NSAC LONG-RANGE PLAN TOWN HALL MEETING ON NUCLEAR STRUCTURE, REACTIONS AND ASTROPHYSICS

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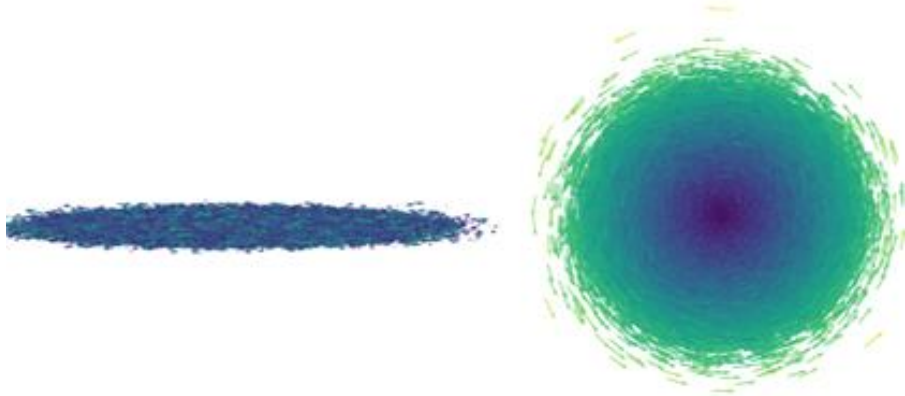
CIRCULAR MODE BEAM OPTICS FOR HIGH LUMINOSITY COLLIDERS



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CIRCULAR MODE BEAM OPTICS FOR HIGH LUMINOSITY COLLIDERS

- Colliders are operating at luminosities well below their theoretical limit!

- One solution is to collide flat beams, which can significantly enhance the luminosity of a collider; one beam size is much smaller: $\varepsilon_x = R^*\varepsilon_y$

$$\mathcal{L} = \frac{f N_1 N_2}{4\pi \sigma_x^* \sigma_y^*} \quad \rightarrow \quad \frac{\mathcal{L}_f}{\mathcal{L}_0} = \sqrt{R},$$

- However, flat beams cannot be effectively transported and accelerated at low-energy; space charge effects are detrimental to flat beams in this regime.

- Circular beams (round & rotating) are intrinsically flat. They can be produced at low-energy, accelerated then converted to flat beams at high-energy.

WHAT WE KNOW, HAS BEEN ACHIEVED SO FAR

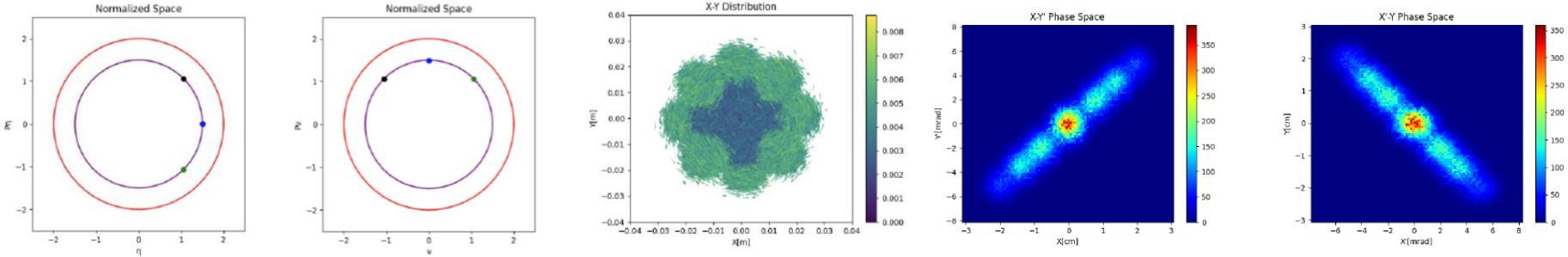
- Different ways to produce a circular mode beam at low-energy:
  - Derbenev's Adapter – 3-skew-quadrupole transformation from a flat beam
  - Beam born inside strong solenoid field:
    - electron gun, ion source in strong solenoid field
    - stripping ion beams inside a solenoid (H- and ions)
  - Injection from a linac into a synchrotron ring; special 4D phase space painting

- Electrons in a storage ring become flat due to synchrotron radiation damping

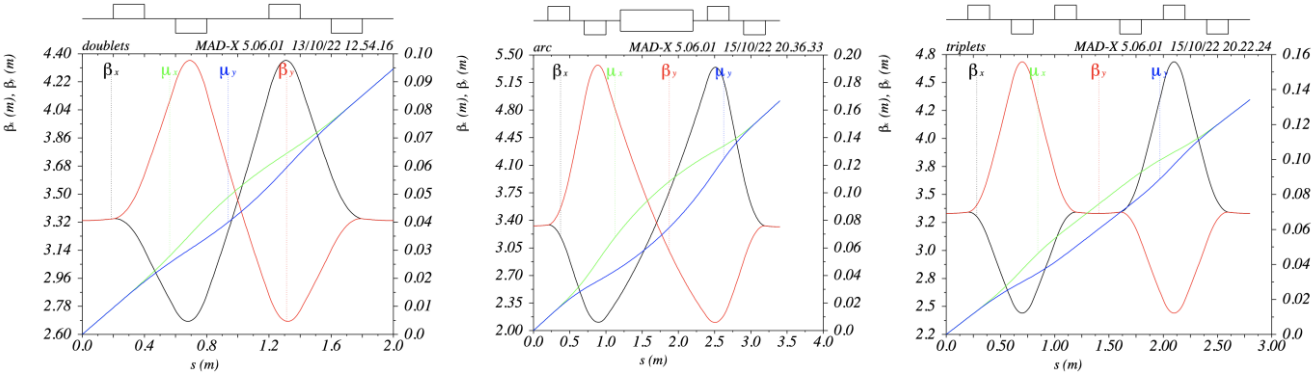
- Our recent studies confirmed: Focused on hadron beams
  - Identified new building blocks that preserve angular momentum (circular mode)
  - Designed a low-energy ring that maintains circular modes through dispersion, acceleration and space charge effects
  - Preliminary proof that circular mode beams also reduce the effect of intra-beam scattering (IBS) → more effective cooling with lower emittance limit for IBS

SOME RECENT RESULTS

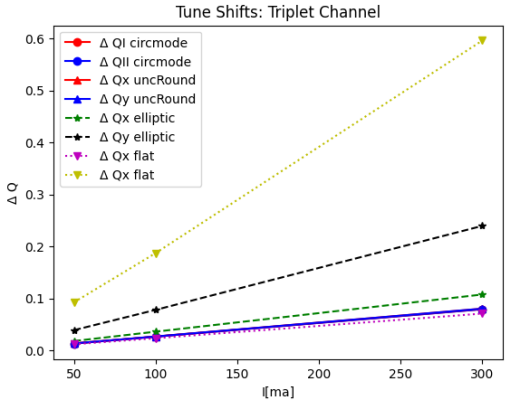
4D painting from linac to ring: the two planes having $\pi/2$ phase difference; particle simulations



Lattice building blocks to preserve angular momentum



Reduced SC effects



Ref: O. Gilanliogullari, B. Mustapha and P. Snopok, Invited talk at ICFA SC Workshop, Oct. 2022

CHALLENGES & OPPORTUNITIES → ACTIONS

- Challenges & Opportunities
  - Circular mode beams can be used to circumvent space charge effects at low-energy while maintaining intrinsic flatness, enabling flat beams at high energy
  - Potential for minimal IBS effects and more effective hadron beam cooling
  - Not clear if the whole accelerator chain need to support circular mode beams
  - Require special lattice design and ring magnets, injection and extraction regions, but not more demanding than the MBA lattices for electron storage rings
  - Such R&D could lead to a future EIC upgrade to enhance the luminosity

- Recommend/Suggested Actions:
  - Build a demonstrator ring for the experimental study of circular mode optics
  - We encourage DOE/NP to sponsor such a development, which would parallel the IOTA ring, which was built at Fermilab to investigate Integrable Optics

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THANK YOU