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# Higgs Diffractive Production

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# Higgs Diffractive Production

Ivan Schmidt

Trieste 2006

# Higgs detection

- Unknown mass
- Small production probability and large backgrounds
- Coupling ~ mass ⟶ hard to observe in pp

But :

1) $\left| p \right\rangle = a_1 \left| qqq \right\rangle + a_2 \left| qqqQ\bar{Q} \right\rangle + \ldots$

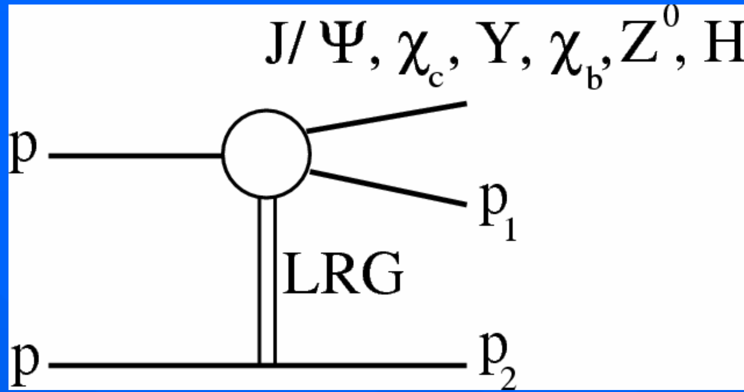
↳ Small (1% probability for c)

~ $1/M^2$

2) Reduce backgrounds from multiparticle production

⟶ Diffractive production in fragmentation region of one of the protons

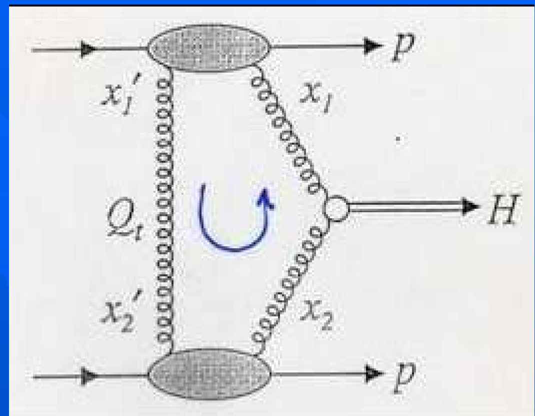
# $p\,p \rightarrow p\,H\,p$




- ✓ Large rapidity gap
- ✓ Missing mass measurement

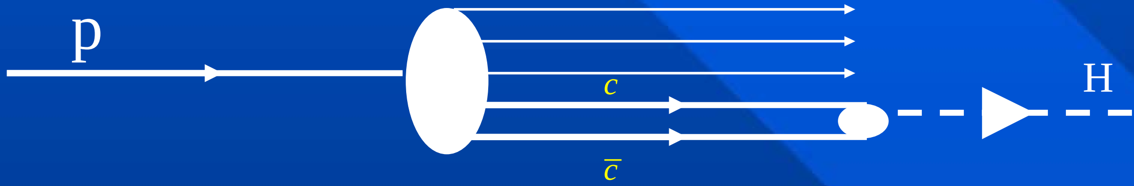
Concrete possibilities :

1) Central region (MKKRS)




2) Heavy quarks in proton

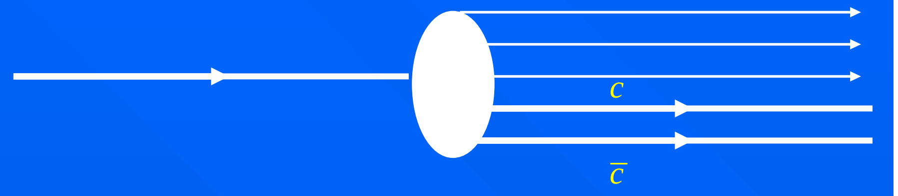
$x_F \simeq x_c + x_{\bar{c}}$ large




S. Brodsky
B. Kopeliovich
J. Soffer
I. S.

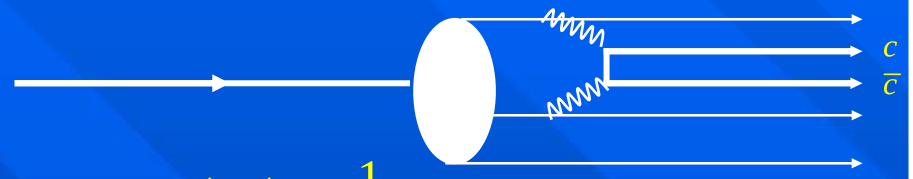
# Large $x_F$ production

1) Non-perturbative (stationary state)




$$\langle r_{c\bar{c}}^2 \rangle = \frac{2}{\omega m_c} \qquad \omega = 300\ \text{MeV}$$

2) Perturbative (quantum fluctuation)

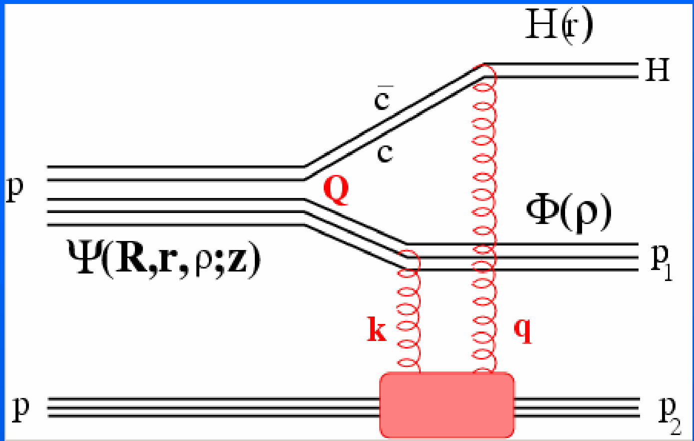



$$\langle r_{c\bar{c}}^2 \rangle = \frac{1}{m_c^2}$$

<u>Experimentally:</u>

DIS data, excess at large $x_{Bj}$

# Exclusive diffraction calculation




Form factors ⇐ (gluon coupling to all quarks)

Vanish as $q \to 0$ (suppression)

$$\frac{d\sigma(pp \to ppH)}{dx_2\, d^2p_1\, d^2p_2} = \frac{1}{(1-x_2)16\pi^2}\left|A(x_2,\vec{p}_1,\vec{p}_2)\right|^2$$

$$\begin{aligned} A(x_2,\vec{p}_1,\vec{p}_2) &= \frac{8}{3\sqrt{2}} \int d^2Q\, \frac{d^2q}{q^2}\, \frac{d^2k}{k^2}\, \alpha_s(q^2)\alpha_s(k^2)\, \delta(\vec{q}+\vec{p}_2+\vec{k})\, \delta(\vec{k}-\vec{p}_1-\vec{Q}) \\ &\times \int d^2\tau\, |\Phi_p(\tau)|^2 \left[e^{i(\vec{k}+\vec{q})\cdot\vec{\tau}/2} - e^{i(\vec{q}-\vec{k})\cdot\vec{\tau}/2}\right] \int d^2R\, d^2r\, d^2\rho\, H^\dagger(\vec{r})\, e^{i\vec{q}\cdot\vec{r}/2} \\ &\times \left(1-e^{-i\vec{q}\cdot\vec{r}}\right) \Phi_p^\dagger(\vec{\rho}) e^{i\vec{k}\cdot\vec{\rho}/2} \left(1-e^{-i\vec{k}\cdot\vec{\rho}}\right) \Psi_p(\vec{R},\vec{r},\vec{\rho},z)\, e^{i\vec{Q}\cdot\vec{R}}. \qquad (5) \end{aligned}$$

Born

# Calculational steps

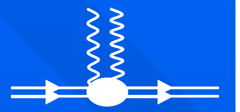
1) Factorized form for proton wf $\psi_p(\vec{R},\vec{r},\vec{\rho},z)=\psi_{IC}(\vec{R},z)\psi_{c\bar{c}}(\vec{r})\psi_{3q}(\vec{\rho})$

$$\int d^2R\left|\psi_{IC}(\vec{R},z)\right|^2 = P_{IC}(z) \qquad z\approx x_F$$

2) Calculate at t=0 $(\vec{q}=-\vec{k})$, and assume Pomeron-type t-dependence

$$\frac{d\sigma}{d^3p_1d^3p_2}\sim e^{-B(s')p_2^2}$$

3) Replace two-gluon proton vertex by gluon density $F(x,k^2)$



fitted to data → Includes higher order corrections

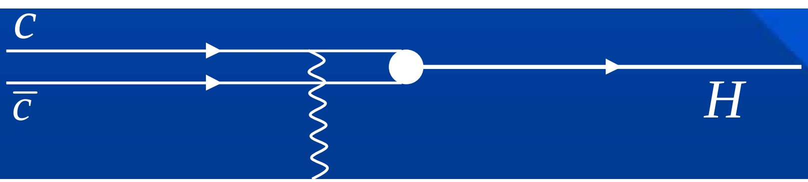
$$\frac{d\sigma^{IC}(pp\to ppH)}{dx_2} = \frac{32\pi P_{IC}(z)}{9B(s')(1-x_2)}\left|\int\frac{d^2k}{k^4}\alpha_s(k^2)\mathcal{F}(x,k^2)\right.$$
$$\times\int d^2r H^{\dagger}(\vec{r})e^{-i\vec{k}\cdot\vec{r}/2}\left(1-e^{i\vec{k}\cdot\vec{r}}\right)\Psi_{\bar{c}c}(\vec{r})$$
$$\times\left.\int d^2\rho\,\Phi_p^{\dagger}(\vec{\rho})e^{-i\vec{k}\cdot\vec{\rho}/2}\left(1-e^{i\vec{k}\cdot\vec{\rho}}\right)\Psi_{3q}(\vec{\rho})\right|^2 .$$

Only odd powers of $\vec{k}\bullet\vec{r}$, $\vec{k}\bullet\vec{\rho}$

change of orbital angular momentum

- initial $\overline{c}c$ in S-wave
- final $\overline{c}c$ in P-wave

H is scalar




( different for $J/\psi, Z^0$ : P-wave initial state)

## 4) Higgs wavefunction (P-wave)

$$H(\vec{r}) = i\,\frac{\sqrt{N_c}G_F}{2\pi}\,m_c\,\overline{\chi}\,\vec{\sigma}\,\chi\,\frac{\vec{r}}{r}\left[\epsilon\,Y_1(\epsilon r) - \frac{ir}{2}\,\Gamma_H M_H\,Y_0(\epsilon r)\right]$$

( for $\overline{c}c$ and $\overline{b}b$ )

$$H_{\overline{t}t}(\vec{r}) = \frac{\sqrt{N_c}G_F}{2\pi}\,m_t\,\overline{\chi}\,\vec{\sigma}\,\chi\,\frac{\vec{r}}{r}\,\epsilon_t\,K_1(\epsilon_t r)$$

( for $\overline{t}t$ )

## 5) $\overline{c}c$ wavefunction

$$\Psi_{\overline{c}c}(\vec{r}) = \beta\,\Psi^{npt}_{\overline{c}c}(\vec{r}) + \sqrt{1-\beta^2}\,\Psi^{pt}_{\overline{c}c}(\vec{r})\ .$$

$$\Psi^{npt}_{\overline{c}c}(\vec{r}) = \sqrt{\frac{m_c\omega}{2\pi}}\,\exp(-r^2\,m_c\,\omega/4)\ ,$$

$$\Psi^{pt}_{\overline{c}c}(\vec{r}) = \frac{m_c}{\sqrt{\pi}}\,K_0(m_c r)\ .$$

( FT of energy denominator )

## 6) Relative motion of $\overline{c}c$ and qqq clusters $\psi_{IC}(\vec{R},z) \Longrightarrow P_{IC}(z)$

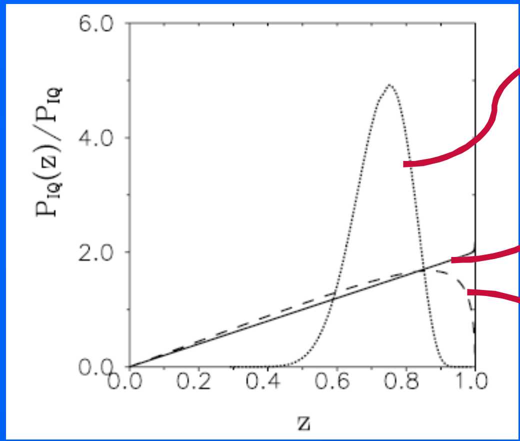
a) Non-perturbative heavy flavors

$$\tilde{\Psi}_{IC}(\vec{Q},z) = \sqrt{P_{IC}(z)}\left(\frac{1}{\pi\omega\mu}\right)^{3/4}\exp\left(-\frac{\vec{Q}^2}{2\omega\mu}\right)$$

$$\frac{P_{IC}(z)}{P_{IC}} = \frac{1}{\sigma^{IC}(pp\to ppH)}\,\frac{d\sigma^{IC}(pp\to ppH)}{dx_1} = \frac{1}{P_{IC}}\int d^2Q\;|\Psi_{IC}(Q,z)|^2$$

b) Perturbative heavy flavors

$$\frac{P_{IQ}(z)}{P_{IQ}} = N z(1-z)\,\frac{\left\{\ln\left[\frac{\left|M_H^2-4m_Q^2\right|(1-z)}{4m_Q^2(1-z)+m_p^2z^2}\right]\right\}^2}{M_H^2(1-z)+m_p^2z^2}$$

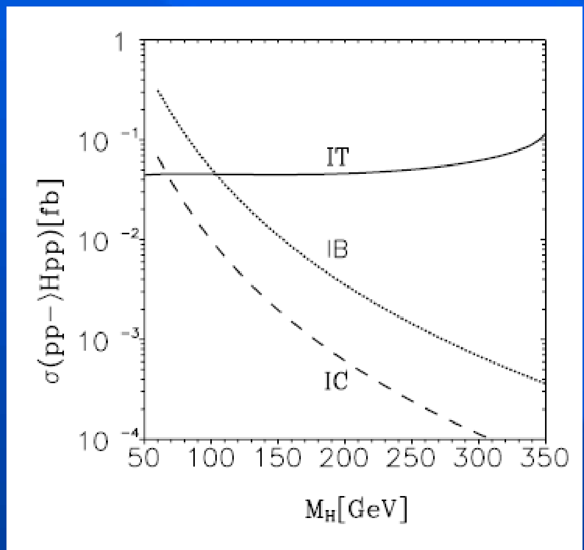



Non-perturbative $\bar{c}c$

Perturbative $\bar{t}t$

Perturbative $\bar{c}c$

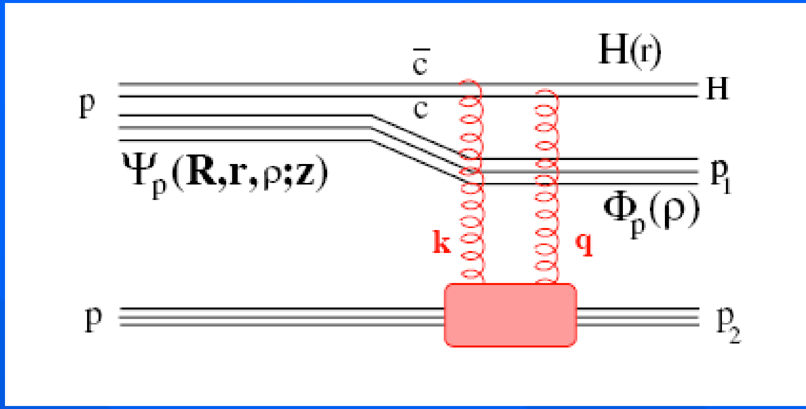
# Final result




- For LHC energy (14 TeV cm)
- Perturbative heavy flavors
- Includes absorptive corrections ( 20% at LHC)
- IT falls for $M_H > 2m_t \approx 350$ GeV
- Heavy quark probability $\sim \frac{1}{M_Q^2}$

# Larger cross section

1) From colorless heavy pair




Does not have proton form factor

But

$$\text{Amplitude} \sim \int d^2 r H^+(\vec{r})\sigma_{\bar{q}q}(r)\psi_{\bar{c}c}(r)$$

$$\sim \frac{1}{M_H^3}$$ suppressed

2) Nuclear enhancement

Not as big as one might think ⟵ Stronger absorptive corrections

Factor of ~ 10 for Pb

# Conclusions

- ✓ Heavy quark components ⟹ carry high momentum fractions.
- ✓ Higgs production in fragmentation region.
- ✓ Diffractive production $pp \rightarrow pHp$
- ✓ Also possible: $pp \rightarrow pHX$ , $pp \rightarrow HX$ .
- ✓ Difficult detection .