Averge energy loss and energy spread increase in Puffin

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1 Usage instruction

The average energy loss and energy spread increase in Puffin allow the user to activate the equations responsible for average energy loss or (and) energy spread increase during the FEL simulation.
Both effects are controlled by the user with two separate switches in the main input file for the simulation. The user can activate only one of the effects, both of them or none. The switches are as follows:

- qAvgLoss = .TRUE.
- qEnergySpread = .TRUE.

By default both switches are set to FALSE. The effect of activating the effect is observable, however it is strongly depending on the correlation between the radiation wavelength λ_r energy and the electron energy beam γ.

2 Changes done in Puffin

The Puffin code required only few changes to add both of the effects. The main equation and algorithm is located in new file 'recoil.f90' which is defined as module. The main subroutine is named 'sig_avgloss' and follows the method and equations proposed in [1] and [2]. The equations are modified to be compatible with Puffin units. The core equation is located in line 79 and look as follows:

```
spread_loss = &
! Average energy loss
   + ((lam_w_g/iSteps4Diff)*(1.0_WP/sGammaR_G)*(-2.0_WP/3.0_WP)*2.818E-15 &
   *(((sgam*sGammaR_G)*(TwoPi/lam_w_g)*aw_mean) &
    **2.0_WP)) * AvLossPrm &
! Energy spread increase
   + (RanNumRecoil_G*(1.0_WP/sGammaR_G)*DSQRT((TwoPi/lam_w_g)**3.0_WP &
   *aw_mean**2.0_WP*(sgam*sGammaR_G)**4.0_WP &
   * FK*1.015E-27*(lam_w_g/iSteps4Diff))*DSQRT(3.0_WP) * EnSpPrm)
```

The 'iSteps4Diff' is describing the name of the step per undulator – this is the way the equation is scaled in Puffin to properly differentiate over dz. 'aw_mean' is just mean value of undulator parameter – Puffin uses peak value of undulator parameter. 'AvLossPrm' and 'EnSpPrmThe' are parameter used to 'zero' the inactive term of the equation – they basically convert the TRUE or FALSE into 1 or 0. The rest of the variables are Puffin global variables. Routine is called each Runge–Kutta iteration thus being compliant with the unaveraged algorithm of Puffin. The routine is called in line 321 of MRK4.f90 file as follow:

```
!$OMP END PARALLEL WORKSHARE

    if ((qAvgLoss_G.OR.qEnergySpread_G).AND.qElectronsEvolve_G) then
    allocate(sigloss(iNumberElectrons_G))
    call sig_avgloss(sElGam_G,sigloss)
!$OMP PARALLEL WORKSHARE
    sElGam_G = sElGam_G + sigloss
!$OMP END PARALLEL WORKSHARE
    deallocate(sigloss)
    endif
```

Finally, the variables are added to FreadData.f90 and EDerivGlobals.f90 source files to allow user using switches and defining some variables and arrays as global. The algorithm results were compared with results from GENESIS [3] and they are almost identical – this is what is expected as GENESIS is basing on exactly same model from [1] and [2].

References

[1] J. Rossbach, E.L. Saladin, E.A. Schneidmiller, M.V. Yurkov, Nuclear Instruments and Methods in Physics Research A, 393, 1997, 152-156

[2] E.L. Saldin, E.A. Schneidmiller, M.v. Yurkov, Proceedings of the 2004 FEL Conference, 2004, 139-142

[3] S. Reiche, Nucl. Instrum. Methods Phys. Res. A429, 243 (1999).