

# Preliminary design of FCCee collimators

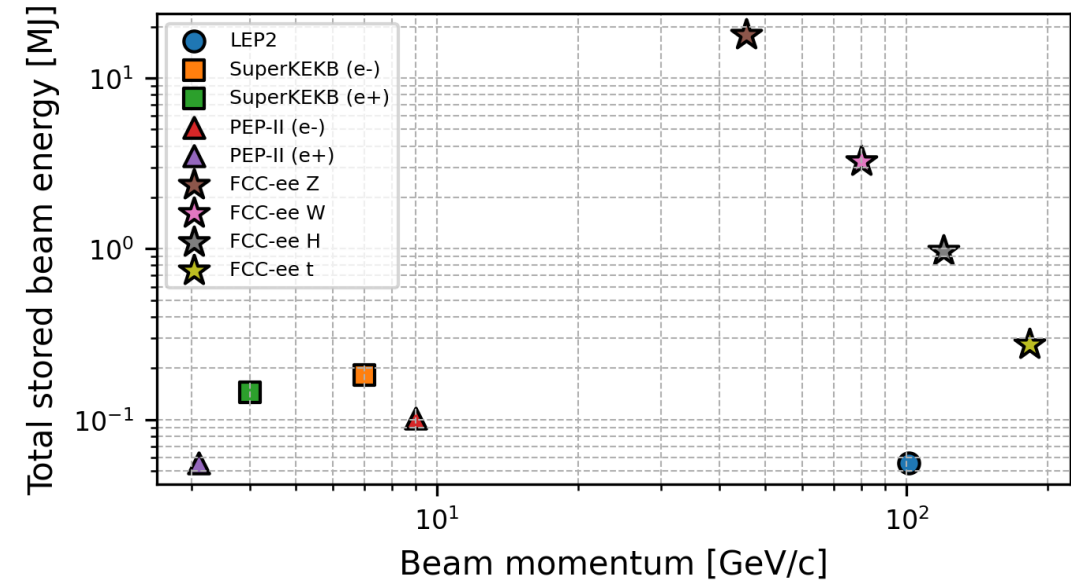
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FCC week 2025



# General Considerations

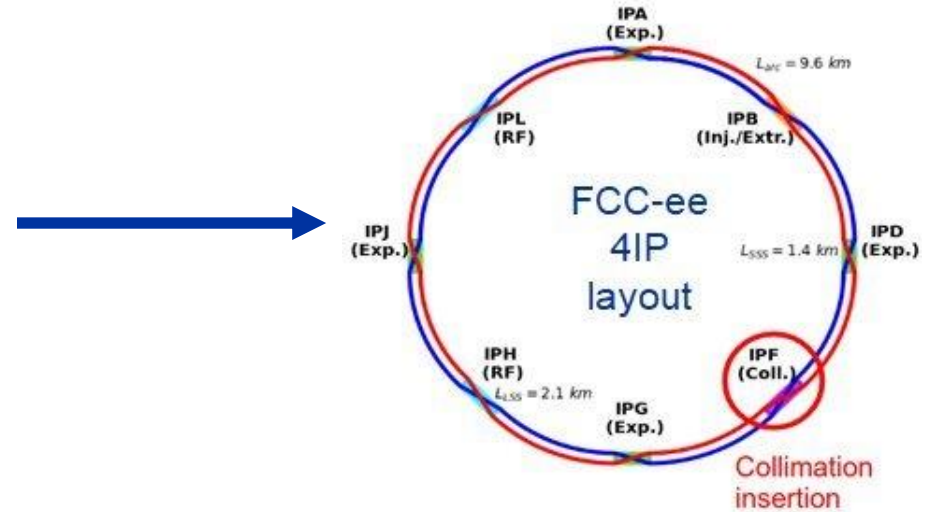
- **FCC-ee is the FCC first stage e+e- collider**
  - 90.7 km circumference, tunnel compatible with FCC-hh
  - 4 beam operation modes: **Z** (45.6 GeV), **W** (80 GeV), **H** (120 GeV), **ttbar** (182.5 GeV)
- FCC-ee presents unique collimation challenges
  - Unprecedented stored beam energy for a lepton collider
    - **17.5 MJ** in the **Z** operation mode
  - Highly destructive beams: **collimation system indispensable**
    - Reduce background in the experiments
    - Protect the machine from unavoidable beam losses
- **Collimation strategy for the FCC-ee**
  - Beam-halo (global) collimation
    - + local protection collimation
  - Secondary particle shower absorbers
  - Synchrotron radiation (SR) collimation – upstream of the IPs



**See G. Broggi's presentation on Tuesday 20/05 for details on collimation studies**

# Devices considered

- **Halo cleaning collimators**
  - Primaries and Secondaries in PF straight section
  - C and Mo based.
- **Shower absorbers**
  - Only few units
  - Mo or W based
- **SR collimators and masks**
  - W based
- **Tertiary collimators**
  - C based



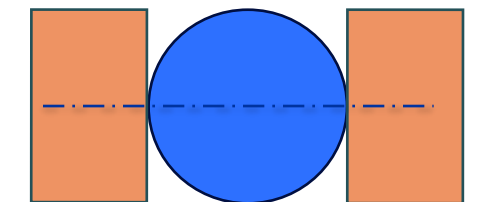
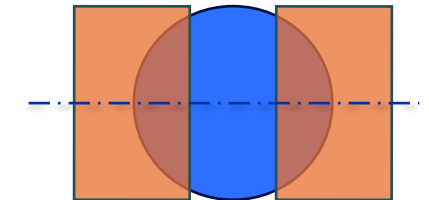
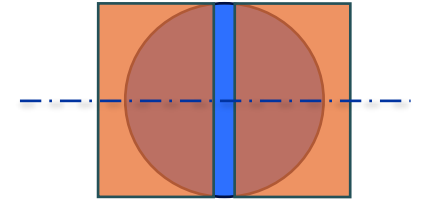
# Hardware Requirements

- **UHV compatible**
- **Low impedance (critical!)**
  - High conductivity absorbing materials
  - Important consideration for jaw geometry/design
- **Movable jaws**
  - In-operation position and angular adjustment (BPM integrated in the jaws)
- **Competing requirements**
  - Short jaw length → Reduce impedance
  - High electrical conductivity → Reduce impedance
  - Low density (high radiation length) → Reduce energy density deposition in case of accidental beam impacts
  - High enough density → Sufficient stopping capability for efficient halo cleaning
  - Good thermal conductivity → Efficiently extract deposited heat

# Requirements for design optimisation

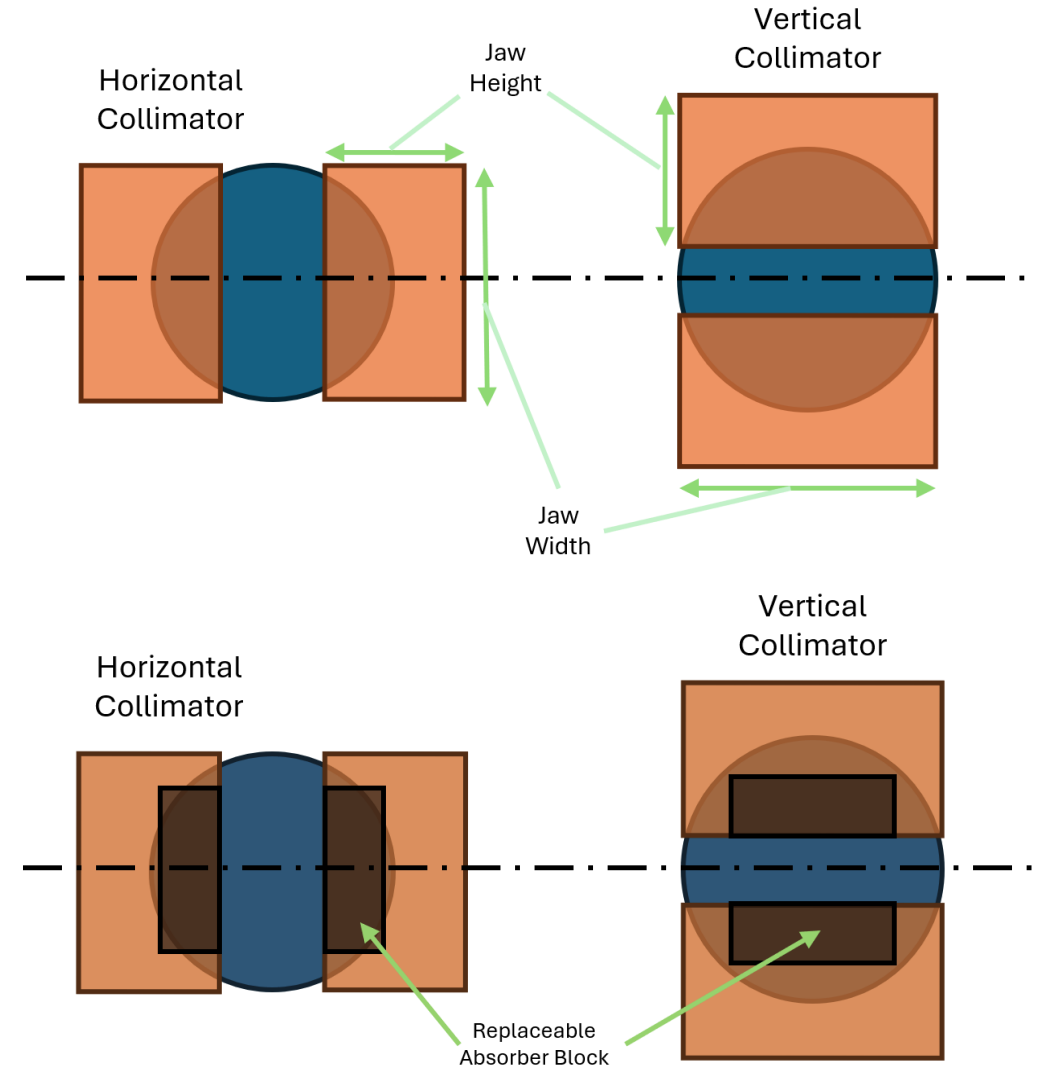
## Aperture and bellows movement

- Nominal  $\text{Ø}60\text{mm}$  pipe (no wings)
- What is the stay-clear aperture needed in each operation phase?
  - Do we need to fully retract the jaws at any point?
  - Currently we assume full aperture needed
- What are the required jaw motions for each operation scenario?
  - e.g. beam-on? parking/beam-off? MD? testing?
  - Far off but important for bellows design + fatigue considerations



# Beam and jaw position

- Orbit variations in Vertical plane and in horizontal plane?
  - For both nominal and accident conditions
- Absorbing material cross-section required on primaries? secondaries? absorbers? tertiaries?
- Currently:
  - It covers the entire  $\text{Ø}60\text{mm}$  pipe
  - 30mm height, 60mm width



# Tolerance and Angular tilt

- Is it needed on all collimators?
  - Cost and mechanical simplicity advantages of one motor – bellows.
  - Looking at alternative designs to improve tilt motion accuracy.
- Angular adjustment required for device placement accuracy?
  - Geometry has accuracy of  $\sim 0.2\text{mm}$   $\rightarrow$  400 $\mu\text{rad}$  misalignment possible over 1m tank length
- First draft tolerances (**they can be improved!**):

	Gap	Tilt	Ra (roughness)	Flatness
Range	40mm (30mm + 2 * 5mm)	+/- 300 $\mu\text{rad}$ ?	-	-
Tolerance	+/- 20 $\mu\text{m}$	+/- 10 $\mu\text{rad}$	1.6 $\mu\text{m}$	20 $\mu\text{m}$

# Absorbing materials considered for FCCee

	Low density (primaries and tertiaries)			Medium/High density (Secondary, SR Masks & Shower Absorbers)		
Properties	Al <sub>2</sub> O <sub>3</sub> CfO(1,2)	Pb	MoCr(1)	TZM	Ta	W(3)
<b>NON-EXHAUSTIVE LIST – OTHER “INNOVATIVE” MATERIALS MAY BE CONSIDERED</b>						
Thermal shock resistance (4)	+++	+	++	+++	+	++

- (1) Customised material – produced on request
- (2) R&D required
- (3) Depending on requirements, an alloy may be more adapted
- (4) Ranking within each category (compared with materials of similar density)

# Other design considerations

- Determine loads in nominal operation and accidental scenarios
  - Thermal deformations
  - Cooling requirements
- Activation studies (to design handling, repair operations)
- Impedance considerations (geometry and materials)
- Other requirements:
  - Maintainability
  - Repairability
  - Quick replacement or transversal shift (5<sup>th</sup> axis-like)?
  - Failure acceptable in case of accident?

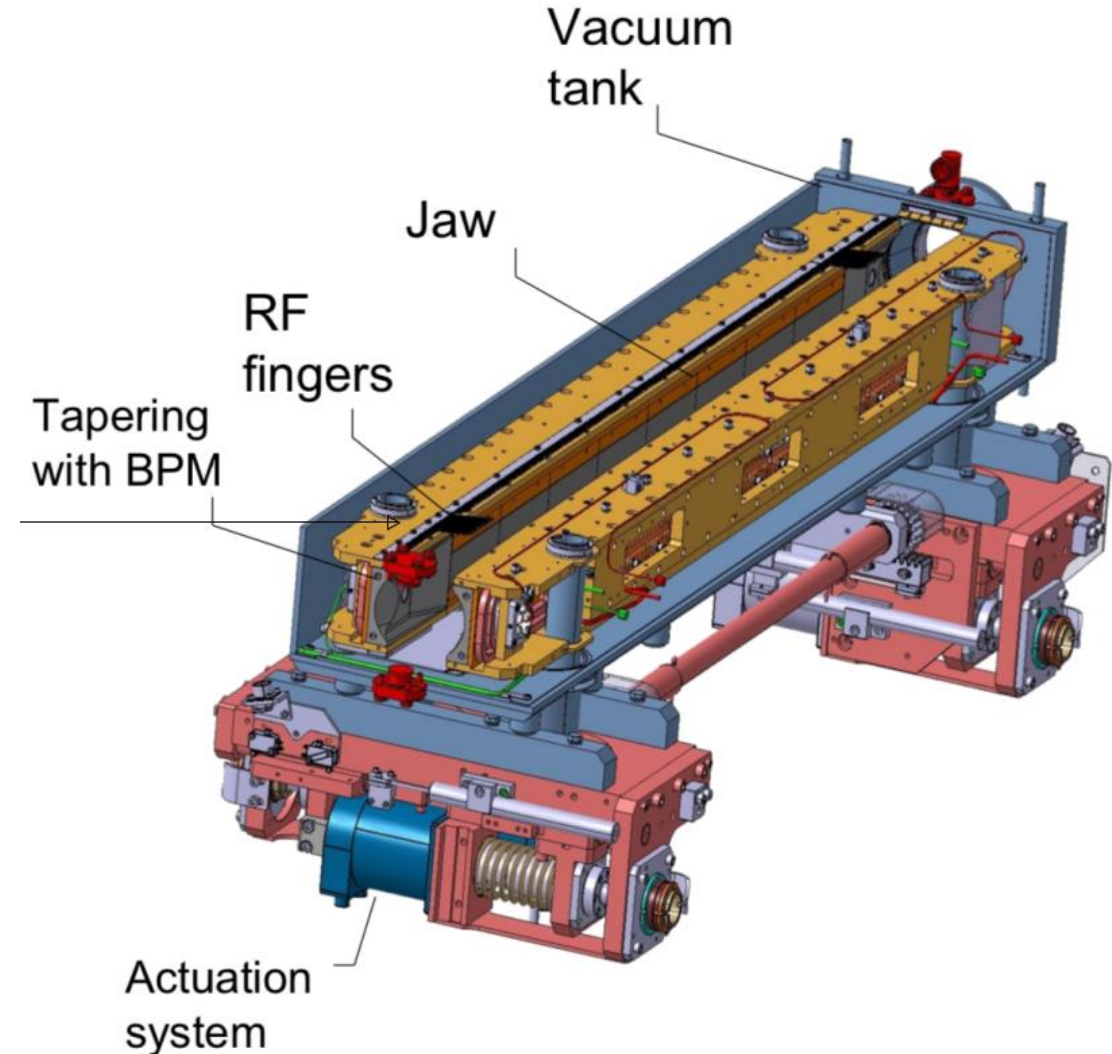


**See D. Gibellieri's presentation on Tuesday 20/05 for details on impedance studies**

# LHC Collimator Design

## Main features

- Long jaws (~1m active length)
- High geometrical/positioning precision
- Fully sealed (welded) UHV tank
- Not openable (not repairable)
- **Geometry not adapted to FCCee**



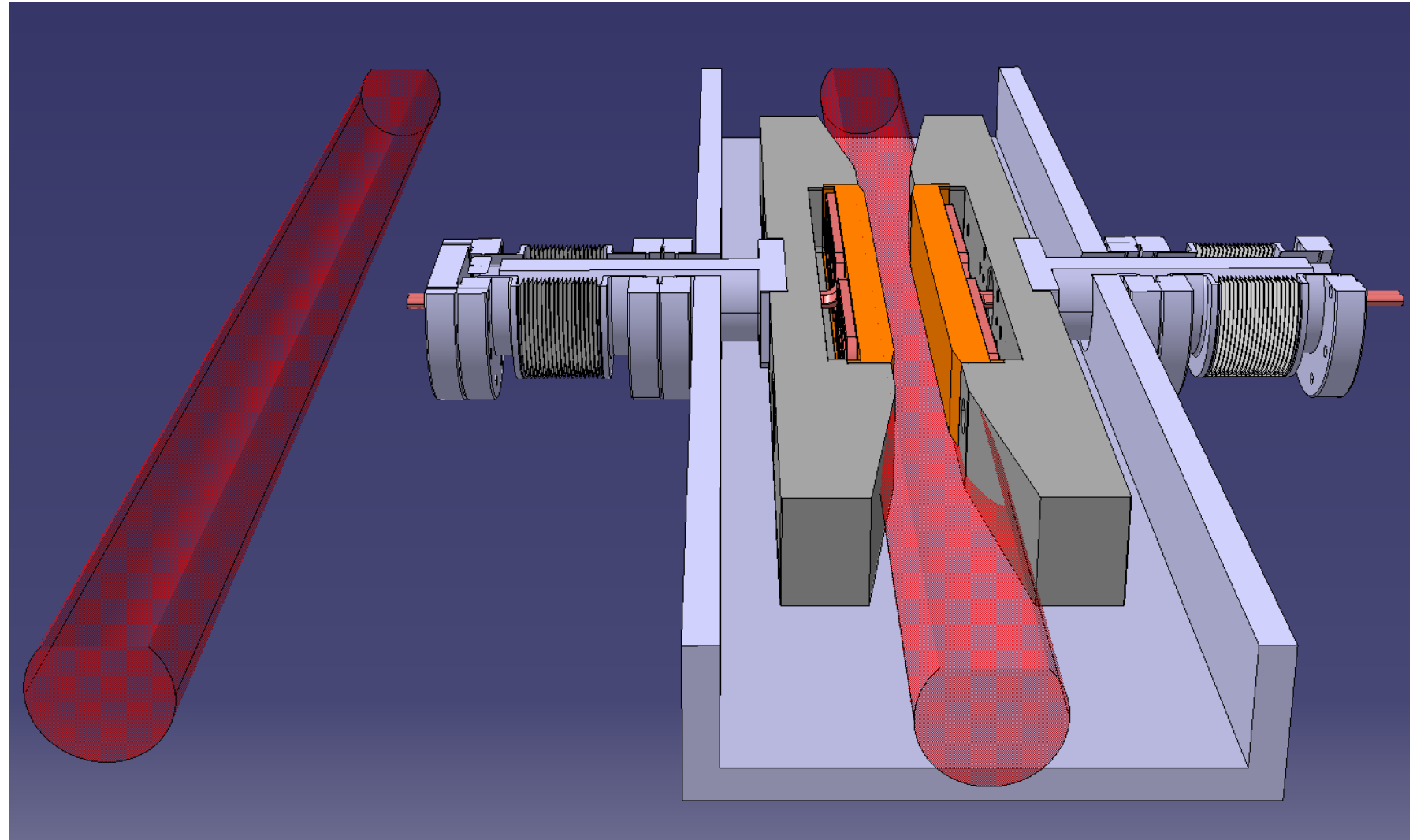
# Initial Design – section view with beam pipes

Axial bellows limited by space available between beams  
(**stroke length critical**)

Absorber block covers only a small portion of beam pipe

Impedance transition  
“unfinished”

Access available for replacement of blocks



# Lessons learnt from other collimators

## From LHC:

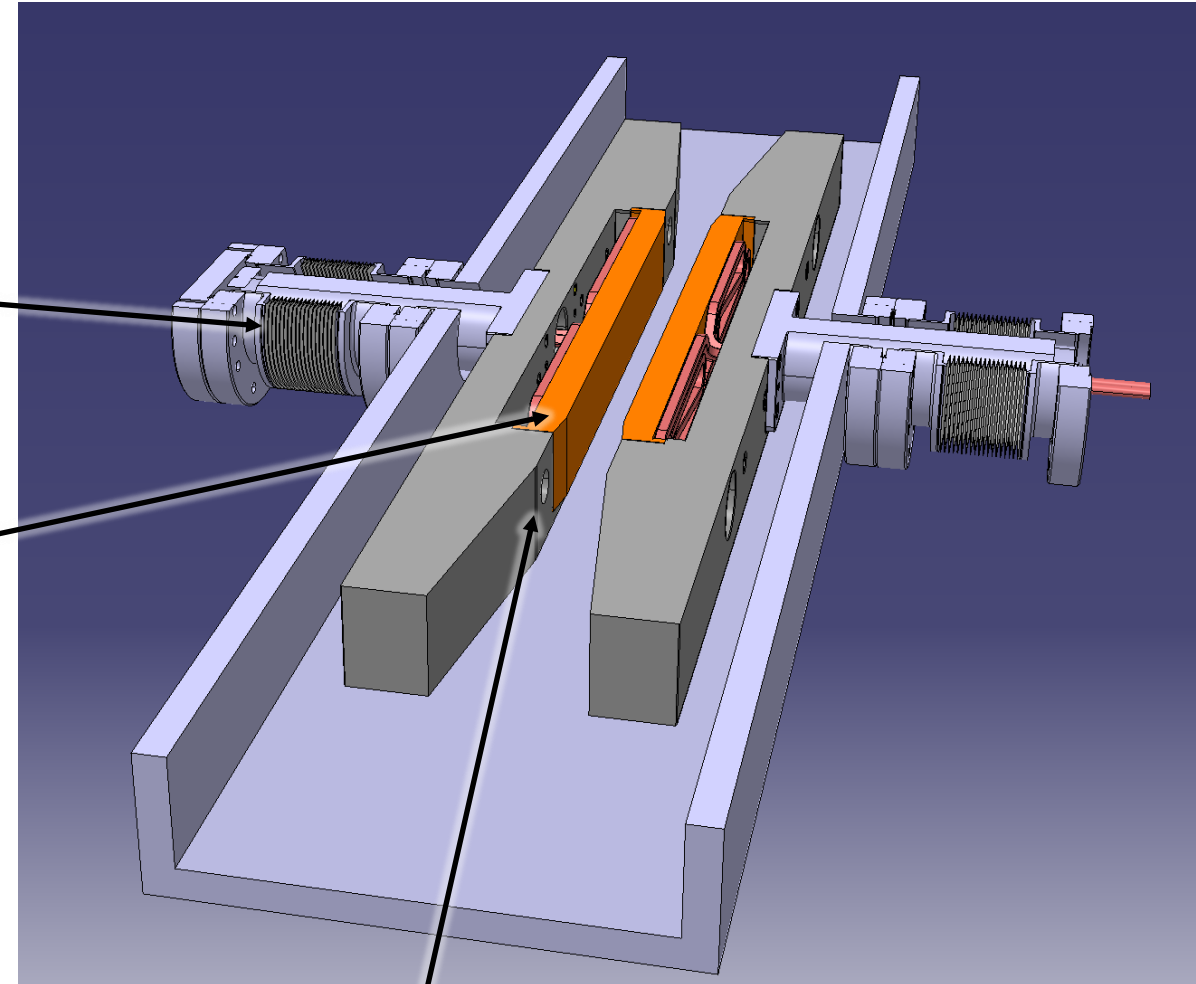
- Bellows lessons:
  - Only standard **axial motion**
  - **Not welded** to the tank

## From SuperKEKB:

- Risk of beam damage on active material
  - **Replaceable active block** (or whole jaw)

### Also considering:

- Transversal jaw shift for fresh collimation surface
- Hot spares if necessary



**BPM x4**

# Proposed Strategy and Timeline

Deliverable <sup>(1)</sup>	Specific tasks	Proposed completion <sup>(2,3)</sup>
Functional requirements for collimators	tracking studies, impedance constraints	2027
Com	Energy deposition studies (FLUKA), thermo-	
Preli	<b>DESIGN ENTIRELY BASED ON FUNCTIONAL REQUIREMENTS</b>	
R&D		
Full c		
Syste		
Full system prototype – Mock-up test	Collimator, supports, handling equipment	2036
Final design		2038

- 1) Deliverables are not sequential. They run in parallel – they are interdependent.
- 2) Dates are only tentative proposals. To be discussed with stakeholders.
- 3) Each task to start as soon as there is enough information

# Conclusions

- **Different collimator designs could be envisaged depending on function**
- **Competing functional requirements → best compromise to be found**
- **A specific design for FCCee needed to best meet specifications**
- **Several studies to be performed (energy deposition, thermo-mechanics, system engineering)**
- **Prototyping and testing required**
- **R&D necessary (materials and manufacturing techniques)**



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# BACK-UP SLIDES