Search for Exclusive $\gamma\gamma$ Production

$$\boxed{p + p \rightarrow p + \gamma\gamma + p}$$ Test of QCD & $$\boxed{p + p \rightarrow p + H + p}$$

Durham Group Khoze, Martin, Ryskin & Stirling
hep-ph/0507040 Eur.Phys.J C38 (2005) 475

1-10 fb at LHC

$$\boxed{|\eta(\gamma)| < 1.0\ ;\ p_T(\gamma) > 5\ \mathrm{GeV/c} \Rightarrow \sigma_{\mathrm{TeV}} = 40\ \mathrm{fb}}$$

Factor ~ 3 uncertainty

Installed trigger: 2 EM showers > 4 GeV + Forward "gap seed" < 1 unit ~ 5

Only single interactions can be used!

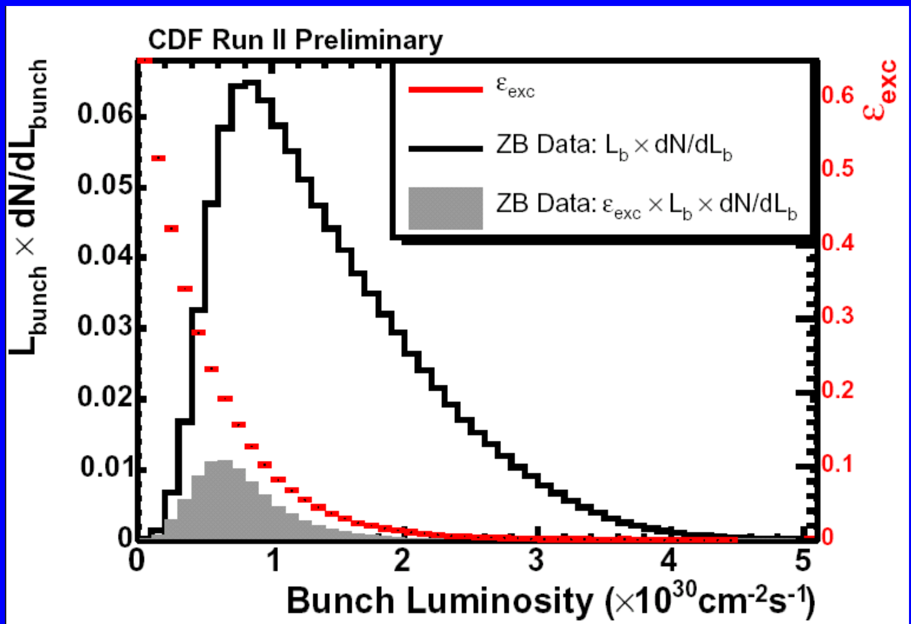
"Exclusive efficiency" : Any 2nd interaction spoils the event.

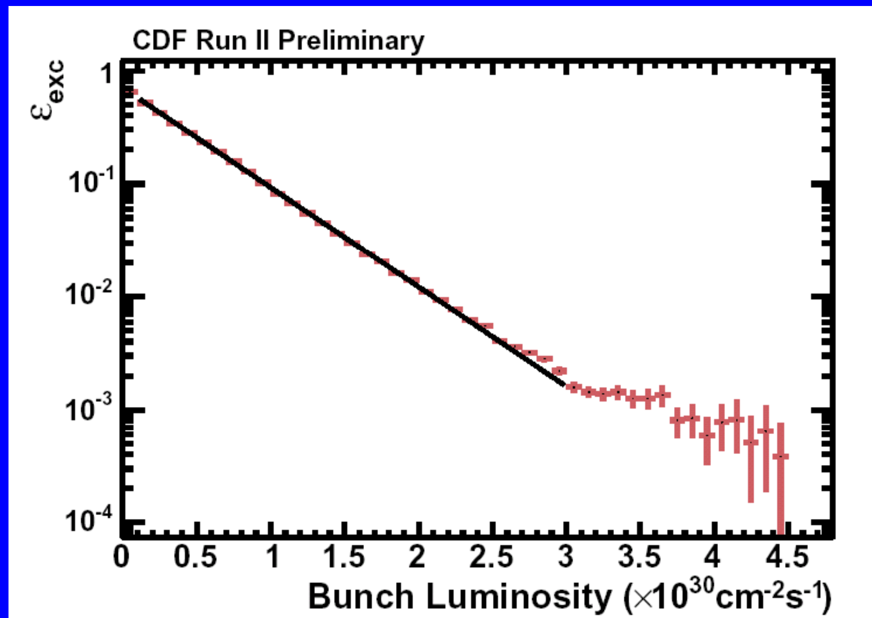
Efficiency depends on bunch x bunch luminosity! (Not all same)

Make distribution of bunch luminosities for whole data set.

Using 0-bias (beam crossing) events find probability of "spoilers" fn(L_bxb)

That gives "effective luminosity" = 45/pb cf 532/pb delivered. (0.086)





After all cuts, found 16 e+e- events, QED prediction 17.1 events

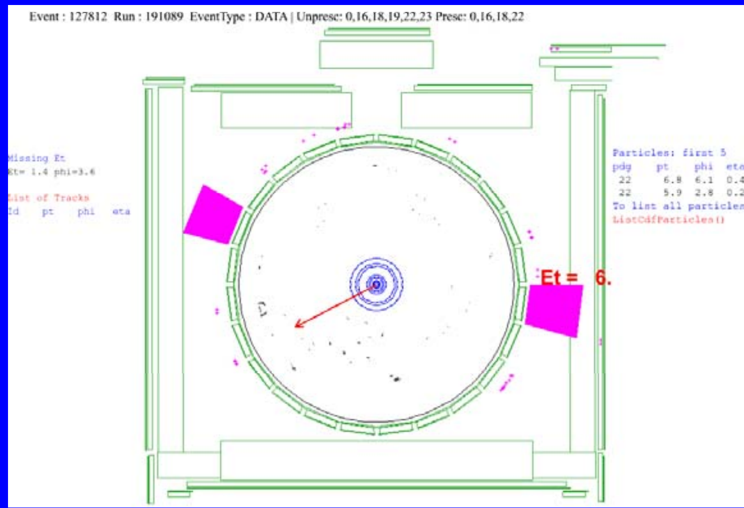
→We understand the exclusivity cuts

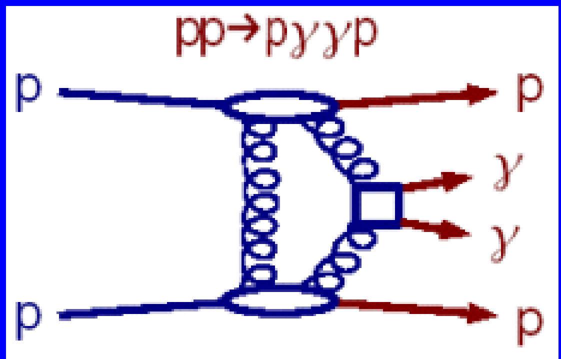
Phys.Rev.Lett. **98**, 112001 (2007)

3 events had no tracks to showers, except one clear photon conversion.

But experimentally identical except no tracks in 2-photon case

Efficiency(tracking) = 100% for isolated ch. particles with $p_T > 1$ GeV/c and $|\eta| < 1.0$



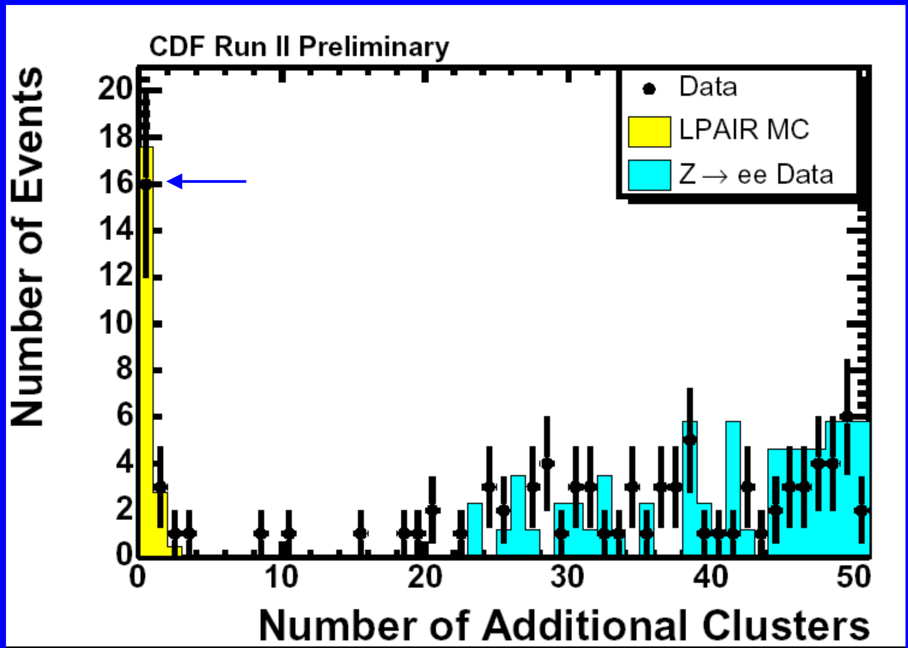


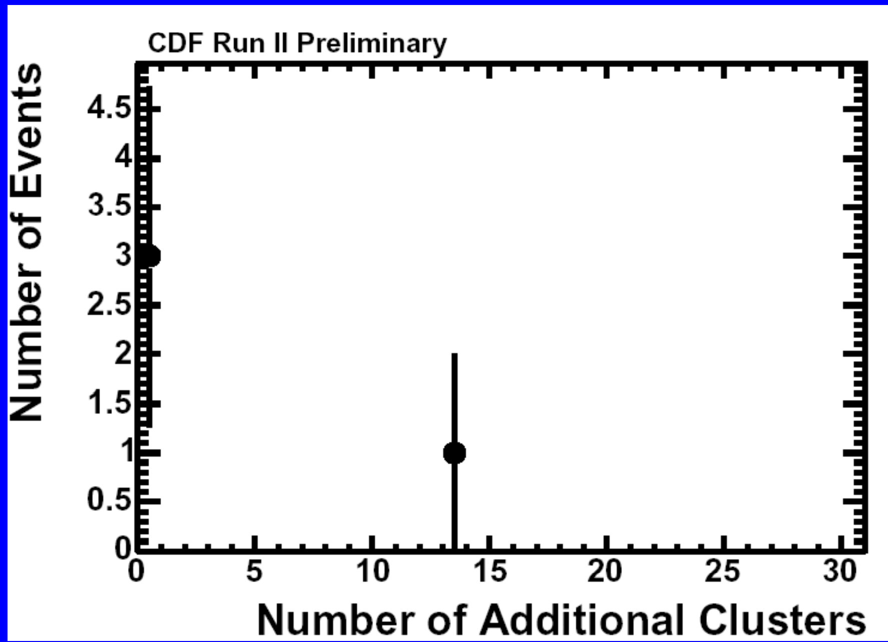
For exclusive production in $p\bar{p}$

$\gamma\gamma \to \gamma\gamma$ is < 5% and $q\bar{q} \to \gamma\gamma$ is < 1%

of $gg \to \gamma\gamma$ (but they are signal not b/g)

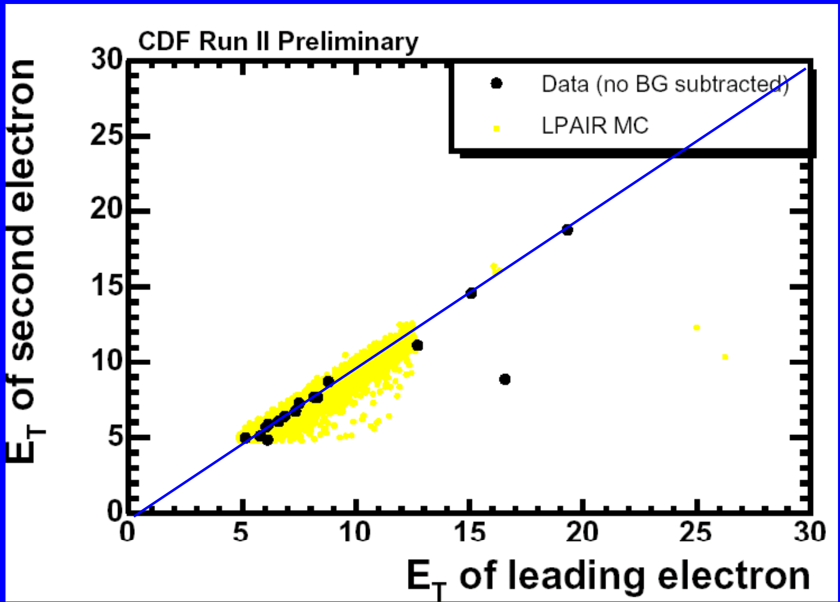
Non-exclusive background: With Forward BSC and calorimetry in noise ("empty") count clusters (not = particles) in addition to 2 EM showers. Left plot is with e+e- events, b/g fit gives 0.3 +- 0.1 under 16 signal (0 bin). Right plot: require no tracks for $\gamma\gamma$ candidates: 0.06 +- 0.03 under 3 events

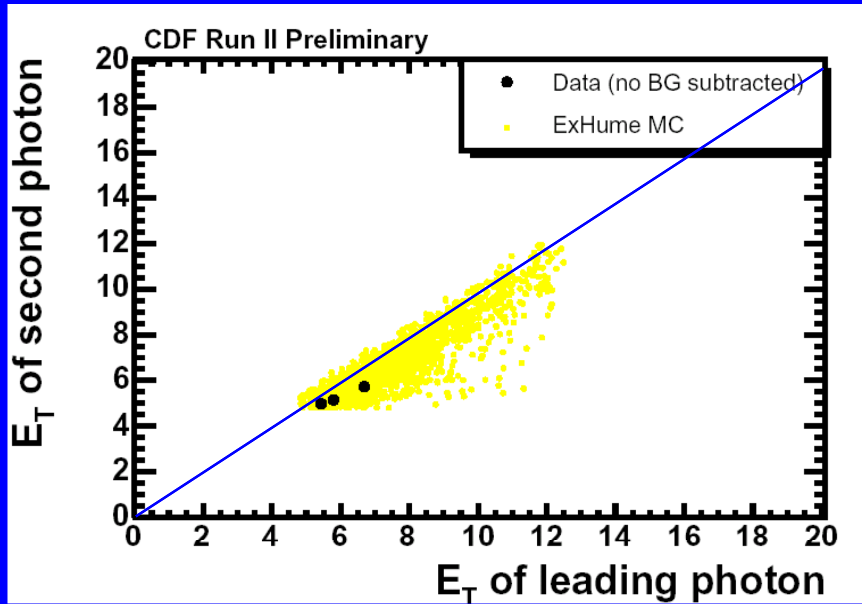




Left plot: pT balance between e+ and e- (one e bremmed)

Right plot: ET balance between photon candidates.





Can the 3 candidates be exclusive $\pi^0\pi^0$ or $\eta\eta$ rather than $\gamma\gamma$?

$\gamma\pi, \gamma\eta$ are forbidden by C-parity

$\pi\eta$ is forbidden by isospin

Theory (Durham): $\pi^0\pi^0 / \gamma\gamma \approx 0.25$ and $\eta^0\eta^0 / \gamma\gamma \approx 1$

We will give an upper limit on the $\gamma\gamma$ cross section, which is valid independent of the $\pi^0\pi^0$ and $\eta\eta$ background in the 3 candidates. It is:

$$\boxed{\begin{array}{l} (\gamma\gamma + \pi^0\pi^0 + \eta\eta) \text{ observed}, \; p = 1.7\times10^{-4}, 3.7\sigma \\ \sigma(p\bar{p} \to p + \gamma\gamma + \bar{p}) \leq 410 \text{ fb (95\% cl)} \\ p_T(\gamma) \geq 5 \text{ GeV/c}; |\eta(\gamma)| < 1.0 \end{array}}$$

Backgrounds to 3 candidates:

Expected number of e+e- with neither track fitted … 0.02 +- 0.02
(Conservative because not even hits in COT)

Expected number with undetected p/pbar dissociation 0.01 +- 0.01
(note: this b/g only exists if fully exclusive process exists)

Expected number associated multiplicity distribution fluctuates to 0,
or associated particle(s) missed (in noise or cracks) … 0.06 +- 0.02

Cosmic background is negligible.

Add backgrounds, & add uncertainties in quadrature $\boxed{0.090 \pm 0.037}$

p-value: convolute Gaussian with Poisson = 1.7 10^-4 = 3.7 sigma

3 $\gamma\gamma$ candidates: A,B,C

Have 2 (standard) handles:
1) CES_chi^2 from fit to shower shape in wires/strips cf. electrons
2) N_CES = Number of found clusters in CES chamber

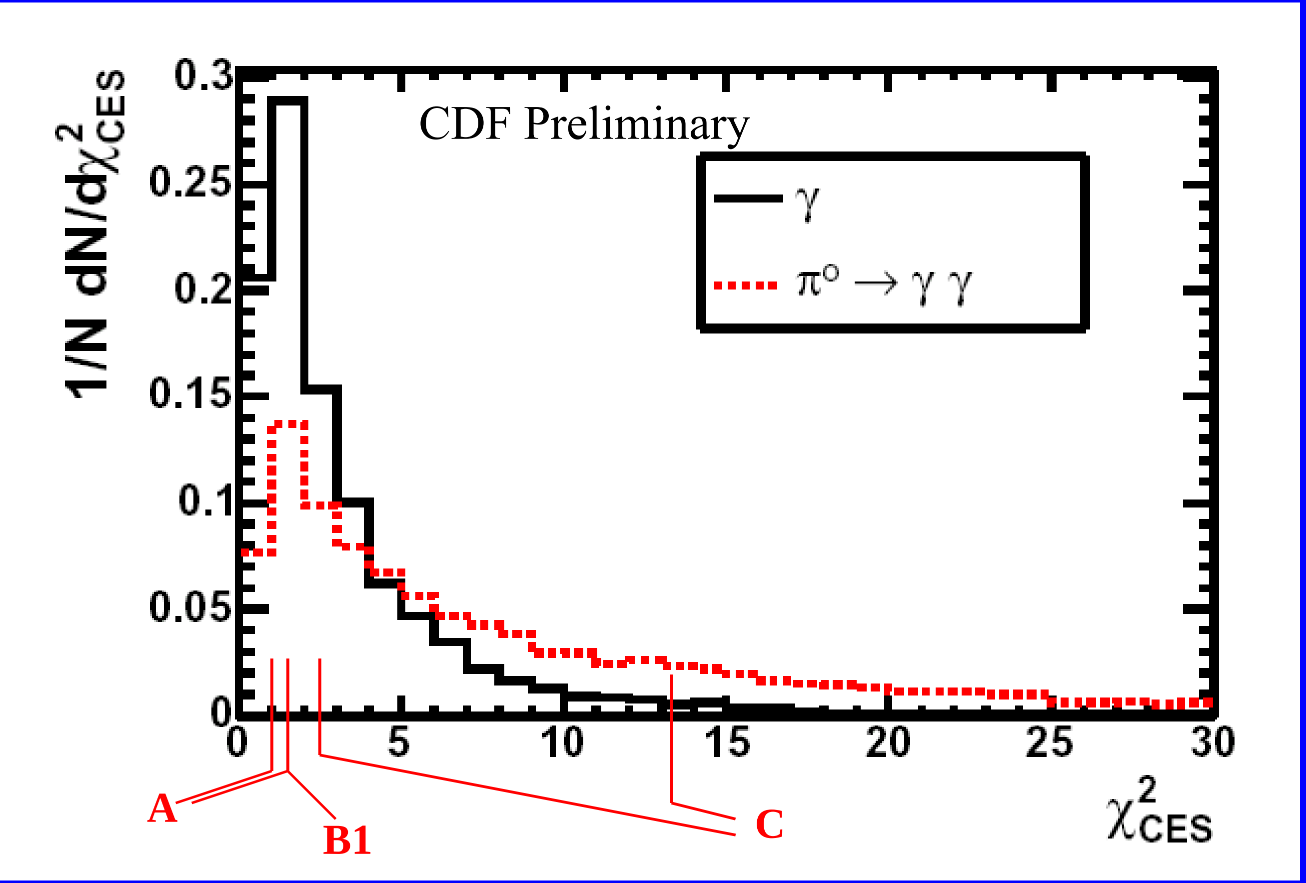
Properties of the 3 candidates.

Event	S	E_T(GeV)	(η,ϕ)	$N_{\rm CES}$	$\chi^2_{\rm CES}$	P(π°)	P(γ)
A	A1	6.8	(0.44,6.11)	1	1.0	0.14	0.26
	A2	5.9	(0.19,2.83)	1	1.3	0.19	0.36
B	B1	5.0	(-0.07,4.86)	1	1.4	0.21	0.39
	B2	5.4	(0.67,1.66)	2	n.a.	n.a.	n.a.
C	C1	6.0	(-0.44,1.66)	1	13.4	0.89	0.98
	C2	5.1	(0.22,5.05)	2	2.2	0.33	0.57

conversion

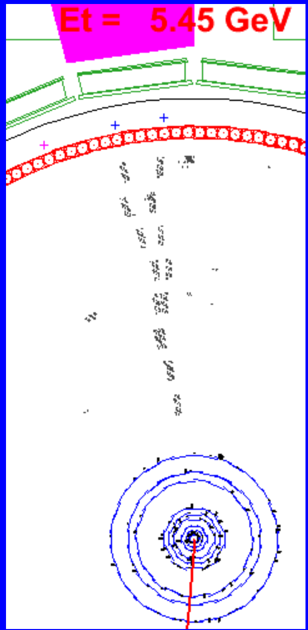
$P(\pi^0)$ and $P(\gamma)$: Probability that π^0 and γ have $\chi^2_{CES} \leq$ observed

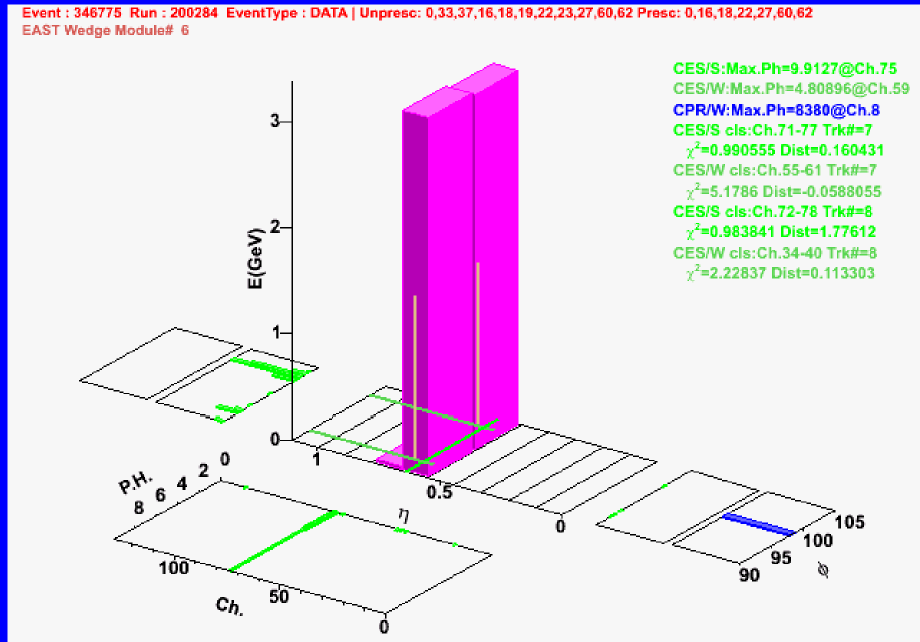
From simulation the probability of one photon from pio/eta not being detected in the CES, by ranging out or not interacting, is 0.125 +/- 0.025.



Using this we calculate probabilities that a γ or a π^0 will have a χ^2_{CES} as small as or smaller than the observed value.

Shower B2 (conversion)





Tracks same η but diverge in ϕ (+/-)

$p_T(e^+) = 3.0$ GeV/c ; $p_T(e^-) = 2.4$ GeV/c

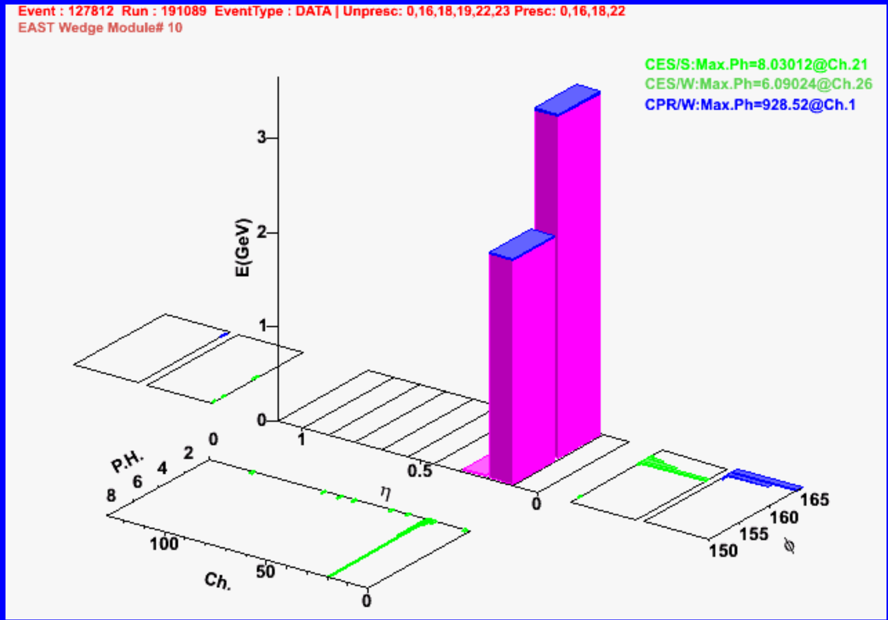
$\sum p_T = 5.40$ GeV/c $\leftrightarrow E_T(\mathrm{cal}) = 5.45 \pm 0.35$ GeV

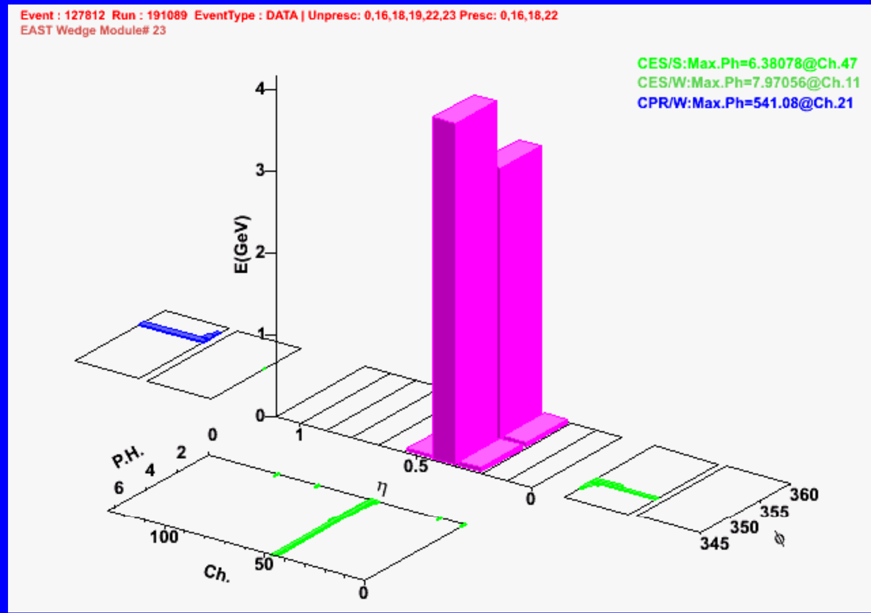
Any other γ had $E_T < 0.55$ GeV (95%c.l)

$P(\pi^0/\eta) < 10\%$ so asymmetric

Run/Event 191089/127812 (Event A)

CES strip/wire chambers at 6 Xo in EM calorimeter





Event	S	E_T(GeV)	(η,ϕ)	N_{CES}	χ^2_{CES}	P(π^0)	P(γ)
A	A1	6.8	(0.44,6.11)	1	1.0	0.14	0.26
	A2	5.9	(0.19,2.83)	1	1.3	0.19	0.36

Both sides are single narrow showers.

Conclusion: We have observed:

3 candidates for exclusive $(\gamma\gamma + \pi^0\pi^0 + \eta\eta)$ production

May be mixture

$\mathrm{B/G} = 0.09 \pm 0.04$; $\mathrm{P}(\geq 3) = 1.7 \times 10^{-4} \equiv 3.7\sigma$

$\sigma(\gamma\gamma) < 410$ fb (95% c.l.)

A, B favor $\gamma\gamma$ and C favors $\pi^0\pi^0$

If we assume that 2 of the 3 candidates are gamma-gamma events we obtain a cross section: $\sigma(2\text{ events}) = (90^{+120}_{-30} \pm 16)$ fb

cf

Durham Group Khoze, Martin, Ryskin & Stirling
hep-ph/0507040 Eur.Phys.J C38 (2005) 475 :
40 fb with factor 3 uncertainty

Existence of exclusive $\gamma\gamma$ implies that exclusive H must exist (if H exists)

Agreement with Durham group suggests H cross section at LHC in reach