Issues concerning diffractive Higgs production at the LHC

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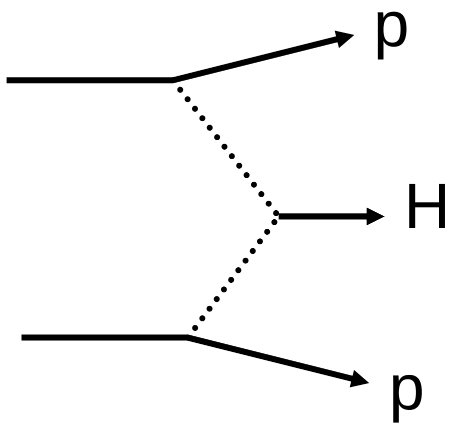
(also with A.B. Kaidalov)



Alan Martin (Durham)
2nd HERA-LHC Workshop
CERN, 6-9th June, 2006

$pp \to p + H + p$

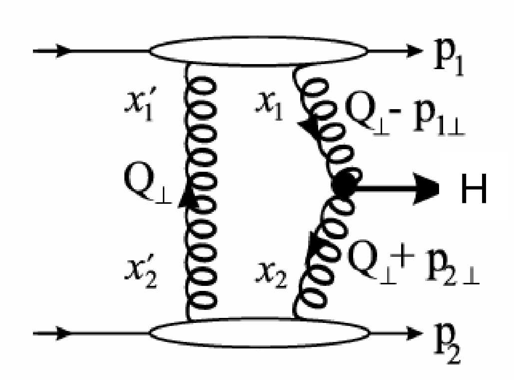
- If outgoing protons are tagged far from IP then $\sigma(M) = 1$ GeV (mass also from H decay products)
- Very clean environment
- $H \to b\bar{b}$: QCD $b\bar{b}$ bkgd suppressed by $J_z=0$ selection rule, and by colour and spin factors

  S/B~1 for SM Higgs M < 140 GeV

  $\mathcal{L}$(LHC)~60 fb^{-1} ~10 observable evts after cuts+effic
- Also $H \to WW$ (L1 trigger OK) and $H \to \tau\tau$ promising
- SUSY Higgs: parameter regions with larger signal S/B~10, even regions where conv. signal is challenging and diffractive signal enhanced----h, H both observable
- Azimuth angular distribution of tagged p's $\to$ spin-parity 0^{++}

FP420: tagging, L1 trigger, pile-up…..
see talks by Brian Cox, Monika Grothe, Marek Tasevsky…

Reliability of pred^n of $\sigma(pp \rightarrow p + H + p)$ crucial



$$\sigma \sim \frac{\hat{S}^2}{b^2} \left| N \int \frac{dQ_t^2}{Q_t^4} f_g(x_1, x_1', Q_t^2, \mu^2) f_g(x_2, x_2', Q_t^2, \mu^2) \right|^2$$

contain Sudakov factor T_g which exponentially suppresses infrared Q_t region → pQCD

$$f_g(x, x', Q_t^2, \mu^2) = R_g \frac{\partial}{\partial \ln Q_t^2} \left[\sqrt{T_g(Q_t, \mu)}\, xg(x, Q_t^2) \right]$$

S^2 is the prob. that the rapidity gaps survive population by secondary hadrons → soft physics → S^2=0.026 (LHC)
S^2=0.05 (Tevatron)

$\sigma(pp \rightarrow p + H + p)$ ~ 3 fb at LHC for SM 120 GeV Higgs
~0.2 fb at Tevatron

Background to $pp \rightarrow p + (H \rightarrow b\bar{b}) + p$ signal

DKMOR

assuming ΔM_{miss}~3 GeV

LO (=0 if m_b=0, forward protons) — **B/S**

$gg \rightarrow gg$ mimics $gg \rightarrow b\bar{b}$ (P(g/b)=1%)

	B/S
after polar angle cut	0.2
$\lvert J_z \rvert$=2 admixture (non-forward protons)	0.25
m_b^2/E_T^2 contribution	<0.2

HO $(gg)_{col.sing} \rightarrow b\bar{b}+ng$

Still suppressed for soft emissions.

Hard emissions if g not seen:

	B/S
extra gluon along beam $M_{miss} > M_{bb} \rightarrow$	0
extra g from initial g along b or $\bar{b}$	0.2

Pom-Pom inel. prod. $B/S < 0.5(\Delta M_{bb}/M_{PP})^2$ <0.004

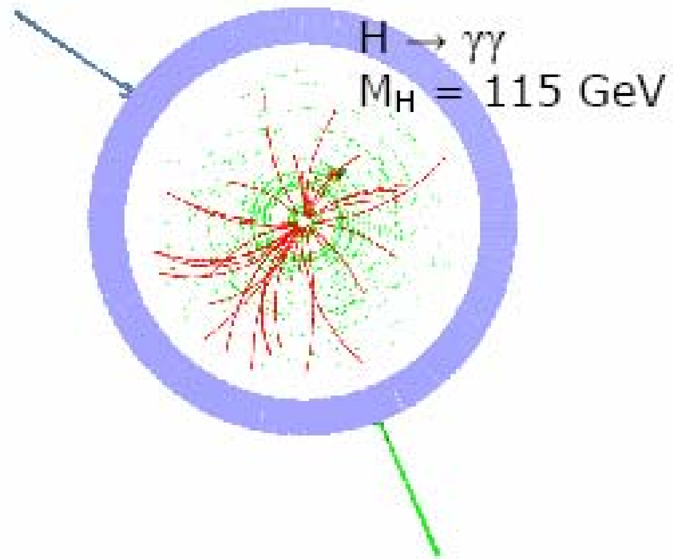
for M=120 GeV→ total B/S~1

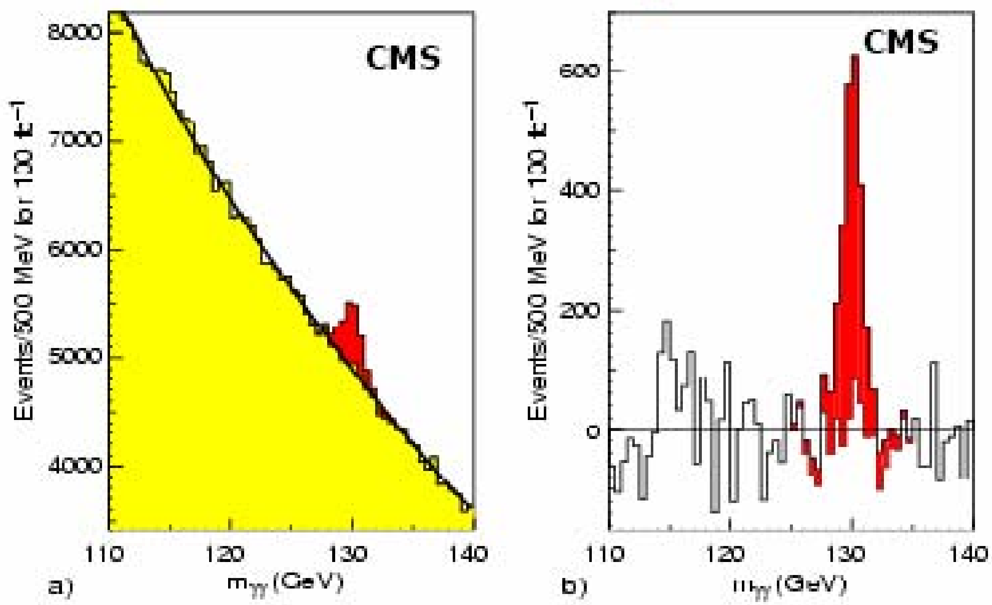
$S \sim 1/M^3$, $B \sim \Delta M/M^6$: triggering, tagging, ΔM better with rising M

$H \to \gamma\gamma$

- Sigma x BR ~90 fb for M_H = 110-130 GeV
- Irreducible backgrounds from $gg \to \gamma\gamma$, $qq \to \gamma\gamma$, $pp \to \gamma$ jet $\to \gamma\gamma$ jet
- Reducible background from fake photons from jets and isolated π^0
- Vertex estimated from the underlying event and recoiling jet
- Very good mass resolution ~1%

conventional
signal for SM
110-130 GeV Higgs





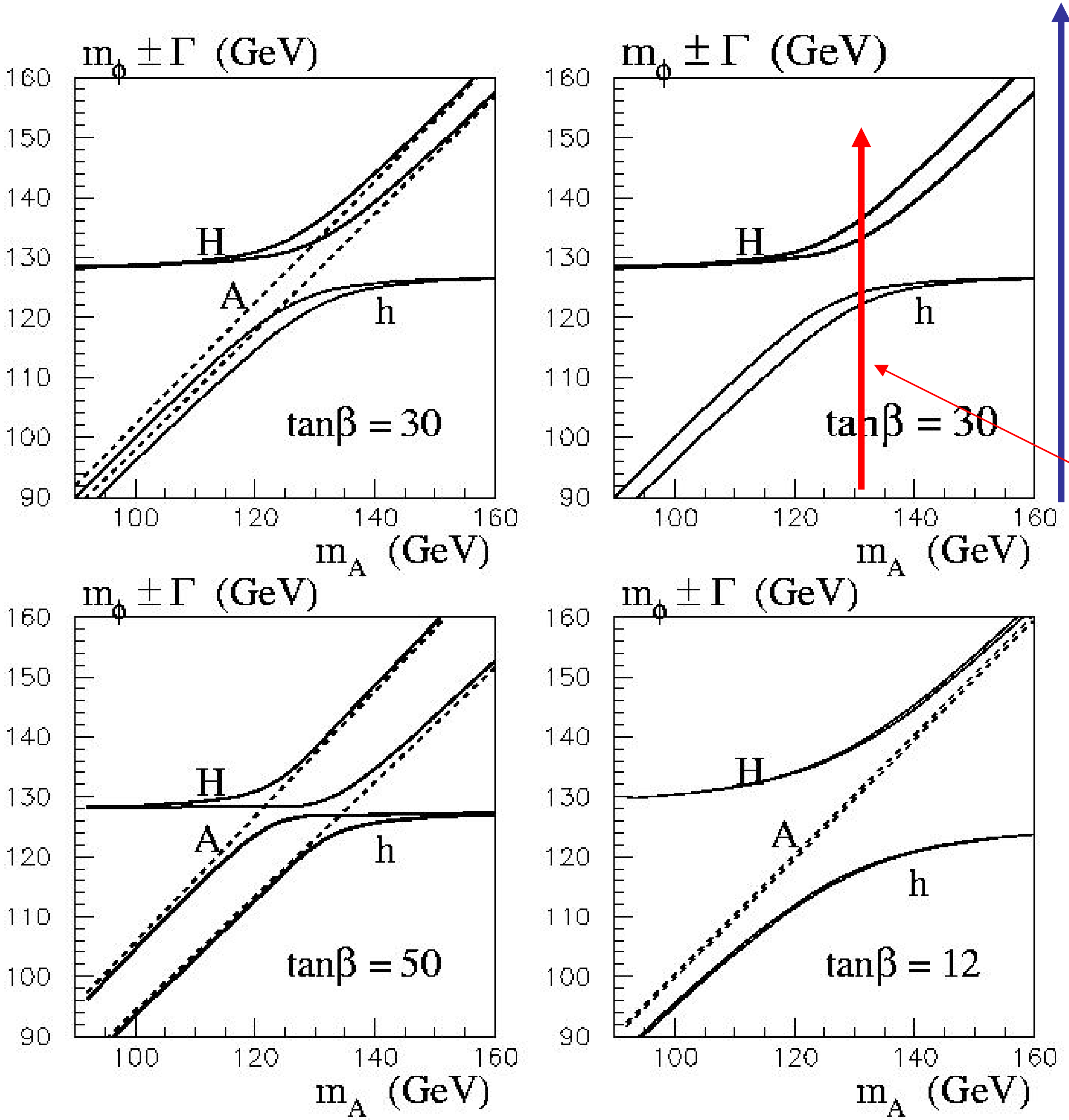
SUSY Higgs: h, H, A, (H^+, H^{--})

There are parameter regions where the

$$pp \rightarrow p + (h,H) + p$$

signals are greatly enhanced in comparison to the SM

Selection rule favours 0^{++} diffractive production



decoupling regime:
$m_A \sim m_H > 150$
h = SM
H,A→ ττ (bb)

intense coup:
$m_h \sim m_A \sim m_H$
γγ,WW.. coup. suppressed

SM: pp $\rightarrow$ p + (H$\rightarrow$bb) + p   S/B~10/10~1

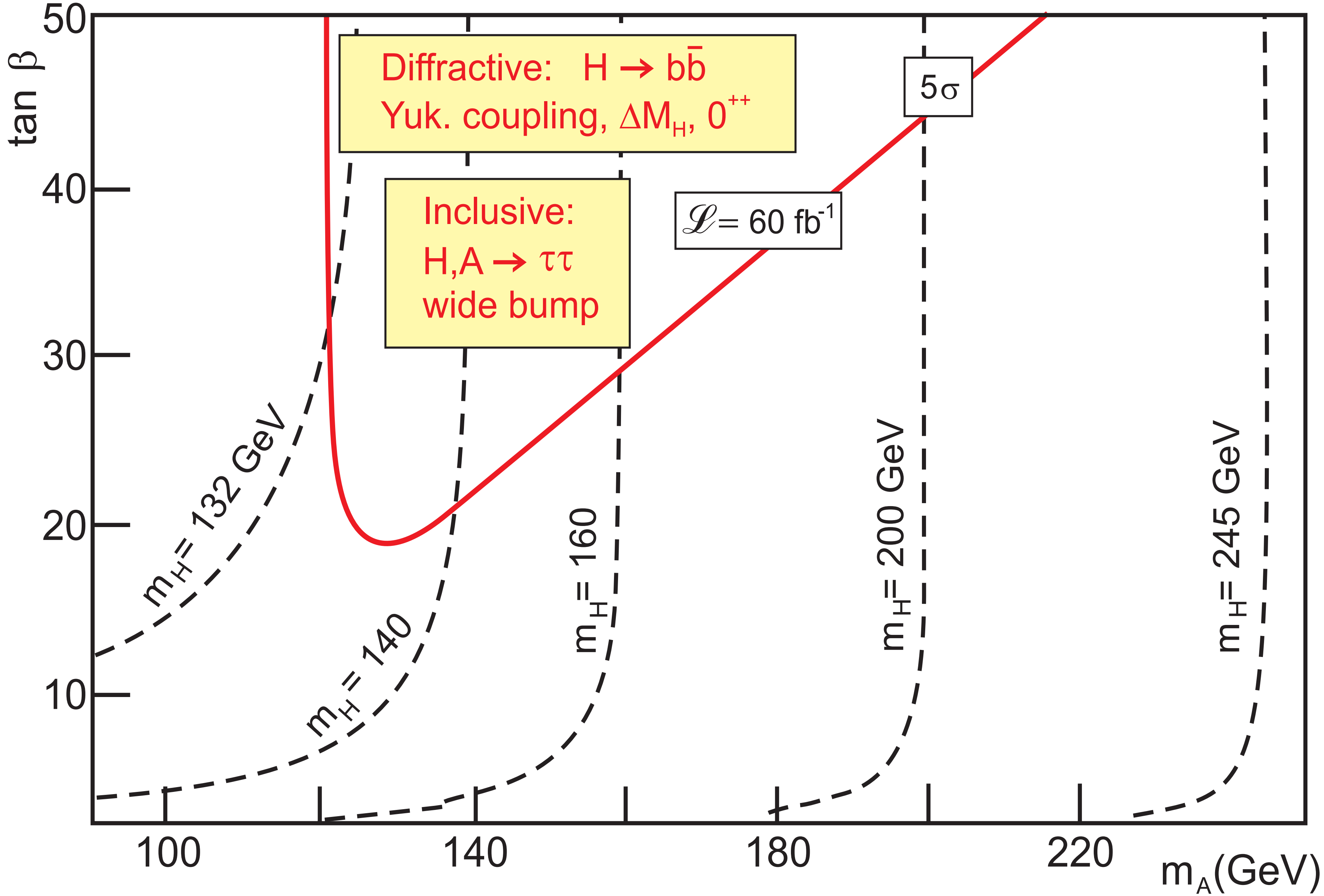
with ΔM = 3 GeV, at LHC with 60 fb^{-1}

e.g. m_A = 130 GeV, tan β = 50

(difficult for conventional detection, but exclusive diffractive favourable)

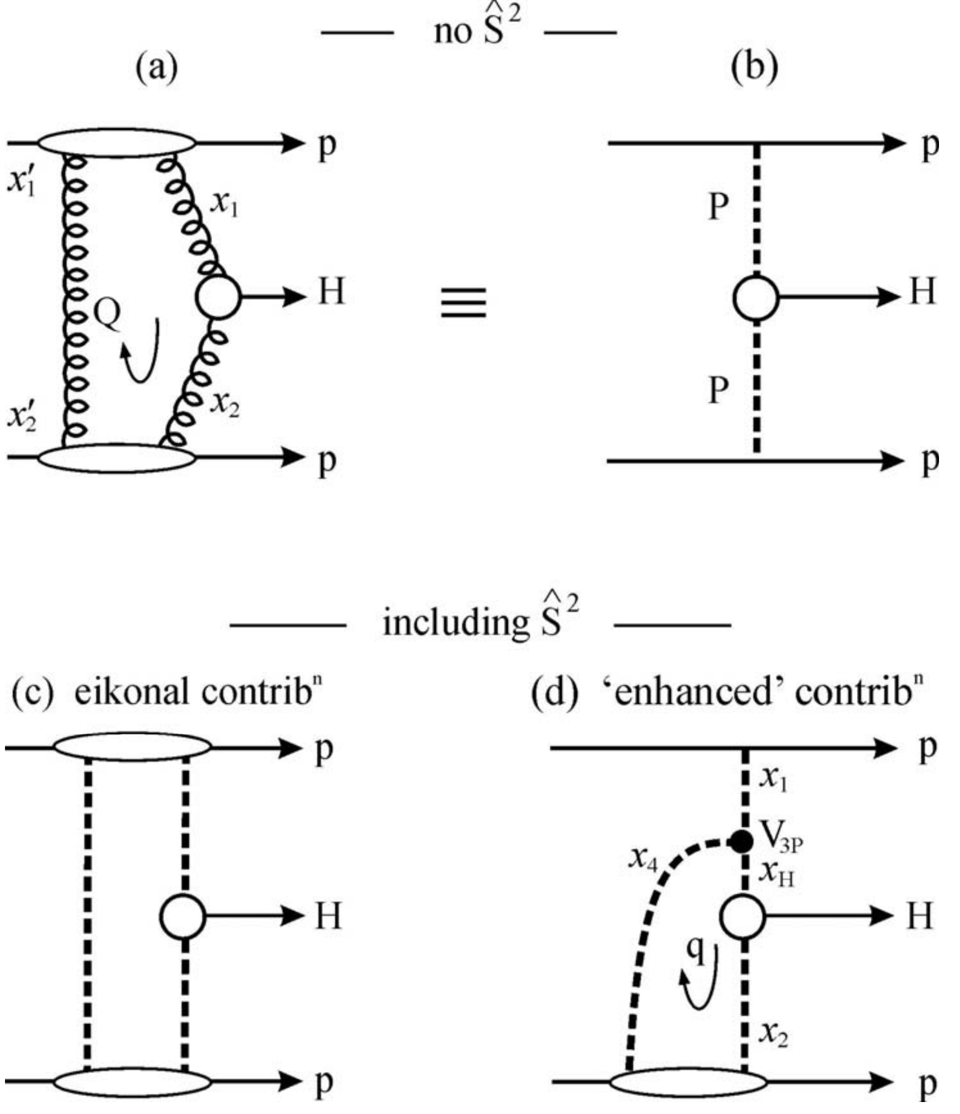
	S	B	
m_h = 124.4 GeV	71	10	events
m_H = 135.5 GeV	124	5	
m_A = 130 GeV	1	5	

enhancement



Adapted from a preliminary plot of Tasevsky et al.

"enhanced" correction to σ_H(excl)?



eikonal

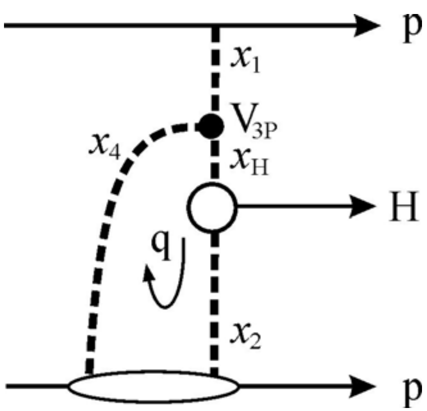
$S^2 = 0.026$

enhanced

KMR: using 2-channel eikonal
Gotsman,Levin,Maor..
Lonnblad, Sjodahl,
Bartels,Bondarenko,Kutak,Motyka

BBKM→use pert.thy.→corr^n could be large and -ve,→ σ_H(excl) reduced ?
KMR → pQCD invalid → strong coup regime → small effect

BBKM use pQCD to calculate enhanced diagram



$$M_1 \sim \int \frac{dx_4}{x_4} \int \frac{d^2 q_t}{2\pi^2} \int \frac{d^2 k_{t,4}}{k_{t,4}^4} \, f_g(x_4, k_{t,4}^2, \ldots) \, V_{3P} \, M_0$$

(x_4 can be v.small, 10^{-5})

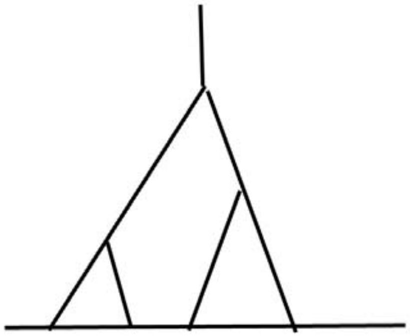
BK eq.

LL

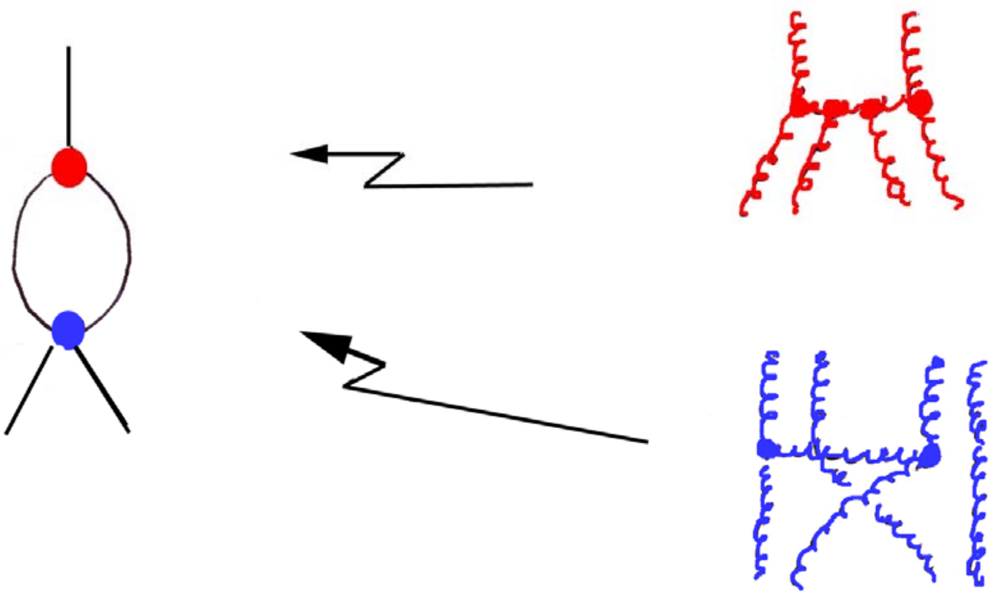
Infrared stability only provided by saturation momentum, $Q_S(x_4)$.
Hope is that at v.low x_4, Q_S allows use of pQCD.
Gluon density is unknown in this region!

BUT multi-(interacting)-gluon Pomeron graphs become important.
These can strongly decrease the effective triple-Pomeron vertex V_{3P} ,
see for example Abramovsky.

True expansion is not in α_S, but in prob. P of additional interaction.
Pert.theory → saturation regime where P=1, dominated by rescattering of
low k_t partons, but already included in phenomenological soft pp amp.



Typical fan diagram, included in the BK eq.



α_s^2

Basic vertex for fan diagrams

$\frac{\alpha_S}{N_c^2}$

Not included !!

Other arguments why "enhanced" correction is small

KMR '06

- ΔY threshold

Original Regge calc. required $\Delta Y \sim 2\text{-}3$ between Regge vertices

(Recall NLL BFKL:

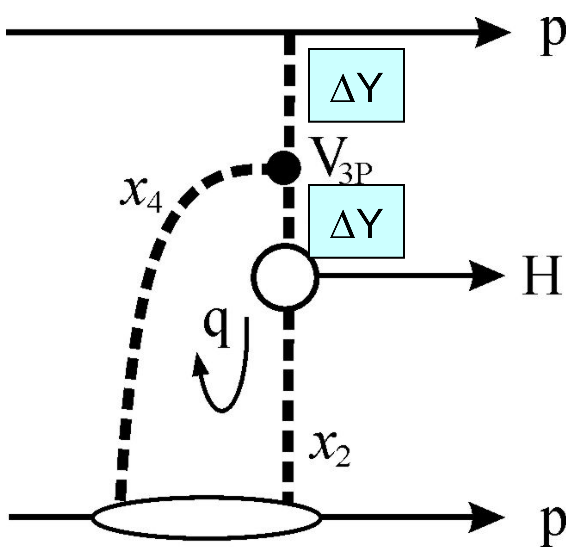
Schmidt; Forshaw,Ross,Sabio Vera

→ major part of all-order resum has kinematic origin

→ $\Delta Y \sim 2.3$ threshold implied by NLL → tames BFKL)

Applying to enhanced diagram need $2\Delta Y > 4.6$, but at LHC only $\log(\mathrm{sqrt}(s)/M_H)$ available for $y_H=0$

= 4.6 for M_H=140 GeV



Higgs prod. via enhanced diagram has v.tiny phase space at LHC

Global fit to "soft" data

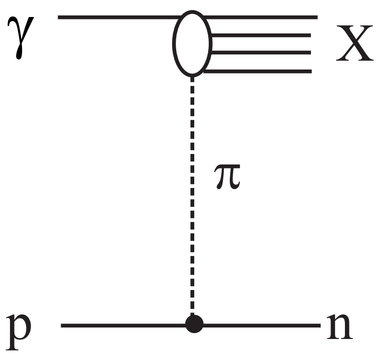
If enhanced diag. important,

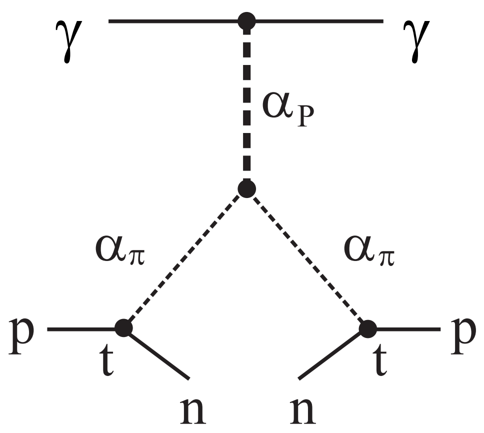
then must include in σ_{tot}, σ_{SD} … in global soft fit

So to calc. S^2 need to fit "soft" data with enhanced rescatt. in
--redistributes abs. effects between eik. and enh.--total S^2 same

Analogously pred^n for σ_{tot}(LHC) has v.weak model dep.
if model fits existing soft data

σ_{SD}, sensitive to enh. effects, ~flat from 50 GeV,
so expect no extra suppression of diffraction at LHC



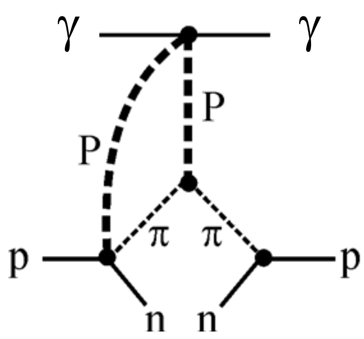


- Leading neutron prod. at HERA

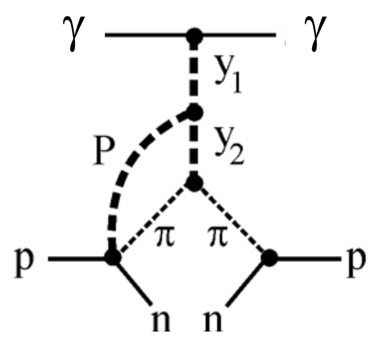
KKMR '06

gap due to π exchange
~ exclusive Higgs

eikonal



enhanced



$y_i > 2 - 3$

correction prop. to rap. interval
prop. to γ energy

(negative)

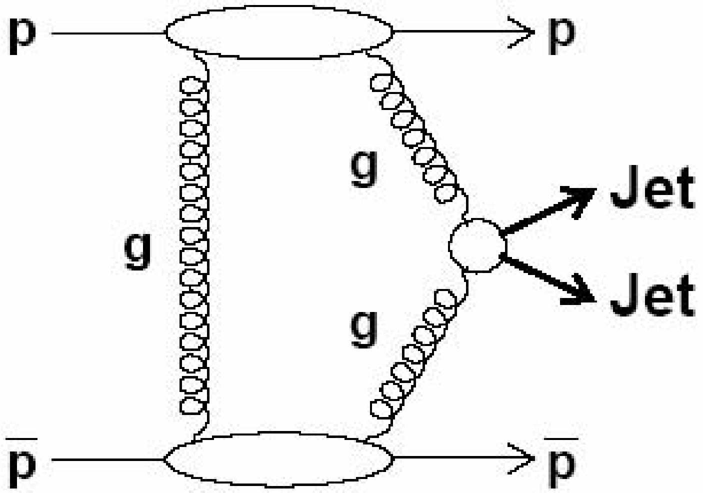
Prob. to observe leading neutron must decrease with γ energy

But expt. → flat

→ small enhanced correction

Tevatron can check exclusive Higgs prod. formalism

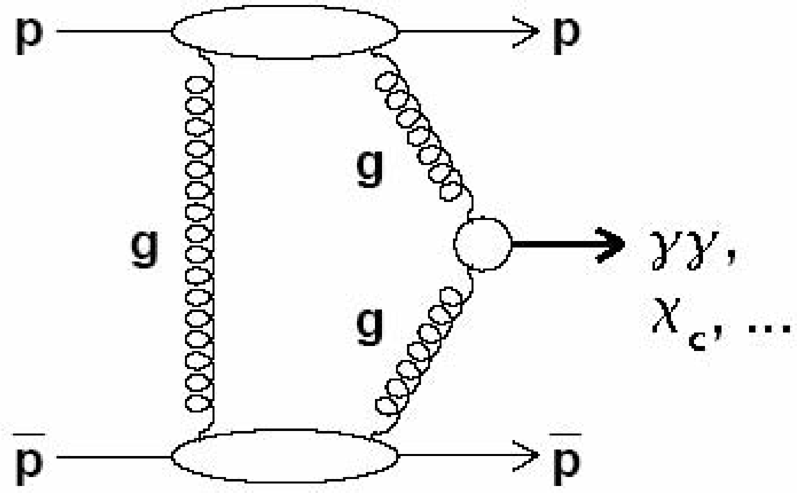
Exclusive Dijet



$gg \rightarrow gg, q\bar{q}g, \ldots$

$gg \rightarrow q\bar{q}$ $J_z=0$ suppressed

Exclusive $\gamma\gamma$, χ_c

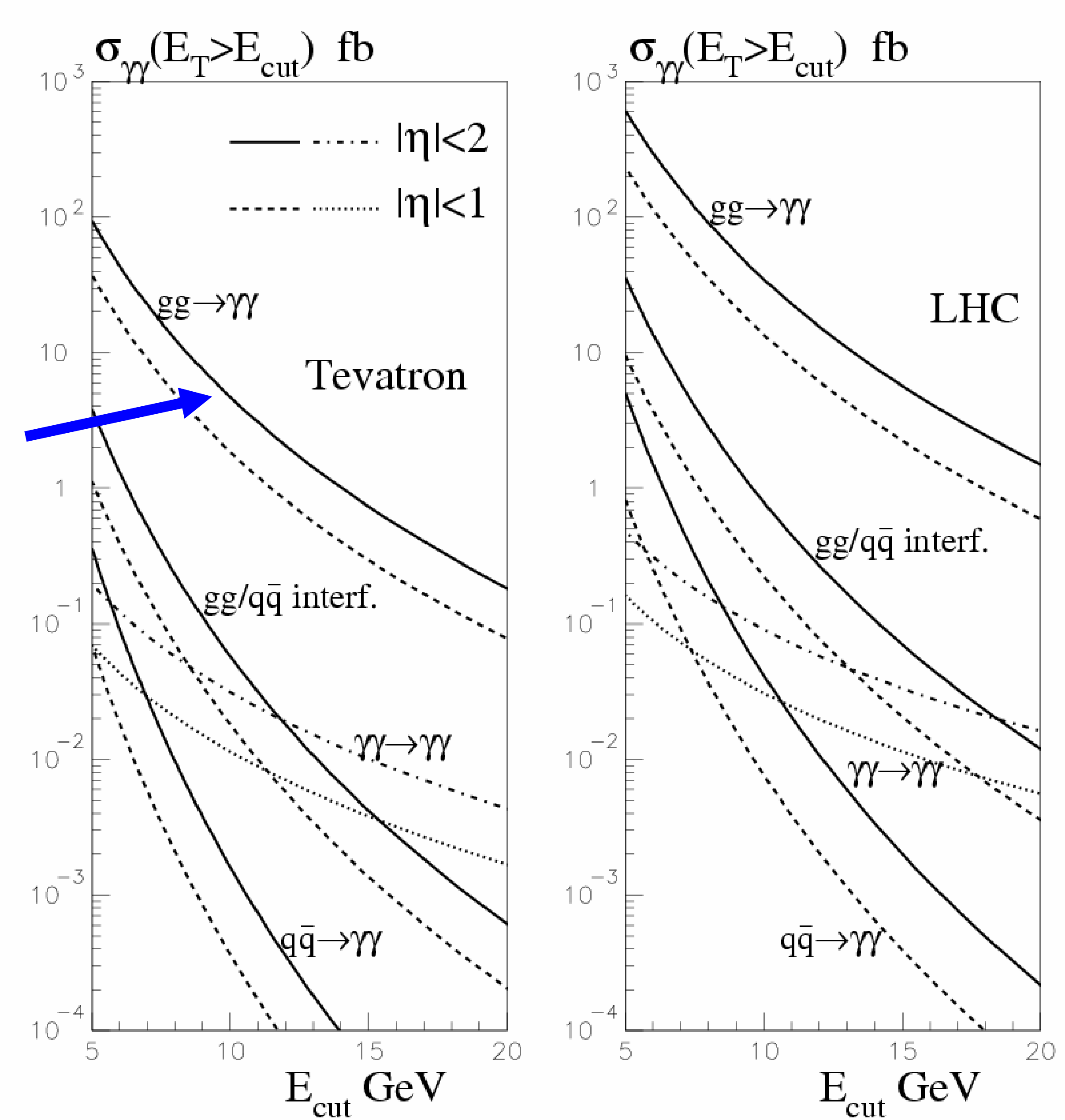


$gg \rightarrow \gamma\gamma$, $gg \rightarrow \chi_c, \ldots$

clean signatures

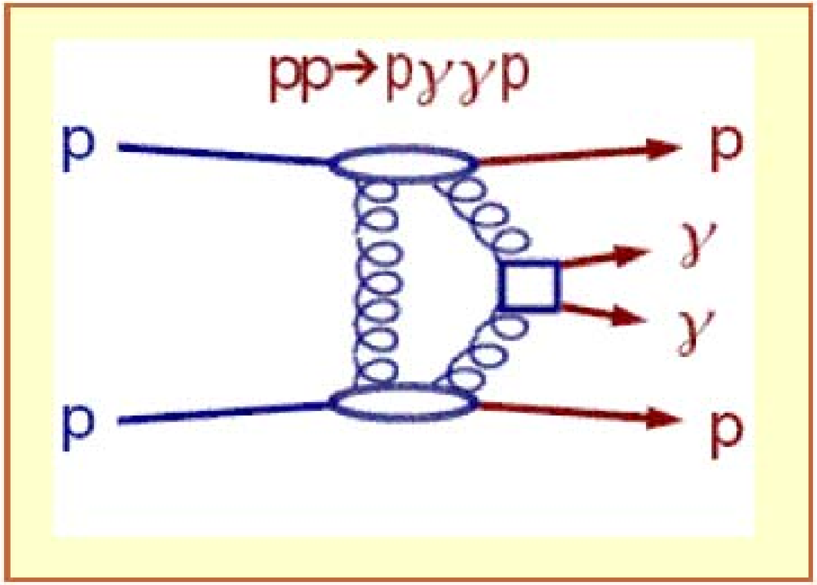
Measure exclusive dijet and $\gamma\gamma$ cross sections to calibrate predictions for exclusive Higgs production at the LHC

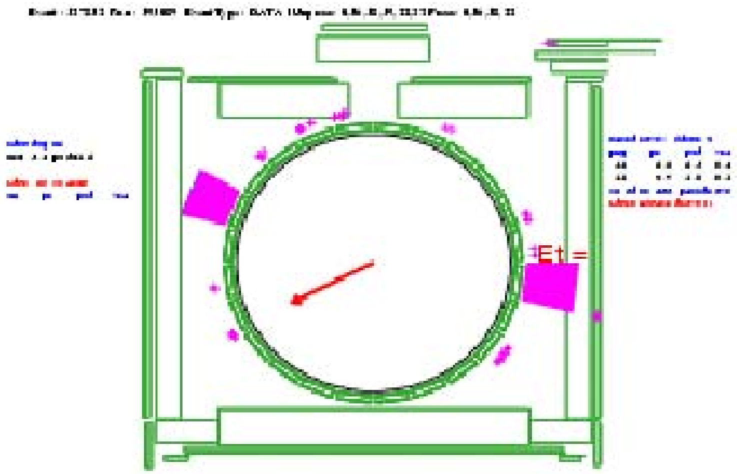
$p\bar{p} \rightarrow p + \gamma\gamma + \bar{p}$

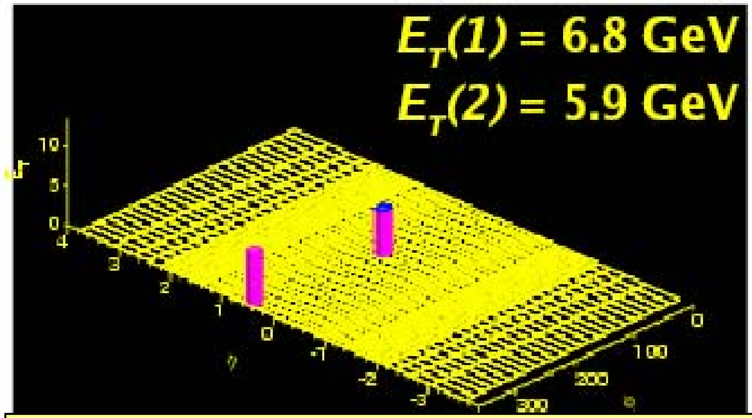


KMR+Stirling

Exclusive γγ Candidates







3 candidate events observed

no background estimate yet

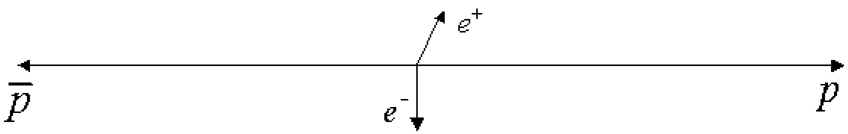
1^{+3}_{-1} events predicted by ExHuME Monte Carlo

(based on Khoze, Martin, Ryskin, Ref: Eur. Phys. J. C38, 475-482, 2005)

Measurements with $M_{\gamma\gamma}$=10-20 GeV could confirm σ_H(excl) prediction at LHC to about 20% or less

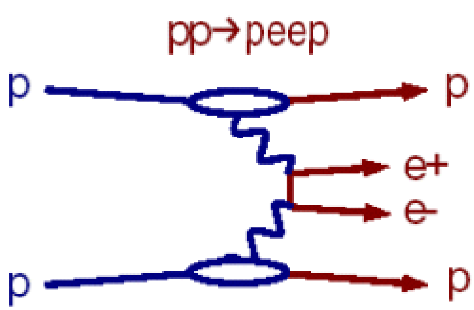
CDF, Albrow et al.

Exclusive e^+e^- pairs



16 events observed

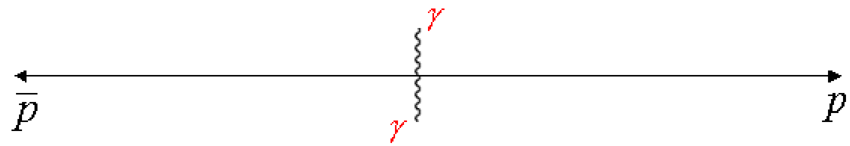
Estimated background = $2.1^{+0.6}_{-0.3}$
(mostly p-dissociation)
$\sigma_{MEAS.} = 1.6\ ^{+0.5}_{-0.3}\ (\text{stat}) \pm 0.3\ (\text{syst})$ pb
Poisson Prob. = $3\times10^{-8} \approx 5.5\sigma$



QED: LPAIR Monte Carlo

$\sigma_{QED} = (1.711 \pm 0.008)$ pb

Exclusive $\gamma\gamma$ pairs



3 events observed

Estimated background = $0.0\ ^{+0.3}_{-0.0}$ events
(p-dissociation, exclusivity, fakes)
$\sigma_{MEAS.} = 0.14\ ^{+0.14}_{-0.04}\ (\text{stat}) \pm 0.03\ (\text{syst})$ pb
Poisson Prob.$(0.3 \rightarrow \geq 3) = 3.6\times10^{-3}$
(conservative)
KMR (Durham) prediction = $0.04 \times\div$ (3-5) pb

Note: $\sigma_{MEAS} \approx 2\times10^{-12}\sigma_{INEL}$!

It means exclusive H must happen (if H exists) and probably $\sigma \sim 10$ fb within factor ~ 2.5.
σ higher in MSSM

100 $\gamma\gamma$ evts per 100 pb^{-1} at LHC!

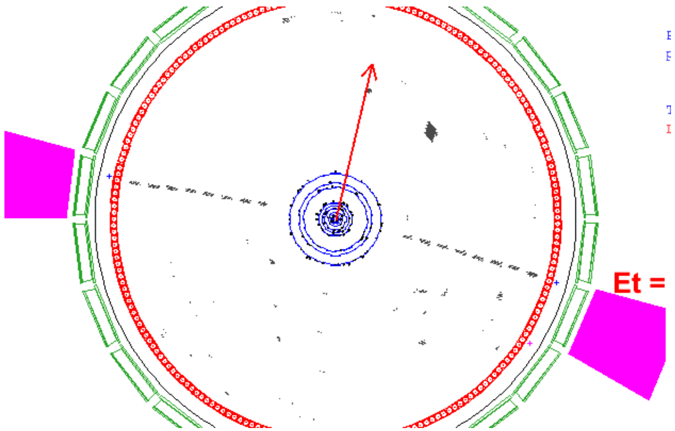
Albrow

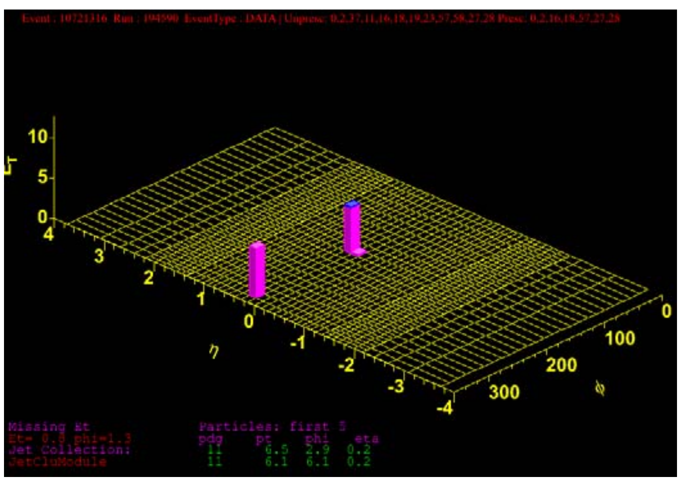
16 events were like this:

$e^+e^-: \qquad \Delta\phi = 180^0 \pm 2^0$

$M(e^+e^-)\, 10 \rightarrow 38$ GeV

Δp_T small ($\cong$ resolution)



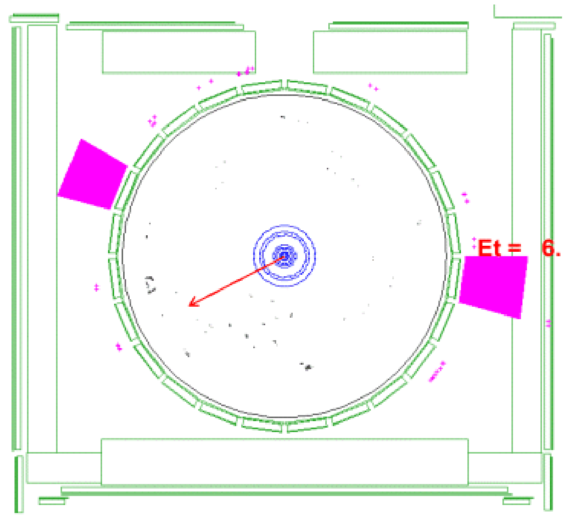


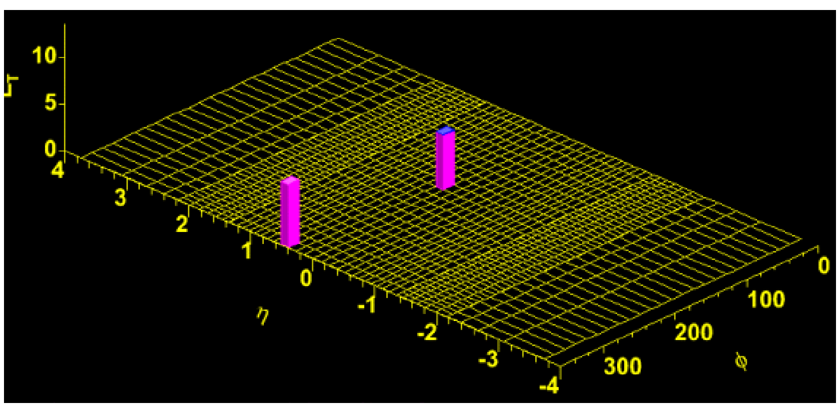
3 events were like this:

$\gamma\gamma: \qquad \Delta\phi > 170^0$

$M(e^+e^-)\, 10 \rightarrow 20$ GeV

ΔE_T small





$p\bar{p} \rightarrow p + jj + \bar{p}$

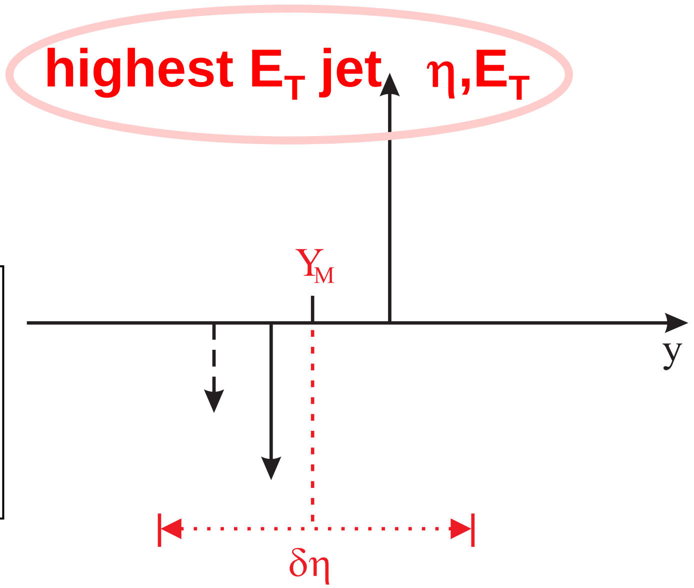
Exptally more problematic due to hadronization, jet algorithms, detector resolution effects, QCD brem…

Data plotted as fn. of $R_{jj} = M_{jj}/M_X$, but above effects smear out the expected peak at $R_{jj} = 1$ (ExHuME MC)

Better variable:

$$R_j = (2E_T \cosh \eta^*)/M_X$$

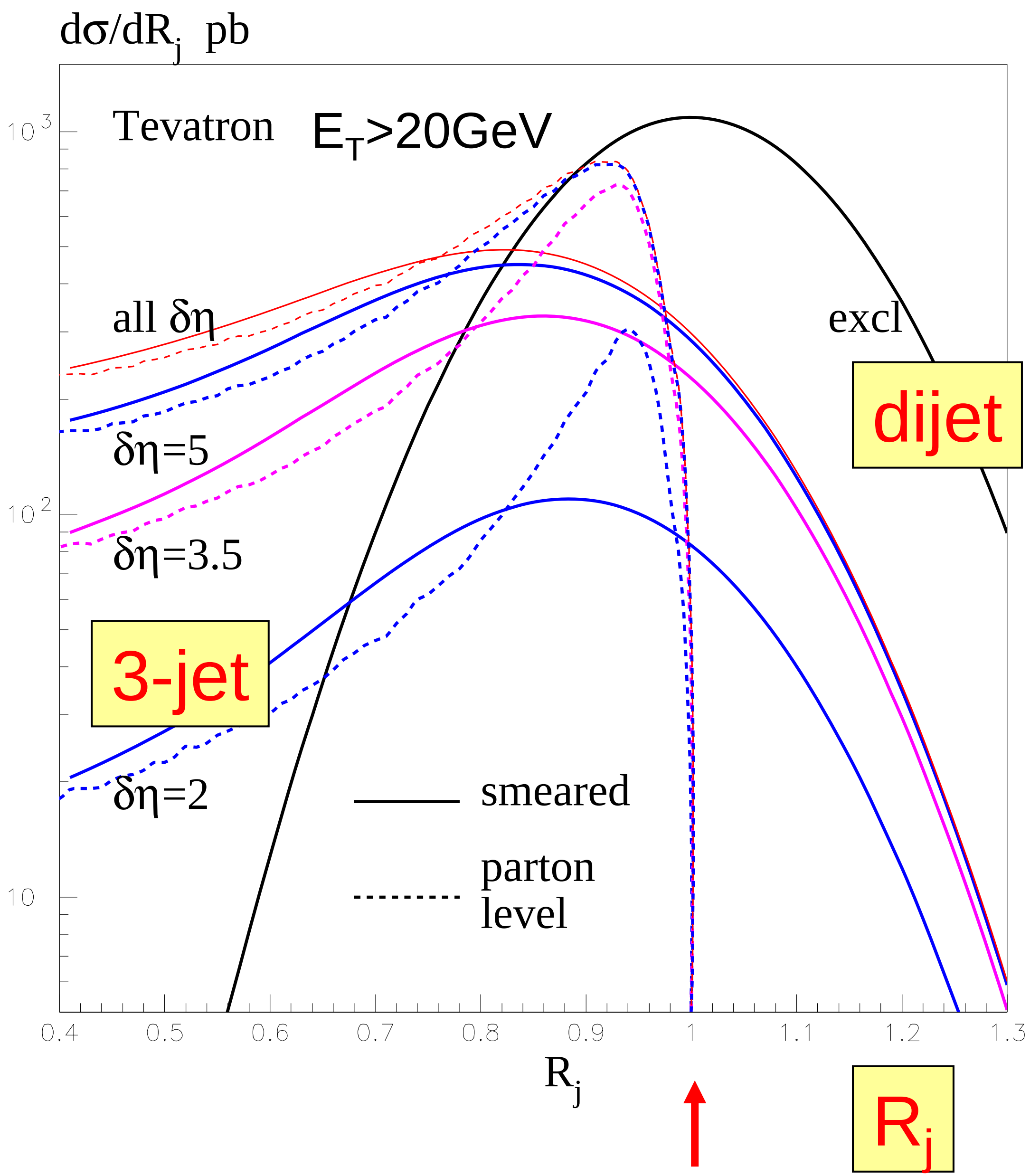
with $\eta^* = \eta - Y_M$

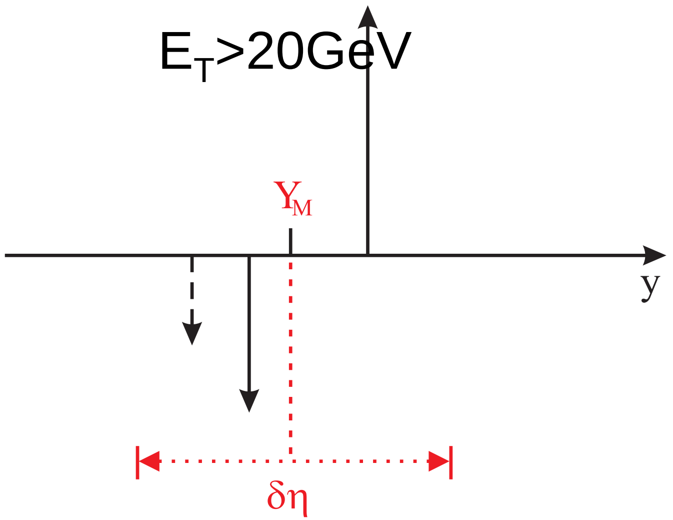


R_j not changed by $O(\alpha_S)$ final state radiation, need only consider extra jet from initial state. Prod.of other jets have negligible effect on R_j due to strong ordering

We compute exclusive dijet and 3-jet prod (and smear with Gaussian with resolution σ=0.6/sqrt(E_T in GeV))

Exclusive dijet and 3-jet prod





dijets dominate $R_j > 0.8$

3-jets dominate $R_j < 0.7$

KMR, 2006

Conclusion

- The exclusive diffractive signal is in pretty good shape. The cross section predictions are robust. Checks are starting to come from Tevatron data ($\gamma\gamma$,dijet…)

- There is a very strong case for installing proton taggers at the LHC, far from the IP ---- it is crucial to get the missing mass ΔM of the Higgs as small as possible

- The diffractive Higgs signals beautifully complement the conventional signals. Indeed there are significant SUSY Higgs regions where the diffractive signals are advantageous
  ---determining ΔM_H, Yukawa $H \rightarrow bb$ coupling, 0^{++} determin^n
  ---searching for CP-violation in the Higgs sector