PHYSICS OPPORTUNITIES AT THE FCC

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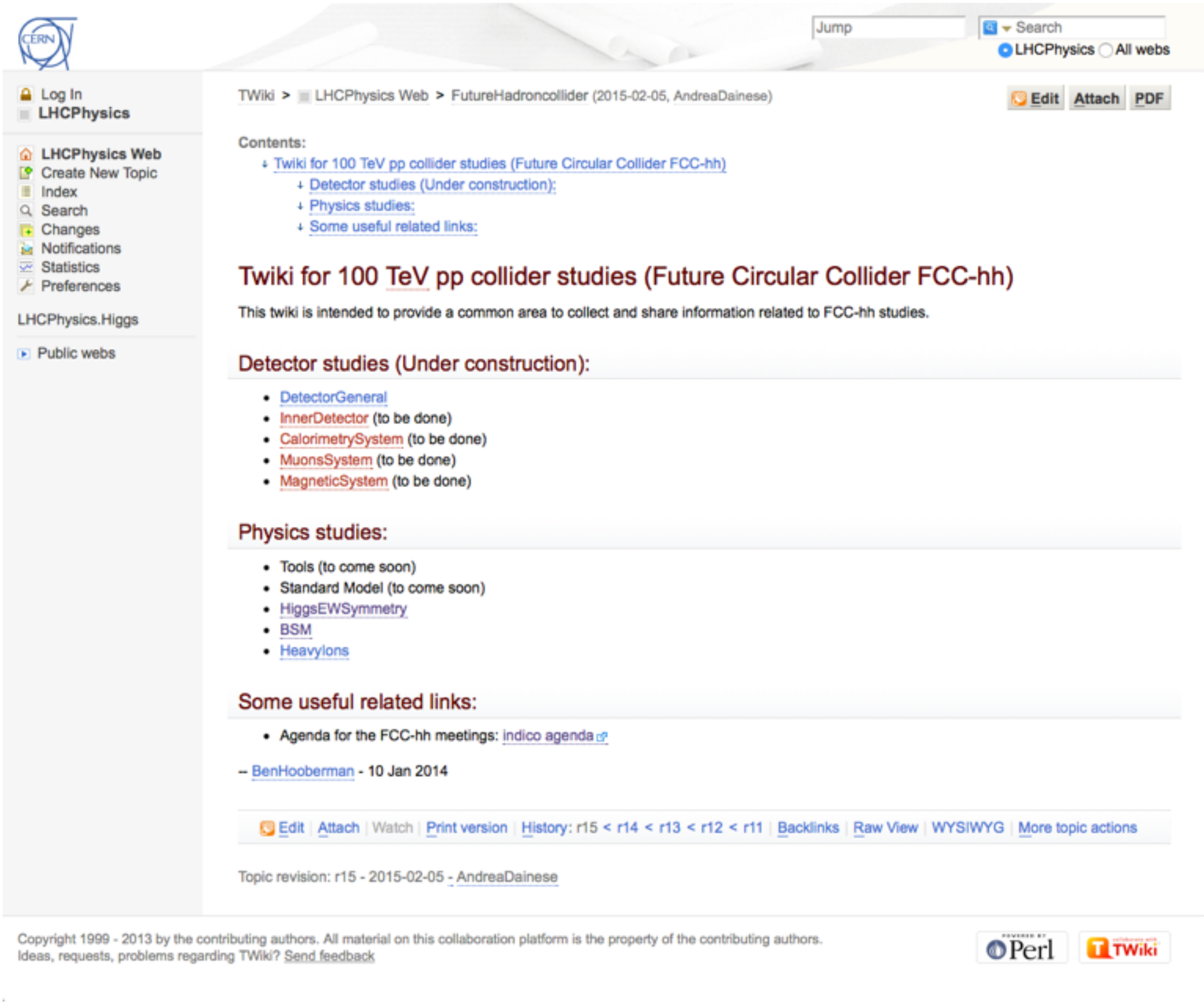
Padova - 27 Feb 2015

Theory overview

(mostly FCC-hh but not only)

Riccardo Torre

FCC-HH TWIKI



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TWiki > LHCPhysics Web > FutureHadroncollider (2015-02-05, AndreaDainese)

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Contents:

- Twiki for 100 TeV pp collider studies (Future Circular Collider FCC-hh)
  - Detector studies (Under construction):
  - Physics studies:
  - Some useful related links:

Twiki for 100 TeV pp collider studies (Future Circular Collider FCC-hh)

This twiki is intended to provide a common area to collect and share information related to FCC-hh studies.

Detector studies (Under construction):

- DetectorGeneral
- InnerDetector (to be done)
- CalorimetrySystem (to be done)
- MuonsSystem (to be done)
- MagneticSystem (to be done)

Physics studies:

- Tools (to come soon)
- Standard Model (to come soon)
- HiggsEWSymmetry
- BSM
- HeavyIons

Some useful related links:

- Agenda for the FCC-hh meetings: indico agenda

-- BenHooberman - 10 Jan 2014

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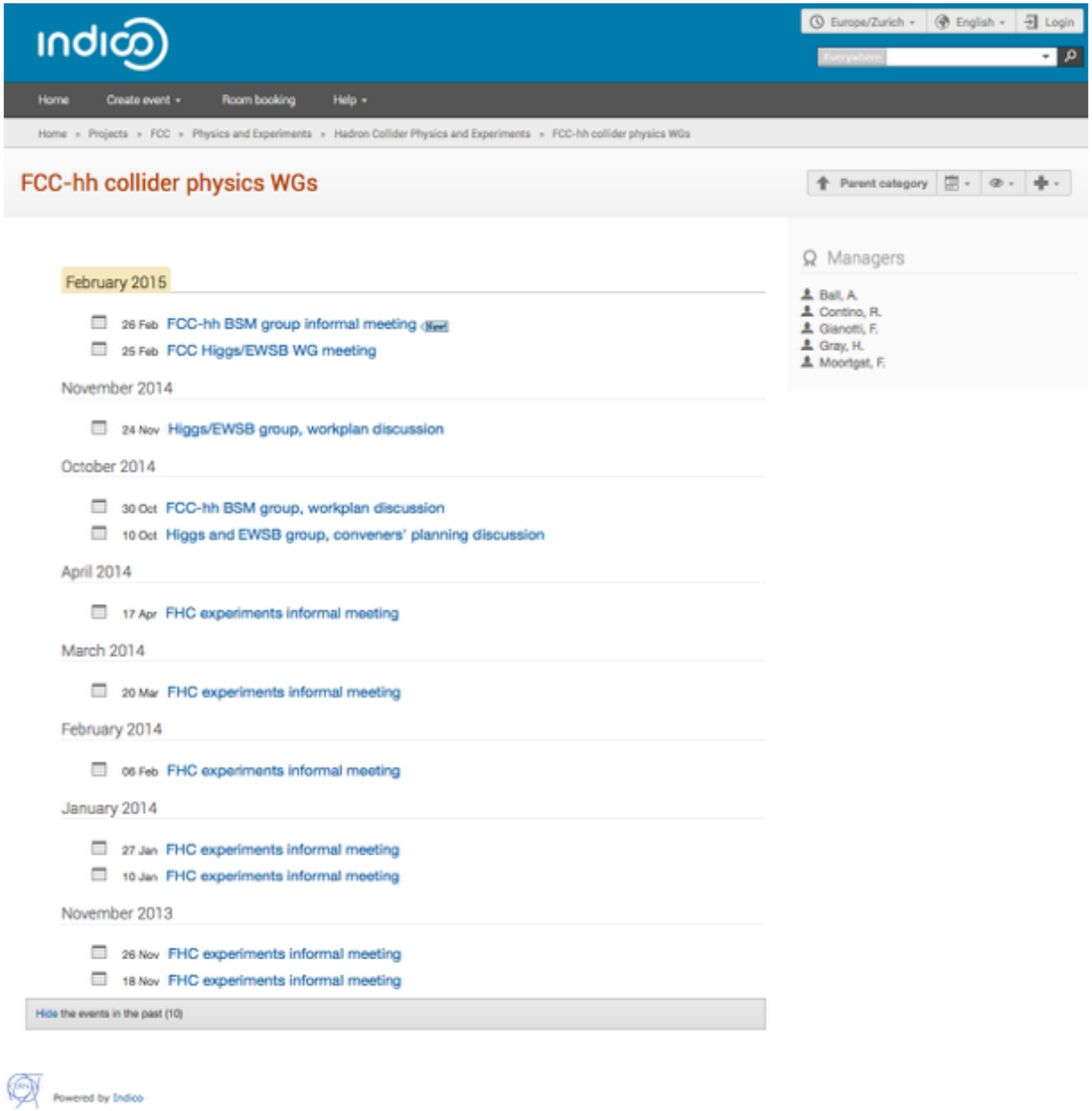
Topic revision: r15 - 2015-02-05 - AndreaDainese

FCC-HH PHYSICS INDICO



SM, HIGGS AND EWSB

- Precision Studies of the SM (FCC-ee)
- Precision Studies of Higgs Properties (e.g.)
  - ✳ Higgs CS at 100 TeV
  - ✳ Extrapolation of single Higgs analyses to 100 TeV
  - ✳ Higgs studies with extreme kinematical configurations
  - ✳ Off-shell Higgs measurements
- Exotic/Rare Higgs decays
- Double Higgs Production
- WW scattering at high energy
- Additional BSM Higgs bosons: discovery reach and precision physics program
- New handles on the study of the EWSB dynamics

BSM

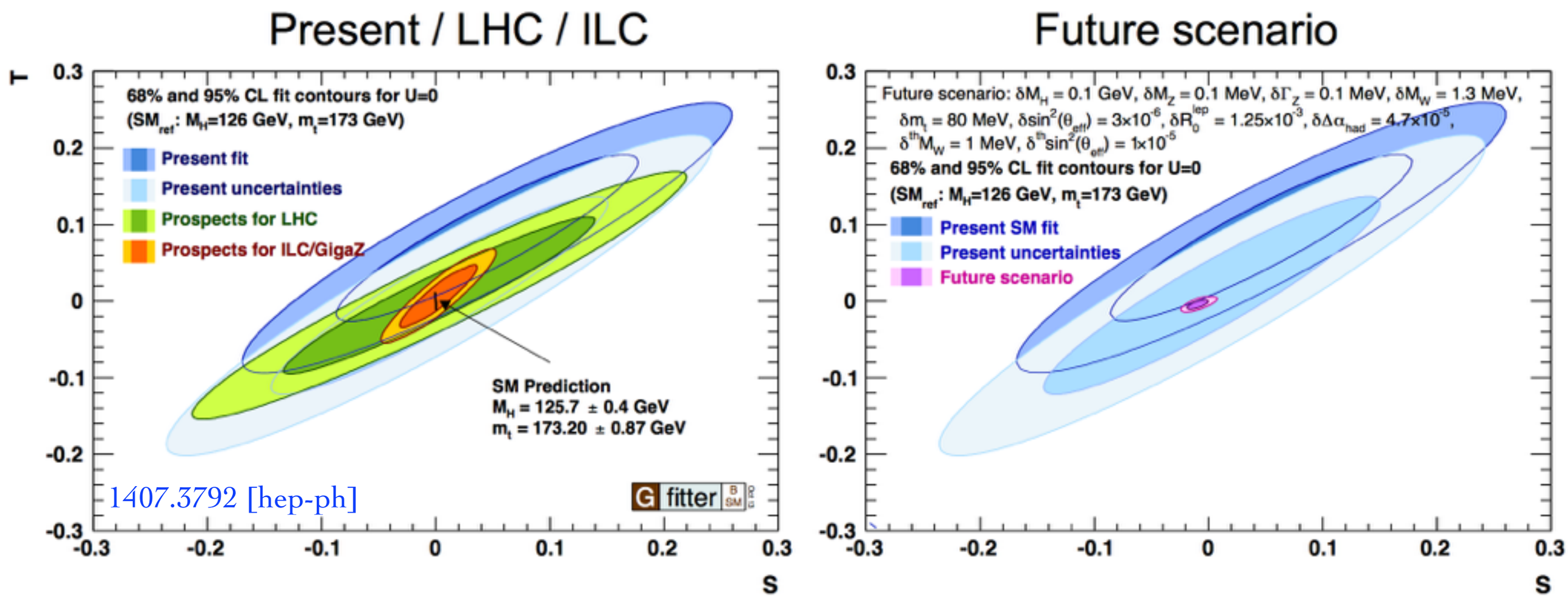
- Dark Matter (e.g.)
  - ✳ Mono-SM like searches for DM (SUSY, non SUSY)
  - ✳ Minimal Dark Matter (directly and indirectly)
- SUSY (e.g.)
  - ✳ Rare susy processes
  - ✳ Test of very compressed spectra
  - ✳ Split SUSY
- Non-SUSY (e.g.)
  - ✳ Resonances (jets vs leptons)
  - ✳ New physics in VBF
  - ✳ Running EW couplings
  - ✳ Top dipole moments
  - ✳ Composite Higgs resonances (vectors, top partners)
  - ✳ Twin Higgs (twin partners, heavy vectors etc.)

Some examples

(from performed or ongoing studies)

OBLIQUE OBSERVABLES AT TLEP

For the oblique precision observables S and T (and possibly U) a factor of 10 improvements at TLEP



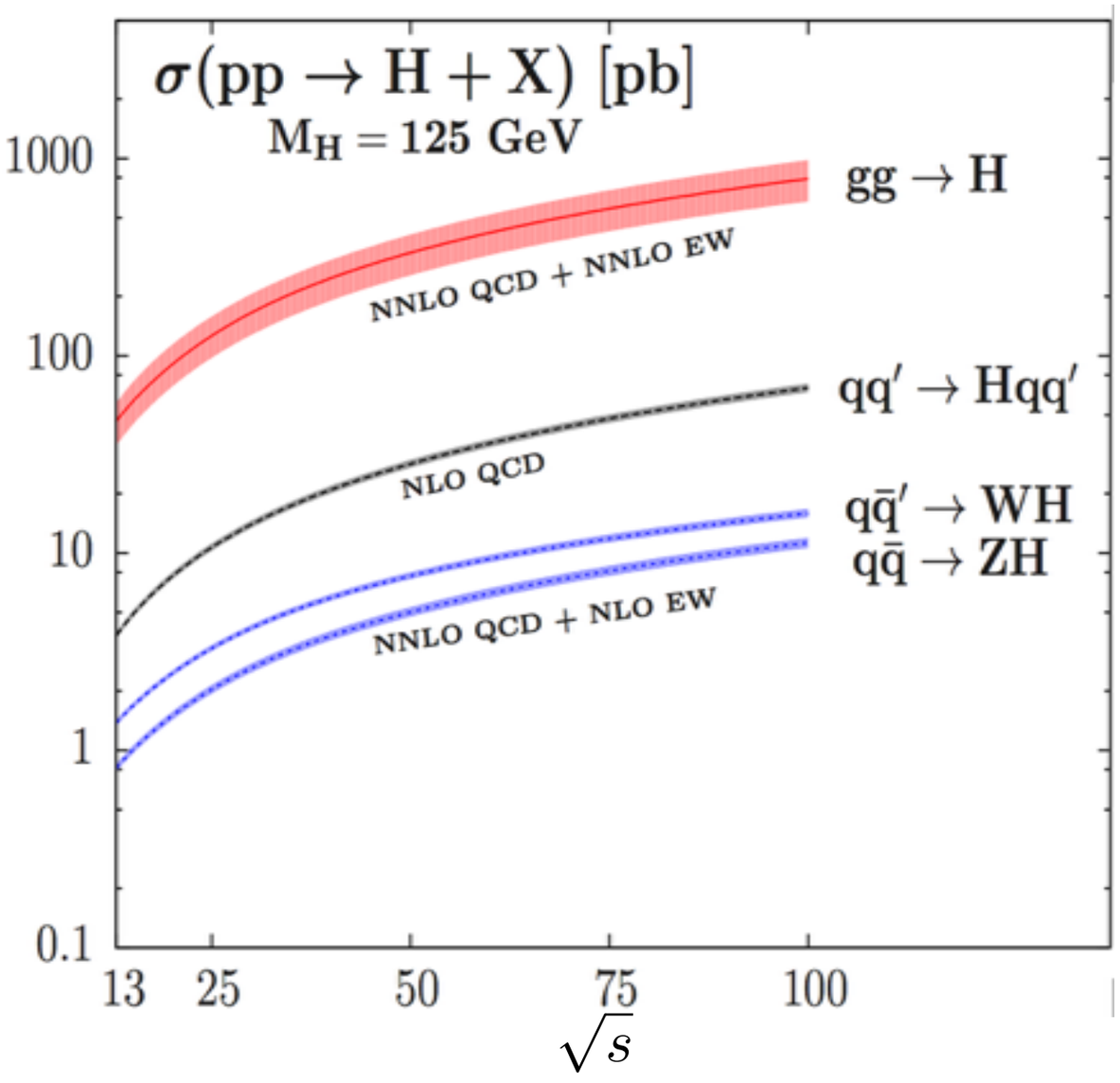
Baak, Cuth

Important to assess the precision possibilities of the FCC-hh

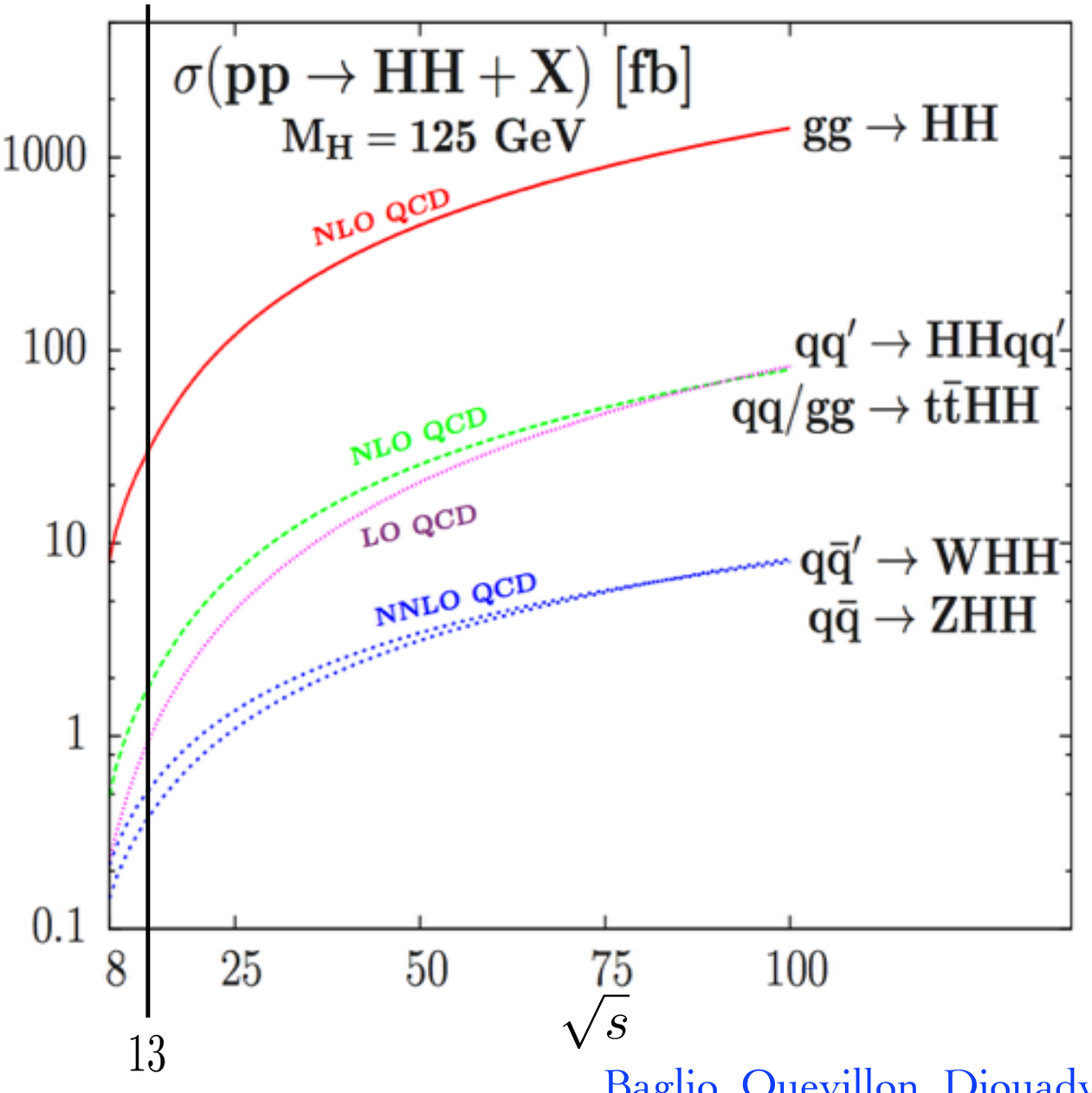
Less clean environment, but enhancement of the higher order observables (W, Y, V, X) with the energy (see EW couplings running in 3 slides)

This could lead to important constraints complementary to the S,T,U ones

HIGGS @ 100 TEV



Single Higgs production CS



Double Higgs production CS

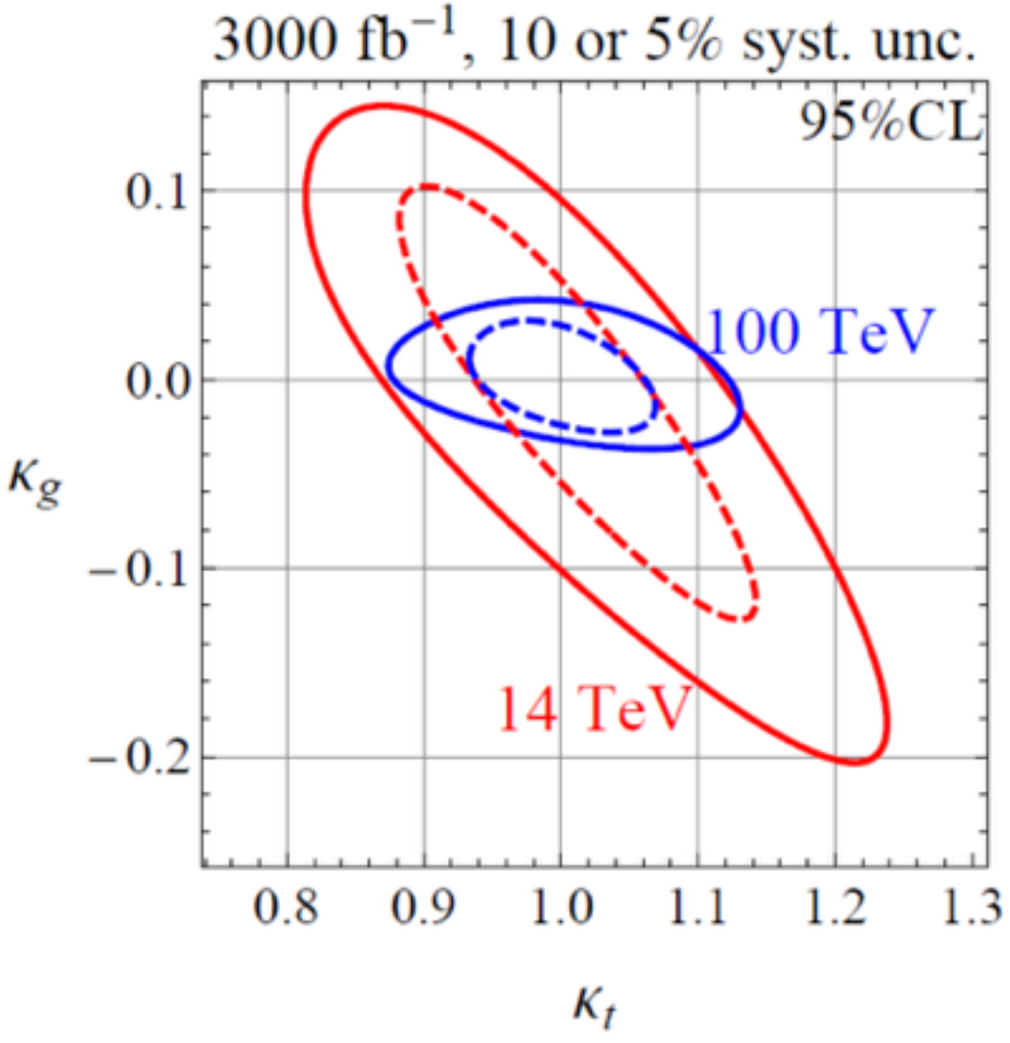
Baglio, Quevillon, Djouady

BOOSTED HIGGS @ 100 TEV

$$\mathcal{L}_{\rm eff} = -k_t \frac{m_t}{v} h t\bar{t} + k_g \frac{\alpha_S}{12\pi v} h G^A_{\mu\nu} G^{A\,\mu\nu}$$

Inclusive production

$$\frac{\sigma(pp \to h)}{\sigma(pp \to h)_{\rm SM}} \simeq (k_t + k_g)^2$$



Recoil against hard jet

$$\frac{\sigma(pp \to h)^{p_T^{\rm min}}}{\sigma(pp \to h)^{p_T^{\rm min}}_{\rm SM}} \simeq (k_t + k_g)^2 + \delta k_t k_g + \epsilon k_g^2$$

$$\mathcal{R}_{14} = \frac{\sigma(p_T{>}650\,{\rm GeV})}{\sigma(p_T{>}150\,{\rm GeV})}$$

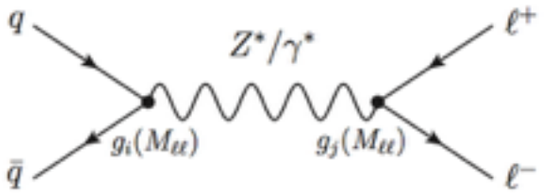
$$\mathcal{R}_{100} = \frac{\sigma(p_T{>}2000\,{\rm GeV})}{\sigma(p_T{>}500\,{\rm GeV})}$$

Discrimination power increases strongly at 100 TeV

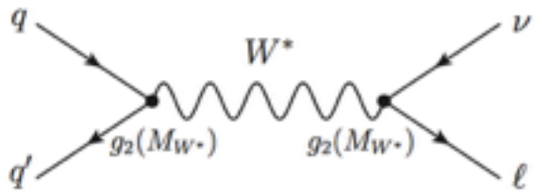
$$\sigma(p_T > 650\ {\rm GeV}, 14\,{\rm TeV}) \quad \approx \quad \sigma(p_T > 2000\ {\rm GeV}, 100\,{\rm TeV})$$

Azatov, Salvioni

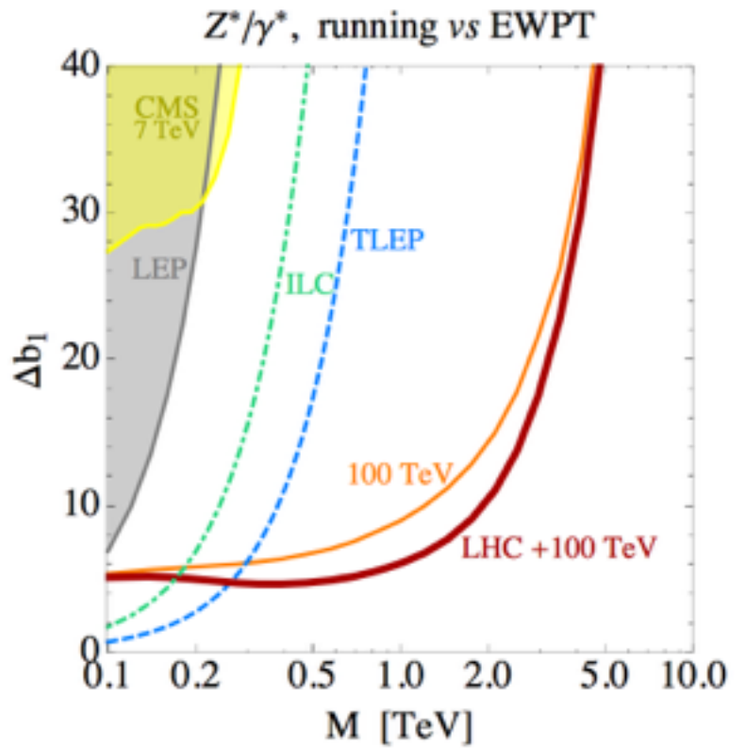
RUNNING EW COUPLINGS @ 100 TEV

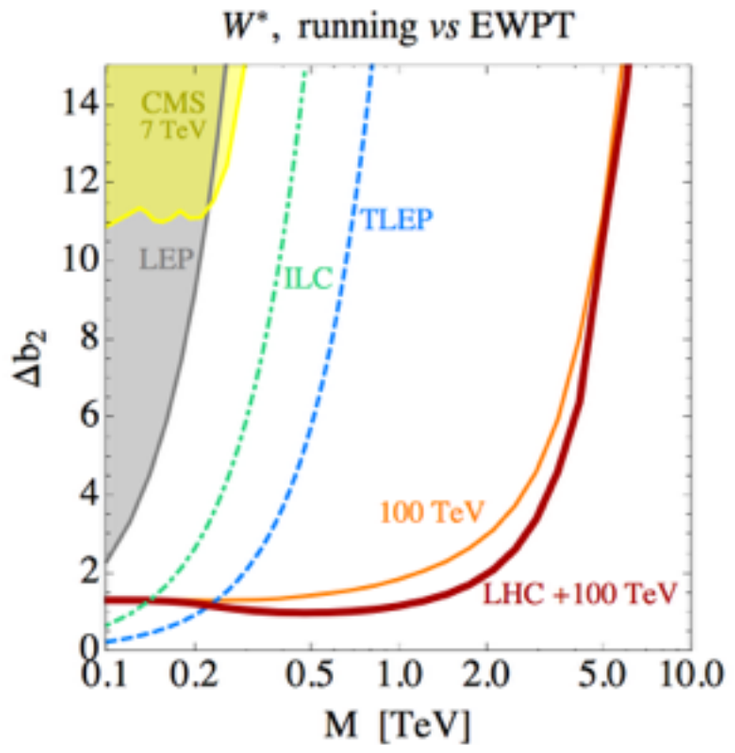


$$\frac{d\sigma}{dm_{ll}} \Rightarrow \alpha_{1,2}(q)$$



$$\frac{d\sigma}{dM_T} \Rightarrow \alpha_2(q)$$

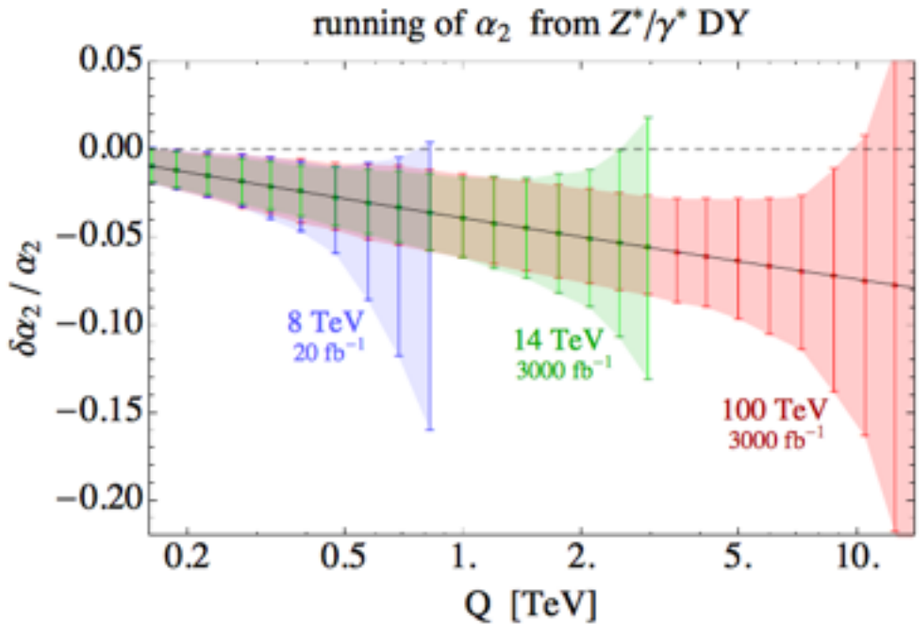




100 TeV:
reach (2σ):

$m_{\tilde{W}} \lesssim 1.3$ TeV

$m_{\mathbf{5}} \lesssim 5$ TeV



$$W,\, Y = \frac{\alpha_{2,1}}{20\pi}\frac{M_W^2}{M_x^2} \times \Delta b_{2,1}$$

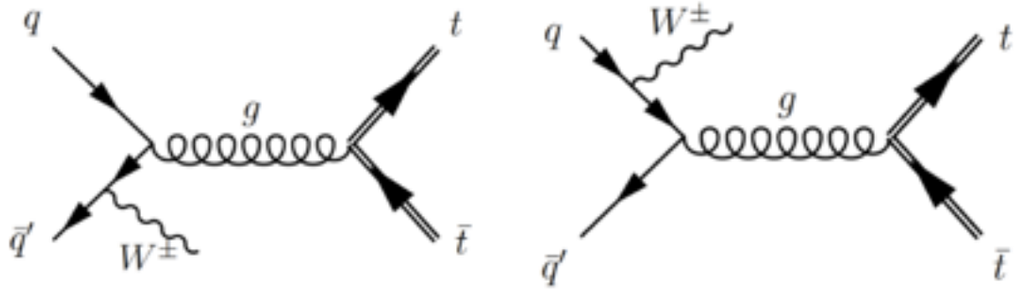
	ΔM_W (GeV)	$\Delta\Gamma_Z$ (GeV)	$\Delta A_{\rm LR}$	ΔW	ΔY
EWPT+LEP2 [61–63]	$3.4 \cdot 10^{-2}$	$2.3 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$	$8 \cdot 10^{-4}$	$1.2 \cdot 10^{-3}$
ILC (GigaZ) [64]	$6 \cdot 10^{-3}$	$8 \cdot 10^{-4}$	10^{-4}	$3 \cdot 10^{-4}$	$3 \cdot 10^{-4}$
TLEP (TeraZ) [65]	$5 \cdot 10^{-4}$ (sys)	10^{-4} (sys)	$1.5 \cdot 10^{-5}$	$7 \cdot 10^{-5}$	$1 \cdot 10^{-4}$

Alves, Galloway, Ruderman, Walsh, 1410.6810 [hep-ph]

TOP CHARGE ASYMMETRY

$$A_c^t = \frac{N(\Delta_\eta^t > 0) - N(\Delta_\eta^t < 0)}{N(\Delta_\eta^t > 0) + N(\Delta_\eta^t < 0)} \qquad \Delta_\eta^t = |\eta_t| - |\eta_{\bar{t}}|$$

Instead of looking at ttbar events we consider also the emission of a W boson



PROS

- qqbar vs gg so that the asymmetry generated at NLO in QCD is larger
- the tops inherit the polarization of the quarks as induced by the W emission so that the decay products of the top show a large asymmetry already at LO in QCD

CONS

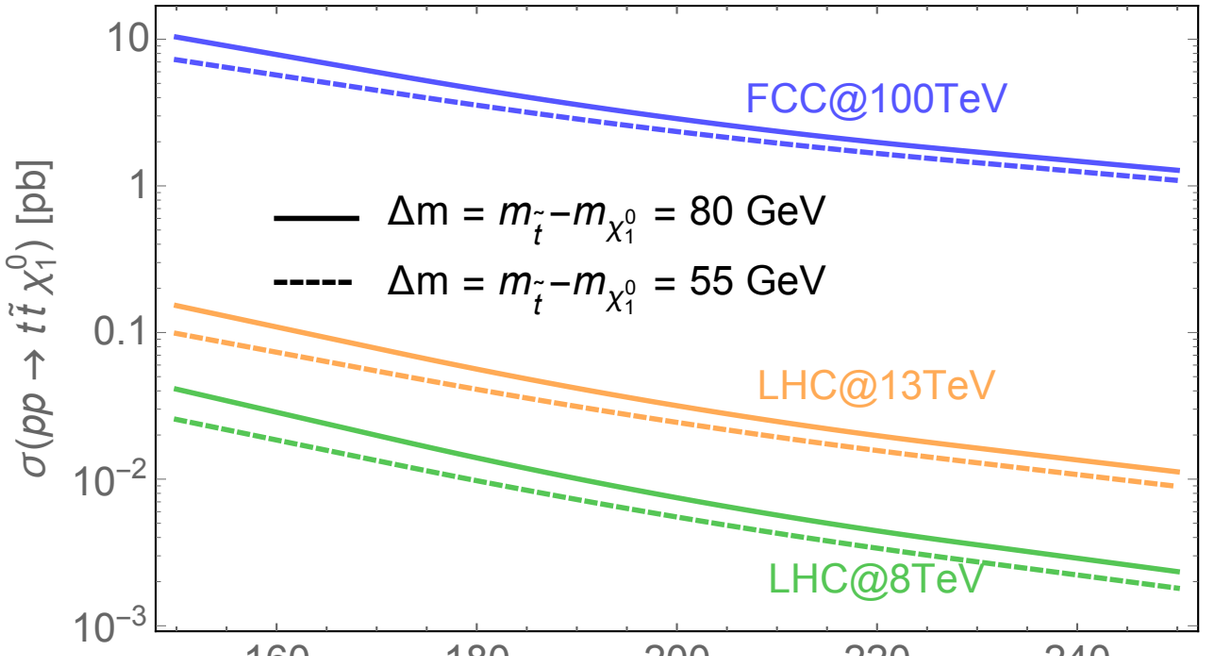
- the rate is dramatically reduced, i.e. the FCC does much better than the LHC

		8 TeV	13 TeV	14 TeV	33 TeV	100 TeV
$t\bar{t}$	σ(pb)	$198^{+15\%}_{-14\%}$	$661^{+15\%}_{-13\%}$	$786^{+14\%}_{-13\%}$	$4630^{+12\%}_{-11\%}$	$30700^{+13\%}_{-13\%}$
	$A_c^t(\%)$	$0.72^{+0.14}_{-0.09}$	$0.45^{+0.09}_{-0.06}$	$0.43^{+0.08}_{-0.05}$	$0.26^{+0.04}_{-0.03}$	$0.12^{+0.03}_{-0.02}$
$t\bar{t}W^\pm$	σ(fb)	$210^{+11\%}_{-11\%}$	$587^{+13\%}_{-12\%}$	$678^{+14\%}_{-12\%}$	$3220^{+17\%}_{-13\%}$	$19000^{+20\%}_{-17\%}$
	$A_c^t(\%)$	$2.37^{+0.56}_{-0.38}$	$2.24^{+0.43}_{-0.32}$	$2.23^{+0.43}_{-0.33}$	$1.95^{+0.28}_{-0.23}$	$1.85^{+0.21}_{-0.17}$
	$A_c^b(\%)$	$8.50^{+0.15}_{-0.10}$	$7.54^{+0.19}_{-0.17}$	$7.50^{+0.24}_{-0.22}$	$5.37^{+0.22}_{-0.30}$	$3.36^{+0.15}_{-0.19}$
	$A_c^e(\%)$	$-14.83^{-0.65}_{+0.95}$	$-13.16^{-0.81}_{+1.12}$	$-12.84^{-0.81}_{+1.11}$	$-9.21^{-0.87}_{+1.05}$	$-4.94^{-0.63}_{+0.72}$

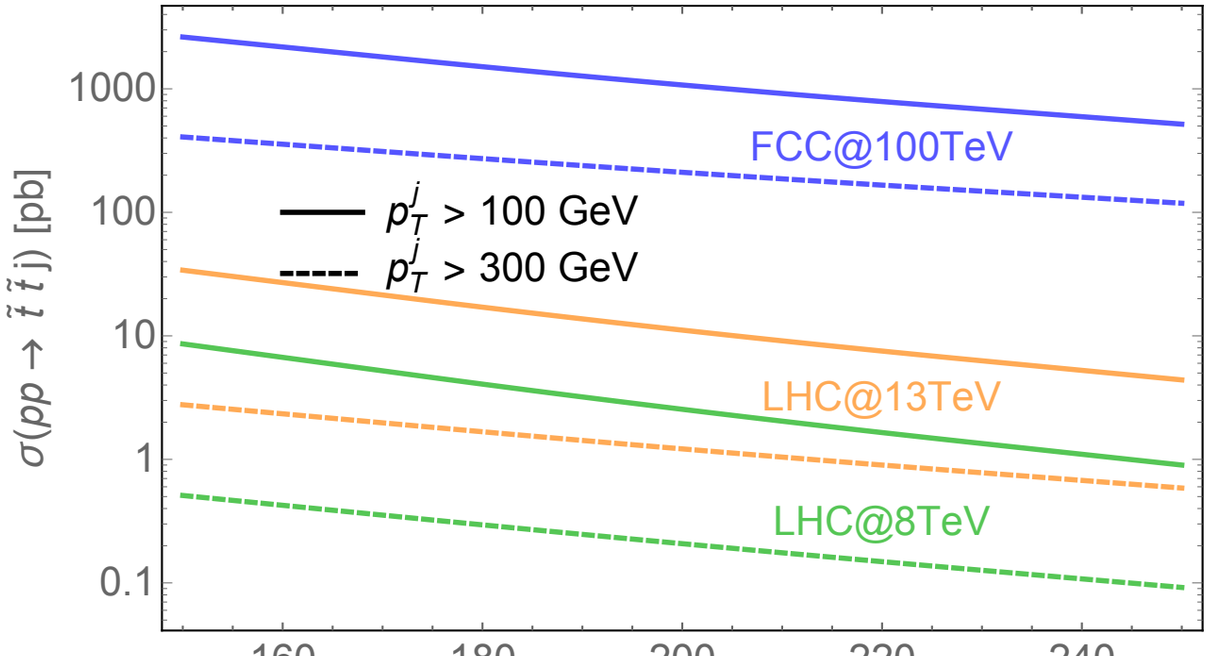
Maltoni, Mangano, Tsinikos, Zaro, 1406.3262 [hep-ph]

SOMETHING SIMILAR WITH SUSY

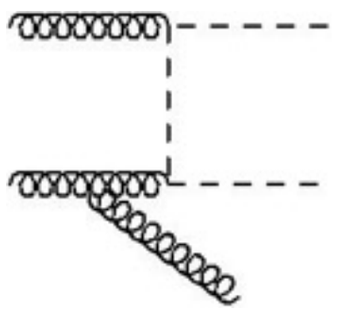
$2 \to 3$ Stop Pair Production + LSP



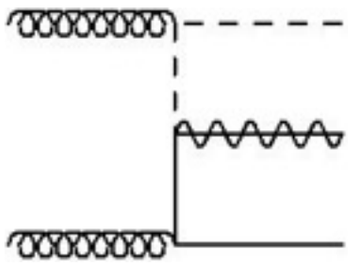
$2 \to 3$ Stop Pair Production + j



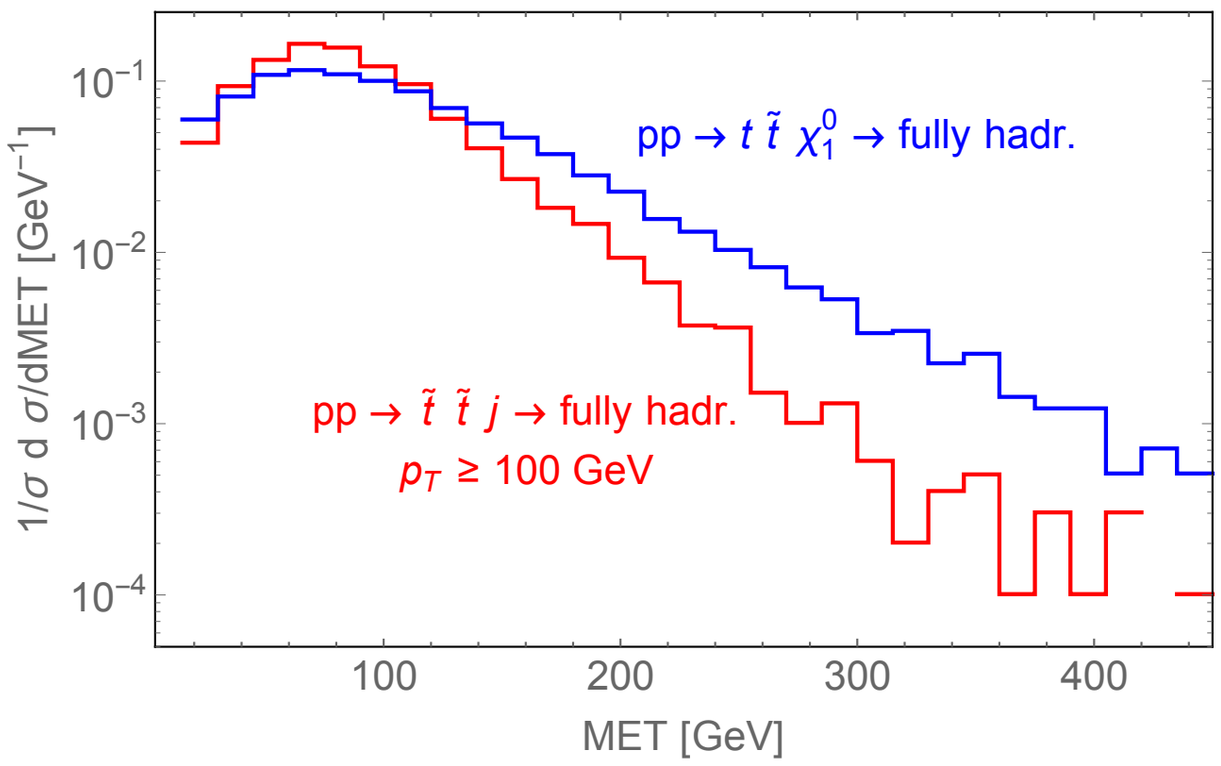
$2 \to 3$ Stop Pair Production + j



$2 \to 3$ Stop Pair Production + LSP



Analogous to the tth measurement of yt



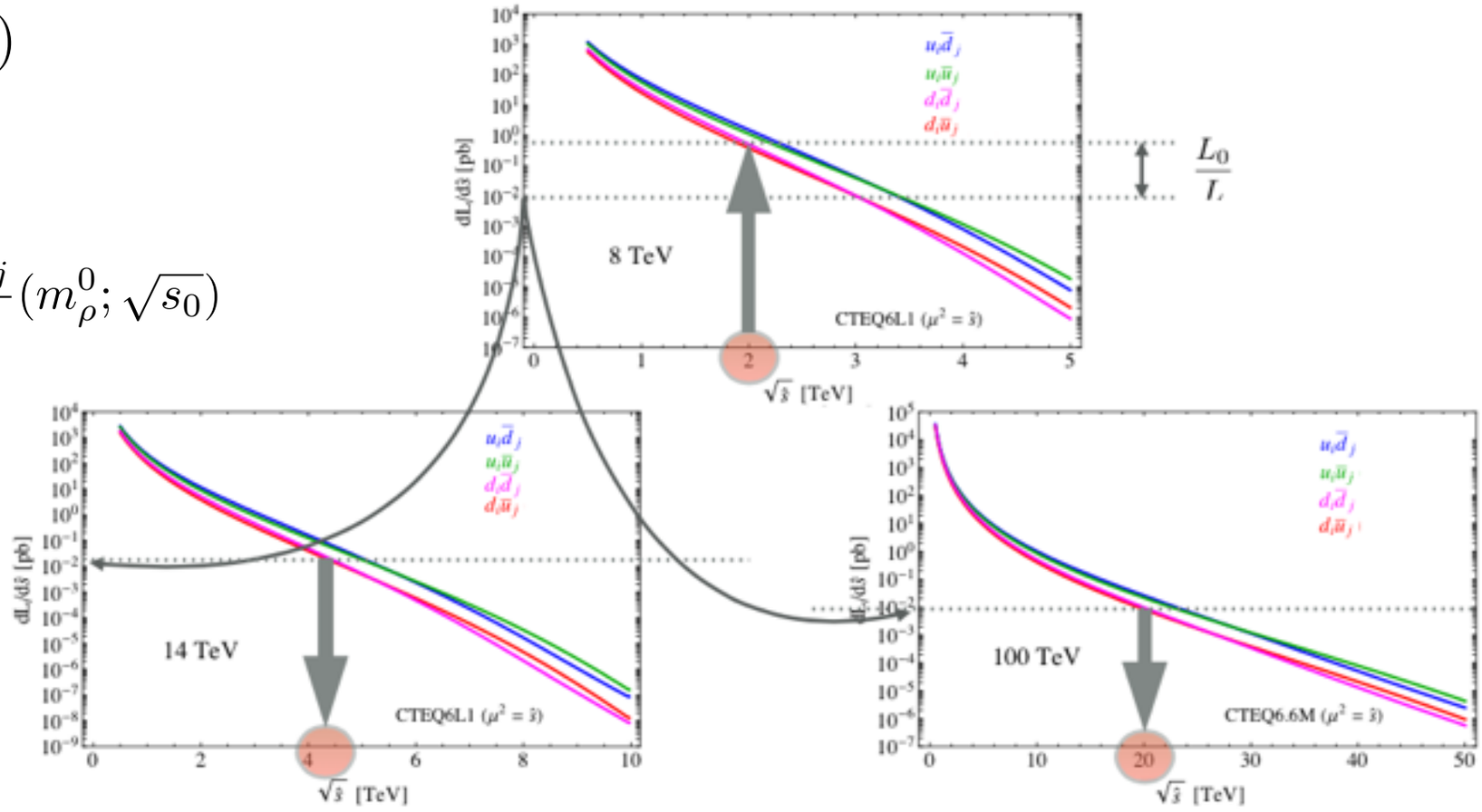
Ferretti, Franceschini, Petersson, Torre

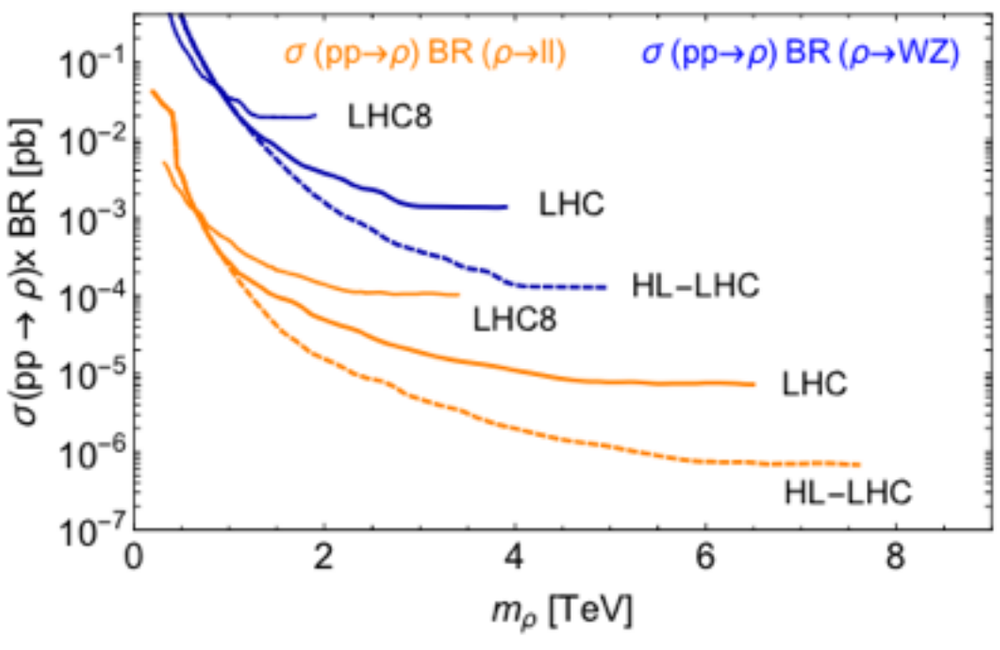
COMPOSITENESS @ 100 TEV

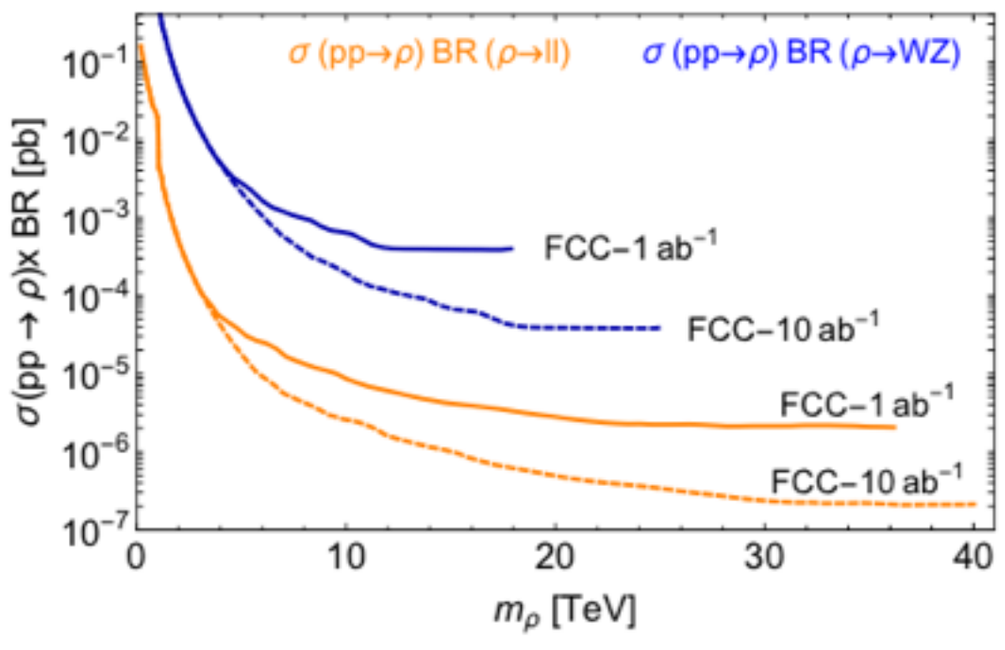
$$B(s, L, m_\rho) = B(s_0, L_0, m_\rho^0)$$

$$\sum_{\{i,j\}} c_{ij} \frac{d\mathcal{L}_{ij}}{d\hat{s}}(m_\rho; \sqrt{s}) = \frac{L_0}{L} \sum_{\{i,j\}} c_{ij} \frac{d\mathcal{L}_{ij}}{d\hat{s}}(m_\rho^0; \sqrt{s_0})$$

Extrapolation of current bounds to 100 TeV based on Background Parton Luminosities

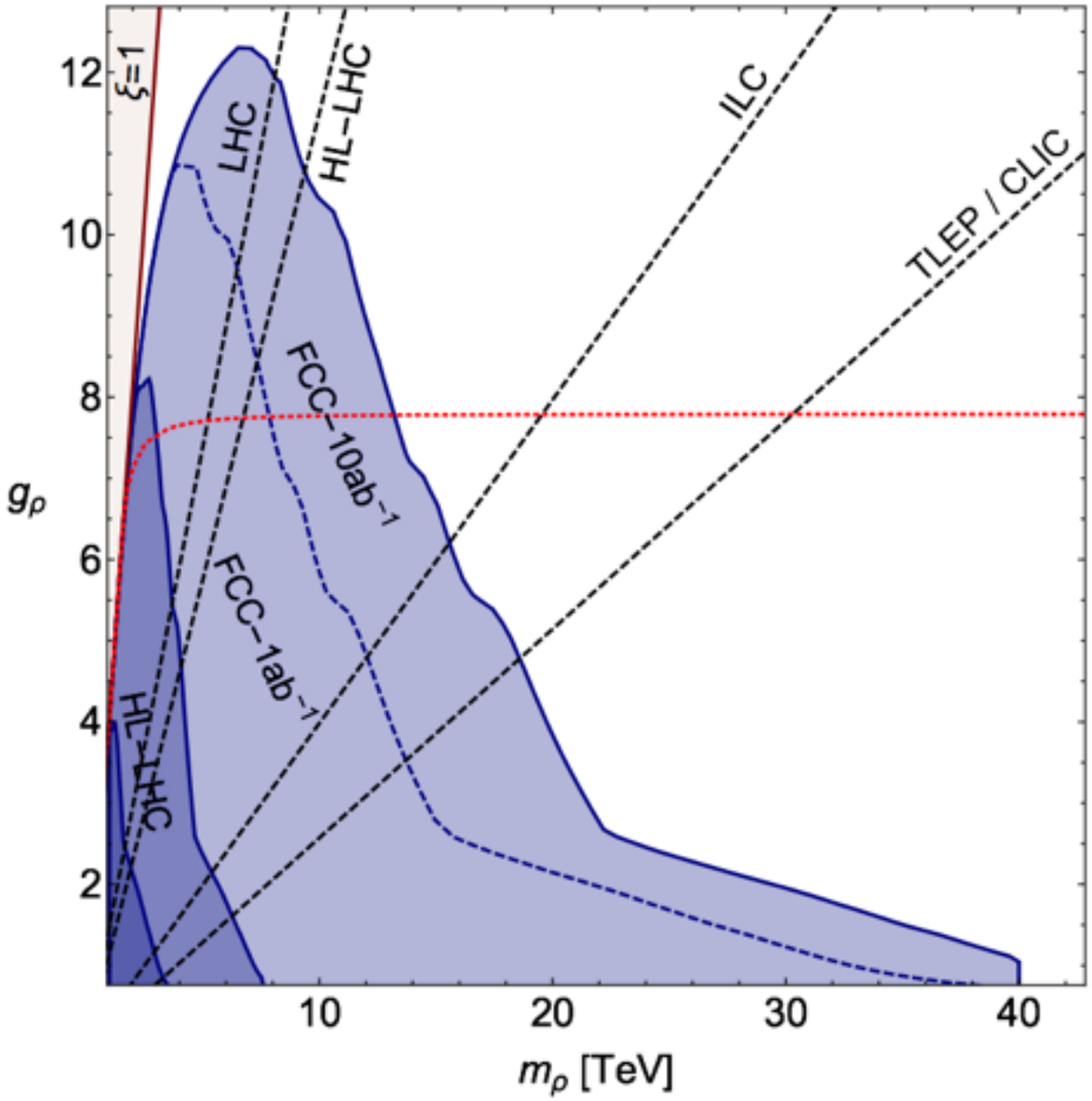


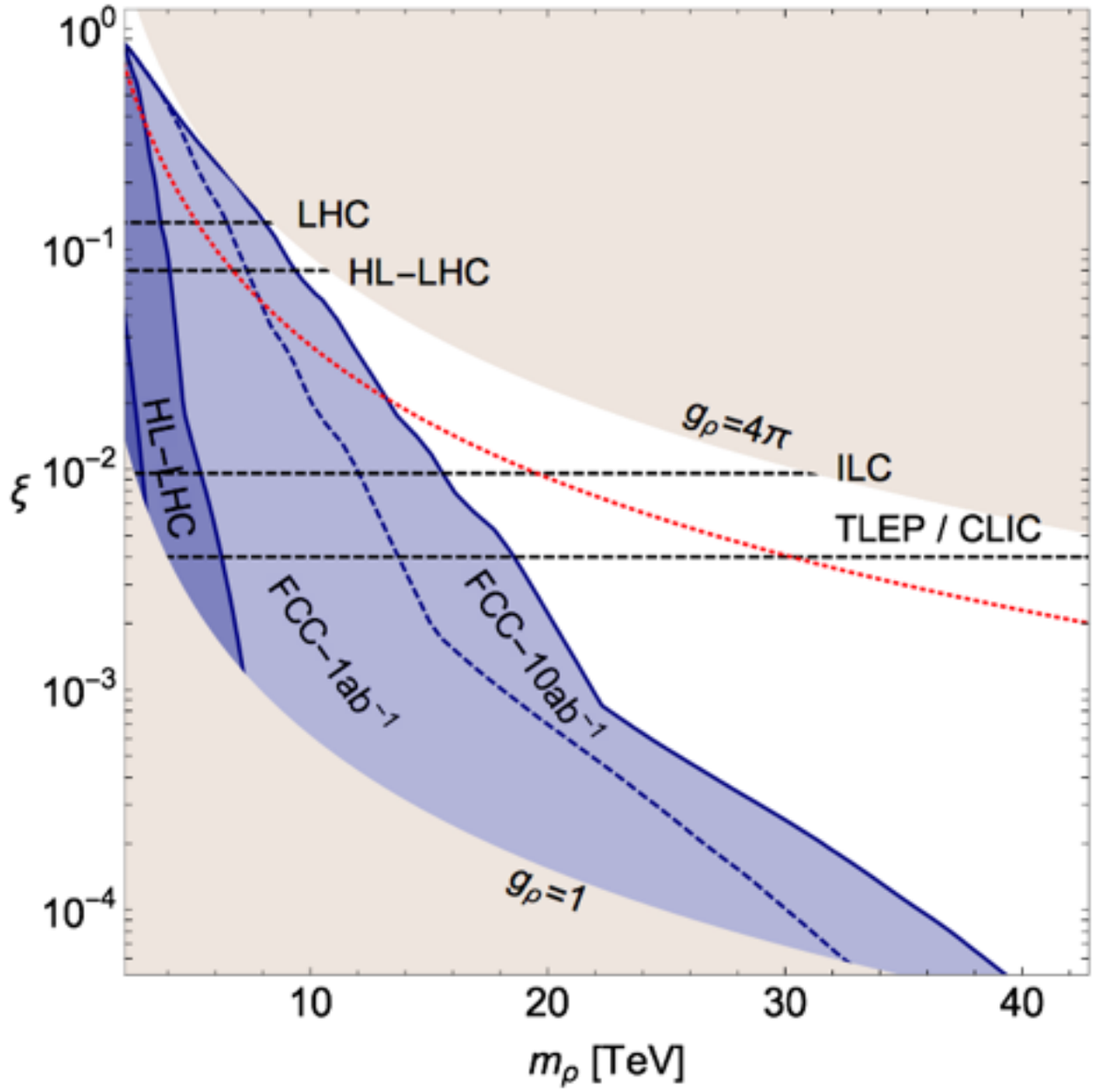




Thamm, Torre, Wulzer, 1502.0170 [hep-ph]

COMPOSITENESS: DIRECT VS INDIRECT





High complementarity between FCC-hh and FCC-ee

Needed studies of precision at FCC-hh for a conclusive comparison between the two

Thamm, Torre, Wulzer, 1502.0170 [hep-ph]

THANK YOU