HERA and the LHC Workshop

WG3 – Heavy Quarks Summary

Part 1. Theory (M.Cacciari)

Part 2. Benchmark cross sections and small-x (A.Dainese)

Part 3. **Outlook on HVQ physics at HERA-II (A.Geiser)**

WG3 Conveners:

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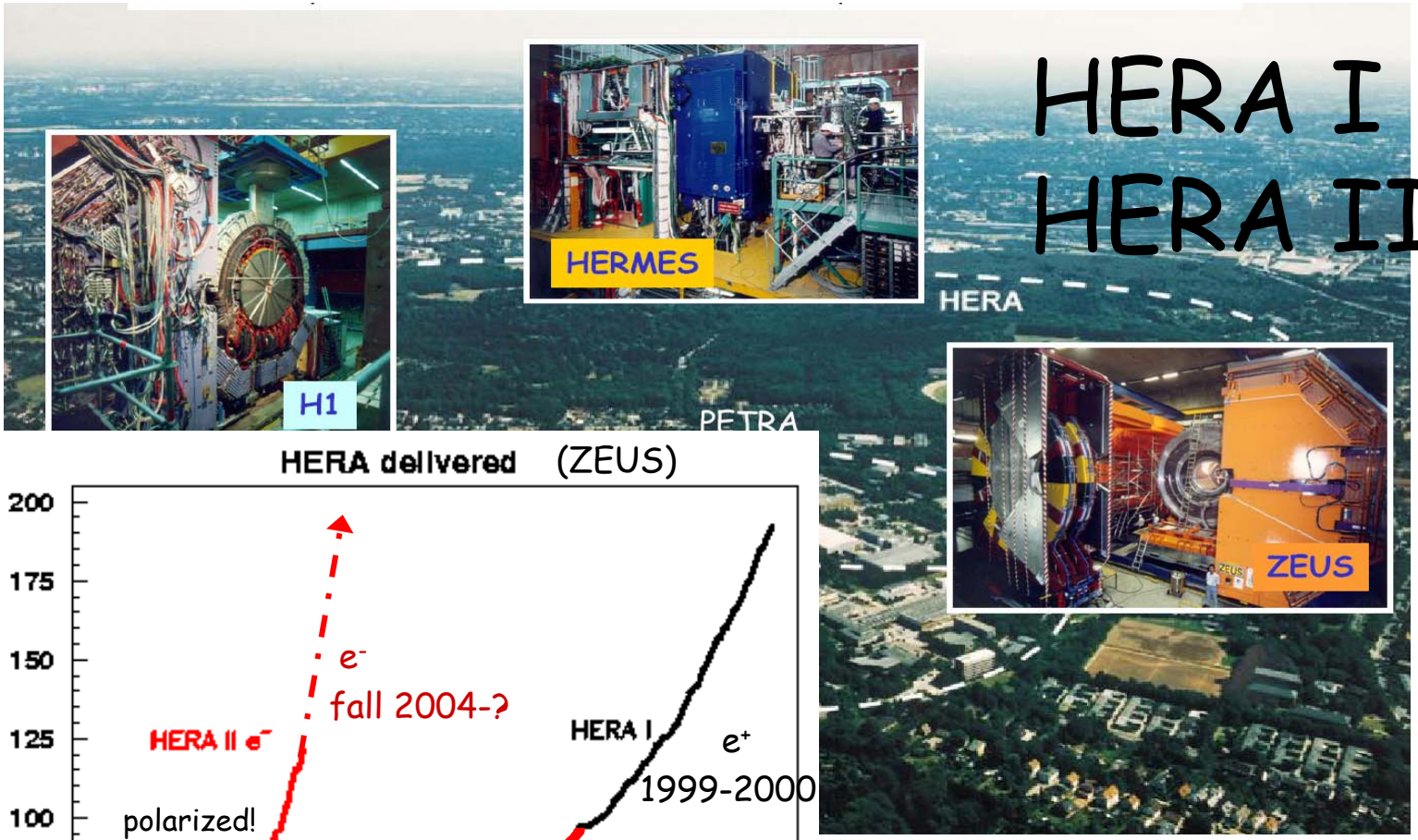
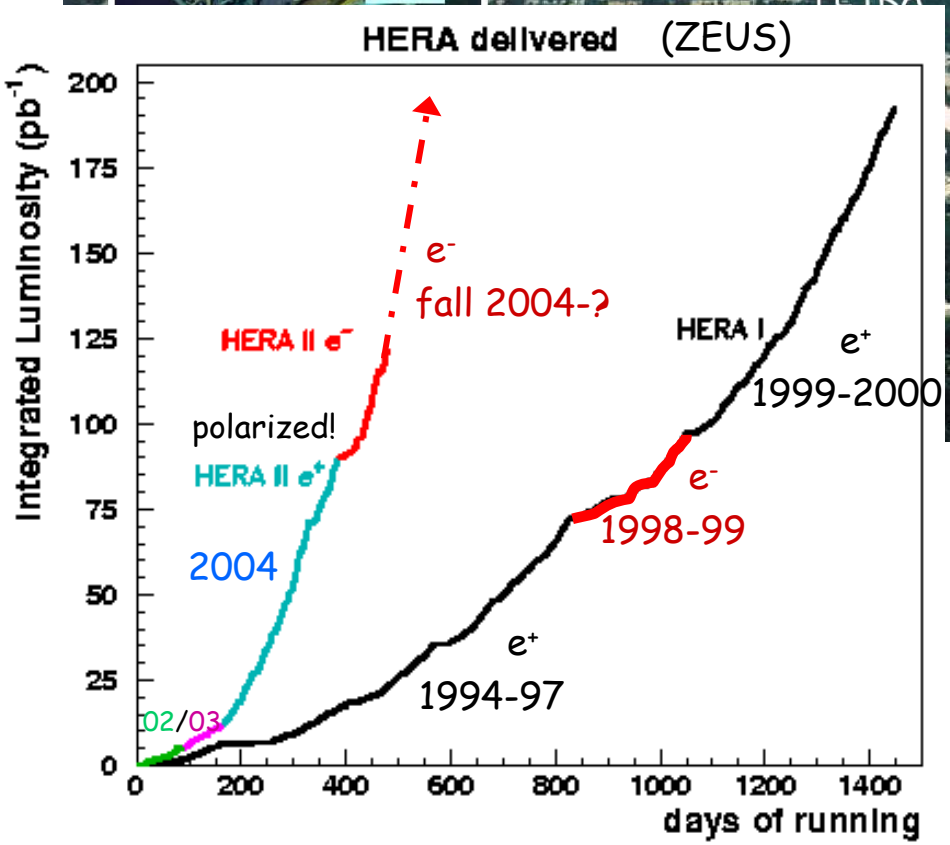
M.Smizanska, U.Uwer, C.Weiser

HERA I and HERA II





HERA I: ~ 120-130 pb^{-1} (physics)

HERA II achieved so far: ~ 130 pb^{-1} (~ 70 pb^{-1}physics)

goal: ~700 pb^{-1} till 2007

Main HFL HERA II Physics Goals

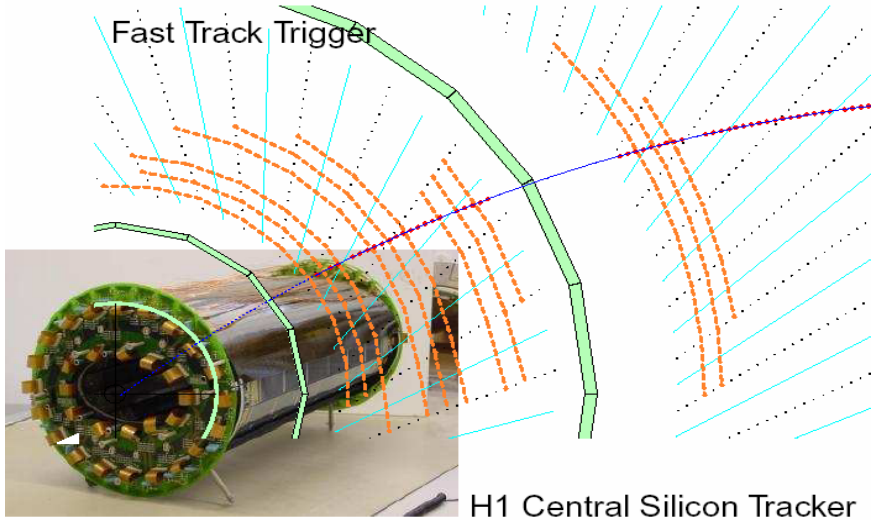
- Tests of perturbative QCD
  - Heavy quark mass sets additional perturbative QCD scale (multiscale problem)
  - Measure single + double differential cross sections with single or double heavy flavour tag + compare with predictions
- Gluon and heavy quark structure of photon and proton
  - study charm and beauty content of DIS events and high E_T dijet events with single or double heavy flavour tag
- J/ψ and Y production
  - study e.g. color octet contribution, polarization
- Strange quark sea of proton
  - study charm production in CC events
- Charm structure of pion
  - study charm production in ZEUS FNC events
- Diffractive heavy flavour production
  - study charm production in diffractive events
- Exotics (e.g. pentaquarks, instantons)

not discussed here

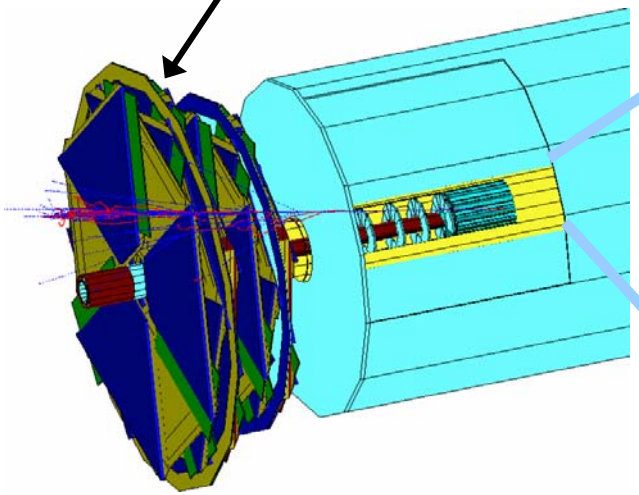
Detector upgrades for HERA II

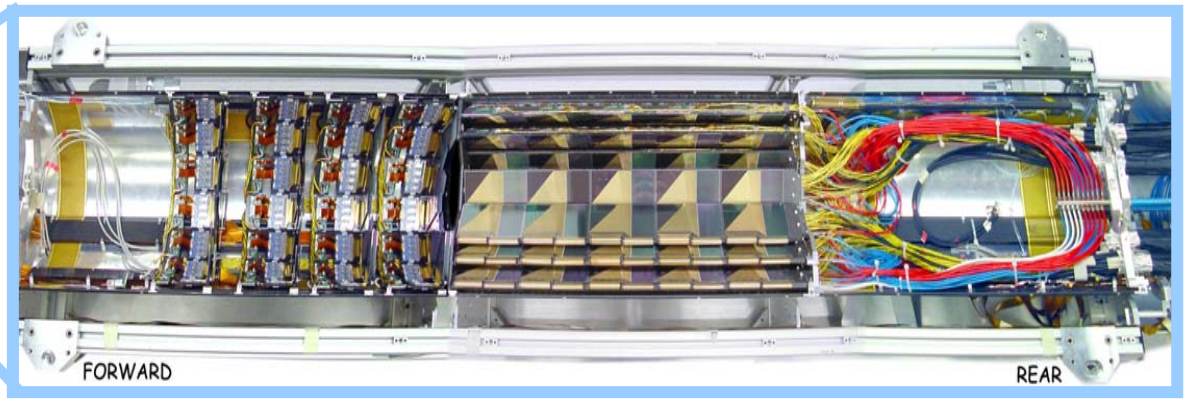
upgrades most relevant for heavy flavour production:

- H1 Fast Track Trigger
  + ZEUS Global Tracking Trigger



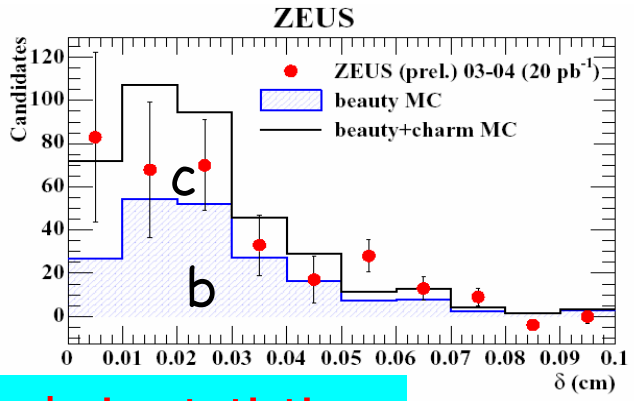
- ZEUS Micro-Vertex Detector (MVD)
  + H1 vertex detector upgrade
  + ZEUS straw tube tracker (STT)





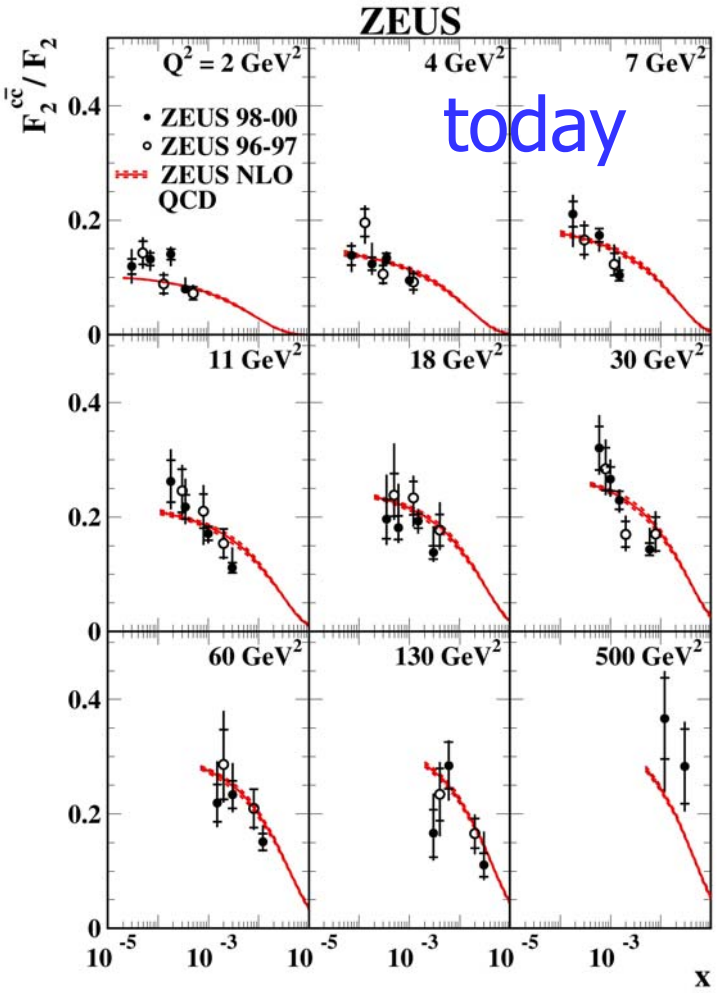
Improvements for HERA II HFL Physics

- Luminosity increase by ~ factor 5
  - from HERA II collider performance
- Maintain high trigger efficiency
  - from trigger upgrades (GTT/FTT)
- ZEUS: added MVD -> gain ~factor 2-10 acceptance (w.r.t. D* or μ)
  - from impact parameter and secondary vertices, as **already used by H1**
- Extend phase space further into forward region and to lower p_T
  - from improved tracking + algorithms (ZEUS+H1)
- Very first heavy flavour results from HERA II (with low statistics) already presented at 2004 summer conferences



- Overall expected gain: ~1-2 orders of magnitude in statistics (2007) larger η coverage, lower p_T thresholds

e.g. charm contribution to F_2

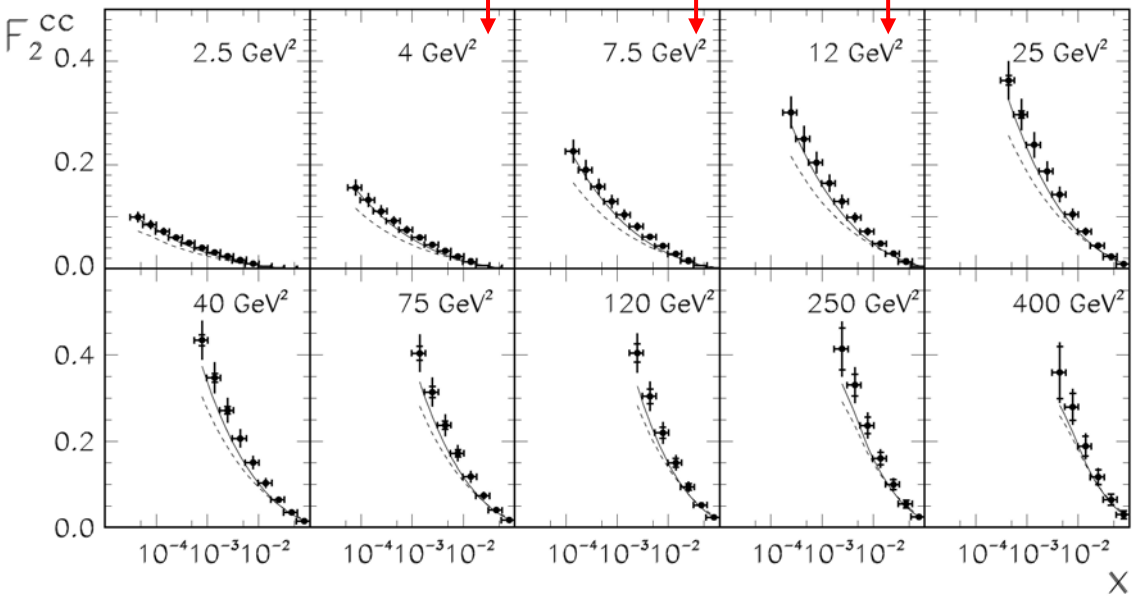


500 pb^{-1}

2007 ?

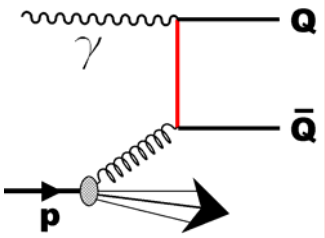
forward trackers (e.g. H1 FST)

extend x to ~0.1

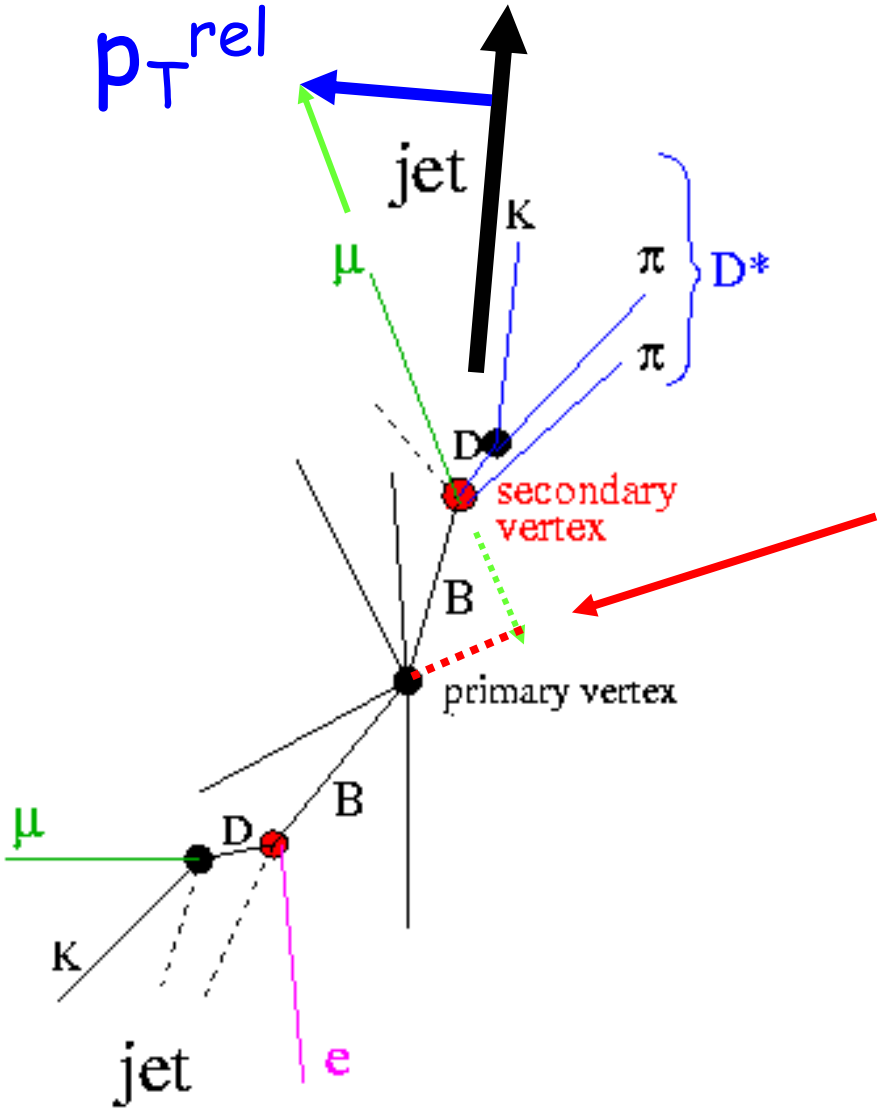


similar improvement for photoproduction

-> can help to test/constrain gluon density



Tagging (semileptonic) beauty decays



1) p_T^{rel} :

p_T of μ with respect to jet axis

2) impact parameter

(H1: HERA I+II, ZEUS: HERA II)

of μ with respect to primary vertex or secondary vertex

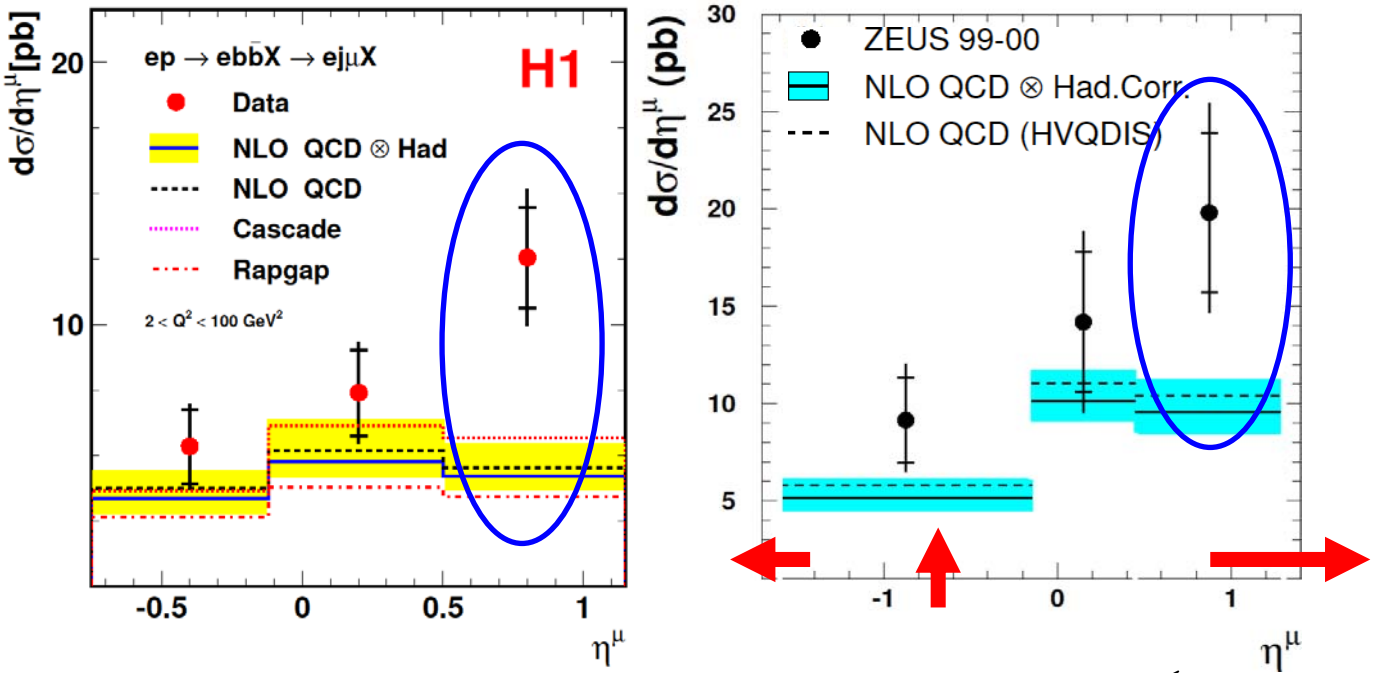
3) D* μ correlations

4) μ μ/e correlations

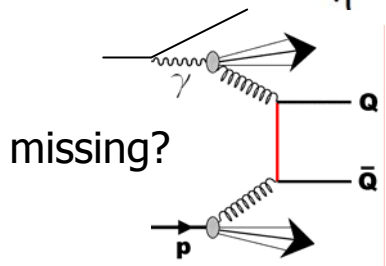
Single Beauty tag: Test of QCD

Example: beauty in DIS

- **Current analysis**
  1 jet in Breit frame
  muon pt > 2/2.5 GeV,
  $-1.6 < \eta < 1.3$
  (talk O. Behnke WG3)



- **HERA II analysis** (expected)
  - **more statistics -> finer binning, double differential**
  - **improved muon η coverage: -2 -> +3**
  - muon p_T coverage down to 1.5 GeV
  - better systematics, theory improvements

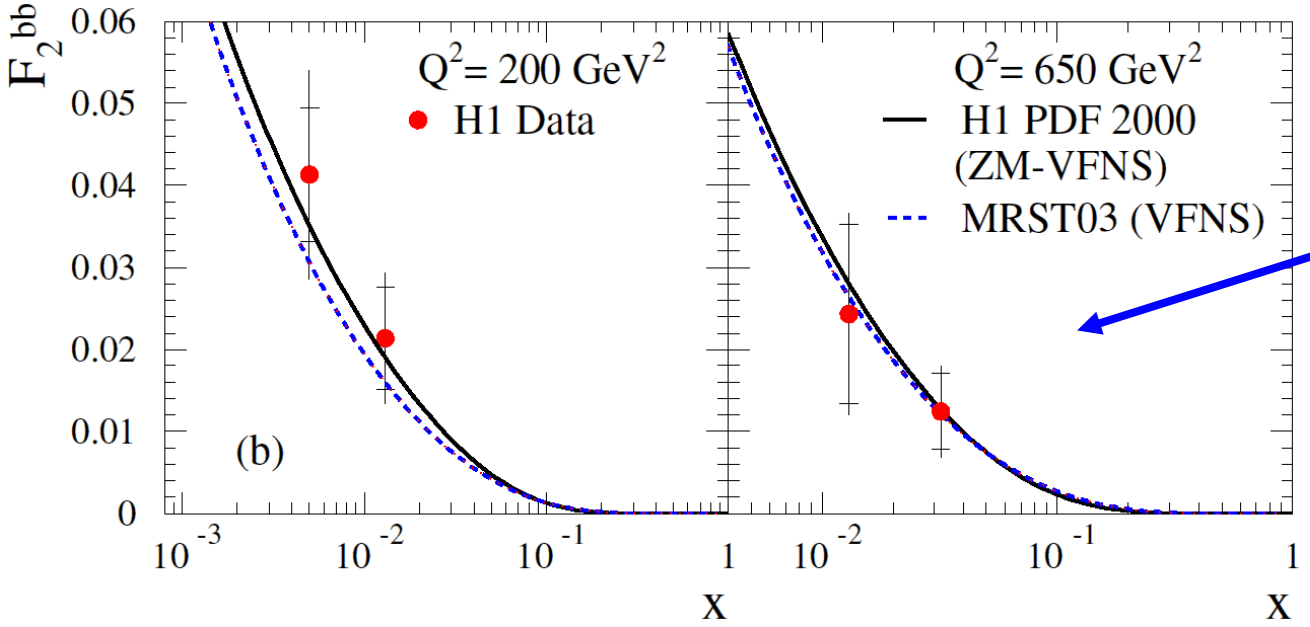


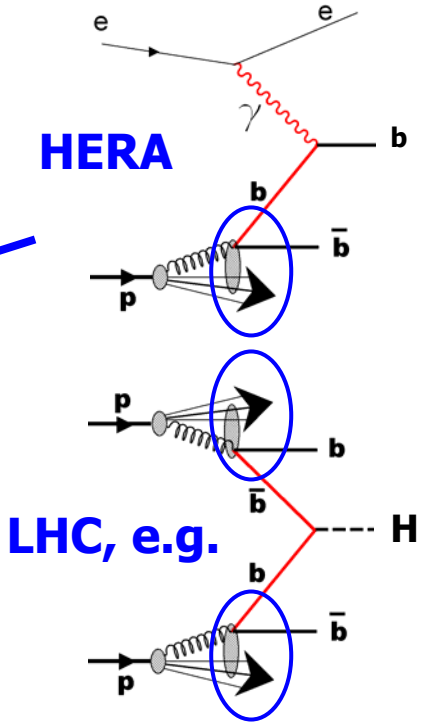
-> more detailed QCD tests, more reliable predictions for LHC

Beauty contribution to F_2

- **Current H1 (HERA I) analysis: first measurement**

  2 impact parameter tags in H1 vertex detector (see talk P. Thompson WG3)





- **HERA II analysis** (expected)
  - more statistics (> factor 10), larger kinematic range, two experiments

-> test „b content of proton" (at $Q^2 >> m_b^2$) much more precisely **relevant for many LHC processes!** (see talk M. Cacciari)

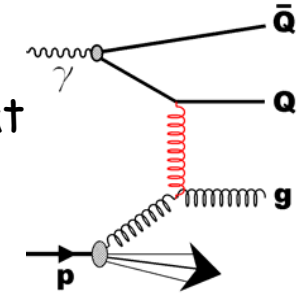
Measurement of Jet-Jet correlations

- **e.g. for charm: D* + dijet (HERA I)**

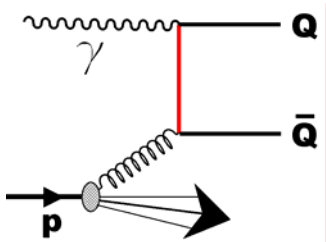
  angular distributions vs. x_γ

  => q or g propagat

  => 2nd jet is likely to be c or g



current NLO predictions
fail to describe detailed angular correlations
(not shown, public soon)

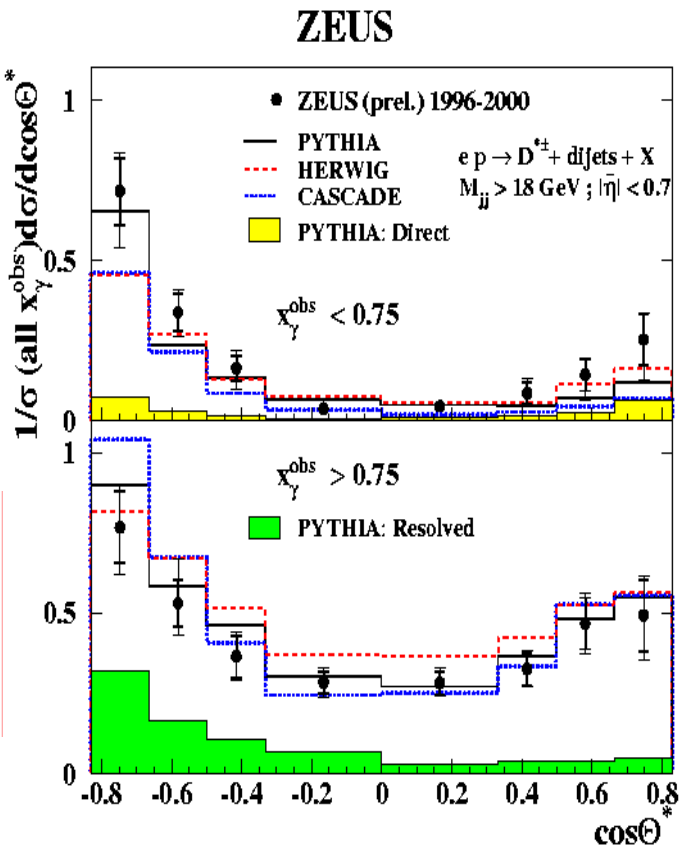


- **HERA II:**

  larger statistics,

  larger rapidity coverage

  -> direct double tag measurements

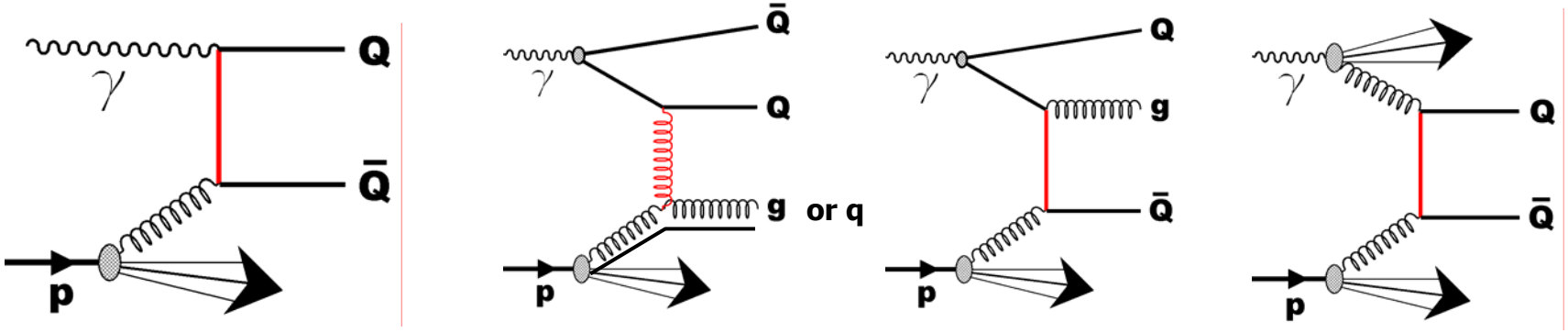


MC@NLO would/will be very important

(includes higher order topologies in NLL approximation)

Why measure $Q\bar{Q}$ correlations?

- some NLO diagrams (massive scheme), **Q**=b,c



- 3rd jet not always detected (forward or low E_T)
- single tag measurement does not distinguish **Q** and g/q for 2nd jet
- **double tag** measurement does => fully tagged final state

=> test and understand NLO QCD in more detail
use result to directly test NLO gluon distribution in proton

Double heavy flavour tag

Examples: D*+μ, μ+μ

- **Current D*+ μ analysis (HERA I)**

  ZEUS:

  ~ 34 events D*+μ from same b

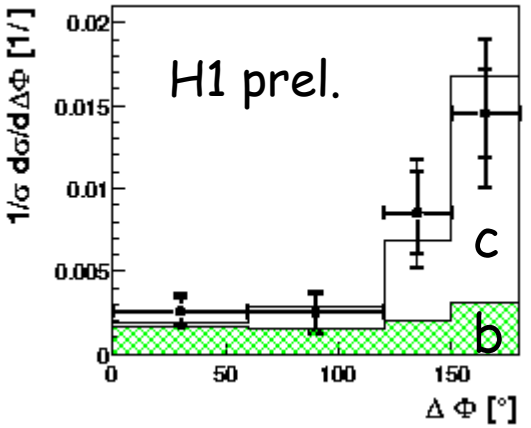
  ~ 15 events D*+μ from different b's

  ~ 60 events D*+μ from different c´s

  muon efficiency + luminosity increasing

  but will stay statistics limited

D* - μ Δφ correlation



talk
O. Behnke
WG3

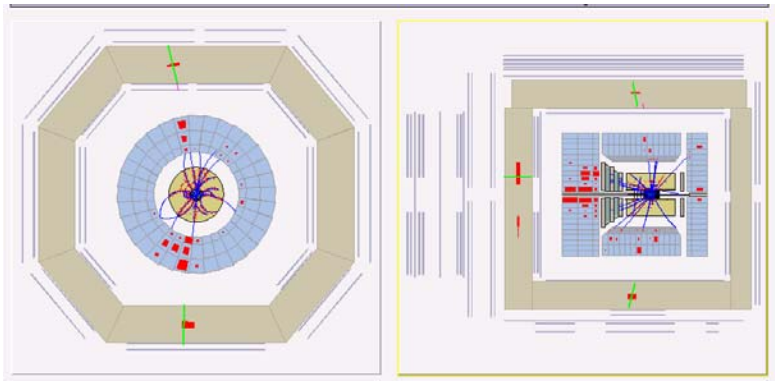
- **HERA I+II dimuon analysis**

  prospects:

  2 low pt muons (no explicit jet requirement)

  => O(10^3) beauty signal events / 100 pb^{-1}

  separate b, c and light flavours through charge + momentum correlations, ptrel, MVD

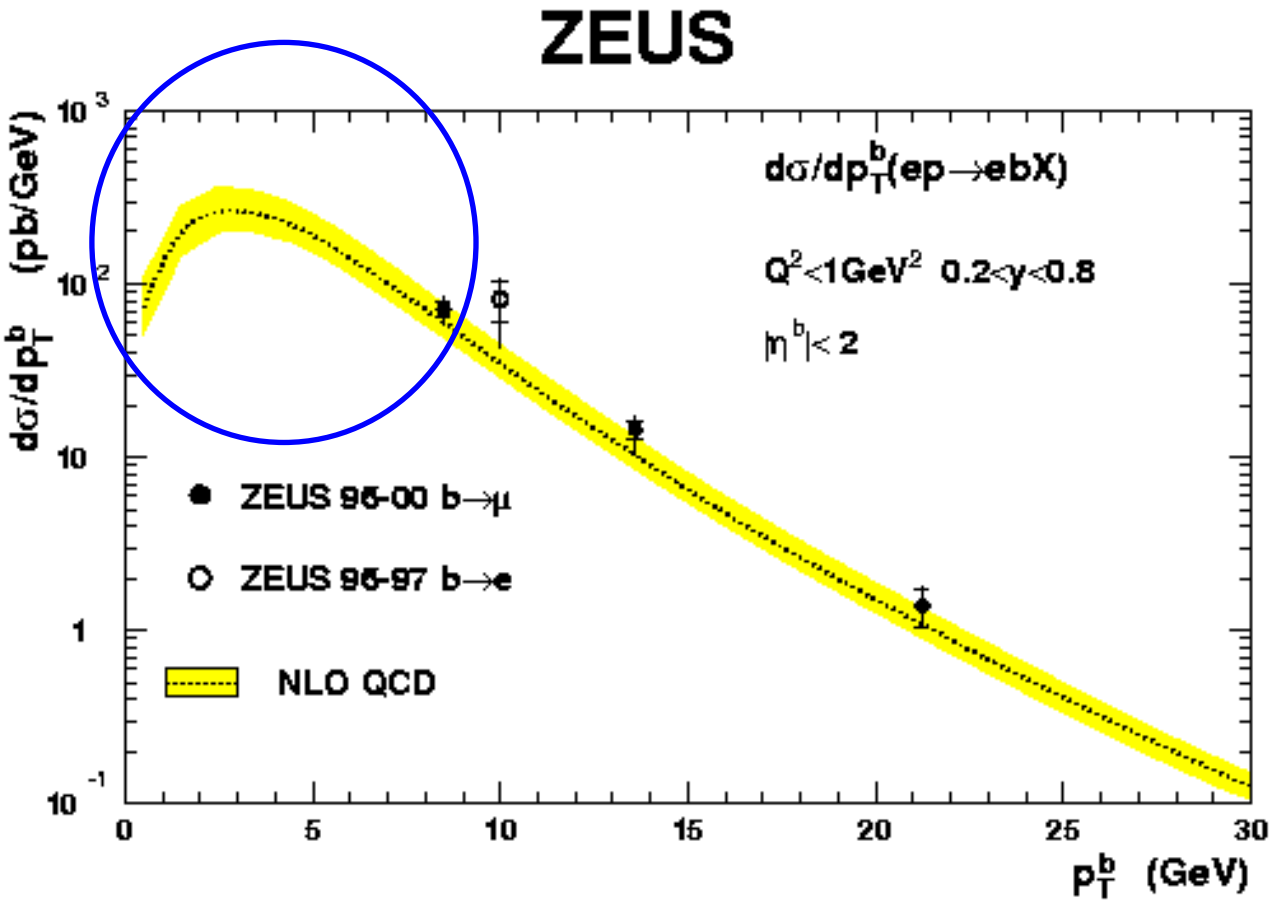


=> high statistics high purity samples, measure double differential distributions

Double beauty tag (D*μ, μμ)

sensitive to very low p_T, almost full rapidity range

-> measure total beauty cross section at HERA



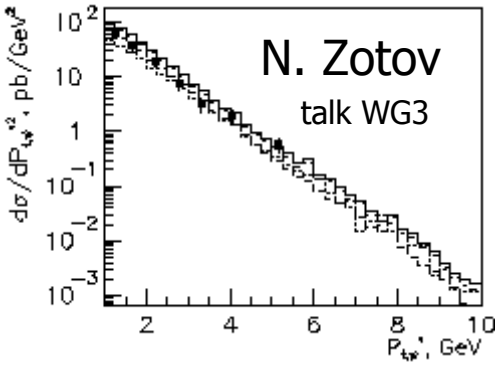
Conclusions

- HERA II era has begun!
- detector upgrades performing well
- first competitive results from heavy flavour production from HERA II expected soon
- extensive studies of multi-differential distributions in single and double tagged charm and beauty events are becoming possible

  => more detailed QCD tests, heavy flavour PDF's, gluon distribution

  => more reliable predictions for LHC
- improved measurements of J/ψ and Y production

  => better discrimination of theoretical models →
- many other interesting HFL physics topics!
- looking forward to continued working group activities including HERA II harvest!



+talk A. Meyer