CORREZIONI DEBOLI AD OSSERVABILI ADRONICHE

EZIO MAINA
UNIV. OF TORINO AND I.N.F.N. TORINO

IN COLLABORAZIONE CON

S. MORETTI, M. NOLTEN AND D.R. ROSS
UNIV. OF SOUTHAMPTON

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CORRECTIONS TO HADRONIC OBSERVABLES: QCD VS EW

- $\alpha_s \approx 10 \times \alpha_{EW}$
- NEW TYPES OF INITIAL STATE PARTON CAN LEAD TO LARGE ENHANCEMENTS
- LARGE SCALE DEPENDENCE OFTEN DOMINATES THEORETICAL UNCERTAINTIES

BUT ....

- THERE ARE LARGE LOG AROUND: AT $\sqrt{s} = 1\,\mathrm{TeV}$

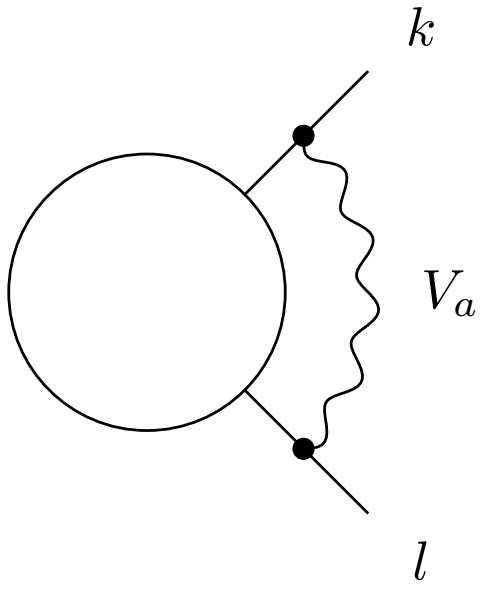
$$\frac{\alpha}{4\pi s_{\mathrm{w}}^2} \log^2 \frac{s}{M_{\mathrm{W}}^2} = 6.6\%, \qquad \frac{\alpha}{4\pi s_{\mathrm{w}}^2} \log \frac{s}{M_{\mathrm{W}}^2} = 1.3\%$$

- NNLO QCD CORRECTIONS WILL SOON BE AVAILABLE $\alpha_s^2 \approx \alpha_{EW}$

SUDAKOV LOGS^2 IN A NUTSHELL

- CORRESPOND TO SOFT AND COLLINEAR SINGULARITIES IN THEORIES WITH MASSLESS BOSONS. THERE THEY ARE CANCELED BY REAL RADIATION
- REGULATED BY BOSON MASS IN EW. THEY ARE FINITE
- REAL EMISSION OF EW BOSONS IS ASSUMED TO BE NEGLIGIBLE
- IN THE FEYNMAN GAUGE THEY ARE ASSOCIATED WITH VIRTUAL GRAPHS WHERE SOFT-COLLINEAR BOSONS ARE EXCHANGED BETWEEN EXTERNAL LEGS (IN AXIAL GAUGE THEY ARE ASSOCIATED WITH SELF ENERGY GRAPHS ON EXTERNAL LEGS). EIKONAL APPROXIMATION.
- DL ARE UNIVERSAL:ONLY DEPEND ON EXTERNAL PARTICLES

$$\sum_{k=1}^{n}\sum_{l<k}\sum_{V_a=\mathrm{A,Z,W}^{\pm}}$$



$$=\sum_{k=1}^{n}\sum_{l<k}\sum_{V_a=\mathrm{A,Z,W}^{\pm}}\alpha/4\pi\log^2(r_{kl}/M^2)T_{kl}$$

$$\log^2\frac{r_{kl}}{M^2}=\log^2\frac{s}{M^2}+2\log\frac{s}{M^2}\log\frac{r_{kl}}{s}+\log^2\frac{r_{kl}}{s}\qquad r_{kl}=(p_k\pm p_l)^2$$

- NUMERICALLY AT TeV ENERGIES THERE ARE LARGE CANCELLATIONS BETWEEN DL AND SL CONTRIBUTIONS.
- DL DO NOT CANCEL IN INCLUSIVE MEASUREMENTS
- SL ARE NOT UNIVERSAL

CALCULATION

$$V(q_1) + q(p_1) \to V'(q_2) + q(p_2)$$

$$p_1 = \frac{(s-Q^2)}{2\sqrt{s}}(1,\ 0,\ 0,\ 1) \qquad q_1 = \left(\frac{(s+Q^2)}{2\sqrt{s}}\ 0,\ 0,\ -\frac{(s-Q^2)}{2\sqrt{s}}\right)$$

$$p_2 = \frac{\sqrt{s}}{2}(1,\ \sin\theta,\ 0,\ \cos\theta) \qquad q_2 = \frac{\sqrt{s}}{2}(1,\ -\sin\theta,\ 0,\ -\cos\theta)$$

$$\epsilon_2 = \left(0,\ \frac{\cos\theta}{\sqrt{2}},\ -i\frac{\lambda_2}{\sqrt{2}},\ -\frac{\sin\theta}{\sqrt{2}}\right)$$

FOR TRANSVERSE(LONGITUDINAL) INCOMING PHOTON/Z:

$$\epsilon_1^T = \left(0,\ \frac{1}{\sqrt{2}},\ -i\frac{\lambda_1}{\sqrt{2}},\ 0\right) \qquad \epsilon_1^{L\,\mu} = 2\frac{\sqrt{Q^2}}{(s-Q^2)}p_1^\mu$$

THUS WE HAVE MADE THE GAUGE CHOICE:

$$p_1 \cdot \epsilon_1 = 0, \qquad p_2 \cdot \epsilon_2 = 0.$$

DEFINE: $n = \sqrt{s}\,(0,\ 0,\ 1,\ 0)$ AND A VECTOR v, WHICH IS ORTHOGONAL TO p_1, p_2 AND n,

$$v^\mu = = \frac{1}{-u}p_1^\mu + \frac{1}{s}p_2^\mu - \frac{-t}{-u\,s}q_2^\mu.$$

$$s = (p_1+q_1)^2, \quad t = (p_2-p_1)^2, \quad u = (q_2-p_1)^2$$

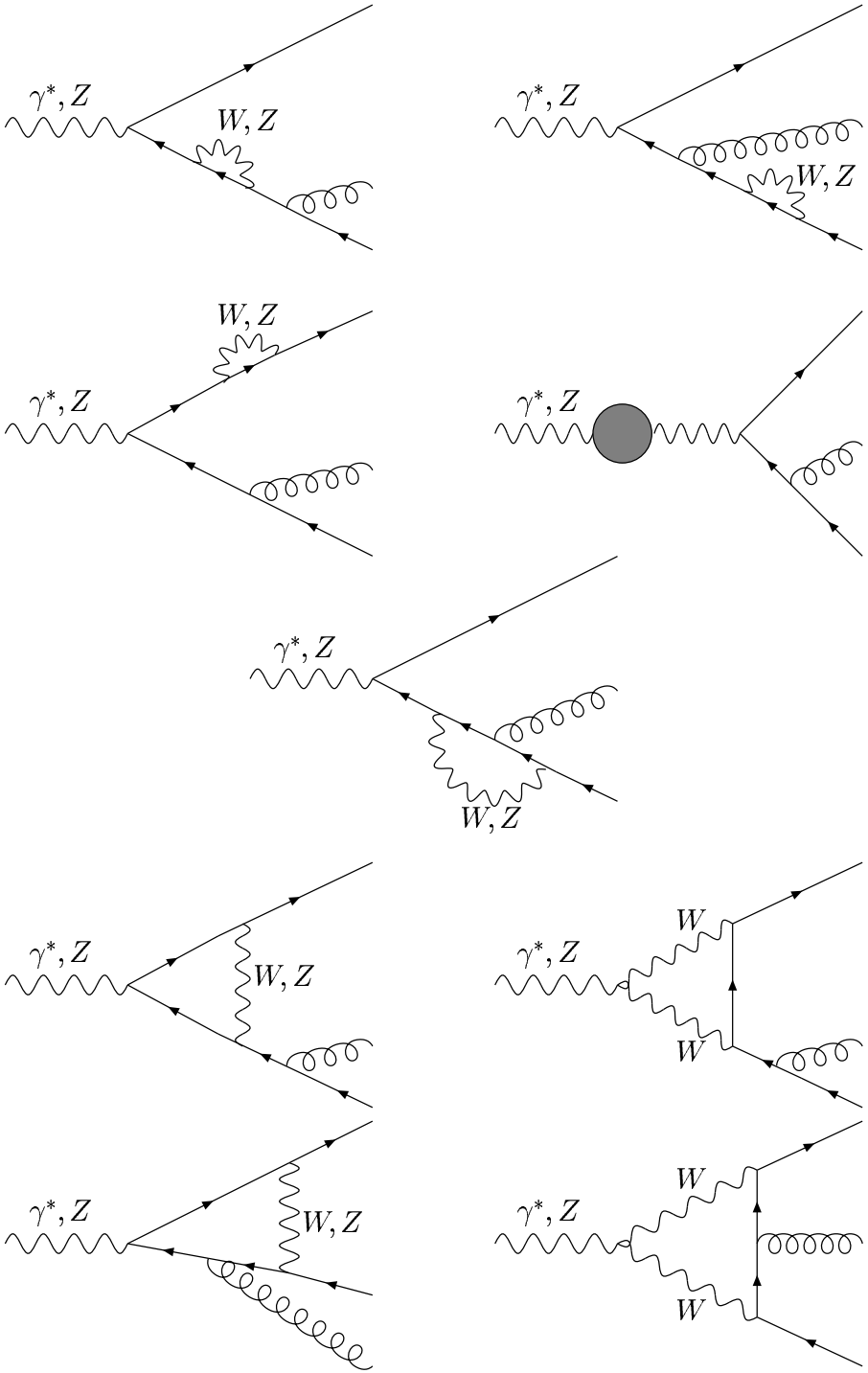
- HELICITY AMPLITUDES: $\mathcal{A}^{(G)}_{\lambda_1,\lambda_2,\sigma} \;=\; \bar{u}(p_2)\Gamma\frac{\left(1+\sigma\gamma^5\right)}{2}u(p_1)$
- HELICITY IS CONSERVED:
  - FOR NEUTRAL BOSONS: NO MASSES
  - FOR W'S AND THE CORRESPONDING $\Phi^{\pm}$: ONLY L STATES CONTRIBUTE
- Γ CONTAINS AN ODD NUMBER OF γ–MATRICES
- FOR THE UV–FINITE TERMS THE CHRYSTOFFEL IDENTITIES LEAD TO:
  $\Gamma \;=\; C_1\,\gamma\cdot p_1 \;+\; C_2\,\gamma\cdot p_2 \;+\; C_3\,\gamma\cdot q_2 \;+\; C_4\,\sqrt{Q^2}\,\gamma\cdot n$
  q_2 = GLUON, $n\cdot p_{1(2)} \;=\; 0$, $n\cdot q_2 \;=\; 0$, AND $Q^2 \;=\; q_1^2$
- $C_3 \;=\; \mathrm{Tr}\left(\Gamma\gamma\cdot v\frac{\left(1+\sigma\gamma^5\right)}{2}\right)$ WHERE $v^\mu \;= = \frac{1}{-u}p_1^\mu \;+\; \frac{1}{s}p_2^\mu - \frac{-t}{-u\,s}q_2^\mu$
  $v\cdot p_1 \;=\; v\cdot p_2 \;=\; 0,\; v\cdot q_2 \;=\; 1$
- $C_4 \;=\; -\frac{1}{2\sqrt{Q^2}}\mathrm{Tr}\left(\Gamma\gamma\cdot n\frac{\left(1+\sigma\gamma^5\right)}{2}\right)$

- STANDARD MATRIX ELEMENTS:

$$\bar{u}(p_2,\sigma)(\gamma\cdot q_2)u(p_1,\sigma) \;=\; \sqrt{-u\,s}$$

$$\bar{u}(p_2,\sigma)(\gamma\cdot n)u(p_1,\sigma) \;=\; -i\,\sigma\,\sqrt{-t\,s}$$

- STANDARD PV REDUCTION WITH FORM (2WAYS)+CHECKED WITH $FeynCalc$
- FF FOR SCALAR INTEGRALS
- CHECKED $\epsilon(\gamma) \to p_\gamma$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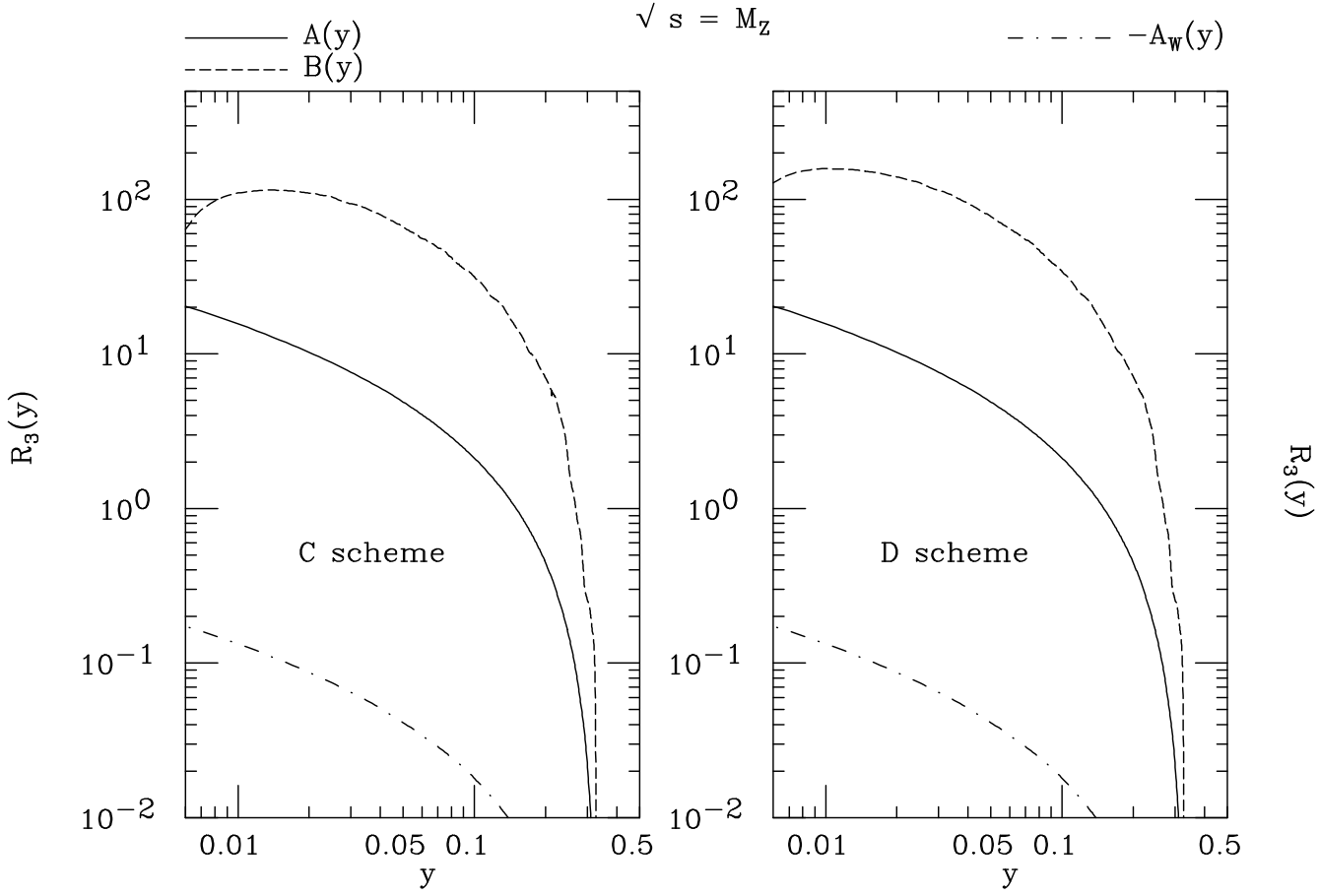
LC GigaZ $\sqrt{s} = M_Z$: R_3

Factorizable corrections

[JHEP 04(2003)056]

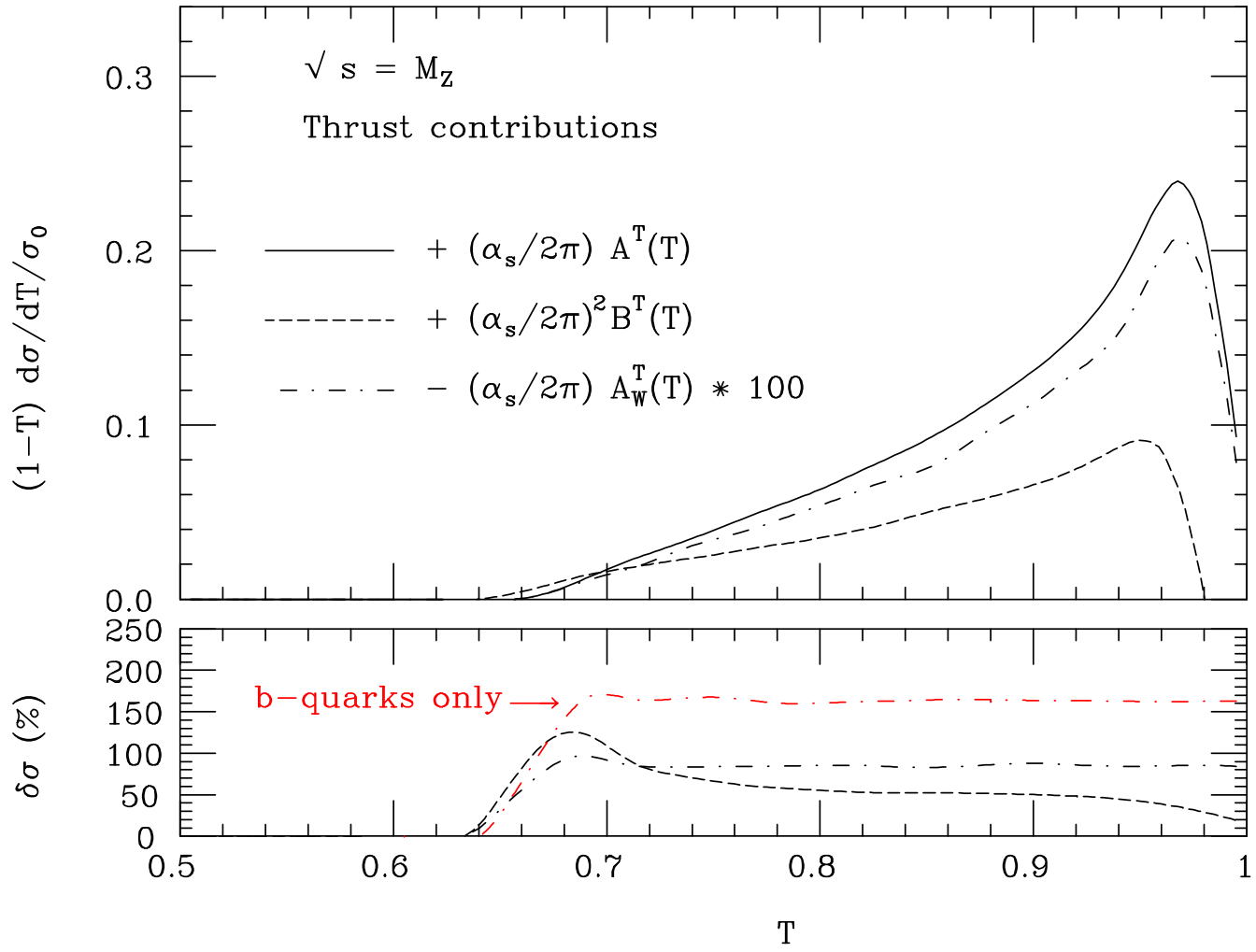


$$R_3(y) = \frac{\sigma_3}{\sigma_0} = \left(\frac{\alpha_S}{2\pi}\right) A(y) + \left(\frac{\alpha_S}{2\pi}\right)^2 B(y) + ...,$$

$$A(y) \to A(y) + A_{\rm W}(y)$$

LC GigaZ $\sqrt{s} = M_Z$: Thrust

Factorizable corrections

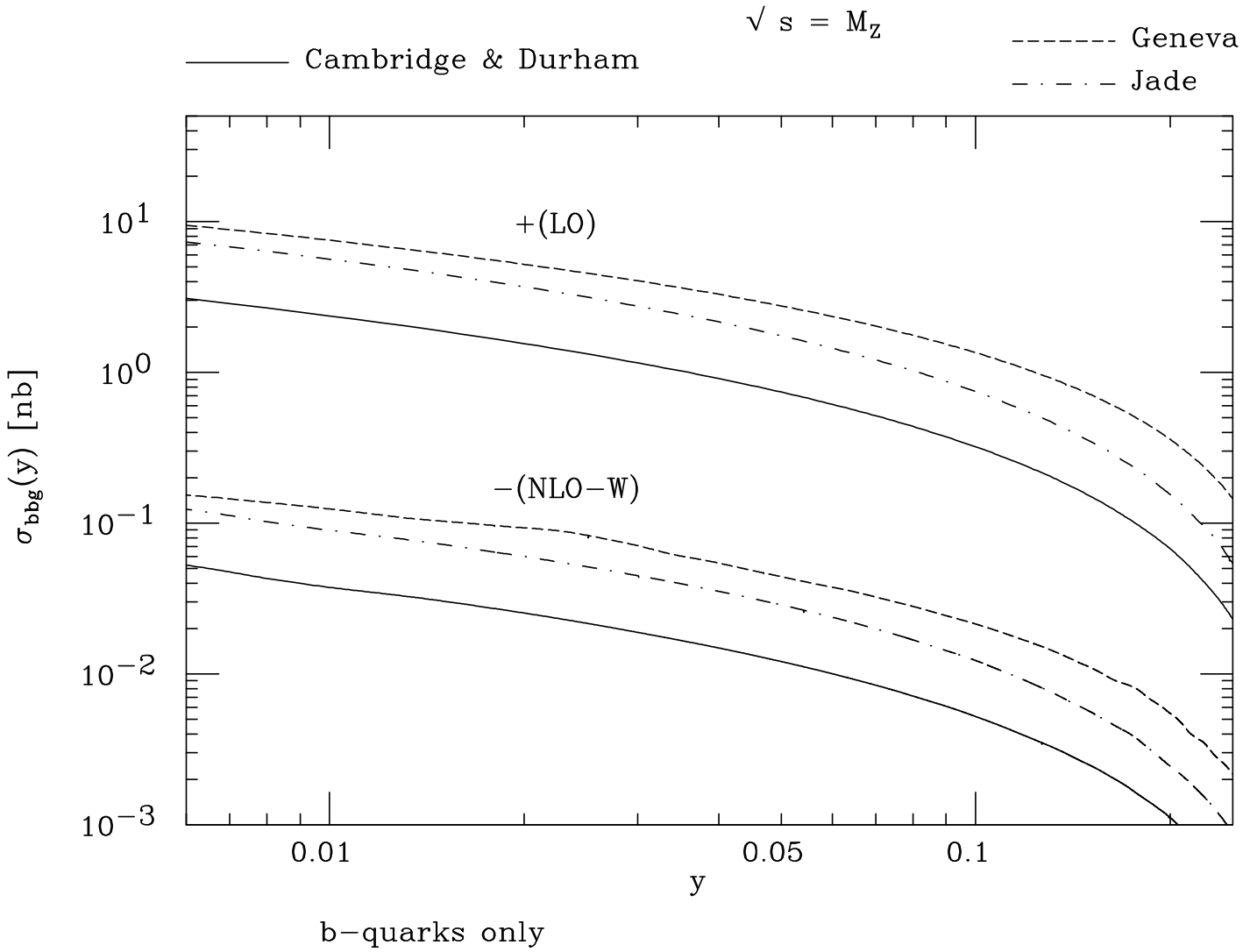


EW Corrections $\times 100$

$$T = \max \frac{\sum_i |\vec{p}_i \cdot \vec{n}_T|}{\sum_i |\vec{p}_i|}$$

LC GigaZ $\sqrt{s} = M_Z$: $b\bar{b}g$ PRODUCTION

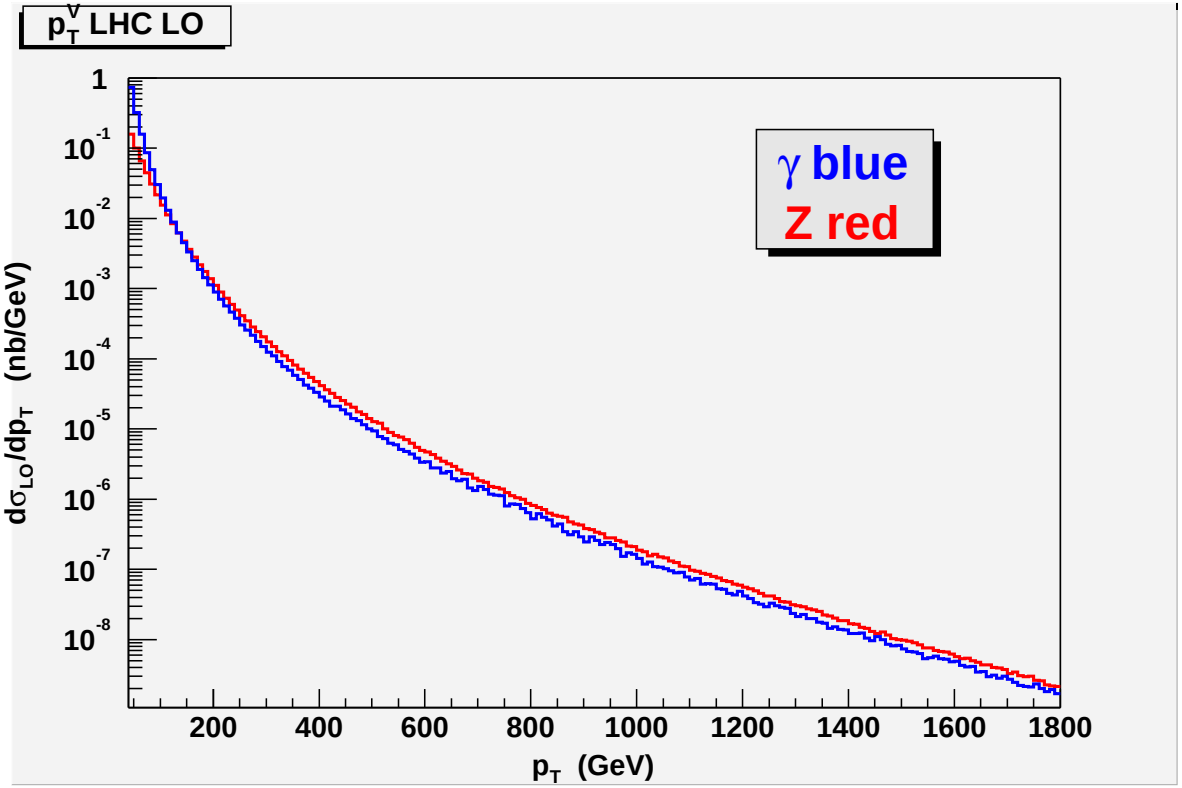
FACTORIZABLE CORRECTIONS



$p\bar{p}, pp \to Z(\gamma) + j$ [HEP-PH/0403050]

LARGE CROSS SECTION PROCESS: AT LHC IN LO

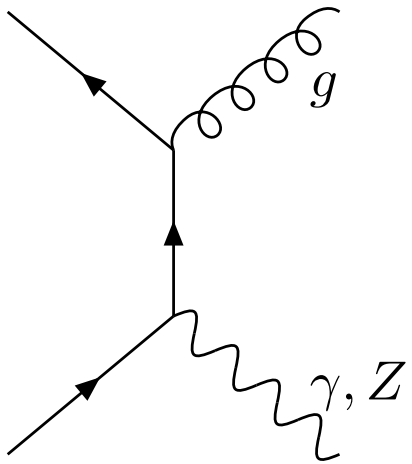
$\sigma_{\gamma+j}(p_T > 40\,\mathrm{GeV}) \approx 1.4 \times 10^7\ fb$, $\sigma_{Z+j}(p_T > 40\,\mathrm{GeV}) \approx 4.9 \times 10^6\ fb$

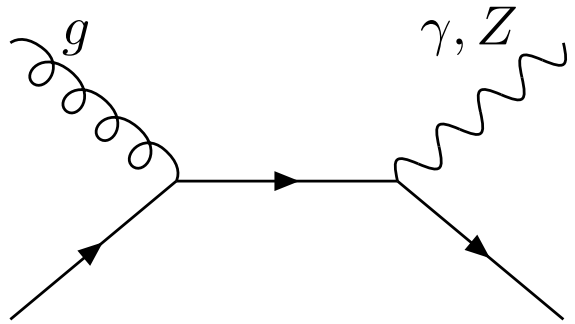


- EASILY SEPARATED USING $Z \to l^+l^-,\ l = e, \mu$
- GIVES ACCES TO q AND g PDF'S
- USEFUL FOR ABSOLUTE JET ENERGY CALIBRATION

- $m_b = 0,\ m_t = 175\,\mathrm{GeV}$
- $M_Z = 91.19\,\mathrm{GeV},\ M_W = 80.35\,\mathrm{GeV}$
- $\sin^2\theta_W = 1 - M_W^2/M_Z^2$
- $\mu = M_Z,\ \alpha^{-1} = 128.07$
- PDF's: MRSTLO20001

TREE LEVEL

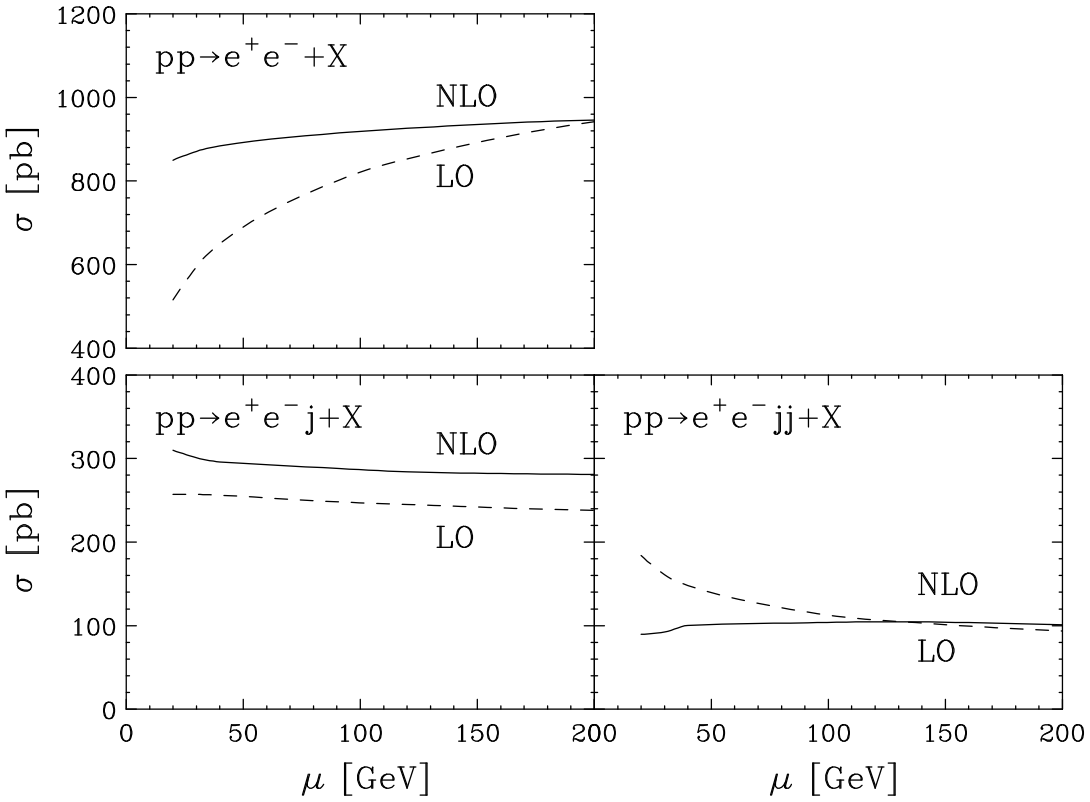


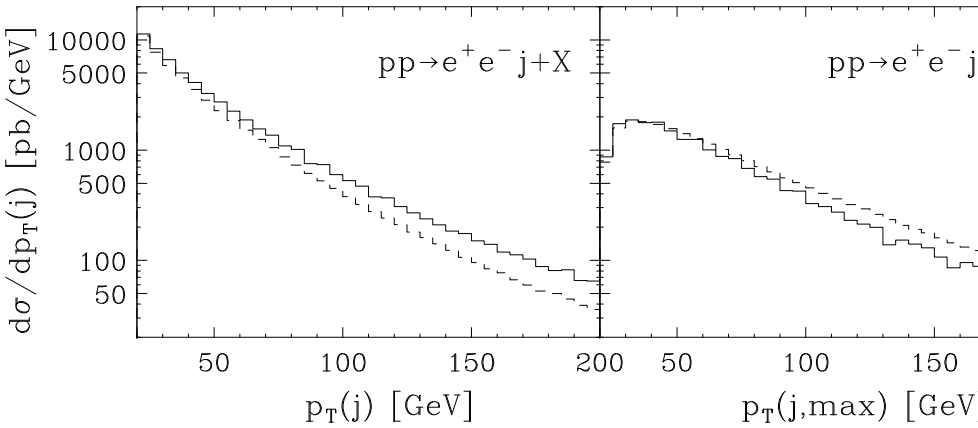


+ CROSSED

LHC: $pp \to \gamma^*, Z^* + j$: *QCD corrections*

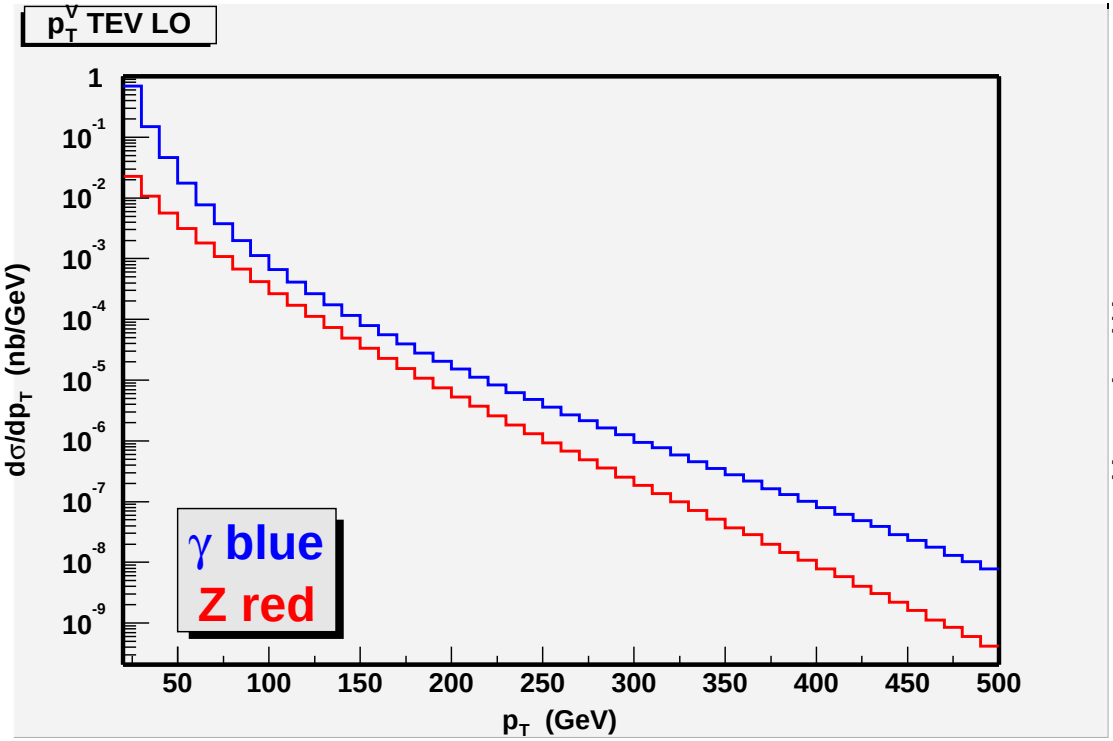
- CAMPBELL,ELLIS,RAINWATER [HEP-PH/0308195]
- ARNOLD,ELLIS,RENO PRD40:912,1989 ARNOLD,RENO NPB319:37,1989
- GIELE,GLOVER,KOSOWER NPB403:633,1993

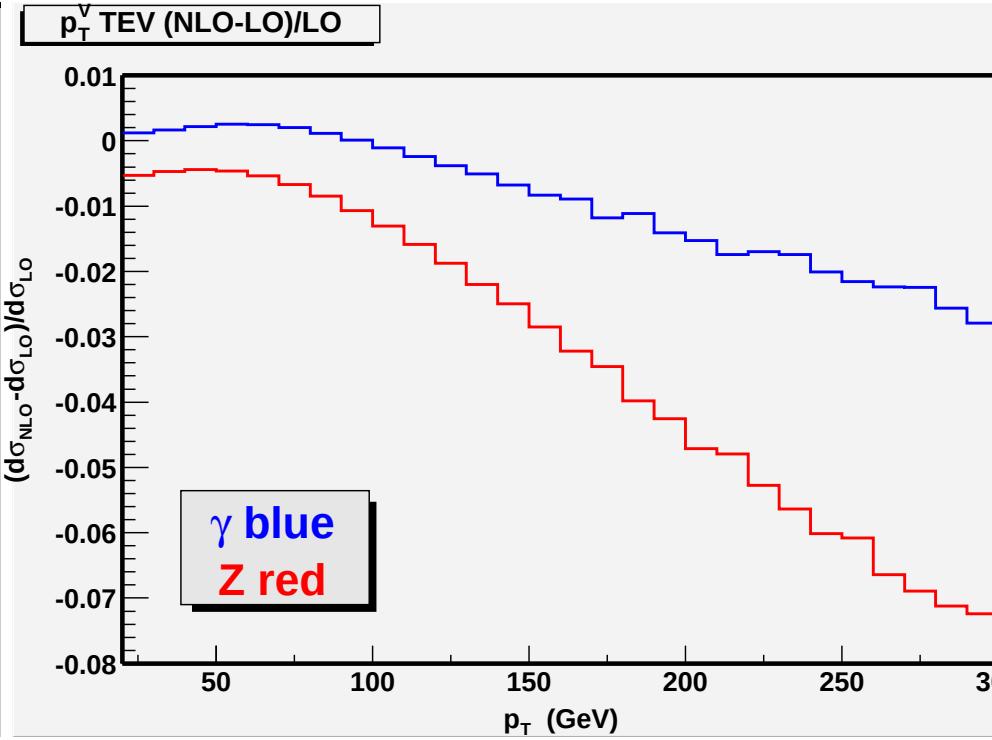




$p_T(l) > 15\,\mathrm{GeV},\ |\eta_l| < 2.4,\ p_T(j) > 20\,\mathrm{GeV},\ |\eta_j| < 4.5,\ \Delta R_{lj} > 0.4,\ \Delta R_{ll} > 0.2$

$\sqrt{s} = 2\,\mathrm{TeV}$: $p\bar{p} \to \gamma, Z + j$: p_{Tj}



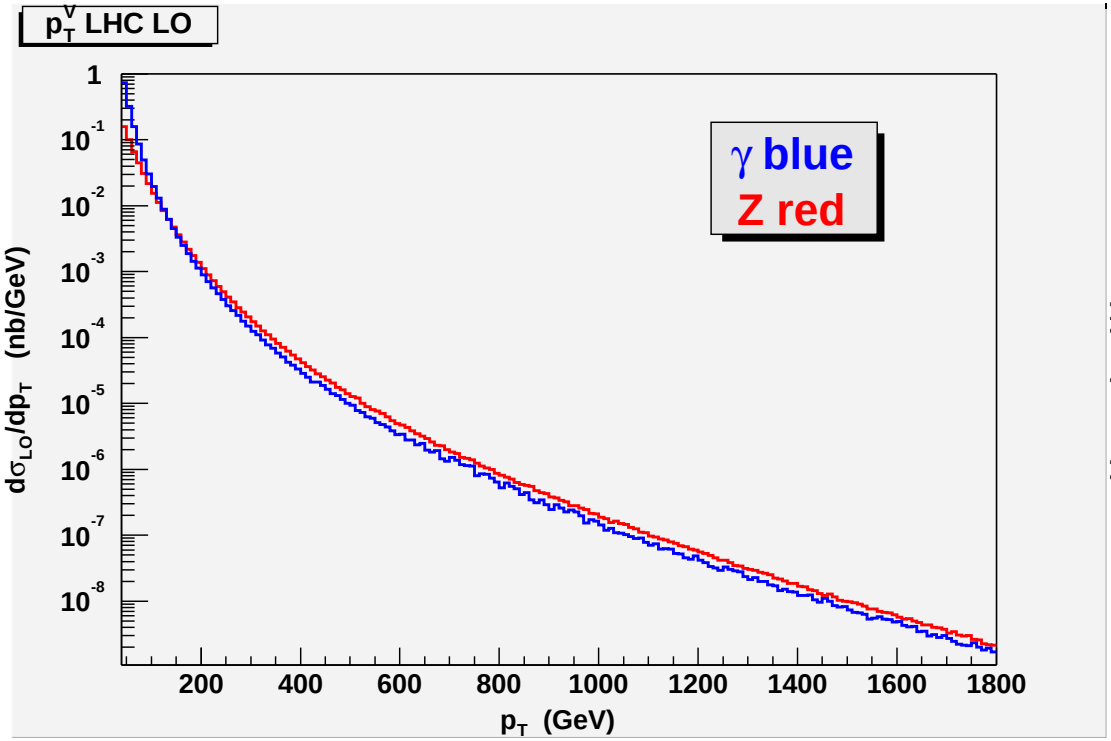


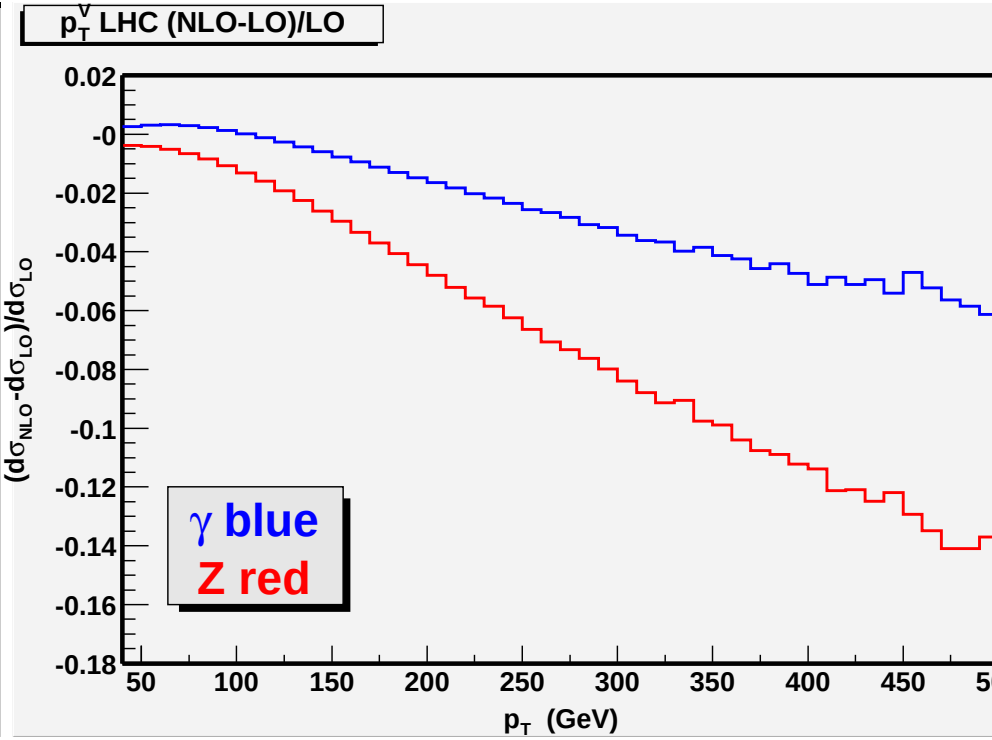
$p_T > 20\,\mathrm{GeV}, |\eta_j| < 3$

$L = 2 - 20 fb^{-1}, \quad BR(Z \to e, \mu) \approx 6.5\%$ In a window of 10 GeV at $p_T = 100\,\mathrm{GeV}$ we expect about 500-5000±22-71 $Z + j$ events

$\delta\sigma/\sigma \approx -1.2\%$ corresponds to 6-60 events

LHC $\sqrt{s} = 14\,\mathrm{TeV}$: $pp \to \gamma, Z + j$: p_{Tj}





$p_T > 40\,\mathrm{GeV}, |\eta_j| < 4.5$

$L = 30 fb^{-1}, \quad BR(Z \to e, \mu,) \approx 6.5\%$ IN A WINDOW OF 40 GeV AT $p_T = 450\,\mathrm{GeV}$ WE EXPECT ABOUT 2000 ± 45 $Z + j$ EVENTS

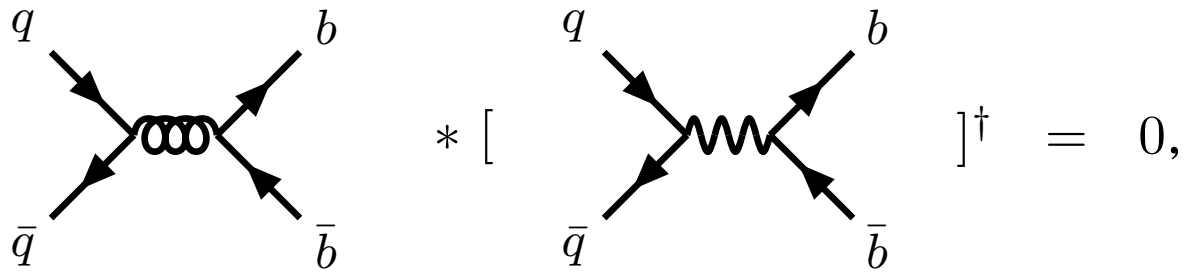
$\delta\sigma/\sigma \approx -12\%$ CORRESPONDS TO 240 EVENTS

$b\bar{b}$ PRODUCTION AT HADRON COLLIDERS

[HEP-PH/0307021]

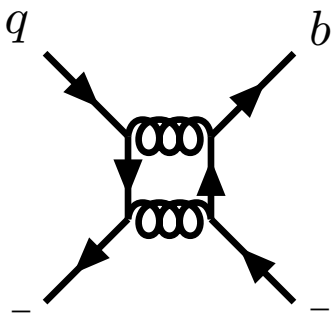
- b PRODUCTION HAS SHOWN DISCREPANCIES WITH SM
- TEVATRON RUN 2 AND LHC WILL PROVIDE LARGER DATA SAMPLES AT LARGER $\sqrt{\hat{s}}$
- WEAK INTERACTIONS LEAD TO MEASURABLE ASYMMETRIES

TREE LEVEL



$$= \quad 0,$$

NLO



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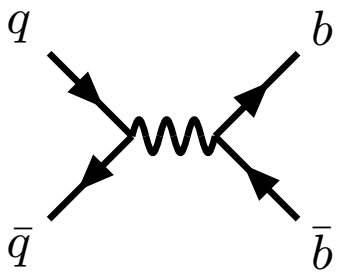
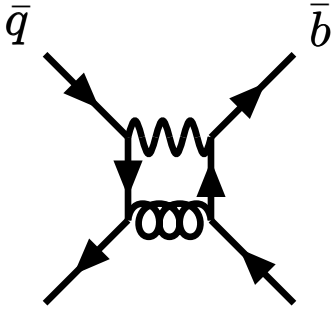


$]^\dagger$ + CROSSED BOX +



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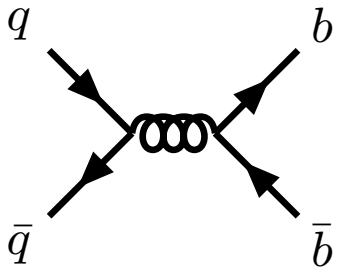

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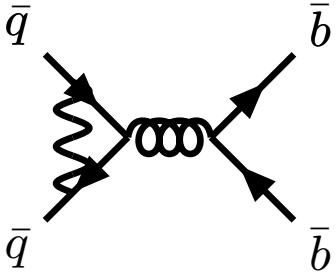

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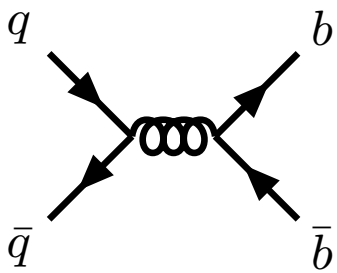
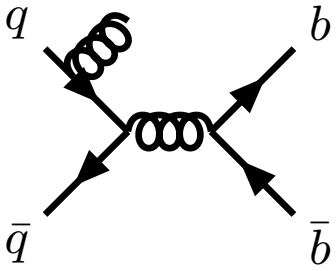


$]^\dagger$ + OTHER THREE VERTICES +

+ ALL SELF-ENERGIES +



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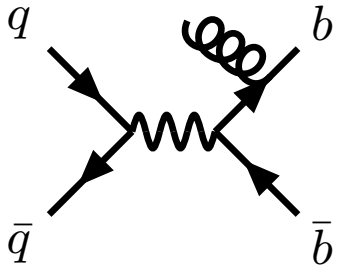
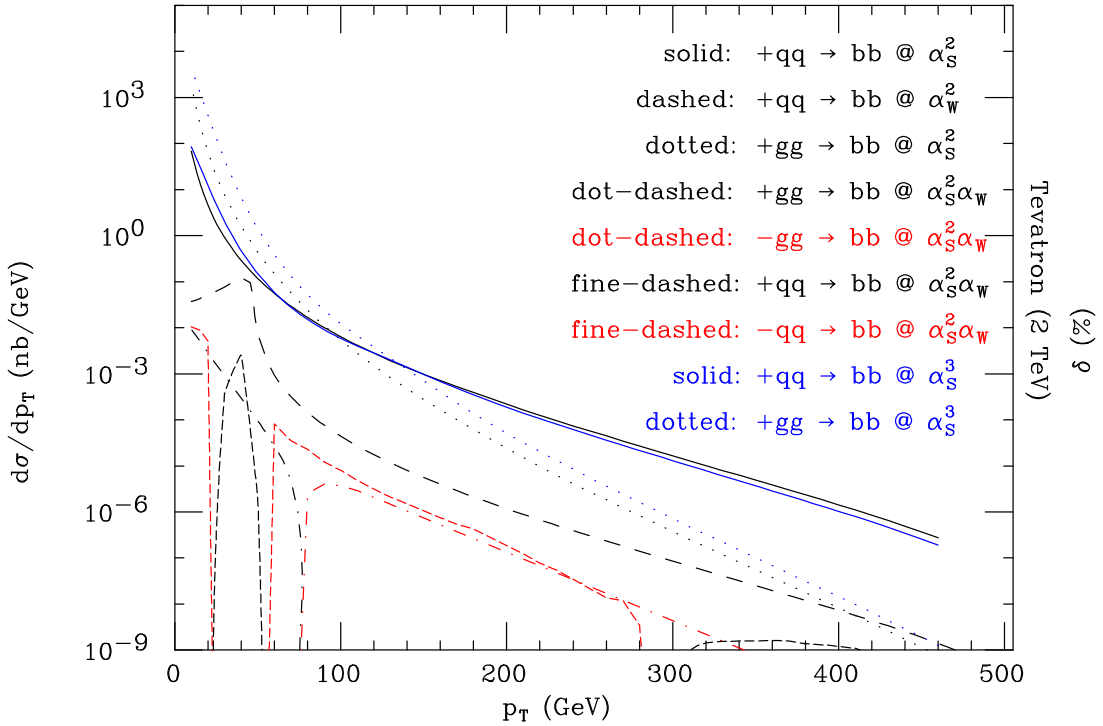
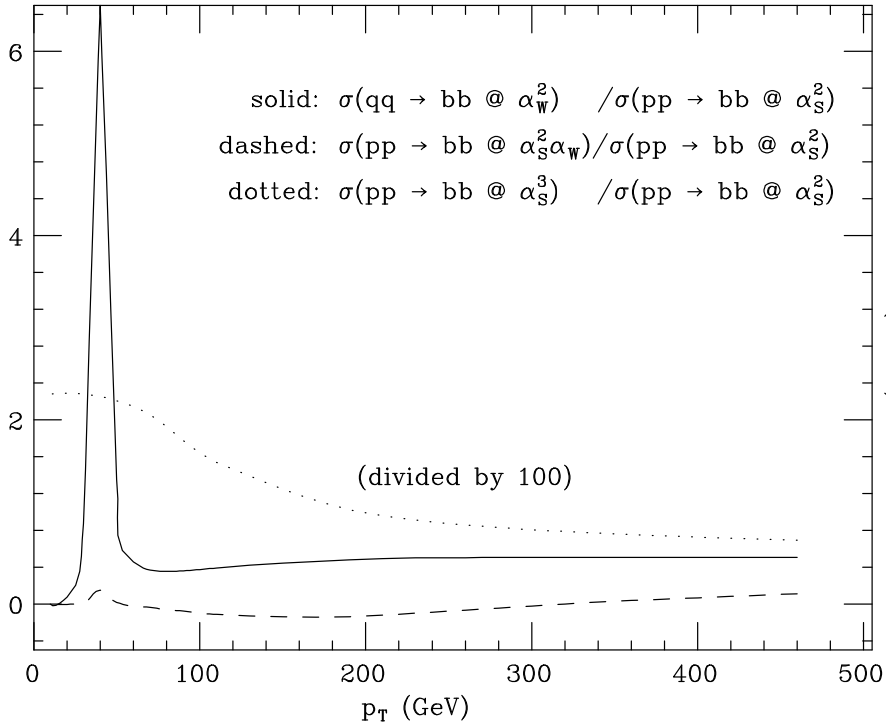


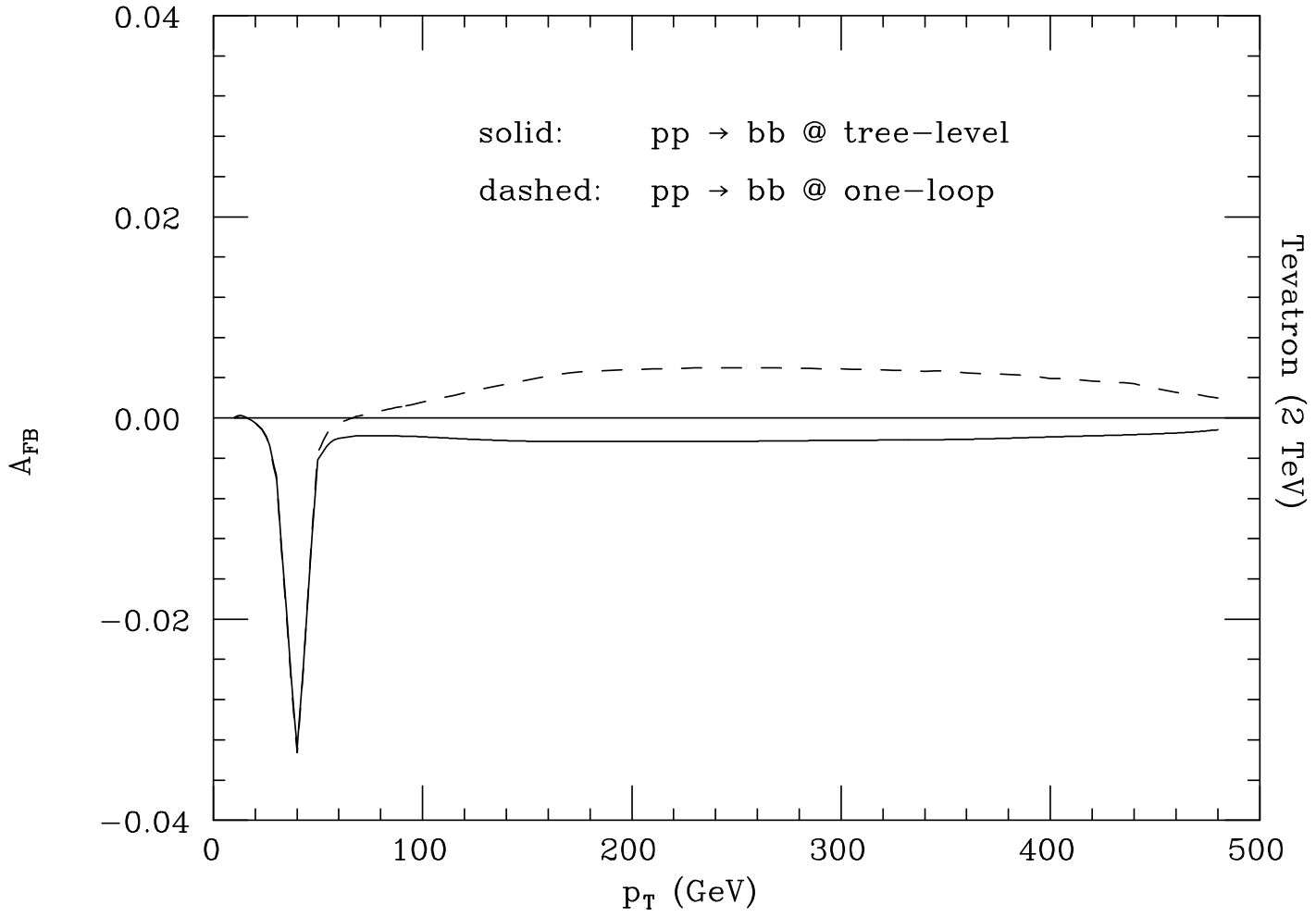
$]^\dagger$ + GLUON PERMUTATIONS.

TEVATRON: $p\bar{p} \longrightarrow b\bar{b}$ $\sqrt{(s)} = 2\,\mathrm{TeV}$



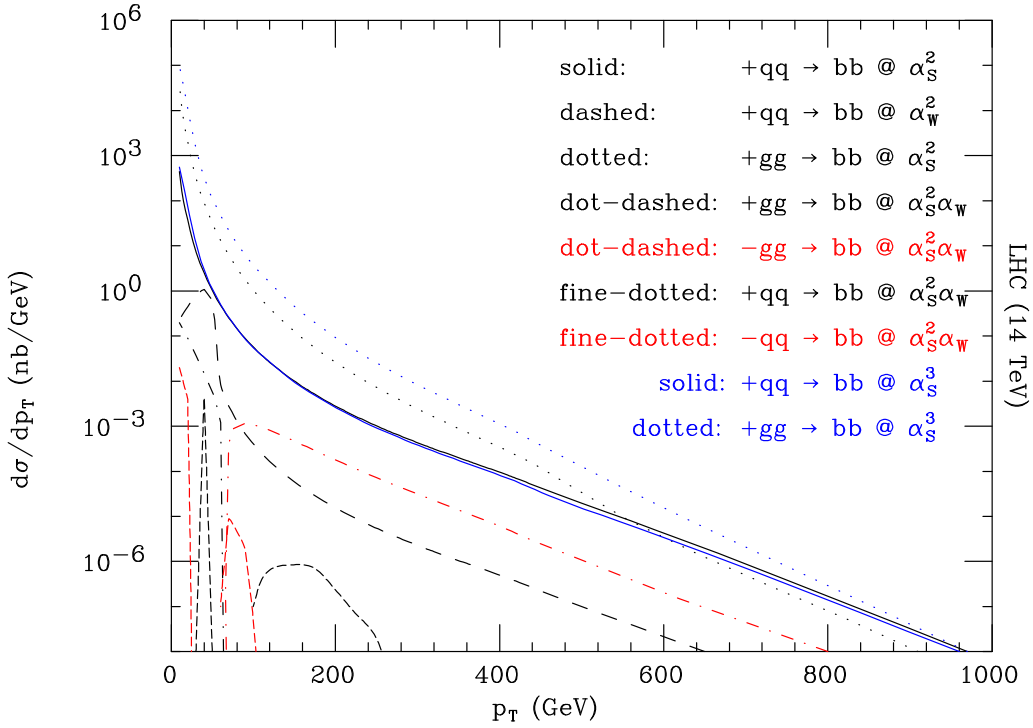


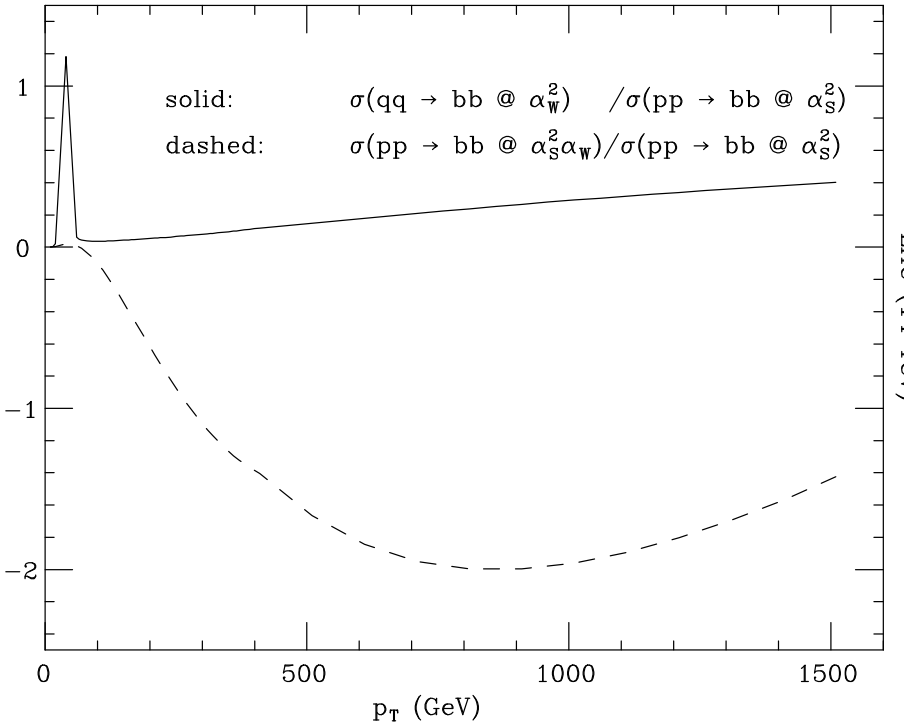
TEVATRON: $p\bar{p} \to b\bar{b}$ FB ASYMMETRY $\sqrt{(s)} = 2\,\mathrm{TeV}$



$$A_{\mathrm{FB}} = \frac{\sigma_+(p\bar{p} \to b\bar{b}) - \sigma_-(p\bar{p} \to b\bar{b})}{\sigma_+(p\bar{p} \to b\bar{b}) + \sigma_-(p\bar{p} \to b\bar{b})},$$

LHC: $pp \to b\bar{b}$ $\sqrt{(s)} = 14\,\mathrm{TeV}$





Conclusions

Weak corrections are available for:

- $e^+e^- \to 3j$ at the Z pole
- $pp, p\overline{p} \to j + Z, \gamma$
- $pp, p\overline{p} \to b\overline{b}$

They are relevant for:

- High precision measurement: LC-GigaZ
- High energy – High p_T processes
- Asymmetry-like observables

- Need to be combined with QCD corrections