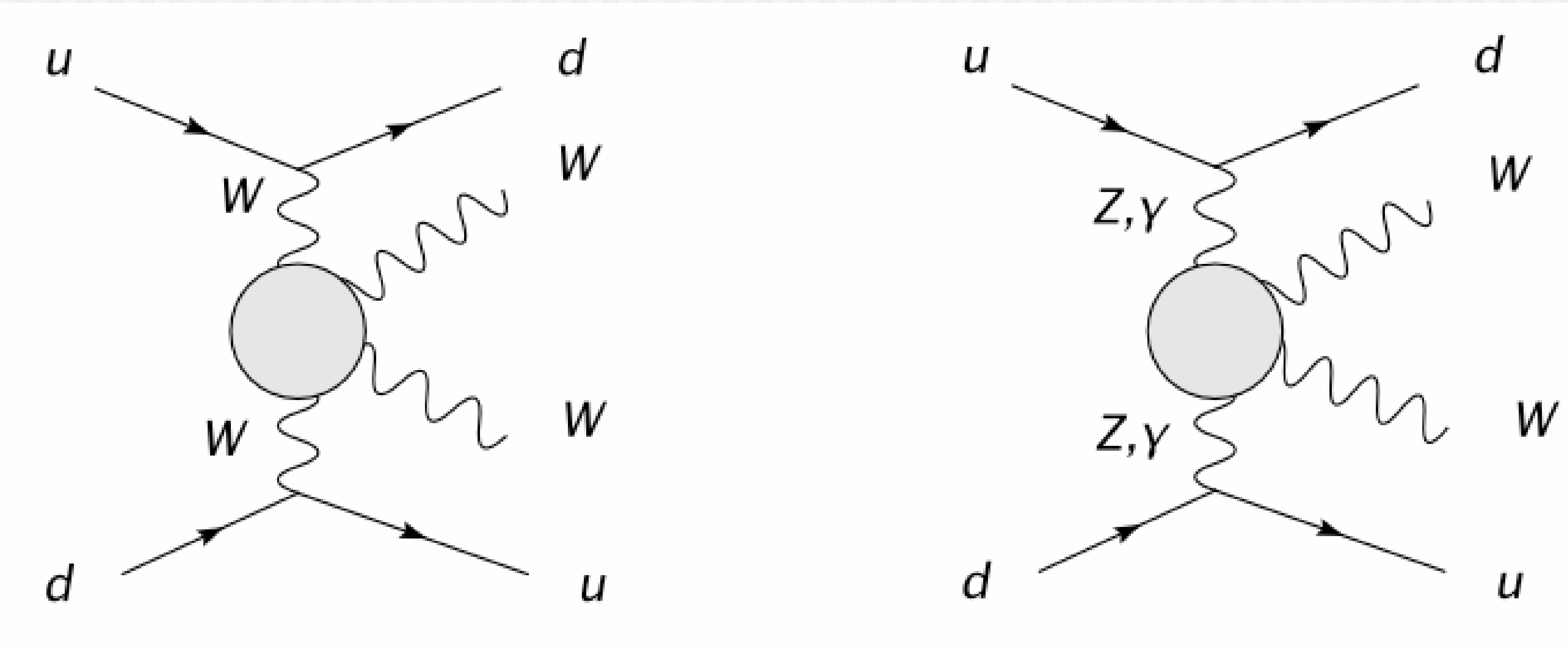
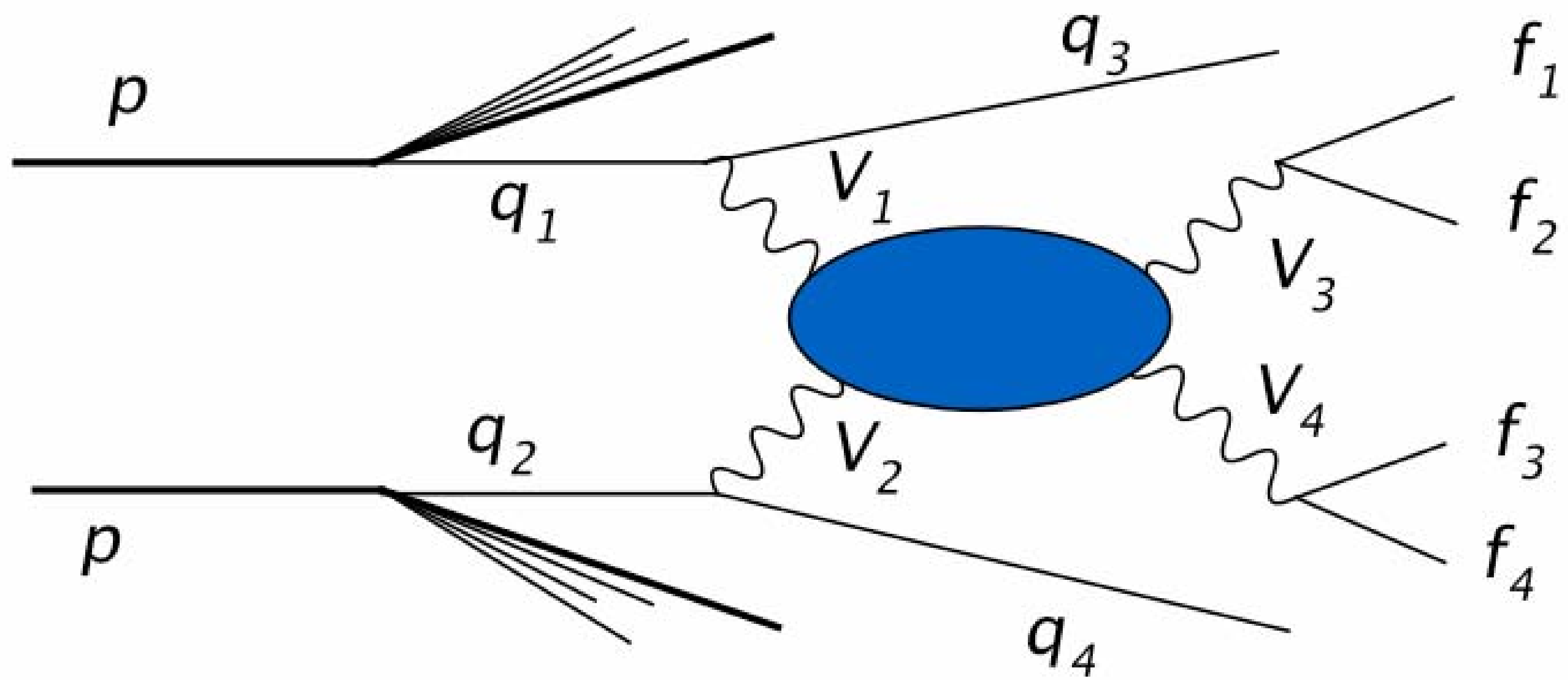
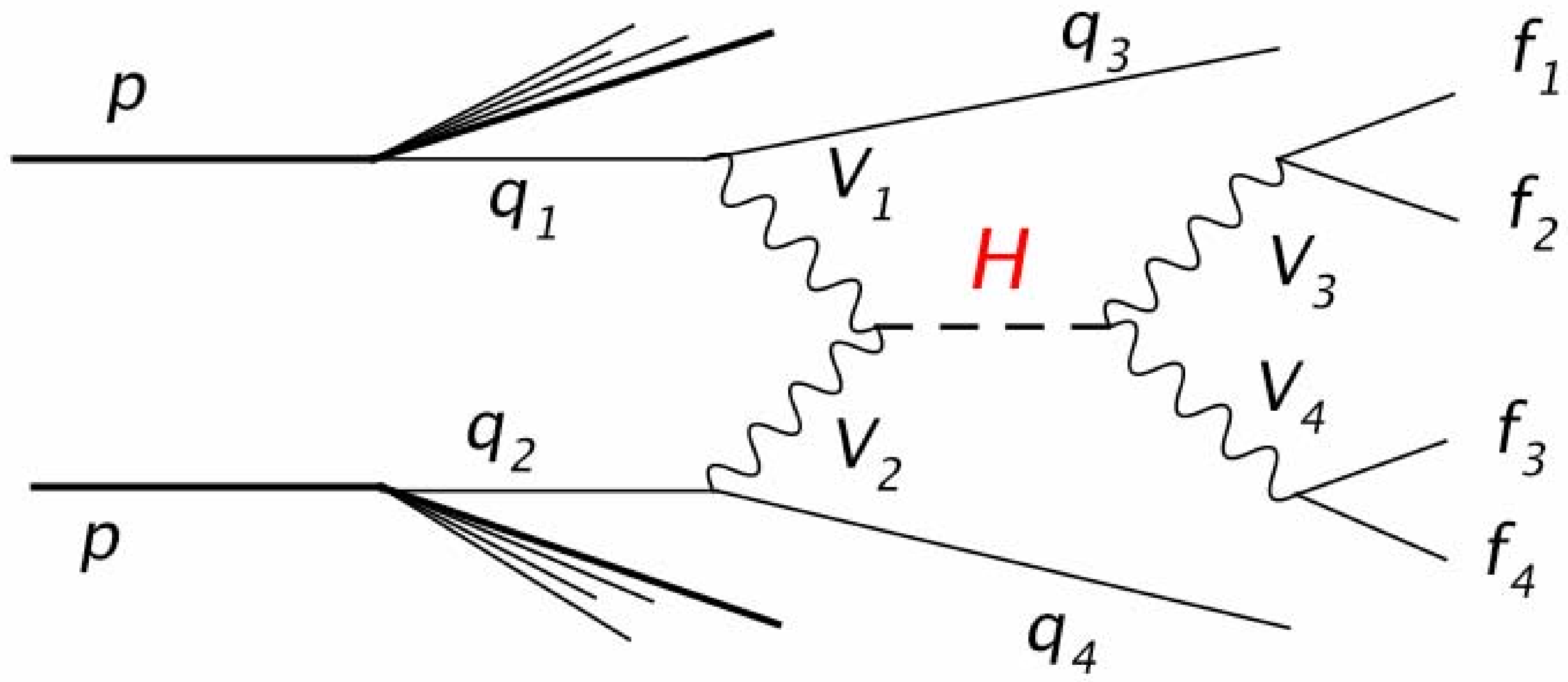
Boson Boson Scattering at LHC with PHASE



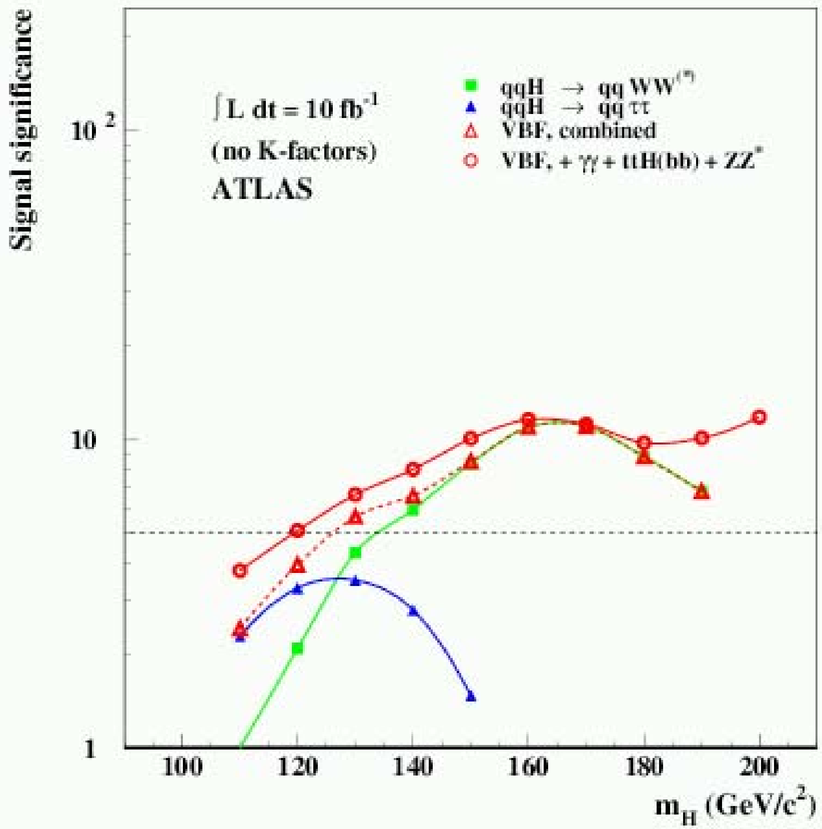
What can we observe at LHC?

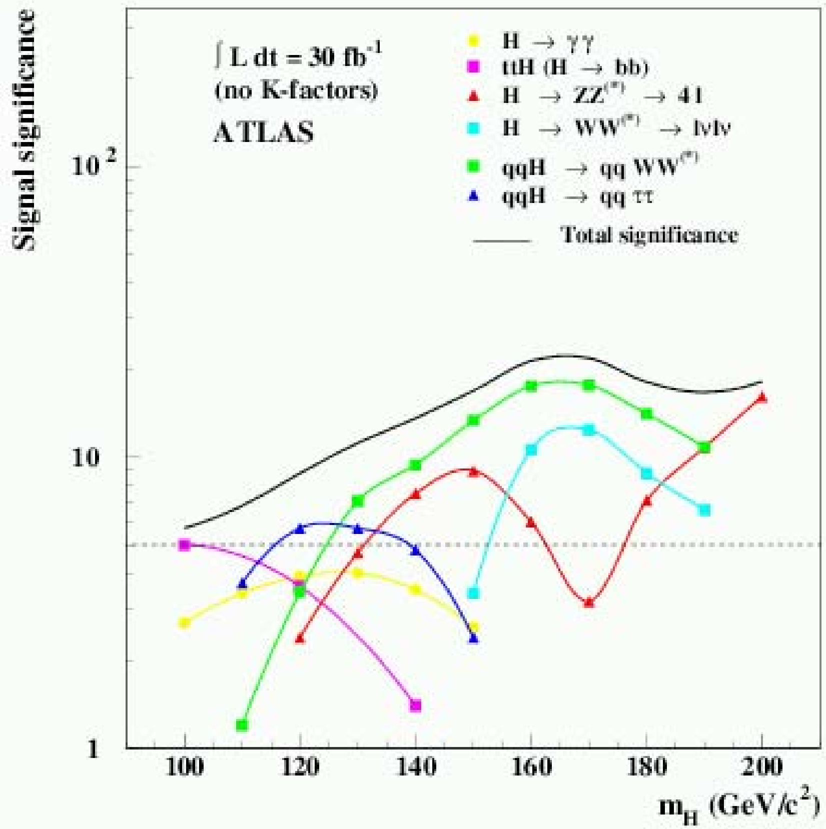


Higgs!



Higgs discovery





Higgs

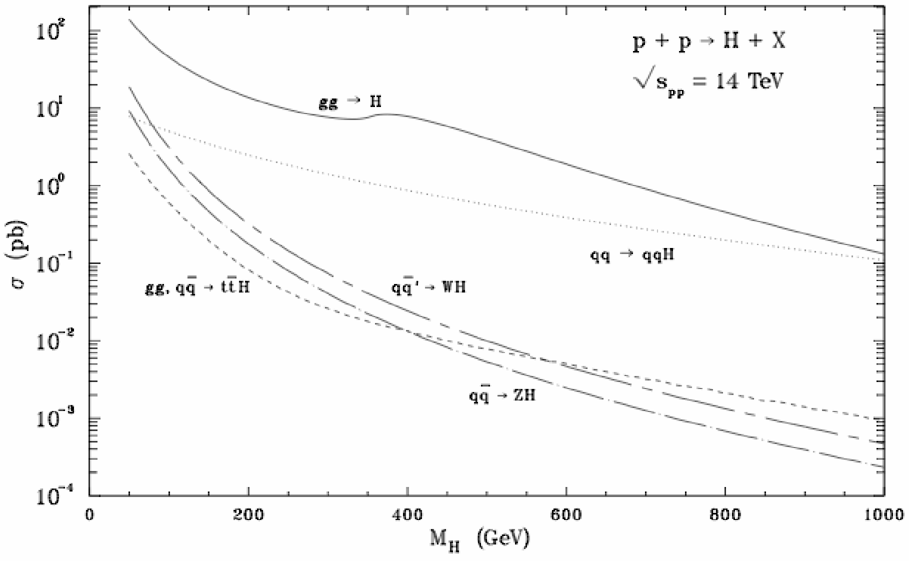


Fig. 5b

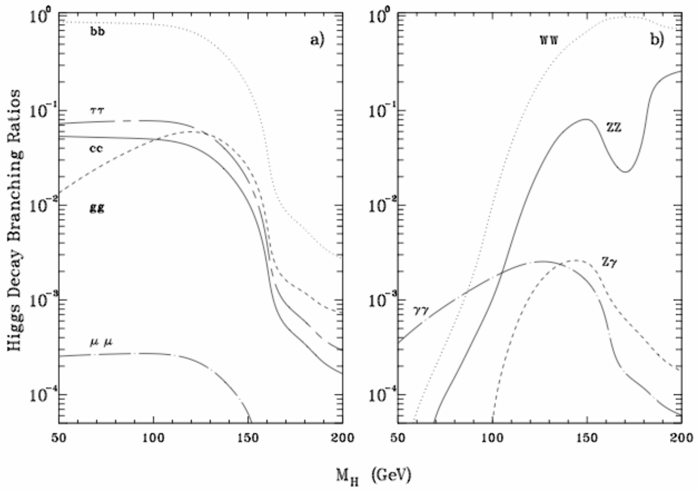


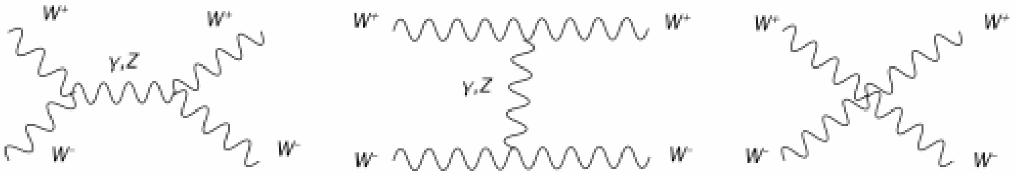
Fig. 1

Unitarity

$$\epsilon_T = \left(0; \pm\frac{1}{\sqrt{2}}, \frac{-i}{\sqrt{2}}, 0\right) \qquad \epsilon_L = \frac{1}{m_W}\left(|\vec{k}|; 0, 0, E_W\right) \qquad \vec{k}//\hat{z}$$

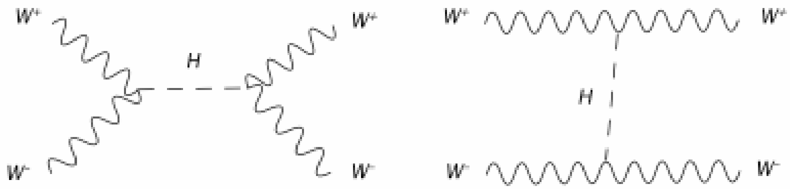
FOR $E_W \gg m_W \qquad \epsilon_L^\mu \approx \frac{k^\mu}{m_W}$

$$\epsilon^L_{W+} \cdot \epsilon^L_{W-} \approx \frac{k_{W+} \cdot k_{W-}}{m_W^2} = \frac{s}{m_W^2} \longrightarrow D_i \propto \frac{k_{W+} \cdot k_{W-}}{m_W^2} \frac{k_{W+} \cdot k_{W-}}{m_W^2} = \frac{s^2}{m_W^4}$$



$\Sigma \propto s$

GAUGE!

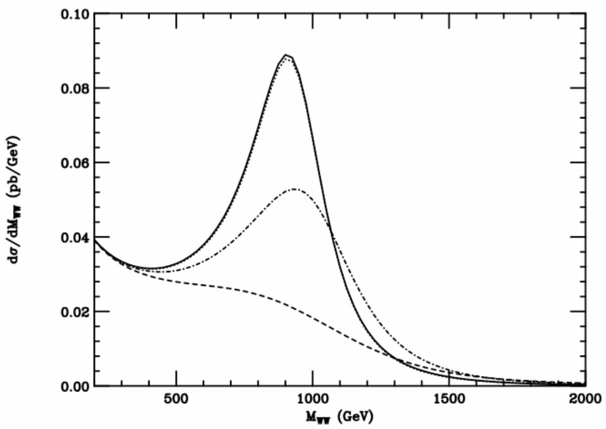


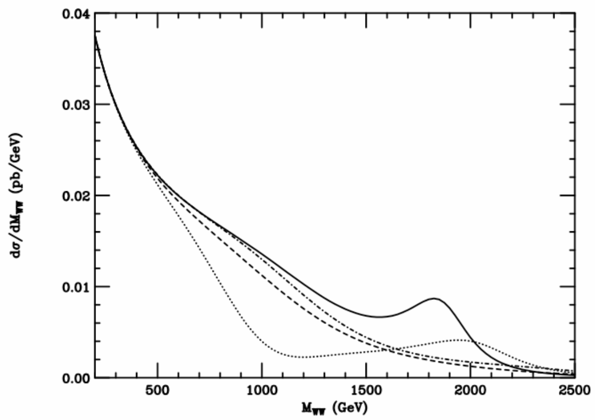
$\Sigma \propto s$

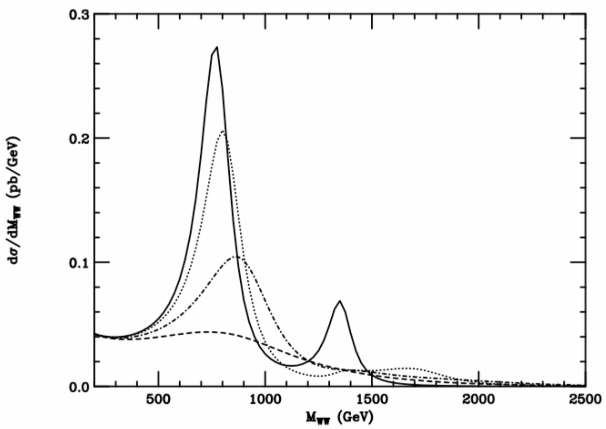
$\Sigma_{all} \approx s^0$

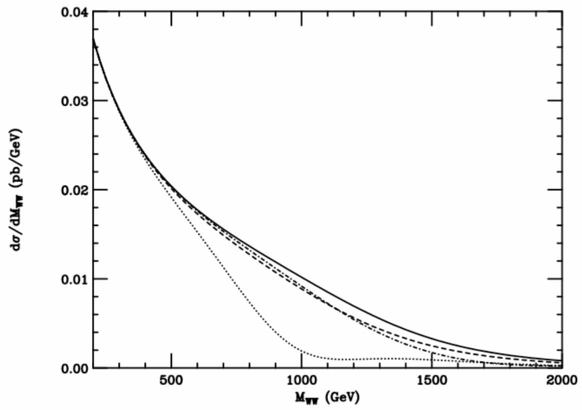
Unitarization: eg:Butterworth,Cox,Forshaw PRD65(02)96014

different ways of constructing amplitudes which are unitary from low order amp

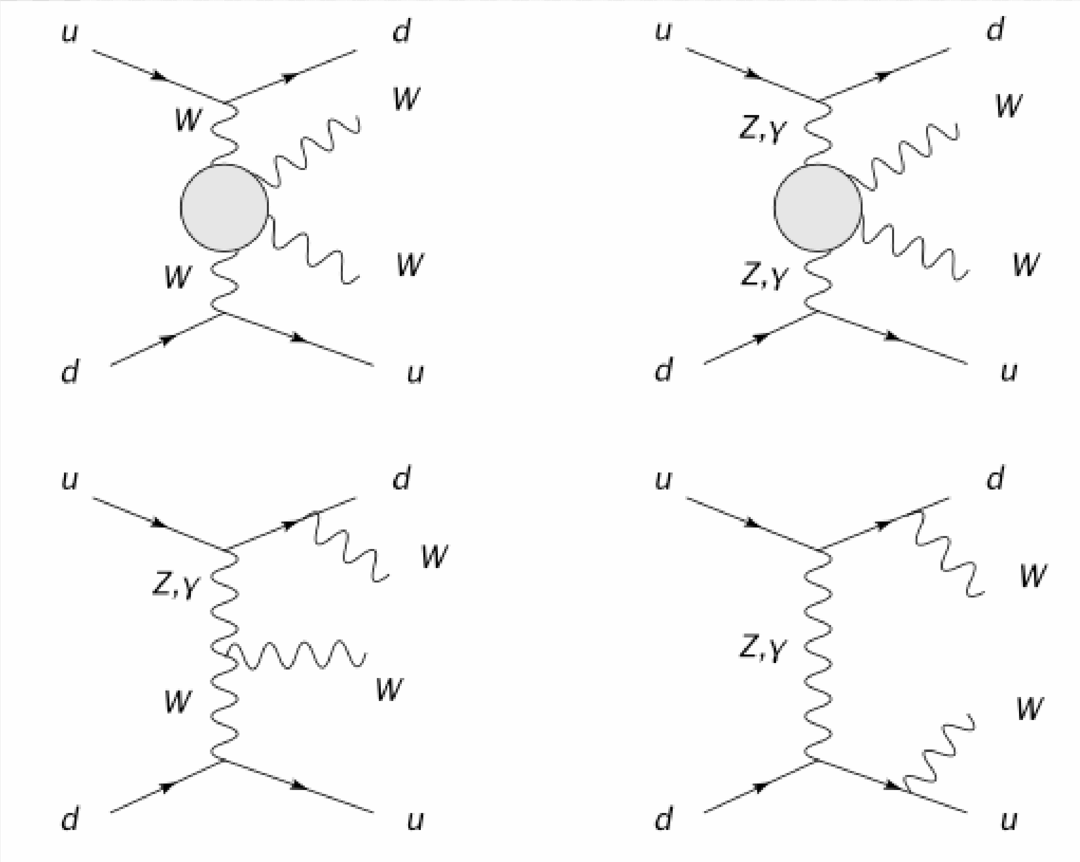








At the LHC

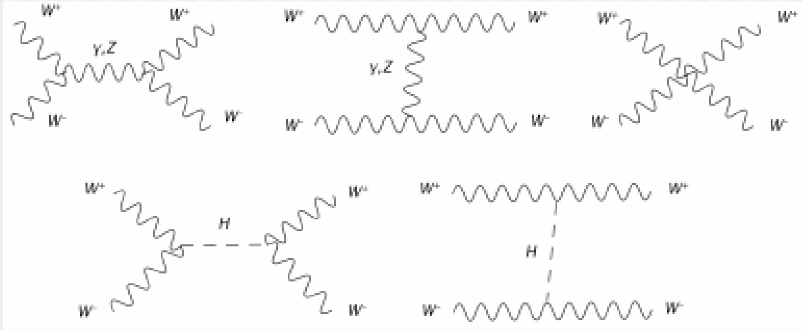


Incoming V's are always off-shell

Large interferences

Kleiss-Stirling, PLB182(86)75

$$V_L(q_1^2 = m^2 + 4\sqrt{s}\Delta_1)V_L(q_2^2 = m^2 + 4\sqrt{s}\Delta_2) \longrightarrow X$$



- The HE off-shell behaviour is worse than on-shell

PROC	OFF-OFF	ON-OFF	ON-ON
$ZZ \rightarrow ee$	$\Delta_1\Delta_2$	$m^2\Delta_1/\sqrt{s}$	m^4/s
$ZZ \rightarrow ZZ$	$(m_h^2;\Delta_1\Delta_2)$	m_h^2	m_h^2
$ZZ \rightarrow WW$	$\Delta_1\Delta_2 s^2/m^4$	$\Delta_1 s\sqrt{s}/m^2$	$(m_h^2;m^2)$
$WW \rightarrow WW$	$\Delta_1\Delta_2 s^2/m^4$	$\Delta_1 s\sqrt{s}/m^2$	$(m_h^2;m^2)$

When the V's are off-shelll emission from f-lines must be included

(a;b)= linear combination of a and b

PHASE

hep-ph/0504009

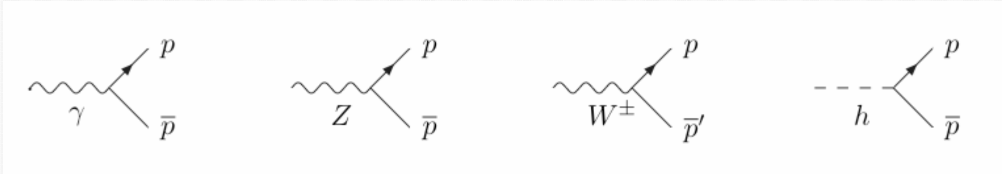
PHact Adaptive Six-fermion Event-Generator

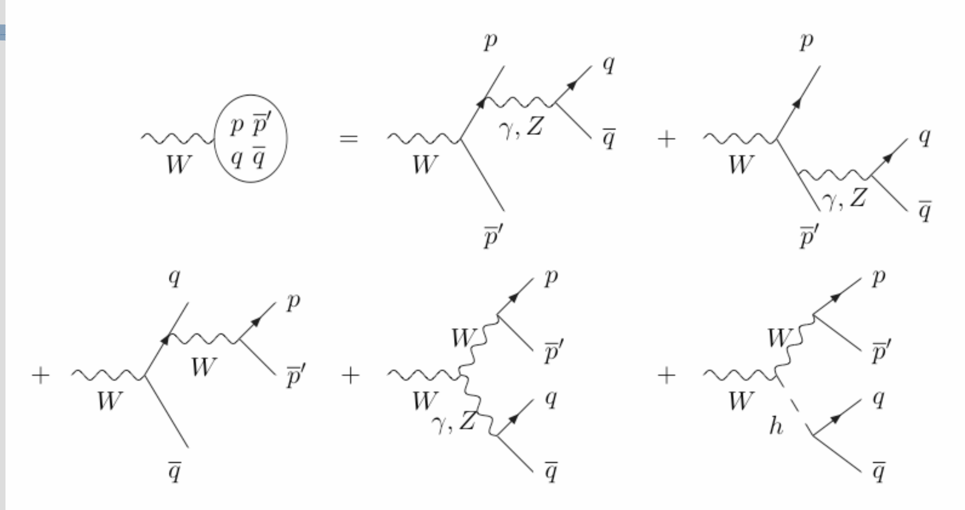
E. Accomando, A. Ballestrero, E. Maina- Univ. Torino

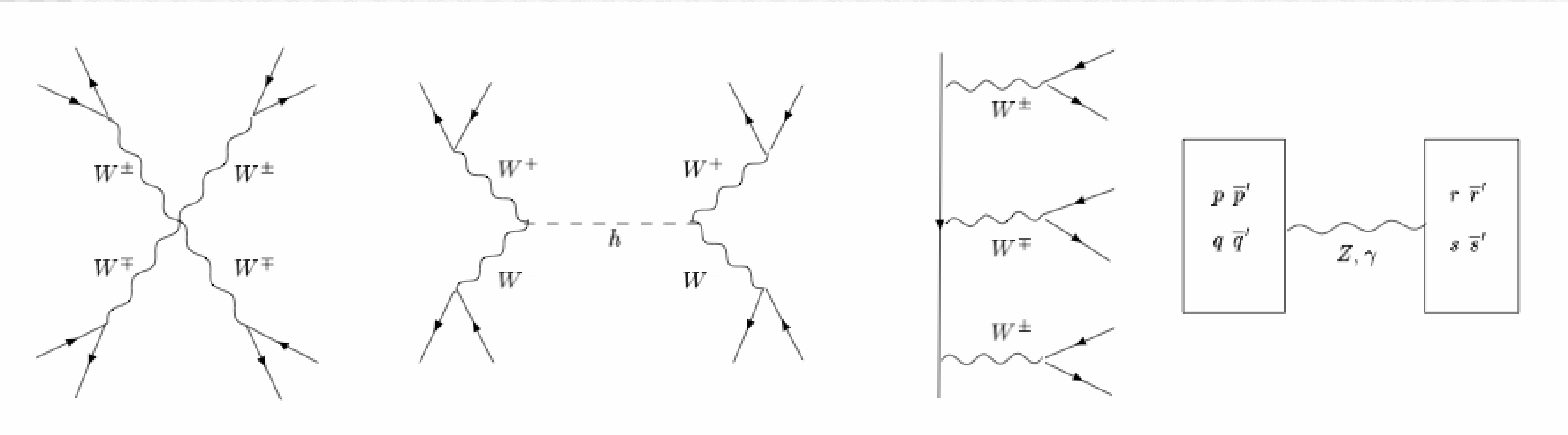
- Dedicated event generator
  - All $q_1 q_2 \longrightarrow q_3 q_4 q_5 q_6 l_1 l_2$
  - One-shot
  - Efficient: good coverage of phase-space
  - Interfaced with showering/hadronization
- Problems
  - Large number of processes
  - Large number of diagrams/process
  - Large number of channels/enhanced regions

PHACT

PLB350(95)225



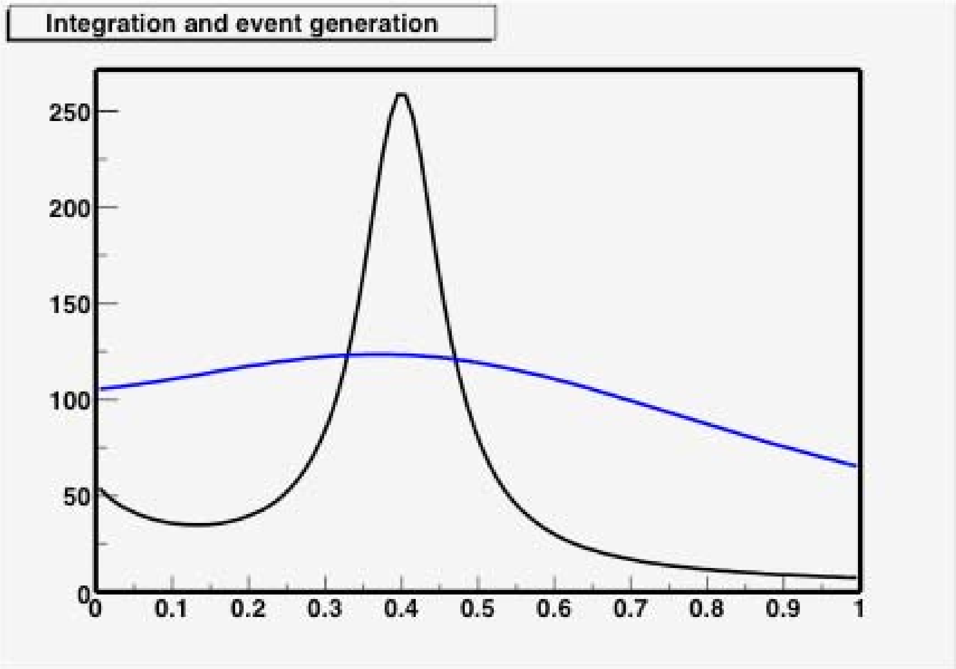




Integration

It is absolutely necessary to obtain a precise cross section: it ensures that the phase-space parametrization matches reasonably well the behaviour of the amplitude squared.

Otherwise generation efficiency will be extremely poor.



Integration can be used to adapt more closely to the integrand

Possible strategies:

- ADAPTIVE INTEGRATION (Vegas)
  - adapts well to cuts
  - a rough estimate of mapping parameters is usually sufficient
  - fails if several sets of enhancements in $| Amp |^2$ or along diagonals ☹
- MULTICHANNEL
  - requires a large number of channels (easy to add)
  - all channels are integrated over simultaneously
  - sensitive to cuts, efficiency generally small ☹
  - mapping parameters to be determined with high accuracy ☹
- ADAPTIVE+MULTICHANNEL
  - Adapts well to cuts
  - A rough estimate of mapping parameters is usually sufficient
  - All channels have to be integrated separately ☹

Processes in PHASE1.0

Particles	type	diag	#proc(2+1)	Particles	type	diag	#proc(2+1)
$c\bar{s}d\bar{u}c\bar{s}\mu\bar{\nu}$	4W	202	6 + 2	$u\bar{u}u\bar{u}c\bar{s}\mu\bar{\nu}$	2Z2W	422	6 + 2
$u\bar{u}c\bar{c}c\bar{s}\mu\bar{\nu}$	2Z2W	422	10 + 1	$u\bar{u}s\bar{s}c\bar{s}\mu\bar{\nu}$	2Z2W	422	10 + 1
$u\bar{u}b\bar{b}c\bar{s}\mu\bar{\nu}$	2Z2W	233	15 + 0	$d\bar{d}d\bar{d}c\bar{s}\mu\bar{\nu}$	2Z2W	422	6 + 2
$d\bar{d}c\bar{c}c\bar{s}\mu\bar{\nu}$	2Z2W	422	10 + 1	$d\bar{d}s\bar{s}c\bar{s}\mu\bar{\nu}$	2Z2W	422	10 + 1
$d\bar{d}b\bar{b}c\bar{s}\mu\bar{\nu}$	2Z2W	233	15 + 0	$c\bar{c}c\bar{c}c\bar{s}\mu\bar{\nu}$	2Z2W	1266	3 + 2
$c\bar{c}b\bar{b}c\bar{s}\mu\bar{\nu}$	2Z2W	466	10 + 1	$s\bar{s}s\bar{s}c\bar{s}\mu\bar{\nu}$	2Z2W	1266	3 + 2
$s\bar{s}b\bar{b}c\bar{s}\mu\bar{\nu}$	2Z2W	466	10 + 1	$b\bar{b}b\bar{b}c\bar{s}\mu\bar{\nu}$	2Z2W	610	6 + 2
$u\bar{u}d\bar{d}c\bar{s}\mu\bar{\nu}$	2Z2W+4W	312	15 + 0	$c\bar{c}s\bar{s}c\bar{s}\mu\bar{\nu}$	2Z2W+4W	1046	6 + 2
TOTAL: 141 + 20							

All particles outgoing

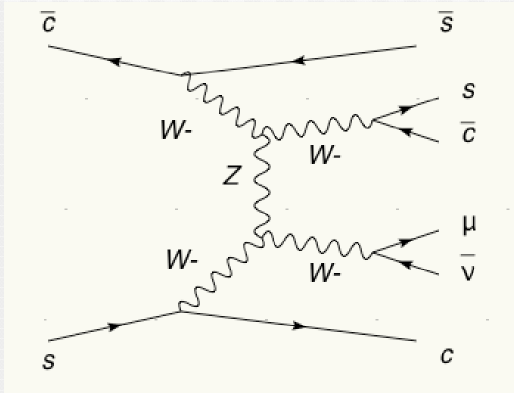
Adding ud<-->cs and e<-->mu
---> 1K processes

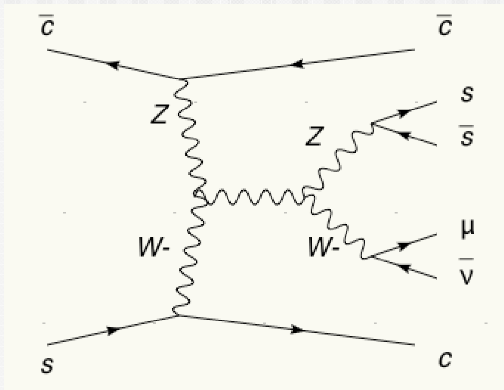
An interesting example: $\bar{c}s \longrightarrow \bar{c}s\bar{s}c\bar{\nu}\mu$

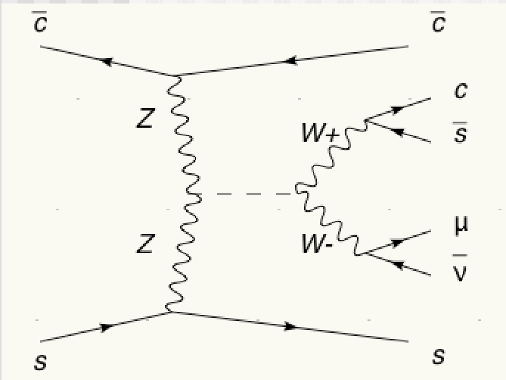
1046 diagrams

It includes:

- ZZ --> W+W-   Higgs --> WW
- ZW- --> ZW-
- W-Z --> ZW-
- W-W- --> W-W-
- W- --> W-W+W-   with 2 Higgs --> WW channels
- W- --> ZZW-   Higgs --> ZZ







Homework: check it out

Future Improvements

- 2q --> 4qlnu @ $O(a_s^2 a_w^4)$ First result later
- 2q --> $4ql^+l^-$ in integration test ZW&ZZ final states semilept
- 2q --> 2q4l all ingredients ready ZW&ZZ final states lept
- 2g --> 4qlnu @ $O(a_s^2 a_w^4)$ & @ $O(a_s^4 a_w^2)$

  Main TOP channel! Amp $O(a_s^2 a_w^4)$ ready

  Good control of tails is essential
- 2g --> 2q4l

With C. Mariotti and S. Bolognesi,
E. Accomando, S. Ballestrero(Torino)

First look

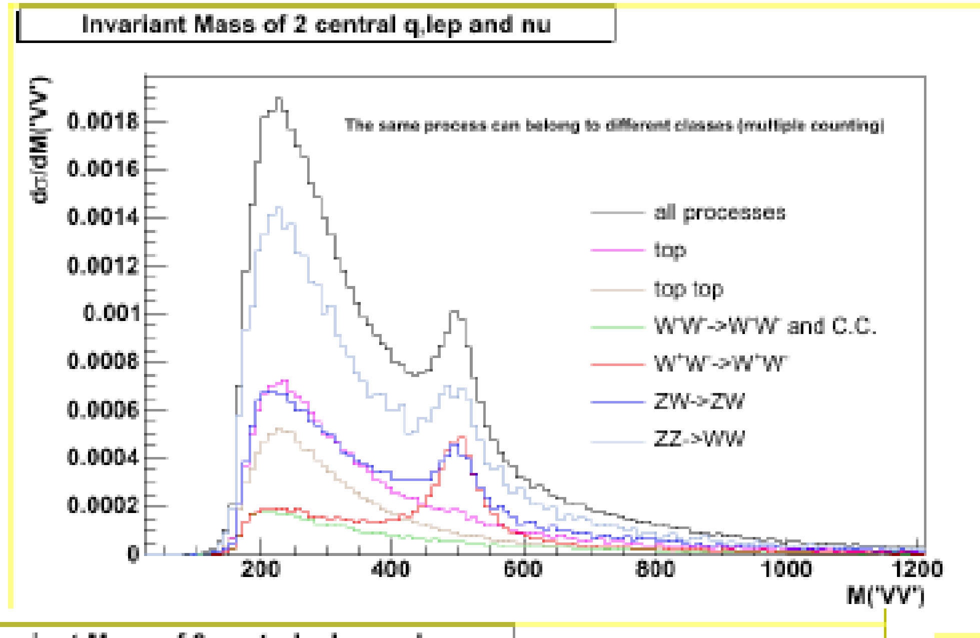
- $p_T(q,l^{+/-})$> 10 GeV
- $E(q,l^{+/-})$>20GeV
- M(q,q)>20GeV
- Abs(eta(q))<6.5
- Abs(eta($l^{+/-}$))<3
- Abs(eta(jc))<3
- eta(jf)>2
- eta(jb)<-2

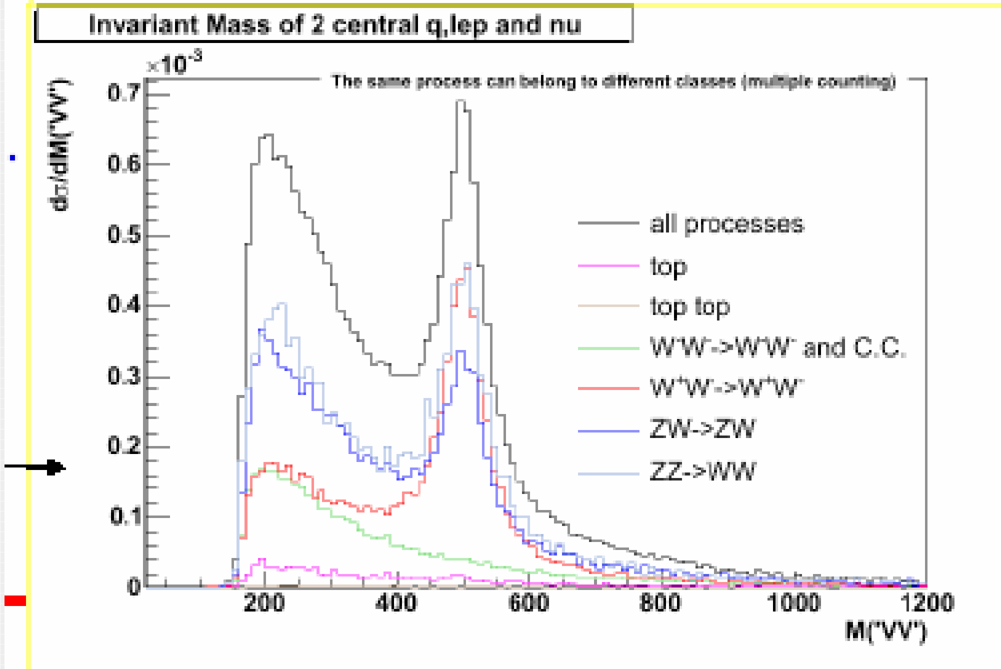
Reject

- 160<M(blnu)<190GeV
- 160<M(bqq)<190GeV

Require

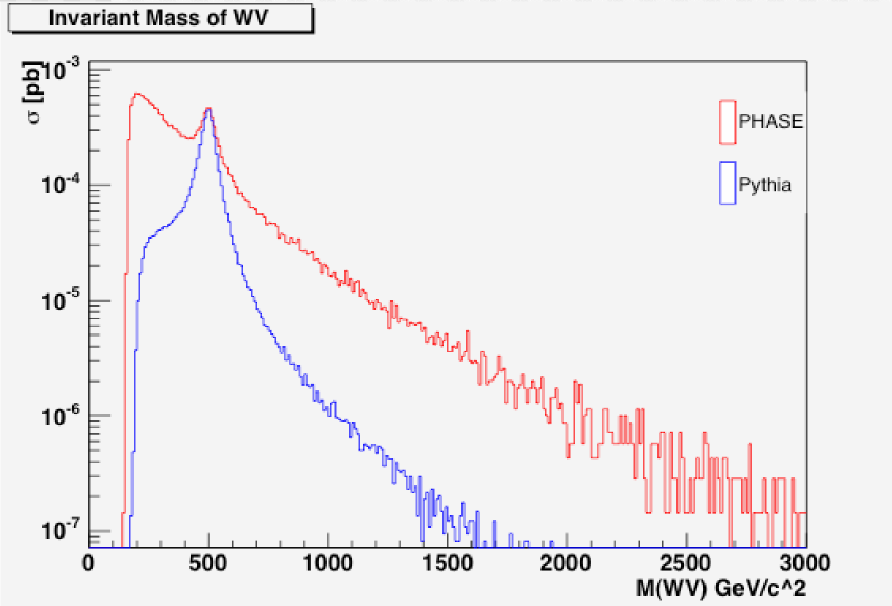
- 70<M(qq)<90GeV



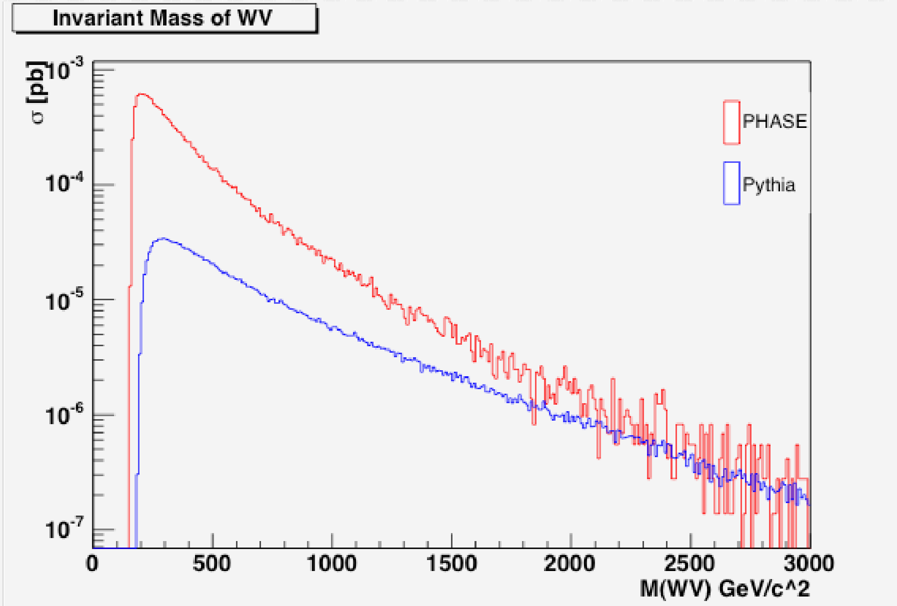


Top rejection
W mass

PHASE vs PYTHIA



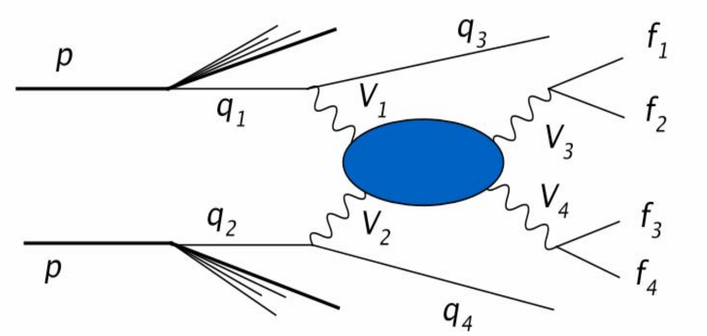
mH=500GeV



No Higgs

PYTHIA has only LL in EVBA approximation

VV scattering



Cannot be separated from all other EW contributions

Expect:

- central high pT JJ and lnu from W's
- high energy, high pT forward and backward spectator J

Background:

- tt
- VV+jets
- V+jets

WW	
SIGNAL	
$M_h = 500$ GEV	$\sigma = 60$ FB
$No - Higgs$	$\sigma = 20$ FB
BACKGROUND	
TOP–TOP	$\sigma = 6.2 \times 10^5$ FB
W+JETS	$\sigma = 7.7 \times 10^4$ FB
WW	$\sigma = 1.1 \times 10^3$ FB

ZZ+ZW	
SIGNAL	
$M_h = 500$ GEV	$\sigma = 9.1$ FB/ 0.7 FB
$No - Higgs$	$\sigma = 1.7$ FB/ 1.4 FB
BACKGROUND	
TOP–TOP	$\sigma = 6.2 \times 10^5$ FB
Z+JETS	$\sigma = 1.4 \times 10^7$ FB
ZZ	$\sigma = 6.6 \times 10^5$ FB
WZ	$\sigma = 6.6 \times 10^5$ FB

S/B from EW processes in PHASE at parton level

Main bkg: tt(EW!), single t, VVV

- $p_T(q,l^{+/-})$> 10 GeV
- $E(q,l^{+/-})$>20GeV
- M(q,q)>20GeV
- Abs(eta(q))<6.5
- Abs(eta(l))<3

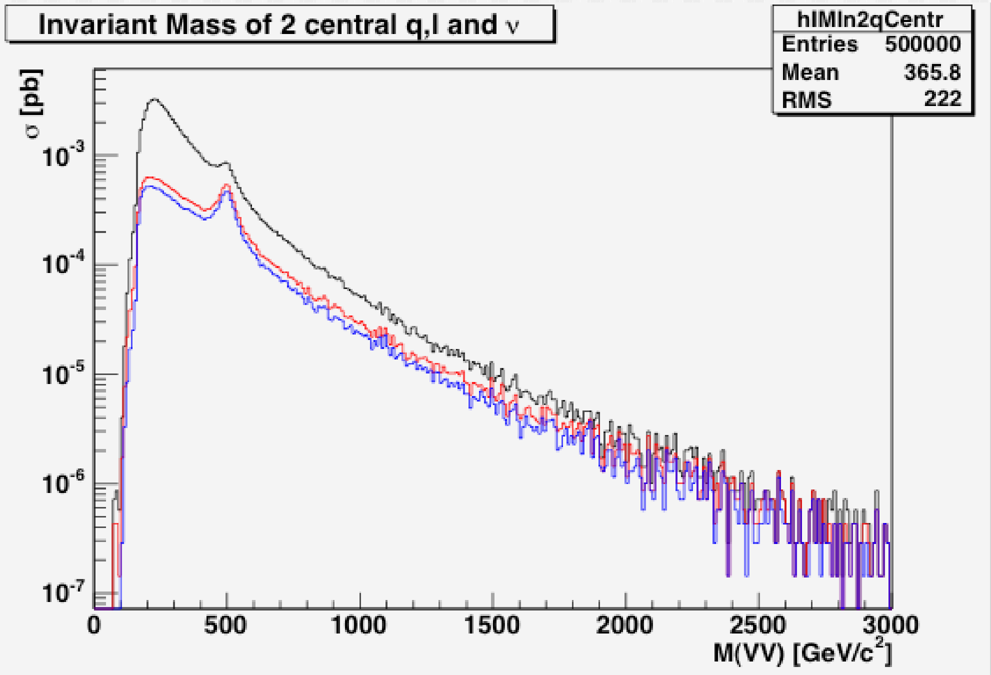
Reject

- 160<M(blnu)<190GeV
- 160<M(bqq)<190GeV

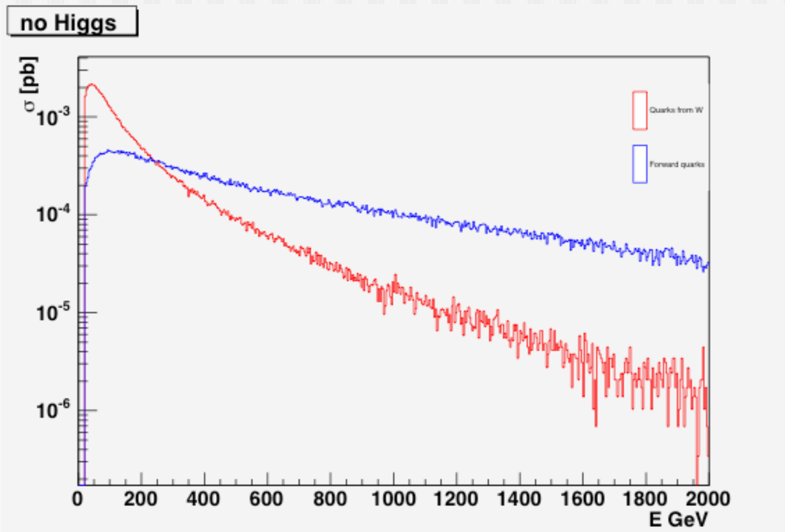
Require

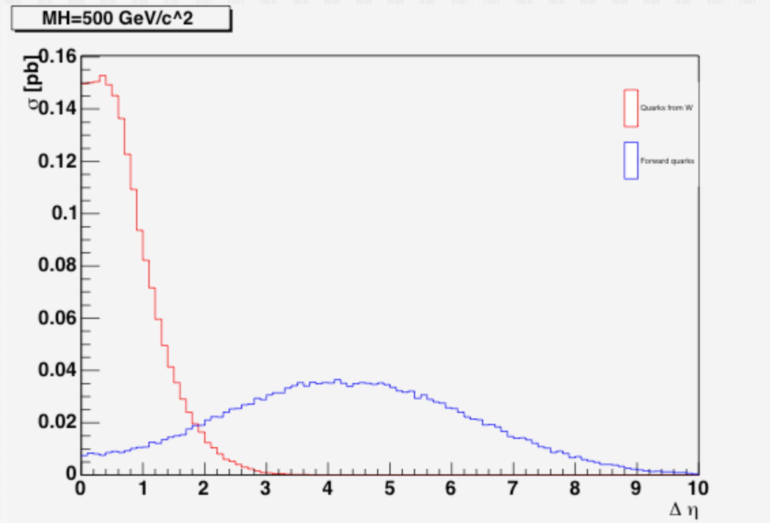
- 70<M(qq)<90GeV
- 70<M(lnu)<90GeV
- M(jf-jb)$\neq M_W, M_Z$

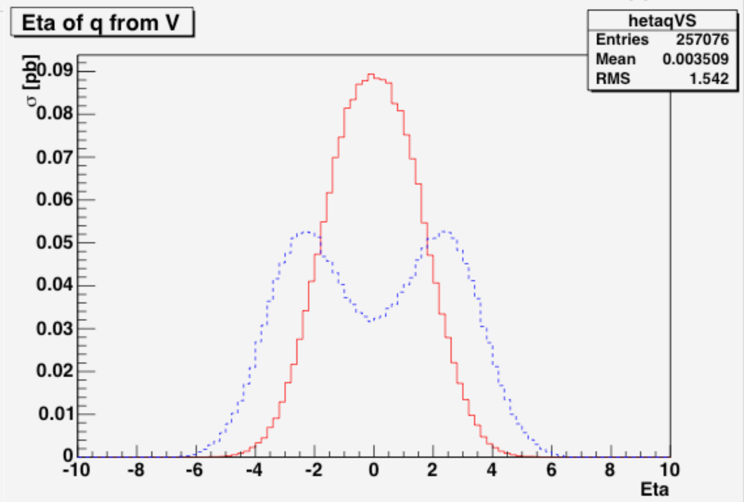
If more than one qq pair is close to $M_{W,Z}$ best match is chosen. Flavour info used.

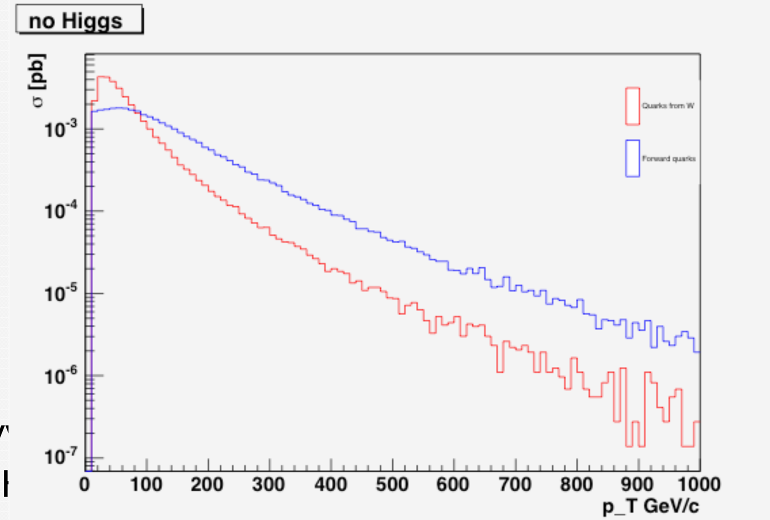


Spectator vs decay partons

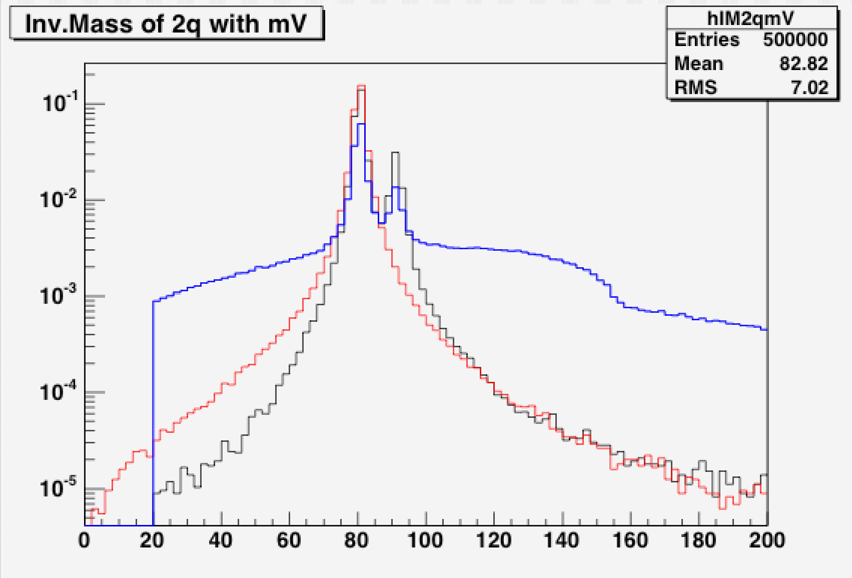




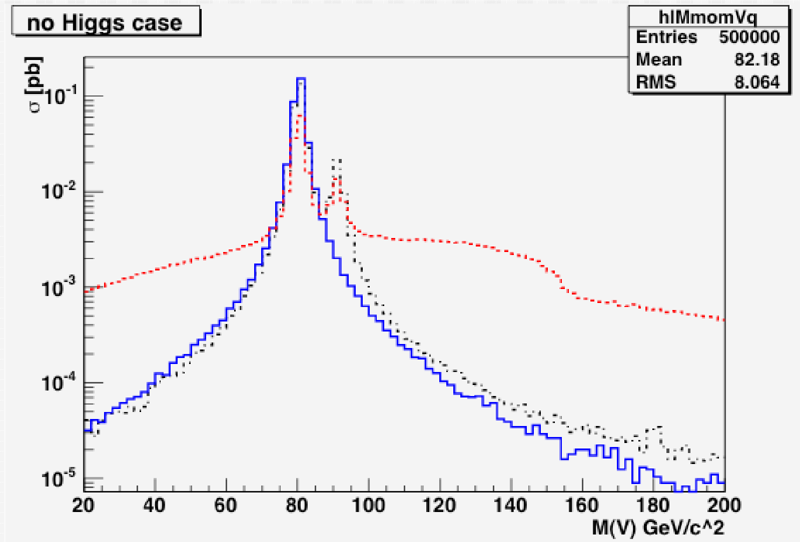




$V(q_c q_c)$ spectrum

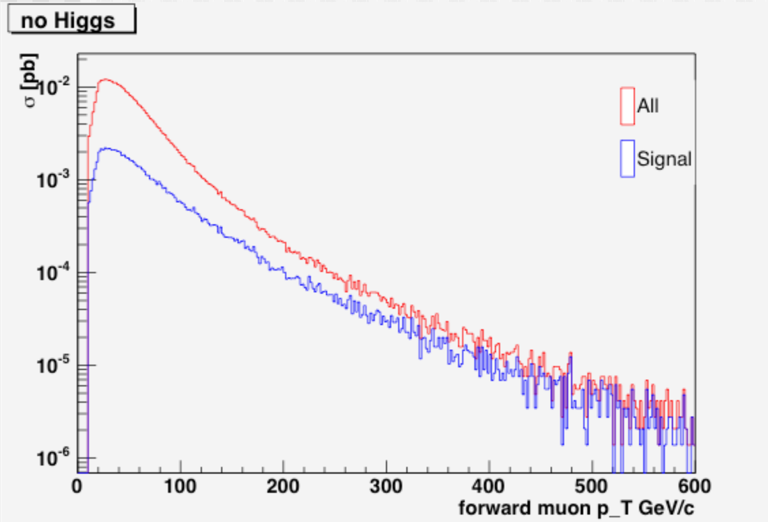


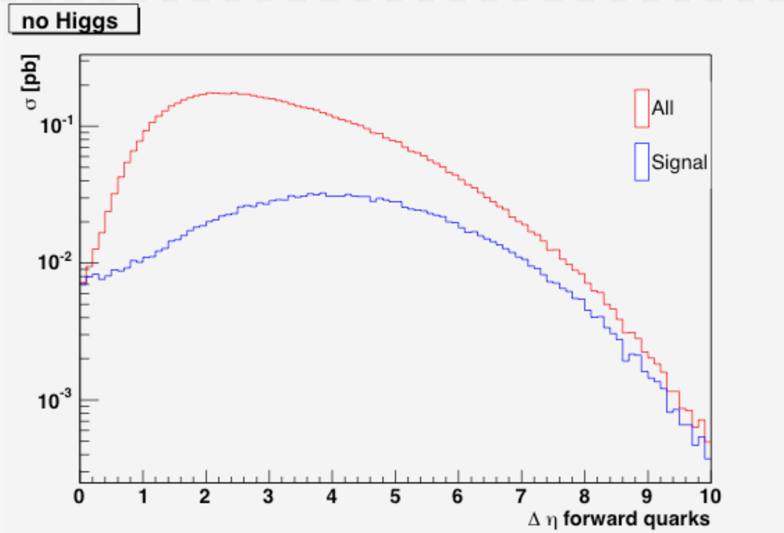
No flavour info

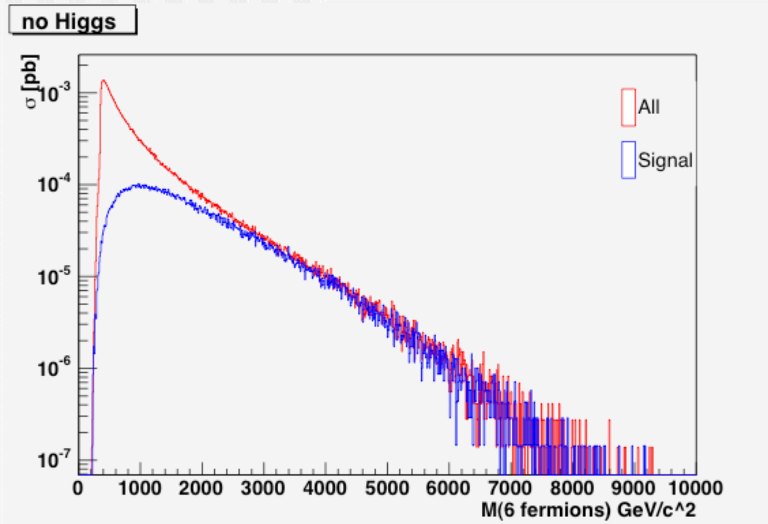


Flavour info

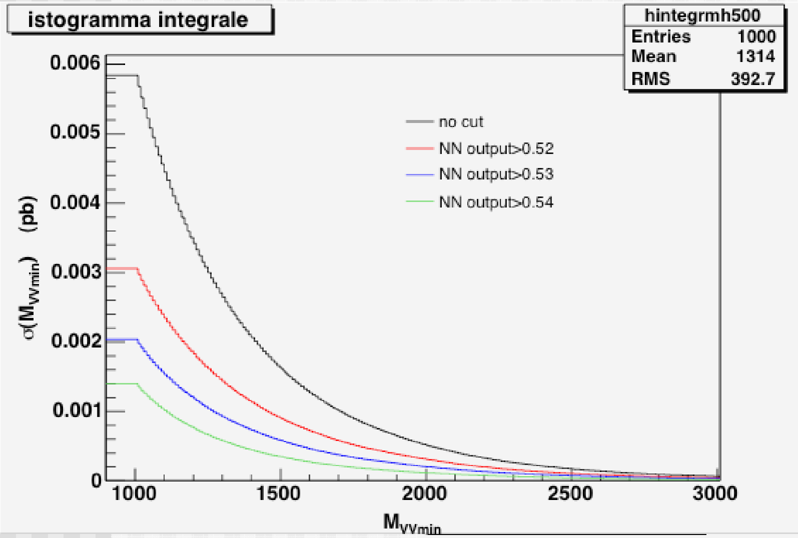
S/B kinematics



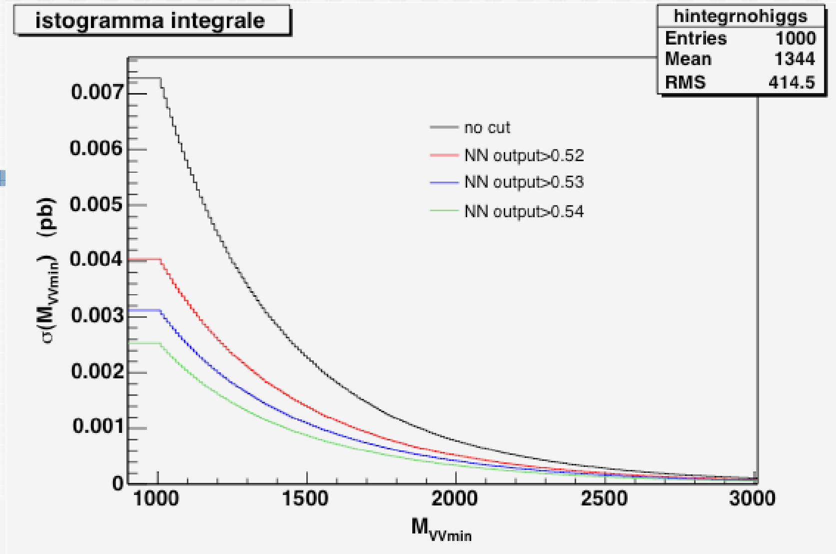




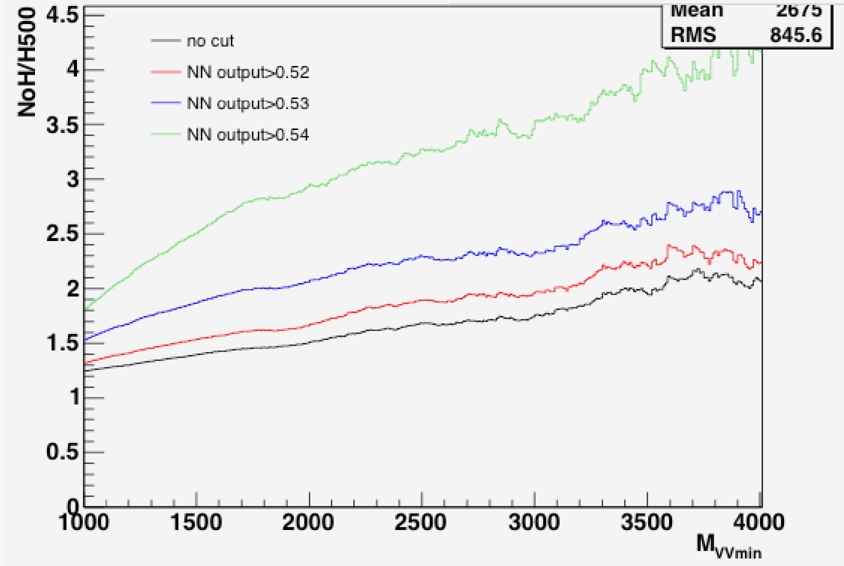
Neural Net Selection of Signal



mH=500GeV



NoHiggs

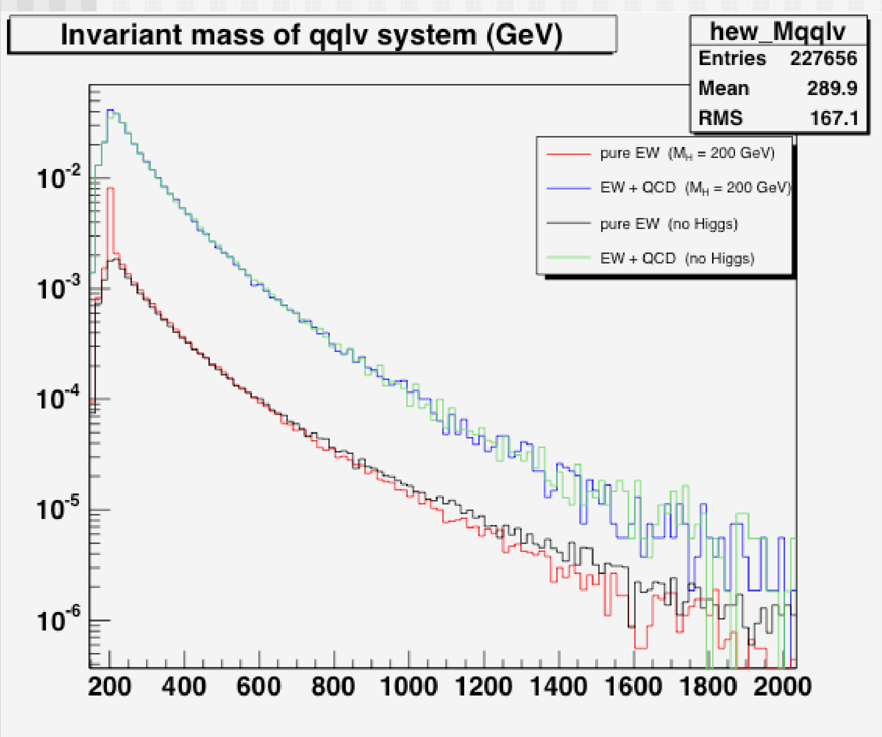


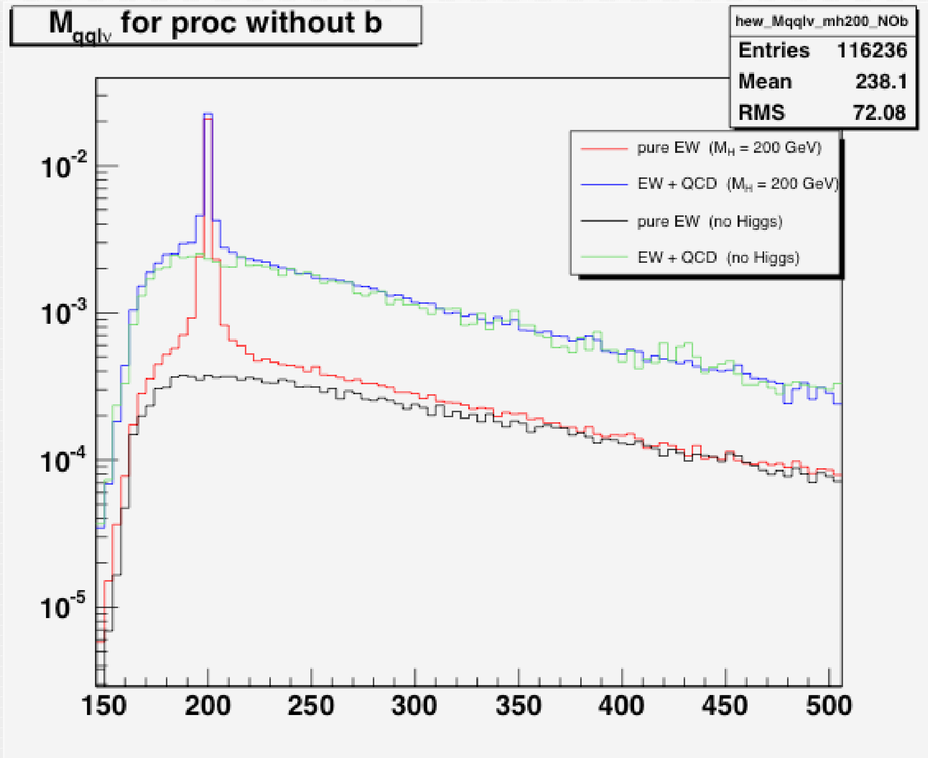
Internal gluon QCD corrections

with G. Bevilacqua (Torino)

Includes qq-->tt
No external g

All PHASE1.0 processes





First results: no real analysis

70<M(jcjc)<90GeV

Conclusions

- A new 6f Event Generator is available for VV scattering, Higgs in VBF, top(soon), VVV physics
- First results in VV scattering and Higgs production
- Extracting Signal is hard

WORK is in PROGRESS

- New processes
- More realistic simulations: FAMOS, CMKIN