Interpretation of e+e- -> bbar

F. Richard LAL-Orsay

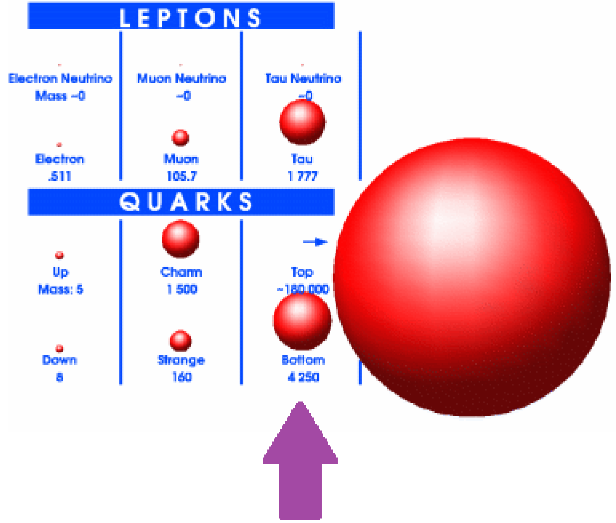
in collaboration with S. Bilokin and R. Poeschl

Workshop on top physics at the LC 2017

CERN 7-9 juin 2017

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Introduction



- The main attention has been up to now focused on the top sector, but e+e- also offers a unique opportunity to study weak couplings of **b quarks** to Z and γ
- While Z couplings can, as for LEP1, be measured at the Z resonance, outside the resonance **beam polarisation** is needed to separate the Z and γ components since, in contrast to the top, b decays are dominated by **scalar meson channels** and offer no observables to disentangle the two components
- Several **composite models** predict a high degree of compositeness both for the t and b quarks. In this respect the well-known deviation observed at LEP1 should be verified/discarded in the future
- Can this be done at **ILC**? To which accuracy ?

Purpose of this talk

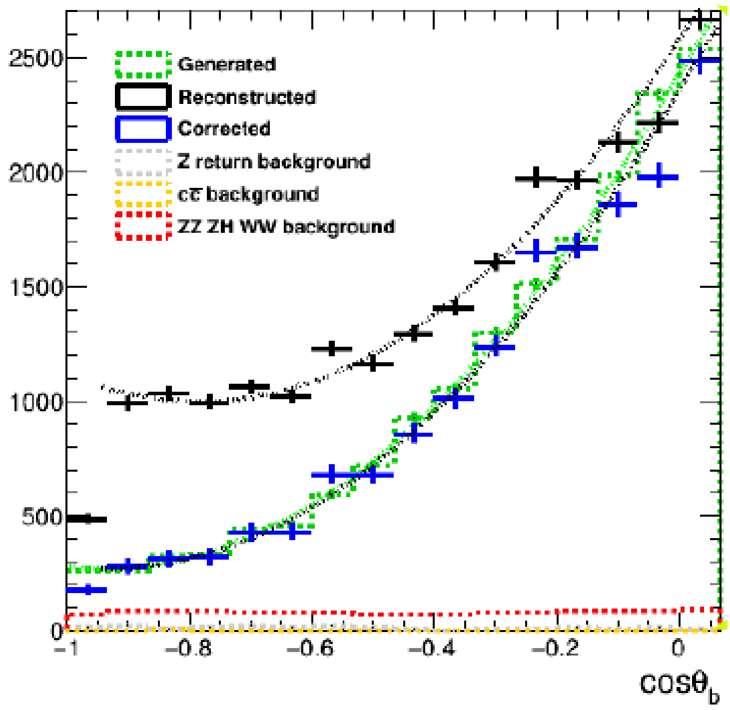
- This presentation intends to discuss a very recent analysis of the channel ee->bb with the ILD set up, collecting 500 fb^{-1} at 250 GeV with **polarized e- (80%) and e+ (30%)**
- I will briefly recall (see talk of **S. Bilokin**) the main features of this analysis relying on b charge determination using the **microvertex information** and the charged **kaon identification** from the TPC of ILD
- I will then derive the accuracies achievable from these measurements on the vector and axial couplings
- I will finally go through the interpretation of these results, recalling the **LEP1 puzzle** and putting this measurement in context with top physics

How to measure e+e- ->bb

- Secondary vertices allow to unambiguously identify **charged B mesons** and therefore the b quark charge
- Unfortunately this can only be done with limited purity, ~80%, given that the secondary track efficiency is limited at ~95% (half of this inefficiency being due to an absence of significant offset) recalling that, on average, one needs to reconstruct 5 charged tracks.
- To cope with this, one requires the presence of two charged B mesons, which reduces the efficiency
- This efficiency is increased to 13% by selecting **charged kaons** which give a comparable purity

Limitation

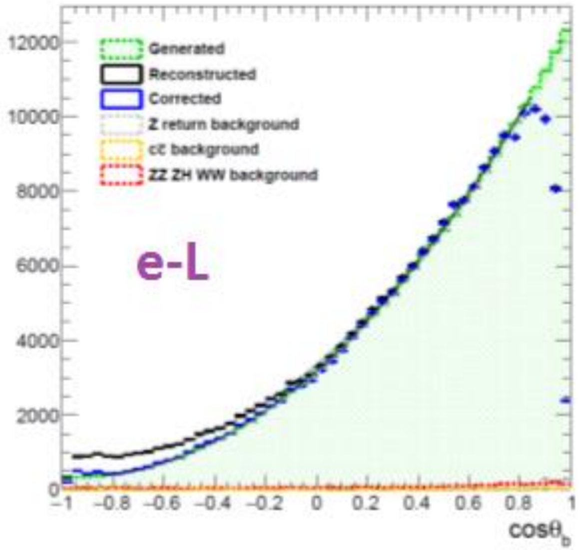
- Selecting two charged B mesons is however insufficient, in particular to measure $e^-_L e^+ \to bb$ which is very forward backward asymmetric
- A method was derived, using the amount of wrong sign events B+B+ and B-B- to correct for this effect
- Migration due to track losses can be **perfectly corrected** from the data themselves
- If BSM physics populate the backward hemisphere, it will be detected with very **high sensitivity**

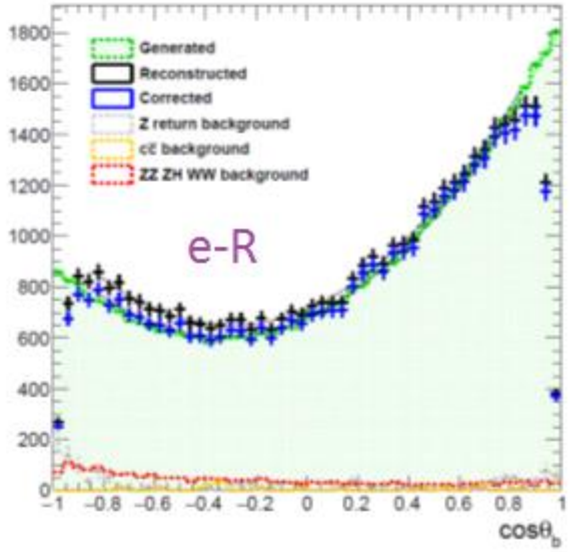


Results

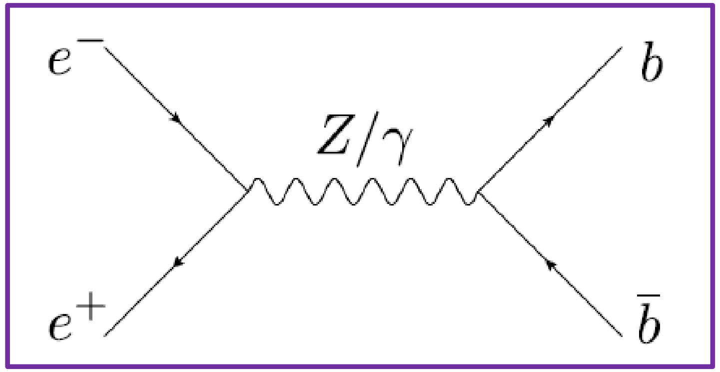
- The two curves are obtained with the two beams **fully polarized** and an integrated luminosity of 250 fb^{-1} for each polarisation
- 3% background coming from ZZ, ZH and radiative return to Z
- In practice 2/3 Lumi. taken with e^-_L and 1/3 with e^-_R [1506.07830](1506.07830)
- One can obtain these two distributions L and R from combining data obtained with partial polarisation
- **$d\sigma_{-,+}/d\cos\theta=0.58L+0.035R$** and $d\sigma_{+,-}/d\cos\theta= 0.58R+0.035L$

  $L=d\sigma_L/d\cos\theta$ and $R=d\sigma_R/d\cos\theta$
- L and R are fitted by $d\sigma/d\cos\theta \sim S(1+\cos^2\theta)+A\cos\theta$
- $S \sim F1V^2+F1A^2$ and $A \sim F1VF1A$ terms in $1/\gamma^2$ can be neglected
- For e^-_L S and A **strongly correlated** ($\rho \sim 0.8$) which reduces the errors
- The fit uses the region where $|\cos\theta|<0.8$

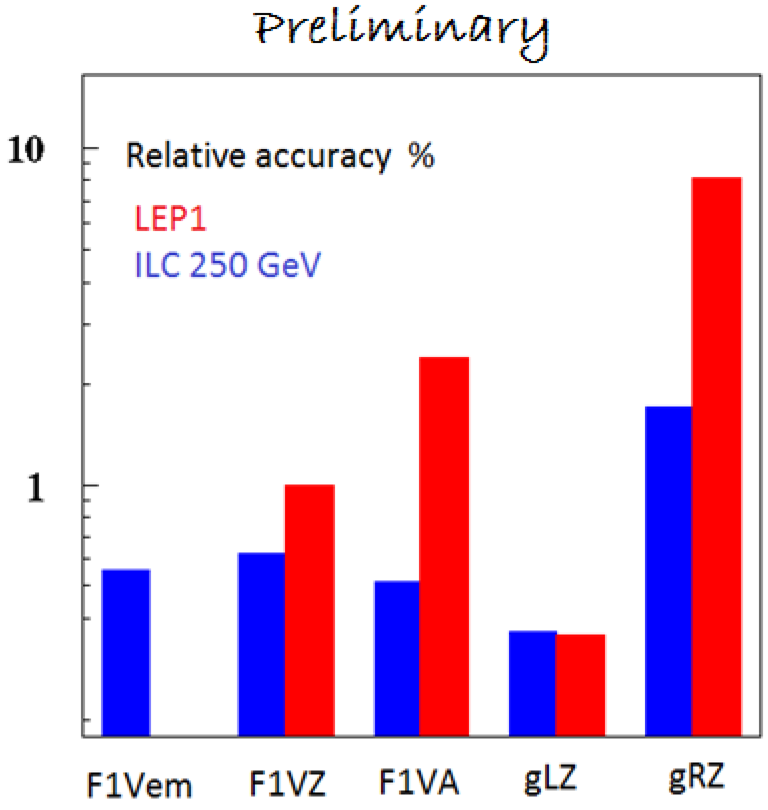




Separating γ from Z exchange

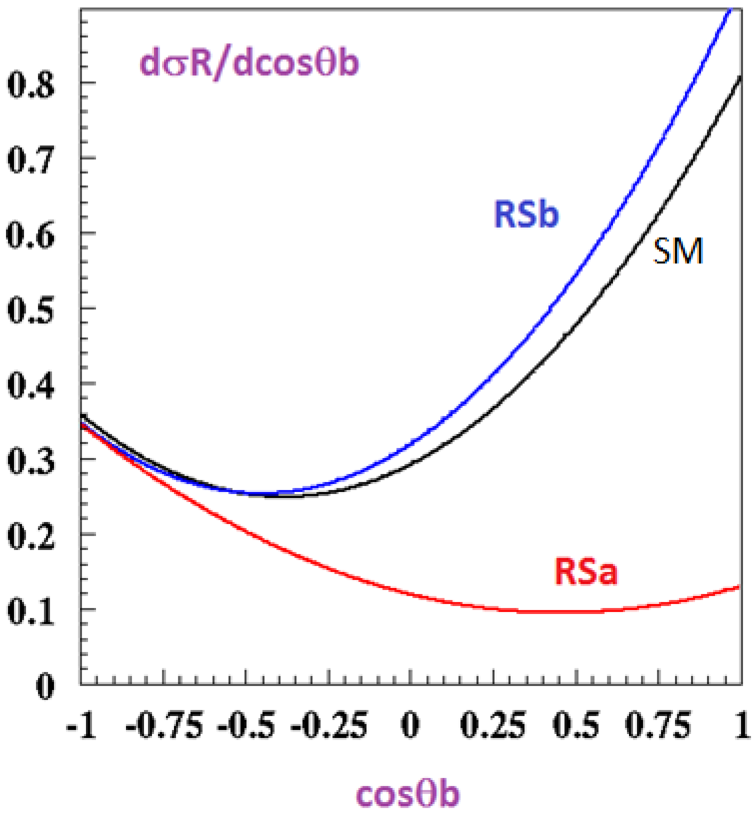


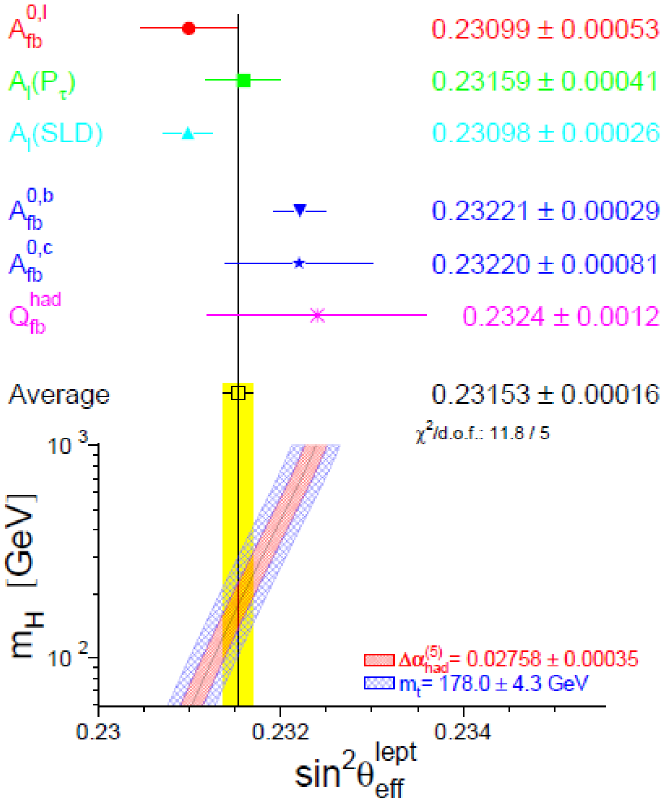
- With the four measurement of S and A for two polarisations one can **fully disentangle** F1VZ, F1AZ (or g_{RZ} and g_{LZ}) and F1Vem
- Precision is not limited **by systematics** (P, Lumi., εb, back. ~**0.4%**) and errors can be reduced with higher luminosity (2000 fb^{-1} is planned at ILC)
- δ**g_{RZ}/g_{RZ} ~2%** sufficient to **confirm at >5σ** or to **discard** the LEP1 effect which is at the **25%** level
- Recall the sign uncertainty on LEP1 solutions dg_{RZ}/g_{RZ}=25% or dg_{RZ}/g_{RZ}=-225%
- Not a problem at 250 GeV to make the right choice for the sign

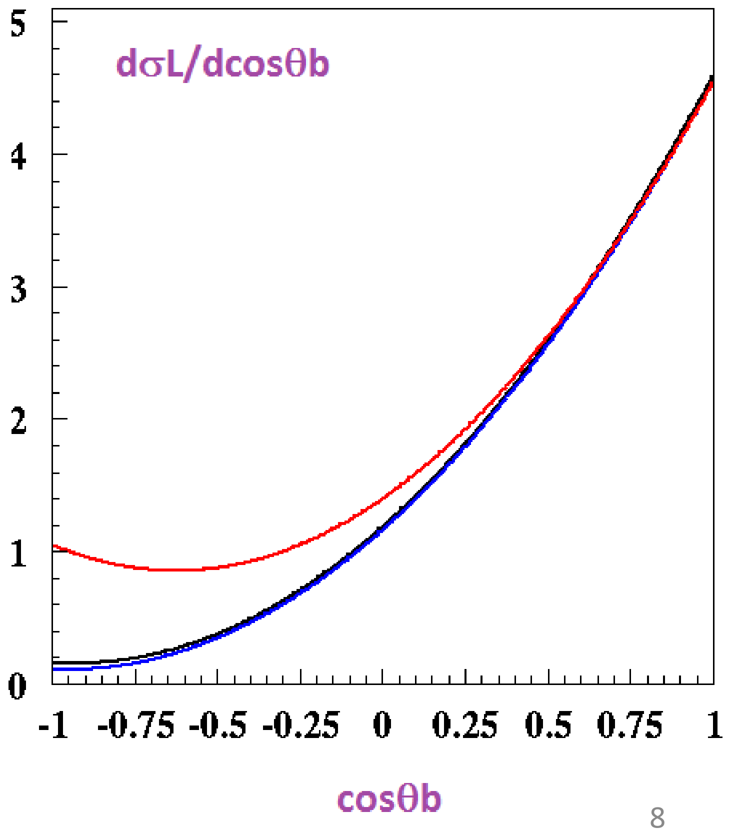


http://lepewwg.web.cern.ch/LEPEWWG/1/physrep.pdf 2005

LEP1 effect





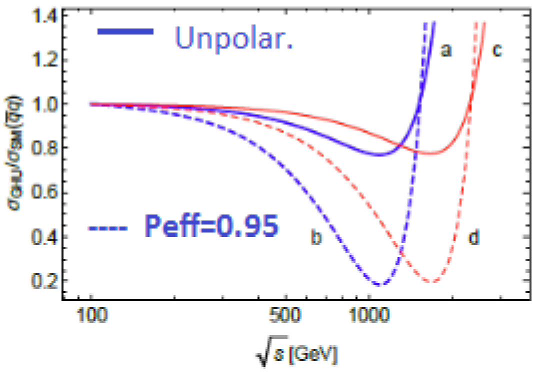


hep-ph/0610173

Interpretations

- Either use **specific models** like RS which has many versions or use **EFT**
- RS alone: Mkk>10 TeV to pass S,T constraints
- RS with **custodial symmetries** to pass S,T constraints: Mkk>5 TeV
- RS with special warping: Mkk>1 TeV **1011.2205 LHCb anomalies**
- Will be explored by t and b measurements as shown in **1403.2893**
- RS with **gauge-Higgs unification**: Mkk 5-10 TeV **1705.05282**
- All flavour affected and will be tested not only with t,b but also will light quarks (**c to be investigated**) and leptons

f	$g^L_{Z^{(1)}f}$	$g^R_{Z^{(1)}f}$	$g^L_{Z_R^{(1)}}$	$g^R_{Z_R^{(1)}f}$	$g^L_{\gamma^{(1)}f}$	$g^R_{\gamma^{(1)}f}$
ν_e	−0.2225	0	0	0	0	0
ν_μ	−0.2225	0	0	0	0	0
ν_τ	−0.2224	0	0	0	0	0
e	0.1196	0.9981	0	−1.3762	0.1880	−1.8165
μ	0.1196	0.9369	0	−1.3029	0.1880	−1.7051
τ	0.1195	0.8847	0	−1.2401	0.1879	−1.6102
u	−0.1539	−0.6536	0	0.9034	−0.1253	1.1896
c	−0.1539	−0.6041	0	0.8439	−0.1253	1.0994
t	0.6888	−0.3431	1.3208	0.5253	0.5616	0.6258
d	0.1882	0.3268	0	−0.4517	0.1303	−1.2369
s	0.1882	0.3021	0	−0.4220	0.1303	−1.1431
b	−0.8470	0.1720	1.3189	−0.2625	−0.5840	−0.6506

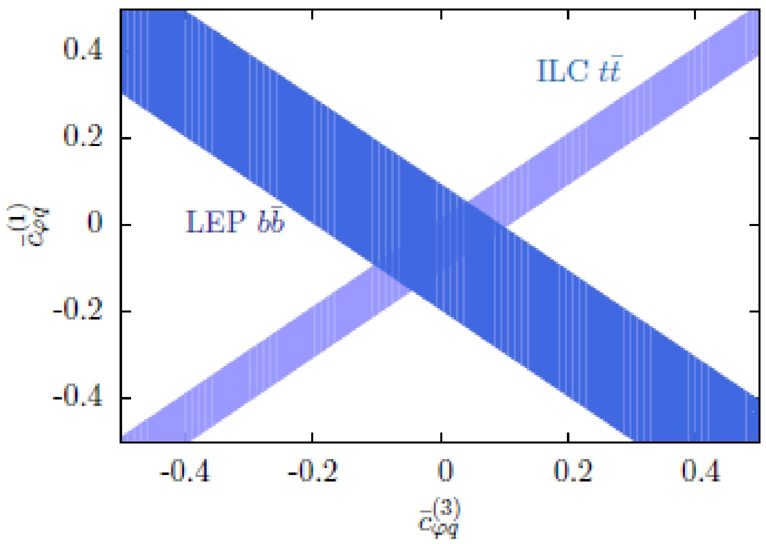


at ILC Peff=0.89

EFT

$$C_{1V} = \frac{v^2}{\Lambda^2}\Re\left[c_{\varphi q}^{(3)} - c_{\varphi q}^{(1)} - c_{\varphi u}\right]^{33}$$
$$C_{1A} = \frac{v^2}{\Lambda^2}\Re\left[c_{\varphi q}^{(3)} - c_{\varphi q}^{(1)} + c_{\varphi u}\right]^{33}$$
$$C_{2V} = \sqrt{2}\frac{v^2}{\Lambda^2}\Re\left[\cos\theta_W c_{uW} - \sin\theta_W c_{uB}\right]^{33}$$
$$C_{2A} = \sqrt{2}\frac{v^2}{\Lambda^2}\Im\left[\cos\theta_W c_{uW} + \sin\theta_W c_{uB}\right]^{33}$$

- Recently have compared and e+e- and LHC potential using the Effective Field Theory approach **1704.01782**
- It clearly states that b measurement are a key feature to **narrow down uncertainties**
- This reference uses a coarse analysis which can be improved using ILC results on top **1505.06020**
- Reach **Λ~10 TeV** is achievable



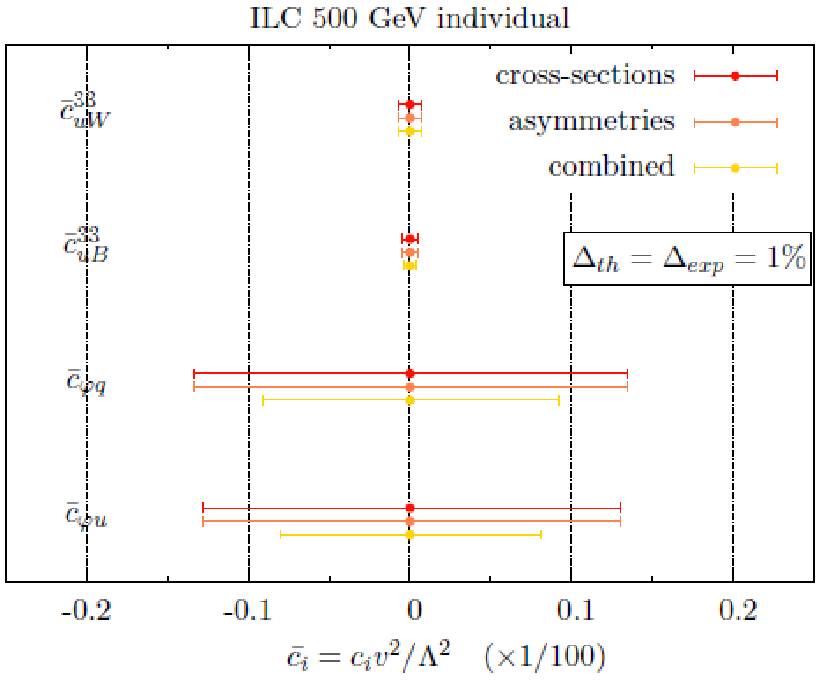
Conclusion

- ee->bb very demanding for the ILD detector (can be used as a **benchmark**)
- **Migration effects can be perfectly corrected** from the data themselves without using external informations
- **Polarisation needed** to separate the γ and Z couplings
- Accuracies surpass LEP1 but **EW corrections are needed**
- The **LEP1 effect** can be conclusively tested at 250 GeV with 500 fb^{-1}
- Reach on composite models, in particular in their RS versions, can be indirectly covered for masses well **beyond the LHC** using top and b EW measurements
- EFT illustrates the strong **complementarity** between **b and t quark** EW measurements and show that a collider reaching 500 GeV can cover effective mass scales up to 10 TeV

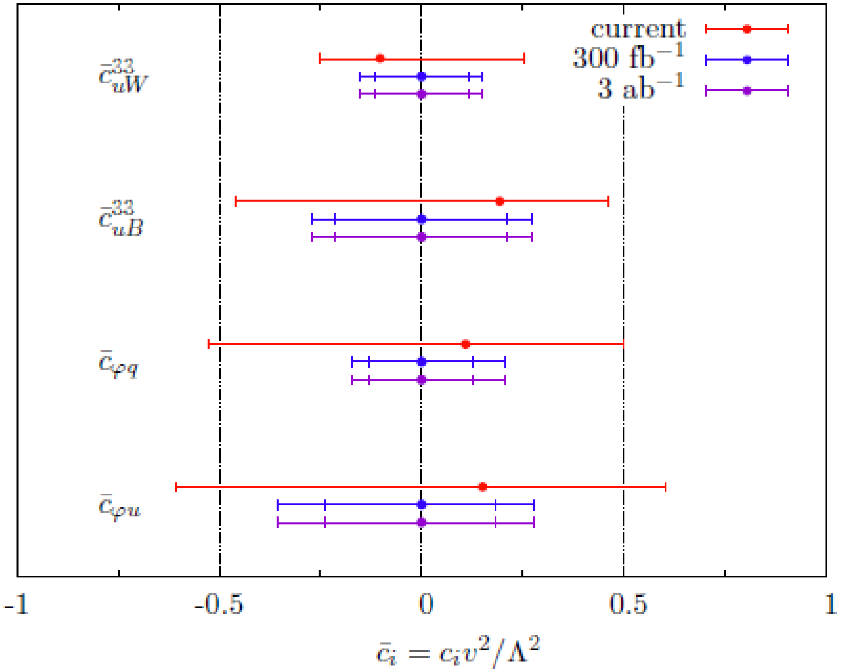
BACK UP SLIDES

EFT

1704.01782



LHC



Formulae

- $d\sigma/d\cos\theta = S_0\{(1+\cos^2\theta)[|F1V+F2V|^2+F1A^2]+(1-\cos^2\theta)|\gamma^{-1}F1V+\gamma\, F2V|^2-4\cos\theta F1A(F1V+\Re F2V)\}$

$$F_{1V}^{L} = -Q_b + e_L BW \frac{-0.25 - Q_b s_W^2}{s_W c_W} \qquad F_{1A}^{L} = e_L BW \frac{0.25}{s_W c_W}$$

- $eL=(-0.5+s^2w)/cwsw$ $BW=s/(s-M^2_Z)$
- $F2V \sim \alpha_s/\gamma^2$ hence $1-\cos^2\theta$ can be neglected for b quarks
- Keeping interference terms and neglecting $1/\gamma^2$ terms
- $d\sigma/d\cos\theta = S_0\{(1+\cos^2\theta)(F1V^2+2F1V\Re F2V+F1A^2)-4\cos\theta F1A(F1V+\Re F2V\}$