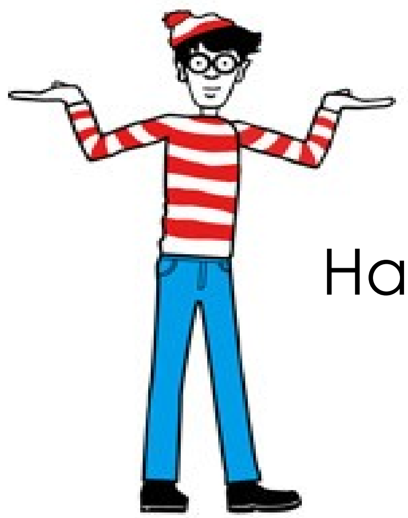
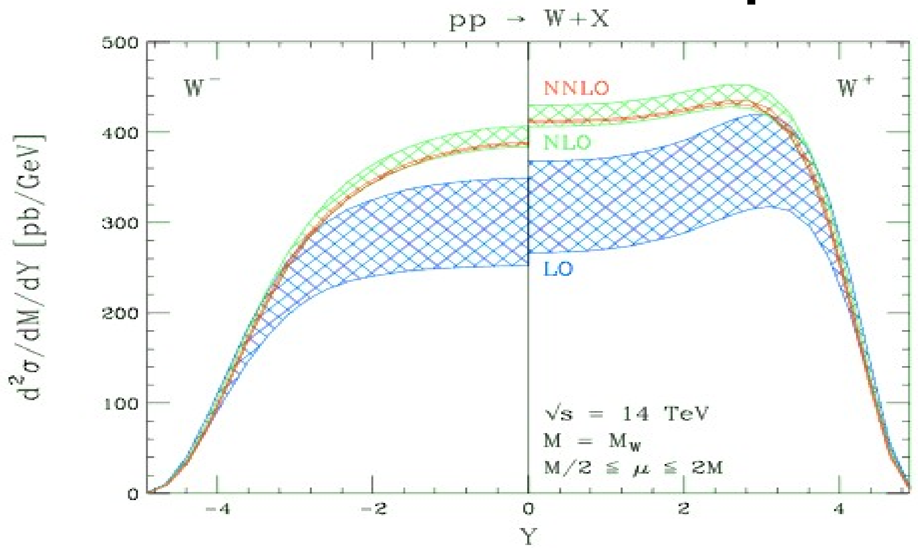


Have you seen my E_T ?

W Cross Section with early CMS Data

Philip Harris
CMS Collaboration
7/5/2009

W cross section prologue



- **Starting point for the rest of physics**
  - All physics with high p_T lepton
    - For starters: W+Jets Higgs or W'
- New constraints on PDFs
  - W asymmetry measurement at $10pb^{-1}$
  - W/Z cross section ratio
- Luminosity measurement
  - Low Systematics => can constrain luminosity
    - pp/qq' luminosity

W cross section ingredients

$N_W = N - N_{QCD} - N_{Z\ell\ell} - N_{W\square} - N_{tt}$

$\sigma_W = N_W / a \square \mathcal{L}$

N_W = Number of W events

a = Acceptance factor

= W efficiency

$\mathcal{L}$ = ∫dt Beam luminosity → Obtained from other analyses

Backgrounds

Predict with Monte Carlo

Predict with data

- Measure W production cross section □ for W⇨ $\ell\nu$
  - ℓ is lepton(e or μ): Start at $p_T > 25$(30GeV for e)
    - No second lepton with $p_T >$ 20GeV
  - ν :use missing E_T (*met*): >20GeV(μ:$m_T >$ 50GeV)
- **Optimize W signal wrt QCD process**
  - QCD background is largest most difficult to calculate

The Analysis

Datasets

Signal Sample
Combination of W/QCD/Z/tt

Di-lepton Events
Z/QCD/W+Jets
Small QCD background

Di Jet Trigger
Non Isolated Lepton
QCD processes

Monte Carlo

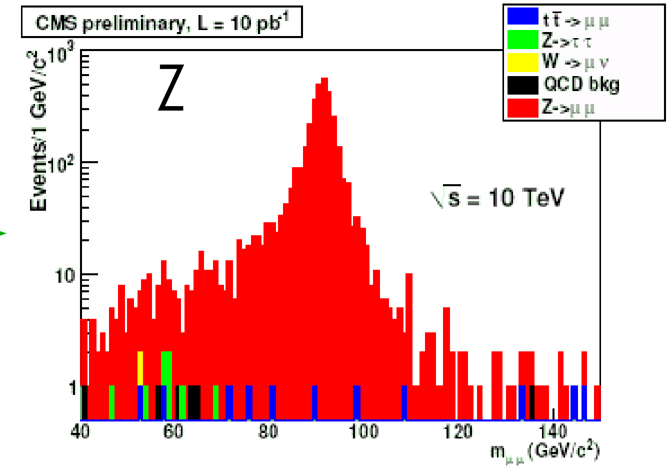
Analysis steps

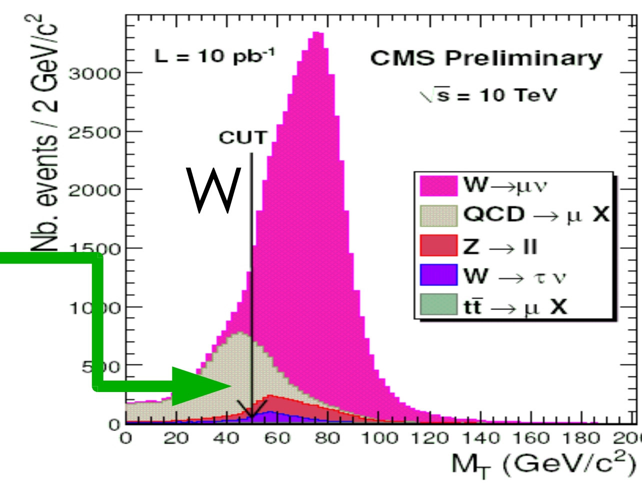
Lepton Selection

QCD Estimation

MET Modelling

Results

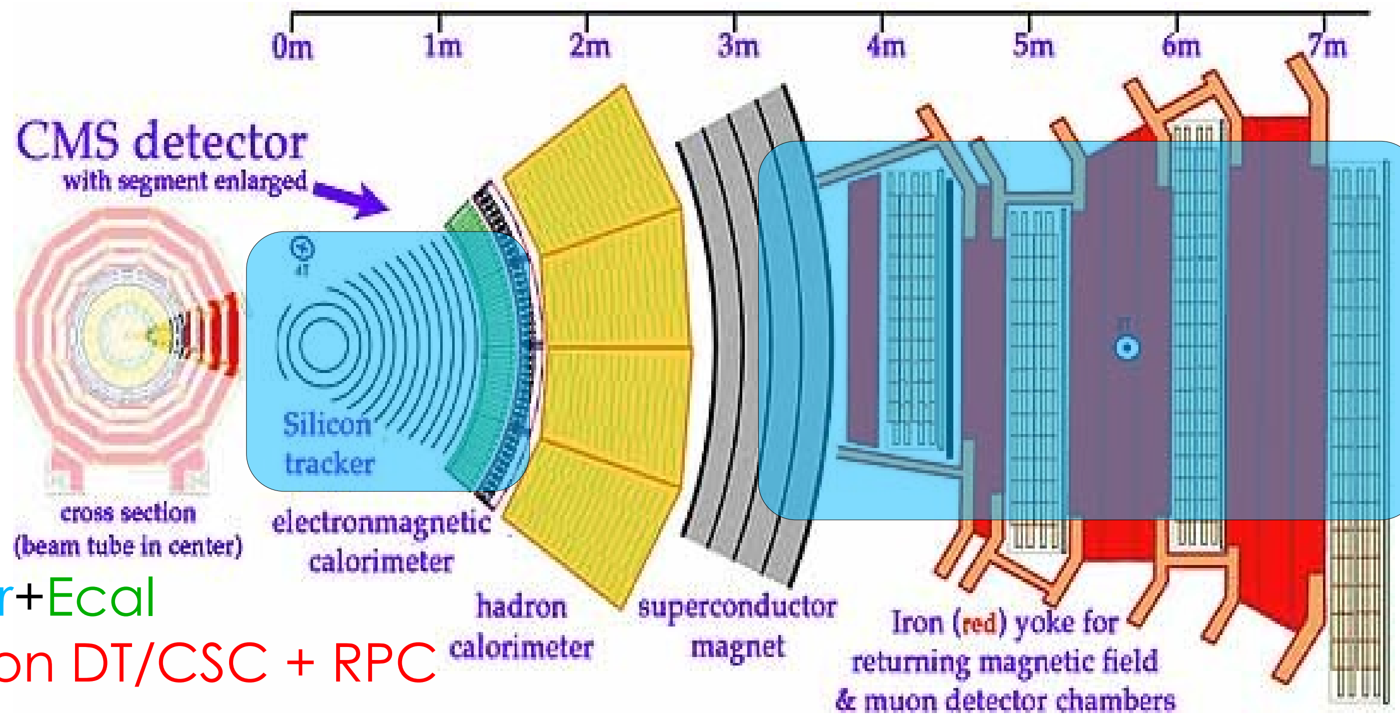




Input
Output
Analysis Flow

The Instrument

Fiducial constraints
Electrons $|\eta| < 2.4$
Muons $|\eta| < 2.0$



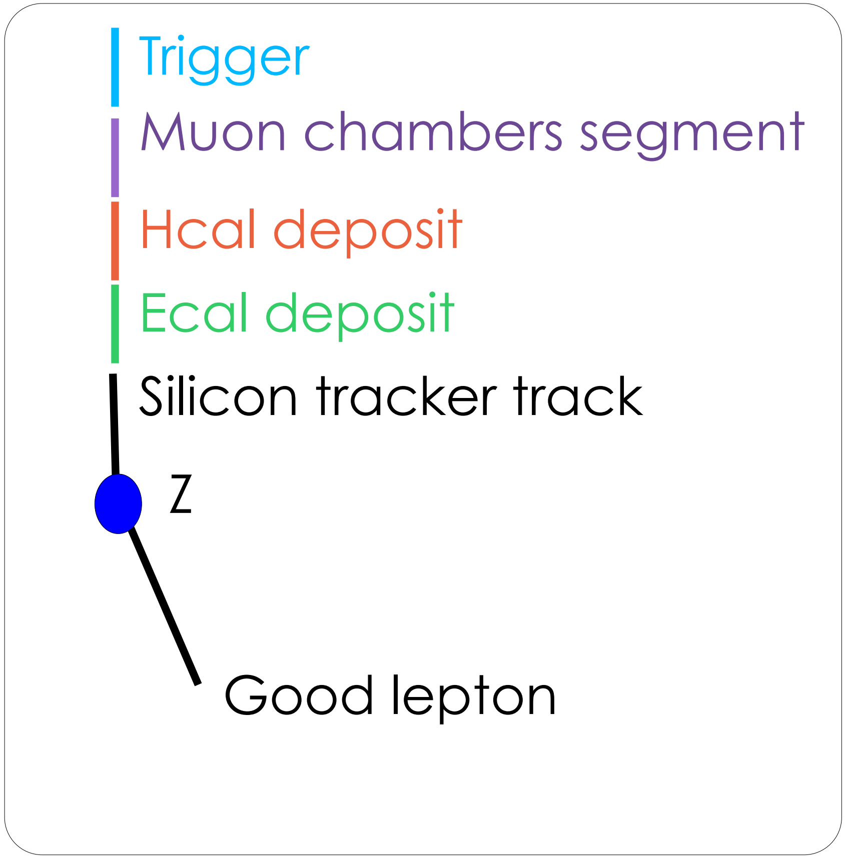
Reconstruction
Electrons : Pixels+Tracker+Ecal
Muons : Tracker + Muon DT/CSC + RPC

- While we wait for the accelerator (cosmic rays)
  - Use muons to align tracking of the detector

Detector	|η| Range
Tracker	0-2.4
Ecal	0-2.5
Hcal	0-5.0
Muon-DT	0-1.2
Muon-CSC	1.2-2.4
Muon-RPC	0-2.1

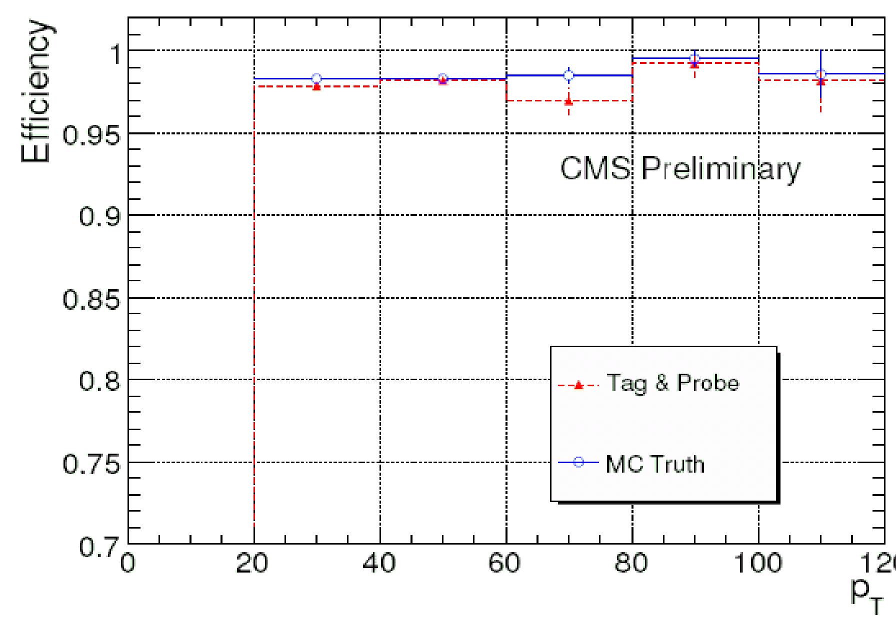
- **What do we need to do at start up**
  - Look at calorimeter:Jet/*MET* scale
  - Detailed studies of momentum scale(J/□)

Selection Efficiencies



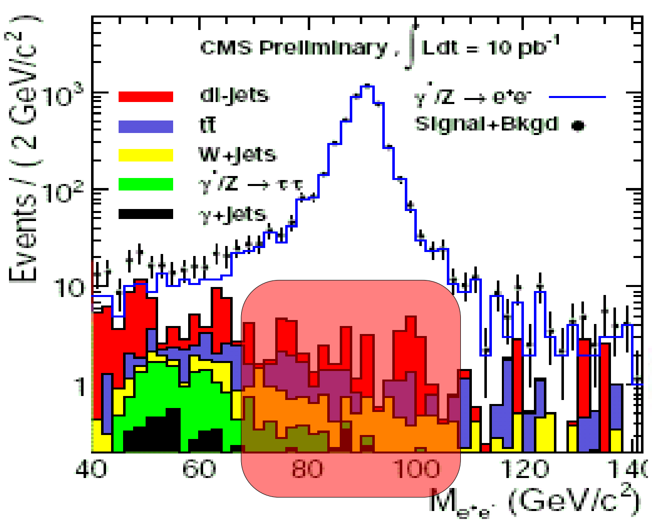
- Lepton tag and probe
  - "Tag" = good triggered lepton
  - "Probe" = another track
    - Tag+Probe mass near Z mass
  - Evaluate additional selection
    - (*i.e.* reco electron or muon)

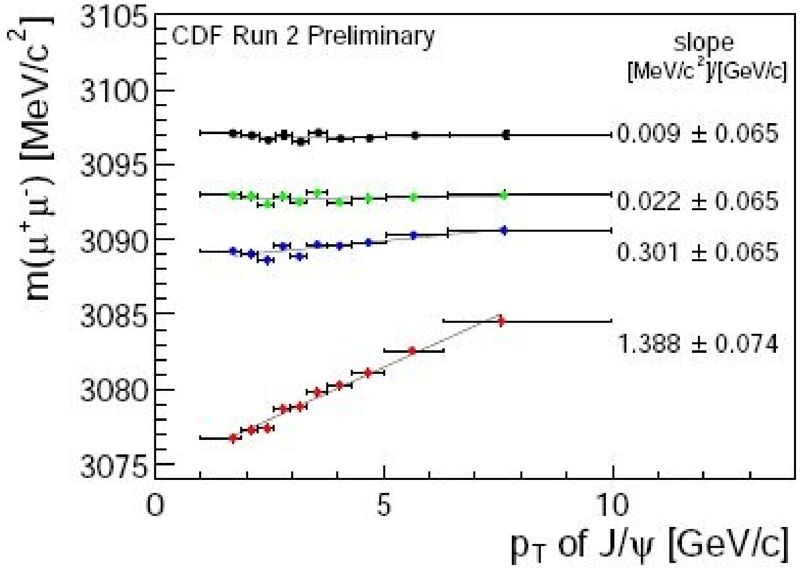
Global Muon Efficiency:
Tag: Muon + Track
Probe: Fully Reco Muon(Global Muon)
(Si+Chamber+Calorimeters)



Understanding Efficiency

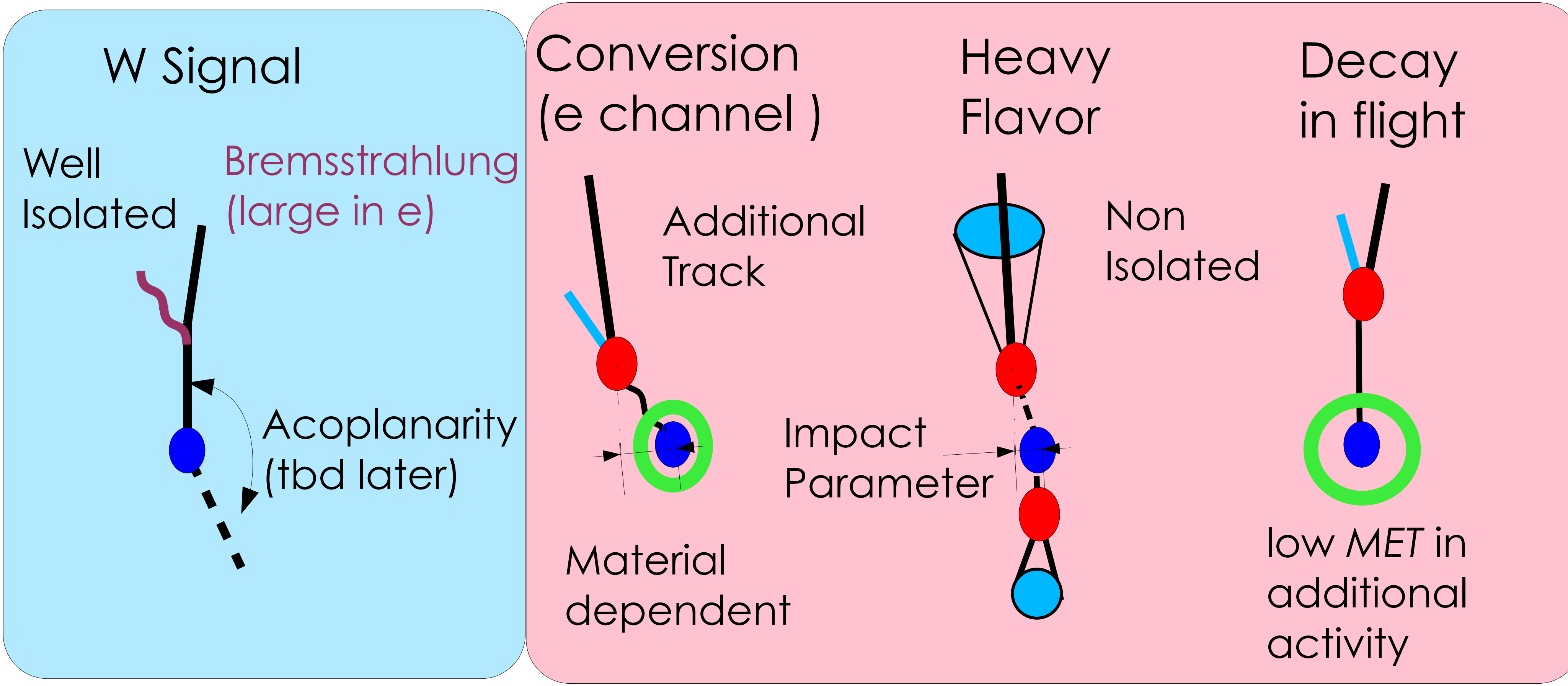
- **Tag and probe events have systematic problems**
  - W kinematics are not the same
    - Bin efficiencies in and p_T → Correct bin by bin
  - Background from QCD di-jet and W+jets events
  - Reconstruction bias from data
    - Material/B field/Momentum mis modeling
    - Look at J/ mass and Z mass throughout detector



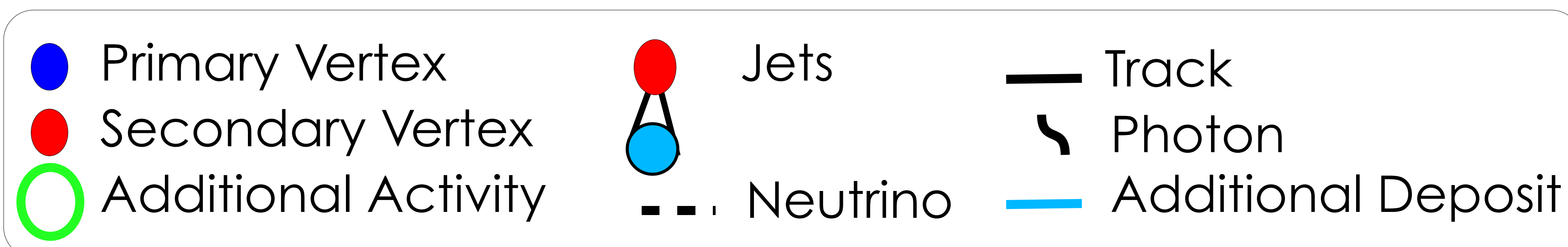


Systematic	Error
Kinematic Binning	<0.5%
Background	1.0%
Momentum Scale	2.7%
Events	0.5%

Separating W leptons from QCD

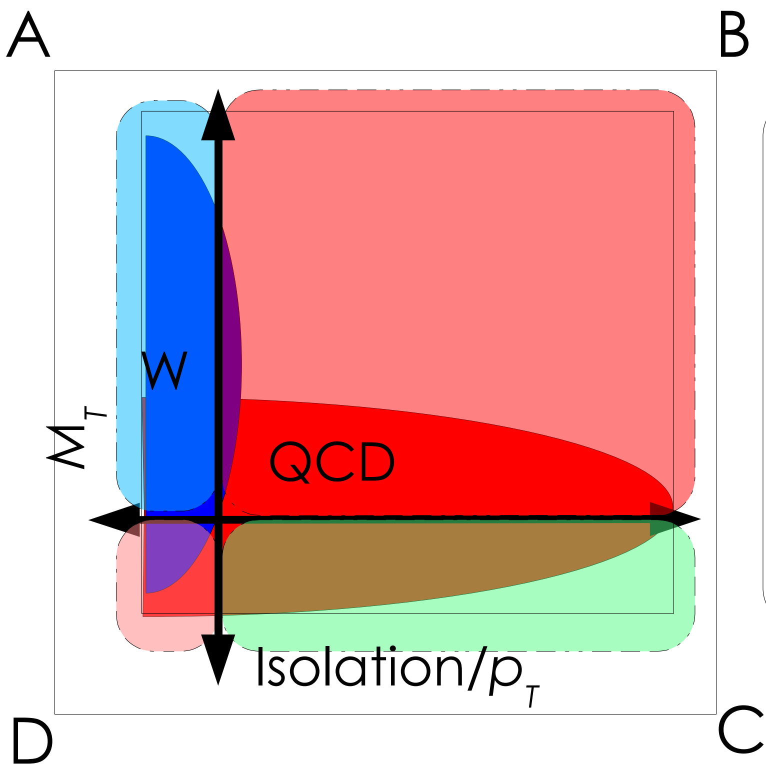


Lepton isolation is the best universal discriminant



QCD Background Estimation

- Method 1: Matrix method (ABCD method)
  - **Estimates Number of QCD Events** in a signal region
  - Two "independent" variables used in selection
    - Muons: m_T vs. Isolation/p_T
    - Electrons: *MET* vs. Isolation

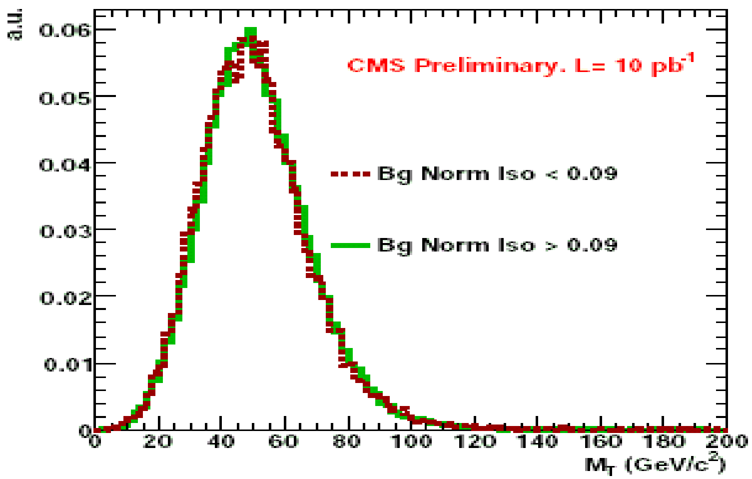


Start with left plot of 2 variables:ABCD
Create signal template(from Z next slide):W
A = # in Signal Region = $W_A + QCD_A$
QCD_A =# of QCD in A = $QCD_D \times QCD_B / QCD_C$
$QCD_A = (D-W_D) \times (B-W_B) / (C-W_C)$
Calculate: $W_A = A - QCD_A$

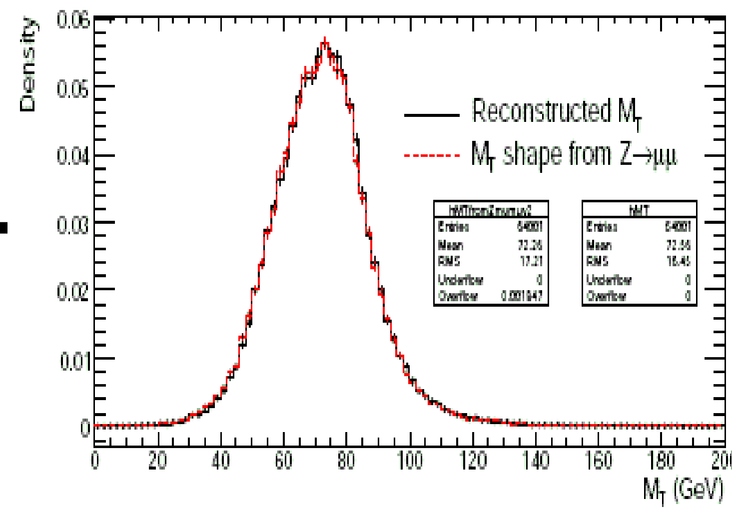
Systematic uncertainty of 0.4%(Muons with $10pb^{-1}$)

QCD Background Estimation

- Method 1: Does not give accurate m_T shape
- Method 2: Template method (**accurate m_T shape**)



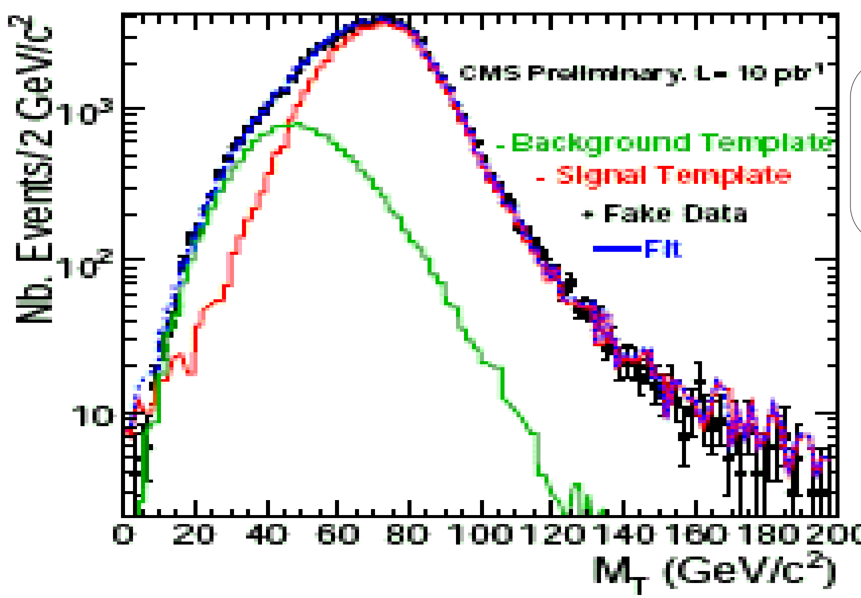
Fit distributions



μ : QCD m_T shape from inverse-isolation

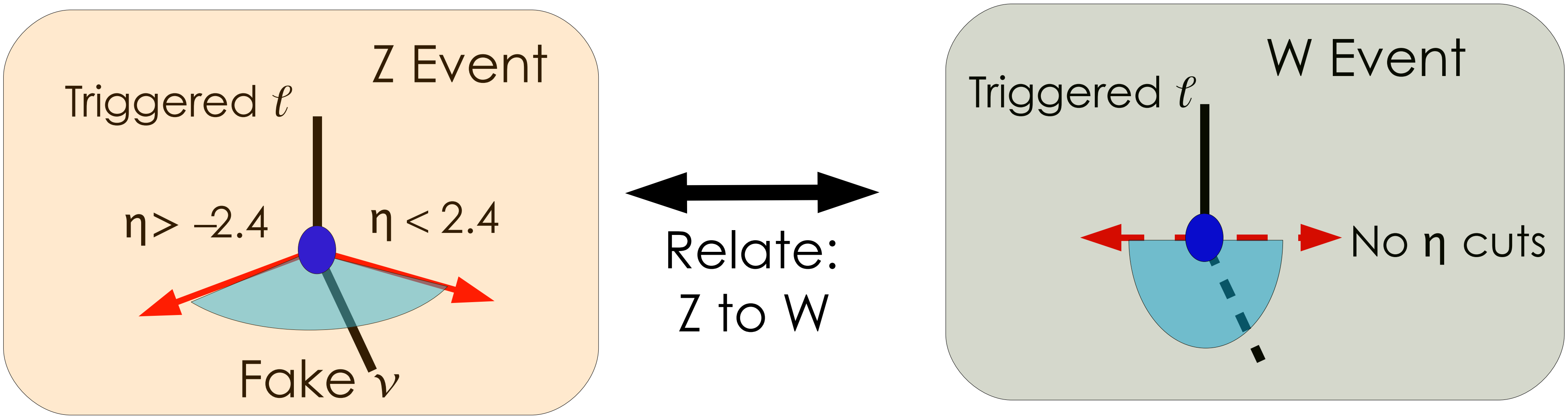
e : QCD *MET* shape from inverse- isolation

Systematic uncertainty < 1%



e&μ: W m_T shape from Z *MET* + W MC

Measuring Missing E_T **with Data**



- Use Z event to model *MET*
  - Triggered $\ell = \ell_W$ Other $\ell = \nu_W$: calculate total *MET*
  - Scale kinematics to W mass as oppose to Z mass
  - Not totally correct: 2nd lepton in Z has different □ range
  - Need monte carlo: monte carlo will need tuning
- Option 2:Use Z to get *MET* resolution apply to W MC
  - With this method *MET* modeled to 0.8%

Calculating Cross Section

$\sqrt{S}$ = 10 TeV $\mathscr{L}$=10pb^{-1}

Measurement	W⇨lν	W⇨τν	Z⇨ℓℓ	tt	QCD
10 TeV □ Events	47544	805	2415	359	3236
14 TeV e Events	26107	166	133	189	1861

$\sigma_W = N_W / a$□$\mathscr{L}$

N_W= Number of W events

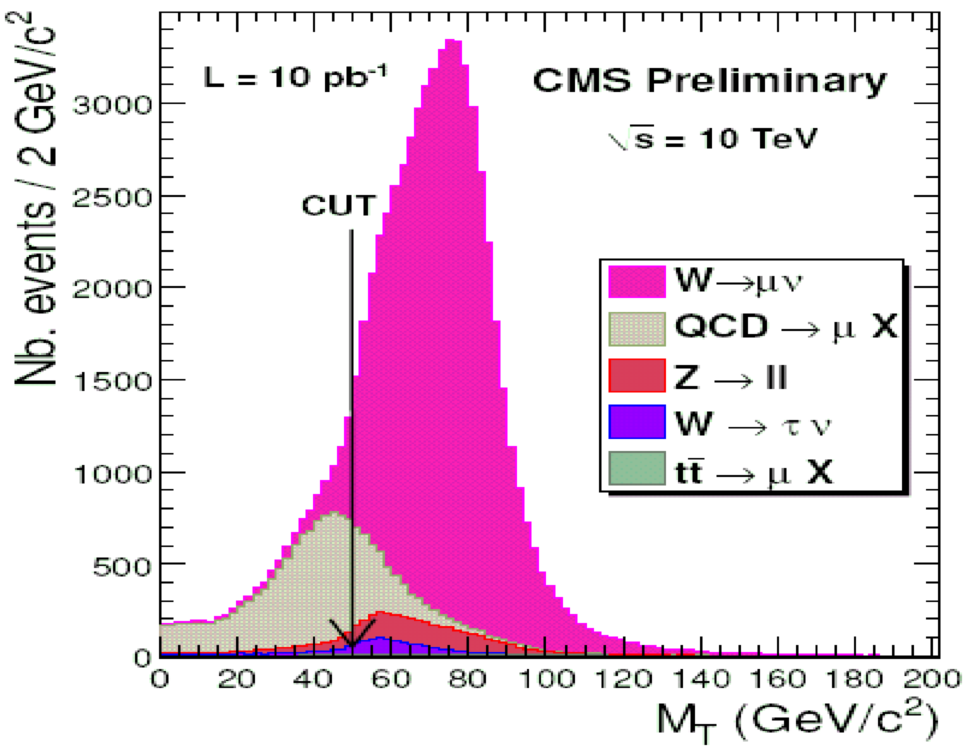
a = Acceptance factor

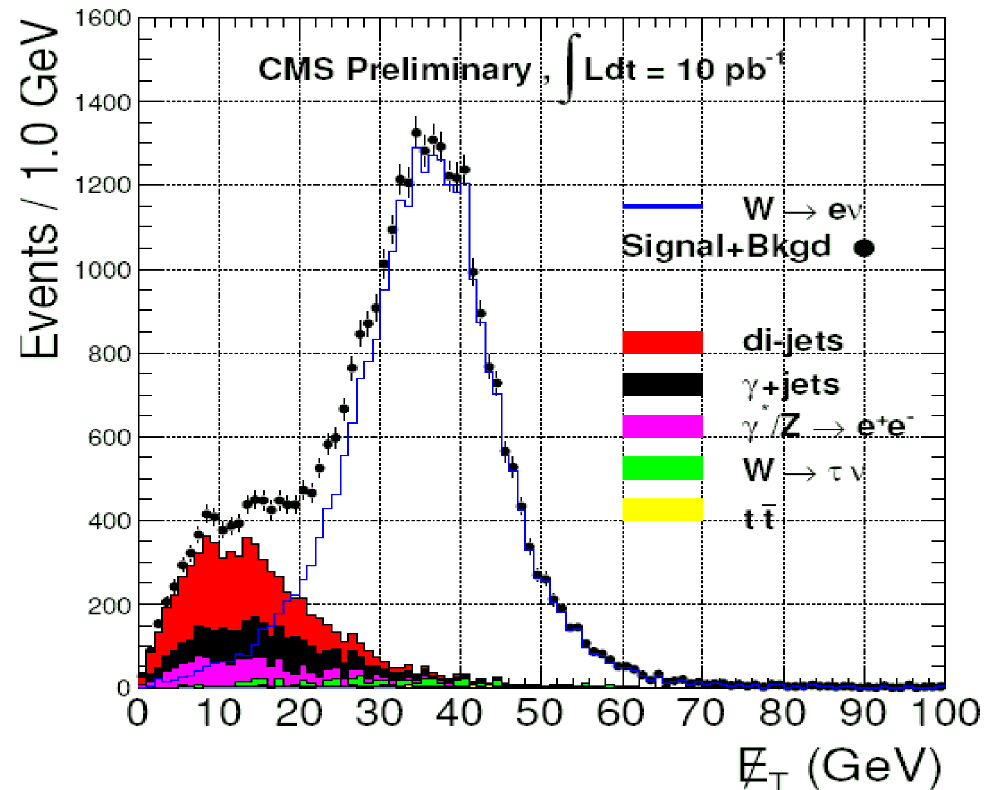
= W efficiency

$\mathscr{L}$ = ∫dt Beam luminosity

$\sigma_{W□lv}$=11.85 pb

$N_W = N - N_{QCD} - N_{Z\ell\ell} - N_{W□} - N_{tt}$





Cross Section Systematics

Particle	Electron	Muon
QCD Description using Data	5.0%	1.0%
Additional Backgrounds using MC	1.0%	1.0%
Acceptance factor from tuned MC	2.6%	2.6%
Efficiency with Tag and Probe	>0.5%	2.7%
Luminosity Error	10%	10%

Systematics are the largest source of error

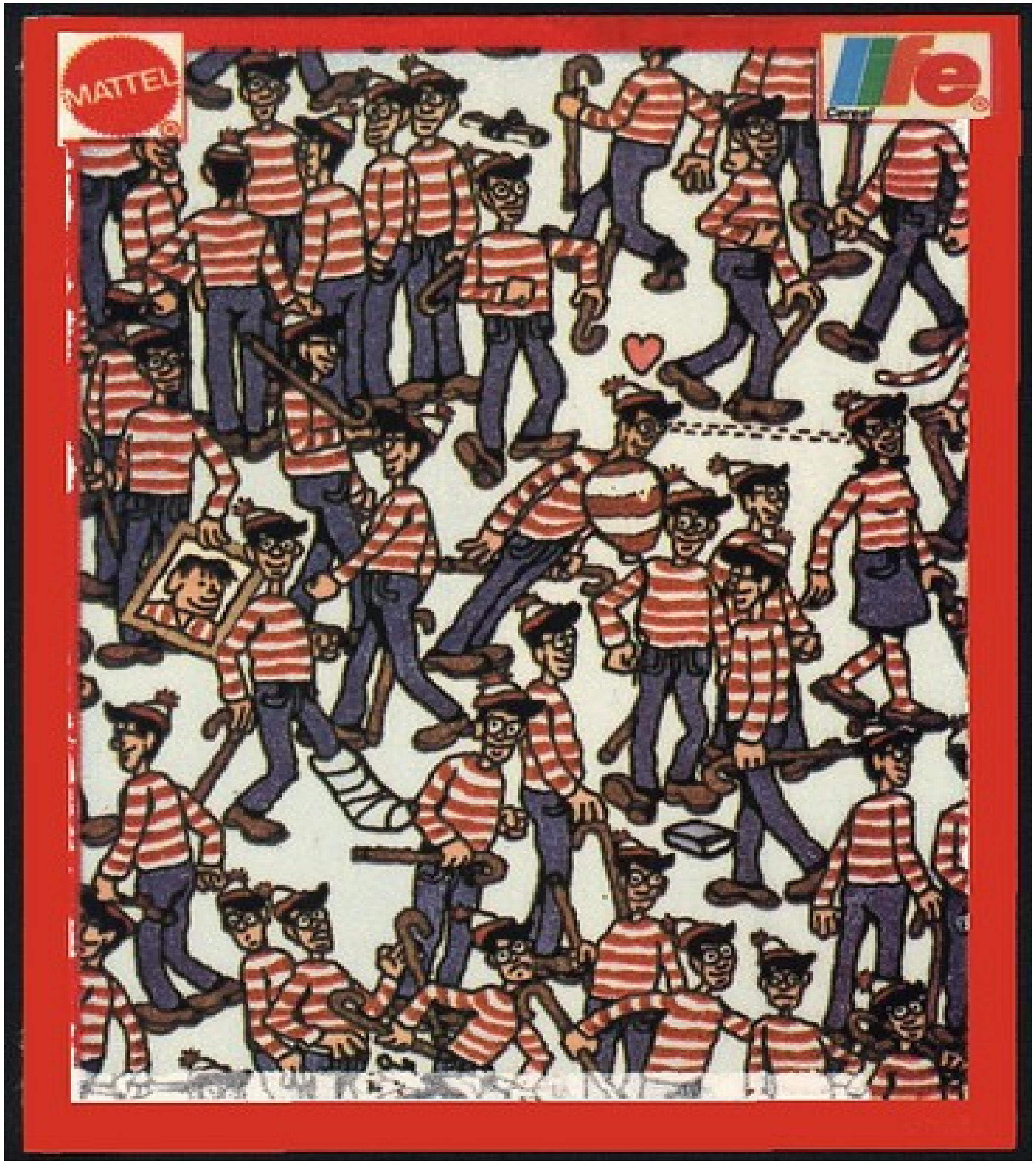
Overall systematic dominated by Luminosity

Summary

- **Presented a method to measure W cross section**
  - Used 10pb^{-1} of integrated luminosity at $\sqrt{S}$=10TeV
  - Statistical error less than 1%
  - Luminosity systematic of 10% is dominant error
  - Other systematics are larger than statistical error
    - **Analysis can be improved**
  - Data driven methods defined for QCD
  - Good lepton id determination
  - Lepton efficiencies measurement demonstrated

- **W cross section measurement is a stepping stone**
  - Same techniques are used for for a W' search
    - Already we can put new bounds at 10pb^{-1}
  - Higgs/SUSY/New Physics measurements

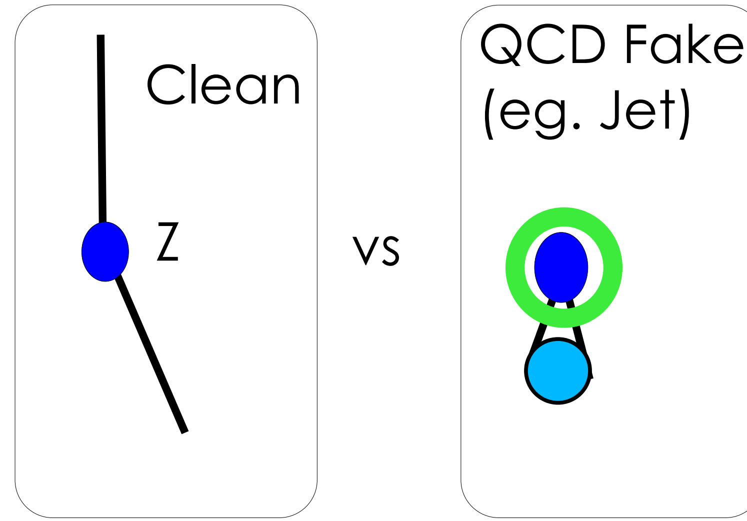
The End



References

- [1] W/Z muon cross section CMS PAS EWK-07-002
- [2] W/Z electron cross section CMS PAS EWK-08-005
- [3] Electron Efficiencies in CMS CMS PAS EGM 07-001
- [4] W Charge Asymmetry CMS PAS EWK-08-002
- [5] Theoretical Uncertainties in W CS at LHC hep-ph/0808.0758v2
- [6] Calibration of Energy loss with J/ψ CDF/DOC/BOTTOM/CDFR 5958
- [7] Electroweak muon at 10 TeV CMS PAS EWK-09-001
- [8] W prime production CMS PAS EXO-08-004
- [9]CMS Data Acquisition & HLT,TDR,CERN/LHCC 2002-26.
- [10] Where's Waldo? Martin Handford 9/1987 ISBN#0316342939

Tuning Lepton Selection



- Obtain clean lepton sample
  - Two good leptons in Z mass
- Obtain fake lepton QCD sample
- Vary a cut (*ie* isolation):
  - Optimize Z eff vs QCD eff
- **Isolation variable is the the most useful in selection**

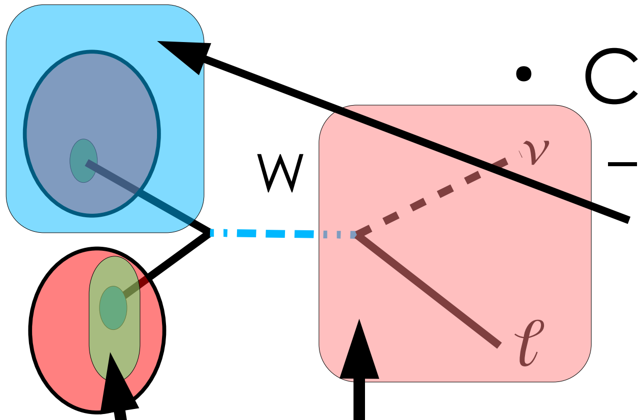
Muons:

$$\sum_{Tracks\ \Delta R<0.3} \frac{p_T}{p_T^{\mu}} < 0.09$$

Electrons use *track*, ecal and hcal:

$$\sum_{Tracks\ 0.02<\Delta R<0.6} \left(\frac{p_T}{p_T^{e}}\right)^2 < 0.02 \quad \sum_{Ecal\ \Delta R<0.3} \left(\frac{p_T}{p_T^{e}}\right) < 0.02 \quad \sum_{Hcal\ 0.15<\Delta R<0.3} \left(\frac{p_T}{p_T^{e}}\right) < 0.1$$

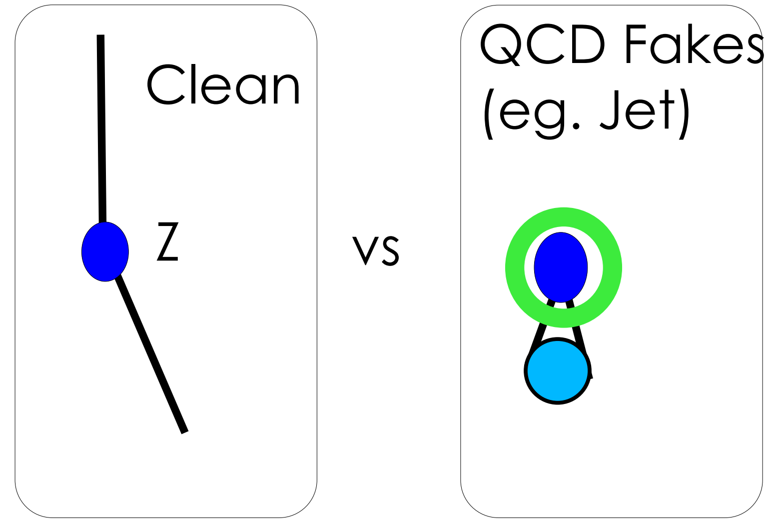
Acceptance factor

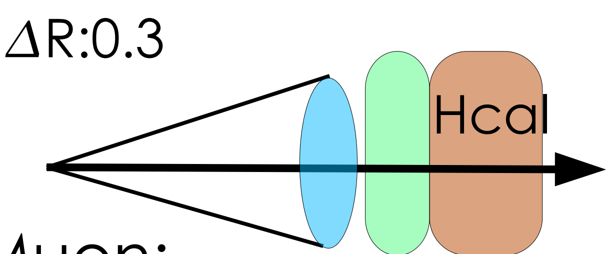


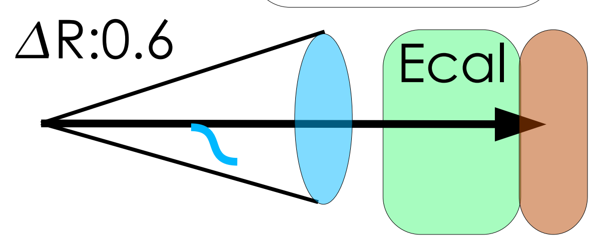
- Calculated with Monte Carlo
  - Monte Carlo PDFs to be tuned on data
    - PDF re-weighting(Hessian error method)
    - Overall Expected 2.2-2.3% uncertainty on PDFs
  - Electroweak corrections in cross section calculation
    - Calculations missing complete order α Corrections
    - Acceptance factor described to < 0.5% (HORACE vs. PHOTOS)
  - QCD corrections to cross section
    - Uncertainty in acceptance between NLO and NNLO to be 1.3%
  - Overall acceptance uncertainty found to be 2.6%
- Tuning of the Monte Carlo to data is crucial
    - Understanding the W p_T and □distributions will be first challenge

Tuning Lepton Selection

- Obtain clean lepton sample
  - Two good leptons in Z mass
- Obtain very dirty QCD sample
- Vary a cut (*ie* isolation):
  - Calculate Z eff vs QCD eff Optimize







Muon:

Track Isolation:

$$\sum_{Tracks\,\Delta R<0.3} \frac{p_T}{p_T^{\mu}} < 0.09$$

~~$\phi-\phi_{ET} > 1$~~

Electron:

Barrel(Endcap)

Track Isolation: $\sum_{Tracks\,0.02<\Delta R<0.6} \left(\frac{p_T}{p_T^{e}}\right)^2 < 0.02$

Hcal/Ecal deposit $H/E < 0.115(0.15)$

Track to Ecal match $\Delta\phi,\Delta\eta < 0.09(0.092,0.105$

Ecal deposit η width $\sigma_{\eta\eta} < 0.0140(0.0275)$