Karlsruher Institut für Technologie

Ultra-fast data acquisition of *CSR (Coherent Synchrotron Radiation)*

M.Caselle, M. Balzer, V. Judin, A.S. Müller, M. Siegel, N. Smale, P. Thoma, M. Weber, S. Wünsch

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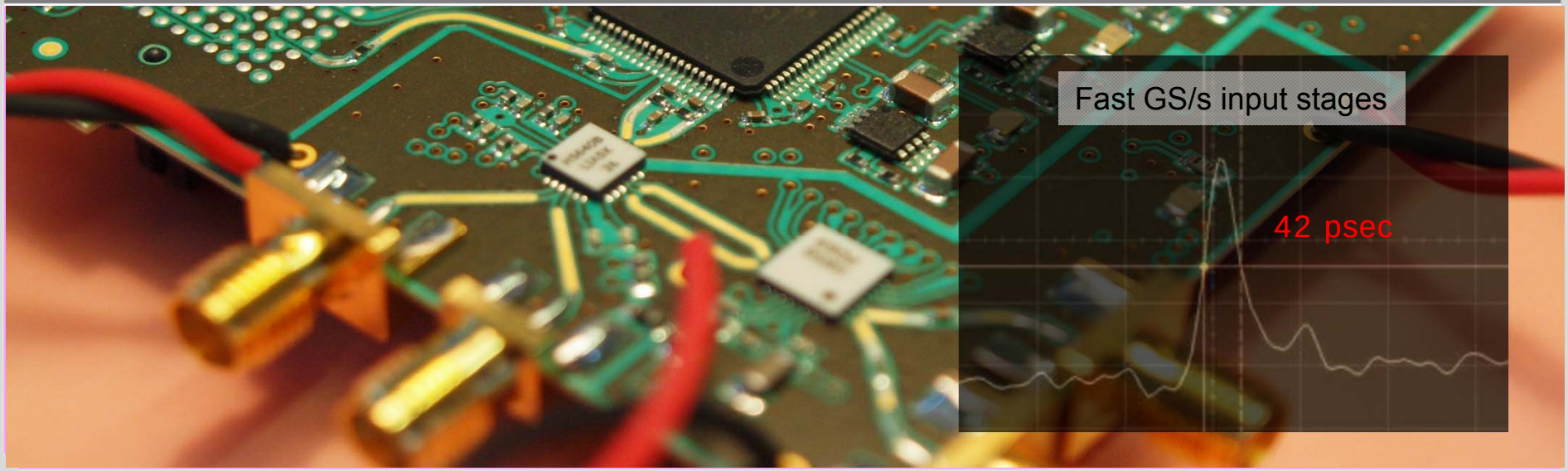
KIT, Institut für Prozessdatenverarbeitung und Elektronik
M. Caselle



Project overview

Karlsruher Institut für Technologie

Funded by the German Federal Ministry of Education and Research
(Grant No. 05K2010)

Design a readout system for measuring of the amplitude and time of fast HEB (Hot Electron Bolometer) signal with a time resolution less than 50ps

Scientific collaboration established between several research institutes in KIT:

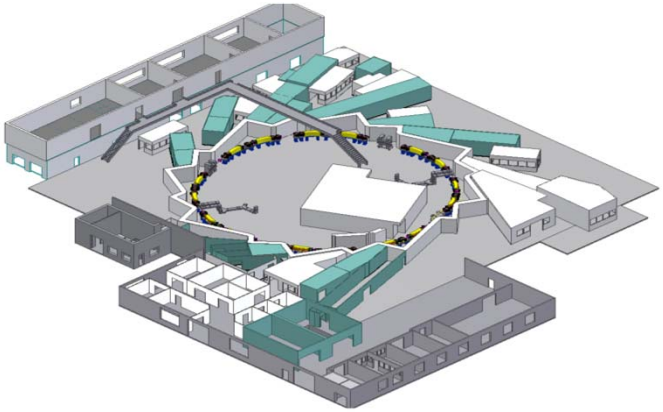
- **IMS** *(Institut für Mikro - und Nanoelektronische Systeme)*
- **IPE** *(Institut für Prozessdatenverarbeitung und Elektronik)*
- **ISS** *(Institut für Synchrotronstrahlung)*

Scientific applications

Possible future applications in the design of novel cryogenic dark matter detector and readout system → ***EDELWEISS*** *and* ***EURECA***

Detection and analysis of CSR (Coherent Synchrotron Radiation) signal in multi-bunch environment

ANKA

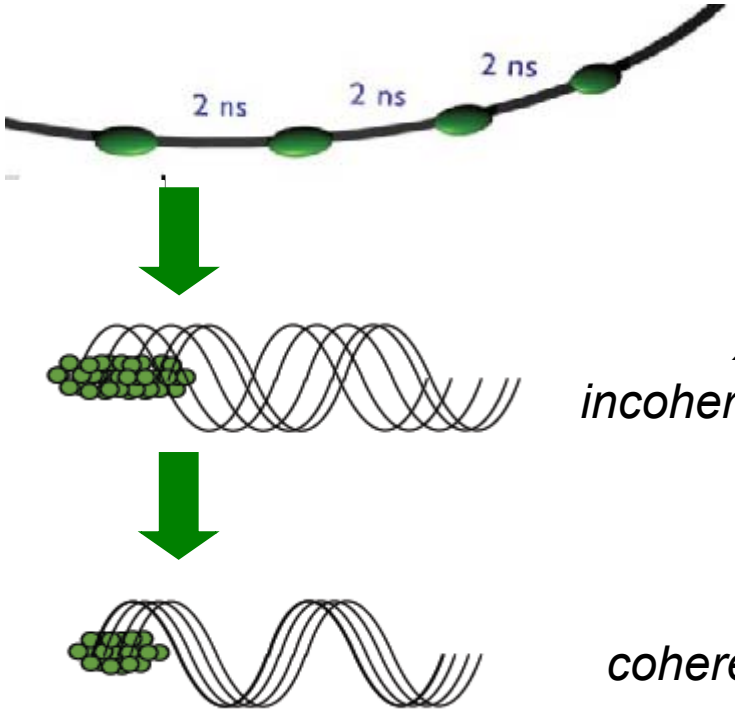


Under development the first experimental station system for CSR at ANKA Synchrotron

An ultra-fast detector can resolve individual buckets of a multi-bunch filling, thus making it possible to study the influences on the THz radiation emission from the filling pattern.

Reference:
OBSERVATION OF COHERENT THZ RADIATION FROM THE ANKA AND MLS STORAGE RINGS WITH A HOT ELECTRON BOLOMETER, Proceedings of PAC09, Vancouver, BC, Canada, (**A.-S. Müller)**

THz radiation at ANKA



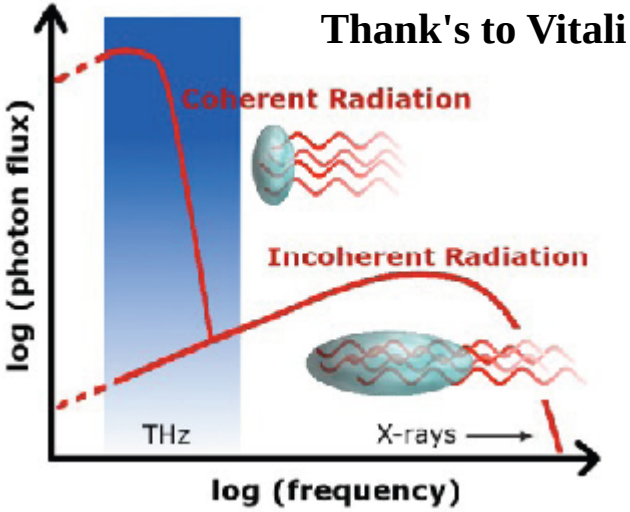
Procedure of bunch compression:

- injection
- ramping to 1.3 GeV
  - "squeeze"

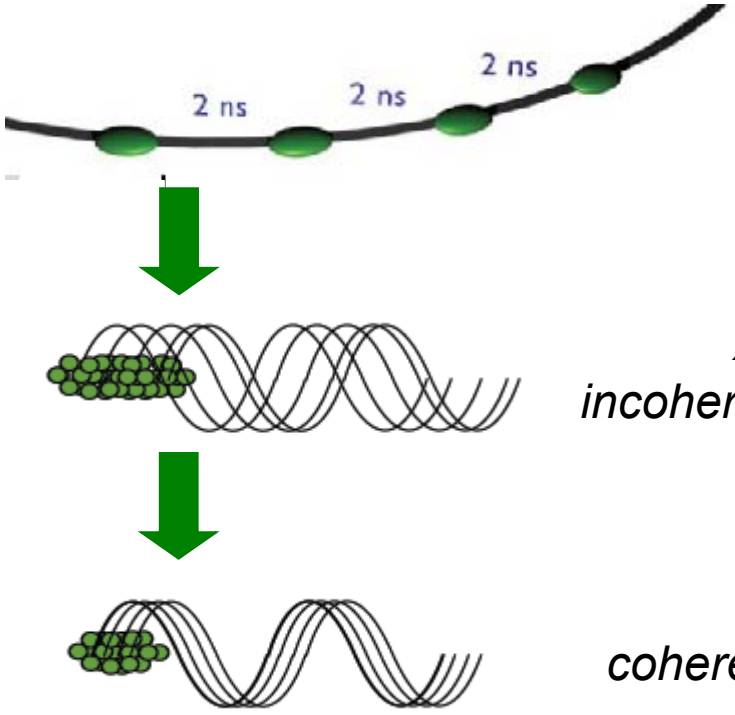
ANKA parameters:

- Circumference: **110.4 m**
- RF-system: **500 MHz**
- Revolution time: **368 ns**
- Harmonic number: **184**
- Revolution frequency: **2.71MHz**
- Beam energy: **2.5 GeV -** low alpha mode: **1.3GeV**
- Bunch length (low alpha mode): few **ps**
- Bunch space: **2ns**

Thank's to Vitali Judin



THz radiation at ANKA



X-ray
incoherent radiation

THz
coherent radiation

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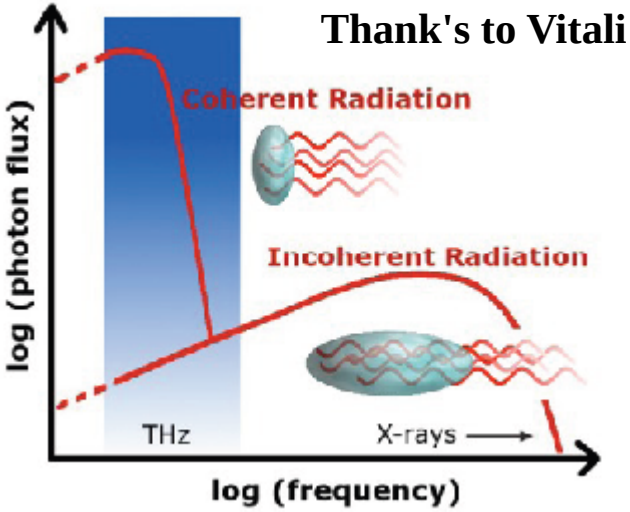
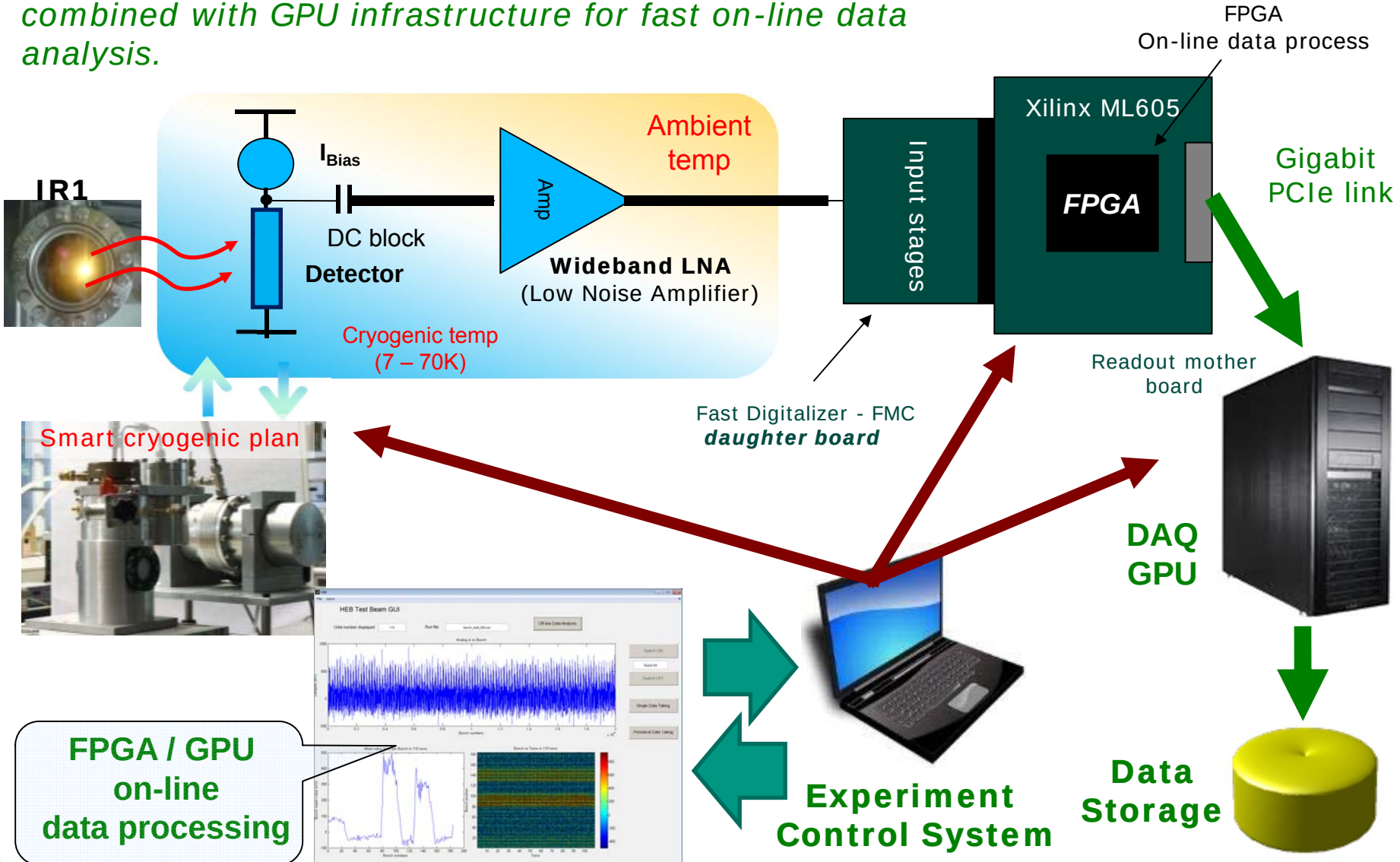


Build a permanent experimental station for measuring of the CSR amplitude and the time jitter between buckets

THz experimental station - Overview

A system based on fast digitizer + data acquisition boards combined with GPU infrastructure for fast on-line data analysis.



YBCO thin film detectors on sapphire substrate

Thin film deposition

Pulsed Laser Deposition, on-axis

Multilayer CeO_2-PBCO-YBCO-PBCO-Au

T_{dep} = 800° C, p_{O2} = 0.7 mbar

Au: T = 75° C, $p \approx 5 \cdot 10^{-5}$ mbar

d_{Au} = 140 nm

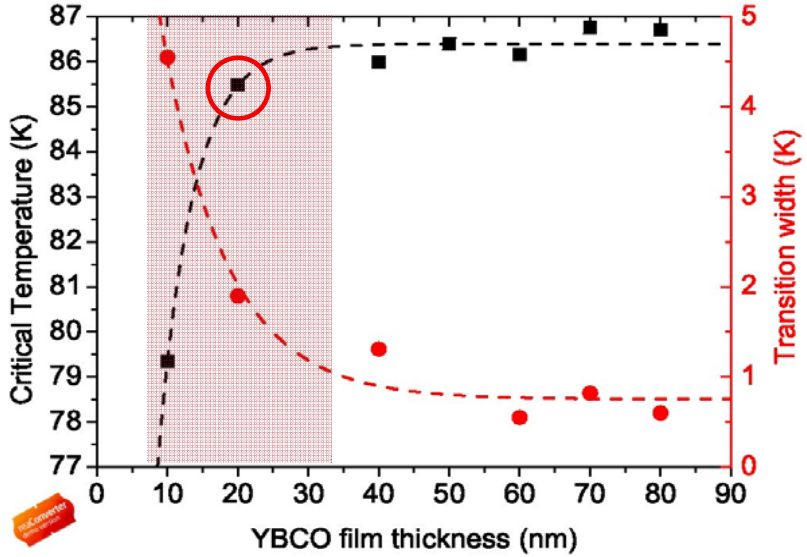
d_{PBCO} = 25 nm

d_{YBCO} = 10 - 100 nm

d_{PBCO} = 25 nm

d_{CeO2} = 8 nm

Dependence of T_c on YBCO film thickness



T_c > 77 K for d = 10 nm by introduction of PBCO

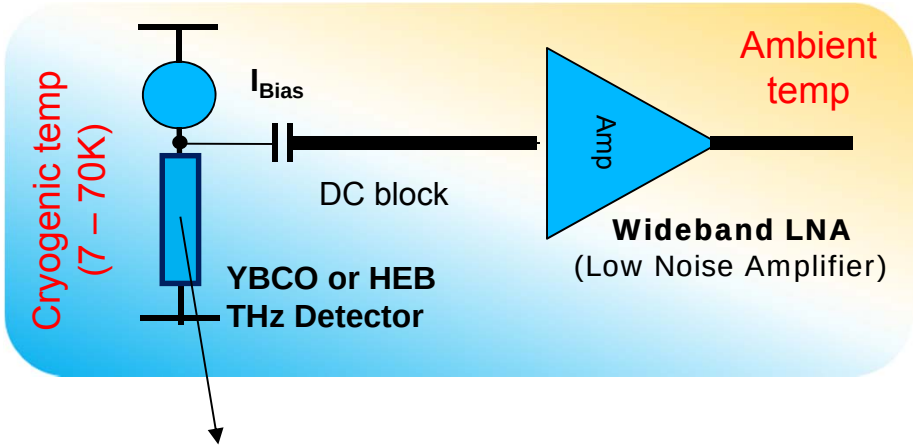
Liquid nitrogen

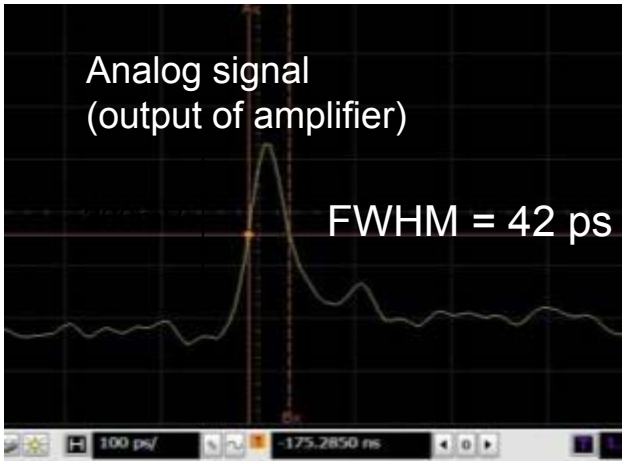
Thank's to Petra Thoma

HEB detector & main low noise amplifier

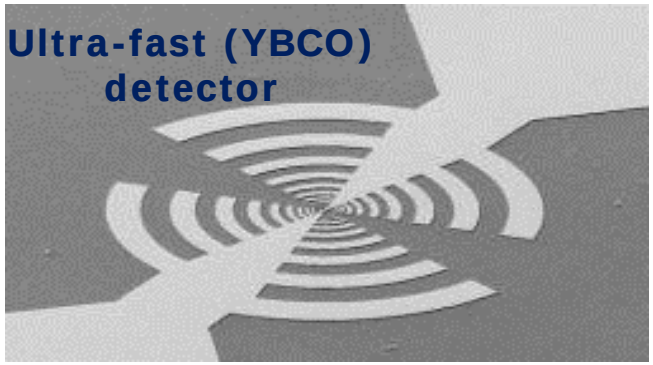
Detector based on a superconducting NbN ultra-fast bolometer with a bandwidth up to 1THz.

The analog circuit contains a low noise MMIC amplifier with a Bandwidth of 60GHz.





to digitalizer stage



Measurements for each pulse (bucket) are:

- Peak amplitude (*range of few - 600mV*)
- Time jitter between buckets (*range 3-40 ps*)
- FWHM (*range of 30-100ps*)

Fast digitalizer stage & readout system

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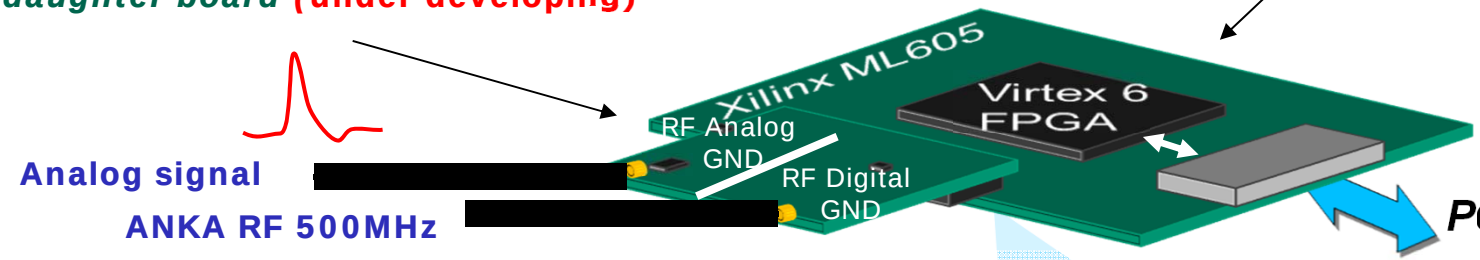
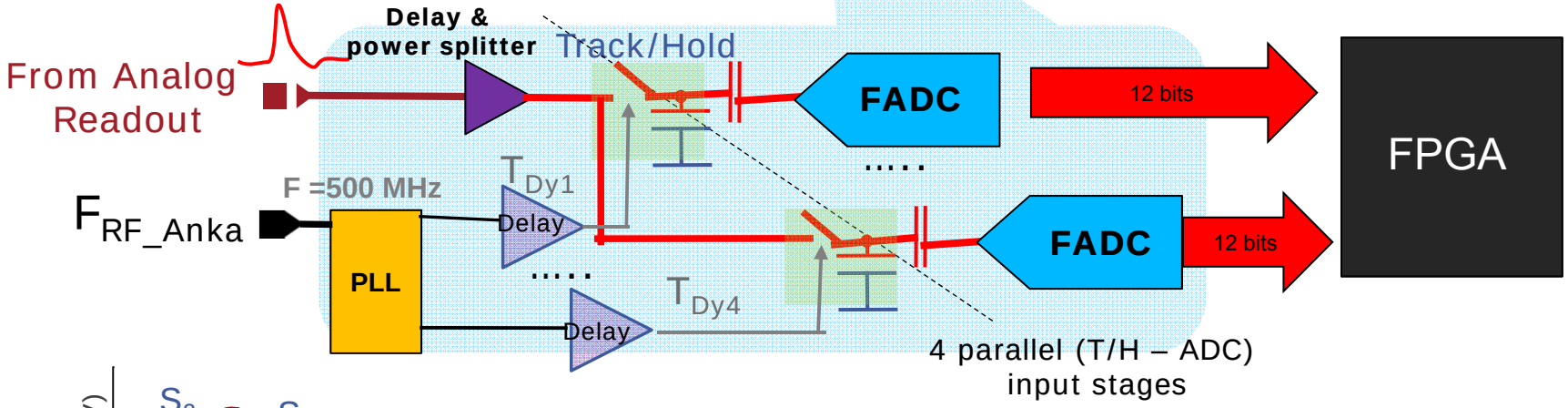
Fast digitalizer "FMC-VITA 57"
***daughter board* (under developing)**

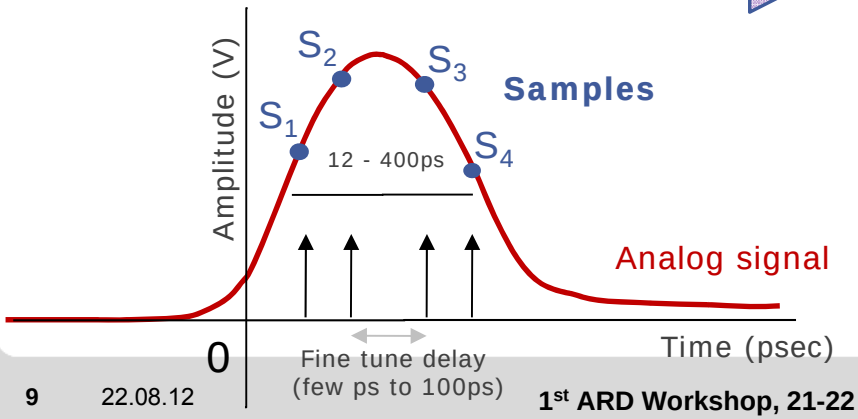
Readout mother board



PCIe link to DAQ (4X gen2)

Fast digitalizer stage - basic concept



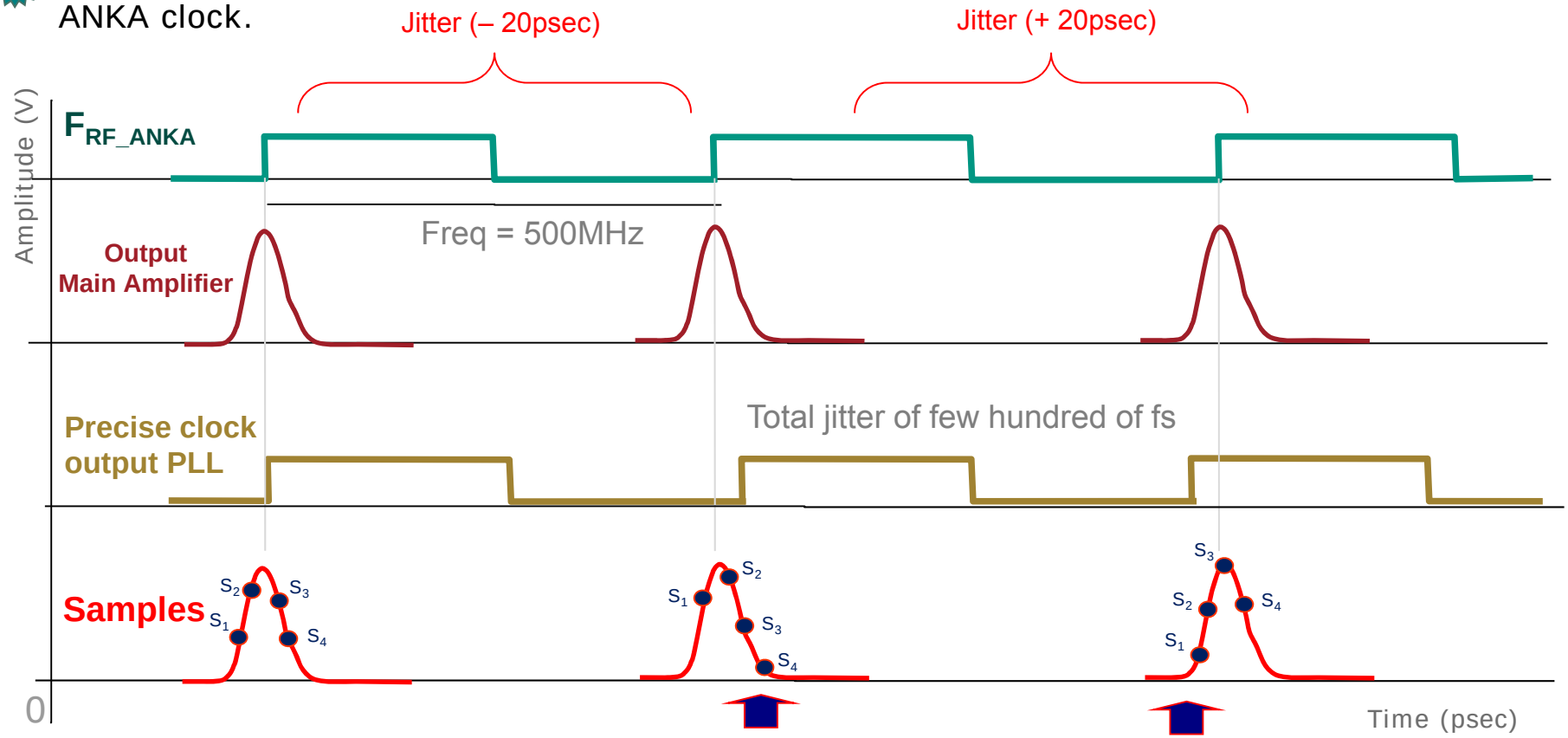


Four samples inside the pulse with independent and FPGA programmable sample time from 3 to 100 ps

The digitalizer board concept → potentially a patent application

Picosecond time jitter estimation between buckets

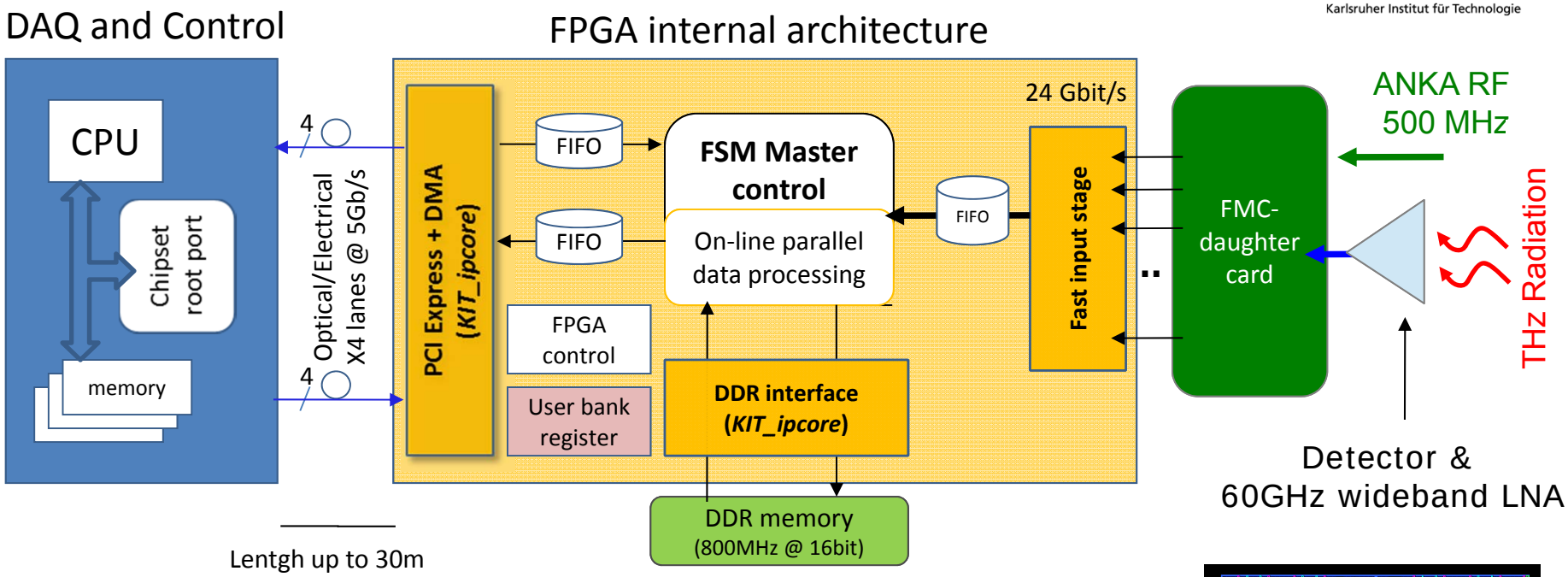
A clean jitter PLL is employed to re-generate a low jitter 500 MHz clock from the RF ANKA clock.



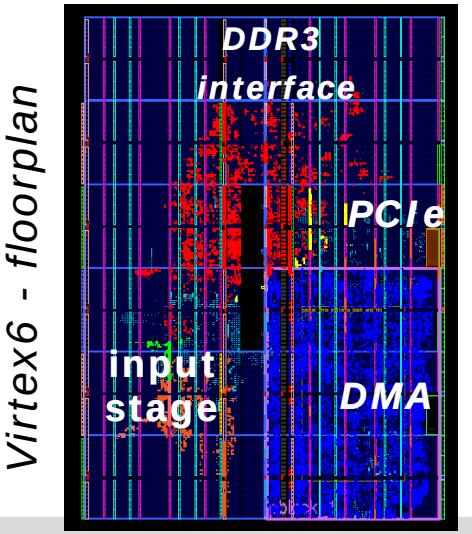
Procedure for time jitter estimation between buckets:

- Fast reconstruction of the analog pulse by the 4 samples (FPGA or GPU)
- Measuring of the pulse amplitude
  - Measuring of the time jitter by the position of the samples in the reconstructed pulse (corrected by a constant fraction discriminator method)

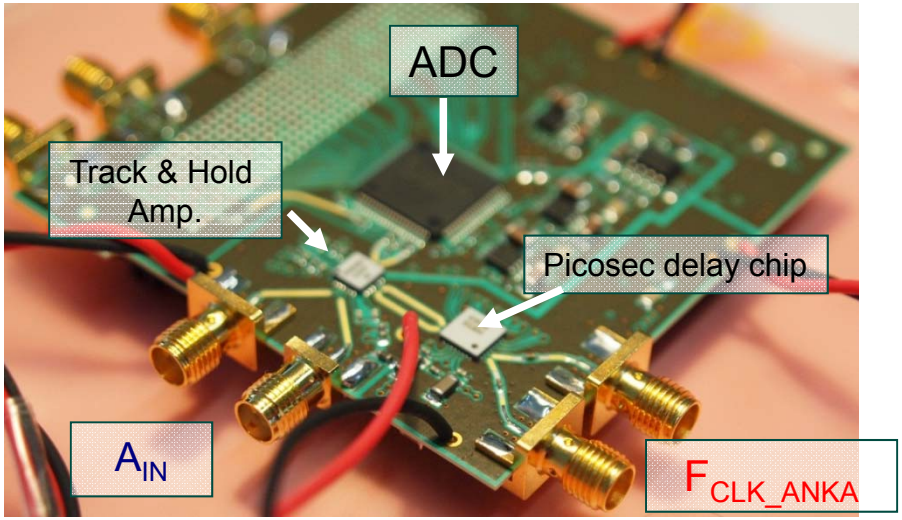
Readout chain – and FPGA firmware overview



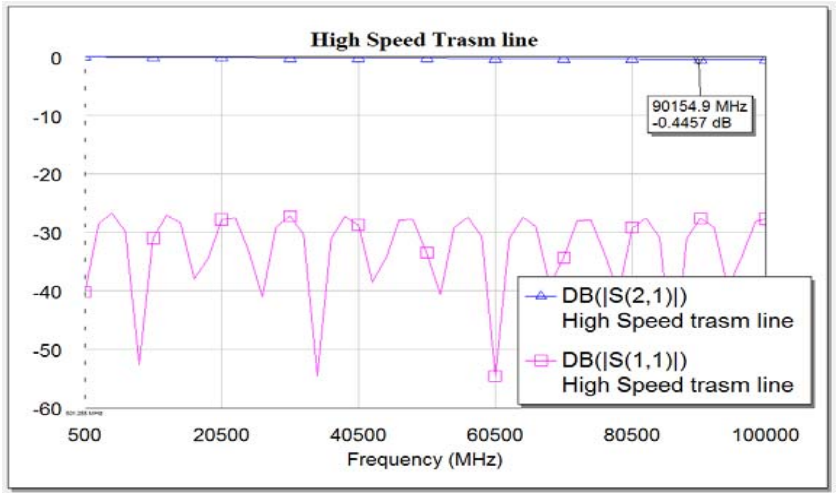
- ✓ **Firmware based on a Bus Master DMA (BMD) architecture up to 16Gb/s**
  (*under study a DMA solution with a data transfer up to 32Gb/s*)
- ✓ **FPGA firmware main blocks developed are**:
  - PCI Express 4x GEN2 + DMA
  - DDR3 Interface
  - Fast input stage 12 bit x 4 x 500MHz → 24 Gbit/s
  - Data compression & On-line FPGA data processing
- ✓ **Linux-32/64 bit driver + GUI application (C/C++ and Matlab)**



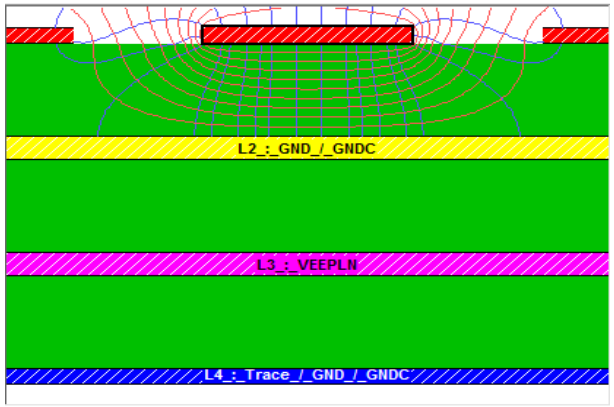
Fast digitalizer prototype board & RF layout



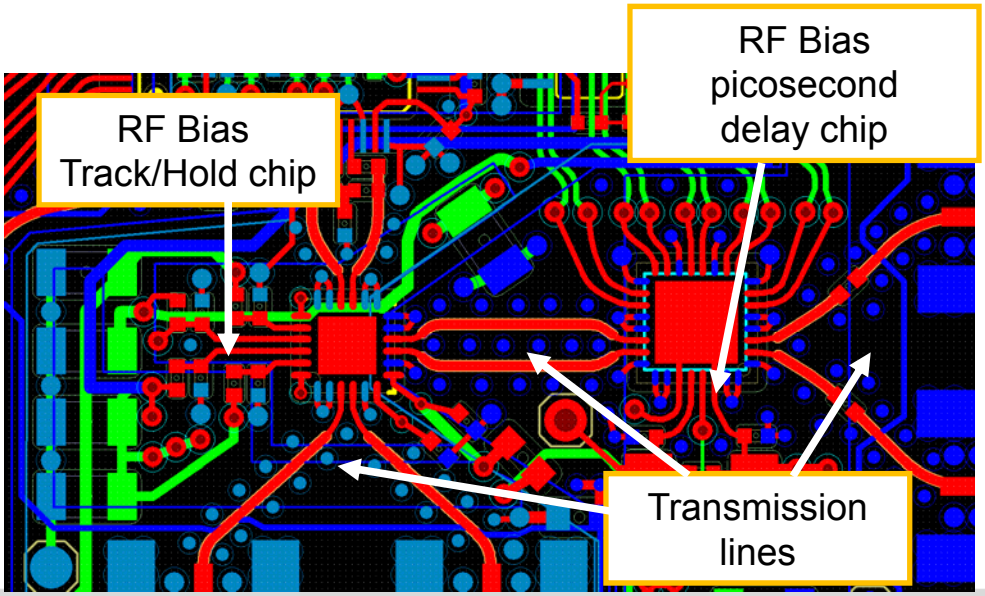
50 GHz Transmission lines



Board Stuck-up & EM simulation



Z0 = 49.487 ohms

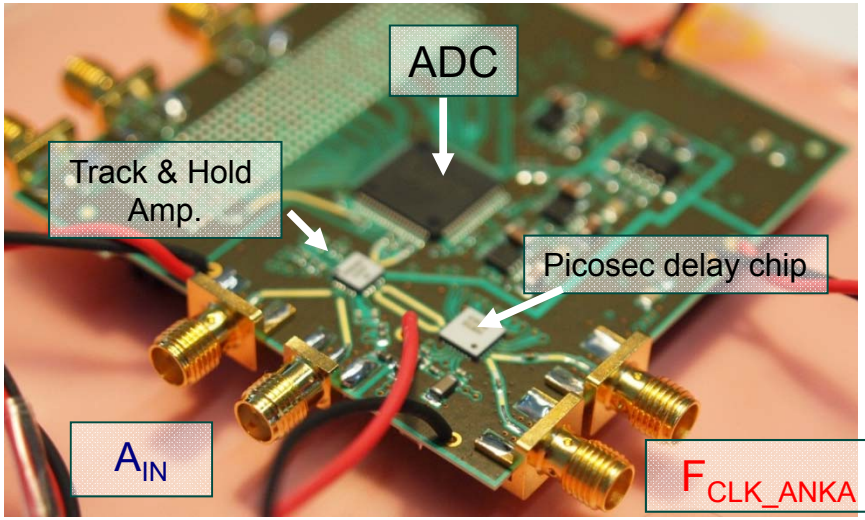


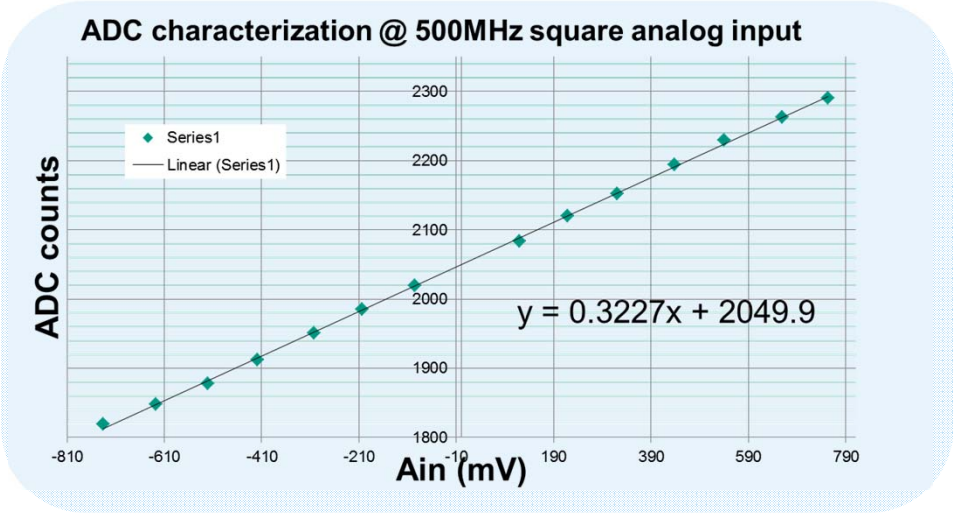
Fast digitalizer prototype board characterization

Board response @
square & pulse shapes

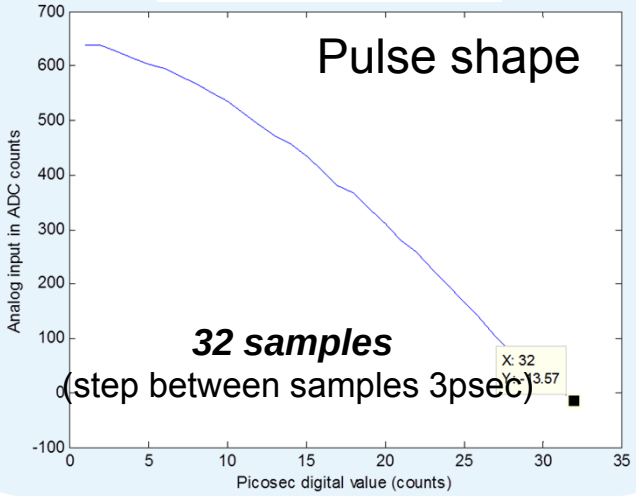
A_{IN}

F = 500MHz



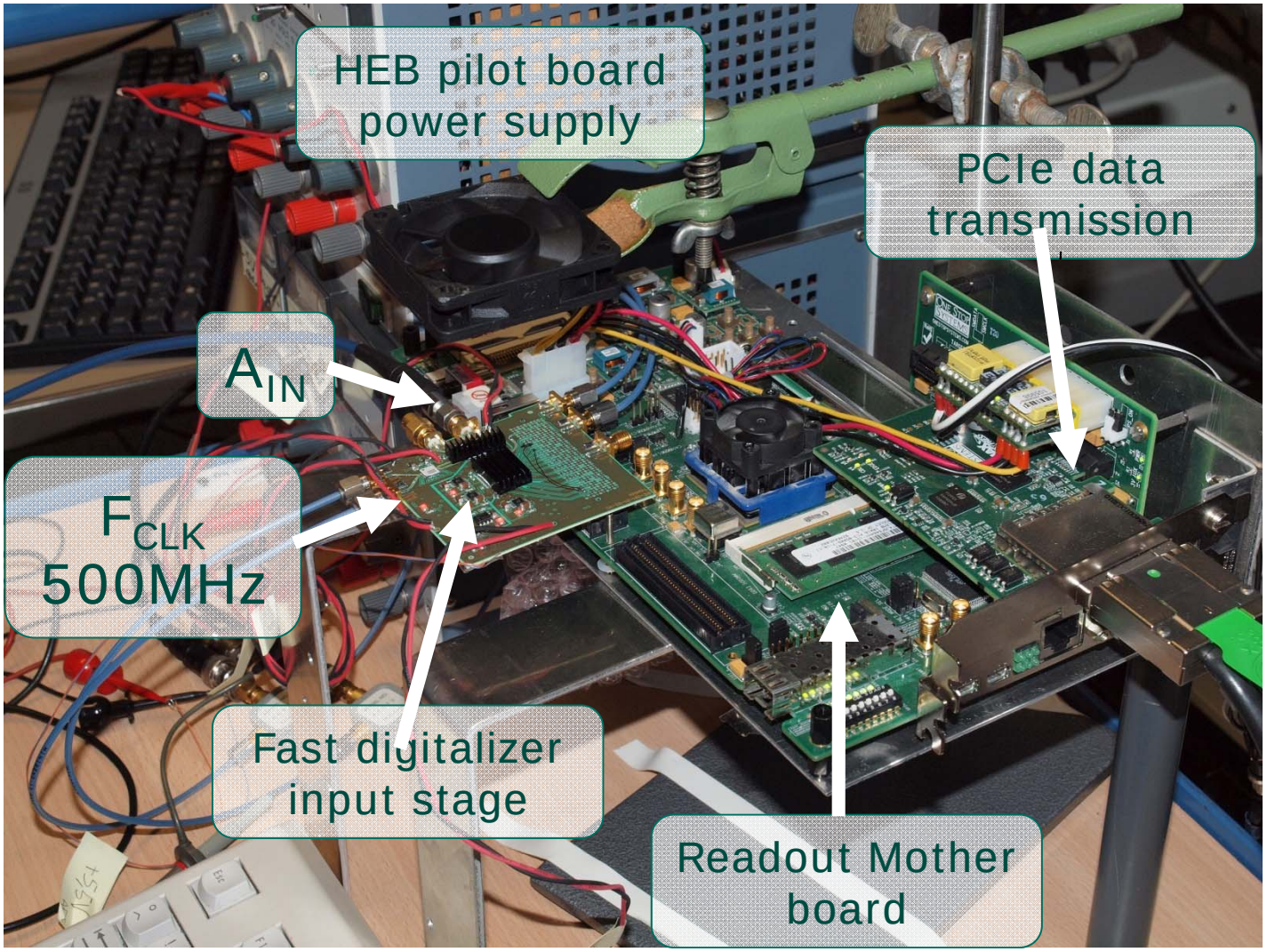


Fast sample time

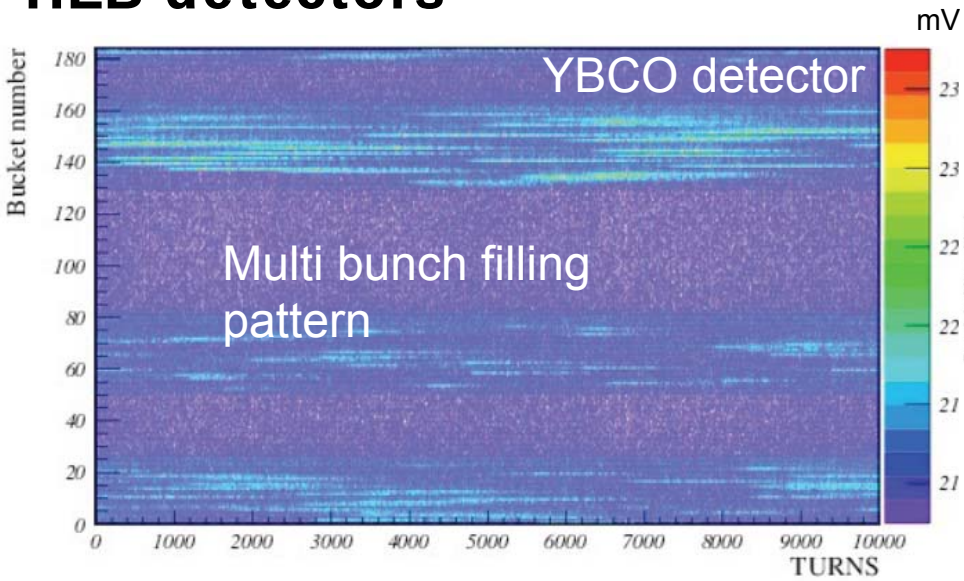


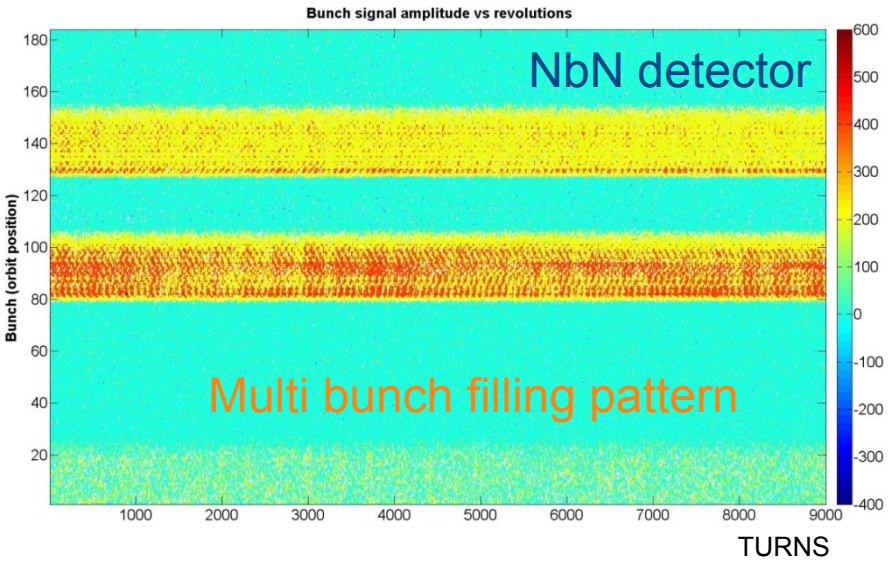
32 samples
(step between samples 3psec)

Test beam setup in ANKA – IR1 (THz port)

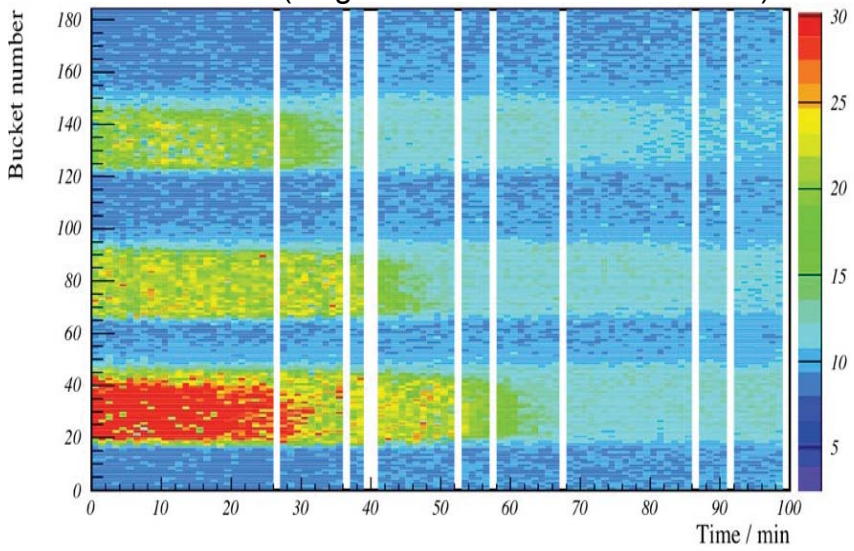


ANKA tests beam measurements with different THz HEB detectors





ANKA CSR (long observation time with YBCO)



- ✓ Simultaneous turn by turn monitoring of all 184 buckets
- ✓ Several hundred-thousand numbers of turns can be stored and analyzed in a single run
- ✓ On-line FPGA/GPU analysis (FFT, time jitter, etc.)
- ✓ Fixed pilot bucket for all measurements

Conclusion & What's next

- ✓ Fast digitalizer prototype *board* → fully tested with several THz superconductivity detectors
- ✓ A low noise and good linearity of the analog - digital conversion → qualified
- ✓ A sample time control with a resolution of 3ps → achieved
- ✓ The FPGA firmware and readout chain → developed
- ✓ The driver and first GUI → developed

- ➢ Fast digitalizer *final board* (with 4 parallel fast G/S) → under development
- ➢ The first version of the full readout system and ANKA test beam → for the end of 2012
- ➢ The commissioning for the experimental station → in the 2013.

Thank you for your attention