Laboratoire d'Annecy-le-Vieux de Physique des Particules

EuCARD

EuCARD WP9.3 NCLinac Highlight talk:

Feedback performance, precision alignment and nanometer scale stabilisation of CLIC magnets

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CERN

JAI

cnrs

In2p3

Outline

- Introduction: teams, main objective, objective
- Magnets to be stabilised
- Mechanical Stabilisation results
- Pre-alignment
- Extra help: beam-based feedback
- Status

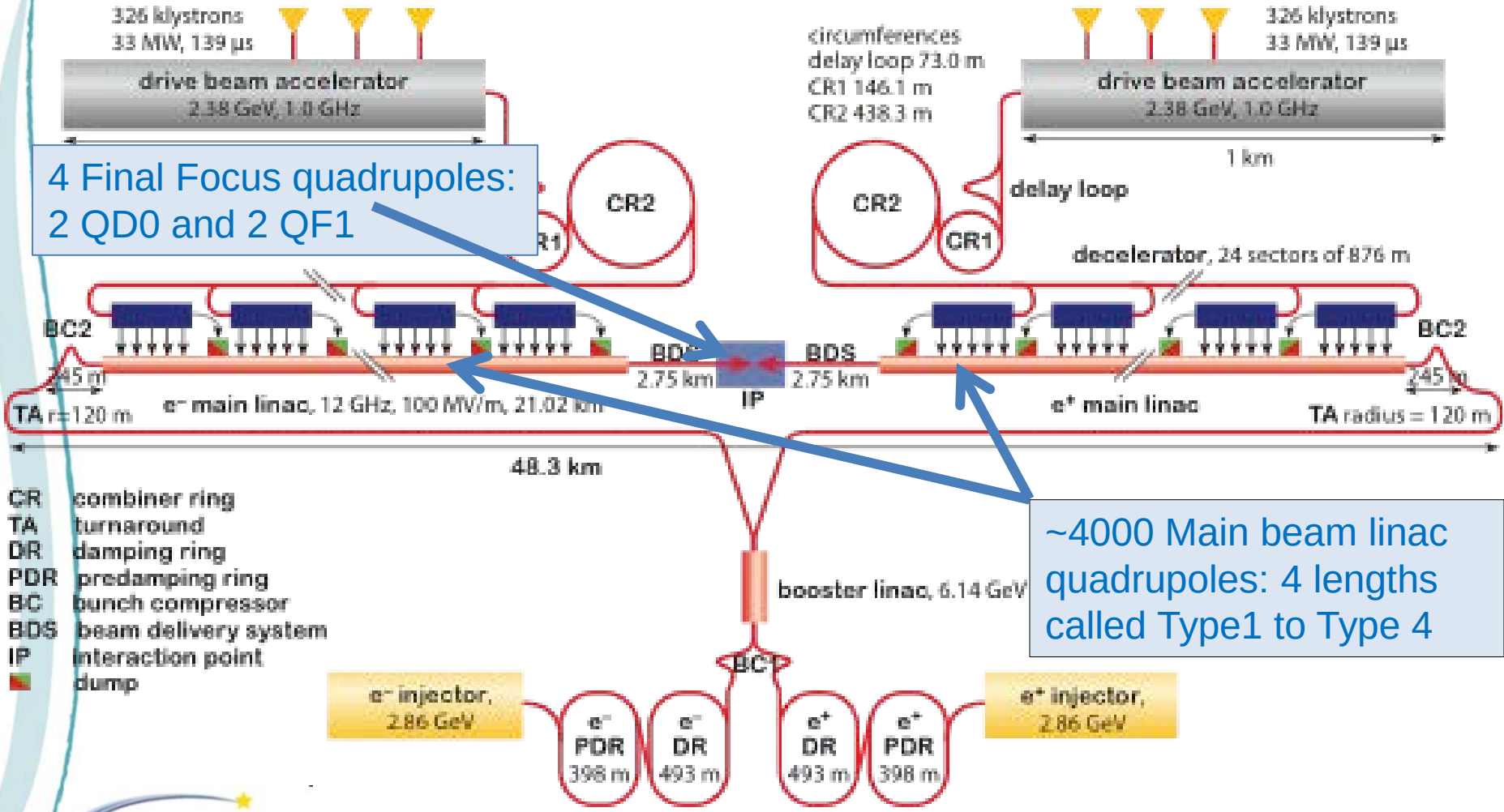
Introduction

Teams involved

- Task Coordinator: A.Jeremie

- Oxford University/ JAI (John Adams Institute)
  - P.Burrows et al; Feedback, simulation
- LAPP/Annecy CNRS
  - A. Jeremie et al; stabilisation, feedback
- CERN
  - K.Artoos et al; stabilisation
  - H. Mainaud-Durand et al; pre-alignment
  - M. Modena et al; magnets
- Associates (stabilisation-feedback):
  - Université de Savoie: B.Caron et al
  - Université Libre de Bruxelles: C.Collette et al

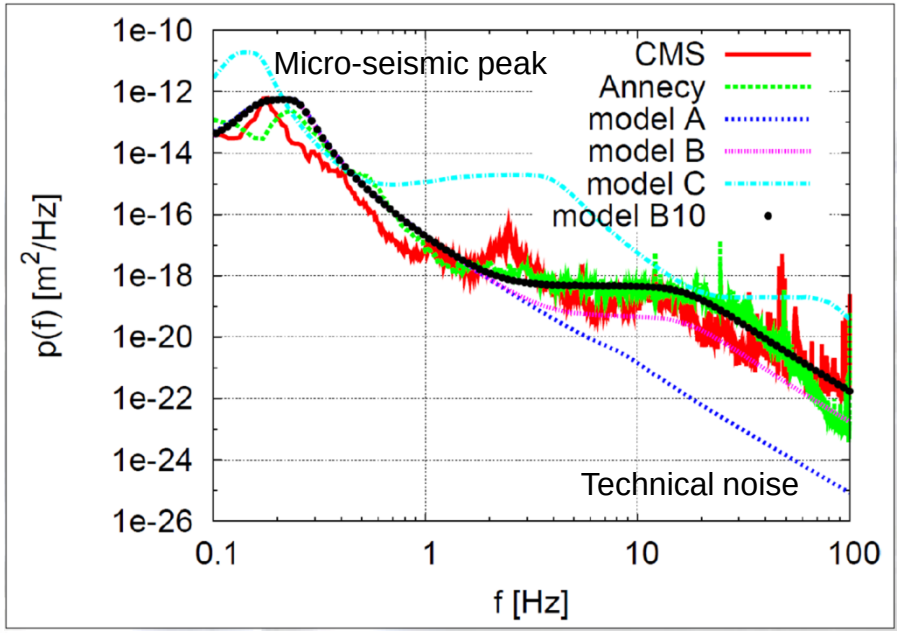
Main objective of task 9.3: Address quadrupole stabilisation issues on CLIC



What we are aiming at

- Ground motion has an impact on luminosity

=> especially when beam guiding quadrupole magnets vibrate

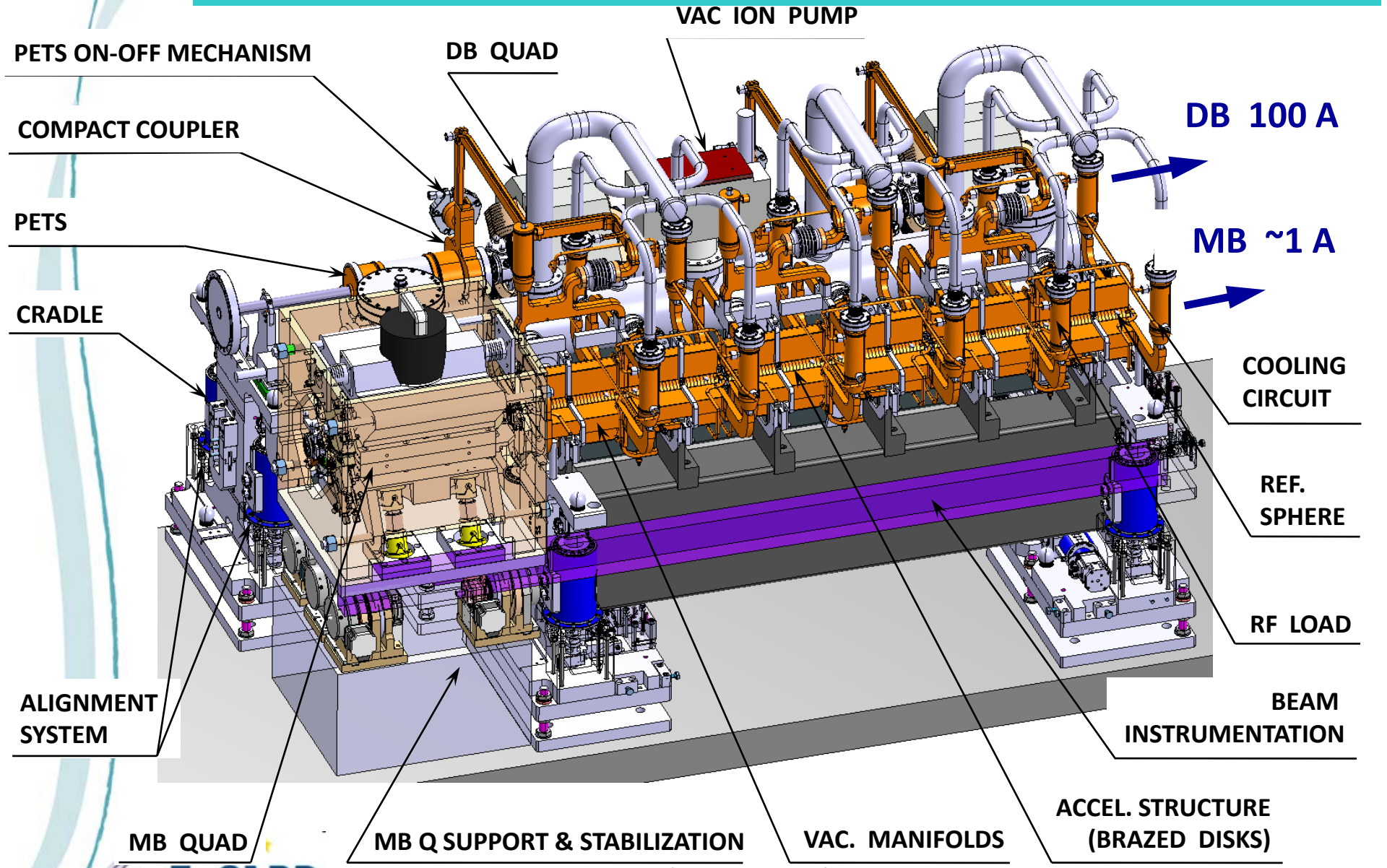


	FF	MBQ
Vert.	**0.2 nm > 4Hz**	**1.5 nm > 1 Hz**
Lat.	**5 nm > 4 Hz**	**5 nm >1 Hz**

- At the IP (mechanical + beam feedback), we aim at 0,1nm at 0,1Hz

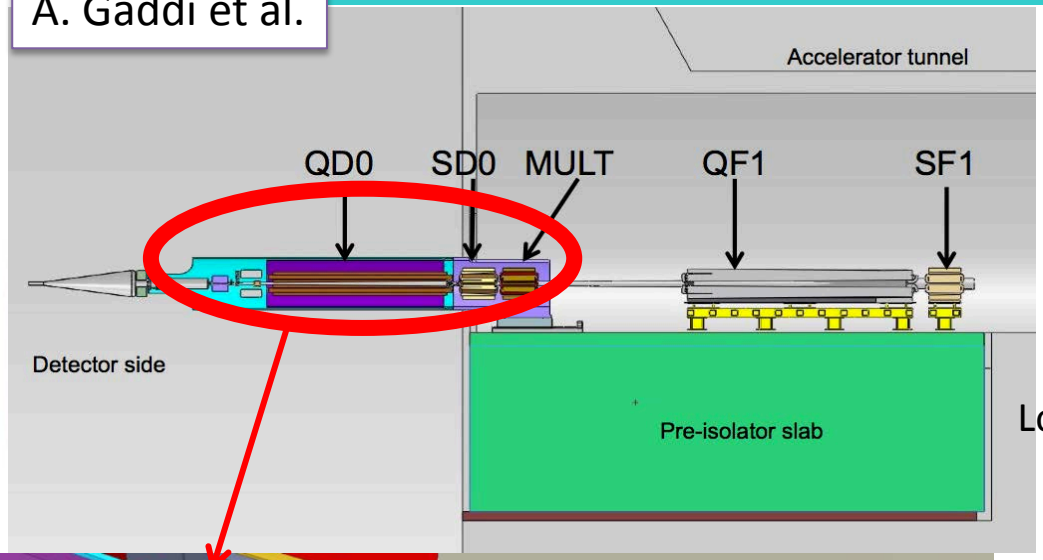
<1Hz	1Hz<f<100Hz	100Hz<f
Beam-based feedback	Mechanical stabilisation	Low Ground motion

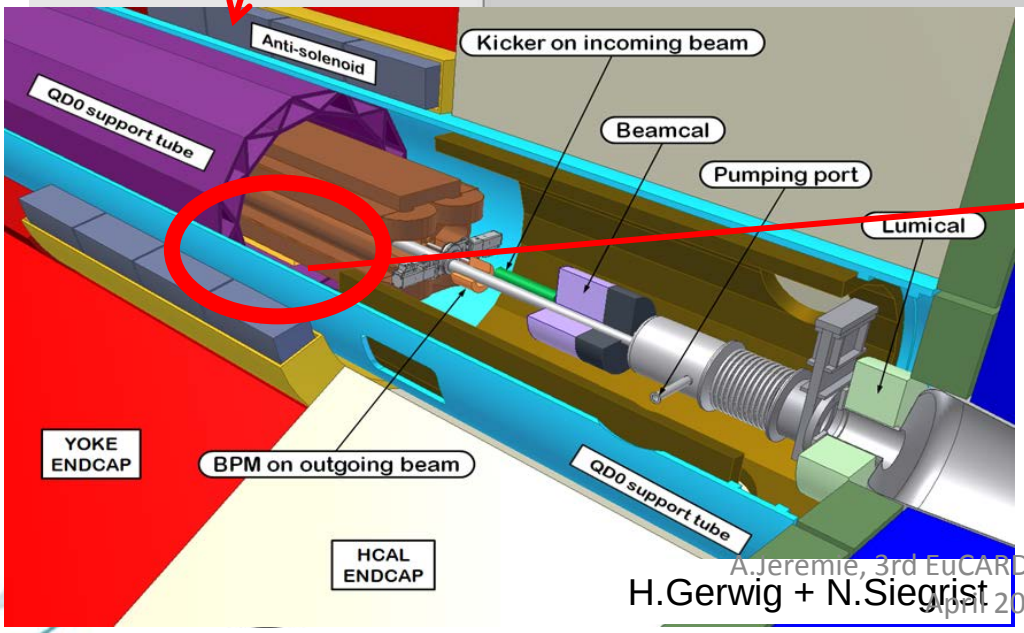
Main Linac Module with Type 1 quadrupole



Final Focus quadrupole: Passive and active solution

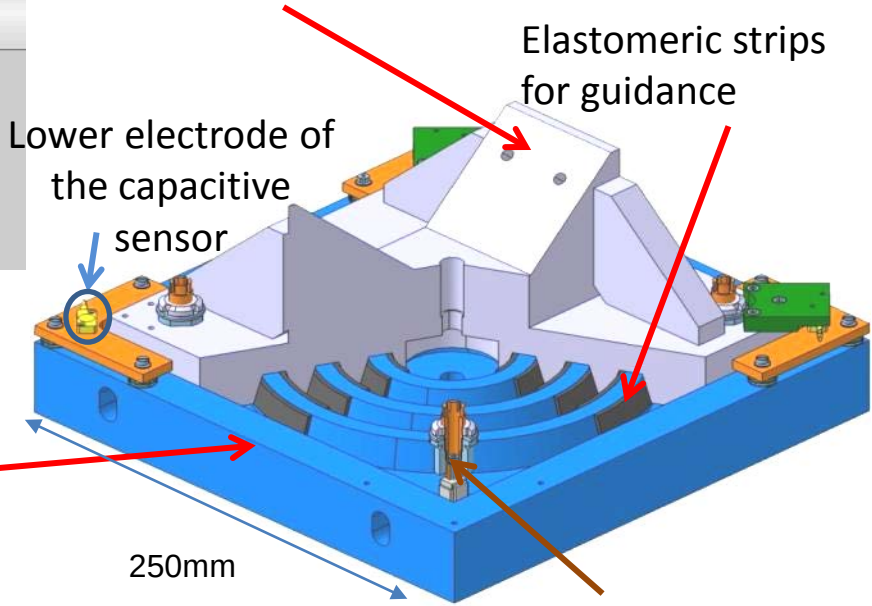
A. Gaddi et al.





H.Gerwig + N.Siegrist

Add coherence between QD0 and QF1 and reduce band-width on which active stabilisation has to act

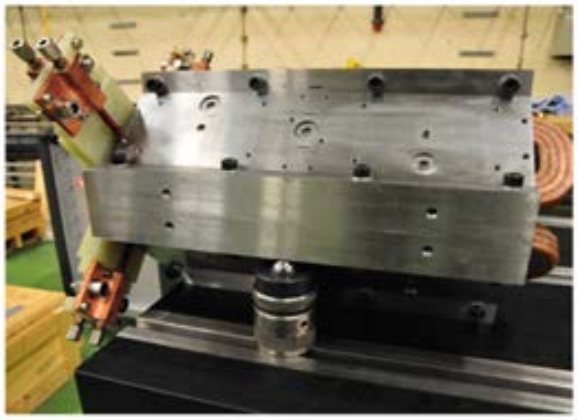


Additional passive stage directly under active system is also envisaged

Magnets to be stabilised

Magnets to be stabilised

Main Beam quadrupoles

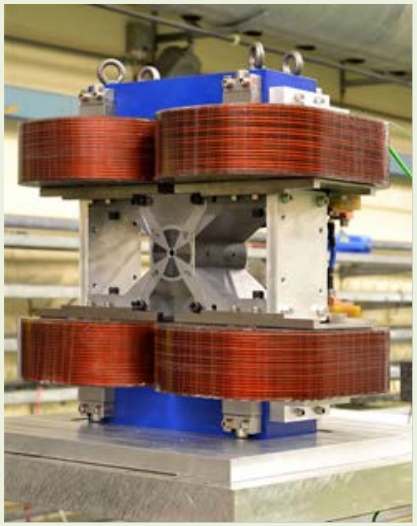


Type 1
500mm
100kg

Type 4
2000mm
450kg

Final focus quadrupole prototype

Permanent magnet (Nd2Fe14B) + coils



Mechanical stabilisation results

- At CERN: stiff active stabilisation

  => MB linac quadrupole

- At LAPP: stiff active support + passive support (under study…not shown in talk)

  => FF quadrupole

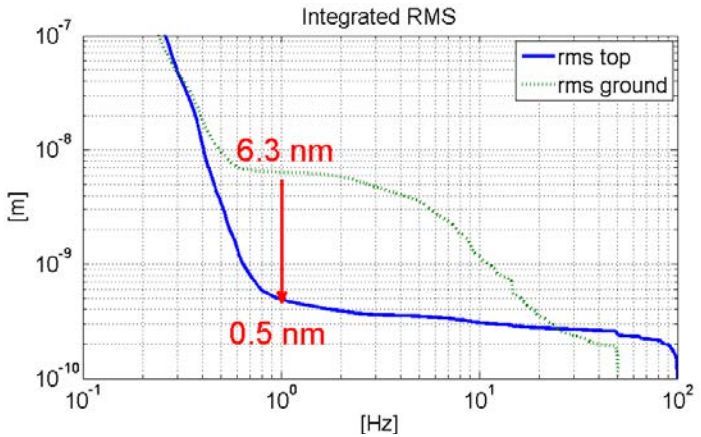
- Active means :

measure => decide action => act

sensor *feedback/-forward* *actuator*

Stabilisation on Type 1 MBQ

- Water cooling 4 l/min
- With magnetic field on
- With hybrid circuit



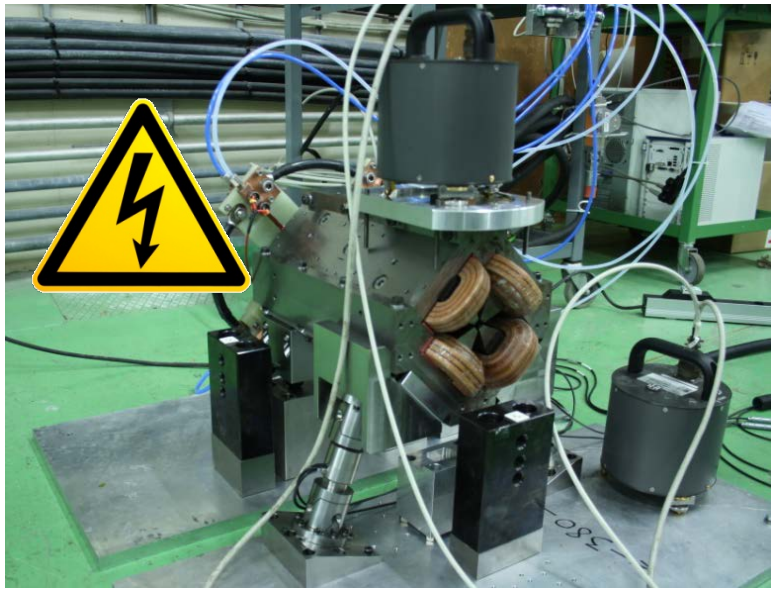
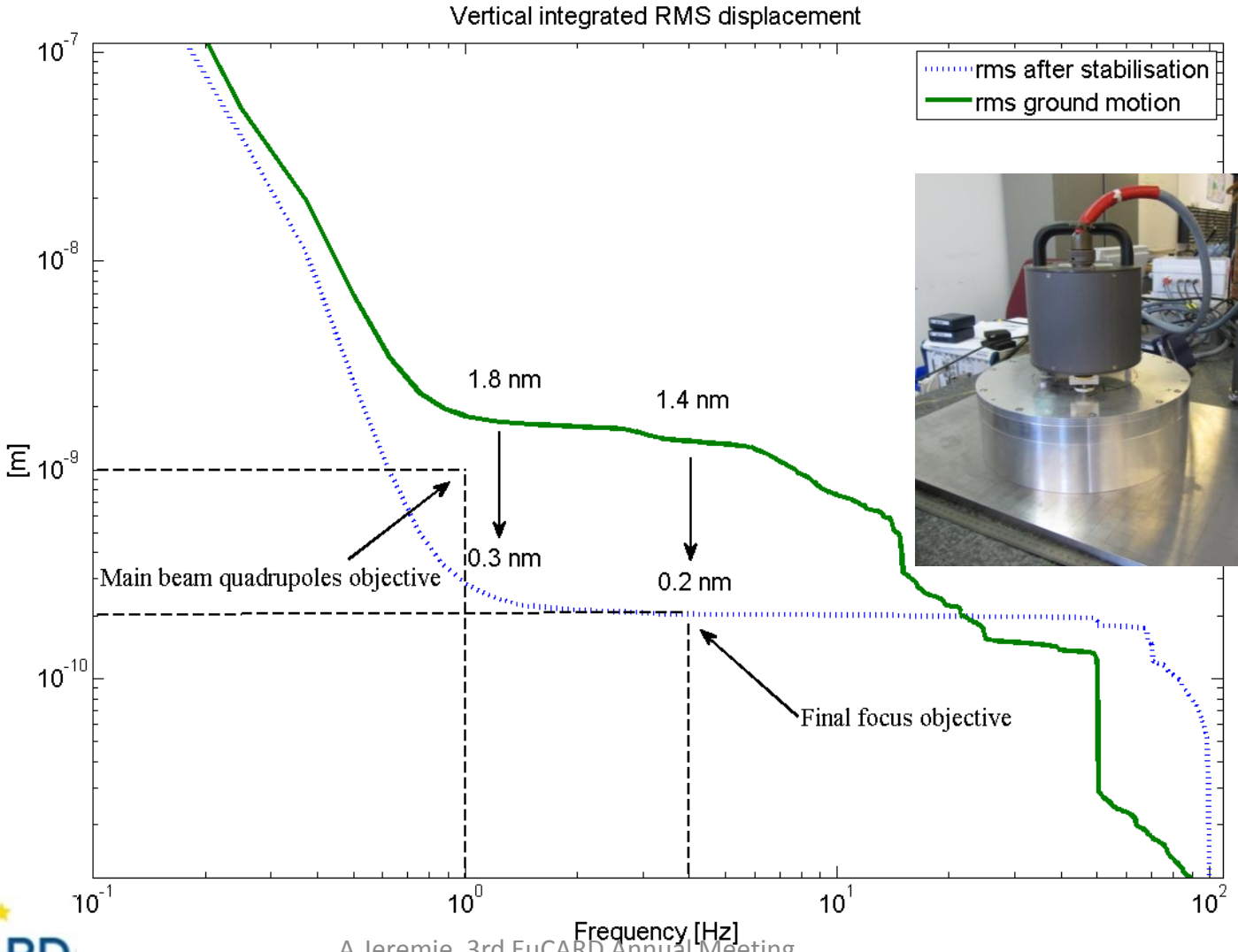
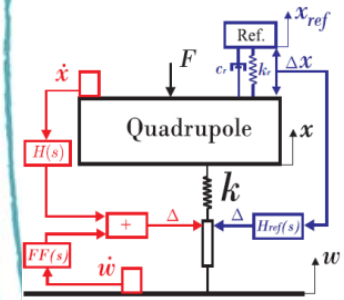


Figure	Value
R.m.s @ 1Hz magnet	**0.5 nm**
R.m.s @ 1Hz ground	6.3 nm
R.m.s. attenuation ratio	**~13**
R.m.s @ 1Hz objective	**1.5 nm**

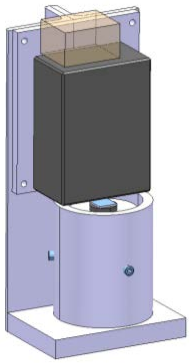
Results on 1 d.o.f. active support at 1 Hz and 4 Hz



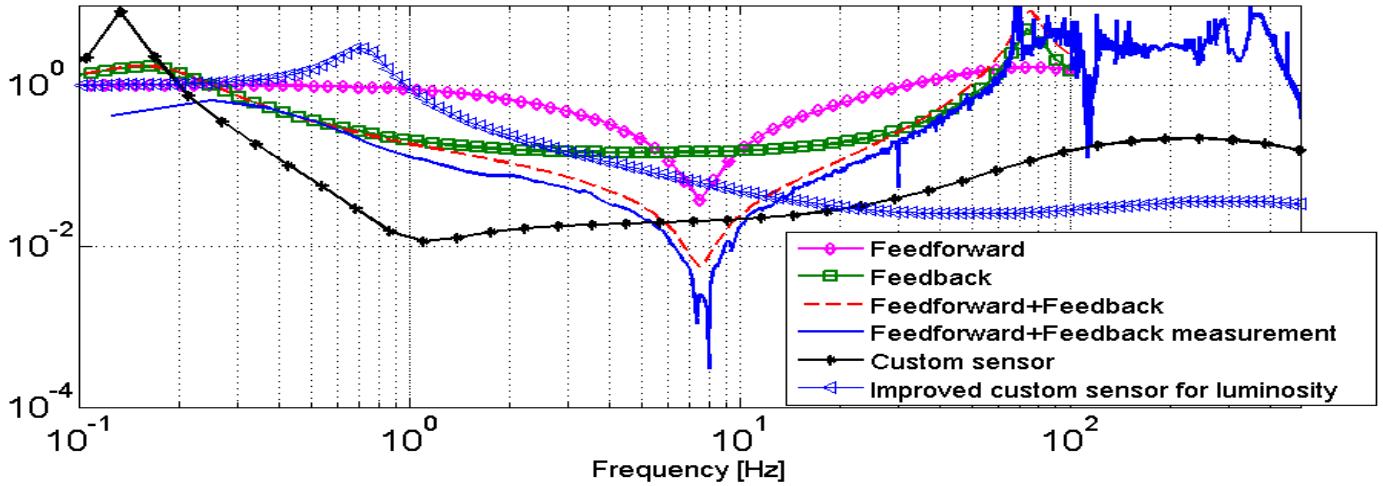
Integrated luminosity simulations Sensor R&D



Commercial Seismometer



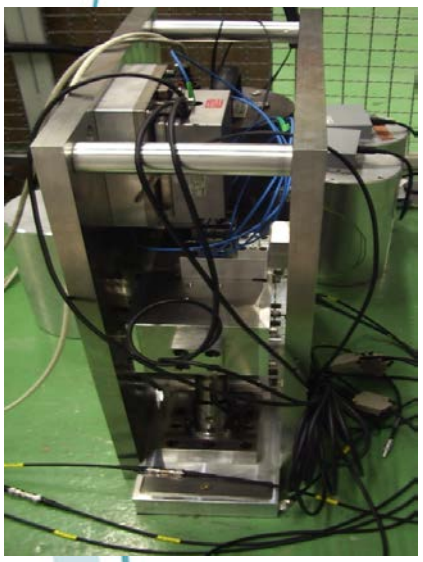
Custom Inertial Reference mass



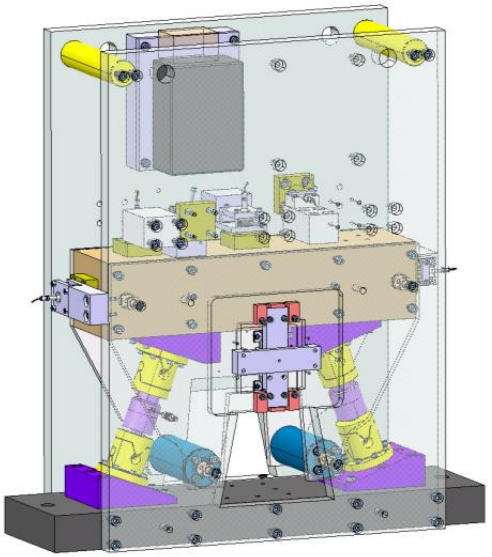
No stabilization	68% luminosity loss
Seismometer FB maximum gain (V1)	13%
Seismometer FB medium gain (V1mod)	**6%**
Seis. FB max. gain +FF (FBFFV1mod)	**7%**
Inertial ref. mass 1 Hz + HP filter (V3)	3% (prototype under test)

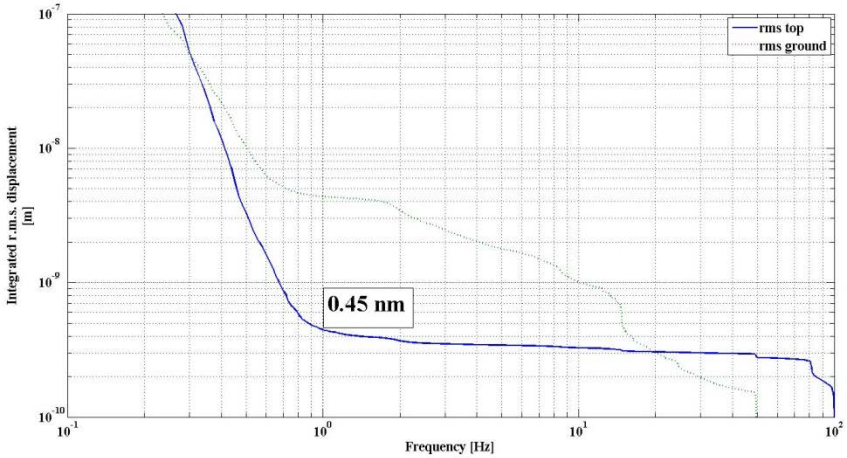
Courtesy J. Snuverink, J. Pfingstner *et al.*

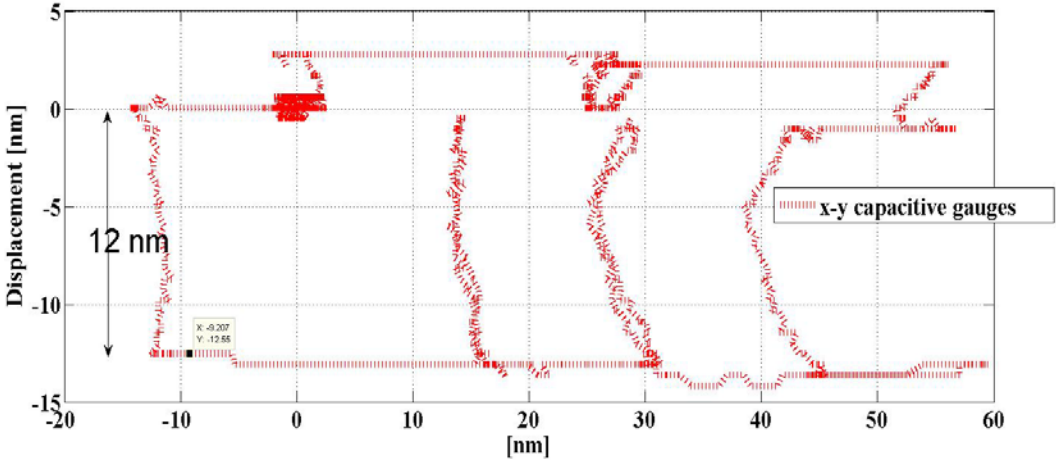
Improved mechanics prototype X-y guide operational



- X-y guide « blocks » roll + longitudinal direction
- Increases lateral stiffness by factor 500, increases band width without resonances to ~100 Hz
- Introduces a stiff support for nano metrology
- cross check with interferometer





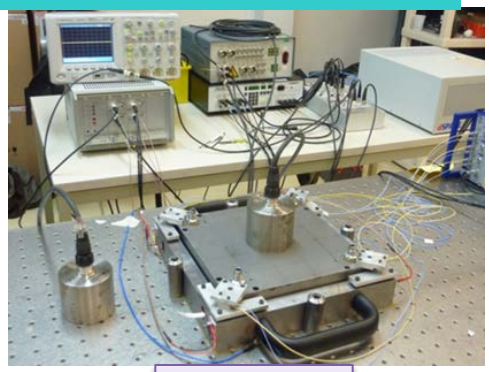


Progress

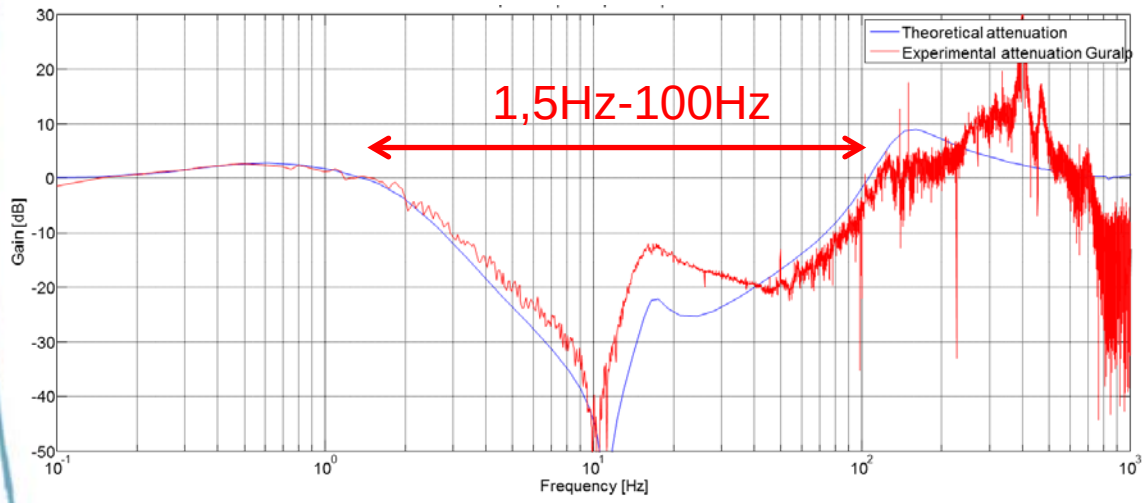
Five R&D themes :

1. Performance increase 
   → Reach requirements from higher background vibrations + include direct forces
   → Increase resolution (Final focus)
2. Compatibility with environment 
   → Radiation, magnetic field, Operation, Temperature
3. Cost optimization 
   → Standardize and optimize components, decrease number of components, simplify mounting procedures,…
4. Overall system analysis 
   → Interaction with the beam-based orbit and IP feedback to optimise luminosity
   Integration with other CLIC components
   → Adapt to changing requirements
5. Pre-industrialization 
   → Ability to build for large quantities

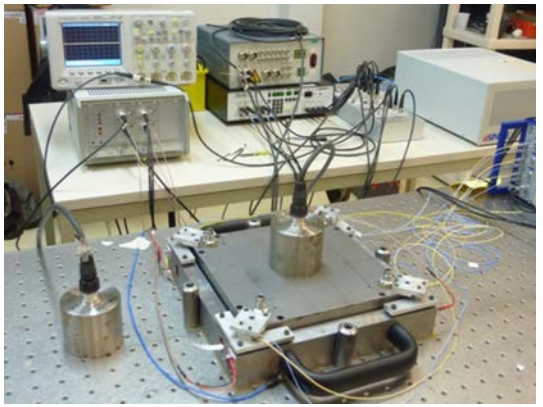
Control scheme for FF quad stabilisation

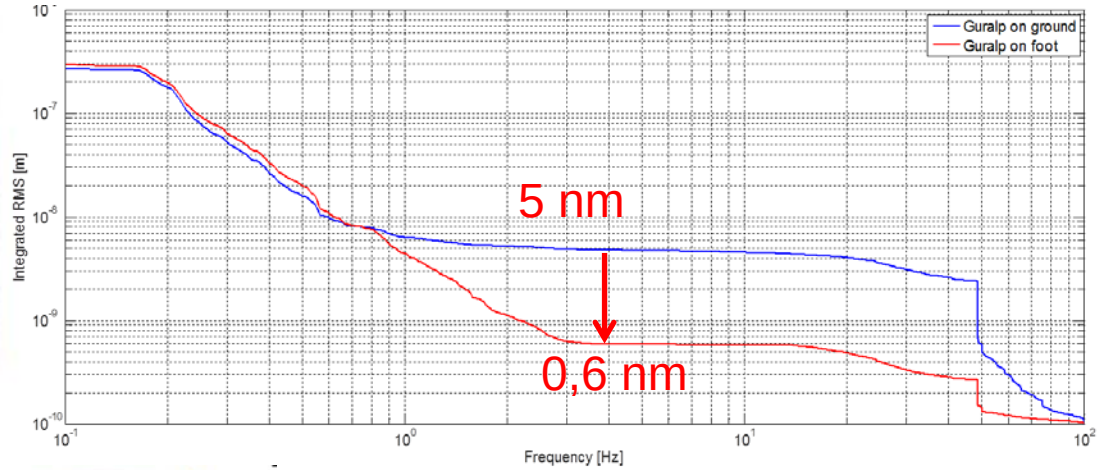


FF stabilisation results



Attenuation up to 50dB between 1,5-100Hz

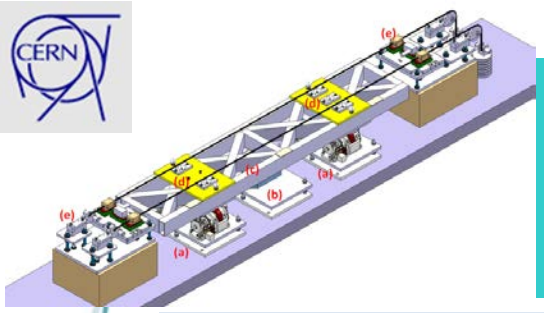




RMS ground at 4 Hz: 5 nm
RMS on foot at 4Hz: 0,6nm
RMS ratio: 8,3

Pre-alignment studies

- The stabilisation system will have to be compatible with the active pre-alignment system on the Linac Main Beam Quadrupole and the Final Focus Quadrupole



5 DOF Cam movers mock-up

- After a first blank assembly of the mock-up ➔ adjustment resolution of vertical and radial translations below 2 µm but in a very noisy area
- The mock-up has now been re-installed in a quiet area (noise on the sensors smaller by a factor 3!)
- First results confirm that the control algorithm is ok, allowing an adjustment in radial and vertical in 2-3 iterations below 1 µm and roll adjustment in few iterations below 1 µrad.

Test program:

-Performances of the cam movers (repeatability, backlash, resolution) carried out on a 1 DOF mock-up

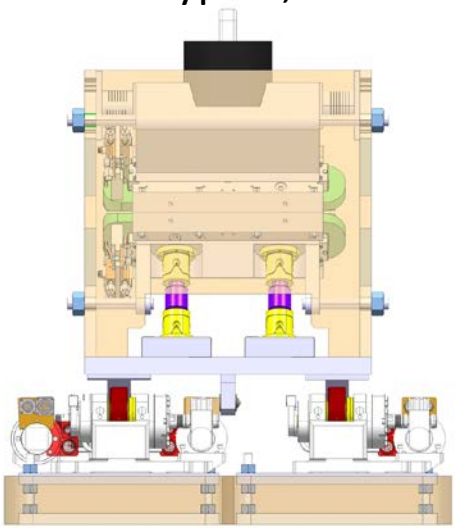
-Determination of positioning precision throughout the range and long term stability in the 5 DOF mock-up

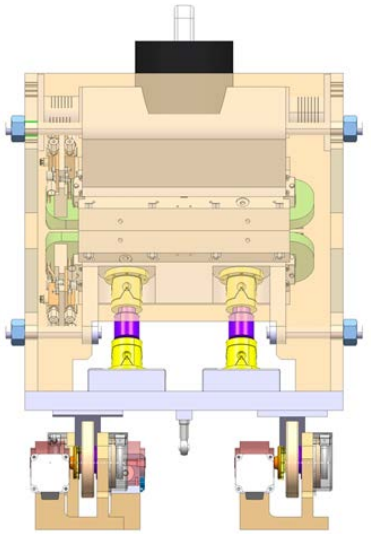
-Determine support EigenFrequencies

-Impact of heating of the motors, power cut tests, impact of loads, cam contact point after 100h of cycles.

Development of mini cam movers

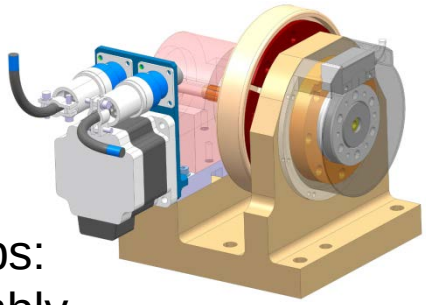
Mini cam movers for MB quad type 1 are under development, with the same requirements as type 4, but with a smaller size





Description of the solution chosen:

- Custom made gearbox
- Gear ratio = 90
- Zero backlash, self-locking
- 5 phase stepper motor (0.36°/step)
- Resolution ≤ 0.35 µm
- Off-the-shelf electronics



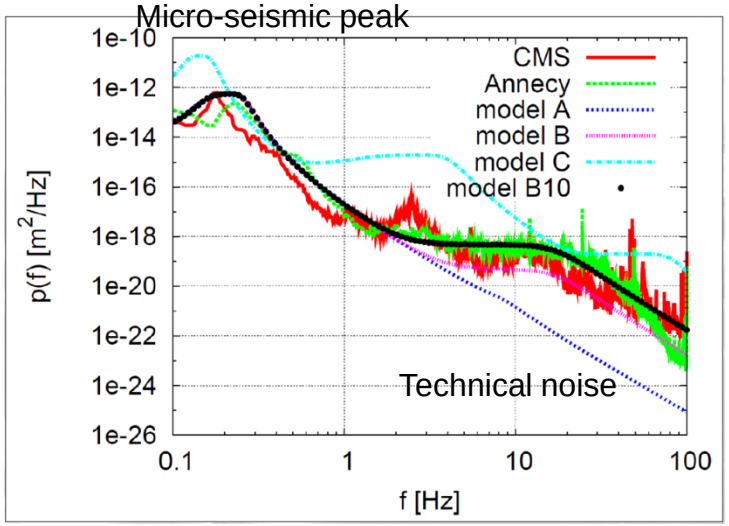
Next steps:

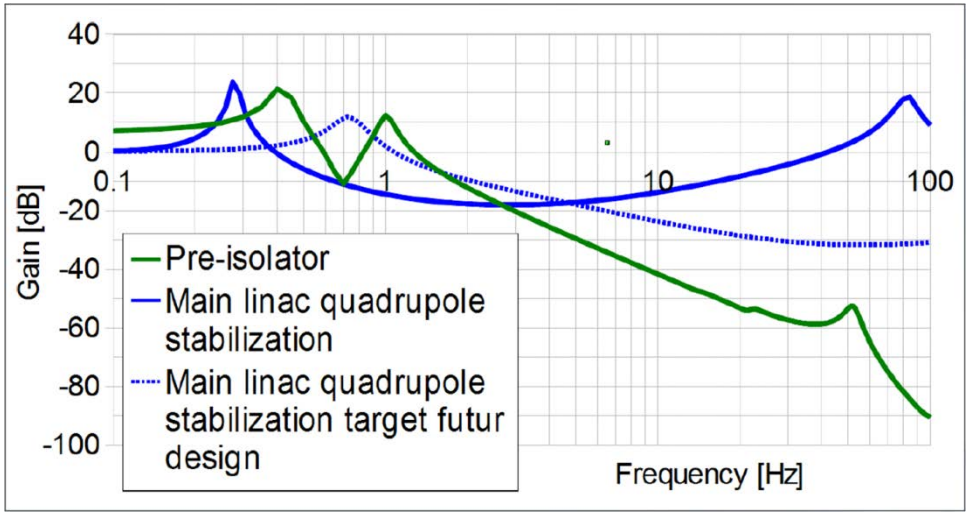
- assembly
- test on 1 DOF test setup.

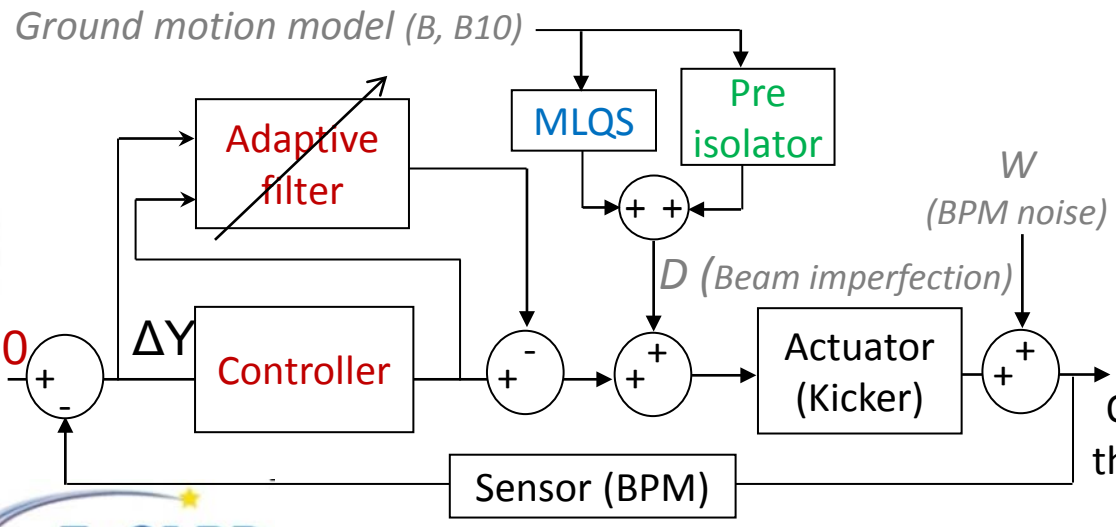
Beam Feedback studies

- 50 Hz (CLIC rep rate) IP feedback
- Intra-train feedback (FONT)

This is what is implemented







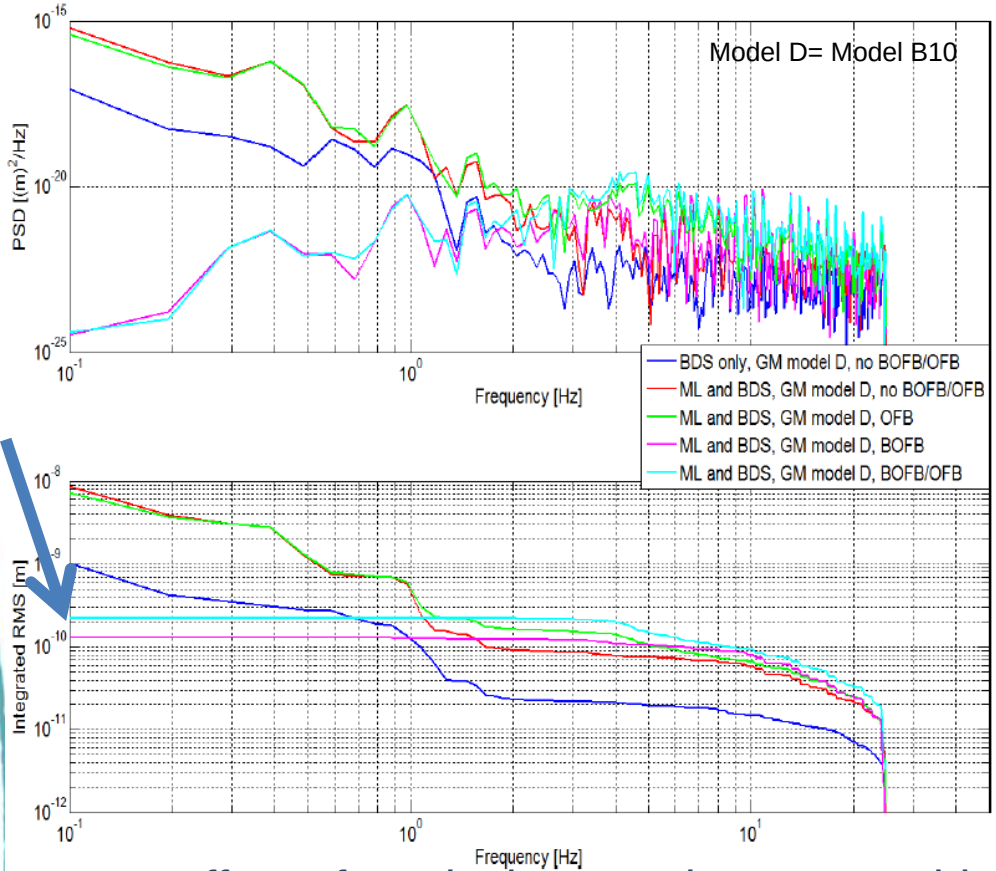
Simulations done with

- PLACET and Guinea-Pig
- Main Linac Quad Stab (MLQS)
- Pre-isolator
- LAViSta IPFB control

Old version: IPAC results

Offset at the IP: ΔY

Integrated simulation for IPFB



0.2nm

-only BDS and pre-isolator

-adding Main linac + MLQS, no FB

-adding LAViSta-IPFB (BOFB) + OFB

-see effect of pre-isolator: reduce rms at high frequencies but peak around 1Hz

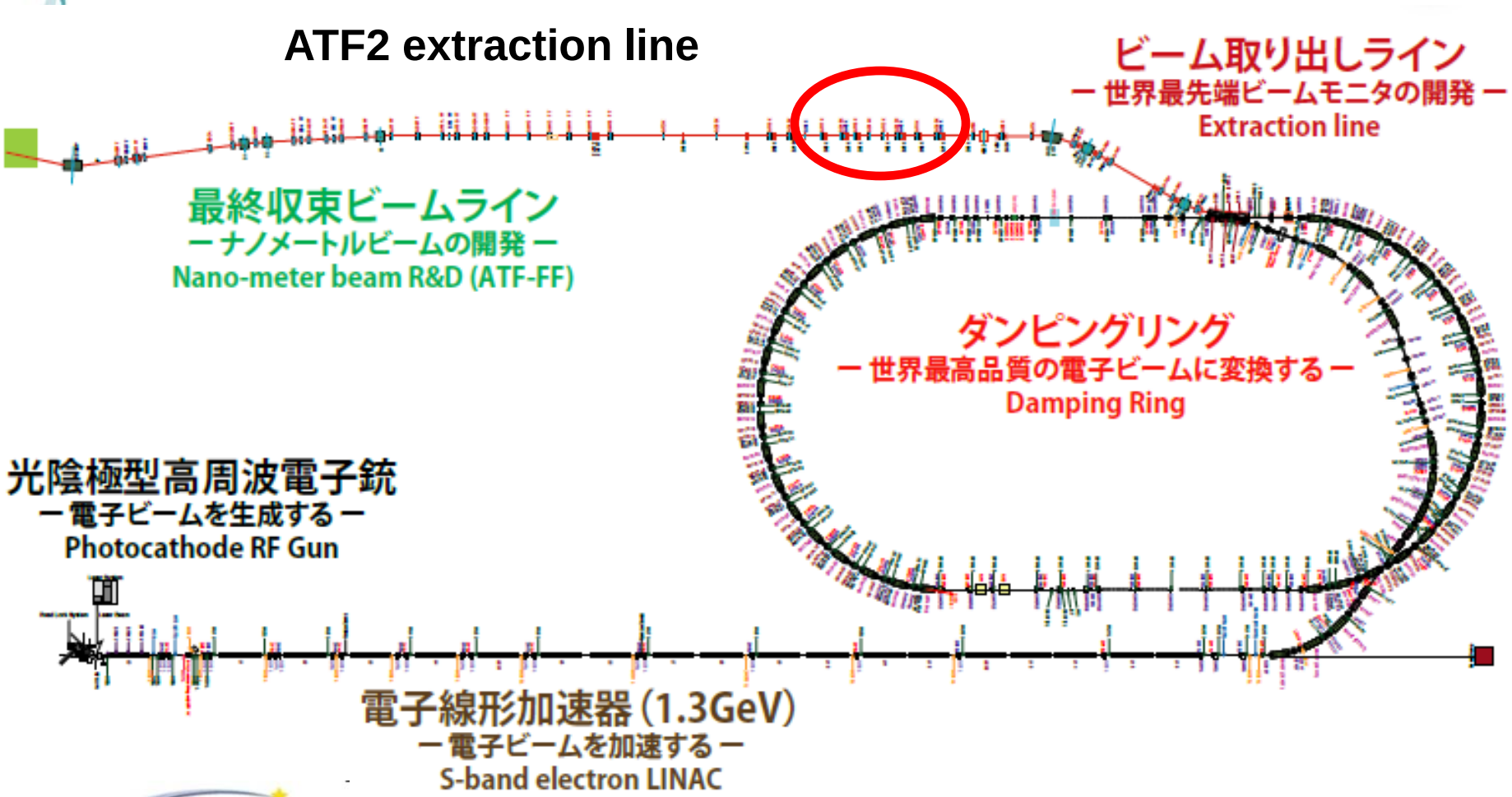
-increases rms at high frequency=> ML beam jitter other than GM

-LAViSta-IPFB reduces rms by factor 45 at 0,1Hz to a sub-nm level

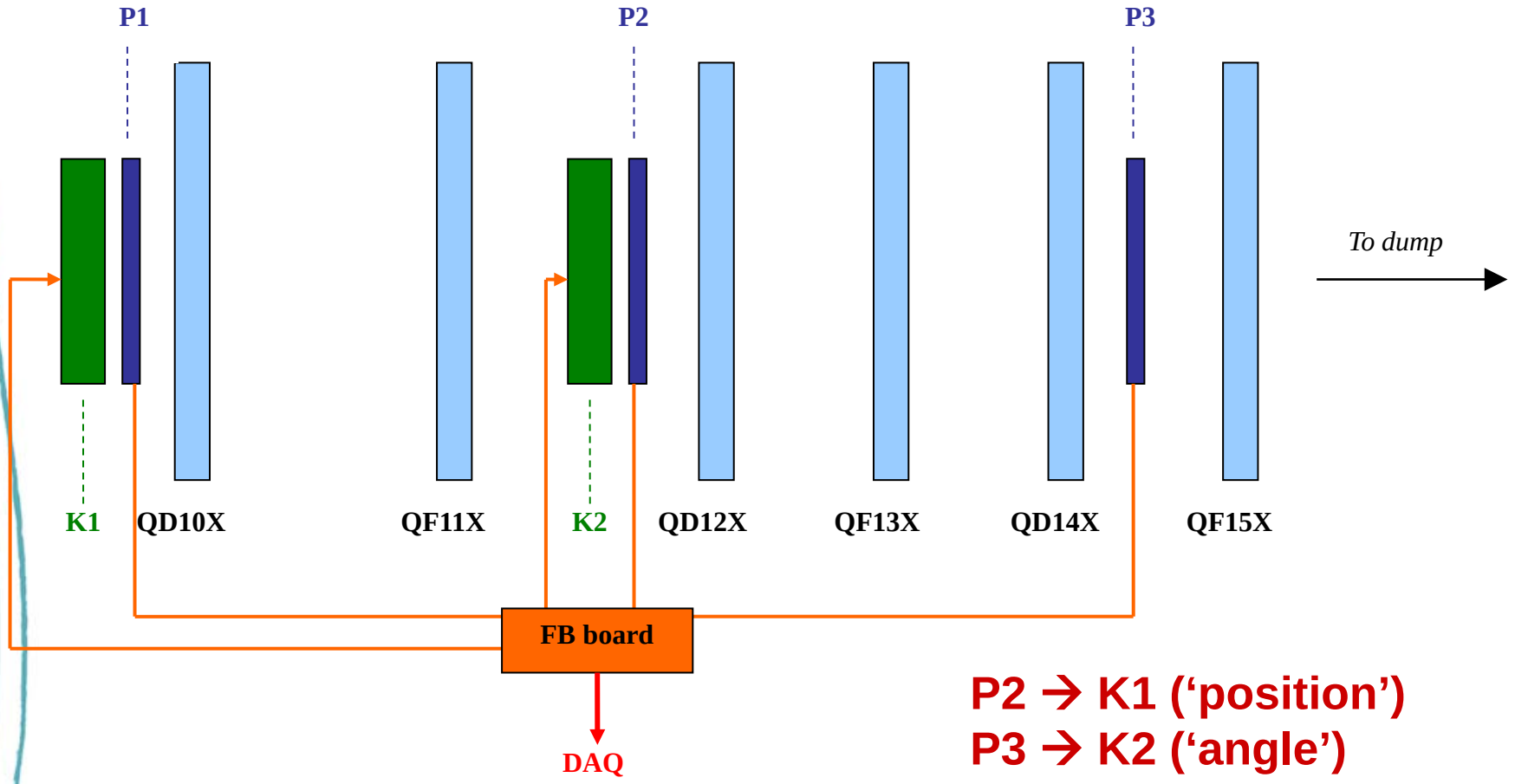
=> need a good beam at FF entrance for good performance

FONT5 location

Design of nm-level beam stabilization system for ATF2

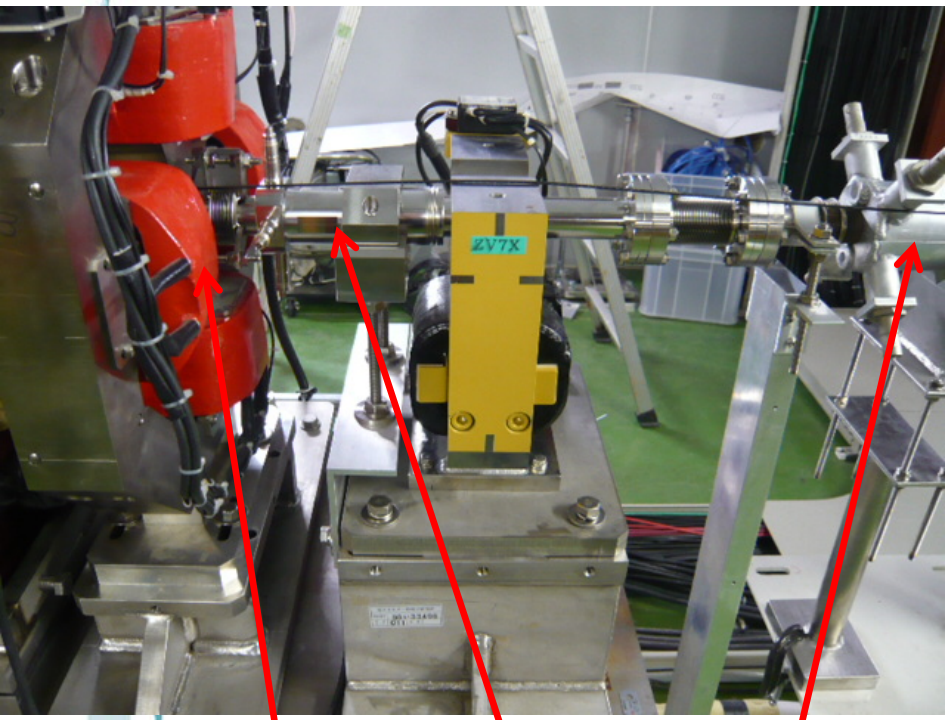


FONT5 setup



P2 → K1 ('position')
P3 → K2 ('angle')
P3 → K1
P2 → K2

FONT5 hardware

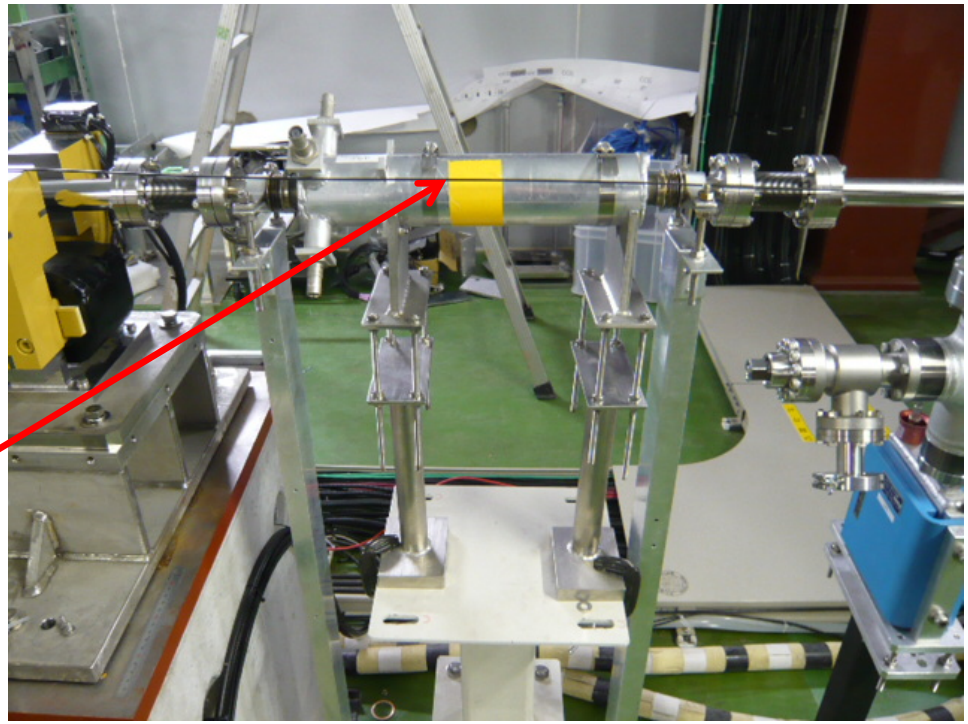


Quadrupole

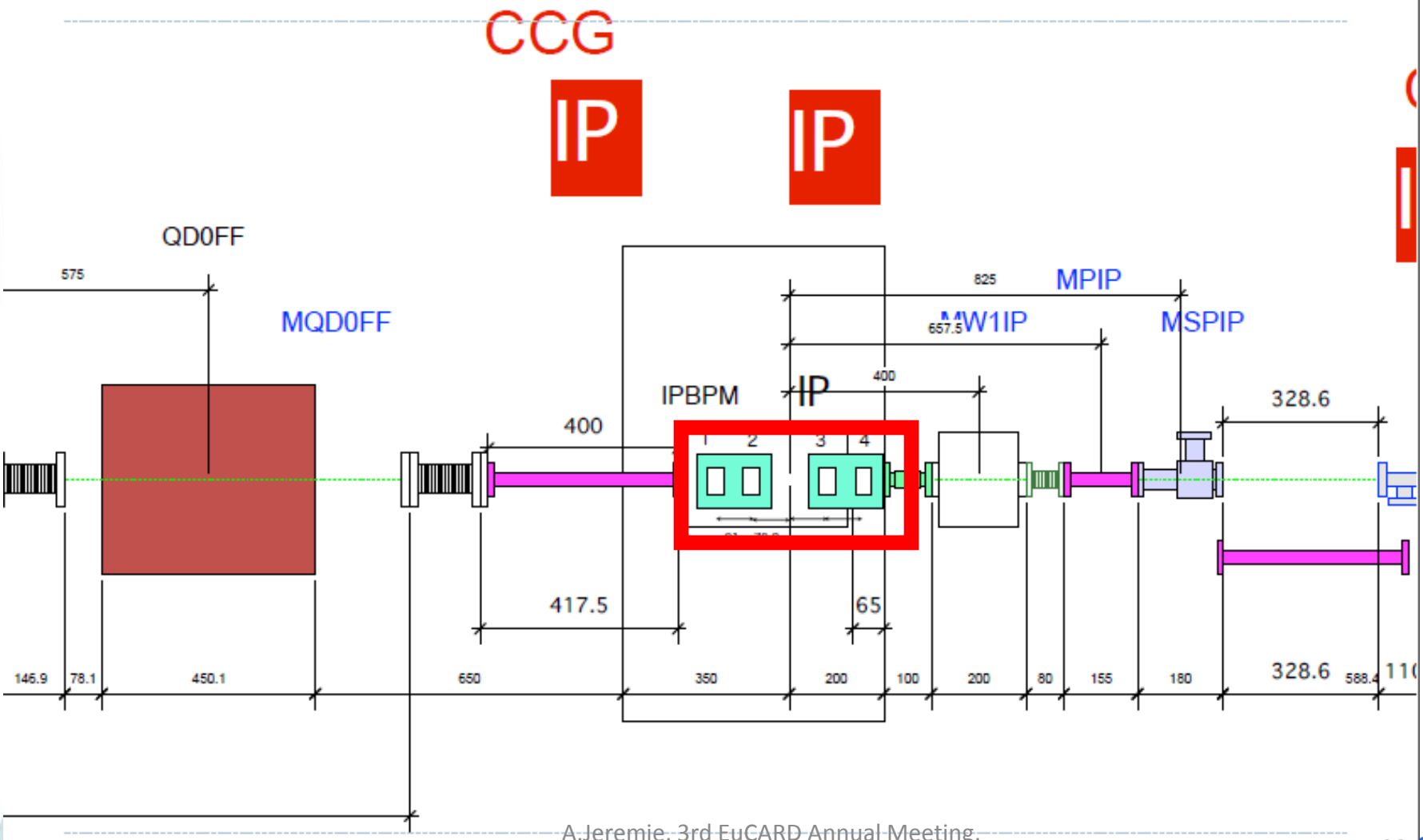
BPM

kicker

- In ATF2 extraction line



Eventual IP configuration



Feedback Performance

(example FB Run 6 13/12)

bunch	1	2
	FB off	FB off
Jitter P2	3.42	3.42
P3	3.24	3.21

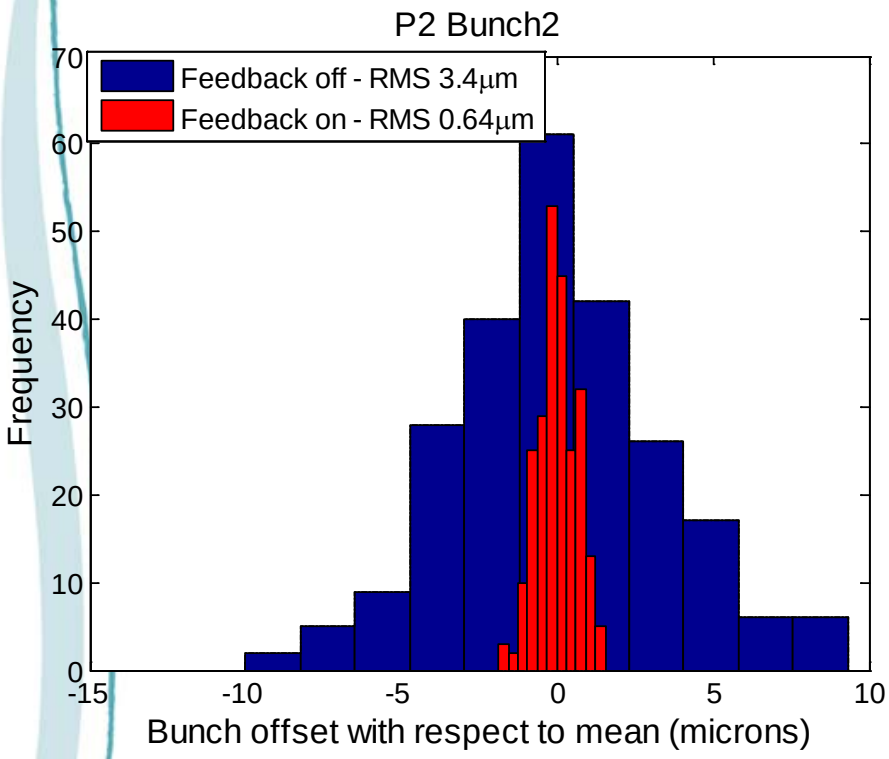
Feedback Performance

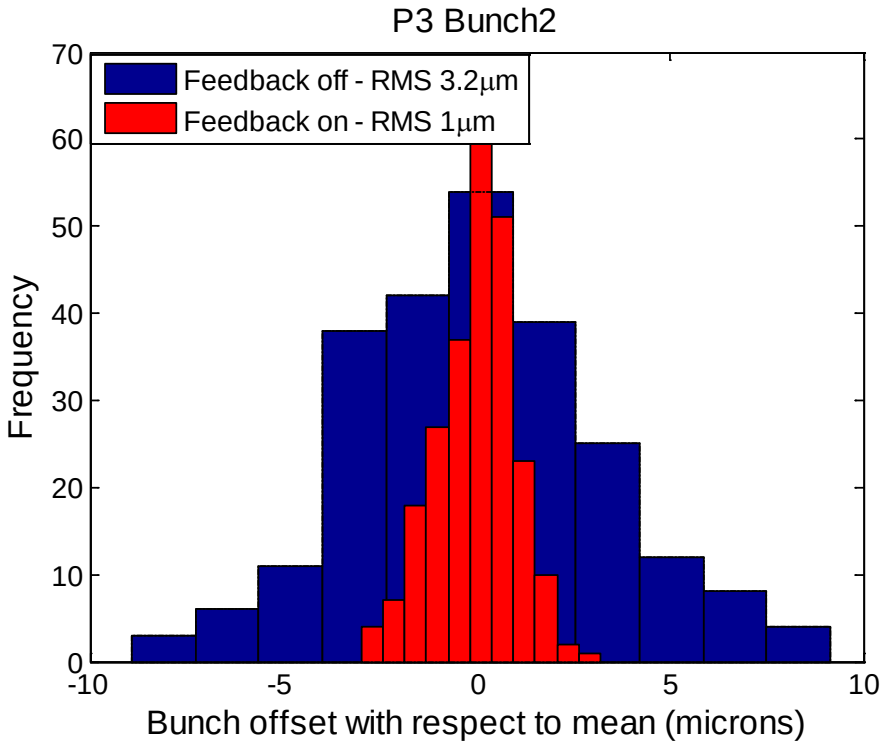
(example FB Run 6 13/12)

bunch	1		2	
	FB off	on	FB off	on
Jitter P2	3.42	3.39	3.42	0.64
P3	3.24	3.16	3.21	1.04

Feedback Performance

(example FB Run 6 13/12)





Feedback Performance

(example FB Run 6 13/12)

bunch	1		2		
	FB off	on	FB off	on	Pred.
Jitter P2	3.42	3.39	3.42	0.64	
1-2 correl 98%					0.67
P3	3.24	3.16	3.21	1.04	
1-2 correl 97%		$\sigma_2'^2 = \sigma_1^2 + \sigma_2^2 - 2\sigma_1\sigma_2\rho_{12} \geq 2\sigma_r^2$			0.83

Deliverables & Milestones

Deliverable	Description/title	Nature	Delivery month
9.3.1	CLIC Quadrupole Module final report	R	M48
9.3.2	Final Focus Test Stand final report	R	M48

Milestone	Description/title	Nature	Delivery month	Comment
9.3.1	Characterization of noise/vibrations sources in an accelerator	O	M24	Done
9.3.2	Installation of interferometers at CTF3 Module	D	M24	Replaced by other means
9.3.3	Installation of ATF2 final-focus alignment monitoring system	D	M6	Tested on ATF2: done
9.3.4	Installation of ILC prototype FB/FF at ATF2	O	M24	Done, under test
9.3.5	Commissioning of CLIC quadrupole module	D	M30	Under progress
9.3.6	Quadruple mock-up manufactured and ready for installation	D	M30	Done

Nice progress on sub-nanometer stabilisation demonstration!

Integration and accelerator environment issues under progress