SiD Benchmarking Analyses With b/c Flavour Tagging

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Overview

- Credits
- LCFI Package
- Higgs Boson Decay Branching Ratios
- Top Quark Analysis
- Sbottom Production Within Sbottom Co-annihilation Scenario
- Remarks and Future Plans

Summary

Credits

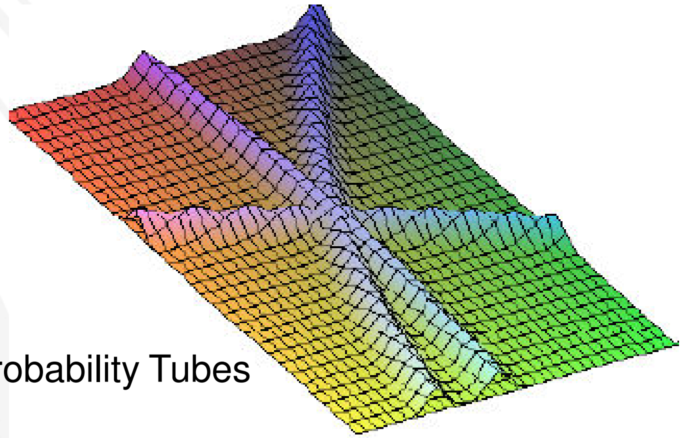
- Simulation/Reconstruction
  - Tim Barklow, Norman Graf, Jan Strube
- Higgs Branching Ratios
  - Yambazi Banda (Oxford)
- Top Analysis
  - Erik Devetak (Oxford)
- Sbottom Production
  - Alexander Belyaev (Southampton)

+ Andrei Nomerotski and myself (Oxford)

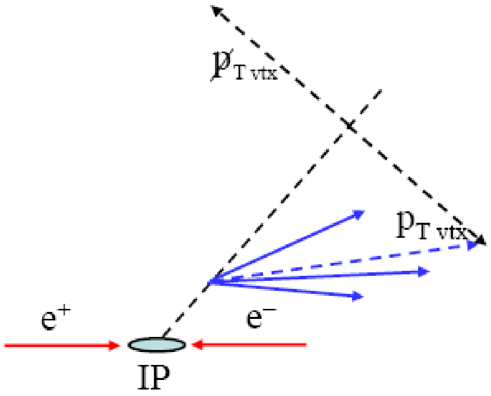
LCFI PACKAGE

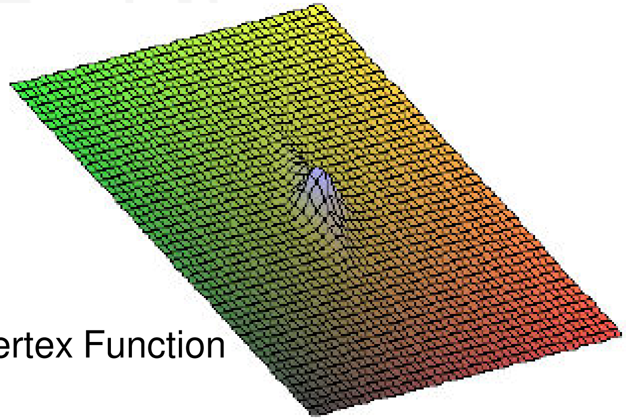
LCFI Package

- Used for jet flavour tagging and secondary vertex reconstruction.
- Topological vertex finder ZVRES.
- Standard LCIO input/output
  - Marlin environment (used for both ILD/SiD)
- Flavour tagging based on Neural Nets.
  - Combine several variables.



Probability Tubes



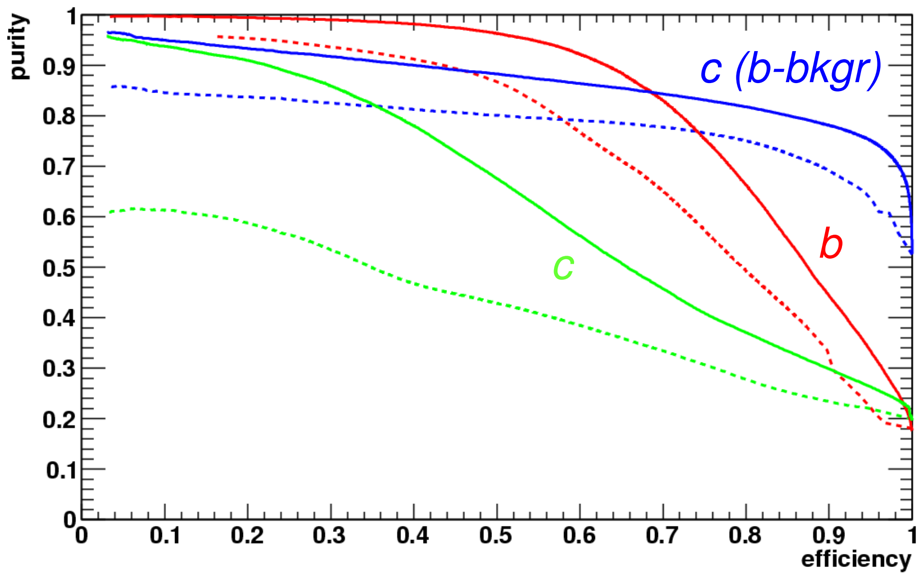


Vertex Function

LCFI Package Optimisation for SiD LoI

- Default LCFI Neural Nets performed poorly with the full sim/rec SiD data.
- LoI Solution:
  – NN retrained and a different approach chosen (1 larger NN per tag, instead of 3 nets)
  – Package parameters not optimised due to very limited time and manpower constraints.

SiD LoI, full sim/dig/rec

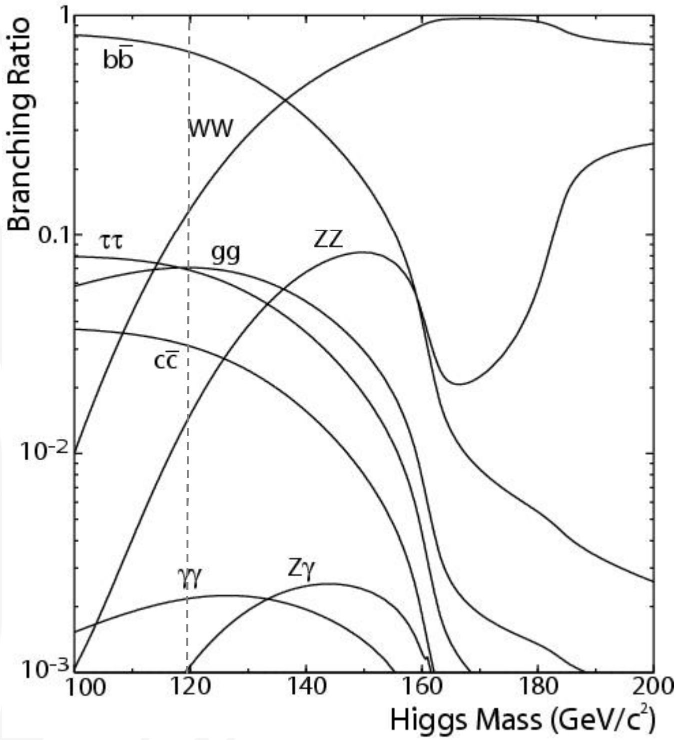


Dashed (LCFI default) vs. re-trained NNs.

HIGGS BOSON DECAY BRANCHING RATIOS

Motivation

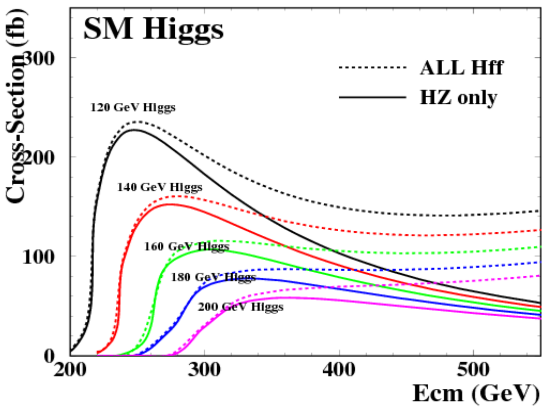
- Measure the Higgs branching ratio to $c\bar{c}$ by looking at the following channels:
  - $Z \rightarrow \nu\nu, H \rightarrow c\bar{c}$
  - $Z \rightarrow q\bar{q}, H \rightarrow c\bar{c}$



- High quality c-tagging required.
- Extend analysis further to H→bB and H→gg.
  - Finished, not a part of LoI.

Data Samples

- For data samples the following is assumed:
  - Centre-of-mass = 250 GeV (peak xsec for higgstrahlung)
  - Integrated luminosity = 250 fb^{-1}
  - Signal Higgs mass = 120 GeV
  - +80% e^- polarization, -30% e^+ polarization
  - ~ 7 Million Standard Model background events
  - ~ 200 000 inclusive ZH signal events
  - Full simulation and reconstruction



Event Selection

1) Classification in two Z-decay modes
   - Neutrino channel (2 jets) and Hadronic Channel (4 jets)
   - Visible energy and a number of leptons cut
2) Basic Event Selection
   - Kinematic and topological cuts
3) Neural Net event selection
   - Based on 2 Neural Nets: 1^{st} trained to separate SM and ZH, and 2^{nd} to separate ZH-background and ZH-signal.
   - Inputs: Jet tags, basic selection variables, ..
   - Then cut on both NN_1 and NN_2 outputs simultaneously.

Results

SiD

	Neutrino	Hadronic
Signal events	178	407
SM background events	140	673
Higgs background events	109	213
Signal efficiency %	28	22
Signal σ_{Hcc}	6.8±0.79 fb	6.9±0.61 fb
Relative uncertainty on σ_{Hcc}	11.6%	8.8%

- Leading to combined BR uncertainty of about 8.5%.
- Similar approach yields
  - 4.5% for BR(H→bB) and 11.1% for BR(H →gg)
  - ZH cross sections uncertainty is dominant for BR(H→bB)
- Analyses still being developed.

TOP QUARK ANALYSIS

Data Samples

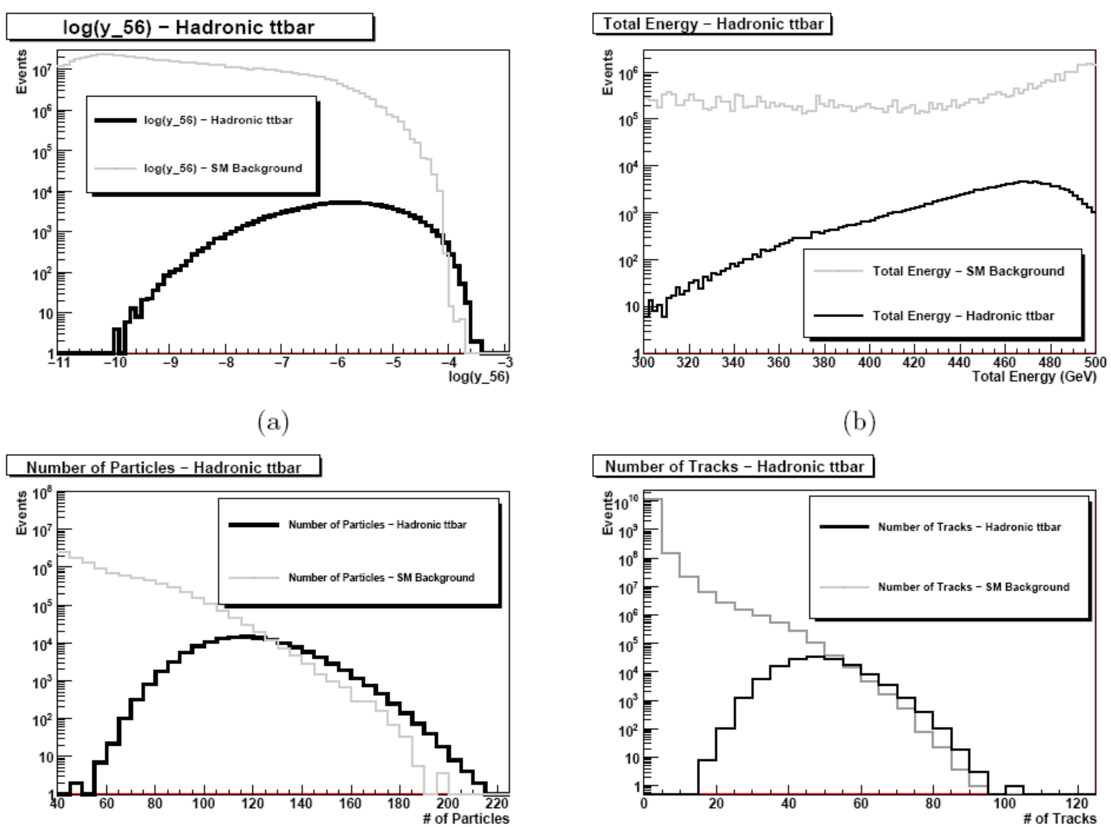
- Standard Model background sample
  - About 7M events, weighted
- bBfFfF sample
  - M_{top} = 174 GeV, 250k events
  - Signal (bBqQqQ) plus remaining background
  - Six jets, at least two of them are b-jets.
- bBfFfF template samples
  - M_{top} = 174 (174.5, 173.5) GeV, each 1.1M events

- All samples normalised to 500 fb^{-1} and produced @ $\sqrt{s}$ = 500GeV.
  - Half of luminosity for -80/+30% polarisation, the other half for +80/-30%.

Event Selection

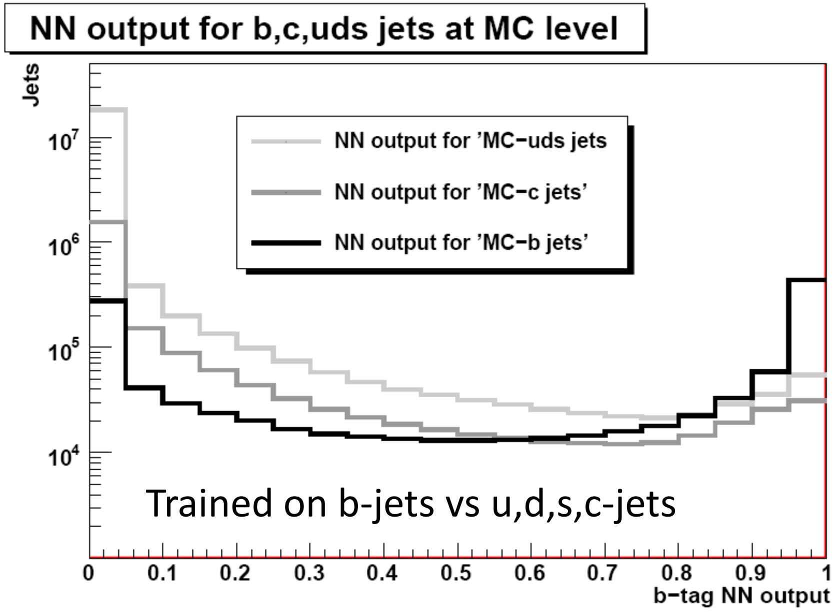
- Basic selection cuts:
  - 99.996% bkg rejection
  - 10% signal rejection eff.

Kinematic and Topological Event Selection		
Variable	*Barrel*	*Value*
E_{tot}	>	400 GeV
$\log(y_{56})$	>	-8.5
number of particles in event	>	80
number of tracks in event	>	30
no isolated leptons		

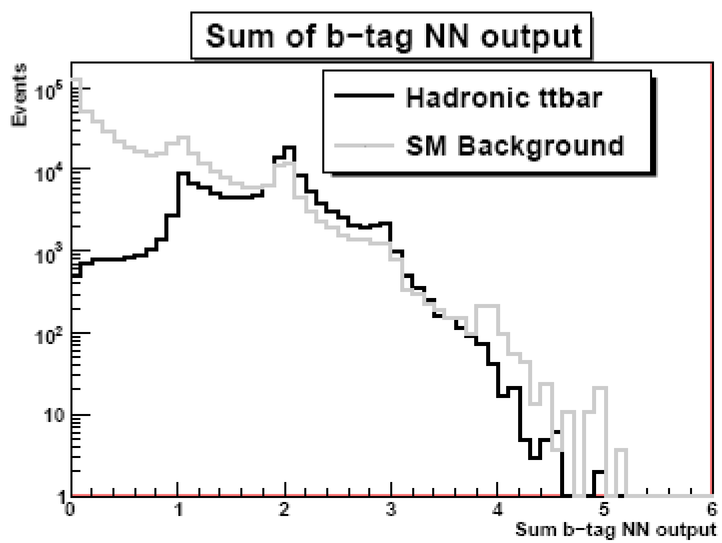


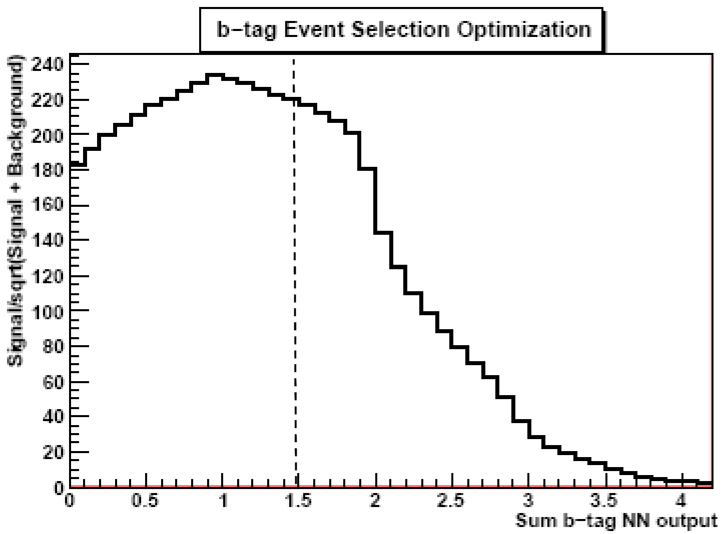
(a) (b)

Jet Flavour Tagging



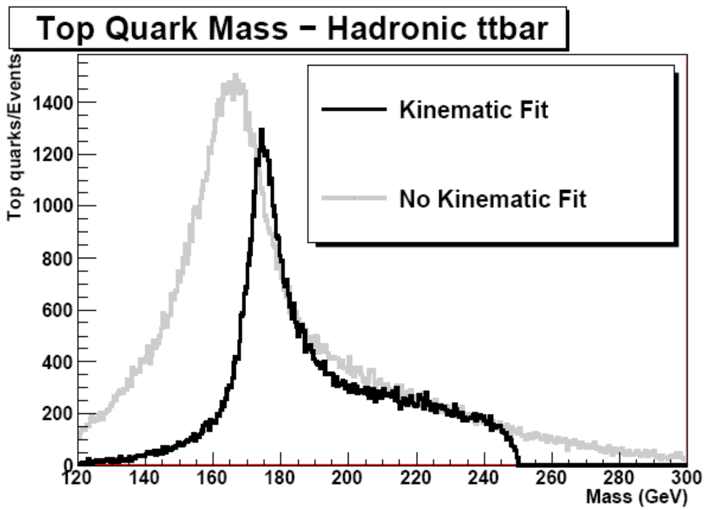
- Good performance for six-jet events.
- Selection done based on a sum of NN outputs (b-tag only) of all jets.

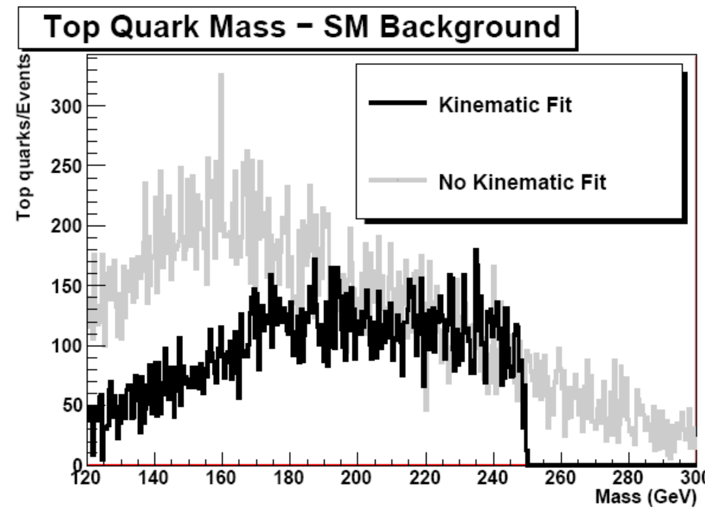


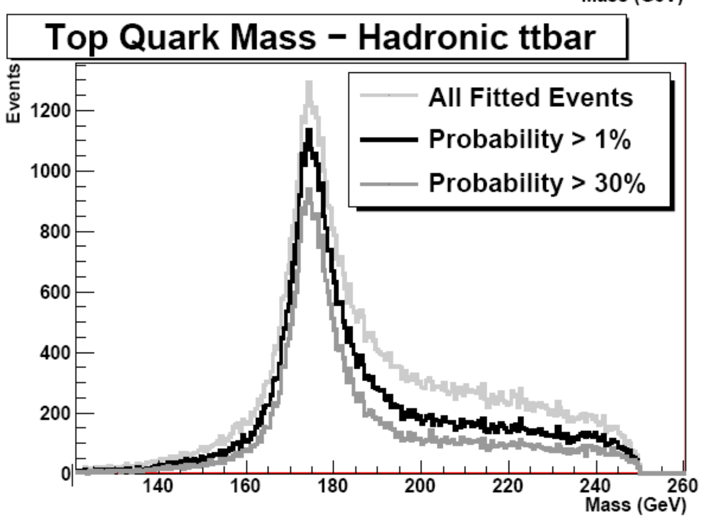


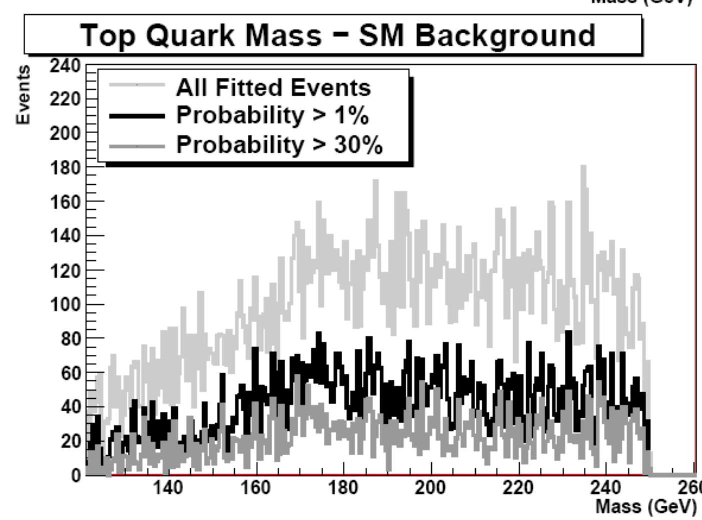
Results – Top Quark Mass

- Kinematic fitting significantly improves the resolution.









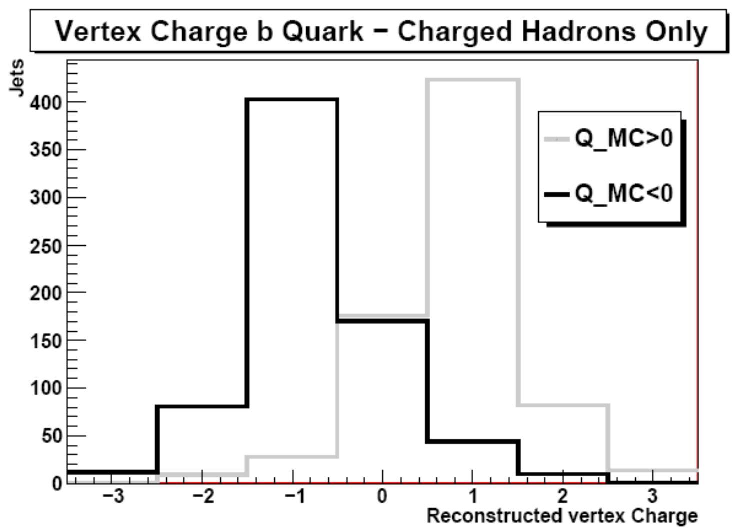
Results – Top Mass Measurement Uncertainty

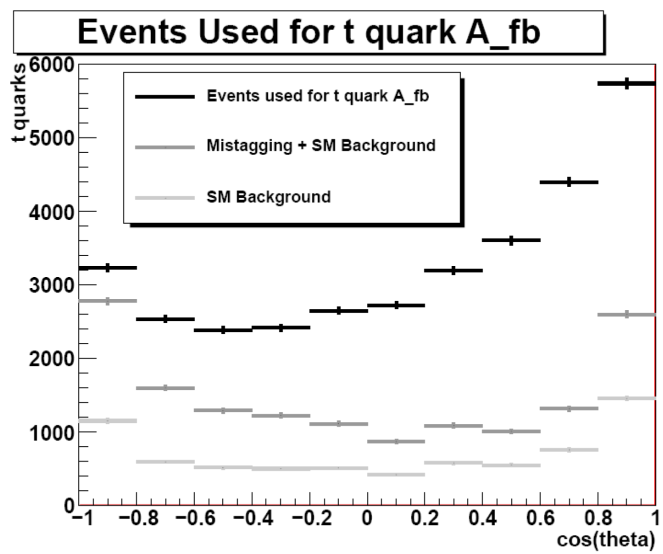
- Mass measurement uncertainty estimated using curve and template fits
  - Both give consistent numbers, around 50MeV
  - Template method preferred, stable and better χ^2 behavior.

Template	*Top Quark Mass*			
Event Selection	*Fit Range (GeV)*	χ^2_{min}/NDF	*Mass (GeV)*	σ *(GeV)*
No Kinematic fit	120-200	148/159	174.135	0.090
No Kinematic fit	140-180	83/79	174.173	0.097
Kinematic fit	150-200	94/99	174.033	0.053
Kinematic fit	165-200	63/69	173.991	0.056
Kinematic fit	165-185	42/39	173.990	0.058
Probability > 1%	150-200	101/99	174.018	0.049
Probability > 1%	165-200	61/69	174.013	0.049
Probability > 1%	165-185	41/39	174.010	0.053
Probability > 5%	150-200	97/99	174.024	0.050
Probability > 5%	165-200	61/69	174.017	0.050
Probability > 5%	165-185	38/39	174.17	0.053
Probability > 10%	150-200	100/99	174.012	0.050
Probability > 10%	165-200	68/69	174.012	0.051
Probability > 10%	165-185	40/39	174.14	0.052
Probability > 20%	150-200	91/99	174.013	0.049
Probability > 20%	165-200	68/69	174.010	0.050
Probability > 20%	165-185	39/39	174.022	0.052
Probability > 30%	150-200	98/99	174.021	0.049
Probability > 30%	165-200	68/69	174.020	0.050
Probability > 30%	165-185	47/39	174.027	0.052

Results – Cross Section and Production Asymmetry

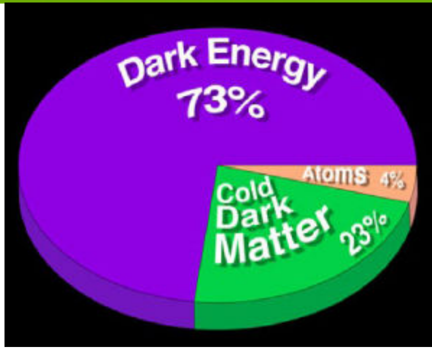
- Cross section measurement
  - Estimated to about 0.5% precision
- Quark charge and forward backward asymmetries
  - Vertex charge, momentum weighted vertex and jet charges (LCFI)
  - For both t-quarks and they decay products b-quarks
  - Precision of about 0.008 reached for A_{fb}





SBOTTOM PRODUCTION

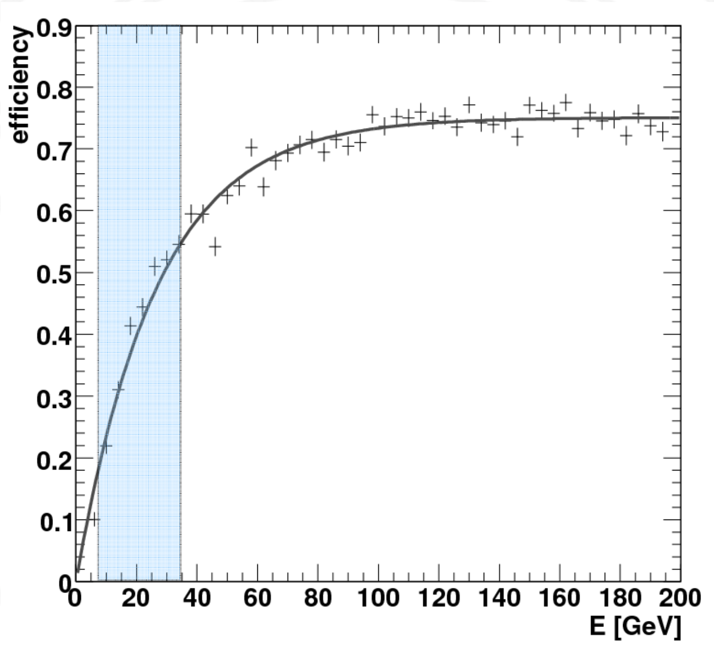
Motivation



- Neutralino is a very attractive CDM candidate.
- Cold Dark Matter favours some particular SUSY scenarios
  - one of them is co-annihilation scenario, when neutralino effectively co-annihilates with others quasi-degenerate SUSY particles into SM ones.
- Neutralino-sbottom co-annihilation scenario has not been studied previously.
  - This scenario is virtually impossible for LHC while feasible but challenging at the ILC.
  - The small mass split between neutralino and sbottom leads to small energy release and softness of the visible particles.

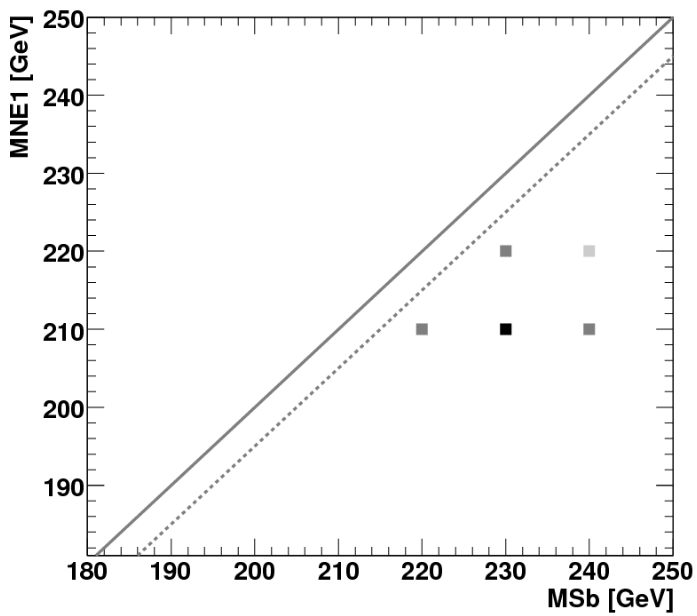
Why are Soft b-jets Difficult to Analyse?

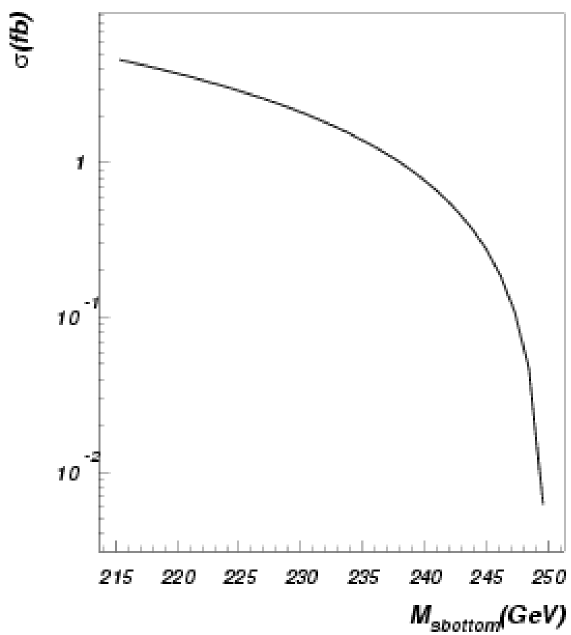
i. Tagging efficiency is dropping down quickly at low energies.
ii. Jet finding algorithms begin to break.
iii. Large gamma-gamma and gamma-e backgrounds.



Data Samples

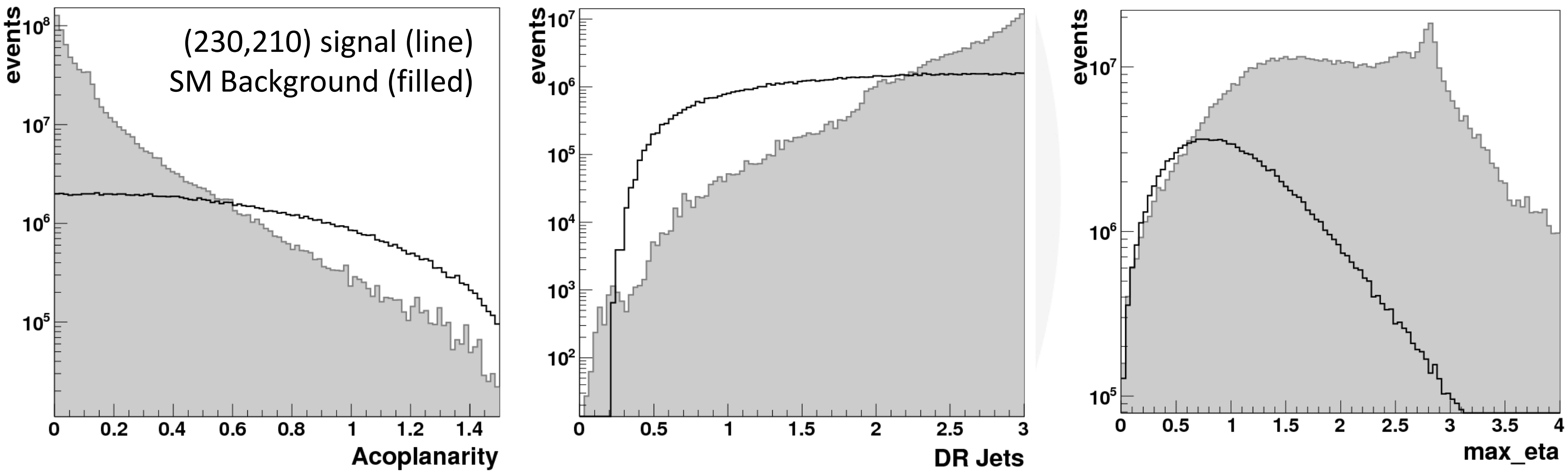
- $\sqrt{s}$ = 500 GeV; 1000 fb^{-1} luminosity; ~ 200k events /sample (CalcHEP)
- Five points close to ILC limits
  - (M_{NE1}, $M_{sbottom}$) = (220,210) , (230,220) - mass difference 10 GeV
  - (M_{NE1}, $M_{sbottom}$) = (230,210) , (240,220) - mass difference 20 GeV
  - (M_{NE1}, $M_{sbottom}$) = (240,220) - mass difference 30 GeV





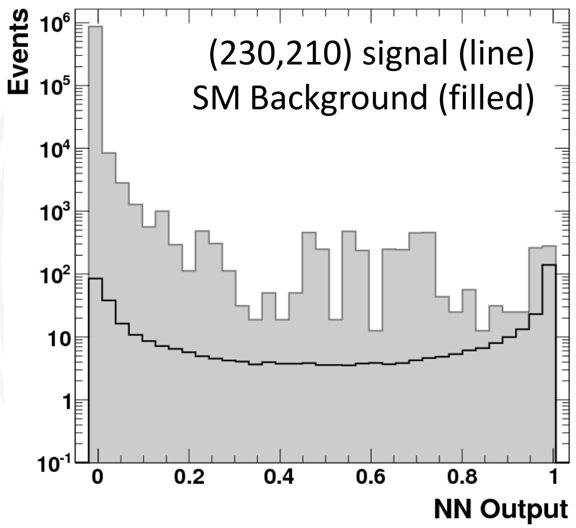
Analysis

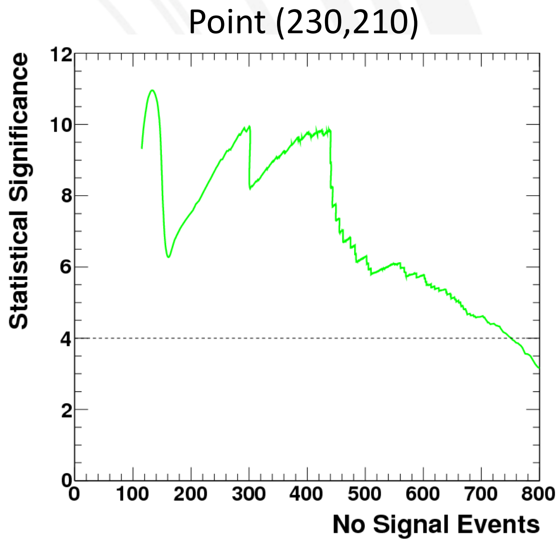
- Events are pre-selected using few basic quantities
  - $E_{visible} < 80$ GeV , $\Delta R_{\eta\phi} < 3.0$, $10 \leq N_{particles} \leq 60$, $max(|\eta_1|, |\eta_2|) < 2.0$
  - Veto on electrons or photons in forward detectors (>10mrad)
- For the final selection Neural Net is trained with additional inputs.
- Example plots for point (230,210) – signal (line) was multiplied by 10^5

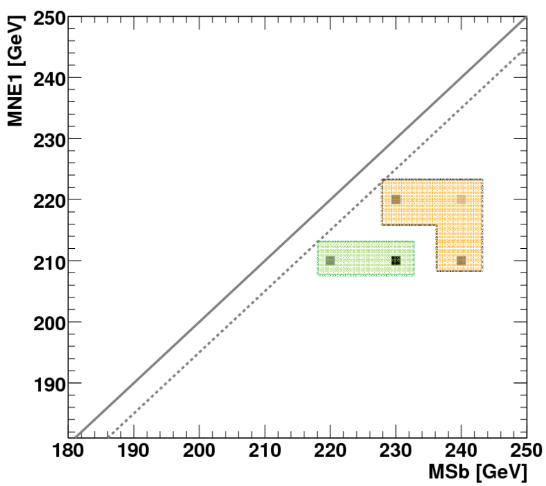


Results

- The measurement is interpreted in terms of signal significance calculated as S / √(S + B) and depending on a particular neural net output cut.
- Points (230,210) and (220,210) both reach above 4σ level.
  - Other points are more difficult (low x-section, jet softness) but they all can be excluded @ 95% CL.





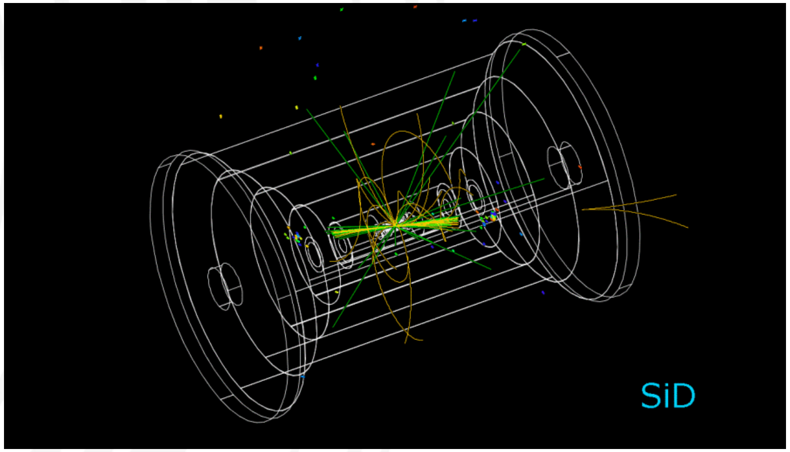


Remarks and Future Plans

- Higgs self-coupling (ZHH) analysis
  - Not included in the SiD LoI.
  - Uncertainty too large, after having FSR and full sim/rec samples.

- Work in progress for TeV Linear Collider
  - Tuning of the LCFI package for CLIC and physics/tagging/vertexing studies.
  - The package was never used in $\sqrt{s}$ = 3 TeV environment before.

3TeV bB-event
vtx+tracker



Summary

H → cC branching ratio uncertainty from e^+e^- → ZH estimated to ~8.5%. Analysis extended to H → bB and H → gg.

Top mass uncertainty about 50 MeV on the tree level. Cross section and production asymmetry addressed.

We study a new cosmologically motivated sbottom co-annihilation scenario which can be uniquely probed at the ILC. Challenge is due to very soft jets and large γγ bkgr.

Higgs self-coupling analysis delivered large errors.

Work in progress for TeV LC in both SiD and CLIC geometries.