Charm Production at HERA/H1

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DESY

for the H1 Collaboration

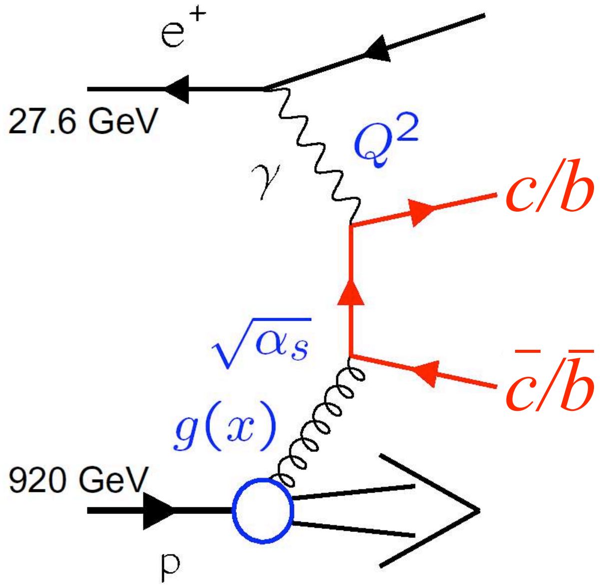
EPS HEP07, Manchester

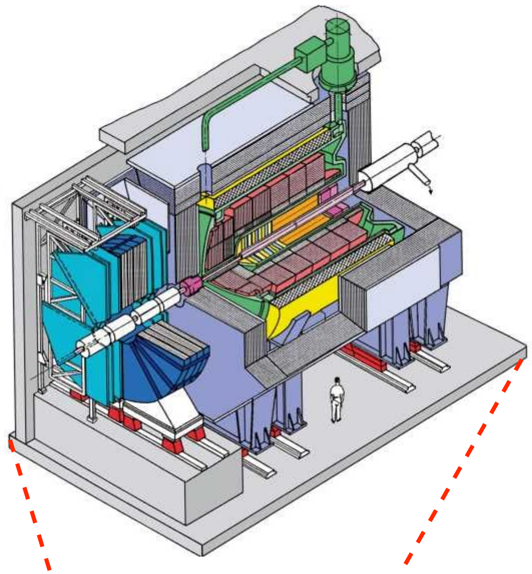
Heavy Quark Production at HERA

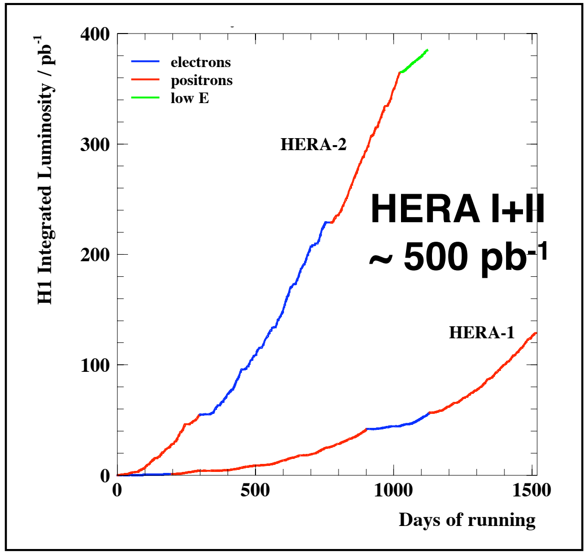
Interest in Charm :

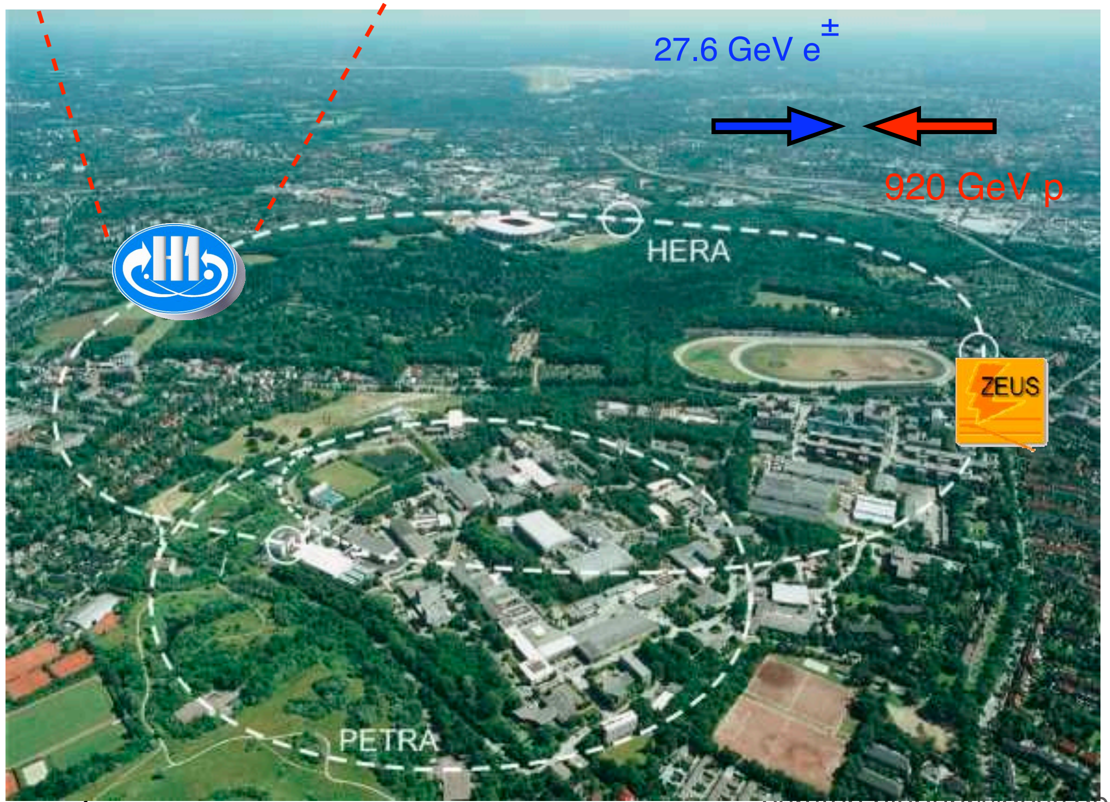
- m_c is large
  - pQCD applicable
  - multi scale problem (Q^2, p_t^2)
- sensitivity to gluon density
- large fraction of cross section
- tool for b-tagging

Boson Gluon Fusion









Theoretical Calculations and Monte Carlo Programs

Calculations and Monte Carlo programs used to describe Heavy Flavour production:

- Monte Carlo Programs
  - leading order (LO) + parton shower (PS) models available
    - DGLAP evolution (collinear factorization):
      - γ**p**: PYTHIA, HERWIG
      - **DIS**: RAPGAP
    - CCFM evolution (k_t factorization) γ**p + DIS**: CASCADE

- Theoretical Calculations
  - full NLO calculations available
    - γ**p**: FMNR
    - **DIS**: HVQDIS

Charm Production in DIS

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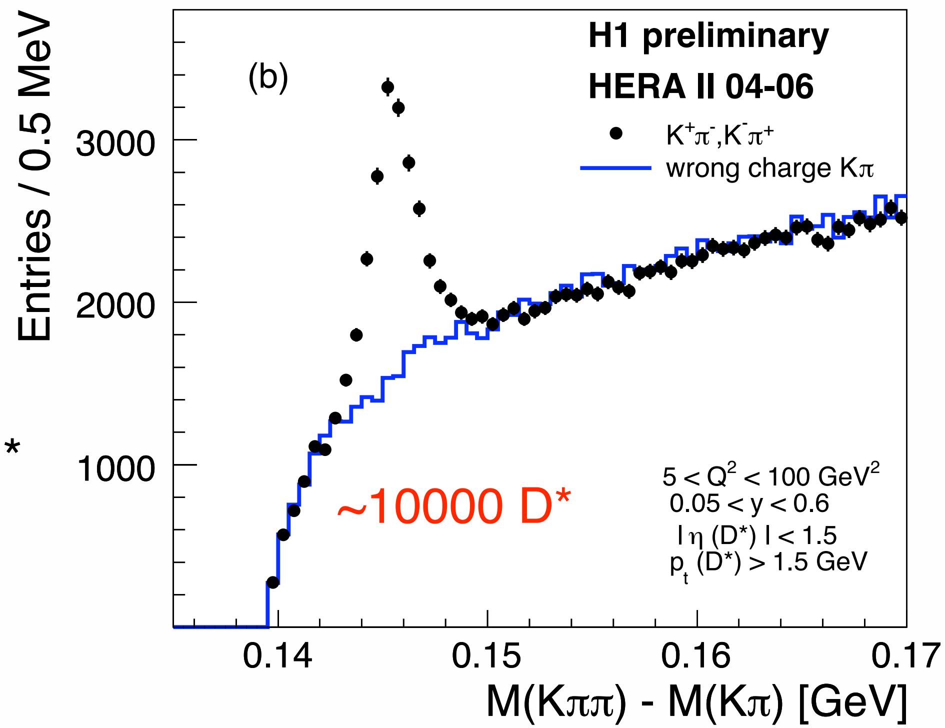
- HERA II data
  - 2004-2006
  - $\mathcal{L}$ = 222 pb^{-1} (4x increase in statistics)
- Kinematic range
  - $5 < Q^2 < 100$ GeV^2
  - $0.05 < y < 0.6$
- Charm tagging via golden decay channel of D*
  - $D^{*\pm} \to D^0\pi^\pm_{\rm slow} \to K^\mp\pi^\pm\pi^\pm_{\rm slow}$
- Cross section in visible range
  - $p_T(D^*) > 1.5$ GeV
  - $|\eta(D^*)| < 1.5$



New preliminary result:

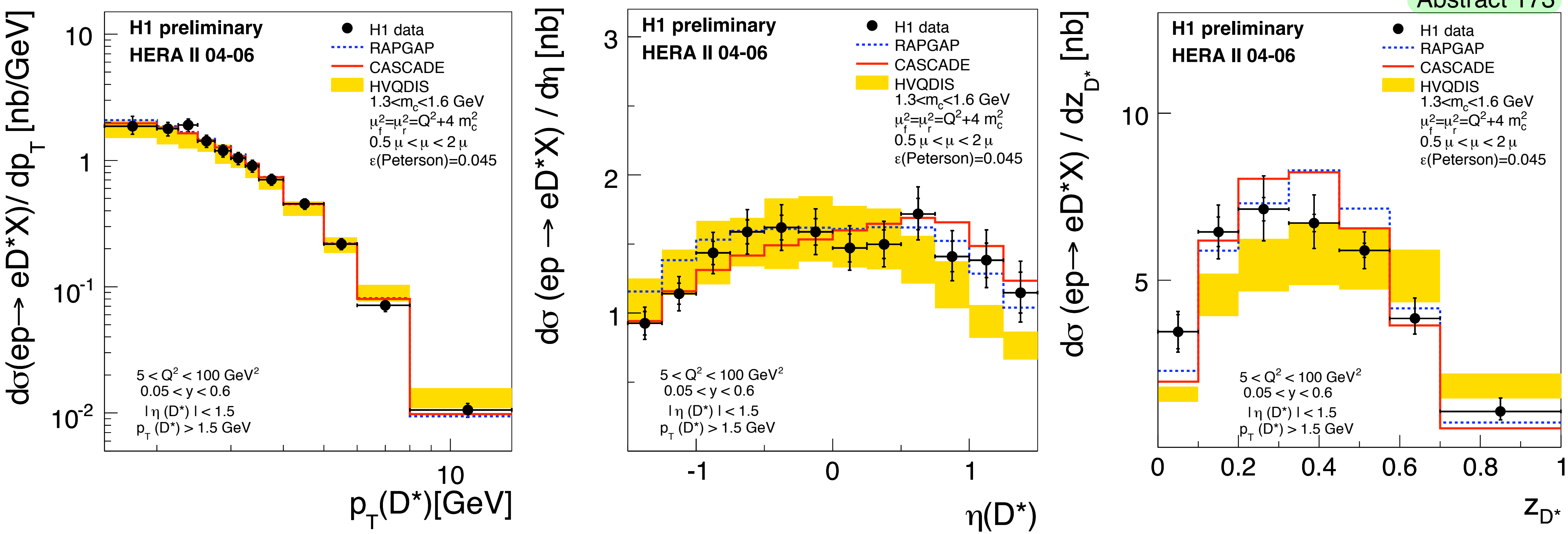
$$\sigma^{\rm tot}_{\rm vis}(e^\pm p \to e^\pm D^{*\pm} X) =$$

$$4.23 \pm 0.09\ ({\rm stat.}) \pm 0.37\ ({\rm syst.})\ {\rm nb}$$

	$\sigma^{\rm tot}_{\rm vis}$	m_c [GeV]
HVQDIS	4.28 nb	1.3
	3.46 nb	1.6
RAPGAP	4.40 nb	1.5
CASCADE	4.29 nb	1.5

Differential D* Cross Sections

Abstract 173



Transverse momentum

- well described by MC programs
- HVQDIS slightly too hard

Pseudorapidity

- CASCADE OK
- HVQDIS too low for $\eta > 0.5$
- RAPGAP too high for $\eta < -1$

Inelasticity

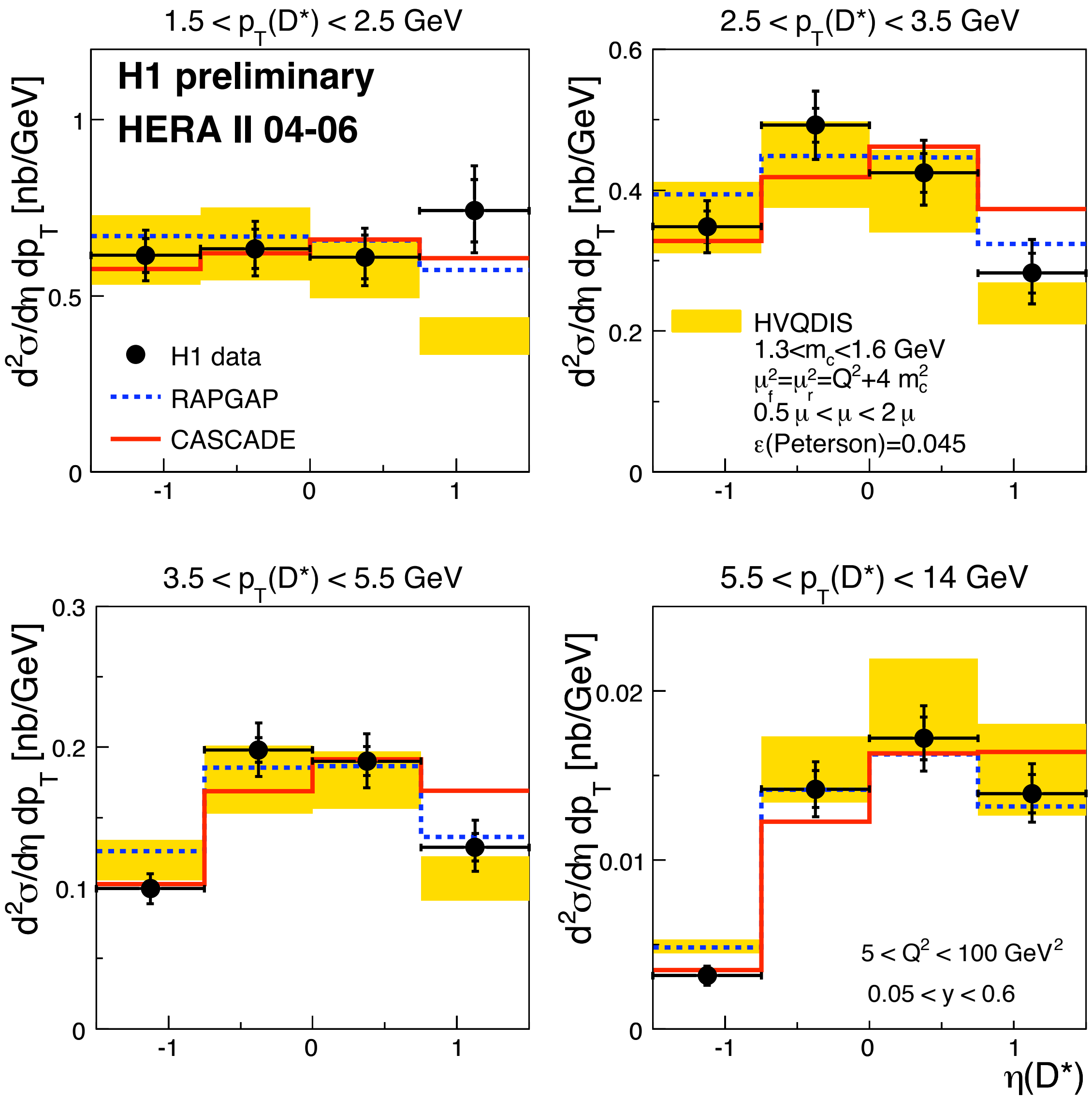
- reasonably described by MC programs
- HVQDIS fails

Double Differential D* Cross Section

Large HERA II statistics make more differential tests possible:

Abstract 173

- HVQDIS
  - discrepancy in forward direction located at **low p_T**
- CASCADE
  - small discrepancy in **most forward** bin for **$p_T > 2.5$ GeV**
- RAPGAP
  - overshoot for $\eta < -1$ concentrated at **$p_T > 3.5$ GeV**
- Need even more precise data to differentiate between models



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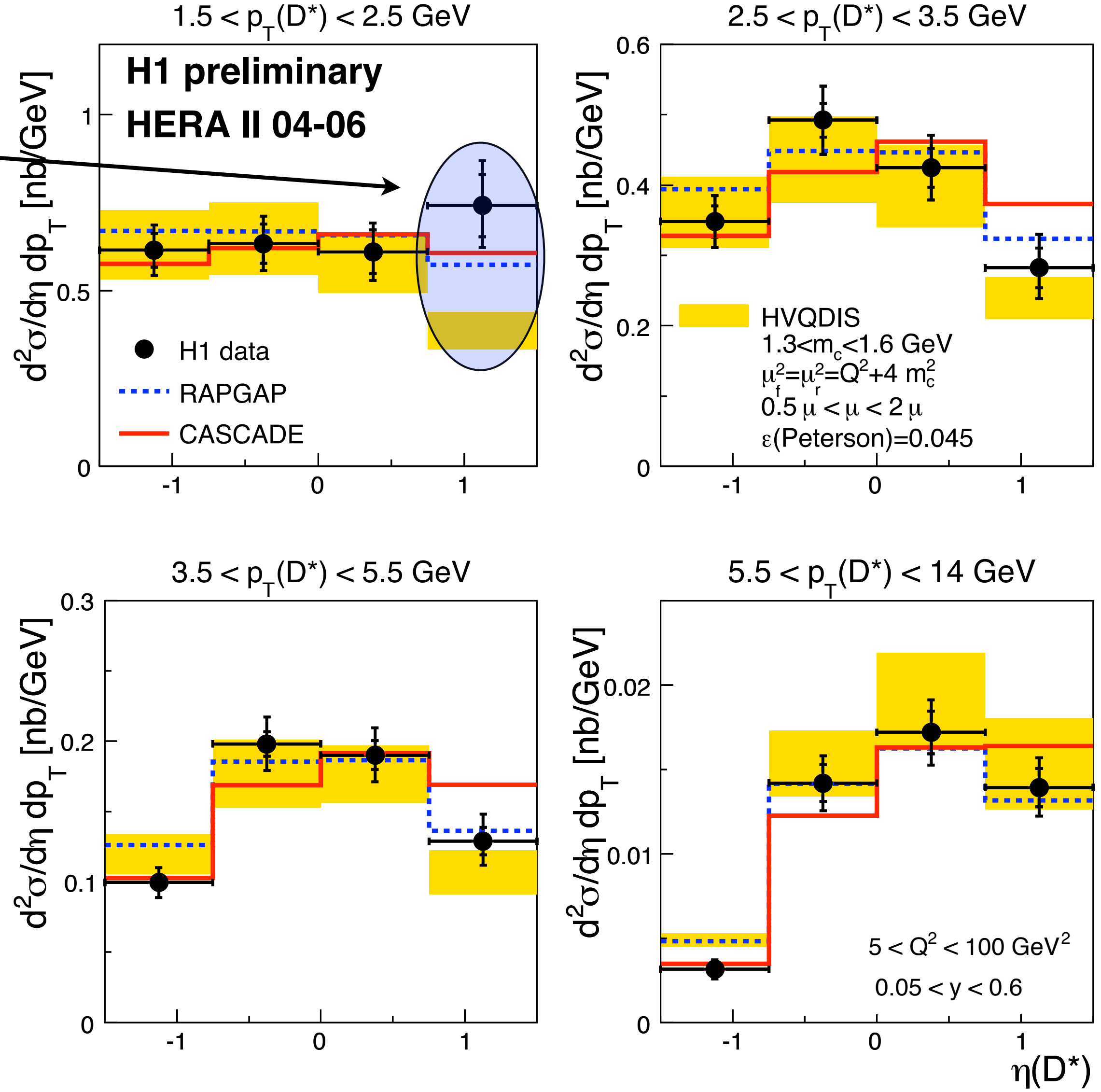

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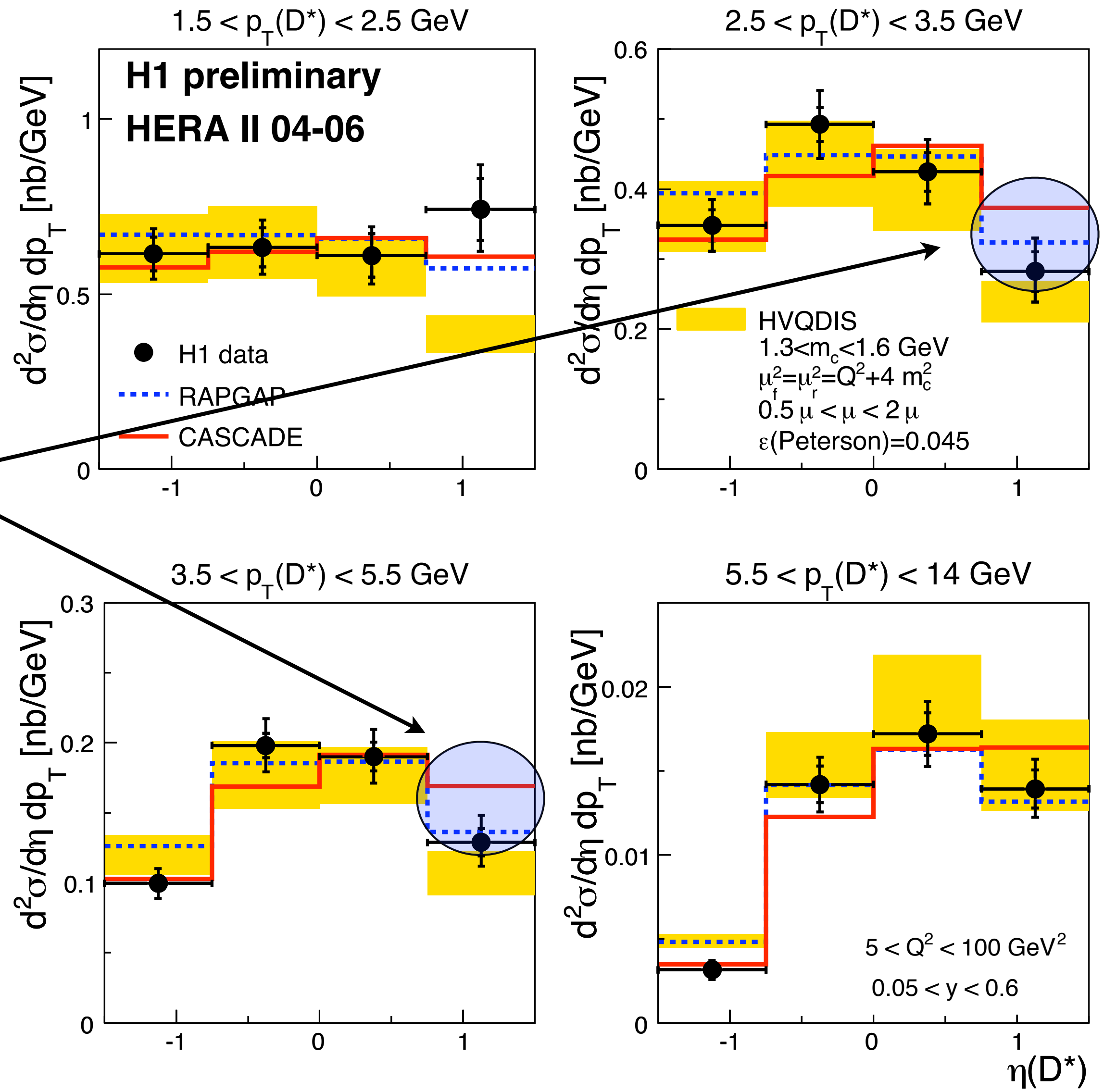

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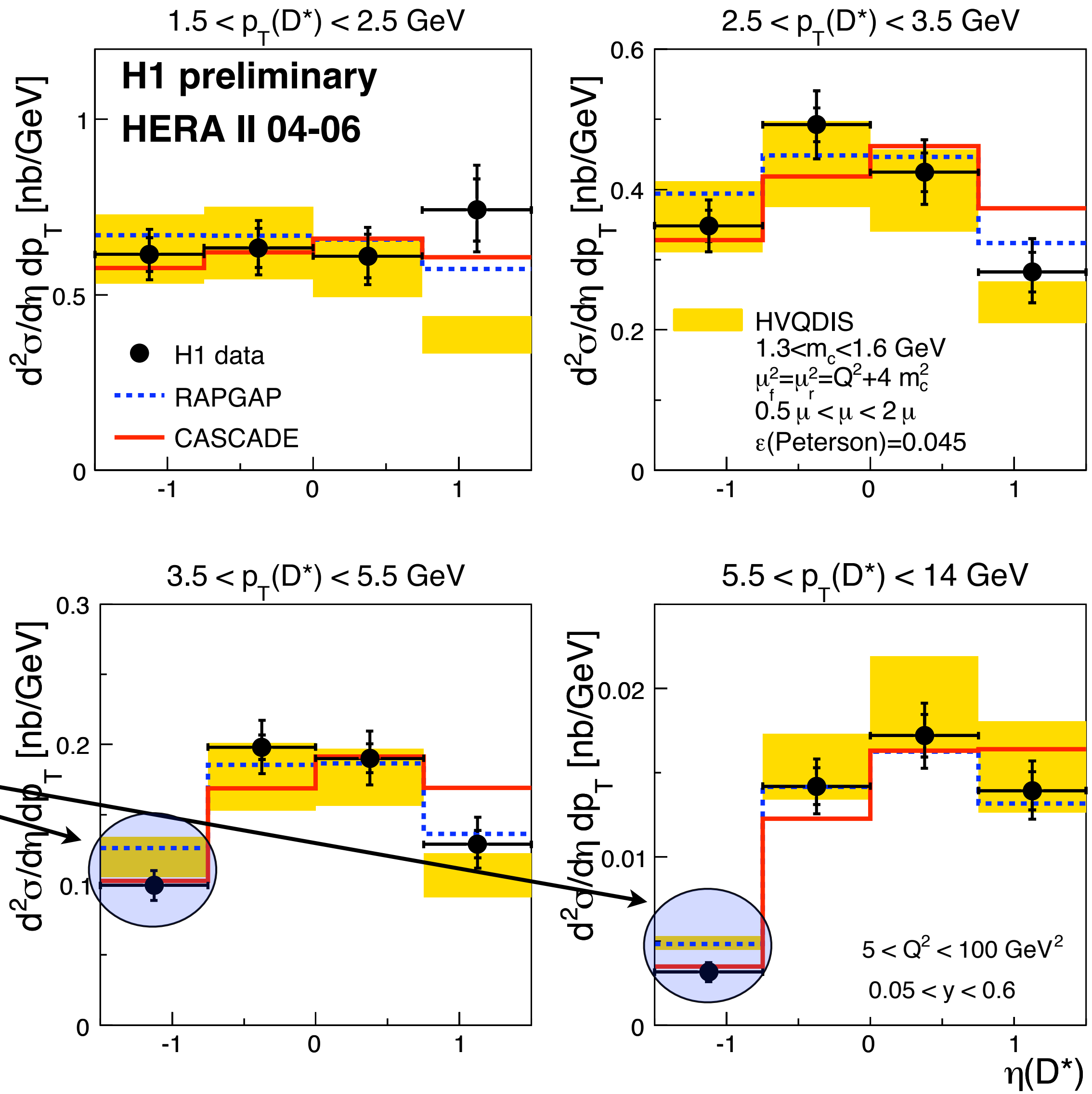
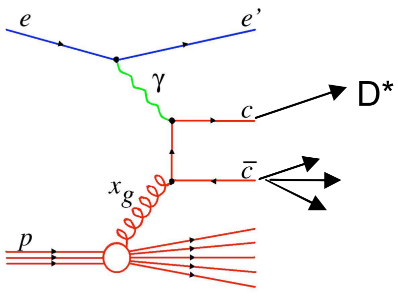
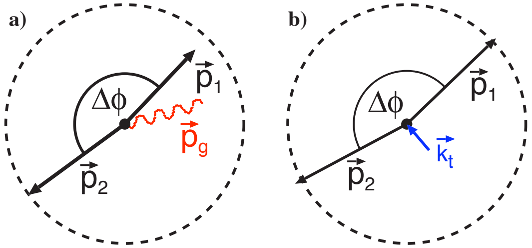


D* + Jets





Study azimuthal correlation between D* and the jet in γp and DIS: $\Delta\Phi(D*, Jet)$

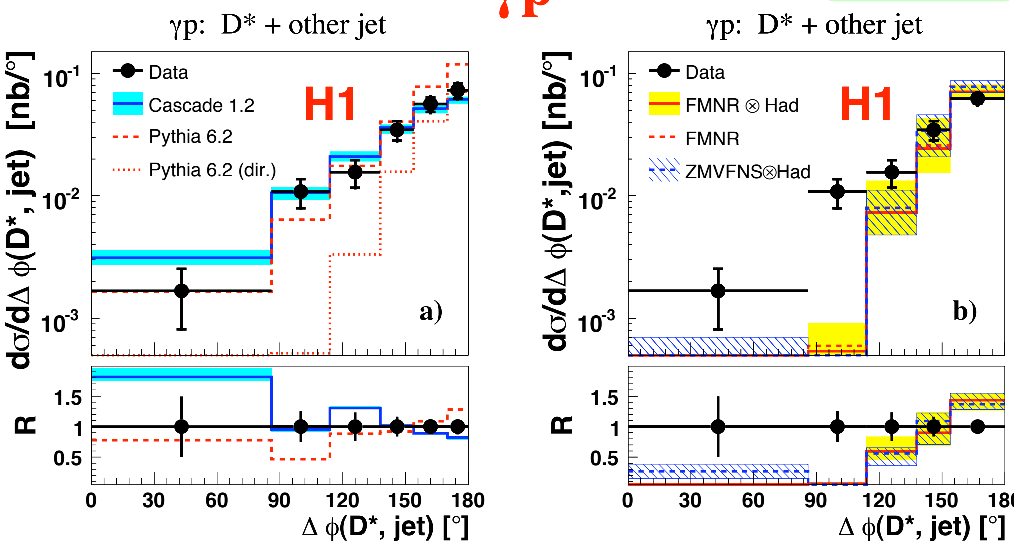
- Gluon radiation or initial parton-k_T can lead to deviation from back-to-back topology

Results based on HERA I data:

- PYTHIA [γp]: good description by LO+PS
- HVQDIS [DIS] and FMNR [γp]: need for contributions beyond NLO
- CASCADE [γp +DIS]: k_T-distribution in unintegrated gluon density too broad

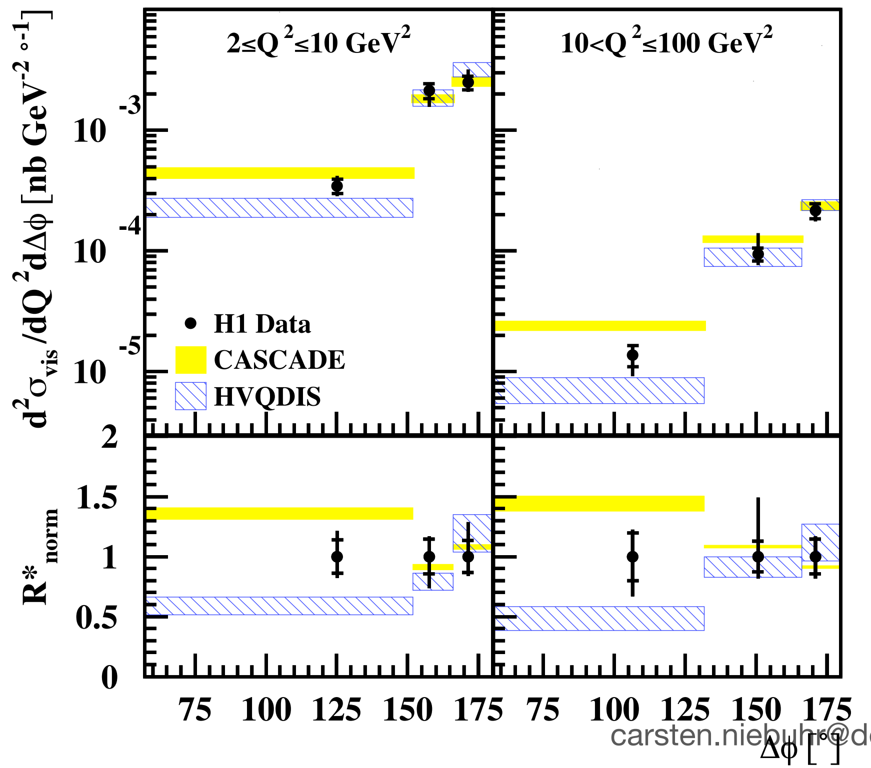
γp

Abstract 191



DIS

Abstract 192



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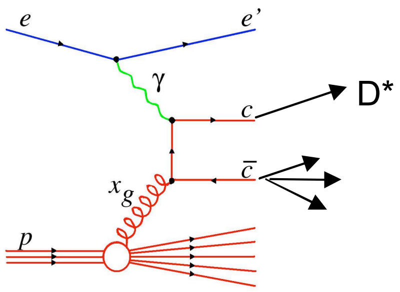

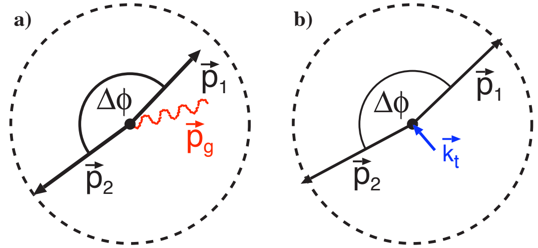

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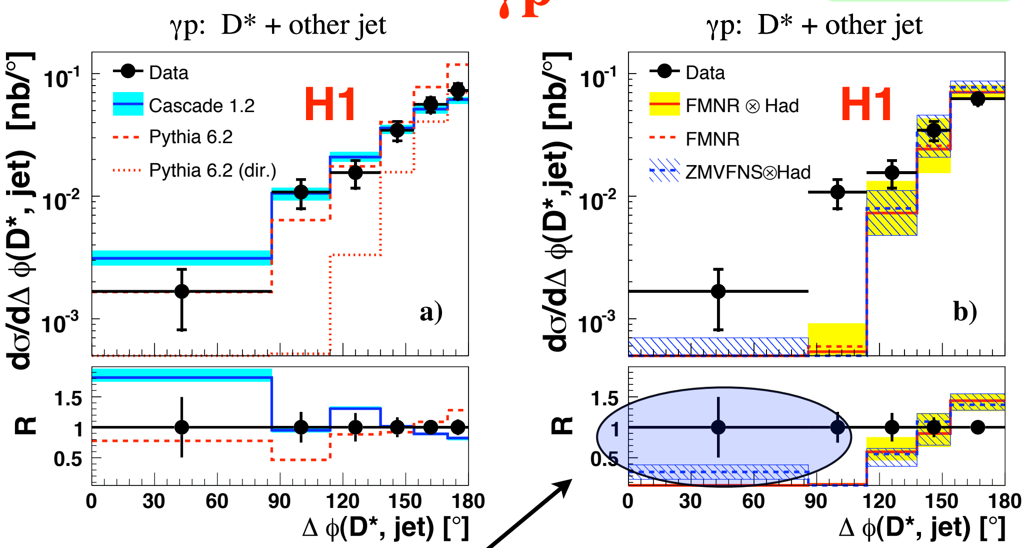

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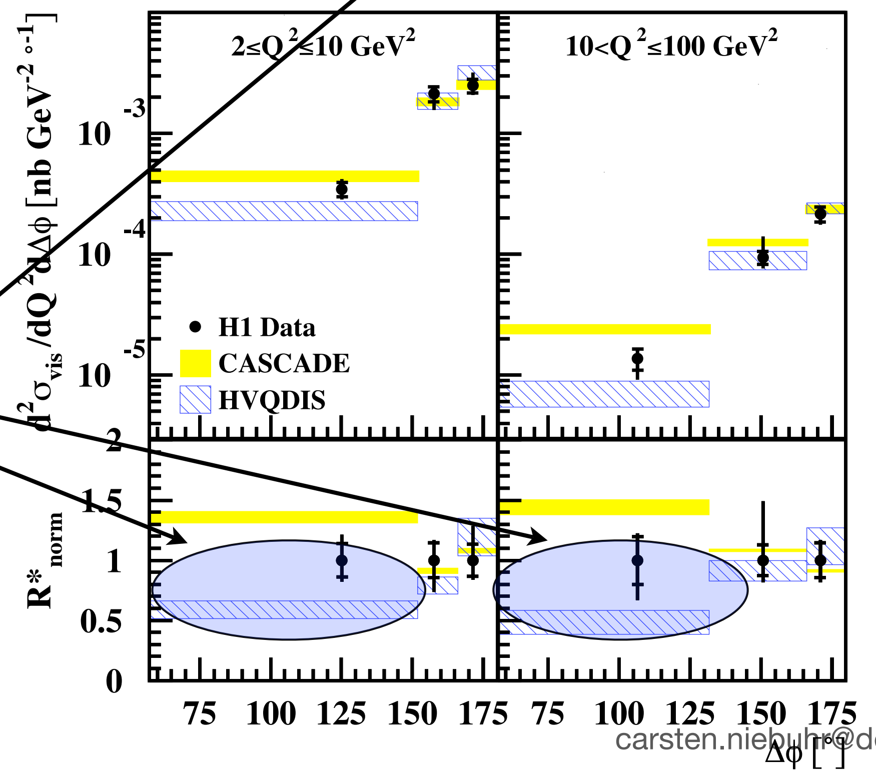

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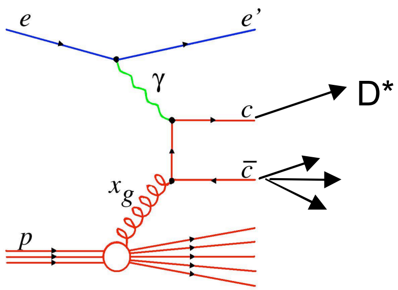

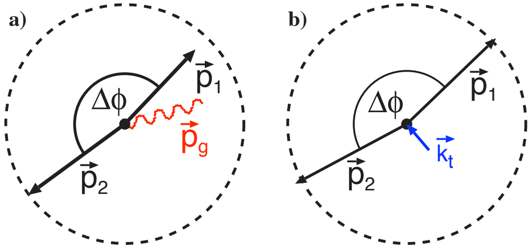

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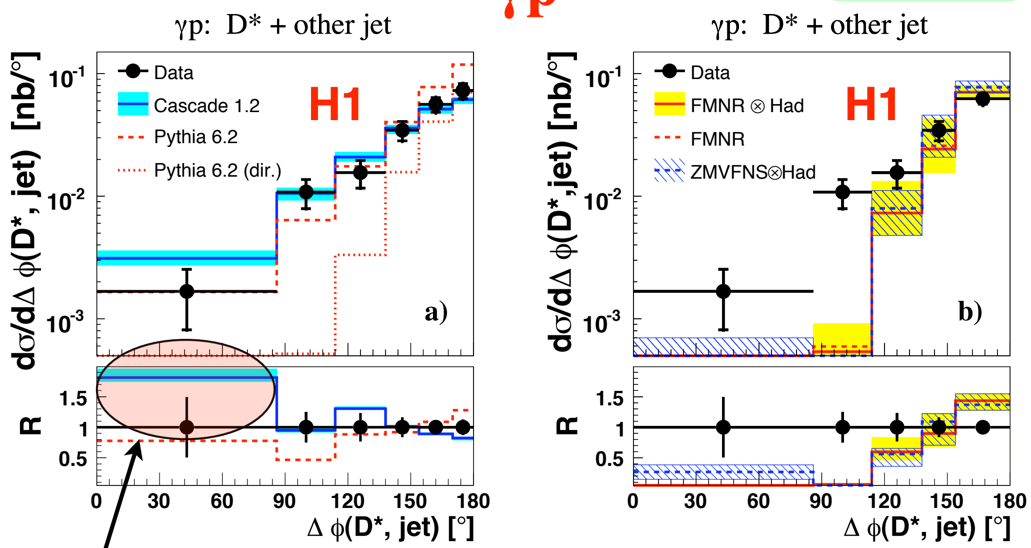

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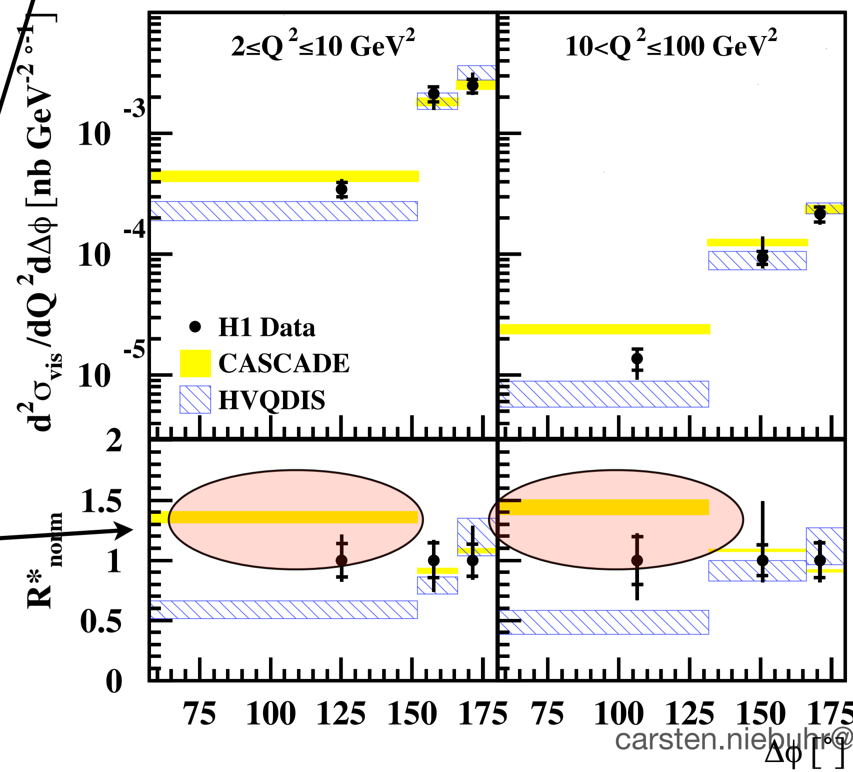

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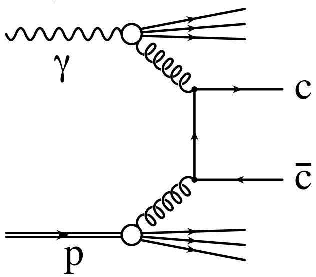
Contribution from Resolved Processes

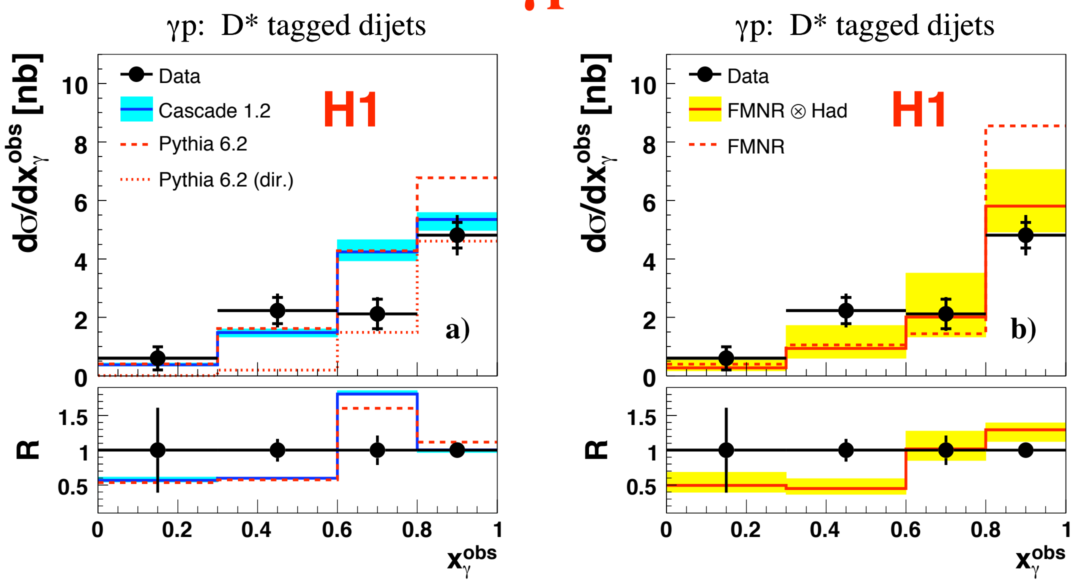
Abstract 191

Fraction of photon momentum participating in hard interaction:



$$x_\gamma^{obs} = \frac{\sum_{J1}(E^* - p_z^*) + \sum_{J2}(E^* - p_z^*)}{\sum_{had}(E^* - p_z^*)}$$

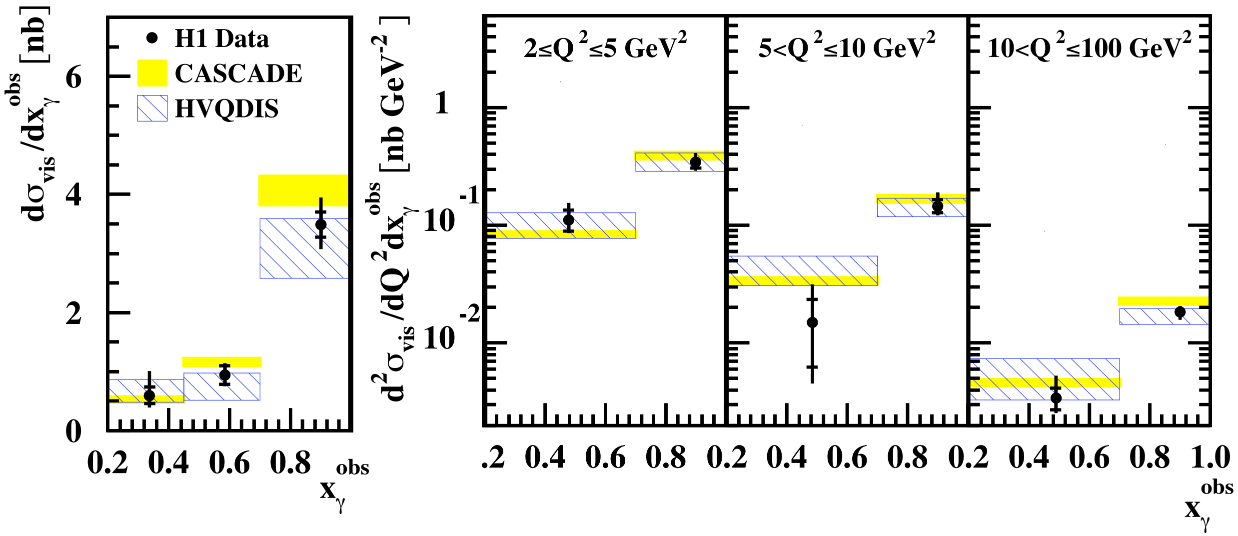
γp



- Photoproduction
  - cross section underestimated at low $x_\gamma^{obs} < 0.6$ by all calculations
- DIS
  - no need for additional resolved photon contribution beyond NLO

DIS

Abstract 192



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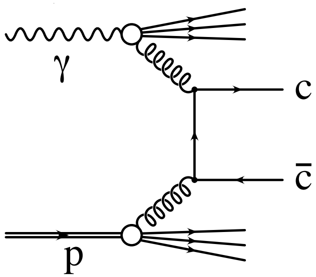

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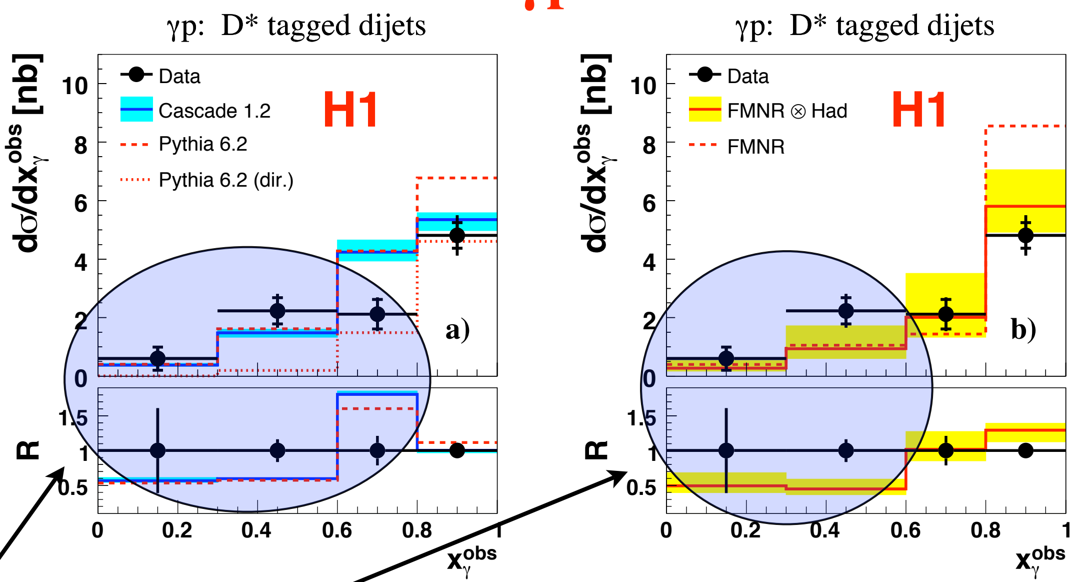

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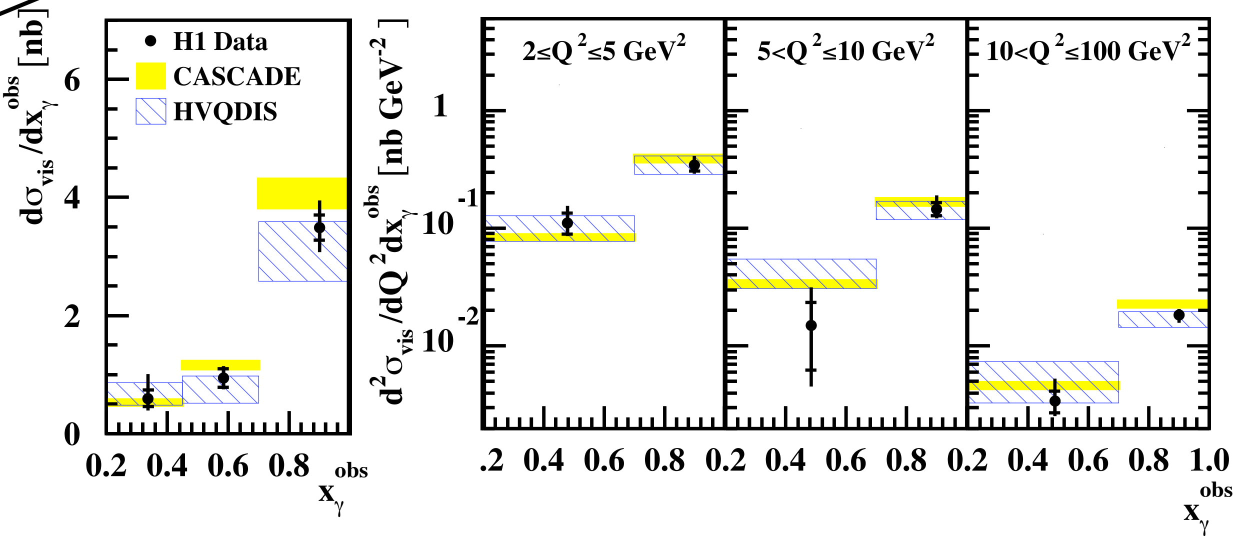
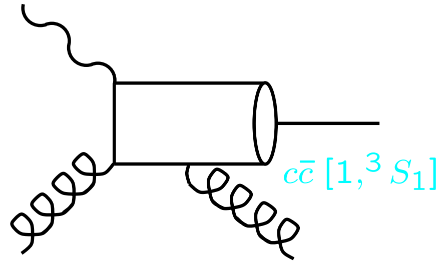


Inelastic J/Ψ Production

Models for Charmonium Production:

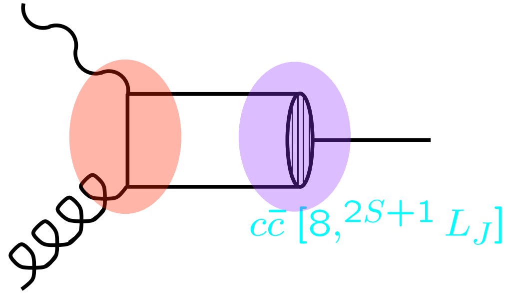
- Colour Singlet Model (CS)
  - radiation of hard gluon
- Colour Octet contribution (CO)
  - introduced in NRQCD to describe Tevatron data
  - factorisation into **hard scattering process** and transition to real J/Ψ by **non-perturbative LDME**
    - LDME extracted from fits to Tevatron data
    - LDME expected to be universal
- Predictions for HERA
  - DIS
    - NRQCD fails to describe HERA data
    - CS Model (LO) generally in agreement with data
    - CS Model (NLO) no calculation available
  - Photoproduction
    - CS Model (NLO) describes HERA data well

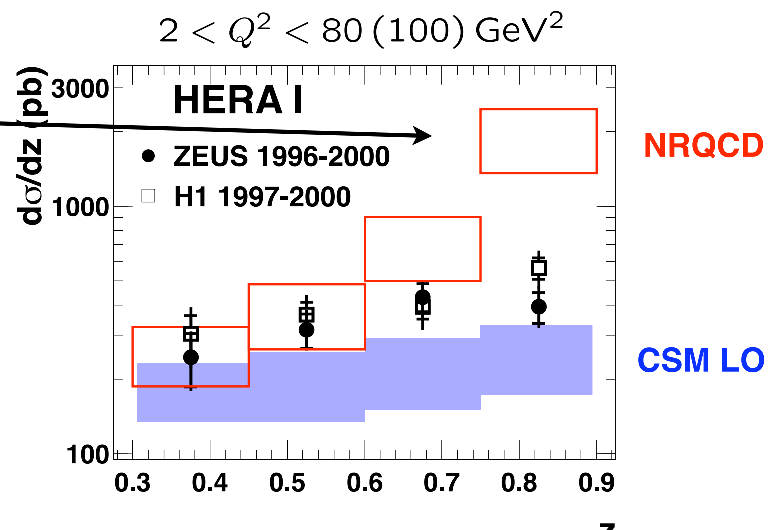
CS



$$\sigma_{J/\Psi X} = \sum \hat{\sigma}(p\bar{p} \to c\bar{c}[n]X) \times \mathrm{LDME}[n]$$

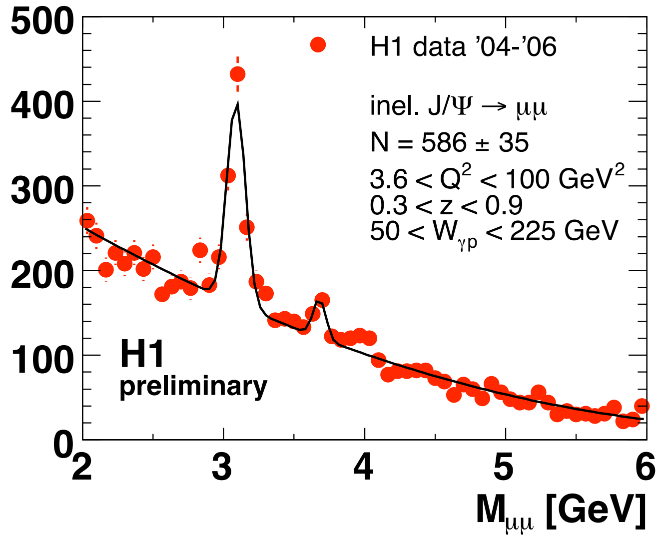
CO

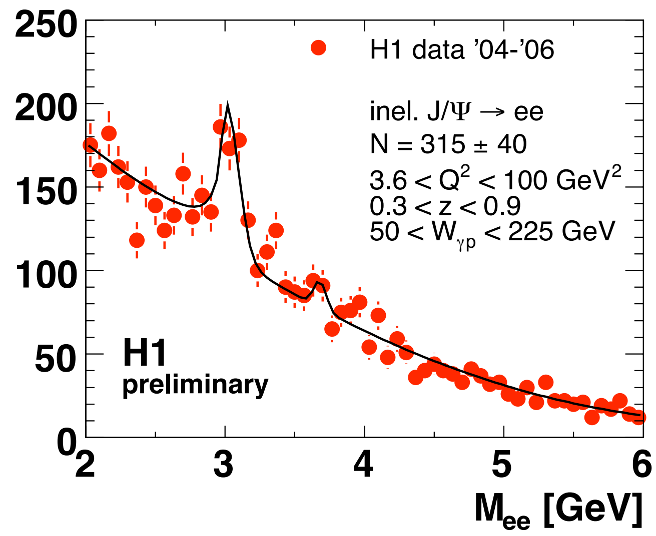




Inelastic J/Ψ Electroproduction

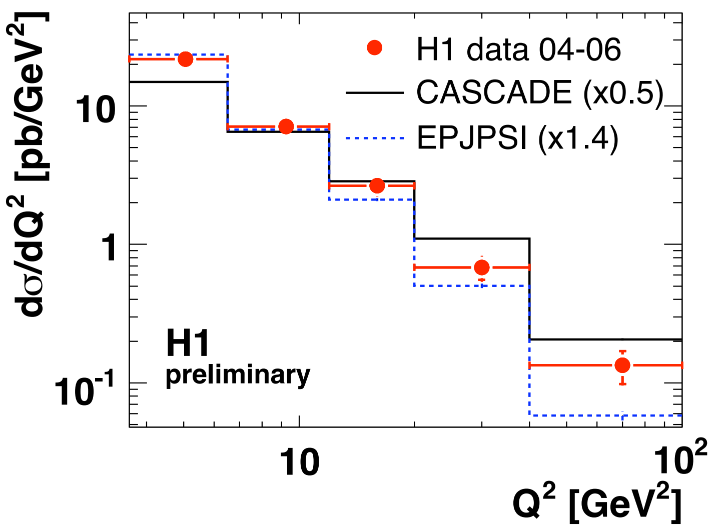
- HERA II data
  - 2004-2006
  - $\mathcal{L}$= 258 pb^{-1}
- Kinematic range
  - $3.6 < Q^2 < 100$ GeV^2
  - $50 < W_{\gamma p} < 225$ GeV
  - $0.3 < z_{J/\psi} < 0.9$
  - $p_{T,\psi}^* > 1.0$ GeV

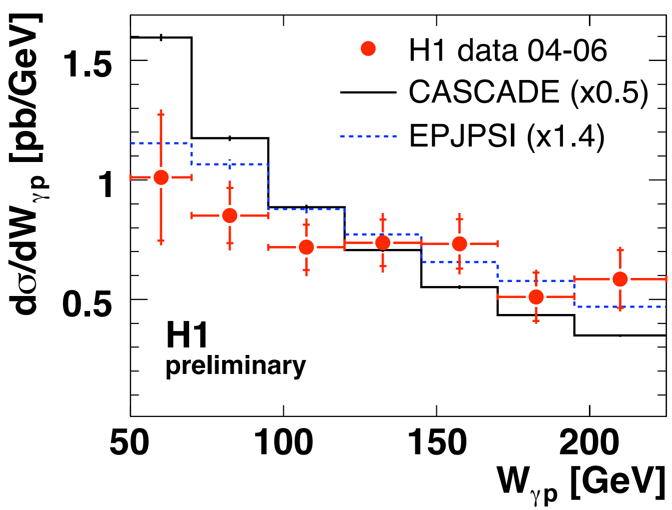




Abstract 178

- CS LO Monte Carlo Programs
  - EPJPSI [DGLAP]
    - normalization too low
    - Q^2 shape too steep
  - CASCADE [CCFM]
    - normalization too high
    - Q^2 shape too hard
    - $W_{\gamma p}$ shape too steep



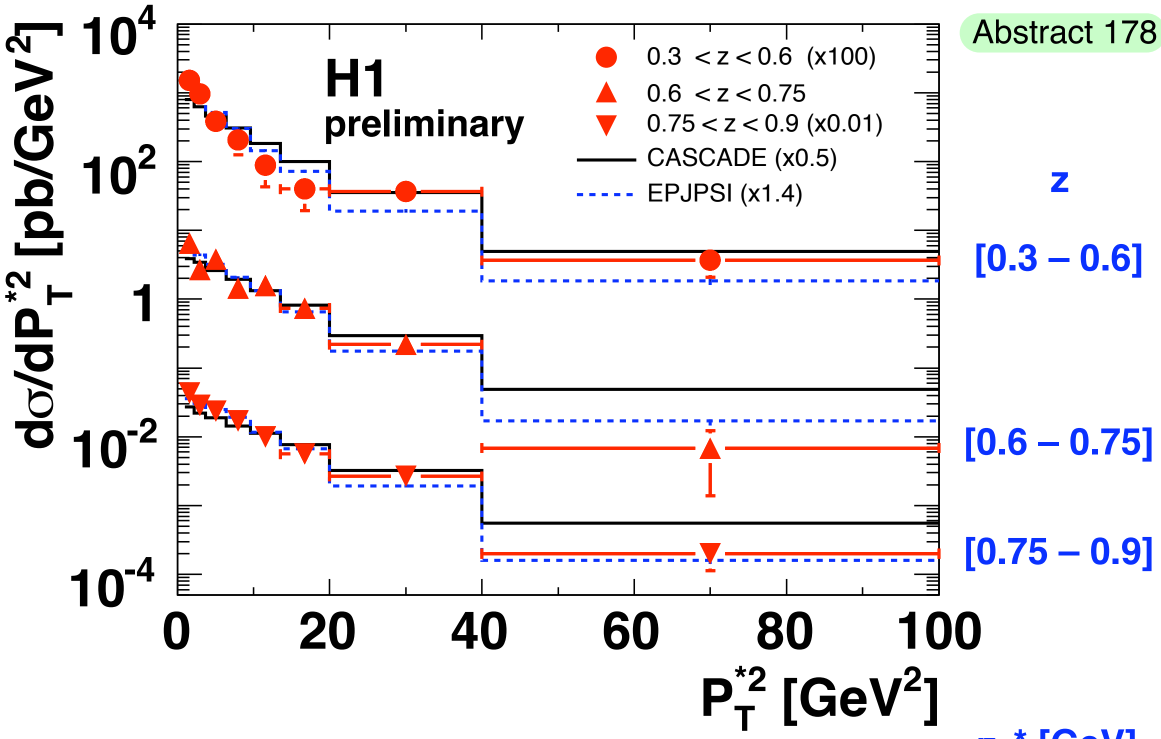


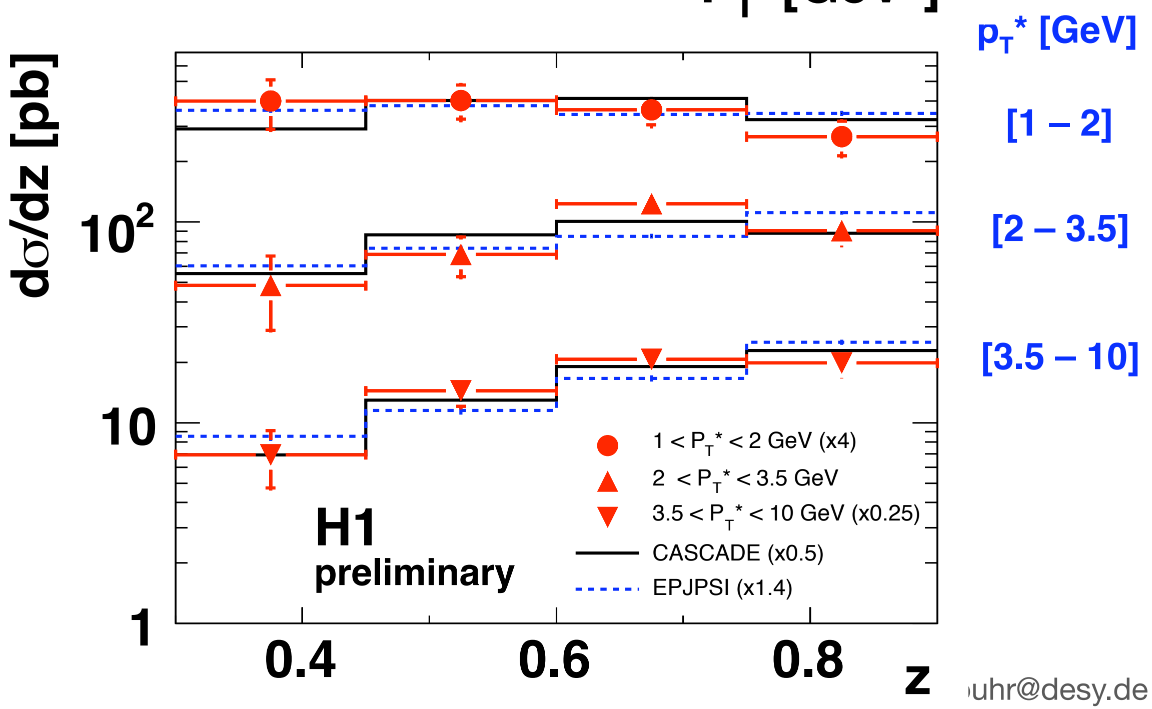
Double Differential J/Ψ Cross Sections

Increased HERA II statistics allow more differential measurements

- hardness of p_T* spectrum increases with z
- this is well reproduced by CS LO MCs
- no indication for contributions beyond CS LO
- additional terms (e.g. colour octet) must be
  - much smaller in size or
  - similar in shape to CS LO

Abstract 178





Conclusion & Outlook

- HERA II data provide large increase in statistics for Charm analyses
  - so far ~ 50% of HERA II data have been analysed
  - further qualitative improvements expected from full exploitation of vertex detectors

- With improved statistics (finally combined HERA I+II) one can study deficits of models in much more detail. This will allow to further
  - differentiate between models
  - tune parameters of models / calculations