

Monte-Carlo samples for FCC-ee studies, Q1 2021

General conditions :

- Delphes samples, using the IDEA_trkCov card
 - Default beam-pipe : still $R = 1.5$ cm
- Beam-energy spread (BES) ON [when possible]
- Vertex smearing on

Monte-Carlo programs :

- Dedicated programs (e.g. from LEP times), state-of-the-art on the theoretical side
 - KKMC, BHLUMI produce LHE events
 - What about the 4-fermions LEP generators ? YSFWW / RacoonWW / Gentle ?
- General purpose programs:
 - PYTHIA8 : “some” BES - probably with some approximation
 - Whizard: extensively used by CLIC; BES implemented, good support.
 - Collection of Whizard steering cards used for the CLIC studies is available
 - Sherpa: work ongoing on “Sherpa for ee”, with esp. a YSF resummation for ISR.
 - Madgraph: no BES afawk

Alain: alternative hadronisation model, e.g. Herwig, for the Z production to begin with

- Can we run the Herwig hadronisation model with the MCs listed above ?
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1 Samples at $\sqrt{s} = 91$ GeV

1.1 Inclusive fermion pair samples

- $Z/\gamma^* \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-$
 - Monte-Carlo: KKMC
 - $\tau^+\tau^-$: decay with TAUOLA
 - BES ?? if yes, link to example steering card/file with BES ?
- $Z/\gamma^* \rightarrow u\bar{u}, b\bar{b}, c\bar{c}$
 - Monte-Carlo: KKMC
 - Produces unfragmented LHE events (frag/had. Done later in the Pythia interface)
- $\gamma\gamma \rightarrow l^+l^-, q\bar{q}$
 - What is the state of the art, PYTHIA ?
 - Link to steering file ? which m_{ll} cut ?
 - Include only EPA photon flux ? or also photons from beamstrahlung?

1.2 Exclusive fermion pair samples

- $Z/\gamma^* \rightarrow \tau\tau$ with $\tau \rightarrow \mu\gamma$
 - KKMC, τ decays selected by Tauola, one leg (eg τ^-) into $\mu\gamma$, the other leg inclusive.
 - Link to steering file ?
- Exclusive samples for flavour studies
 - Combination of Pythia + EvtGen
 - Possible to combine with KKMC ? YES.
 - List of samples to be defined.
 - Starting point: the samples here:
http://fcc-physics-events.web.cern.ch/fcc-physics-events/Delphesevents_fccee_tmp.php, namely :
 - Bu2D0Pi, Bd2D0PiPi, Bs2TauTau, Bs2TauTau ($\tau \rightarrow \text{had}$), Bd2KstarTauTau, Bd2KstarTauTau ($\tau \rightarrow \text{had}$), Bd2KstarEE, Bd2MuMu, Bd2DstarTauNu, Bd2DstarTauNu ($\tau \rightarrow \text{had}$), Bd2DTauNu, Bd2TauNu ($\tau \rightarrow \text{had}$), Bd2KsPi0, Bs2PhiGamma, Bc2TauNu, Bc2TauNu ($\tau \rightarrow \text{had}$), D2PiPi0, Bs2DsK
 - To be added (Stephane) :
 - backgrounds for B2K* $\tau\tau$
 - LFV companions like $b \rightarrow s \tau \mu$.
 - Bs2Dslu and backgrounds for a_{SL}^s ,
 - Bs2DsK (w/ several Ds decays), Bs2J/Psphi (Roy: also Bs2JPsiEta), and Bs2phiphi. And a set of backgrounds, to be devised. More information below from Roy.
 - Bs2mumu and B02pipi (to complete the already existing B02mumu)
 - Bu2taunu and backgrounds (to complete Bc2taunu)
 - Also add Bs to gamma gamma (Roy) - excellent test for calorimetry
 - Background: B0 $\rightarrow$ gamma gamma
 - For Bs $\rightarrow$ Ds K (Roy) :
 - Signal : Ds $\rightarrow$ Phi pi and Ds $\rightarrow$ Phi rho, with Phi $\rightarrow$ KK, and rho $\rightarrow$ pi pi0
 - Exclusive backgrounds :
 - B0 $\rightarrow$ Ds K : same decays as above for the Ds
 - Bs $\rightarrow$ Ds Pi : same decays as above for the Ds
 - Bs $\rightarrow$ Ds* K : Ds* $\rightarrow$ gamma Phi pi and Ds* $\rightarrow$ gamma Phi rho, same decays as above for the Phi and the rho
 - Bs $\rightarrow$ Ds K* : as above for the Ds, K* $\rightarrow$ K pi0
 - Bs $\rightarrow$ Ds rho : Ds $\rightarrow$ Phi(KK) pi and rho $\rightarrow$ pi pi0
 - Lambdab $\rightarrow$ Ds p : same decays as above for the Ds
 - LambdaB $\rightarrow$ Ds* p : Ds* $\rightarrow$ gamma Phi pi and Ds* $\rightarrow$ gamma Phi, same decays as above for the Phi and the rho
 - For Bs $\rightarrow$ JPsi Phi (Roy) :
 - Signal: JPsi $\rightarrow$ mumu, ee, or eegamma, Phi $\rightarrow$ KK
 - Exclusive backgrounds:

- Lambda $\rightarrow$ JPsi K p : same JPsi decays as for the signal
- For Bs $\rightarrow$ JPsi Eta (Roy) :
 - Signal: JPsi $\rightarrow$ mumu, ee, or eegamma, Eta $\rightarrow$ gamma gamma
 - Exclusive backgrounds :
 - B0 $\rightarrow$ JPsi Eta : same JPsi and Eta decays as for the signal

1.3 Others

- ee $\rightarrow$ gamma gamma
 - BhabhaYagga ?
 - Alain: Z $\rightarrow$ W W* (background to HNLs)
 - Which generator ? LEP times: Gentle / RacoonWW / YFSWW
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2 Samples at WW

- Z/gamma* $\rightarrow$ e+e, mu+mu-, tau tau, uds, bb, cc
 - ee $\rightarrow$ gamma nu nubar
 - KKMC - which phase space cuts for the photon ? steering card ?
 - About 5% efficiency to have a photon outside the beam pipe (5deg and 10% beam energy). Should be fast now.
 - ee $\rightarrow$ Z nu nubar
 - Note: this does not exist in Pythia
 - Could use Whizard, or dedicated LEP generator (Patrick, wrote the LHE output)
 - Total x-section: good agreement between the two
 - Distributions are now in good agreement too.
 - ee $\rightarrow$ W e nu
 - ee $\rightarrow$ Z e e
 - These two processes above were (partially) in Pythia6 (ISUB = 35, 36), but not in Pythia8 ?
 - Could use Whizard, or KORALW has them
 - ee $\rightarrow$ gamma gamma
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3 Samples at $\sqrt{s} = 125 \text{ GeV}$

- $Z/\gamma^* \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, u\bar{d}, d\bar{u}, c\bar{c}, s\bar{s}$
 - $ee \rightarrow Z \nu \bar{\nu}$
 - $ee \rightarrow W e \nu$
 - $ee \rightarrow Z e e$
 - $ee \rightarrow H$ with $H \rightarrow gg$; $H \rightarrow b\bar{b}$; $H \rightarrow c\bar{c}$; $H \rightarrow \tau^+\tau^-$; $H \rightarrow \gamma\gamma$; $H \rightarrow ZZ$; $H \rightarrow WW$
 - Pythia8 for s-channel good enough
 - diboson production: $ee \rightarrow WW, ee \rightarrow ZZ, \gamma\gamma$
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4 Samples at $\sqrt{s} = 240 \text{ GeV}$

- $Z/\gamma^* \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, u\bar{d}, d\bar{u}, c\bar{c}, s\bar{s}$
 - $ee \rightarrow Z \nu \bar{\nu}$
 - $ee \rightarrow W e \nu$
 - $ee \rightarrow Z e e$
 - $ee \rightarrow ZH$
 - diboson production: $ee \rightarrow WW, ee \rightarrow ZZ$
 - $ee \rightarrow H \nu \bar{\nu}$
 - $ee \rightarrow tq^-, t^-\bar{q}$ (semi-leptonic top decay; top-FCNC_Lag, define $q = u, c$, define $q^- = \bar{u}, \bar{c}$)
 - $e^-e^+ \rightarrow Z l^+l^-$ (hadronic decay of Z)
 - $e^-e^+ \rightarrow W^+jj$ (leptonic decay of W)
 - $e^-e^+ \rightarrow HZ$; $H \rightarrow WW$ (both leptonic and hadronic decays of W)
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 - $ee \rightarrow tq^-, t^-\bar{q}$ (hadronic top decay; top-FCNC_Lag, define $q = u, c$, define $q^- = \bar{u}, \bar{c}$)
 - $e^-e^+ \rightarrow WW$ (hadronic decay of W)
 - $e^-e^+ \rightarrow Zjj$ (hadronic decay of Z)
 - $e^-e^+ \rightarrow HZ$ (hadronic decay of H)
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5 Samples at $\sqrt{s} = 365 \text{ GeV}$

- $Z/\gamma^* \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, uds, bb, cc$
- $ee \rightarrow Z \nu \bar{\nu}$
- $ee \rightarrow W e \nu$
- $ee \rightarrow Z e e$

- $ee \rightarrow t \bar{t}$
- $ee \rightarrow ZH$
- $ee \rightarrow H \nu \bar{\nu}$
- diboson production: $ee \rightarrow WW, ee \rightarrow ZZ$

- Do we want separate exclusive samples ?

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- $ee \rightarrow tq^-, t^-\bar{q}$ (semi-leptonic top decay; top-FCNC_Lag, define $q = u, c$, define $q^- = u^-, c^-$)
 - Madgraph: produce LHE privately
- $e^-e^+ \rightarrow Z l^+l^-$ (hadronic decay of Z)
- $e^-e^+ \rightarrow W^+ j j$ (leptonic decay of W)
- $e^-e^+ \rightarrow HZ; H \rightarrow WW$ (both leptonic and hadronic decays of W)
- $e^-e^+ \rightarrow t \bar{t}$ (semi-leptonic top decay, both leptonic and hadronic decays of W)
- $e^-e^+ \rightarrow t W^-j, t^- W^+ j$ (semi-leptonic top decay, both leptonic and hadronic decays of W)
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- $ee \rightarrow tq^-, t^-\bar{q}$ (hadronic top decay; top-FCNC_Lag, define $q = u, c$, define $q^- = u^-, c^-$)
- $e^-e^+ \rightarrow WW$ (hadronic decay of W)
- $e^-e^+ \rightarrow Z j j$ (hadronic decay of Z)
- $e^-e^+ \rightarrow HZ$ (hadronic decay of H)
- $e^-e^+ \rightarrow t \bar{t}$ (hadronic top decay)
- $e^-e^+ \rightarrow t W^-j, t^- W^+ j$ (hadronic top decay)
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