

# **Diagnostics and components in the FCC-ee IR**

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**On Behalf of the FCC-collaboration**

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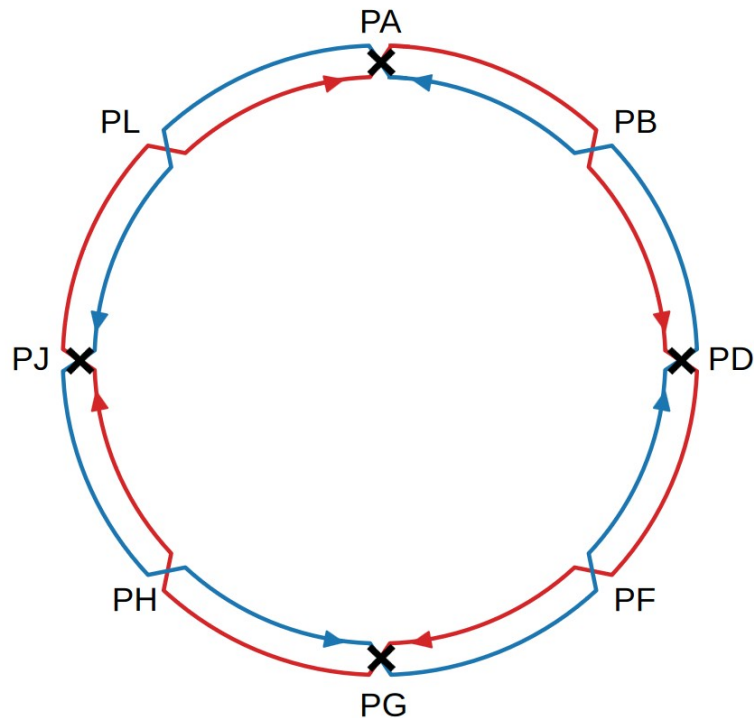
**US-FCC Workshop**  
**Brookhaven National Laboratory**  
**24<sup>th</sup> - 26<sup>th</sup> April 2023**



**FCCIS – The Future Circular Collider Innovation Study.**  
This INFRADEV Research and Innovation Action project receives funding from the European Union's H2020 Framework Programme under grant agreement no. 951754.

# Overview FCC-ee

- Present design with ~ 91 km circumference
- 8 long straight sections
- Option of up to 4 Experimental Interaction Regions (EIRs)



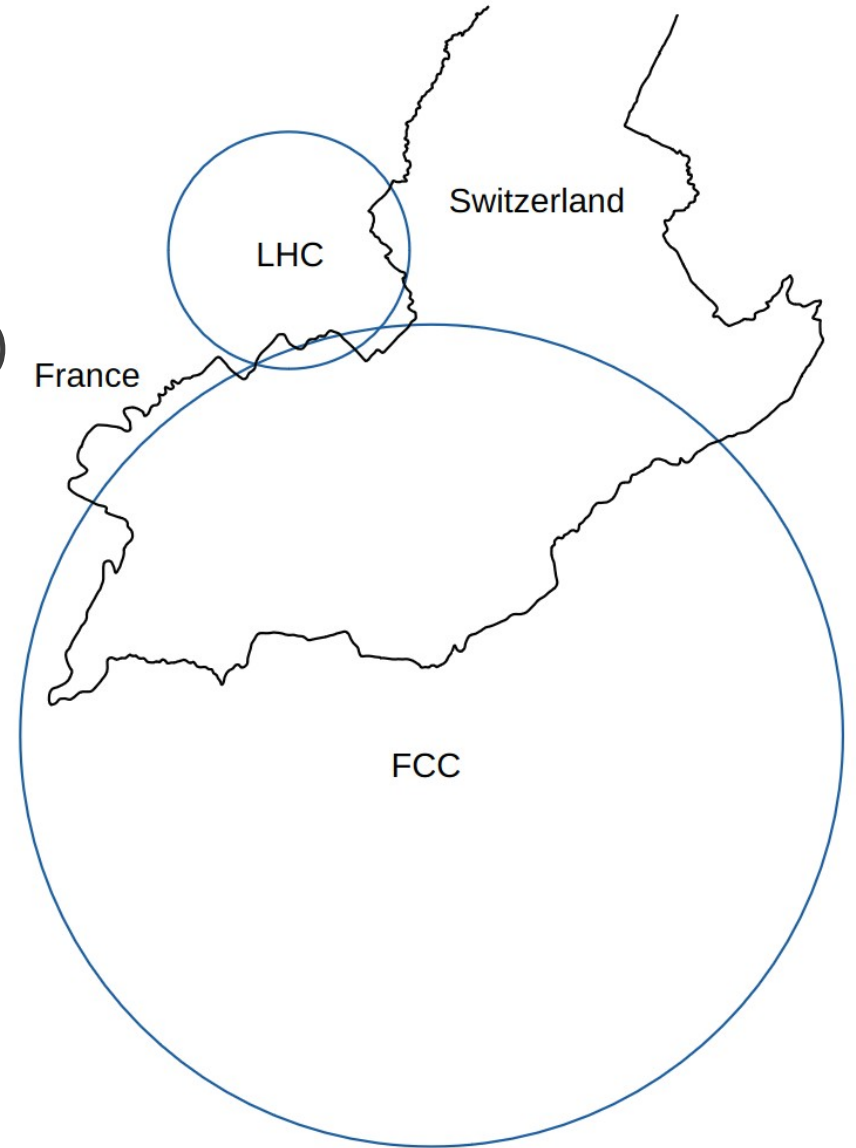
Crossing beams in all IRs

Other long straight sections host:

- Beam Injection (PB)
- Beam extraction (PB)
- RF main rings (PL or PH)
- Collimation (PF)

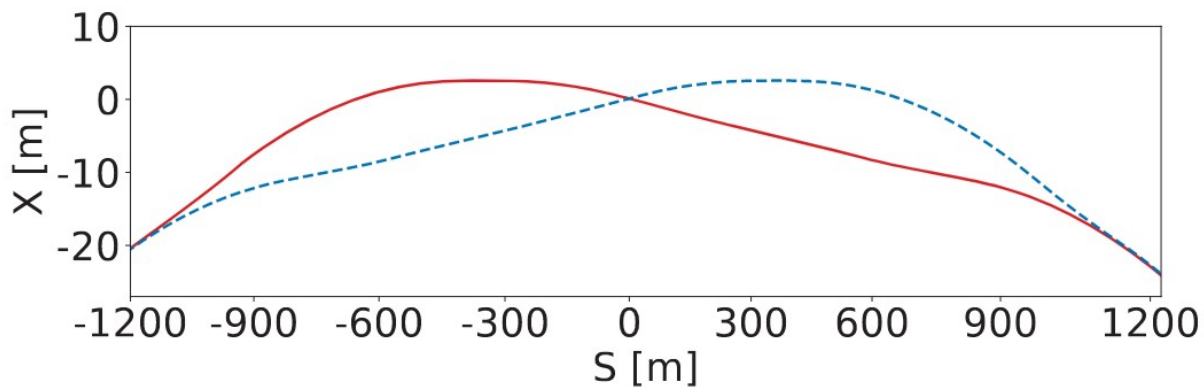
Must also include

- BPMs
- Wiggers, polarimeter, ...
- Lumical, beamstrahlung dump, ...



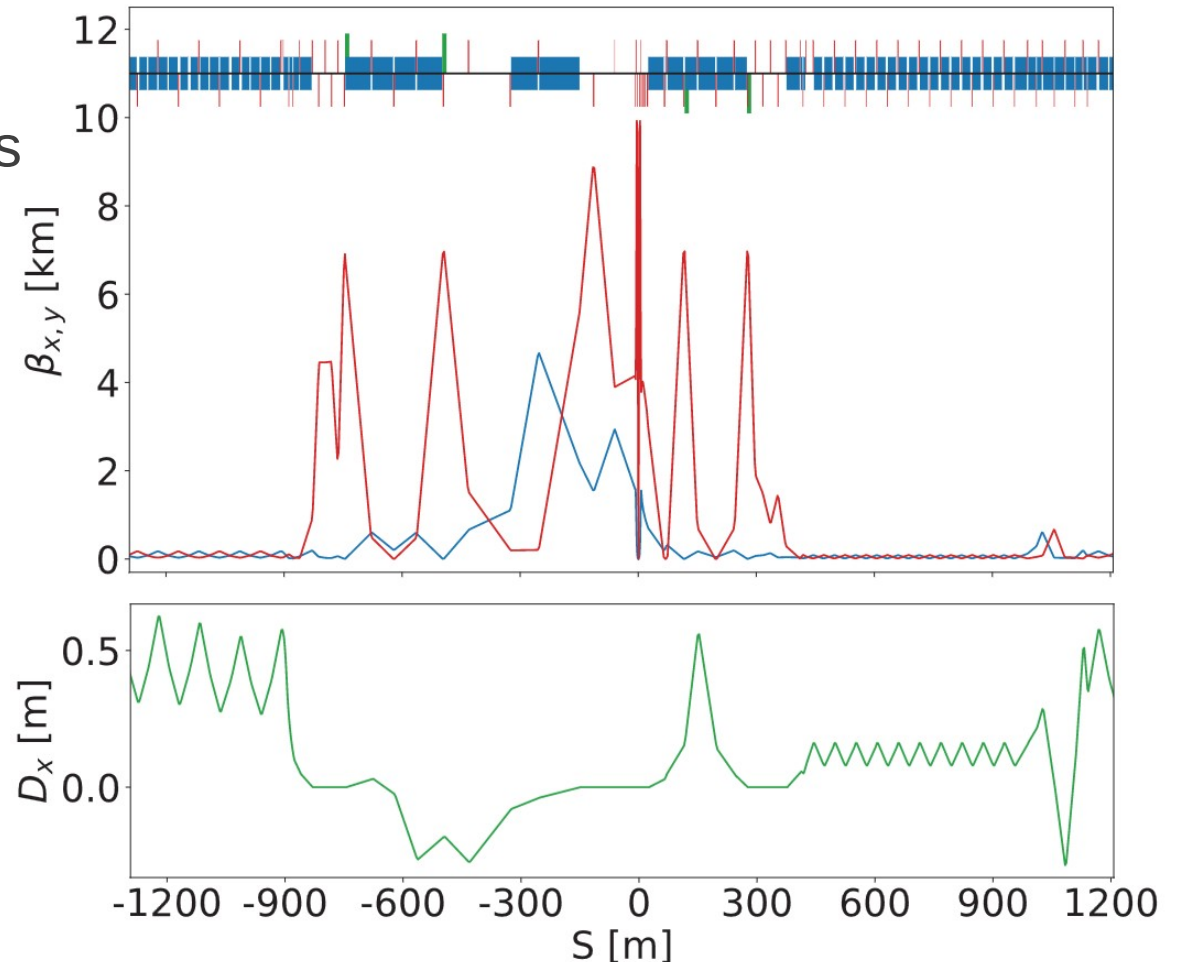
# Lattice and Optics in EIR

- Most studies with asymmetric EIR design
- Crossing beams
  - Inside outwards → limit to 100 keV photons
  - 30 mrad crossing angle
- Recently: symmetric EIR design (back-up)



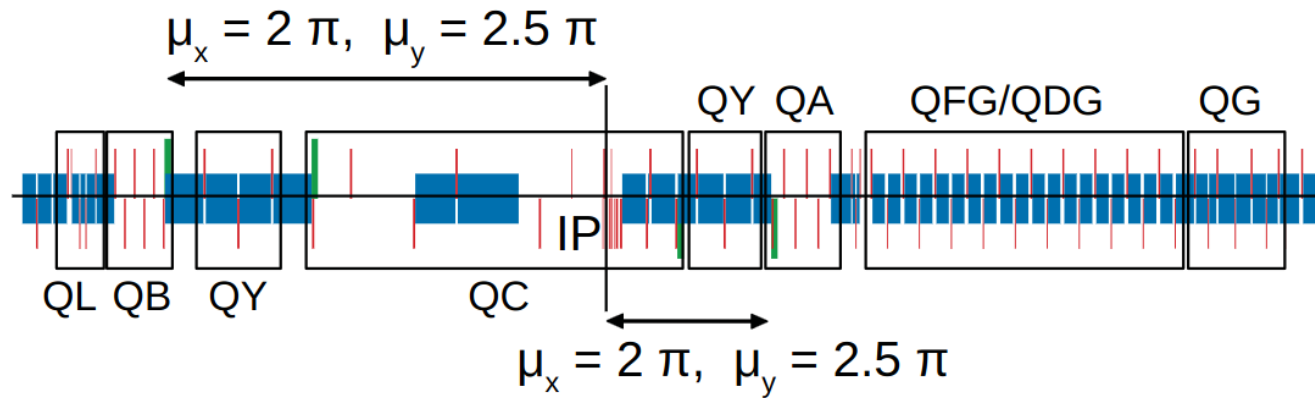
Blue: electrons; red: positrons

Blue: dipoles; red: quadrupoles; green sextupoles

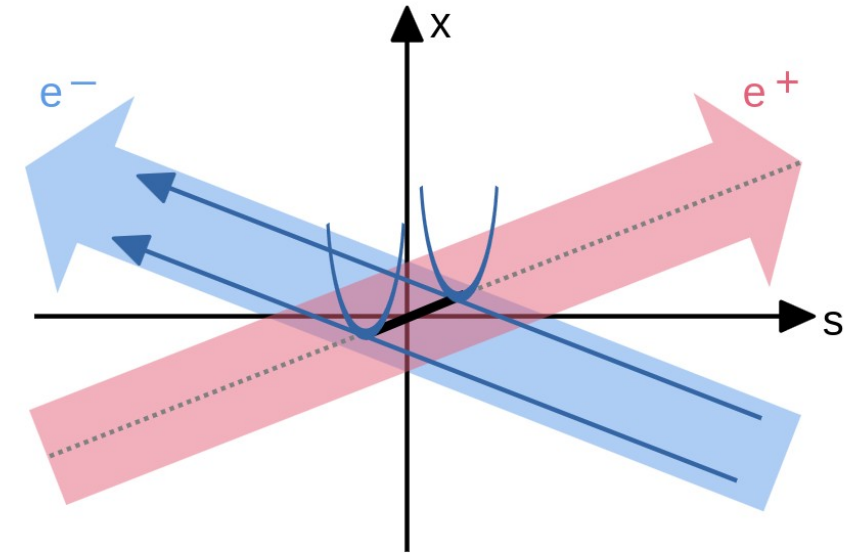


# EIR Magnets

- Very complex EIR → possibility for polarimeter, wigglers, anti-solenoids, correctors, etc.
- 7 different quadrupole families
- Superconducting Final Focus (FF) quadrupoles: QC\*
- Superconducting Crab Sextupoles
- BPMs close to the final focus required



Blue: dipoles; red: quadrupoles; green sextupoles

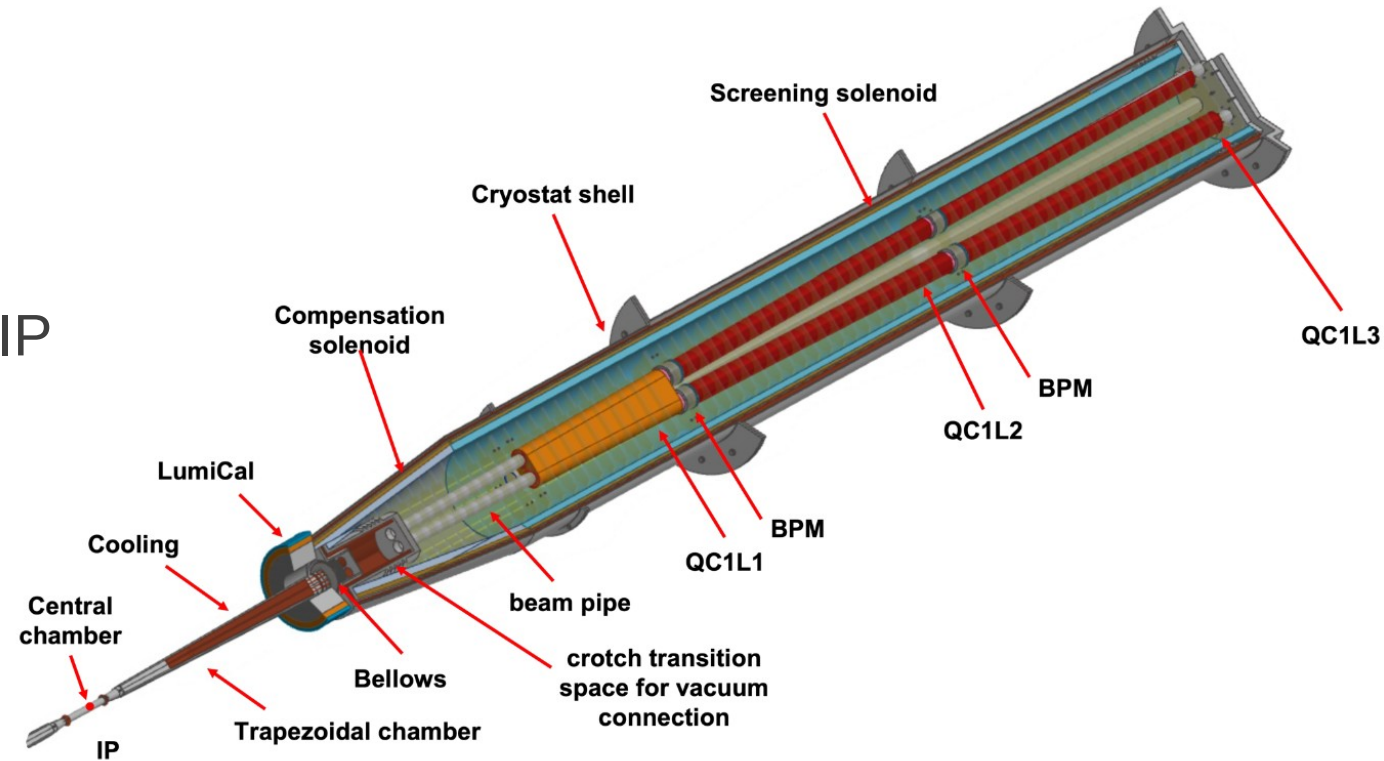
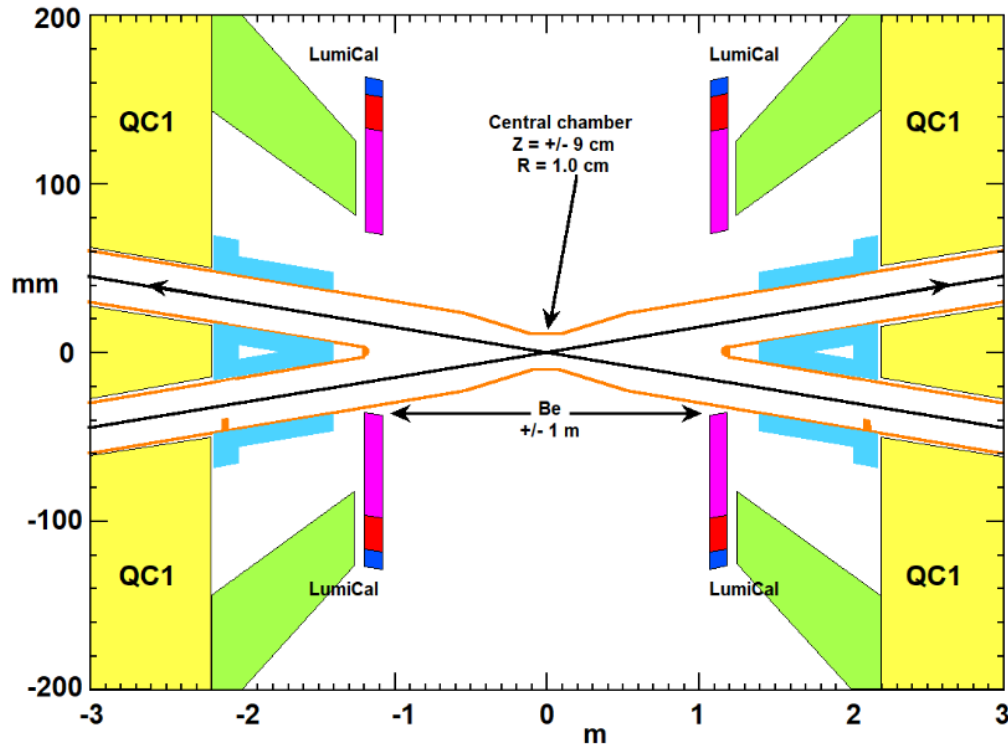


Sextupoles for crab-waist transformation

- Aligns waists of beta-functions on axis of the other beam
- Can limit dynamic aperture

# EIR MDI

- 2.2 m L\*
- 10 mm central radius over +/- 9 cm
- 15 mm beam pipe merged 1.2 m before IP

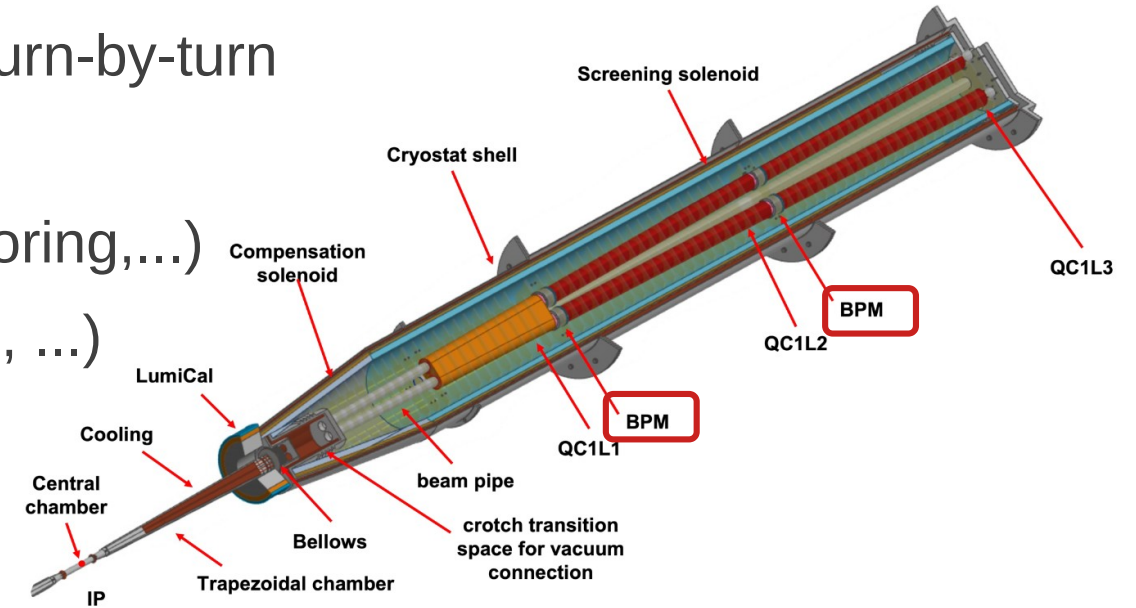
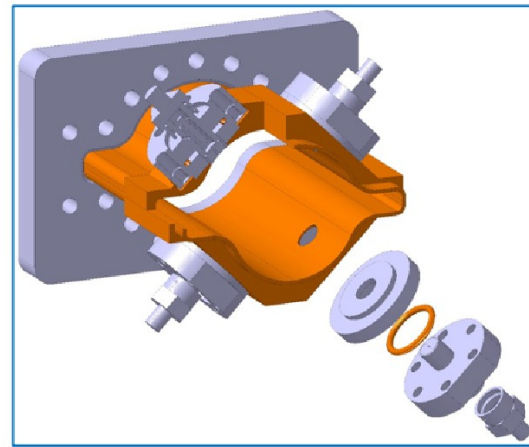
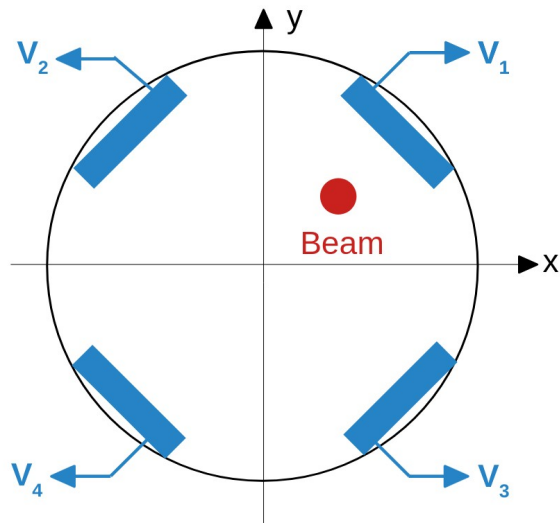


3D view of the FCC-ee EIR until the end of the first final focus quadrupole

- Half-length of 8.4 m until QC1L3
- Inside the detector (6m half length)

# BPMs in EIR

- About 1  $\mu\text{m}$  resolution (average) and  $\sim 10$   $\mu\text{m}$  turn-by-turn
- Need to distinguish between
  - High-intensity colliding bunches (Orbit monitoring,...)
  - Low-intensity bunches (MDs, commissioning, ...)



Challenging pick-up BPM installation for final focus

- Cold magnet
- Warm beam pipe
- Inside cryostat
- Alignment and long-term stability

Schematic view of BPM pick-ups, aligned 45° wrt transverse axes



# Beamstrahlung

- Dominant process for lifetime limitations
- Photons emitted collinear to beam
- Intense radiation O(100kW)
- Would hit beam pipe → heat, possible damage
- Requires beamstrahlung dump

$\rho_{\min}$  ... bending radius

$N_p$  ... bunch population

$\gamma$  ... relativistic gamma

$\sigma_x$  ... hor. Beam size

$\sigma_z$  ... bunch length

$\xi_i$  ... vert. Beam parameters

$\beta_{x,y}$  ...  $\beta$ -function at IP

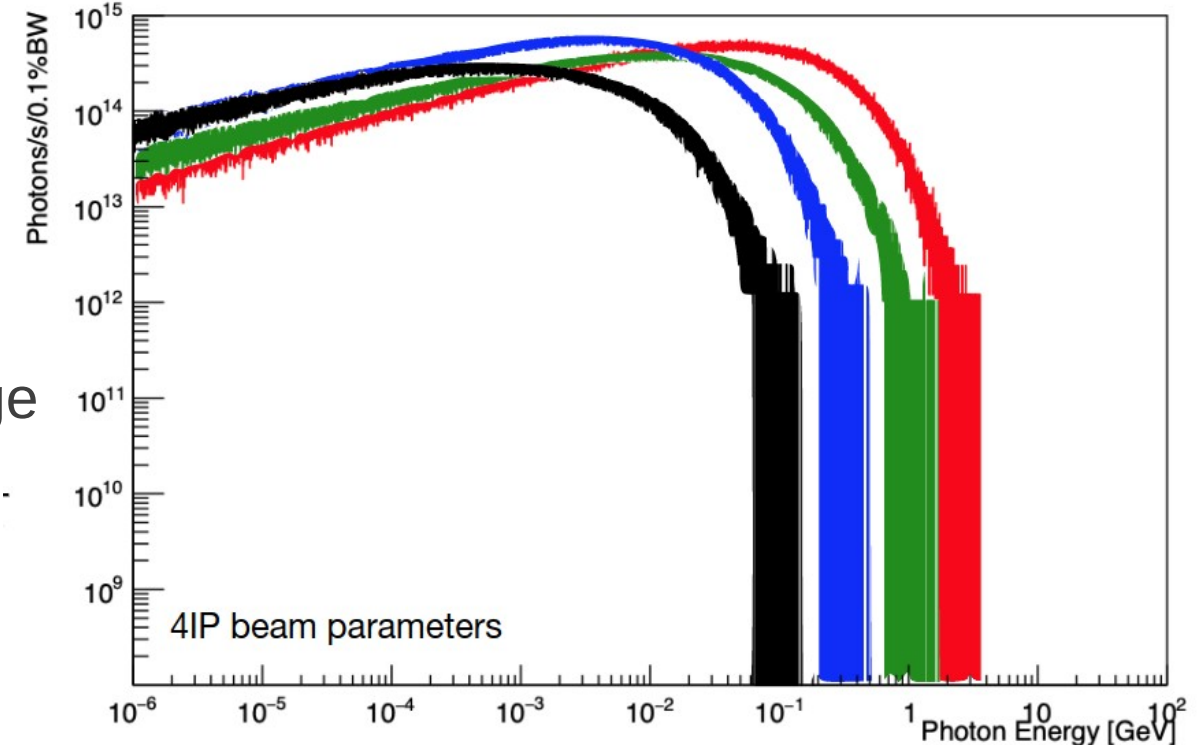
$\varepsilon_{x,y}$  ... Transverse emittances

Bunch interacts with force field of opposing bunch, bending radius:

$$\frac{1}{\rho_{\min}} \propto \frac{N_p}{\gamma \sigma_x \sigma_z} \propto \frac{\xi_y}{\sqrt{\beta_x^* \beta_y^*}} \sqrt{\frac{\varepsilon_y}{\varepsilon_x}}$$

Synchrotron photons are emitted with critical energy:

$$u_c \propto \frac{\gamma^3}{\rho} \propto \xi_y$$

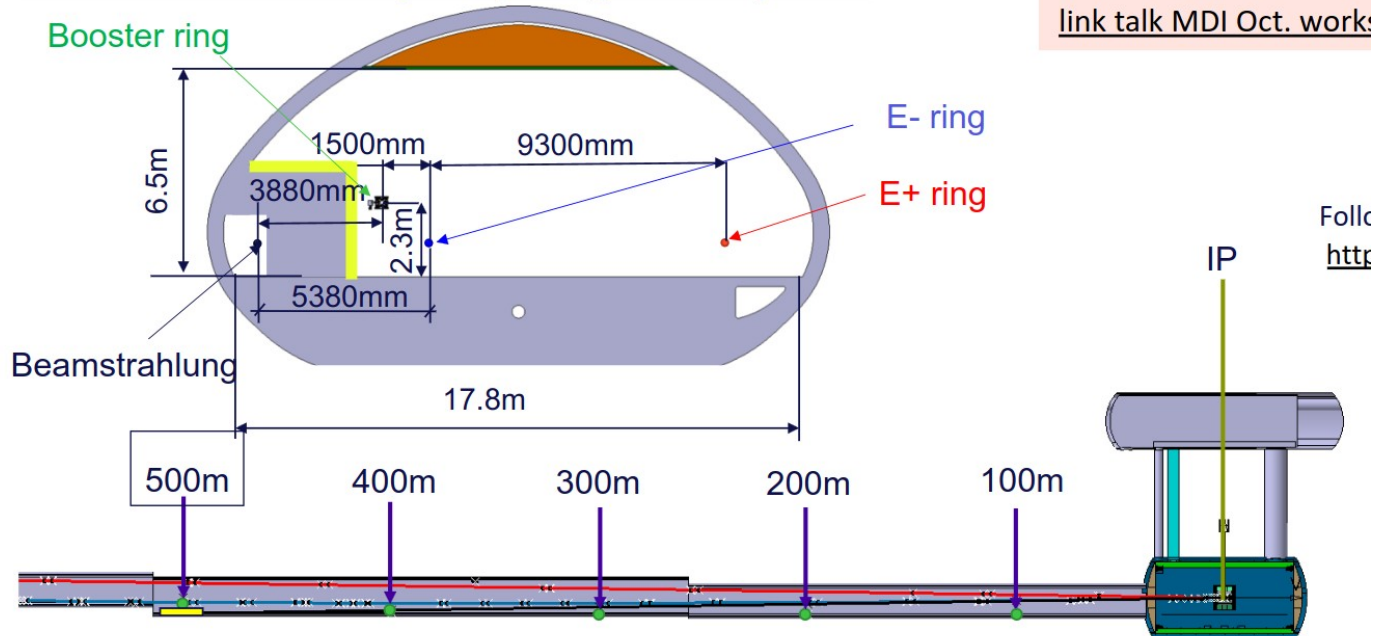


	Total Power [kW]	Mean Energy [MeV]
<b>Z</b>	370	1.7
<b>WW</b>	236	7.2
<b>ZH</b>	147	22.9
<b>Top</b>	77	62.3

# Beamstrahlung Dump

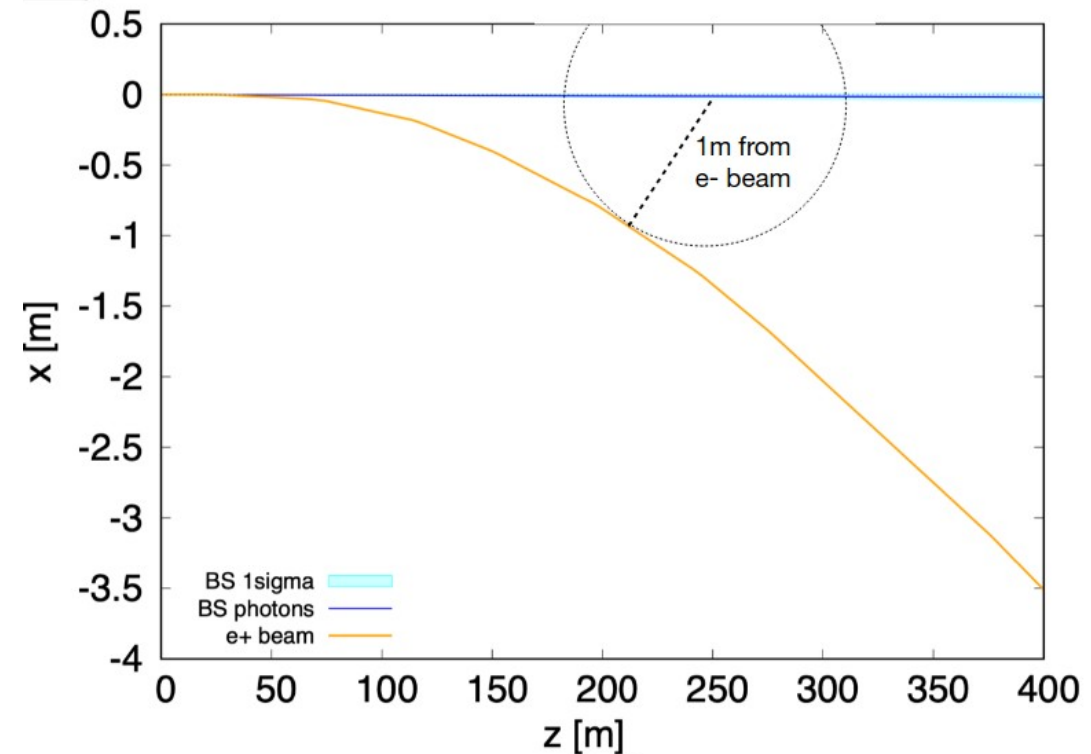
- About 400 – 500 m downstream of IP
- Possibility to have instrumented beam dump
- Will dump all radiation from IP

## FCC-ee beamstrahlung dump integration at point A



Fani Valchkova:  
link talk MDI Oct. work:

Follc  
<http://>





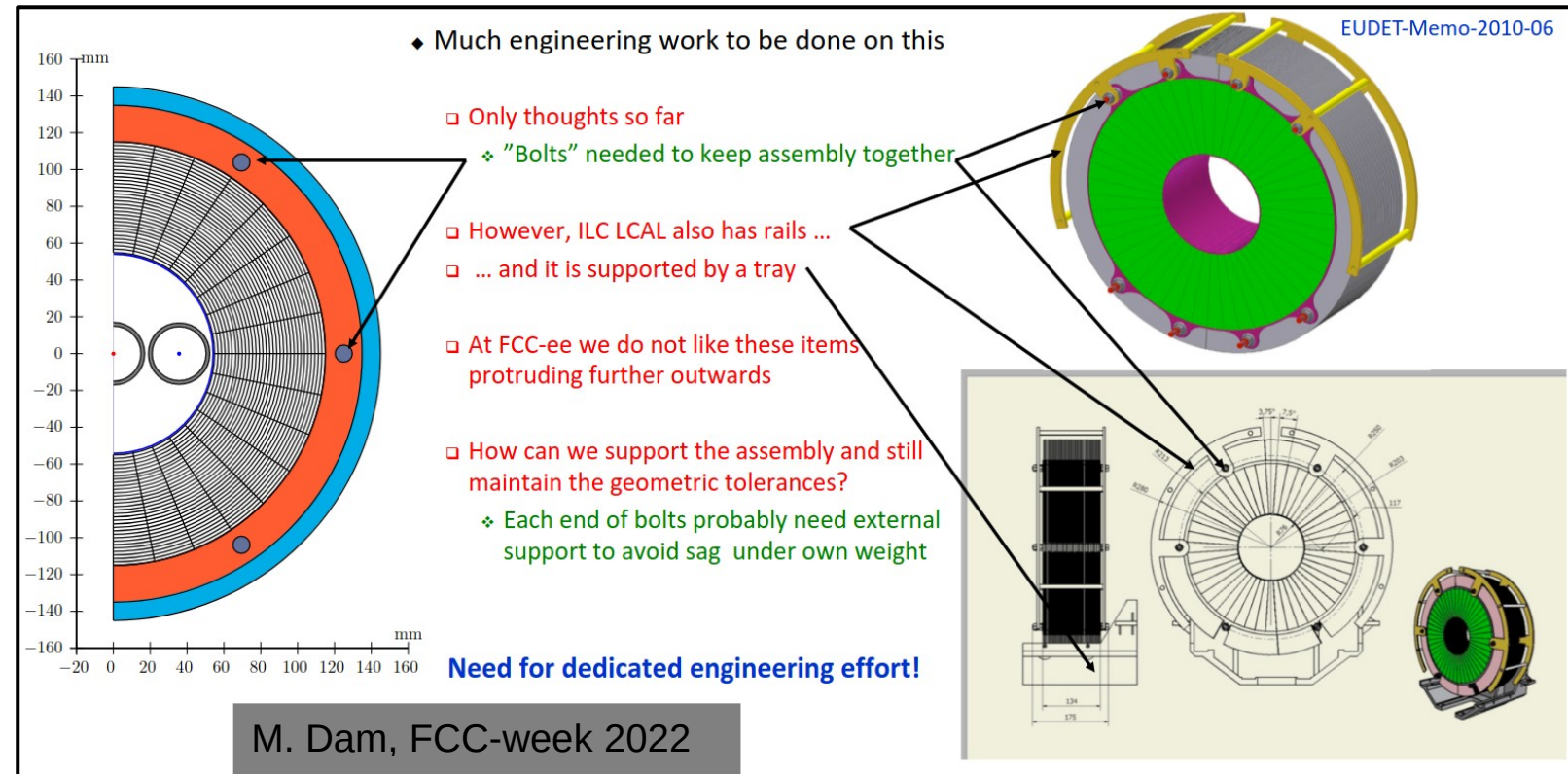
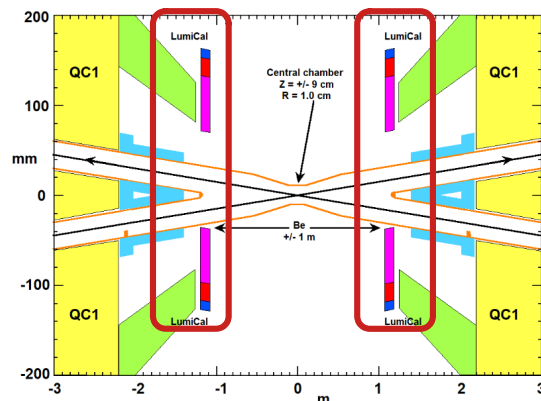
# LumiCal

- Integrated into mechanical model of the MDI
- Standard process is Bhabha scattering and goal is absolute normalization of  $10^{-4}$
- Best so far at OPAL at LEP with  $3.4 \times 10^{-4}$

LumiCals pushed far inside detector  
- only ~ 1 m away from IP

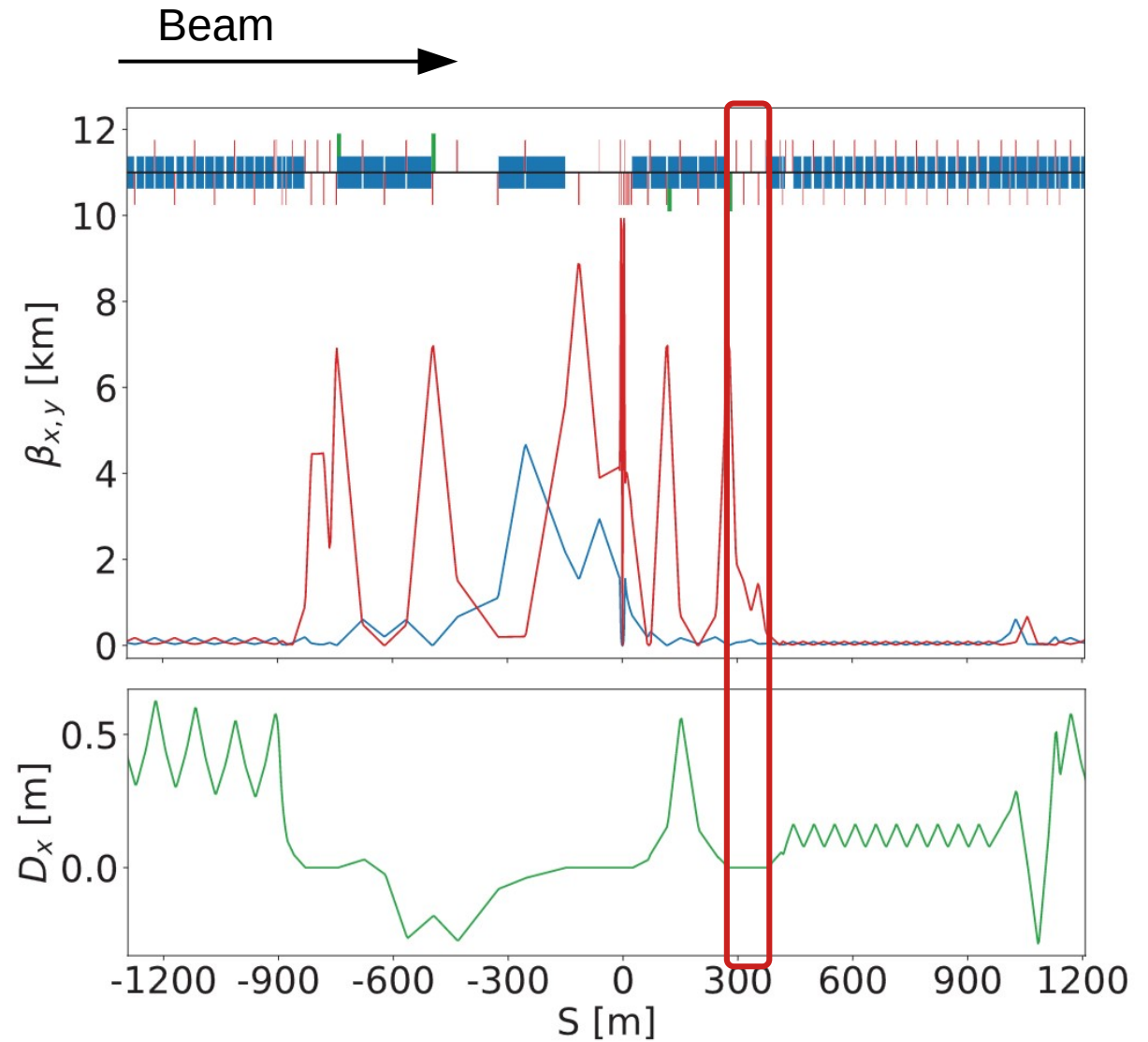
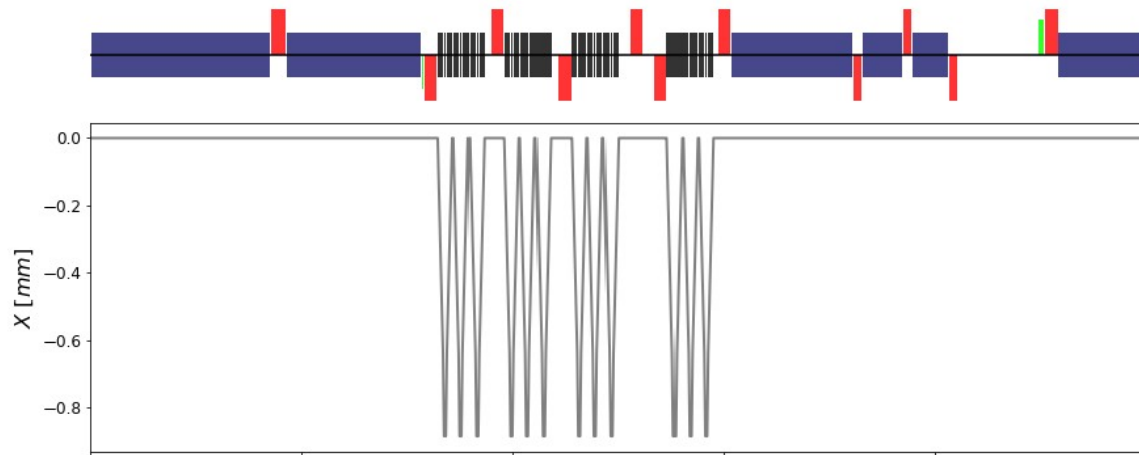
## Challenges

- Detector radius controlled  $1 \mu\text{m}$
- Distance between 100  $\mu\text{m}$



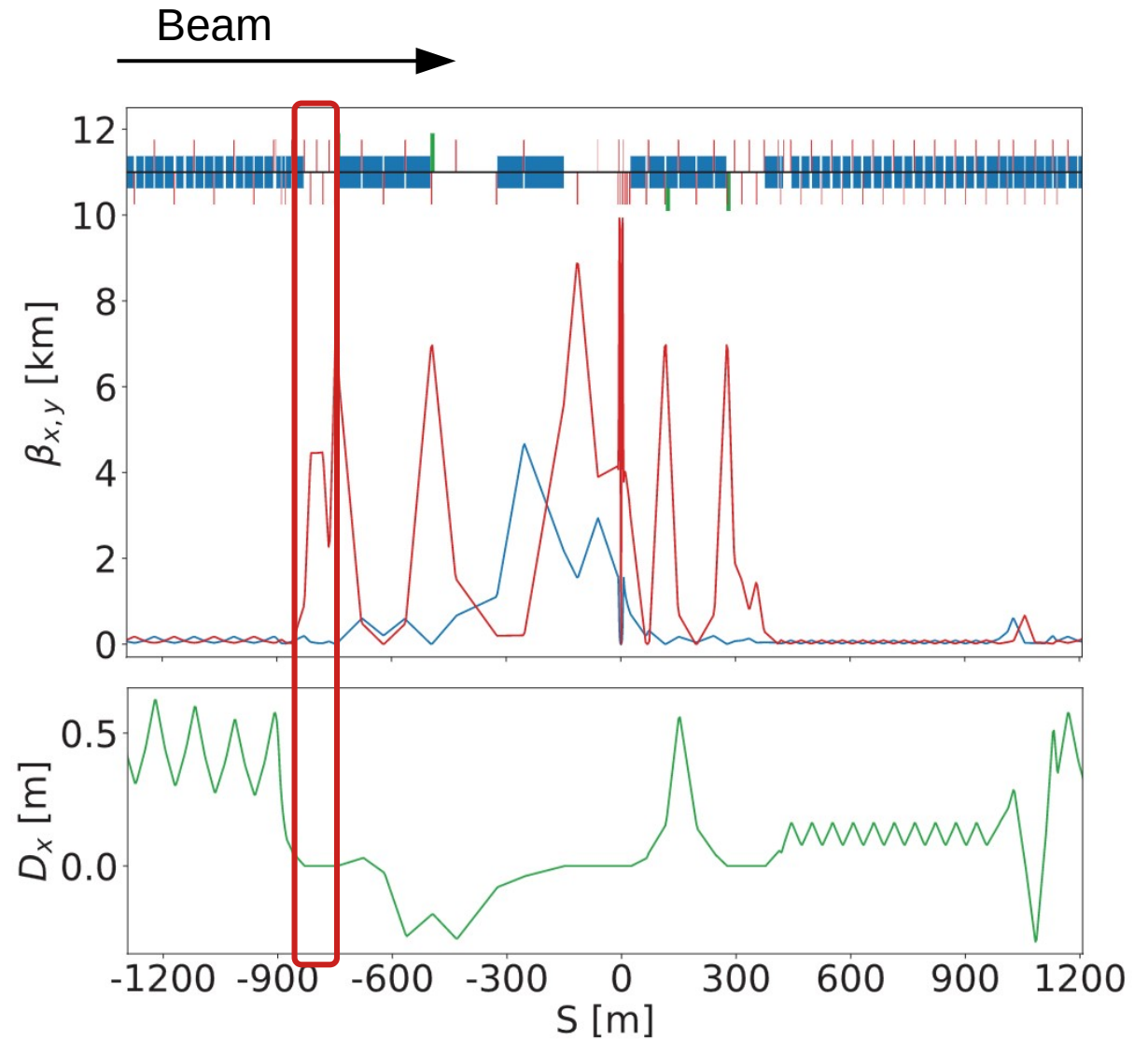
# Wigglers

- Installed in dispersion free section
- 16 m long drift section downstream of IP
- Only required for Z- and W- energy
- Only switched on with ~100 pilot bunches
- No polarization at higher beam energies



# Polarimeter

- Main requirements
  - ~ 2 mrad bending dipole
  - ~ 50 m long driftspace
  - ~ 3 m for laser interaction region
- Full-filled upstream of IP in newest optics
- Just before crab-sextupoles
- Alternatively: integration in other IRs



# Summary and Outlook

- Long way to finalize design of the EIR region, for example:
  - Engineering of the lumiCal (integration, assembly, support as a whole)
  - Refinement of the detector and environment model for detector backgrounds evaluation
  - Understand and control impact of alignment errors, multipole errors vibration, etc.
  - Integration and design of BPMs
  - Beamstrahlung dump
- EIR mock-up
- ...

**Regular EPOL meetings:**

[indico.cern.ch/category/8678/](https://indico.cern.ch/category/8678/)

Typically every second Thursday 16:30-18:30

**Regular MDI meetings:**

[indico.cern.ch/category/5665/](https://indico.cern.ch/category/5665/)

Typically every second Monday 16:00-18:00

**Mailing list:**

[fcc-ee-PolarizationAndEnergyCalibration@cern.ch](mailto:fcc-ee-PolarizationAndEnergyCalibration@cern.ch)

**Mailing list:**

[fcc-ee-mdi@cern.ch](mailto:fcc-ee-mdi@cern.ch)

**Self-subscription from:**

<https://e-groups.cern.ch/e-groups/EgroupsSearch.do>

# Questions?

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# Symmetric EIR



*Dispersion suppressor and Final Focus*

