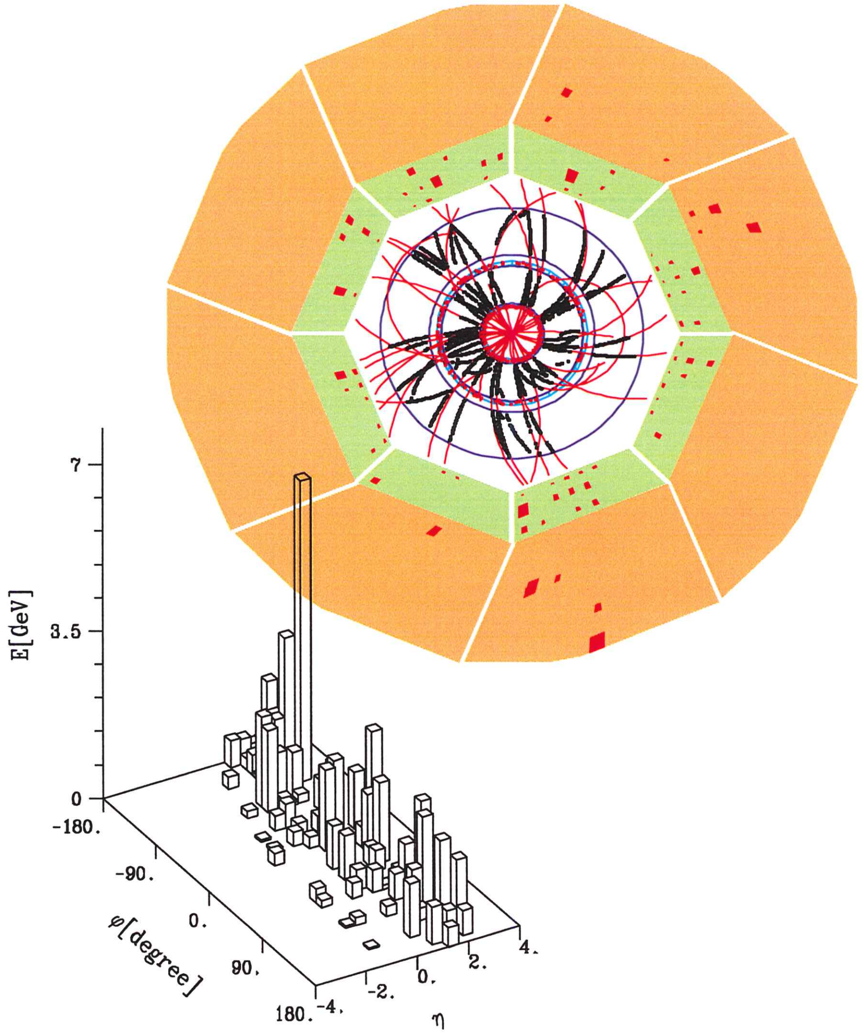
Search for Instantons



Birger Koblitz
for
the H1-Collaboration

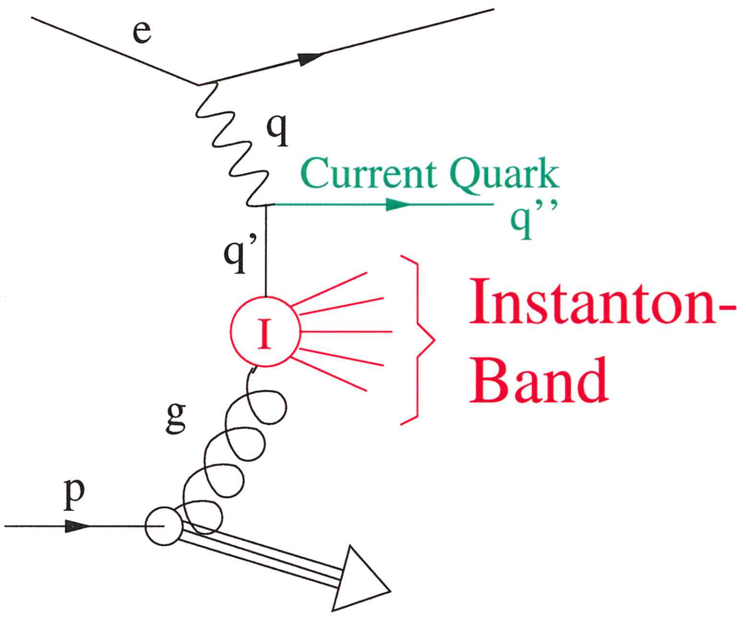
Overview:

- Reminder: Instantons in DIS
- Experimental Signature
- First Results at Low Q^2
- Outlook at High Q^2

Ringberg Workshop, June 19th, 2001

QCD Instantons in DIS

Dominant process in DIS is quark-gluon-fusion:



Variables of I-subprocess:

$Q'^2 = -q'^2$

$x' = Q'^2/(2g \cdot q')$

Theory and phenomenology worked out by
F. Schrempp & A. Ringwald:

- Most recent cross section prediction for

$$0.1 < y < 0.9, \quad x > 10^{-3}, \quad Q^2 \approx Q'^2 > 113\,\mathrm{GeV}^2$$

$$\sigma^{(I)}_{\mathrm{HERA}} = 29.2^{+9.9}_{-8.1}\,\mathrm{pb}$$

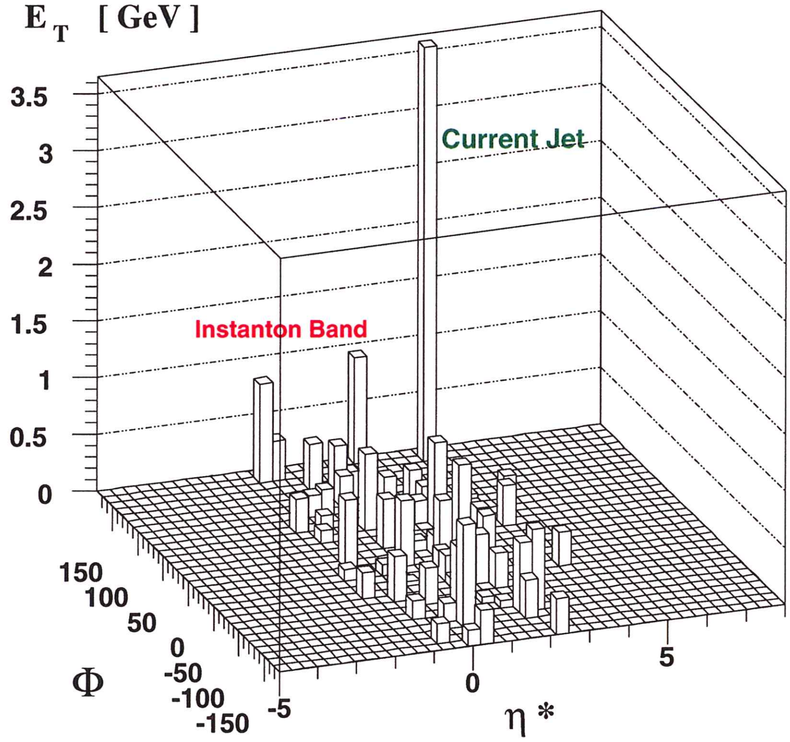
  $\Rightarrow$ sizable number of events on tape,
  but high ($O(1000)$) background

  $\Rightarrow$ Experimental analysis behind recent development

- QCDINS Monte-Carlo generator provides full topology

Properties of I-induced Events

E_T-map of a 'nice' QCDINS generated event in hadronic CMS ($\vec{q}+\vec{p}=0$):



Characteristics:

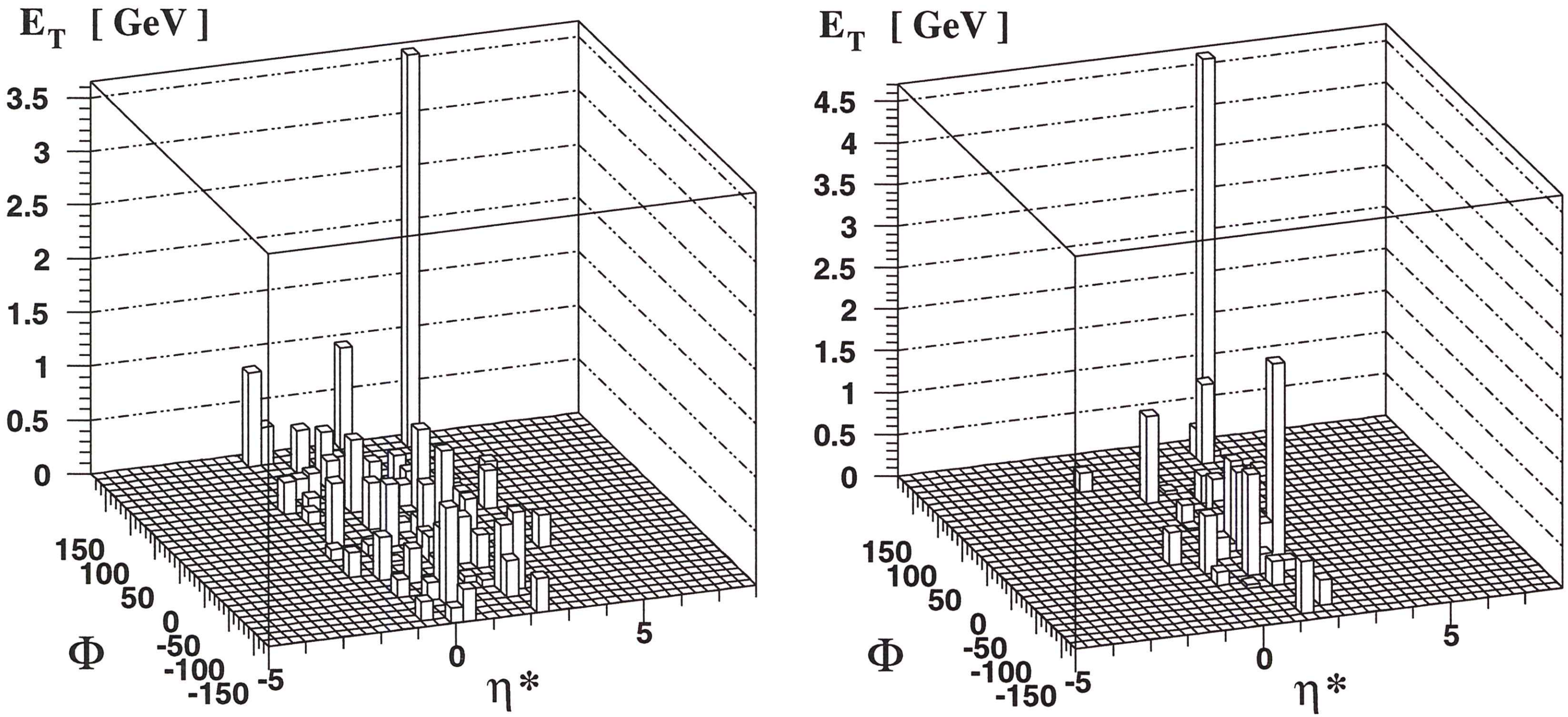
- Hard jet ($\rightarrow Q'^2_{\text{rec}}$) (✓)
- Densely populated band in η, with high E_T, isotropic in its rest frame (→ Shape-variables) (✓)
- Enhanced strangeness production ($\rightarrow \#K^{\pm}, \#K^0$)
- Chirality violation (→ Λ-polarisation)

⇒ Search is difficult: high background reduction required!
Currently study of data only for $Q^2 < 100\,\text{GeV}^2$!

Typical Events?

$x_{Bj} = 0.0012$ $Q^2 = 66\ GeV^2$
p_T (Jet) = 3.6 GeV

$x_{Bj} = 0.0037$ $Q^2 = 96\ GeV^2$
p_T (Jet) = 6.1 GeV

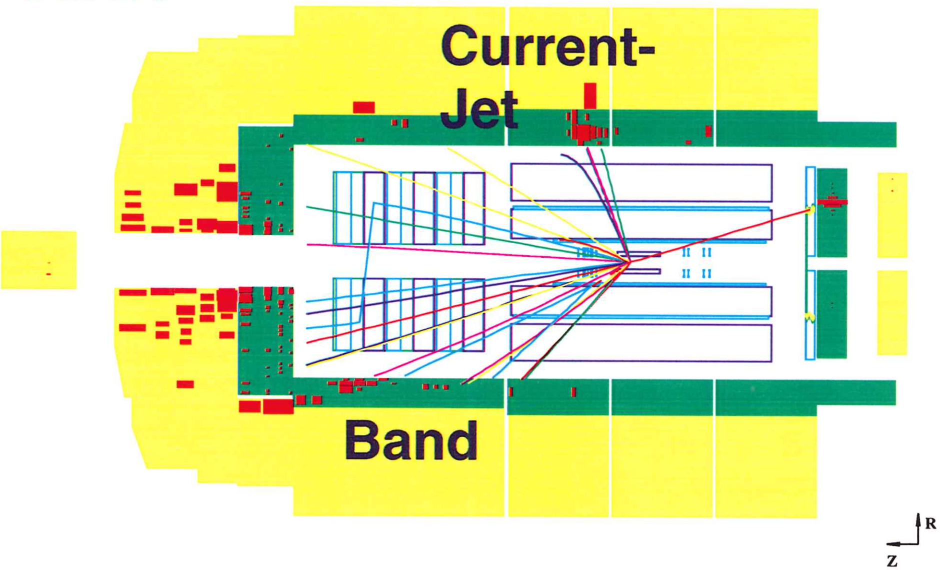


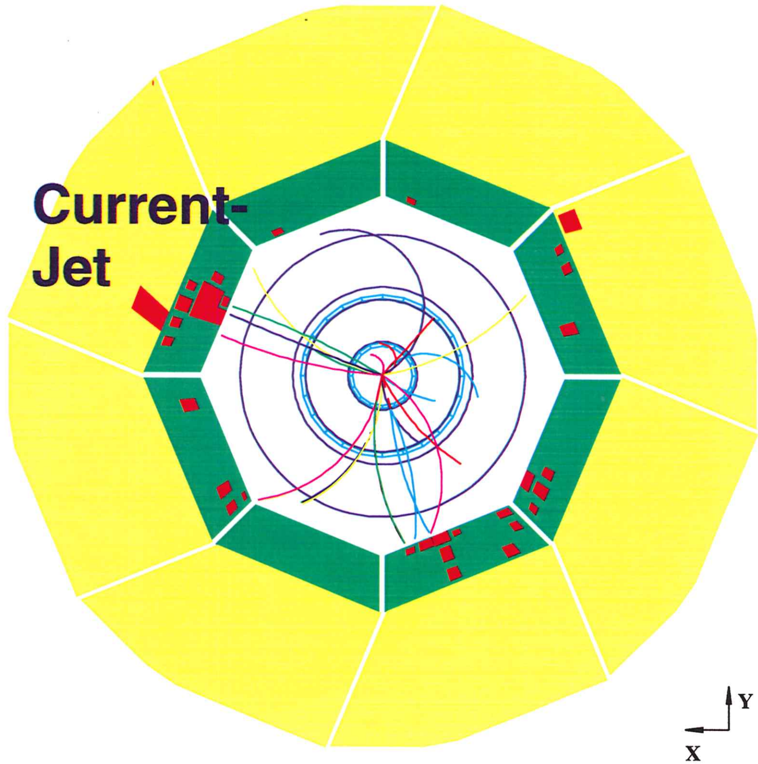
a) b)

Events topology varies widely with kinematic configuration (x', Q')

I-Induced events in the H1 detector

Monte Carlo!





Kinematics:

$Q^2 = 54$ GeV ^{2}

$x = 2.97 \times 10^{-3}$

I-Subprocess:

$Q'^2 = 136.5$ GeV ^{2}

$x' = 0.48$

Reconstructed quantities: Sphericity $S = 0.51$, $p_{\mathrm{T,Jet}} = 8.5\,\mathrm{GeV}$

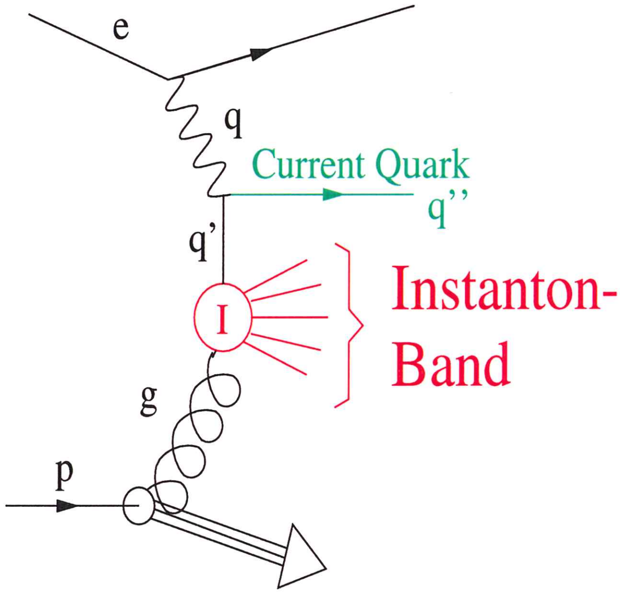
Reconstruction of I-variables

Several procedures studied, for data analysis we use:

1. Reconstruct the band using

$$\bar{\eta} = (1/E_{T,tot}) \sum_{\text{clusters}} E_T \cdot \eta$$

   Band defined by $\bar{\eta} \pm 1.1$



2. Find the current jet:
   Highest E_T-jet using cone algorithm with $R = 0.5$, right in $\approx 70\%$ of cases $\Rightarrow Q'^2_{rec}$

3. Remove jet from band

4. Boost to rest system of the band

5. Calculate shape variables, and charged particle multiplicities of the band

Observables

1. Virtuality of quark entering I-subprocess: $Q'^2_{\rm rec}$
2. Number of charged particles in band: $n_{\rm B}$
3. Sphericity of the band $\rm Sph_B$

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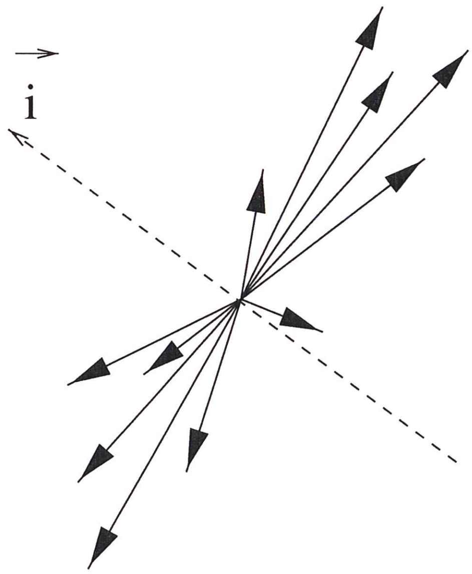
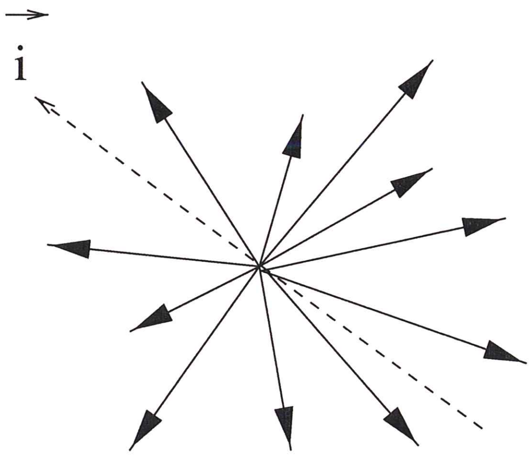
4. $E_{\rm t,Jet}$ of current jet
5. Total transverse energy $E_{\rm t,B}$
6. Isotropy of band $\Delta_{\rm B} = (E_{\rm in,B} - E_{\rm out,B})/E_{\rm in,B}$

$$E_{\rm out} = \min \sum_{n\ \rm Hadr.} \left| \vec{p}_n \cdot \vec{i} \right|$$

$$E_{\rm in} = \max \sum_{n\ \rm Hadr.} \left| \vec{p}_n \cdot \vec{i} \right|$$



$\Delta_{\rm B} \approx 1$



$\Delta_{\rm B} \approx 0$

DIS Event Selection

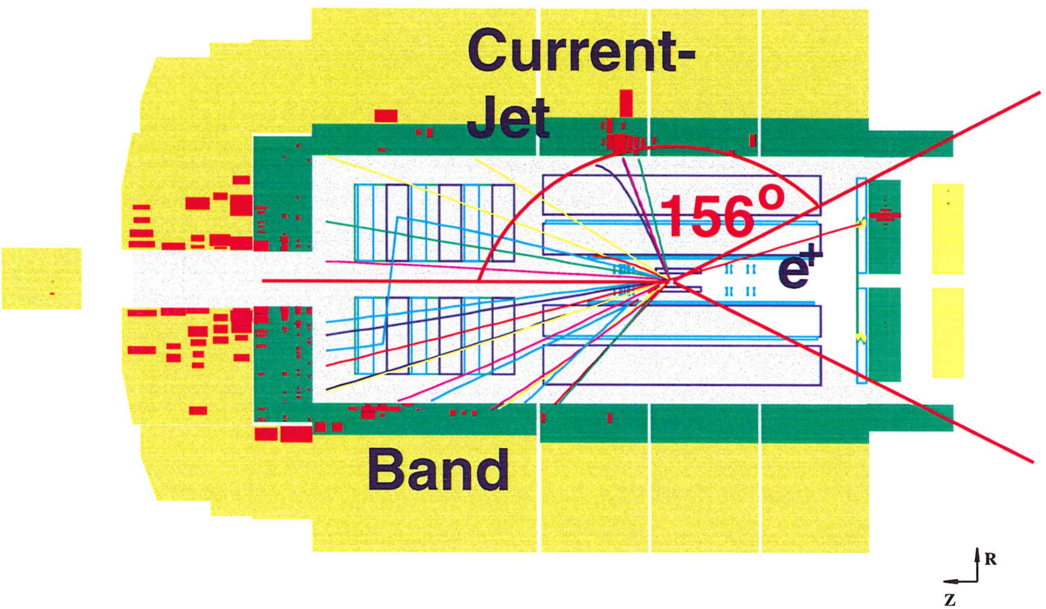
Using data taken in 97

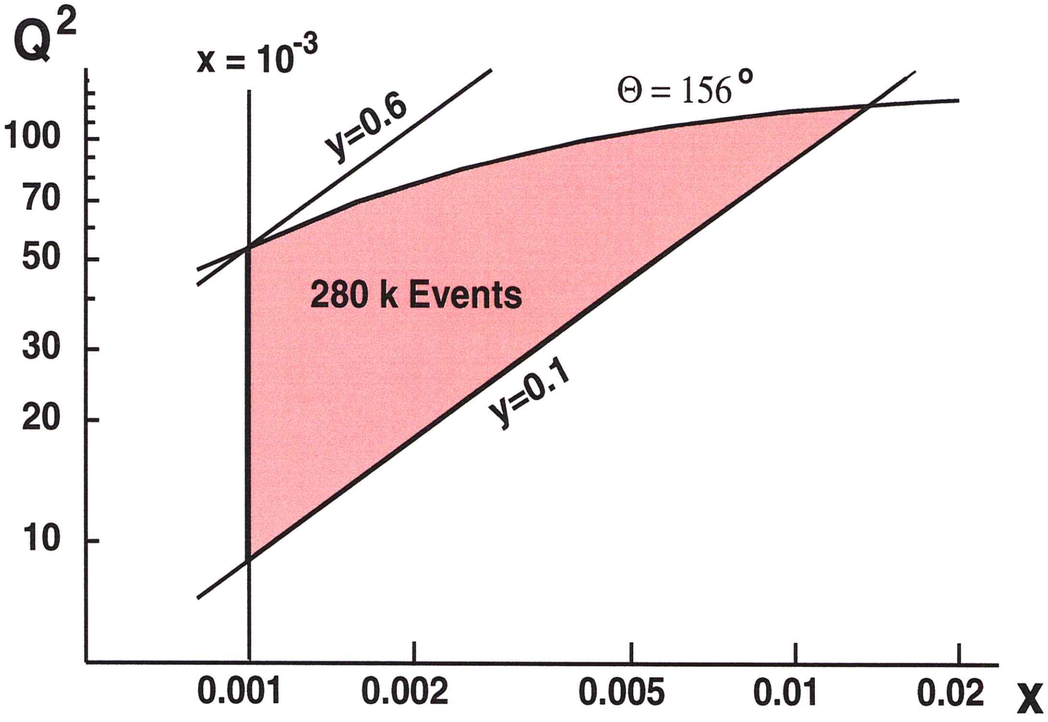
$\mathcal{L} = 15.78\,\mathrm{bp}^{-1}$

Phase space:

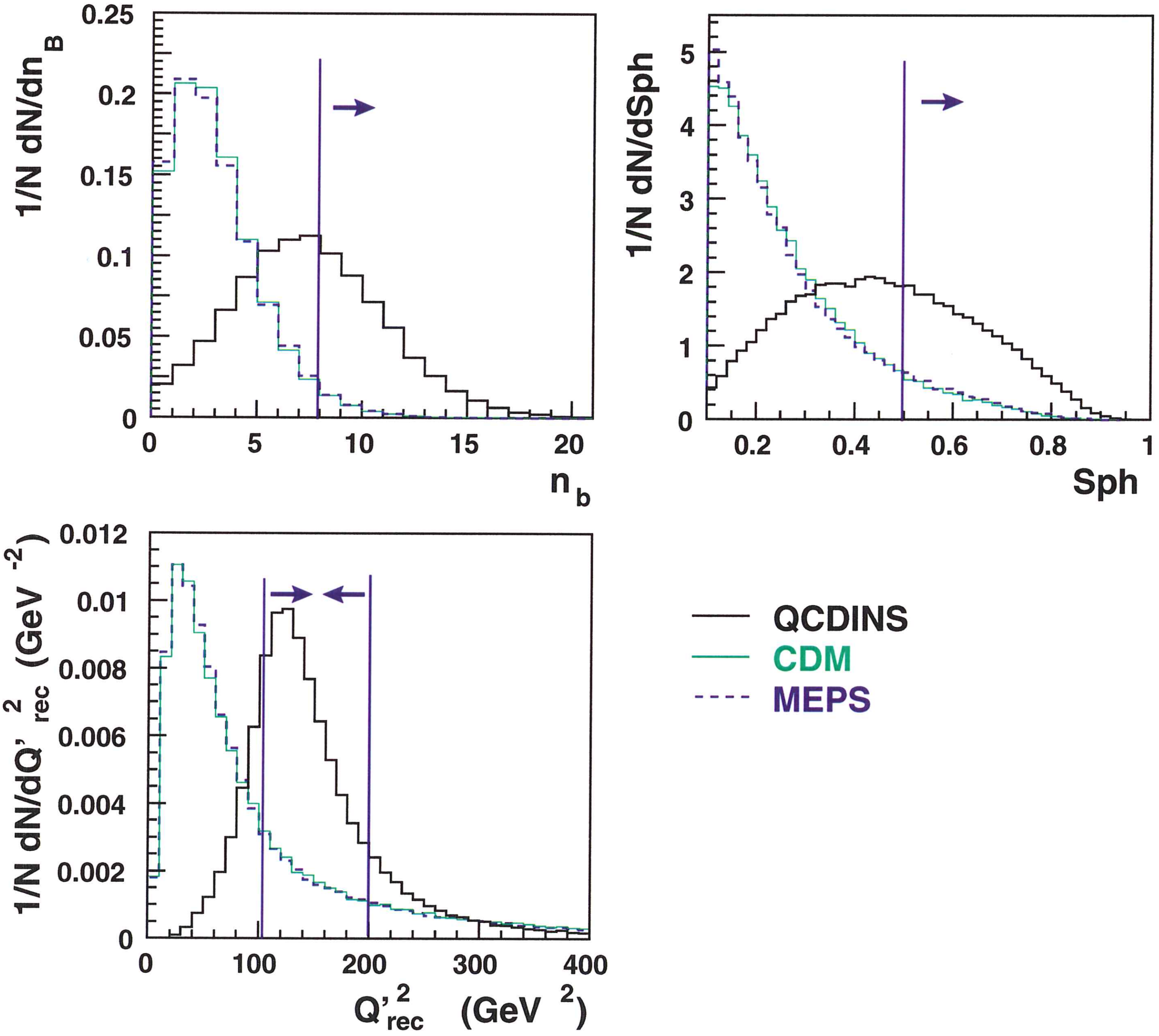
$\theta_{el} > 156°$,

$0.1 < y_{el} < 0.6, \quad x_{bj} > 10^{-3}$





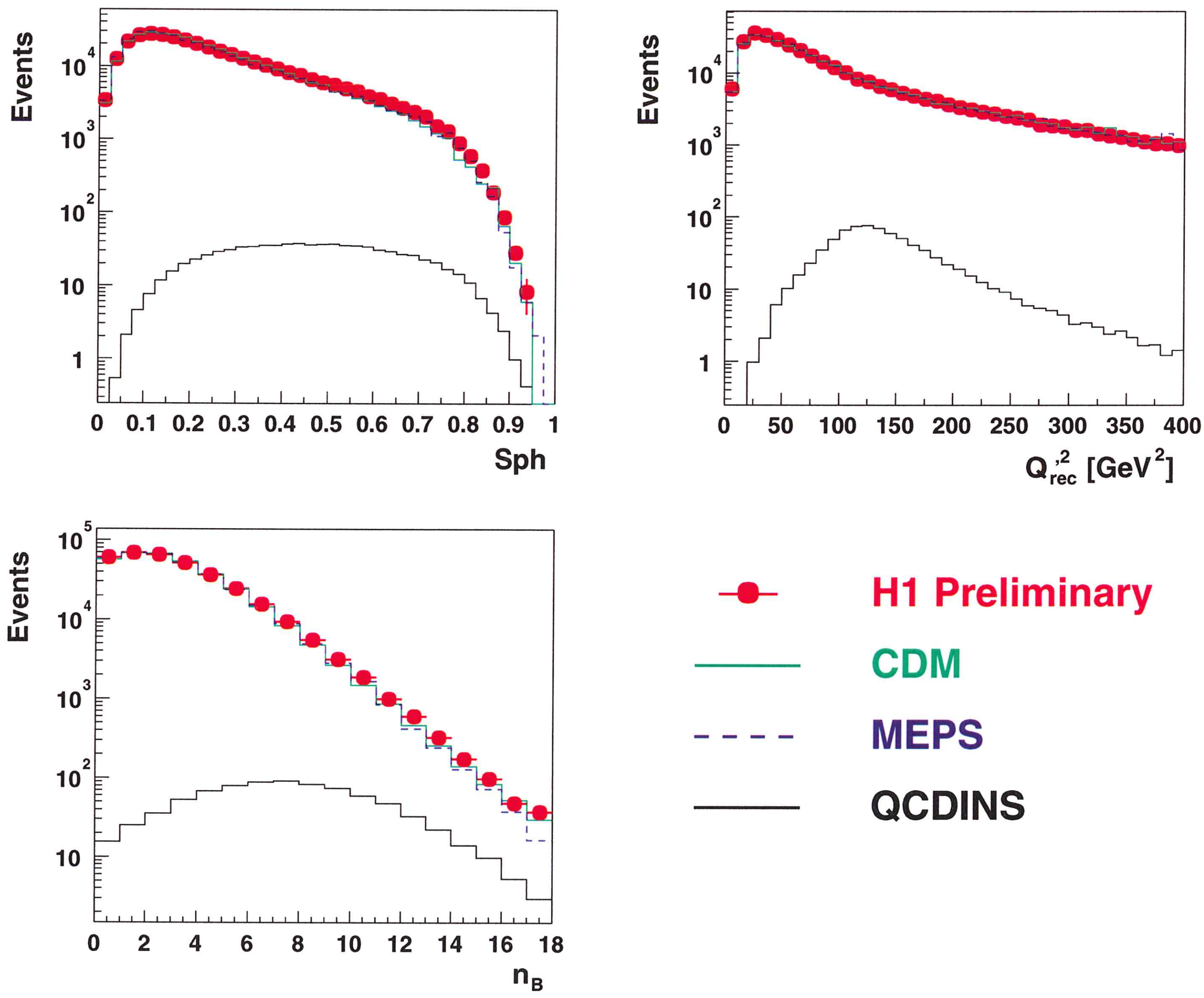
Instanton Variables for Cuts



Strategy: Cut in 3 observables and look at control variables after the cuts

The cuts are obtained by studying 125 different combinations of cuts on the 3 observables and taking the one with best separation power $S = \frac{\varepsilon_{INS}}{\varepsilon_{DIS}}$ requiring $\varepsilon_{INS} > 10\%$.

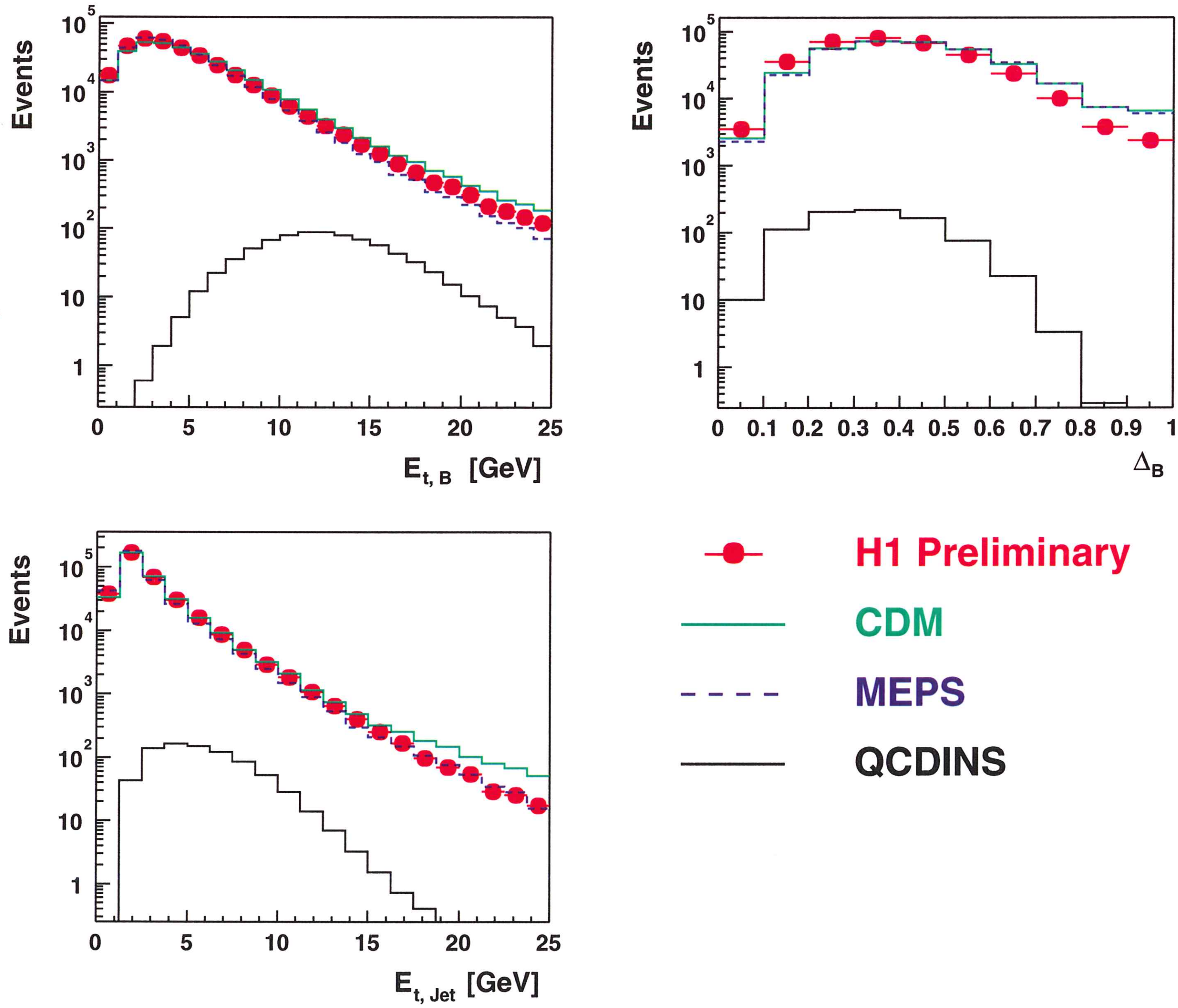
Instanton Variables for Cuts



Data well described by QCD Monte Carlos before cuts!

Small signal to background ratio ($O(10^{-3})$)

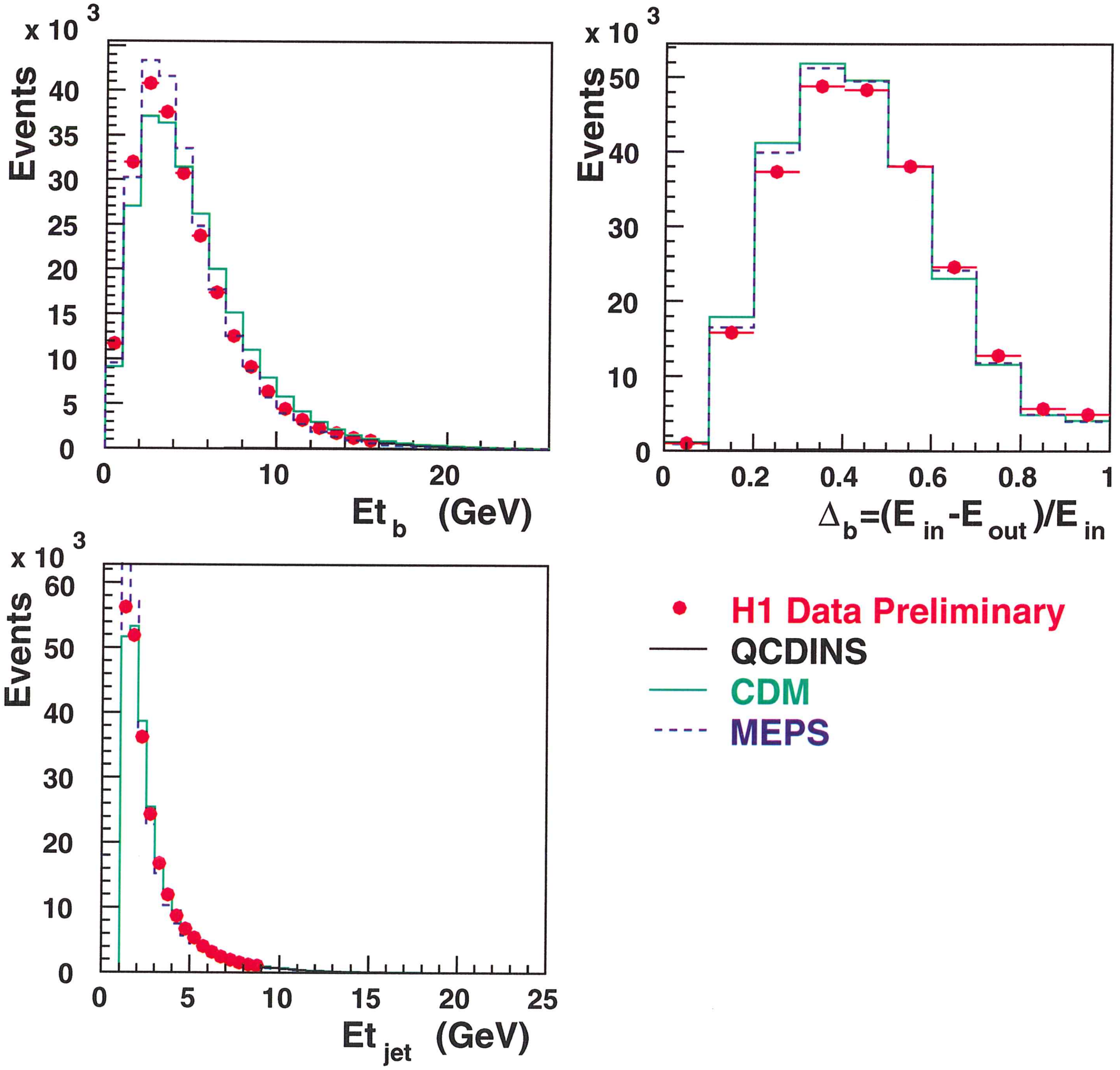
Control Distributions



Slightly worse description of data by QCD Monte Carlos, still within 5 – 20%

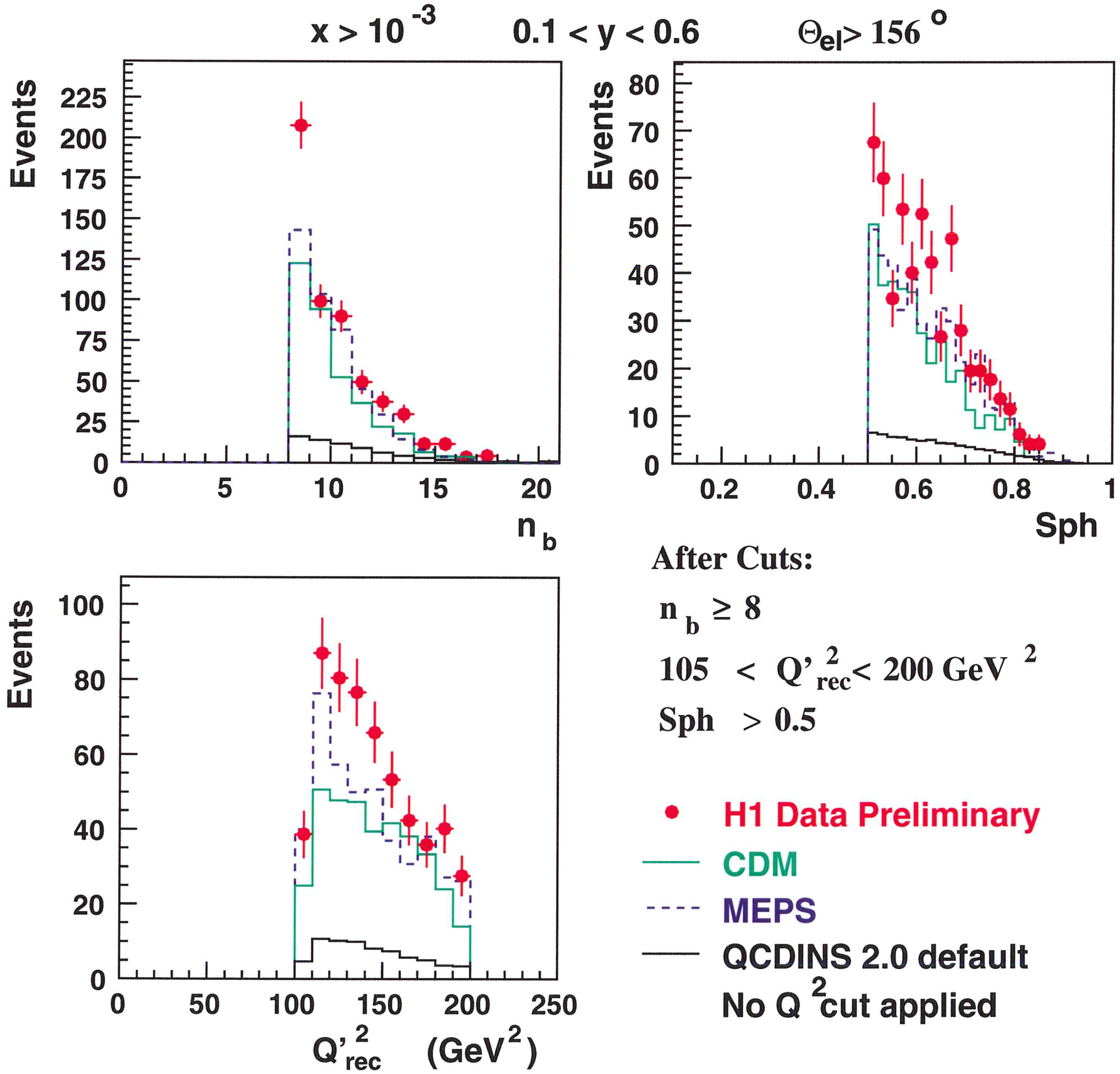
CDM too large at high Et_b and Et_{jet}

Control Distributions



CDM & MEPS have problem with describing low Et_b and Et_{jet}

Variables after Cuts

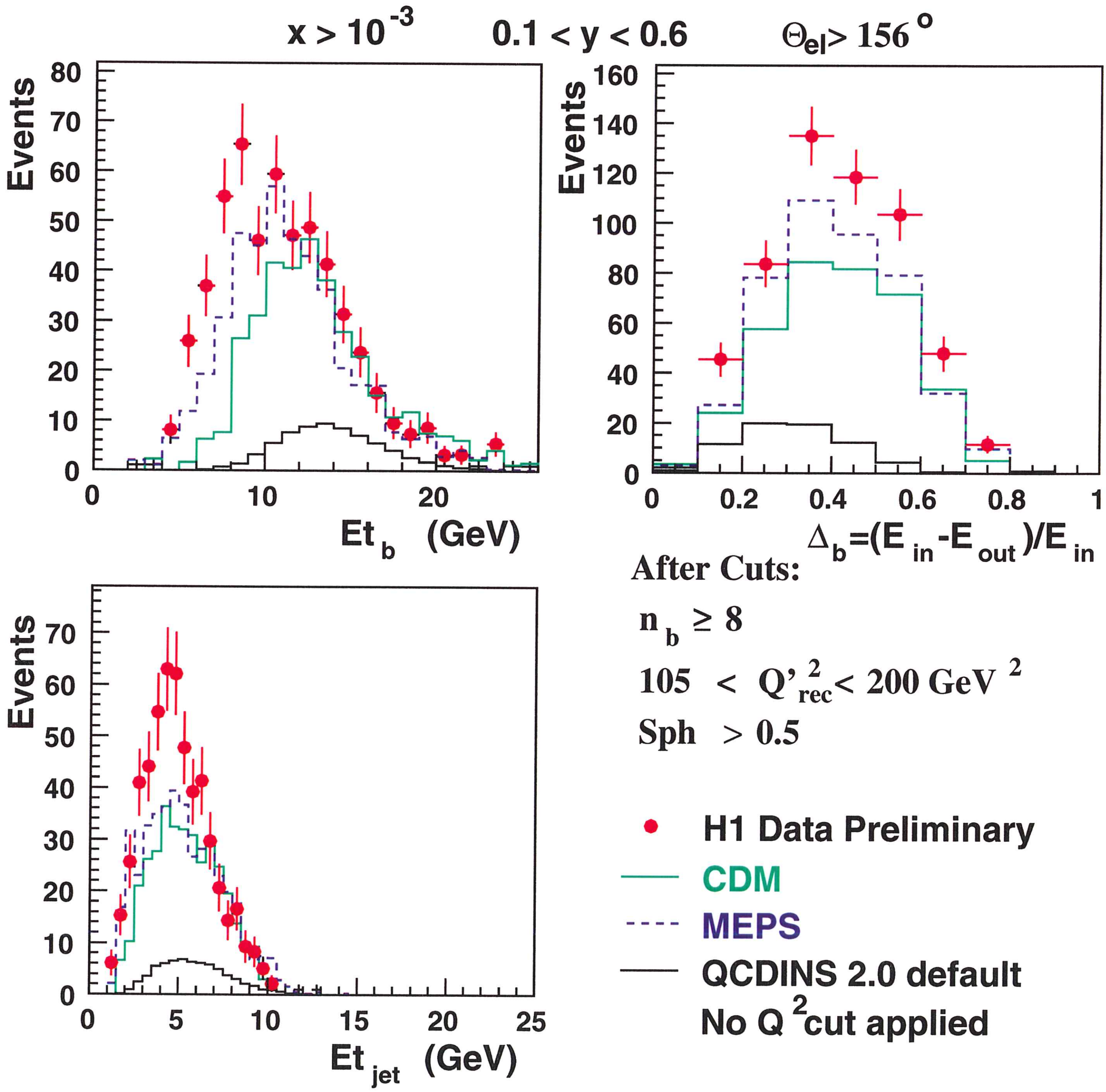


Achieved background reduction by factor $\approx 600 - 800$

In some regions more data observed than expected from models: 549 events measured, 363^{+22}_{-26} (CDM) and 435^{+36}_{-22} (MEPS) expected.

Expected I-signal at level of discrepancy of QCD models.

Control Variables After Cuts



Shape of observables not used to cut is neither well reproduced by CDM nor MEPS.

QCDINS predictions are not supported but can not be excluded given the uncertainties in default values.

Conclusions from Study of Low Q^2 Data

Scenario	Q'^2 [GeV^2]	$Sph >$	$n_b \geq$	ε_{INS}	$\frac{\varepsilon_{INS}}{\varepsilon_{DIS}}$ CDM	$\frac{\varepsilon_{INS}}{\varepsilon_{DIS}}$ MEPS	# Events CDM	# Events MEPS	# Events Data
A	95–200	0.4	5	32%	35	34	2469^{+242}_{-238}	2572^{+237}_{-222}	3000
B	105 – 200	0.4	7	21%	56	52	1005^{+82}_{-70}	1084^{+75}_{-46}	1332
C	105 – 200	0.5	8	11%	86	71	363^{+22}_{-26}	435^{+36}_{-22}	549

Increasing discrepancy between pQCD models and Data with tighter cuts, however of the order of the DIS model uncertainties

I-hypothesis not supported by Et_{jet} & Et_b shapes, but largest theoretical uncertainties of in these variables: F. Schrempp, A. Ringwald: Phys. Lett. B503, p331

$\Rightarrow$ Need to make high Q^2 analysis:

- cross section predictions safer
- background uncertainties might be smaller
- separation is, however, more difficult $\rightarrow$ sophisticated classification algorithms