Diffractive and DPE Production of Hard Color Singlet Pairs

γ too; V = γ, W or Z

→ Standard Model direct (non-Higgs, top) VV Production

→ V,VV in CDF and in D0 ... so far and future prospects.

→ VV in CMS and ATLAS ... importance of pots.

→ Non-SM Diffractive VV processes; the White Pomeron

S.M. Diagrams for Prompt VV Pair Production in pp/ppbar

(Prompt i.e. not from top and not from Higgs)

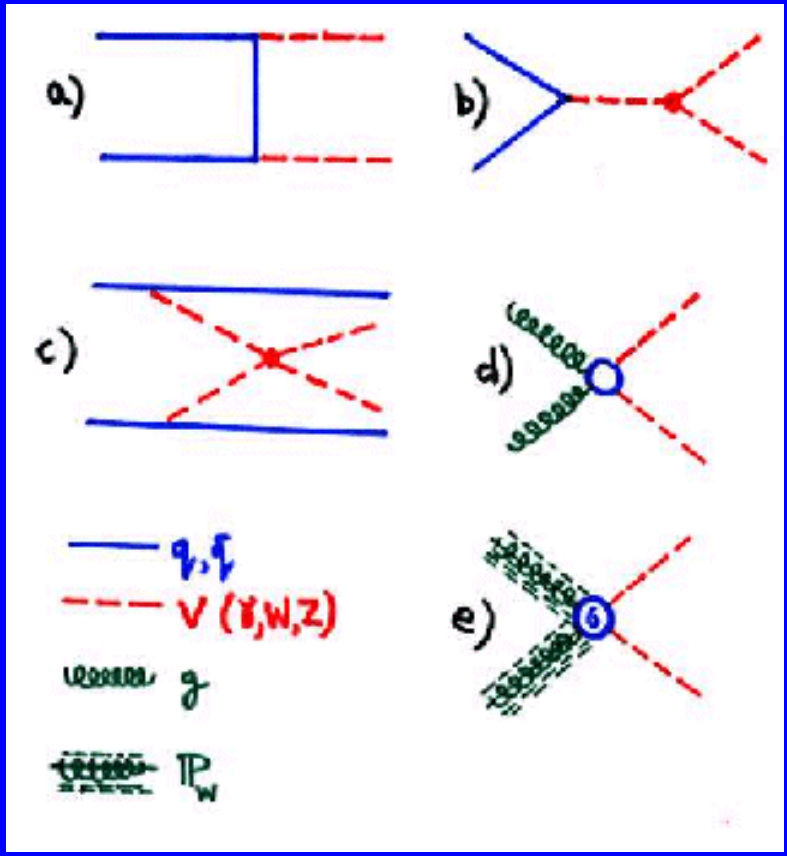
a) Any Q = 0, ±1 pair. 90% of WW at TeV

b) Only γW, WW, WZ

c) Any pair (even W^+W^+).
Negligible at Tevatron

d) Negligible

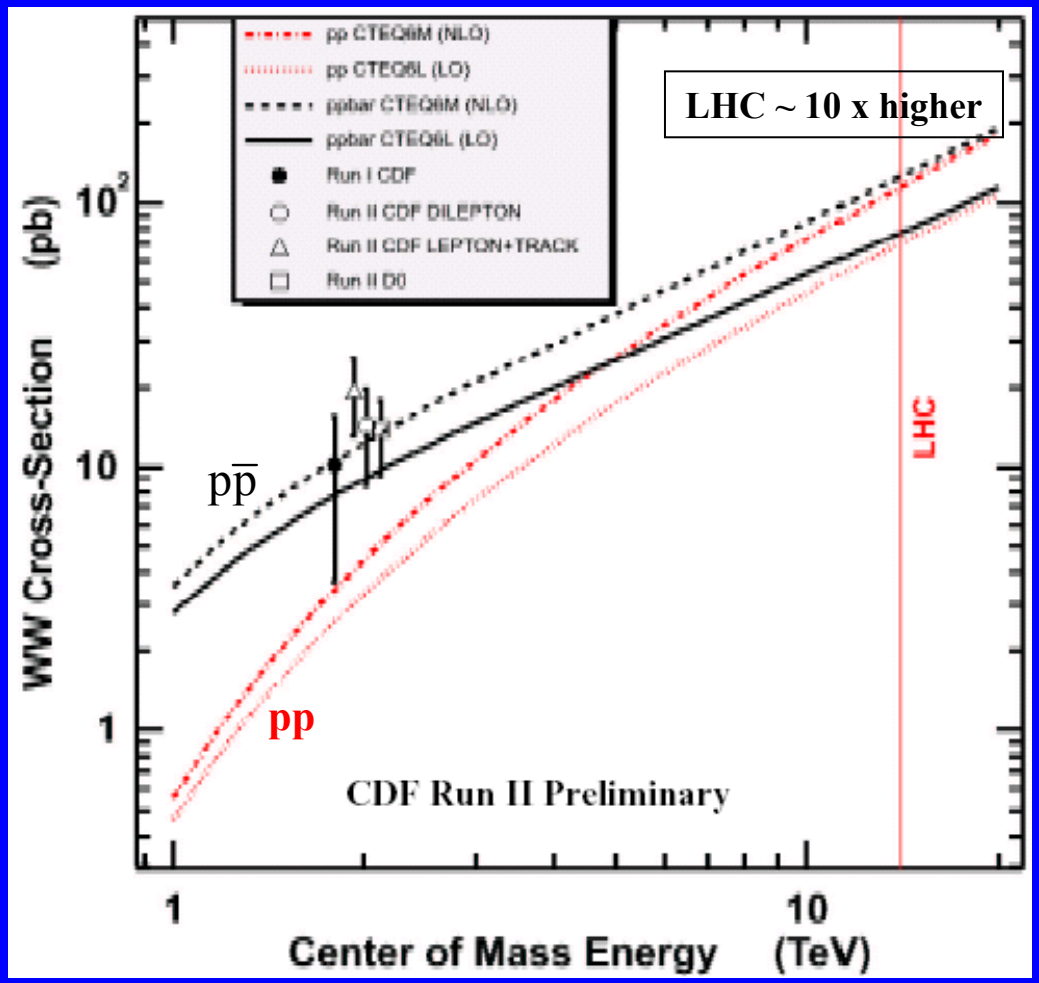
e) Not SM, but very large
if Alan White is right



Note different color flows in these diagrams can give different hadronic activity.

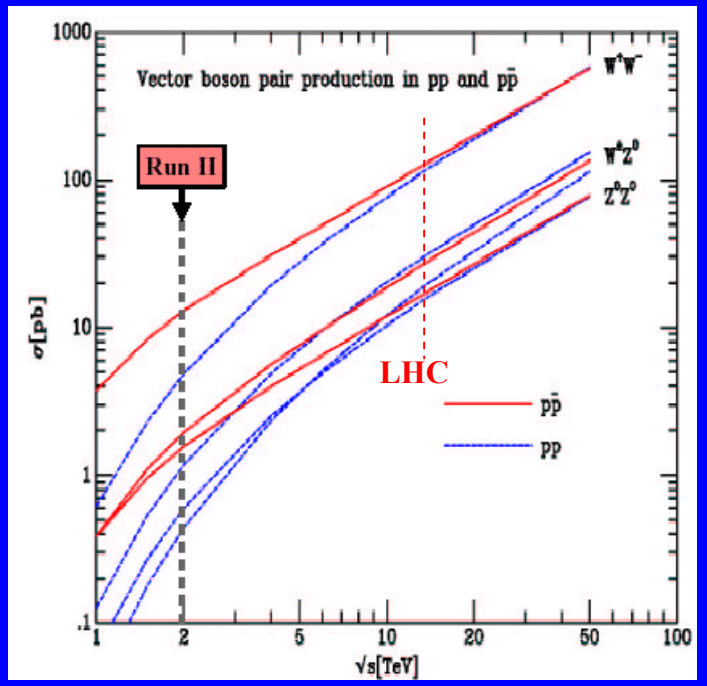
(a) and (b) have color 3 annihilation
(d) has color 8 annihilation
(c) and (e) have color singlet exchange.
(c) high pT q – forward jets; (e) low pT p's – no jets, can be exclusive

Cross section for WW Production: Energy Dependence

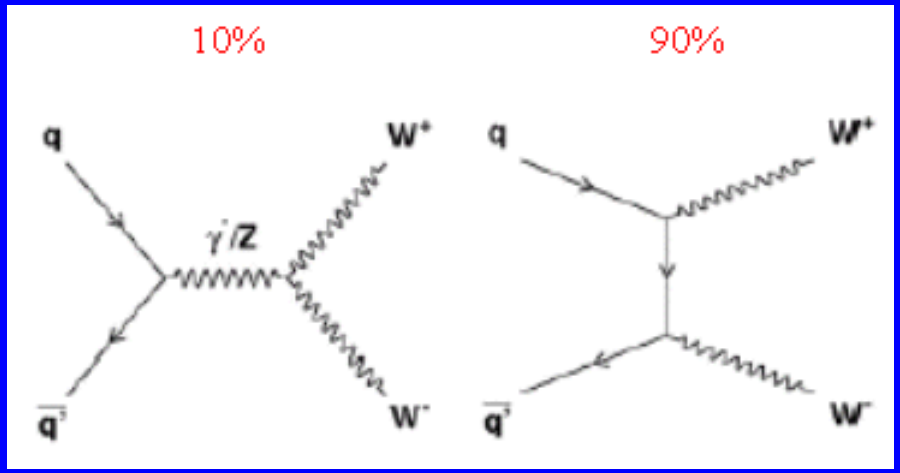


Tevatron cross section agrees with CTEQ NLO

CDF:
sig (ZZ + ZW) < 15.2 pb (95%)
sig (WW) = (14.6 +- ~ 6) pb
D0: sig(WW) = 13.8 pb



WW Production (also WZ, ZZ)

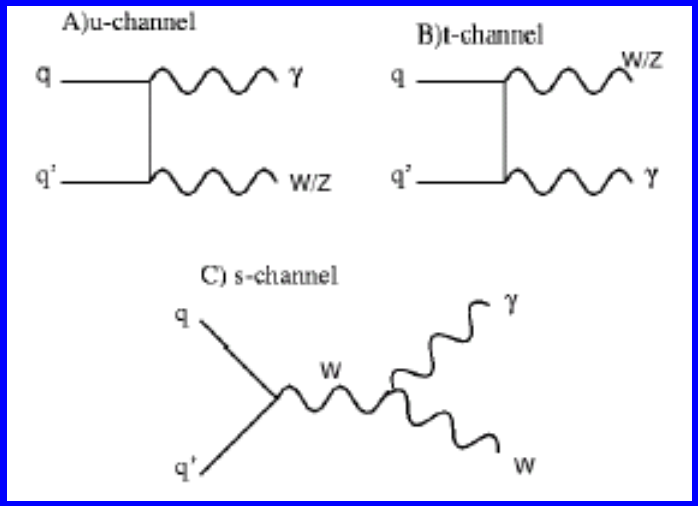


CDF: $\sigma(p\bar{p} \rightarrow W^+W^- + ...) = 14.6^{+5.8}_{-5.1}(\text{stat})^{+1.8}_{-3.0}(\text{syst}) \pm 0.9(\text{lum})$ pb

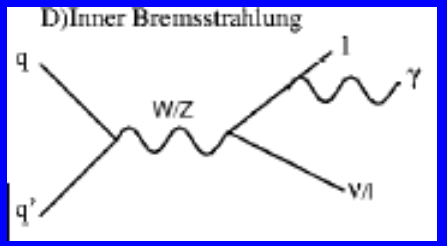
D0: $\sigma(p\bar{p} \rightarrow W^+W^- + ...) = 13.8^{+4.3}_{-3.8}(\text{stat})^{+1.2}_{-0.9}(\text{syst}) \pm 0.9(\text{lum})$ pb

SM(Campbell+Ellis): 12.4 ± 0.8 pb

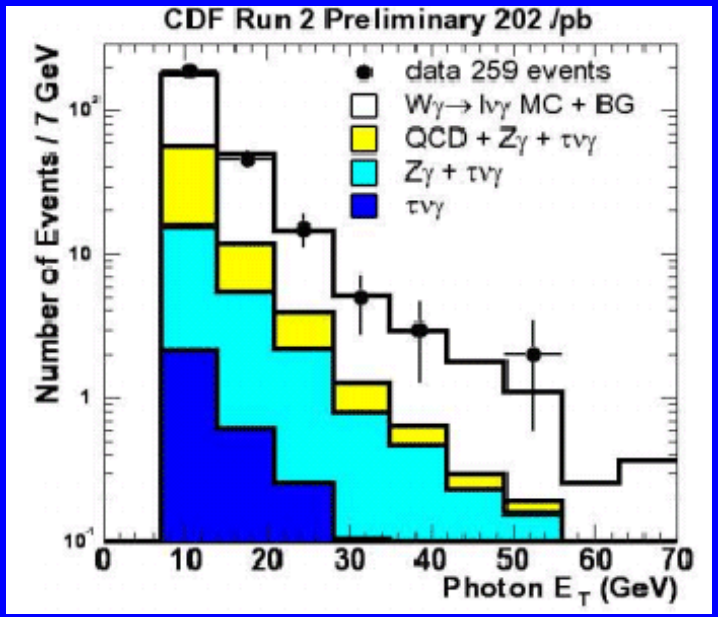
W,Z + high pT photon



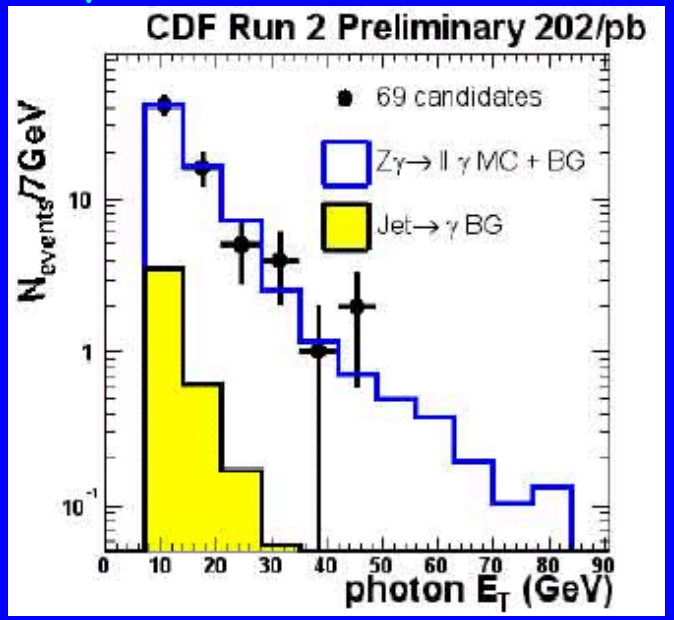
+ inner brems



Wγ



Zγ

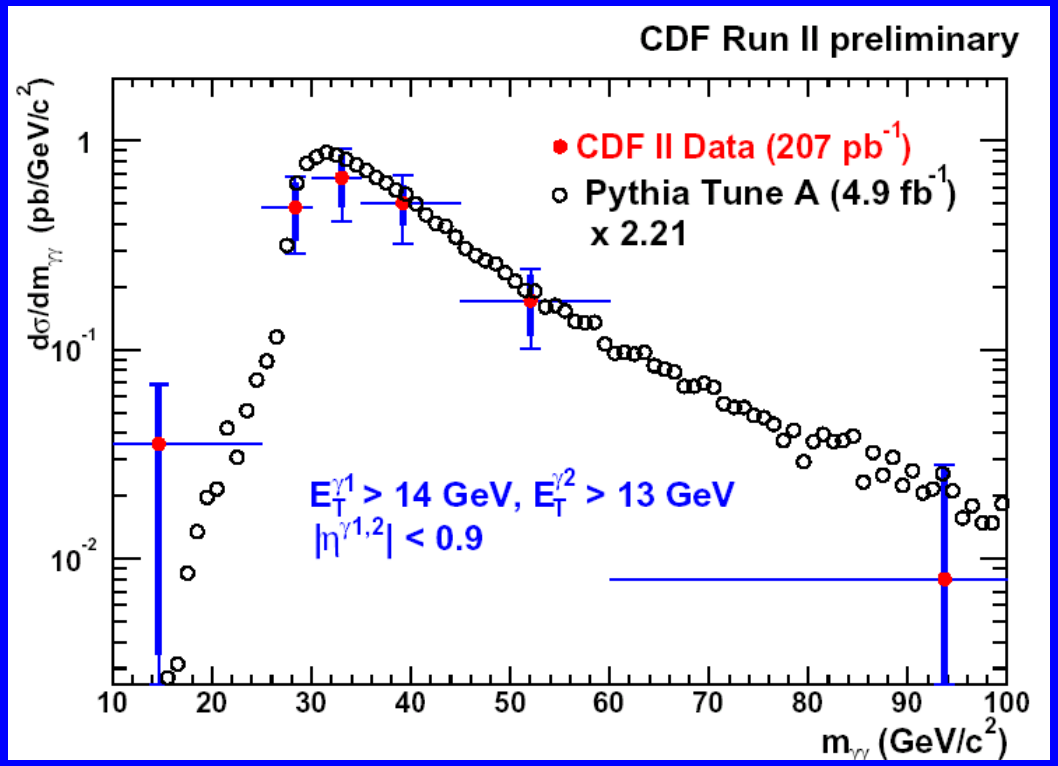


CDF: PRL(submitted 9/04 hep-ex/0410008)

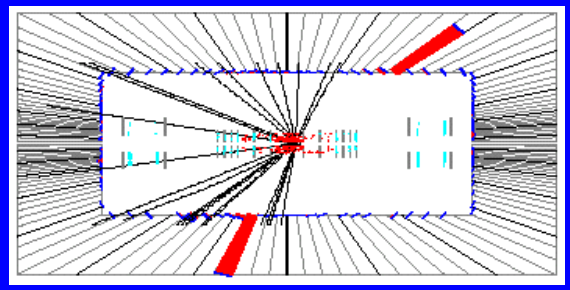
Photon-Photon Mass Spectrum

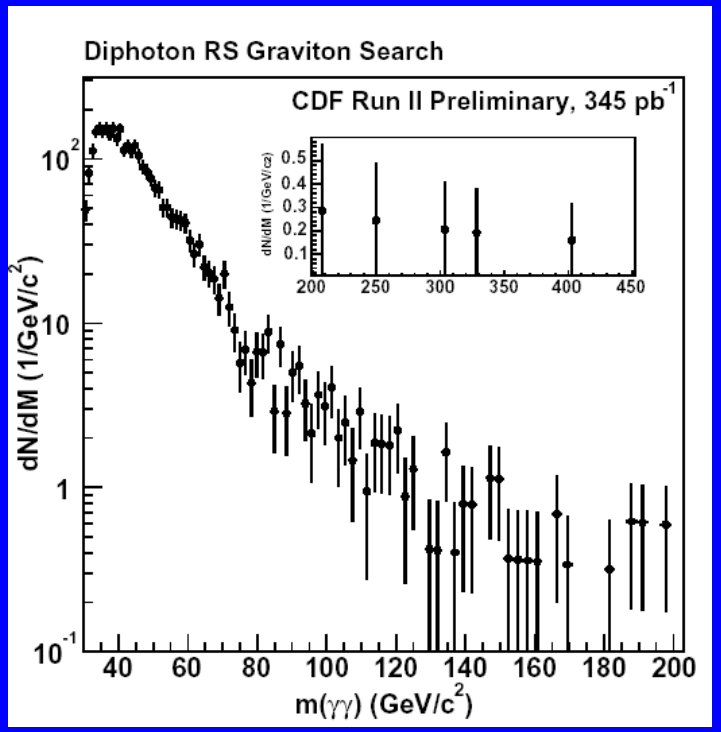
$q\bar{q}$ (X?) $\rightarrow \gamma\gamma$

Tight cuts:



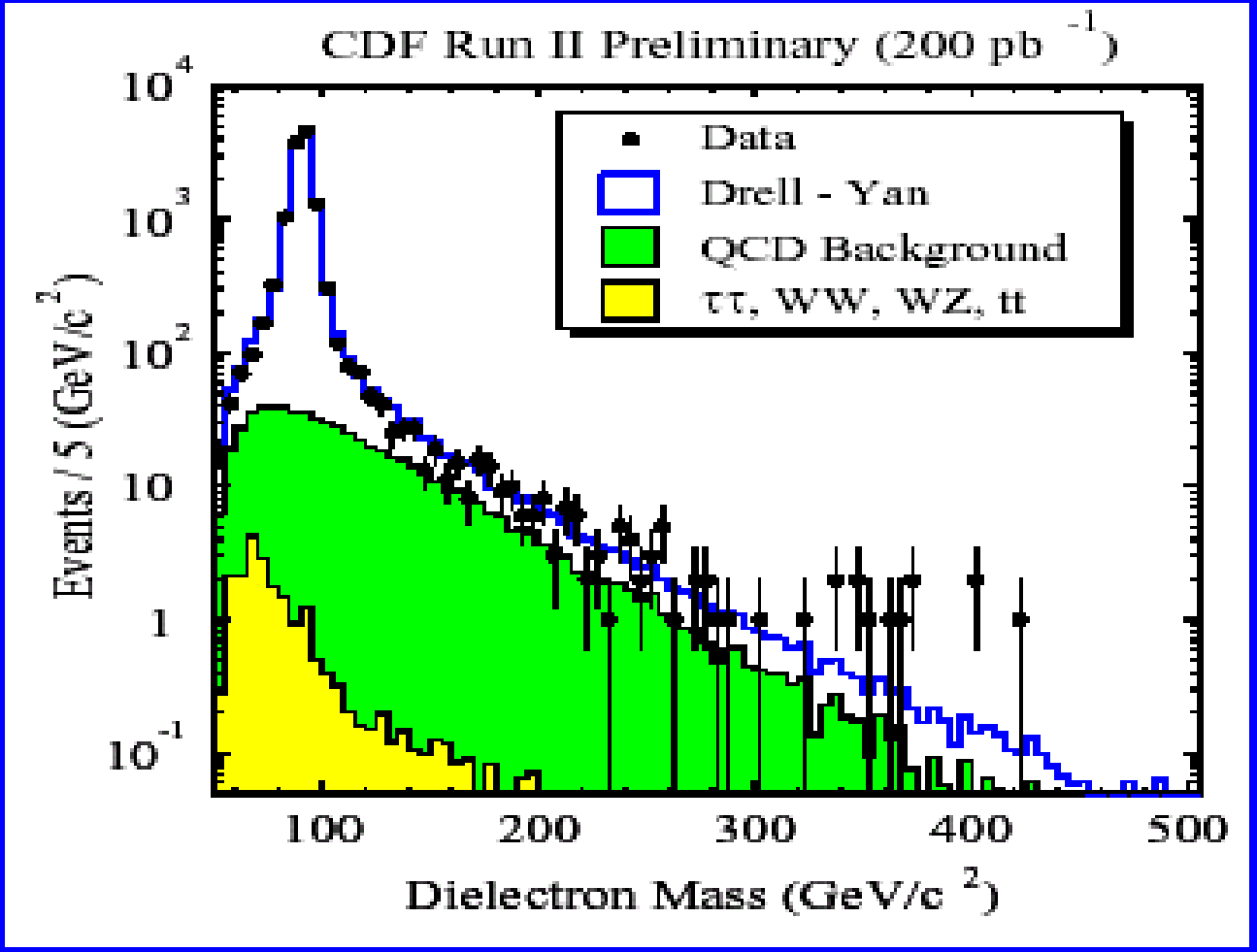
D0: highest $M_{\gamma\gamma}$ = 436 GeV!





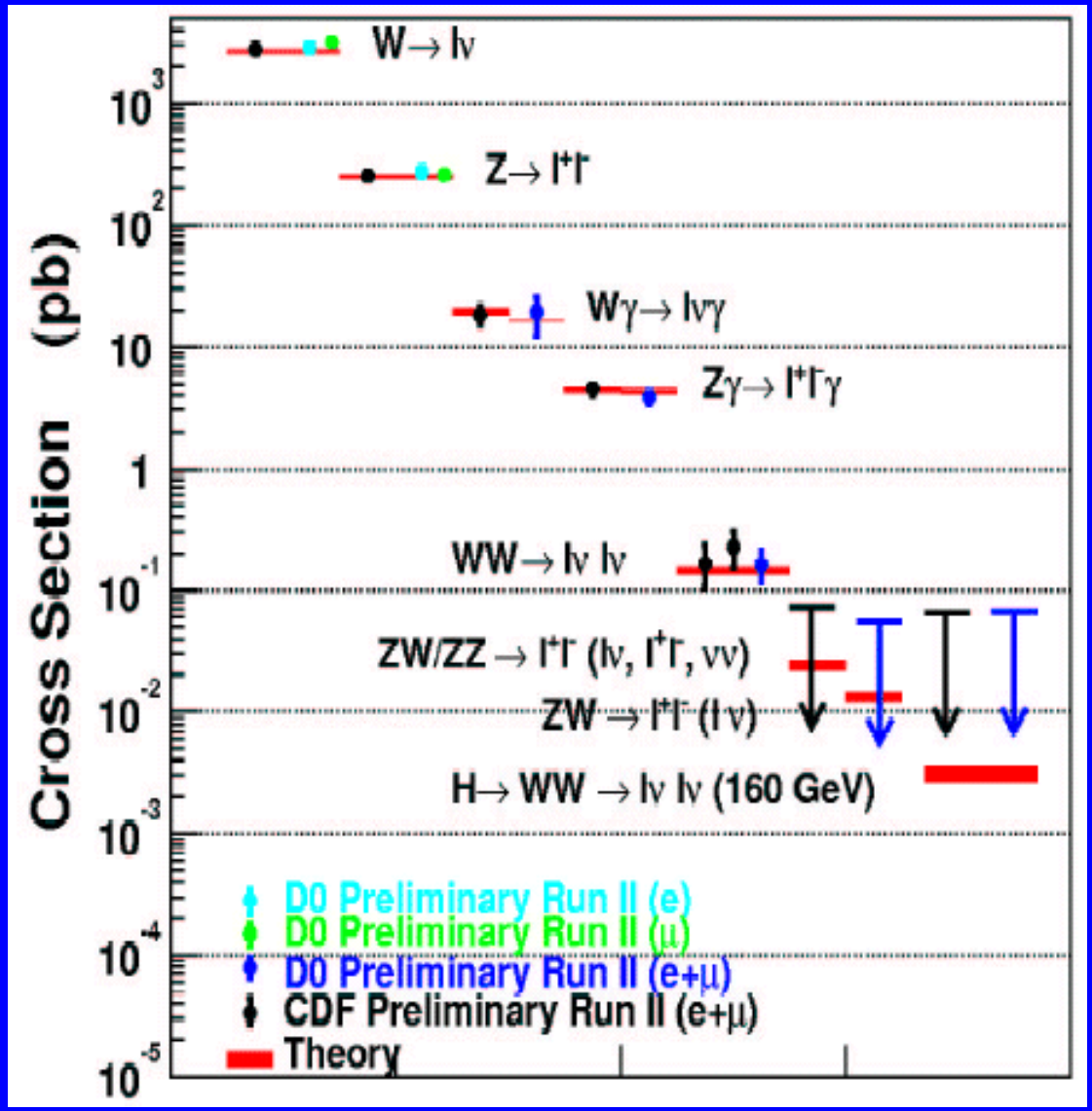
Looser cuts to search for "bumps"

Z and High Mass Drell-Yan



~ 200 events above 110 GeV

Summary of Cross Sections at Tevatron Run 2



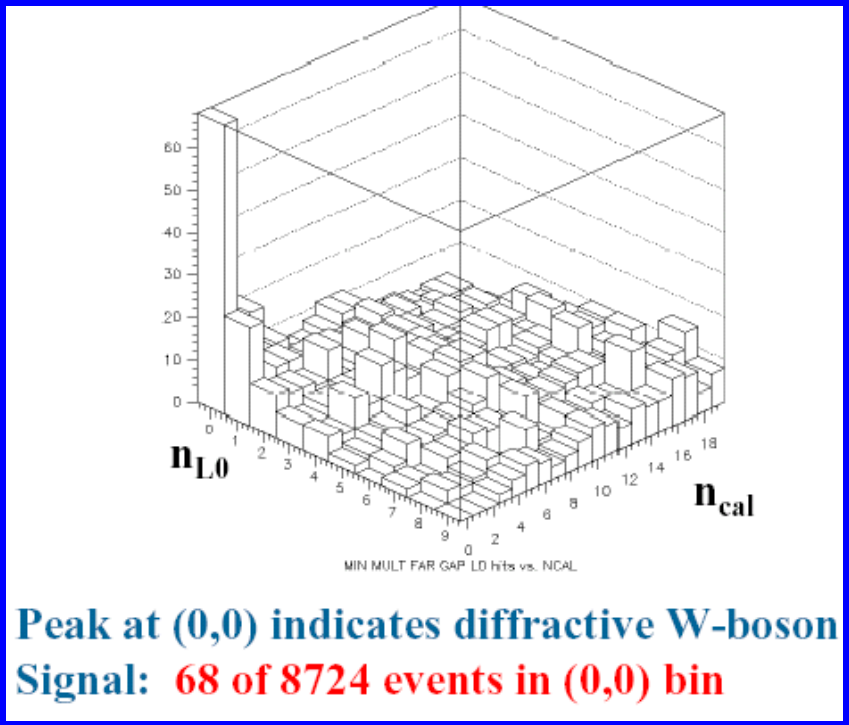
Rule of Thumb

DPE

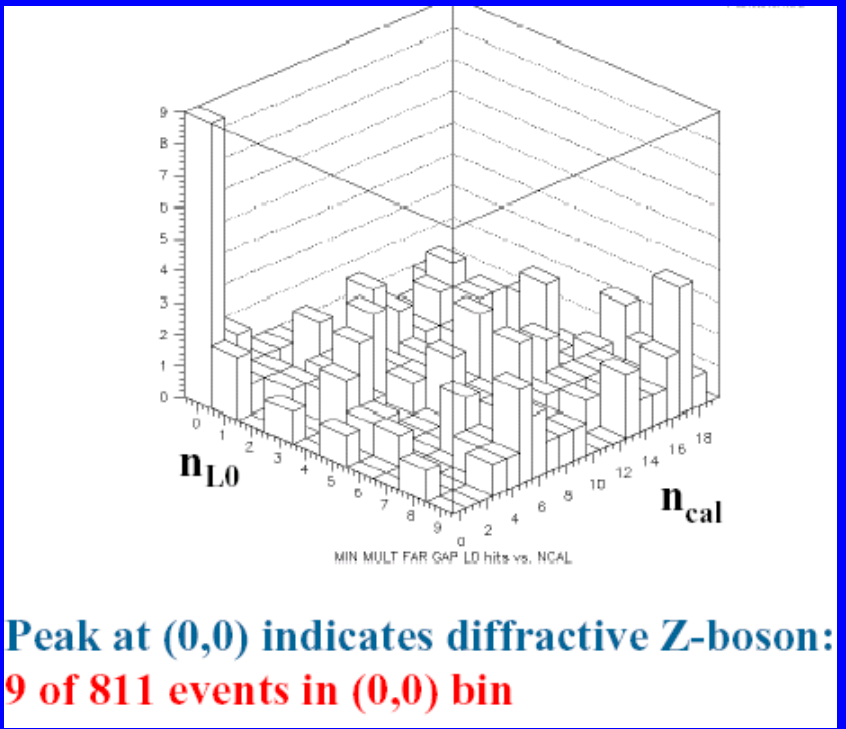
SDE

Single Diffractive Production of W & Z at Tevatron

D0 gap (3.0-5.2 in Cal, LO) signals:



Peak at (0,0) indicates diffractive W-boson
Signal: 68 of 8724 events in (0,0) bin

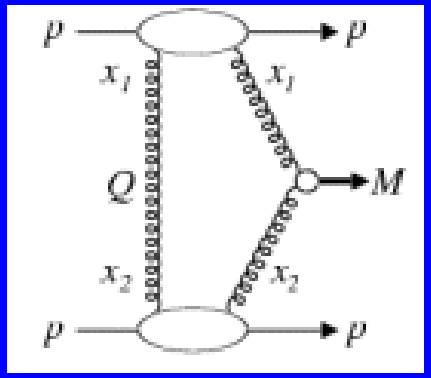


Peak at (0,0) indicates diffractive Z-boson:
9 of 811 events in (0,0) bin

Sample	Diffractive/All	Probability Background Fluctuates to Data	
Central W	(1.08 + 0.21 - 0.19)%	1×10^{-13}	**7.7σ**
Forward W	(0.64 + 0.19 - 0.16)%	6×10^{-7}	**5.3σ**
All W	**(0.89 + 0.20 – 0.19)%**		
Z	(1.44 + 0.62 - 0.54)%	5×10^{-5}	**4.4σ**

Rule-of-Thumb:
~ 1% (hard process) diffractive

Exclusive Higgs Production by Double Pomeron Exchange?



$pp \rightarrow pHp$ through t-loop

$pp \rightarrow p\chi_b p$ through b-loop

$pp \rightarrow p\chi_c p$ through c-loop

$pp \rightarrow p\gamma\gamma p$ through u-loop

→ Can be **inclusive** (soft central hadrons) but **exclusive** (nothing else) most interesting. Precision measurement of both p → M(central) by MM
Possible resolutions **~ 250 MeV** at Tevatron, **~ 2 GeV** at LHC.

→ Can go for dominant H(110-130) b-bbar decay mode

→ Exclusive DPE → **q-qbar dijets strongly suppressed** (Jz = 0 rule)

→ Selection Rule on **central Q.Nos:**

$I^G J^{PC} = 0^+ 0^{++}$ dominant esp. as $t \rightarrow 0$

$I^G J^{PC} = 0^+ 2^{++}$ next

→ pp Correlations tell Q.Nos → **scalar** (need statistics!)

→ Tevatron too low for SM H $\quad \sigma_{excl} \sim$ 0.2 fb (KMR)

→ LHC possible (but difficult) $\quad \sigma_{excl} \sim$ 3 fb (KMR)

→ Non-SM H interesting!

Relevant studies we are doing in CDF:

$DPE \rightarrow JJ,\ J_bJ_b,\ \gamma\gamma,\ \chi_c, WW$

(χ_b and ZZ would be great too!)

DPE Exclusive is gold-plated

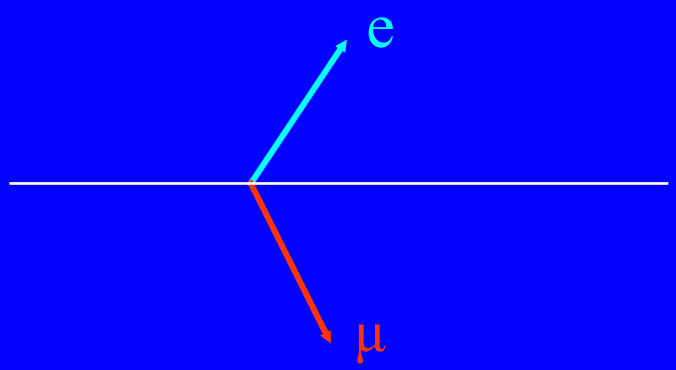
DPE Inclusive is silver-plated, also interesting.

Central Exclusive WW Production at LHC

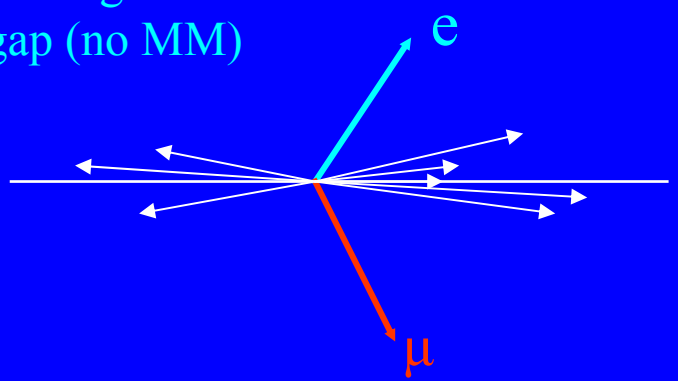
$$H(160) \rightarrow W^+W^- \rightarrow p\ e^+\mu^-\not{E}_T\ p$$

$$MM^2 = (p_1 + p_2 - p_3 - p_4)^2 = M_H^2$$

Nothing else on 2-lepton vertex! ee μμ eμ



... or inside large track rapidity gap (no MM)



+ White Pomeron search

Is there any evidence for a diffractive component, or anomalous high or low activity, in events with two vector bosons?

Single diffraction → single W and Z established at Tevatron
Double pomeron → W, Z, 2 photon (inclusive and exclusive) – under study

Plan: study distributions of associated hadrons in color-singlet VV events:

$\gamma\gamma$, γW, γZ, WW, WZ, ZZ and for comparison W, Z

Many variables (CDF):
(& D0 forward & central)

(look for distinct near-zero peak in n-dimension plot)

- BSC counter hits
- MiniPlug Energy
- # CLC hits
- $\sum E_T$ (Central + Plug)
- $n^{\pm}$ (ass.) (central fiducial region)
- p_T (V or VV)

Many variables can not be used in presence of pile-up → need 1 vertex

Of course see if roman pots see the p/p-bar
(Roman pots read out for every event)

At LHC when $\bar{N}_{coll}$ > few, only $n^{\pm}$(ass.), maybe p_T(VV) OK?

Must measure forward protons in pots

$pp \rightarrow p\, e^+ \mu^-\, p$ all measured (MM_{pp}) and $n^{\pm}(ass.) = 0$

Also $pp \rightarrow p\, Z(ee,\mu\mu) + \not{E}_T\, p$

MM $(1+2-3-4-\sum_{all}$ visible$) \approx M_Z$

& MM $(1+2-3-4) \approx M(ZZ)$

Finding a distinct **"superbusy"** or **"superclean"** class of events will require a significant deviation from a control (fit to the bulk, peak at or near origin, cf another channel)

We have started this study with the Run 2 WW sample (17 events) and plan to compare to the other channels.

Approximate numbers in 200 pb^{-1}: $W \to e\nu$ and $W \to \mu\nu$

W(eν & μν) 200,000

Z(ee & μμ) 18,000

Wγ ($p_{T\gamma} > 7$ GeV/c) ~ 300

Zγ ($p_{T\gamma} > 7$ GeV/c) ~ 70

γγ ($M_{\gamma\gamma} > 50$GeV) ~ 50 Not possible with > 1 interaction

Plan:
Look not just at **means** (of energy flow, multiplicities etc)
but at **extremes** (events in high and low tails of distributions).

Events with **high Q^2** but **no** (QCD) Final State Radiation **FSR**

$$W, Z, l^+l^- (DY), WW, WZ, ZZ, W\gamma, Z\gamma, \gamma\gamma$$

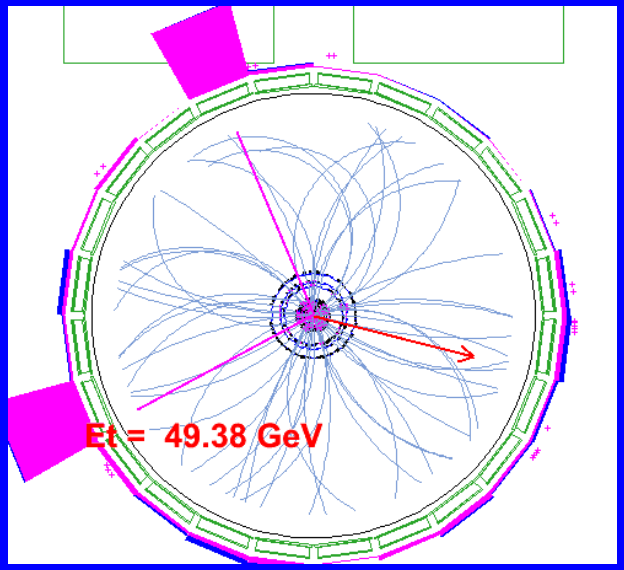
Only **high pT** objects are **leptons** and **photons**, Q^2 large (>~ 50 GeV)

Are there events with **anomalously high or low activity**, compared to Monte Carlos (e.g. Pythia Tune A) and to other channels in the set?

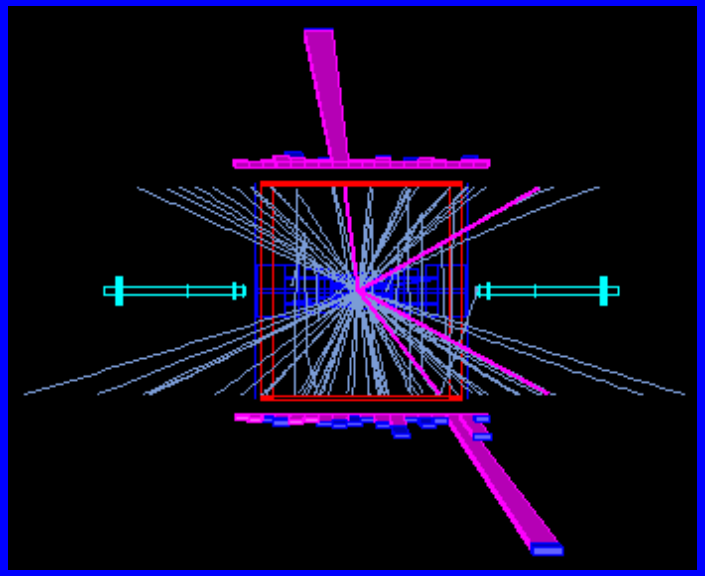
Overall or in rapidity regions (e.g. E,W,both,central)?

Event B: ZZ → 4e Candidate

R/E 147806/1167222

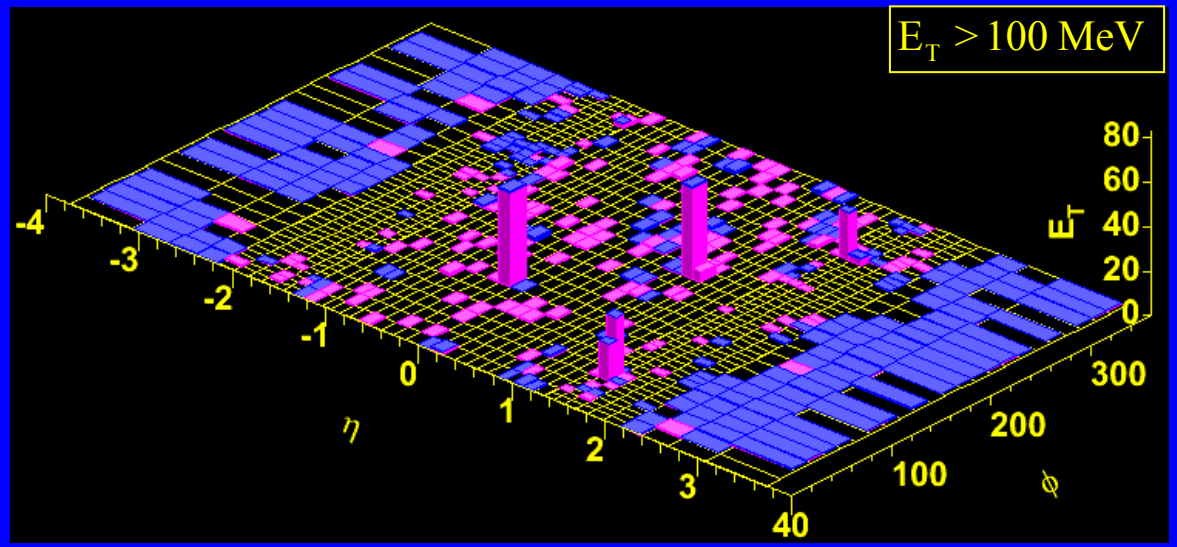


$p_T > 200$ MeV/c ; $|\eta| < 1.0$



$p_T > 200$ MeV/c

Note:
Cannot detect smaller polar angle tracks



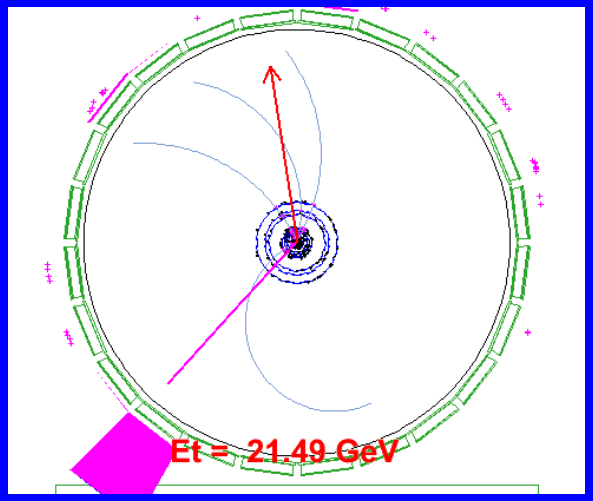
Good ZZ(4e) candidate except 1 e just fails ISO cut (so excluded from x-sn limit)

Exceptionally active event How unusual is that?

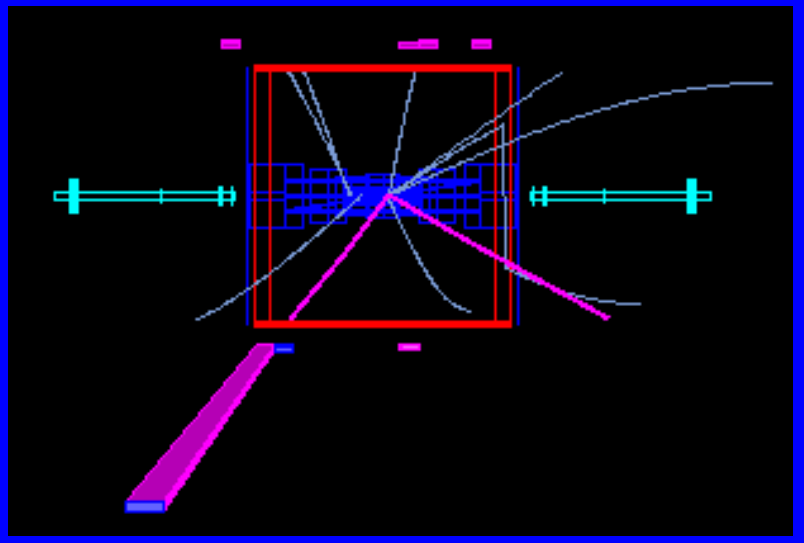
Is it > 1 interaction?

Event C: WW → ev ev Candidate

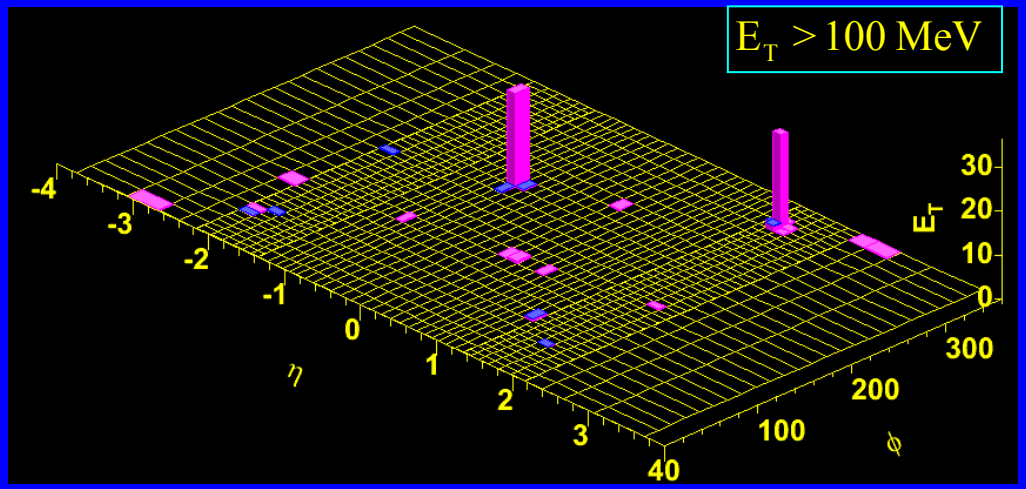
R/E 165906/1741744



$p_T > 200$ MeV/c ; $|\eta| < 1.0$



$p_T > 200$ MeV/c



Cleanest event in sample
also in E & W forward detectors.

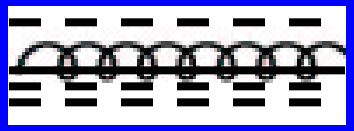
2 tracks in R-phi view dissociated
-or badly measured?
0 vtx tracks with $p_T > 0.4$ GeV/c and $|\eta| < 1.0$

$$p_T(W^+W^-) \;\&\; \sum E_T(\text{ass.})$$

also very small (of course)

Alan White's Theory of Critical Pomeron

ARW, hep-ph/0412062



reggeized gluon
wee gluons

("white pomeron")

Pomeron has two parts:
"Reggeized gluon" : single g in LO QCD is "sick": not gauge invariant.
Reggeized gluon from summing procedure → gauge invariant.

Infinite number of "wee **gluons**": no momentum even in infinite momentum frame.
wee **gluons** have properties of **vacuum**: in a sense they ***are*** the vacuum.
Rg color compensated at large distance by accompanying wg "cloud".

wg couple strongly to ***color sextet Q*** and hence to W,Z once energy ~ EW

At LHC and above, diffractive W/Z production may be prolific

Color Sextet Quarks: a Kindergarten Introduction

Asymptotic Freedom is saturated in Critical Pomeron theory:
→ 16 color triplet quark q flavors. We know only 6.
(Higher) Color Sextet Quarks Q count 5 x q: so two Q's {U,D} will saturate.

color triplets	color sextets
u c t	U
d s b	D

+ $L\nu_6$?

WIMP

Q's have 0 current mass, EW scale constituent mass. Stronger color charge than q.
Electric charges like $\bar{q}$ → **Can form "SuperHadrons":**

$P_6 = \{UUD\}; N_6 = \{UDD\}$ ← **STABLE**

SIMP at EWK scale, WIMP at low Q^2

{UDD} ← **Several (?) stable heavy neutrals! Dark Matter?**

Hadrons : $Q\bar{Q} \Rightarrow \{\Pi^-\Pi^0\Pi^+\}$ η_6

$\{\Pi^+\Pi^0\Pi^-\}$ are composite zero-helicity components of $\{W^-Z^0W^+\}$

(Get "eaten" by massless $\{W^-Z^0W^+\}$)

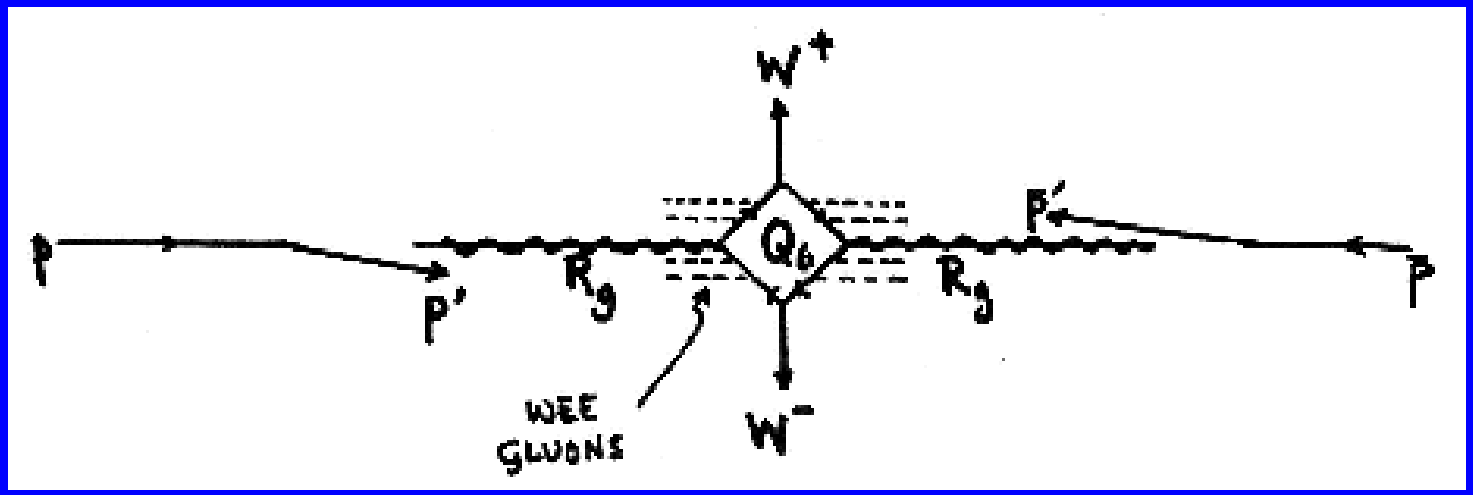
η_6 plays role of Higgs, EW symmetry breaking

There is no fundamental Higgs Boson

(η_6 has very different properties)

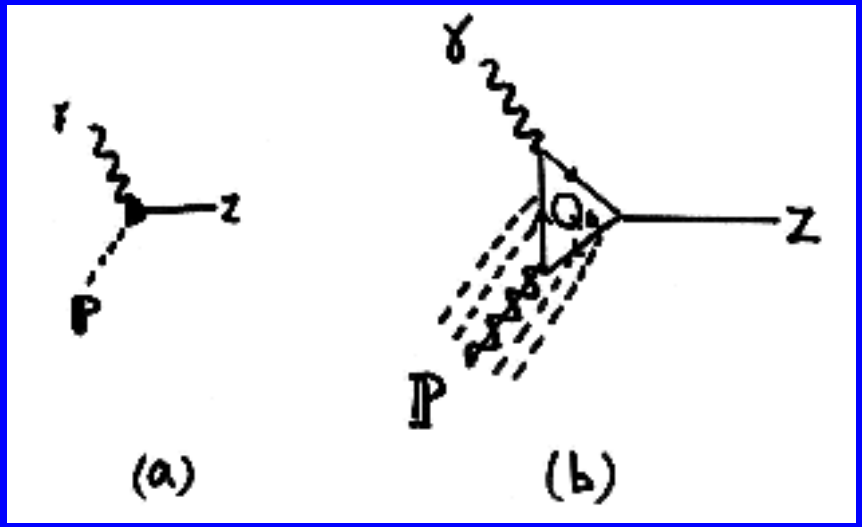
Once above ElectroWeak scale, should have prolific production of W's and Z's .... at UHE Cosmic Ray energies they are almost like pions! Auger project might see this.

Double Pomeron → W+W- via Q6 Loop



Photon-Pomeron-Z vertex via Q6 loop

→ ep
(eg LC+p (Tev,HERA,LHC)) could be *very* interesting!



Some thoughts for future:

CDF data with 200 pb^-1 do not show a significant anomaly in WW/ZZ production, but there's room.
Will get ~ 25 x more data

If we had precision roman pots E&W ...
If any events have both p & pbar detected →
M(WW/ZZ) Even ZZ → 4 neutrinos !! (in principle)

This is a TeV4LHC study. Need simulations at both machines.

All V and VV channels interesting for QCD and Diffraction.

Possibly dramatic effects at LHC in WW, ZZ ??

END

Back-up Slide

WW, WZ and ZZ Searches in CDF and D0

Run 1: CDF observed 5 WW candidates. Phys.Rev.Lett 78 (1997) 4356. (CDFNOTE–3673)

$\sigma_{WW}^{1800} = 10.2^{+6.3}_{-5.1}(stat) \pm 1.6(syst)$ pb BG(est) = 1.2±0.3

in good agreement with SM-NLO

Run 1: D0 observed 5 WW candidates. Phys.Rev.D58 (1998) 051101

SM $\Rightarrow$ 1.9±0.1 ; BG(est) = 3.1±0.4

Run 2: D0 observe 25 WW candidates, BG(est) ~ 8. hep-ex/0410066

$\sigma_{WW}^{1960} = 13.8^{+4.3}_{-3.8}(stat)^{+1.2}_{-0.9}(syst) \pm 0.9(lum)$ pb

Run 2: CDF observes 17(32) WW candidates, BG(est) ~ 5(12) (CDFNOTE-7255)

$\sigma_{WW}^{1960} = 14.5^{+5.8}_{-5.1}(stat)^{+1.8}_{-3.0}(syst) \pm 0.9(lum)$ pb (17 events)

Run 2: CDF observes 3 WZ+ZZ candidates, BG(est) ~ 1.0 +- 0.2 (CDFNOTE-6920)

2 events are common to both searches (WW/ZZ ambiguous)

Consistent with NLO theory (Campbell & Ellis): $\sigma_{WW}^{1960}(th-nlo) = (12.4 \pm 0.8)$ pb