Heavy Flavour Physics at HERA2

Benno List

ETH IPP

Institute for Particle Physics

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- **Introduction:** Why
- **The Measurements:** What
- **The Tools:** How

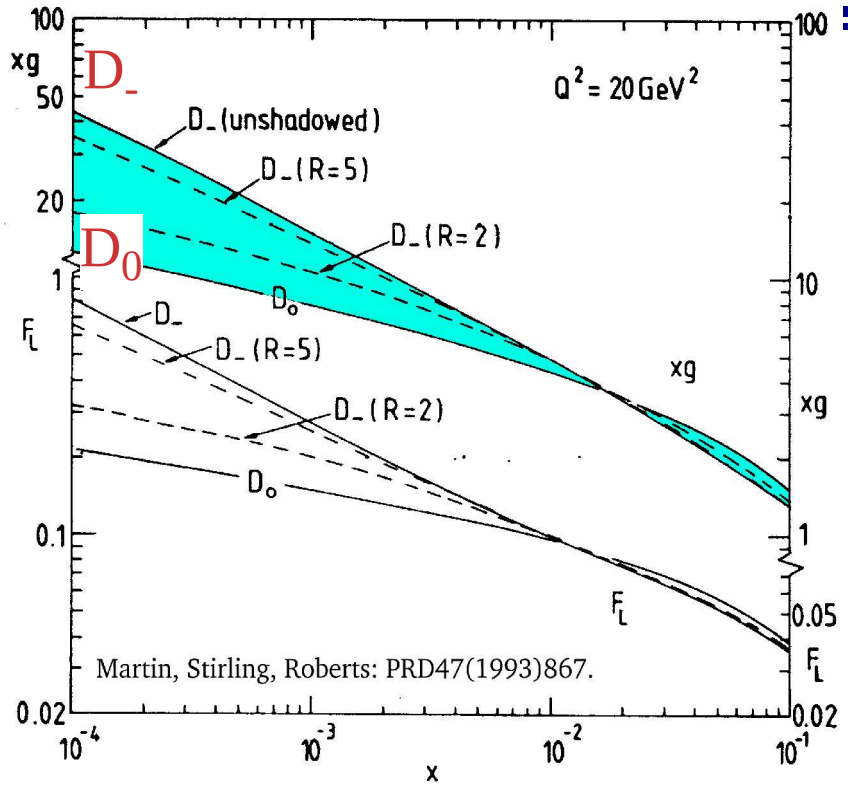
Many thanks to: Christoph Grab, Felix Sefkow, Ralf Gerhards, Andreas Meyer for useful discussions!

Introduction

- HERA II workshop 1995:
  - 8 papers on HERA-B
  - 2 papers on rare charm decays, D0 mixing
  - 3 papers on heavy flavour production (2 by theorists)
- Decay measurements made obsolete by PEPII+BaBar, KEKB+Belle, CESR+CLEO-c
- Understand the production: QCD

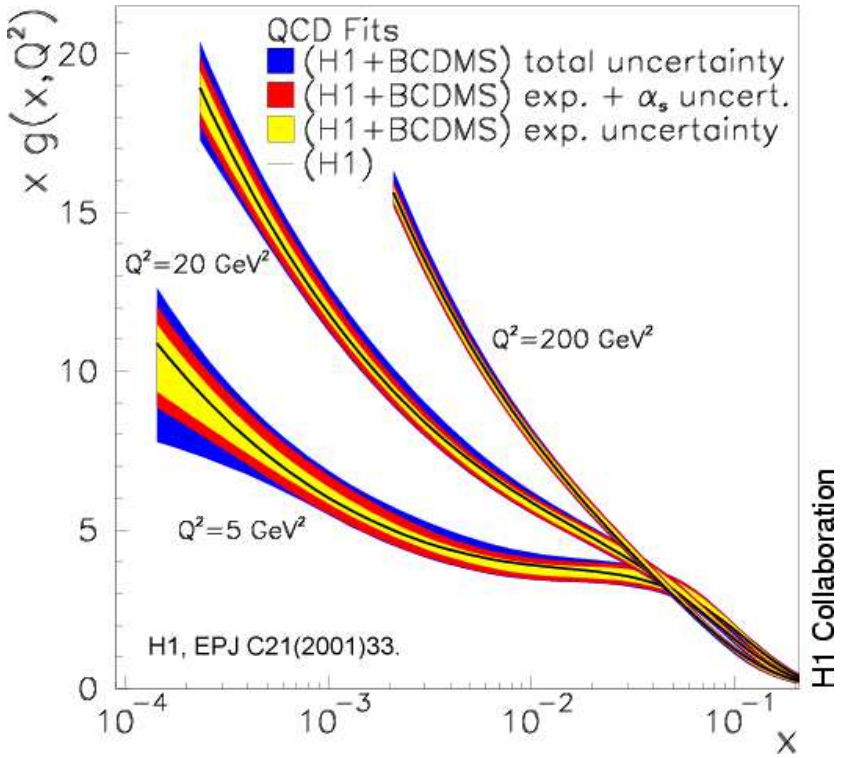
HERA is still a unique place to learn how heavy, strongly interacting (s)quarks are formed by low-x gluons!

...After All Those Years



Pre-HERA status:
gluon guess uncertain by a factor 3 at Q^2=20GeV^2 and x=3·10^{-4} .

Today: gluon known to better than 10% at Q^2=20GeV^2 and x=3·10^{-4} .

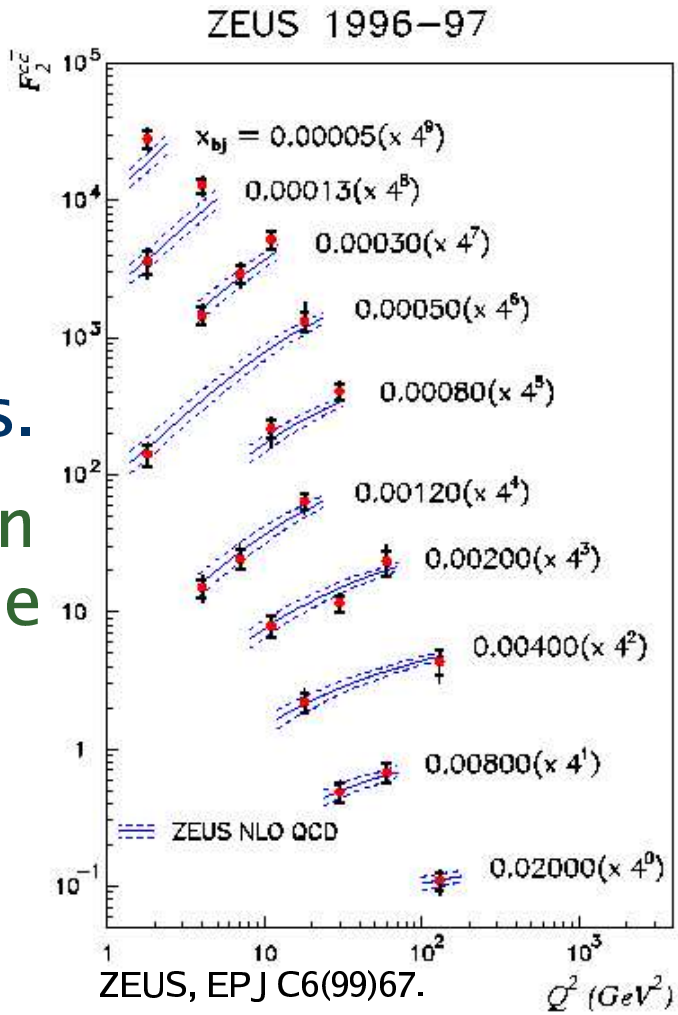


A Success

The Good News:
Perturbative QCD works!

QCD fits to inclusive F_2 data and measurements of charm production result give compatible gluon densities.

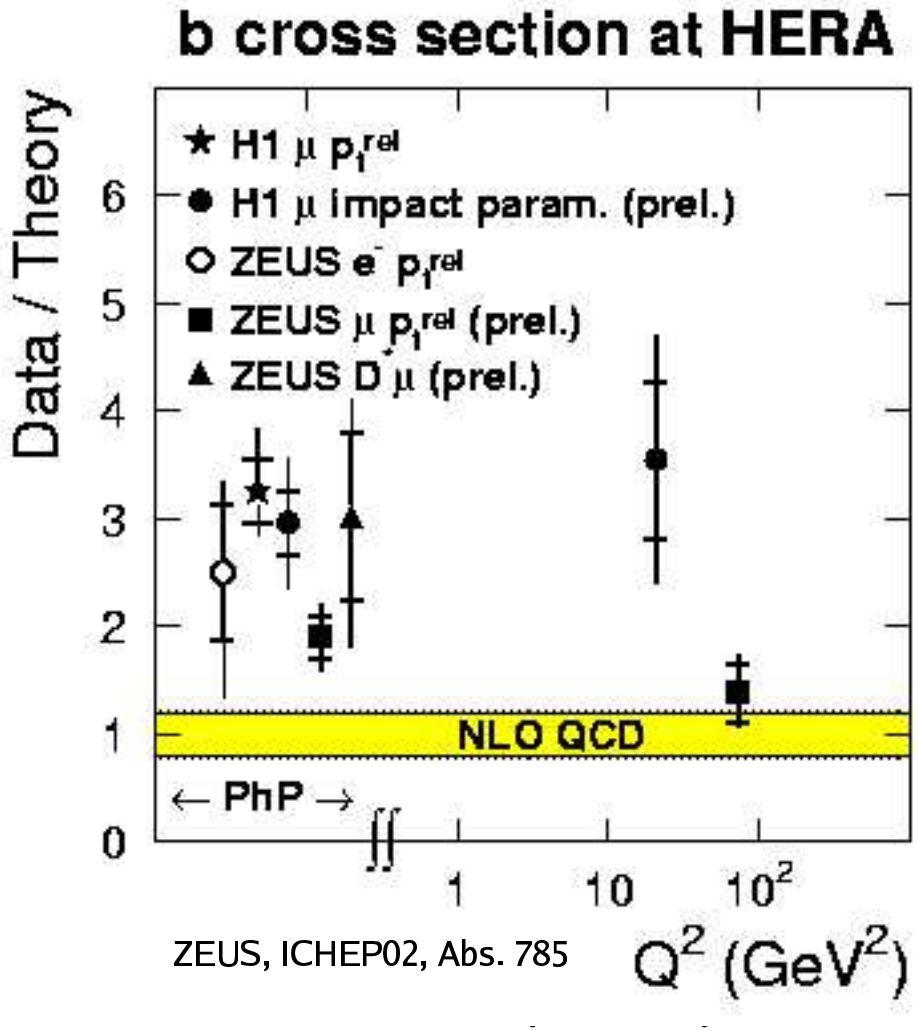
Measuring the gluon density has been one of the most important topics of the HERA-I physics program.



ZEUS, EPJ C6(99)67.

...But Still Problems

- B cross section!
- Also in other fields:
  η, p_t distributions, jets...



ZEUS, ICHEP02, Abs. 785

Why Attack These Problems?

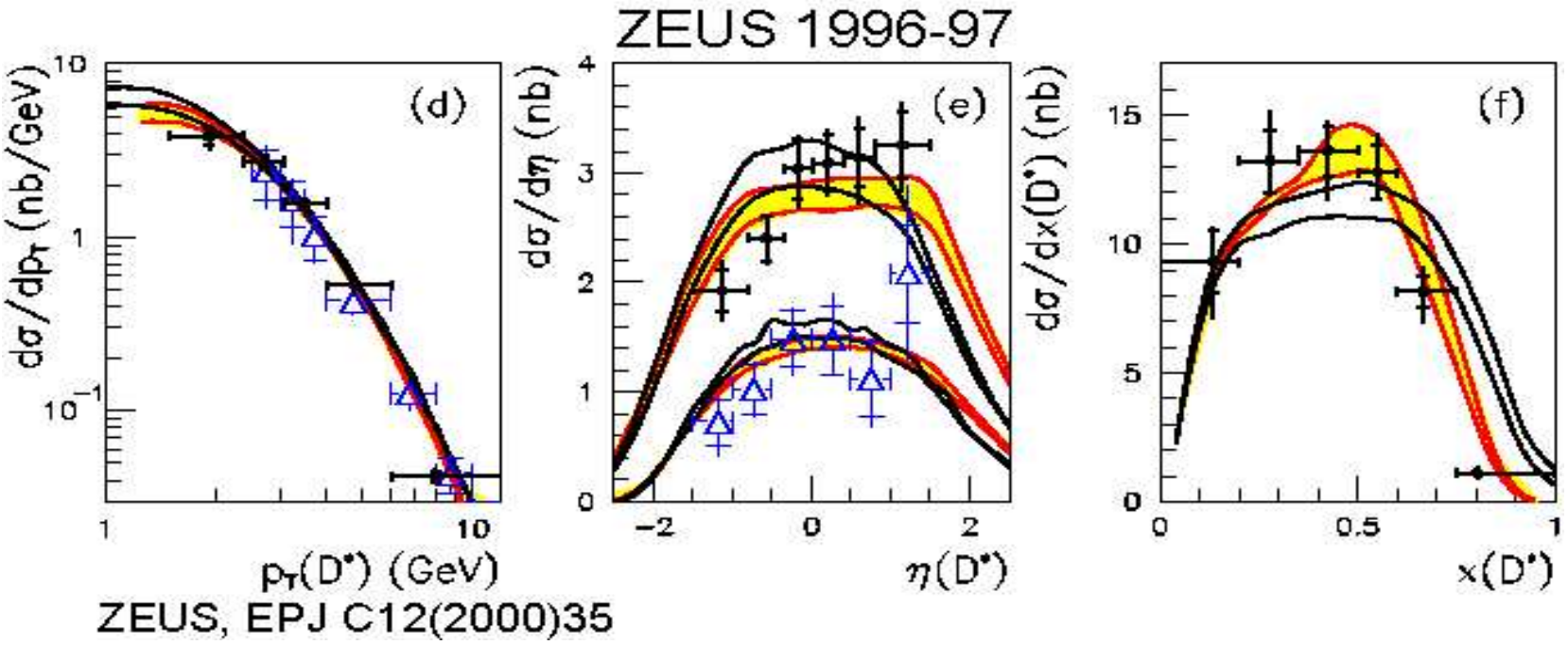
- Because they are there!
  We aim for a quantitative understanding of the QCD of heavy flavour production.
- The understanding of heavy quark (or squark!) production by low-x partons is of central importance for current and next-generation hadron colliders.

Some (Almost) Random Topics

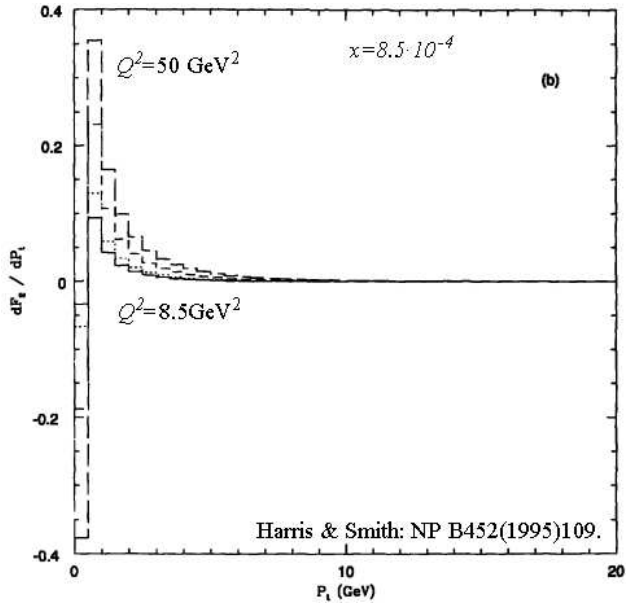
- Production Cross Sections („Size *does* matter.“)
- Differential Distributions („shape, too“)
- Can we observe NLO effects?
- When is a heavy quark heavy?
- Fragmentation: Beam drag, polarization
- Color Octet vs. Color Singlet

Shapes

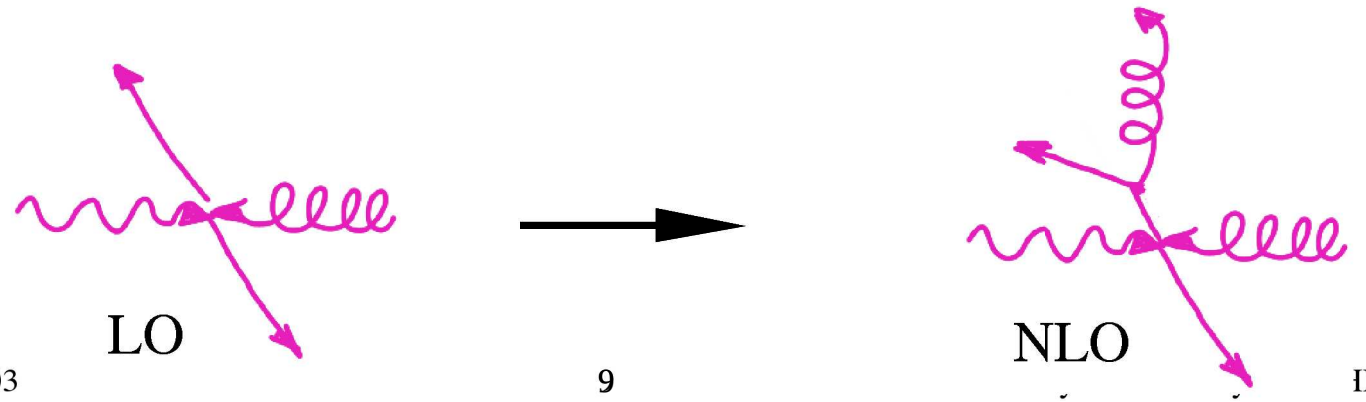
- NLO QCD describes overall cross sections (F_2^c) well
- But: Description of differential distributions not yet perfect



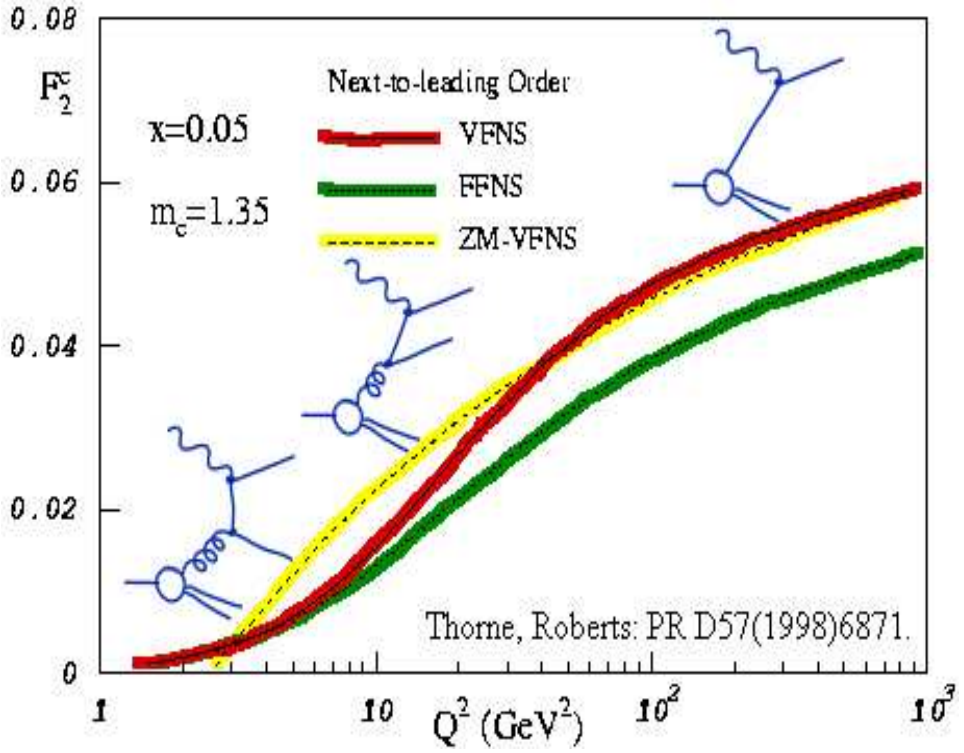
Can One Directly Observe NLO Effects?



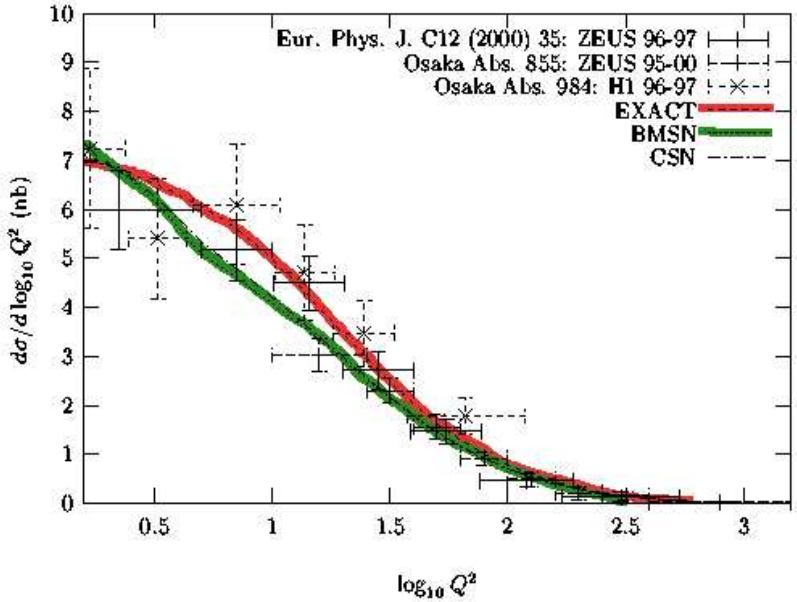
- Study observables that vanish at tree level, e.g. pt(ccbar), $\Delta\varphi$
- Important tool: double tags: $\varepsilon \rightarrow \varepsilon^2$ => use more channels, extend kinematic acceptance, develop (better) inclusive c-tags
- A full NLO Monte Carlo is needed!



Heavy Partons



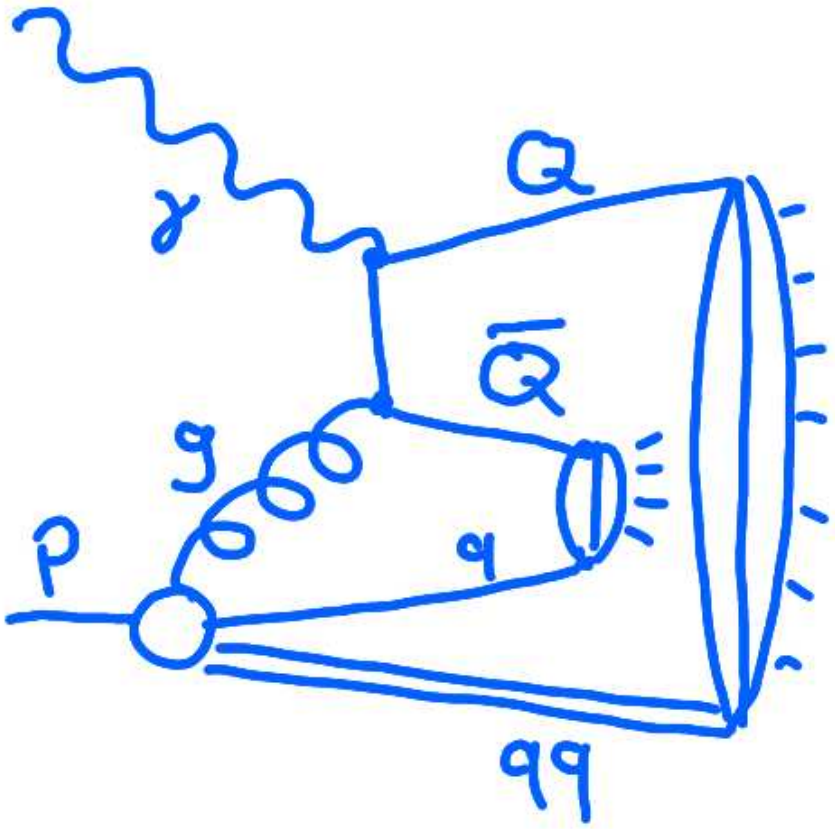
For $Q^2 > 4m_c^2$, charm behaves like a „normal“ parton



Chuvakin, Smith, Harris: EPJ C18(2001)547.

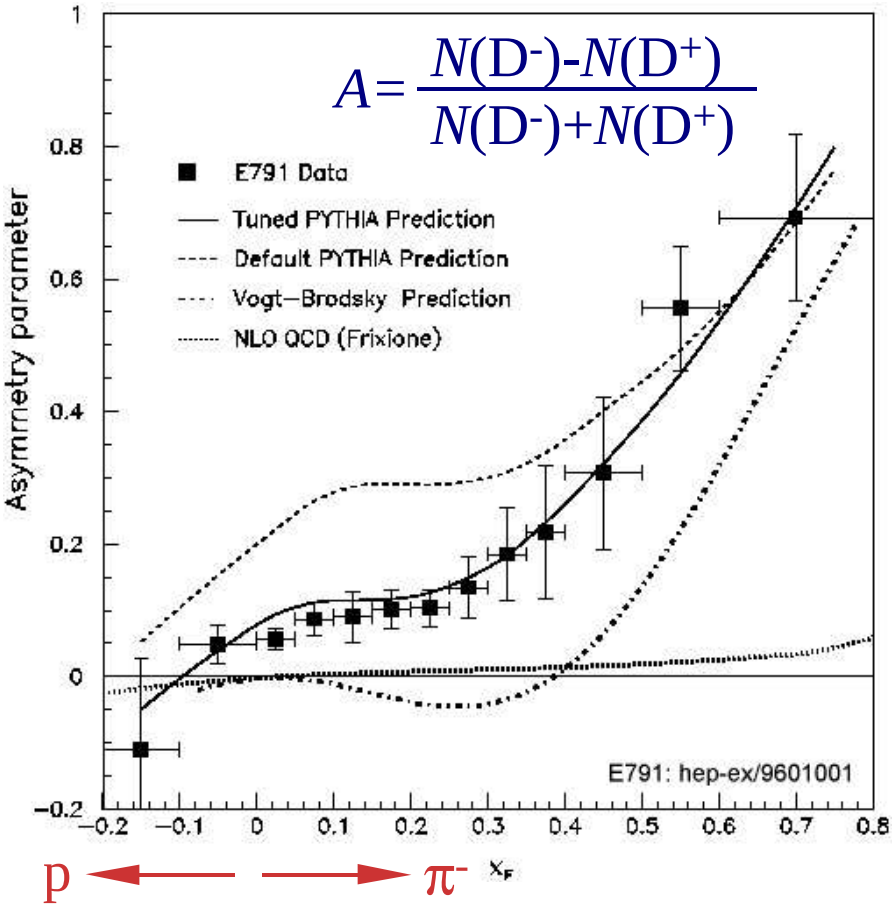
Do we understand this transition?

Fragmentation



- Is this really the right picture?
- Can we verify it?
- Look close to the beam remnant: forward!

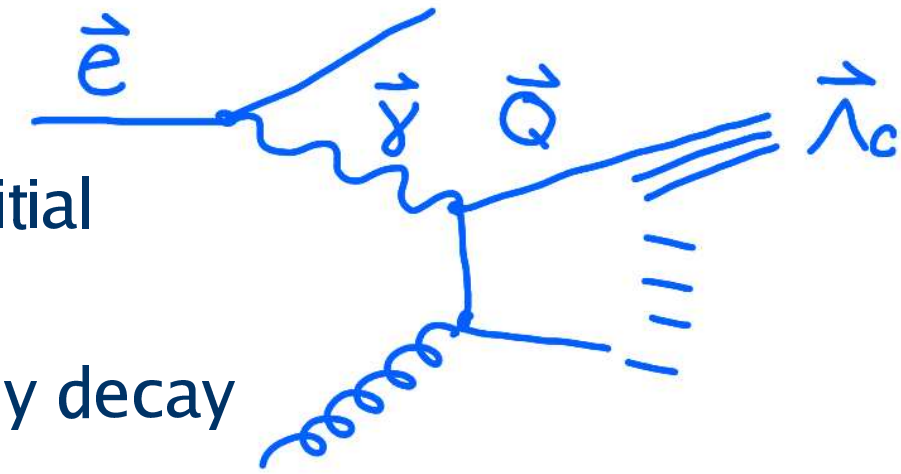
Leading Particles, Beam Drag Effect



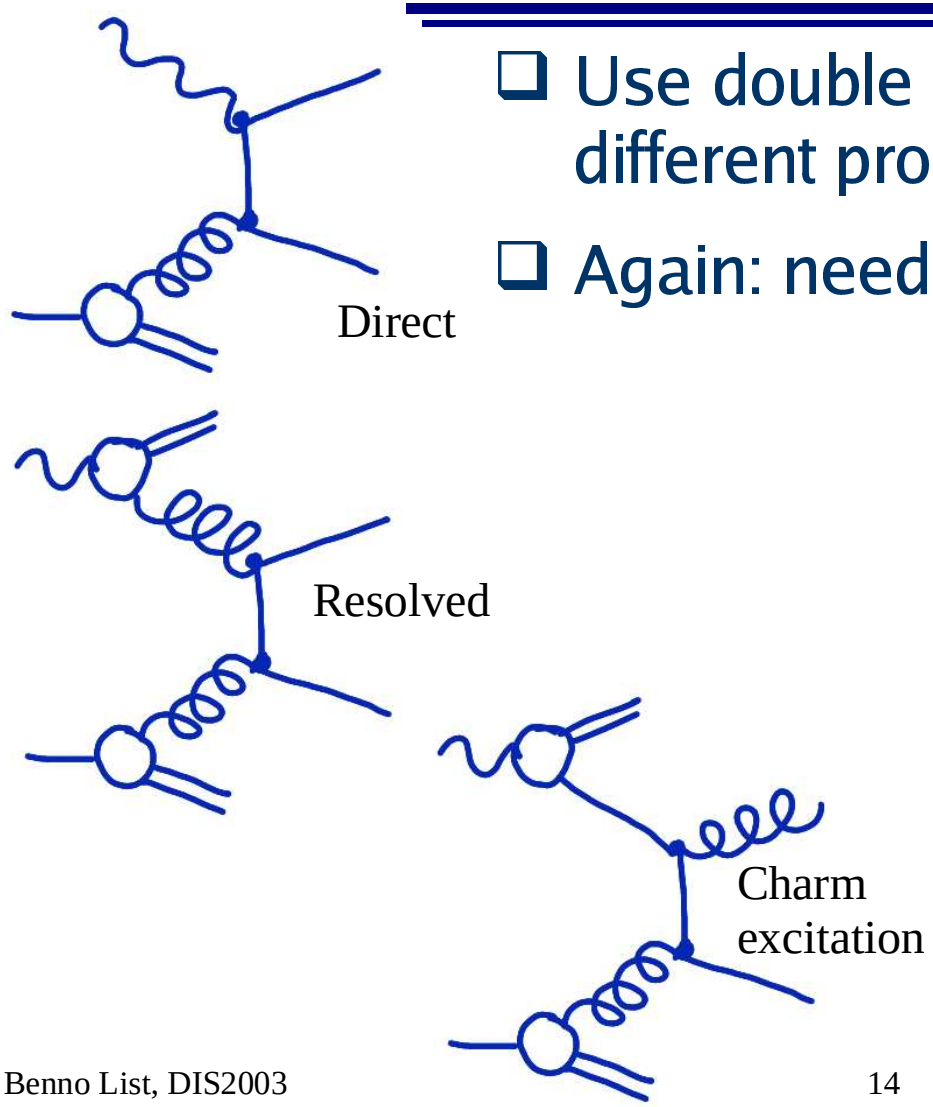
- Asymmetries in production rates (e.g. D^+ vs. D^-) come from fragmentation
- Double Tags:
  Λ_c (udc)+D^{*0} (uc^-) vs.
  Λ_c (udc)+D^{*+} (dc^-)
- Look for „Target drag“ in proton direction (forward!)

Polarization

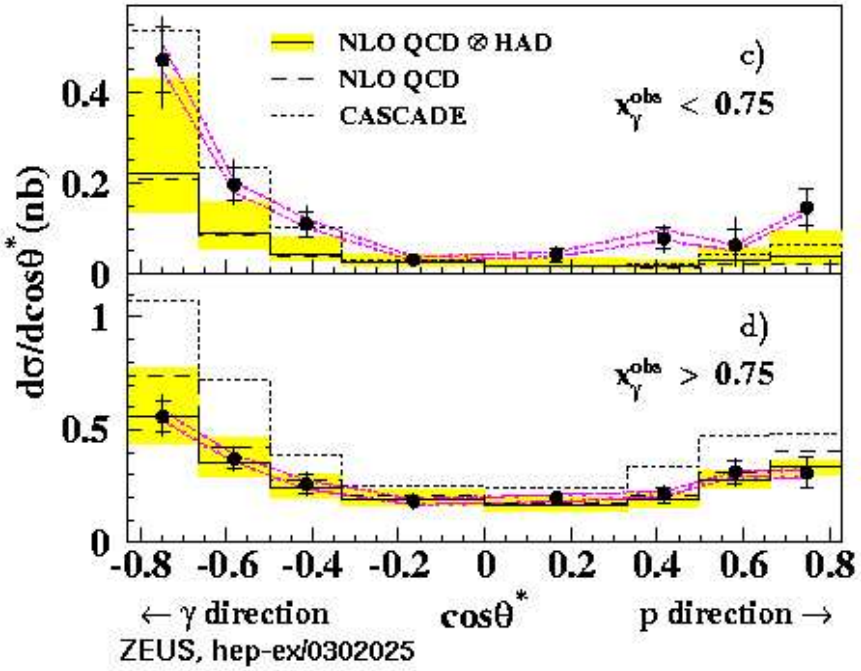
- HERA-2 offers polarized beams
- Use weak decays as spin analyzers
- Study spin transfer from initial quark to hadron
- Does a spin-0 particle really decay isotropically?
- Might be fun!



Double Tags Could Do More

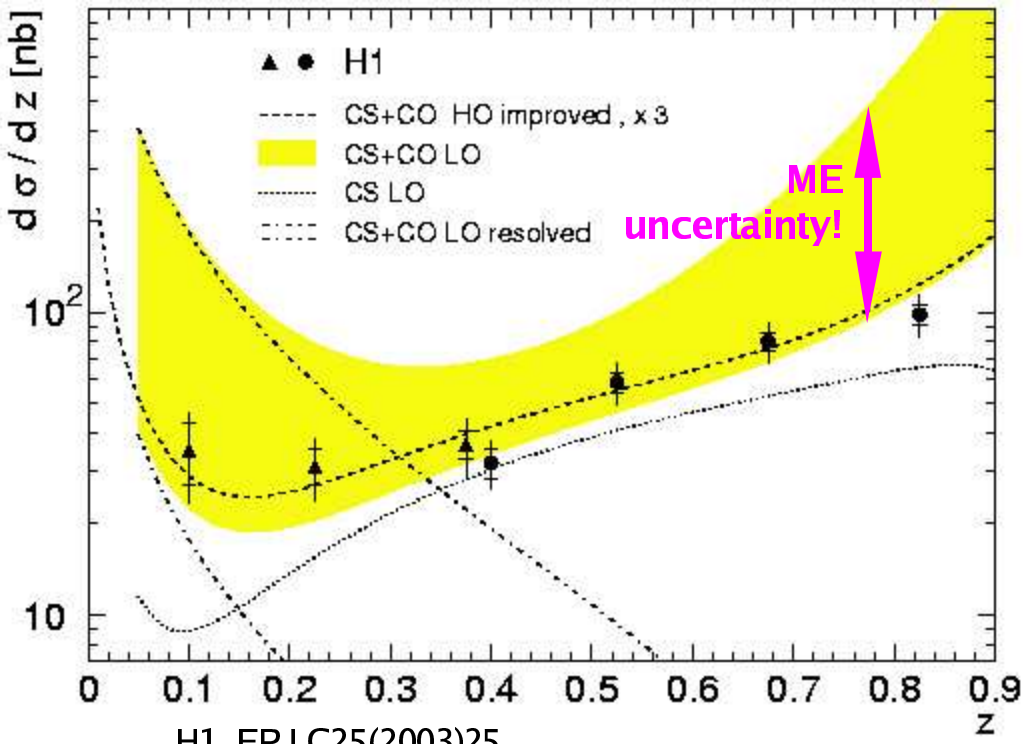


- Use double tags to disentangle different production mechanisms
- Again: needs high efficiency



Inelastic J/ψ (ψ', ϒ) Production

- Interplay between Color Singlet and Color Octet Contributions to inelastic J/ψ production still not fully understood.
- Needs more data:
  - higher pt (overlap with Tevatron)
  - Polarization!
- Inelastic ψ' Production
- Re-evaluation of long-distance ME's needed!



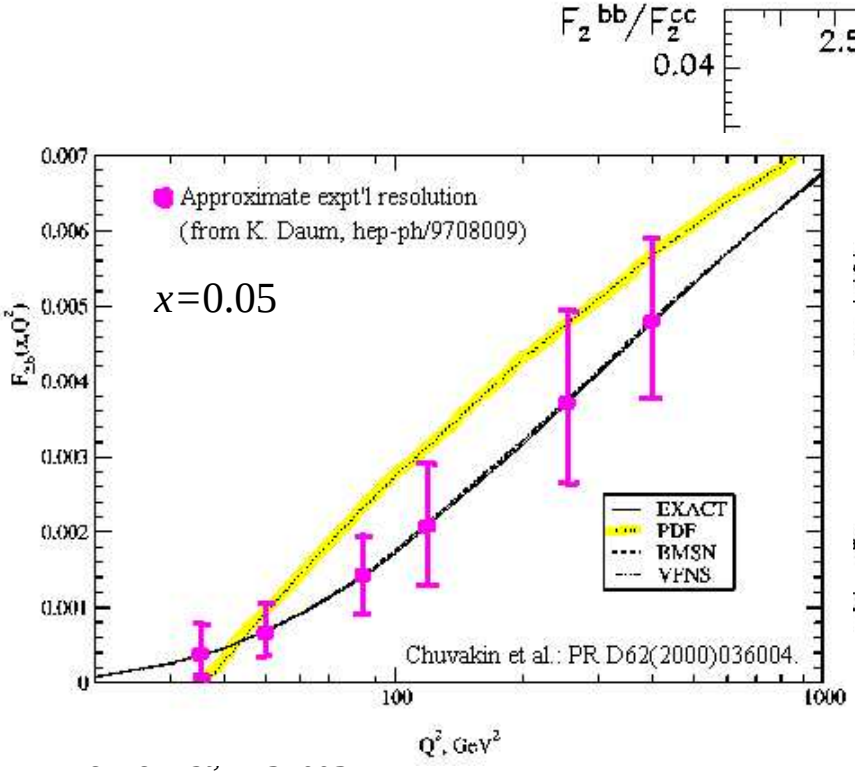
H1, EPJ C25(2003)25.

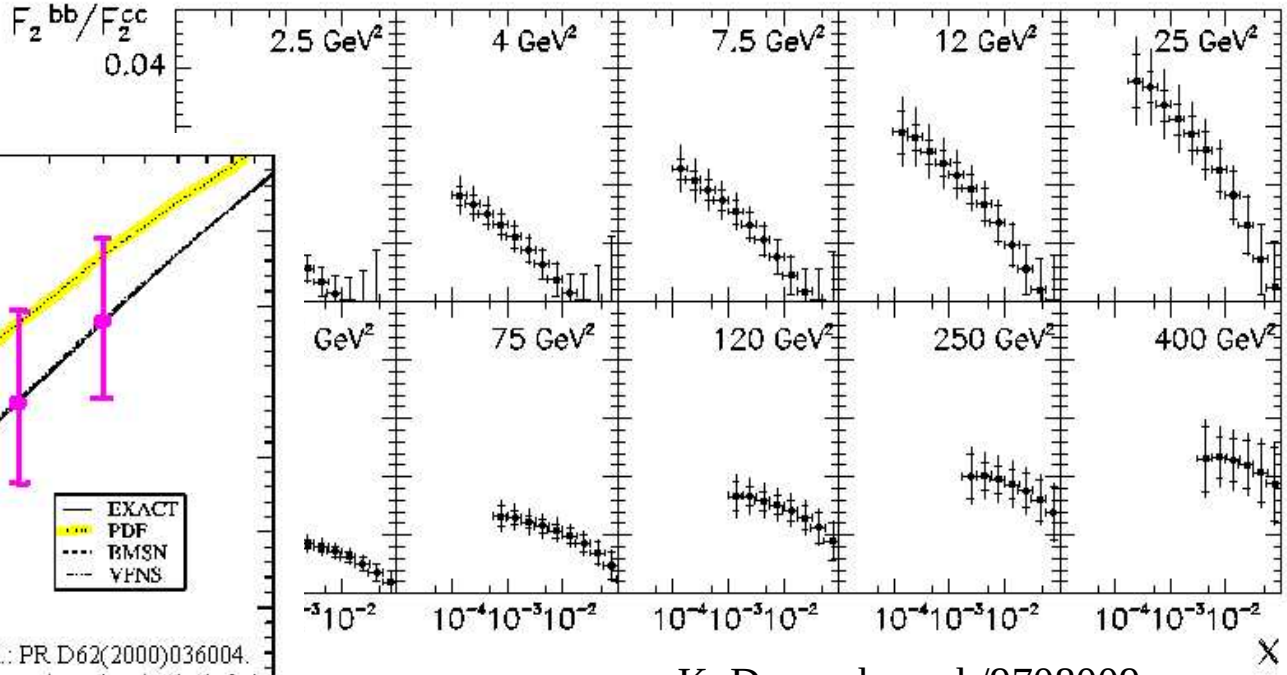
CCC: Charm in Charged Current

- HERA2: Expect about 50k CC events;
  charm produced off strange sea (anti)quarks
- Charm tagging via golden channel ($D^* \rightarrow K\pi\pi_s$):
  yield too low
- High p_t>12GeV of quark jet and no b background
  facilitate inclusive tagging (leptons and lifetime)

F_2^b!

- With 500pb^{-1}: accuracy of 10% (relative) possible
- Important test of our understanding of heavy flavour formation



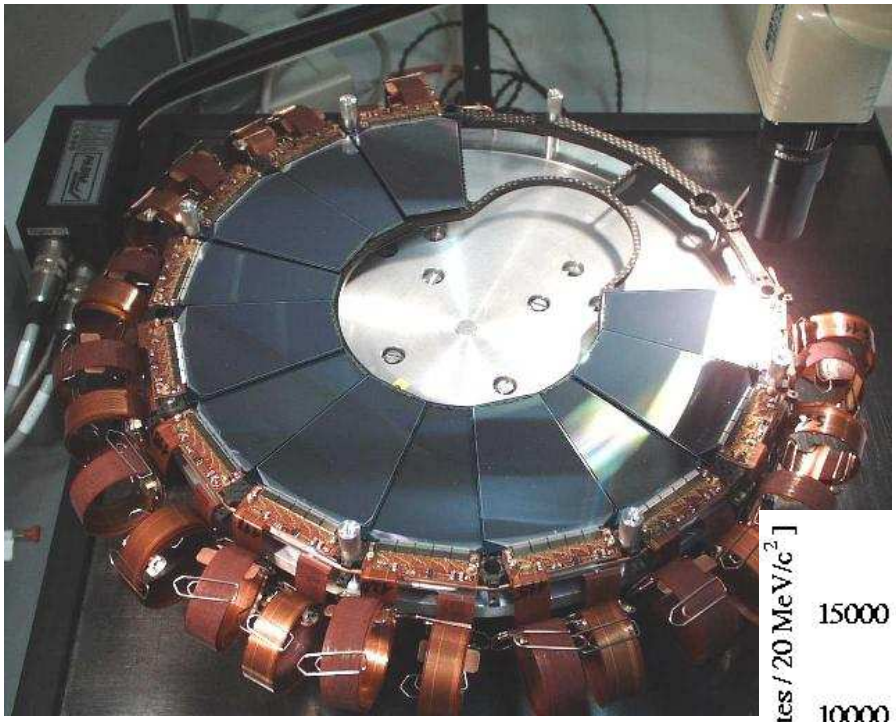


K. Daum: hep-ph/9708009

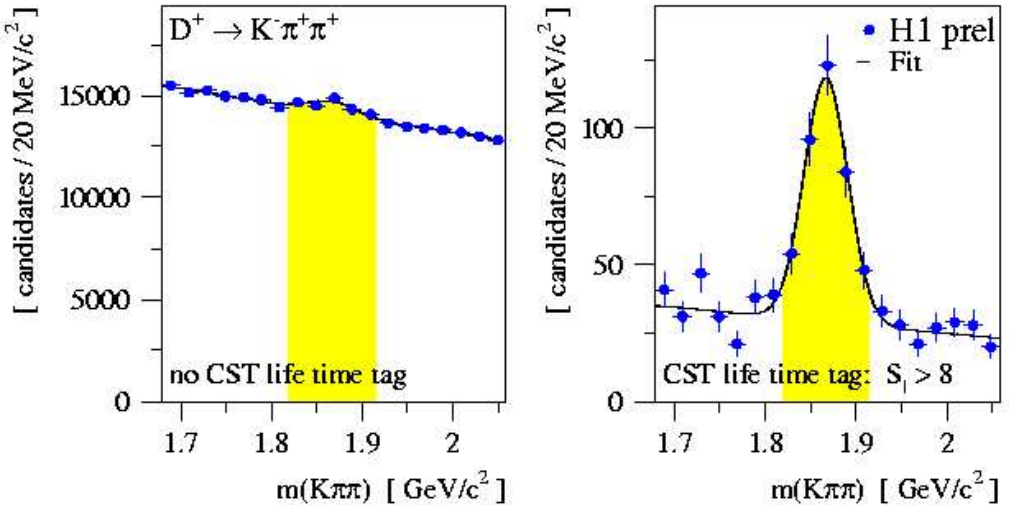
Tools And Opportunities

- New Silicon Trackers extend kinematic range
- New triggers help to find the needle in the haystack
- New MC generators allow to correct for what we don't see

The H1 Central + Forward Silicon Tracker

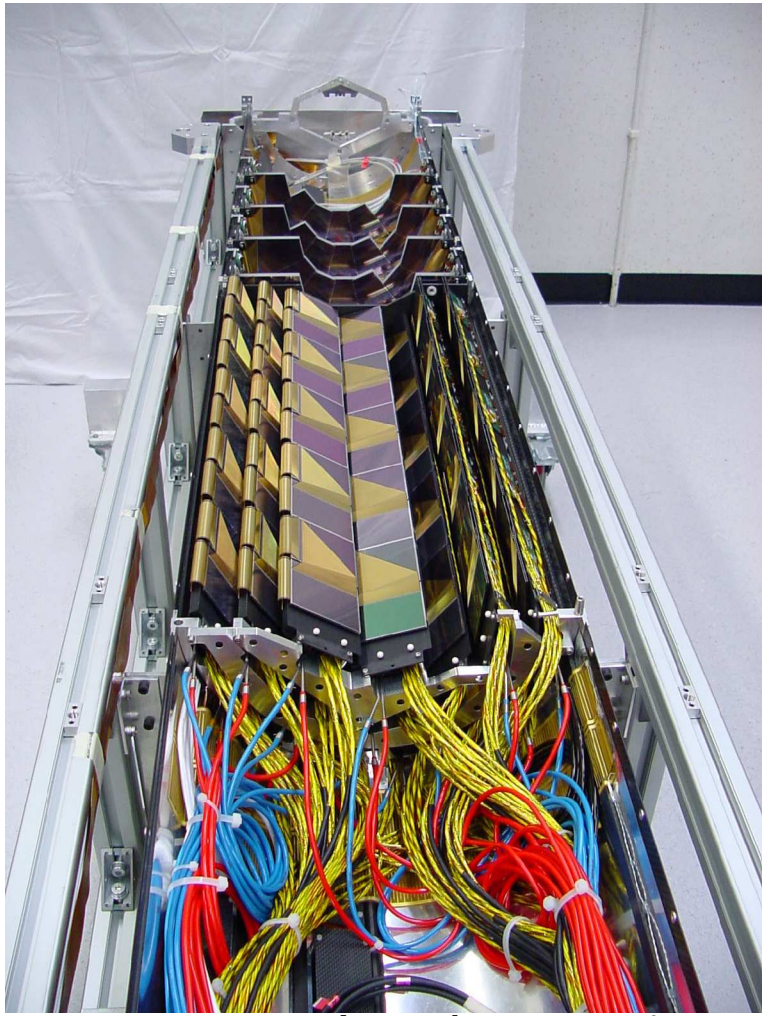


- CST: 2 layers, very thin (good vertex resolution for low momentum tracks)
- FST: 5 disk layers cover polar angles of approx. $8° < \vartheta < 17°$.



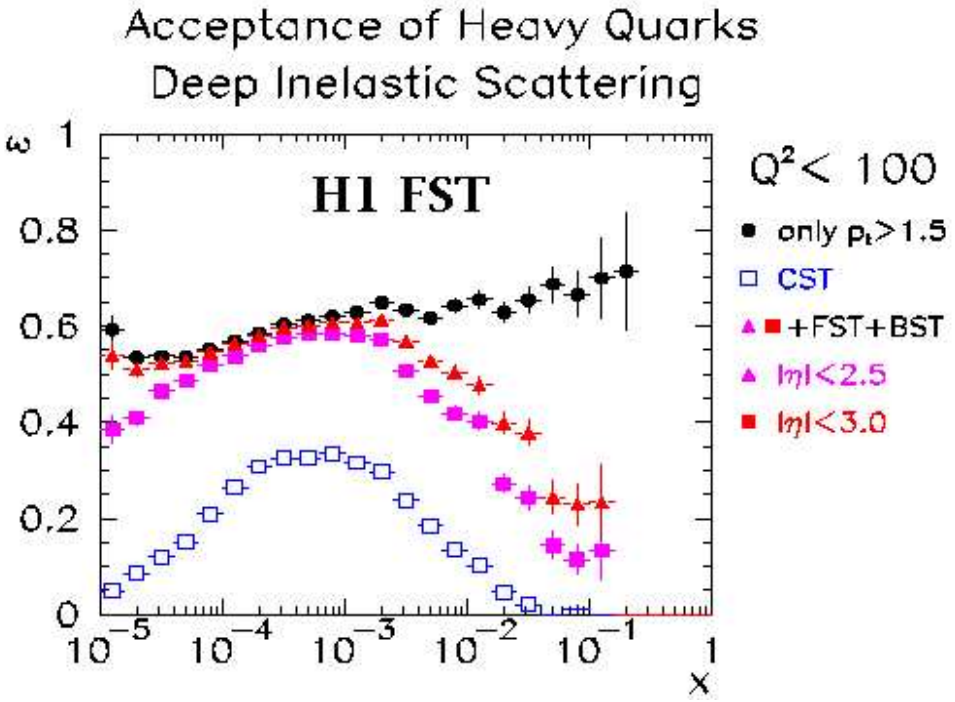
The ZEUS Microvertex Detector

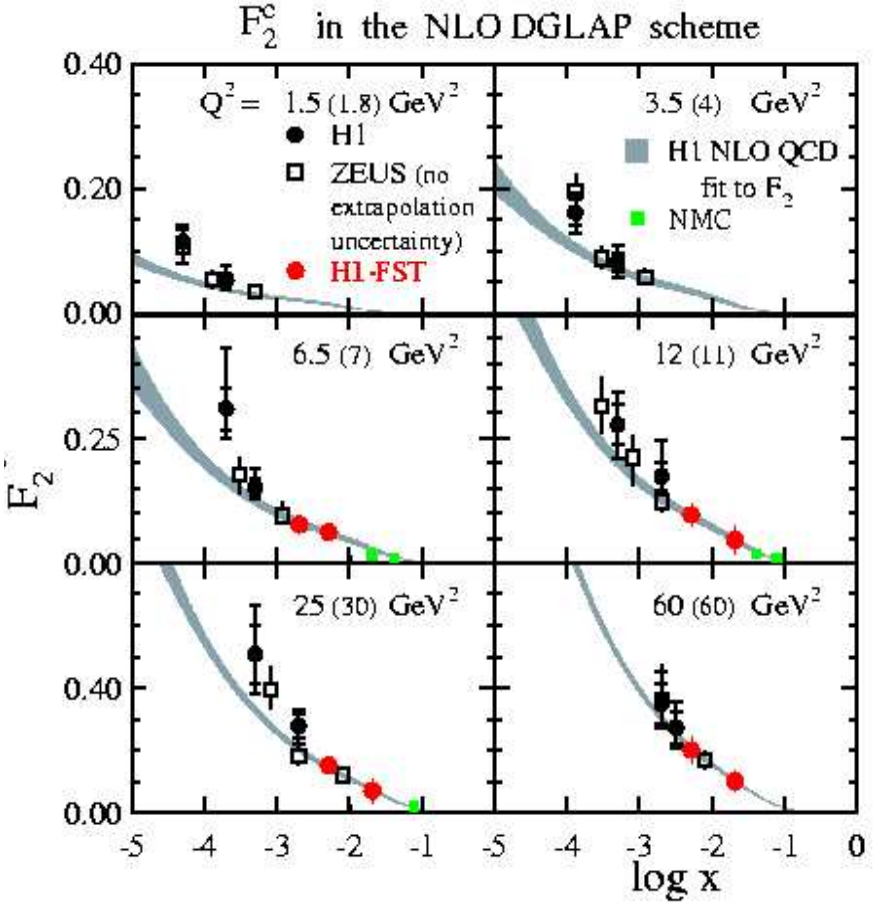
- Excellent angular coverage
- 3 barrel layers
- 4 forward wheels



Example: F_2^c at High x

- Forward silicon trackers extend acceptance to $x \approx 0.1$

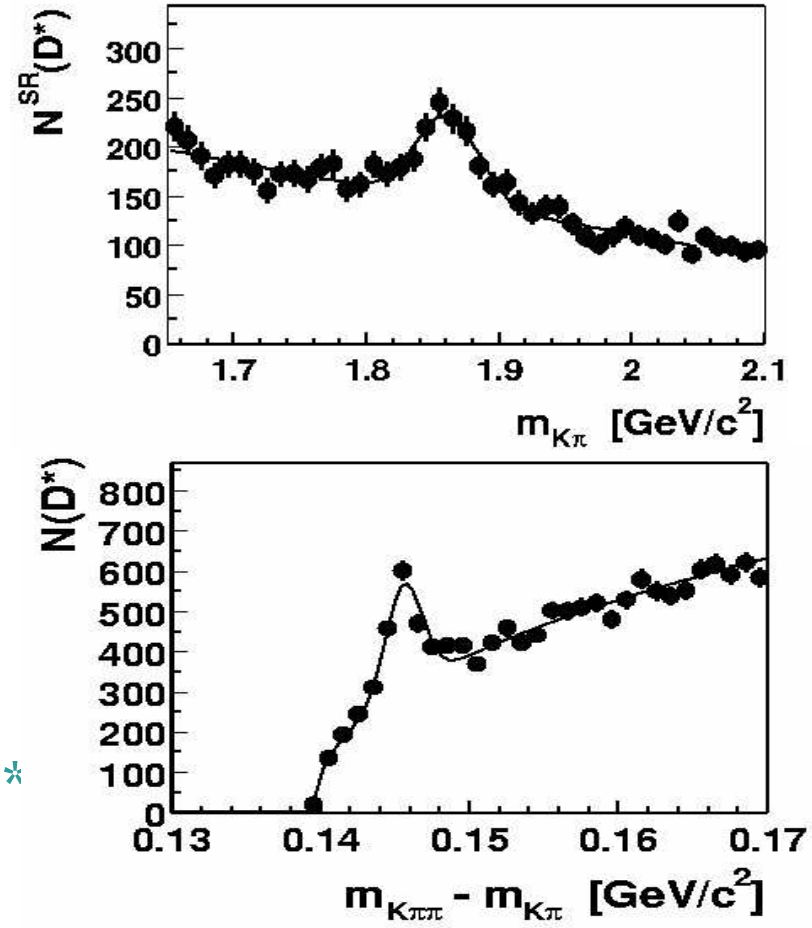




K. Daum, Study for HERA-2, for 10pb^{-1}; stat. errors only

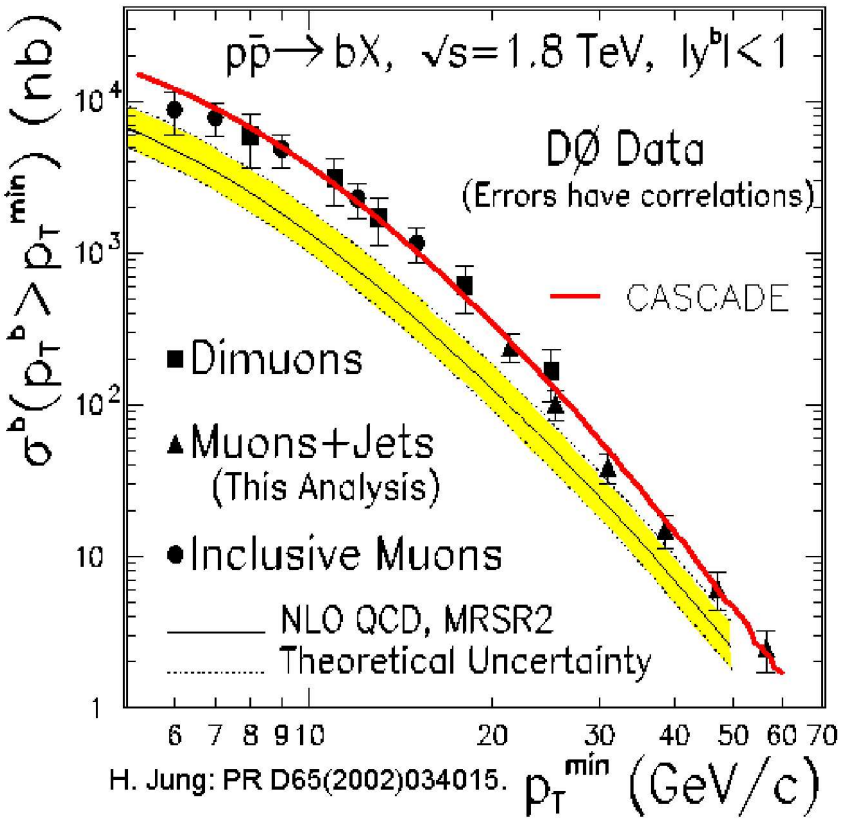
The Fast Track Trigger

- New track trigger for H1: uses drift chamber signals for fast track reconstruction.
  - 2.3μs: reliable number of tracks in coarse p_t, ϕ bins
    $\Rightarrow$ trigger on 2-prongs
  - 23μs: fine p_t, ϕ bins
  - 100μs: mass reconstruction
    $\Rightarrow$ trigger on (inelastic) J/ψ, ϒ, D*



J. Wagner: D* reconstruction with the H1 fast track trigger

Cascade: a CCFM Monte Carlo



- Unintegrated gluon densities have come of age!
- Better description of many x-sections compared to NLO
- Allows to test predictions of CCFM model

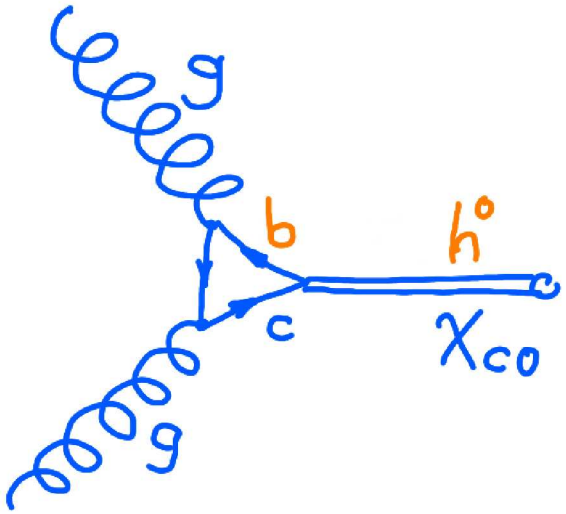
Better MCs give better data (with smaller systematic errors)!

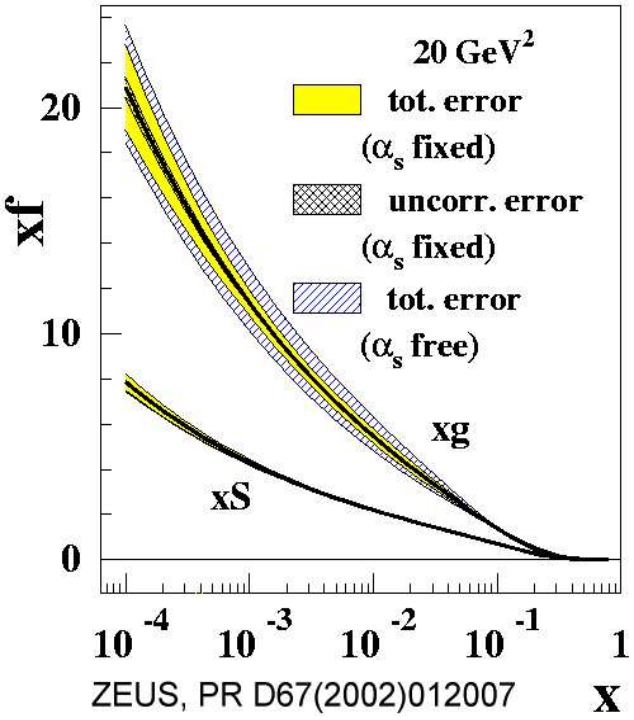
Conclusions

- Heavy flavour physics at HERA-2 is a unique place to test QCD and to learn QCD.
- At HERA-1 we have come a long way.
  Now the real fun starts!
- ZEUS and H1 are well equipped and prepared for a rich harvest!
- A full NLO Monte Carlo Program is needed.

Scalar Meson Production

- Resolved Photoproduction $\gamma p \rightarrow \chi_{c0} X \rightarrow J/\psi\, \gamma\, X$:
  - BR ($\chi_{c0} \rightarrow J/\psi\, \gamma$): 1.0%, m ($\chi_{c0}$): 3415MeV, Γ (χ_{c0}): 16.2MeV
  - p*(γ)=303MeV




20 GeV^2
tot. error
(α_s fixed)
uncorr. error
(α_s fixed)
tot. error
(α_s free)
xg
xS
xf
20
10
0
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x
ZEUS, PR D67(2002)012007

The Tools: Silicon Trackers

- Both, H1 and ZEUS, have now central+forward ST
- Central Part: Barrel shape, 2 (H1) or 2½ (ZEUS) layers
- Forward Part: Disks

Both Experiments are well equipped to study heavy flavour events.

Measurements at high η_{lab} or x_F become possible with the new forward silicon detectors and upgraded forward trackers.