ECFA Higgs/Top/EW Factory
WG 1 - Physics Potential

Higgs Top Electroweak

11 October 2024

  

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The report…

Today:

- Where we stand
- Some examples

Focus topic: 2 fermion final states

4.3 FOCUS TOPIC: 2-fermion final states

Editors: Adrian Irles – EXP: Adrian Irles, Daniel Jeans, Manqi Ruan, THEORY: Emanuele Bagnaschi, Alessandro Vicini, Juergen Reuter, Ayres Freitas, Bernnie Ward

4.3.1 Introduction

Editors: All

4.3.2 Theoretical and phenomenological aspects

Editors: Emanuele Bagnaschi, Alessandro Vicini, Juergen Reuter, Ayres Freitas, Bernnie Ward

Precision Z-boson coupling measurements

Four-fermion interactions

4.3.3 Experimental aspects

Editors: Adrian Irles, Daniel Jeans, Manqi Ruan

Full simulation studies

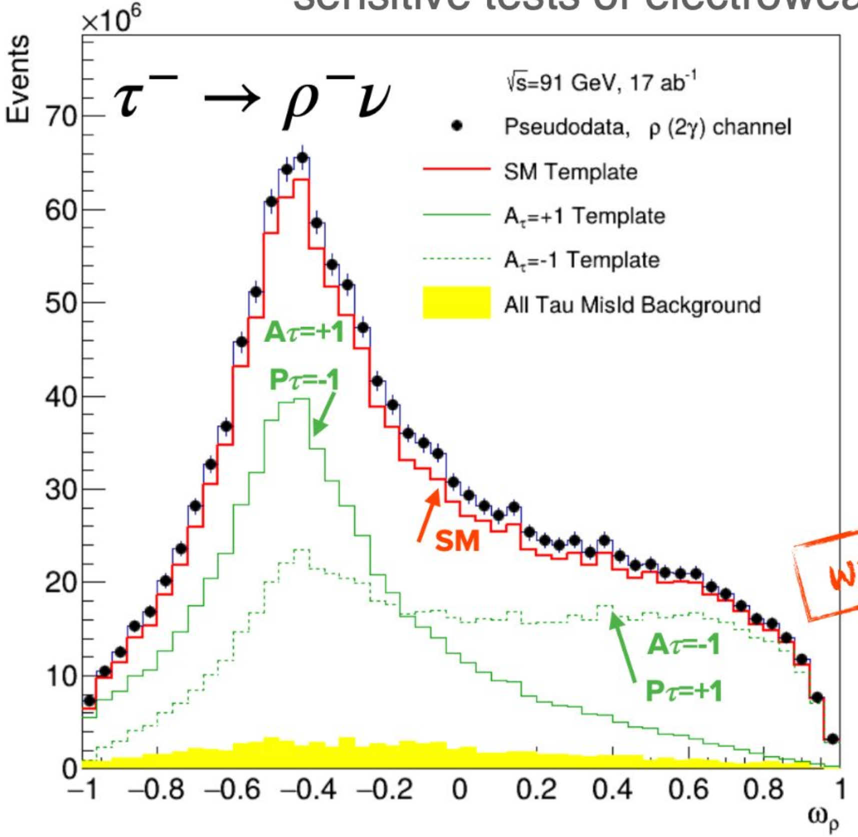
- Asymmetries on Z-pole
- Higher energies…
  - e.g., 4-fermion operators, etc.
- …

→ see overview two days ago [Daniel Jeans, link]

New studies: τ polarization at FCC-ee

María Cepeda [link]

Probe of the vector and axial couplings of the Z. One of the most sensitive tests of electroweak parameters, including $\sin^2\theta_W$.



$$\mathscr{A}_e(LEP) = 14.98 \pm 0.48(stat) \pm 0.09(syst)$$

$$\mathscr{A}_\tau(LEP) = 14.39 \pm 0.35(stat) \pm 0.26(syst)$$

- As a first approach: extraction of Polarization via LogLikelihood fit of the 'optimal variable'
  - Eventually, full analysis in bins of cos **θ**
- For now only statistical uncertainties in the fit

$$N_i = B_i + S \times \left(\frac{1 + \mathcal{P}_\tau}{2} T_i^P + \frac{1 - \mathcal{P}_\tau}{2} T_i^M \right)$$

WIP

Statistical uncertainty from fit for 17 ab⁻¹ (just 1 exp, 1 year, only one decay mode): (15.000 +- 0.007)%

Extrapolating to full statistics, full set of final states and decay modes: <<0.01%

Focus topic: ZH production and angular studies

3.1 FOCUS TOPIC: ZH production and angular studies

Editors: Ivanka Brozovic, Chris Hays, Markus Klute, Sandra Kortner, Cheng Li, Ken Mimasu, Gudrid Moortgat-Pick

3.1.1 CP-odd coupling studies

Models of CP violation in the Higgs sector

Editor: Gudrid Moortgat-Pick

CP studies at the LHC

Editor: Sandra Kortner

HZZ **CP studies at the FCC**

Editors: Andrei Gritsan, Nicholas Pinto, Valdis Slokenbergs

CP studies at the CEPC

Editor: Qiyu Sha

CP tests with polarised beams

Editor: Cheng Li

HVV **CP studies at the ILC with** $\sqrt{s} = 1$ **TeV**

Editor: Ivanka Bozovic

CP studies in $\mathrm{H} \to \tau\tau$

Editor: Kazuki Sakurai

3.1.2 CP-even coupling studies

Impact of additional Higgs bosons

Editor: Sven Heinemeyer

Coupling measurements at the LHC

Editor: Sandra Kortner

$\mathrm{H} \to \mathrm{ZZ}$ **coupling sensitivity at CLIC**

Editor: Ivanka Brozovic

3.1.3 Entanglement sensitivity

Entanglement in $\mathrm{H} \to \mathrm{VV}$

Editor: Juan Antonio Aguilar Saavedra

Entanglement in $\mathrm{H} \to \tau\tau$

Editor: Kazuki Sakurai

Topics being discussed:

- Reconstruction of production and decay angles
- CP-violation in H-Z coupling
- Higgs couplings in HZ production
- CP-odd observables
- Global context, CP-conserving SMEFT,...

Many areas of work:

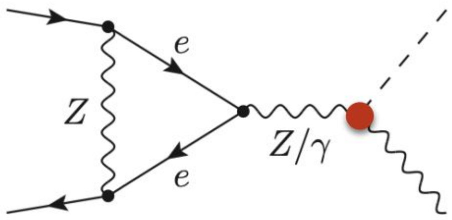
- Pheno
- MC
- Reco
- …

New studies: CP-odd in ZH

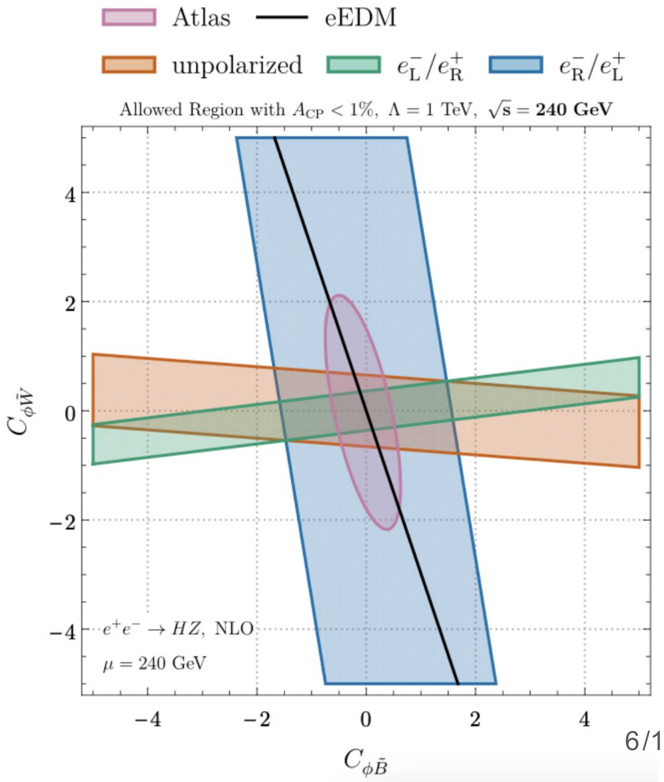
Pier Paolo Giardino [link]

CP-odd operators do appear at LO

$$\mathscr{A}(e^+e^- \to HZ) \propto \mathscr{A}_{CP-even} + i\mathscr{A}_{CP-odd}$$



Use the fact that NLO integrals have imaginary parts, and study only the p_t distribution of the Z



We define a CP violating asymmetry to study the sensitivity to each operators.

$$A_{\mathrm{CP},i} \equiv \frac{C_i(\mu)}{\Lambda^2} \frac{|\Delta^{(\mathrm{NLO})}_{i,\mathrm{weak}}(\cos\theta < 0) - \Delta^{(\mathrm{NLO})}_{i,\mathrm{weak}}(\cos\theta > 0)|}{\sigma^W_{\mathrm{SM,NLO}}}$$

New studies: CP-odd in ZH

CP-odd operators do appear at LO

$$\mathscr{A}(e^+e^- \to HZ) \propto \mathscr{A}_{CP-even} + i\mathscr{A}_{CP-odd}$$

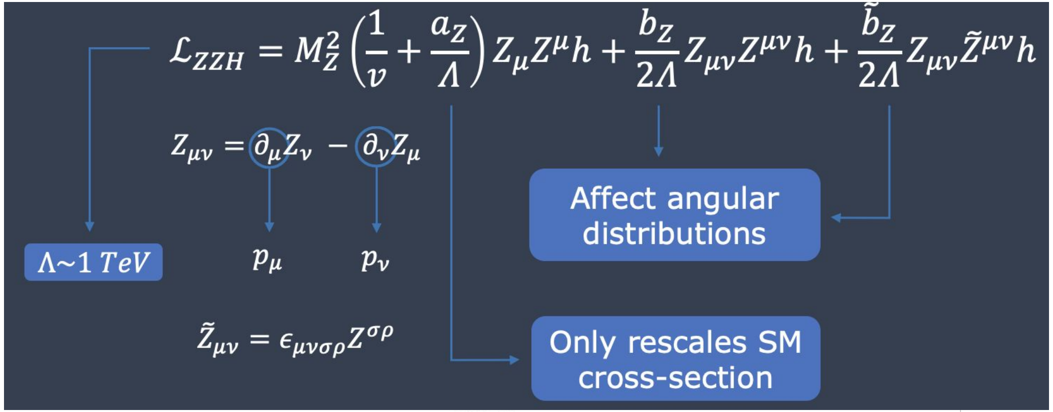
Study CP-odd HZZ couplings using transversely polarized beams at ILC

Gudrid Moortgat-Pick [link]

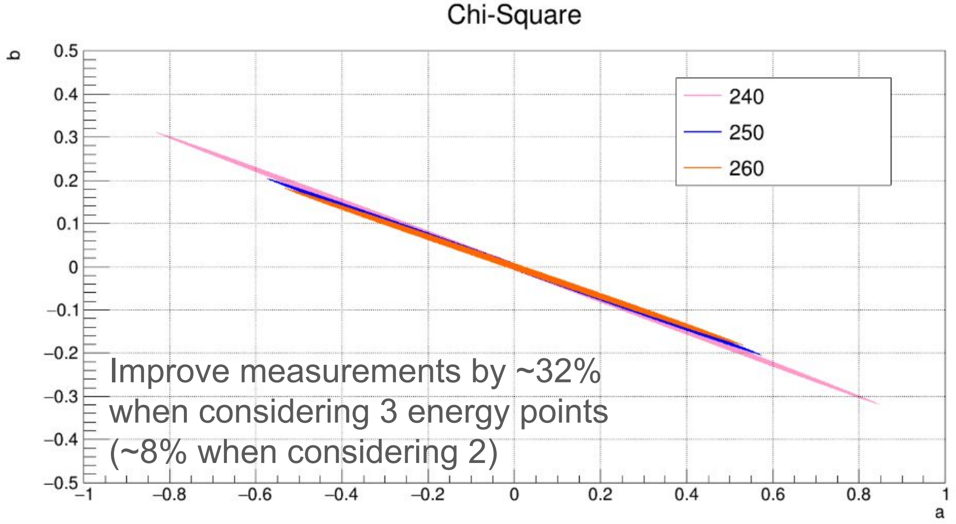
	95% C.L. (2σ)limit						
Experiments	ATLAS	CMS	HL-LHC	CEPC	CLIC	CLIC	ILC
Processes	$H \to 4\ell$	$H \to 4\ell$	$H \to 4\ell$	HZ	W-fusion	Z-fusion	$HZ,\ Z \to \mu^+\mu^-$
$\sqrt{s}$ [GeV]	13000	13000	14000	240	3000	1000	250
Luminosity [fb^{-1}]	139	137	3000	5600	5000	8000	5000
$(\lvert P_-\rvert, \lvert P_+\rvert)$							(90%, 40%)
$\tilde{c}_{HZZ}$ ($\times 10^{-2}$)	[-16.4, 24.0]	[-9.0, 7.0]	[-9.1, 9.1]	[-1.6, 1.6]	[-3.3, 3.3]	[-1.1, 1.1]	[-1.1, 1.0]
$f_{CP}^{HZZ}(\times 10^{-5})$	[-409.82, 873.58]	[-123.78, 74.91]	[-126.54, 126.54]	[-3.92, 3.92]	[-16.66, 16.66]	[-1.85, 1.85]	[-1.85, 1.53]
$\tilde{c}_{ZZ}$	[-1.2, 1.75]	[-0.66, 0.51]	[-0.66, 0.66]	[-0.12, 0.12]	[-0.24, 0.24]	[-0.08, 0.08]	[-0.08, 0.07]

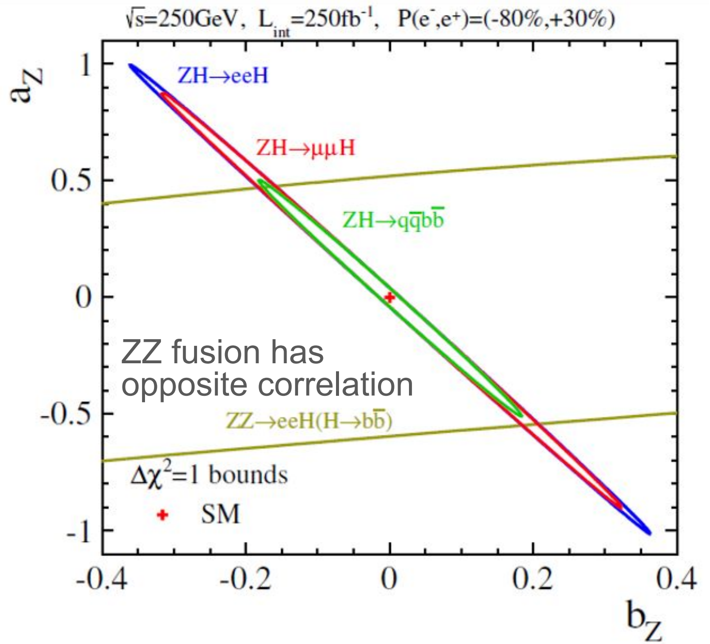
New studies: ZZH anomalous couplings

Andrea Siddharta Maria [link]

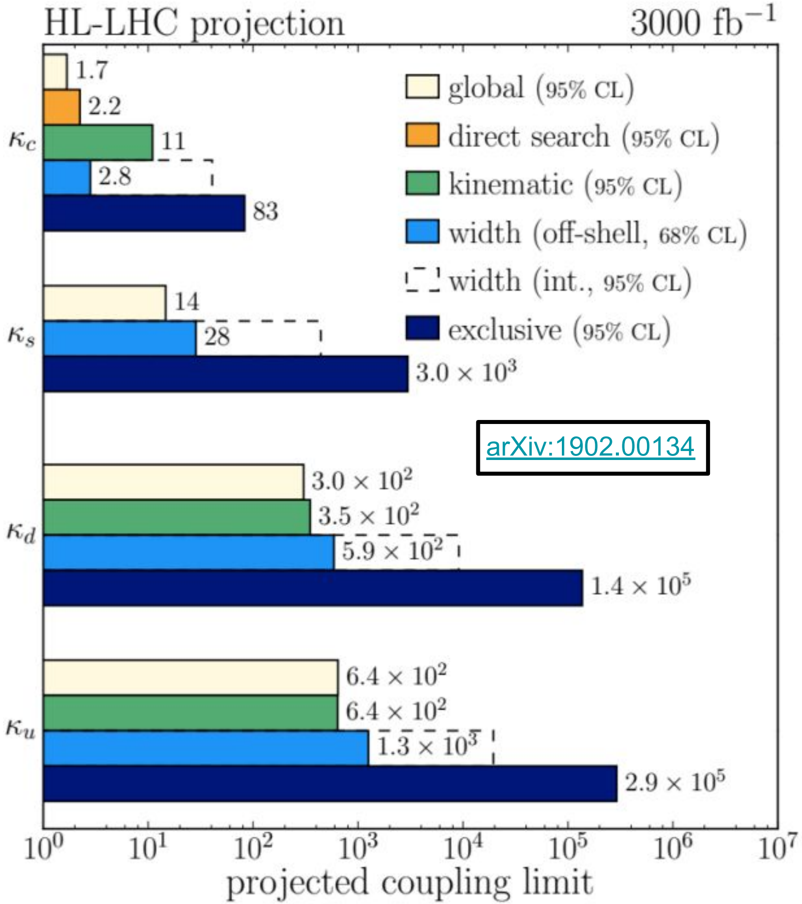


"The (SMEFT) new Lorentz structures induced by BSM theories lead to different angular distributions and energy dependence"





Focus Topic: $H \rightarrow s\bar{s}$



Light Yukawas out of reach at (HL-)LHC.
(Nearly) within reach at e^+e^- collider:

- Need strange jet tagging!
  - Which needs excellent particle identification and machine learning

→ see also overview at Virtual Overflow Session next week Wednesday afternoon & Thursday afternoon [Caterina Vernieri, Wed. link, Thu link]

New developments for $H \to s\bar{s}$ (and not only for this…)

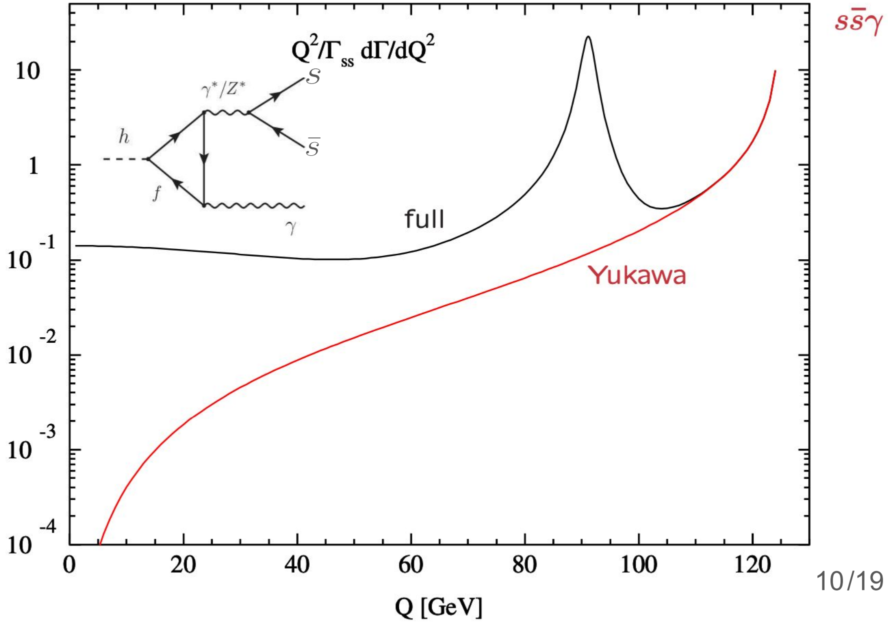
Fragmentation and hadronization impact taggers, and thus measurements

- See Wednesday plenary talk by Loukas Gouskos

Strange-Yukawa interpretation of $BR(H \to s\bar{s})$?

- "strong and weak Dalitz decays do not pose a severe problem on the determination of the strange Yukawa coupling"
- "necessity to define $BR(H \to s\bar{s})$ on the theory side ⇒ LHC Higgs WG"

From Michael Spira (PSI) here



New developments for $H \rightarrow s\bar{s}$ (and not only for this…)

Expected sensitivity (%) of σ(ZH).BR(H⟶jj) at 68% CL **L = 10.8ab-1**

Alexis Maloizel [link]

240 GeV	H⟶bb	H⟶cc	H⟶gg	H⟶ss	H⟶ZZ	H⟶WW	H⟶ττ
Combined (BNL)	0.21	1.66	0.8	104.99	10.07	1.16	3.97
Combined (APC)	0.22	1.65	0.93	121	9.56	1.11	3.79

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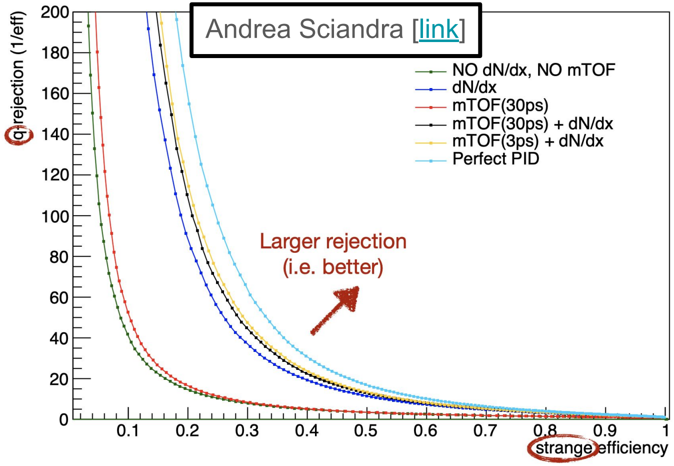
- Impact of detector design on flavor taggers…



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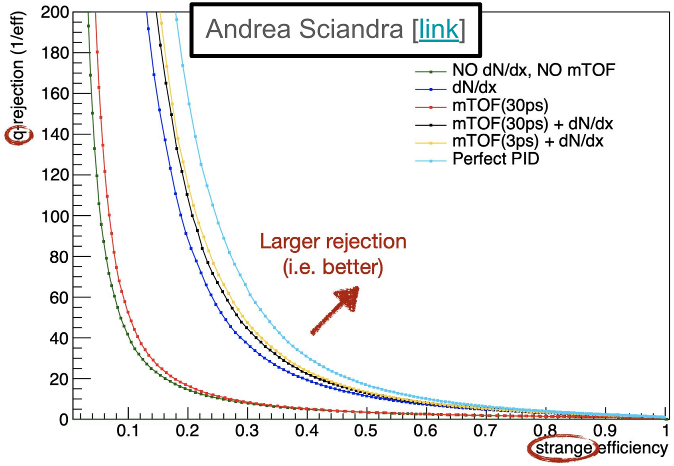
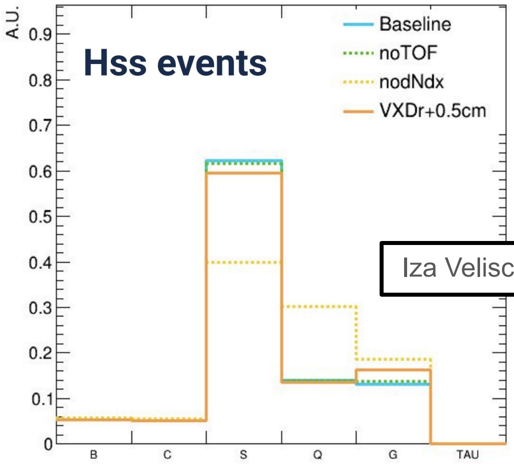
- Impact of detector design on flavor taggers…
- …and ZH all-hadronic analyses

Andrea Sciandra [link]





Iza Veliscek [link]

VARIATION	68% CL precision			
	$\Delta\mu_{Hbb}$	$\Delta\mu_{Hcc}$	$\Delta\mu_{Hgg}$	$\Delta\mu_{Hss}$
Baseline	**±0.3%**	**±4.2%**	**±2.8%**	**+674% -669%**
Relative change compared to baseline($\Delta\mu_{variation}$ / $\Delta\mu_{baseline}$)				
No TOF	x1.3	x1.02 (upper limit only)	x1	x1.03
No dNdX	x1.3	x1.07	x1.07	**x1.6**
Vertex layer radius +0.5cm	x1.3	x0.98 (lower limit only)	x1.04	x1

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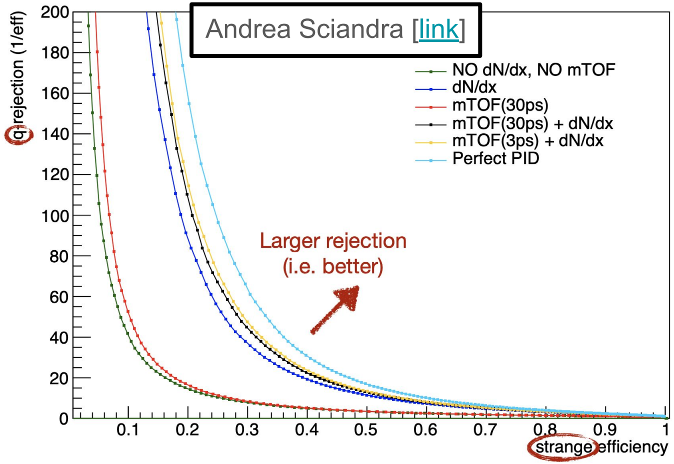
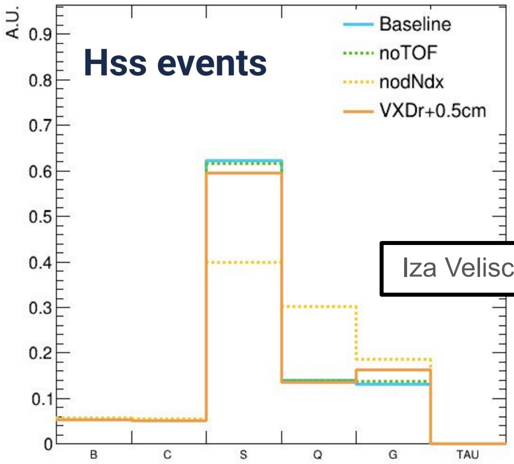


Iza Veliscek [link]



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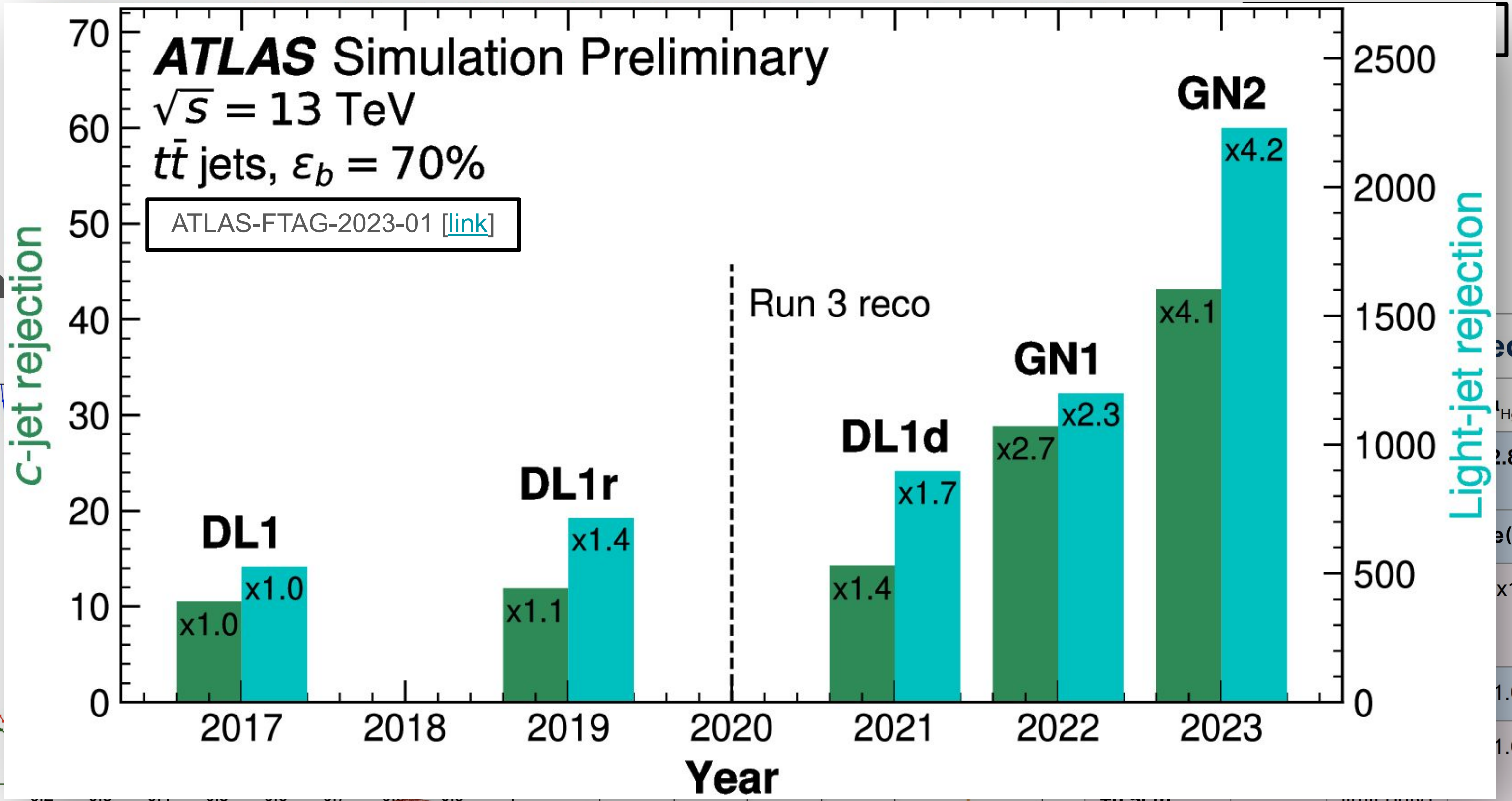
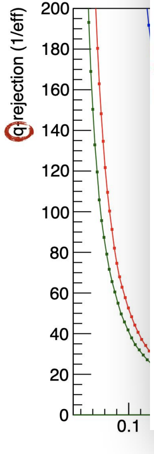
- Train flavor tagger with new transformer architecture and full simulation

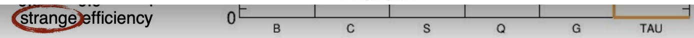
Taikan Suehara [link]

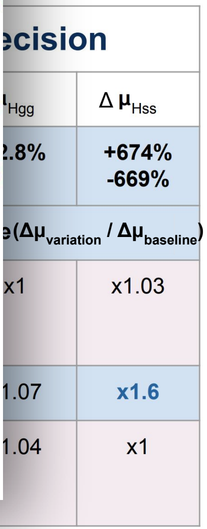
New developments for $H \to s\bar{s}$ (and not only for this…)

- In
- ..









- Train flavor tagger with new transformer architecture and full simulation

Taikan Suehara [link]

Other topics: FCC-ee Higgs mass measurement

Gregorio Bernardi [link]

at 240 GeV, 10.8 ab-1

- **Nominal configuration** → Nominal
- **Crystal ECAL to Dual Readout** → Degradation electron resolution
- **Nominal 2 T → field 3 T** → Magnetic field 3T
- **IDEA drift chamber → CLD Si tracker** → Silicon tracker
- **Impact of Beam Energy Spread** → BES 6% uncertainty, Disable BES
- **Perfect (=gen-level) momentum resolution** → Ideal resolution

Final state	Muon	Electron	Combination
Nominal	3.92(4.74)	4.95(5.68)	3.07(3.97)
Categorized	3.92(4.74)	4.95(5.68)	3.10(3.97)
Degradation electron resolution			3.24(4.12)
Magnetic field 3T	3.22(4.14)	4.11(4.83)	2.54(3.52)
Silicon tracker	5.11(5.73)	5.89(6.42)	3.86(4.55)
BES 6% uncertainty	3.92(4.79)	4.95(5.92)	3.07(3.98)
Disable BES	2.11(3.31)	2.93(3.88)	1.71(2.92)
Ideal resolution	3.12(3.95)	3.58(4.52)	2.42(3.40)
Freeze backgrounds	3.91(4.74)	4.95(5.67)	3.07(3.96)
Remove backgrounds	3.08(4.13)	3.51(4.58)	2.31(3.45)

Stat. only

Total

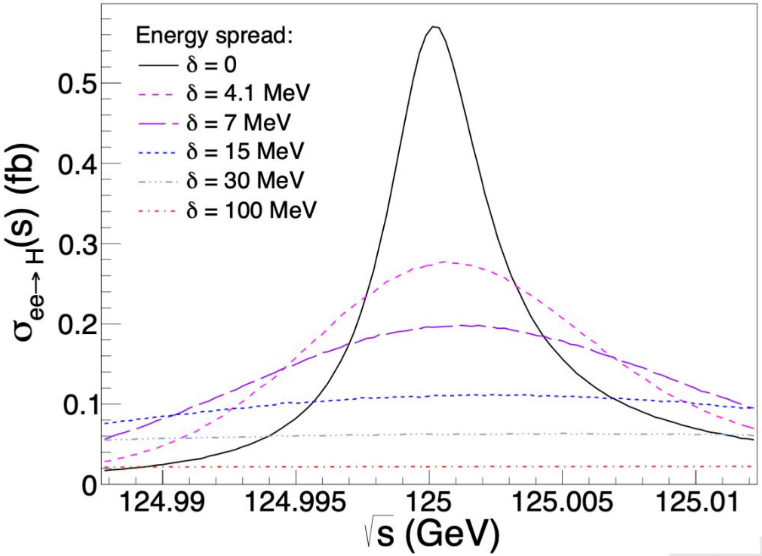
- we want to get down to **$\Delta m_H \sim \Gamma_H \sim$ 4 MeV** to allow for electron Yukawa at $\sqrt{s}$ = 125 GeV
- as expected, tracking resolution highly impacts m_H precision
- light tracker/ **high B field** highly preferable

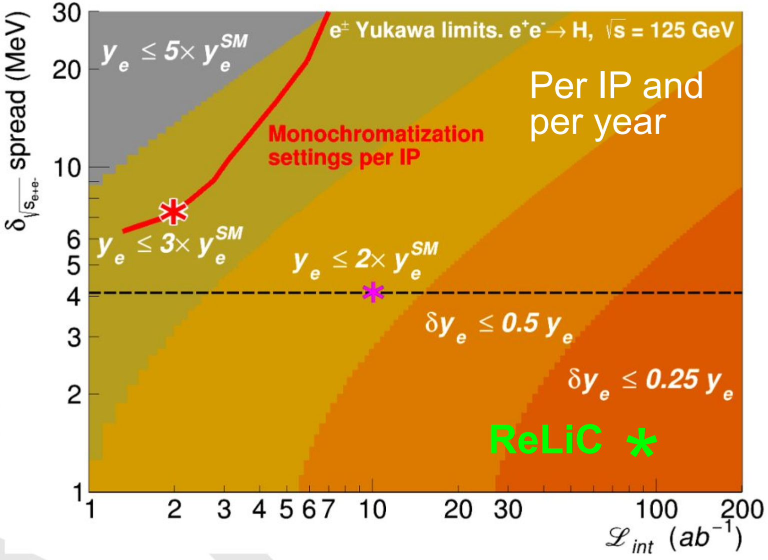
Other topics: electron Yukawa

Is the Higgs mechanism responsible for defining all of our chemistry, *i.e.*, the mass of the electron?

David D'Enterria (FCC-ee) and Vladimir N Litvinenko (ERL) [link]

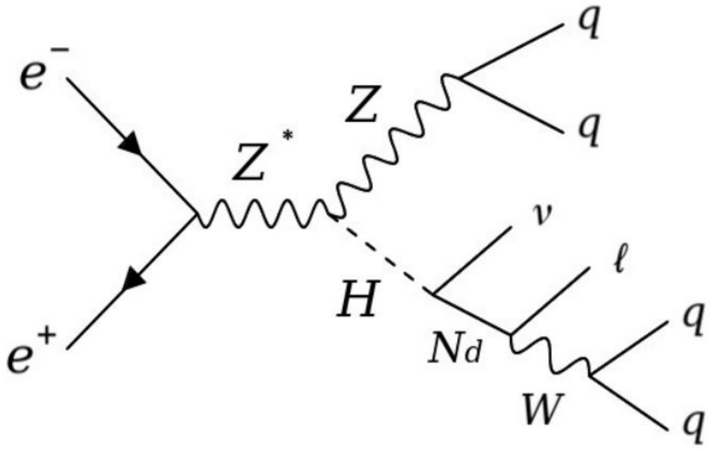
FCC-ee monochromatization



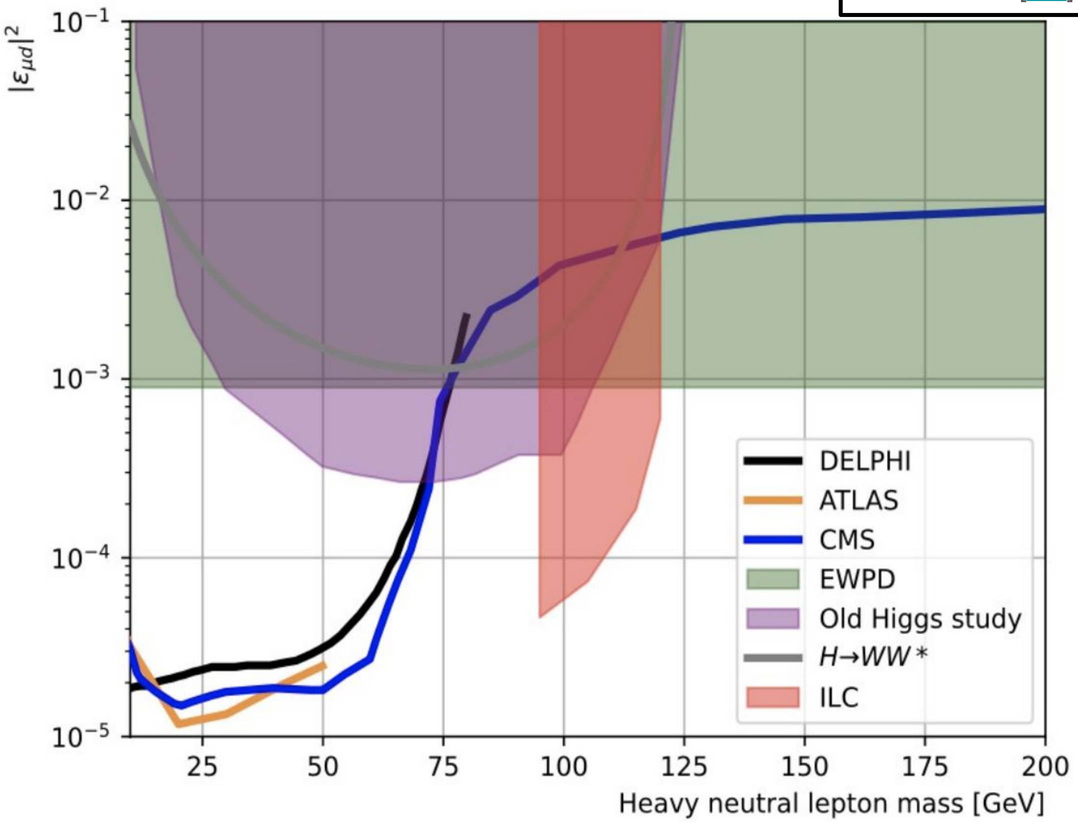


Other topics: Heavy neutral leptons in Higgs decays

Simon Thor [link]



- ILC full detector simulation
- $m_Z < m_{Nd} < m_H$
- BR(H→vNd)BR(Nd→lW) < 0.1 (at 2σ)
- 25x higher significance compared to HL-LHC



Summary

- Lots of interesting results produced over the last year(s)
    - People are assigned and are writing their reports
- Several new and interesting results shown in this workshop
- Quite some crunch time ahead of us!

Please join our WG1 overflow session next week

Wednesday afternoon & Thursday afternoon (virtual only)

[Wed. link, Thu link]

https://gitlab.in2p3.fr/ecfa-study/ECFA-HiggsTopEW-Factories/-/wikis/WG1-HTE