Diboson Production at the Tevatron

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- Tevatron run 2 and the CDF upgrade
- Diboson production at CDF
- NLO Diboson MC programs
- Current measurements and run 2 WW event selection

Tevatron run 2

- Tevatron is a $p\bar{p}$ collider.

- Higher Centre of mass energy: $\sqrt{s} = 1.96 TeV$

- Increased luminosity in run 2:

$$1 \times 10^{31} (run1) \rightarrow 5 \times 10^{31} (2a) \rightarrow 2 \times 10^{32} cm^{-2} s^{-1} (2b)$$

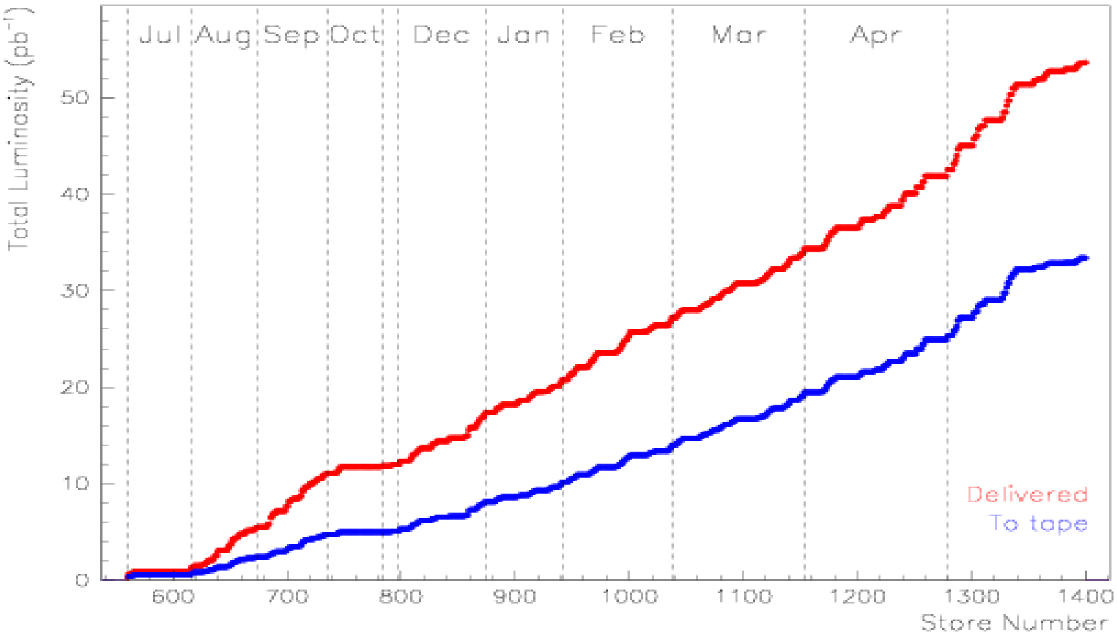
- More bunches: 6×6(run 1) 36×36(run 2a) 140×121(run2b)

reduce # of interactions/bunch crossing

bunch separation run 2a = 396ns, run 2b = 132ns.

Current status:

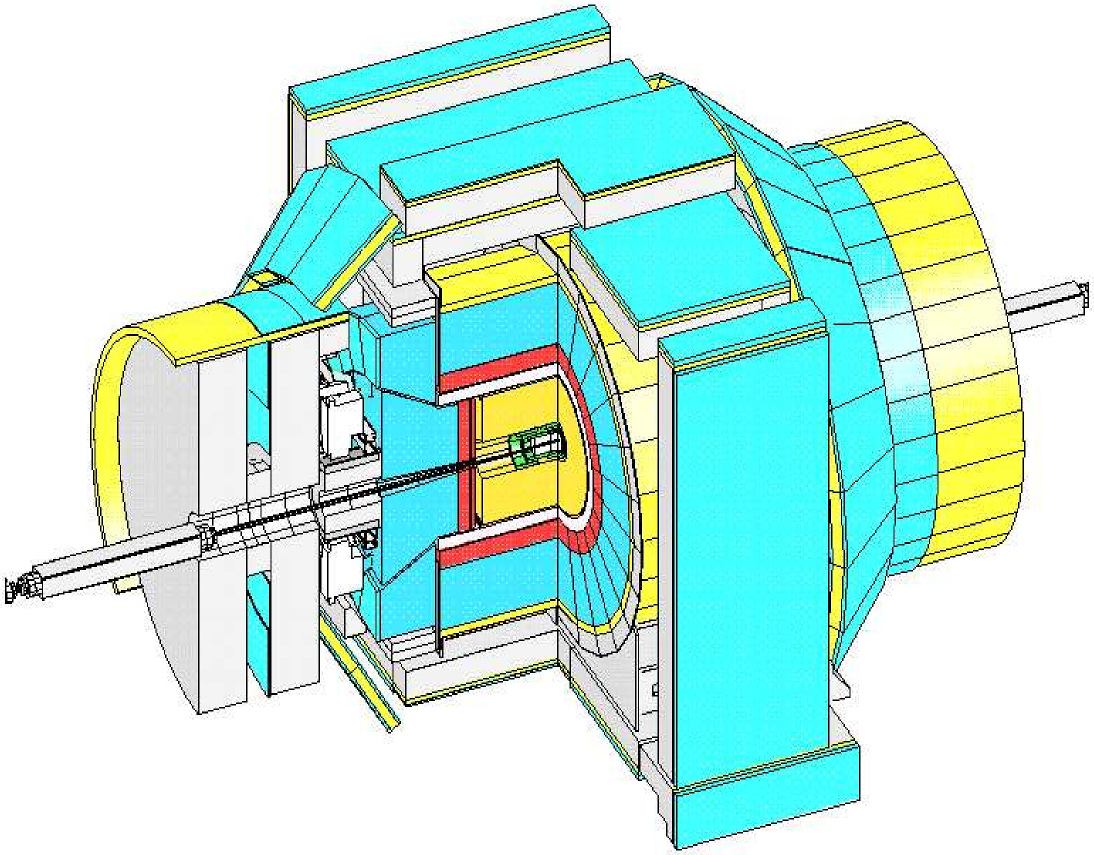
- highest Lum $=2 \times 10^{31} cm^{-2} s^{-1}$
- Need reclcyer before $5 \times 10^{31} cm^{-2} s^{-1}$
- Data so far:



The CDF upgrade

- Driven by luminosity & bunch structure.

- Improved tracking, increased kinematic coverage and improved tagging of secondary vertices.



The CDF upgrade

- Tracking: Entire tracking volume replaced.

1. Silicon: layer00(impact param), SVX2(secondary vertices) and ISL(pt resolution & b-tagging)

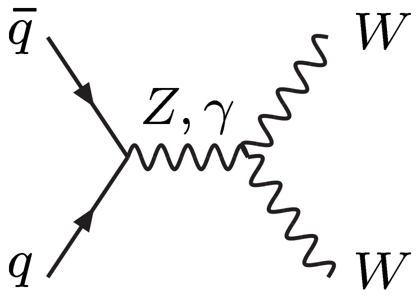
2. Central Outer Tracker(COT): 6 times more wires, drift time 132ns(avoid occupancy problems)

- Muon: fill gaps & $|\eta| < 1$

- Trigger and DAQ: 2 hardware, 1 processor farm.

Diboson Production at CDF

- Measure WW cross-section, look for anomalous couplings.



- Limit search to C and P conserving and EM gauge invariant couplings: $\kappa_\gamma, \kappa_z, \lambda_\gamma, \lambda_z$ and g_1^z

- In the SM: $\lambda_\gamma = \lambda_z = 0$ and $\kappa_\gamma = \kappa_z = g_1^z = 1$

- usual notation $\Delta\kappa_\gamma = \kappa_\gamma - 1 = 0$ likewise for κ_z,g_1^z

- Test the SM prediction

- Major background to $H \to WW$

NLO Diboson Monte Carlo programs

- anomalous coupling enhances x-sec at high W pt, $O(\alpha_s)$ corrections largest at high W pt

Campbell & Ellis (MCFM)

- unified description of all processes with heavy q, leptons and missing Et at @NLO accuracy.

- only program with all processes of interest.

$p\bar{p} \to W/Z, W+Z, WW, ZZ, W/Z+H, H, W+g(\to b\bar{b})$

$p\bar{p} \to W+2jets, W/Z+1jet, Z/\gamma+b\bar{b}, Z/\gamma+2jets$

- needs Validation; compare to Baur et al(BHO)

- BHO: $WW \to e\nu e\nu$ at NLO; used in run 1

MCFM vs BHO

- compare BHO to MCFM by generating large number of *weighted* events with each program , until errors ~1% and comparing:

1. SM cross-section predictions

2. kinematic distributions

3. cross-section as a function of anomalous couplings.

- Expect to be a parabola since total amplitude given by:

$$[M(sm)+M(anom)]^2 = M(SM)^2+M(anom)^2+interference$$

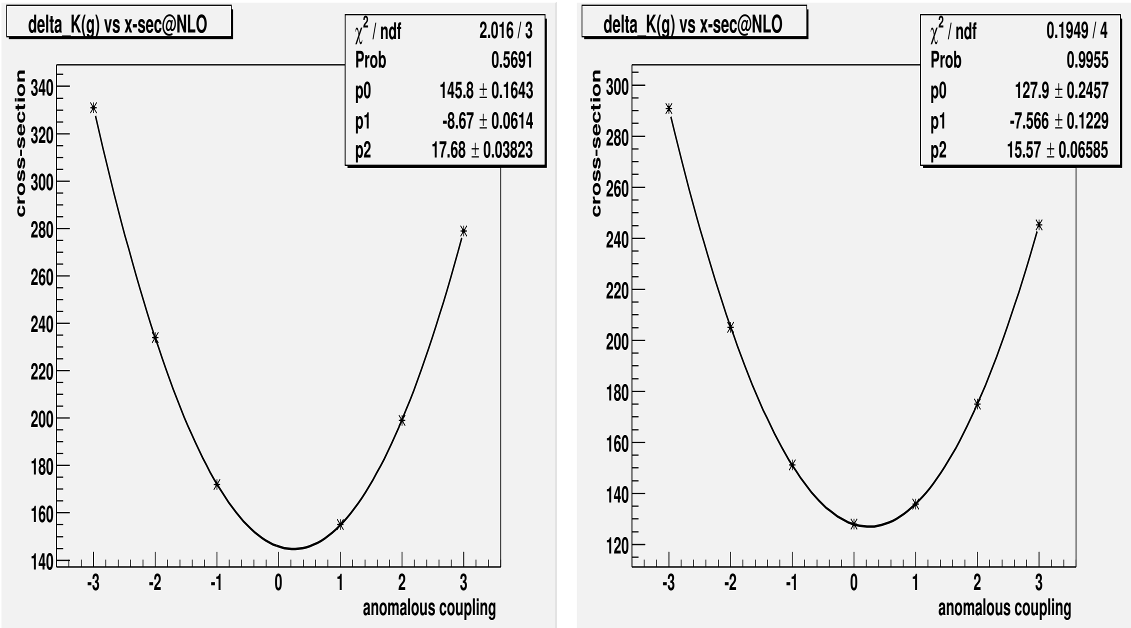
Results: SM cross-sections:

Program	NLO SM x-sec	LO SM x-sec
MCFM	$146.7 \pm 0.2pb^{-1}$	$108.2 \pm 0.3pb^{-1}$
BHO	$127.1 \pm 0.9pb^{-1}$	$97.2 \pm 0.8pb^{-1}$

why different? Due to different scales. MCFM sets the QCD scale to be M_w and BHO sets the QCD scale to be $\widehat{s}$.

Results:Cross-section vs $\Delta\kappa_\gamma$

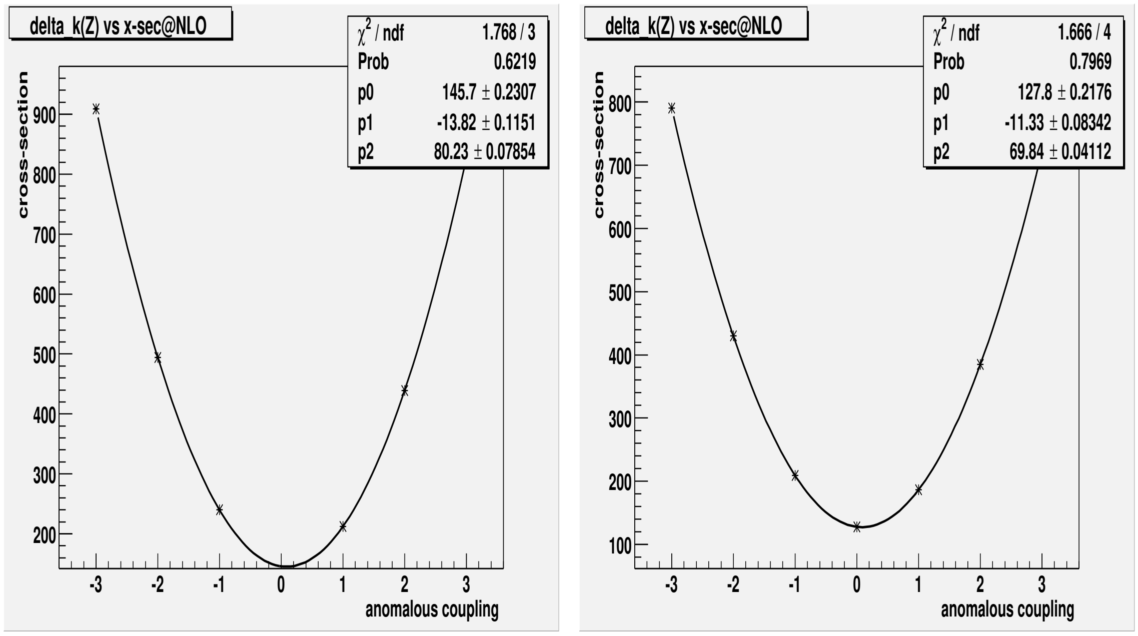
- MCFM(left) and BHO(right)



- minimum in approx same place(0.3)

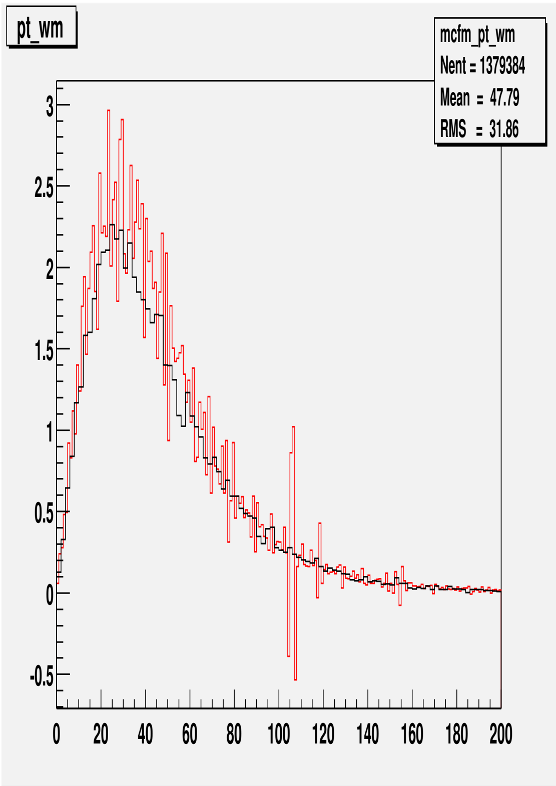
Results: Cross-section vs $\Delta\kappa_z$

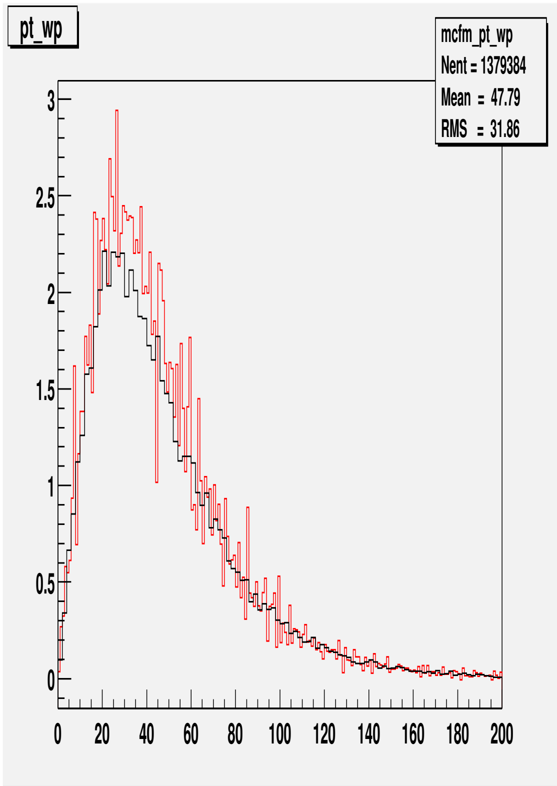
- MCFM(left) and BHO(right)



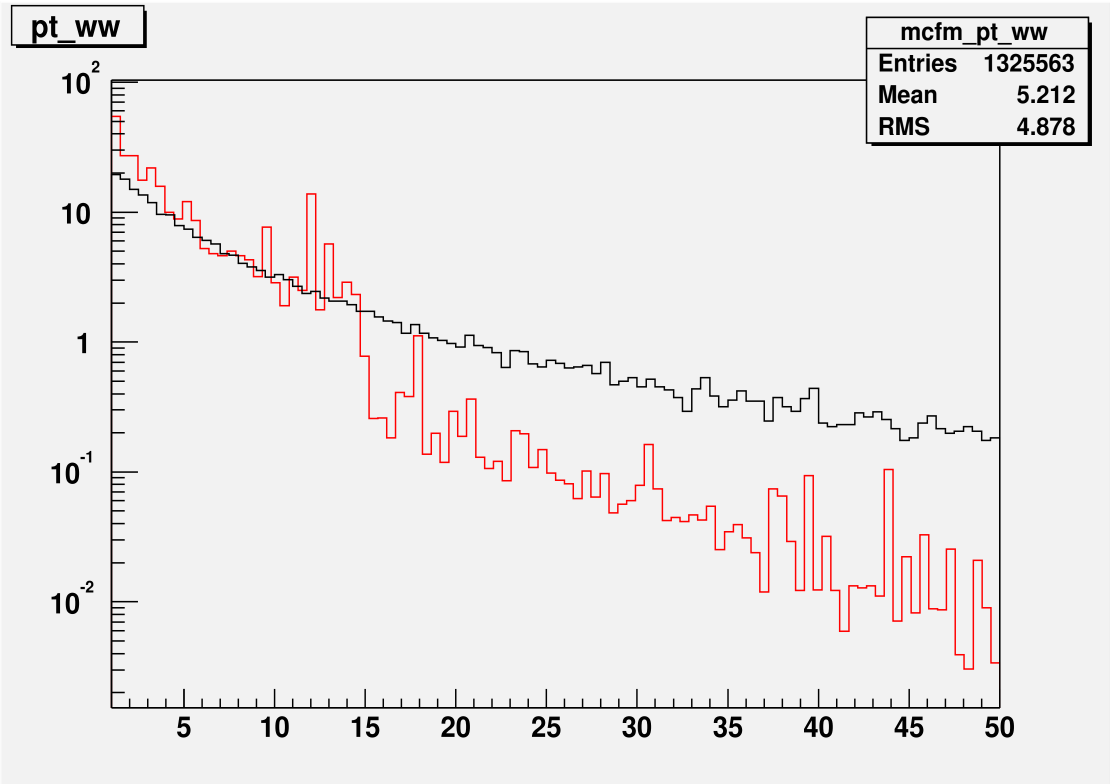
- σ_{ww} more sensitive to $\Delta\kappa_z$ than $\Delta\kappa_\gamma$ because Z coupling to q and $W^\pm$larger than γ coupling.

Results: Pt(GeV) of $W^+$and W^-normalised to cross-section. (MCFM=red,BHO=black)

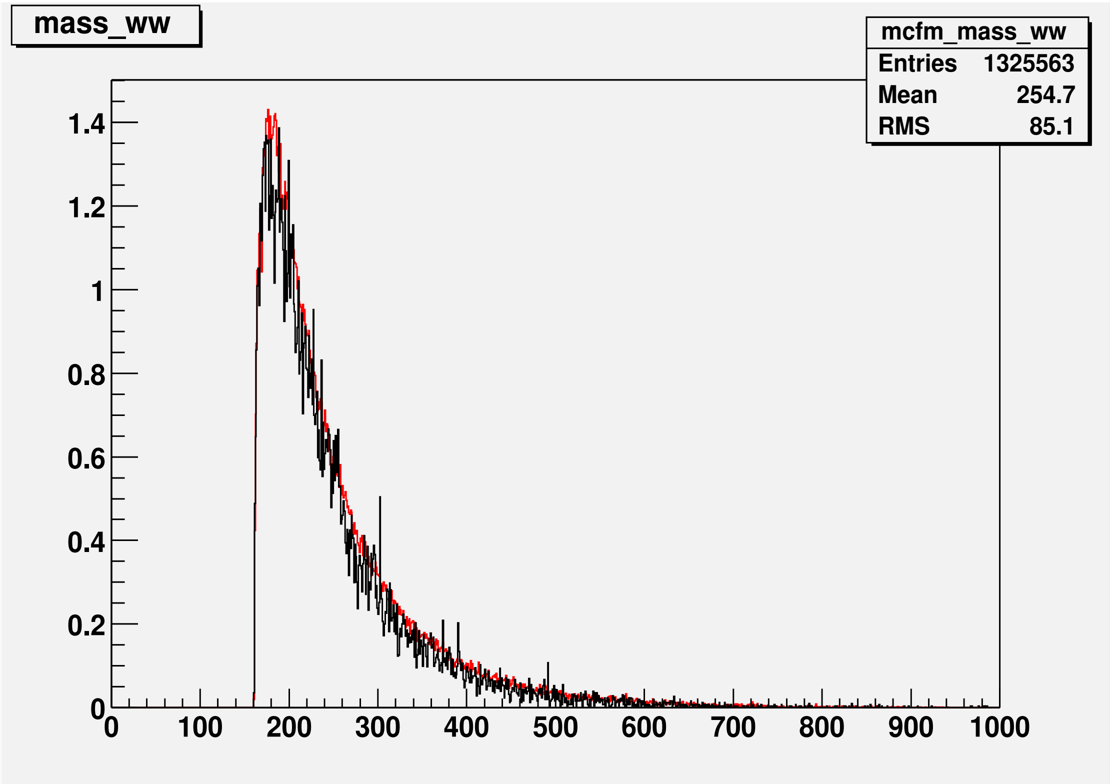




Results:Pt(GeV) of WW pair normalised to cross-section.
MCFM=red, BHO=black.



Results: Mass of WW pair(GeV) normalised to the cross-section. MCFM=red BHO=black.



Run 1 results.

- Run 1 cross-section results

Mode	L	data	Bkgd	σ^{dibos}_{meas}	σ^{dibos}_{theor}
$(l = e, \mu)$	(pb^{-1})	(evnt)	(evnt)	(pb)	(pb)
$W\gamma \to l\nu\gamma$	67	109	26.4 ± 3.6	20.7 ± 3.0	18.6
$WW \to l\nu l\nu$	110	5	1.21 ± 0.3	$10.2^{+6.5}_{-5.3}$	9.5
$WZ \to l\nu ll$	110	1	$0.3^{+0.8}_{-0.3}$	$3.2^{+5.0}_{-3.2}$	2.5
$Z\gamma \to ll\gamma$	67	31	1.4 ± 0.4	5.7 ± 1.4	4.8
$ZZ \to llll$	120	1	?	?	1.0

Run 1 anomalous coupling limits at 95%CL

- using $W\gamma$ and $Z\gamma$ events:

$-1.8 < \Delta\kappa_\gamma < +2.0$
$-0.7 < \lambda_\gamma < +0.6$

- using WW events and assumptions: $\Delta\kappa_\gamma = \Delta\kappa_z$,$\lambda_\gamma = \lambda_z$,$g_1^z = 0$

$-0.7 < \Delta\kappa_z < +0.9$
$-0.5 < \lambda_z < +0.5$

LEP2(ALEPH Jan 2001) limits at 95%CL:

- Assume SU(2)$\times$U(1).

- Gives constraints: $\Delta\kappa_z = -\Delta\kappa_\gamma tan^2\theta_w + \Delta g_1^z$ and $\lambda_z = \lambda_\gamma$

$-0.087 < \Delta g_1^z < +0.141$
$-0.200 < \Delta\kappa_\gamma < +0.258$
$-0.062 < \lambda_\gamma < +0.147$

Run 2 expectations:

- $p\bar{p} \to WW$ SM cross-section = $10.1 pb^{-1}$

- based on run 1 analysis, using simple luminosity scaling, expected limits:

- ± 0.3 on $|\Delta\kappa_v|$ and ± 0.1 on $|\lambda_v|$

- expected event yields of 1500 $W\gamma$, 450 $Z\gamma$ and 100 $WW \to l\nu l\nu$

Run 2 measurement of $WW \to e\nu jj$

- Branching ratio much higher than $WW \to l\nu l\nu$

- Larger backgrounds

- strategy: find electron, find leptonic W decay, look for jets consistent with hadronic W decay.

- Electron reconstruction:

EM transverse energy

Track Pt

matching shower-max cluster position

HAD/EM

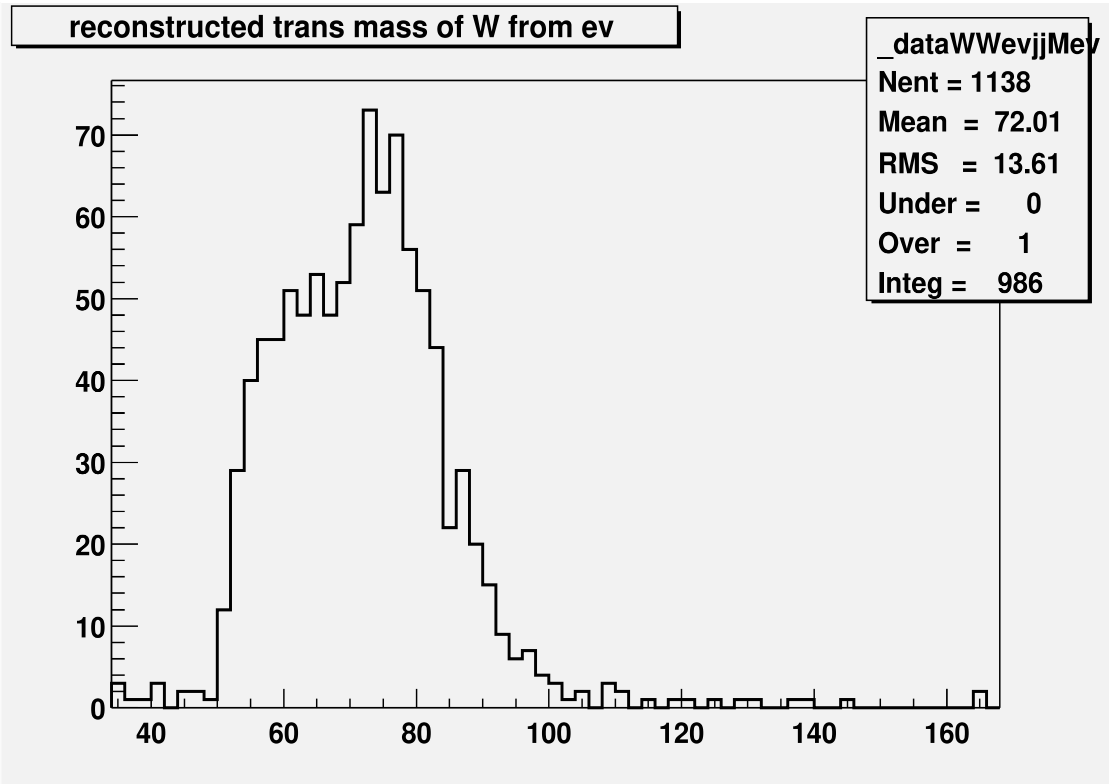
Isolation

no of hits in COT

- efficiency = $86.3\% \pm 3.4\%(stat)$

- Now look for the leptonic W decay.

- Require one good electron plus Missing Et>25GeV.



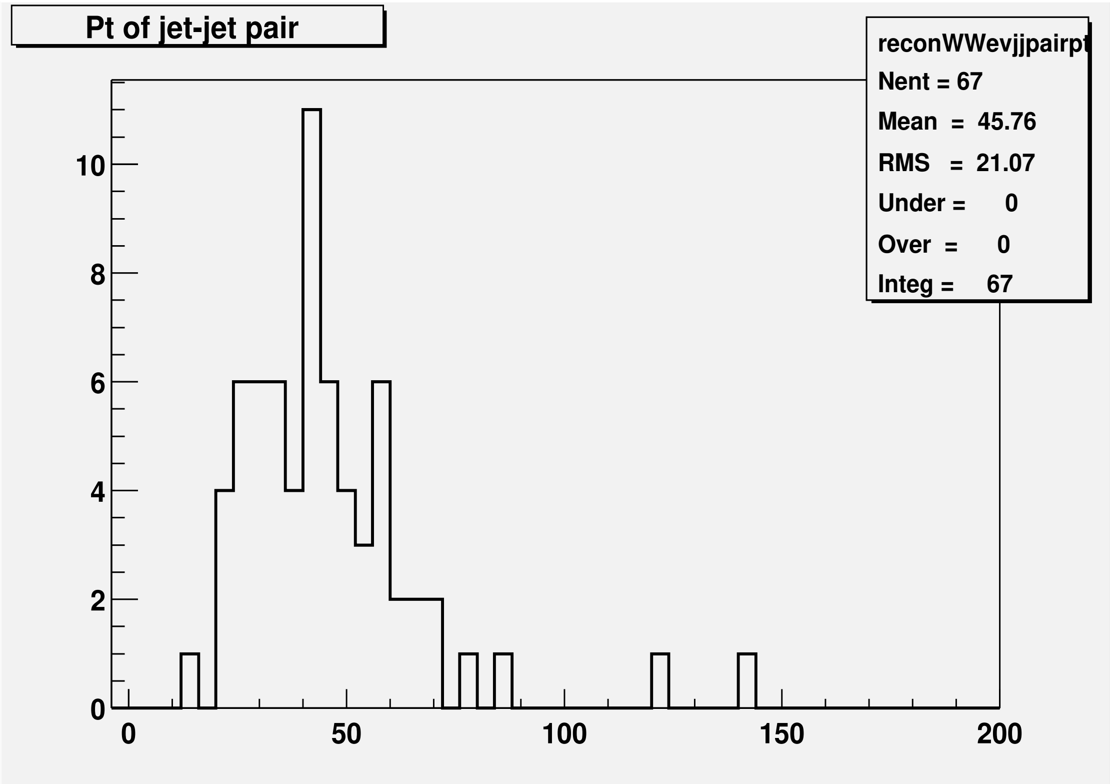
- CDF reports approx 92% efficient relative to electron efficiency (bkgd=QCD,$W \to \tau\nu$ $Z \to ee$).

- $WW \to e\nu jj$ selection

- one leptonic W decay & 2 jets Et > 30GeV

- $60GeV < M_{jj} < 110GeV$

- To suppress the bkgd in run 1: Pt(jj)>XGeV



conclusions

- shown status of CDF and Tevatron
- Discussed comparison of diboson MC programs
- outlined preliminary investigations into WW cross-section measurement.
- next steps: comfirm cause of descrepency of mcfm and bho. Compare with pythia.
- optimise Pt(jj) cut: need run 2 background sample
- can we do better? neural networks etc?