Fermion asymmetries $A_{FB}^{0,b/c}$ and tau polarization measurements @ FCC-ee

aka **RAZOR**

G. Panizzo M. Cobal P. Azzi

Università degli Studi di Udine
INFN Gruppo Collegato di Udine

RD_FCC Collaboration Meeting
February 17, 2021

Outline

LEP A_{FB}^{b}

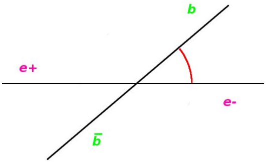
- Definition:

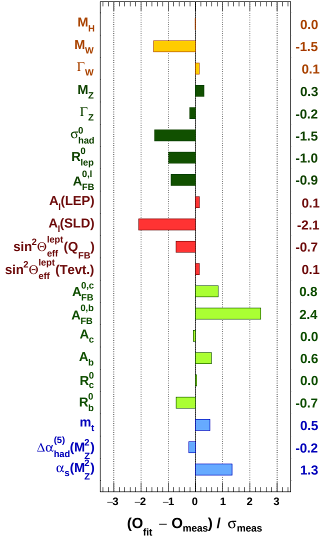
$$A_{FB}^{b} \equiv \frac{\sigma_{bF} - \sigma_{bB}}{\sigma_{bF} + \sigma_{bB}}$$

- Tree level prediction:

$$A_{FB}^{b} = \frac{3}{4} A_b A_e$$

$$A_f \equiv \frac{g_{Lf}^2 - g_{Rf}^2}{g_{Lf}^2 + g_{Rf}^2}$$



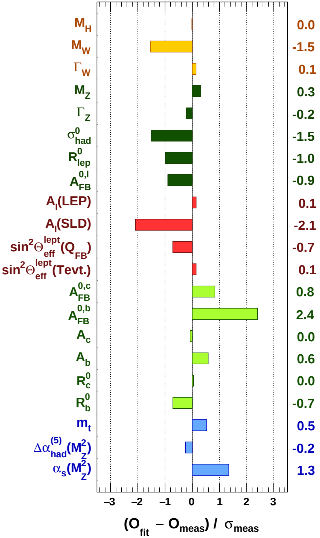


"Update of the global electroweak fit and constraints on two-Higgs-doublet models", Eur.Phys.J.C 78 (2018) 8, 675

- Pull value:

$$\frac{O_{fit} - O_{meas}}{\sigma_{meas}}$$

- Bottom quark observables give largest discrepancies!
- Indirect $A_b(A^{FB}_{0,b}, A^{SLD}_e)$ $\rightarrow$ **2.8**σ

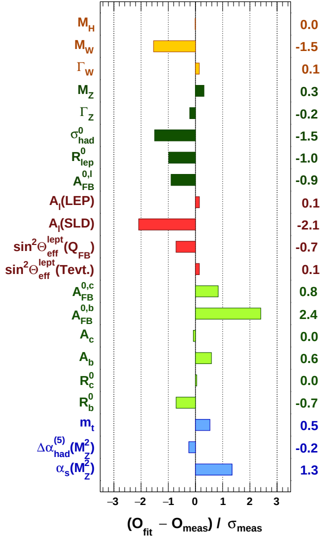


"Update of the global electroweak fit
and constraints on two-Higgs-doublet models",
Eur.Phys.J.C 78 (2018) 8, 675

- Pull value:

$$\frac{O_{fit} - O_{meas}}{\sigma_{meas}}$$

- Bottom quark observables give largest discrepancies!
- Indirect $A_b(A^{FB}_{0,b}, A^{SLD}_e)$ $\rightarrow$ **2.8**σ

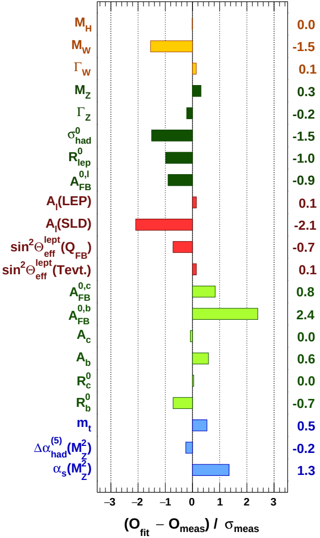


"Update of the global electroweak fit and constraints on two-Higgs-doublet models", Eur.Phys.J.C 78 (2018) 8, 675

- Pull value:

$$\frac{O_{fit} - O_{meas}}{\sigma_{meas}}$$

- Bottom quark observables give largest discrepancies!
- Indirect $A_b(A^{FB}_{0,b}, A^{SLD}_e) \rightarrow$ **2.8**σ



"Update of the global electroweak fit
and constraints on two-Higgs-doublet models",
Eur.Phys.J.C 78 (2018) 8, 675

- Pull value:

$$\frac{O_{fit} - O_{meas}}{\sigma_{meas}}$$

- Bottom quark observables give largest discrepancies!
- Indirect $A_b(A^{FB}_{0,b}, A^{SLD}_e)$ $\rightarrow$ **2.8**σ

Key message

Of -fundamental- importance to measure **BOTH**

- $A^{FB}_{0,b/c}$
- A^{SLD}_{e}

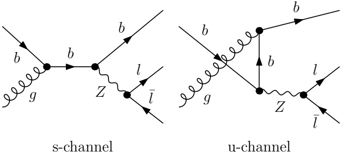
Curiosity: what LHC can do for $A_{0,b}^{FB}$

(*M. Beccaria, G. Macorini, G.P., C. Verzegnassi, Phys.Lett.B 730 (2014) 149-154*)

- At LHC, $b\, l\, \bar{l}$ production, $l\, \bar{l}$ rest frame:

$$A_{FB}^{b,LHC} \equiv \frac{\sigma_{bF} - \sigma_{bB}}{\sigma_{bF} + \sigma_{bB}}$$

where F is the lepton versus.



- Tree level prediction:

$$A_{FB}^{b,LHC} = \mathrm{k}\, A_b A_e$$

with k nearly scale independent

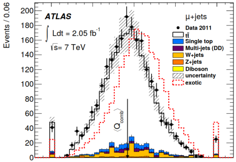
Back to FCC, $A_{0,b}^{FB}$: how ?

- Jet charge can be measured with two classes of methods
- Here naive (but concrete) examples (from LHC feasibility study experience):
  - Q_{jet} variable (weighted $>$ 6 charged tracks sum)

$$Q_{jet} \equiv \sum q_{tr}\ w_{tr}, \quad w_{tr} \equiv \frac{(p_{tr}^{||})^r}{\sum (p_{tr}^{||})^r}$$

  - Soft muon charge (here in a simplified variant "$Q_{\mu,jet}$")

$$p_{T\mu}^{lab} > 4\ \text{GeV}, p_{T\mu}^{rel} > 0.8\ \text{GeV}, \quad Q_{\mu,jet} \equiv q_{\mu} \left(\frac{p_T^{rel}}{m_b} \right)^r$$



Complete expression for $A_{0,b}^{FB}$

- With both methods, ideal $\epsilon_b = 1$, $\epsilon_{c,l} = 0$:

$$\langle Q^b \rangle \equiv \delta^b$$
$$\langle Q_{FB} \rangle \equiv \langle (-1)^{FB} \, Q \rangle = 2\delta^b A_{FB}^b$$

- Real life one measures together:

$$\langle Q_{FB} \rangle = \sum_f c_f \delta^f A_{FB}^f$$
$$c_f = \frac{\sigma_f \ \epsilon_f}{\sum_i \sigma_i \ \epsilon_i}$$

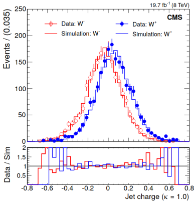
Analisis assumptions

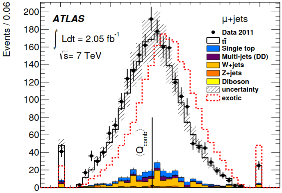
As a first attempt, will use simplified assumptions:

- Only b,c events, no background (that otherwise should affect only c_f determination)

$$\langle Q_{FB} \rangle = \sum_{f=b,c} c_f \delta^f A_{FB}^{f,LHC}$$

- δ^b taken from simulations (but it can be measured in principle)





Systematics

- Need to check JES impact, expected to be negligible
- Showering model and *b*tagging algorithm implementation
  - Need detailed studies: `Delphes` is enough? What about `Key4HEP`?
- QED ISR: should be included in the theoretical definition
- FSR: need to recheck that it should not influence the measure
- c_f: should be estimated using NLO predictions on σ_f
  - Astonishing tools improvements in last 20 years!

τ polarization

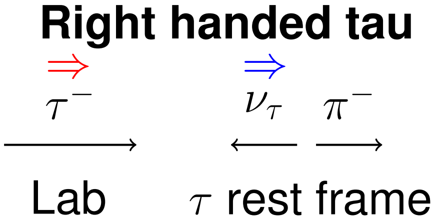
- Expression τ polarization vs polar angle:

$$P_\tau(\cos\theta) \quad = \quad -\frac{A_\tau(1+\cos^2\theta)+2A_e\cos\theta}{(1+\cos^2\theta)+\frac{8}{3}A^{FB}_{0,\tau}\cos\theta}$$

  - measuring P_τ gives access to A_ℓ
- ...but how to determine P_τ ?

P_τ determination

Simplest example from easiest $\tau \to \pi\nu$ decay:

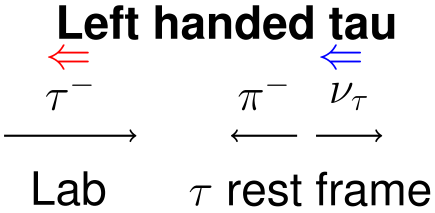


- Assumption
- Physics

Pion boosted in τ direction

P_τ determination

Simplest example from easiest $\tau \to \pi\nu$ decay:



- Assumption
- Physics

Pion boosted in opposite direction

P_τ observable

Then it is (hopefully) more clear that, defining $x_\pi = \frac{E_\pi}{E_{beam}}$, one has:

$$\frac{1}{\Gamma}\frac{d\Gamma}{dx_\pi} = 1 + P_\tau(2x_\pi - 1)$$

- Started looking at particle level distributions
- Need to carefully study new tools features for tau decays (e.g. Pythia 8 related switches)
- A lot to do here from the analysis side!

Conclusions

- RAZOR already started collecting efforts from several italian clusters to measure Heavy fermion asymmetries and Tau polarization
- At the moment still in planning step, but ramping up fastly

Whihlist

- Start to use present analysis experience to produce concrete studies, comparing/choosing where useful between `Key4HEP` and `Delphes`

Thanks !