Linear Collider Vision

Top & ElectroWeak Physics at Linear Collider Facility at CERN

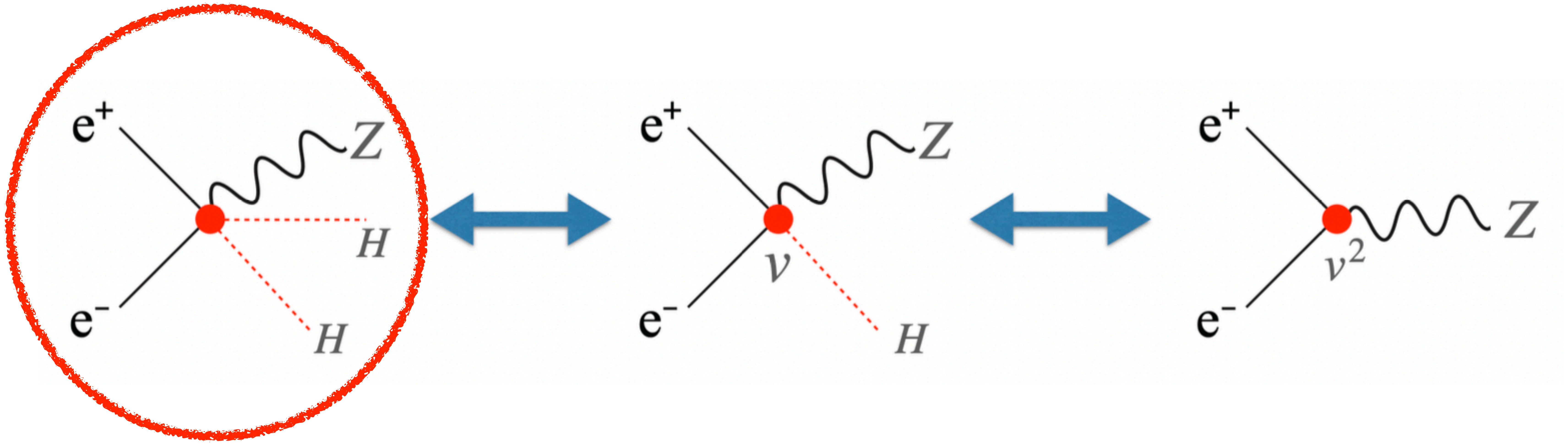
Toshinori MORI, on behalf of the *ILD Concept Group*
ICEPP, The University of Tokyo

XLIII ICHEP, Natal, Brazil, 1 August 2026

Why Study Top & EW Now?

Our priority is Higgs Factory!

- We want to scrutinise the 125GeV Higgs boson for possible signs of New Physics.



New Physics

$i\frac{c_{HL}}{v^2}(\Phi^\dagger \overleftrightarrow{D}^\mu \Phi)(\overline{L}\gamma_\mu L)$

HZ^0 production

Z^0 resonance

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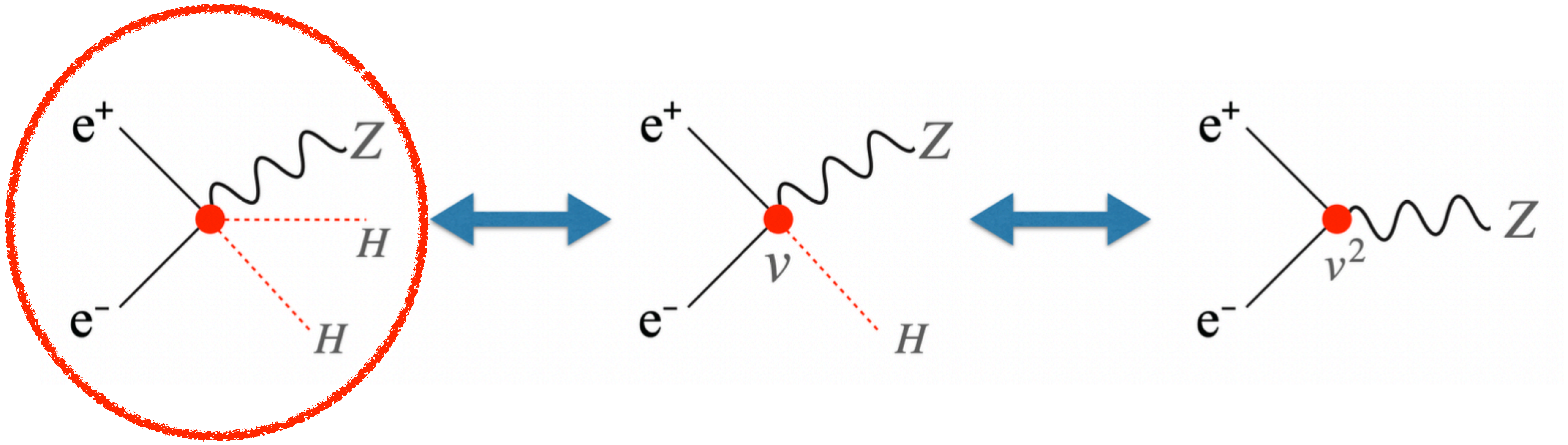

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Precise EW measurements helps!

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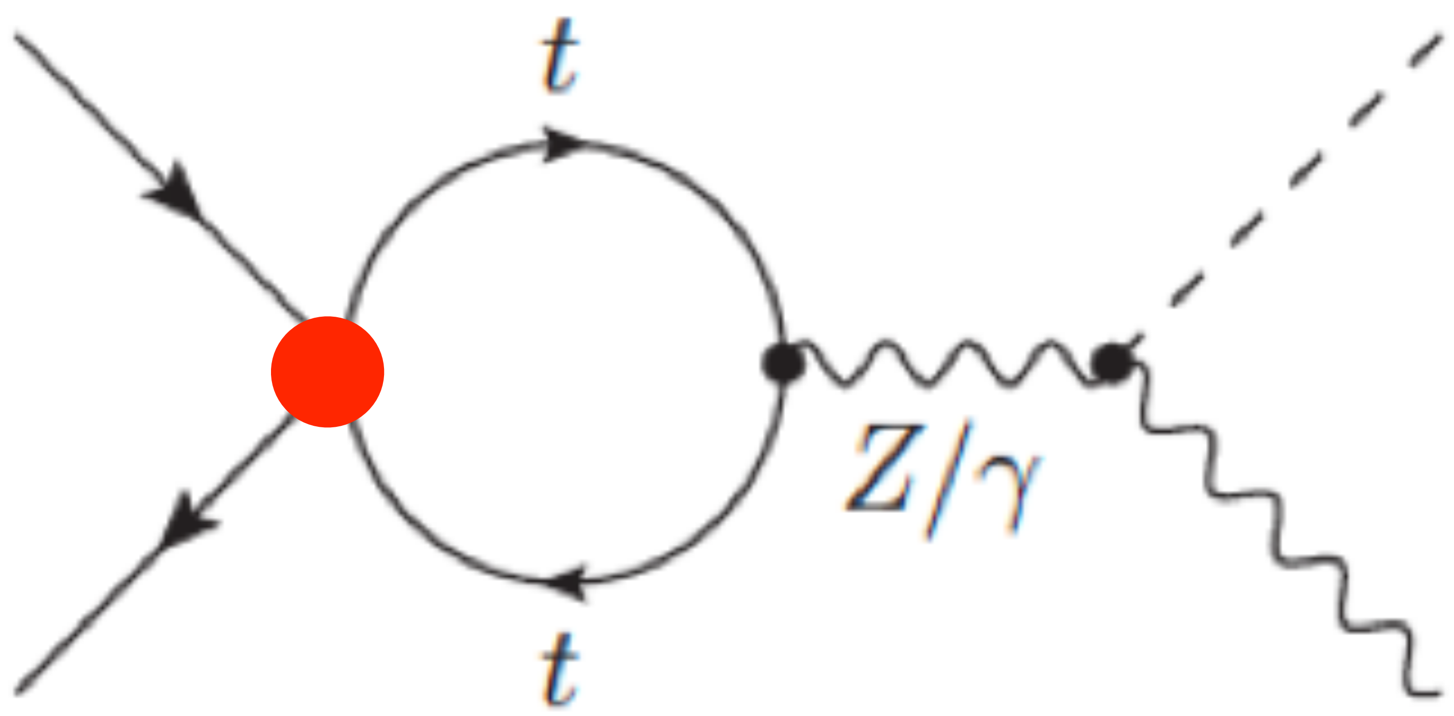
New Physics Op. in the Loops



$e^+e^-t\bar{t}$

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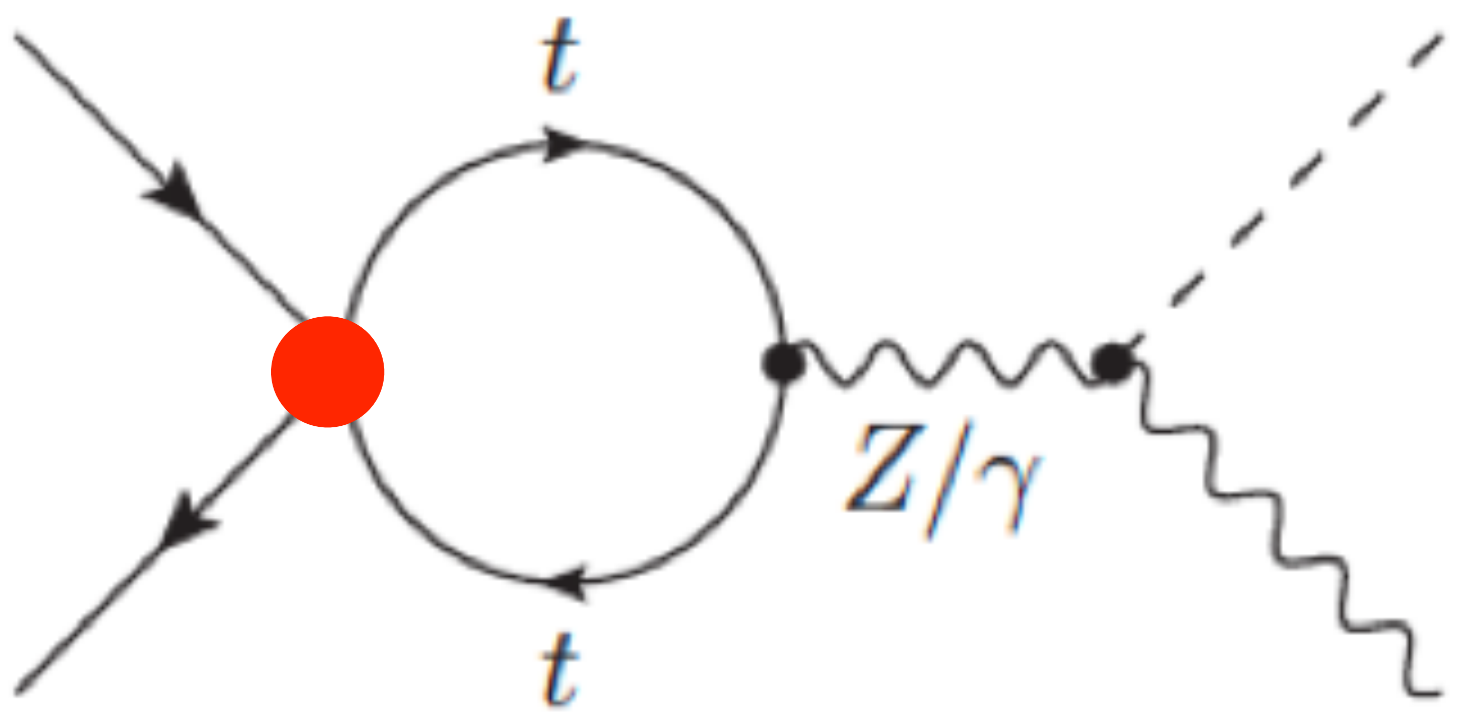

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Top quark important if composite Higgs

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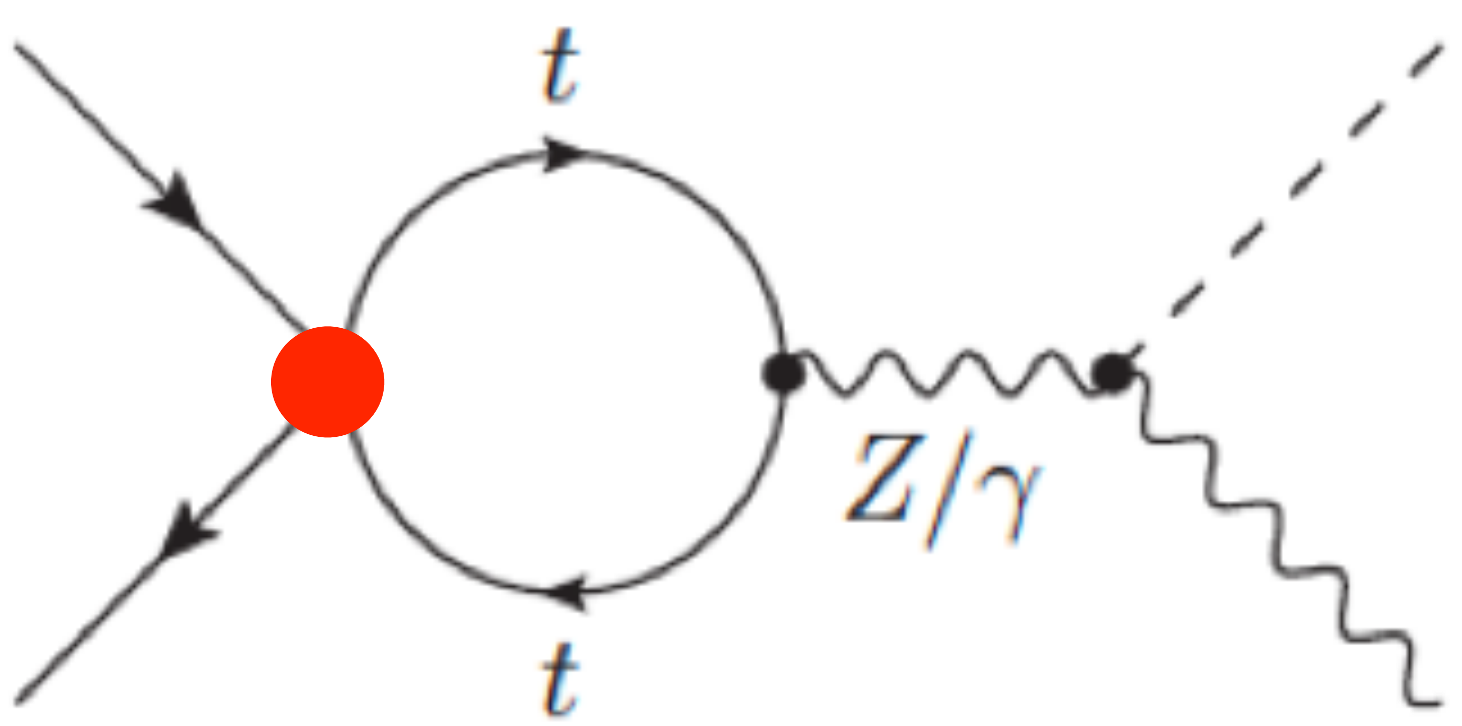

$e^+e^-t\bar{t}$

Top quark important if composite Higgs

→ More sensitive at higher energies

SM Effective Field Theory (SMEFT)

A global framework to find & identify New Physics

- Global analysis of precision observables of Higgs / Top / Electroweak
  - Assumption: no new physics below $M \sim 10\ \mathbf{TeV}$
    - No signature found at LHC (so far). But we may be mistaken.

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{C_i}{M^2}\mathcal{O}_i^{(6)} + \sum_j \frac{D_j}{M^4}\mathcal{O}_j^{(8)} + \cdots$$

Suppressed by M^n

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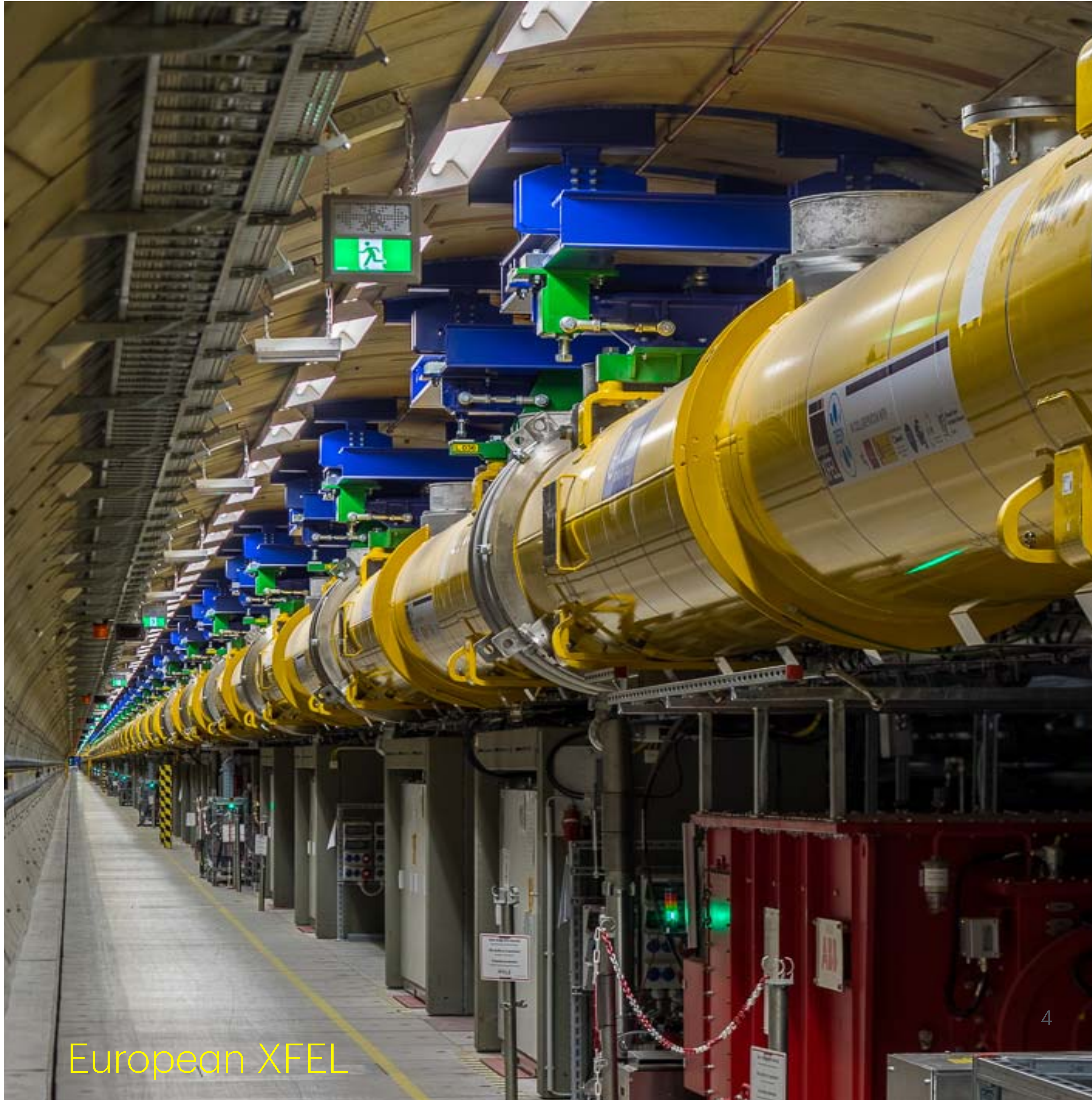
Suppressed by M^n

A strategic approach to solidly identify New Physics is important.
Not just a collection of more & more precise measurements...

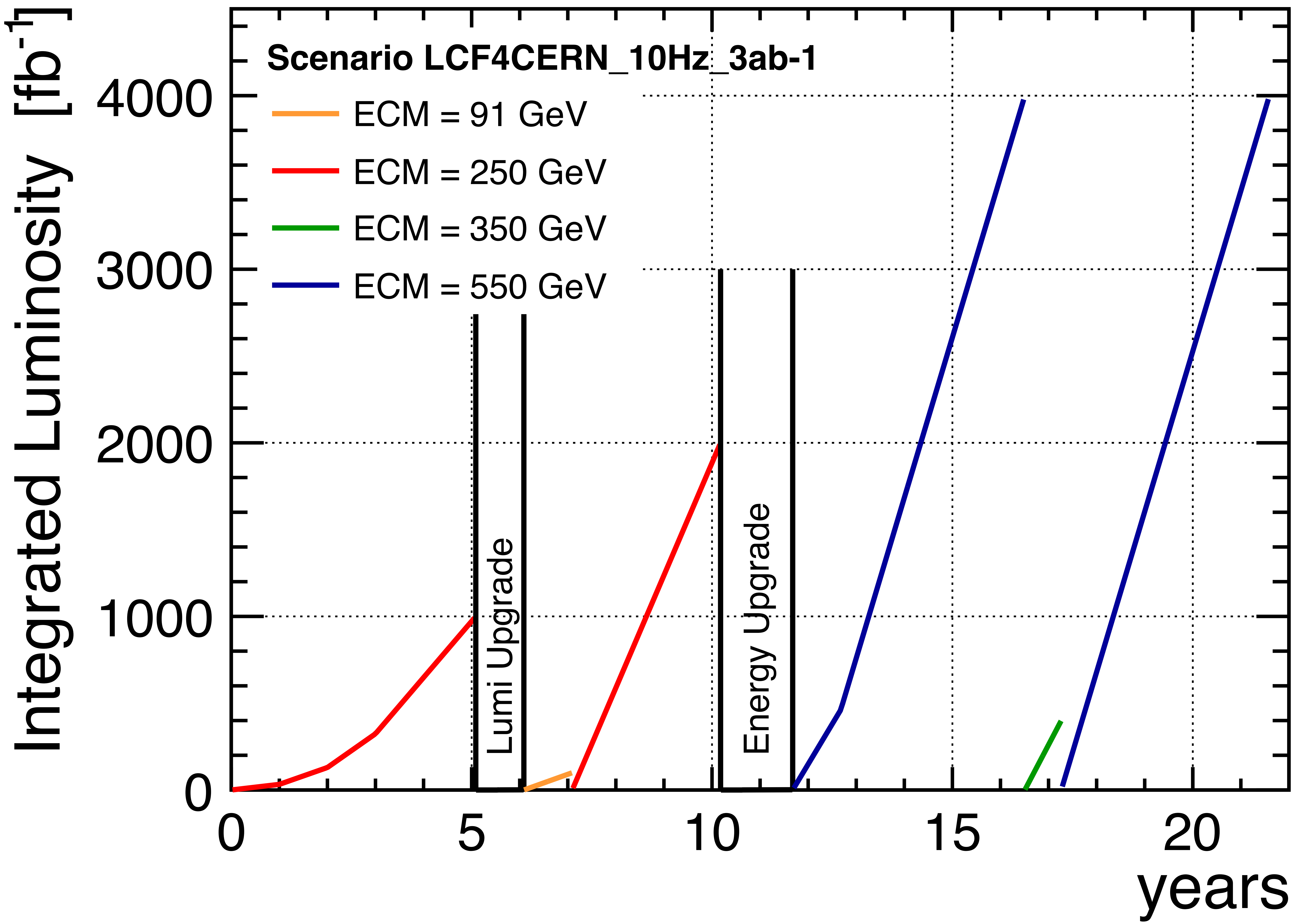
Linear Collider Facility @CERN

- Higher energy reach
- Polarised Beams



A LCF Operation Scenario

A Proposed Strategic Approach for Solid & Robust Discoveries



	91 GeV	250 GeV	350 GeV	550 GeV	1-3 TeV
$\int \mathscr{L}$ (ab^{-1})	0.1	3	0.4	8	8
beam polarisation (e^-,e^+; %)	80/30	80/30	80/30	80/60	80/20
($--$, $-+$, $+-$, $++$) (%)	(10,40,40,10)	(5,45,45,5)	(5,68,22,5)	(10,40,40,10)	(10,40,40,10)

C.Hensel on LC Vision, 18:15 July 31, Rm#3

LC Vision arXiv: 2503.19983

LCF at CERN arXiv: 2503.24049

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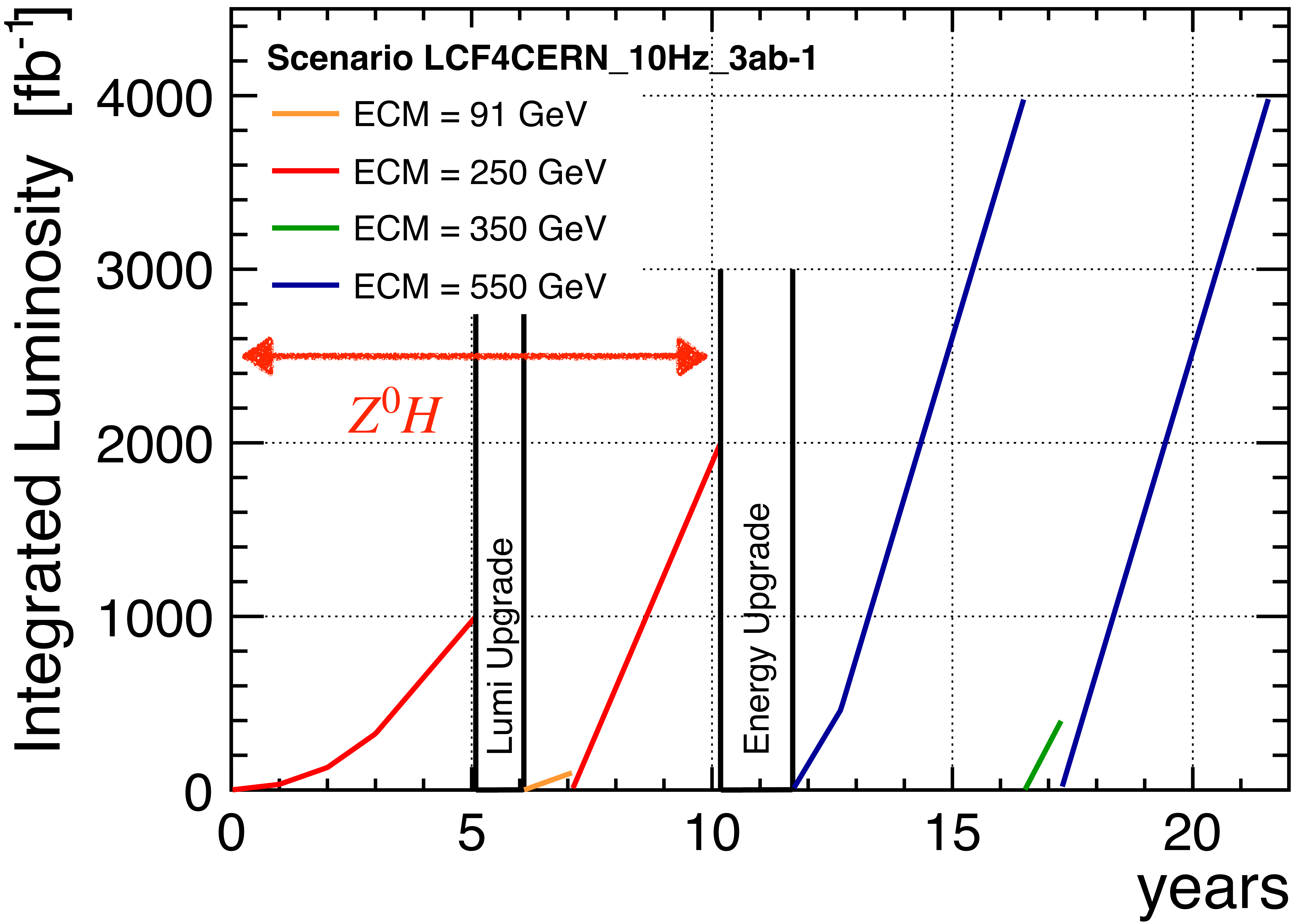

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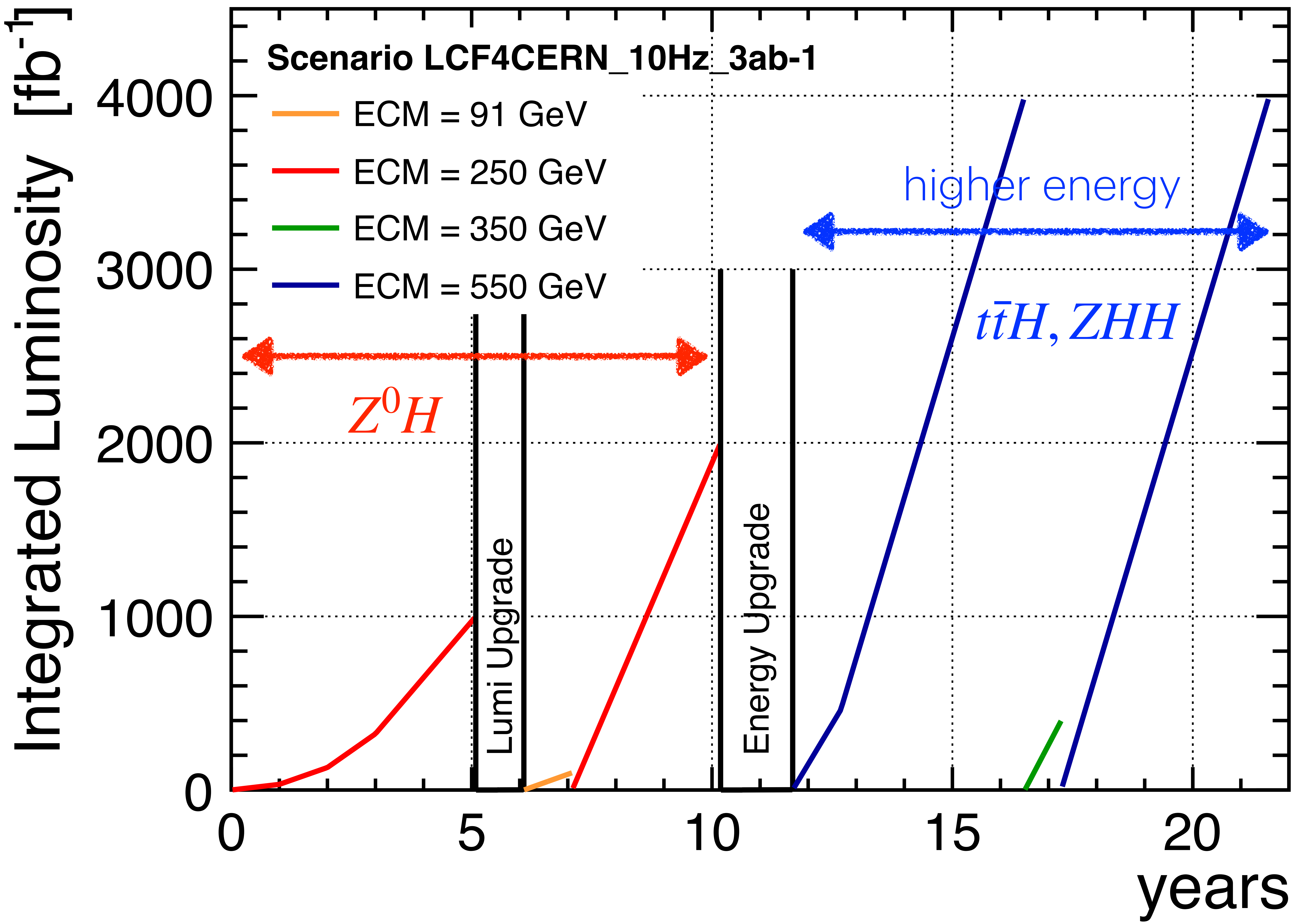

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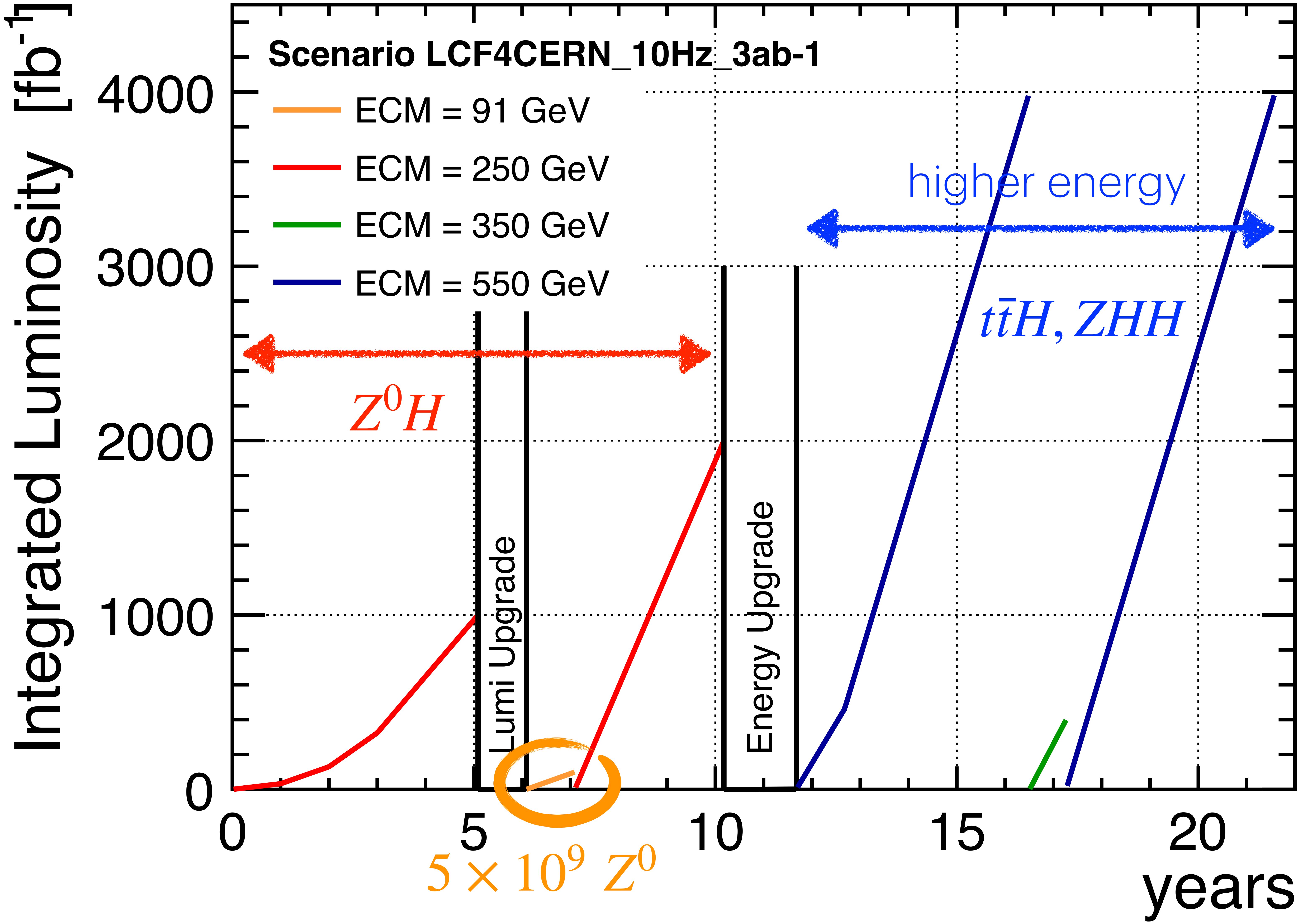

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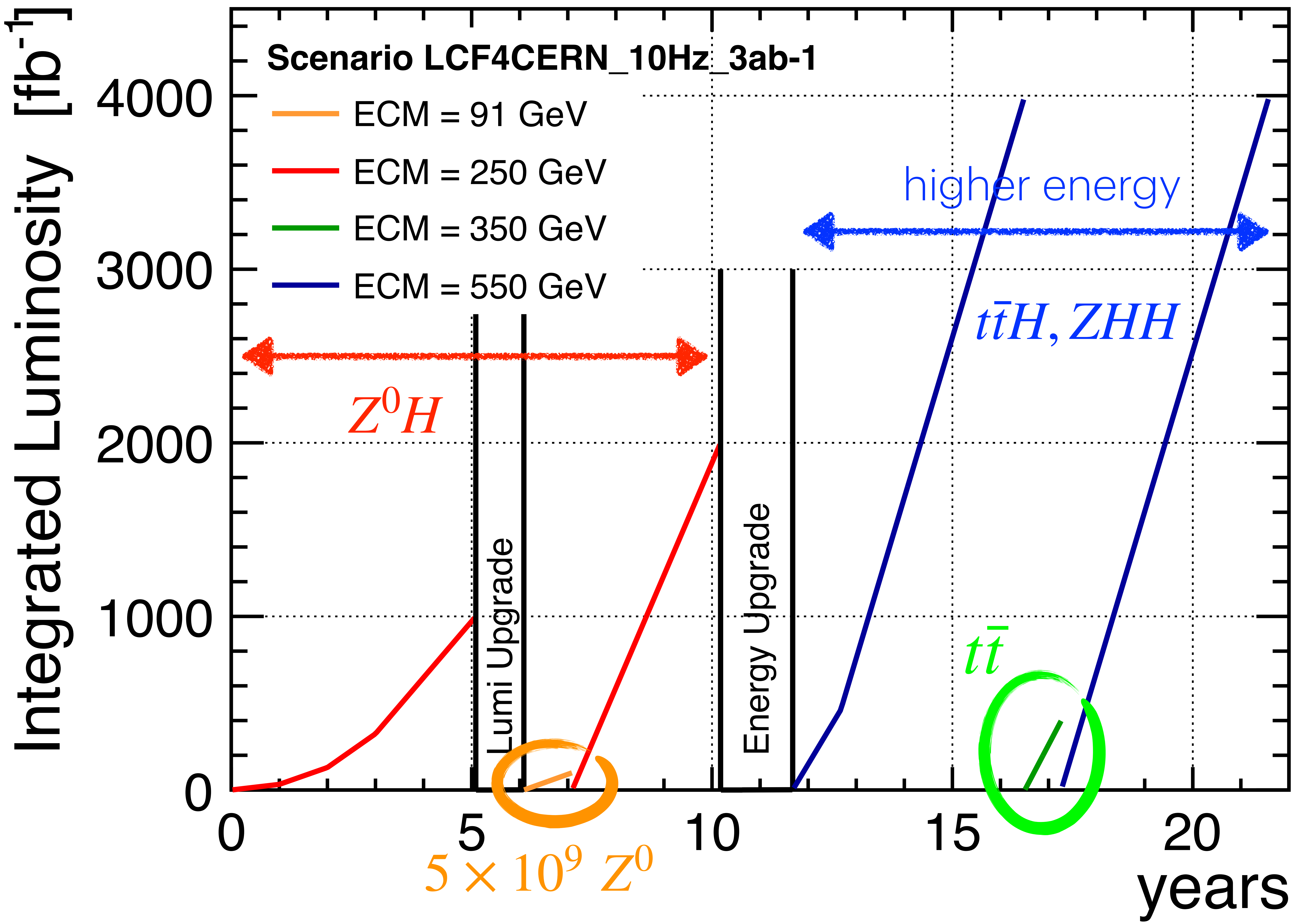

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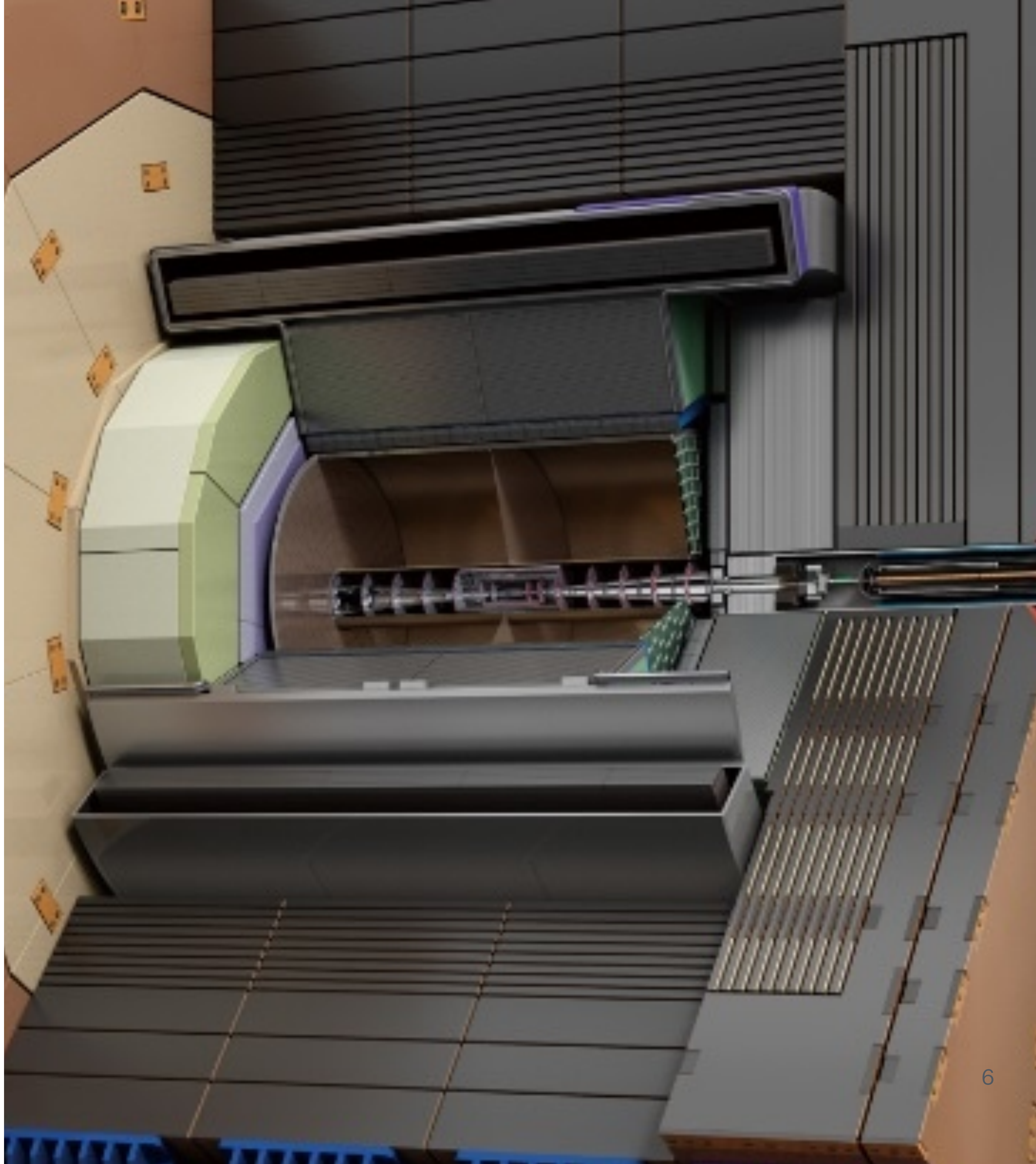
ILD

International Large Detector

- Optimised for Particle Flow
- 3.5T Solenoid outside the Calorimeter
- Hermetic, ~4π coverage
- High precision low mass Si -TPC tracking
- Highly granular calorimeter
- Particle ID

T.Mori on ILD Detector, 10:00 July 31, Rm#8



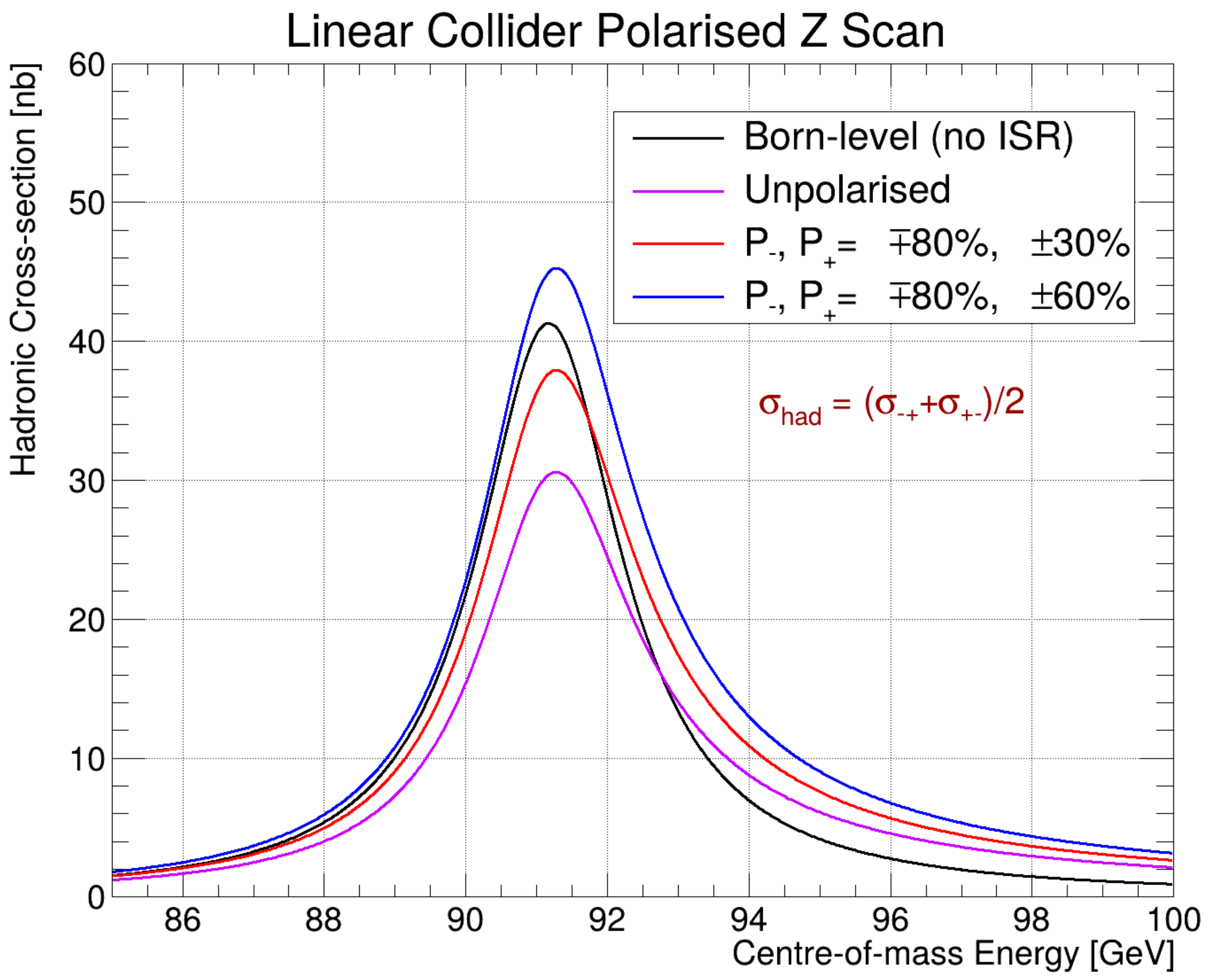
Top & EW Physics at LCF

Polarised Beams & Higher Energy Reach

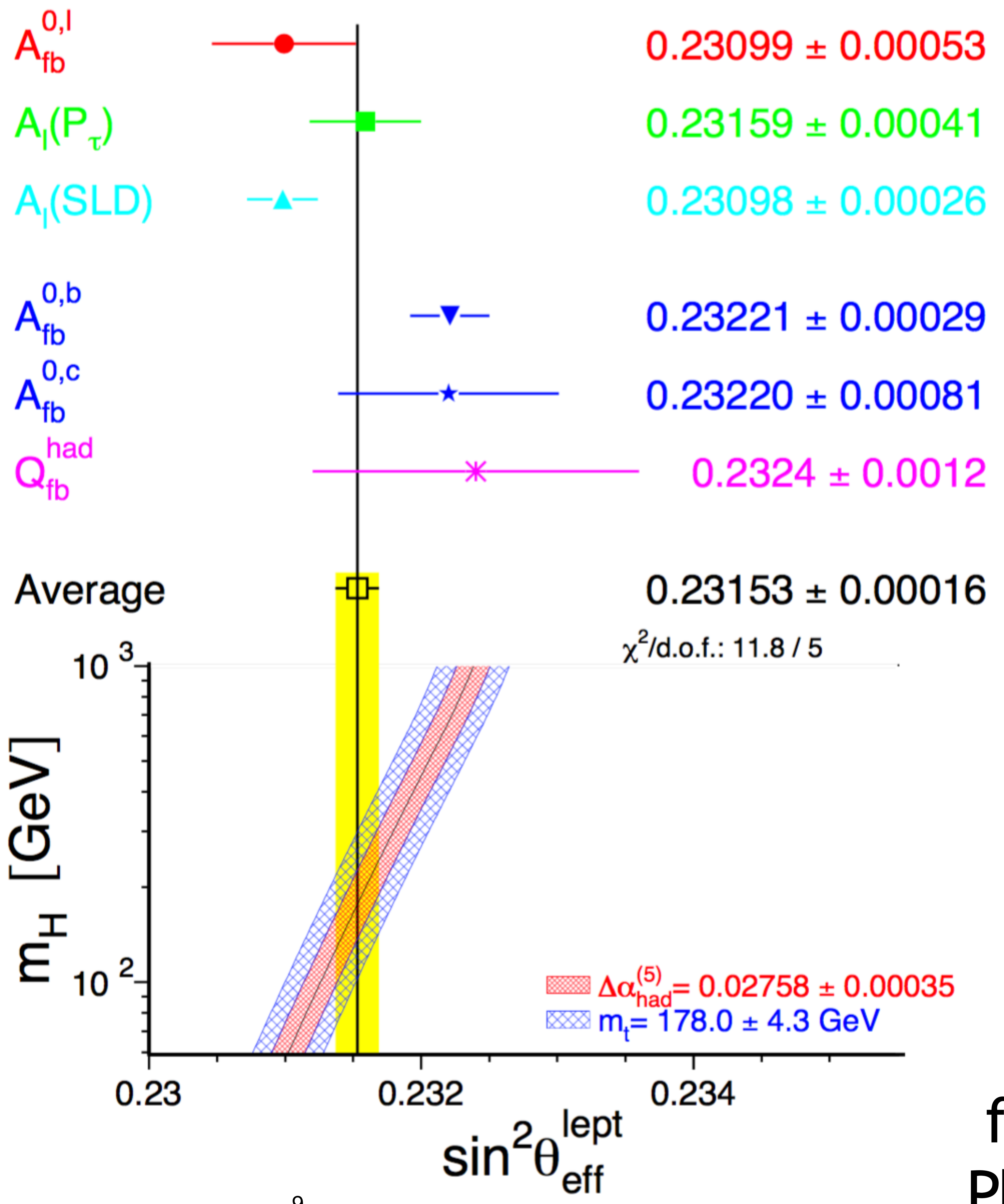
- Z^0 Resonance — Direct measurements of "chiral observables"
- HZ^0 250GeV — $\mathrm{W}^+\mathrm{W}^-$ for m_W C.Hensel on Higgs at LC, 9:00 July 31, Rm#12
- $\mathrm{t\bar{t}}$ Threshold — m_{top}
- Higher Energies $\geq 550\ \mathrm{GeV}$
  - $\mathrm{t\bar{t}H}$ for direct y_t measurement
  - Top compositeness $\mathrm{e^+e^-t\bar{t}}$, Multi-boson processes

Z^0 Resonance

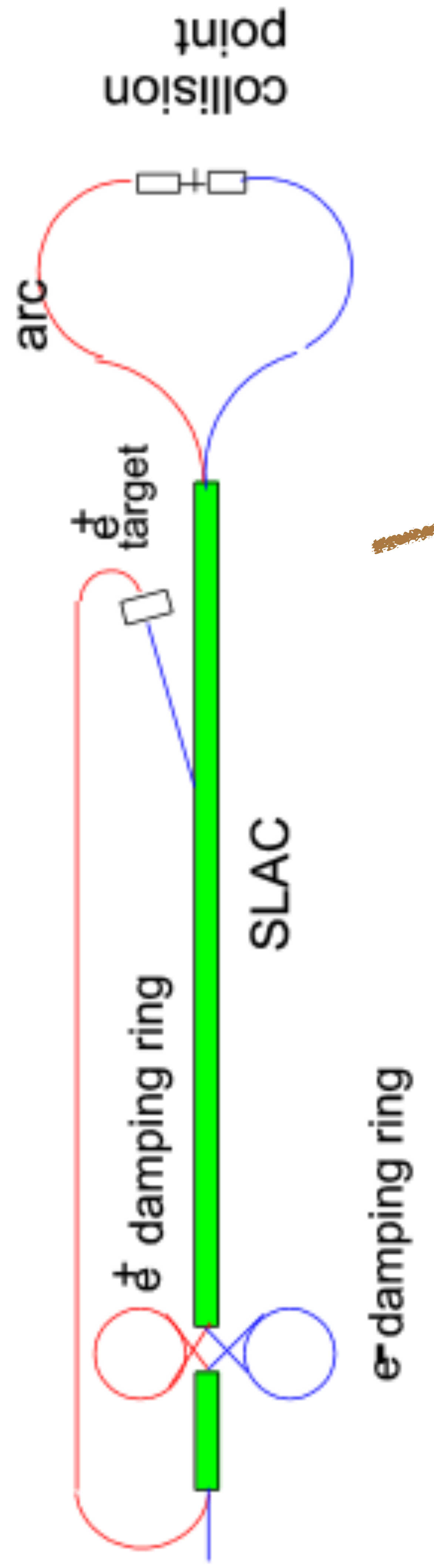
Direct measurements of chiral observables



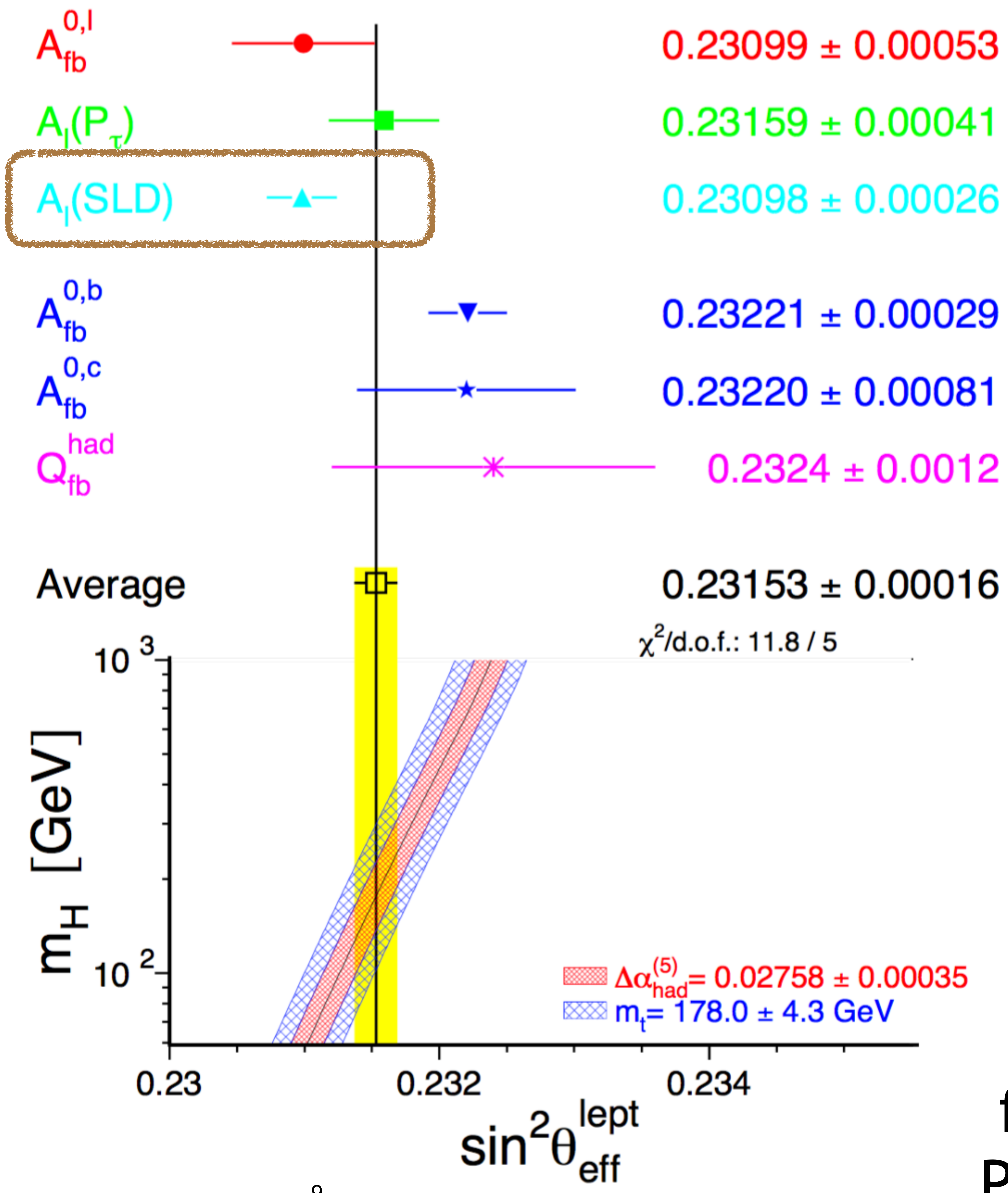
- Z^0 Line shape: m_Z, Γ_Z
- Conventional observables:
  - $R_q = \Gamma_q/\Gamma_{\rm had}$, $R_\ell = \Gamma_{\rm had}/\Gamma_\ell$; $A_{\rm FB}^f = \dfrac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \dfrac{3}{4}\mathscr{A}_e\mathscr{A}_f$
- Polarised observables:
  - $A_{LR} = \dfrac{1}{\mathscr{P}}\dfrac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \mathscr{A}_e$, $A_{FB;LR}^f = -\dfrac{3}{4}\mathscr{A}_f$ higher sensitivity, smaller systematics
- EW theory expected to achieve N3LO level accuracy.



final LEPEWWG
Phys. Rept. 2006



SLC:
World's first
"Linear Collider"



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Z^0 Resonance

Direct measurements of chiral observables

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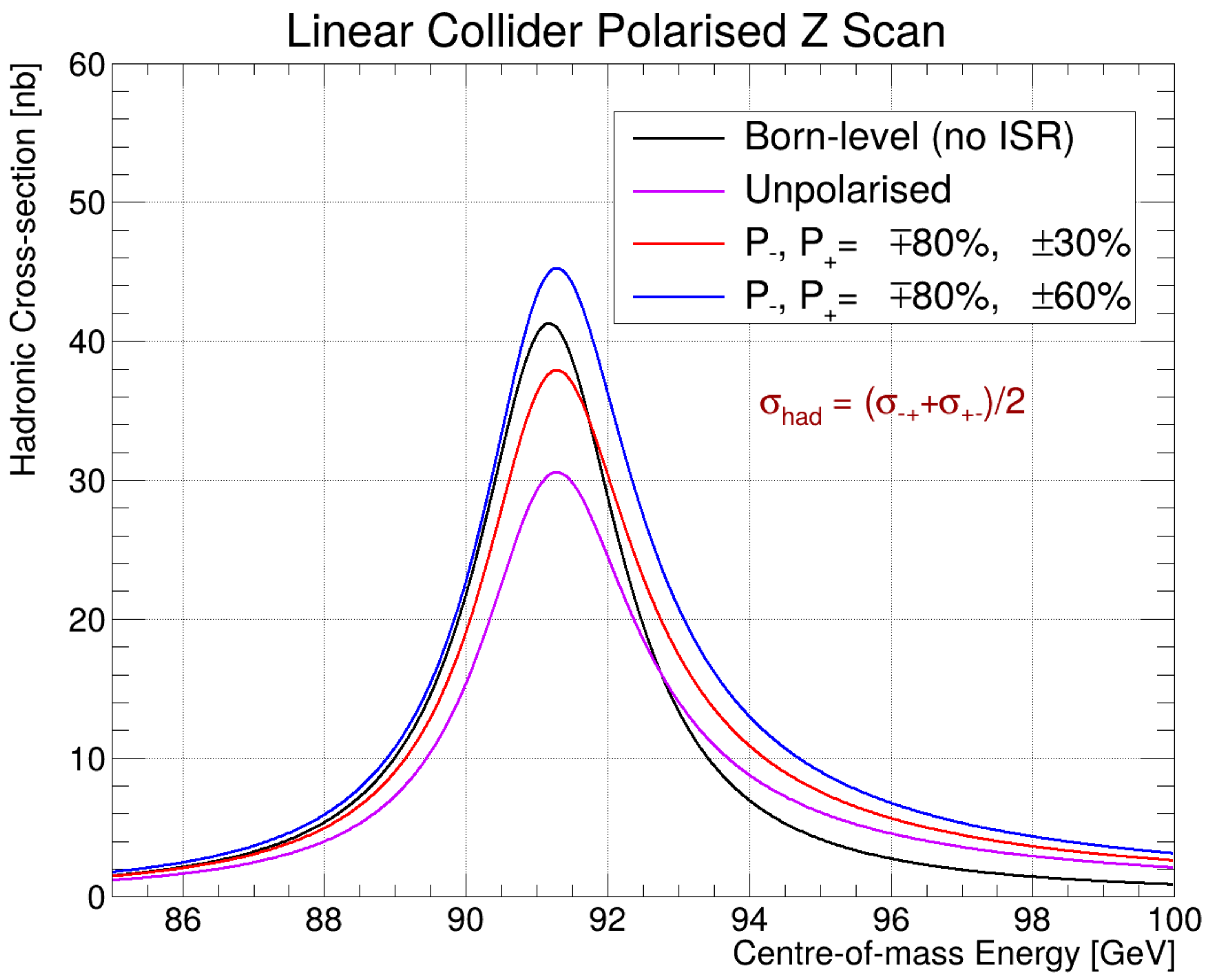

Relative Errors $(\times 10^{-5})$

Γ_Z	R_ℓ	R_Q	A_e	M_W
5	13	9	19	2

Z^0 Resonance

Direct measurements of chiral observables

- Z^0 Line shape: m_Z, Γ_Z

- Conventional observables:

  - $R_q = \Gamma_q / \Gamma_{had}$, R_ℓ

Relatively less statistical strength than Circular Collider
But robust and solid results with more handles to identify
New Physics / problems when any deviations found

- Polarised observables:

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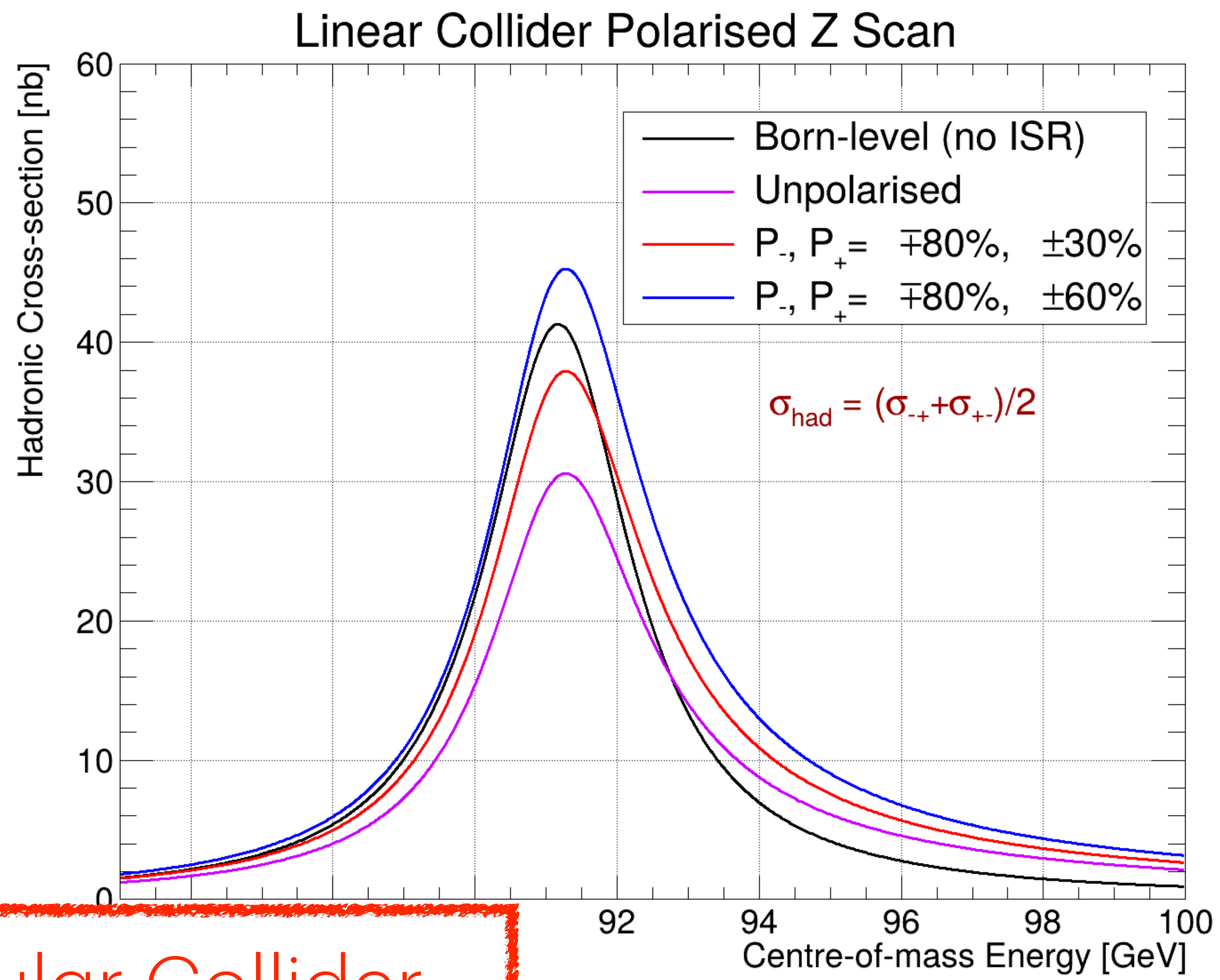

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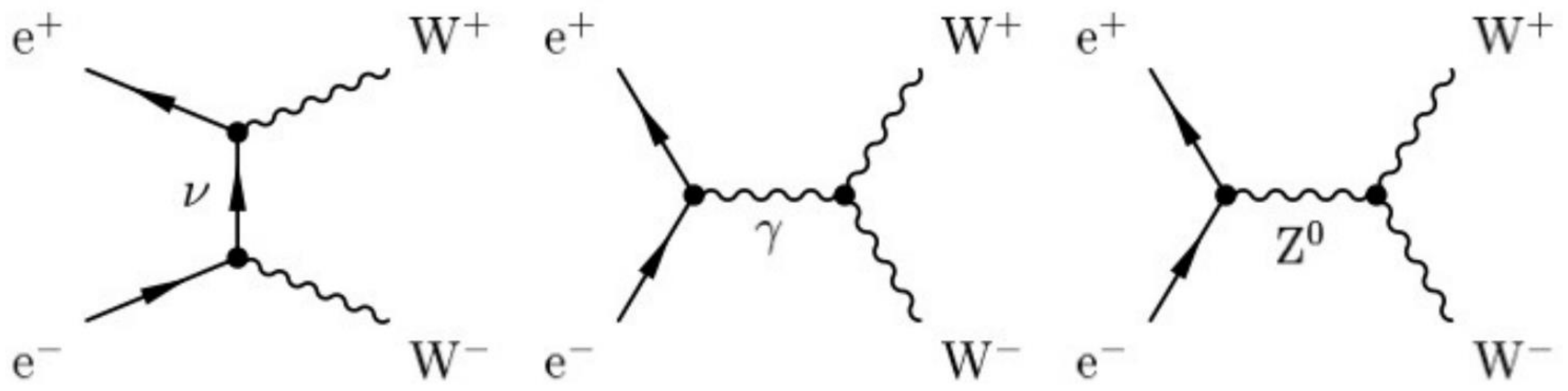
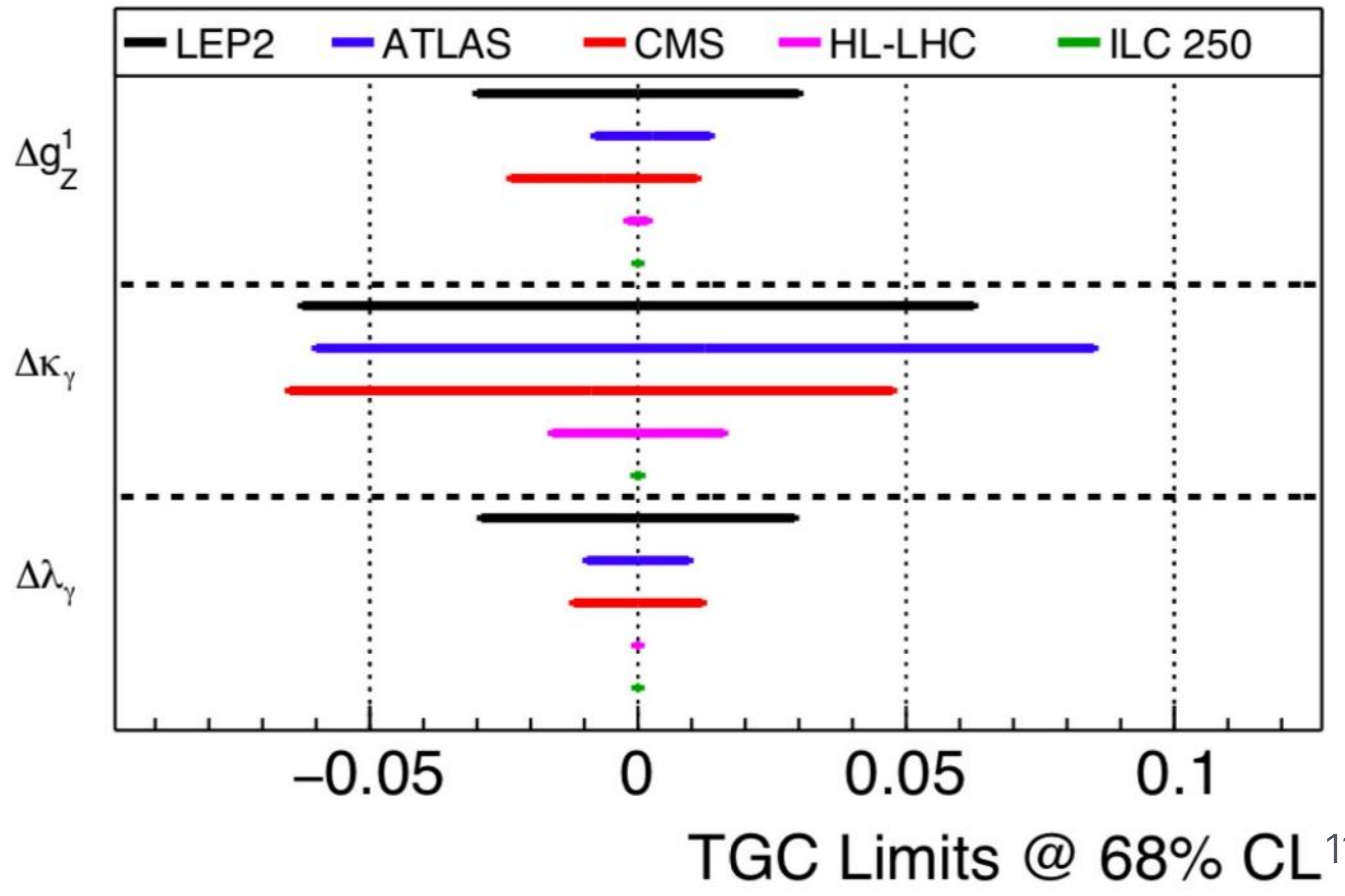
HZ^0 250GeV

ElectroWeak measurements other than Higgs

- W^+W^- kinematical fits for m_W measurements
- Triple Gauge Boson Couplings:
  - The beam polarisation enable to
    - disentangle Z^0 and γ couplings
    - enhance cross sections
- Can study multi-gauge boson couplings at higher energies



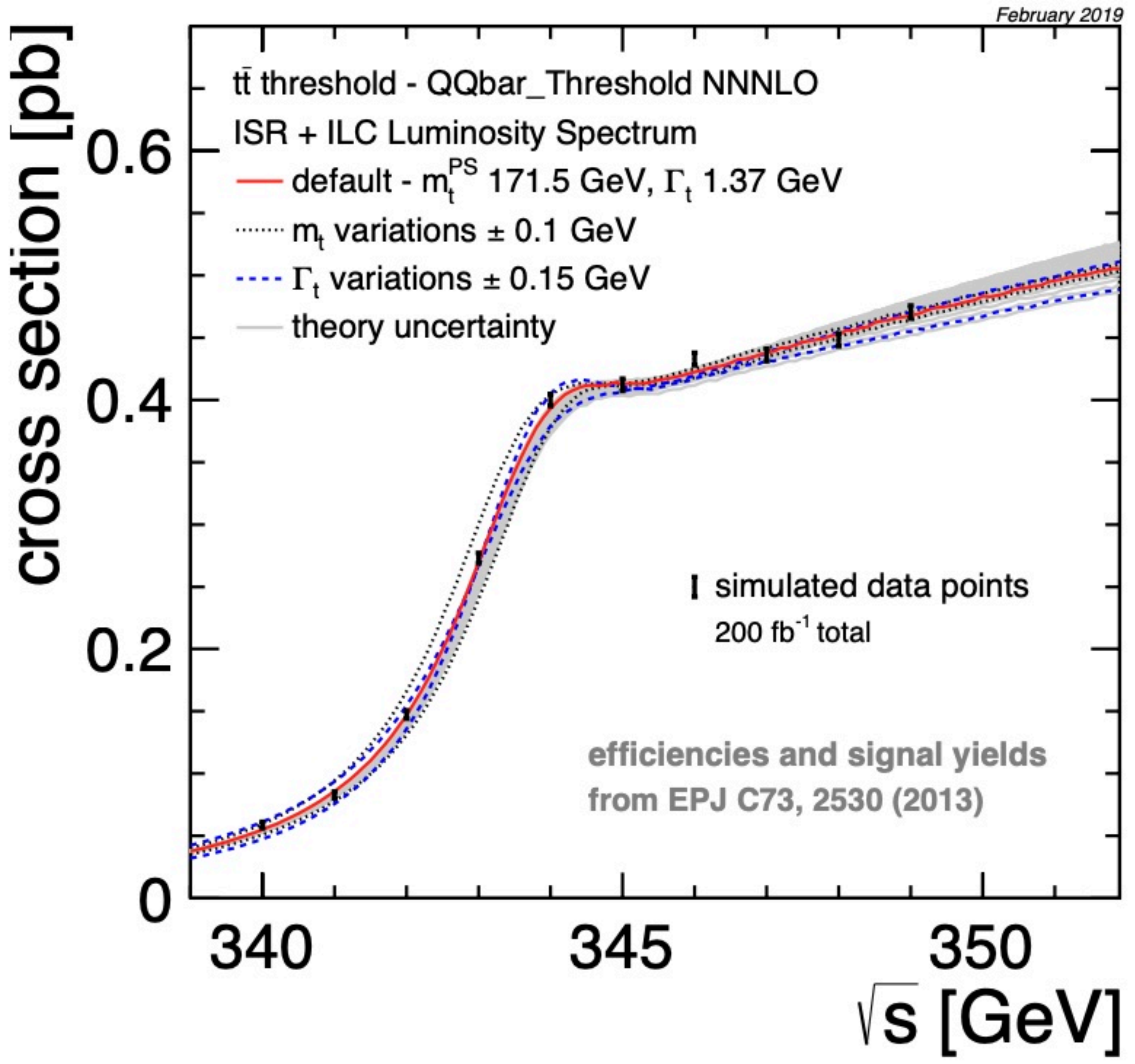


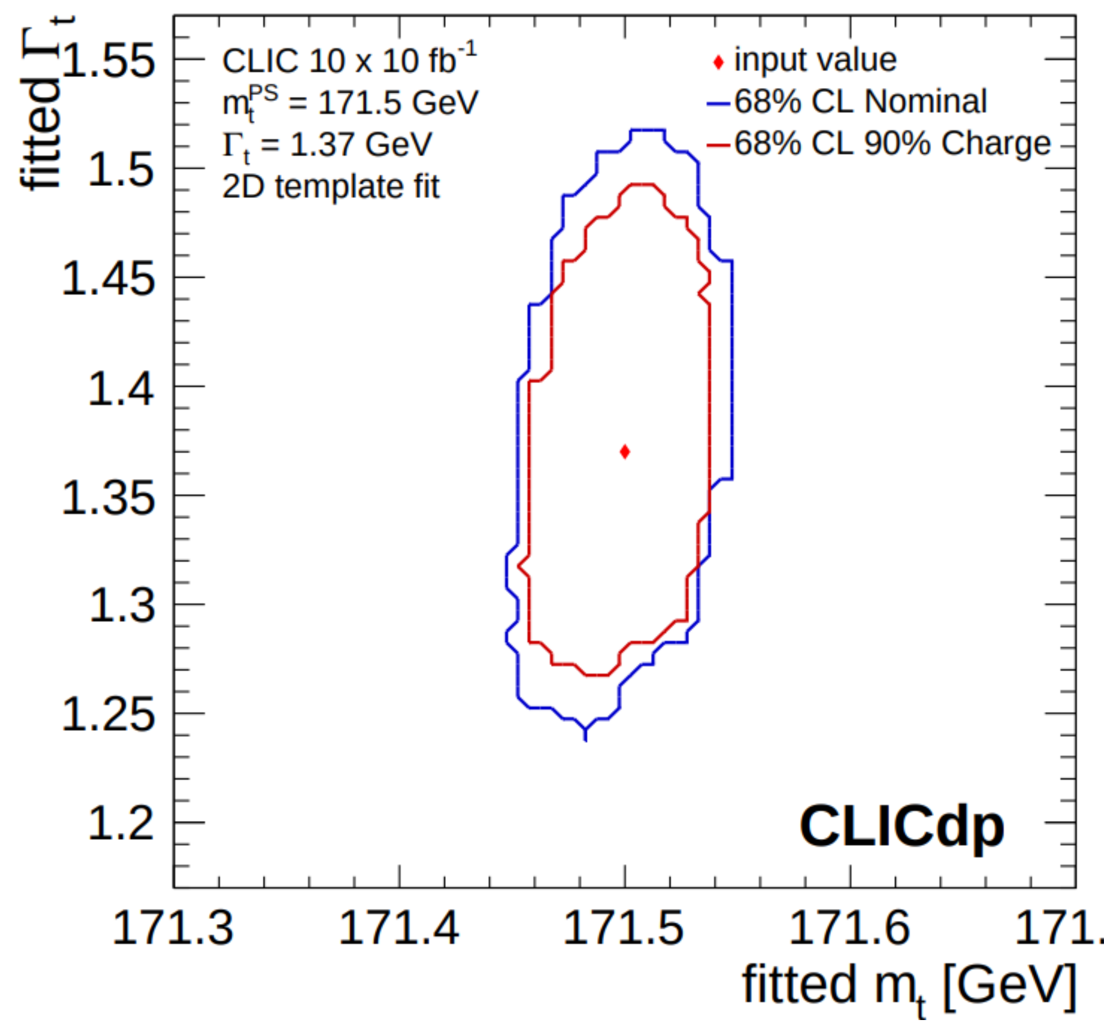
$t\bar{t}$ threshold

top quark mass

- The top quark mass measured at LHC suffer hadronisation uncertainties that make it difficult to interpret their values.

- The $t\bar{t}$ threshold scan, free from such uncertainties, can deliver $\Delta m_t \approx 20 - 40$MeV and $\Delta\Gamma_t \approx 50$MeV if the beam energy and luminosity under control.





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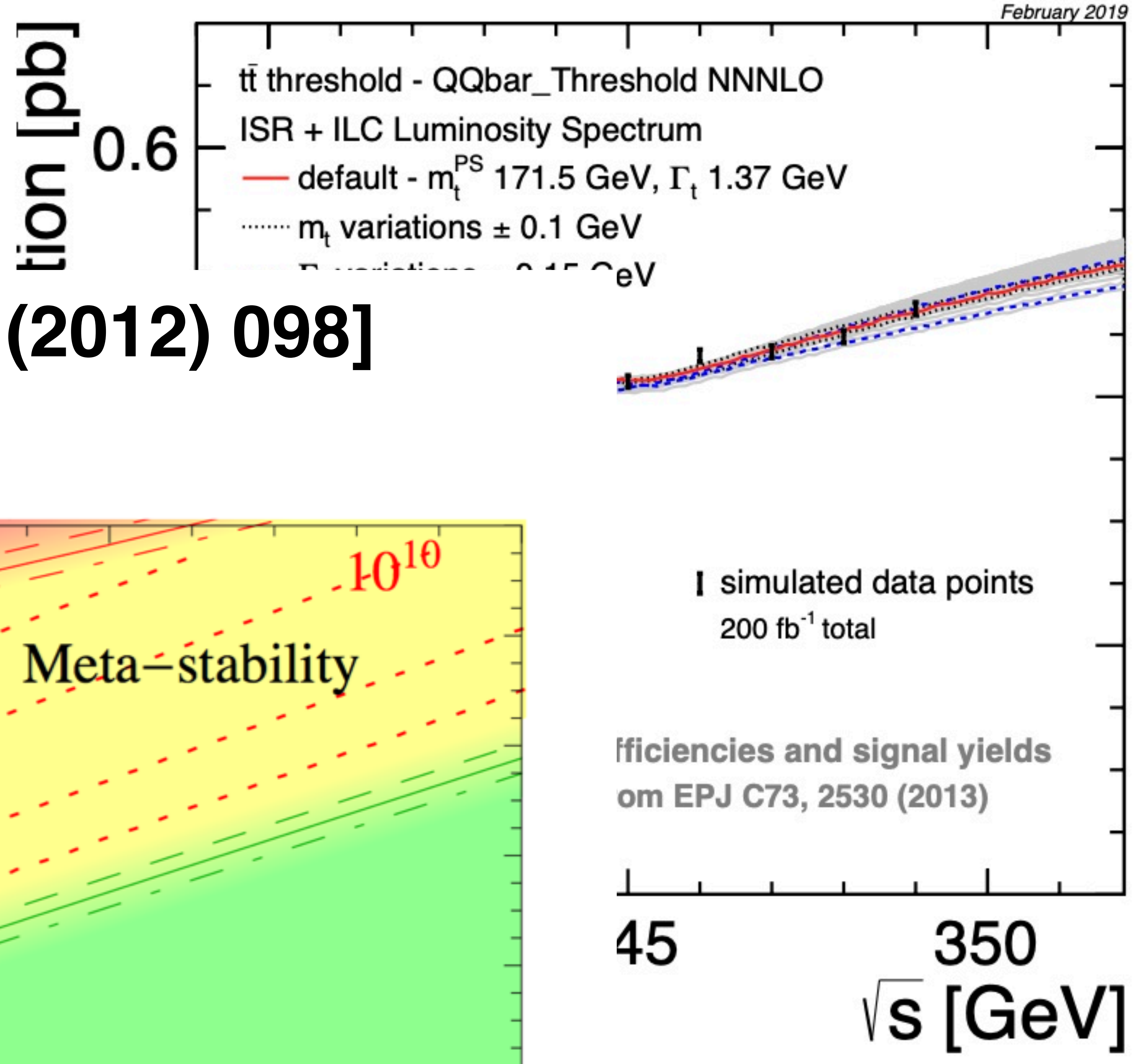
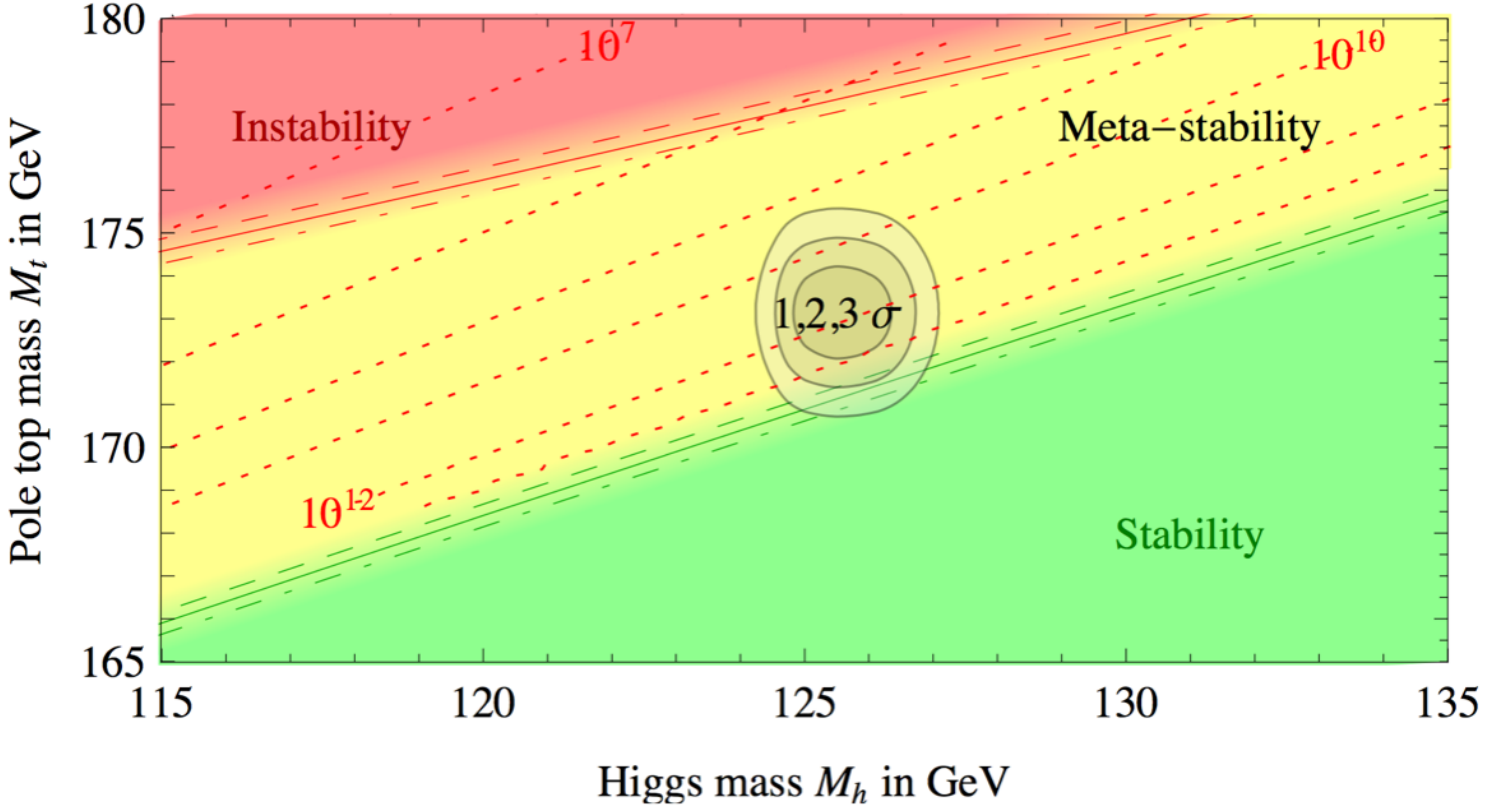
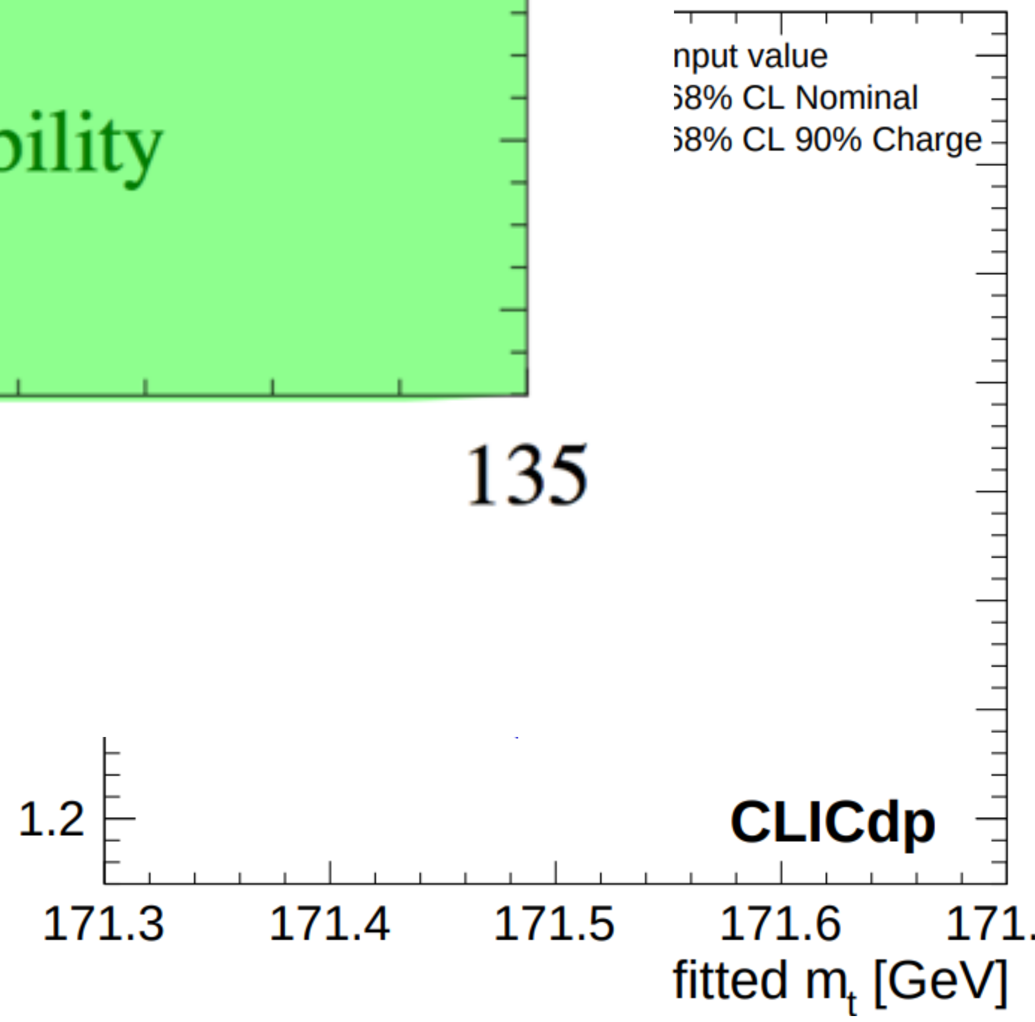


[Degrassi et al, JHEP 1208 (2012) 098]

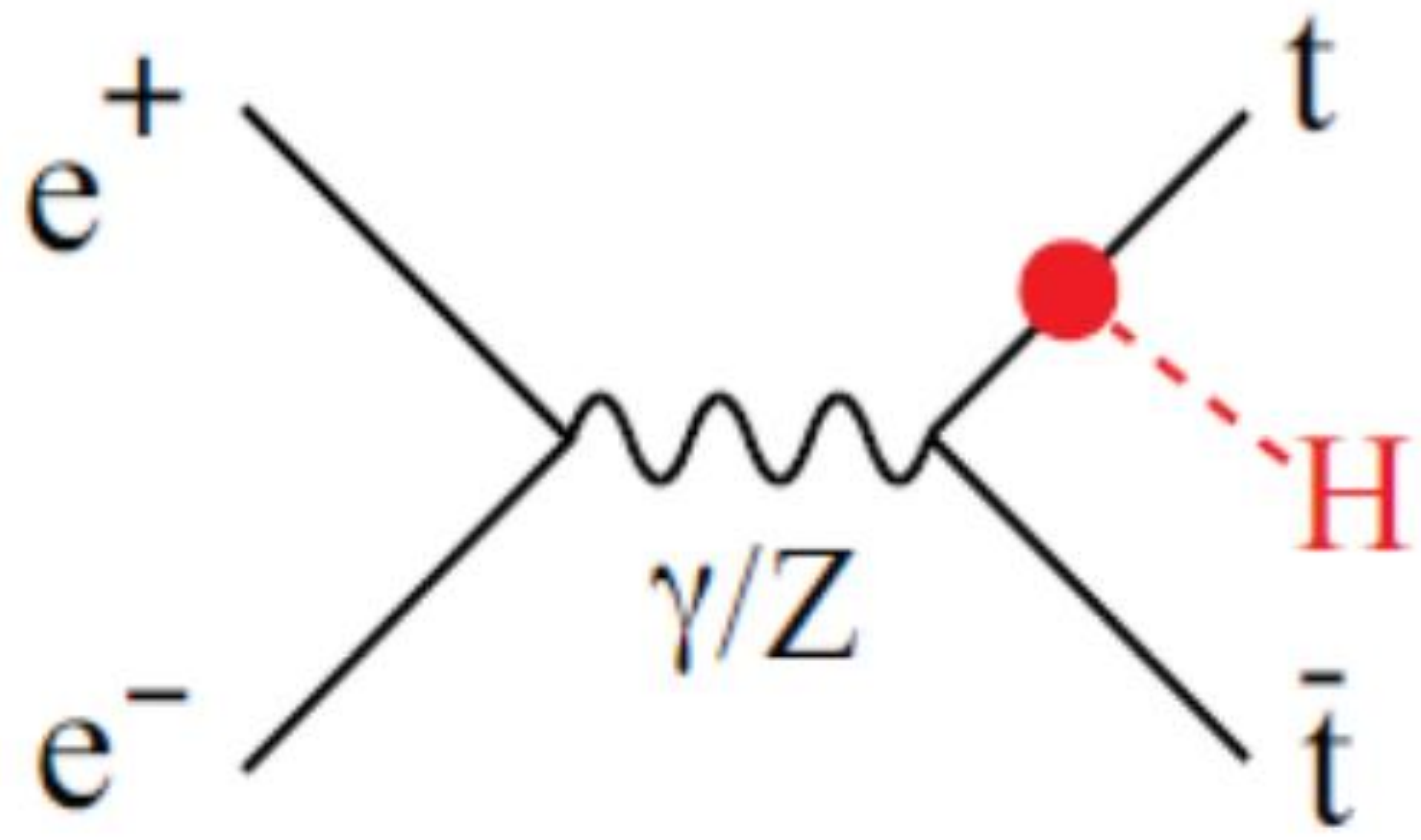




Higher Energies $\geq$ 550 GeV

Top Yukawa Coupling

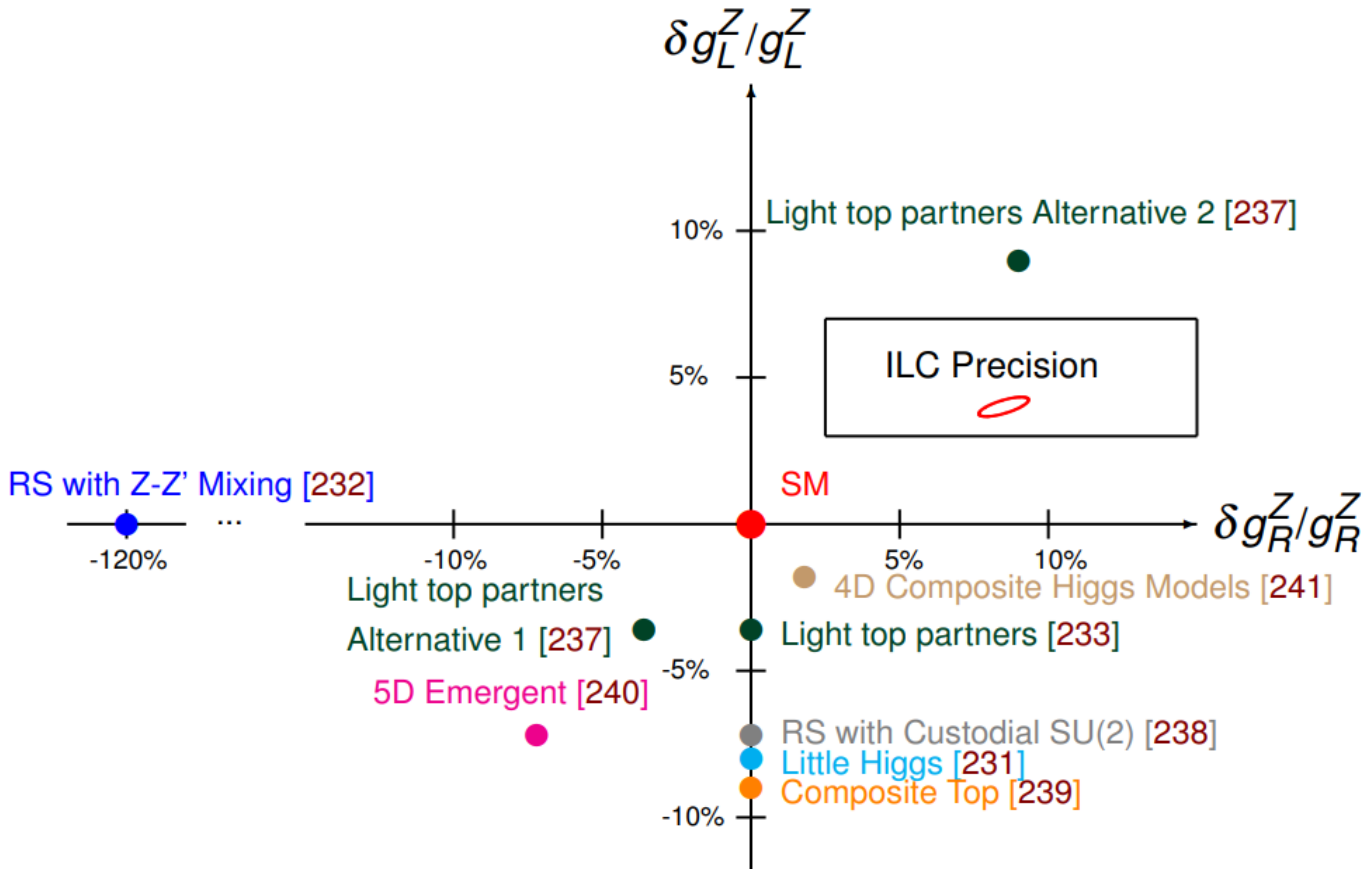
- The $t\bar{t}$ threshold scan can yield experimental accuracy of 4%, but suffers theoretical uncertainty of 20%
- The $t\bar{t}H$ process provides direct measurement of the top Yukawa coupling y_t.
- With 4 ab^{-1} at 550GeV, a precision of 2.8% is expected, and 1% with 8 ab^{-1} at 1TeV.



Higher Energies $\geq$ 550 GeV

Top ElectroWeak Couplings

- If the Higgs is composite, the strongly coupled top quark may also become "partially composite."
- The top can mix with vector-like fermions (Little Higgs) or couple to new vector bosons (R-S).
    - The top EW couplings may deviate from SM.
- The top compositeness may manifest itself in the four-fermion couplings.



Higher Energies ≥ 550 GeV

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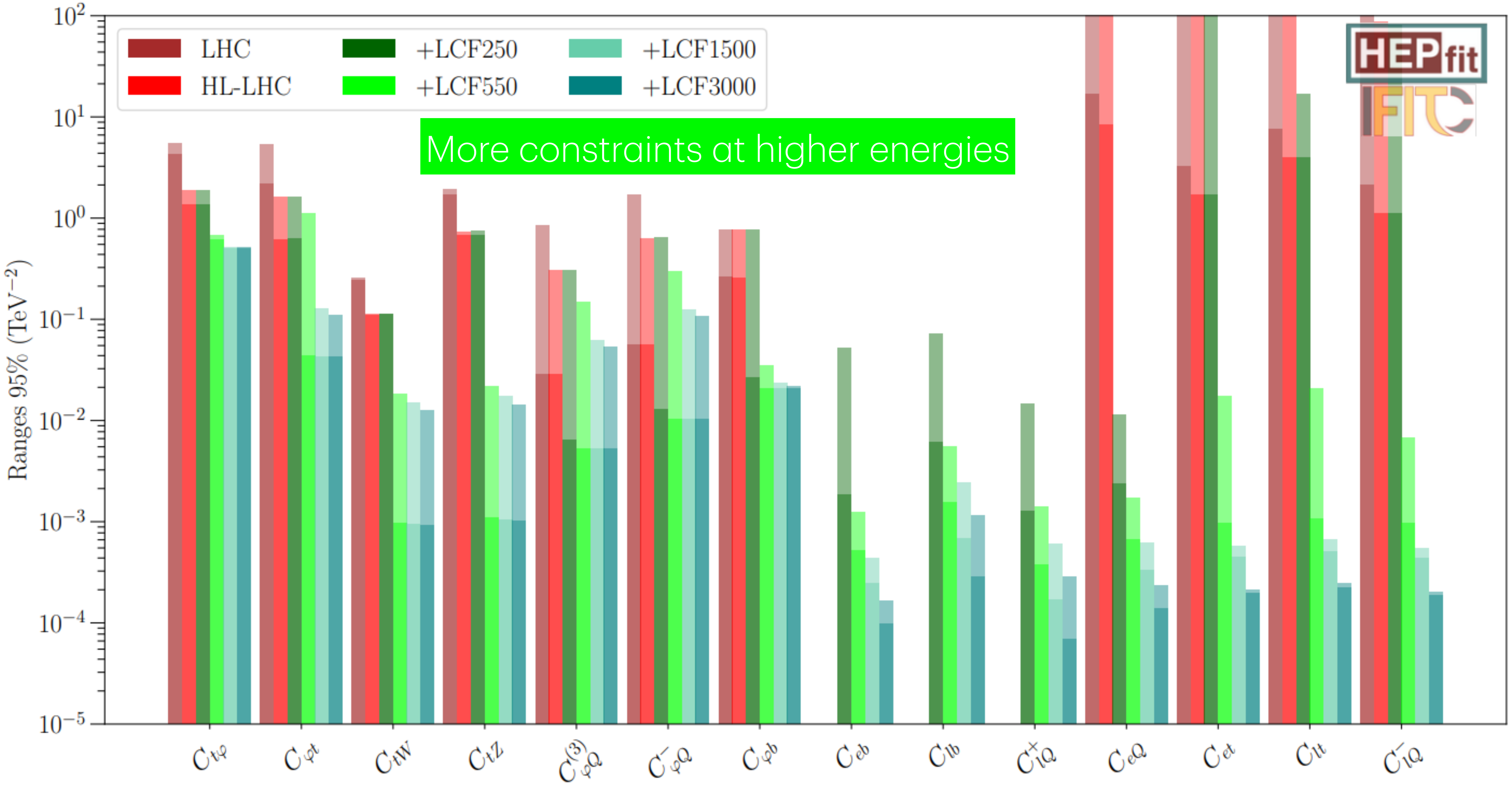

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on

$\delta g^{Z}_{R}/g^{Z}_{R}$

%
Higgs Models [241]
233]

SU(2) [238]

9]

- The top
  itself in the four-fermion couplings.

Conclusion

The LCF Offers Great Opportunities for Top/EW Studies for Discovery.

- The Top / EW studies are important ingredients of an overall program to find and identify New Physics behind the EW Symmetry Breaking.

- The Linear Collider Facility offers a strategically integrated program to achieve this goal, with more solid and robust methodologies and handles to identify New Physics.