Five Questions with Dra. Tessa Kathleen Charles

Caustics: a mechanism behind the intense current modulations in particle accelerators

Optical **Caustics** occur when reflections or refractions of the light rays results in strong focusing. A similar phenomenon can be seen in accelerators, where **Caustics** of particle trajectories can drive intense current modulations [1,2].

Could you introduce yourself?


dipole magnet.

My name is *Tessa Kathleen Charles*, I am an accelerator physicist from Australia.

Could you tell me about your institute and research topic?

I work at the European Organization of Nuclear Research (CERN) [3], working on the e+/e- Future Circular Collider (FCC-ee) [4]. We are already planning the next big collider for once the Large Hadron Collider (LHC) has run its course. FCC-ee is one of the proposed designs that could follow the LHC. Unlike the LHC which collides protons, FCC-ee will collide electrons and positrons. And it will be big! With a circumference of 100 km, the collider will fit snugly in the Geneva basin, with the Jura mountain range on one side, the alps on the other, FCC-ee will circumnavigate Mount Salève and pass under the shallow end of Lake Geneva.

How or why did you choose that topic?

I have worked on particle colliders and light sources; on linear machines and circular machines. I enjoy working on types of particle accelerators.

Micro-bunching Instability is currently a major limitation at Free-electron lasers (FEL) facilities. I plan to extend some of the previous work I have done relating to singularities in particle trajectory densities, which are known as **caustics**. **Caustics** are readily observable and easily identifiable in optics. The bright lines that appear in a well-lit coffee cup and the dancing network of lines seen on the bottom of a pool on a sunny day, are two examples of **caustics**. The appearance of **caustics** is widespread, permeating many areas of science, including accelerator physics.

Understanding that certain effects we witness in accelerator physics are **caustic** in nature, can be very telling as to how we best manipulate the beam dynamics.

Right now, what is the biggest challenge of your work?

I am working on emittance tuning for the 100 km ring. Once constructed an accelerator will never be perfectly aligned and the magnets will not be perfect. Small misalignment and field errors distort the optics and in a highly non-linear machine like the FCC-ee, this threatens to greatly reduce the luminosity unless we can correct the distorted optics. Over 100 km, we have thousands of magnets and Beam Position Monitors (BPMs). We need precise control of beam parameters such as the emittance and aim to achieve luminosities of the order of $10^{35}\ cm^{-2}s^{-1}$. These are challenging and ambitious design parameters, which makes for interesting work.

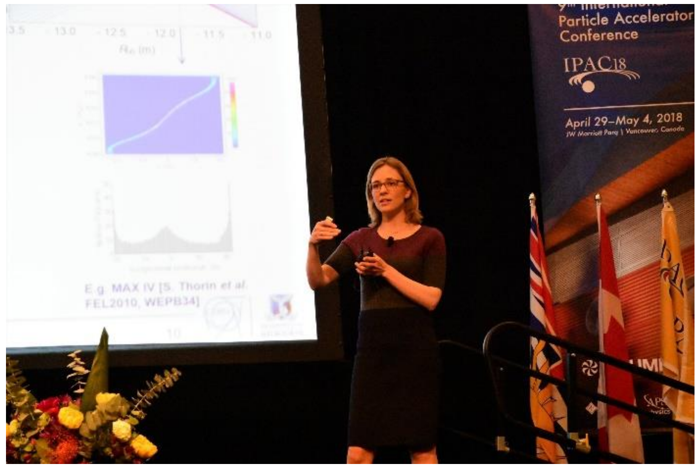

Figure 2. Dra. Tessa Kathleen Charles giving a talk during the 9th International Particle Accelerator Conference 2018 in Vancouver, Canada.

What did you think that will be the future of you research area?

I have a number of research questions that I am planning to tackle. One of these involves research into a particular method to reduce micro-bunching instability in FELs. Micro-bunching grows from small density modulations in the beam. These small density modulations are converted into energy modulations by Coherent Synchrotron Radiation (CSR) and/or Longitudinal Space Charge. The energy modulations are in turn, converted into density modulations through longitudinal dispersion, which creates stronger CSR, which creates more density modulation... which creates an infinite loop, hence the instability!

References

[1] T. K. Charles et al, *Caustic-based approach to understanding bunching dynamics and current spike formation in particle bunches*, Phys. Rev. Accel. Beams, vol. **19** 104402 (2016).

[2] T. K. Charles et al, *Applications of Caustic Methods to Longitudinal Phase Space Manipulation* in Proceedings of the 9th Int. Particle Accelerator Conference (IPAC'18), Vancouver, Canada, April 29th to May 4th 2018, page 1790.

[3] CERN main page, https://home.cern/

[4] M. Benedikt, et al, *Future Circular Collider: Conceptual design report Vol. 2 The Lepton Collider (FCC-ee)*, European Physical Journal ST **228**, 261–623 (2019).