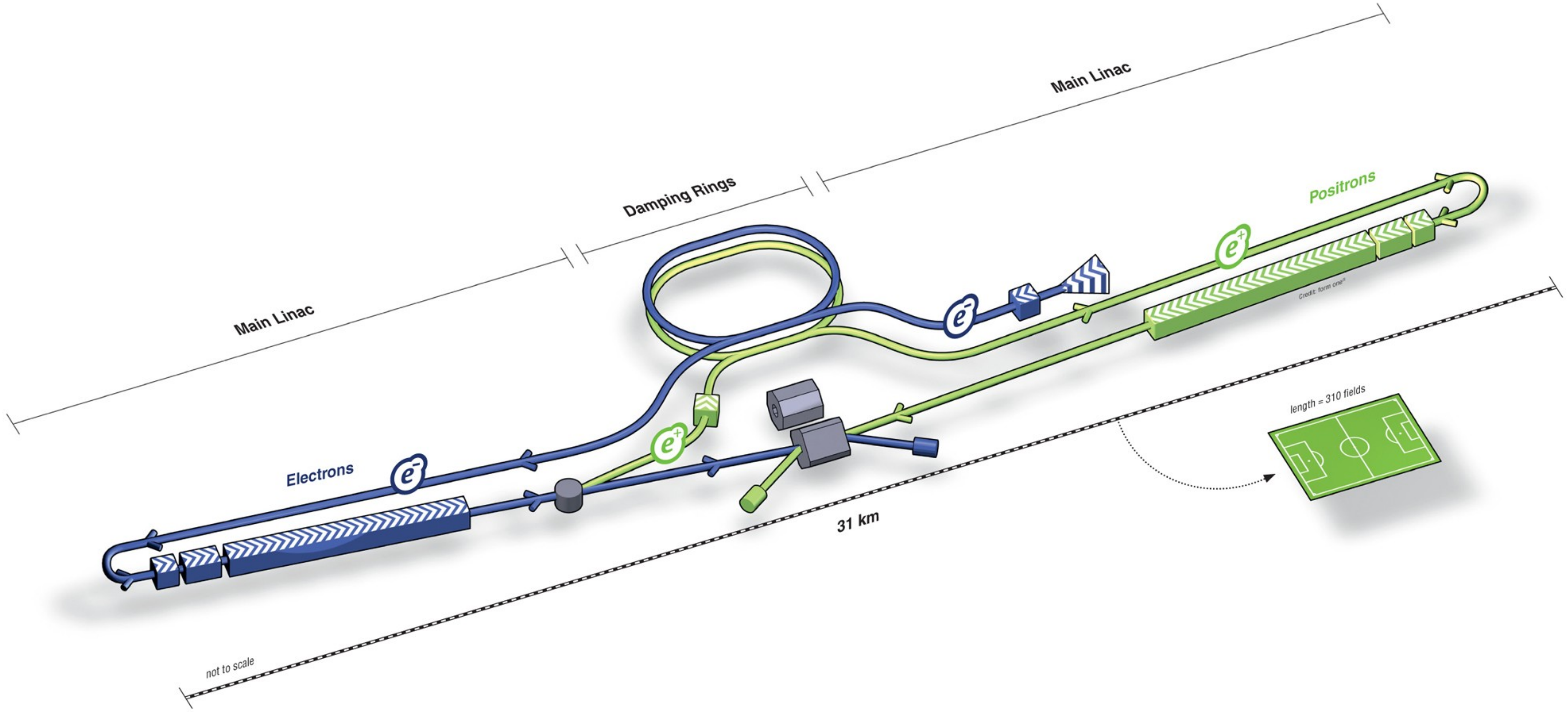


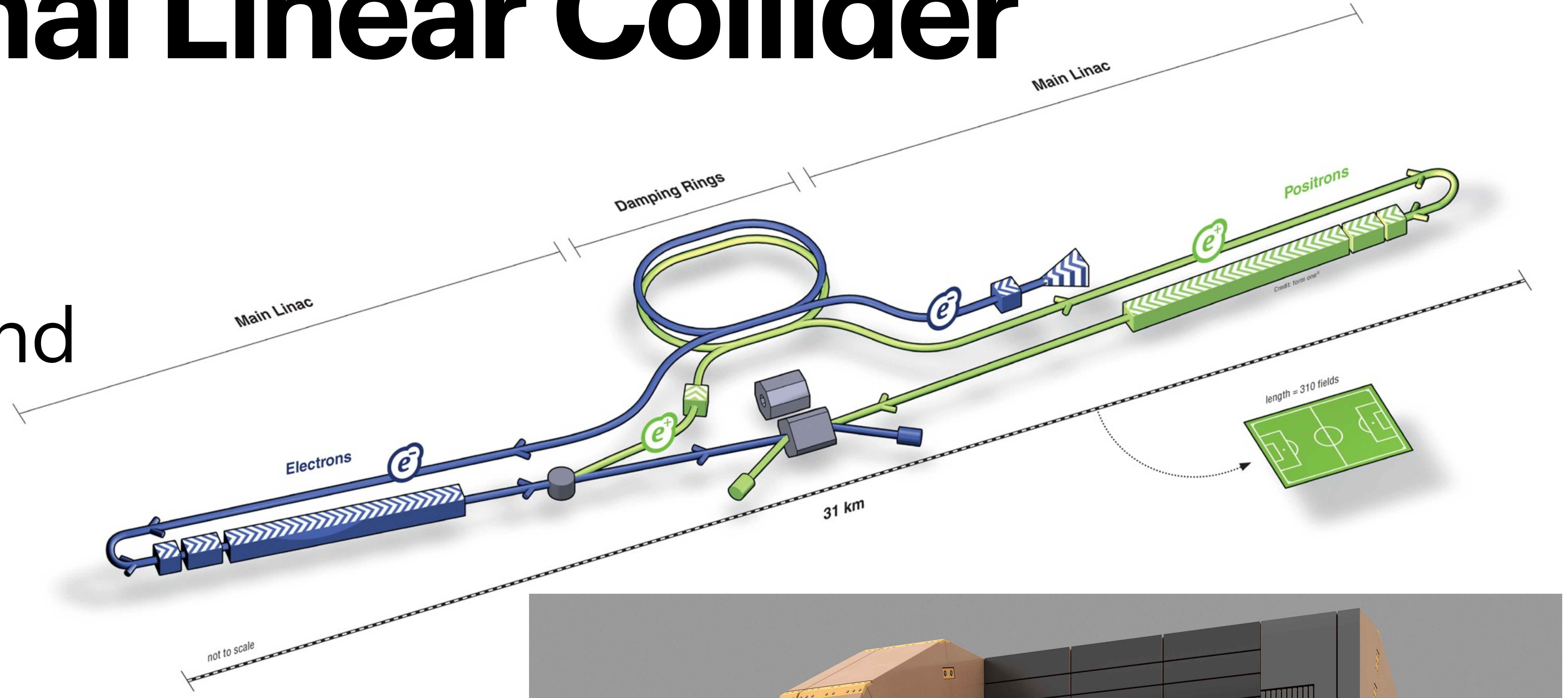
ILC Scheme | © www.form-one.de

Heavy flavor studies at ILC

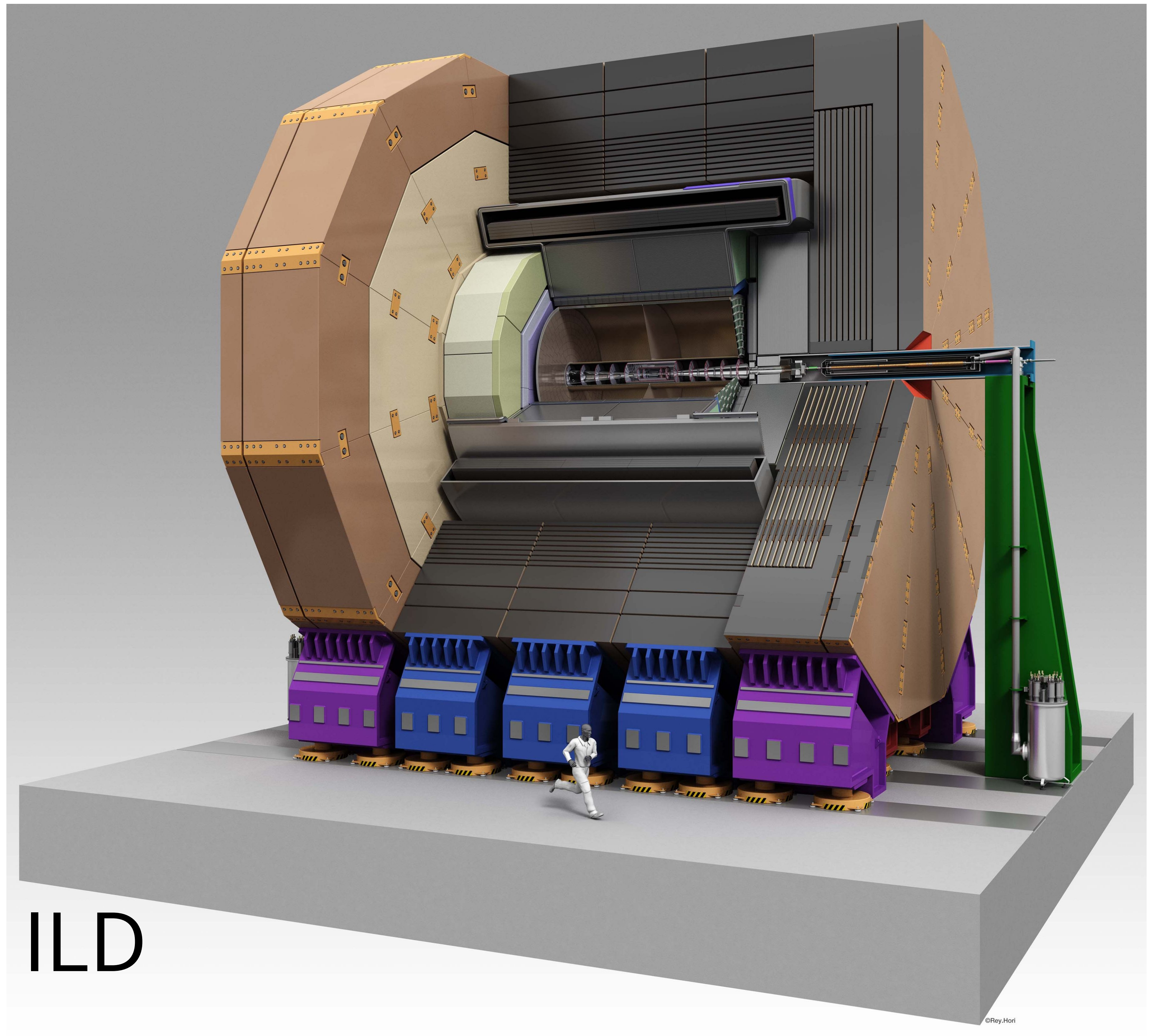
Andrej Saibel, ICHEP 2024 18th of July
On behalf of the ILC International Development Team Physics and Detector Working Group

International Linear Collider

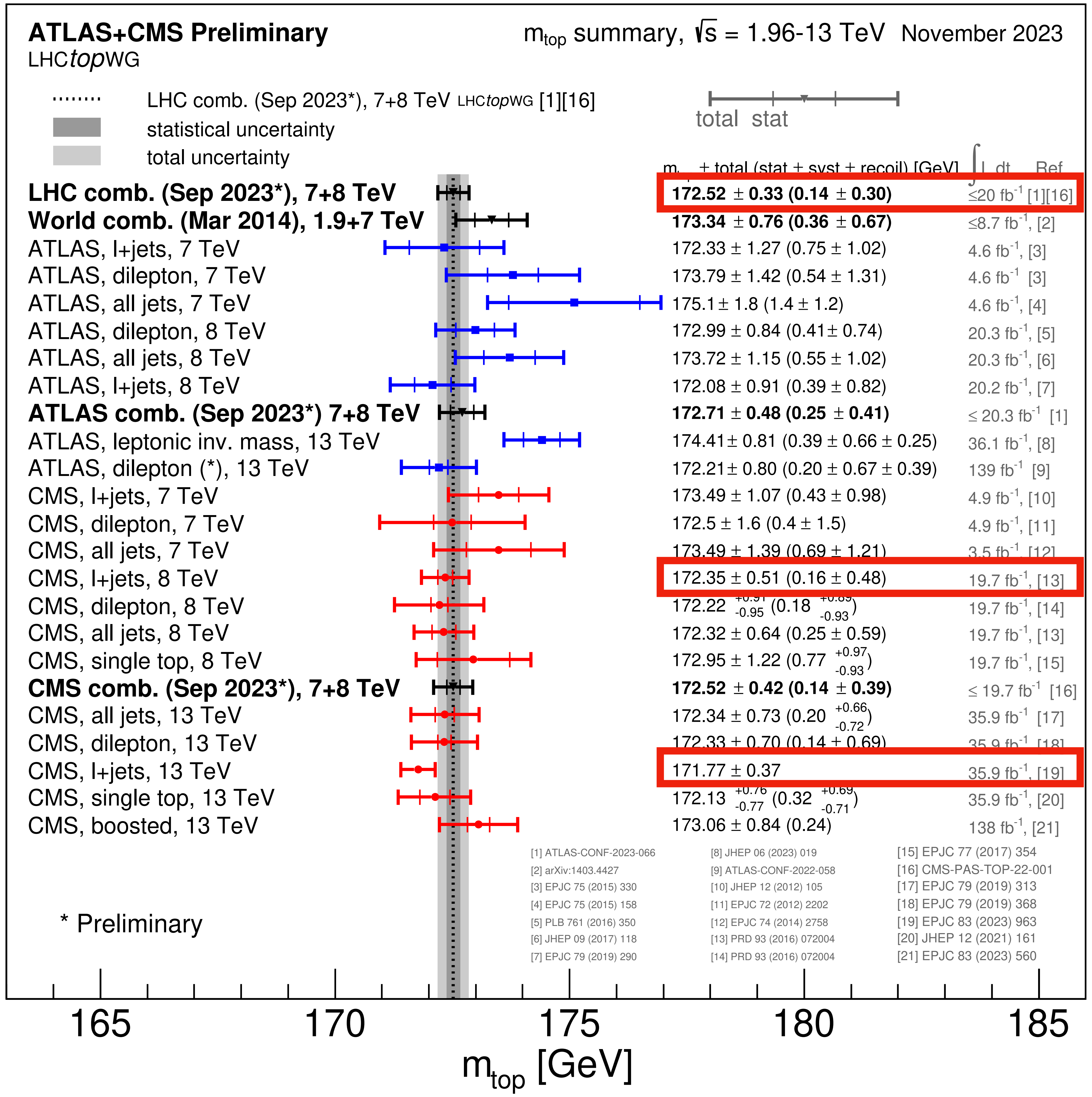
- ILC Runs: 250 - 500 - 1000 GeV and “GigaZ”
- Luminosity: 2 - 4 - 8 ab^{-1}
- **Polarisation**: $e^{+}(20/30\%), e^{-}(80\%)$
- Clean environment
- Detectors optimised for **Particle Flow**
- Precise tracking, vertexing, and PID



ILC Scheme | © www.form-one.de



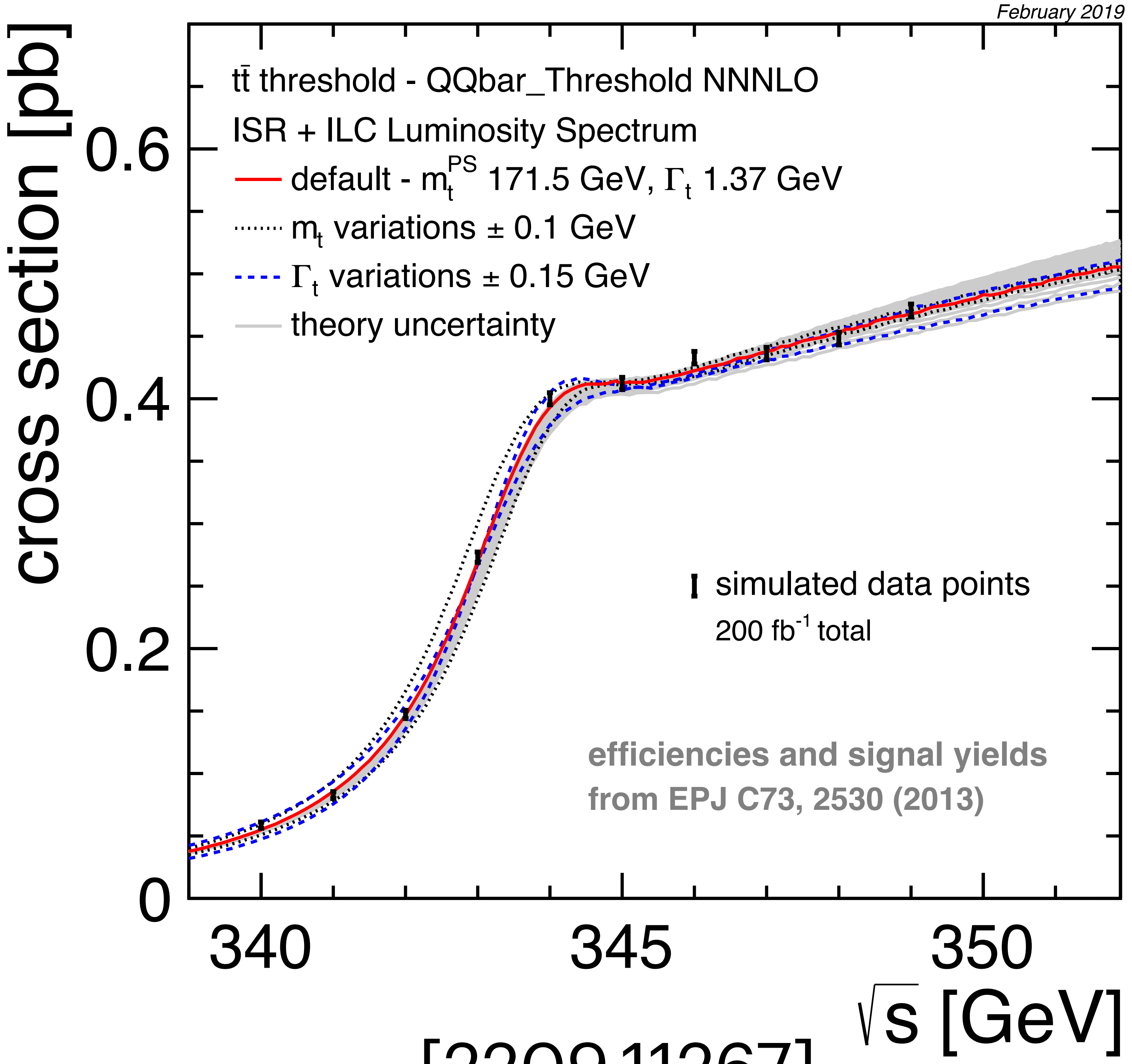
Top-quark and its properties



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

Threshold scan of $t\bar{t}$ production

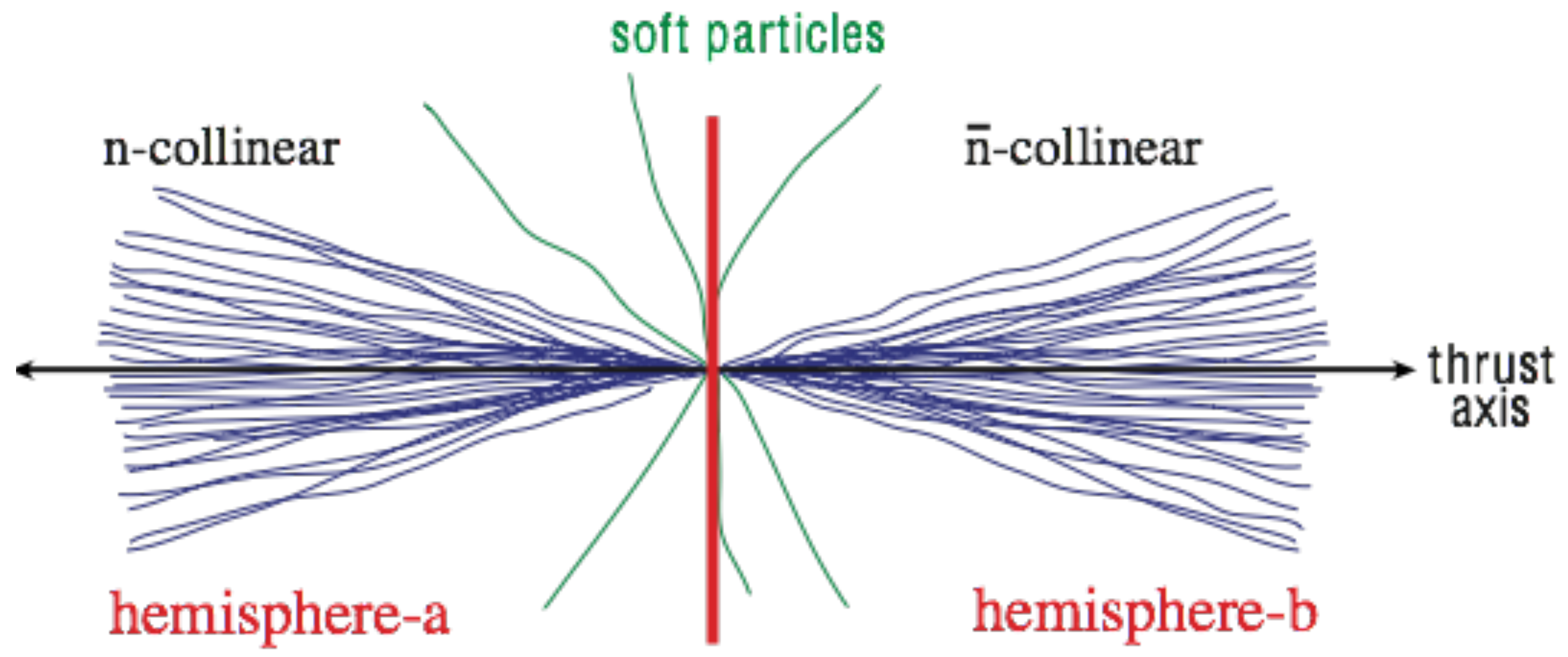
- "Golden channel" for top quark mass
  - Scan: 340 - 350 GeV
- Simultaneous measurement of **width** and **mass** in optimised scan
- Access to non-relativistic QCD and toponium
- Achievable **precision < 50 MeV**
  - Limited by theory

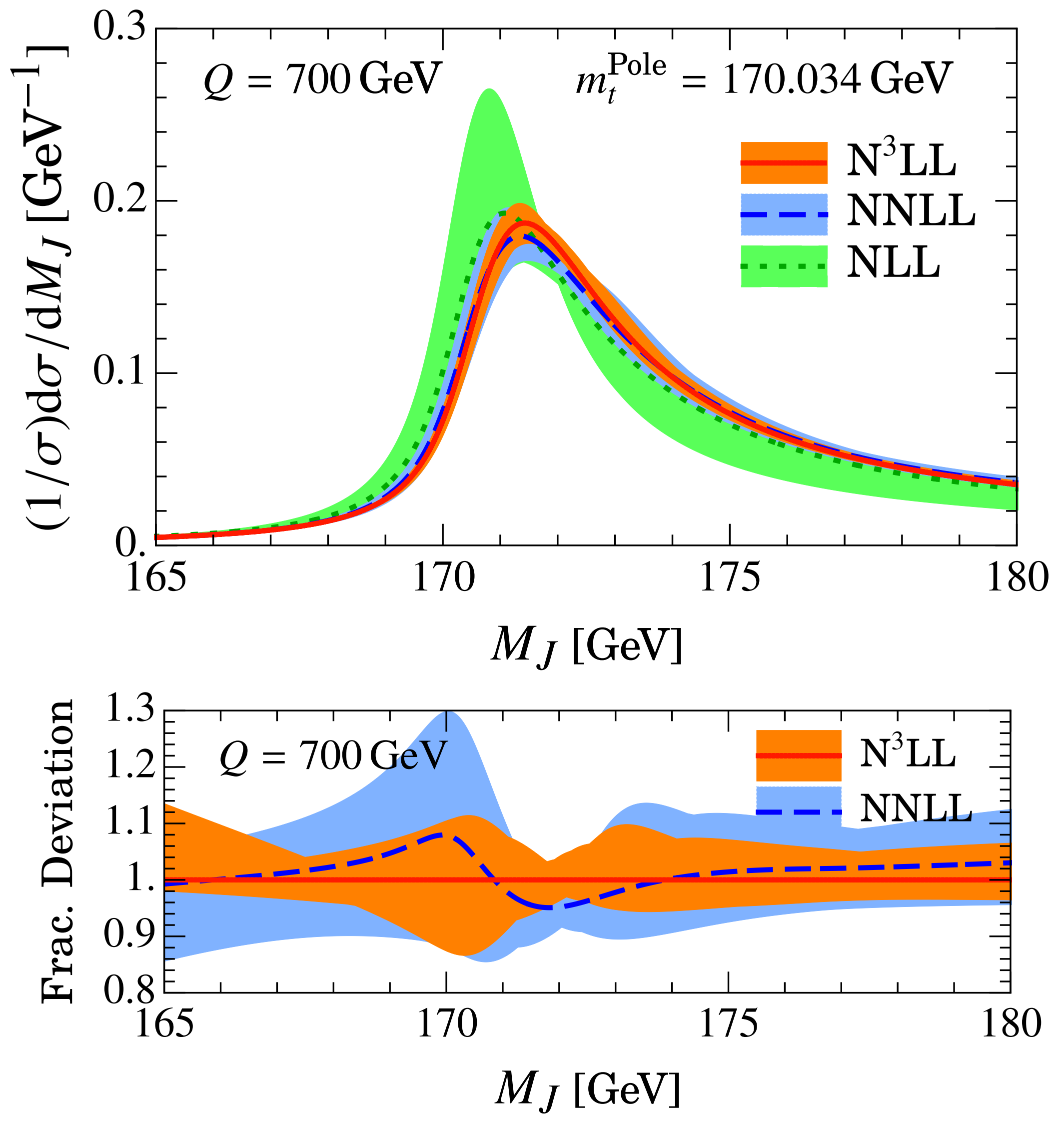


[2209.11267]

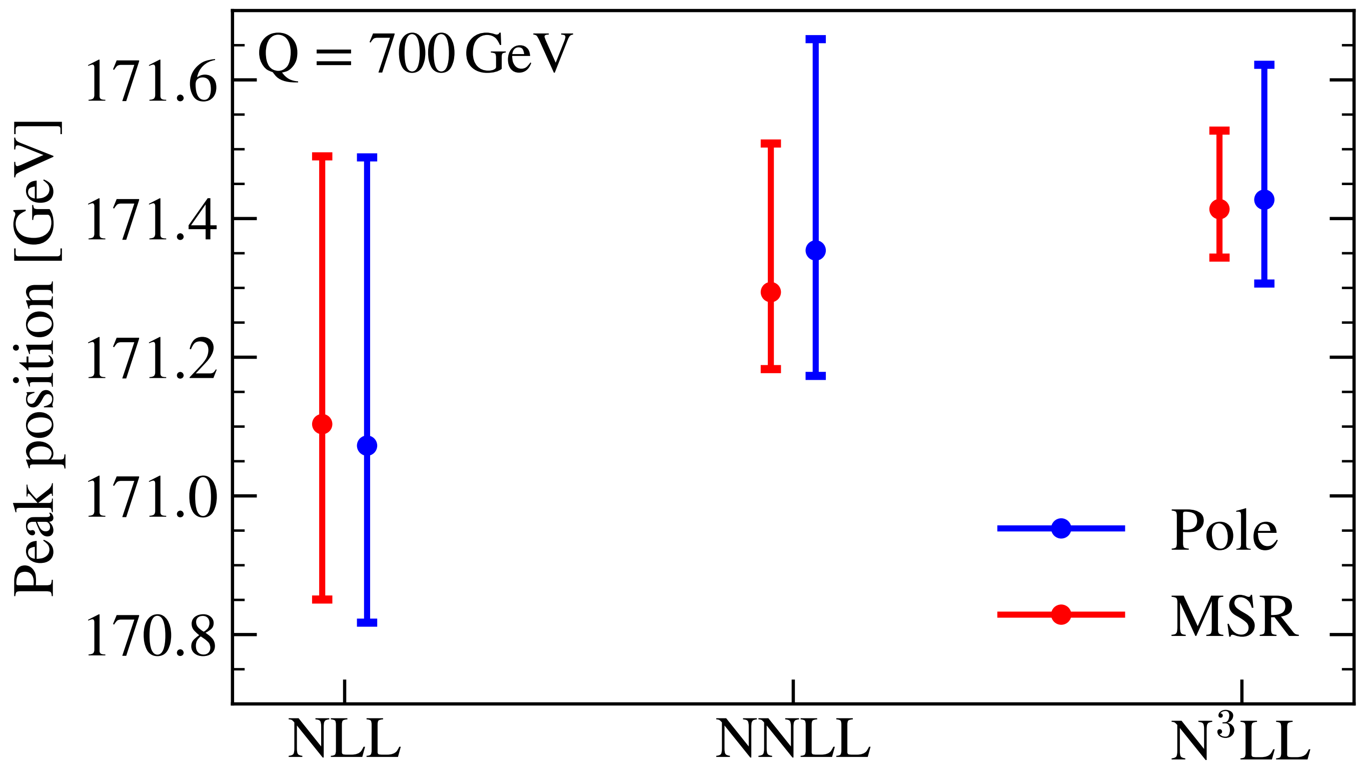
δm_t^{PS} [MeV]	ILC	CLIC	FCC-ee
$\mathcal{L}[fb^{-1}]$	200	100 [200]	200
Statistical uncertainty	10	20 [13]	9
Theoretical uncertainty (QCD)	40 – 45		
Parametric uncertainty α_s	26	26	3.2
Parametric uncertainty y_t (HL-LHC)	5		
Non-resonant contributions	< 40		
Experimental systematic uncertainty	15 – 30		11 – 20
Total uncertainty	40 – 75		

Boosted top quarks





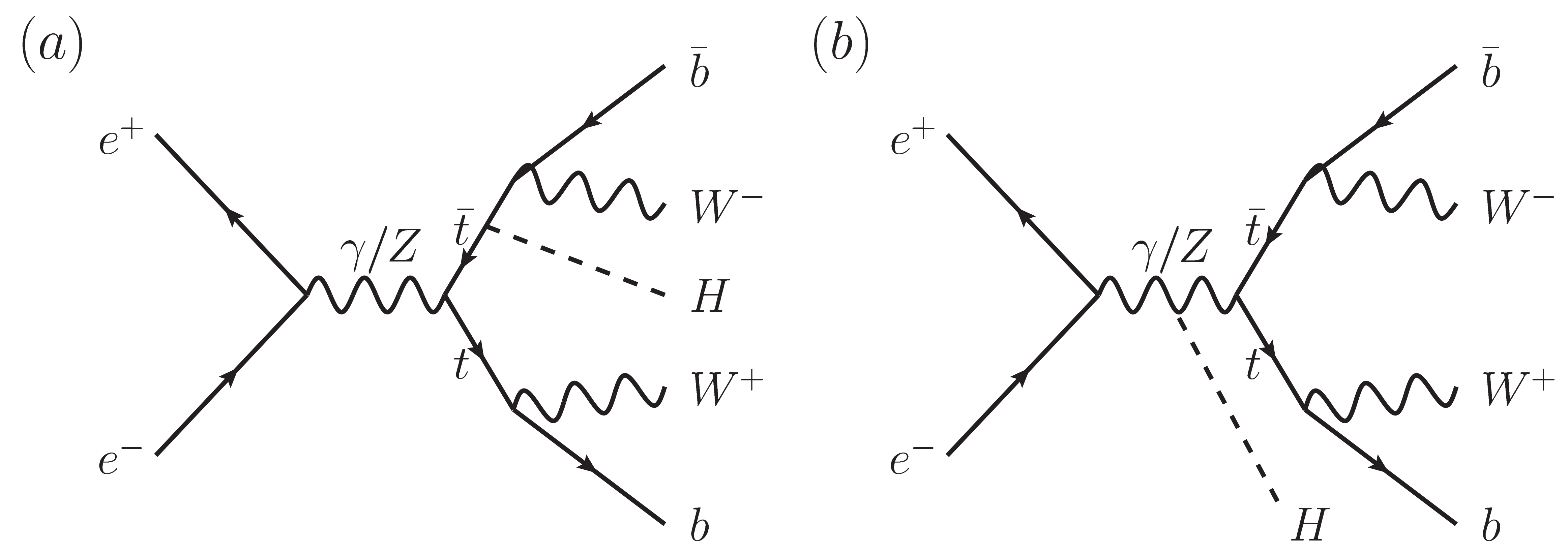
[PhysRevD.104.014026]



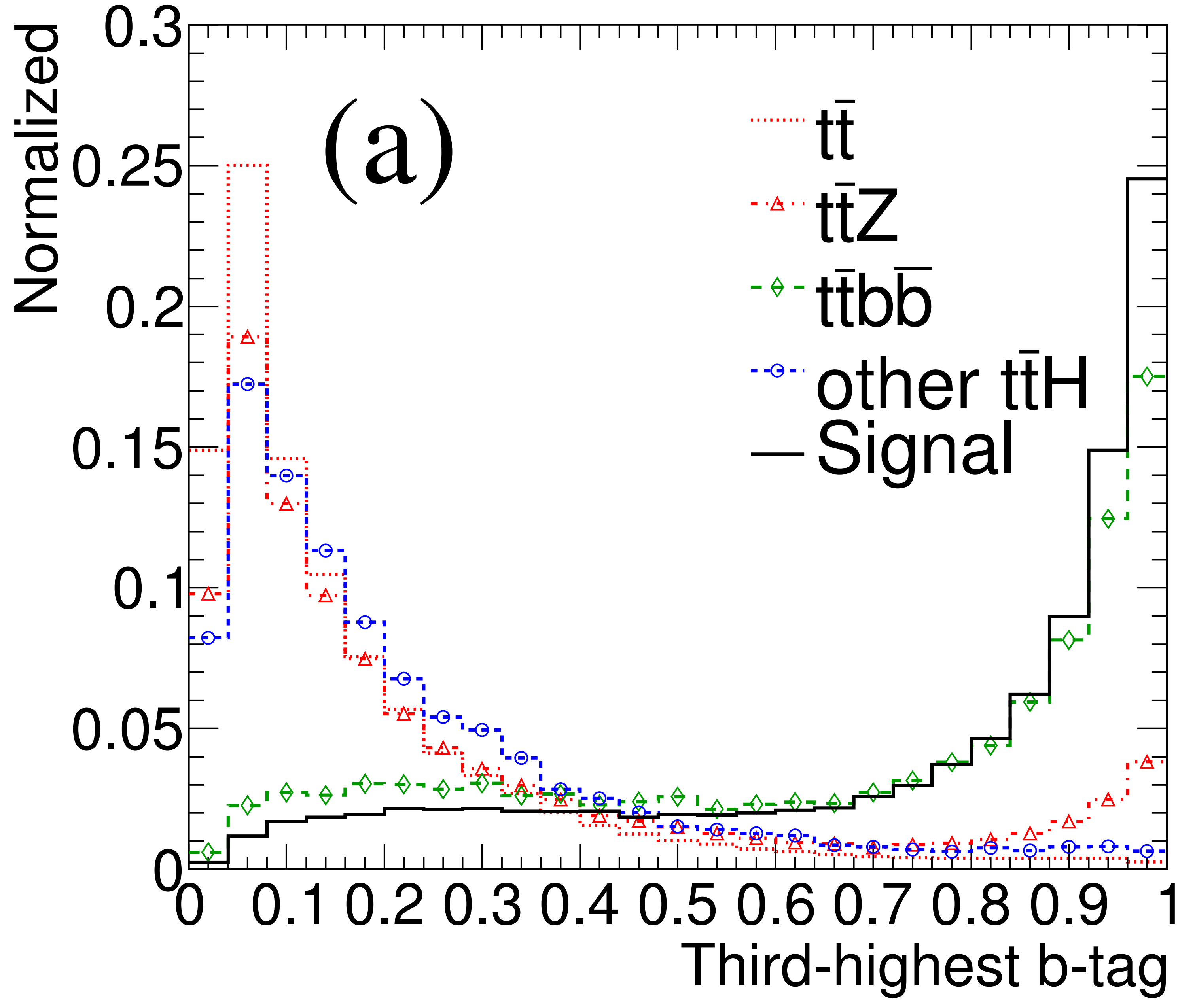
- Measurement of collimated "top jets", thrust
  - Accesible at ILC - 1 TeV
- Interpretation of measured value in theory
  - $m_t^{\mathrm{MC}} \rightarrow m_t^{\mathrm{Pole}}$
- Achievable precision ≈ 100 MeV

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

$t\bar{t}H$ production



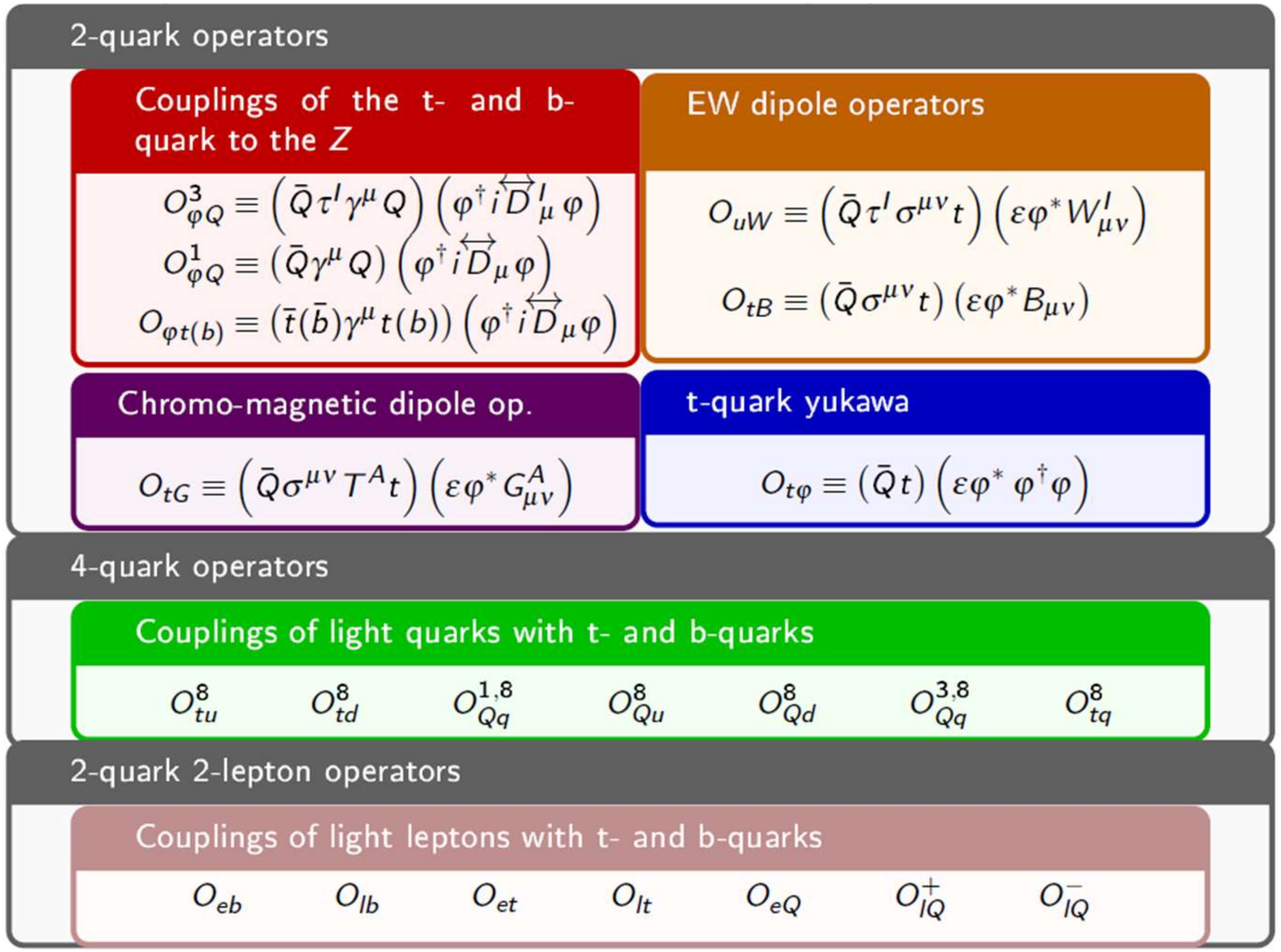
[Eur. Phys. J. C 75, 309 (2015)]



- Direct measurement of top-Higgs Yukawa coupling
- Accesible at 500 and 1000 GeV
- CP nature of the Higgs field
- Using BDTs to distinguish signal and backgrounds
- Combination of 6 and 8 jet final-state:
  - **Top Yukawa**: 4.5% uncertainty at ILC 1 TeV and 0.5 ab^{-1}

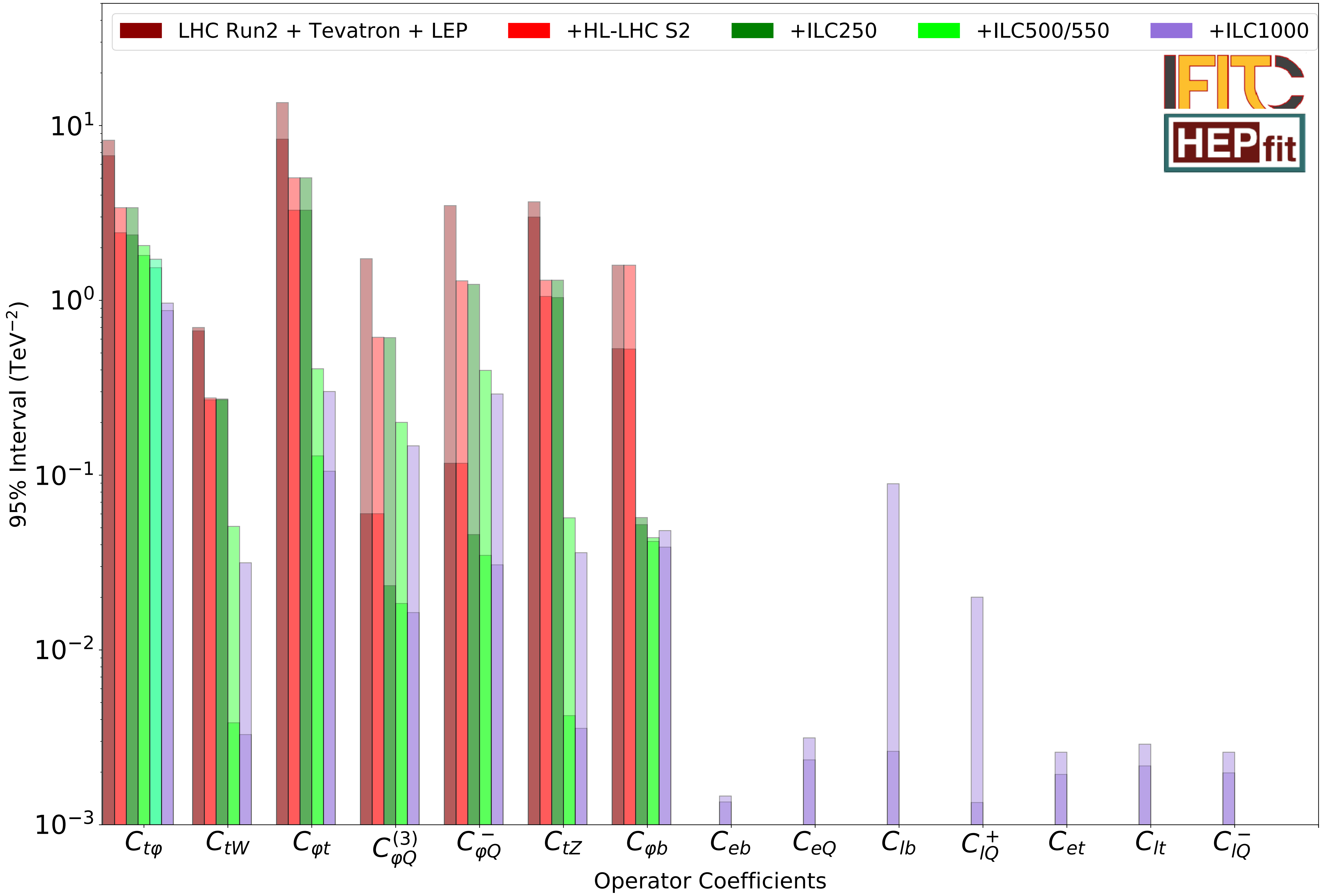
SMEFT at ILC

- Model independent search/exclusion of new physics at high energies
- Measurements above $t\bar{t}$ threshold give access to **electroweak couplings**
- Two and four fermion operators
- Contributions from Z and photon can be disentangled through **beam polarisation**



SMEFT at ILC

[2206.08326]



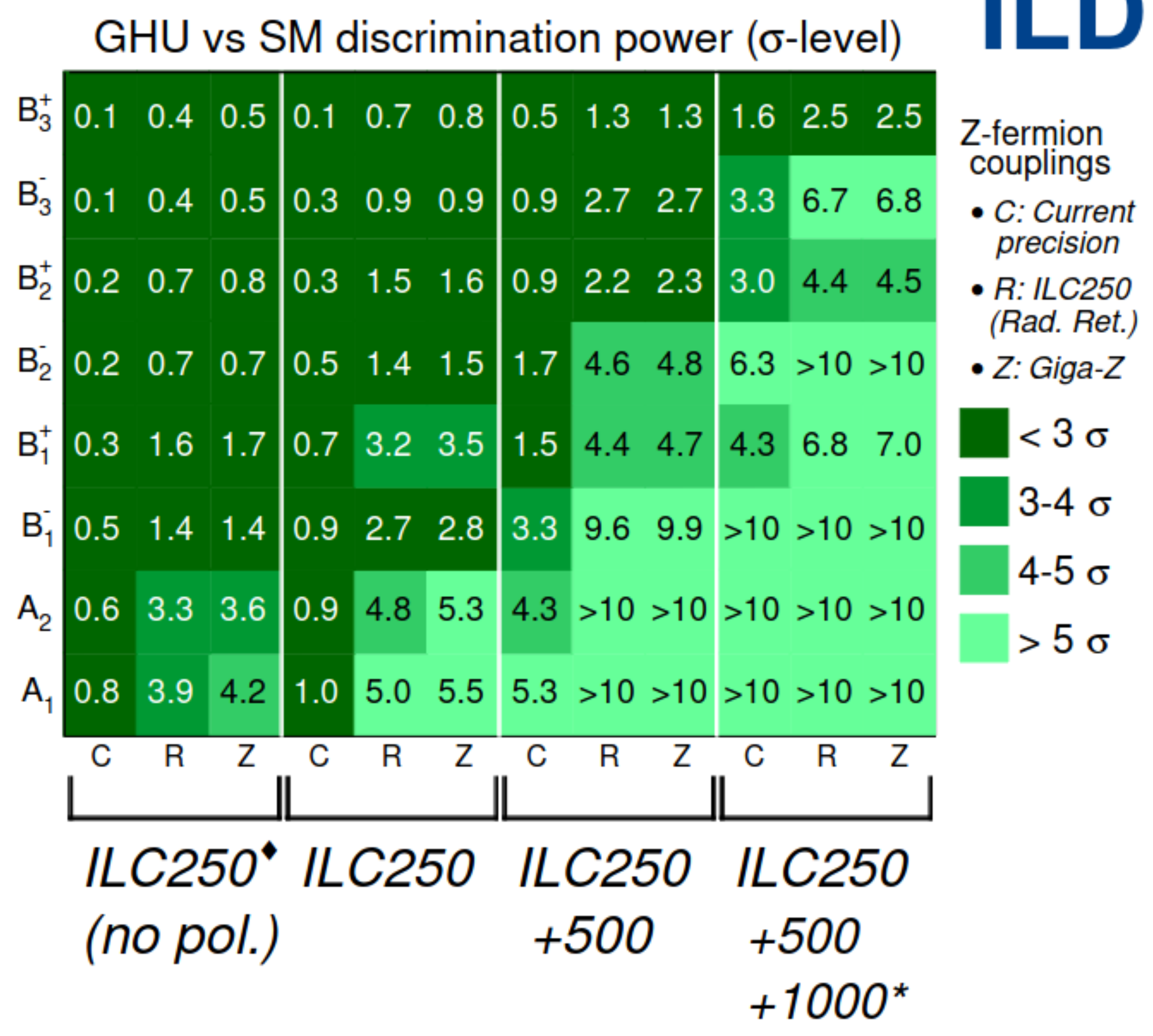
Improvements of up to two orders of magnitude compared to HL-LHC

Z-boson couplings and BSM

NEW

- 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 talk Friday, 9am

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



	ILC250♦ (no pol.) C	R	Z	ILC250 C	R	Z	ILC250 +500 C	R	Z	ILC250 +500 +1000* C	R	Z
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
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

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