



# Top quark pair production near the threshold

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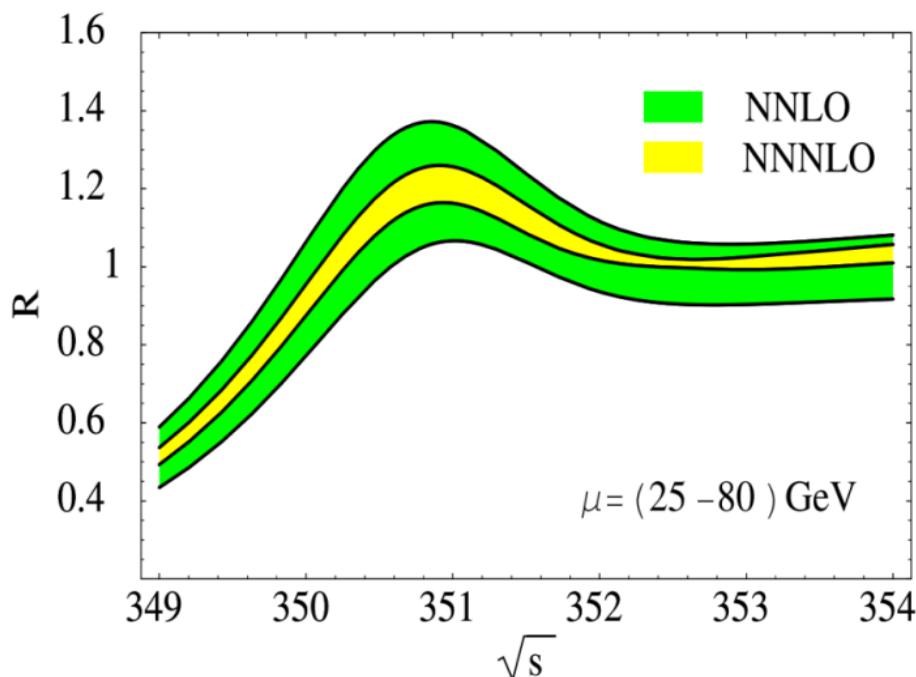
# Contents

- Update of ttbar Xs study
  - Wrong sample was used.
  - Ttbar samples ( $\sim 200 \text{ fb}^{-1}$  par  $\sqrt{s}$ ) has “1 TeV” overlay (other samples which has 350 GeV info. were made by Miyamoto-san. ).
  
- Changing how to estimation yt
  - Old : amplitude calculation
  - New : normalization of 2D fitted Xs

# $\sigma_{tt}$ Measurement

Near the threshold region of top pair production ( $\sqrt{s}=2m_t$ ), the energy dependence of  $\sigma_{tt}$  is large. And  $\sigma_{tt}$  depend on fundamental parameters. Then, using threshold scan technic, measuring  $\sigma_{tt}$  precisely and fitting it, these parameters are determined !!

$$\sigma_{tt} \propto f(\sqrt{s}, m_t, \Gamma_t, \alpha_s, y_t, m_h)$$



$$\begin{aligned}\sigma/\delta\sigma(\text{theoretical}) &\sim 4-5 \% \\ \sigma/\delta\sigma(\text{theoretical goal}) &\sim 2\%\end{aligned}$$

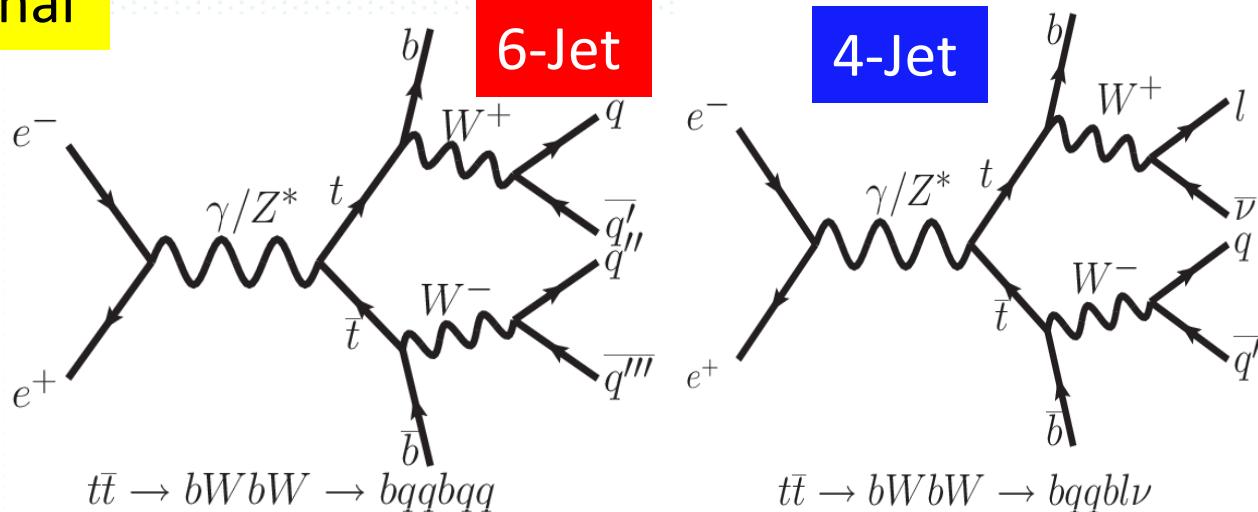
arXiv:0801.3464 [hep-ph]  
M. Beneke, Y. Kiyo and K. Schuller,

# Simulation set up

Top quark mass	174 GeV
$\sqrt{s}$ ( <u>threshold scan</u> )	<u>341 - 350GeV (every 1 GeV, 10 points)</u>
<u>Polarization</u>	$p(e^+, e^-) = (-30\%, +80\%), (+30\%, -80\%)$ (In this talk, I call them “Right” and “Left”)
Integrated Luminosity	5 $\text{fb}^{-1}$ (each $\sqrt{s}$ & pol, total 100 $\text{fb}^{-1}$ ) <u>※Running schedule around 350GeV is not determined.</u>
Event Generation	Physsim (LO ,no higgs exchange/on QCD enhancement, on ISR/ beamstralung/beam energy spread)
Simulation	ILD_01_v05 ( <b>DBD ver.</b> )

# Signal and background

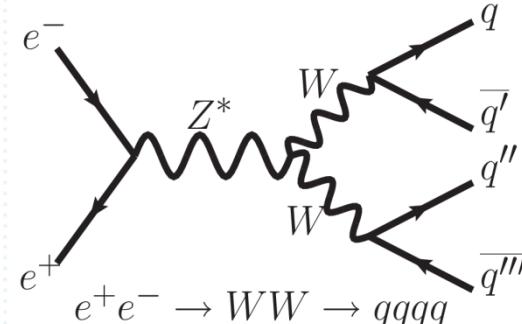
Signal



background

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

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



# Top Quark Reconstruction (6-Jet & 4-Jet)

Reconstruction method	6-Jet	4-Jet
<del>Suppressing the background overlay using anti <math>k_T</math> algorithm ( R=0.7 )</del>		
Isolated Lepton( $l_{iso}$ ) finding using Econe	# of $l_{iso} = 0$	# of $l_{iso} = 1$
Jet clustering using Durham algorithm	Cluster to <b>6jets</b>	Cluster to <b>4jets</b>
2 b-likeness Jets were found using LCFIPlus	-	-
Reconstruction of two W bosons	$q_1 + q_2 \& q_3 + q_4$	$q_1 + q_2 \& l_{iso} + v$
Reconstruction of two top quarks	$(b+W) \times 2$	$(b+W) \times 2$
Minimizing the $\chi^2$	<b>①</b>	<b>②</b>

①

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

②

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

# Selection Table 6-Jet @350GeV

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
<b>Generated</b>	1643	1583	381	108053	4.9
# of lepton = 0	1592	357	19	75657	5.7
btag > 0.1 × 2	1515	340	18	12869	12.5
Thrust<0.84	1485	313	13	2298	23.2
Evis>290 GeV	1481	159	1	927	29.2
missPt<38GeV	1473	72	0	907	29.7
m <sub>t</sub> >100 GeV × 2	1467	69	0	751	30.7
y45> 0.0015					
y56 >0.0007	1419	45	0	255	34.2
<b># of pfos&gt;86</b>	<b>1406</b>	<b>38</b>	<b>0</b>	<b>210</b>	<b>34.6</b>

OLD SAMPLE

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
<b>Generated</b>	1643	1583	381	133321	4.4
# of lepton = 0	1590	353	18	100576	5.0
btag > 0.06 × 2	1550	342	17	36141	7.9
Thrust<0.83	1497	301	12	4173	19.4
Evis>298 GeV	1484	72	0	1819	25.5
m <sub>t</sub> >100 GeV × 2	1455	48	0	879	29.8
# of pfos>86	1436	38	0	664	30.8
y45> 0.0015					
y56 >0.0007	1442	40	0	715	31.1
<b>Sphericity&gt;0.23</b>	<b>1413</b>	<b>28</b>	<b>0</b>	<b>516</b>	<b>31.9</b>

NEW SAMPLE

$$S = \frac{N_{Sig}}{\sqrt{N_{Sig} + N_{BG.}}}$$

Old sample = include 1 TeV overlay bkg sample

“wworzz bkg” is added.

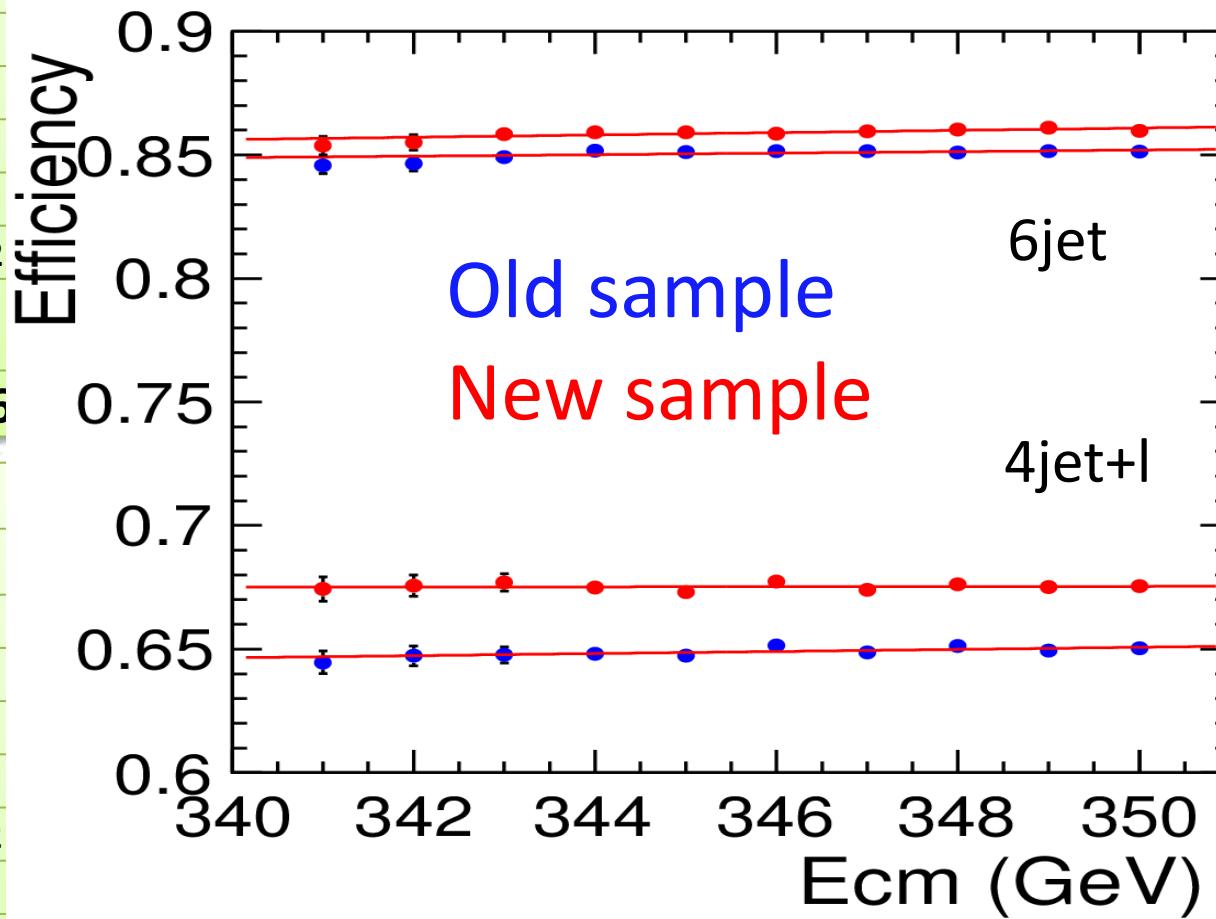
$S_{n\text{-Jet}}$	Old	New
6-Jet right	24.3	23.4
4-Jet left	31.6	30.6
4-Jet right	22.0	21.7

# Selection Table 6-Jet @350GeV

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
Generated	1643	1583	381	108053	4.9
# of lepton = 0					
btag > 0.1 × 2					
Thrust < 0.84					
Evis > 290 GeV					
missPt < 38 GeV					
$m_t > 100 \text{ GeV} \times 2$					
$y_{45} > 0.0015$					
$y_{56} > 0.0007$					
# of pfos > 86					

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
Generated	1643	1583	381	108053	4.9
# of lepton = 0					
btag > 0.1 × 2					
Thrust < 0.84					
Evis > 290 GeV					
missPt < 38 GeV					
$m_t > 100 \text{ GeV} \times 2$					
$y_{45} > 0.0015$					
$y_{56} > 0.0007$					
# of pfos > 86					

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
Generated	1643	1583	381	108053	4.9
# of lepton = 0					
btag > 0.1 × 2					



$$\int \mathcal{L}(t) dt = 5(\text{fb}^{-1})$$

$\overline{\sqrt{BG}}$

|e 1 TeV

d.

New

23.4

30.6

21.7

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
Generated	1643	1583	381	108053	4.9
# of lepton = 0					
btag > 0.1 × 2					

Left	tt6j	tt4j	tt2j	SM bkg.	$S_{6j}$
Generated	1643	1583	381	108053	4.9
# of lepton = 0					
btag > 0.1 × 2					

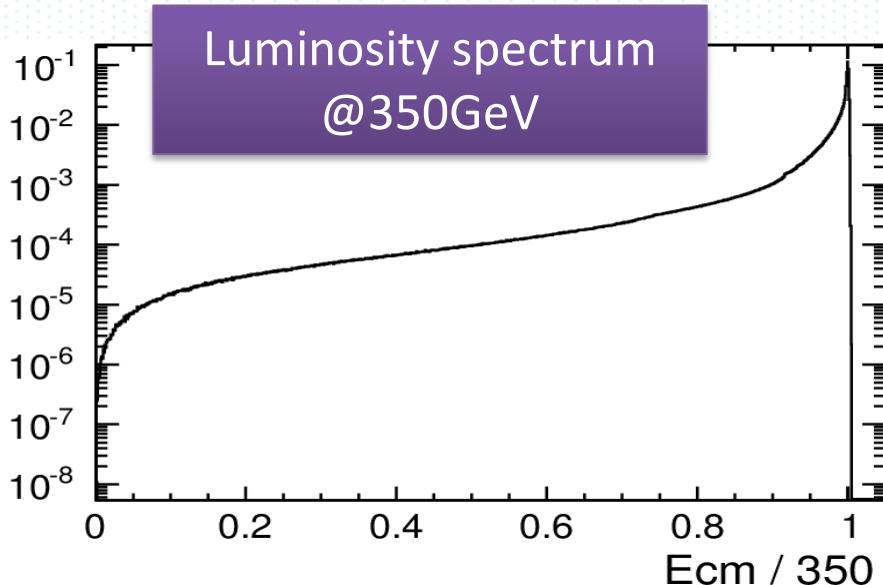
# Measurement of “ $m_t$ ”, “ $\Gamma_t$ ” and “ $y_t$ ”

# Fit - convolution -

© We must consider “Beam effects” around threshold.

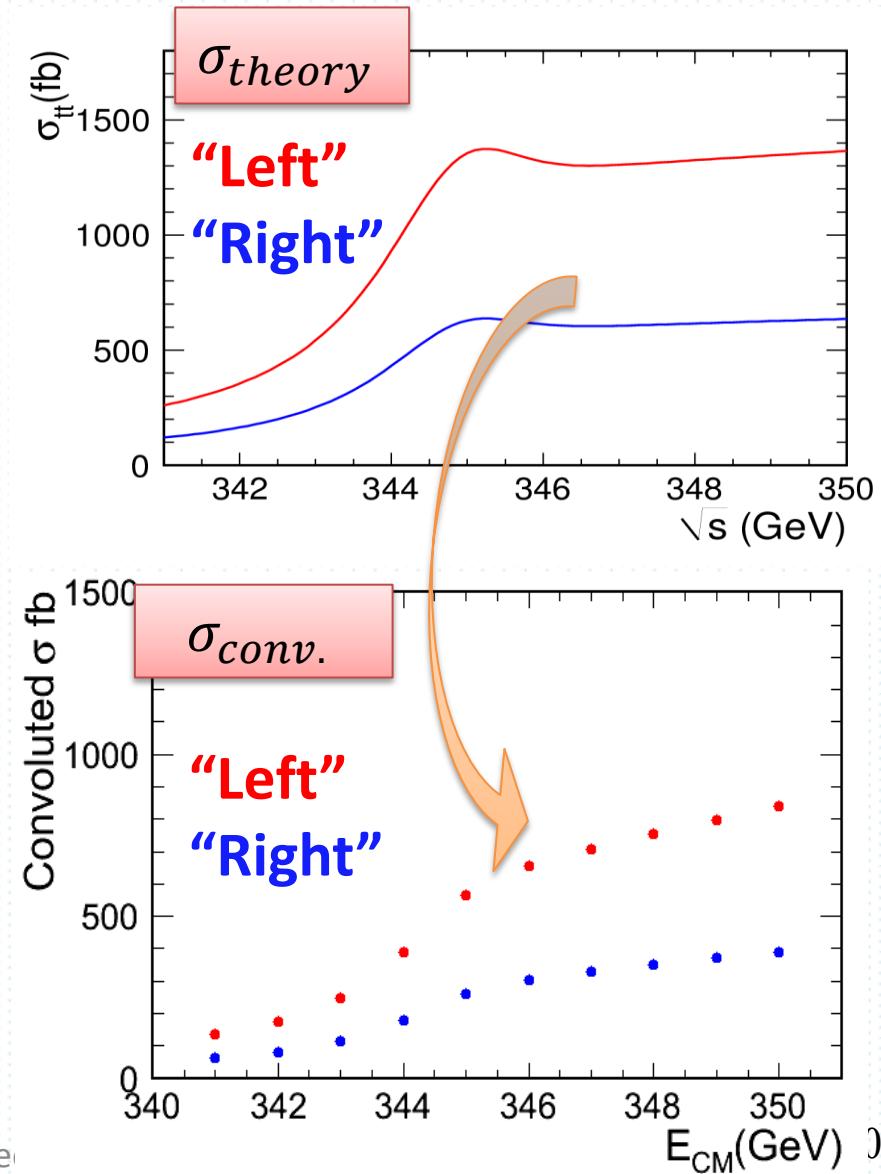


Using luminosity spectrum,  
theoretical cross section is convoluted.



$$\sigma_{conv.}(\sqrt{s}) = \int \mathcal{L}(t) \sigma_{th}(t) dt$$

$\mathcal{L}$ : luminosity spectrum,  $\sqrt{s}$ : nominal,  $\sigma_{th}$ : theoretical  $\sigma$ ,  
 $\sigma_{conv.}$ : convoluted  $\sigma$ ,  $t(=\sqrt{s'}/\sqrt{s})$  where  $\sqrt{s'}$  is collision energy



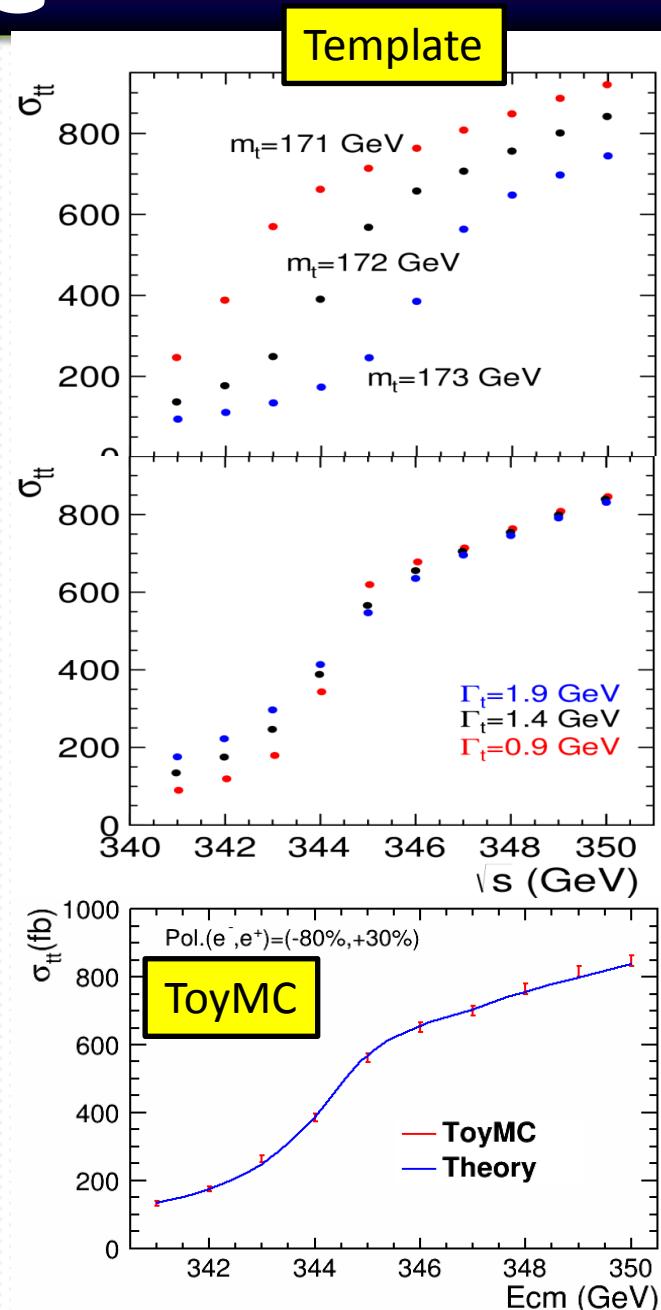
# Fit -toyMC

## ➤ Setting the Template:

- Floating  $m_t^{PS}$ ,  $\Gamma_t$  and  $\sqrt{s}$  / Fixed  $\alpha_s (=0.12)$
- The center value  $(m_t^{PS}, \Gamma_t) = (172.000, 1.400)$
- Since  $\alpha_s$  will be determined by lattice QCD calculation in the future, here we make the template of  $m_t$  and  $\Gamma_t$ .

## ➤ Fitting the $\sigma_{tt}$ :

- $\sigma_{tt}$  is scaled from LO to NNLO calculation.
- Since the measurement of  $y_t$  is to extract the normalization of Xs, the normalization is used for Xs fit.
- Interpolating  $y_t$ ,  $m_t$  and  $\Gamma_t$ ,  $\sigma_{tt}$ s are fitted at each center of mass energy.
- Using all center of mass energies (341 – 350 GeV),  $y_t$ ,  $m_t$  and  $\Gamma_t$  are optimized.



# Fit -Result-

Stat. Error	6-Jet			4-Jet		
	$m_t^{PS}$	$\Gamma_t$	$y_t$	$m_t^{PS}$	$\Gamma_t$	$y_t$
Left(50fb $^{-1}$ )	30	40	0.058	32	46	0.067
Right(50fb $^{-1}$ )	41	56	0.086	49	64	0.102
Left (50fb $^{-1}$ ) + Right(50fb $^{-1}$ )	<b>24</b>	<b>32</b>	<b>0.048</b>	<b>27</b>	<b>37</b>	<b>0.056</b>

## Combined ALL

$m_t^{PS}(\text{GeV})$	$\Gamma_t(\text{GeV})$	$y_t$
$172 \pm 0.018$	$1.4 \pm 0.024$	$1 \pm 0.037$

◎ PS → MS

$$m_t^{\overline{MS}} \sim m_t^{PS} - \frac{4}{3\pi}(m_t^{PS} - 20)\alpha_s + \dots$$

$$m_t^{\overline{MS}} = 163.800 \pm 0.017 \text{ (stat.) (GeV)}$$

# Compare the result- $m_t$ & $\Gamma_t$

Center value

$M_t = 172 \text{ GeV}$ ,  $\Gamma_t = 1.4 \text{ GeV}$

Stat. Error (MeV)	6-Jet old		6-Jet new		4-Jet old		4-Jet	
	$m_t^{\text{PS}}$	$\Gamma_t$	$m_t^{\text{PS}}$	$\Gamma_t$	$m_t^{\text{PS}}$	$\Gamma_t$	$m_t^{\text{PS}}$	$\Gamma_t$
Left( $50\text{fb}^{-1}$ )	30	41	30	40	34	47	32	46
Right( $50\text{fb}^{-1}$ )	42	59	41	56	48	65	49	64
$L(50\text{fb}^{-1})+R(50\text{fb}^{-1})$	<b>24</b>	<b>34</b>	<b>24</b>	<b>32</b>	<b>28</b>	<b>38</b>	<b>27</b>	<b>37</b>

Comb.	Old	new
$M_t \text{ (MeV)}$	18	18
$\Gamma_t \text{ (MeV)}$	25	24

# Past estimation of $y_t$

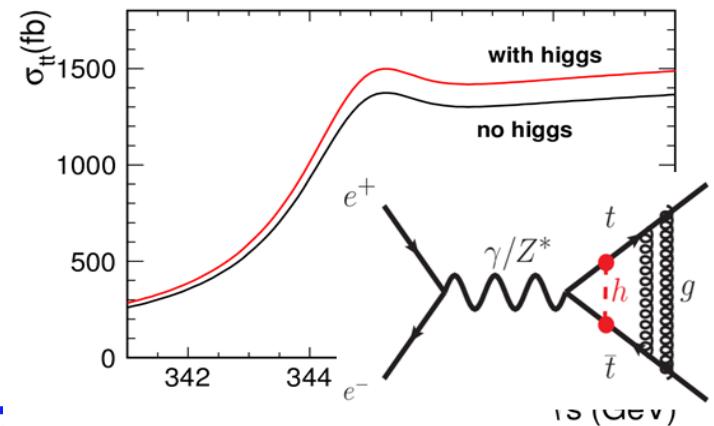
Using the significances of the all  $\sqrt{s}$  (341 – 350 GeV) for each polarization, the statistical error of  $y_t$  is estimated.

“Amp”

The cross section is enhanced about 9% by exchanging the Higgs boson !!

$$\sigma_{tt} \propto |\mathcal{M}_{w/o \text{ higgs}} + y_t^2 \mathcal{M}_{w/ \text{ higgs}}|^2$$

$$\frac{\delta y_t}{y_t} \sim \frac{109 \times \frac{1}{2} \times \frac{\delta \sigma}{\sigma}}{9}$$



LO calculation

# Compare $y_t$

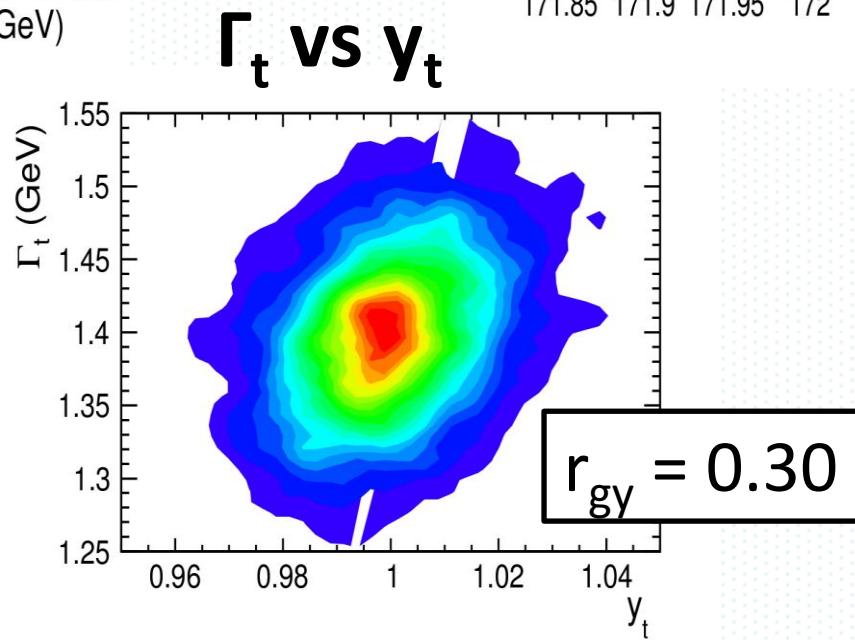
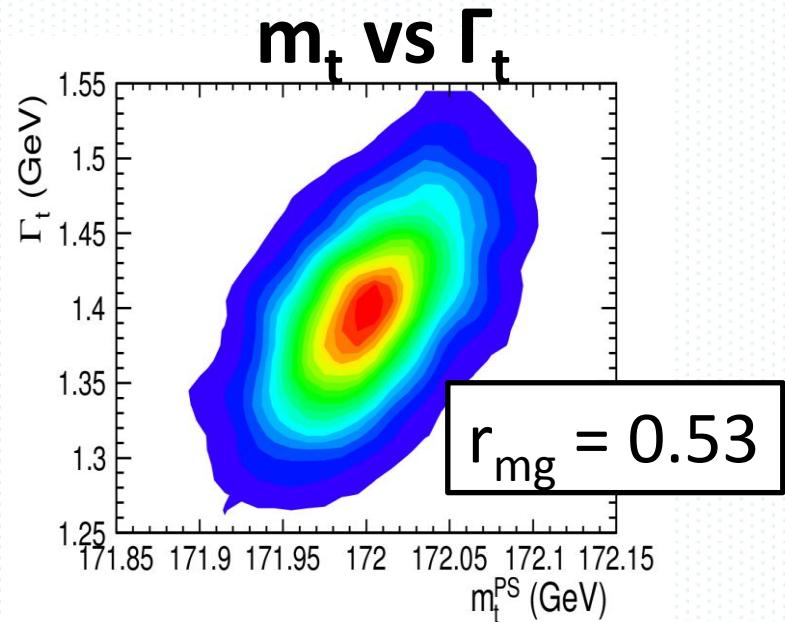
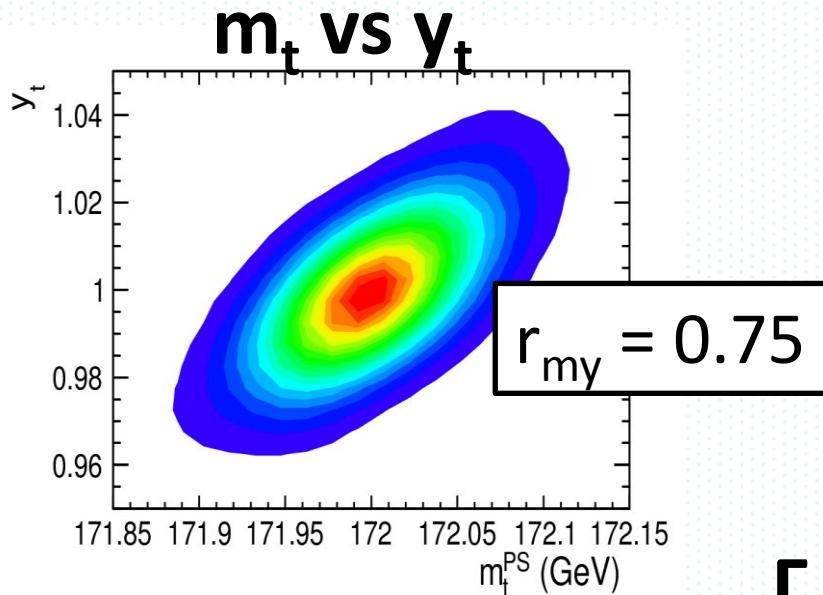
Here  $y_t$  is set “1”

“Amp” Stat. Error	6-Jet old	6-Jet new	4-Jet old	4-Jet new
Left( $50\text{fb}^{-1}$ )	0.072	0.080	0.078	0.088
Right( $50\text{fb}^{-1}$ )	0.102	0.107	0.11	0.123
$L(50\text{fb}^{-1})+R(50\text{fb}^{-1})$	0.059	0.064	0.063	0.072

“Norm” Stat. Error	6-Jet old	6-Jet new	4-Jet old	4-Jet new
Left( $50\text{fb}^{-1}$ )	0.062	0.058	0.070	0.067
Right( $50\text{fb}^{-1}$ )	0.087	0.086	0.098	0.102
$L(50\text{fb}^{-1})+R(50\text{fb}^{-1})$	0.049	0.048	0.057	0.056

Combined	Old	new
$y_t$ “Amp”	0.044	0.048
$y_t$ “Norm”	0.038	0.037

# Correction



# Summary

## ➤ Update of $\sigma_{tt}$ measurement

- Using new sample, we can obtain the result.
- $y_t$  is estimated from normalization fitting.
- Integrated luminosity :  $5 \text{ fb}^{-1} \times 20 \text{ points}$ , total  $100 \text{ fb}^{-1}$

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### Old results

$m_t^{\text{PS}}(\text{GeV})$	$\Gamma_t(\text{GeV})$	$y_t$
$172 \pm 0.018$	$1.4 \pm 0.025$	$1 \pm 0.044$



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### New results

$m_t^{\text{PS}}(\text{GeV})$	$\Gamma_t(\text{GeV})$	$y_t$
$172 \pm 0.018$	$1.4 \pm 0.024$	$1 \pm 0.037$