#### Constraining parton density functions using HERA data

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- Introduction
- Status of PDFs from HERA
- Status of other data and future prospects
  - Charged current DIS valence quarks and strange
  - Heavy flavours charm and beauty
  - Jet data
- Summary

#### Introduction

- Have seen the effect of HERA I F<sub>2</sub> data and prospects for HERA II F<sub>2</sub> data
- What other measurements at HERA give information on PDFs?
- What is the status of these measurements now from HERA I data?
- What can we expect from HERA II?

## Status of PDFs from HERA



### Status of PDFs from HERA



## e $\nu$ $W^{\pm}$ $q_i$ $q_j$

# Charged current DIS

- W<sup>±</sup> exchange
- Sensitivity to quark flavour

$$\dot{o}(e^{-}p) \propto \left[ u + c + (1 - y)^2 (\overline{d} + \overline{s}) \right]$$
  
$$\dot{o}(e^{+}p) \propto \left[ \overline{u} + \overline{c} + (1 - y)^2 (d + s) \right]$$

- e<sup>+</sup>p sensitive to d(x,Q<sup>2</sup>)
- e<sup>-</sup>p sensitive to u(x,Q<sup>2</sup>)



## Charged current DIS

- HERA I cross section measurements
- See areas in x where valence quarks dominate cross section
- Input to fits now!
- Constrain valence quarks almost as well as fixed target data
- Statistics dominated
- Room for improvement at HERA II



#### Charged current DIS

- Behaviour of d/u as x->1
- x<0.3 well constrained by CDF and NMC data
- 0.3<x<0.7 NMC data but with large nuclear corrections
- x>0.7 little information
- No nuclear corrections necessary for HERA data
- d-quark density at high x only from charged current
- Factor of 10 more luminosity



# Strange

- Current HERA data from φ meson production
- First direct observation of strange sea at HERA
- Level of comparing different MC models of strange quarks
- Collect a large sample of high-P<sub>T</sub>  $\phi$  events at HERA II
- Constraint on strange sea?



## Strange

- Direct access to strange sea also possible through tagging charm in charged current DIS
  - Low cross section
  - Low charm tagging efficiency
- Only a handful of D\* events in HERA I CC data
- Will be a challenge at HERA II
- Use maximum number of decay channels
- Strange-quark density error 15-30% at HERA II



## Charm

- Fixed flavour number scheme
  - Charm generated only through BGF
  - Measurements provide constraints on gluon density
  - Should break down when Q<sup>2</sup>>>m<sub>c</sub><sup>2</sup>
- Charm density in proton for higher Q<sup>2</sup>/P<sub>T</sub>



## Charm

- Charm measurements in DIS
- Measure cross sections and extrapolate to F<sub>2</sub><sup>c</sup>
- Visible cross section ~30% of total
- Fraction of charm >25% at higher values of Q<sup>2</sup>
- Uncertainties from m<sub>c</sub>, hard scale, fragmentation...
- 5.10<sup>-5</sup><x<3.10<sup>-3</sup>



## Charm

- What can be expected from HERA II?
- Increased luminosity and tagging efficiency will lead to much improved precision
- At some point uncertainty in m<sub>c</sub> will limit precision
- x range up to 0.1
- May observe charm acting like a parton?



#### 500 pb<sup>-1</sup>

• Conclusion: Increases in precision through higher luminosity and improved tagging will benefit gluon density extraction





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charm

- Precision to compare ulletcharm and beauty contributions to proton
- Probably not to • constrain PDFs

- Jets in NC DIS sensitive to quark distributions in the proton
- Directly sensitive to gluon distribution through subprocess



BGF



**QCDC** 



- Ratios of measured cross sections to theory
- At higher E<sub>T</sub> and Q<sup>2</sup> values theoretical uncertainties and systematic uncertainties are smaller
- Can we use this to constrain the gluon and quark PDFs in future?

- Gluon extraction
- Including jet and inclusive data
- $\alpha_{\rm S}$  fixed
- 0.01<x<0.1
- Consistent with global fits



- Jets in photoproduction
- Direct and resolved processes
- Both directly sensitive to the gluon density
- Easier to consider direct process when considering proton PDFs





- Current status of PhP di-jets
- $X_{y}^{obs} > 0.75$ 
  - direct process enriched
- x range from 0.01 to 0.5



# Summary

- Status of HERA I measurements that give information on PDFs
  - Still data left to analyse
  - Expect improvement in precision at high  $Q^2/E_T$
- Prospects for these and other measurements at HERA II
  - Higher statistics
  - Extend kinematic reach
  - Flavour specific measurements
- Measurements do offer information on PDFs but in many cases challenging to utilise as input to fits effectively
- Best possible knowledge of PDFs and QCD relevant to future experiments