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Dijet Photoproduction and Photon Structure at TERA

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and

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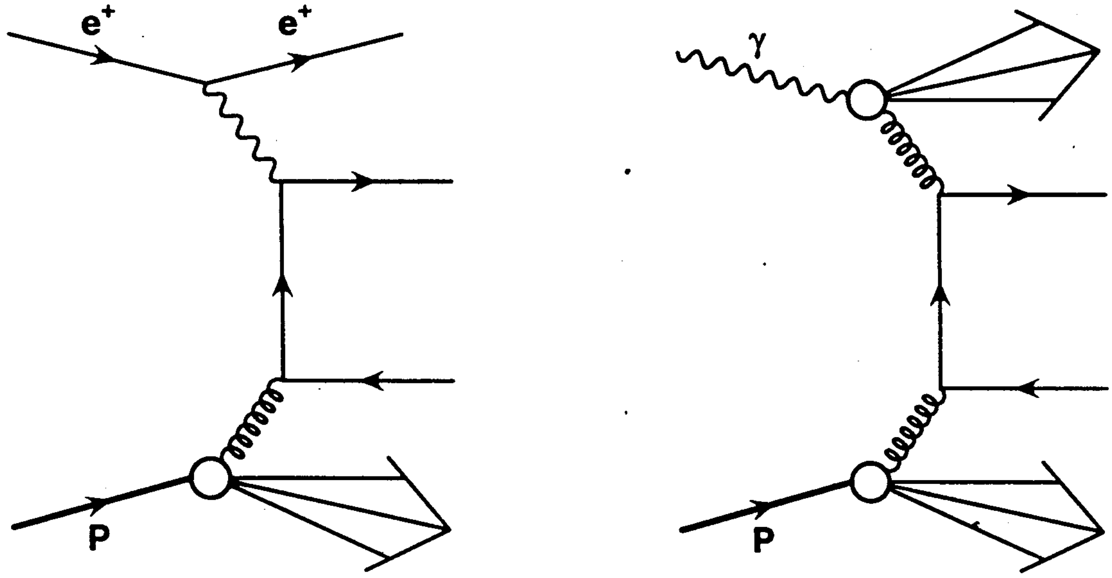
TERA Workshop

9 February 2000

M. Krawczyk

Introduction to Photoproduction

Leading Order (LO) picture:



Direct Resolved

Resolved cross-section

$$d\sigma_{\gamma p\to cd} = \sum_{ab}\int_{x_p}\int_{x_\gamma} f_{p\to b}(x_p,\mu^2) f_{\gamma\to a}(x_\gamma,\mu^2)\mathcal{M}_{ab\to cd}$$

$\mu^2 \Rightarrow$ scale $\to (E_T^{\text{jet}})^2$

$\mathcal{M}_{ab\to cd} \Rightarrow$ perturbatively calculable

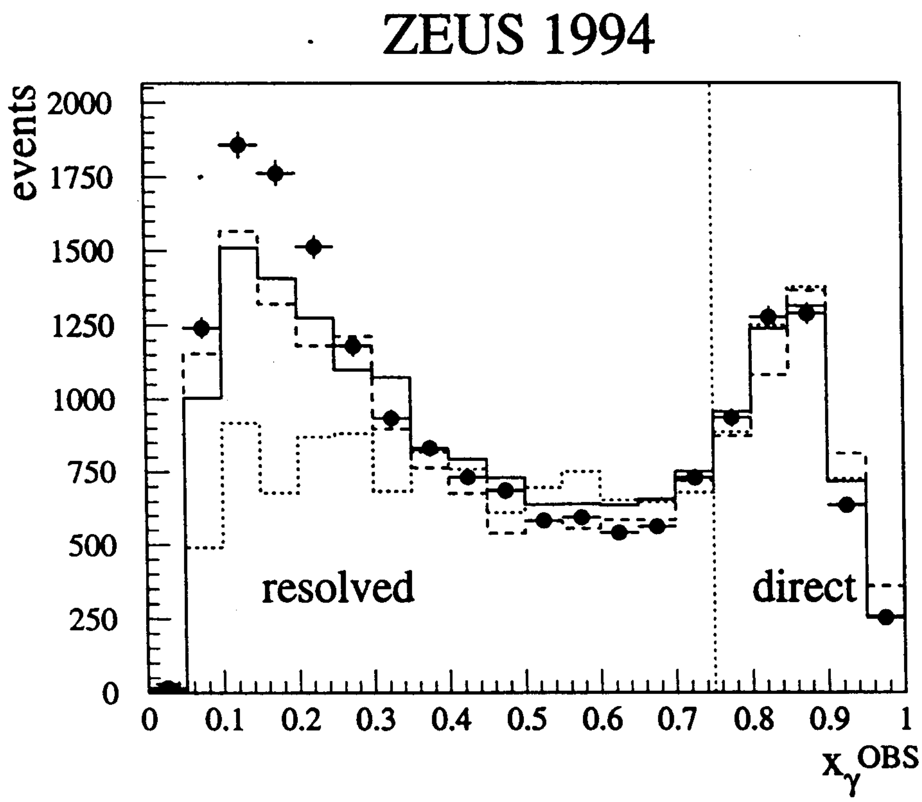
$f_{p\to b} \Rightarrow$ experimentally constrained

$f_{\gamma\to a} \Rightarrow$ photon structure?

Dijet photoproduction at HERA; lower E_T^{jet}

Here $E_T^{\text{jet}} > 6$ GeV, data compared with MC:

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



- Large resolved photon cross-section.

BUT:

- Need additional soft physics model to "describe" data.
- Additional soft physics is obstacle to photon structure sensitivity.
- Answer: goto higher E_T^{jet}

Cross-Sections in x_γ^{obs} THERA

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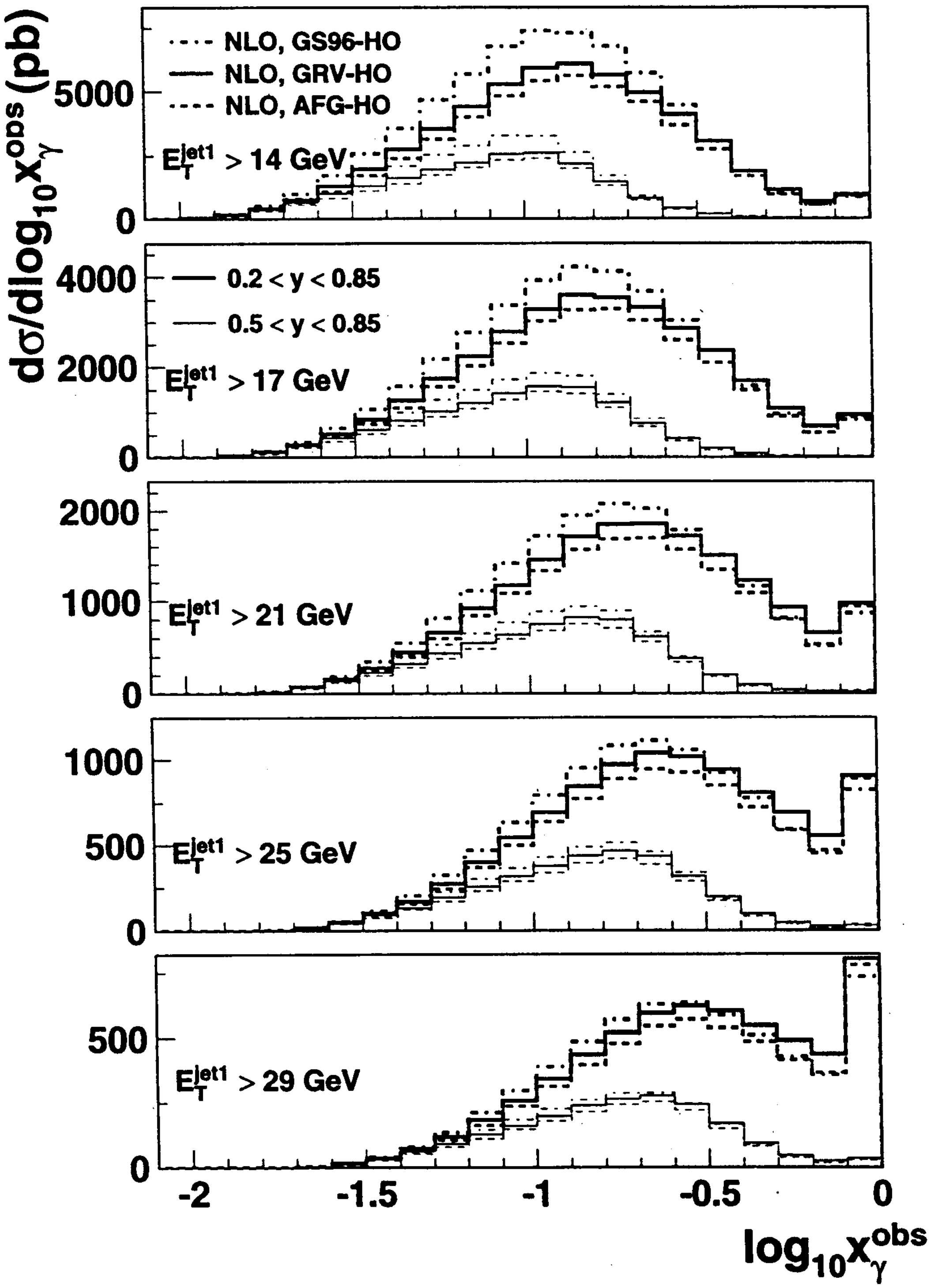
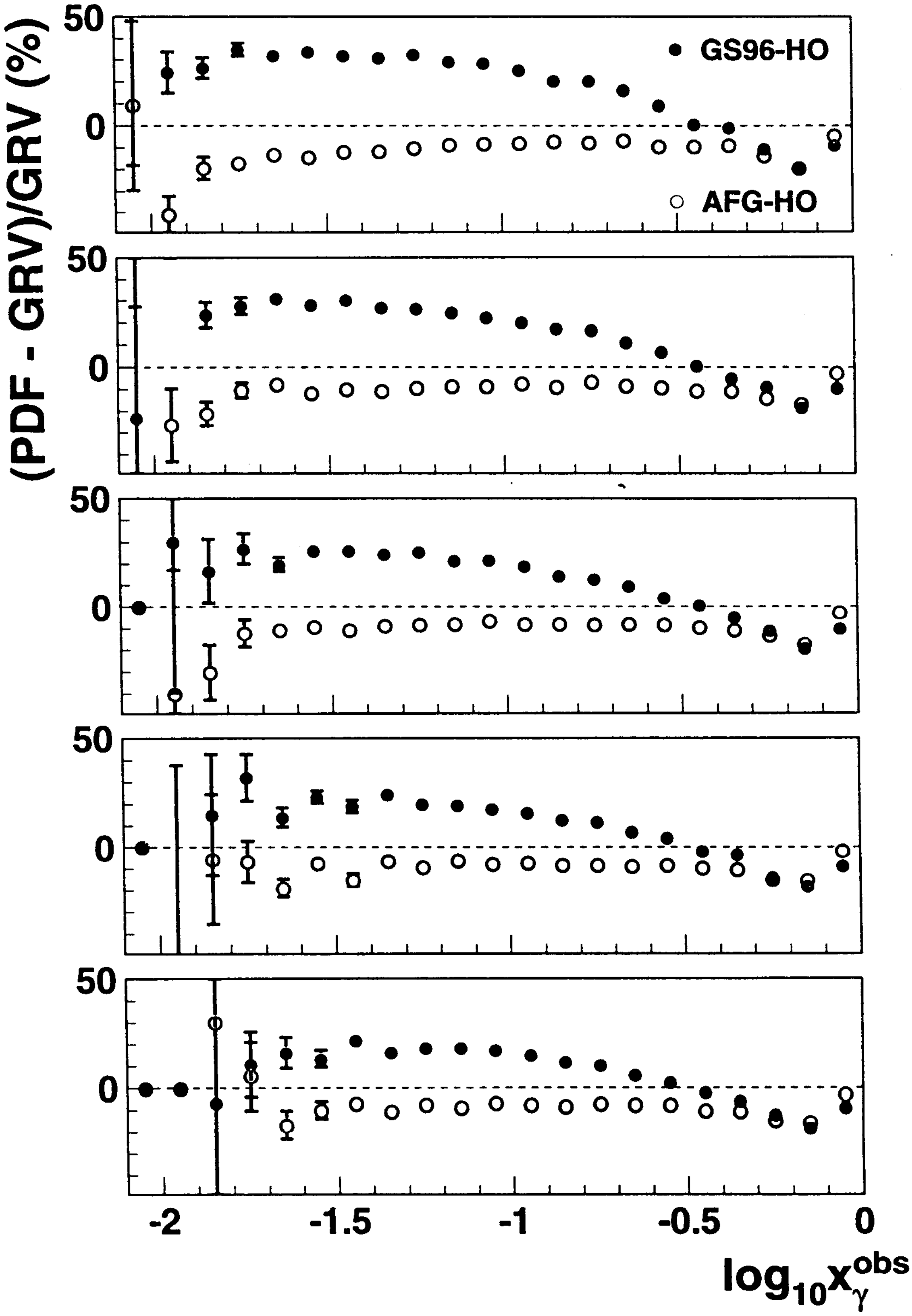
$$x_\gamma^{obs} = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2yE_e}$$



- Large cross-section at low x_γ^{obs}.
- Large variation due to structure function particularly at lower E_T^{jet}.

Differences in PDF

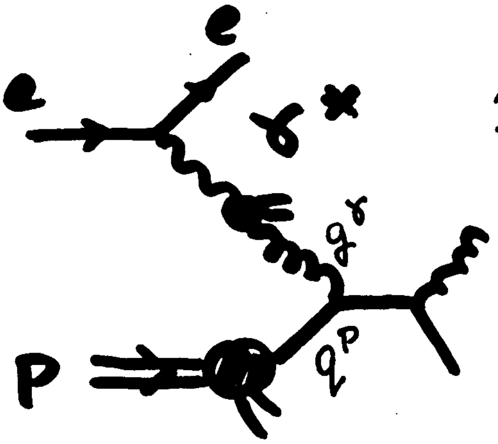
Look at differences with respect to GRV-HO.



- GS96-HO about 30% higher at low x_γ^{obs}. Difference decreasing with increasing x_γ^{obs}.

- AFG-HO generally 10% lower than GRV-HO.

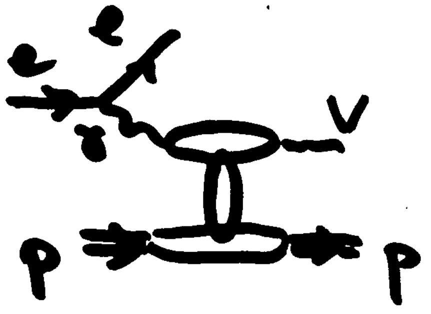
PHOTOPRODUCTION at THERA



inclusive photoproduction

$\uparrow p_T$ → structure of γ and γ^* (resolved photon processes)

- dijet
- heavy quark
- prompt photon ↳ g^{γ^*}



exclusive photoproduction

- $\gamma p \to V p$ ← $\rho, \omega, \ldots$
- $\gamma p \to \pi^0, \eta, \eta', \eta_c, \ldots, p$ (IG)

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M. Wing	I. Ginzburg
S. Söldner-Rembold	M. K.
M. Klasen	F. Cornet
B. Surrow	⋮
A. de Roeck	
P. Jankowski	
A. Zembrzuski	

(LOW) Q^2 RANGE AT THERA

* PHOTOPRODUCTION AT HERA:

UNTAGGED $Q^2 < 1\,GeV^2$

$Q^2_{median} \sim 10^{-3}\,GeV^2$

* AT THERA: (ASSUMING SIMILAR DETECTOR CONFIGURATIO

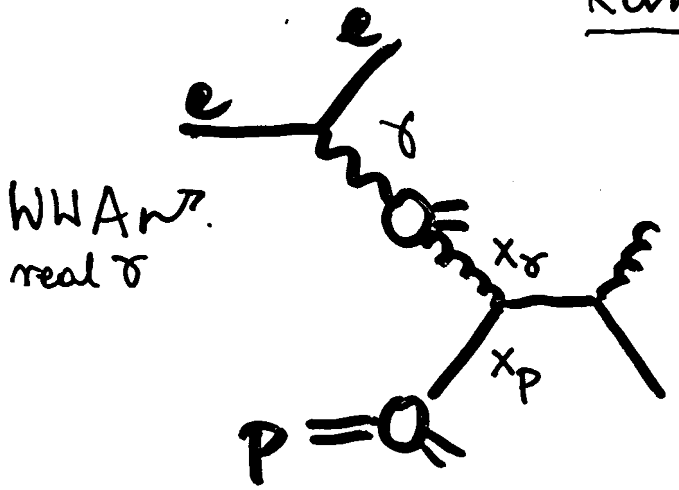
UNTAGGED $Q^2 \lesssim 100\,GeV^2$

$Q^2_{median} \sim 10^{-2}\,GeV^2$ (?)

$\Rightarrow$ TWO SCALE PROBLEM!!

* NEED TO INVESTIGATE HAVING A (LOW Q^2) TAGGER. *

Range of x_γ at THERA



$E_\gamma = y E_e$

↑ p_T

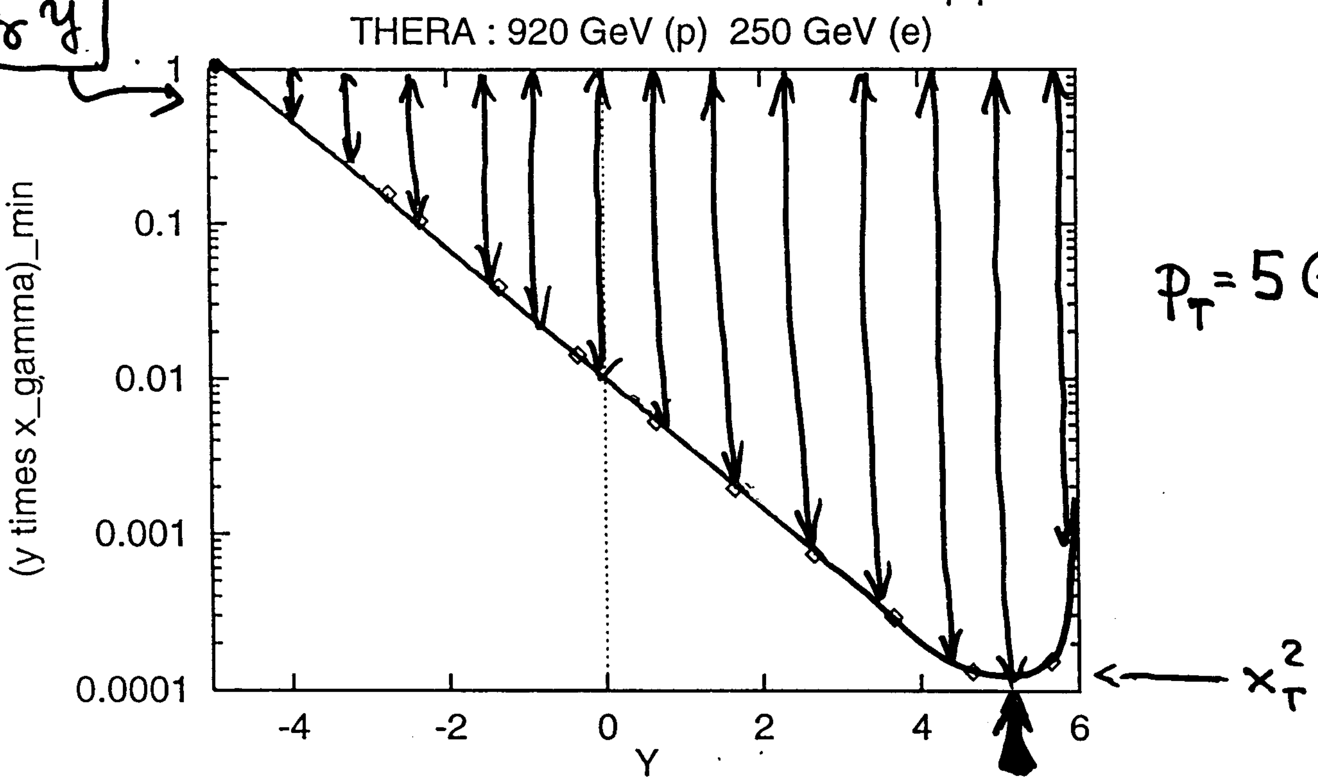
$5 \lesssim p_T \lesssim 100$G

$-4.6 \lesssim Y \lesssim 5.9$

rapidity range (p_T=5

$$x_p x_\gamma y S_{ep} \geq (2 p_T)^2 \rightarrow (x_\gamma y)_{min} = x_T^2$$

range of $x_\gamma y$



$p_T = 5$ GeV

min $x_\gamma = 0.0001$

(at $Y_0 \sim 5.2$) (y=1)

U.Katz → θ=0.5° ↔

Y = 5.43!

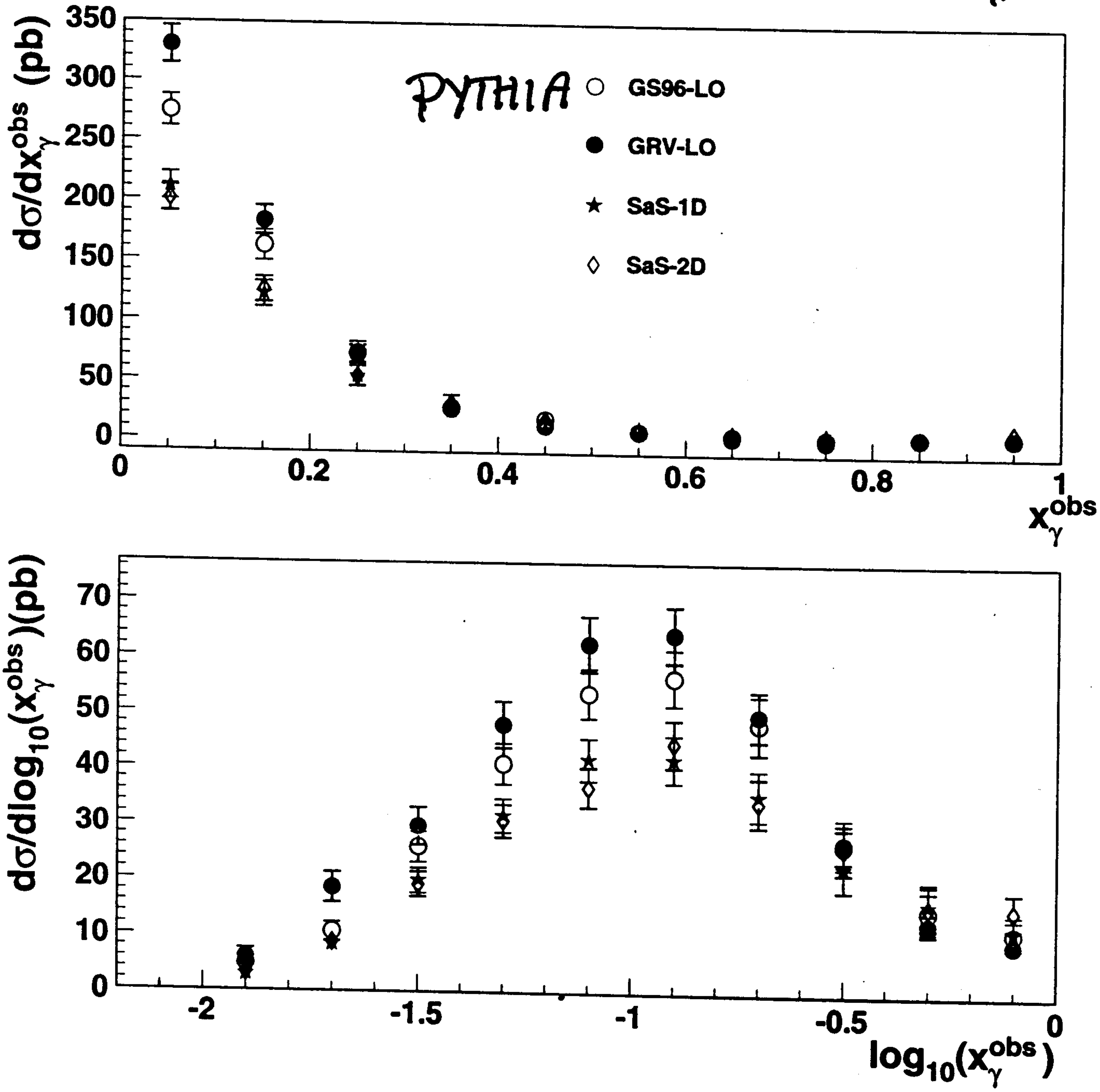
(max exp)

Heavy quark production at THERA

MC $b\bar{b} \to \mu$ PRODUCTION

M. WING

SENSITIVITY TO CHOICE OF PHOTON PDF.



* SIMILAR RESULTS FOR HERWIG
* BUT MULTIPARTON INTERACTIONS COULD PLAY A RÔLE.

LO : c, b, τ

NOWE
P. Jankowski

Heavy quark production in TERA, $E_p = 920$ GeV, $E_e = 250$ GeV

The calculation was made in LO approximation. Though we used HO parametrization functions:

- photon - GRVHO: M.Glück, E.Reya and A.Vogt, Phys.Rev. D46 (1992) 1973
- proton - MRS(G): A.D.Martin, W.J.Stirling and R.G.Roberts, Phys.Lett. B354 (1995) 155-162

as it was done in following work:
B.A.Kniehl, M.Krämer, G.Kramer and M.Spira, Phys. Lett. B356 (1995) 539-545; hep-ph/9505410

We utilized two schemes for heavy quarks treatment:

- FFNS - with only light quarks active
- VFNS - with the number of active quarks depending on the process energy scale (here it doesn't change as the total cross-sections are always computed in FFNS and $p_T = const$ in case of differential cross-sections)

We used two loop formula for α_s and the WW function of Equivalent Photons Approximation.

Each total cross-section was calculated with various values of the process energy scale μ and various values of masses of the heavy quarks. Also we did our computation with and without a cut on the part of electron energy carried by the photon y.

FFNS

HERA

μ^2:	$1/4(p_T^2 + m_c^2)$	$p_T^2 + m_c^2$	$4(p_T^2 + m_c^2)$
$m_c = 1.2$ GeV	632	825	939
$m_c = 1.5$ GeV	602	694	732
$m_c = 1.8$ GeV	386	425	438

(c)

Table 1: HERA: $E_p =$ [illegible]20 GeV, $E_e = 27.5$ GeV. All values in **nb**. LO calculated $\sigma(ep \rightarrow cc/\bar{c}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0 < y < 1$

THERA

μ^2:	$1/4(p_T^2 + m_c^2)$	$p_T^2 + m_c^2$	$4(p_T^2 + m_c^2)$
$m_c = 1.2$ GeV	2956	4315	5368
$m_c = 1.5$ GeV	1571	2126	2532
$m_c = 1.8$ GeV	899	1146	1317

(c) nb

Table 2: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **nb**. LO calculated $\sigma(ep \to ec/\bar{c}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0 < y < 1$

μ^2:	$1/4(p_T^2 + m_c^2)$	$p_T^2 + m_c^2$	$4(p_T^2 + m_c^2)$
$m_c = 1.2$ GeV	866	1423	1928
$m_c = 1.5$ GeV	505	749	957
$m_c = 1.8$ GeV	315	432	526

Table 3: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **nb**. LO calculated $\sigma(ep \to ec/\bar{c}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0.15 < y < 0.86$

μ^2:	$1/4(p_T^2 + m_b^2)$	$p_T^2 + m_b^2$	$4(p_T^2 + m_b^2)$
$m_b = 4.25$ GeV	30.6	30.5	29.8
$m_b = 4.5$ GeV	26.1	25.9	25.2
$m_b = 4.75$ GeV	22.4	22.1	21.5

(b) nb

Table 4: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **nb**. LO calculated $\sigma(ep \to eb/\bar{b}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0 < y < 1$

μ^2:	$1/4(p_T^2+m_b^2)$	$p_T^2+m_b^2$	$4(p_T^2+m_b^2)$
$m_b = 4.25$ GeV	14.1	14.6	14.7
$m_b = 4.5$ GeV	12.1	12.5	12.6
$m_b = 4.75$ GeV	10.5	10.8	10.8

Table 5: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **nb**. LO calculated $\sigma(ep \to eb/\bar{b}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0.15 < y < 0.86$

t

μ^2:	$1/4(p_T^2+m_t^2)$	$p_T^2+m_t^2$	$4(p_T^2+m_t^2)$
$m_t = 170$ GeV	0.01264	0.00995	0.00801
$m_t = 174$ GeV	0.01041	0.00818	0.00657
$m_t = 178$ GeV	0.00858	0.00672	0.00539

pb

Table 6: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **pb**. LO calculated $\sigma(ep \to et/\bar{t}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0 < y < 1$

μ^2:	$1/4(p_T^2+m_t^2)$	$p_T^2+m_t^2$	$4(p_T^2+m_t^2)$
$m_t = 170$ GeV	0.00880	0.00686	0.00548
$m_t = 174$ GeV	0.00715	0.00556	0.00443
$m_t = 178$ GeV	0.00581	0.00451	0.00359

Table 7: TERA: $E_p = 920$ GeV, $E_e = 250$ GeV. All values in **pb**. LO calculated $\sigma(ep \to et/\bar{t}X)$. GRVHO and MRS(G)HO parametrizations of the real photon and proton were used. $0.15 < y < 0.86$

direct / resolved

P. Jankowski

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$ep \to c/\bar{c}\,X$ (THERA)

$p_T = 10$ GeV

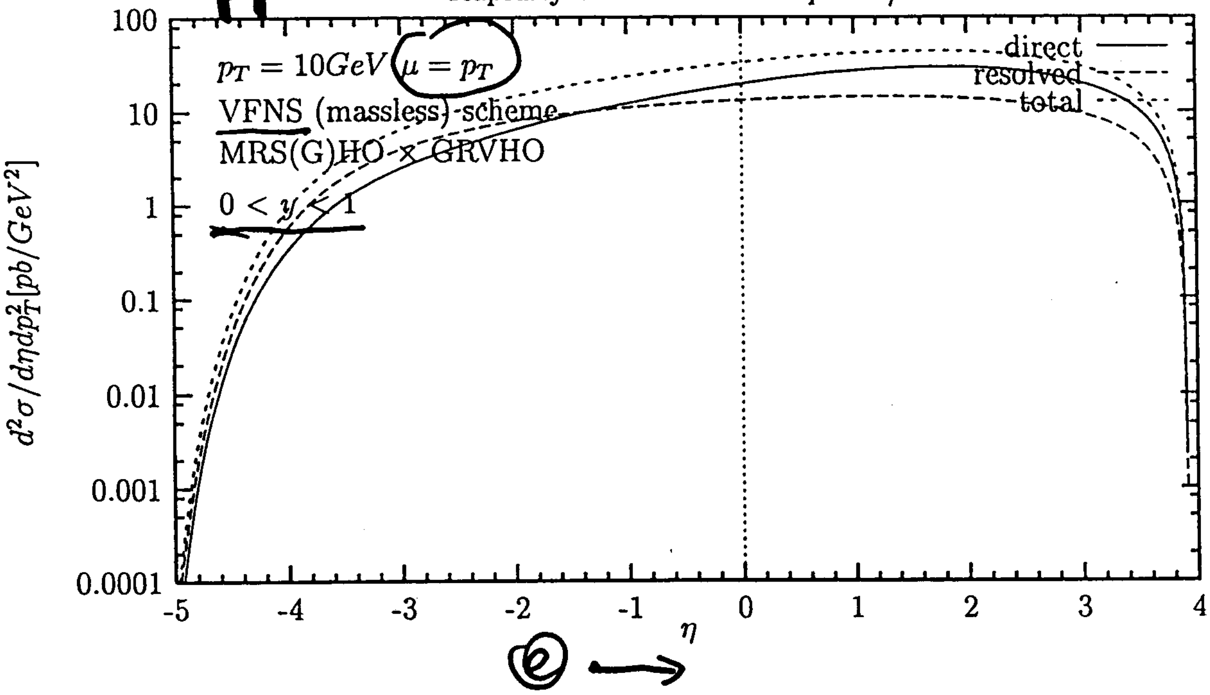


Figure 3: $c/\bar{c}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

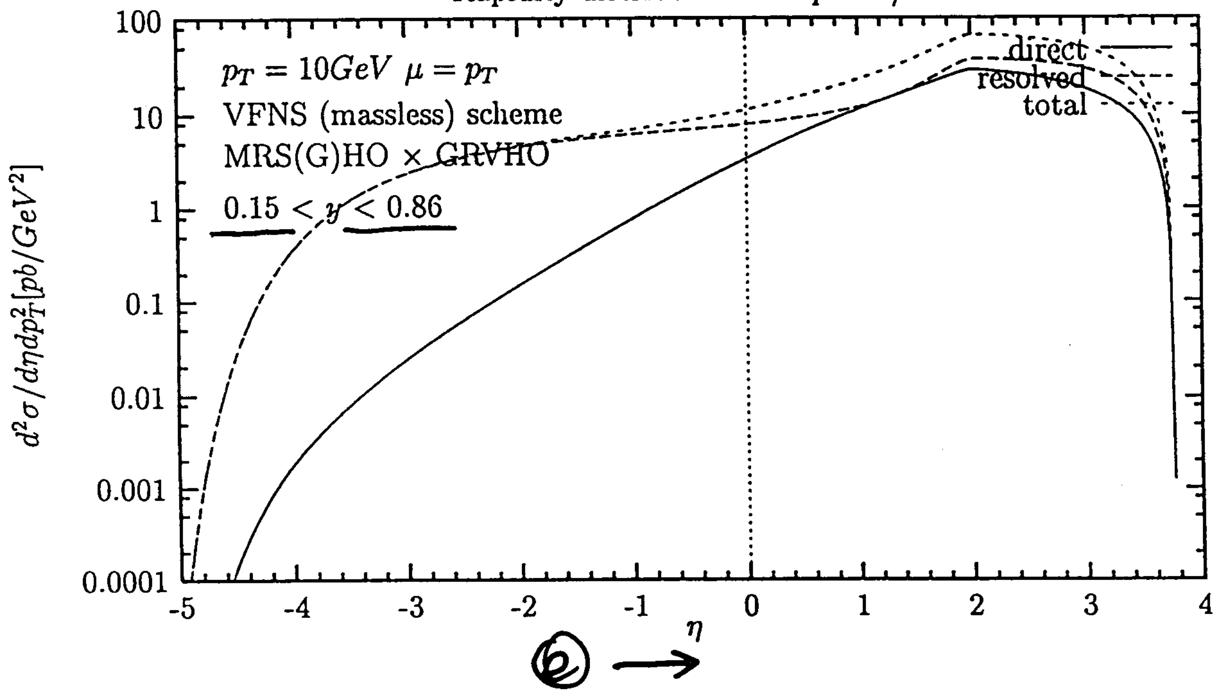


Figure 4: $c/\bar{c}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

(C)

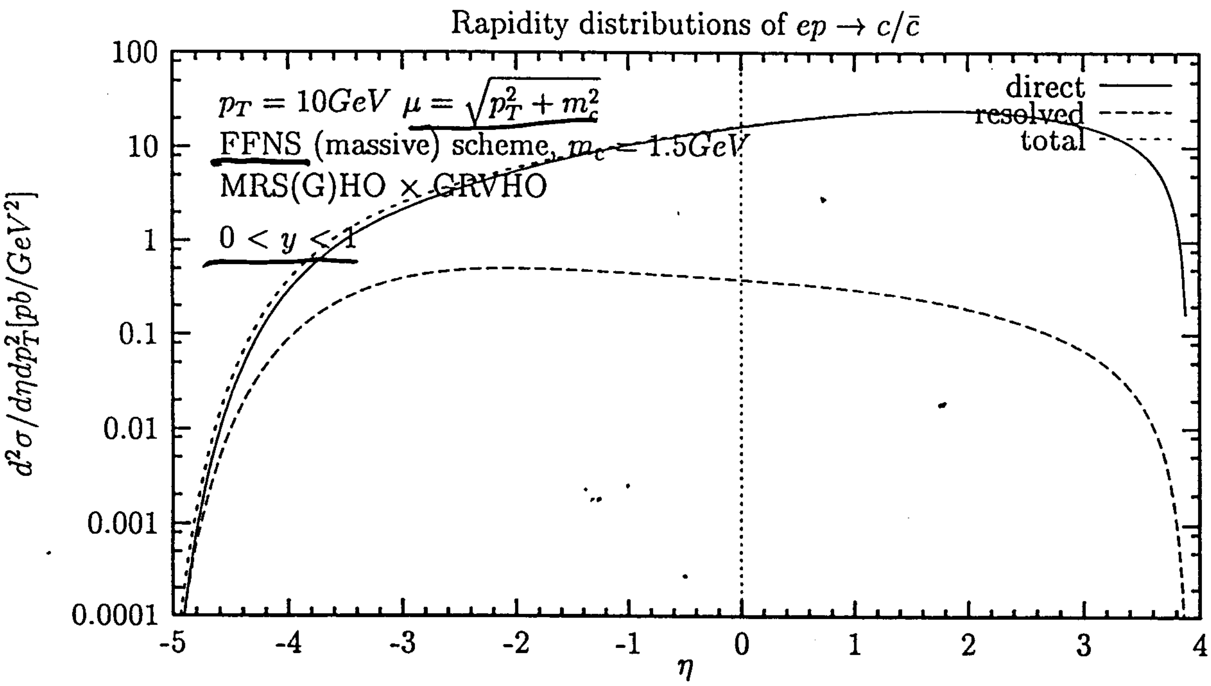


Figure 1: $c/\bar{c}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

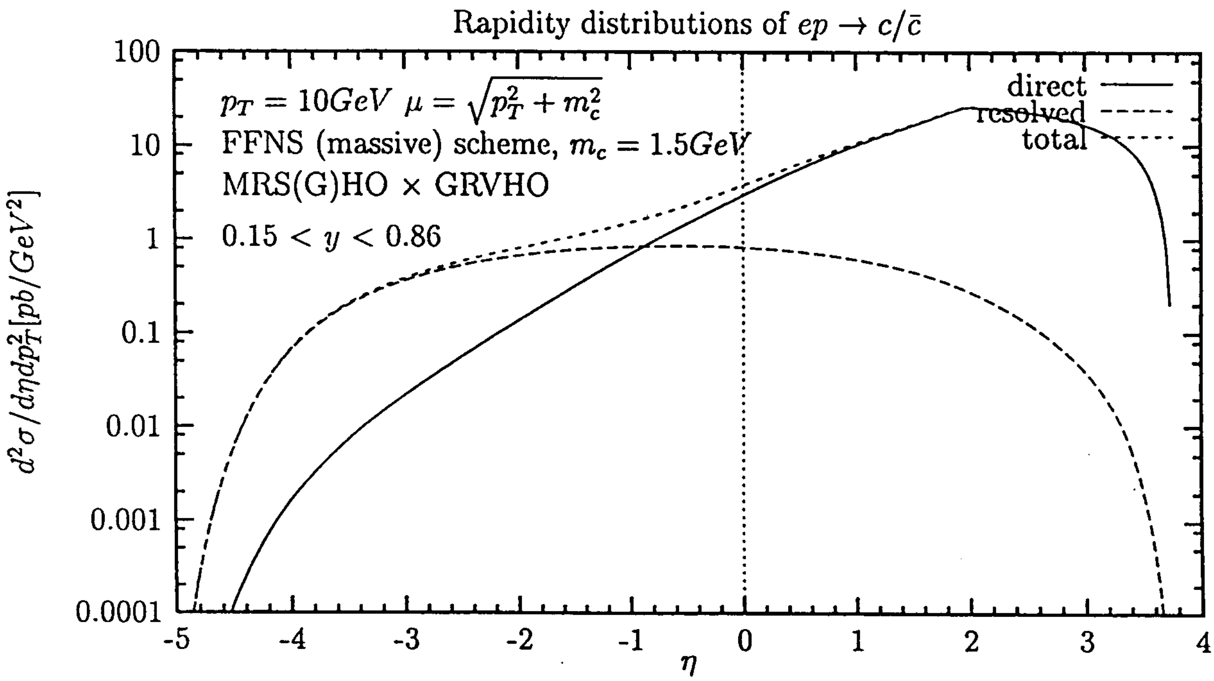


Figure 2: $c/\bar{c}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

(b) $P_T = 10$ GeV

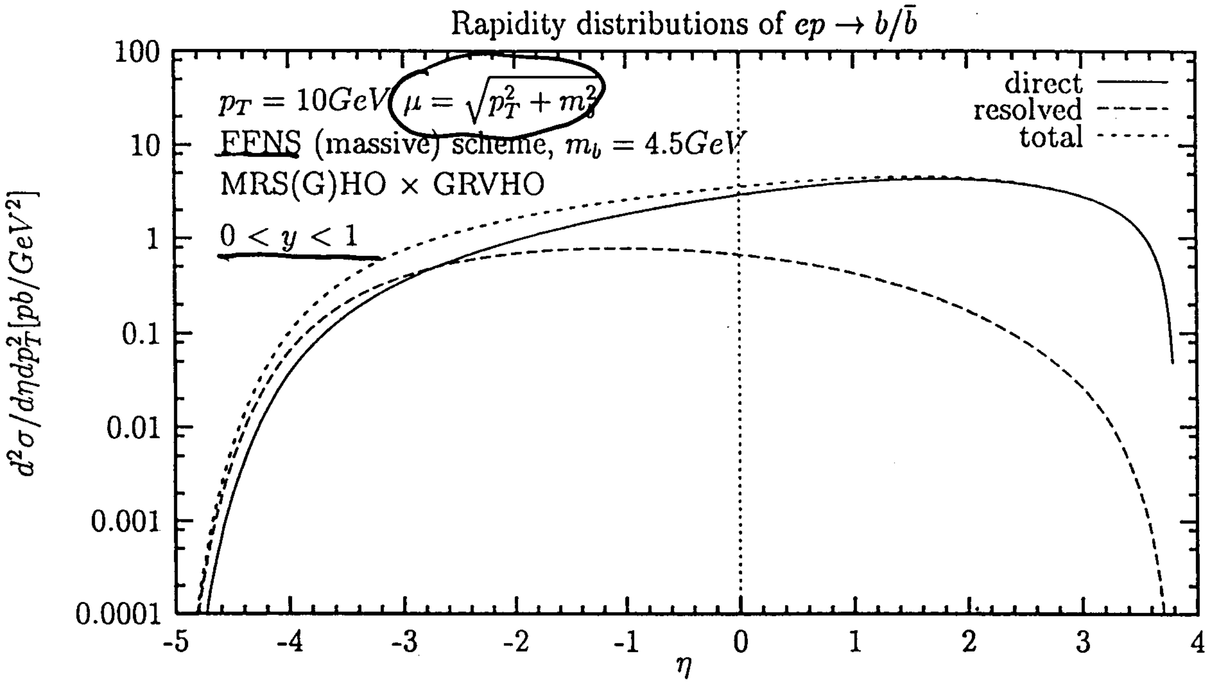


Figure 5: $b/\bar{b}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

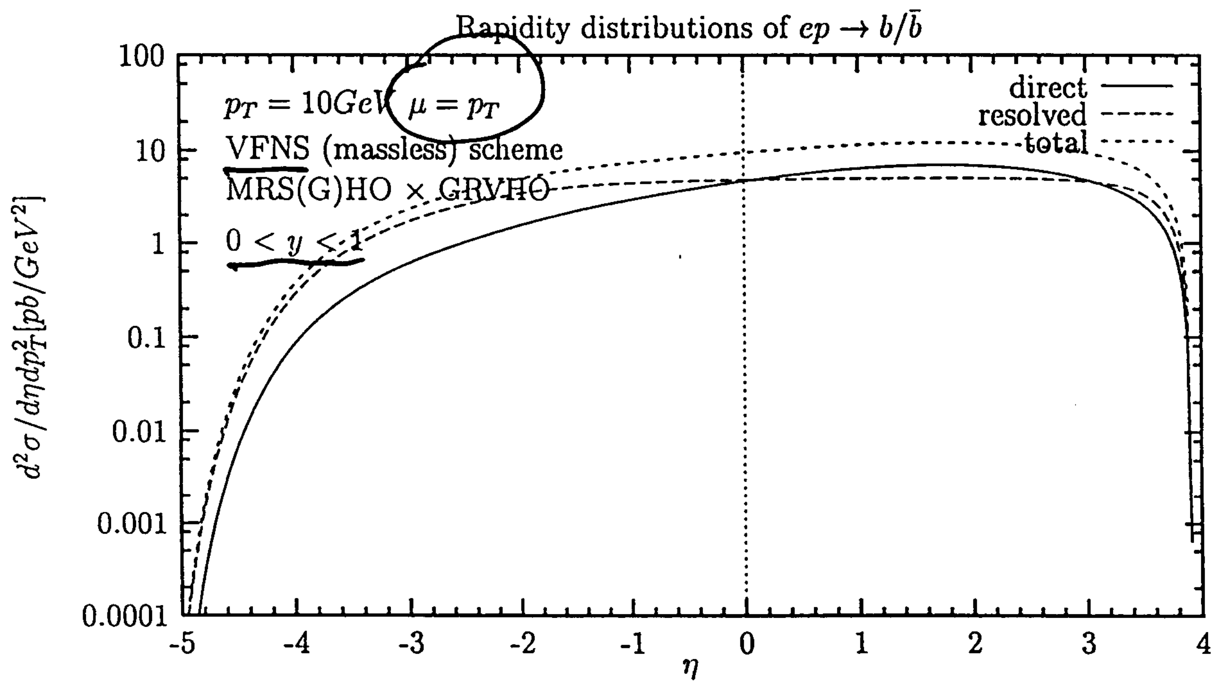


Figure 6: $b/\bar{b}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

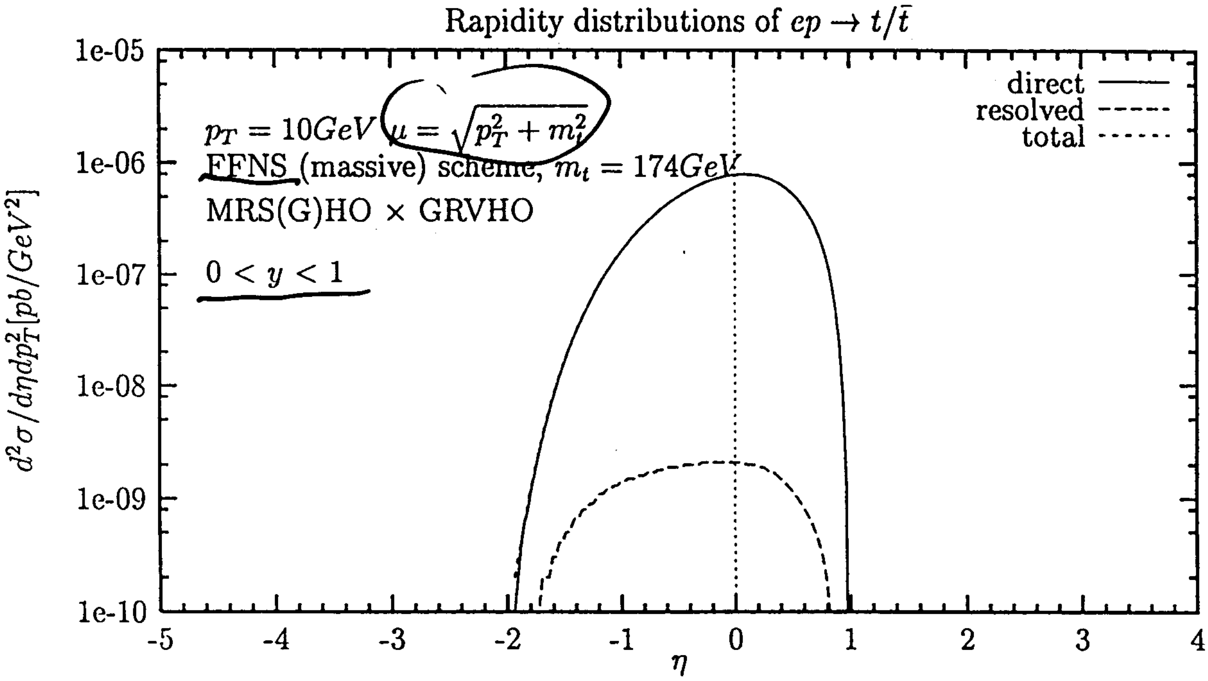
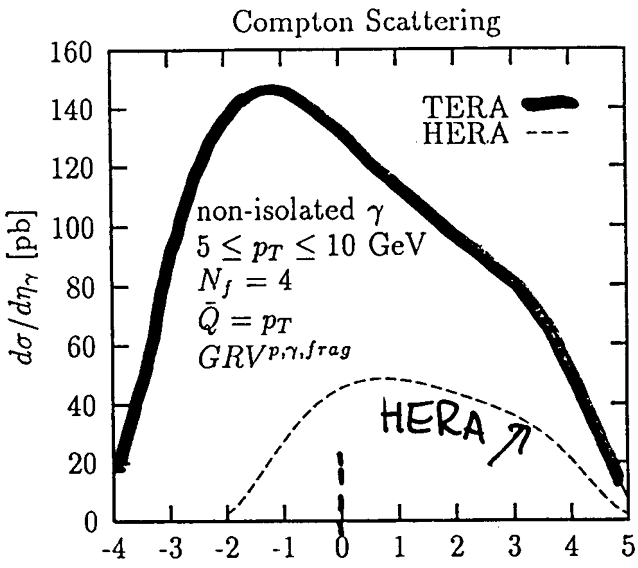


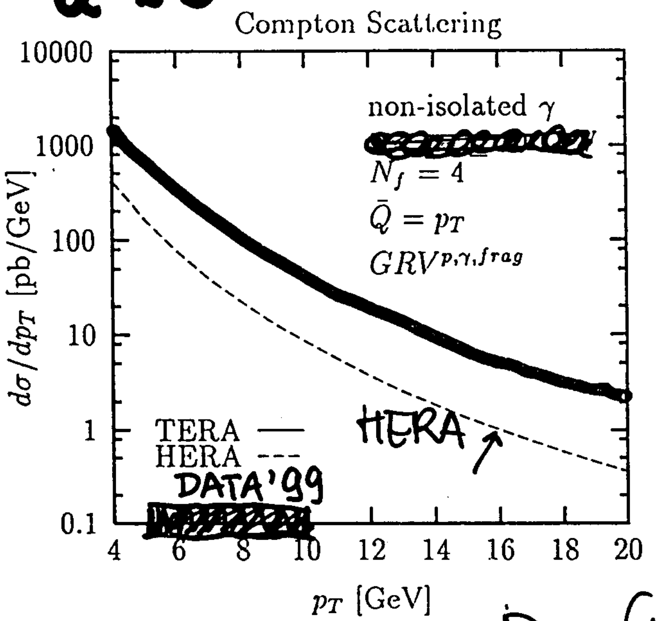
Figure 7: $t/\bar{t}$ production, TERA, $Ep = 920$ GeV, $Ee = 250$ GeV

Prompt photons at THERA

A. Zembrzuski
NLO calc. MK

- photoproduction
  $Q^2 \approx 0$





$p \rightarrow$ η_γ Y

p_T, GeV

- also for $Q^2 \neq 0$ ($Q^2 \ll p_T^2$)
  ↳ virtual photon γ^*
  with virtuality P^2 ($=Q^2$)
  up to few GeV^2

Can we probe individual parton density in γ? in γ^*?

--→

A. Zembruski
MK

Prompt photon production (Compton) process

LO calc.
(hep-ph/9912368)
PRD 57 (98)

virtuality of γ
$P^2 \approx 0 - 1.0$ GeV^2

Ratio:
$$\frac{\bullet\; g^{\gamma} q^{p} \to \gamma q}{\gamma q^{p} \to \gamma q} \leftarrow \text{Born}$$

and for

- $q^{\gamma} g^{p} \to \gamma q$
- $\bar{q}^{\gamma} q^{p} + q^{\gamma} \bar{q}^{p} \to \gamma g$

we study the diff. cross sections

$$\frac{d\sigma}{dE_{\gamma}\, dY\, dP^2\, dy}$$

$g^{\gamma} q^{p} \to \gamma q$ dominate here

HERA

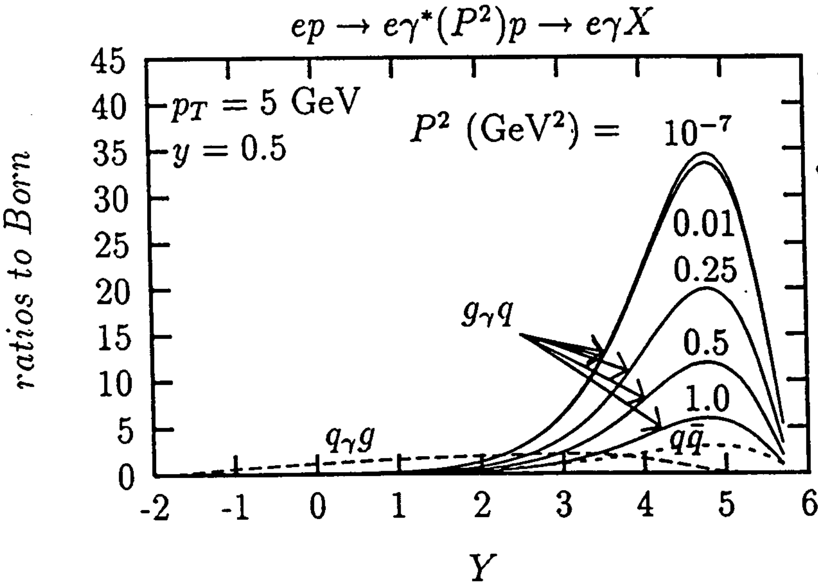
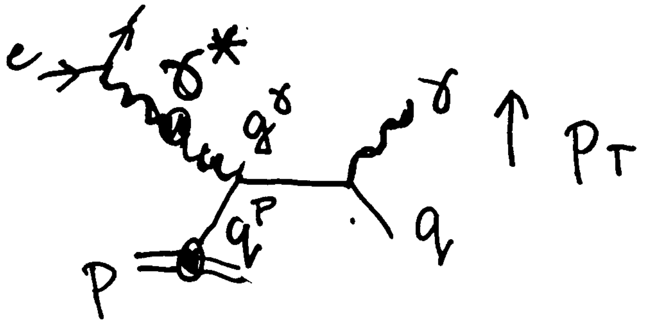


Figure 2. Ratios of the cross sections (see eq. 13) for the reaction $ep \to e\gamma X$, with y=0.5 and $p_T = 5$ GeV. The ratios of the contributions due to $g_\gamma\cdot q_p \to \gamma q$ (solid lines), $q_\gamma\cdot g_p \to \gamma q$ (long-dashed line) and $\bar{q}_\gamma\cdot q_p$, $q_\gamma\cdot \bar{q}_p \to \gamma g$ (short-dashed line) to the Born cross section are presented for various values of the virtuality P^2 as a function of the rapidity Y. For $g_\gamma\cdot q_p \to \gamma q$ the results correspond to $P^2 = 10^{-7}, 0.01, 0.25, 0.5$ and 1 GeV^2. For $q_\gamma\cdot g_p \to \gamma q$ and $q_\gamma\cdot \bar{q}_p$, $\bar{q}_\gamma\cdot q_p \to \gamma g$ we take $P^2 = 0.1$ GeV^2.

$ep \to \gamma X$

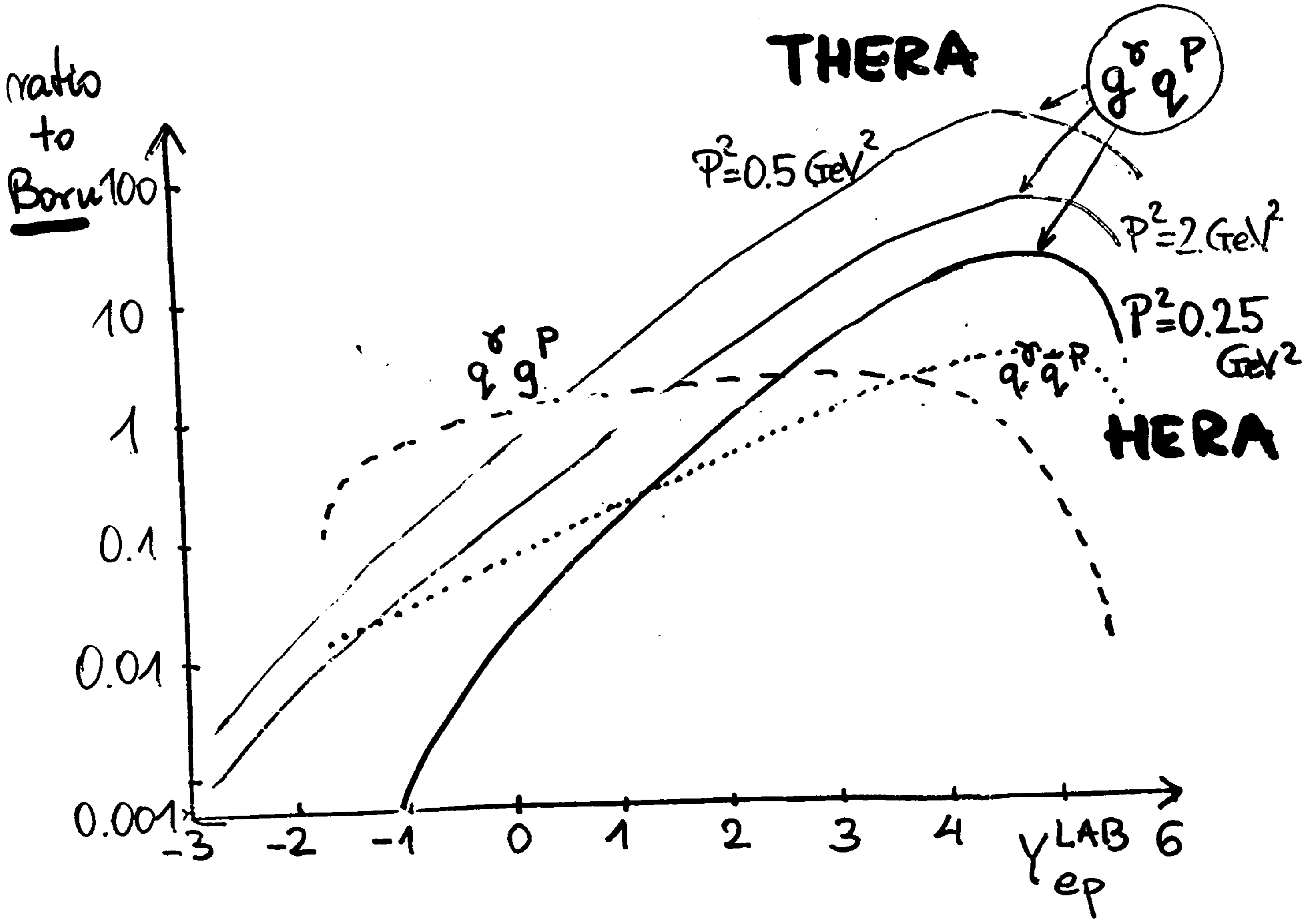


γ^* with virtuality P^2

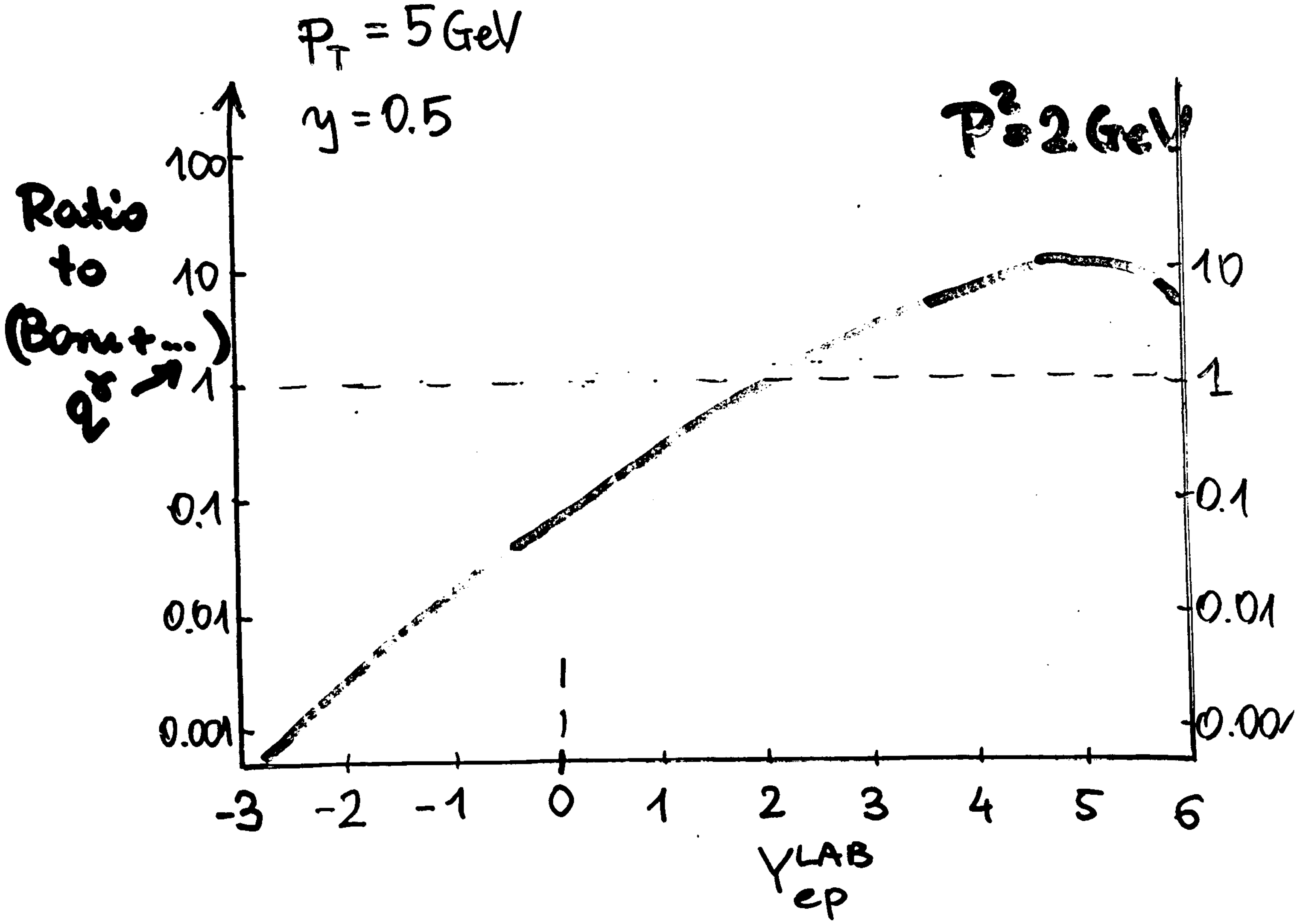
$p_T = 5$ GeV

$y = 0.5$

HERA → **THERA**

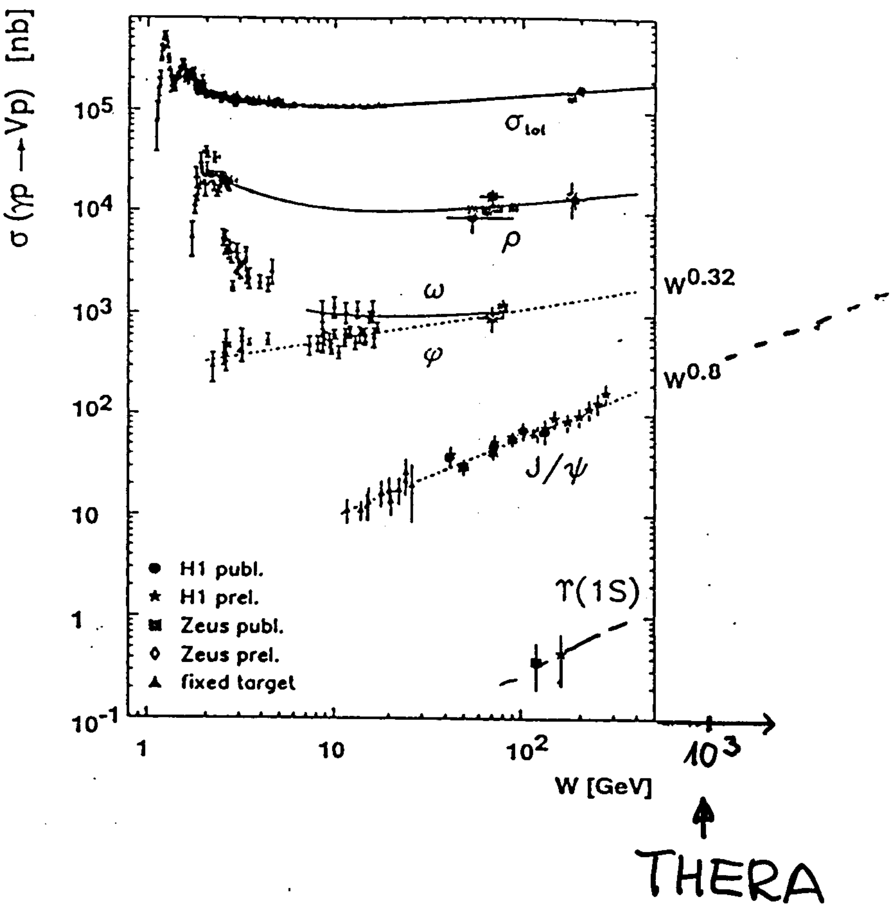


THERA


P_T = 5 GeV
y = 0.5
P² = 2 GeV
Ratio to (Born+...)
q^γ
100
10
1
0.1
0.01
0.001
-3 -2 -1 0 1 2 3 4 5 6
Y ep LAB

Exclusive photoproduction

$\gamma p \to V p$ $\qquad$ $V = \rho, \omega, \varphi, J/\psi, \Upsilon$



$\gamma p \to \pi^0 p$
$\quad \llcorner \eta, \eta', \eta_c \ldots$ $\quad \to$ J. Ginzburg talk