Key Luminosity Issues of the Main Linac

Andrea Latina for AWG4

LCWS13 – Nov 11-15, 2013 – The University of Tokyo, Japan

Luminosity Issues in ILC ML

- Misalignments:
  - Pre-alignment in a distance range up to betatron period, ~ 400m
  - Tolerances based on simple assumptions (independent, random) are given.
  - Need realistic survey/alignment models.

- BPM scale error (calibration)
  - <10% required.
  - For adjusting to non-zero design vertical dispersion.

- Cavity to cavity accelerating voltage flatness
  - (Cavity tilt) x (voltage change) < (0.3 mm) x (1%) .

ILC ML static errors and cures

- **Agreed "standard"**
  - Random Gaussian distributions are used for most studies
- **DMS (Dispersion Matching Steering)** as standard correction method
  - For dispersion measurement, change beam energy 10% ~ 20%
  - BPM scale error is important ← non-zero design dispersion
  - Emittance / dispersion tuning bumps
- **Other methods** (Kick minimum, Ballistic, wake bumps, etc.) as additional or alternative corrections.
- **Simulations** have shown that the required performance are met
  - Several codes have been benchmarked at the occasion

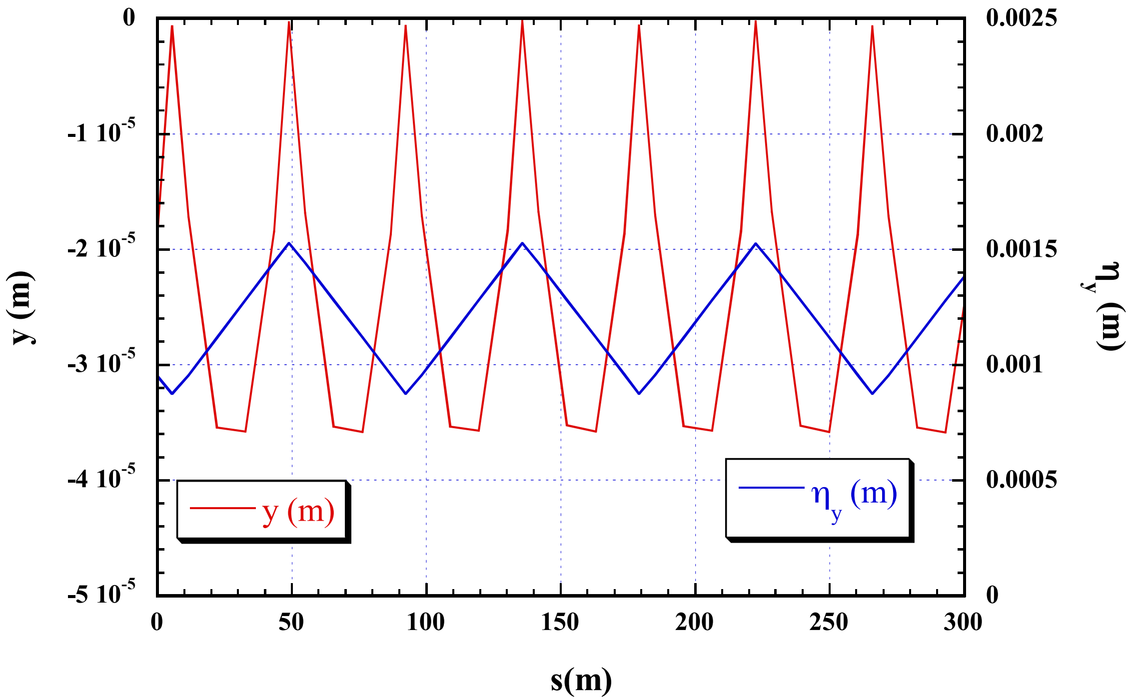
Alignment, BPM requirements

"standard" alignment errors

Error	RTML and ML Cold	with respect to
Quad Offset	300 µm	cryo-module
Quad roll	300 µrad	design
RF Cavity Offset	300 µm	cryo-module
RF Cavity tilt	300 µrad	cryo-module
BPM Offset (initial)	300 µm	cryo-module
Cryomoduloe Offset	200 µm	design
Cryomodule Pitch	20 µrad	design

Independent Gaussian Random assumed in evaluation of all errors.
Not based on realistic survey/alignment models.
Distance range up to betatron period, ~ 400 m, is important.

Linac following earth's curvature, Vertical orbit w.r.t. the reference line and dispersion



DFS correction need to measure nonzero dispersion accurately. → BPM Scale should be accurately calibrated.

Cavity Acc. Voltage Flatness

- Cavity tilt (alignment) + voltage change cause transverse orbit change

- Cavity by cavity Acc. Voltage “Flatness” required
  - RF control for individual cavity, not only “Vector Sum”

- Tolerance:
  - (RMS cavity tilt) x (RMS Flatness) < (300 um) x (1%)

Demonstrated at FLASH (TDR Part I 3.2)

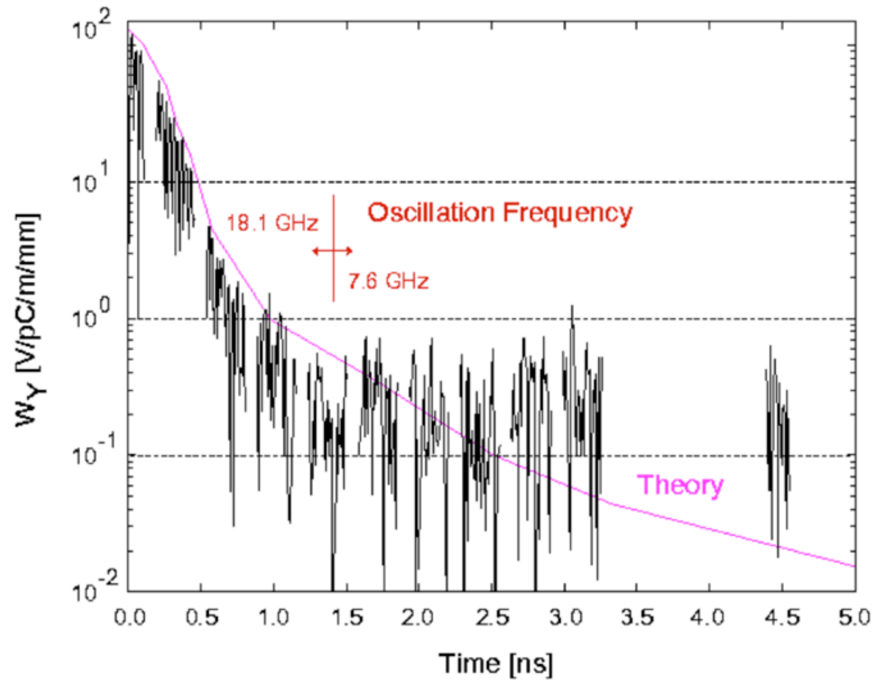
Luminosity Issues in CLIC ML

(See also D. Schulte's overview yesterday)

- **Misalignments** -> pre-alingment, PACMAN, wake-monitors, beam-based alignment and tuning procedures
- **Ground motion and technical noise** -> stabilisation + feedback
- RF phase and amplitude jitter -> drive beam phase feedback, energy feedback
- **RF breakdown rate**
- Fast beam-ion instability -> vacuum
- **Temperature variations and effects on the beam** -> module programme
- Reliability -> FEL developments

Long-range wakefields

Bunch-to-bunch long-range wakefields can induce transverse instabilities leading to beam break-up.



Long-range wakefields are sine-like functions:

$$W_\perp(z) = \sum_i^\infty 2k_i \sin\left(2\pi \frac{z}{\lambda_i}\right) \exp\left(-\frac{\pi z}{\lambda_i Q_i}\right)$$

They can be reduced by

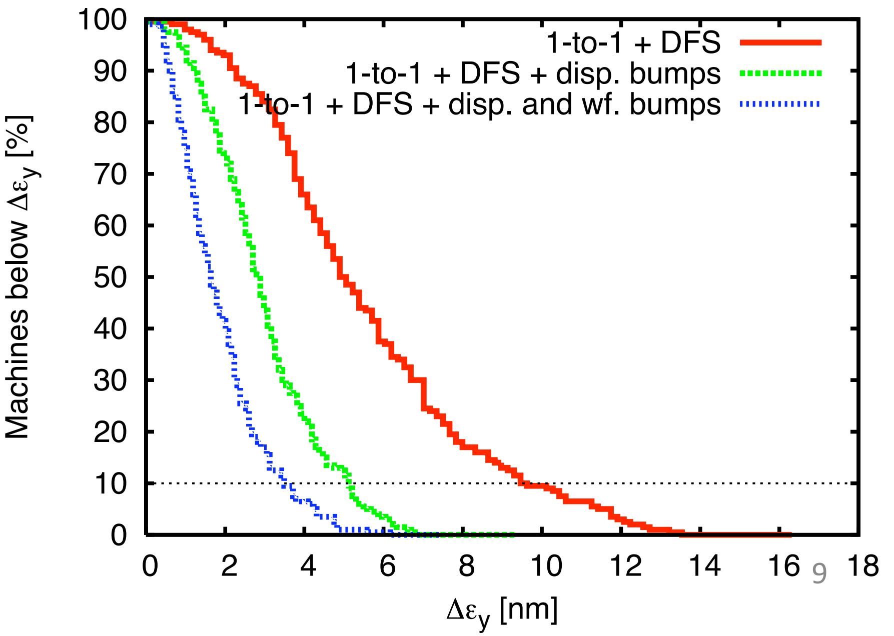
- Damping
- Detuning

Misalignments and BBA

- Rely on **Pre-Alignment of the main linac components**
  – to a level O(10 um) over a window of 200 m

- **Beam-based Alignment** procedure
  – Orbit steering correction
  – Dispersion-free steering using the Bunch Compressor
  – RF Alignment using the wakefield monitors

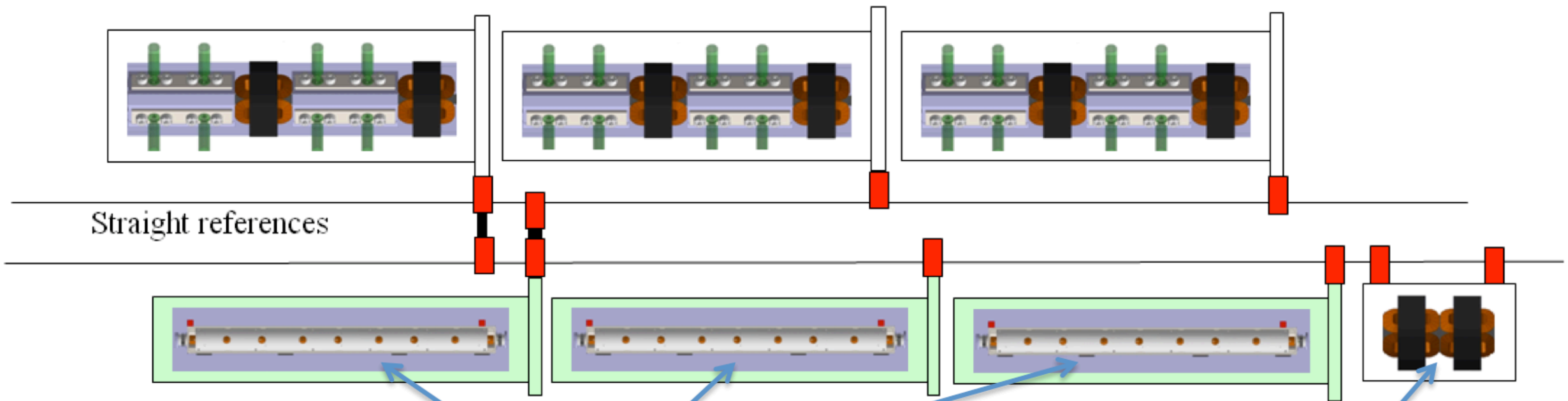
- **Other methods** as a reserve
  – Tuning bumps
  – Wakefield-free steering



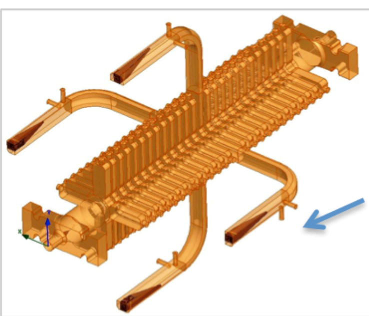
Simulations show that the performance goals are met

CLIC Main Linac Alignment

Emittance preservation feasibility for LC: mainly simulation studies
Currently and next period: experimental studies of alignment methods

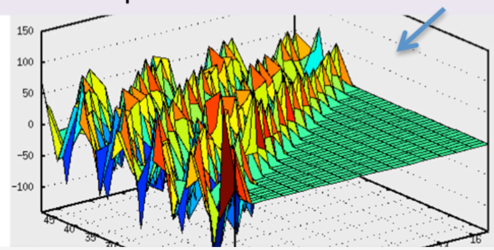


1) Pre-align BPMs+quads
accuracy O(10µm) over about 200m and
Stabilize quadrupole O(1nm) @ 1Hz
Next period: dedicated research test stand



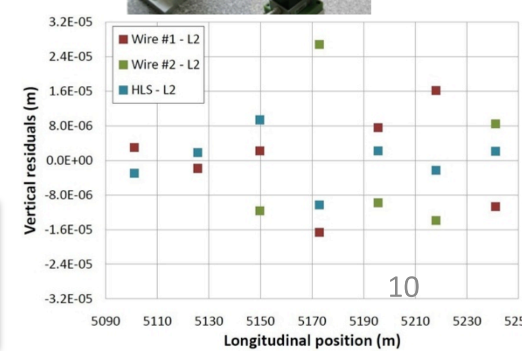
3) Use wake-field monitors
accuracy O(3.5µm).
Next period: improved design and testing in the CLIC Test Facility.

2) Beam-based alignment
Next period: experimental tests at FACET



Pre-alignment O(10 um) over a window of 200 meters

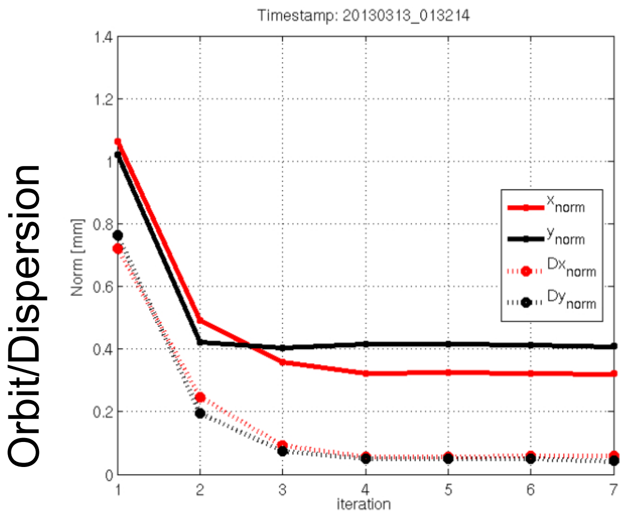
- Test of prototype shows
  - vertical RMS error of 11µm
  - i.e. accuracy is approx. 13.5µm



CLIC Beam-Based Alignment tests at FACET

Dispersion-free Steering (DFS) proof of principle – March 2013

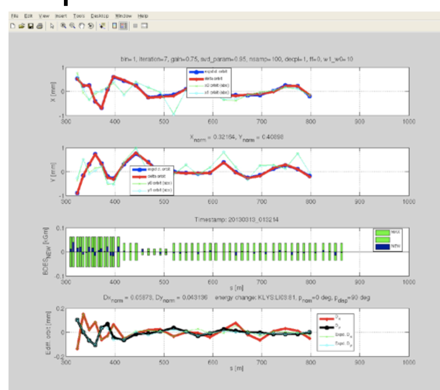
A. Latina,
J. Pfingstner,
E. Adli,
D. Schulte

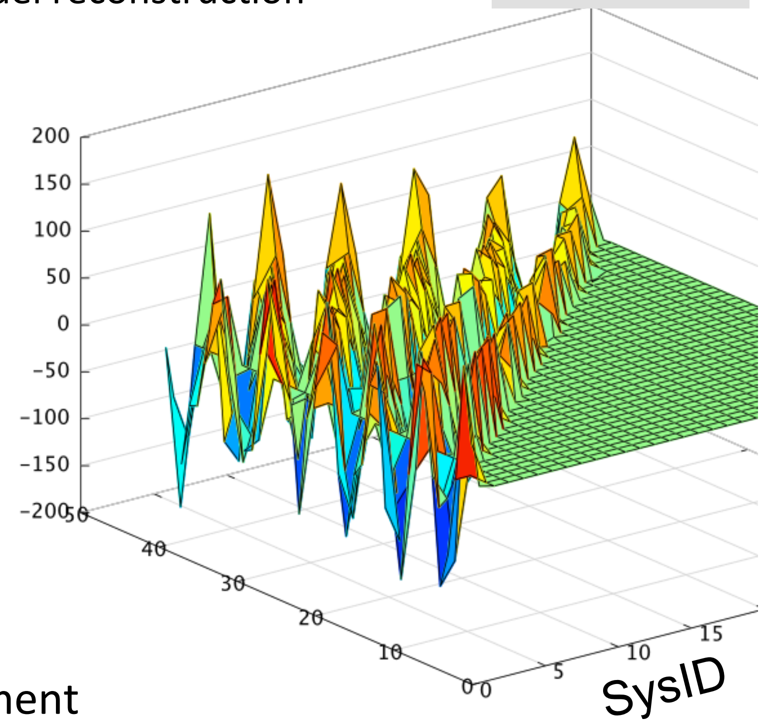


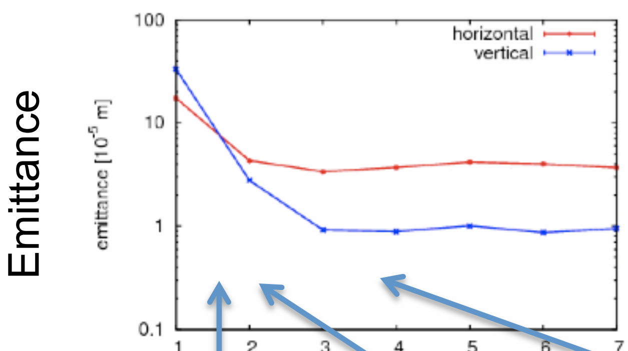
DFS correction applied to 500 meters of the SLC linac

- SysID algorithms for model reconstruction
- DFS correction with GUI
- Emittance growth is measured

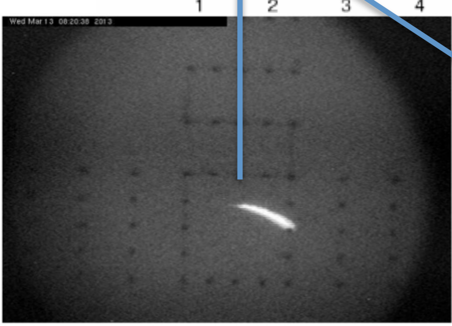
Graphic User Interface:



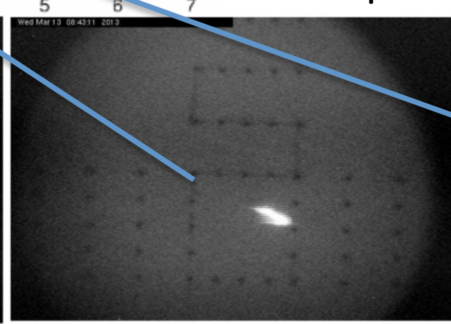




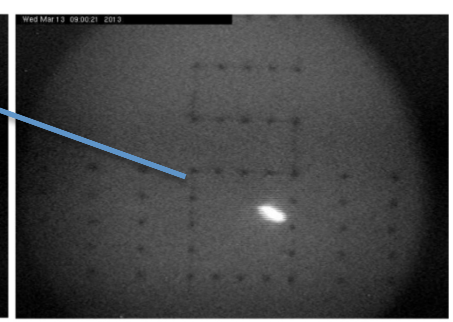
Beam profile measurement



Before correction



After 1 iteration



After 3 iterations

Incoming oscillation/ dispersion is taken out and flattened; emittance in LI11 and emittance growth significantly reduced.

Emittance preservation – To do List

- Simulations with more realistic models of pre-alignment
- Integrated simulations of RTML+ML
  - DFS in the main linac relies on the BC
- More experimental tests of BBA:
  - On-going experiments at FACET
  - emittance / dispersion tuning bumps
  - BC used for DFS: Tests at a FLASH / XFEL?
- More hardware tests (see next slide)

More hardware component tests

- Specific to CLIC:
  - Measurement of Long-range Wakefields in the CLIC AS
    - Experiment at SLAC does not seem to be possible
  - Wakefield monitors in the CLIC AS

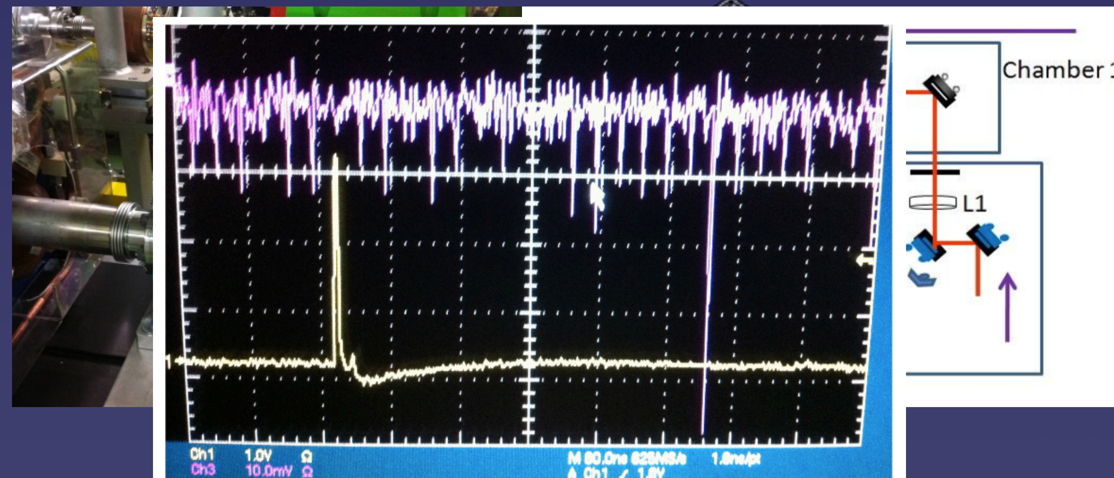
- Common with ILC:
  - Impact of misaligned cavities on the beam
  - Impact of tilted cavities

- Specific to ILC:
  - Tests of cold Cavity-BPMs
  - Tests of Linearity of BPMs in cryomodules

Wakefield monitors: CTF3 as diagnostics test bed

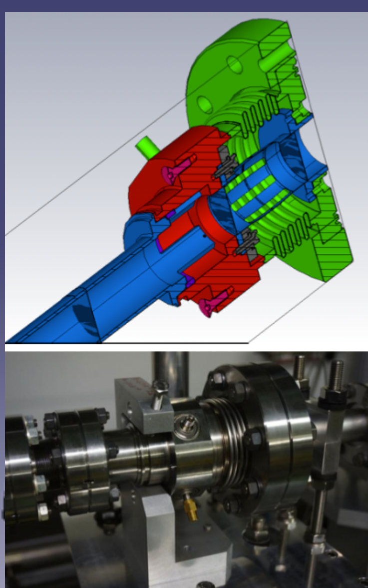
(See R. Corsini's talk later)

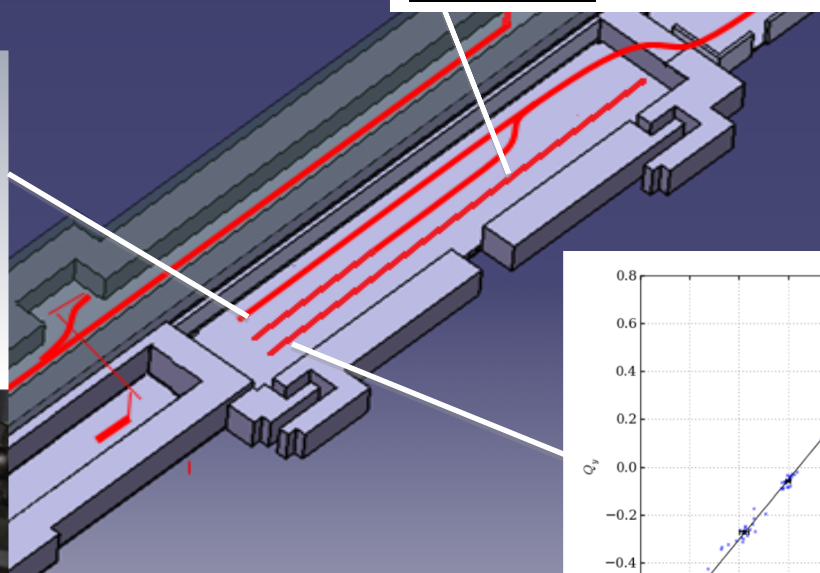
Electro-optic bunch profile monitor
in CALIFES
(CERN-Dundee University)



R. Pan, T. Lefebre

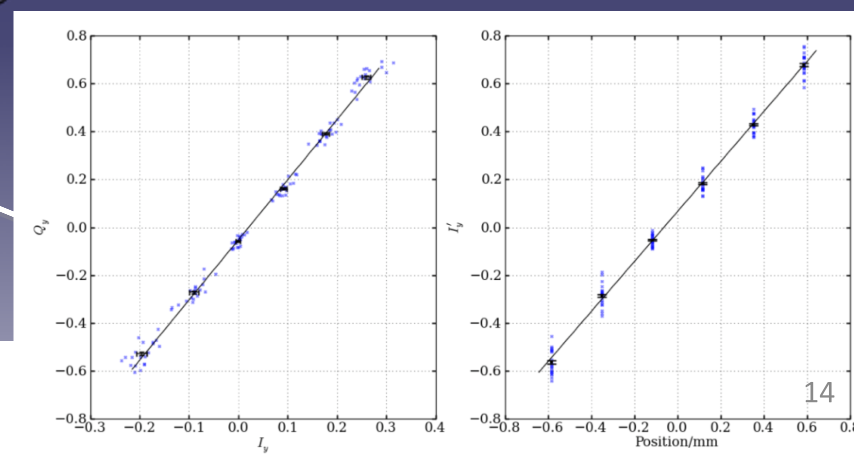
Stripline Drive Beam BPM
in TBL
(CERN-LAPP)





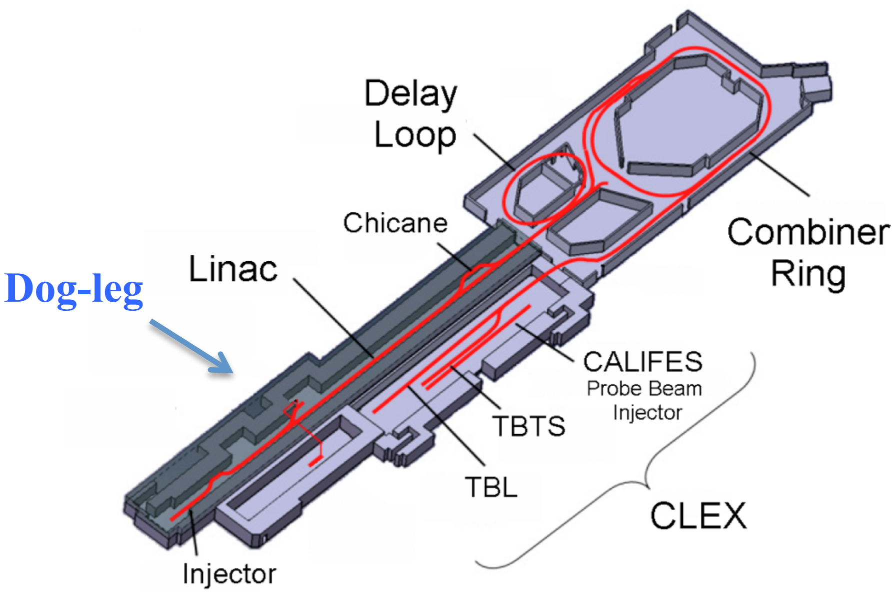
2013 Goals

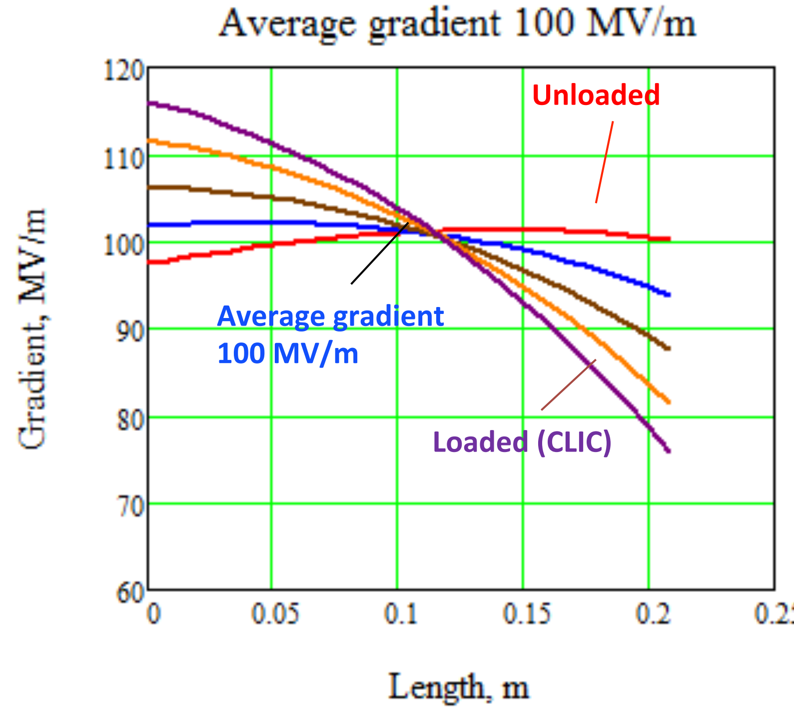
Cavity Main Beam BPM
in CALIFES/TBTS
(CERN-JAI at Royal Holloway)

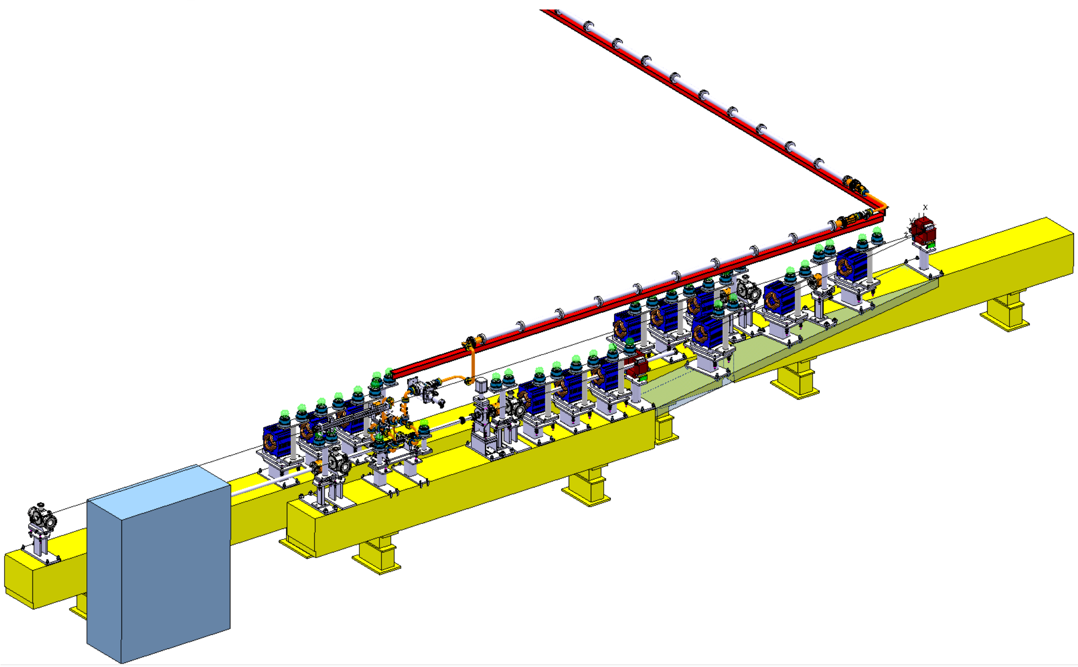


F. Cullinan, J. Towner, W. Farabolini, M. Wendt…

Beam loading test facility



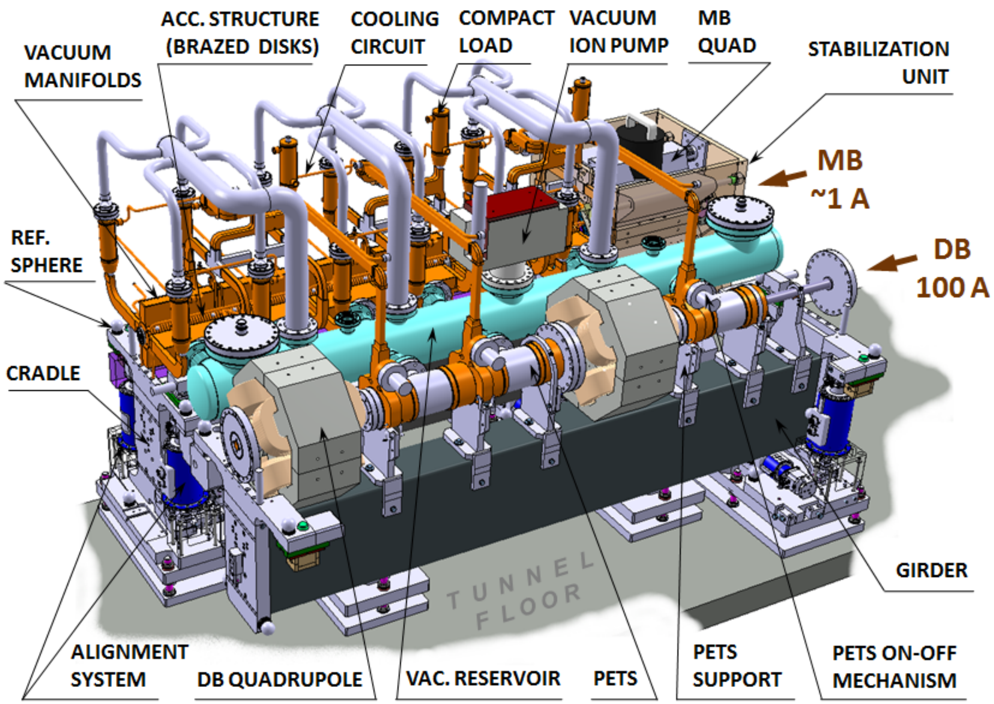


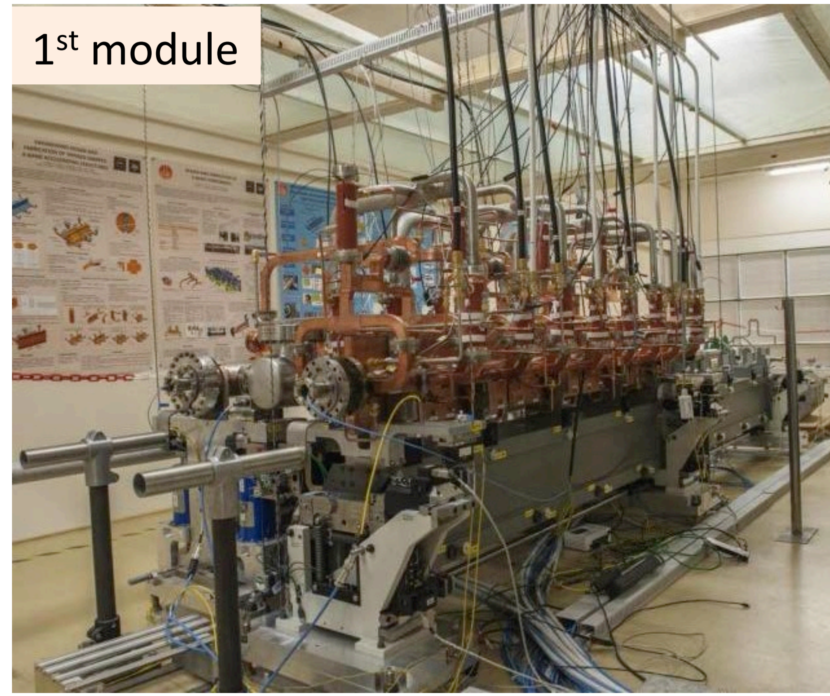


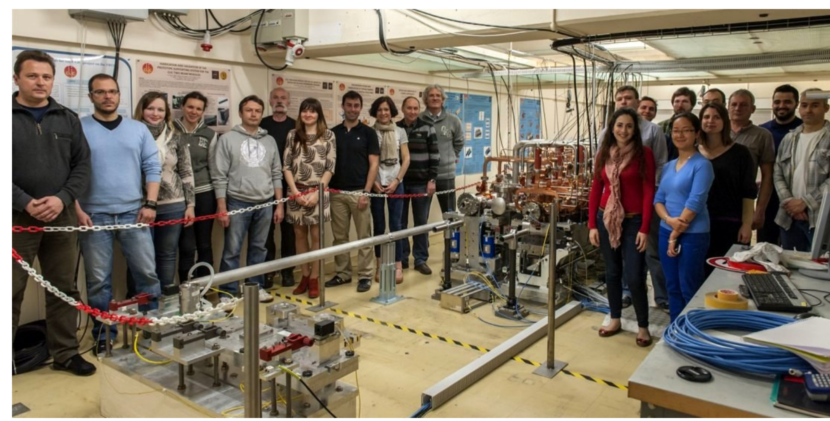
Test stand in CTF3 dog-leg to test gradient with **beam loading**

- Structure powered at full power with 12 GHz klystron
- 1 A drive beam sent through structure
- System begin commissioned
- Conditioned structure to come this year

CLIC Two-beam Module







Complete test modules:

- All safety measures implemented (power dissipation ~7 kW per module)
- DAQ and control system (Labview based) tested and validated
- First tests promising and in line with FEA simulations
- Tests of airflow possible in tunnel mockup
- Modules are equipped with heaters to study temperature changes and slow variations

Stabilisation: PACMAN

PACMAN Training Network, a study on:
Particle **A**ccelerator **C**omponents' **M**etrology and **A**lignment to the **N**anometer scale

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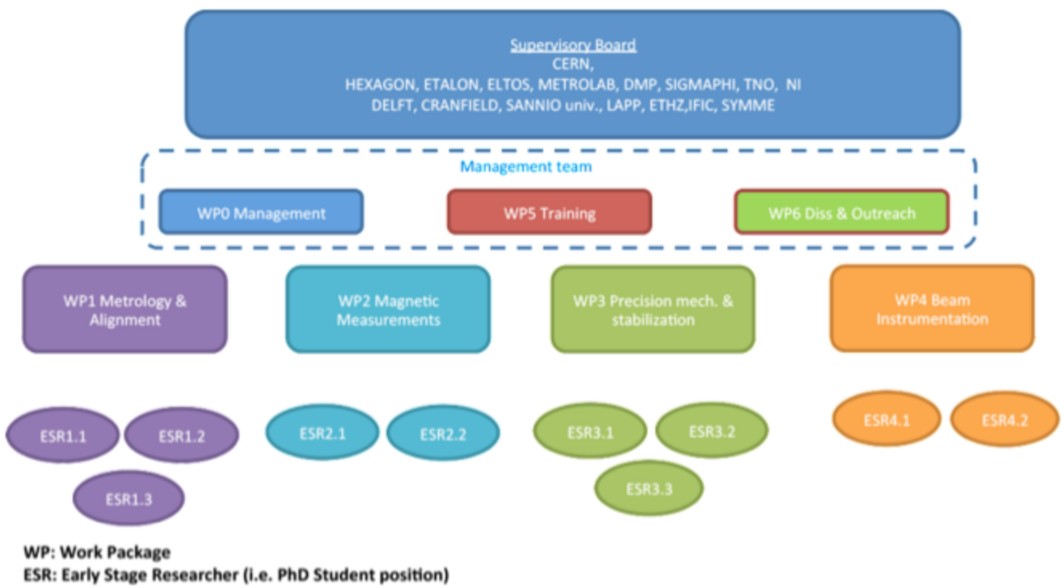
Quadrupoles need to be stable to O(1nm) level @ 1HZ: Dedicated research test stand

MAIN MENU

- Home
- Scientific Project
- Vacancies-Application
- Network Partners
- **Organization**
- Past & Future Events
- Publications
- Outreach
- For Members only

Organization



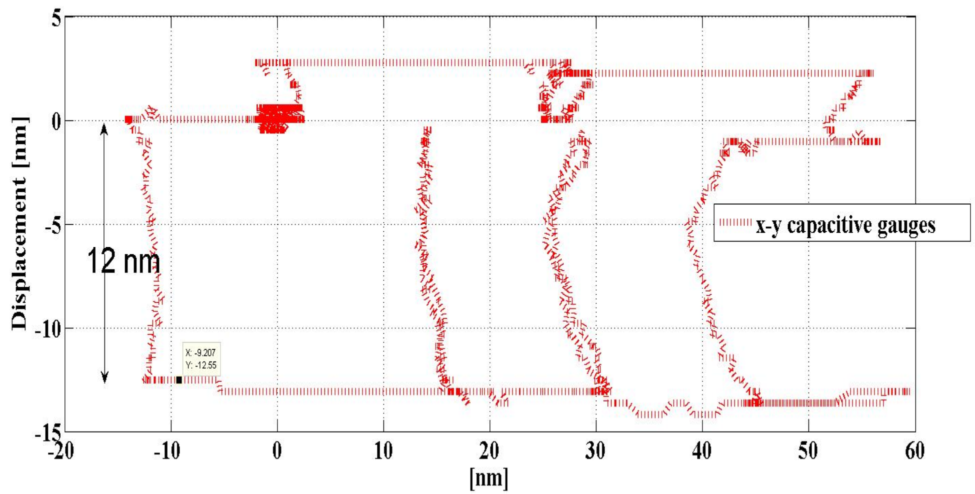
See talk by J. Pfingstner later

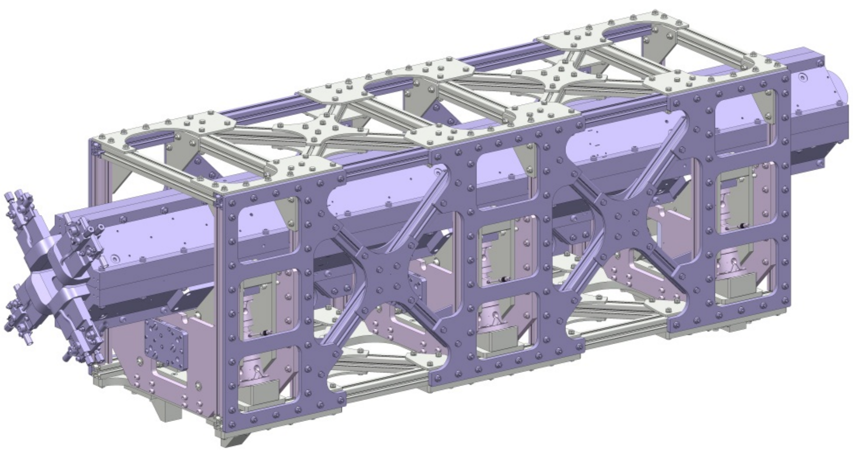
Stabilisation Progress

Integrated studies of ground motion, hardware and beam allowed to define new specifications for motion sensors

New sensor is being developed
First promising results

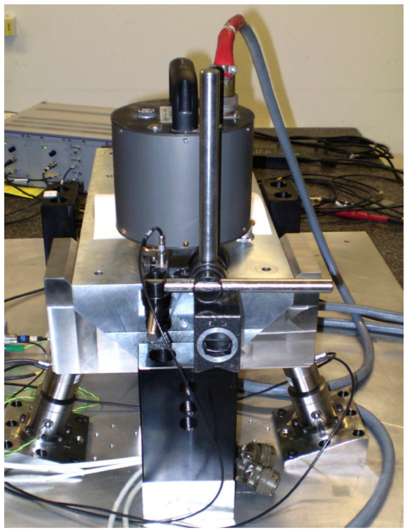
Position verified to be 0.25nm



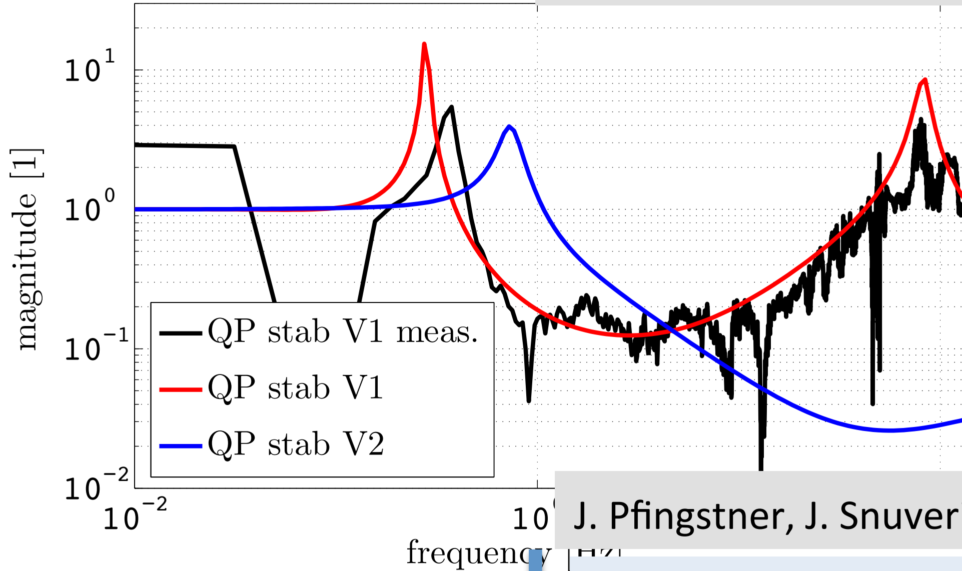


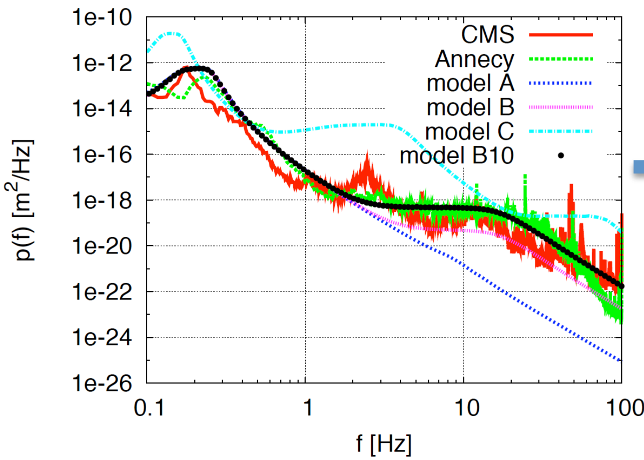
Prototypes for module under production
Long magnet design

Active Stabilisation Results



K. Artoos, A. Jeremie et al.





Code

Machine model
Beam-based feedback

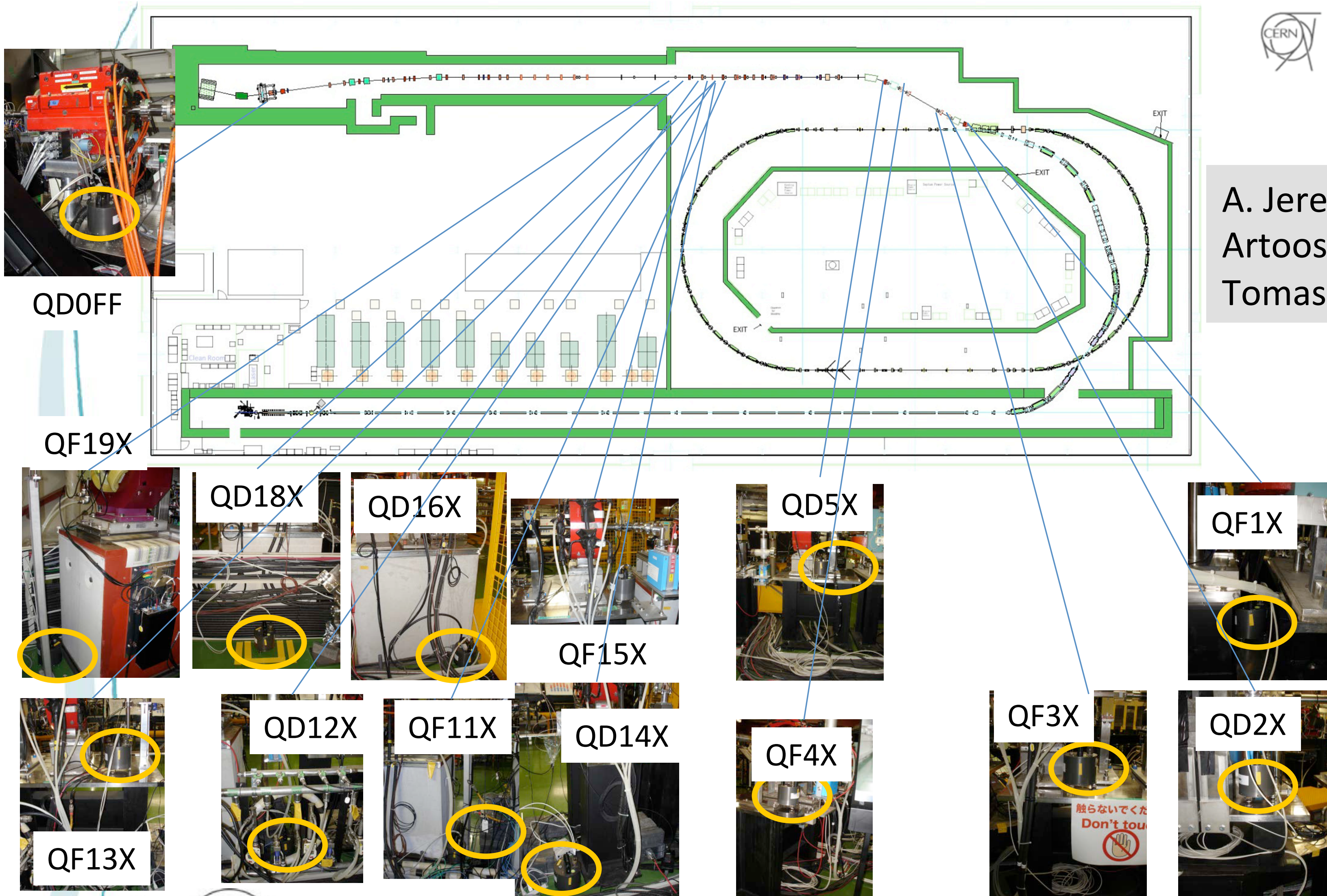
J. Pfingstner, J. Snuverink et al.

Luminosity achieved/lost

	B10
No stab.	53%/68%
Current stab.	~~108%/13%~~ 114%/7%
Future stab.	118%/3%

Close to/better than target

Stabilisation Experiment



A. Jeremie, K. Artoos, R. Tomas et al.

Conclusions, and review of test facilities

- Long list of on-going experimental activities and experimental successes
  - CTF3, CLIC Two-Beam Module, FLASH, FACET, ATF2, etc. etc.
  - Keep going

- Theoretical studies are on-going, some new are needed
  - Pre-alignment models and simulations of integrated BBA: BC+ML
  - DMS with BPM calibration errors in ILC
  - Stabilisation
  - Review vacuum / fast ion-beam instability

- Experiments should continue, new experiments and hardware tests should be envisaged
  - BBA and emittance preservation, different methods, BC for DFS
  - CLIC AS long-range wakefields
  - Reliability: FEL developments