PHASE

PHact Adaptive Six-Fermion Event Generator

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- Introduction
- Common approximations vs complete calculation
- Gauge invariance and interference at high energy
- PHASE: an overall view
- Some application to VV scattering
- Work in progress

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PHASE

PHact Adaptive Six-Fermion Event Generator

[Accomando, Ballestrero and Maina]

- **All processes with 6 fermion final states.**
  [$q_1 q_2 \to q_3 q_4 q_5 q_6 l \bar{\nu}_l$ $O(\alpha^6)$ **up to now**]
- **Exact matrix elements**
- **Adaptive-multichannel integration over the full phase space**
- **ONE-SHOT: all processes generated at once**
- **Interfaced with PYTHIA with Les Houches protocol**

PROCESSES

All particles outgoing

$(u, d) \rightarrow (c, s)$ symmetry

CC symmetry

μ and e

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

$\rightarrow$ **1288**

PROCESSES vs VV scattering: 4W and 2W2Z

$u\bar{u}d\bar{d}c\bar{s}\mu\bar{\nu}$ 312 diagrams				
Process	$w^+w^- \to w^+w^-$	$w^-w^- \to w^-w^-$	$zw^- \to zw^-$	$zz \to w^+w^-$
$\bar{u}u \to d\bar{d}c\bar{s}\mu\bar{\nu}$	x			
$\bar{u}\bar{d} \to \bar{u}\bar{d}c\bar{s}\mu\bar{\nu}$	x			x
$\bar{u}d \to \bar{u}dc\bar{s}\mu\bar{\nu}$				x
$\bar{u}\bar{c} \to \bar{u}d\bar{d}\bar{s}\mu\bar{\nu}$		x	x	
$\bar{u}s \to \bar{u}d\bar{d}c\mu\bar{\nu}$		x	x	
$u\bar{d} \to u\bar{d}c\bar{s}\mu\bar{\nu}$				x
$ud \to udc\bar{s}\mu\bar{\nu}$	x			x
$u\bar{c} \to ud\bar{d}\bar{s}\mu\bar{\nu}$	x		x	
$us \to ud\bar{d}c\mu\bar{\nu}$	x		x	
$\bar{d}d \to u\bar{u}c\bar{s}\mu\bar{\nu}$	x			
$\bar{d}\bar{c} \to u\bar{u}\bar{d}\bar{s}\mu\bar{\nu}$	x		x	
$\bar{d}s \to u\bar{u}\bar{d}c\mu\bar{\nu}$	x		x	
$d\bar{c} \to u\bar{u}d\bar{s}\mu\bar{\nu}$	x	x		
$ds \to u\bar{u}dc\mu\bar{\nu}$	x	x		
$\bar{c}s \to u\bar{u}d\bar{d}\mu\bar{\nu}$				

Signal + all irreducible background

AMPLITUDES AND DIAGRAMS

- 16 different amplitudes
- amplitudes with the same number of diagrams can be programmed in the same way
- diagrams:

202=101 x 2	**233=211 + 22**
312 = 101 + 211	**422 = 211 x 2**
466 = 233 x 2	**610 = (211 + 94) x 2**
1046 = 101 x 2 + 211 x 4	**1266 = 422 x 3**

ONLY 4 independent sets with
101, 211, 22 and 94 diagrams

- built with **PHACT**: MODULAR and FAST

Few building blocks easy to get modified !

e.g. including new couplings, vertices...

ADAPTIVE-MULTICHANNEL
Integration

A new method which combines

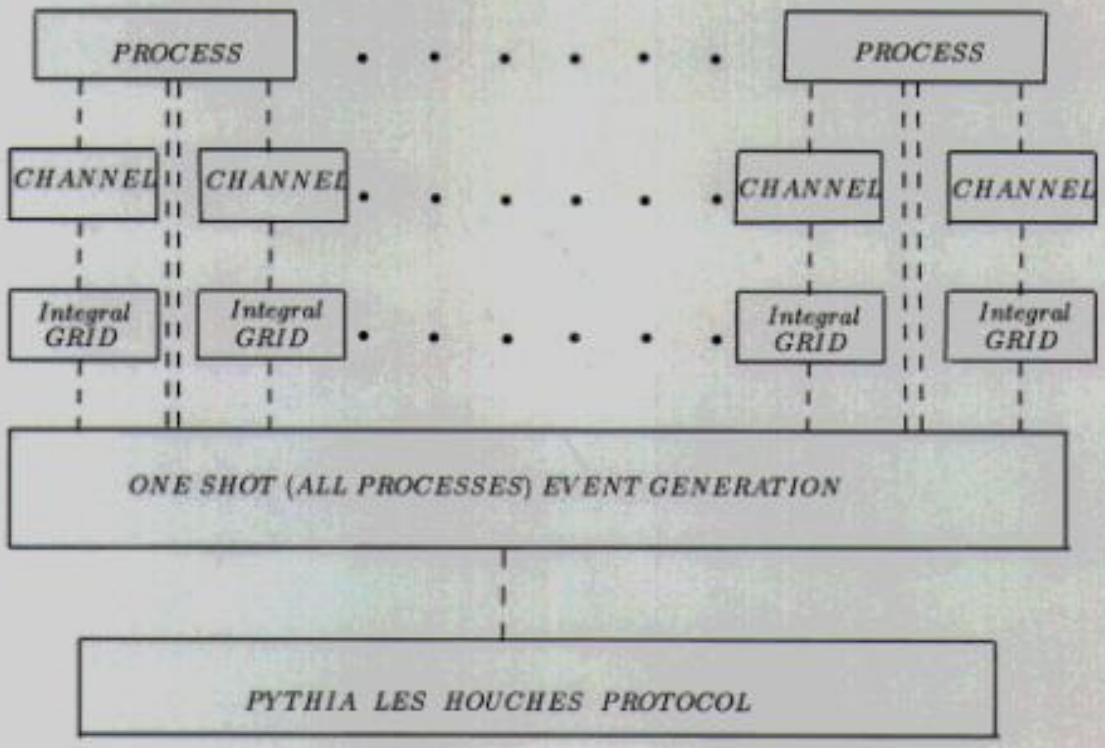
-Adaptive integration: use of a modified VEGAS, which adapts the integration grid

-Multichannel: integrates separately different resonant contributions (channels) of the same process.

OUTCOME

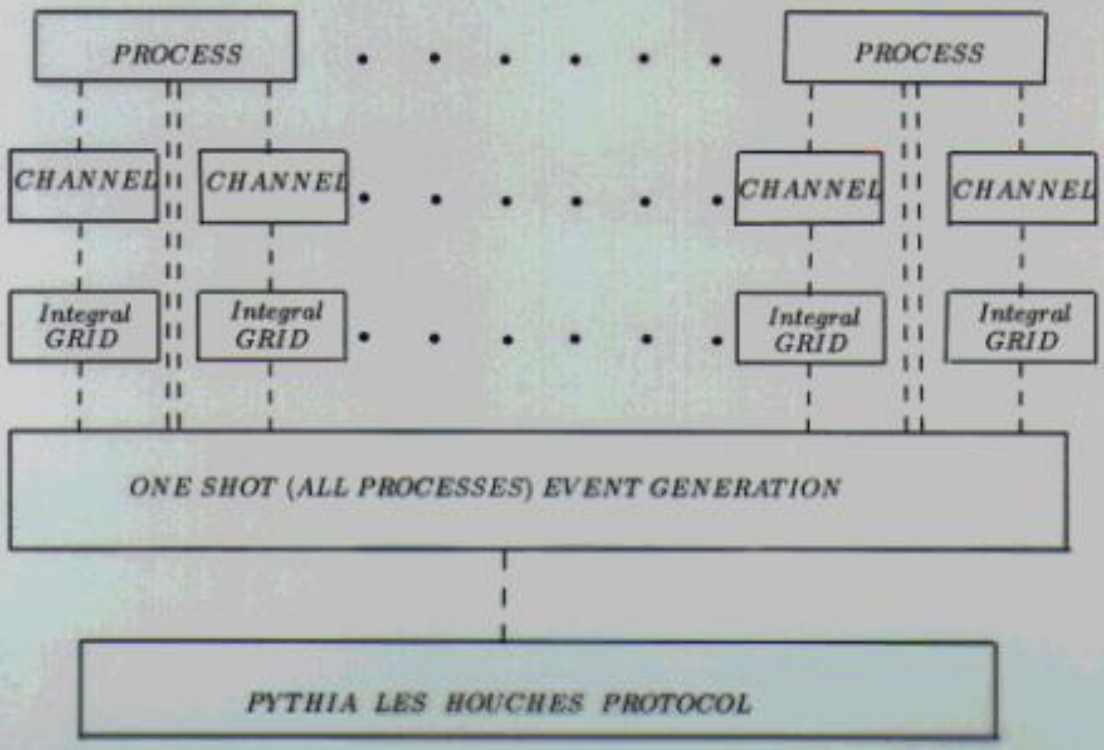
- adapts to cuts and peaks with good efficiency
- no large number of channels is required: Max=4
  - different mappings are combined toghether
- a rough estimate of mapping parameters is sufficient
- each channel must be integrated separately

General scheme



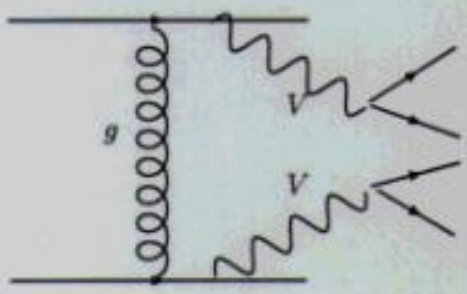
What is the current status?

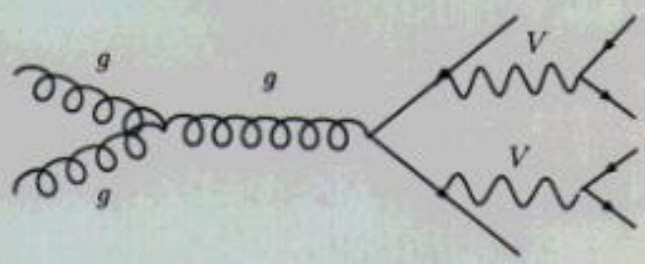
- PHASE is assembled and running
- Amplitudes $qq \to qqqql\nu$ at $O(\alpha^6)$ ready and fast!
- Single process integration OK testing efficiency vs cuts
- Separation of doubly resonant outgoing bosons contributions: almost ready
- Interface to PYTHIA via LesHouches Protocol OK
- ONE-SHOT algorithm: almost ready
- Large scale generation of Input Files for One-Shot Integration GRIDs): to be done



To be continued..

- Extracting the Signal: $q_1 q_2 \to q_3 q_4 V V' \to q_3 q_4 q_5 q_6 \mu \bar{\nu}_\mu$
  - Large interferences? Gauge cancellations?
  - Can it be extrapolated with proper cuts?
- Covering new final states
  $q_1 q_2 \to q_3 q_4 q_5 q_6 l^- l^+$
  - it has $WW \to ZZ$ and $ZZ \to ZZ$
  - additional information on $WZ \to WZ$
- QCD Background $O(\alpha_s^2 \alpha^4)$
  - adding virtual gluons in $q_1 q_2 \to q_3 q_4 q_5 q_6 l_1 l_2$
  - new initial states: $q_1 g \to q_2 q_3 q_4 g l_1 l_2$ and $gg \to q_1 q_2 q_3 q_4 l_1 l_2$
  - new final states $q_1 q_2 \to q_3 q_4 g g l_1 l_2$





Increasing complexity

Much work ahead!