Ongoing electronic development in the CERN beam instrumentation group: challenges and solutions for the measurement of particle accelerator beam parameters

Andrea Boccardi on behalf of the
Beam Instrumentation group (CERN BE-BI)

What do we measure

- Beam Position
- Beam Loss
- Machine Tune and Chromaticity
- Luminosity
- Transfer line - Accelerator Matching
- Beam Intensity
  - Bunch charge
  - Total current
- Beam Profile
  - Transverse
  - Longitudinal

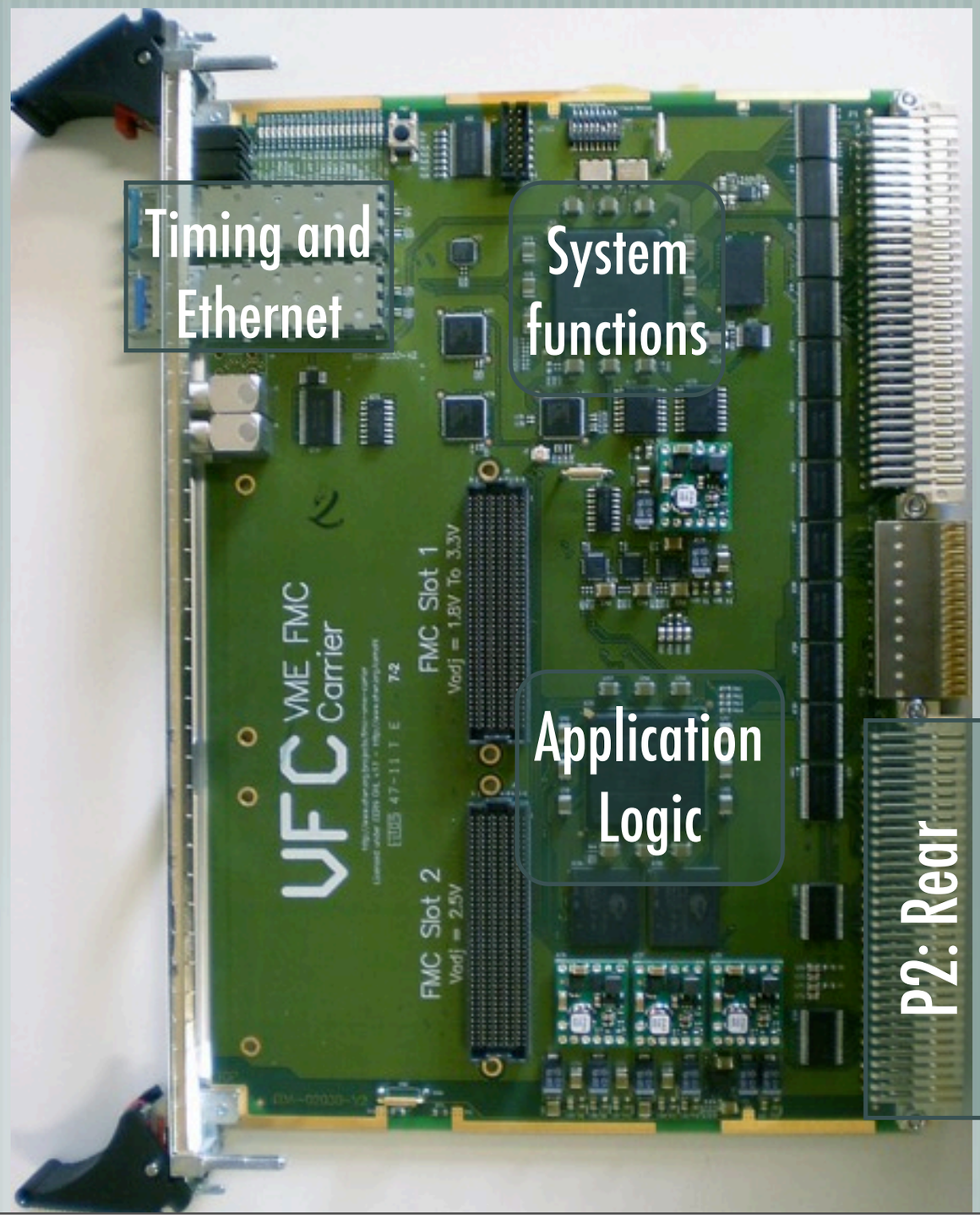
Write once use many times

- A common software front end
- Common carrier / specific mezzanine
- The DAB64x (the 1st LHC standard Carrier) is used for several systems
  - Beam position monitor
  - Beam current transformer
  - Abort Gap Monitor
  - Luminosity monitor
  - Beam loss monitors
  - Tune system

Write once use many times

The VFC (VME FMC Carrier)

- 2 FMC slots
- 40 pins on the P2 dedicated to Rear Transition Modules
- A configurable low jitter PLL per mezzanine
- 2x 72Mb SRAM
- 2Gb DDR3
- Programmable clock sources and voltage controlled & temperature compensated oscillators
- 2 x SFP connected to Gbit capable interfaces
- A Spartan6 (150T) fully dedicated to application logic

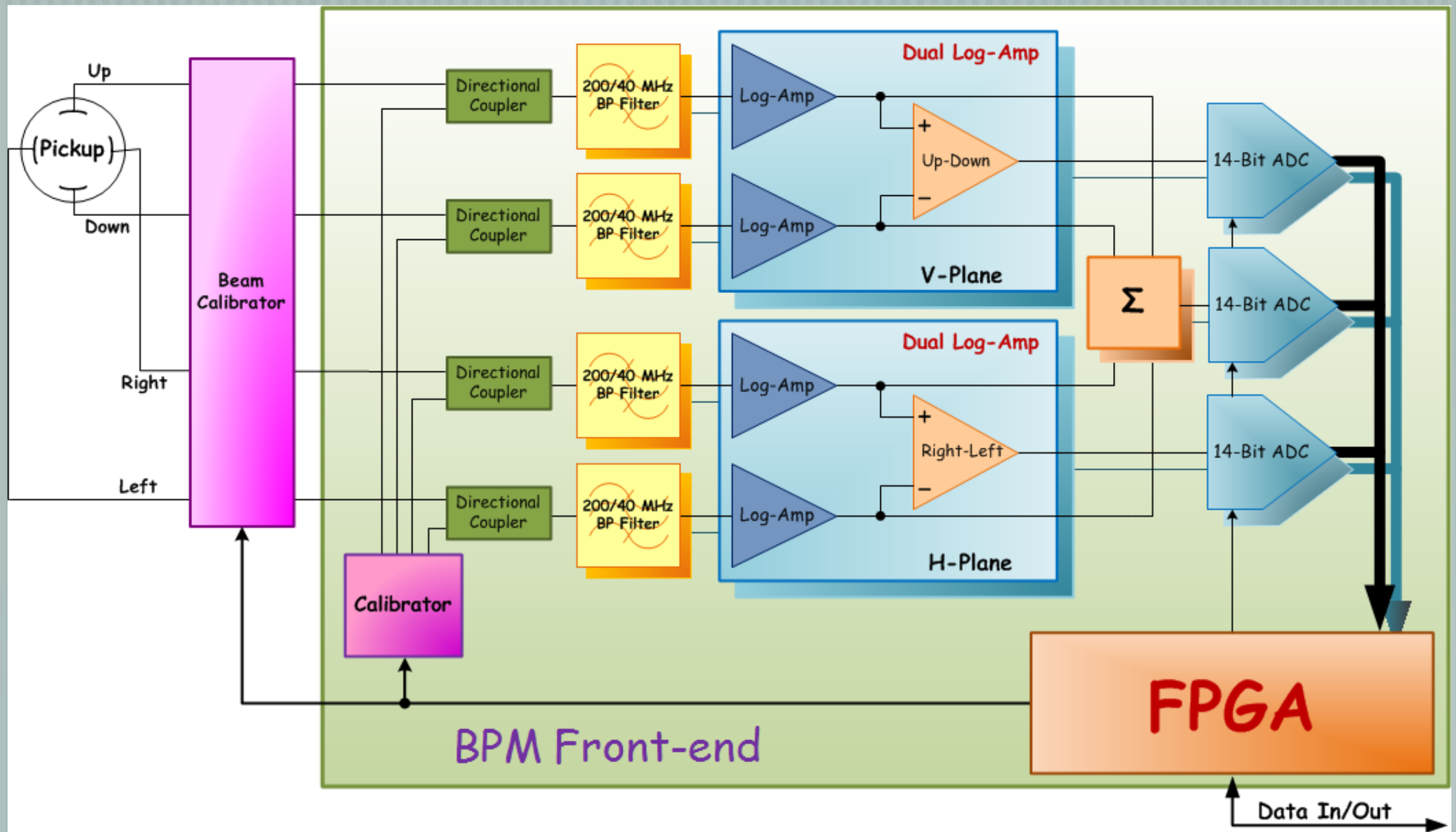


New Beam Position Monitoring (BPM) System for the Super Proton Synchrotron (SPS)

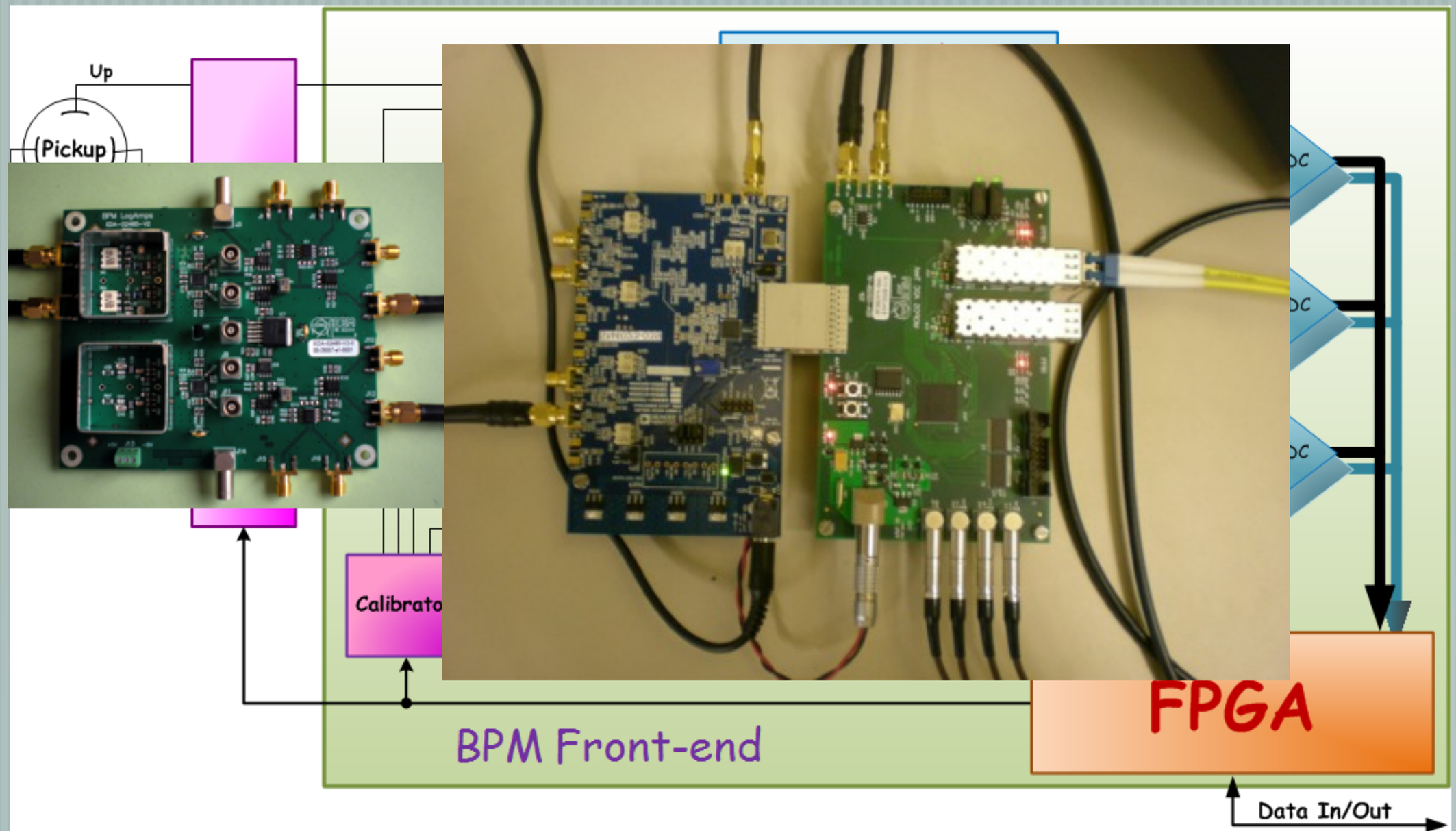
New Beam Position Monitoring (BPM) System for the Super Proton Synchrotron (SPS)

- High dynamic range (from 40mVpp up to 580Vpp)
- High resolution required (200uV for ions at the injection) even in single passage mode
- Distributed system: up to 1.5km from the measuring area to the crate area
  - need to put the electronics for the front-ends close to the beam (100krad/10years)
  - qualification of COTS required (240 systems ‘only’)

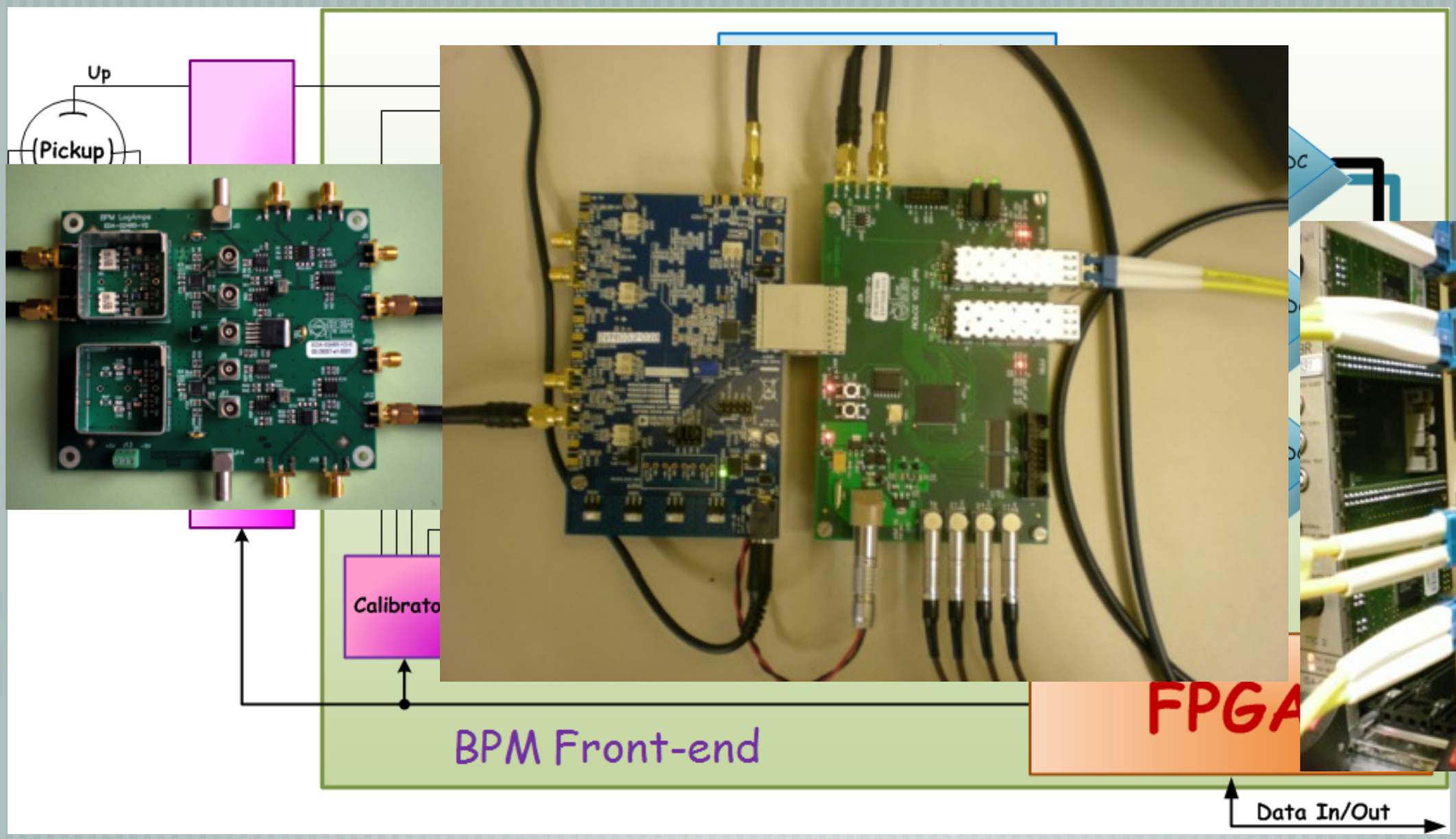
New BPM System for the SPS



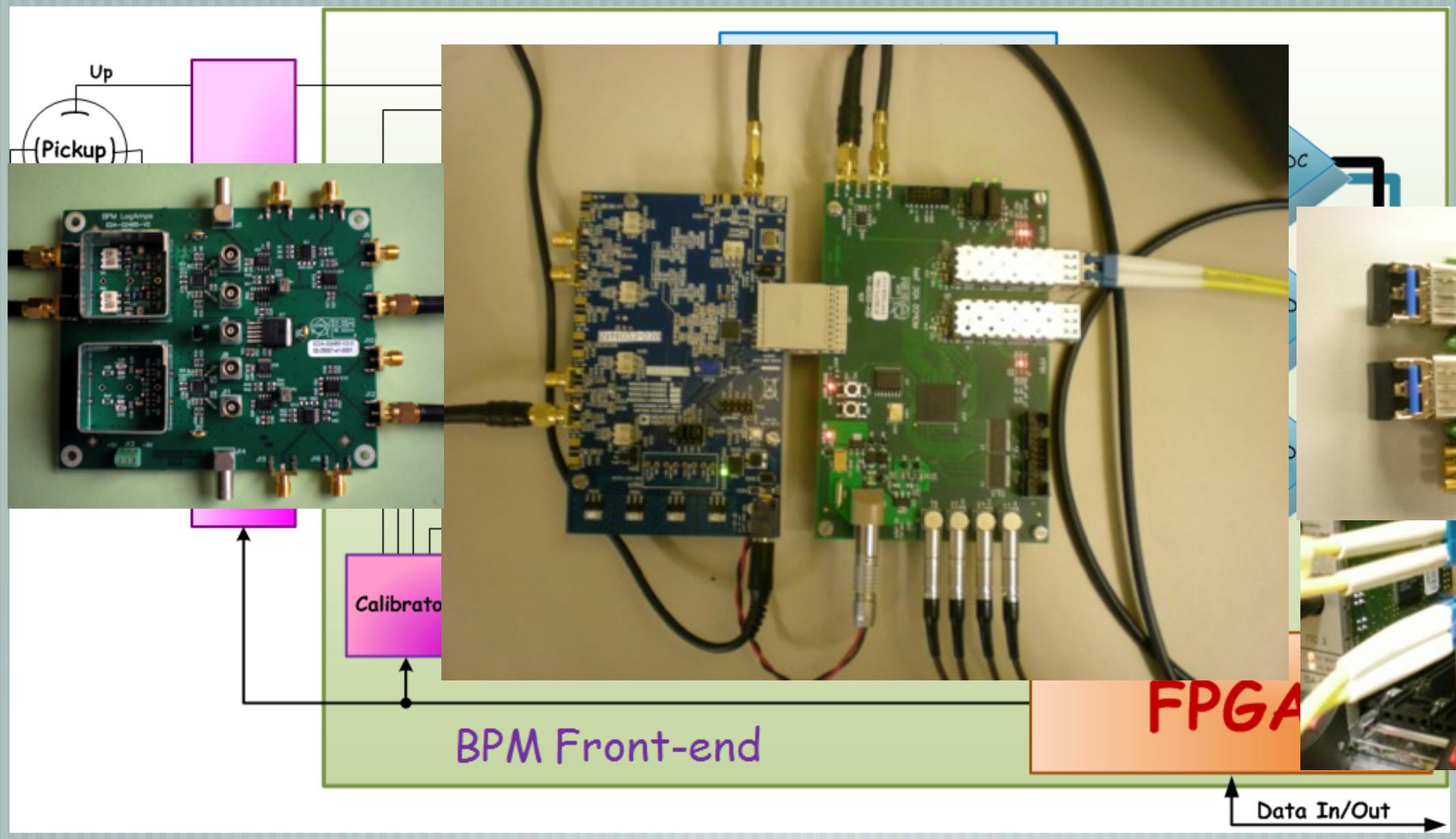
New BPM System for the SPS



New BPM System for the SPS



New BPM System for the SPS



New BPM System for the SPS: COTS tests

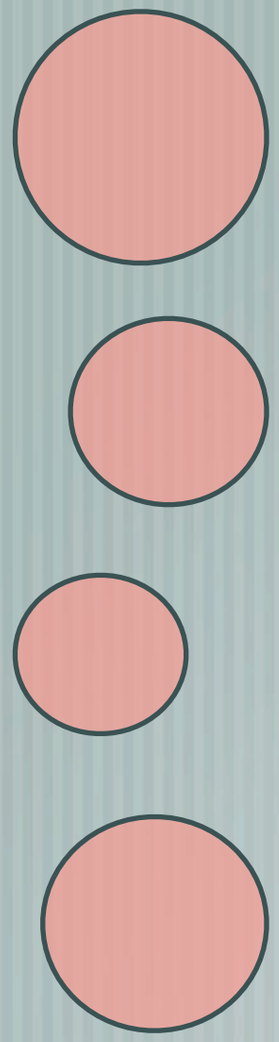
- The components already tested (total dose 100krad):
  - None of the tested ADC drivers and LogAmps experienced a noticeable degradation of performances for this dose
  - The FTTX-FT3A05D optical transceiver would be a suitable candidate, unfortunately other tested models are no more an option because of a change in the BW specification
  - Al the voltage dividers suffered a shift of the output voltage with the increasing dose, but 2 models seem to be compatible with the application (LT1963-KTT and TPS7A4501KTT)
- Components to be tested:
  - ADC (any available rad tolerant 14+ bits @ >10 MHz?)
  - FPGA (mostly for probability of configuration SRAM corruption)

SPS and LHC matching monitor

SPS and LHC matching monitor

- Aim: measuring the beam size oscillations in the first turns after the injection
- Measuring technique: OTR screens and imaging system
- Requirements:
  - tens of pixels
  - at least 44KHz acquisition rate

SPS and LHC matching monitor



SPS and LHC matching monitor

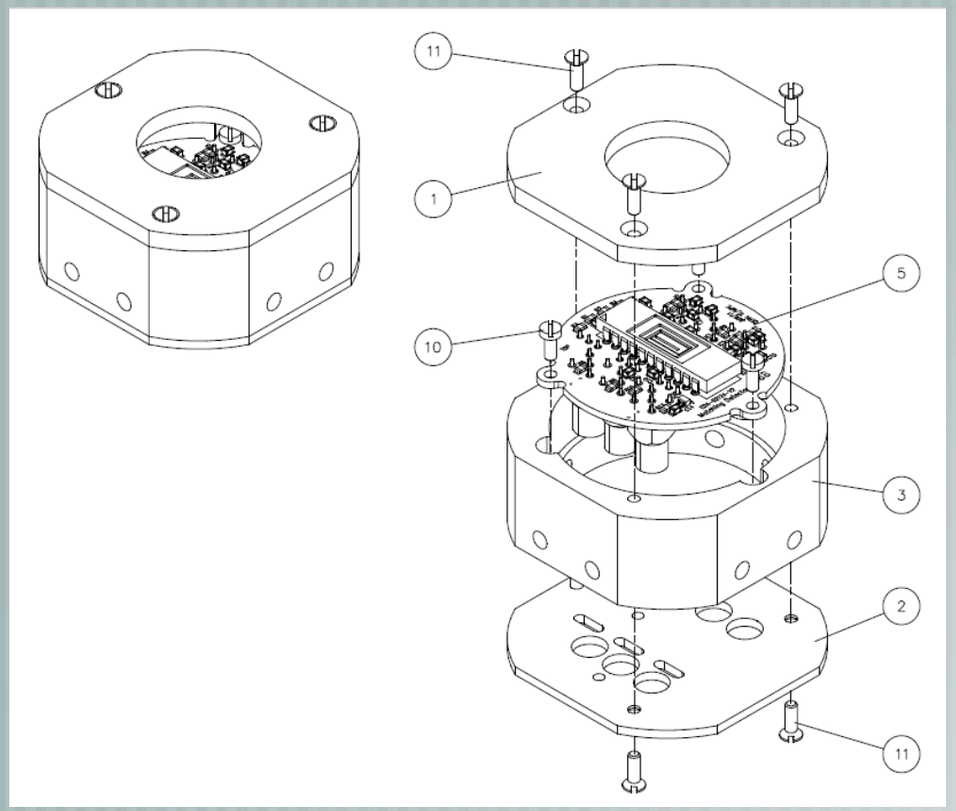
SPS and LHC matching monitor

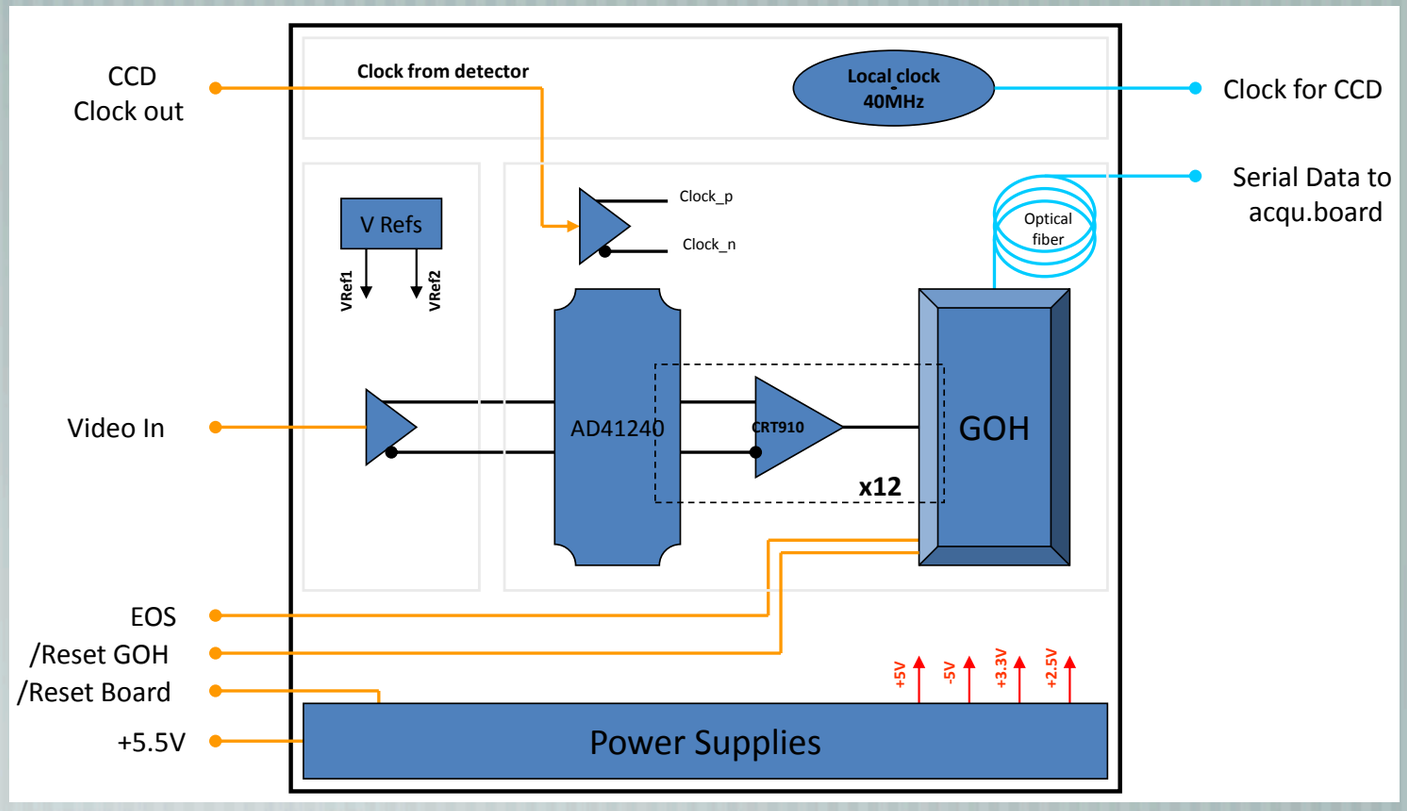
SPS and LHC matching monitor

Hamamatsu linear CMOS:

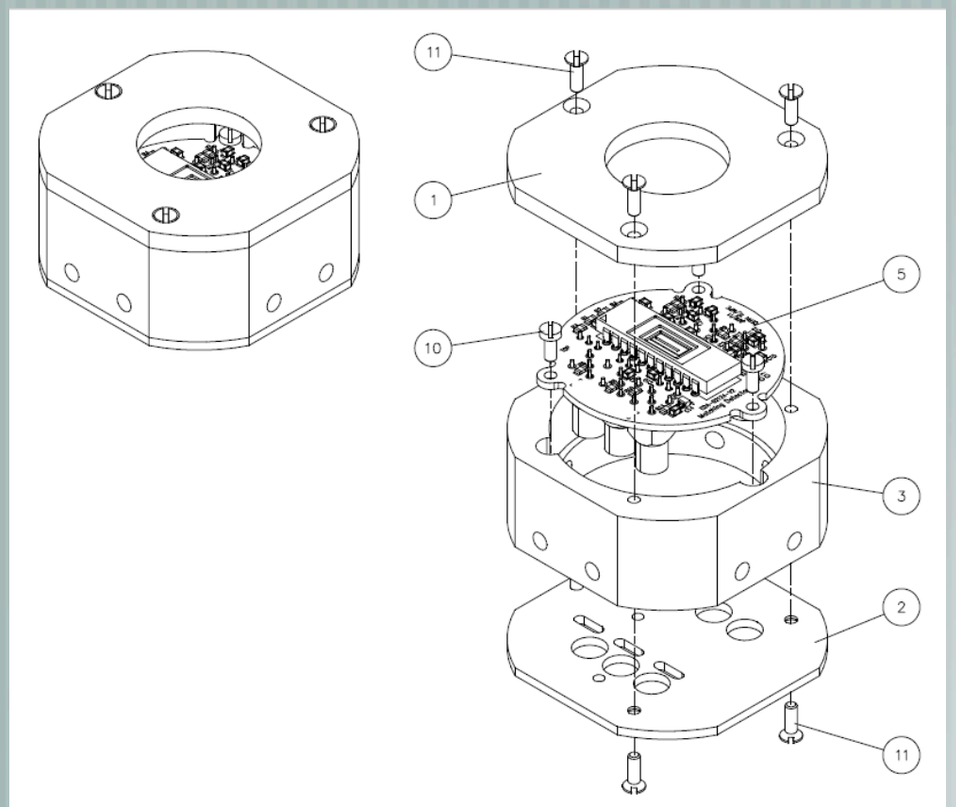
- 512 pixels
- 1-50MHz readout

SPS and LHC matching monitor

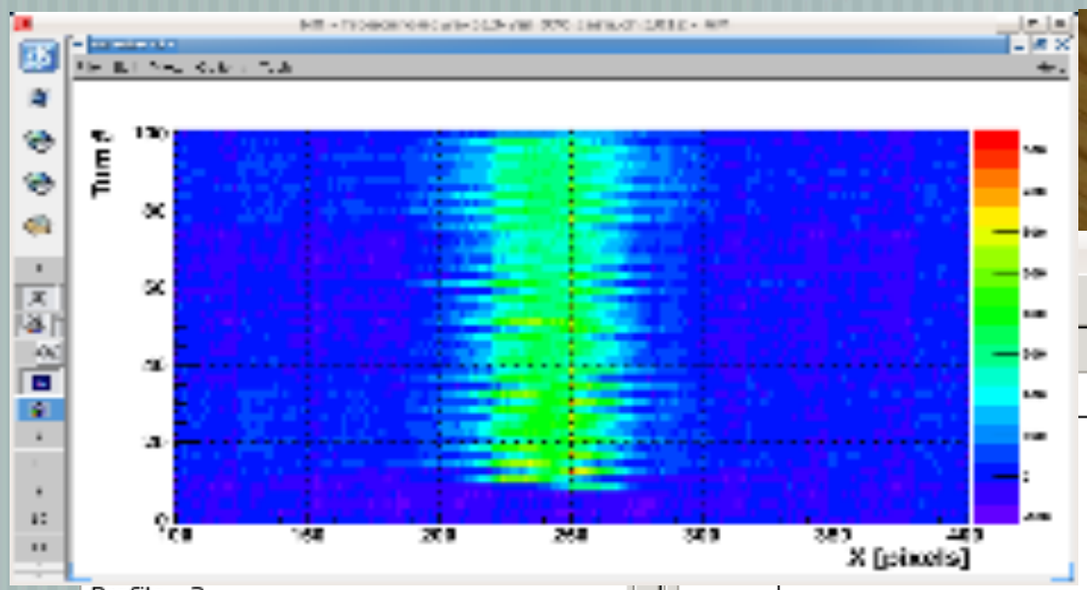


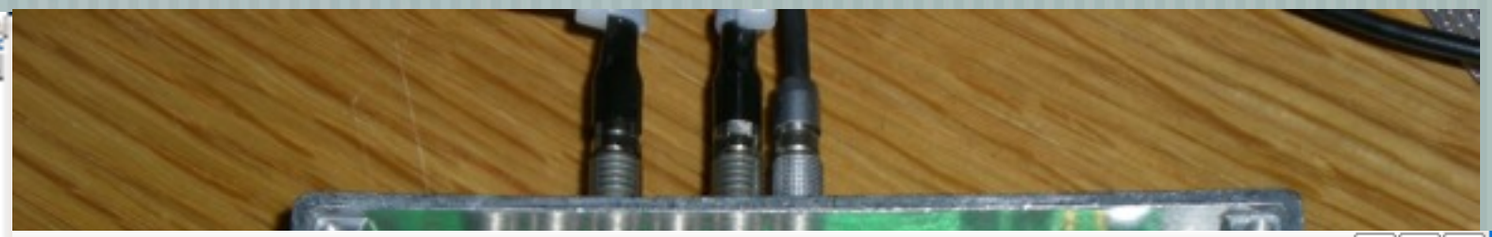


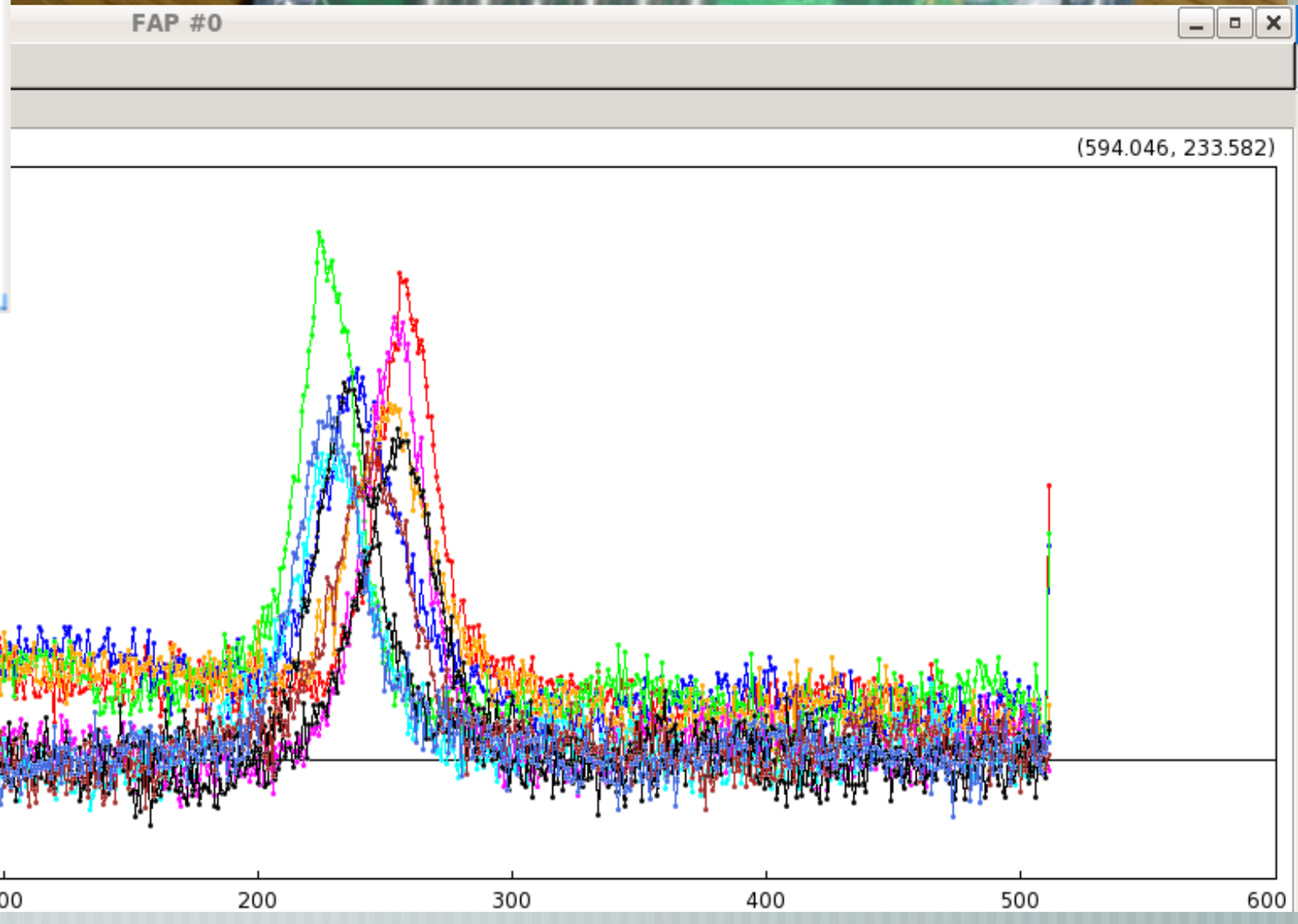
SPS and LHC matching monitor



SPS and LHC matching monitor







New Beam Loss Monitor for the injectors

- Several Detector types: ionization chambers, diamond, photo multipliers...
  - need to cope with currents of different polarities
- 146dB dynamic range : from 200mA (2us) down to 10pA (6ms)
  - use of 2 measuring techniques:
    1. direct measure of voltage drop on a shunt (200mA down to 100uA)
    2. fully differential frequency converted (improved current to frequency converter) (10mA down to 10pA)
  - automatic switch from a measurement technique to the other
- High reliability

New Beam Loss Monitor for the injectors

ral

ne

B c

us

au

reliability

s...

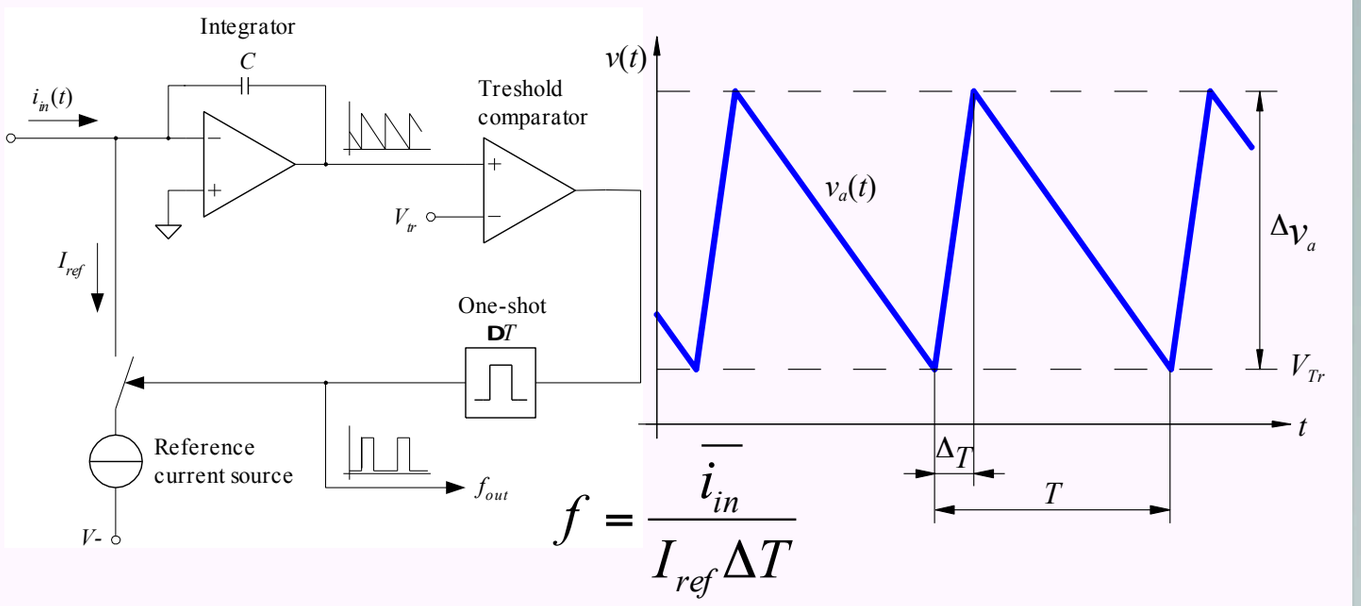
vn to 100uA)

nt to frequency

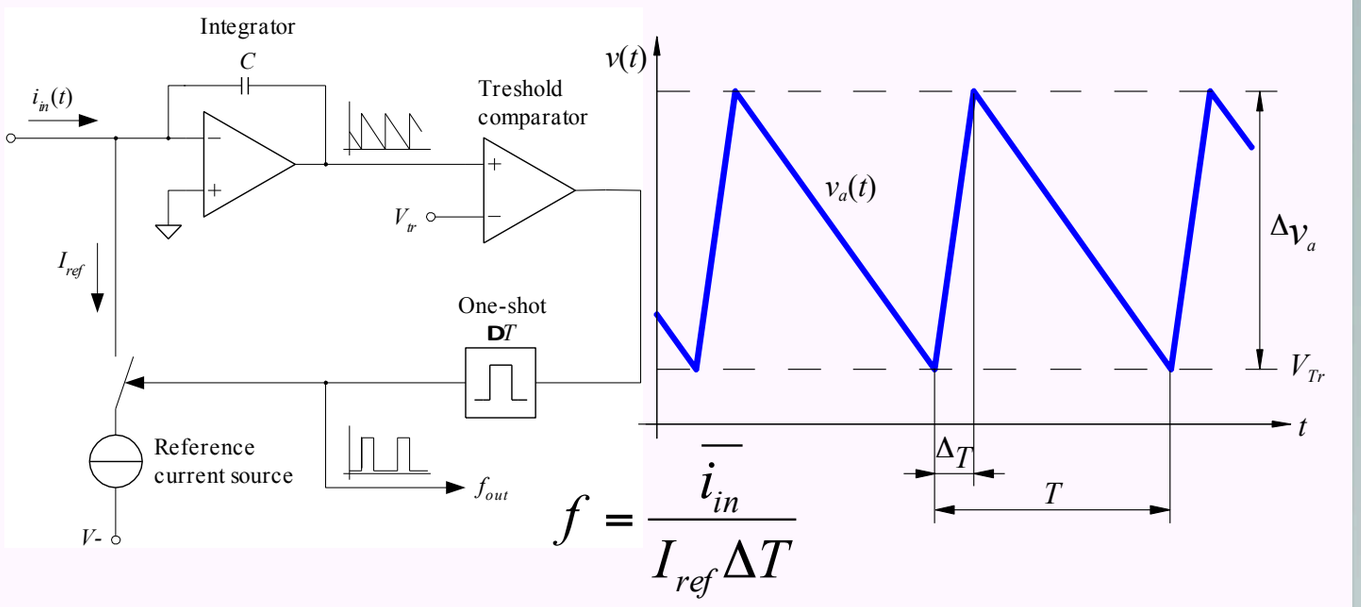
New Beam Loss Monitor for the injectors

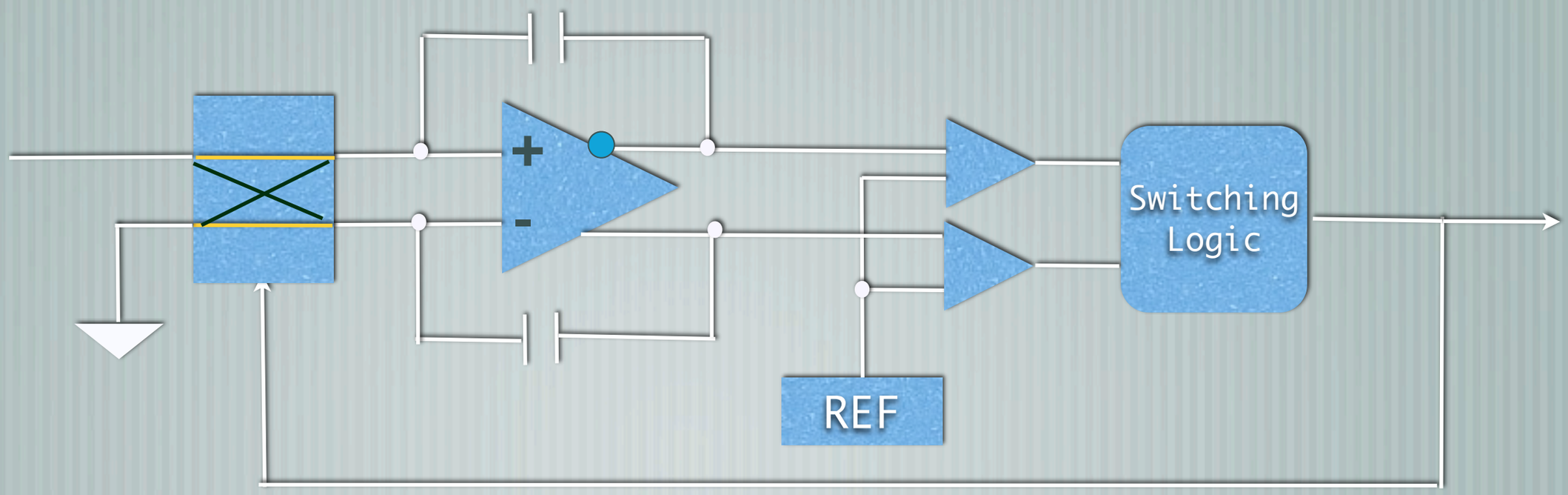
- Several Detector types: ionization chambers, diamond, photo multipliers...
  - need to cope with currents of different polarities
- 146dB dynamic range : from 200mA (2us) down to 10pA (6ms)
  - use of 2 measuring techniques:
    1. direct measure of voltage drop on a shunt (200mA down to 100uA)
    2. fully differential frequency converted (improved current to frequency converter) (10mA down to 10pA)
  - automatic switch from a measurement technique to the other
- High reliability

New Beam Loss Monitor for the injectors

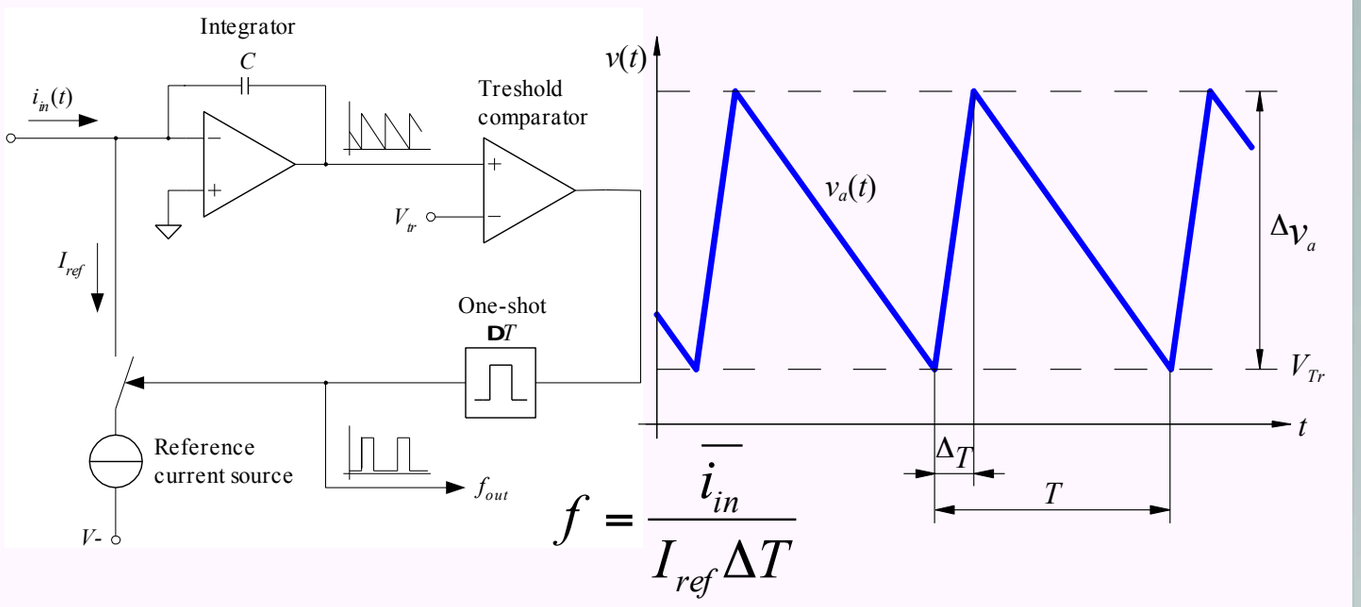


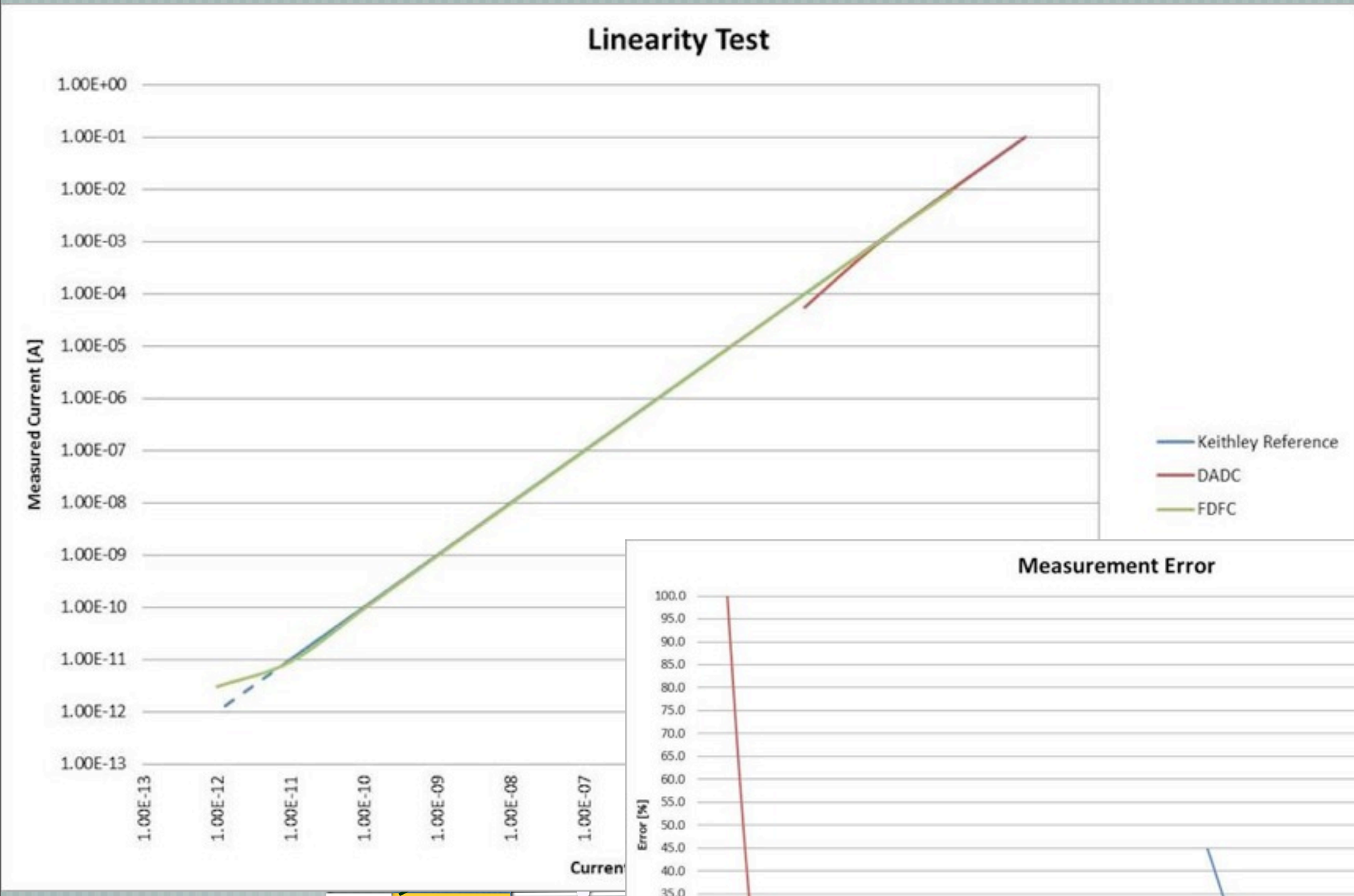
New Beam Loss Monitor for the injectors

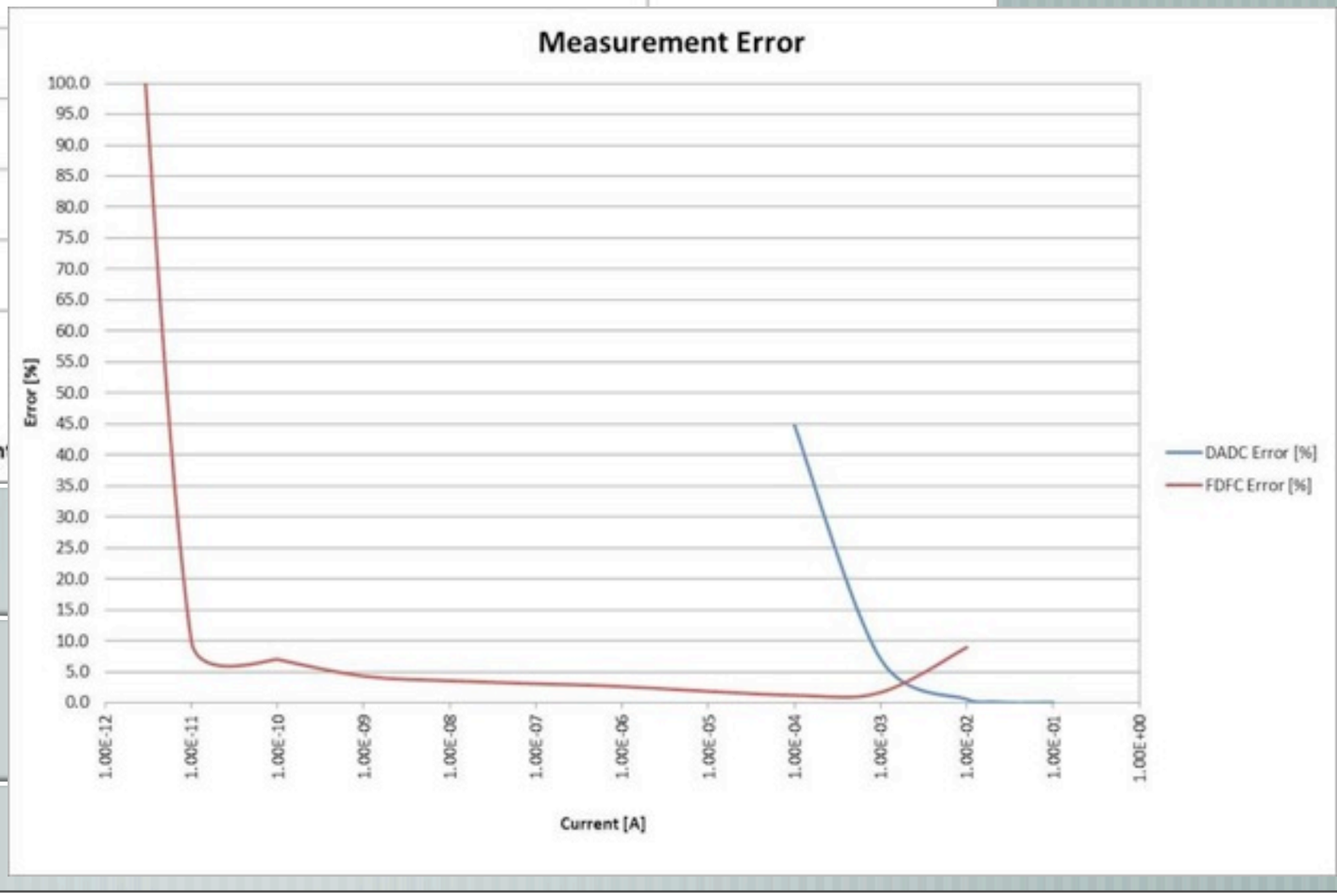


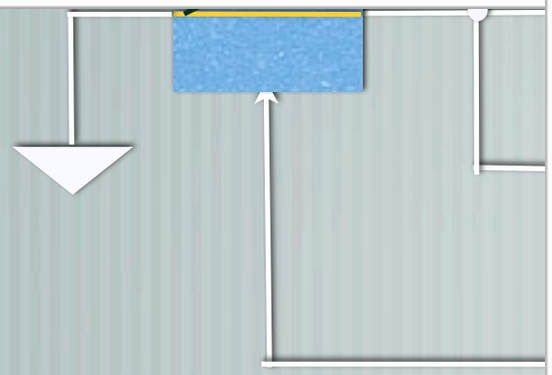


New Beam Loss Monitor for the injectors

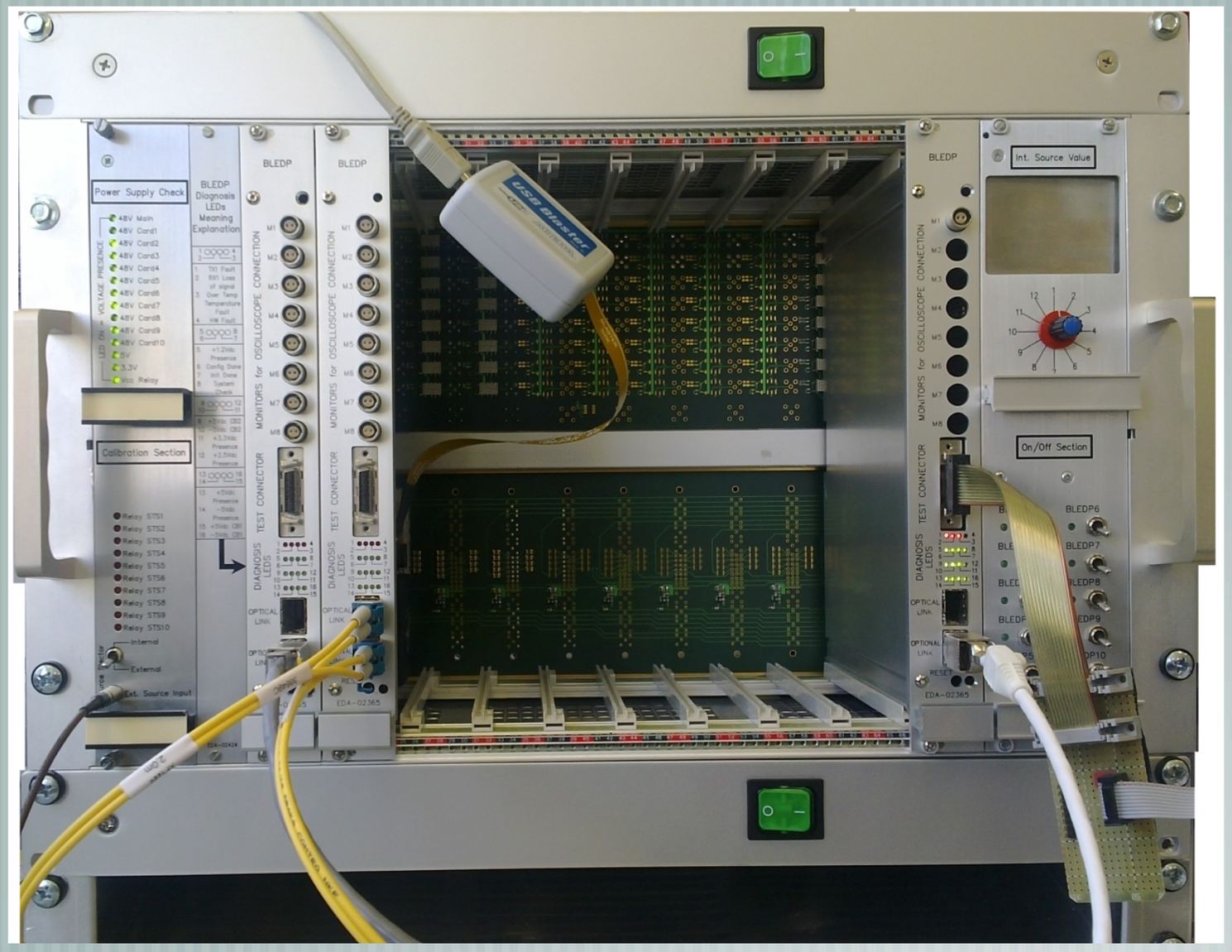



Linearity Test
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
1.00E-08
1.00E-09
1.00E-10
1.00E-11
1.00E-12
1.00E-13
Measured Current [A]
1.00E-13
1.00E-12
1.00E-11
1.00E-10
1.00E-09
1.00E-08
1.00E-07
Keithley Reference
DADC
FDFC


Measurement Error
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Error [%]
1.00E-12
1.00E-11
1.00E-10
1.00E-09
1.00E-08
1.00E-07
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-02
1.00E-01
1.00E+00
Current [A]
DADC Error [%]
FDFC Error [%]

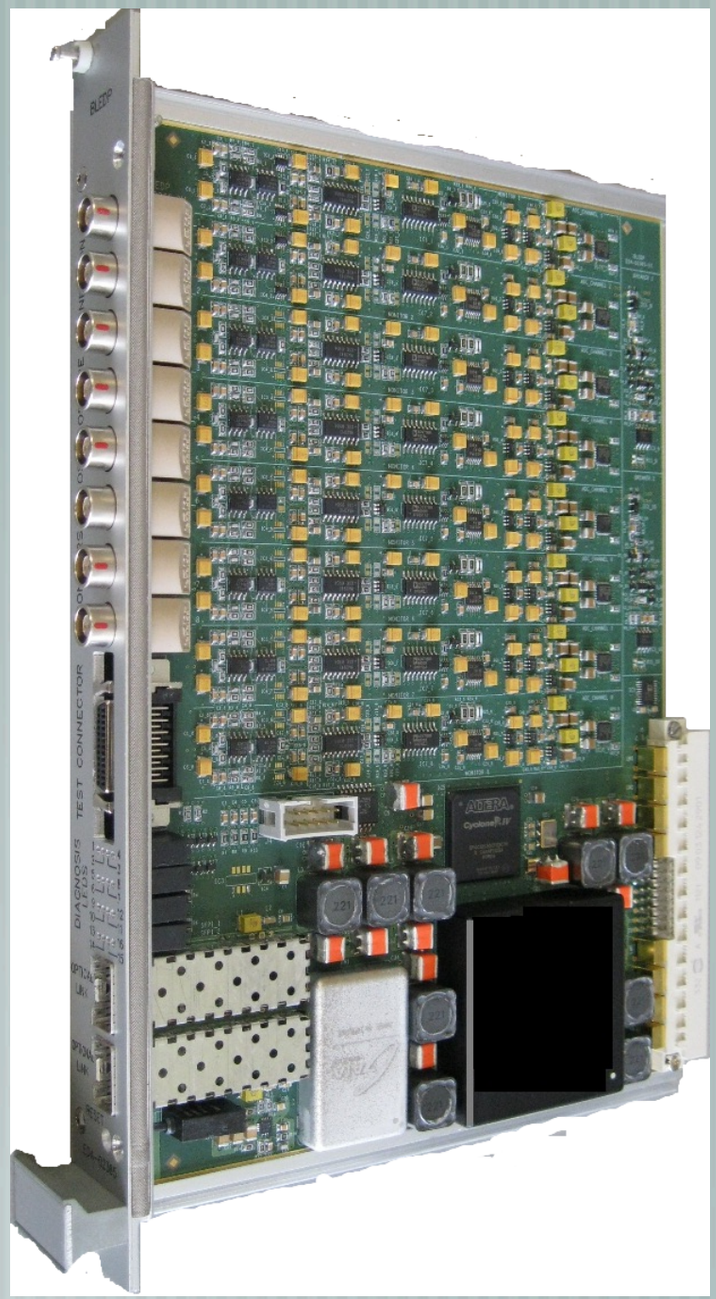


New Beam Loss Monitor for the injectors



New Beam Loss Monitor for the injectors

See Giuseppe Venturini's Presentation



Conclusions

- Due to the high variety of parameters to measure in many different conditions we make an effort to reuse and standardize
- Often our requirements are similar to those of the experiments ... and we are always happy to reuse also electronic modules and ASICs developed in other groups
  - indeed i come here with a shopping list: a 40MHz integrator with no dead time, a rad tolerant 14+bits ADC @40MHz.....