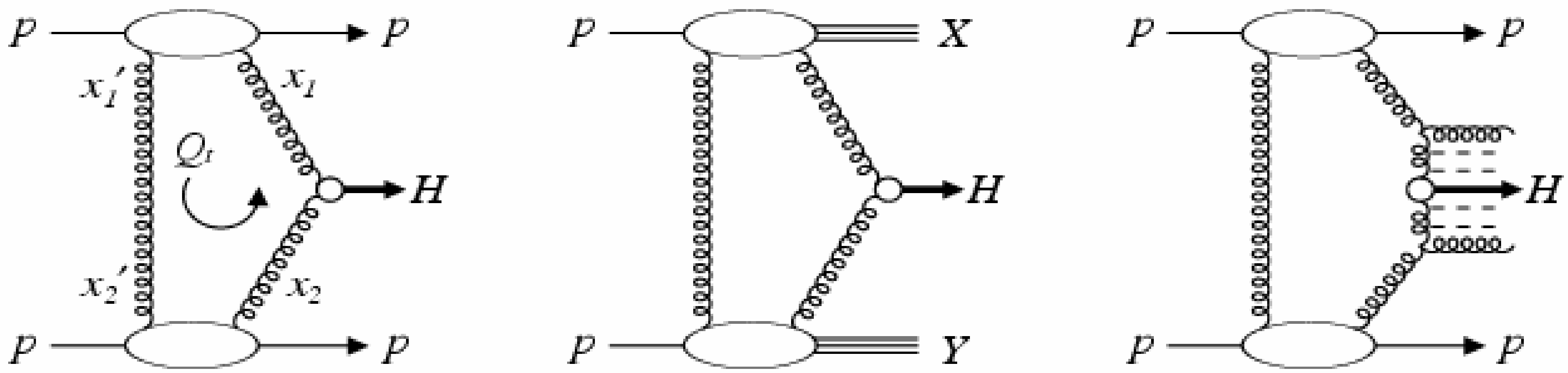
Diffractive Higgs production

Kaidalov, Khoze, Martin, Ryskin, Stirling

- Introduction
- SM Higgs pp → p + H + p
- Calculation of bb_{bar} background
- 0^+ and 0^- Higgs diffractive production
- SUSY Higgs diffractive production
- standard candles: excl. χ, $\gamma\gamma$, jj prod.

Physics at LHC, Vienna, July 2004
Alan Martin (IPPP,Durham)

(a) exclusive	(b) inclusive	(c) central-inelastic



(a) exclusive	(b) inclusive	(c) central-inelastic
$M_{miss} = M_H$	no M_{miss}	$M_{miss} > M_H$
$J_z = 0$ rule for background	no rule	no rule
$S/B \sim 3$	$S/B \sim 0.01$	$S/B \sim 0.001$
pile-up may be overcome	pile-up problems	pile-up may be overcome

pp → p + H + p

Detection of Higgs

- Big expt$^{\underline{al}}$ challenge if Higgs is 'light'

  ($m_H \lesssim 130\,\text{GeV}$)

- Need to use all possible ways

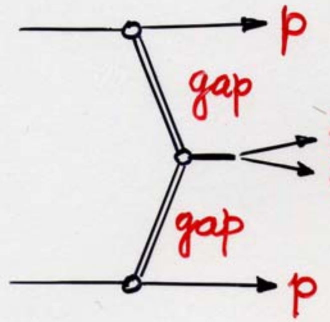
- Unique signal if forward proton taggers are installed at the LHC

$$pp \to p + H + p$$

Khoze, M, Ryskin

Exclusive Diffractive Higgs Production

$$pp \to p + H + p$$



+De Roeck, Orava

- $M_H = \begin{cases} M(b\bar{b}) \\ M_{missing} \end{cases}$ if p's tagged
  $\Delta M_{miss} \sim 1\,\mathrm{GeV}$

- LO background $gg \to b\bar{b}$
  V. suppressed (by $J_z = 0$ selection rule)
  (= 0 for $m_q = 0$ and forward p's)

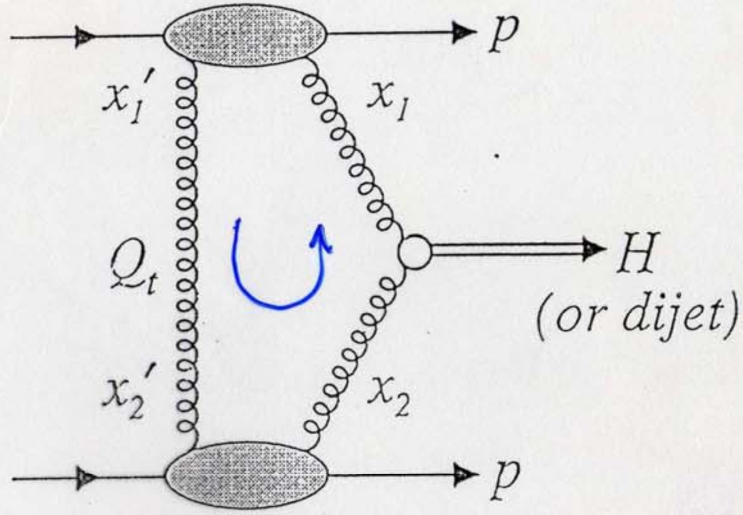
- The 'price' of the gaps ?

$pp \to p + H + p$

Survival prob. of rap. gaps

$$W = S^2 \; T^2$$

price for: no soft rescatt. (S^2); no g rad^n in $gg \to H$ (T^2)



$$\Lambda^2_{QCD} \ll Q_t^2 \ll M_H^2 \quad \to \text{pQCD}$$

$$\left(x' \sim \frac{Q_t}{\sqrt{s}}\right) \ll \left(x \sim \frac{M_H}{\sqrt{s}}\right) \ll 1$$

need unintег. skewed gluons

$pp \to p + H + p$

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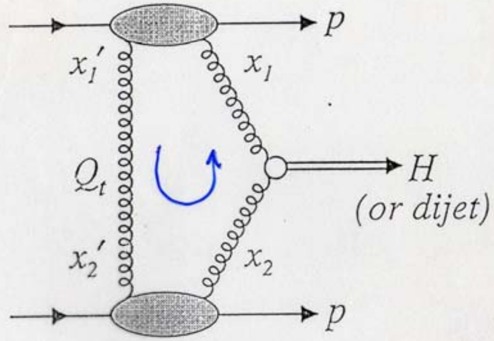

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need uninteg. skewed gluons

$$\mathcal{M} = \frac{A}{M_H^2} \int \vec{Q}_{1t} \cdot \vec{Q}_{2t} \, \frac{d^2 Q_t}{Q_t^6} \, f\left(x_1, x_1', Q_t^2, \frac{M_H^2}{4}\right) f\left(x_2, x_2', Q_t^2, \frac{M_H^2}{4}\right)$$

where $f(x, x', Q_t^2, \mu^2) \approx R \, \frac{\partial}{\partial \ln Q_t^2} \left[\sqrt{T(Q_t, \mu)} \, x g(x, Q_t^2) \right]$

R is calculable skewed effect (R=1.2 at LHC)

$$T(Q_t, \mu) = \exp\left(- \int_{Q_t^2}^{\mu^2} \frac{dk_t^2}{k_t^2} \frac{\alpha_s}{2\pi} \int_0^{1-k_t/\mu} dz \, z P_{gg} \ldots \right)$$

strongly suppresses Q_t infrared region

no emission when $(\lambda \sim 1/k_t) > (d \sim 1/Q_t)$

i.e. only emission with $k_t > Q_t$

$pp \rightarrow p + H + p$

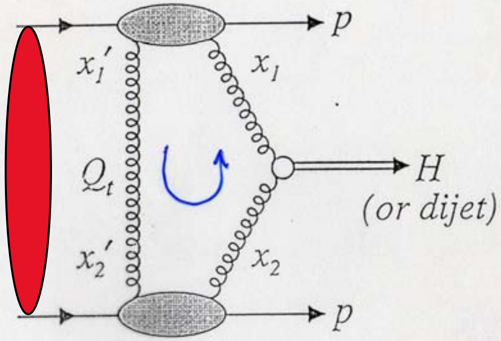
Survival prob. of rap. gaps

$$W = S^2 \, T^2$$

price for [no soft rescatt.] → S^2; [no g rad^n in $gg \rightarrow H$] → T^2

calculated using detailed 2-channel eikonal global analysis of soft pp data
$S^2 = 0.026$ at LHC
$S^2 = 0.05$ at Tevatron

Lonnblad Monte Carlo
$S^2 = 0.026$
$S^2 = 0.040$



$$\Lambda^2_{QCD} \ll Q_t^2 \ll M_H^2 \rightarrow \text{pQCD}$$

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strongly suppresses Q_t infrared region

$M_H = 120\text{GeV}$ →

$$\sigma(p + H + p) \simeq \begin{cases} 3 \text{ fb} & \text{at LHC} \\ 0.2 \text{ fb} & \text{at Tevatron} \end{cases}$$

Description of soft hadronic processes

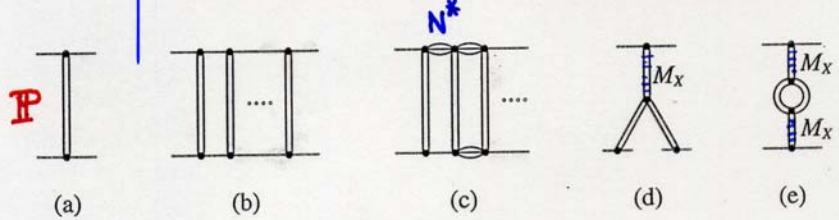
DL:

$\alpha_{eff} = 1.08 + 0.25t$

describes $\frac{d\sigma_{el}}{dt}$, σ_{tot}

but $\sigma_{SD} \sim s^{2\alpha_{eff}-2}$

multi $\mathbb{P}$ effects essential



(c): $p \to N^*$, 2 ch. eik, low M diff$^{\underline{n}}$

(d): high M SD

(e): high M DD

(a): $\alpha_{bare} \sim 1.1 - 1.2$

$\alpha'_{bare} \sim 0$

(α'_{eff} from diff^n)

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Global descrip. of σ_{tot}, $\frac{d\sigma_{el}}{dt}$, ρ, σ_{SD}, σ_{DD}, $\langle n_{ch} \rangle$

↑ ISR – Tevatron

Suppression factor / survival prob. of rap. gap

prob. of p to be in diff. estate ϕ_n

prob. of producing heavy system from ϕ_n

prob. to have no inel. reaction

$$S^2 = \frac{\sum_n \int d^2b\, |a_{pn}|^2\, |\mathcal{M}_n|^2\, e^{-\Omega_n}}{\sum_n \int d^2b\, |a_{pn}|^2\, |\mathcal{M}_n|^2}$$

Two-channel:

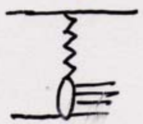
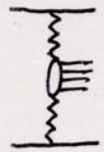
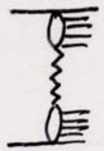
small size

$$\Omega_{val} = (1-\gamma)\,\Omega_0$$

$$\Omega_{g,sea} = (1+\gamma)\,\Omega_0$$

large size

$$\left(\Omega_0 = \frac{g^2 (s/s_0)^{\epsilon}}{4\pi B}\, e^{-b^2/4B}\right.$$

Values of S^2	SD	CD	DD
			
Tevatron	0·10	0·05	0·15
LHC	0·06	0·02	0·10

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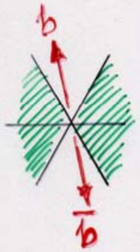
Backgrounds to $pp \to p + H + p$ signal ($H \to b\bar{b}$)

	B/S
• LO (= 0 if $m_q = 0$, forward p's)	
▪ $gg \to gg$ mimics $gg \to b\bar{b}$; $P(g/b) = 1\%$	0.07
▪ $\lvert J_z \rvert = 2$ admixture (non-forward p's)	0.08
▪ m_b^2/E_T^2 contribution	0.06

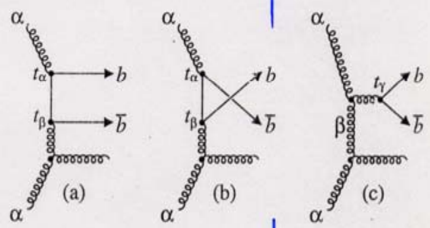


• HO

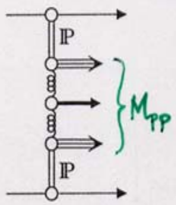
$(gg)_{col.sing} \to b\bar{b}\, ng$

cancell^n of soft emission

($J_z = 0$ rule suppression)



		B/S
▪ extra g along beam ($p_t \gtrsim 1$ GeV, $\eta > 5$)	$M_{miss} > M_{b\bar{b}}$	0
▪ extra g along $b, \bar{b}$		0.06
• Pomeron-Pomeron inel. collisions: $B/S < \frac{1}{2}\left(\frac{\Delta M_{b\bar{b}}}{M_{PP}}\right)^2$		< 0.004



Total B/S ≃ 0.3

First level trigger 2 jets $E_T > 40$ GeV + collinearity + "gapiness"

$LHC \quad \mathcal{L} = 30\ fb^{-1}$ 120GeV Higgs

$\sigma(pp \to p + H + p) = 3 fb$

90 events

↓ efficiency of p taggers

54

↓ $BR(H \to b\bar{b})$

36

↓ $b, \bar{b}$ tag efficiency

22

↓ polar angle cut

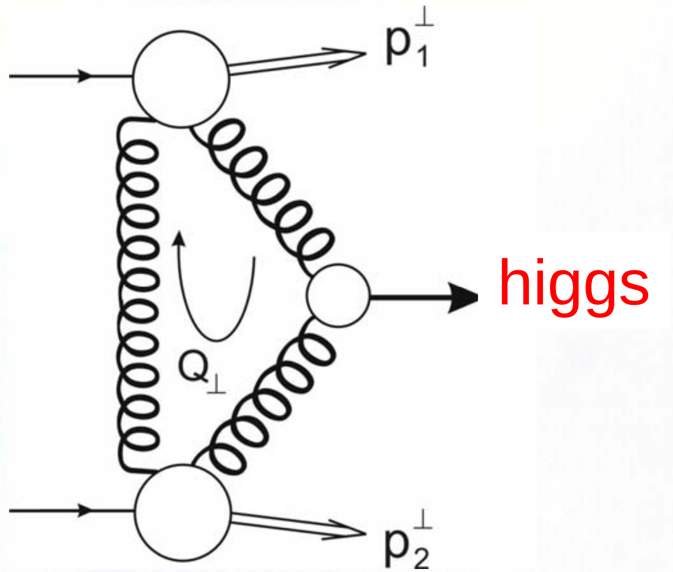
11 events

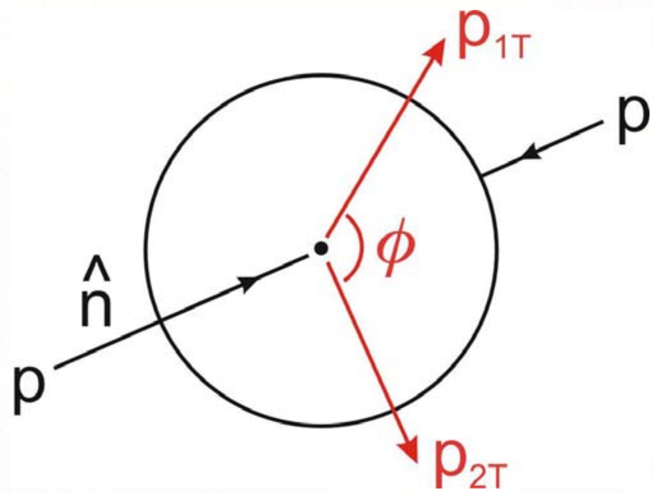
If the bulk of the events are in $\Delta M_{missing}$=1GeV

Value of diffractive SUSY Higgs production KKMR

MSSM: $h, H\ (0^+)$ $A(0^-)$

$pp \rightarrow p_1 + \text{higgs} + p_2$





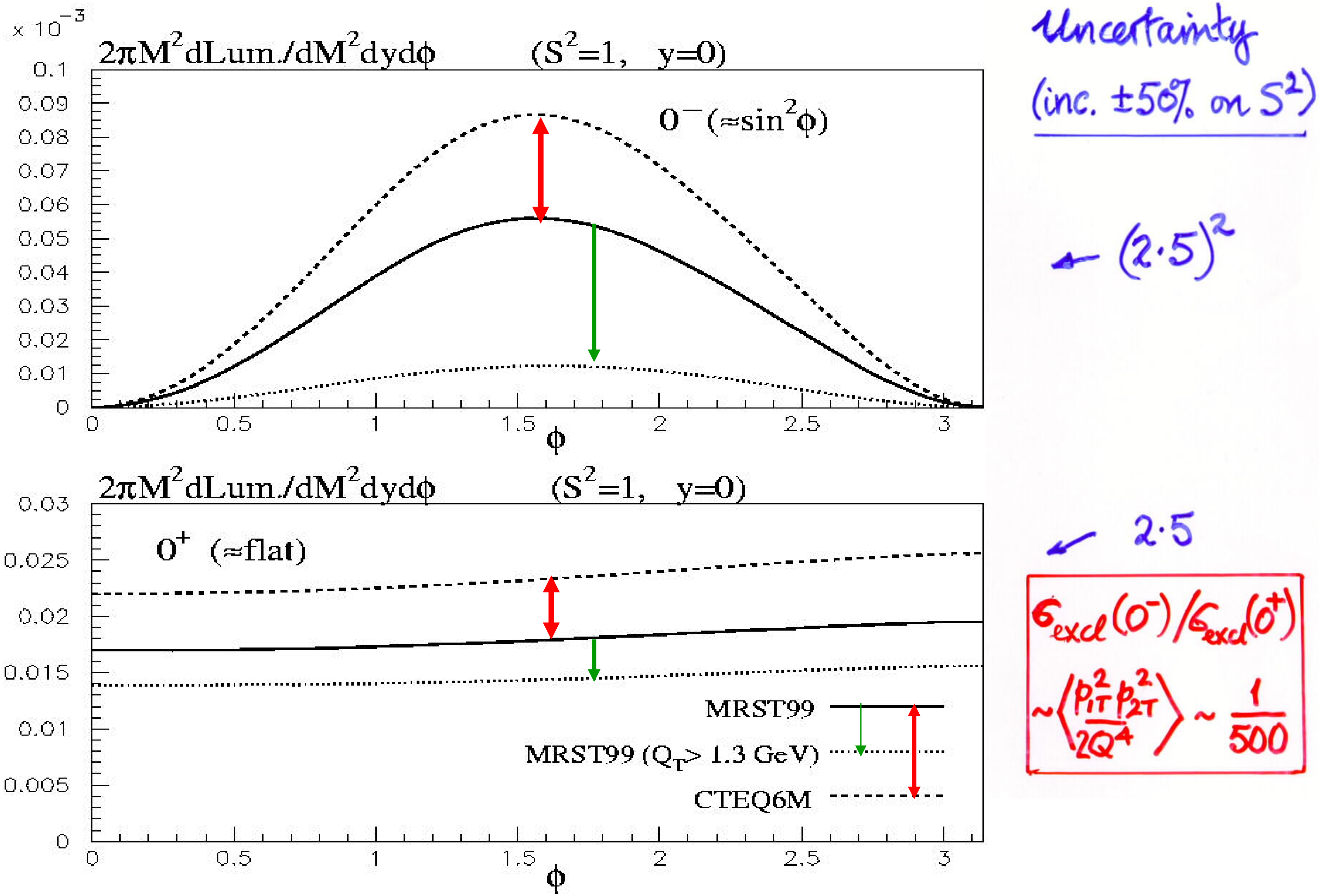
also Regge

$V(0^+) \sim \text{const.},$ $V(0^-) \sim (\vec{p}_{1T} \times \vec{p}_{2T}) \cdot \hat{n} \sim |t_1|^{1/2} |t_2|^{1/2} \sin\phi$

$\int \frac{d^2 Q_T}{Q_T^4}$ for 0^+ $\rightarrow$ $p_{1T}\, p_{2T} \int \frac{d^2 Q_T}{Q_T^6}$ for 0^-

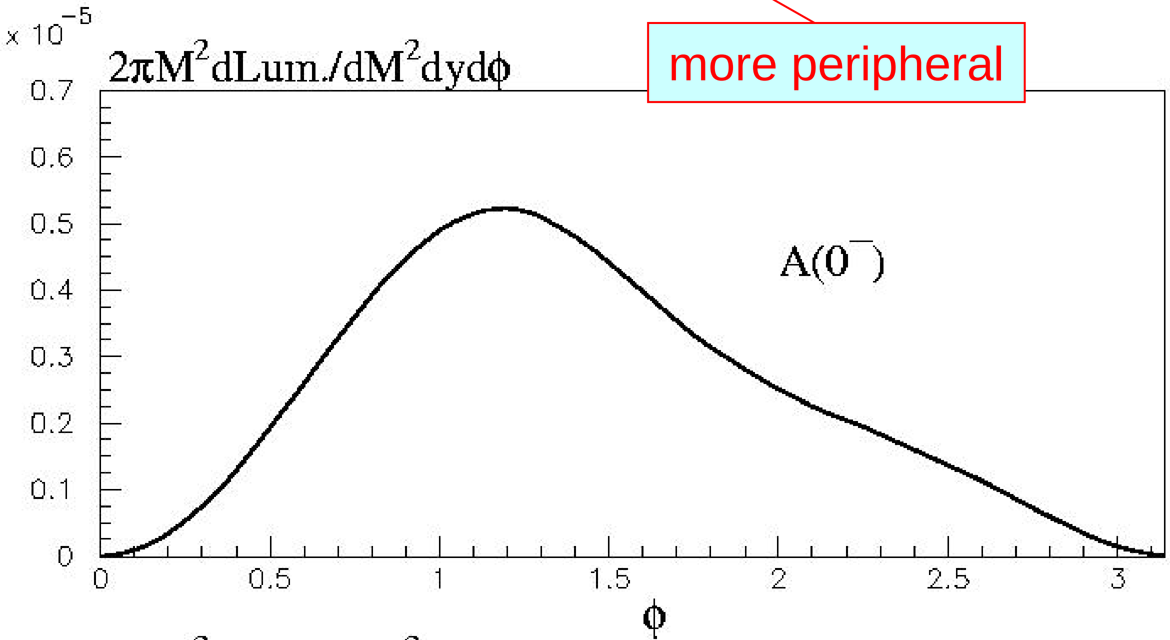
(more sensitive to IR region)

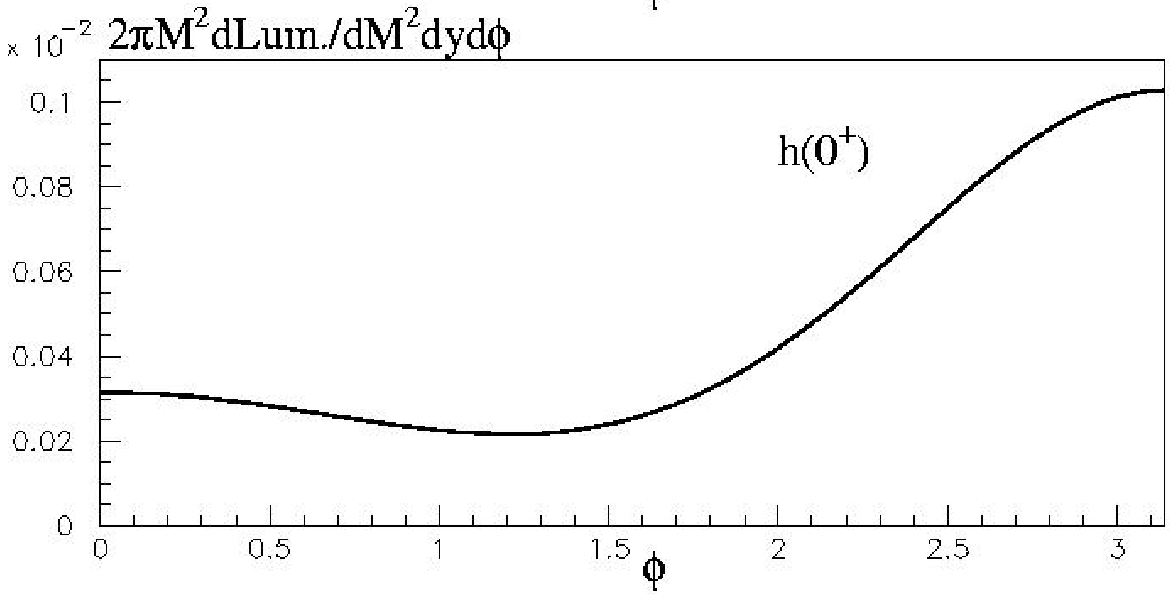
rescatt. corr. omitted $S^2=1$



With absorp. corr. $\langle S^2(0^-)\rangle \sim 3\text{-}4\,\langle S^2(0^+)\rangle$

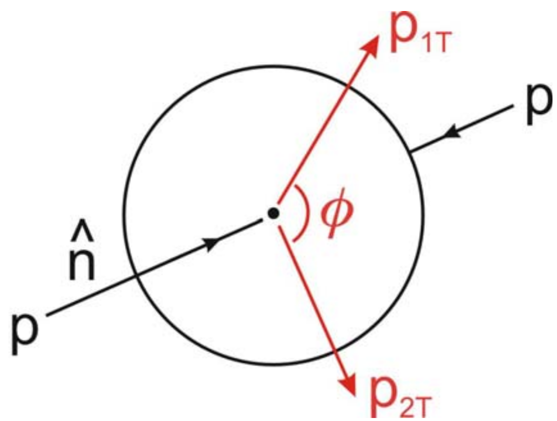
more peripheral

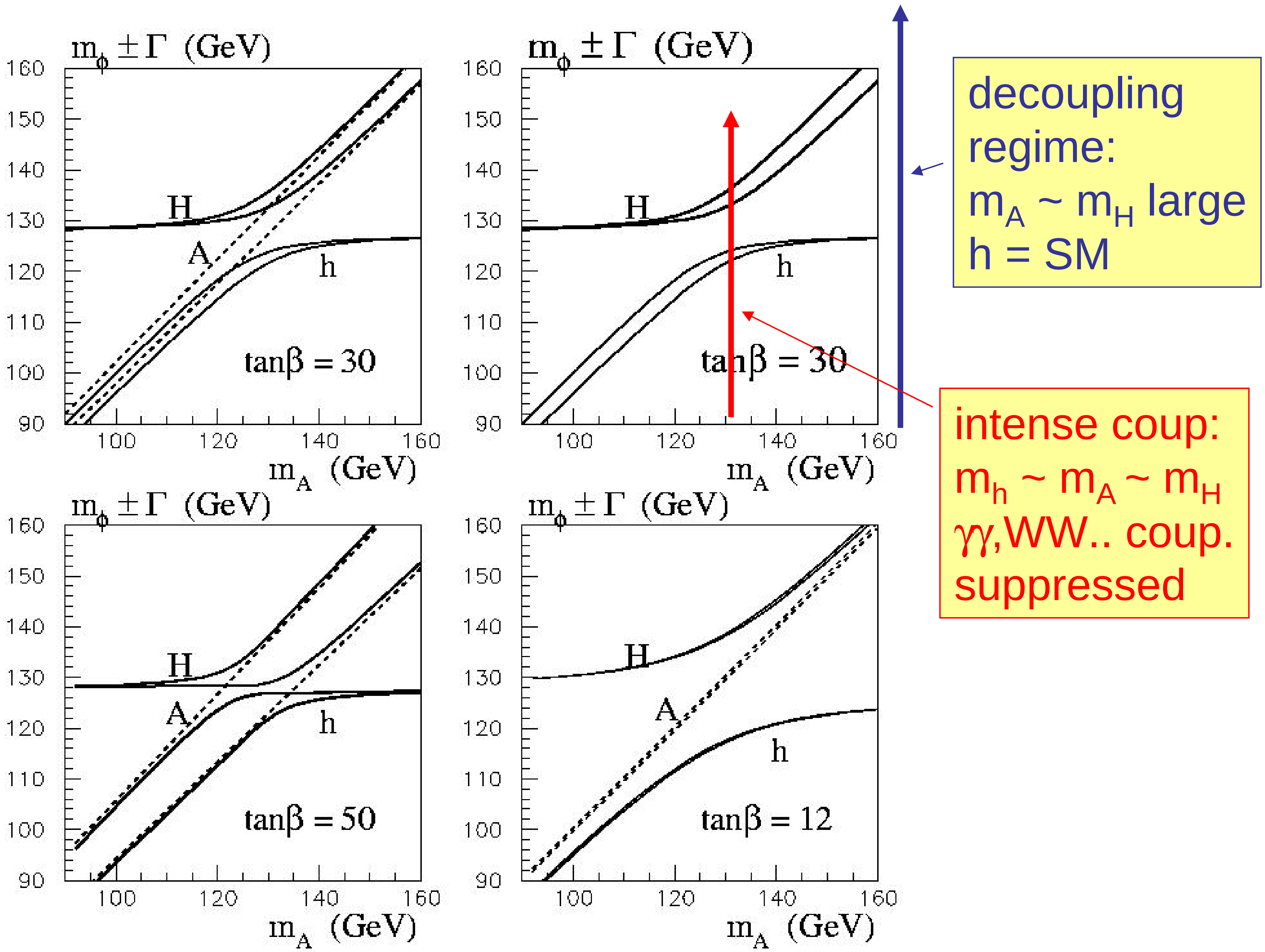




p_{1T}, p_{2T} correlations reflect spin-parity of central system: can distinguish 0^- from 0^+

$pp \rightarrow p_1 + H + p_2$





m_φ ± Γ (GeV)
m_A (GeV)
H
A
h
tanβ = 30
tanβ = 50
tanβ = 12
decoupling
regime:
m_A ~ m_H large
h = SM
intense coup:
m_h ~ m_A ~ m_H
γγ,WW.. coup.
suppressed

SM: pp → p + (H→bb) + p S/B~11/4

with ΔM = 1 GeV, at LHC with 30 fb^{-1}

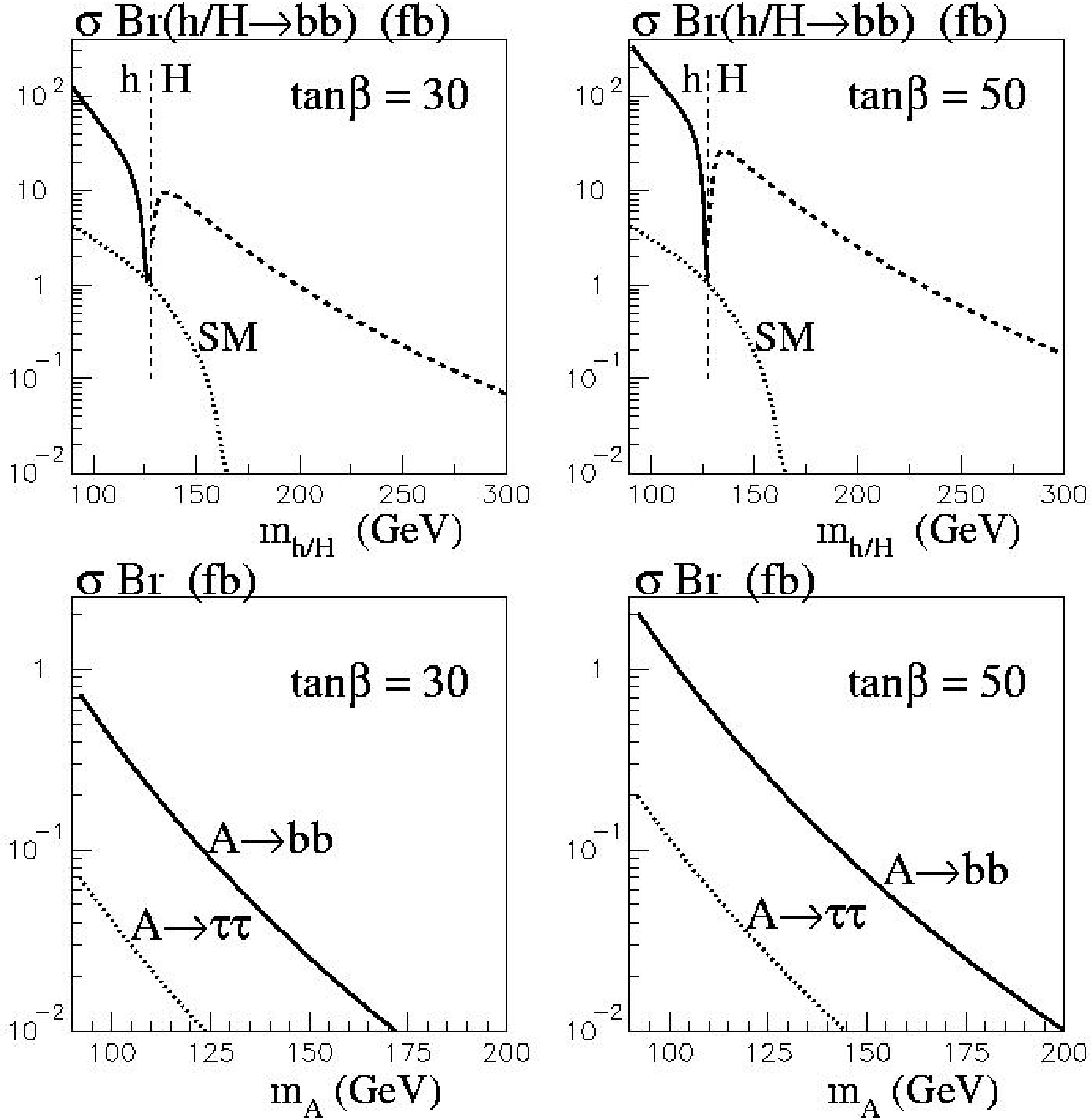
e.g. m_A = 130 GeV, tan β = 50

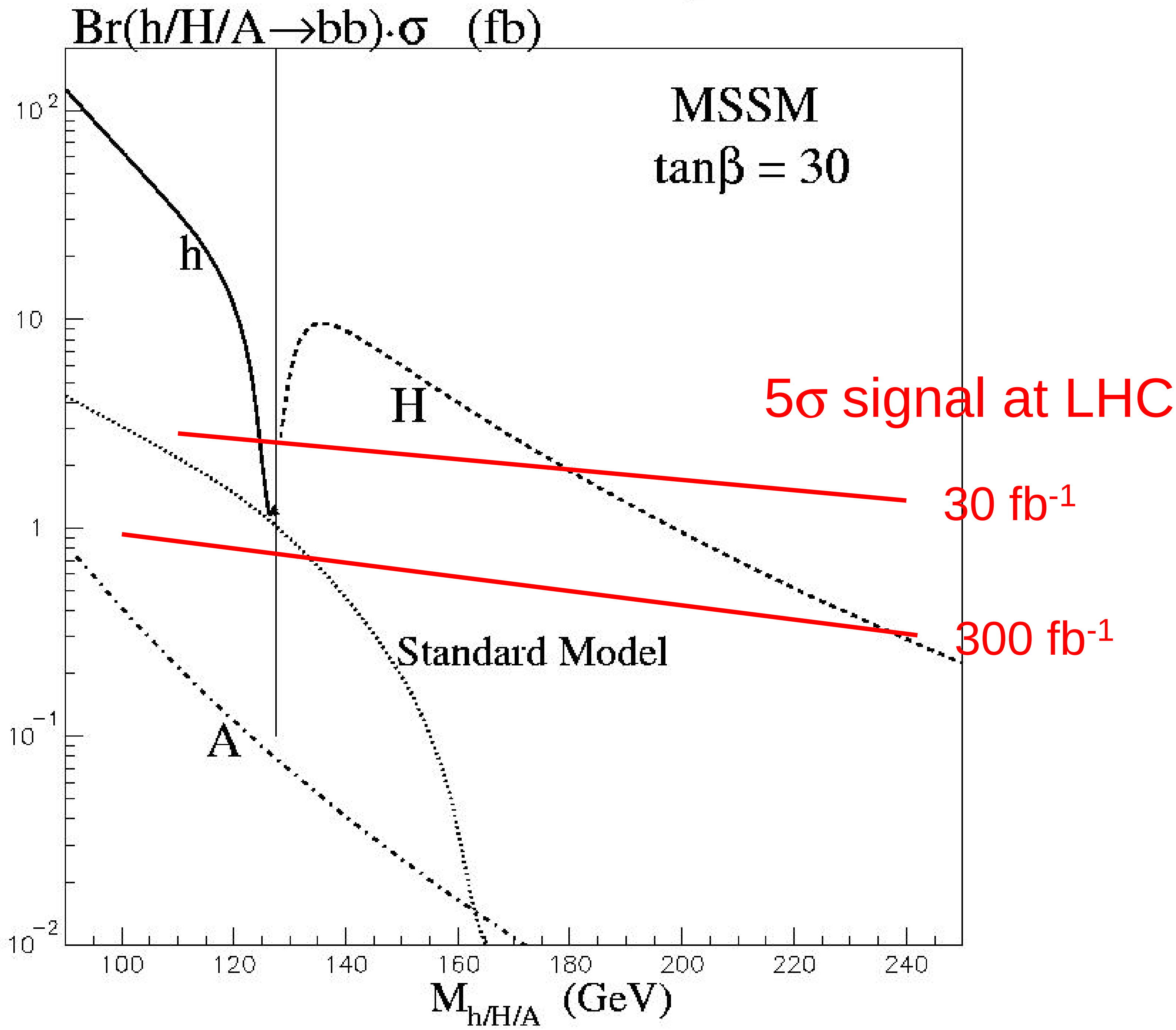
(difficult for conventional detection, but exclusive diffractive favourable)

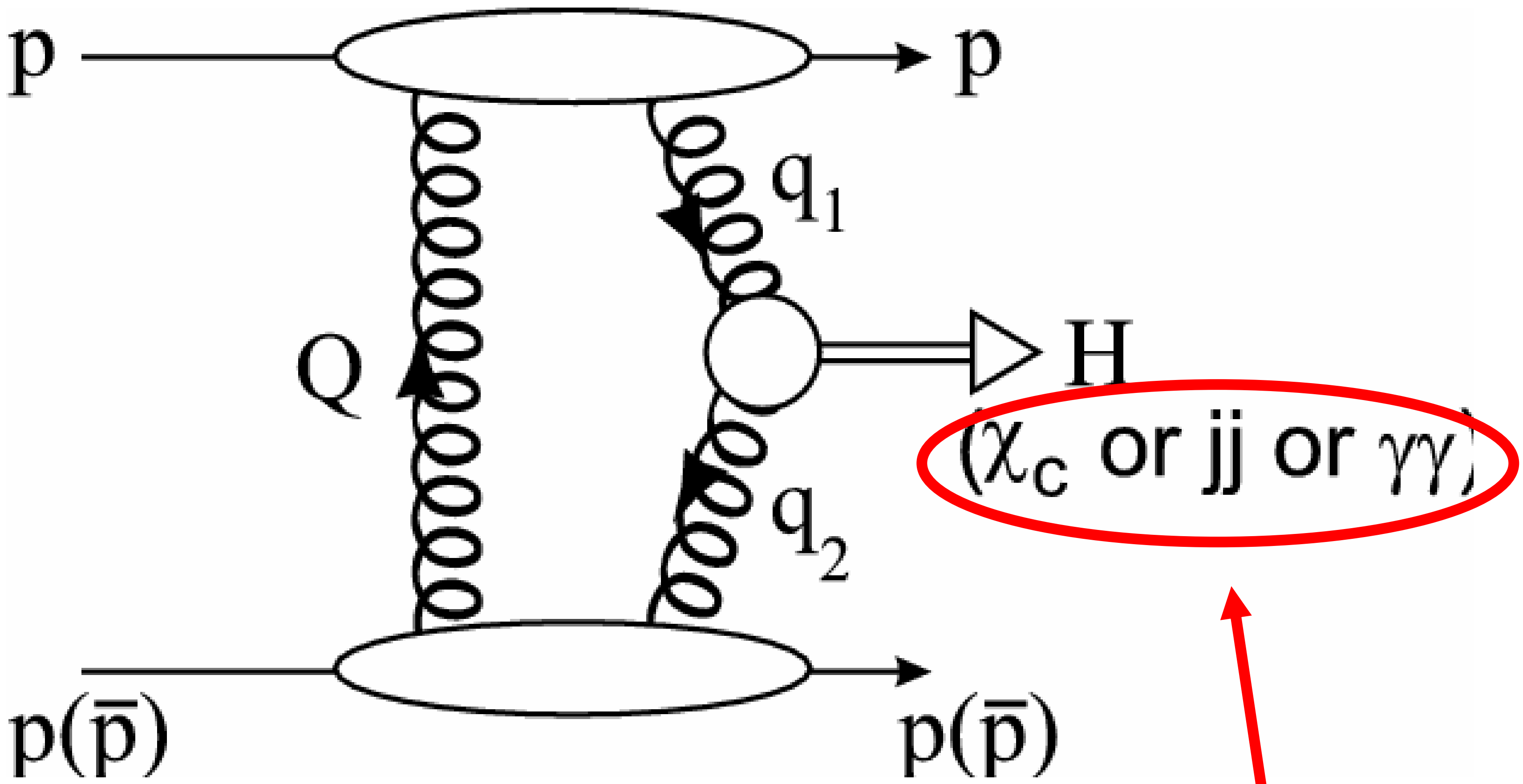
	S	B	
m_h = 124.4 GeV	71	3	events
m_H = 135.5 GeV	124	2	
m_A = 130 GeV	1	2	

enhancement

Central exclusive diffractive production



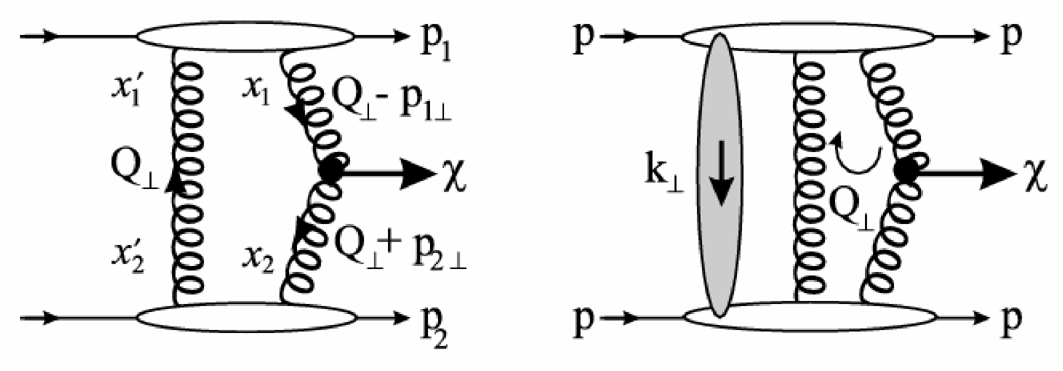

Br(h/H/A→bb)·σ (fb)
MSSM
tanβ = 30
5σ signal at LHC
30 fb-1
300 fb-1
h
H
A
Standard Model
10^2
10
1
10^-1
10^-2
100
120
140
160
180
200
220
240
M h/H/A (GeV)



Possible
“standard candles”

Diffractive χ production

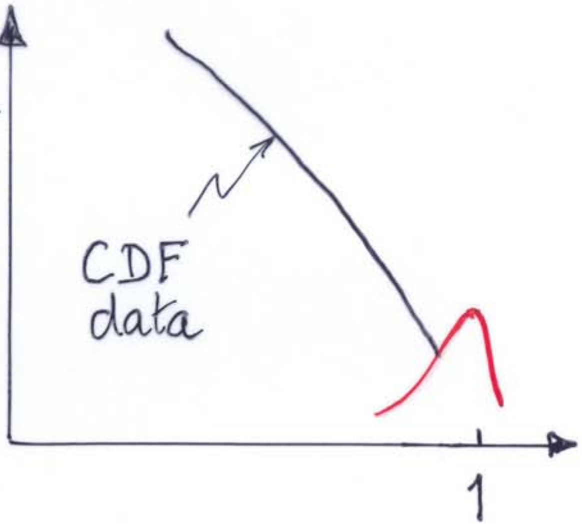
KMR+Stirling



	Tevatron $\sqrt{s} = 2$ TeV		LHC $\sqrt{s} = 14$ TeV	
	χ_c	χ_b	χ_c	χ_b
$d\sigma_{\rm excl}/dy\|_{y=0}$	130	0.2	340	0.6
$\sigma_{\rm excl}$	650	0.5	3000	4
$d\sigma_{\rm incl}/dy\|_{y=0}$	13	0.06	30	0.2
$\sigma_{\rm incl}$	70	0.3	200	2

only order-of-magnitude estimates possible for χ production

$R_{jj} = \frac{E_{dijet}}{E_{\mathbb{P}\mathbb{P}}}$



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

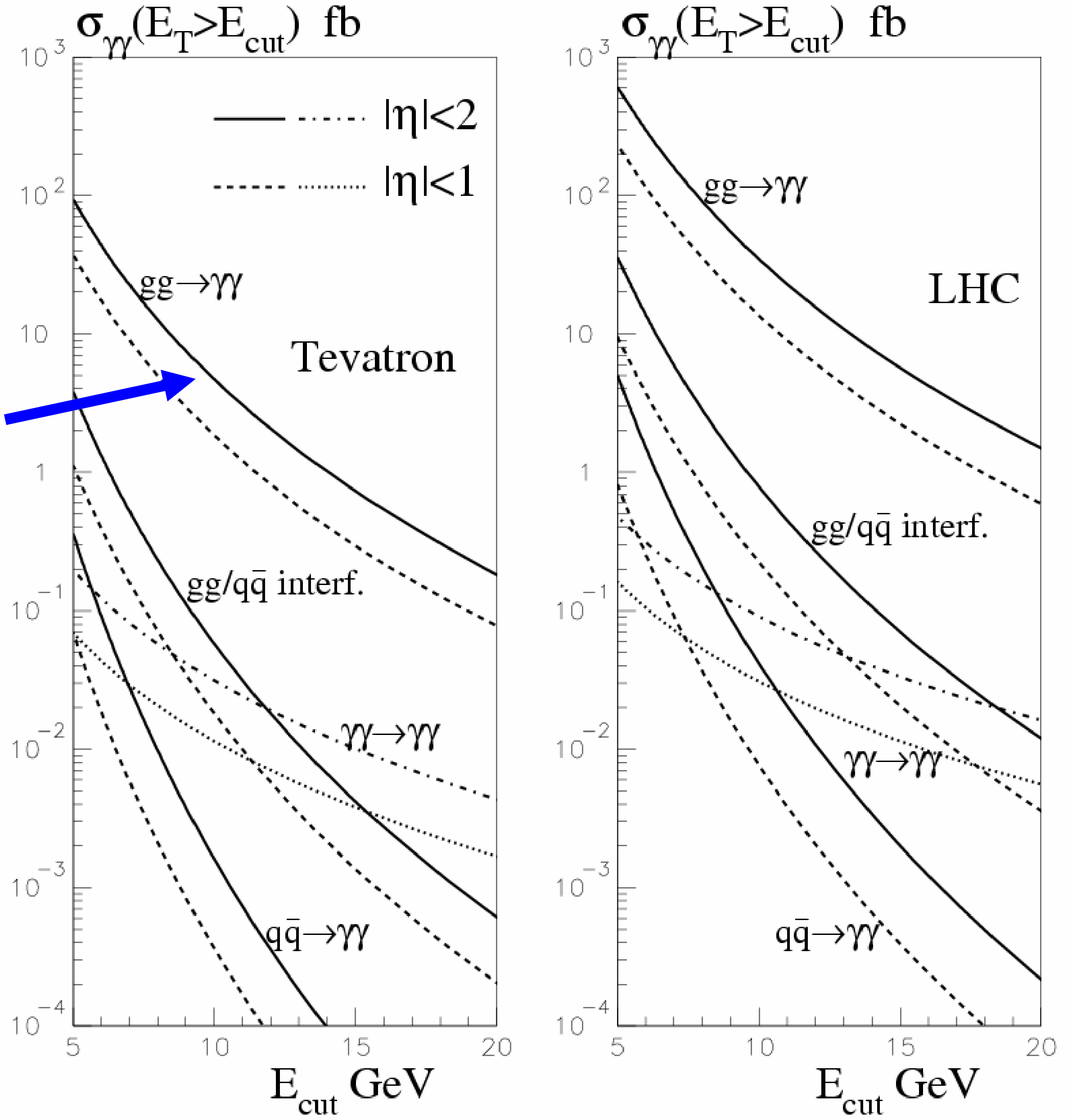
Exclusive peak
(not seen)

CDF: $\sigma(R_{jj} > 0.8,\ E_T > 25\,\text{GeV}) = 34 \pm 5 \pm 10$ pb
uncorrected

KMR predn: CDF cuts $E_T > 26$ GeV $\sigma_{exclusive} \sim 40$ pb

However no visible peak $R_{jj} \lesssim 1$
(smeared out by hadronization and jet searching algorithm

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



KMR+Stirling

Conclusions

Proton tagging is a valuable weapon in LHC Higgs physics
$pp \rightarrow p + H + p$: S/B~3, ΔM_{miss}~1GeV, $M_{miss} = M_{bb}$

SUSY Higgs: unique signals in certain domains of MSSM
tan β large (i) $m_h \sim m_H \sim m_A$ (σ enhanced), (ii) m_A large

Exclusive double diff. prod. strongly favours 0^+

Azimuthal correlations are valuable spin-parity analyzer
Distinguish 0^- from 0^+ Higgs

"standard candles" at Tevatron to test excl. prod. mechanism

$p\bar{p} \rightarrow p + \chi + \bar{p}$	high rate, but only an ord.-of-mag.estimate
$p\bar{p} \rightarrow p + jj + \bar{p}$	rate OK, but excl. peak washed out
$p\bar{p} \rightarrow p + \gamma\gamma + \bar{p}$	low rate, but cleaner signal