Status and Plan for the Analyses of ttbar near threshold at the ILC

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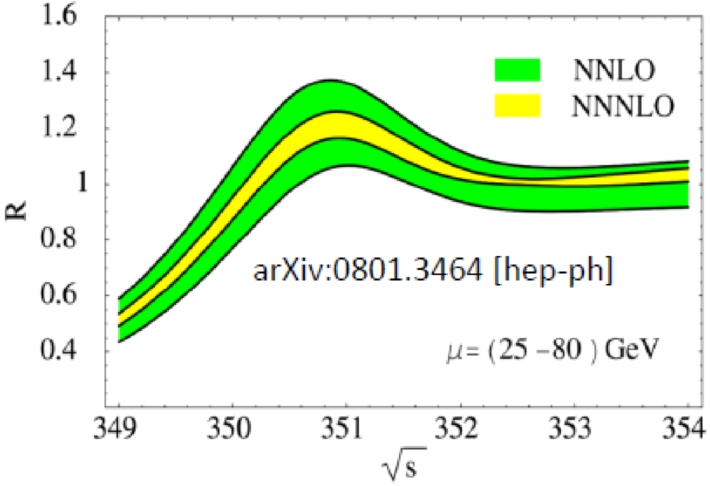
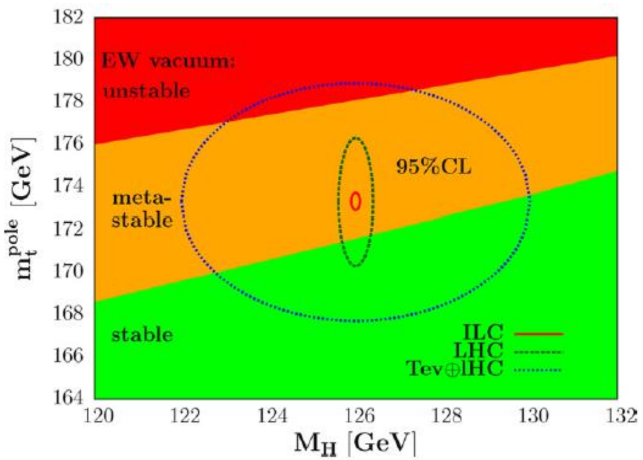
Analysis was done by T. Horiguchi

ttbar at threshold

- σ_{tt} VS √s is sensitive to
  - M_t
    - Theoretically well-defined running mass
    - Vacuum instability in the SM
  - Γ_t (or V_{tb})
    - Deviated from SM if new physics in decays
  - y_t
    - Higgs exchange diagram gives 9% enhancement
  - α_s
    - not yet done

- Fit to σ_{tt} to obtain m_t, Γ_t and y_t simultaneously.



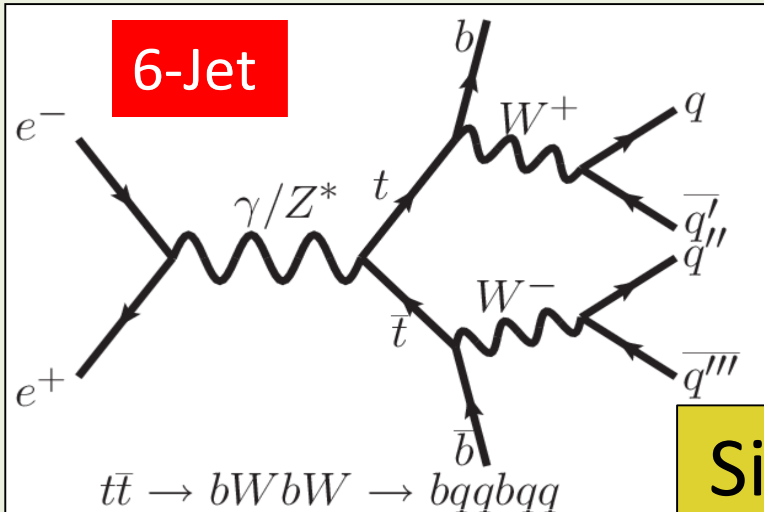


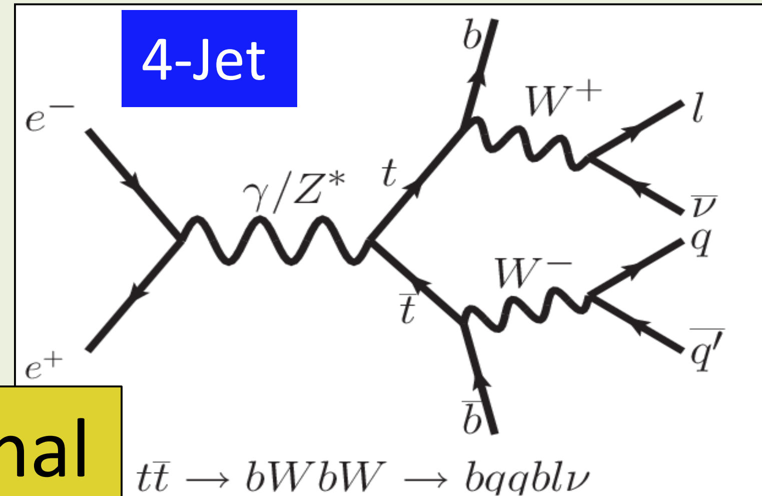
S. Alekhin et al

Simulation Setup for σ_{tt}

Top quark mass	174 GeV
$\sqrt{s}$ (threshold scan)	341 - 350GeV (every 1 GeV, 10 points)
Polarization	$\mathrm{p(e^+, e^-) = (-30\%, +80\%), (+30\%, -80\%)}$ (In this talk, I call them "Right" and "Left")
Integrated Luminosity	5 fb^{-1} (each $\sqrt{s}$ & pol, total 100fb^{-1})
Event Generation	Physsim (LO ,QCD enhancement, on ISR/ beamstralung/beam energy spread)
Simulation	ILD_01_v05 (DBD ver.)

Signal and Backgrounds





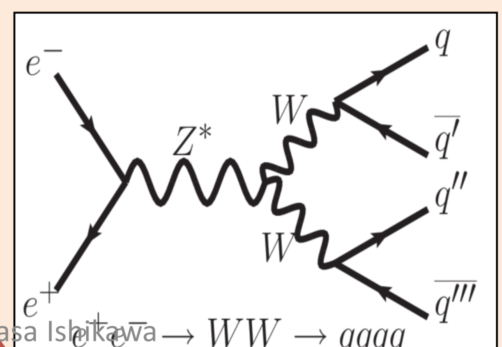
Signal

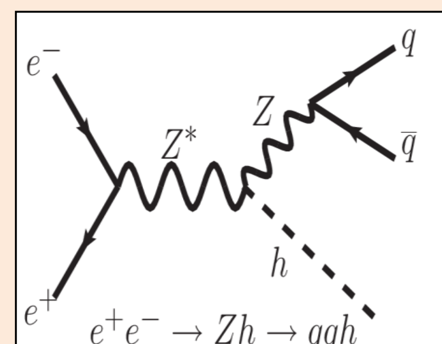
Branching Ratio	
6-Jet	45%
4-Jet	44%
2-Jet	11%

e^+e^- → tbW not included

background

SM bkg. which have 4 or 6 fermions in final state Main bkg. : WW, ZZ, ZH





Reconstruction

Reconstruction method	6-Jet	4-Jet
Isolated Lepton(l_{iso}) finding using cone energy cut ($\cos\theta_{cone}$> 0.96, P_{track}> 15 GeV, E_{cone}< 10 GeV)	# of l_{iso} = 0	# of l_{iso} = 1
Jet clustering using Durham algorithm	6jets	4jets
Extraction of 2 b-likeness jets		
Reconstruction of top quark pair and finding the best candidate by χ^2 from invariant mass	(b+q+q') × 2	(b+q+q') & (b+l_{iso}+ν)

$$\chi^2_{6-\mathrm{Jet}} = \frac{(m_{3\mathrm{j^a reco.}} - m_t)^2}{\sigma_t^2} + \frac{(m_{3\mathrm{j^b reco.}} - m_t)^2}{\sigma_t^2} + \frac{(m_{2\mathrm{j^a reco.}} - m_w)^2}{\sigma_w^2} + \frac{(m_{2\mathrm{j^b reco.}} - m_w)^2}{\sigma_w^2}$$

$$\chi^2_{4-\mathrm{Jet}} = \frac{(m_{3\mathrm{jreco.}} - m_t)^2}{\sigma_t^2} + \frac{(m_{\mathrm{jl}\nu\mathrm{reco.}} - m_t)^2}{\sigma_t^2} + \frac{(m_{2\mathrm{jreco.}} - m_w)^2}{\sigma_w^2}$$

Cut-flow for 350GeV

Table : 6-Jet Left handed

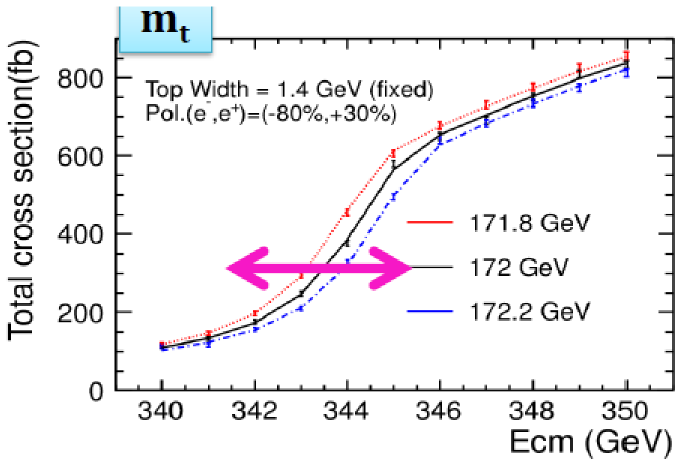
$$\int \mathcal{L}(t)dt = 5(\mathrm{fb}^{-1}) \quad S = \frac{N_{Sig}}{\sqrt{N_{Sig} + N_{BG.}}}$$

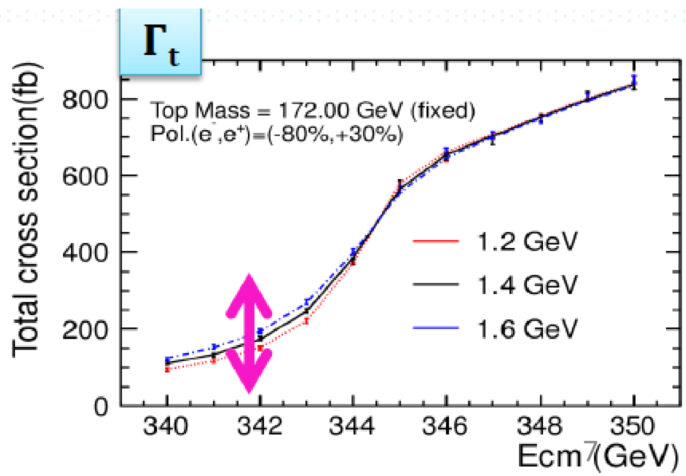
(e+,e-)=(+30,-80%)	tt6j	tt4j	tt2j	SM bkg.	S_{6j}	ε_{6j}
Generated	1643	1583	381	0.13M	4.4	100
# of lepton = 0	1590	353	18	0.11M	5.0	96.8
btag > 0.09 × 2	1499	330	17	19336	10.3	91.2
Thrust<0.825	1439	285	11	2447	22.3	87.6
Evis>300 GeV	1424	61	0	1092	28.0	86.6
m_t>107 GeV × 2	1383	37	0	492	31.6	84.1
# of pfos>84	1376	33	0	442	32.0	83.8
y45> 0.0012 y56 >0.0006	1362	31	0	392	32.2	82.9
Sphericity>0.22	1347	24	0	329	**32.7**	**82.0**

√s=350 GeV	$S_{n\text{-}Jet}$	$\varepsilon_{n\text{-}Jet}$
6-Jet (e+,e-)=(-30, +80%)	23.5	84.6
4-Jet (e+,e-)=(+30, -80%)	31.0	66.3
4-Jet (e+,e-)=(-30, +80%)	21.9	68.2

Fitting with templates

- fit to σ_{tt} with template to extract three variables, m_t, Γ_t and y_t simultaneously.
  - Two dimensional template (m_t, Γ_t)
  - y_t from normalization
  - α_s is fixed at 0.12
- Template is made from
  - Theoretical $\sigma_{tt}(s)$ from Y. Kiyo-san (NLO calc)
  - Efficiency from Physsim (LO) and DBD setup





Results

Stat. Error (m_t , Γ_t :MeV/y_t:%)	6-Jet			4-Jet		
	m_t^{PS}	Γ_t	y_t	m_t^{PS}	Γ_t	y_t
Left($50fb^{-1}$)	47	65	9.6	52	71	11
Right($50fb^{-1}$)	68	94	14	75	106	16
Left ($50fb^{-1}$) + Right($50fb^{-1}$)	**39**	**53**	**7.9**	**43**	**59**	**9.1**

Combined ALL		
m_t^{PS}(GeV)	Γ_t(GeV)	y_t
172 ± 0.029	1.4 ± 0.039	5.9 %

- Error estimated in arXiv:1310.0563 is wrong and should be replaced to above.
- y_t uncertainty from theory (error on total cross section ~4%) is 22%
  - M. Beneke et al pointed out in Arxiv.1506.06865, that 4.2% error is not likely and we fully agree (and we did not say the error is determined only from exp. stat.). Theoretical uncertainty should be reduced if we want to observe Higgs exchange effect with 5σ.
- Uncertainty from luminosity spectrum to be estimated.
- If $200fb^{-1}$ data is accumulate (H20 run scenario), errors can reduced by factor √2

Comparison with (2+1) and 3

- (2+1) par fit : m_t and Γ_t simultaneously. y_t from normalization
- 3 par fit : all simultaneously
- Mt worse than (2+1) fit
- Simultaneous fit gives correct error matrix

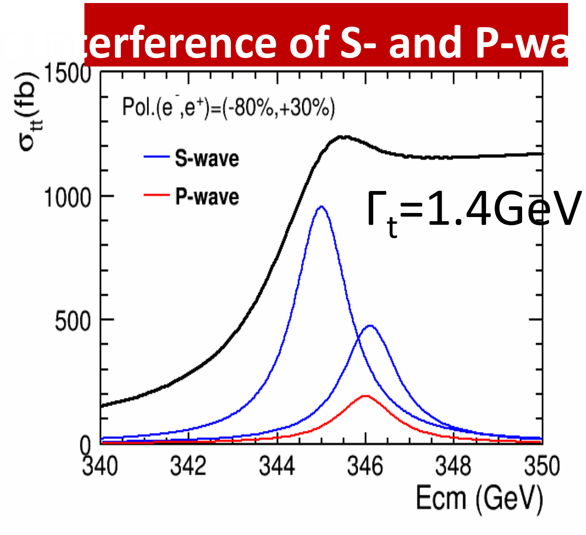
error	(2 + 1) param fit	3 param fit
m_t	19 MeV	29 MeV
Γ_t	38 MeV	39 MeV
y_t	4.6%	5.9%

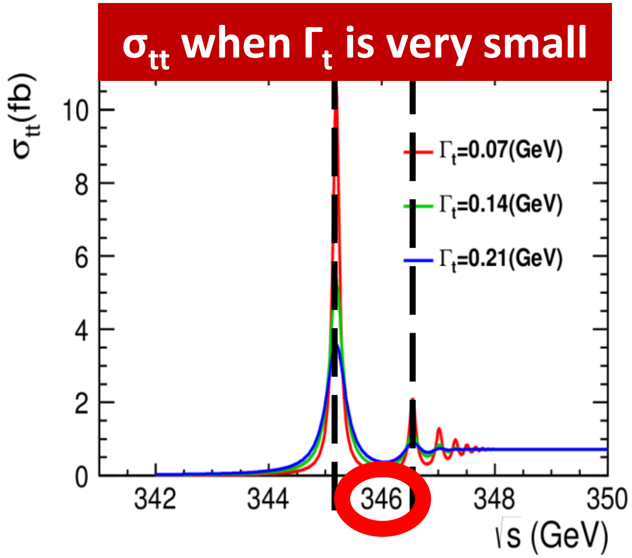
Correlation	(2 + 1) param fit	3 param fit
m_t vs Γ_t	0.52	0.57
m_t vs y_t	-	0.72
Γ_t vs y_t	-	0.33

A_{FB}

Forward-Backward Asymmetry

- From S and P waves interference, A_{FB} is generated at threshold which is sensitive to Γ_t and α_s which control the overlap of S and P waves.



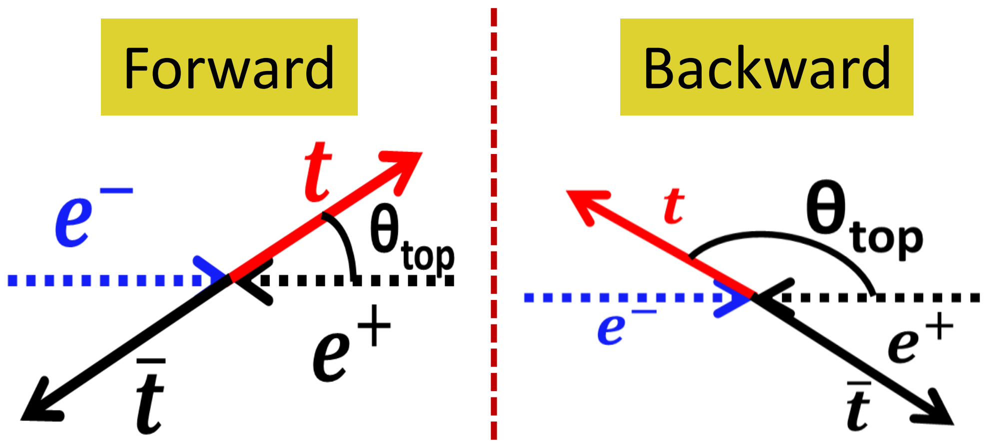


- To identify the charge, 4jets+lepton mode is used.
- We choose the √s=346GeV which gives the maximum interference

Setup

$\sqrt{s}$ = 346 GeV (between S- and P- wave)
$\mathcal{L}$ = 50fb^{-1} (e+,e-) = (+0.3, -0.8)
$\mathcal{L}$ = 50fb^{-1} (e+,e-) = (-0.3, +0.8)

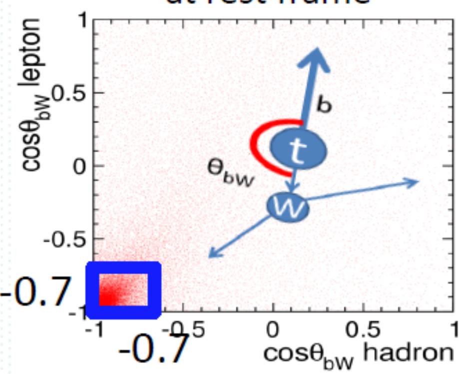
$$A_{FB} \equiv \frac{N(cos\theta_{top} > 0) - N(cos\theta_{top} < 0)}{N(cos\theta_{top} > 0) + N(cos\theta_{top} < 0)}$$



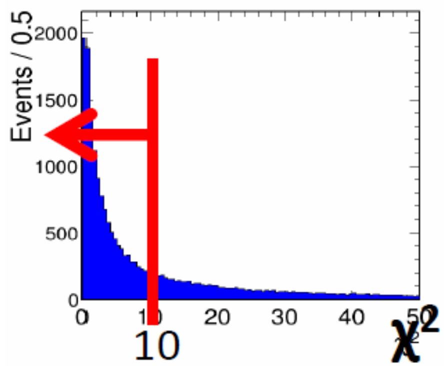
Reconstruction

- To get correct combination, several selections are applied.
- 38% efficiency

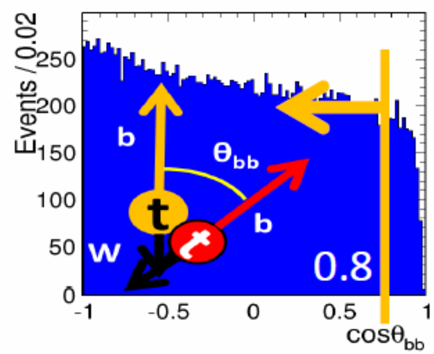
Angle of b and W at rest frame



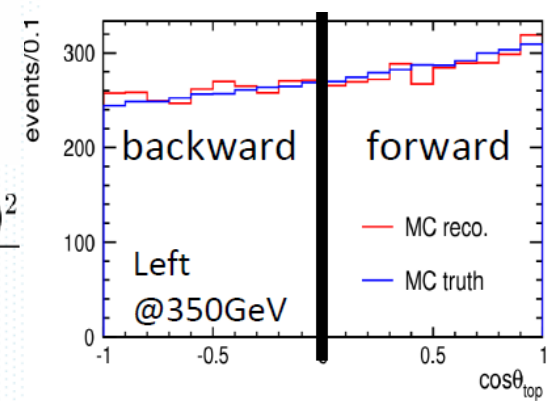
X^2 from mass

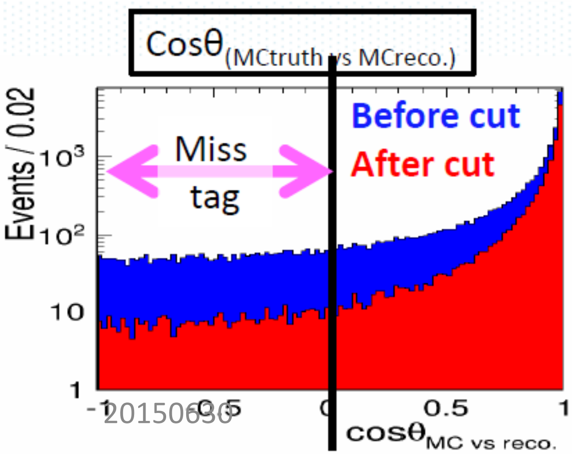


Closeness of 2 b quarks



Angle distribution after the selections.





$$\chi^2 = \frac{(m_t - m_{3j})^2}{\sigma_t^2} + \frac{(m_t - m_{jl\nu})^2}{\sigma_t^2} + \frac{(m_w - m_{2j})^2}{\sigma_w^2}$$

Cut for top ID

$\cos\theta_{bW}<-0.7$, $X^2<10$, $\cos\theta_{bb}<0.8$

Misreconstruction is reduced.

13% ⇒ 3.7 %

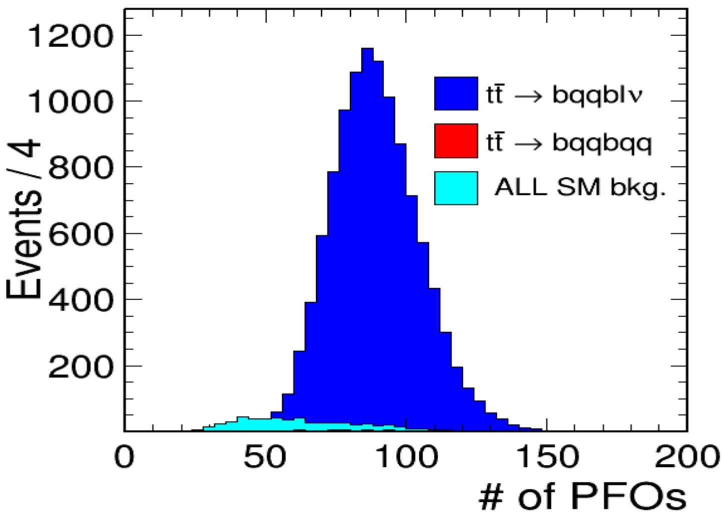
2014 in CHICAGO 15

Cut flow tables

- To maximize the significance (S_{top}), bkg. are rejected.

$$S_{top} = \frac{N_{signal}}{\sqrt{N_{signal} + N_{bkg.}}}$$

- # of PFOs is used except top tagging cut (previous page).

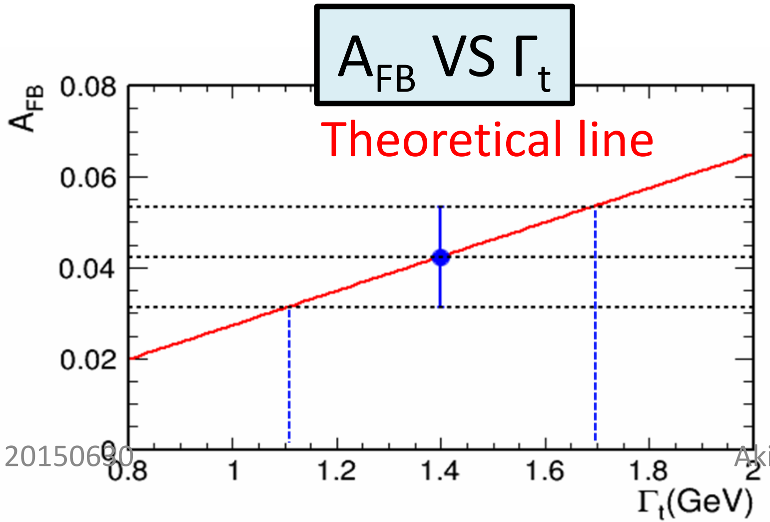


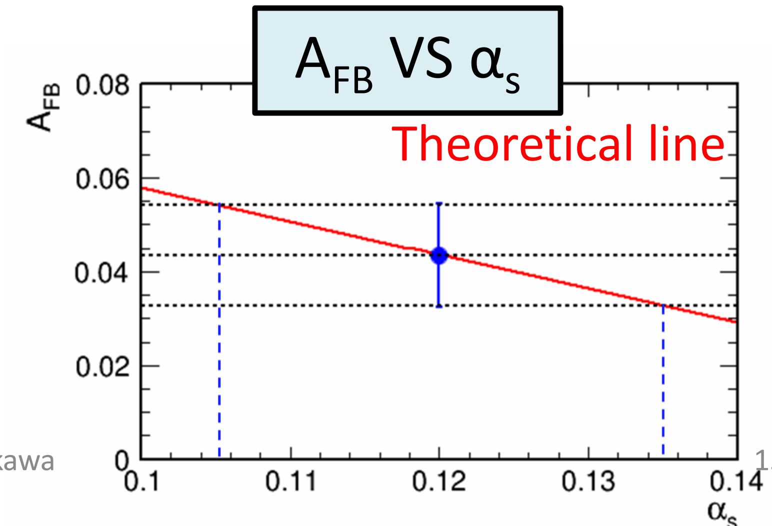
Left 50fb^{-1}	tt4j	tt6j	tt2j	SM bkg.	S_{top}	Efficiency
Gen.	12619	13101	3039	1 M	12.2	100
# of l_{iso} = 1	9648	418	909	0.3M	16.9	76.5
$\cos\theta_{bW}$<-0.7	8989	397	834	0.2M	18.4	71.2
X^2<10	6856	65	164	13134	48.2	54.3
$\cos\theta_{bb}$<0.8	4881	3	6	271	67.9	38.7
# of PFOs > 50	4872	3	4	182	**68.5**	**38.6**

Results

- From the 1σ error of A_{FB}, we estimated statistical errors of Γt and αs.
  - $\delta\Gamma_t$ = 290 MeV
  - $\delta\alpha_s$ = 0.015
- Input A_{FB}= 0.0427

50 fb^{-1}	# of events (NNLO)	δA_{FB}
Left handed	5537	0.013
Right handed	2564	0.020
Left + Right (100 fb^{-1})	8101	0.011





Summary

- We measured m_t, Γ_t and $y\tau$ from cross section VS √s
  - δm_t = 29MeV
  - $\delta\Gamma_t$ = 39MeV
  - δy_t = 5.9%
- We also measured AFB to extract α_s and Γ_t
  - $\delta\Gamma_t$ = 290MeV
  - $\delta\alpha_s$ = 0.015 (not so sensitive)

  - We need some improvement

Plan

- Publication. Horiguchi is preparing the paper draft.

- New student Ozawa will study
  - Top momentum (to measure Γ_t and α_s)
  - Systematic error from beam spectrum
    - Which is also important for σ_{ZH}, m_H (and m_W) measurement.
  - Perform combined fit to σ_{tt}, A_{FB} and top momentum simultaneously to extract four parameters : M_t, Γt , Y_t and α_s
    - But α_s can be measured precisely from other measurements?

- Coupling measurements
  - Angular analysis with polarized beam

backup