Study of top-quark production and decay vertices at NLC

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Top-quark physics

Top-quark is already discovered

… no longer ‘search’ physics

It also has potential to search new physics

m_{top} = 175 GeV … Uniquely heavy

Γ_t = 1.4 GeV … Decays very fast

NLC is excellent and much cleaner place to do it

…than LHC!!

Top-quark anomalous coupling analysis

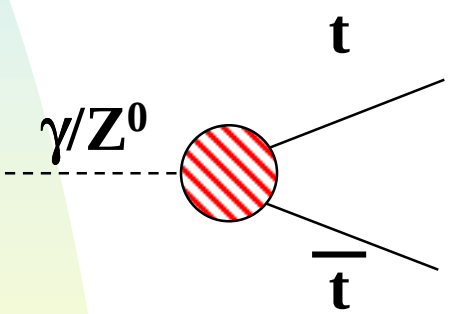
Top-quark decays before forming a hadron

→ **Top spin information is transferred to its daughters**

→ **can probe the couplings with their angular distributions**

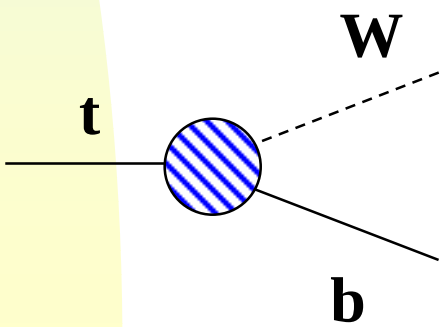
At NLC, we can probe both top-production + decay couplings

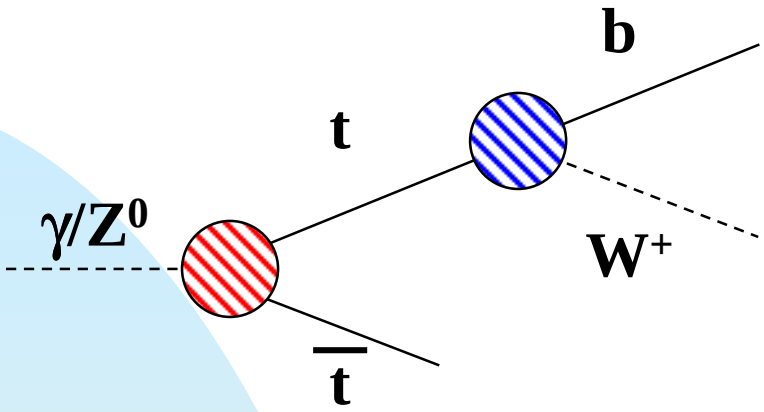
production



← **can't do at LHC!**

decay





: Form Factors

Form Factors at $\gamma/Z^0 \rightarrow t\bar{t}$ vertex:

$$iM = \{\gamma^\mu[\ F_{1V} + F_{1A}\gamma_5] + i\sigma^{\mu\nu}q_\nu/2m_t[\ F_{2V} + F_{2A}\gamma_5]\}$$

SM(Z):	$(1/4-\sin\theta_W^2)/\sin\theta_W\cos\theta_W$	$(-1/4)/\sin\theta_W\cos\theta_W$	0	0
(γ):	2/3	0	0	0

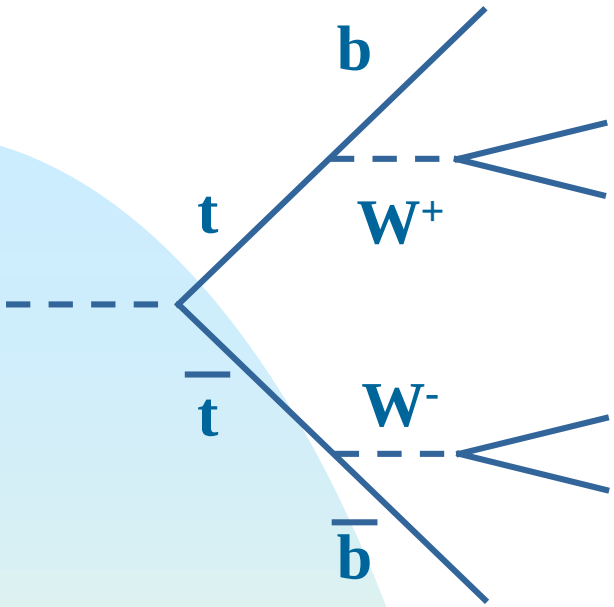
F_{2V}: Electroweak Magnetic Dipole moment

F_{2A}: Electric Dipole moment .. Non-zero → ~~CP~~

Form Factors at t→b W vertex:

$$iM = ig/\sqrt{2}\{\gamma^\mu[F_{1L}^{\ W}P_L + F_{1R}^{\ W}P_R] + i\sigma^{\mu\nu}q_\nu/2m_t[F_{2L}^{\ W}P_L + F_{2R}^{\ W}P_R]\}$$

SM:	1	0	0	0



Signal of $t\bar{t}$ production

… 2b's and 2W's

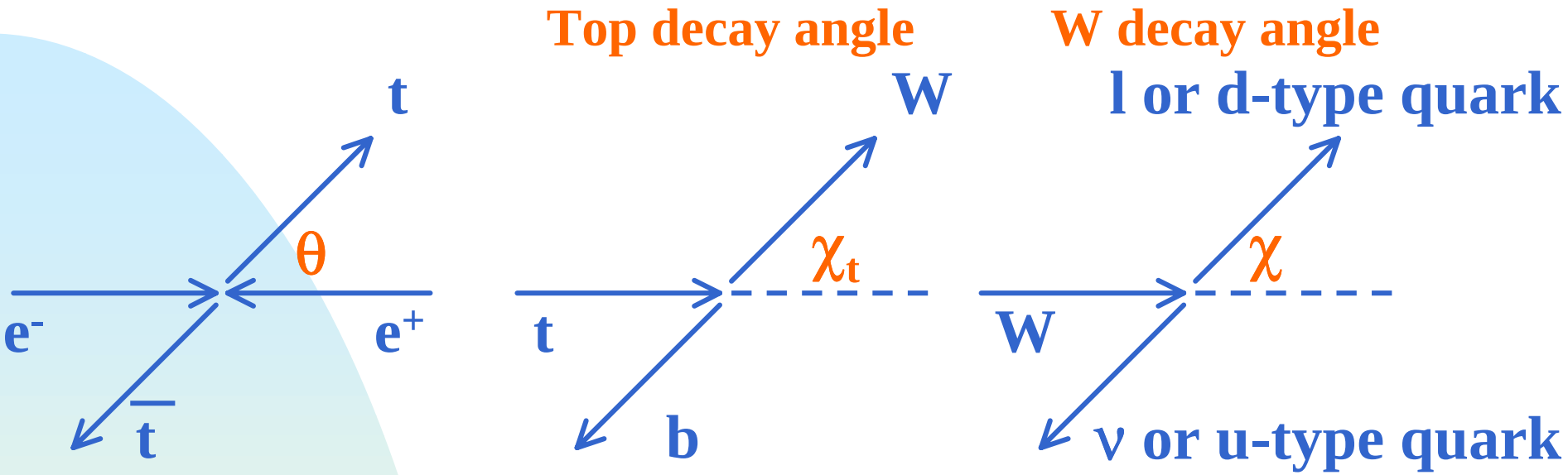
Depending on the W decay, there are 3 final states:

1) 2 leptons + 2 jets (both leptonic)

2) 1 lepton + 4jets (1 leptonic 1 hadronic)

3) 6 jets (both hadronic)

Here we define the angles



We want to measure these angles

Which one is t or $\bar{t}$? … use charge of the lepton

4-momentum of the leptonic decayed top-quark

… from the opposite top-quark

In this analysis, we use $t\bar{t} \rightarrow$ 4 jets + 1 lepton (μ or e)

Generate tt events with Pandora-Pythia

m_t = 175 GeV, E_{CM} = 500 GeV
including QCD effect(parton shower), ISR+beamstrahlung

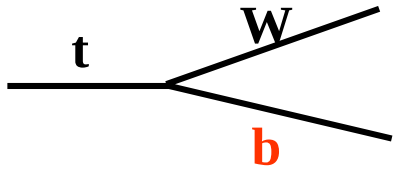
Beam polarization…

1) $P(e^-) = -0.8$	$P(e^+) = 0$	σ_{tt} = 742 fb
2) No polarization		565 fb
3) $P(e^-) = +0.8$	$P(e^+) = 0$	398 fb
4) $P(e^-) = -0.8$	$P(e^+) = +0.5$	1078 fb
	→ $P_{eff} = 0.93$	

- Generate 100 fb^{-1} each … Through LCD Fast Detector simulator
- Reconstruct 4 jets by Jet-clustering (JADE)
  … use charged tracks + Neutral clusters
  (charged/neutral cluster separation .. Perfect)
- Reconstruct W by 2 jets
- Reconstruct Top by W + b-jet (Apply $0.85 < E_{3jets}/E_{beam} < 1.05$)

Flavor-tagging

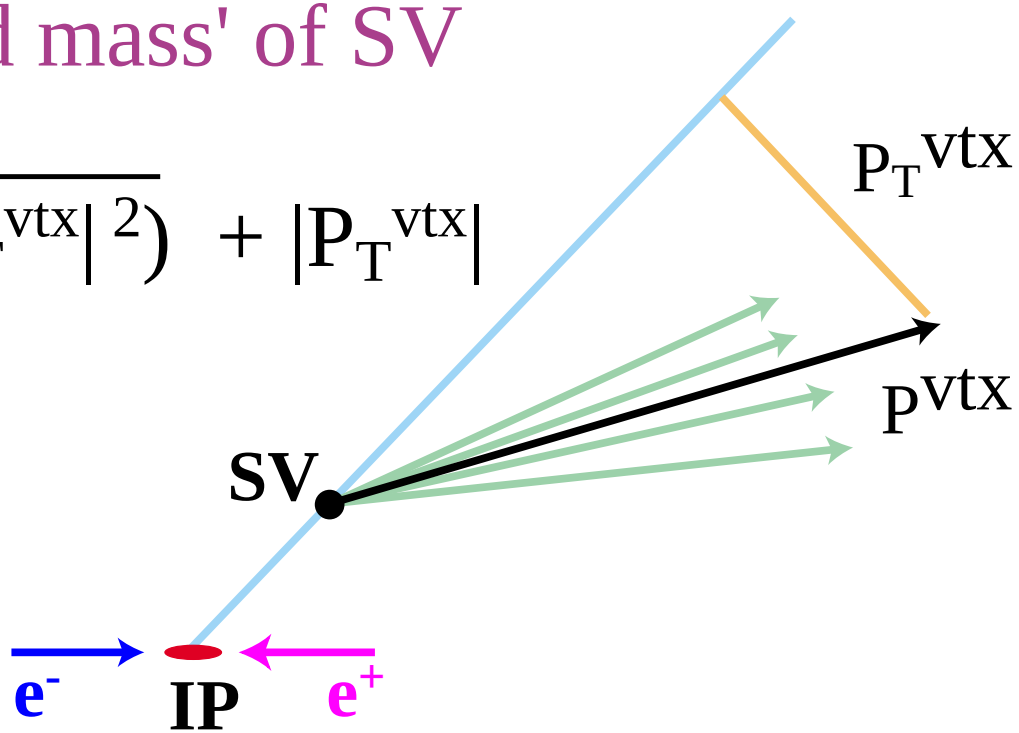
To tag b-quark, we use mass-tag method



1. Reconstruct Secondary Vertex

2. Form 'P_T-corrected mass' of SV

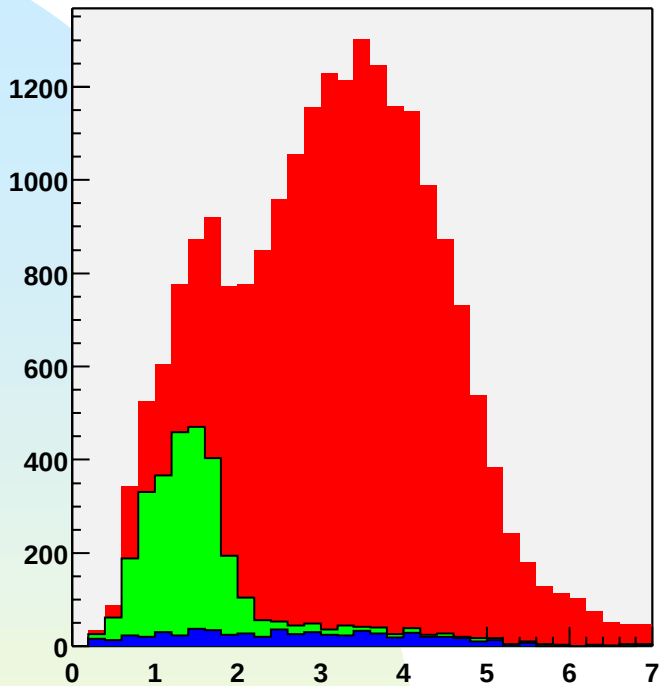
$$M_{corr.} = \sqrt{(M_{vtx}^2 + |P_T^{vtx}|^2)} + |P_T^{vtx}|$$



3. Identify heavy-quark signals with M_{corr}

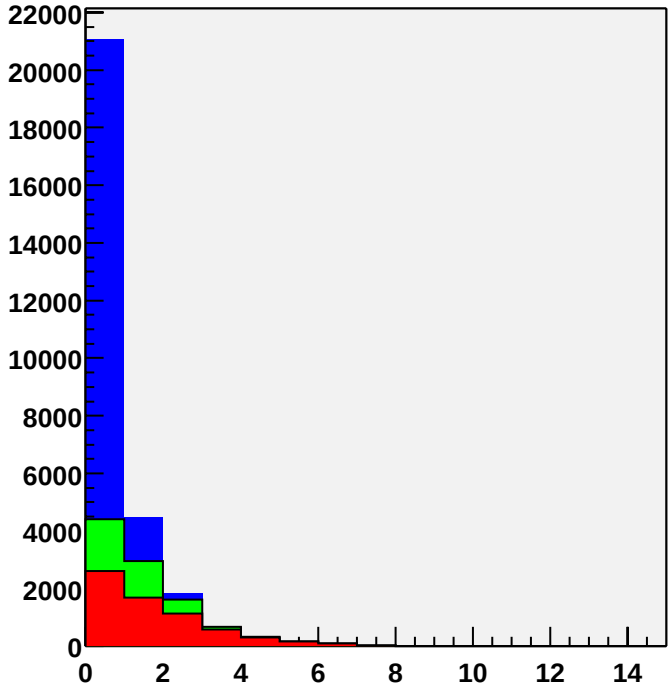
Flavor tagging

heavy-quark



P_T corrected mass(GeV)

uds-quark



# of significant tracks in jet

b : P_T corrected mass > 1.8 GeV

efficiency = 67% purity = 95%

c+b: P_T corrected mass > 0.5 GeV

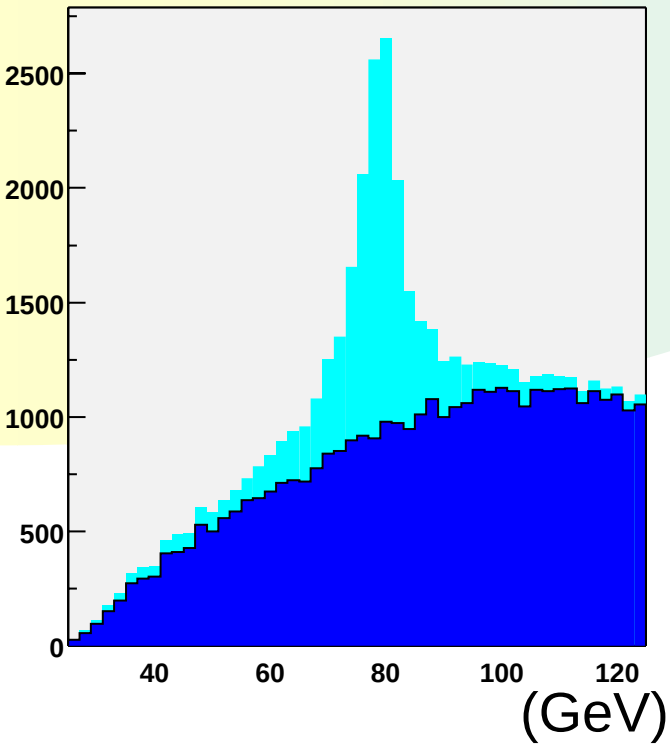
efficiency = 67% purity = 97%

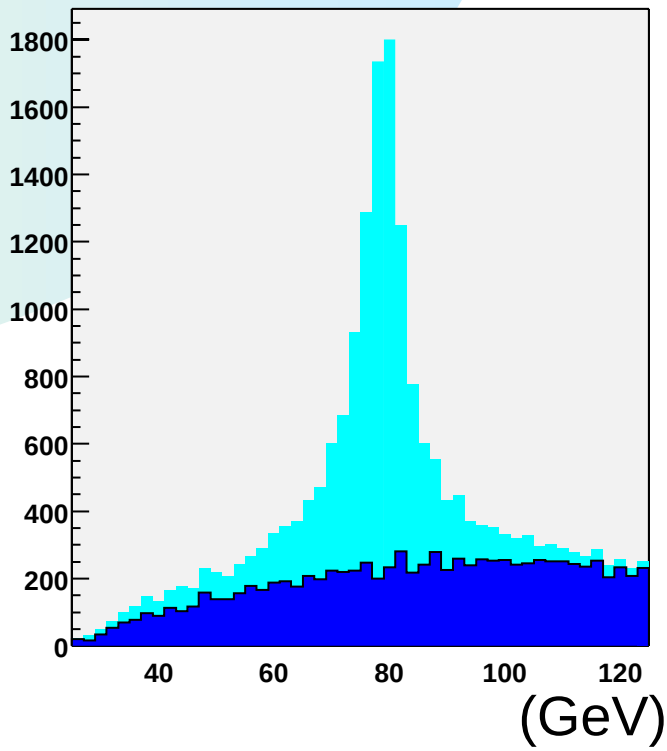
uds: Nsig = 0

efficiency = 87% purity = 79%

Reconstructed W with 2 jets

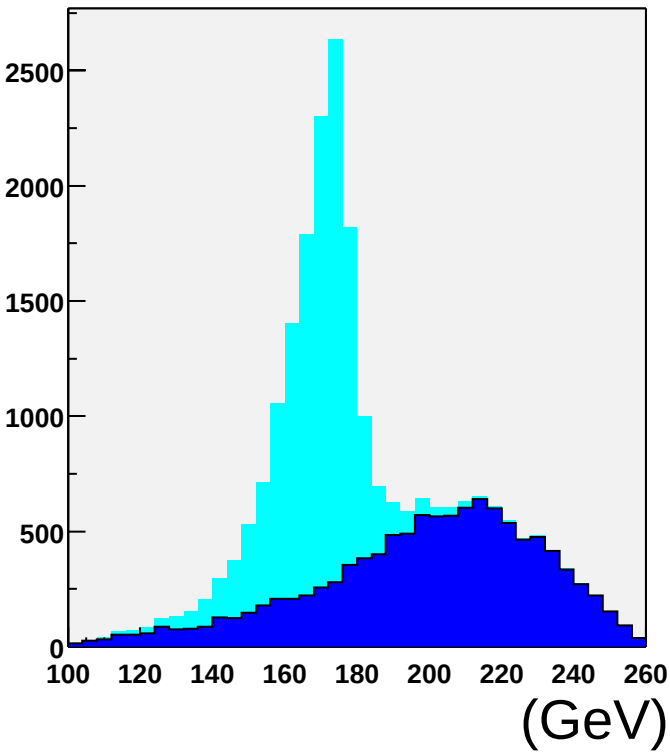
With flavor-tag

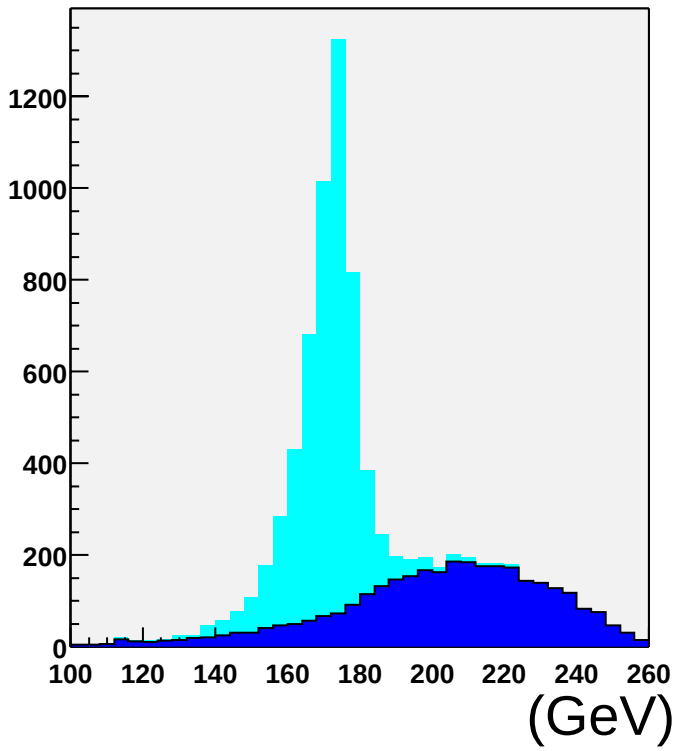




Reconstructed top with 3 jets

With flavor-tag





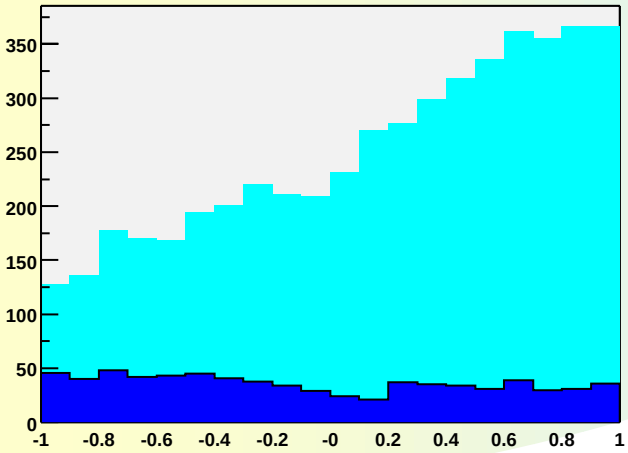
Selection efficiency::

Event selection	$\varepsilon = 60\%$
Top selection	50%
Flavor-tag	67%
Total	20%

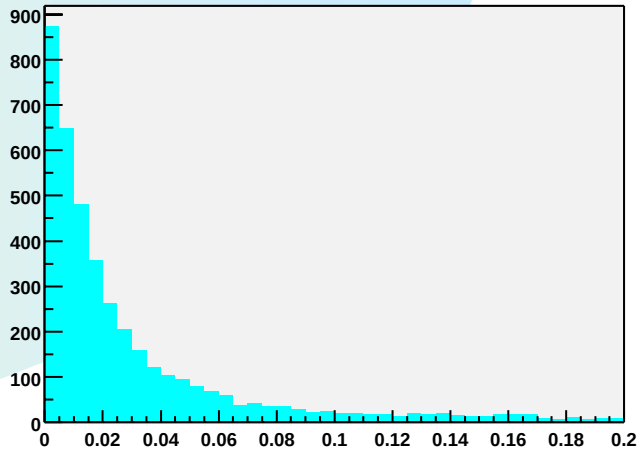
Top-reconstruction performance::

purity	88%	(80% without flavor-tag)
correct b-assign	86%	(53%)
Mass resolution	7.6 GeV	(10.0 GeV)

Reconstructed Angular Distributions

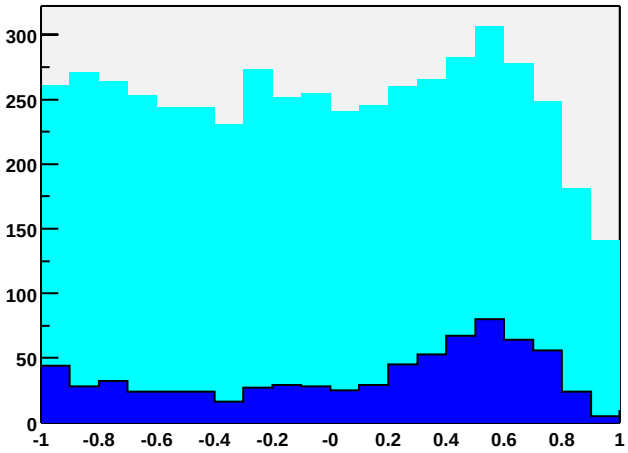


$\cos\theta$

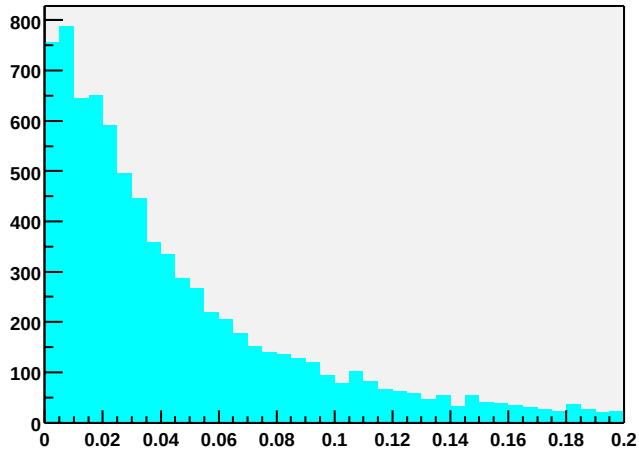


$\Delta\theta(\theta - \theta_{gen})$

$\Delta\theta = 23\text{mrad}$

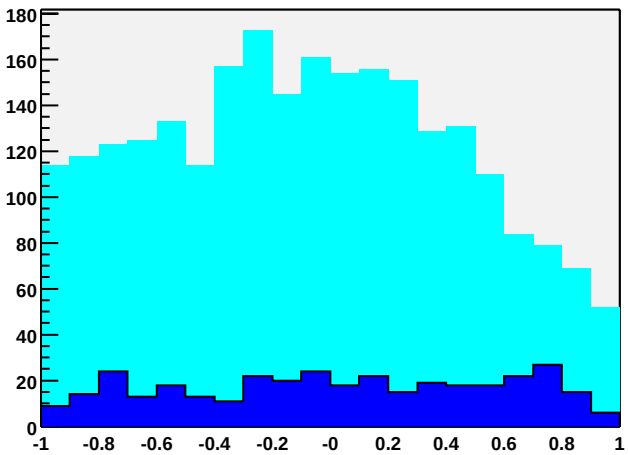


$\cos\chi_t$

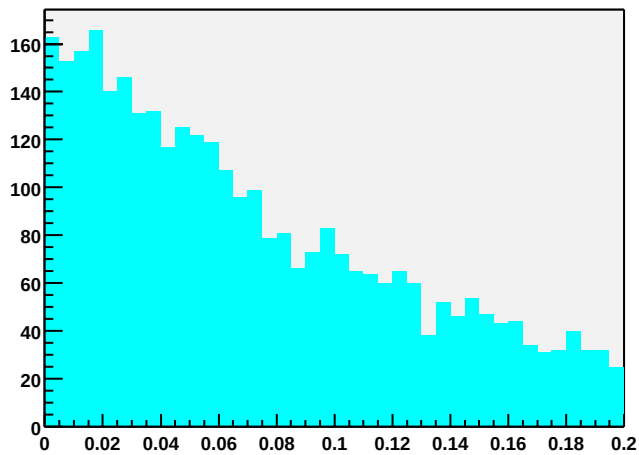


$\Delta\chi_t$

$\Delta\chi_t = 52\text{mrad}$



$\cos\chi$



$\Delta\chi$

$\Delta\chi = 100\text{mrad}$

Preliminary sensitivities to the couplings (γ/z t $\bar{t}$ vertex)

1) $F_{1,2A}^{Z,\gamma}$ → Maximum Likelihood method

2) $F_{1,2V}^{Z,\gamma}$ → L/R asymmetry

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1) Sensitivities to $F_{1,2A}^{Z,\gamma}$ for 100 fb^{-1} (68% CL)

	F_{1A}^{γ}	F_{1A}^{Z}	F_{2A}^{γ}	F_{2A}^{Z}
$P(e^-) = -0.8$	0.011	0.013	0.016	0.049
$P(e^-) = -0.8$ $P(e^+) = +0.5$	**0.009**	**0.011**	0.021	**0.033**
No polarization	0.011	0.014	**0.013**	0.059
P(e-) = +0.8	0.011	0.015	0.014	0.052

→ positron polarization is useful (~20% effect)

2) Sensitivities to $F_{1,2V}^{Z,\gamma}$ using L/R asymmetry (200 fb^{-1})

$A_{LR} = (0.335 \pm 0.017)/0.8$ (for |Pe| = 0.8)

→ F_{1V}^{γ} : 0.047 F_{1V}^{Z} : 0.012

F_{2V}^{γ} : 0.038 F_{2V}^{Z} : 0.009

$P(e^-) = -0.8$

1) Without ISR, Beamstlahlung, parton-shower
2) With ..
3) With .. + Energy Flow (detector LD)

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	1)	2)	3)
Top efficiency	24%	20%	14%
Top purity	90%	87%	86%
Δm_{top}	5.8 GeV	7.6 GeV	9.4 GeV
$\Delta\theta$	14 mrad	23 mrad	39 mrad
F_{1A}^{γ} sensitivity	0.010	0.011	0.012
F_{1A}^{Z}	0.012	0.013	0.015
F_{2A}^{γ}	0.012	0.016	0.018
F_{2A}^{Z}	0.039	0.049	0.058

Summary

We estimate very preliminary sensitivities (real parts)

1) From Maximum Likelihood analysis (100 fb^{-1})

F_{1A}^{γ} ~0.01 F_{1A}^{Z} ~0.01 F_{2A}^{γ} ~0.02 F_{2A}^{Z} ~0.05

2) From L/R asymmetry (100+100 fb^{-1})

F_{1V}^{γ} ~0.05 F_{1V}^{Z} ~0.01 F_{2V}^{γ} ~0.04 F_{2V}^{Z} ~0.01

Positron polarization is useful (P=0.5 ~20% effect)

ISR, beamstrahlung, parton-showering

… inflate error by 10-30%

Perfect Energy-Flow → Realistic analysis

… inflate error by 10-20%

Future plan

1) tt→ 6 jets analysis

top-quark sign.. determined by vertex charge of b-jet

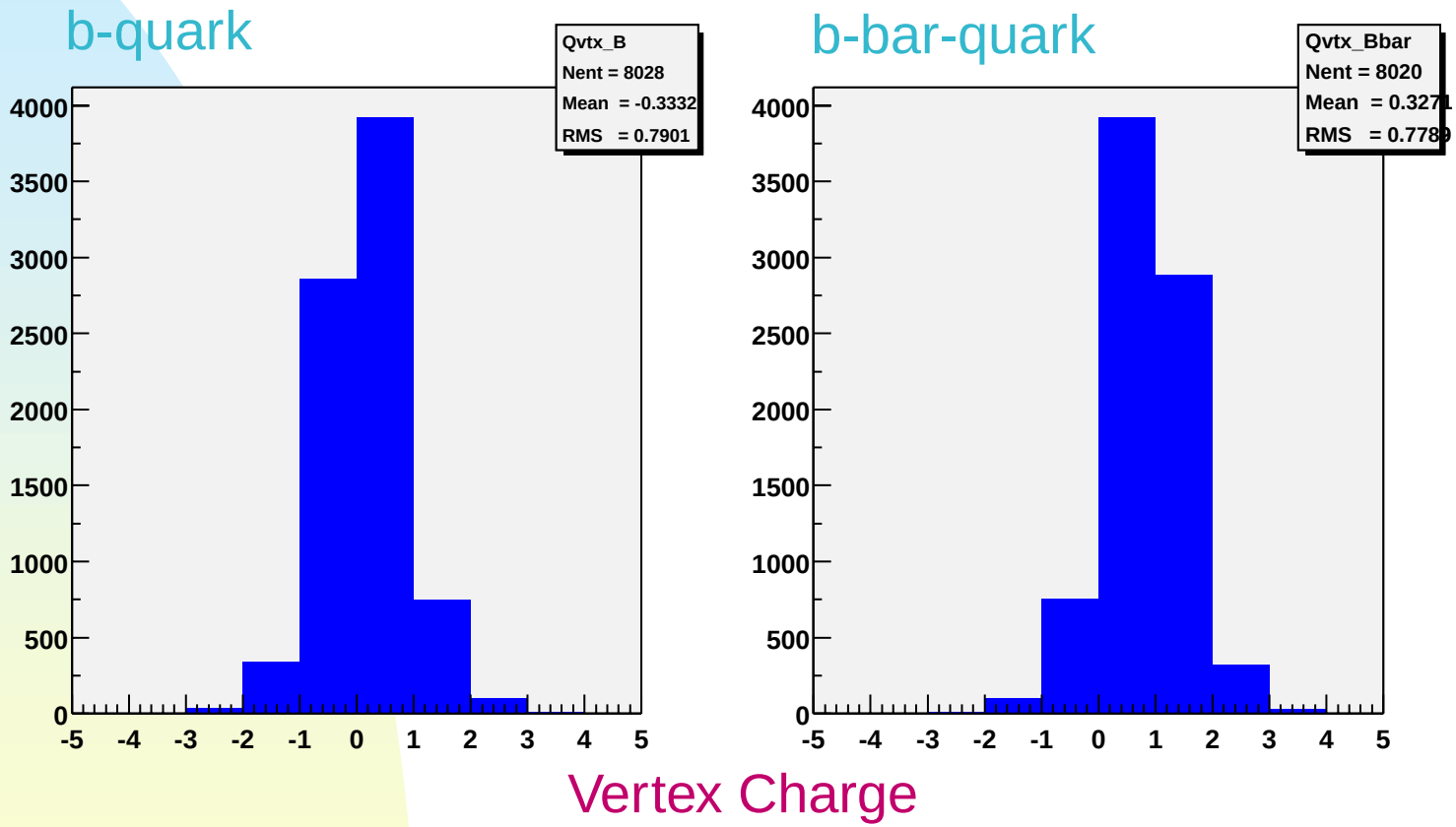
2) Kinematical constraint fit

How to tag t or t-bar??

Using Vertex charge of b-jet,

we know b or $\bar{b}$ → t or $\bar{t}$!

(Vertex Charge … Charge sum of the reconstructed Secondary Vertex)



Require at least 1 b-jet has Vertex Charge ≠ 0

→ We can determine t or $\bar{t}$ with purity 83%

efficiency 57%