ALEGRO workshop working group 3 summary

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LWFA and PWFA

The tools to model the *acceleration* in the plasma have been already developed for each stage of a future PWFA or LWFA based collider.

Full PIC and many reduced models available to reduce compute time: quasi-static, boosted frame, amr, hybrid PIC fluid, quasi-3D, envelope,… The limitations, workarounds, and strengths of each model needs to be systematically evaluated and explored. Systematic benchmark of codes is critical and requires community-based efforts.

There is some disagreement between modelling and observations: initial conditions in experiments and in simulations are possibly (much) different. This discrepancy may explain part or all the disagreement. Access to crucial experimental features is thus important (e.g. driver structure, plasma density profiles…) Precise characterisation of initial conditions (e.g. spatiotemporal laser couplings, initial plasma state, etc) could considerably reduce the parameter space required to model the collider. ML techniques combined reduced modelling might have the potential to make the search for optimal collider regimes more efficient.

Conclusion: most of the tools are developed, but they are not integrated and the current parameter space to reliably simulate a collider is too large. The strengths, limitations and solutions for those limitations for each tool and model is still on-going research. Systematic comparisons with experiments required.

LWFA and PWFA

Hardware development will not be driven by our community. Need to adapt to the new hardware architectures that will come up. Future architectures driven by ML are potentially better for PIC because they are data intensive and require high throughput.

Important to find ways to grant access to large supercomputing resources for the whole community (e.g. equivalent to laserlab) because unlike other fields (e.g. conventional accelerators codes like elegant or geant4), our simulations towards plasma based linear colliders will be computationally (very) expensive.

Funding for dedicated research positions for code validation, code optimisation, adaptation to new architectures, detailed analysis is important for a collider roadmap.

LWFA and PWFA

Integrating current plasma based acceleration modelling tools with every other aspect required to model a collider has not been achieved. Such modelling is very complex and there are many open questions:

- Is the plasma hydrodynamics important? Is the long term plasma evolution important?
- What is the role of the actual plasma profile (e.g. at entrance and exit)?
- Coupling with conventional beamlines?
- Are current ionisation models correct?
- Sensitivity studies and role of misalignments?
- Production of secondary particles?
- Theory to understand the physics at the interaction point is unknown and it is important to develop new numerical models.
- Beam polarisation?
- New wakefield and accelerated beam structures?
- …

We do not know the answers for these questions. Answering them is crucial to model a future collider.

SWFA and DLA

There are two components in the simulations: beam tracking and photonics modelling. Beam tracking is rather not challenging (a laptop is currently sufficient). The fields in the structure are challenging to model. Specific material science questions need to be addressed by experiments that will trigger the development of the computing algorithms.

Roughness of the surface of structure can play an important role on the electron beam dynamics. Simulations that use the actual structure need to be carried out to decide if the cell can be used to accelerate particles in a future collider. This needs to be automated when building a machine with 1000's of cells.

Lack of 3D models to model the field structure in the SWFA is a limitation.

Beam tracking tools are the same for SWFA and DLA, but modelling the field structure requires different tools.

Interesting beams have a few 10's as duration. Corresponding current profile has components into the deep UV and x-ray. Material response to such wavelengths and durations is unknown and needs to be characterised experimentally. The erosion of the dielectric due to the pulse is not accounted in current models.

Conclusion: modelling tools for a future collider are not ready yet. Input from material science and experiments are critical to identify the proper models.