57th Meeting of the LHC Collimation working group
May 2nd, 2005

Sound and vibration measurements at the collimator robustness test

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Overview

- Motivation
- Experimental Setup
- Software
- Analysis Data
- Conclusions

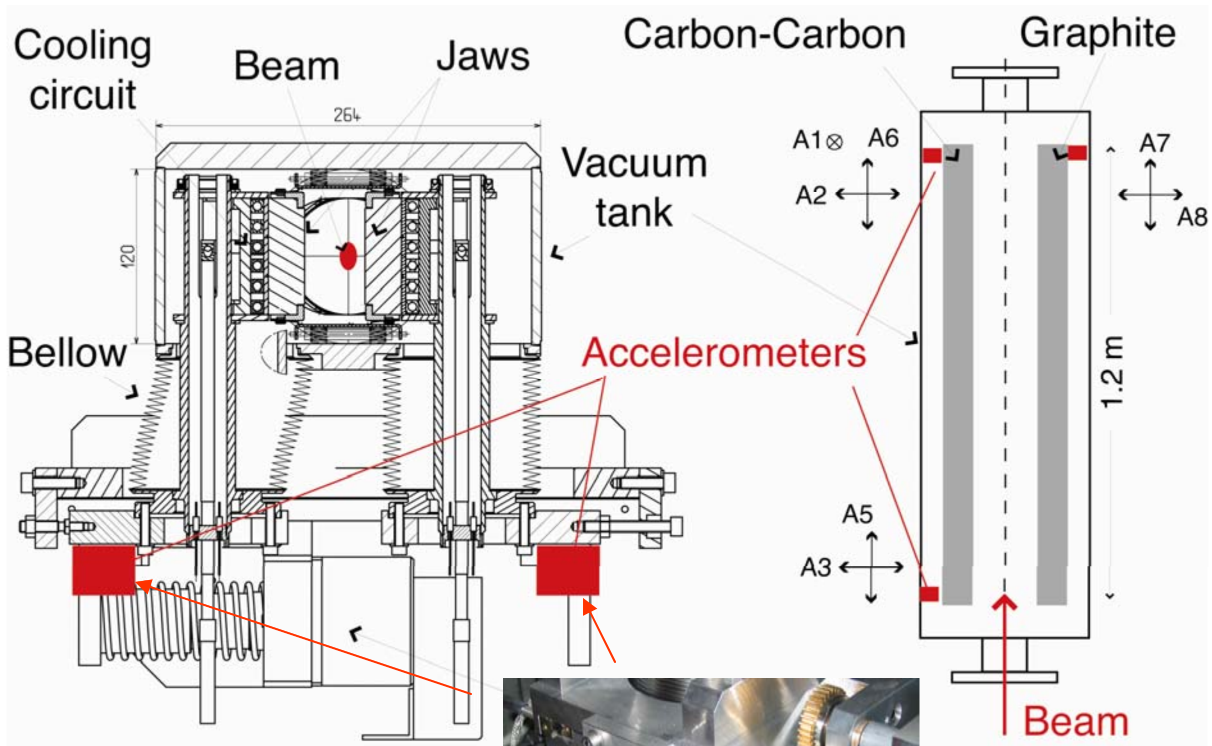
Motivation

- Detect impacts of high intensity, high energy proton beams is an issue for other operating machines!
- How can we detect beam impacts ($\rightarrow$ damage) on the LHC collimators??
- Sound and vibration measurements proposed to achieve this goal.
- System developed and implemented in the collimator prototype for the robustness test at TT40 (November 2004)

Goals:

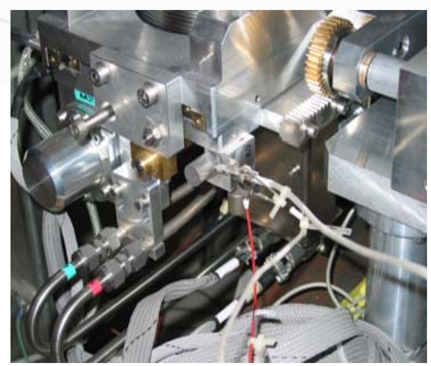
1. Detect impacts of proton beams on the LHC collimator
2. *Possibly* reveal damage of the mechanical structure (Not done because the collimator survived!)

Available Sensors



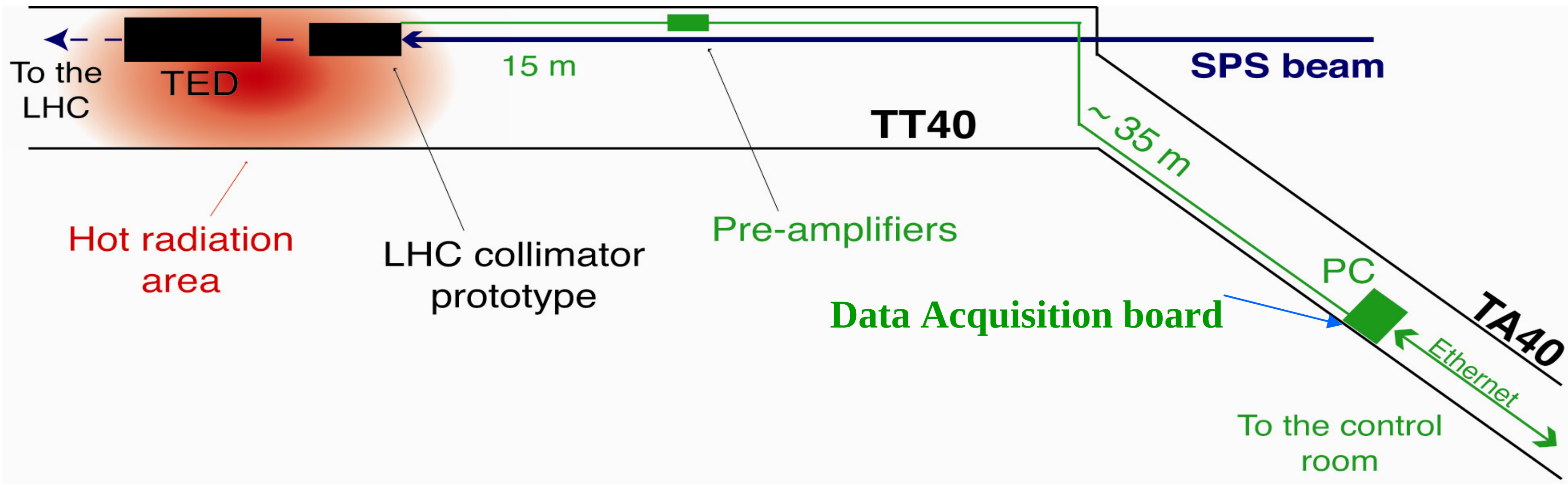
Sensor type	N.	Sensitivity	Freq. range
B&K 2273AM1	1	1.1 pC/ms^{-2}	1Hz-6kHz
B&K 2273A	2	0.38 pC/ms^{-2}	1Hz-10kHz
AP40	2	2.1 pC/ms^{-2}	0.5Hz-10kHz
AP37	2	1 pC/ms^{-2}	0.5 Hz-20kHz
Mic. B&K4189	1	41.6 mV/Pa	6.3 Hz-20kHz

Piezoelectric accelerometers usable over a wide frequency range measurement (radiation hard)



Free field microphone for sound measurements

Robustness Test: TT40Installation

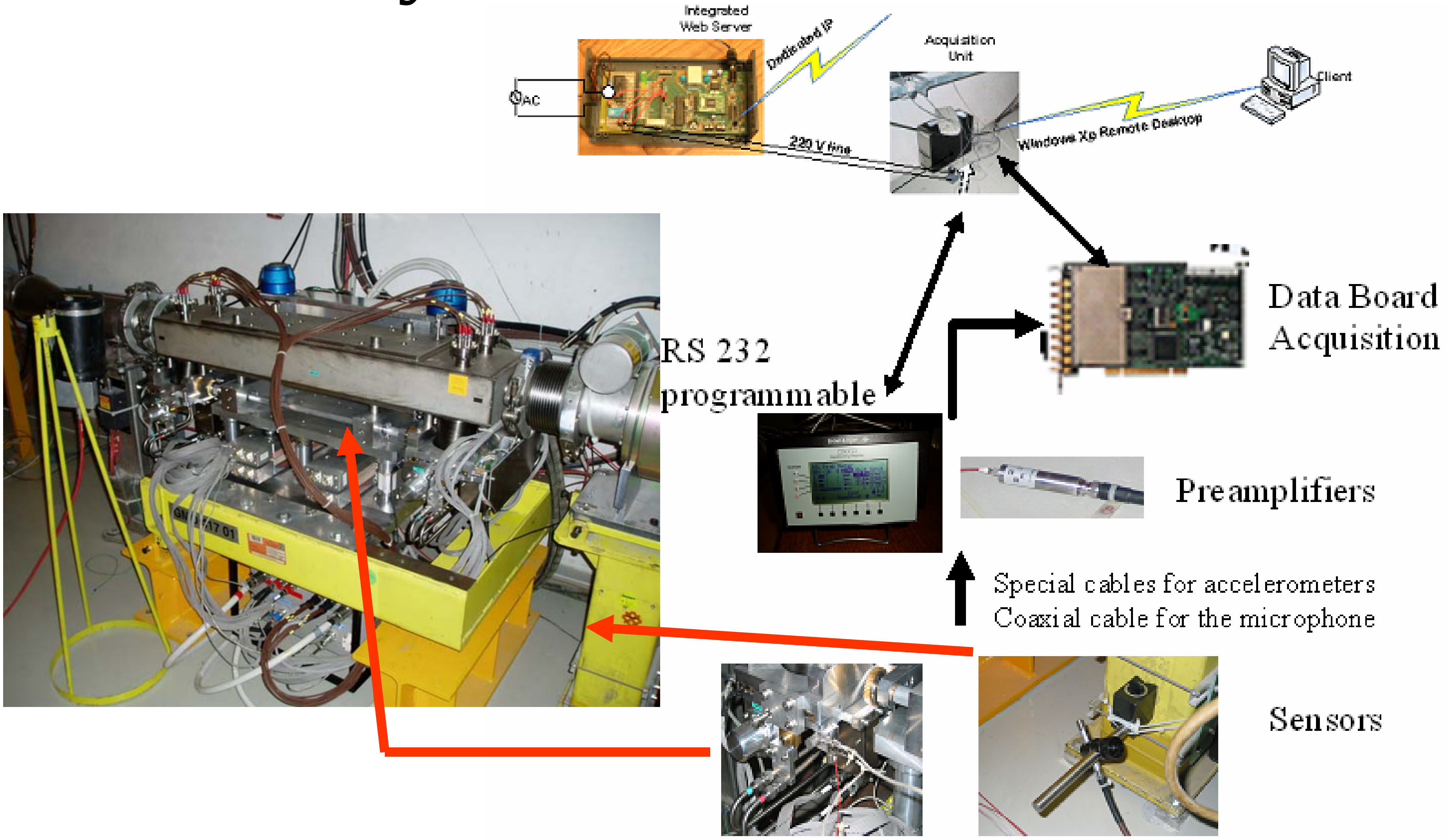


Technical Challenges

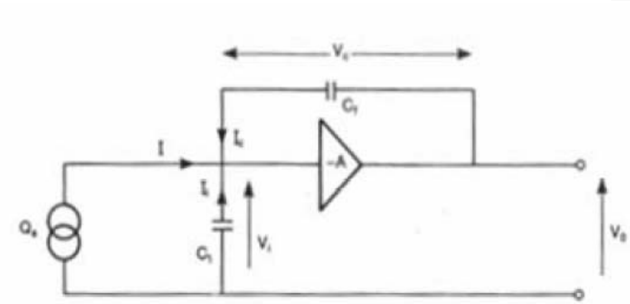
•High radiation environment
•Long cables for installation
•High frequency acquisition
•Short time
(Beginning of the project in August,
First measurement in October)

→ Remote control of the hardware placed in the tunnel

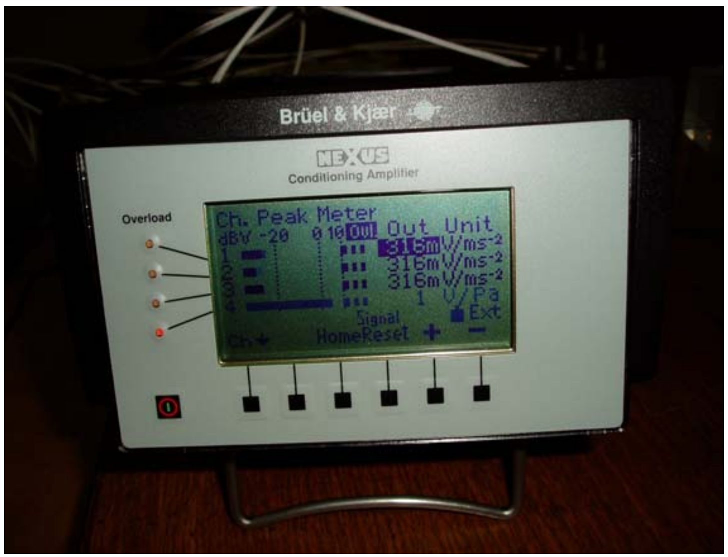
System Architecture



Preamplifiers



Working principle: Charge-voltage conversion of the accelerometer signals



4-Channels Nexus Preamplifier for the B&K accelerometers and the microphone

- Setting sensor sensitivity
- Setting low and high pass filter for each channel
- Setting gain for each channel (6 orders of magnitude)
- Automatic test to check the correct installation of the accelerometers
- RS-232 Programmable

Lower cost solution

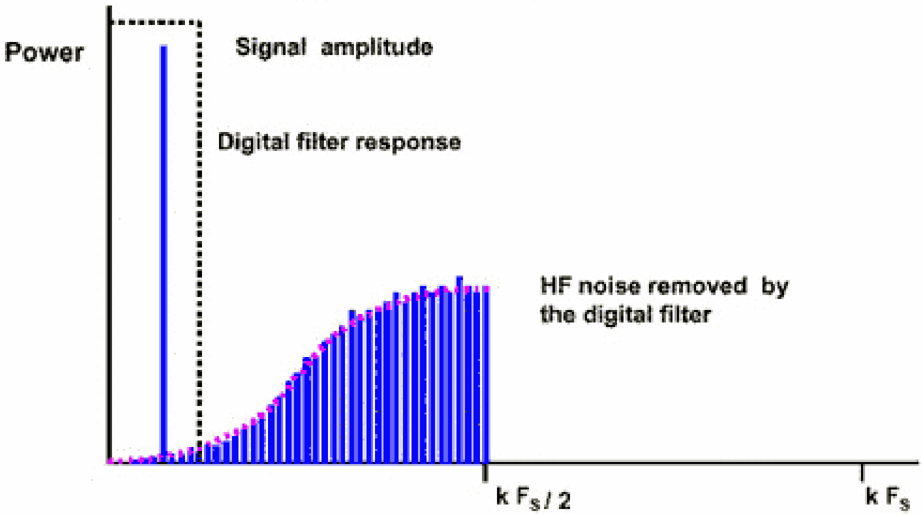
4 AP-5000 line drive preamplifiers for the AP accelerometers

- Fixed gain
- No control is possible
- Powered by a constant current source provided by the data acquisition board

Data Acquisition Board NI 4472

N° channels	8- simultaneously sampled
Sampling rate	102.4 kS/s down to 1.0 kS/s
ADC type	Sigma-delta converter
ADC modulator oversample rate	64 f_s for 51.2kS/s<fs≤102.4kS/s 128fs for 1.0 kS/s≤fs≤51.2kS/s
Idle channel noise	110 dB min 1.0 kS/s≤fs≤51.2kS/s 105 dB min for 51.2kS/s<fs≤102.4kS/s
Resolution	24 bit
Input Range	±10 Volt
Input Configuration	Pseudo-differential
Input Coupling	AC or DC software selectable
Input current source	0 or 4 mA each channel independently software-selectable

- **24 bit resolution ensures an acceptable quantization noise level even for no full scale signal.**
- **8- Simultaneously-sampled channels (up to 100 kHz)**

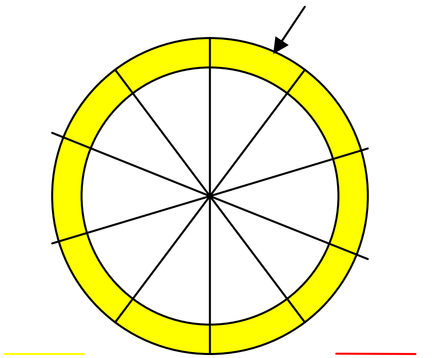


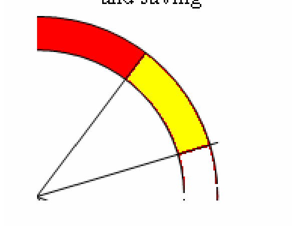
Software

Applications developed in Labwindows 7.0

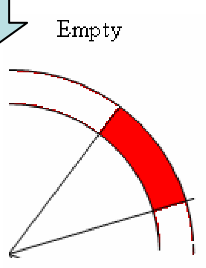
- Acquisition and saving Data
- Preliminary analysis off line
- Remote control of the NEXUS preamplifier.

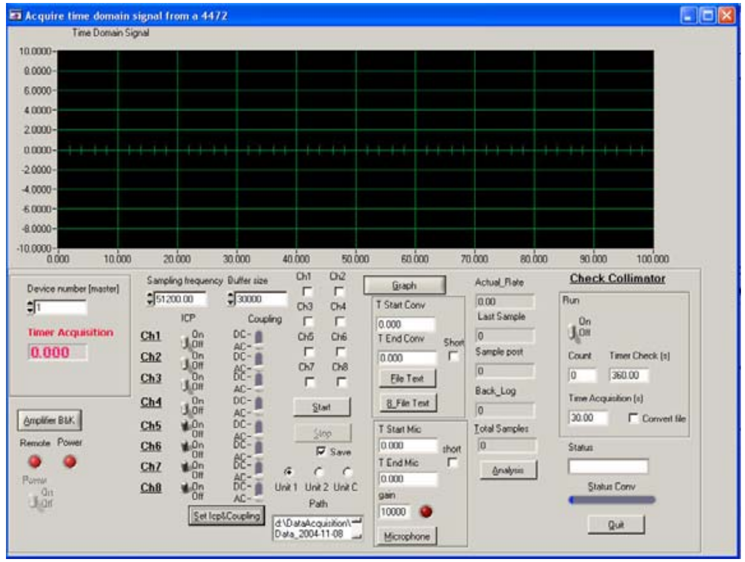
Acquisition Data





Empty





60 sec Acquisition at 51.2 kS/s

~ 200MB Data

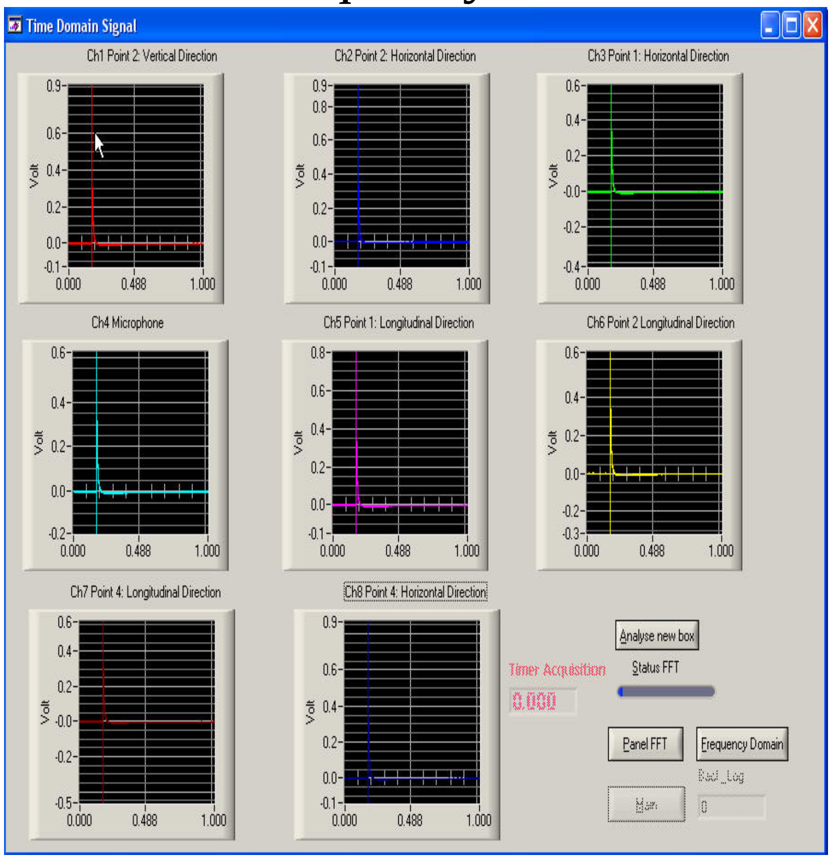
Size Ring Buffer = *10*nb_channel*nb_samples*

1/10 buffer full → Event trigger → Conversion and saving → 1/10 buffer full

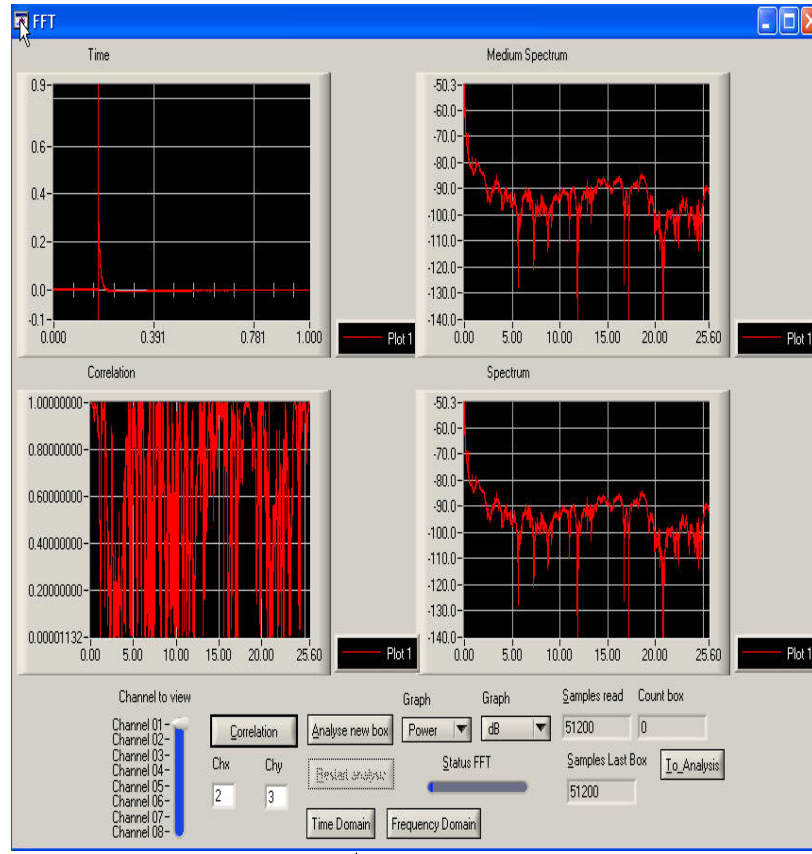
1. Setting of the software selectable parameters of the board.
2. Check of the writing operations on the disk.
3. Conversion operations from binary to text format.
4. Reproduction of the microphone data.
5. Setting for an automatic continuous acquisition.

Preliminary Analysis

Frequency Domain

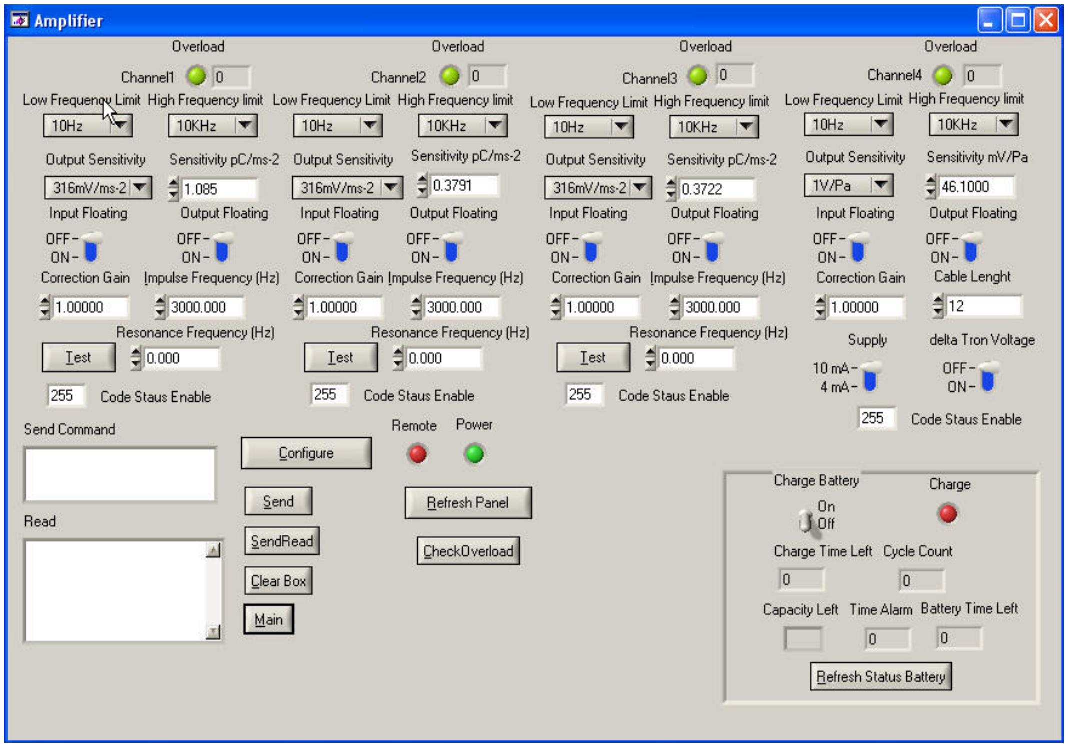


Time Domain

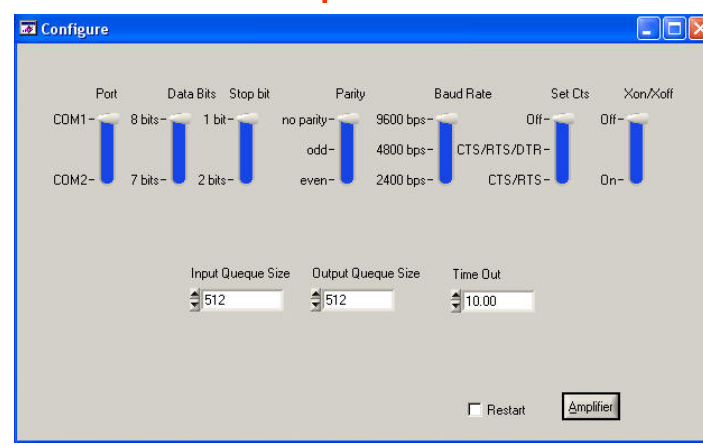


Detailed off line analysis performed with Matlab 7.0.1

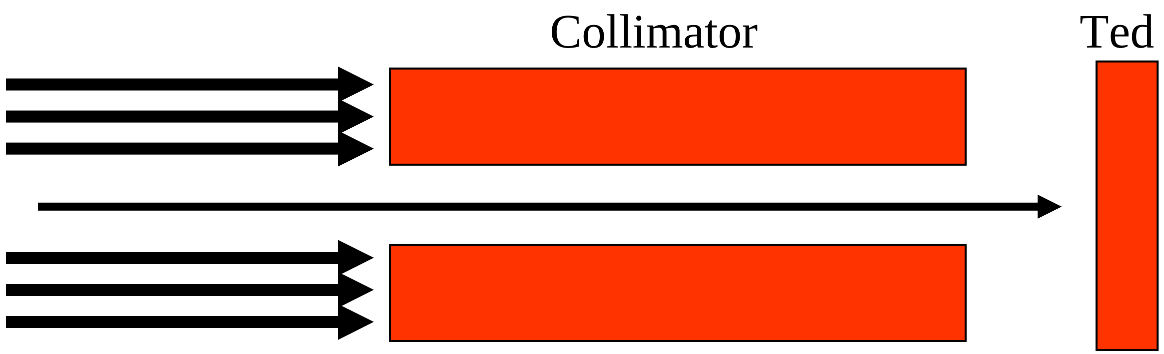
B&K Preamplifier



1. Setting RS232 parameter
2. Setting input output parameters
3. Check status device
4. Resonance test
5. Setting parameters for microphone



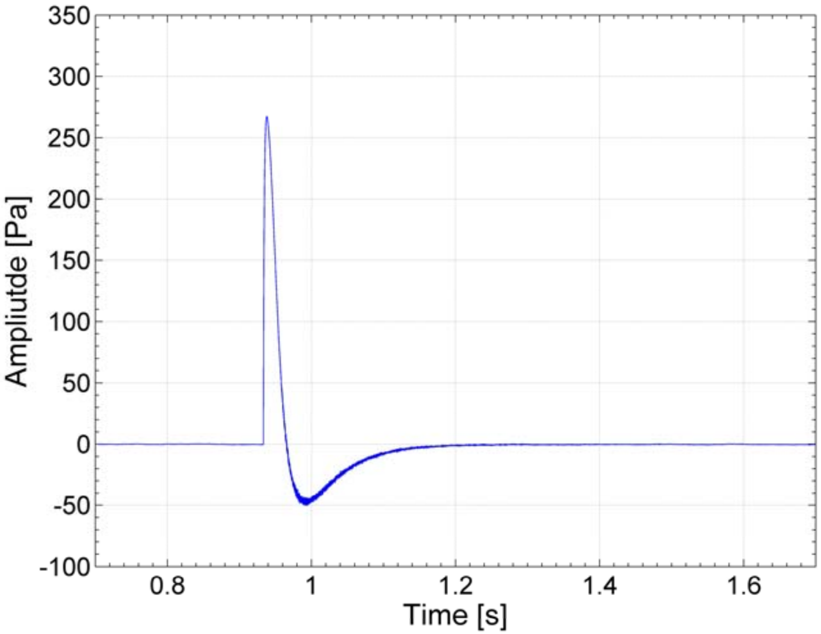
Measurement Conditions



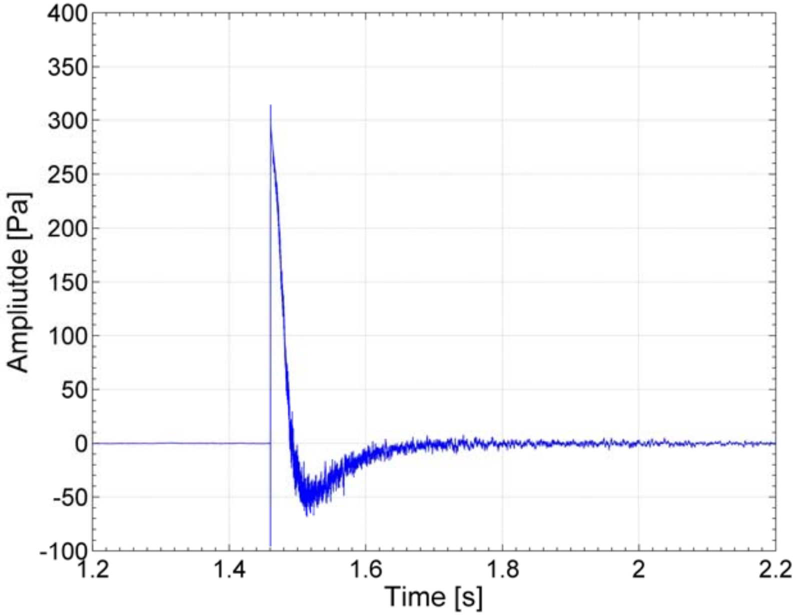
- For each jaw, collision at the maximum proton beam intensity (4 x 72 bunches) for different transverse impact depth (~1 mm up to ~6 mm)
- For each jaw, collision at increasing proton beam intensity for a specific transverse impact depth (~ 5 mm)
- Bump on the TED (target 5 m distant from the collimator) at increasing proton beam intensity

Measurement results

TED



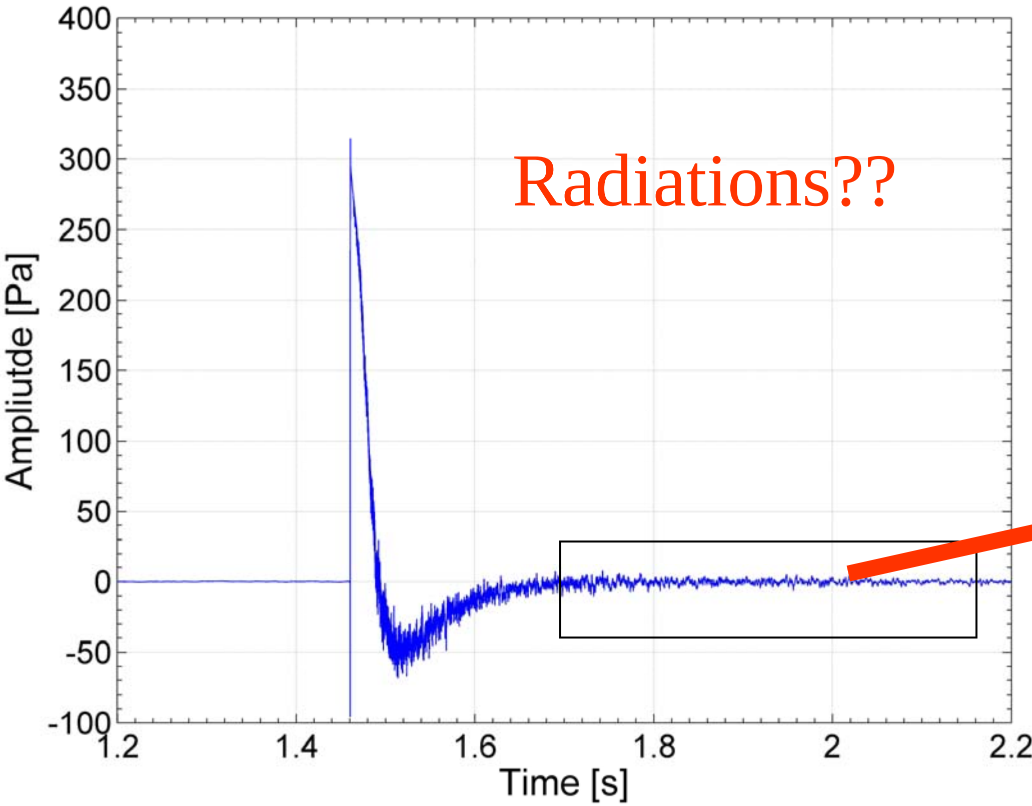
COLLIMATOR

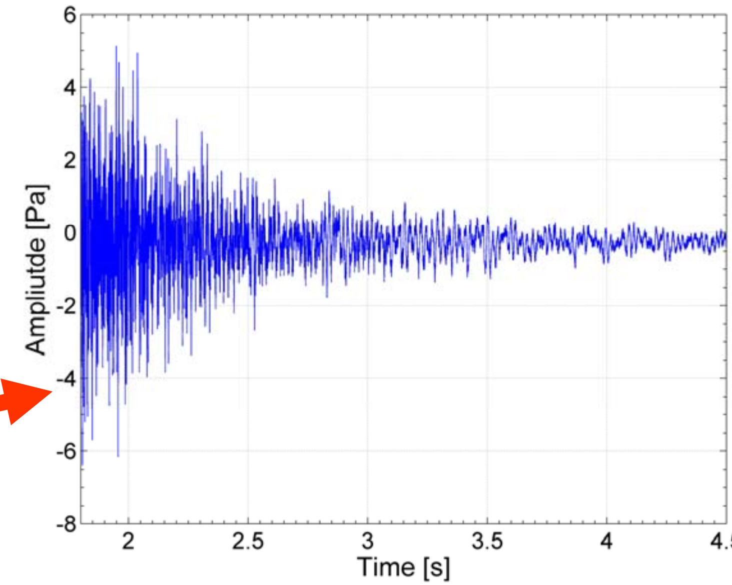


We can distinguish between impact on the Ted and on the collimator

Detection of the impact on the collimator for TT40 test achieved

Data Analysis

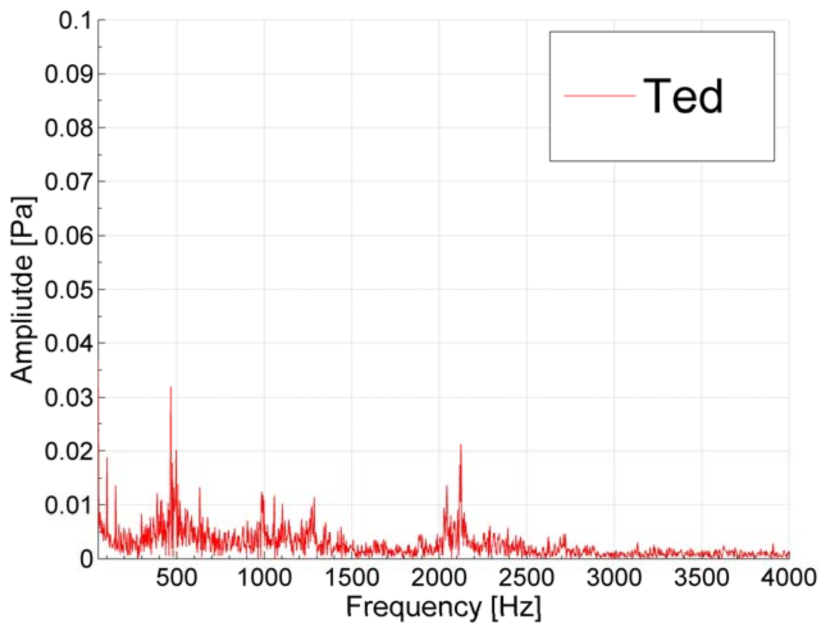


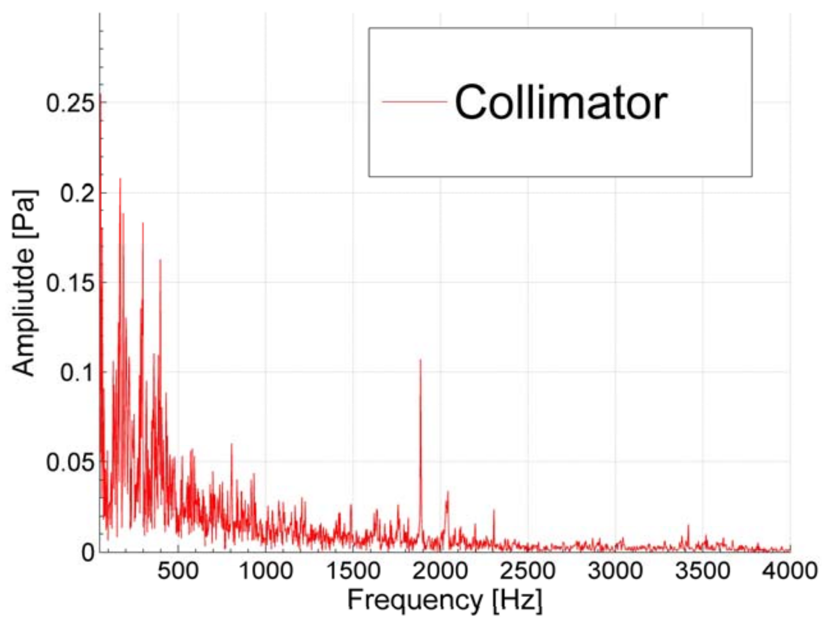


The shape peak is mainly noise (neglected in the Fourier analysis)

Frequency analysis focused on the comparison of the signal before the peak with the signal after the exponential decay

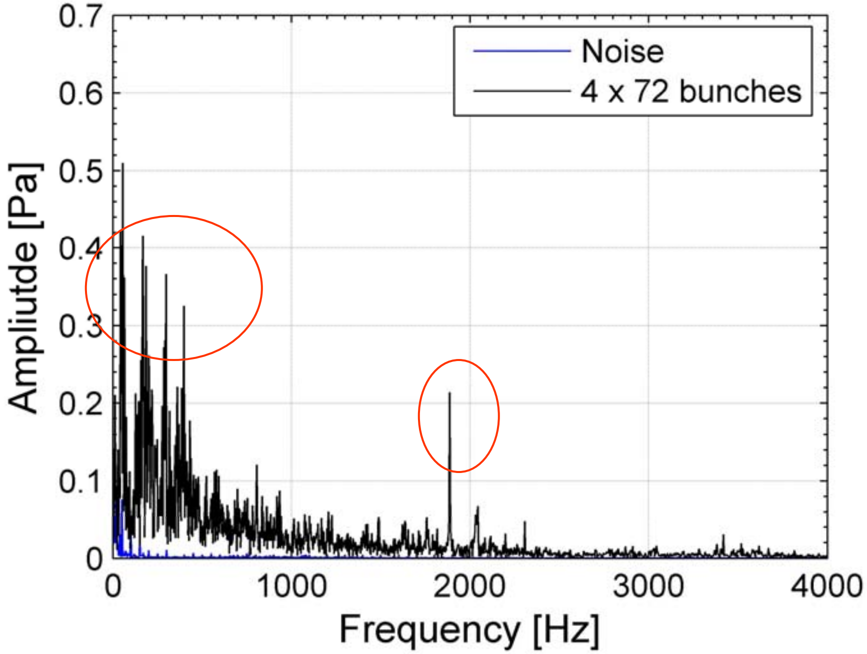
Comparison with Sound spectrum of TED

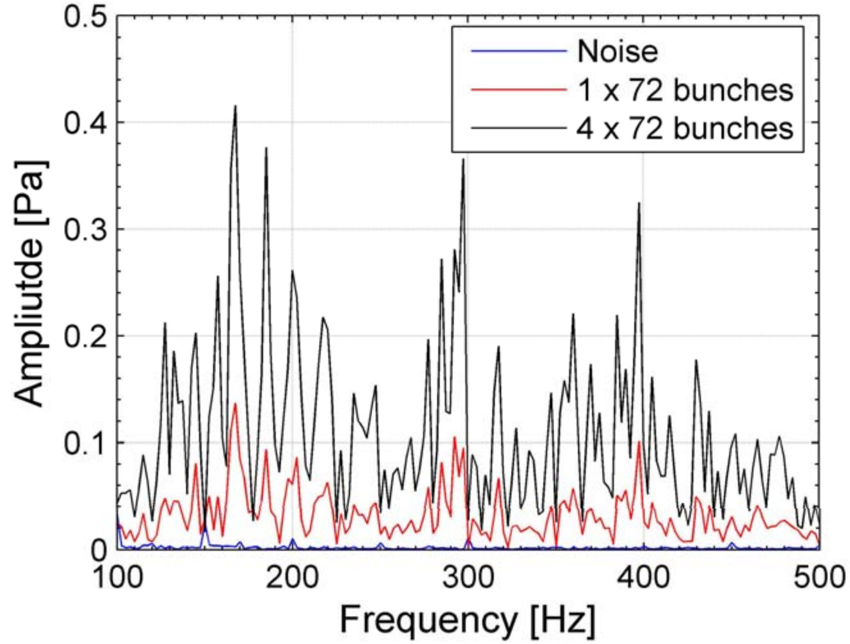




The excited frequency components change when the beam hits the TED

Frequency Analysis



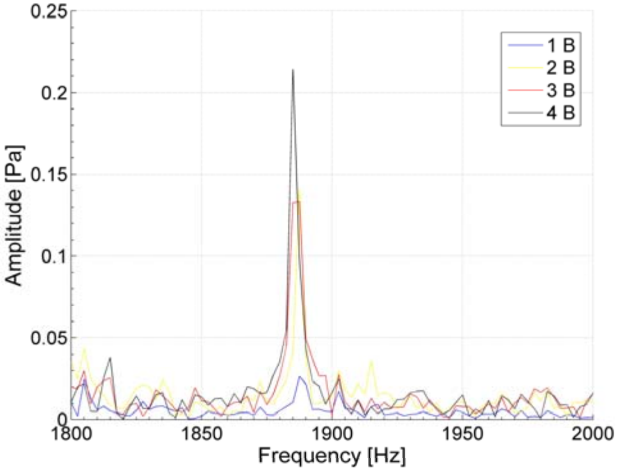


The main frequency components are the same for different beam intensities

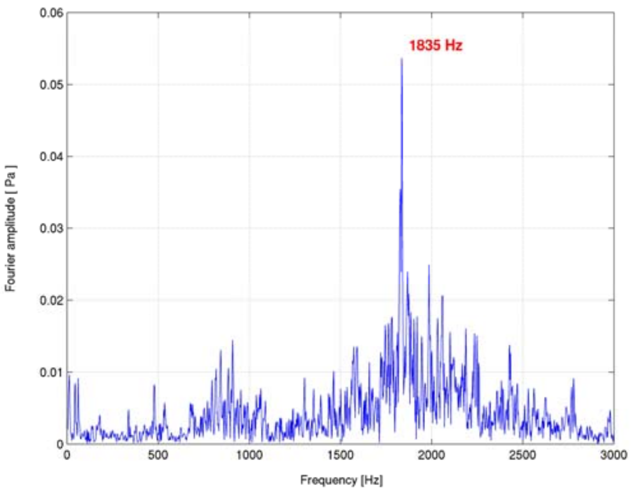
This is in according with mechanical inspection of the jaws

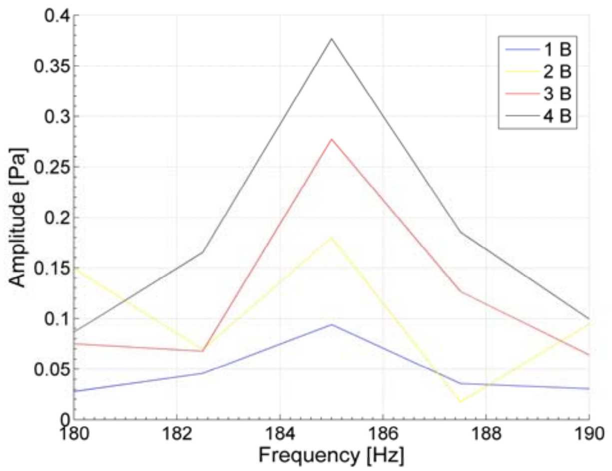
Comparisons with Lab Test

TT40 TEST

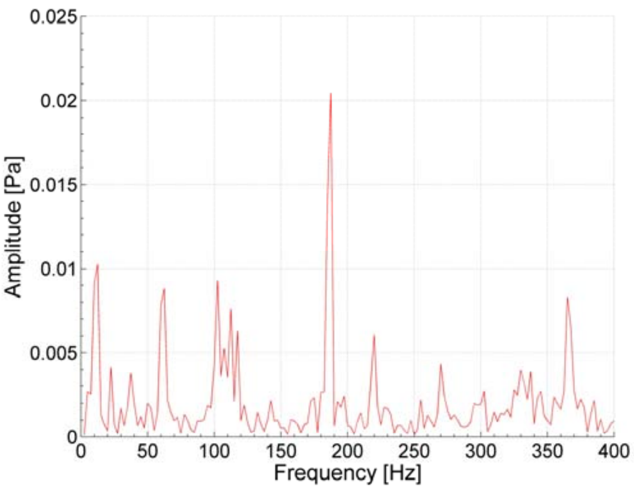


LAB TEST: Vacuum Tank



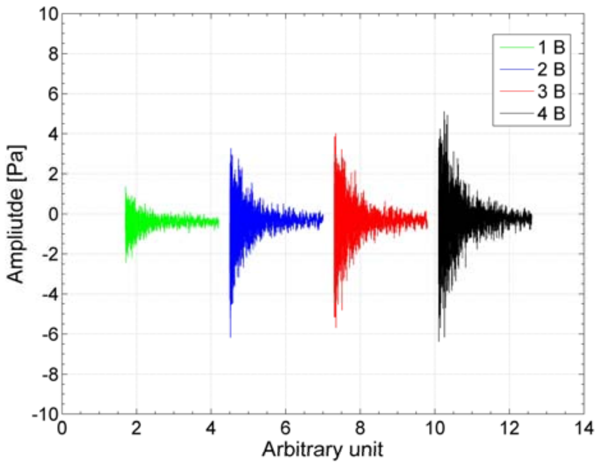


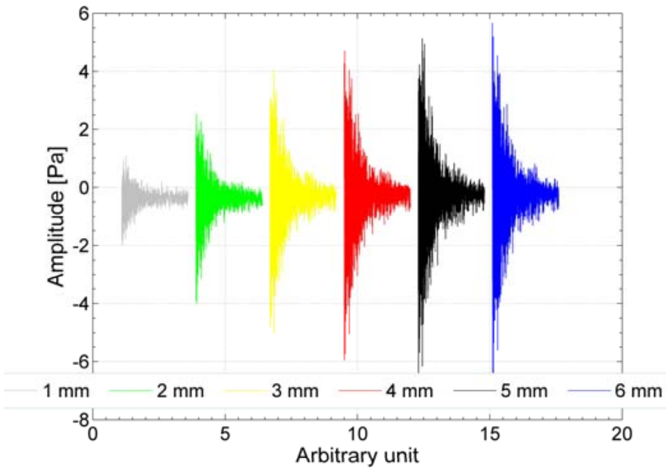
LAB TEST: Bellow

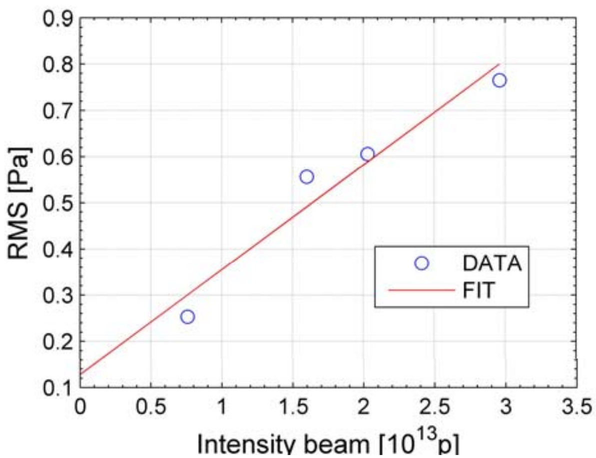


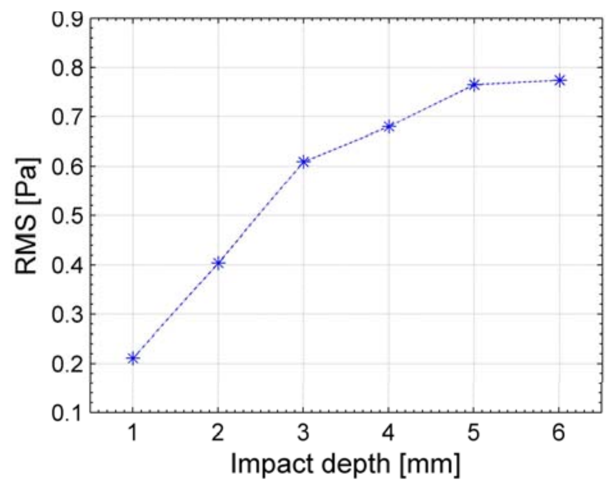
Dependence on beam intensity and depth

Good correlation of the microphone signal with the beam intensity and the impact depth on the jaw







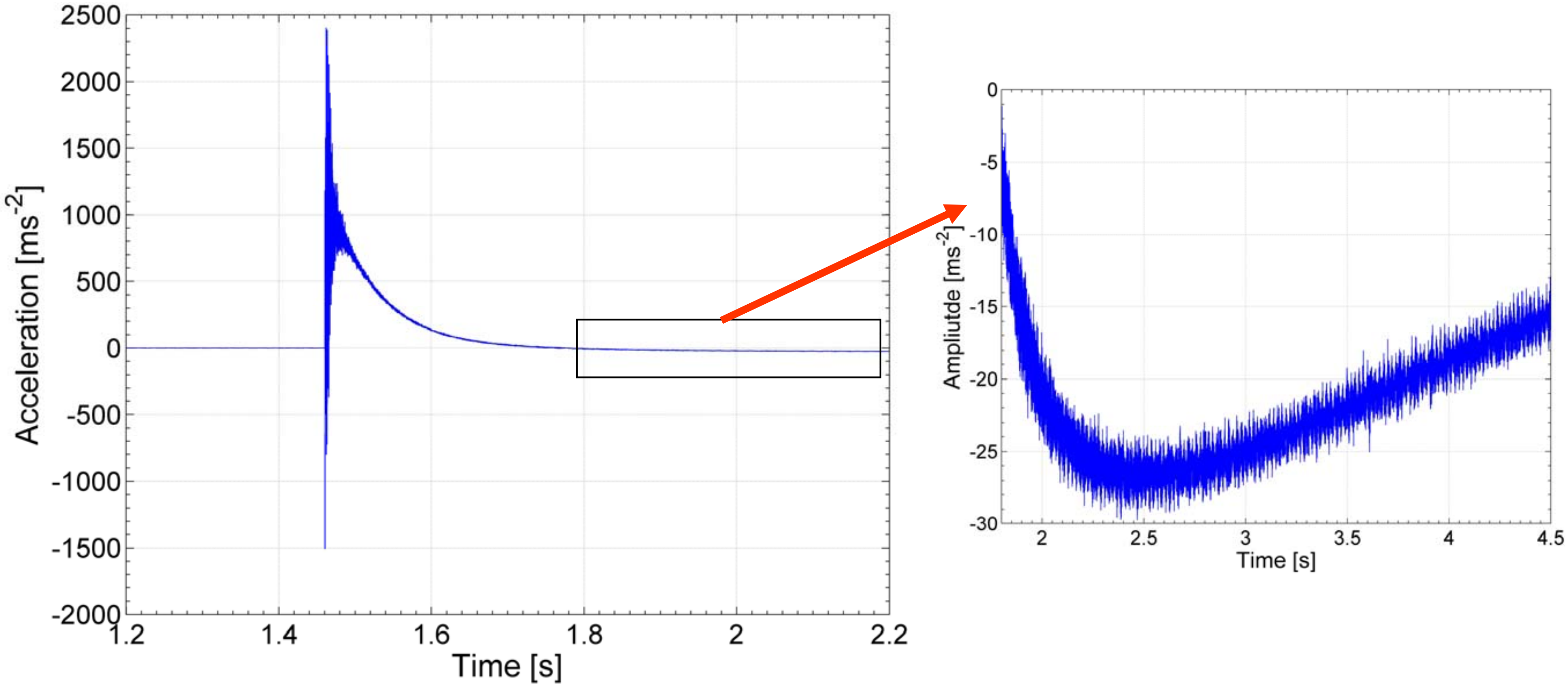


Accelerometers

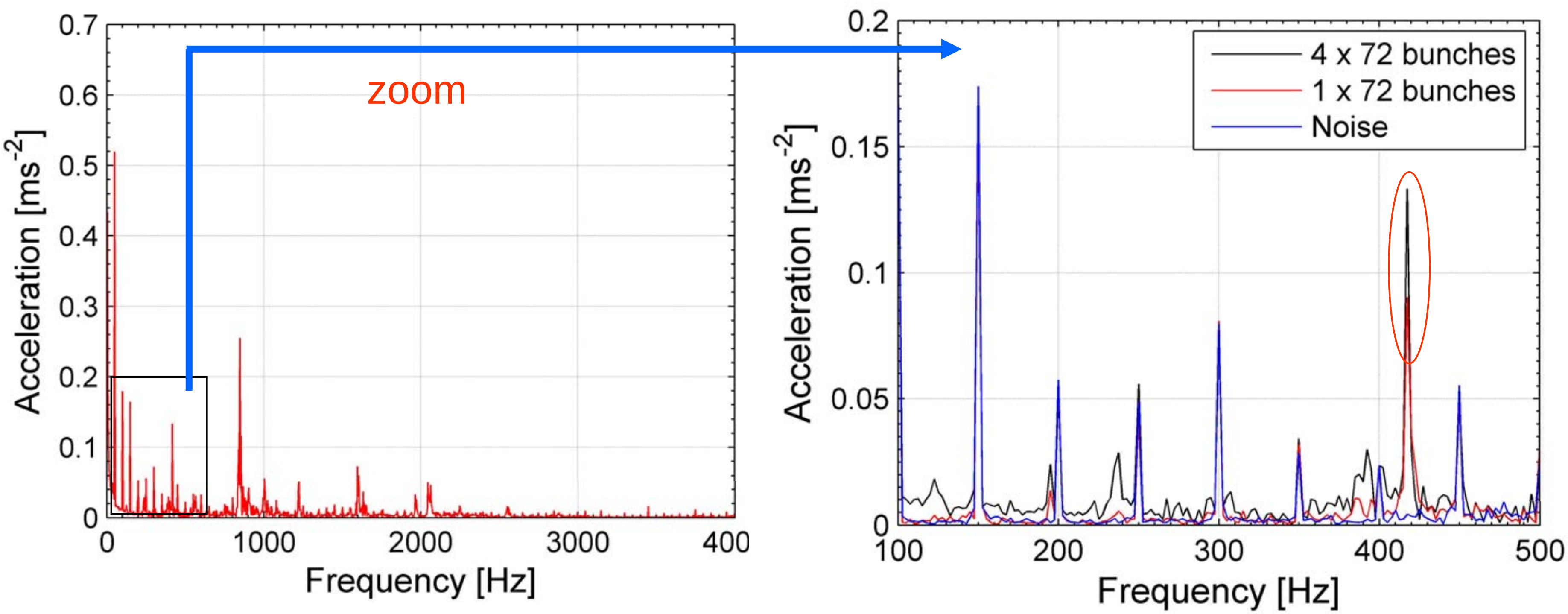
As for the microphone, “saturation” peak and the consequent exponential decay

BUT vibration signal decays earlier (less precise Fourier analysis) Not clear which is the part of the instrumentation (cables, sensor or preamplifier) more influenced by the critical measurement conditions

Accelerometer signals evaluated in the time interval individualized with the microphone



Frequency Analysis



- Some frequency components come out after the impact
- Comparisons with the expected vibrations of the mechanical structure is on going

Conclusions

- Successful detection of beam impacts on the collimator with sound/vibration measurements achieved at TT40!
- This is a powerful tool that can in principle be used for the LHC.
- Dependence on beam intensity and impact depth were measured with the microphone and are in qualitative agreement with expectations
- Frequency analysis showed vibrations of the whole collimator mechanical structure after beam impact (confirmed by laboratory measurements)
- Effect of the radiations under investigation with the manufacturer (more important for accelerometer signals)

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