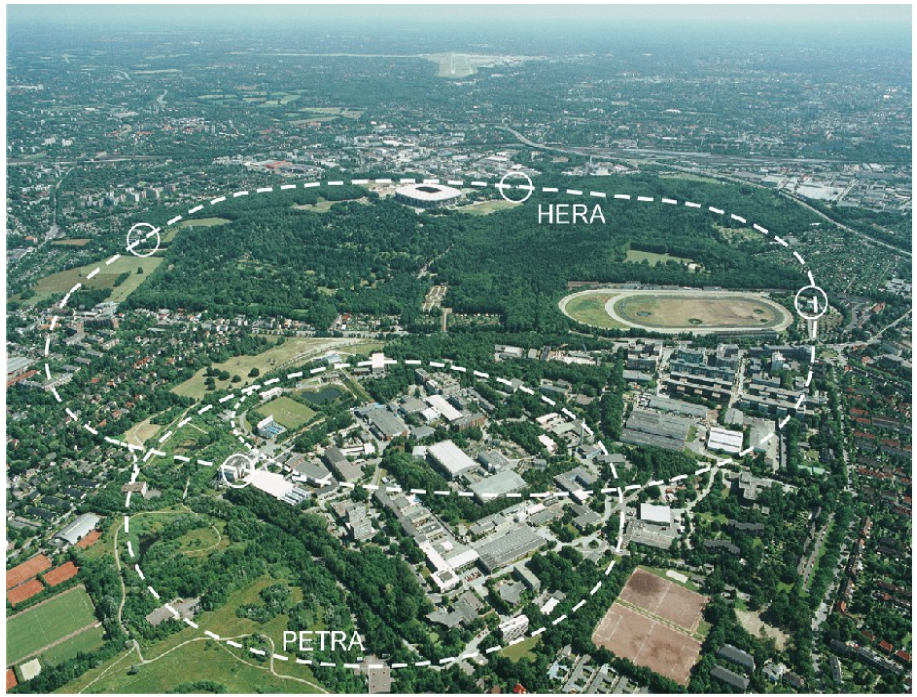
D* production in DIS at low Q^2



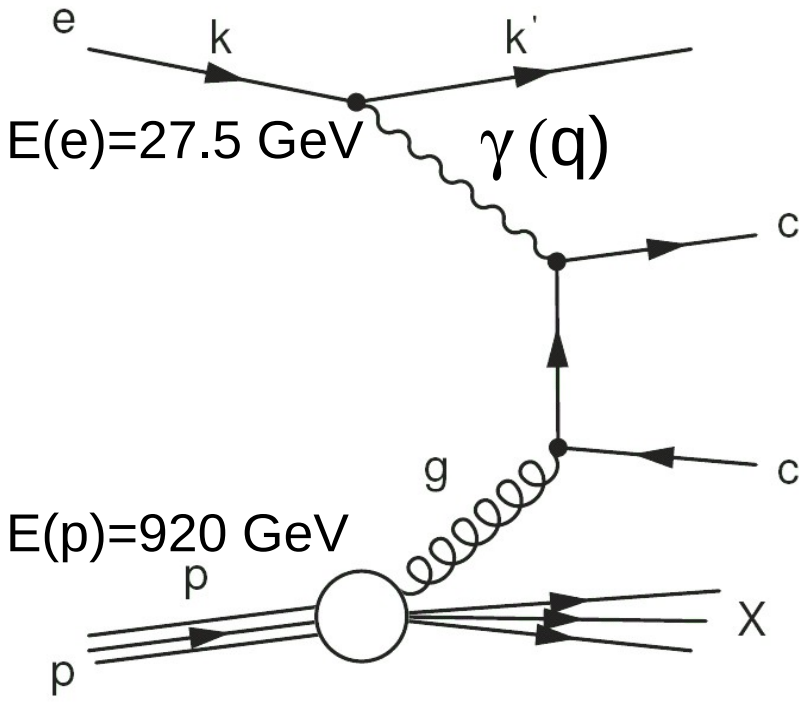
- Introduction
- Theoretical models
- D* cross sections
- Conclusions

Andreas W. Jung (Fermilab) for the H1 collaboration

XIX International Workshop on Deep-Inelastic Scattering and Related Subjects
April 11-15, 2011, Newport News, Virginia

D* production: boson-gluon-fusion

Dominant process for charm-production in *ep* -scattering:



Kinematic at $\sqrt{s} \approx 320$ GeV:

- Photon Virtuality:

$$Q^2 = -q^2 = -(k - k')^2$$

$Q^2 \sim 0$ GeV^2: Photoproduction
$Q^2 > 2$ GeV^2: Deep Inelastic Scattering

- Inelasticity: $y = \frac{qp}{kp}$ Bjorken x: $x := \frac{Q^2}{2(\mathbf{p} \cdot \mathbf{q})}$

D* via Fragmentation:

- Pseudorapidity: $\eta = \ln \tan\left(\frac{\theta}{2}\right)$
- Transverse momentum: p_t
- Elasticity:

$$z = \frac{E(D^*) - p_z(D^*)}{2 \cdot yE_e}$$

Study production mechanism:

- Q^2, m^2_c or p^2_T provides a hard scale for pQCD → multiscale problem
- Test of heavy flavor treatment in pQCD
- Parton densities ("gluon structure") in the proton → test universality

Theoretical models

Factorisation ansatz:

$$d\sigma = \sum_{i,j,k} f_j^B(x_2, \mu_f) \otimes d\hat{\sigma}_{ij\to kX}(\mu_f) \otimes D_k^H(z, \mu_f)$$

Parton density functions (PDFs): from global fits to data

Matrix element: calculable to different oders of α_s

Fragmentation function: from data

Many approaches on the market:

- LO(α_s) + PS: - collinear factorization RAPGAP (DGLAP, massive)
  - k_T factorization CASCADE (CCFM, massive)

  (all MCs use Lund fragmentation (uds) and Bowler (c)

- NLO(α_s^2): - Collinear factorization HVQDIS (DGLAP, FFNS, massive, independent Fragmentation)

  ZMVFNS (DGLAP, ZM-VFNS, massless, KKKS08)

Theoretical models

Factorisation ansatz:

$$d\sigma = \sum_{i,j,k} f_j^B(x_2, \mu_f) \otimes d\hat{\sigma}_{ij\to kX}(\mu_f) \otimes D_k^H(z, \mu_f)$$

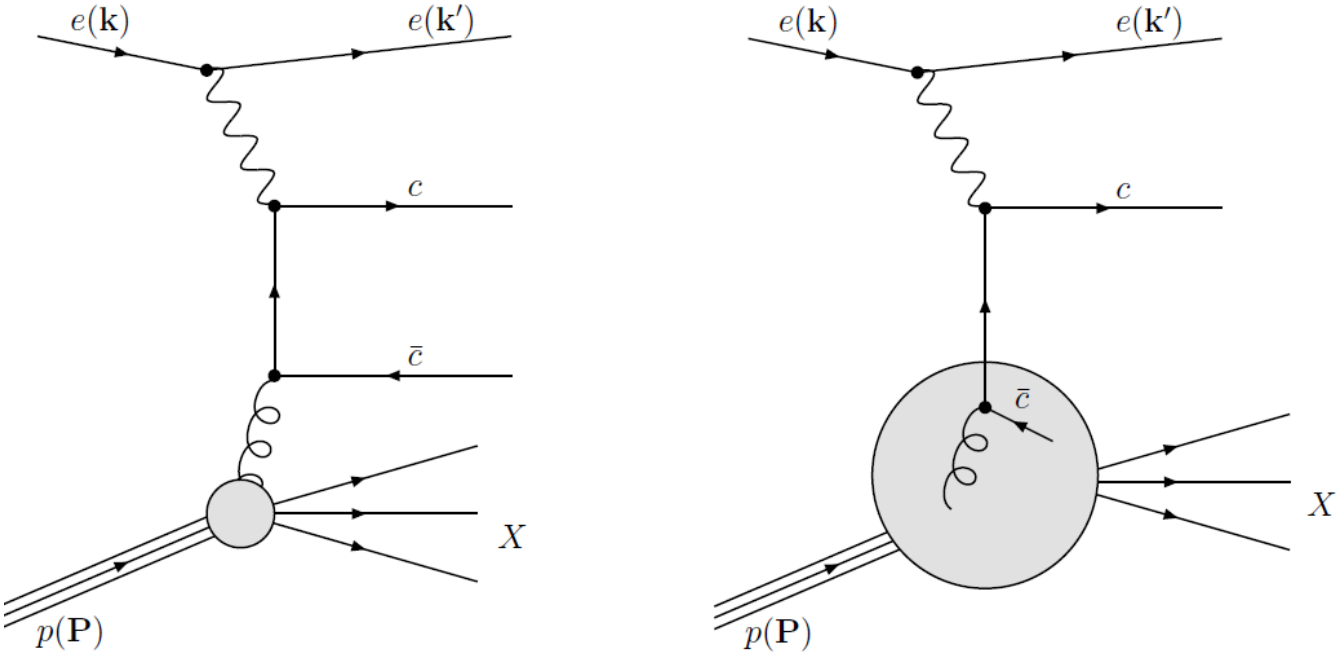
Parton density functions (PDFs): from global fits to data

Matrix element: calculable to different oders of α_s

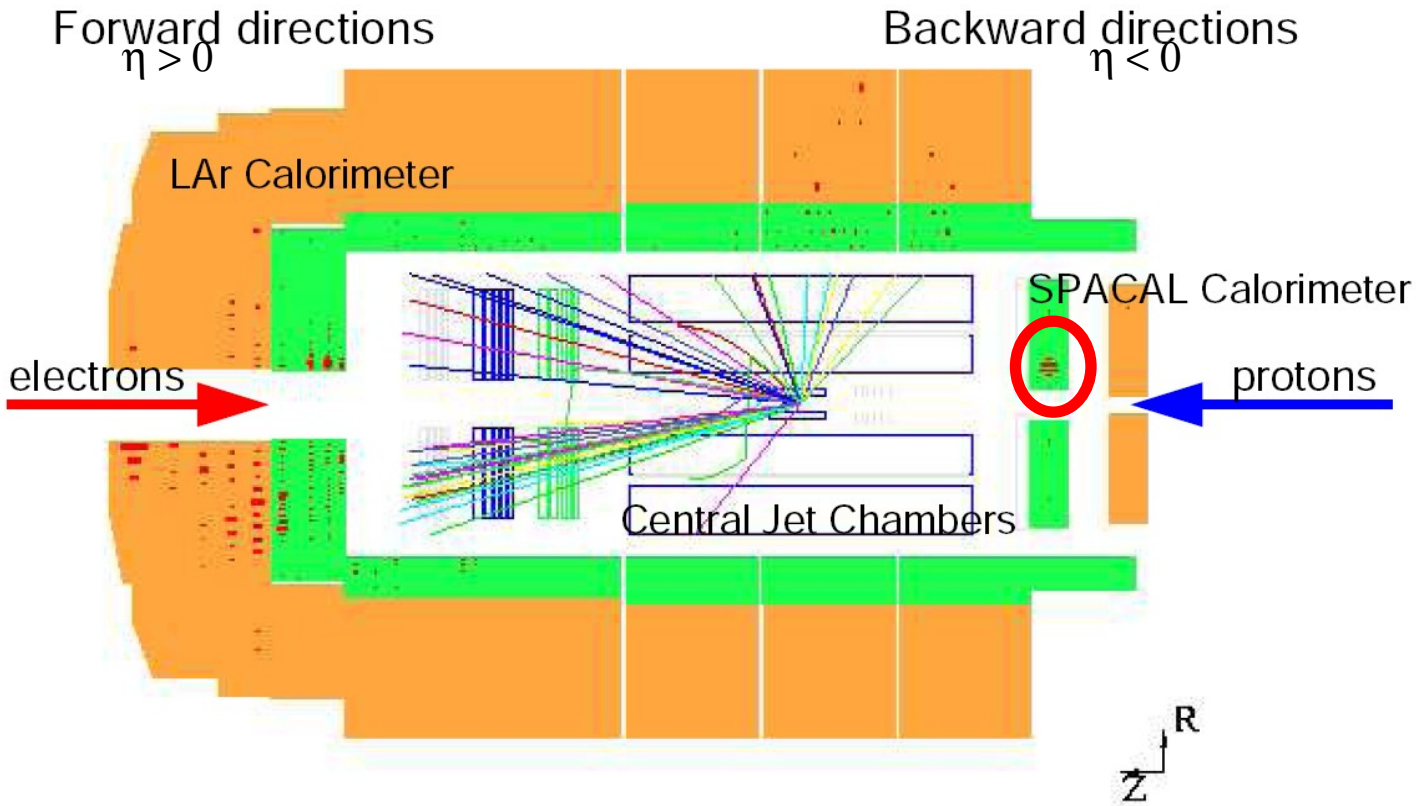
Fragmentation function: from data

Many approaches on the market:

- NLO(α_s^2): HVQDIS (FFNS, massive) vs. ZMVFNS (ZM-VFNS, massless)



Event selection & techniques



- Scattered electron in backward calorimeter:

  $5 < Q^2 < 100$ GeV^2

- High statistic region of DIS

- Tracks reconstructed in Central Jet Chambers

Experimental techniques:

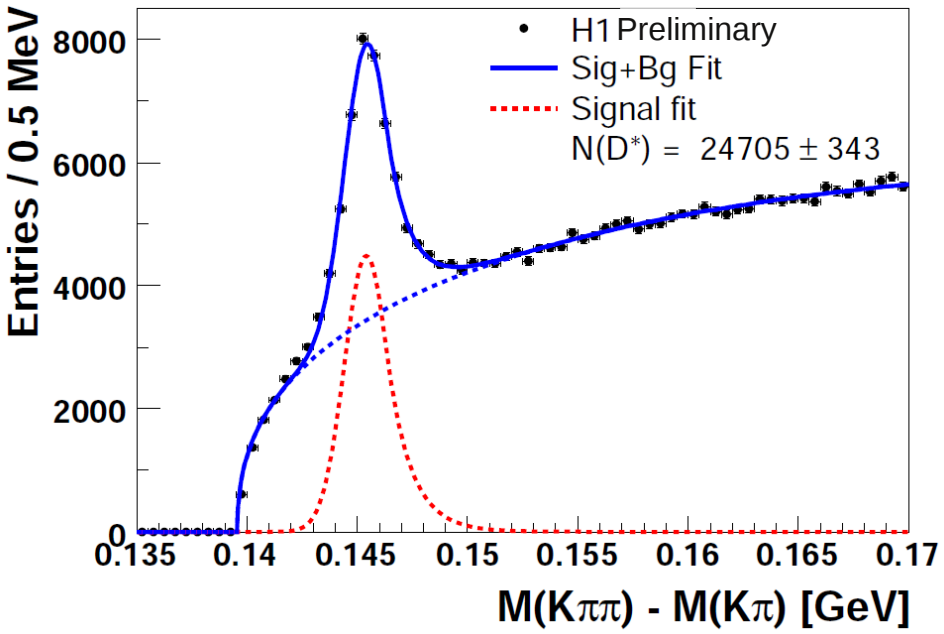
- Fully reconstructed D*:

  total BR of 2.57%

$$D^{*\pm} \rightarrow D^0 \pi^{\pm}_{slow} \rightarrow (K^{\mp}\pi^{\pm})\pi^{\pm}_{slow}$$

Event selection & techniques

D* in DIS:



- Decay: $D^{*\pm} \rightarrow D^0 \pi^{\pm}_{slow} \rightarrow (K^{\mp}\pi^{\pm})\pi^{\pm}_{slow}$
- Higher resolution in mass difference:
  $\Delta M = M(K\pi\pi) - M(K\pi)$
- Select events by mass difference ΔM
- Apply dE/dx to reduce bg
- Well understood detector allows phase space increase in p_T and η:

$5 < Q^2 < 100\ GeV^2$ $\quad 0.02 < y < 0.70$

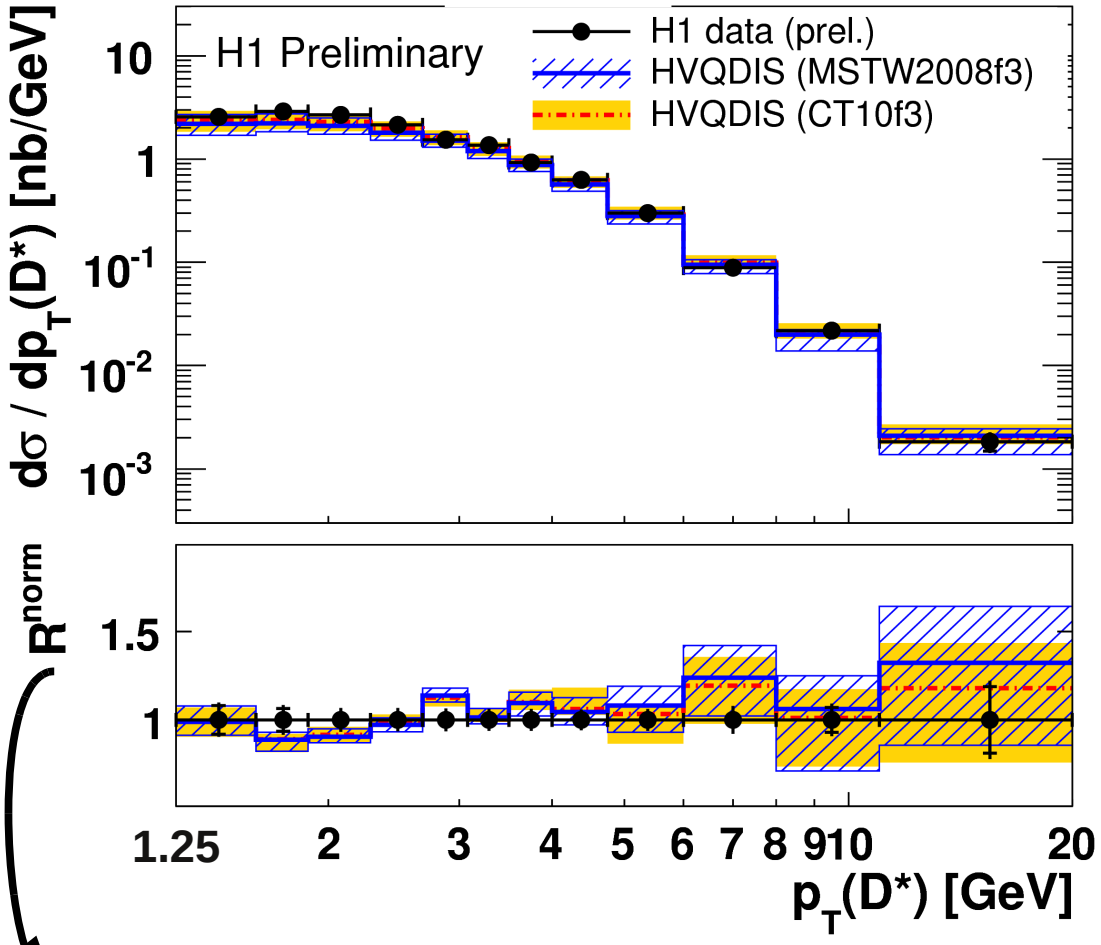
$p_T(D^*): > 1.25\ GeV$ $\quad |\eta(D^*)|: < 1.8$

DIS sample (int. Lum. = 347 pb^{-1}):

- Full HERAII data set: ~24700 D* mesons (~10x HERAI statistic)
- Born-level cross sections by correcting for radiative effects
- Use regularized Matrix Unfolding for treatment of migrations
- Total systematic error: ~ 7.6%

D* production: low Q^2

Link: H1prelim-10-172



Error estimation of the NLO calculation using parameter variation:

charm mass: $1.3 < m_c < 1.7$ GeV

renormalization & factorization scale:

$0.5 < \mu_{f,r}/\mu_0 < 2$

with $\mu_0^2 = Q^2 + 4m_c^2$

fragmentation: at threshold ($\bar{s} < 70$ GeV^2)

α(Kartvelishvili) = $6.1^{+0.9}_{-0.8}$

$\bar{s} > 70$ GeV^2

α(Kartvelishvili) = 3.3 ± 0.4

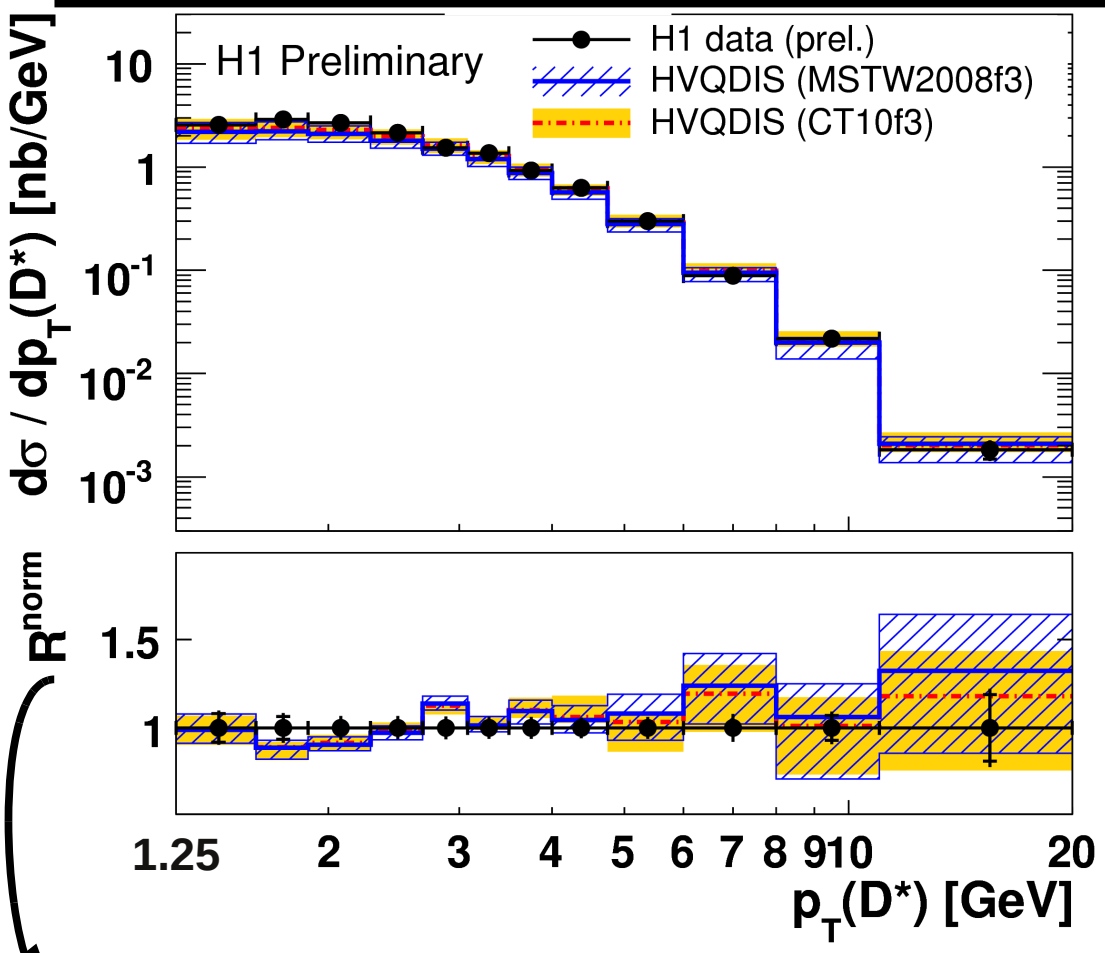
Shape comparison via normalized ratio:

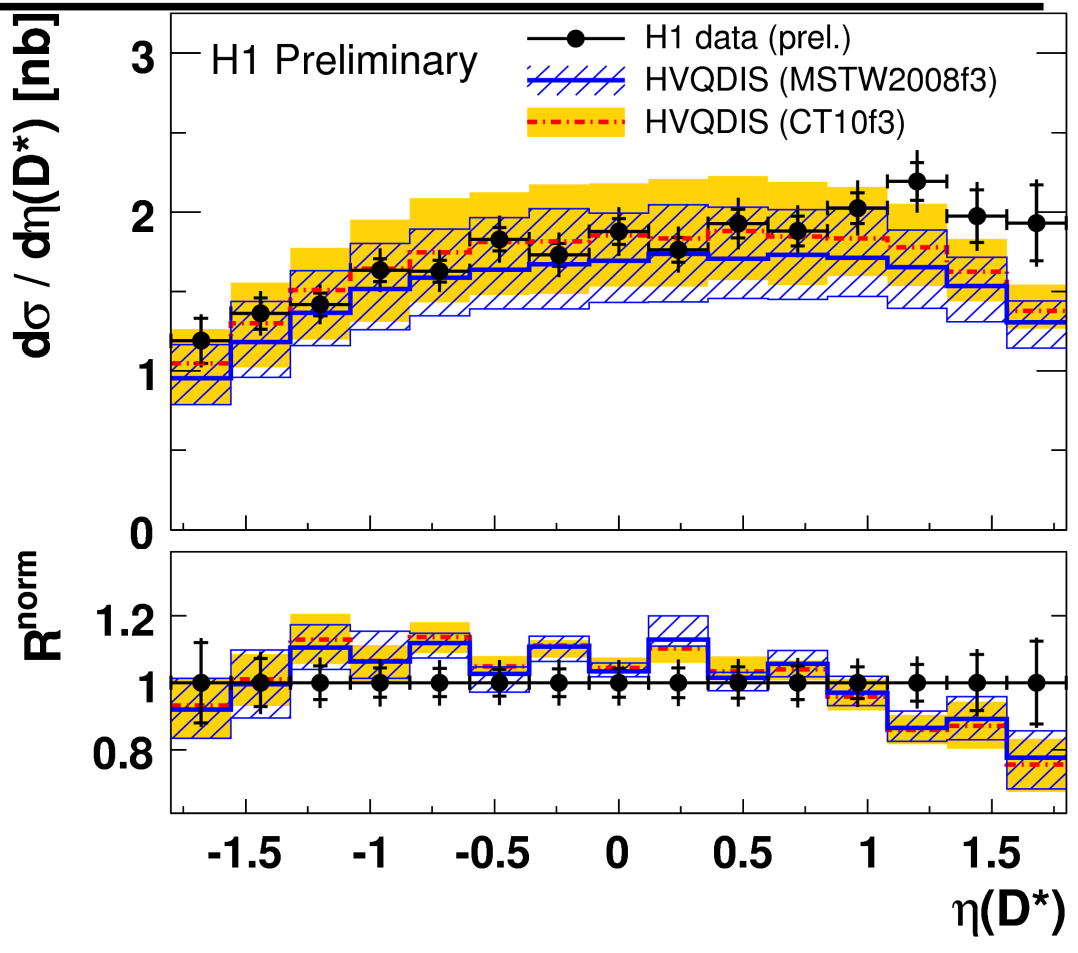
$$R = \frac{1/\sigma^{calc}_{tot,vis} \cdot \frac{d\sigma^{calc}}{dY}}{1/\sigma^{data}_{tot,vis} \cdot \frac{d\sigma^{data}}{dY}}$$

- All normalization uncertainties in data & NLO are removed in R^{norm}: only shape comparison
- Data are reasonable described by HVQDIS

D* production: low Q^2

Link: H1prelim-10-172





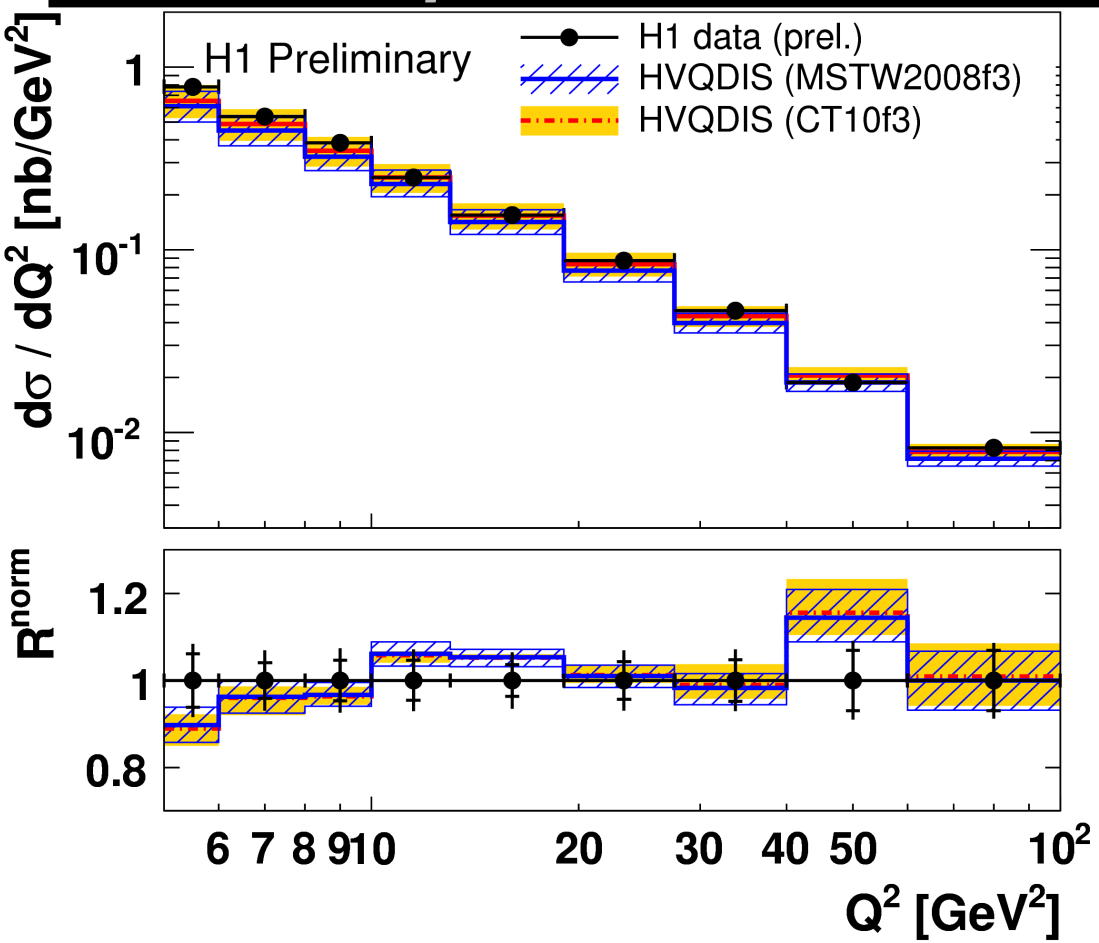
Shape comparison via normalized ratio:

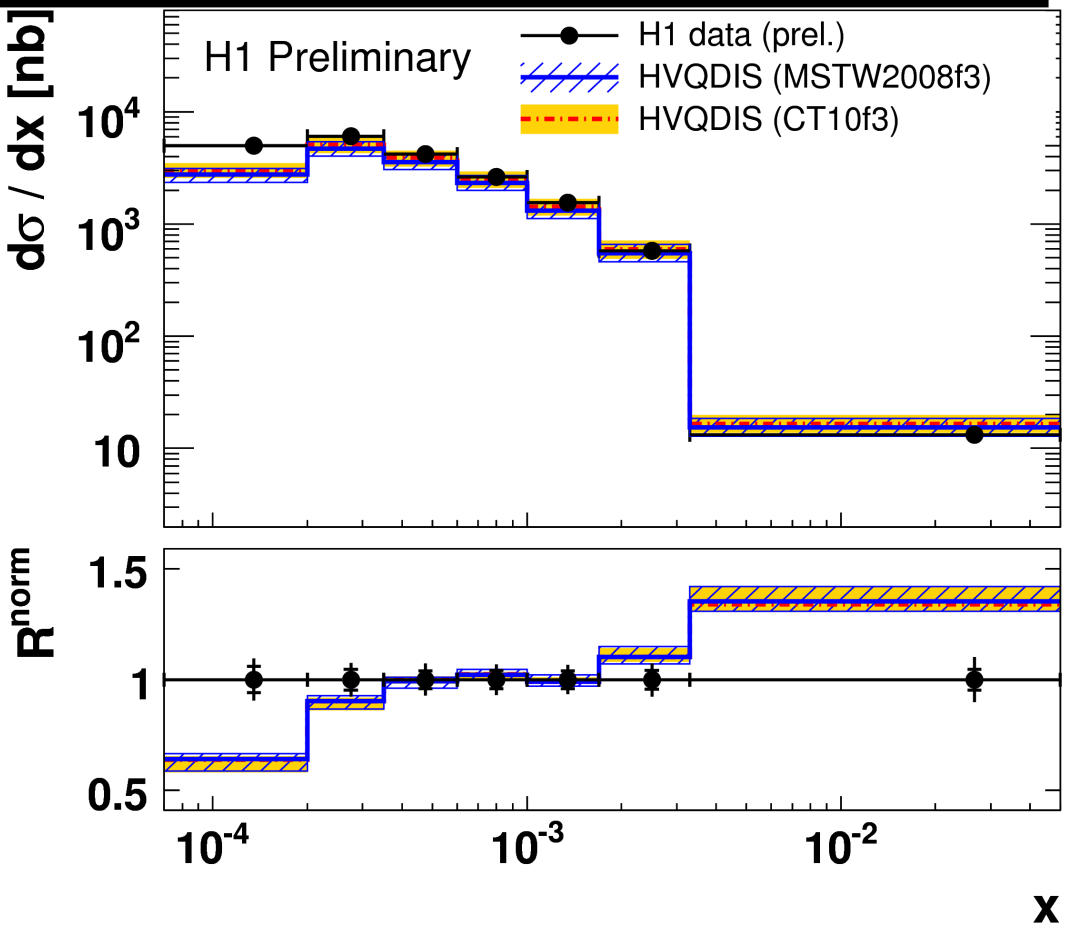
$$R = \frac{1/\sigma^{calc}_{tot,vis} \cdot \frac{d\sigma^{calc}}{dY}}{1/\sigma^{data}_{tot,vis} \cdot \frac{d\sigma^{data}}{dY}}$$

- Data are reasonable described by HVQDIS
- Forward direction: HVQDIS slightly undershoots data

D* production: low Q^2

Link: H1prelim-10-172

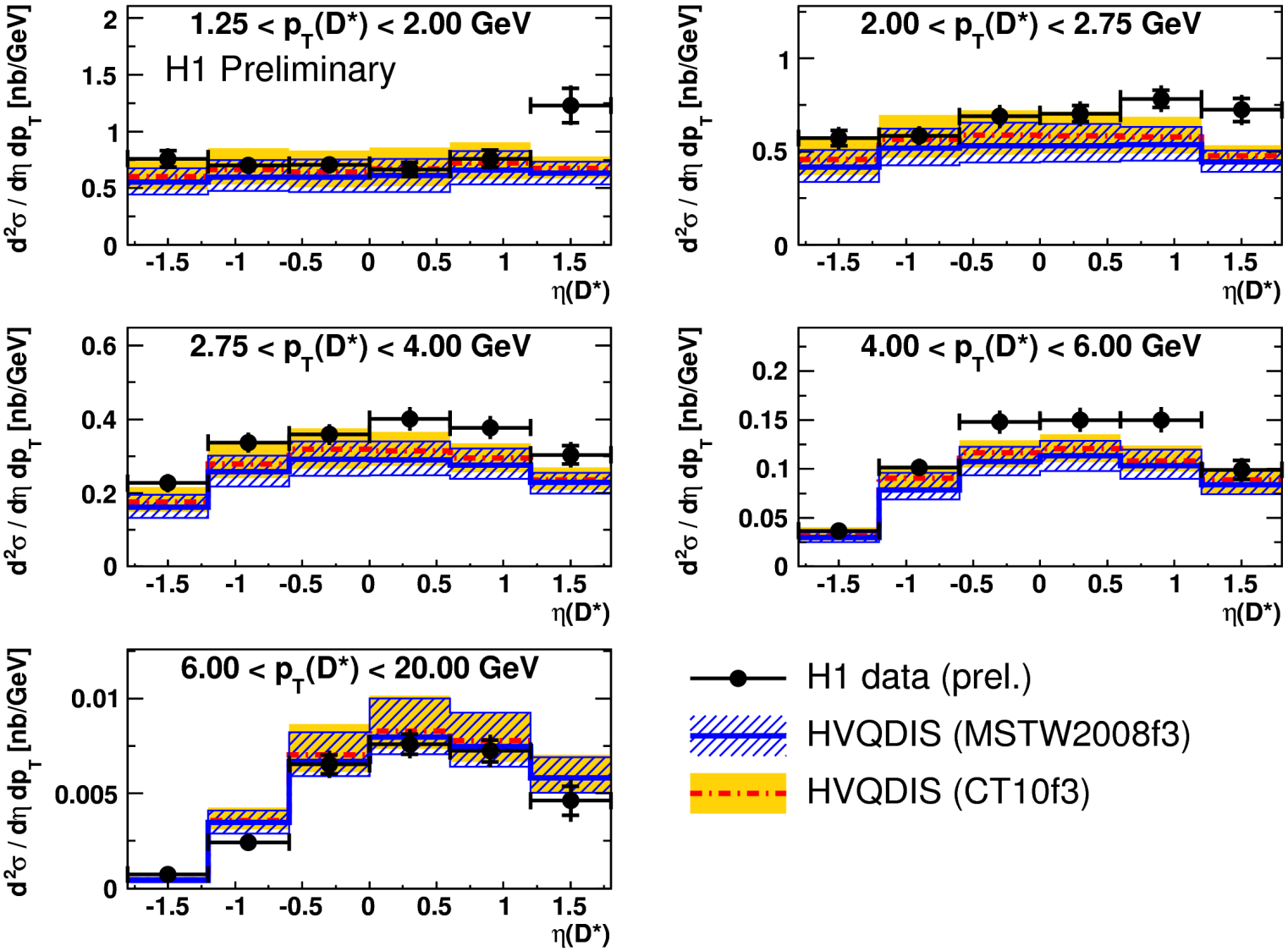




- HVQDIS describes nicely the Q^2 dependency
- Slope in x not very well reproduced!
- Double differential y-Q^2 has also been measured, can be used to extract $F_2^c(x,Q^2)$

D* production: low Q^2

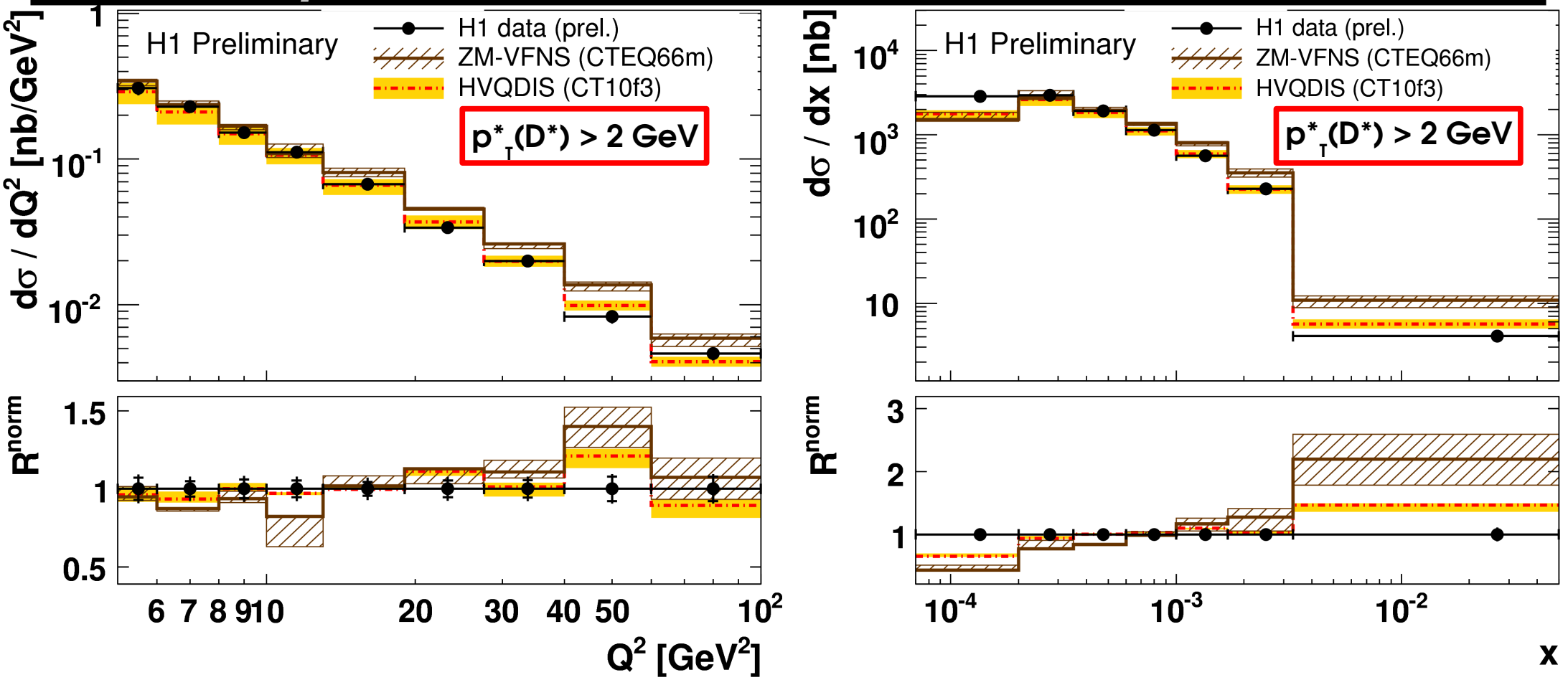
Link: H1prelim-10-172



- In general $\eta(D^*)$-$p_T(D^*)$ cross section reasonable described by HVQDIS
- Forward direction: HVQDIS undershoots data located at low $p_T(D^*)$

D* production: low Q^2

Link: H1prelim-10-172

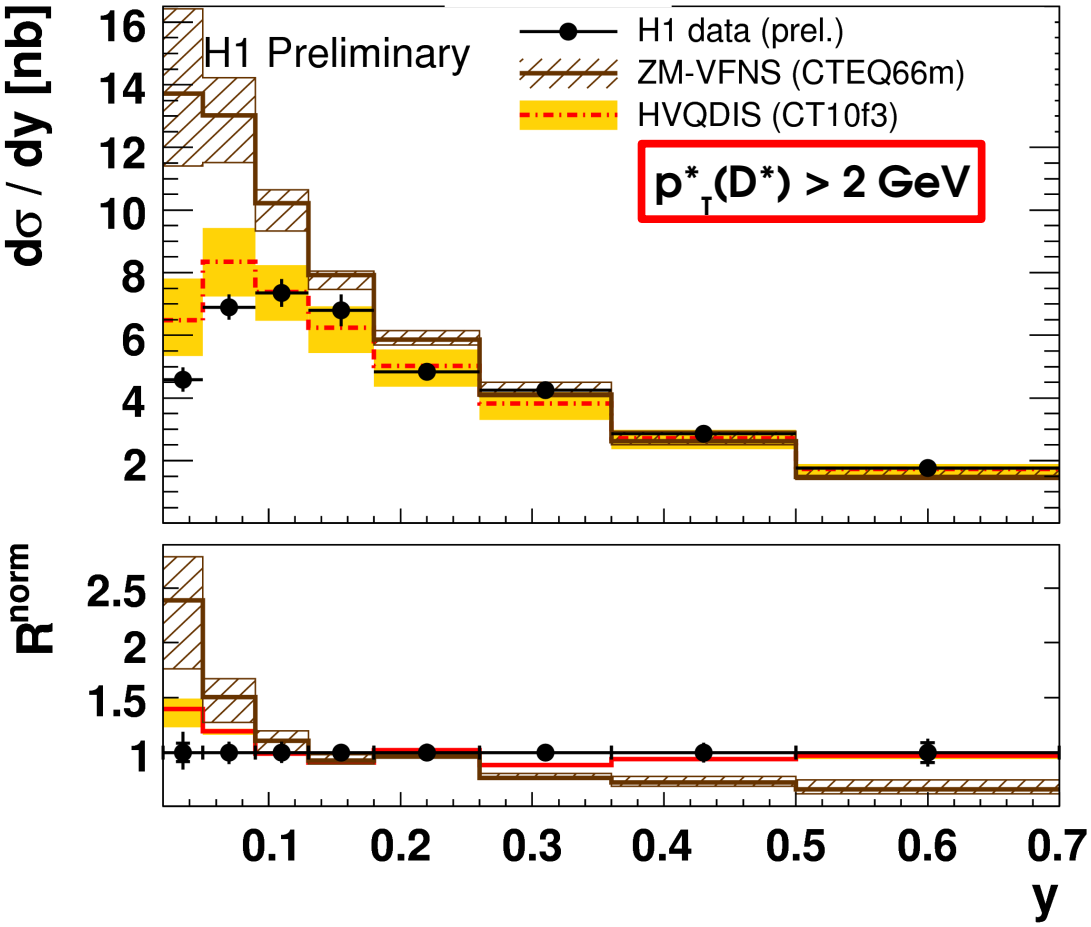


- For comparison with ZM-VFNS: Cut in photon-proton rest frame: $p_T^*(D^*) > 2$ GeV
- ZM-VFNS: Theoretical uncertainty taken from scale variations

- Reasonable description of Q^2 by both NLO calculations, HVQDIS is better in shape
- ZM-VFNS predicts completely different slope in x & fails especially at large x

D* production: low Q^2

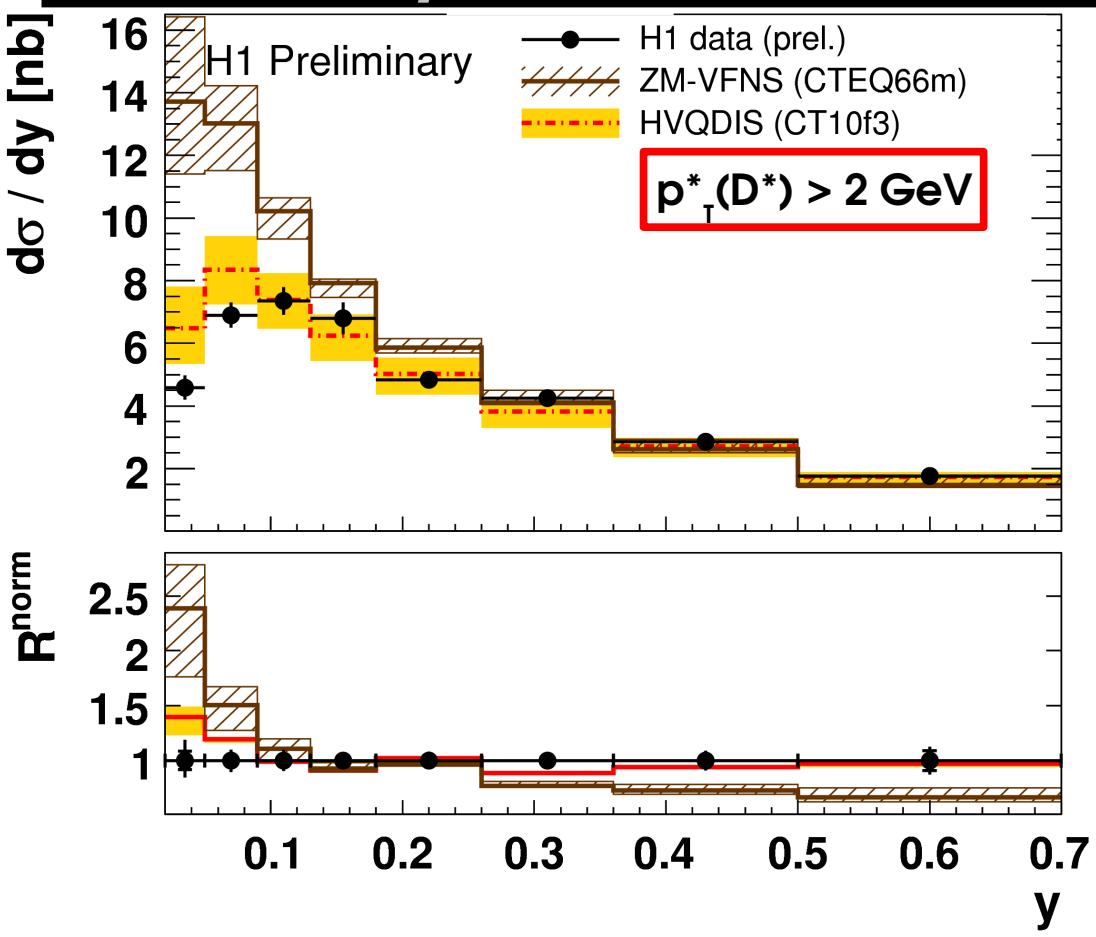
Link: H1prelim-10-172

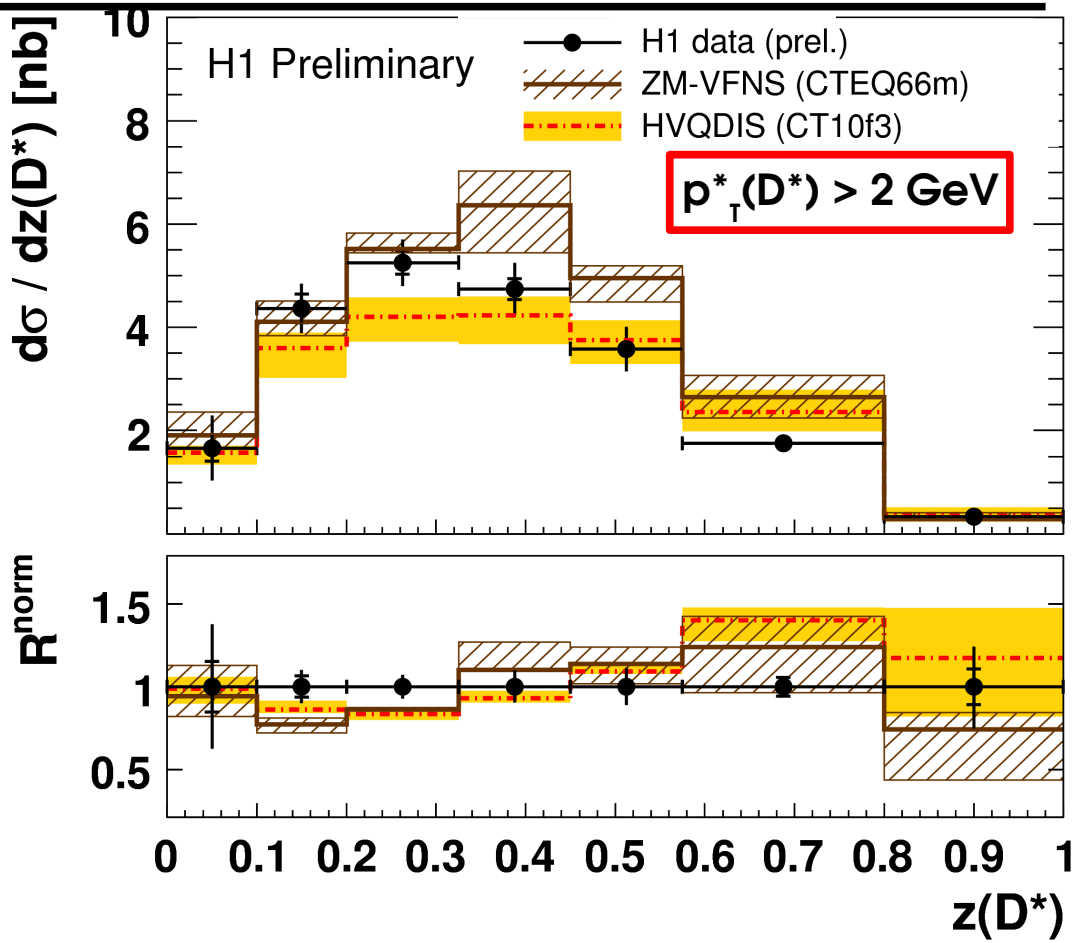


- As seen in x also in y ZM-VFNS fails completely!
- HVQDIS overshoots at low y

D* production: low Q^2

Link: H1prelim-10-172

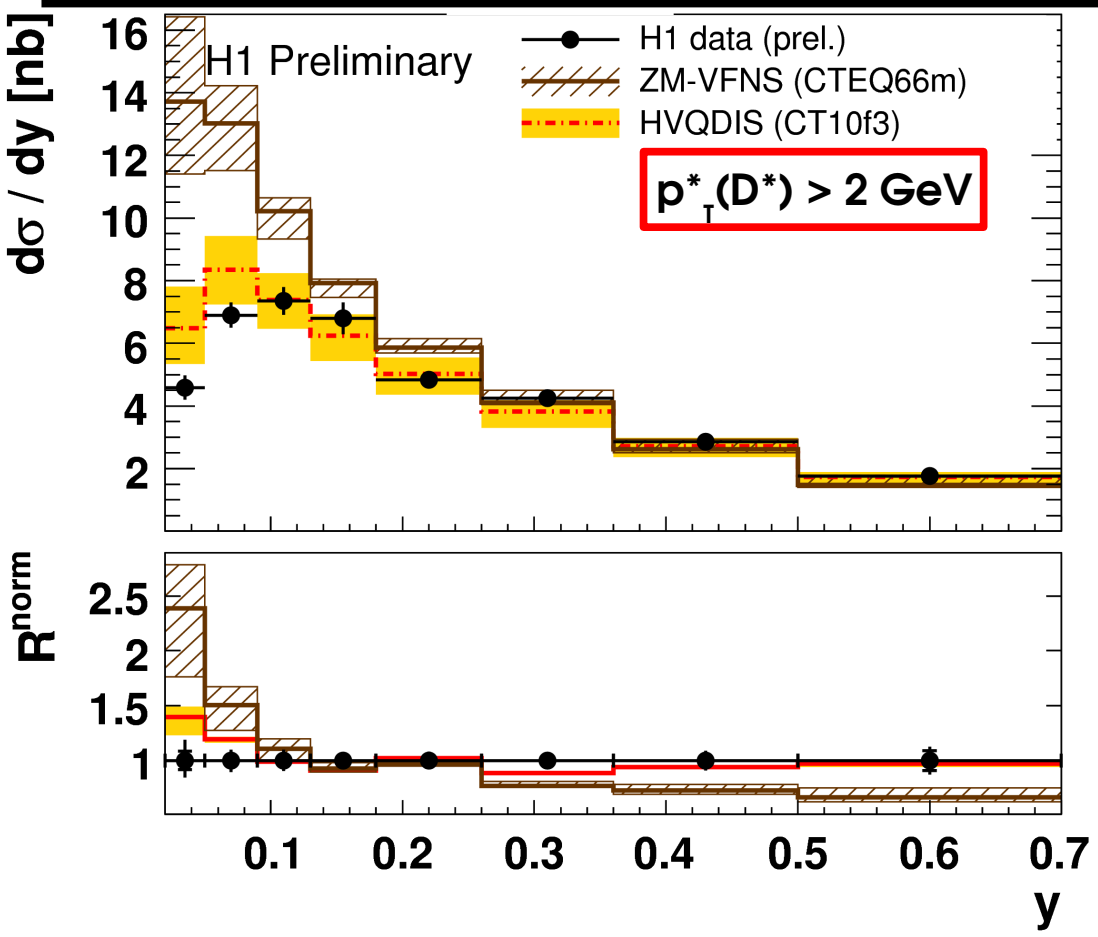


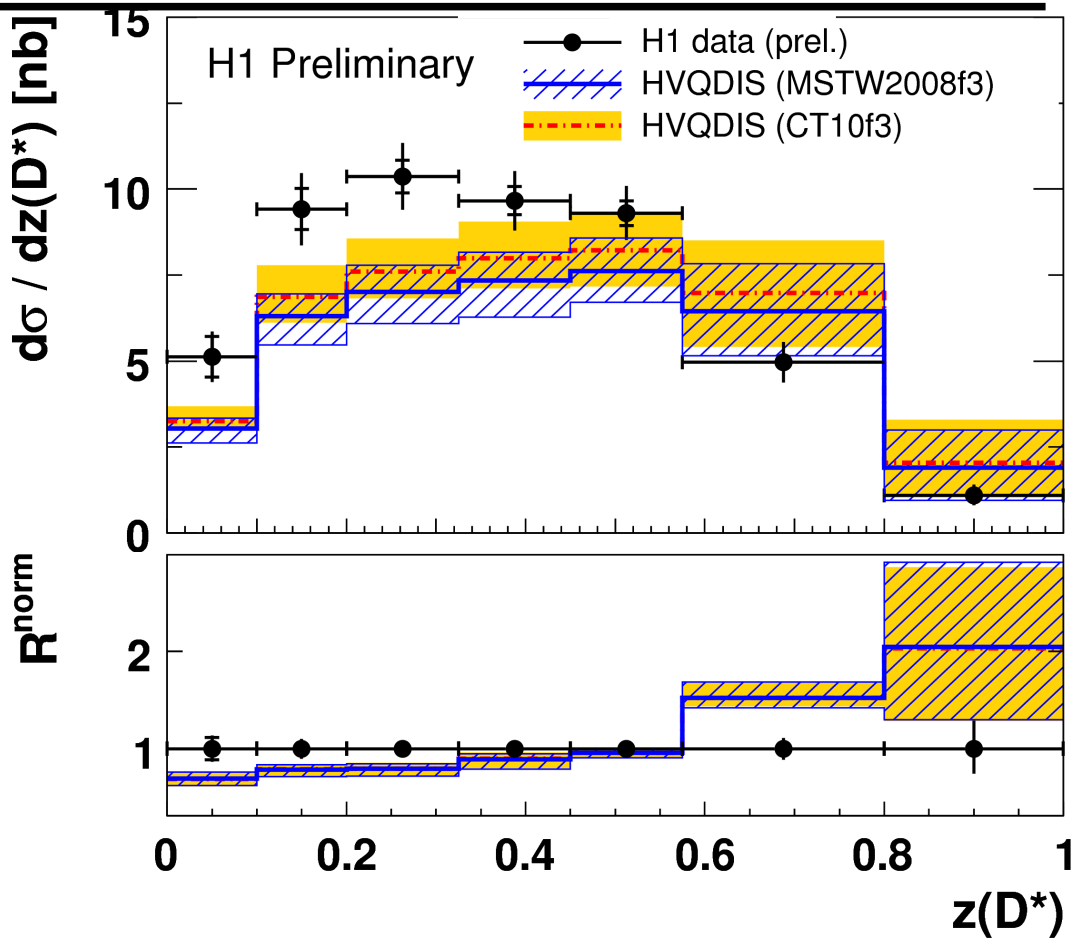


- As seen in x also in y ZM-VFNS fails completely!
- HVQDIS overshoots at low y
- z(D*) reasonable described by ZM-VFNS & HVQDIS

D* production: low Q^2

Link: H1prelim-10-172

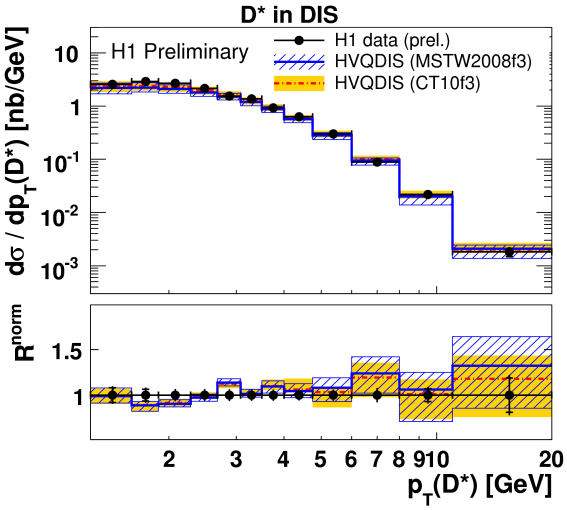


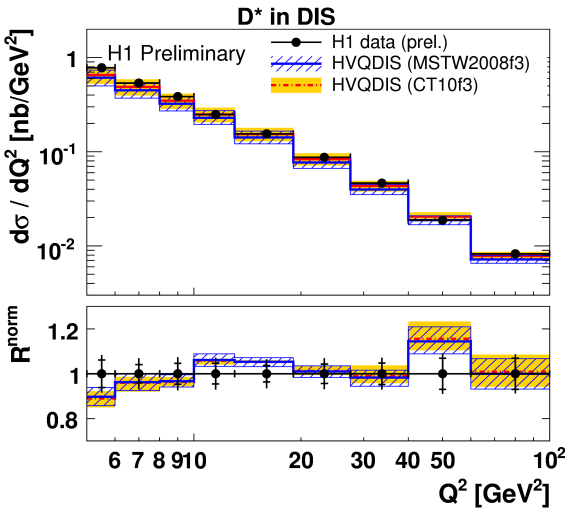


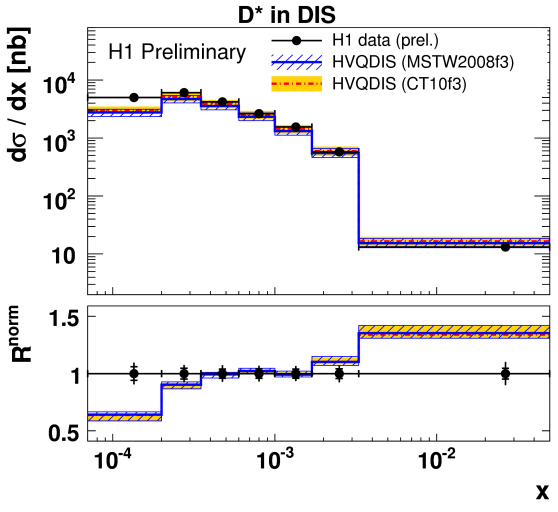
- As seen in x also in y ZM-VFNS fails completely!
- HVQDIS overshoots at low y
- z(D*) reasonable described by ZM-VFNS & HVQDIS
- Without the additional $p_T^*(D^*)$ cut HVQDIS fails to describe z(D*)

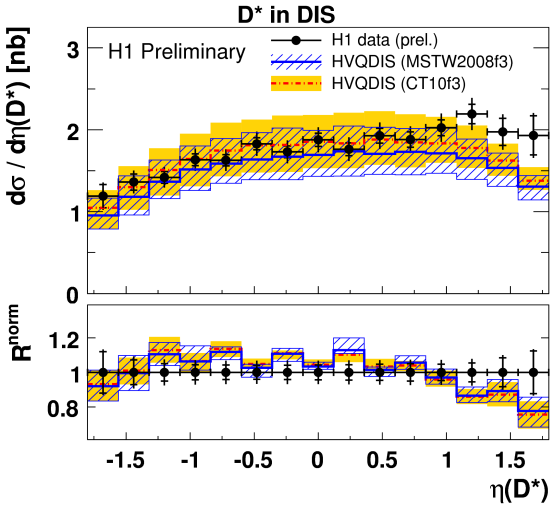
Conclusions

- Full H1 HERA II data sample analyzed for low Q^2 D* production:
  - Increased phase space in η and p_T
  - HVQDIS describes data quite reasonable
  - ZM calculation fails to describe x (and y)
  - The final word on D* in DIS from HERAII



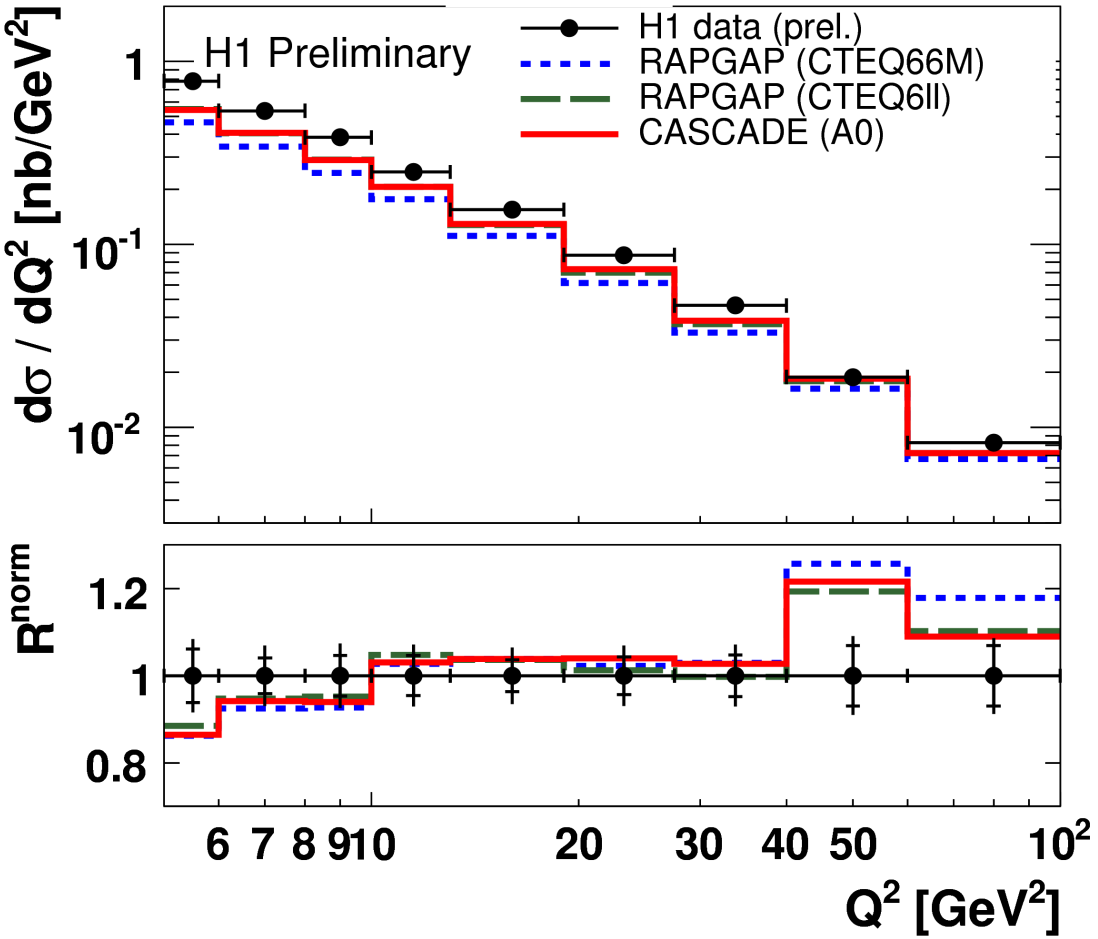


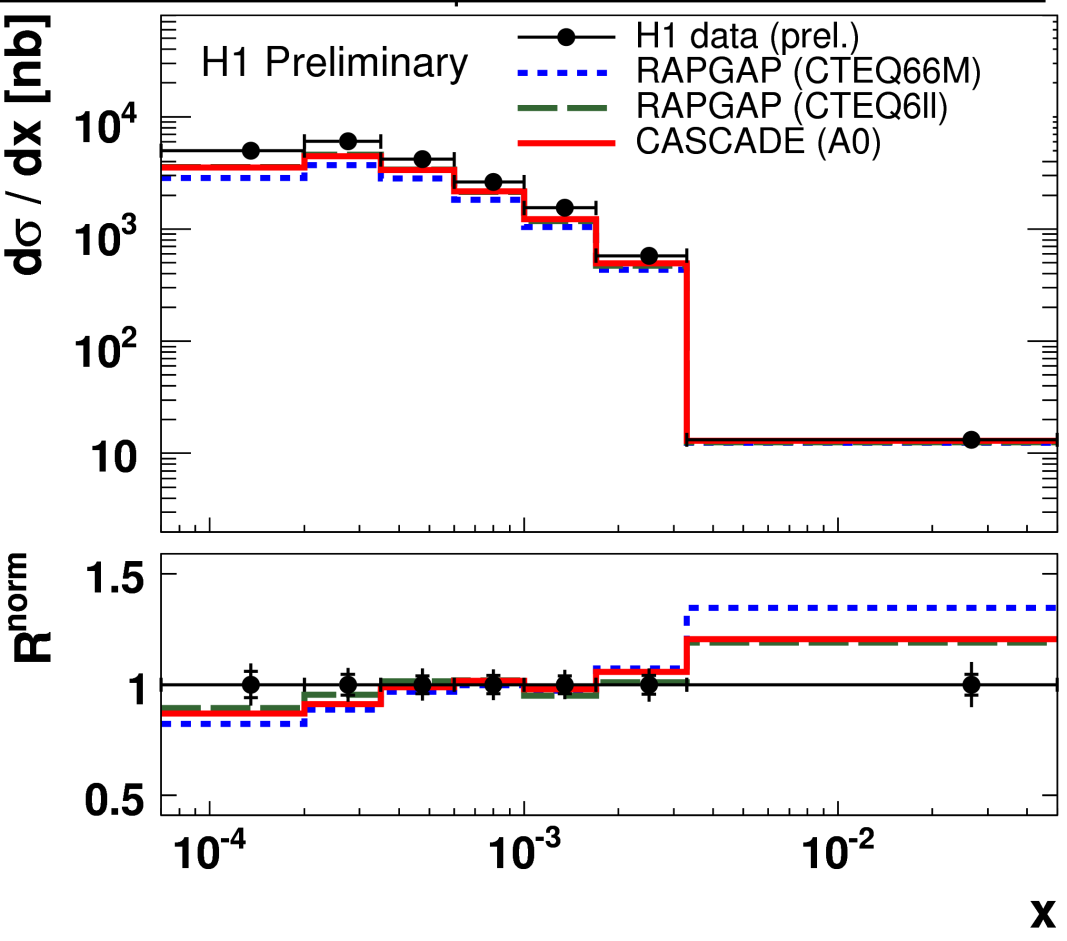




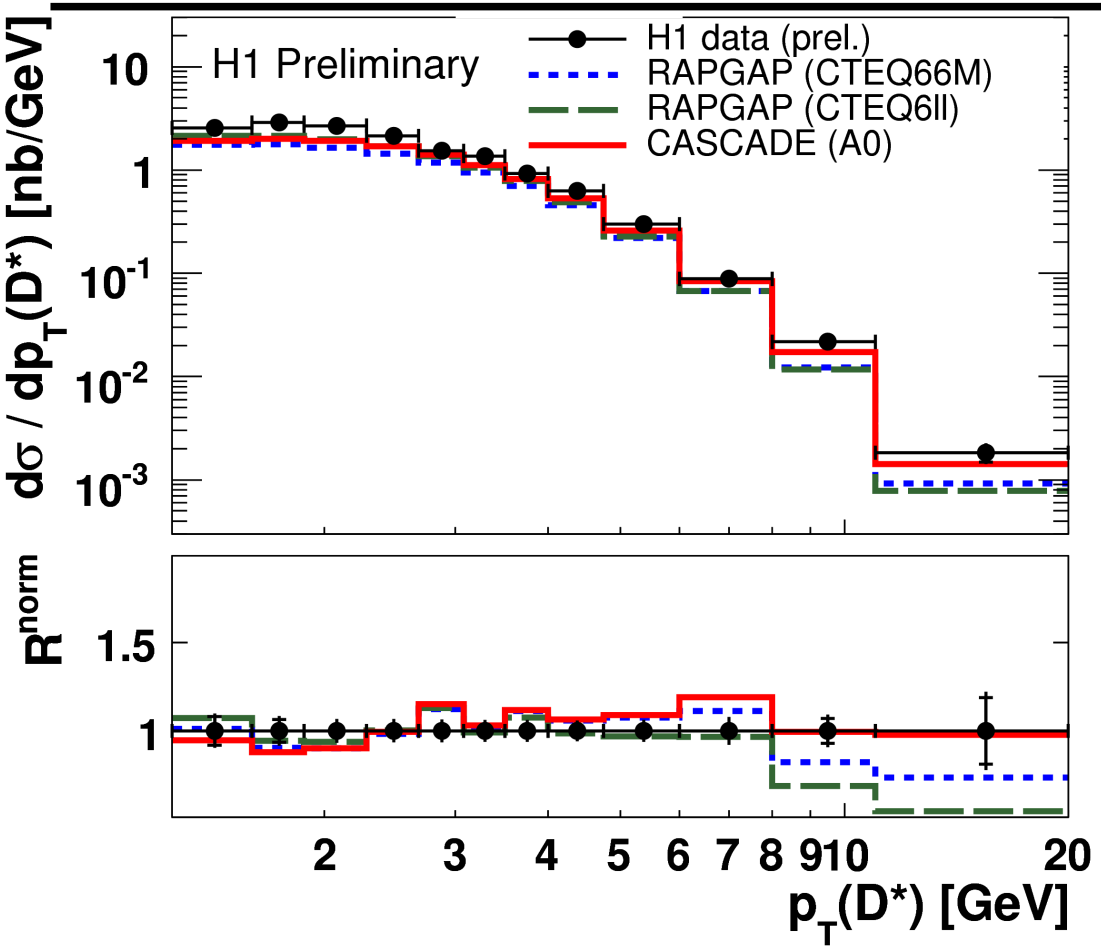
Backup

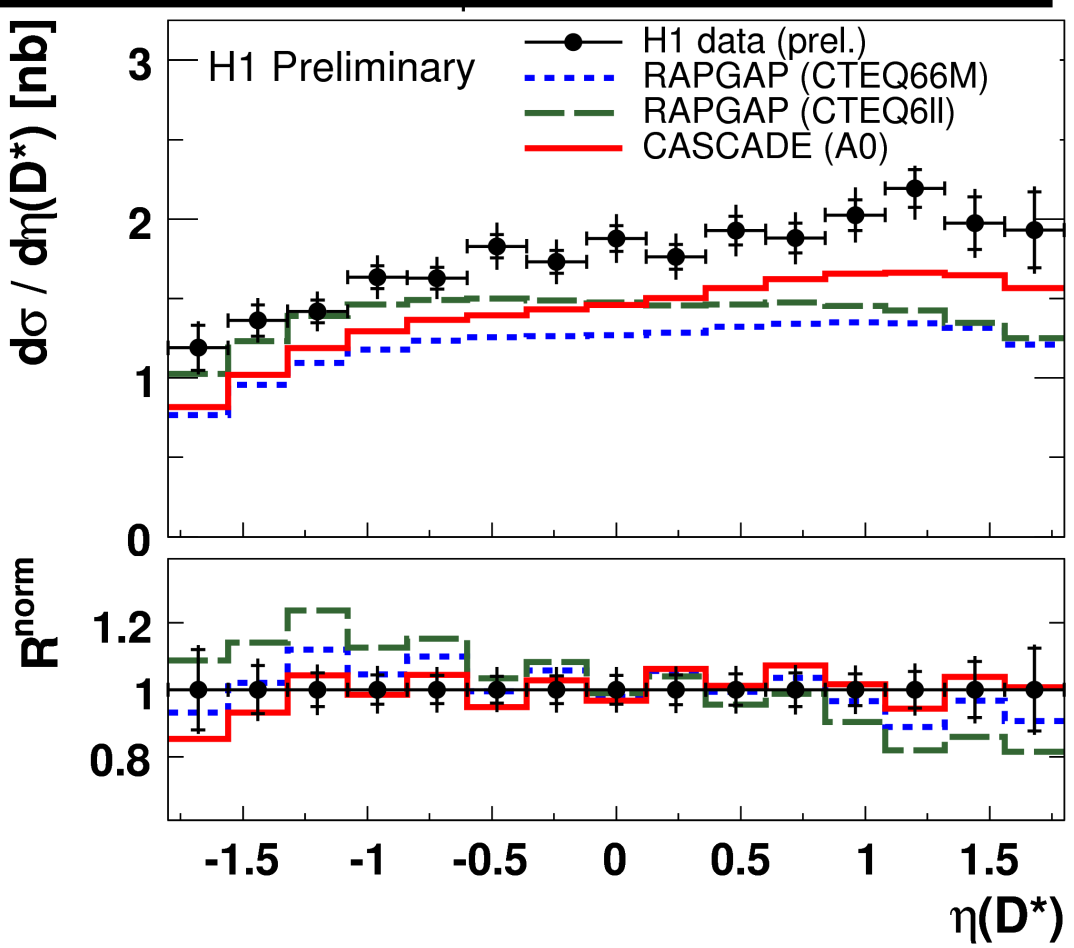
D* production: low Q^2





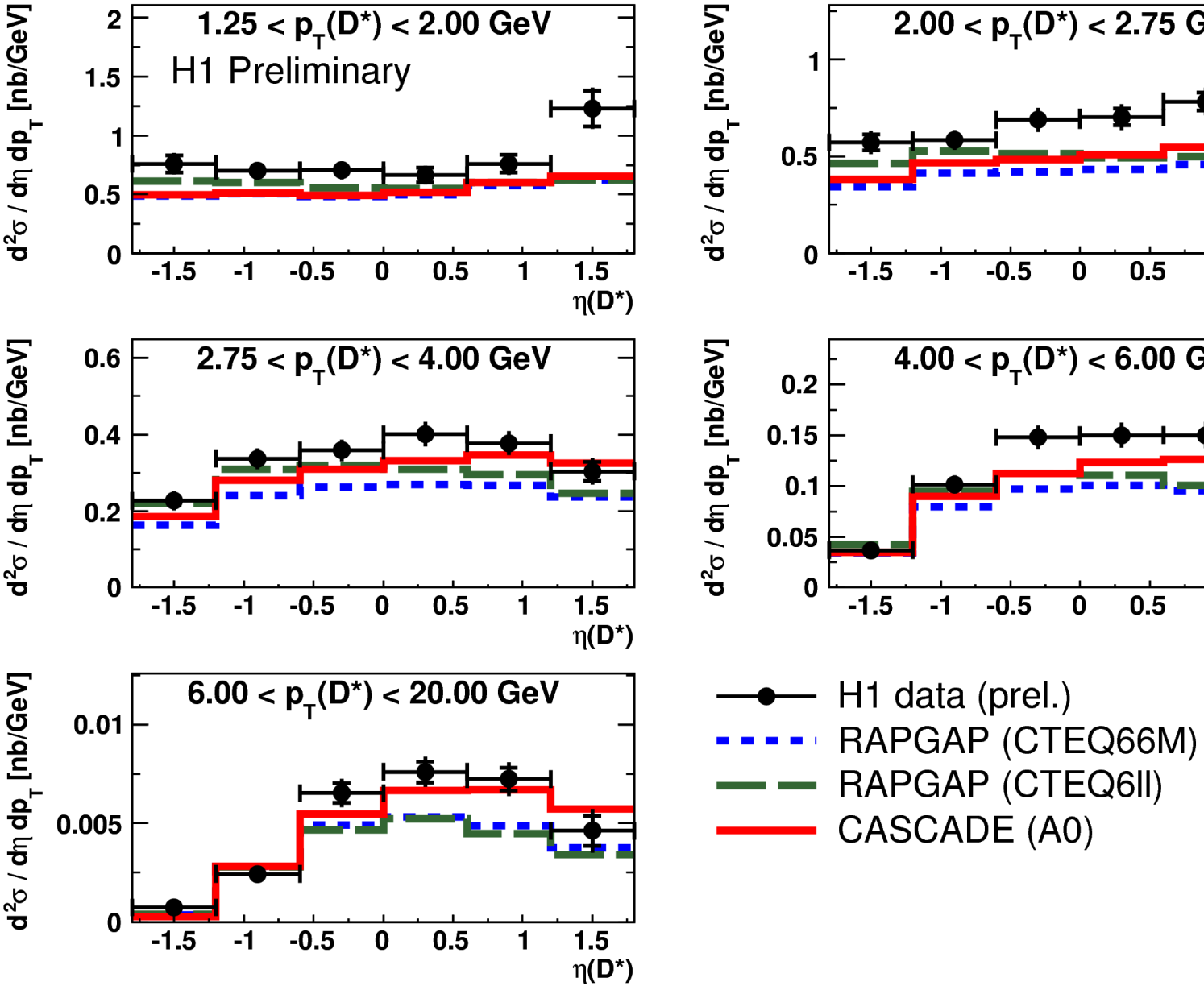
- Q^2 reasonable described by either RAPGAP or CASCADE
- Compared to HVQDIS the MC describe the slope in x



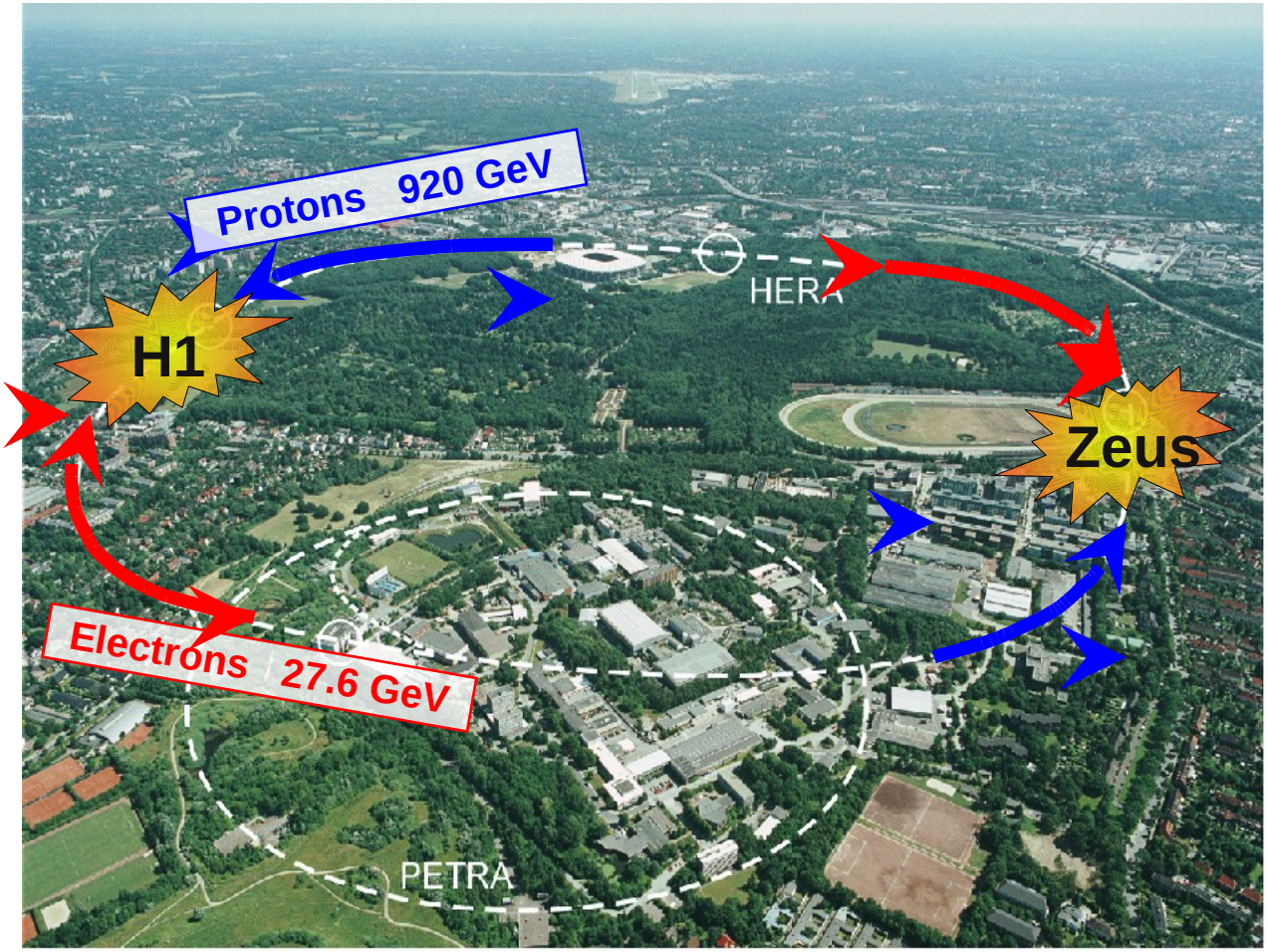


- Reasonable description by RAPGAP
- CASCADE is doing a good job in D* variables

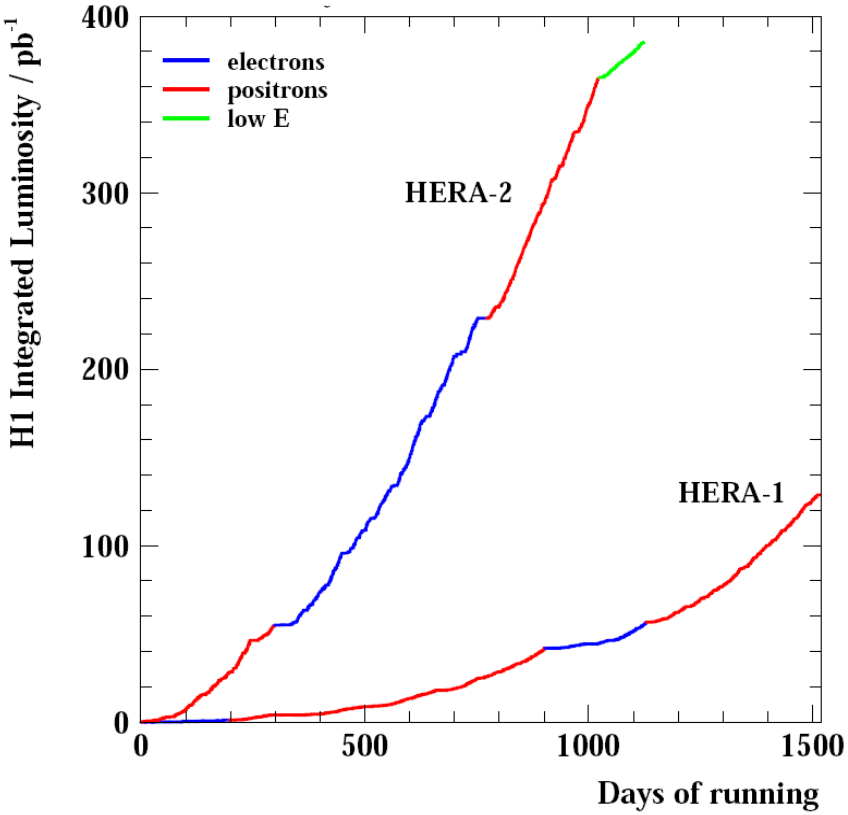
D* production: low Q^2



The HERA Collider (1994-2007)



Collected Data samples:



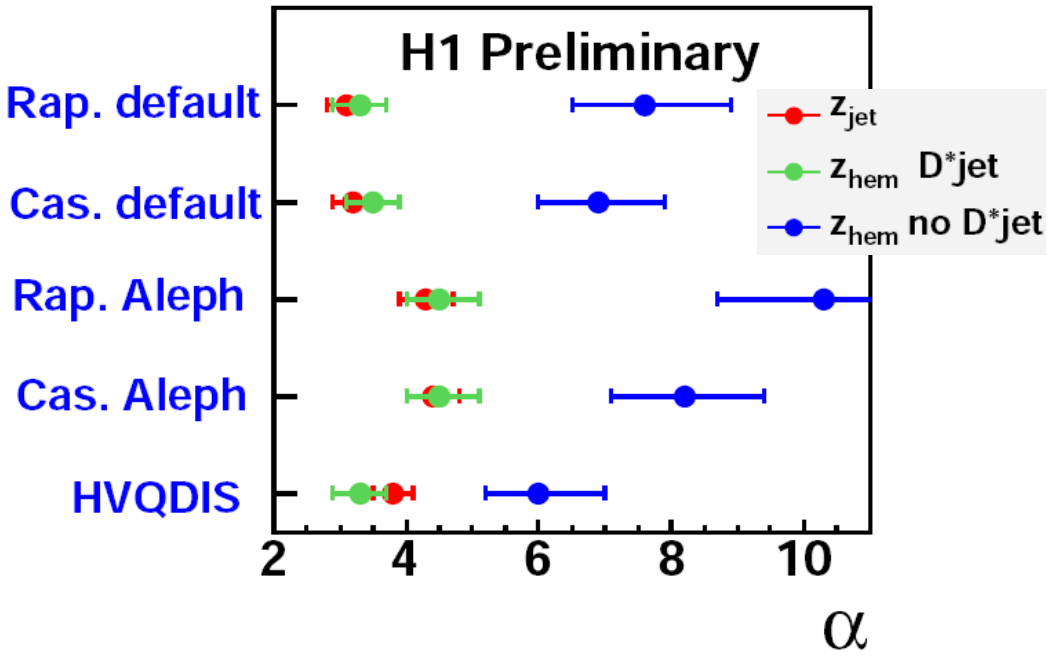
--> Two multi-purpose detectors: H1 & Zeus

--> Collected Luminosity: HERAI + HERAII ~ 0.5 fb^{-1}

Fragmentation function

- If **a hard scale** is involved:
  - jet- & hemisphere method agree well
  - FF also agrees with ZEUS and LEP data
- If **no hard scale** is involved:
  - discrepancy at charm production threshold in QCD models
  - much harder fragmentation

More information:
http://arxiv.org/abs/0808.1003v2



- Fragmentation uncertainty from FF values for charm production:

	HVQDIS:	CASCADE:	RAPGAP:
at-threshold:	$\alpha = 6.0^{+1.0}_{-0.8}$	$\alpha = 8.2 \pm 1.1$	$8.7 < \alpha < 12.2$
above-threshold:	$\alpha = 3.3 \pm 0.4$	$\alpha = 4.6 \pm 0.6$	$3.9 < \alpha < 5.0$

- Threshold position from $\hat{s}$ (cms energy of hard subprocess):

$70 \pm 20\ \mathrm{GeV}^2$	$70 \pm 20\ \mathrm{GeV}^2$	$70 \pm 20\ \mathrm{GeV}^2$