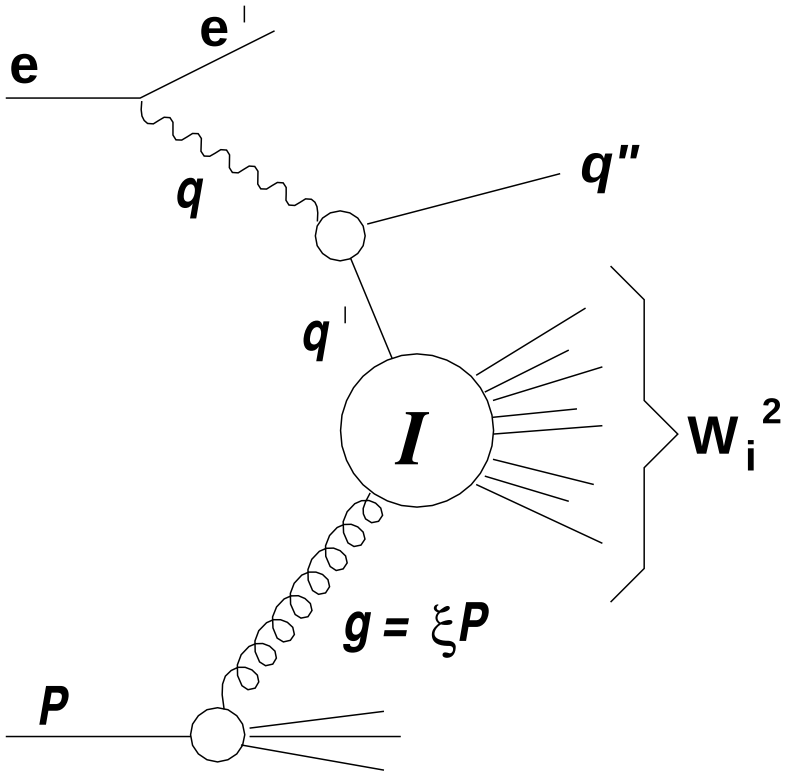
Search for QCD Instantons-induced Processes in Deep-inelastic Scattering at HERA

S. Mikocki
INP Cracow
for H1 Collaboration

- Motivation
- Search Strategy based on characteristics of hadronic final state
- Results
- Conclusion

DIS2000
Liverpool April 25-30, 2000

Motivation



Variables of I-subprocess:

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

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

$$W_i^2 = Q'^2 \;(1 - x'\;)/x'$$

experimentally:
difficult or impossible
to reconstruct/cut

Instantons-induced events produced in quark/gluon fusion
Theory and phenomenology worked out by A. Ringwald
and F. Schrempp
Implementation in QCDINS Monte Carlo generator
makes full event topology available

Cross section prediction:

for $0.1 < y < 0.9$ and $x > 10^{-3}$ no Q^2 cut applied

with $Q'^2 > 113\; GeV^2$ $x' > 0.35$ $\Lambda^{(3)}_{\overline{MS}}$ =345 MeV $n_f = 3$

$$\sigma_{ins} = 50 \text{ - } 100 \text{ pb}$$

→ expect sizeable number of events on tape !
but large background O(1000) higher

DIS Event Selection

Data 1997: $\int \mathcal{L} = 15.78 \text{ pb}^{-1}$

Phase space cuts:

$\theta_{el} > 156°, \quad 0.1 < y_{el} < 0.6, \quad x_{el} > 10^{-3}$

Technical cuts:

Scattered electron in H1 backward calorimeter
with $E_{el} > 10$ GeV,
$-30 \text{ cm} < z_{vtx} < 30 \text{ cm}$
$35 < \sum E - P_z < 70$ GeV

Hadronic Final State Objects:

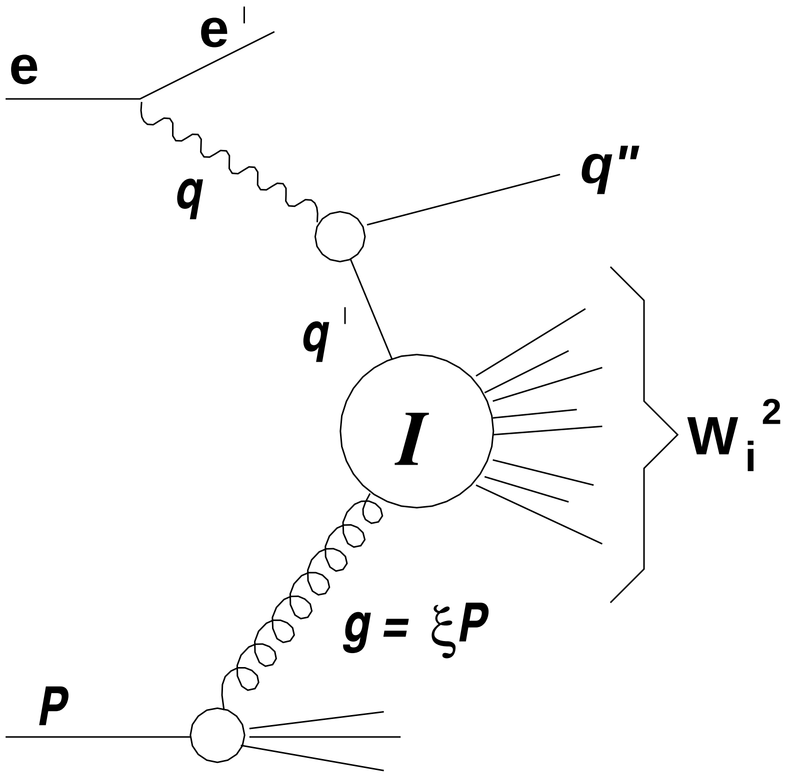
Presence of charged particles in region of acceptance of Central Track Chambers:
$20° < \theta < 155°$, $p_T > 0.15$ GeV

and

combination of Tracks and Calorimeter Clusters to measure particle flow

$\Rightarrow \sim$ 280k events in data

Experimental Signature

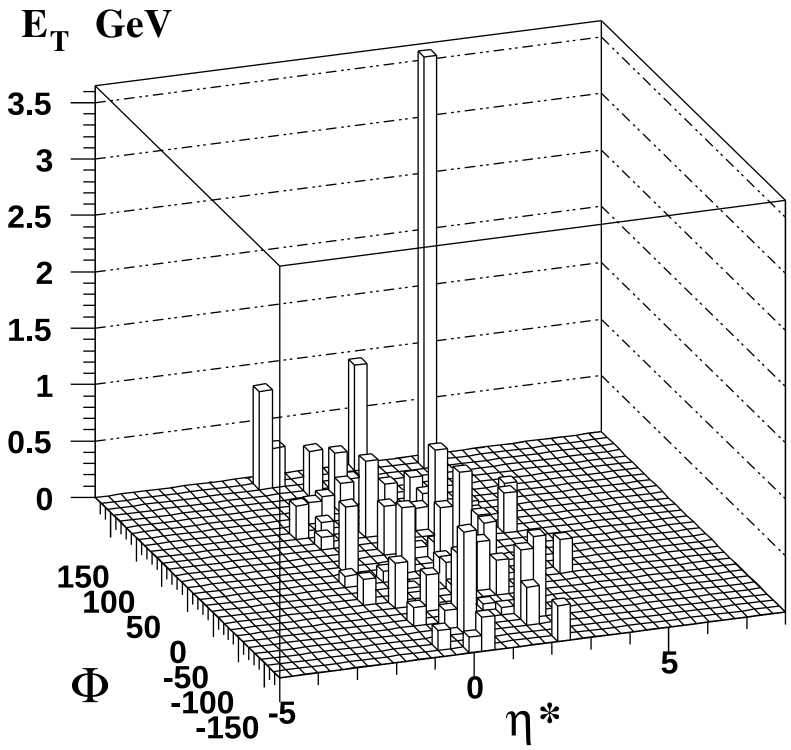


Variables of I-subprocess:

$$Q'^2 = -q'^2$$
$$x' = Q'^2 \,/\, (2\, g \cdot q')$$
$$W_i^2 = Q'^2\ (1 - x'\ )/x'$$

- hard jet
- Q'^2 poorly reconstructed
- x' reconstr. impossible

'Typical event'
$(\eta, \phi)-$plane: hadronic CMS



- Densily populated
  narrow band
  flat in Φ from
  isotropic parton decay
  in $I-$rest system
  (central part of detector)

- Large total Et
- Large Multiplicities
- All kinds of flavours
  e.g. K^0, Λ
  → no flavour tagging
  exploited yet in exp. analysis

Observables

Find highest E_T jet ('current jet'): cone algorithm, $R = 0.5$

1) Transverse energy of jet: Et_{jet} in hCMS

2) Virtuality of quark entering I-subprocess: Q'^2

Remove particles of jet to define band:

With $\bar{\eta} = \sum_h Et_h\, \eta_h / \sum_h Et_h$: define band as: $\bar{\eta} \pm 1.1$

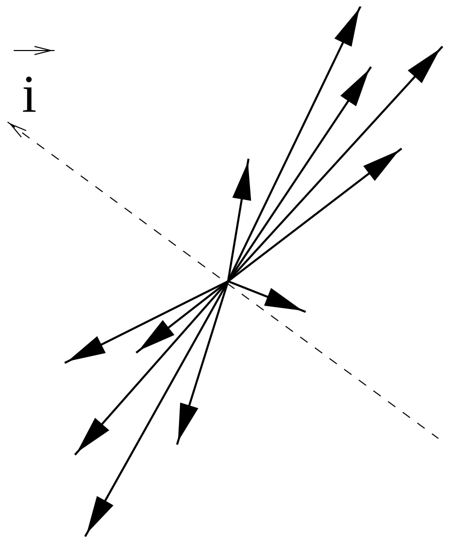
3) Count number of charged particles: n_b

4) Total transverse energy: Et_b

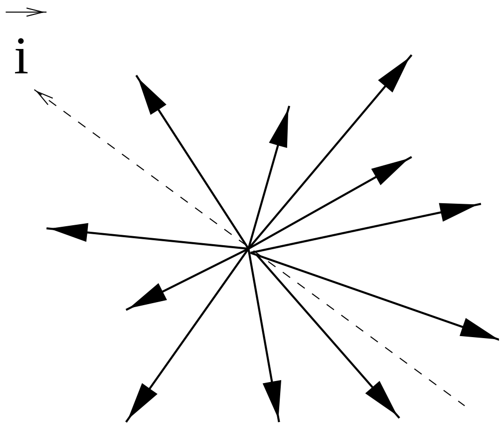
5) Sphericity in the rest system of particles not in jet: Sph

6) $\Delta_b = (E'_{in,B} - E'_{out,B}) \,/\, E'_{in,B}$

$$
\begin{aligned}
E_{out} &= \min \textstyle\sum_{n\ Hadr.} |\, \vec{p_n} \cdot \vec{i}\, | \\
E_{in} &= \max \textstyle\sum_{n\ Hadr.} |\, \vec{p_n} \cdot \vec{i}\, |
\end{aligned}
$$

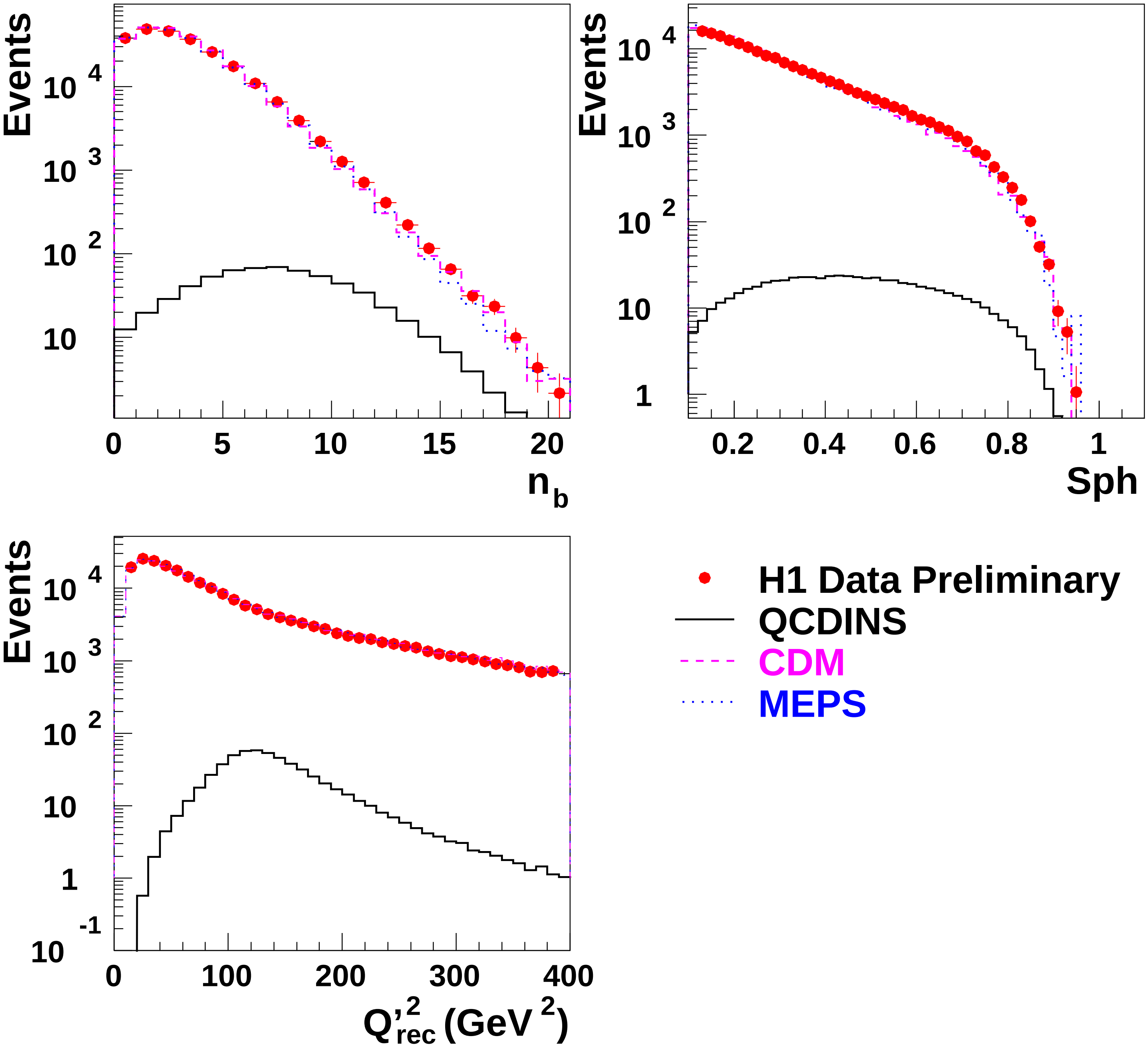


$\Delta_b \approx 1$



$\Delta_b \approx 0$

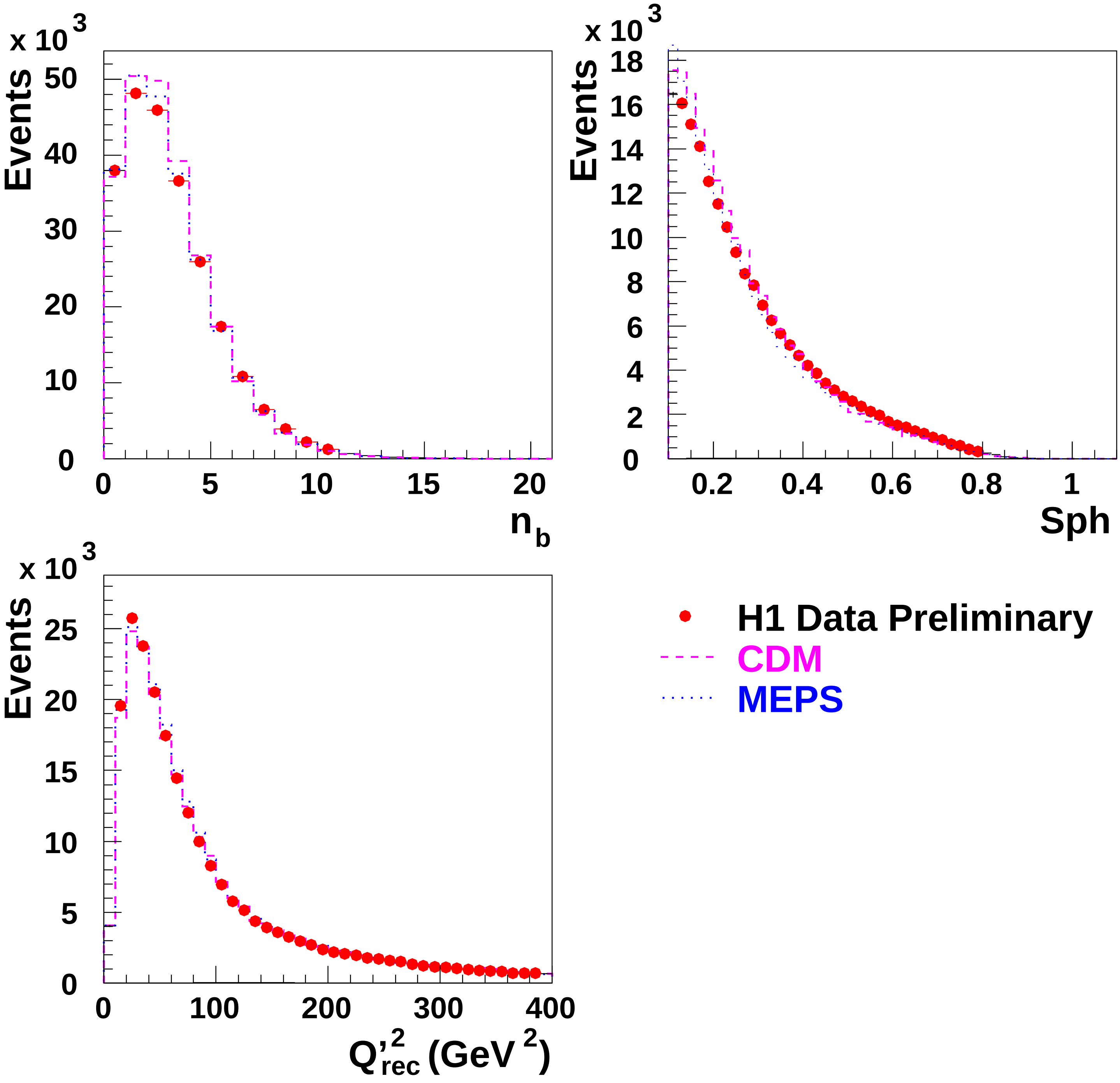
Observable Distributions before Cuts



QCD Monte Carlo models fairly well describe data $(5-20\%)$

Expected instanton signal $O(10^3)$ below background

Observable Distributions before Cuts

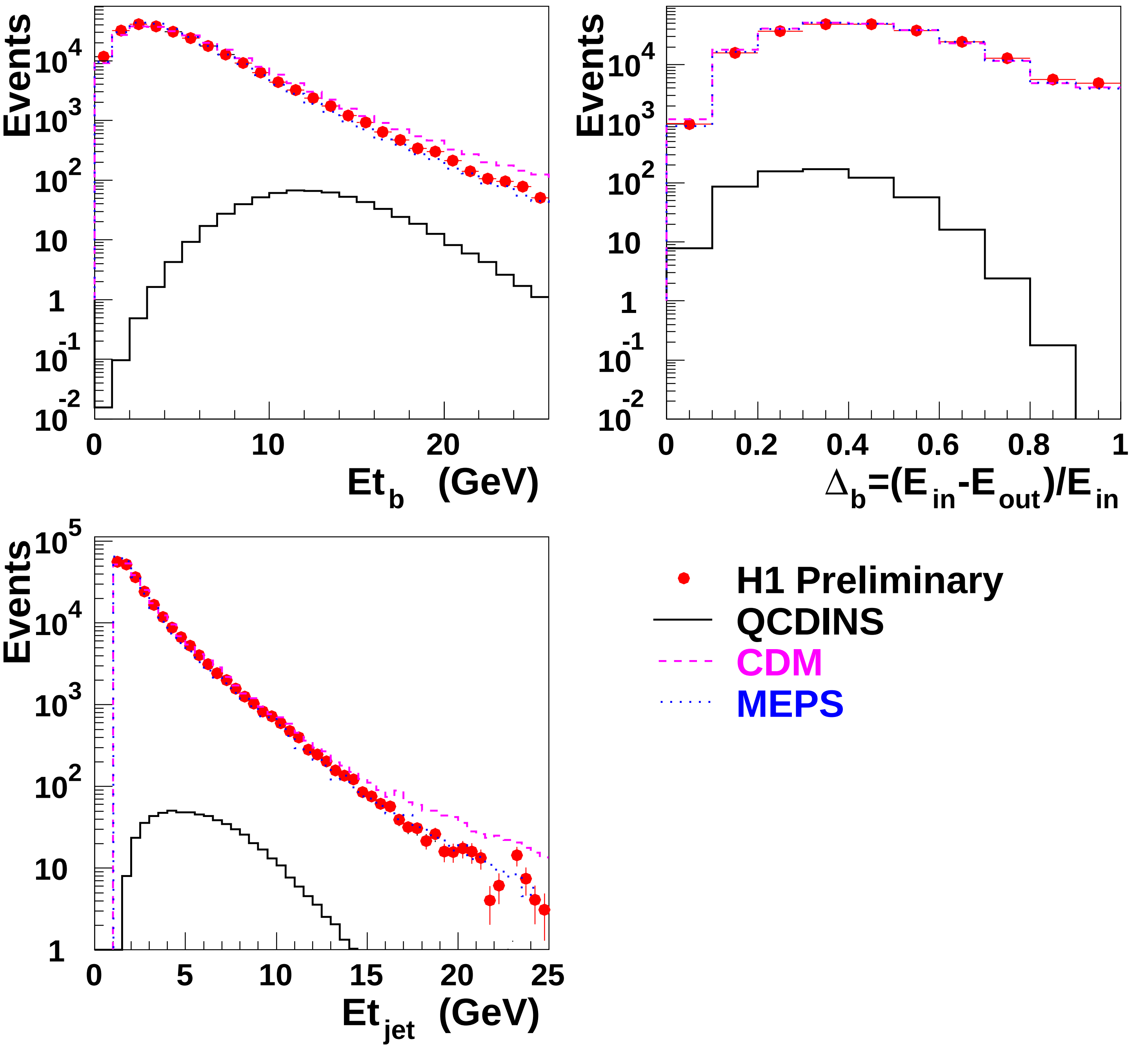


QCD Monte Carlo models fairly well describe data $(5 - 20\%)$

Expected instanton signal too small to be visible

Observable Distributions before Cuts

Observables not used to cut:



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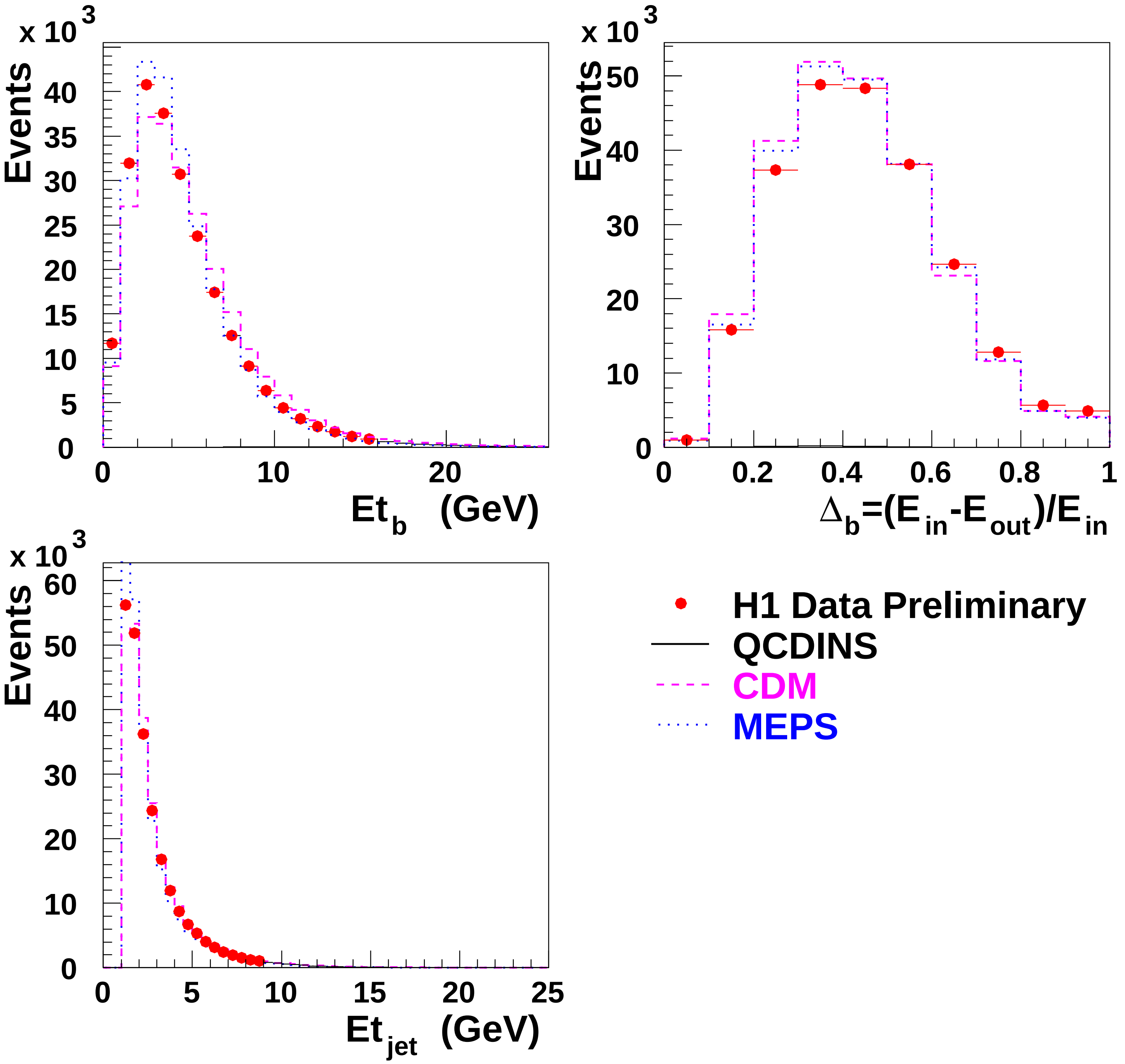

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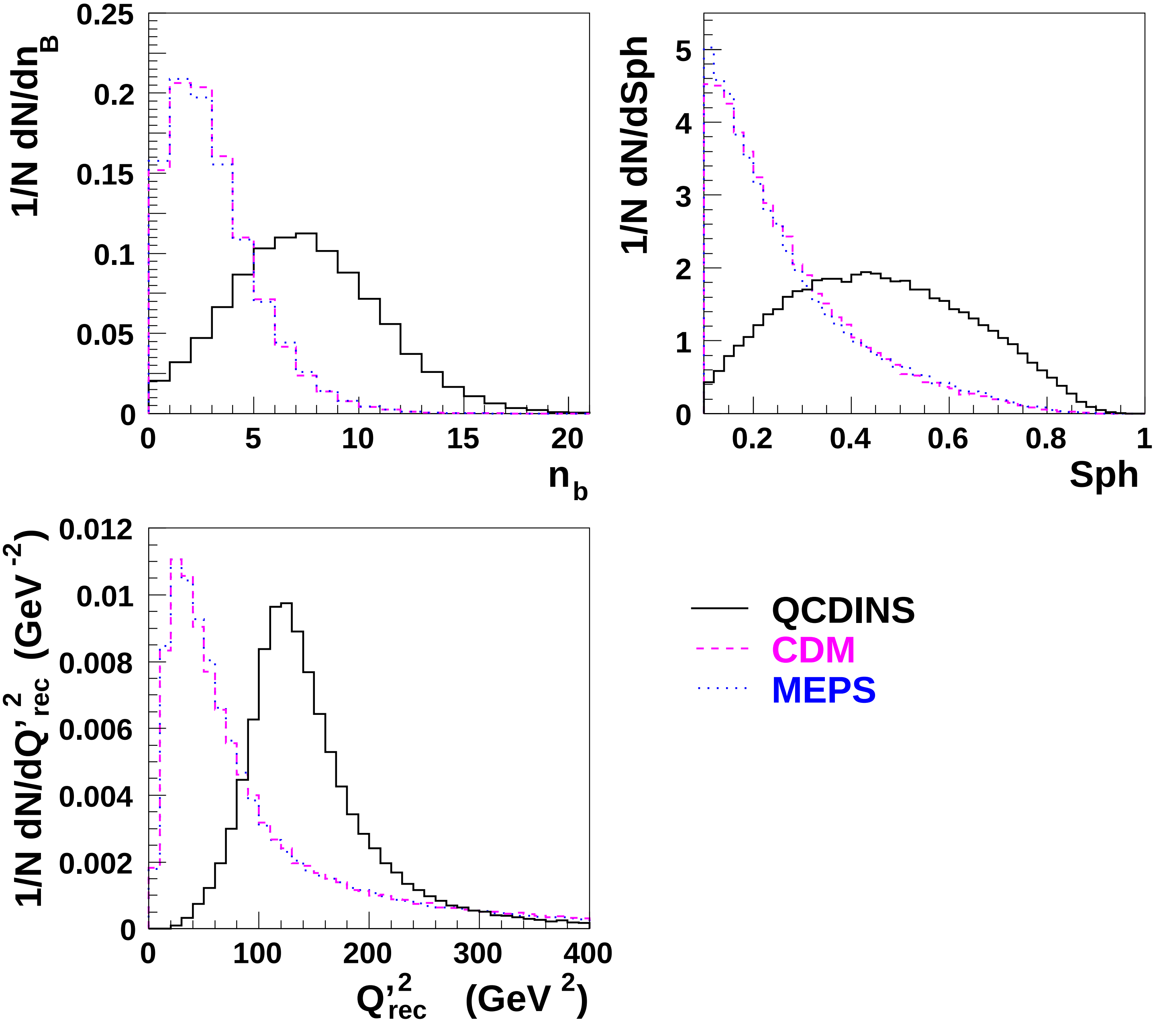
Search Strategy



Selection of Cut Scenario

Cut values:

$n_b \geq$ 5 6 7 8 9

Sph $\geq$ 0.4, 0.5, 0.55, 0.6, 0.65

95, 100, 105, 110, 115 $< Q'^2 <$ 200 GeV^2

in total 125 combinations !

Scenario	Cuts			ϵ_{ins}	$\frac{\epsilon_{ins}}{\epsilon_{DIS}}$	
	Q'^2 (GeV^2)	Sph	n_b		CDM	MEPS
A	95.0-200.0	0.40	5	32 %	35	34
B	105.0-200.0	0.40	7	21 %	56	52
C	105.0-200.0	0.50	8	11%	86	71

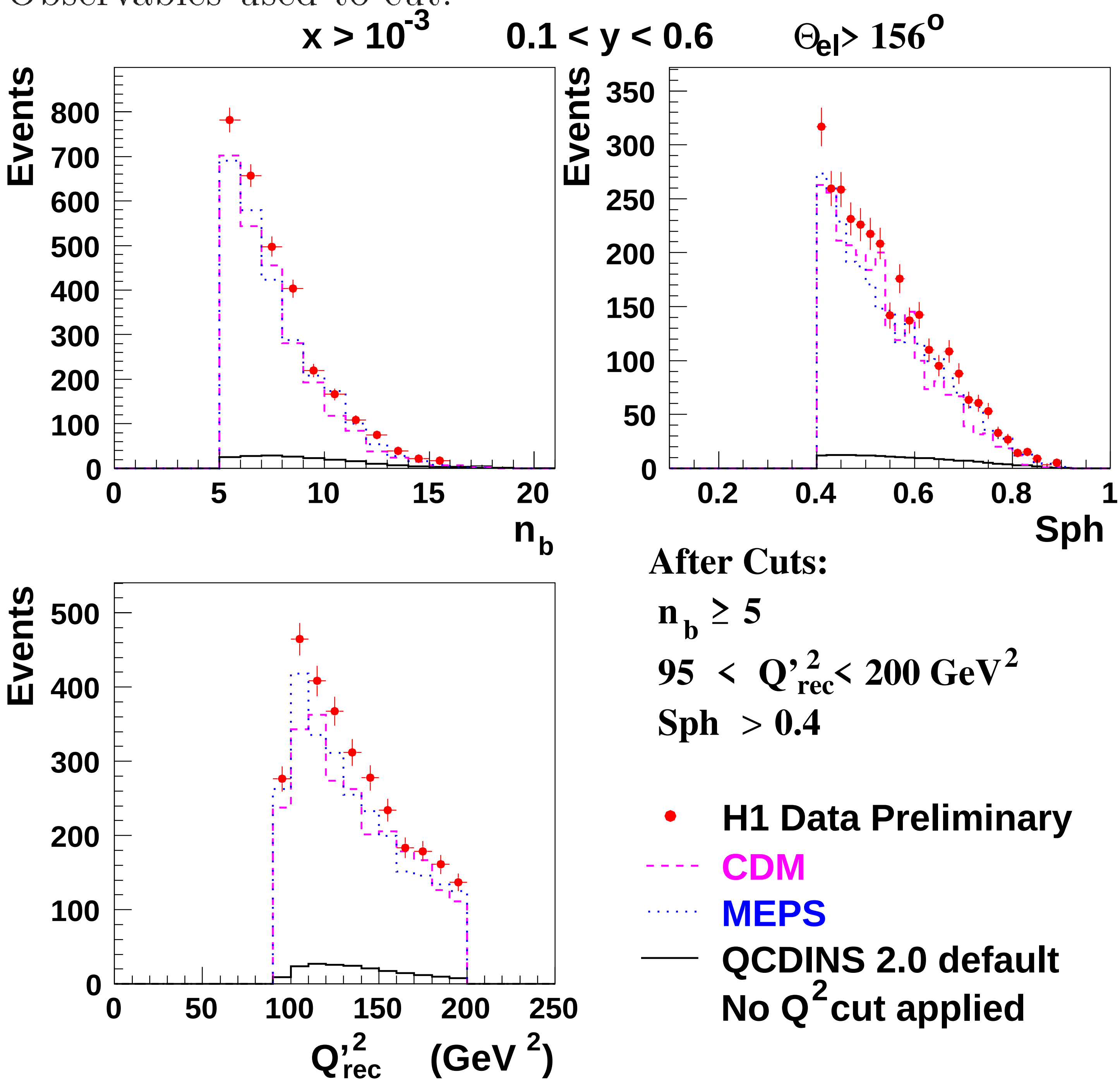
A) Highest instanton efficiency (ϵ_{ins})

B) High ϵ_{ins} at reasonable separation power ($\frac{\epsilon_{ins}}{\epsilon_{DIS}}$)

C) Highest separation power at $\epsilon_{ins} > 10\%$

Observable Distributions after Cuts A

Observables used to cut:



Achieved background reduction by factor ~ 100

In some region more data observed than expected by models

3000 events measured

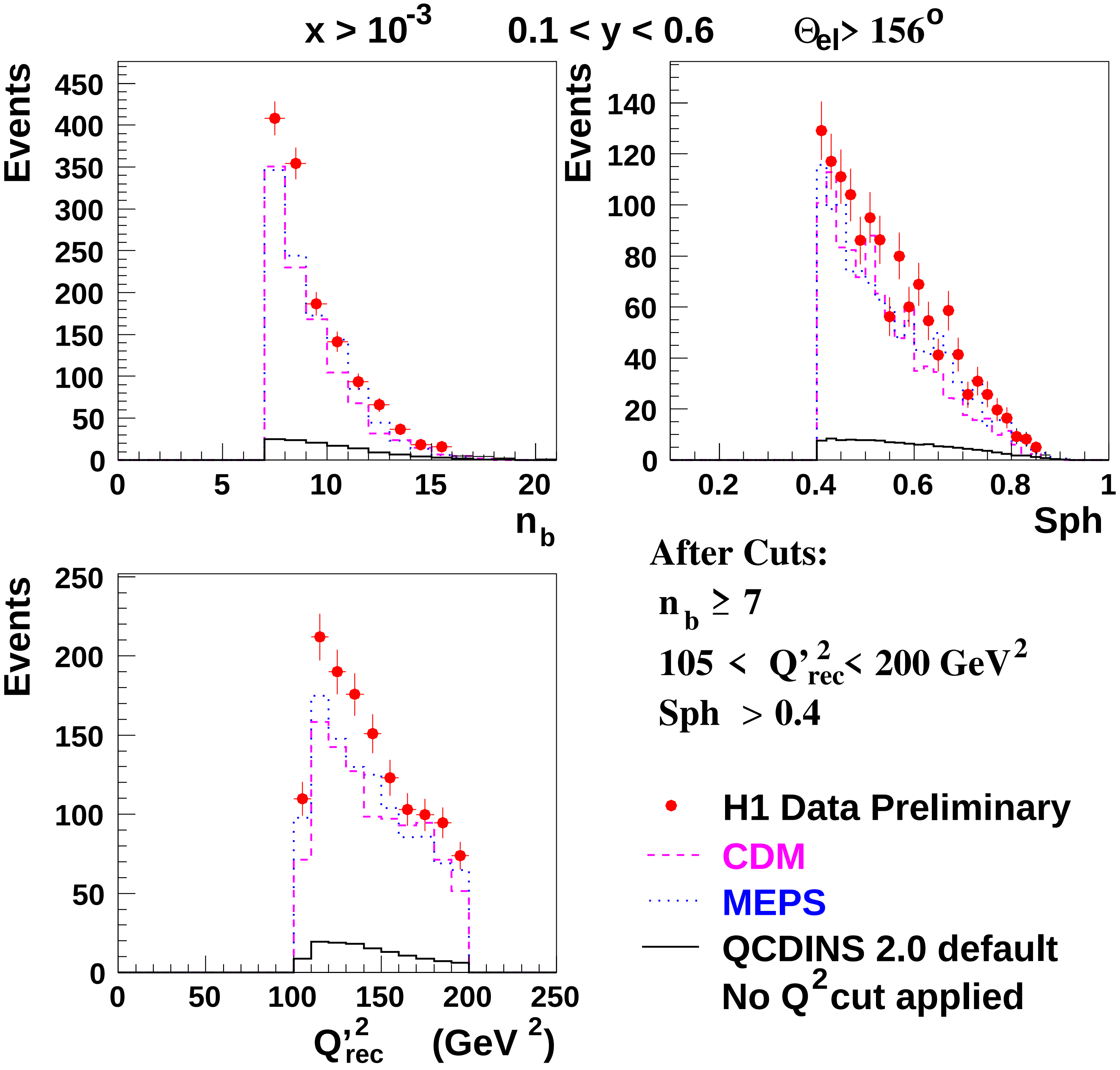
2469^{+242}_{-238} (CDM) and 2572^{+237}_{-222} (MEPS) expected

Expected instanton signal at level of discrepancy of QCD Models

For the uncertainties of QCDINS prediction see F.Schrempp talk

Observable Distributions after Cuts B

Observables used to cut:



Achieved background reduction by factor $\sim 250 - 280$

In some region more data observed than expected by models

1332 events measured

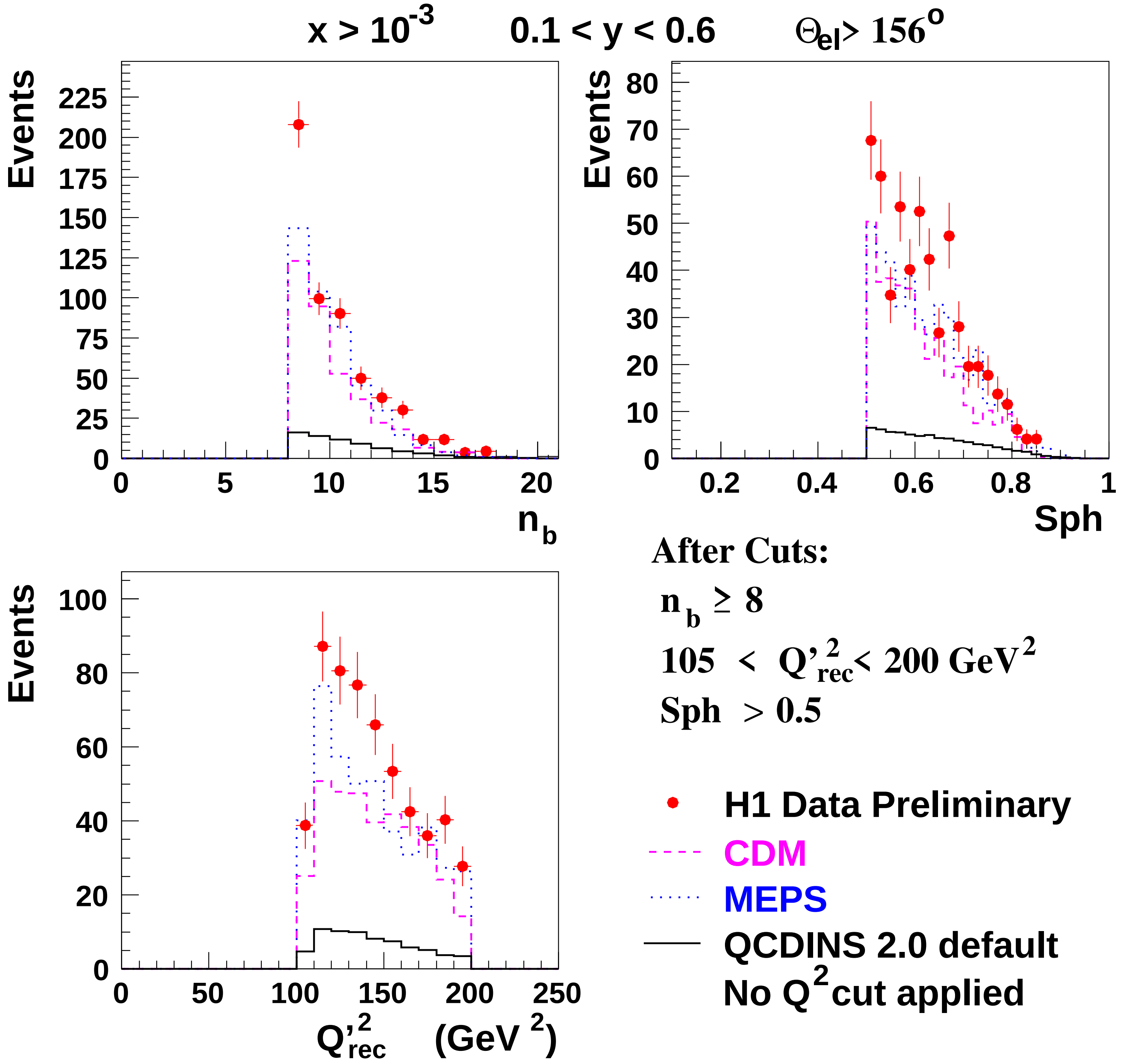
1005^{+82}_{-70} (CDM) and 1084^{+75}_{-46} (MEPS) expected

Expected instanton signal at level of discrepancy of QCD Models

For the uncertainties of QCDINS prediction see F.Schrempp talk

Observable Distributions after Cuts C

Observables used to cut:



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

In some region more data observed than expected by models

549 events measured

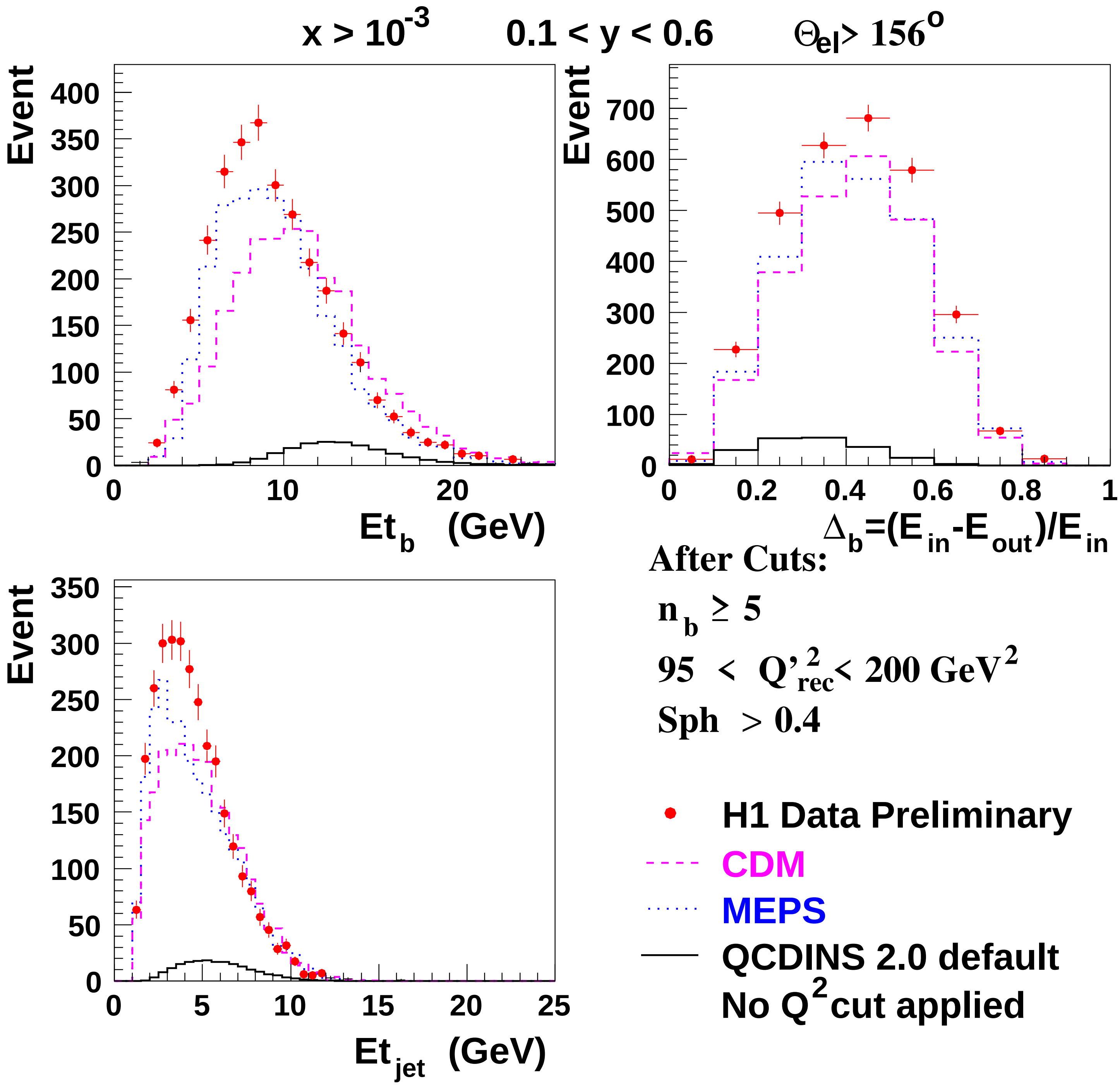
363^{+22}_{-26} (CDM) and 435^{+36}_{-22} (MEPS) expected

Expected instanton signal at level of discrepancy of QCD Models

For the uncertainties of QCDINS prediction see F.Schrempp talk

Observable Distributions after Cuts A

Observables not used to cut:

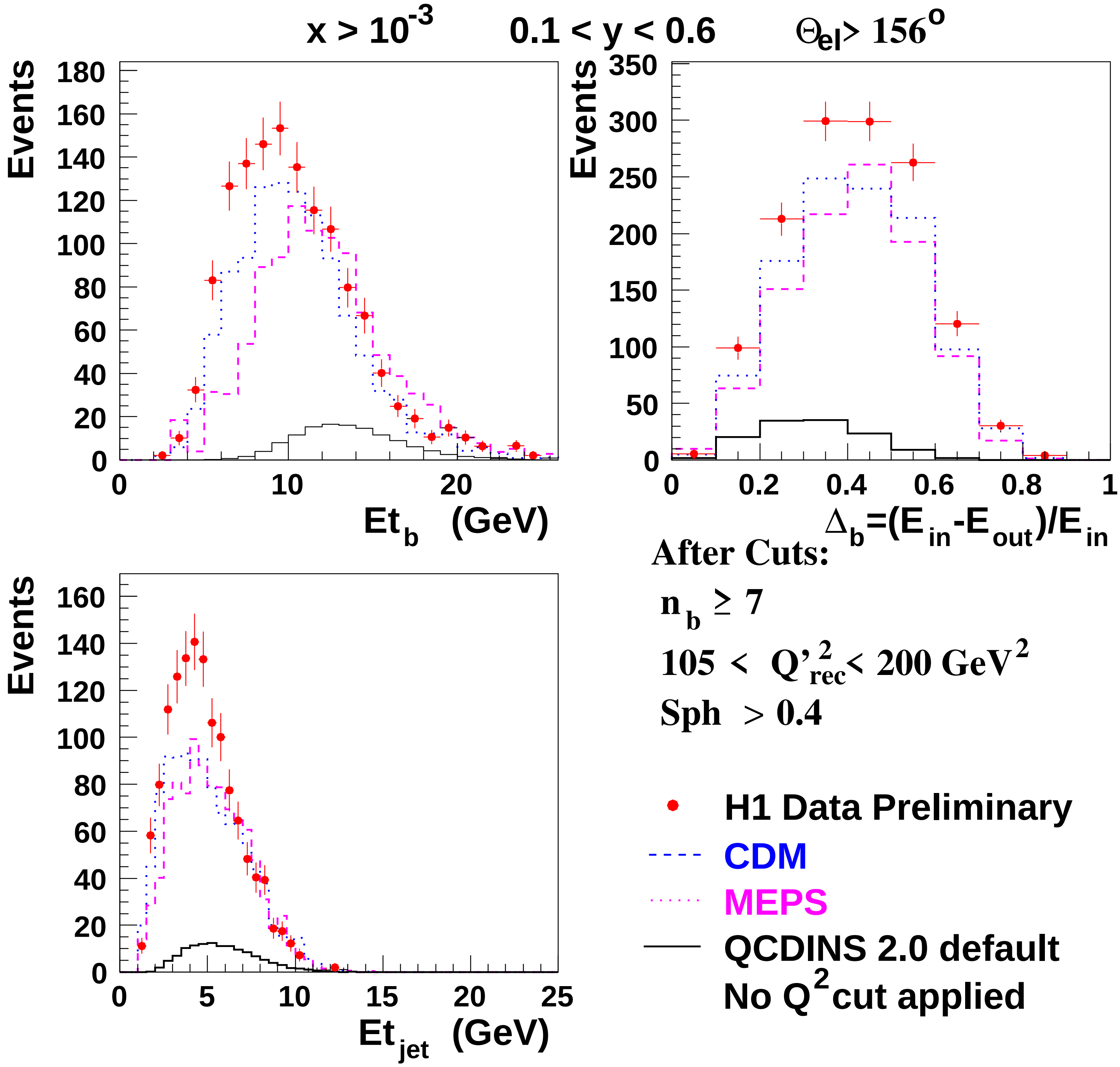


Shape of the spectra of observables not used to cut is neither well reproduced by CDM nor MEPS

QCDINS predictions are not supported but can not be excluded given the uncertainties in default values (further on theory uncertainties in QCDINS see F.Schrempp talk)

Observable Distributions after Cuts B

Observables not used to cut:



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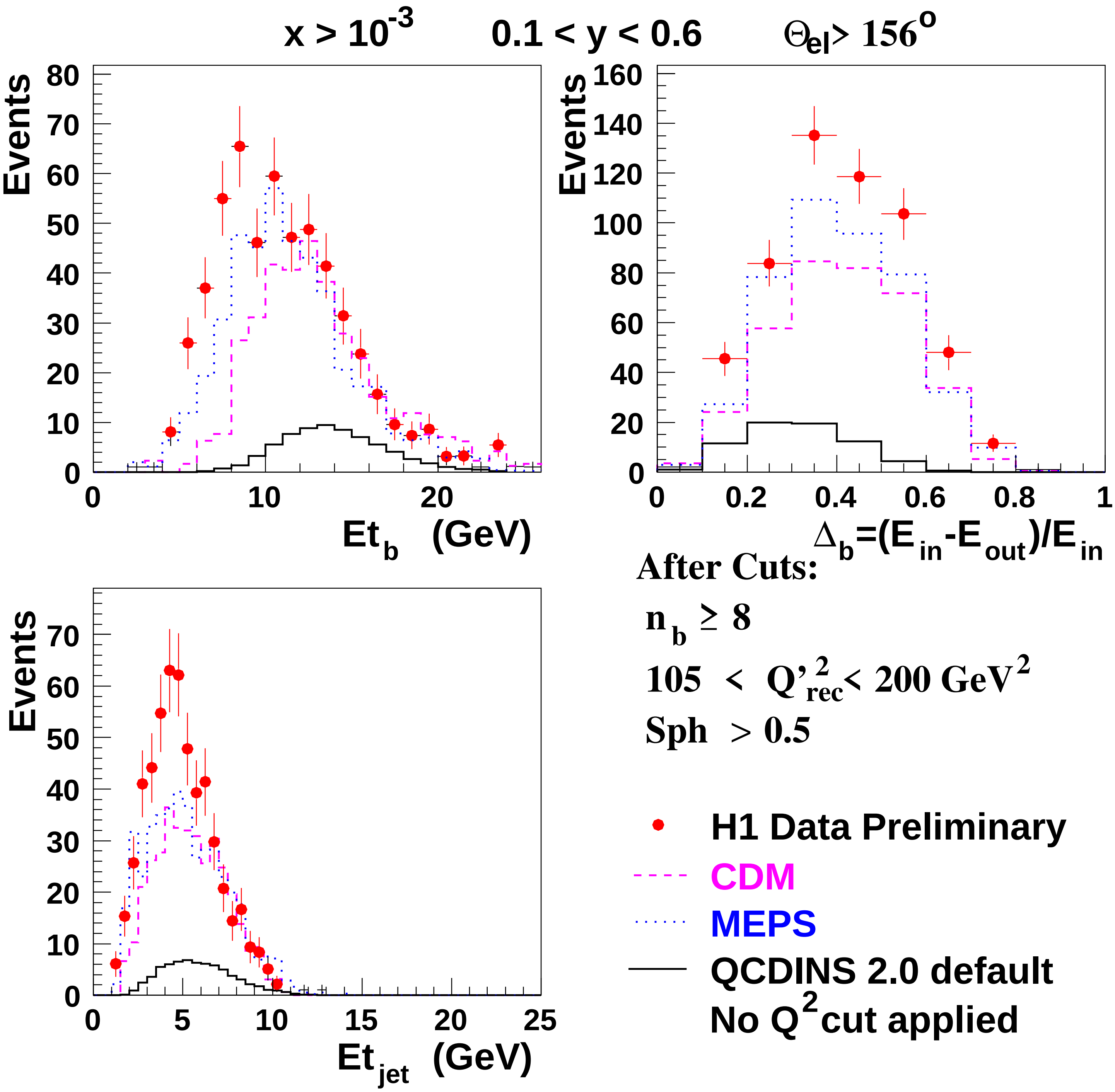
Observable Distributions after Cuts C

Observables not used to cut:



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Conclusions

- Discovery of instantons would be the first evidence for topological fluctuations of non-perturbative aspect of QCD at high energies
- We have searched for instanton-induced DIS processes predicted by A. Ringwald and F. Schrempp to be measureable at HERA
- Search strategy based on three observables was optimised to exploit the characteristics of instanton-induced processes
- Requiring $n_B \geq 8$, $105 \leq Q'^2 \leq 200$ GeV^2, $Sph \geq 0.5$:
  549 events have been measured in the data,
  363^{+22}_{-26} (CDM) and 435^{+36}_{-22} (MEPS) are expected,
  qualitative similarity between observed excess and shape predicted by QCDINS for 3 cut observables
- Expected instanton signal is at the level of the difference of the pQCD models predictions
- Shape of three other discriminating observables not used to cuts is neither well reproduced by CDM nor by MEPS
- QCDINS predictions are not supported by shape of 3 variables not used in the cuts but can not be excluded given uncertainties in the choice of default values of parameters and uncertainties in standard pQCD Monte-Carlo models.