MAD-NG review summary 20.01.2021

A first review of the MAD-NG code, version 0.9.3, reporting the experience of seven users simulating CERN present and future machines took place in: https://indico.cern.ch/event/991905/
MAD-X is the current tool for optics design at CERN and widely adopted outside CERN as well. Long-term support of MAD-X is planned with recent improvements for FCC-ee. MAD-NG was conceived to alleviate the dependency on PTC, implementing similar physics with a modern scripting approach.

PS is the machine where MAD-NG and PTC show a perfect agreement on linear optics calculations. Chromaticity presents small differences to be investigated. MAD-NG is faster than PTC for Twiss calculations in the PS. Alexander sees potential for MAD-NG.

In the **Linac4** transfer lines, serious discrepancies are observed that need understanding, as it is the first time that MAD-NG is benchmarked on a transfer line with accelerating structures. Laurent is aware of the problem and investigates the discrepancy to fix it as soon as possible and re-check the results.

For **FCC-ee** linear and non-linear optics parameters show a good agreement for now but need investigations. MAD-NG is again significantly faster than PTC in optics calculations but slower than PTC for single-particle tracking with potential speed improvements presented by Laurent. MADX remains the fastest code. Discrepancy observed with the I_1 integral is probably related to the above-mentioned problem with Linac4. To be investigated and re-checked.

LHC with strong coupling features good agreement between MADX and MAD-NG in the coupled optics parameters. Again in terms of speed, the codes are ordered as MADX, MAD-NG, and PTC (from fastest to slowest). To be noted that for tracking 900 particles MAD-NG is faster than PTC in this test case.

In the **CLIC** Final Focus system (FFS) significant discrepancies are observed in the dispersion, hopefully, related to the above-mentioned problem. This inevitably affects all higher orders of the transfer map. The great advantage is that MAD-NG generates the parametric high order transfer map almost 10 times faster than MADX-PTC. This can open the door to advances in nonlinear optics design once the problem is fixed.

Concerning **general considerations,** MAD-NG is built on top of the outstanding Just-in-Time compiler LuaJIT, which brings benefits and challenges. The entire physics and methods are written in the scripting language clearly and concisely with the help of the flexible GTPSA library developed by Laurent, yet the code is sufficiently fast to outpace PTC. As a benefit, it is an ideal platform to implement and investigate parametric normal form methods as well as for R&D and educational purposes and to secure documentation of the accumulated physics knowledge. As a challenge, the underlying LuaJIT technology will require follow-up for long term support (time scale of about 5 years) until suitable alternatives arise.

For a larger adoption by the community, in particular at CERN, MAD-NG will have to feature tight interaction with MAD-X and Python in the same way as the CPyMAD tool for MAD-X. Low-level in-depth compatibility between LuaJIT 2.1 and Python through the Lupa library has been questioned and it will need to be reviewed, but a higher-level dedicated interface like in CPyMAD might also be a suitable alternative.

The review ended with the **online demo** of Laurent's examples showing how parametric DA maps (i.e. map with knobs) can be used to efficiently match the coupling around IP2 in the LHC using four skew thin quadrupoles. This demo highlighted the potential of this feature leading to the recommendation that the next development step of MAD-NG should **focus on the parametric nonlinear normal forms for nonlinear optics**.

Reported by R. De Maria, L. Deniau and R. Tomas