Study of the top quark mass and couplings by SiD

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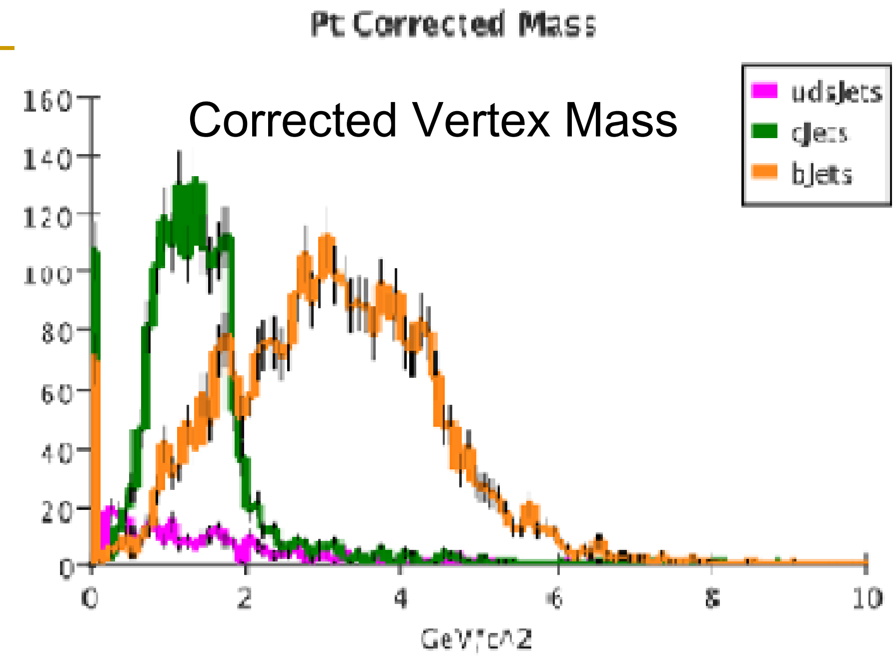
Simulation & Reconstruction

- Used canonical LOI benchmarking event sample with 80% e-, 30% e+ polarization, plus signal samples with m_{top}=174, 173.5 GeV for analysis development.
- Full event simulation using the sid02 detector model.
- Full, ab initio, event reconstruction:
  - Tracker hit digitization, track finding and fitting
  - Calorimeter clustering
  - Track-cluster association
  - Lepton ID (e, μ)

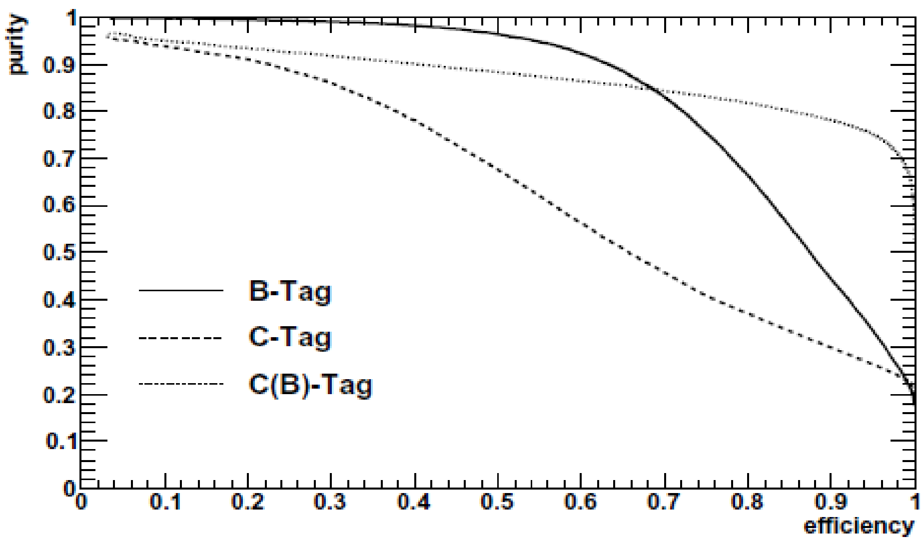
  $\rightarrow$ List of ReconstructedParticle
- Events processed at SLAC, Fermilab & RAL
  - ~1 min/event each for slic and reco

Analysis

- Pythia jet clustering
- Marlin Kinematic Fitter
- Vertexing: LCFI package
  - NN based on flavour discriminants
  - Re-optimized for SiD
  - Beam-beam background: e+e- pairs and photons from GuineaPig
    - One BX for Tracker, variable # of BX for VD

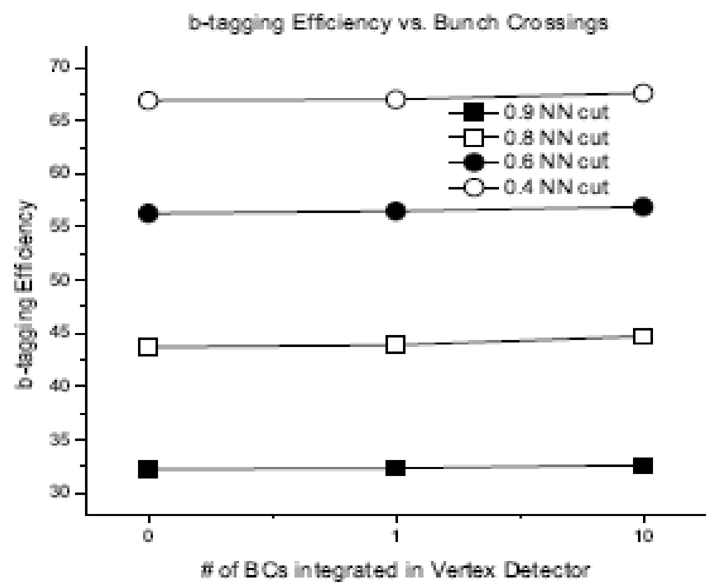


Corrected Vertex Mass



Flavor-tagging Purity vs Efficiency

Eff. vs # Background in VTX



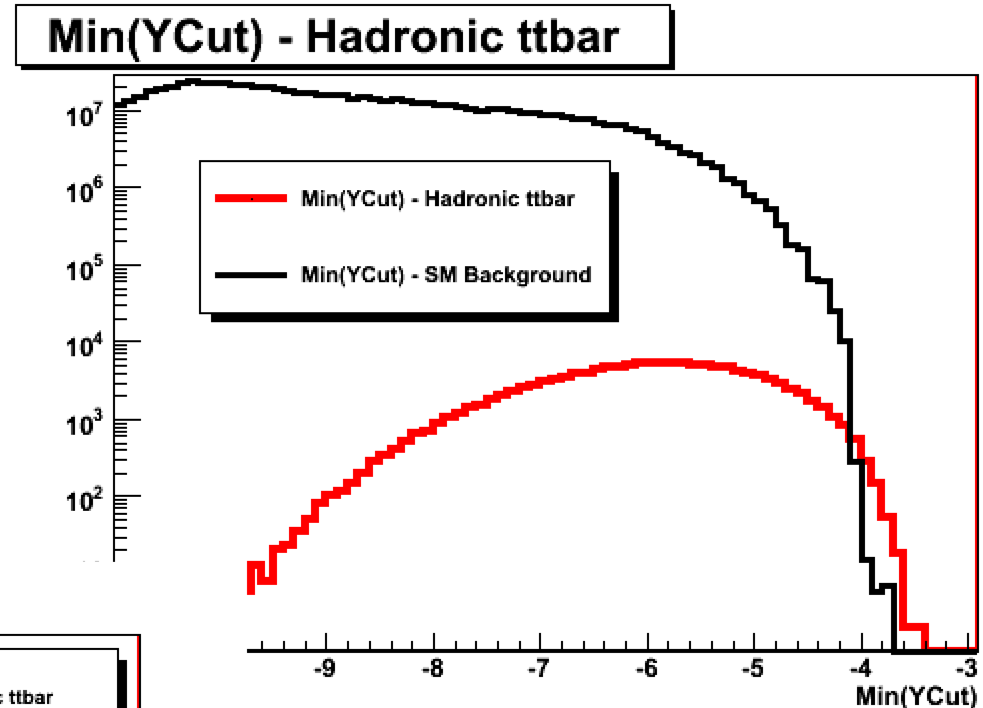
List of cuts for hadronic final state

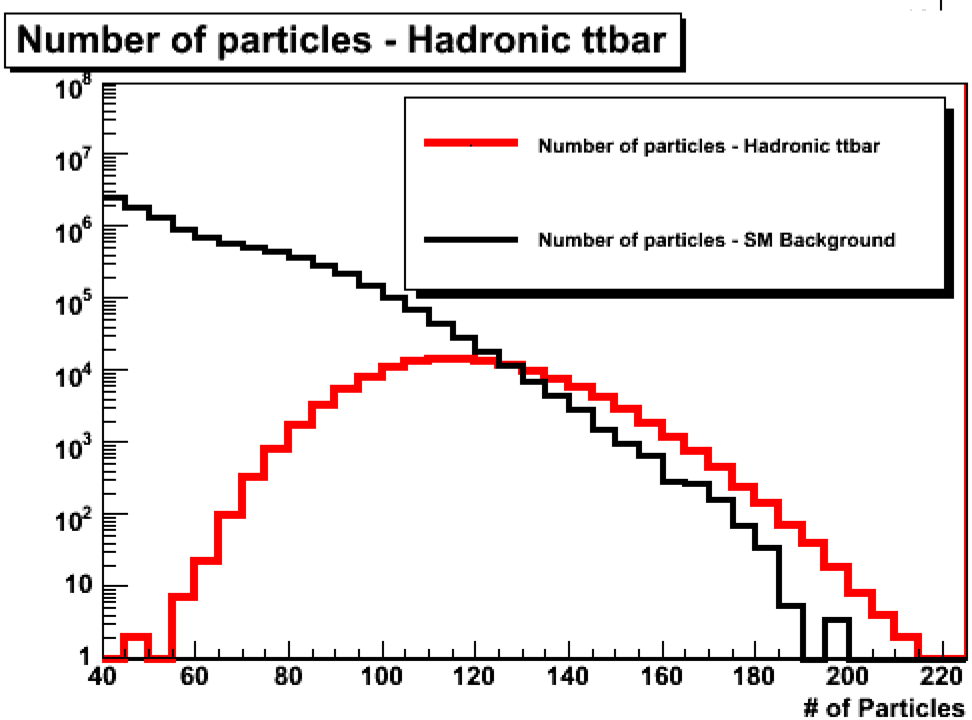
	selection	value
	E_{total}	> 400 GeV
	$\log(ycut_{min})$	$>$ -8.5
	number of particles in event	> 80
	number of tracks in event	> 30
50 GeV $<$	W mass	< 110 GeV
	NN_{b-tag} output for the most b-like jet	> 0.9
	NN_{b-tag} output for the 2^{nd} most b-like jet	> 0.4
	Sum of NN_{b-tag} outputs for all jets	> 1.5

- $Ycut_{min}$ – y value from jet algorithm used to distinguish between 5 and 6 event topology.
- W mass is intended after kinematic fitting, which is performed using only 4 least b-like jets.

Cut Examples

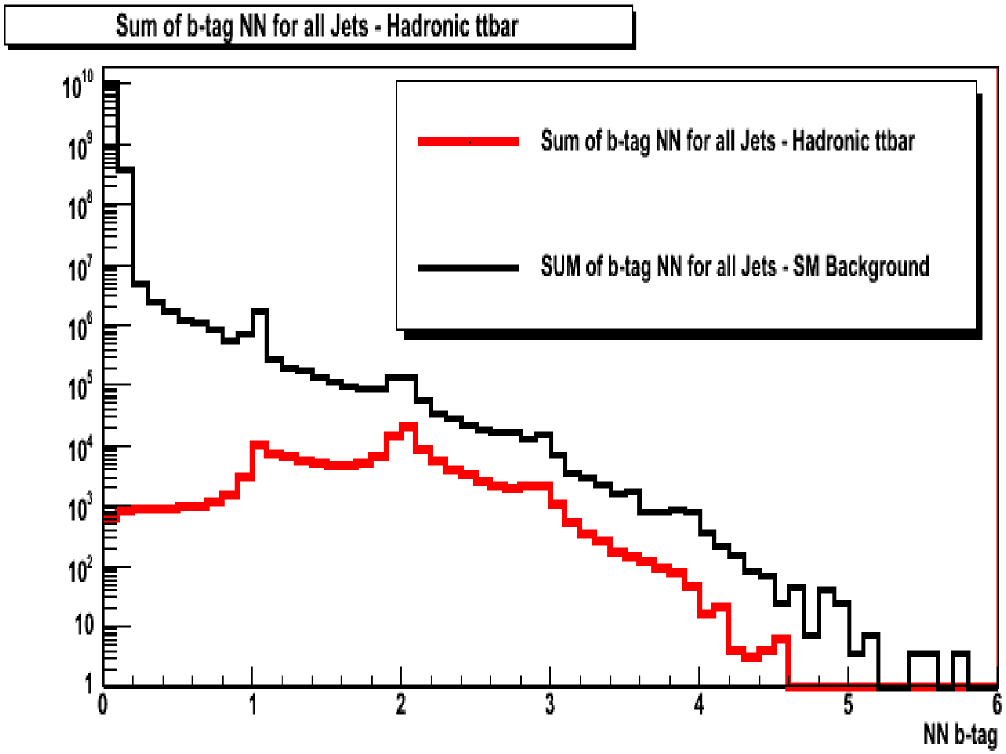
- Main background, WW with final state radiation, 6 jet events …
- Eliminating all not hadronic t-tbar background (including leptonic/semi-leptonic t-tbar)



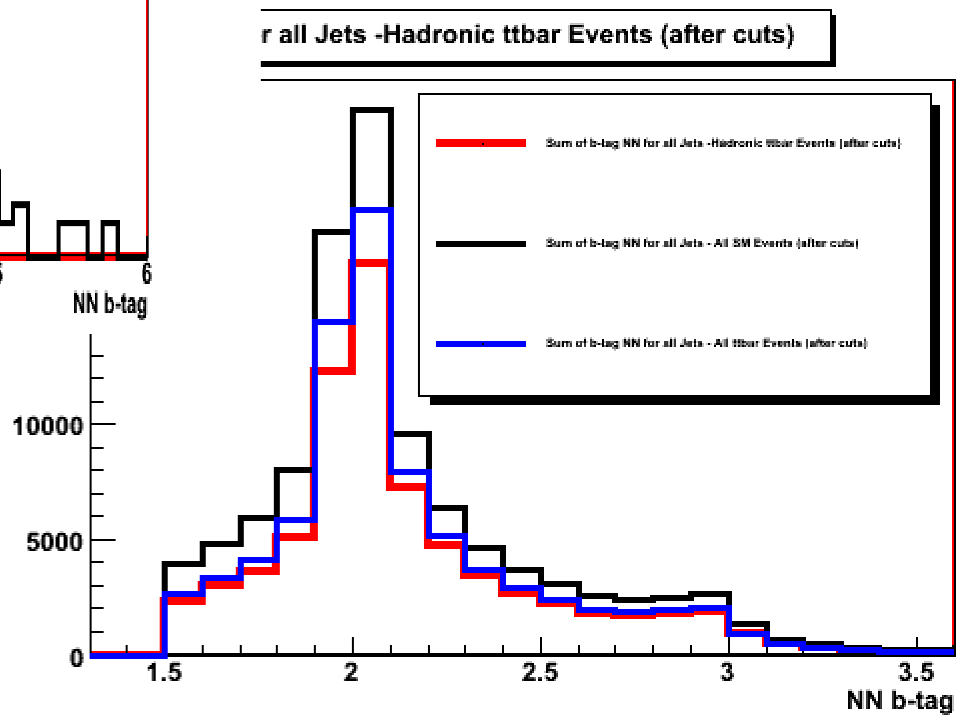


- Number of particles; at ILC reconstruct neutral and charged particles in jet from tracking+calorimetry.

Cut performance



- b tagging really powerful tool.
- After cuts:
  - Efficiency: 51.2%
  - Purity: 68.8%



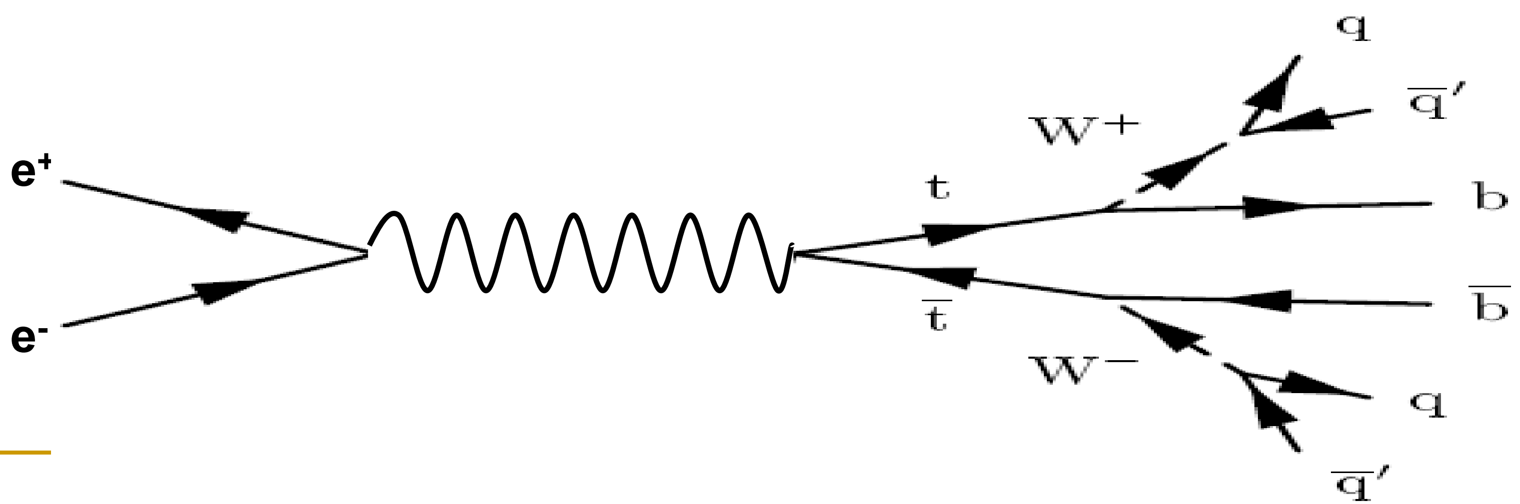
- Rejection efficiency:
  - Non top SM: 99.99..%
  - Leptonic top: 99.97%
  - Semi-leptonic top: 93.90%

Mass Analysis

- Used a kinematic fitting package (Marlin KinFit)

  http://ilcsoft.desy.de/portal/software_packages/marlinreco/

- Developed two methods to estimate statistical error on mass
- Curve fitting
- “Template fitting”
- Used data sample with mass 174GeV, templates with 174 and 173.5GeV



Kinematic Fitting

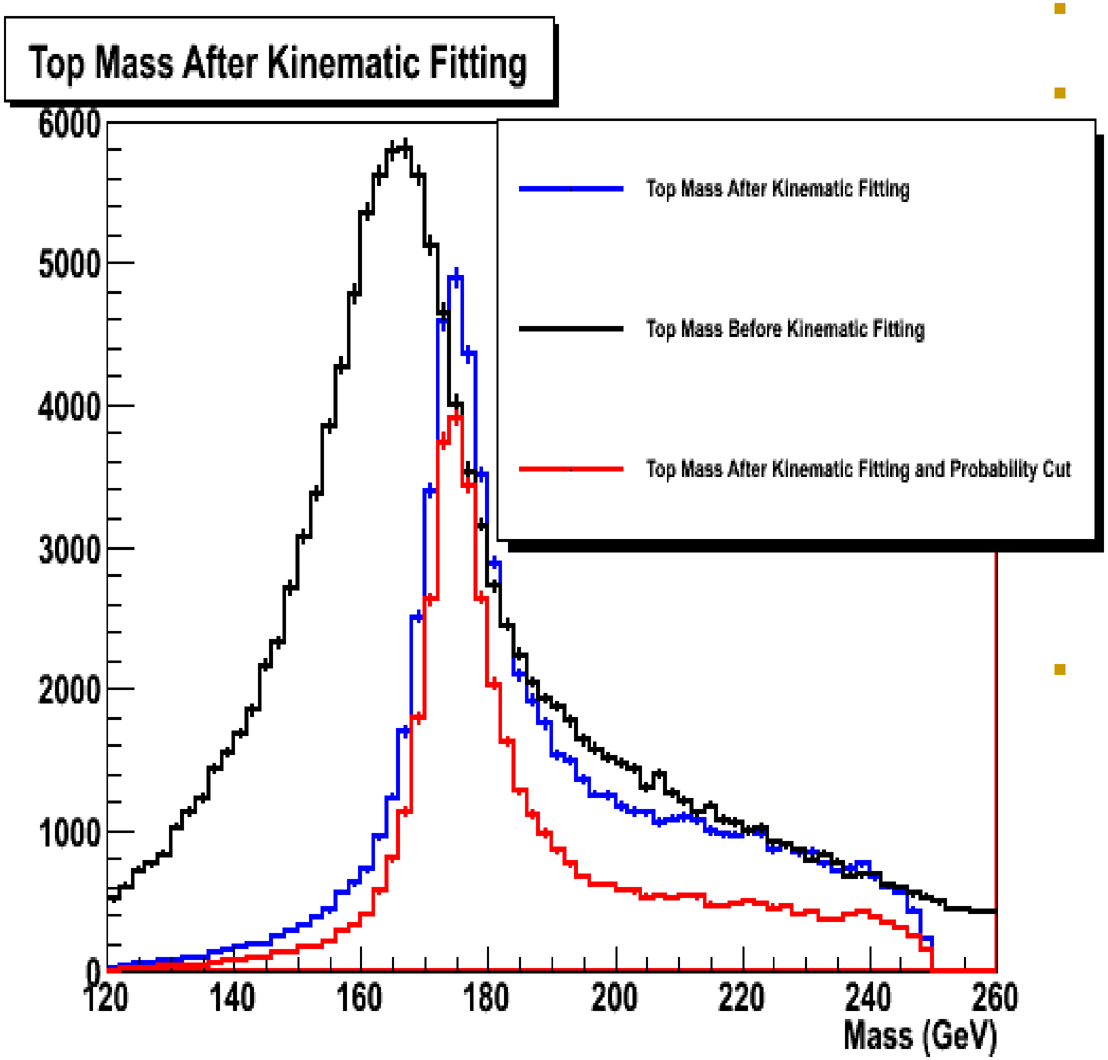
Constraints

mass(top1)	= mass(top2)
mass(W1)	= 80.4 GeV
mass(W2)	= 80.4 GeV
E_{total}	= 500 GeV
p_x; p_y; p_z	= 0

- Set kinematic constraints.
- Use uncertainty on jet energy and angles.
- By method of Lagrange multipliers finds optimized results, by varying energy and angles
- Calculates probability of event meeting the constraint.

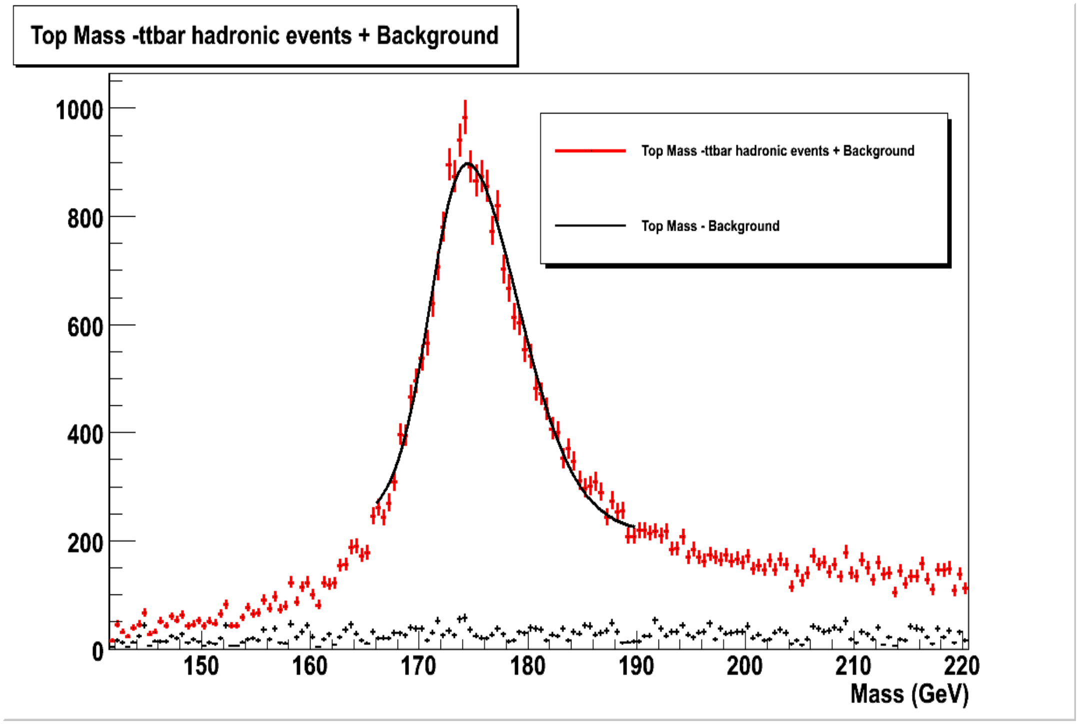
- Constraints set by event topology ($mass_W$ and $mass_{top}$) and by ILC environment (E_{total} and momentum).
- Use b tagging to reduce combinatorial possibilities (from 10 to 6) if two most b-like jets used as "b-quarks.

Kinematic Fitting - Results



- Clearly improves resolution
- However it halves the number of "usable" tops !
  - Before two top masses in event are separate entity
  - Now they have the same mass
  - Think of it as "better" way of using same information
- Also select on probability event satisfies constraints
  - Better resolution
  - Eliminate background and poorly reconstructed events

Mass Fit

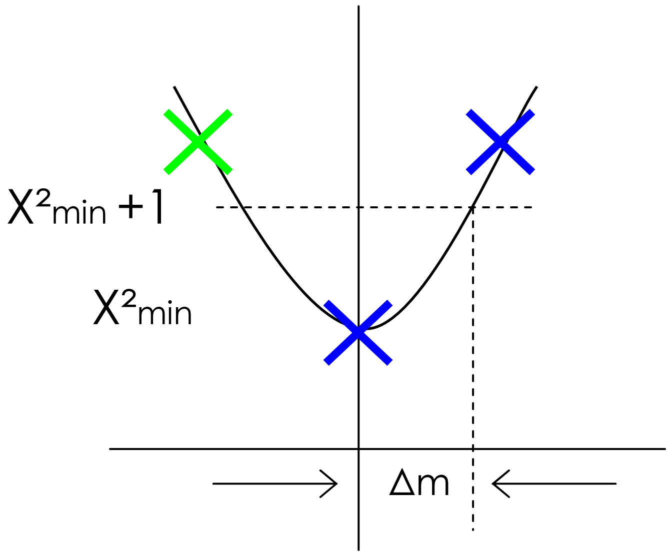


- Fit top mass after kinematic fitting and probability cut.
- Fit central region 165-190GeV
- Asymmetric double Gaussian used as resolution function

- Use template sample to determine the resolution function.
- On the "data" sample impose resolution function, vary mass and width of Breit Wigner. Background fitted with polynomial.
- **Result: mass_{top} = 173.918 ± 0.053(stat)**

Mass from Template fitting

- Problem1 : only two template samples and “data” sample available
- Not enough to minimize X²
- Use symmetries of parabola, assume minimum: mass template = mass data
  - Implications none for stat. error



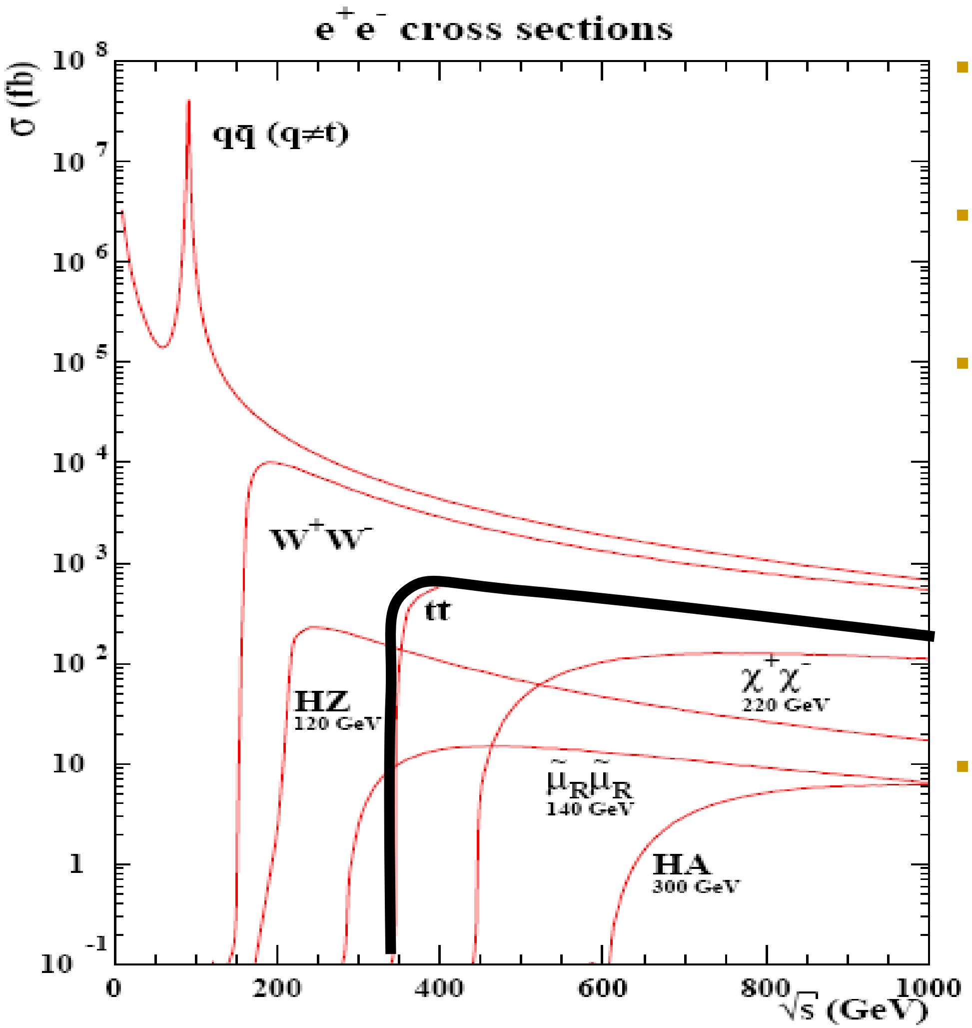
$$\chi_1^2 = \sum_{i=0}^{Nbins} \frac{(y_{template1,i} - y_{data,i} + \delta_i)^2}{\sigma^2_{template1,i} + \sigma^2_{data,i} + \sigma^2_{SM,i}}$$

- Problem 2: only one background sample available
- Use technique of Gaussian smearing on value of background sample

- Use top mass after kinematic fitting and probability cut.
- Fit region 150-200GeV
- **Result: $mass_{top}$ = 174.000 ± 0.038(stat)**

t-tbar Cross-Section

(fully hadronic channel only)



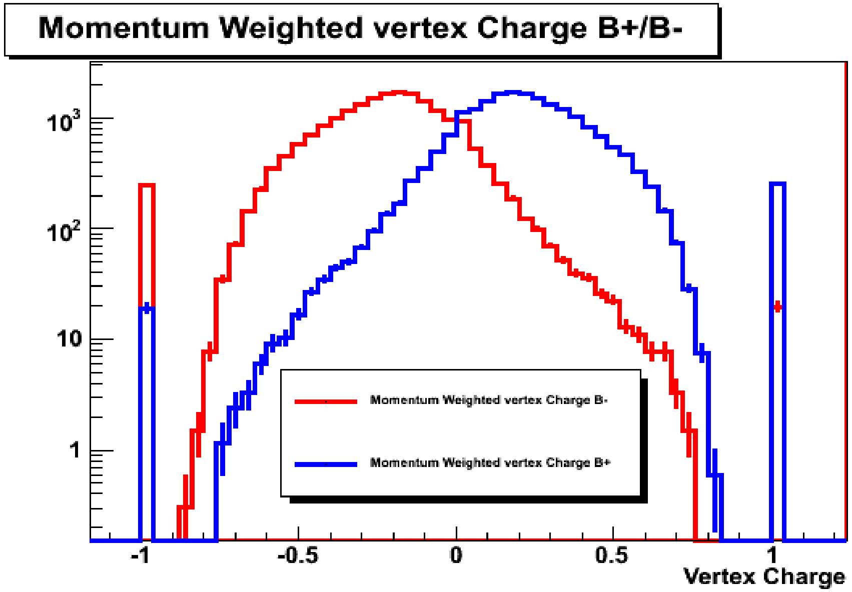
arXiv:hep-ph/0410364v1

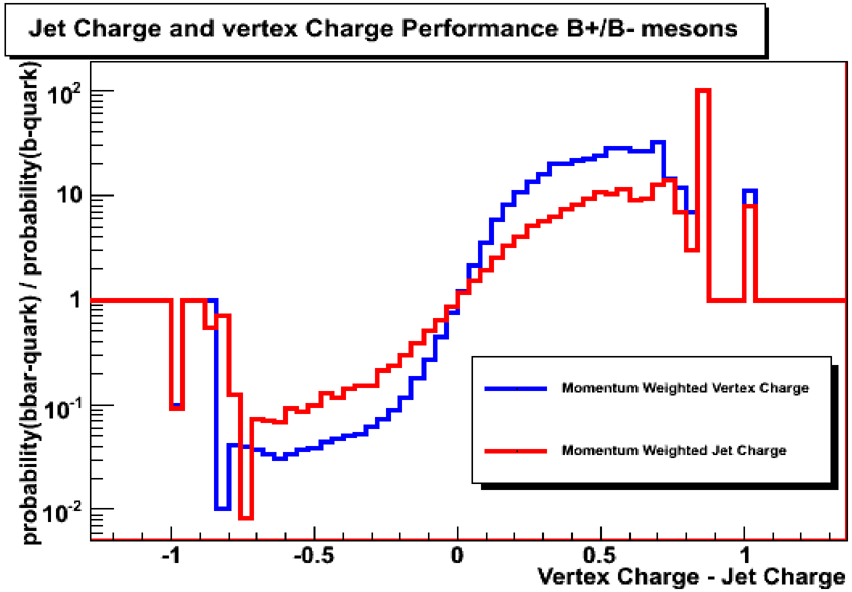
- Estimate efficiency on template sample 49.7%
- Total number of events passing cuts 96.2k
- Background events 24.8k

$$\sigma = \frac{N_{ALL} - N_{BG}}{\varepsilon \times \int L dt}$$

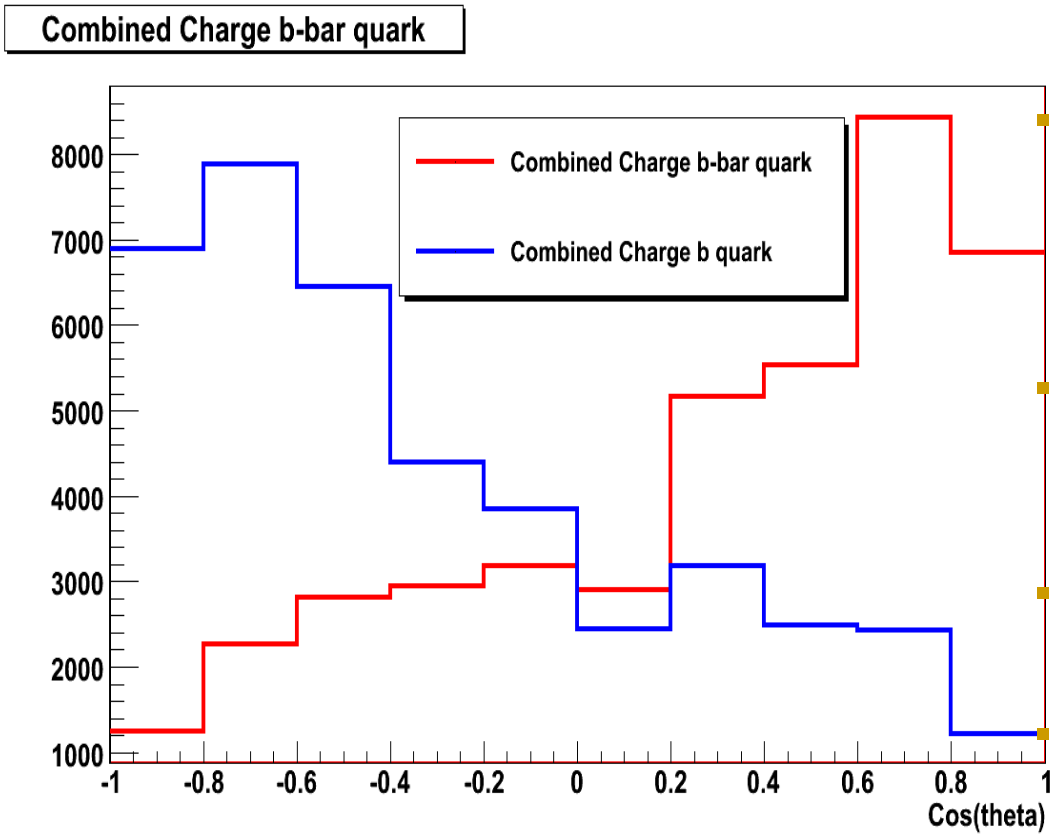
Reconstructing Parton Charge

- Develop series of discriminating variables, then recombining them
  - Similar to what it is done in the flavour tagging.
- Momentum weighted secondary vertex charge
  - This is the weighted sum of the charge of all tracks in a vertex
  - Good for B+/B- if secondary found
- Momentum weighted Jet charge
  - This is the weighted sum of the charge of all tracks in a jet
  - Good for B0s and if no secondary.





Combining charge variables



To calculate Combined Charge variable:

- Use "template sample" to determine ratio of signal to backgrounds in each bin for each variable.
- Use this ratio as a discriminating power of each variable in any specific "data" event
- Multiplies the ratios of each variable considered.
- Apply transformation to get a result between -1 and 1.

Method describe in: arXiv:hep-ex/0609034v1

t and b quark A_{fb}

SM coupling. EW (V-A)

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

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

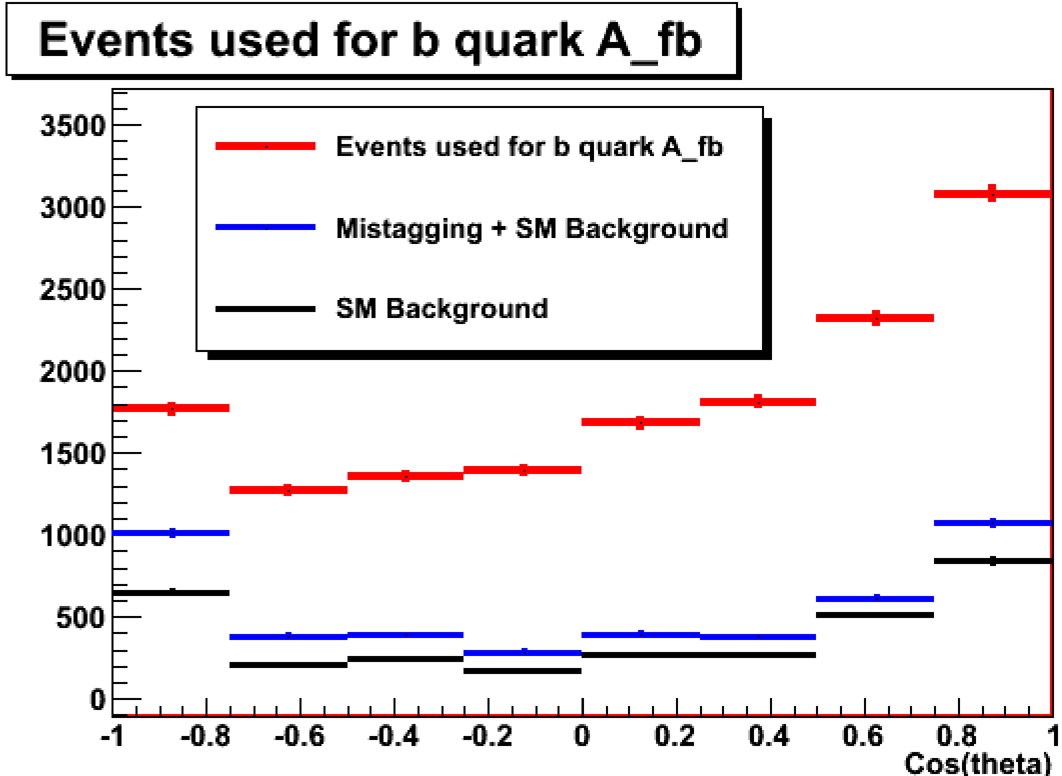
where $W_{\mu\nu} = D_\mu W_\nu - D_\nu W_\mu$, $D_\mu = \partial_\mu - ieA_\mu$, $P_\pm = 1/2(1 \pm \gamma_5)$ and $\sigma^{\mu\nu} = i/2(\gamma_\mu\gamma_\nu - \gamma_\nu\gamma_\mu)$.

Higher order anomalous couplings. These 0 in SM.

arXiv:hep-ph/0001048v2

b quark A_{fb}

- Cut on combined charge
  - $Charge_{Jet1}$ x $Charge_{Jet2}$<-0.3
- Efficiency low: 7.1%
  - Events without secondary
  - B0/B0bar



Theoretical Prediction

	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. arXiv:hep-ph/0001048v2

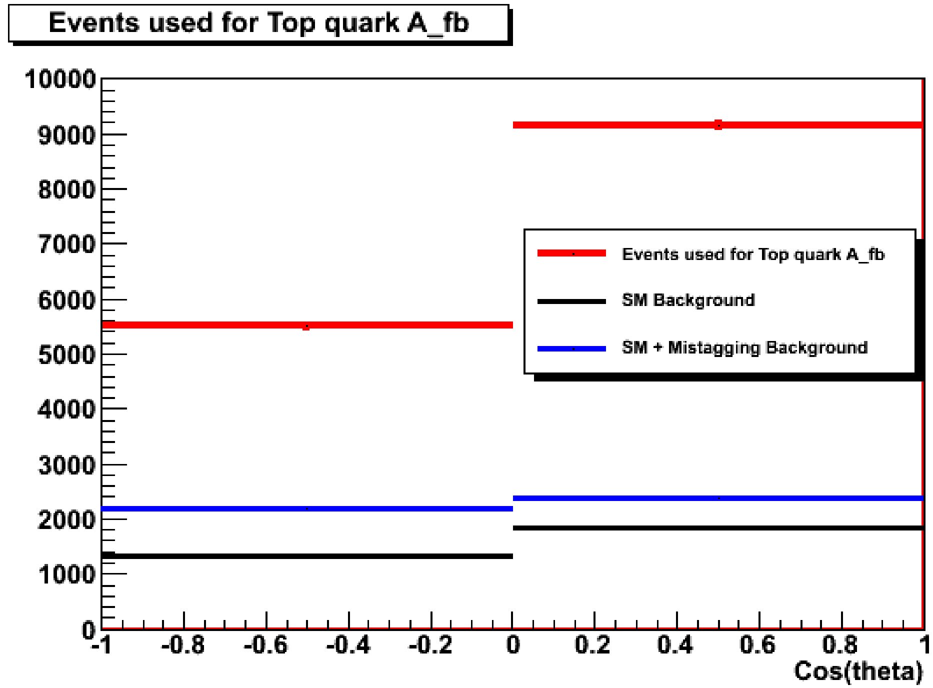
- Background from:
  - Standard model
  - b quark and charge mistagging

$$A_{FB} = \frac{\sigma(\theta < 90^\circ) - \sigma(\theta > 90^\circ)}{\sigma(\theta < 90^\circ) + \sigma(\theta > 90^\circ)}$$

- Calculate A_{fb}: 0.272 ± 0.015 (stat)

t quark A_{fb}

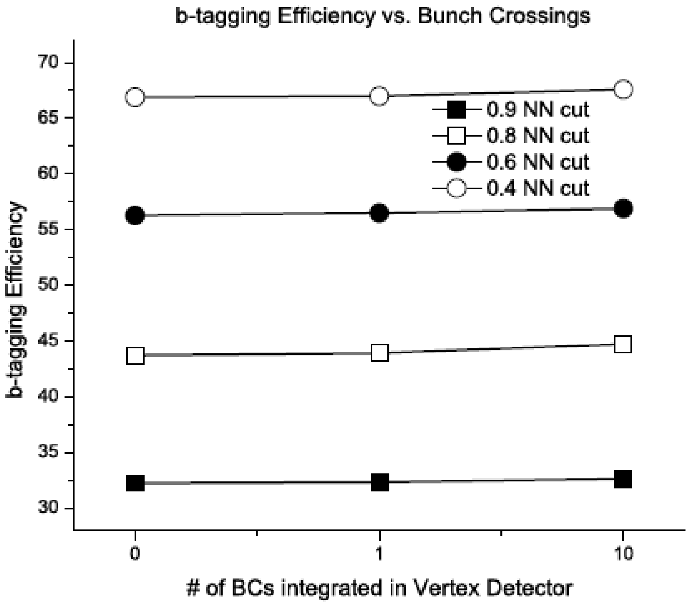
- Same events as for b quark
- Complication associate b quark with the correct W jets.
- Use kinematic fitter for correct jet pairing



- Calculate A_{fb}: 0.342 ± 0.015 (stat)
- Compare with data at MC pre-reconstruction level: 0.351
- It is now possible to extract Wtb coupling (from b quark A_{fb}) and Ztt coupling (from t quark A_{fb}).

Effects of backgrounds

- Eventual goal of SiD is to have bunch-timing available in all subdetectors.
- In the interim, investigate the effect of adding the beam-generated backgrounds to the signal events.
- One in-time event added to ALL sub-detectors, additional events added only to Vertex detector.



- Analysis of signal + beam bckgrnd in progress.

Results

- Cross section = 287.1 ±1.4fb (stat)
- Top Mass = 173.918 ± 0.053 GeV(stat) – curve fitting technique
- Top Mass Error = ± 0.038 (stat) – template fitting technique
- A_{fb} b quark = 0.272 ± 0.015 (stat)
- A_{fb} t quark = 0.342 ± 0.015 (stat)