Summary Talk: Loop/Top/QCD Session

(J. Fuster, R.Godbole, Y.Kurihara, F.Maltoni, SM, T.Tait,)

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LCWS 2010, Beijing, China

Topics discussed at Session

- Anomalous top quark couplings
  (R. Godbole, P. Saha, R. Santos)
- Top polarization as a probe of new physics
  (R. Godbole)
- Heavy resonances decaying to top quarks
  (G. Rodrigo)
- Top mass extraction near the top pair threshold
  (Y.Kiyo)
- Top FCNC
  (R.Santos)
- Experimental aspects of BSM searches with top quarks
  (M.Vos)
- One-loop radiative corrections in SUSY using GRACE
  (M.Jimbo)
- QCD Static potential
  (Y.Kiyo)

Topics discussed at Session

Large focus on top physics!

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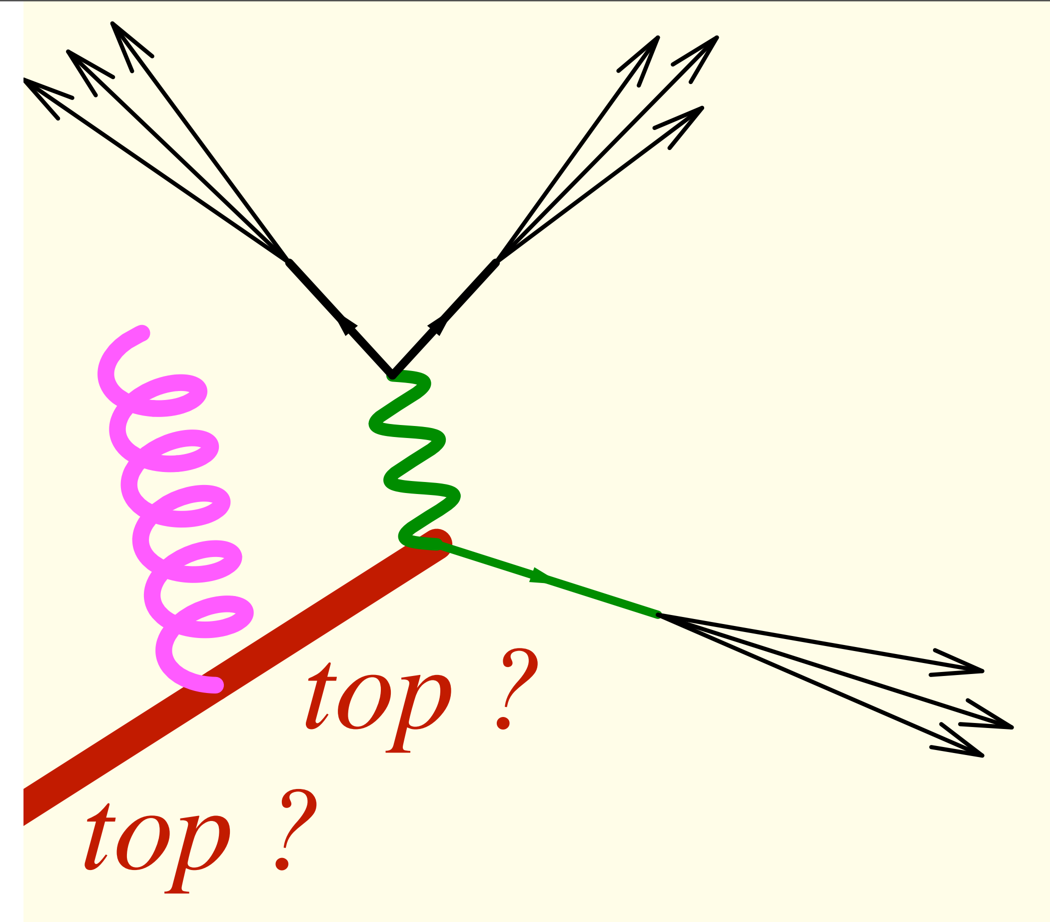
Top Mass



- What is the top mass?

- Scale and scheme dependent:

  Pole, MSbar, 1S, jet mass,...

- Tevatron measurement:

$$M_t = 173.1 \pm 0.6 \ (\text{stat.}) \pm 1.1 \ (\text{syst.}) \ \text{GeV}/c^2$$

Which mass is this?

- "Kinematic reconstruction" not sufficient at high precision.

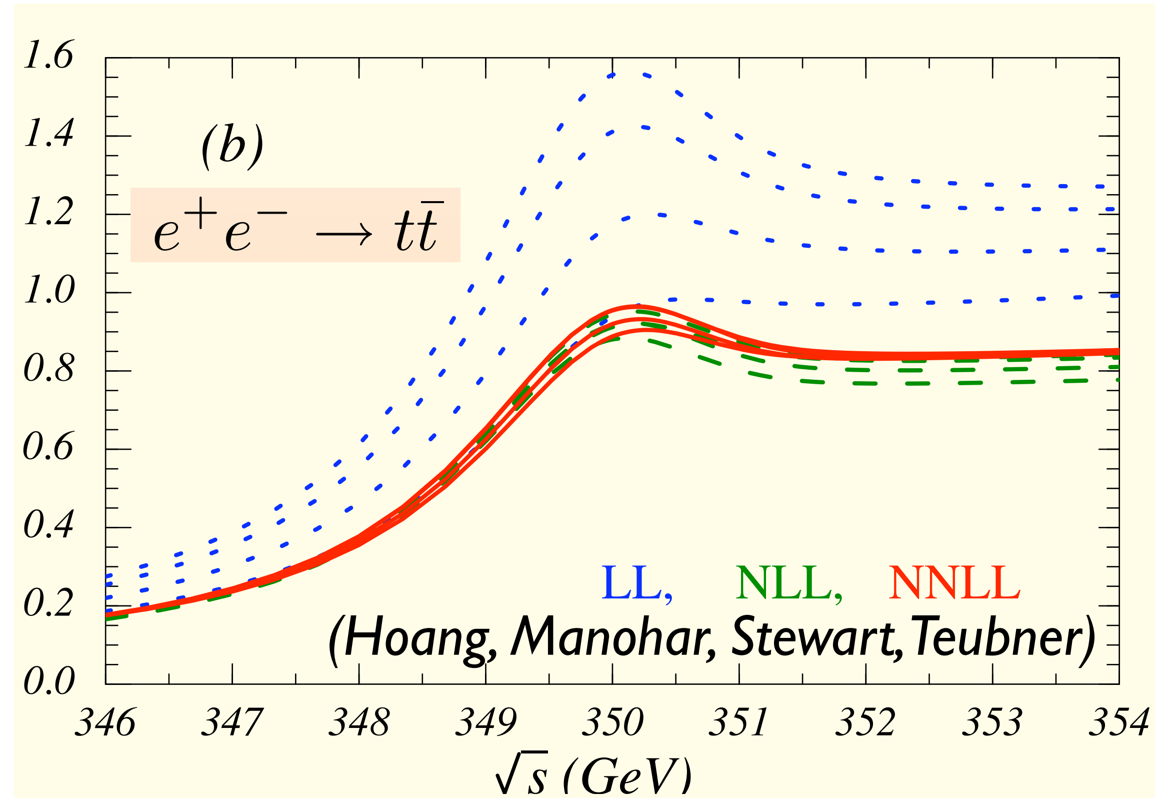
- NLC can be ideal for precision mass extraction with field theoretically rigorous knowledge of top mass schemes.

Top Mass

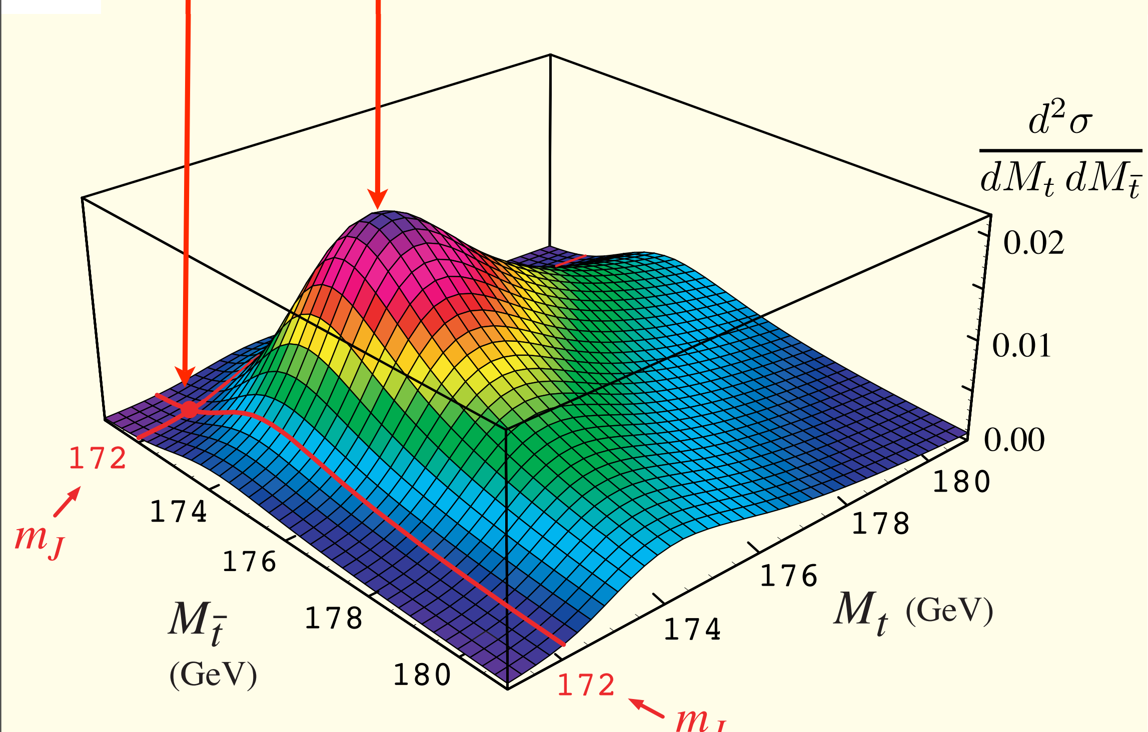
- Threshold scan

  1S mass scheme

  (Fadin &Khoze; Peskin & Strassler,...)



$$m = M_{\rm peak} - \Gamma(\alpha_s + \alpha_s^2 + \cdots) - \frac{Q\Lambda_{QCD}}{m}$$



- Top hemisphere jet mass distribution

  Jet mass scheme

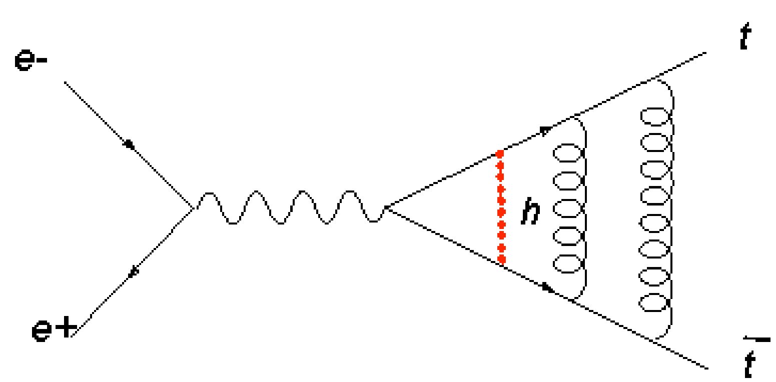
  (S.Fleming, A.Hoang, SM, I.Stewart)

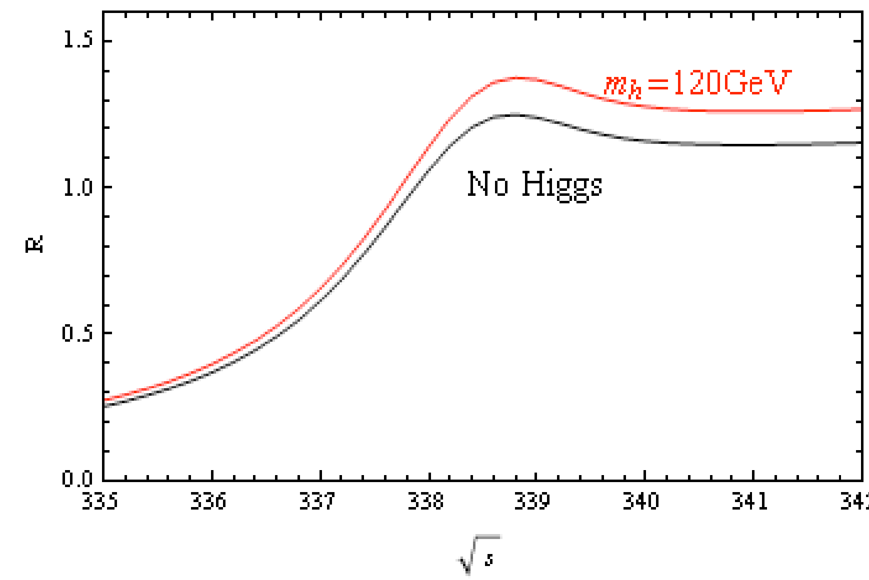
(Y.Kiyo)

m_t , y_t measurements near top threshold

- Threshold scan around tt-resonance

Fadin-Khoze, Strassler-Peskin(1991), Fujii-Matsui-Sumino(1994), ...





- SM Higgs contribution with m_h =120(200)GeV
  - 1-loop: +6(3)% to |R| Grzadkowski-Kuhn-Krawczyk-Stuart(1992)
  - h+QCD: +3(1)% to |R| (δE=-50(20)MeV) Eiras-Steinhauser(2006)

- Higgs shifts height of peak, top mass shifts position of peak.
- Also, studied the effect of SUSY models on the the line shape.

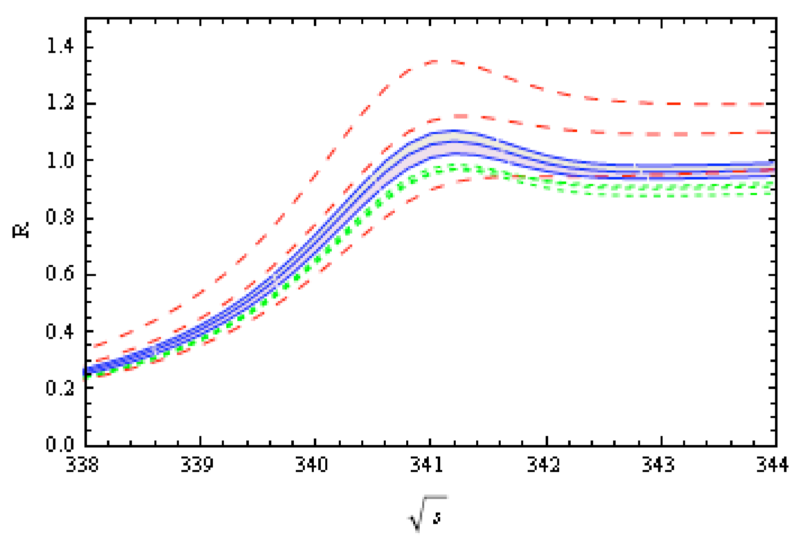
(Y.Kiyo)

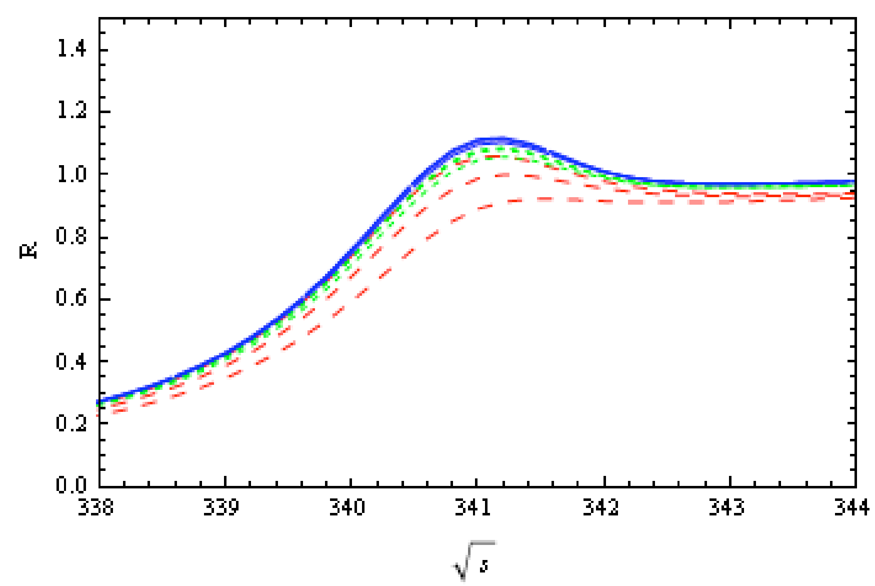
RG improvement for threshold XS

- Threshold enhancement is due to Coulomb resummation

  ⬇

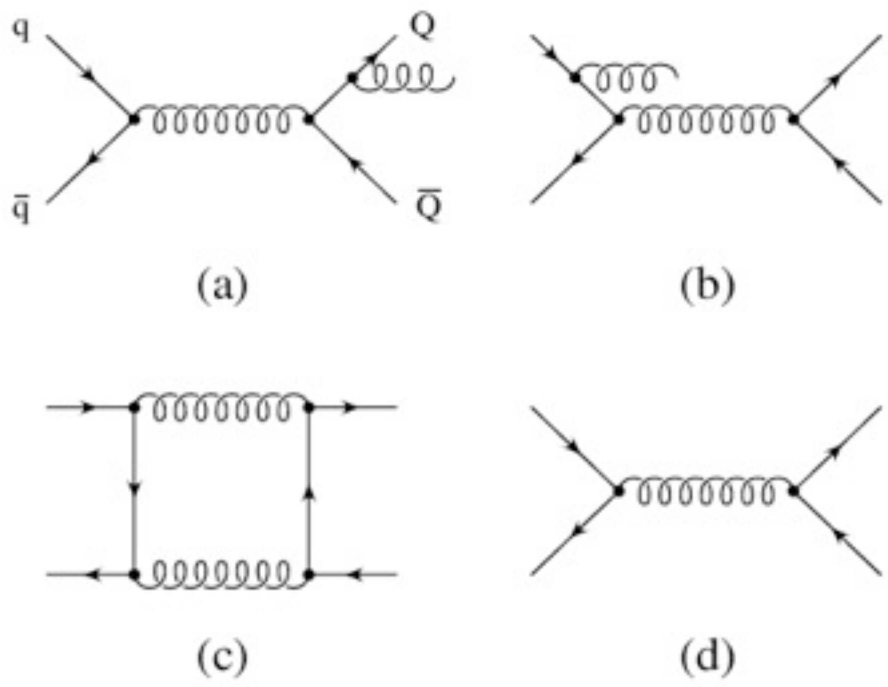
  RG improved potential to reach high accuracy
- Below RG improvement is applied to QCD static potential.
  (In the plots below we neglected other corrections as a first study)





$M_{t,PS}$ =170GeV, LO(Red)/NLO(Green)/NNLO(Blue) for μ=20, 30, 40GeV

(G.Rodrigo)

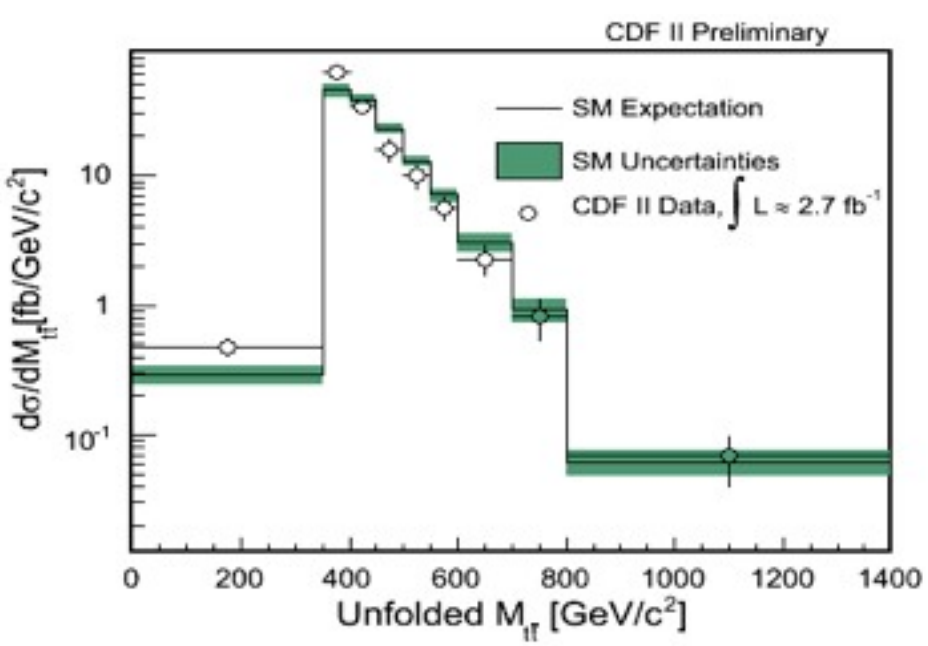


A charge asymmetry arises at O(α_S^3)

$$A^{p\bar{p}} = \frac{N_t(y>0) - N_{\bar{t}}(y>0)}{N_t(y>0) + N_{\bar{t}}(y>0)} = 0.051(6)$$

[Kühn, GR,1998; Antuñano, Kühn, GR, 2008]

CDF [Conf. Note 9724, PRL101(2008)202001, new measurement soon, Rob Roser]



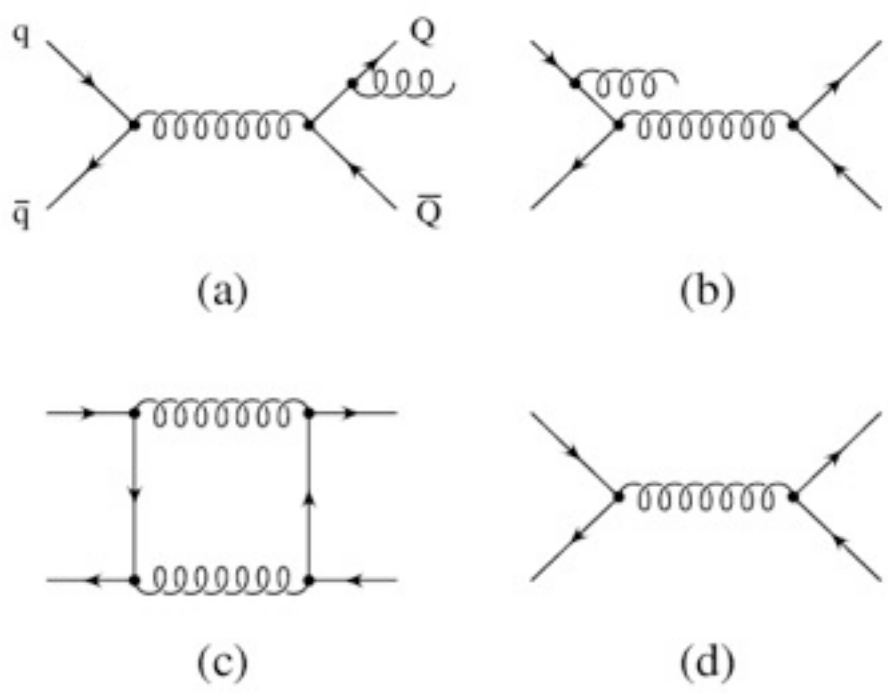
[CDF note 9602 (Nov 2008)]

$A_{FB}^{ppbar} = 0.193 \pm 0.065\ (\text{stat}) \pm 0.024$

$A_{FB}^{ppbar} = 0.17 \pm 0.07\ (\text{stat}) \pm 0.04\ (\text{syst})$

- Top quarks like to be produced in the direction of the incoming quark.

(G.Rodrigo)



A charge asymmetry arises at $O(\alpha_S^3)$

$$A^{p\bar{p}} = \frac{N_t(y>0) - N_{\bar{t}}(y>0)}{N_t(y>0) + N_{\bar{t}}(y>0)} = 0.051(6)$$

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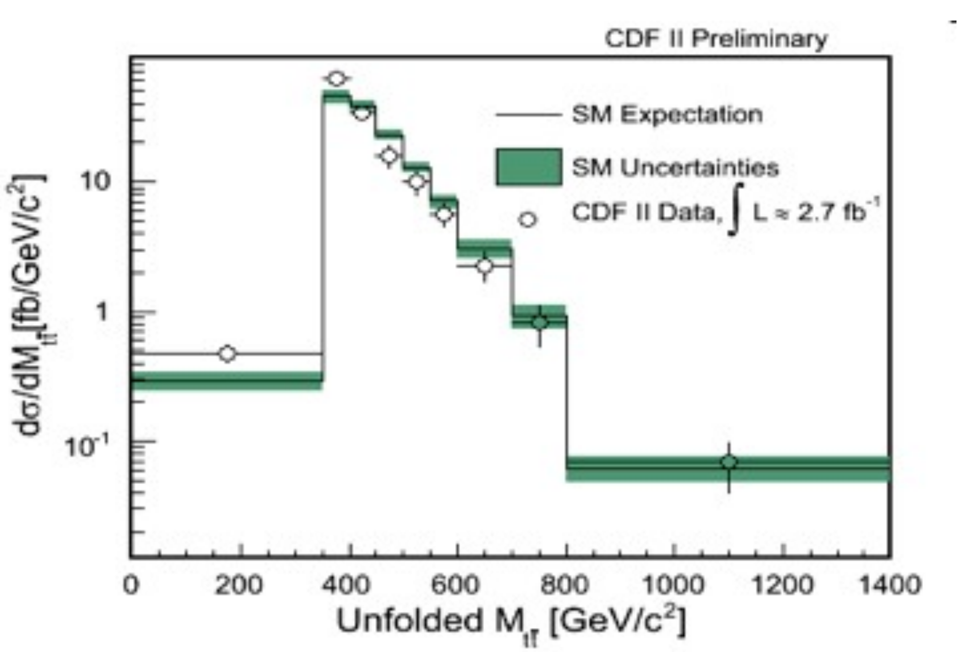


[CDF note 9602 (Nov 2008)]

$A_{FB}^{ppbar} = 0.193 \pm 0.065$ (stat) $\pm\, 0.024$

$A_{FB}^{ppbar} = 0.17 \pm 0.07$ (stat) $\pm\, 0.04$ (syst)

2.8σ from zero, $(A^{exp} - A^{SM})_{ppbar} = 0.142 \pm 0.069$

room for BSM within 2σ

- Top quarks like to be produced in the direction of the incoming quark.

(G.Rodrigo)

- room for BSM within 2σ at the Tevatron from the measurement of the top quark charge asymmetry (forward-backward), early to claim new physics, but, together with $d\sigma/dM_{ttbar}$, allows to set constrains in the top quark sector

  - ✔ Flavour Universal axigluons with large vector couplings
  - ✔ Flavour non-Universal axigluons: $\mathrm{sign}(g_A^q) = -\mathrm{sign}(g_A^t)$
  - ✔ Flavour violating scalars in the t-channel: triplet or sextet
  - ✔ Flavour violating Z´ and W´ relatively light O(200 GeV)

with very positive and exciting evolution

- The charge asymmetry can be measured at the LHC too, and is a good observable to discriminate among different models

- If BSM colored physics is discovered at hadron colliders, the ILC will study loop-effects or multijet events, LQ are still an option

(P.Saha)

$$\text{SM} \quad : \quad g_s \bar{t} \gamma^\mu T_a t G_\mu^a$$

$$g_s \frac{1}{\Lambda} \bar{t} \sigma_{\mu\nu} T_a t F_a^{\mu\nu} \qquad i g_s \frac{1}{\Lambda} \bar{t} \sigma_{\mu\nu} \gamma_5 T_a t F_a^{\mu\nu}$$

Chromomagnetic Dipole Moment Chromoelectric Dipole Moment

$$\mathcal{L}_{int} \ni \frac{g_s}{\Lambda} \bar{t} \sigma_{\mu\nu} (\rho + i \rho' \gamma_5) T_a t F_a^{\mu\nu}$$

Summary of Limits from Hadron Colliders

D. Choudhury and PS (arXiv:0911.5016)

Considering chromomagnetic and chromoelectric dipole moments separately and rephrasing the results in terms of commonly used notation :

$$\frac{1}{\Lambda}(\rho + i\rho') \longleftrightarrow \frac{1}{2m_t}(\kappa + i\tilde{\kappa})$$

$\rho = +1 : \Lambda \geq 10$ TeV

$\rho = -1 : \Lambda \geq 9$ TeV

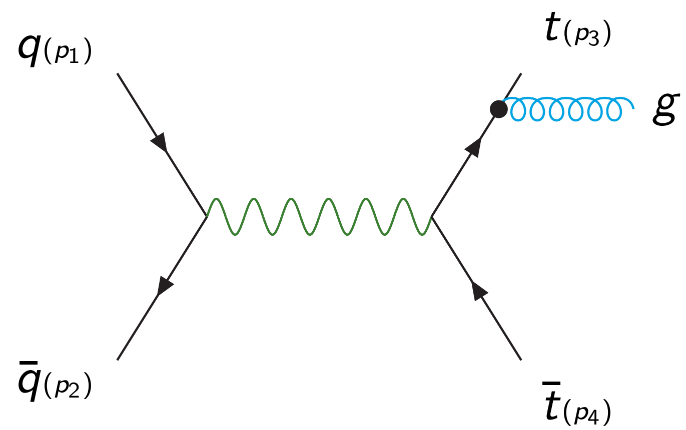
$\Rightarrow$ -0.038 $\leq \kappa \leq$ 0.034

$\rho' = \pm 1 : \Lambda \geq 3$ TeV $\Rightarrow$ $|\tilde{\kappa}| \leq 0.12$

(P.Saha)

Linear Collider Prospects

$$e^+e^- \longrightarrow t\bar{t}g$$

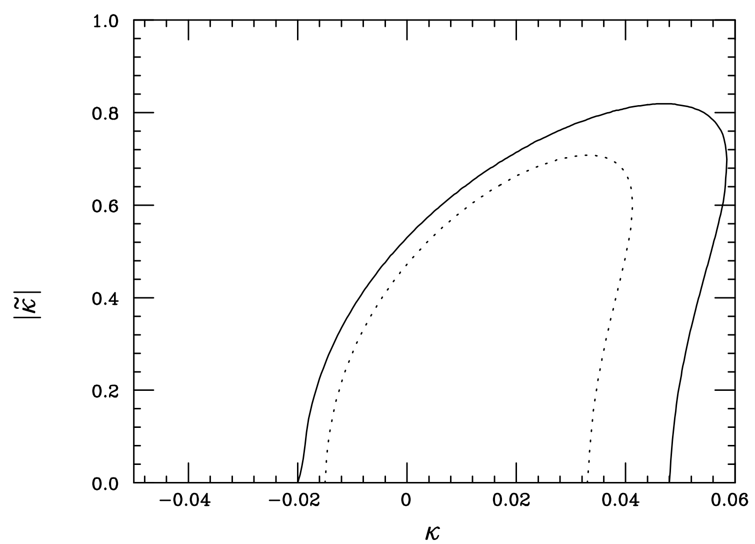


- Limits on anomalous magnetic moment can be improved at 1 TeV FLC.

T.G. Rizzo, Phys. Rev. D **50**, 4478 (1994); arXiv:hep-ph/9605361

Limits obtained by fitting the energy spectrum of the gluon.

$\sqrt{s} = 500$ GeV ; $\mathcal{L} = 50\ fb^{-1}$(solid), $100\ fb^{-1}$ (dotted) ; $E_g^{min} = 25$ GeV

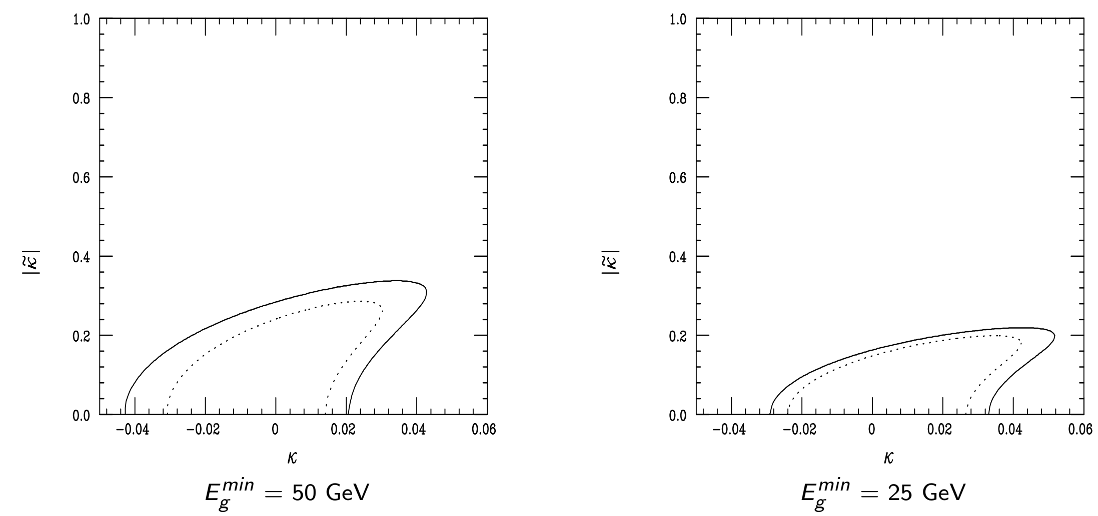


95% CL allowed region

Considering only one of κ and $\tilde{\kappa}$ to be non-zero at a time, from the dotted curve we have :

$$-0.015 \leq \kappa \leq 0.033 \qquad |\tilde{\kappa}| \leq 0.47$$

$\sqrt{s} = 1$ TeV ; $\mathcal{L} = 100\ fb^{-1}$(solid), $200\ fb^{-1}$ (dotted)



95% CL allowed region

Considering only one of κ and $\tilde{\kappa}$ to be non-zero at a time, from the dotted curve on the right panel we have :

$$-0.024 \leq \kappa \leq 0.026 \qquad |\tilde{\kappa}| \leq 0.14$$

Better sensitivity to κ but not to $\tilde{\kappa}$

(R.Godbole)

Top polarization as probe of New Physics

- Measurement of Top polarization can be a very good probe of some types of BSM physics

- Secondary decay lepton angular distributions are the most faithful polariometers, robust to effects of non standard tbW couplings as well as higher order corrections.

- Energy fraction of the lepton and b–jet can be used for the boosted tops. Lepton distribution less sensitive to the anom. coupling and hence a better probe.

- At the LHC showed that ϕ distibutions can be used to construct obeservables which directly probe the polarisation produced in the decay of a resnonance. An example of an extra Z' decaying into $t\bar{t}$ was presented.

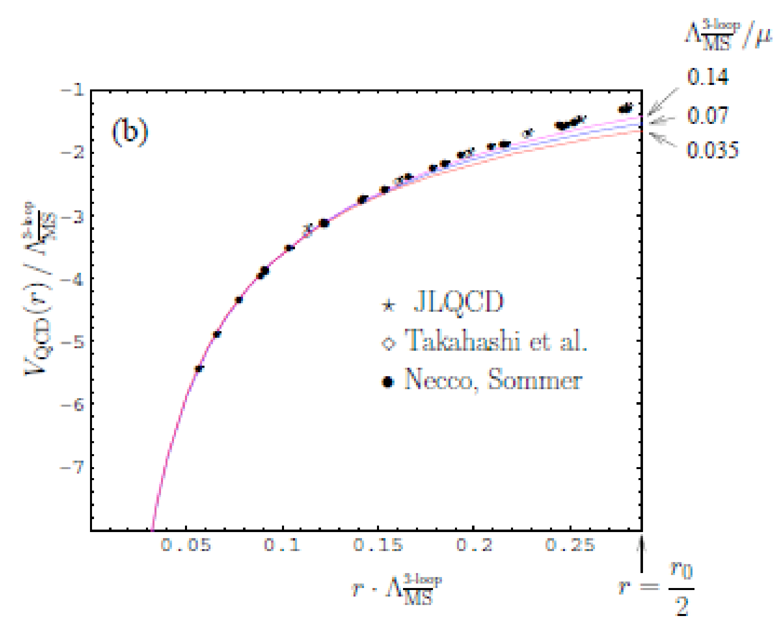
(Y. Kiyo)

QCD Static potential V(r)

$$V_{\rm QCD}(r) = -\lim_{T\to\infty} \frac{1}{iT} \ln \frac{\langle 0 \,|\, {\rm Tr\,P}e^{ig\oint_C dx^\mu A_\mu} \,|\, 0 \rangle}{\langle 0 \,|\, {\rm Tr}\,\mathbf{1} \,|\, 0 \rangle}$$

Wilson loop in large T limit defines the static potential

- W[C] is gauge invariant, and well-defined quantity
  e.g. comparison possible with Lattice QCD
- Important quantity in heavy quark physics, $J/\psi, \Upsilon$
  Quarkonia energy spectrum



- Comparison with Lattice data for 0-flavour QCD, region roughly corresponds to Upsilon 1S.

(Y. Kiyo)

- QCD static potential at three loop is completed after 32 (10) years from 1-loop (2-loop) computation.

(Anzai-YK-Sumino, Smirnov-Smirnov-Steinhauser 2009)

- Scale dependence is tiny for top, convergence to quench Lattice data is also good, which encourage us for phenomenological applications.

a. Precision determination of QCD coupling with Lattice data
b. Quarkonium phenomenology with obaitned potential
c. Another applications of technology to three loop?

LHC probing BSM physics through top

top reconstruction to cope with boosted topology (M.Vos)

Lillie, Randall, Wang, JHEP 09 (2007) 074, hep-ph/0701166,

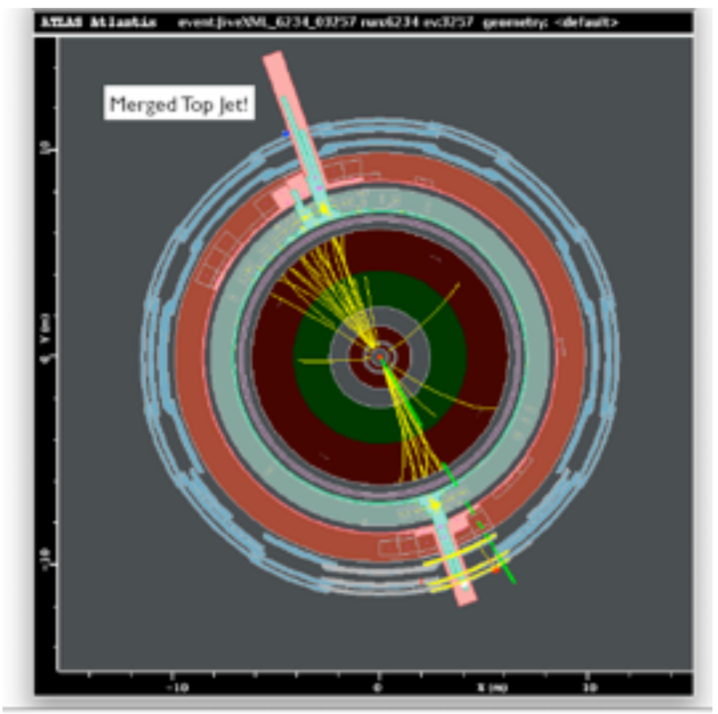
K. Agashe et al., Phys. Rev. D77 (2008) 015003, hep-ph/0612015,

U. Baur and L.H. Orr, Phys. Rev. D76 (2007), 094012, 0707.2066,

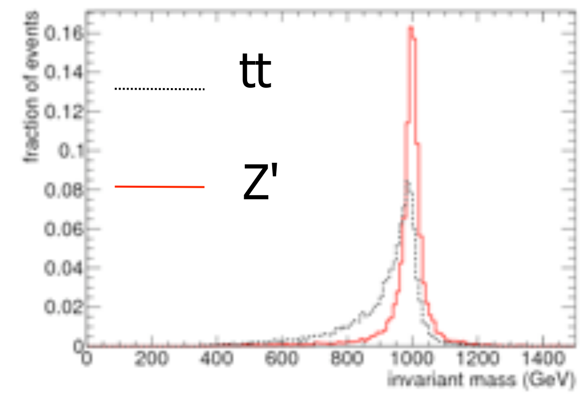
J. Thaler and L.T. Wang, JHEP 07 (2008) 092, 0806.0023.

L.G. Almeida et al., Phys. Rev. D79 (2009) 074017, 0807.0234.

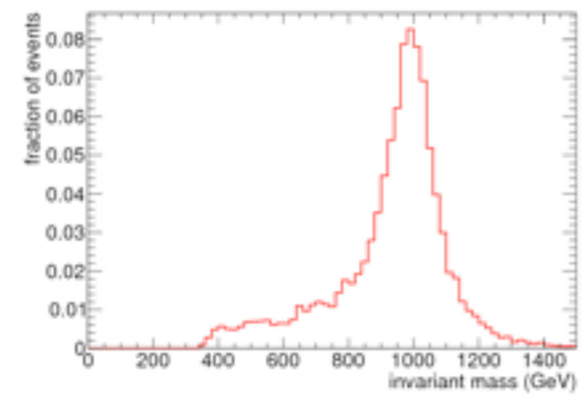
D.E. Kaplan et al., , Phys. Rev. Lett. 101 (2008) 142001, 0806.0848.

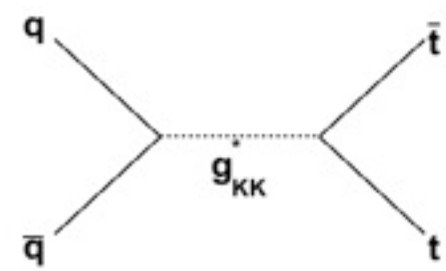


Narrow electro-weak resonance Z'
G ~ 3 % M
s x BR (X->tt) ~ 1 pb

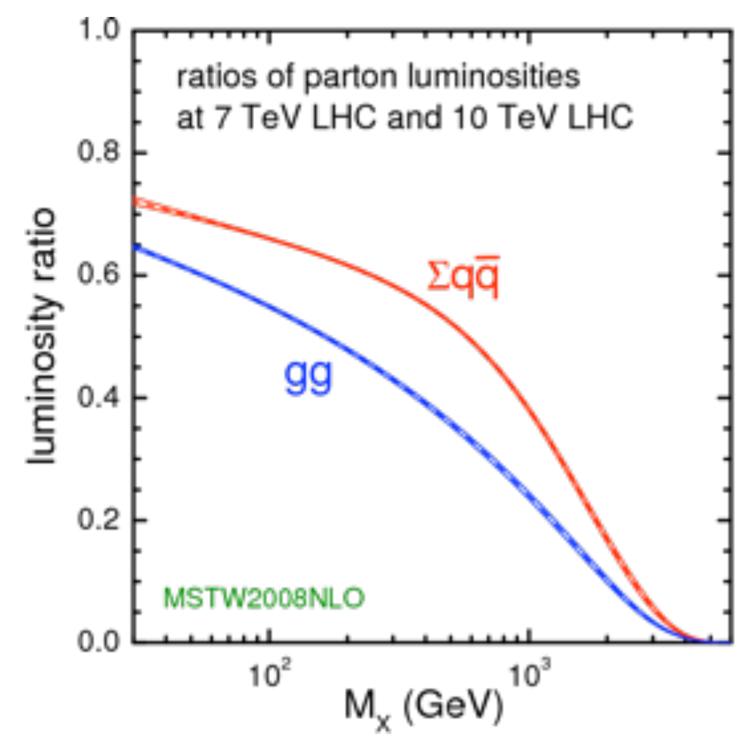


Broad coloured resonance: KK gluon
Randall, Lillie and Wang, JHEP 0709:074 (2007)
G = 15.3 % M
s x BR (X->tt) > 10 pb





Early = 2011 = 1 fb^{-1} @ 7 TeV



New approach boosts expected early LHC sensitivity for tt resonances:

Could see 1 TeV state if s x BR = several pb

(CMS-JME-09-001-PAS, CMS-TOP-09-009-PAS, CMS-EXO-09-002-PAS, CMS-EXO-09-009-PAS

ATL-PHYS-CONF-2008-008, ATL-PHYS-CONF-2008-016, ATL-PHYS-PUB-2009-081, ATL-PHYS-COM-2010-153)

Impact parameter resolution

tt production cross section at ILC:
~0.6 pb (√s = 500 GeV)
at (nominal) LHC:
~833 pb (√s = 14 TeV)

Sensitivity to heavy Z' through interference with standard model production (A_{FB})

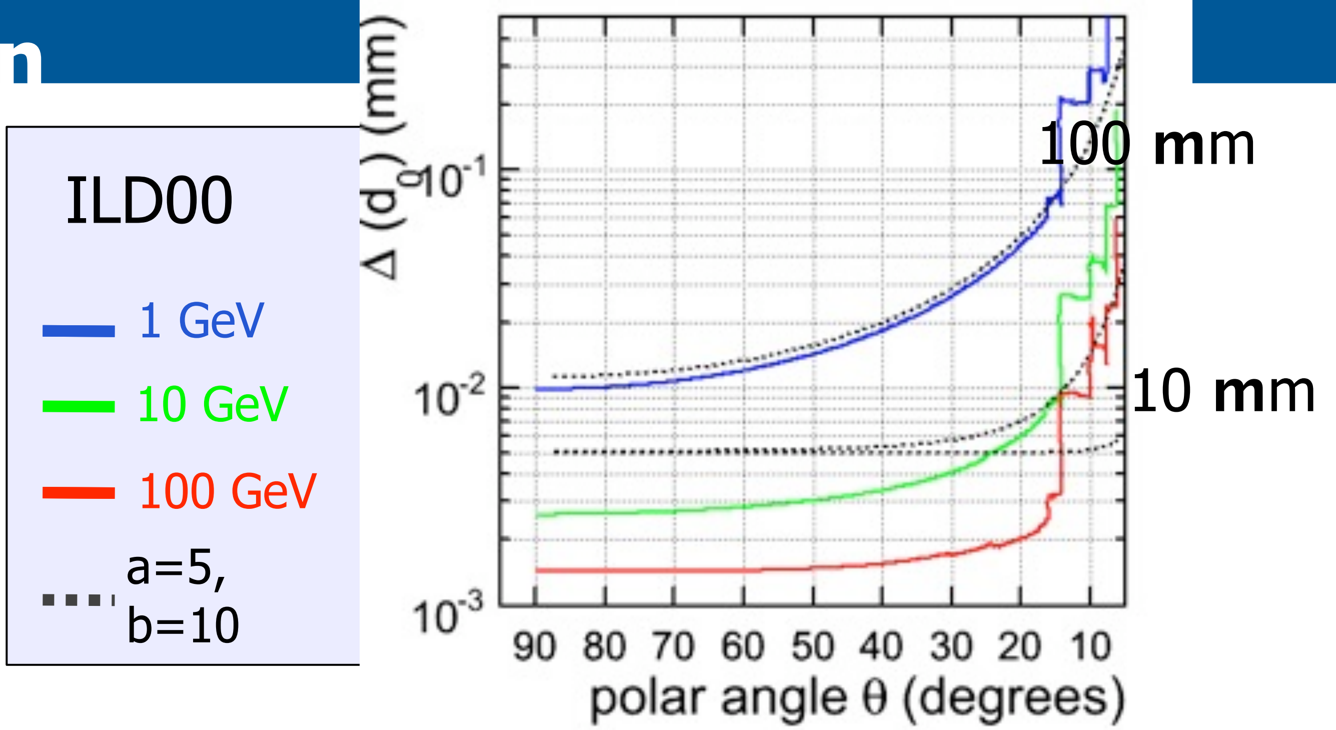
Coloured resonances?

ILC can constrain Ztt vertex, taking advantage of excellent detector performance.

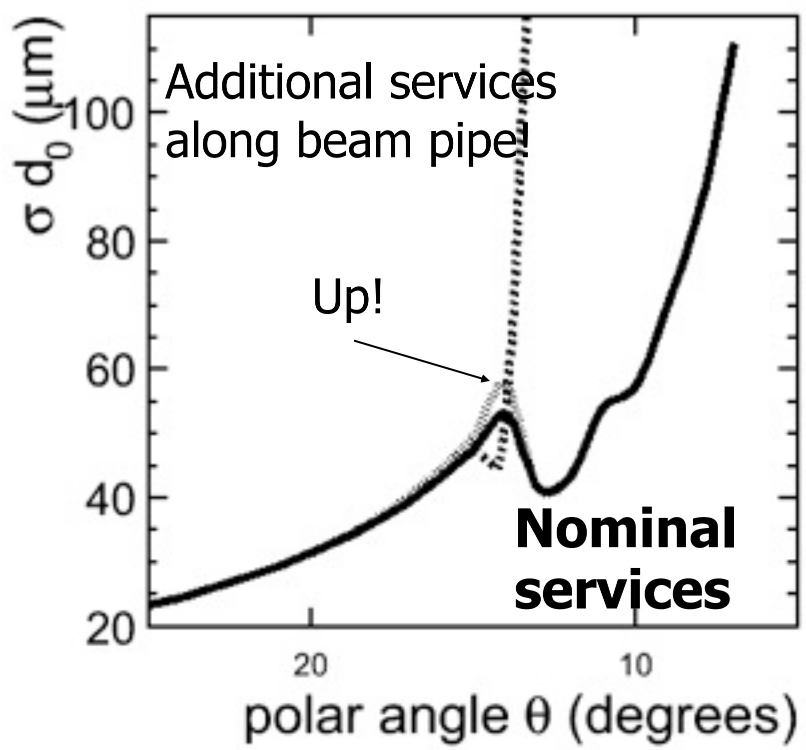
25 % of tt-bar events have a b-jet emitted in forward region (q < 30º)

Understand relation with detector performance!

(M.Vos)



Impact parameter resolution vs polar angle of shallow tracks



BSM with tops: take-away

(M.Vos)

BSM with tops at the LHC is very exciting

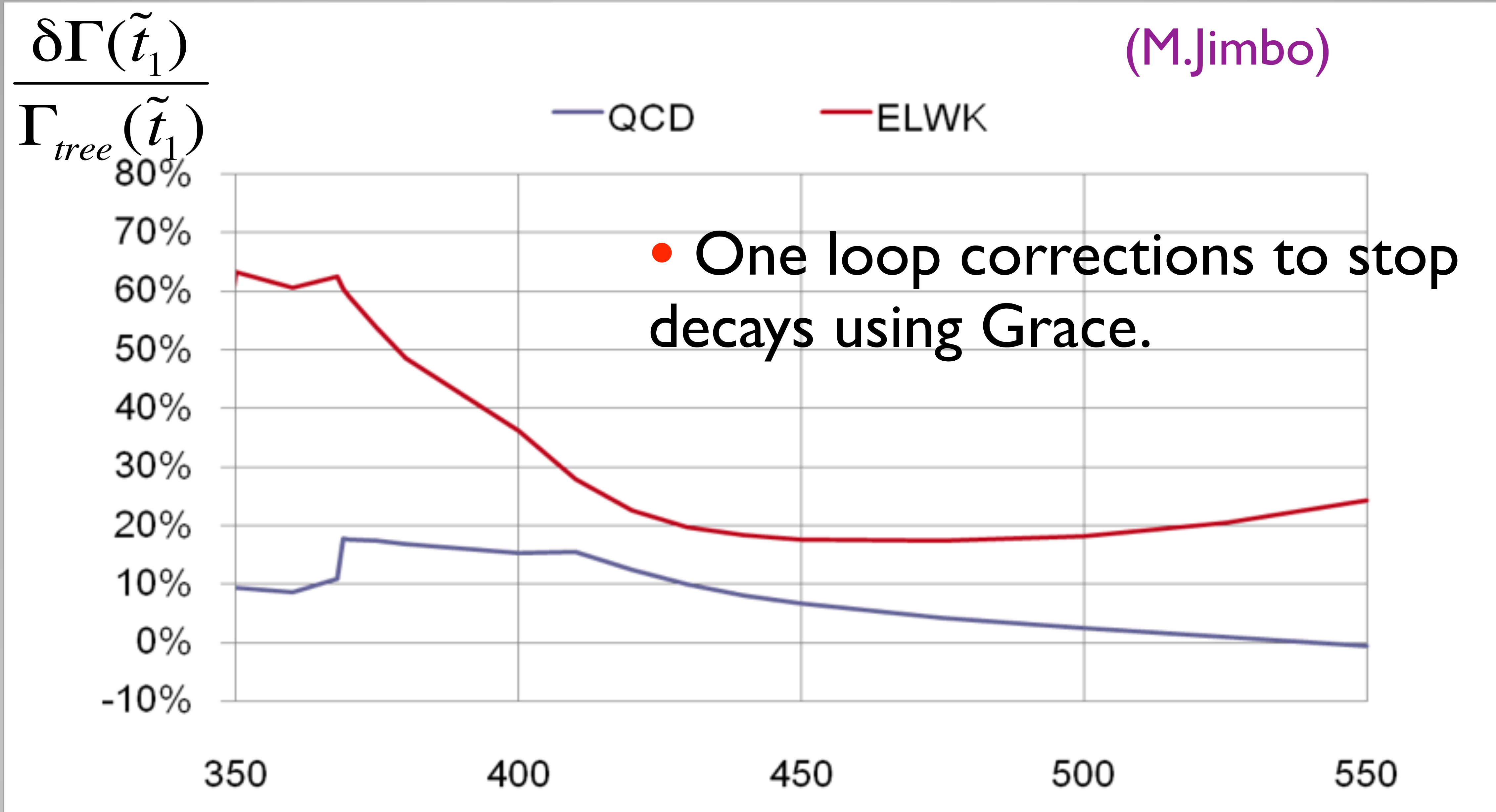
Translation of discovery into physics case for the ILC had received little attention, but this going to change (i.e. benchmark list from the physics panel)

Whole set of detector requirements to be derived:
- forward vertexing
- jet substructure analyses

Can we include a tt sample at 1 TeV to complete the series 350, 500, ..., multi-TeV?

If you're looking for a challenge: BSM with 4 tops at FLC

1-loop corrections for total width of $M_{\tilde{t}_1}$



- One loop corrections to stop decays using Grace.

$M_{\tilde{t}_1}\ (\mathrm{GeV})$

Conclusions

- Top quarks will play a dominant role in search for new physics.
- FLC has clear advantage for high precision top mass determination needed to better constrain BSM physics.
- Independent determinations of top Yukawa and top mass possible at FLC with high precision.
- FLC can be a precision machine for physics discovered at the LHC or a discovery machine depending on the new physics.