A first look at Afb for c-cbar signatures at ILC 250GeV

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ILD Analysis/Software Meeting

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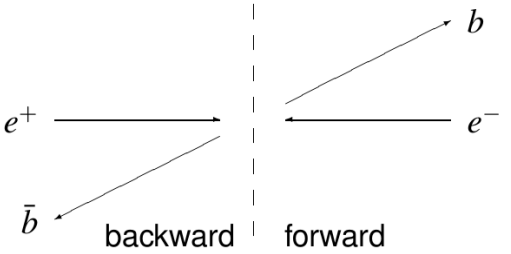
Quick reminder: bbar-case

Physics case: measurement of the forward-backward asymmetry in e+e- → bb @250GeV.

The analysis is based in:

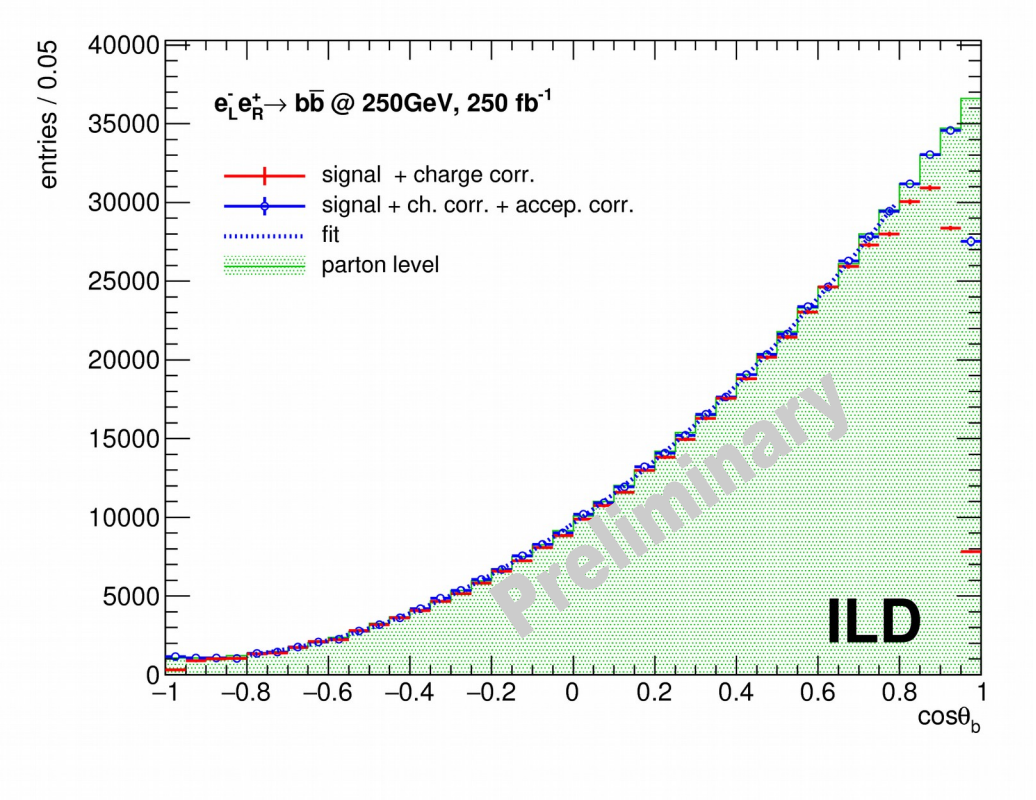
- **Vertexing**, jet **reconstruction and flavour tagging** (**LCFIPlus processor**)
- **Kaon Identification** (**ParticleTagger processor**)
- Recovery of lost tracks in reconstructed vertexes (**VertexRestorer processor**)
- Jet **charge measurement** & Jet angle determinatio (**QQbarAnalysis processor**)



$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

$$\frac{d\sigma^I}{d\cos\theta} = A^I(1+\cos^2\theta) + B^I\cos\theta + C^I\sin^2\theta \qquad I = L, R$$

Quick reminder: bbar-case



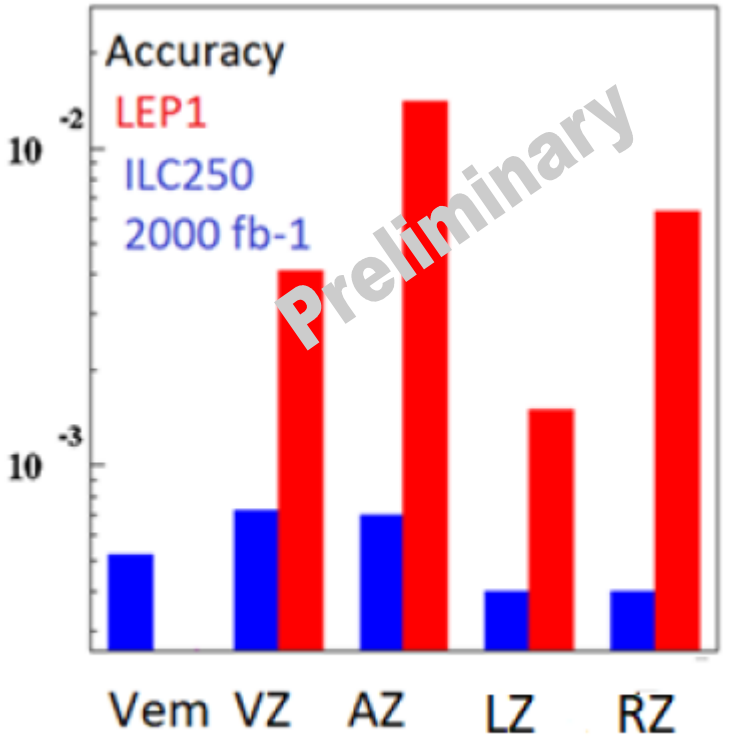
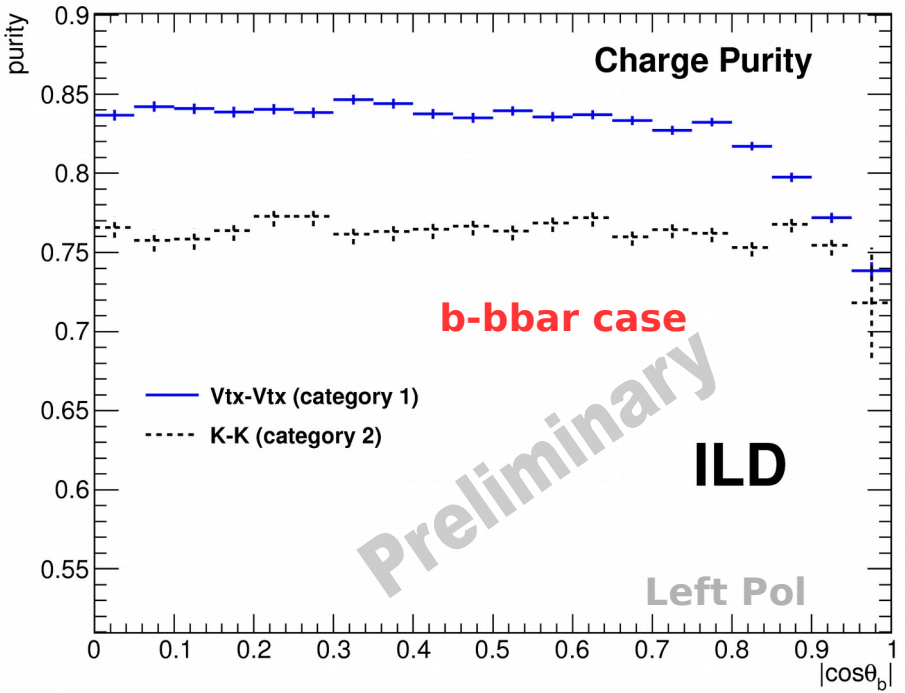


Figure 6: Comparison of accuracies achieved at LEP1 (in red) and those predicted for ILC (in blue).

ILD note under review at present moment.

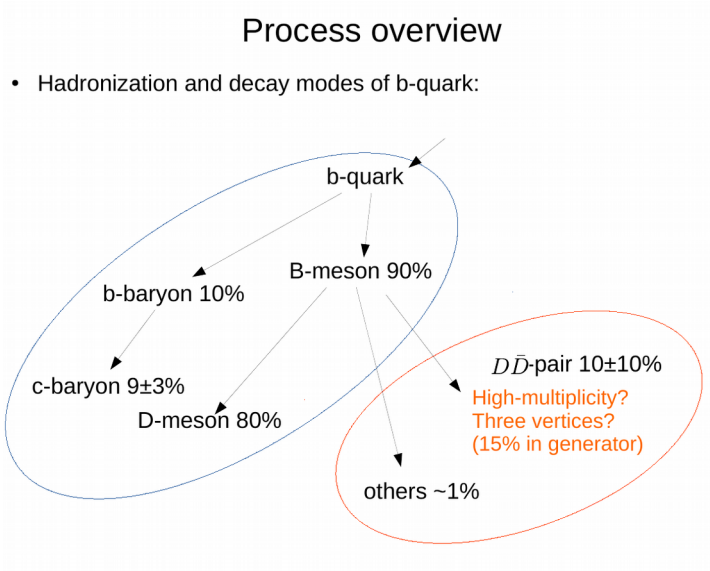
c-cbar vs b-bbar

- B-charge was done using double charge measurements (**Vtx** for final states including b-hadrons and **K** for final states including Kaons).
- We duplicate the logic but we associate...
  - **...Vtx** to charged D decays
- We applied this double charge measurement in very pure b-bbar samples thanks to the b-tagging. What about the c-quark tagging?



b-bbar vs c-cbar

- **Cross section increase** by a factor ~1.4 (left polariz) and ~3 (right polariz)
- B-quark vs c-quark charge measurement



- C-quark hadronization + decay
  - D0

    70% have 2 prongs

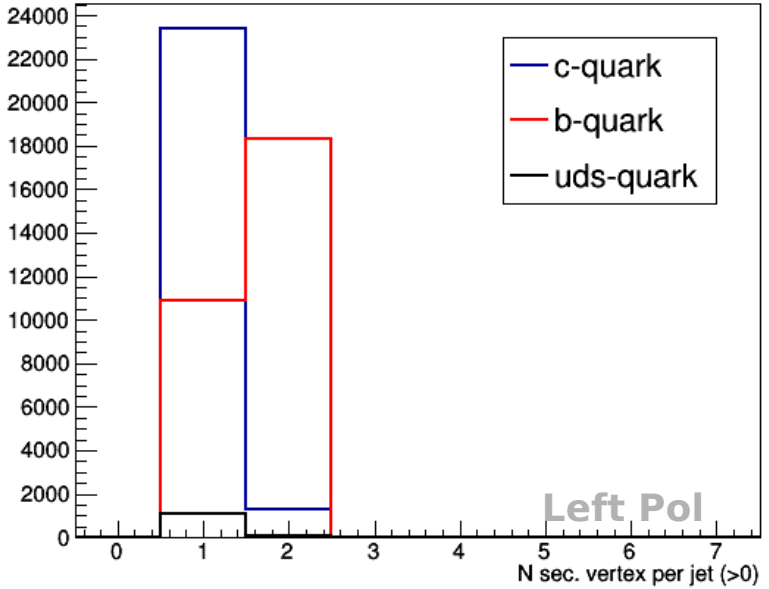
    55% with K- and 3.4% K+ -> **High purity offered by K tag**
  - D+

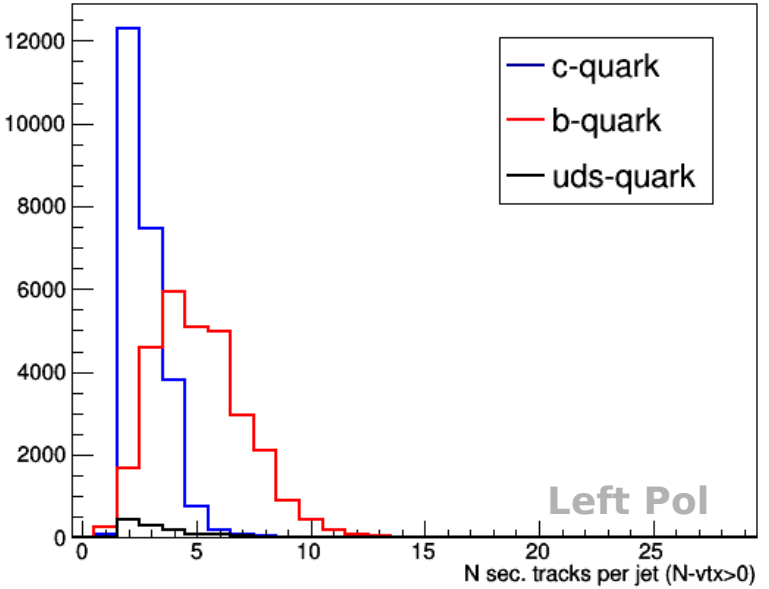
    Very likely that 1 and 3 prongs are sufficient. No need for Kaon tag
  - Ds+-

    1 and 3 prongs. No need for Kaon tag

C-quark identification in single jets

- We explore the c-tagging capabilities following first principles and exploiting the tools developped for the b-bbar analysis → we do not store information about the tracks in the 0 secondary vertexes cases in the ntuple.

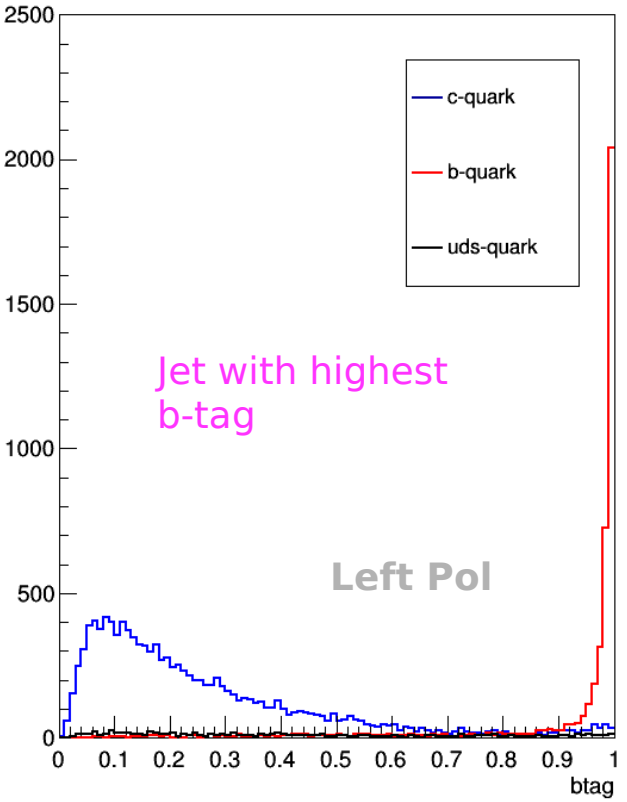


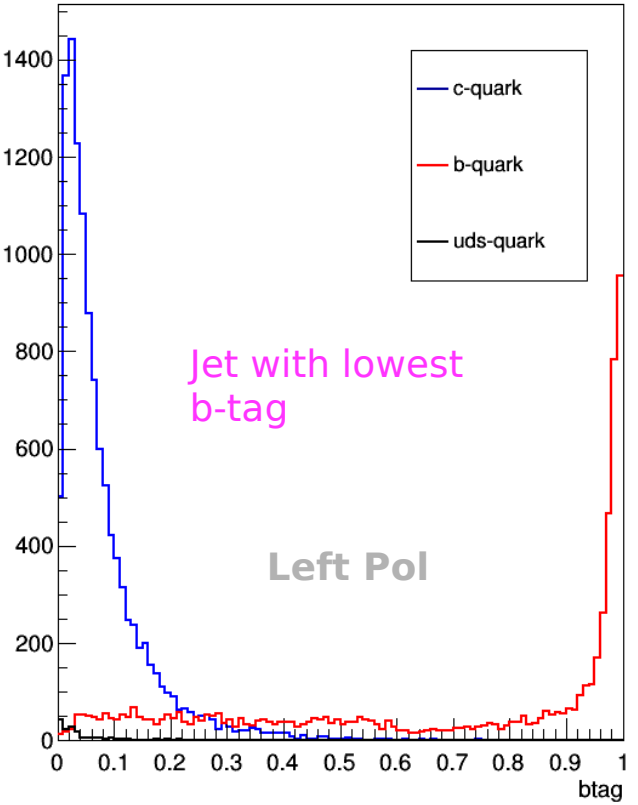


- Requiring at least 1 secondary vertex mostly kills all uds background.
- Requiring less than 2 secondary vertexes will kill 60% of the b-quark background.

C-quark identification in single jets (Nvtx = 1)

- b-likeness can be also used for the c-quark separation from b-quarks, once that the uds- background has been clean up





A preliminary selection of cuts for ccbar selection

- Kinematic cuts (common for bbbar and ccbar). We reject events with:
  - a photon with E>40GeV;
  - m(j1j2)<180GeV and;
  - m(j1)+m(j2)<120.
- B-tag cut (for bbbar):

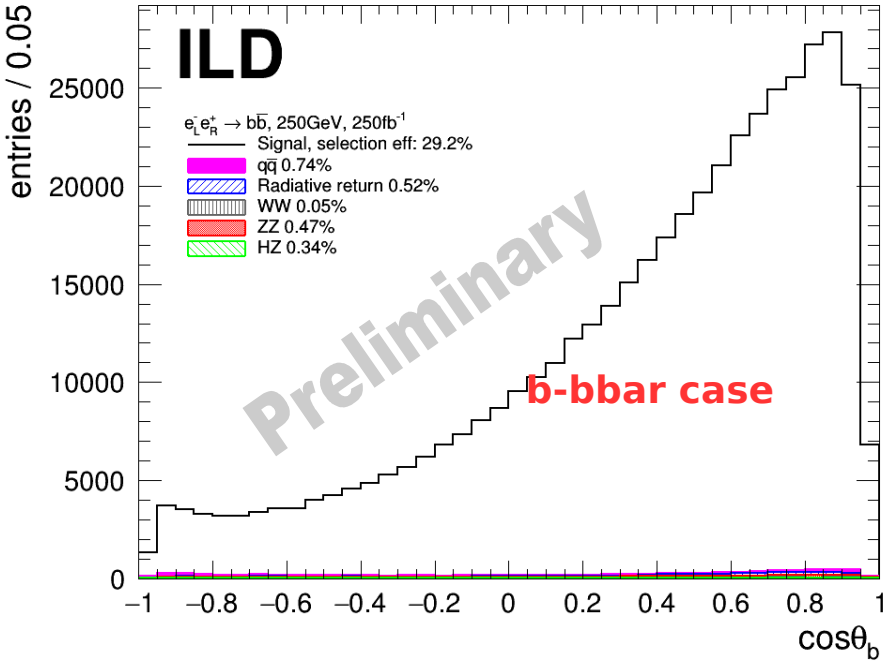
  b-Btag(j1)>0.9 && b-tag(j2)>0.2
- Simplistic c-tag (for ccbar)
  - Nvtx==1 && b-tag(j1)<0.8 && b-tag(j2)<0.3

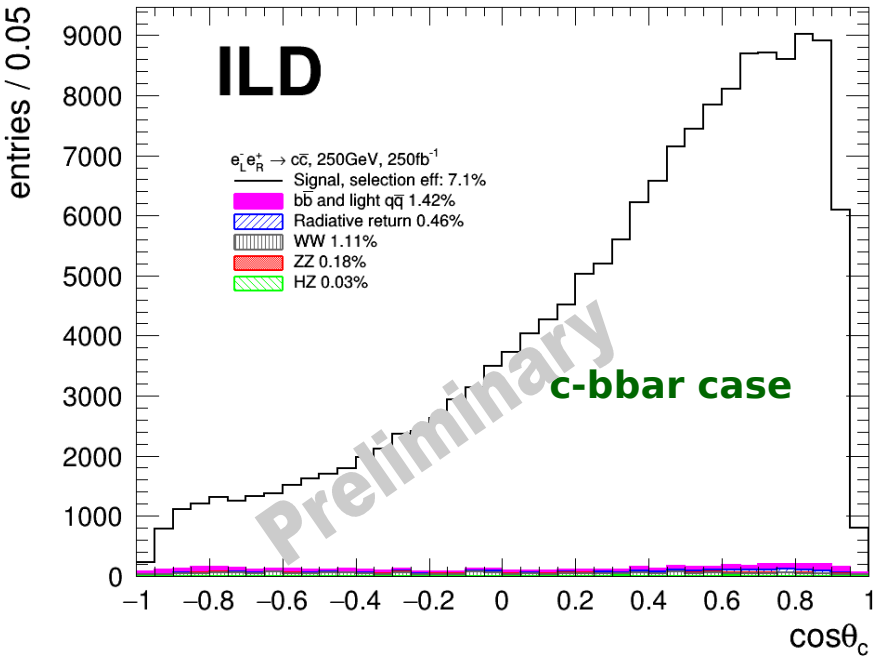
	Left Handed Polarization			
	bbbar		ccbar	
	Signal Eff (%)	Bkg/S (%)	Signal Eff (%)	Bkg/S (%)
kinematics	80.7%	557.5%	76.1%	385.0%
+ quark tag	65.9%	4.4%	18.3%	4.9%
+double charge	29.2%	2.1%	7.1%	3.2%

Right Handed Polarization			
bbbar		ccbar	
Signal Eff (%)	Bkg/S (%)	Signal Eff (%)	Bkg/S (%)
80.6%	679.3%	76.1%	210.0%
65.7%	9.0%	18.4%	2.6%
29.1%	4.5%	7.1%	1.6%

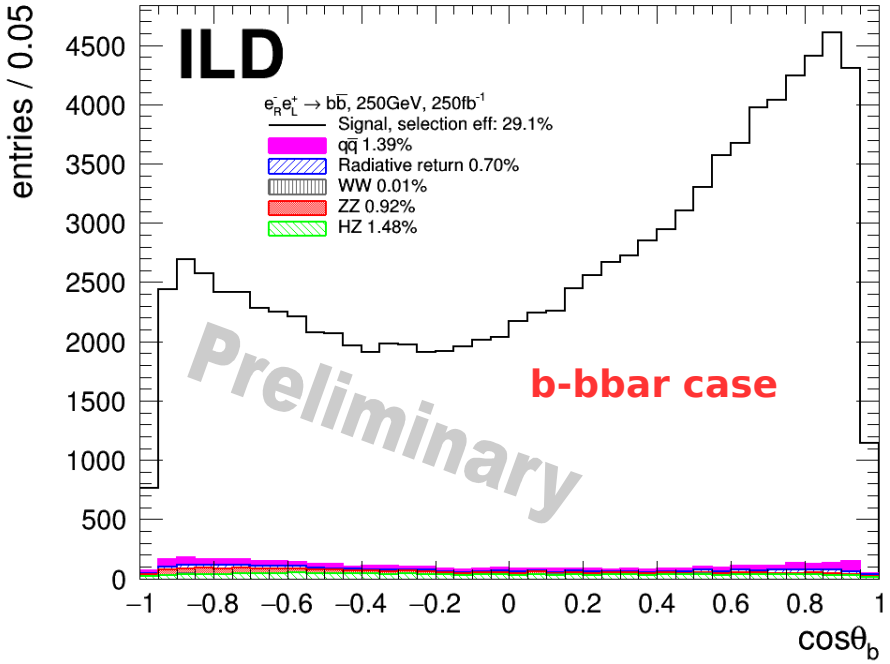
- The simplistic (and non-optimized) c-tag cut is around ~ 3 times more aggressive than the dedicated b-tag cut.
- Partially compensated by the largest cross section.

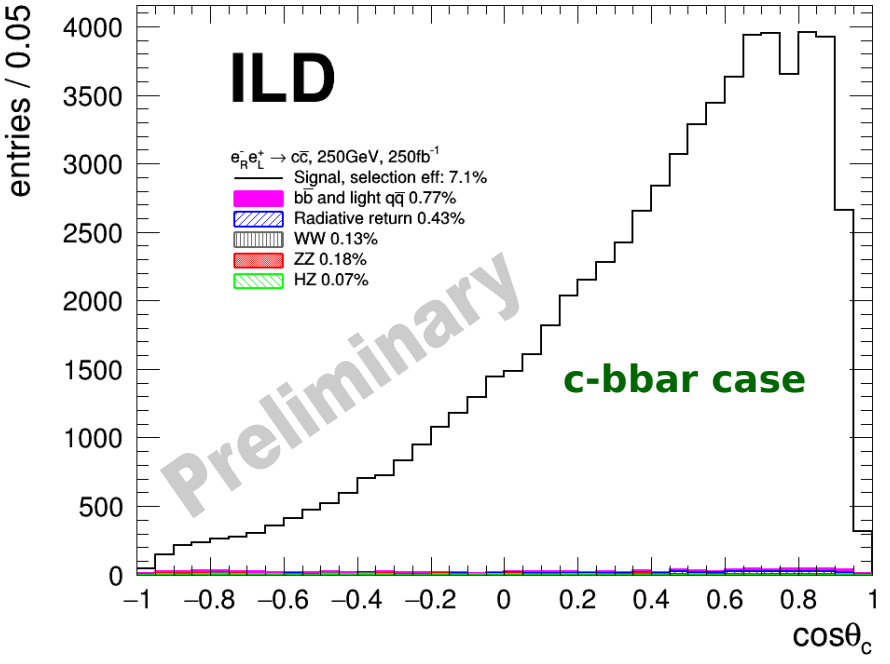
Afb bb vs cc, left handed polarization





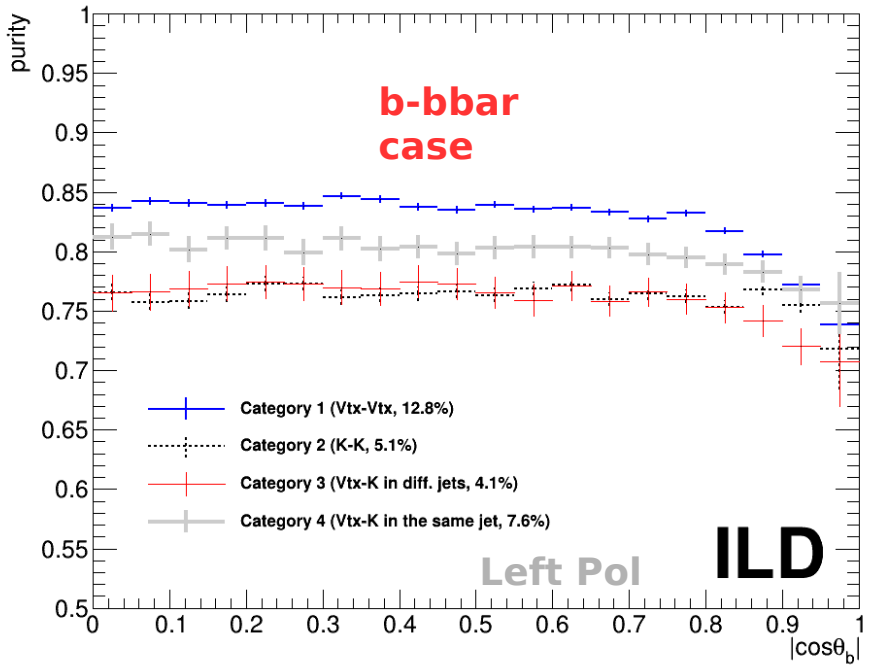
Afb bb vs cc, right handed polarization

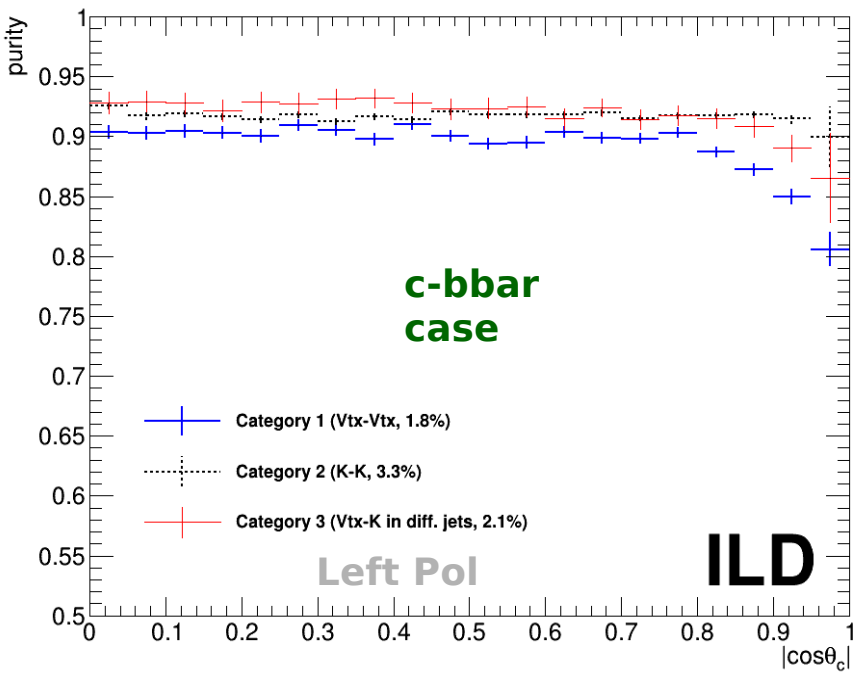




Single charge measurement?

- The expected high purity in the charge measurement may allow for single charge measurements which will allow for a factor ~2-3 of gain in efficiency.





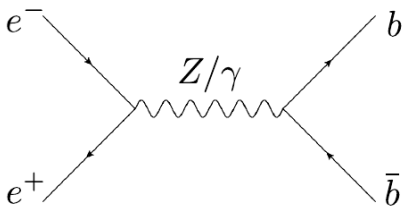
Summary / conclusions

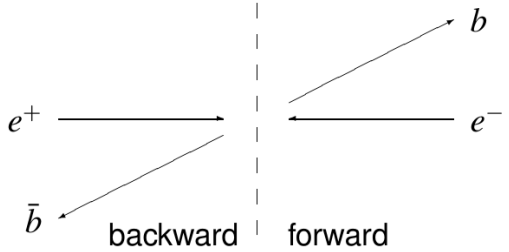
- This first look into the AFB measurement at 250 GeV for the c-cbar case shows a great potential for the channel.
- The methodology and the challenges of the two channels are very similar.
- Using the simplistic c-tag described in the slides, we reconstruct in absolute value, similar number of events for bbbar and ccbar (although still a factor 1.5-2 less)
  - Similar precision levels can be achieved.
- There is clear room for improvement
  - The simplistic c-tagging applied is very preliminary. LCFIPlus?
  - In addition we didn't consider, for the charge calculation, all 1-prong cases.
  - Thanks to the large purities for the charge measurement, we may be able to use single charge measurements instead of double tag measurements.

Backup slides

Motivation

- B-quark electroweak couplings can be inferred from cross section and forward backward asymmetry (Afb) observables.





$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

$$\frac{d\sigma^I}{d\cos\theta} = A^I(1+\cos^2\theta) + B^I\cos\theta + C^I\sin^2\theta \qquad I = L, R$$

where the $A\ B\ C$ are

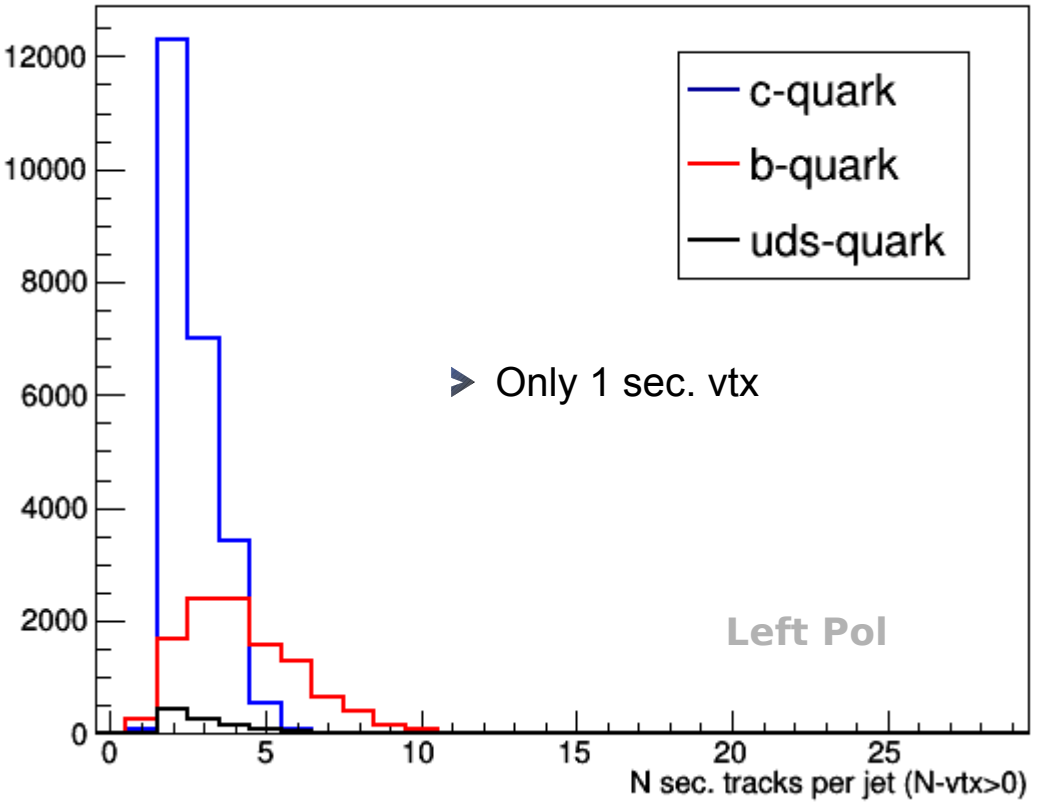
A^I cross section magnitude $\propto \mathcal{F}^I_{1V}, \mathcal{F}^I_{2V}, \mathcal{F}^I_{1A}$

B^I asymmetry magnitude $\propto \mathcal{F}^I_{1A}, \mathcal{F}^I_{1V}, \mathcal{F}^I_{2V}$

C^I spin flip $\propto \gamma^{-1}\mathcal{F}^I_{1V}, \gamma\mathcal{F}^I_{2V}$

- Afb has been measured in SLC and LEP at the Z-pole

C-quark identification in single jets (Nvtx = 1)

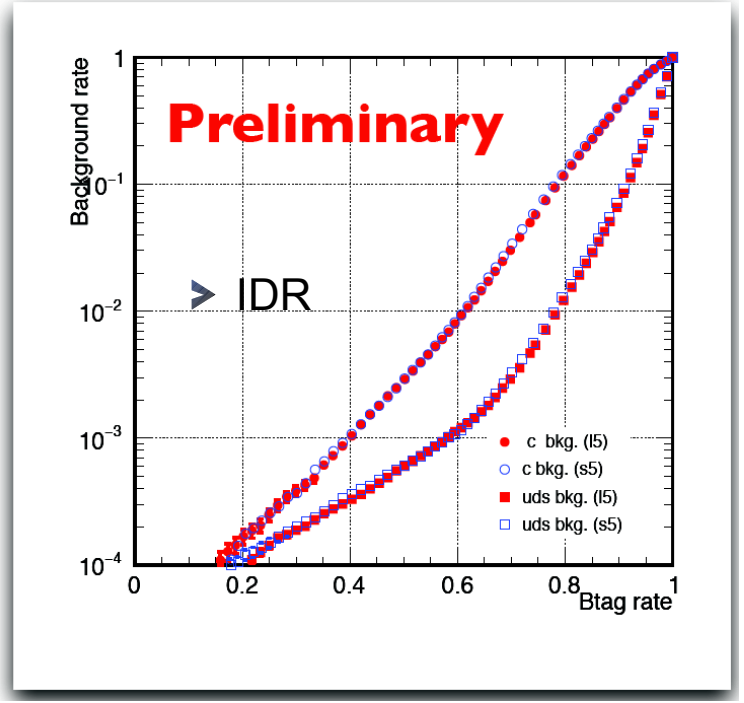


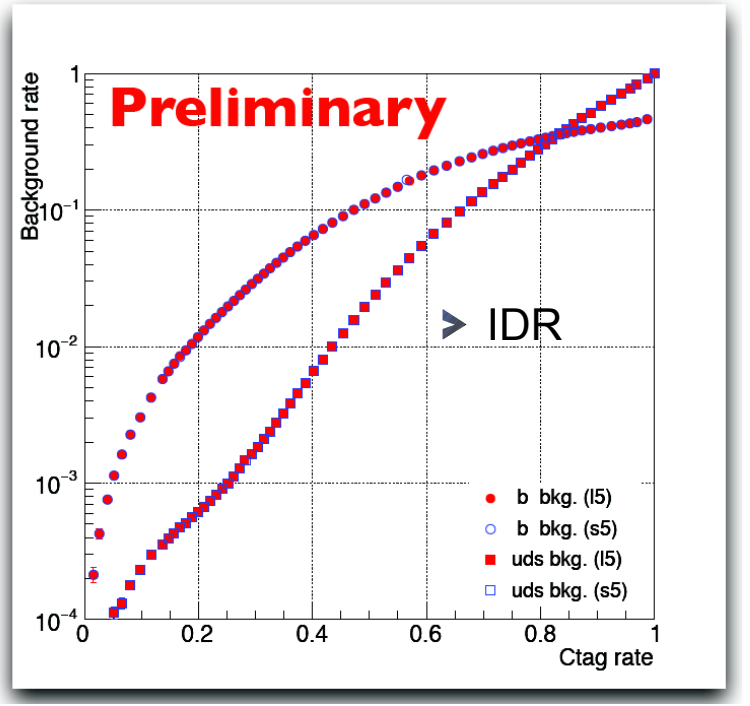
- Only 1 sec. vtx

- Requiring less than 4 secondary tracks will kill another 50% of b-quark background

Potential improvements

LCFIPlus C-tagging



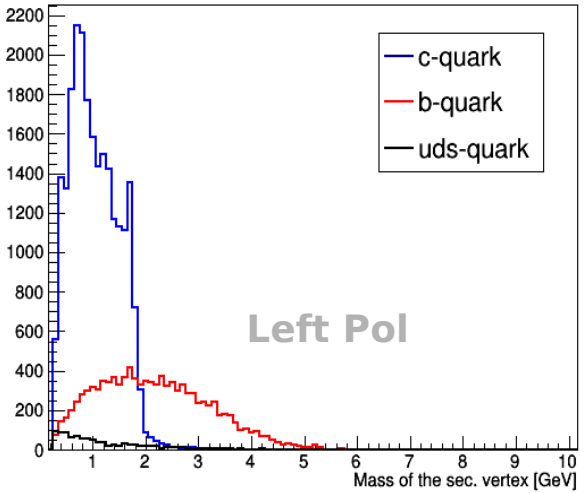


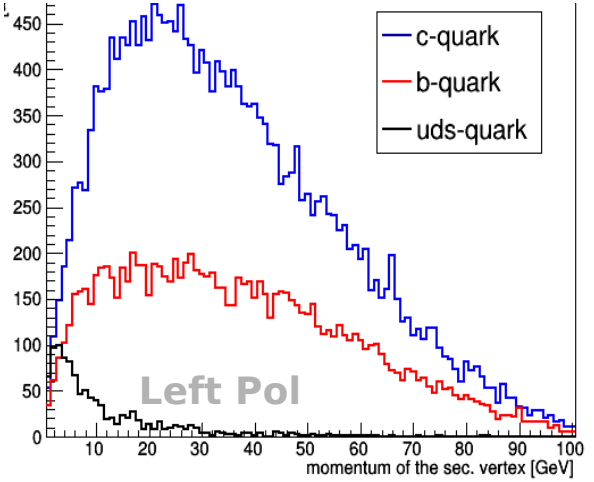
- R. Yonamine's slides, ILD benchmarking days 2019.

6b, 500 GeV, w/ beam bkg.

C-quark identification in 1-prong D/Ds decays

- So far, only jets with at least one reconstructed secondary vertex are studied.
- Including 1-prong cases, can enhance the statistics by a factor ~2.
- At the cost of having larger uds background. Could do we remove it? Probably with lcfiplus.
- First principles approach: we could look at mass / momentum of the reconstructed vertexes (as in the c-tag described in SLAC-PUB-8199)

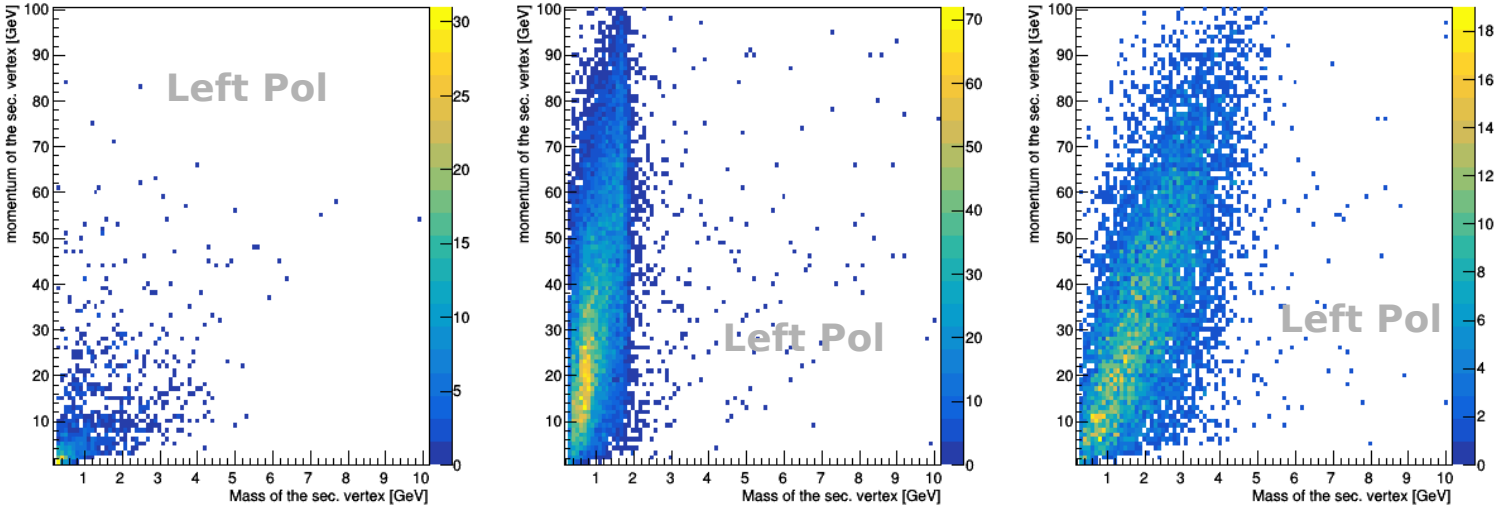




- Not 1-prong cases included yet

C-quark identification in 1-prong D/Ds decays

- It looks difficult to separate c and b-quarks using this methods at this energy
- But it seems that for c vs uds can work nicely.



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