# ***Missing Mass in Central Exclusive WW/ZZ***

How to use ~ all WW/ZZ exclusive final states

(Shorter version of talk at CMS/TOTEM mtg June 05)

**Warning**

These are concepts using 4-vectors.
Questions of resolution, signal and background
are not addressed

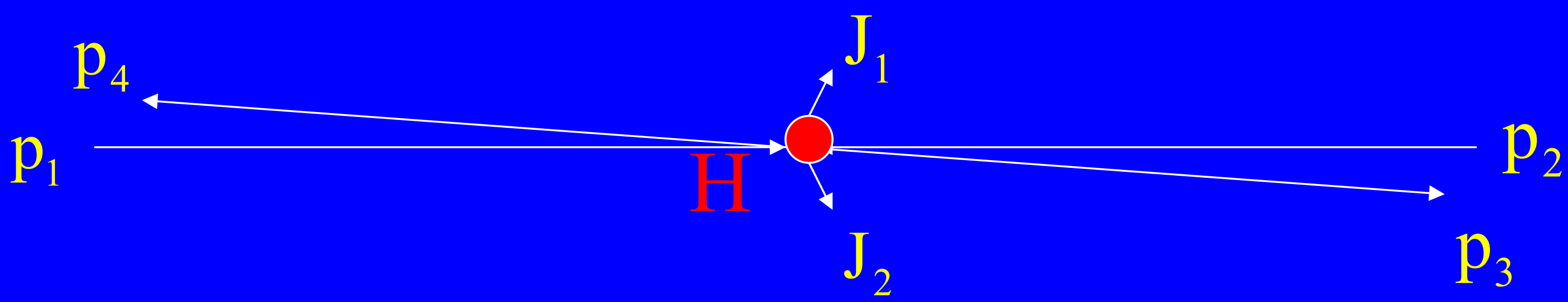
## ***Summary***


→JJ and JJJJ events with 220m … can use xi(220) – J ET,eta correlations in Level 1 trigger.

→Several missing mass variables allow almost all decay modes of exclusive WW, ZZ to be used (given central L1 trigger)

# “Classical” * use of missing mass in central exclusive processes:

* MGA & A.Rostovtsev, hep-ph/0009336




4-vectors: $\{E, ip_x, ip_y, ip_z\}$

$$M_H^2 = (J_1 + J_2)^2 = (p_1 + p_2 - p_3 - p_4)^2$$

$$\sigma(M_H) <\approx 2 \text{ GeV}$$

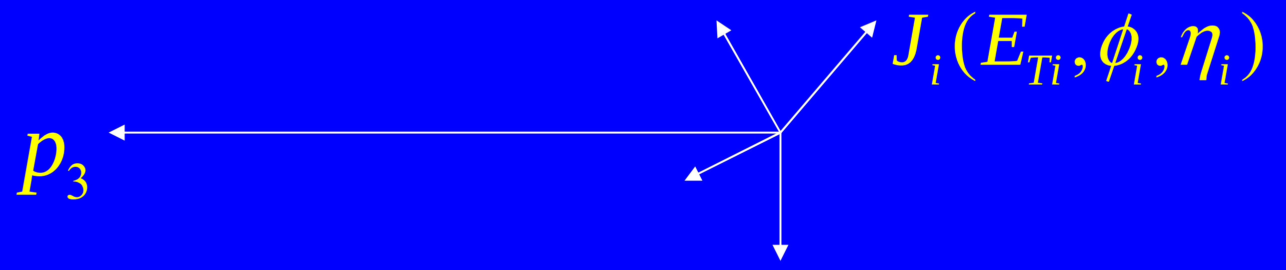
$$M_p^2 = p_i^2 \; ; \quad s = (p_1 + p_2)^2 \; ; \quad t_{13} = (p_1 - p_3)^2$$

# But exclusiveness brings other rewards

Two jets' $E_T$ are the same to ~ 1 GeV, $\Delta\varphi = 180^0$
and, knowing that and $\eta_1, \eta_2$ and(??) $\xi_1(220)$
in L1 trigger (fast look-up) can use correlation
to reduce L1 trigger rate.

$$\xi_{1(2)} = \frac{1}{\sqrt{s}} \sum_{\text{jets}} E_{Ti} e^{+(-)\eta_i}$$

# Triggering on WW/ZZ → JJJJ + one (220m) forward proton, L1




$$\xi(p_{3(4)}) = \frac{1}{\sqrt{s}}\left[\sum_{i=1,4} E_{Ti} e^{-(+)\eta_i}\right]$$

So, it is very important to push RP(220) xi resolution hard, and get a xi value into L1 trigger, as well as ET, eta of all jets. Same as for JJ case, but then had ET1 = ET2 and dphi = 180.

Kinematics fully determined without 420m FP ….
(4 equations and 4 unknowns)
FP420 needed for MM → M(H) though of course!

$$\mathrm{MM}^2 = (p_1 + p_2 - p_3 - p_{J1} - p_{J2})^2 = M_p^2 \approx 0$$

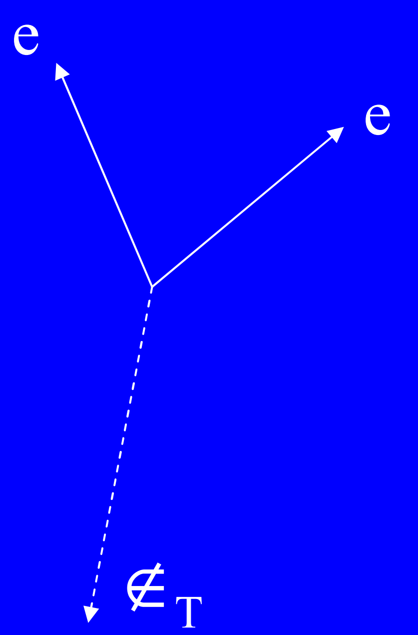
If we cannot get 420 m detectors into L1 trigger, very important to be able to **use jets (ET,eta,phi) and xi (approximately e.g. 4 bits) from 220 m pot.**
If L1 bandwidth is remaining issue, get more (preempt upgrade!)

→ **This needs simulation and technical evaluation**

Now consider exclusive WW production:

That is either $\gamma\gamma \rightarrow W^+W^-$ (100 fb), $H \rightarrow W^+W^-$

or BSM, e.g. White Pomeron




Super-clean is $e/\mu + e/\mu + \not{E}_T$

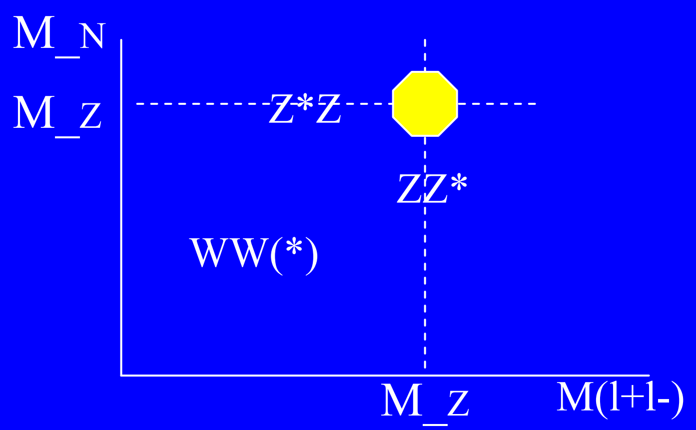
**No other tracks on vertex!**

WW or ZZ ?

Unfortunately B(W →l-nu) = 0.106 ; B(WW→llnunu) = 0.045

Ambiguity WW/ZZ resolved both by M(ee) and:

$$M_N^2 = (p_1 + p_2 - p_3 - p_4 - p_{l_1} - p_{l_2})^2$$




***NB: Does not use calorimetry. Good resolution!***

**(But OK, one Z may be off-shell Z*)**

**Really want to use B(W→JJ) = 0.68**
**Unlike generic (non-diffractive) WW → l-nu-JJ (v.hard!)**
**we have more handles (only one invisible particle):**

$$M_N^2 = (p_1 + p_2 - p_3 - p_4 - p_{l_1} - p_{J_1} - p_{J_2})^2 = 0$$

(massless neutrino)

M(JJ) = M(W), Jets on same vertex as lepton, and:

$$MM^2 = (p_1 + p_2 - p_3 - p_4 - p_{J_1} - p_{J_2})^2 = M_W^2$$

(IF ON SHELL)

**This is true even if the lepton is a tau!!**
**Now get not 4.5% of WW but 47.9%, more than 100x !**

Rest are mostly JJJJ events … see later

# ZZ Case

B(Z→ll) = 0.03366 (each type)
B(Z→nunu) = 0.20 (all 3 types)
B(Z→JJ) = 0.699

**So, if only use superclean e/mu decays get 4 x (0.03366)^2 = 0.00453!**

**But one can use Z→tau-tau, recognizing 2 x 1 or 3 prongs on vertex and:**

$$MM^2 = (p_1 + p_2 - p_3 - p_4 - p_{l_1} - p_{l_2})^2 = M_Z^2$$

This gives x2 → 0.00906, one small step for mankind

**But this equation works also for one Z → nu-nu, easily recognised!**
**We get very good mass resolution on invisible Z, not using CAL!**

This adds 0.0269, another small step. Best yet to come?

## B(ZZ → l+l- JJ for l = e,mu,tau) = 0.1456

Require 2 jets on l+l- vertex (want to use multiple interactions)

Not only M(JJ) = M(Z) but also:

$$MM^2 = (p_1 + p_2 - p_3 - p_4 - p_{J_1} - p_{J_2})^2 = M_Z^2$$

**This equation works also for leptonic Z → nu-nu!**

**B(ZZ→JJ nu-nu) = 0.2796. That's a giant leap!**

**0.0045 + 0.0045 + 0.0269 + 0.1456 + 0.2796 = 0.46 (100x)**

ee&μμ also ττ also $\nu\bar{\nu}$ also llJJ also $\nu\bar{\nu}$JJ

**The remaining ~ 50% of both WW and ZZ are JJJJ**

**(and 4-tau & 4-nu (only 4%))**

**JJJJ Hard but maybe not impossible IFF we can trigger well.**

## ***Summary***

→JJ and JJJJ events with 220m … can use xi(220) – J ET,eta correlations in Level 1 trigger.

→Several missing mass variables allow almost all decay modes of exclusive WW, *ZZ* to be used (given central L1 trigger)

4.5% for WW only ee,eμ,μμ decays + $\not\in_T$
48% using other MM variables
(all except JJJJ)