Single Top Studies for ATLAS

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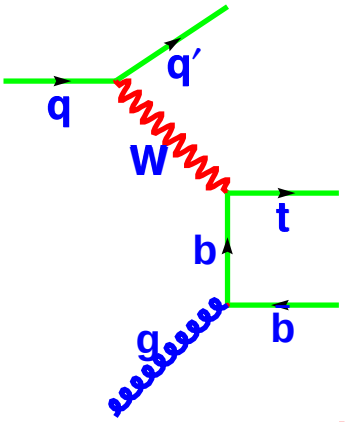
Outline

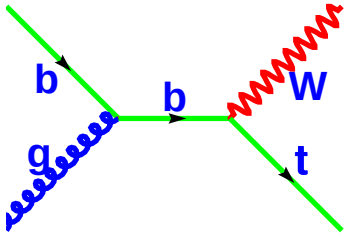
- Introduction/Motivation
- Signal/Background Separation
  - Wg fusion
  - Wt
  - W*
- Measurement of V_{tb}
- Angular Distributions
  - Polarization of the W
  - Polarization of the top
- Summary

Motivation

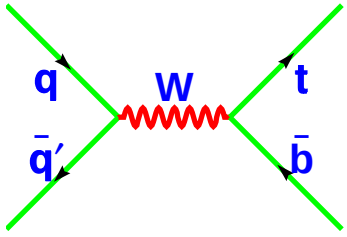
- At LHC it is possible to produce top quarks singly via the weak interaction



Wg
large LHC x-sec $\approx$ 245 pb
high rate, $V_{\rm tb}$, polarized tops, etc.



Wt
LHC x-sec $\approx$ 60 pb
$V_{\rm tb}$, not very sensitive....



W*
LHC x-sec $\approx$ 10 pb
low th. errors, $V_{\rm tb}$

- Single top provides the best opportunity to study W-t-b vertex:
  - cross-section $\propto |V_{tb}|^2$
  - source of polarized tops (precise prediction)

Motivation

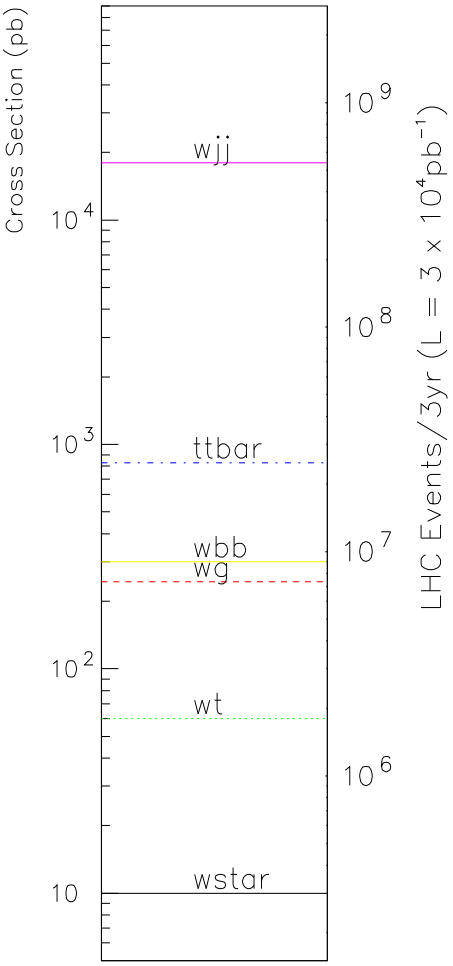
- Perform measurements independently in the three single top channels. Each is sensitive to different "new Physics".
  - Wg - FCNC, V+A, others....
  - Wt - V+A, not very sensitive to others....
  - W* - W′, V+A, others....

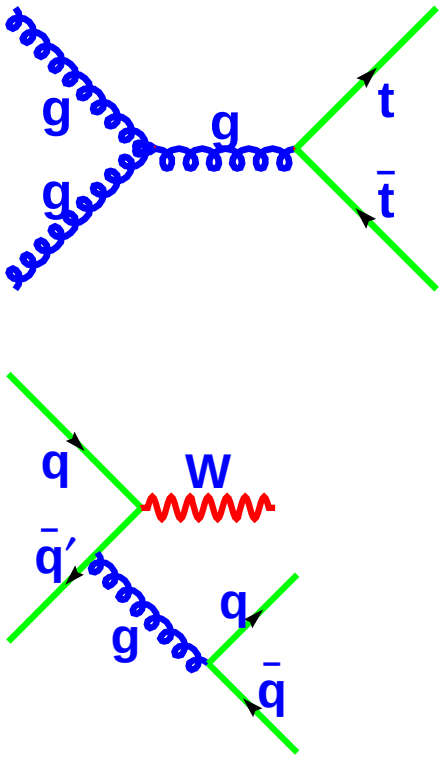
- Each channel has different theoretical errors:

Source	W*	Wg	Wt
PDF	4%	10%	?
μ (scale)	4%	5%	?
M_t (< 3 GeV)	7.5%	5%	?

Signal/Background Separation

- Goal: to isolate each single top signal from its backgrounds (including other single top).
- The difficulty with single top production (W* in particular) is that the backgrounds at LHC are large.





Signal/Background Separation

Generators

- need generators for signals (Wg,Wt,W*) and backgrounds ($t\bar{t}$,$Wb\bar{b}$,Wjj)
- For polarization measurement we must keep track of helicity information in single top $\rightarrow$ angular distributions.

process	generator	cross-section(pb)
Wg	ONETOP, PYTHIA	244
Wt	ONETOP, SGPM	60
W*	ONETOP	10
$t\bar{t}$	ONETOP, PYTHIA	830
$Wb\bar{b}$	HERWIG*, ONETOP, SGPM	300
Wjj	HERWIG	18000**

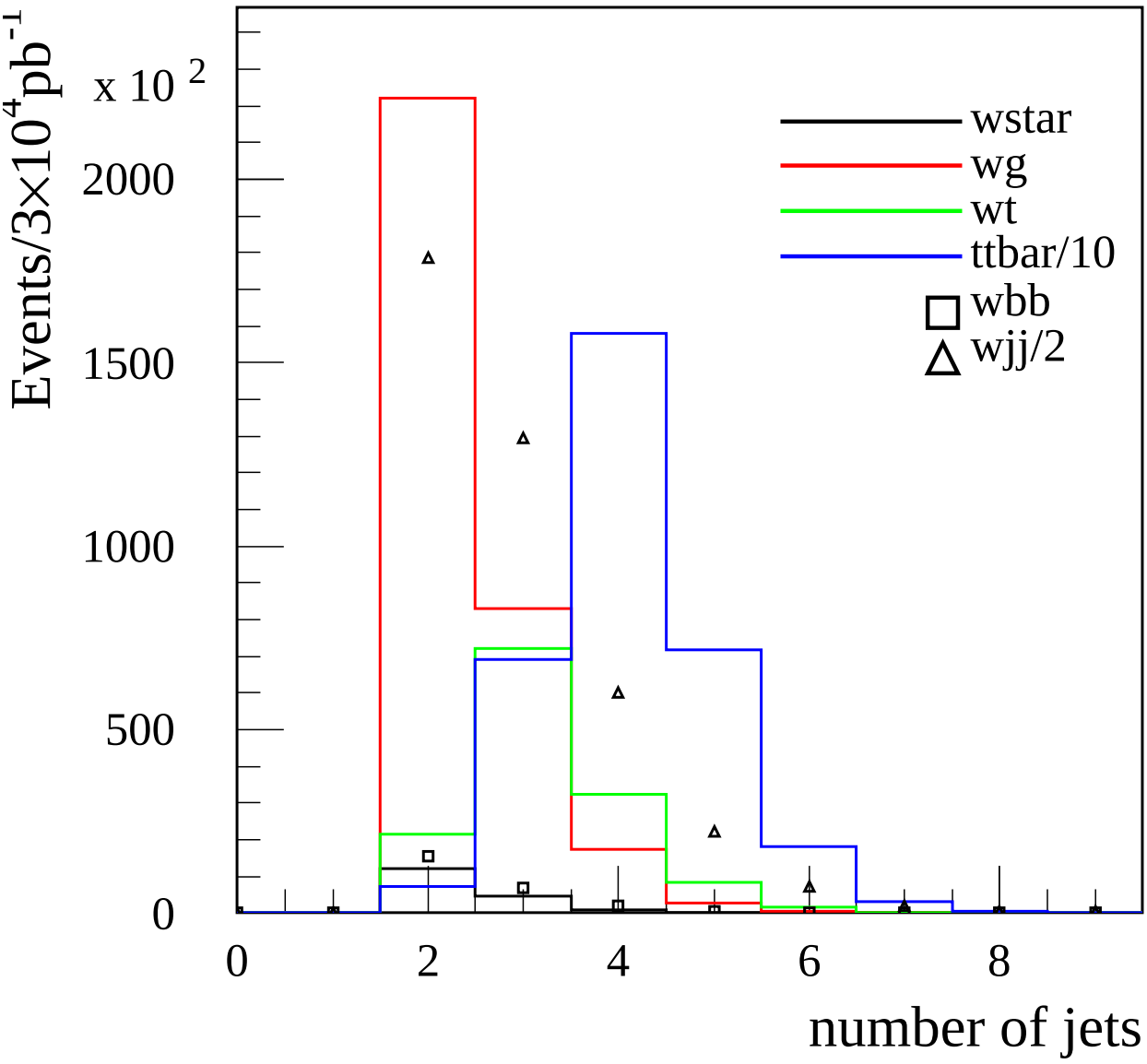
* M.E. from Mangano interfaced to HERWIG
** require 2 jets above 15 GeV P_{T} , $|\eta| < 5$

- ONETOP (MSU) keeps helicity information.
- ONETOP, SGPM use PYTHIA for fragmentation.
- All events are passed through ATLAS detector fast simulation program (ATLFAST).

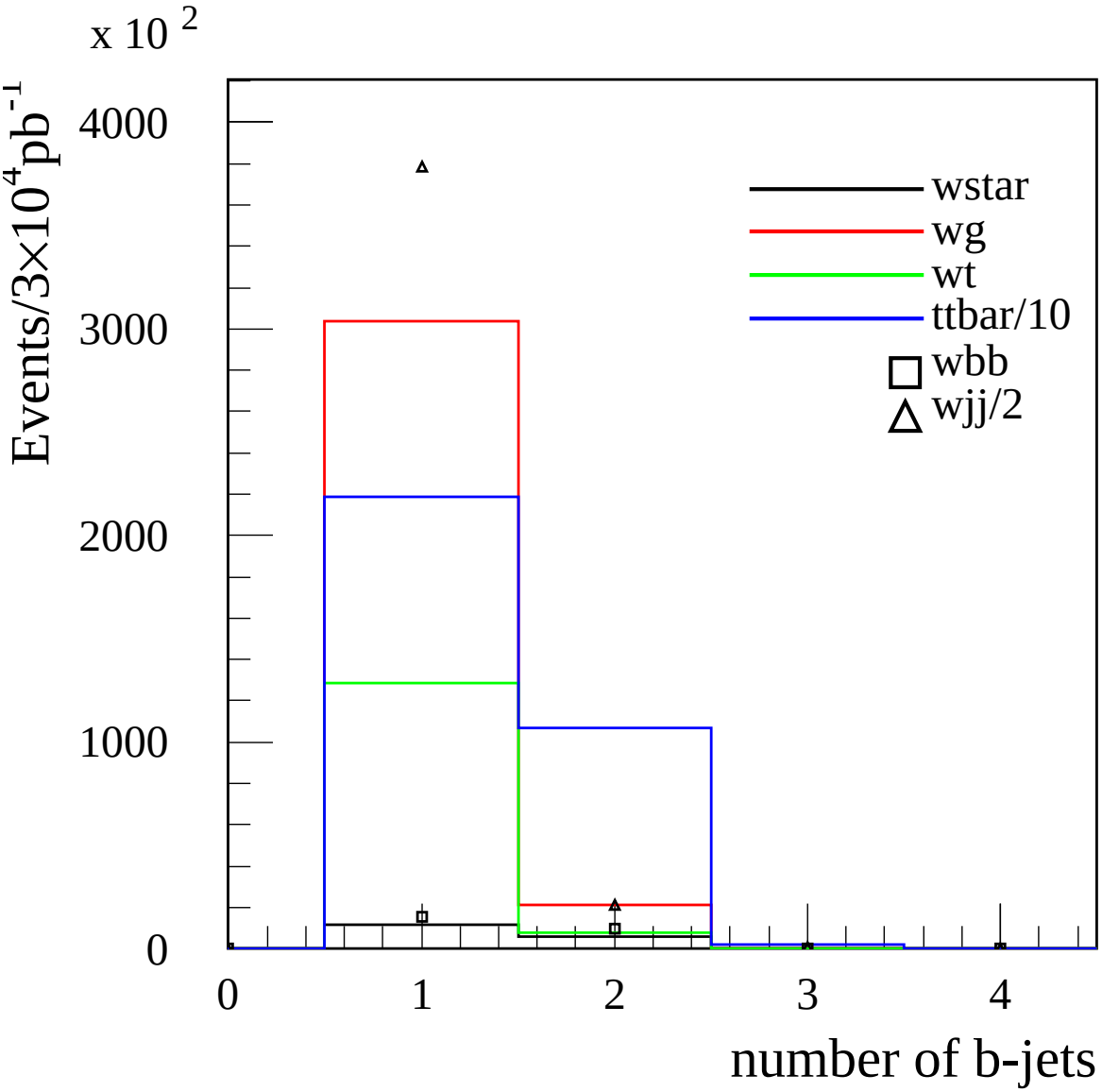
Signal/Background Separation

- Signals have kinematic differences. Useful variables include:
  - jet multiplicity
  - b-jet multiplicity
  - reconstructed invariant mass of event
  - sum of jet P_{T}
  - reconstructed top mass
- Use jet multiplicity, P_{T} to suppress $\mathrm{t\bar{t}}$.
- Use b-tagging, event mass, top mass to suppress non-top backgrounds.

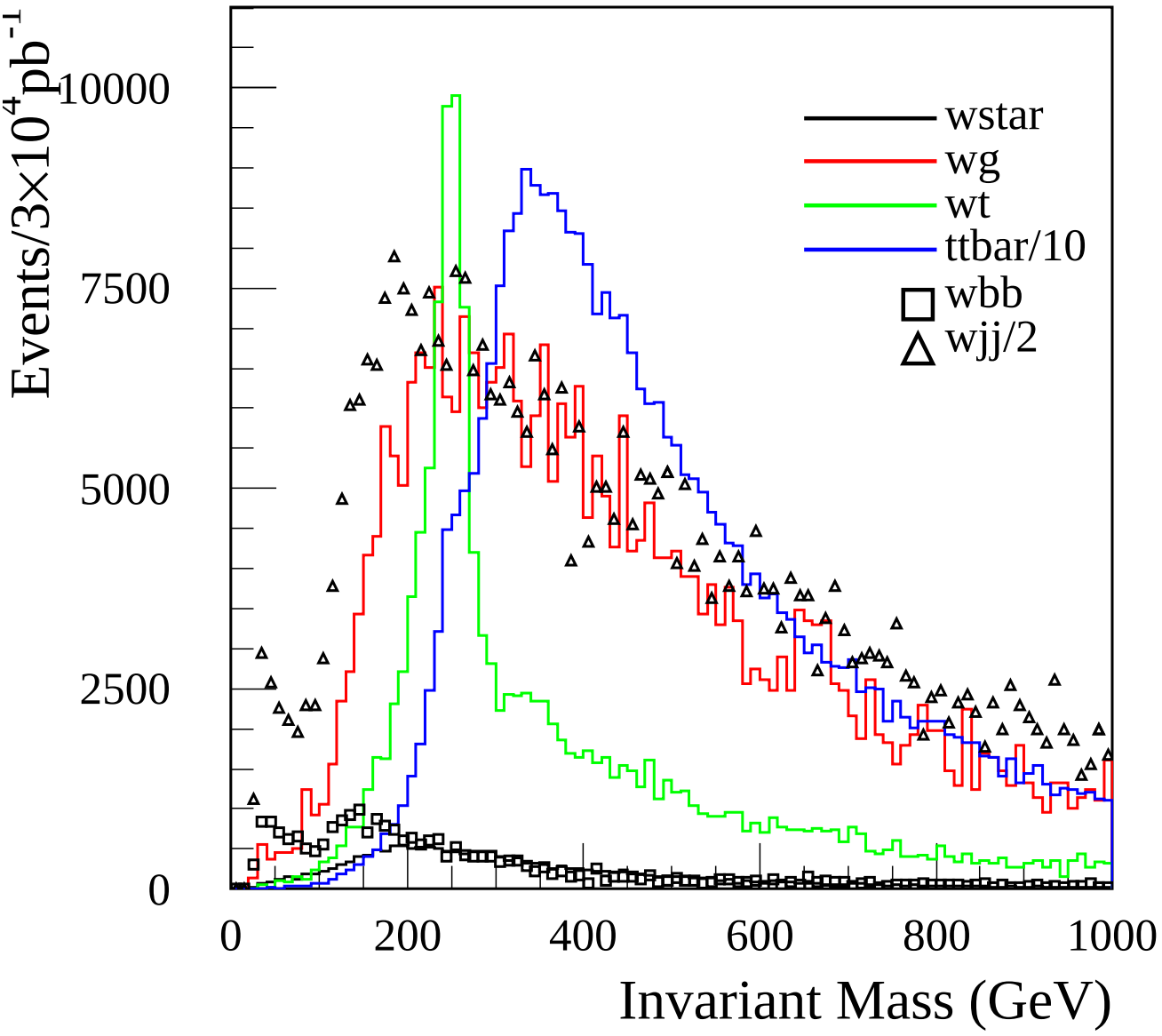
Signal/Background Separation



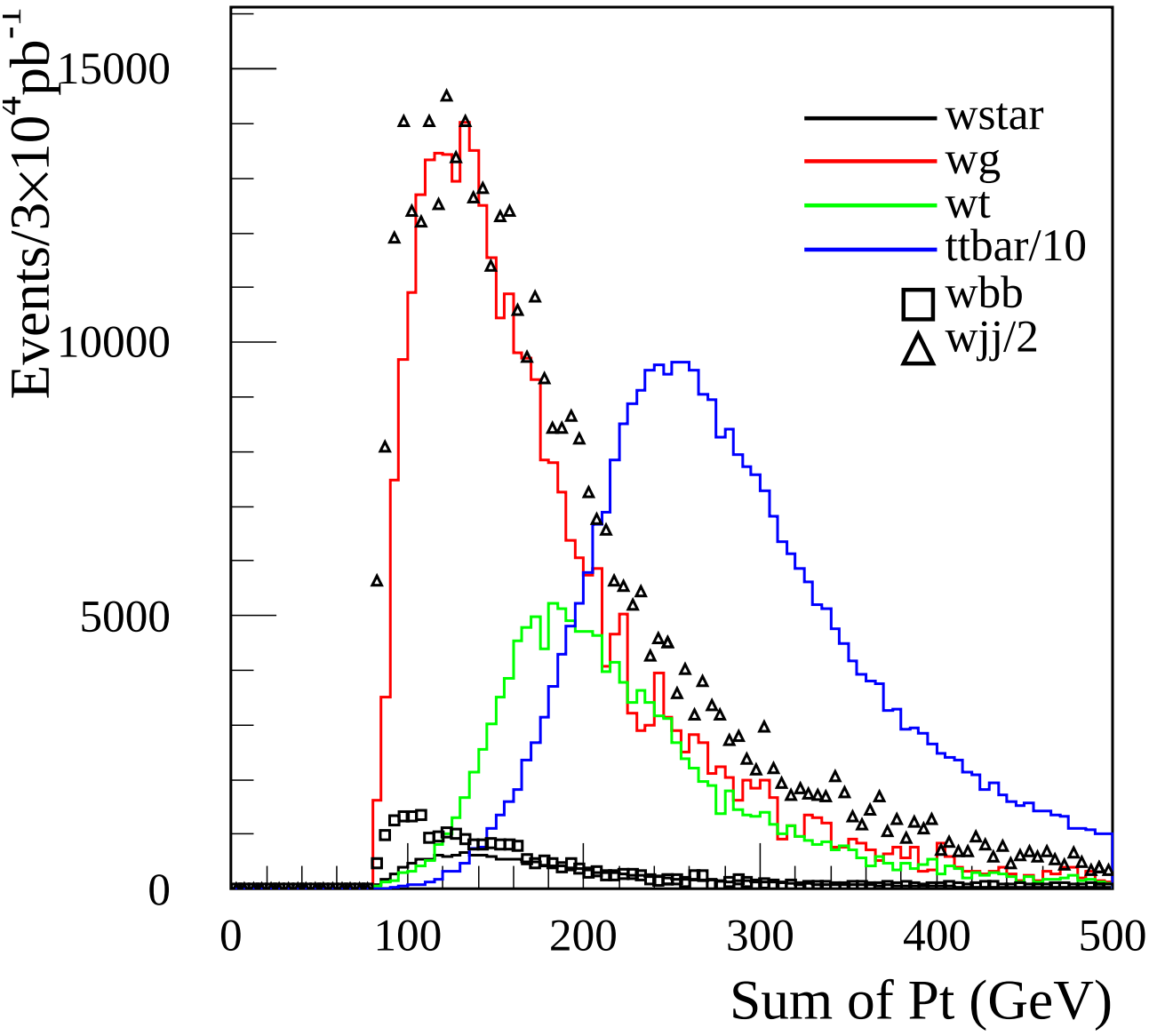
Signal/Background Separation



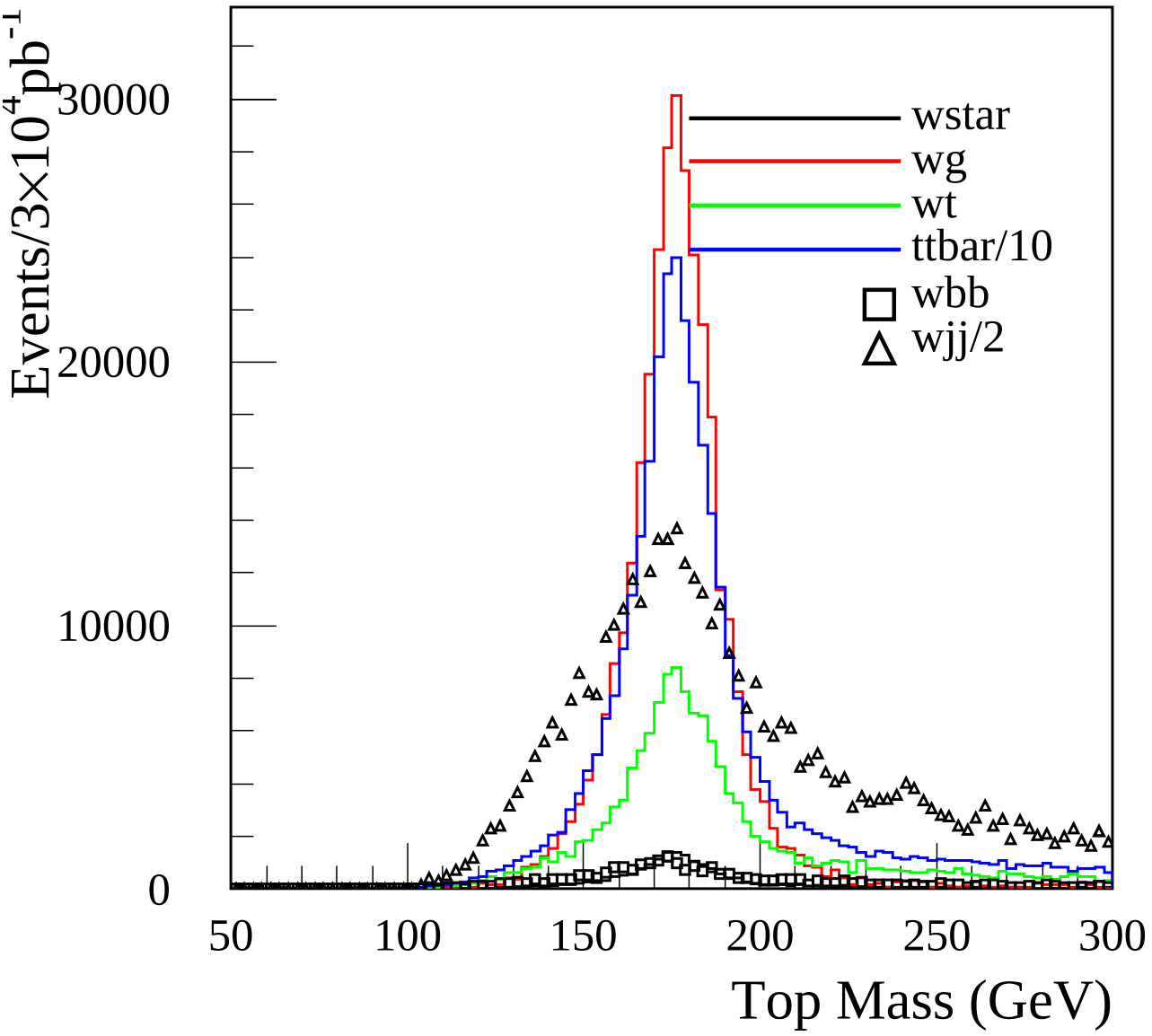
Signal/Background Separation



Signal/Background Separation



Signal/Background Separation



Event Selection

- Effort has been made to agree on minimum cuts (trigger) for all three single top processes.
  - b-jet above 50 GeV P_{T}
  - isolated lepton above 20 GeV P_{T}
- Other possible cuts at this level:
  - jet multiplicity (2 for Wg, W*, 3 for Wt)
  - forward jet above 50 GeV P_{T} for Wg

W-g fusion: MSU, Dubna

- Add "offline" cuts optimized for Wg:
  - njet = 2
  - forward jet above 50 GeV P_{T}
  - ΣP_{T} (j) > 200 GeV
  - $\mathrm{M_{total}} > 300$ GeV
  - $150 < \mathrm{m}_t < 200$ GeV
- Results for these example cuts ($3 \times 10^4 \mathrm{pb}^{-1}$):

Wg	=	26800 events	$\frac{S}{B} = 3.1$
$\mathrm{t\bar{t}}$	=	720 events	
Wbb	=	104 events	$\frac{S}{\sqrt{B}} = 286$
Wjj	=	7900 events	

- We can measure V_{tb} , polarization.

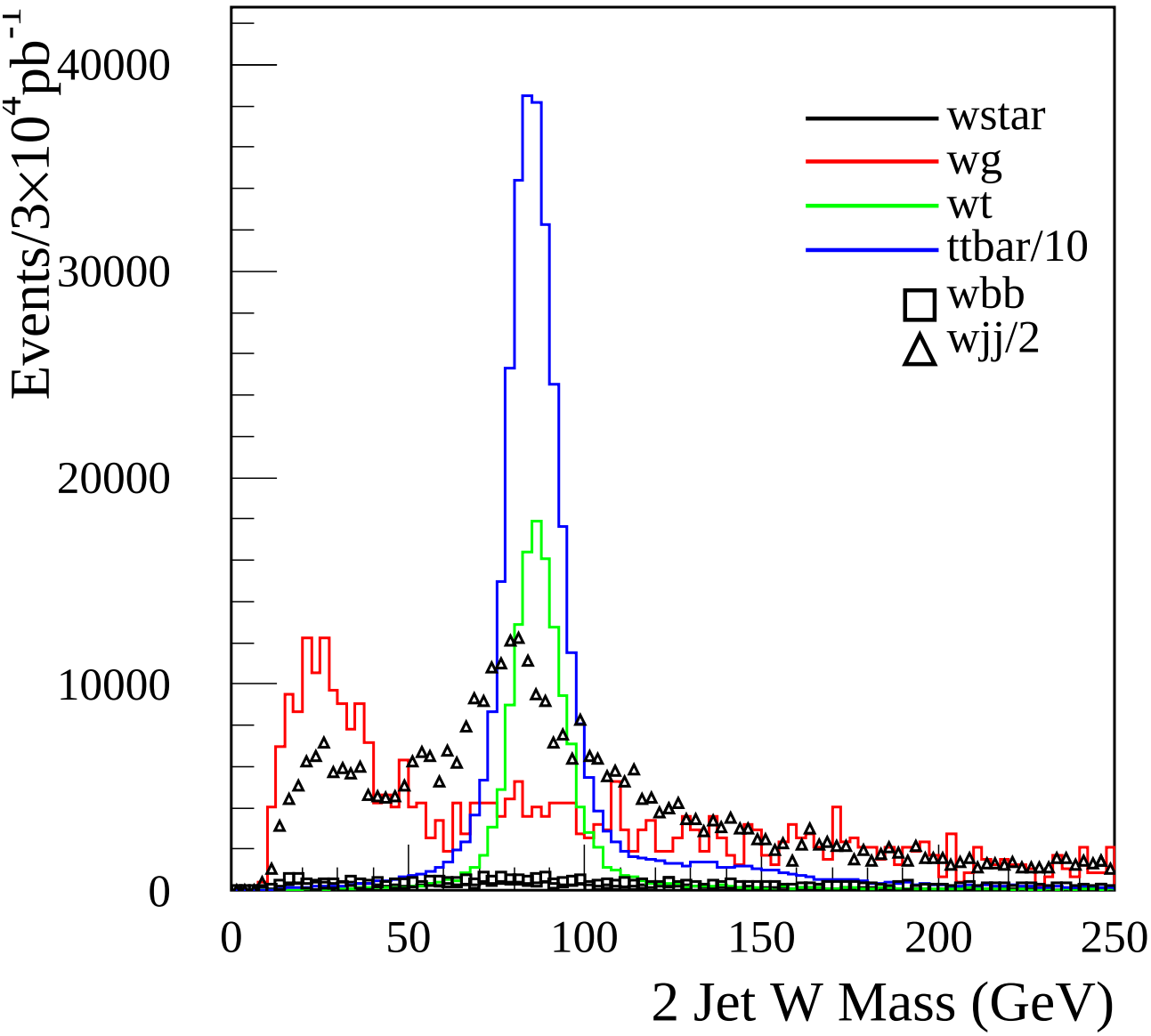
Wt: Protvino, Victoria

- looks like $t\bar{t}$
- Add "offline" cuts optimized for Wt:
  - njet = 3
  - nbjet = 1
  - $M_{total} < 300$ GeV
  - M_{jj} window 65-95 GeV
- 2-jet mass removes backgrounds except $t\bar{t}$
- Results for these example cuts ($3 \times 10^4 pb^{-1}$):

Wt	=	6828 events	$\frac{S}{B} = 0.22$
$t\bar{t}$	=	30408 events	
Wg	=	≈ 0 events	
Wbb	=	58 events	$\frac{S}{\sqrt{B}} = 39$
Wjj	=	≈ 0 events	

- We can measure V_{tb} . Polarization?

Wt: Protvino, Victoria



W*: Victoria

- Add "offline" cuts optimized for W*:
  - njet = 2
  - nbjet = 2, $P_{\mathrm{T}} > 75$ GeV
  - ΣP_{T} (j) > 175 GeV
  - $\mathrm{M}_{\mathrm{total}} > 200$ GeV
  - $150 < \mathrm{m}_t < 200$ GeV
- Results for these example cuts ($3 \times 10^4 \mathrm{pb}^{-1}$):

W*	=	1106 events
Wg	=	510 events
Wt	=	42 events
$\mathrm{t\bar{t}}$	=	1290 events
Wbb	=	328 events
Wjj	=	226 events

$$\frac{S}{B} = 0.46$$

$$\frac{S}{\sqrt{B}} = 23$$

- We can measure V_{tb} , polarization??

Measuring $V_{\rm tb}$

- Single top is the only way to directly measure $V_{\rm tb}$ at ATLAS. Rate $\propto |V_{\rm tb}|^2$.
- If we know the rates of the major backgrounds (from measurement at ATLAS) then we can measure the rate of single top to the following precision:

$$\frac{\Delta(\sigma)}{\sigma} = \frac{\sqrt{S+B}}{S}$$

- There is the potential to measure $V_{\rm tb}$ separately in each channel.

	$V_{\rm tb}$ stat	$V_{\rm tb}$ stat + th.
Wg	0.36%	6.0%
Wt	1.4%	??
W*	2.7%	5.7%

- Measurements are dominated by theoretical error (systematic?)
- Results show good statistical measurement in each single top channel!

Measuring W Polarization: MSU

- Probe the W-t-b vertex in top **decay**
- Measure angle between W and charged lepton in W rest frame. In SM:

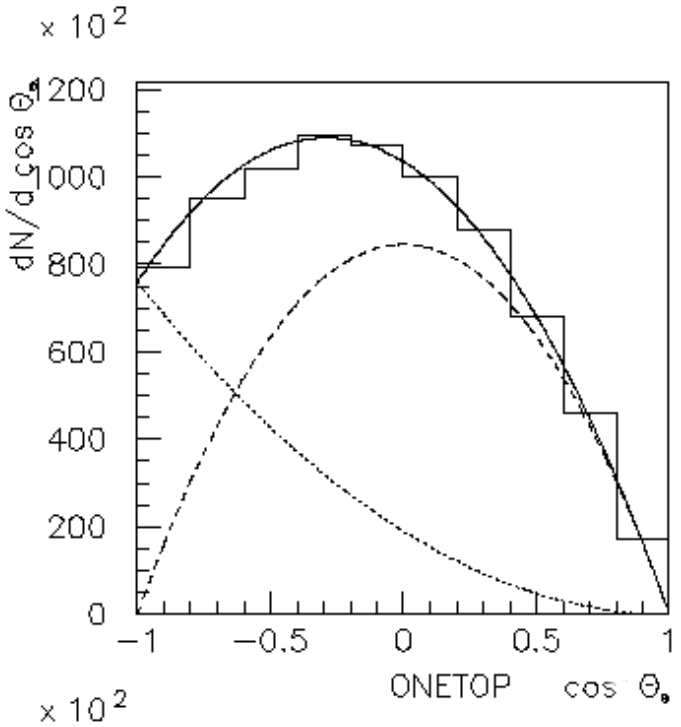
$$F(cos\theta_l) = \frac{3}{2}\left(f_{RH}\left(\frac{1+cos\theta_l}{2}\right)^2 + f_{LH}\left(\frac{1-cos\theta_l}{2}\right)^2 + f_{long}\left(\frac{sin\theta_l}{\sqrt{2}}\right)^2\right)$$

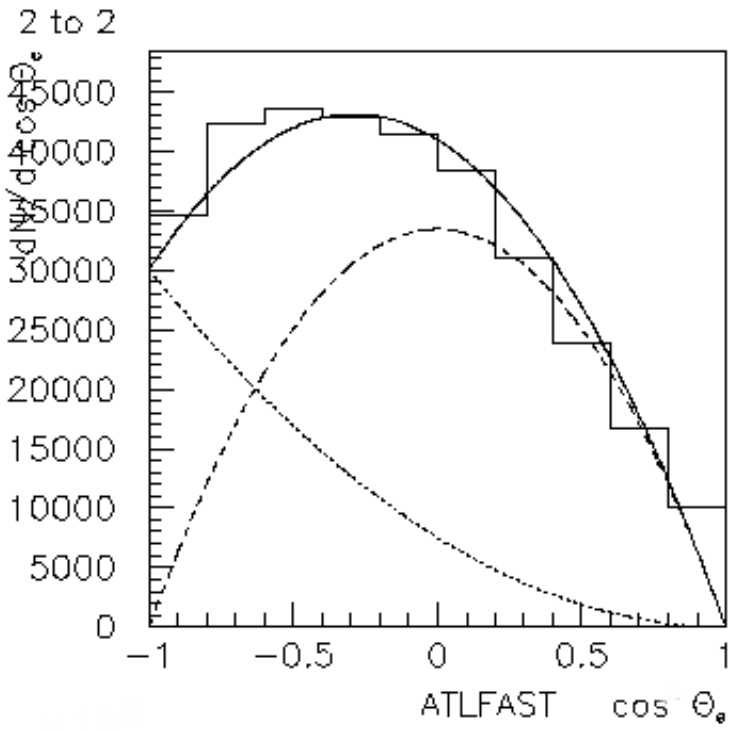
- For SM, $M_{top} = 175$ GeV, $f_{LH} = 30\%$, $f_{long} = 70\%$
- There is a "trick" to measure this in the lab frame:

$$cos\theta_l \approx \frac{2M_{lb}^2}{M_t^2 - M_W^2} - 1$$

- The distribution of $cos\theta_l$ can then be fit to a mixture of helicities $\rightarrow$ figure.

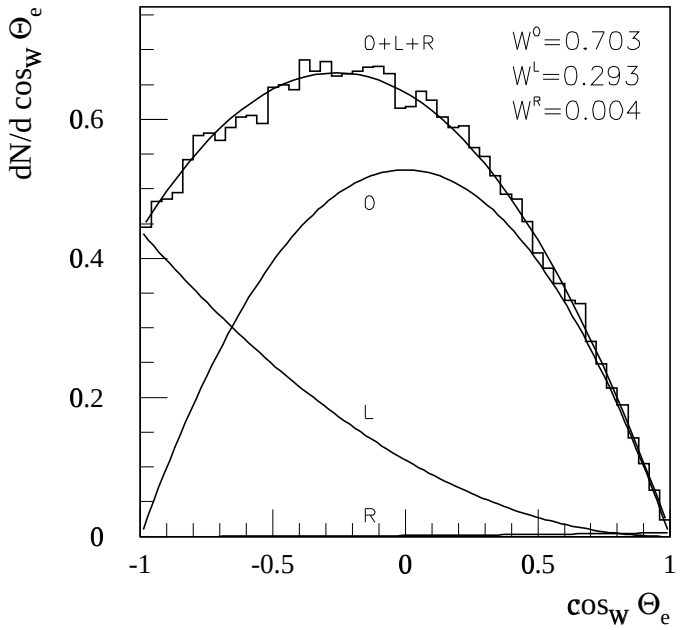
Measuring W Polarization: MSU



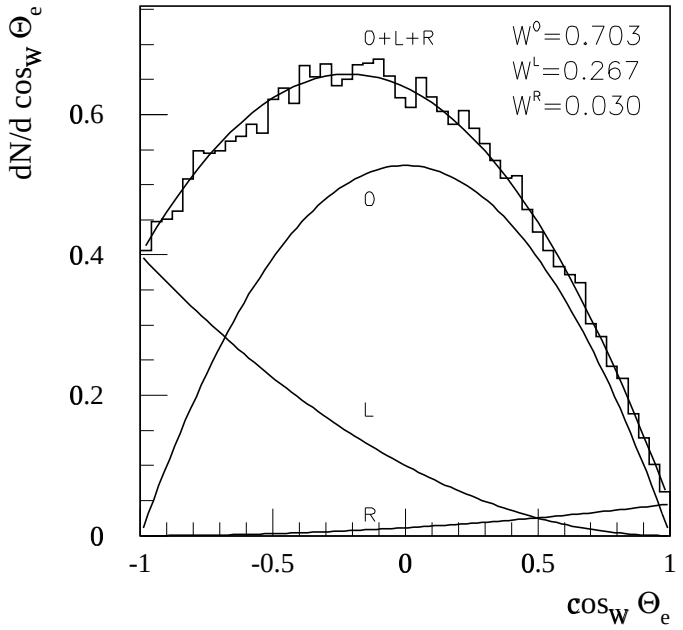


Measuring W Polarization: MSU

- RH component = 0 for SM

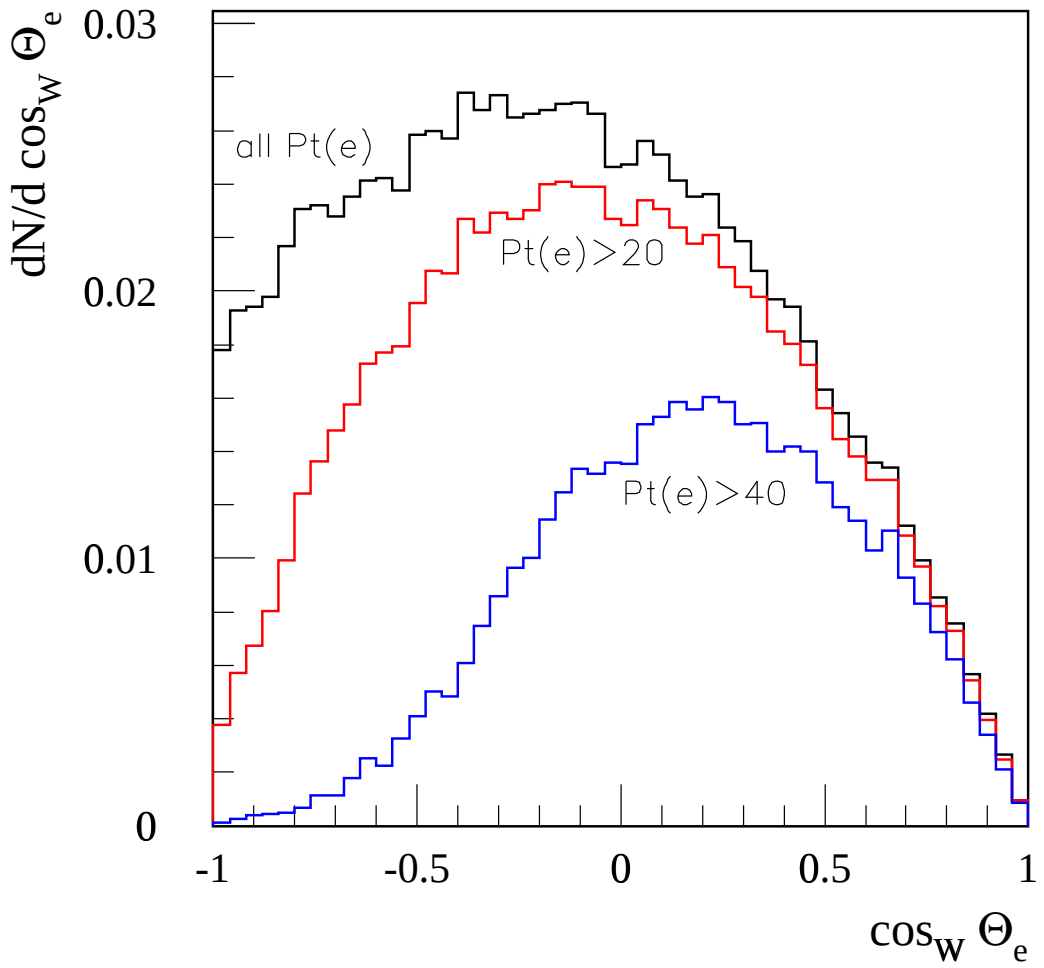


- We can use neutrino distribution to add RH component.



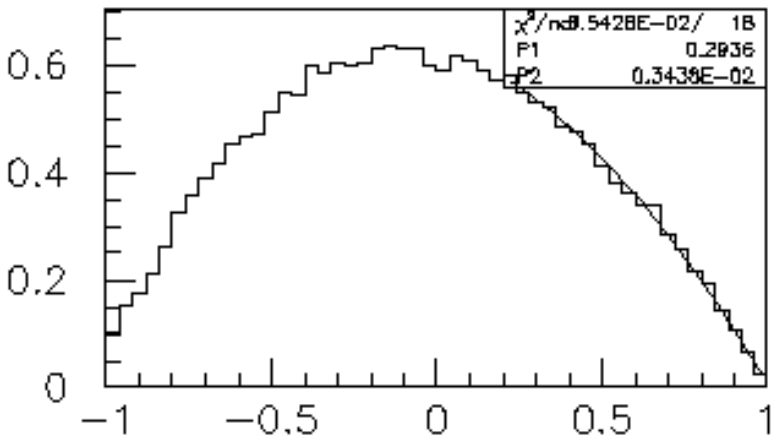
Measuring W Polarization: MSU

- Experimental cuts influence only part of distribution

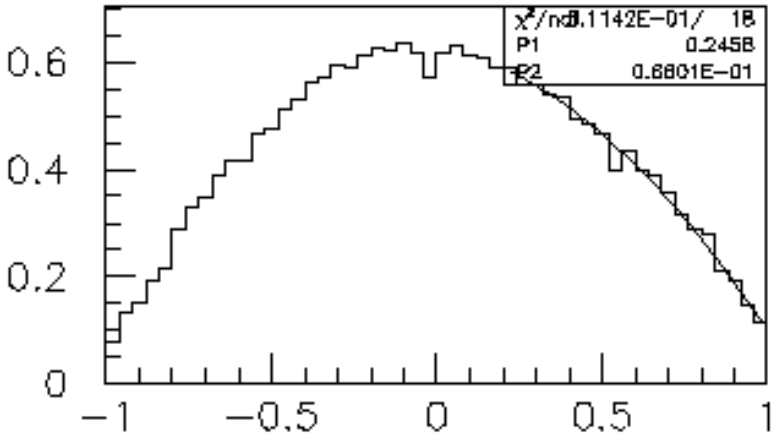


Measuring W Polarization: MSU

- We can still fit one edge of distribution.



L100 cos(eb) pt>20 (ε=0.95)



L80 cos(eb) pt>20 (ε=0.95)

Measuring Top Polarization: MSU, Victoria

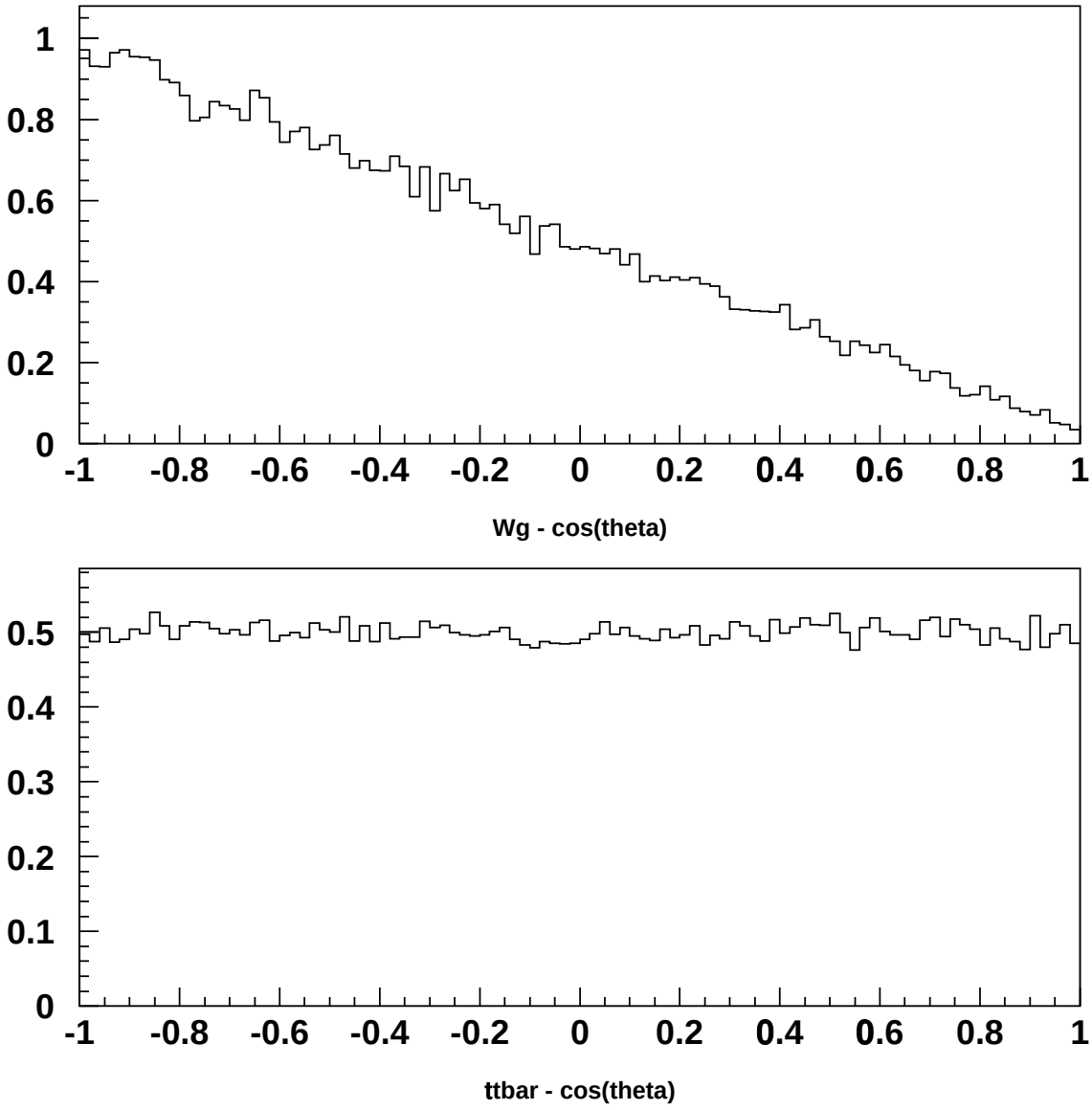
- Probe the W-t-b vertex present in top production - only single top!!
- We have a generator (ONETOP) which keeps the necessary helicity information. Interfaced to PYTHIA and ATLFAST.
- Boost to frame of incoming partons to get polarization axis (top direction). Ambiguities choosing neutrino momentum, b-jet.
- Measure charged lepton angular distribution in top frame

$$F_l(cos\theta_l) = \frac{1}{2}\left(1 \pm P cos\theta_l\right)$$

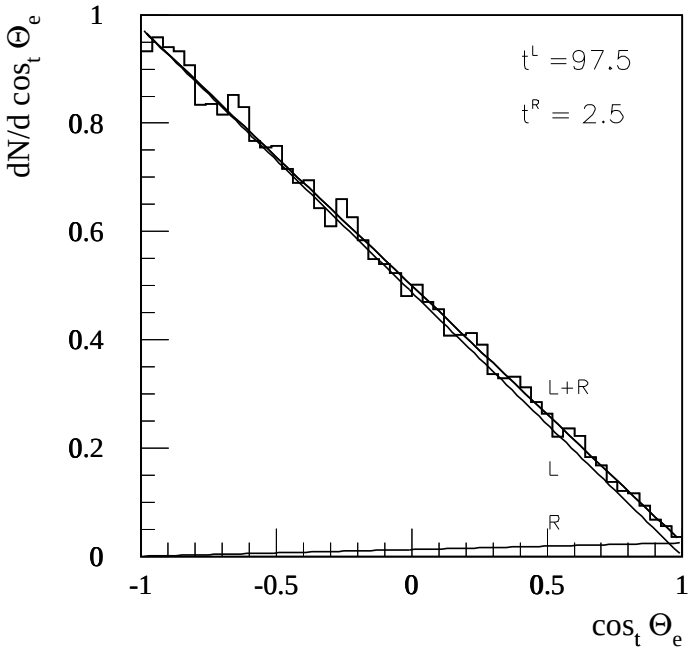
- Obtain P through fit or forward-backward asymmetry

Measuring Top Polarization: MSU, Victoria

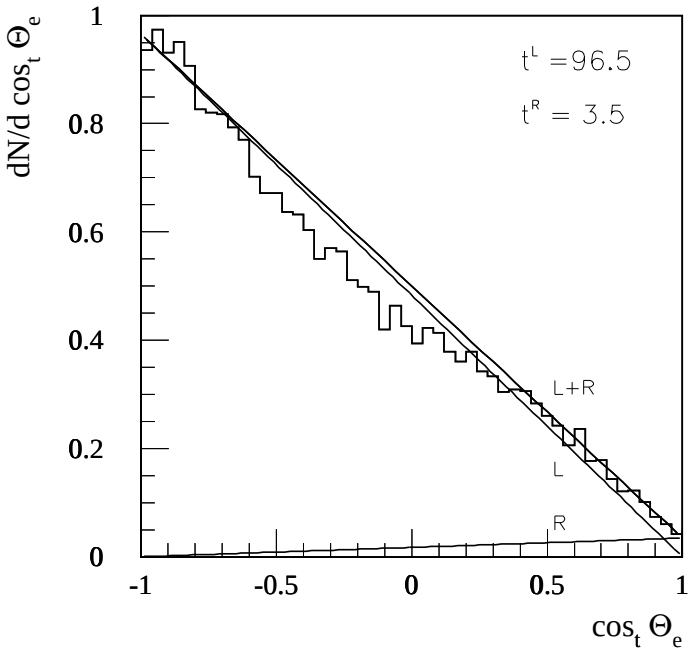
- Signal distribution is very asymmetric, ttbar background is flat



Measuring Top Polarization: MSU, Victoria



"perfect" reconstruction of ν momentum



ν momentum that gives best top mass

Polarization Measurement

- Work on measuring top and W polarization is ongoing.
- We have confirmed that we see the right things at particle level (ie. the generators work).
- More work is needed to measure effect of cuts and detector and make a statement about ATLAS measurement potential.
- ATLAS note to follow in the coming months

Summary

- Progress has been made in understanding signal/background separation at ATLAS.
- Three separate single top channels can be seen, $V_{\rm tb}$ can be measured in all three:

	S/B	$S/\sqrt{B}$	$V_{\rm tb}$ stat
Wg	3.1	286	0.36%
Wt	0.22	39	1.4%
W*	0.46	23	2.7%

  statisical error is smaller than theretical error
- Work is in progress on W and top polarization measurements. Next we need detailed examination of these results after detector and cut effects.
- Question: Is there anything else we should be doing? Suggestions?

Contact People

V_{tb}	R. Mekhtiev, D. Salighagic
	R. Brock, B. Gonzalez-Pineiro
	I. Gouz, S. Slabospitski
	M. Lefebvre, D. O'Neil
Polarization	R. Brock, B. Gonzalez-Pineiro
	M. Lefebvre, D. O'Neil