



Survey of LLRF Development for the ILC

Julien Branlard, FNAL

Brian Chase, FNAL

Shin Michizono, KEK

Stefan Simrock, DESY

And also

V. Ayvazyan, A. Brandt, G. Cancelo, R. Carcagno, J. Carwardine, T. Czarski, K. Czuba, H. Edwards, P. Fafara, R. Fliller, S. Fukuda, Z. Geng, W. Giergusiewicz, A. Grasselino, M. Grecki, B. Hanna, E. Harms, A. Hocker, Mark. Hoffmann, Matt. Hoffmann, M. Hüning, W. Jalmuzna, T. Jezynski, P. Joireman, H. Katagiri, J. Keung, T. Koeth, W. Koprek, M. Kucera, N. Lockyer, F. Ludwig, A. Makulski, T. Matsumoto, U. Mavrič, M. McGee, S. Michizono, M. Newcomer, A. Paytyan, K. Perkuszewski, Y. Pischalnikov, K. Pozniak, P. Prieto, P. Pucyk, R. Rechenmacher, K. Rehlich, J. Reid, R. Romaniuk, H. Schlarb, K. Treptow, V. Tupikov, P. Varghese, E. Vogel, M. Votava, H.C. Weddig, N. Wilcer, Y. Yano, G. Zheqiao, T. Zmuda





E Pluribus Unum

- TTF/A0 Photo Injector collaboration
 - Started in the mid 1990's
 - H. Edwards, S. Simrock
 - Exchange of knowledge and expertise
- ILC is the **International** Linear Collider
 - Need for a global collaboration
 - Across the globe video conferencing and LLRF workshops are now routine
 - This talk: DESY, KEK, and FNAL for the 3 ILC regions



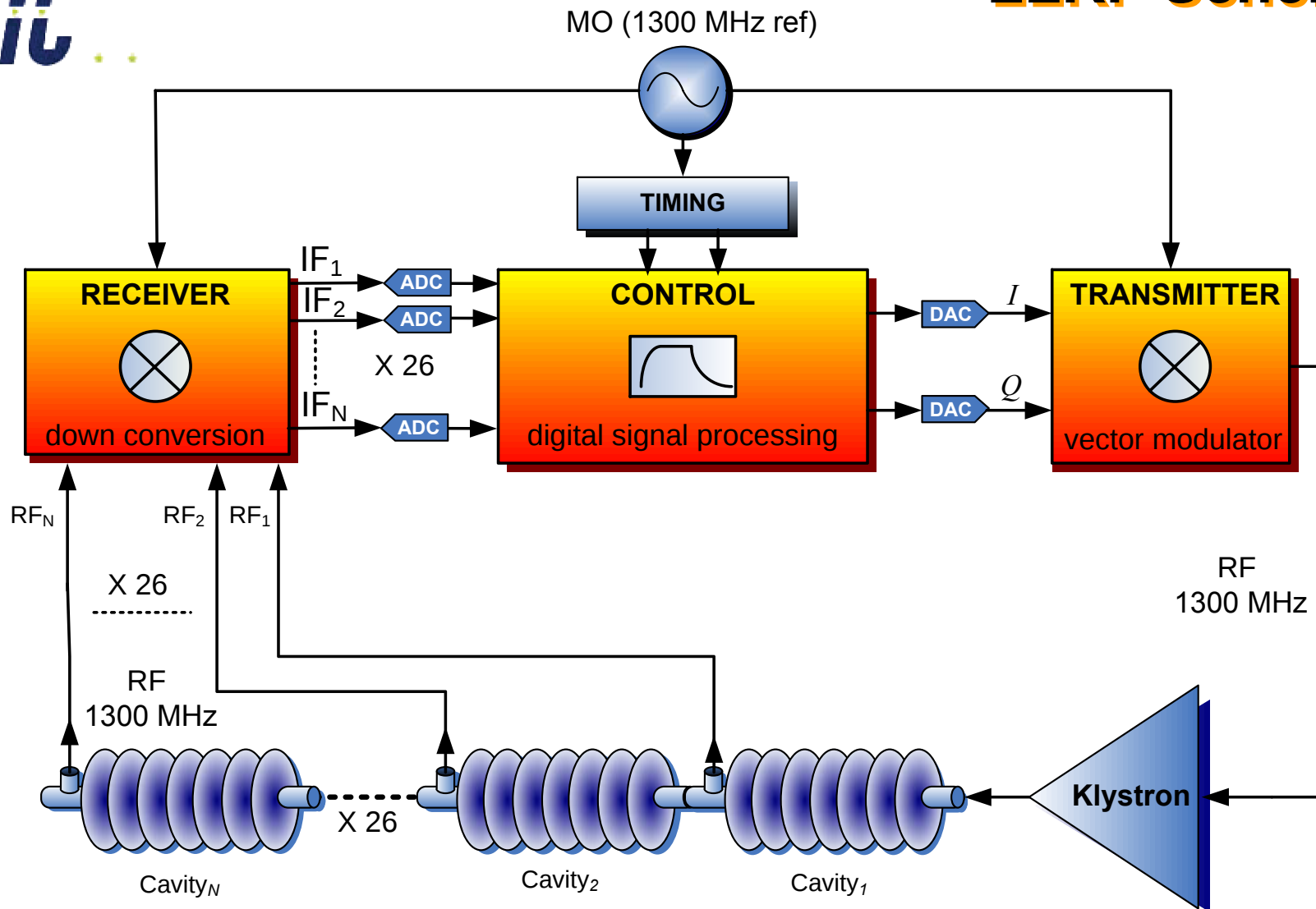
Future Projects Goals (ILCTA, XFEL, STF, ILC)

Require the next generation RF Control System

- Global **0.1% RMS** beam energy regulation
- **Multi-cavity** regulation per klystron system (e.g. 26 for ILC, 48 for HINS)
- Active **piezo-electric tuner** feedback system
- Phase **reference distribution** over kilometers
- **Automation** to fit the ILC machine scale (~16,000 cavities)
- High **reliability**, modularity, and cost effective



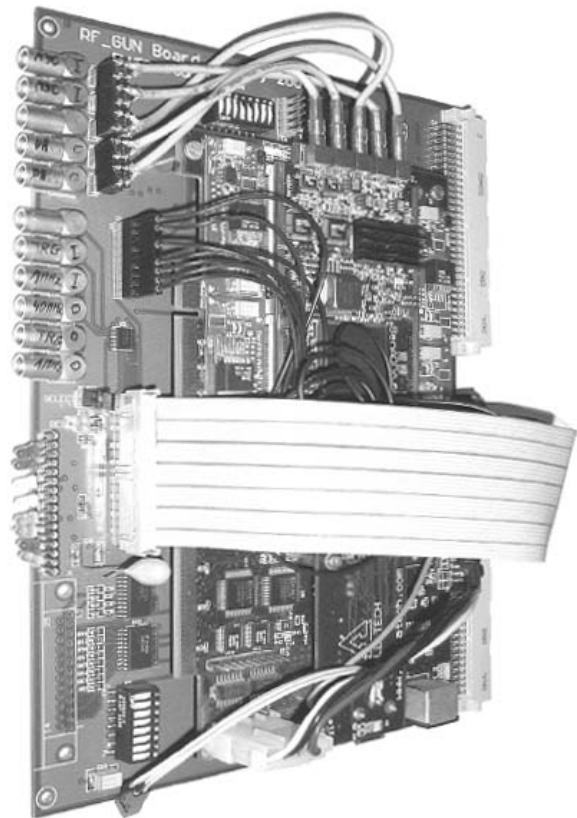
LLRF Scheme



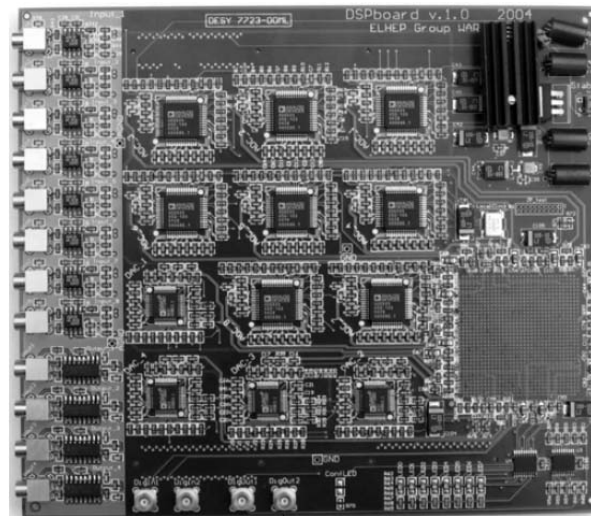


New generations of FPGA controllers

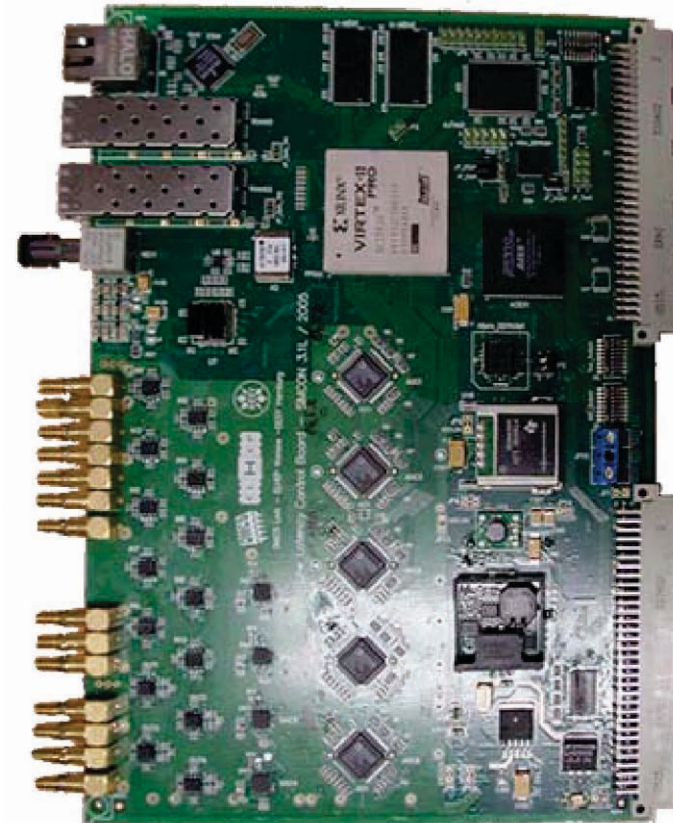
SIMCON boards (DESY, Lodz, Warsaw)



SIMCON2.1



SIMCON3.0

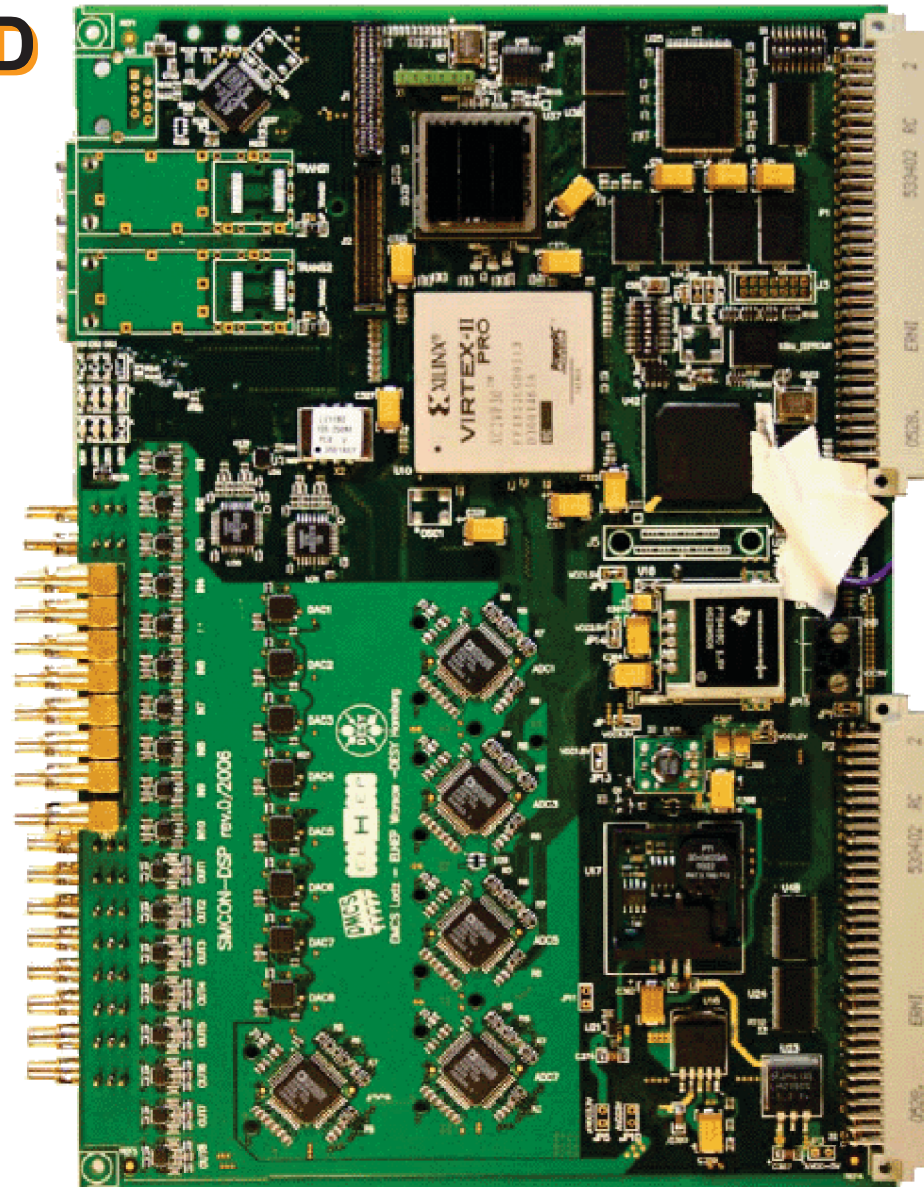


SIMCON3.1



DESY – Hardware R&D

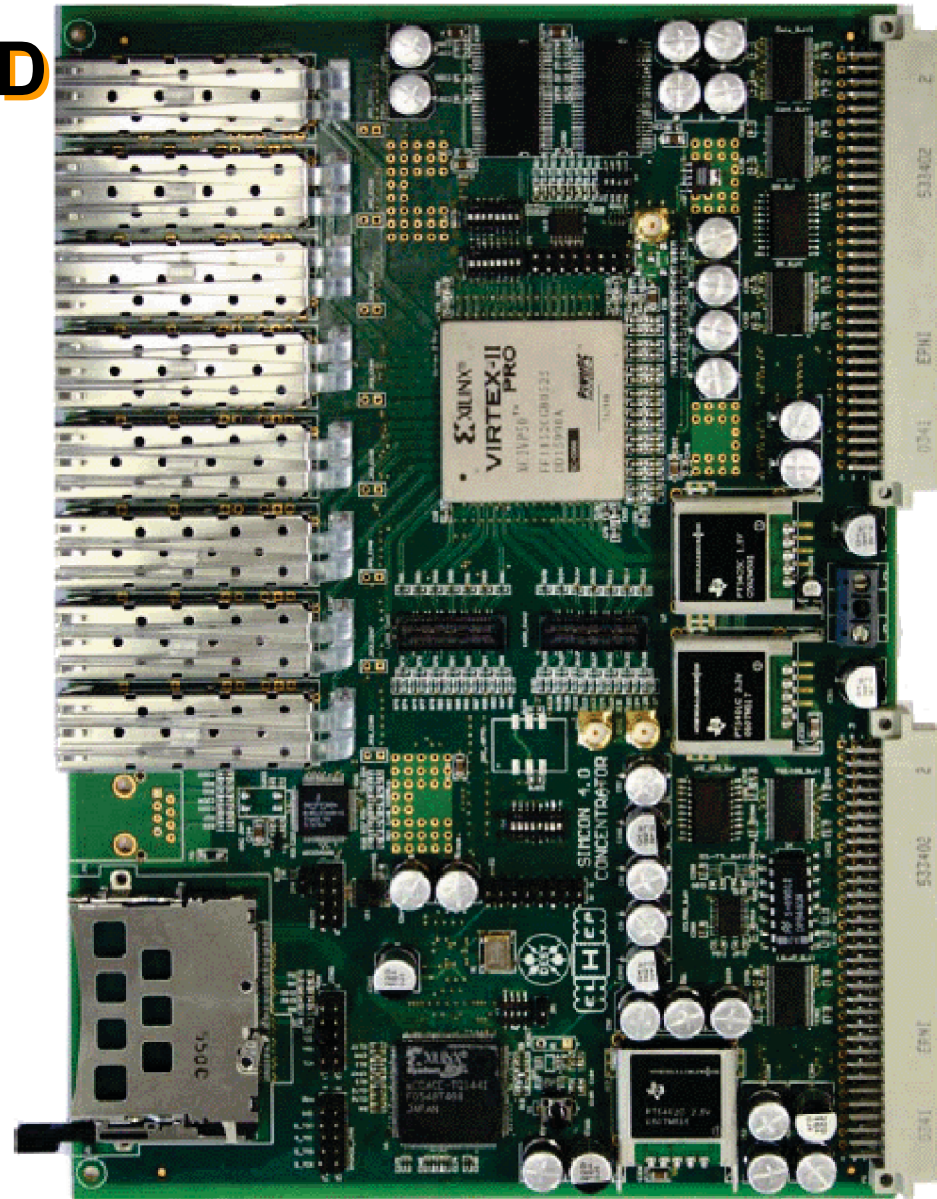
- SIMCON DSP:
 - Xilinx Virtex II
 - TigerShark DSP
 - 10 ADCs
 - 8 DACs
 - 2 opto gigalinks
 - VME interface
- DSP
 - pulse to pulse algorithms
- FPGA
 - fast corrections during pulse





DESY – Hardware R&D

- For 24 cavities
→ 3 SIMCON controllers
(for cavity probes only)
- SIMCON4.0 (concentrator board)
 - Xilinx Virtex II Pro
 - 8 opto gigaLinks





Receiver Prototype

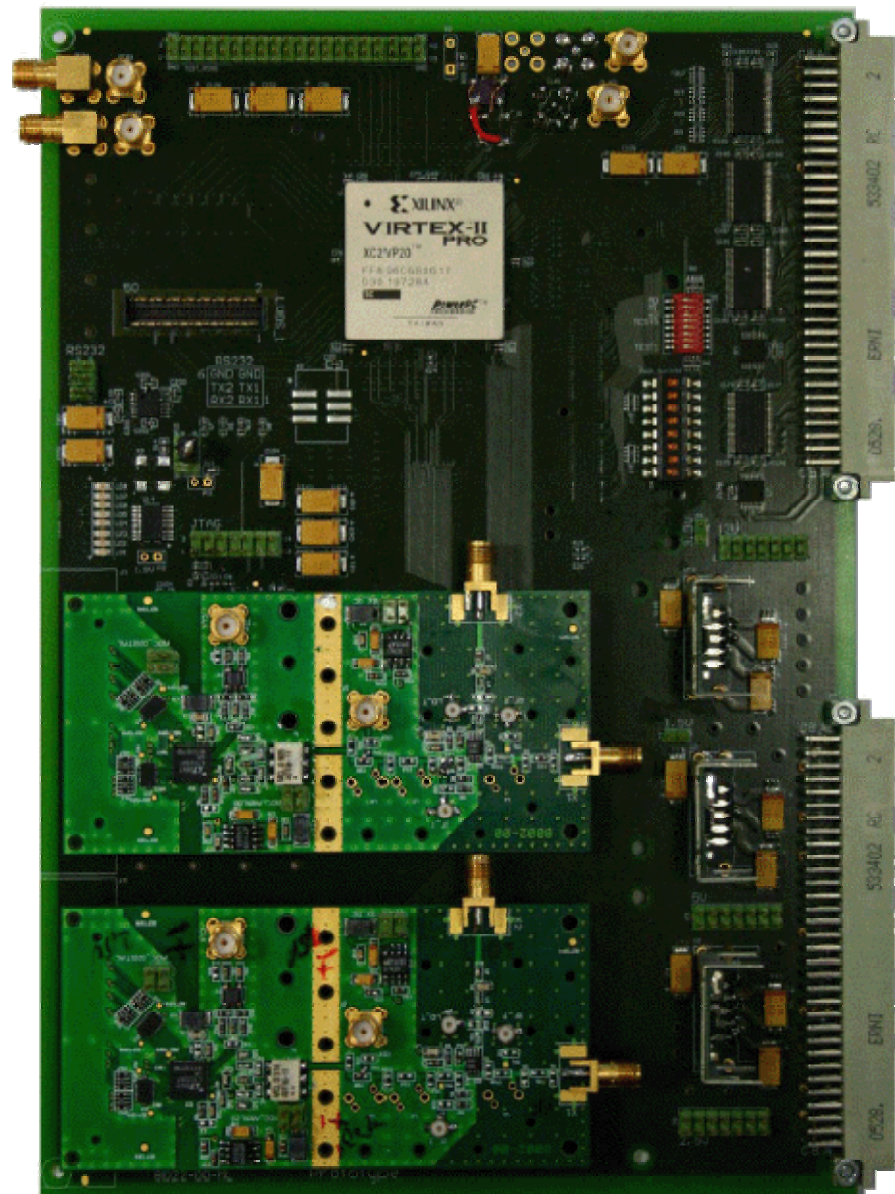
- IF down converters (WEPN011)

➔ Digital mother board for testing analog multi channel down converter daughter boards

Other hardware R&D include

- Master Oscillator (MOPAN019)

➔ Investigate a laser based reference distribution





Use of hardware

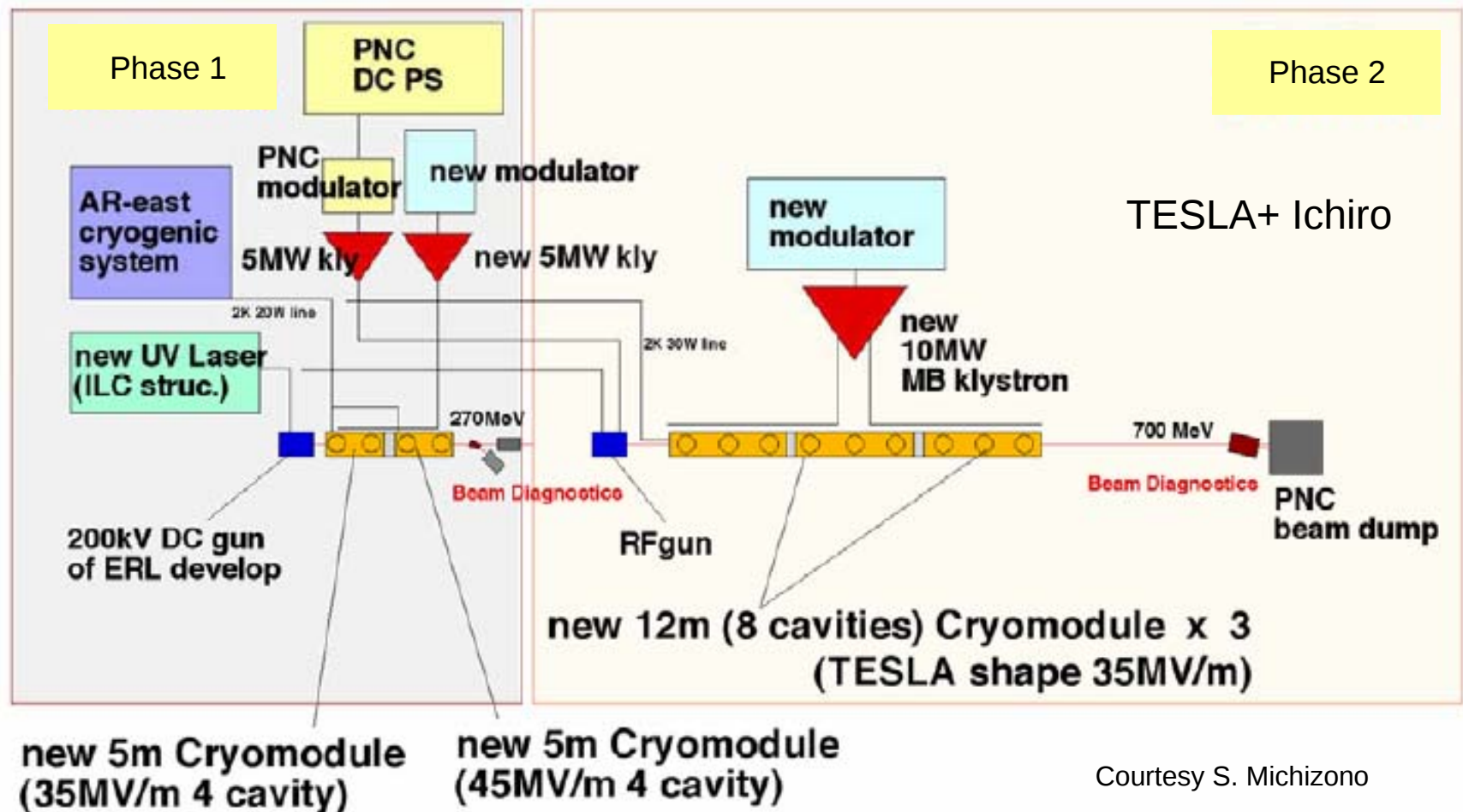
- Cross lab applications for SIMCON
 - DESY
 - RF gun controller at FLASH
 - ACC1 controller at FLASH
 - Desy Module Test Stand controller
 - FNAL
 - SC Capture Cavity I at A0 (~ 16 MV/m)
 - SC Capture Cavity II at Meson (~ 32 MV/m)
 - Horizontal Test Stand at Meson
- Hardware / Firmware exchange
- Knowledge / Expertise transfer



KEK

STF for the ILC

STF-0.5	2 cavities	-2007
STF-1	8 cavities+ gun	-2008
STF-2	26 cavities+ gun	-2010

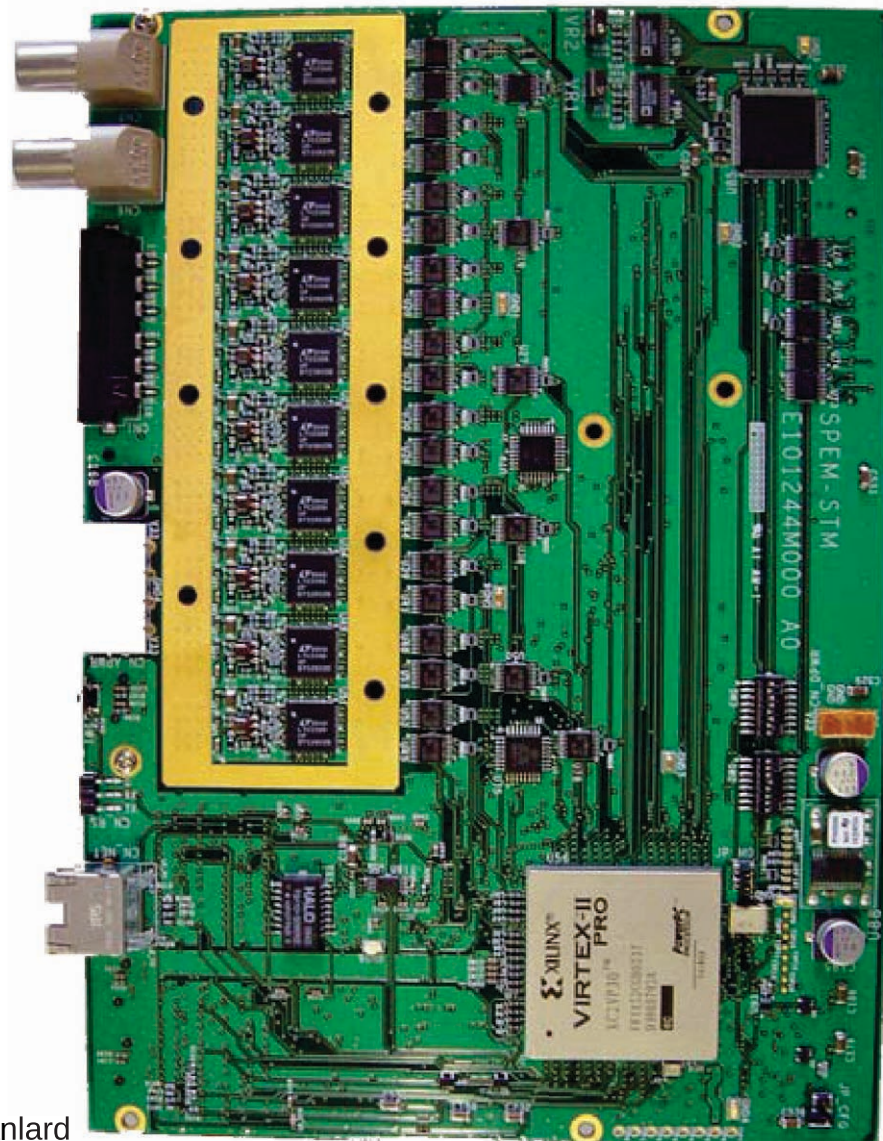




KEK

Multichannel FPGA controller

- 10x 16 bit ADCs
- Virtex II Pro
- 2 DACs
- Commercial DSP board
- low-profile coaxial multiple contact connector
- EPICS GUI interface



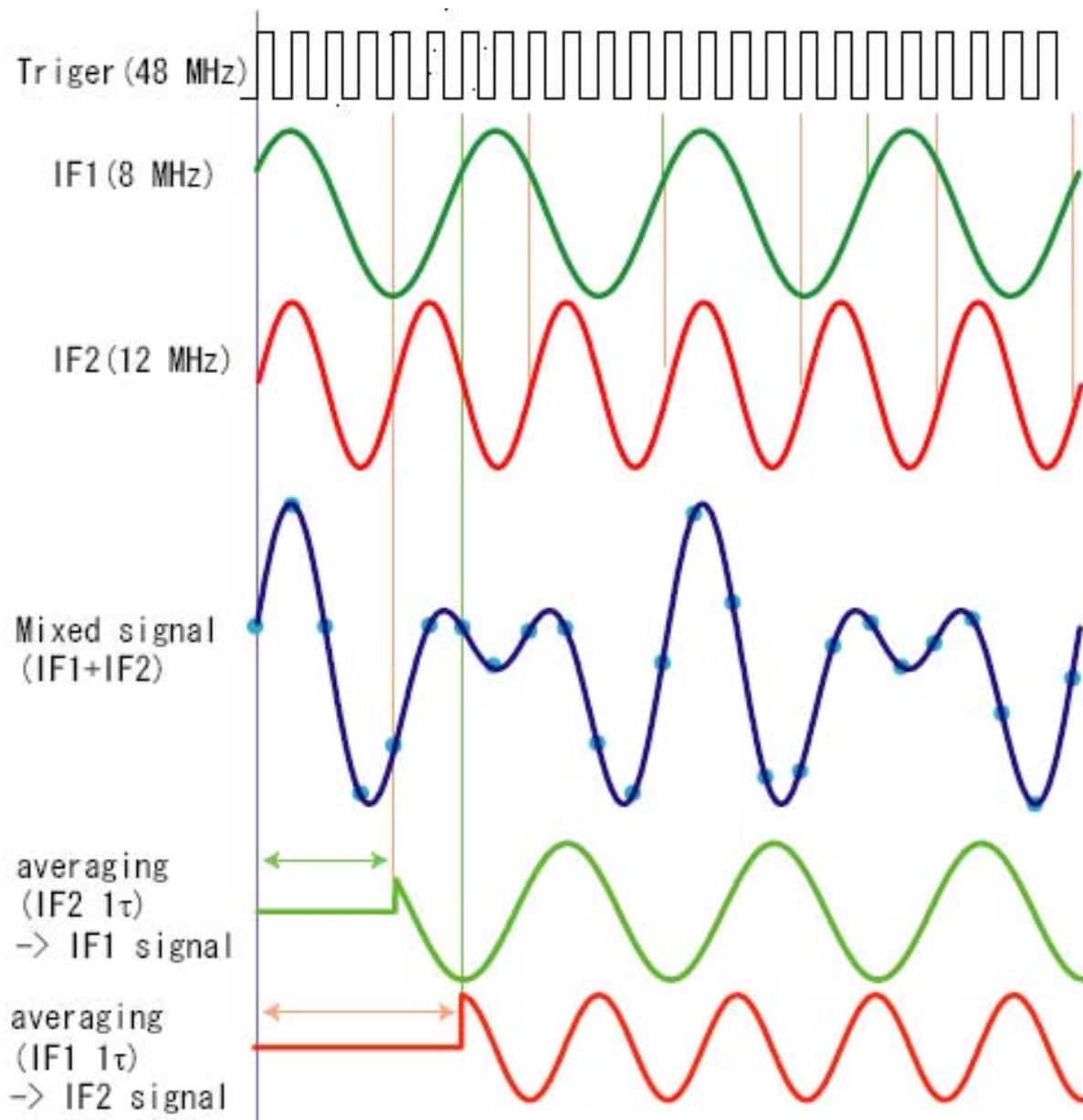


KEK

Summing IFs

- Reduce ADC channel count
- Freq. multiplexing and summing before ADC
- Demultiplexing in FPGA

Preliminary stability results:
amplitude: $\pm 0.2\%$
phase: $\pm 0.2^\circ$



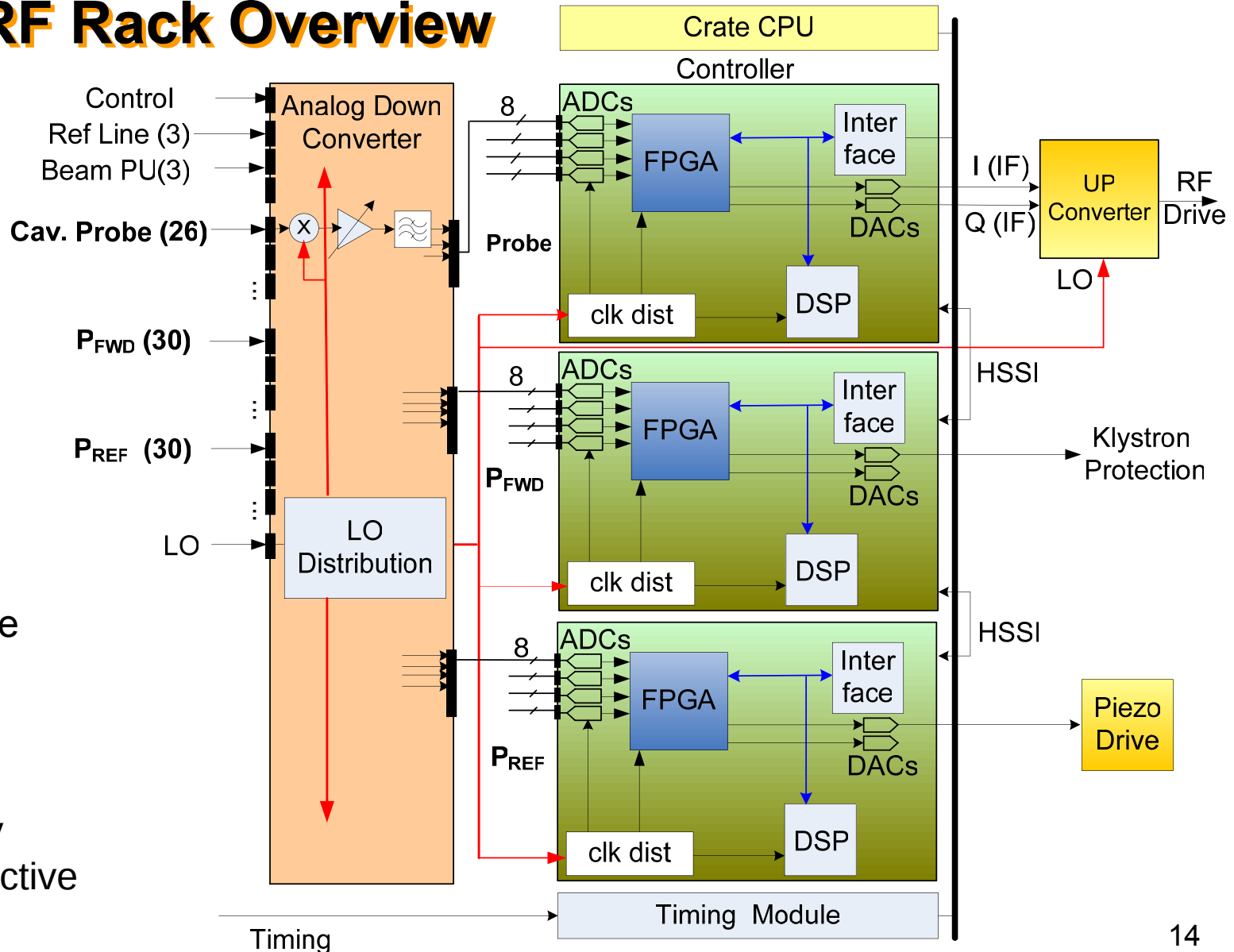


ILCTA at FNAL for the ILC

- Adopted the DESY Simcon system
- Contributed by implementing higher IF and firmware development
- Fermilab has produced a new version Simcon card
- Develop a Multi-Channel Field Control Module (MFC)
 - 32 ADC channels, FPGA, DSP, 4 DAC channels
 - High density, low cost, low power
- Develop the analog RF sections
 - 96 channel receivers
 - Transmitter
 - Master Oscillator



LLRF Rack Overview



- Cav. Probe
- P_{FWD}
- P_{REF}
- Modularity
➔ cost effective



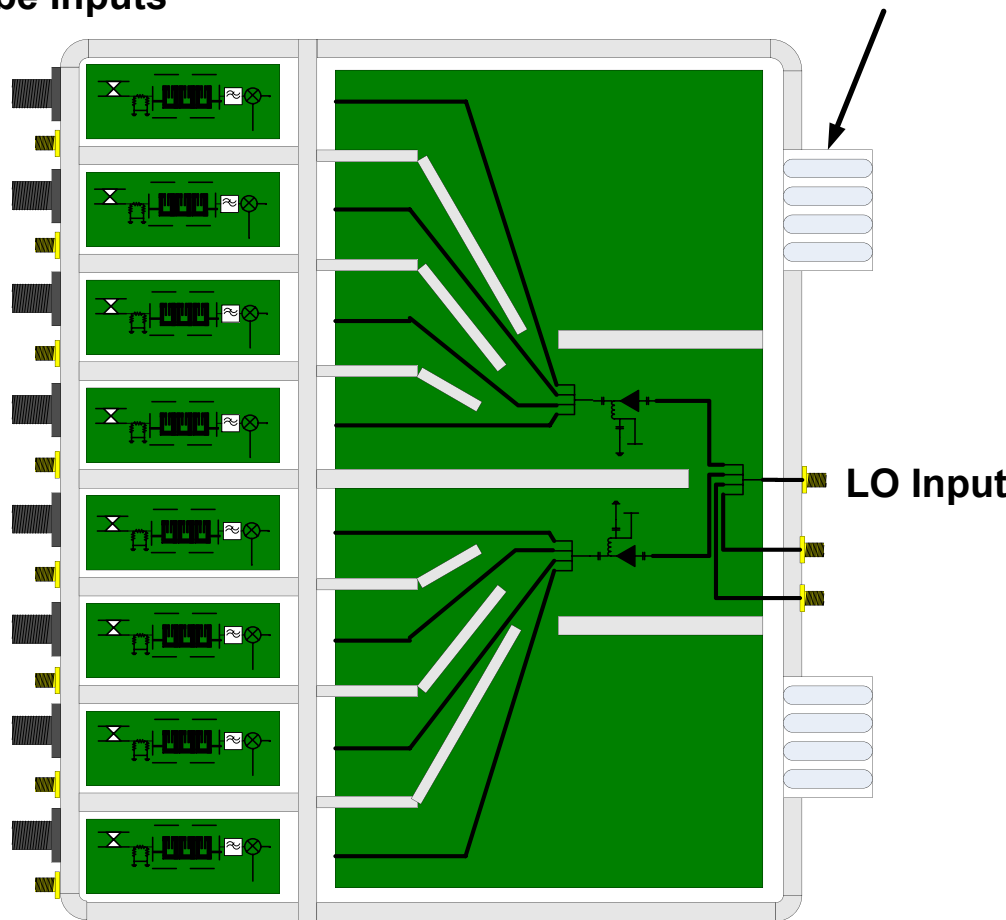
8 channel module IF down converter

8 RF Cavity
Probe Inputs

8 LLRF IF Outputs
Harting Connectors

- 13 MHz IF downconverter
(8 channel module)
- 96 channel crate
(12 modules)

(WEPMN102)



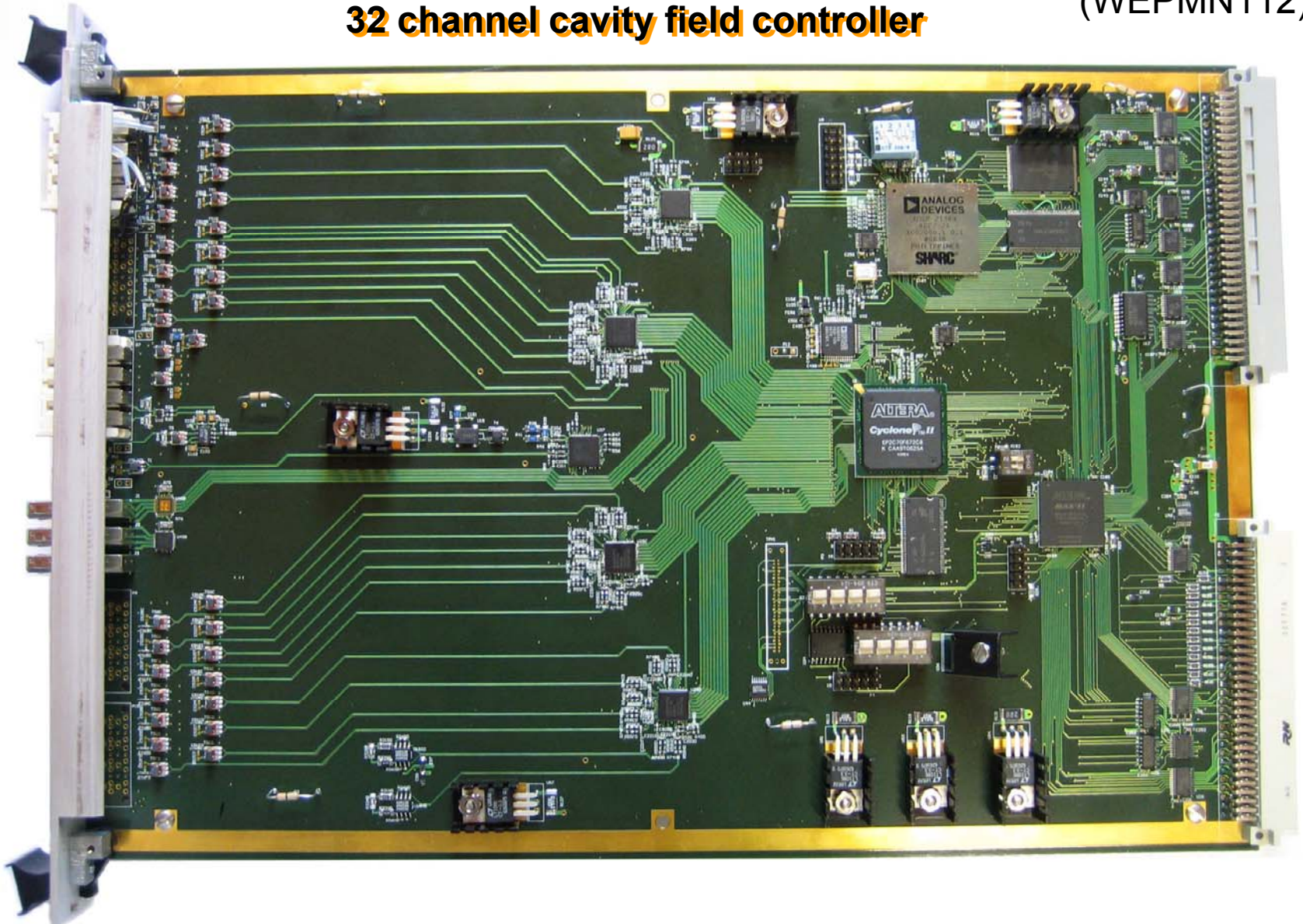
**Down-Converter
Section**

**LO Distribution
Section**



Multi Field Controller (MFC) 32 channel cavity field controller

(WEPMN112)

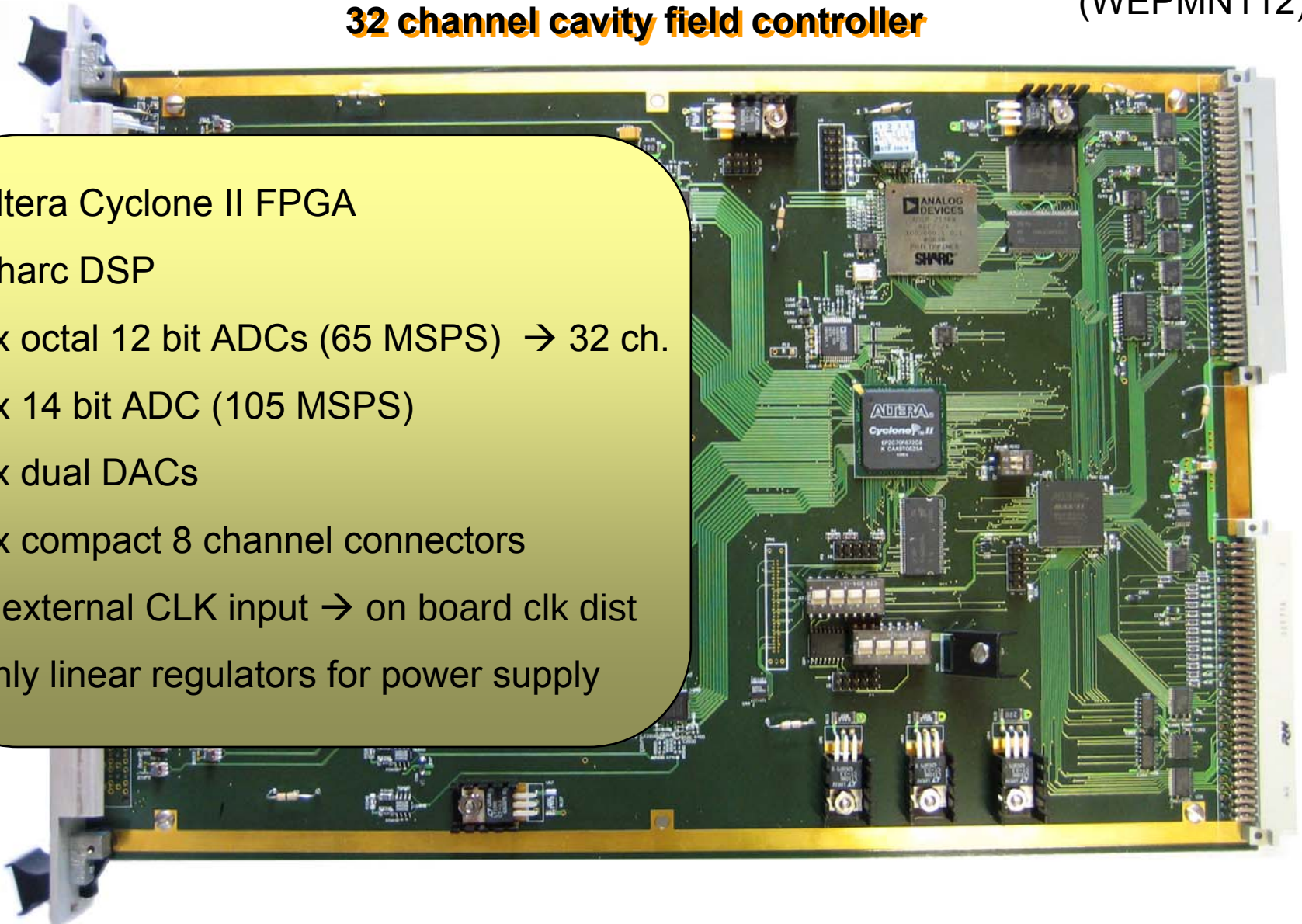




Multi Field Controller (MFC) **32 channel cavity field controller**

(WEPMN112)

- Altera Cyclone II FPGA
- Sharc DSP
- 4x octal 12 bit ADCs (65 MSPS) → 32 ch.
- 1x 14 bit ADC (105 MSPS)
- 2x dual DACs
- 5x compact 8 channel connectors
- 1 external CLK input → on board clk dist
- only linear regulators for power supply





CONCLUSION: Exciting Times

- Many projects ahead worldwide
 - FLASH, XFEL (DESY)
 - STF (KEK)
 - ILCTA, HTS, HINS (FNAL)
 - Etc...
 - Gain experience with tools and techniques
 - ➔ make value-based judgments/decisions for the ILC
- On going cross lab collaborations
 - RDR completed this year
 - EDR developed over the next 3 years



Thank you for your attention!