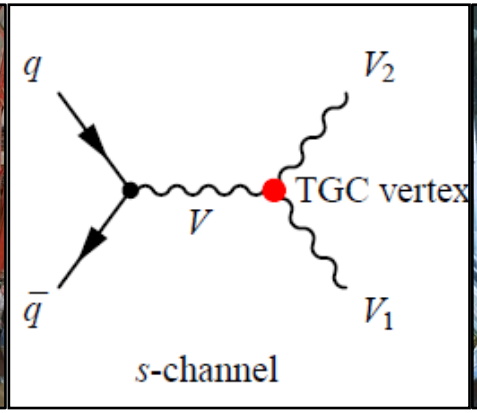
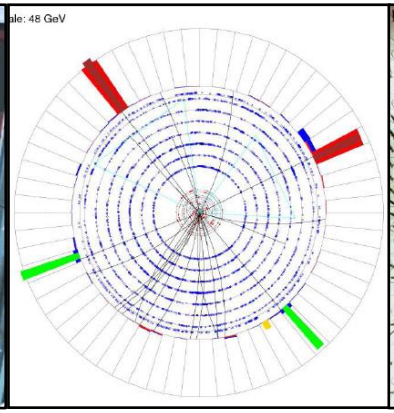
DI-BOSON PHYSICS AT DØ

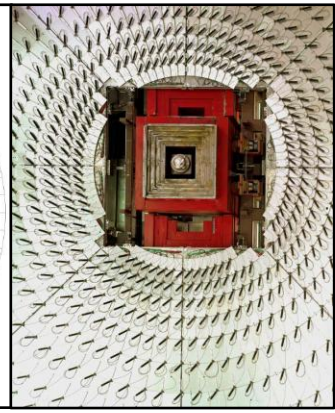
URSULA BASSLER

ON BEHALF OF THE DØ COLLABORATION

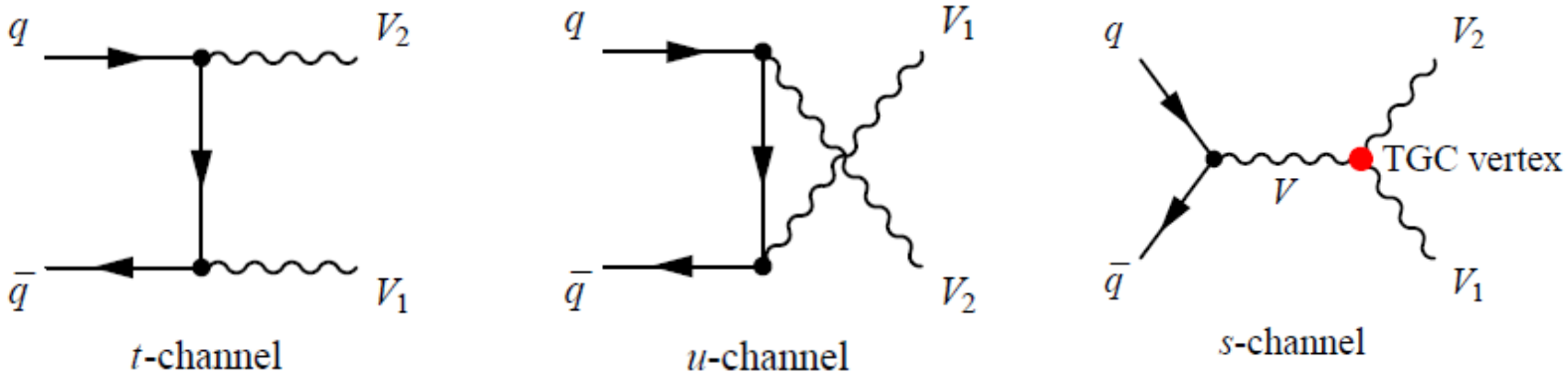
IRFU/SPP CEA-SACLAY







Di-boson Production



s-channel sensitive to Triple Gauge Couplings:

Charged TGC

$$q\bar{q}' \to W^* \to W\gamma : WW\gamma$$
$$q\bar{q}' \to W^* \to WZ : WWZ$$

Charged final states only possible at hadron colliders!

$$q\bar{q} \to Z/\gamma^* \to WW : WW\gamma, WWZ$$

Neutral TGC

$$q\bar{q} \to Z/\gamma^* \to Z\gamma : Z\gamma\gamma, ZZ\gamma$$
$$q\bar{q} \to Z/\gamma^* \to ZZ : Zz\gamma, ZZZ$$

absent in SM!

Motivation For Di-boson Physics

Test of Standard Model :

• SM provides precise prediction of Di-boson production cross-sections

➔ WW and ZZ production measured in e^+e^- collisions at LEP

Search for New Physics :

• Enhancement of triple gauge coupling (TGCs)

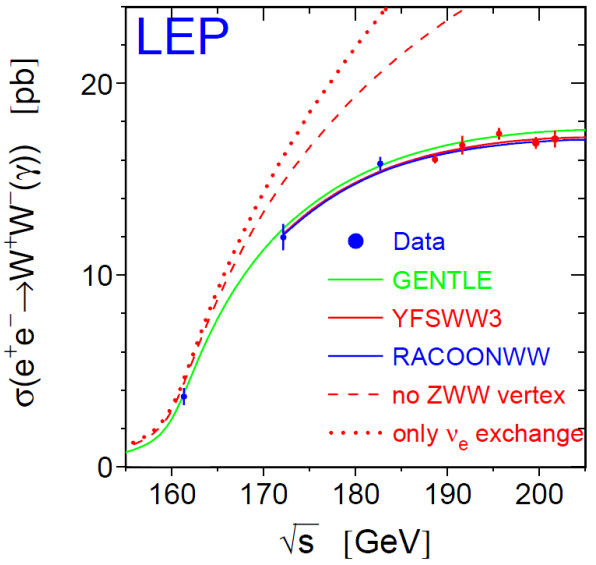
• Resonances decaying to pairs of bosons

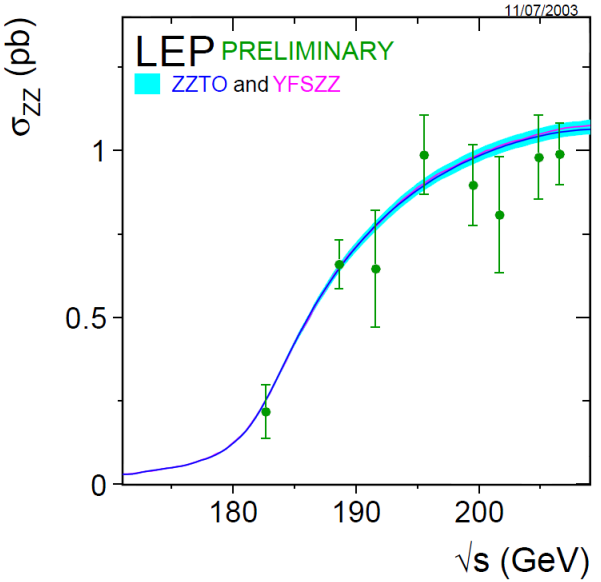
Higgs Hunting :

• Higgs decays in Di-boson final states:

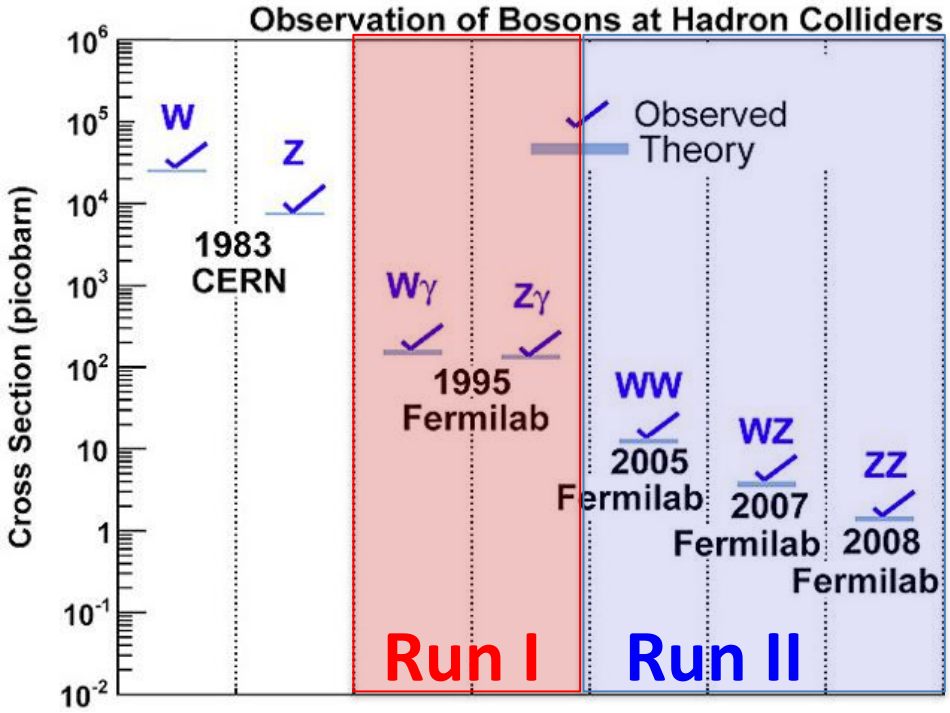
$H \rightarrow WW$ / $H \rightarrow ZZ$

• Associated production WH/WZ with same final states





Di-boson Physics at the Tevatron



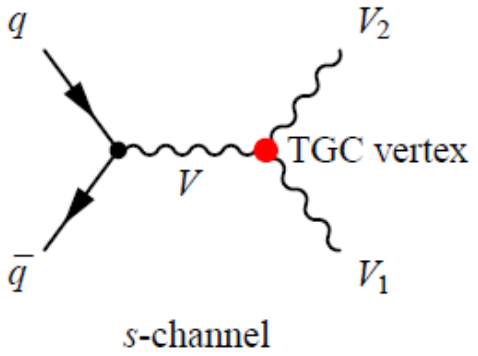
# of events $10fb^{-1}$ at the TeVatron	Process with l=e or μ
50 000 000	W → lν
5 000 000	Z→ ll
320 000	Wγ→ lνγ
80 000	Zγ→ llγ
5 500	WW→ llγγ
500	WZ → lllν
50	ZZ → llll

- **Probe of electroweak sector**
  - cross sections
  - kinematic distributions
  - gauge boson coupling
- **"Validation" of multivariate analysis techniques**

Observation of combined production possible in hadronic channels :
WW+WZ→ lν + 2 jets
WW+WZ+ZZ → 2 jets + mE_T

CHARGED TRIPLE GAUGE COUPLING

$$\frac{\mathcal{L}_{WWV}}{g_{WWV}} = ig_1^V (W^\dagger_{\mu\nu} W^\mu V^\nu - W^\dagger_\mu V_\nu W^{\mu\nu}) + i\kappa_V W^\dagger_\mu W_\nu V^{\mu\nu} + \frac{i\lambda_V}{M_W^2} W^\dagger_{\lambda\mu} W^\mu{}_\nu V^{\nu\lambda}$$



s-channel

V:Z/γ and W: W

C, P, and CP conservation for WWγ and WWZ production leads to:

➔ $g_1^\gamma = 1$: minimal coupling term from em gauge invariance

➔ 5 free parameters : g_1^Z, κ_γ, κ_Z , λ_γ , λ_Z

with: κ_γ: anomalous magnetic momentum of the W

λ_γ : related to the magnetic and electric quatrupole momentum of the W

SM constraints : $\kappa_\gamma = g_1^Z = \kappa_Z = 1$ and $\lambda_\gamma = \lambda_Z = 0$

BSM searches use two reduced parameter sets :

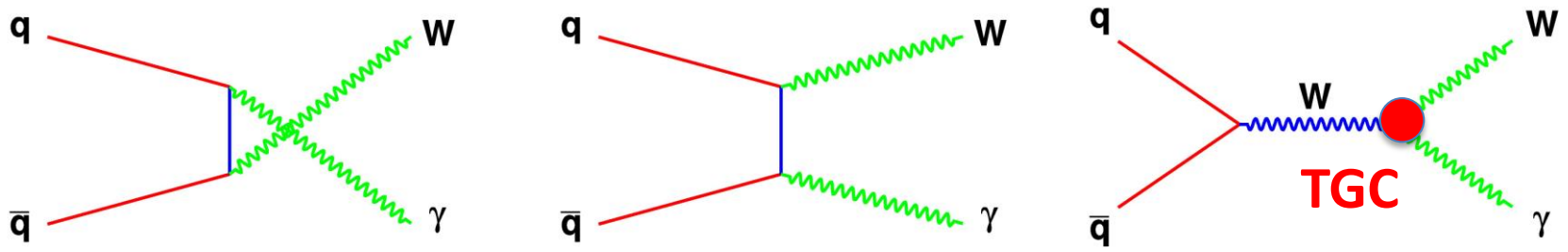
$SU(2)\times U(1) : \Delta\kappa_z = \Delta g_1^Z - \Delta\kappa_\gamma \tan^2\theta_W$ **and** $\lambda_\gamma = \lambda_Z$

Related to tree-level unitarity constraints: 3 parameters

$HISZ : \Delta\kappa_z = \Delta g_1^Z (\cos^2\theta_W - \sin^2\theta_W)$

Equal coupling between SU(2)xU(1) and Higgs fields : 2 parameters

Wγ PRODUCTION



- Sensitivity to BSM signatures: $\rho_T^{\pm}$, $a_T^{\pm}$ → W±γ (Technicolor)
  - General GMSB (Wino-like neutralino)

Study of Wγ → μνγ : smaller effect of Bremsstrahlung than in eνγ

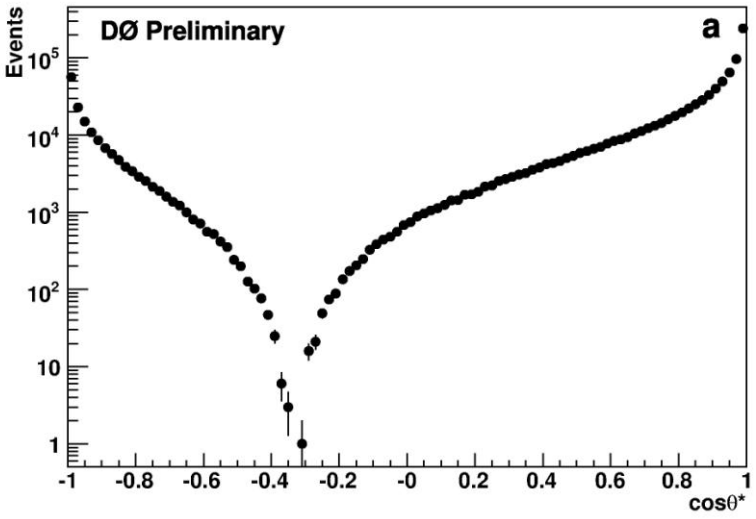
492 events observed in 4.2 fb^{-1}: 375.6 signal events - 134.2 backgrounds (γ mis-id, W+jets)

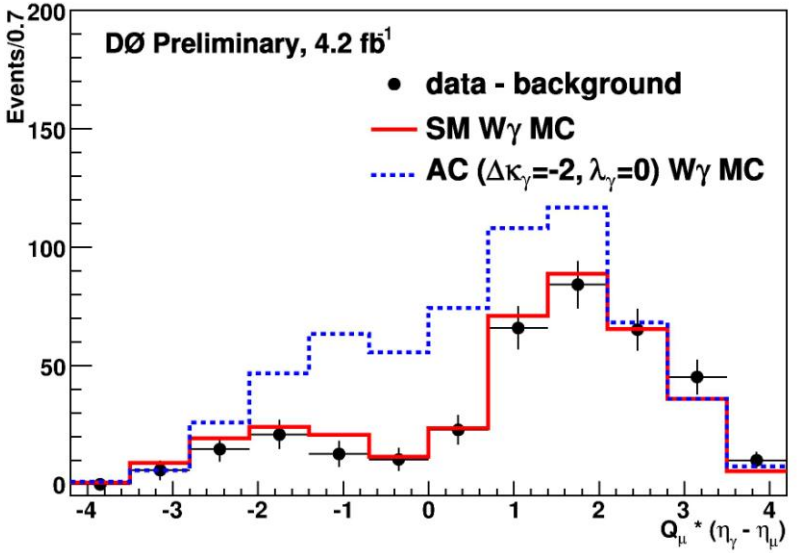
Measurement of the Wγ+X cross-section x branching ratio :

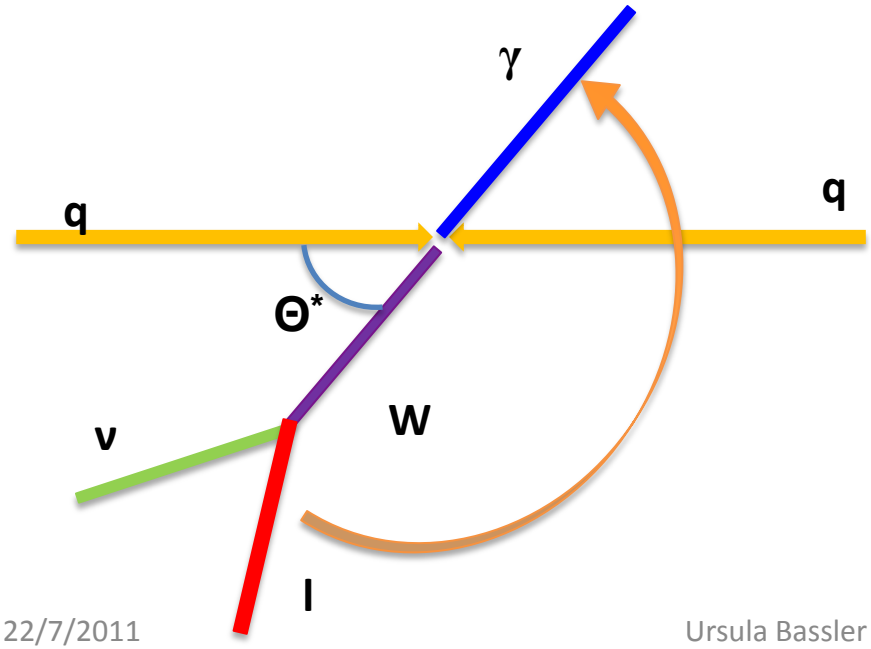
$$\sigma(W\gamma) = 15.2 \pm 0.4(\text{stat}) \pm 1.6(\text{syst})\ \text{pb}$$

SM expectation (CTEQ6L1): 16.0 ± 0.4 pb

Wγ Kinematics







Destructive interference between tree-level diagrams :

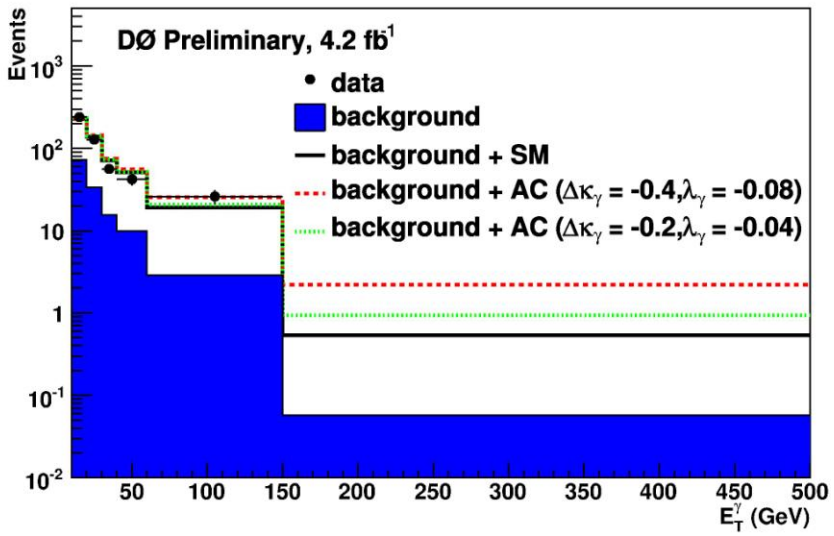
Radiation amplitude zero

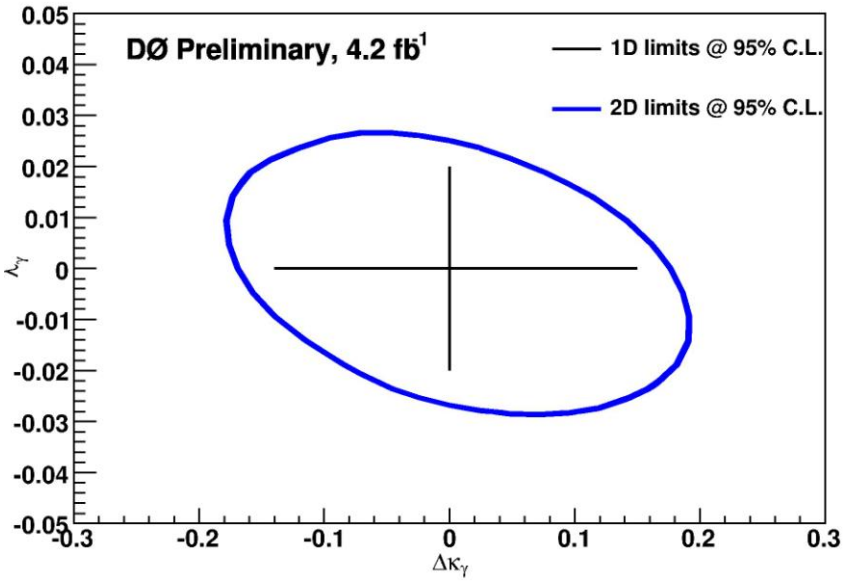
- Dip in sign(l) × | η(γ) – η(l) |

➔Unique test of the SM

WWγ COUPLING

- **Extraction of the TGC parameters from ET(γ) distribution**

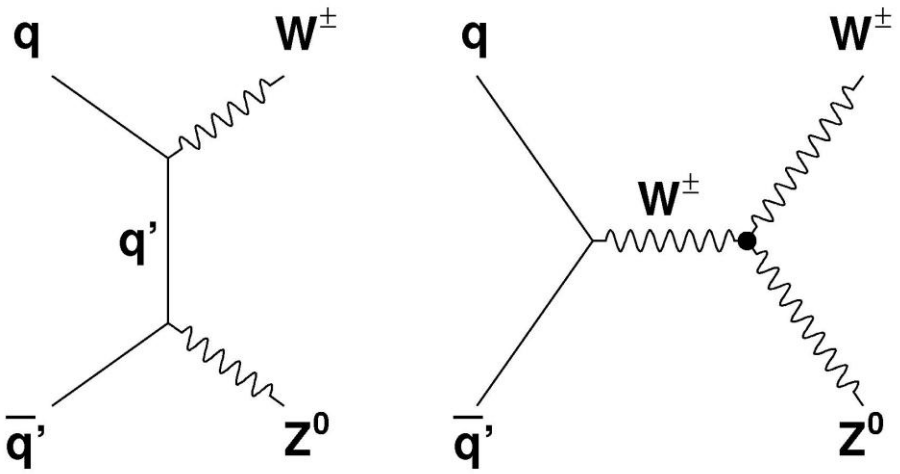




Sensitivity comparable to LEP limits!

68% CL		form factor for unitarity conservation Λ=2TeV
DØ	$-0.07<\Delta\kappa_\gamma<0.07$	$-0.012<\lambda_\gamma<0.011$
LEP 2 combined	$-0.072<\Delta\kappa_\gamma<0.017$	$-0.049<\lambda_\gamma<0.008$

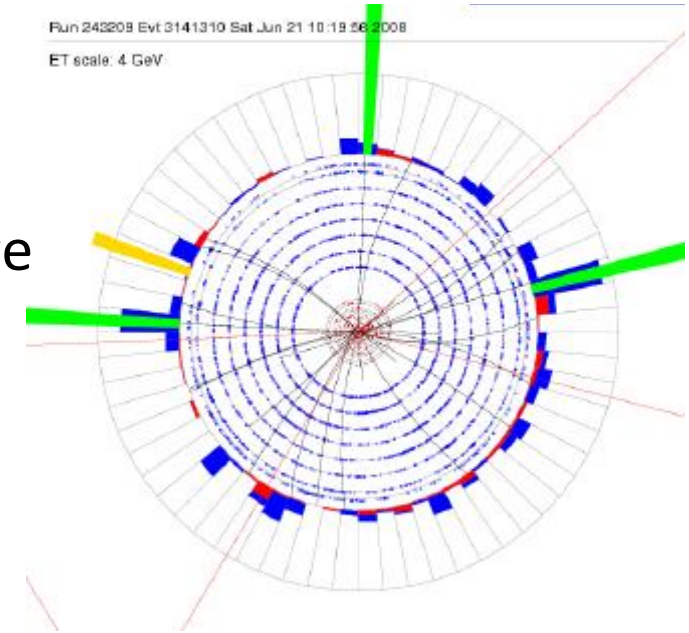
WZ PRODUCTION



Possible BSM production:

- $W^* \rightarrow \tilde{x}_1^{\pm}\tilde{x}_2^0 \rightarrow (W^{\pm}x_1^0)(z^0\tilde{x}_1^0)$ (SUSY)
- $\rho_T^{\pm} \rightarrow W^{\pm}Z$ (Technicolor)

WZ→ μνμμ



Selection based on 3 leptons (e or μ) with E>15GeV and missing ET > 20 GeV:

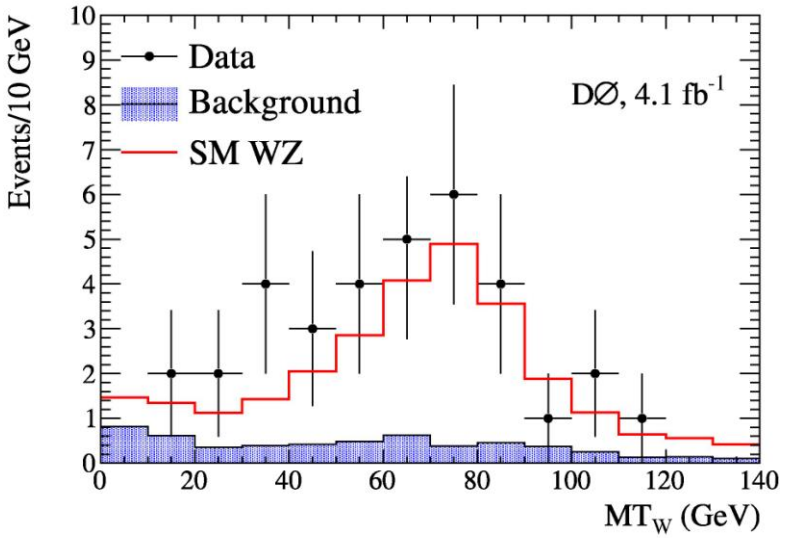
2 leptons of same type with opposite charge from Z-decay, 3rd lepton from W

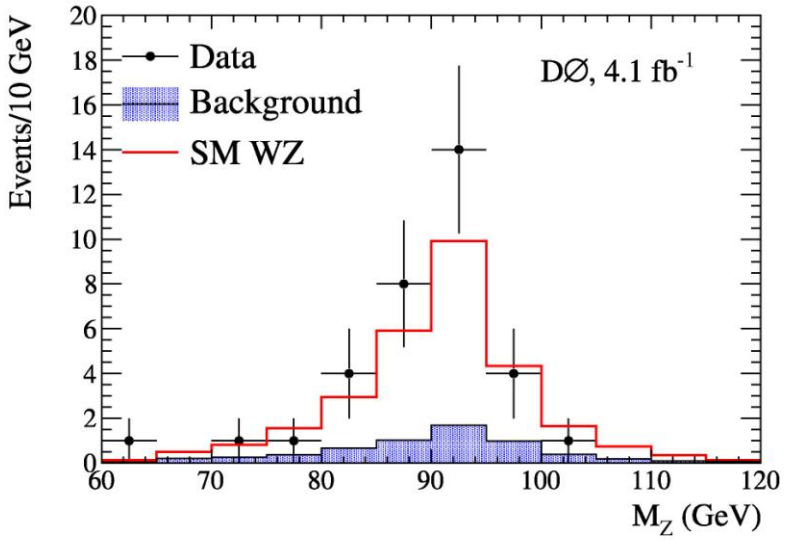
Assignment to Z and W:

➔100% match for eeμ and μμe

➔ ~90% match for eee and μμμ

WZ CROSS-SECTION





34 events observed : 23.3 signal events - 6 backgrounds (mainly W mis-id)

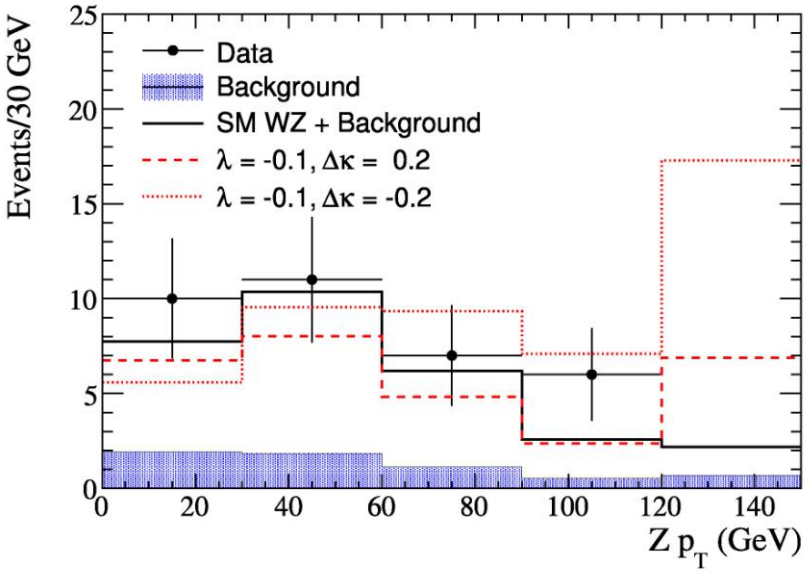
Measurement of the Wγ+X cross-section x branching ratio :

$$\sigma(WZ) = 3.9\ ^{+1.01}_{-0.85}\ (\text{stat+syst})\ \text{pb}$$

SM expectation NLO: 3.25 ± 0.19 pb

WWZ COUPLING

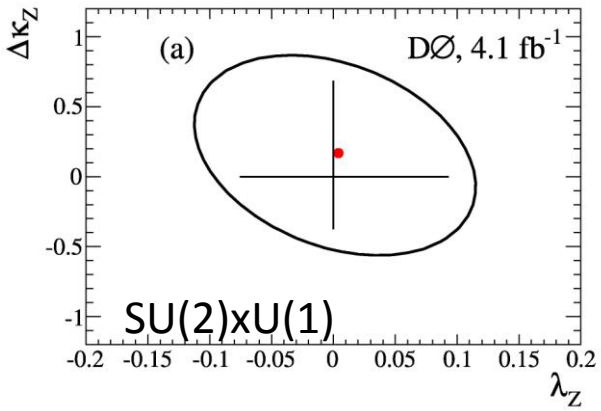
Extract limit on WWZ coupling from DØ Zp_T distribution (Λ=2TeV)

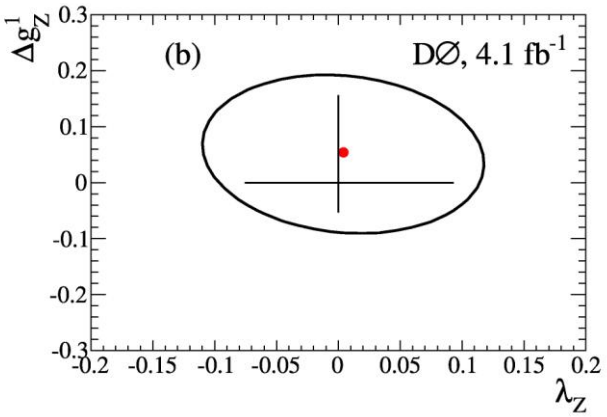


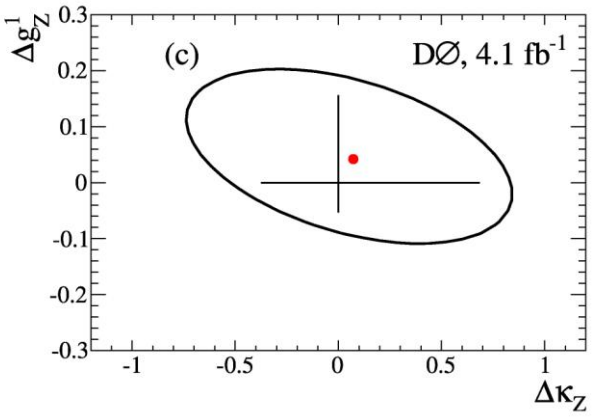
λ_Z	Δg_1^Z	$\Delta\kappa_Z$
-0.075, 0.093	0	0
0	-0.053, 0.156	0
0	0	-0.376, 0.686

HISZ parameterization
$-0.027<\Delta\kappa_Z<0.080$ for $\lambda_Z=0$
$-0.075<\lambda_Z<0.093$ for $\Delta\kappa_Z=0$

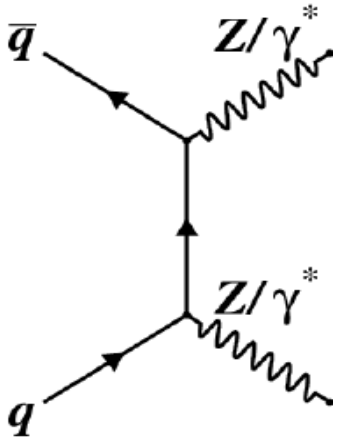
Most stringent limits from direct study of WZ production!







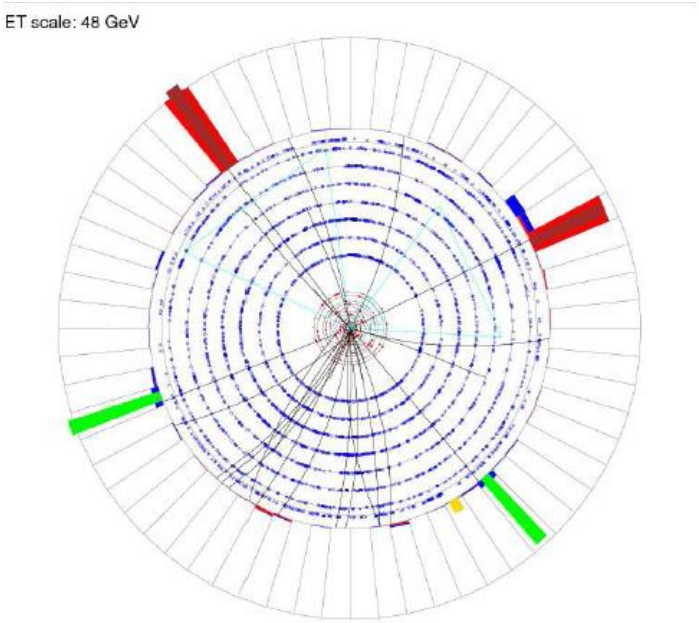
ZZ Production



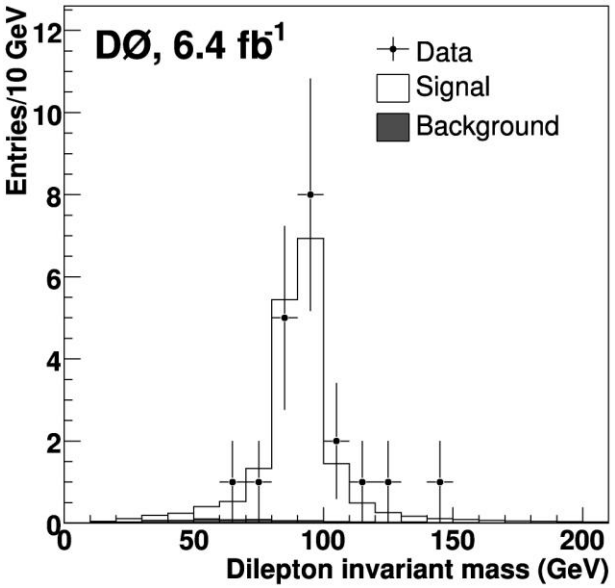
Possible other signatures:

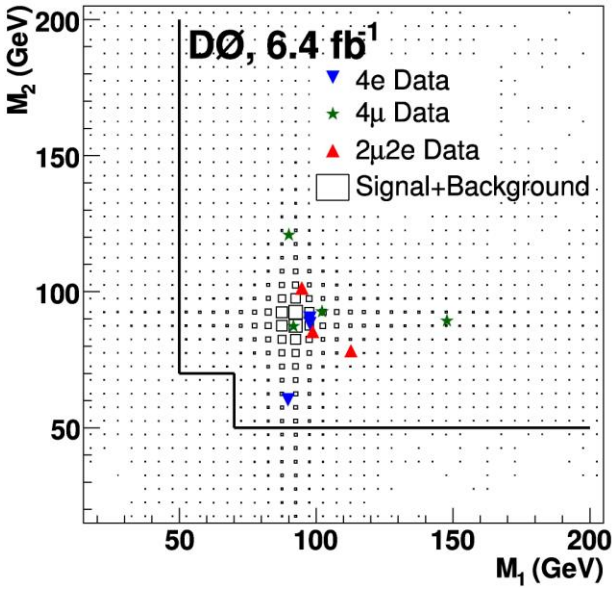
- H→ZZ (SM, MSSM)
- $\tilde{\chi}_1^0\tilde{\chi}_1^0 \rightarrow Z(\ell^+\ell^-)Z(\ell^+\ell^-)\tilde{G}\tilde{G}$ (GMSB)

- Two pairs of opposite-sign, same flavor leptons → very clean signature
- First observation of ZZ in 2008 with three 4-leptons events



ZZ Cross-Section





- **Selection of 4 leptons events** (e or μ) with E> 30, 25, 15 and 15 GeV
- **10 events observed for 0.37 ± 0.13 background events expected**

Measurement of the ZZ cross-section 4 lepton events:

$$\sigma(ZZ) = 1.26^{+0.47}_{-0.37}\ (stat) \pm 0.11\ (syst)\ pb$$

correction factor 0.93 applied for $\sigma(Z/\gamma^* Z/\gamma^*) \rightarrow \sigma(ZZ)$

Previous measurement in the llνν channel with 2.7 fb^{-1} :

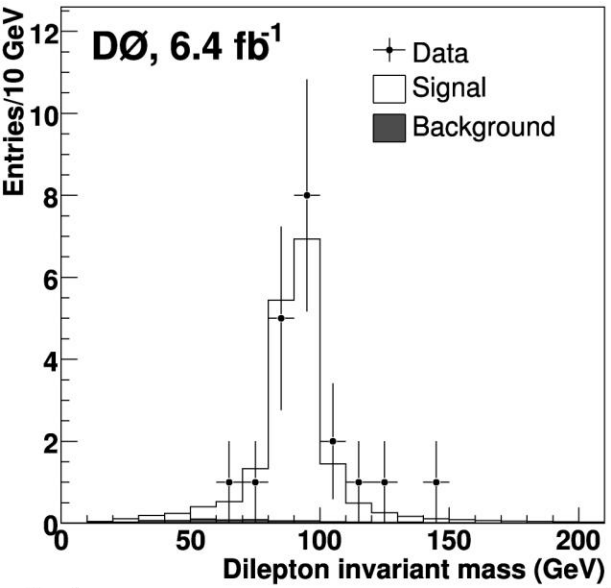
$$\sigma(ZZ) = 2.01 \pm 0.93\ (stat) \pm 0.29\ (syst)\ pb$$

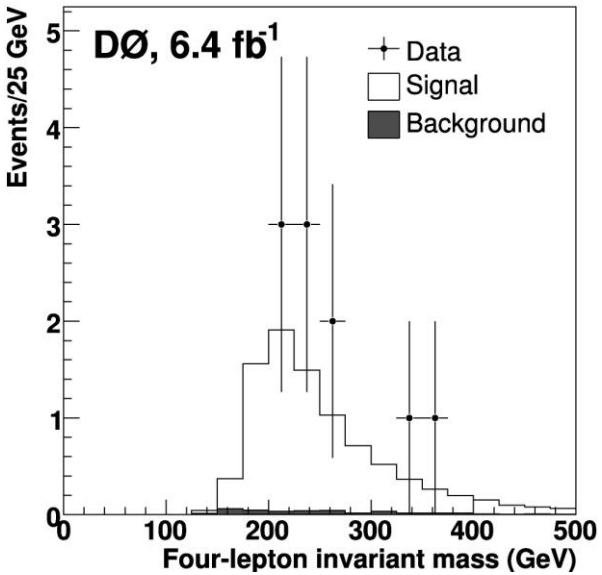
Combined result:

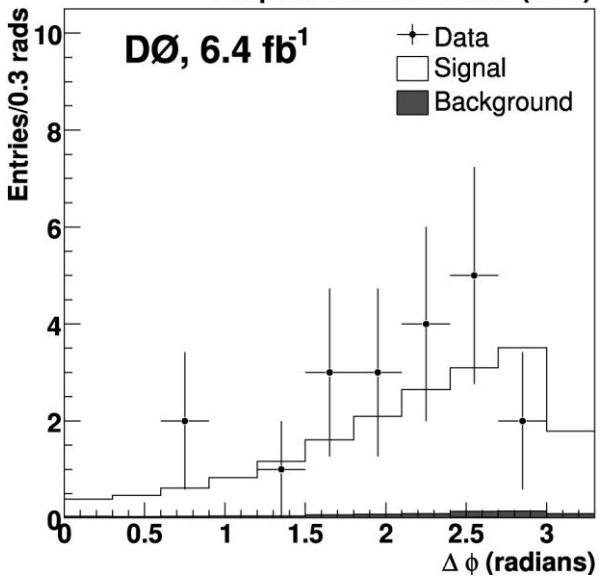
$$\sigma(ZZ) = 1.40^{+0.43}_{-0.37}\ (stat) \pm 0.14\ (syst)\ pb$$

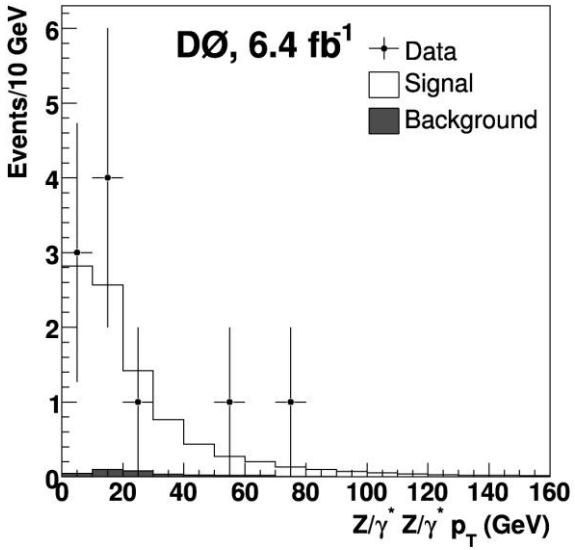
SM expectation NLO: 1.3 ± 0.1 pb

ZZ KINEMATICS









First kinematic distributions in 4 leptons channel:
agreement with SM

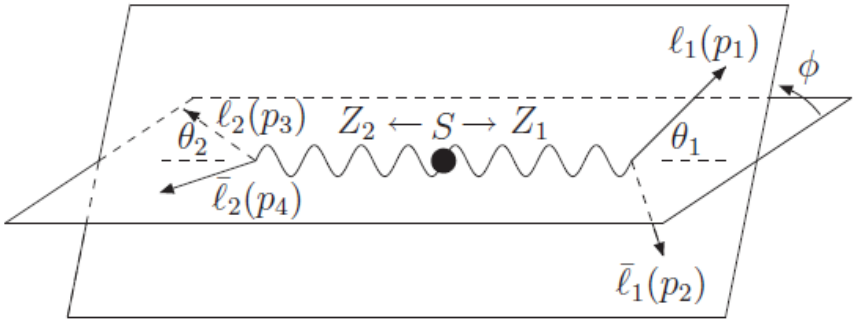
-no accumulation pointing towards a resonant production with low statistics

-angular distribution consistent with back-to-back production

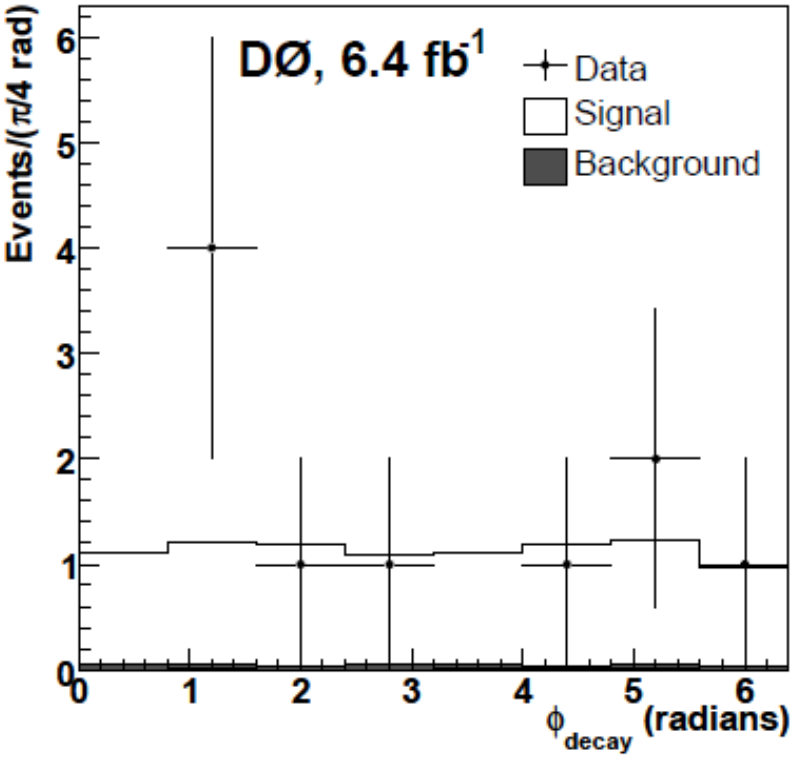
- p_T spectrum described by simulation

ZZ and Higgs Production

- **Decay plane angle of some interests to Higgs hunters**

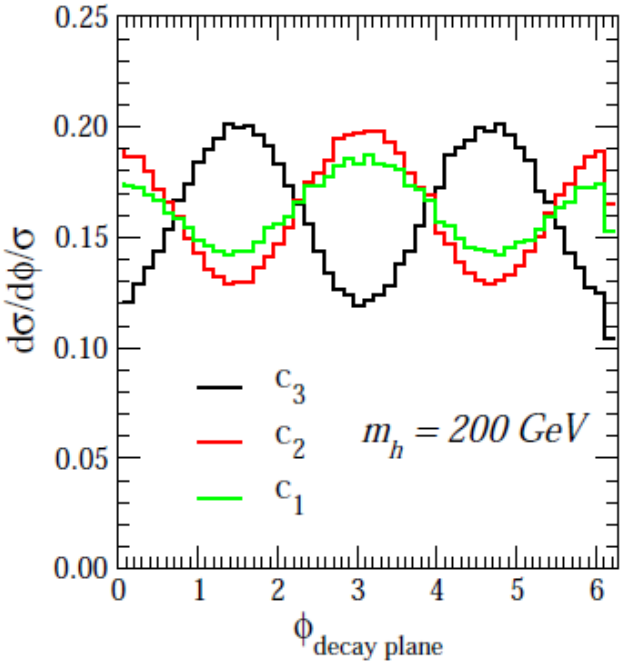


Rotates l_2 leg into l_1 leg



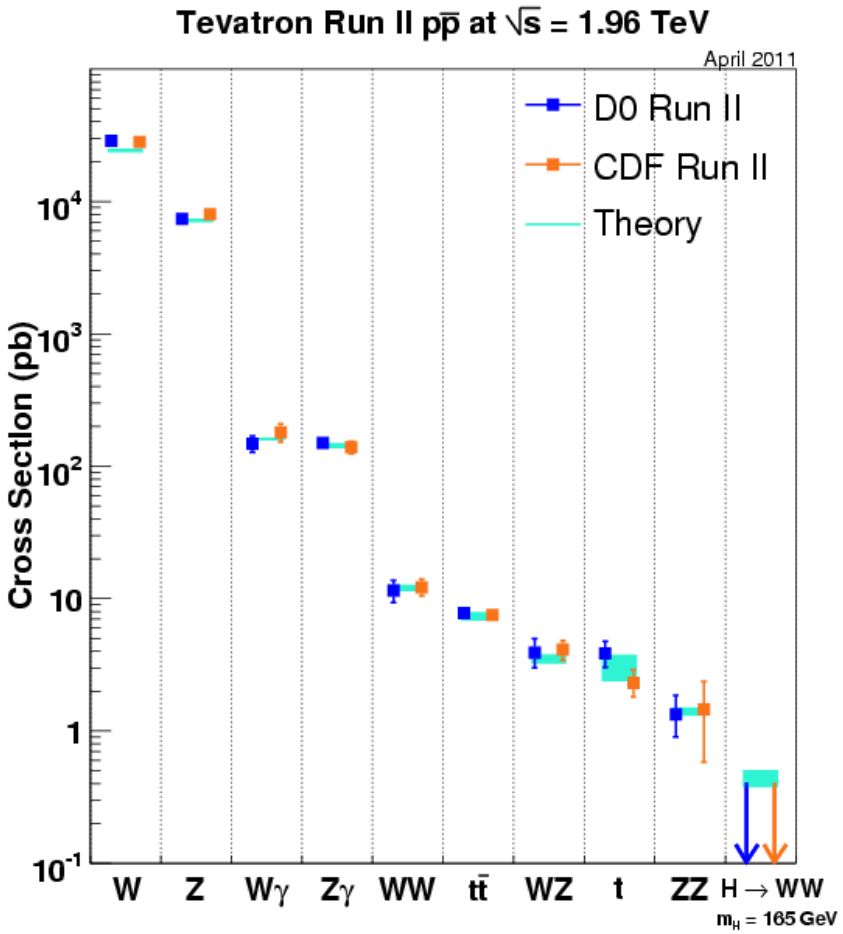
Higgs Like Scalar
Heavy Scalar
CP-Odd Scalar

➔ Should help to understand the nature of a Higgs Boson!



SUMMARY OF DØ DI-BOSON RESULTS

Wγ	**4.2 fb^{-1}**	15.2 ± 1.6 pb
WW	**1.1 fb^{-1}**	11.5 ± 2.1 pb
WZ	**4.1 fb^{-1}**	$3.90^{+1.01}_{-0.85}$ pb
Z γ	**3.6 fb^{-1}**	4.96±0.42 pb
Z γ →νν̄γ	***3.6 fb^{-1}***	*32 ±9 fb*
ZZ	**6.4 fb^{-1}**	$1.40^{+0.45}_{-0.40}$
hadronic channel:		
WW+WZ	**1.1 fb^{-1}**	20.2 ± 4.4 pb



CONCLUSIONS

- 4 – 6 fb^{-1} of Run-II Tevatron data used within Di-bosons analysis

➔ Allows for measuring very small cross sections

- Setting some of the tightest limits on anomalous TGCs
- Most results are still statistics limited
- Expect ~2 × more data to be analyzed for the entire Tevatron run.