Inclusive c and b dijets at HERA

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Introduction

Experimental Method

Cross Sections

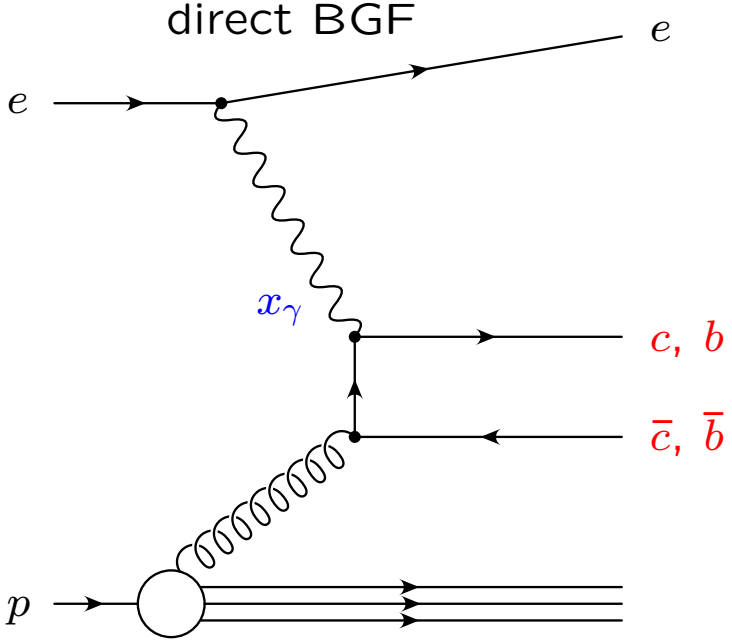
High Purity Sample

HERA-LHC Workshop 2006, CERN

Introduction: b and c Dijet Production Processes

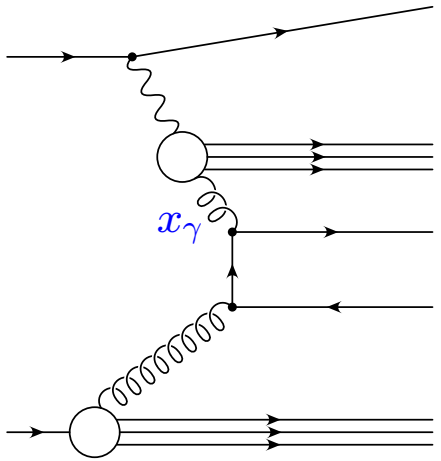
$x_\gamma = 1$

direct BGF

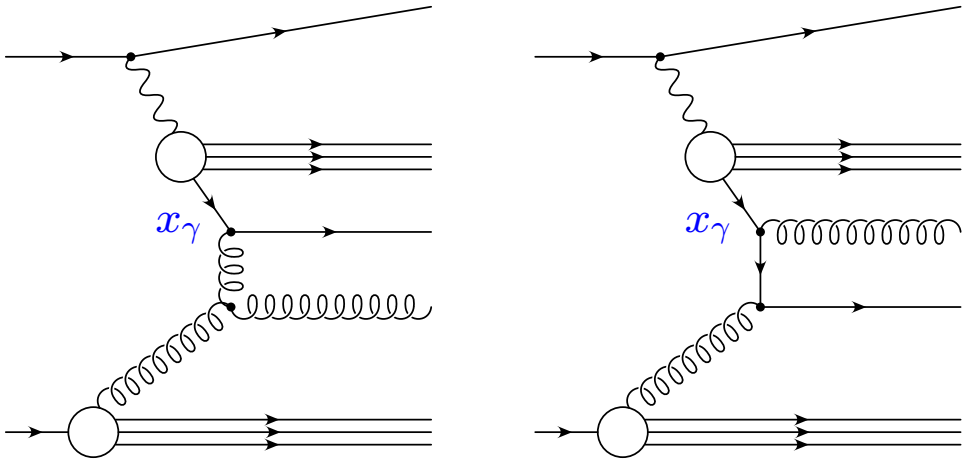


$x_\gamma < 1$

resolved BGF



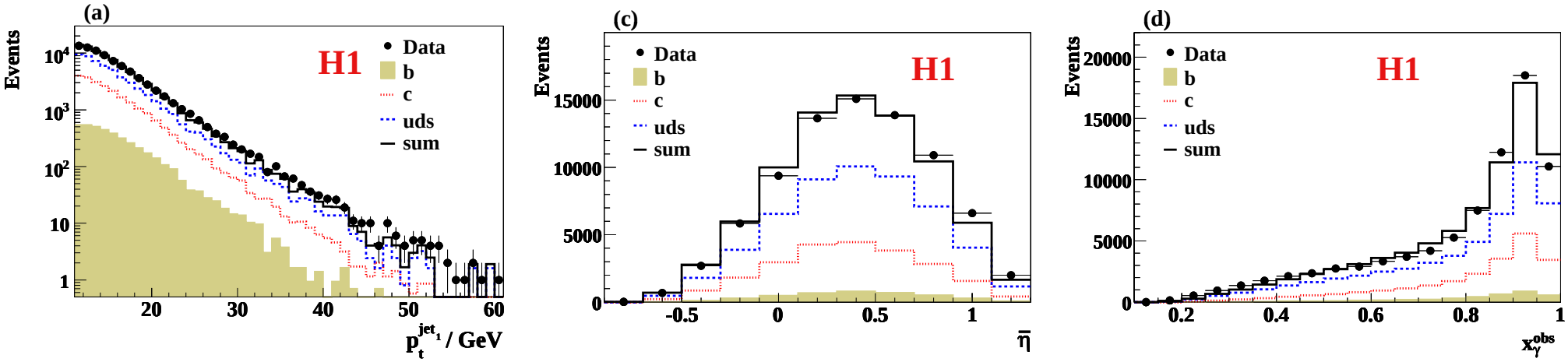
resolved excitation



Data Sample

$Q^2 < 1$ GeV^2, $0.15 < y < 0.8$, $\mathcal{L} = 56.8$ pb^{-1}

Jets: inklusive k_t algorithm, $-0.9 < \eta < 1.3$, $p_t^{\text{jet}_{1(2)}} > 11(8)$ GeV



$\bar{\eta}$: mean η of the two jets

x_γ^{obs}: photon momentum fraction reconstructed from the two jets

good description by PYTHIA (with normalisation factors)

Inclusive Lifetime Tag

aim: inclusive measurement of charm and beauty dijets in photoproduction

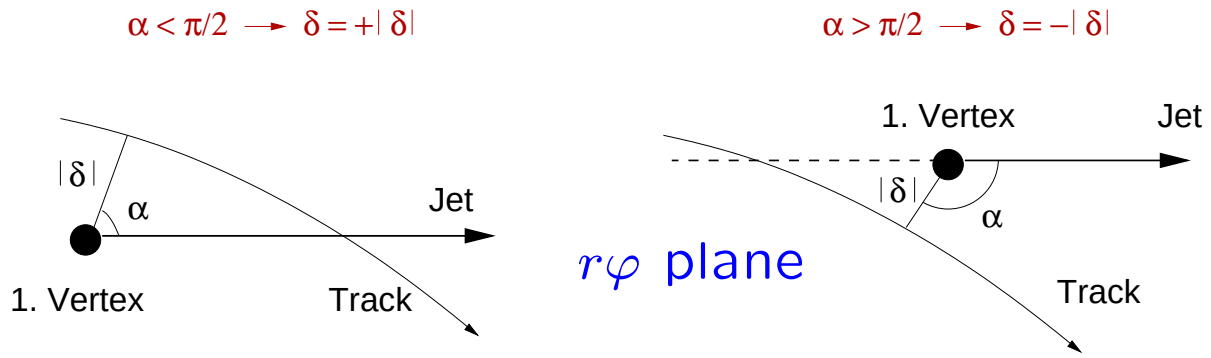
method: exploit long lifetimes of heavy hadrons which result in displacement of tracks from primary vertex

advantages:

- high statistics
- high p_t reachable
- simultaneous measurement of charm and beauty

Experimental Method

Study the signed impact parameter in the $r\varphi$ plane for all tracks with precise measurement from Central Silicon Tracker (CST)



sign determination relative to jet axis

heavy flavours:

- long-lived particles
- large positive impact parameters

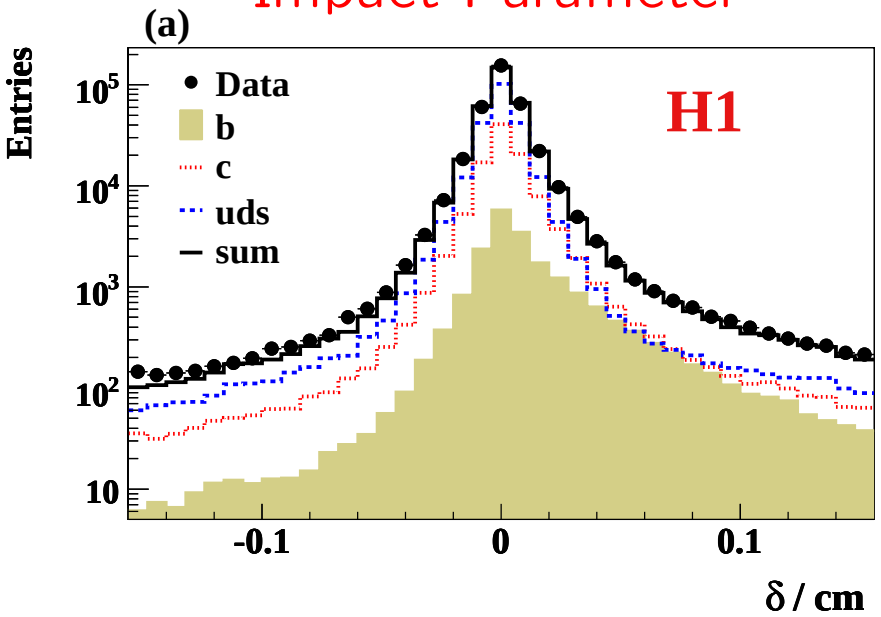
light flavours:

- resolution effects
- small negative and positive impact parameters

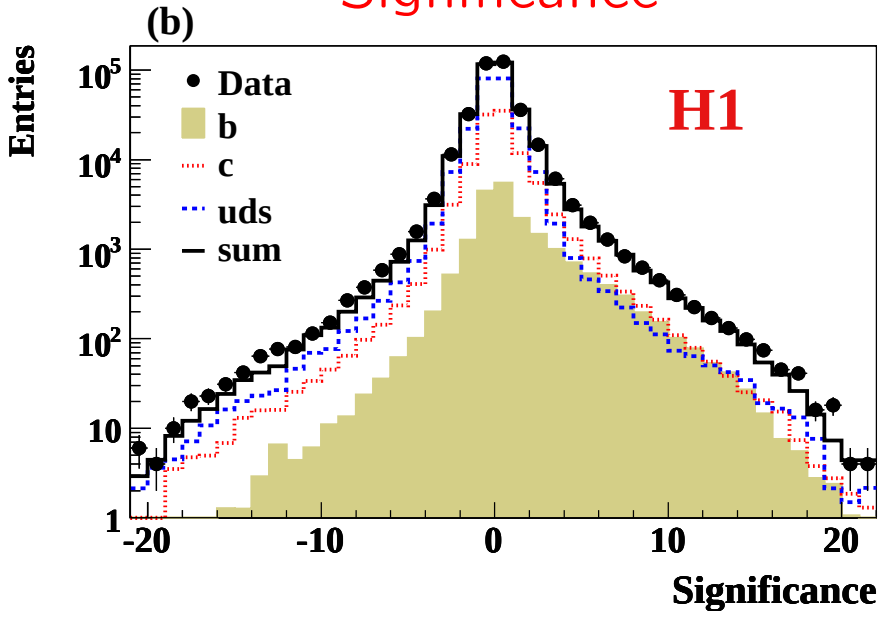
Impact Parameter and Significance

- for tracks measured in CST, plot impact parameter δ in $r\varphi$ plane cut $|\delta| < 0.1\,\text{cm}$ to remove e.g. K^0s
- significance of each track given by $S_i = \delta/\sigma_\delta$

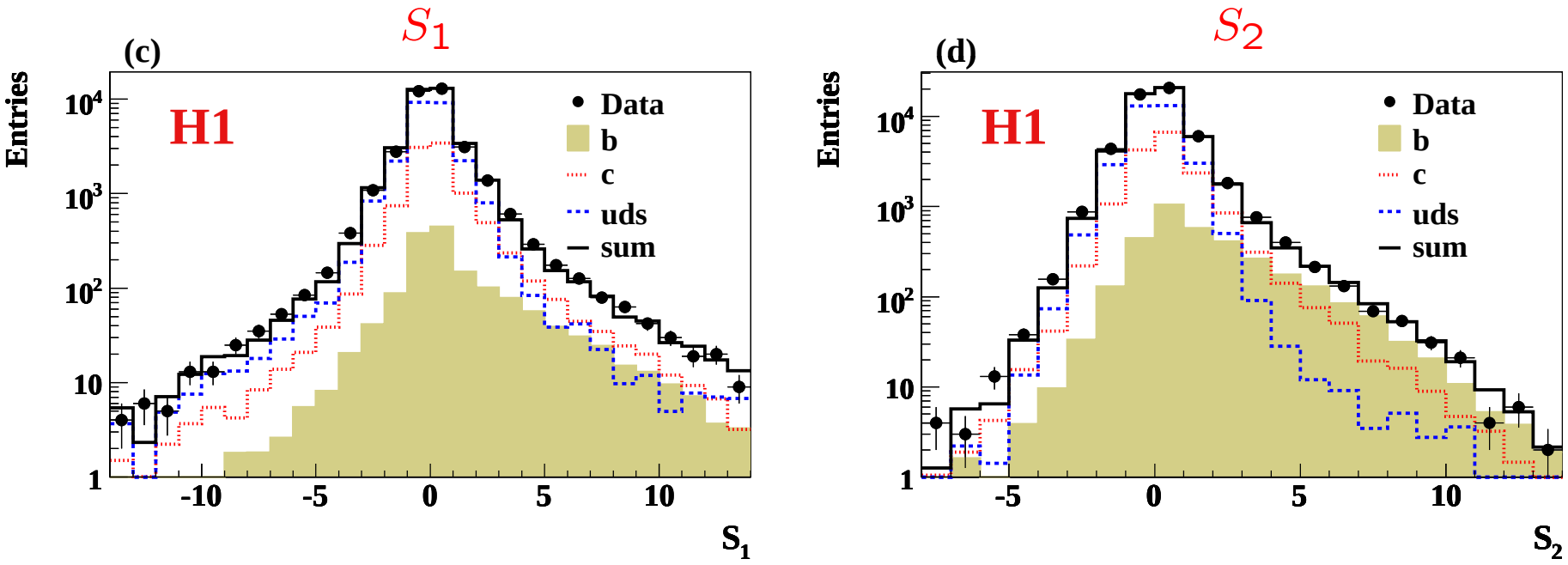
Impact Parameter



Significance



Significance Distributions

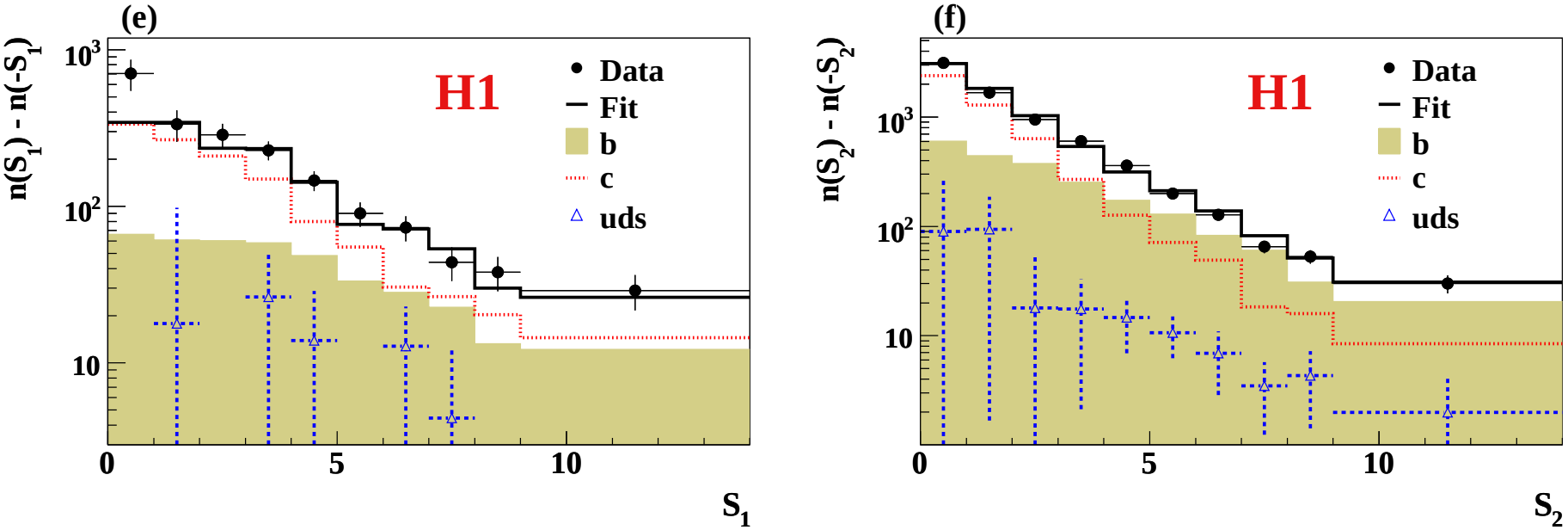


- S_1 significance of highest significance track (1 track events)
- S_2 significance of 2nd highest significance track with same sign as S_1 ($\geq$ 2 track events)

$\Rightarrow$ S_2 provides separation power between charm and beauty

'Negatively Subtracted' Significance Distributions

subtract bins at negative S_i from the corresponding positive bin
$\Rightarrow$ reduce sensitivity to resolution effects



fit simultanously the subtracted S_i distributions and the total number of events in the sample (before CST selection) with 3 parameters:

- P_b scale factor for beauty MC $\quad P_b = 1.98 \pm 0.22$
- P_c scale factor for charm MC $\quad P_c = 1.45 \pm 0.14$
- P_l scale factor for light quark MC $\quad P_l = 1.44 \pm 0.05$

QCD Models

NLO prediction: FMNR

- fixed order, massive scheme
- proton pdf: CTEQ5F3
- photon pdf: GRV-G HO
- hadronisation correction with PYTHIA

PYTHIA: DGLAP evolution

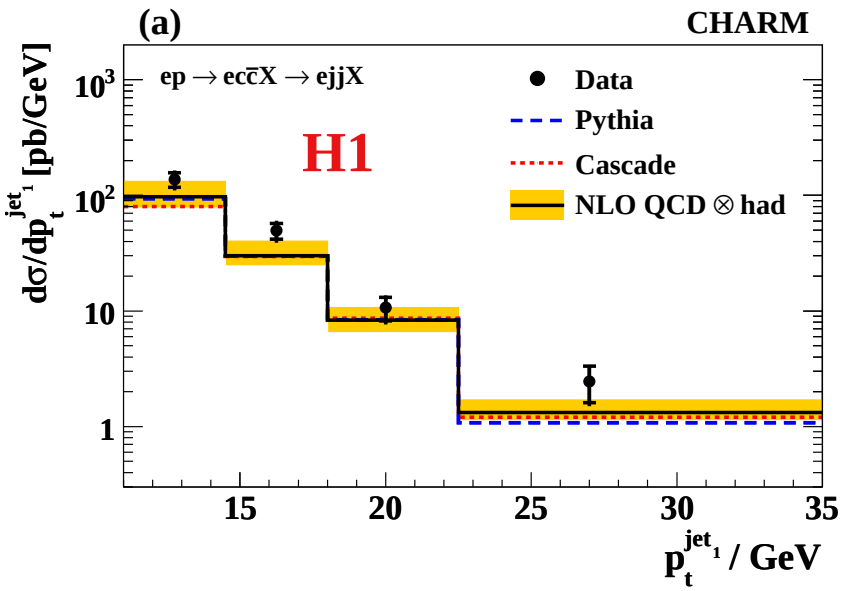
- direct and resolved photon contribution
- proton pdf: CTEQ5L
- photon pdf: SaS1D

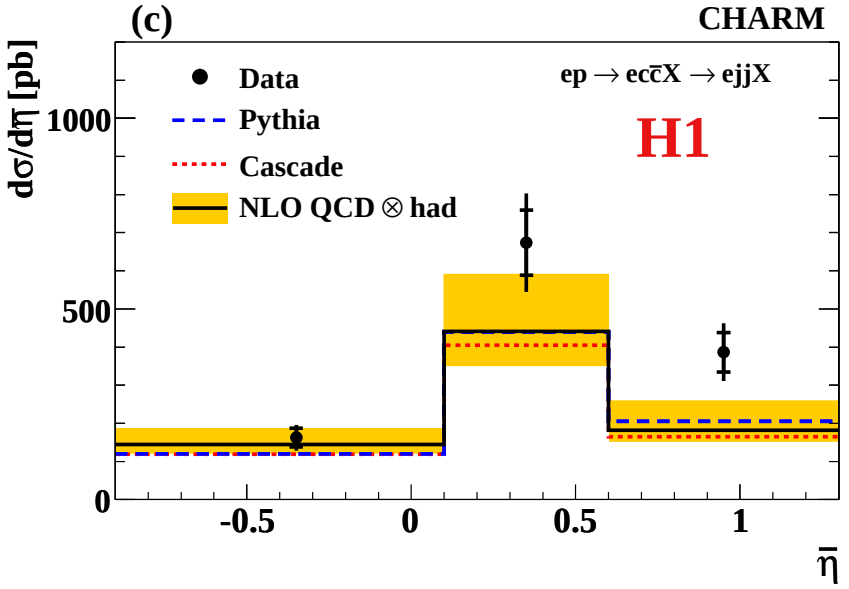
CASCADE: CCFM evolution

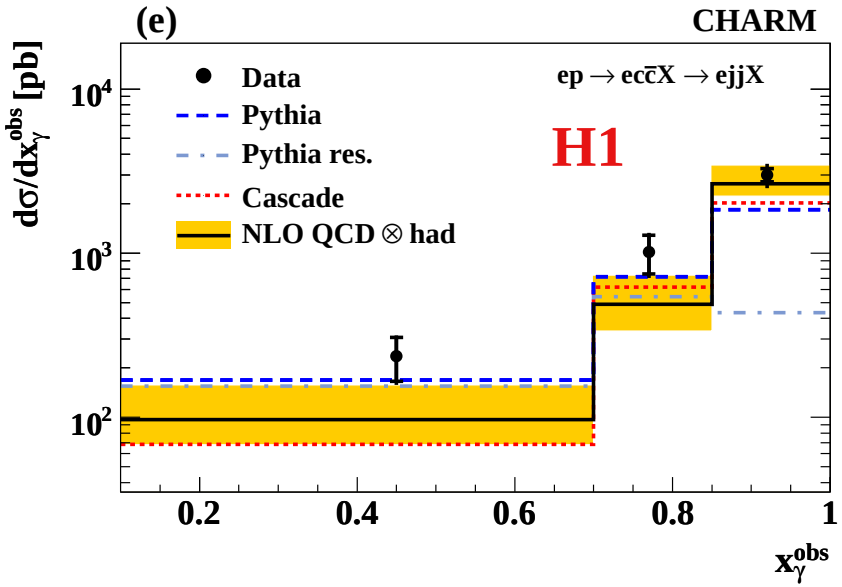
- only direct photon contribution
- proton pdf: A0

- $m_c = 1.5$ GeV, $m_b = 4.75$ GeV

Charm Cross Sections





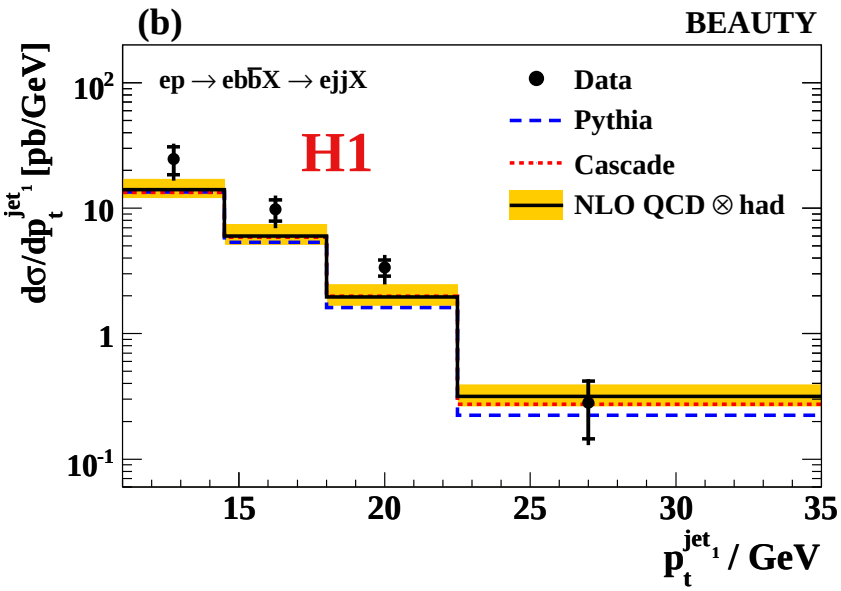


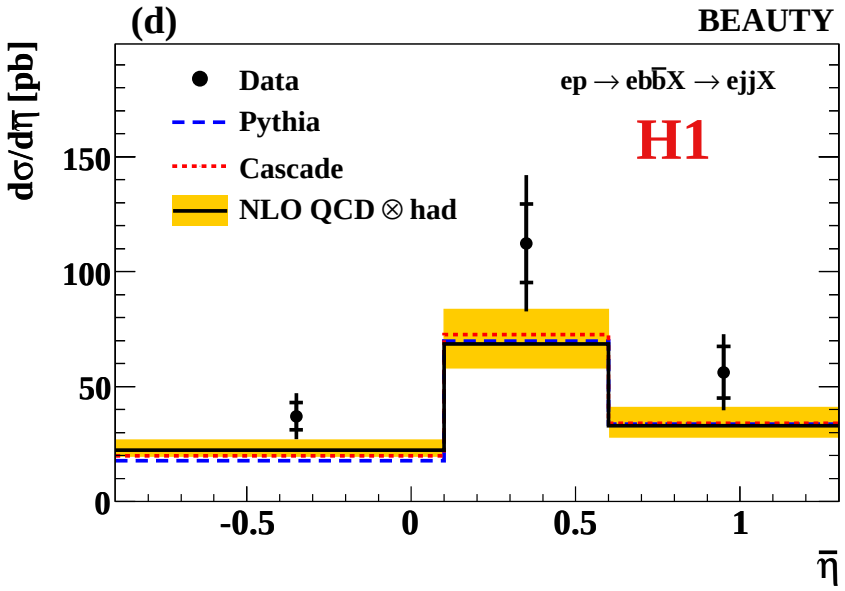
NLO calculation describes data reasonably well

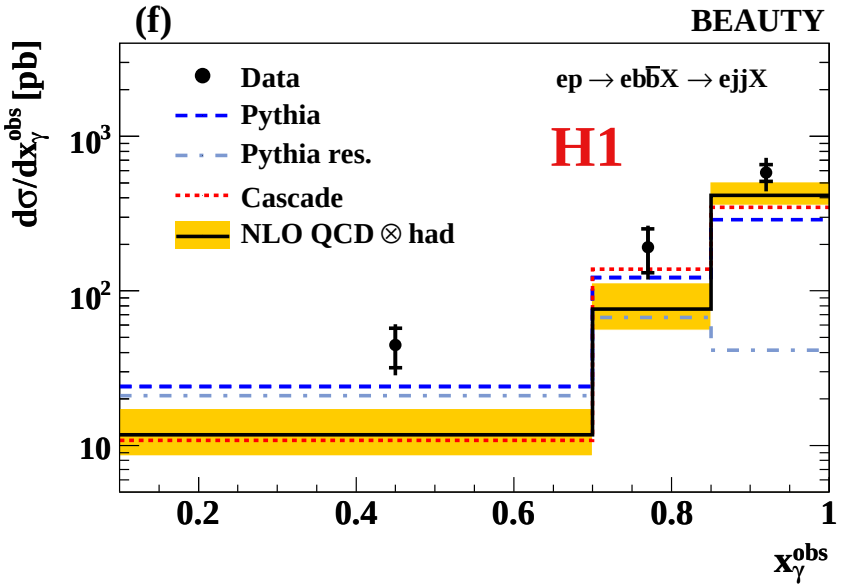
PYTHIA is too low

CASCADE is too low at small x_γ^{obs}

Beauty Cross Sections







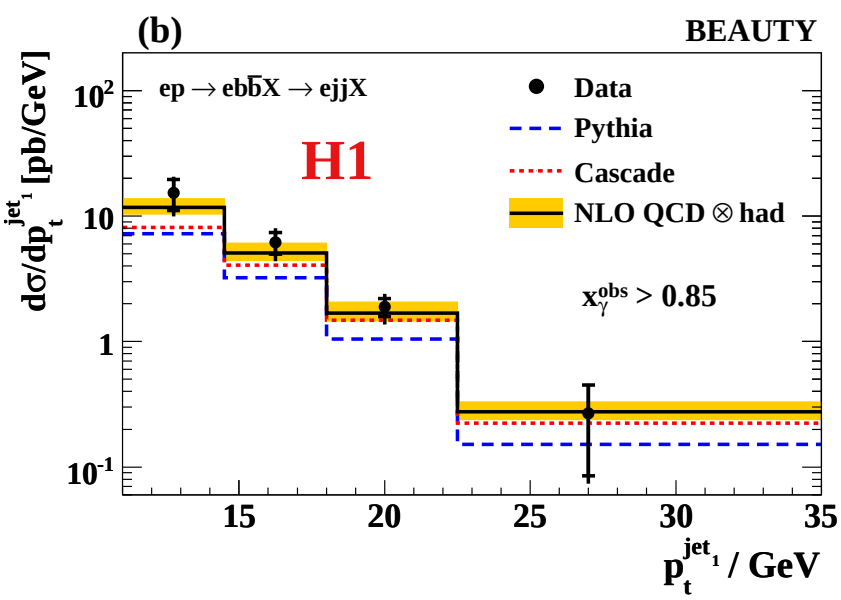
NLO calculation is somewhat too low, mainly at small x_γ^{obs} (resolved)

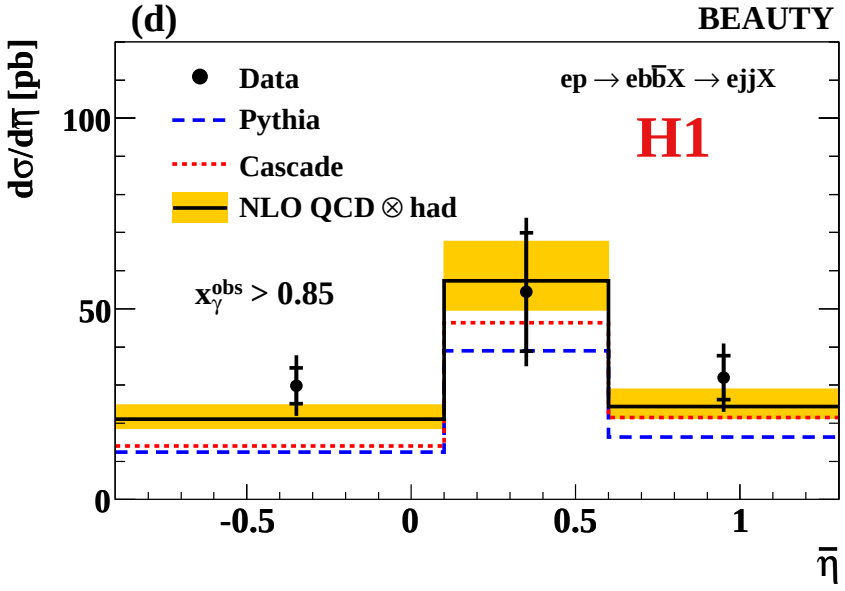
PYTHIA is too low

CASCADE is too low at small x_γ^{obs}

Direct Enriched Sample

use $x_\gamma^{\text{obs}} > 0.85$ to define a sample in which
direct photon processes are expected to dominate

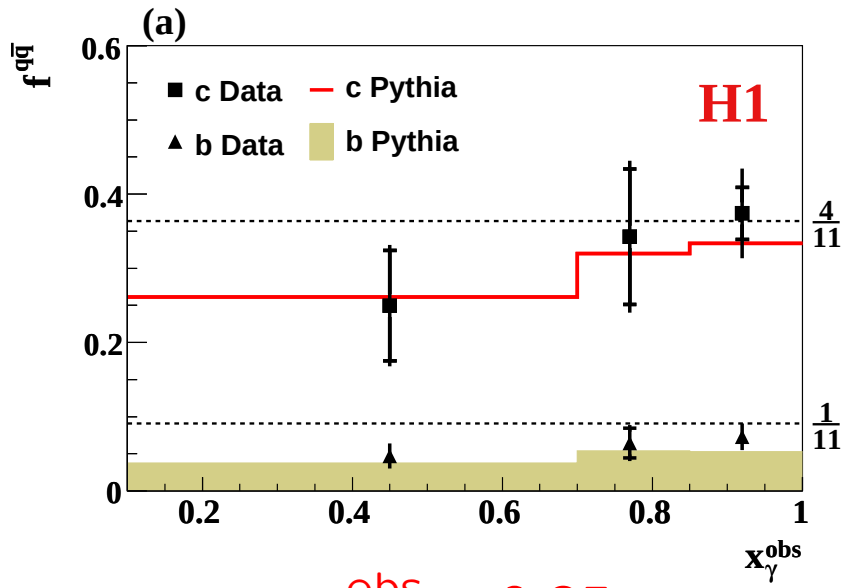


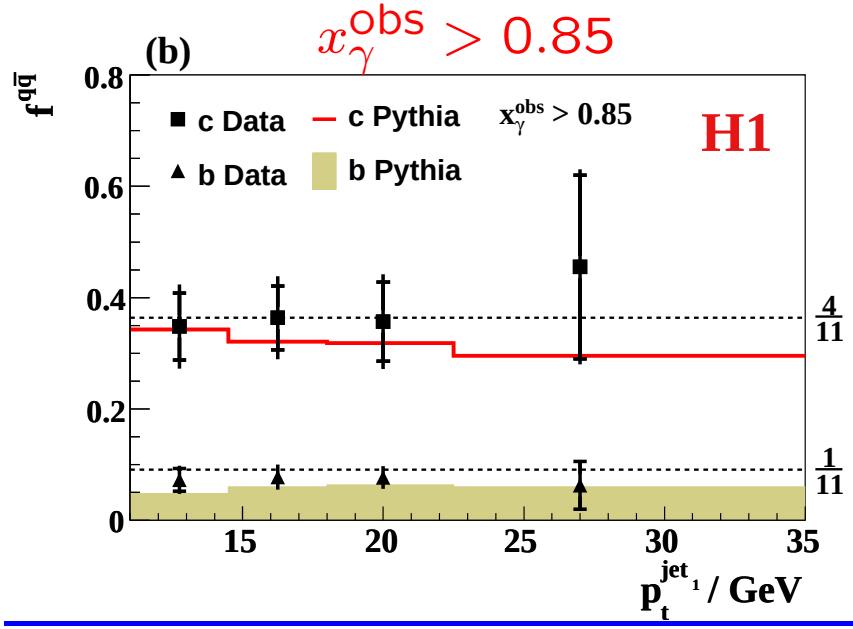


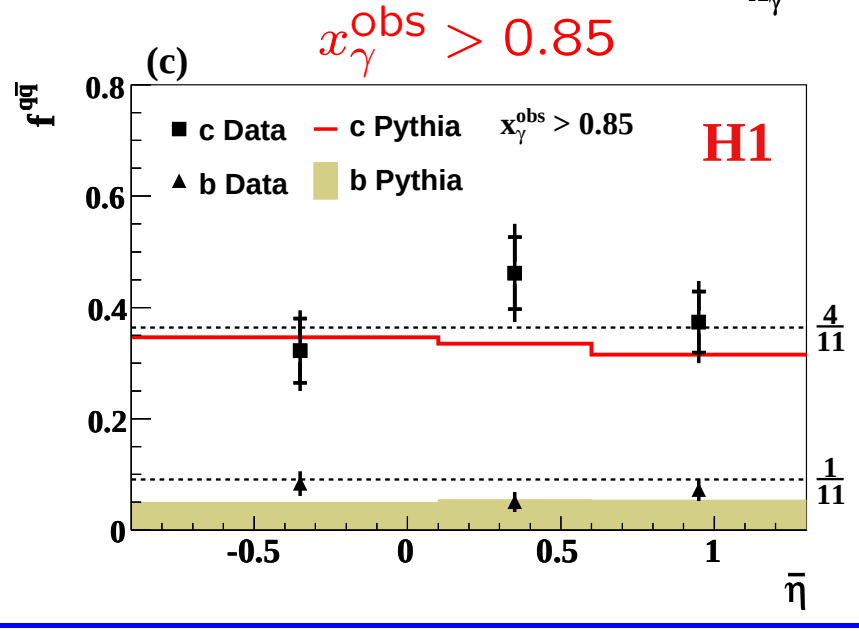
$\Rightarrow$ NLO calculation agrees significantly better
than for the whole x_γ^{obs} range

Heavy Quark Fractions

naive quark charge counting:
ratio 4:1 for charm:beauty
in direct photon gluon fusion
(massless quarks)





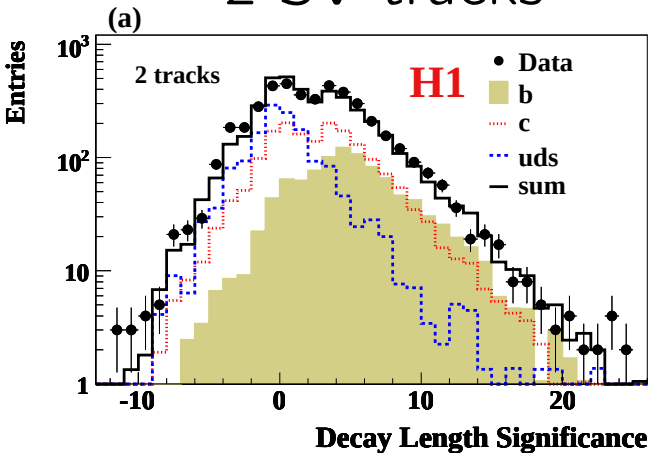


Secondary Vertex Fit

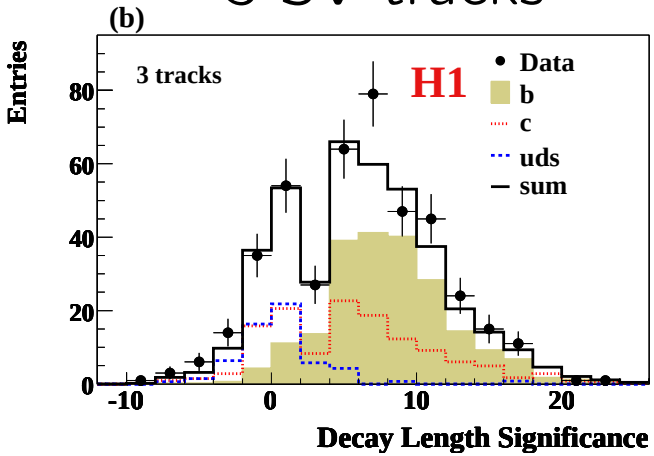
cross check results with different method

MC scaling factors from fit to subtracted impact parameter significance distributions

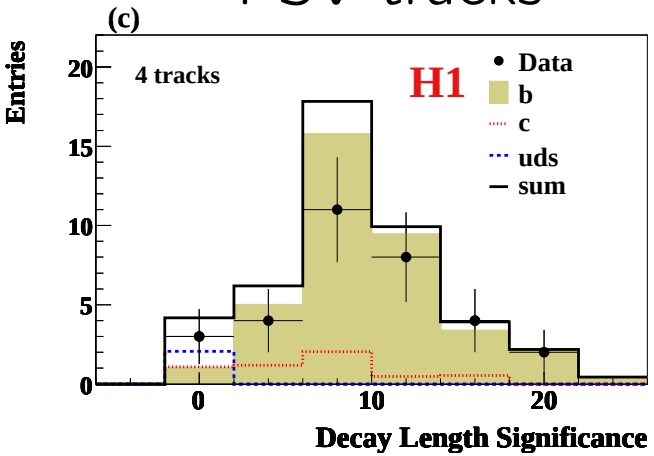
2 SV tracks



3 SV tracks



4 SV tracks

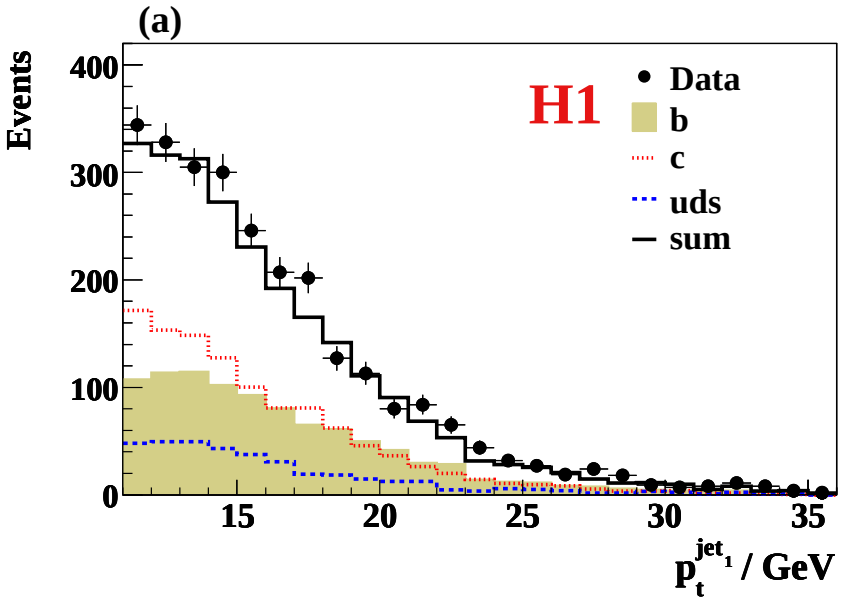


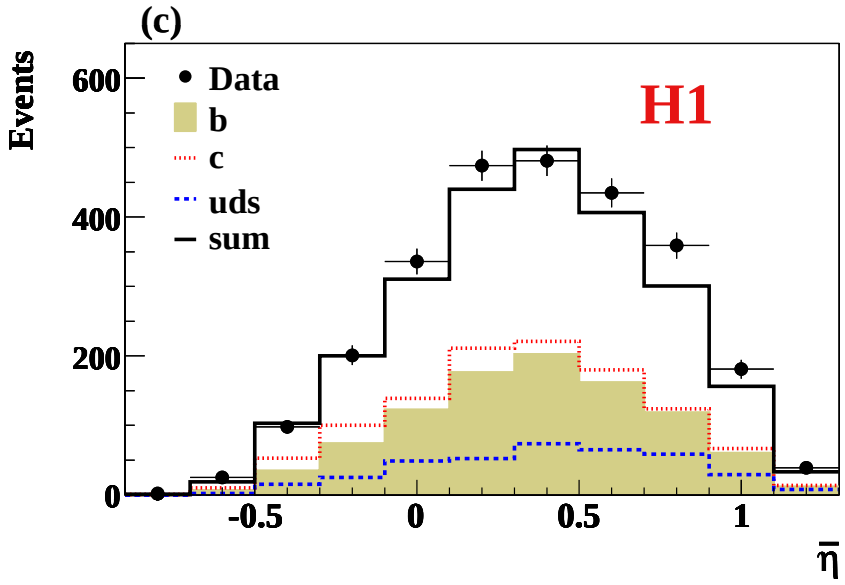
- good agreement of the two methods
- good separation power between light and heavy quarks

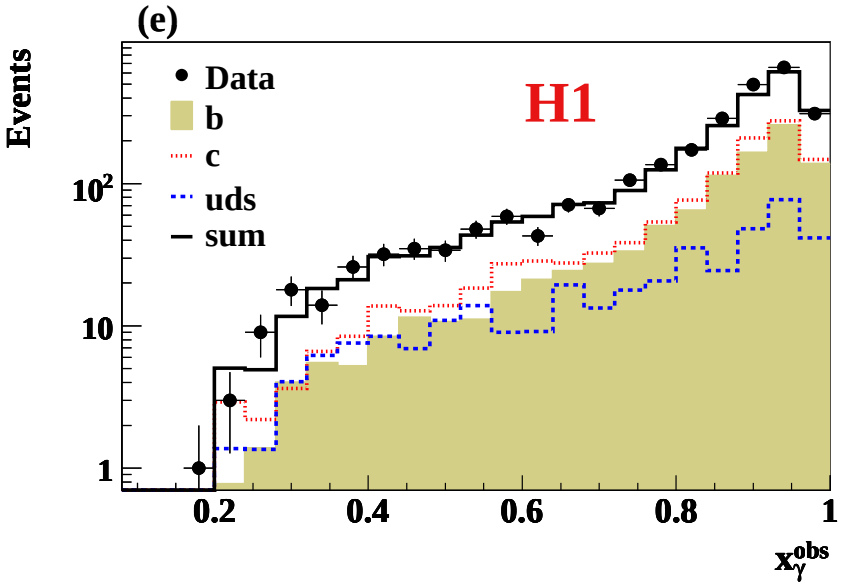
$\Rightarrow$ used to define high purity heavy quark sample:

≥ 2 secondary vertex tracks, Significance > 2

High Purity Heavy Quark Sample



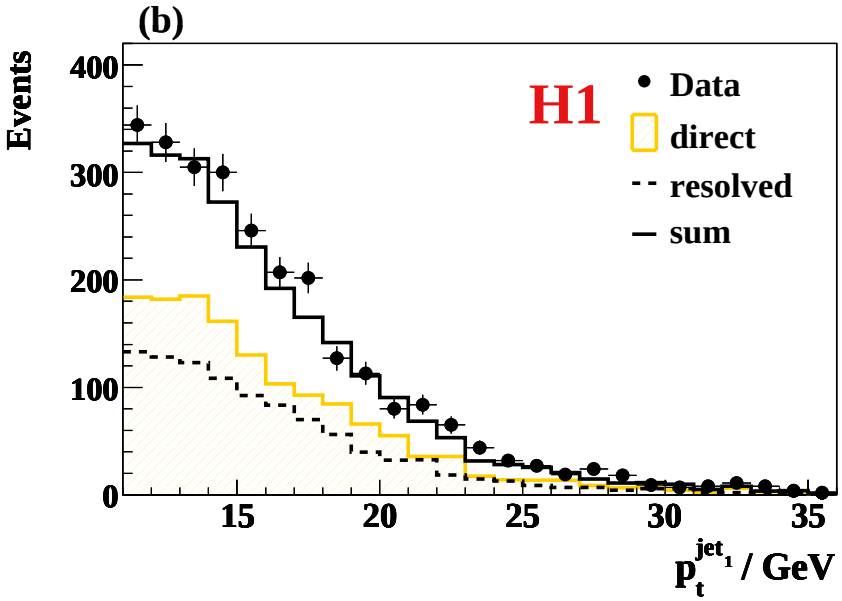


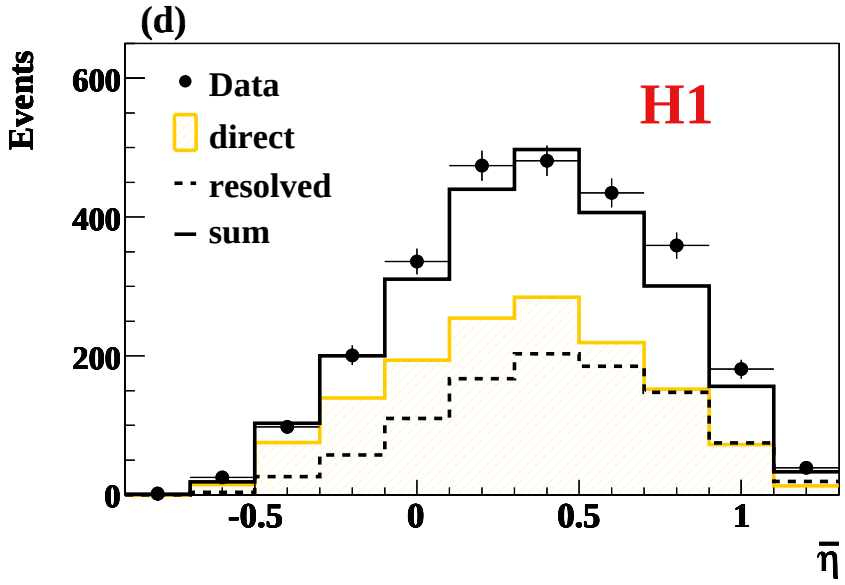


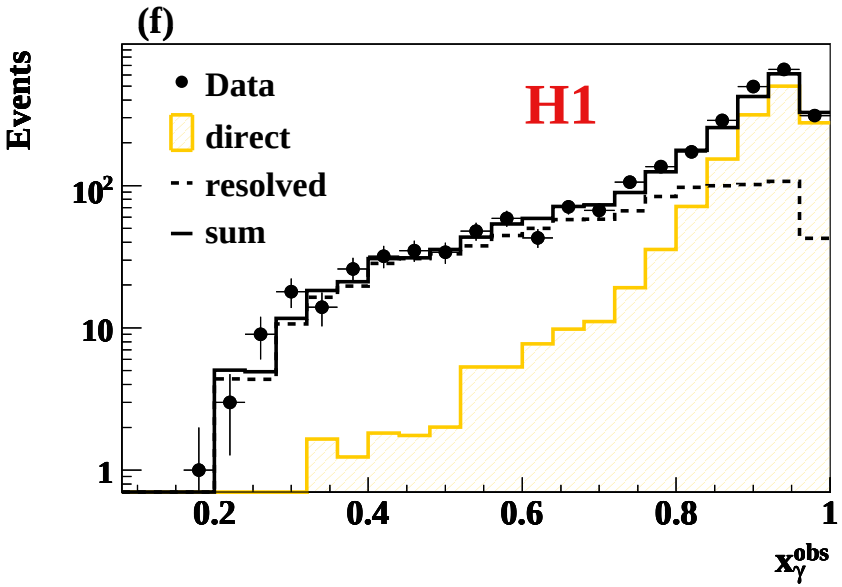
quark fractions described by PYTHIA (with normalisation from impact parameter significance method)

$\sim 85\%$ heavy flavours

High Purity Heavy Quark Sample







PYTHIA: $\sim 40\%$ resolved

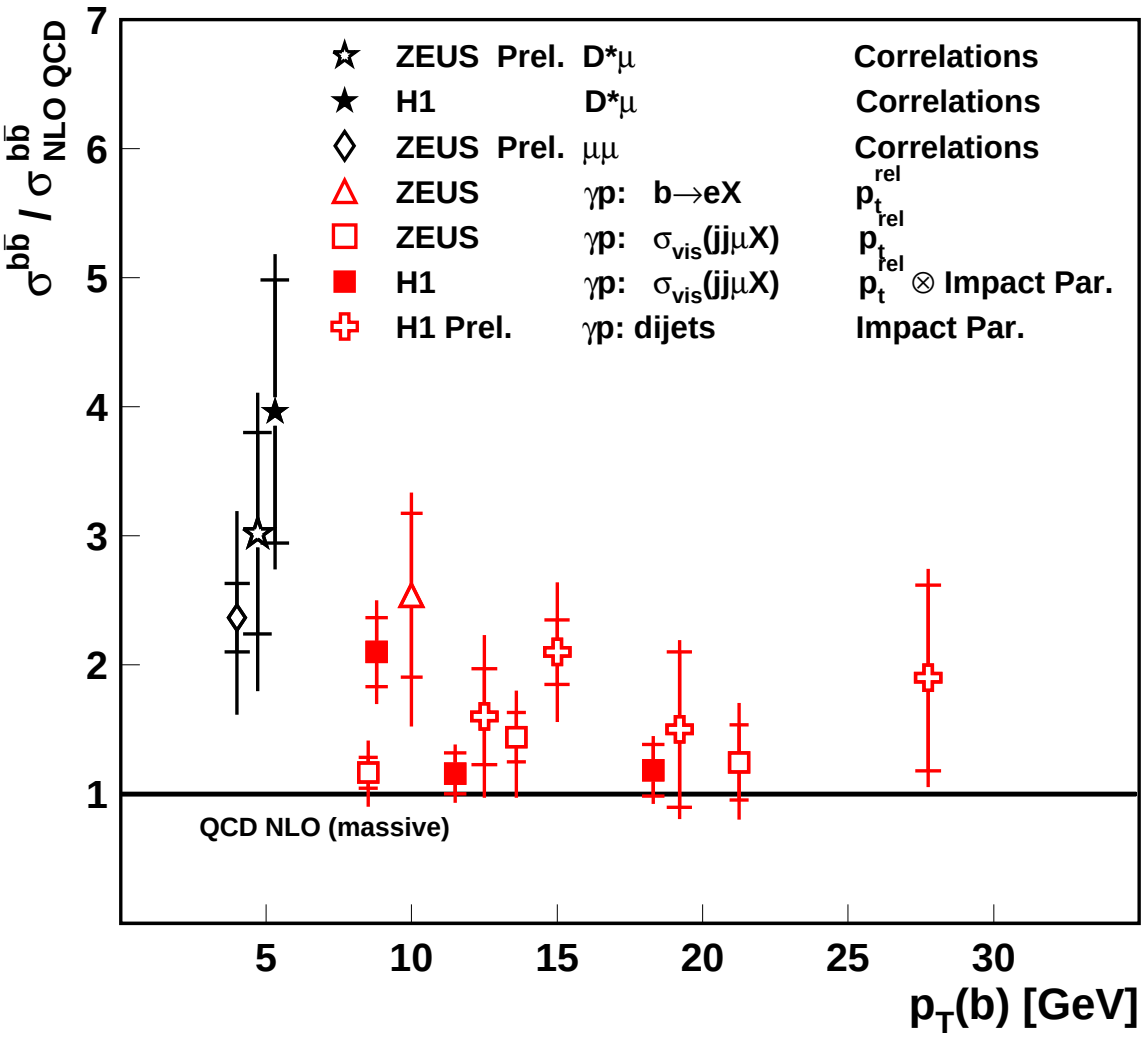
$x_\gamma^{\mathrm{obs}} < 0.85$: $\sim 80\%$ resolved

dominant contribution to resolved from heavy quark excitation processes

Conclusion

- inclusive measurement of photoproduction of charm and beauty
  - lifetime tag (impact parameter significance)
  - simultaneous measurement of charm and beauty
- NLO calculation for beauty production is somewhat lower than data, especially at small x_γ^{obs} ($\sim 2\sigma$)
- heavy quark fractions at large x_γ^{obs} compatible with naive quark charge counting (massless quarks)
- LO MC (PYTHIA) needs large resolved contribution, including excitation processes, to describe heavy flavour production

Backup


ZEUS Prel. D*μ Correlations
H1 D*μ Correlations
ZEUS Prel. μμ Correlations
ZEUS γp: b→eX p_t^{rel}
ZEUS γp: σ_{vis}(jjμX) p_t^{rel}
H1 γp: σ_{vis}(jjμX) p_t^{rel} ⊗ Impact Par.
H1 Prel. γp: dijets Impact Par.
QCD NLO (massive)
$\sigma^{b\bar{b}}$ / $\sigma^{b\bar{b}}_{NLO\ QCD}$
p_T(b) [GeV]