EIC Collimation Studies

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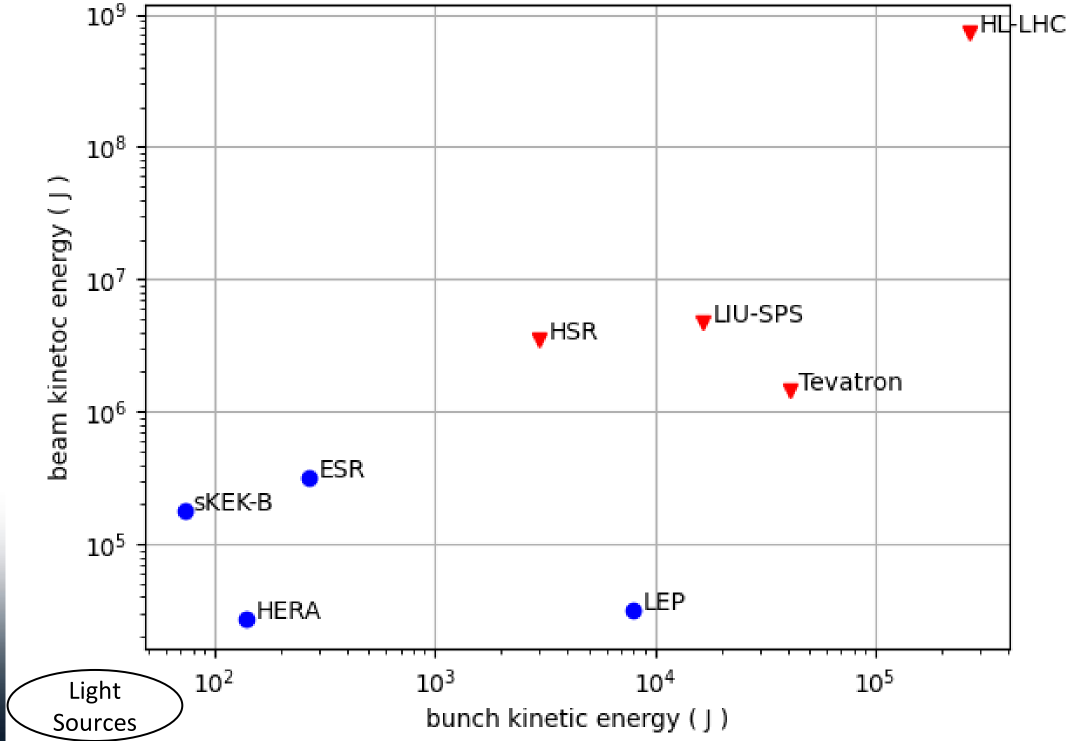
US FCC Workshop

Electron-Ion Collider

BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

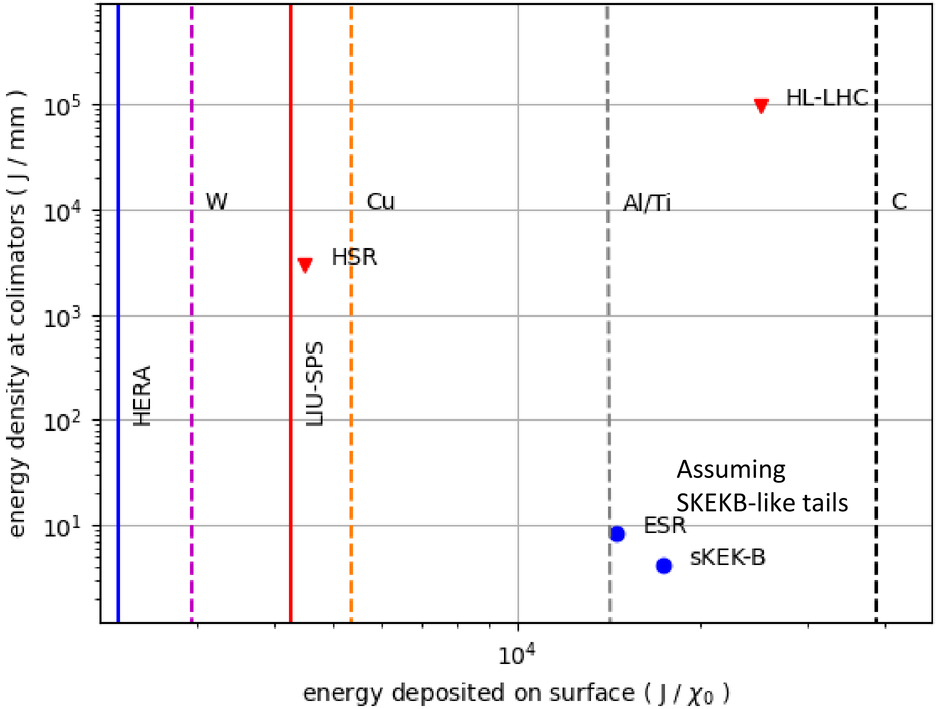
Context

- The EIC will feature powerful beams
  - 10x the stored energy of RHIC
  - 2x Super KEK-B target stored energy in the ESR with 1/2 the bunches
- Collimators accomplish 2 main missions
  - Beam cleaning to reduce radiation & backgrounds from lost particles
  - Machine & Detector protection from accidental beam loses (CCs, kickers, instabilities, …)
- Constraints
  - Impedance budget
  - Beam lifetime
  - $ budget



Introduction

- The e⁻ bunches will be very dense (0.5 mm²) and melt metals in case of normal impact.



- The p⁺ beam will have similar parameters as the post-LIU SPS.

- Other complexes have reported issues limiting performance:
  - Super KEK-B experienced instabilities causing collimator damage and limiting beam currents.
  - HL-LHC will switch to coated collimators (MoGr) to reduce impedance.

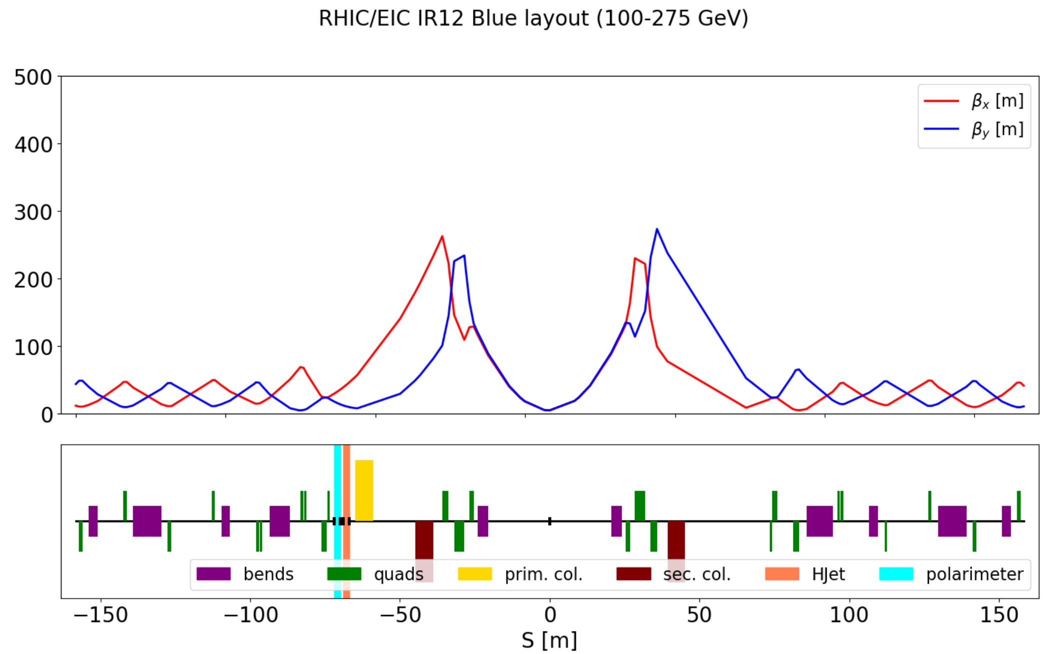
HSR Collimators

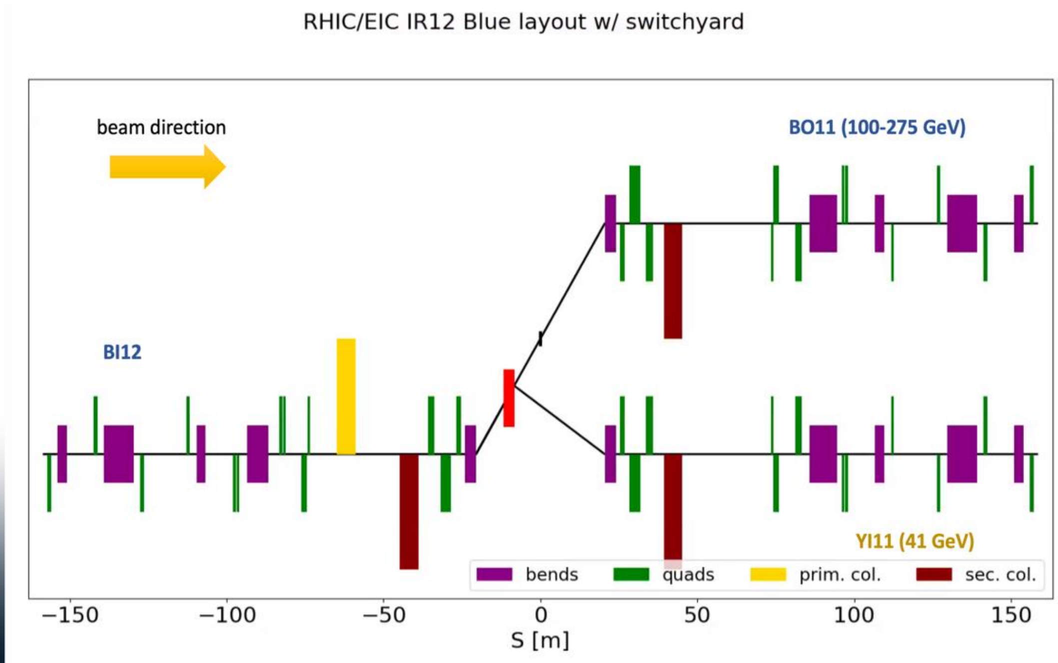
- Special constraints:
  - Different loss behavior for protons/ions
  - Cold ring requires good cleaning efficiency in the arcs
  - More flexibility on the optics

- We can benefit from RHIC and LHC experience.

- Planned in IR12 :
  - issues with other users due to radiation
  - switchyard doubles the second secondary

- Momentum collimators are planned for the sector 12 ”D7” dummy.

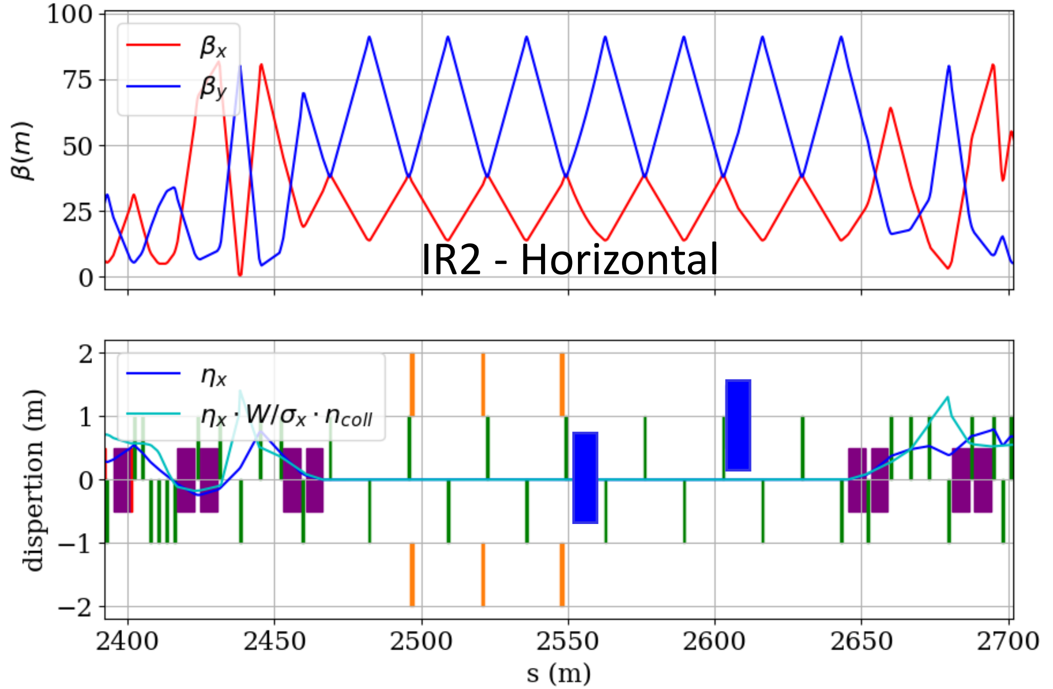


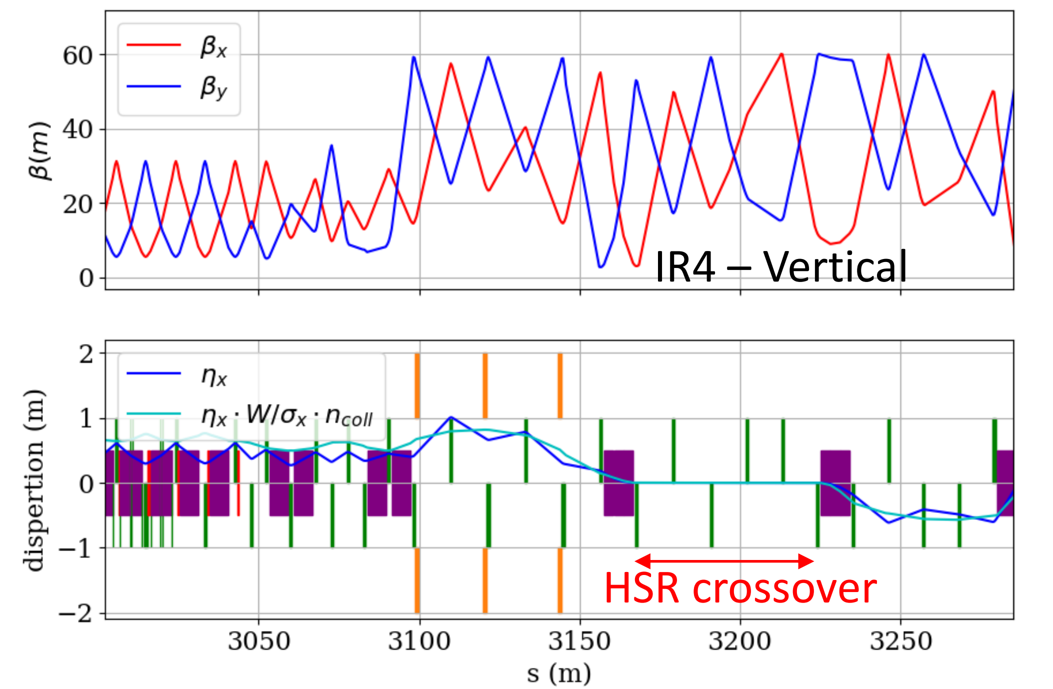


Courtesy of G. Robert-Demolaize

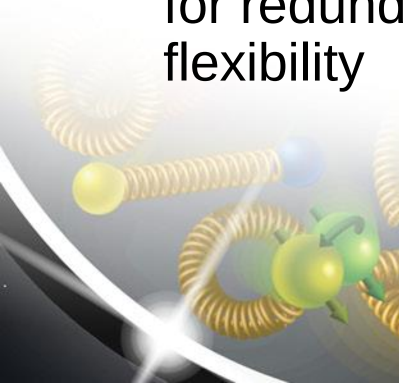
ESR collimation

- Focus on the 10 GeV case with the most stored energy.
- Planned in IR2 & 4 :
  - 1 double-sided primary
  - 2 double-sided secondary for cleaning and flexibility with phase advances and optics
  - Possibility to double each set for redundancy and extra flexibility



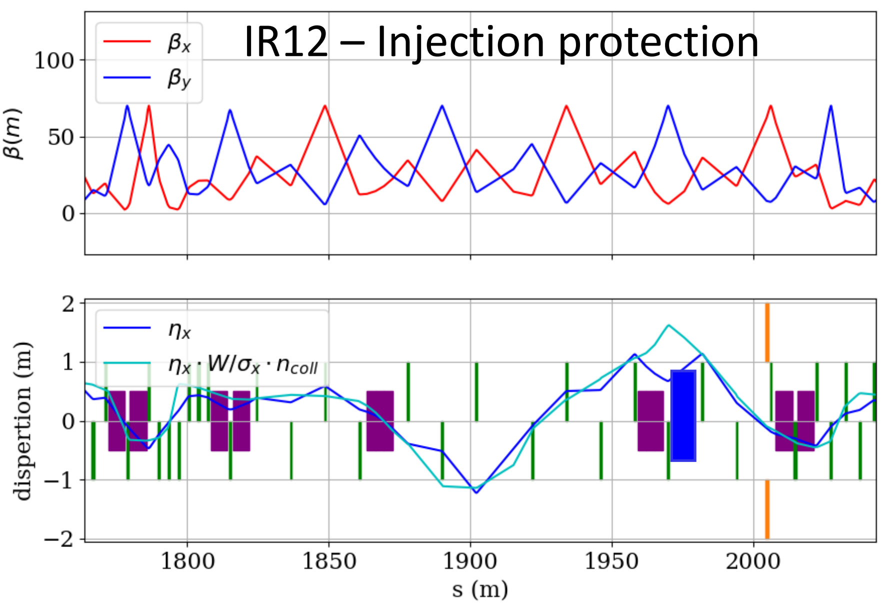


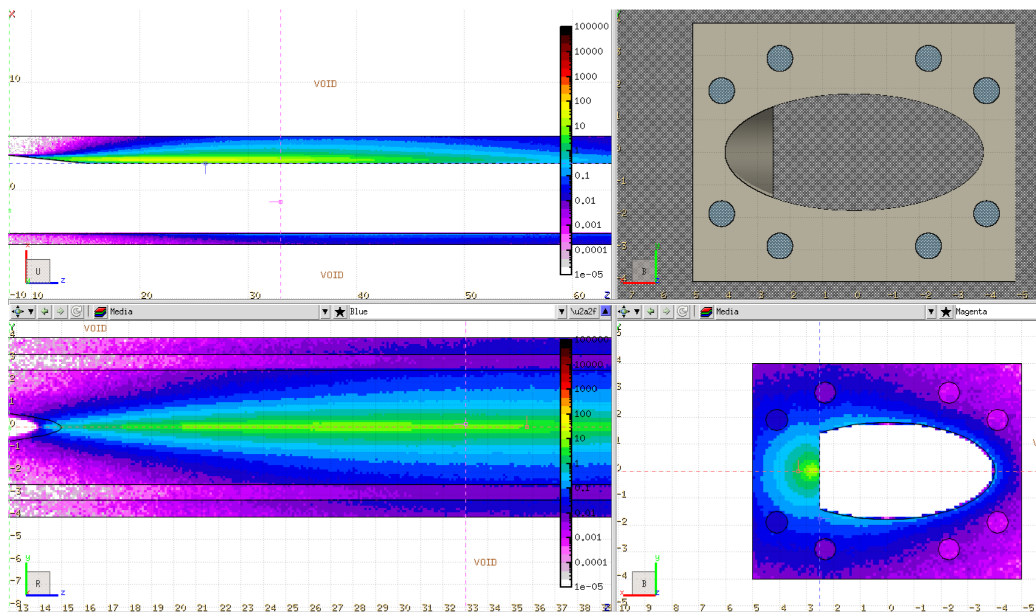
Collimators
Quadrupoles
Dipoles
Dump kickers &
Lambertson



ESR collimation (continued)

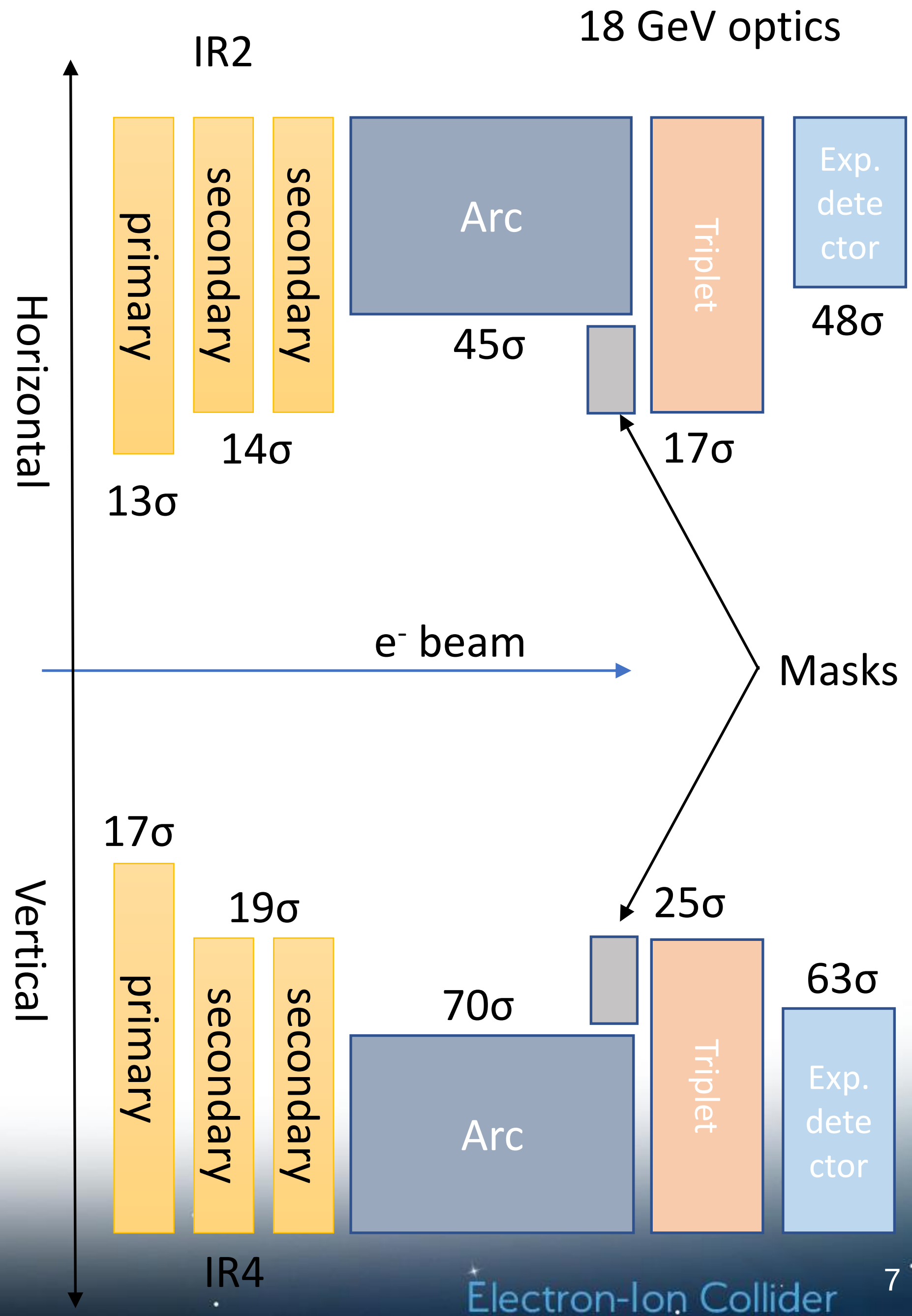
- Electron bunches have a short polarization lifetime (~35 min) and will be replaced every 10 minutes. The ~250 J of the used bunch will be absorbed in-vacuum.
- The Titanium transfer-absorber will be in IR12 with 2 jaws for injection failure cases.
- IR12 is also the location with the largest dispersion and the most suitable for momentum collimation.





Collimation hierarchy

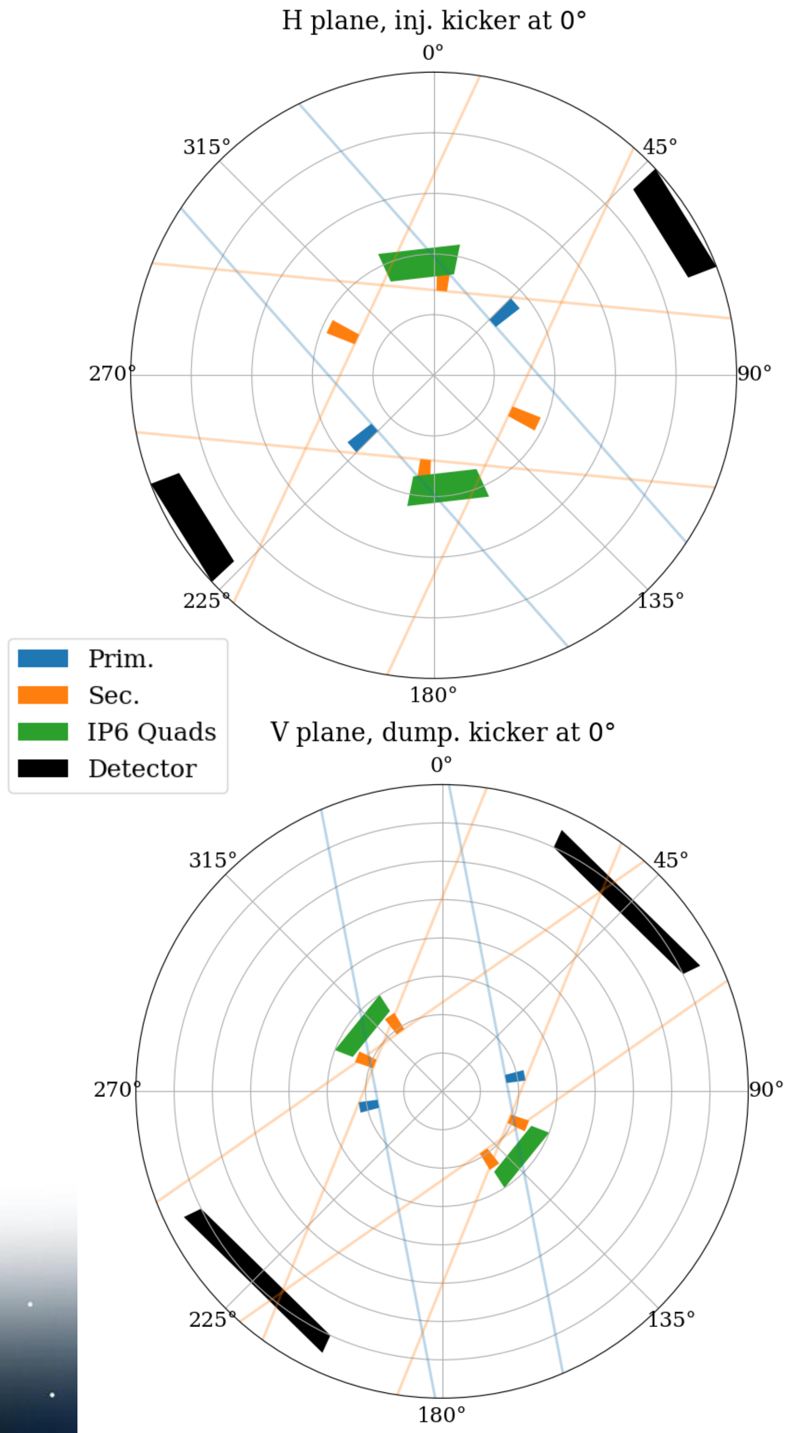
- Imposed by squeezed optics in the IRs
- Retraction from prim -> sec -> aperture based on orbit stability
- Arc is tighter than experiment in the horizontal plane
- Masks upstream of IRs will prevent losses into the focusing quads from showering to the detectors



Optics considerations

- Phase advances :
  - key to protect against kicker failures
  - important to ensure cleaning efficiency with secondaries
  - Orbit/optics will have to be monitored to ensure protection/cleaning

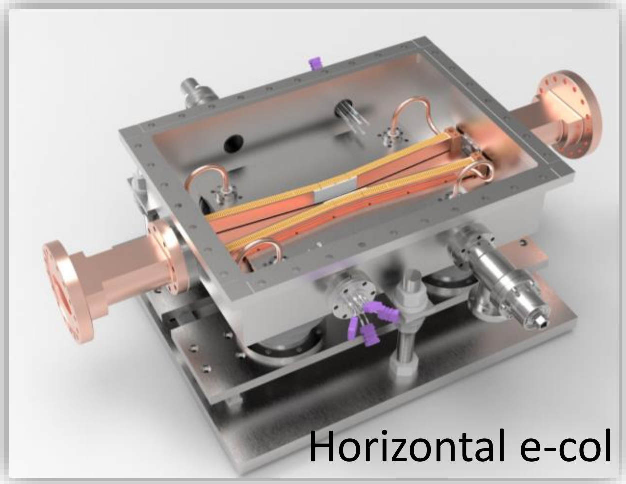
- Orbit stability, β-beat, errors, … will affect collimations hierarchy and retraction margins.
- Failure case simulations are needed once powering circuits are being finalized.
- We are following developments at KEK-B closely to learn from their experience.

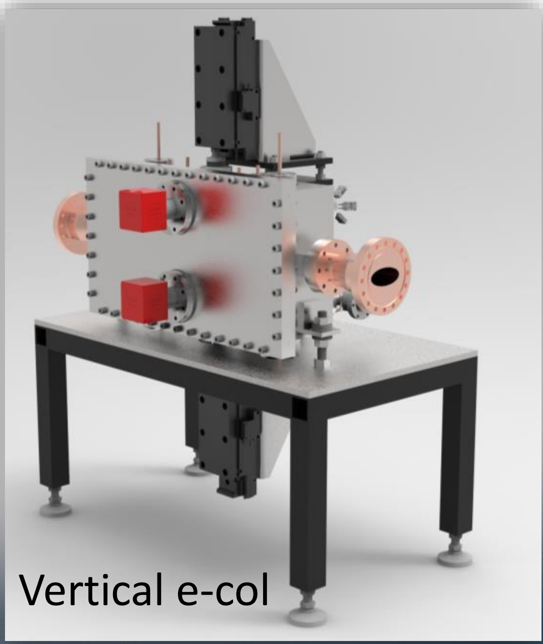


Mechanical design

- The HSR will feature long LHC-like collimators.
  - The jaws will be several meters long and made of amorphous Carbon

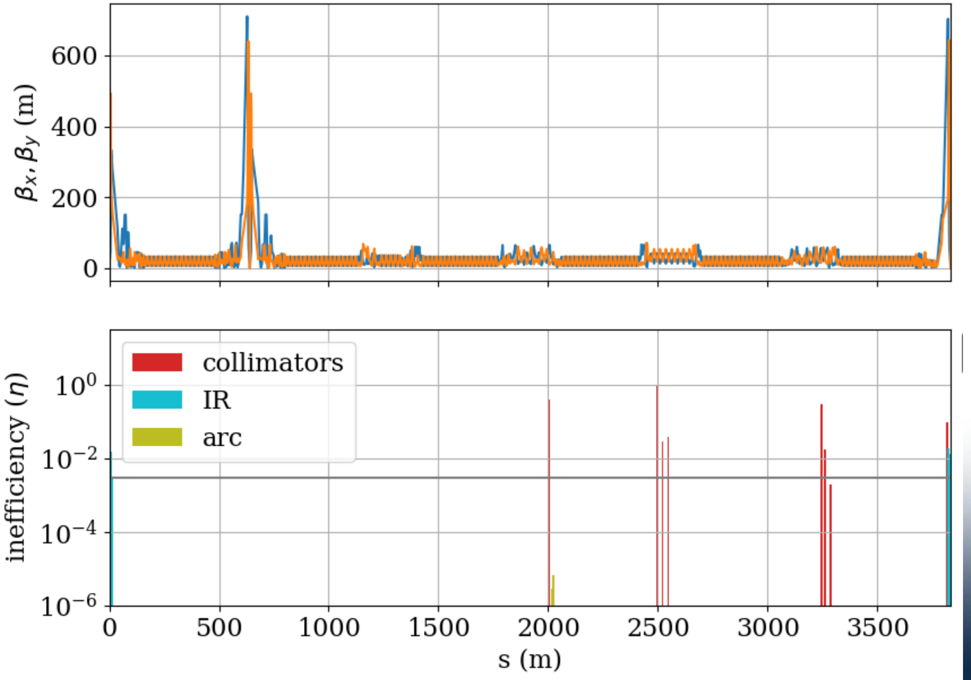
- The ESR will feature short KEKB-like collimators.
  - Coated Carbon would benefit energy absorption and impedance.
  - Composite materials are also under consideration (MoGr).
  - All collimators will feature the same design for replaceability.


Horizontal e-col


Vertical e-col

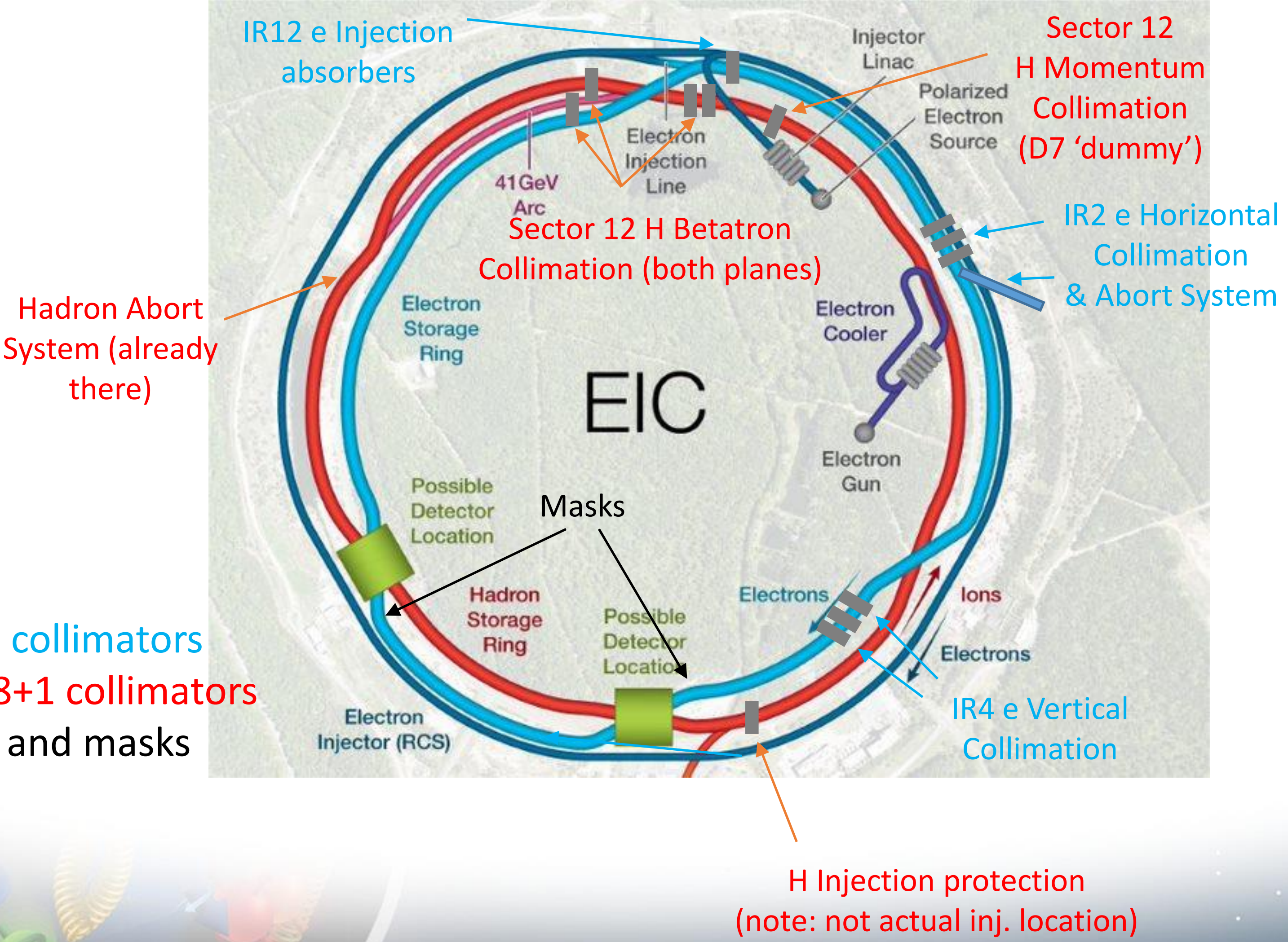
Tracking simulations

- Xsuite + BDSIM used as a tracking tool.
- Sample loss maps for the ESR are ready and allow design validation.
    - More elaborated simulations will follow, including SR, beam-gas and generation of secondary particles.



Special thanks go to CERN's collimation team : Frederik, Andrey, Pablo and Stefano for their help.

Summary



electron : 6 collimators

Hadrons : 8+1 collimators

+absorbers and masks

Conclusion & Outlook

- Collimation system design :
  - Space, impedance and budget constrains are included to ensure background reduction and protection from failure cases.
  - Global/Local optics requirements are defined for the lattice integrators.
  - IR4 optics are being finalized and moveable mask location conflict need to be ironed-out.

- Tracking simulations :
  - ESR : preliminary loss maps are ready, more detailed studies on cleaning inefficiency and errors are next
  - HSR : pending software functionalities
  - A dedicated simulation sever is being purchased

- Failure simulations will follow once some design parameters are settled.