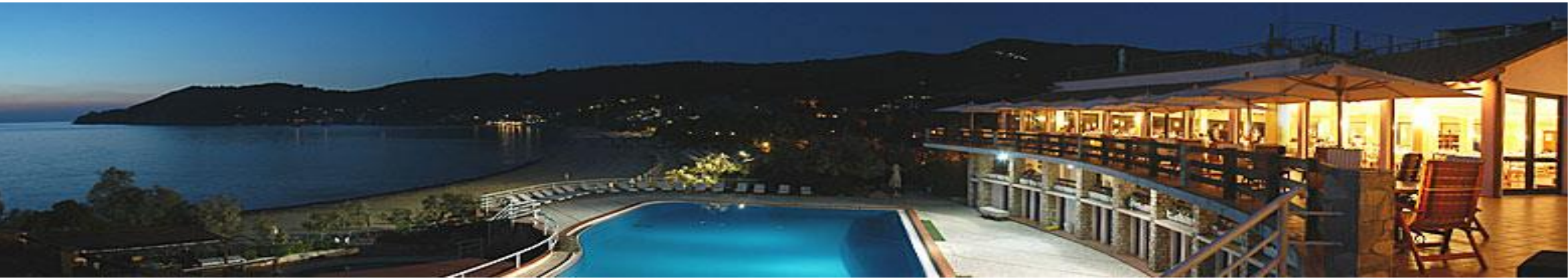
Sixth e-cloud workshop, **ECLOUD'18**, 3-7 June, 2018, La Biodola (Isola d'Elba), Italy



Intrabunch feedback system development at DAFNE

Alessandro Drago

INFN Frascati & Tor Vergata Rome University

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

I will report on behalf of a large collaboration project leaded by John Fox.

The names of all the participants are shown below.
However conclusions of the talk will be only by me.

J. Cesaratto[1], J. Dusatko[1], J. D. Fox[1], J. Goldfield[1], J. Olsen[1], M. Pivi[1], N. Redmon[1], C. Rivetta[1], O. Turgut[1], D. Aguilera[2], G. Arduini[2], H. Bartosik[2], S. Calvo[2],W. Hofle[2], G. Iadarola[2], G. Kotzian[2], K. Li[2], E. Metral[2], E. Montesinos[2], G. Rumolo[2], B. Salvant[2], U. Wehrle[2], M. Wendt[2], C. Zanini[2], S. De Santis[3], H. Qian[3], D. Alesini[4], A. Drago[4], S. Gallo[4], F. Marcellini[4], M. Zobov[4], M.Tobiyama[5]

[1] Accelerator Research Department, SLAC
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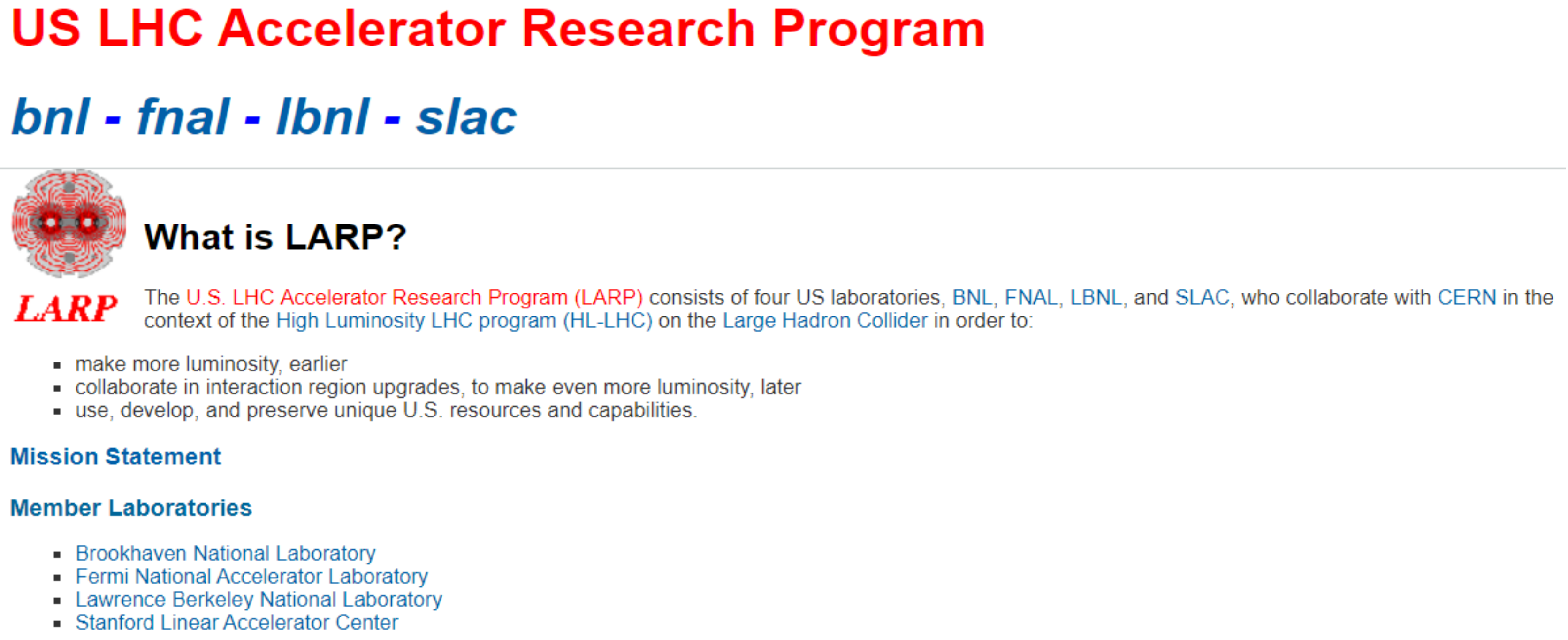
[5] KEK

Topics

- Introduction
- LARP collaboration for SPS/LHC e-cloud feedback (USA)
- Hi-Lumi-LHC collaboration (Europe, FP7)
- DAFNE team contributes
- Other developments
- A feasibility study for DAFNE?
- Conclusion

Introduction

- After the year 2009, John Fox start to ask funds to the LARP program in USA for research on a new type of feedback, able to damp bunch slices independently and to be implemented in SPS/LHC



US LHC Accelerator Research Program

bnl - fnal - lbnl - slac

What is LARP?

LARP

The U.S. LHC Accelerator Research Program (LARP) consists of four US laboratories, BNL, FNAL, LBNL, and SLAC, who collaborate with CERN in the context of the High Luminosity LHC program (HL-LHC) on the Large Hadron Collider in order to:

- make more luminosity, earlier
- collaborate in interaction region upgrades, to make even more luminosity, later
- use, develop, and preserve unique U.S. resources and capabilities.

Mission Statement

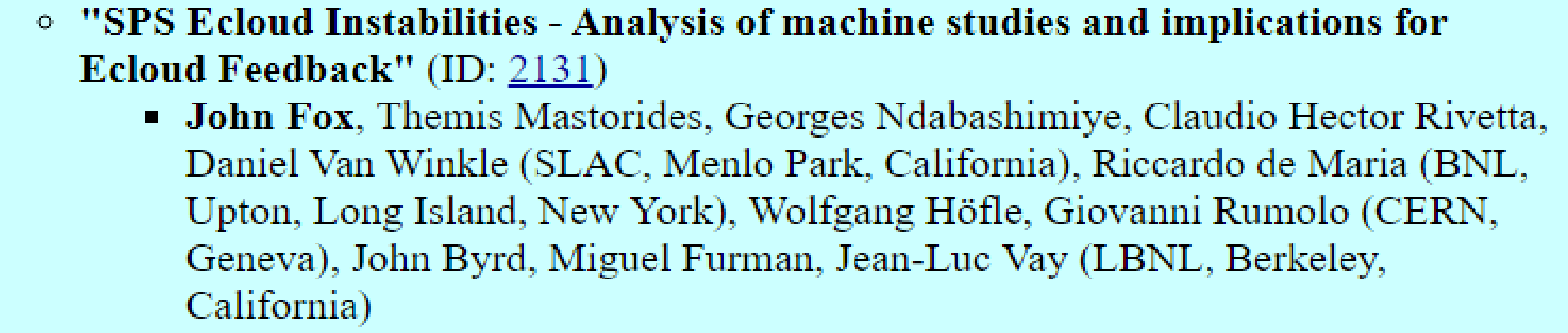
Member Laboratories

- Brookhaven National Laboratory
- Fermi National Accelerator Laboratory
- Lawrence Berkeley National Laboratory
- Stanford Linear Accelerator Center

- Unfortunately the LARP funding for the wideband feedback ended on September 2017

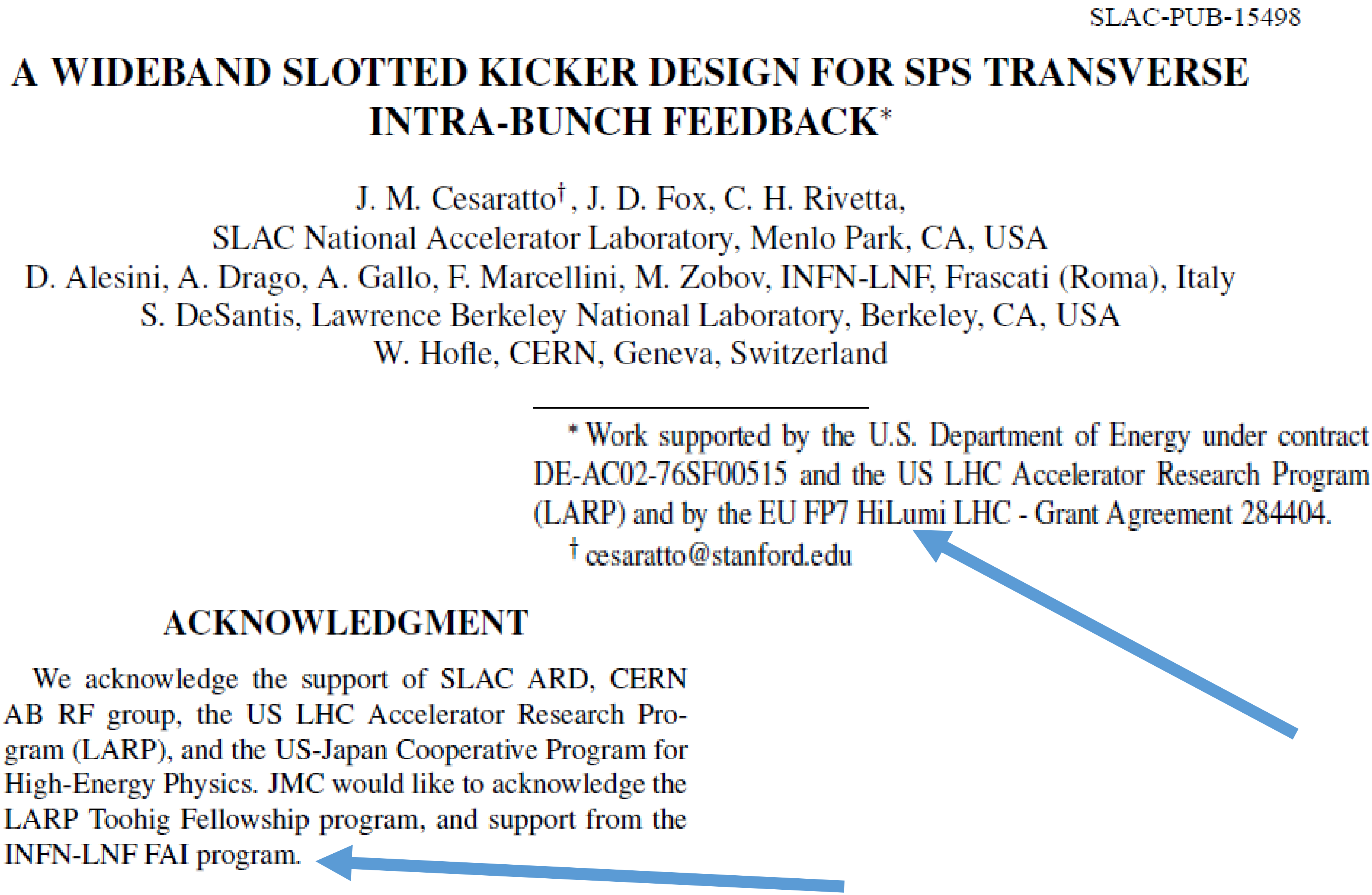
How it began

- The first paper was presented at IPAC’10 and John proposes an *Ecloud Feedback* with a name indicating the object of the cure



- **"SPS Ecloud Instabilities - Analysis of machine studies and implications for Ecloud Feedback"** (ID: 2131)
  - **John Fox**, Themis Mastorides, Georges Ndabashimiye, Claudio Hector Rivetta, Daniel Van Winkle (SLAC, Menlo Park, California), Riccardo de Maria (BNL, Upton, Long Island, New York), Wolfgang Höfle, Giovanni Rumolo (CERN, Geneva), John Byrd, Miguel Furman, Jean-Luc Vay (LBNL, Berkeley, California)

- Many researchers start to call *intrabunch feedback* the project, hence reporting the action of the system on the bunch dynamics, while later Fox preferred to use *wideband feedback system (WBFS),* by reporting the feedback main feature.
- From the end of 2011, also some people of DAFNE team start to collaborate with the SLAC/CERN/LBNL task force as participating to Hi-Lumi-LHC collaboration funded by EU (nov.2011-2015, FP7)



SLAC-PUB-15498

A WIDEBAND SLOTTED KICKER DESIGN FOR SPS TRANSVERSE INTRA-BUNCH FEEDBACK*

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[*] Work supported by the U.S. Department of Energy under contract DE-AC02-76SF00515 and the US LHC Accelerator Research Program (LARP) and by the EU FP7 HiLumi LHC - Grant Agreement 284404.

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ACKNOWLEDGMENT

We acknowledge the support of SLAC ARD, CERN AB RF group, the US LHC Accelerator Research Program (LARP), and the US-Japan Cooperative Program for High-Energy Physics. JMC would like to acknowledge the LARP Toohig Fellowship program, and support from the INFN-LNF FAI program.

In the first phase, the collaboration focused on the best 1 GHz frequency band kicker solution

- Three different kicker proposed:
  - Standard *stripline kicker*(s) with a much larger bandwidth than the previous models. This idea was followed by Stefano De Santis from ALS-Berkeley that designed an array of kickers for SPS (funded by LARP and installed in ~2015, I suppose)
  - *Slotted kicker* studied by John Cesaratto at SLAC and LNF and later designed and made by CERN kicker team (to be installed soon in SPS)
  - *Cavity kicker* proposed by Sandro Gallo at LNF
- Note that for the feedback backend power amplifier, the R&K (Japan) offered a model with 1GHz frequency bandwidth and very good flatness and pulse response (communication by John Fox to me at the 4th LARP Joint Meeting held at TSUKUBA in November 2014)
- So the R&K amplifiers were bought for SPS

2013: collaboration at LNF about the slotted kicker design

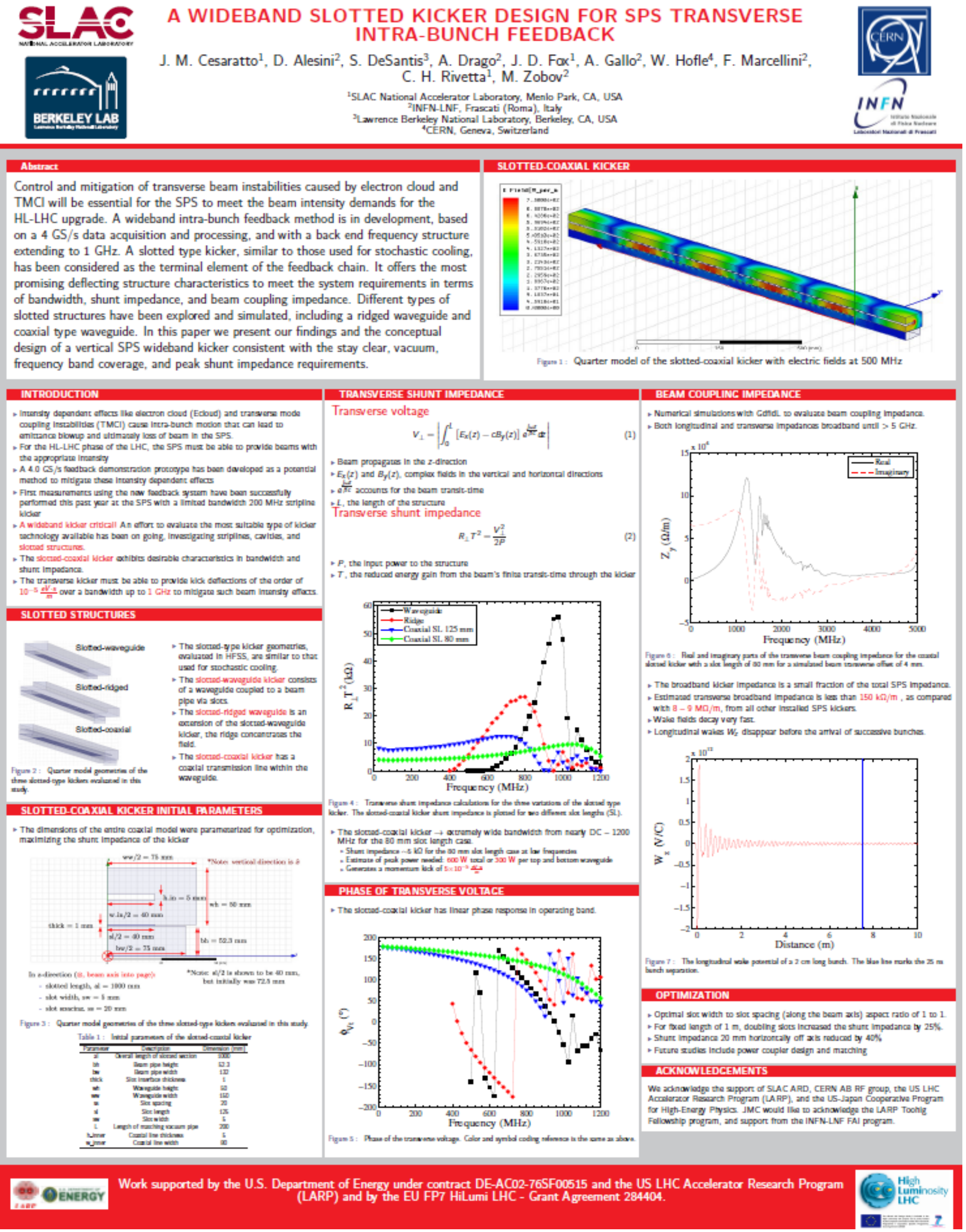
- Oggetto: Fondi FAI 2012
- Mittente Alessandro Drago
- Destinatario dosselli
- Cc Rita Bertelli, Andrea.Ghigo@lnf.infn.it, maria rita ferrazza, Maria Luisa Bontempi, alessandro.Drago@lnf.infn.it
- Data 2013-02-22 12:00

- Gentile Direttore,
- la presente per richiedere che i fondi FAI 2012 assegnati come segue:
- Prof. John FOX (SLAC): un soggiorno di 15 gg. più 1 viaggio a/r;
- siano trasferiti al dr. John M. Cesaratto (SLAC).

- Ringrazio in anticipo,
- cordiali saluti

- Alessandro Drago

John M. Cesaratto spent few weeks at LNF in 2013 working on the slotted kicker design for the wideband feedback back end and funded by INFN-LNF FAI program



A WIDEBAND SLOTTED KICKER DESIGN FOR SPS TRANSVERSE INTRA-BUNCH FEEDBACK

J. M. Cesaratto[1], D. Alesini[2], S. DeSantis[3], A. Drago[2], J. D. Fox[1], A. Gallo[2], W. Hofle[4], F. Marcellini[2], C. H. Rivetta[1], M. Zobov[2]

[1]SLAC National Accelerator Laboratory, Menlo Park, CA, USA
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[4]CERN, Geneva, Switzerland

Abstract

Control and mitigation of transverse beam instabilities caused by electron cloud and TMCI will be essential for the SPS to meet the beam intensity demands for the HL-LHC upgrade. A wideband intra-bunch feedback method is in development, based on a 4 GS/s data acquisition and processing, and with a back end frequency structure extending to 1 GHz. A slotted type kicker, similar to those used for stochastic cooling, has been considered as the terminal element of the feedback chain. It offers the most promising deflecting structure characteristics to meet the system requirements in terms of bandwidth, shunt impedance, and beam coupling impedance. Different types of slotted structures have been explored and simulated, including a ridged waveguide and coaxial type waveguide. In this paper we present our findings and the conceptual design of a vertical SPS wideband kicker consistent with the stay clear, vacuum, frequency band coverage, and peak shunt impedance requirements.

SLOTTED-COAXIAL KICKER

Figure 1 : Quarter model of the slotted-coaxial kicker with electric fields at 500 MHz

INTRODUCTION

- Intensity dependent effects like electron cloud (Ecloud) and transverse mode coupling instabilities (TMCI) cause intra-bunch motion that can lead to emittance blowup and ultimately loss of beam in the SPS.
- For the HL-LHC phase of the LHC, the SPS must be able to provide beams with the appropriate intensity
- A 4.0 GS/s feedback demonstration prototype has been developed as a potential method to mitigate these intensity dependent effects
- First measurements using the new feedback system have been successfully performed this past year at the SPS with a limited bandwidth 200 MHz stripline kicker
- A wideband kicker critical! An effort to evaluate the most suitable type of kicker technology available has been on going, investigating striplines, cavities, and slotted structures.
- The slotted-coaxial kicker exhibits desirable characteristics in bandwidth and shunt impedance.
- The transverse kicker must be able to provide kick deflections of the order of $10^{-5}\,\frac{eV\cdot s}{m}$ over a bandwidth up to 1 GHz to mitigate such beam intensity effects.

SLOTTED STRUCTURES

Figure 2 : Quarter model geometries of the three slotted-type kickers evaluated in this study.

- The slotted-type kicker geometries, evaluated in HFSS, are similar to that used for stochastic cooling.
- The slotted-waveguide kicker consists of a waveguide coupled to a beam pipe via slots.
- The slotted-ridged waveguide is an extension of the slotted-waveguide kicker, the ridge concentrates the field.
- The slotted-coaxial kicker has a coaxial transmission line within the waveguide.

SLOTTED-COAXIAL KICKER INITIAL PARAMETERS

- The dimensions of the entire coaxial model were parameterized for optimization, maximizing the shunt impedance of the kicker

In z-direction (ẑ, beam axis into page):
- slotted length, al = 1000 mm
- slot width, sw = 5 mm
- slot spacing, ss = 20 mm

*Note: sl/2 is shown to be 40 mm, but initially was 72.5 mm

Figure 3 : Quarter model geometries of the three slotted-type kickers evaluated in this study.

Table 1 : Initial parameters of the slotted-coaxial kicker

Parameter	Description	Dimension (mm)
al	Overall length of slotted section	1000
bh	Beam pipe height	52.3
bw	Beam pipe width	132
thick	Slot interface thickness	1
wh	Waveguide height	50
ww	Waveguide width	150
ss	Slot spacing	20
sl	Slot length	125
sw	Slot width	5
L	Length of matching vacuum pipe	200
h_inner	Coaxial line thickness	5
w_inner	Coaxial line width	80

TRANSVERSE SHUNT IMPEDANCE

Transverse voltage

$$V_\perp = \left| \int_0^L \left[E_x(z) - cB_y(z) \right] e^{\frac{j\omega z}{\beta c}} dz \right| \tag{1}$$

- Beam propagates in the z-direction
- $E_x(z)$ and $B_y(z)$, complex fields in the vertical and horizontal directions
- $e^{\frac{j\omega z}{\beta c}}$ accounts for the beam transit-time
- L, the length of the structure

Transverse shunt impedance

$$R_\perp T^2 = \frac{V_\perp^2}{2P} \tag{2}$$

- P, the input power to the structure
- T, the reduced energy gain from the beam's finite transit-time through the kicker

Figure 4 : Transverse shunt impedance calculations for the three variations of the slotted type kicker. The slotted-coaxial kicker shunt impedance is plotted for two different slot lengths (SL).

- The slotted-coaxial kicker → extremely wide bandwidth from nearly DC – 1200 MHz for the 80 mm slot length case.
  - Shunt impedance ~6 kΩ for the 80 mm slot length case at low frequencies
  - Estimate of peak power needed: 600 W total or 300 W per top and bottom waveguide
  - Generates a momentum kick of $5\times10^{-5}\,\frac{eV\cdot s}{m}$

PHASE OF TRANSVERSE VOLTAGE

- The slotted-coaxial kicker has linear phase response in operating band.

Figure 5 : Phase of the transverse voltage. Color and symbol coding reference is the same as above.

BEAM COUPLING IMPEDANCE

- Numerical simulations with GdfidL to evaluate beam coupling impedance.
- Both longitudinal and transverse impedances broadband until > 5 GHz.

Figure 6 : Real and imaginary parts of the transverse beam coupling impedance for the coaxial slotted kicker with a slot length of 80 mm for a simulated beam transverse offset of 4 mm.

- The broadband kicker impedance is a small fraction of the total SPS impedance.
- Estimated transverse broadband impedance is less than 150 kΩ/m , as compared with 8 – 9 MΩ/m, from all other installed SPS kickers.
- Wake fields decay very fast.
- Longitudinal wakes W_z disappear before the arrival of successive bunches.

Figure 7 : The longitudinal wake potential of a 2 cm long bunch. The blue line marks the 25 ns bunch separation.

OPTIMIZATION

- Optimal slot width to slot spacing (along the beam axis) aspect ratio of 1 to 1.
- For fixed length of 1 m, doubling slots increased the shunt impedance by 25%.
- Shunt impedance 20 mm horizontally off axis reduced by 40%
- Future studies include power coupler design and matching

ACKNOWLEDGEMENTS

We acknowledge the support of SLAC ARD, CERN AB RF group, the US LHC Accelerator Research Program (LARP), and the US-Japan Cooperative Program for High-Energy Physics. JMC would like to acknowledge the LARP Toohig Fellowship program, and support from the INFN-LNF FAI program.

Work supported by the U.S. Department of Energy under contract DE-AC02-76SF00515 and the US LHC Accelerator Research Program (LARP) and by the EU FP7 HiLumi LHC - Grant Agreement 284404.

This poster on the slotted kicker was presented by John Cesaratto at IPAC 2013

CERN-ACC-NOTE-2013-0047
SLAC report number: SLAC-R-1037
20-12-2013
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SPS Wideband Transverse Feedback Kicker: Design Report

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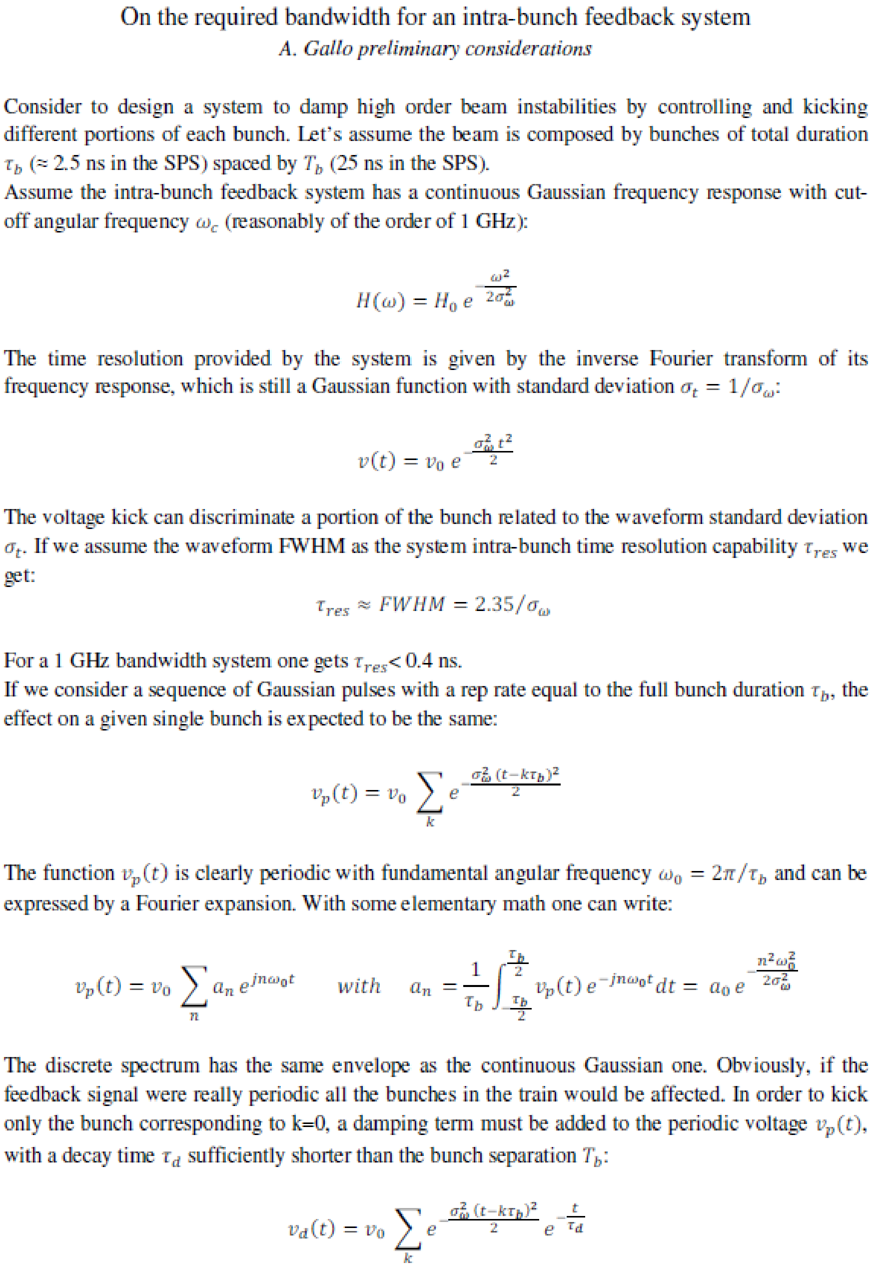
Keywords: LIU-SPS, Wideband Transverse Feedback

Abstract: The SPS wideband transverse feedback system is being developed to control vertical beam instabilities arising from intensity dependent effects like electron cloud instability (ECI) and the transverse mode coupling instability (TMCI). As part of the LHC Injector Upgrade (LIU) project, a wideband kicker is necessary as a damper to control unstable modes within a bunch. Several types of kicker structures, including cavities, striplines, and slotted structures have been studied to evaluate the operating bandwidth, transverse shunt impedance, and beam coupling impedance. Studies and results from all structures are described below, including three potential paths to implement these structures as a wideband kicker system. A single, slotted-coaxial kicker of 1 m length provides substantial kick strength (integrated transverse voltage) over a bandwidth ranging from nearly DC to 1 GHz. An array of four 10 cm long striplines provides substantial kick strength from DC to 750 MHz. For a given amplifier power of 500 W, the array of striplines can provide twice the transverse detecting voltage as the slotted kicker for frequencies up to 200 MHz. At frequencies 800 – 1000 MHz the transverse voltage generated by the slotted kicker dominates that of the stripline array. We recommend to CERN that both the slotted-coaxial kicker and the array of striplines should undergo more detailed mechanical design and be built as prototype wideband kickers for installation in the SPS.

Cavity kicker, 2012



On the required bandwidth for an intra-bunch feedback system

A. Gallo preliminary considerations

Consider to design a system to damp high order beam instabilities by controlling and kicking different portions of each bunch. Let's assume the beam is composed by bunches of total duration τ_b ($\approx$ 2.5 ns in the SPS) spaced by T_b (25 ns in the SPS).

Assume the intra-bunch feedback system has a continuous Gaussian frequency response with cut-off angular frequency ω_c (reasonably of the order of 1 GHz):

$$H(\omega) = H_0\, e^{-\frac{\omega^2}{2\sigma_\omega^2}}$$

The time resolution provided by the system is given by the inverse Fourier transform of its frequency response, which is still a Gaussian function with standard deviation $\sigma_t = 1/\sigma_\omega$:

$$v(t) = v_0\, e^{-\frac{\sigma_\omega^2 t^2}{2}}$$

The voltage kick can discriminate a portion of the bunch related to the waveform standard deviation σ_t. If we assume the waveform FWHM as the system intra-bunch time resolution capability τ_{res} we get:

$$\tau_{res} \approx FWHM = 2.35/\sigma_\omega$$

For a 1 GHz bandwidth system one gets $\tau_{res} < 0.4$ ns.

If we consider a sequence of Gaussian pulses with a rep rate equal to the full bunch duration τ_b, the effect on a given single bunch is expected to be the same:

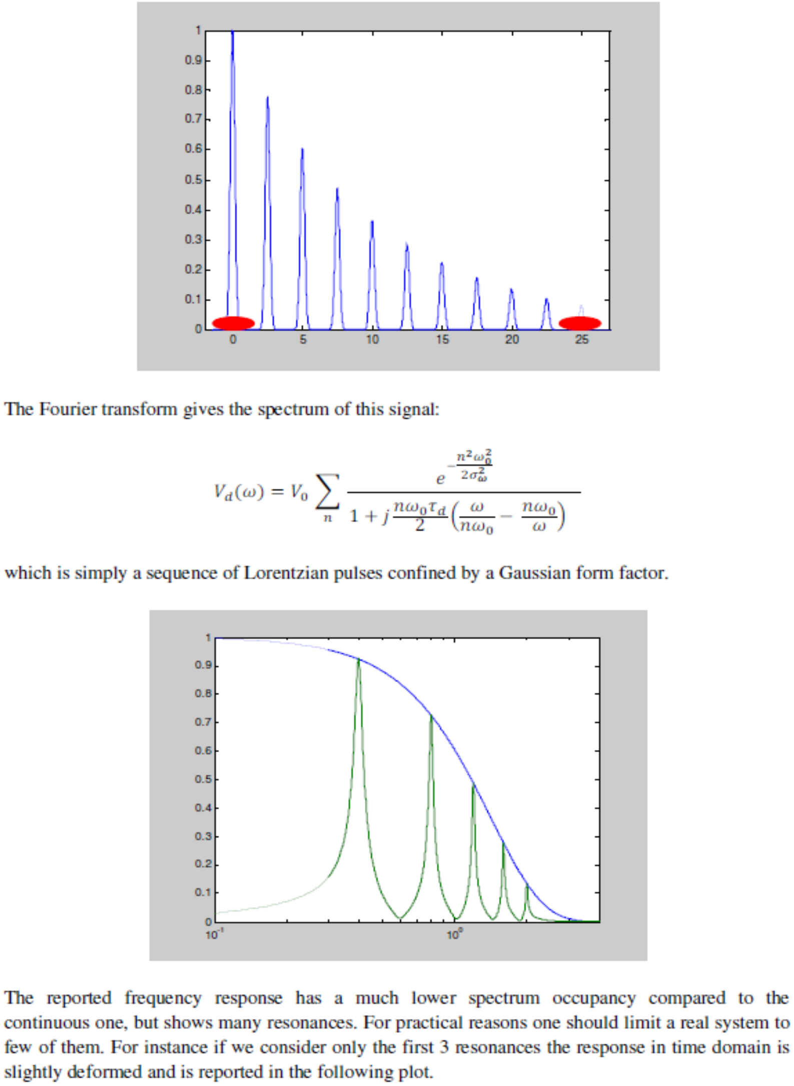
$$v_p(t) = v_0 \sum_k e^{-\frac{\sigma_\omega^2 (t-k\tau_b)^2}{2}}$$

The function $v_p(t)$ is clearly periodic with fundamental angular frequency $\omega_0 = 2\pi/\tau_b$ and can be expressed by a Fourier expansion. With some elementary math one can write:

$$v_p(t) = v_0 \sum_n a_n\, e^{jn\omega_0 t} \qquad with \quad a_n = \frac{1}{\tau_b}\int_{-\frac{\tau_b}{2}}^{\frac{\tau_b}{2}} v_p(t)\, e^{-jn\omega_0 t} dt = a_0\, e^{-\frac{n^2\omega_0^2}{2\sigma_\omega^2}}$$

The discrete spectrum has the same envelope as the continuous Gaussian one. Obviously, if the feedback signal were really periodic all the bunches in the train would be affected. In order to kick only the bunch corresponding to k=0, a damping term must be added to the periodic voltage $v_p(t)$, with a decay time τ_d sufficiently shorter than the bunch separation T_b:

$$v_d(t) = v_0 \sum_k e^{-\frac{\sigma_\omega^2 (t-k\tau_b)^2}{2}}\, e^{-\frac{t}{\tau_d}}$$



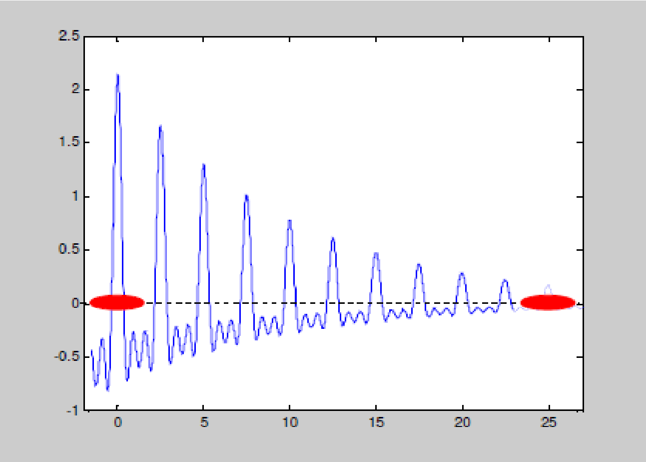
The Fourier transform gives the spectrum of this signal:

$$V_d(\omega) = V_0 \sum_n \frac{e^{-\frac{n^2\omega_0^2}{2\sigma_\omega^2}}}{1 + j\frac{n\omega_0\tau_d}{2}\left(\frac{\omega}{n\omega_0} - \frac{n\omega_0}{\omega}\right)}$$

which is simply a sequence of Lorentzian pulses confined by a Gaussian form factor.

The reported frequency response has a much lower spectrum occupancy compared to the continuous one, but shows many resonances. For practical reasons one should limit a real system to few of them. For instance if we consider only the first 3 resonances the response in time domain is slightly deformed and is reported in the following plot.

Even if interesting design, this approach was not carried on mainly for the difficulty to equalize and to time the different frequency bands of the correction signal

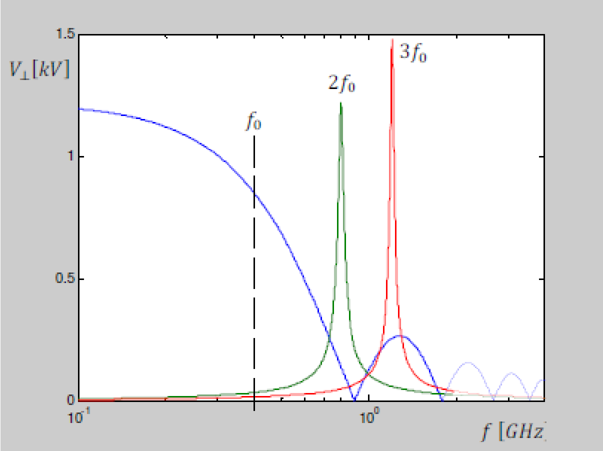


To set the kick baseline for each bunch, as well as for damping rigid coupled bunch instabilities, the system must provide adequate frequency response also at DC and in a low frequency band. The overall required system bandwidth could be built by combining a stripline kicker, covering the range from DC to the fundamental frequency $\omega_0 = 2\pi/\tau_b$, with 2 transverse cavities centered at the 2nd and 3rd harmonics with bandwidths of the order of the bunch repetition frequency.

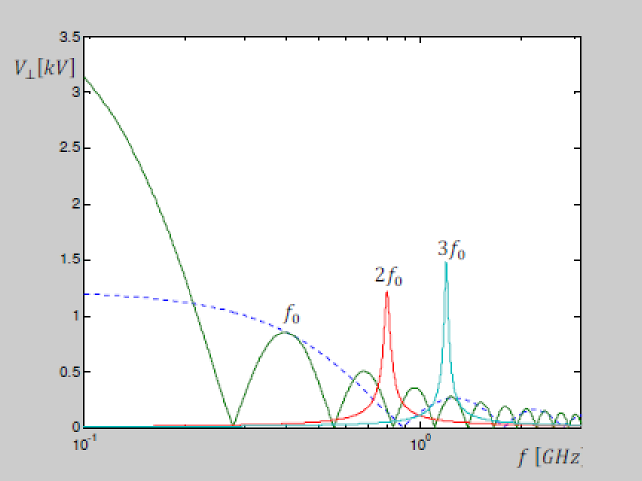
A preliminary estimate of the transverse shunt impedances of the various kickers can be extrapolated by scaling results reported in literature. This exercise is summarized in the following table.

	Kicker #1	Kicker #2	Kicker #3
Type	Stripline	Cavity, TM110 defl. mode	Cavity, TM110 defl. mode
3-dB bandwidth	DC – 400 MHz	800 ± 16 MHz	1200 ± 16 MHz
Length	17 cm	15 cm	10 cm
Filling time	0.6 ns	10 ns	10 ns
Q_L	---	25	38
Shunt Impedance	≈ 1.5 kΩ (@ DC)	≈ 1.5 kΩ (@ 800 MHz)	≈ 2.2 kΩ (@ 1200 MHz)

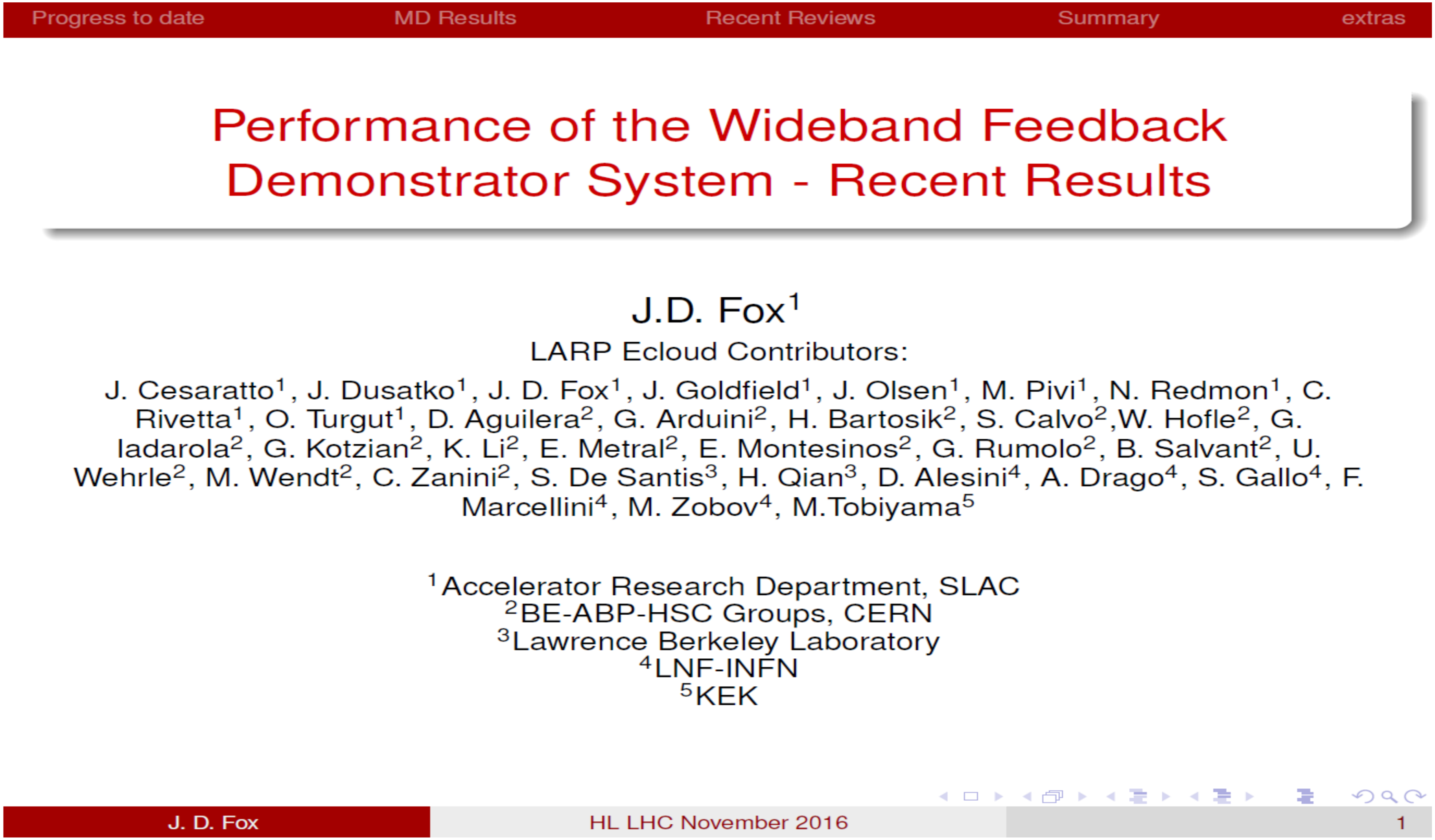
Assuming that each kicker is powered by a 1 kW source covering the entire device bandwidth, the resulting transverse voltage transferred to the beam as a function of the frequency is shown in the following plot.



Following the approach of discontinue bandwidth, a ≈ 3 times longer strip can be considered in order to tune the second lobe of the sinc response on the fundamental frequency $f_0 = 1/\tau_b$. By doing this a much higher transverse impedance at DC will result, increasing the system damping efficiency of rigid transverse coupled bunch instabilities.



2016 John Fox's last presentation is partially reported below and in the following slides



Progress to date | MD Results | Recent Reviews | Summary | extras

Performance of the Wideband Feedback Demonstrator System - Recent Results

J.D. Fox[1]

LARP Ecloud Contributors:

J. Cesaratto[1], J. Dusatko[1], J. D. Fox[1], J. Goldfield[1], J. Olsen[1], M. Pivi[1], N. Redmon[1], C. Rivetta[1], O. Turgut[1], D. Aguilera[2], G. Arduini[2], H. Bartosik[2], S. Calvo[2],W. Hofle[2], G. Iadarola[2], G. Kotzian[2], K. Li[2], E. Metral[2], E. Montesinos[2], G. Rumolo[2], B. Salvant[2], U. Wehrle[2], M. Wendt[2], C. Zanini[2], S. De Santis[3], H. Qian[3], D. Alesini[4], A. Drago[4], S. Gallo[4], F. Marcellini[4], M. Zobov[4], M.Tobiyama[5]

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[5] KEK

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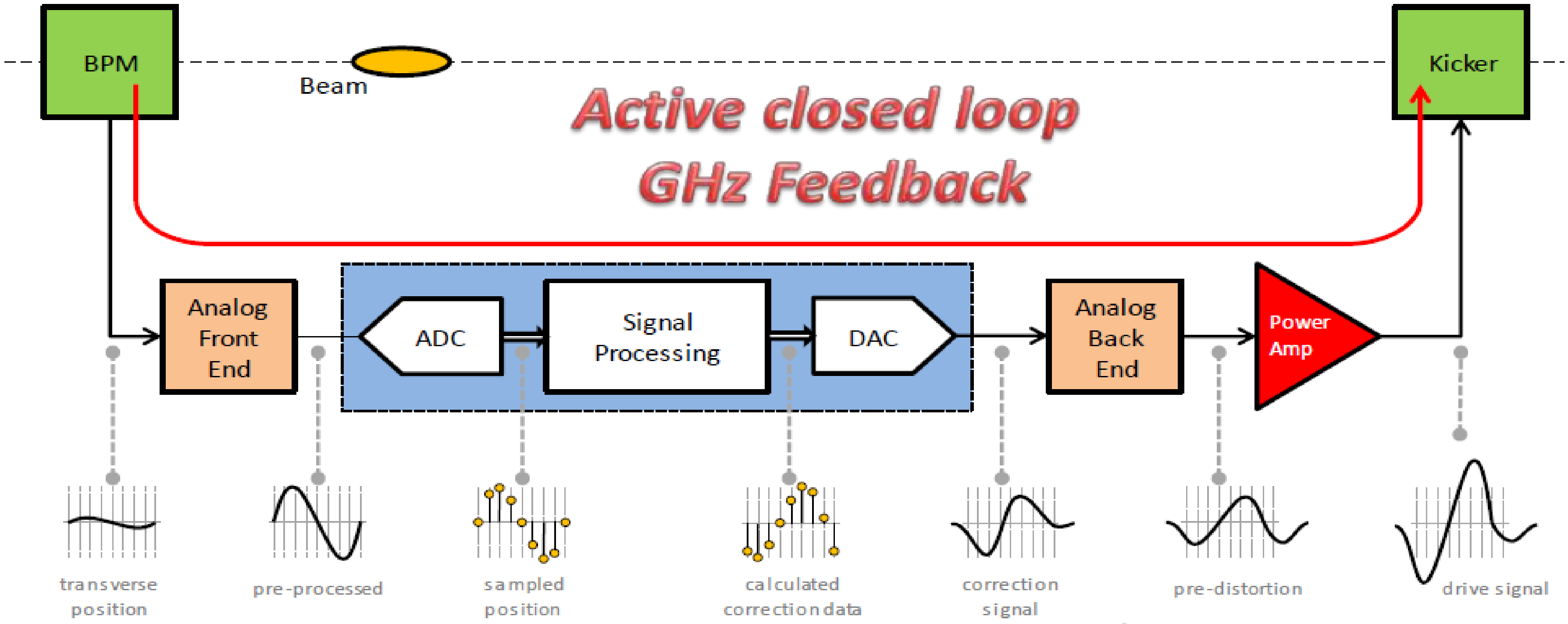
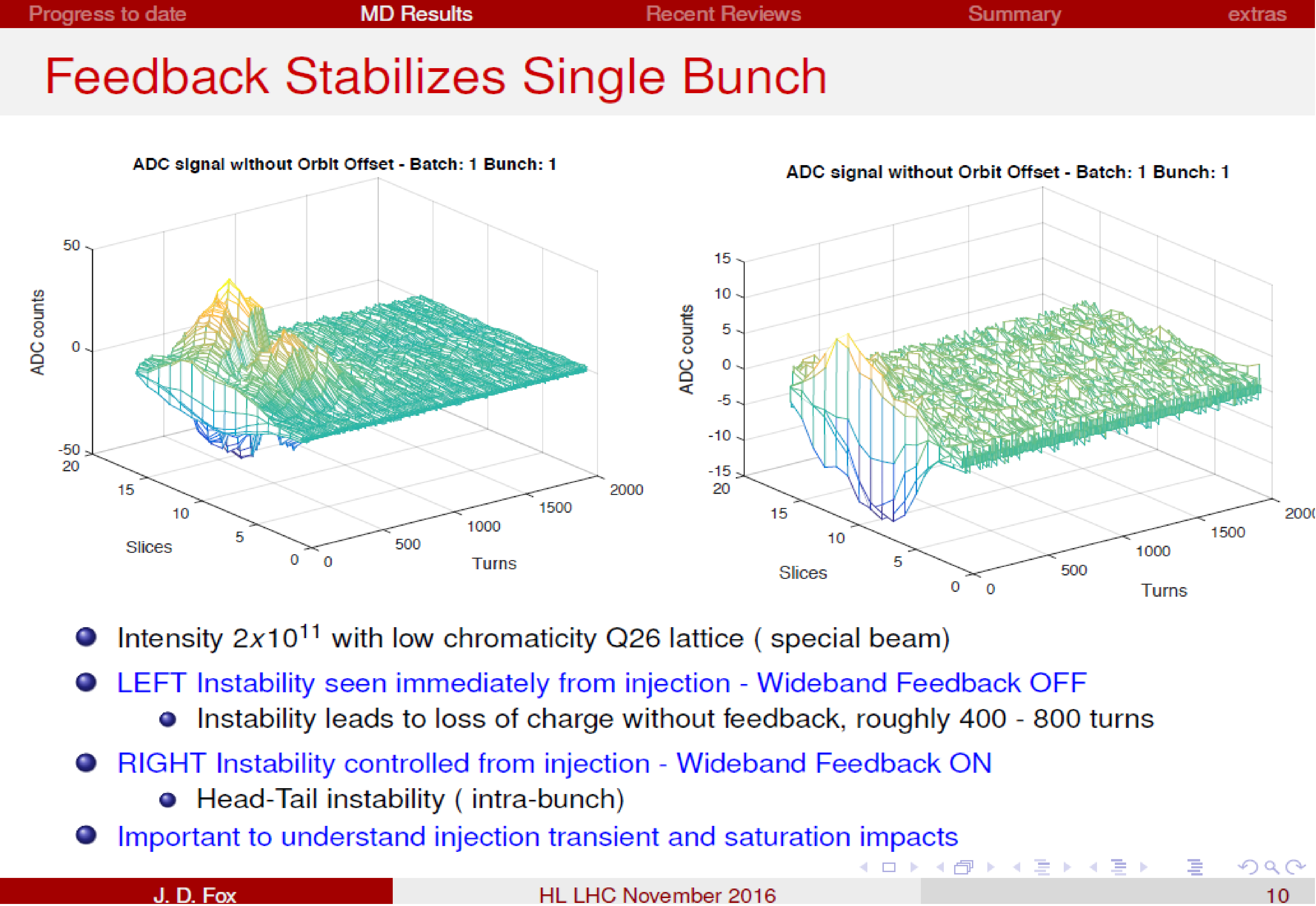
WBFS - Functional requirements



- Pickup - provides moment (charge*position)
- Analog Front End - Δ and Σ
- GHz Bandwidth, equalization

- 4 - 8 GS/s DSP
- Orbit rejection, processing gain
- Tailored gain vs. phase for damping

- Back End - RF drive to power stages, equalization
- Kickers - converts RF to transverse kick
- Timing, Synchronization, Diagnostics



Feedback Stabilizes Single Bunch

- Intensity 2x10^{11} with low chromaticity Q26 lattice (special beam)
- LEFT Instability seen immediately from injection - Wideband Feedback OFF
  - Instability leads to loss of charge without feedback, roughly 400 - 800 turns
- RIGHT Instability controlled from injection - Wideband Feedback ON
  - Head-Tail instability (intra-bunch)
- Important to understand injection transient and saturation impacts

Single Bunch - Stabilized by feedback

- Q26 Optics, Charge $\simeq 2.05 \times 10^{11}$ part.
- Transverse damper is ON. Wideband feedback is ON.
- TWC $= 1.4$MV, Chromaticity posiitve, tune $= 0.183$, $\epsilon_y = 1.7\mu m$.

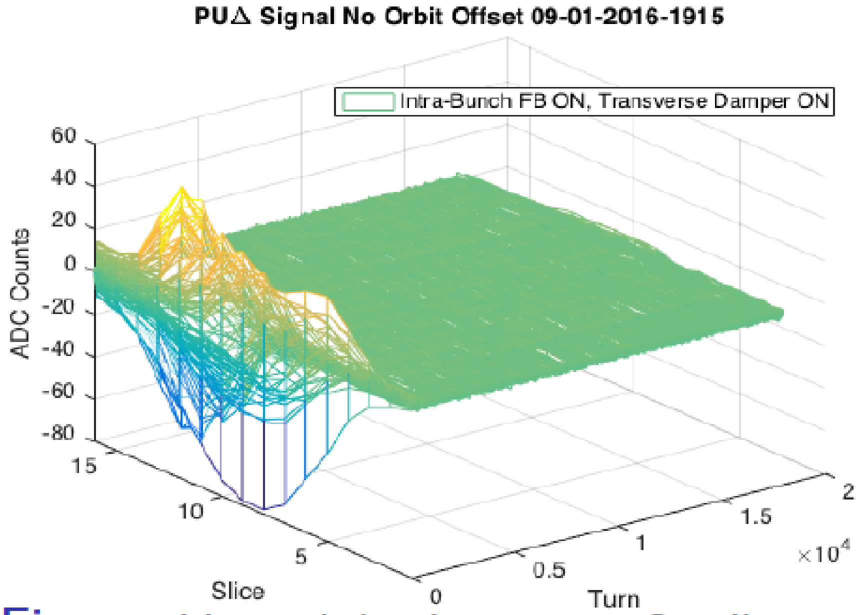


Figure: Vertical dipole motion. Small amount of charge is lost at injection.

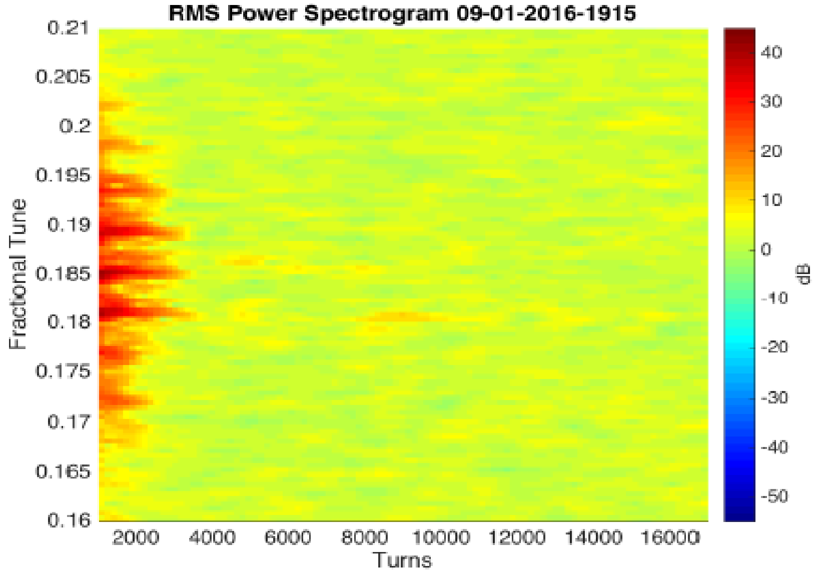
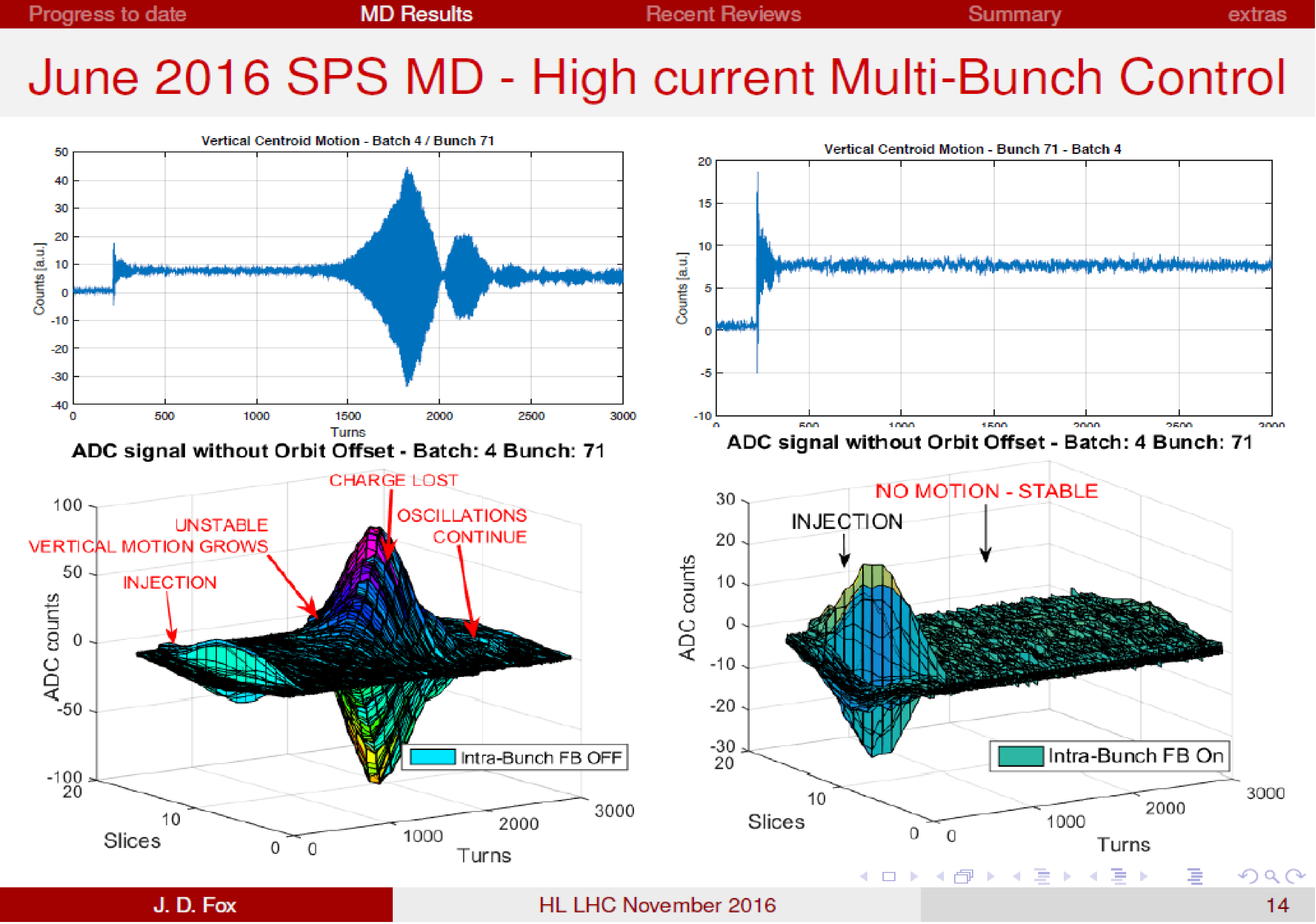


Figure: Spectrogram.



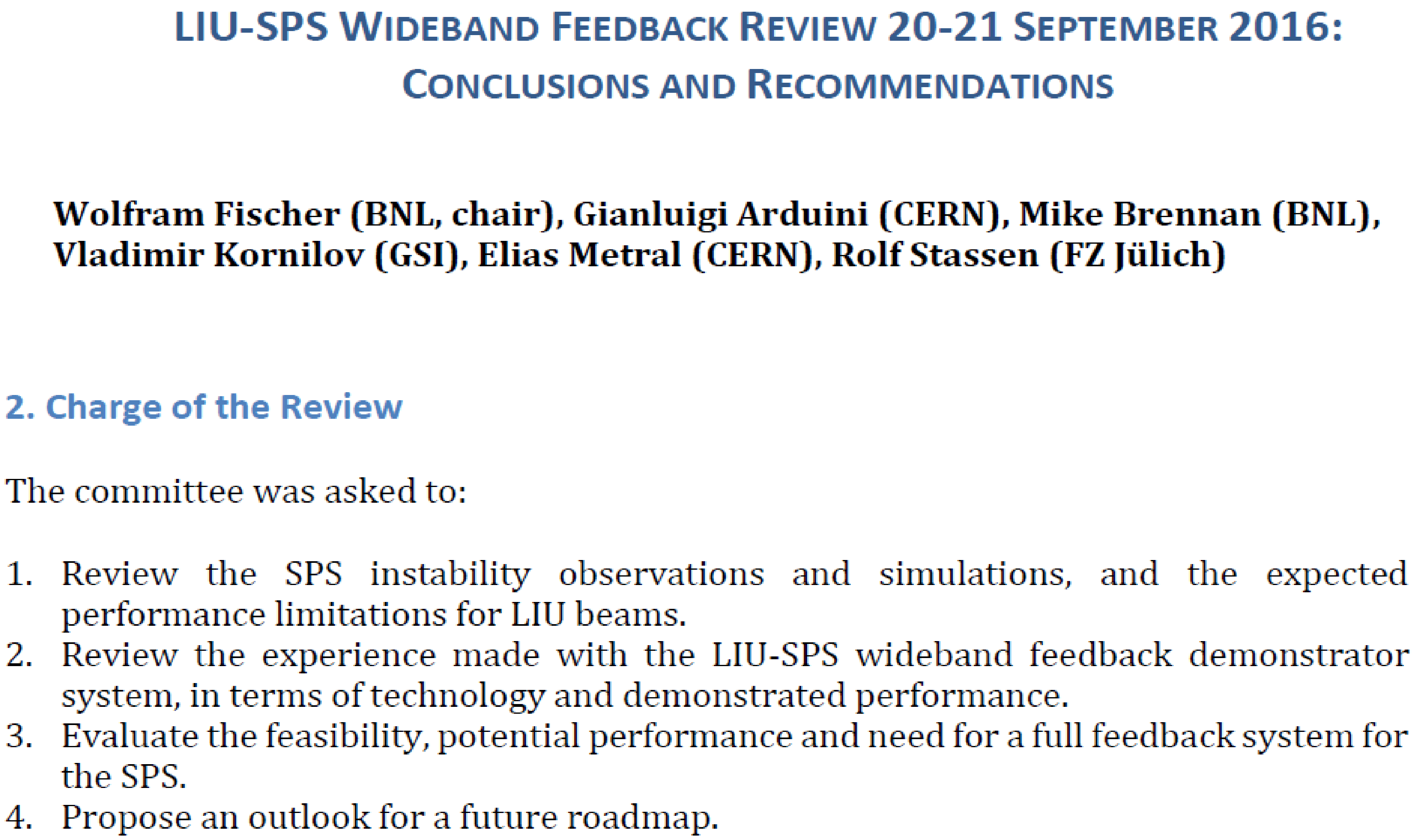
Progress to date | MD Results | Recent Reviews | Summary | extras

June 2016 SPS MD - High current Multi-Bunch Control

ADC signal without Orbit Offset - Batch: 4 Bunch: 71

ADC signal without Orbit Offset - Batch: 4 Bunch: 71

J. D. Fox | HL LHC November 2016 | 14



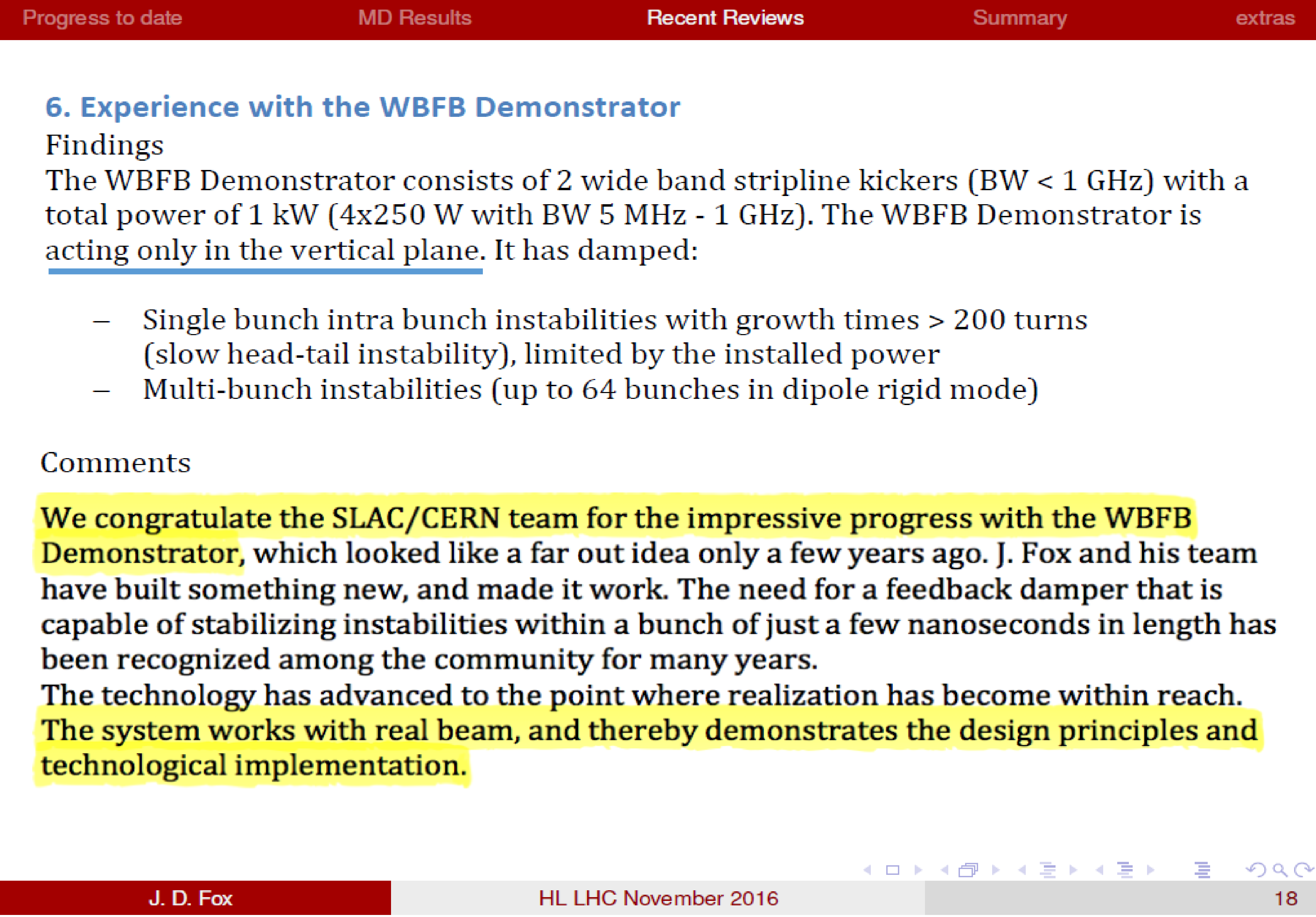
LIU-SPS WIDEBAND FEEDBACK REVIEW 20-21 SEPTEMBER 2016: CONCLUSIONS AND RECOMMENDATIONS

Wolfram Fischer (BNL, chair), Gianluigi Arduini (CERN), Mike Brennan (BNL), Vladimir Kornilov (GSI), Elias Metral (CERN), Rolf Stassen (FZ Jülich)

2. Charge of the Review

The committee was asked to:

1. Review the SPS instability observations and simulations, and the expected performance limitations for LIU beams.
2. Review the experience made with the LIU-SPS wideband feedback demonstrator system, in terms of technology and demonstrated performance.
3. Evaluate the feasibility, potential performance and need for a full feedback system for the SPS.
4. Propose an outlook for a future roadmap.



6. Experience with the WBFB Demonstrator

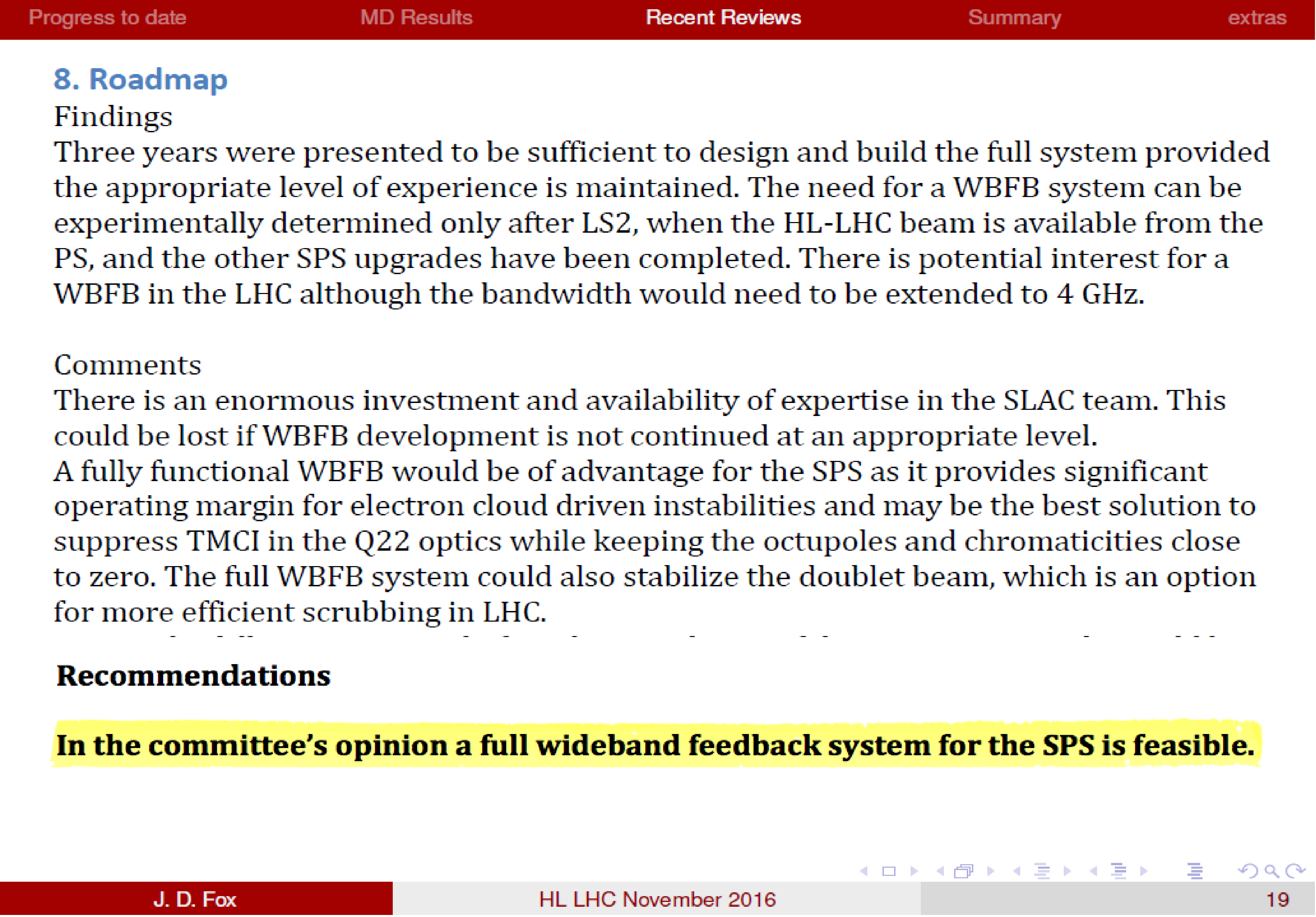
Findings

The WBFB Demonstrator consists of 2 wide band stripline kickers (BW < 1 GHz) with a total power of 1 kW (4x250 W with BW 5 MHz - 1 GHz). The WBFB Demonstrator is acting only in the vertical plane. It has damped:

- Single bunch intra bunch instabilities with growth times > 200 turns (slow head-tail instability), limited by the installed power
- Multi-bunch instabilities (up to 64 bunches in dipole rigid mode)

Comments

We congratulate the SLAC/CERN team for the impressive progress with the WBFB Demonstrator, which looked like a far out idea only a few years ago. J. Fox and his team have built something new, and made it work. The need for a feedback damper that is capable of stabilizing instabilities within a bunch of just a few nanoseconds in length has been recognized among the community for many years.
The technology has advanced to the point where realization has become within reach. The system works with real beam, and thereby demonstrates the design principles and technological implementation.



8. Roadmap

Findings

Three years were presented to be sufficient to design and build the full system provided the appropriate level of experience is maintained. The need for a WBFB system can be experimentally determined only after LS2, when the HL-LHC beam is available from the PS, and the other SPS upgrades have been completed. There is potential interest for a WBFB in the LHC although the bandwidth would need to be extended to 4 GHz.

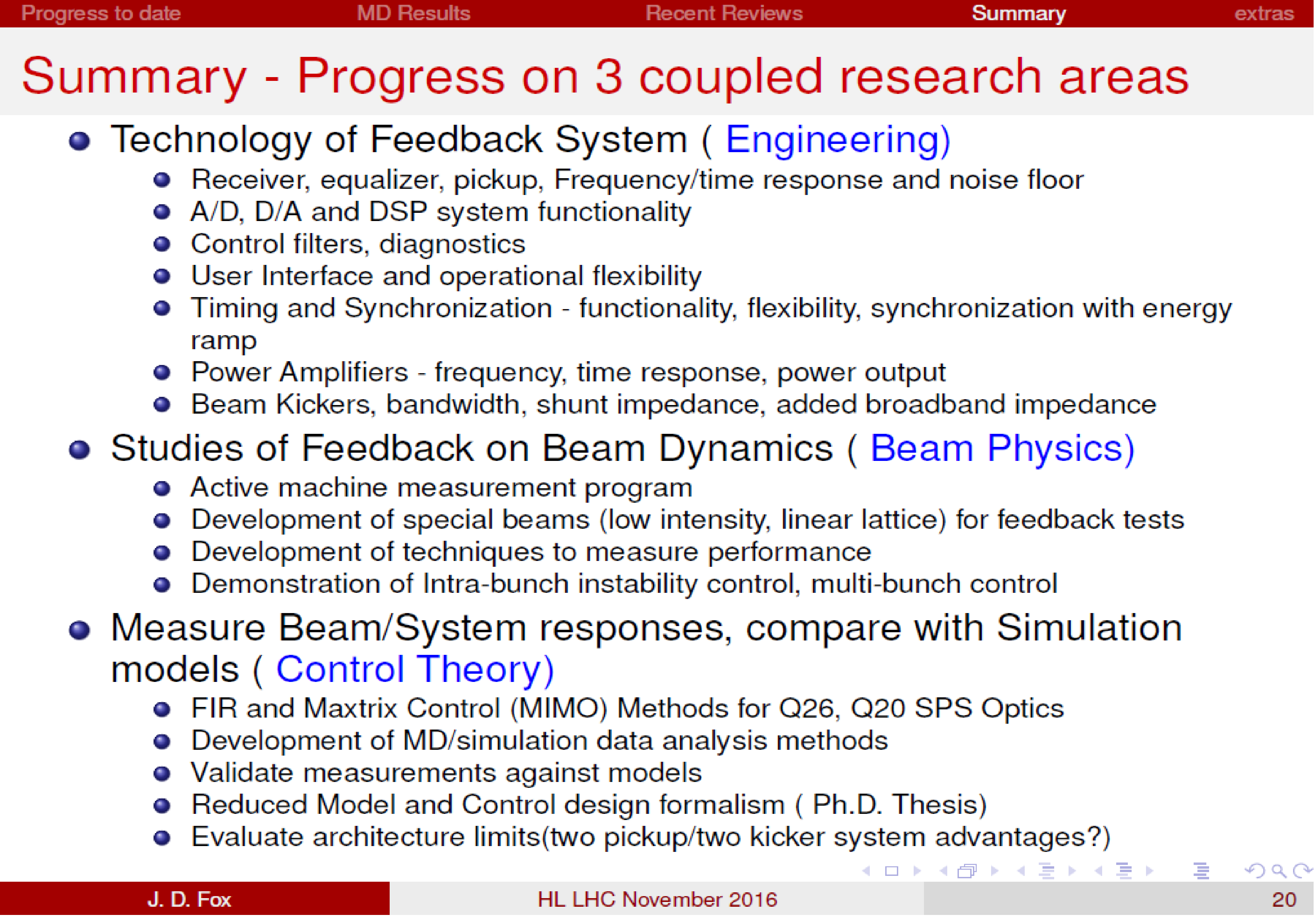
Comments

There is an enormous investment and availability of expertise in the SLAC team. This could be lost if WBFB development is not continued at an appropriate level.

A fully functional WBFB would be of advantage for the SPS as it provides significant operating margin for electron cloud driven instabilities and may be the best solution to suppress TMCI in the Q22 optics while keeping the octupoles and chromaticities close to zero. The full WBFB system could also stabilize the doublet beam, which is an option for more efficient scrubbing in LHC.

Recommendations

In the committee's opinion a full wideband feedback system for the SPS is feasible.



Summary - Progress on 3 coupled research areas

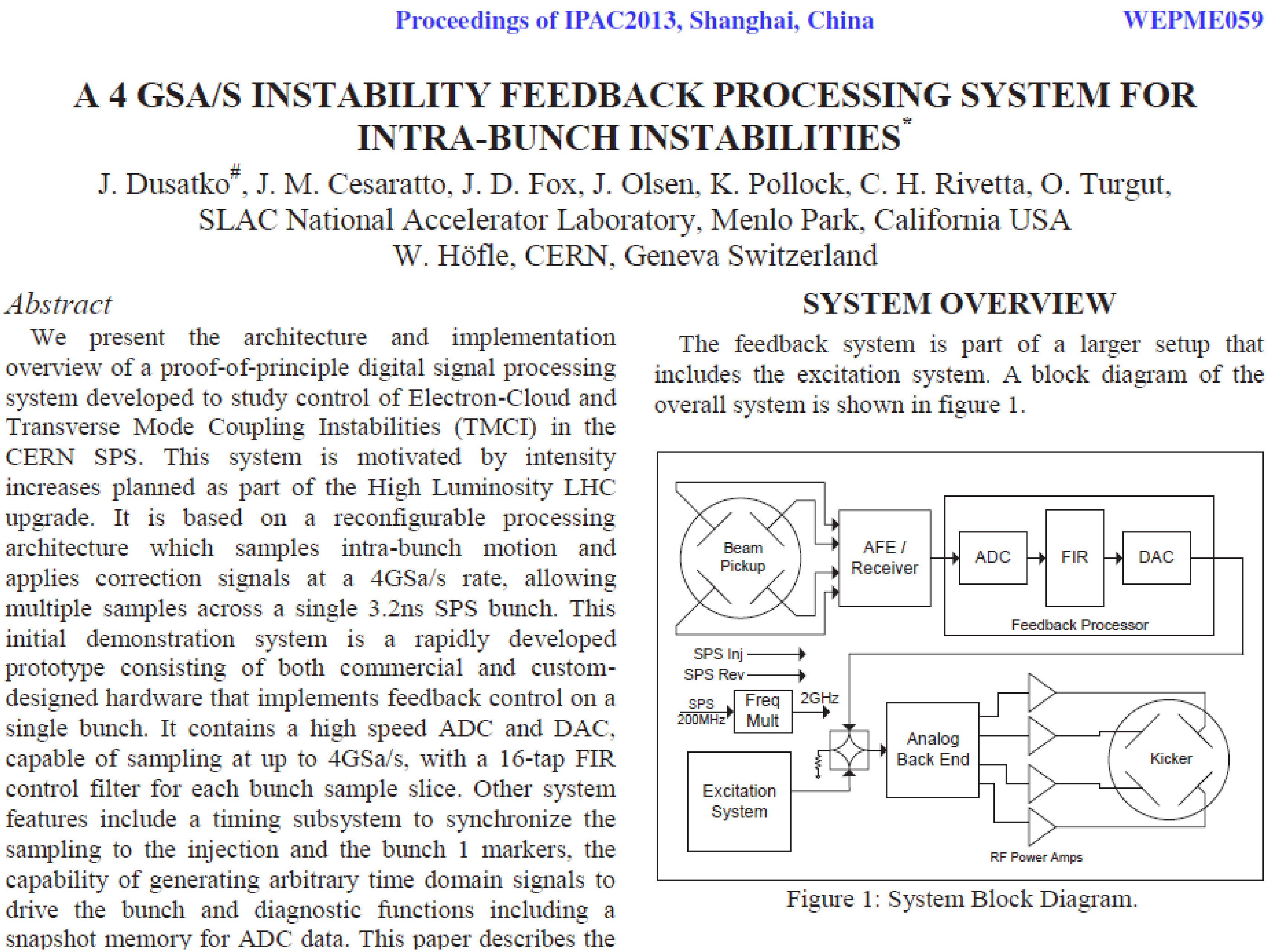
- Technology of Feedback System (Engineering)
  - Receiver, equalizer, pickup, Frequency/time response and noise floor
  - A/D, D/A and DSP system functionality
  - Control filters, diagnostics
  - User Interface and operational flexibility
  - Timing and Synchronization - functionality, flexibility, synchronization with energy ramp
  - Power Amplifiers - frequency, time response, power output
  - Beam Kickers, bandwidth, shunt impedance, added broadband impedance
- Studies of Feedback on Beam Dynamics (Beam Physics)
  - Active machine measurement program
  - Development of special beams (low intensity, linear lattice) for feedback tests
  - Development of techniques to measure performance
  - Demonstration of Intra-bunch instability control, multi-bunch control
- Measure Beam/System responses, compare with Simulation models (Control Theory)
  - FIR and Maxtrix Control (MIMO) Methods for Q26, Q20 SPS Optics
  - Development of MD/simulation data analysis methods
  - Validate measurements against models
  - Reduced Model and Control design formalism (Ph.D. Thesis)
  - Evaluate architecture limits(two pickup/two kicker system advantages?)

A feasibility study for DAFNE?

- In the 2020 DAFNE should stop to work as a collider
- The idea to continue activities is to propose DAFNE-TF (DAFNE Test Facility) to run for small experiments.
- They are still to be defined and funded
- It could be an occasion to implement in DAFNE e+ main ring, a wideband feedback system for diagnostics and testing purpose <u>working in the horizontal plan.</u>
- This plan can be more convenient for DAFNE, where the e-cloud effects are more evident in horizontal than in the vertical plan.
- First of all, it would be necessary to have a longer bunch. So we need to study how to achieve this goal.

A feasibility study for DAFNE?

- For the pickup we need at least 2GHz bandwidth pickup, that maybe it will be not so difficult to have
- Given that the slotted kicker seems the more compact solution for back end, we can use the 1.1 meter space that we have where now the dump kicker is placed
- We should design and make a slotted kicker fitting in the space considered
- We need to buy two 250W R&K power amplifiers ($$$)
- We need electronics and fast processing units (maybe borrowed by SLAC) as in the following slide



Proceedings of IPAC2013, Shanghai, China WEPME059

A 4 GSA/S INSTABILITY FEEDBACK PROCESSING SYSTEM FOR INTRA-BUNCH INSTABILITIES*

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Abstract

We present the architecture and implementation overview of a proof-of-principle digital signal processing system developed to study control of Electron-Cloud and Transverse Mode Coupling Instabilities (TMCI) in the CERN SPS. This system is motivated by intensity increases planned as part of the High Luminosity LHC upgrade. It is based on a reconfigurable processing architecture which samples intra-bunch motion and applies correction signals at a 4GSa/s rate, allowing multiple samples across a single 3.2ns SPS bunch. This initial demonstration system is a rapidly developed prototype consisting of both commercial and custom-designed hardware that implements feedback control on a single bunch. It contains a high speed ADC and DAC, capable of sampling at up to 4GSa/s, with a 16-tap FIR control filter for each bunch sample slice. Other system features include a timing subsystem to synchronize the sampling to the injection and the bunch 1 markers, the capability of generating arbitrary time domain signals to drive the bunch and diagnostic functions including a snapshot memory for ADC data. This paper describes the

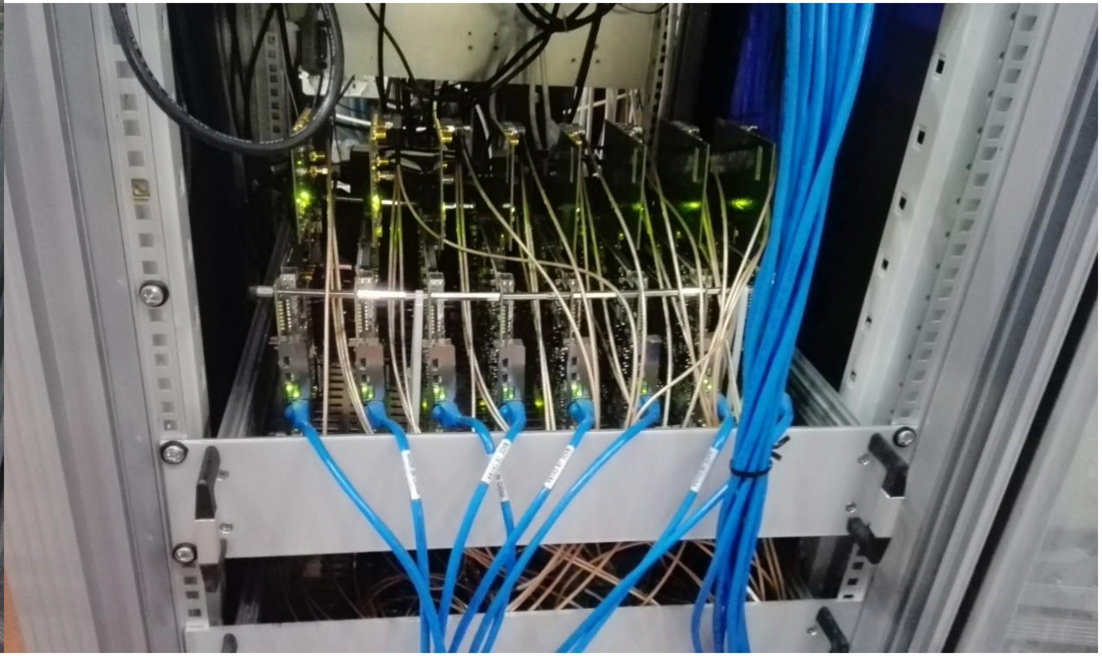
SYSTEM OVERVIEW

The feedback system is part of a larger setup that includes the excitation system. A block diagram of the overall system is shown in figure 1.

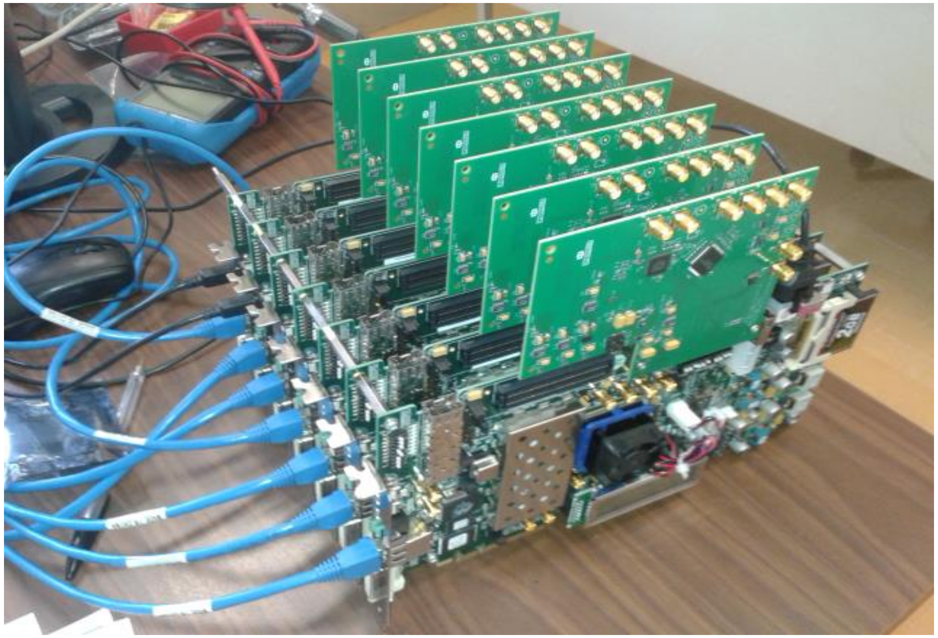
Figure 1: System Block Diagram.

Otherwise…

- We can use an array of FPGA boards with a timing module that are already running in DAFNE hall for another experiment
- Note that in this case, the FPGA needs to be completely reprogrammed to implement the FIR feedback program

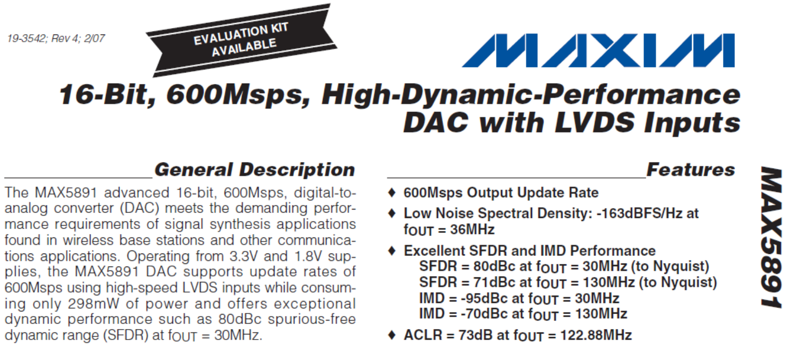


FPGA based acquisition system



- Supposing to split the bunch in 8 or 12 slices, the analogue input signals can be processed independently by the FPGA farm by using 8 or 12 module
- Each ML605 board has a Xilinx Virtex-6 FPGA inside and can store up to 16M contiguous values in real time
- The acquisition will use 368 MHz as sampling clock (DAFNE RF frequency)
- The custom board (in green on the top) contains ADC and DAC, and has in input sampling clock and injection trigger

- 14 bit ADC from Texas Instruments with 1.4 GHz input bandwidth, with LVDS outputs fitting well the ML605 inputs
- 16 bit DAC, 600 Msps



19-3542; Rev 4; 2/07

EVALUATION KIT AVAILABLE

MAXIM

16-Bit, 600Msps, High-Dynamic-Performance DAC with LVDS Inputs

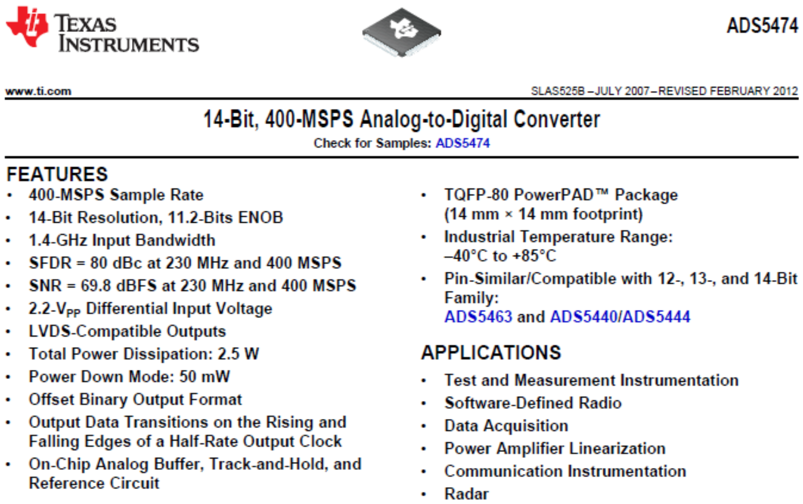
General Description

The MAX5891 advanced 16-bit, 600Msps, digital-to-analog converter (DAC) meets the demanding performance requirements of signal synthesis applications found in wireless base stations and other communications applications. Operating from 3.3V and 1.8V supplies, the MAX5891 DAC supports update rates of 600Msps using high-speed LVDS inputs while consuming only 298mW of power and offers exceptional dynamic performance such as 80dBc spurious-free dynamic range (SFDR) at f_{OUT} = 30MHz.

Features

- ♦ 600Msps Output Update Rate
- ♦ Low Noise Spectral Density: -163dBFS/Hz at f_{OUT} = 36MHz
- ♦ Excellent SFDR and IMD Performance
  - SFDR = 80dBc at f_{OUT} = 30MHz (to Nyquist)
  - SFDR = 71dBc at f_{OUT} = 130MHz (to Nyquist)
  - IMD = -95dBc at f_{OUT} = 30MHz
  - IMD = -70dBc at f_{OUT} = 130MHz
- ♦ ACLR = 73dB at f_{OUT} = 122.88MHz

MAX5891



TEXAS INSTRUMENTS

ADS5474

www.ti.com

SLAS525B – JULY 2007 – REVISED FEBRUARY 2012

14-Bit, 400-MSPS Analog-to-Digital Converter

Check for Samples: ADS5474

FEATURES

- 400-MSPS Sample Rate
- 14-Bit Resolution, 11.2-Bits ENOB
- 1.4-GHz Input Bandwidth
- SFDR = 80 dBc at 230 MHz and 400 MSPS
- SNR = 69.8 dBFS at 230 MHz and 400 MSPS
- 2.2-V_{PP} Differential Input Voltage
- LVDS-Compatible Outputs
- Total Power Dissipation: 2.5 W
- Power Down Mode: 50 mW
- Offset Binary Output Format
- Output Data Transitions on the Rising and Falling Edges of a Half-Rate Output Clock
- On-Chip Analog Buffer, Track-and-Hold, and Reference Circuit
- TQFP-80 PowerPAD™ Package (14 mm × 14 mm footprint)
- Industrial Temperature Range: –40°C to +85°C
- Pin-Similar/Compatible with 12-, 13-, and 14-Bit Family: ADS5463 and ADS5440/ADS5444

APPLICATIONS

- Test and Measurement Instrumentation
- Software-Defined Radio
- Data Acquisition
- Power Amplifier Linearization
- Communication Instrumentation
- Radar

Timing control for the FPGA board

- This is the timing module with 8 digital delay lines to de-skew the sampling frequency for each slice
- To set the correct delay value for each slice, an Arduino Due board (in blue) interfaces by USB the pc
- Minimum delay step is 10 ps
- Rms clock jitter is ~1ps

Conclusion

- Wideband feedback has already demonstrated at SPS that works very well
- No more funding from LARP and Hi-Lumi-LHC
- In 2020 DAFNE-TF could offer the occasion to implement a wideband feedback system in the positron ring (for the horizontal plan)
- The cost of the experiment could be limited to about 300k€
- In case of green light to the project, studies for understanding how to stretch the bunches should be carried on as soon as possible