Heavy Quarks at THERA

summary of ZEUS HFL group discussions

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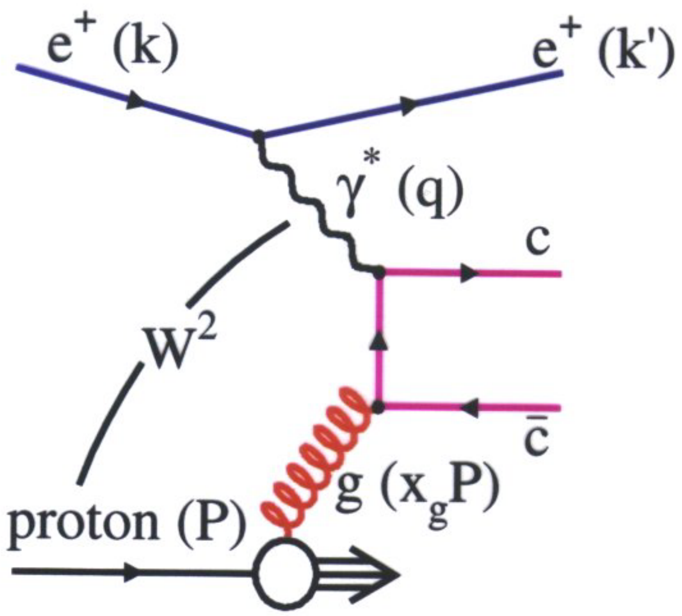
OUTLINE:

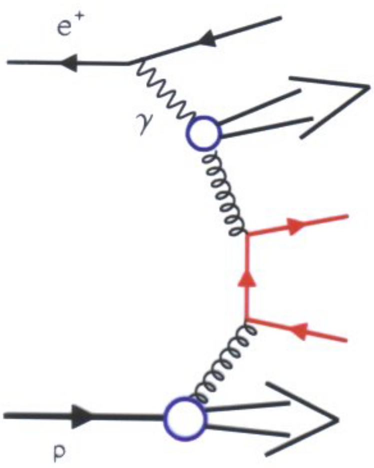
- DIS and Photoproduction at THERA
- High Q^2 charm production
- High Q^2 beauty production
- $\gamma p \rightarrow t\bar{t}$ at THERA and THERA500
- Charm and Beauty Photoproduction
- Charge Current Charm production
- First Conclusions

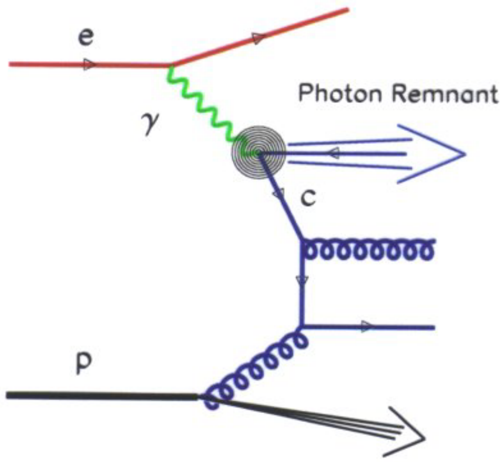


Charm Production Mechanisms

In Photoproduction one can also expect resolved γ^* : $gg \to c\bar{c}$, $cg \to cg$

Charm excitation





Only a fraction of photon momentum participates in hard interaction: $x_\gamma < 1$

This is a Leading Order picture

In all orders one can define x_γ^{OBS}, a fraction of the photon momentum participating in the dijet production :

$$x_\gamma^{OBS} = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2yE_e}$$

NLO QCD Calculations

Fixed-order ("massive") approach:

$n_f = 3$: (u, d, s) are active flavours in p and γ
no explicit charm excitation component
charm is only produced dynamically
not valid for $Q, p_\perp \gg m_c$

DIS : HVQDIS, B. Harris and J. Smith
Photoproduction : FMNR, S. Frixione et al.

Resummed ("massless") approach:

$n_f = 4$: (u, d, s, c) are active flavours
explicit charm excitation component
large logarithms ($\frac{Q}{m_c}$, $\frac{p_\perp}{m_c}$) are resummed
valid only for $Q, p_\perp \gg m_c$

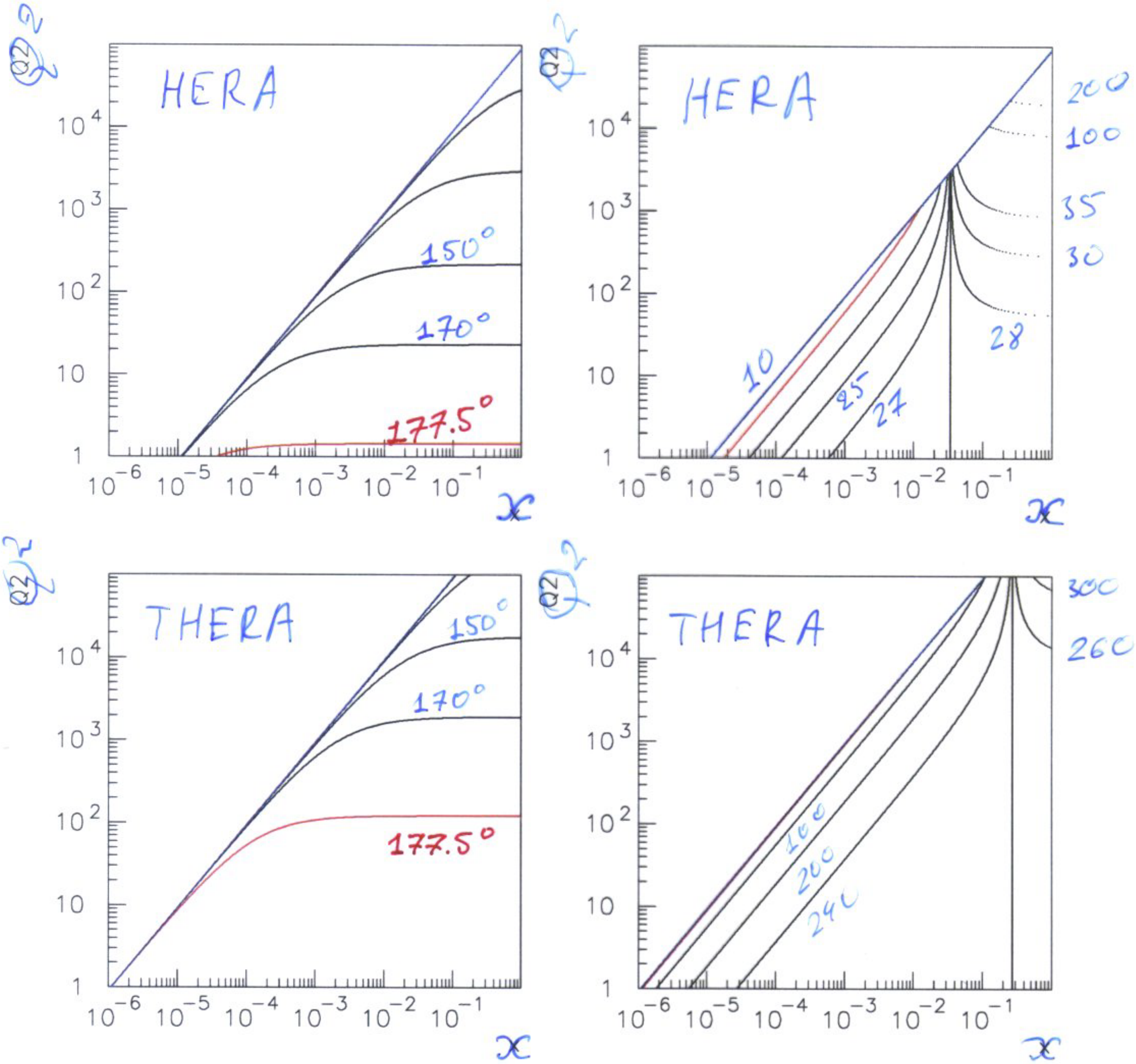
Photoproduction : B. Kniehl et al.
M. Cacciari et al.

And matched/merged calculations in progress (see theoretical talks).

Which detector we will have at THERA?

Θ_e ?

E_e ?



1 order lower x (till 10^{-6})

"main" detector : $Q^2 \gtrsim 100$ GeV^2

DIS and Photoproduction at THERA

at HERA:

Photoproduction	$Q^2 < 1\,GeV^2$
DIS	$Q^2 > 1\,GeV^2$

at THERA:

Photoproduction	$Q^2 < 100\,GeV^2$
DIS	$Q^2 > 100\,GeV^2$

To have more definite information about
$1 < Q^2 < 100\,GeV^2$:
BPC (Beam Pipe Calorimeter)

To study "clean" Photoproduction
$(Q^2 \simeq 0\,GeV^2)$:
either taggers or γp mode

Have we tools (LO and NLO) to simulate
HQ production with $0 < Q^2 < 100\,GeV^2$?

LO for BGF : AROMA, HERWIG, RAPGAP.
Probably, they are not too bad.

LO for resolved processes : HERWIG, PYTHIA
Are they really o.k. till $Q^2 \approx 100\,GeV^2$?

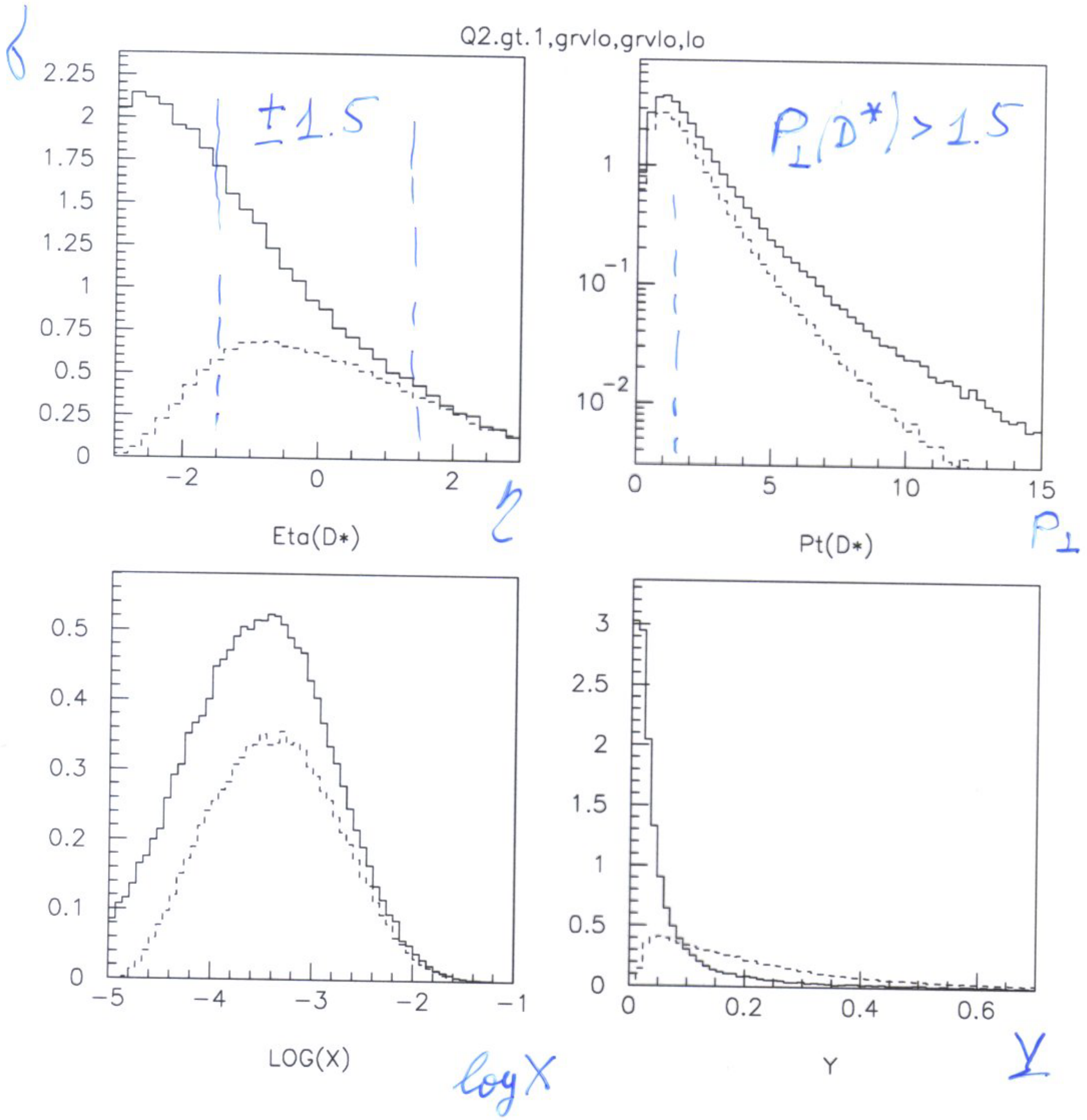
NLO codes: HVQDIS, FMNR.
No, they are not tuned for such range (scale).

HVQ DIS, GRV LO, $m_c = 1.4$

$Q^2 > 1\ GeV^2$

—— THERA

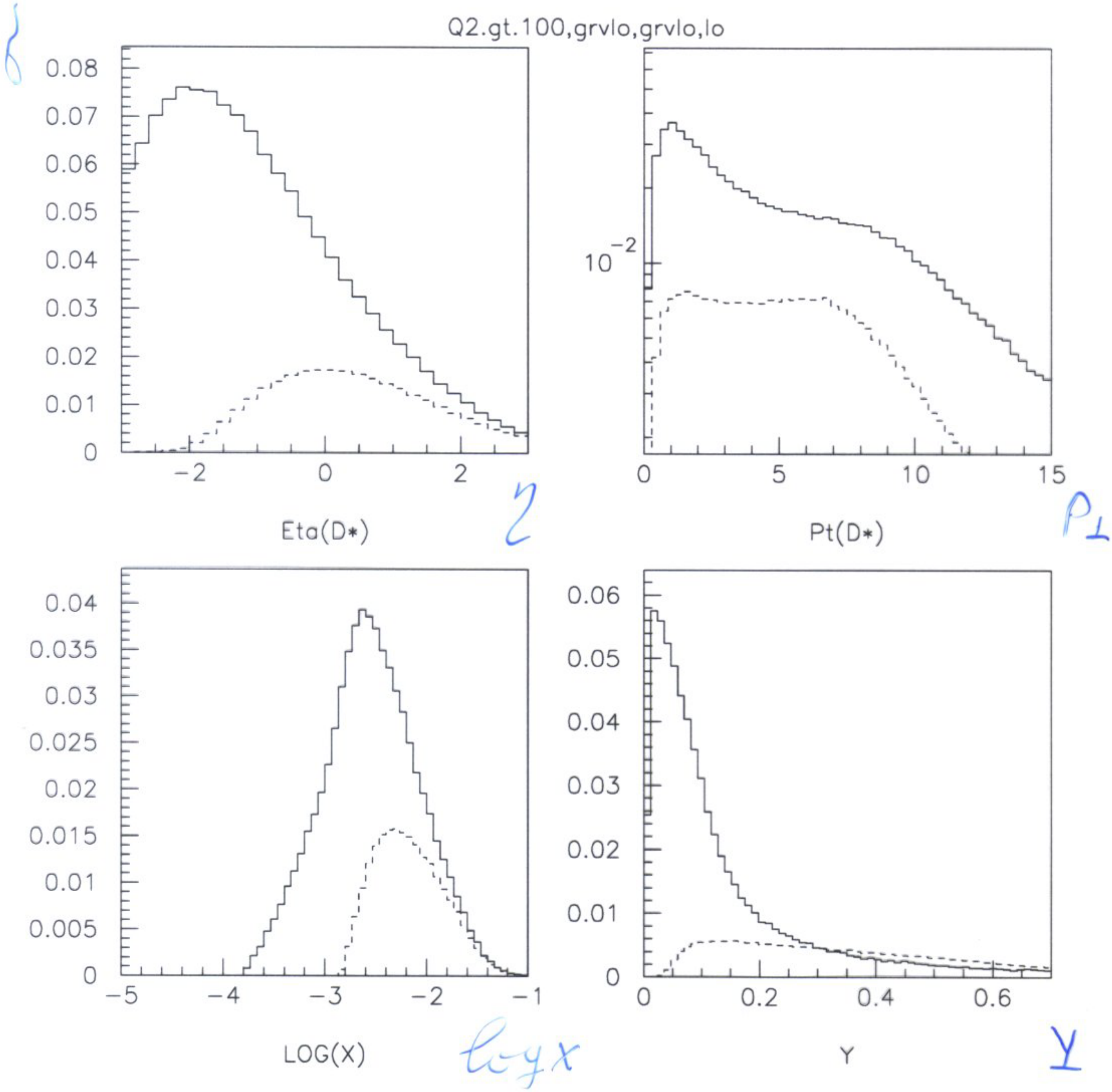
- - - HERA



vary backward!

$Q^2 > 100$ GeV^2

HVQDIS, GRV LO, $m_c = 1.4$



still backward.

great gain in large Q^2 and large $P_\perp$ regions!

High Q^2 charm production

AROMA, NC BGF, GRV94 LO, $m_c = 1.5$

$Q^2 > [GeV^2]$	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
0.6	**94.**	**301.**	$\approx$ **3.2**
100.	**0.91**	**4.4**	$\approx$ **4.8**
200.	**0.30**	**1.64**	$\approx$ **5.5**

For $Q^2 > 0.6\,GeV^2,\ P_\perp(D^*) > 1.5\,GeV$ **:**

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\lvert\eta(D^*)\rvert < 1.5$	**11.8**	**19.2**	$\approx$ **1.6**
$\lvert\eta(D^*)\rvert < 2.5$	**17.4**	**36.2**	$\approx$ **2.1**

For $Q^2 > 100.\,GeV^2,\ P_\perp(D^*) > 1.5\,GeV$ **:**

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\lvert\eta(D^*)\rvert < 1.5$	**0.29**	**0.88**	$\approx$ **3.0**
$\lvert\eta(D^*)\rvert < 2.5$	**0.39**	**1.5**	$\approx$ **3.8**

For $Q^2 > 200.\,GeV^2,\ P_\perp(D^*) > 1.5\,GeV$ **:**

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\lvert\eta(D^*)\rvert < 1.5$	**0.11**	**0.37**	$\approx$ **3.4**
$\lvert\eta(D^*)\rvert < 2.5$	**0.14**	**0.61**	$\approx$ **4.4**

$N(D^*) = \sigma \cdot L \cdot BR \cdot Acc = 610\,pb \cdot 100\,pb^{-1} \cdot 0.026 \cdot 0.25 =$

$\approx 400\ D^{*\pm} \to (K^- \pi^+)\pi_s^+ + c.c.$

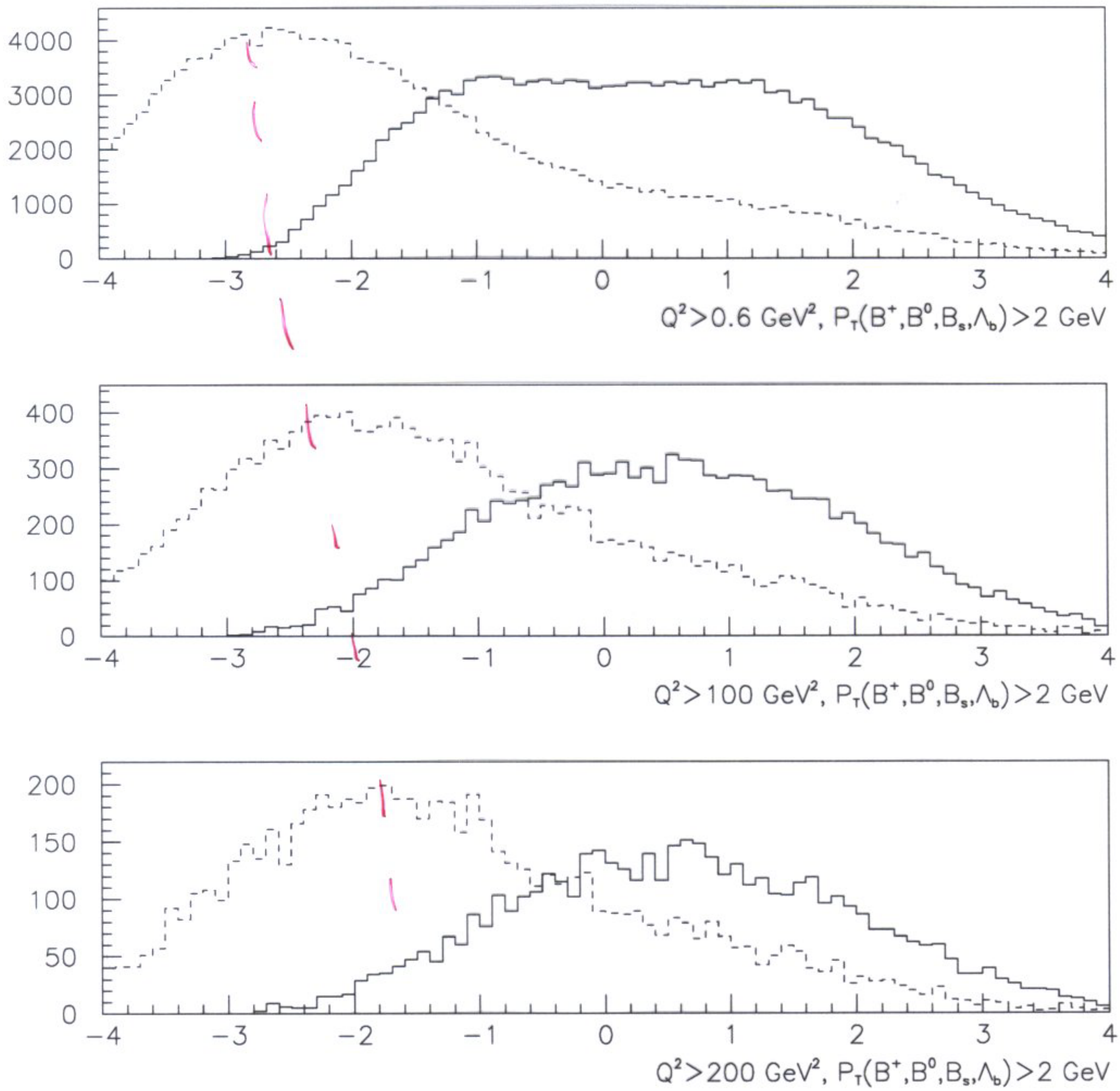
AROMA, GRV94LO, $m_b = 4.75$

$\gamma g \rightarrow b\bar{b}$

- - - - THERA

—— HERA

Beauty in DIS at HERA and THERA



Rear μ-detector !

High Q^2 beauty production

AROMA, NC BGF, GRV94 LO, $m_c = 4.75$

$Q^2 > [GeV^2]$	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
0.6	**0.94**	**4.2**	$\approx$ **4.5**
100.	**0.062**	**0.343**	$\approx$ **5.5**
200.	**0.026**	**0.162**	$\approx$ **6.2**

For $Q^2 > 0.6\,GeV^2$, $P_\perp(B^+, B^0, B_s, \Lambda_c) > 2.0\,GeV$ **:**

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\|\eta(B)\| < 1.5$	**0.89**	**2.1**	$\approx$ **2.3**
$\|\eta(B)\| < 2.5$	**1.3**	**3.9**	$\approx$ **3.1**

For $Q^2 > 100.\,GeV^2$, $P_\perp(B^+, B^0, B_s, \Lambda_c) > 2.0\,GeV$ **:**

	$\sigma_{HERA}[pb]$	$\sigma_{THERA}[pb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\|\eta(B)\| < 1.5$	**73**	**256**	$\approx$ **3.5**
$\|\eta(B)\| < 2.5$	**99**	**444**	$\approx$ **4.5**

For $Q^2 > 200.\,GeV^2$, $P_\perp(B^+, B^0, B_s, \Lambda_c) > 2.0\,GeV$ **:**

	$\sigma_{HERA}[pb]$	$\sigma_{THERA}[pb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\|\eta(B)\| < 1.5$	**31**	**133**	$\approx$ **4.3**
$\|\eta(B)\| < 2.5$	**42**	**225**	$\approx$ **5.4**

$N(\mu^{\pm}) = \sigma \cdot L \cdot BR \cdot ACC = 225\ pb \cdot 100\,pb^{-1} \cdot 0.1 \cdot 0.1 \approx 225\ \mu^{+/-}$

High Q^2 beauty production

AROMA, NC BGF, GRV94 LO, $m_c = 4.75$

For $Q^2 > 2500.\, GeV^2$, $P_\perp(B^+, B^0, B_s, \Lambda_c) > 2.0\, GeV$:

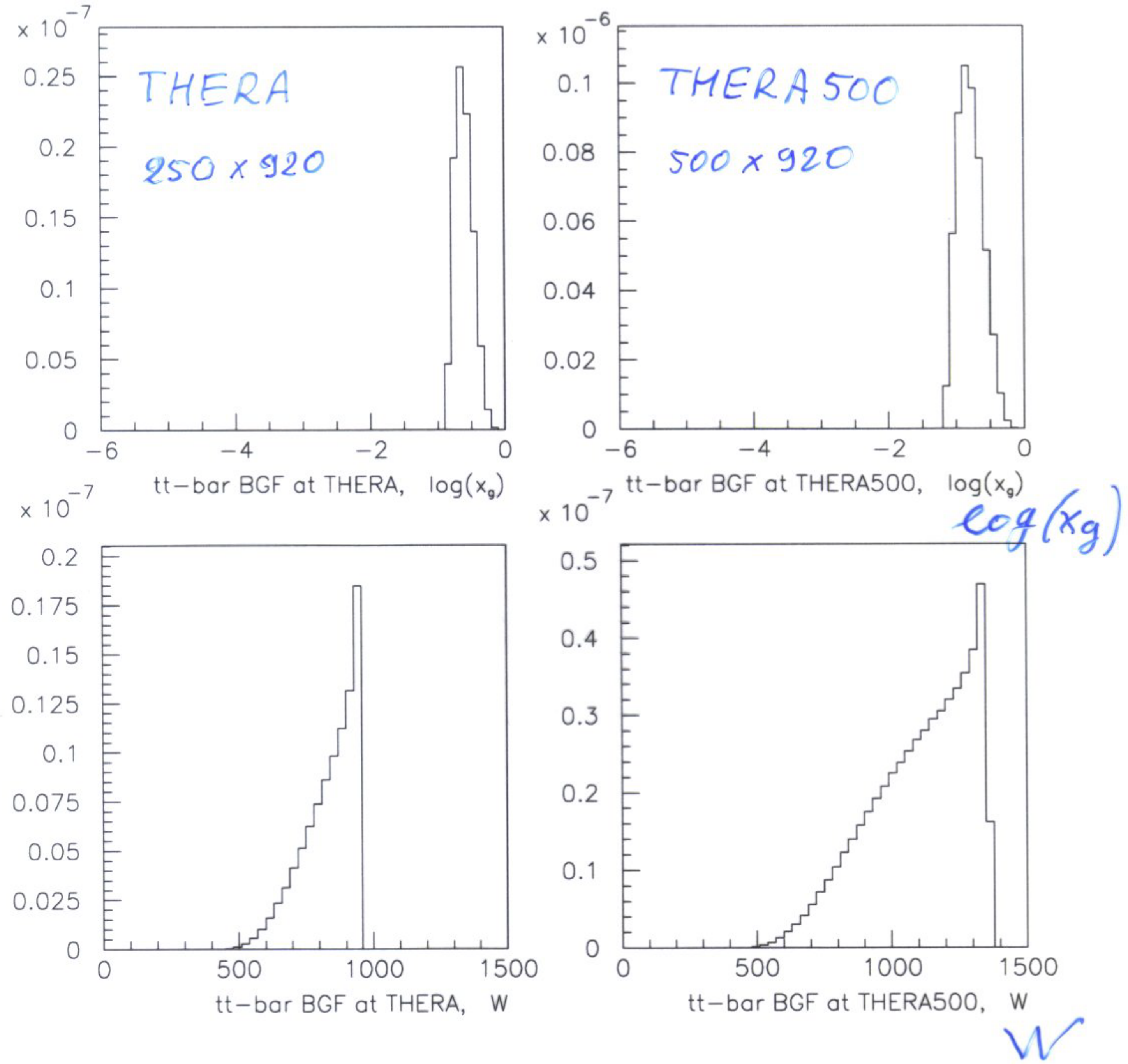
	$\sigma_{HERA}[pb]$	$\sigma_{THERA}[pb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\|\eta(B)\| < 1.5$	**0.35**	**5.0**	$\approx$ **14**
$\|\eta(B)\| < 2.5$	**0.42**	**8.0**	$\approx$ **19**

It is a question of luminosity.

$\gamma g \to t\bar{t}$ $0. < Q^2 < 100.$ GeV "Photoproduction"

NLO QCD (FMNR), MRSG, $m_t = 174$ GeV

Top BGF production at THERA and THERA500



$\sigma^{THERA} \simeq 0.0093$ pb

$\sigma^{THERA500} \simeq 0.053$ pb

⟹ THERA will not serve as t-factory.

Photoproduction

FMNR (NLO), BGF, MRSG, $Q^2 < 100(1) GeV^2$,
$m_c = 1.5$, $m_b = 4.75$

Charm :

	$\sigma_{HERA}[\mu b]$	$\sigma_{THERA}[\mu b]$	$\sigma_{THERA}/\sigma_{HERA}$
FMNR	**0.74**	**2.5**	$\approx$ **3.4**

FMNR for $P_\perp(c) > 2.0\, GeV$:

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\lvert\eta(c)\rvert < 2.0$	**119**	**289**	$\approx$ **2.4**
$\lvert\eta(c)\rvert < 3.5$	**150**	**506**	$\approx$ **3.4**

Beauty :

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
FMNR	**4.0**	**18.9**	$\approx$ **4.7**
HERWIG 5.9	**4.6**	**23.8**	$\approx$ **5.1**
PYTHIA 5.7	**6.9**	**35.3**	$\approx$ **5.2**

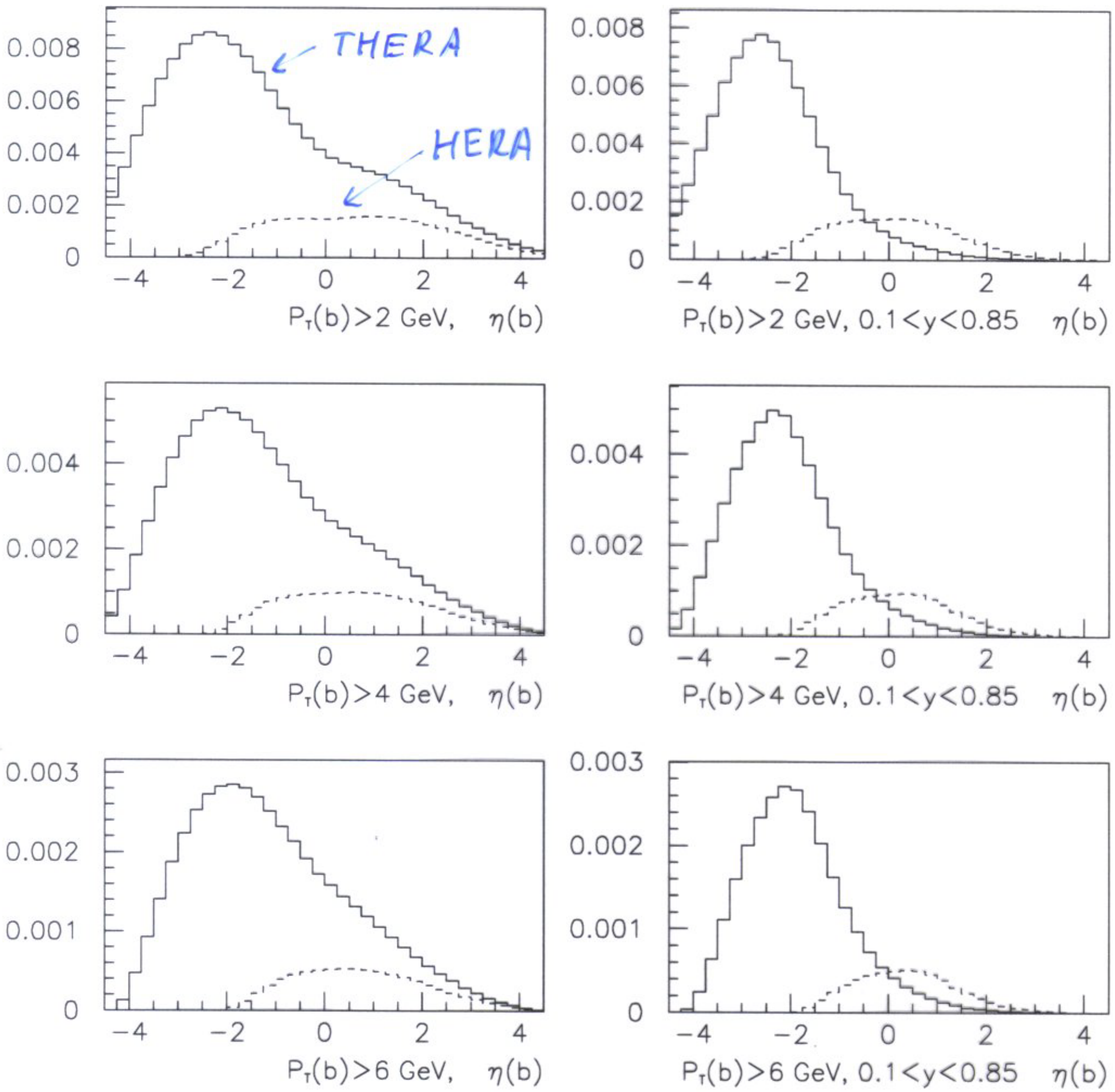
FMNR for $P_\perp(b) > 5.0\, GeV$:

	$\sigma_{HERA}[nb]$	$\sigma_{THERA}[nb]$	$\sigma_{THERA}/\sigma_{HERA}$
$\lvert\eta(b)\rvert < 2.0$	**0.93**	**3.74**	$\approx$ **4.0**
$\lvert\eta(b)\rvert < 3.5$	**1.12**	**6.01**	$\approx$ **5.4**

$\gamma g \to b\bar{b}$ $0. < Q^2 < 100.$ GeV^2

NLO QCD (FMNR), MRSG, $m_b = 4.75$

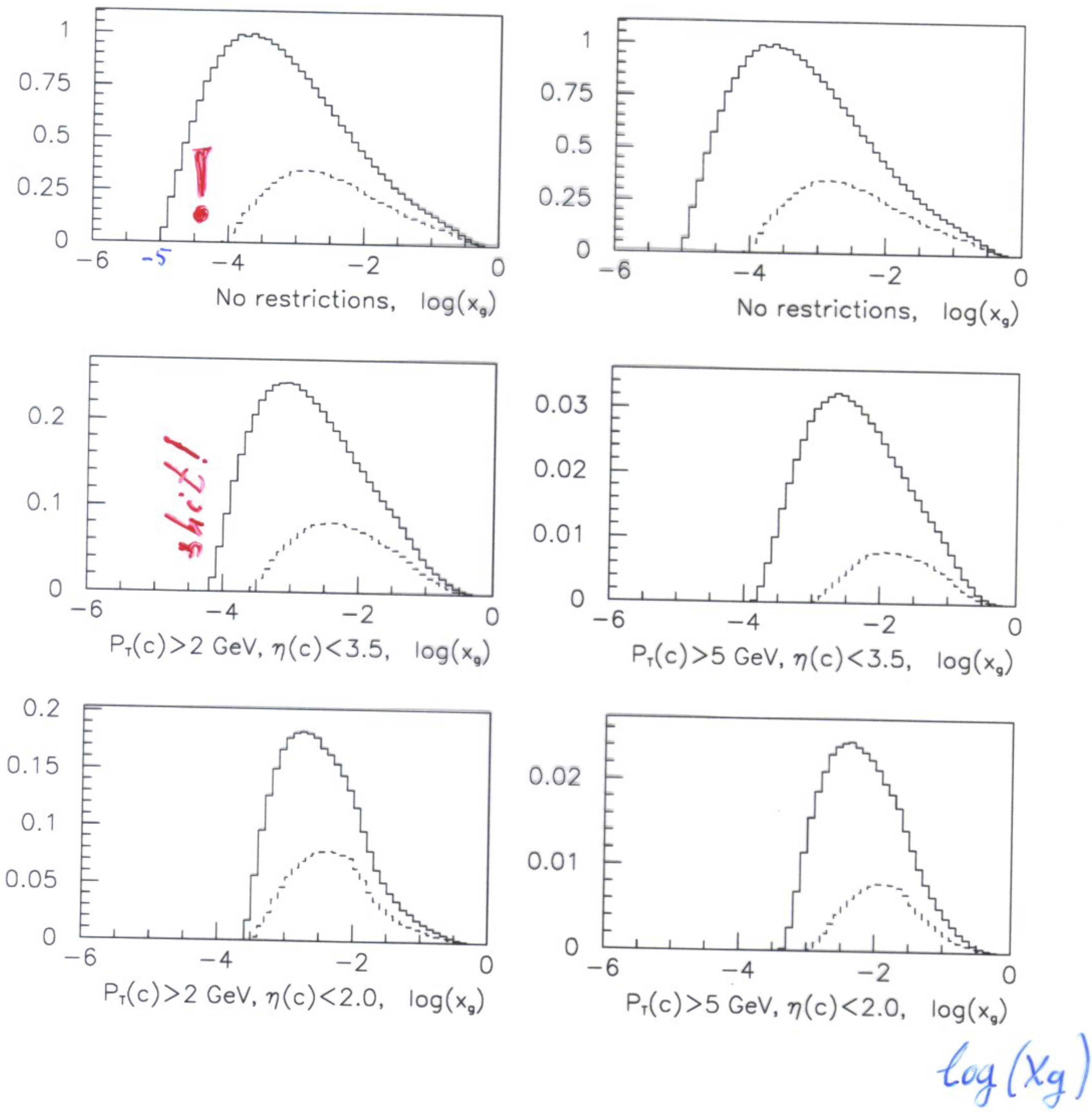
Beauty BGF production at HERA and THERA



$\gamma g \to c\bar{c}$; $0. < Q^2 < 100.$ GeV^2

NLO QCD (FMNR), MRSG, $m_c = 1.5$

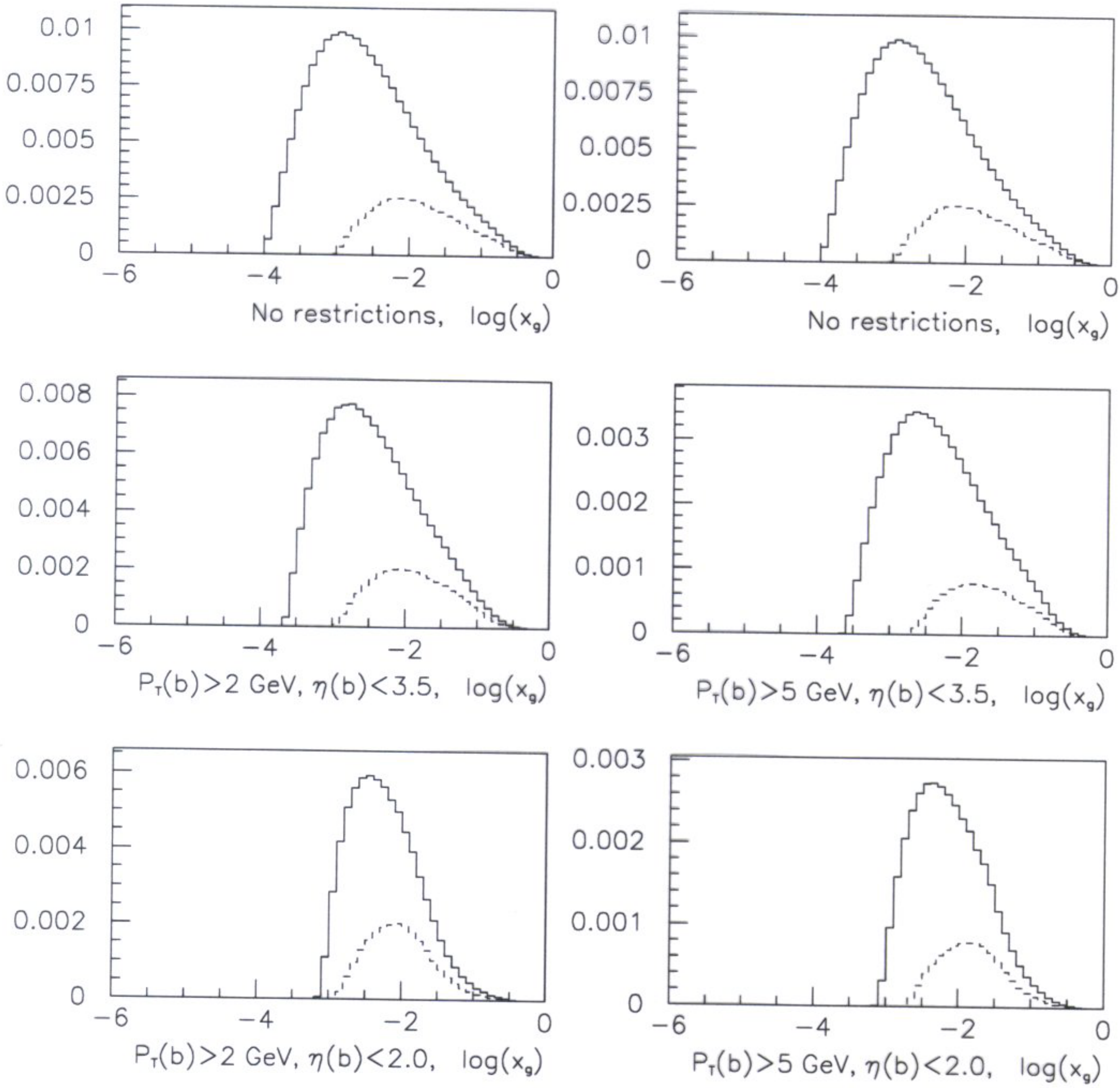
Charm BGF production at HERA and THERA



$\gamma g \to b\bar{b}$; $0. < Q^2 < 100.\ GeV^2$

NLO QCD (FMNR), MRSG, $m_b = 4.75$

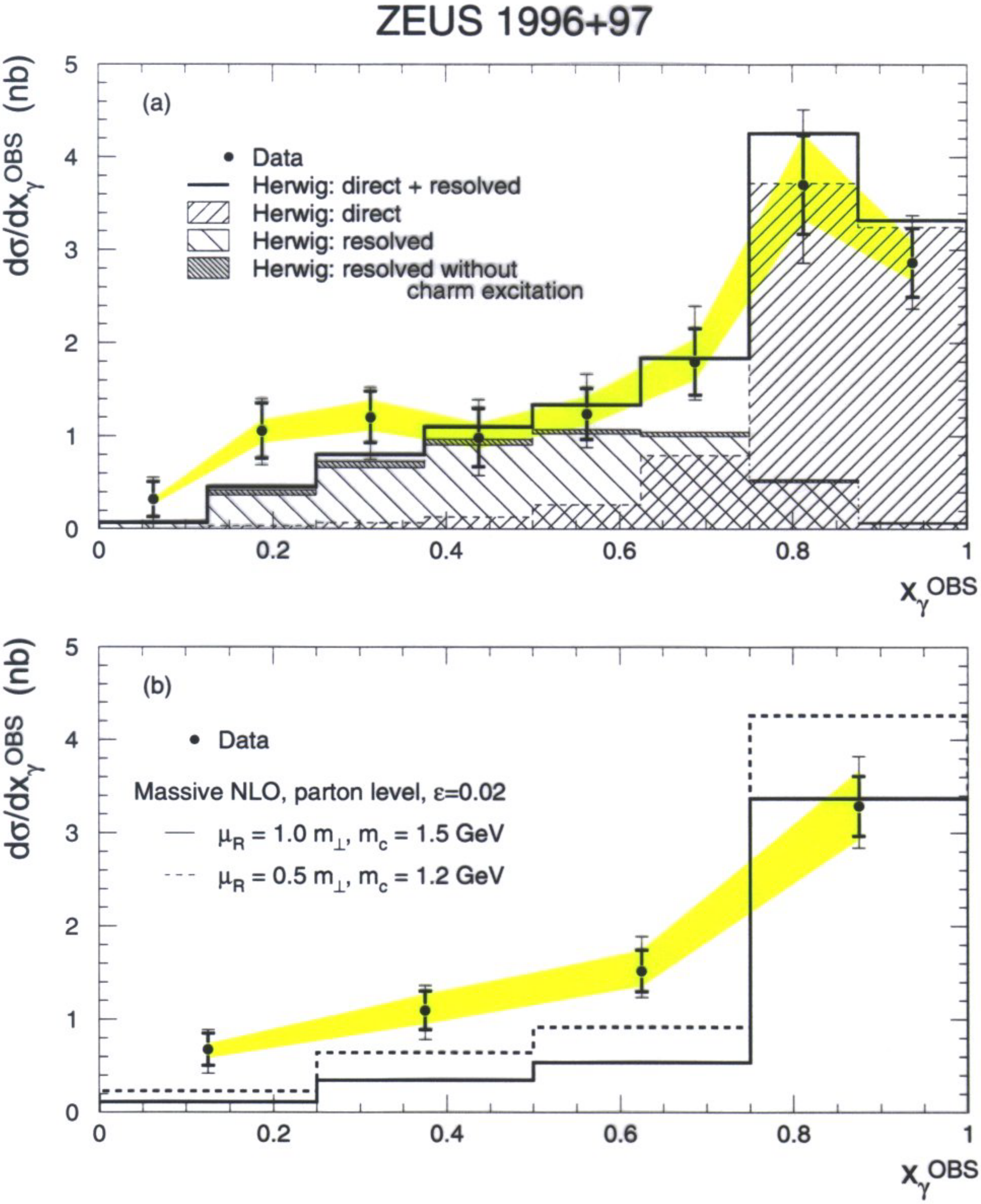
Beauty BGF production at HERA and THERA



$\log(x_g)$

Cross-Section $d\sigma(ep \to D^{*\pm}X)/dx_{\gamma}^{OBS}$

$E_T^{jet1} > 7.0\,GeV$ and $E_T^{jet2} > 6.0\,GeV$

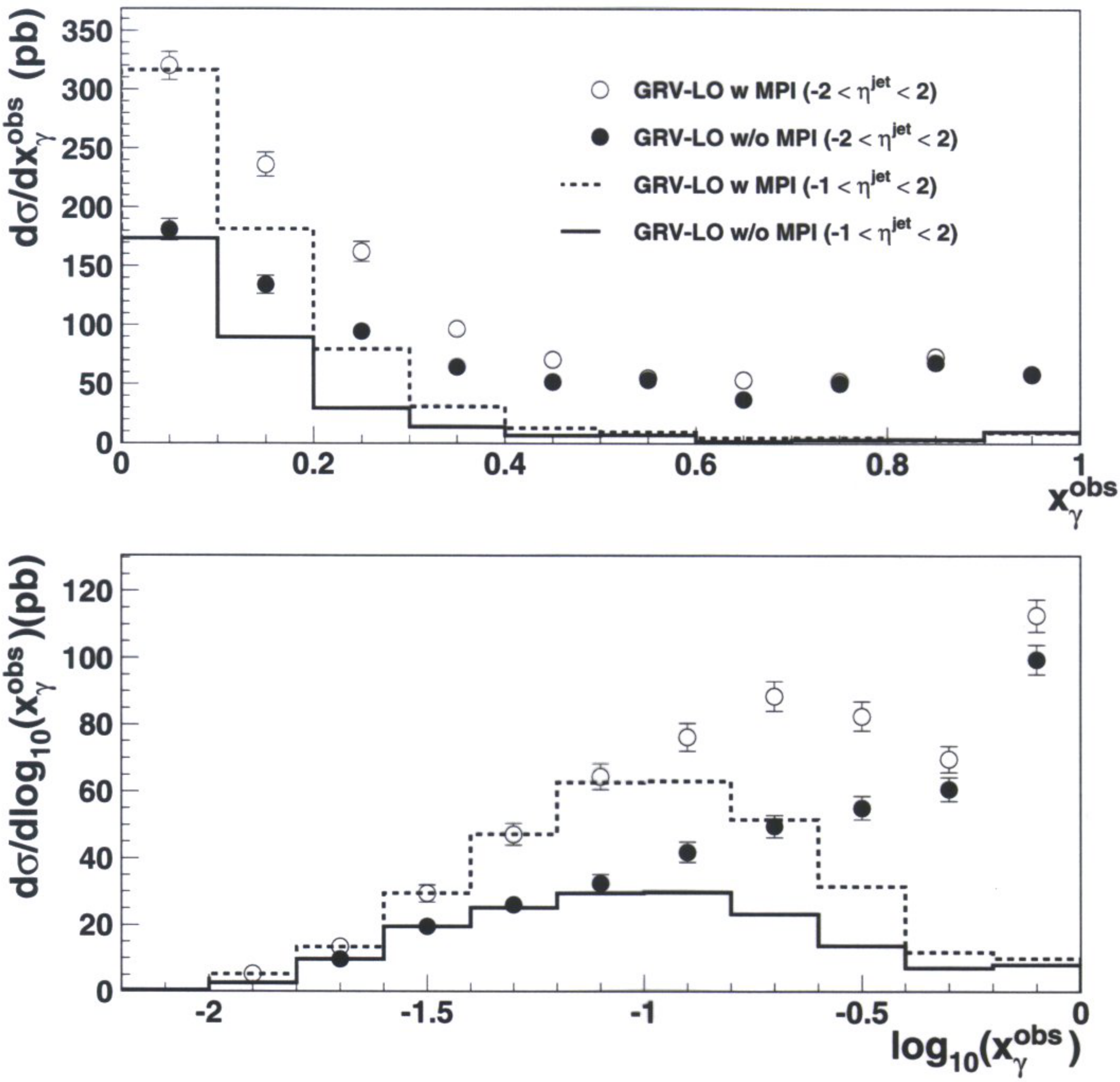


LO Charm Excitation in the Photon ($\sim 45\,\%$)

Massive NLO are below the DATA at $x_{\gamma}^{OBS} < 0.75$ (NNLO ?)

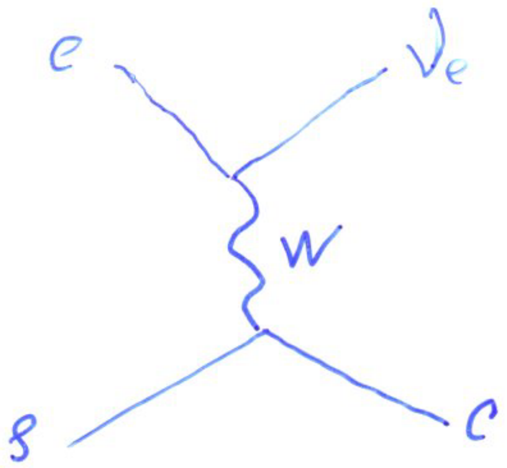
Resolved Processes

Beauty at THERA, two jets and μ in final state; HERWIG 5.9:

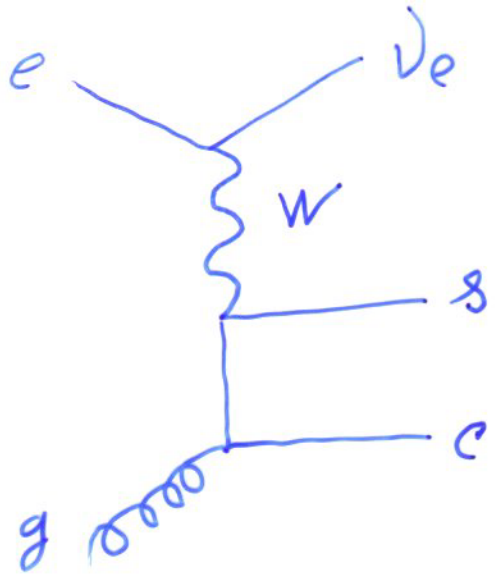


sensitivity to x_γ^{obs} till 10^{-2};
central production;
(c,b,g) content of photon;
multi-parton interactions.

Charge Current Charm Production.



	HERA	THERA	$\sigma_{THERA}/\sigma_{HERA}$
PYTHIA	4.4 pb		
HERWIG	3.7 pb	23 pb	≈ 6.2

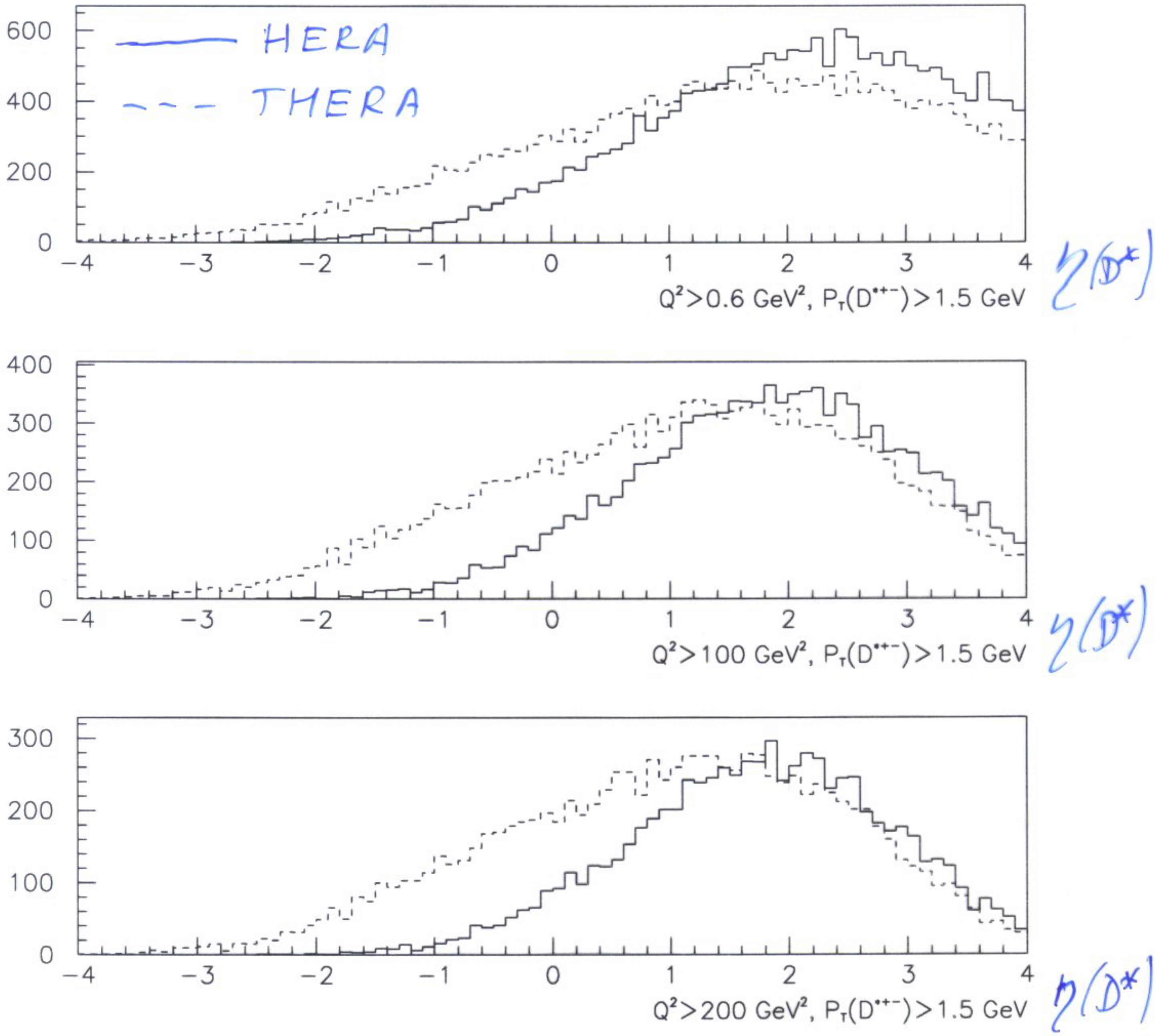


	HERA	THERA	$\sigma_{THERA}/\sigma_{HERA}$
HERWIG	7.8 pb	48 pb	≈ 6.2
AROMA	65 pb (?)	770 pb (?)	

Wg → s̄c AROMA, GRV94LO, $m_c = 1.5$

more central at THERA!

CC BGF at HERA and THERA



Looks like THERA can measure this process better than HERA.

... more studies are needed

First Conclusions

- **THERA will provide HQ measurements at high Q^2 and high $P_\perp$ values. Proper place to varify ressumed NLO calculations.**
- **THERA is more competetive with HERA in beauty sector.**
- **x_g range till 10^{-5} is kinematically available but hardly measurable. 10^{-4} is more realistic.**
- **Rear tracking (in addition to central, of course,) is crucial for charm studies.**
- **Rear μ-detector (in addition to central, of course,) is crucial for beauty studies.**
- **THERA is great machine for resolved processes and photon structure (g, c, b) measurements.**