PO Revitalized

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Revitalized by what?

Need for PO Ad Usum Delphini, The sudden ‘discovery’ of the High - Mass problem, support from my buddies, CSR

Why revitalized?

”What giants?” asked Sancho Panza.

(Cervantes’ Don Quixote)

ggF, VBF, WH/ZH, ttH, MSSM Higgs

Cross Section

ggF
HIGLU (NLO QCD+EW)
HPro (NLO QCD)
FEHiPro (NNLO QCD+EW)
HNNLO (NNLO QCD)
ggh@NNLO (NNLO QCD)

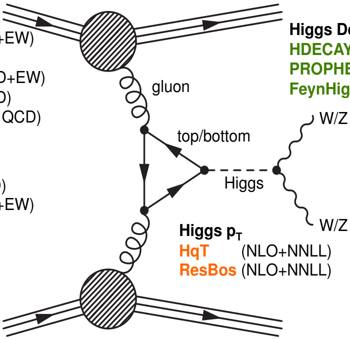
VBF
VV2H (NLO QCD)
VBFNLO (NLO QCD)
HAWK (NLO QCD+EW)

WH/ZH
V2HV (NLO)

ttH
HQQ (QCD LO)

bbH
bbH@NNLO (NNLO)

+ private codes.



Higgs Decay
HDECAY (NLO)
PROPHECY4f (NLO)
FeynHiggs, CPSuperH

Higgs p_T
HqT (NLO+NNLL)
ResBos (NLO+NNLL)

PDF: MSTW, CTEQ, NNPDF, etc.

Higgs @ MC: cfr. arXiv:0812.0578

definition of production $\otimes$ decay:

the MC *produces* a scalar resonance (H), with a momentum distributed according to a Breit–Wigner where peak and width are related to the on-shell mass and width of the Higgs boson.

$$\delta\left(\hat{s} - M_H^2\right) \rightarrow \begin{cases} \dfrac{1}{\pi}\dfrac{M_H\,\Gamma_H}{\left(\hat{s}-M_H^2\right)^2+\left(M_H\,\Gamma_H\right)^2} & \text{MC@NLO} \\[2ex] \dfrac{1}{\pi}\dfrac{\hat{s}\,\Gamma_H/M_H}{\left(\hat{s}-M_H^2\right)^2+\left(\hat{s}\,\Gamma_H/M_H\right)^2} & \text{Pythia/POWHEG} \end{cases}$$

where M_H, Γ_H are the on-shell mass and width.

Complex pole scheme → approximations?

Higgs-boson propagator ⟺ Breit–Wigner distribution

Given the complex pole (nothing more than a parametrization)

$$s_H \quad = \quad \mu_H^2 - i\,\mu_H\,\gamma_H$$

perform the **transformation** (**Bar** – scheme)

$$\overline{M}_H^2 \quad = \quad \mu_H^2 + \gamma_H^2 \qquad \mu_H\,\gamma_H = \overline{M}_H\,\overline{\Gamma}_H$$

It follows the remarkable identity:

$$\frac{1}{\hat{s} - s_H} \quad = \quad \left(1 + i\,\frac{\overline{\Gamma}_H}{\overline{M}_H}\right)\left(\hat{s} - \overline{M}_H^2 + i\,\frac{\overline{\Gamma}_H}{\overline{M}_H}\,\hat{s}\right)^{-1},$$

Question time

ComplexPole FAQ

Q What is μ_H?

A An imput parameter as the OS mass; QFT doesn't provide an answer for them.

Q Can I compute γ_H?

A Yes, $\gamma_H(\mu_H)$, more or less as you compute $\Gamma_H^{OS}(M_H^{OS})$.

Q What is the difference?

A OS quantities are ill defined.

Q Are they related?

A Yes, in PT which – however – breaks down in the HM region

From *C*omplex to *R*eal: a fact of life

What is the *common sense* definition of mass and width of an unstable particle?

Options

$$
\begin{aligned}
s_H &= \mu_H^2 - i\,\mu_H\,\gamma_H, \\
s_H &= \left(\mu'_H - \frac{i}{2}\,\gamma'_H\right)^2, \\
s_H &= \frac{\overline{M}_H^2 - i\,\overline{\Gamma}_H\,\overline{M}_H}{1 + \overline{\Gamma}_H^2/\overline{M}_H^2}
\end{aligned}
$$

which one is

- correct,
- approximate,
- closer to the **exp** peak
- $\cdots$?

Answers to the previous question

Definition of mass for exclusion and discovery

$\gamma_H \ll \mu_H$

- $\overline{M}_H$ good approximation for on-shell mass
- $\overline{M}_H$ closer to the exp peak

$\gamma_H \sim \mu_H$

$\Longleftarrow$ Not true

- $\overline{O}_H \neq O_H^{OS}$

Don't use the computed on-shell width to

estimate $\mu_H - \overline{M}_H$

$\smile$ for the Z boson $\overline{M}_Z \equiv$ mass measured at Lep

Dialogue Concerning the Two Chief World Systems: Salviati, Sagredo, Simplicio

TH How do you want to proceed? Full scenario?

EX No, we separate Higgs production and decay, and MCs implement an ad-hoc Breit-Wigner

TH Hope you are not going for high-mass!

EX Up to 600 GeV via ggF(+VBF) ($H \to WW \to l\nu qq$)

TH Then you got problems, the three bricks need a proper definition:

1. The full $\mathcal{S}$-matrix element is $S \oplus B$
2. S is $\left[\text{ production } \otimes \text{ propagation } \otimes \text{ decay }\right]$
3. each of them must be defined consistently

EX We are working with a mass spectrum peak, but what about the on-shell mass peak? Are there other definitions?

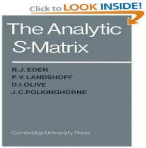
TH This I told you before

High–Mass

What is the physical meaning of an *heavy Higgs* search?

New Physics

- An Higgs above 600 GeV requires new physics at 1 TeV;
- This is based an partial-wave unitarity but should not be taken quantitatively or too literally:
  - With Fermi theory the unitarity bound is at $\mathcal{O}\left(10^2\right)$ GeV and we have been lucky that the vector boson scale is $80-90$ GeV
- Violation of unitarity bound $\hookrightarrow$ $J = 0, 1$, resonances
  - but there is no way to predict their masses, simply scaling the $\pi - \pi$ system gives you the 1 TeV ballpark.
- Anyway, it would be a good idea to address it as *search* for $J = 0, 1$ *heavy new resonances* decaying into $VV \rightarrow 4\,$f.

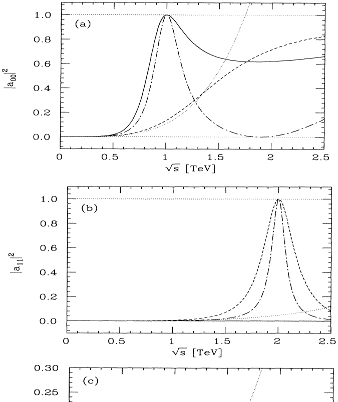


Do we want to go back to the Sixties?

- This is not anymore our beloved Lagrangian QFT landmark;
- it is the territory of other keywords:
  - *unitarized partial waves*,
  - N/D *formalism*, etc, etc.
- For high-mass VBF should be a *Fitter* more than a *Calculator*:
  - one should be more interested in a model-independent parametrization of *VV* scattering than in its SM determination

[14] of WZ and $W^{\pm}W^{\pm}$ channels at hadron colliders.

How reliable is the simple N/D result for a vector resonance? As already mentioned, the full N/D for the vector channel has no solution because of bad high-energy behavior. This means that N/D iteration would not converge and our simple N/D solution should be regarded as the first term of an asymptotic series. On the other hand, the vector coupling is reasonably small even for relatively large vector masses, as may be seen from the narrowness of the resonance compared to the scalar. This implies that the single iteration can be a good approximation. If one measures the convergence as we did for the scalar case by the condition that $D_{11}(-m_V^2)$ deviates from 1 by within, say, 15%, one finds $m_V < 2.2$ TeV.



IV. COMPARISON WITH DIFFERENT APPROACHES

Various methods [15] have been used to obtain unitary amplitudes. The most widely used methods are K matrix unitarization and the Padé approximant. Here we compare these methods with our simple N/D approach. The N/D language provides a convenient basis for the comparison, since it allows us a unified description of all these methods. Since elastic unitarity for the partial wave amplitude a is equivalent to Eq. (3), any unitarized amplitude can be written in the form $a=N/D$ with N real and $\mathrm{Im}D=-N$ (in the physical region $s>0$). Various unitarization schemes correspond to different choices of N and $\mathrm{Re}D$.

Suppose that we have an approximation amplitude a_0 which is real and therefore nonunitary. The K matrix unitarization is equivalent to setting $N=a_0$ and $\mathrm{Re}D=1$ (with $\mathrm{Im}D=-N$). Though being unitary, the K-matrix-unitarized amplitude does not necessarily satisfy analyticity [16]. On the other hand, in the simple N/D approach, we set $N=a_0$ and calculate D by a dispersion relation. The result always gives an analytic amplitude.

The Padé approximant can be used if the first two terms of an expansion (in coupling constant or energy) are known. For a real amplitude of the form $a_0=a_{\#}(1+\delta)$, the [1,1] Padé is equivalent to $N=a_{\#}$, $\mathrm{Re}D=1-\delta$. Analyticity of the result is again not obvious. [If the K matrix is used for the same amplitude, one finds $N=a_{\#}$, $\mathrm{Re}D=1/(1+\delta)$.]

These unitarization methods are often used [17–20] in the chiral Lagrangian approach. The chiral Lagrangian for ww scattering is nothing but low-energy expansion with the constraint of the low-energy theorem. One starts with the expansion to $O(s^2)$: $a_0(s)=As(1+Cs)$, where A is fixed by the low-energy theorem and C depends on the parameters of the chiral expansion. A unitary amplitude is obtained by setting $N=As$, $\mathrm{Re}D=1-Cs$ (Padé) or $\mathrm{Re}D=1/(1+Cs)$ (K matrix). These two methods are known to give very different re-

[14] of WZ and $W^{\pm}W^{\pm}$ channels at hadron colliders.

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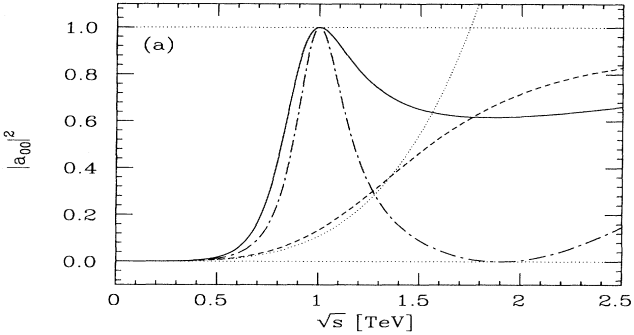

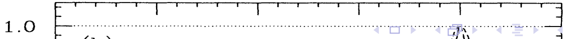

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N/D in a nutshell: cfr. Phys.Rev.D48:3055-3061,1993

$$a(s) = \frac{N(s)}{D(s)}$$

- Elastic unitarity + analiticity

$$\begin{aligned} \mathrm{Im}\, D(s) &= -N(s), \quad s > 0 \\ D(s) &= 1 - \frac{s}{\pi} \int_0^\infty d\tau \, \frac{N(\tau)}{\tau(\tau - s)} \end{aligned}$$

- Define the width from peak M_s

$$a(s) \sim -\frac{M_s \Gamma_s}{s - M_s^2 + i\, M_s \Gamma_s}, \quad \Gamma_s = -\frac{N(M_s^2)}{M_s \, \mathrm{Re}\, D'(M_s^2)}$$

1. $a(s)$ is a partial wave
2. *Invent* N,
3. derive D
4. get a plot
5. baptize your resonance

Or you go Higgsless

There have been several alternatives proposed. All of the alternative mechanisms use strongly interacting dynamics to produce a vacuum expectation value that breaks EWSB. A partial list of these alternative mechanisms includes:

- Technicolor models
- Extra-dimensional Higgsless models
- Models of composite W, Z vector bosons
- Top quark condensate
- Unitary Weyl gauge
- Asymptotic safety of some nonlinear sigma models
- Regular Charge Monopole Theory
- Ribbon model

About interference

Hot @ High *mass*

$$A_T \quad = \quad A^S_{\rm LO} + \exp\left(i\,\theta_s\right) A^S_{\rm NLO} + \exp\left(i\,\theta_b\right) A^B_{\rm LO}$$

- LO = lowest (non zero) order
- S= signal, B= background, $\theta_{s,b}$ = phases.

What's available?

- $\left|A^S_{\rm LO}\right|^2, \quad \left|A^S_{\rm NLO}\right|^2 + \cdots, \quad \left|A^B_{\rm LO}\right|^2$

? $\left|A^S_{\rm LO} + \exp\left(i\,\theta_b\right) A^B_{\rm LO}\right|^2 \quad \rightsquigarrow \quad$ LO interference

! $\sigma_{\rm NLO} = {\rm K}\,\sigma_{\rm LO}$ does not imply ${\rm interference}_{\rm NLO} = {\rm K}\,{\rm interference}_{\rm LO}$

About interference II

For

$\sqrt{s} = 14\,\text{TeV}\ M_H = 600\,\text{GeV}$

$$\begin{aligned} \sigma(gg \to l\nu l'\nu') &= 60\,\text{fb} \\ \sigma_c(gg \to l\nu l'\nu') &= 1.4\,\text{fb} \\ \sigma(gg \to H) &= 2.4\,\text{pb} \\ \text{BR}(H \to l\nu l'\nu') &= 7\,10^{-2} \end{aligned}$$

- Cut dependence? $\Longrightarrow$
- T. Binoth et al. $\Longrightarrow$

- $I = \pm 90\,|\cos\theta|\,\%$
- $I_c = \pm 20\,|\cos\theta|\,\%$
- θ = B/S (unknow) phase $\rightsquigarrow$ Action needed
- Exact $I(I_c) = -0.7\%(10.6\,\%)$ at 200 GeV.
- Exact $I(I_c) = -5.2\%(-3.8\,\%)$ at 140 GeV.

Example

$$\sigma\left(gg(\rightarrow H) \rightarrow WW \rightarrow l\bar{\nu}\bar{l}'\nu'\right)$$

arXiv:hep-ph/0611170v1 14 TeV

sel.	$\sigma(S)$ [fb]	$\sigma(B_{gg})$ [fb]	$\sigma(S+B_{gg})$ [fb]	$\approx \theta_b$
tot	75.4	60.0	134.5	90.4^o
bkg	1.67	1.74	3.41	84.5^o

About interference III

Message

For I we need amplitudes A (interfacing different codes?) but codes have $\left|A\right|^2$ and $I = 2\,\mathrm{Re}\,(A_S\,A_B^*)$

$M_H < 2\,M_t$

- A_S from EFT $\smile$
- A_B $\smile$
- assembling A_{S+B} $\frown$

$M_H > 2\,M_t$

- A_S $\frown$
- finite width effect $\frown$

consistency

S known at NLO, B at LO $\rightsquigarrow$ $I = I_{\mathrm{app}}$ at NLO

Moving towards modernity

Which

best language to simulate intuition?

- production of on-shell Higgs
- intermediate Breit–Wigner
- Higgs on-shell decay

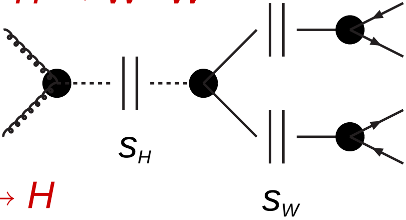
- *production* of a Higgs at its complex pole
- Dyson resummed propagator
- Higgs *decay* at its complex pole

Right column

cannot yet produce fast answers, that's why the PO oblivion

LHC example of POs

$H \to W^+W^-$ $\quad W \to \bar{f}f$



$gg \to H$

Subliminal messaging

@ Low masses

CPs are for high-precision physics (after my retirement?)

@ High masses

CPs also tell us that it is difficult to accomodate an heavy Higgs; W, Z, H and t complex poles are solutions of a (coupled) system of equations

$$f_i\left(s_W\,,\,s_Z\,,\,s_H\,,\,s_T\right) = 0, \quad i = W, Z, H, t$$

but for W, Z and (partially) t we can compare with the *exp* CPs

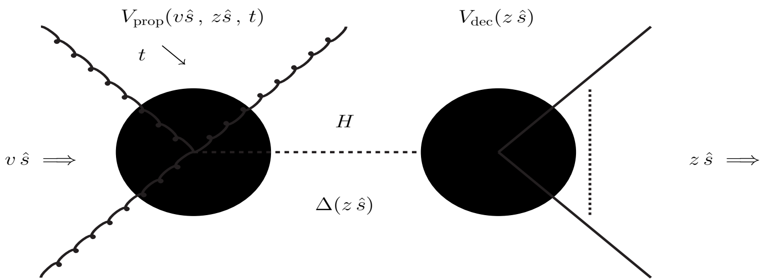
γ_H [GeV] for $\gamma_{w,t}$ fixed and complete calculation

μ_H [GeV]	$\gamma_{w,t}$ fixed	complete
200	1.264	1.262
	2.093	1.932
	1.481	1.171
250	3.369	3.364
	2.093	1.822
	1.481	0.923
300	7.721	7.711
	2.093	1.738
	1.481	0.689

Bar-scheme vs OS-scheme

μ_H [GeV]	Γ_H^{OS} [GeV] (YR)	γ_H [GeV]	$\overline{M}_H$ [GeV]	$\overline{\Gamma}_H$ [GeV]
200	1.43	1.26	200	1.26
400	29.2	24.28	400.7	24.24
600	123	102.17	608.6	100.72
700	199	159.54	717.95	155.55
800	304	228.44	831.98	219.66
900	449	307.63	951.12	291.09

Scales



$$\Longrightarrow \quad \sigma_{gg \to H+X}(v\hat{s}\,,\; \hat{t}\,,\; s_H)\, \frac{(z\hat{s})^2}{\left|z\hat{s} - s_H\right|^2}\, \frac{\Gamma_{H \to f}(s_H)}{\left|s_H\right|^{1/2}}$$

What is signal?

Complete Amplitude (simplified, no p_T)

$$A(s) \;=\; V_{\rm prod}(s)\,\Delta_{\rm prop}(s)\,V_{\rm dec}(s) + A_{\rm bckg}(s)$$

- $V_{\rm prod} \longleftarrow gg \to H$
- $V_{\rm dec} \longleftarrow H \to \gamma\gamma$, 4 f etc.

If no attempt is made to *split* $A(s)$ no ambiguity arises but, usually, the two components are known at different orders.

- Ho to *define* the **Signal**?

Options

- at present **ONBW**

$$
\begin{aligned}
A_{\rm sig}(s) &= V_{\rm prod}(\mu_H^2)\,\Delta_{\rm prop}(s)\,V_{\rm dec}(\mu_H^2) \\
\Delta_{\rm prop}(s) &= \text{Breit–Wigner}
\end{aligned}
$$

- in general violates gauge invariance, neglects the Higgs off-shellness and introduces an *ad hoc* BW
- Also possible **OFFBW**

$$
\begin{aligned}
A_{\rm sig}(s) &= V_{\rm prod}(s)\,\Delta_{\rm prop}(s)\,V_{\rm dec}(s) \\
\Delta_{\rm prop}(s) &= \text{Breit–Wigner}
\end{aligned}
$$

- in general violates gauge invariance, and introduces an *ad hoc* BW

Options

- improving **ONP**

$$\begin{aligned} A_{\rm sig}(s) &= V_{\rm prod}(\mu_H^2)\,\Delta_{\rm prop}(s)\,V_{\rm dec}(\mu_H^2) \\ \Delta_{\rm prop}(s) &= \text{propagator} \end{aligned}$$

- in general violates gauge invariance and neglects the Higgs off-shellness
- Also possible **OFFP**

$$\begin{aligned} A_{\rm sig}(s) &= V_{\rm prod}(s)\,\Delta_{\rm prop}(s)\,V_{\rm dec}(s) \\ \Delta_{\rm prop}(s) &= \text{propagator} \end{aligned}$$

- in general violates gauge invariance

Options

- **Ideal CPP**

$$
\begin{aligned}
A_{\mathrm{sig}}(s) &= V_{\mathrm{prod}}(s_H)\,\Delta_{\mathrm{prop}}(s)\,V_{\mathrm{dec}}(s_H) \\
\Delta_{\mathrm{prop}}(s) &= \text{propagator}
\end{aligned}
$$

- Only the pole, the residue and the reminder of $A(s)$ are gauge invariant!
- Furthermore **CPP** allows to identify POs

$$
\sigma_{\mathrm{prod}} \qquad \Gamma_{\mathrm{dec}}
$$

- by putting in one-to-one correspondence robust theoretical quantities and experimental data

What id background?

Consistent definition of S, B

$$
\begin{aligned}
A_{\rm sig}(s) &= \frac{V_{\rm prod}(s_H)\, V_{\rm dec}(s_H)}{s - s_H} \\
A_{\rm bckg}(s) &= A_B(s) + V_{\rm prod}(s_H)\, V^R_{\rm dec}(s) + V_{\rm dec}(s_H)\, V^R_{\rm prod}(s) \\
V(s) &= V(s_H) + (s - s_H)\, V^R(s)
\end{aligned}
$$

! the reminder $\Longrightarrow$ **background**

Conclusion?

- What is the best choice for heavy Higgs NLO MCs?
- Well,

that all true believers break their eggs at the convenient end.

Jonathan Swift's Travels into Several Remote Nations of the World

But nobody touch QFT. Someone do something quick, before we're all killed. El sueño de la razõn produce monstruos

Francisco Goya

Short Dialogue of Natural Philosophy

EX In trying to understand MC for a heavy Higgs, I am increasingly suspicious of theoretical treatment for such cases, including cross sections.

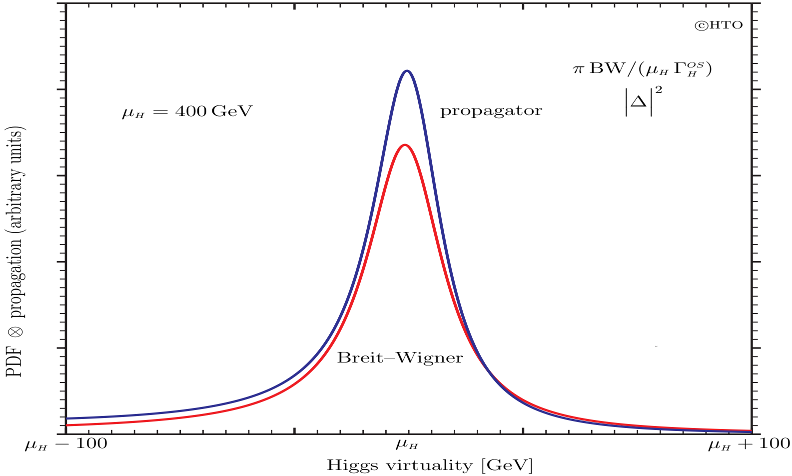
TH God could have made the universe any way he wanted to and still made it appear to us the way it does (*Galileo, Dialogo sopra i due massimi sistemi del mondo*)

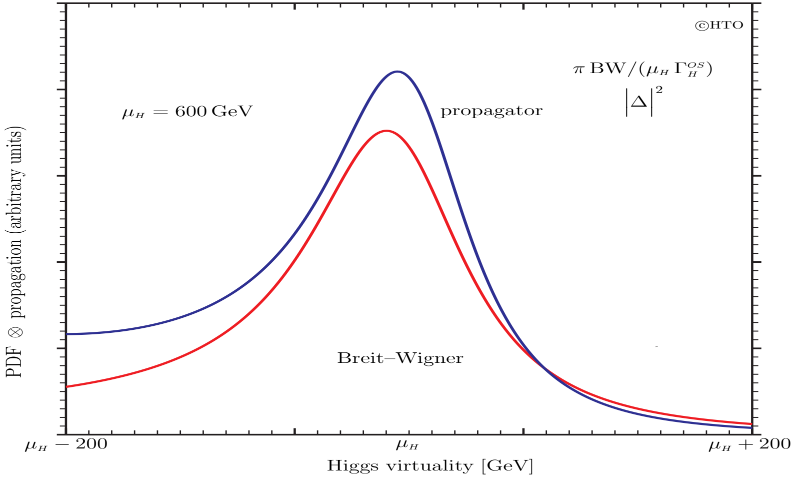
among THs: ”Who shall go in?” said one. ”Not I,” said the other. ”Nor I,” rejoined his companion but numbers are here it appears!

Legenda

Abb.

FW	Breit–Wigner Fixed Width
RW	Breit–Wigner Running Width
OS	parameters in On-Shell scheme
Bar	parameters in Bar-scheme
FS	Ren (fact) scales fixed
RS	Ren (fact) scales running (virtuality)


©HTO
$\pi\,\mathrm{BW}/(\mu_H\,\Gamma_H^{OS})$
$|\Delta|^2$
$\mu_H = 400\,\mathrm{GeV}$
propagator
Breit–Wigner
PDF ⊗ propagation (arbitrary units)
$\mu_H - 100$
μ_H
$\mu_H + 100$
Higgs virtuality [GeV]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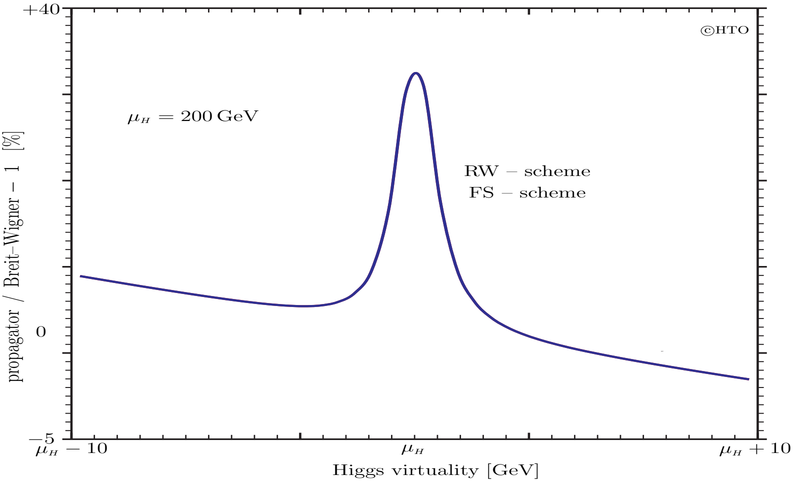
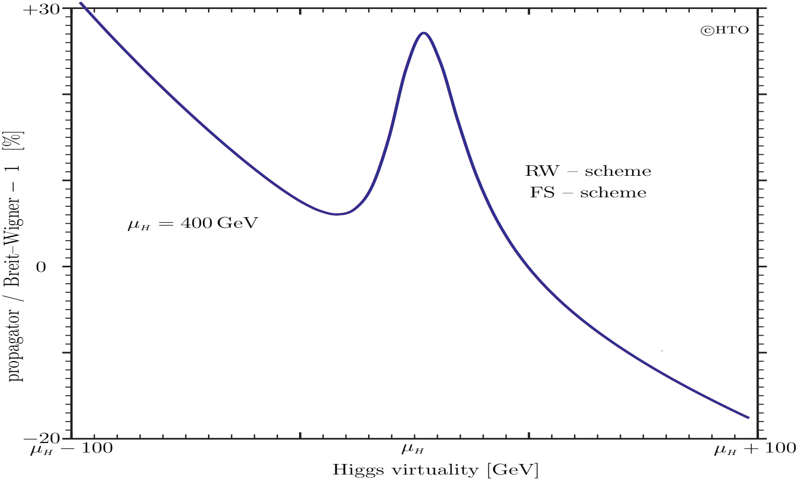
$\pi\,\mathrm{BW}/(\mu_H\,\Gamma_H^{OS})$
$|\Delta|^2$
$\mu_H = 600\,\mathrm{GeV}$
propagator
Breit–Wigner
PDF ⊗ propagation (arbitrary units)
$\mu_H - 200$
μ_H
$\mu_H + 200$
Higgs virtuality [GeV]


+40
0
−5
©HTO
μ_H = 200 GeV
RW − scheme
FS − scheme
propagator / Breit–Wigner − 1 [%]
μ_H − 10
μ_H
μ_H + 10
Higgs virtuality [GeV]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RW − scheme
FS − scheme
$\mu_H = 400$ GeV
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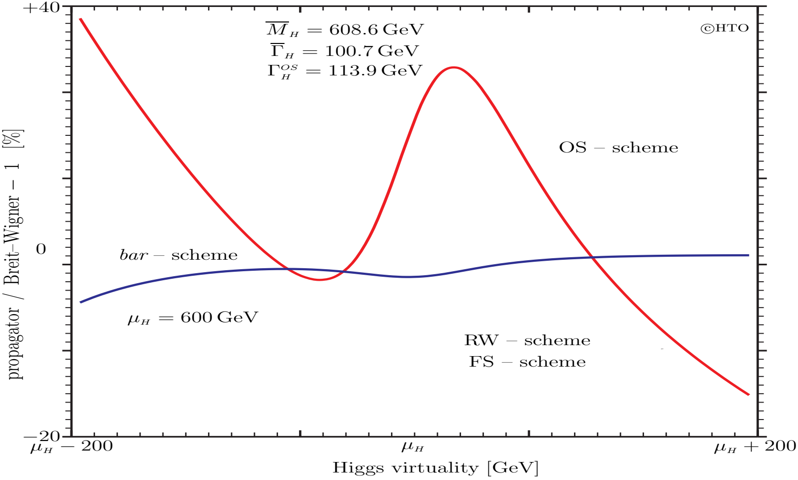
Higgs virtuality [GeV]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$\overline{M}_H = 608.6$ GeV
$\overline{\Gamma}_H = 100.7$ GeV
$\Gamma_H^{OS} = 113.9$ GeV
©HTO
OS − scheme
bar − scheme
$\mu_H = 600$ GeV
RW − scheme
FS − scheme
propagator / Breit–Wigner − 1 [%]
$\mu_H - 200$
μ_H
$\mu_H + 200$
Higgs virtuality [GeV]

The μ_R problem

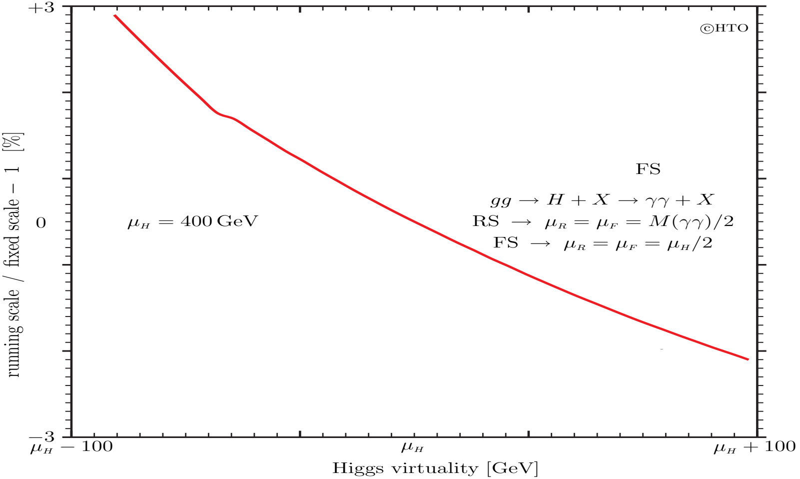
QED

- Is there a μ_R in QED? **Yes**
- Is it a problem? **No**, $q^2 = 0$ is physical!

EW

- Is there a μ_R in EW? **Yes**
- Is it a problem? **No**!
- Are there large **logs**? **Yes**
- Use G_F - scheme and not $\alpha(0)$, i.e. **resum**

QCD one(multi)-scale? Once again, **resum** or, at least **minimize**!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running scale / fixed scale − 1 [%]
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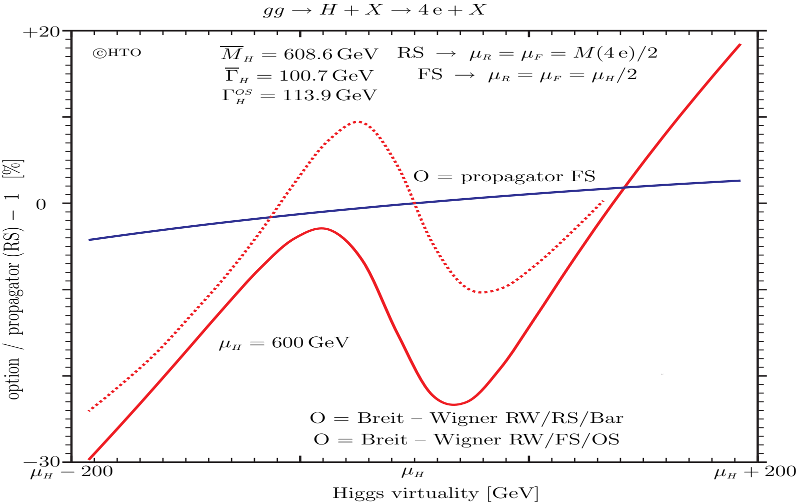
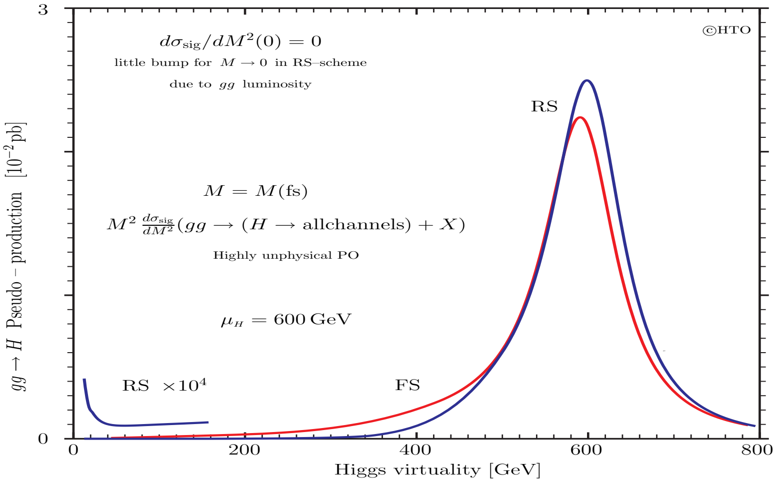
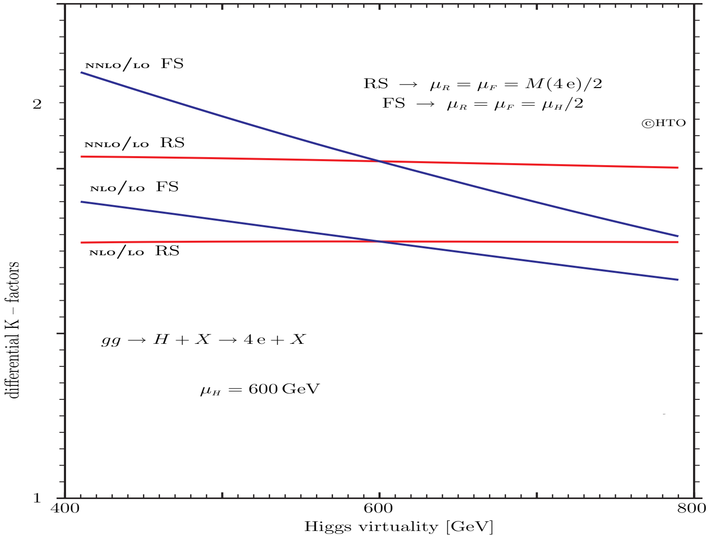
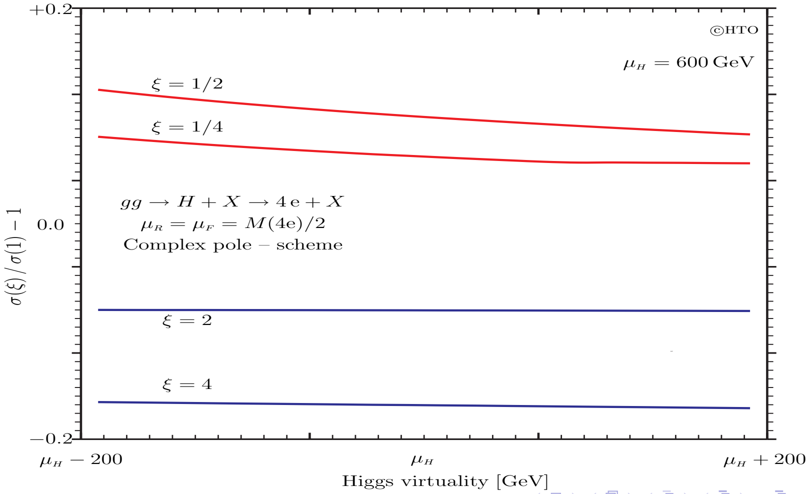
μ_H = 400 GeV
FS
gg → H + X → γγ + X
RS → μ_R = μ_F = M(γγ)/2
FS → μ_R = μ_F = μ_H/2
μ_H − 100
μ_H
μ_H + 100
Higgs virtuality [GeV]


$gg \to H + X \to 4\,e + X$
©HTO
$\overline{M}_H = 608.6\,$GeV
$\overline{\Gamma}_H = 100.7\,$GeV
$\Gamma_H^{OS} = 113.9\,$GeV
RS $\to \mu_R = \mu_F = M(4\,e)/2$
FS $\to \mu_R = \mu_F = \mu_H/2$
O = propagator FS
$\mu_H = 600\,$GeV
O = Breit − Wigner RW/RS/Bar
O = Breit − Wigner RW/FS/OS
+20
0
−30
$\mu_H - 200$
μ_H
$\mu_H + 200$
Higgs virtuality [GeV]
option / propagator (RS) − 1 [%]

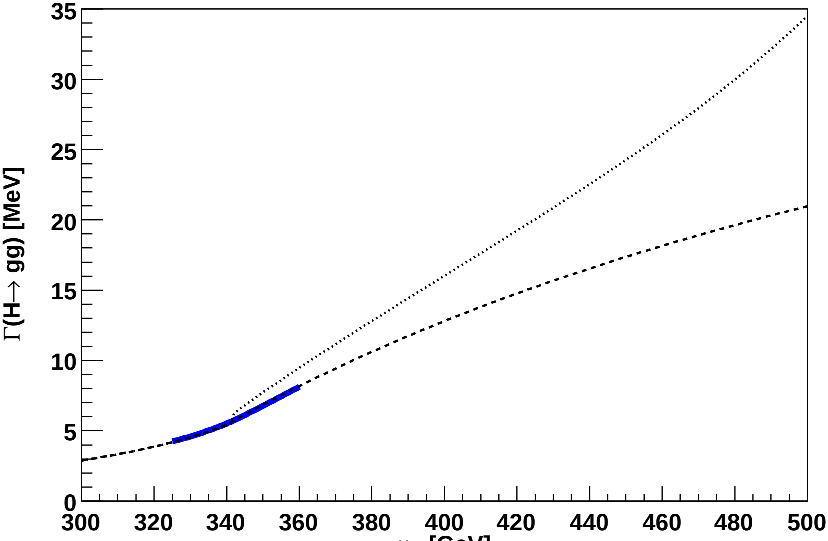


©HTO
$d\sigma_{\rm sig}/dM^2(0) = 0$
little bump for $M \to 0$ in RS–scheme
due to gg luminosity
RS
$M = M(\rm fs)$
$M^2 \frac{d\sigma_{\rm sig}}{dM^2}(gg \to (H \to \text{allchannels}) + X)$
Highly unphysical PO
$\mu_H = 600\,\text{GeV}$
RS $\times 10^4$
FS
$gg \to H$ Pseudo – production $[10^{-2}\text{pb}]$
Higgs virtuality [GeV]
0
3
0
200
400
600
800


NNLO/LO FS
RS → $\mu_R = \mu_F = M(4\,e)/2$
FS → $\mu_R = \mu_F = \mu_H/2$
©HTO
NNLO/LO RS
NLO/LO FS
NLO/LO RS
$gg \to H + X \to 4\,e + X$
$\mu_H = 600\,\text{GeV}$
differential K − factors
2
1
400
600
800
Higgs virtuality [GeV]



+0.2
0.0
−0.2
©HTO
$\mu_H = 600$ GeV
$\xi = 1/2$
$\xi = 1/4$
$gg \to H + X \to 4\,\mathrm{e} + X$
$\mu_R = \mu_F = M(4\mathrm{e})/2$
Complex pole − scheme
$\xi = 2$
$\xi = 4$
$\sigma(\xi)\,/\,\sigma(1) - 1$
$\mu_H - 200$
μ_H
$\mu_H + 200$
Higgs virtuality [GeV]


35
30
25
20
15
10
5
0
Γ(H→ gg) [MeV]
300
320
340
360
380
400
420
440
460
480
500

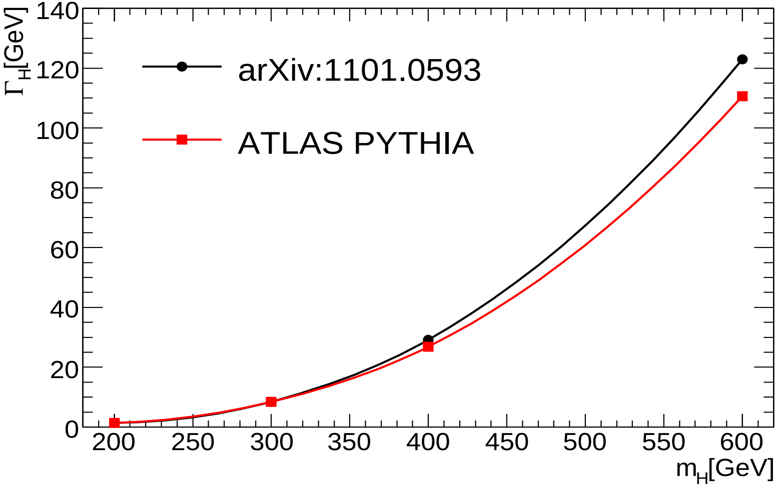
PO rec.

Temporary Entries

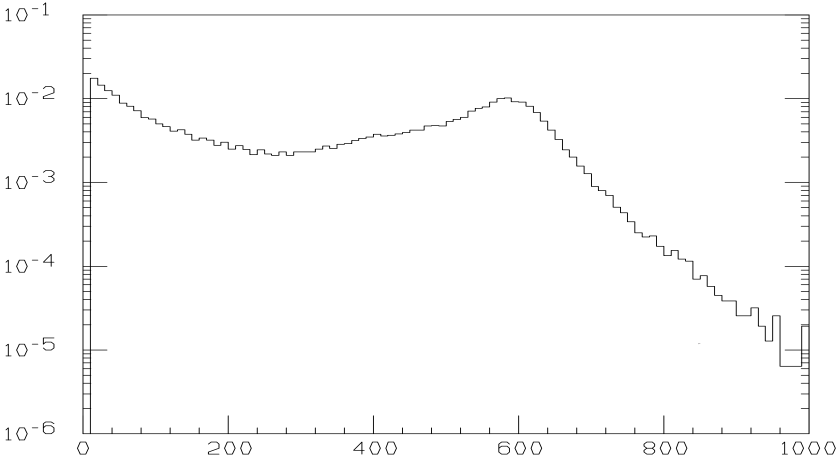
- Search for heavy Higgs: address it as *search* for heavy Higgs and $J = 0, 1$ *heavy new resonances* decaying into $VV \rightarrow 4\,\mathrm{f}$.
- Use definition of production $\otimes$ decay (**at least**) with a momentum distributed according to a Breit–Wigner à la Pythia/POWHEG (now also in MC@NLO). Beware, BW parameters are *not* OS parameters ("Thy evil spirit, Brutus: I shall see thee at Philippi", Shakespeare's Julius Caesar).
- Assign a *conservative* $\pm 20\%$ uncertainty for missing interference at high masses ($\geq 600\,\mathrm{GeV}$).
- Use *running* QCD scales, taking into account the kinematics of final four fermions in $gg \rightarrow H + X \rightarrow 4\,\mathrm{f} + X$.

PO conclusions: before, after?

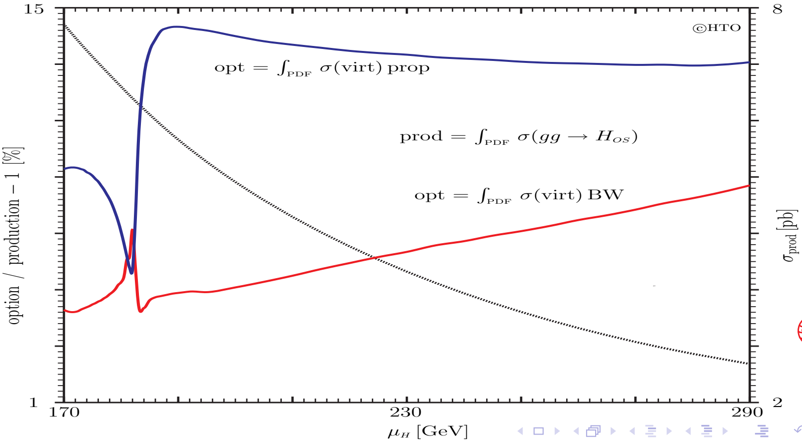
Backup: courtesy R. Tanaka



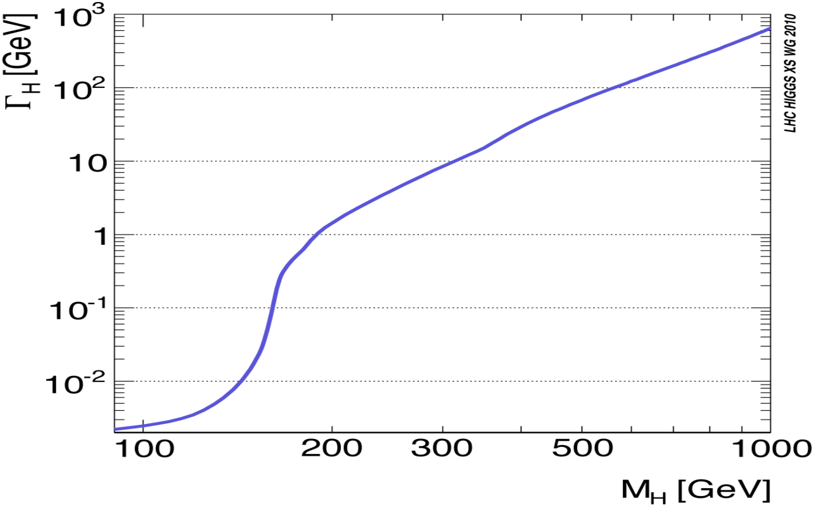
Backup: courtesy S. Frixione



Backup

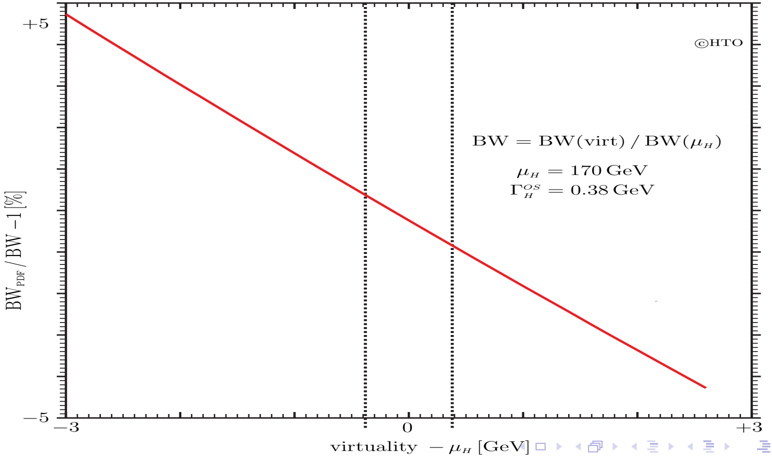

15
8
©HTO
opt = $\int_{\rm PDF}$ σ(virt) prop
prod = $\int_{\rm PDF}$ $\sigma(gg \to H_{OS})$
opt = $\int_{\rm PDF}$ σ(virt) BW
option / production − 1 [%]
$\sigma_{\rm prod}$ [pb]
1
2
170
230
290
μ_H [GeV]

Backup



Γ_H [GeV]
10^3
10^2
10
1
10^{-1}
10^{-2}
100
200
300
500
1000
M_H [GeV]
LHC HIGGS XS WG 2010

Backup


+5
−5
−3
0
+3
©HTO
BW = BW(virt) / BW(μH)
μH = 170 GeV
Γ_H^OS = 0.38 GeV
BW_PDF / BW −1 [%]
virtuality − μH [GeV]