CLIC contributions to ATF2&ATF3

Kurt Artoos, Mike Barnes, Benoit Bolzon, Yannis Papaphilippou, Jürgen Pfingstner, Yves Renier, Hermann Schmickler, Daniel Schulte, Steinar Stapnes, Rogelio Tomas, Frank Zimmermann

ATF2 Project Meeting, 14 January 2011

ATF + ATF2 past and current profits

- **THE most important test facility for damping ring and beam delivery system issues**
  - Demonstration of **compact final focus & BDS tuning** are critical issues for CLIC and ILC, ATF2 experience invaluable
  - **FONT** (Feedback On Nano-second Timescales) test
  - World leading **BPM resolution**
  - **Extraction kickers**
  - **Operation** of ATF

ATF + ATF2 past and current profits

- **Training of young people** at ATF/ATF2
  - **very important**
  - **CERN hired three former PhD students from ATF/AFTF2 as fellows** (Maria del Carmen Alabau Pons, Yves Renier and Benoît Bolzon)!
    F. Zimmermann had suggested the topic for M. Alabau's ATF thesis work
  - **CERN PhD student Eduardo Marin is working on ATF2**

some past CLIC contributions

- **Optics** measurements (J.-P. Potier)
- **Nonlinear dynamics analysis & dynamic aperture studies** (F Schmidt, F. Zimmermann)
- **Design & tuning studies**, **optimization code (MAPCLASS**, R. Tomas)
- Proposal of **very low beta* optics** (R. Tomas)
- **CSR** calculations for ATF (F. Zimmermann)
- **CERN/Spanish PhD student work on ATF2** (Eduardo Marin Lacoma)

proposed future CLIC contributions

1) **Ultra-low beta-function**

   Limited by QF1, CLIC considers providing one with larger aperture

2) **Ground motion feedback/feed-forward**

   Ground motion sensors on each relevant magnet to predict beam orbit

3) **Test of quadrupole stabilisation in ATF extraction**

   Could be best way to verify stabilisation performance with beam

4) **Developing damping ring extraction kickers systems**

   Would need ATF3 to verify kicker performance

5) **CSR induced beam instability in ATF-DR**

   Experiments to distinguish between theories

6) **DR optics, emittance tuning & IBS studies**

7) **Superconducting wiggler for ATF**

8) **BPM tests**

   CLIC main linac BPMs developed by FNAL tested at ATF2; more in future

9) **Contributions to ATF2/3 operation**

1) ultra-low beta-function

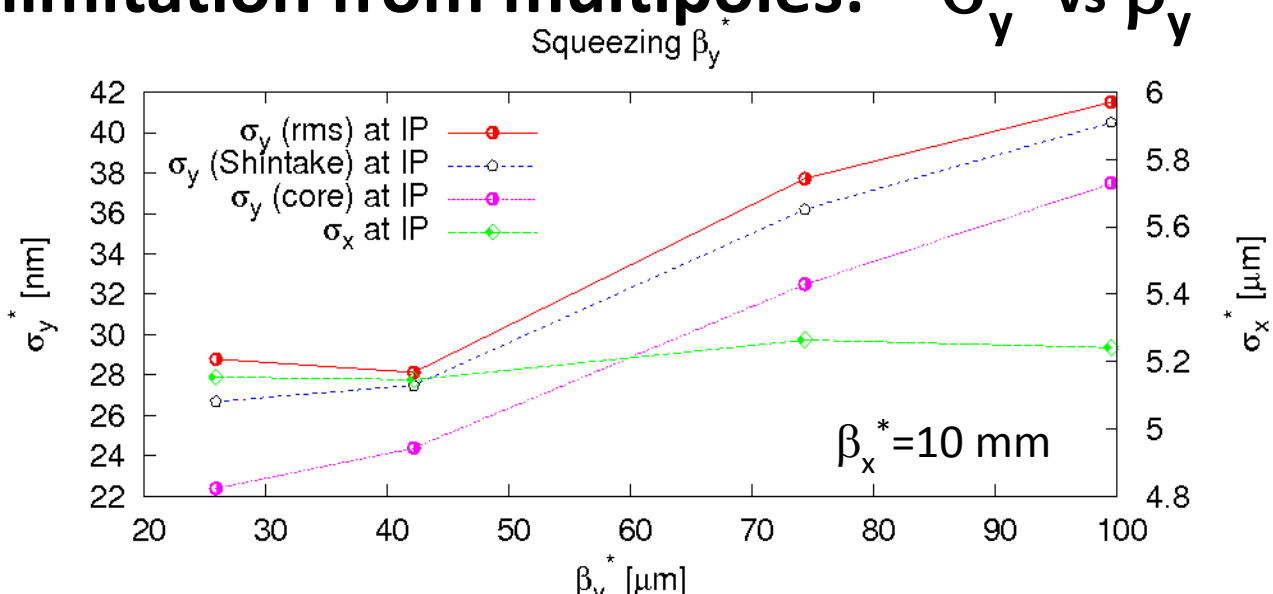
R. Tomas

motivation

project	L^*[m]	β_y^* [μm]	ξ_y
ATF2 nominal	1.0	100	~19000
ILC design	3.5	400	~15000
ATF2 ultra-low	1	25	~76000
CLIC 3 TeV	3.5	90	~63000

To prove CLIC chromaticity levels in ATF2 requires a factor 4 lower IP beta function. The main obstacle is the field quality (already issue for ATF2 nominal)

limitation from multipoles: σ_y^* vs β_y^*



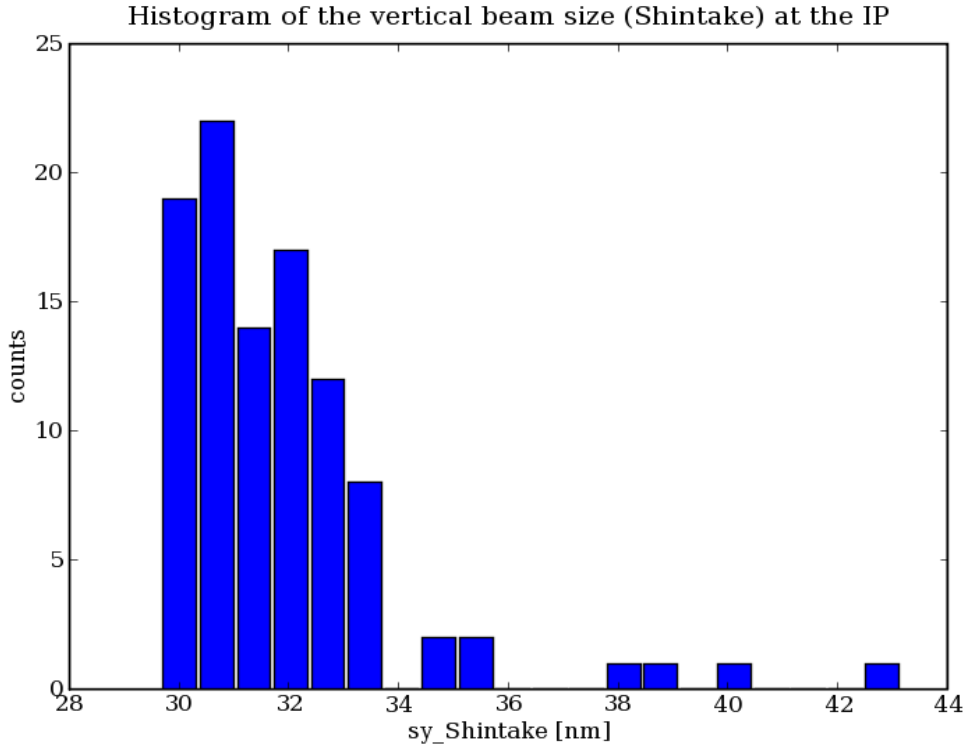
with measured magnetic multipoles; optimization with MAPCLASS; no further reduction when decreasing β_y^* below 40 μm

1) ultra-low beta-function cont'd

β_y^*=40 μm; β_x^*=10 mm

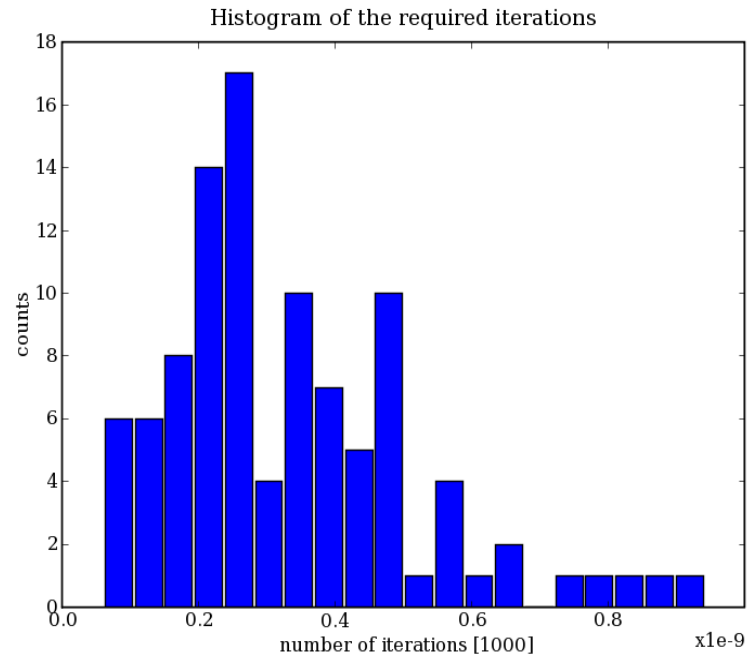
tuning ATF2 ultra-low β_y

R. Tomas,
E. Marin



90% seeds reached a $\sigma_y^* < 34$ nm

Tuning based on an iterative application of knobs. All seeds converge below 1000 iterations.



all elements misaligned and tuning knobs applied; beam sizes after tuning not as good as design; work in progress to improve further

1) ultra-low beta-function cont'd

ways to reach β_y^*=25μm

E. Marin, D. Schulte, R. Tomas

1. **Replacing QF1** with a superconducting quadrupole (B. Parker) removes most of the harming nonlinearities; **if SC Q1 does not become available, CLIC considers building better-quality warm Q1(2) magnets for ATF2(3)**

2. **Reducing DR horizontal emittance** (SC wigglers) **CLIC considers contributing new high-field low-period *Nb_3Sn* wiggler (~15-20% emittance reduction)**

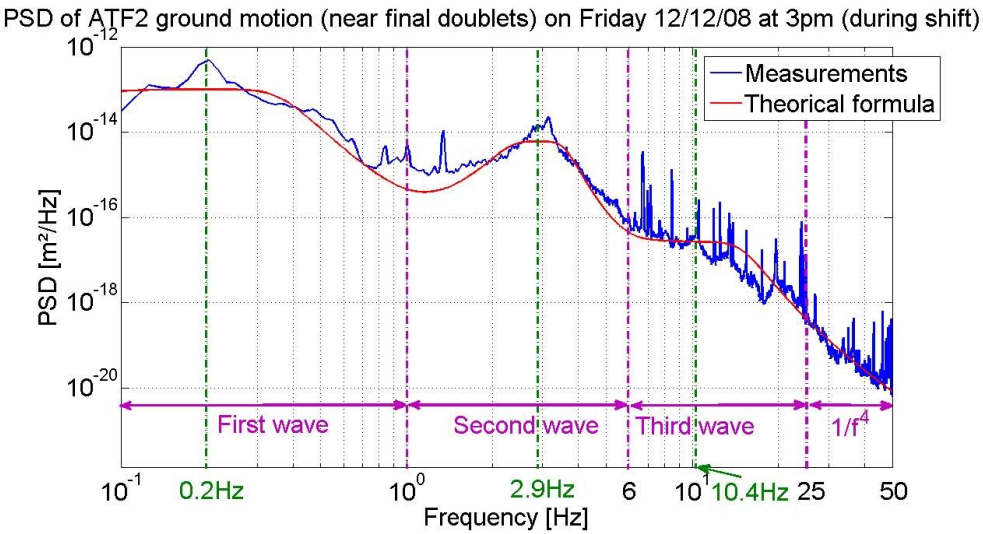
3. **New non-linear corrector magnets** in ATF2 beam line **CLIC could also provide such elements (instead of or in addition to Q1(2))**

2) ground motion feedforward

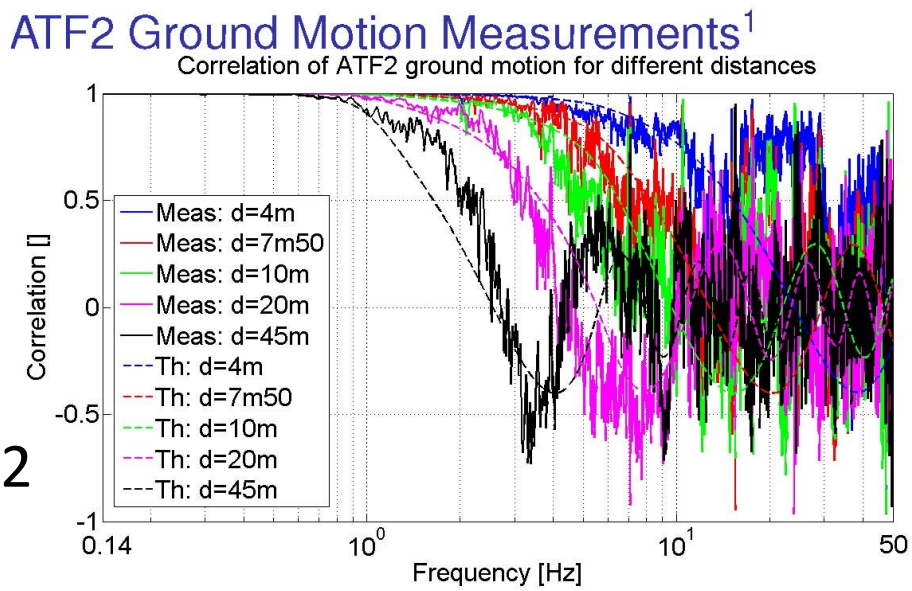
Y. Renier, D. Schulte

direct feed-forward on ground motion

correct beam motion created by relative displacement of quadrupole magnets due to ground motion by measuring the latter with vibration sensors & correcting it in feed forward with orbit kickers



ground motion p.s.d. at ATF2



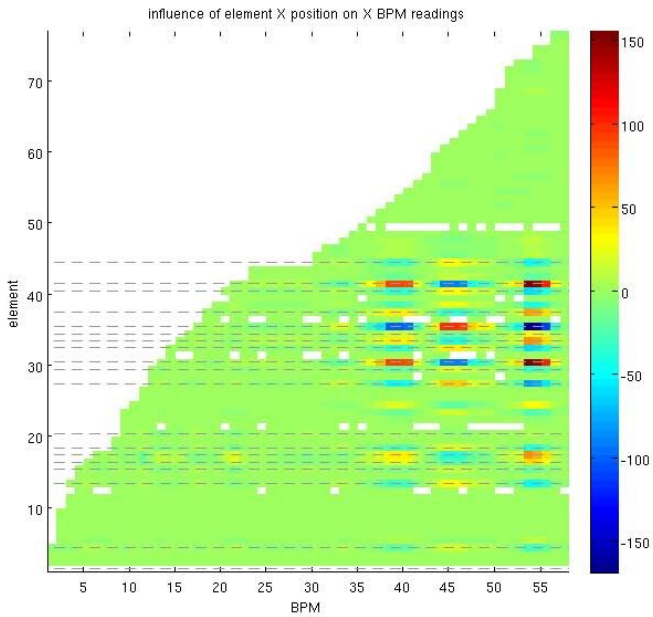
ground motion correlation at ATF2

2) ground motion feedforward – cont'd

PLACET simulation with ATF2 ground motion model

- Compute the matrice of the effects of element displacements on BPM readings.
- Find the elements with the higher effects and select them to have GM sensor.
- Put also a sensor on the first and last element.

Y. Renier,
D. Schulte

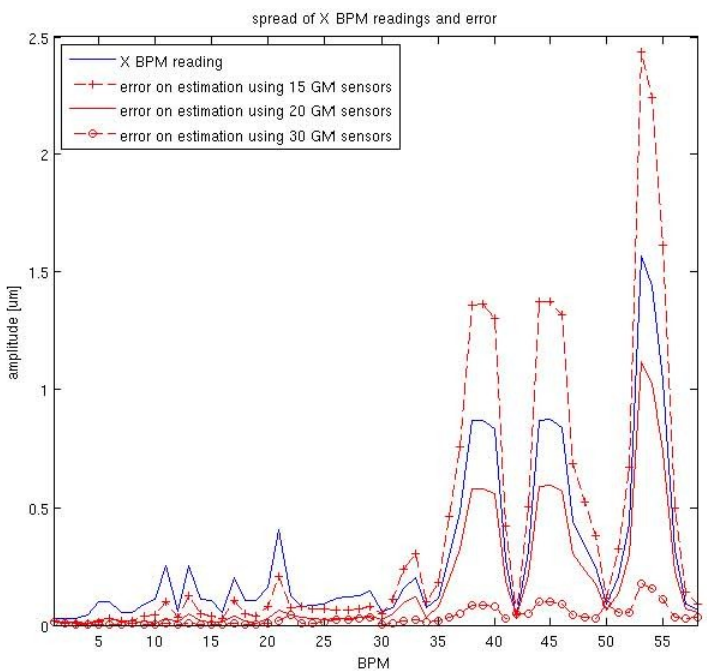


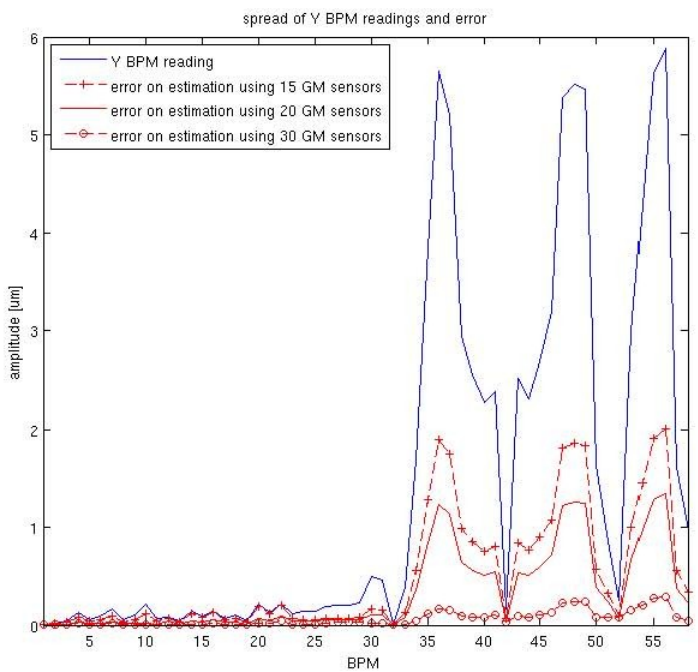
2) ground motion feedforward – cont'd

Algorithm - Each Pulse

- From the measured GM interpolate linearly with the distance the displacements of other elements.
- Deduce the induced beam displacements.

Y. Renier,
D. Schulte





residual trajectory error using different # of GM sensors

2) ground motion feedforward – cont'd

simulation results

Y. Renier,
D. Schulte

- study to determine number of sensors needed was completed

- with 20 sensors at 6Hz, GM effect reduced from several μm to 1 μm stability at high-β points

- **with 30 sensors at 6Hz, GM effect reduced from several μm to 200 nm stability at high-β points**

- caveat:
  no imperfections considered yet (incoming beam jitter, BPM and GM sensor resolution, ...).

2) ground motion feedforward – cont'd

proposed ATF2/3 experiment:

1. installing ground motion sensor on floor next to quadrupoles (20-30 vertical seismometers) **CLIC can provide the seismometers**	2012
2. simultaneous recording of seismometers & BPMs (about 20)	2012
3. analysis of correlation between beam trajectory and ground motion	2012
4. determining the feasibility of feed forward correction and system design	2012
5. installation/implementation of orbit kickers	2013
6. test feed-forward with beam	2013

3) test of quadrupole stabilisation in ATF extraction line

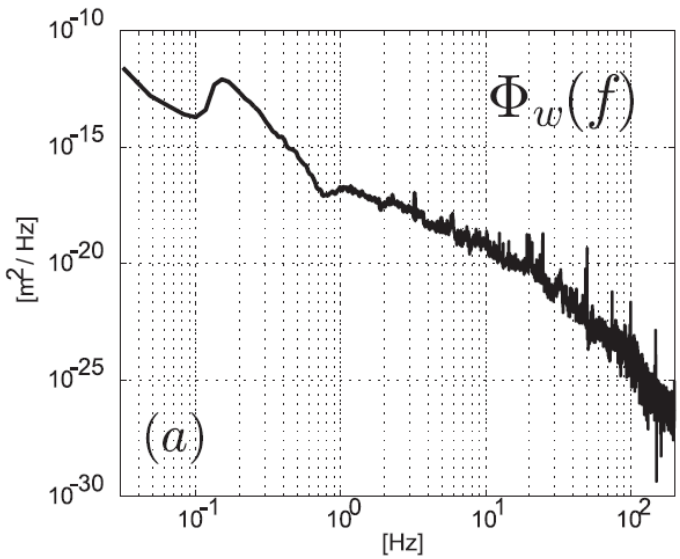
	Final Focus quadrupoles	Main beam quadrupoles
Vertical	0.1 nm > 4 Hz	1 nm > 1 Hz
Lateral	5 nm > 4 Hz	5 nm > 1 Hz

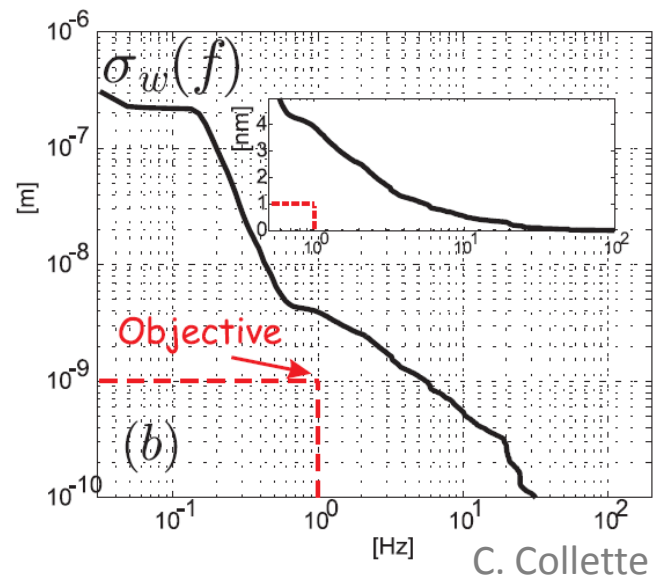
CLIC stability requirements

K. Artoos, H. Schmickler

Values in **integrated r.m.s. displacement at 1 Hz**

$$\sigma_x(1) = \sqrt{\int_1^\infty \Phi_x(f)\,df}$$





C. Collette

3) test of quadrupole stabilisation in ATF extraction line – cont'd

present CLIC design approach

K. Artoos, H. Schmickler

(CLIC stabilization WG, K.Artoos et al.)

- **active stabilization in feedback loop using electromechanical sensors & (piezo) actuators**
- **optimized mechanical design**
  - girders, magnets and electromechanical alignment system
  - best choice for number and position of actuators and sensors
  - low Q mechanical resonances in order to avoid vibration amplification
  - mechanical resonances at the highest possible frequencies
- **mimimization of environmental noise**
  - through isolation from vacuum chamber vibration, cooling flows, cable vibration and microphonic coupling
- **experimental verification of the stabilization result**
  - construction of real hardware based on a **quadrupole prototype and active stabilization system**

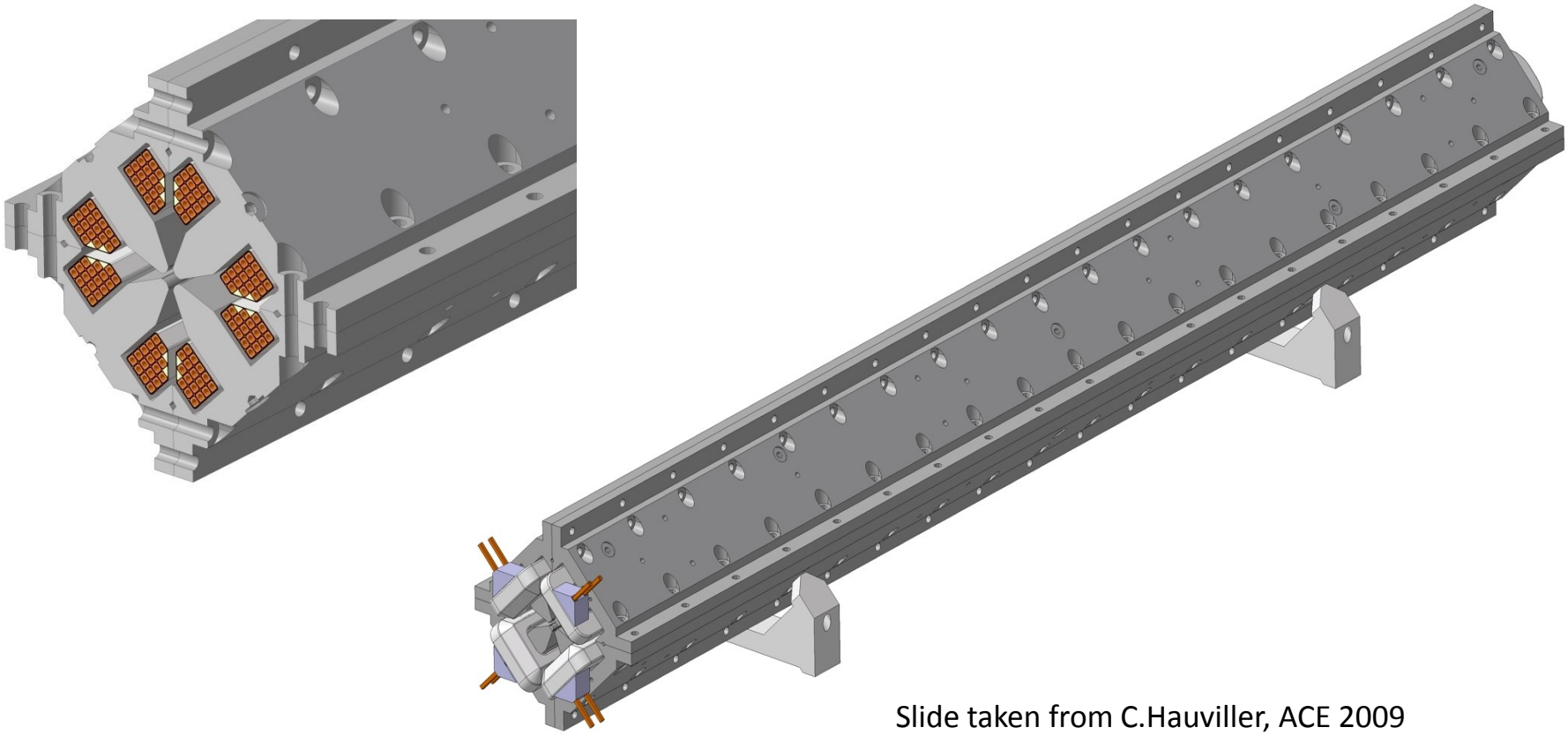
Present work program: A "type 4" quad ready for lab tests mid 2011

3) test of quadrupole stabilisation in ATF extraction line – cont'd

CLIC main beam quadrupole

K. Artoos, H. Schmickler

- Under final design
- Assembly methods to be tested (micron accuracy!)



Slide taken from C.Hauviller, ACE 2009

3) test of quadrupole stabilisation in ATF extraction line – cont'd

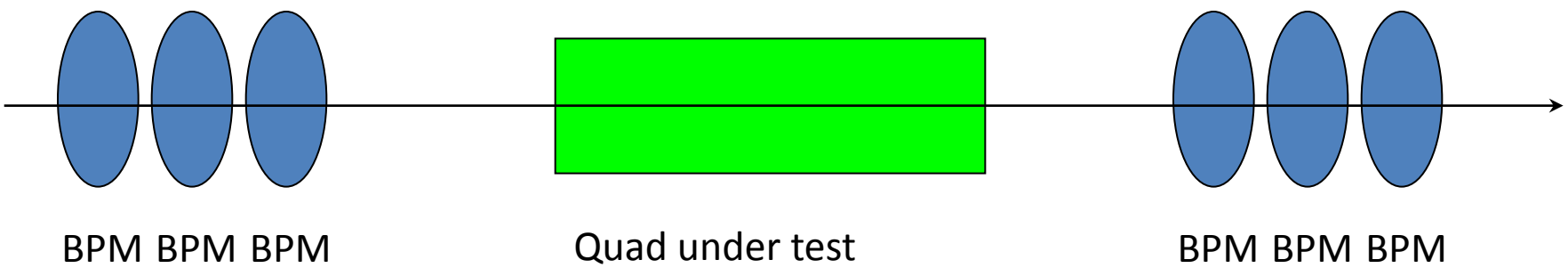
K. Artoos, H. Schmickler

necessary complementary verification ?

- System uses electromechanical sensors on outer shell
- Pole-tip & coil vibrations might not be detected
- Limited number of monitors might not catch all vibrations

→ **Verify field stability by high-E low-ε particle beam at ATF2/3**

spectrometer like configuration



-qualify BPM resolution within blocks of 3 and within the 2 blocks
-measure additional BPM jitter with quadrupole powered
-deduce quad jitter from measurements

3) test of quadrupole stabilisation in ATF extraction line – cont'd

K. Artoos, H. Schmickler

ATF2/3 extraction line test – ingredients & objectives

- generic **high resolution (cavity) BPM development** including electronics:
  target: **nm-level for single shot 1 nC pulses**
- **implementation study of spectrometer setup at ATF3 anticipated problems:**
  - **small quad aperture** (8 mm)
  - **high gradient** (200 T/m)
  - **low rep-rate**: Limited information about frequency dependence on **residual quadrupole vibration**
- the **beam experiment** itself (**2013 or later**)

4) damping ring extraction kickers

selected CLIC DR, ILC & DAΦNE kicker parameters

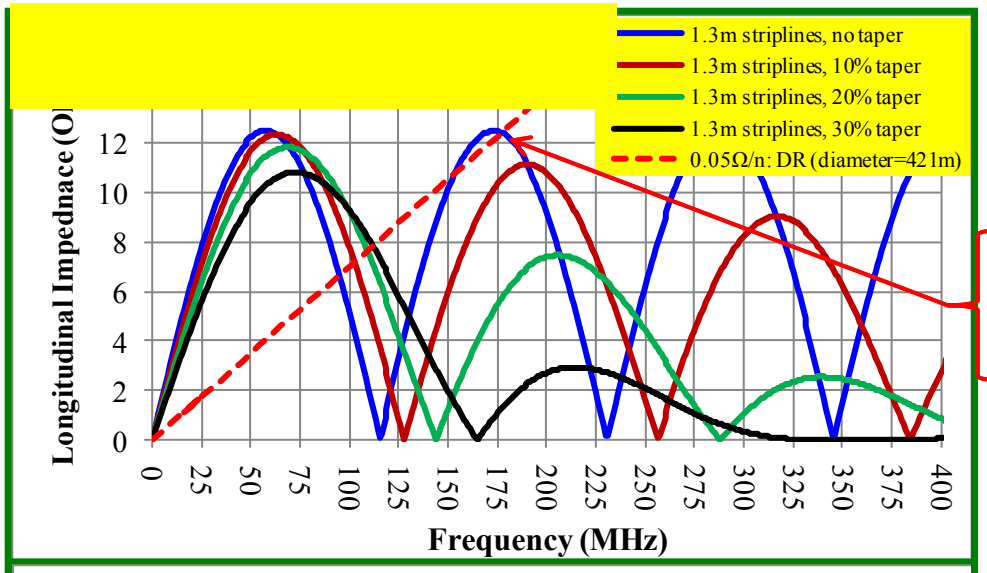
M. Barnes

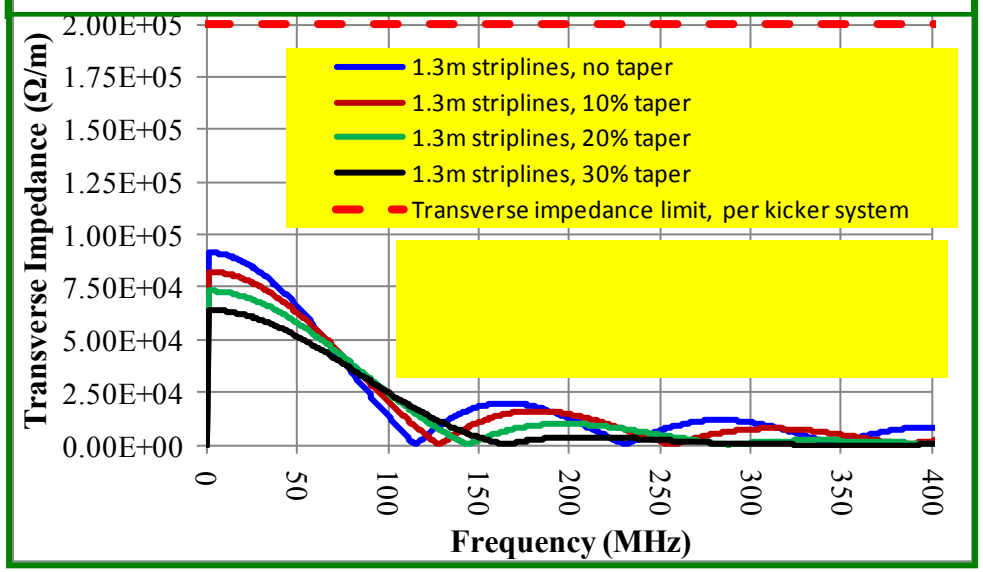
	CLIC Pre-Damping Ring	CLIC Damping Ring	CTF3 Tail-Clipper	ILC	DAΦNE
Beam energy (GeV)	2.86	2.86	0.2	5	0.51
Total kick deflection angle (mrad)	2.0	1.5	1.2	0.7	5
Aperture (mm)	~40	20	40	24[6] (tapered)	54.8 (tapered)
Effective length (m)	**2*1.7**	**1.7**	4*0.295	20*0.32=~6.4	0.94
Field rise time (ns)	700	1000	≤5	3	~5
Field fall time (ns)	700	1000	NA	3	~5
Pulse flattop duration (ns)	~160	~160	Up to 140	NA	NA
Input pulse duration (ns)					5.3
Flat-top reproducibility	1×10^{-4}	1×10^{-4}	NA	1×10^{-3}	??
Flat-top stability [inc. droop], per Kicker **SYSTEM** (Inj.) (Ext.)	$\pm2\times10^{-2}$ $\pm2\times10^{-3}$	$\pm2\times10^{-3}$	NA	1×10^{-4} 1×10^{-4}	?? ??
Field homogeneity (%) [CLIC: **3.5mm** radius] [CLIC: **1mm** radius]	±0.1 (Inj.) ±0.1 (Ext.)	±0.1 (Inj.) ±0.01(Ext.)	±18	±??	
Repetition rate (Hz)	50	50	50	5 (3M burst)	50
PFN voltage per Stripline (kV)	**~±34**	**~±25**	±5.6		
Pulse voltage per Stripline (kV)	**±17**	**±12.5**	±2.65	±5	±45
Stripline pulse current [50 Ω load] (A)	**±340**	**±250**	±53	±100	±900

4) damping ring extraction kickers – cont'd

beam impedance of CLIC DR striplines

M. Barnes





M. Barnes

Allowable longitudinal broad band beam impedance, in the CLIC PDR & DR, is ~1 Ω/*n*. The maximum longitudinal impedance per kicker system is assumed to be 5% of this allowance, i.e. 0.05Ω/*n*.

Tapers are required to ensure that the longitudinal impedances in the range from 150 MHz to 180 MHz are less than 0.05Ω/*n*.

To maximise the efficiency of the stripline kickers, the length of the taper should be minimised: however tapers reduce the non-uniformity of transverse deflection, as a function of the transverse position (Alesini), hence the length of taper must be optimised.

The allowable transverse broad band beam impedance, in the CLIC PDR & DR, is 10 MΩ/m. The maximum transverse impedance per kicker system is assumed to be 2% of this allowance for each ring, i.e. 200kΩ/m.

Striplines will be researched, designed and prototyped under the Spanish Program "Industry for Science".

4) damping ring extraction kickers – cont'd

M. Barnes

"n-Cell" Inductive Adder

An **Inductive Adder** is a promising means of **compensating for ripple as well as attenuation and dispersion** in transmission cables. Adder will consist of:

- **a multi-cell primary circuit**;
- **a single secondary winding**;
- a fast pulse transformer with adequate voltage isolation.

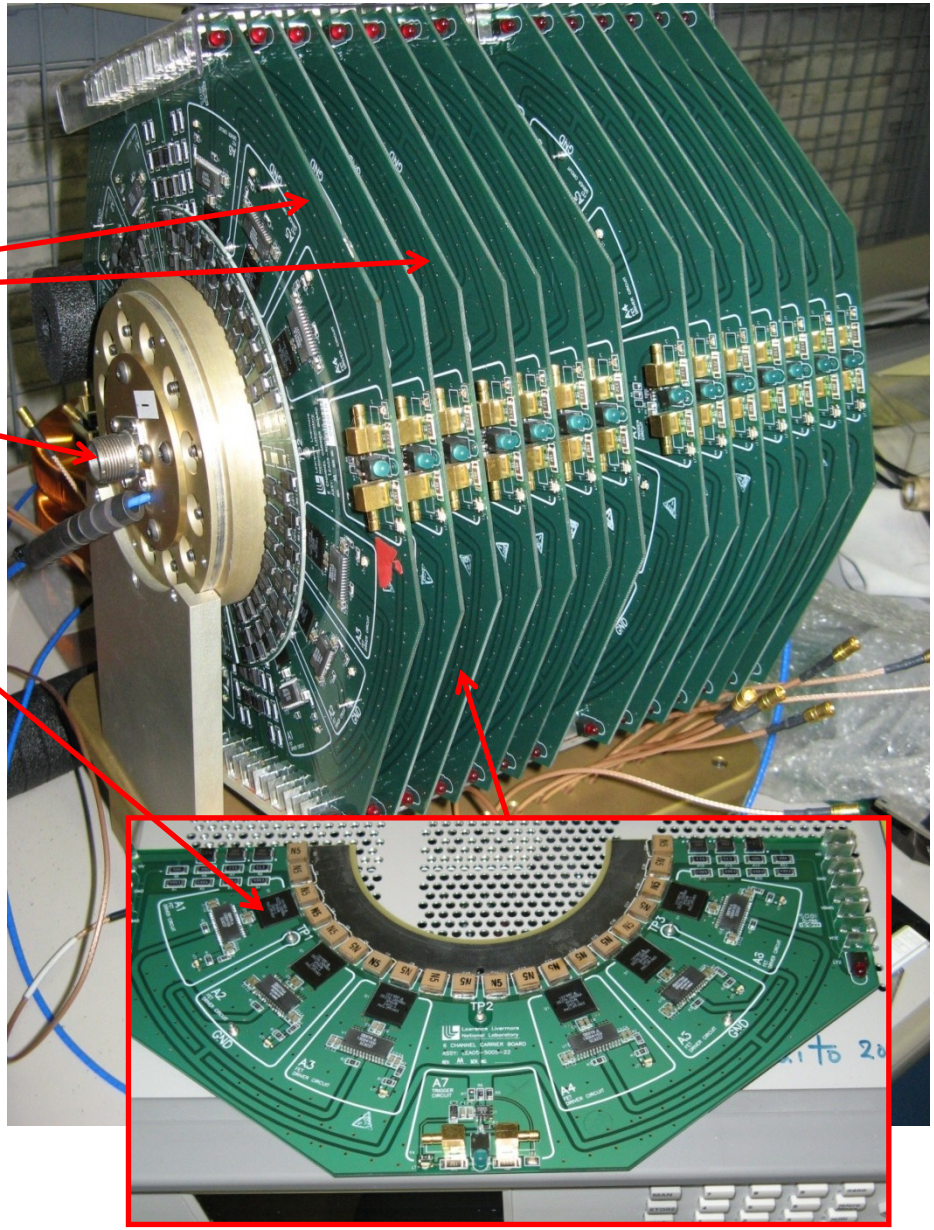
Each primary circuit has a **fast switch**. For CLIC the switches could be operated **independently**, in a digital and/or analogue manner, to provide pulse shaping.

➢ **Many cells may be required** to achieve fine control over pulse shape (to be studied further).

➢ **Good for machine protection & reliability (redundancy of switches).**

Being studied by **PhD STUDENT Janne HOLMA, Aalto University, Finland**.

The inductive adder may be applied with or without a double-kicker system.



4) damping ring extraction kickers – cont'd

M. Barnes

1. **CLIC PDR & DR kickers** are challenging
2. A **set of tapered striplines** is **researched, designed and prototyped** under the Spanish Program "Industry for Science": detailed design to be carried out by PhD student Carolina BELVER, IFIC, Spain.
3. An **Inductive Adder** to pulse the stripline is **under development** at CERN in collaboration with Finland
4. This kicker system, with relatively long and very stable pulses, would also be of interest to the X-ray storage ring community, where top-up operation requires very stable kicker systems for closing very tightly the injection bump, and minimize the source spot jitter from the stored beam in the IDs.
5. **In late 2013 or in 2014, beam tests at the ATF appear ideal to check beam impedance issues of the striplines and to verify the kick stability of the inductive adder with extracted beam**.

5) CSR induced beam instability in ATF-DR

theoretical approaches / references

F. Zimmermann

[1] G. Stupakov and S. Heifets, “Beam Instability and Microbunching due to Coherent Synchrotron Radiation,” PRST-AB 5, 054402 (2002); http://prst-ab.aps.org/pdf/PRSTAB/v5/i5/e054402

[2] S. Heifets and G. Stupakov, “Single-mode Coherent Synchrotron Radiation Instability,” PRST-AB 6, 064401 (2003); http://prst-ab.aps.org/pdf/PRSTAB/v6/i6/e064401

[3] K.L.F. Bane, Y. Cai, G. Stupakov, “Comparison of Simulation Codes for Microwave Instability in Bunched Beams,” Proc. IPAC’10, Kyoto Japan (2010) ; http://epaper.kek.jp/IPAC10/papers/tupd078.pdf

[4] D. Zhou et al, “CSR in the SuperKEKB Damping Ring,” IPAC’10 Kyoto (2010), http://epaper.kek.jp/IPAC10/papers/tupeb018.pdf

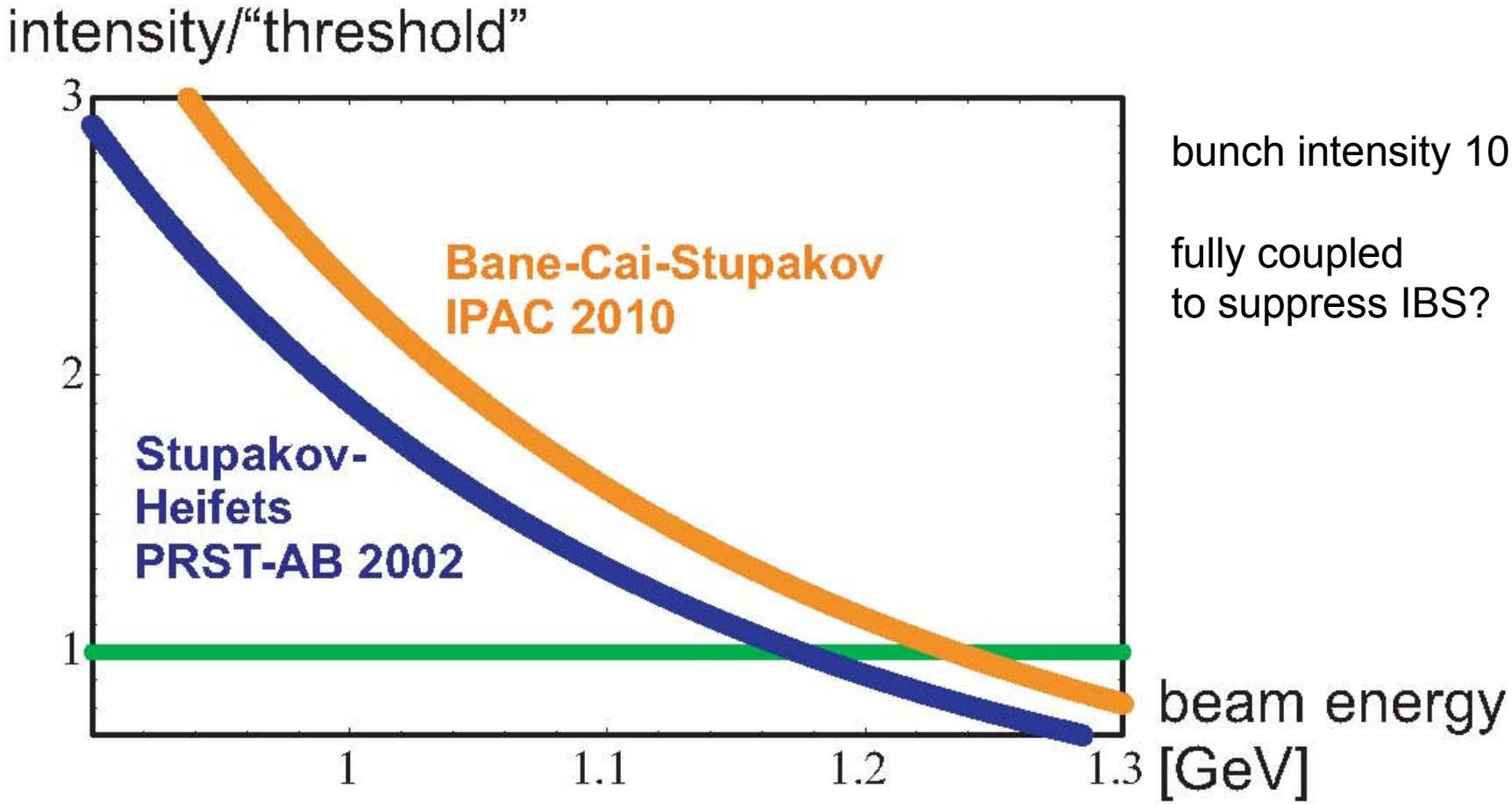
[5] F. Zimmermann, « Estimates of CSR Instability Thresholds for Various Storage Rings,” CERN ATS-Note-2010-049, CLIC-Note-861 (2010)

5) CSR induced beam instability in ATF-DR

ATF damping ring	nominal	lower energy
beam energy [GeV]	**1.28**	**1.00**
slip factor η	0.0019	
rms momentum spread $\sigma_{\delta,rms}$ [%]	0.06	0.047
bunch population [10^9]	10	10
circumference *C* [m]	138.6	
bending radius ρ [m]	5.73	
vert. beam pipe radius *b* [cm]	1.2?	
Stupakov-Heifets parameter Λ	**339**	**906**
ρ/b	**478**	
σ_z [cm]	**0.5**	**0.39**
$\rho/(2\Lambda\sqrt{2\pi}$ [cm]	**0.05**	**0.011**
$N_b r_0/(\sigma_z\sigma_\delta\gamma)$	0.0015	0.0031
β_x at bend [m]	3?	
ε_x [nm]	~1.5	0.9
σ_x at bend [μm]	67	52
$\rho^{4/3}/(\sigma_x\beta_x)^{2/3}$	2990	3540
τ_x [ms]	17.2	36.1
Q_s	-0.0045	
$N_{nb,thr}$	1.15×10^{10}	4.3×10^9
$N_b/N_{nb,thr}$	**0.86**	**2.32**
$\Lambda b/\rho$	**0.71**	**1.90**

5) CSR induced beam instability in ATF-DR

lowering ATF beam energy → CSR instability



bunch intensity 10^{10}

fully coupled
to suppress IBS?

Note: Bane-Cai-Stupakov predict instability in a regime where it is excluded by Stupakov-Heifets
Also note: ATF Damping Ring has initially operated at 0.96 GeV beam energy, in 1997

5) CSR induced beam instability in ATF – cont'd

instability threshold in the single-mode regime

for ATF-DR, "C*03*<1," and from [2]
there is always an instability if

$$C03b \equiv \frac{\left(\dfrac{r_e N_b 2a}{\gamma\sqrt{a\rho}\,\sigma_z}\right)^{1/3}}{\left(\eta\pi\sqrt{\dfrac{\rho}{a}}\,\sigma_\delta\right)} >> 1.$$

	SuperKEK B LER	SuperKEK B HER	SuperKEK B DR	ATF	ATF at 1 GeV	SuperB LER	SuperB HER	CLIC DR	
								2009	2010
C03b	**239**	**175**	**27**	**75**	**113**	**177**	**100**	**3851**	**540**

so, this 3rd theory" predicts instability always

5) CSR induced beam instability in ATF – cont'd

sketch of the ATF CSR experiment

single bunch with $N \geq 10^{10}$;
no small transverse emittance because of IBS; **no careful tuning** ;
operation on linear coupling resonance to blow up the vertical emittance, so that the effect of IBS is not strong, and the emittances almost independent of bunch intensity;

region of CSR instability should be reached at **beam energies below about 1 GeV**. ATF already operated at lower energy, 0.96 GeV, in 1997.

to **observe the CSR instability**:
=> Direct detection of **microwave radiation**
=> Monitoring **bunch length and shape** by streak camera
⇒Extract bunches and measure **energy spread with a wire scanner in the extraction line** by scanning over many bunches, and doing so for different bunch intensities.

We should perhaps hope to see a **kink in the bunch length versus bunch intensity curve, and at the same time an increase in energy spread, plus the emission of microwaves**, all happening at the same bunch intensity

possible contributors to ATF CSR experiment
Alexander Aryshev, Karl Bane, Anne Dabrowski, Hitomi Ikeda, Mitsuo Kikuchi, Anke Susanne Muller, Kazuhito Ohmi, Katsunobu Oide, Nobuhiro Terunuma, Junji Urakawa, Demin Zhou, Frank Zimmermann

5) CSR induced beam instability in ATF – cont'd

energy spread & bunch length on coupling resonance

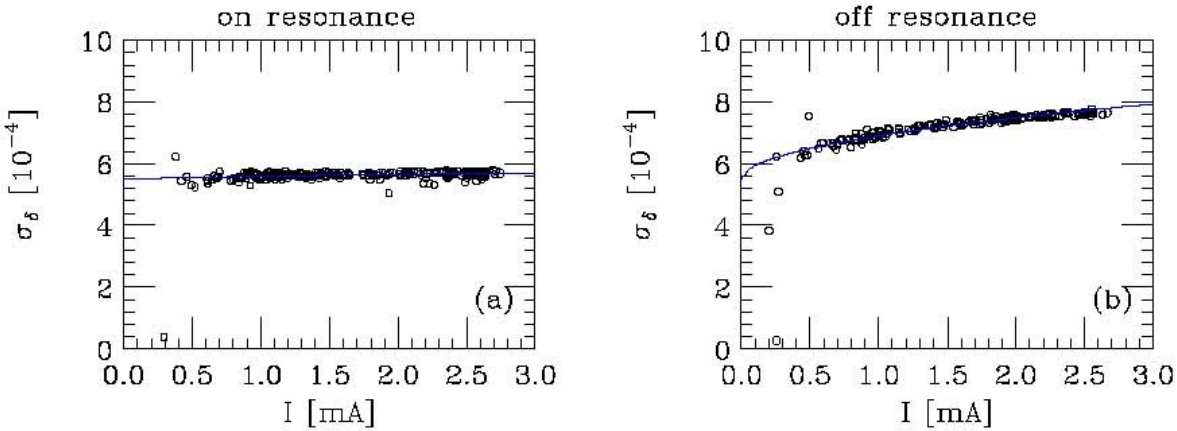


Figure 1: Energy spread as function of current when the ring voltage $V_c =$ 300 kV, with the beam on (a) and off (b) the coupling resonance.

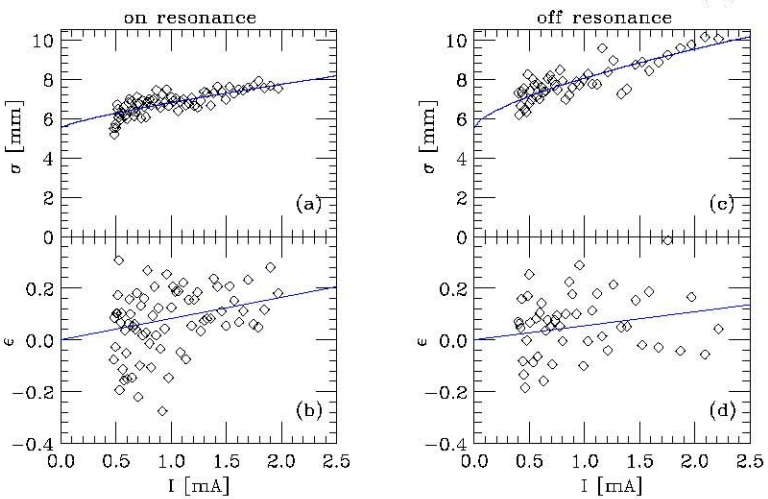


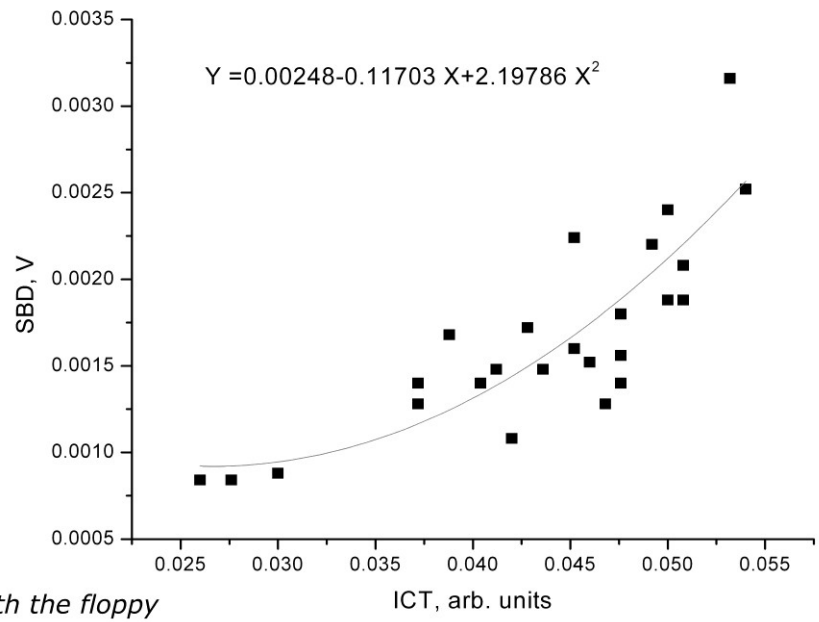
Figure 2: Bunch length (σ) and asymmetry parameter (ϵ) of the asymmetric Gaussian fit to the measured bunch distributions, as functions of current, for the beam on resonance (a,b) and off (c,d). $V_c = 250$ kV. The curves are fits to these results.

from K. Bane et al, "Impedance Analysis of Bunch Length Measurements at the ATF Damping Ring," SLAC=PUB-8846, May 2001

5) CSR induced beam instability in ATF – cont'd

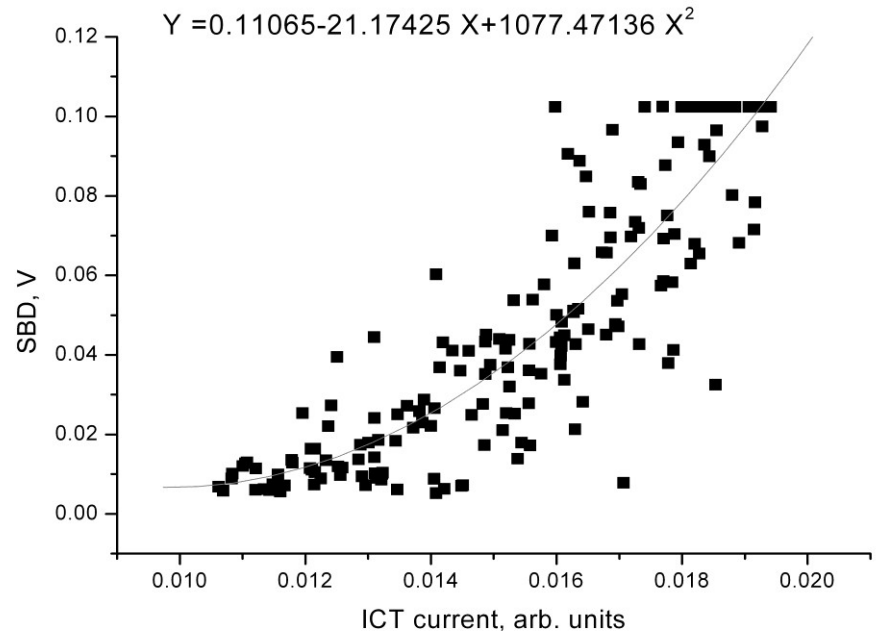
in 2006 CSR signal had been seen at ATF using Schottky barrier diode detector

CSR current dependence



Taken with the floppy

Current dependence



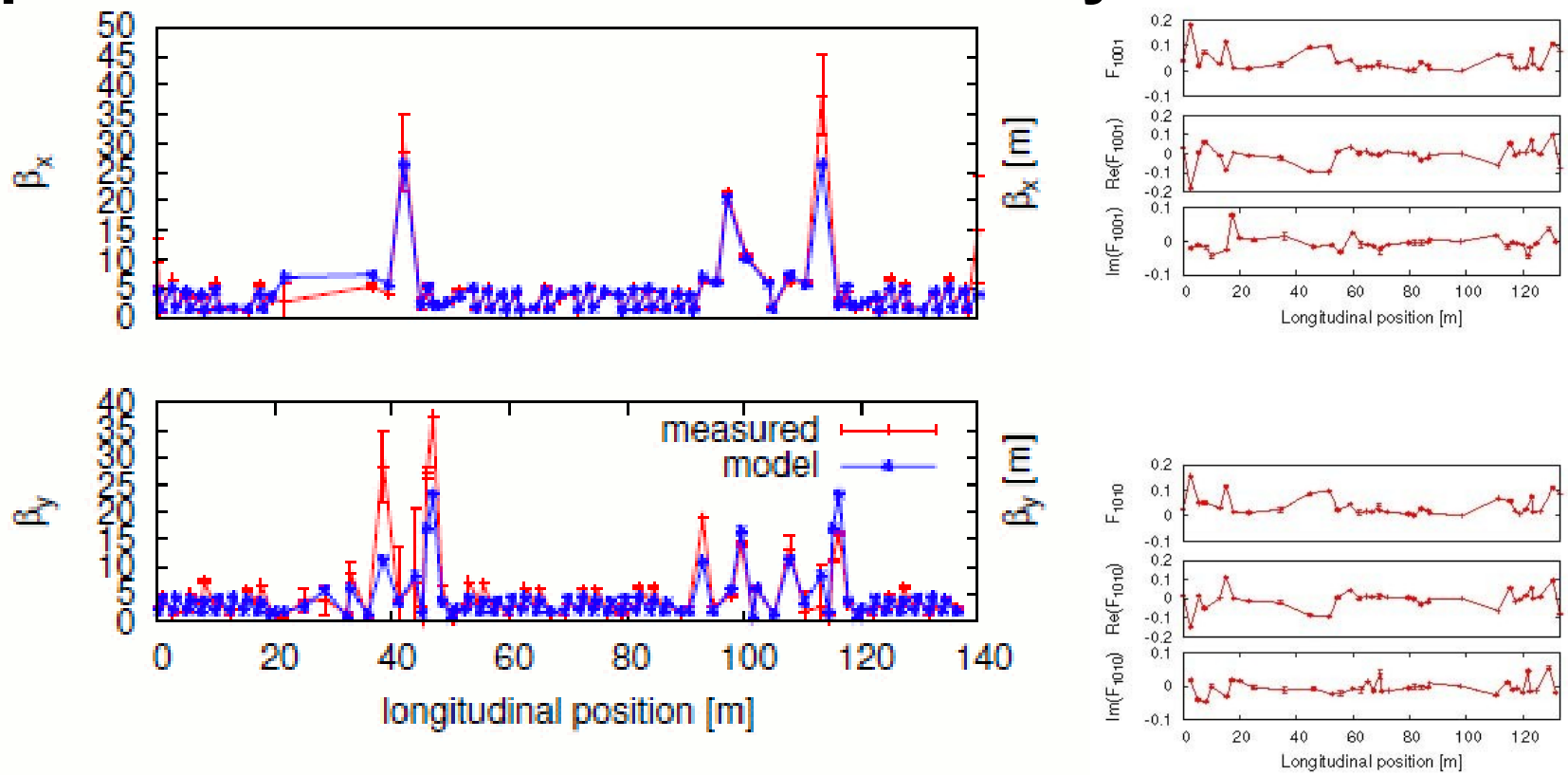
from A. Aryshev et al, "KEK ATF Coherent Synchrotron Radiation Study," July 2006

6) DR optics, emittance tuning & IBS studies

E. Gianfelice, R. Tomas, G. Vanbavinckhove

FNAL-CERN collaboration

optics reconstruction from turn-by-turn data

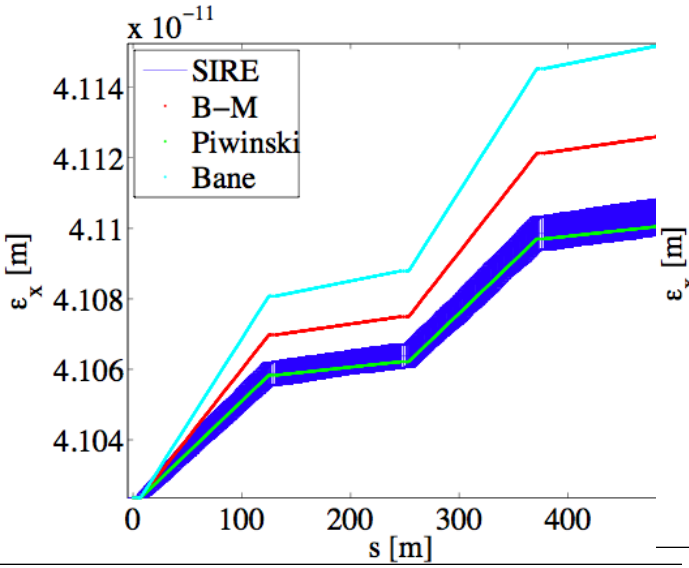


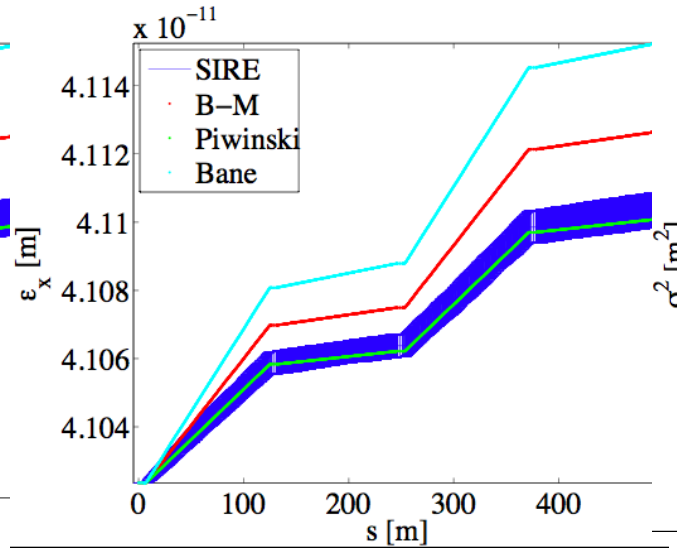
- Beta-beat in vertical plane is higher than in horizontal plane.
- First analysis of coupling was done using resonance driving terms.
- Sextupolar or octupolar components could not be identified. Data with stronger kick would be needed.

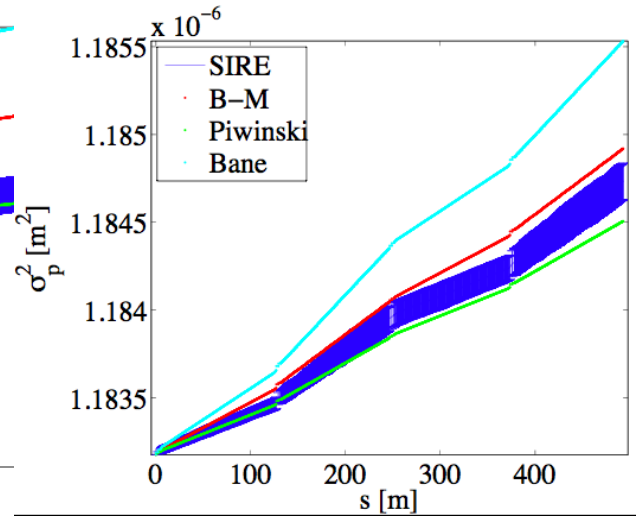
6) DR optics, emittance tuning & IBS studies ct'd

F. Antoniou, A. Vivoli, et al.

IBS tracking code benchmarking







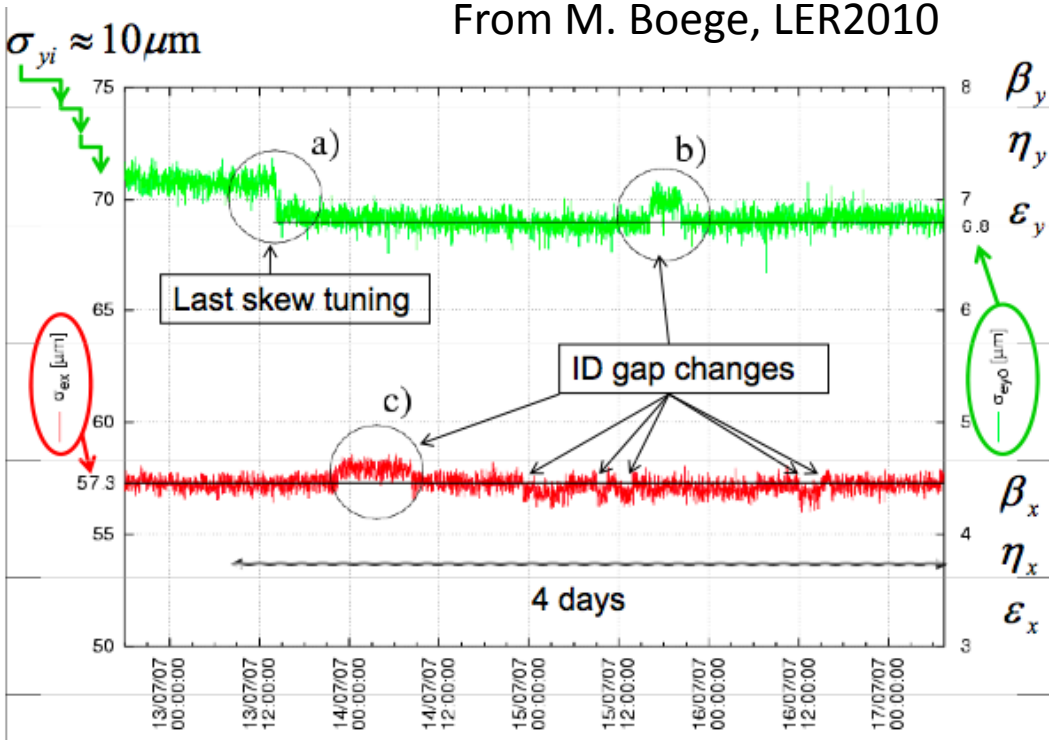
- Developed **Monte-Carlo tracking code for IBS** including synchrotron radiation damping and quantum excitation (SIRE, based on MOCAC)
- Agreement between analytical emittance growth and the mean values obtained from 20 SIRE runs
- Next need to benchmark theory and code with beam measurements
- ATF damping ring can be an ideal test-bed for low emittance tuning combined with IBS growth measurements

6) DR optics, emittance tuning & IBS studies ct'd

Low emittance tuning

- CLIC DR target vertical emittance less than 1pm at 2.86GeV
- SLS achieved 2.8pm emittance with very good reproducibility
- DIAMOND claims 2.2pm and ASP quoting 1-2pm (pending direct beam size measurements)
- ATF has achieved 2pm depending on the measurement technique (next slide)

Example: SLS vertical emittance
From M. Boege, LER2010

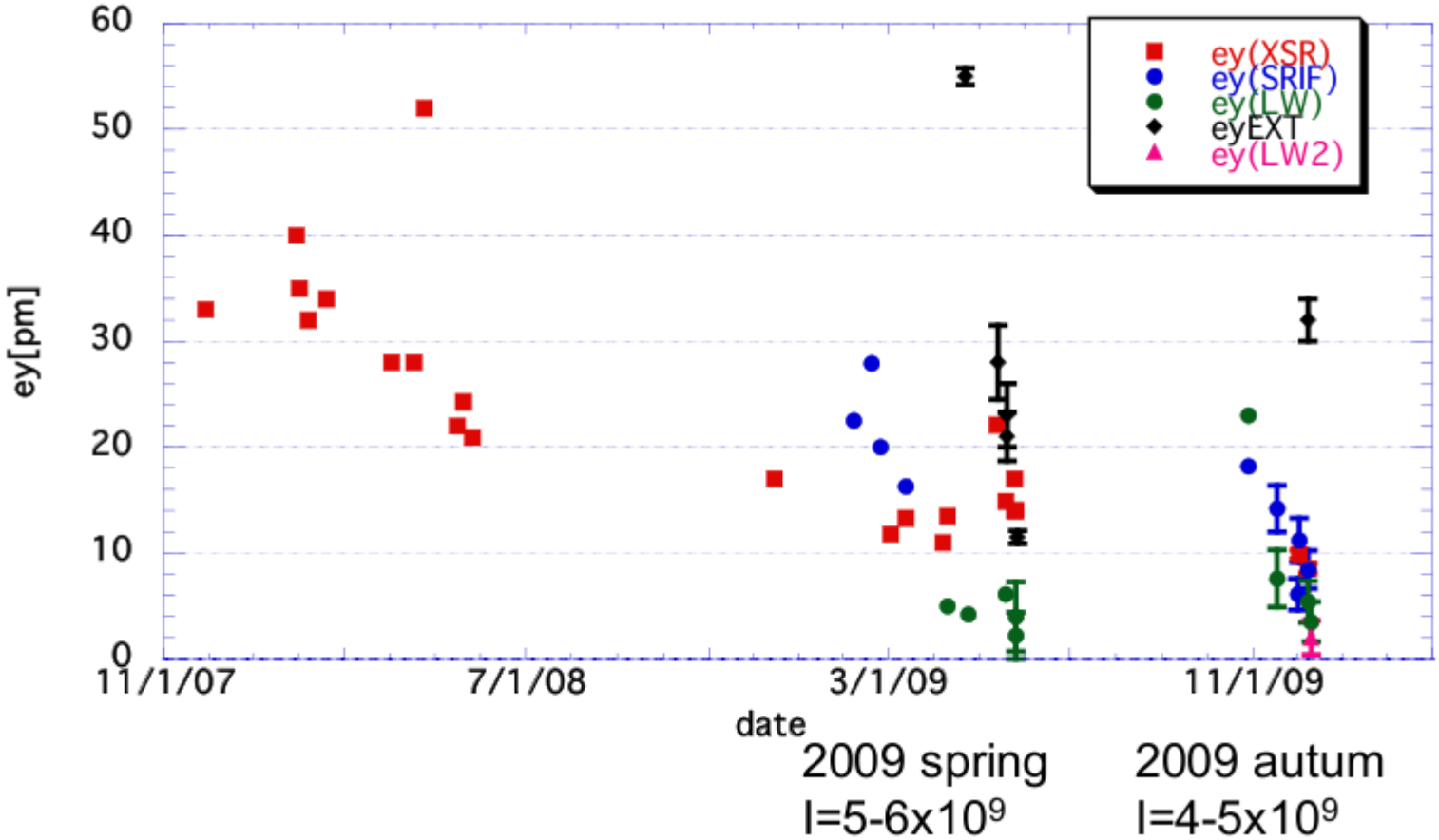


Using the new high-resolution ATF BPM system electronics, explore possibility of reaching ~1 pm emittance, based either on classical response matrix analysis techniques (as in synchrotron light sources) or by using frequency analysis of TBT data (less sensitive to BPM alignment errors)

6) DR optics, emittance tuning & IBS studies ct'd

ATF vertical emittance

S. Kuroda, 9th ATF meeting 12/2009



- Different points correspond to different measurement devices: X-ray monitor, SR interferometer, Laser Wire I and II
- Measured geometrical emittance: **8.6 ± 0.5 pm, 8.4 ± 1.8 pm, 3.5 ± 1.8 pm, 2.0 ± 1.2 pm**

7) superconducting wiggler for ATF

Y. Papaphilippou, S. Russenschuck,
D. Tommasini

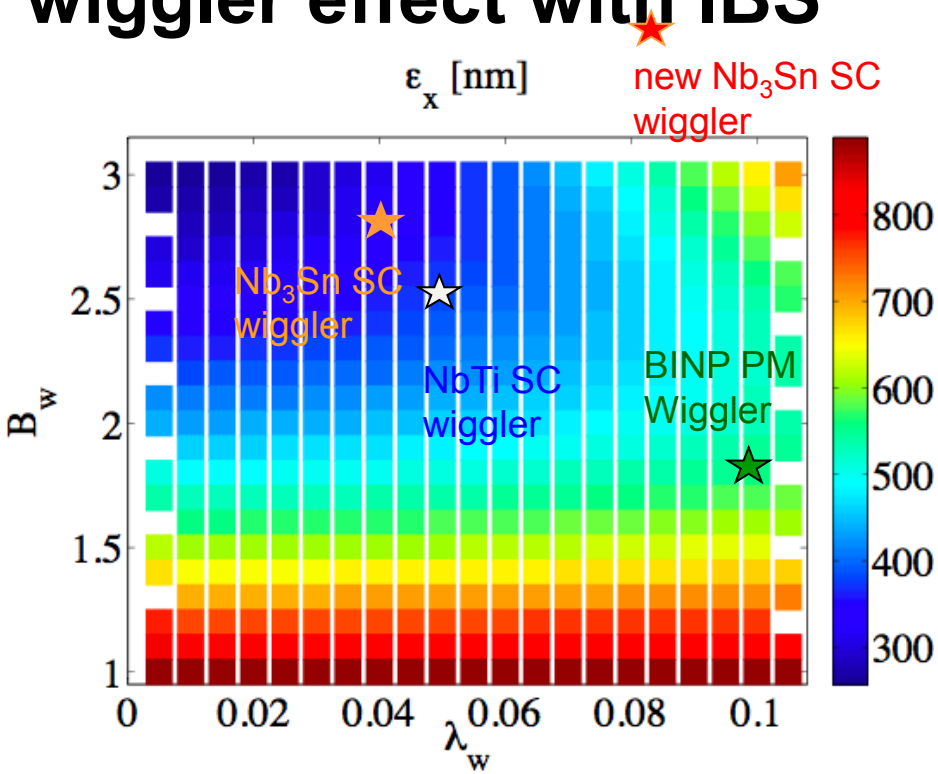
motivation

- a main ATF/ATF2 goal is the creation and preservation of very low emittance beams
- high-field damping wigglers can further reduce DR emittance and damping time
- superconducting wigglers are considered in the design of the CLIC damping rings
- short prototypes are being constructed and magnetically measured
- final magnet should be tested with beam

7) superconducting wiggler for ATF cnt'd

wiggler effect with IBS

Y. Papaphilippou, S. Russenschuck

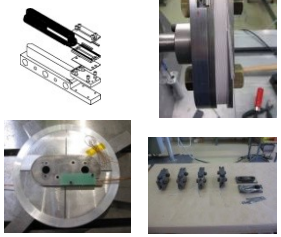


Parameters	BINP	CERN
B_{peak} [T]	2.5	2.8
λ_W [mm]	50	40
Beam full gap [mm]	13	
Conductor type	NbTi	Nb_3Sn
Operating temperature [K]	4.2	

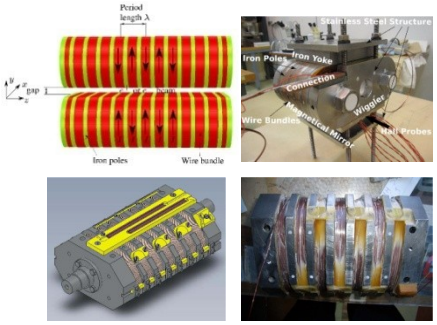
- stronger wiggler fields and shorter wavelengths necessary to reach target emittance due to strong IBS effect
- maximum current density depends on conductor type
- Nb_3Sn can sustain higher heat load (potentially 10 times higher than Nb-Ti)
- **two wiggler prototypes**
  - 2.5T, 5cm period, built and currently tested by BINP
  - 2.8T, 4cm period, designed by CERN/Un. Karlsruhe
- mock-ups built and magnetically tested
- prototypes to be installed in a storage ring for beam measurements

7) superconducting wiggler for ATF cnt'd

Nb_3Sn Technology



Nb-Ti Technology



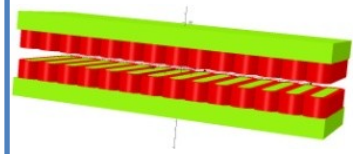
First Tests Short Model

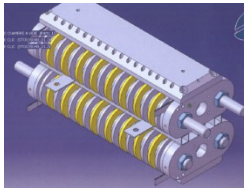
- Conceptual Design for Short Model (Design Office Support needed!)
- 5 Test Coils for Insulation and Heat Treatment tests
- One Vertical Racetrack Coil ready to be tested
- Horizontal racetrack coil planned to wind
- 2-period wiggler in mirror and full configuration (planned)

CDR

Small Prototype

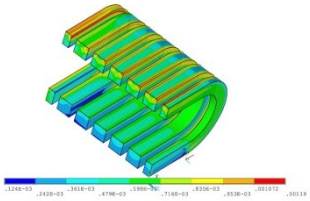
- Modules, Design and Test
- Joint Testing
- Field Quality Measurements at CASPER at ANKA





Full-Scale Prototype

- Full Scale Nb_3Sn Prototype with cryogenics to be tested at ANKA
- Design and manufacturing at CERN but with synergies from Nb-Ti wiggler!



SCU14 in ANKA

TDR

DEPENDING ON APPROVED FUNDING!

D. Schoerling,
S. Russenchuck, et al.

7) superconducting wiggler for ATF cnt'd

damping wiggler experiments

- need to test the wiggler for real beam conditions
  - validate cryogenic performance, reliability and heat load evacuation (absorber)
  - test quench performance in presence of beam and synchrotron radiation (especially for Nb_3Sn)
  - validate measured field quality (wiggler should not affect beam stability)
  - possible combination with vacuum chamber tests (photo-emission yield, desorption)
- experimental set up
  - straight section of ~3 m downstream of a dipole
  - ability to install the cryogenic system
  - average current of up to ~200 mA for testing

7) superconducting wiggler for ATF cnt'd

ATF2 parameters

- wiggler effect for typical ATF2 parameters, w/o coupling and IBS
- emittance can be evaluated as

$$\varepsilon_x = \frac{C_q \gamma^3}{J_x} \frac{I_{50} + I_{5w}}{I_{20} + I_{2w}}$$

and the horizontal damping time

$$\tau_x = \frac{960.13}{B\ \gamma^2} \frac{C}{J_{x0} + F_w}$$

with $I_{5w} \approx \frac{\lambda_w^2 \beta_w L_w}{384\ \rho_w^5}, \quad I_{2w} = \frac{L_w}{2\rho_w^2}, \quad J_x = \frac{J_{x0} + F_w}{1 + F_w}$

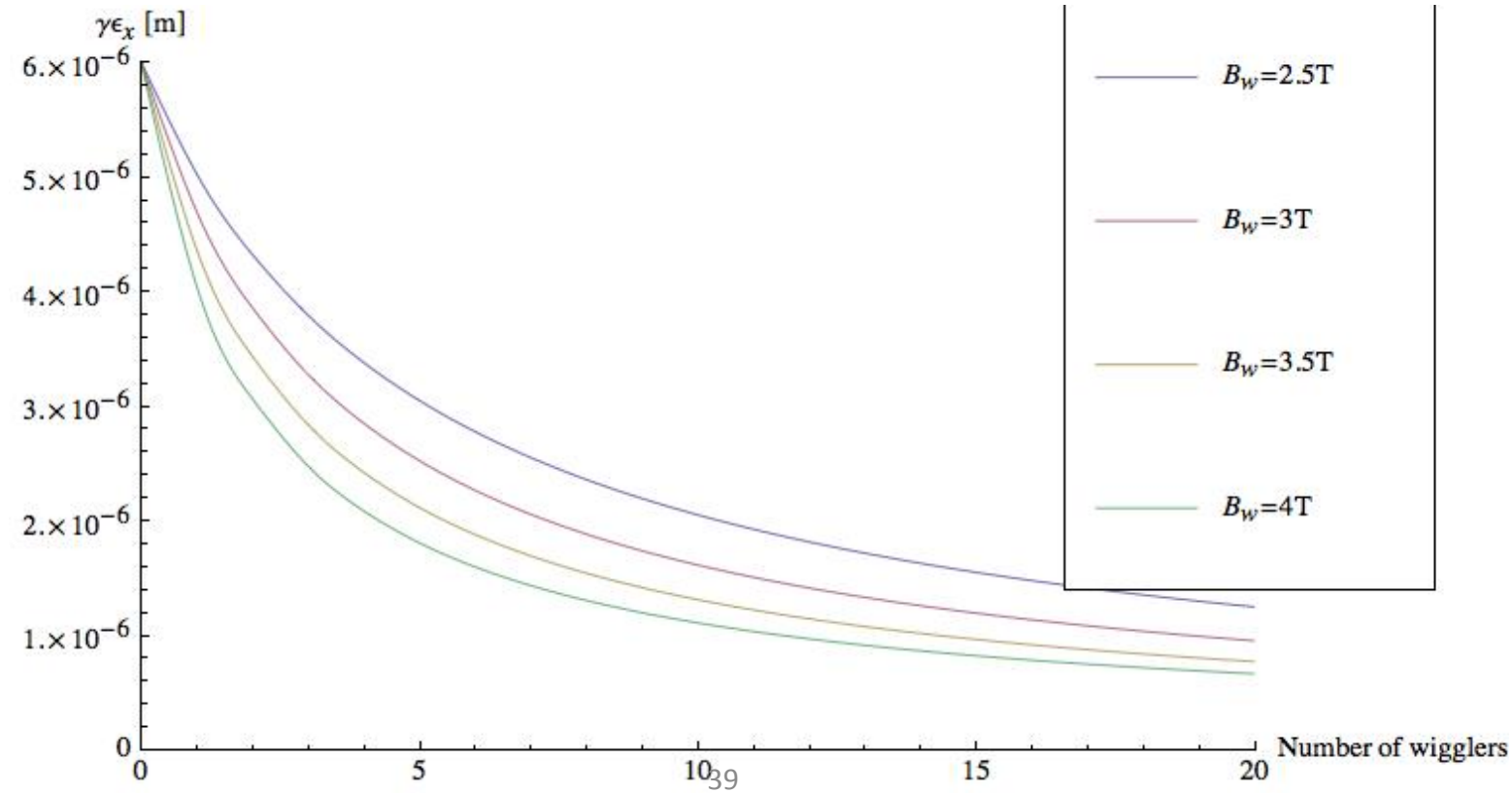
and $F_w = \frac{B_w^2 L_w}{4\pi\ 0.017\ \gamma\ B}, \quad \rho_w = \frac{0.017\ \gamma}{B_w}$

Energy [GeV]	1.3
Circumference [m]	138
Hor. damping partition number	1.84
Number of arc cells	36
Bend field [T]	0.69
Wiggler length [m]	2
Beta function on wiggler [m]	2
Hor. Norm. Emittance [μm.rad]	6

7) superconducting wiggler for ATF cnt'd

wiggler effect on emittance

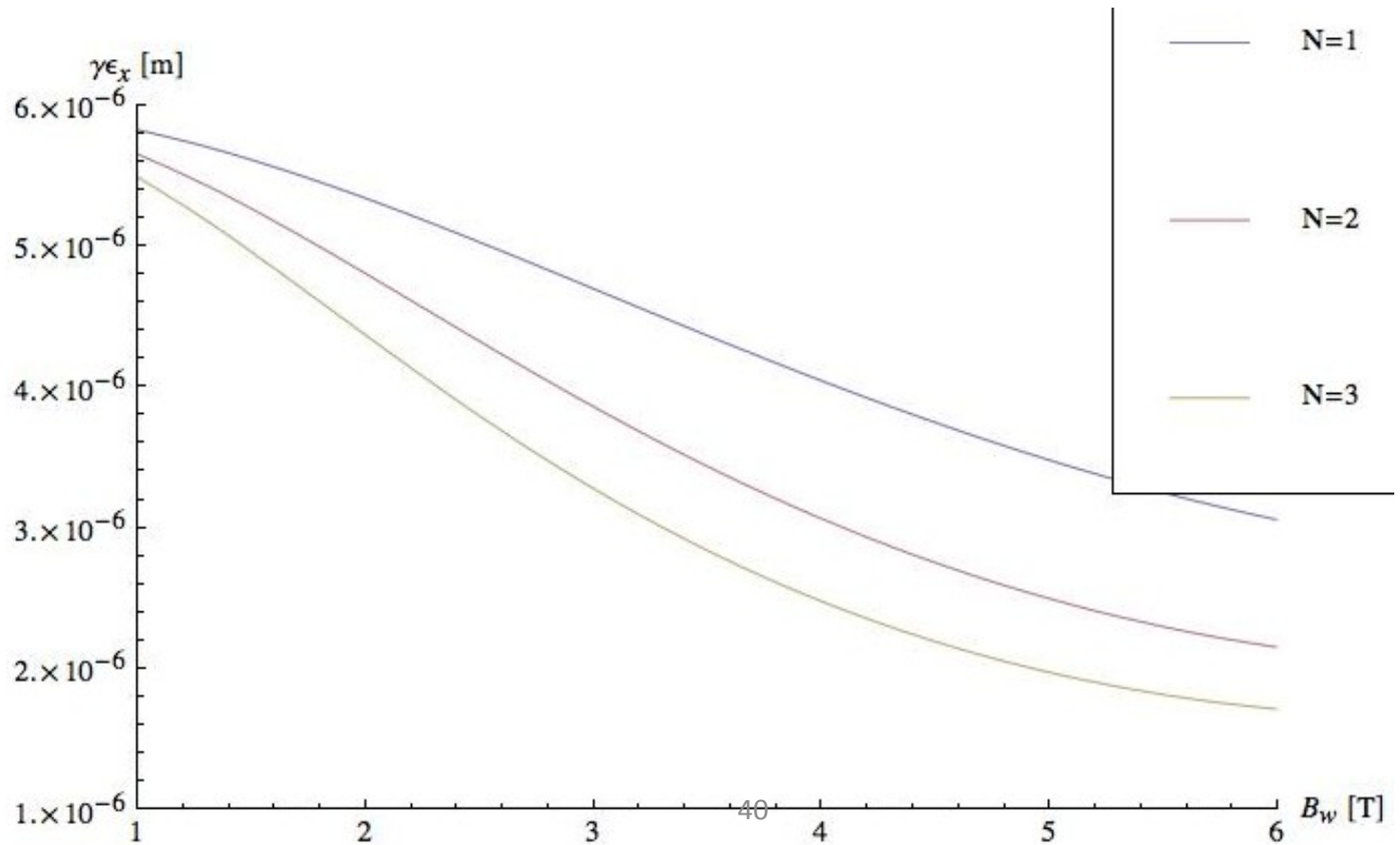
- important emittance reduction for a few wigglers, saturating as number of wigglers grows
- strong dependence on wiggler peak field
- weaker dependence on period length



7) superconducting wiggler for ATF cnt'd

wiggler effect on emittance

- with 4 T wiggler field and 1 wiggler, >30% emittance reduction
- emittance reduced by factor 2 for two 4-T wigglers



8) BPM tests

H. Schmickler, D. Schulte, M. Wendt

ATF2/ATF3 is the ideal machine to test ultra-high precision, single-shot beam position monitors.

CERN would like to **test in 2012 at ATF2 a set of three beam position monitors**, which have been developed by FNAL for the CLIC main linac.

Further beam position monitor development is foreseen for CLIC, to meet the requirements of the beam delivery system. ATF3 would be ideal test bed.

9) contributions to ATF2/3 operation & studies

annual resources (rough estimate)

total CLIC man power for ATF2/3: 1.5 person-years

presence at ATF: ~0.5 person-years

personnel

Anne Dabrowski
Andrea Latina
Eduardo Marin
Yannis Papaphilippou
Yves Renier
Daniel Schulte
Rogelio Tomas
Frank Zimmermann

summary - future CLIC contributions

1) Ultra-low beta-function
   CLIC considers providing **warm QF1 with larger aperture**
2) Ground motion feedback/feed-forward
   Ground motion sensors on each relevant magnet to predict beam orbit
3) Test of **quadrupole stabilisation** in ATF extraction
   Verify stabilisation performance with beam
4) Developing damping ring **extraction kickers systems**
   Would need ATF3 to verify kicker performance
5) CSR induced beam instability in ATF-DR
   Experiments to distinguish between theories
6) DR optics, emittance tuning & IBS studies
7) **Superconducting wiggler for ATF-DR**
8) BPM tests
   CLIC main linac **BPMs** developed by FNAL tested at ATF2
9) Contributions to ATF2/3 operation