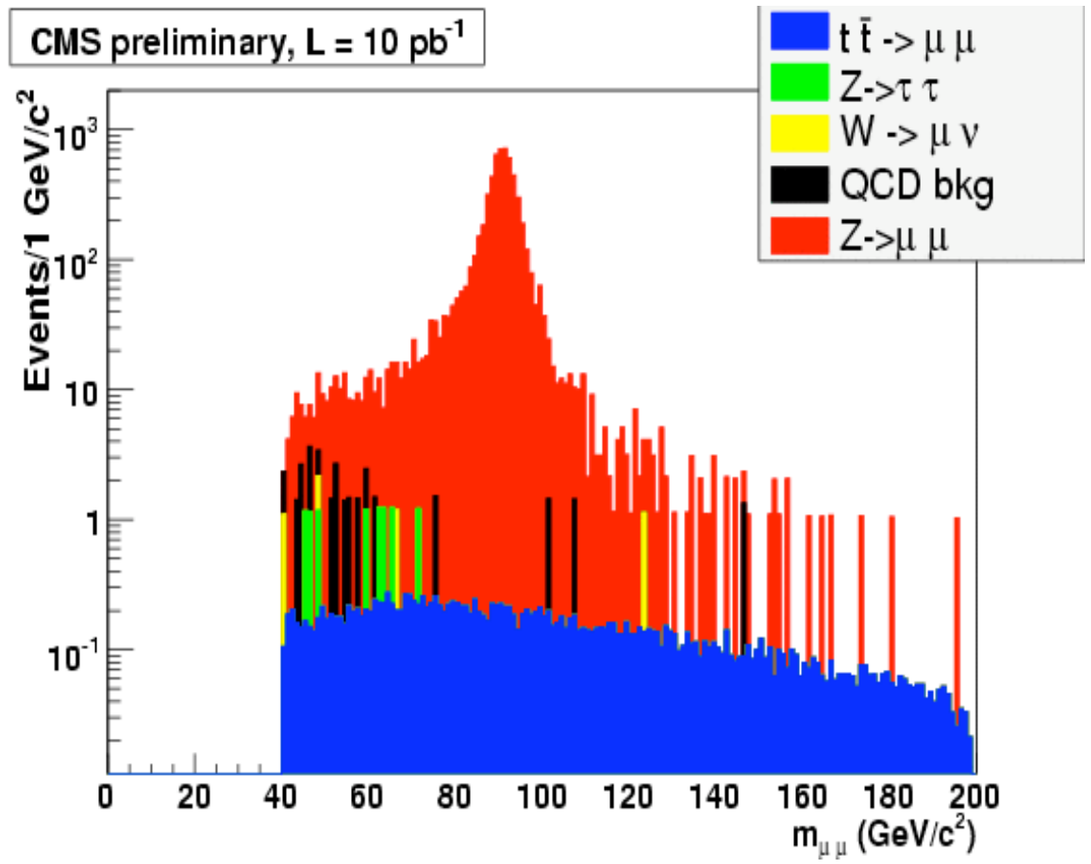
$\gamma^*/Z \rightarrow \mu^+\mu^-$

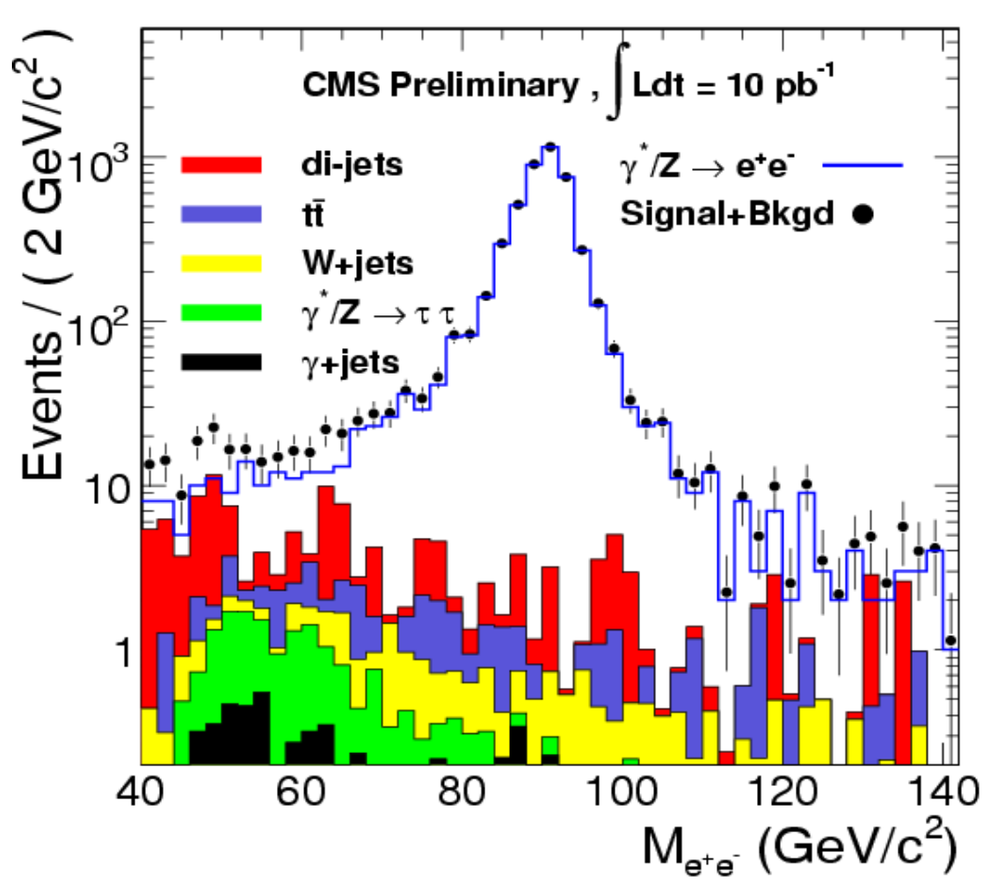
- Single Muon HLT
- 2 high P_T muons (P_T>20 GeV) within $|\eta|$<2
- Opposite charge sign
- Track Isolated: ΣP_T<3 GeV in ΔR<0.3 around muon
- $M_{\mu,\mu}$ > 40 GeV

$\gamma^*/Z \rightarrow e^+e^-$

- Single Isolated electron HLT
- 2 high E_T electrons (E_T>20 GeV, $|\eta|$<2.5)
- Track Isolated: $\Sigma(P_T/P_T^e)^2$<0.02, P_T>1.5 GeV, ΔR<0.6
- Electron Id: H/E, $\Delta\eta$, $\Delta\varphi$, $\sigma_{\eta\eta}$
- 70 GeV < $M_{e,e}$ < 110 GeV

$\gamma^*/Z \rightarrow \mu^+\mu^-(e^+e^-)$ selection





✓Current selections provide a pure sample of $\gamma^*/Z \rightarrow e^+e^-, \mu^+\mu^-$ events.

✓Assuming NLO cross sections at 14 TeV and 10pb^{-1} of integrated luminosity
~4.6K e^+e^- pairs in the $70<M_{e,e}<110$ mass region
~5.5K $\mu^+\mu^-$ pairs in the $70<M_{\mu,\mu}<140$ mass region.

✓Data driven methods (Tag & Probe using known properties of Z) to evaluate the Selection, Reconstruction & Trigger efficiencies are developed

W→μ(e)ν selection

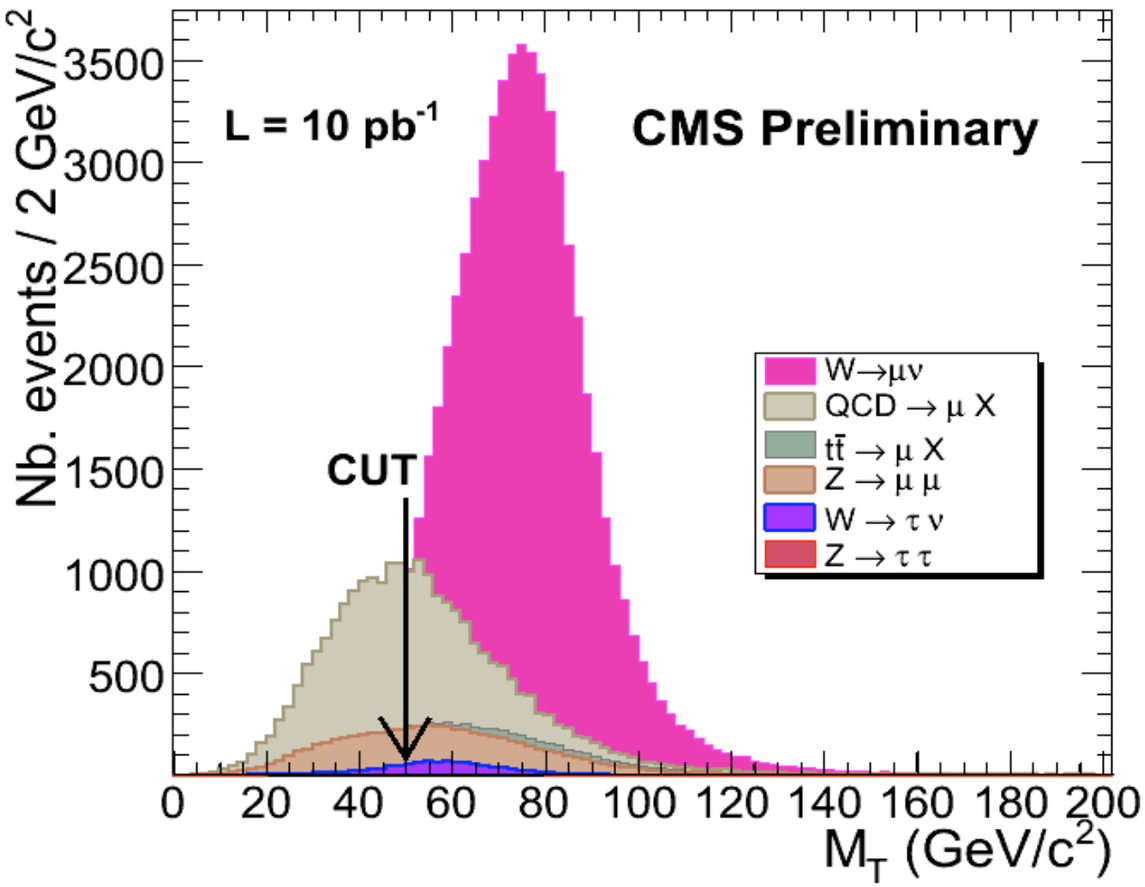
$W \rightarrow \mu^{\pm}\nu$

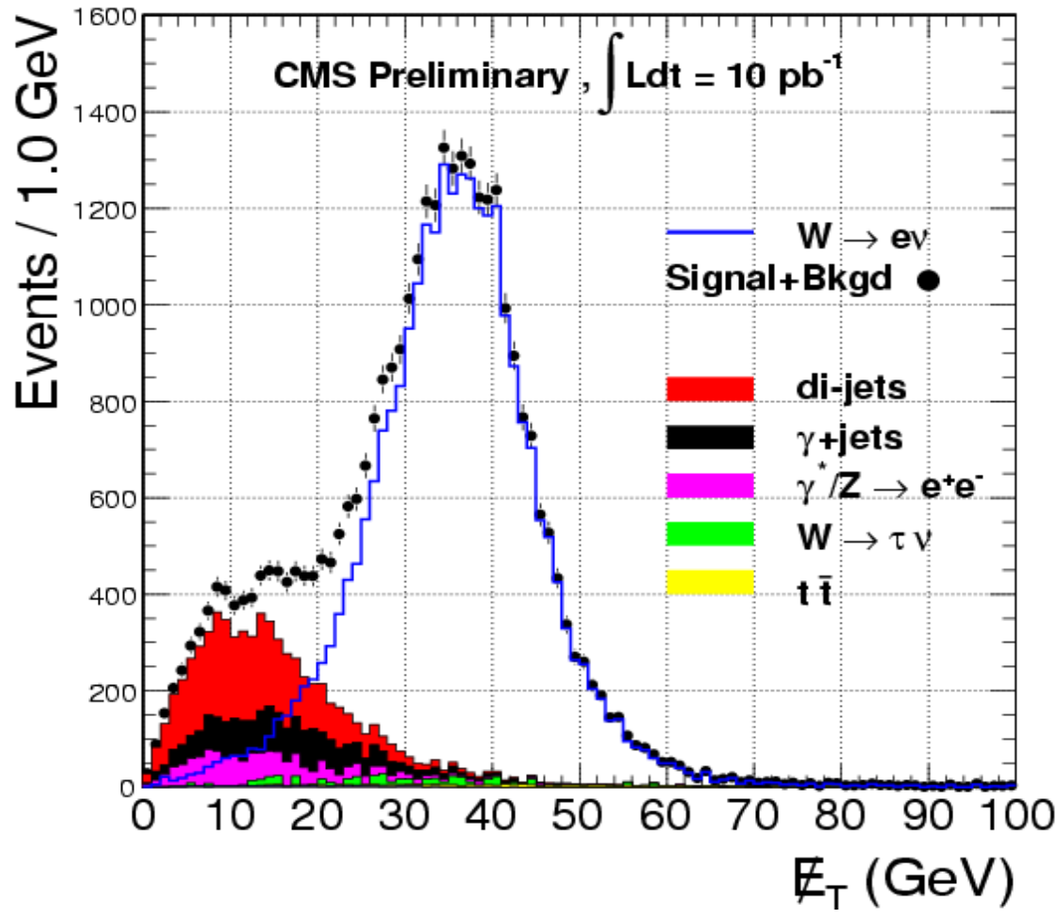
- Single muon HLT
- A high P_T muon (P_T>25 GeV) within |η|<2
- Track Isolated: $\Sigma P_T/P_T^{\mu} < 0.09$, $\Delta R<0.3$
- M_T > 50 GeV
- Reject events with more than 3 jets with E_T > 40 GeV
- Reject events with acoplanarity ζ < 1rad (ζ= 180 – Δφ) defined between μ & ME_T.
- Reject events with 2 P_T>20 GeV muons.

$W \rightarrow e^{\pm}\nu$

- Single Isolated electron HLT
- A high E_T electron (E_T>30 GeV) within |η|<2.5
- Isolated: no tracks with P_T>1.5 GeV in a cone of $\Delta R<0.6$ around the electron.
- Electron Id: H/E, Δη, Δφ, $\sigma_{\eta\eta}$
- Reject events with a 2nd electron having E_T>20 GeV.

W→μ(e)ν selection



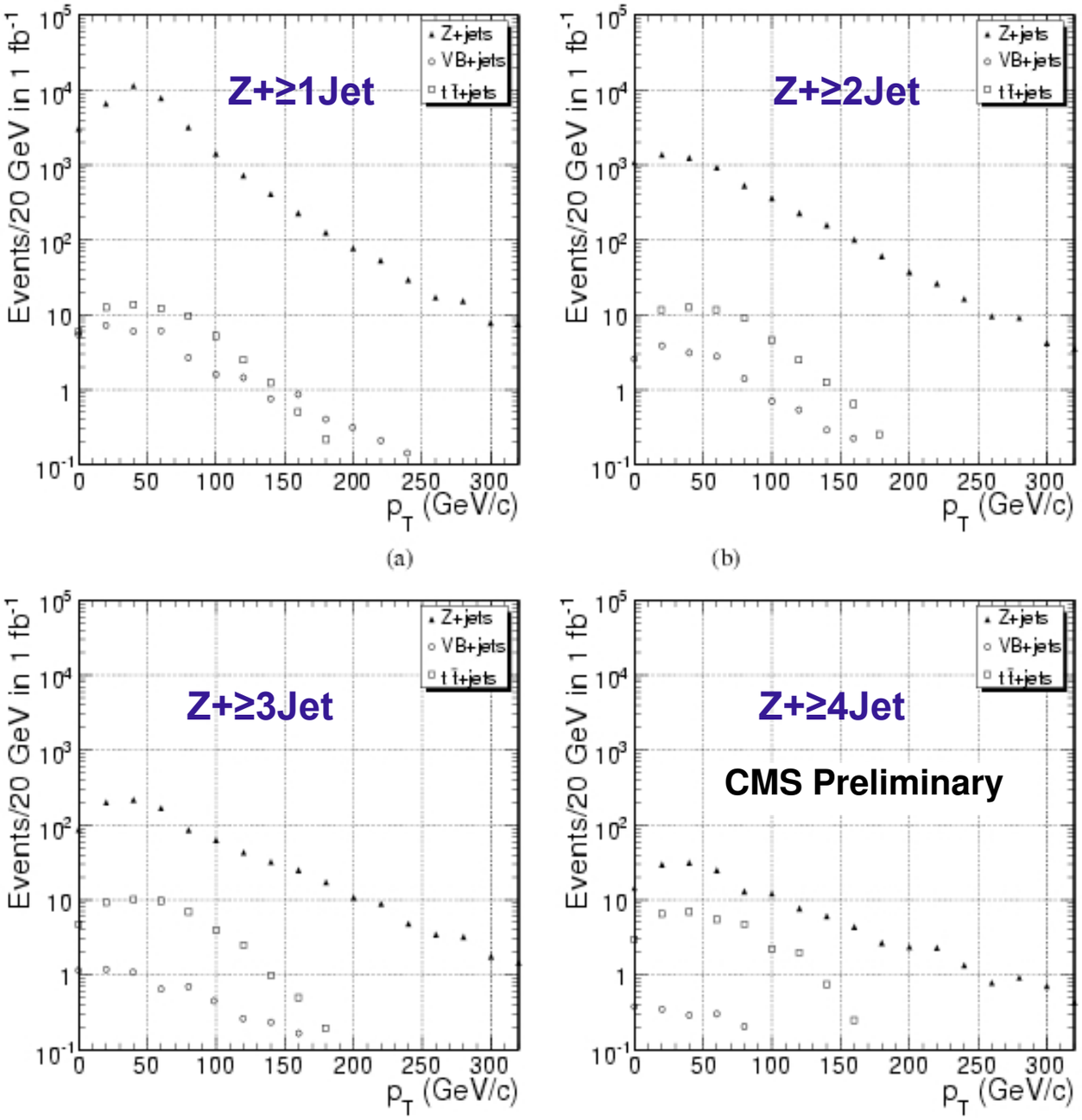


✓QCD is the major background in both final states and methods to estimate it from data are developed, while EWK background estimation will be based on MC

✓Assuming cross sections at 14 TeV and 10pb^{-1} of ∫Ldt we expect:
~28K W→ev events and ~ 6K QCD events
~64K W→μv events and ~16K QCD events

Inclusive Z→μμ(ee)+jets selection

Z pT distributions for signal and backgrounds



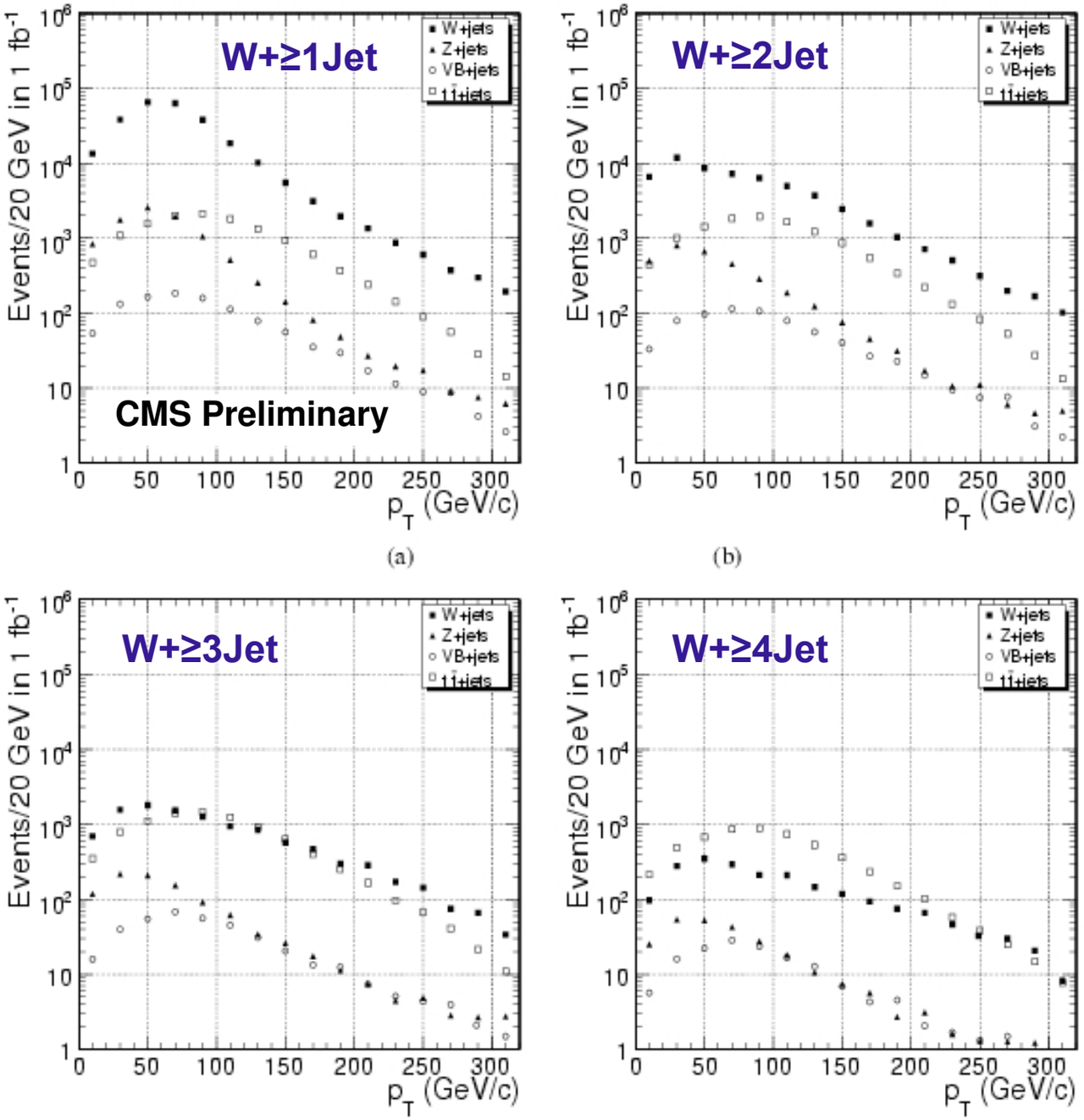
Event selection

- double electron/double muon triggers
- two isolated lepton with p_T(μ/e) >20 GeV
- opposite charged e/μ
- tight $M_{ee}/M_{\mu\mu}$ cut around Z mass
- Jets are reconstructed with IterativeCone algorithm using energy deposited in the calorimeter. Jet energy calibrations using γ+jet events
- E_T^{miss} is required to be small taking into account the expected resolution.
- Events with at least one jet with E_T> 50 GeV are counted.

Background from QCD events are not shown (found to be negligible), recent studies show larger contamination from QCD

Inclusive W→μ(e)ν+Jets selection

W p_T distributions for signal and backgrounds



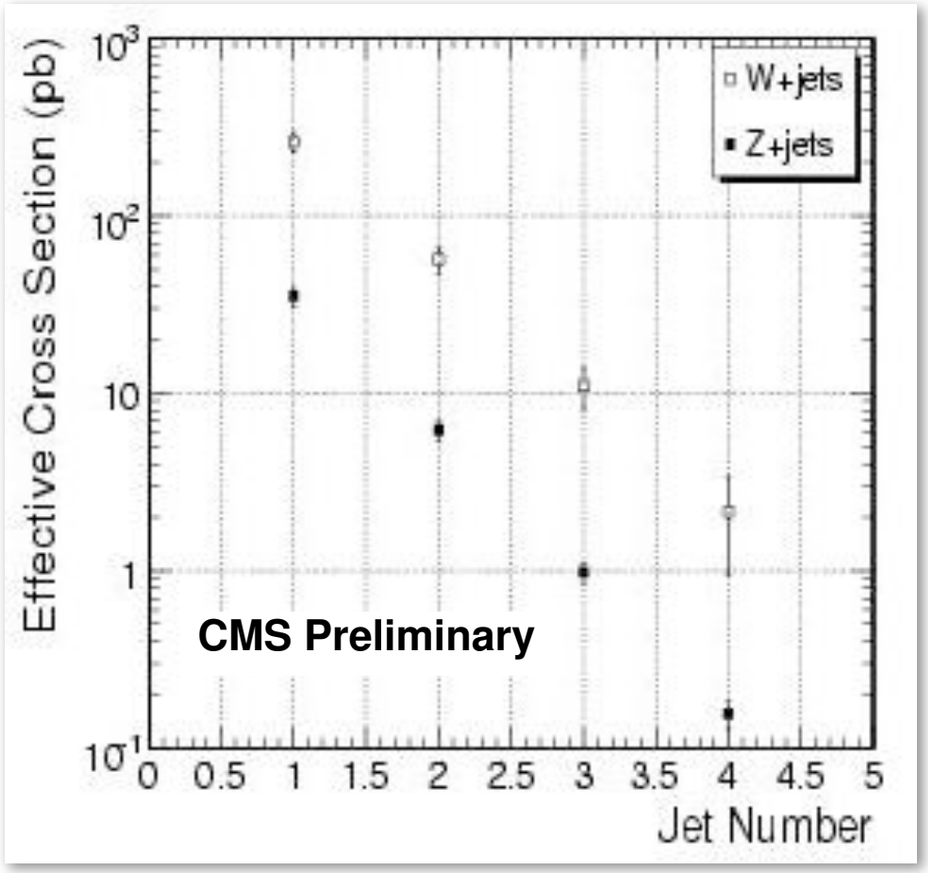
Event Selection

- single electron/single muon triggers
- tight isolation criteria, both Tracker & Calorimeter
- $p_T(\mu/e)$ >30 GeV and only one such isolated lepton
- Jets are reconstructed with IterativeCone algorithm using energy deposited in the calorimeter. Jet energy calibrations using γ+jet events.
- E_T^{miss} is corrected for both muons and jet energy corrections. E_T^{miss} >45 GeV
- Events with at least one jet with E_T> 50 GeV are counted.

Background processes are simulated with PYTHIA which is known not to produce high jet multiplicities realistically. Studies using more appropriate background simulation (i.e. using ALPGEN) are ongoing

W/Z+jets event rates

Expected effective cross section for W+jets and Z+jets as a function of jet multiplicity



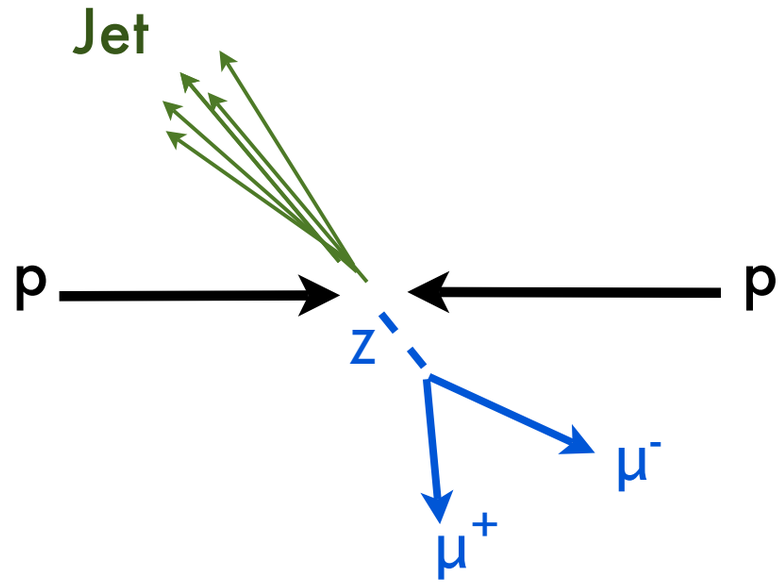
Expected Systematic uncertainties of W+jets Cross Section at 10 fb^{-1}

Source	Uncertainty (%)
Luminosity	5
Jet	8
E_T^{miss}	5
Trigger, Lepton ID	3.5
Lepton Isolation	5
Background Subtraction	~10

✓ **The cross sections for W(Z)+jets decrease with increasing jet multiplicity as predicted in QCD**

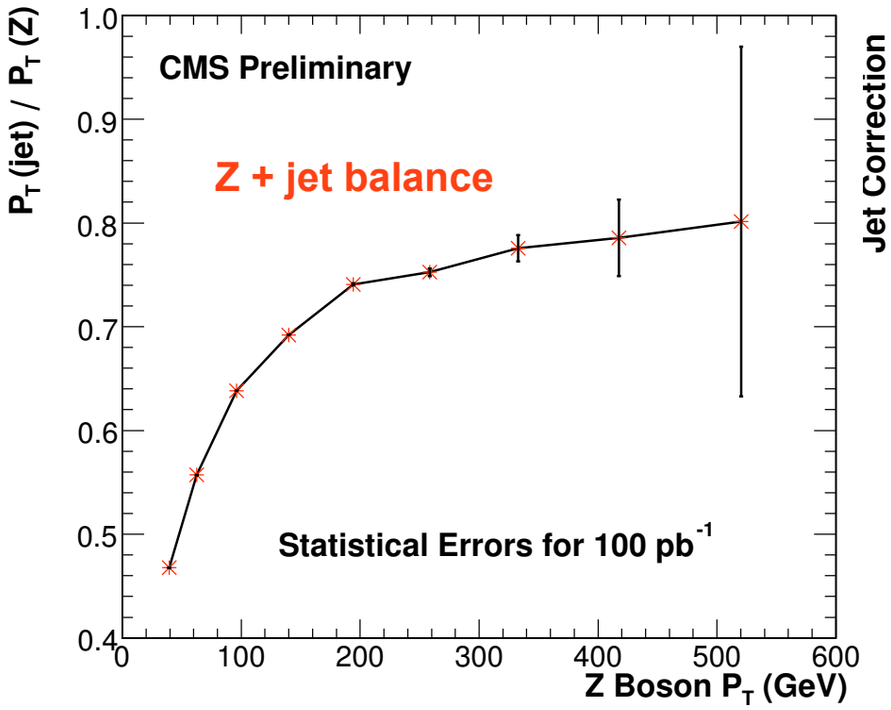
Jet energy correction using Z+jets

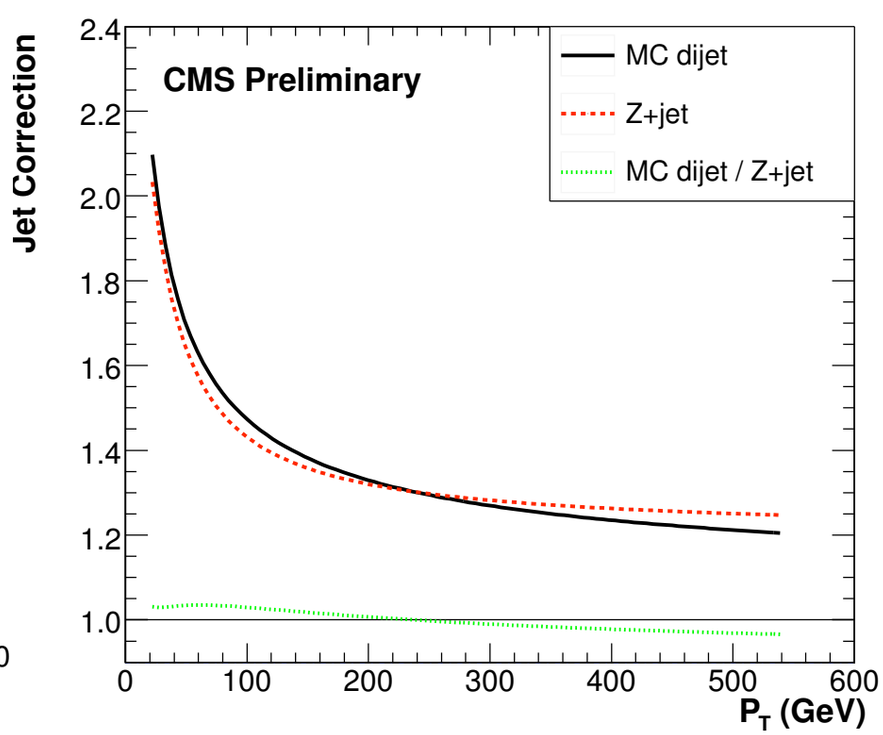
Z+jet events can be used for jet calibration: the key point is p_T balance between Z boson and the jet



(Z→μμ) + jet:

- muons reconstructed in the tracker (independent from calorimeter),
- clean events with well separated Jet-Z
- NO extra jet with $P_T > 0.2P_T(Z)$.
- $m_{\mu\mu}$ within m(Z)±20 GeV





✓measure jet correction up to 400 GeV with 100 pb^{-1}.

✓ correction factors from MC dijet & Z+jet consistent within 5%

✓ combine jet calibration constants from Z+jet and MC truth, extrapolate to higher p_T

✓consistent results using γ+jet events exists, larger QCD background compare to Z+jet.

Summary

☑ A strategy for the early measurement of the inclusive W & Z production cross section have been developed for the first 10pb^{-1} of data

☑ W(Z)+jets have wide range of physics potential. Measurements of W(Z)+jets versus jet multiplicity will be one of the early measurements in CMS.

☑ The analysis strategy for W/Z+jets will be adapted from W/Z measurement for the EWK part. Multiple choice for jet reconstruction: Calorimeter/Tracker/ParticleFlow jets

☑ The ratio measurement of W+Njets to Z+Njets will allow cancellation of most of the relevant systematic uncertainties. Extremely important at the startup and the studies for ratio measurement are ongoing.

☑ One crucial point will be the reduction of background in the W+>2 jets from top events: ttbar production rate increases by a factor of ~100 from Tevatron to LHC, while W(Z) production increases by a factor of ~5. 2124652387

Event Generation and Simulation

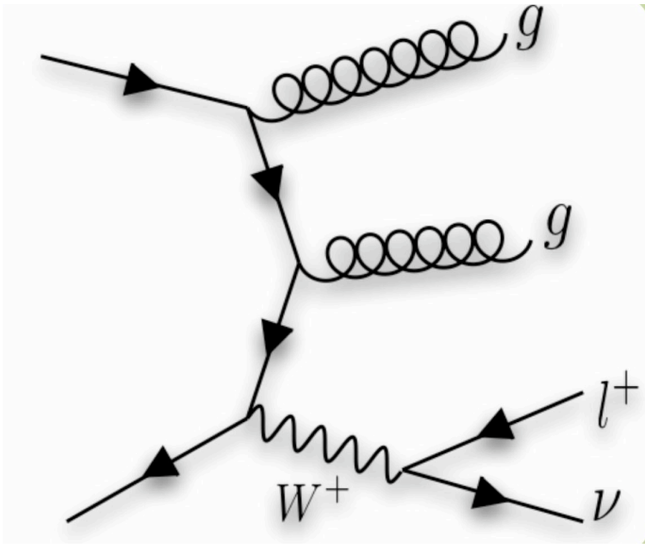
✓A number of physics generators are available to simulate major kinematic properties of W/Z+jets

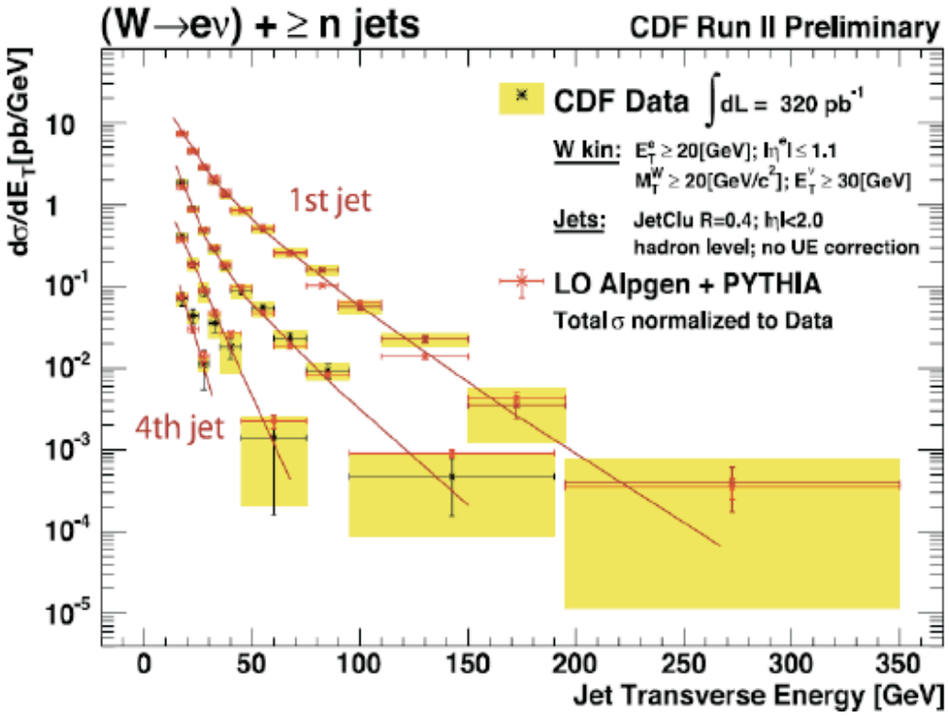
✓ matrix-element(ME) event generator ALPGEN is used to generate exclusive parton level W/Z+Njets (N=0,1,2,3,4,5) events.PYTHIA is used for parton showering(PS) and hadronization.

✓ In order to avoid double counting of processes from ME and PS, MLM recipe is used for matching partons and jets.

✓The SM processes ttbar+jets, WW+jets, WZ+jets, ZZ +jets and QCD multi-jet are considered as background and generated with PYTHIA in fully inclusive decay modes for W and Z.

✓Measurement of pT spectrum of jets made by CDF collaboration shows good agreement with predictions obtained with ALPGEN program.





CMS detector