Performance studies of heavy flavour tagging with the ATLAS detector

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Outline

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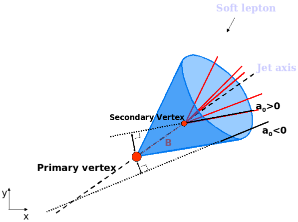
Heavy flavour tagging

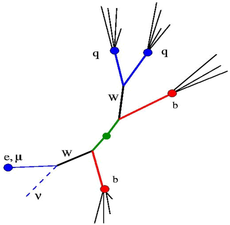


Lifetime of B hadrons: $c\tau \sim 470 - 390\mu m$,

Flight length $\sim$ 5mm, for $E \sim$ 50 GeV.

Pixels and mostly b-layer are crucial.

Event Selection



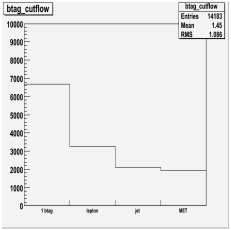
$t\bar{t}$ semileptonic channel.

Improved S/B ratio,

decreased uncertainty on W+Jets.

Cut Flow

Signal Only $\sim$ $20pb^{-1}$



10k $t\bar{t}$ events, Cuts: at least one bjet,

1 lepton E_T>20 GeV, 3 jets E_T> 40 GeV,

4th jet E_T>20 GeV, $\not{E}_T$>20 GeV.

Reconstruction and calibration

Different jet reconstruction algorithms/parameters,

- Cone ($\delta R = 0.4, 0.7$) Tower/TopoCluster,
- $k_T(D = 0.4, 0.6, 0.7)$ TopoCluster.

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Data

- Athena release 12.0.6 (ATLAS software framework),
- $\sim 35k$ $t\bar{t}$ events with at least one W decaying into leptons.
- For calibration and for analysis statistically independent data sets: trig1_misal1_mc12.005200.T1_McAtNlo_Jimmy.recon.AOD.v12000604_tid008037.

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Jet selection

- $|\eta| < 2.5$,
- $E_T > 15 GeV$.

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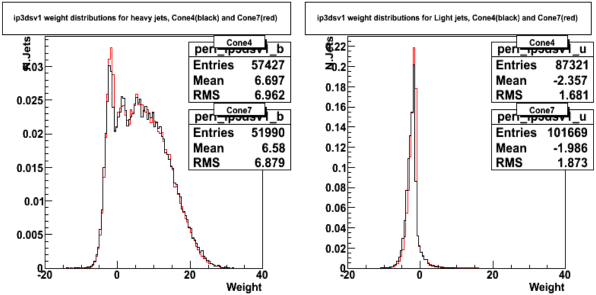
Light jet purification

- Removal of true light flavour jets within $\delta R < 0.8$ of true heavy flavour or tau jets.

Calibration procedure: fills the weight distributions for the selected heavy and light jets (backup slide).
Analysis procedure: finds weight cut corresponding to the desired heavy flavour tagging efficiency;
finds the number of light jets which will pass this cut.



Weight distributions for heavy and light flavour jets, reconstructed with Cone4(black) and Cone7(red) algorithms.

IP3D+SV1 recommended b-tagger.

Combines in likelihood:

- secondary vertex information,
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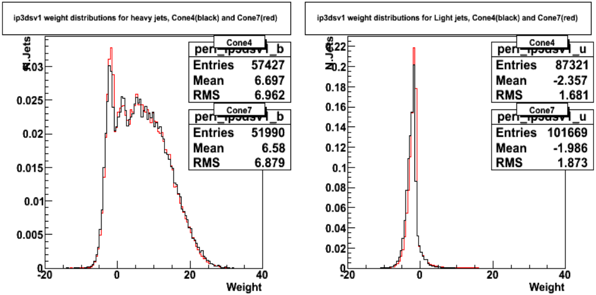

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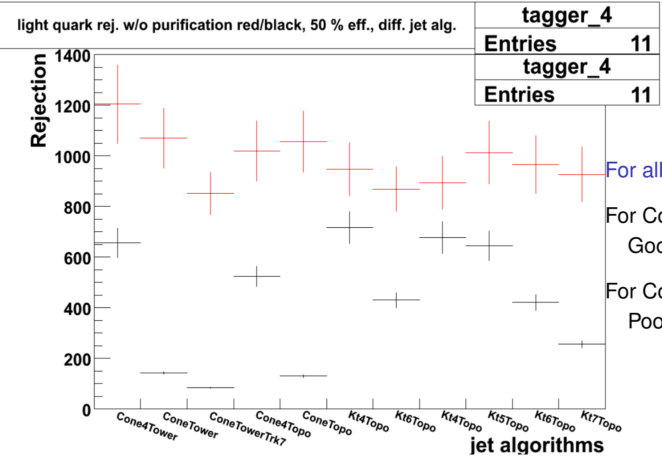
Variables plotted on the following slides:

Efficiency of b tagging = tagged true b jets / all b jets,
Light quark Rejection = 1 / efficiency of light quark selection (for given weight cut),
Purity of b quark selection = true b jets tagged as b / all jets tagged as b.

Performance studies

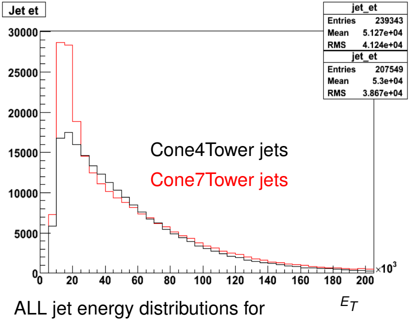


For all jet collections $\varepsilon_b = 50\%$;

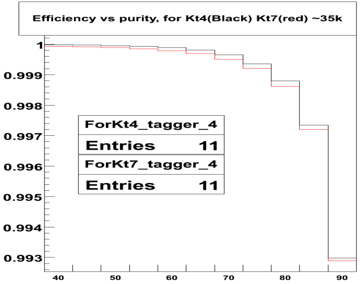
For Cone4 and k_T, $D = 0.4$ jets,
Good performance (R_light $\sim$ 650);

For Cone7 and k_T, $D = 0.7$ jets,
Poor performance (R_light $\sim$ 200.)

We tried to tune the track to jet association cone size. Third bin shows results for Cone7Tower jets when the track to jet association cone size was increased from default cone4 to cone7.

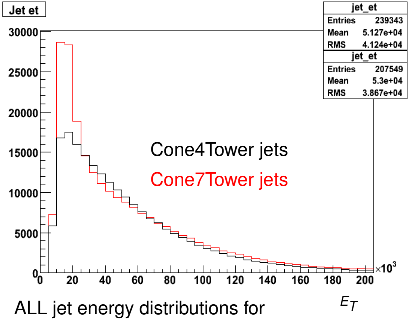


ALL jet energy distributions for Cone4(black) and Cone7(red) jets



Purity of the selected heavy flavour: $k_T, D = 0.4$(black) and $k_T, D = 0.7$(red) jets

More jets and especially more low energetic jets (most likely light jets) are reconstructed with Cone7 than Cone4 ! Some of them are above 15 GeV (default cut for b tagging procedure), which will increase the number of selected jets for b tagging and can explain poor performance for Cone7Tower jets.



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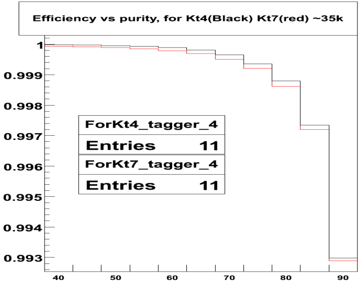

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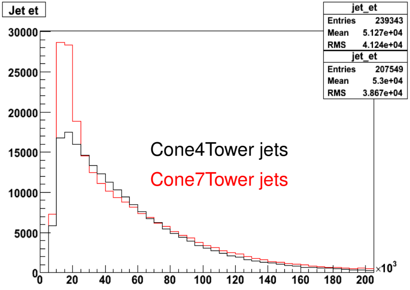
Nevertheless purity is still flat and 1 because the best possible settings were used:



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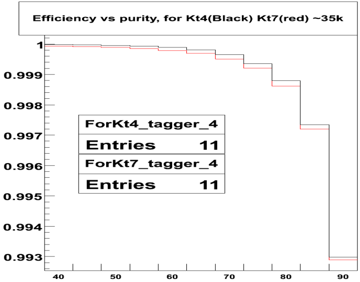

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Nevertheless purity is still flat and 1 because the best possible settings were used:

Dedicated calibration for the specific event topology,

Only signal events for performance studies.

Summary

We studied heavy flavour tagging performance for different jet collections, which showed:

- Performance (without purification procedure) depends on jet reconstruction algorithm, cone size;
- Tuning of the cone size for the track to jet association does not help;
- Corresponding energy and weight distributions are shifted for cone7 jets with respect to cone4 jets.

Outlook

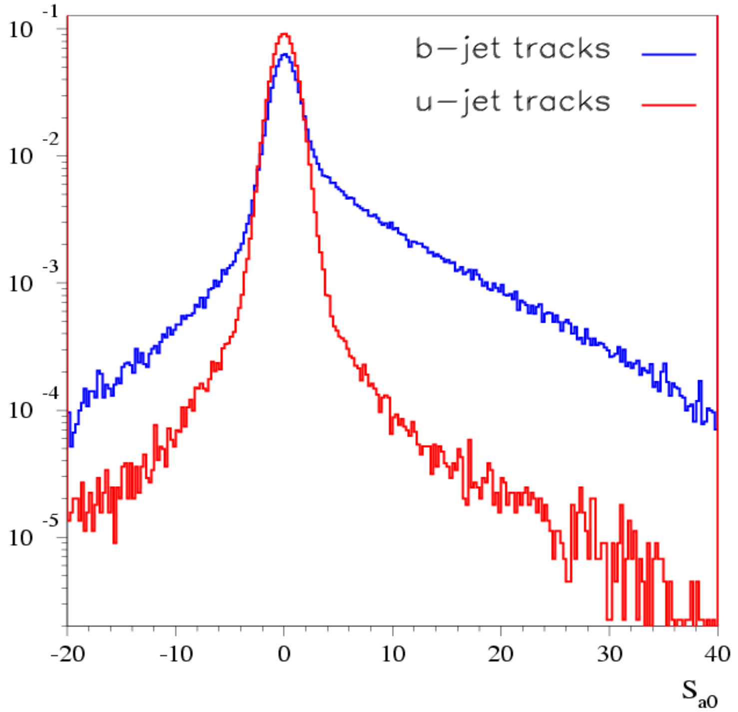
- For this study I used only signal samples. I need to investigate background samples: W+jets, QCD. In principle jet tagging performance must not depend too much on event topology, however different steps of the procedure are still sensitive to it.
- I will try to include different ATLAS geometry tags, to have b tagging performance plots for misaligned, aligned and perfect ATLAS geometry. (This has not been done yet within ATLAS. Not feasible for full statistics, needs to be done on Geant digits.)

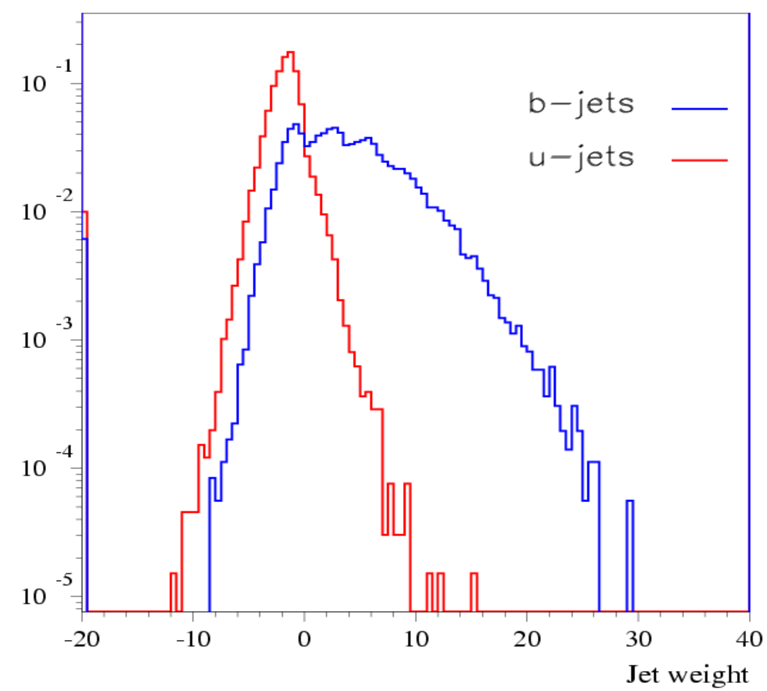
Backup Slides

Likelihood Ratio & IP2D Tagger

- Smoothed & normalized distributions of significances for the two b | u hypotheses: b(S), u(S)
- For each track: ratio b(S)/u(S)

$$W_{jet} = \sum_{i=1}^{N_{tr}} \ln \frac{b(S_i)}{u(S_i)}$$





Advantages:

- more powerful
- allows to combine non-correlated variables just by adding the weights

Drawbacks:

- requires p.d.f. for b and u hypotheses: may be difficult to measure in data

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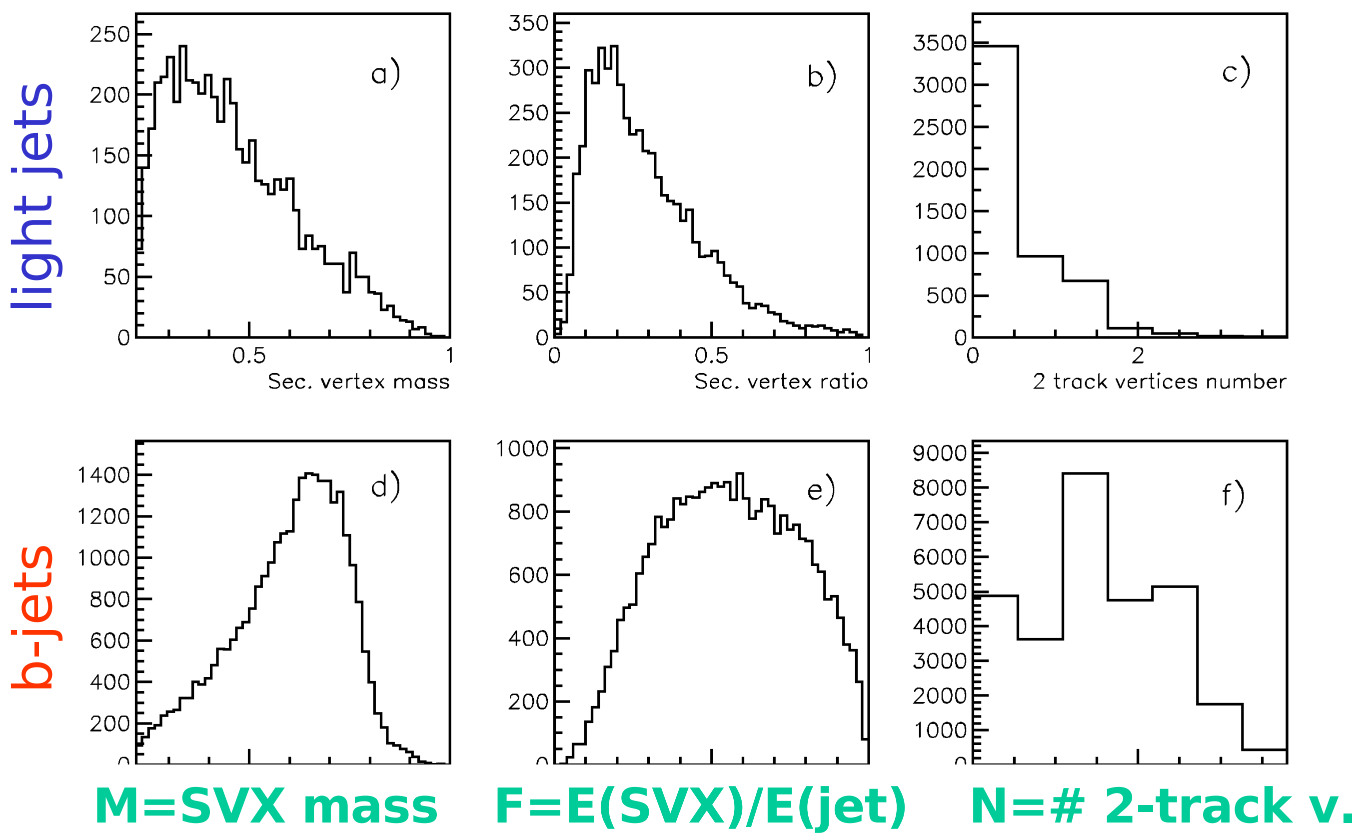
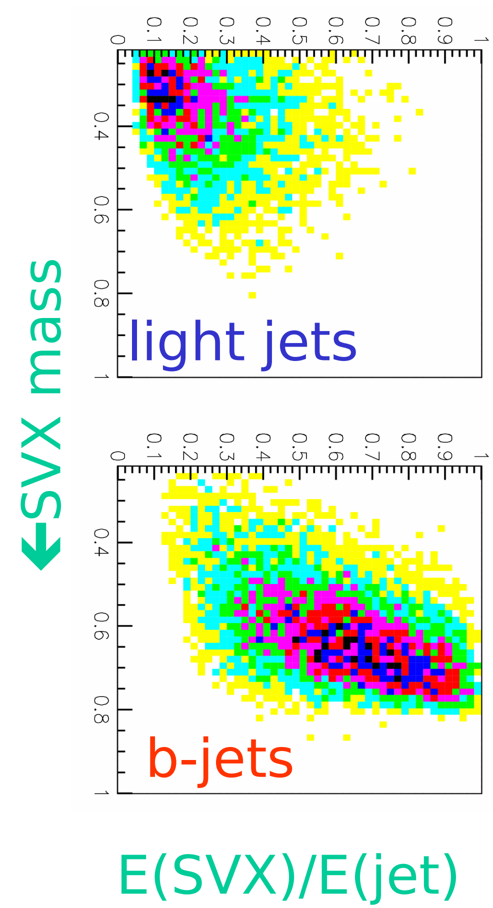
Secondary Vertex (SV) Tagger

- Track selection, search for 2-track vertices, V0/inter. removal
- Common inclusive vertex for remaining tracks
- Variables used: low correlation with IP
- Use multiD distributions → correlations





Combined with IP: $$W_{jet} = W_{tracks} + W_{vertex} = \sum_{i=1}^{N_{track}} \log \frac{b(a_{0_i}, Z_i)}{u(a_{0_i}, Z_i)} + \log \frac{b(M,F,N)}{u(M,F,N)}$$

Main Taggers

Taggers based on likelihood ratios		
IP1D	Long. impact parameter	Mostly for debugging
IP2D	Trans. impact parameter	Simple, robust
IP3D		Combination
SV1 (not for standalone)	Secondary vertex	Powerful, but delicate
SV2 (not for standalone)		Variation on SV1
IP3D+SV1	Recommended combination for physics studies	
Other taggers		
JetProb	Impact parameter	à la ALEPH
SoftElectron	ECAL+TRT+tracker	
SoftMuon	MUCH (Staco+Mutag)	(HCAL not used yet)
………	Counting tracks w/ IP	(in preparation)

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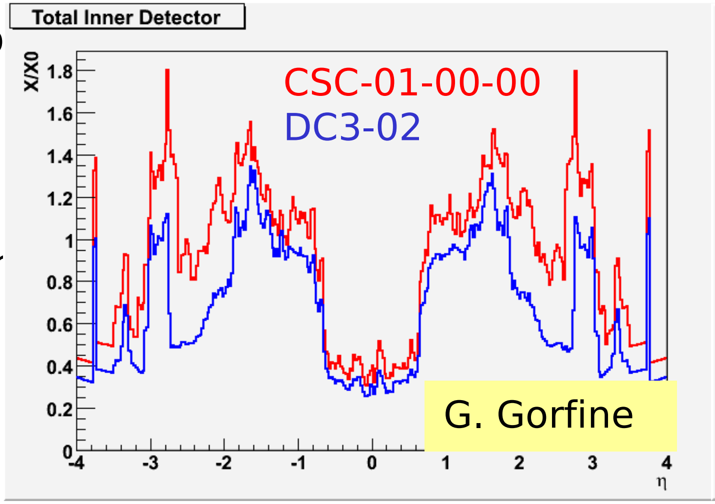
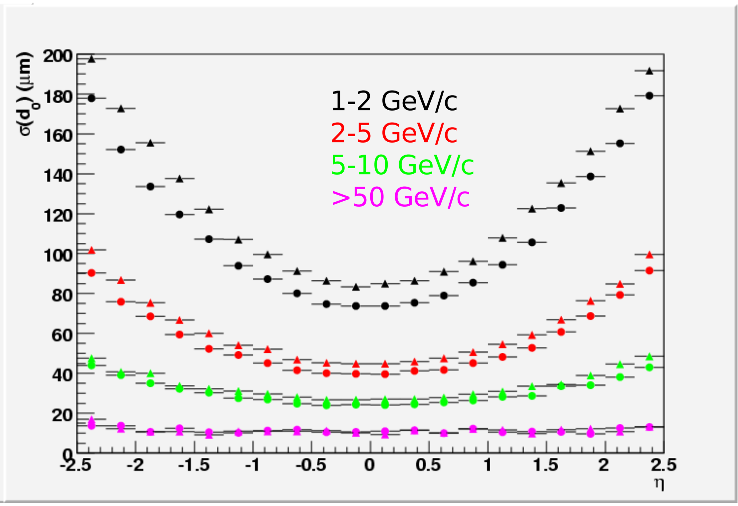
Impact of material with CSC geometries

- More realistic description o material
- Biggest change is from DC3-02 to CSC-01-00-00
- Additional degradation with CSC-01-02-00 (and a bit more to come)

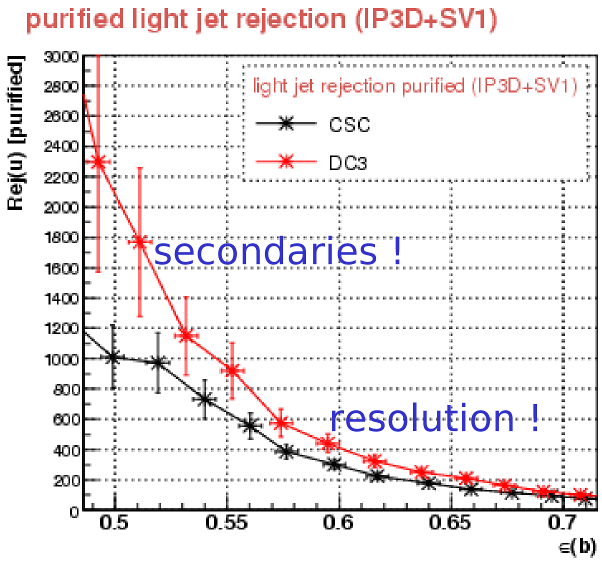
Material increase:

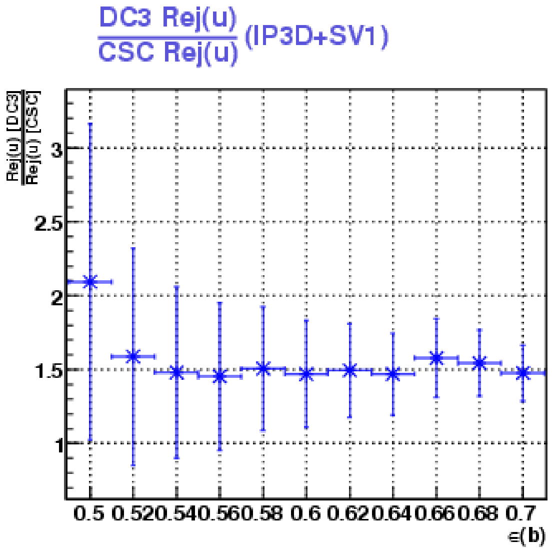


d0 resolution:



Impact on b-tagging: rejection /~1.5 for fixed ε(b), for R(u)=100 <~5% absolute on ε(b)





Understanding:

- rescaling in DC3 of IP resolution to match CSC
- removal of G4 secondaries

➔ Explain 60-70% of losses (more in central region, ~100%)

➔ Need to understand the missing part & address recoverability