CLIC Physics Potential YR
- STATUS REPORT-

Francesco Riva
(Université de Genève)

CLIC Physics Potential WG

(Conveners: J. de Blas, J. Wells, A. Wulzer)

- Particular emphasis on BSM:
  - Guidance
  - Comparison with other machines

- 3 Working Units:

Precision Measurements (EFT)
(F.Riva)

Direct Searches
(R.Franceschini, M.Spannowski)

Flavour Physics
(J.Zupan)

Timeline

August 30: First draft available merging author's contributions

September 30: Complete draft for "informal" community review

October 30: submission to ArXiV and to YR

Precision Measurements at CLIC

(F. Riva - UNIGE)

Precision Measurements at CLIC

- Language: Effective Field Theory (EFT) - Dimension-6
  - Model-independent
  - Perfect Comparison tool (with direct searches/other machines)
  - A guidance for SM precision Tests

$$\delta_{BSM} \sim \frac{v^2}{\Lambda^2}$$

Benefit from High Luminosity (FCC)

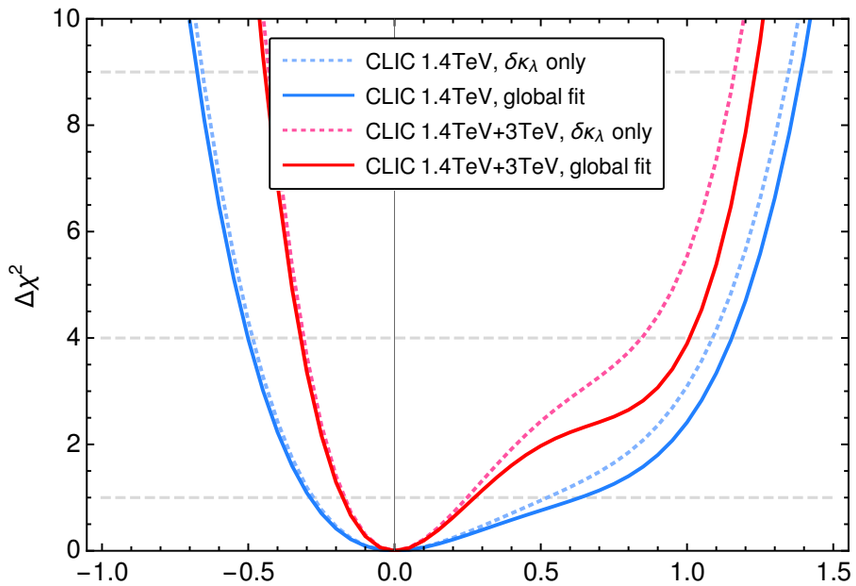
$$\delta_{BSM} \sim \frac{E^2}{\Lambda^2}$$

Benefit from High Energy (CLIC)

- Focus on off-shell processes (WW,ZH,tt,hh,...)

Precision Measurements at CLIC

1) hh



See talk by Riembau

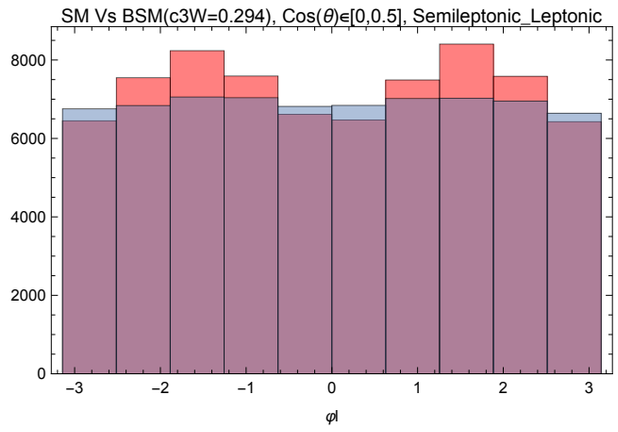
H-trilinear: $\delta\kappa_h$ only, in global fit, at different runs, vs LHC...

$\delta\kappa_\lambda$

2) WW

No interference at high-E in inclusive measurements

- Azimuthal angle important

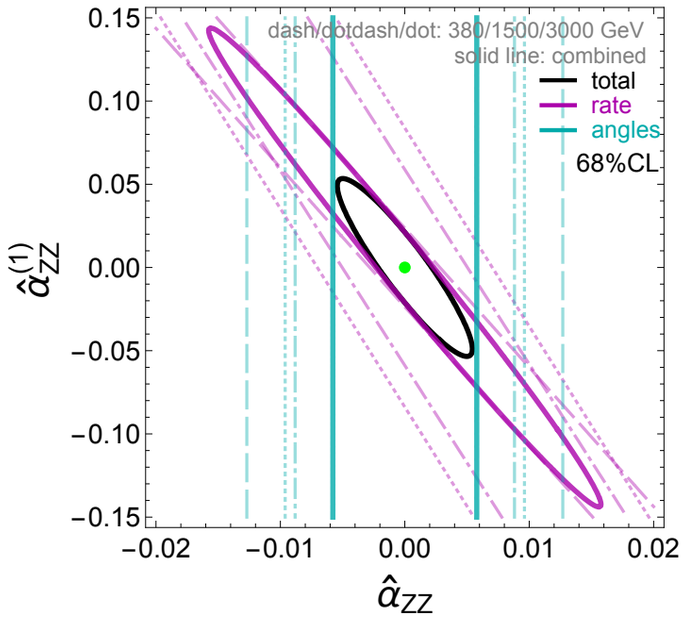


See talk by Lombardo

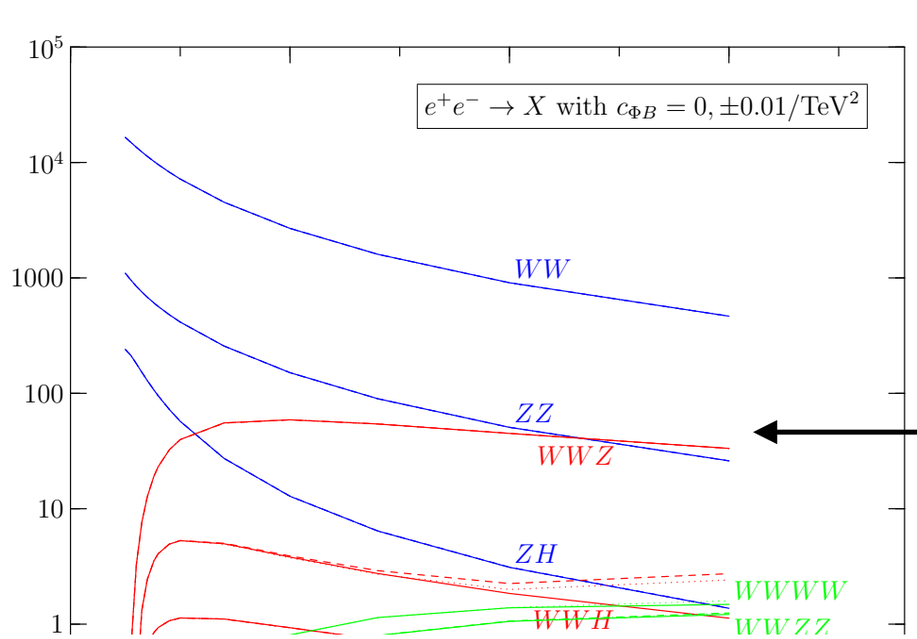
Precision Measurements at CLIC

3) ZH

Angles also important



4) Multibosons

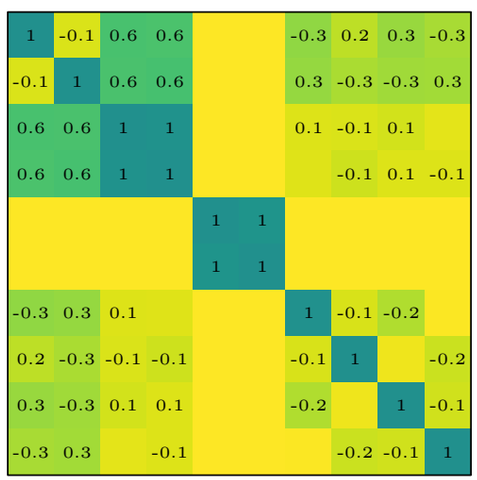


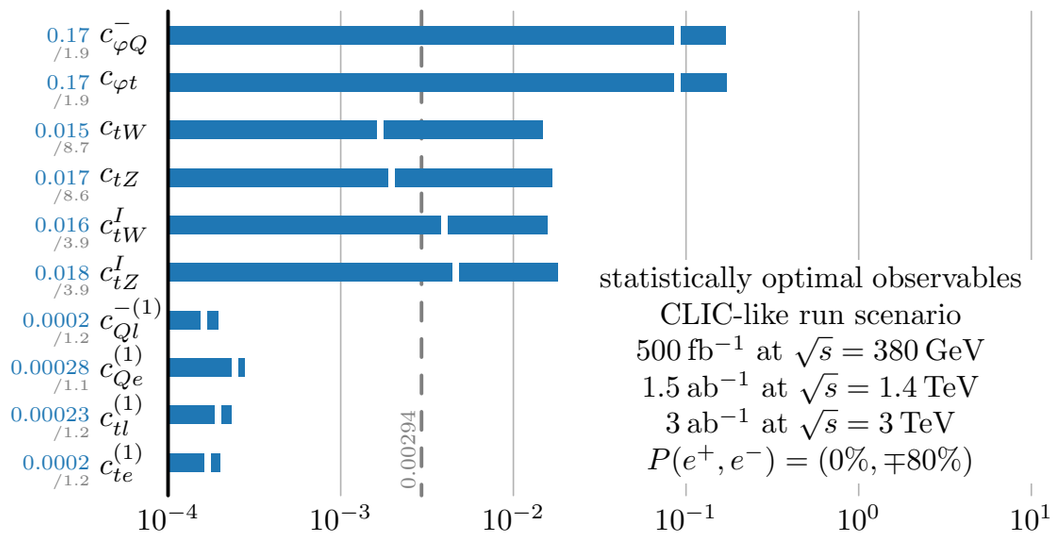
See talk by Kilian

Sizeable!

Precision Measurements at CLIC

5) tt





See talk by Durieux

Global fit to tt, optimized, combining runs,...

6) tth in loop

7) THE global fit

8) Interpretation (Composite Higgs)

See talk by Durieux

FLAVOR@CLIC

Jure Zupan
u. of cincinnati

UPSHOT

- CLIC provides two important probes to the origin of SM flavor
  - top quark
  - Higgs boson
- deviations from SM expectations = New Physics
- can also search for new states
  - motivated by B physics anomalies, neutrino mass generation, ...

EXOTIC TOP DECAYS

- potential FCNC modes: $t \to ch$, cZ, $c\gamma$, c+*MET*
- typical sizes of branching ratios:

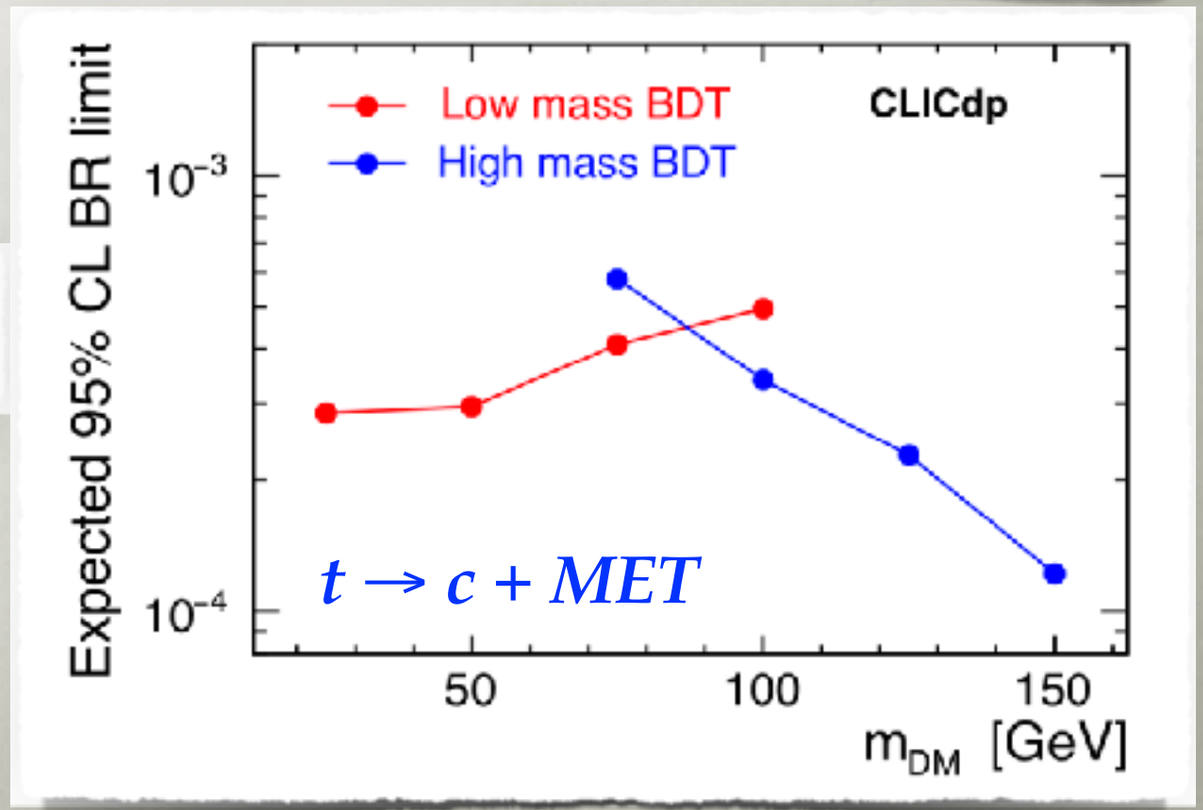
	SM	MSSM	2FHDM	CH	RS
$\mathrm{Br}(t \to ch)$	3×10^{-15}	$< 10^{-5}$	$< 10^{-3}$	$<1.3 \times 10^{-5}$	$<2.6 \times 10^{-5}$
$\mathrm{Br}(t \to c\gamma)$	4.6×10^{-14}	$< 5 \times 10^{-7}$	$< 3.4 \times 10^{-6}$	$< 5 \times 10^{-9}$	$< 5 \times 10^{-9}$

- experimental prospects at CLIC:

$$\mathrm{BR}(t \to ch) \times \mathrm{BR}(h \to b\bar{b}) < 1.2 \times 10^{-4}.$$

$$\mathrm{BR}(t \to c\gamma) < 4.7 \times 10^{-5}.$$

$500\ \mathrm{fb}^{-1}, \sqrt{s} = 380\ \mathrm{GeV}$



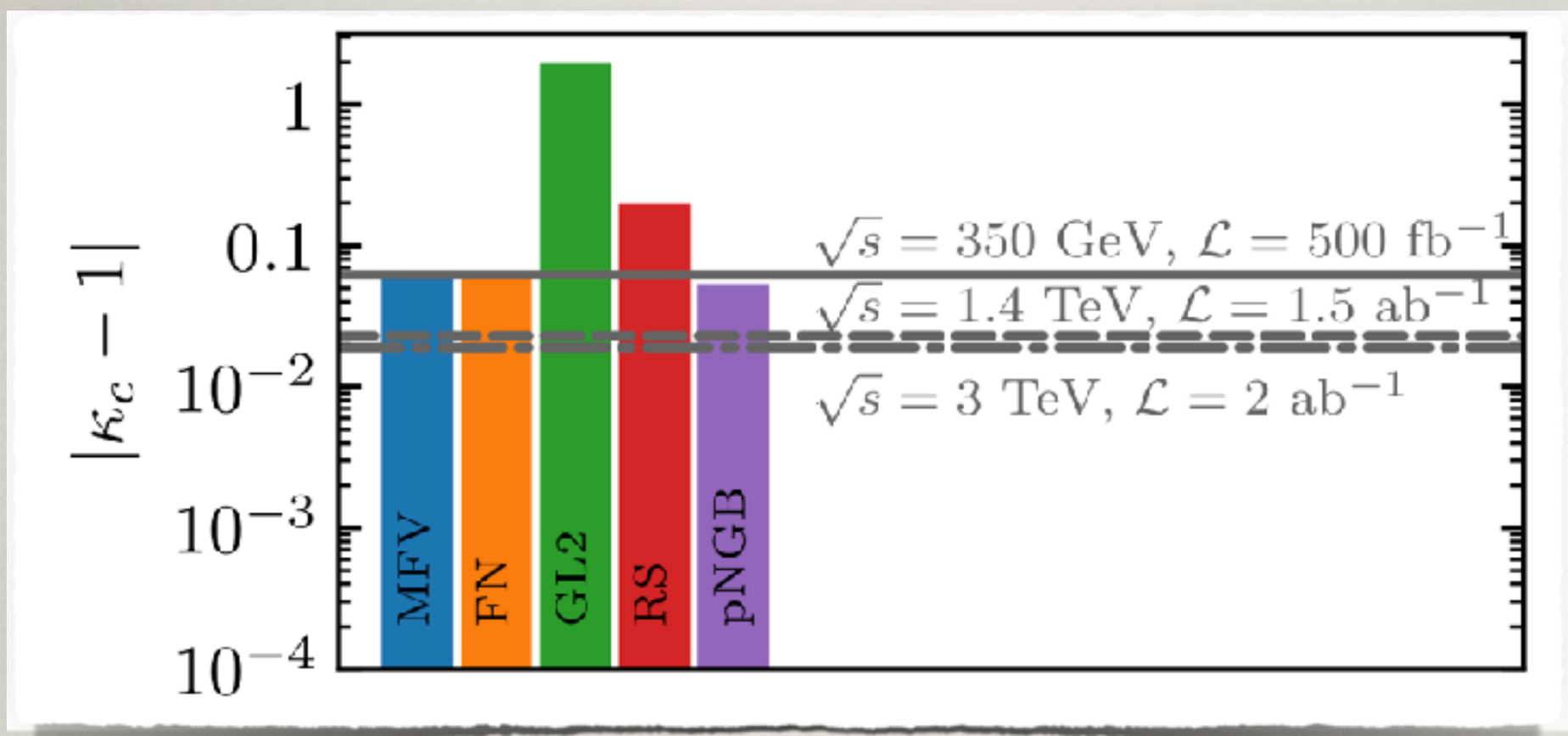
TOP FCNC FROM PRODUCTION

- can search for top FCNC couplings in the production, e.g., $e^+e^- \to t\,\bar{u}$

$\sqrt{s}$ [GeV]	$\mathcal{L}$ [fb^{-1}]	$P(e^+, e^-)$	BR after fit
240	3000	$(0, 0)$	3.7×10^{-5}
350	3000	$(0, 0)$	1.1×10^{-5}
500	3000	$(0, 0)$	6.0×10^{-6}
500	300	$(0, 0)$	1.9×10^{-5}
800	500	$(0, 0)$	8.7×10^{-6}

HIGGS COUPLINGS

- in the SM the flavor structure comes from the Higgs sector $y_f^{\rm SM} = \sqrt{2} m_f / v$
- can test this at CLIC
- several questions
  - proportionality $y_{ii} \propto m_i$
  - factor of proportionality $y_{ii}/m_i = \sqrt{2}/v$
  - diagonality (flavor violation) $y_{ij} = 0, \quad i \neq j$
  - reality (CP violation) $\mathrm{Im}(y_{ij}) = 0$



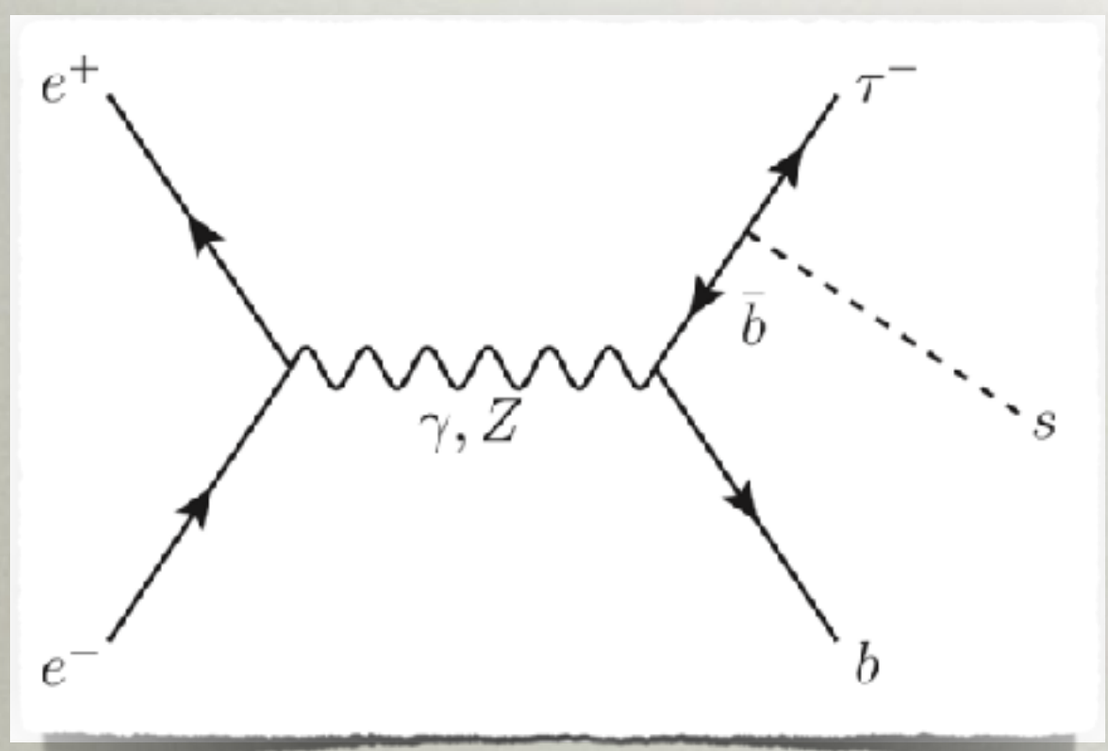
ne

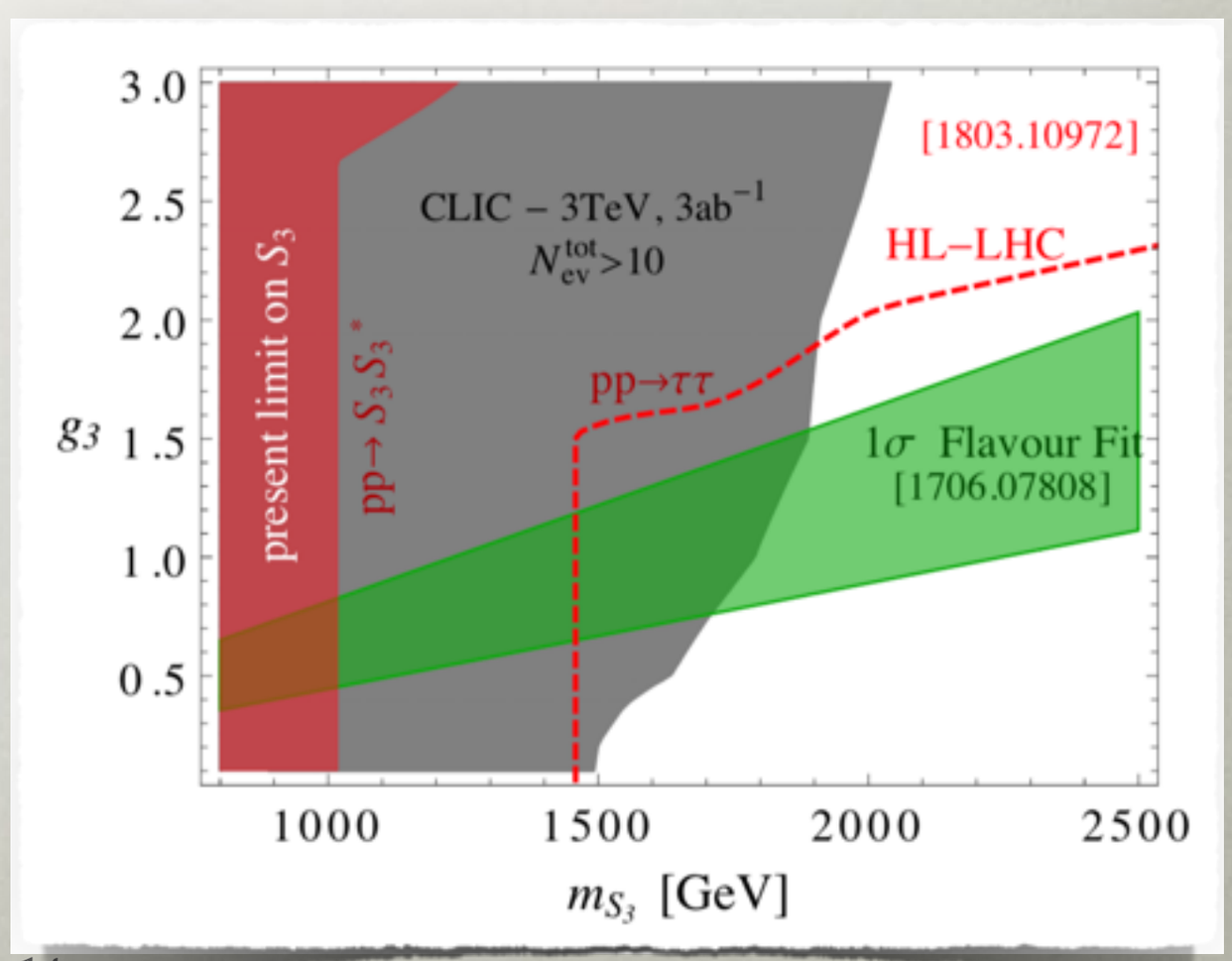
- several questions
  - proportionality $y_{ii} \propto m_i$
  - factor of proportionality $y_{ii}/m_i = \sqrt{2}/v$
  - diagonality (flavor violation) $y_{ij} = 0, \quad i \neq j$
  - reality (CP violation) $\mathrm{Im}(y_{ij}) = 0$

SEARCHING FOR NEW STATES

See talk by Buttazzo

- flavor anomalies in B physics may imply new state at electroweak scale
- could be produced at CLIC





NEUTRINO MASS GENERATION

See talk by Zhang

- could probe neutrino mass generation
- search for beyond SM neutral scalar with FCNC couplings

$$\mathcal{L}_Y = h_{\alpha\beta}\bar{\ell}_{\alpha,L}H\ell_{\beta,R} + \text{H.c.}.$$

FCNC interactions

- searches for FCNC point interactions

$$V_{LL}\,[\bar{e}\gamma^{\mu}P_L e]\,[\bar{\tau}\gamma_{\mu}P_L e]$$

- present bound: $1/V_{LL} > (8.8\,\mathrm{TeV})^2$
- Belle 2: *20-30 TeV*
- CLIC:

250 GeV	500 GeV	1 TeV	3 TeV
8.0 TeV	11.7 TeV	18.0 TeV	34.9 TeV

$1/\sqrt{V_{LL}}$

BSM: direct searches

ROBERTO FRANCESCHINI (ROMA)
MICHAEL SPANNOWSKI (DURHAM)

Outline

- ElectroWeak Symmetry Breaking ⇒ New Scalars
  (NMSSM, Twin Higgs, …)
- Dark Matter ⇒ General EW matter (precision $e^+e^- \to f\bar{f}$)
- Simplified Models ⇒ Hidden Valley

1807.04743 - Buttazzo, Redigolo, Sala, Tesi

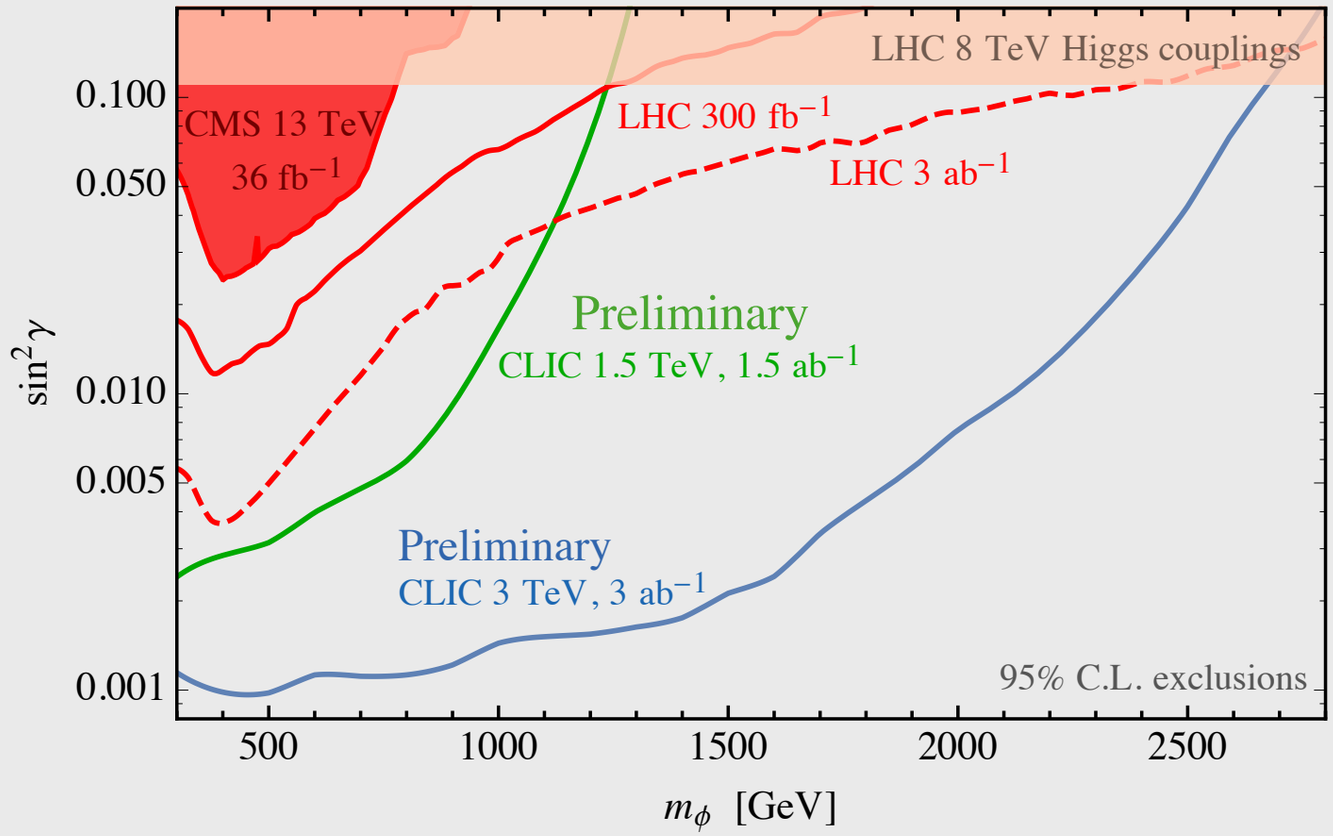
Higgs + Heavy Singlet

See talk by Buttazzo (and Zarnecki)

MIXING VS. MASS

$e^+e^- \to \nu\nu\, S$

$S \to h\, h \to 4b$



Roberto Franceschini & Michael Spannowsky

1807.04743 - Buttazzo, Redigolo, Sala, Tesi

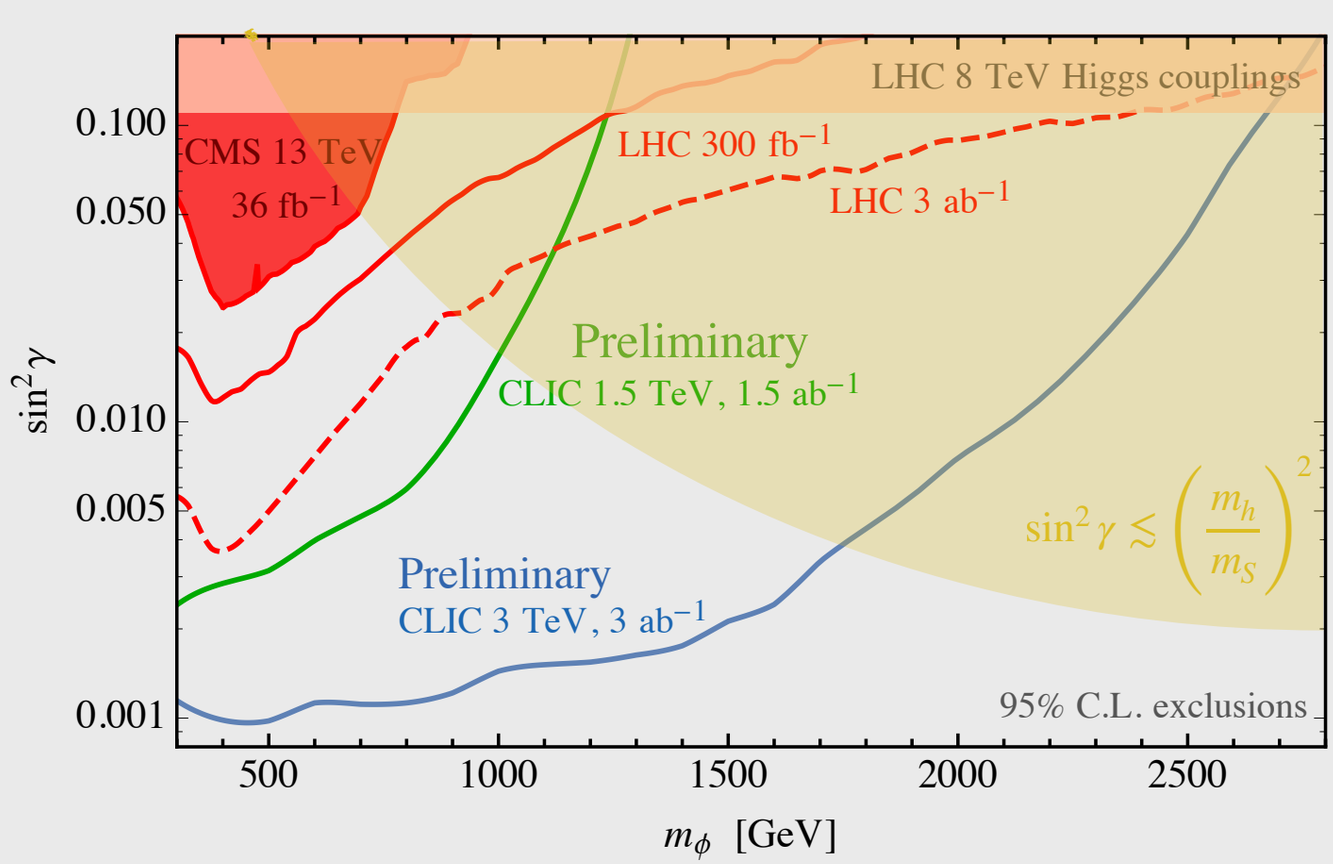
Higgs + Heavy Singlet

See talk by Buttazzo (and Zarnecki)

MIXING VS. MASS

$e^+e^- \to \nu\nu\, S$

$S \to h\, h \to 4b$



Roberto Franceschini & Michael Spannowsky

1807.04743 - Buttazzo, Redigolo, Sala, Tesi

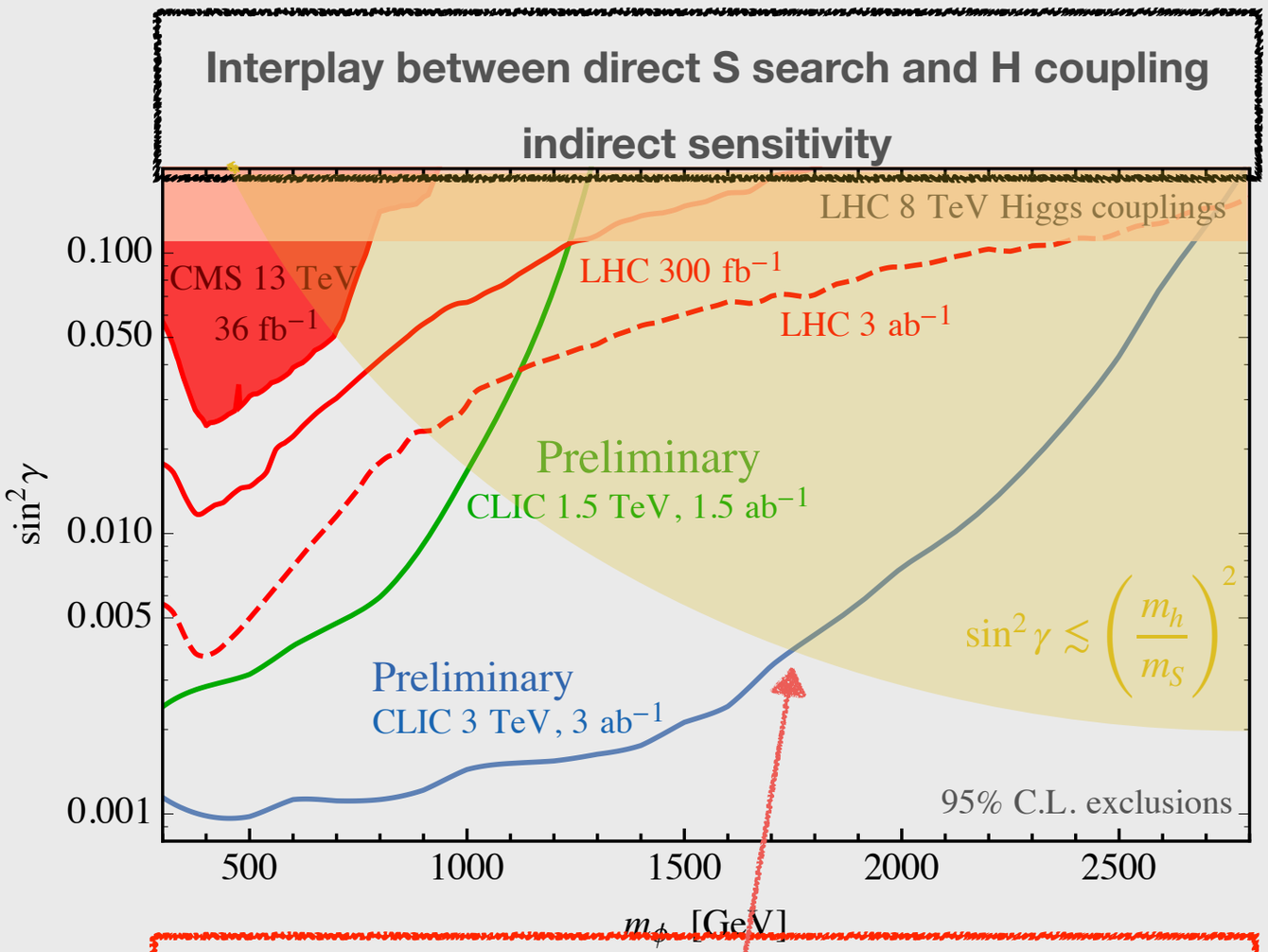
Higgs + Heavy Singlet

See talk by Buttazzo (and Zarnecki)

MIXING VS. MASS

$e^+e^- \to \nu\nu\, S$

$S \to h\, h \to 4b$



Test motivated values of the mixing beyond TeV singlet mass

Roberto Franceschini & Michael Spannowsky

1807.04743 - Buttazzo, Redigolo, Sala, Tesi

Higgs + Heavy Singlet

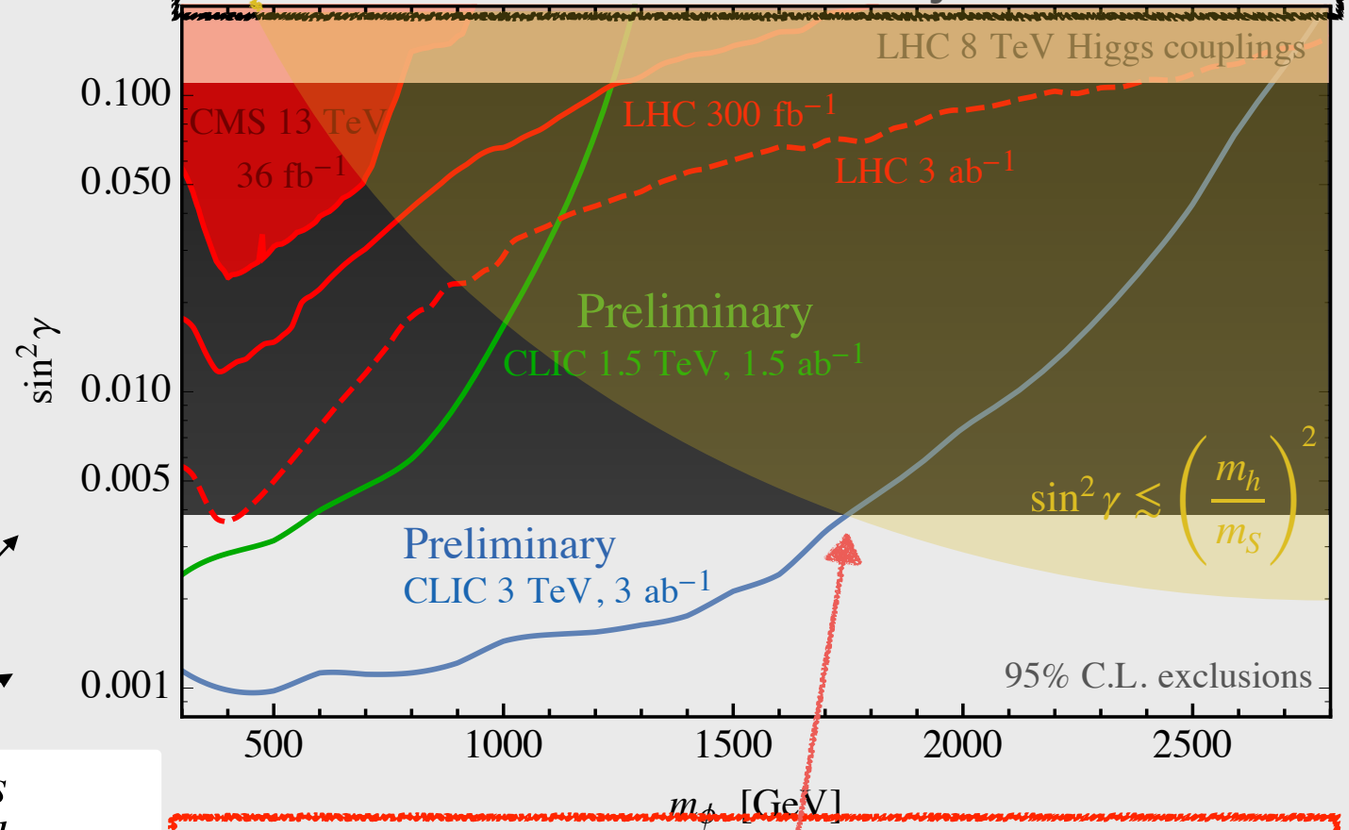
See talk by Buttazzo (and Zarnecki)

MIXING VS. MASS

$e^+e^- \to \nu\nu\, S$

$S \to h\, h \to 4b$

Interplay between direct S search and H coupling indirect sensitivity



Test motivated values of the mixing beyond TeV singlet mass

1608.07538 + Roloff

Higgs couplings
$e^+e^- \to Zh$ & $\nu\nu\, h$
$\sin^2\gamma < 0.4$ % 95% CL (stage

Roberto Franceschini & Micha

1807.04743 - Buttazzo, Redigolo, Sala, Tesi

Higgs + Heavy Singlet

See talk by Buttazzo (and Zarnecki)

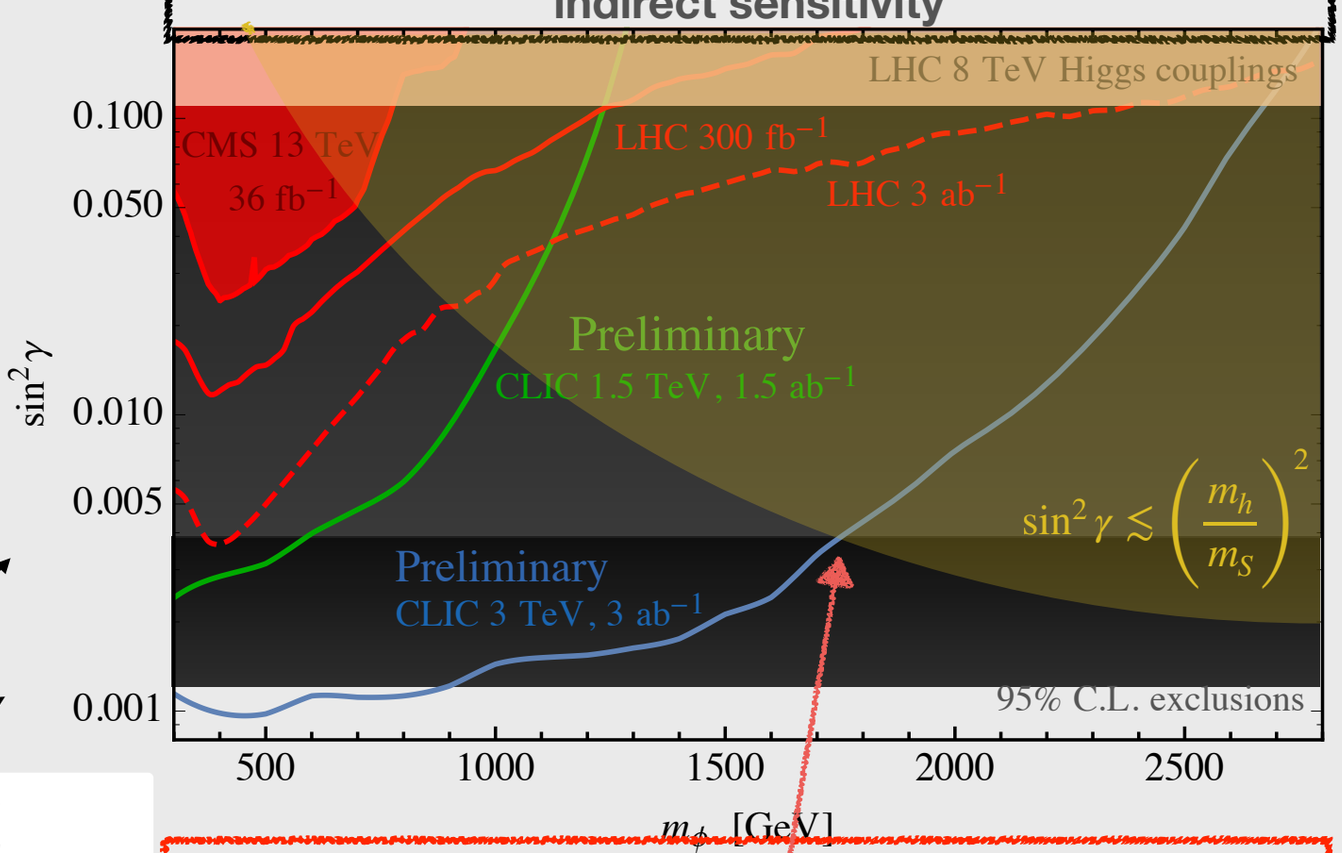
MIXING VS. MASS

$e^+e^- \to \nu\nu\, S$

$S \to h\, h \to 4b$

Interplay between direct S search and H coupling

indirect sensitivity



Test motivated values of the mixing beyond TeV singlet mass

1608.07538 + Roloff

Higgs couplings

$e^+e^- \to Zh$ & $\nu\nu\, h$

$\sin^2\gamma < 0.4$ % 95% CL (stage

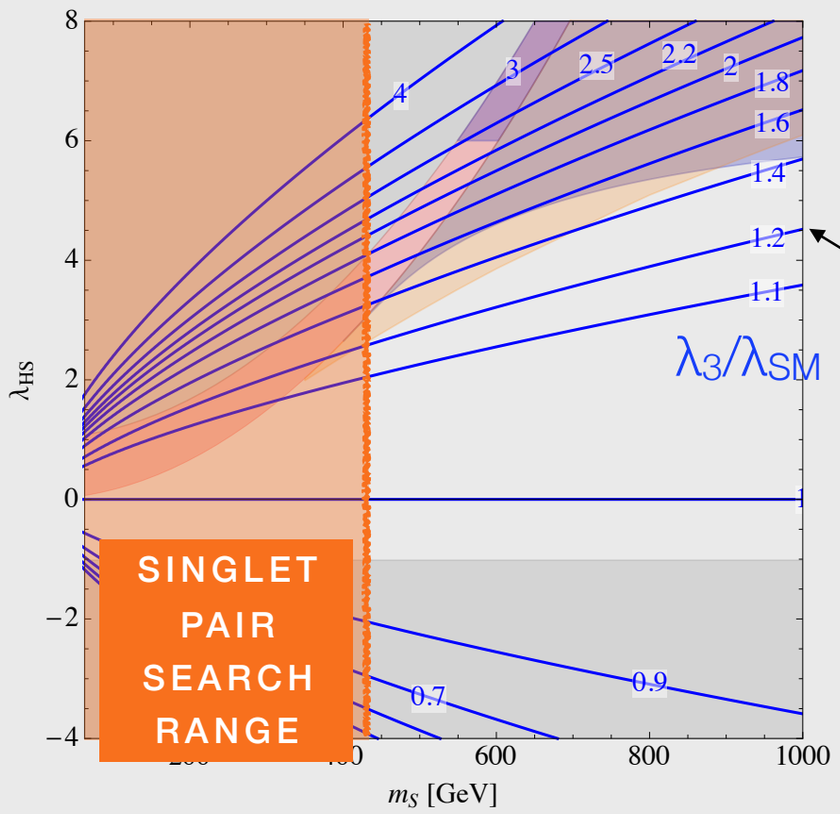
Roberto Franceschini & Micha

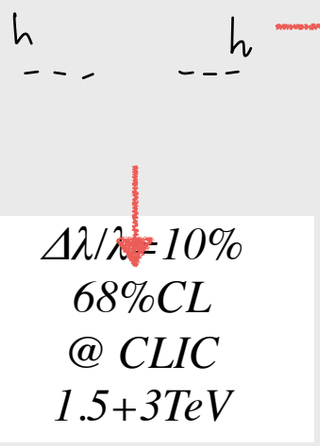
See talk by JM NO

1409.0005 1608.07538

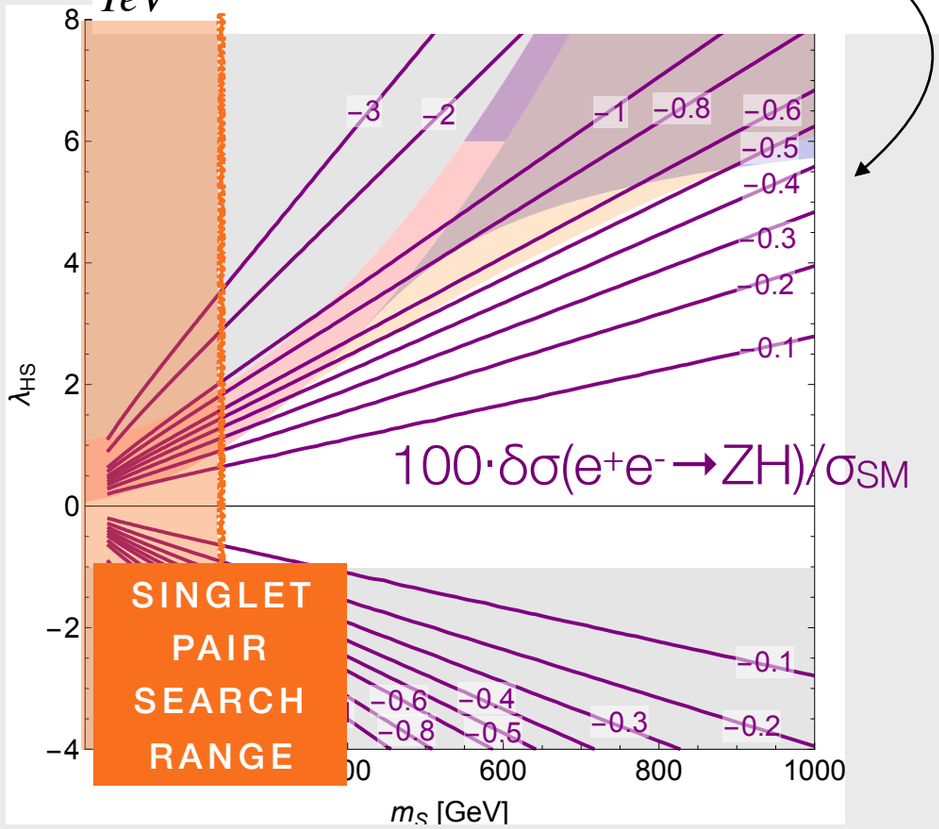
H+S for Electroweak Baryogenesis

HHH COUPLING | VH COUPLING | SINGLET PAIR PRODUCTION





$\Delta g(HXX) = 0.12\%$ 95%CL @ CLIC 0.38+1.5+3 TeV



Roberto Franceschini & Michael Spannowsky

DM: Short (disappearing) tracks

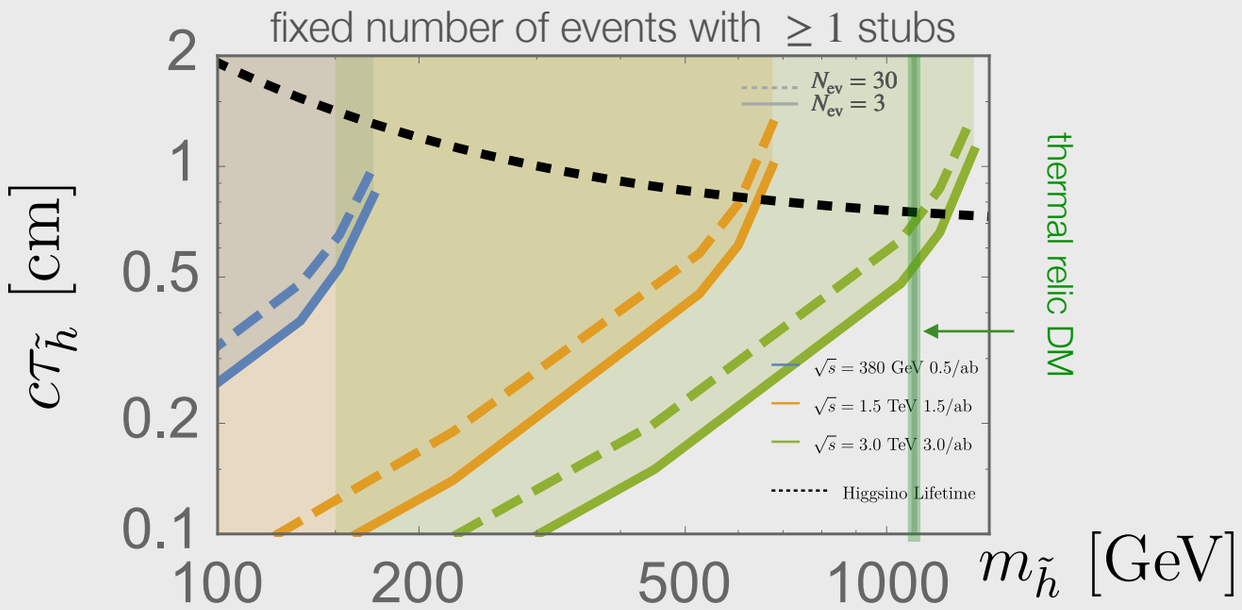
HIGGSINO DM

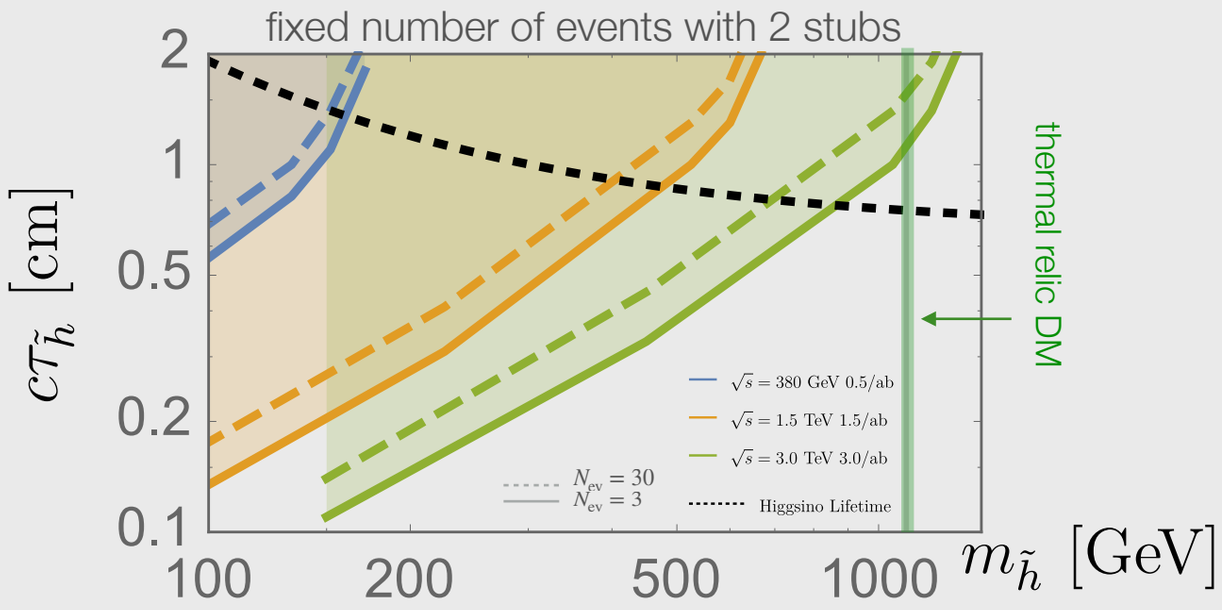
O(CM) DISAPPEARING TRACKS

Charged-Neutral mass splitting
can be different if Higgsino Mixed with other states (e.g. Wino)

TAKE LIFETIME AS FREE PARAMETER

ISOLINES FOR NUMBER OF EVENTS ASSUMED FOR DISCOVERY





Roberto Franceschini & Michael Spannowsky

Hidden Valley: similar signals

Conclusions

EXTENT: good response from broad community

CONTENT: varied, innovative, unique
makes the most out of CLIC

STATUS: on schedule as planned