AI-Driven Multi-Objective Optimization of the EIC Interaction Region

We develop a physics-informed AI co-design framework to optimize IR performance, cost, and feasibility simultaneously.

List of Collaborators

- (Lead) MIT
- JLAB?

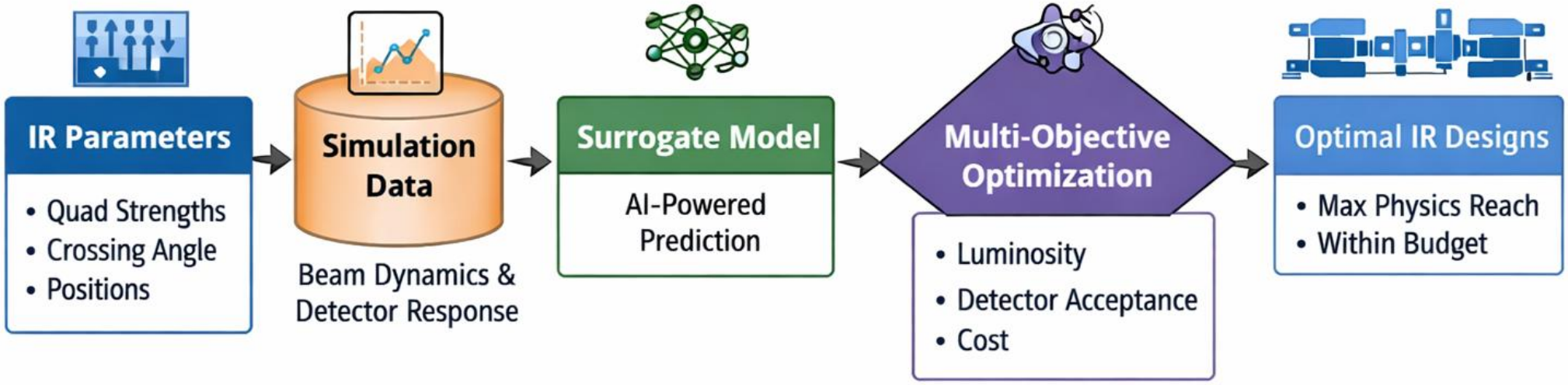
Focus area 13.A: Enhancing Particle Accelerators for Discovery: AI Driven Accelerator Facilities

Project Overview

- Challenge
  - Interaction Regions (IR) highly constrained and expensive
  - Competing objectives:
    - Luminosity
    - Detector acceptance
    - Optics vs synchrotron radiation
    - Engineering feasibility
    - Cost vs physics reach
- Approach
  - AI-enabled surrogate model of IR performance
  - Physics-informed multi-objective optimization
  - Co-design framework integrating:
    - Beam physics, Detector constraints, Engineering limits

Project Overview

- Impact
  - Faster IR design space exploration (orders of magnitude)
  - Enables globally optimal, realistic designs
  - Extensible to EIC, muon collider, future facilities



9-months work plan

Month 0-3:
Baseline + Data Generation

- Build baseline IR lattice model
- Define parameter space:
  - Quadrupoles, crossing angle, positions
- Generate simulation dataset

Months (3–6):
Surrogate + AI Framework

- Train surrogate model
- Develop optimization framework
- Define multi-objective targets:
  - Luminosity
  - Acceptance
  - (Radiation)
  - Cost

Month 6-9:
Optimization + Validation

- Apply multi-objective optimization
- Incorporate constraints:
  - Magnet limits
  - Aperture
  - Cost models
- Validate against full simulations

9-months deliverables & Metrics

- Month 3
  - Baseline IR model + parameterized design space
- Month 6
  - Validated surrogate model
- Month 9
  - Validated optimized IR configurations
    - Demonstrated Pareto improvements
    - Verified feasibility constraints
  - Benchmark vs traditional design methods

Workforce Development Plan

- MIT LNS:
  - Post-doc 1: 0.35 FTE
    - Lattice
  - Post-doc 2: 0.5 FTE
    - AI
  - Engineer: 0.35 FTE
    - Engineering feasibility
  - Scientist: 0.25 FTE
    - Physics and validation