Anomalous Single Top Quark Production at the LHeC based γp Colliders

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OUTLINE

- Top Quark Properties
- Phenomenology
- FCNC Constraints
  - LEP
  - HERA
  - LHC
- Anomalous top production
- Limits on $\left(\kappa_{ut\gamma}, \kappa_{ct\gamma}\right)$
- Conclusion

Top Quark

The heaviest quark to date, mass 171.3±1.2 GeV

Electric charge Q=+2/3, and T_3 =+1/2 member of weak isospin

Short life time, O(10^{-24} s)

Weak decay, |Vtb|>0.89

The ratio R=BR(t-->W^+b)/BR(t-->W^+q)>0.79

Top quark could be sensitive to new physics BSM

Anomalous (FCNC) couplings

Anomalous interactions

Effective lagrangian for the anomalous interaction $tq\gamma$,

$$L=-g_e\sum_{q=u,c} Q_q \frac{\kappa_\gamma^q}{\Lambda}\bar{t}\,\sigma^{\mu\nu}(f_\gamma^q+h_\gamma^q\gamma_5)\,qA_{\mu\nu}+h.c.$$

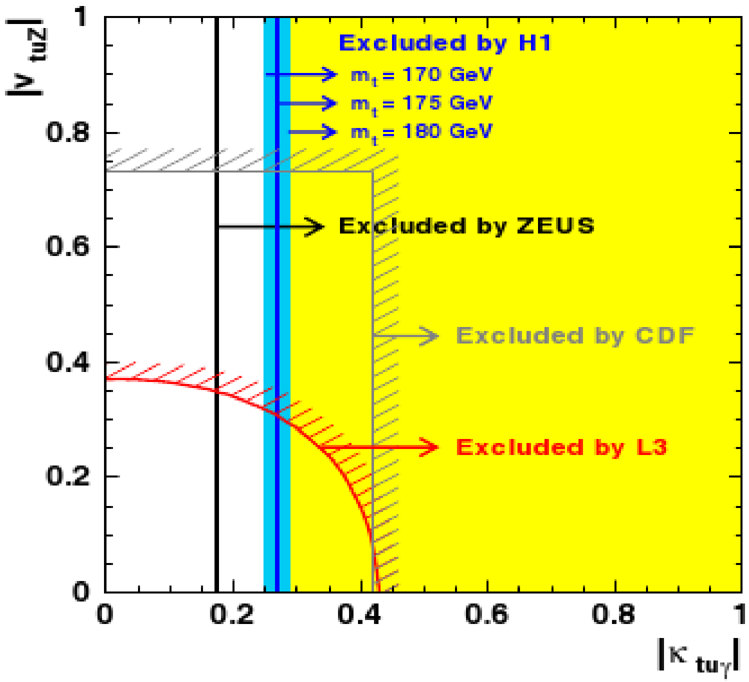
$$A_{\mu\nu}=\partial_\mu A_\nu-\partial_\nu A_\mu$$

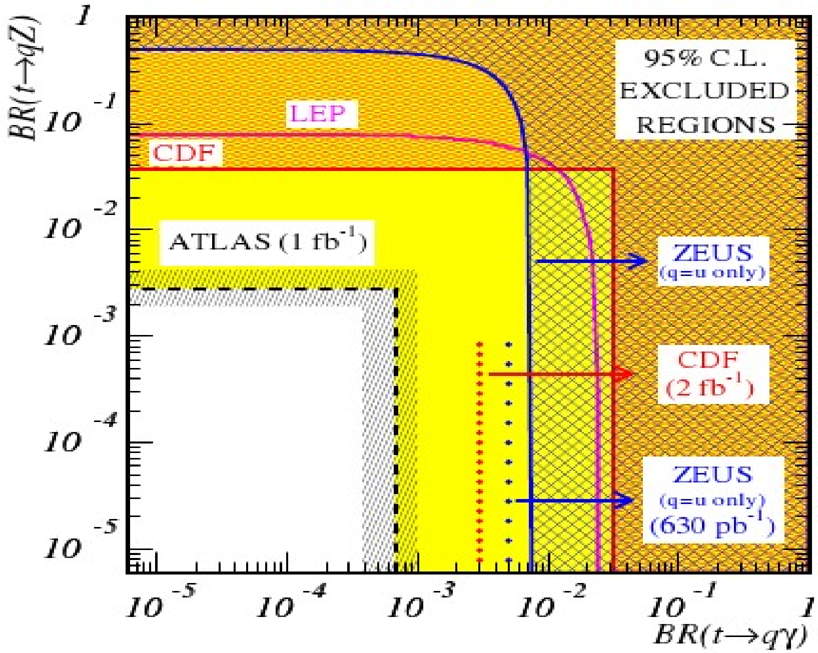
Anomalous decay width (*t-->qg*)

$$\Gamma(t\rightarrow q\gamma)=\left(\frac{\kappa_\gamma^q}{\Lambda}\right)^2\frac{2}{9}\alpha_{em}\,m_t^3$$

Top Quark FCNC Constraints from Experiments/Expectations

H1 Collab.,EPJC33 (2004)





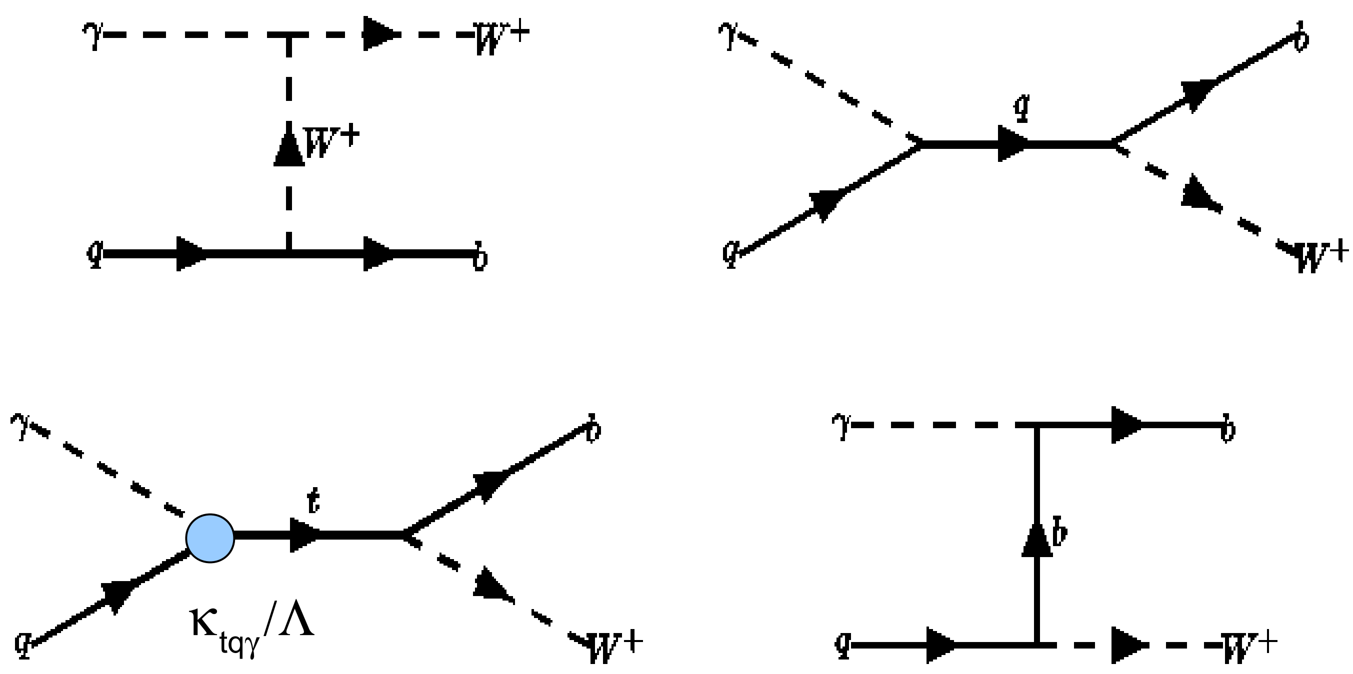
[ATLAS Collab. CERN-OPEN-2008-020]

<u>**Constraints on Br(t->gamma q)**</u>

<0.0132 95% CL, [H1 Collab. 2004]
<0.0059 95% CL, [ZEUS Collab. 2003]
<0.041 95% CL, [L3 Collab. 2002]
<0.032 95% CL, [CDF Collab. 1998]

ATLAS($1fb^{-1}$) with the conversion $\kappa_{tu\gamma}$=0.059.
For 100 fb^{-1} the expectations $\kappa_{tu\gamma}$=0.01

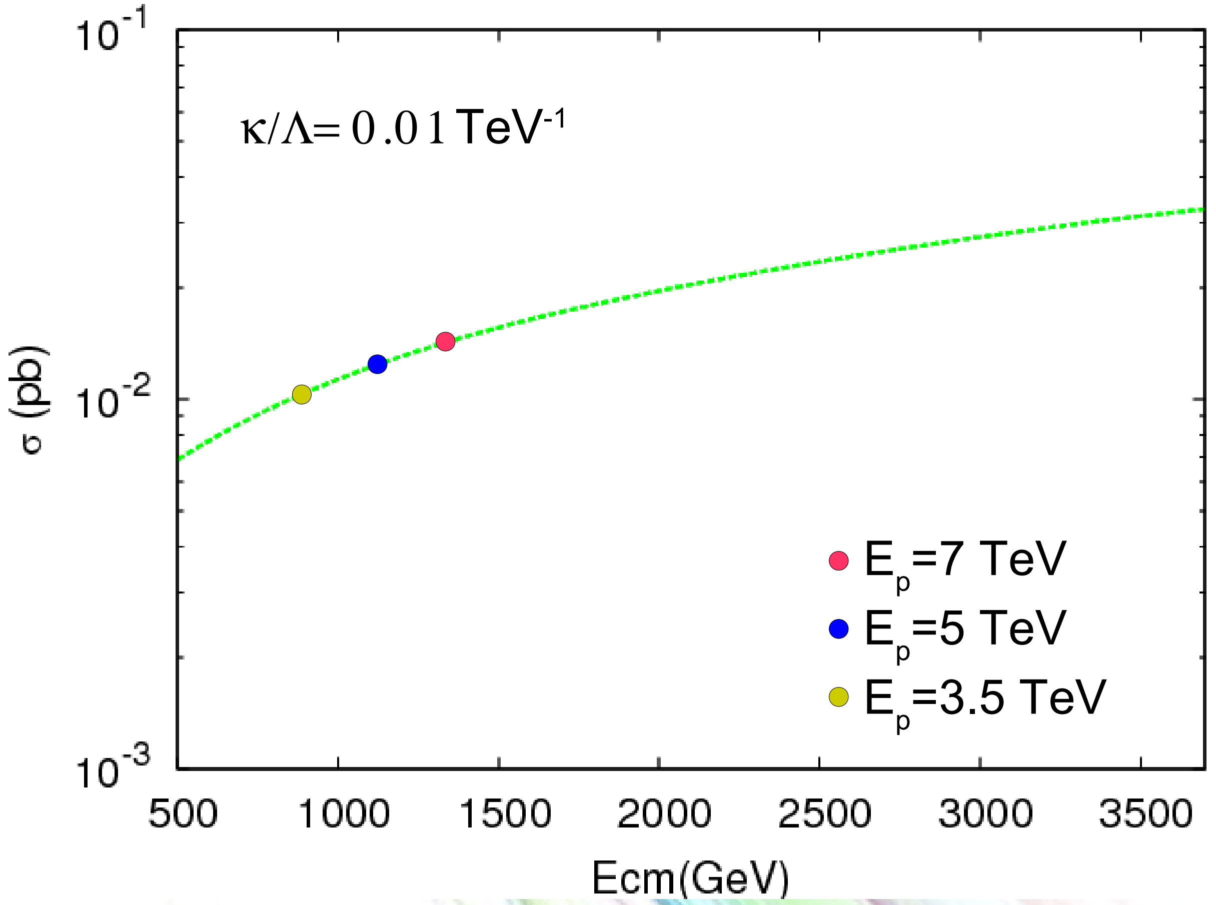
Anomalous production in γp collisions



Study the process $\gamma p \text{-->} W^+ bX$, and then decay $W^+ \text{-->} l^+ \nu$

- **Signal:** $\gamma p \text{-->} tX \text{-->} W^+ bX$
- **Major background:** $\gamma p \text{-->} (W^+b, W^+c, W^+j)X$, *where j=u,d,s*

Cross section vs center of mass energy (Ee=70 GeV)

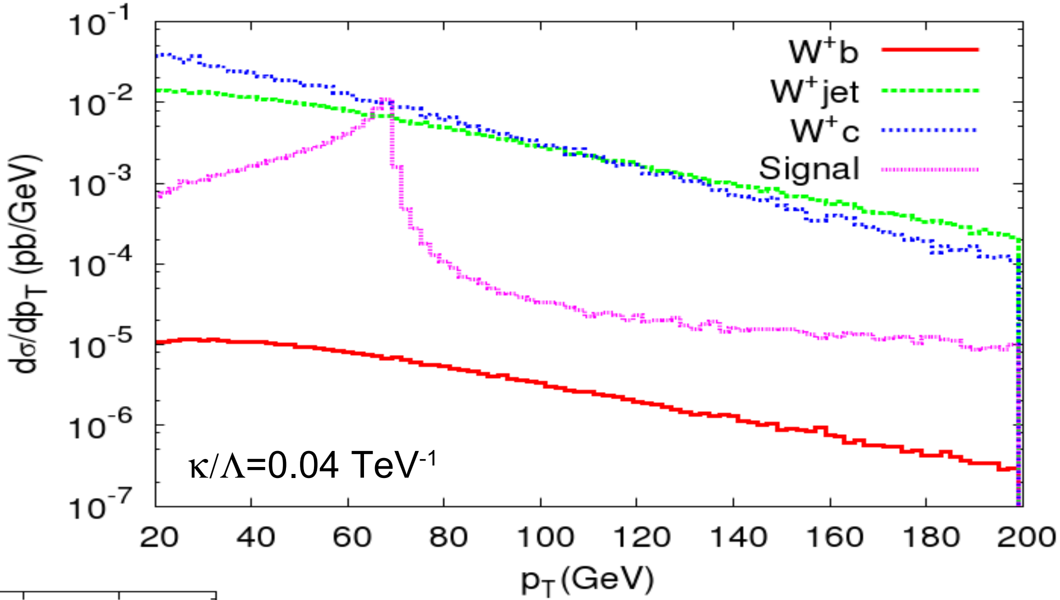


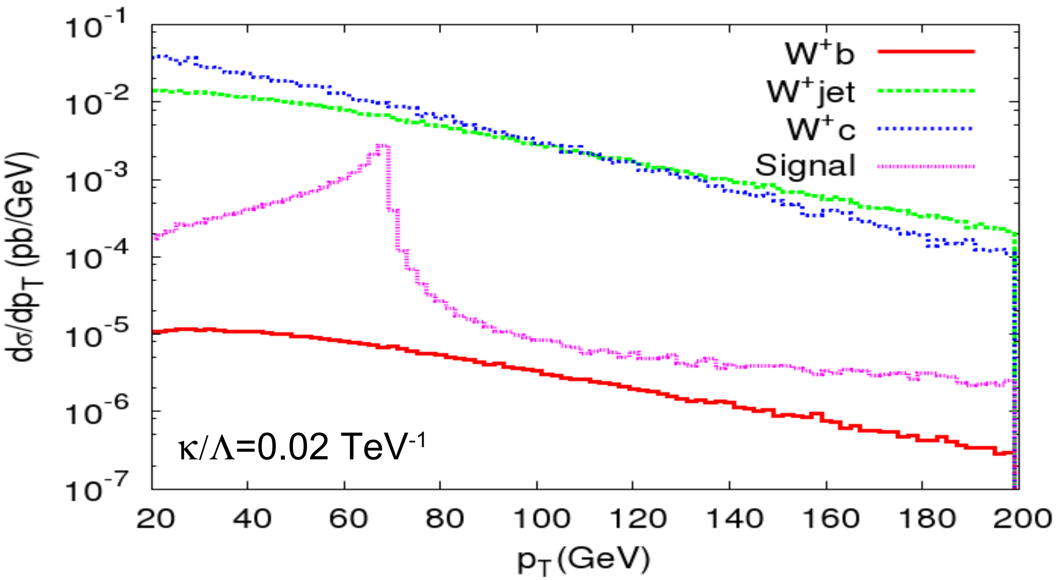
Cross sections in pb (E:70x7000)

$\kappa=0.01$	No cut	$p_T>20$	Pt>40	pt>50
Signal	1.590×10^{-2}	1.527×10^{-2}	1.307×10^{-2}	1.110×10^{-2}
Bkg:Wb	1.600×10^{-2}	1.030×10^{-2}	5.800×10^{-3}	4.250×10^{-3}
Bkg:Wc	3.106×10^{1}	1.268×10^{1}	6.850×10^{0}	4.900×10^{0}
Bkg: Wj	1.796×10^{2}	7.237×10^{1}	4.796×10^{1}	3.770×10^{1}

$\kappa=0.01$	M_{Wb}=150-200 GeV; $p_T>20$ GeV	M_{Wb}=150-200 GeV; $p_T>40$ GeV	M_{Wb}=150- 200 GeV; $p_T>50$ GeV
Signal	1.476×10^{-2}	1.256×10^{-2}	1.065×10^{-2}
Bkg:Wb	2.890×10^{-3}	1.869×10^{-3}	1.282×10^{-3}
Bkg:Wc	3.484×10^{0}	2.303×10^{0}	1.635×10^{0}
Bkg: Wj	1.393×10^{1}	9.115×10^{0}	6.386×10^{0}

p_T distribution of b-jet at $\sqrt{s}$=1.4 TeV

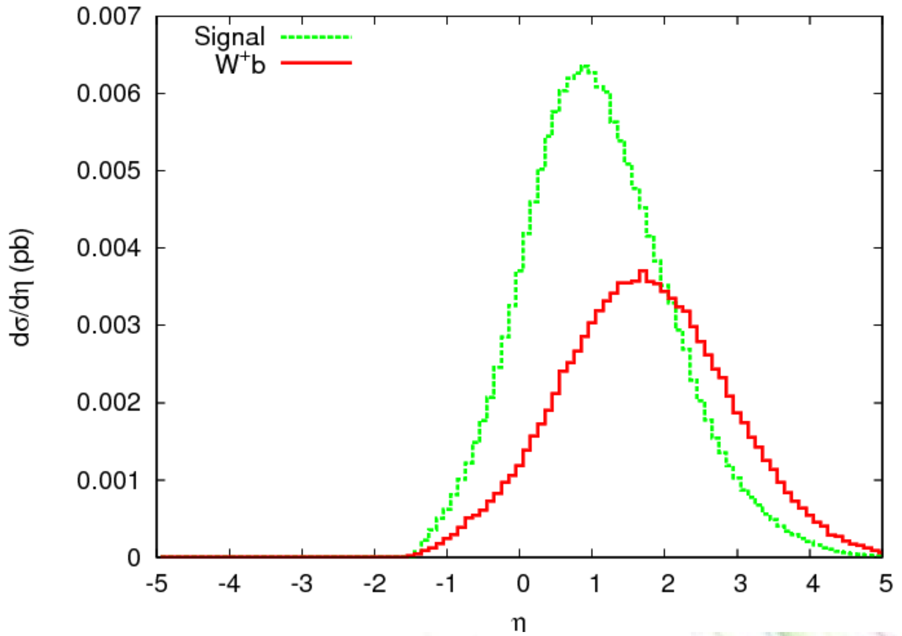


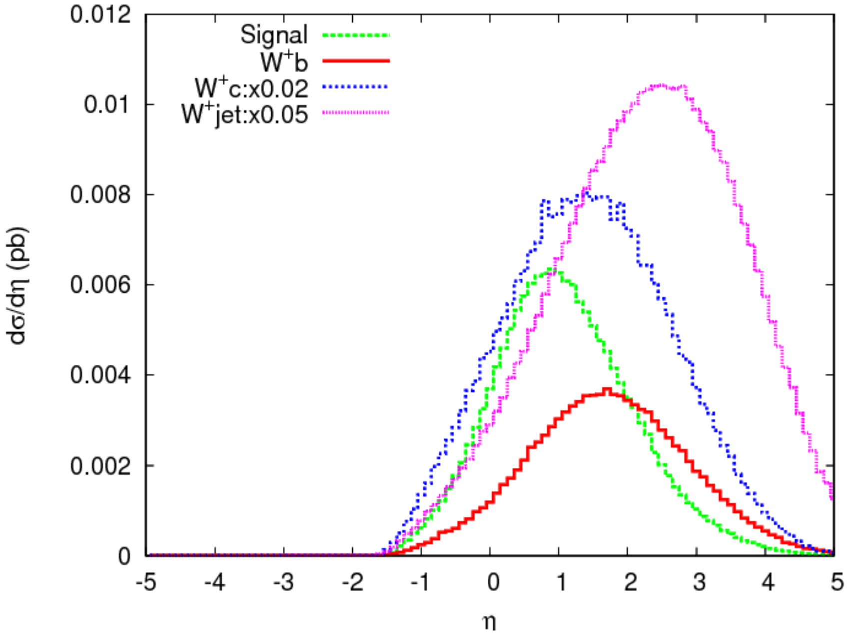


where the jets have at least p_T>20 GeV and the b-tagging is applied with the rejections for light jets

Rapidity distributions at LHeC(E:70x7000)

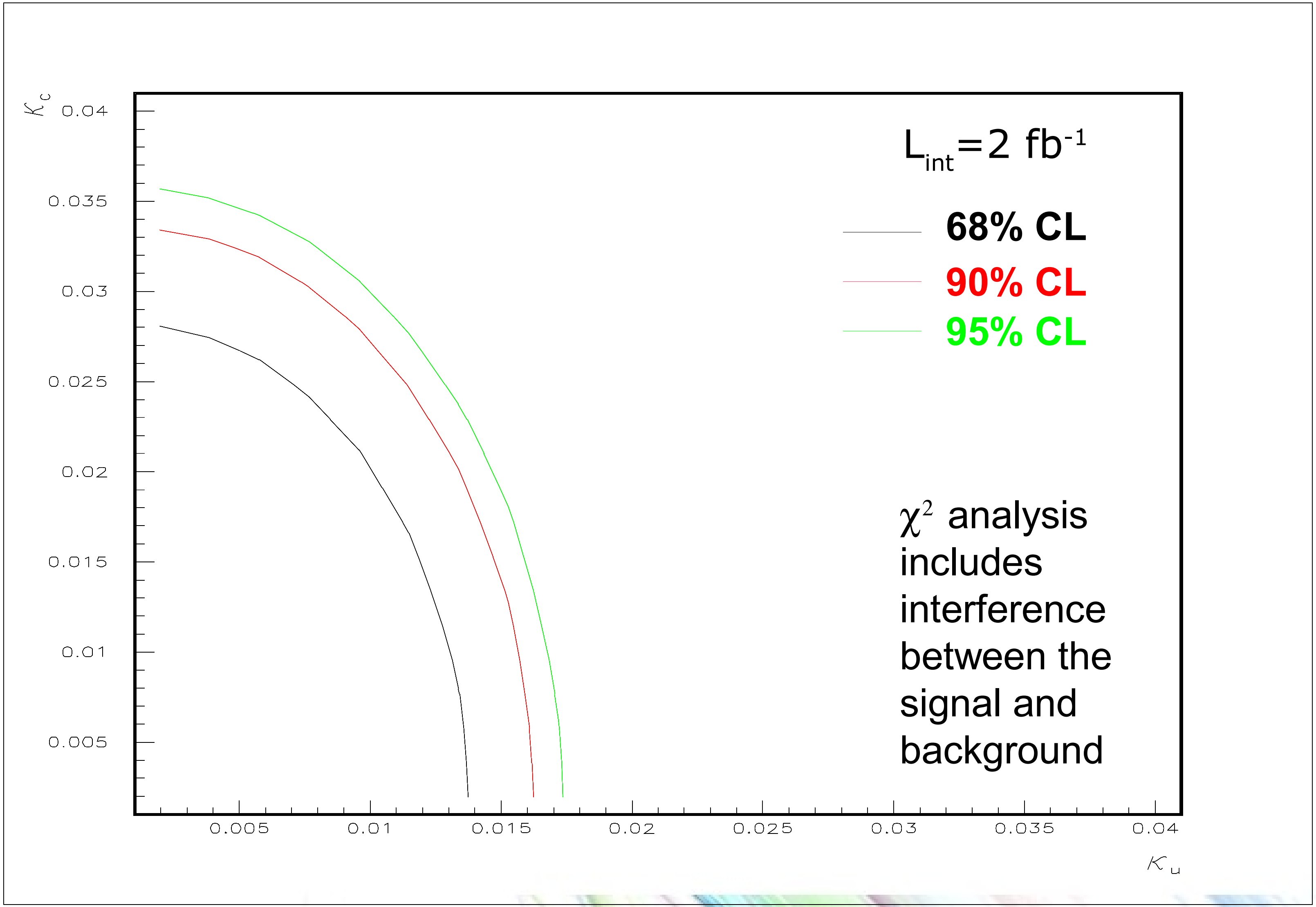
Rapidity distribution of b-jets for both signal and corresponding background (IB).



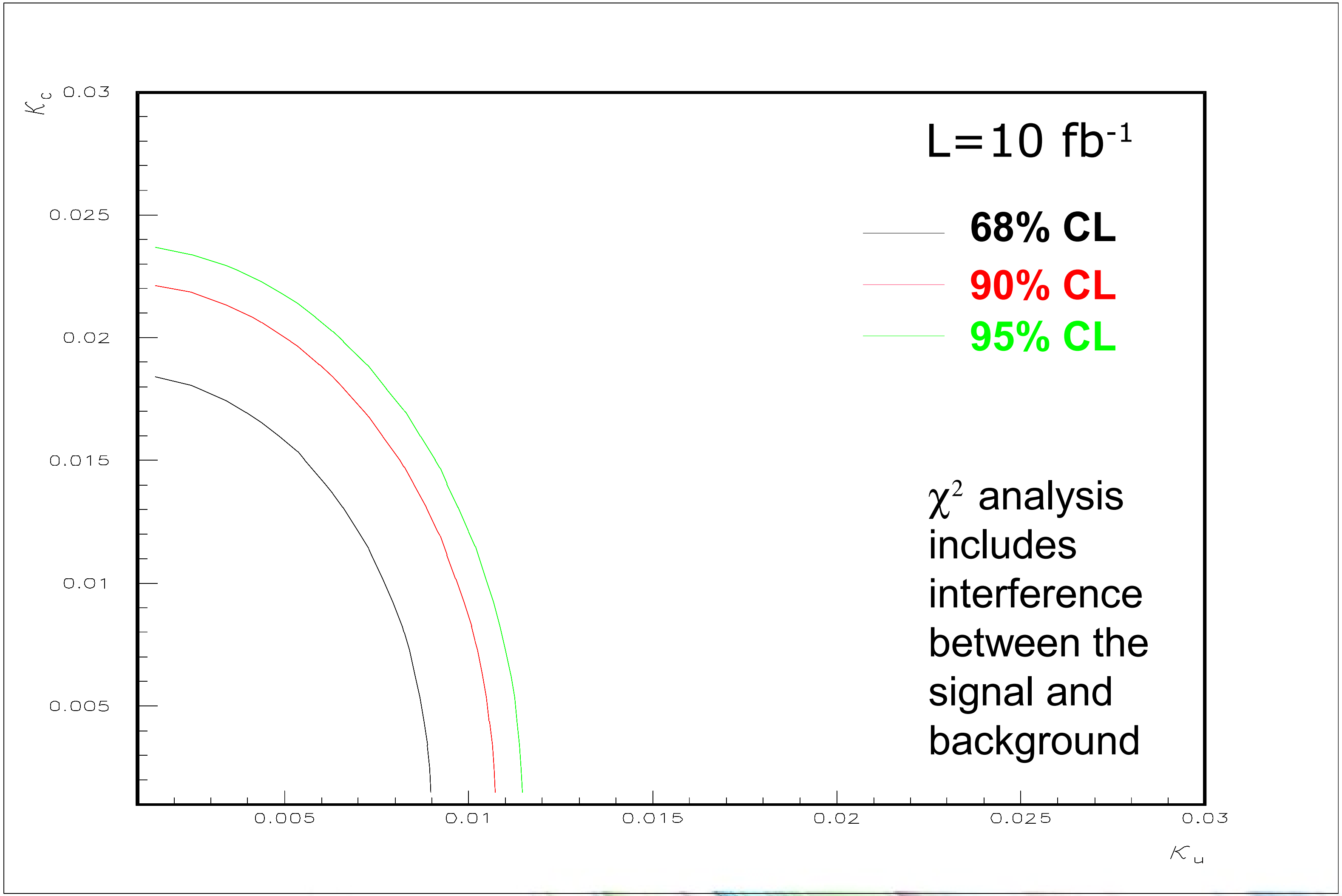


to keep in the same range W+c(blue) and W+j(purple) backgrounds (RB) are multiplied with the respective factors.

Top FCNC discovery at LHeC (2 fb^{-1})



Top FCNC discovery at LHeC (10 fb^{-1})



Signal Significance

Energy: 70x7000

cuts	$L=2\ fb^{-1}$ ($\kappa\gamma u=0.01$) ($\kappa\gamma c=0.01$)	$L=10\ fb^{-1}$ ($\kappa\gamma u=0.01$) ($\kappa\gamma c=0.01$)
M_{wb}=150-200 GeV p_T=50 GeV	2.38	5.33
M_{wb}=150-200 GeV p_T=40 GeV	2.58	5.79

Energy: 140x7000

cuts	$L=1\ fb^{-1}$ ($2\ fb^{-1}$) ($\kappa\gamma u=0.01$) ($\kappa\gamma c=0.01$)	$L=10\ fb^{-1}$ ($\kappa\gamma u=0.01$) ($\kappa\gamma c=0.01$)
M_{wb}=150-200 GeV p_T=50 GeV	1.88(2.66)	5.96
M_{wb}=150-200 GeV p_T=40 GeV	2.04 (2.88)	6.47

CONCLUSION

- Due to its large mass top quark is expected to be sensitive to new physics BSM. In particular, the study of FCNC couplings involving the top quark is well motivated.
- The benefit of b-tagging usage is apparent.
- As precise limits attainable at the LHC, even better limits ($\kappa_{tu\gamma}/\Lambda=0.01$ TeV^{-1} and $\kappa_{tc\gamma}/\Lambda=0.02$ TeV^{-1}) on the anomalous couplings of top quark can be obtained at LHeC based gamma-p collider.

BACKUP

Brandt,G. - 1st ECFA-CERN LHeC Workshop

Finally: Estimations at LHeC

$$N = \underbrace{c_\gamma \cdot \kappa_{tu\gamma}^2}_{\sigma} \cdot L \cdot Br \cdot \varepsilon$$

Option	Ee [GeV]	Ep [GeV]	Int. Lumi [fb]	$\sigma(\kappa_{tu\gamma}=0.01)$ [pb]	N_{obs}	
LHeC (RR)	70	7000	100	0.0152 31.4 2	760 94000 10000	FCNC top SM W SM top
LHeC (LR)	140	7000	10	0.0207 pb	103	