Measurement of $A_{FB}^{b\bar{b}}$ using $\mathrm{K}^{\pm}$ for $\mathrm{b}/\bar{\mathrm{b}}$ separation

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I Introduction

II Selection criteria

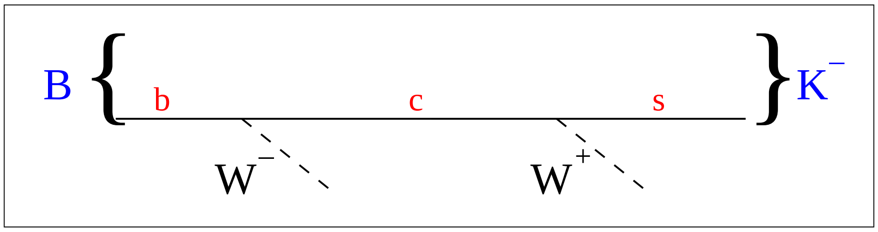
III Tests

IV First results

V Comments

Introduction

- Aim: Measuring $A_{FB}^{b\bar{b}}$
- Quark decay chain: $\mathrm{b} \rightarrow \mathrm{c} \rightarrow \mathrm{s}$ $(\bar{\mathrm{b}} \rightarrow \bar{\mathrm{c}} \rightarrow \bar{\mathrm{s}})$



Correct tag:

$$\mathrm{K}^- \Rightarrow \mathrm{b} \qquad \mathrm{K}^+ \Rightarrow \bar{\mathrm{b}}$$

For $\mathrm{b\bar{b}}$ events and kaons only:

$$N_{\mathrm{K}}^-(\vartheta) = c(\vartheta)\, N_{\mathrm{b}}(\vartheta) + w(\vartheta)\, N_{\bar{\mathrm{b}}}(\vartheta)$$

$$N_{\mathrm{K}}^+(\vartheta) = w(\vartheta)\, N_{\mathrm{b}}(\vartheta) + c(\vartheta)\, N_{\bar{\mathrm{b}}}(\vartheta)$$

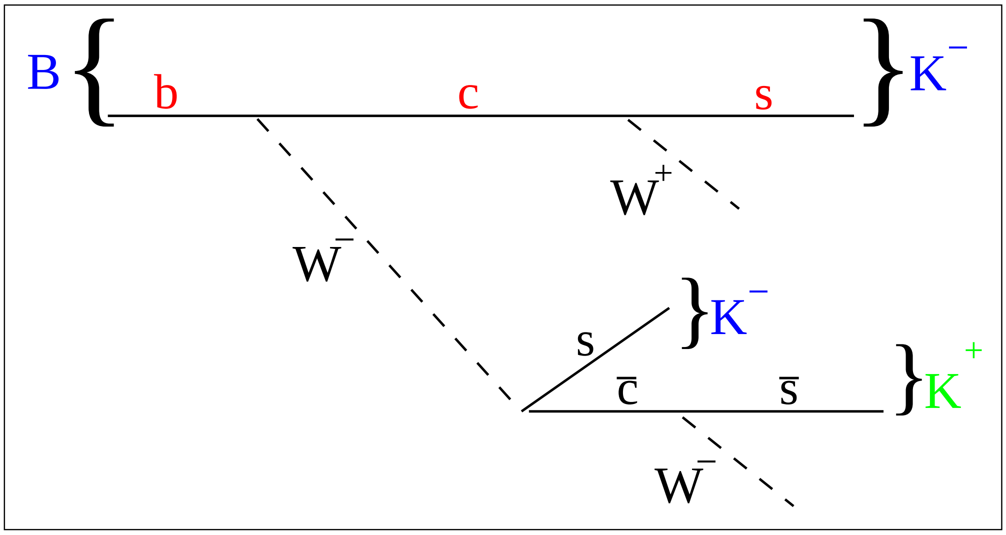
$c_{\mathrm{b}}(w_{\mathrm{b}})$: Efficiency for getting kaons with correct(wrong) charge from b quarks

Measured asymmetry is then:

$$A_{\mathrm{K}}(\vartheta) = \frac{N_{\mathrm{K}^-}(\vartheta) - N_{\mathrm{K}^+}(\vartheta)}{N_{\mathrm{K}^-}(\vartheta) + N_{\mathrm{K}^+}(\vartheta)} = \frac{c_{\mathrm{b}}(\vartheta) - w_{\mathrm{b}}(\vartheta)}{c_{\mathrm{b}}(\vartheta) + w_{\mathrm{b}}(\vartheta)} \frac{N_{\mathrm{b}}(\vartheta) - N_{\bar{\mathrm{b}}}(\vartheta)}{N_{\mathrm{b}}(\vartheta) + N_{\bar{\mathrm{b}}}(\vartheta)}$$

$$\boxed{A_{\mathrm{K}}(\vartheta) = \frac{c_{\mathrm{b}} - w_{\mathrm{b}}}{c_{\mathrm{b}} + w_{\mathrm{b}}} \cdot \frac{8}{3} A_{FB}^{\mathrm{b\bar{b}}} \frac{\cos\vartheta}{1+\cos^2\vartheta}}$$

- Problems of the method:
  - Several charged kaons in the decay chain:



  - Mixing of the B mesons
  - $\pi^{\pm}$ / $K^{\pm}$ identification
  - Asymmetry due to the material in the detector: Cross sections for reactions $K^{+}p(n)$ in $K^{-}p(n)$ are different
  - Direct $K^{\pm}$ from the fragmentation
  - Background from $Z^0 \rightarrow c\,\bar{c}$

– Measured asymmetry now reads:

$$\boxed{A_{FB}^{obs}(\vartheta) \approx \tfrac{8}{3}\,\tfrac{c_{\mathrm{b}}-w_{\mathrm{b}}}{c_{\mathrm{b}}+w_{\mathrm{b}}}\,\alpha_{\mathrm{b}}\,A_{FB}^{\mathrm{b\bar{b}}}\,\tfrac{\cos\vartheta}{1+\cos^2\vartheta} - A^{mat} + A_{\not{\mathrm{b}}}(\vartheta)}$$

The coefficient is:

$$\frac{c_{\mathrm{b}} - w_{\mathrm{b}}}{c_{\mathrm{b}} + w_{\mathrm{b}}} = P_{\mathrm{b}} \frac{c_{\mathrm{b}}^{\mathrm{K}} - w_{\mathrm{b}}^{\mathrm{K}}}{c_{\mathrm{b}}^{\mathrm{K}} + w_{\mathrm{b}}^{\mathrm{K}}} + (1 - P_{\mathrm{b}}) \frac{c_{\mathrm{b}}^{bg} - w_{\mathrm{b}}^{bg}}{c_{\mathrm{b}}^{bg} - w_{\mathrm{b}}^{bg}}$$

P_{b}: Purity of kaons from $\mathrm{b\bar{b}}$ events
$\alpha_{\mathrm{b}} = \frac{[N^{\pm}]_{\mathrm{b\bar{b}}}}{N^{\pm}}$: Fraction of selected events coming from $\mathrm{b\bar{b}}$

* Material asymmetry is (only kaons are taken into account):

$$A^{mat}(\vartheta) = \frac{1 - r(\vartheta)}{1 + r(\vartheta)}$$

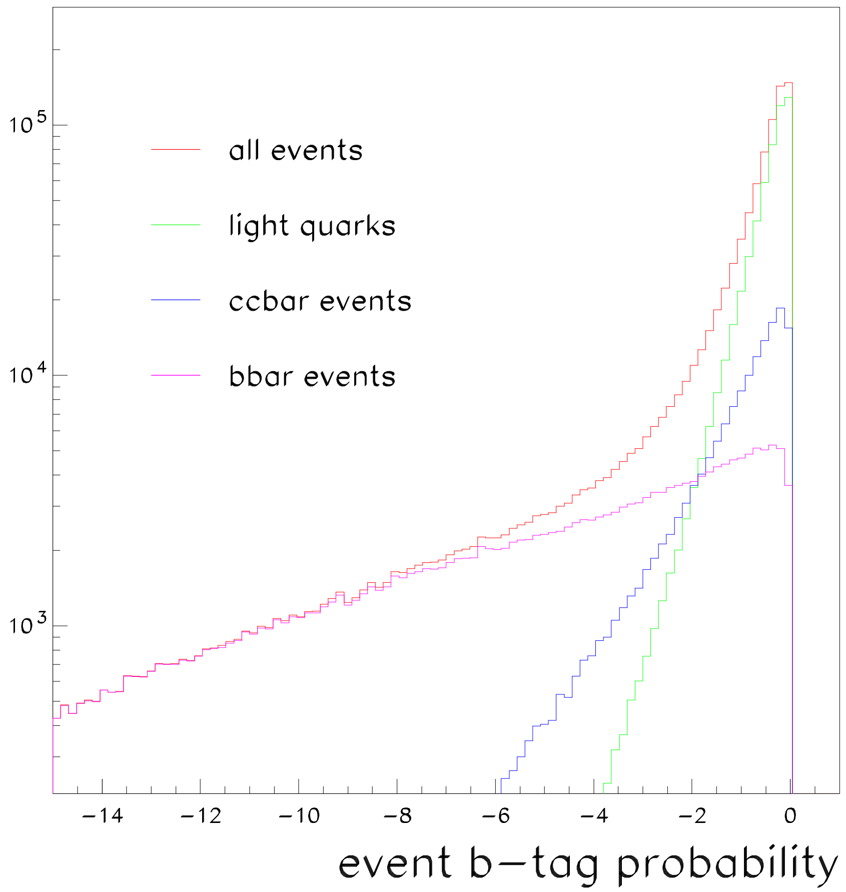
  $r = \frac{\varepsilon_{\mathrm{K}}^{-}(\vartheta)}{\varepsilon_{\mathrm{K}}^{+}(\vartheta)}$: fraction of the probabilities for $\mathrm{K}^{\pm}$ reaching the B-RICH
  In the barrel region this asymmetry can be treated as a constant not depending on $\vartheta \Rightarrow$ contributes only a shift

* Asymmetry coming from other flavours can be expressed as:

$$A_{\not{\mathrm{b}}}(\vartheta) = \frac{8}{3} \sum_{\mathrm{q} \neq \mathrm{b}} \frac{c_{\mathrm{q}} - w_{\mathrm{q}}}{c_{\mathrm{q}} + w_{\mathrm{q}}}\, \alpha_{\mathrm{q}}\, A_{FB}^{\mathrm{q\bar{q}}} \frac{\cos\vartheta}{1 + \cos^2\vartheta}$$

Selection criteria

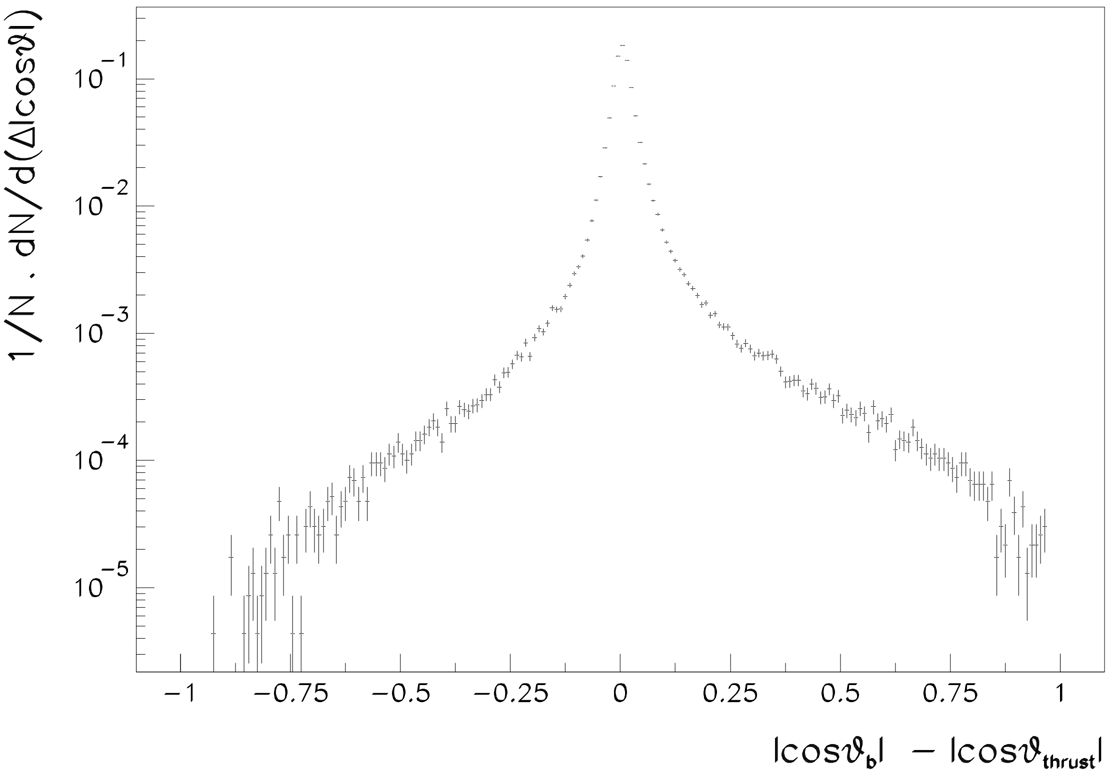
- Event selection:
  - Multihadronic Z^0 decays
  - $b\overline{b}$ events are selected with b-tagging:



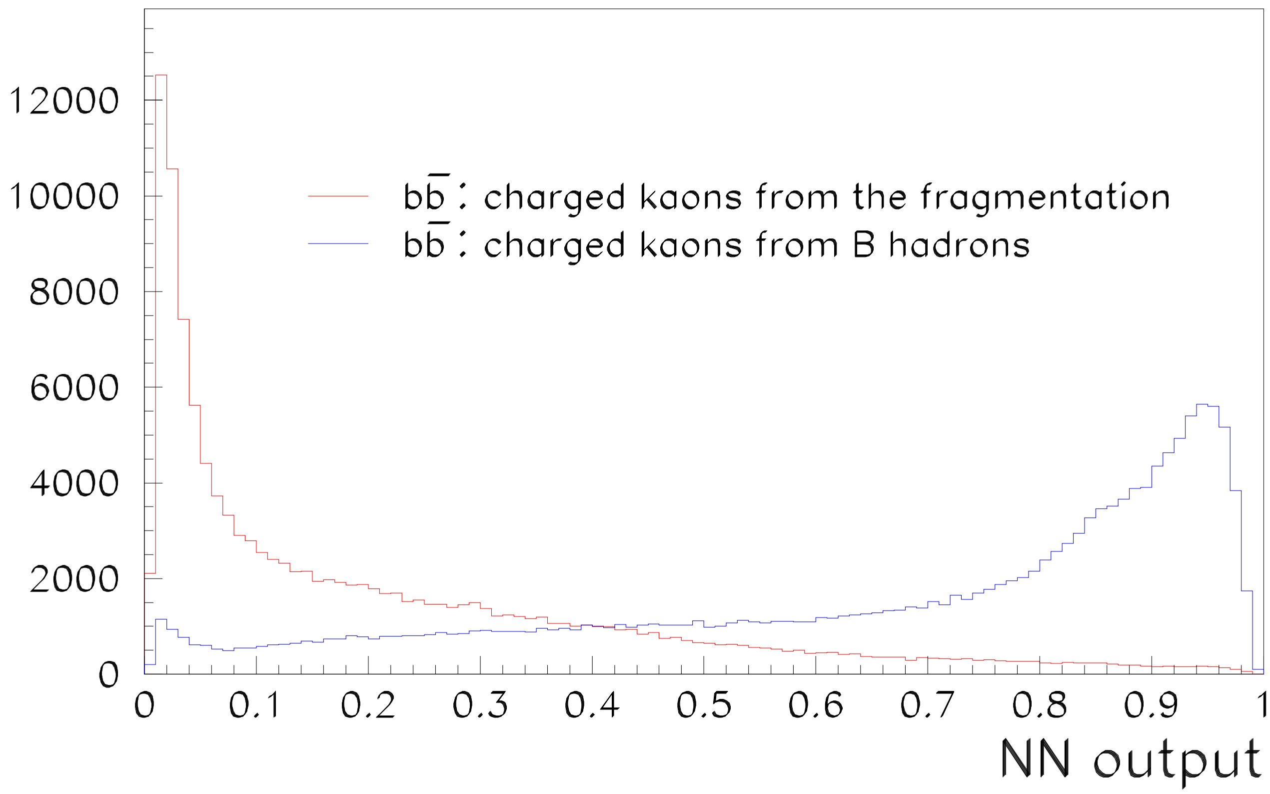
– Direction of the produced (anti)quark:

This direction is approximated with the direction of trust axis:

$$\overrightarrow{T} = \max_{\overrightarrow{n}} \left\{ \frac{\sum_{i=1}^{N} \overrightarrow{n} \cdot \overrightarrow{p_i}}{\sum_{i=1}^{N} |\overrightarrow{p_i}|} \right\}$$



- Charged kaon selection:
  - Charged kaons are identified with B-RICH (liquid and gaseous radiator)
  - $p_K > p_{min}(K^{\pm})$
  - $K^{\pm}$ from the decays of B hadrons are selected according to the B-SAURUS neural network output:
    1: $K^{\pm}$ is from a B hadron decay ; 0: $K^{\pm}$ is from fragmentation



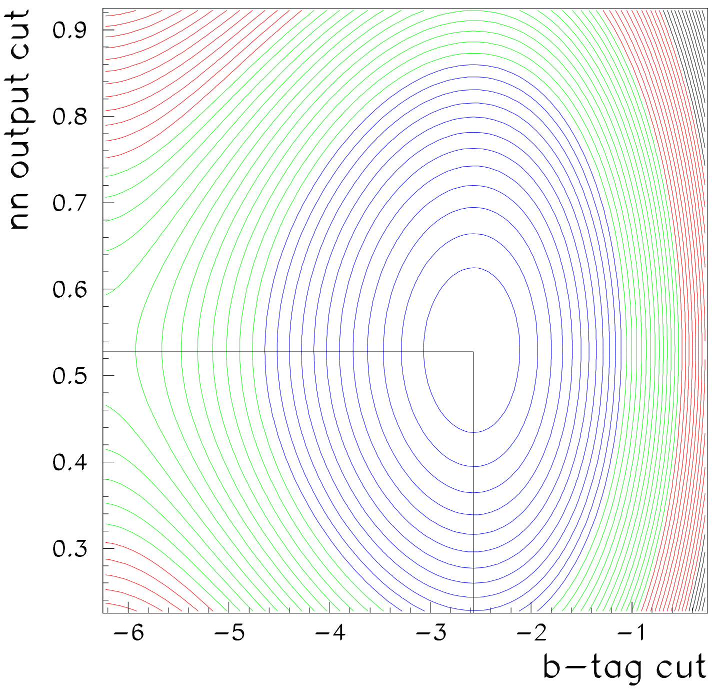
$\Rightarrow$ $K^{\pm}$ with the highest value of the NN output is selected in each event (NN output value also to be larger than some cut value)

- Working points:

Values of b-tag and NN output cuts are determined by the optimization of the statistical significance:

$$S = \frac{A'_{FB}}{\sigma_{A'_{FB}}}$$

The values for the significance are obtained from the fit of the kaon asymmetry with the function $\frac{8}{3}A'_{FB}\frac{\cos\vartheta}{1+\cos^2\vartheta} - \frac{\delta'}{2}$



From this plot working points can be determined:

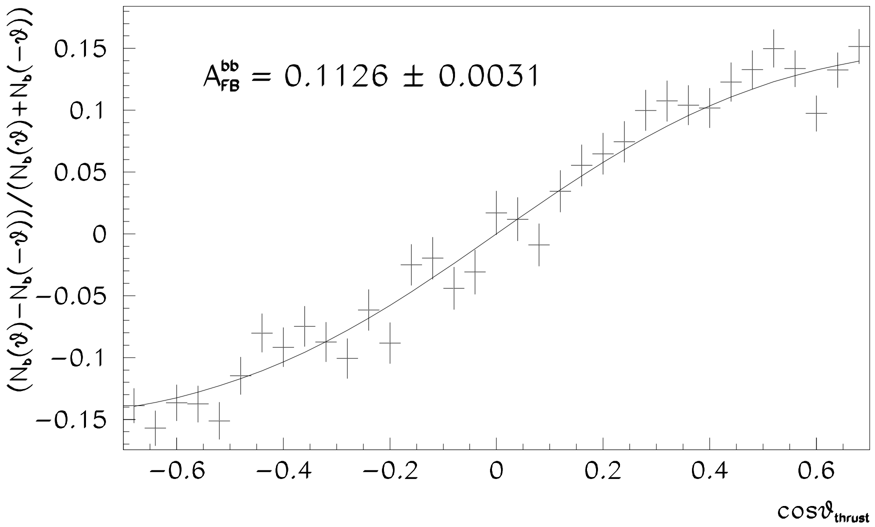
- $p_{min}(\mathrm{K}^{\pm}) = 2.5\ \mathrm{GeV}/c$
- $(\log_{10} P_b)_{max} = -2.525$
- $(NNoutput)_{min} = 0.5275$

Tests

- Asymmetry calculated for $b\bar{b}$events:

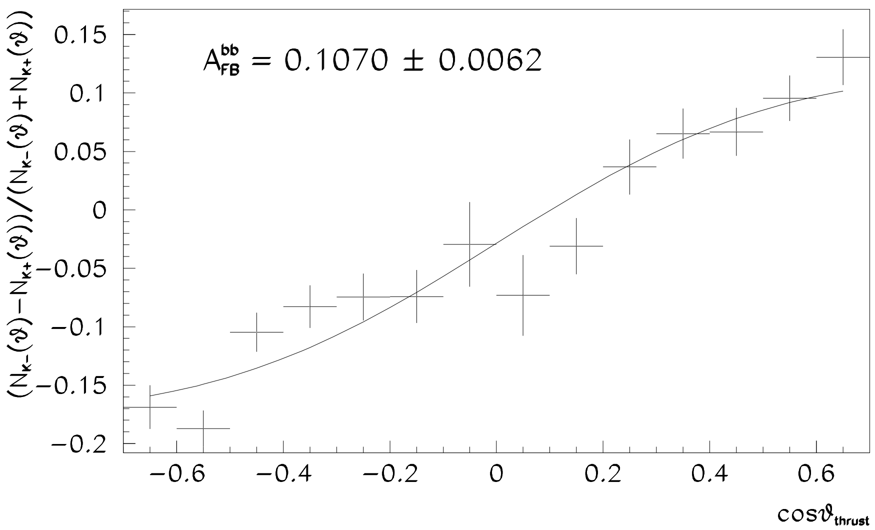
  - Generated asymmetry: MC 1994 C2($2{\cdot}10^5$)

    $\frac{N_b(\vartheta)-N_{\bar{b}}(\vartheta)}{N_b(\vartheta)+N_{\bar{b}}(\vartheta)}$ fitted with $\frac{8}{3}A_{FB}^{b\bar{b}}\frac{\cos\vartheta}{1+\cos^2\vartheta}$



  - Asymmetry calculated with kaons: MC 1994 C2($1.5{\cdot}10^6$)

    $\frac{N_{K^-}(\vartheta)-N_{K^+}(\vartheta)}{N_{K^-}(\vartheta)+N_{K^+}(\vartheta)}$ fitted with $\frac{8}{3}\frac{c_b-w_b}{c_b+w_b}A_{FB}^{b\bar{b}}\frac{\cos\vartheta}{1+\cos^2\vartheta}-\frac{\delta}{2}$



Material asymmetry was left as a free (constant) parameter of the fit

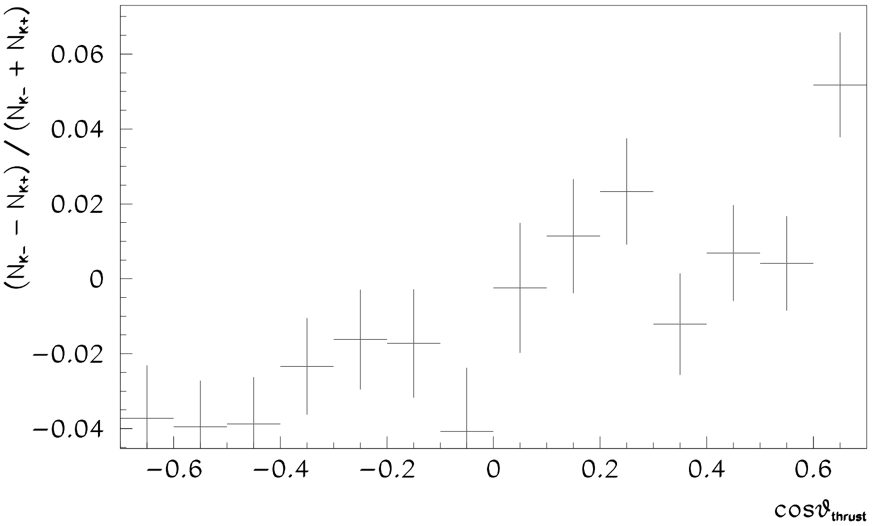
$$\frac{8}{3}A'_{FB}\frac{\cos\vartheta}{1+\cos^2\vartheta}-\frac{\delta'}{2}$$

$\Rightarrow$ Value of the shift parameter obtained (cross check) leads to a rough estimate:

$$\frac{\delta'}{2}\rightarrow\frac{1-r}{1+r}=(1\pm 0.2)\%$$

First results

- Real data: 94 multihadronics $\approx 1.5 \cdot 10^6$ events ($\sim$ half of the statistics) After all the selection criteria $\sim$76000 events remained. Asymmetry looks like:



After checking the fractions from the simulation:

$$\alpha_{\mathrm{b}} = 0.834 \pm 0.006 \quad \alpha_{\mathrm{c}} = 0.148 \pm 0.002$$

$\Rightarrow$ Only $\mathrm{b\bar{b}}$ and $\mathrm{c\bar{c}}$ events were taken into account.

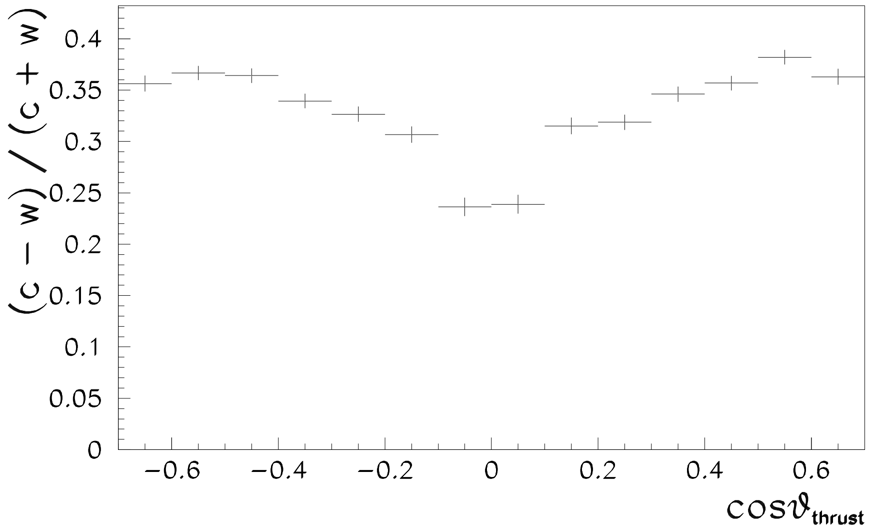
The asymmetries $A_{FB}^{\mathrm{b\bar{b}}}$ and $A_{FB}^{\mathrm{c\bar{c}}}$ were combined according to the standard model:

$$A_{FB}^{\mathrm{c\bar{c}}} = \frac{a_{\mathrm{c}} v_{\mathrm{c}} (a_{\mathrm{b}}^2 + v_{\mathrm{b}}^2)}{a_{\mathrm{b}} v_{\mathrm{b}} (a_{\mathrm{c}}^2 + v_{\mathrm{c}}^2)} A_{FB}^{\mathrm{b\bar{b}}} \equiv \lambda A_{FB}^{\mathrm{b\bar{b}}} \,,$$

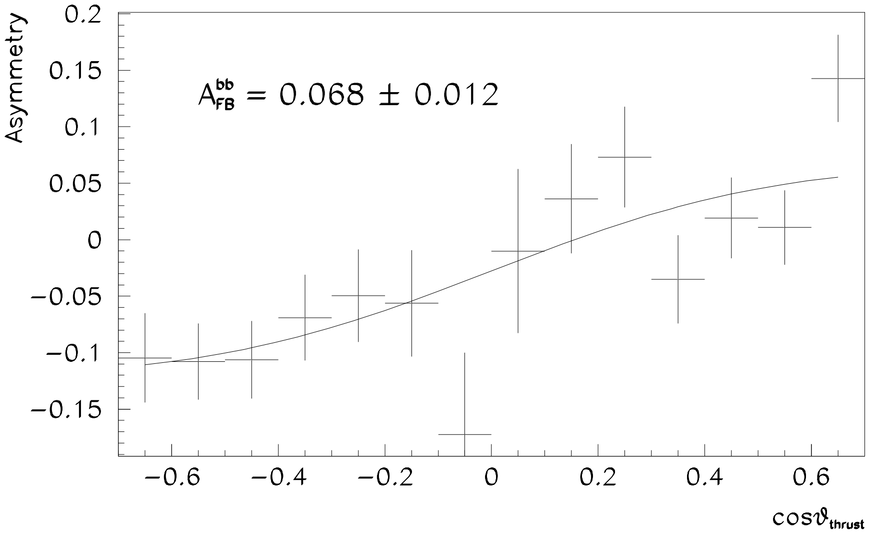
where $\lambda \approx 0.7184$.

The combined coefficient was calculated from MC:

$$\frac{c-w}{c+w} = \frac{c_{\rm b}-w_{\rm b}}{c_{\rm b}+w_{\rm b}}\alpha_{\rm b} + \lambda\frac{c_{\rm c}-w_{\rm c}}{c_{\rm c}+w_{\rm c}}\alpha_{\rm c}$$



Final result was then obtained by fitting the function $\frac{8}{3}A_{FB}^{\rm b\bar{b}}\frac{\cos\vartheta}{1+\cos^2\vartheta} - \frac{\delta}{2}$ to the ratio of these two histograms:



With the entire statistics: expected significance $\sim 10\ \sigma$

Comments

- Very preliminary results that have to be cross checked once again.
- Matching data/MC should be done. Kinematical quantities, RICH efficiency, purity of the sample should be ckecked (the fraction of purities P_{data}/P_{MC} is suspected to be the major cause of a smaller asymmestry)
- Coefficients (c-w)/(c+w) should be corrected. $\Rightarrow$ measured from the real data in order to avoid corrections
- Material asymmetry should be determined and subtracted before fitting.
- Minor corrrection: Material asymmetry should be treated as a function of ϑ_{K}, instead of ϑ_{thrust}.