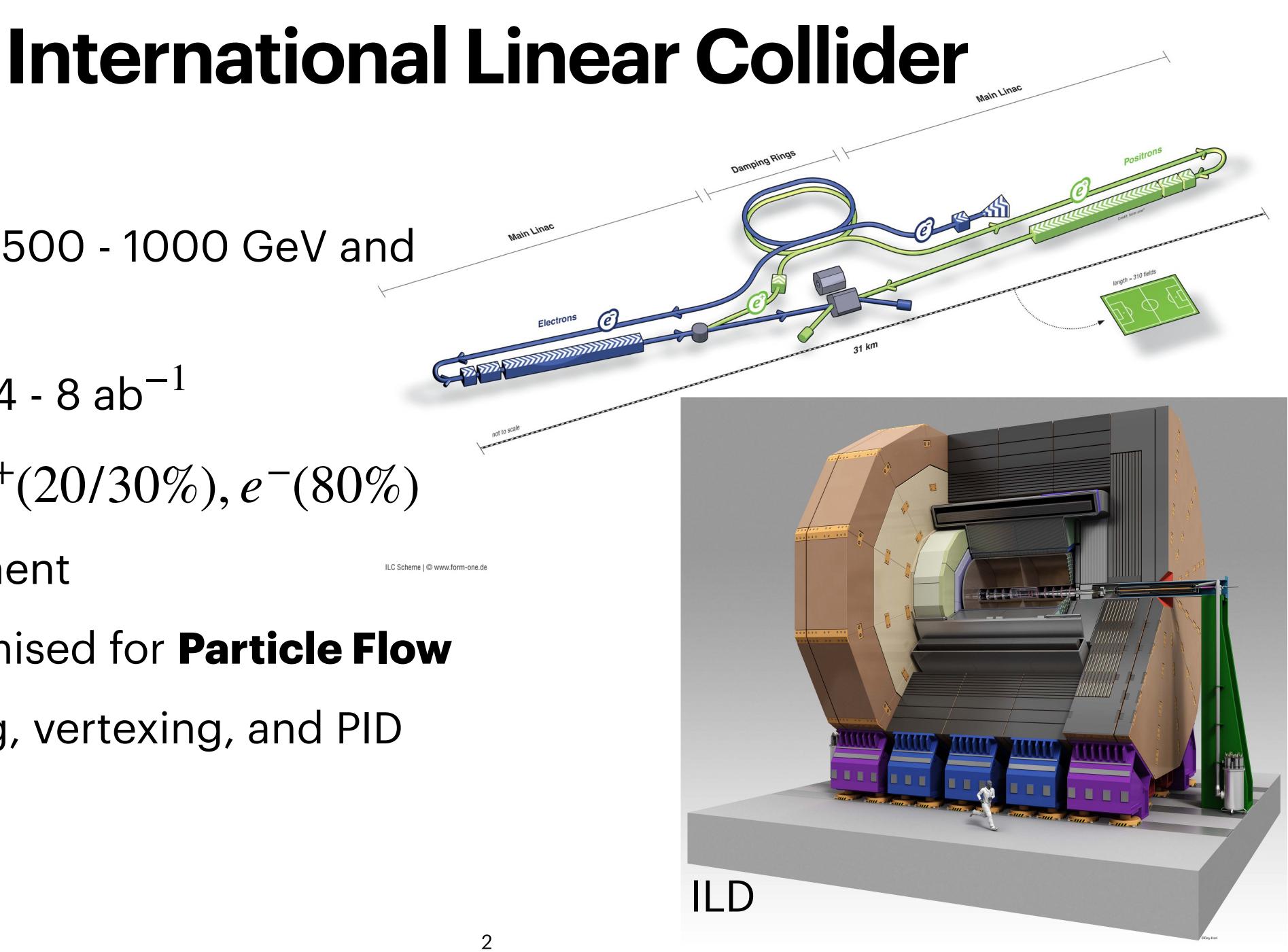


Andrej Saibel, ICHEP 2024 18th of July On behalf of the ILC International Development Team Physics and Detector Working Group



- ILC Runs: 250 500 1000 GeV and "GigaZ"
- Luminosity: $2 4 8 ab^{-1}$
- Polarisation: $e^+(20/30\%), e^-(80\%)$
- Clean environment

- Detectors optimised for Particle Flow
- Precise tracking, vertexing, and PID

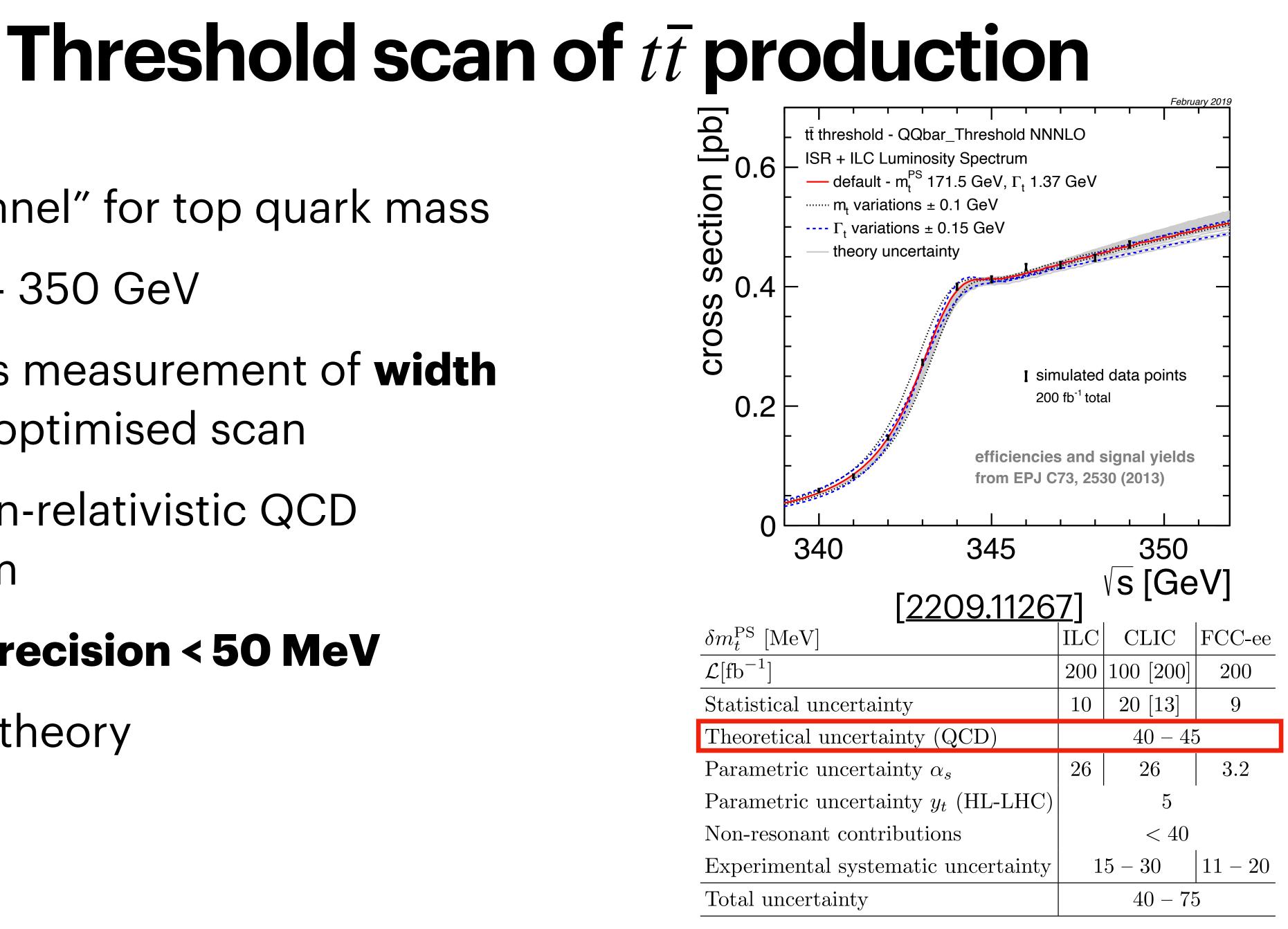


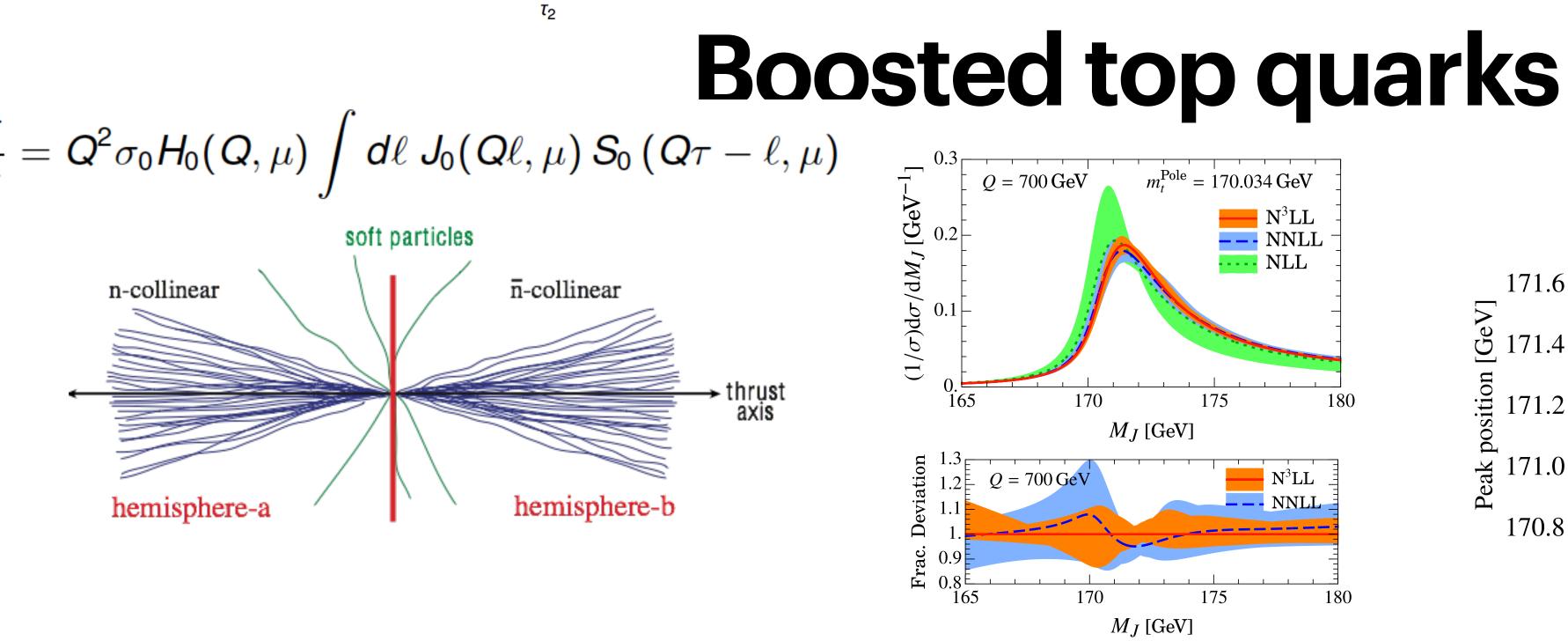
Top-quark and its properties

ATLAS+CMS Preliminary LHC <i>top</i> WG	m _{top} summa	ary, √s = 1.96-13 TeV Nove	ember 2023
LHC comb. (Sep 2023*), 7+8 TeV LHC top	wg [1][16]		
statistical uncertainty		total stat	
total uncertainty		_m + total (stat + syst + recoil) [Ge]	/1 L dt Bef
LHC comb. (Sep 2023*), 7+8 TeV		172.52 ± 0.33 (0.14 ± 0.30)	≤20 fb ⁻¹ [1][16]
World comb. (Mar 2014), 1.9+7 TeV	н	173.34 ± 0.76 (0.36 ± 0.67)	≤8.7 fb ⁻¹ , [2]
ATLAS, I+jets, 7 TeV		172.33 ± 1.27 (0.75 ± 1.02)	4.6 fb ⁻¹ , [3]
ATLAS, dilepton, 7 TeV		173.79 ± 1.42 (0.54 ± 1.31)	4.6 fb ⁻¹ [3]
ATLAS, all jets, 7 TeV		↓ 175.1±1.8 (1.4±1.2)	4.6 fb ⁻¹ , [4]
ATLAS, dilepton, 8 TeV	4	172.99 ± 0.84 (0.41± 0.74)	20.3 fb ⁻¹ , [5]
ATLAS, all jets, 8 TeV		173.72 ± 1.15 (0.55 ± 1.02)	20.3 fb ⁻¹ , [6]
ATLAS, I+jets, 8 TeV		172.08 ± 0.91 (0.39 ± 0.82)	20.2 fb ⁻¹ , [7]
ATLAS comb. (Sep 2023*) 7+8 TeV H +++		172.71 ± 0.48 (0.25 ± 0.41)	≤ 20.3 fb ⁻¹ [1]
ATLAS, leptonic inv. mass, 13 TeV	+ = + - 1	$174.41 \pm 0.81 \; (0.39 \pm 0.66 \pm 0.25)$	36.1 fb ⁻¹ , [8]
ATLAS, dilepton (*), 13 TeV ⊢++-		$172.21 \pm 0.80 \; (0.20 \pm 0.67 \pm 0.39)$	139 fb ⁻¹ [9]
CMS, I+jets, 7 TeV	+1	$173.49 \pm 1.07 \; (0.43 \pm 0.98)$	4.9 fb ⁻¹ , [10]
CMS, dilepton, 7 TeV		$172.5 \pm 1.6 \; (0.4 \pm 1.5)$	4.9 fb ⁻¹ , [11]
CMS, all jets, 7 TeV		173.49 ± 1.39 (0.69 ± 1.21)	3.5 fb ⁻¹ . [12]
CMS, I+jets, 8 TeV		172.35 ± 0.51 (0.16 ± 0.48)	19.7 fb⁻¹, [13]
CMS, dilepton, 8 TeV		$172.22 \begin{array}{c} +0.91\\ -0.95 \end{array} (0.18 \begin{array}{c} +0.93\\ -0.93 \end{array})$	19.7 fb ⁻¹ , [14]
CMS, all jets, 8 TeV		172.32 ± 0.64 (0.25 ± 0.59)	19.7 fb ⁻¹ , [13]
CMS, single top, 8 TeV	H	172.95 \pm 1.22 (0.77 $^{+0.97}_{-0.93}$)	19.7 fb ⁻¹ , [15]
CMS comb. (Sep 2023*), 7+8 TeV		172.52 \pm 0.42 (0.14 \pm 0.39)	≤ 19.7 fb ⁻¹ [16]
CMS, all jets, 13 TeV		172.34 \pm 0.73 (0.20 $^{+0.66}_{-0.72}$)	35.9 fb ⁻¹ [17]
CMS, dilepton, 13 TeV		172.33 + 0.70 (0.14 + 0.69)	35.9 fb ⁻¹ [18]
CMS, I+jets, 13 TeV ⊢⊶		171.77 ± 0.37	35.9 fb ⁻¹ , [19]
CMS, single top, 13 TeV		172.13 $^{+0.76}_{-0.77}$ (0.32 $^{+0.69}_{-0.71}$)	35.9 fb⁻¹, [20]
CMS, boosted, 13 TeV	4	173.06 ± 0.84 (0.24)	138 fb ⁻¹ , [21]
* Preliminary	 ATLAS-CONF-2023-066 arXiv:1403.4427 EPJC 75 (2015) 330 EPJC 75 (2015) 158 PLB 761 (2016) 350 JHEP 09 (2017) 118 EPJC 79 (2019) 290 	[9] ATLAS-CONF-2022-058 [16] CMS [10] JHEP 12 (2012) 105 [17] EPJG [11] EPJC 72 (2012) 2202 [18] EPJG [12] EPJC 74 (2014) 2758 [19] EPJG [13] PRD 93 (2016) 072004 [20] JHE	C 77 (2017) 354 -PAS-TOP-22-001 C 79 (2019) 313 C 79 (2019) 368 C 83 (2023) 963 P 12 (2021) 161 C 83 (2023) 560
165 170	175	180	185
	_p [GeV]		

- Fundamental parameter of SM
- Only particle with Yukawa coupling $\,\approx\,1$
- Contribution to many Higgs processes
- Stability of electroweak vacuum
 - Limited by m_t precision
 - Necessity of new physics/SUSY

- "Golden channel" for top quark mass
 - Scan: 340 350 GeV
- Simultaneous measurement of width and mass in optimised scan
- Access to non-relativistic QCD and toponium
- Achievable precision < 50 MeV
 - Limited by theory



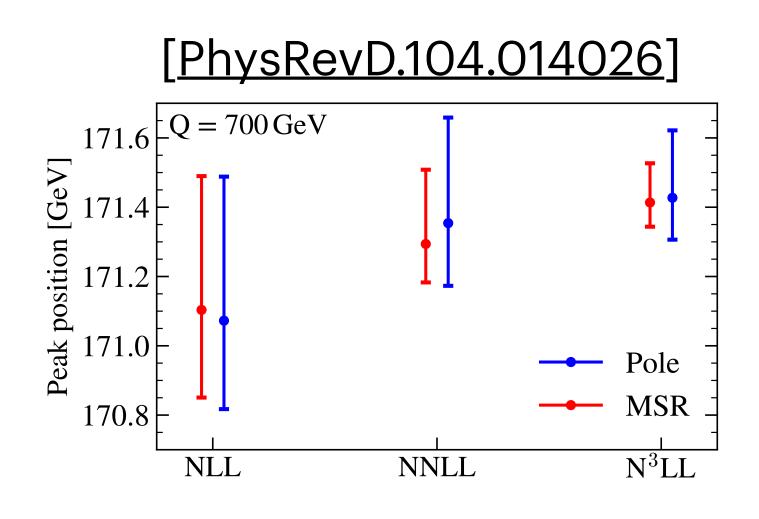


- Measurement of collimated "top jets", thrust
 - Accesible at ILC 1 TeV
- Interpretation of measured value in theory

•
$$m_t^{\text{MC}} \rightarrow m_t^{\text{Pole}}$$

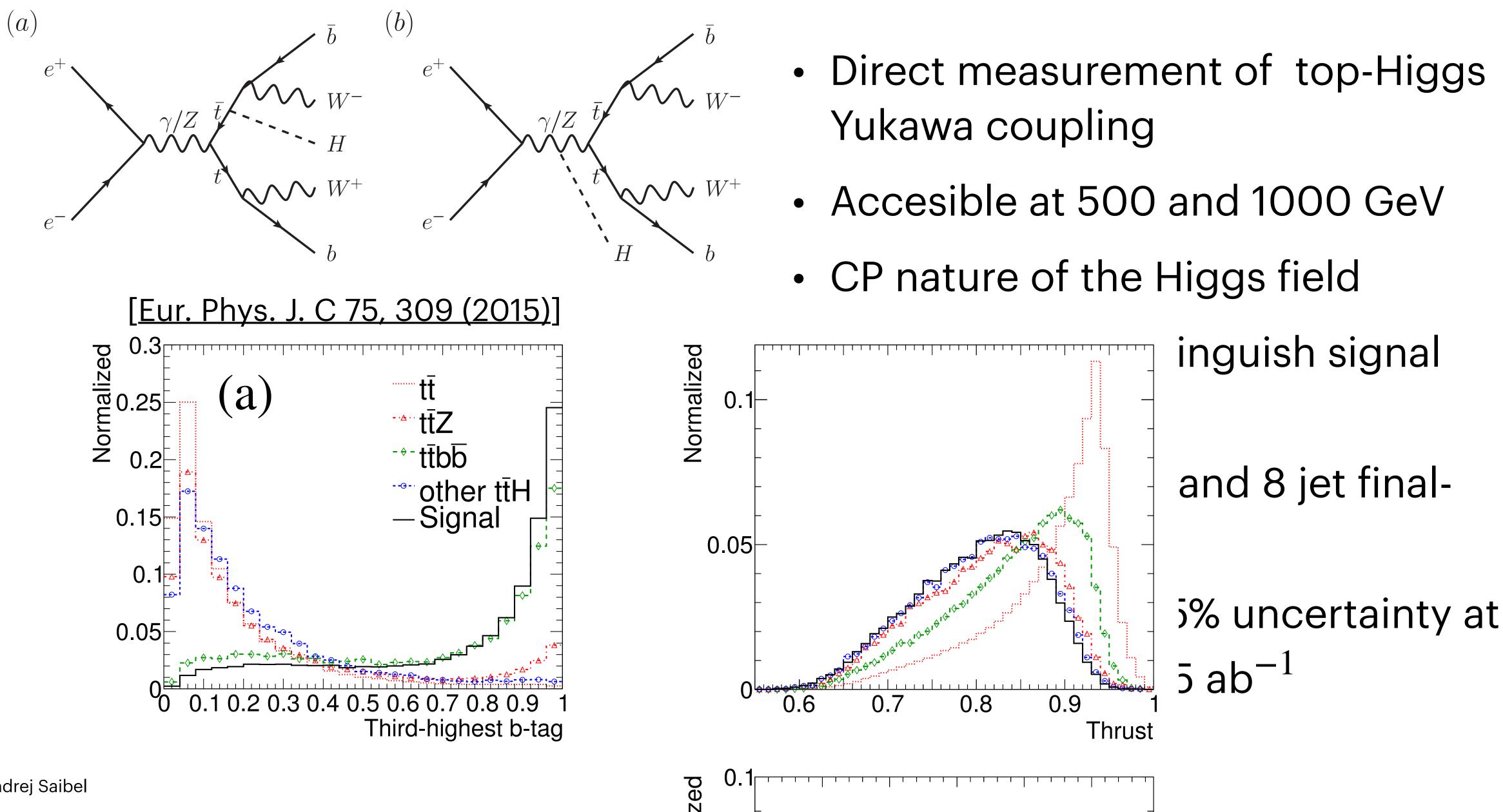
• Achievable precision ≈ 100 MeV

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mass	Q	Peak Positions [GeV]						
scheme			NNLL	$N^{3}LL$				
MSR	700	$171.104^{+0.386}_{-0.253}$	$171.294\substack{+0.214\\-0.111}$	$171.414_{-0.070}^{+0.113}$ $176.541_{-0.367}^{+0.574}$ $171.427_{-0.121}^{+0.195}$ $176.448_{-0.587}^{+0.750}$				
	2000	$175.008^{+1.858}_{-0.910}$	$176.403^{+1.287}_{-0.690}$	$176.541_{-0.367}^{+0.574}$				
Pole	700	$171.073^{+0.416}_{-0.255}$	$171.354_{-0.181}^{+0.305}$	$171.427\substack{+0.195\\-0.121}$				
1 010	2000	$174.377^{+2.087}_{-0.938}$	$176.126^{+1.461}_{-0.915}$	$176.448\substack{+0.750\\-0.587}$				

ttH production

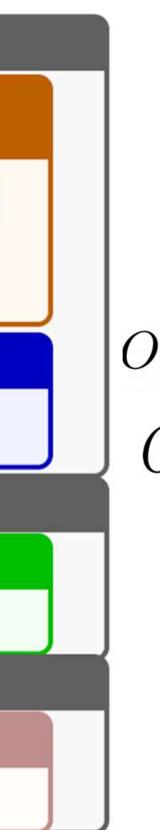


- Direct measurement of top-Higgs
- Accesible at 500 and 1000 GeV
- CP nature of the Higgs field

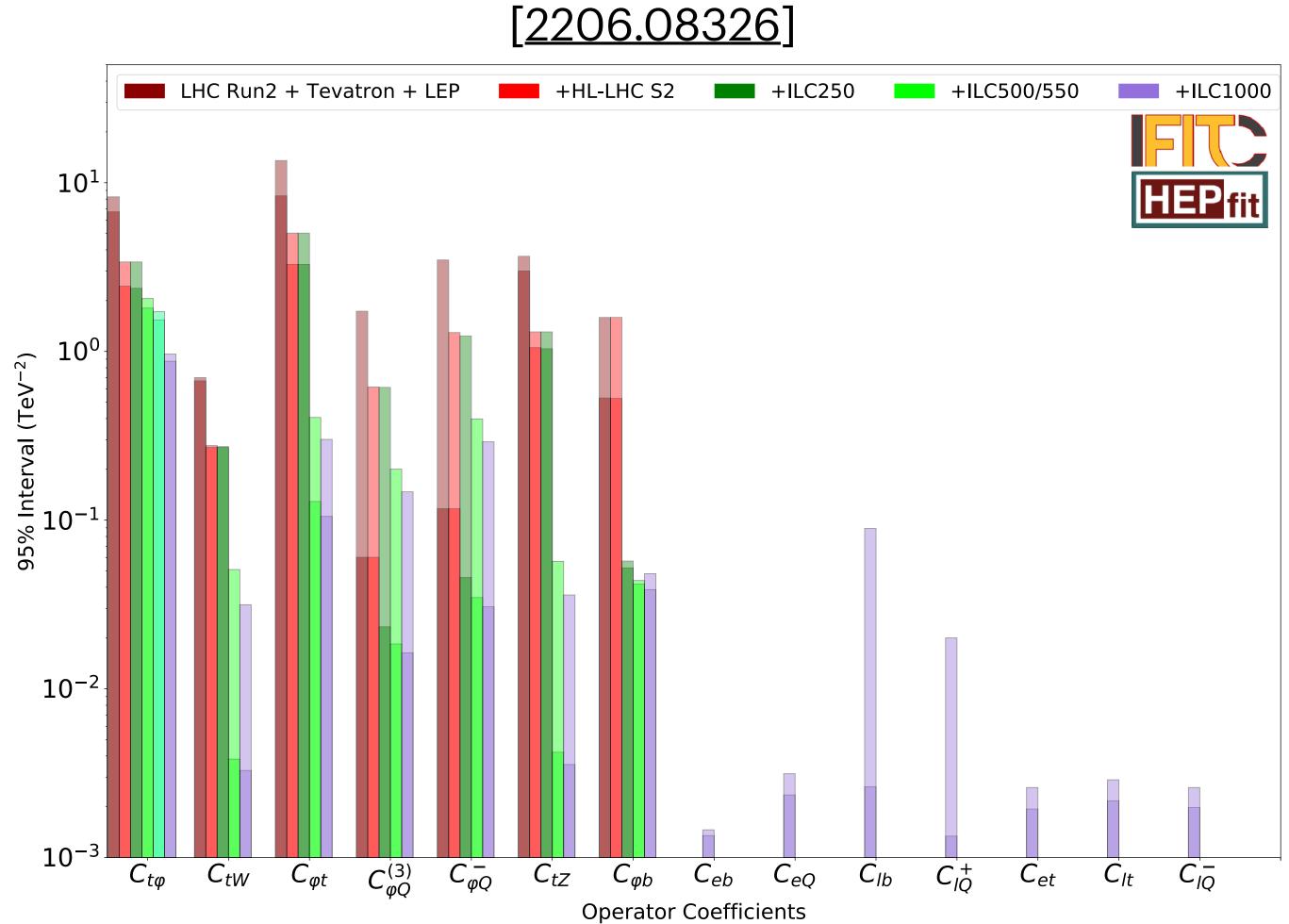
SMEFT at ILC

- Model independent search/exclusion of new physics at high energies
- Measurements above tt
 therease the text of text of
- Two and four fermion operators
- Contributions from Z and photon can be disentangled through beam polarisation

2-quark operators Couplings of the t- and b-EW dipole operators quark to the Z $O_{\varphi Q}^{3} \equiv \left(\bar{Q} \tau^{\prime} \gamma^{\mu} Q\right) \left(\varphi^{\dagger} i \overleftrightarrow{D}_{\mu}^{\prime} \varphi\right)$ $O_{uW} \equiv \left(\bar{Q}\tau'\sigma^{\mu\nu}t\right)\left(\varepsilon\varphi^*W_{\mu\nu}'\right)$ $O^{1}_{\varphi Q} \equiv \left(\bar{Q}\gamma^{\mu}Q\right) \left(\varphi^{\dagger}i\overleftrightarrow{D}_{\mu}\varphi\right)$ $O_{tB} \equiv \left(\bar{Q}\sigma^{\mu\nu}t\right)\left(\varepsilon\varphi^*B_{\mu\nu}\right)$ $O_{\varphi t(b)} \equiv \left(\overline{t}(\overline{b})\gamma^{\mu}t(b)\right)\left(\varphi^{\dagger}i\overleftarrow{D}_{\mu}\varphi\right)$ Chromo-magnetic dipole op. t-quark yukawa $O_{tG} \equiv \left(\bar{Q}\sigma^{\mu\nu}T^{A}t\right)\left(\varepsilon\varphi^{*}G^{A}_{\mu\nu}\right)$ $O_{t\varphi} \equiv \left(\bar{Q}t\right) \left(\varepsilon \varphi^* \, \varphi^{\dagger} \varphi\right)$ 4-quark operators Couplings of light quarks with t- and b-quarks $O_{Qq}^{3,8}$ $O_{Qq}^{1,8}$ O_{td}^8 O_{tq}^8 O_{tu}^8 $O_{Q_u}^8$ O_{Qd}^8 2-quark 2-lepton operators Couplings of light leptons with t- and b-quarks O_{IQ}^+ OIL O_IQ O_{eb} O_{et} O_{lt} O_{eQ}



SMEFT at ILC



Improvements of up to two orders of magnitude compared to HL-LHC

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Z-boson couplings and BSM

- Precise measurements of Z-boson couplings enable study of BSM physics
- Gauge Higgs Unification models predict new Bosons at high energies
 - Modification of couplings
- Studies at ILC can lead to observation/exclusion
- Dedicated <u>talk</u> Friday, 9am

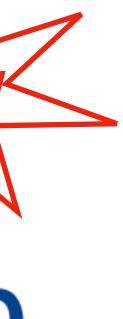
[Eur. Phys. J. C 84, 537 (2024)]

	GHU vs SM discrimination power (σ-level)												
B_3^+	0.1	0.4	0.5	0.1	0.7	0.8	0.5	1.3	1.3	1.6	2.5	2.5	Z-
B ₃	0.1	0.4	0.5	0.3	0.9	0.9	0.9	2.7	2.7	3.3	6.7	6.8	•
B ₂ +	0.2	0.7	0.8	0.3	1.5	1.6	0.9	2.2	2.3	3.0	4.4	4.5	•
B ₂	0.2	0.7	0.7	0.5	1.4	1.5	1.7	4.6	4.8	6.3	>10	>10	•
B_1^+	0.3	1.6	1.7	0.7	3.2	3.5	1.5	4.4	4.7	4.3	6.8	7.0	
B ₁	0.5	1.4	1.4	0.9	2.7	2.8	3.3	9.6	9.9	>10	>10	>10	
A ₂	0.6	3.3	3.6	0.9	4.8	5.3	4.3	>10	>10	>10	>10	>10	
A ₁	0.8	3.9	4.2	1.0	5.0	5.5	5.3	>10	>10	>10	>10	>10	1
	C	R	Z	С	R	Z	C	R	Z	С	R	Z	
	IL	C2:	50 [•]	IL	C2:	50	IL	C2	50	IL	C2	50	

-fermion couplings

- C: Current precision
- R: ILC250 (Rad. Ret.)
- Z: Giga-Z
- <3σ 3-4 σ 4-5 σ >5σ

+500 +500 (no pol.) +1000*



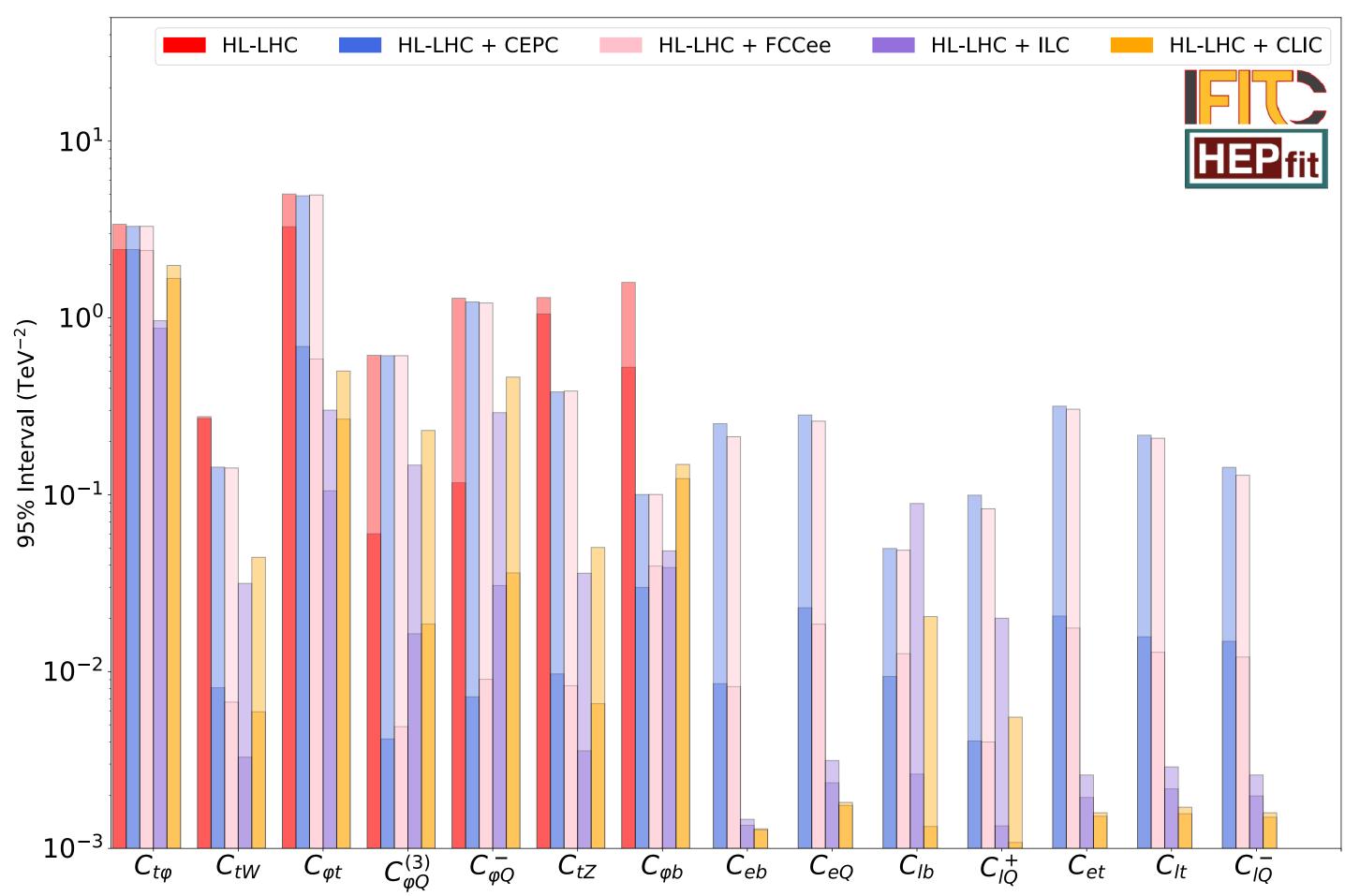
Conclusion

- Rich heavy flavor physics program at ILC
- Clean environment enables precise measurements
- The top-quark is properties are important ingredients for SM and BSM physics
- Beam polarisation improves sensitivity of measurements
- Improvements compared to HL-LHC often orders of magnitude



BACKUP

SMEFT all future colliders



Operator Coefficients