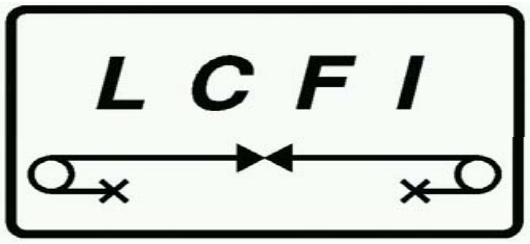

Anomalous Wtb @ILC – from tools to physics

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SiD 04/2008
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Anomalous coupling (Motivation – Theory)

Tools needed (b tagging– charge)

Top-ID

Conclusion (The way forward)

Aim

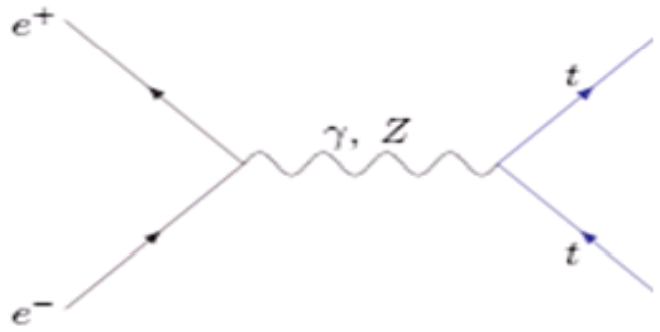
- **We plan to measure non standard model (anomalous) Wtb couplings of the top quark**
  - **In order to do this we identify a set of sensitive observables.**
  - **We develop reconstruction tools: b tagging, vertex charge.**
  - **Need good top reconstruction.**

Why?

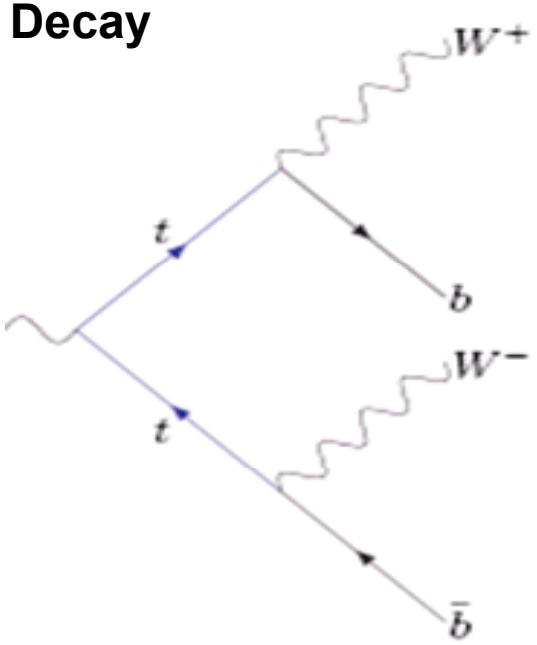
- **The top quark mass approaches the energy scale of new physics. New physics often couples to mass! The top is thus useful to probe non standard model (anomalous) couplings.**
  - **The Wtb vertex defines the top total width and the characteristics of the decay products.**

Top production – decay

ILC - main production channel



Decay



The top production at the ILC ≈ 0.8pb

Measurements of the CKM Matrix for the top quark give: V_{tb} = 0.999 implies t→Wb > 99.8%

Need good b-tagging!

Channels :

- **tt → bbll*vv*** ***(11%)***
- **tt → bbl*v* + *2 jets*** ***(44%)***
- **tt → bb + *4 jets*** ***(45%)***

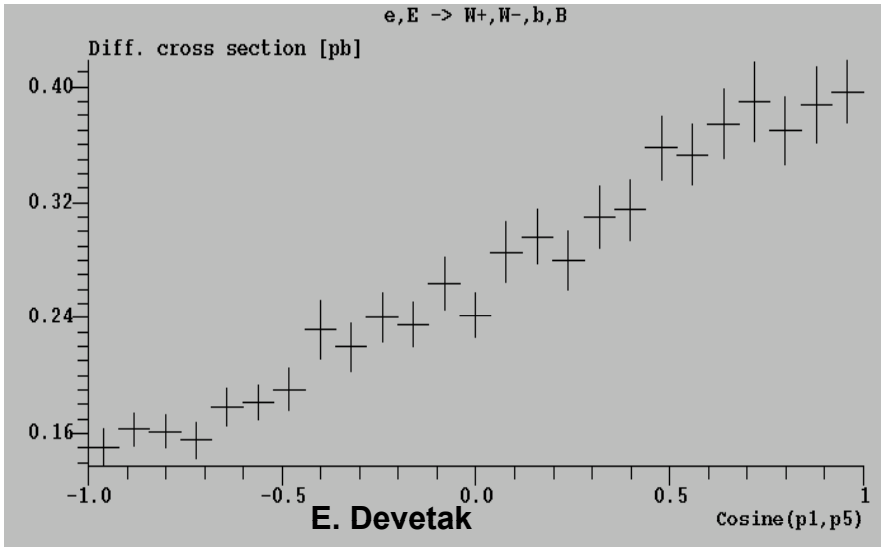
Missing energy.

No missing energy, top frame easy to identify. High statistics!

Observable - A_{FB}

(Forward-Backward Asymmetry)

• Can parameterise anomalous couplings as right and left handed form factors



	f_{2R}	f_{2L}	A_{FB}, e^+e^- c.m.s.	A_{FB}, top frame
	unpolarized $e^+e^- \to t\mu\bar{\nu}_\mu\bar{b}$			
$\bar{b}$	0.0	0.0	0.279	0.030
$\bar{b}$	0.0	-0.2	0.243	0.010
$\bar{b}$	0.0	-0.4	0.218	-0.004
$\bar{b}$	0.0	-0.6	0.197	-0.020
$\bar{b}$	0.0	-1.0	0.169	-0.039
$\bar{b}$	-0.6	0.0	0.301	0.041
$\bar{b}$	-1.0	0.0	0.315	0.045
μ	0.0	0.0	0.079	-0.091
μ	0.0	-0.6	0.085	-0.084
	polarized $e_L^-e^+ \to t\mu\bar{\nu}_\mu\bar{b}$			
$\bar{b}$	0.0	0.0	0.354	0.100
$\bar{b}$	0.0	-0.2	0.265	0.034
$\bar{b}$	0.0	-0.4	0.200	-0.011
$\bar{b}$	0.0	-0.6	0.152	-0.047
$\bar{b}$	0.0	-1.0	0.087	-0.095
μ	0.0	0.0	0.145	-0.262
μ	0.0	-0.6	0.104	-0.233

E. Boos et al. Analysis on t → bμ*ν*

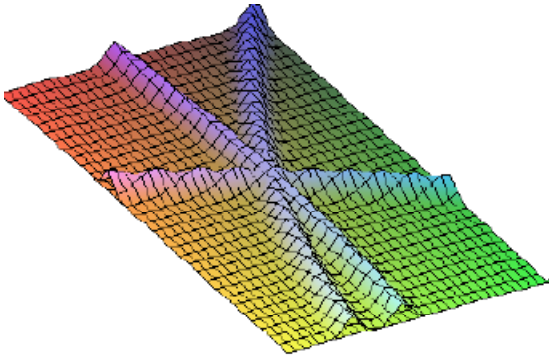
• Asymmetries larger in cms frame. These superposition of production and decay asymmetries. The top frame asymmetries are 'pure'.

• b quark asymmetries are larger than the lepton ones.

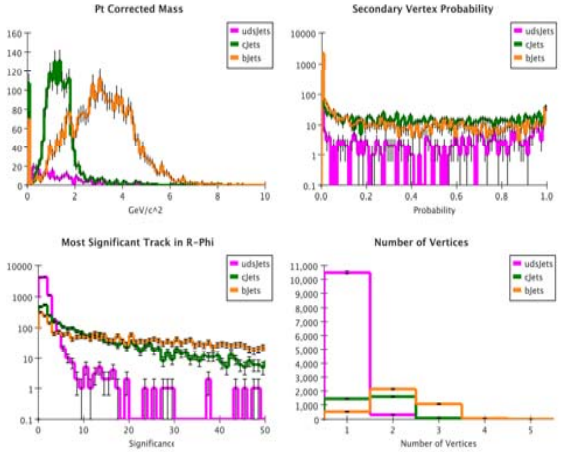
• Polarization of the electron beam increases the asymmetries.

Need to discriminate b and $\bar{b}$

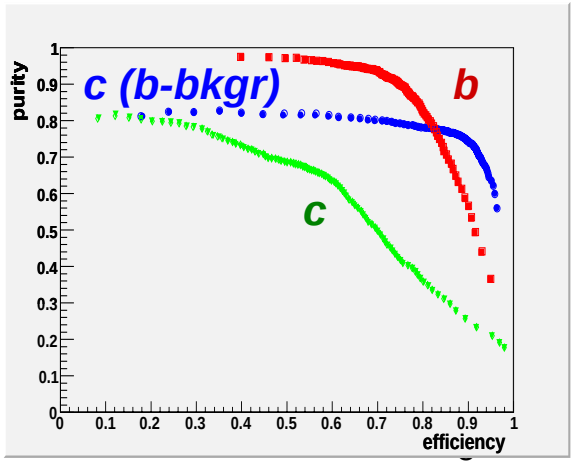
Vertexing - Flavour Tagging



USE LCFI Vertexing and Flavour tagging

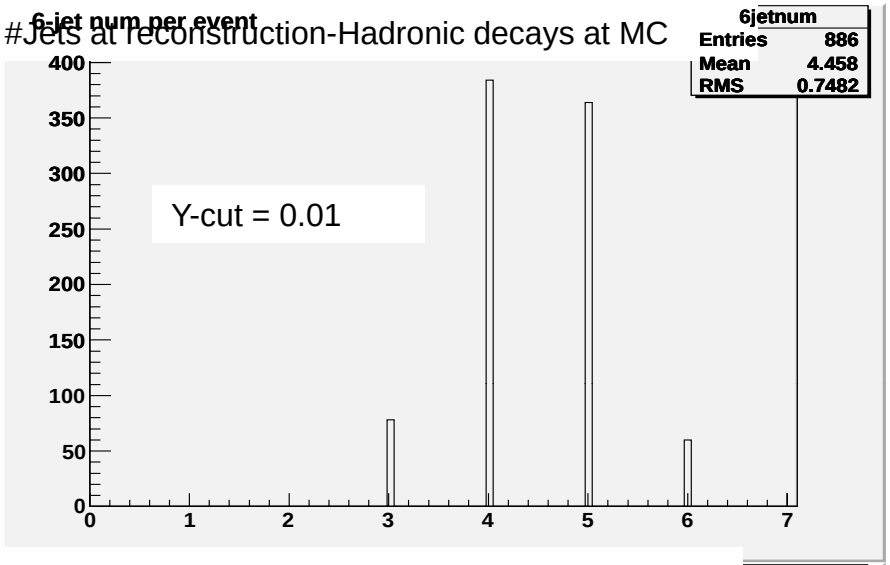


- Vertexing: ZVTOP – ZVRES algorithm
- Flavour Tagging Inputs: Pt Corrected Mass, Joint Probablility, Number of vertices …
- Neural Net : discriminate b,c, light quark jets
- Also use Calculation of Charge of Seed (“Secondary”) Vertex…

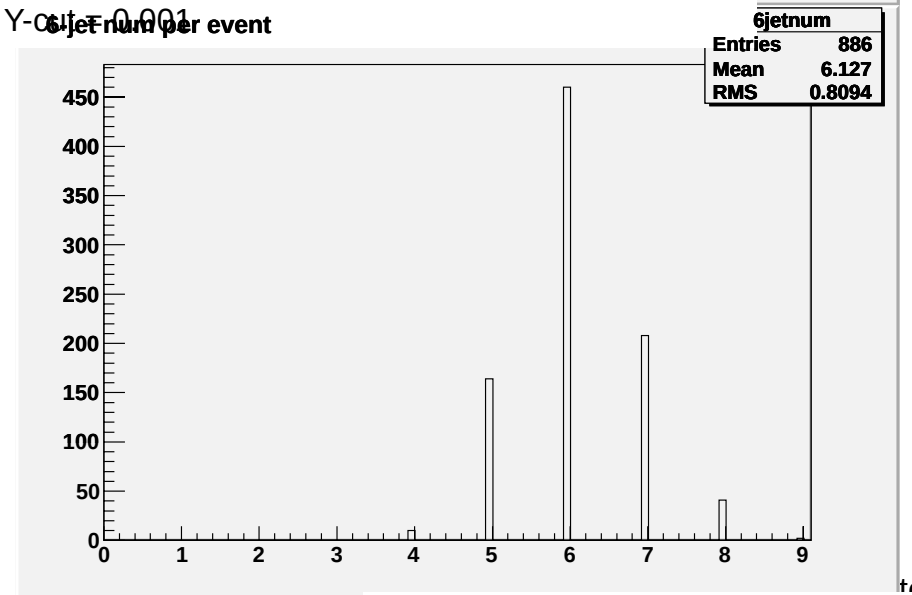


6 jets – Optimize the Ycut

#Jets at reconstruction-Hadronic decays at MC



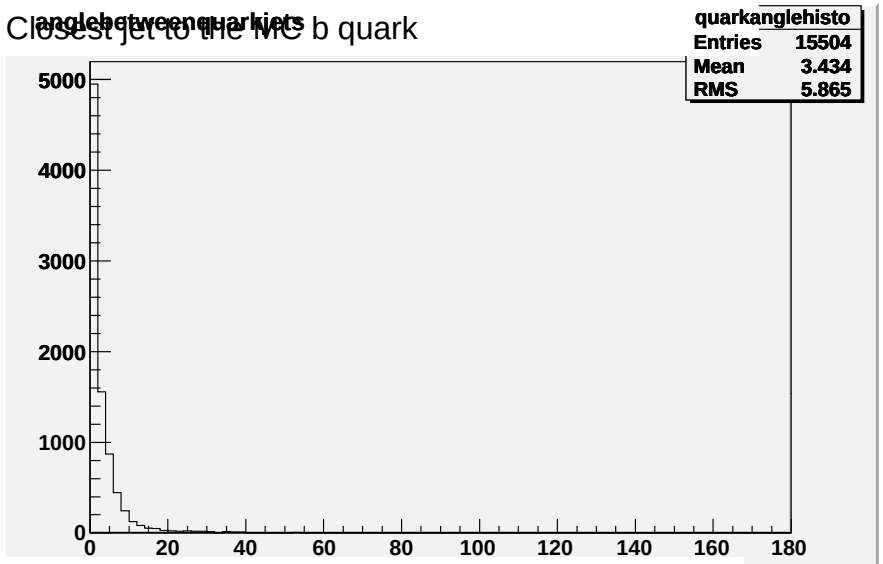
Y-cut = 0.001



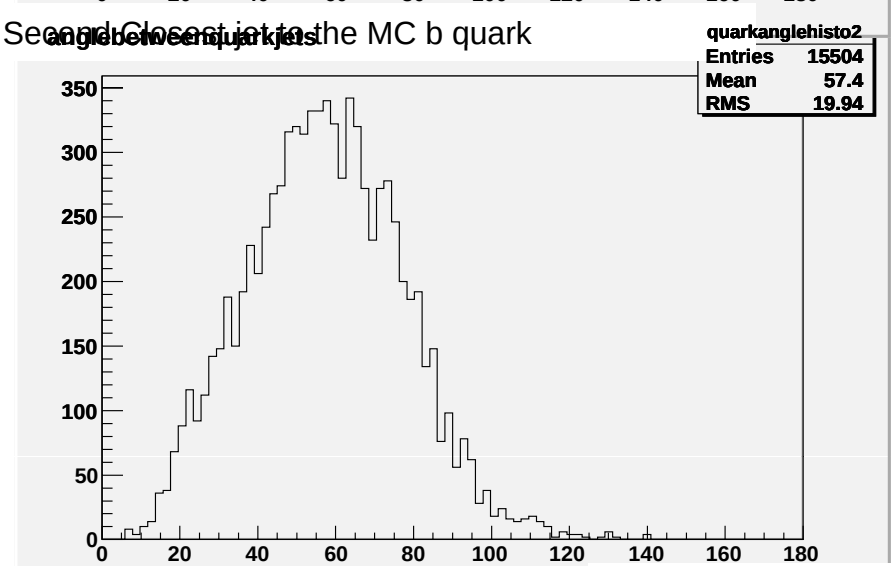
- Jet finder extremely sensitive to the applied y-cut.
- Need to optimise jet finder
- Take top events with all hadronic W-decays at MC and search for peak at 6.
- Can probably use also 7 and 8 jet events.
- 5 – Jets more problematic?
- Y-cut used 0.001

MC b quark –jet matching

Closest jet to the MC b quark



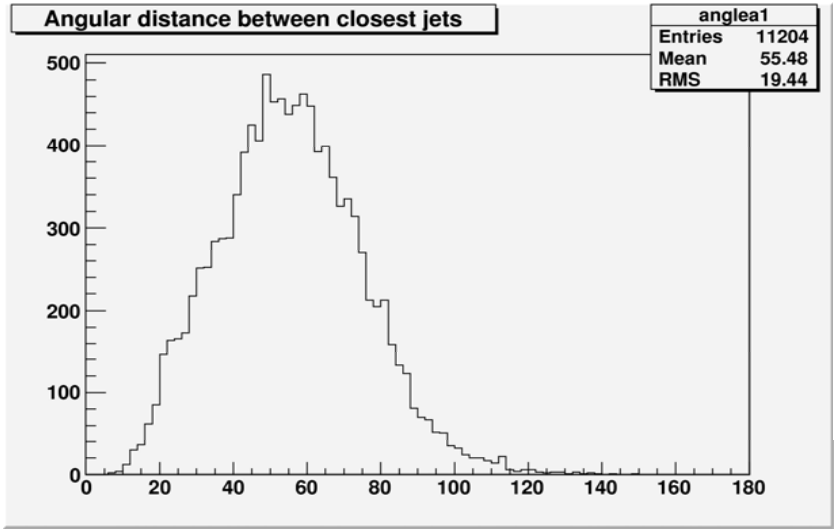
Second Closest jet to the MC b quark

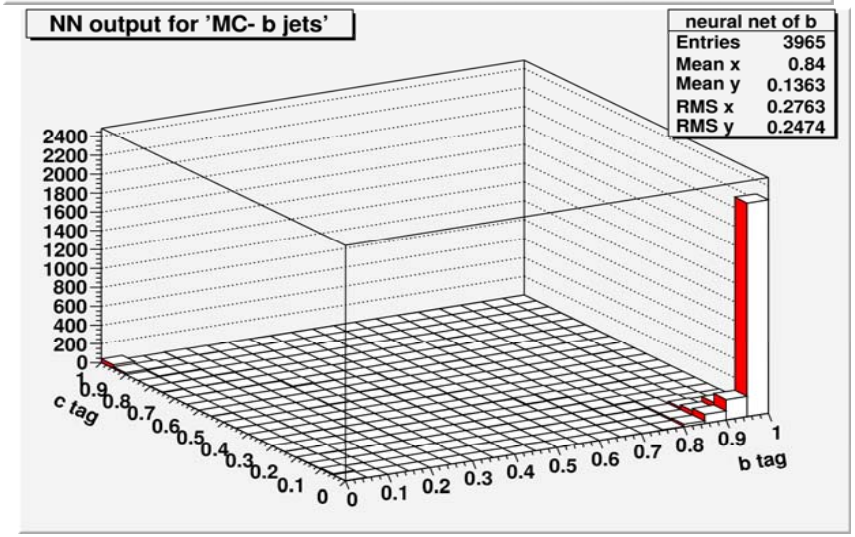


Degrees

- Can we use the true angular jet flavour to 6 jet events?
- Check angular distance between MC b-quark and closest jet
- Compare with second closest jet.
- Seems to work just fine.

Flavour Tagging

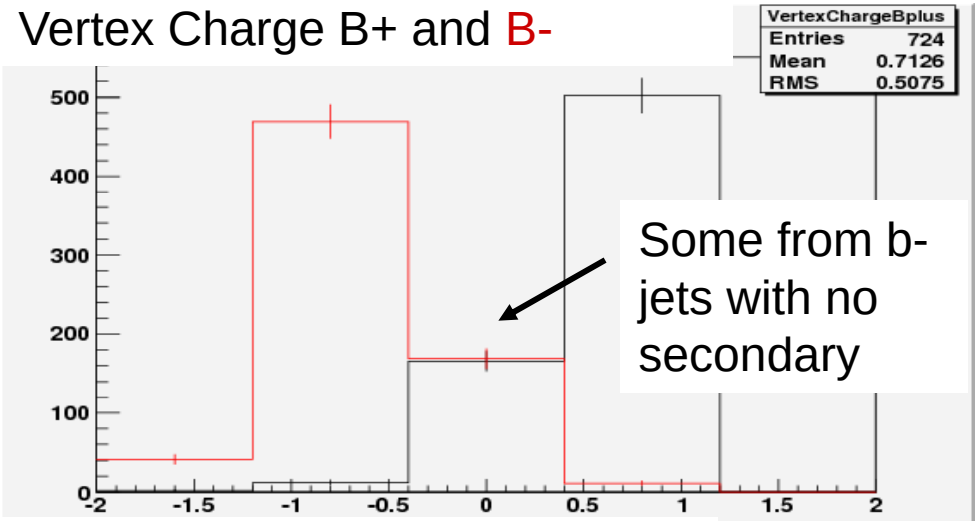




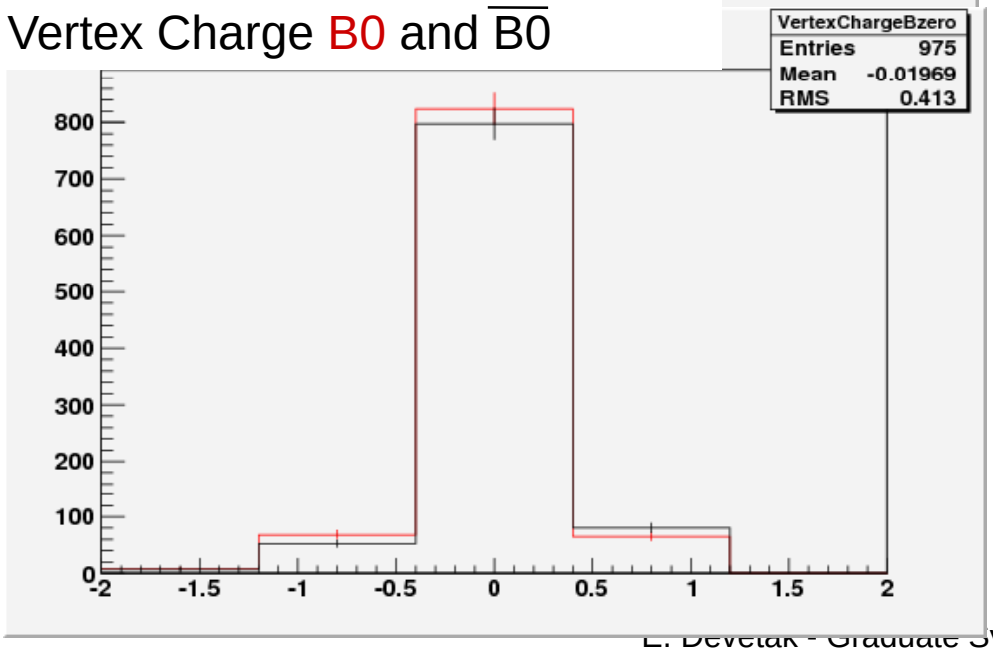
- First look if jets well separated at reconstruction level
- Then look at b tag given only b jets at MC level
- Performance not degraded in any noticeable way.
- Still need to check degradation of parton (vertex) charge…
- Caveat: Used SID fast MC – expecting worst performance with full MC but not dramatic decrease.

Vertex Charge

Vertex Charge B+ and B-



Vertex Charge B0 and $\overline{B0}$



- Important to find the charge of the b-quark originating the jet
- Done by finding charge of the decaying b vertex
- If charge +/- then assume meson and infer parton charge
- Hadronisation into baryons rare
- So far we discard the neutrally reconstructed vertices and also events where no vertex present…

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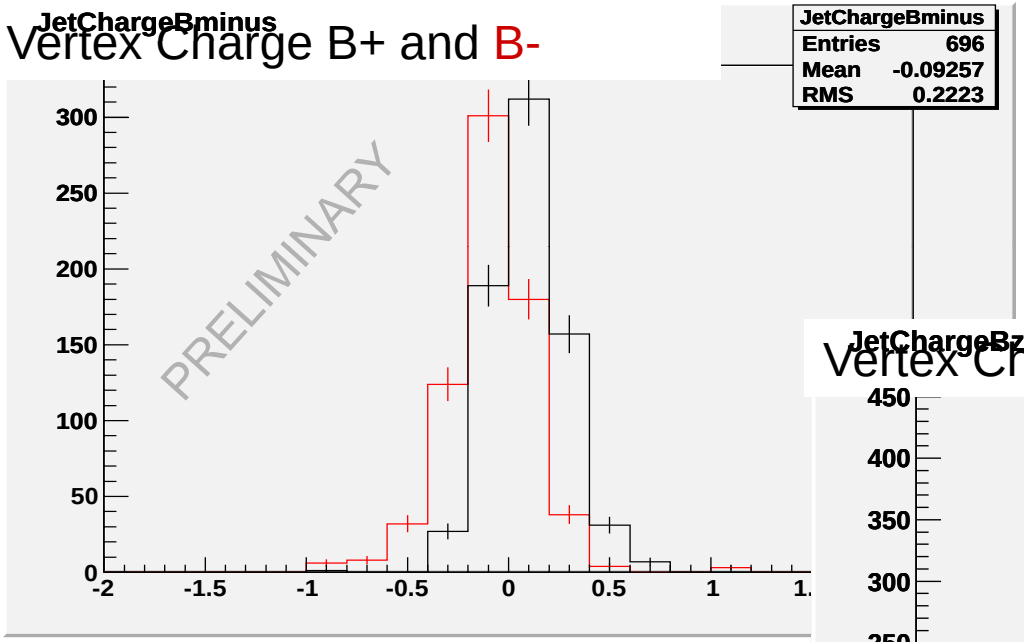
Jet Charge

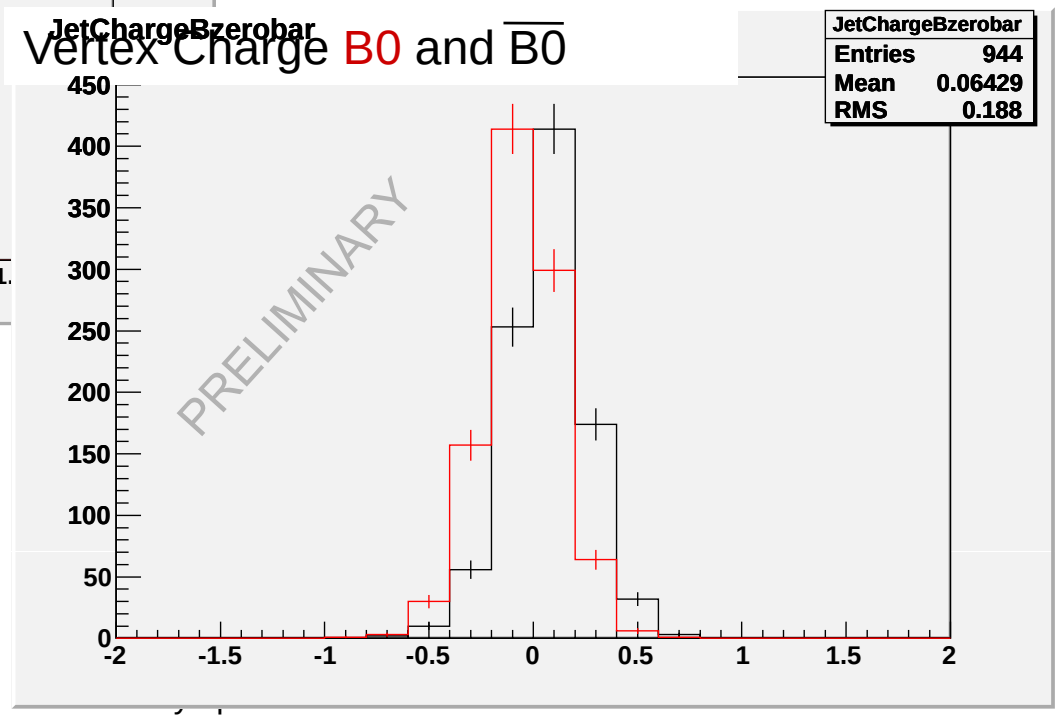
IDEA: Use different variables to help us recoup extra efficiency?

Vertex Charge B+ and B-



$$C_J = \frac{\sum_{i=0}^{n} P_i^{0.5} q_i}{\sum_{i=0}^{n} P_i^{0.5}}$$

Vertex Charge B0 and $\overline{B0}$

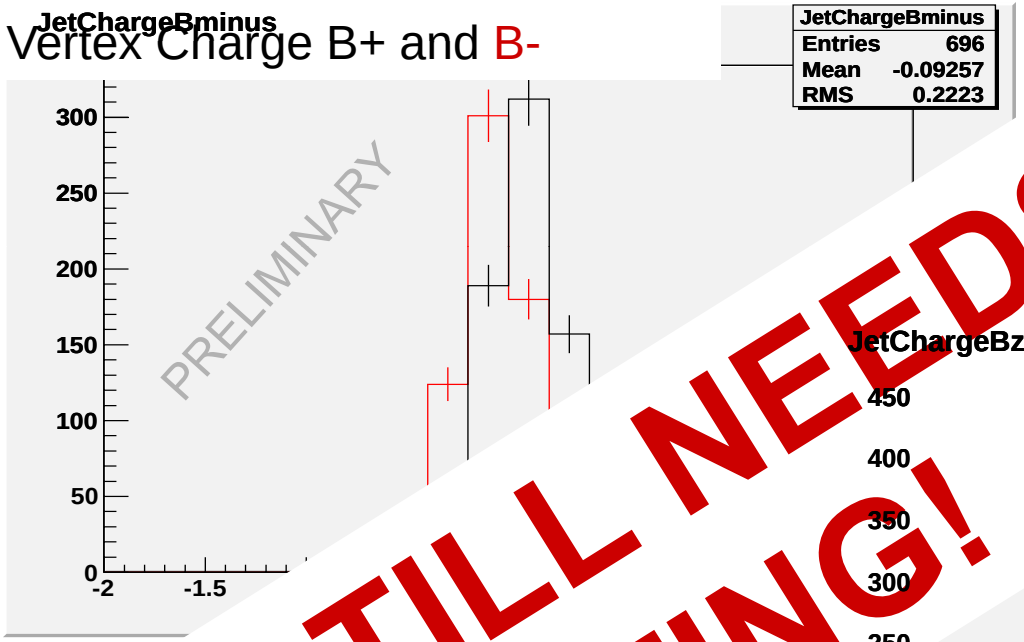


- Seems to work for B+ and B-
- Not as well as Vertex charge but extra info, and no need for secondary
- Discriminates also B0 and $\overline{B0}$? (kinematics of decay…)

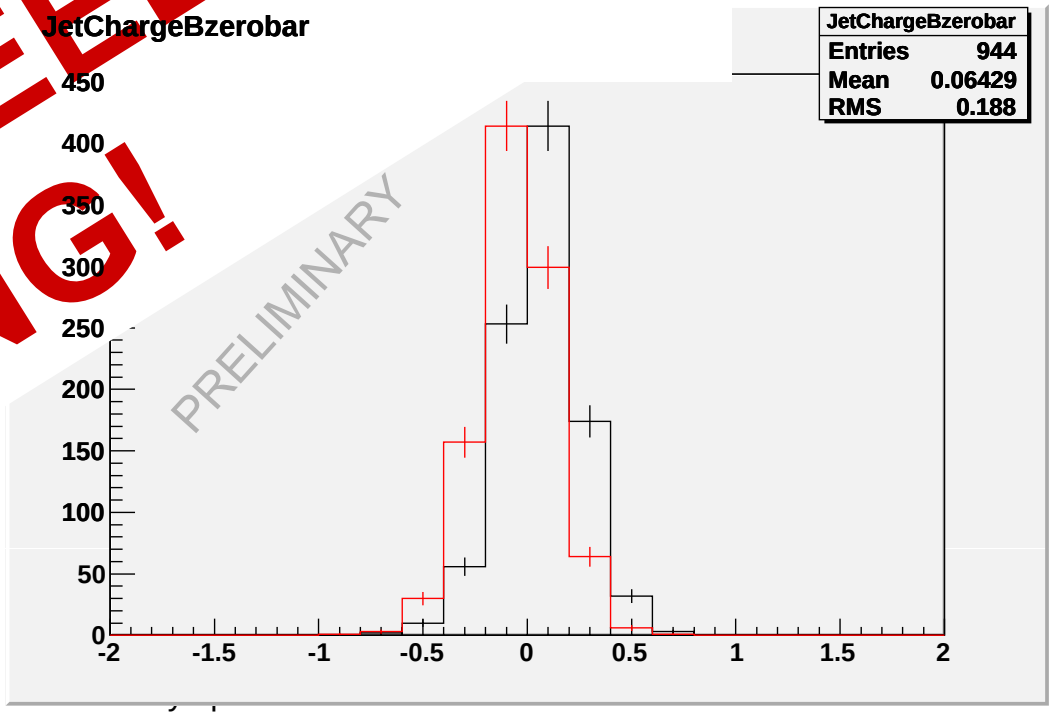
Jet Charge

IDEA: Use different variables to help us recoup extra c

Vertex Charge B+ and B-



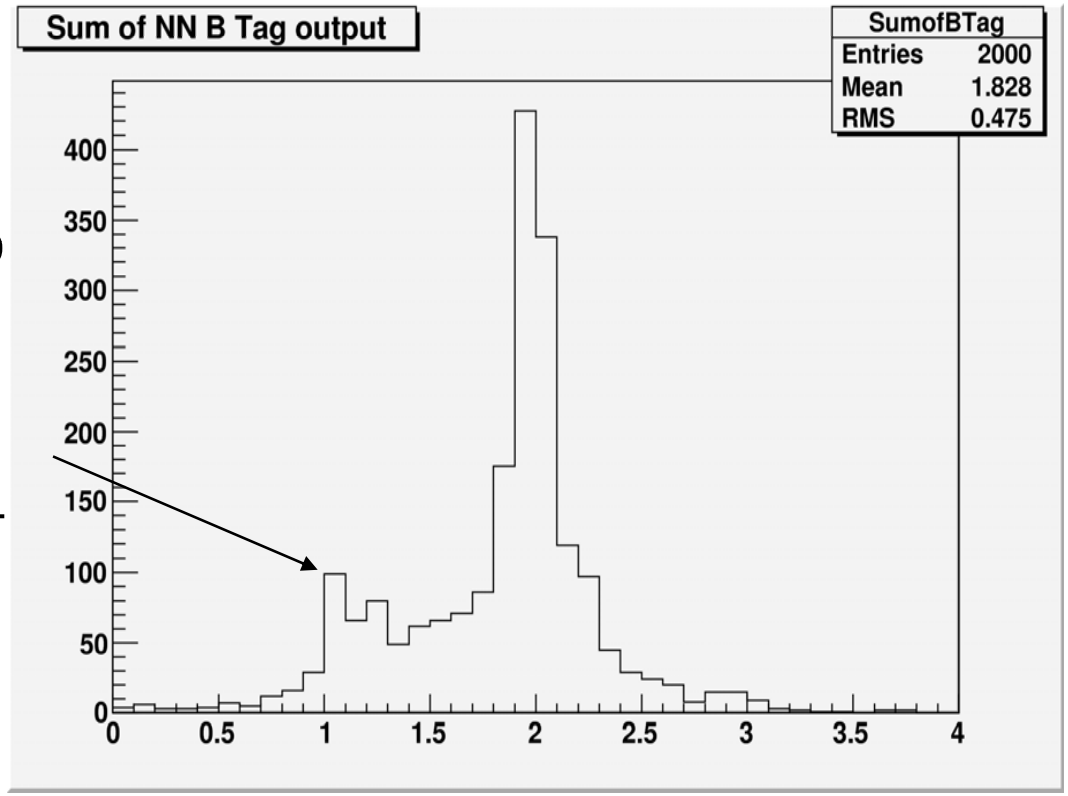
STILL NEEDS SOME TESTING!



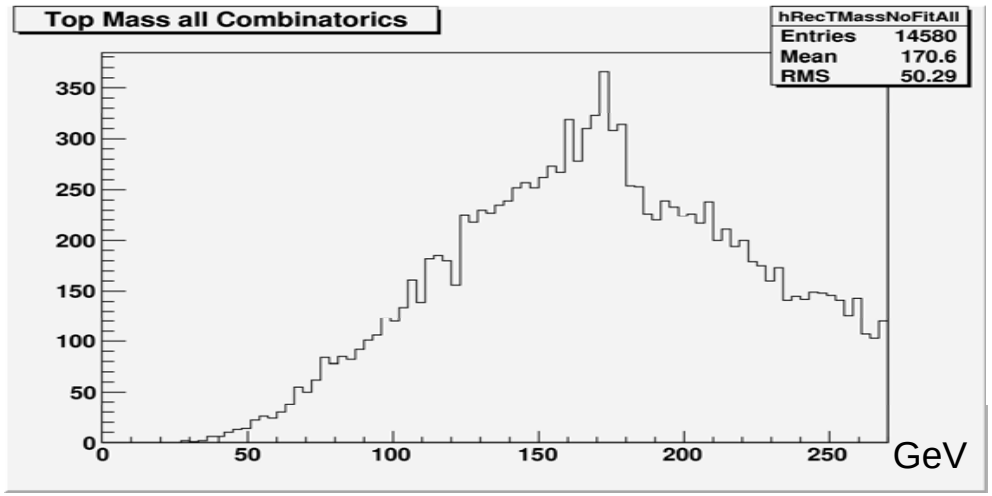
- Seems
- Not as we
extra info, an ondary
- Discriminates and $\overline{B0}$?
(kinematics of dec y…)

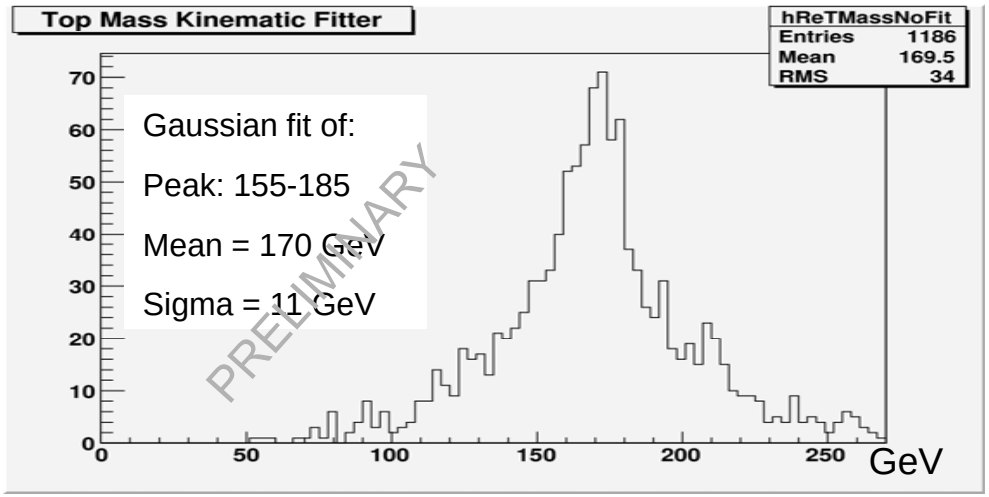
B - tagging identifying tt

- All inclusive decays. Use only events where 6 jets reconstructed
- Clear peak at 2 reconstructed b quarks. Good discriminator for top
- Corruption from missing acceptance cuts and failure of b reconstruction reason of peak at 1
- **Useful to take care of such events! (not yet done)**



Top Mass - identifying the top





- All inclusive decays. Use only events where 6 jet reconstructed
- If plot all 6 jets combinatorics top peak barely visible
- Setting energy and momentum constrains peak is much sharper
- Still present wrong w – b combinatorics.
- Corruption from events with one top decaying leptonicaly.
- **Use previous 2 slides to take care of these effects!**

Not quite the asymmetries yet

- Analysis not concluded
  - Need to include background
  - Need to include acceptances
  - Study of asymmetries and of errors!

However ….

- Found suitable observables
- Developed tools for b tagging (used to ID the top)
- Developed tools for charge reconstruction (needed for A_{FB})
- Developed a method of identifying the top by using the b tag and mass

ALL PIECES IN PLACE - NEED TO BRING THEM TOGETHER

BACK UP SLIDES

The Wtb effective lagrangian

The effective CP conserving lagrangian of the Wtb can be written as:

SM coupling. EW (V-A)

Right handed (V+A). 0 in SM. Experimentally constrained ≤ 0.4x10^{-2} (CLEO)

$$\mathcal{L} = \frac{g}{\sqrt{2}}\Big[W_\mu^- \bar{b}(\gamma_\mu f_{1L} P_- + \gamma_\mu f_{1R} P_+)t - \frac{1}{2M_W} W_{\mu\nu}\bar{b}\sigma^{\mu\nu}(f_{2R}P_- - f_{2L}P_+)t\Big] + \text{h.c.} \quad (1)$$

where $W_{\mu\nu} = D_\mu W_\nu - D_\nu W_\mu, D_\mu = \partial_\mu - ieA_\mu, P_\perp = 1/2(1 \pm \gamma_5)$ and $\sigma^{\mu\nu} = i/2(\gamma_\mu\gamma_\nu - \gamma_\nu\gamma_\mu)$.

Higher order anomalous couplings. These are 0 in SM. These are the couplings we propose to study.

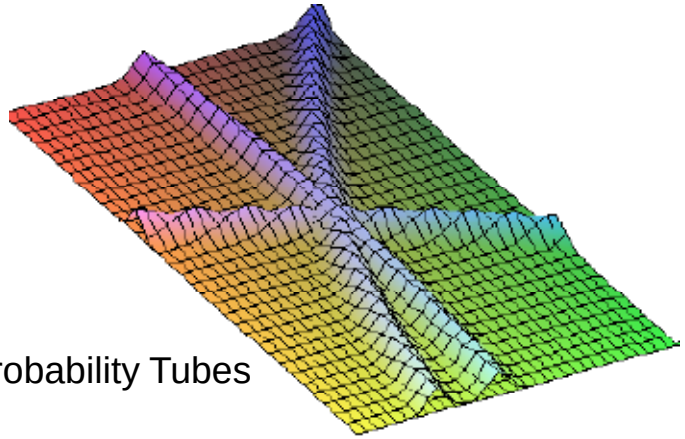
Vertex Finding

D. Jackson,

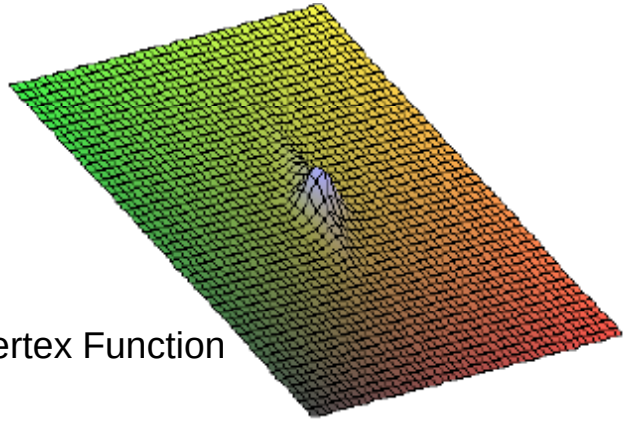
NIM A 388 (1997) 247

AIM: Find secondary and tertiary vertices

- LCFI implemented general ZVRES algorithm:
  - Represent tracks with Gaussian ´probability tubes´
  - Calculate vertex function
  - Search 3D-space for maxima of this function
  - Combine close-by vertices - resolve ambiguities



Probability Tubes



Vertex Function

Vertexing - Flavour Tagging

AIM: Distinguish between b-jets, c-jets and light-quark jets

- LCFI coded and implemented procedure developed by R. Hawkings as default (LC-PHSM-2000-021), however the code is extremely flexible

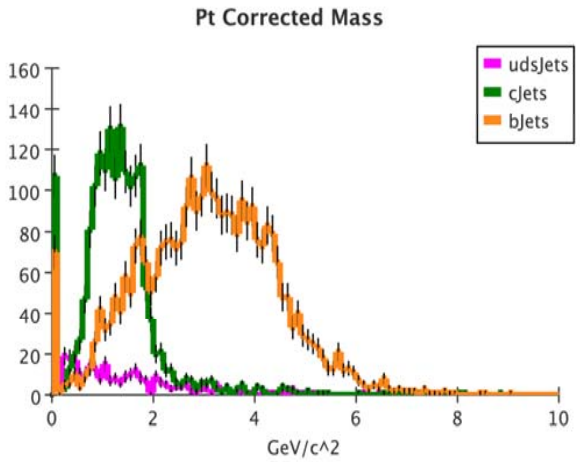
- Define highly discriminating tagging parameters

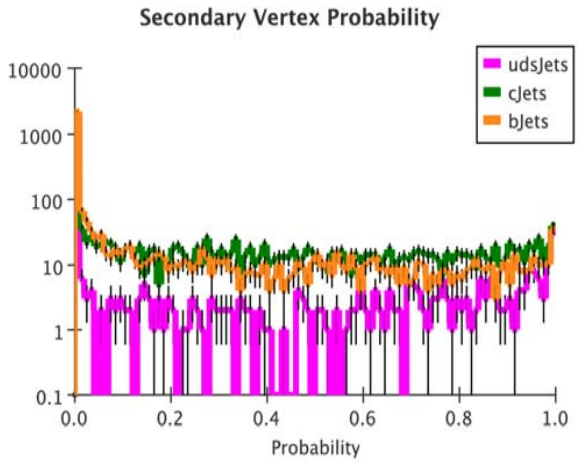
- Use parameters as inputs to Neural Network; this discriminates between b, c and light jets. Different inputs used depending on number of vertices

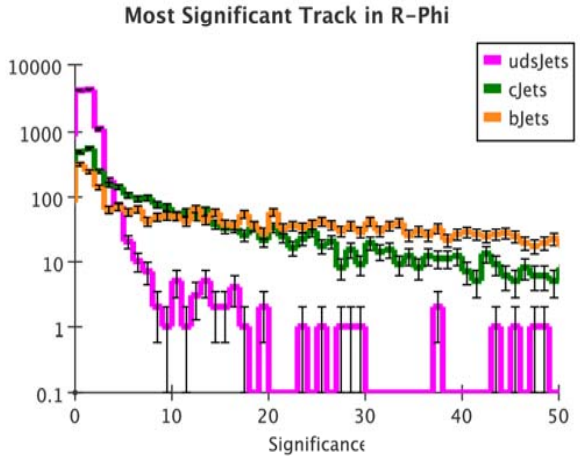
- Procedure's tagging inputs:

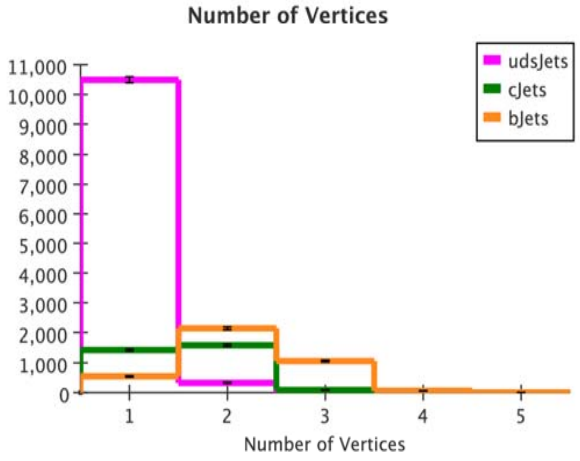
  distance primary to furthest secondary vertex and its significance, track impact parameter significances, vertex momentum, number of tracks in secondary vertices …

Tagging Inputs









- Number of vertices found good indication of underlying event
- M_{Pt} of secondary vertex most discriminating variable. (secondary needs to be found!)
- Probability that all tracks come from same secondary also good indicator
- Significance of tracks good discriminator when only interaction point is found

E. Devetak

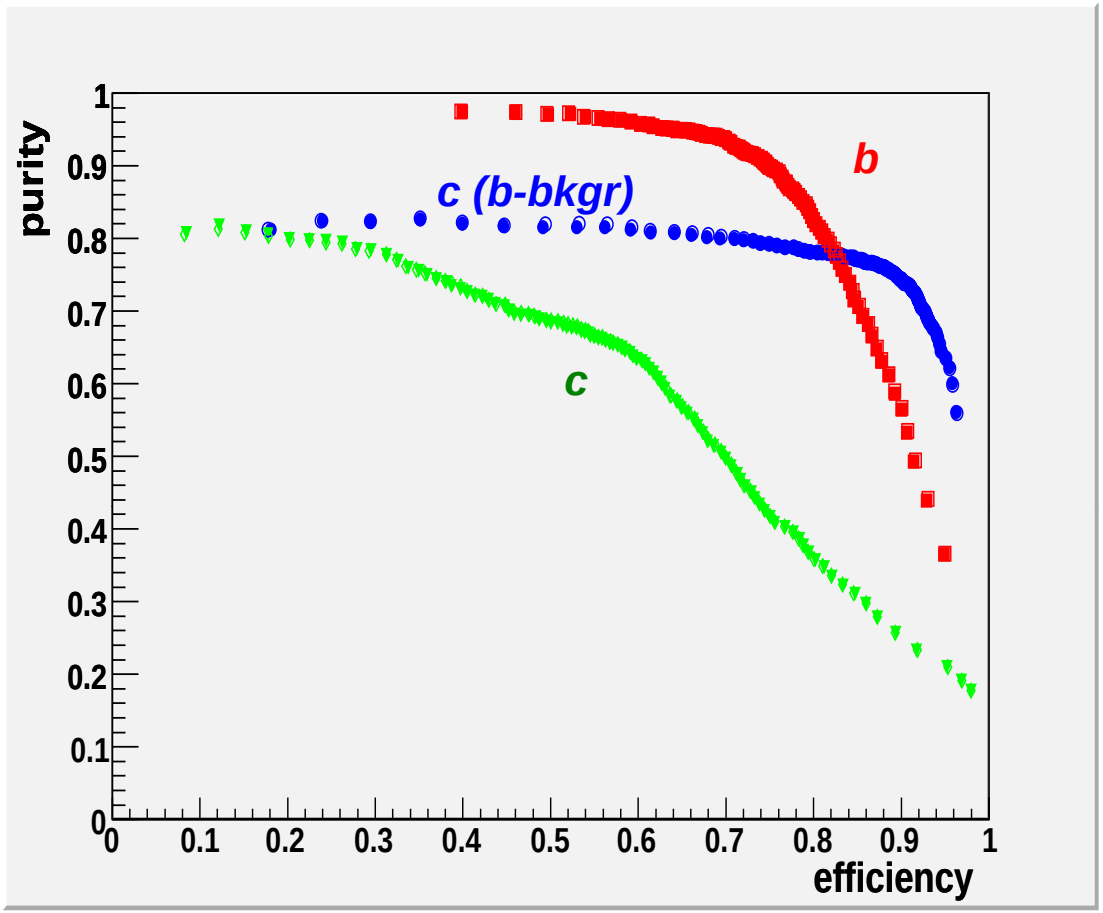
Purity-Efficiency

- Analysis at **500 GeV** E_{CM} Done with di-jet events

- Using Mokka (Geant4) + LDC Tracking + PandoraPFA

- b tagging is very good. Should suit the top analysis.

- We can reconstruct most of the b quarks with little contamination!



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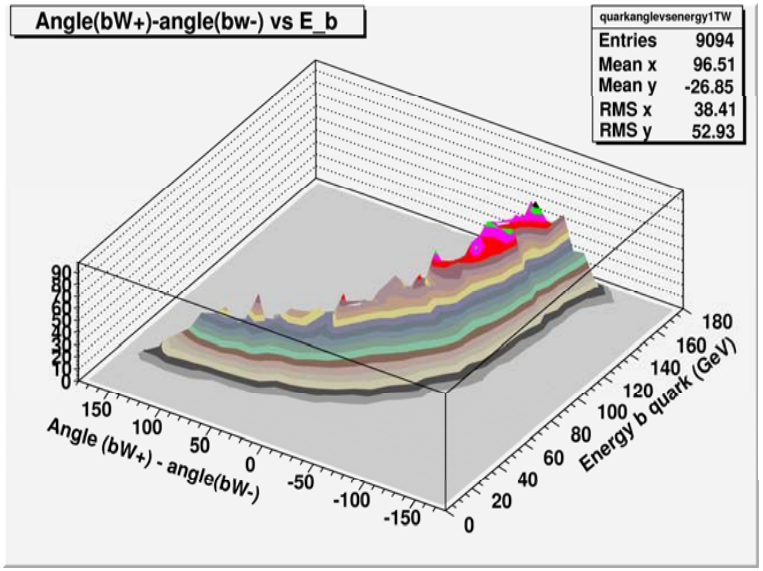
- Still working on optimisation of all parameters and cuts!

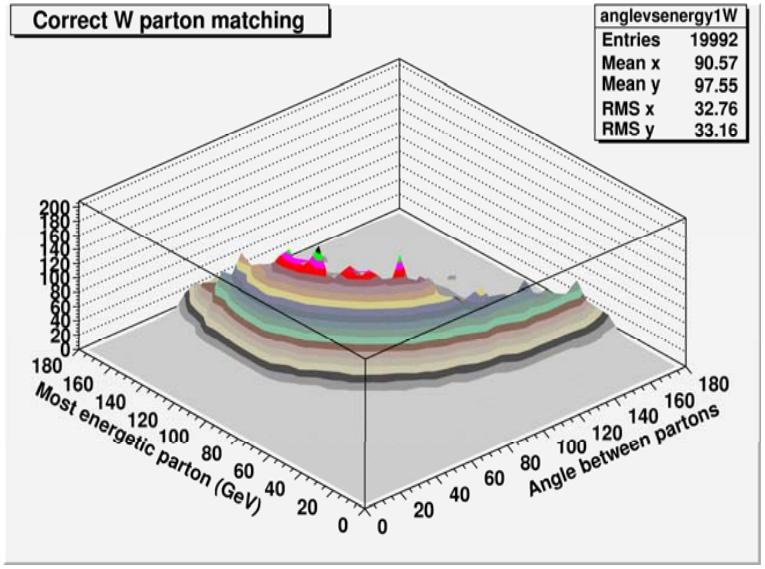
Top reconstructions – phase space

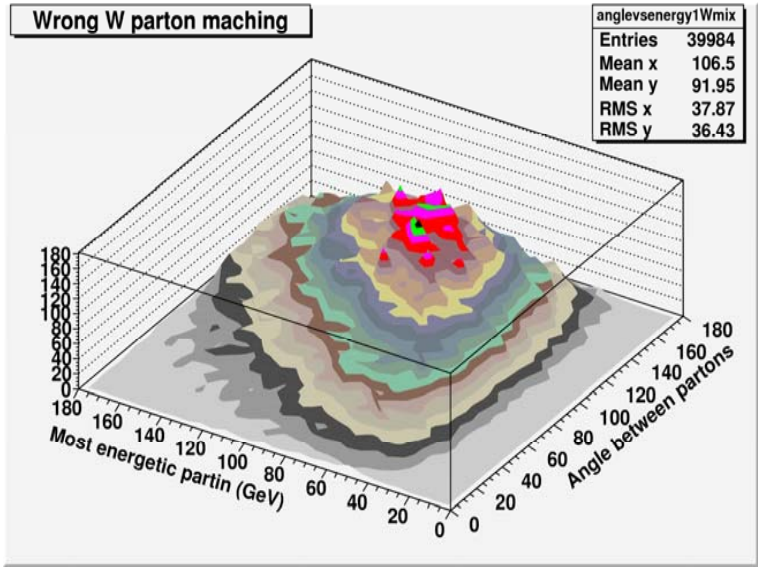
- Searching the phase space to get hints for various possible cuts

- In particular looking at angular cuts to lower the jet combinatorics in top reconstruction

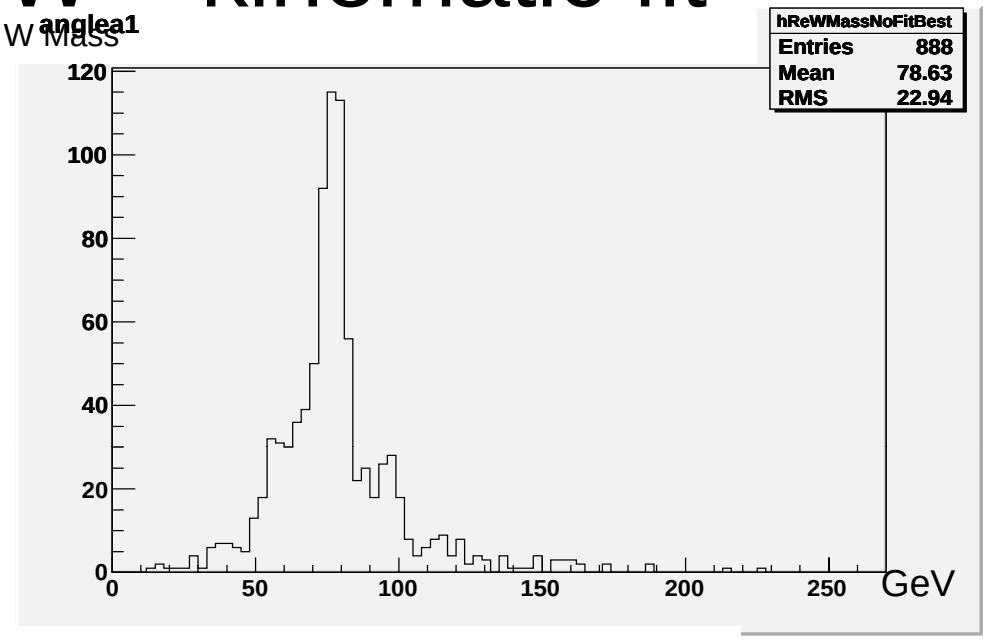
- This has been done at parton level







W – kinematic fit



- All inclusive decays. Use only events where 6 jet reconstructed
- Use kinematic fit to identify W.
- Constrain MassW_1 =MassW_2
- 4-Jet combinatorics use less b like jets plot best result
- Combine with b jets for top mass