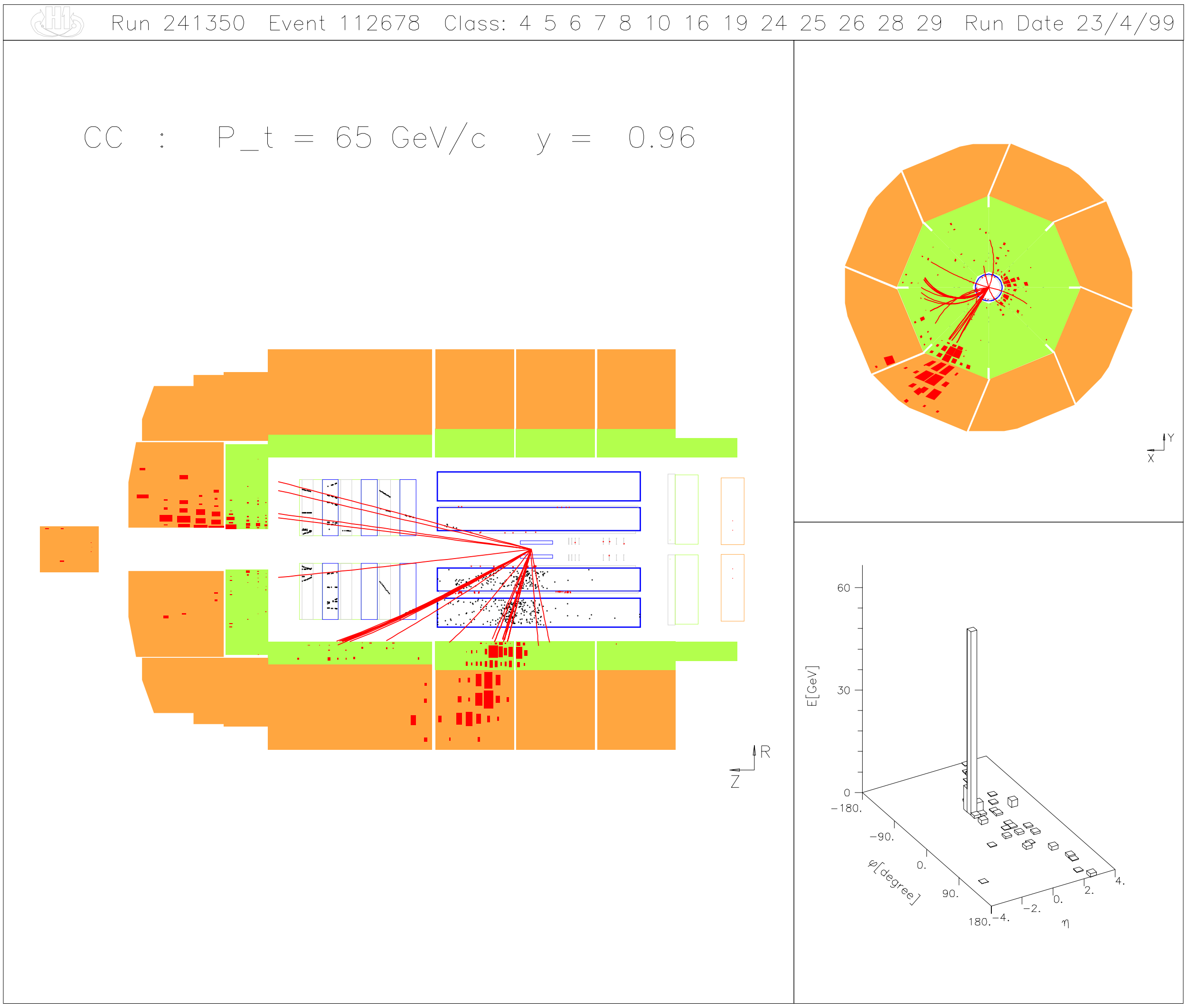
Charm Production in Charged Current Interactions at HERA

- Motivation
- Method
- Measurement of Charm in Neutral Current
- Measurement of Charm in Charged Current
- Results
- Conclusion

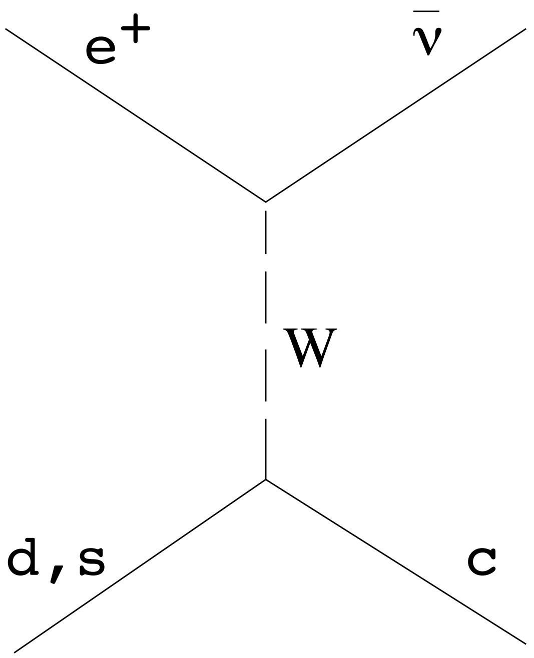
Event Display for CC

In deep inelastic scattering the electron couples to an exchanged boson which probes the structure of the proton.



Charged Current events have a large missing transverse momentum , assumed to be carried by an unseen neutrino.
Selection cuts for CC $p_{t,Miss} > 12\ GeV$

Measurement of $s(x,Q^2)$ through Charm in Charged Current



with charge conservation
$e^+ + d \Rightarrow c + \bar{\nu}$
$+1 \; -\frac{1}{3} \Rightarrow \frac{2}{3} + 0$

The charm in charged current reactions is sensitive to the $s(x)$ and $d(x)$ quark density of the proton.

At low x we are sensitive to sea quarks
$d \to c$ Cabbibo suppressed
$s \to c$ Cabbibo allowed

Q^2 = virtuality of exchanged boson
x = fractional momentum of proton carried by struck parton

$$\frac{d^2\sigma(e^+p \to cX)}{dx\; dQ^2} \sim (1-y)^2\; [d(x,Q^2)\; |V_{cd}|^2 + s(x,Q^2)\; |V_{cs}|^2]$$

Measure $\frac{d^2\sigma(e^+p\to cX)}{dxdQ^2}$ and assume $d(x,Q^2), |V_{cd}|^2, |V_{cs}|^2 \Rightarrow s(x,Q^2)$

Remark: b-quarks are strongly suppressed in CC ($|V_{ub}|^2$).

Inclusive Method

Knowledge:

	$c\tau$ [μm]	event rate
K, Λ, π	≥ 26000	10
D	300	1

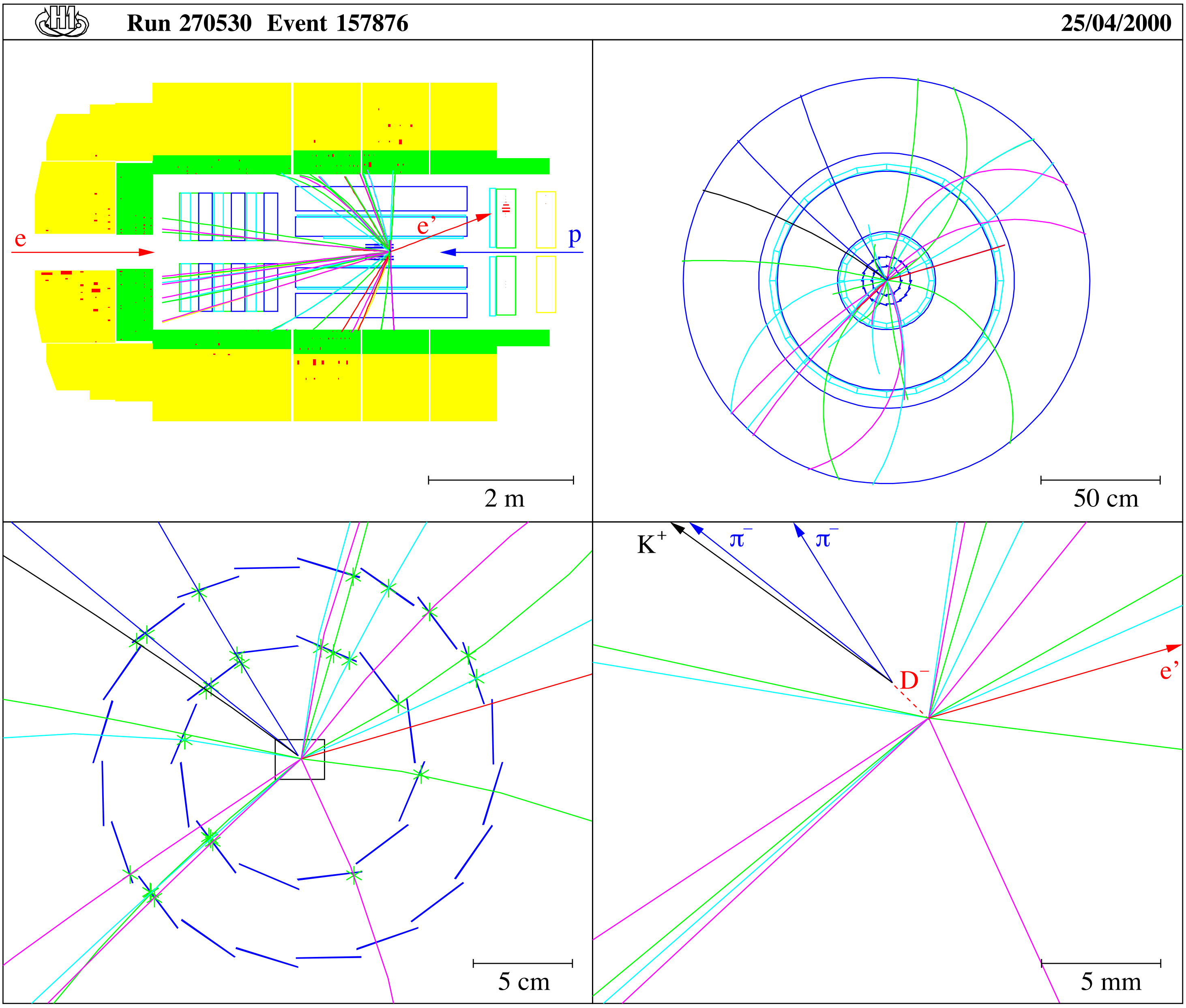
Transition and decay $\quad c \rightarrow D \rightarrow K, \pi, ...$

Strategy:

- To distinguish an event with a charm-quark from an event with uds-quark we use the finite life time of the charmed-hadron in jets.

  $\Rightarrow$ Search of secondary vertex .

To measure the decay length of the charmed-hadron $c\tau \sim 300\ \mu m$ we have to use Central Silicon Tracker (CST), the innermost part of the H1 tracking system, surrounded by the central jet, drift and proportional chambers.



- The charm in CC-sample has a low statistic (150 charm in CC events produced).

  ⇒ Try a inclusive method to extract a signal.

In the inclusive method we are not forced to fit all tracks coming from the charmed-hadron to a common vertex, two (three, one) of them can already determine a secondary vertex!

How to measure a Secondary Vertex?

Method:

- For each event take two 'well' measured tracks in a jet and fit them to a secondary vertex. The other tracks are used to improve the primary run vertex.
- If there are more then two good tracks in this jet, then use all possible combinations to get several hypotheses per event.
- With a cut based selection we enrich charm events.

Definition of a secondary vertex:

- By reconstructing an isolated decay vertex we indicates charmed hadron. The separation from primary to secondary vertex can be described with the decay length significance:

$$S_l = \frac{l}{\sigma_l}$$

  where l is the transverse distance between the primary and secondary vertex (this means the transverse decay length of the charm meson).

  The error σ_l is composed of the primary and the secondary vertex resolution.

- Even with one track we can quantify if the track is coming from a primary or a secondary vertex. This is done with the impact parameter significance:

$$S_d = \frac{d}{\sigma_d}$$

The impact parameter d denotes the minimal distance of the non-vertex-fitted track to the event's primary vertex. Its sign is determined by the jet direction.

Test the algorithm in NC

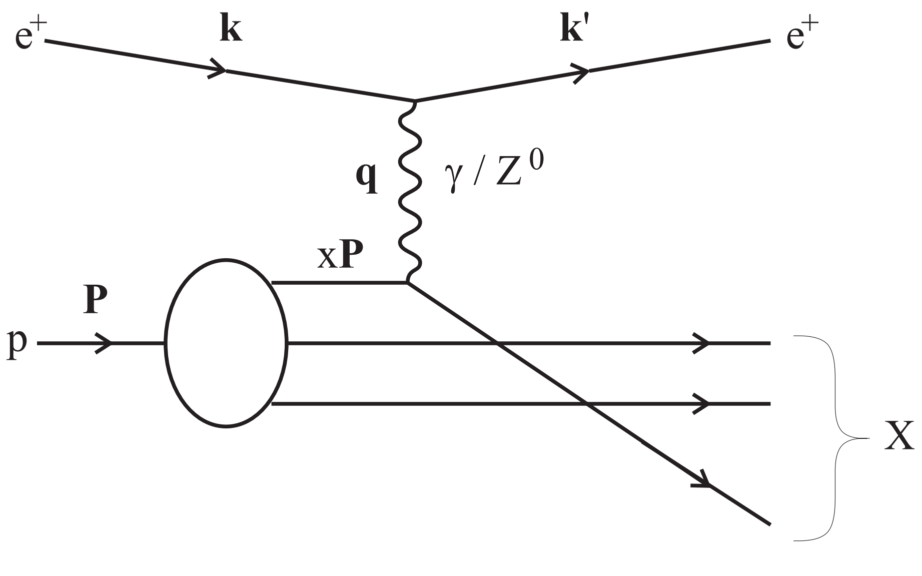
In the NC-sample we have more statistics. So we test the algorithm and make a measurement in the NC-sample with same kinematics like CC.

Because of the high pt_{miss} in the CC we take NC with a high $Q^2 > 150\ GeV^2$. ($Q^2 = \frac{pt^2_{miss}}{1-y}$)

David Meer tests the algorithm in a other kinematic region.

The inclusive selection can be split into three tasks:

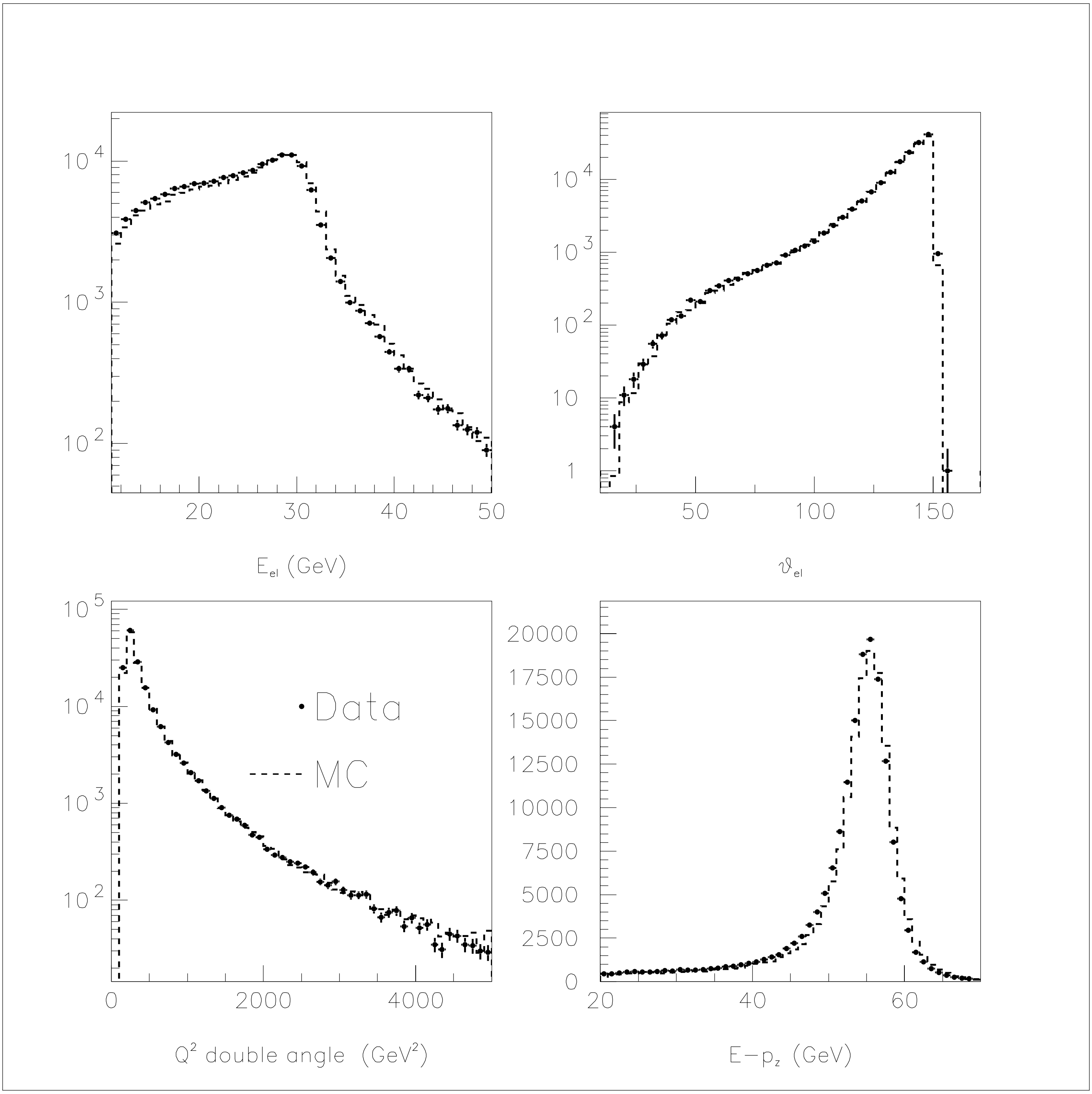
1. NC-selection ($e^+p \rightarrow e^+X$)
2. Good track criteria
3. Charm selection cuts ($e^+p \rightarrow ce^+X$)



NC-kinematics

MC (Django NC) all flavors, absolute normalization

NC-sample $\approx$ 170000 events ($L \approx 65\ pb^{-1}$)

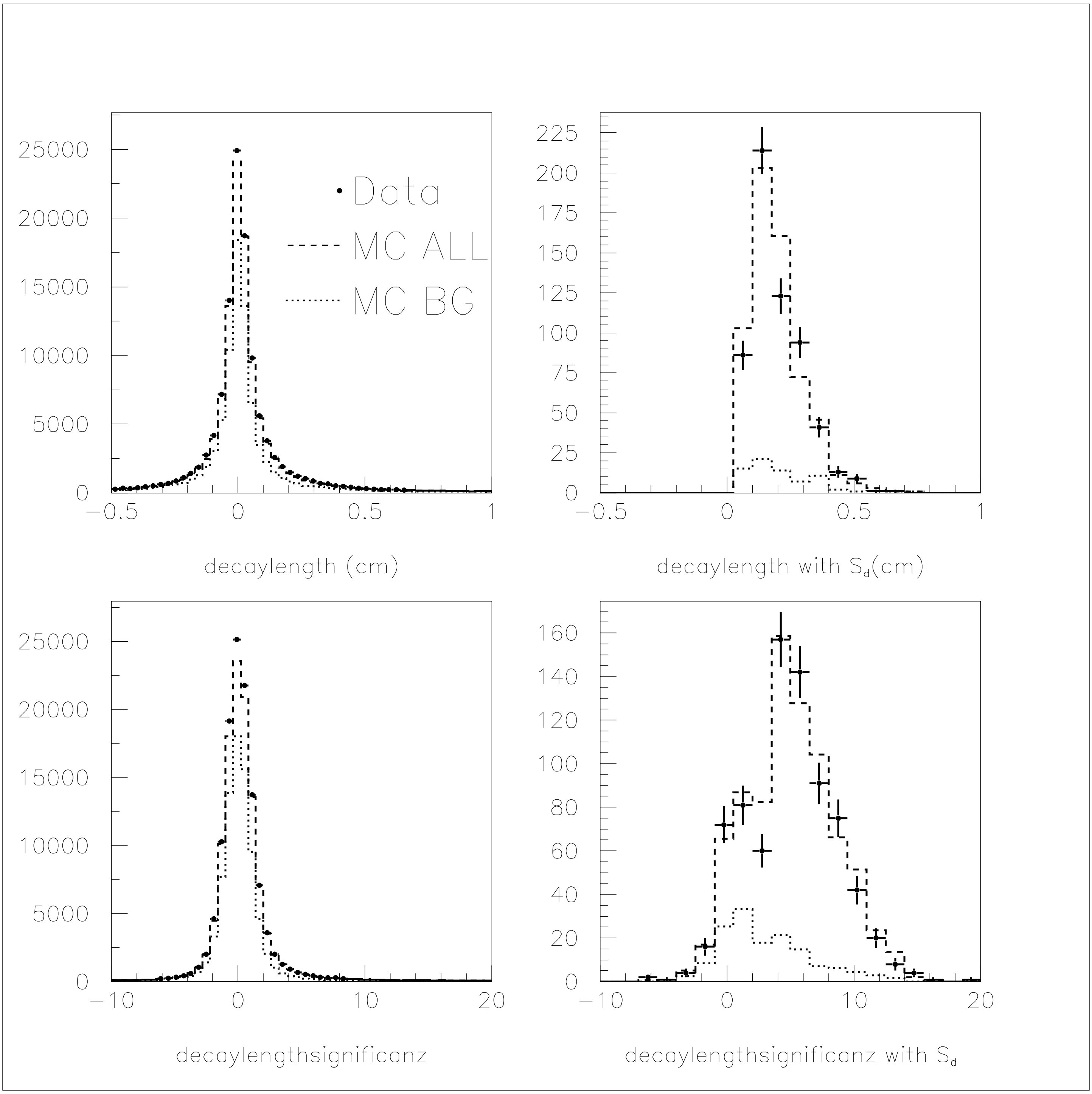


MC describes data pretty well

Charm in NC with two tracks-fit (2du)

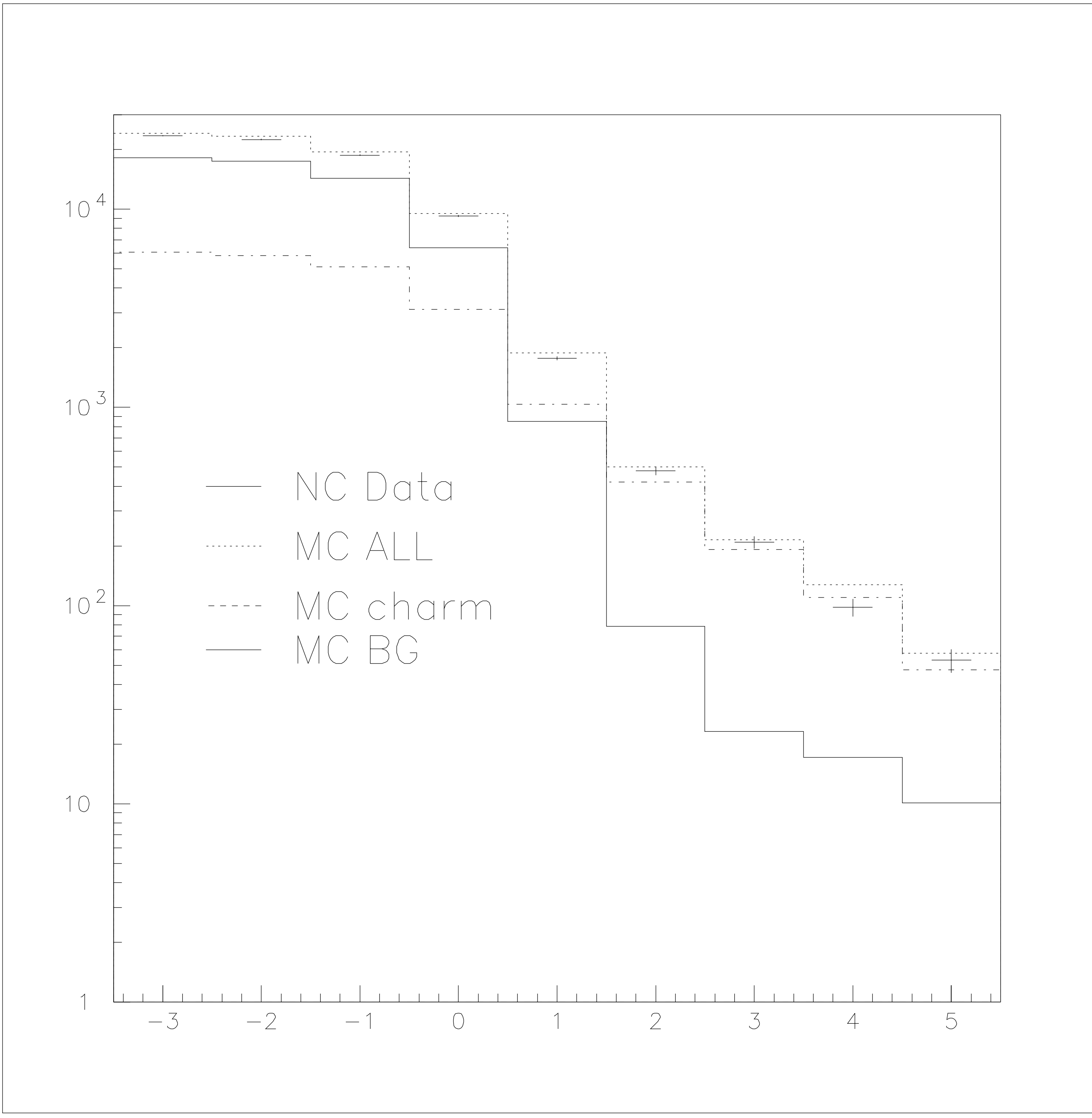
MC (Django NC) all flavors, absolute normalization

BG = events without charm



good agreement between data and MC and clean charm sample

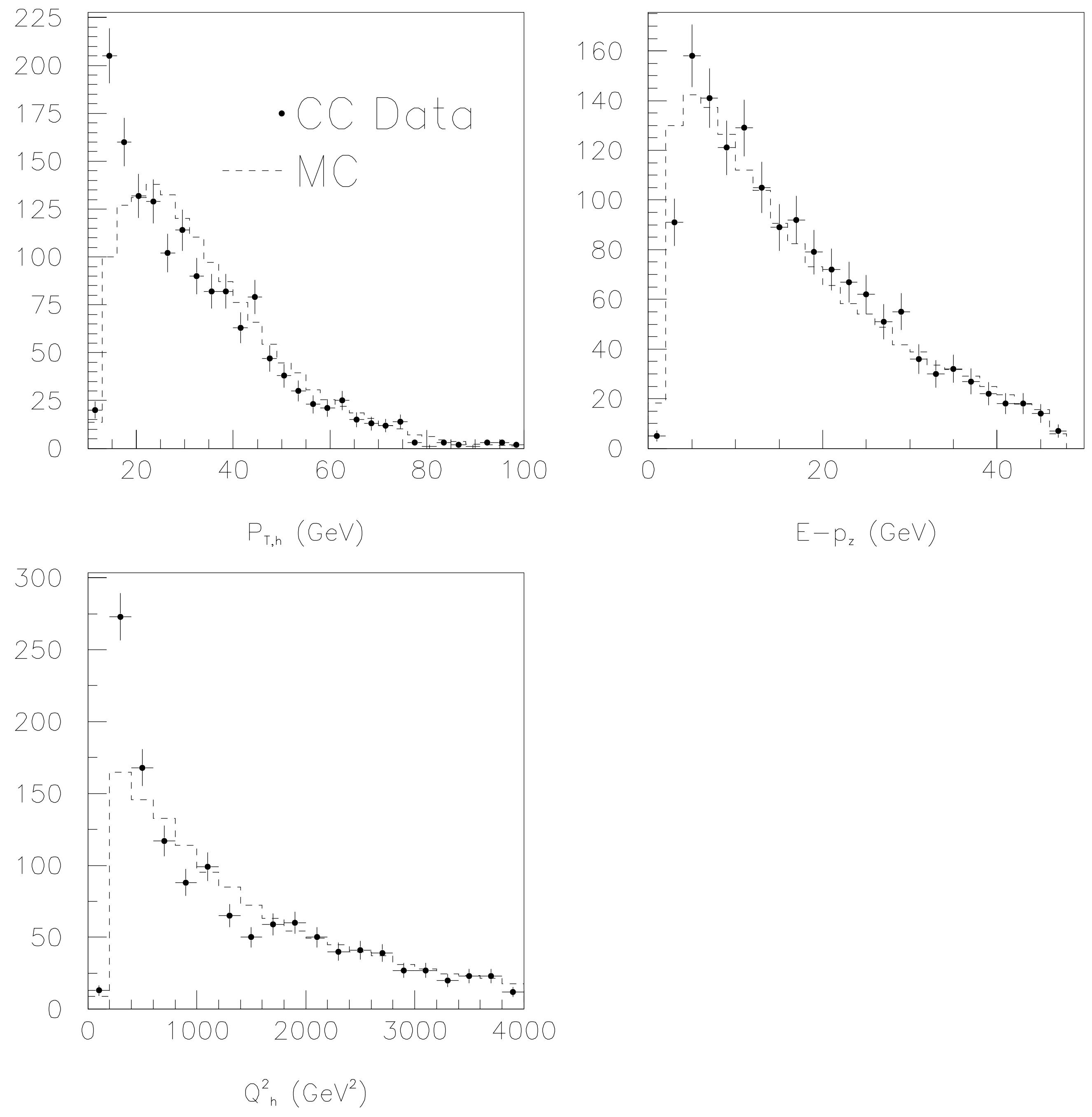
Enrichment of charm in NC as a function of S_l and S_d



CC-kinematics

MC (Django CC) all flavors, absolute normalization

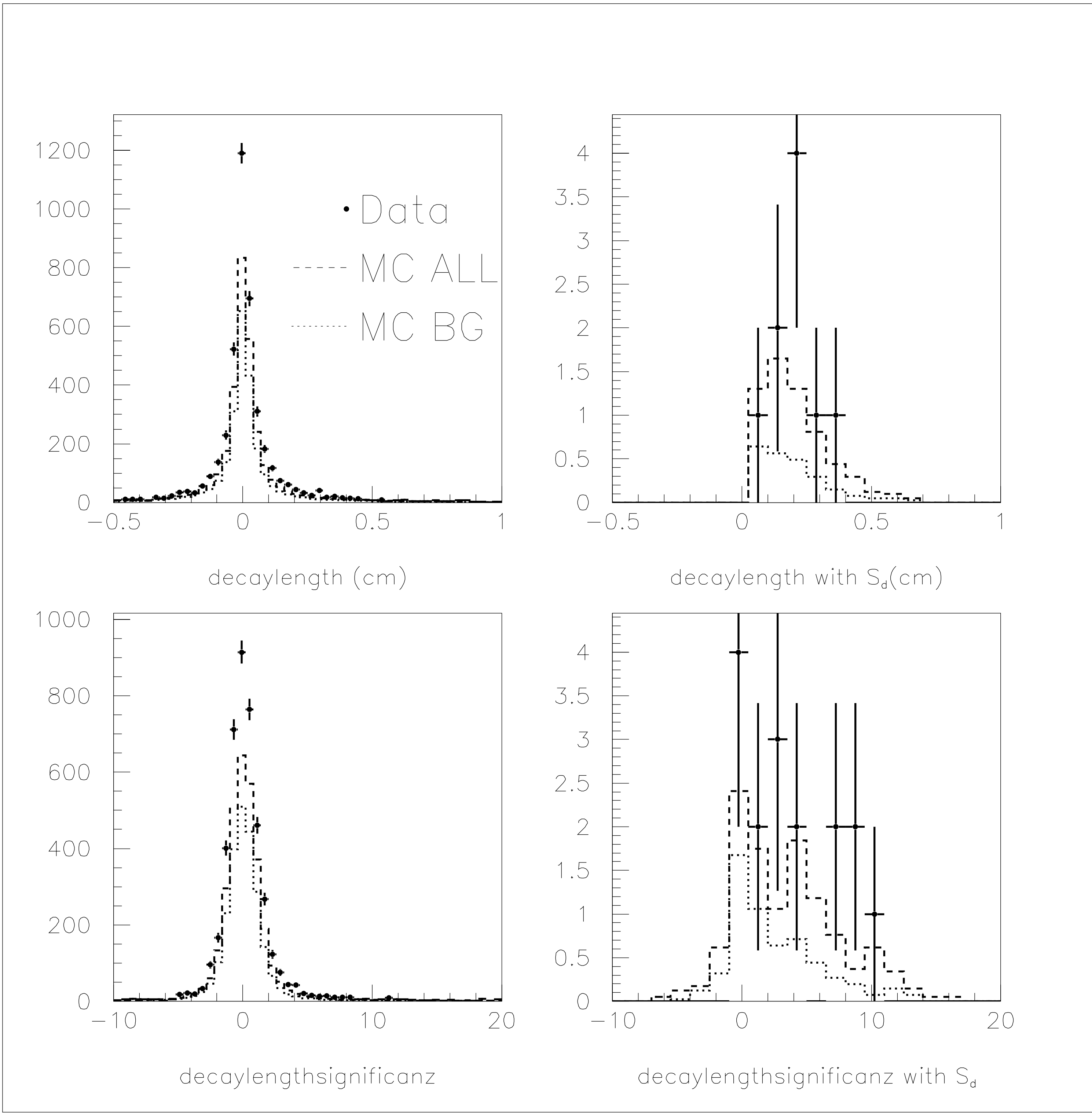
CC-sample $\approx$ 1500 events ($L \approx 65\ pb^{-1}$)



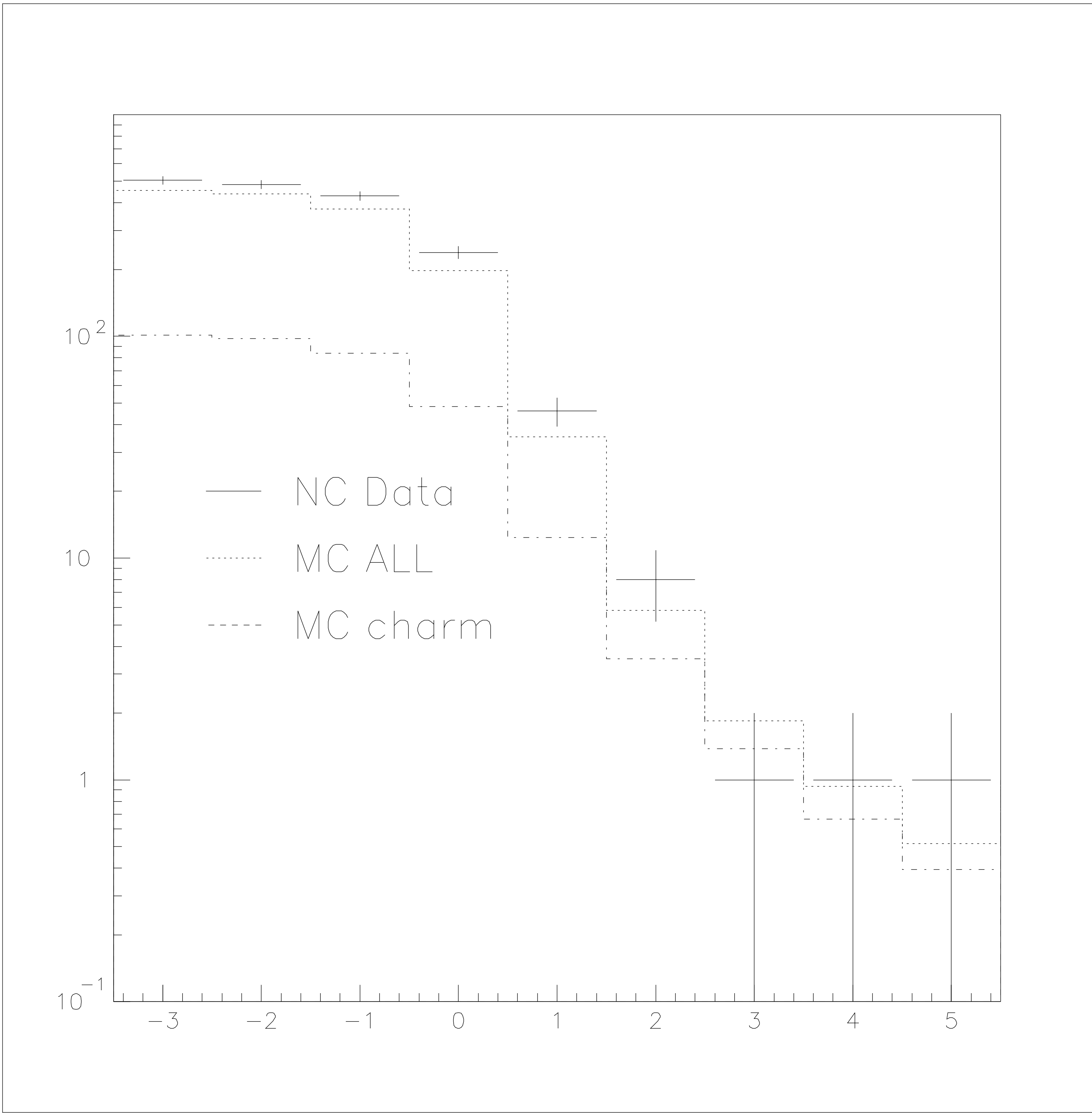
Charm in CC with two tracks-fit (2du)

MC (Django CC) all flavors, absolute normalization

BG = events without charm



Enrichment of charm in CC as a function of S_l and S_d



Results: charm in NC/CC

After NC respectively CC selection, track criteria and charm selection cuts:

1 track	2 track	3 track
$4 < \frac{d}{\sigma_d} < 20$ $\sigma_d < 0.008\ cm$ $d < 0.05\ cm$	$2.75 < \frac{l}{\sigma_l} < 20$ $2 < \frac{d_{1,2}}{\sigma_{d_{1,2}}} < 10$ $\sigma_l < 0.05\ cm$	$2 < \frac{l}{\sigma_l} < 20$ $1 < \frac{d_{1,2,3}}{\sigma_{d_{1,2,3}}} < 10$ $\sigma_l < 0.05\ cm$ fit probability ≥ 0.1

NC	MC CHARM/BG	MC total	DATA
sample		171000	170000
1 Track	661/490	1151	1160
2 Track	404/73	477	469
3 Track	230/57	287	264

CC	MC CHARM/BG	MC total	DATA
sample		1530	1521
1 Track	7.7/9.5	17.2	19
2 Track	3.5/2.1	5.6	7
3 Track	2.1/2.5	4.6	5

- agreement between DATA and MC
- low statistics in CC but possible to extract a signal

Conclusion

- Analysis Idea:
  - use finite lifetime of c-hadron to suppress background from uds
  - need inclusive method to extract signal in CC
- Algorithms tested in NC (charm/BG $\approx$ 400/70) and good agreement between MC and data.

  $\Rightarrow$ Measured NC-charm production at high Q^2

  $\Rightarrow$ Method applicable to tag charm in CC.
- Possible to measure the total charm in CC cross section at H1.