Higgs $H \to \gamma\gamma$ sensitivity extrapolation

A crude back-of-the envelope exercise

Marco Delmastro
CNRS/IN2P3 LAPP

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A back-of-the-envelope extrapolation

$$\frac{\mathcal{S}(\sqrt{s_2},\mathcal{L}_2)}{\mathcal{S}(\sqrt{s_1},\mathcal{L}_1)} = \sqrt{\frac{\mathcal{L}_2}{\mathcal{L}_1}} \times \frac{\sigma_S(\sqrt{s_2})}{\sigma_S(\sqrt{s_1})} \Bigg/ \sqrt{\frac{\sigma_B(\sqrt{s_2})}{\sigma_B(\sqrt{s_1})}}$$

- Idea: estimate increase in sensitivity from cross section evolution only
- **This is extremely crude!**
  - ✓ Assume same detector performance…
  - ✓ **Assume all backgrounds scale with same factor**
    - Might not be true for al channels
    - It's certainly not true for ttH categories with ttbar background
  - ✓ Even under the hypothesis of identical detector performance, **phase space for signal and background will be different** (e.g. PDF evolution)…
  - ✓ Things can get even more complicated with high S/B channels (e.g. H→4l)
- I gave the idea a try with a "simple" channel (H→γγ)…

Higgs cross section evolution

- https://twiki.cern.ch/twiki/bin/view/LHCPhysics/HiggsEuropeanStrategy
  - ✓ It might not be the most up-to-date…

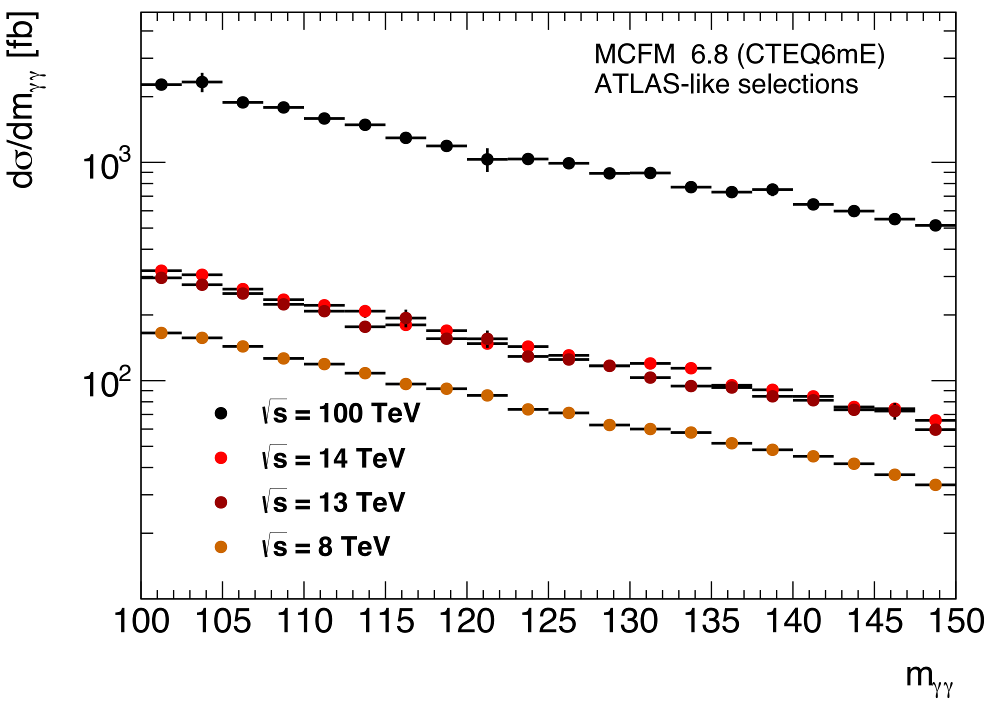
Xsec [pb]	8 TeV	14 TeV	33 TeV	40 TeV	60 TeV	80 TeV	100 TeV
ggH	19.120	50.350	178.300	231.900	394.400	565.100	740.300
VBF	1.573	4.400	16.500	23.100	40.800	60.000	82.000
WH	0.695	1.630	4.710	5.880	9.230	12.600	15.900
ZH	0.410	0.904	2.970	3.780	6.190	8.710	11.260
ttH	0.128	0.623	4.560	6.790	15.000	25.500	37.900
bbH	0.208	0.581	2.130	2.770	4.690	6.650	8.640
gg HH		0.034	0.207	0.298	0.609	0.980	1.420

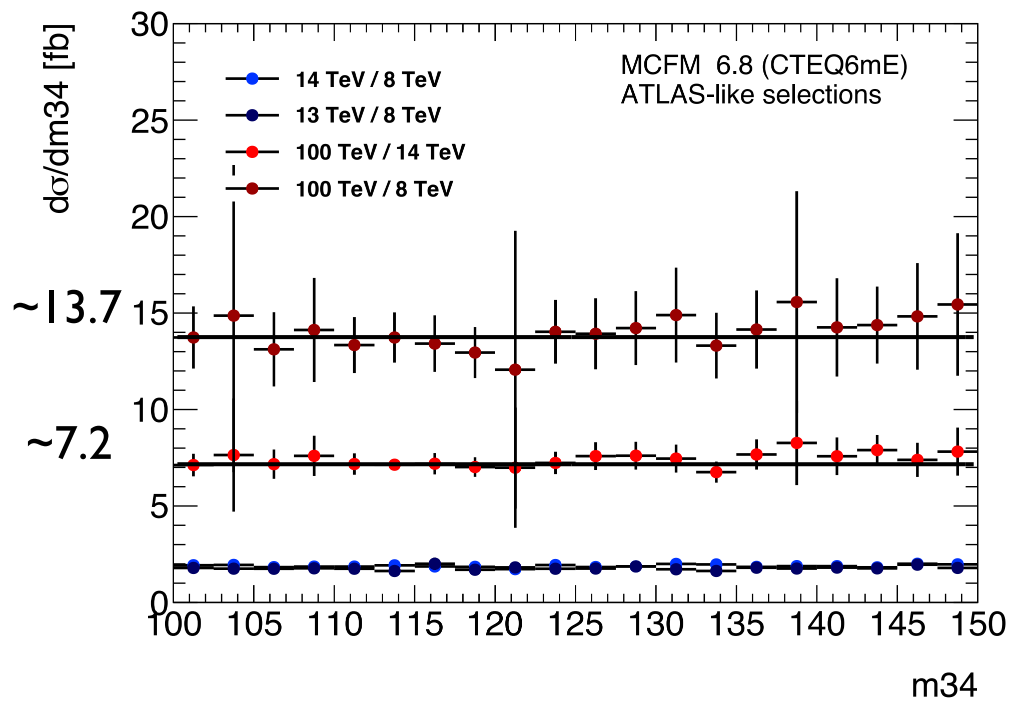
14/8	100/8	100/14
2.6	38.7	14.7
2.8	52.1	18.6
2.3	22.9	9.8
2.2	27.5	12.5
4.9	296.8	60.8
2.8	41.6	14.9
		42.0

- ✓ ggH production increase
  - 8 TeV → 100 TeV : ~40
  - 14 TeV → 100 TeV: ~15
- ✓ VBF and ttH production modes have larger gain factors (phase space opening)…
  - … but both will need real analysis treatment!
- ✓ ggHH have ~40 increase factor 14 TeV → 100 TeV
  - … looks interesting to be studied wrt to HL-LHC

H→γγ background evolution

- Backgrounds (fraction in ATLAS 8 TeV H→γγ): **γγ** (77%), **γj** (20%), **jj** (3%)
  - ✓ Caveat: fraction can change coording to identification/rejection perfomance
  - ✓ ttbar background relevant for ttH/H→γγ category, ignored here
- Cross-section ratio 8 TeV / 14 TeV
  - ✓ **γγ : ~1.9** (dominant, given all caveats I will only consider this for now)
  - ✓ **γj and jj : ~2.1** (not so different, but things could evolve differently at 100 TeV: to be checked)
- γγ cross-section (average) ratios using MCFM
  - ✓ 500k events per c.m. energy point
  - ✓ Fixed scales ($\mu_{ren} = \mu_{fac} = \mu_{frag}$ = 80 GeV) (is this the correct way to do it, especially at 100 TeV?)



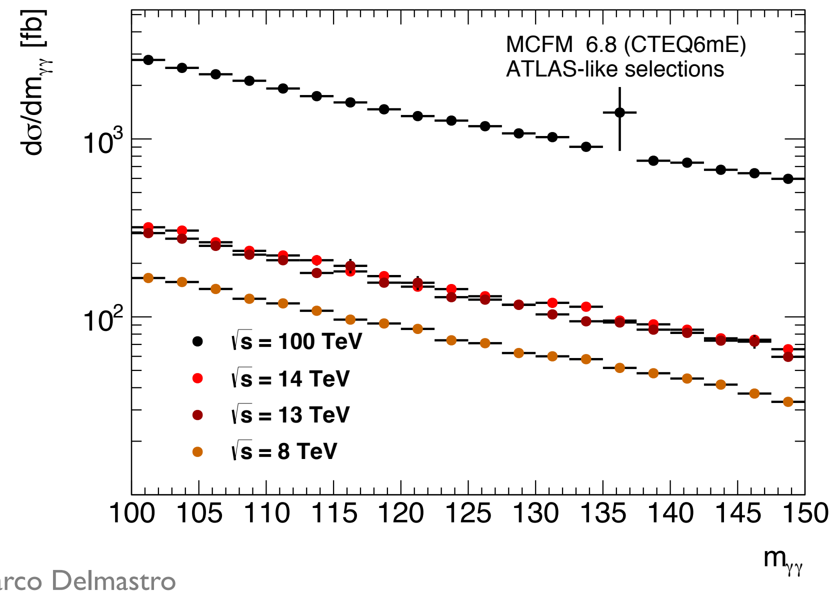


Significance increase factor

$$\frac{\sigma_S(\sqrt{s_2})}{\sigma_S(\sqrt{s_1})} \Big/ \sqrt{\frac{\sigma_B(\sqrt{s_2})}{\sigma_B(\sqrt{s_1})}}$$

	S (ggH)	B (γγ)	Increase factor
100 TeV/ 14 TeV	14.7	7.2	5.5
100 TeV/ 8 TeV	38.7	13.7	10.5
14 TeV / 8 TeV	2.6	1.9	1.8

- Using "fixed-scale" background simulation
- Equivalent Luminosity to get same significance with 8 TeV data (~20 fb^{-1})
  - ✓ 14 TeV → ~ 6 fb^{-1}
  - ✓ 100 TeV → ~ 0.2 fb^{-1}
- With dynamic scales ($\mu_{ren} = \mu_{fac} = \mu_{frag} = m_{\gamma\gamma}$):



	S (ggH)	B (γγ)	Increase factor
100 TeV/ 14 TeV	14.7	8.6	5.1
100 TeV/ 8 TeV	38.7	16.3	9.6

Questions…

- Is it worth to proceed with this approach (and its limitations)? What direction?
  - ✓ Try to have a look to VBF and ttH categories?
  - ✓ Background evolution might be tricky to get (e.g. $\gamma\gamma jj$)

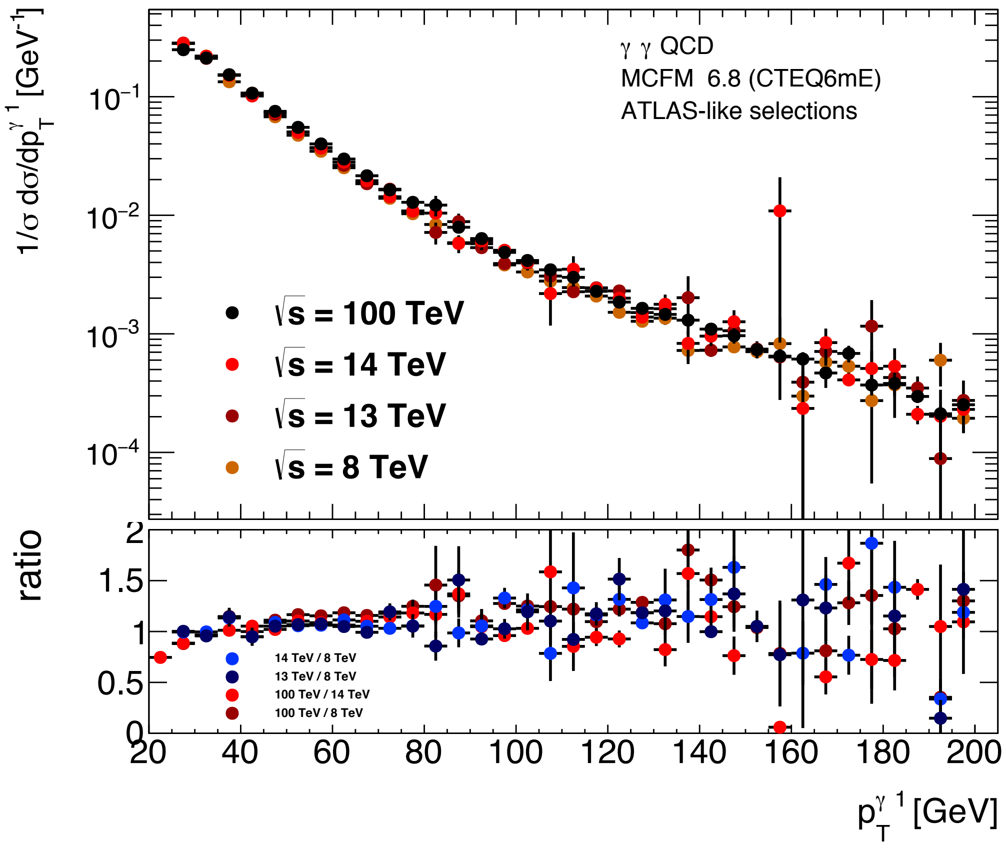
- Where to get different background cross-sections?

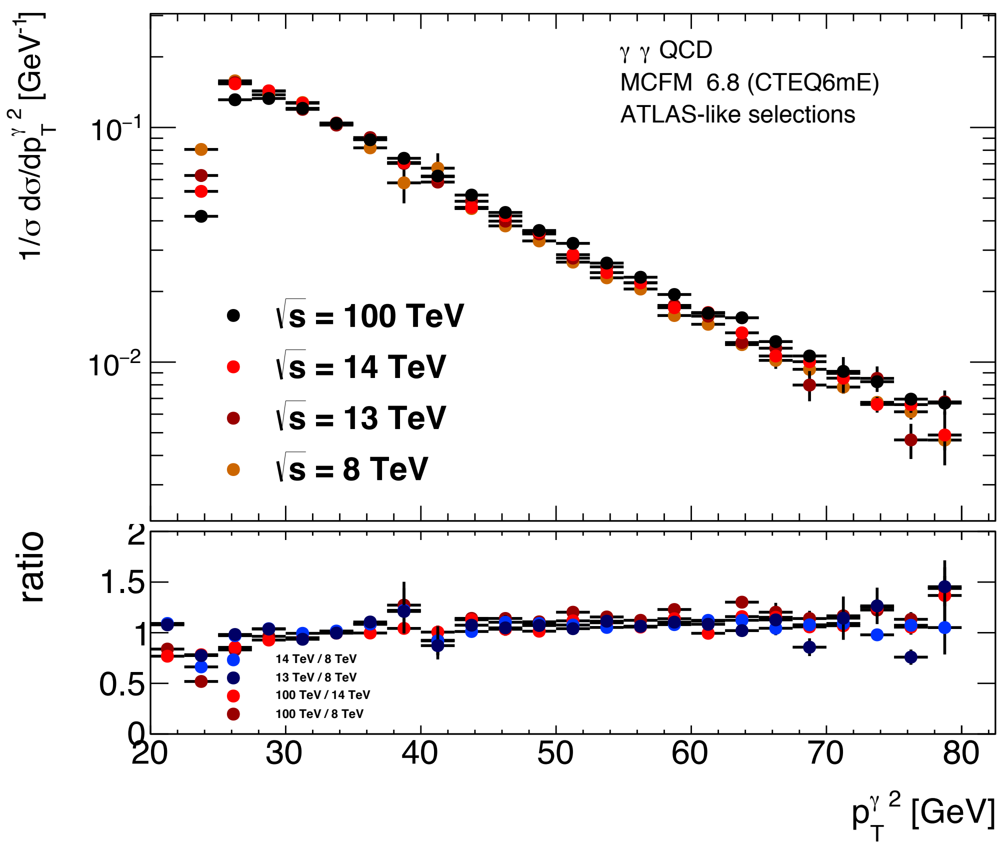
- How do I/we properly generate background process at 100 TeV?
  - ✓ e.g. fixed scales vs. dynamic scales, NLO→NNLO K-factors, …

- Anyway, how far can this approach go?
  - ✓ Would at least need to properly estimate phase space evolution (S *and* B)
  - ✓ Not sure using "more reliable" detector performance would help
    - At that level, a more serious analysis would

Bonus: background phase space evolution

- Background photons somewhat harder at higher c.m. energy
  - ✓ but not much…





Bonus: background phase space evolution

- Background photons somewhat more forward
  - ✓ but not much…