

# Higgs Exclusive Production at Hadronic Colliders

Low-x Meeting, Ischia Island

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IFPA, University of Liège

In collaboration with: J.R. Cudell, O.F. Hernández and I.P. Ivanov

11/09/09

# 1 Exclusive Production in High-Energy Physics

- Motivation

# 2 Higgs Exclusive Cross Section: Theory

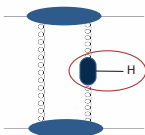
- Ingredients

# 3 Higgs Exclusive Cross Section: Results

- Reduce the Uncertainties

# 4 Conclusions

## Higgs Central Exclusive Production



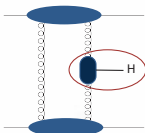
[A. Bialas and P. V. Landshoff, 1991 ]

## Higgs CEP: theoretical situation

- $\sigma_H \sim 3 \text{ fb}$   
@  $m_H = 120 \text{ GeV}$

[V. A. Khoze, A. D. Martin  
and M. G. Ryskin, 2002 ]

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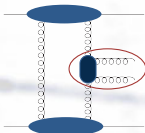
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[FERMILAB-PUB-09-060-E.]

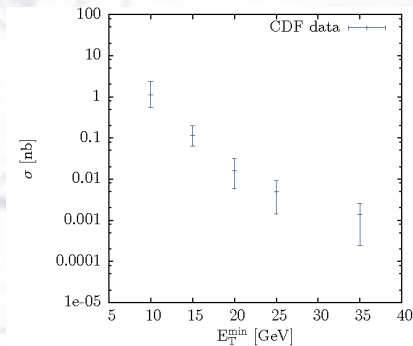
## Dijet Central Exclusive Production



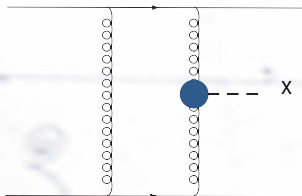
[ A. Berera and J. C. Collins, 1996 ]

[ V. A. Khoze, A. D. Martin and M. G. Ryskin, 2000 ]

[A. Bzdak, 2005 ]

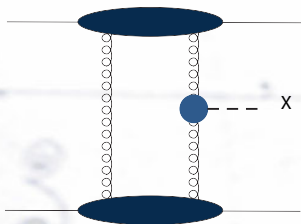


Standard scheme of a Central Exclusive Production calculation:



- Lowest order QCD calculation at the parton level: the produced system is in a colour singlet state
- Embed partons in the proton via a Proton Impact Factor
- Add virtual corrections via a Sudakov Form Factor
- Take proton rescattering corrections into account
- Include the effect of Splash-out

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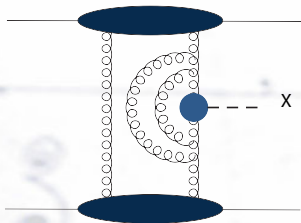


[I. P. Ivanov, N. N. Nikolaev and A. A. Savin, 2006 ]

[J. R. Cudell and O. F. Hernandez, 1996 ]

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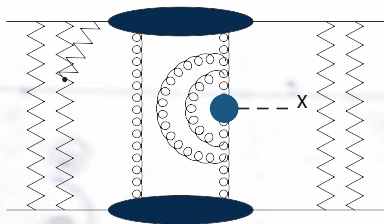


[Y. L. Dokshitzer, D. Diakonov and S. I. Troian,1980]

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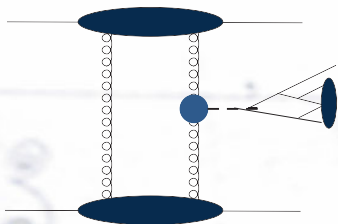
[J.D. Bjorken, S.J. Brodsky, H.J Lu, 1992]

[L. Frankfurt, C. E. Hyde-Wright, M. Strikman and C. Weiss, 2007]

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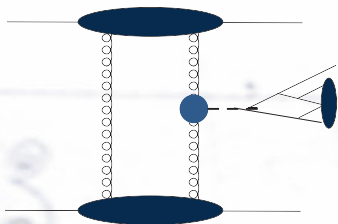
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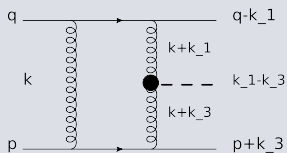
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### Not Under Theoretical Control

- Proton Impact Factor
- Sudakov Form Factor
- Proton rescattering
- Splash-out

= Higher-order + Soft corrections

## 1: Lowest Order

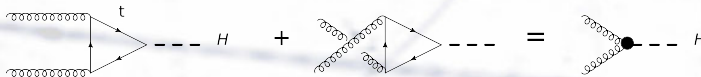


Exact transverse  
kinematic

$$k_i = \alpha_i p^\mu + \beta_i q^\mu + \mathbf{k}_i$$

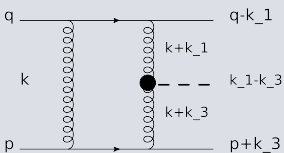
$$\frac{k_{1,2}^2}{s} \ll \alpha_i, \beta_i \ll 1 \quad (i=1,3)$$

$$d\sigma \propto \left| \int \frac{d^2\mathbf{k}}{\mathbf{k}^2(\mathbf{k} + \mathbf{k}_1)^2(\mathbf{k} + \mathbf{k}_3)^2} \times \mathcal{V}^{\text{eff}}(gg \rightarrow H) \right|^2$$



End of the Analytic QCD Calculation

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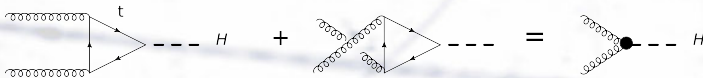


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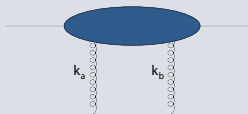
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End of the Analytic QCD Calculation

## 2: Proton Impact Factor



Models the behavior of a **real proton**  
 Goes to zero when the gluons  
 become very soft  
 $\sim$  proton form factor

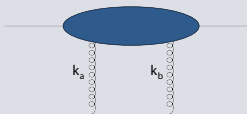
Soft quantity  
 $\rightarrow$  models and fit must  
 be used

- Evolving partons in a Skewed Unintegrated Gluon Density:

$$\mathcal{G}(x, \mathbf{k}_a, \mathbf{k}_b)$$

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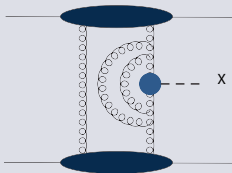
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Factor 3 of uncertainty

### 3: Sudakov Form Factor



Virtual corrections  $e^{-S(\mu, \ell)}$   
 $S(\mu, \ell) \Rightarrow$  Large double logarithms

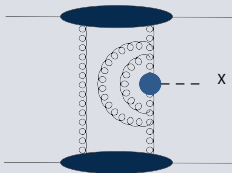
$$S(\mu, \ell) = \alpha_s \left( a \log^2 \left( \frac{\mu^2}{\ell^2} \right) + b \log \left( \frac{\mu^2}{\ell^2} \right) + c \right)$$

- Double logs and single logs contribution are known
- Upper scale  $\mu = 0.62 m_H$

[A.B Kaidalov, V. A. Khoze, A. D. Martin and M. G. Ryskin, 2003 ]

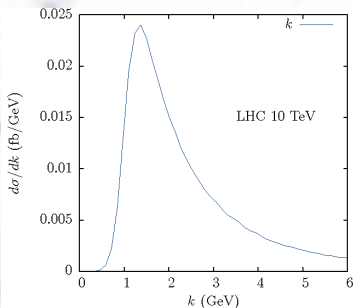
- Strongly suppresses the cross section: factor  $\mathcal{O}(100-1000)$
- Changes the mean value of loop momentum

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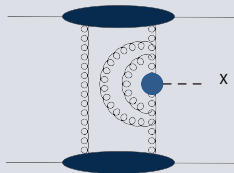
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Large contribution from the soft region where gluons momentum is small

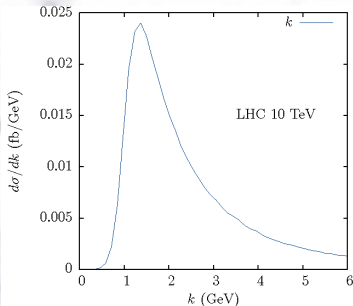


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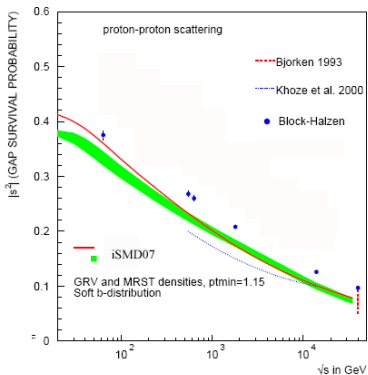
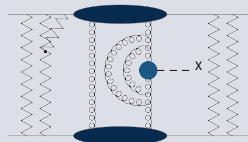
**Factor 7 of uncertainty**

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## 4: Gap survival $S^2$

Protons rescattering might destroy the gap

[R. M. Godbole, A. Grau, G. Pancheri and  
Y. N. Srivastava, 2007 ]

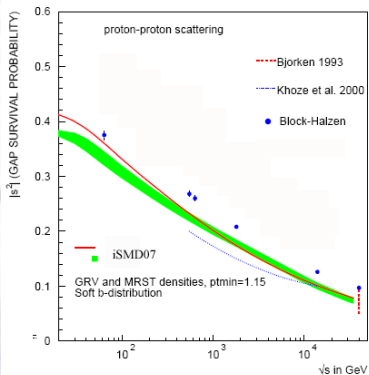
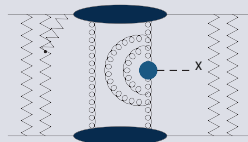


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Depends on the unitarisation scheme

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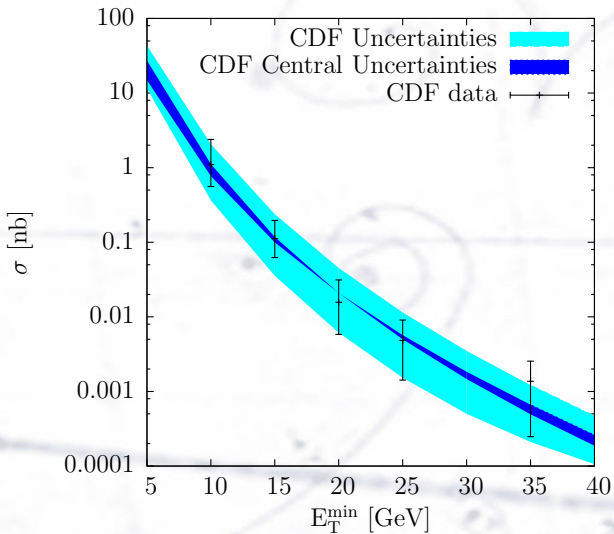
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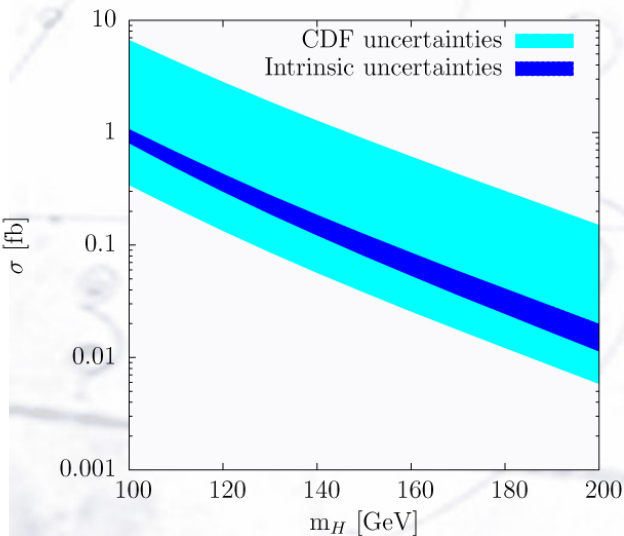


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Factor 3 of uncertainty



[J.R Cudell, AD, O.F Hernández and I.P Ivanov, 2008 ]



Typical cuts of FP420

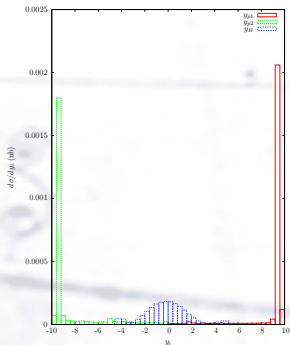
$$\xi_1, \xi_2 \quad [0.002, 0.02]$$

$$|y_{jet}| \quad < 1$$

$$M_{jj} \quad > 50 \text{ GeV}$$

[M.G. Albrow *et al.*, report  
CERN-LHCC-2005-025.]

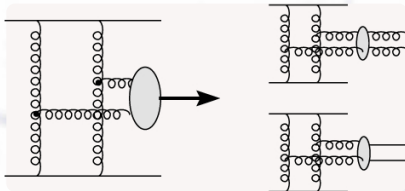
Monte-Carlo integration → Parton level generators



- Code behaves as an event generator
- Direct access to several distributions
- Possibility to apply experimental cuts and compare with measurements and experimental quantities
- Possibility of interfacing with hadronization code, jet algorithms and running detector response simulation

## Conclusions

- Large contribution from the non-perturbative region
- Uncertainties can be large → Dijets measurement at TEVATRON and LHC may help to constrain the Higgs CEP cross section
- Background contribution from non-standard mechanisms  
→ Igor Ivanov's talk



Back up slides

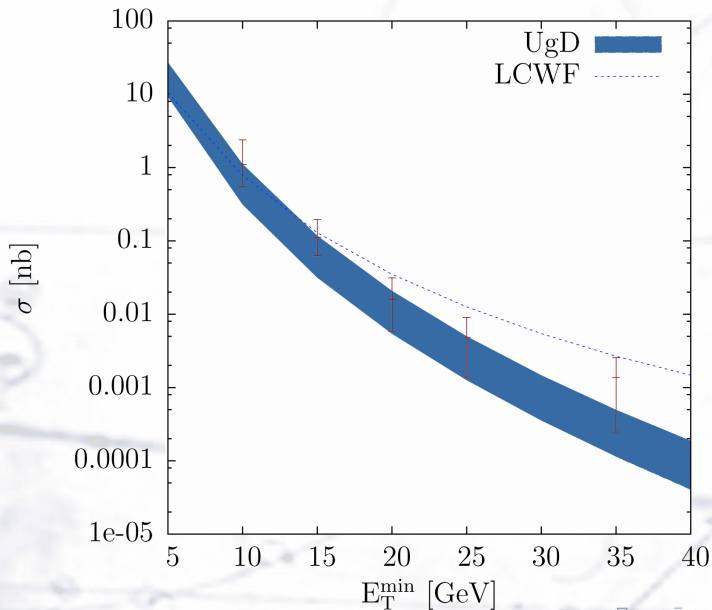


$$T = e^{-S(\mu^2, \ell^2)}$$

$$S(\mu^2, \ell^2) = \int_{\ell^2}^{\mu^2} \frac{d\mathbf{q}^2}{\mathbf{q}^2} \frac{\alpha_s(\mathbf{q}^2)}{2\pi} \int_0^{1-\Delta} dz [zP_{gg} + N_f P_{qg}]$$

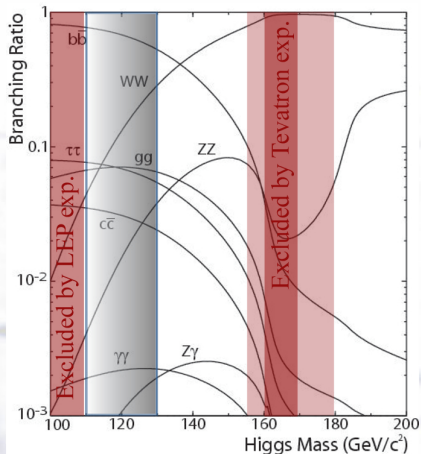
- $\mu^2$ : Hard scale of the sub-process  $\mathcal{O}(M_{gg}^2)$
- $\ell^2$ : Virtuality from which the evolution starts (gluons virtuality)
- $\alpha_s$ : Can be fixed at some arbitrary scale or evolved
- $P_{gg}, P_{qg}$ : Splitting function
- $\Delta$ : Cut-off that depends on the prescription

[Y. L. Dokshitzer, D. Diakonov and S. I. Troian, Phys. Rept. **58** (1980) 269. ]  
 [V. A. Khoze, A. D. Martin and M. G. Ryskin, Eur. Phys. J. C **48** (2006) 467]



# Implication for the Higgs boson(s) search

→ Important channel: Central Exclusive Production



[FERMILAB-PUB-09-060-E.]

- Search strategy depends on Higgs decay preferences
- Light Higgs:  $m_H \leq 130$  GeV

$$H \rightarrow b\bar{b}$$

hidden in QCD background