Higgs couplings and VBF at Muon Colliders

[A. Costantini et al. arXiv:2005.10289] [M. Chiesa al. arXiv:2003.13628]

Luca Mantani

In collaboration with:
F. Maltoni, R. Ruiz, A. Costantini, F. De Lillo,
X. Zhao, M. Chiesa, B. Mele, F. Piccinini

UCLouvain

Hadron collider

QCD background

High energy

Initial state unknown

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e+ e- collider

Synchroton radiation

Precision

Known initial state

High energy **Precision**

Muon collider

Muons decay! → **R&D needed in accelerator and detector physics**

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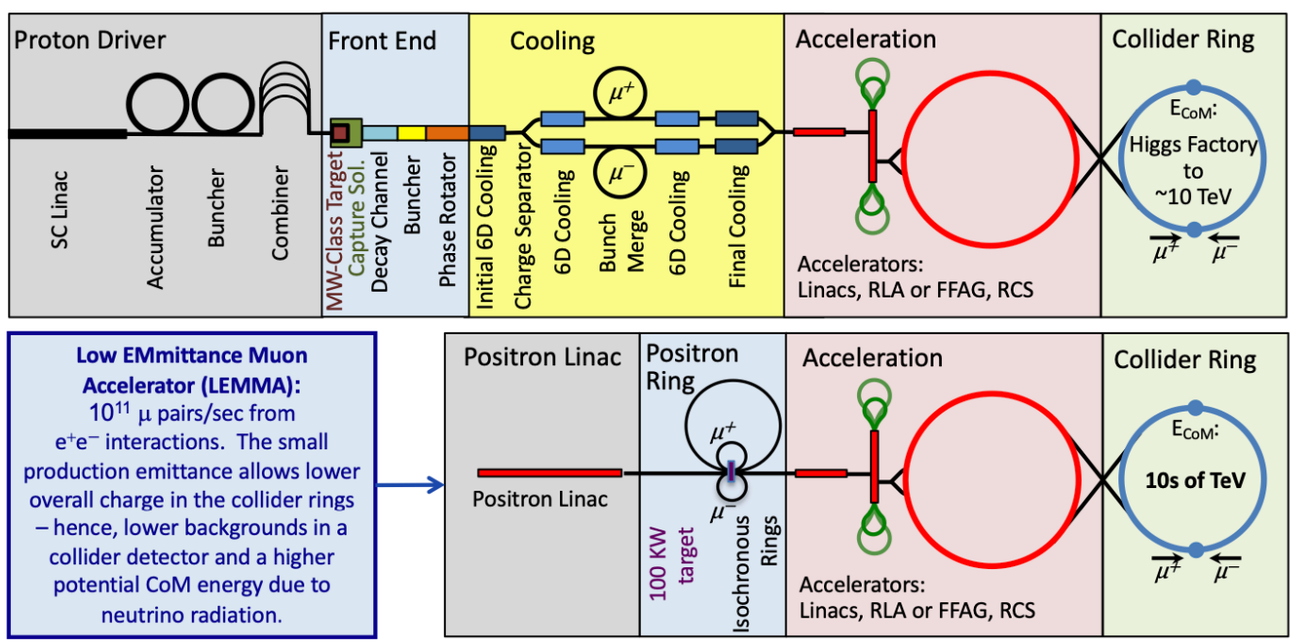
Beam production



[Delahaye et al. arXiv:1901.06150]

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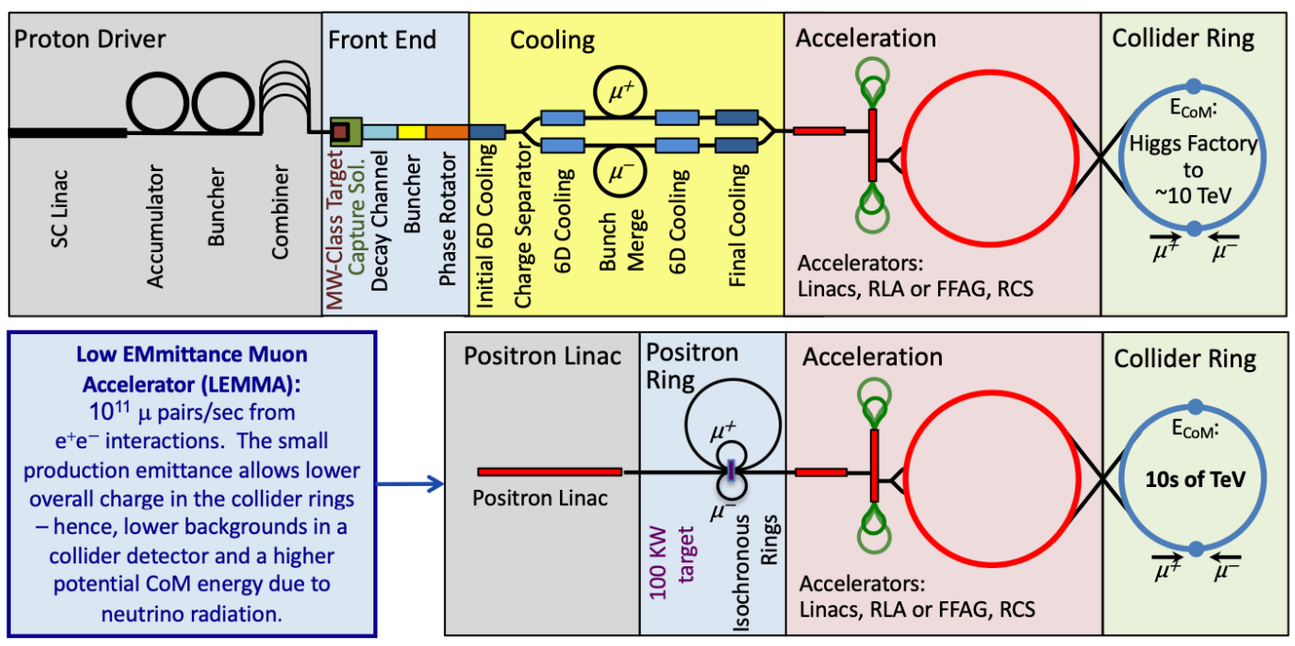

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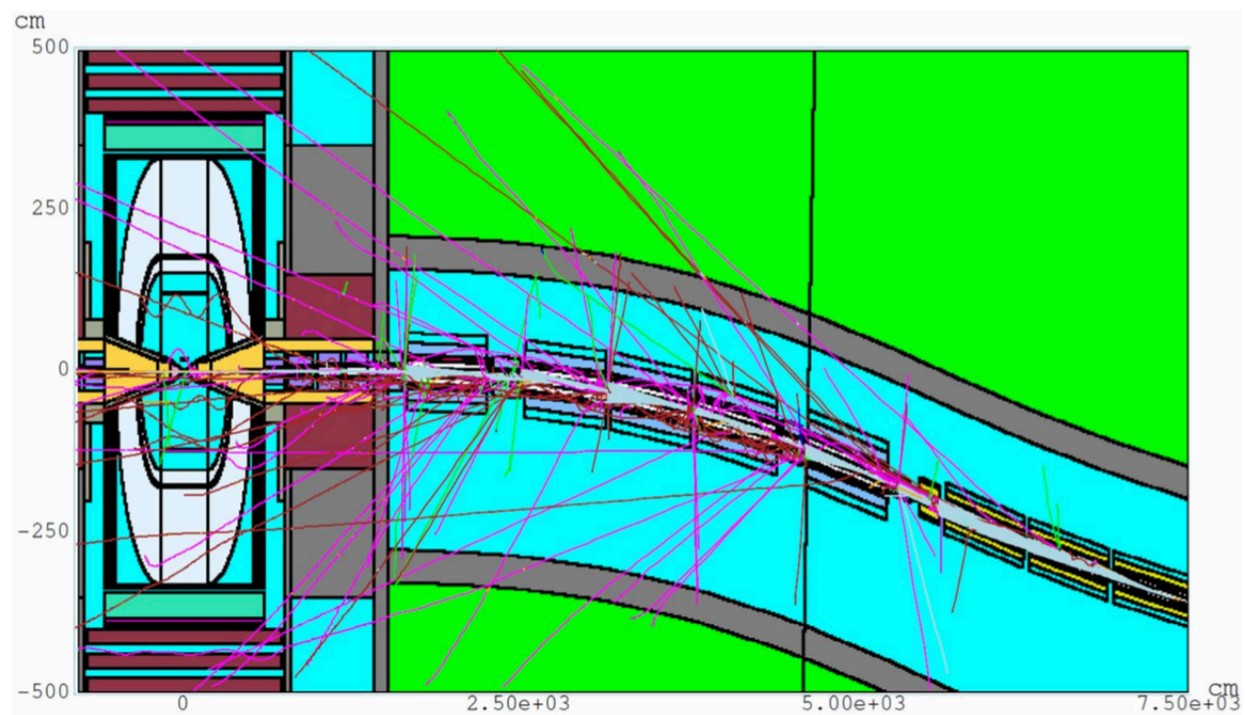
Detector



[Bartosik et al. arXiv:2001.04431]

Luminosities are assumed from MAP studies

Typical EW process at muon collider

$$\sigma = \left(\frac{10\,\mathrm{TeV}}{\sqrt{s_\mu}} \right)^2 \cdot 10^3\,\mathrm{ab}$$

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For $N \sim 10^4$ → $\mathcal{L} \cdot \mathrm{years} = \left(\frac{\sqrt{s_\mu}}{10\,\mathrm{TeV}}\right)^2 \cdot 10\,\mathrm{ab}^{-1}$

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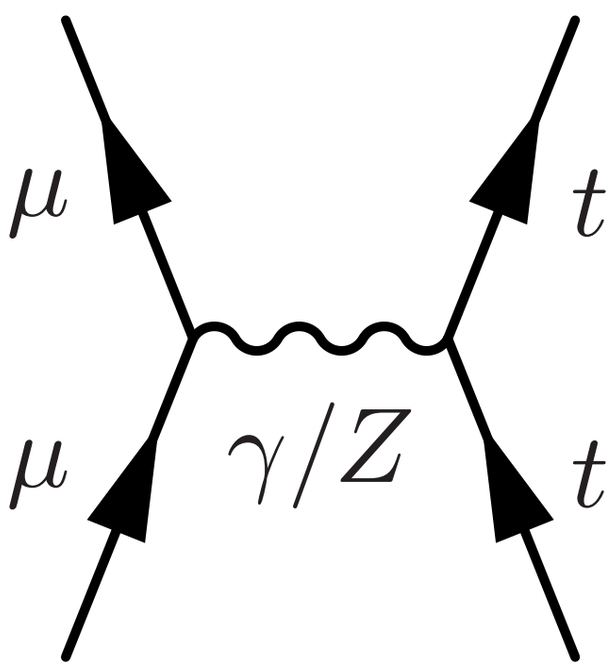
$\sqrt{s} \lesssim$ 1-5 TeV



s-channel

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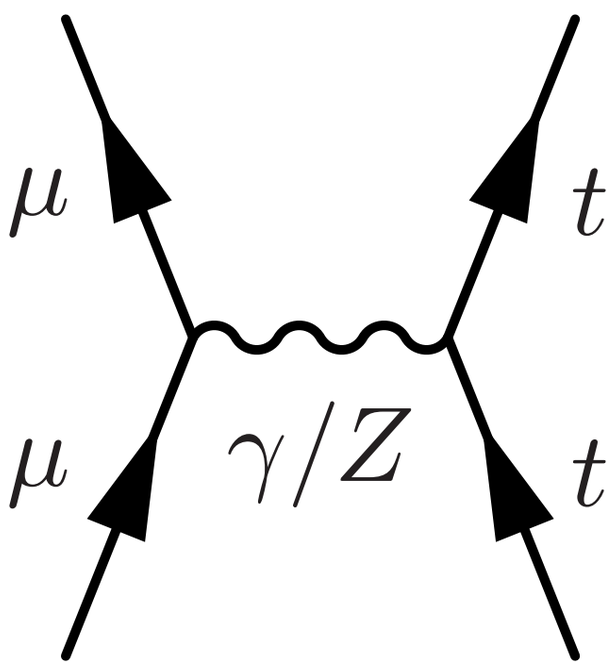

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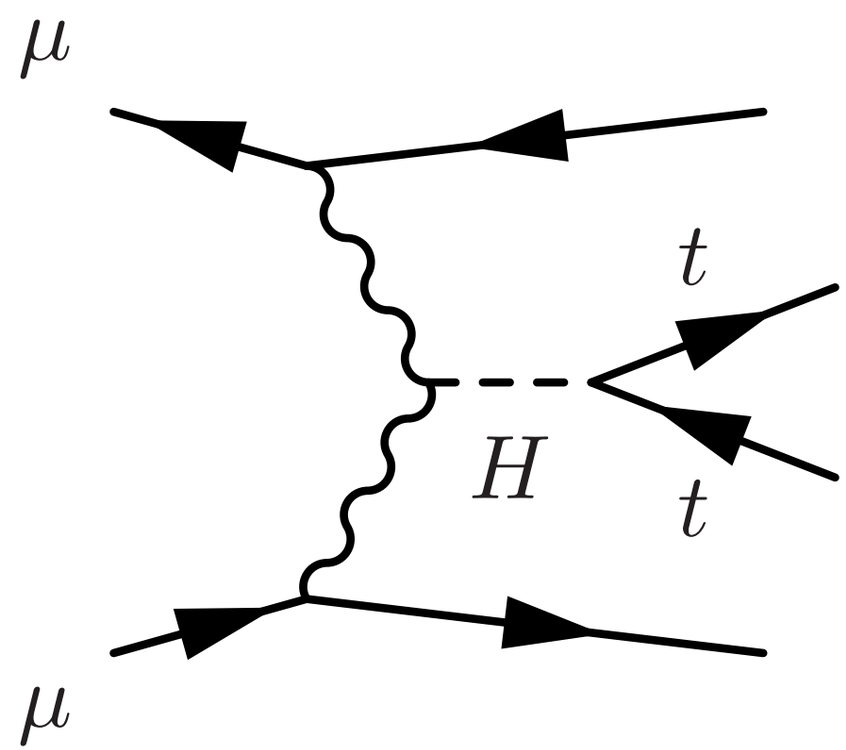

VBF

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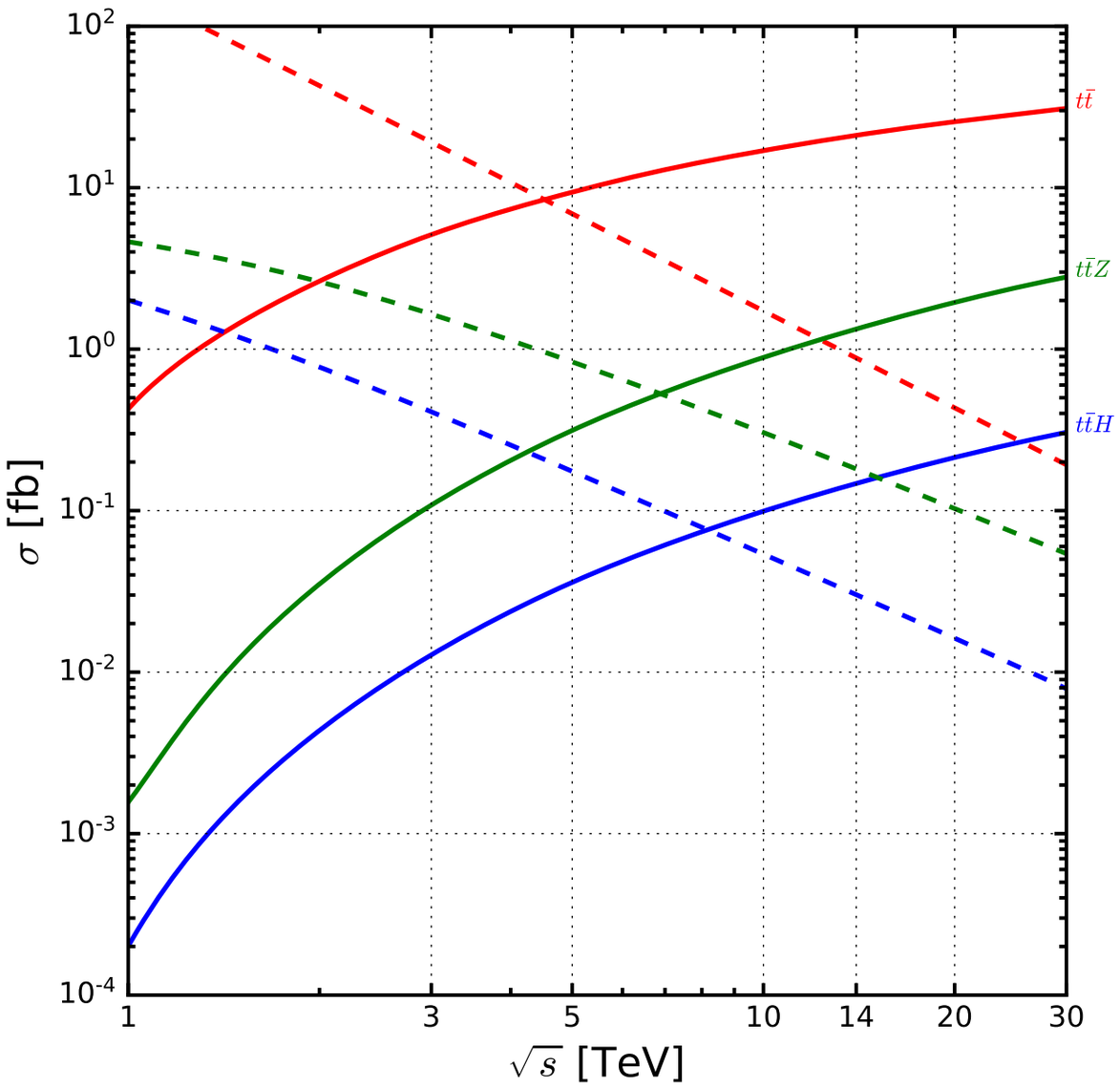
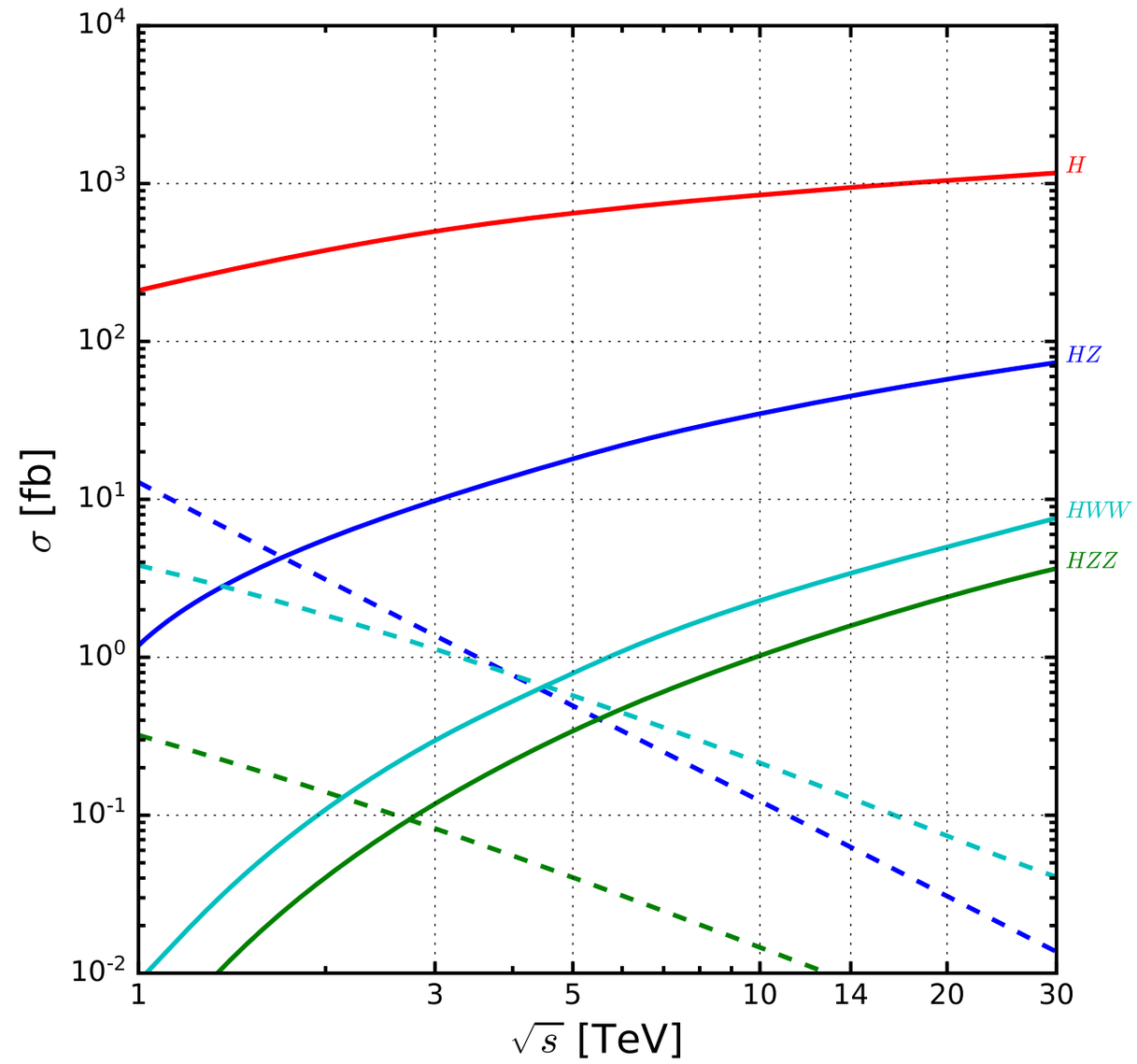
ttX



HX



Discovery potential

Pair production

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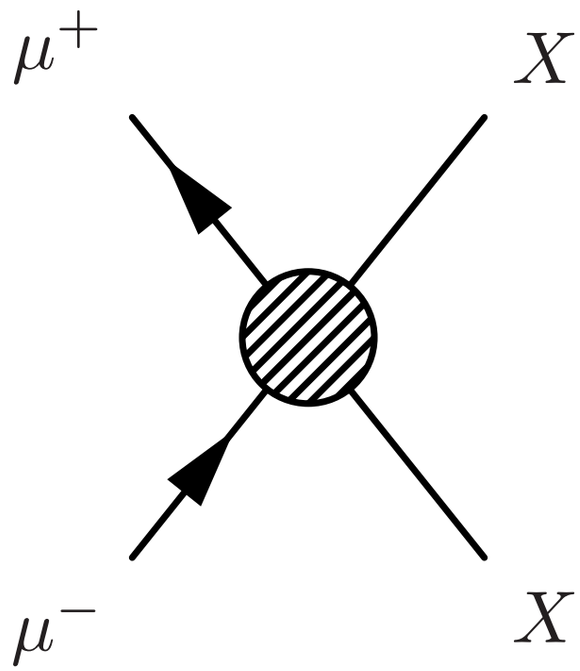

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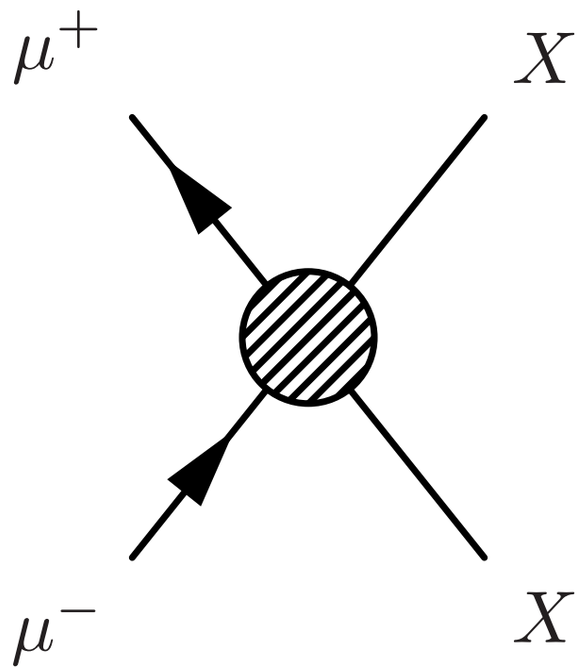

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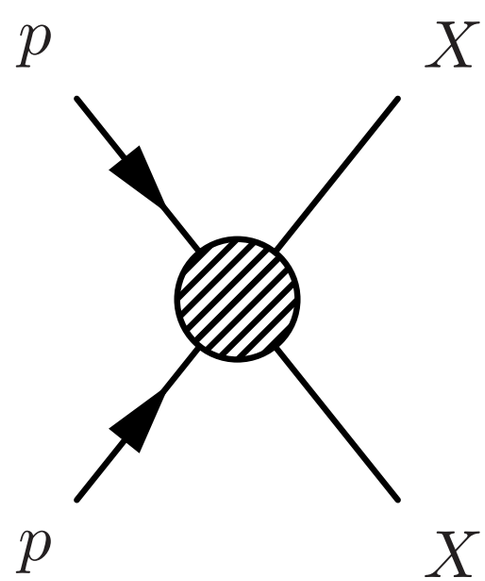

$$\sigma_p(s_p) = \frac{1}{s_p}\int_{\tau_0}^{1} d\tau \frac{1}{\tau} \sum_{ij} \Phi_{ij}(\tau, \mu_f) \; [\hat{\sigma}_{ij}\hat{s}]_p$$

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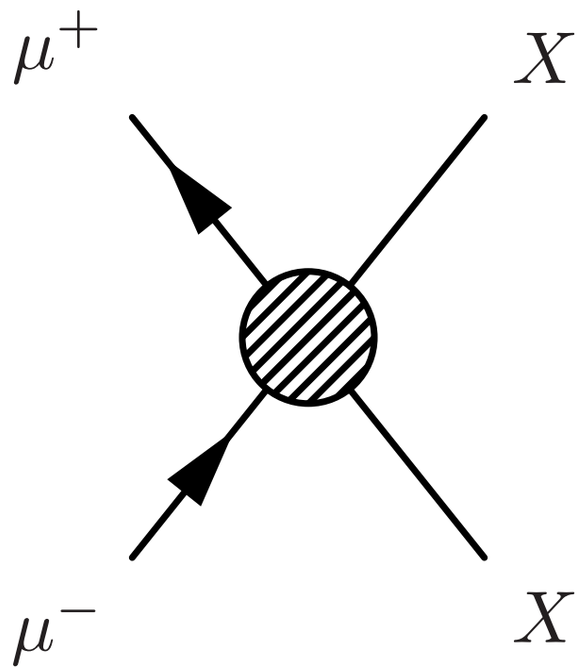

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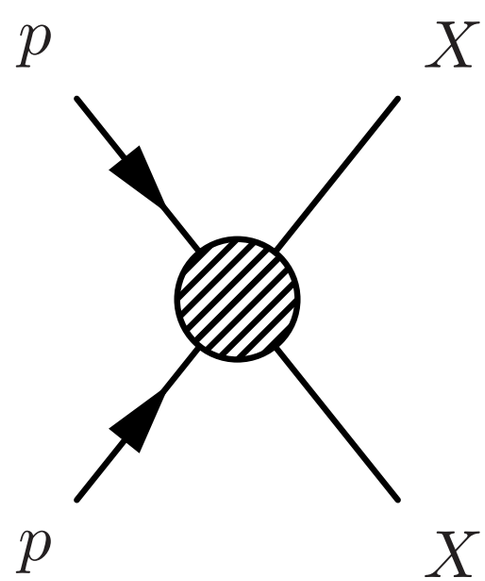

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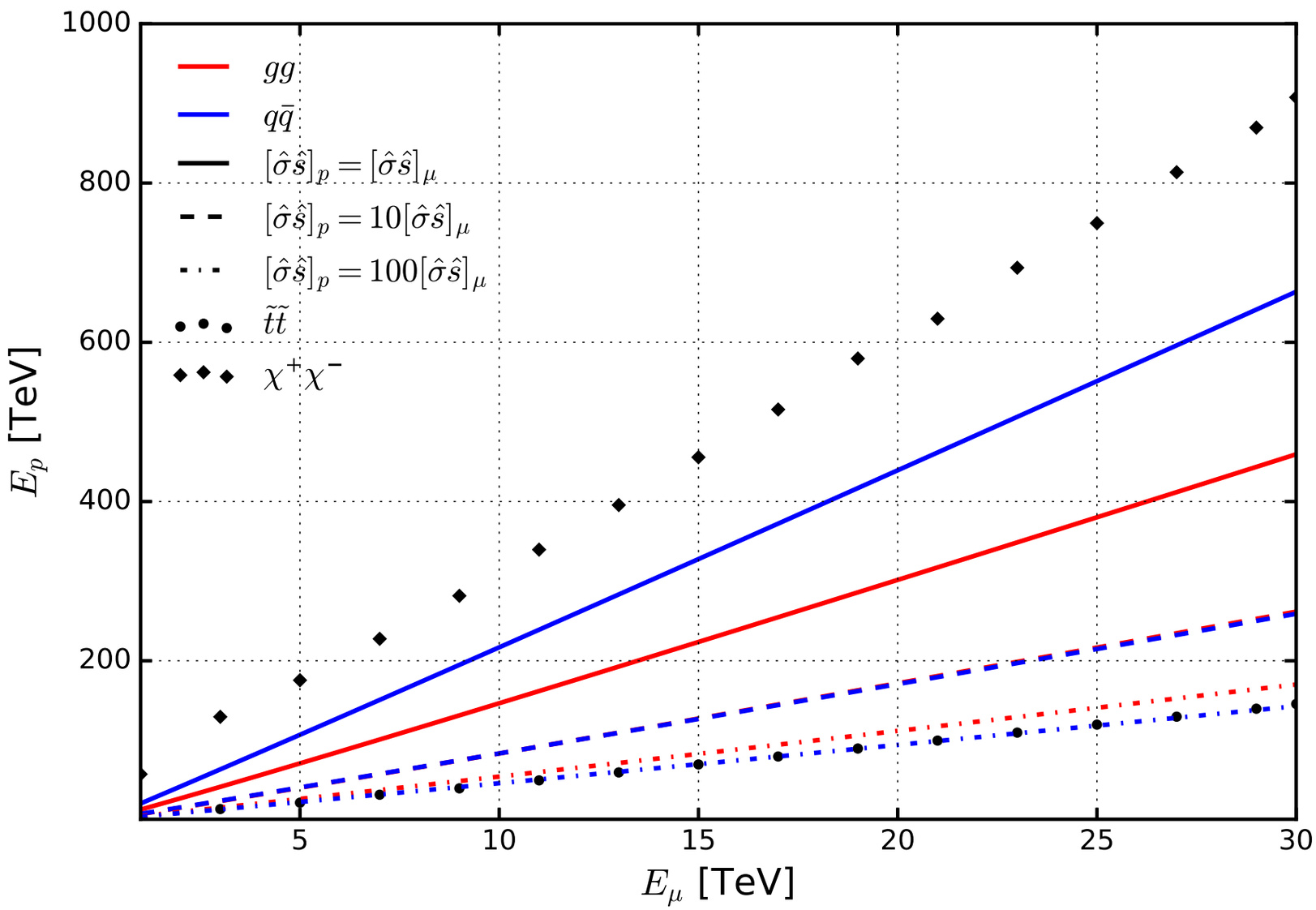

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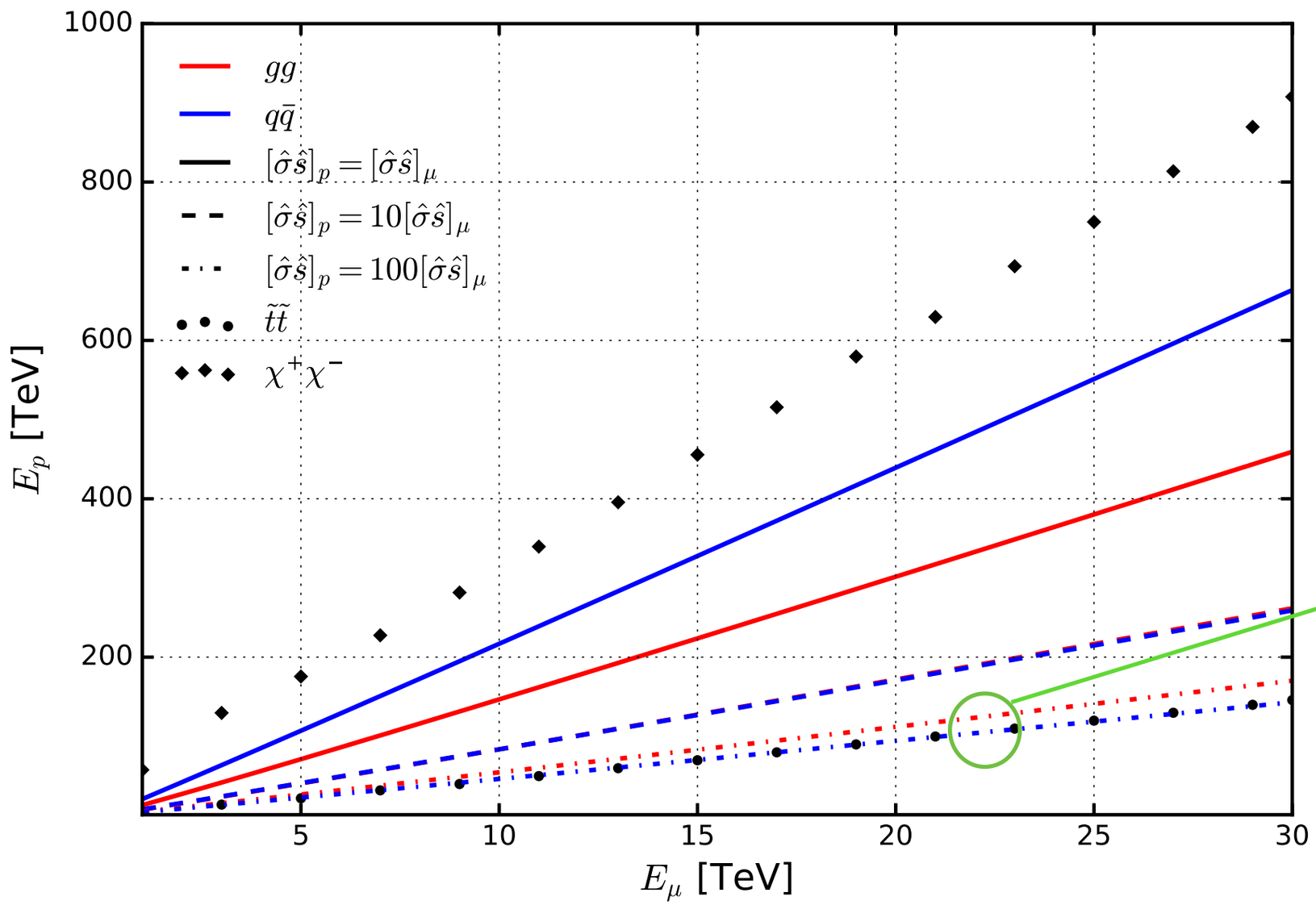


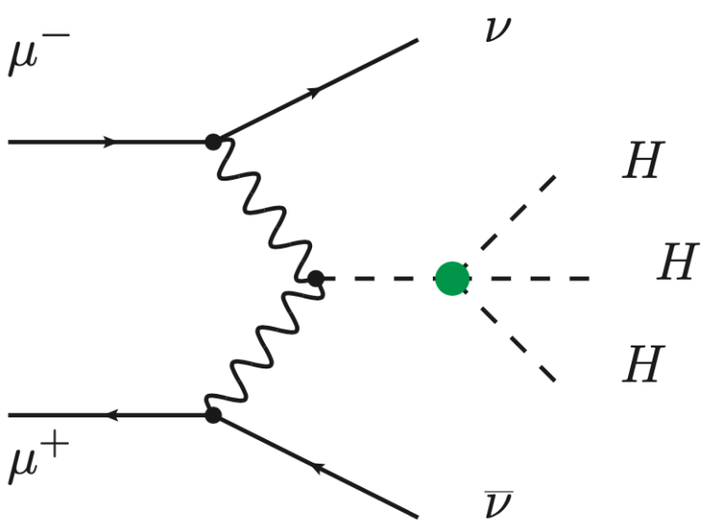
Stop prod well described

H quartic coupling

$$V(H) = \frac{1}{2} m_H^2 H^2 + \lambda_3 v H^3 + \frac{1}{4} \lambda_4 H^4$$

[A. Abada et al.
Eur. Phys. J. C 79 (2019) no.6, 474]

$$\lambda_3 = \lambda_4 = m_H^2 / 2v^2 \equiv \lambda_{SM}$$



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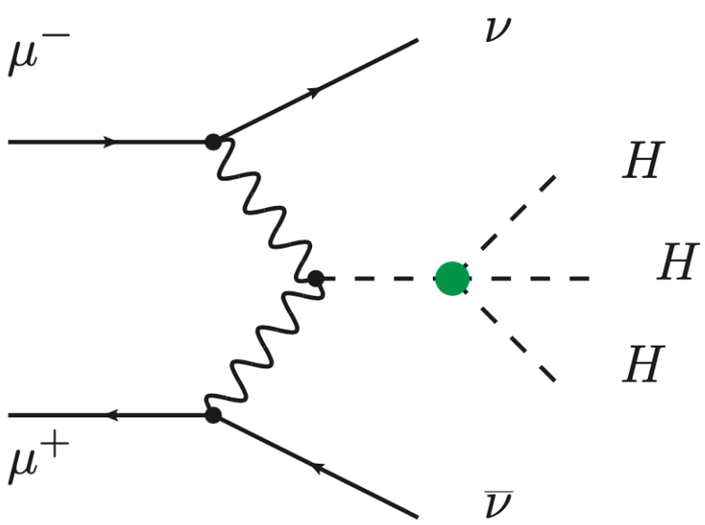
HH and radiative corrections to single Higgs
FCC ~ 5%



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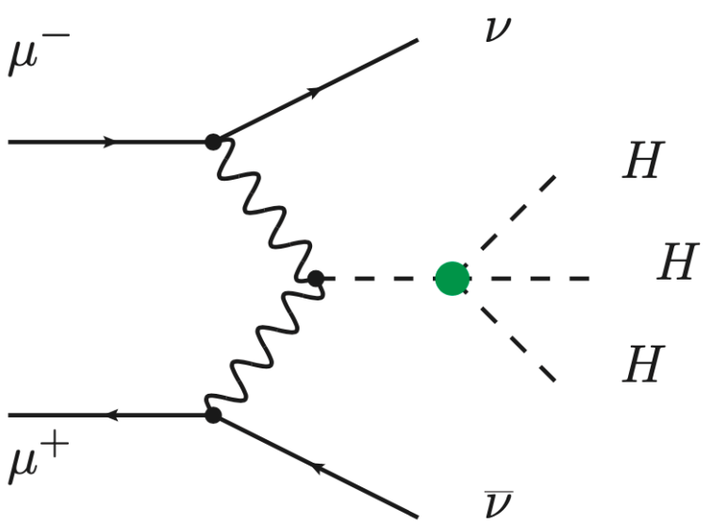

Challenging even at FCC!

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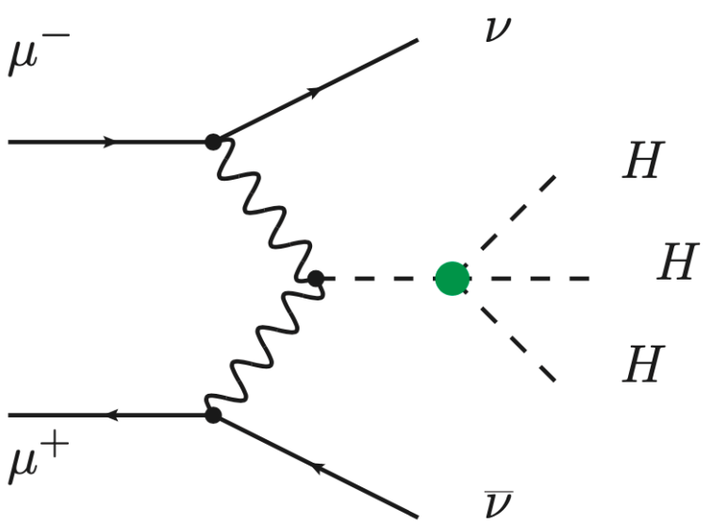

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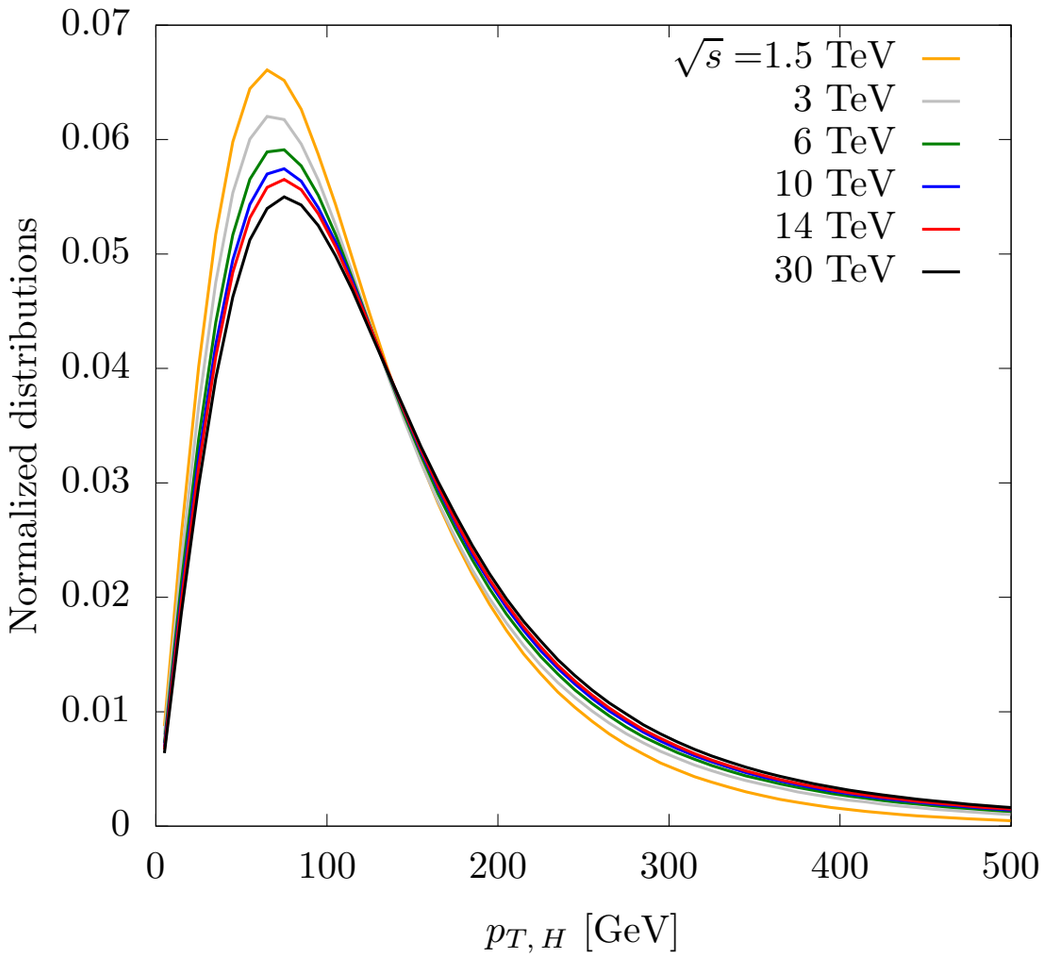
$\sqrt{s}$ (TeV) / L (ab^{-1})	1.5 / 1.2	3 / 4.4	6 / 12	10 / 20	14 / 33	30 / 100
σ_{SM} (ab) [$N_{\rm ev}$]						
$\sigma^{\rm tot}$	0.03 [0]	0.31 [1]	1.65 [20]	4.18 [84]	7.02 [232]	18.51 [1851]
$\sigma(M_{HHH} < 3$ TeV)	0.03 [0]	0.31 [1]	1.47 [18]	2.89 [58]	3.98 [131]	6.69 [669]
$\sigma(M_{HHH} < 1$ TeV)	0.02 [0]	0.12 [1]	0.26 [3]	0.37 [7]	0.45 [15]	0.64 [64]

SM distributions



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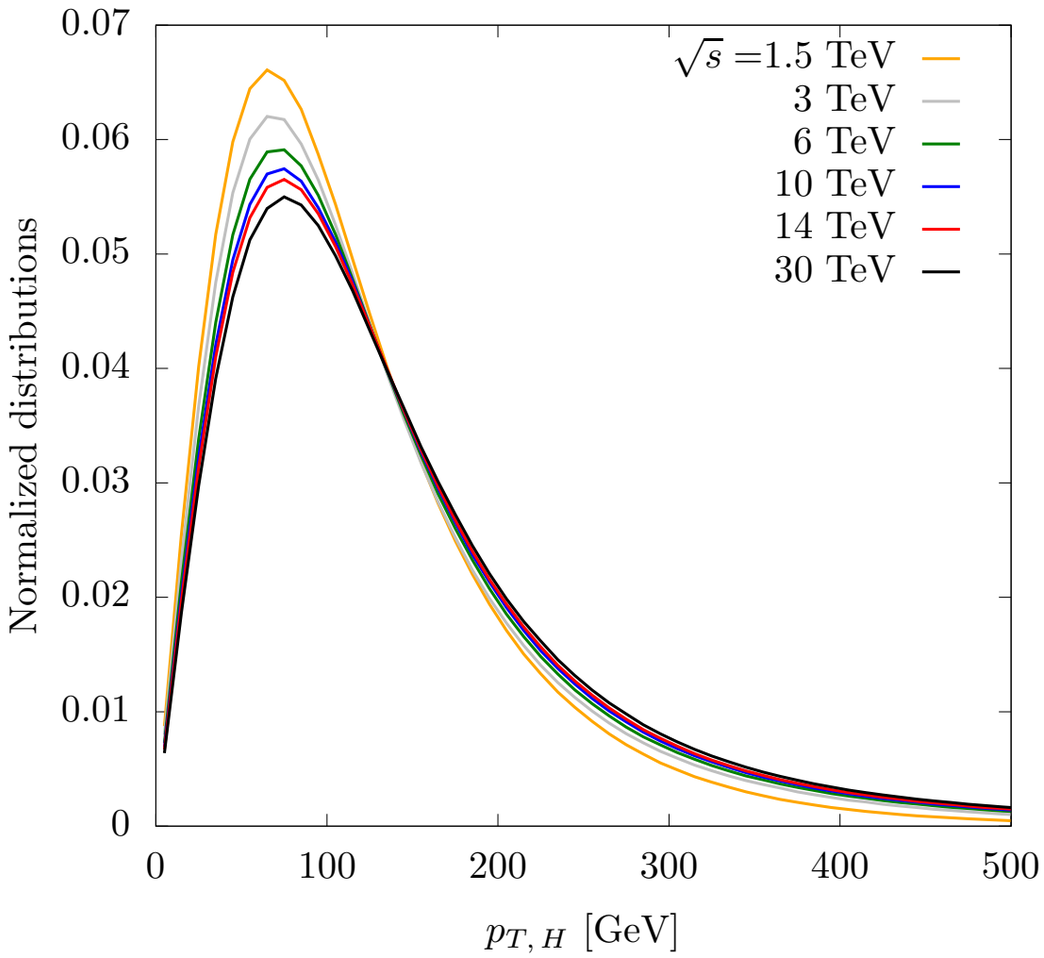

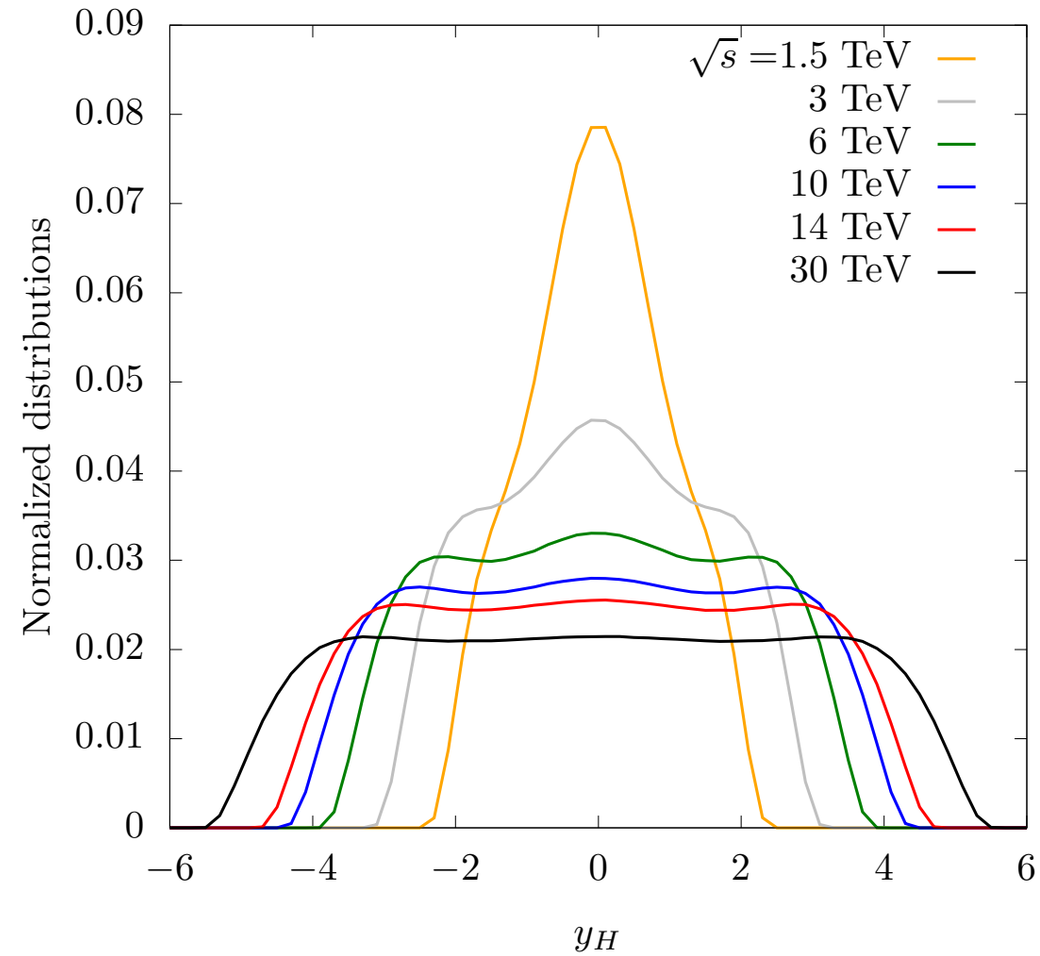

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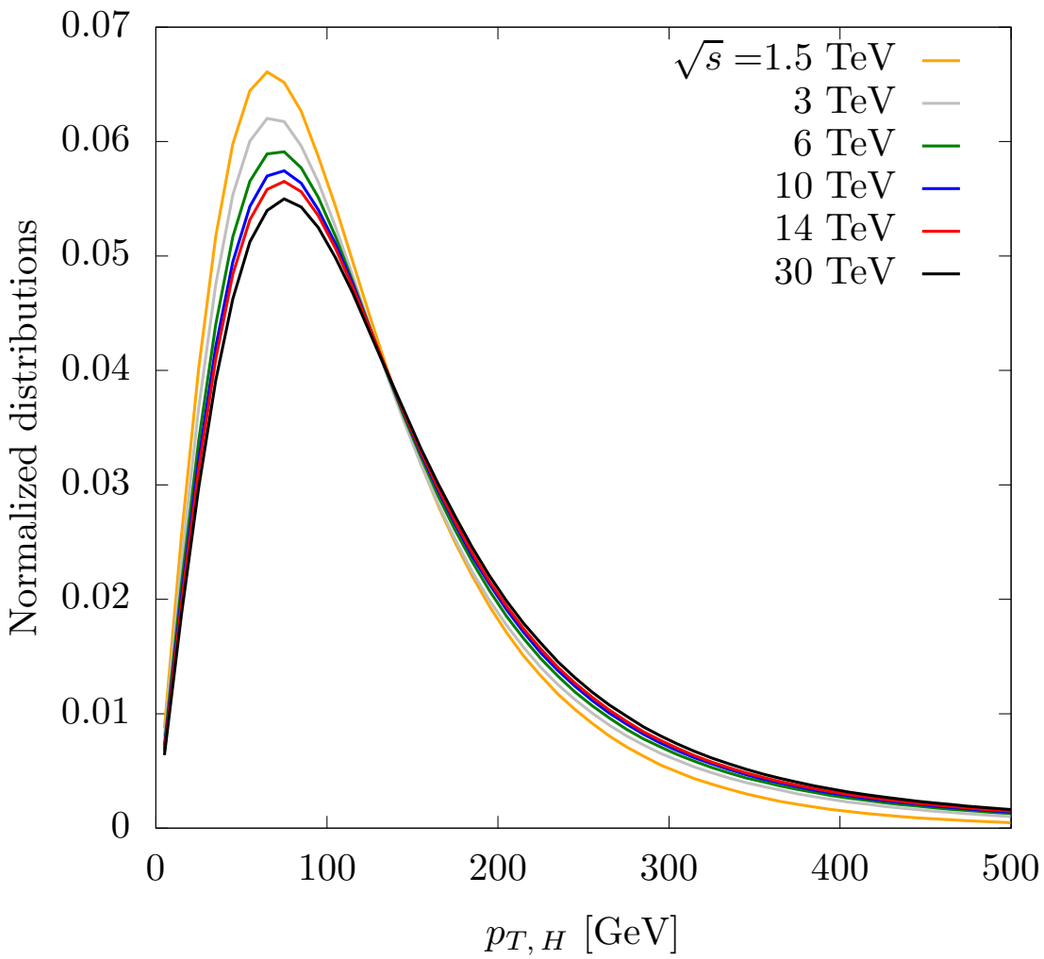
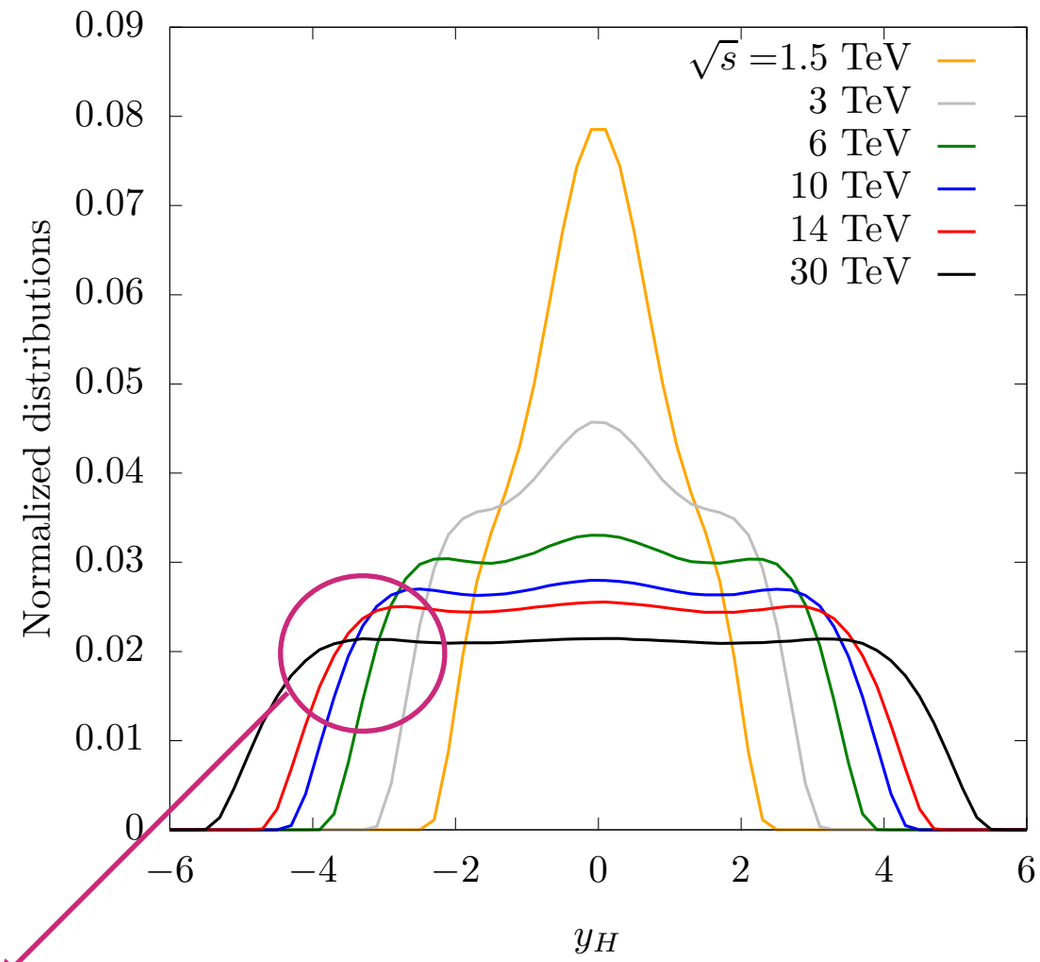
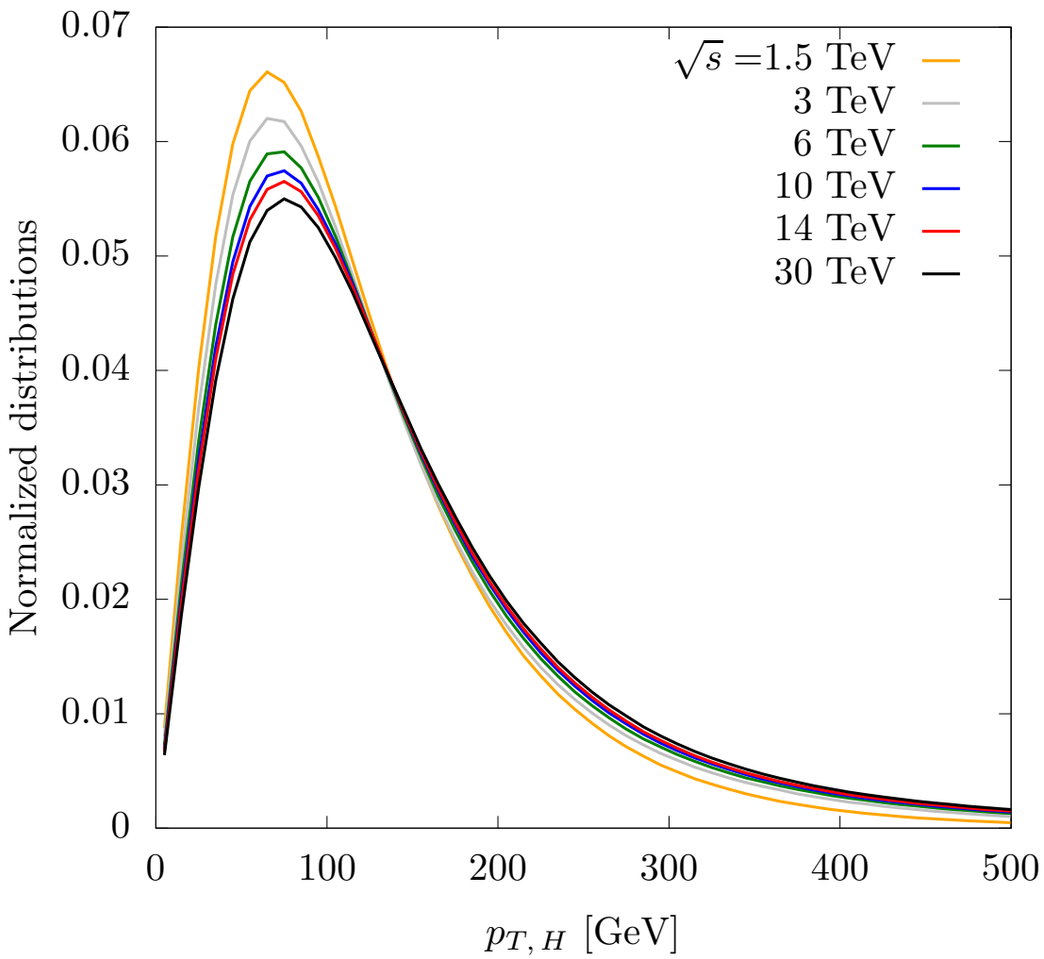


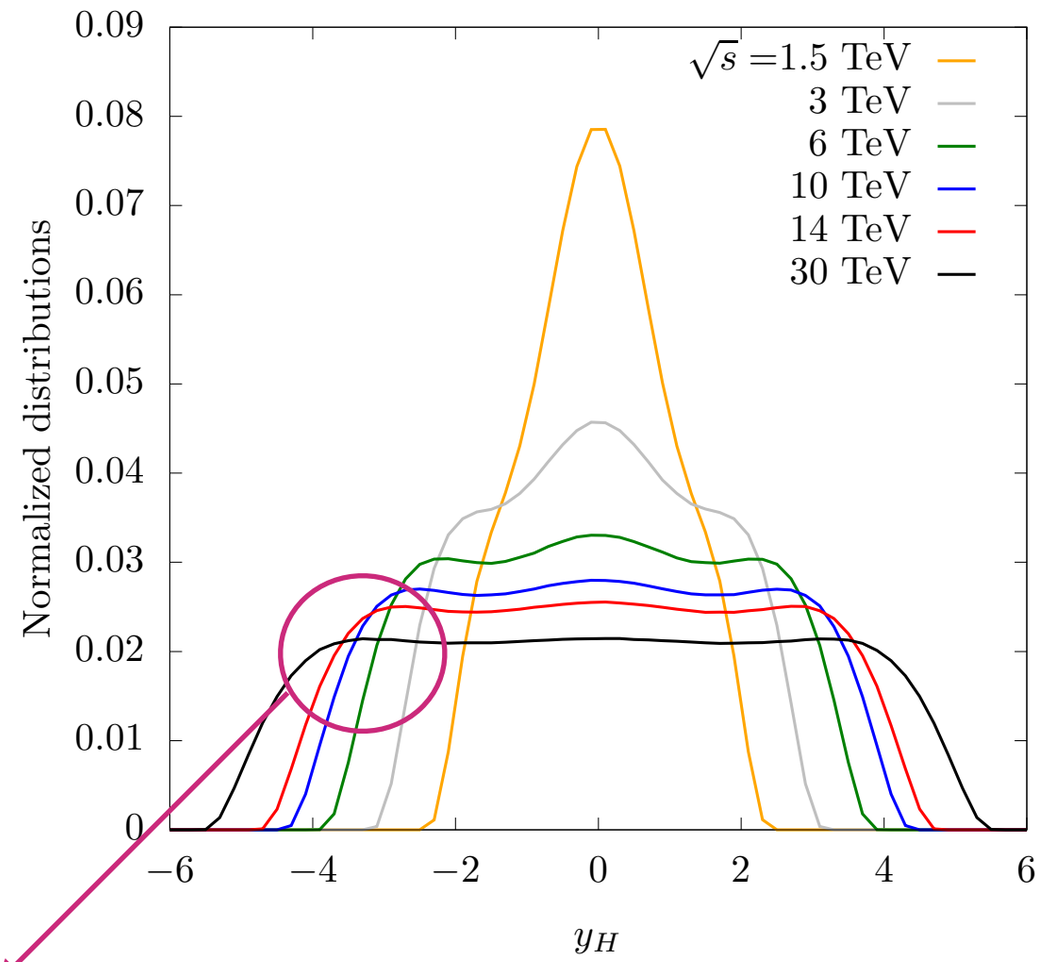


Production in forward region at high energy!

SM distributions

Luca Mantani





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Detector studies have shields in the forward region due to beam-induced background

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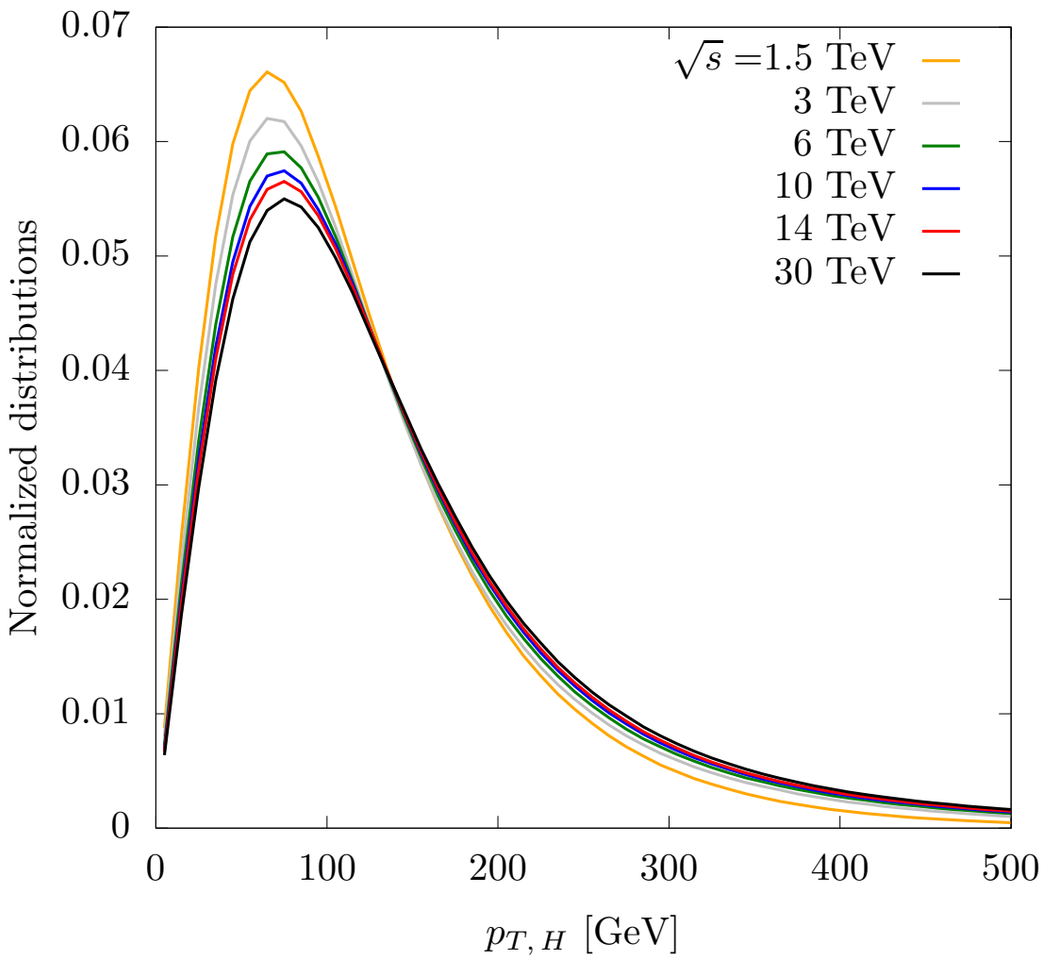

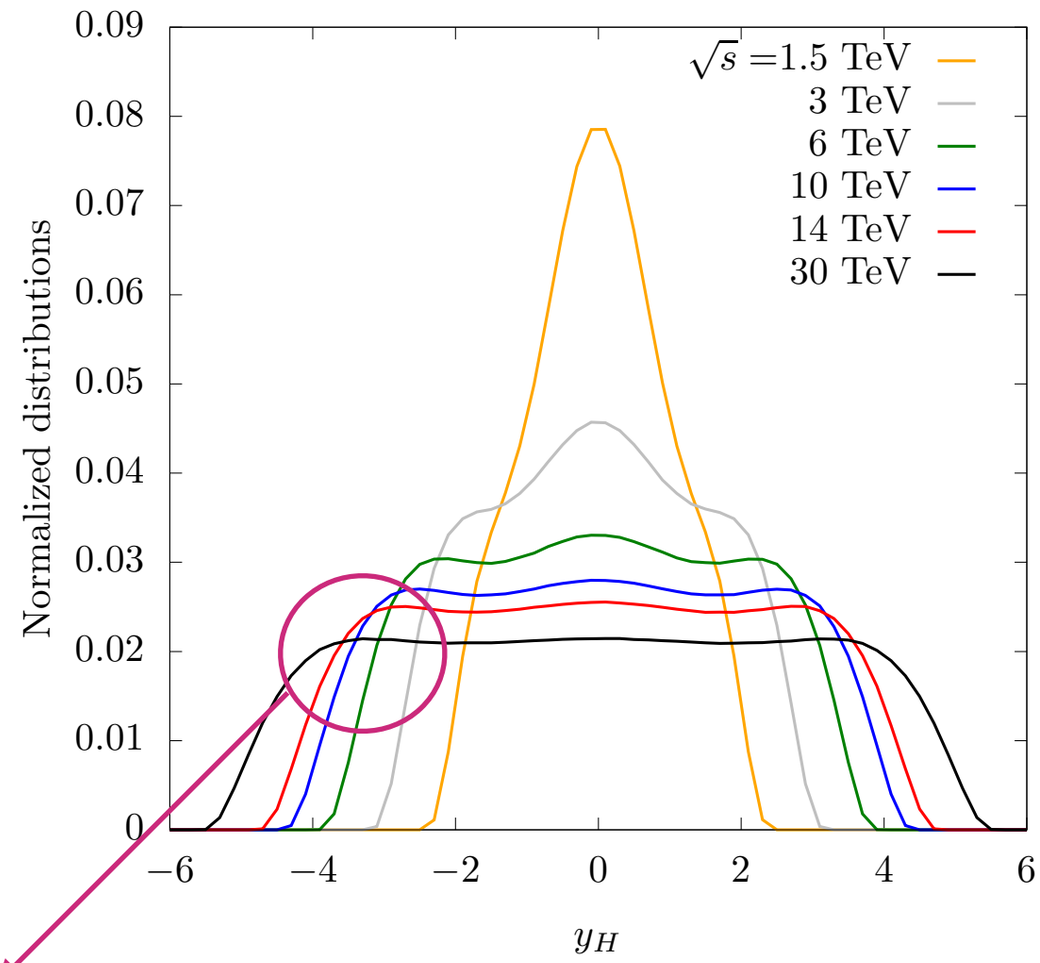

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Important to have high rapidity coverage

$$|\eta| < 5$$
$$p_T^b > 20\text{GeV}$$
$$A \sim 60 - 70\%$$

$$\frac{S}{\sqrt{B}} = \frac{|\mathcal{L} \cdot (\sigma - \sigma_{SM})|}{\sqrt{\mathcal{L} \cdot \sigma_{SM}}} \leq 1$$

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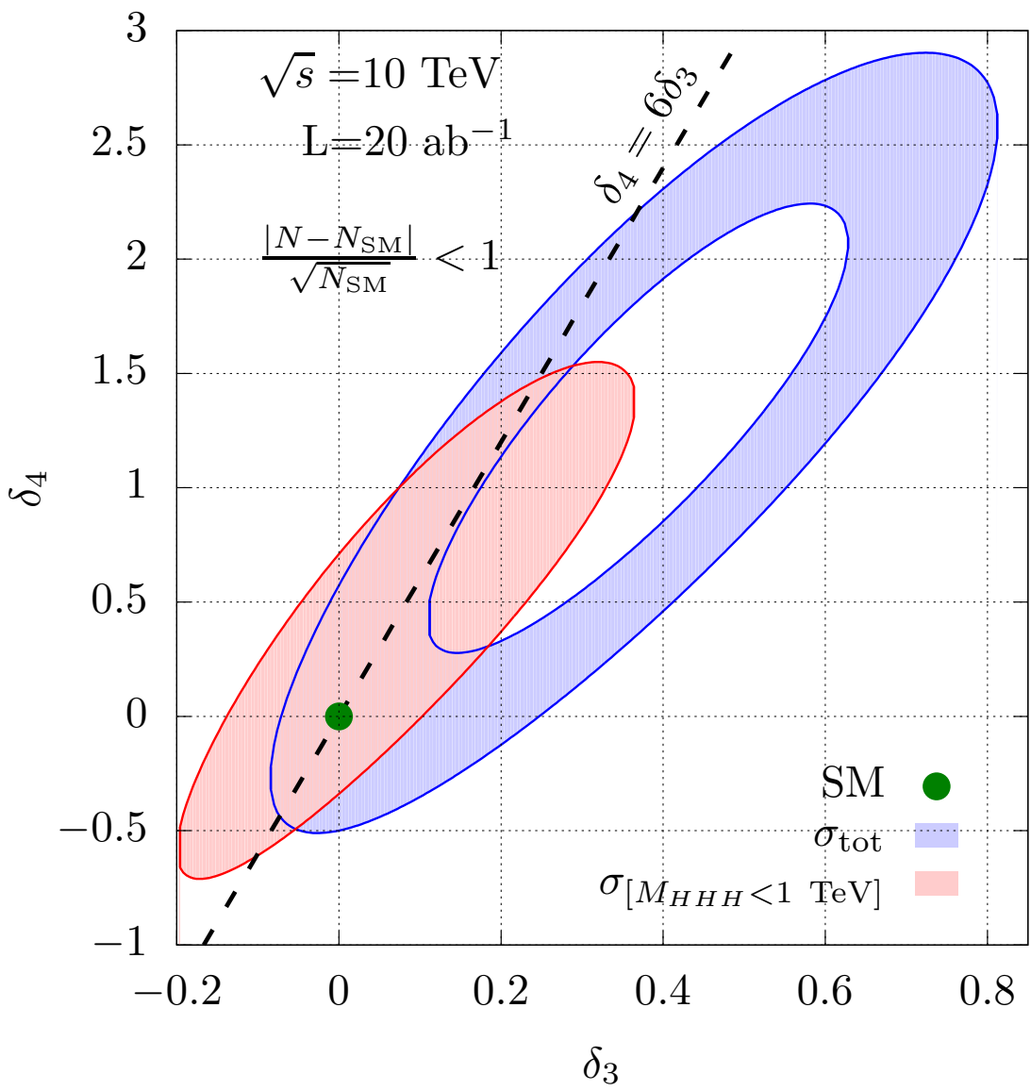

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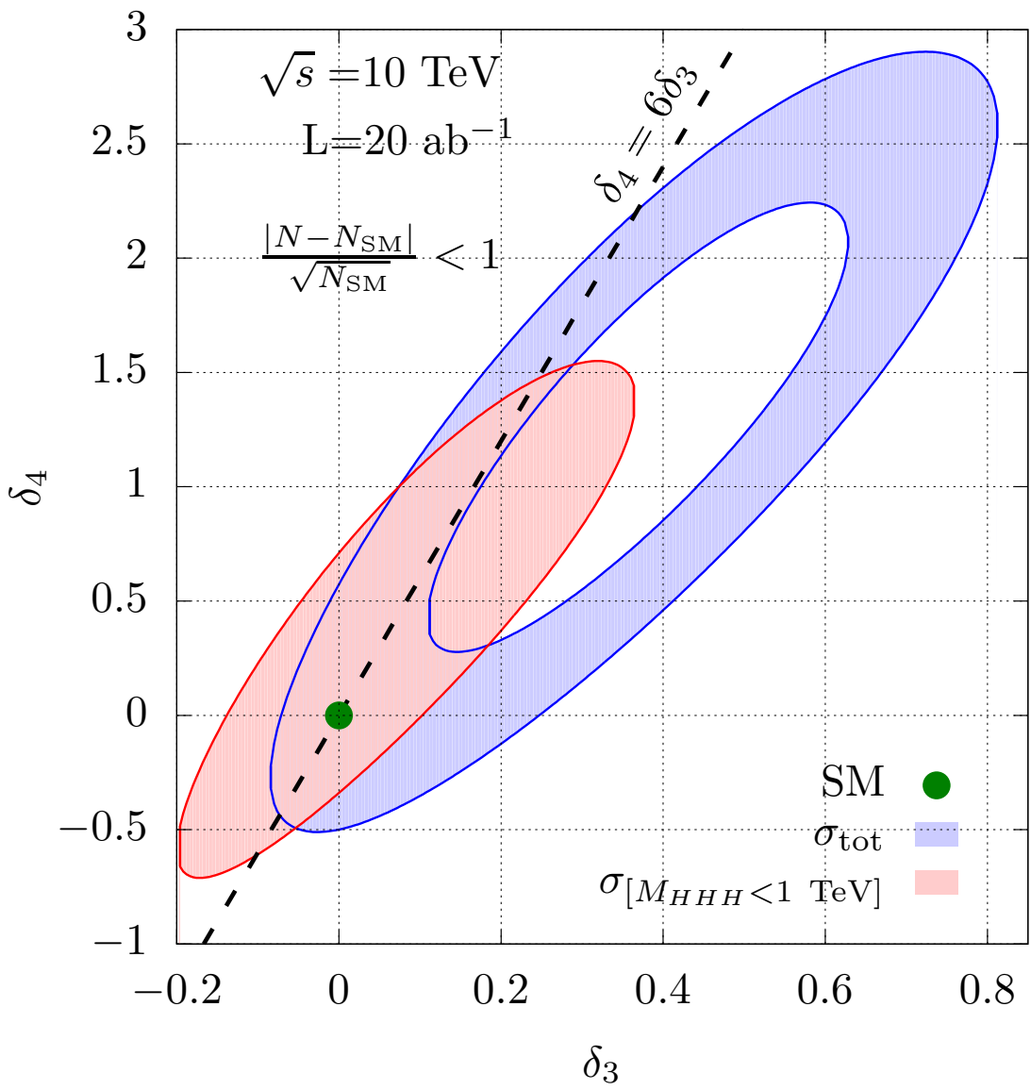

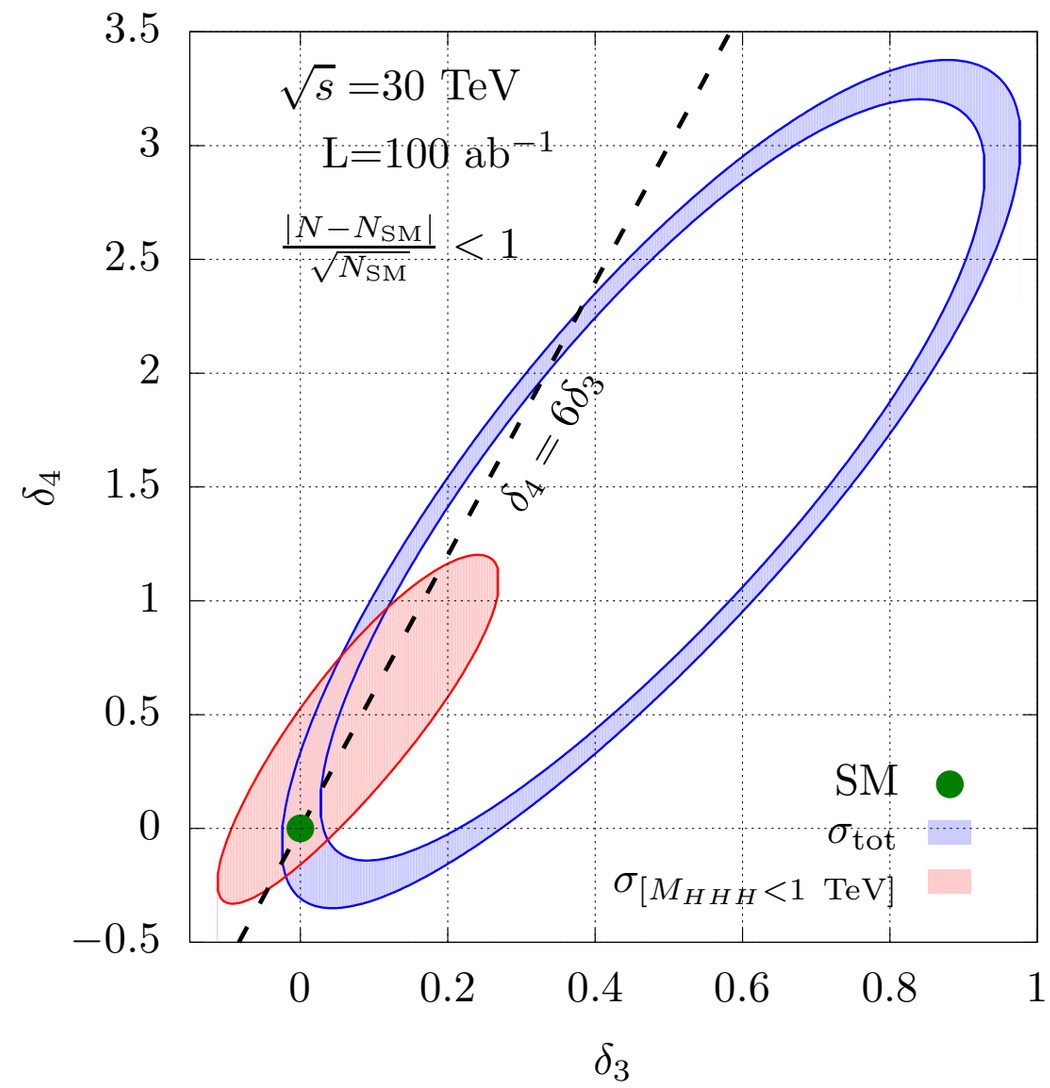

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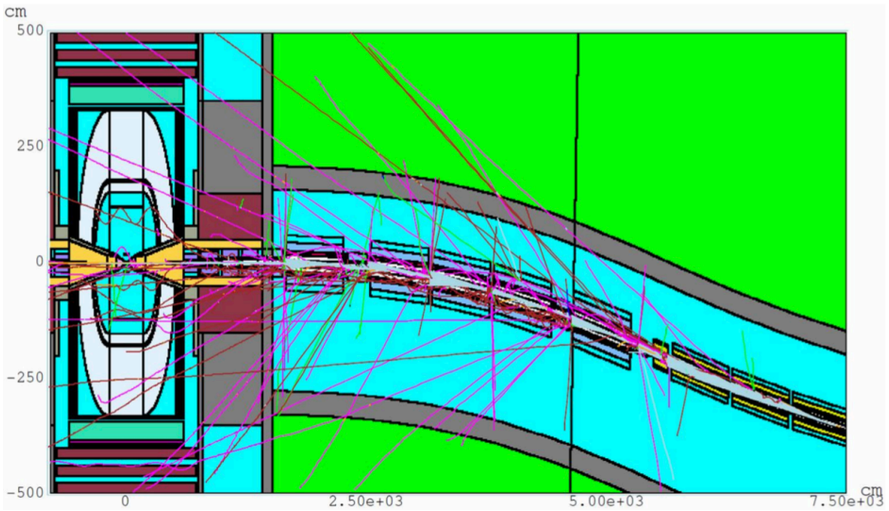
Rapidity coverage



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Detector must be shielded from beam radiation

5-10 degrees blind spot at 3 TeV

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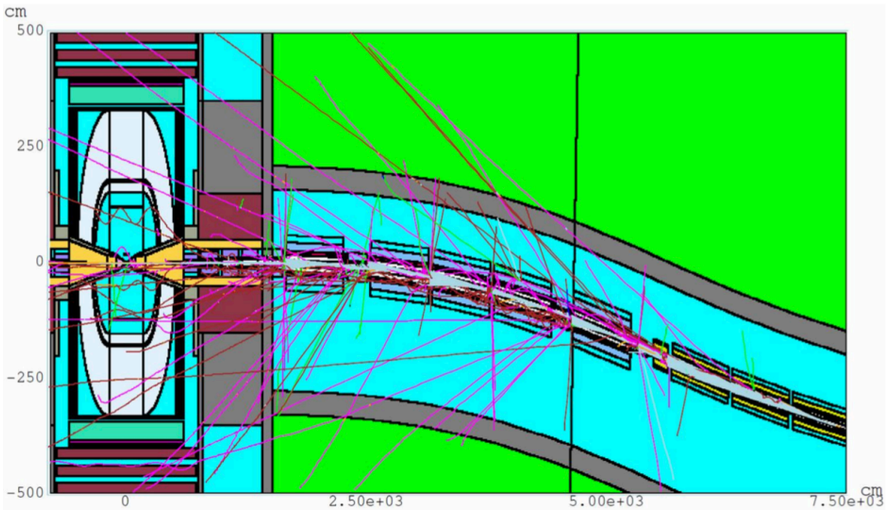

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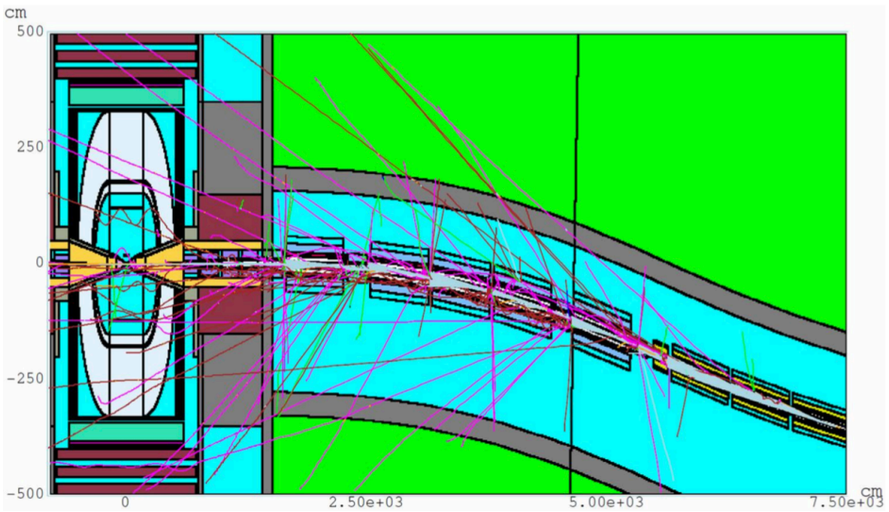
Luca Mantani



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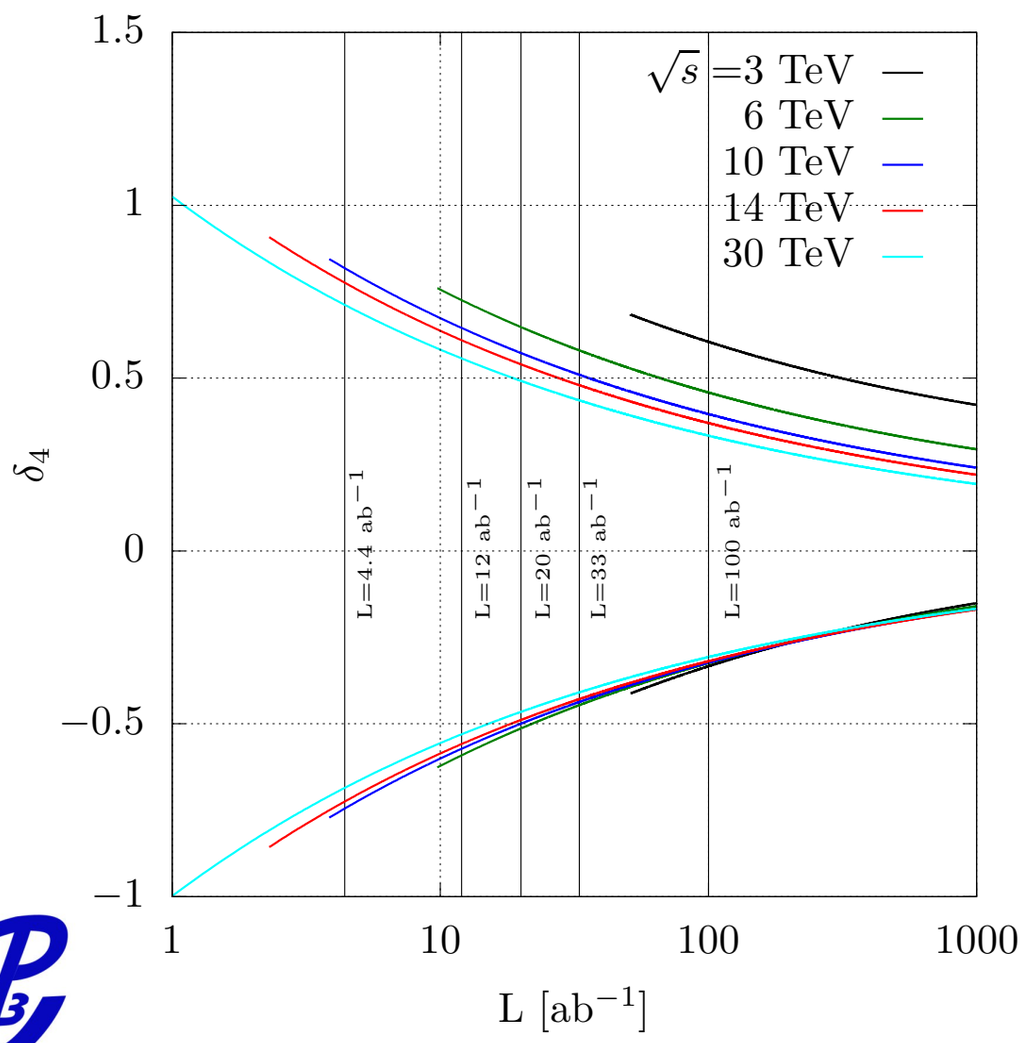

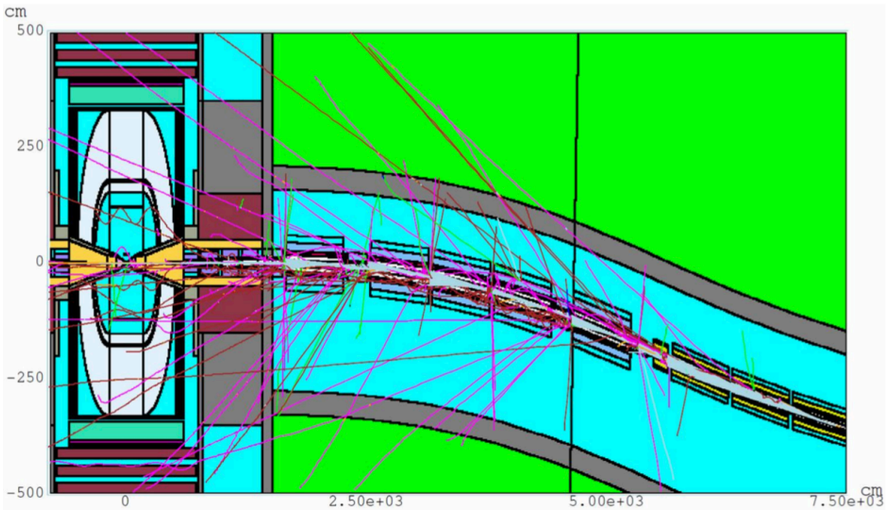

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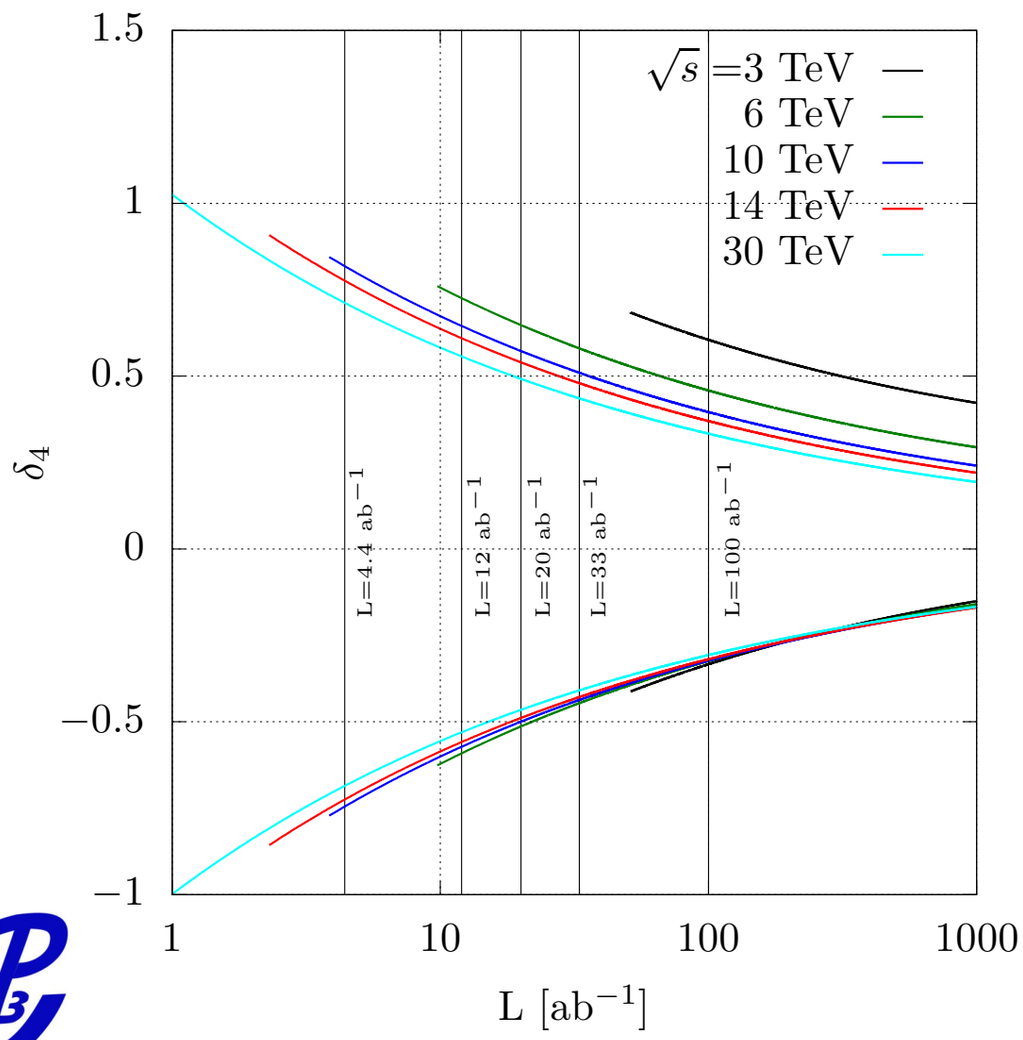

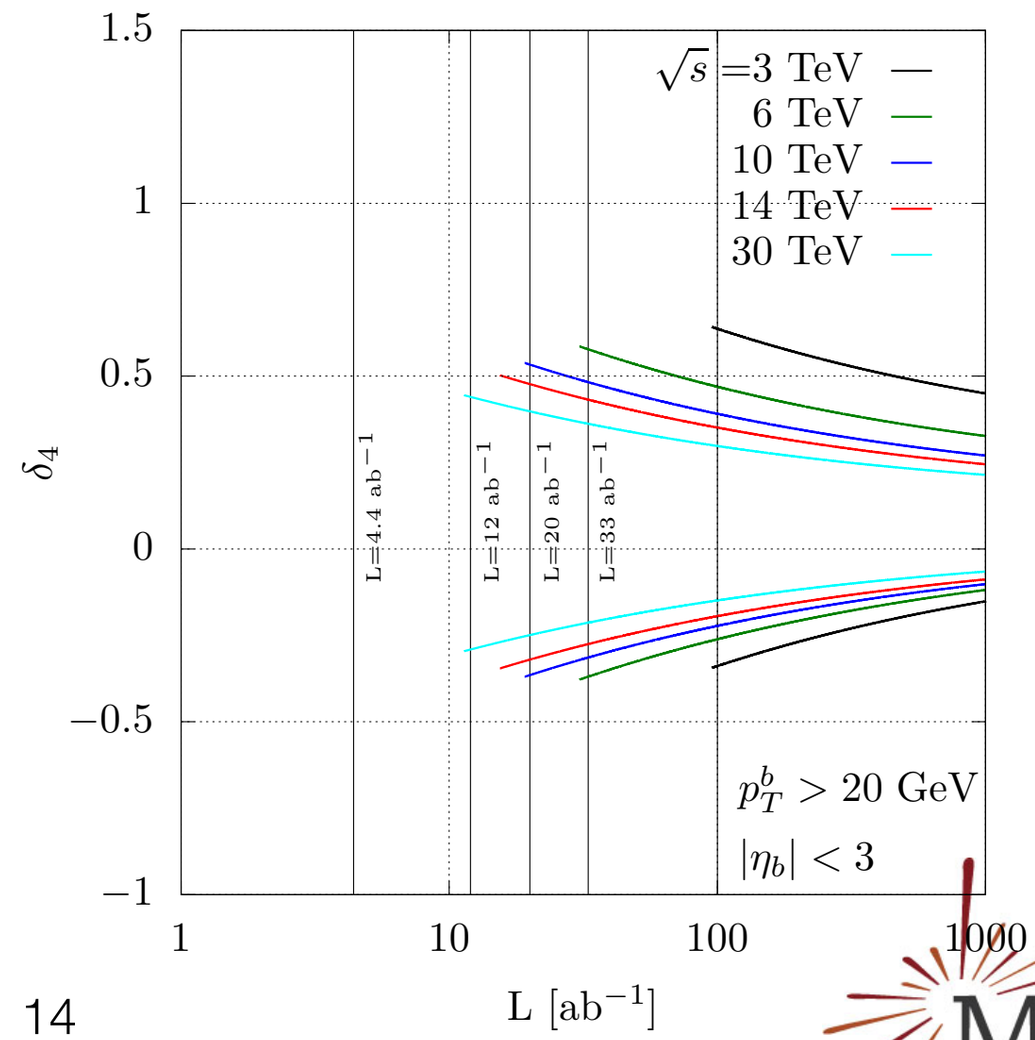

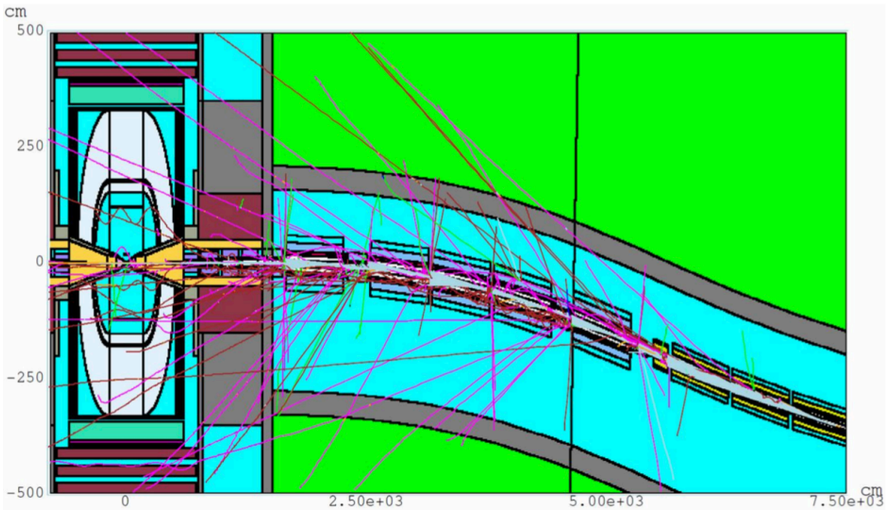

Nozzles:
Detector must be shielded from beam radiation

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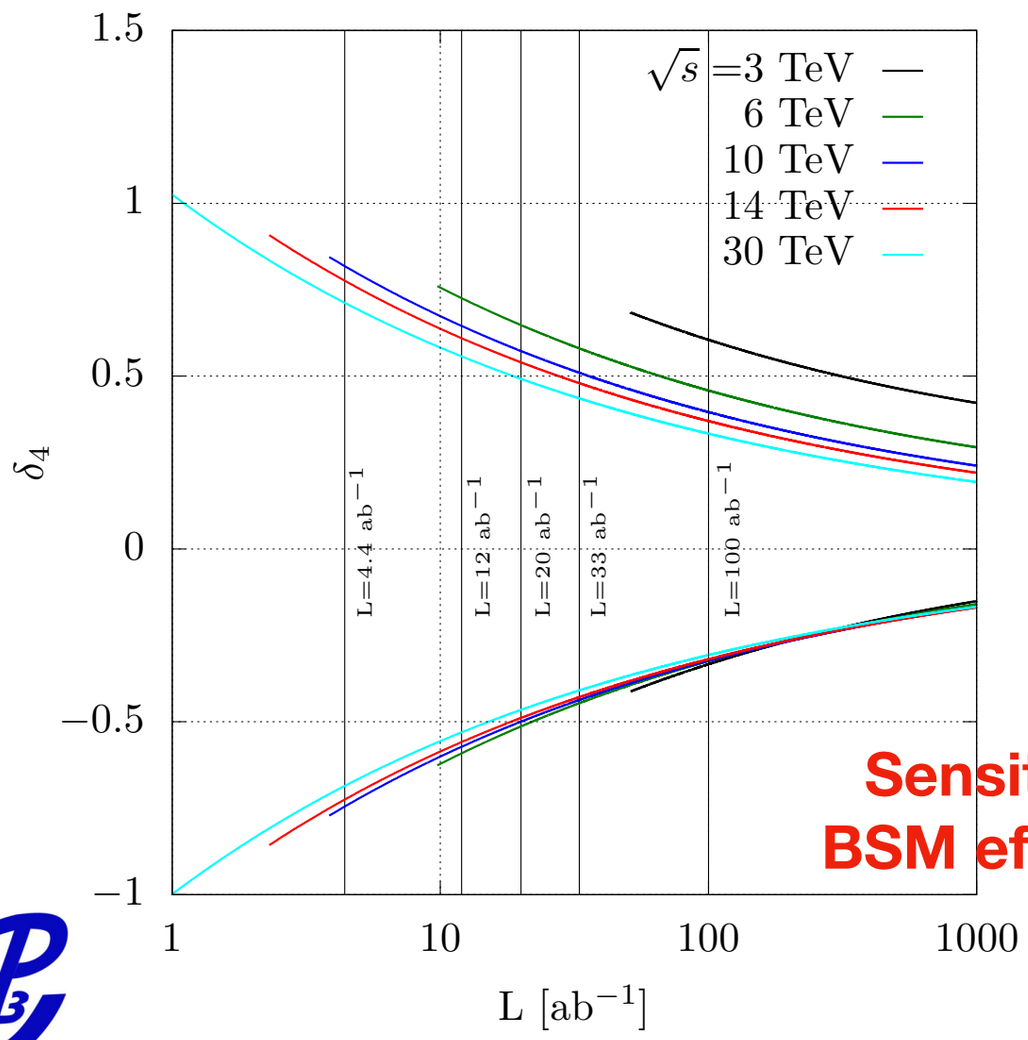

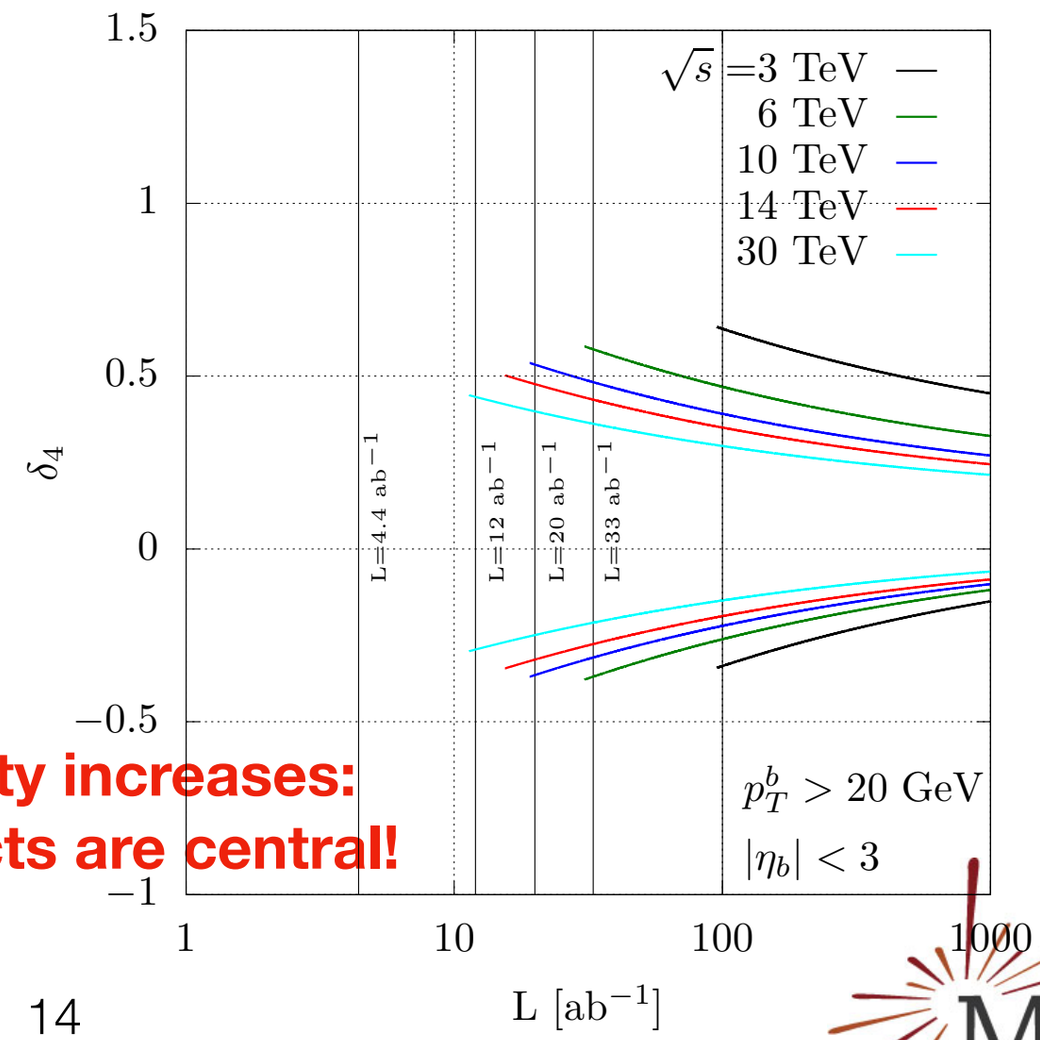

Sensitivity increases:
BSM effects are central!

Conclusions

- **Muon collider is a dream machine**
- **Both precision and discovery potential are top notch**
- **A multi-TeV machine would be effectively a EW boson collider**
- **Projected to be better than every proposed collider to measure the Higgs self interaction**
- **For the quartic coupling, factor ~10 improvement over FCC**
- **No background or optimisation on kinematics was performed**

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Thanks!