IR AND LSS DESIGN FOR A RING-RING LHeC

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Outline

- Complete conceptual LHeC Ring-Ring IR and LSS Solution
  - CDR and beyond
- Electron Interaction Region
  - Beam Separation
  - Acceptance vs Luminosity
  - Synchrotron Radiation
- LHC IR Integration
  - Beam Separation
  - Second Proton Beam
- Electron Long Straight Section
  - Geometry
  - Integration with LHC
  - CDR solution
  - Further development

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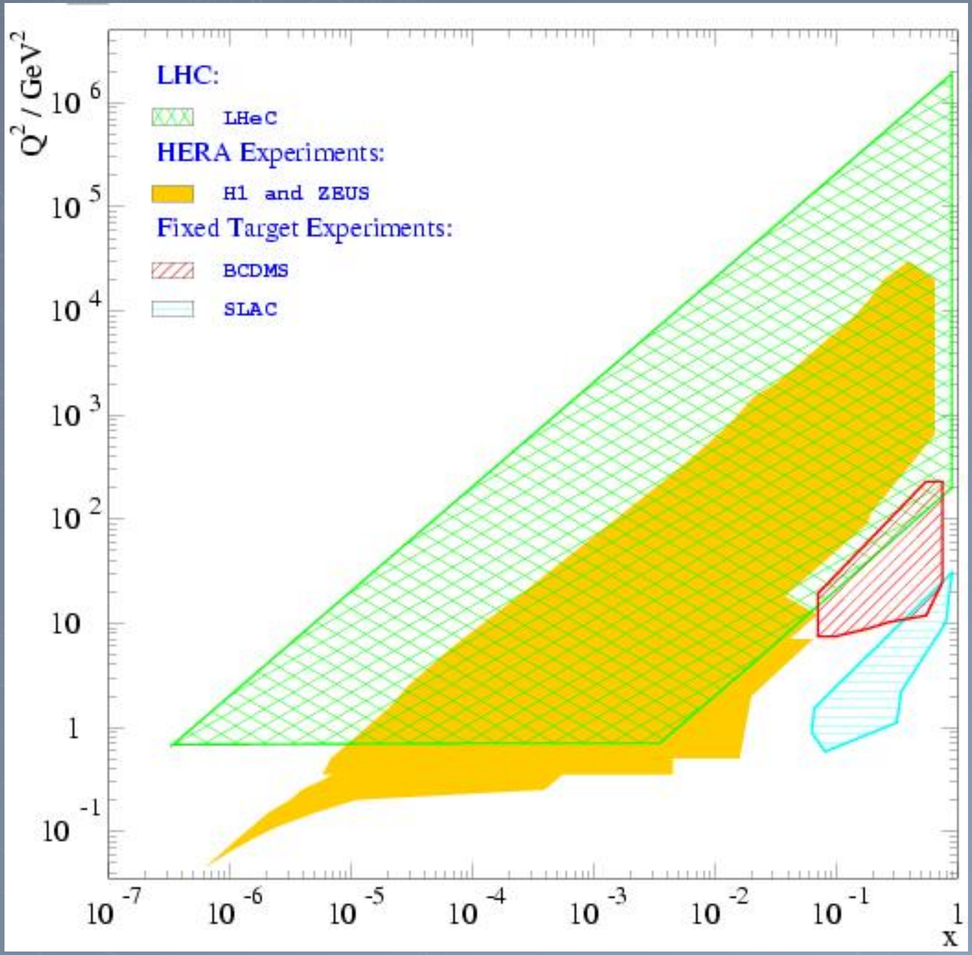
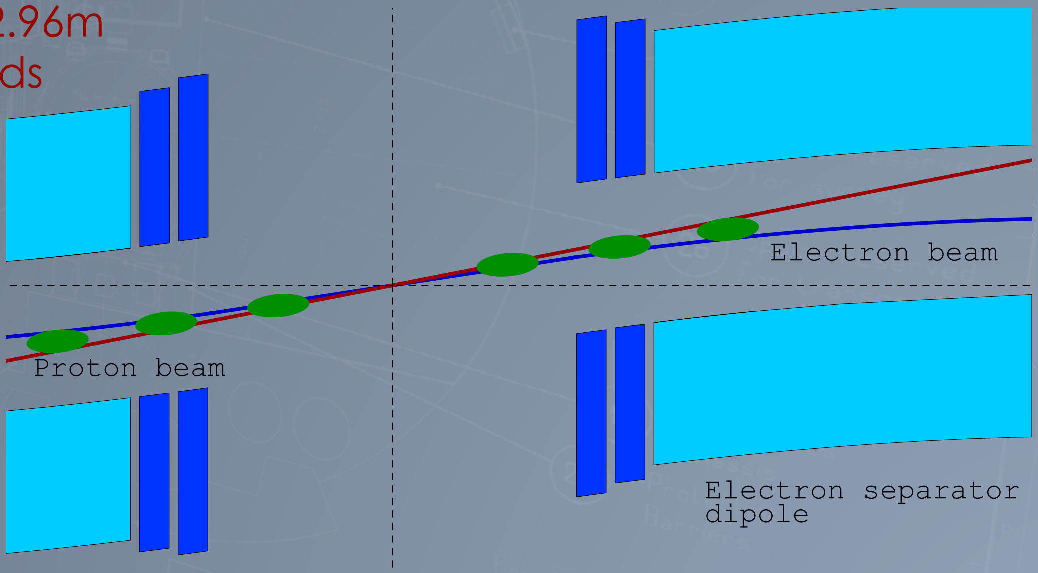
Electron IR: Overview

- Large kinematic range
- For high Q^2 and x, high luminosity
- For low Q^2 and x, sensitivity at high rapidity
- Manageable SR
- Minimal beam-beam
- Integration with two proton beams

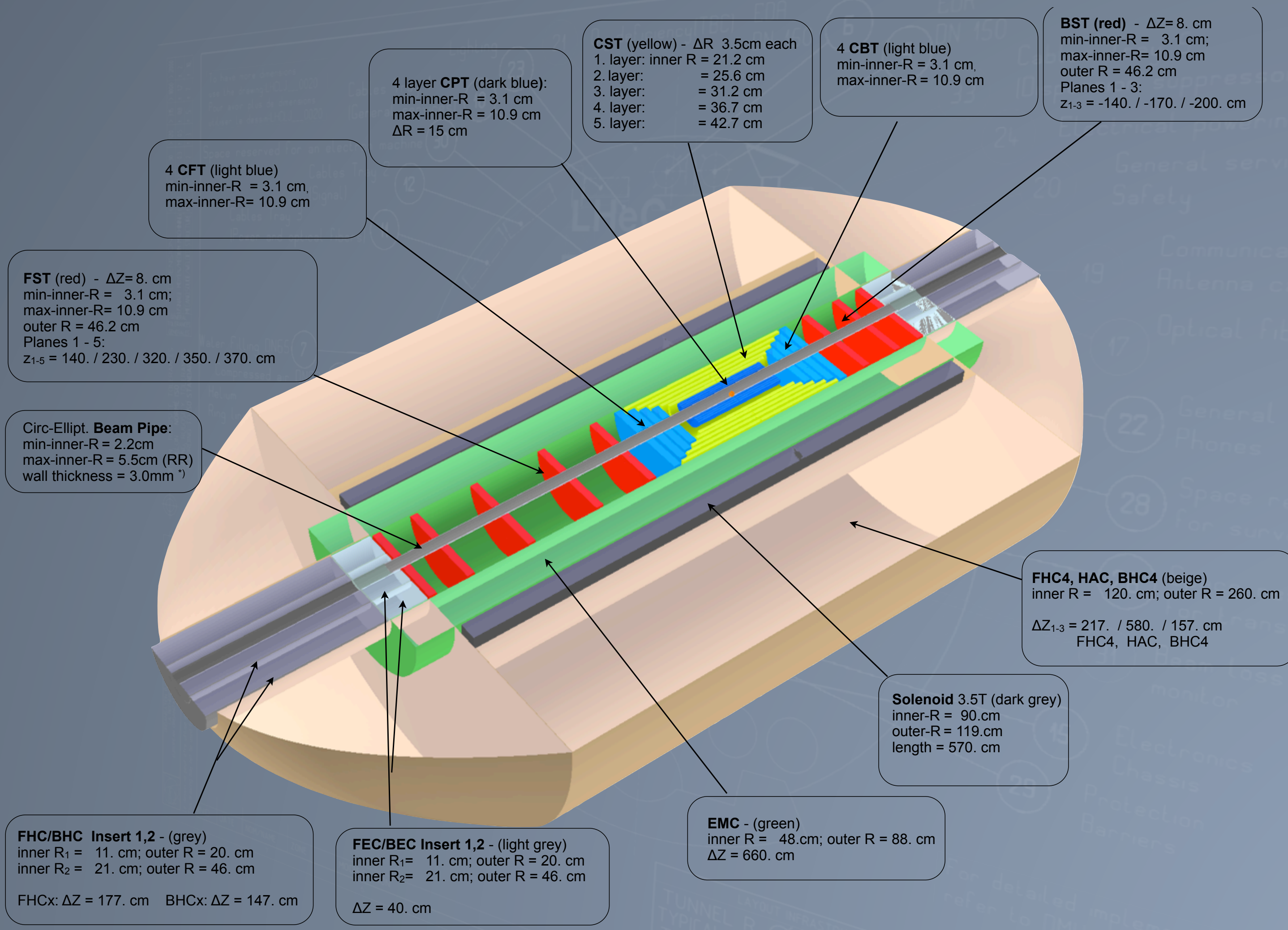


Electron IR: Beam Separation

- Beam-beam considerations
  - Parasitic interactions every 3.75m
    - Bunch spacing 25ns
  - $5\sigma_p+5\sigma_e$ separation at each parasitic node
- Proton IR integration
  - >55mm separation at ±22.96m to avoid proton quad fields
  - Discussed later
- "Toolkit":
  - Separation dipoles
    - Produces SR
  - IP crossing angle
    - Decreases luminosity
  - Offset quadrupoles



Detector Acceptance

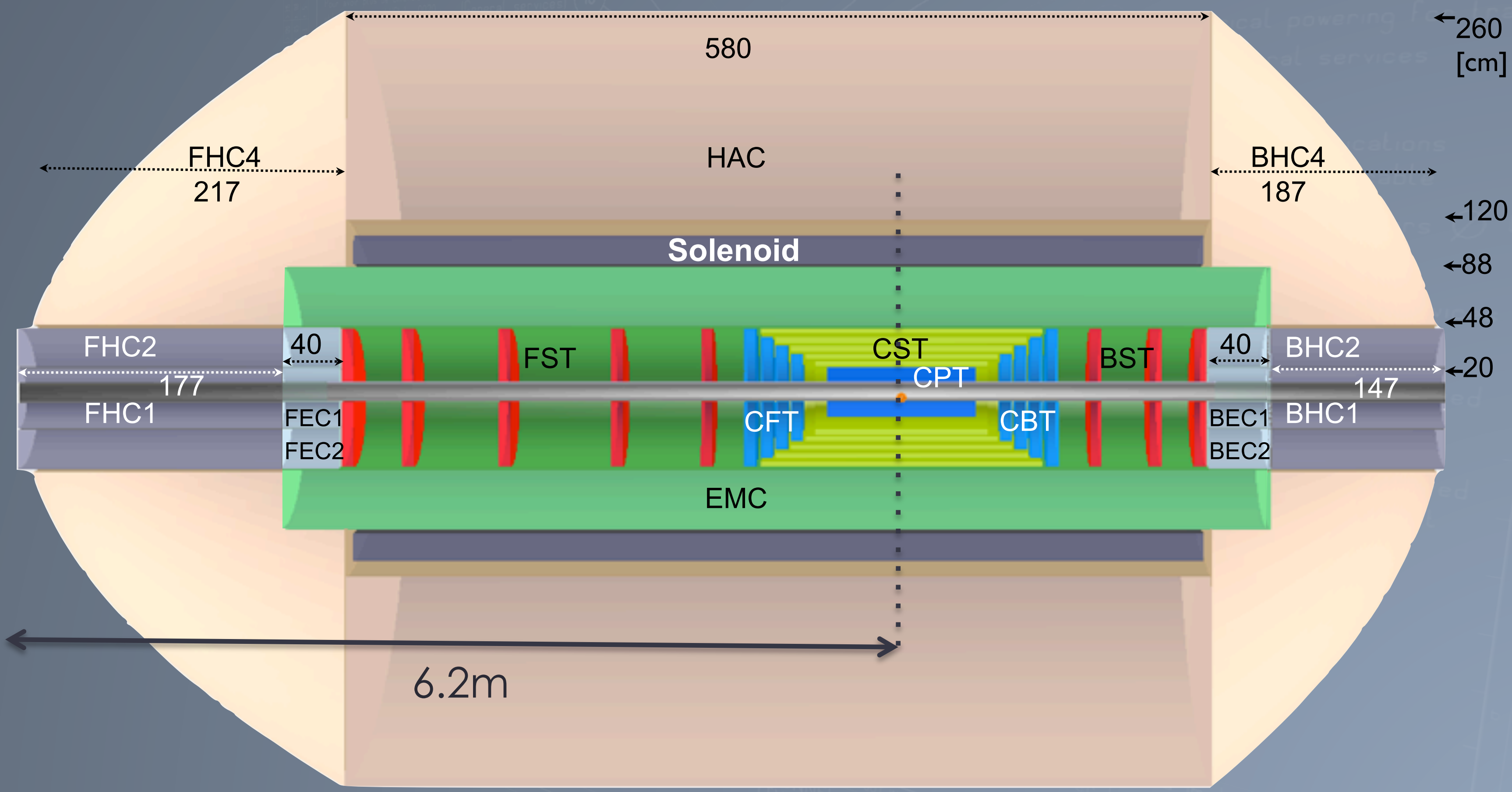


Electron IR: Acceptance

- Two IR layouts
- High Acceptance (HA)
  - Electron triplet outside detector
  - L^* = 6.2m
  - 1° acceptance (nominal)
  - Sensitivity at small angles
- High Luminosity (HL)
  - Electron triplet embedded in detector
  - L^* = 1.2m
  - 10° acceptance
  - Higher luminosity via tighter focusing

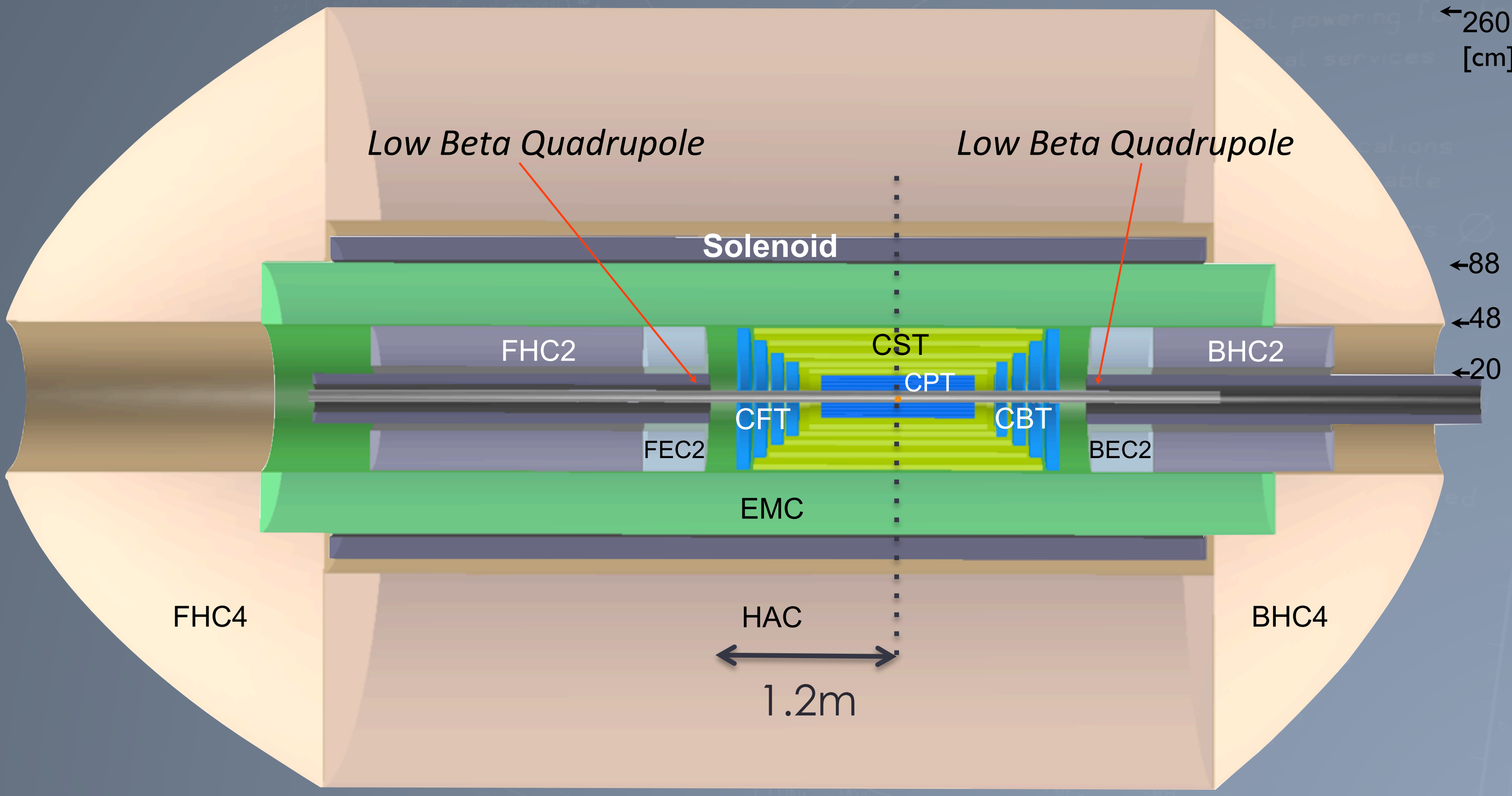
Detector Acceptance: 1° / HA

High Acceptance (HA) Layout



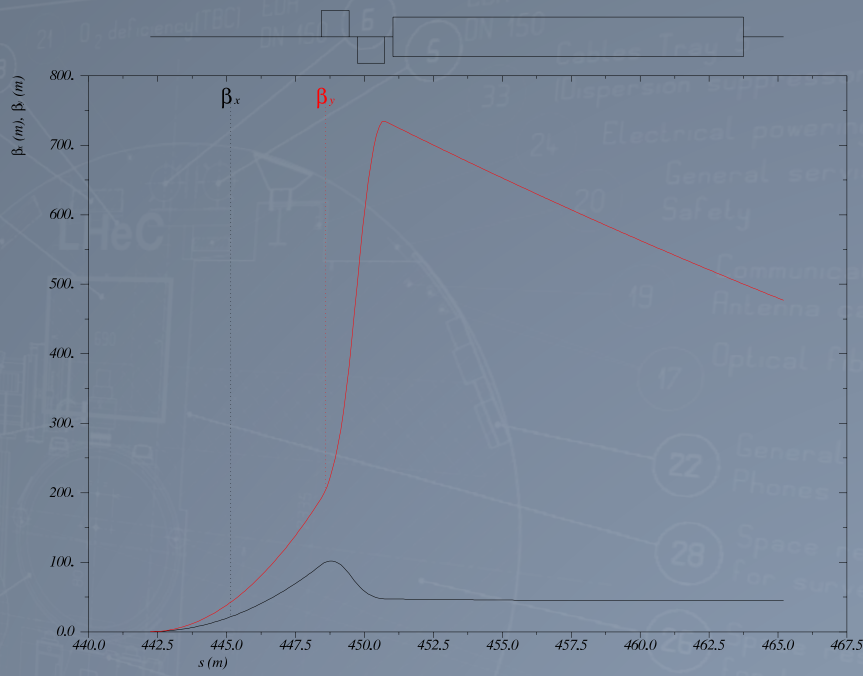
Detector Acceptance: 10° / HL

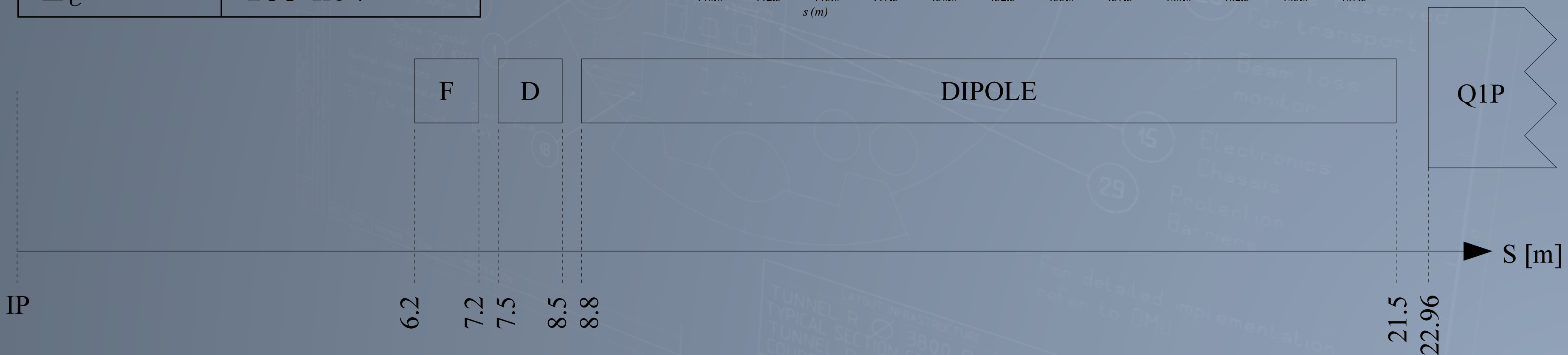
High Acceptance (HA) Layout



Electron IR: High Acceptance

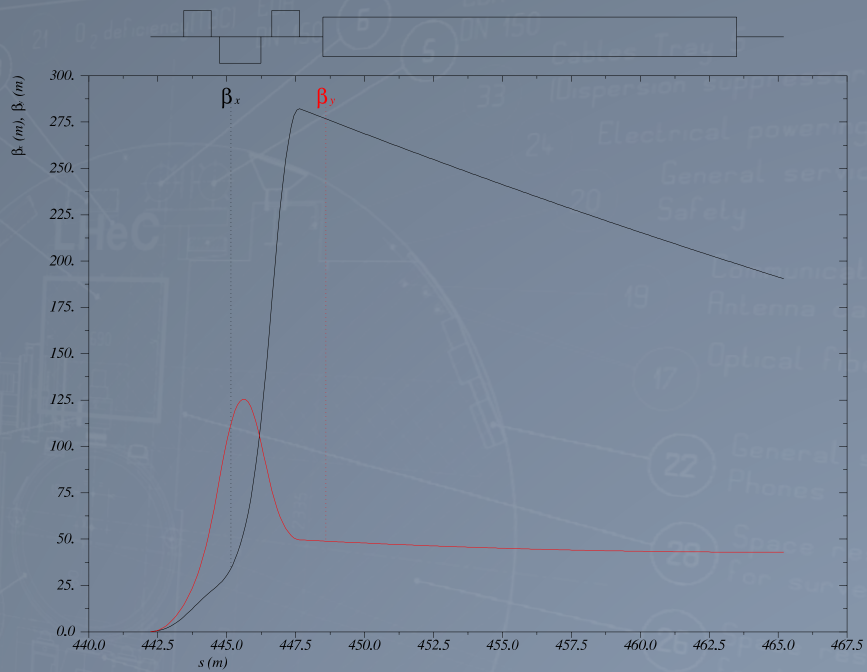
$L(0)$	8.54×10^{32}
θ	1×10^{-3}
$S(\theta)$	0.858
$L(\theta)$	7.33×10^{32}
β_x*	0.4 m
β_y*	0.2 m
σ_x*	4.47×10^{-5} m
σ_y*	2.24×10^{-5} m
SR Power	51 kW
E_c	163 keV

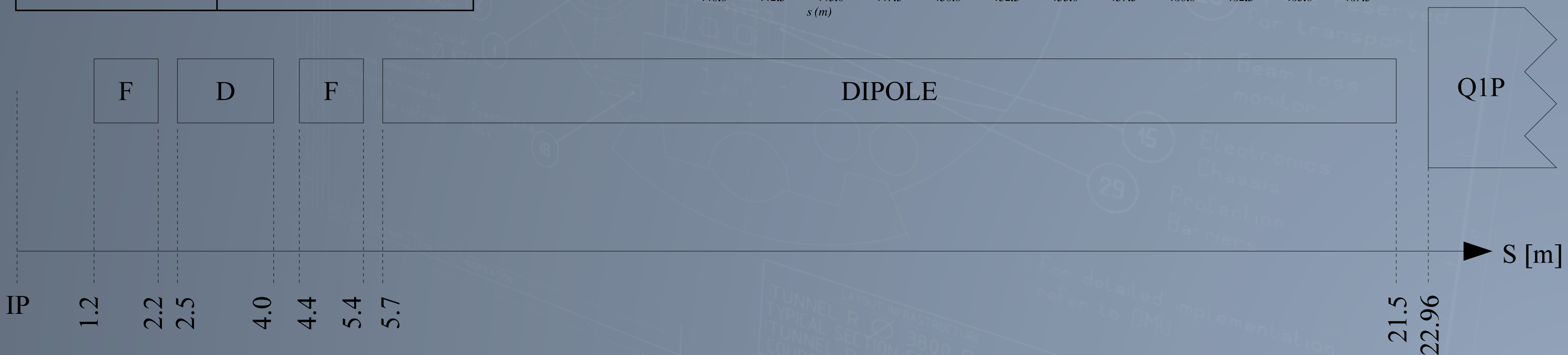




Electron IR: High Luminosity

$L(0)$	1.8×10^{33}
θ	1×10^{-3}
$S(\theta)$	0.746
$L(\theta)$	1.34×10^{33}
β_x*	0.18 m
β_y*	0.1 m
σ_x*	3.00×10^{-5} m
σ_y*	1.58×10^{-5} m
SR Power	33 kW
E_c	126 keV





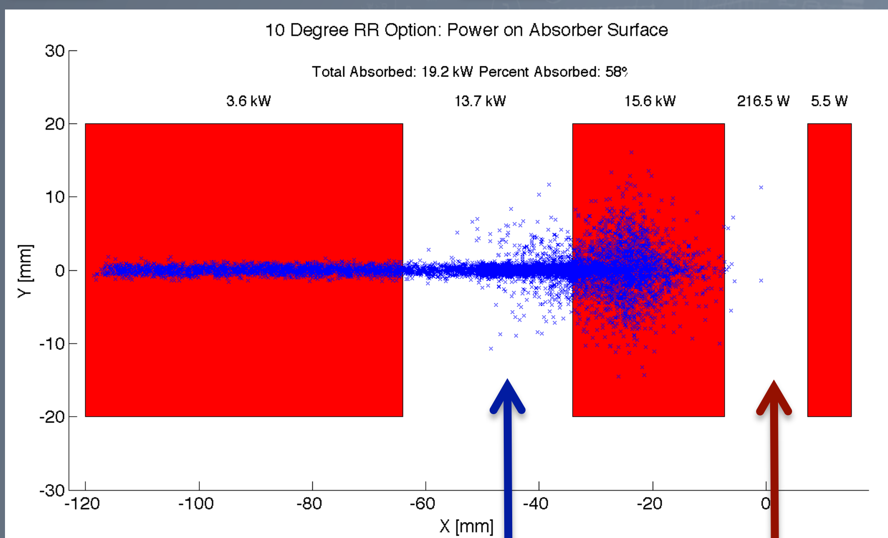
Electron IR: SR

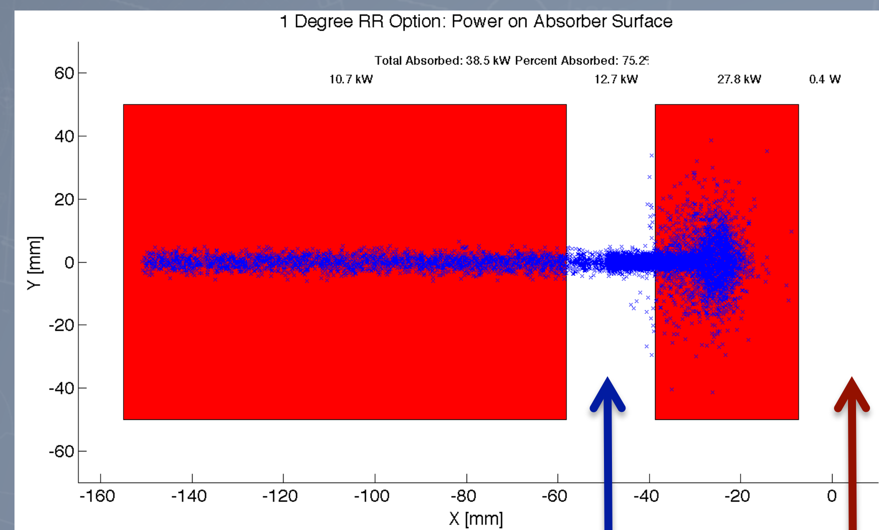
	Power [kW]		Critical Energy [keV]	
	Geant4	IRSYN	Geant4	IRSYN
Total/Avg	33.2	33.7	126	126

	Power [kW]		Critical Energy [keV]	
	Geant4	IRSYN	Geant4	IRSYN
Total/Avg	51.1	51.3	163	162

SR power incident on face of proton quadrupole

Absorber   Incident photons





e beam aperture   p beam aperture

e beam aperture   p beam aperture

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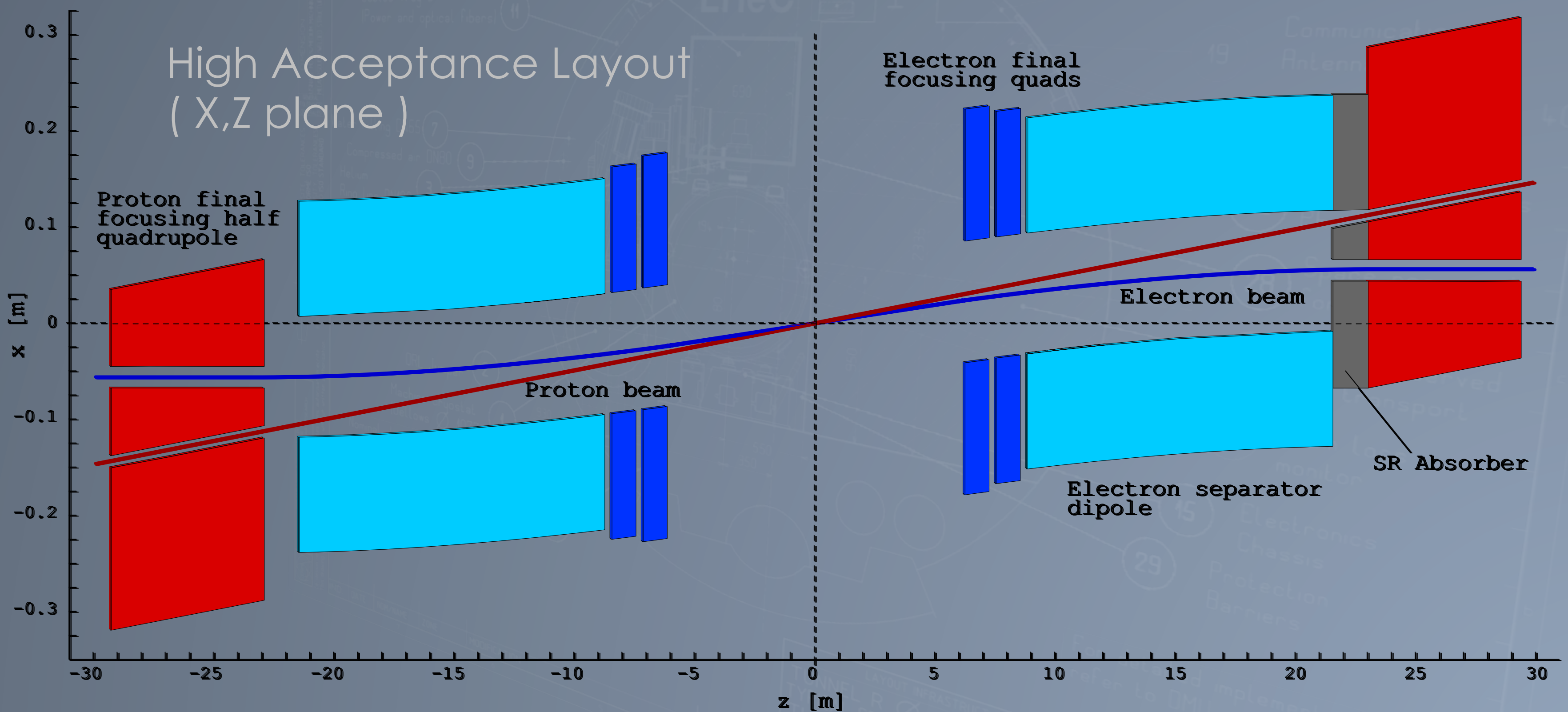
LHC IR Integration

- Shared beampipe between ±22.96m
- Proton final triplet at ±22.96m



LHC IR Integration: Beam Separation

- Electron beam must not pass through proton fields
  - Require separation between beams at ±22.96m
- Proton quad yoke ~200mm radius
  - Infeasible to separate beams this much

- Proton half-quadrupole design
  - Quasi field-free aperture for electron beam
- Beam separation >55mm at ±22.96m

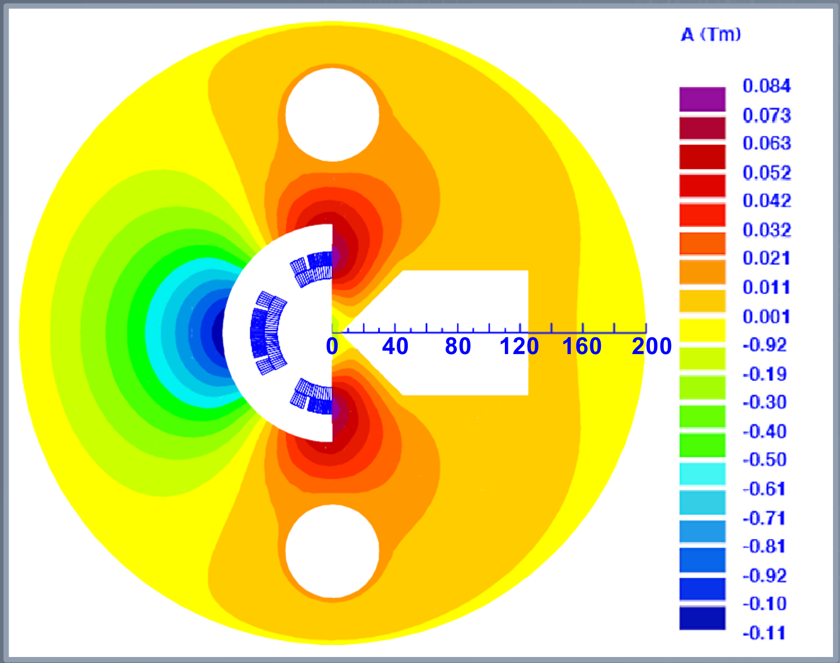
- 55mm separation achievable
  - Combination of crossing angle, dipoles, offset quadrupoles

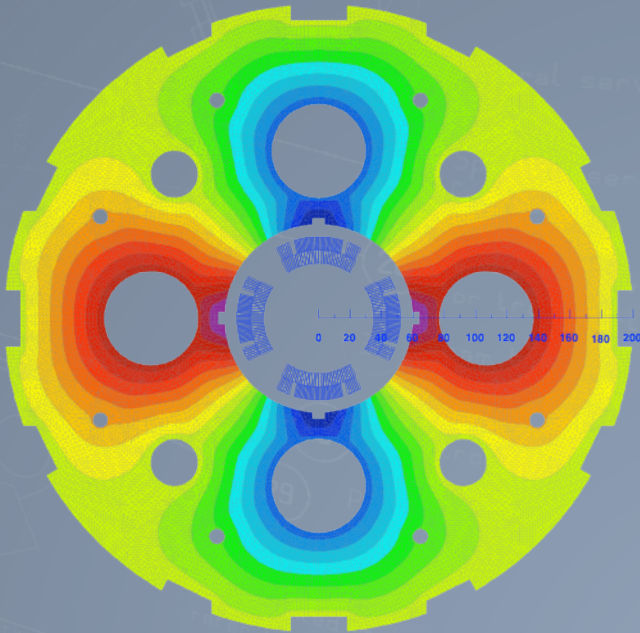
LHC IR Integration: 2nd Proton Beam

- Second proton beam
  - Must not collide with p or e beams
  - Minimise beam-beam interaction
  - Detector: shared beam pipe
- Toolkit:
- Bunch offset
  - No collision at IP
  - Can co-rotate with electron beam
- Crossing angle
- "Unsqueezed" optics
  - Cannot pass through proton triplet
  - Matched via LSS2 matching section
- Proton half-quadrupole Q1
  - Use electron aperture
  - Tailor p-p crossing angle for this purpose

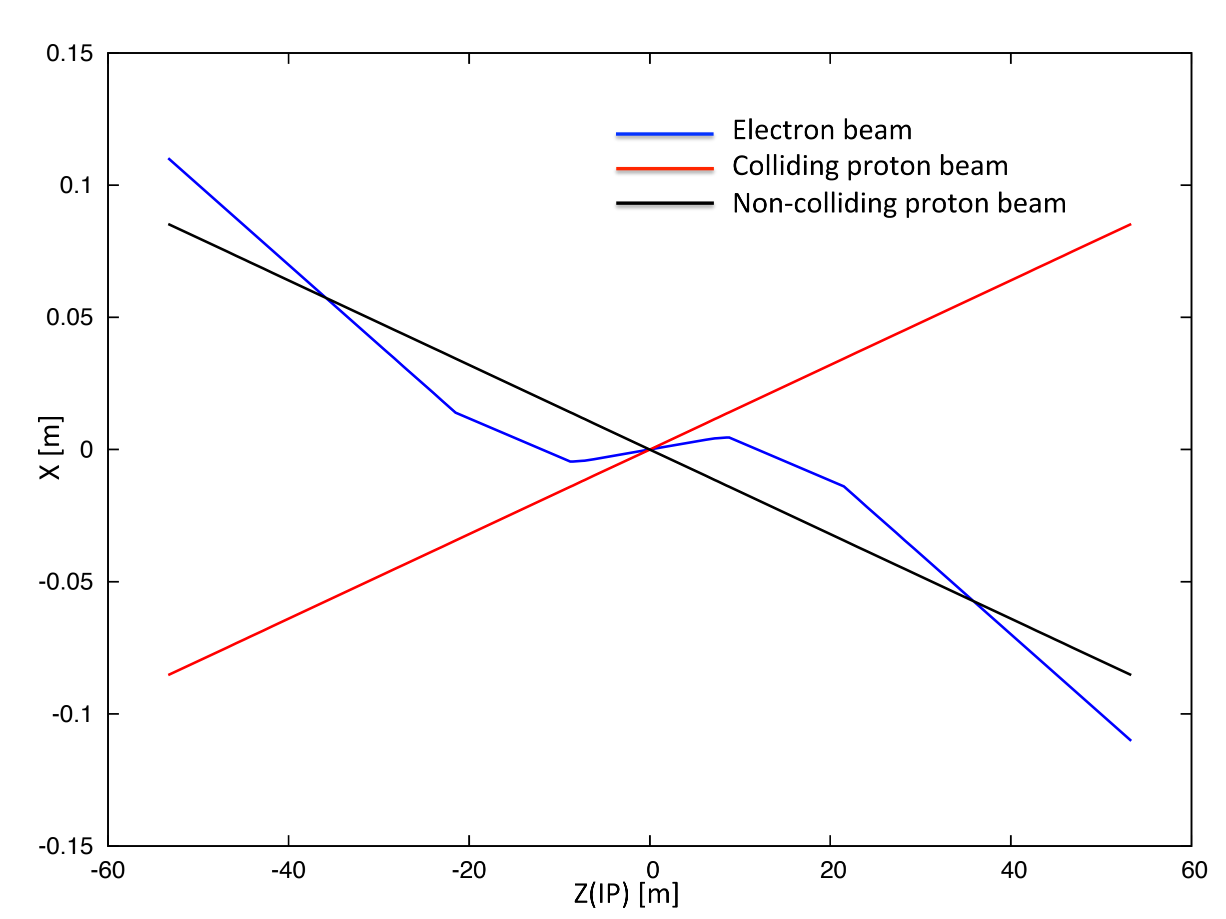
LHC IR Integration: Proton Quadrupoles

- Q1: Half quadrupole
  - Large low-field electron aperture
- Q2, Q3: Conventional SC quads
  - Low field pockets used as apertures
- Yokes can be up to 270mm radius



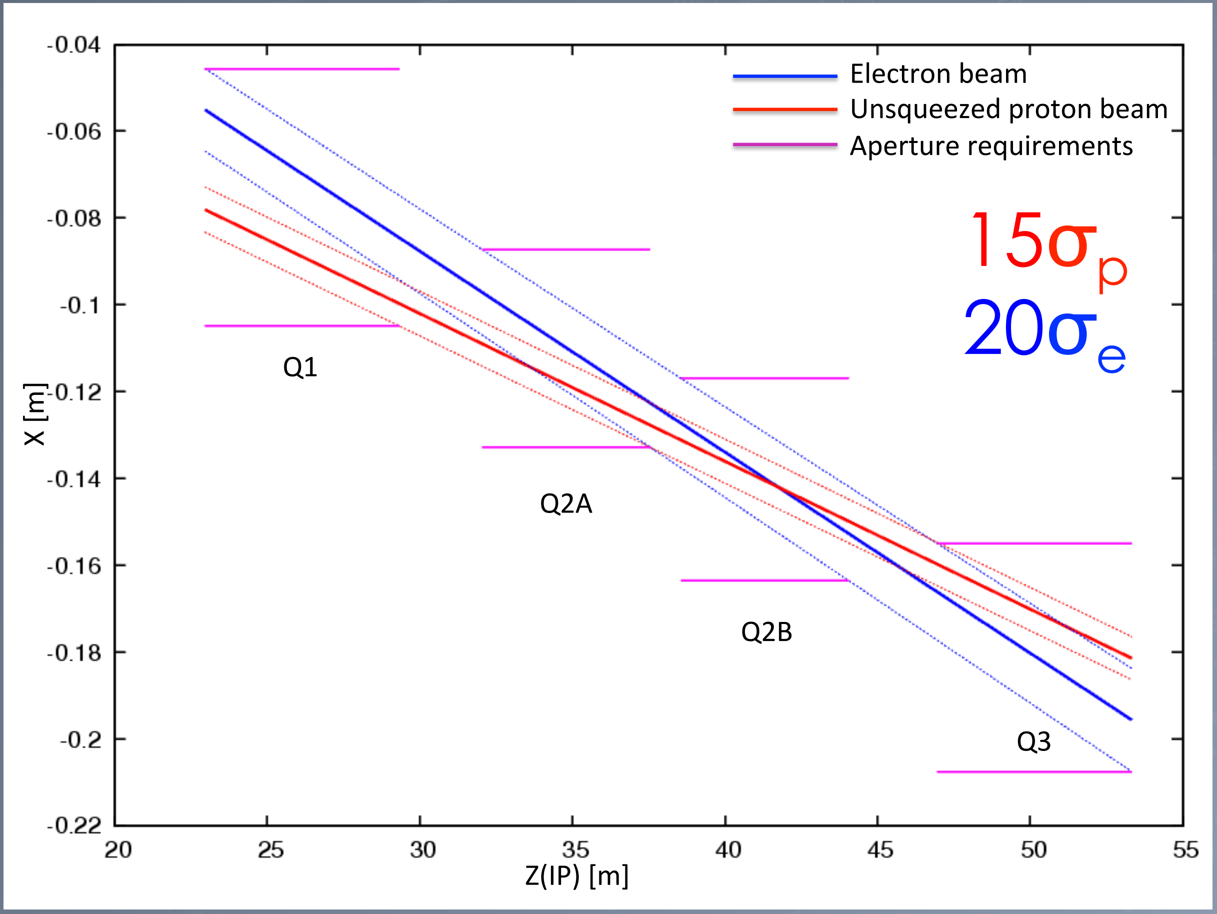


LHC IR Integration: 2nd Proton Beam



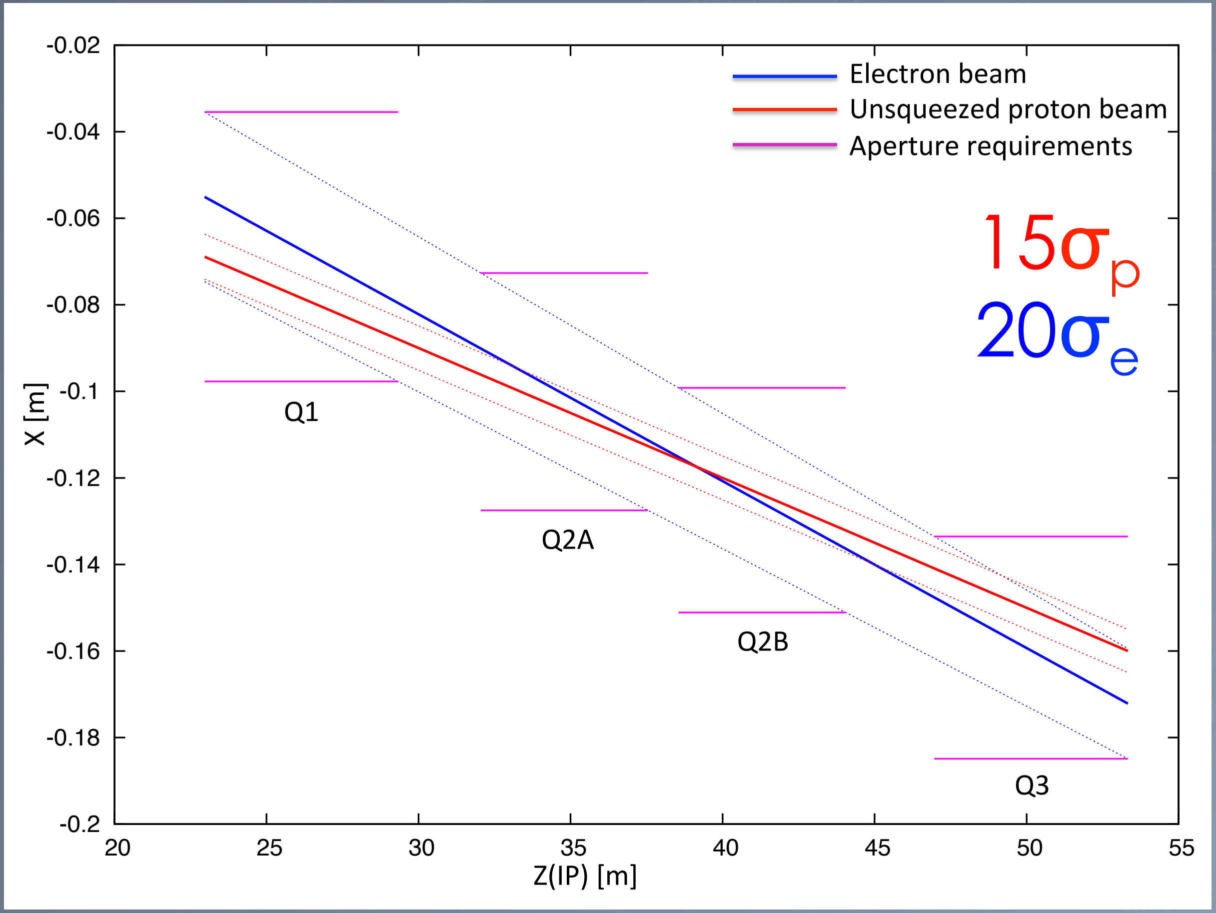
Beam trajectories for HA IR

LHC IR Integration: 2nd Proton Beam HA



Proton triplet apertures for HA IR – 3.4mrad p-p crossing angle

LHC IR Integration: 2nd Proton Beam HL



Proton triplet apertures for HL IR – 3.0mrad p-p crossing angle

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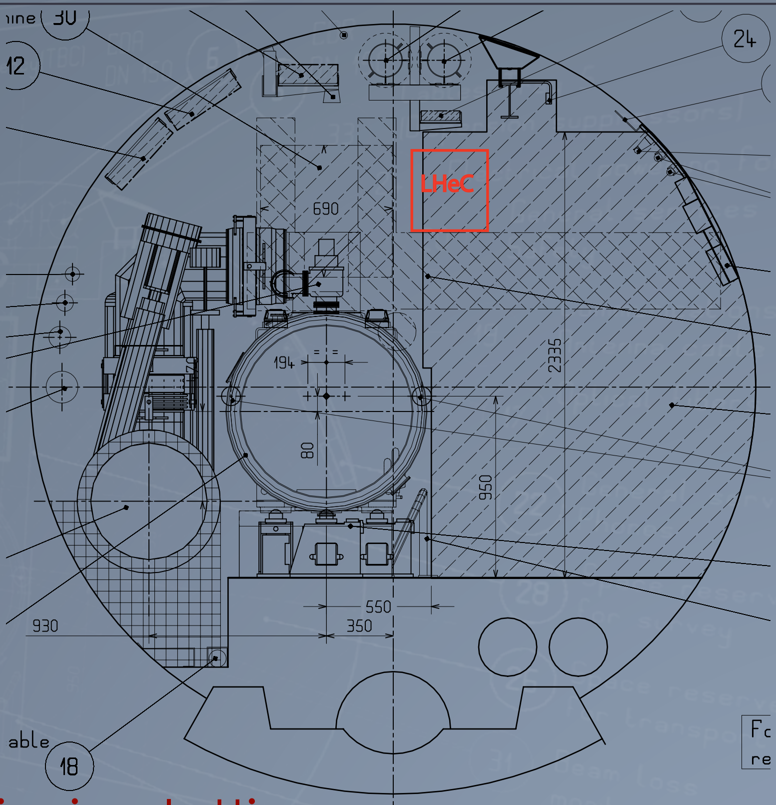
Electron LSS: Overview

- Transport
  - Ring - IR - Ring
- Well-matched optics
- Adhere to LHC space constraints
- Manageable SR

Electron LSS: Geometry

- Complex bending required
  - LHeC ring 1m above LHC
  - Account for IR horizontal separation scheme
  - ~60cm radial offset
  - Dipoles generate SR

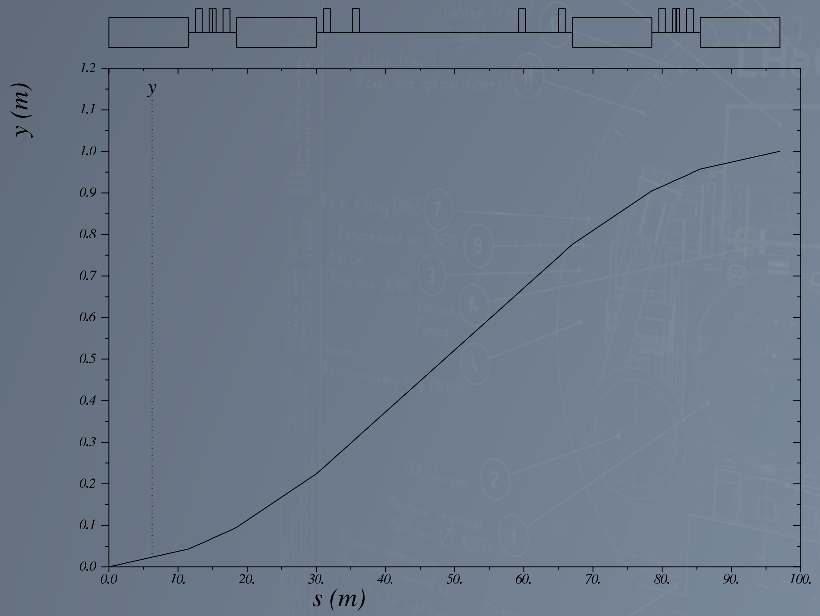


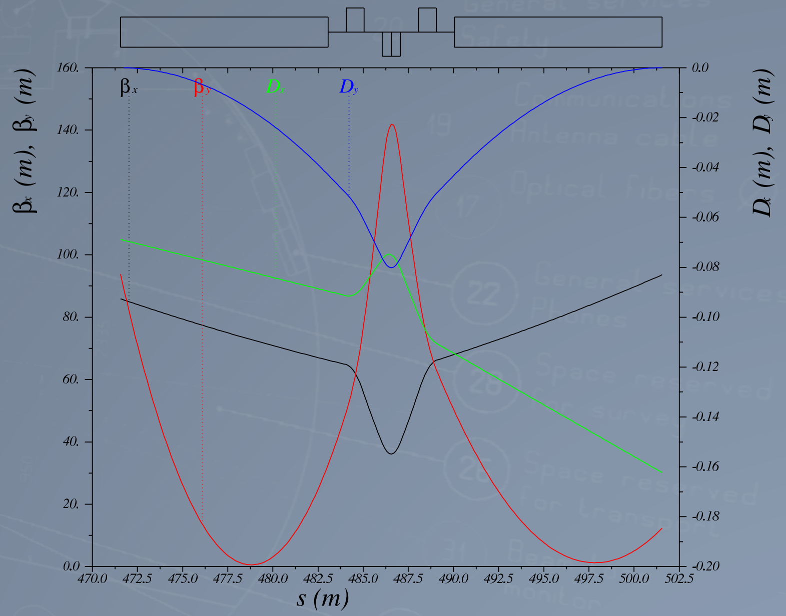
- Dispersion couples geometry and optics

- Existing dispersion suppressors in ring lattice
  - Designed to match horizontal dispersion
  - No equivalent systems for vertical dispersion
  - Large vertical bending required in LSS

Electron LSS: Achromatic Bending

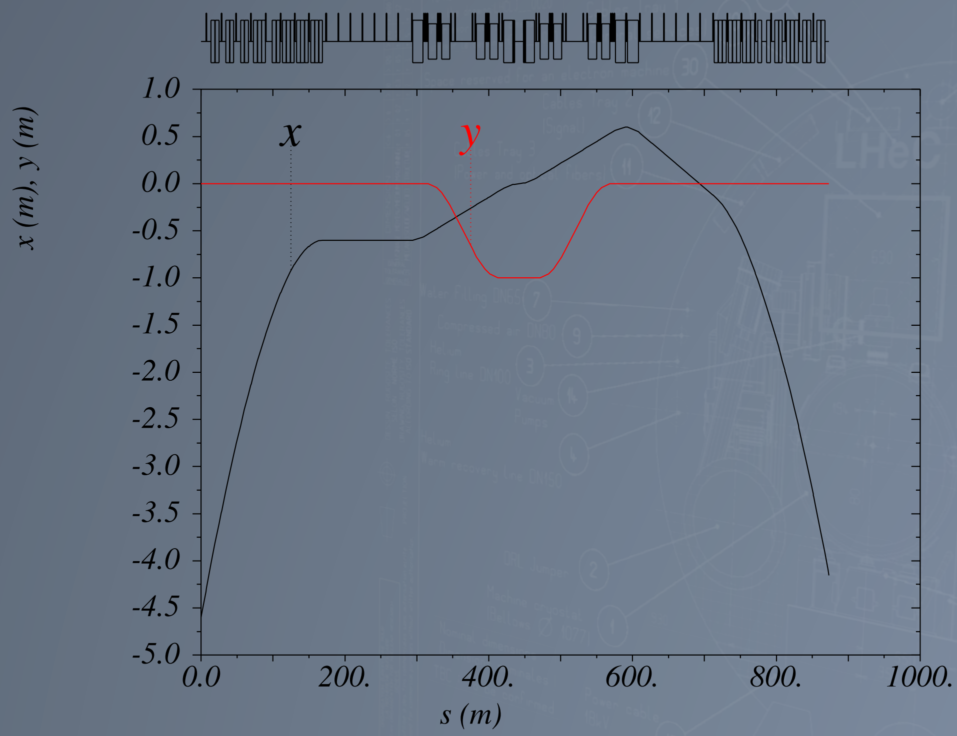
- Difficult to deal with large amounts of vertical dispersion
- Use Double Bend Achromat modules

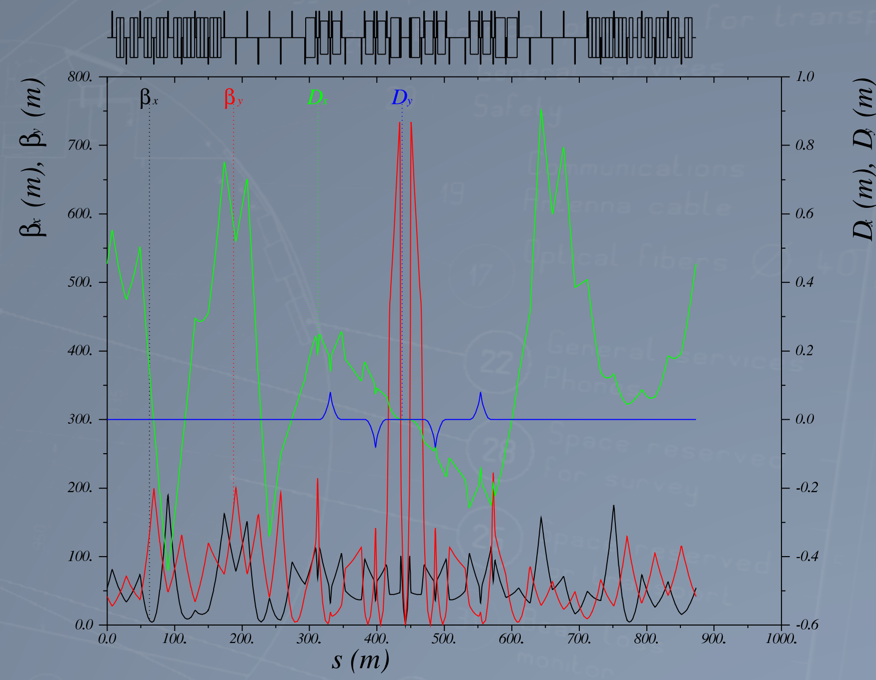




- Optical match still difficult due to strong quads
  - Characteristic twiss shape
- Non-negligible contribution to SR
  - Mainly from dipoles

Electron LSS: CDR version

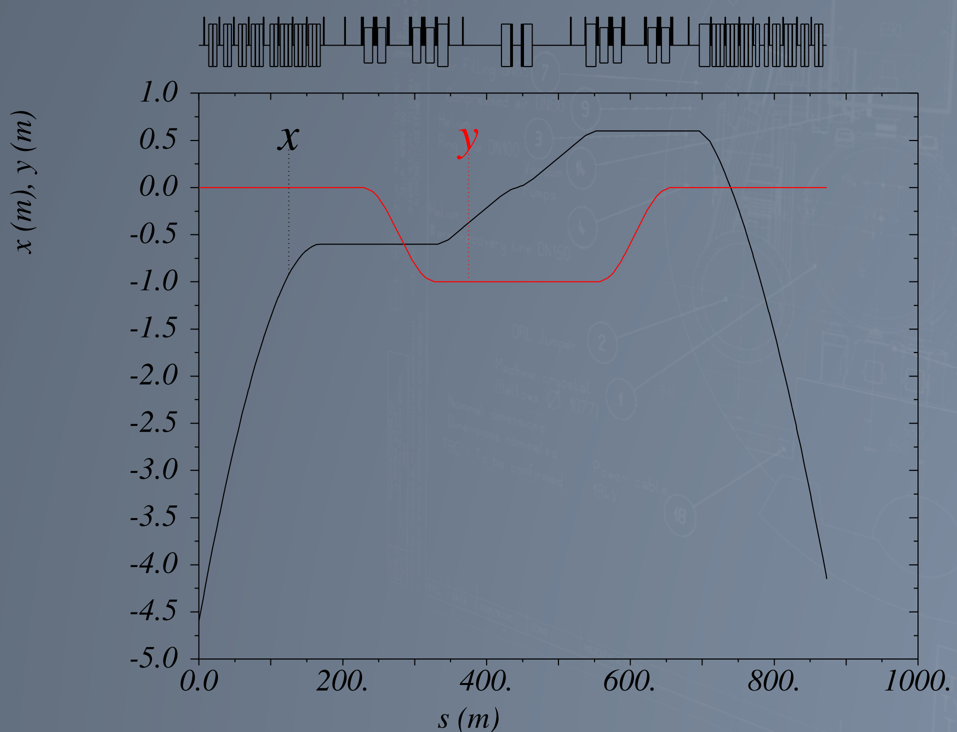


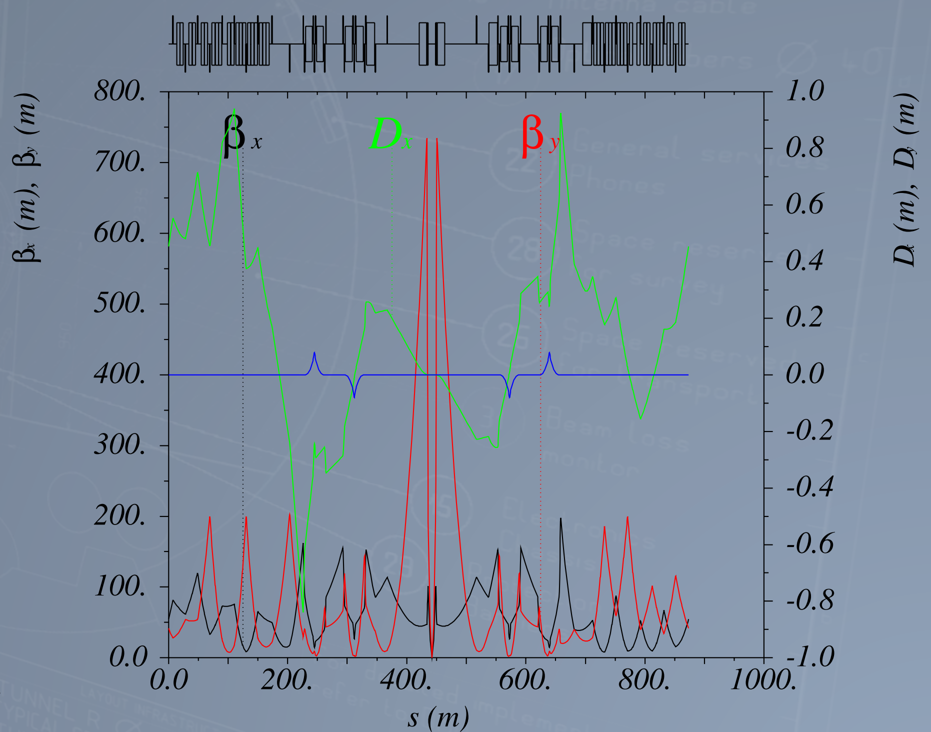


- Does not incorporate non-colliding beam solution
- Limited flexibility to avoid LHC conflicts

Electron LSS: LVS version

- "Late Vertical Separation" (LVS)
  - Allows horizontal separation to propagate before starting vertical bends
  - Aided by non-colliding beam solution which adds crossing angle
  - More flexibility to avoid conflicts with LHC elements

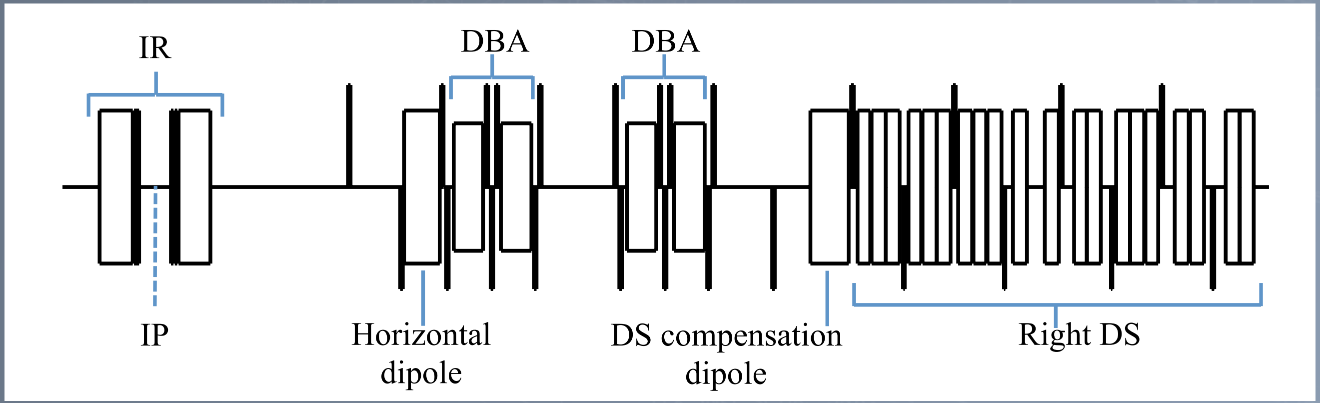




Electron LSS: SR

- Significant but manageable levels of SR

- CDR version:
  - ~1.3 MW total SR power
  - Compare to ~50 MW for ring lattice
- LVS version:
  - ~1.5 MW total SR power
  - Good agreement between simulations and analytic methods
  - Ongoing work on SR study and optimisation



Summary

- Complete conceptual solution for Ring-Ring LSS and IR
- All major issues solved, or shown to be solvable
- Technically incomplete but flexibility for further iterations
- General Manchester/Cockcroft interest in continuing on and helping with Linac-Ring