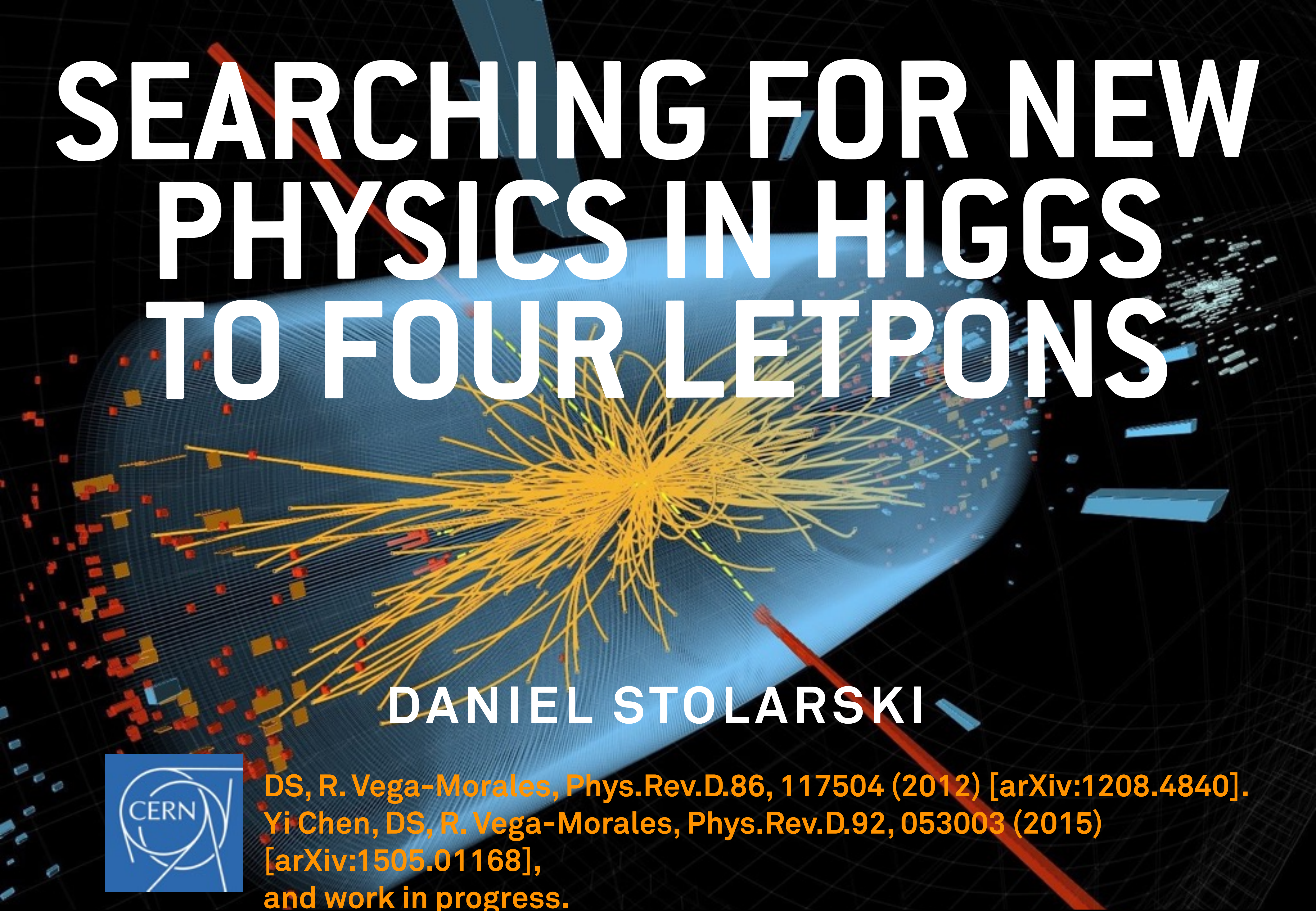


SEARCHING FOR NEW PHYSICS IN HIGGS TO FOUR LETPONS

DANIEL STOLARSKI

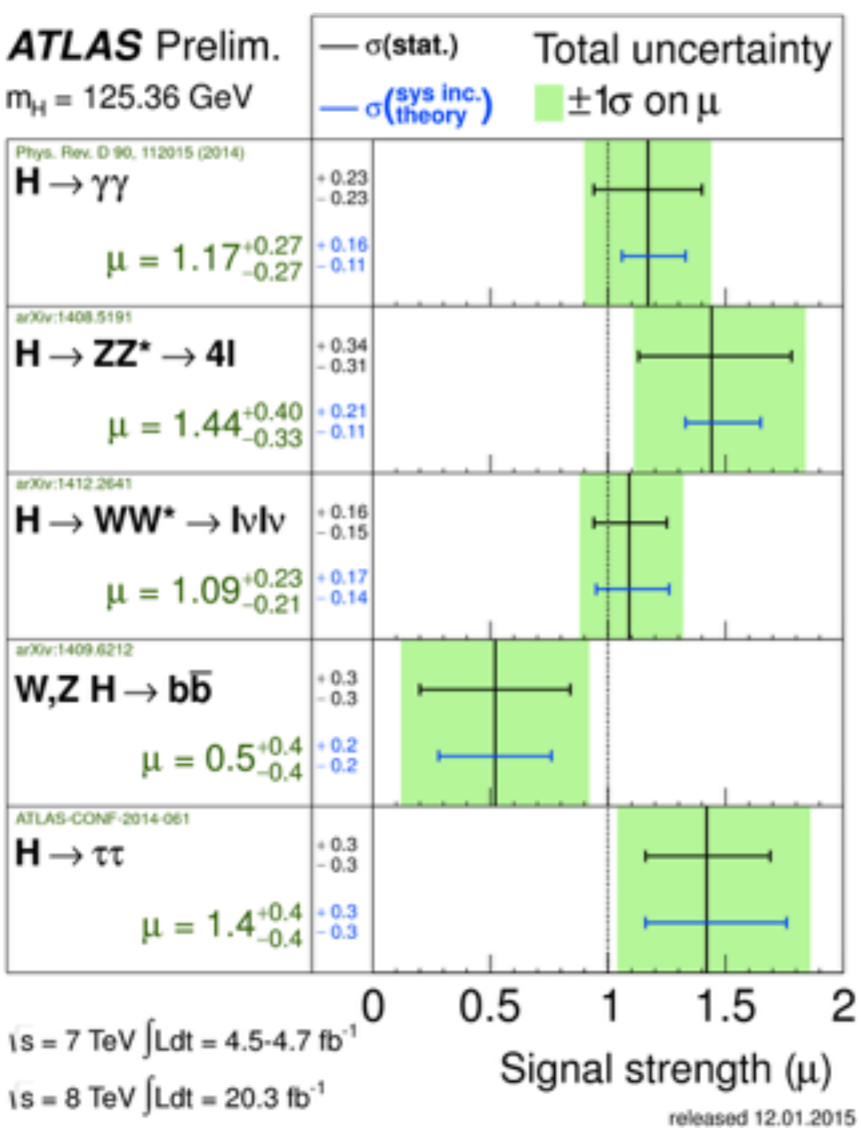
DS, R. Vega-Morales, Phys.Rev.D.86, 117504 (2012) [arXiv:1208.4840].
Yi Chen, DS, R. Vega-Morales, Phys.Rev.D.92, 053003 (2015) [arXiv:1505.01168],
and work in progress.

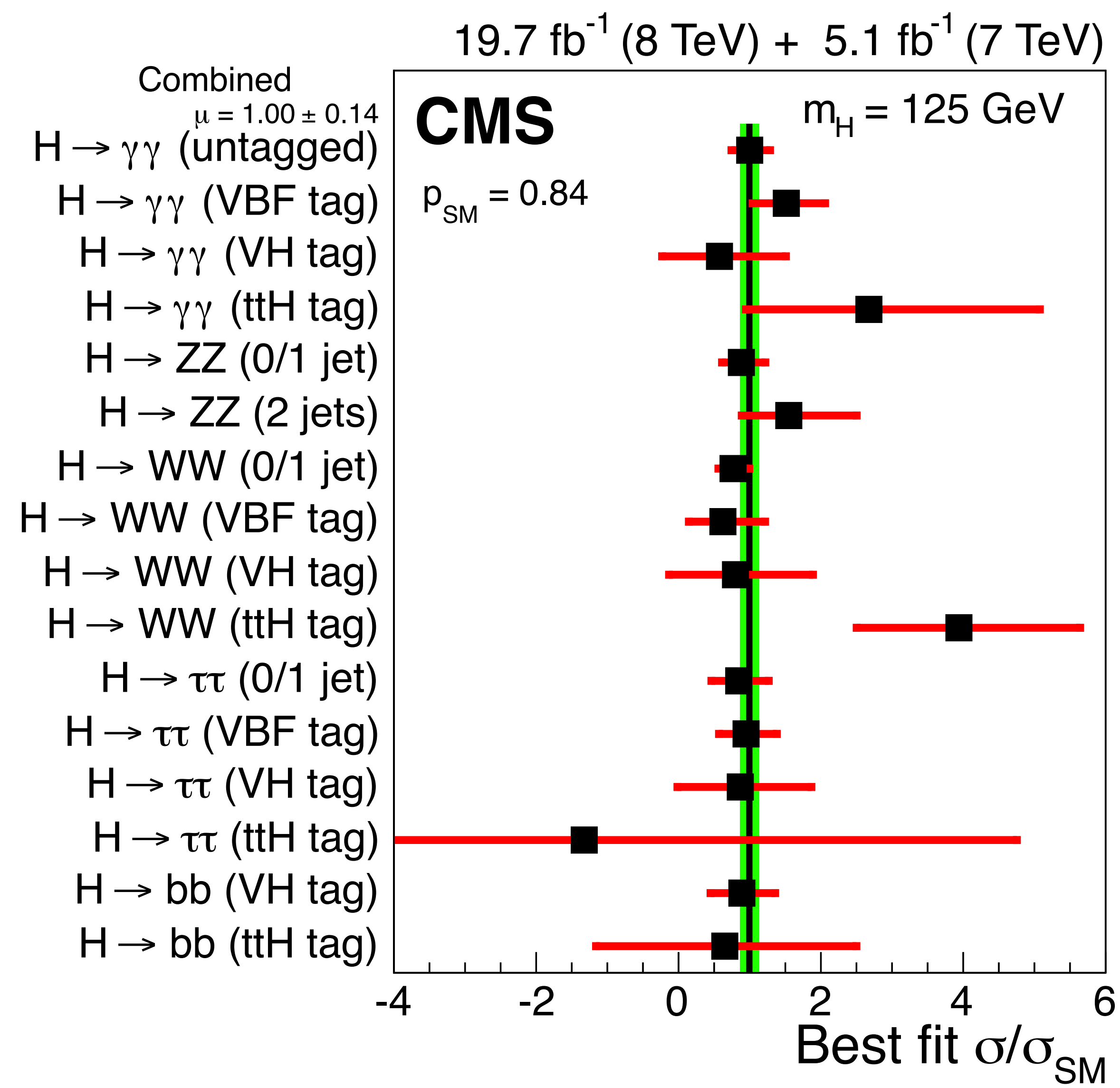
DESY Workshop October 1, 2015

THE HIGGS

Rate measurements current state of the art to characterize the Higgs.

See talk by G. Quast.

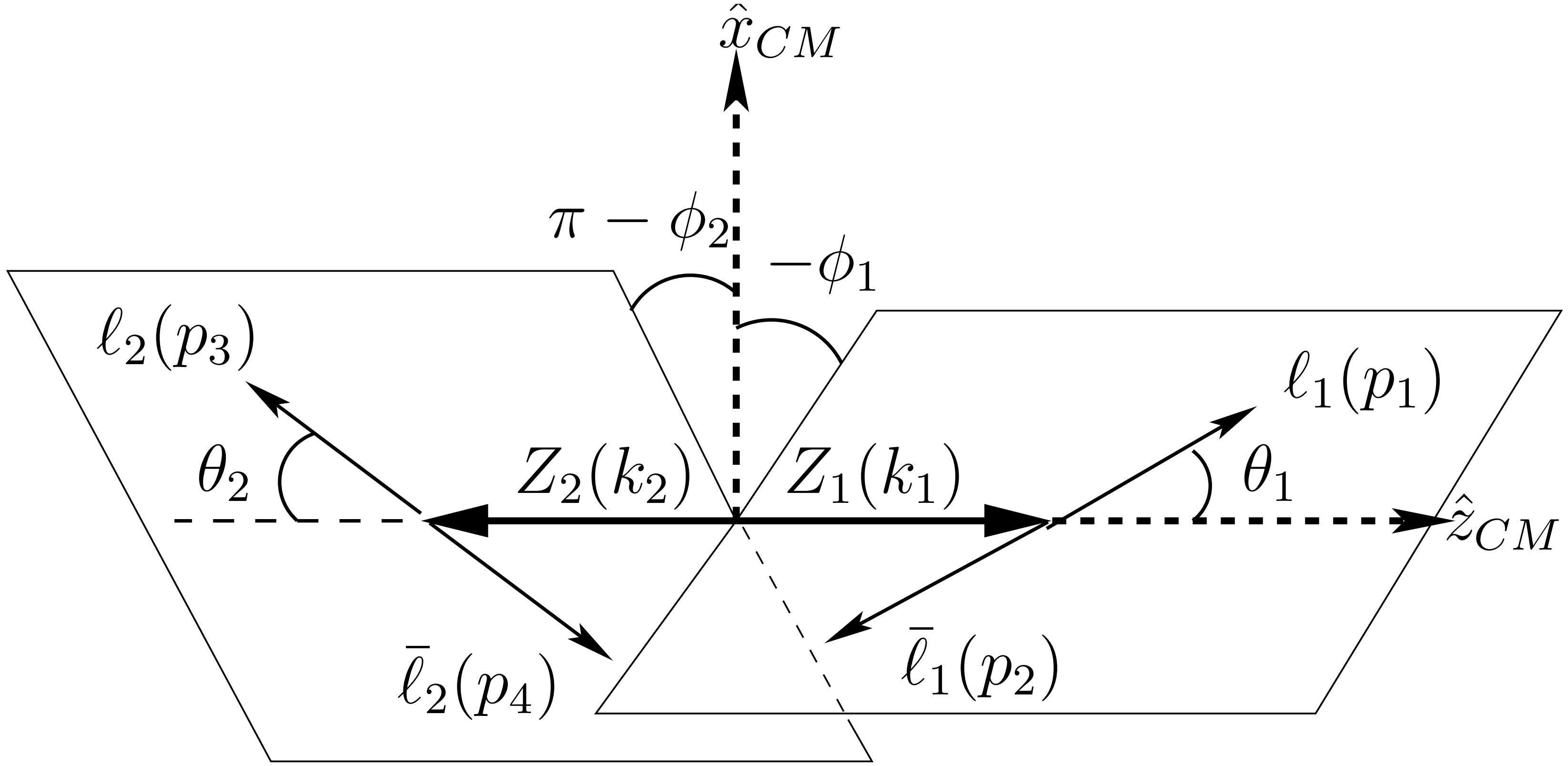




KINEMATIC DISTRIBUTIONS

Study $h \to 4e/4\mu/2e2\mu$:

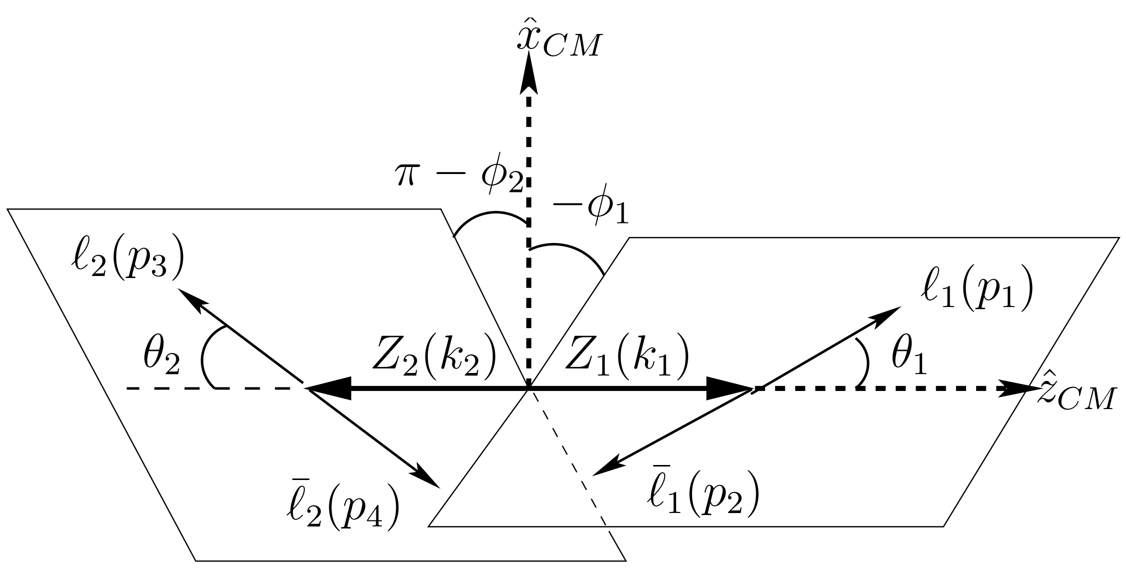
Each event is characterized by five different variables.

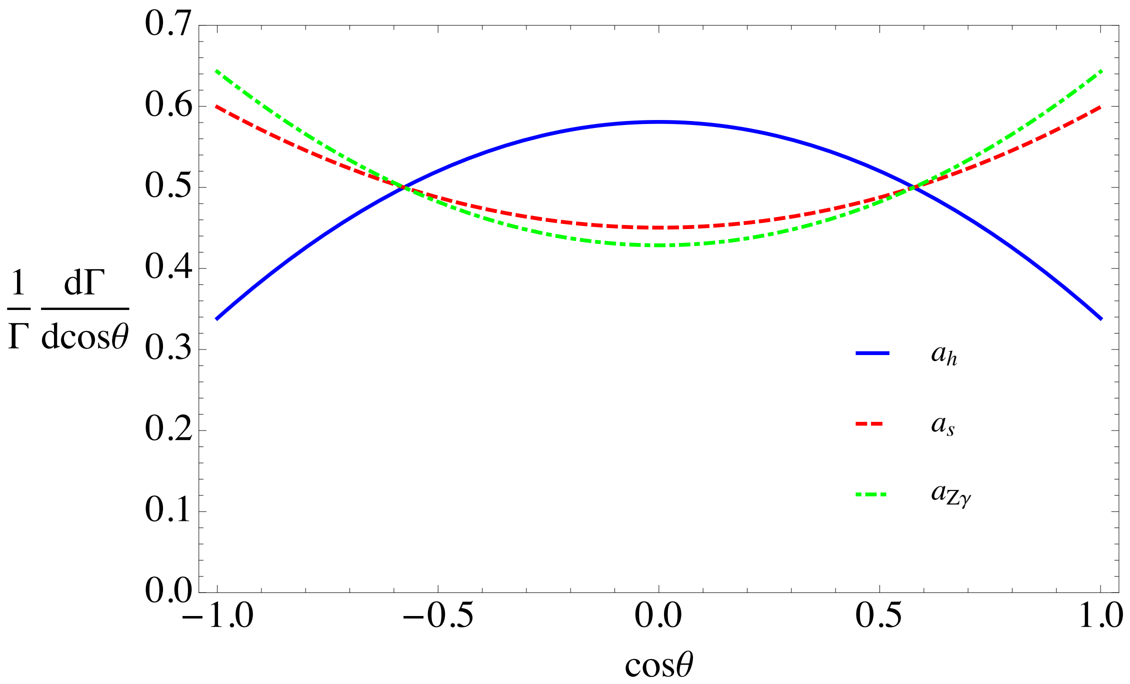


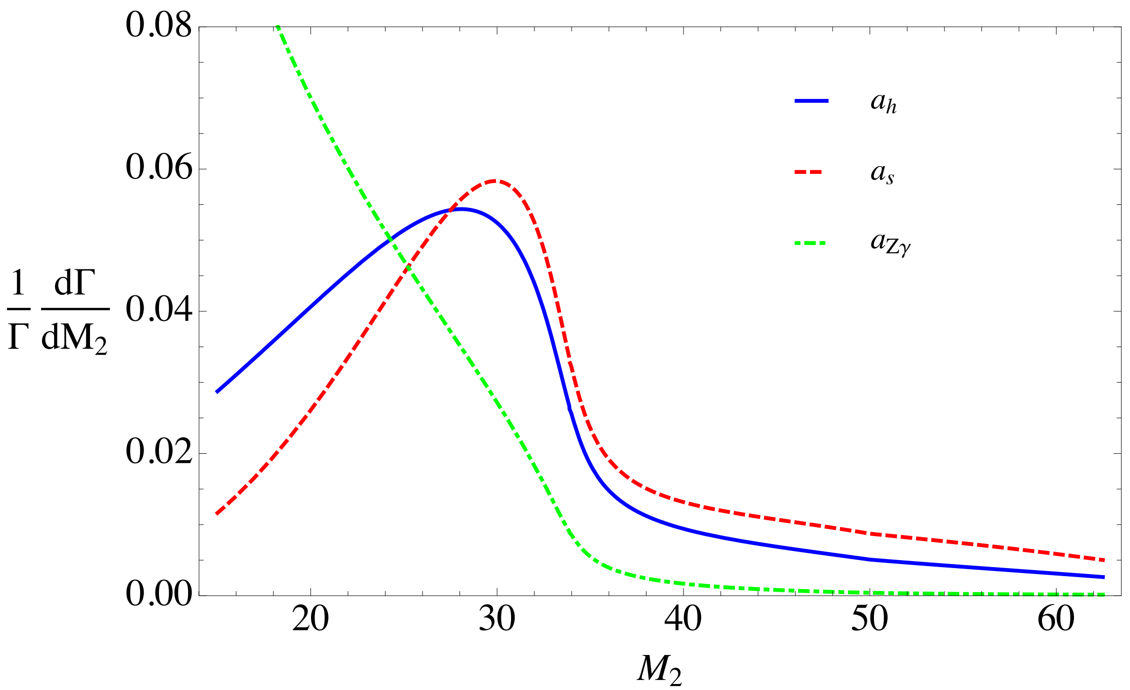
Compare to $h \to \gamma\gamma$.

KINEMATIC DISTRIBUTIONS

Distributions encode information about tensor structure.





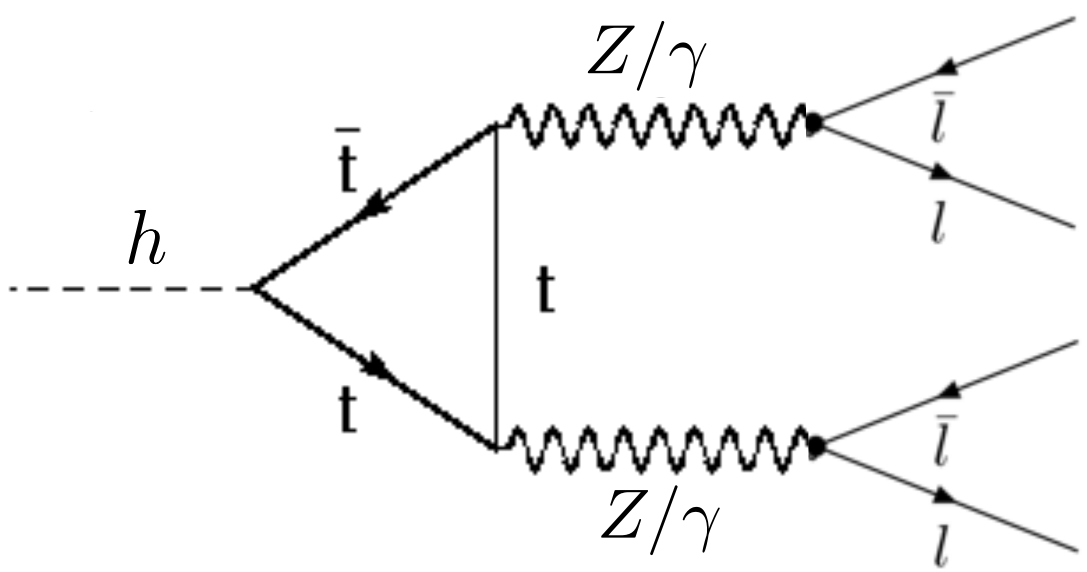


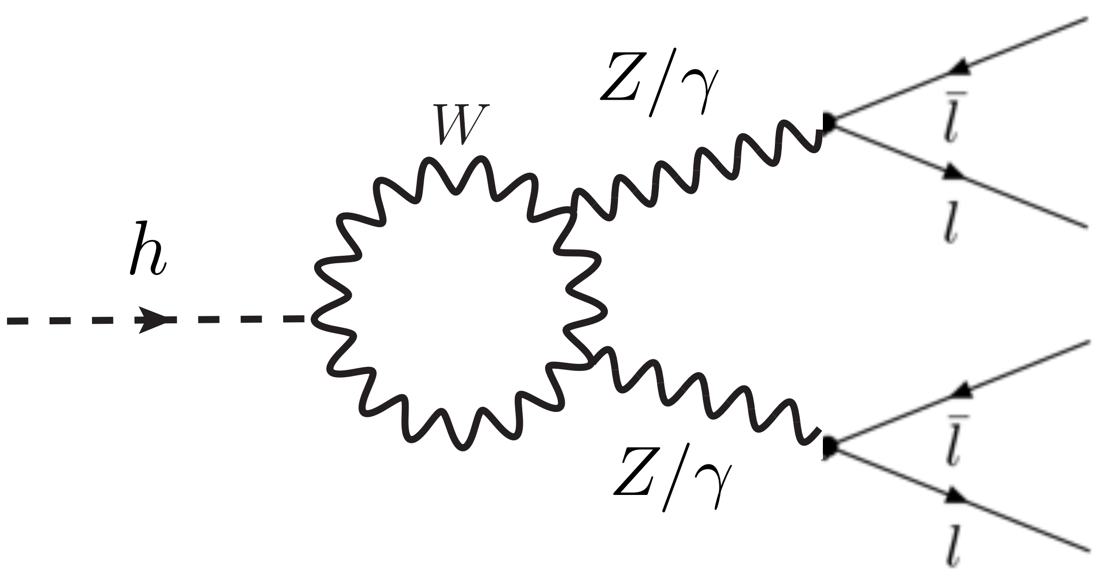
DS, R. Vega-Morales, Phys.Rev.D.86, 117504 (2012) [arXiv:1208.4840].

LOOP PROCESSES

Kinematic distributions can reveal more than just rates measurements can.

Put this to use with loop processes.





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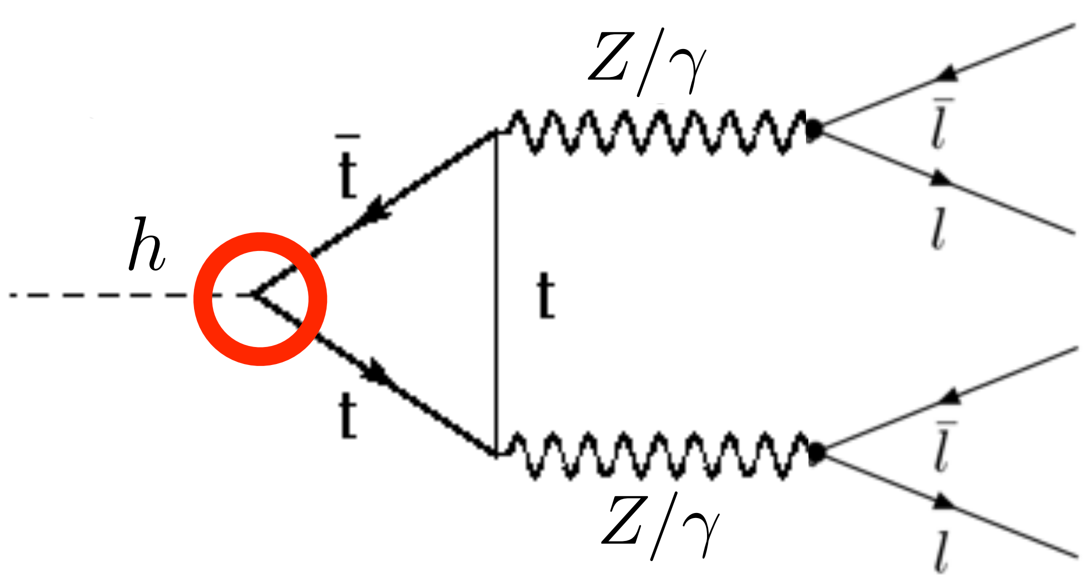
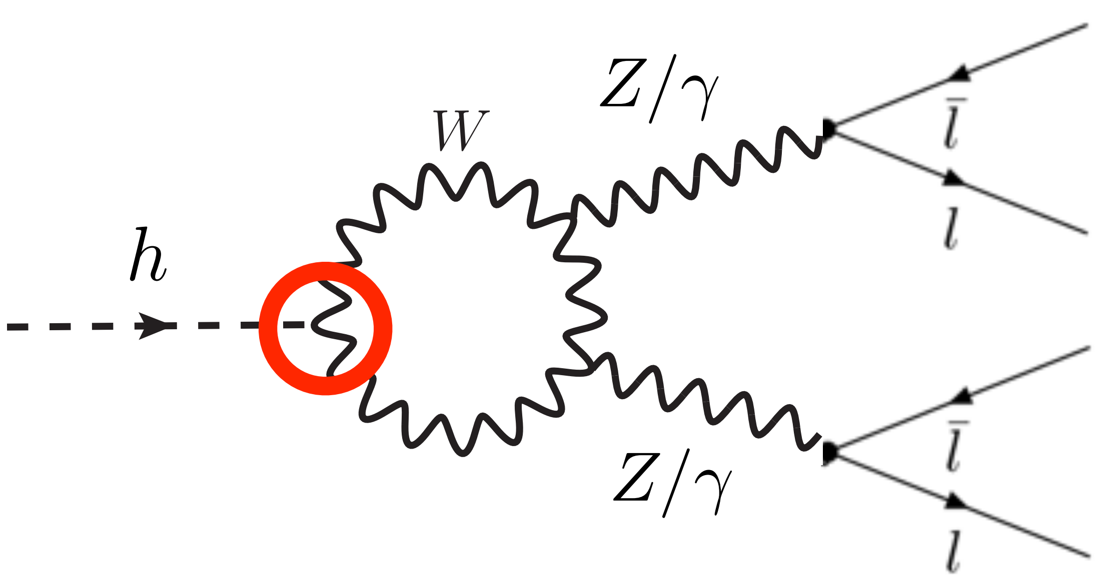
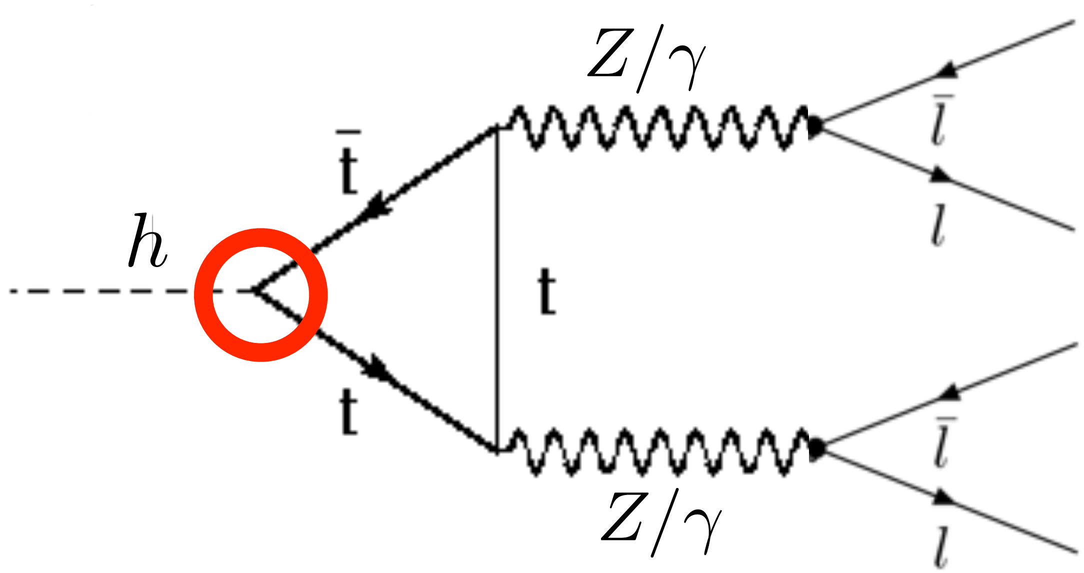




TOP YUKAWA

Start with just top, keep all other couplings fixed.

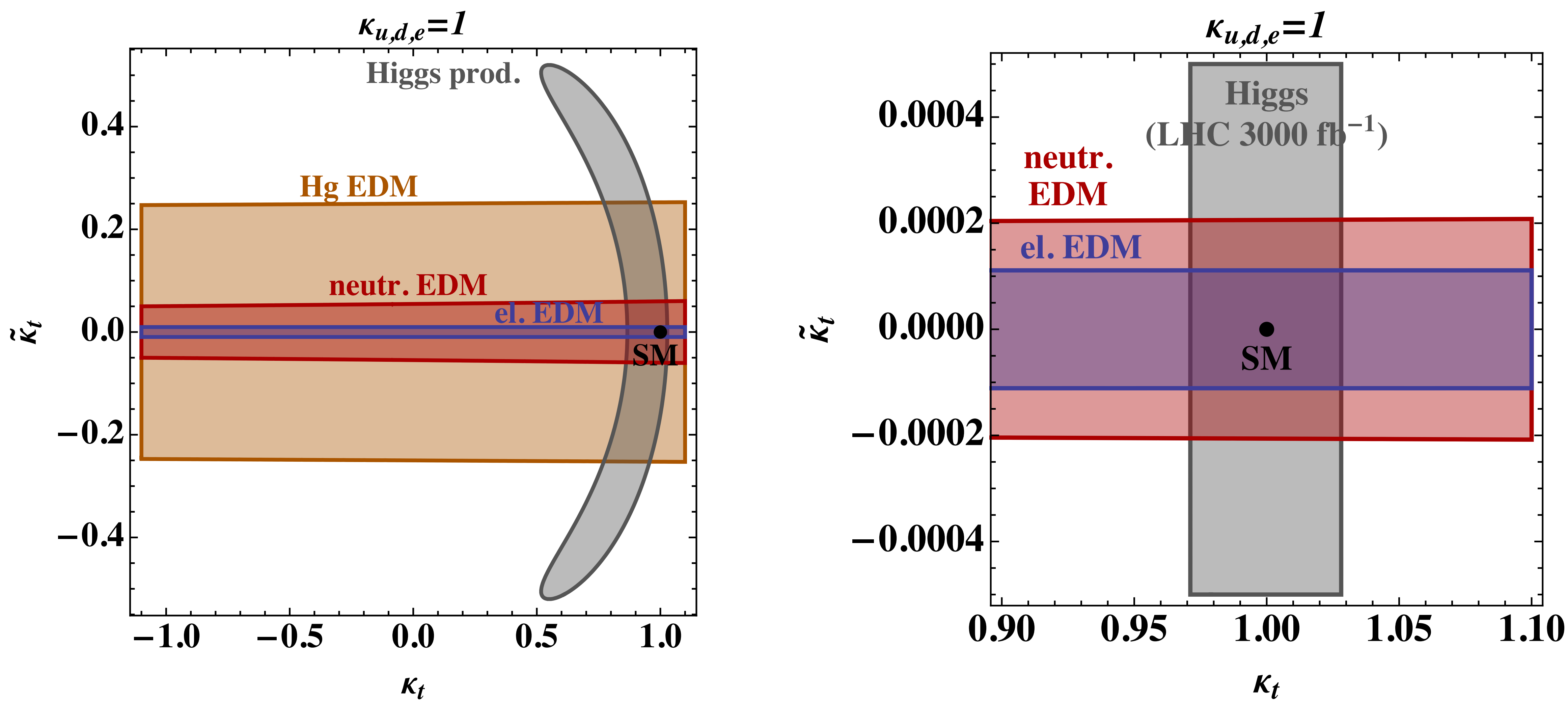
$$h\,\bar{t}\,(y_t + i\,\tilde{y}\,\gamma^5)\,t$$



Can probe CP nature of top Yukawa coupling.

EDM BOUNDS

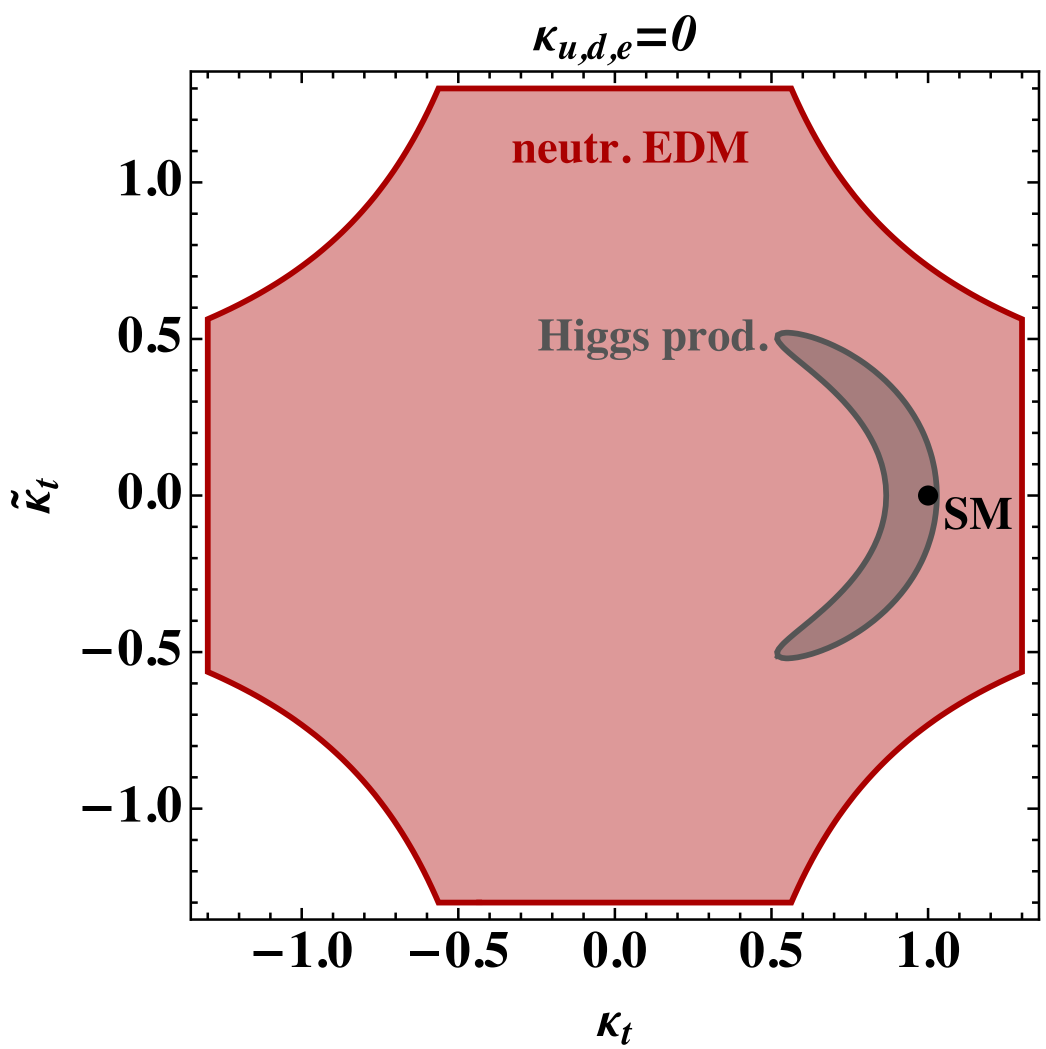
Can place strong bounds on CP violation from EDMs.

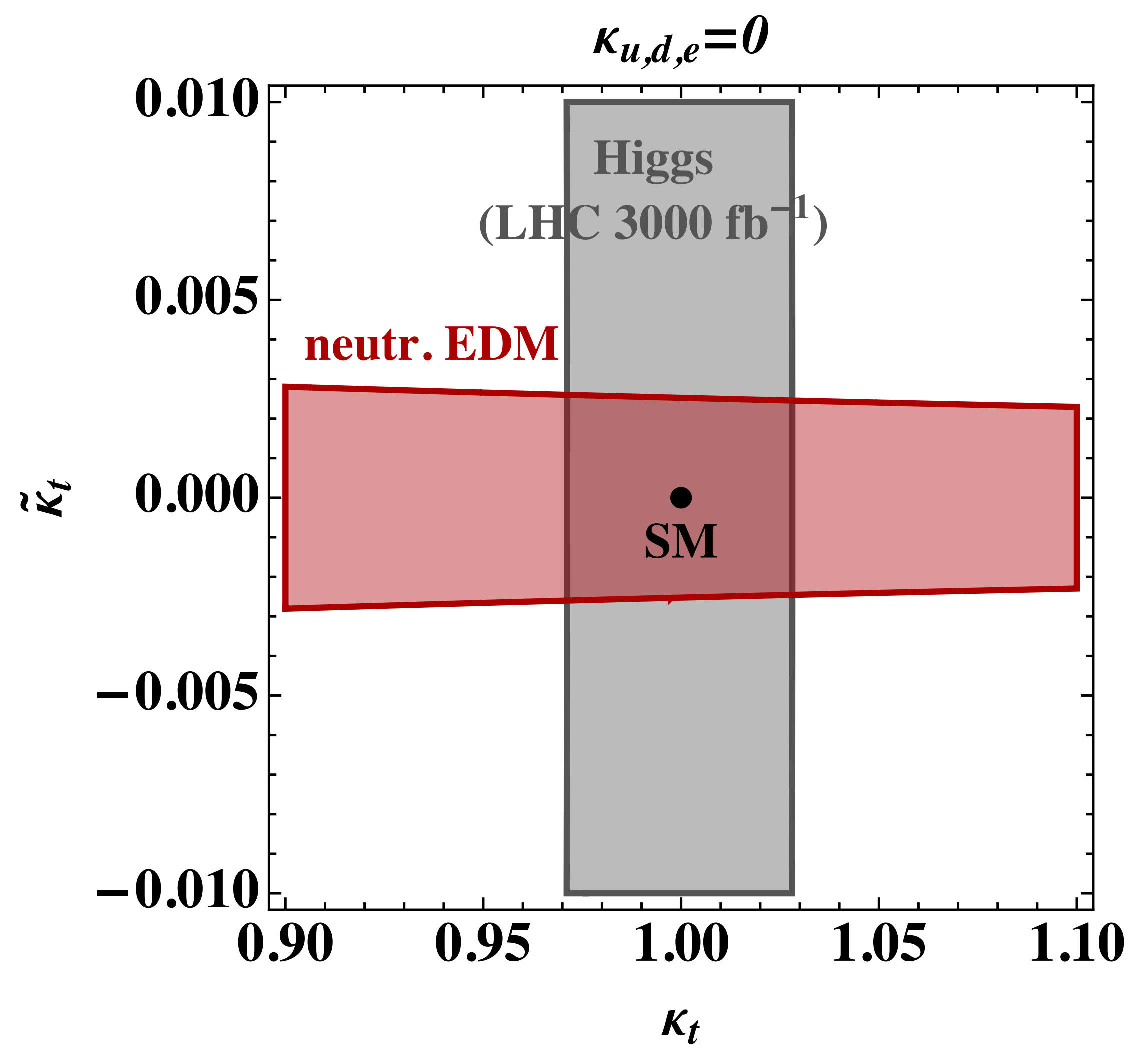


Brod, Haisch, Zupan, [arXiv:1310.1385].

EDM BOUNDS

Depend on knowing Higgs coupling to first generation.





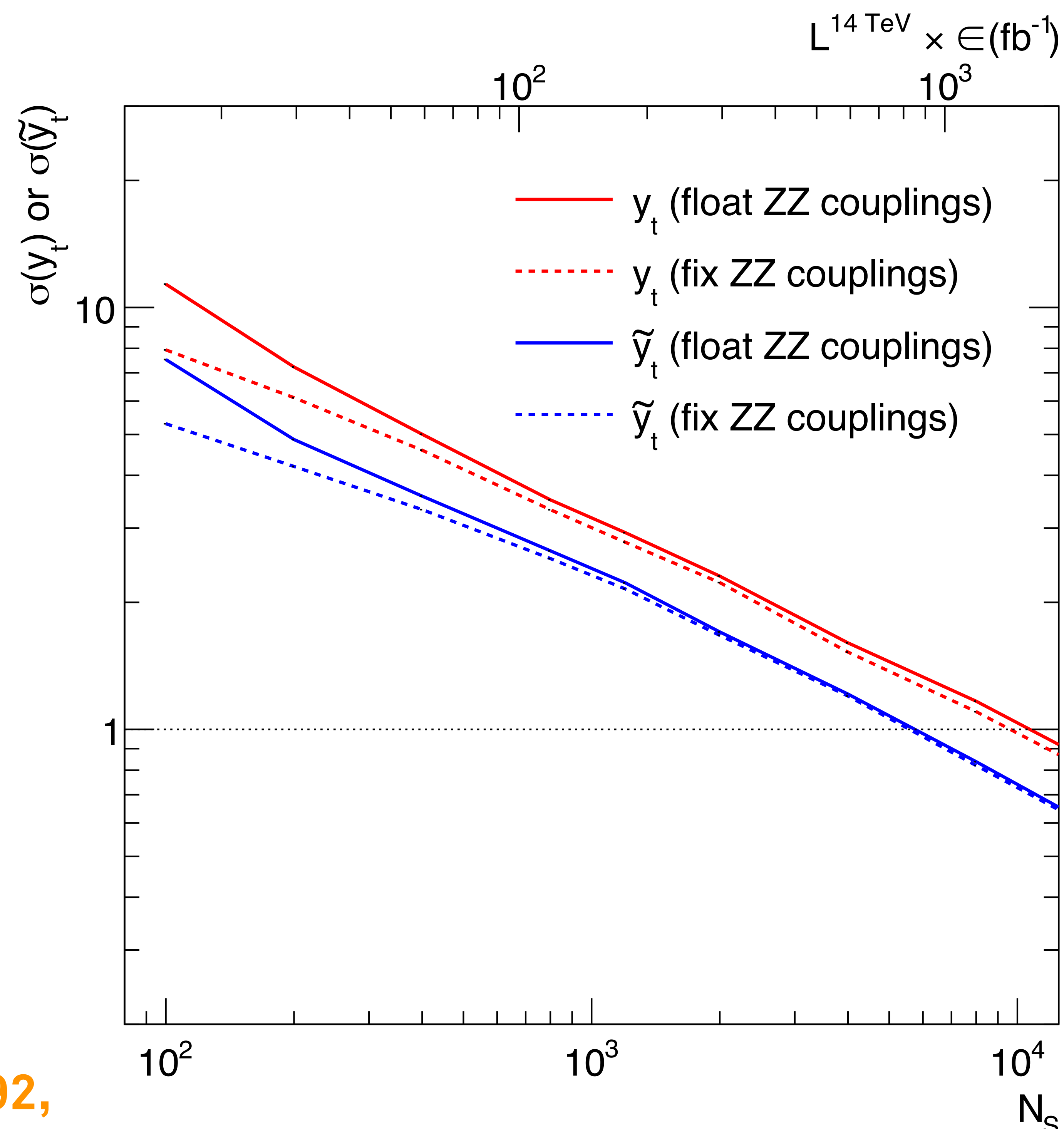
Brod, Haisch, Zupan, [arXiv:1310.1385].

SENSITIVITY

Measurement gets better with more events.

Better sensitivity to pseudo-scalar coupling.

Need large number of events.



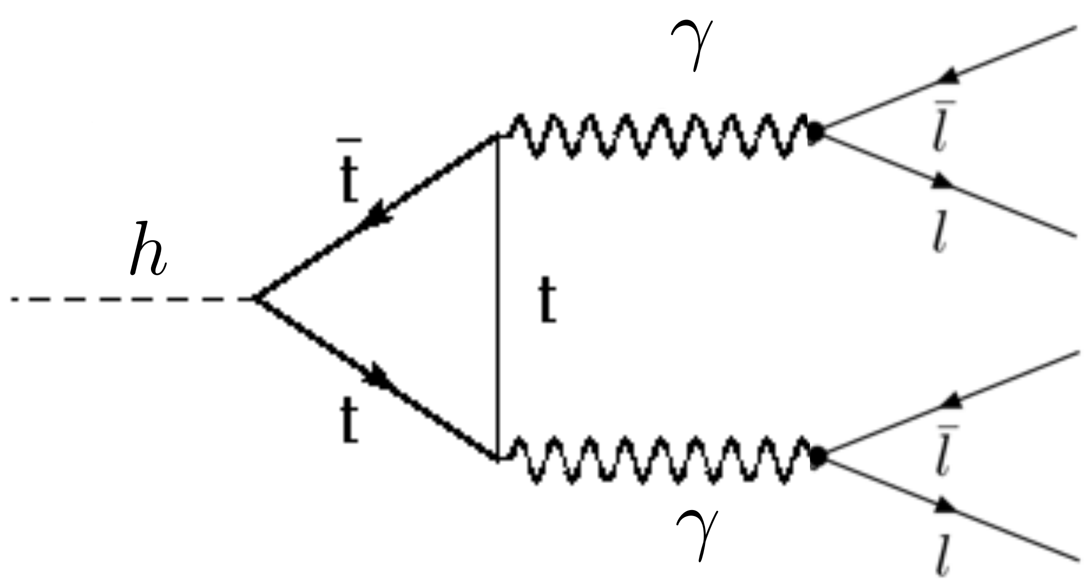
Chen, DS, Vega-Morales, Phys.Rev.D.92, 053003 (2015) [arXiv:1505.01168].

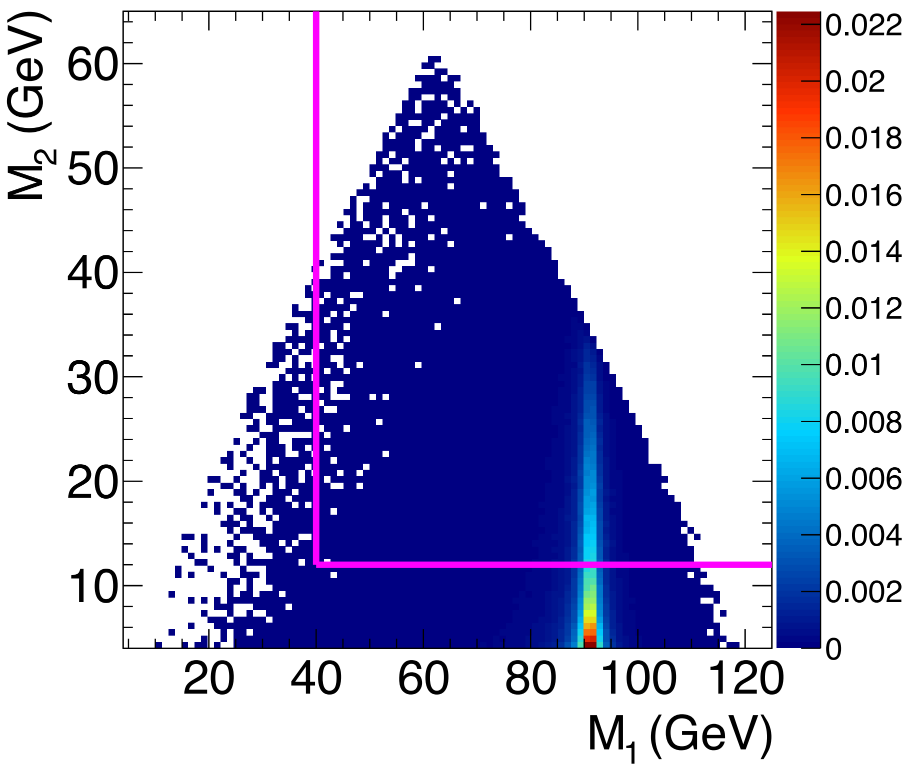
EXPERIMENTAL CUTS

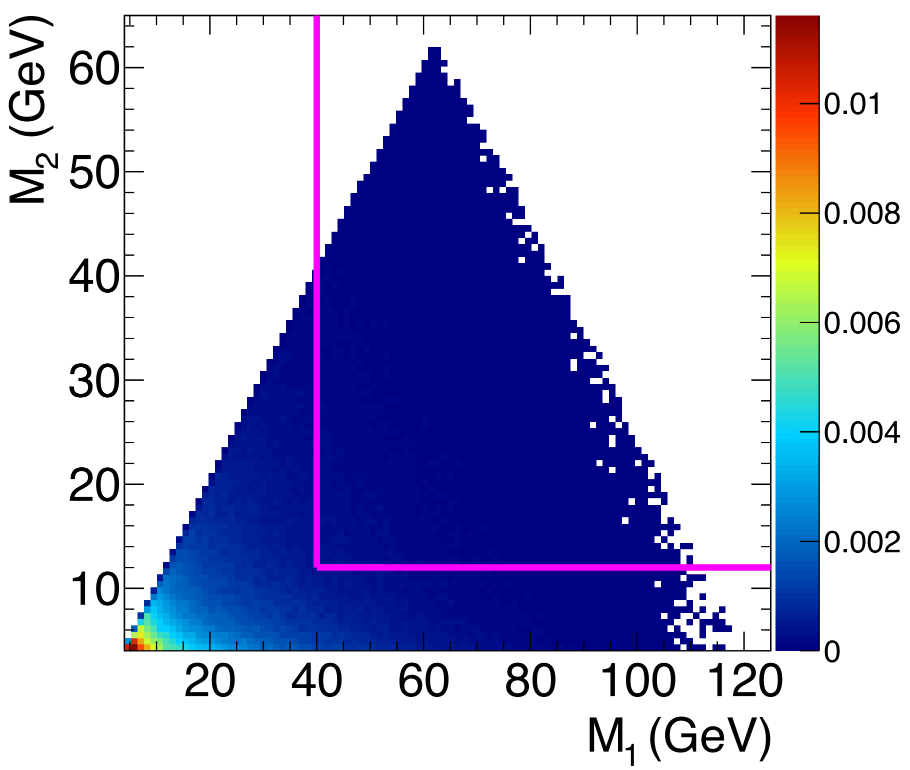
CMS cuts optimized for discovery:

$$M_1 > 40,\ M_2 > 12,\ M_{\ell\ell} > 4$$

Want to gain sensitivity to NLO effects.







EXPERIMENTAL CUTS

CMS cuts optimized for discovery:

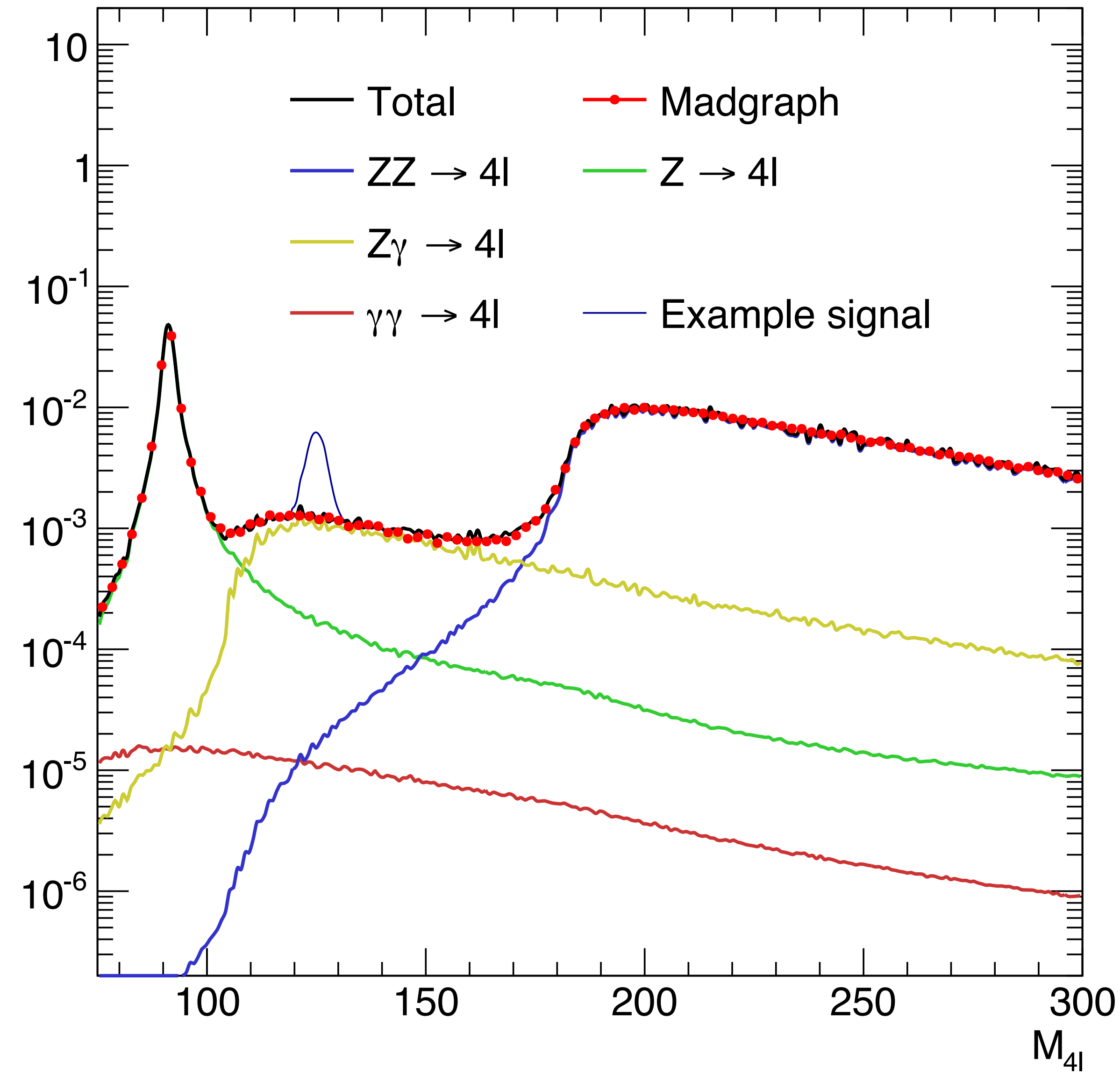
$$M_1 > 40, \;\; M_2 > 12, \;\; M_{\ell\ell} > 4$$

Modified "Relaxed - Υ"

$$M_{\ell\ell} > 4,$$

$$M_{\ell\ell}(\mathrm{OSSF}) \notin (8.8, 10.8)$$

S/B gets worse, but sensitivity improves.

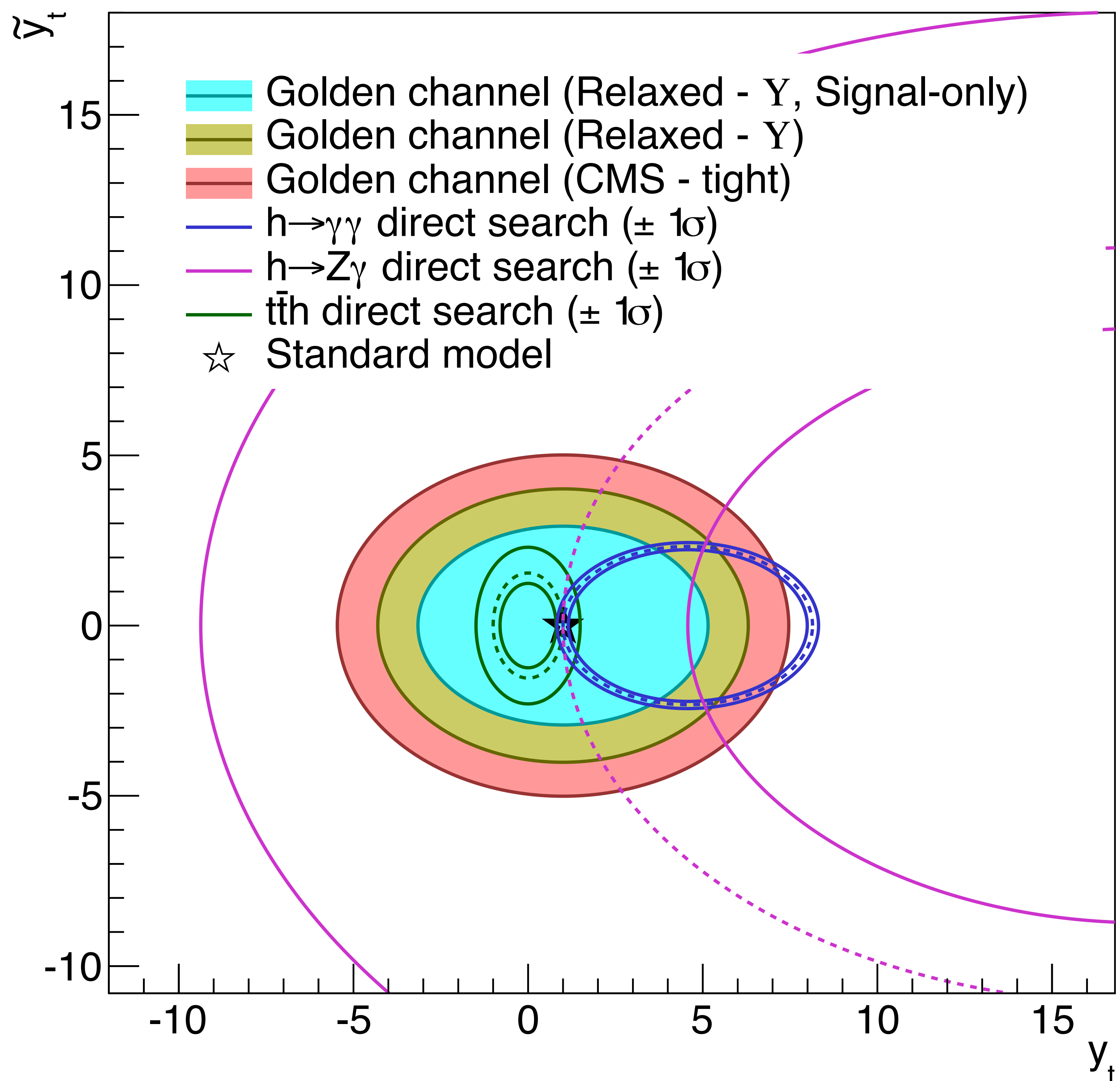


Chen, Harnik, Vega-Morales, [arXiv:1503.05855].

SENSITIVITY

800 events ~ 300 fb^{-1}

Non-trivial constraint.

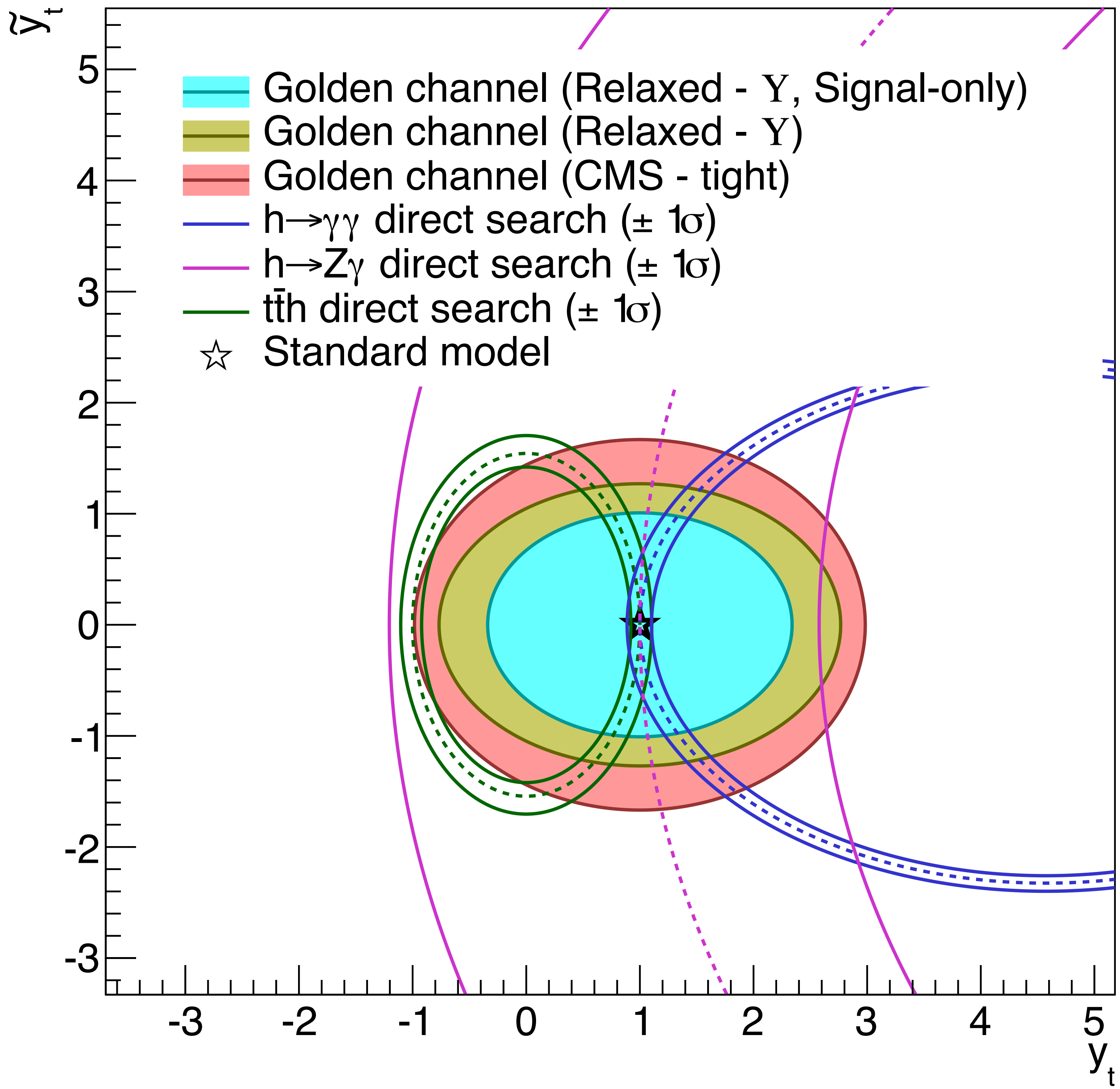


HIGH LUMINOSITY

8,000 events ~ 3,000 fb^{-1}

Better constraint.

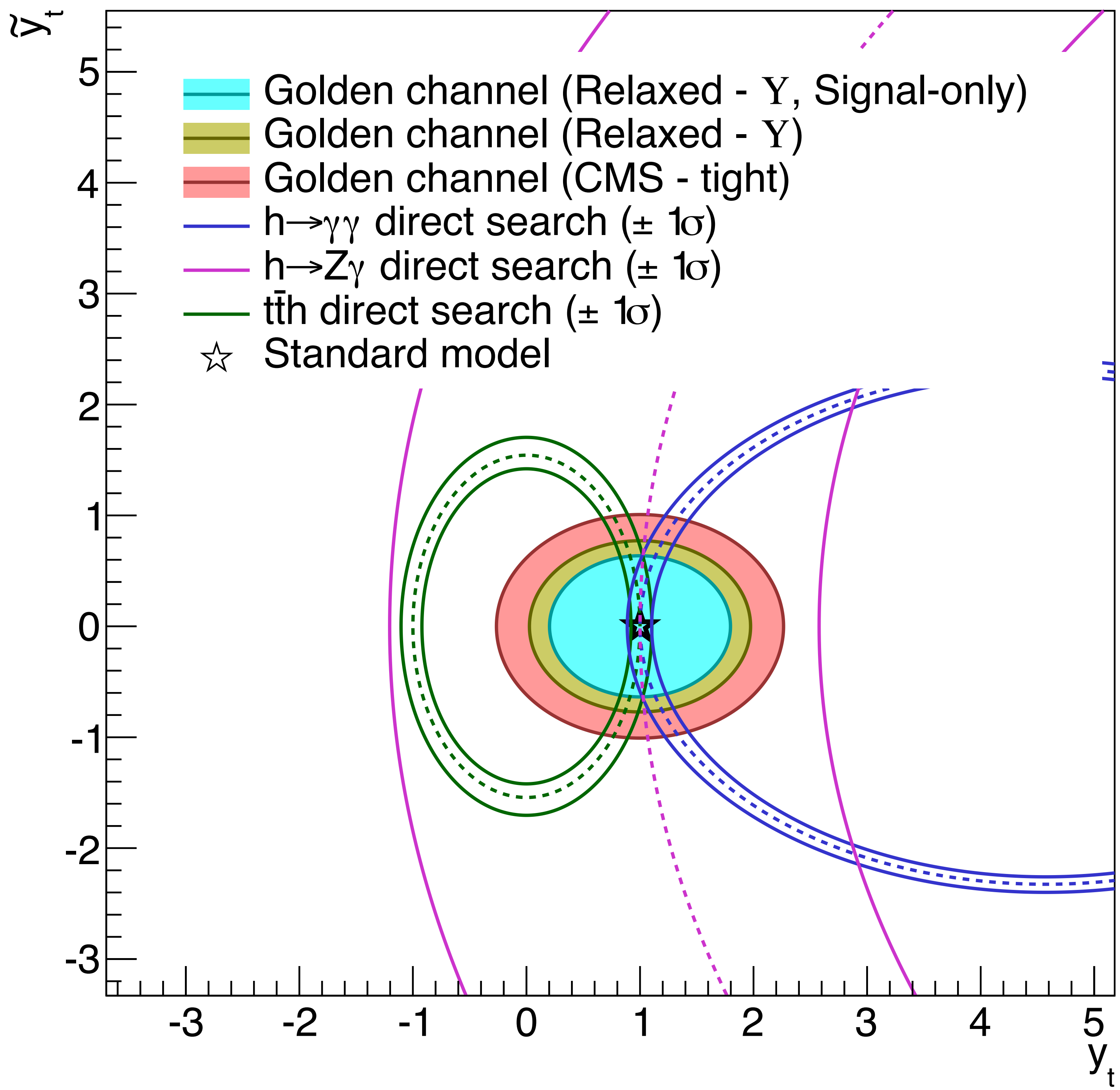
If there is anomaly, will help characterize.



100 TEV?

20,000 events ~
3,000 fb^{-1} @ 100 TeV

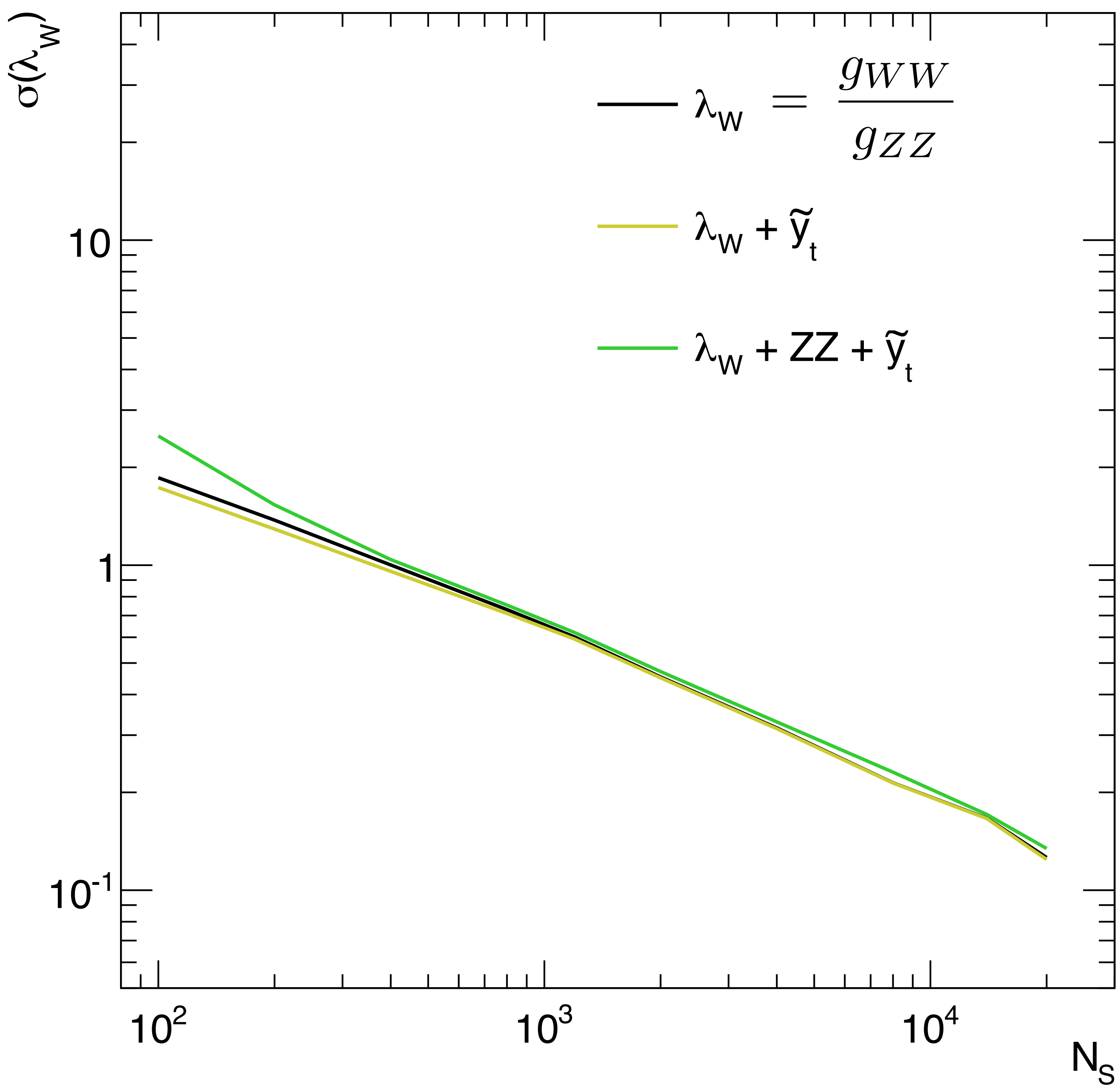
Further improved.



CUSTODIAL SYMMETRY

Can measure deviations from custodial symmetry.

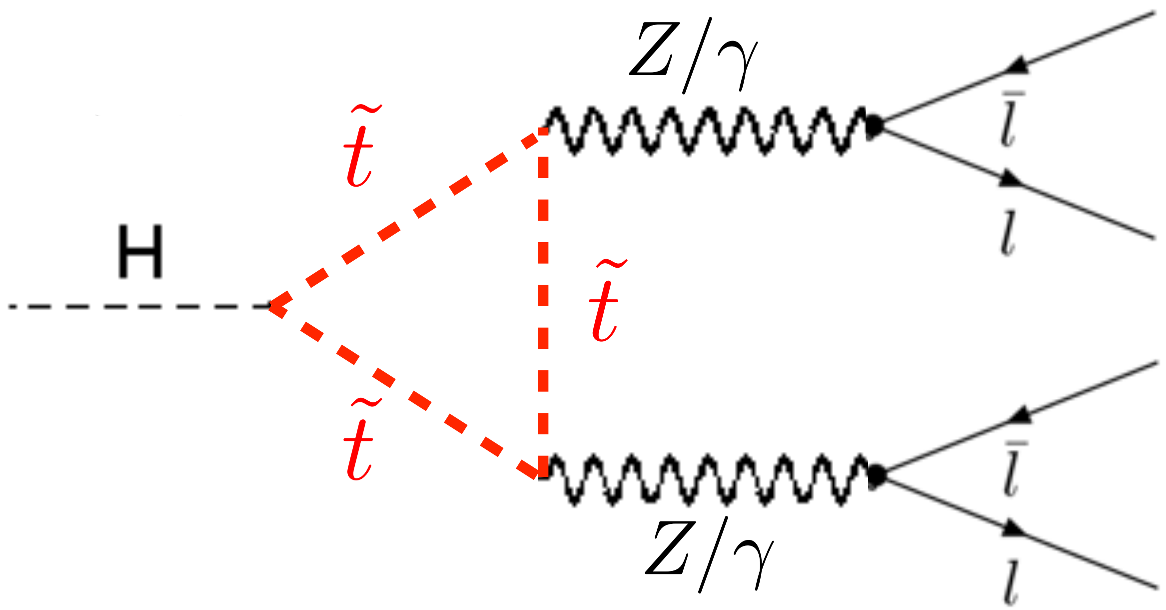
Can rule out $\lambda_W = -1$ at LHC.



Work in progress with
R. Vega-Morales and Y. Chen.

STOP LOOPS

Searching for loop effects much more model independent.



Independent of decay, do not have to carry color.

Work in progress with R. Vega-Morales and Y. Chen.

CONCLUSIONS

- Kinematic distributions in $h \to 4\ell$ can provide information that is independent from and complimentary to rate measurements.

- NLO contributions make this channel sensitive to large Higgs couplings.

- Can measure CP violation or modified values in top Yukawa coupling.

- Use to place model-independent bounds (or discover) deviations from SM prediction.

THANK YOU

DETAILS

- $115 \text{ GeV} < M_{4\ell} < 135 \text{ GeV}$
- $p_T > (20, 10, 5, 5)$ GeV for lepton p_T ordering,
- $|\eta_\ell| < 2.4$ for the lepton rapidity,
- $M_{\ell\ell} > 4$ GeV, $M_{\ell\ell}(\text{OSSF}) \notin (8.8, 10.8)$ GeV,

$\mathcal{L}$	$\mu(tth)$	$\mu(h \to \gamma\gamma)$	$\mu(h \to Z\gamma)$
Current	2.8 ± 1.0 [5]	1.14 ± 0.25 [103]	NA
300 fb^{-1}	1.0 ± 0.55 [105]	1.0 ± 0.1 [104]	1.0 ± 0.6 [106]
3000 fb^{-1}	1.0 ± 0.18 [105]	1.0 ± 0.05 [104]	1.0 ± 0.2 [106]

$$\begin{aligned}
\mu(tth) &\simeq y_t^2 + 0.42\,\tilde{y}_t^2 \\
\mu(h \to \gamma\gamma) &\simeq (1.28 - 0.28\,y_t)^2 + (0.43\,\tilde{y}_t)^2 \\
\mu(h \to Z\gamma) &\simeq (1.06 - 0.06\,y_t)^2 + (0.09\,\tilde{y}_t)^2,
\end{aligned}$$

MATRIX ELEMENT METHOD

For a given $h \to 4\ell$ event, can compute probability of that even given underlying theory.

$$P(\vec{\phi}\,|a_i) = \frac{|\mathcal{M}(\vec{\phi})|^2}{\int d\vec{\phi}\,|\mathcal{M}(\vec{\phi})|^2}$$

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Phase space point

Underlying model

MATRIX ELEMENT METHOD

For a given $h \to 4\ell$ event, can compute probability of that even given underlying theory.

$$P(\vec{\phi}\,|a_i) = \frac{|\mathcal{M}(\vec{\phi})|^2}{\int d\vec{\phi}\,|\mathcal{M}(\vec{\phi})|^2}$$

For *N* events, can compute likelihood for different underlying theories.

$$\mathcal{L}(a_i) = \prod_{j=1}^{N} P(\vec{\phi}_j\,|a_i)$$