

# Precision QCD & Electroweak Physics *Issues for CDR*

LHeC Convenors  
Meeting, CERN 15th dec 2009  
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Thomas Gehrmann

## 4 Precision QCD and Electroweak Physics

### 4.1 Inclusive Measurements

#### 4.1.1 Cross Sections

#### 4.1.2 Structure Functions $F_2$ , $F_L$ , $xF_3$ , $F_2^{\gamma Z}$

### 4.2 Precision Measurements

#### 4.2.1 QCD Fit Assumptions and Basic Results

#### 4.2.2 Projected Accuracy of $\alpha_s$

#### 4.2.3 Weak Coupling Constants

### 4.3 Physics at Large Bjorken $x$

#### 4.3.1 Theoretical Interest

#### 4.3.2 Relation to LHC

#### 4.3.3 Gluon Distribution

#### 4.3.4 Light Quarks (d/u)

### 4.4 Strange, Charm and Beauty Densities

#### 4.4.1 Experimental Conditions

#### 4.4.2 Measurement of $s$ and $\bar{s}$ in Charged Currents

#### 4.4.3 $F_2^{cc}$ and Intrinsic Charm

#### 4.4.4 $F_2^{bb}$

### 4.5 Single $t$ and $\bar{t}$ Production

### 4.6 High $p_T$ Jets

#### 4.6.1 Experimental Conditions and Scale Uncertainties

#### 4.6.2 Differential Cross Sections

#### 4.6.3 Gluon Density and $\alpha_s$

#### 4.6.4 Final State Physics

### 4.7 Partonic Structure of the Photon

# Precision QCD & Electroweak Physics *Issues for CDR*

Electroweak Physics

PDF fits

Charm & beauty

Single Top

High  $p_T$  jets

Photon structure &  
(other) final state physics

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$\alpha_s$

# CDR issues: PDF-fits

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## Existing studies:

- Max Klein, Emmanuelle Perez
  - using NLO QCDFIT programme + estimated uncertainties (?)
  - **Can/should be redone with the pseudodata ?**
- Claire Gwenlan
  - using NLO QCDNUM programme on pseudodata
  - **Some differences to Emmanuelles fit, e.g.  $g(x)$  at large  $x$  with considerable larger uncertainty, is the agreement between the two fits satisfactory? Further checks?**
- Stefano Forte, Alberto Guffanti, Juan Rojo,
  - using NNPDF fit on pseudodata
  - **What needs to be done to complete the analysis? E.g. add the pseudo data sets that were not yet used (high  $Q^2$  ?)**



Assume that results from all three studies find their way into the CDR in a well balanced mixture

# CDR issues: $\alpha_s$

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## Existing studies:

- Thomas Kluge
  - using NLO QCDFIT programme on inclusive NC & CC Pseudodata
  - Analysis so far didn't use/exhaust all the expected/available data sets (?), to be completed
  - Could add jet data in DIS and  $\gamma p$  for which Pseudodata need to be generated first



Benchmark:  $\alpha_s$  with 1 permille exp. precision



Probably with some final efforts the nice results on  $\alpha_s$  will/can go into the CDR

# CDR issues: charm & beauty

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## Existing studies:

- Max Klein
  - using NLO QCDFIT programme + estimated uncertainties (?)
  - charm & beauty densities in massless scheme (ok for reasonably large  $Q^2$  )
- Olaf Behnke
  - using RAPGAP MC,  $F_{2cc}$  also calculable for  $Q^2 \sim Mc^2$

## Planned study:

- Philipp Roloff (DESY)
  - using HVQDIS, massive NLO calculation (standard tool in hfl physics)



Rather well covered, would be nice to demonstrate that charm and beauty tagging could work with the designed detector down to the smallest theta = few degrees (“proof of principle”)

# CDR issues: Single Top

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## Existing studies:

- Max Klein
  - using NLO QCDFIT programme (?) for  $bW \rightarrow t$
- Gerhard Brandt
  - using PYTHIA MC for  $bW \rightarrow t$  and some background process estimations
- Olaf Behnke
  - using LEPTO MC for  $bW \rightarrow t$



$\sigma \sim \text{few pb}$



Hubert Spiesberger: used MC models rather inappropriate (massless ME)  
--> use tools like Sherpa  
Have to find person to do it

# CDR issues: High pt jets

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## Existing studies:

- Thomas Schoerner, Joerg Behr
  - Jets in DIS using DISENT NLO Programme
- Claudia Glasman, Juan Terron
  - Jets in photoproduction using Frixione NLO Programme



All studies so far on *hadron/parton level*  
calculating expected jet rates and theory uncertainties,  
Some assessment of expected  
*experimental uncertainties*  
would be nice (energy scale uncertainties)

# CDR issues: Other final states

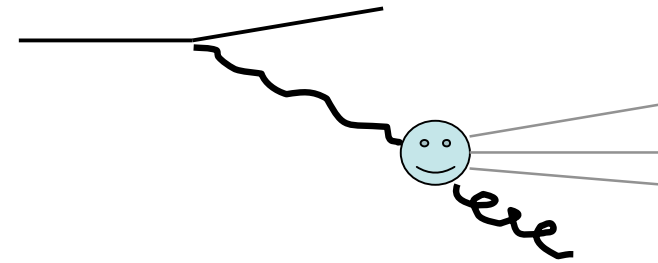
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## Partonic photon structure:

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Existing studies:

None



Would be nice to have studies like for the THERA project  
(e.g. Maria Krawczyk on  $x_\gamma$  coverage)

## Other final states:

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- Prompt photons: Some ideas about who could do studies within the next half year
- Other final state studies, e.g. on fragmentation functions using charged particles etc.



Any further study is welcome and can be included  
in the CDR if it's ready within reasonable time



# CDR issues: Summary

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- For many topics: PDF,  $\alpha_s$ , heavy flavour, high pt jets, a great deal of material is already there... to be supplemented where necessary
- For some topics, new/further studies would be useful (single top, photon structure)
- General remark: A dedicated meeting/workshop like the low x group preblois could be very useful
  - The authors of the QCE chapter of the CDR could meet to discuss details about the writing
  - We could still attract more people

1. Precision PDFs, electroweak parameters and  $\alpha_s$  from inclusive polarised  $e^\pm p$  neutral and charged current events:

(a) *Max Klein, Claire Gwenlan, Emmanuelle Perez:*

Introduction, simulated data and NLO QCD fit

- Structure functions and relations/sensitivities to PDFs and electroweak parameters
- Selected accelerator/detector scenarios, simulated data and uncertainties and expected NC and CC yields vs  $Q^2$
- Introduction of NLO-QCD fit
- Expected (improvements for) PDF uncertainty bands compared to HERA for  $u_v, d_v, S$  and  $g$  vs  $x$  for fixed  $Q^2$ .
- Selected highlights:  $u/d$  for  $x \rightarrow 1$ ;  $xF_3$  and valence quark determination down to low  $x$ ;  $F_L$  for gluon; Possible extensions: exclusive final states jets, charm and beauty for: gluon and effective heavy quark densities in the proton; charm in CC for  $s$  and  $\bar{s}$

(b) *Claire Gwenlan, Paolo Gambino, Nandi Soumitra:* Combined electroweak and PDF fit

- Light quark axial and vector couplings to  $Z$ , Propagator mass  $m_W, \sin\theta_w$
- Theoretical uncertainties, higher order corrections
- Electroweak analysis/sensitivity to new physics, fit oblique parameters

(c) *Thomas Kluge:*  $\alpha_s$  determination

(d) *Stefano Forte, Alberto Guffanti, Juan Rojo:* PDF fits with NNPDF

(e) *Alessandro Vicini:* Relevance of LHeC PDF determination to LHC physics.

2. High pt jet data in DIS and photoproduction: *Thomas Gehrmann, Joerg Behr, Thomas Schoerner-Sadenius, Claudia Glasman, Juan Terron*

(a) Experimental conditions: minimal pt cuts (trigger), acceptance and expected energy resolutions and scale uncertainties

(b) Differential Jet Cross sections vs  $E_T$  and  $Q^2$ ; (c) Sensity to the proton gluon density; (d) Determination of  $\alpha_s$ ; (e) Photoproduction: resolved photon structure

3. Heavy Quark Production (charm and beauty) measurements at LHeC: *Olaf Behnke, Gokhan Unel, Max Klein (+ find some Theoretician?)*

• Experimental conditions: minimal pt cuts,  $\theta$  acceptance, tagging efficiencies and purities

- Charm and beauty photoproduction and the proton gluon density
- Heavy quark production in neutral current DIS
  - $F_2^{c\bar{c}}$  and the gluon density in the proton, intrinsic charm at large  $x$
  - $F_2^{b\bar{b}}$  and effective  $b$ -density in the proton, compared to  $Z + b$  at LHC
- Charm production in charged current DIS and determination of  $s$  and  $\bar{s}$  densities in the proton

• Charm and beauty production at a  $\gamma\gamma$  collider

4. Single top production at the LHeC: *Uta Klein*

5. Partonic structure of the Photon: *NN*

6. Prompt photons: *NN*

7. Other final state analyses (e.g. fragmentation studies of identified particles): *NN*

# CDR sketches

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