Machine Learning Meets the Challenges of HEP Research and Development

Brendan D. O'Shea[1], Auralee Edelen[1], Claudio Emma[1], Adi Hanuka [1], Remi Lehe[3], Daniel Ratner[1], Ryan Roussel[2]

[1]SLAC National Accelerator Laboratory

[2]University of Chicago

[3]Lawrence Berkeley National Laboratory

LoI Link

Machine Leaning Meets the Challenges of HEP Research and Development

SLAC

<u>What is needed to advance the physics? Enable new capabilities?</u>

- Advanced accelerator technologies have beam quality requirements that are beyond state of the art
- The entire 6D phase space is at issue
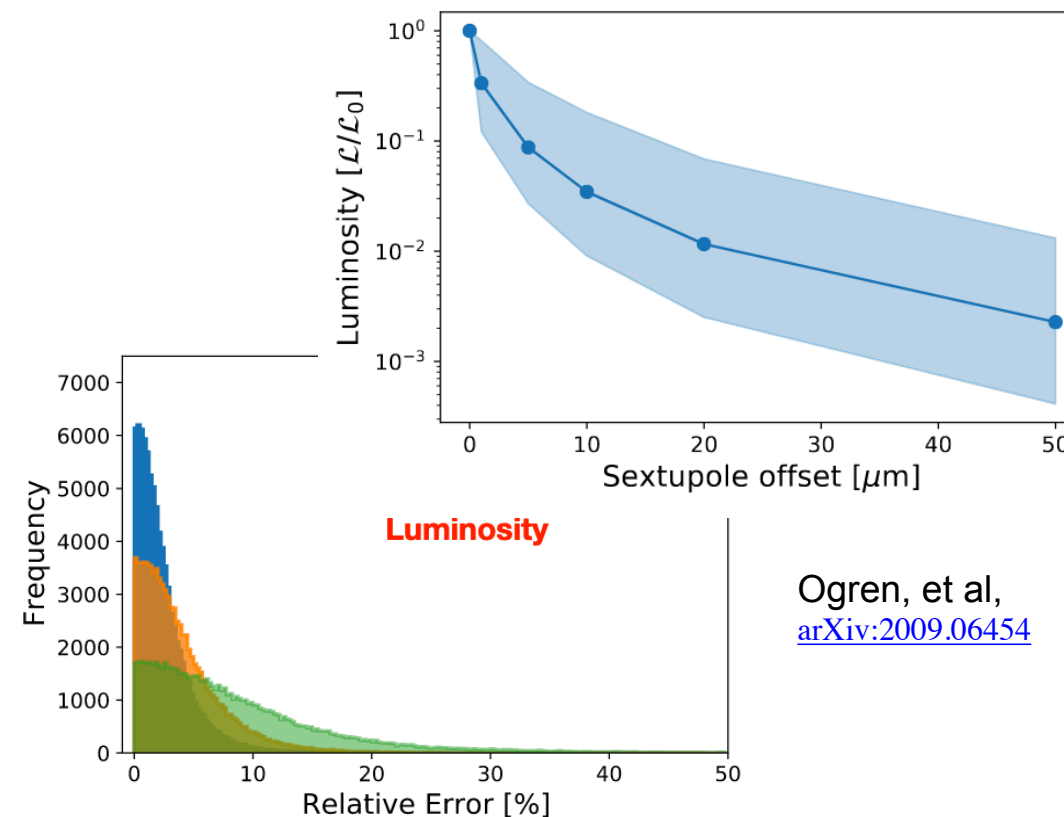- 'the calculated tolerances are 18X – 170X tighter than achievable'

White and Raubenheimer
doi:10.18429/JACoW-IPAC2019-THPGW087

<u>What is currently available (state of the art) around the world?</u>

Incorporate Physics in ML
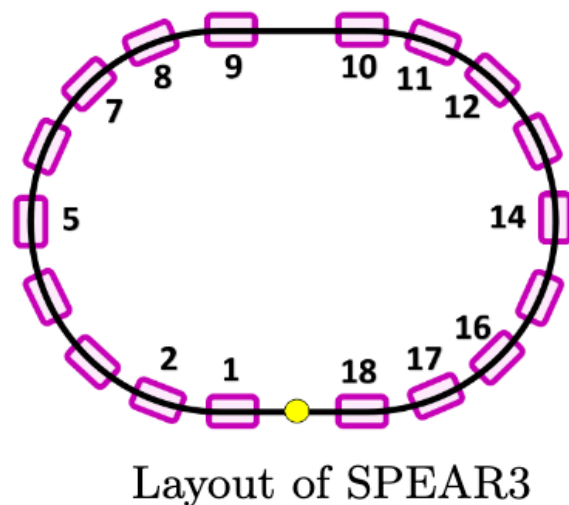
'Surrogate' models used to develop tuning methods

Extract Physics using ML

Layout of SPEAR3

Hanuka, et al,
arXiv:2009.03566

Luminosity

Ogren, et al,
arXiv:2009.06454
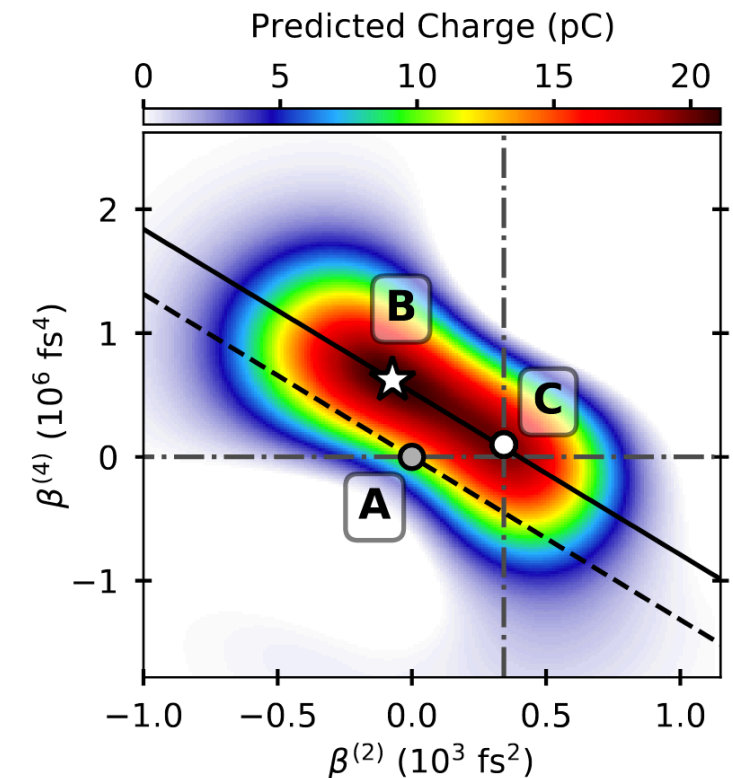
Shalloo, et al
arXiv:2007.14340

Next generation HEP machines are a radical shift in accelerator technology and scale that require new methods of design, study and control

The future of ML in Accelerators

What new accelerator facilities could be available on the next decade (or next next decade)?

- FACET-II preparing broad program to address diagnostics (transverse quality and longitudinal shaping), add physics into ML models to meet design challenges (CSR), develop control strategies
  - uncertainty quantification and safe algorithms are required
- Next facility could use ML based <u>design</u> and tuning
  - Final focus - luminosity scales poorly with energy - ILC Afterburner
  - Beam combining and transport systems of high-quality beams (plasma FEL, short bunch)
  - HEP needs to be proactive about HEP needs, but joint work with BES and NP should be kept in mind

What R&D would enable these future opportunities?

- Diagnostics! New capabilities only work if we 'see' them work
  - 'non-invasive phase space for 10s nm emittance'

- Getting more physics into models is critical (both control and diagnostics)
  - Model what you know, model what you don't know, model what you can

The future is using machine learning to design accelerators that accommodate machine learning control