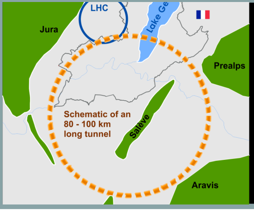

BES/BST in KKMCee

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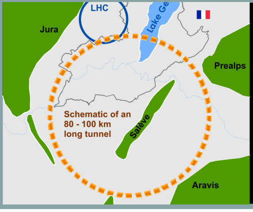
ECFA Higgs factories, CERN

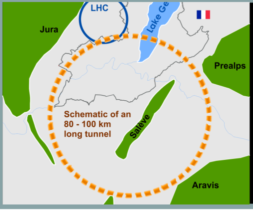
January 12th, 2022



Recent developments in KKMCee

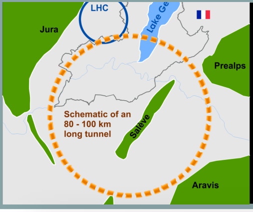
- Upgrade of DIZET electroweak library, hadronic VP routine, more steering parameters for manipulating EW corrections.
- Upgrade of TAUOLA library.
- Output LHE event record.
- Upgraded F77 code including BES and BST is now available on GitHub.
- Complete and well tested version of KKMCee entirely in C++ (except DIZET and TAUOLA) is there on GitHub but not published yet.

More on GitHub repository:
https://github.com/KrakowHEPSoft/KKMCee
The current version:
https://github.com/KrakowHEPSoft/KKMCee/releases/tag/v4.32.01



BES/BST in MC generators

- Generally one may include BES/BST ***inside*** the MC event generator or ***outside***.
- Second method in principle is easy, just generate beam energies E_1 and E_2, run MC at the reduced CM energy $s^{1/2} = 2(E_1 E_2)^{1/2}$ and boost events to LAB.
- (Patrick Janot has provided compact algorithm for generating E_1 and E_2 according to correlated double-gaussian distribution of FCCee.)
- In practice it does not work like above, because most of MCs memorise $s^{1/2}$ and internal variables dependent on $s^{1/2}$. Cannot change $s^{1/2}$ event per event:(
- One may apply workaround proposed by Patrick Janot:
  Using an additional MC create look-up tables of correction due to (small) change of $s^{1/2}$ for the total cross section and/or for other important observables.
  Next proceed as before, correcting MC events with the weight from tables.
- There will be always some other distributions which will be not corrected:(
- The only perfect solution is to include generation of E_1 and E_2 as any other variables in the MC algorithm of the event generator.
- This is presently implemented in KKMCee.



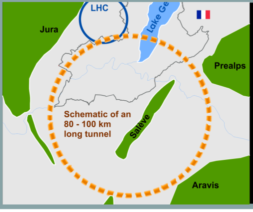
BES/BST distribution in KKMCee

- In KKMC there is since long an option of the variable beam energies due to beamstrahlung (BST) distributions of ILC with CIRCE spectra.
- BST distributions reside in the 3-dimensional integrand of **FOAM**, along with the total energy loss due to initial state radiation ISR.
- Recently Gaussian **BES** spectrum from Patrick Janot has been added as another new option in public KKMCee in the same FOAM integrand.
- Input data activating **BES** *ffbench/Mu/Mu_input_1k_KeFix=4*, looks like:

```
BeginX
********************************************************************************
*                  ACTUAL DATA FOR THIS PARTICULAR RUN
********************************************************************************
*indx____data______ccccccccc0ccccccccc0ccccccccc0ccccccccc0ccccccccc0ccccccccc0
*      Center-of-mass energy [GeV]
    1        91.0e0       CMSene =xpar( 1) Average Center of mass energy [GeV]
   25             4      KeyFix=0 normal, =2 beamsstrahlung =3,4 for gaussian BES
*indx____data______ccccccccc0ccccccccc0ccccccccc0ccccccccc0ccccccccc0ccccccccc0
   80          0.0e0      ParBES(0) E1=0 will be replaced by CMSene/2
   81          0.0e0      ParBES(1) E2=0 will be replaced by CMSene/2
   82      0.132e-2       ParBES(2) sigma1/E1
   83      0.132e-2       ParBES(3) sigma2/E2
   84        0.300e0      ParBES(3) rho correlation parameter, dimensionles
********************************************************************************
*      Define process
  413             1       KFfin, muon
  100             1       store lhe file to (LHE_OUT.LHE)
************************  one can change the lhf file name between brackets
********************************************************************************
EndX
```

```
********************************************************************************
* Beamstrahlung parameters for Thorsten Ohl's package CIRCE
   71          350e0      IRCroots    sqrt(s) [GeV] discrete values 350,500,800GeV
   72            3e0      IRCacc
   73            5e0      IRCver      version
   74     19980505e0      IRCdat      date
   75            1e0      IRCxchat    printout level
**\\\\\writing vegas grid on the disk, KeyGrid=-1 create and dump, =+1 read\\\\
   76            0e0  KeyGrid=0 create, not read, default\\\\\\\\\\\\\\\\\\\\\
********************************************************************************
```

In the KKMCee implementation of the CIRCE spectra using FOAM all delta-like components are replaced by the narrow Gaussian distributions!!!

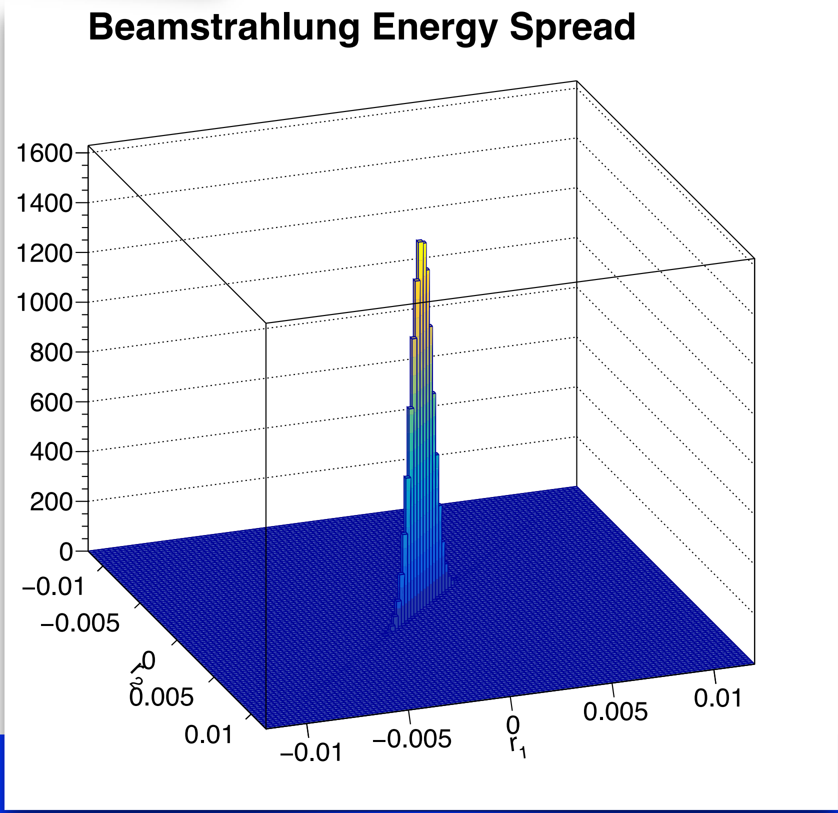


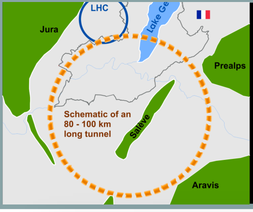
Gaussian BES in KKMCee

- Correlated double-Gaussian BES from Patrick Janot implemented in KKMCee:

$$P(x,y)=\frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}}\exp\left\{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{x-x_0}{\sigma_x}\right)^2+\left(\frac{y-y_0}{\sigma_y}\right)^2-2\rho\left(\frac{x-x_0}{\sigma_x}\right)\left(\frac{y-y_0}{\sigma_y}\right)\right]\right\}$$

Histogram of two beam energies (relative deviations from central values) from KKMCee, 1M events.





BES: technical point

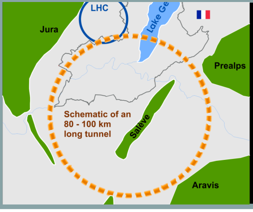
- Correlated double-Gaussian BES from Patrick Janot is implemented twice in KKMCee, using two different methods — once using mapping invented by Patrick (KeyFix=3):

```
C mapping of Patrick Janot for 2-dim Gaussian BES with optional correlation
C in this case Jacobian*distribution=1 is omitted.
       E1    = m_BES_ene1
       E2    = m_BES_ene2
       corho = m_BES_rho
       x1 = sqrt(-2.*log(r1)) * cos(2.*m_PI*r2)
       x2 = sqrt(-2.*log(r1)) * sin(2.*m_PI*r2)
       y1 = x1
       y2 = corho * x1 + sqrt(1.-corho*corho) * x2
       rr1= y1 * m_BES_sig1
       rr2= y2 * m_BES_sig2
       Ebeam1 = E1 * (1.0 + y1 * rr1)
       Ebeam2 = E2 * (1.0 + y2 * rr2)
```

- and alternatively by providing FOAM with the distribution — mapping is done by FOAM (KeyFix=4).

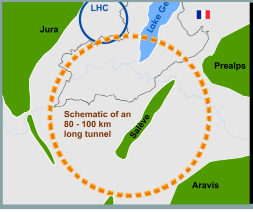
```
! the same BES distribution from Patrick Janot
       E1    = m_BES_ene1
       E2    = m_BES_ene2
       sigma1= m_BES_sig1*E1
       sigma2= m_BES_sig2*E2
       corho = m_BES_rho
! standard distribution for FOAM
       sigma = SQRT(sigma1*sigma2)
       delE1 = 10*sigma*(2*r1-1.0)  ! range is +-10sigma
       delE2 = 10*sigma*(2*r2-1.0)  ! range is +-10sigma
       Rho = Rho* (20*sigma)**2  ! Jacobian
       m_x1 = delE1/E1 ! can be negative
       m_x2 = delE2/E2 ! can be negative
       dGauss = (delE1/sigma1)**2+ (delE2/sigma2)**2 -2*corho*(delE1/sigma1)*(delE2/sigma2)
       dGauss = EXP(-0.5/(1-corho**2)*dGauss)
       dGauss = dGauss* 1/(2.0*m_PI)/(sigma1*sigma2)/SQRT(1-(corho)**2) ! Normalization fac
       Rho = Rho* dGauss;
```

- The resulting generated distribution is the same (providing proof/cross-check of the Patrick’s mapping :).



C++ version of KKMCee

- Complete code in C++ of KKMCee is already there in the non-public repository on GitHub since a few months,
  waiting for publication…
- It is interfaced with electroweak library DIZET 6.24 and TAUOLA, both in F77.
- It reproduces exactly all classic benchmarks of KKMC from the 1999 LEP workshop and from PRD63 (2000) article.
- From the physics point of view it is identical with F77 version, but is planned as a starting point for the future development.
- It is armed with LHE interface and includes BES of FCCee.
- Complete documentation (CPC article) is urgently needed.
- Repository to be be cleaned up of unused F77 source code.



Summary

- **KKMC legacy code written F77 is alive and is available for FCCee/ILC related studies since long.**
- **KKMCee in C++ is already there, to be published soon.**
- **Two web pages and public GitHub repository with the F77 source codes and extensive documentation are available.**
- **Both CIRCE BST and Gaussian BES are in public F77 KKMCee**
- **BES is presently in the C++ version.**