Monte-Carlo event generation for CEPC

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Outline

- Introduction
  - Whizard 1.95 & 2.2.x
  - SM & BSM
  - Other generators
- Production of event for Standard Model
  - Signal
  - Background
- Other issues
  - ISR & beam
  - Cuts

Introduction of CEPC

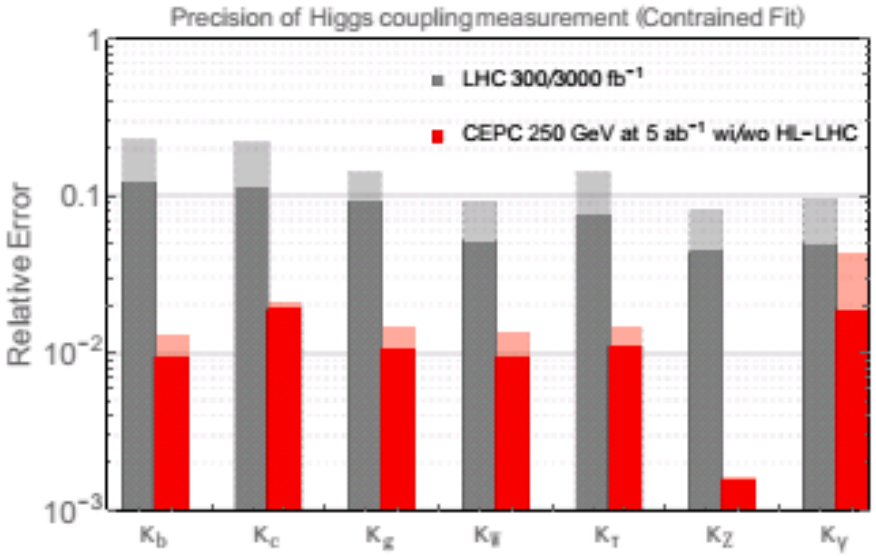
Circular electron-positron collider for next generation

Period: 10 years

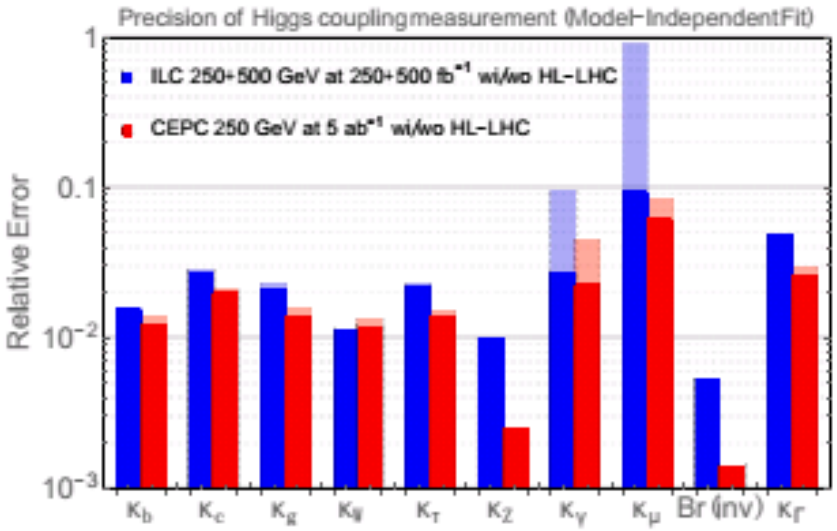
Luminosity: 5 ab^{-1}

Features of CEPC

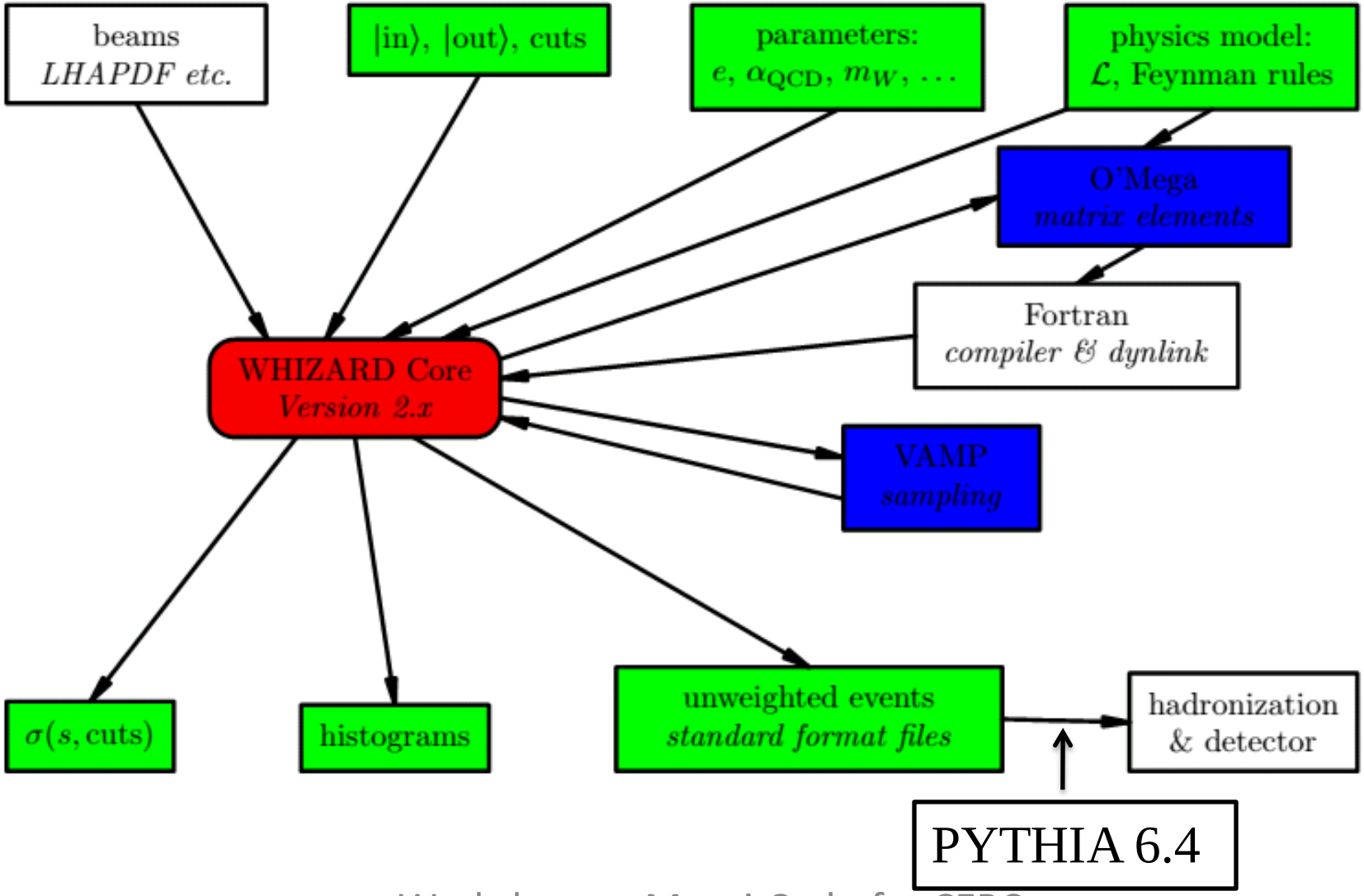
Compared with LHC



Compared with ILC



Tips for generation



Mass production

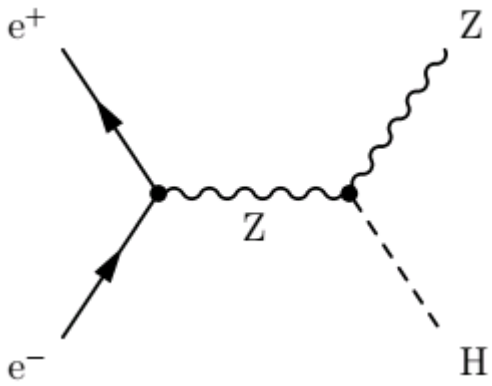
Signal part

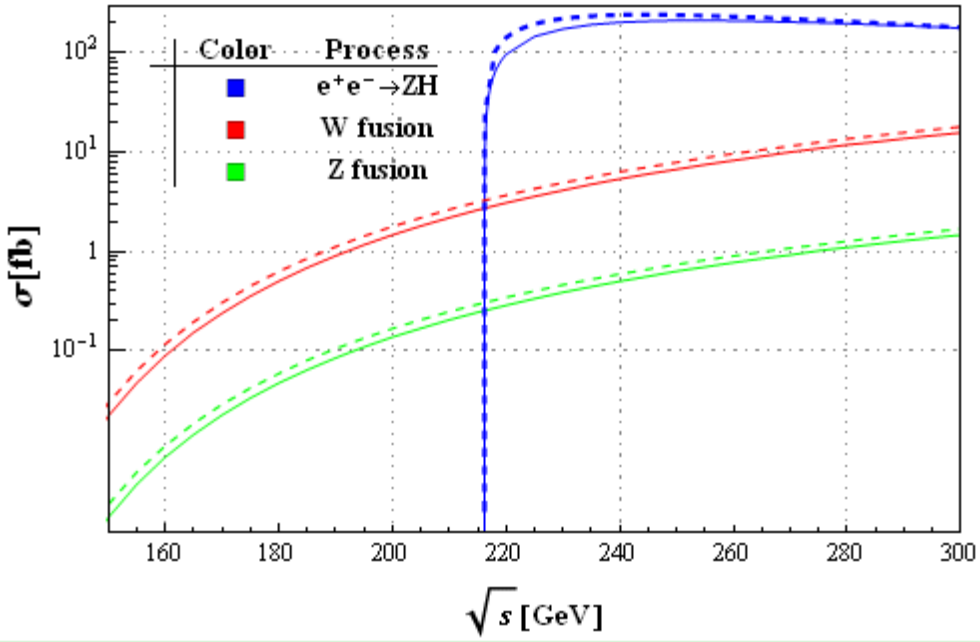
Background part

- 2 fermions
- 4 fermions

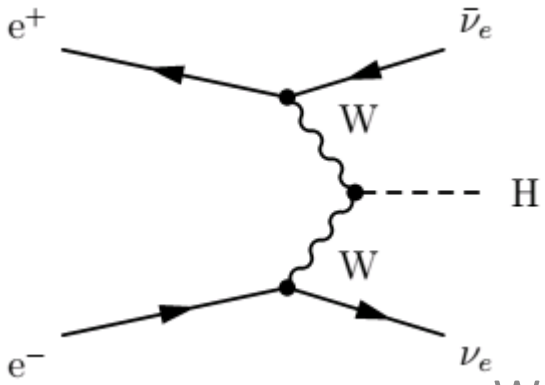
Signal Part

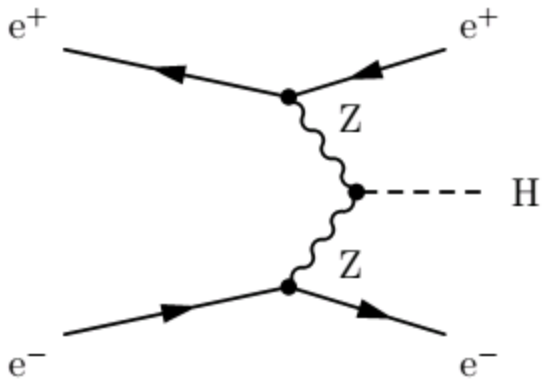
Higgs-strahlung





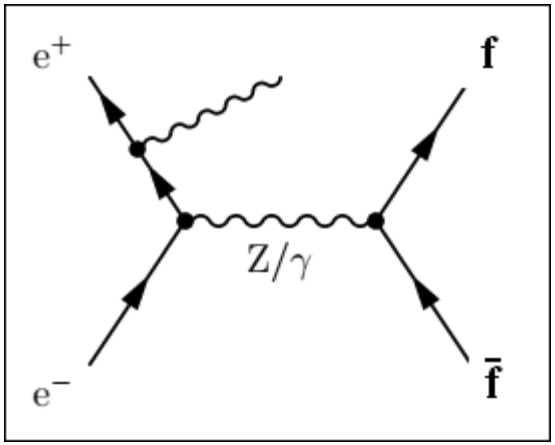
Vector boson fusion

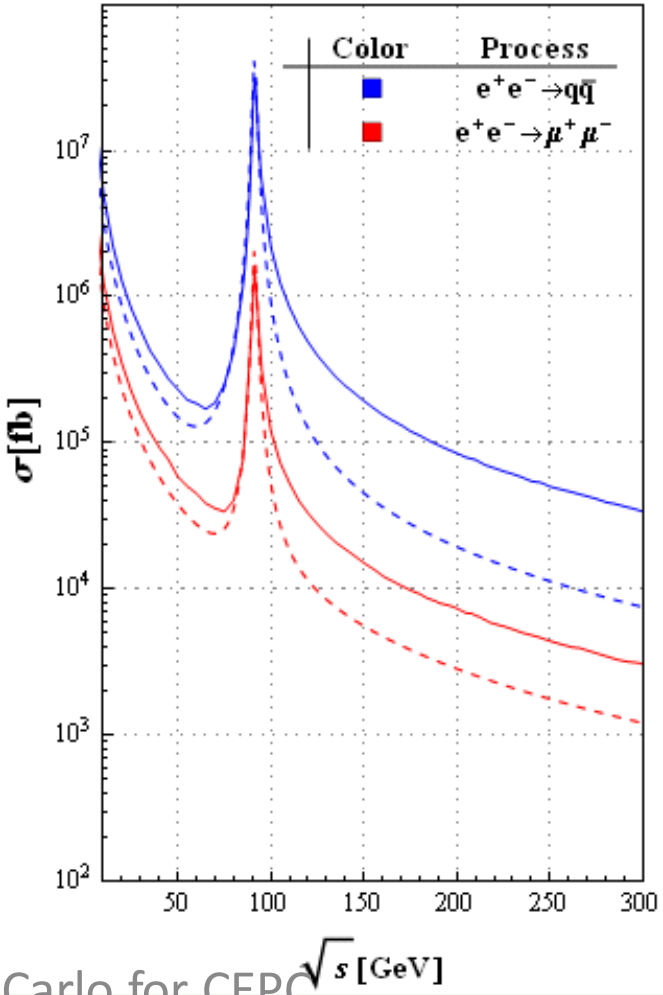




Background processes

Final state with two fermions

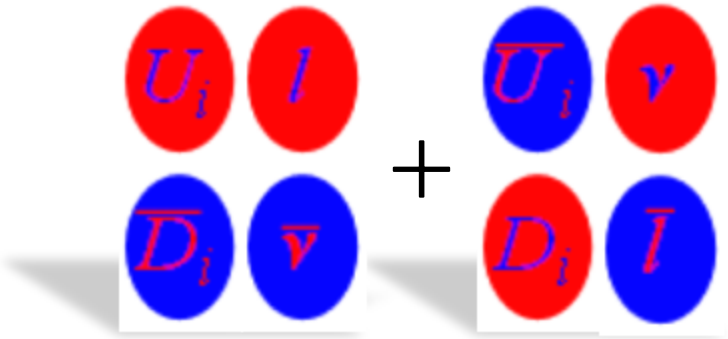




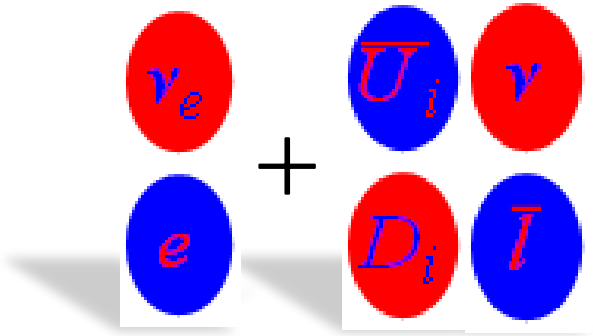
- $e^+e^- \rightarrow ff$
- Z pole physics
- Calibrating the detector

Classification of 4 fermions

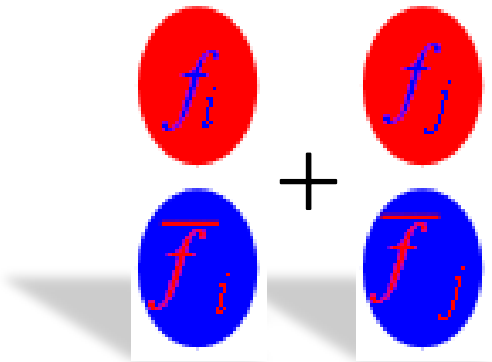
- WW type



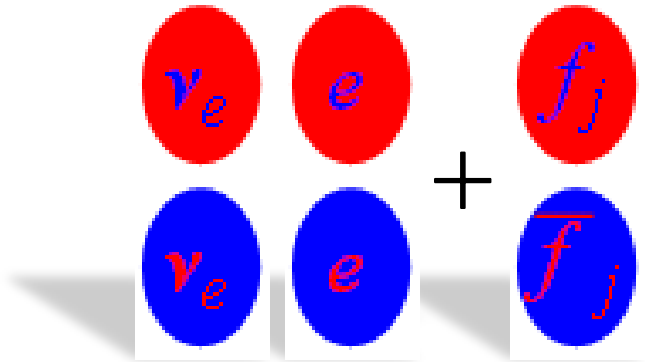
- Single W type



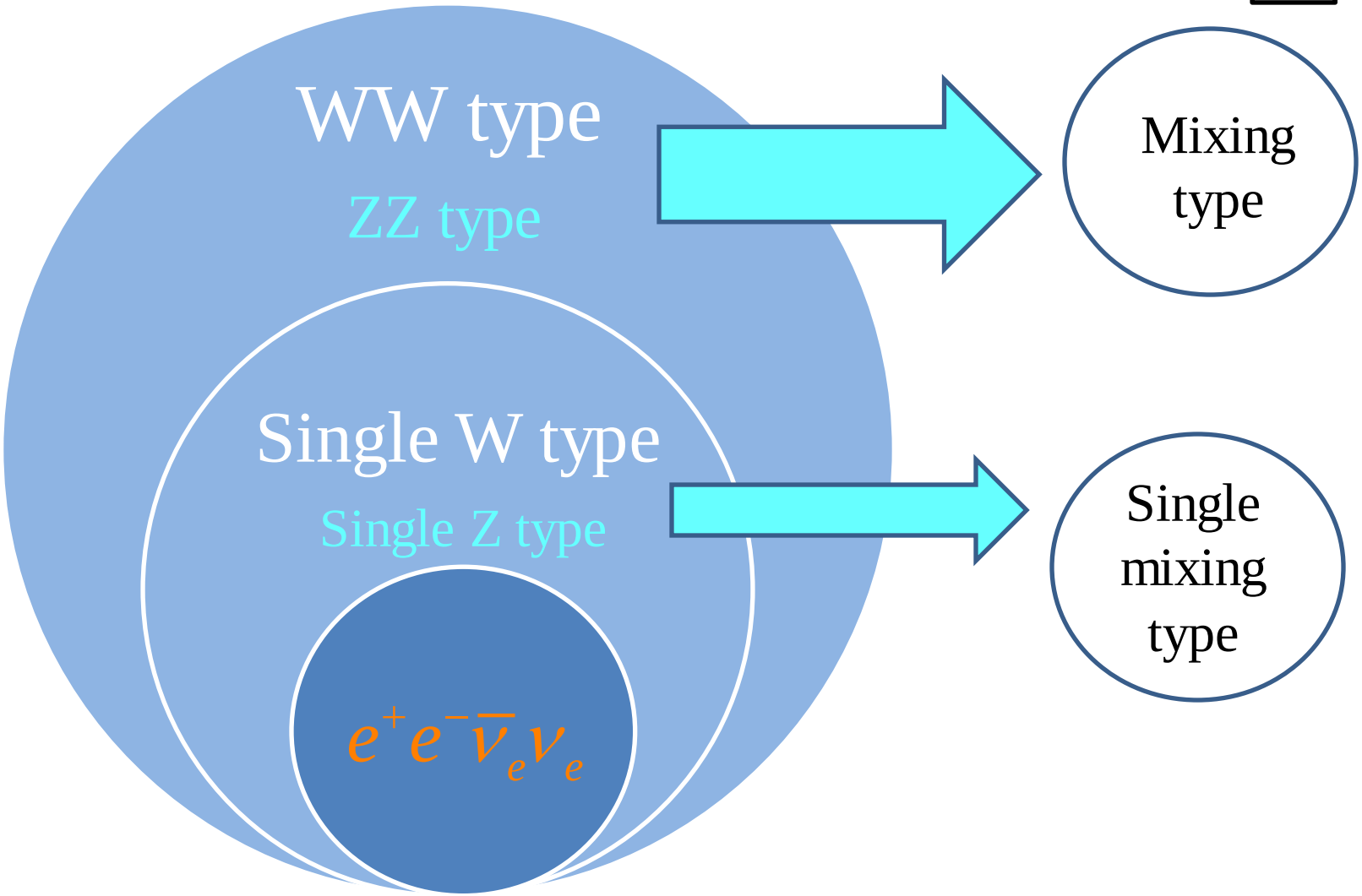
- ZZ type



- Single Z type



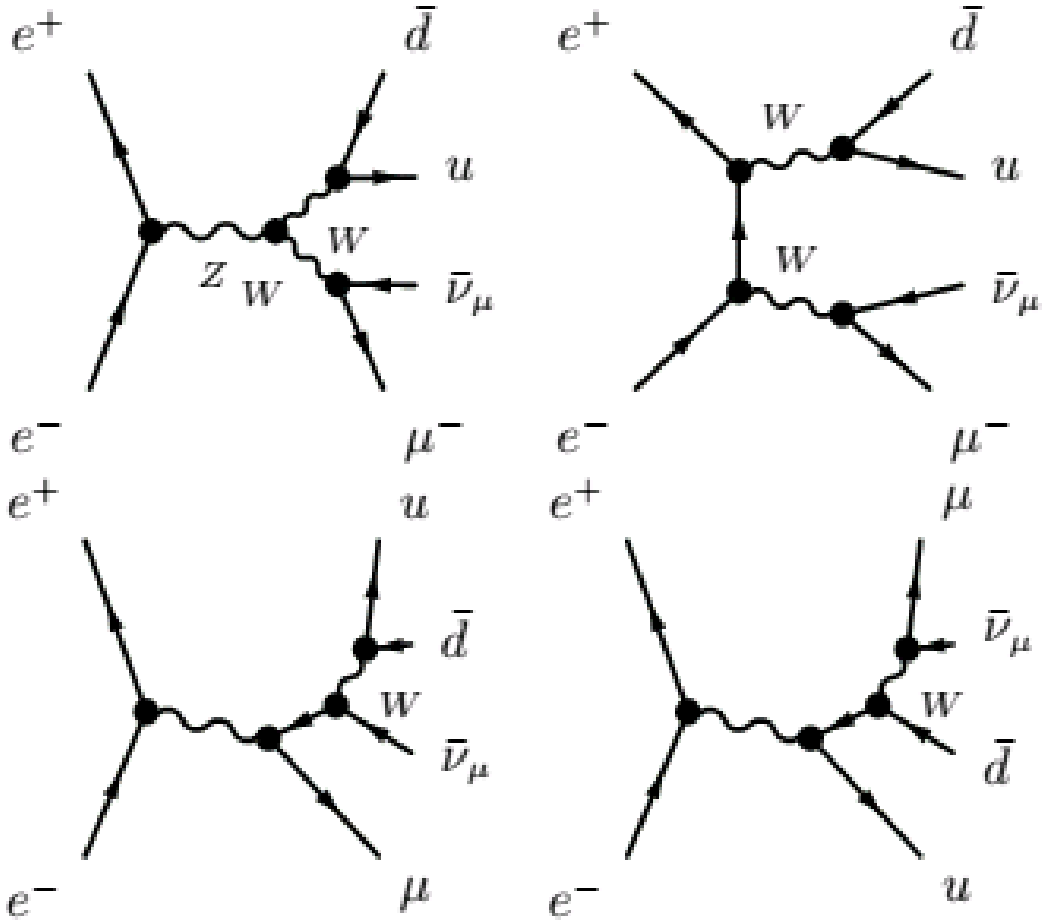
Classification of 4 fermions



W type

	$u\bar{d}$	$c\bar{s}$	$\bar{e}\nu_e$	$\bar{\mu}\nu_\mu$	$\bar{\tau}\nu_\tau$
$d\bar{u}$	*43*	**11**	20	**10**	**10**
$s\bar{c}$	**11**	*44*	20	**10**	**10**
$e\bar{\nu}_e$	20	20	*56*	18	18
$\mu\bar{\nu}_\mu$	**10**	**10**	18	*19*	**9**
$\tau\bar{\nu}_\tau$	**10**	**10**	18	**9**	*20*

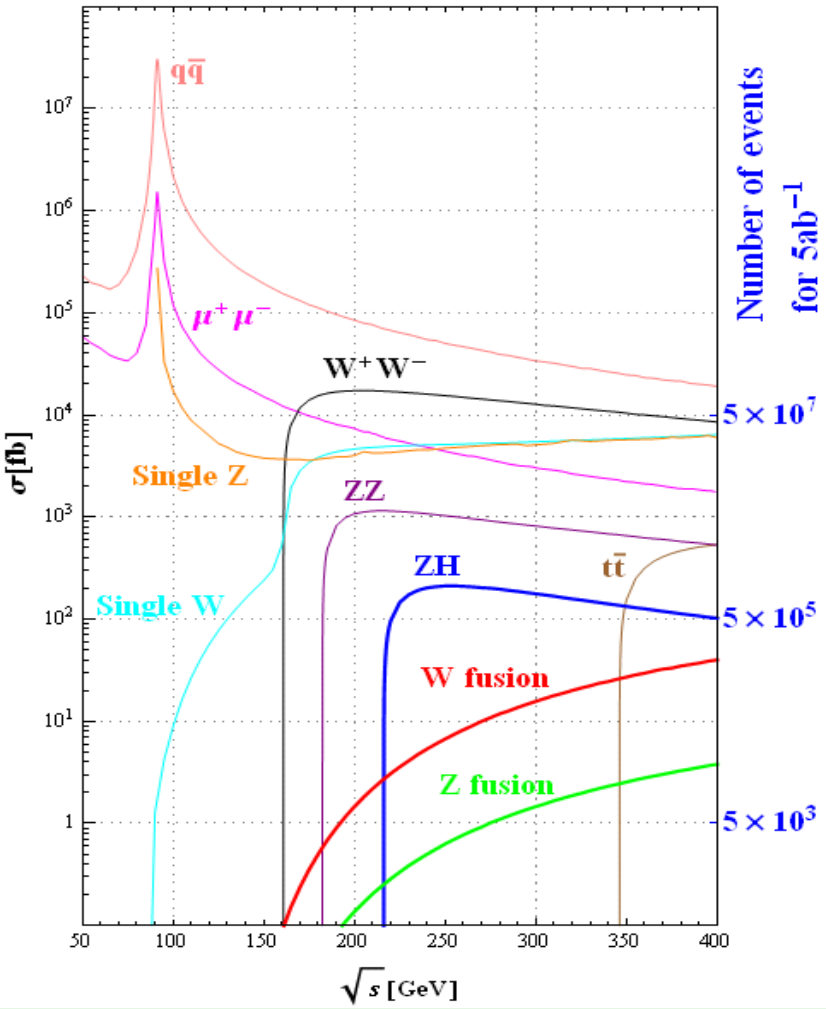
Topological structure



Summary table

Cross sections [fb]

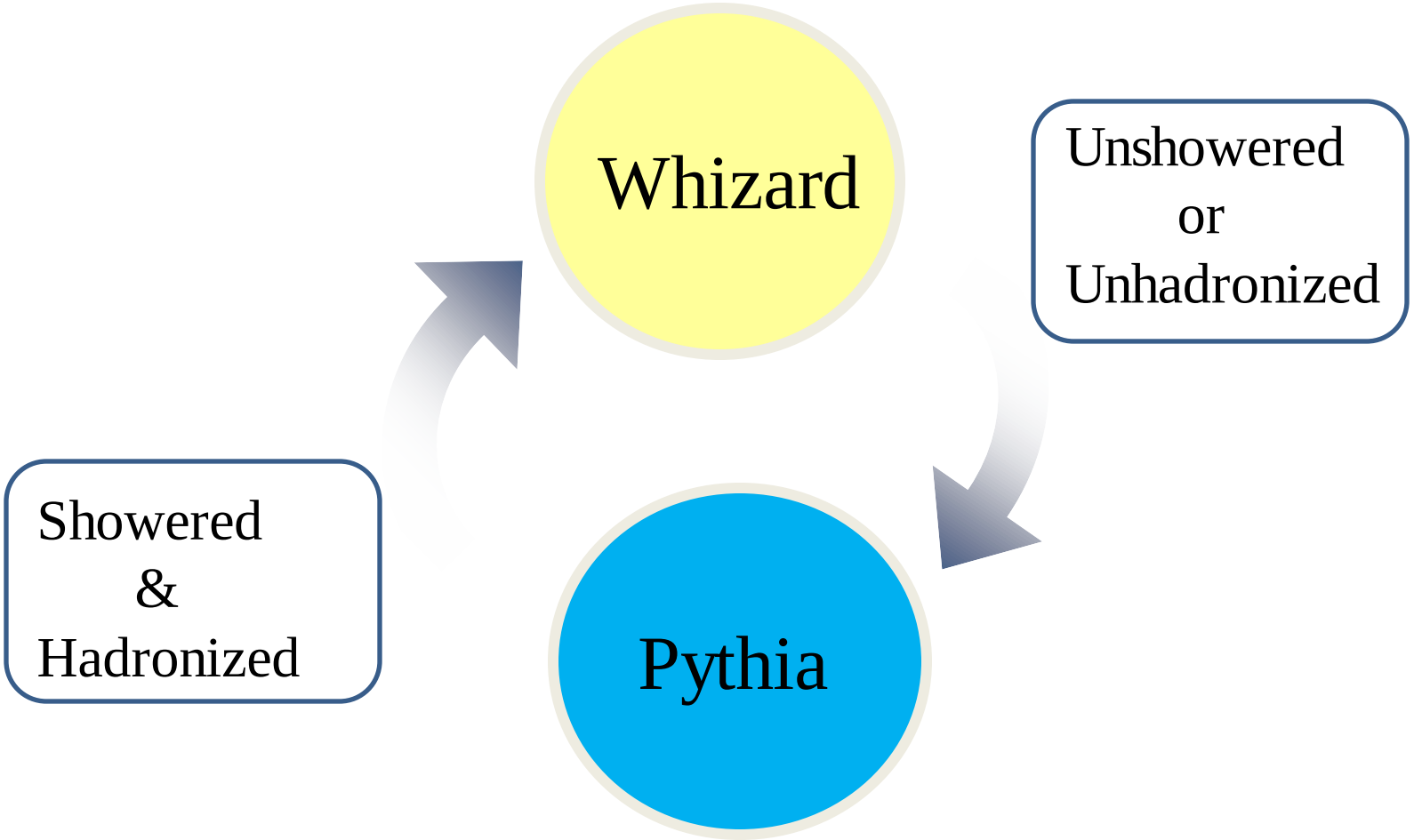
	240GeV	250GeV
qq	54662	50216
$\mu^+\mu^-$	4685	4405
single Z	4538	4734
single W	5086	5144
W^+W^-	16004	15484
ZZ	1079	1033
ZH	203	212
W fusion	5.36	6.72
Z fusion	0.50	0.63



Number of events

Process	Cross section	Nevents in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6
Background processes, cross section in pb		
$e^+e^- \to e^+e^-$ (Bhabha)	25.1	1.3×10^8
$e^+e^- \to qq$	50.2	2.5×10^8
$e^+e^- \to \mu\mu$ (or $\tau\tau$)	4.40	2.2×10^7
$e^+e^- \to WW$	15.4	7.7×10^7
$e^+e^- \to ZZ$	1.03	5.2×10^6
$e^+e^- \to eeZ$	4.73	2.4×10^7
$e^+e^- \to e\nu W$	5.14	2.6×10^7

Event simulaion

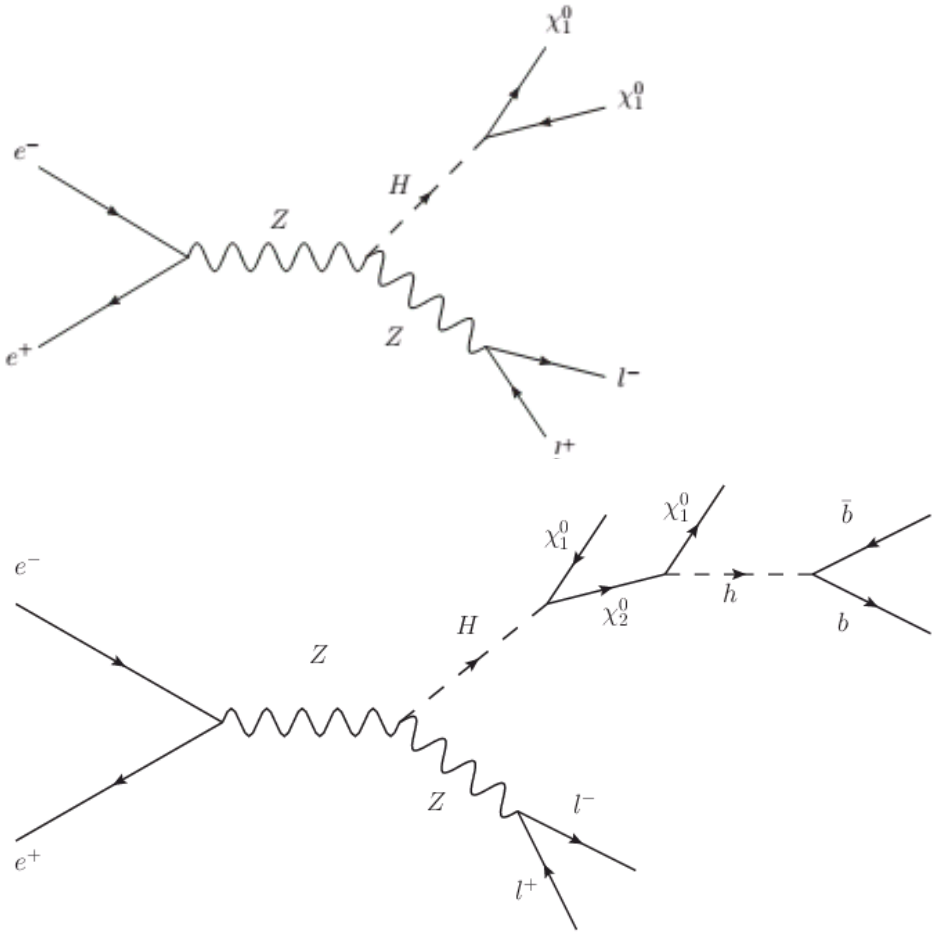


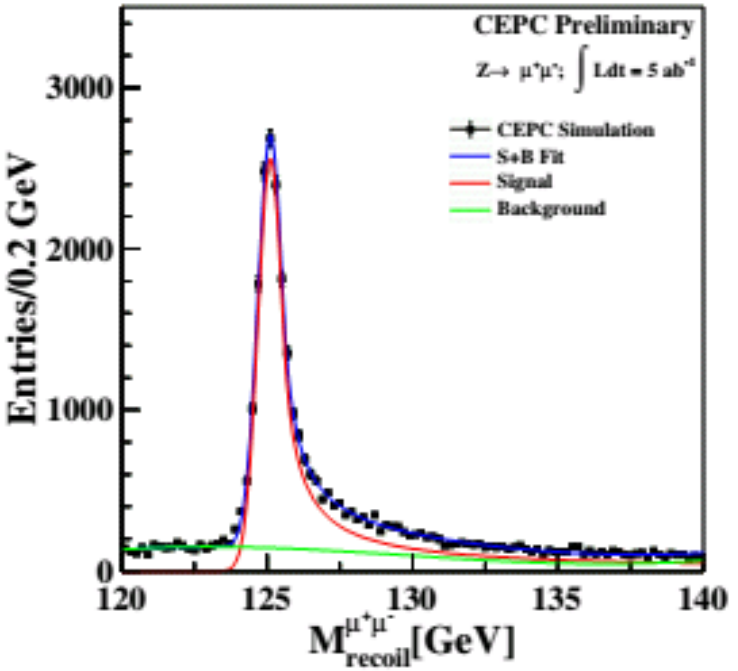

```
fragment = T
fragmentation_method = 3
```

```
$shower_method = "PYTHIA6"
?hadronization_active = true
```

Exotic decay

Exotic decay





$$m_h = 60\text{GeV}$$

$$m_{\chi_2^0} = 85\text{GeV}$$

$$m_{\chi_1^0} = 15\text{GeV}$$

Tips for NMSSM generation

- SLHA interface

read_slha (<*filename*>)

Useful for supersymmetric models: read a parameter in the SUSY Les Houches Accord format.

- Les Houches Accord format

Defines parameter values and, optionally, decay widths

Cuts

➢ Default cuts

default cuts applied on the invariant mass of colored or charged particle pairs, on the energy of emitted photons or gluons, and on the momentum transfer to exchanged photons or gluons.

➢ Whizard version 1

```
! Automatically generated set of cuts
! Process bhabha:
!    e a-e ->   e a-e gamma
!   16   8 ->   1   2     4
process bhabha
cut M of    3      within  1.00000E+01  1.00000E+99
cut M of    5      within  1.00000E+01  1.00000E+99
cut M of    6      within  1.00000E+01  1.00000E+99
cut M of   17      within -1.00000E+99 -1.00000E+01
cut M of   20      within -1.00000E+99 -1.00000E+01
cut M of   10      within -1.00000E+99 -1.00000E+01
cut M of   12      within -1.00000E+99 -1.00000E+01
```

➢ Whizard version 2

```
real default_M_cut = 10 GeV
real default_E_cut = 10 GeV
real default_Q_cut = 10 GeV
alias visible = colored:charged

cuts =
  all M > default_M_cut [visible, visible]
  and
  all E > default_E_cut [visible]
  and
  all M < - default_Q_cut [incoming particle, visible]
```

Default cuts test

Comparison among different version

```
# Define the precess
process e2e2h    = e1,E1 => e2, E2, h
process mumu     = e1,E1 => e2, E2
process sw_l0mu  = e1,E1 => n2:n3:N2:N3, e2:E2 , e1:E1, n1:N1
process ffh      = e1,E1 => (fermion, fermion, h)+(e2,E2,h)+(e3,E3,h)
```

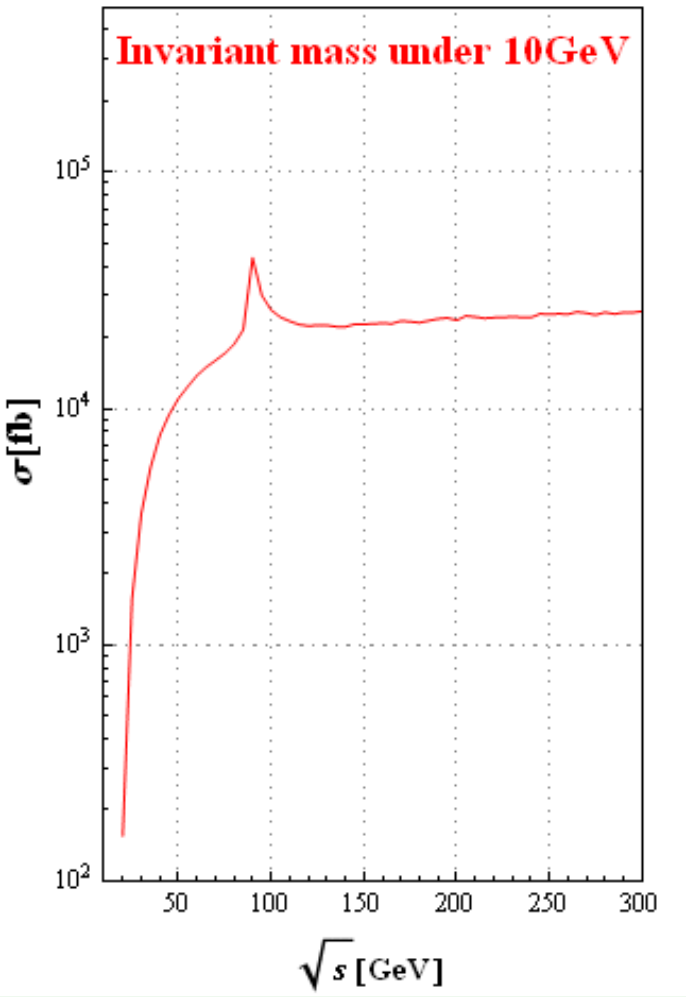
Process	ISR(v2)	Err(v2)	ISR(v1)	Err(v1)
ffh	209.63	0.70	210.80	0.61
e2e2h	6.89	0.02	7.10	4.45E-03
sw_l0mu	422.85	1.21	429.20	0.52
mumu	3884.74	28.0	4967.58	23.9

Bhabha

The Bhabha process

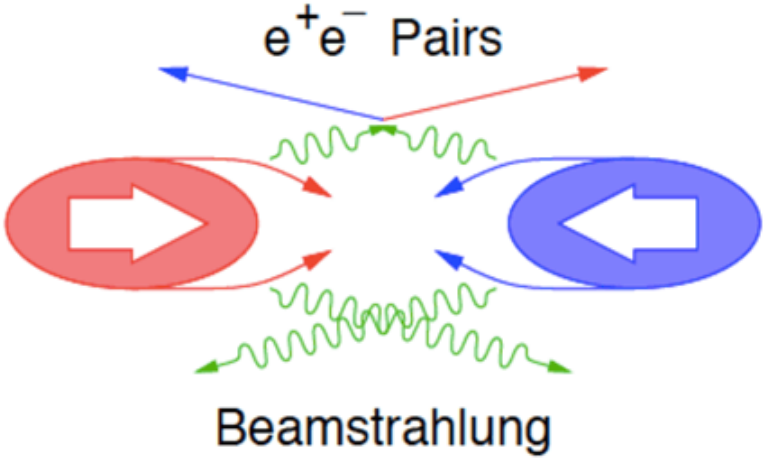
- Leading background
- Measurements for luminosity

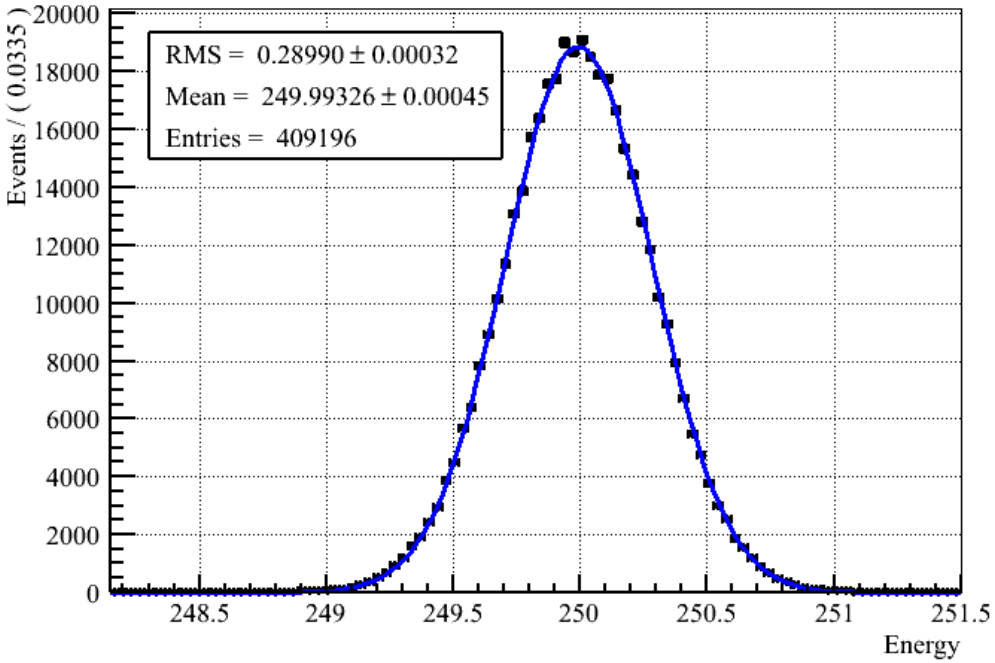
Cut	σ [fb]	Error [fb]
10GeV	2705545	O(10^4)
5GeV	11062568	O(10^4)
1GeV	276518660	O(10^6)
0.5GeV	1077946300	O(10^7)



Beamstrahlung

- GuineaPig
- Beam energy spectral



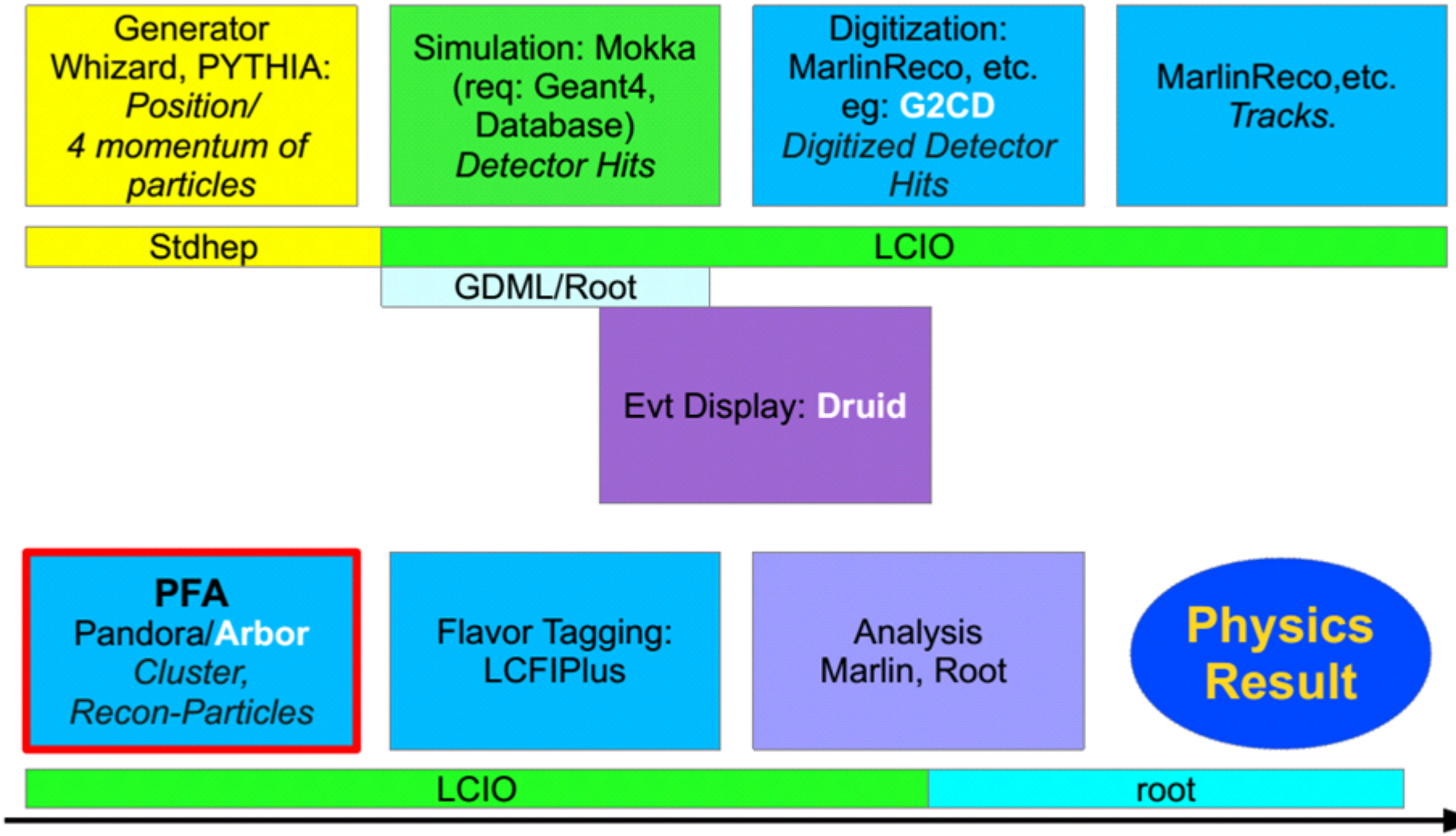


- Whizard version 1

  GuineaPig→lumilinker→ user.f90

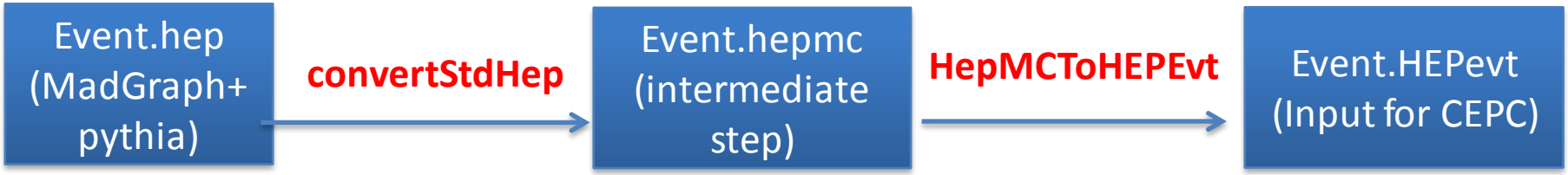
- Whizard version 2
  - Circe2
  - Internal CEPC spectral

SLCIO


Generator
Whizard, PYTHIA:
Position/
4 momentum of
particles
Simulation: Mokka
(req: Geant4,
Database)
Detector Hits
Digitization:
MarlinReco, etc.
eg: G2CD
Digitized Detector
Hits
MarlinReco,etc.
Tracks.
Stdhep
LCIO
GDML/Root
Evt Display: Druid
PFA
Pandora/Arbor
Cluster,
Recon-Particles
Flavor Tagging:
LCFIPlus
Analysis
Marlin, Root
Physics
Result
LCIO
root

Interface of MadGraph+pythia to CEPC

- MadGraph+pythia showering output format is not directly readable by CEPC simulation inputs
- A temporary solution is investigated by convert file formats
- Convertors

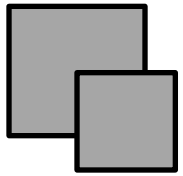


  - Standard alone packages/executables
- This could be generalized to convert other generators' output to be readable by CEPC simulation
  - As far as it can provide stdHep or HepMC format

Summary & Outlook

- The SM event generation
  - Higgs physics study
- Improvements for BSM processes
- Deeper study
  - Bhabha process
  - Cuts optimization
  - Beamstrughlang effects

Thanks



Thanks for attention!

Backup

Backup

Tips for generation

Initial and Final State:

- ISR and FSR
- Beamstrahlung: CIRCE2

Event Formats:

- Binary: STDHEP, HEPMC(version 2)
- ASCII: Les Houches Accord format, HEPEVT

Libs contained:

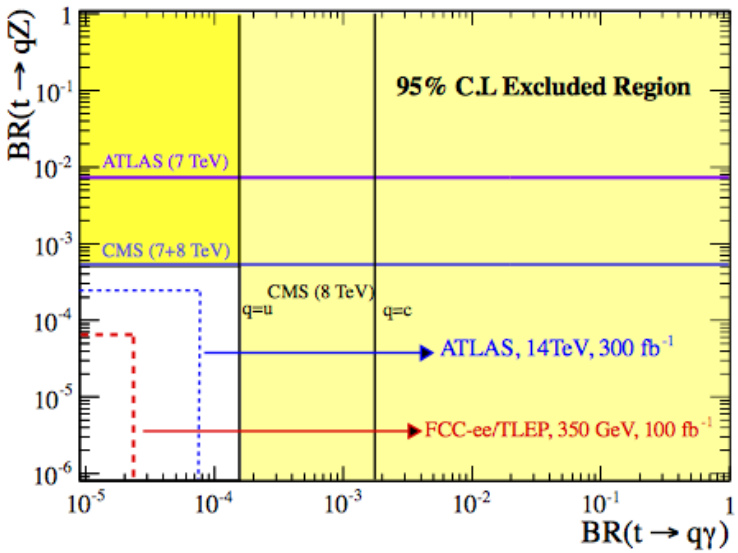
- S-Marix: O'mega
- Events generation: PYTHIA

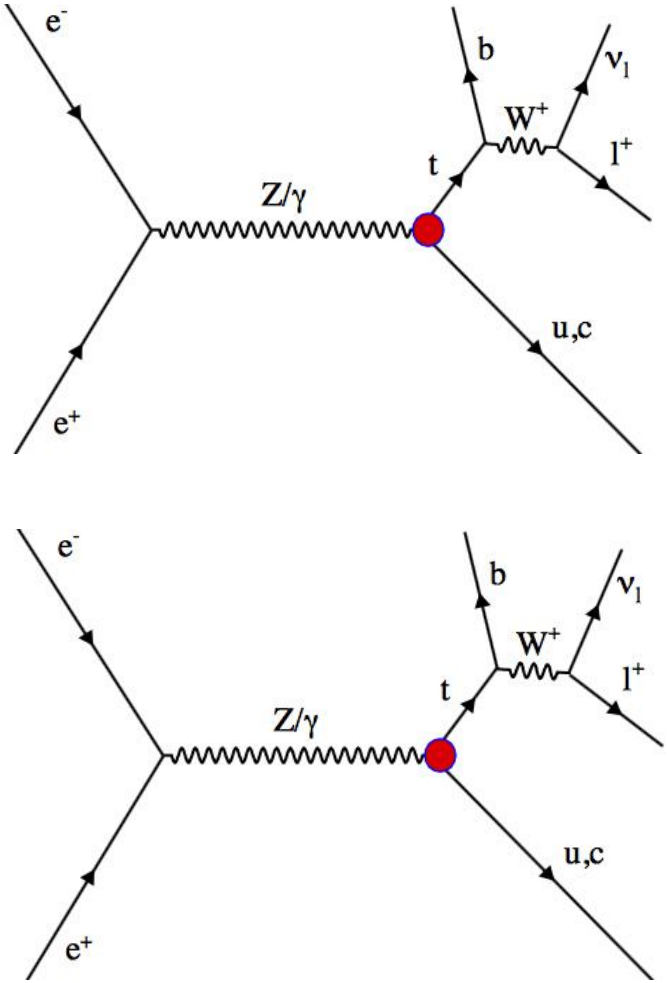
Top physics

Process

$$e^+e^- \to t\bar{q} \to bW^+\bar{q} \to bl^+\nu_l\bar{q}$$

FeynRules & Madgraph/MadEvent





Whizard interface for beam

- Whizard version 1

  GuineaPig→lumilinker→user.f90

- Whizard version 2
  - Circe2
  - A internal CEPC spectral