Diffractive Higgs Production

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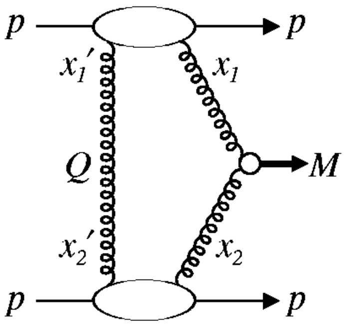
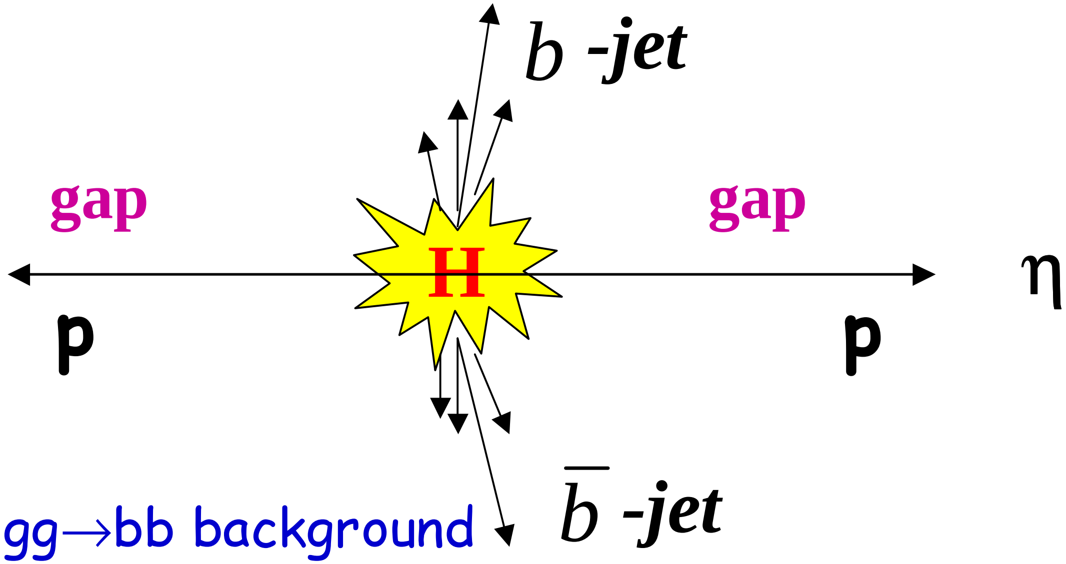
MC Workshop
July 03

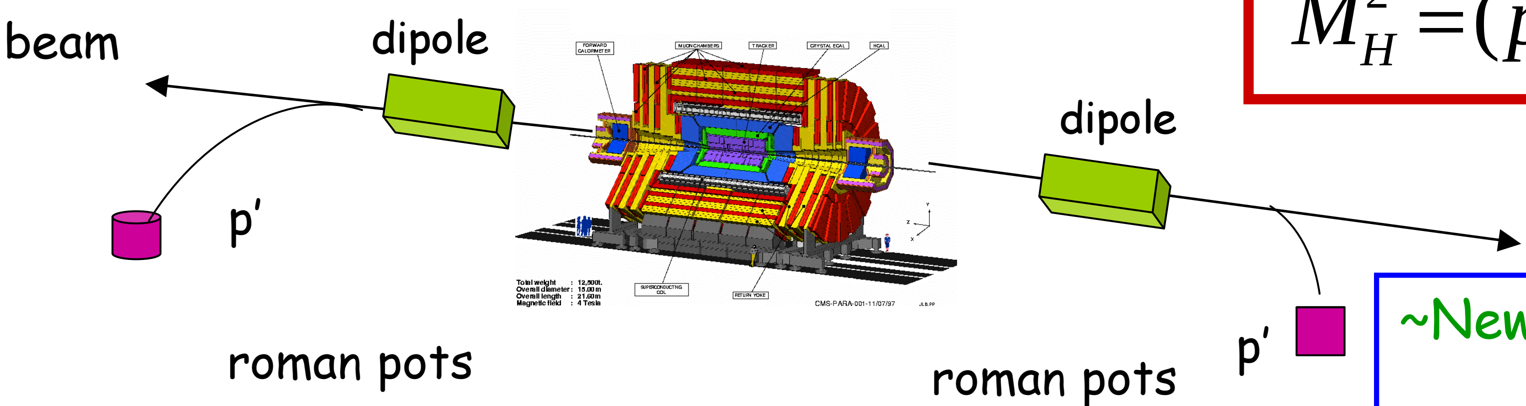
Diffractive Higgs Production

Exclusive diffractive Higgs production pp→ p H p : 3-10 fb
Inclusive diffractive Higgs production pp → p+X+H+Y+p : 50-200 fb





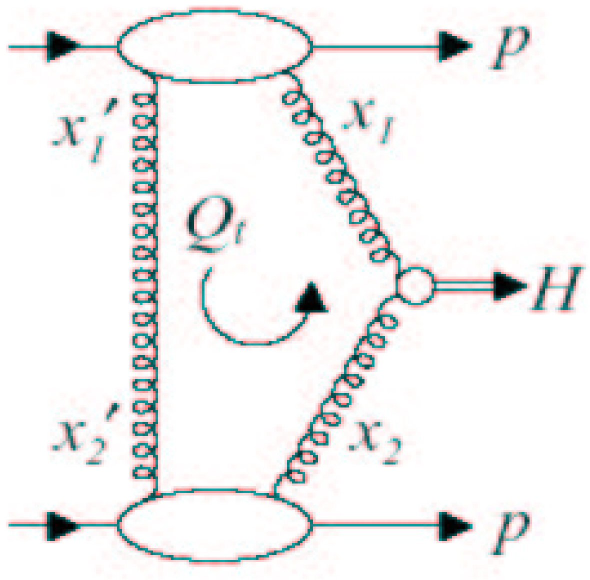
Advantages:
- Jz=0 suppression of gg→bb background
- Mass measurement via missing mass



$$M_H^2 = (p + \bar{p} - p' - \bar{p}')^2$$

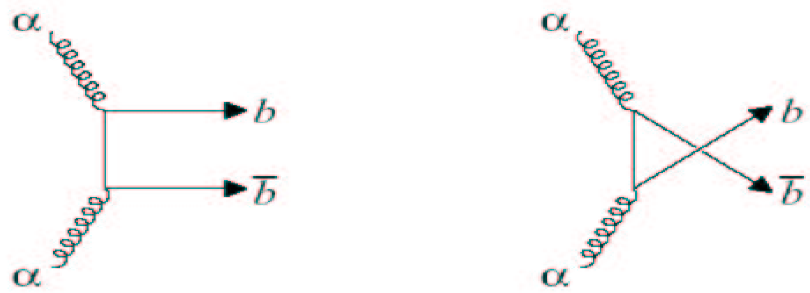
~New: Under study by several groups

Interest in Diffraction



- For light Higgs, dominant decay mode is $H \longrightarrow b\bar{b}$
- For inclusive production, the QCD $b\bar{b}$ background is overwhelming

- For double diffractive production (2 tagged protons) there is a $J_Z = 0$, parity even selection rule :



e.g. V. Khoze

cancel each other in the $m_b \longrightarrow 0$ limit

- Cross section suppressed as m_b^2/E_T^2

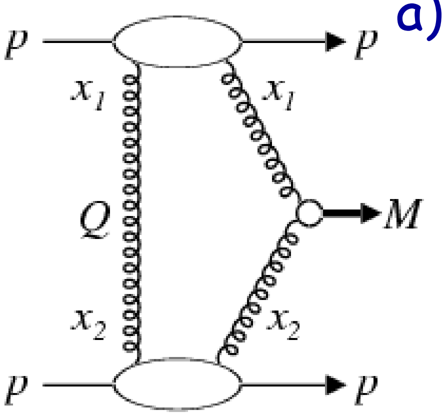
where $E_T \sim M_H/2$

Problem: diffractive production = mixture of perturb.+non-peturb. QCD

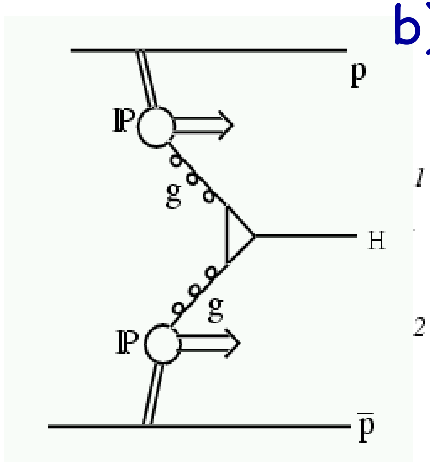
Studied Processes

a) Exclusive process

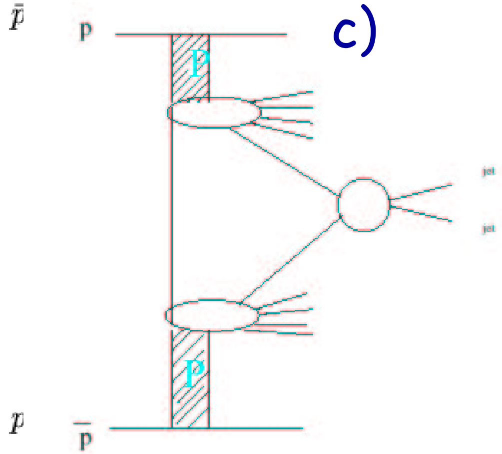
b,c,d) Inclusive processes



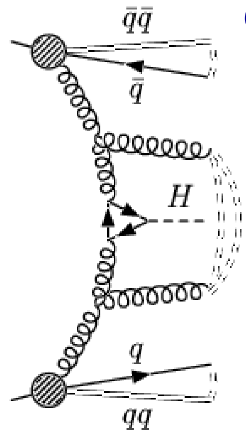
a)



b)



c)



d)

a) and d) proton induced   b) and c) pomeron induced

b) "factorizable" pomeron model: $\varepsilon = 0.2$ (flux factor $d\sigma(s') \sim (s')^{2\varepsilon}$)
c) "non-factorizable" pomeron model: $\varepsilon = 0.08$ (R. Peschanski)
d) Soft Colour Interaction/GAL proton models (no explicite colour singlet exchange/coherence $\rightarrow$ expect low cross section)

Cross Section Calculations

- Fold either pomeron structure functions (as measured at HERA) or proton structure functions with the cross section $gg \rightarrow H$

$$\sigma_H \approx \frac{G_F \alpha_s^2}{288\pi\sqrt{2}} \tau \int_\tau^1 \frac{dx}{x} g_1(x, m_h^2) g_2(\tau/x, m_h^2)$$

$$g_i(x, Q^2) = \int_x^{\xi_{max}} d\xi_i f_{I\!P/i}(\xi_i) g_{I\!P}(x/\xi_i, Q^2).$$

Important unknowns

- Energy dependence Pomeron flux factor $f_{I\!P/i}(\xi_i)$
- Normalization to di-jets (colour factor)
- Gap survival probability (SP) (factorization breaking)
  Normalize at Tevatron (di-jet data)
  Calculate (Khoze et al.: soft rescattering/QCD radiation in the gap)
  Some group do not take such SP into acount $\Rightarrow$ High cross sections!

Reliability of the cross section calculations?

Inclusive cross sections (fb) for LHC

M_{Higgs}	(1)	(2)	(3)	(4)
100	182.3	152.1	12.4	1.5
120	158.5	114.3	9.6	18.1
140	137.7	54.3	4.6	61.6
160	122.5	6.2	0.5	109.0
180	108.9	0.8	0.1	101.4
200	98.1	0.3	0.0	72.5

- (1): generator level
- (2): $b\bar{b}$ channel
- (3): $\tau\tau$ channel
- (4): W^+W^- channel

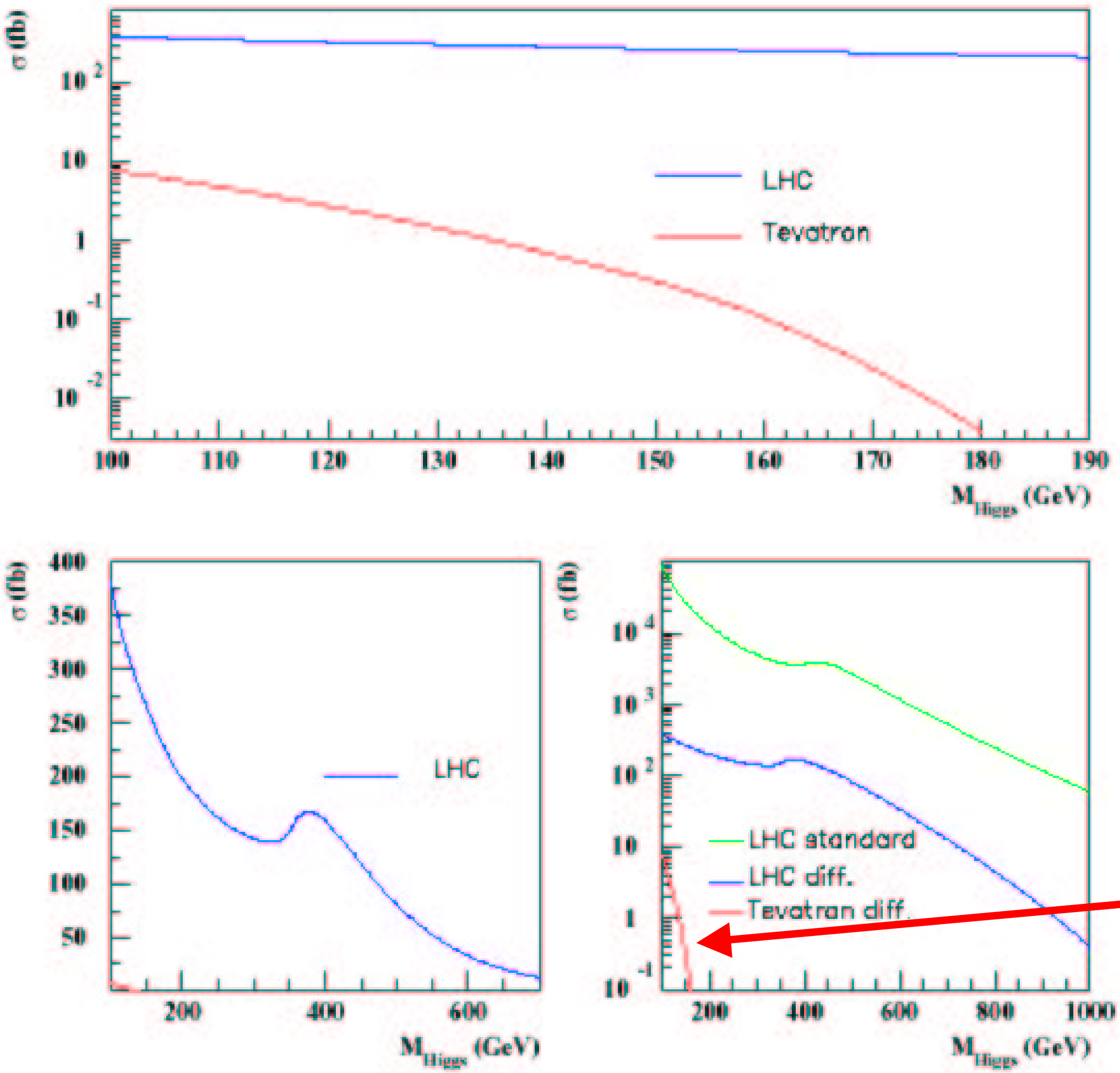
1. Boonekamp et al.(*) hep-ph/0301244
2. Cox et al. (*) 5-20 fb (120GeV) hep-ph/0100173
3. Khoze et al. 40 fb (120 GeV) hep-ph/0207042
4. Enberg, et al. 0.2fb (115 GeV) hep-ph/0210408

Difference in predictions about a factor 10-20. (except #4)
Difference essentially due to the flux factor (and gap suppression)
Model assumptions can be tested with (Run-II) Tevatron data.

(*) both normalized to the CDF Diffractive di-jet data

Inclusive Production Cross sections

Boonekamp et al.

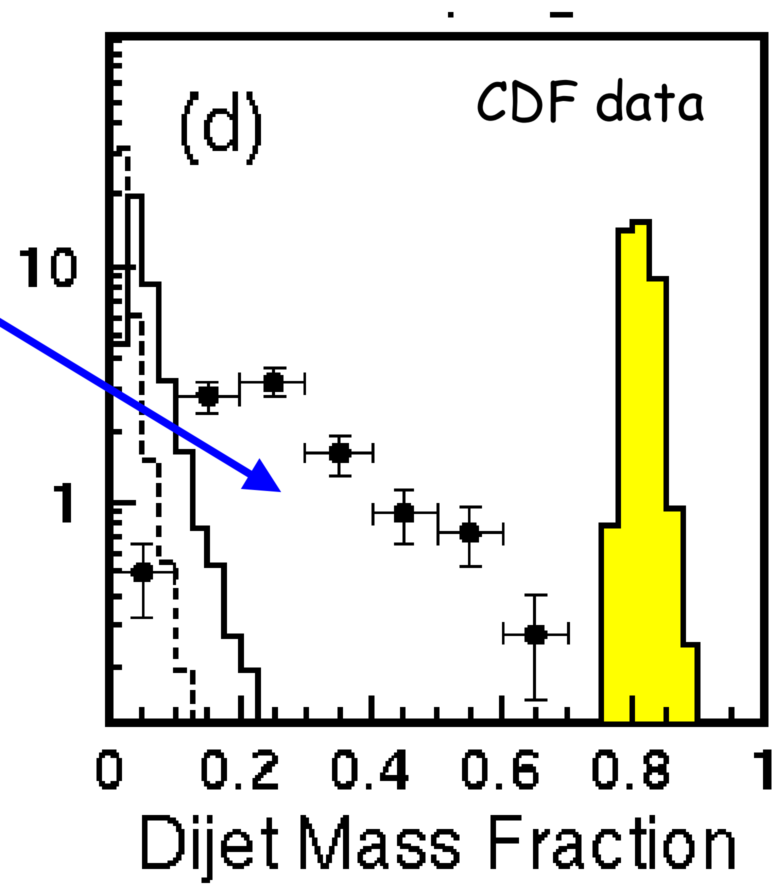


Inclusive Higgs production

Rather hopeless at the Tevatron

Test for Exclusive Production

There is a published measurement of double diffractive dijet production from Run I from CDF,



CDF di-jets in DPE
Upper limit 3.7 nb

Generally predictions of >O(100) pb for the Higgs
Overshoot this predictions
By a factor 10-100

Hence → ruled out!

CDF and D0 should find & measure a signal with run IIa

Smooth decrease of the cross section.
Can exclusive processes be seen on top of the non-exclusive background?

Comparison of models

V. Khoze et al., hep-ph/0207313

Reference	Process	Survival factor T^2	Survival factor S^2	Norm.	σ_{Higgs} (fb) Teva.	σ_{Higgs} (fb) LHC	Notes
Cudell, Hernandez [21]	excl incl	no	no	σ_{tot}	30 200	300 1200	~~Overshoots CDF dijets by 1000.~~
Levin [20]	excl incl	yes No DL	yes	σ_{tot}	20 70	–	~~Overshoots CDF dijets by 300.~~
Khoze, Martin, Ryskin [16]	excl incl C.inel	yes	yes	pdf pdf	0.2 1 ~ 0.03	3 40 50	Uses skewed gluons. CDF dijets OK.
Cox, Forshaw, Heinemann [5]	C.inel	$T \simeq 1$	norm	CDF dijet	0.02	6	No LO, only NLO, QCD i.e., no Fig.2(a), only 2(c).
Boonekamp, De Roeck, Peschanski, Royon [7]	C.inel	$T \simeq 1$	norm	CDF dijet	**1.9**	**180**	No LO, only NLO, QCD. Assume $S^2_{\text{CDF}} = S^2_{\text{LHC}}$.
Enberg, Ingelman, Kissavos, Timneanu [19]	incl C.inel	yes	yes	$F_2^{\text{Diff.}}$	< 0.01	0.2	~~No coherence.~~

Higgs signal	number of events: signal	number of events: background	S/B	significance $S/\sqrt{S+B}$
a) $H \to \gamma\gamma$ CMS	313	5007	$0.06\left(\frac{1\,\mathrm{GeV}}{\Delta M_{\gamma\gamma}}\right)$	4.3σ
a) $H \to \gamma\gamma$ ATLAS	385	11820	$0.03\left(\frac{2\,\mathrm{GeV}}{\Delta M_{\gamma\gamma}}\right)$	3.5σ
b) $t\bar{t}H$, $H \to b\bar{b}$	26	31	$0.8\left(\frac{10\,\mathrm{GeV}}{\Delta M_{b\bar{b}}}\right)$	3σ
c) $gg^{PP} \to p + H + p$, $H \to b\bar{b}$	11	4	$3\left(\frac{1\,\mathrm{GeV}}{\Delta M_{\mathrm{missing}}}\right)$	3σ
d) $gg^{PP} \to X + H + Y$, $H \to b\bar{b}$	190	21,000	$0.009\left(\frac{10\,\mathrm{GeV}}{\Delta M_{b\bar{b}}}\right)$	1.3σ
e) Weak Boson Fusion (WBF) $qWWq \to jHj \to j\gamma\gamma j$	17	9	CMS	3.3σ
	18	17	ATLAS	3σ
$\to j\tau\tau j$	25	8		4.4σ
$\to jW(l\nu)W^*(l\nu)j$	49	31		5.4σ
f) WBF with rapidity gaps $qWWq \to j + H(\mathrm{high}\, q_t) + j$, $H \to b\bar{b}$	jet E_T cuts: 250	1800	$0.14\left(\frac{10\,\mathrm{GeV}}{\Delta M_{b\bar{b}}}\right)$	5.5σ
	Higgs q_t cut: 400	3700	$0.11\left(\frac{10\,\mathrm{GeV}}{\Delta M_{b\bar{b}}}\right)$	6.2σ
g) $gg \to ZZ^* \to 4l$	6	4	CMS	1.9σ
	3	1.5	ATLAS	1.4σ
h) $gg \to WW^* \to l\nu l\bar{\nu}$	44	272	CMS	2.5σ
i) $WH \to l\nu b\bar{b}$	161	7095	0.02	1.9σ

LHC 30 fb^{-1} for 120 GeV Higgs

Khoze, Martin, Orava, Ryskin and ADR, Eur.Phys.J. C25 (2002) 391-403

Numbers for 30 fb^{-1} and a Higgs of 120 GeV

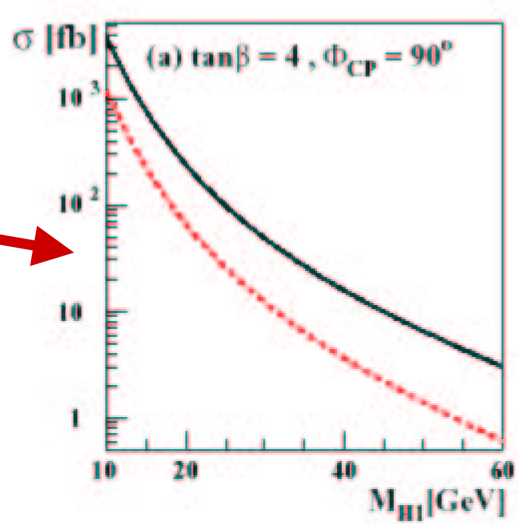
A light Higgs will be a challenge for the LHC!

Beyond Standard Model

Diffractive production of new heavy states pp→ p + M + p
Particularly if produced in gluon gluon fusion processes

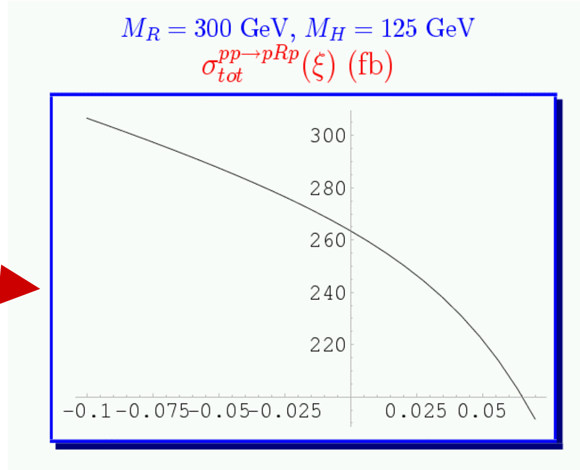
Examples:

Light CP violating Higgs Boson M_H < 70 GeV
B. Cox et al.



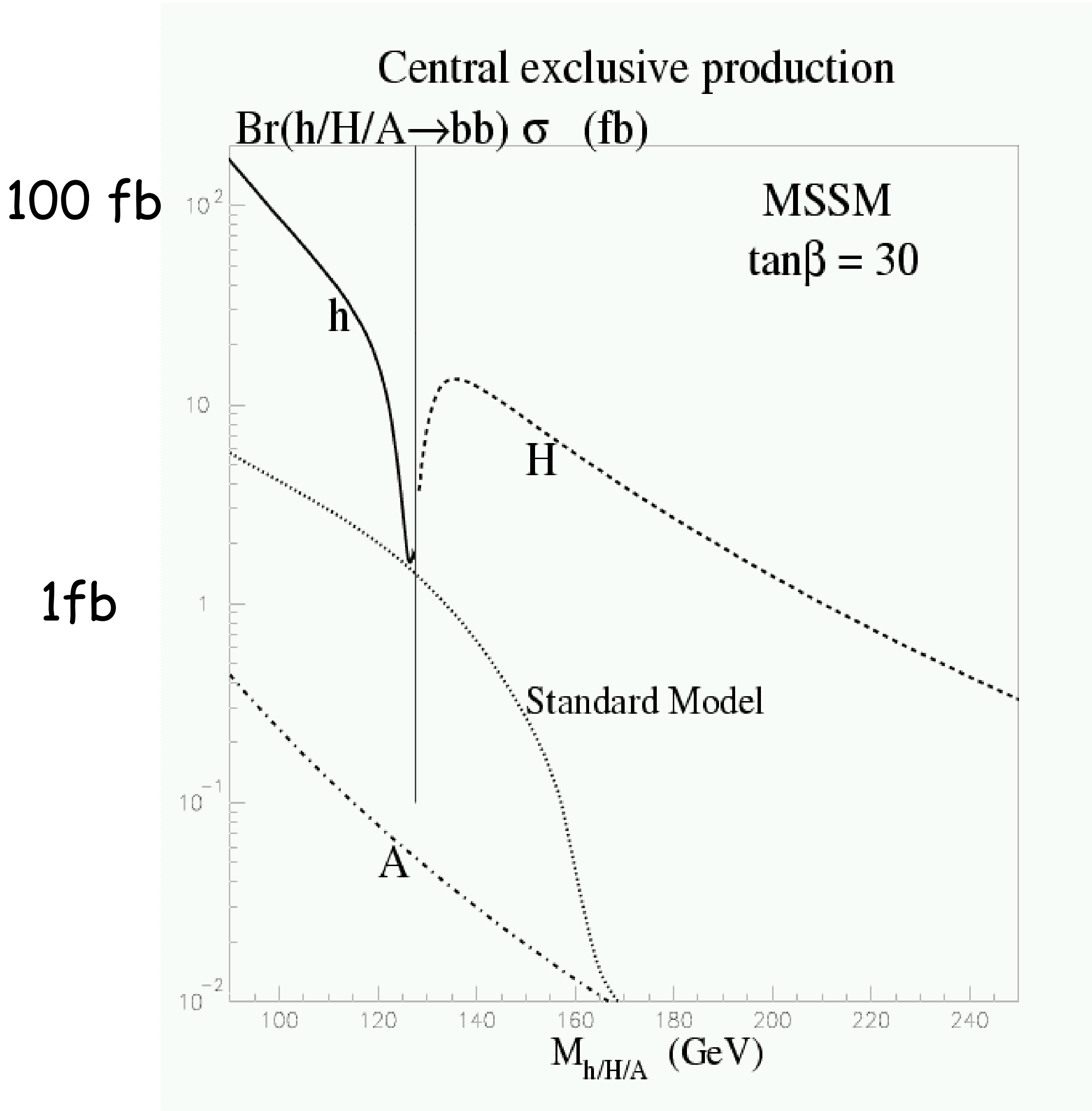
Light MSSM Higgs h→bb at large tan β
Light H,A (M<150 GeV) in MSSM with
large tan β (~ 30) → S/B > 10
Medium H,A (M=150-200 GeV) medium tan β?
V. Khoze et al.

Radion production - couples strongly to gluons
Ryutin, Petrov



Exclusive gluino-gluino production?
Only possible if gluino is light (< 200-250 GeV)
V. Khoze et al.

MSSM Higgs



Kaidalov et al.,
hep-ph/0307064

Cross section factor ~ 10 larger in MSSM (high tanβ)

Also:
Study correlations between the outgoing protons to analyse the spin-parity structure of the produced boson

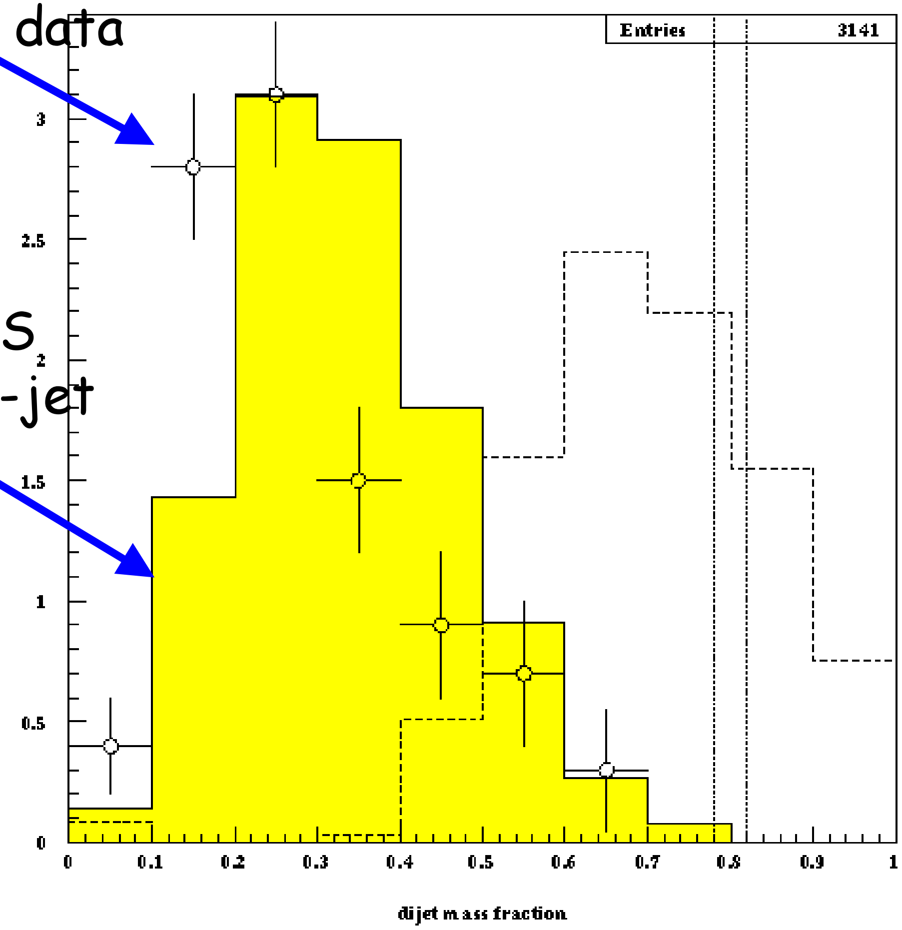
Monte Carlo Programs

- Inclusive Diffractive Higgs Production
  - DIFFHIGGS (Boonekamp et al.)
    - Soft pomeron flux, "pomeron" structure functions from DIS
    - Normalized to CDF dijet data (factorization breaking)
    - Uses PYTHIA for the hadronzation
  - POMWIG (Cox et al.)
    - Hard pomeron flux,"pomeron" structure functions from DIS
    - Normalized to CDF dijet data (factorization breaking)
    - Uses HERWIG for the hadronization
  - SCI model (Enberg et al.)
    - SCI/GAL to produce gaps, implemented in PYTHIA
- Exclusive diffractive production
  - DPEHIGGS (A Sobol)
    - Based on PYTHIA
    - Cross sections: Godizov et al (CMS Note IN-2003/016)/changeable

CDF diffractive dijets

CDF dijet data

DIFFHIGGS
used for di-jet
production



Boonekamp et al.

Use same formalism to describe the diffractive di-jets

Shape well described (normalization factor 3.8 off)

Discussion: Diffractive Higgs production

Range of predictions by different models: different approaches
⇒ Differences are expected.
How can we distinguish these approaches. Use Tevatron data..
Understanding gap survival probabilities? Extrapolation to LHC?

- Exclusive predictions
  - CDF dijets are a serious constraint. Excludes large Higgs cross section predictions. What is the range of predictions that is left? Only Khoze et al. i.e. 3-6 fb^{-1}?
  - Criticism: do pure exclusive high mass processes at such high energies exist? --aren't there always soft gluons around?
    Can we demonstrate this at the Tevatron?
    - High mass di-jets (but can one be sure about pure exclusiveness?)
    - Two photon production (too small a cross section? Trigger?)
    - low mass systems, (χ_c , χ_b)...
  - Uncertainty on the cross sections (Khoze et al: Factor 2). How to reduce that with measurements?

Discussion: Diffractive Higgs production

- Inclusive predictions
  - What can we believe? Pomeron intercept (hard/soft)?
  - What are the uncertainties on the individual calculations?
  - What do we gain in inclusive diffraction?

    No spin selection rule

    Better (sufficient) S/B ? Use of remnants to improve M_H resolution ?
  - Test the models with present or upcoming Tevatron/HERA to

    reduce the uncertainty (e.g. measure ε)
    - Diffractive dijet cross sections. Dijet mass fraction. VM at HERA?
    - 2-photon production
    - Do all models give the good description of the di-jets?

Summary

- Higgs at the Tevatron: chances look rather dim
- Exclusive Higgs production at the LHC: small if gap survival probability is taken into account. Large Higgs cross sections lead to large dijet rates which can be tested/excluded by upcoming Tevatron data. Theoretical uncertainties?
- Inclusive Higgs production: larger cross sections but less clean signal and no J=0 suppression of the background.

  What do we gain in inclusive diffraction? Better M_H resolution in bb?

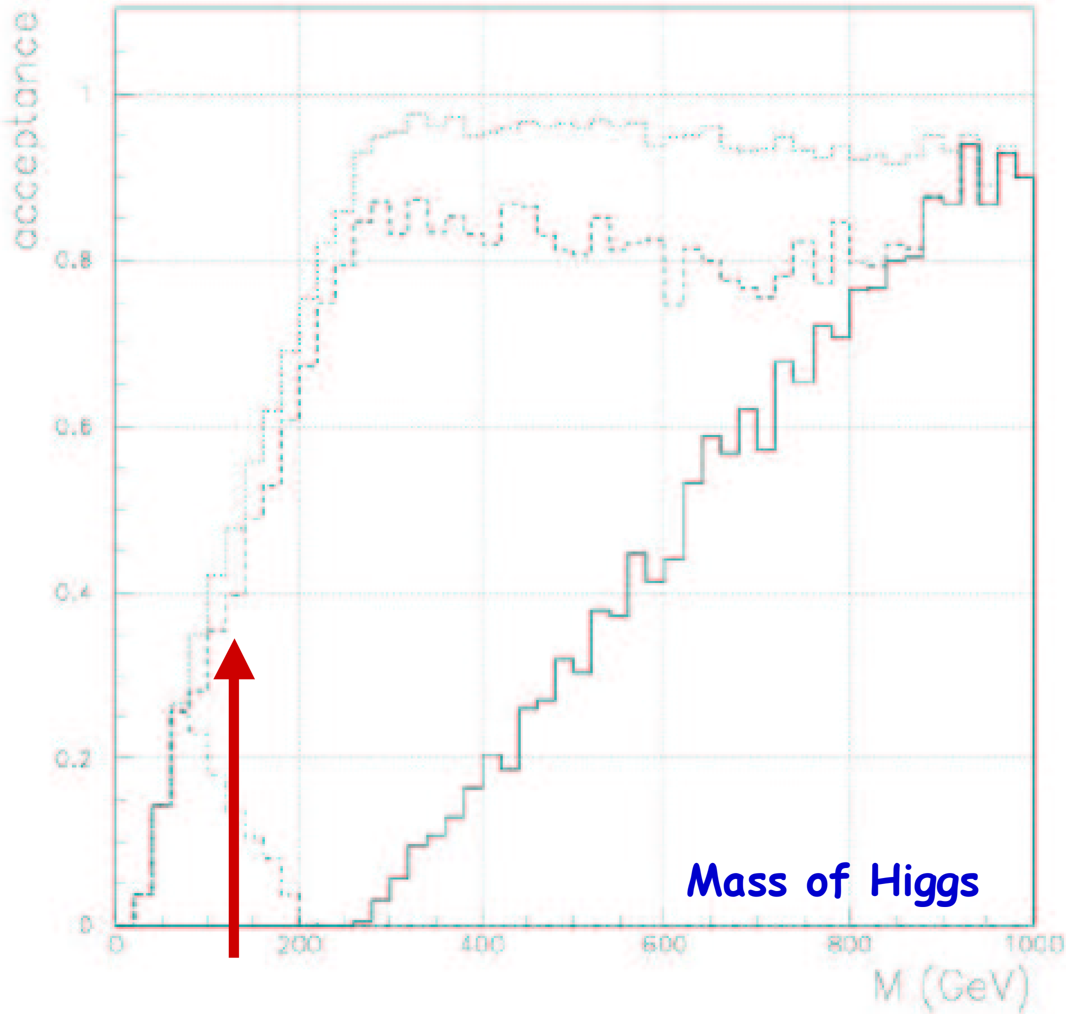
  Use of pomeron remnants? Other channels (e.g. τ decays?)
- Others channels: light MSSM Higgs, Radions… (theory)

$\Rightarrow$ Monte Carlo generators exist for different models (DPE Higgs)

- Experimental issues/studies in progress
  - Roman pot acceptances/trigger question most important
  - Forward tagging $|\eta| \sim 5\text{-}7$ (remant tagging)

SM Higgs Studies: Exclusive Production

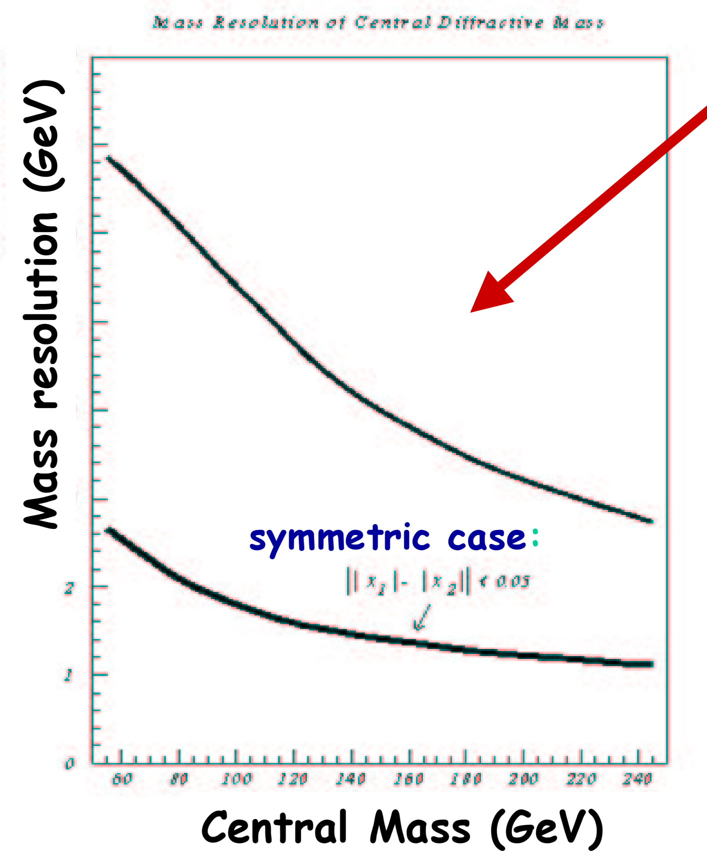
Needs Roman Pots at new positions 320 and/or 420 m
Technical challenge: "cold" region of the machine, Trigger signals…



- Combined acceptance of
  - → All detectors
    - Dotted line
  - → 420 m + 215 m
    - Dashed line
  - → 215 m alone
    - Solid line
  - → 420 m alone
    - Dash-dotted line
- without 308 / 338 m location
  - → 10-15 % loss in acceptance

R. Orava et al.

Diffractive Higgs Production



Mass resolution vs. central mass
from protons measured in roman pots
assuming $\Delta x_F/x_F = 10^{-4}$

Exclusive channel pp→ p H p advantages
Good mass resolution thanks to missing mass method:
$\Delta M = O(1.0 - 2.0)$ GeV   (including systematics)

Study possible in the b-quark decay mode
b-quark background suppression: (J_Z =0 states)!!
⇒Switch of dominant background (at LO)!