

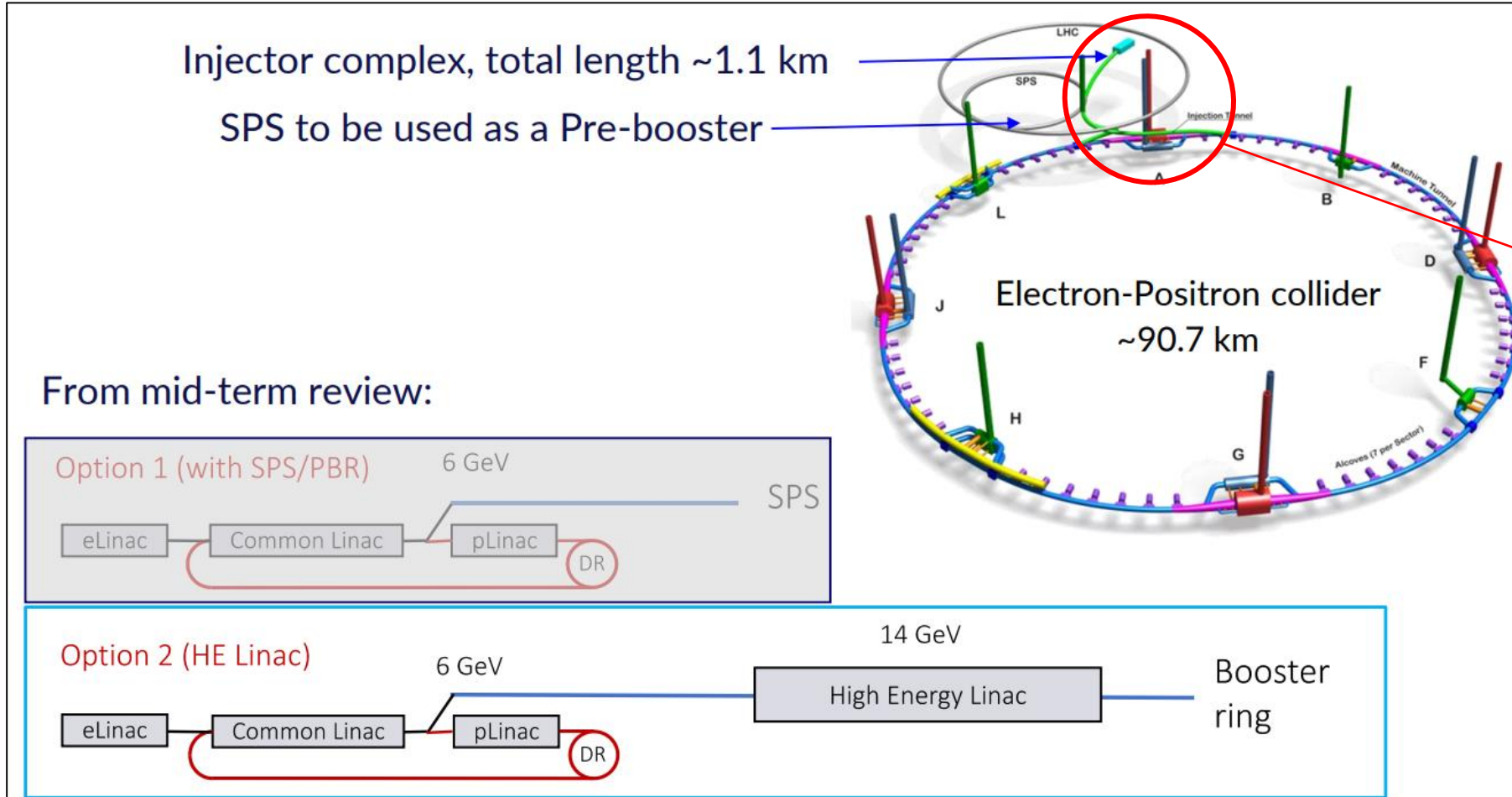


AITANA (IFIC) FCC plans

Daniel Esperante Pereira ¹
on behalf of the IFIC-AITANA accelerators group

¹ IFIC (UV, CSIC)

FCC complex: Injector linacs



We have a primary interest in this part of the accelerator complex, though other contributions are not discarded:

- cBPMs
- Linac RF

Presentation: THE FCC-ee INJECTOR COMPLEX: Status of the injector parameters for the booster, CERN, March 5, 2024

Beam position monitoring system

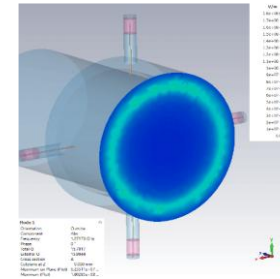
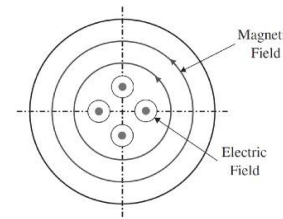
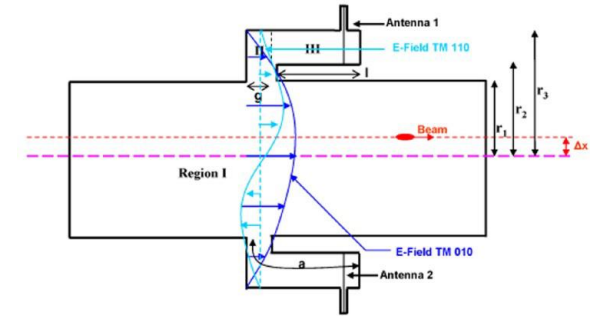
- ❑ Development of a re-entrant cavity BPM for linear colliders with single bunch resolution $< 1 \mu\text{m}$ for cryogenic temperatures
- ❑ Cavity BPMs are resonant systems crossed by the beam pipe. EM modes are induced on the cavity by the beam and beam position measurement depends on their amplitude

- $V_{\text{position}}(t) = V_{\text{out},0} \sin(\omega_{110}t + \varphi) \exp(-t/\tau)$

- ❑ Develop the know-how to design new cavity BPMs and readout:

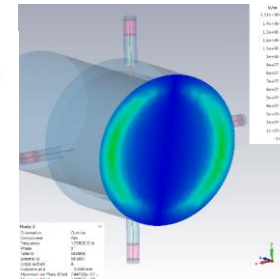
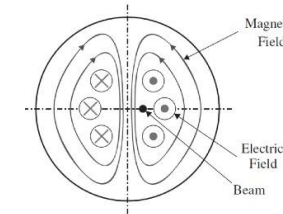
- Use commercial vacuum feedthroughs
- Multiparametric design
- Tolerance analysis to in order to reduce fabrication costs
- Complex readout with mixing electronics and fast ADC
- Complex data processing: DDC, IQ demodulation

- ❑ Now we have the capability to adapt the design to different beam pipe sizes, operational frequencies, understand mechanical fabrication, optimal manufacturing cost



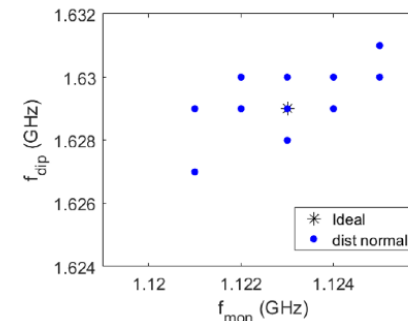
The Monopole mode TM_{010} , $f_{010} = 1.25 \text{ GHz}$ gives the reference signal:

$$V_{\text{TM}010} \propto q_{\text{bunch}}$$



The Dipole mode TM_{110} , $f_{110} = 1.72 \text{ GHz}$ gives the position information:

$$V_{\text{TM}110} \propto q_{\text{bunch}} \times \delta x$$

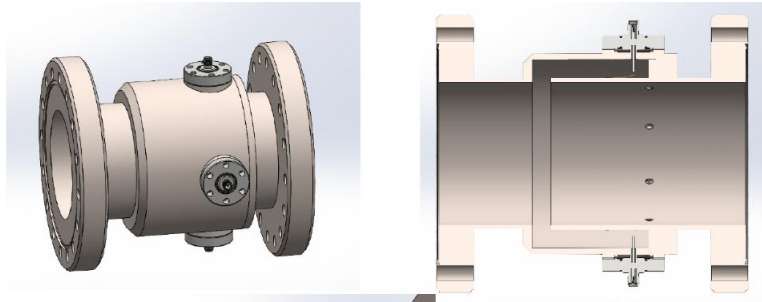


Manufacturing tolerances with $= 50 \mu\text{m}$ 20 cases with different variations in all parameters simultaneously

Beam position monitoring system

Design and construction of a new cBPM in close collaboration with industry:

Built a new cBPM with Neptury Technologies, now under characterization at IFIC and to be tested in June 2026 at KEK

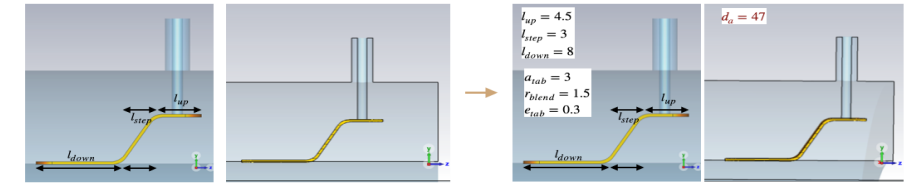


New DAQ system to process data accurately and consistently:

- Beam-tests at KEK (Japan) with prototype readout and processing algorithms with cBPM from CEA Saclay shows a resolution $< 3\mu\text{m}$
- Data processing, analysis and beam test conditions to be improved
- New beam tests in May 2026

But FCC baseline design is based on button BPMs

- They are cost-effective solution
- Less technical problems with wakefields, port heating with respect cBPMs



Mode	Monopole			Dipole (on x)				
	Freq (GHz)	Q	R/Q (Ω) @ 3 mm	Freq (GHz)	Q	R/Q (Ω) @ 3 mm	S ₁₁ (dB)	S ₂₂ (dB)
CEA SACLAY	1.250	22.95	12.9	1.719	50.96	0.27	-25.0	-33
Optimization (ideal)	1.120	37.65	14.47	1.626	72.30	0.357	-16.3	-30.6
After inclusion of the tab and optimization	1.118	34.91	14.50	1.620	64.09	0.350	-22.5	-31

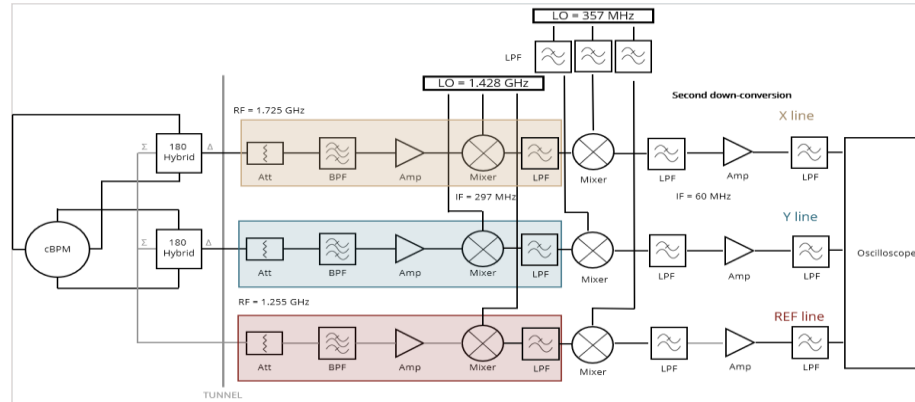
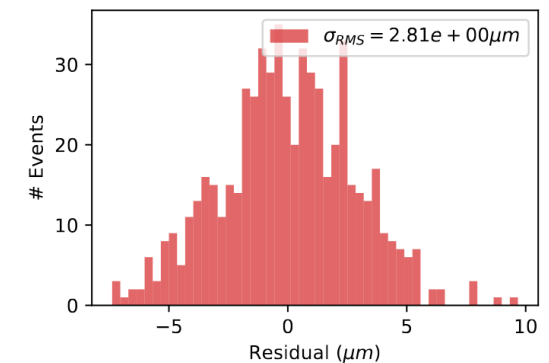
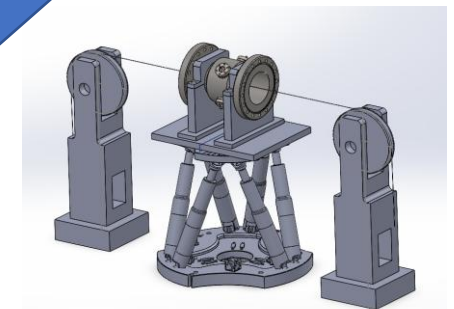
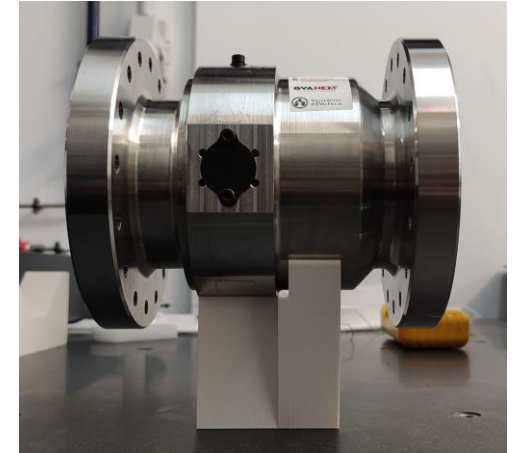


Figure: CEA Saclay cBPM installed at ATF



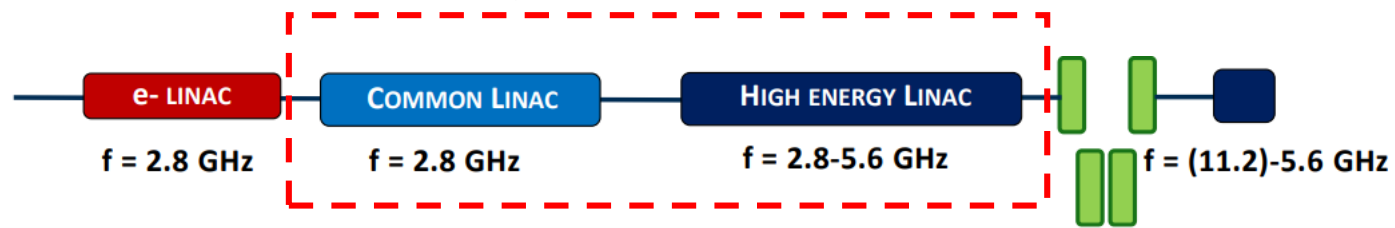
Beam position monitoring system

- ❑ cBPMs may be interesting for other parts of the FCC complex other than the storage and booster rings:
 - Injector transfer lines and matching/injection sections.
 - Particularly in: damping ring extraction, compressor section inputs/outputs, matching to the booster, and areas where “beam jitter” must be separated from optical errors
 - A cavity BPM at strategic points can provide better diagnostics of: pulse-to-pulse stability, residual offsets after correctors ...
- ❑ In collaboration with Frank Zimmermann (FCC Deputy Study Leader) and Thibaut Lefevre (Head of the CERN Beam Instrumentation group) we have agreed in carrying out feasibility studies together with FCC collaboration:
 - Study potential locations: Injector or HE linac
 - Requirements: bunch-by-bunch measurements (to be integrated in feedback systems)
 - Challenges: beam impedance, heating and impact in beam dynamics
 - Activities: performance to cost evaluation and comparison among different technologies (needs to be re-evaluated as it was done many years ago)
- ❑ Also, a system to calibrate BPMs where we can measure the geometrical center with respect to the electrical center was a common interest



RF accelerator

- ☐ Injector complex, total length ~1.1 km



- ☐ We have experience in RF systems and RF cavity design, Photo-injector designs and testing at X-Band and S-Band frequency for different projects (CLIC, IFIC RF laboratory, XLS-CompactLight)
- ☐ Contacted FCC-ee injector responsible Alexej Grudiev and have agreed in looking for potential interests and contributions:
 - Groups currently involved: CERN, PSI, IJCLab, INFN-LNF, SLAC
 - IFIC contribution to be studied with FCC responsables
 - RF R&D: S-Band design
 - Multipactor expertise
 - This contribution may have a potential involvement of Spanish Industry
 - Cavity construction
 - RF sources (power modulators)
 - Magnets

Ongoing work, plans and funding

❑ In development:

- Development of BPM electronics readout and data processing system
- Study potential integration of cBPM in FCC
- Develop a new BPM calibration system
- Beam tests of BPM
- Tests on cryogenic conditions with KEK colleagues

❑ Funding:

- **ASFAE/2022/013**, “RF technologies for beam monitors in accelerators and for dark-matter axion detectors.”
- **S8A**, PhD student **Laura Pedraza Motavita**
- **PROMETEO CIPROM/2021/073**: PhD student **Juan Carlos Fernandez**
- Plan nacional: **PID2021-122134NB-C21**, **PID2024-158190NB-C21**
- Participants of the European project (Marie Curie Action - SE): **EAJADE** (Europe-America-Japan Accelerator Development Exchange) Program. Stays in KEK for the beam test of the BPM.
- Requested a continuation project, **GEAR-NG**, more focused on FCC accelerator activities

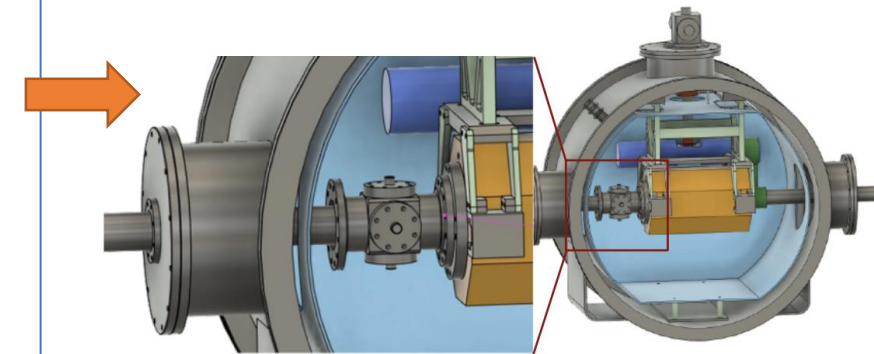


Figure: Cryostat accommodating BPM and SC quadrupole



EAJADE
Europe-America-Japan Accelerator
Development Exchange Programme

Thank you

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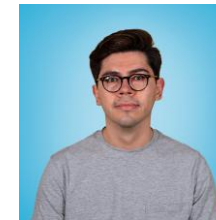
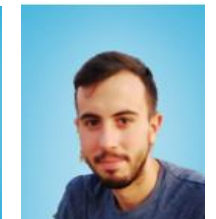
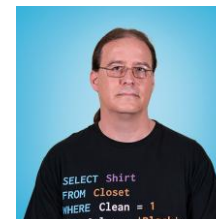
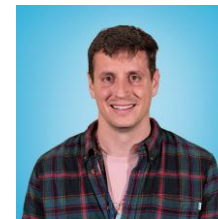
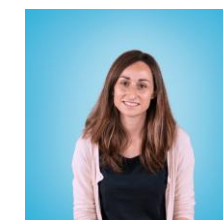
Conclusions

- Our group has a solid background:
 - RF design and simulation (CST, HFSS, Superfish)
 - Particle accelerators electronic systems
 - Low Level RF systems
 - Embedded systems (FPGA, MPSoC, microTCA, PXI...)
 - Electronics instrumentation
 - Beam diagnostics
 - cBPMs, BPMs
 - Test setups
 - Non-linear RF phenomena: multipactor and RF-breakdows
 - Beam dynamics
 - Lattice design, collimation, collective effects
 - Theoretical developments

Accelerator physics and technology team

Team members:

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