HIGGS PRODUCTION AT THE LHC

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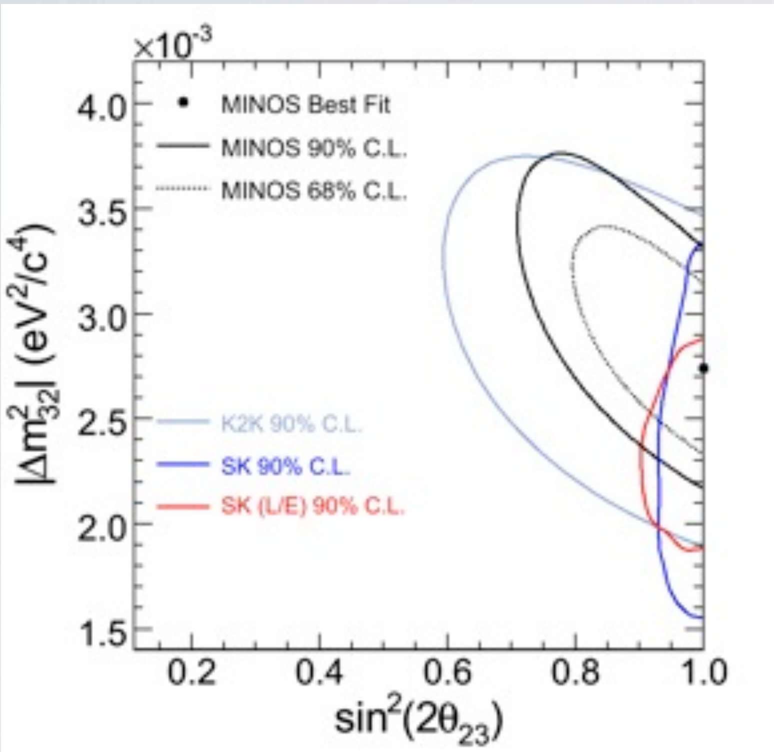
Κολυμπαρι, Κρήτη
Ιούνιος 2012

WHAT DO WE NOT UNDERSTAND WITH THE SM?

Neutrinos have mass



Gravity?

$$F = G\frac{m_1 m_2}{r^2}$$

Dark matter in the universe

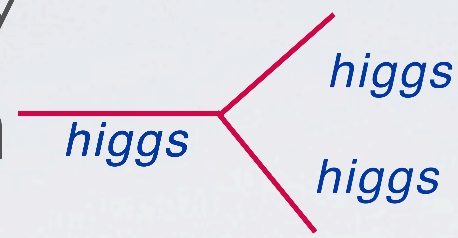
The Standard Model explanation for

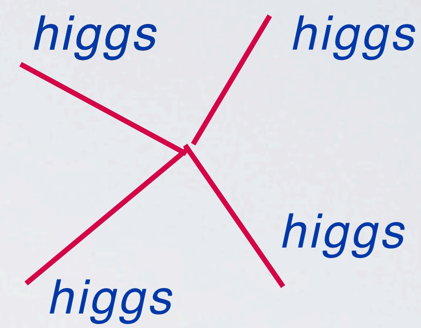
$$M_W, M_Z, M_{top}, \ldots \neq M_\gamma$$

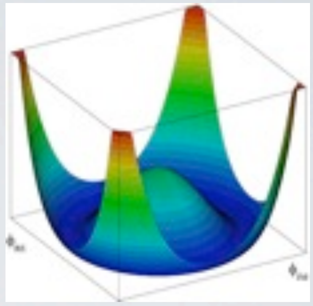
...an untested hypothesis!

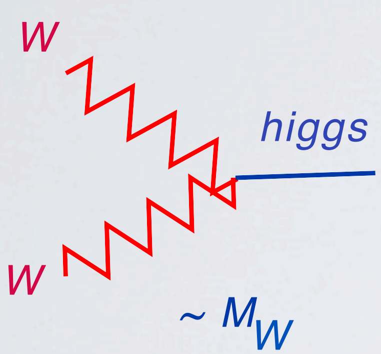
WHAT IS THE HIGGS BOSON?

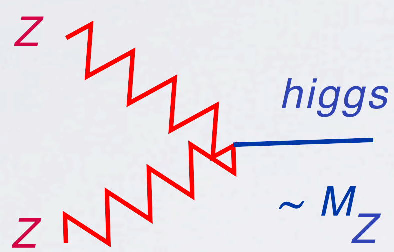
A neutral elementary scalar field which can interact with itself:

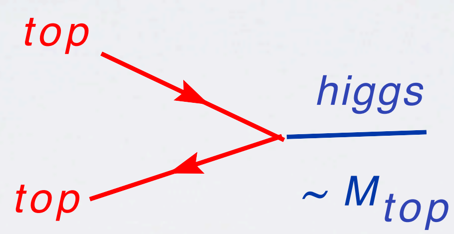










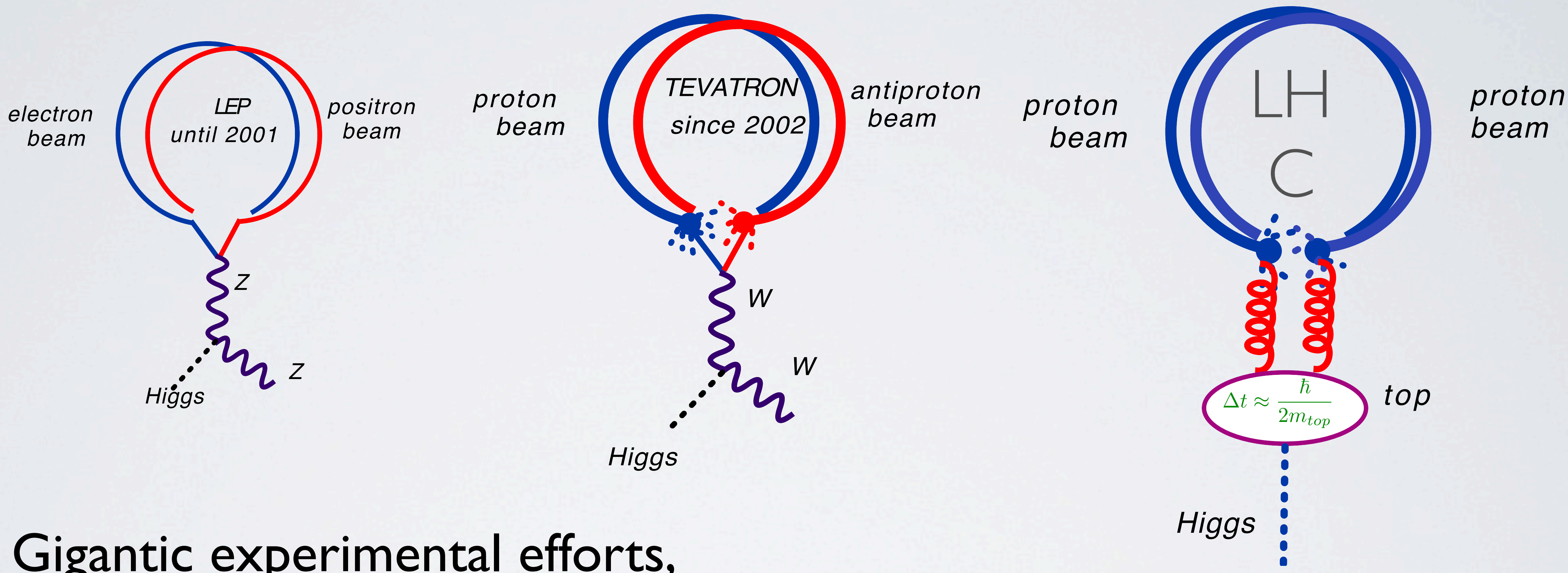


It interacts stronger with short-lived very massive particles

Hard to find since it does not interact at tree-level with the almost massless particles that we know how to collide, i.e.electrons, gluons, up and down quarks

The discovery of the Higgs boson is the main reason for constructing the LHC. ***Anything more is a present of nature that we have not paid the bill for.***

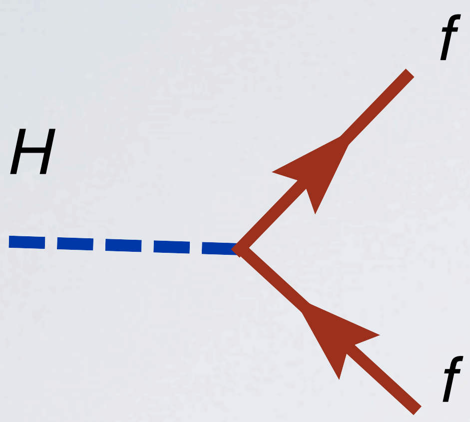
COLLIDERS AND THE HIGGS SEARCH



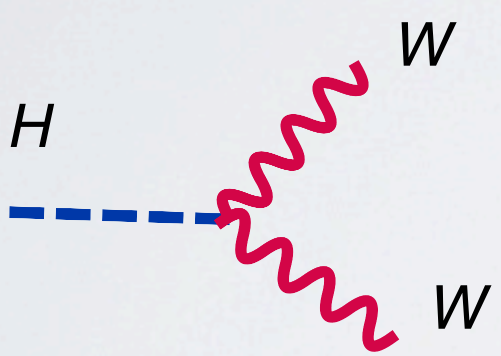
Gigantic experimental efforts,
which primarily aim to discover the Higgs boson.

Elusive particle! Bulk of its interaction creates mass, leaving pale experimental traces.

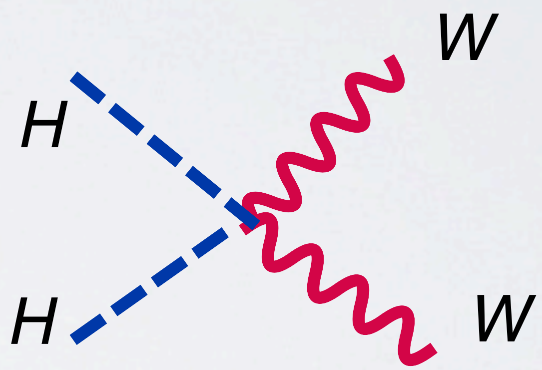
FEYNMAN RULES



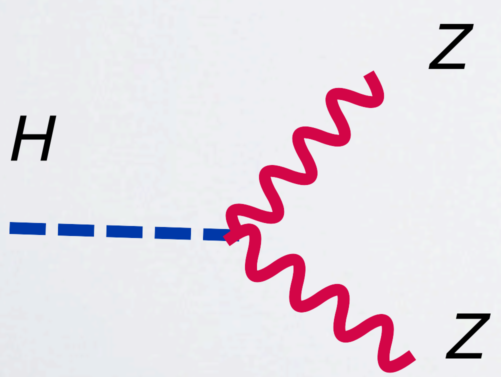
$$i\frac{m_f}{v}\delta_{ij}$$



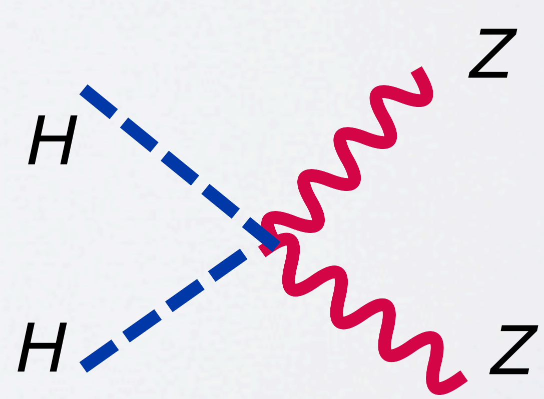
$$2i\frac{M_W^2}{v}g_{\mu\nu}$$



$$2i\frac{M_W^2}{2v}g_{\mu\nu}$$

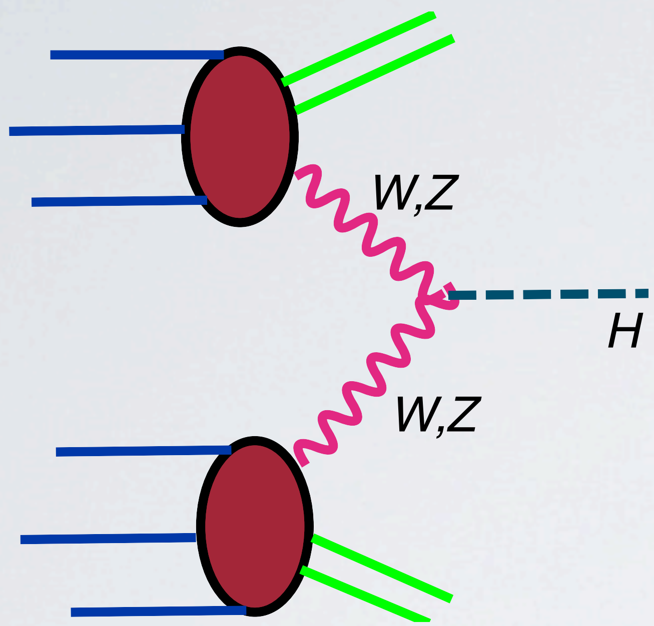


$$2i\frac{M_Z^2}{2v}g_{\mu\nu}$$

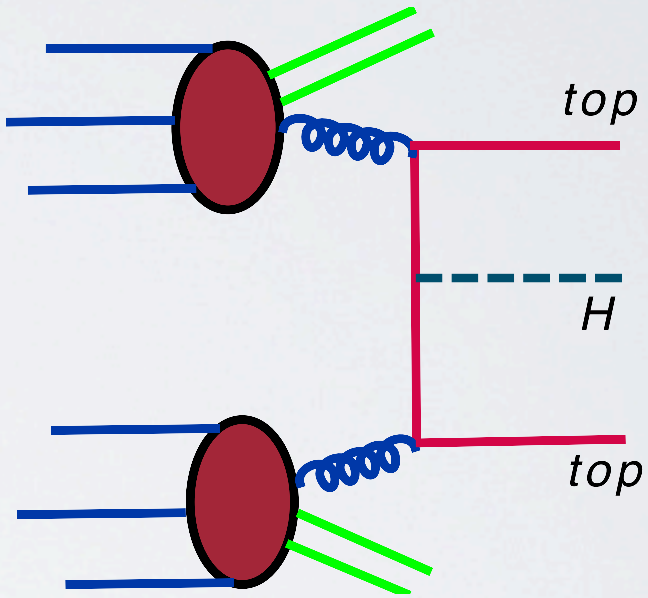


$$2i\frac{M_Z^2}{4v}g_{\mu\nu}$$

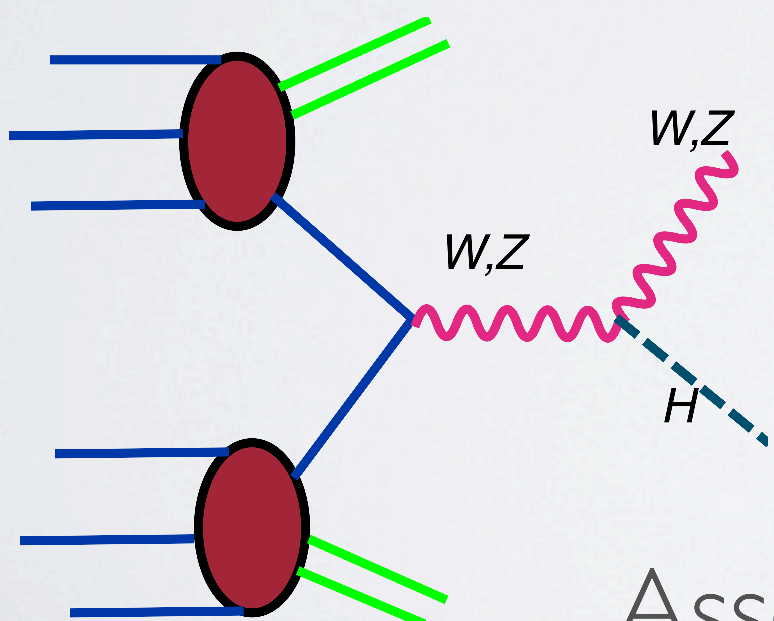
HIGGS HADROPRODUCTION



Weak boson fusion



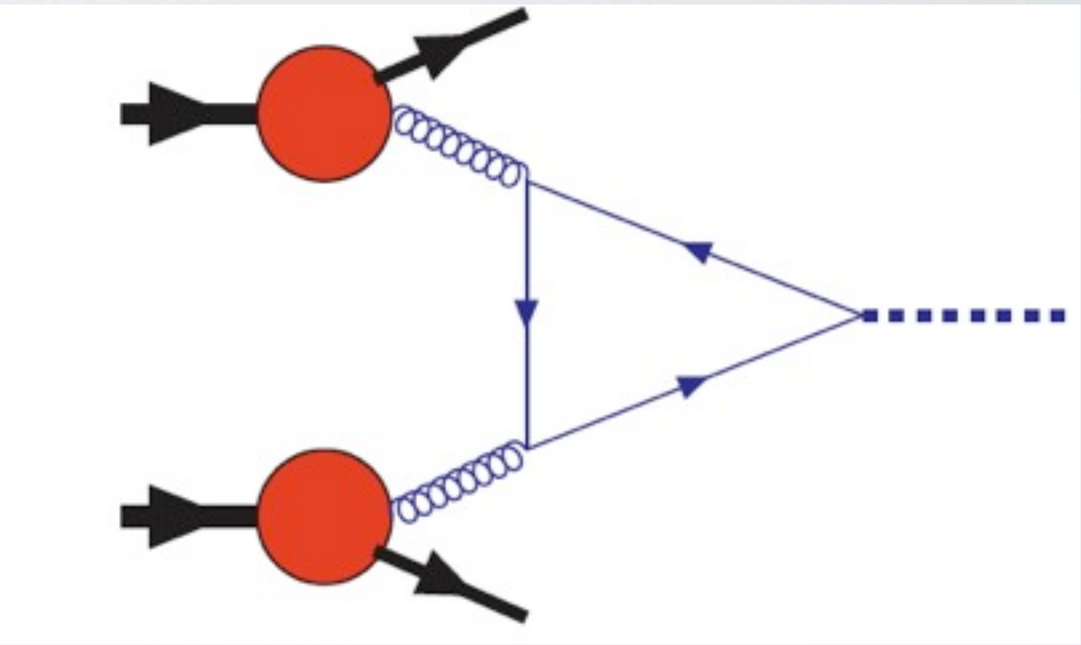
Associated Top pair



Associated Drell-Yan

THE GLUON-FUSION PROCESS

- A loop process
- Sensitive to particles which we may not know about.
- Significant due to the large gluon density in the proton and the large top Yukawa coupling



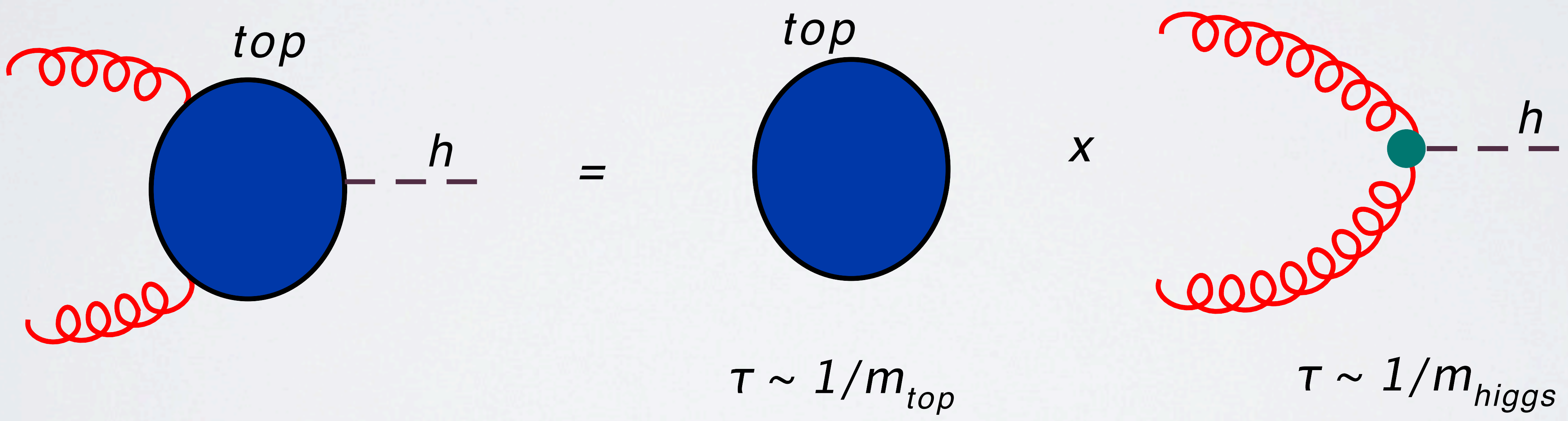
NON-DECOUPLING OF HEAVY STATES

$$\sim \frac{\delta^{ab}}{v}\left[p_1 \cdot p_2 \epsilon_1 \cdot \epsilon_2 - \epsilon_1 \cdot p_2 \epsilon_2 \cdot p_1\right] \alpha_s \times \left[1 + \mathcal{O}\left(\frac{m_H^2}{4M_f^2}\right)\right]$$

The Yukawa coupling compensates for the loop suppression! It costs no more to "tickle" very heavy states since they couple stronger to the Higgs boson

CHARACTERISTIC TIMES

Infinitely heavy internal particles approximation is the limit of zero external to external momenta or slow varying external fields.



Factorization of phenomena at different time-scales

EFFECTIVE THEORY

$$\mathcal{L}_{hgg} = C(m_t)\,\frac{h}{v}\left[-\frac{Z}{4}G^a_{\mu\nu}G^{\mu\nu;a}\right]$$

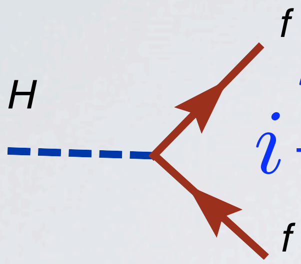
Wilson coefficient C(M)
encapsulates the (heavy)
particle content of the vacuum

Higgs-gluon
operator describes QCD

effects

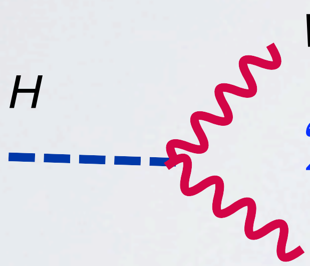
A neat separation of QCD from
the details of the electroweak symmetry
breaking model

THE DECAYS OF THE HIGGS BOSON



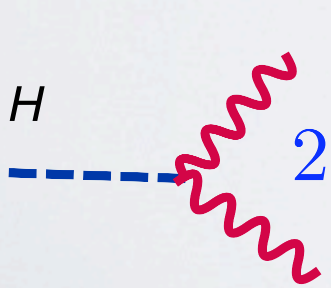
$$i\frac{m_f}{v}\delta_{ij}$$

$$\Gamma\left(H \to f\bar{f}\right) = \frac{M_H}{8\pi}\left(\frac{M_f}{v}\right)^2 N_c \left(1 - \frac{4M_f^2}{M_H^2}\right)^{\frac{3}{2}}$$



$$2i\frac{M_W^2}{v}g_{\mu\nu}$$

$$\Gamma\left(H \to WW\right) = \frac{M_H}{16\pi}\left(\frac{M_H}{v}\right)^2 \left(1 - \frac{4M_W^2}{M_H^2}\right)^{\frac{1}{2}} \times \left[1 - 4\left(\frac{M_W^2}{M_H^2}\right) + 12\left(\frac{M_W^2}{M_H^2}\right)^2\right]$$

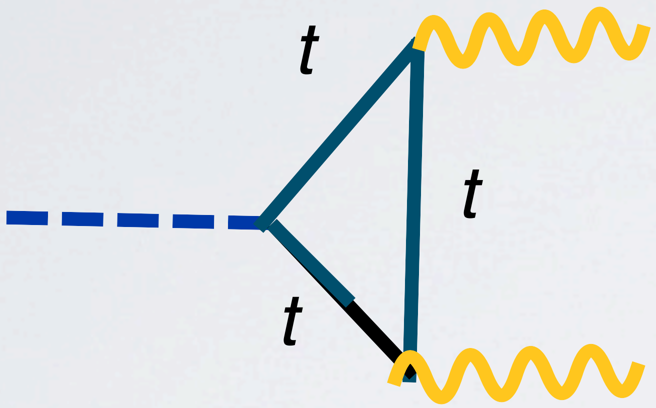


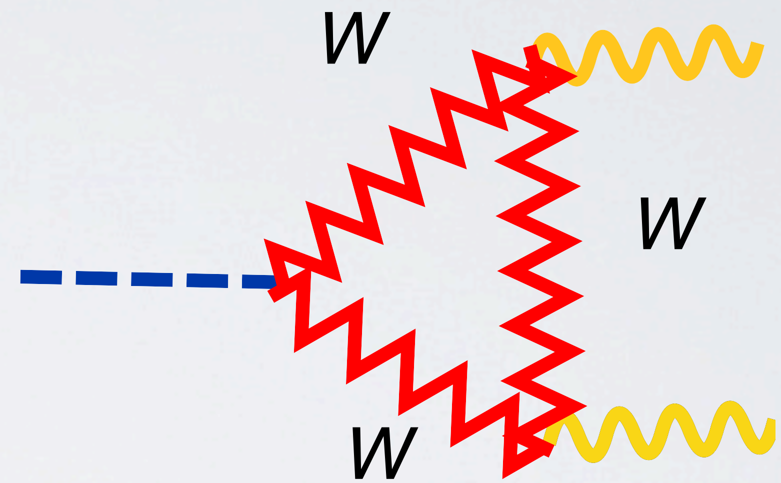
$$2i\frac{M_Z^2}{2v}g_{\mu\nu}$$

$$\Gamma\left(H \to ZZ\right) = \frac{M_H}{32\pi}\left(\frac{M_H}{v}\right)^2 \left(1 - \frac{4M_Z^2}{M_H^2}\right)^{\frac{1}{2}} \times \left[1 - 4\left(\frac{M_Z^2}{M_H^2}\right) + 12\left(\frac{M_Z^2}{M_H^2}\right)^2\right]$$

TWO PHOTON DECAY

Small decay width





(Light Higgs)

$$N_c Q_t^2 (4/3) \qquad\qquad (-7)$$

Probes the electroweak content of the vacuum. Sensitive to new heavy gauge bosons.

SOURCES OF UNCERTAINTY

$$\sigma = \sum_{ij} f_i(x_1) \otimes f_j(x_2) \otimes \sigma_{ij}(\mathcal{L}, E, M_H, \alpha_s, \alpha, M_t, M_b, M_w, M_z, \ldots, \text{“cuts”})$$

- Higher order perturbative corrections (Th)
- Parton densities (Exp + Th)
- Coupling and mass parameters (Exp + Th)
- Model (Th)
- Infrared behavior of cross-sections with colliding energy (Th)
- Infrared behavior of cross-sections with cuts (Exp+Th)

PRECISION OF HIGGS CROSS-SECTIONS

- In general, we have achieved precision of the order of ~10-20% for Higgs cross-sections.
- I would not like to review today the very important computations that were needed for such a level of precision.
- Instead I would like to focus on the most challenging cross-sections, in the gluon fusion channel, which has required many efforts to control its perturbative expansion.

INCLUSIVE HIGGS X-SECTION

- Painstaking checking or recalculation of of virtually all higher order contributions to the cross-section
- Extending it to include consistently non-SM Yukawa couplings (3-loop Wilson coefficient by E. Furlan).
- A beautiful tool for studies of Higgs couplings. Currently relies on manual input or HDECAY for the width and branching ratios. Soon, it will perform an automated calculation of width+BRs in a “SM” with anomalous Higgs couplings.

PREDICTIONS AT 8 TEV

m_H(GeV)	MSTW08 $\sigma(pb)$	$\%\delta_{PDF}$	$\%\delta_{\mu_F}$	ABM11 $\sigma(pb)$	$\%\delta_{PDF}$	$\%\delta_{\mu_F}$
114	24.69	$^{+7.92}_{-7.54}$	$^{+8.83}_{-9.32}$	22.78	$^{+2.28}_{-2.28}$	$^{+8.0}_{-8.85}$
115	24.27	$^{+7.91}_{-7.54}$	$^{+9.07}_{-9.31}$	22.38	$^{+2.29}_{-2.29}$	$^{+7.98}_{-8.84}$
116	23.94	$^{+7.9}_{-7.61}$	$^{+8.75}_{-9.59}$	22.0	$^{+2.29}_{-2.29}$	$^{+8.0}_{-8.83}$
117	23.55	$^{+7.93}_{-7.54}$	$^{+8.64}_{-9.33}$	21.68	$^{+2.29}_{-2.29}$	$^{+7.92}_{-9.05}$
118	23.17	$^{+7.92}_{-7.54}$	$^{+8.6}_{-9.38}$	21.33	$^{+2.3}_{-2.3}$	$^{+7.84}_{-8.84}$
119	22.79	$^{+7.92}_{-7.53}$	$^{+8.55}_{-9.35}$	20.98	$^{+2.3}_{-2.3}$	$^{+7.79}_{-8.87}$
120	22.42	$^{+7.91}_{-7.53}$	$^{+8.53}_{-9.3}$	20.63	$^{+2.3}_{-2.3}$	$^{+7.77}_{-8.85}$
121	22.06	$^{+7.91}_{-7.53}$	$^{+8.51}_{-9.34}$	20.29	$^{+2.3}_{-2.3}$	$^{+7.75}_{-8.82}$
122	21.7	$^{+7.91}_{-7.53}$	$^{+8.47}_{-9.28}$	19.96	$^{+2.31}_{-2.31}$	$^{+7.74}_{-8.82}$
123	21.36	$^{+7.8}_{-7.53}$	$^{+8.42}_{-9.28}$	19.64	$^{+2.31}_{-2.31}$	$^{+7.72}_{-8.86}$
124	21.02	$^{+7.81}_{-7.52}$	$^{+8.41}_{-9.25}$	19.32	$^{+2.31}_{-2.31}$	$^{+7.68}_{-8.81}$
125	20.69	$^{+7.79}_{-7.53}$	$^{+8.37}_{-9.26}$	19.01	$^{+2.32}_{-2.32}$	$^{+7.65}_{-8.82}$
126	20.37	$^{+7.8}_{-7.53}$	$^{+8.35}_{-9.24}$	18.71	$^{+2.32}_{-2.32}$	$^{+7.64}_{-8.8}$
127	20.05	$^{+7.8}_{-7.52}$	$^{+8.34}_{-9.21}$	18.41	$^{+2.32}_{-2.32}$	$^{+7.6}_{-8.84}$
128	19.74	$^{+7.79}_{-7.52}$	$^{+8.3}_{-9.2}$	18.13	$^{+2.33}_{-2.33}$	$^{+7.58}_{-8.79}$
129	19.44	$^{+7.8}_{-7.52}$	$^{+8.28}_{-9.26}$	17.84	$^{+2.33}_{-2.33}$	$^{+7.56}_{-8.79}$
130	19.14	$^{+7.79}_{-7.51}$	$^{+8.24}_{-9.19}$	17.57	$^{+2.33}_{-2.33}$	$^{+7.54}_{-8.84}$

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no_error_flag = 0
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mur/mhiggs :  {0.5,0.25,1.0}
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ProductionMode = gg
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K_ewk_real_b = 1.0
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Y_top = 1.0
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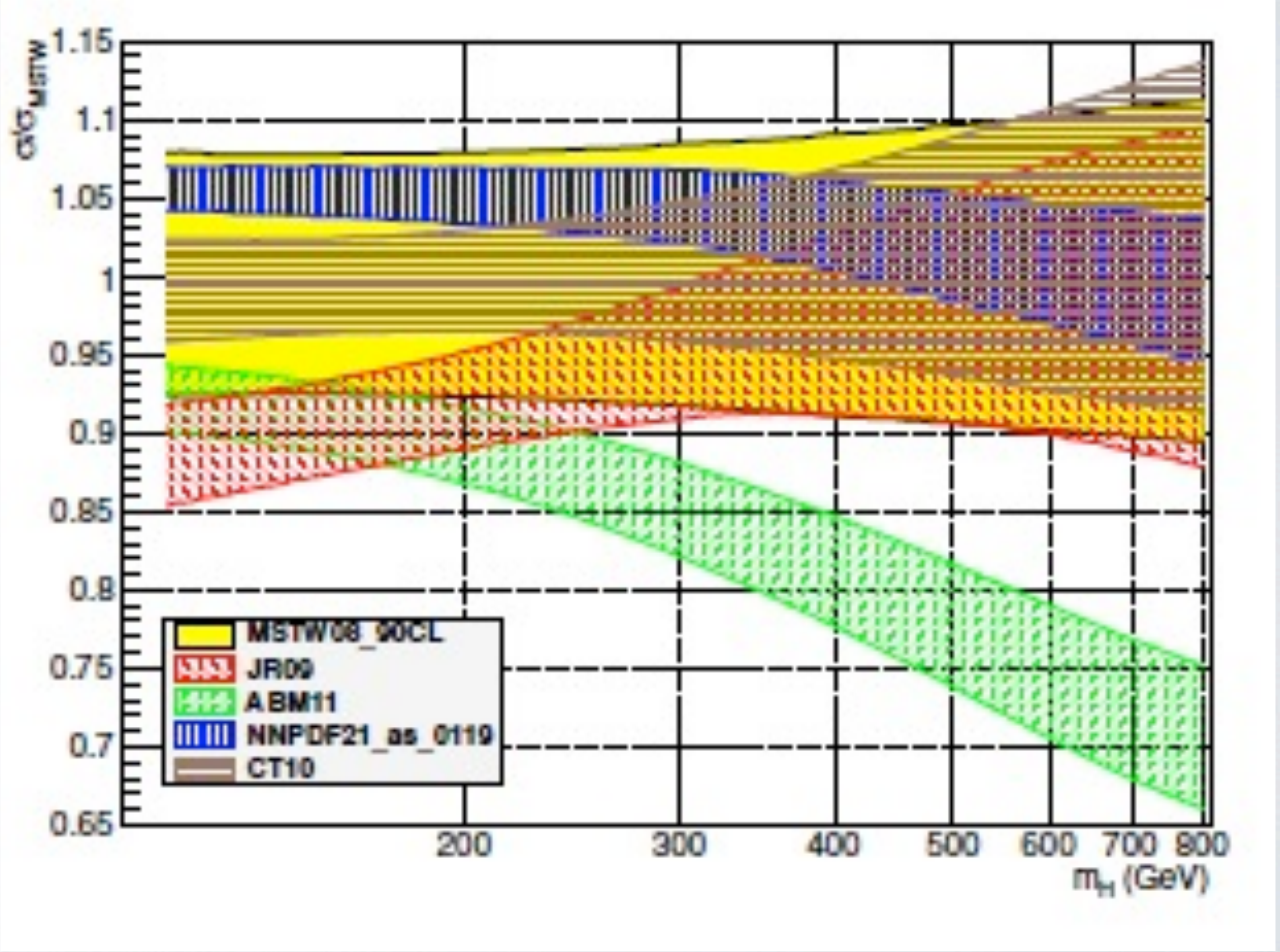
Gamma_bot = 0.0
Y_bot = 1.0
m_Z = 91.1876
Gamma_Z = 2.4952
m_W = 80.403
Gamma_W = 2.141
```

Perturbative uncertainties estimated with scale variations

Uncertainty of parton densities

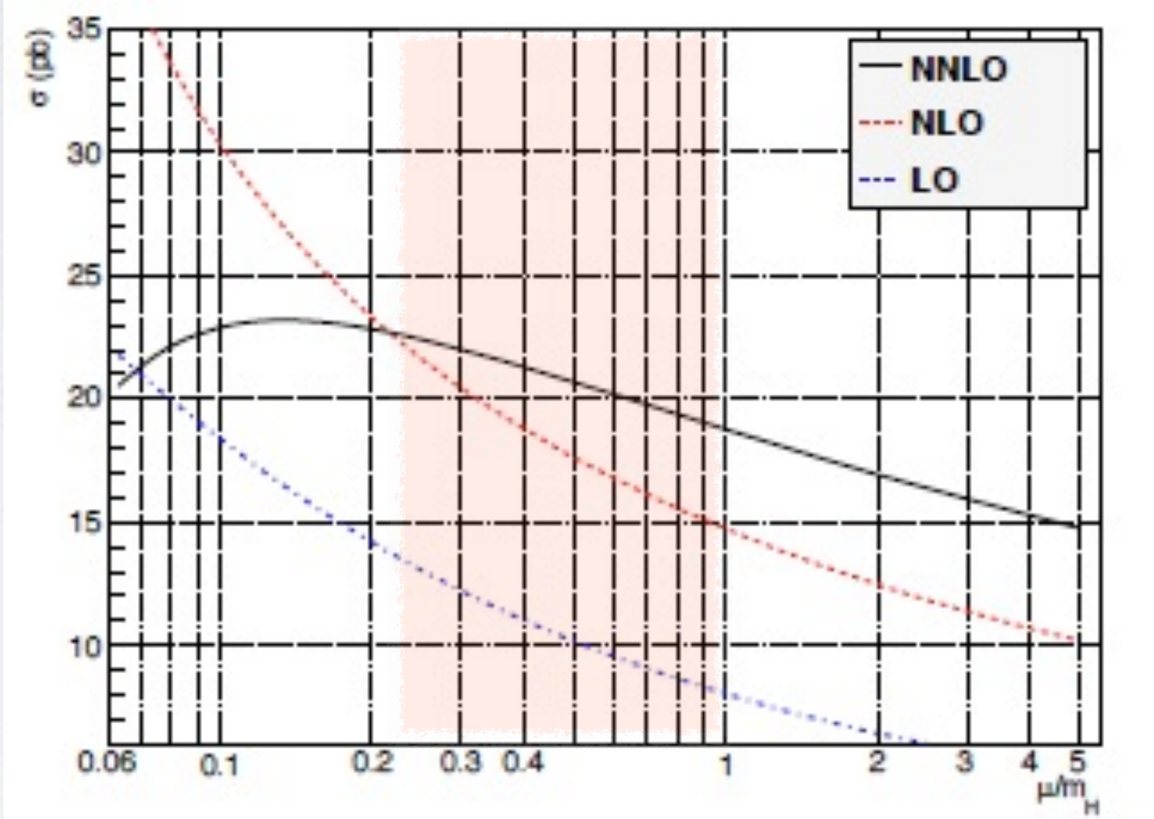
PDF UNCERTAINTIES

- Five NNLO pdf sets
- 68% confidence level uncertainties show discrepancies
- Situation can be ameliorated by adopting the 90%CL uncertainty of MSTW
- Still, ABM11 set is quite different
- ABM11 finds a lower value of alpha strong, relies on less data, but not yet shown to disagree with LHC data
- Difference with other pdfs is systematic. We do not try to reconcile it by enlarging further the pdf uncertainty. Instead, we provide a nominal prediction based on MSTW@90%CL and a typically lower prediction of ABM11



SCALE VARIATIONS

- We find that the perturbative series converges well for scales around half the Higgs mass
- We vary the scale in the interval [Mh/4, Mh]



We illustrate this point by considering the NLO correction to the Higgs production cross-section. Concentrating on the gluon-gluon subprocess, and keeping the most singular terms in the $x \to 1$ limit, we can write

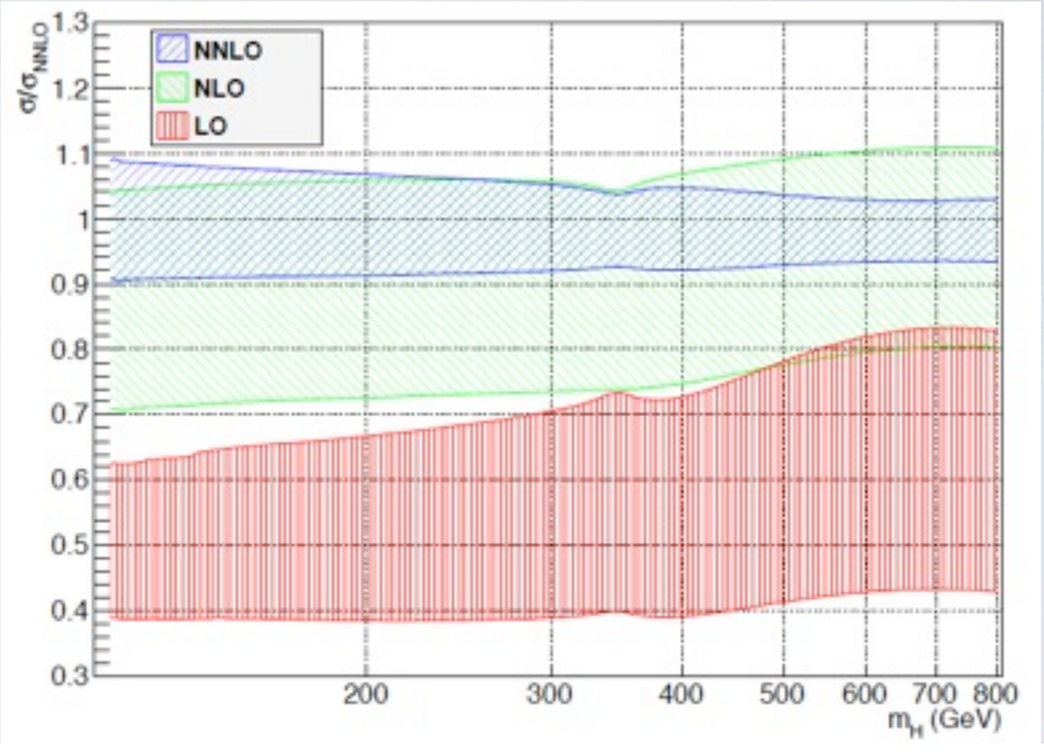
$$\eta_{gg}^{(1)}(x) = \left(\frac{\alpha_s}{\pi}\right)\left\{\left(\frac{11}{2} + 6\zeta_2\right)\delta(1-x) - 6\left[\frac{1}{1-x}\ln\left(\frac{\mu^2}{m_H^2(1-x)^2}\right)\right]_+ + \ldots\right\}. \quad (64)$$

It is obvious from the above expression that if the dominant contribution to the integrated cross-section comes from the region $x \sim 1$, then choosing $\mu = m_H$ leaves large logarithmic corrections of the form $\log(1-x)$ in the hard scattering cross-section. To avoid this problem, we should choose $\mu \sim m_H(1-x)$, which is parametrically smaller than the mass of the Higgs boson. While it is not possible to use an x-dependent factorization scale without resorting to a full resummation program, in the fixed order calculation we can attempt to do this on average. This choice *decreases* the NNLO corrections and the Higgs boson production cross-section *increases* as compared to conventional choice of the scales, $\mu_r = \mu_f = m_H$.

CA, Melnikov; 2002

THEORY ERROR PROPAGATION IN THE LIKELIHOOD DETERMINATION

- PDF uncertainties can be treated with Gaussian priors in the calculation of the likelihood.
- Perturbative uncertainties have no such statistical interpretation.
- Notice, for example, that the NNLO band lies at the upper extremity of the NLO band.
- A flat prior must be assigned to the pdf uncertainty.



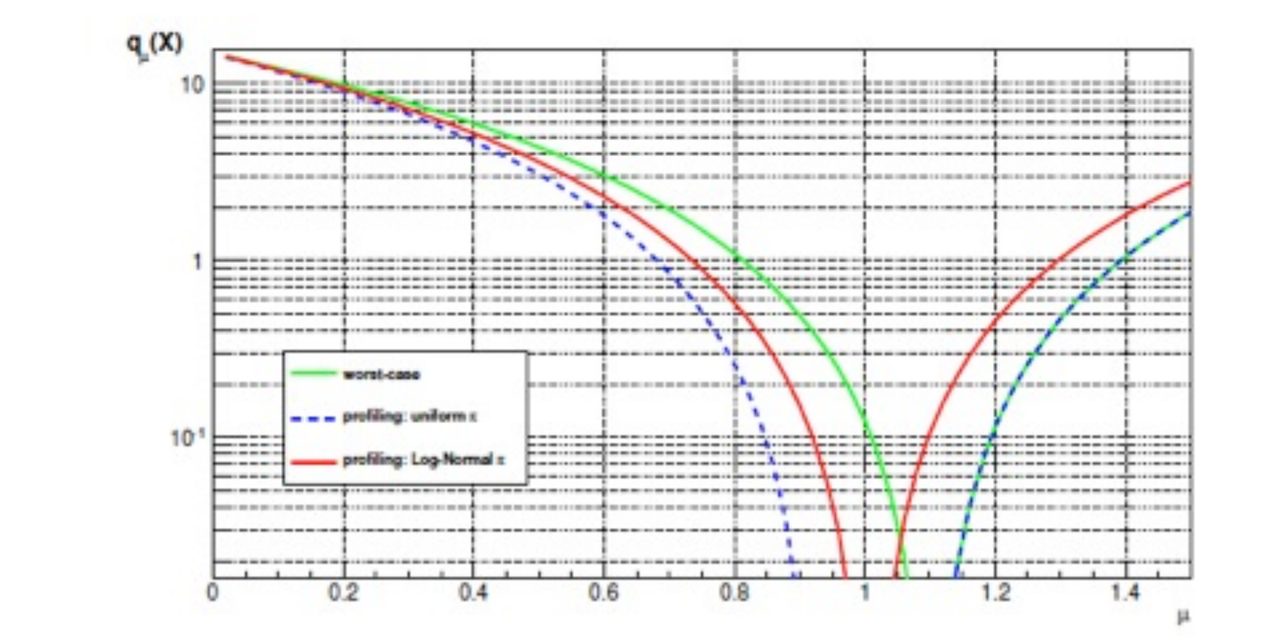


Figure 3. The test-statistic obtained with the worst-case (green) and the profiling method using a uniform (blue) or log-normal (red) likelihood $\pi(1|\hat{\nu}_\mu)$ as a function of μ. As one can see, the worst-case method and the profiling method with a flat π result in equal values for the test-statistic in the region $\mu > \mu'$. Consequently, the exclusion limits obtained from both methods are the same.

NLO QCD CORRECTIONS

cross-section for gluon fusion via a heavy (top) quark:

$$\sigma \sim \mathcal{L}_{gg}(\mu) \times \left(\frac{\alpha_s(\mu)}{\pi}\right)^2$$

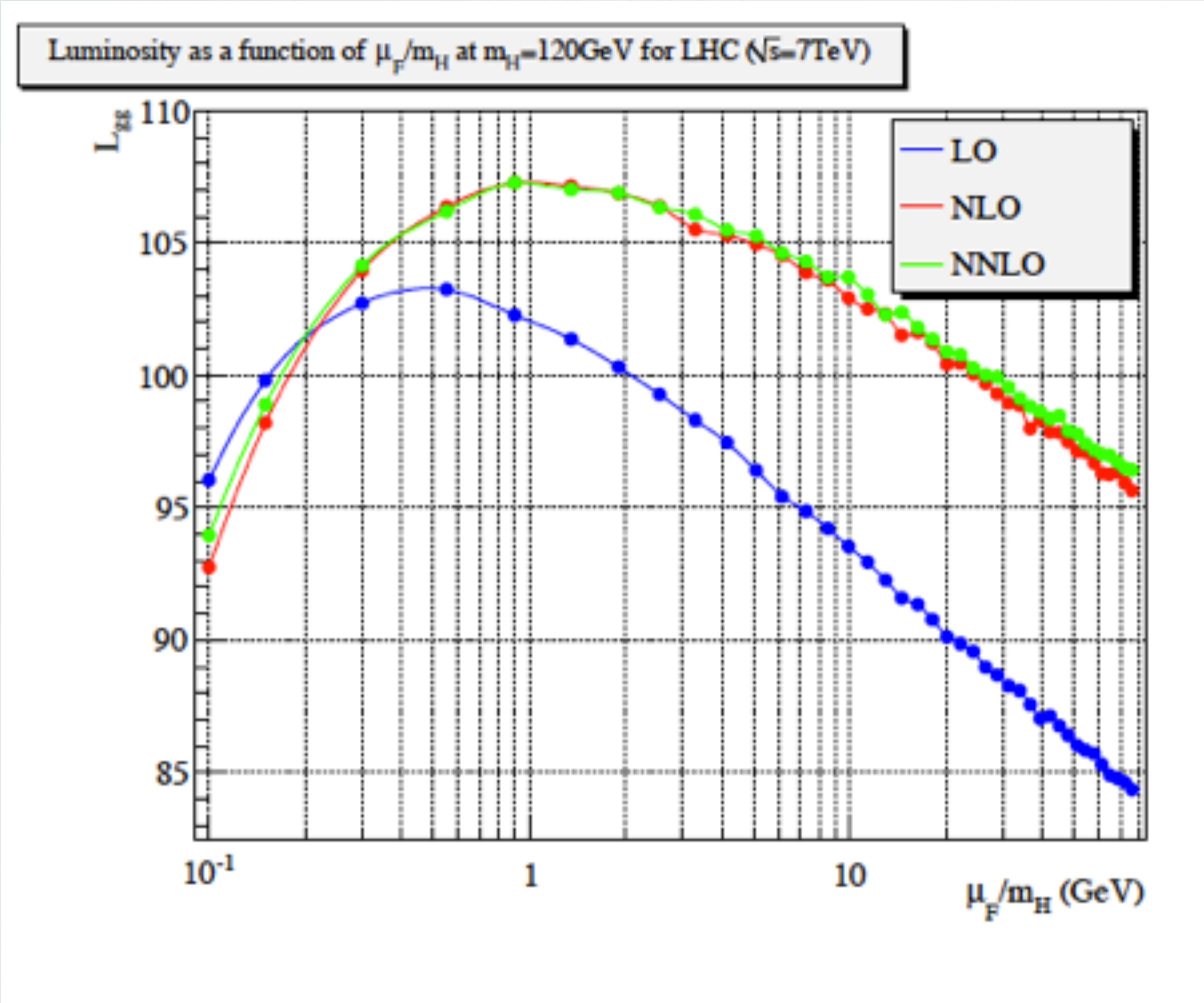
$$\left\{1 + \frac{\alpha_s(\mu)}{\pi}\left[N_c\frac{\pi^2}{3} + \frac{11}{2}\right] + 2\log\left(\frac{\mu^2}{p_T^2}\right) N_c \mathrm{Coll}\left(\frac{p_t^2}{M_h^2}\right) + \mathrm{Reg}\left(\frac{p_t^2}{M_h^2}, \theta\right)\right\}$$

Soft real and virtual corrections $\quad \pi^2, \log\left(\frac{\mu^2}{p_T^2}\right)$

$\frac{11}{2} = 2\,C_1$ Wilson coefficient of Heavy Quark Effective Theory (~ UV nature)

$\mathrm{Reg}\left(\frac{p_t^2}{M_h^2}, \theta\right) \to 0,$ hard, vanishes in $p_t, \theta, \pi - \theta \to 0$

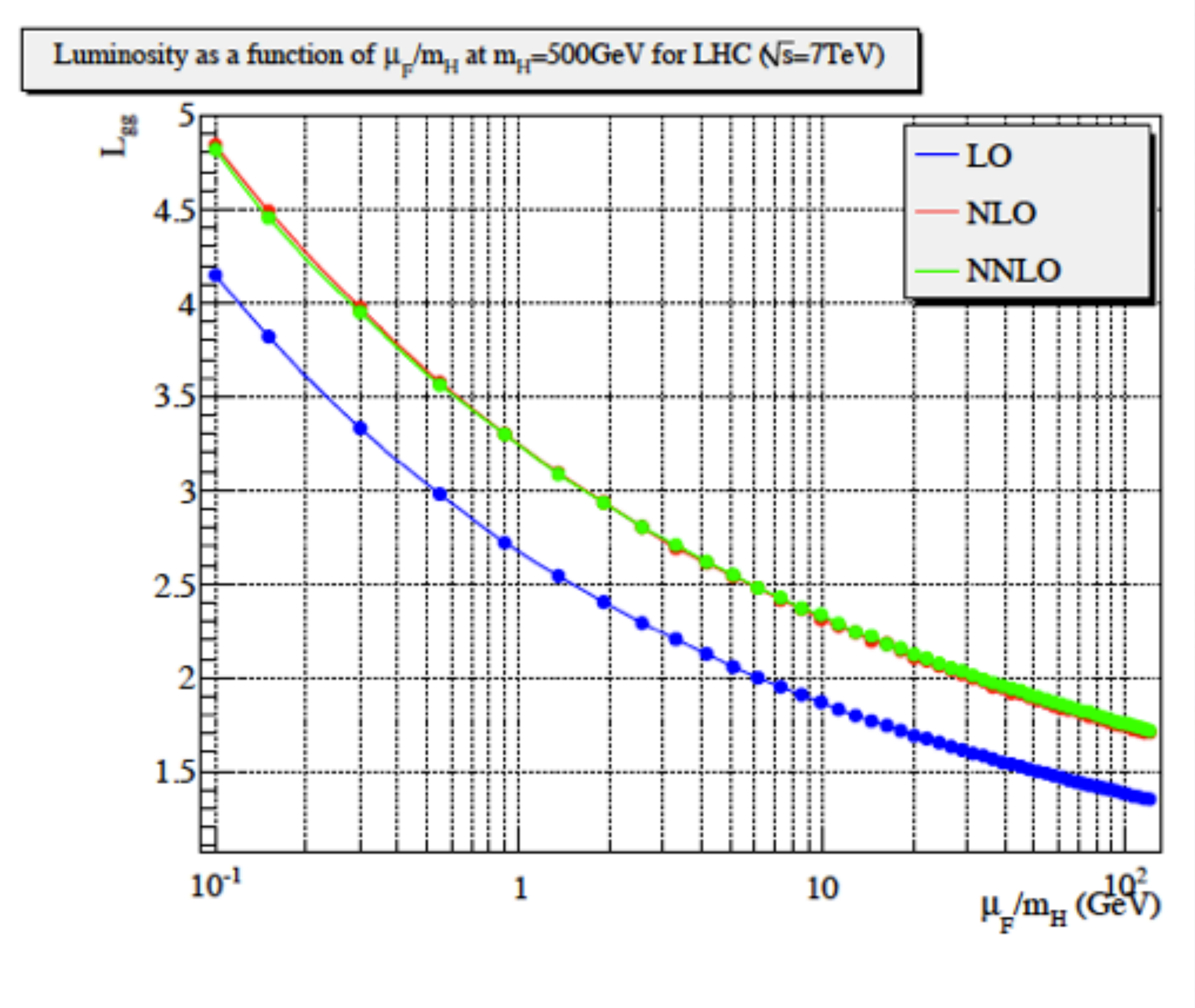
GLUON-GLUON LUMINOSITY



Lgg(Mh=120GeV, LHC7, MSTW08)

- Very stable from NLO to NNLO
- Within 5% from LO for a light Higgs boson at the LHC for reasonable factorization scales.
- ~ 20% higher than LO for large factorization scales

GLUON-GLUON LUMINOSITY



Lgg(Mh=500GeV, LHC7, MSTW08)

- Very stable from NLO to NNLO
- Within 15-20% from LO for a heavy Higgs boson at the LHC.

LARGE K-FACTORS

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%)\left\{1 + 4\%\left[\overset{\pi^2}{9.876} + \underset{\text{Wilson coefficient}}{5.5}\right] + \ldots\right\}$$

NLO/LO gluons and alpha_s

Wilson coefficient

Bound to have a large K-factor of at least 1.5-1.6 due to pi's and the Wilson coefficient

Milder K-factor if gluon fusion is mediated through a light quark (bottom) as, for example, in large tan(beta) MSSM.

Two-loop bottom amplitude.

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%)\left\{1 + 4\%\left[\underset{\pi^2}{9.876} + 0.9053\right] + \ldots\right\}$$

LARGE K-FACTORS (II)

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%) \left\{ 1 + \frac{\alpha_s(\mu)}{\pi} \left[\ldots + 6 \log \left(\frac{\mu^2}{p_T^2} \right) + \ldots \right] \right\}$$

NLO/LO gluons and alpha_s

- Logarithmic enhancement at small transverse momentum
- Integrable: reliable perturbative expansion for inclusive cross-sections.
- The mu scale is arbitrary, but no need to be senseless.
- Choices very different than pt spoil the perturbative expansion.

$$M_H = 165\,\text{GeV @TEVATRON} \rightsquigarrow < p_t > \sim 25\,\text{GeV}$$

$$\left\{ 1 + 4\% \left[9.876 + 5.5 + \mathcal{O}(20.) \right] + \ldots \right\} \mu = M_h$$

π^2 | *Wilson coefficient* | *Pt-Log*

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%)$$

NLO/LO gluons and alpha_s

$$\left\{ 1 + 4\% \left[9.876 + 5.5 + \mathcal{O}(6.) \right] + \ldots \right\} \mu = \frac{M_h}{4}$$

LARGE K-FACTORS (II)

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%) \left\{ 1 + \frac{\alpha_s(\mu)}{\pi} \left[\ldots + 6 \log\left(\frac{\mu^2}{p_T^2}\right) + \ldots \right] \right\}$$

NLO/LO gluons and alpha_s

- Logarithmic enhancement at small transverse momentum
- Integrable: reliable perturbative expansion for inclusive cross-sections.
- The mu scale is arbitrary, but no need to be senseless.
- Choices very different than pt spoil the perturbative expansion.

$$M_H = 120\,\text{GeV @LHC7} \rightsquigarrow < p_t > \sim 35\,\text{GeV}$$

$$\left\{ 1 + 4\% \left[9.876 \; + \; 5.5 \; + \mathcal{O}(15.) \right] + \ldots \right\} \quad \mu = M_h$$

π^2 — *Wilson coefficient* — *Pt-Log*

$$\frac{\text{NLO}}{\text{LO}} \sim (80\% - 105\%)$$

NLO/LO gluons and alpha_s

$$\left\{ 1 + 4\% \left[9.876 \; + \; 5.5 \; + \mathcal{O}(1.) \right] + \ldots \right\} \quad \mu = \frac{M_h}{4}$$

PERTURBATIVE CONVERGENCE?

- Three main worries from the NLO calculation:
  - Large NLO Wilson coefficient ~15-20%
  - Pi^2 = 2 x Nc x (Pi^2/6) term ~ 30-40%
  - Large logs (2 x Nc x Log(pt^2/mu^2)) of transverse momentum (sensitive to mu) ~1% - 80%
- Comforting that the NNLO corrections are mild. The Wilson coefficient has a regular perturbative expansion.

At NNLO:

Wilson coefficient

$$C \sim 1 + (4\%) \cdot 5.5 + (4\%)^2 \cdot 10.$$

Chetyrkin, Kniehl, Steinhauser

PERTURBATIVE CONVERGENCE?

- Half of Pi^2 belongs to a different Wilson coefficient when matching to SCET. It ``exponentiates''. We are left to explain with the other half, which is not as much of a concern.

At NNLO and beyond:

Ahrens, Becher, Neubert

$$1 + \frac{\alpha_s}{\pi} \cdot (\pi^2) + \ldots \sim e^{\frac{\alpha_s}{\pi} \cdot \left(\frac{\pi^2}{2}\right)} \left(1 + \frac{\alpha_s}{\pi} \left[\frac{\pi^2}{2}\right] \ldots\right)$$

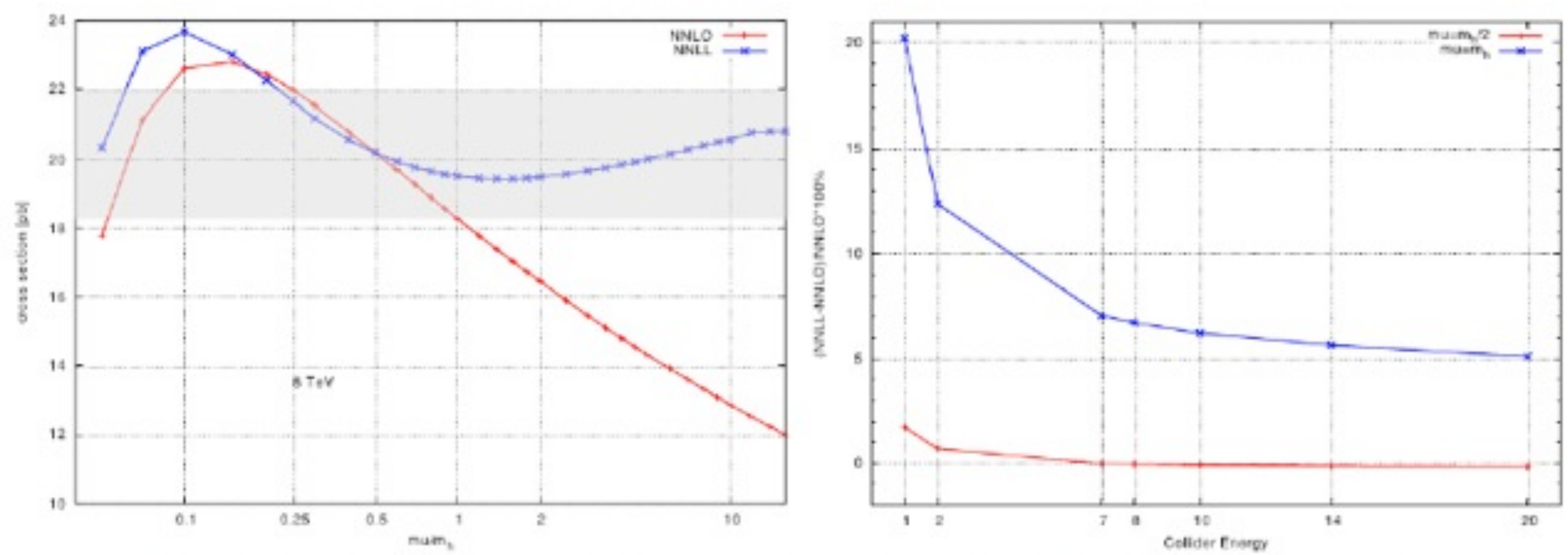
- Logs due to soft radiation exponentiate and can be resummed with NNLL accuracy at all orders.

Catani, de Florian, Grazzini

- Yield small corrections beyond NNLO which are negligible for natural scale choices close to $\mu \sim < p_t > - m_H$

Ahrens, Becher, Neubert

CHECKS AGAINST KNOWN BEYOND NNLO EFFECTS

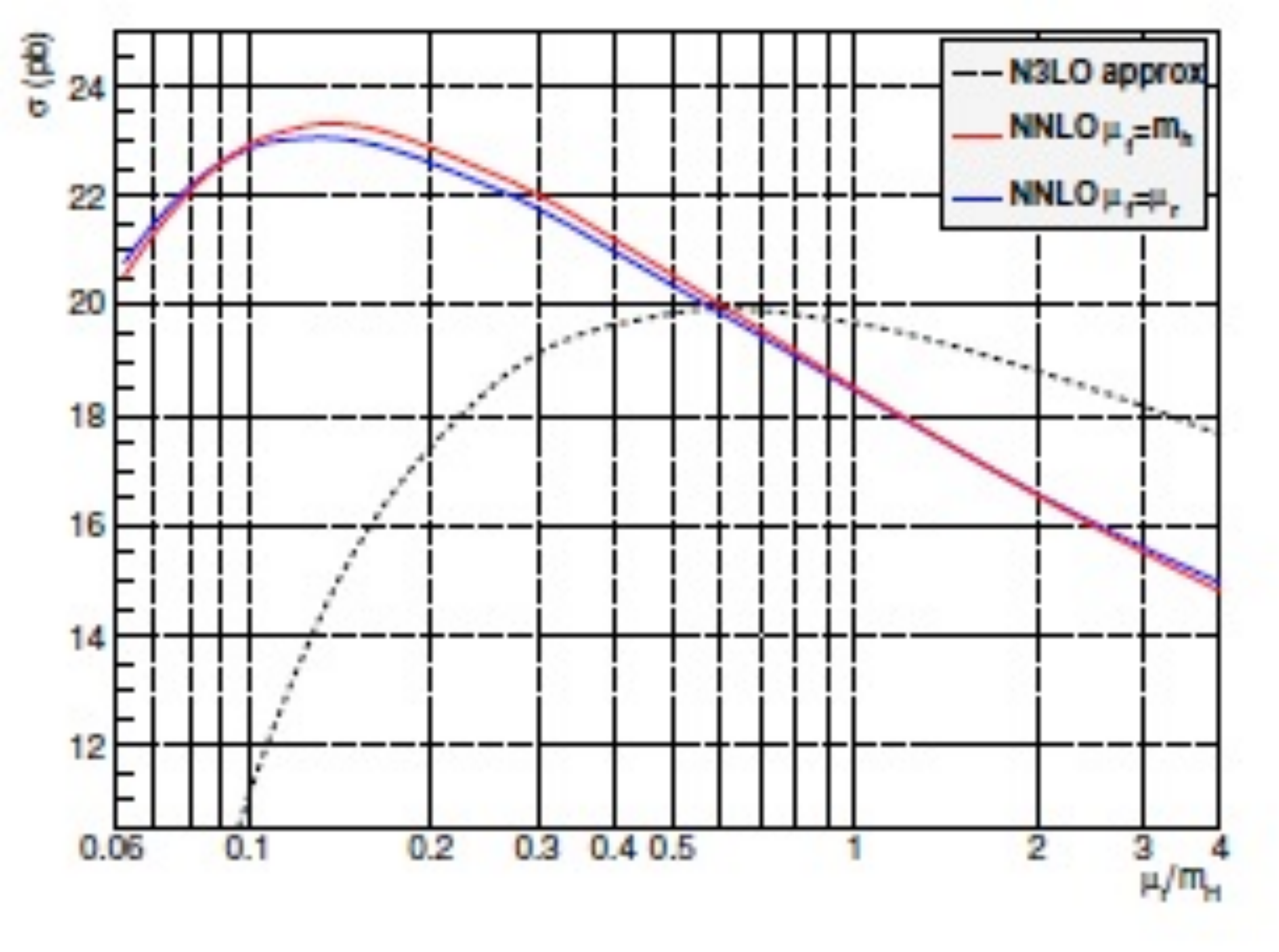


All numbers for these plots are calculated with the online calculator by M. Grazzini, see http://theory.fi.infn.it/grazzini/hcalculators.html

- We have compared NNLO vs NNLL resummation of Grazzini, de Florian.
- For low renormalization scales < Mh, the NNLL and NNLO results agree extremely well.
- For higher scales, outside our variation choices, NNLO keep decreasing monotonically but NNLL develops a minimum at around mu_R = Mh
- For our scale choice, NNLL and NNLO agree extremely well for a vast range of collider energies, from the Tevatron to beyond LHC energies.
- We notice that NNLO is virtually insensitive to variations of the factorization scale (~1%). NNLL is more sensitive (~5%). An interesting feature that we would like to investigate further.

SOFT LOGS AT NNNLO

Moch, Vogt



Implemented in ihixs

Not part of our recommended predictions, since log-dominance is not anticipated over other NNNLO contributions

Consistent with NNLO

DIFFERENCES OF THE IHIXS GROUP AND THE RECOMMENDATIONS OF THE HIGGS CROSS-SECTION WORKING GROUP

- PDFs: We are considering all NNLO pdf sets which are available and present predictions for all sets. The pdf uncertainty is derived using NNLO sets, not NLO.

- We have justified our renormalization and factorization scale choices, and consider low scales which appear natural to us. These low scales are disregarded by the HXSWG. Differences of about 6%.

- Small differences in the estimation of mixed QCD and electroweak corrections < 3%.

- The case of a large Higgs mass. We stop our predictions at 400 GeV, while the HXSWG presents total cross-section results up to 1 TeV.

TOTAL CROSS-SECTION

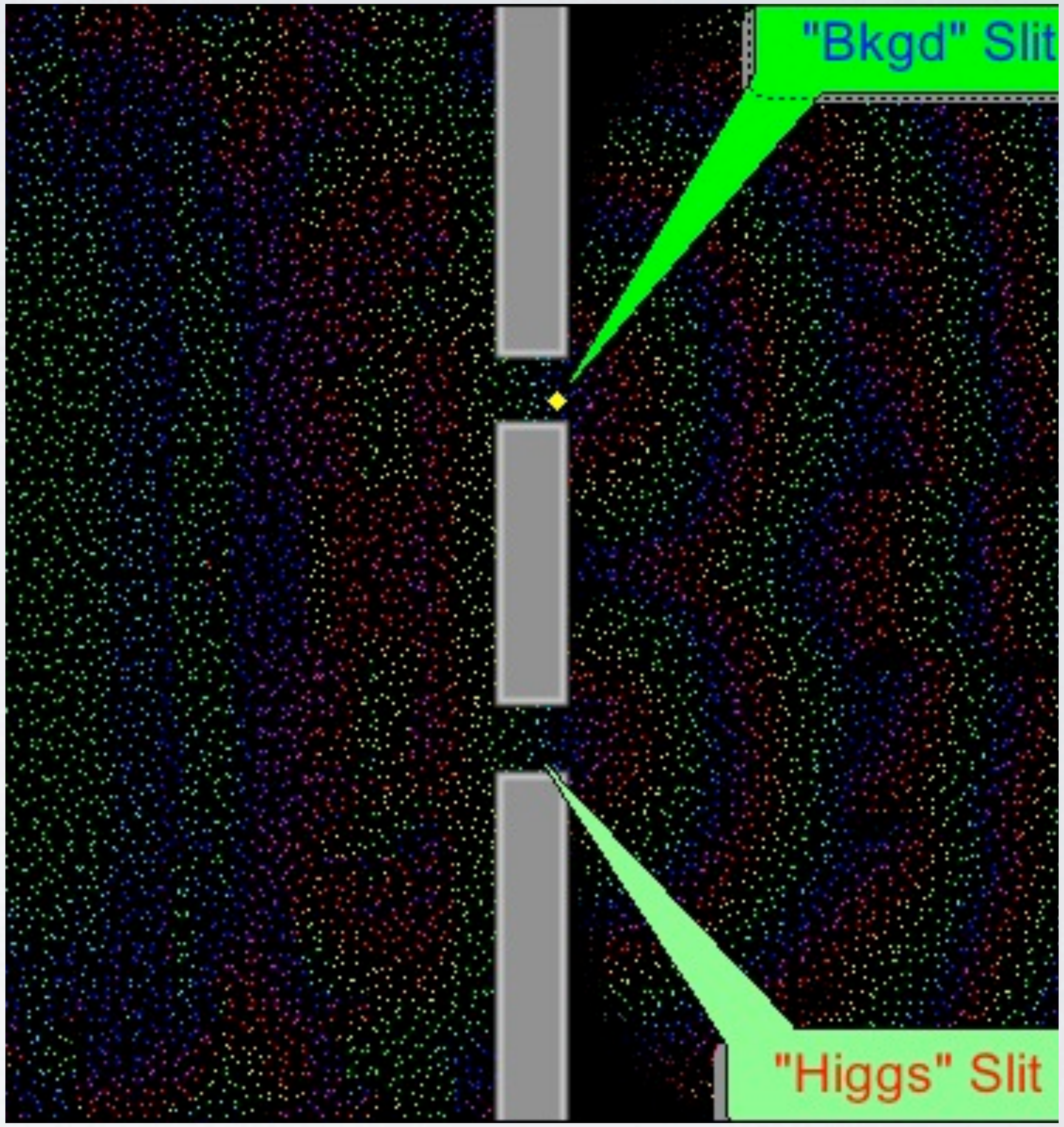
- Can we condense, at least in practice, the SM predictions into:

  $$\sigma_{total} \times \text{BR} \times \text{efficiency?}$$

- Experiments can prepare |in> states and measure the probability that they overlap with a certain final |out> state.

- The S-matrix <in|out> is constructed out of *stable* particles. Unstable particles, such as a Higgs boson, propagate but cannot be in a final state.

- The "total Higgs cross-section" is ill-defined: both experimentally and theoretically.



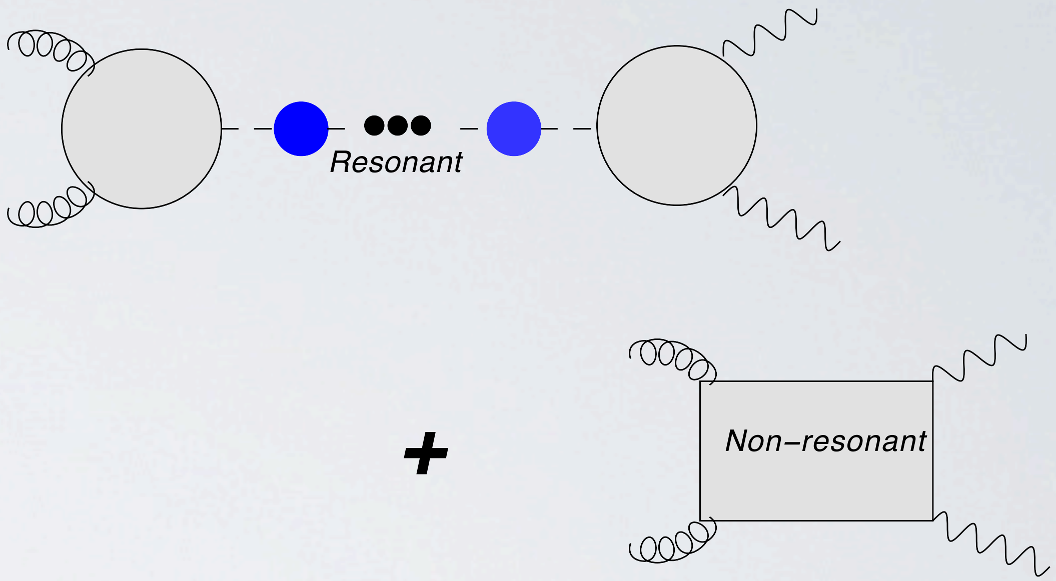
ATLAS/CMS

Interference is strong in ZZ and WW production at high invariant masses.

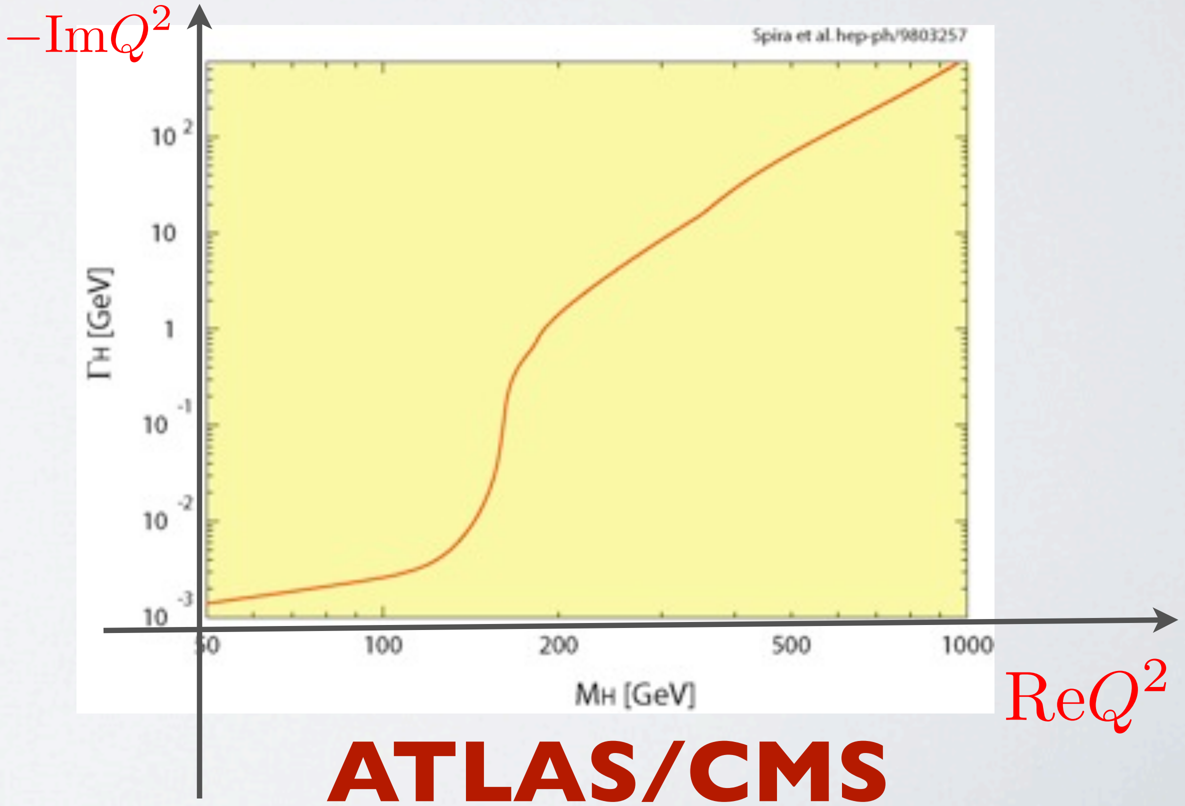
The "Higgs Slit" is not always safely bigger than the "Background Slit"!

POLES OF AMPLITUDES

- Amplitudes for WW,ZZ,… production have a pole due to the Higgs boson.
- The position of the pole is outside the physical region, for complex invariant masses of final state particles.
- Experiments measure squared probability amplitudes for real momenta.
- Still, the pole may influence strongly the value of the amplitude if it lies very close to the real axis (small width).
- The physical amplitude becomes increasingly insensitive to the complex pole by increasing the Higgs mass-width.



$$Q^2_{pole} = \mu_H^2 - i\gamma_H \mu_H$$



ATLAS/CMS

UNSTABLE PARTICLES AND PERTURBATION THEORY

Problem

- For zero couplings (no interactions) all particles are stable.
- For finite couplings, no matter how minute their value, particles may become unstable.
- Naive perturbation theory around the zero coupling limit cannot capture such a non-smooth transition

Solution

- Find a kinematic region where perturbation theory converges, for virtuality far away from the real part of the pole.
- Sum up at all orders in perturbation theory all "relevant" contributions which blow up as one approaches the pole region.
- Analytically continue the result to the pole region
- **Complications: Isolate "relevant only" contributions.** Impossible to sum everything at all orders in perturbation theory.
- Clumsy remnants can lead to loss of gauge invariance and unitarity.

THE FULL PROCESS

VECTOR BOSON PAIR PRODUCTION VIA GLUON FUSION

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Received 5 December 1988

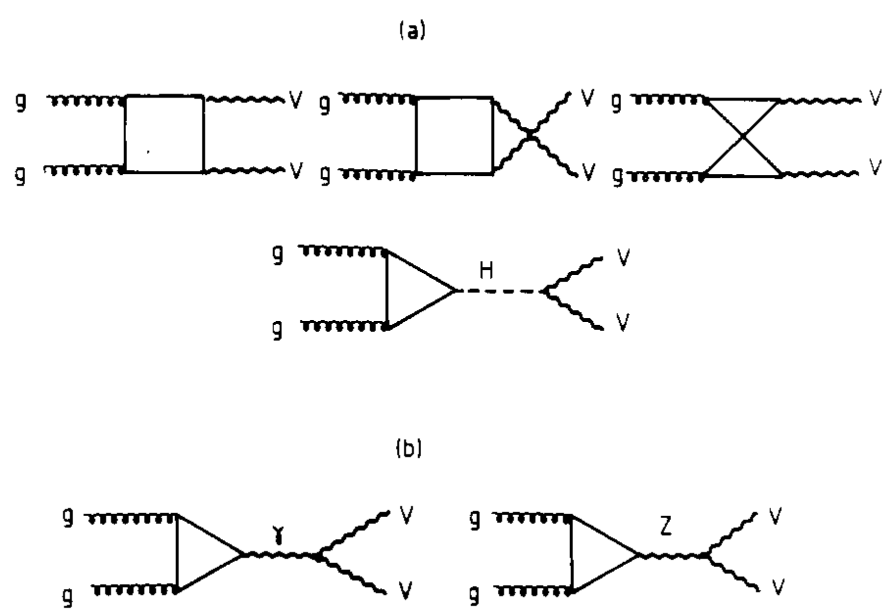


Fig. 1. Diagrams contributing to the process $gg \to VV$, where V is either a Z or a W boson. The diagrams in fig. 1a contribute to ZZ and to WW production. Those in fig. 1b contribute only to WW production.

For a large width, interference effects are large. We must compute the full process, assessing consistently the uncertainty due to higher order corrections. Not the first time that we are interested in this physics. Before LEP and when SSC was considered, the case of a large Higgs mass was very serious

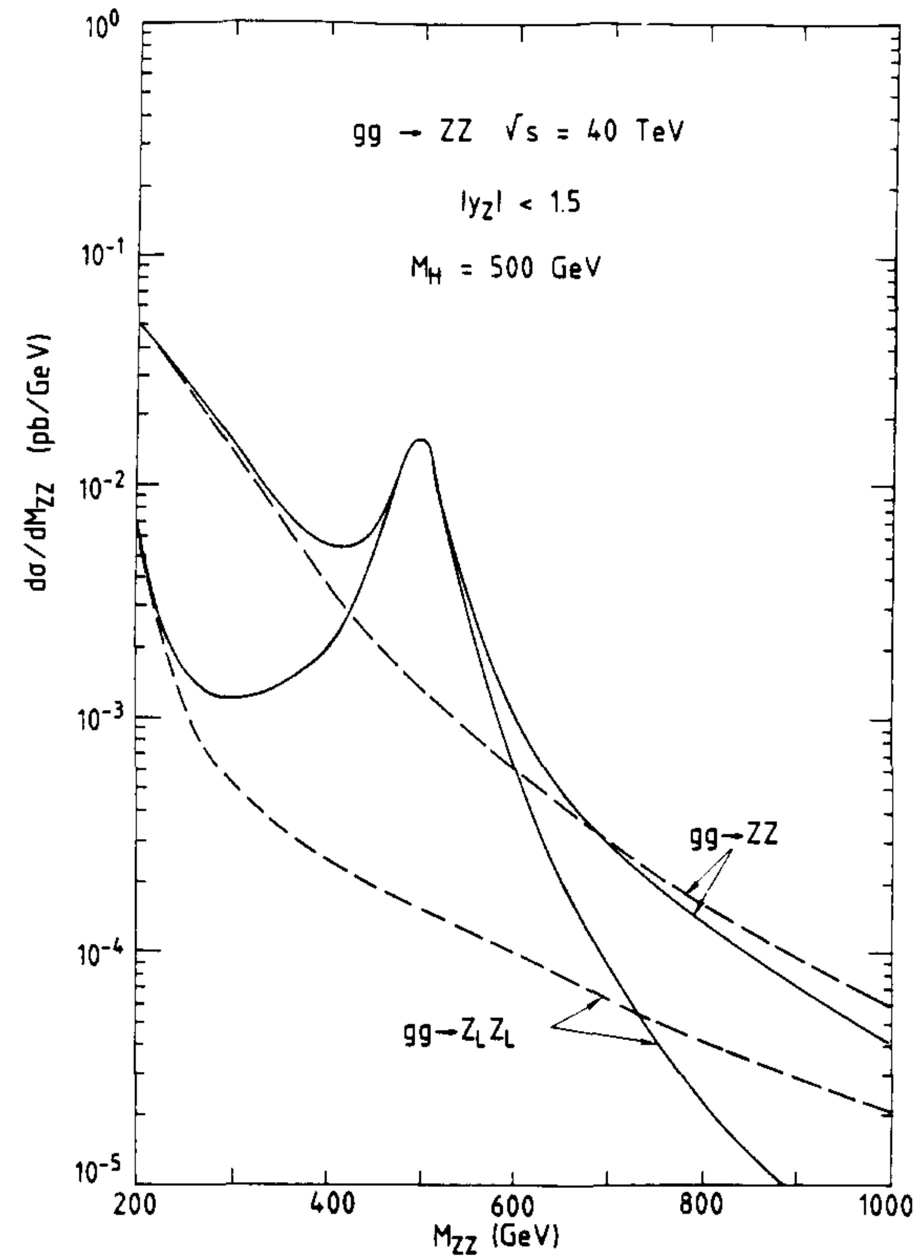
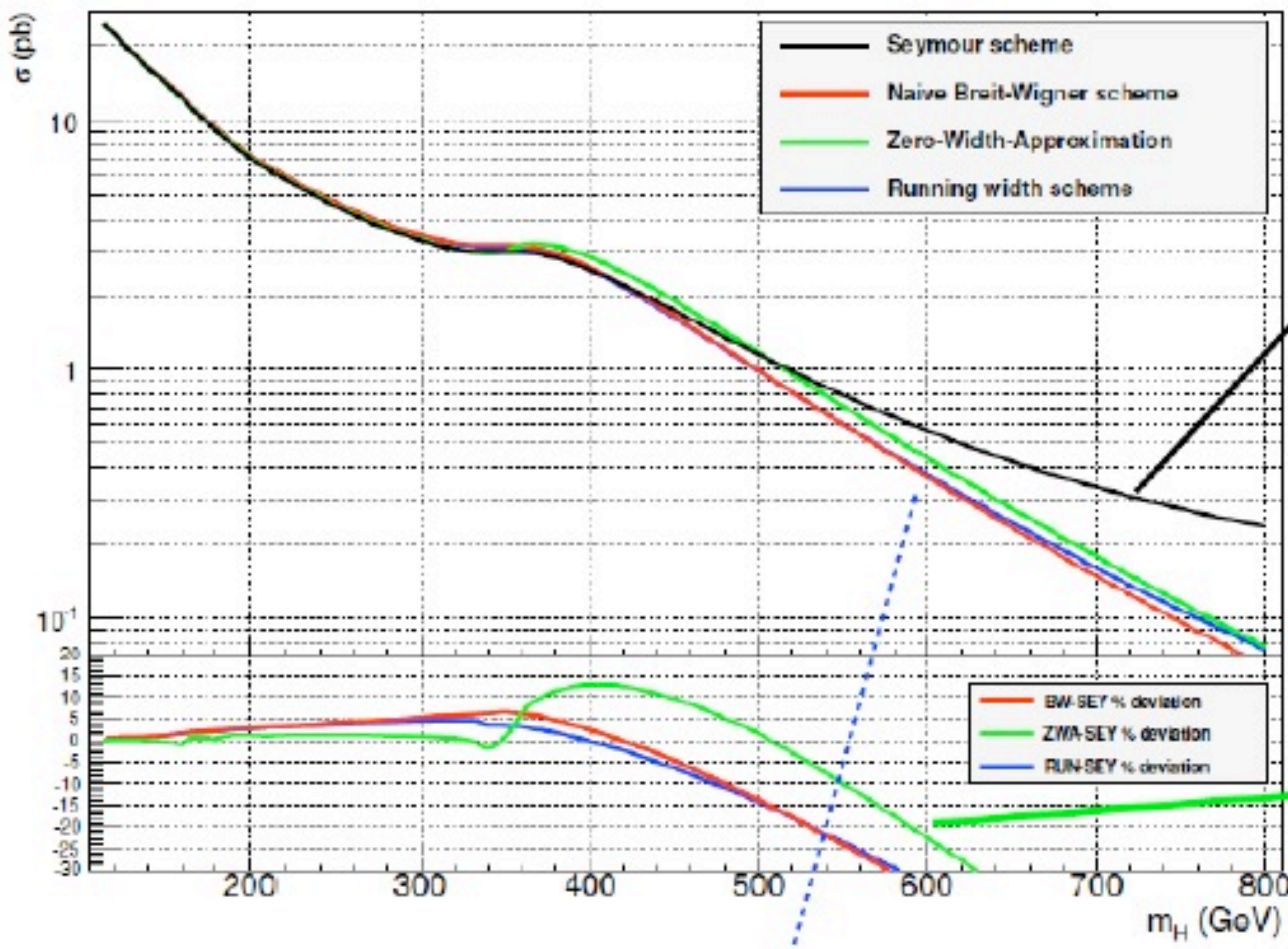


Fig. 3. The invariant mass distribution for $gg \to ZZ$ in pp collisions at $\sqrt{s} = 40$ TeV. We took $m_t = 100$ GeV and show curves both with a Higgs boson of mass $M_H = 500$ GeV (solid lines) and without the Higgs boson (dashed lines). We show curves for longitudinally polarised Z boson pair production in addition to the sum over all Z boson polarisations. A rapidity cut on the Z bosons of $|y_Z| < 1.5$ has been applied.

IHIXS ALERT OF IMPORTANT NON-FACTORIZED EFFECTS



Seymour scheme: emulates the S-B interference effects (not necessarily in an accurate way, see the LO study on the interference by Ellis, Campbell, Williams)

ZWA is more than 20% off the Seymour scheme at 600GeV

Various treatments of the propagator (signal only) seem to not affect the total cross section drastically, but...

WHY DO WE NOT PROVIDE "SIGNAL ONLY" INCLUSIVE CROSS-SECTIONS ABOVE 400 GEV?

- The distinction of resonant vs non-resonant is not diagrammatic. It is kinematic (Beneke,Chapovsky,Signer,Zanderighi)
- We shall do the separation carefully, expanding all diagrams in the amplitude of the full process in width/mass.
- The outcome depends on the final state...
- and the cuts designed to uncover such a wide resonance.

CONCLUSIONS

- I am confident that we have very solid predictions for Higgs cross-sections at the Large Hadron Collider (as long as the width of the Higgs boson is small).
- Predictions in gluon fusion are extended to more generic cases of Higgs boson couplings and Higgs effective operators (ihixs).
- Precision is promising for a better determination of Higgs couplings.
- So far, experimentalists have been asking theorists about the value of the Higgs cross-section. I hope that time has arrived that the roles are inverted!