Naïve-T-odd asymmetry in W+jet events at the LHC

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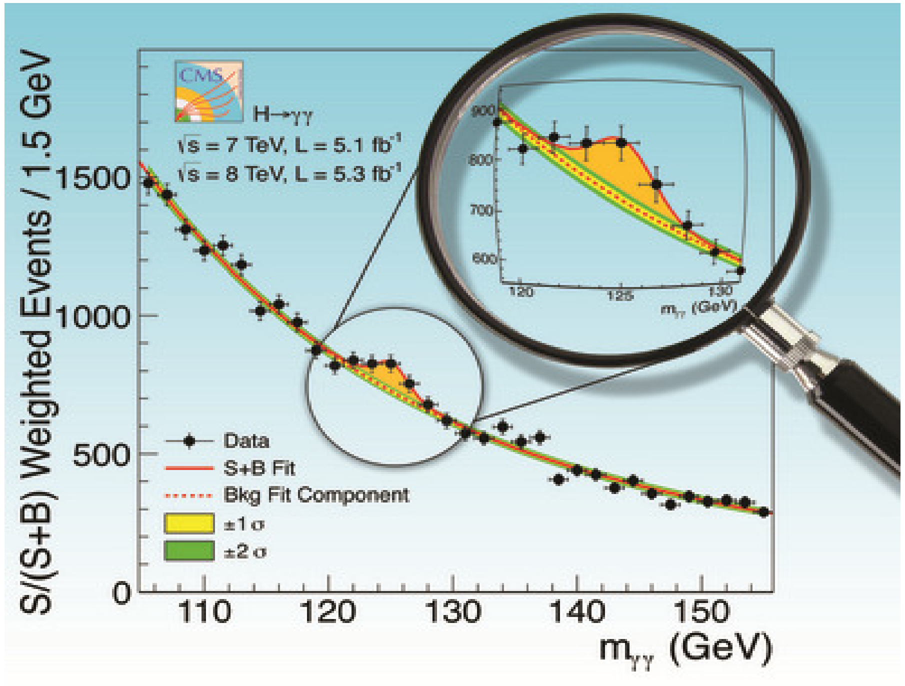
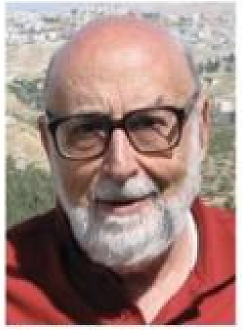
Outline:

1. Introduction: W production at hadron colliders
2. Parity-odd and naïve-T-odd observables
3. Simulation study
4. Summary

Introduction



Physics 2013



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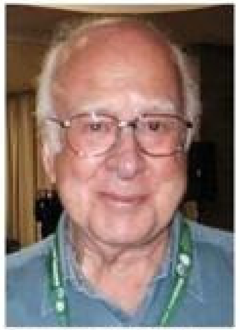

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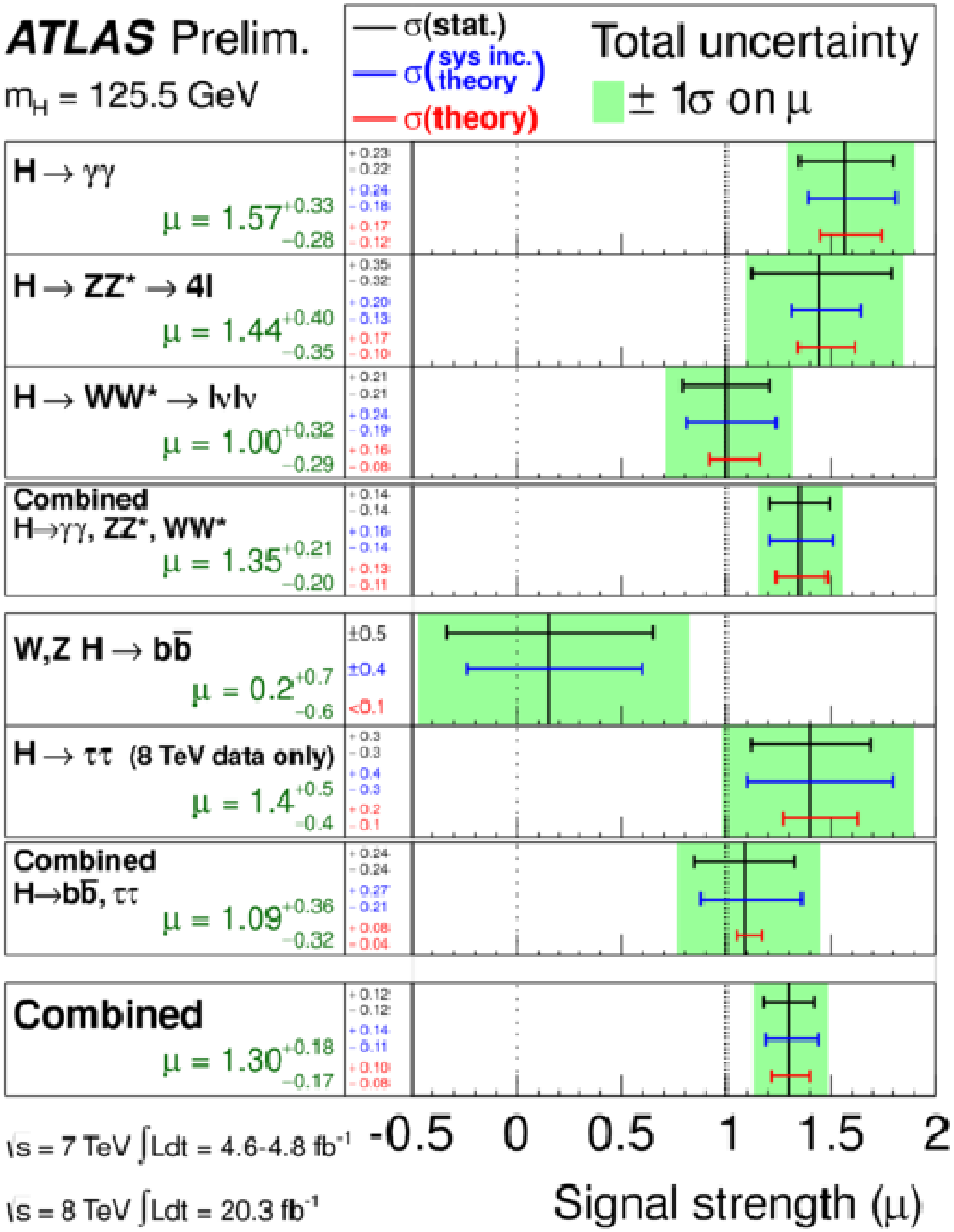
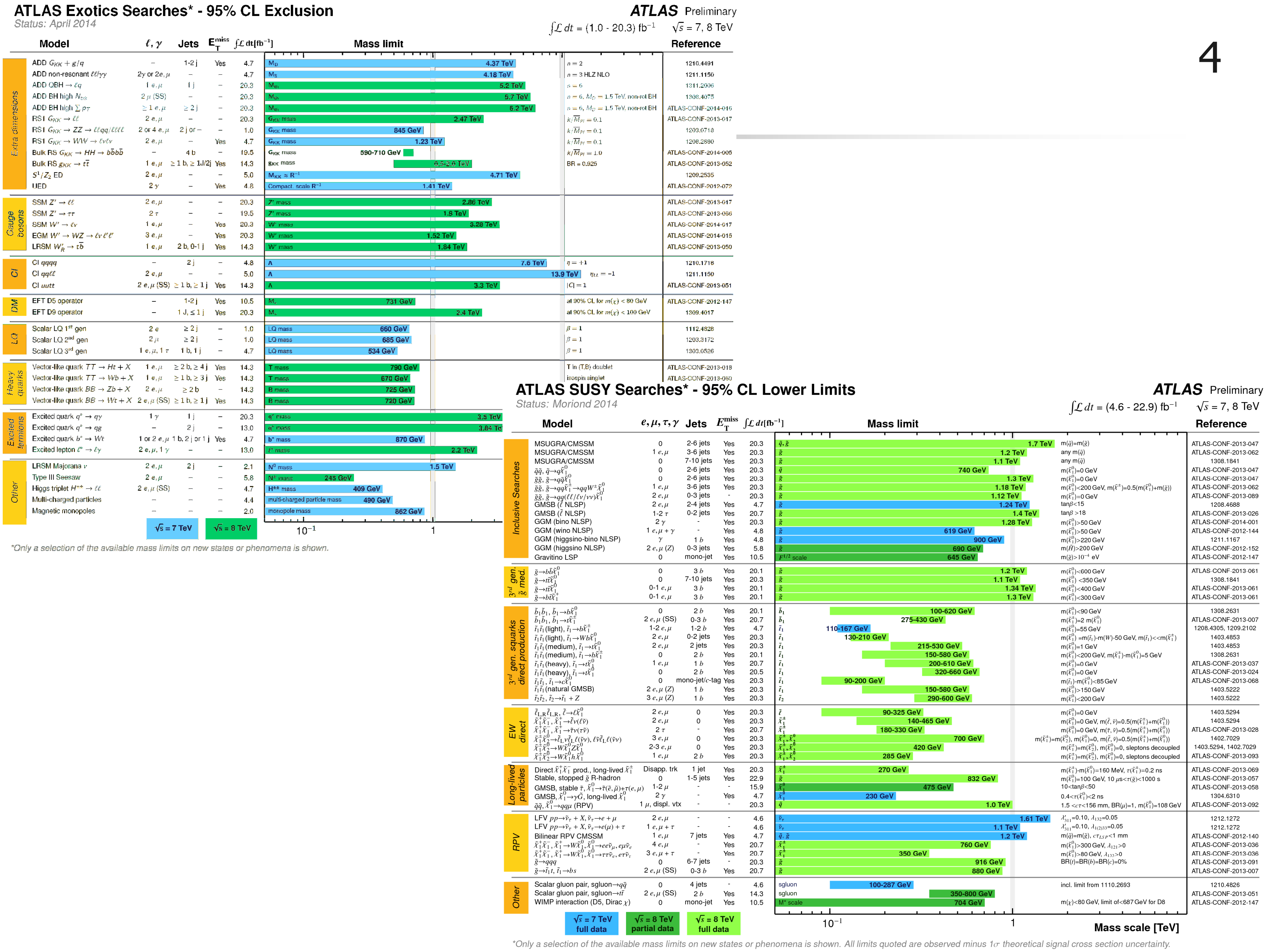




ATLAS Exotics Searches* - 95% CL Exclusion
Status: April 2014

ATLAS Preliminary
$\int\mathcal{L}\,dt$ = (1.0 - 20.3) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	ℓ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[fb^{-1}]$	Mass limit		Reference
Extra dimensions	ADD $G_{KK}+g/q$	–	1-2 j	Yes	4.7	M_D 4.37 TeV	$n=2$	1210.4491
	ADD non-resonant $\ell\ell/\gamma\gamma$	2γ or $2e,\mu$	–	–	4.7	M_S 4.18 TeV	$n=3$ HLZ NLO	1211.1150
	ADD QBH $\to\ell q$	$1\ e,\mu$	1 j	–	20.3	M_{th} 5.2 TeV	$n=6$	1311.2006
	ADD BH high N_{trk}	$2\ \mu$ (SS)	–	–	20.3	M_{th} 5.7 TeV	$n=6$, $M_D=1.5$ TeV, non-rot BH	1308.4075
	ADD BH high $\sum p_T$	$\geq 1\ e,\mu$	≥ 2 j	–	20.3	M_{th} 6.2 TeV	$n=6$, $M_D=1.5$ TeV, non-rot BH	ATLAS-CONF-2014-016
	RS1 $G_{KK}\to\ell\ell$	$2\ e,\mu$	–	–	20.3	G_{KK} mass 2.47 TeV	$k/\overline{M}_{Pl}=0.1$	ATLAS-CONF-2013-017
	RS1 $G_{KK}\to ZZ\to\ell\ell qq/\ell\ell\ell\ell$	2 or 4 e,μ	2 j or –	–	1.0	G_{KK} mass 845 GeV	$k/\overline{M}_{Pl}=0.1$	1203.0718
	RS1 $G_{KK}\to WW\to\ell\nu\ell\nu$	$2\ e,\mu$	–	Yes	4.7	G_{KK} mass 1.23 TeV	$k/\overline{M}_{Pl}=0.1$	1208.2880
	Bulk RS $G_{KK}\to HH\to b\bar{b}b\bar{b}$	–	4 b	–	19.5	G_{KK} mass 590-710 GeV	$k/\overline{M}_{Pl}=1.0$	ATLAS-CONF-2014-005
	Bulk RS $g_{KK}\to t\bar{t}$	$1\ e,\mu$	≥ 1 b, ≥ 1J/2j	Yes	14.3	g_{KK} mass 0.5-2.0 TeV	BR = 0.925	ATLAS-CONF-2013-052
	S^1/Z_2 ED	$2\ e,\mu$	–	–	5.0	$M_{KK}\approx R^{-1}$ 4.71 TeV		1209.2535
	UED	$2\ \gamma$	–	Yes	4.8	Compact. scale R^{-1} 1.41 TeV		ATLAS-CONF-2012-072
Gauge bosons	SSM $Z'\to\ell\ell$	$2\ e,\mu$	–	–	20.3	Z' mass 2.86 TeV		ATLAS-CONF-2013-017
	SSM $Z'\to\tau\tau$	$2\ \tau$	–	–	19.5	Z' mass 1.9 TeV		ATLAS-CONF-2013-066
	SSM $W'\to\ell\nu$	$1\ e,\mu$	–	Yes	20.3	W' mass 3.28 TeV		ATLAS-CONF-2014-017
	EGM $W'\to WZ\to\ell\nu\,\ell'\ell'$	$3\ e,\mu$	–	Yes	20.3	W' mass 1.52 TeV		ATLAS-CONF-2014-015
	LRSM $W'_R\to t\bar{b}$	$1\ e,\mu$	2 b, 0-1 j	Yes	14.3	W' mass 1.84 TeV		ATLAS-CONF-2013-050
CI	CI $qqqq$	–	2 j	–	4.8	Λ 7.6 TeV	$\eta=+1$	1210.1718
	CI $qq\ell\ell$	$2\ e,\mu$	–	–	5.0	Λ 13.9 TeV	$\eta_{LL}=-1$	1211.1150
	CI $uutt$	$2\ e,\mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	Λ 3.3 TeV	$\lvert C\rvert=1$	ATLAS-CONF-2013-051
DM	EFT D5 operator	–	1-2 j	Yes	10.5	M_* 731 GeV	at 90% CL for $m(\chi)<80$ GeV	ATLAS-CONF-2012-147
	EFT D9 operator	–	1 J, ≤ 1 j	Yes	20.3	M_* 2.4 TeV	at 90% CL for $m(\chi)<100$ GeV	1309.4017
LQ	Scalar LQ 1st gen	$2\ e$	≥ 2 j	–	1.0	LQ mass 660 GeV	$\beta=1$	1112.4928
	Scalar LQ 2nd gen	$2\ \mu$	≥ 2 j	–	1.0	LQ mass 685 GeV	$\beta=1$	1203.3172
	Scalar LQ 3rd gen	$1\ e,\mu,\ 1\ \tau$	1 b, 1 j	–	4.7	LQ mass 534 GeV	$\beta=1$	1303.0526
Heavy quarks	Vector-like quark $TT\to Ht+X$	$1\ e,\mu$	≥ 2 b, ≥ 4 j	Yes	14.3	T mass 790 GeV	T in (T,B) doublet	ATLAS-CONF-2013-018
	Vector-like quark $TT\to Wb+X$	$1\ e,\mu$	≥ 1 b, ≥ 3 j	Yes	14.3	T mass 670 GeV	isospin singlet	ATLAS-CONF-2013-060
	Vector-like quark $BB\to Zb+X$	$2\ e,\mu$	≥ 2 b	–	14.3	B mass 725 GeV		
	Vector-like quark $BB\to Wt+X$	$2\ e,\mu$ (SS)	≥ 1 b, ≥ 1 j	Yes	14.3	B mass 720 GeV		
Excited fermions	Excited quark $q^*\to q\gamma$	$1\ \gamma$	1 j	–	20.3	q* mass 3.5 TeV		
	Excited quark $q^*\to qg$	–	2 j	–	13.0	q* mass 3.84 Te		
	Excited quark $b^*\to Wt$	1 or 2 e,μ	1 b, 2 j or 1 j	Yes	4.7	b* mass 870 GeV		
	Excited lepton $\ell^*\to\ell\gamma$	$2\ e,\mu,\ 1\ \gamma$	–	–	13.0	ℓ^* mass 2.2 TeV		
Other	LRSM Majorana ν	$2\ e,\mu$	2 j	–	2.1	N^0 mass 1.5 TeV		
	Type III Seesaw	$2\ e,\mu$	–	–	5.8	$N^\pm$ mass 245 GeV		
	Higgs triplet $H^{\pm\pm}\to\ell\ell$	$2\ e,\mu$ (SS)	–	–	4.7	$H^{\pm\pm}$ mass 409 GeV		
	Multi-charged particles	–	–	–	4.4	multi-charged particle mass 490 GeV		
	Magnetic monopoles	–	–	–	2.0	monopole mass 862 GeV		

$\sqrt{s}$ = 7 TeV $\sqrt{s}$ = 8 TeV

*Only a selection of the available mass limits on new states or phenomena is shown.

ATLAS SUSY Searches* - 95% CL Lower Limits
Status: Moriond 2014

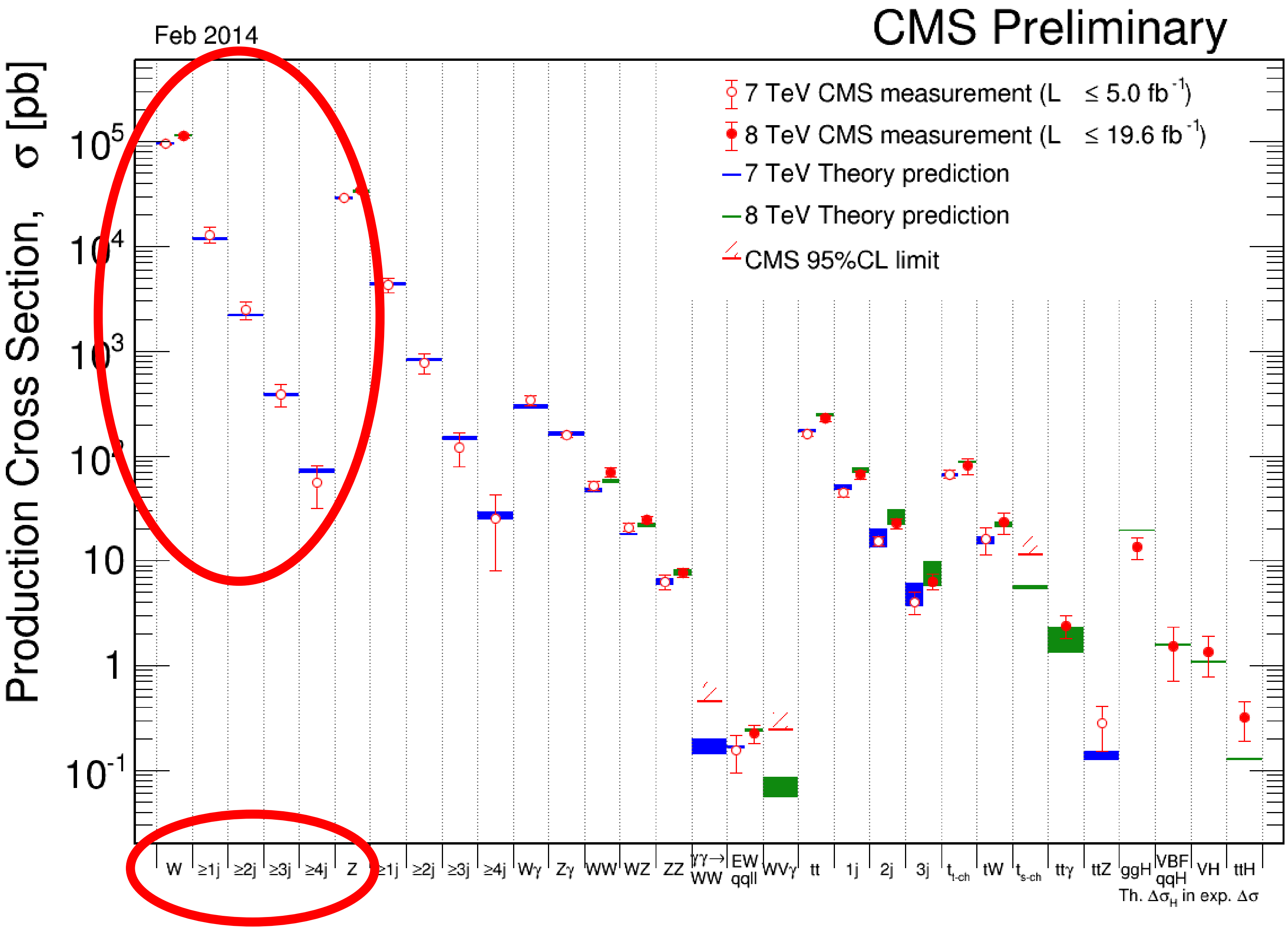
ATLAS Preliminary
$\int\mathcal{L}\,dt$ = (4.6 - 22.9) fb^{-1} $\sqrt{s}$ = 7, 8 TeV

	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[fb^{-1}]$	Mass limit		Reference
Inclusive Searches	MSUGRA/CMSSM	0	2-6 jets	Yes	20.3	$\tilde{q},\tilde{g}$ 1.7 TeV	m($\tilde{q}$)=m($\tilde{g}$)	ATLAS-CONF-2013-047
	MSUGRA/CMSSM	$1\ e,\mu$	3-6 jets	Yes	20.3	$\tilde{g}$ 1.2 TeV	any m($\tilde{q}$)	ATLAS-CONF-2013-062
	MSUGRA/CMSSM	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	any m($\tilde{q}$)	1308.1841
	$\tilde{q}\tilde{q},\ \tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$ 740 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-047
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq\tilde{\chi}_1^\pm\to qqW^\pm\tilde{\chi}_1^0$	$1\ e,\mu$	3-6 jets	Yes	20.3	$\tilde{g}$ 1.18 TeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}^\pm$)=0.5(m($\tilde{\chi}_1^0$)+m($\tilde{g}$))	ATLAS-CONF-2013-062
	$\tilde{g}\tilde{g},\ \tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	$2\ e,\mu$	0-3 jets	-	20.3	$\tilde{g}$ 1.12 TeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-089
	GMSB ($\tilde{\ell}$ NLSP)	$2\ e,\mu$	2-4 jets	Yes	4.7	$\tilde{g}$ 1.24 TeV	tanβ<15	1208.4688
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ	0-2 jets	Yes	20.7	$\tilde{g}$ 1.4 TeV	tanβ >18	ATLAS-CONF-2013-026
	GGM (bino NLSP)	$2\ \gamma$	-	Yes	20.3	$\tilde{g}$ 1.28 TeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2014-001
	GGM (wino NLSP)	$1\ e,\mu+\gamma$	-	Yes	4.8	$\tilde{g}$ 619 GeV	m($\tilde{\chi}_1^0$)>50 GeV	ATLAS-CONF-2012-144
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	4.8	$\tilde{g}$ 900 GeV	m($\tilde{\chi}_1^0$)>220 GeV	1211.1167
	GGM (higgsino NLSP)	$2\ e,\mu$ (Z)	0-3 jets	Yes	5.8	$\tilde{g}$ 690 GeV	m($\tilde{H}$)>200 GeV	ATLAS-CONF-2012-152
	Gravitino LSP	0	mono-jet	Yes	10.5	$F^{1/2}$ scale 645 GeV	m($\tilde{g}$)>10^{-4} eV	ATLAS-CONF-2012-147
3rd gen. $\tilde{g}$ med.	$\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$ 1.2 TeV	m($\tilde{\chi}_1^0$)<600 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$ 1.1 TeV	m($\tilde{\chi}_1^0$) <350 GeV	1308.1841
	$\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.34 TeV	m($\tilde{\chi}_1^0$)<400 GeV	ATLAS-CONF-2013-061
	$\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$ 1.3 TeV	m($\tilde{\chi}_1^0$)<300 GeV	ATLAS-CONF-2013-061
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$ 100-620 GeV	m($\tilde{\chi}_1^0$)<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1,\ \tilde{b}_1\to t\tilde{\chi}_1^\pm$	$2\ e,\mu$ (SS)	0-3 b	Yes	20.7	$\tilde{b}_1$ 275-430 GeV	m($\tilde{\chi}_1^\pm$)=2 m($\tilde{\chi}_1^0$)	ATLAS-CONF-2013-007
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	1-2 e,μ	1-2 b	Yes	4.7	$\tilde{t}_1$ 110-167 GeV	m($\tilde{\chi}_1^0$)=55 GeV	1208.4305, 1209.2102
	$\tilde{t}_1\tilde{t}_1$(light), $\tilde{t}_1\to Wb\tilde{\chi}_1^0$	$2\ e,\mu$	0-2 jets	Yes	20.3	$\tilde{t}_1$ 130-210 GeV	m($\tilde{\chi}_1^0$) =m($\tilde{t}_1$)-m(W)-50 GeV, m($\tilde{t}_1$)<<m($\tilde{\chi}_1^\pm$)	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to t\tilde{\chi}_1^0$	$2\ e,\mu$	2 jets	Yes	20.3	$\tilde{t}_1$ 215-530 GeV	m($\tilde{\chi}_1^0$)=1 GeV	1403.4853
	$\tilde{t}_1\tilde{t}_1$(medium), $\tilde{t}_1\to b\tilde{\chi}_1^\pm$	0	2 b	Yes	20.1	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)<200 GeV, m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=5 GeV	1308.2631
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	$1\ e,\mu$	1 b	Yes	20.7	$\tilde{t}_1$ 200-610 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-037
	$\tilde{t}_1\tilde{t}_1$(heavy), $\tilde{t}_1\to t\tilde{\chi}_1^0$	0	2 b	Yes	20.5	$\tilde{t}_1$ 320-660 GeV	m($\tilde{\chi}_1^0$)=0 GeV	ATLAS-CONF-2013-024
	$\tilde{t}_1\tilde{t}_1,\ \tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$ 90-200 GeV	m($\tilde{t}_1$)-m($\tilde{\chi}_1^0$)<85 GeV	ATLAS-CONF-2013-068
	$\tilde{t}_1\tilde{t}_1$(natural GMSB)	$2\ e,\mu$ (Z)	1 b	Yes	20.3	$\tilde{t}_1$ 150-580 GeV	m($\tilde{\chi}_1^0$)>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2,\ \tilde{t}_2\to\tilde{t}_1+Z$	$3\ e,\mu$ (Z)	1 b	Yes	20.3	$\tilde{t}_2$ 290-600 GeV	m($\tilde{\chi}_1^0$)<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R},\ \tilde{\ell}\to\ell\tilde{\chi}_1^0$	$2\ e,\mu$	0	Yes	20.3	$\tilde{\ell}$ 90-325 GeV	m($\tilde{\chi}_1^0$)=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	$2\ e,\mu$	0	Yes	20.3	$\tilde{\chi}_1^\pm$ 140-465 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	$2\ \tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 180-330 GeV	m($\tilde{\chi}_1^0$)=0 GeV, m($\tilde{\tau},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	ATLAS-CONF-2013-028
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu),\ \ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	$3\ e,\mu$	0	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 700 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, m($\tilde{\ell},\tilde{\nu}$)=0.5(m($\tilde{\chi}_1^\pm$)+m($\tilde{\chi}_1^0$))	1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 Z\tilde{\chi}_1^0$	2-3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 420 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^\pm\tilde{\chi}_2^0\to W\tilde{\chi}_1^0 h\tilde{\chi}_1^0$	$1\ e,\mu$	2 b	Yes	20.3	$\tilde{\chi}_1^\pm,\tilde{\chi}_2^0$ 285 GeV	m($\tilde{\chi}_1^\pm$)=m($\tilde{\chi}_2^0$), m($\tilde{\chi}_1^0$)=0, sleptons decoupled	ATLAS-CONF-2013-093
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^\pm$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^\pm$ 270 GeV	m($\tilde{\chi}_1^\pm$)-m($\tilde{\chi}_1^0$)=160 MeV, $\tau(\tilde{\chi}_1^\pm)$=0.2 ns	ATLAS-CONF-2013-069
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	22.9	$\tilde{g}$ 832 GeV	m($\tilde{\chi}_1^0$)=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	ATLAS-CONF-2013-057
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	15.9	$\tilde{\chi}_1^0$ 475 GeV	10<tanβ<50	ATLAS-CONF-2013-058
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	$2\ \gamma$	-	Yes	4.7	$\tilde{\chi}_1^0$ 230 GeV	0.4<$\tau(\tilde{\chi}_1^0)$<2 ns	1304.6310
	$\tilde{q}\tilde{q},\ \tilde{\chi}_1^0\to qq\mu$ (RPV)	1 μ, displ. vtx	-	-	20.3	$\tilde{q}$ 1.0 TeV	1.5 <$c\tau$<156 mm, BR(μ)=1, m($\tilde{\chi}_1^0$)=108 GeV	ATLAS-CONF-2013-092
RPV	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e+\mu$	$2\ e,\mu$	-	-	4.6	$\tilde{\nu}_\tau$ 1.61 TeV	λ'_{311}=0.10, λ_{132}=0.05	1212.1272
	LFV $pp\to\tilde{\nu}_\tau+X,\ \tilde{\nu}_\tau\to e(\mu)+\tau$	$1\ e,\mu+\tau$	-	-	4.6	$\tilde{\nu}_\tau$ 1.1 TeV	λ'_{311}=0.10, $\lambda_{1(2)33}$=0.05	1212.1272
	Bilinear RPV CMSSM	$1\ e,\mu$	7 jets	Yes	4.7	$\tilde{q},\tilde{g}$ 1.2 TeV	m($\tilde{q}$)=m($\tilde{g}$), $c\tau_{LSP}$<1 mm	ATLAS-CONF-2012-140
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to ee\tilde{\nu}_\mu,\ e\mu\tilde{\nu}_e$	$4\ e,\mu$	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 760 GeV	m($\tilde{\chi}_1^0$)>300 GeV, λ_{121}>0	ATLAS-CONF-2013-036
	$\tilde{\chi}_1^+\tilde{\chi}_1^-,\ \tilde{\chi}_1^+\to W\tilde{\chi}_1^0,\ \tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e,\ e\tau\tilde{\nu}_\tau$	$3\ e,\mu+\tau$	-	Yes	20.7	$\tilde{\chi}_1^\pm$ 350 GeV	m($\tilde{\chi}_1^0$)>80 GeV, λ_{133}>0	ATLAS-CONF-2013-036
	$\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$ 916 GeV	BR(t)=BR(b)=BR(c)=0%	ATLAS-CONF-2013-091
	$\tilde{g}\to\tilde{t}_1 t,\ \tilde{t}_1\to bs$	$2\ e,\mu$ (SS)	0-3 b	Yes	20.7	$\tilde{g}$ 880 GeV		ATLAS-CONF-2013-007
Other	Scalar gluon pair, sgluon$\to q\bar{q}$	0	4 jets	-	4.6	sgluon 100-287 GeV	incl. limit from 1110.2693	1210.4826
	Scalar gluon pair, sgluon$\to t\bar{t}$	$2\ e,\mu$ (SS)	2 b	Yes	14.3	sgluon 350-800 GeV		ATLAS-CONF-2013-051
	WIMP interaction (D5, Dirac χ)	0	mono-jet	Yes	10.5	M* scale 704 GeV	m(χ)<80 GeV, limit of<687 GeV for D8	ATLAS-CONF-2012-147

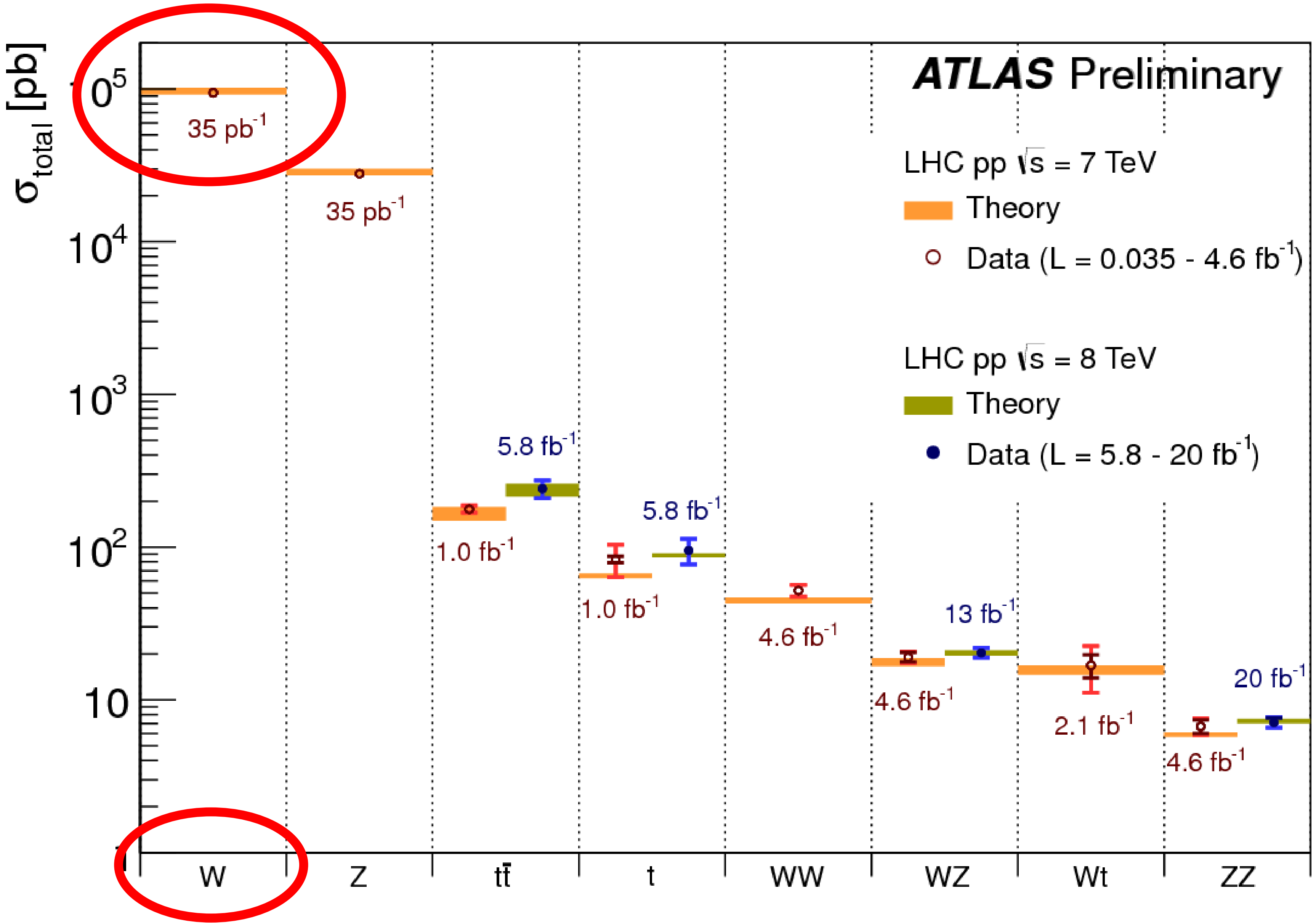
$\sqrt{s}$ = 7 TeV full data $\sqrt{s}$ = 8 TeV partial data $\sqrt{s}$ = 8 TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Introduction



Introduction



Introduction

LHCで、既に、

$100\ \mathrm{nb} \times 20\ \mathrm{fb}^{-1} = 2 \times 10^{9}$ 個のWボソンが生成。

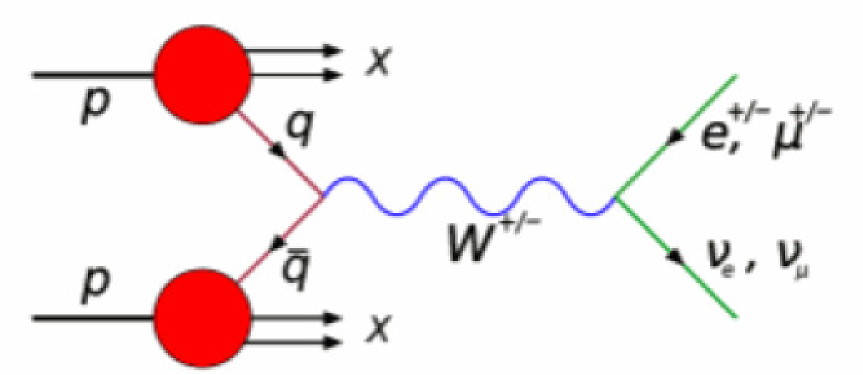
そのうちの一割くらい、ジェットが一個以上同時に生成される。

(ジェットが同時に生成されると、Wボソンは反跳横運動量を持つ。)

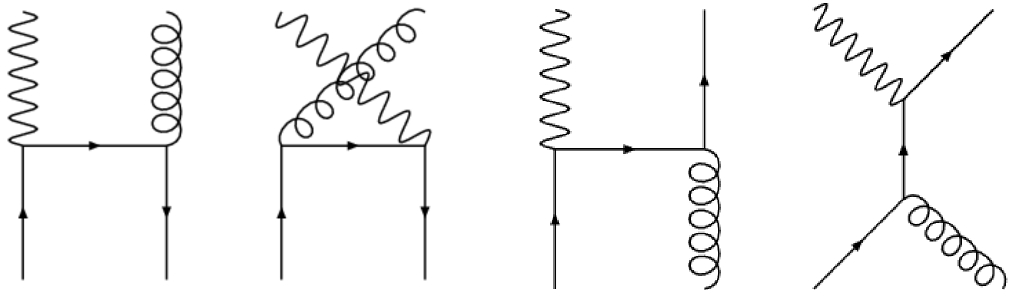
eν, μνへの崩壊は、それぞれ、1割ずつ程度。

既に、10^{7}個程の W(→eν, μν) + jet イベントが生成されている。

Inclusive W :



W+ 1jet :



Introduction

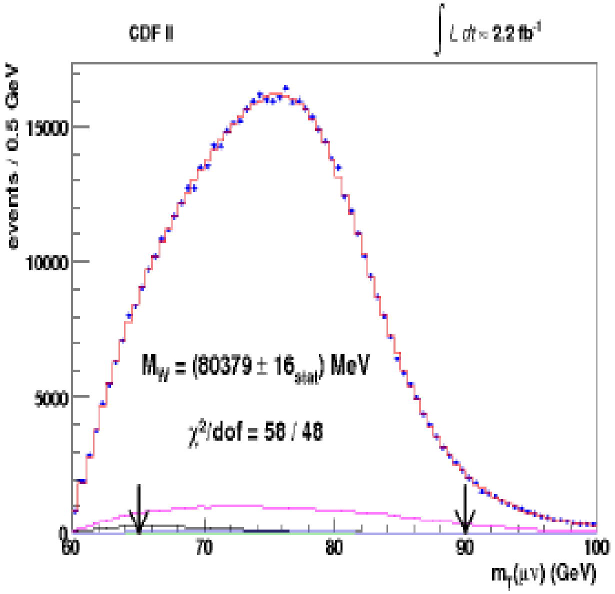
- Physics of W-boson:

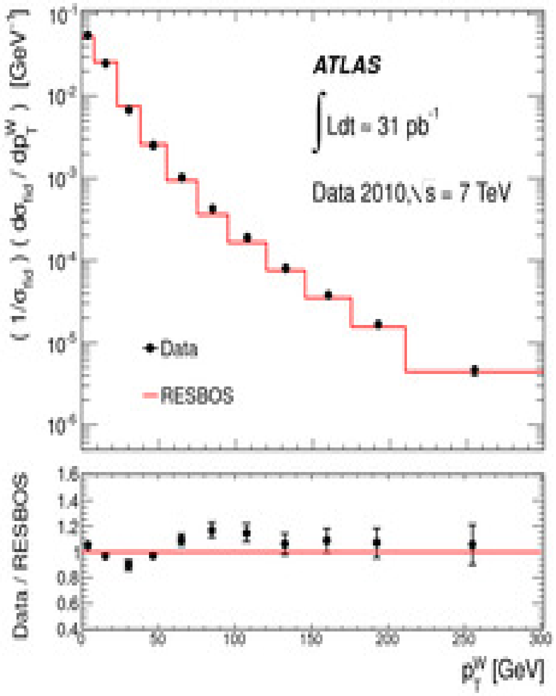
Cross-sections → pQCD prediction, parton distribution functions

Distributions (leptonic decay)→ mass, width, polarization

Associated Jets → QCD showering, MonteCarlo modeling

- QCD や PDF の理解
- NP プロセスへの応用
- NP Search の BG として
- 物理量の決定





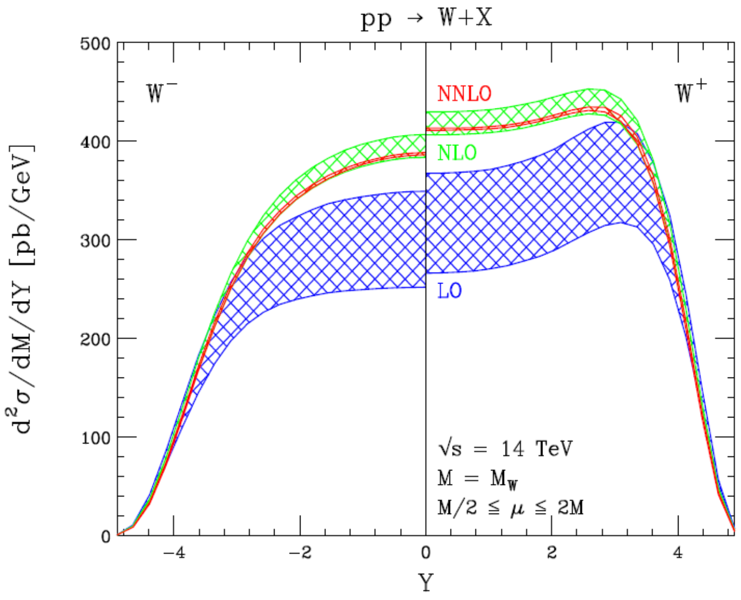
$$\begin{cases} m_W = 80.385 \pm 0.015\ \text{GeV} \\ \Gamma_W = 2.085 \pm 0.042\ \text{GeV} \end{cases}$$

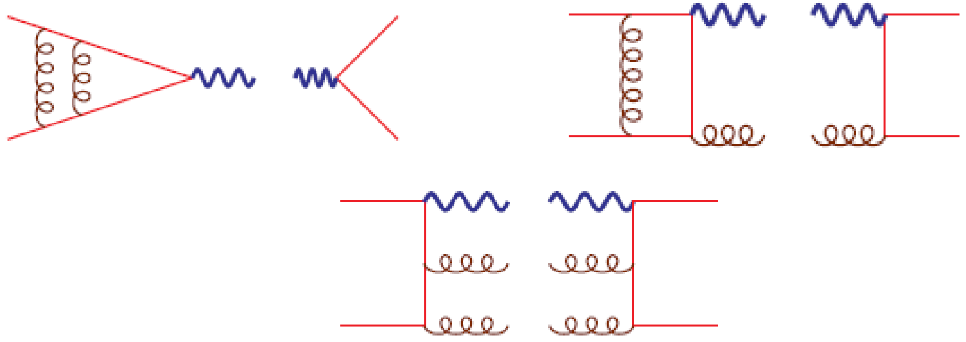
Theory calculations on the cross-sections

$$pp \to W^{\pm} + X$$

NNLO available only for
the inclusive cross-section

Anastasiou,Dixon,Melnikov,Petriello ('03)

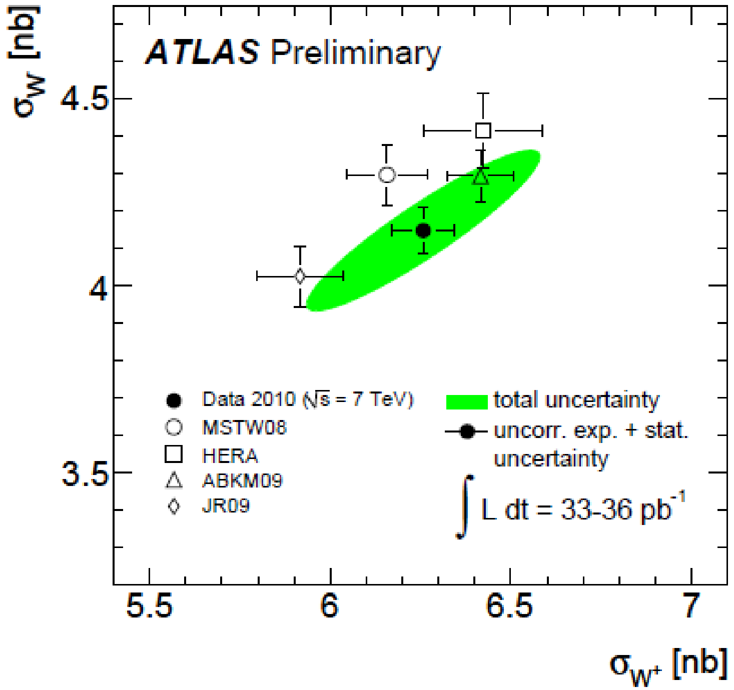




	MSTW08	ABKM09	HERA	JR09
W^+	6.16 ± 0.11	6.42 ± 0.09	6.42 ± 0.16	5.92 ± 0.12
W^-	4.30 ± 0.08	4.29 ± 0.07	4.42 ± 0.10	4.03 ± 0.08

theory uncertainty : scale uncertainty : <1%

PDF uncertainty : 4-6%



Theory calculations on the cross-sections

NLO calc. for W + multi-jets processes
(W+3jets, 4jets, 5jets,,,)

- NLO for W+1jet, 2jets known for long time.

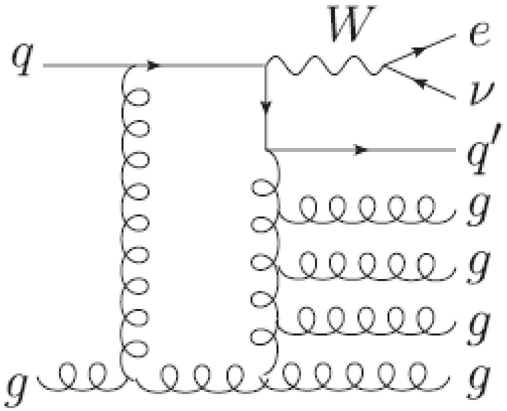
  Arnold,Reno ('90), Campbell,Ellis ('02)

- Around ~2009, several groups finished W+3jets.

  Ellis,Melnikov,Zanderighi(09), BlackHat collab.,,,

- **BlackHat + SHERPA collaboration**

  further completed W+4jets ('10) and W+5jets ('13)



Breakthrough in new methods
to evaluate loop amplitudes (BCF,OPP,,,)

Lepton Angular Distributions

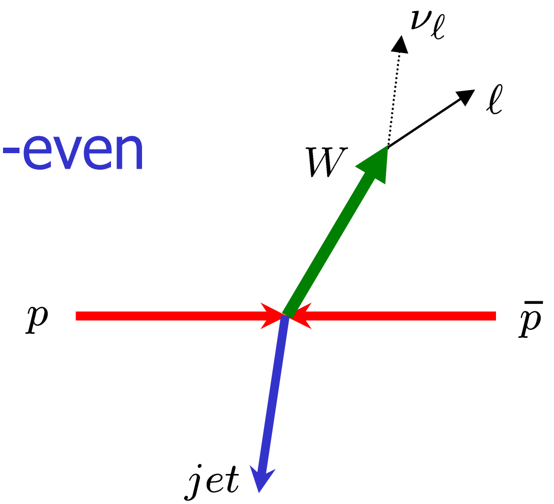
- Information of the polarization of W-boson

  → details of production mechanism

- Distributions can be expressed by using 9 structure functions.

$$
\begin{aligned}
\frac{d^4\sigma}{dq_T^2\, d\cos\hat{\theta}\, d\cos\theta\, d\phi} = {} & \left.\begin{aligned}
& F_1(1+\cos^2\theta)+F_2(1-3\cos\theta^2) \\
+ {} & F_3\sin 2\theta\cos\phi + F_4\sin^2\theta\cos 2\phi \\
+ {} & F_5\cos\theta + F_6\sin\theta\cos\phi
\end{aligned}\right\} \text{P-even} \\
& \left.\begin{aligned}
+ {} & F_7\sin\theta\sin\phi + F_8\sin 2\theta\sin\phi \\
+ {} & F_9\sin^2\theta\sin 2\phi
\end{aligned}\right\} \text{P-odd}
\end{aligned}
$$

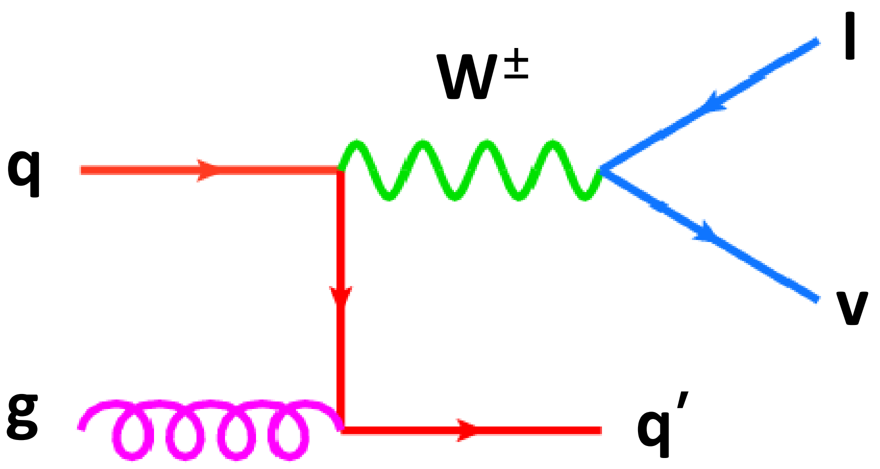
P : $\phi \to -\phi$



$\cos\hat{\theta}$: scattering angle

θ, ϕ: lepton angles in W-rest frame

Density Matrix Formula



$$-g^{\mu\nu} + \frac{q^\mu q^\nu}{m_W^2} = \sum_{\lambda=+,0,-} \epsilon_\lambda^\mu \epsilon_\lambda^{*\nu}$$

Amplitude: $\mathcal{M} \propto \mathcal{P}^\mu \frac{-g_{\mu\nu} + \frac{q_\mu q_\nu}{m_W^2}}{q^2 - m_W^2} \mathcal{D}^\nu = \sum_\lambda \frac{(\epsilon_\lambda^* \cdot \mathcal{P})(\mathcal{D} \cdot \epsilon_\lambda)}{q^2 - m_W^2}$

Squared: $|\mathcal{M}|^2 \propto \sum_{\lambda,\lambda'} \left[(\epsilon_\lambda^* \cdot \mathcal{P})(\epsilon_{\lambda'}^* \cdot \mathcal{P})^*\right] \left[(\mathcal{D} \cdot \epsilon_\lambda)(\mathcal{D} \cdot \epsilon_{\lambda'})^*\right]$

$$\equiv \sum_{\lambda,\lambda'} \underline{P_{\lambda\lambda'}(\cos\hat{\theta}, q_T^2)} \cdot \underline{D_{\lambda\lambda'}(\cos\theta, \phi)}$$

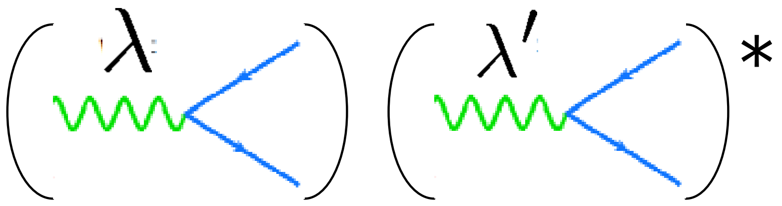
Density matrix

Density Matrix Formula

- W-boson’s decay density matrix (lepton DM)

  can be explicitly evaluated by using the LO amplitude.

$D_{\lambda\lambda'} =$



$\theta,\ \phi$: lepton angles
in W-rest frame

$$= \left(\begin{array}{ccc} \frac{(1+\cos\theta)^2}{2} & \frac{\sin\theta(1+\cos\theta)}{\sqrt{2}}e^{i\phi} & \frac{\sin^2\theta}{2}e^{2i\phi} \\ \frac{\sin\theta(1+\cos\theta)}{\sqrt{2}}e^{-i\phi} & \sin^2\theta & \frac{\sin\theta(1-\cos\theta)}{\sqrt{2}}e^{i\phi} \\ \frac{\sin^2\theta}{2}e^{-2i\phi} & \frac{\sin\theta(1-\cos\theta)}{\sqrt{2}}e^{-i\phi} & \frac{(1-\cos\theta)^2}{2} \end{array}\right) \begin{array}{c} + \\ 0 \\ - \end{array}$$

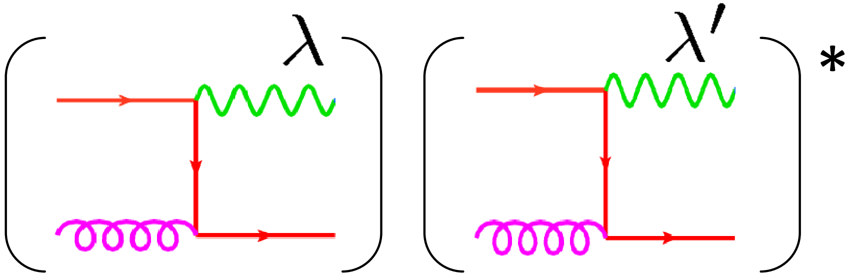
対角成分 : Wの3つの偏極状態(+,0,-)からの崩壊分布

非対角成分 : 異なる偏極状態の干渉効果 → 方位角依存性

Density Matrix Formula

◆ W-boson’s Production DM

$$P_{\lambda\lambda'} = (\epsilon^*_\lambda \cdot \mathcal{P})(\epsilon^*_{\lambda'} \cdot \mathcal{P})^*$$



- Structure functions :

$$\begin{aligned}
\widehat{F}_1 &= \frac{1}{2}\left(P_{++} + P_{00} + P_{--}\right), & \widehat{F}_6 &= \sqrt{2}\,\text{Re}\left(P_{+0} + P_{-0}\right), \\
\widehat{F}_2 &= \frac{1}{2}P_{00}, & \widehat{F}_7 &= i\sqrt{2}\,\underline{\text{Im}\left(P_{+0} - P_{-0}\right)}, \\
\widehat{F}_3 &= \frac{1}{\sqrt{2}}\text{Re}\left(P_{+0} - P_{-0}\right), & \widehat{F}_8 &= \frac{i}{\sqrt{2}}\underline{\text{Im}\left(P_{+0} + P_{-0}\right)}, \\
\widehat{F}_4 &= \text{Re}\left(P_{+-}\right), & \widehat{F}_9 &= \underline{i\,\text{Im}\left(P_{+-}\right)} \\
\widehat{F}_5 &= P_{++} - P_{--}
\end{aligned}$$

7,8,9 ⇔ Imaginary part

- Convolute with parton distribution functions

$$F_i(q_T^2, \cos\hat{\theta}) = \sum_{a,b}\int dY\, f_{a/p}(x_+, \mu_F^2)\, f_{b/\bar{p}}(x_-, \mu_F^2)\, \widehat{F}_i^{ab\to W^- j}$$

Lepton Angular Distribution

$$\begin{aligned}\frac{d^4\sigma}{dq_T^2 d\cos\hat{\theta} d\cos\theta d\phi} &= F_1(1+\cos^2\theta) + F_2(1-3\cos\theta^2) \\ &+ F_3\sin 2\theta\cos\phi + F_4\sin^2\theta\cos 2\phi \\ &+ F_5\cos\theta + F_6\sin\theta\cos\phi \\ &+ F_7\sin\theta\sin\phi + F_8\sin 2\theta\sin\phi \\ &+ F_9\sin^2\theta\sin 2\phi\end{aligned}$$

P : $\phi \to -\phi$

P-even : $F_{1\sim6}$

LO : Chaichian et.al.('82)

NLO: Mirkes('92)

P-odd : $F_{7\sim9}$

LO (one-loop) :
Hagiwara,Hikasa,Kai('84)

NLO: not yet

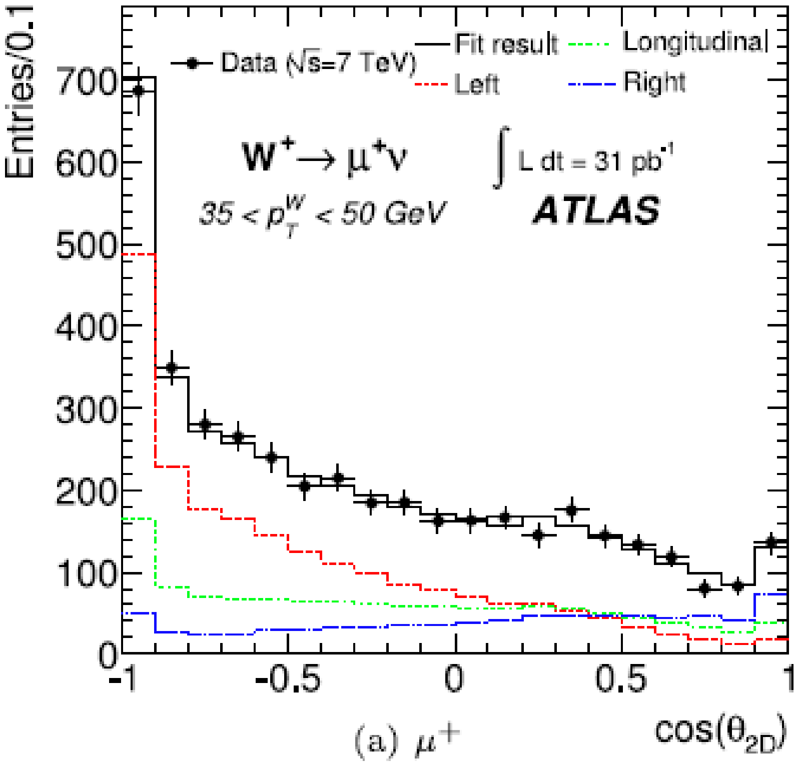
- 角度積分するとF_1項のみが残る → 断面積はF_1のみで決まる。
- 9個の構造関数は、Wボソンの偏極の情報を反映している。
- 方位角依存性は、干渉効果から生ずる。

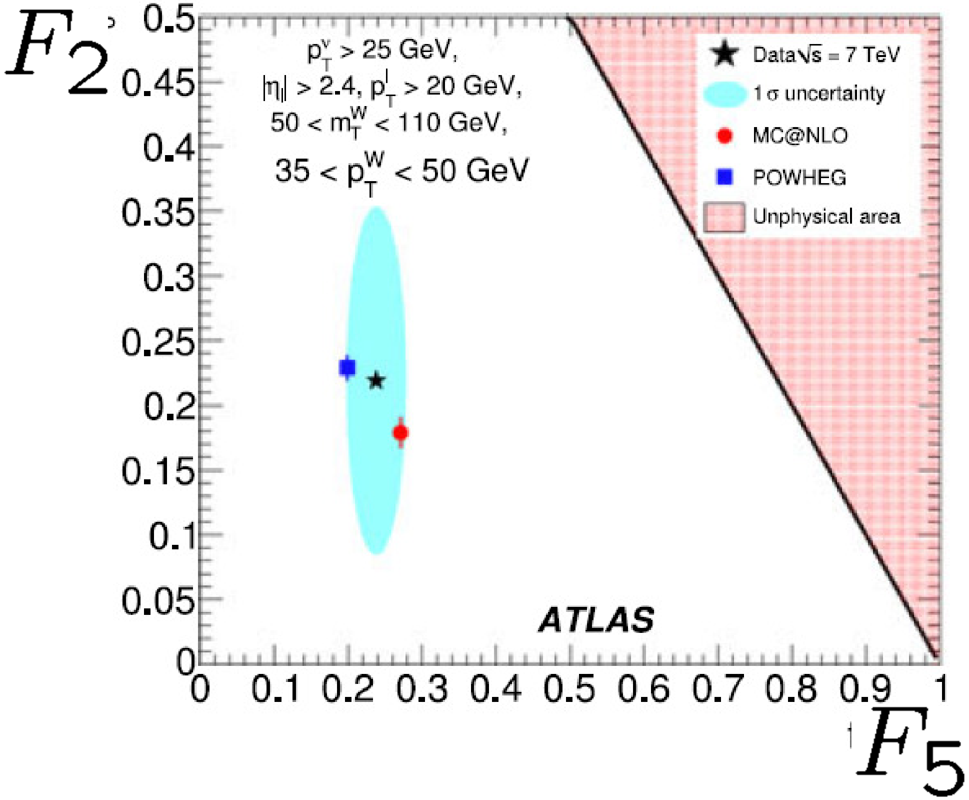
Measurement of Angular Distributions

ATLAS EPJC72,2001(2012)

At the LHC, only polar angular distribution has been measured, so far.

天頂角分布(対角要素)はTevatron, LHCで測られていて、理論計算とよく一致。





Measurement of azimuthal angular distribution

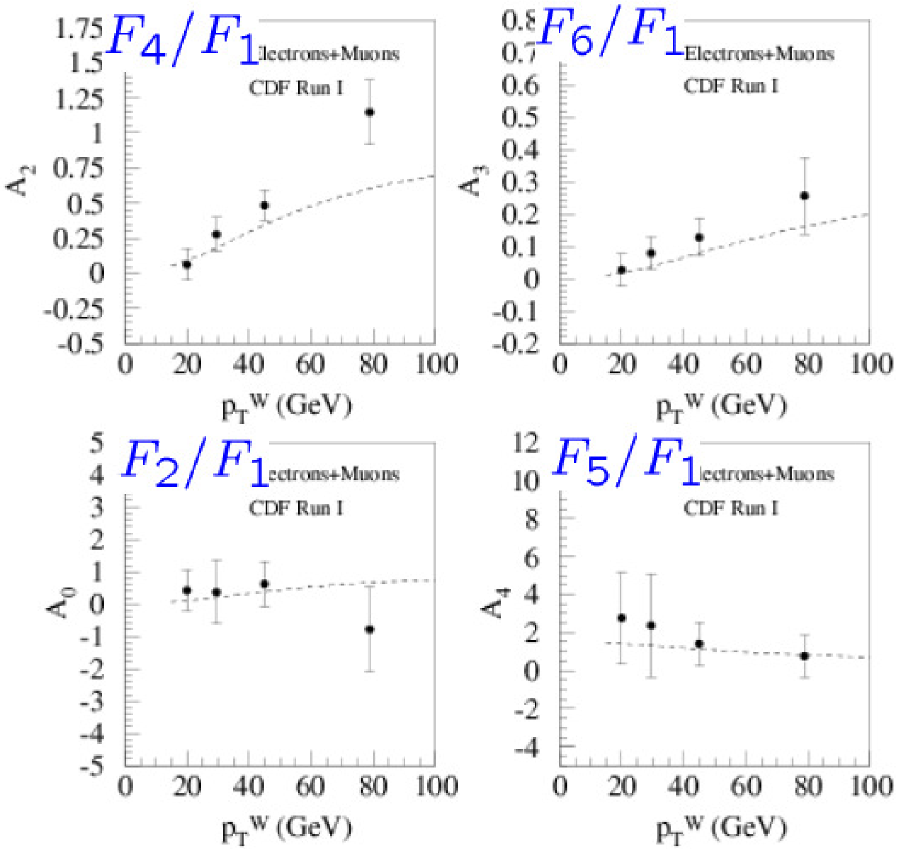
方位角分布(非対角要素)は、
P-even分布のみ測定されている
(CDF実験)。

- Some of P-even distributions have been measured by CDF collaboration.

  → agree with pQCD (NLO) calc. within errors.

- However, P-odd distributions have not been measured at all.

PRD73,052002 ('06) $L = 110\ \mathrm{pb}^{-1}$



Our work : revisit the P-odd effects and demonstrate the method to measure the P-odd distributions for the LHC.

Parity-odd and naïve-T-odd observables

Parity-odd asymmetry

General arguments of parity-odd asymmetry

- Parity transformation : $(\vec{p},\vec{s}) \to (-\vec{p},\vec{s})$

- Parity-odd observables :
  - with spin : $\langle \vec{p}_\ell \cdot \vec{s} \rangle \to -\langle \vec{p}_\ell \cdot \vec{s} \rangle$
  - without spin : $\langle \vec{p}_p \times \vec{q} \cdot \vec{p}_\ell \rangle \to -\langle \vec{p}_p \times \vec{q} \cdot \vec{p}_\ell \rangle$

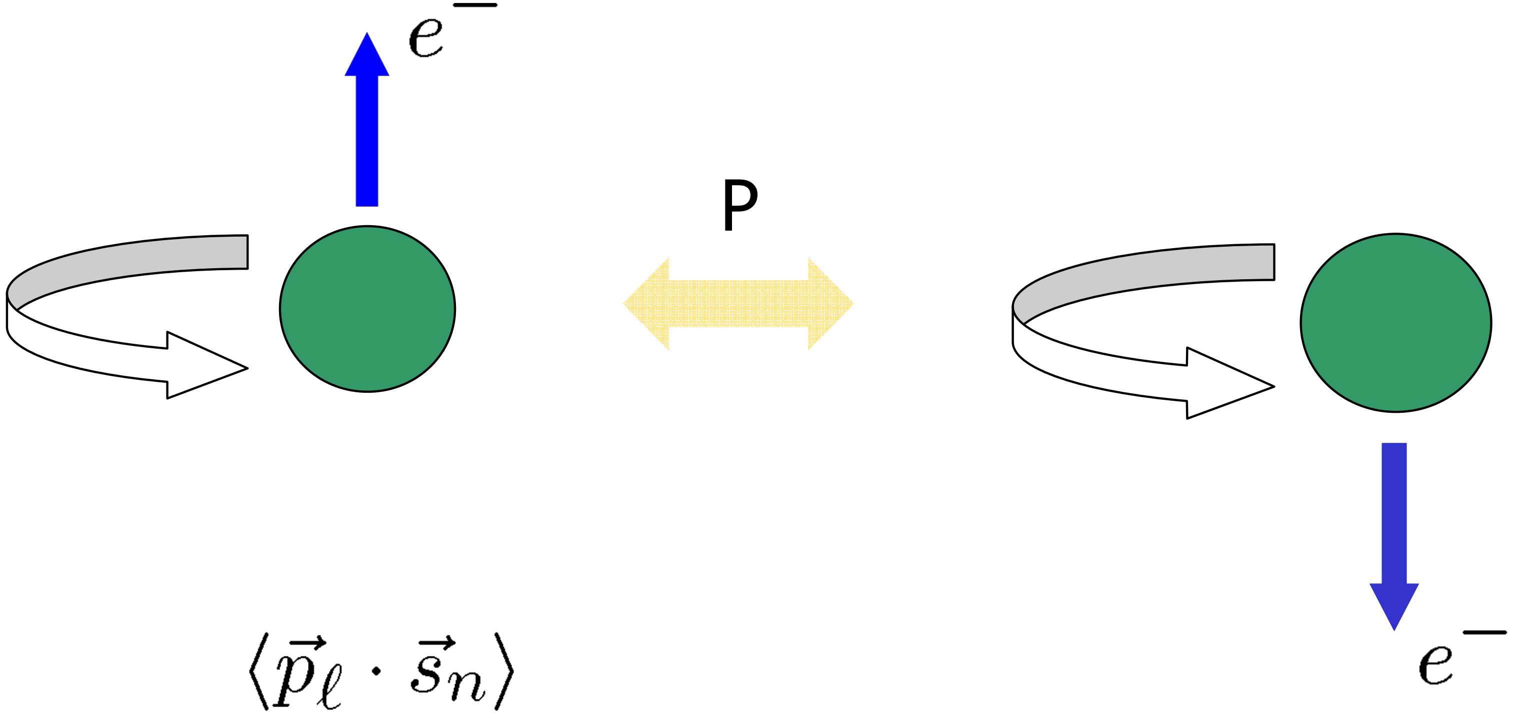
(need a source of parity-violation, e.g. weak int.)

(we don’t consider the other type of parity-violating
phenomena, such as charge asymmetry,,,)

Parity-odd asymmetry

T.D. Lee and C.N. Yang; C.S. Wu

- β-decay of polarized nucleus : $\mathrm{Co}^{60} \to \mathrm{Ni}^{60} + e^- + \nu$



$\langle \vec{p}_\ell \cdot \vec{s}_n \rangle$

Parity-odd and Naïve-T ($\tilde{\mathrm{T}}$)-odd

- P-odd observables without spins are interesting, because these are naïve-T ($\tilde{\mathrm{T}}$)-odd at the same time.

$\tilde{\mathrm{T}}$-transformation :
(unitary)

$$(\vec{p},\vec{s}) \to (-\vec{p},-\vec{s})$$

$$\widetilde{\mathsf{T}}|i(\vec{p},\vec{s})\rangle = |\tilde{i}(-\vec{p},-\vec{s})\rangle$$

T-transformation :
(anti-unitary)

$$(\vec{p},\vec{s}) \to (-\vec{p},-\vec{s})$$

$$\mathsf{T}|i(\vec{p},\vec{s})\rangle = \langle\tilde{i}(-\vec{p},-\vec{s})|$$

Unitarity and T̃-odd quantity

- Unitarity of S-matrix

$$SS^\dagger = 1$$

$$S_{fi} = \delta_{fi} + i(2\pi)^4\delta^4(P_f - P_i)T_{fi}$$

$$T_{fi} - T^*_{if} = iA_{fi} \quad \text{where} \quad \underline{A_{fi} = \textstyle\sum_n T^*_{nf}T_{ni}(2\pi)^4\delta^4(P_n - P_i)}$$

absorptive part

gives $$|T_{fi}|^2 = |T_{if}|^2 - 2\,\mathrm{Im}(T^*_{if}A_{fi}) + |A_{fi}|^2$$

- T̃-odd quantity

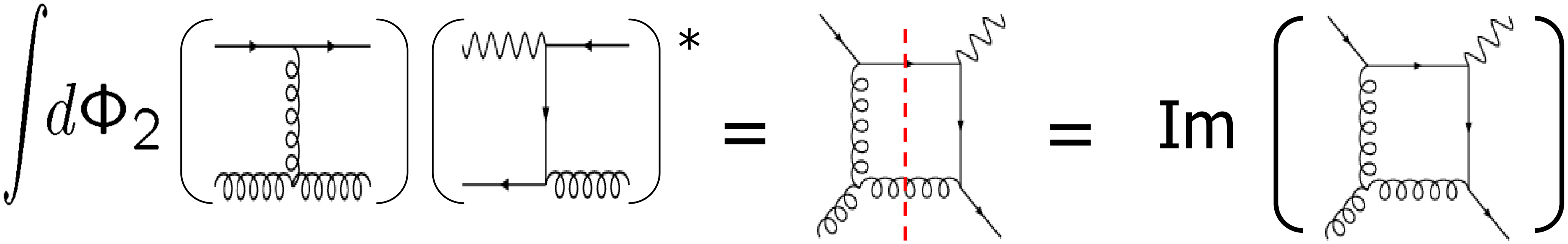
subtract $|T_{\tilde{f}\tilde{i}}|^2$

$$\boxed{|T_{fi}|^2 - |T_{\tilde{f}\tilde{i}}|^2 = \underbrace{\cancel{(|T_{if}|^2 - |T_{\tilde{f}\tilde{i}}|^2)}}_{\text{Time-reversal violation}} - 2\,\mathrm{Im}(T^*_{fi}A_{fi}) - |A_{fi}|^2}$$

→ emerges from the absorptive parts of the scattering amplitude

Unitarity and T̃-odd quantity

In perturbation theory, the absorptive part of scattering amplitudes can be calculated by the imaginary part of the amplitudes.

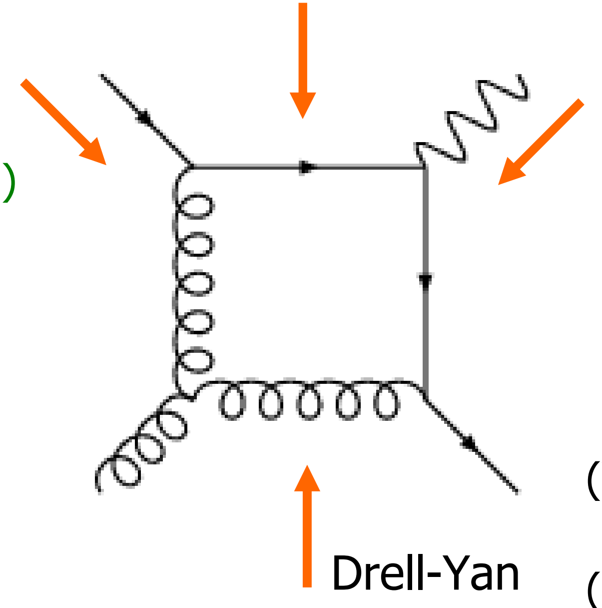


Cutkosky rule

Therefore, measurement of naïve-T-odd quantities can test the perturbative predictions for the absorptive part of scattering amplitudes; i.e. the scattering phase or the strong phase.

$\tilde{T}$-odd asymmetry in hard processes

- $\tilde{T}$-odd asymmetries in hard processes have been calculated in the $e^+e^-\to$3jets, Semi-Inclusive DIS, DY and top decay processes.



Semi-Inclusive DIS Hagiwara,Hikasa,Kai ('83)

Top-quark decay

Hagiwara,Mawatari,HY (07)

$e^+e^- \to$ 3-jets

Korner,Kramer,Shcierholz,Fabricius, Schmitt ('80)

Brandenburg,Dixon,Shadmi ('96)

Drell-Yan

(W-jet) Hagiwara,Hikasa,Kai('84), Hagiwara,Hikasa HY('06)

(Z-jet) Hagiwara,Kuruma,Yamada ('92)

(SLSA) HY('06)

- Absorptive parts of these processes are related with each other by crossing and analyticity

Korner,Malic,Merebashvili ('00)

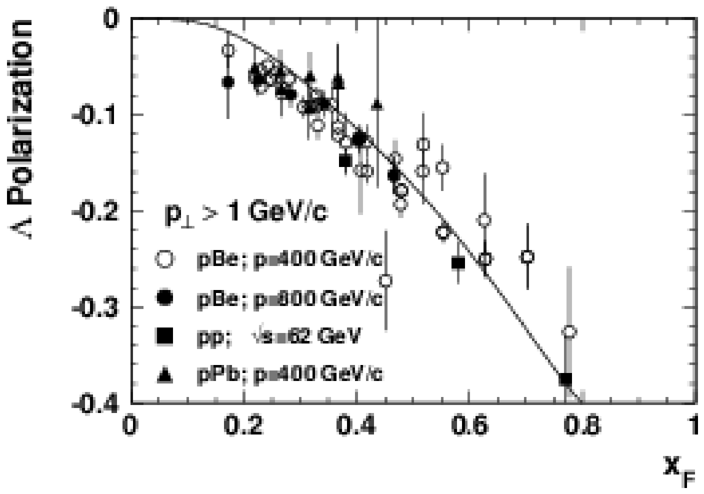
- So far, no experimental measurements for these processes

$\tilde{\mathrm{T}}$-odd asymmetry in hadron physics

(P-even, pure QCD effect)

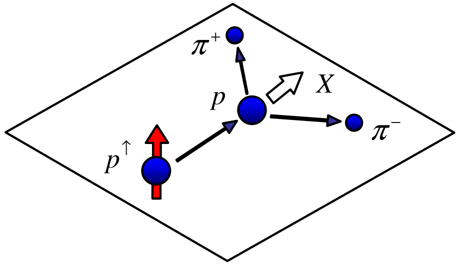
- Large $\tilde{\mathrm{T}}$-odd asymmetries have been observed in hadron spin physics

1. Λ-polarization $\sim \langle \vec{p}_p \times \vec{p}_\Lambda \cdot \vec{s}_\Lambda \rangle$
   in $p + N \to \Lambda^\uparrow + X$



2. A_N in $p + p^\uparrow \to \pi + X$

$$A_N = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} \sim \langle \vec{p}_p \times \vec{s}_p \cdot \vec{p}_\pi \rangle$$



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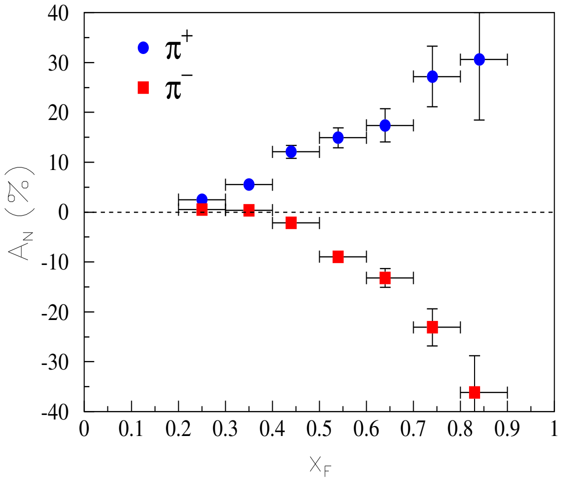


- STSA needs chirality-flip amplitude, in addition to the complex phase
  - Non-perturbative QCD effects inside nucleon
    1. Transverse-momentum-dependent PDF
    2. Higher-twist effects

Strong phase in direct CP violation

- Direct CP violation in the meson decay

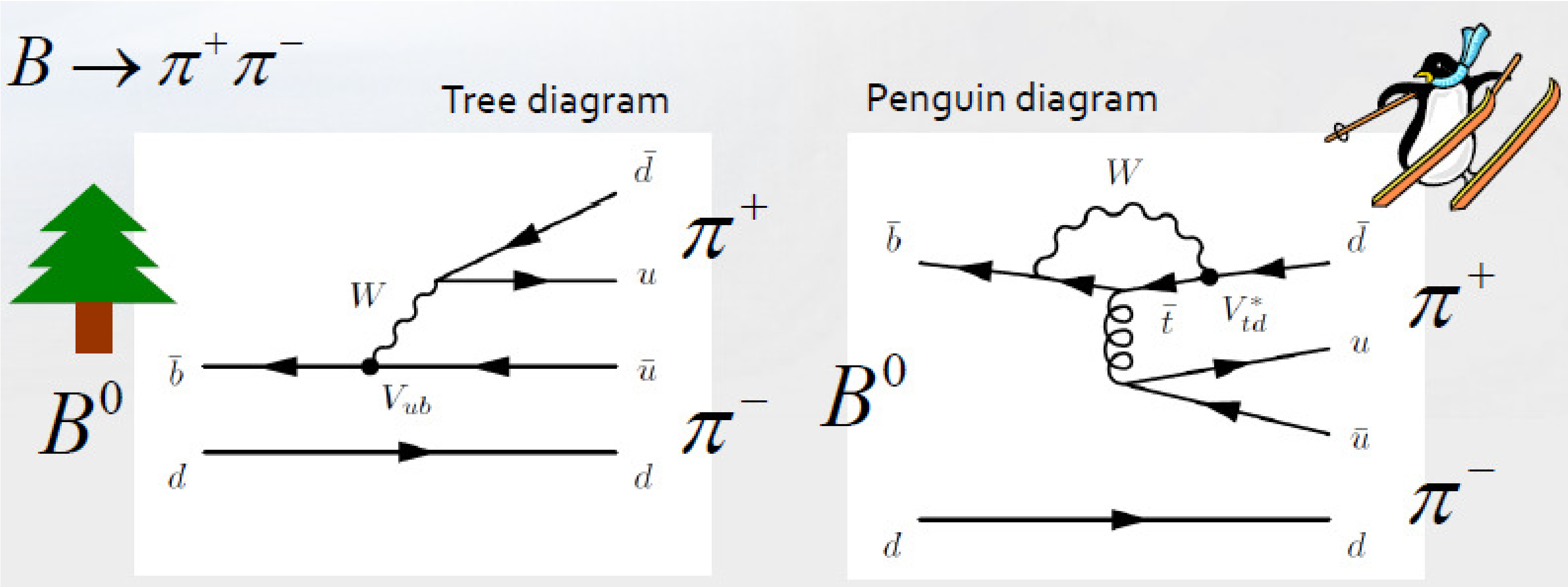
$$A(B \to f) = |D_1|e^{i(\theta_1+\phi_1)} + |D_2|e^{i(\theta_2+\phi_2)}$$

$$A(\bar{B} \to \bar{f}) = |D_1|e^{i(-\theta_1+\phi_1)} + |D_2|e^{i(-\theta_2+\phi_2)}$$

θ_i : weak phases

ϕ_i : strong phases

$$|A|^2 - |\bar{A}|^2 \propto \sin(\theta_1 - \theta_2)\sin(\phi_1 - \phi_2)$$



後田さん

Lepton Angular Distribution

$$\begin{aligned}\frac{d^4\sigma}{dq_T^2\, d\cos\hat{\theta}\, d\cos\theta\, d\phi} &= F_1(1+\cos^2\theta)+F_2(1-3\cos\theta^2)\\ &+ F_3\sin 2\theta\cos\phi + F_4\sin^2\theta\cos 2\phi\\ &+ F_5\cos\theta + F_6\sin\theta\cos\phi\\ &+ F_7\sin\theta\sin\phi + F_8\sin 2\theta\sin\phi\\ &+ F_9\sin^2\theta\sin 2\phi\end{aligned}$$

P : $\phi \to -\phi$

P-even : $F_{1\sim6}$

LO : Chaichian et.al.('82)

NLO: Mirkes('92)

P-odd : $F_{7\sim9}$

LO (one-loop) :
Hagiwara,Hikasa,Kai('84)

NLO: not yet

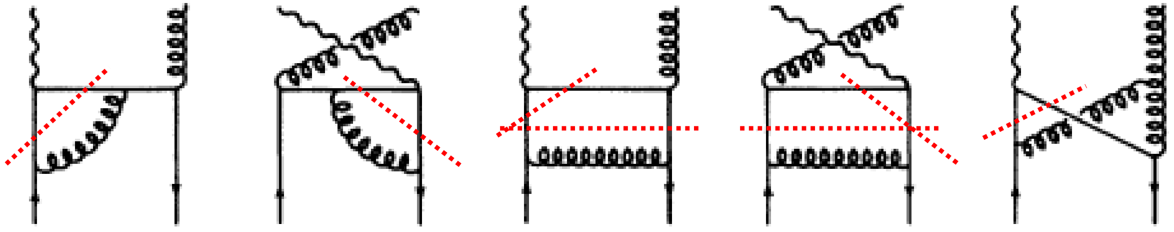
- 9個の構造関数は、Wボソンの偏極の情報を反映している。
- 方位角依存性は、干渉効果から生ずる。
- 角度積分するとF_1項のみが残る → 断面積はF_1のみで決まる。
- P-odd な分布は、loop-levelで、absorptive partから生じる。

One-loop calculation

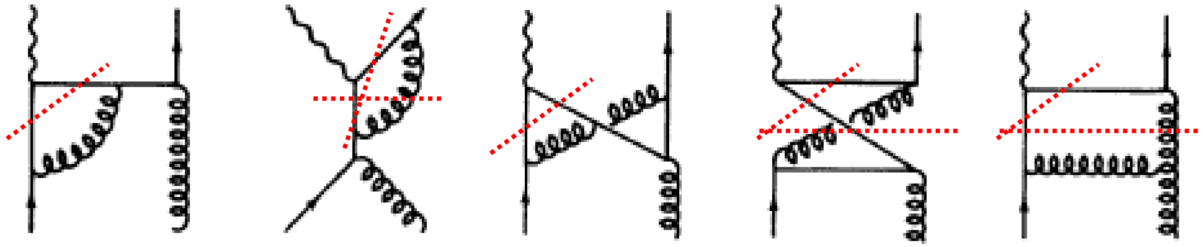
Hagiwara,Hikasa,Kai('84)

- Absorptive part for the W-jet production in one-loop level :

1. Annihilation subprocess : $q\bar{q}' \to W g$



2. Compton subprocess : $qg \to W q'$ $(\bar{q}g \to W\bar{q}')$



One-loop calculation

Origin of the imaginary part in the loop (Feynman) integrals;

$$\begin{cases} \log(x - i\epsilon) \to -i\pi\,\theta(-x) \\ \mathrm{Li}_2(x - i\epsilon) \to i\pi \ln(x)\,\theta(x-1) \end{cases}$$

$$\frac{1}{\Delta - i\epsilon} \to \mathrm{P}\frac{1}{\Delta} + i\pi\,\delta(\Delta)$$

in the integrand

Methods of calculation;

1. Analytic calculation by standard Feynman parameter integrals
2. Express by loop scalar functions and use the fortran code "FF"

Passarino,Veltman ('79), Oldenborgh ('91)

- IR divergences are regulated by using gluon mass scheme or DR.
- Check of the results by the gauge invariance

Parity-odd asymmetries

$$A_i(q_T^2, \cos\hat{\theta}) = F_i \,/\, F_1 \text{ for } i = 7, 8, 9$$

Tevatron

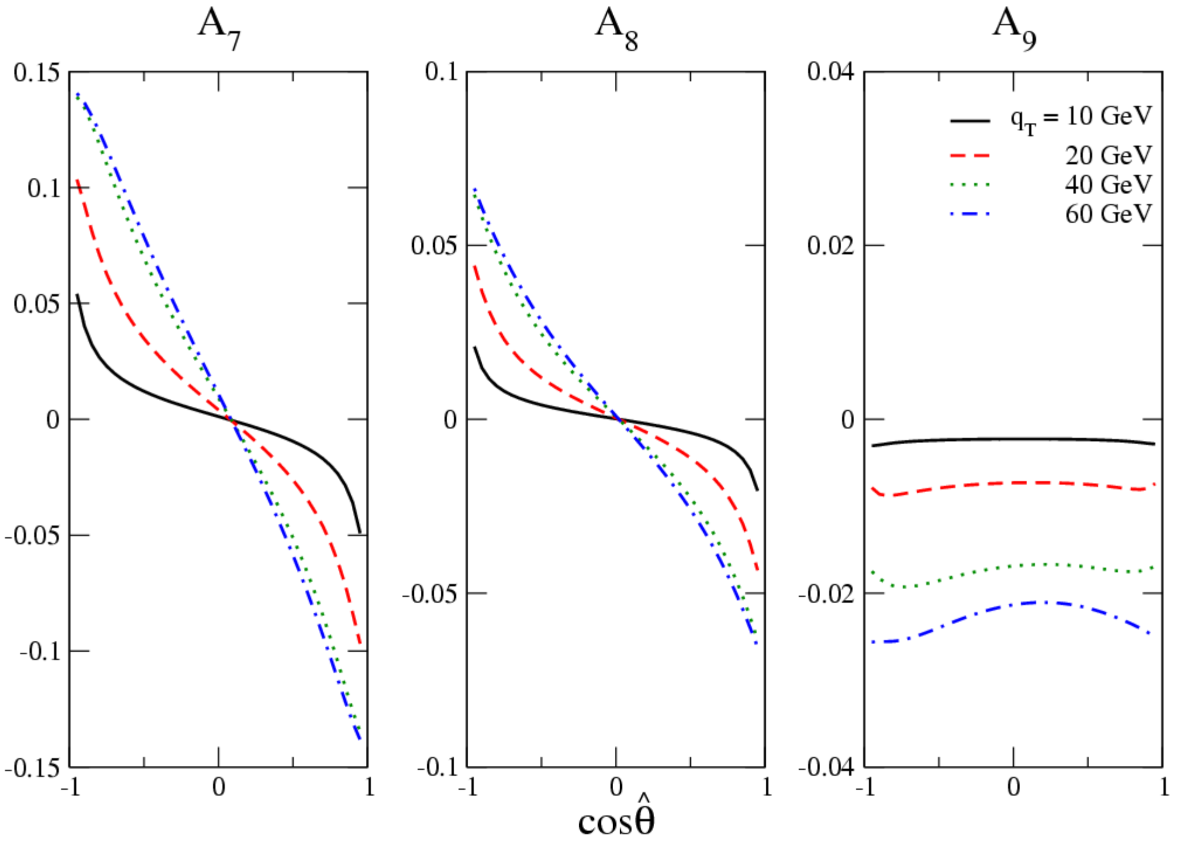
$p\bar{p}$, $\sqrt{S} = 1.96$ TeV

with CTEQ6M

A_7 ~ 5-15%,

A_8 ~ a few to 5%,

A_9 ~ a few %



$\sin\theta\sin\phi$ $\sin 2\theta\sin\phi$ $\sin^2\theta\sin 2\phi$

Parity-odd asymmetries

$A_i(q_T^2, \cos\widehat{\theta}) = F_i \,/\, F_1$ for $i = 7, 8, 9$

LHC

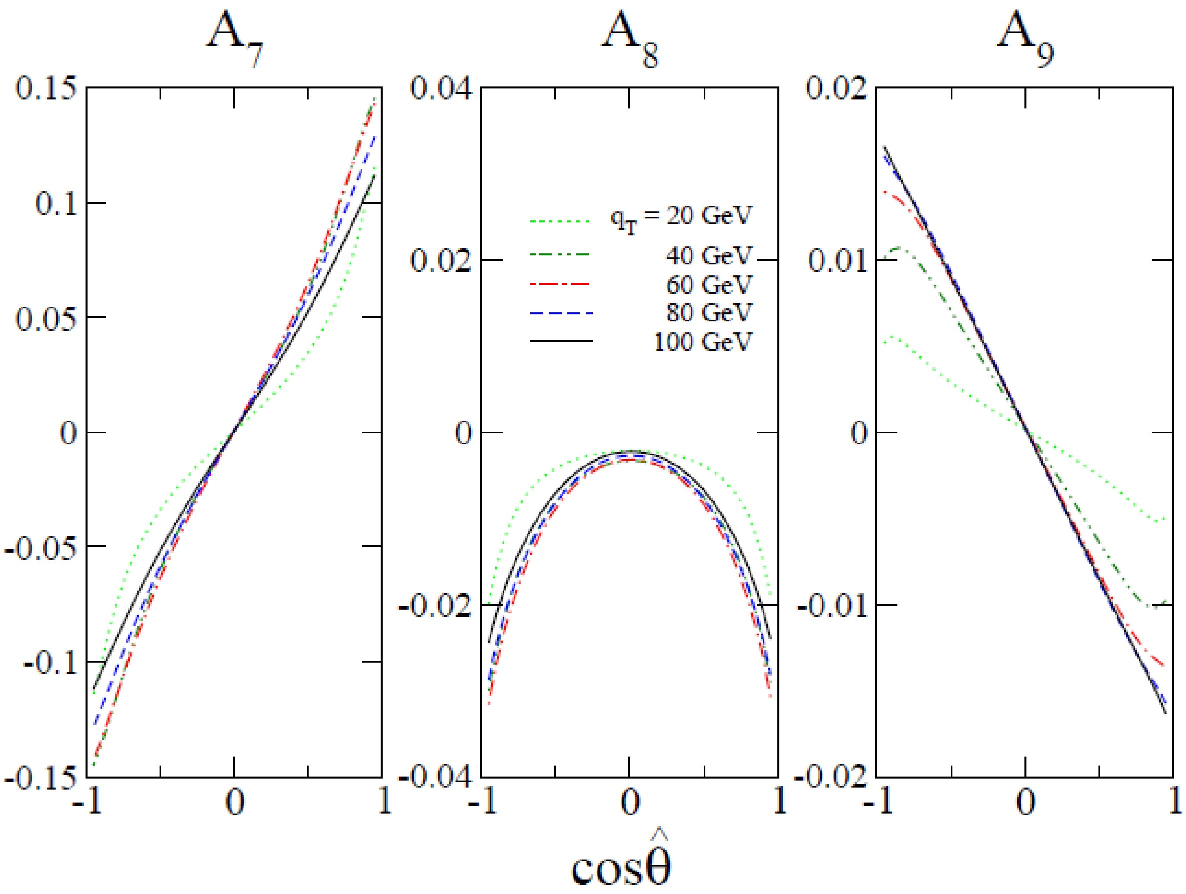
$pp,\ \sqrt{S} = 8$ TeV

with CTEQ6M

A_7 ~ 10-15%,

A_8 ~ a few %,

A_9 ~ a few %



$\sin\theta \sin\phi$ $\sin 2\theta \sin\phi$ $\sin^2\theta \sin 2\phi$

Simulation study for the LHC measurement

R.Frederix(CERN), K.Hagiwara(KEK), T.Yamada(NCU,Taiwan), HY, in progress

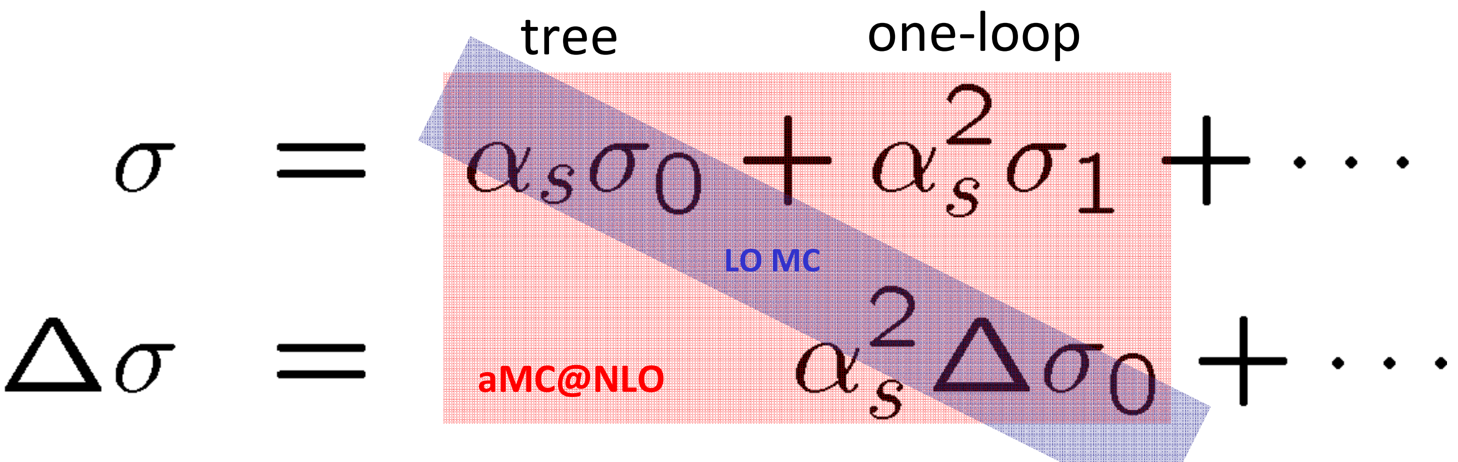
(focusing on A_7)

MC simulation with P-odd effects

MC tools are required by experimentalists to simulate their measurement. Detect effects (acceptance, resolution), ISR/FSR, hadronization → smearing of distribution, asymmetries

- We have two tools:

1. **aMC@NLO** one-loop level **(NLO for P-even, LO for P-odd)** multi-purpose
2. **LO MC** (handmade) LO calc. (no UV/IR div.) only for W+1jet



tree one-loop

Total cross-section, P-even dist.

$$\sigma = \alpha_s \sigma_0 + \alpha_s^2 \sigma_1 + \cdots$$

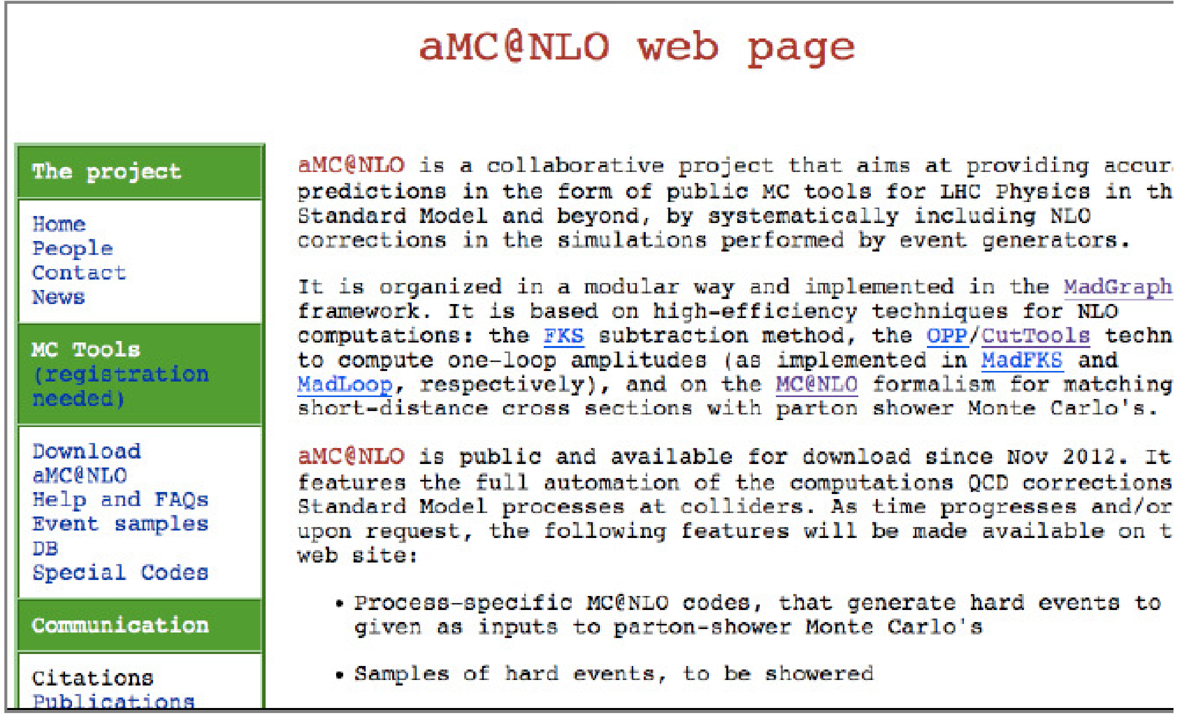
P-odd dist.

$$\Delta\sigma = \alpha_s^2 \Delta\sigma_0 + \cdots$$

aMC@NLO

- Download the code from

  https://launchpad.net/mg5amcnlo



aMC@NLO is a collaborative project that aims at providing accur
predictions in the form of public MC tools for LHC Physics in th
Standard Model and beyond, by systematically including NLO
corrections in the simulations performed by event generators.

It is organized in a modular way and implemented in the MadGraph
framework. It is based on high-efficiency techniques for NLO
computations: the FKS subtraction method, the OPP/CutTools techn
to compute one-loop amplitudes (as implemented in MadFKS and
MadLoop, respectively), and on the MC@NLO formalism for matching
short-distance cross sections with parton shower Monte Carlo's.

aMC@NLO is public and available for download since Nov 2012. It
features the full automation of the computations QCD corrections
Standard Model processes at colliders. As time progresses and/or
upon request, the following features will be made available on t
web site:

- Process-specific MC@NLO codes, that generate hard events to
  given as inputs to parton-shower Monte Carlo's
- Samples of hard events, to be showered

- NLO Event generation just in four lines

```
$ ./bin/mg5
```

```
MG5_aMC> generate p p > mu+ vm j [QCD]
MG5_aMC> output
MG5_aMC> launch
```

↓
parton-level
↓
hadron-level
(pythia,herwig)
↓
detector-level
(PGS,delphes,,)

Measurement at collider experiments

$$W^+(\to \mu^+\nu_\mu) + \text{1-jet}:$$

- Cross-section of the generated events (Q_T>15 GeV): 1.2 nb

- Cross-sections after cuts

$p_T^\mu,\ |\eta_\mu| < 2.5$: 0.94 nb

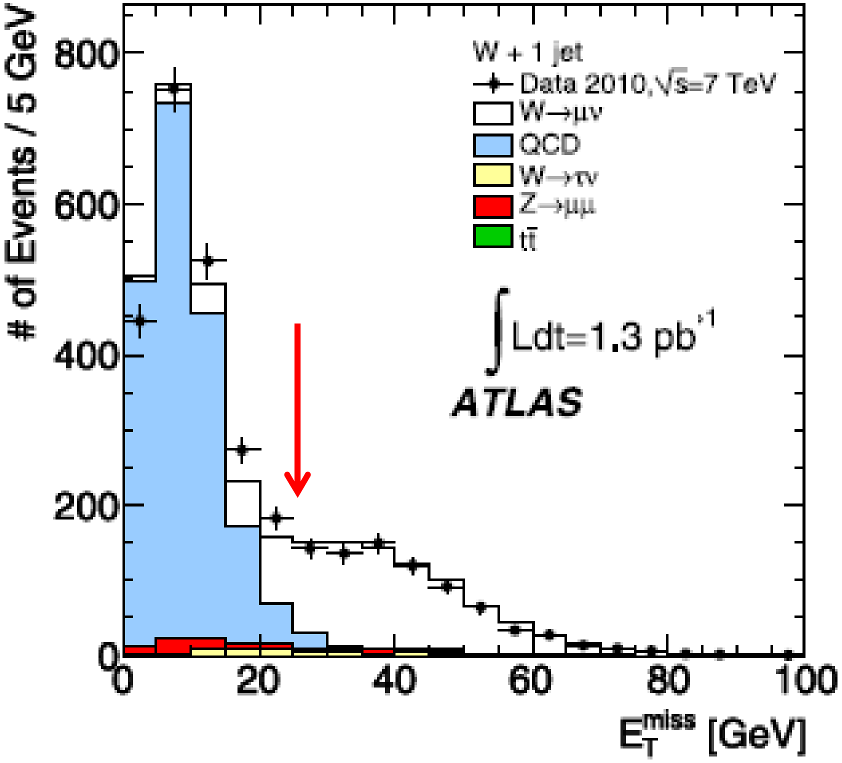
$\not{E}_T > 25$ GeV : 0.75 nb

$Q_T > 30$ GeV : 0.29 nb

$M_T^W > 60$ GeV : 0.29 nb

$p_T^j > 30$ GeV, $|\eta_j| < 5$: 0.13 nb

$$0.13 \text{ nb} \times 20 \text{ fb}^{-1} = 2.6 \times 10^6 \text{ events}$$



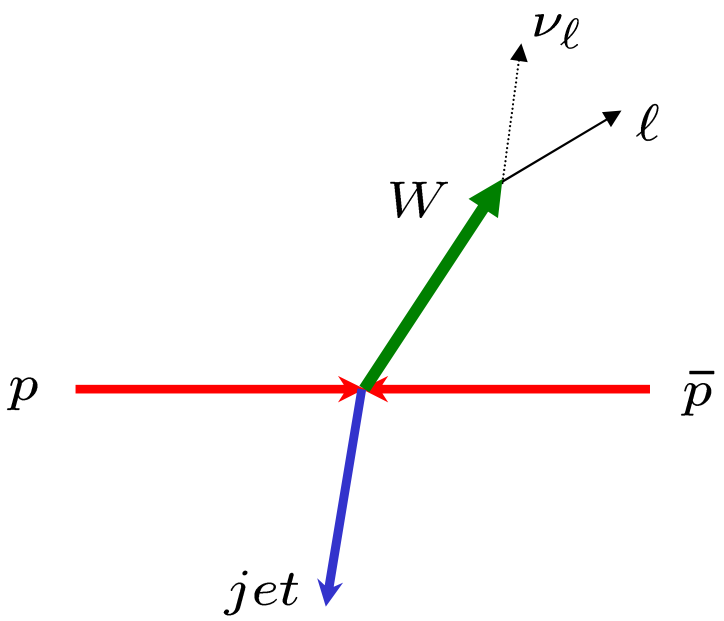
- Background :

$\text{QCD},\ Z \to \mu^+\mu^-,$
$W^+ \to \tau^+\nu_\tau$

< 10% level

Measurement at collider experiments

- Two-fold ambiguity:



(longitudinal) neutrino momentum cannot be measured, but solved by using W-boson on-shell condition.

→ Two-fold ambiguity in determining

- W-jet c.m. frame $\cos\widehat{\theta},\ \widehat{s},\ x_\pm,,,$
- W-rest frame $\cos\theta,\ (\sin\theta,\ \phi)$

- However, to measure A_7, we only need to measure

$\sin\theta\sin\phi$ → y-component of p_l in the lab. frame

$\cos\widehat{\theta}$ → use pseudo-rapidity difference of lepton and jet, instead. $\Delta\eta = \eta_\ell - \eta_{jet}$

(to avoid cancellation)

Measurement at collider experiments

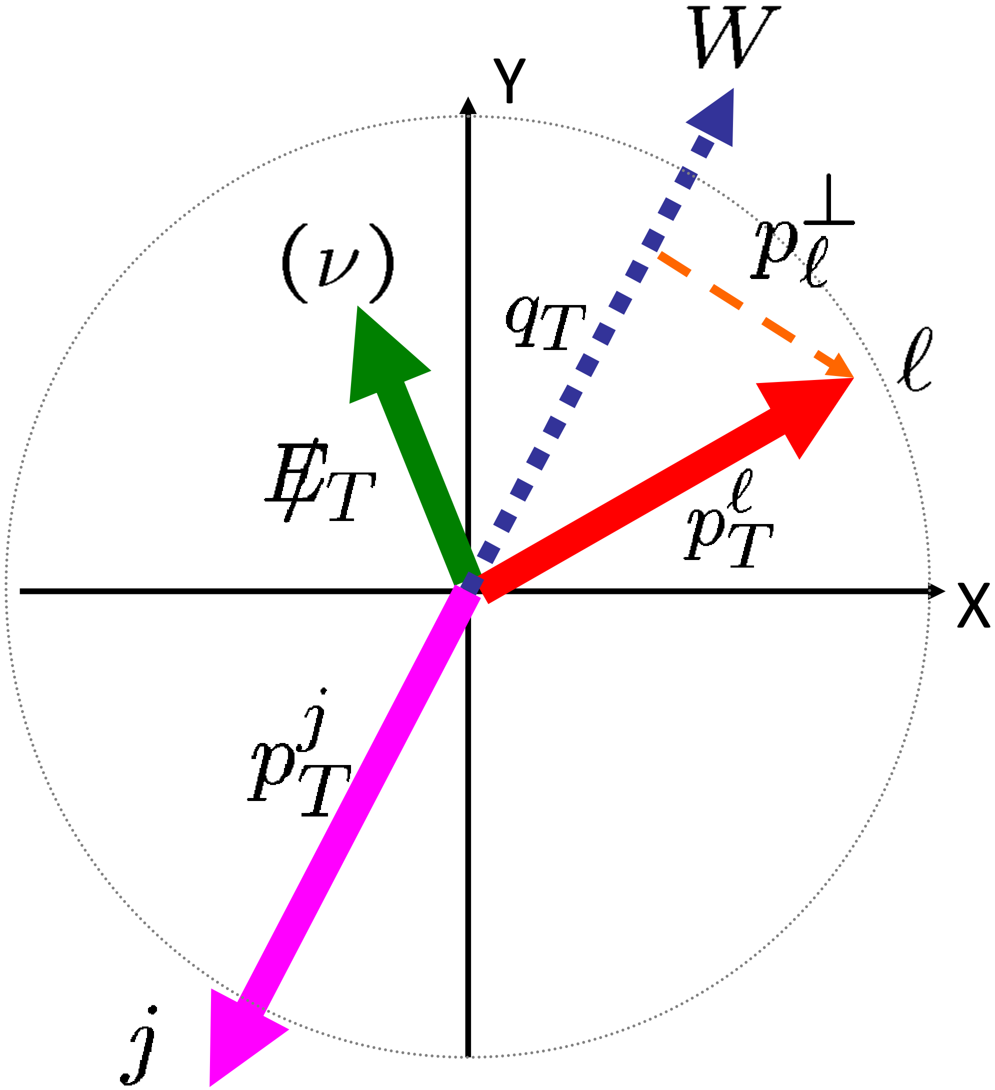
- Events in the transverse plane

$(p^y)_l$ is invariant under the Lorentz Boost from lab. frame to the W-rest frame

$$p_\ell^\perp = p_y^\ell(W - \text{rest}) = \frac{m_W}{2}\sin\theta\sin\phi$$

$$p_\ell^\perp = \frac{\not{E}_T^x p_\ell^y - \not{E}_T^y p_\ell^x}{q_T}$$

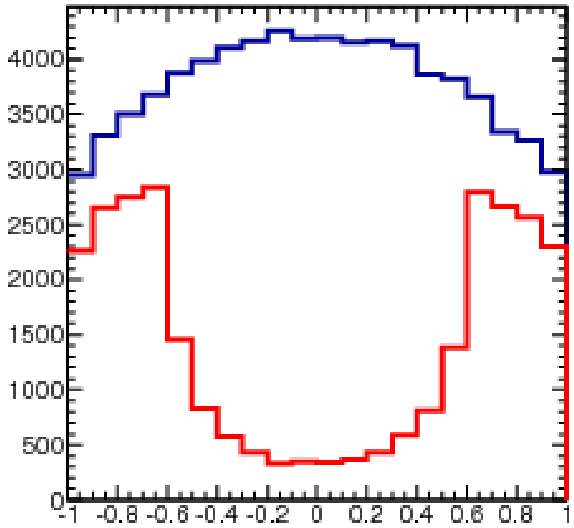
Missing E_T resolution may be crucial for the accuracy of $(p^l)_y$ measurement



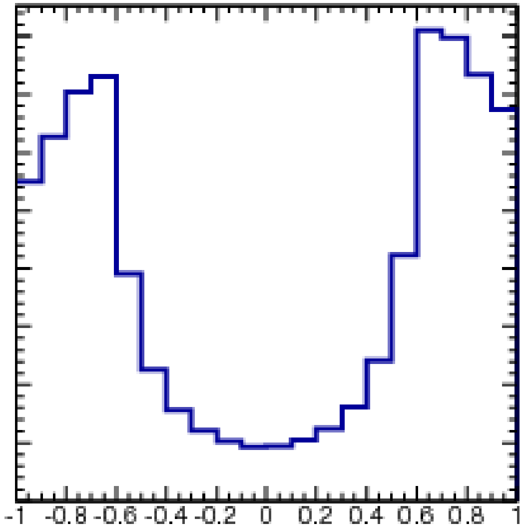
MC simulation : distributions (parton-level)

$$p_\ell^\perp \leftrightarrow \widehat{p}_\ell^{\,y}$$
$$= \sin\theta \sin\phi$$

observable from lepton momentum and missing ET



before/after cuts

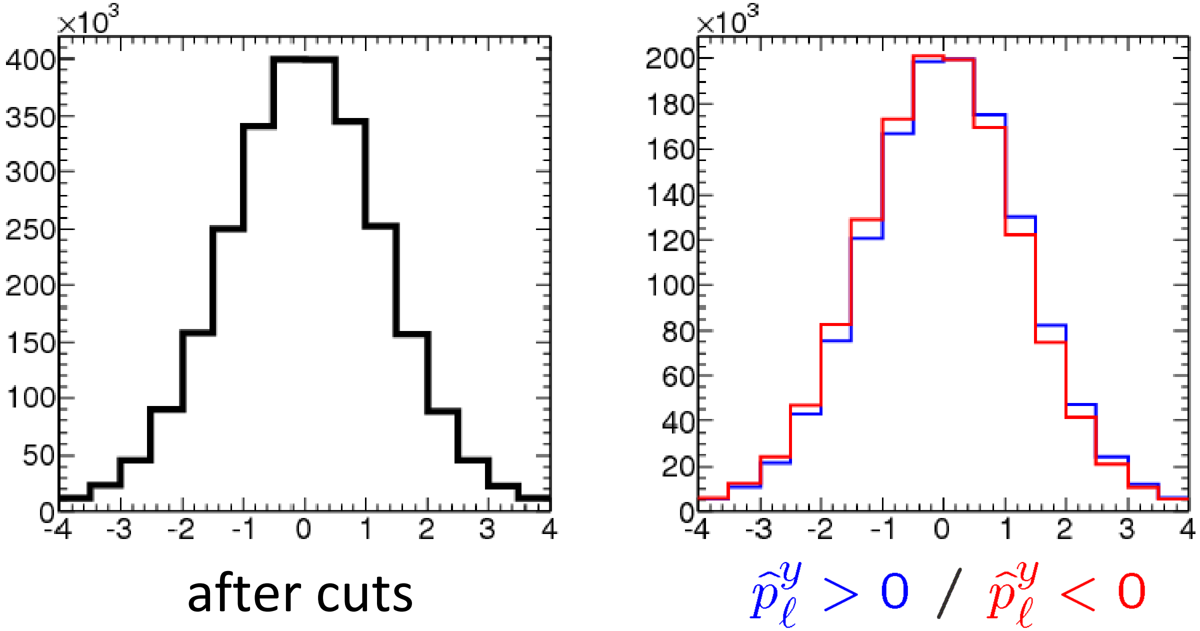


$\Delta\eta > 1$

- Asymmetric distribution appears when the scattering angle is fixed.
- Small p^y_l events are cut → Good for P-odd, because sign mis-id becomes rare.

MC simulation : distributions (parton-level)

$\Delta\eta (= \eta_\ell - \eta_j)$ distribution (instead of $\cos\hat{\theta}$)



after cuts $\hat{p}_\ell^y > 0$ / $\hat{p}_\ell^y < 0$

- Strong positive correlation with the scattering angle.
- Measurement of Δη is affected by ISR jets.
  → Smearing of the P-odd distribution and the P-odd asymmetry.

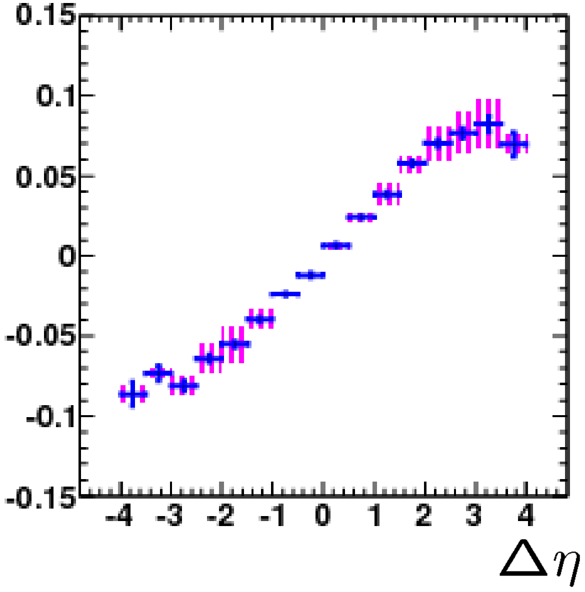
MC simulation : P-odd asymmetry

- Comparison of the P-odd asymmetry
  at the parton-level and detector-level(PGS).

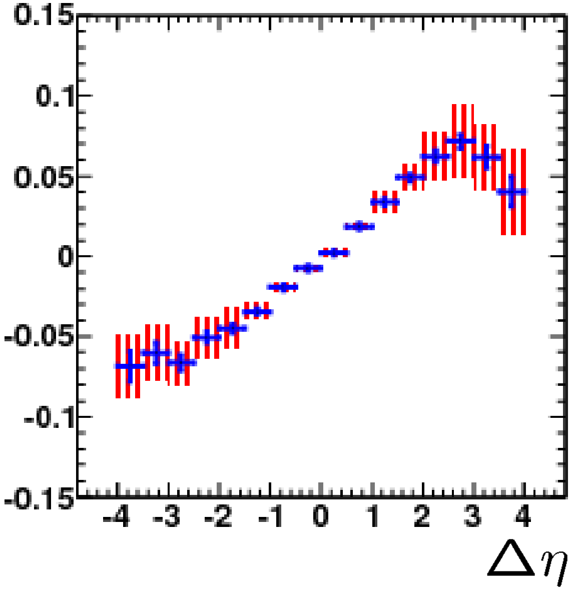
$$A_{LR} = \frac{N(\widehat{p}_\ell^{\,y} > 0) - N(\widehat{p}_\ell^{\,y} < 0)}{N(\widehat{p}_\ell^{\,y} > 0) + N(\widehat{p}_\ell^{\,y} < 0)}$$

left-right asymmetry
(A_7を反映)

parton-level



detector-level



5% - 10% asymmetry is predicted.

破線 : スケール不定性

$$\mu = Q_T/2, Q_T, 2Q_T$$

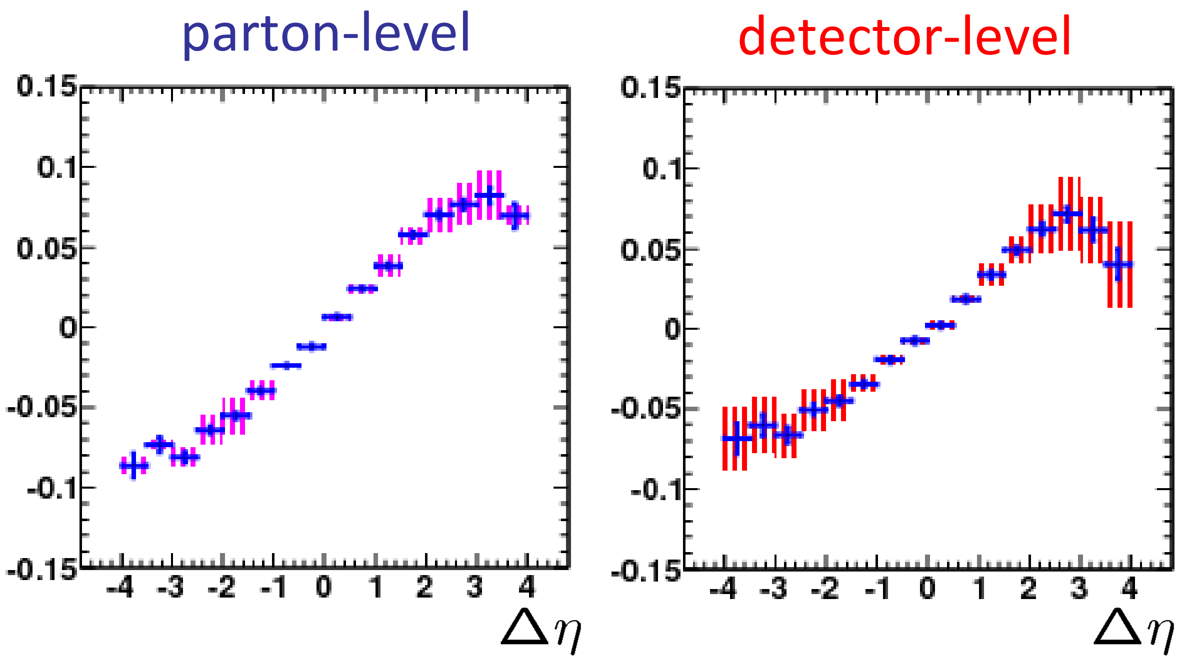
誤差棒 :

8TeV, 20fb^{-1}での統計エラー

$$\delta A(\mathrm{bin}) = \sqrt{1/N_{\mathrm{evt}}(\mathrm{bin})}$$
$$\simeq 0.1\%$$

$$|A|/\delta A = 4 \sim 20$$

MC simulation : ISR/FSR and detector effects



- Asymmetry reduction by ISR/FSR effects and detector smearing

  ~ 10%-20%

- Possible sources: $\vec{\not{E}}_T$ resolution → small, since small p^l_y events are cut.

  miss $\Delta\eta$ measurement by ISR jets

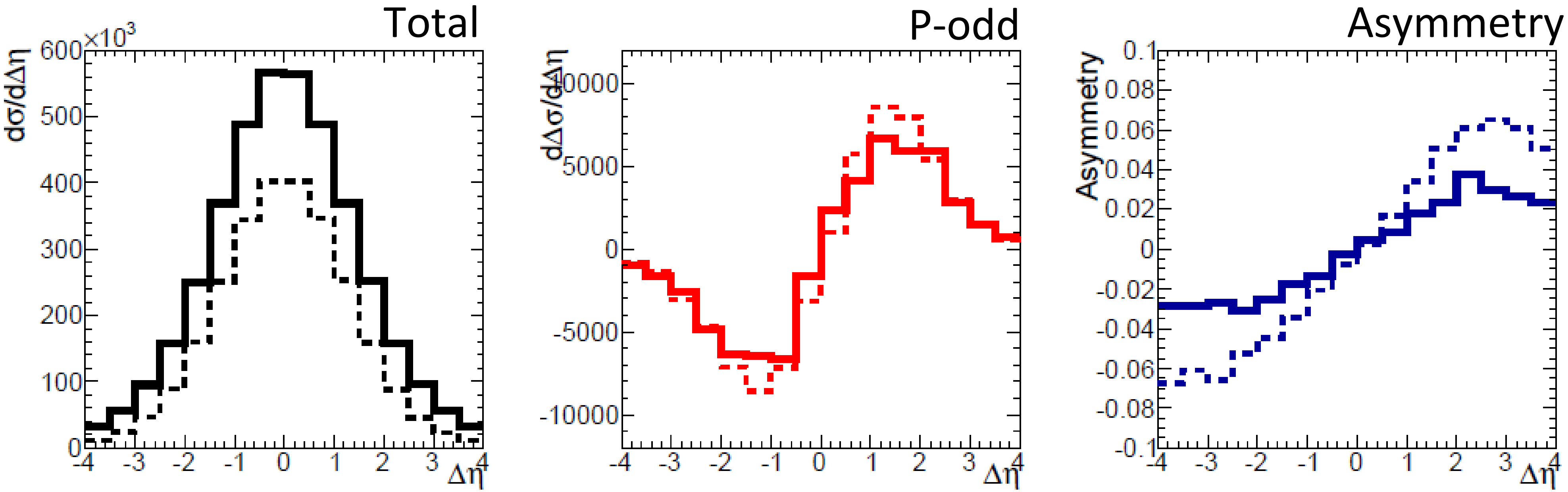
  → can be large, especially for larger $\Delta\eta$

- Scale uncertainty is also enlarged by detector effects:

  → (probably) change of the ISR jets distribution

MC simulation : LO MC vs aMC@NLO

- LO MC vs. aMC@NLO : after the detector sim.(PGS)



- P-odd cross-section unchanged → consistent with the order of calculation.
- Reduction of the asymmetry in aMC@NLO,

  due to the K-factor (~ 1.5 - 2) in the denominator (total cross-section).

→ **It must be important to check the P-odd part at NLO (2-loop calc).**
At present, it is a kind of theory uncertainty.

Future prospects :

this study

$W+$ 1-jet @ 1-loop

- LO in P-odd part
- analytically known since long time ('84~)

next step

$W+$ n-jet @ 1-loop

- LO in P-odd part
- no analytic cal.
- calculable by aMC@NLO

future

$W+$ 1-jet @ 2-loop

- **NLO** in P-odd part
- check the K-factor for P-odd
- check the perturbative convergence of the P-odd asymmetries

other process

$t \to bW^+g$ @ 1-loop

- LO is known analytically
- observability at the **LHC** or **ILC**
- reconstruction at collider is challenging

Summary

- Naïve-T-odd asymmetry emerges from the absorptive part of the scattering amplitudes. In a hard process it can be predicted, and comparison with experimental measurement would be an interesting test.
- We study the naïve-T-odd (P-odd) asymmetry in W+jet production at the LHC at one-loop level, with detailed simulation study for the realistic experimental situations.
- The asymmetry is 5%-10% level, and would be observable even after NPQCD effect and detector smearing.
- It will be a first observation of naïve-T-odd observables in hard process.