Feedbacks

Alessandro Drago

Workshop on Tau Charm at High Luminosity

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Introduction

Since 1992, PEP-II and DAFNE beam feedback systems have been developed in collaboration, sharing common approach and technologies and involving in common design and implementation also other circular lepton accelerators like ALS-Berkeley (USA), Bessy (Germany) and KEK (Japan).

The SuperB synchrotron and betatron bunch-by-bunch feedback systems have been designed keeping in mind the previous experience but also making necessary upgrades in terms of better signal resolution, larger dynamic range, most modern and powerful components and updating the software/firmware/gateware releases.

The upgrade of the feedback systems designed for the SuperB is absolutely valid also for the Tau-Charm Factory.

It is not even foreseen a scaled version respect to SuperB feedback design in terms of power or digital processing hardware, although Tau-Charm harmonic number should be smaller than Superb one, so, it asks for less computing but this variation is basically negligible.

Research activities that are common to DAFNE and Tau-Charm feedback systems

- Transverse feedback

- Low noise analog front end: evaluation & studies with beam signals to have a better signal/noise ratio
- The new horizontal feedback kicker
- Remote signal/clock jitter control
- New 12-bit FPGA processing units under test during DAFNE runs

- Longitudinal feedback

- Simplified analog longitudinal back end without QPSK modulation (only with amplitude modulation)
- 8-bit FPGA processing units tests during DAFNE runs

Collaboration with KEK

- Even if not officially signed, an informal collaboration with Makoto Tobiyama responsible of feedback at the KEK Accelerator Laboratory is continuing along the years with the goal to discuss new ideas or to fix any problems.
- DAFNE and KEK share same feedback systems both in terms of hardware and software.
- This collaboration between two e+/e- collider makes possible an easier analysis of unexpected behaviors.
- Also for SuperKekB and Tau-Charm will be possible, I hope, to continue the feedback collaboration.

Low noise front end motivations

In the past years, both at DAFNE and at KEK, some influence of the vertical feedback gain has been observed on the beam size in collision (i.e. vertical enlargement) in some conditions.

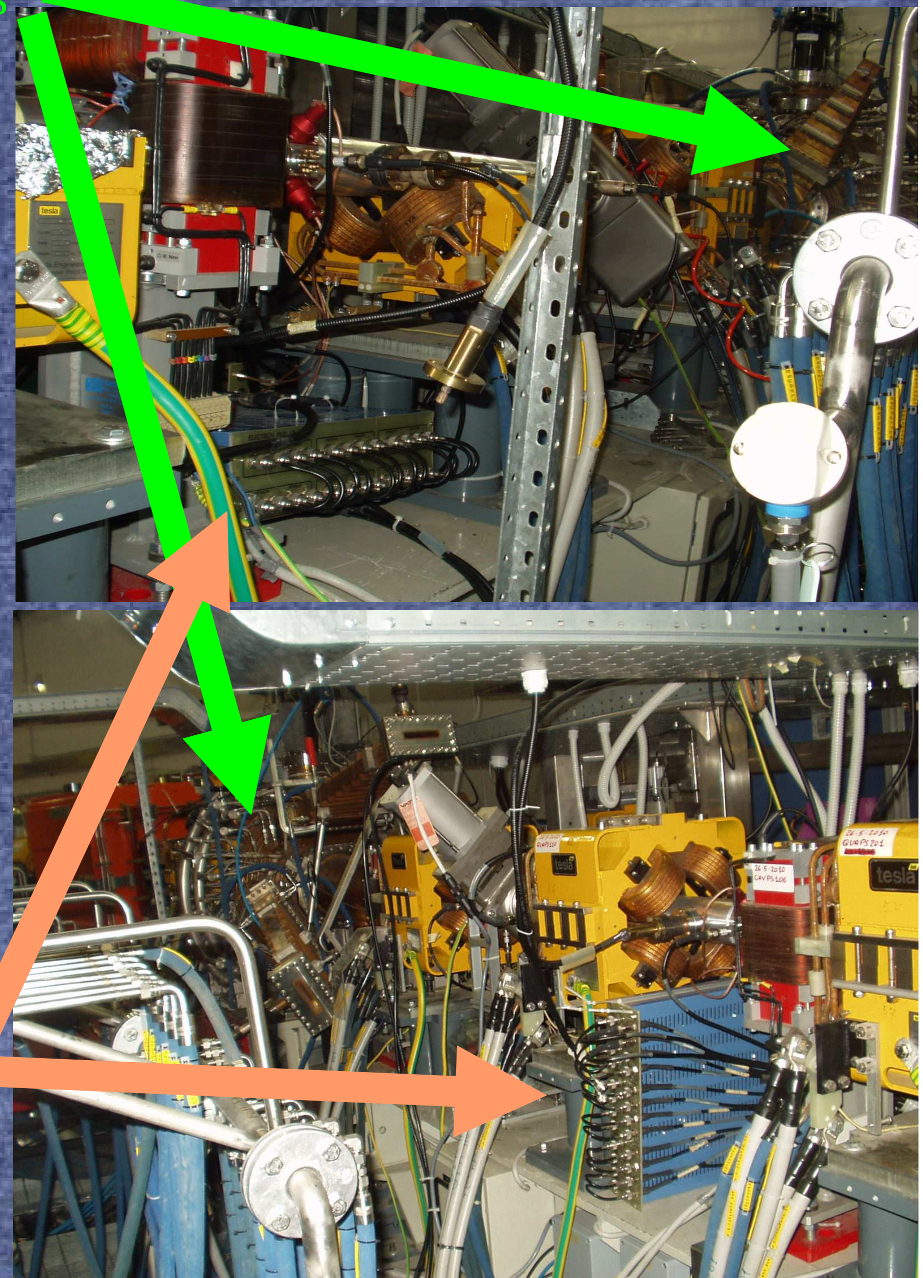
Experiments on this topics have beam jointly carried on by KEK, DAFNE, PEP-II experts to clarify better the terms of problem planning new strategies even if it is proved that it's a beam-beam effect and not a single beam behavior.

First of all, the 8-bit A-to-D conversion for transverse feedback processing unit has been upgraded to 12-bit to decrease the quantization noise.

Furthermore an R&D activity has started about an innovative low noise front end receiver.

Low noise front end motivations/2

- In DAFNE main rings, to decrease the environmental noise effects, it has been proposed to move the parts of the circuits that are very close to the pickup, outside the main hall with the vacuum chamber, far away from fringe fields coming from magnets and RF klystrons.



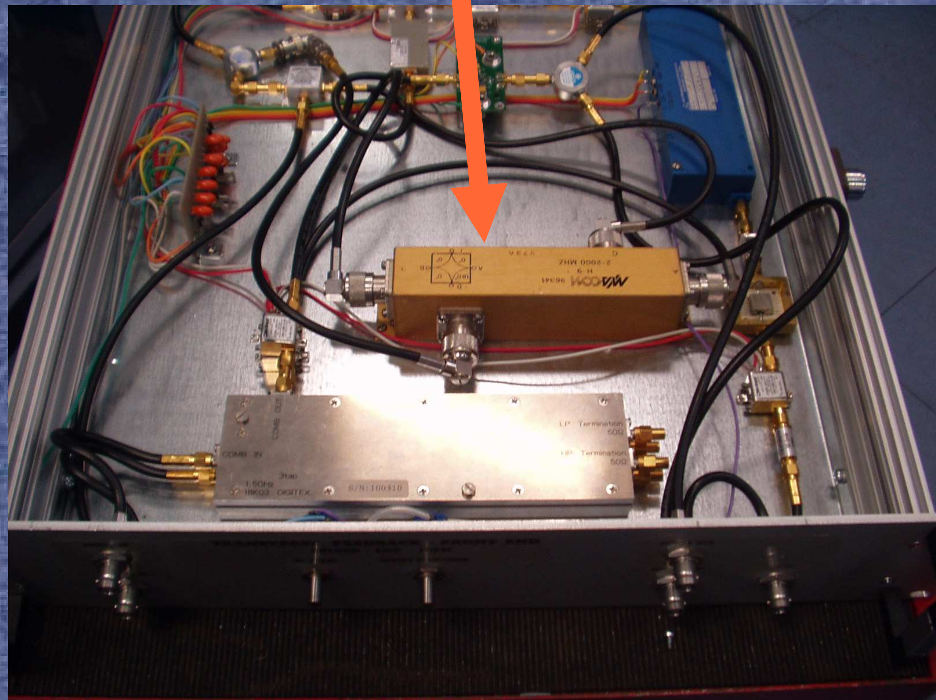
Faraday cages with hybrids inside (the hybrids are parts that make pulse addition & difference)

Low noise front end R&D

- This proposal brought to a completely new FE design that was tested at DAFNE in March 2011 and Jan/Feb 2012 by Makoto Tobyiama and myself using hardware from KEK.

- These tests done in DAFNE were not conclusive because needing high beam currents and very flat colliding bunches (conditions still not available during tests).

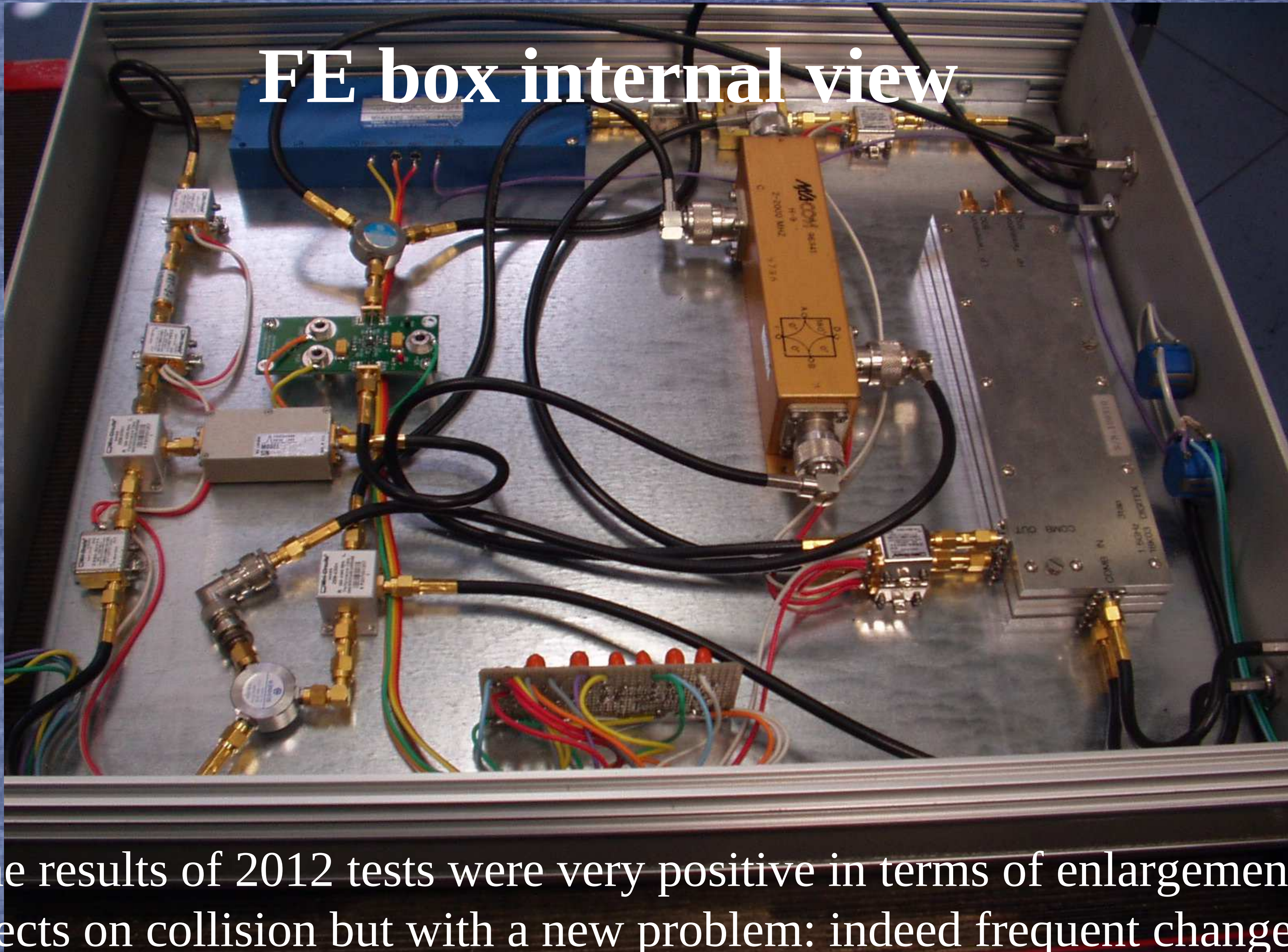
H9 Hybrids have been moved from DAFNE hall to instrumentation hall



Transverse feedback front end

During fall 2012, a new front end box, assembled in at LNF by Servizio SELCED with similar but not identical parts, was tested with DAFNE e+ beam by myself. Even if the FE is basically common to the two colliders, at DAFNE is more critical because the area needs for much longer cables and the signal attenuation is higher than at KEK.

FE box internal view



The results of 2012 tests were very positive in terms of enlargement effects on collision but with a new problem: indeed frequent changes of the digital gain was necessary with beam current variation.

Front end conceptual schematics

A complete discussion on this approach with pro and con is beyond the goal of this talk, nevertheless we can summarize that:

- Up and down button signal are brought from high beta pickup in DAFNE hall to instrumentation hall by long cables
- Up and down signal are managed separately by trombone delays and comb filters used to make 3 replicas for each bunch
- Orbit offset correction is done by a dedicated mixer with manual correction by using a knob
- 4*RF is generated inside the front end where is put in phase by using a manual knob
- Detection is made at 4*RF

Programmable trombone delay line Colby PDL-10A

This high-resolution delay line based on the Electro-Mechanical Trombone delay line structure has a total delay range from 0 to 625 ps and bandwidth from DC to 18 Ghz.

An internal stepper motor produces precise delay steps with a resolution to 0.5 ps when operated in series connected mode.

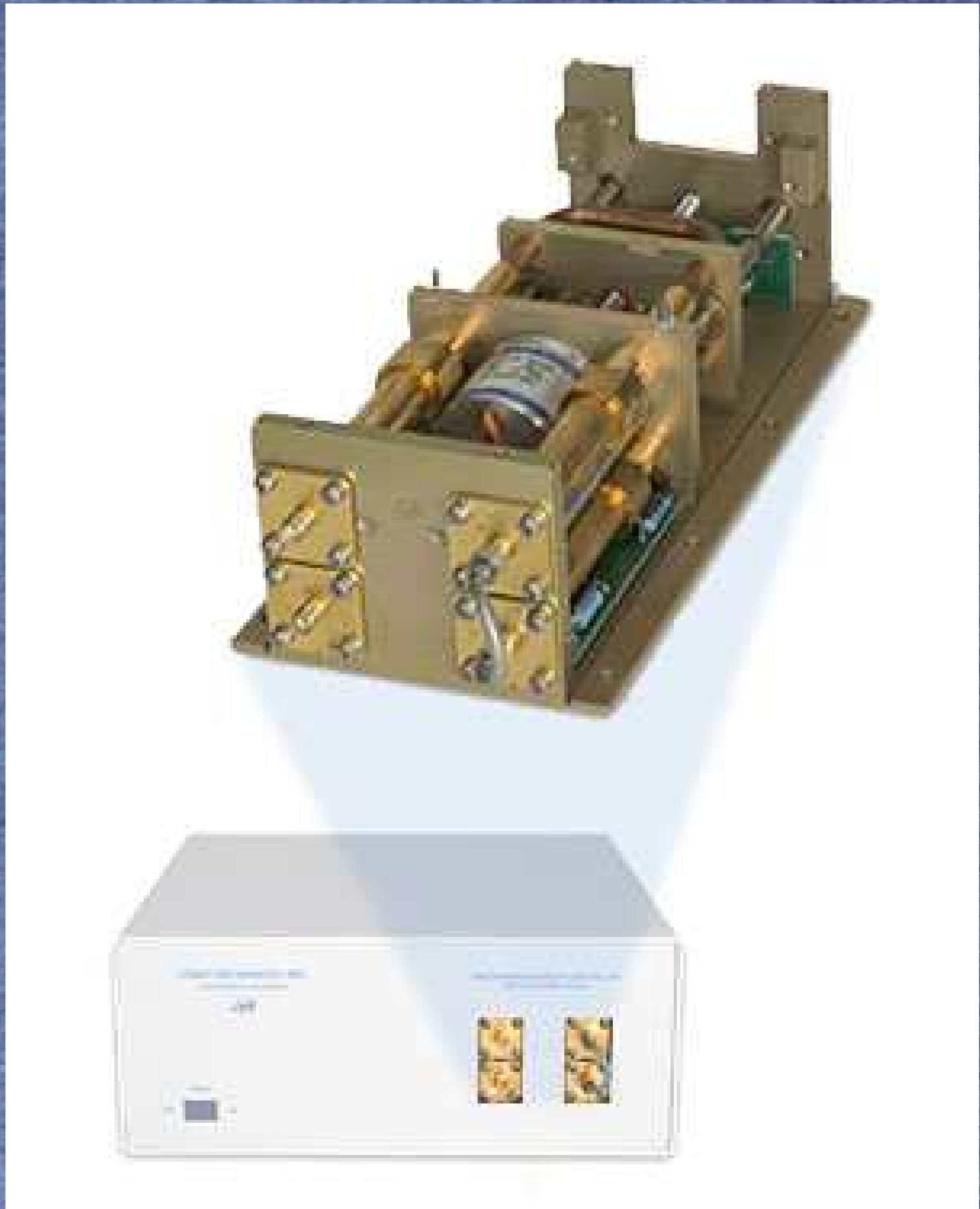
The trombone design has an absolute accuracy of ± 0.2 ps.

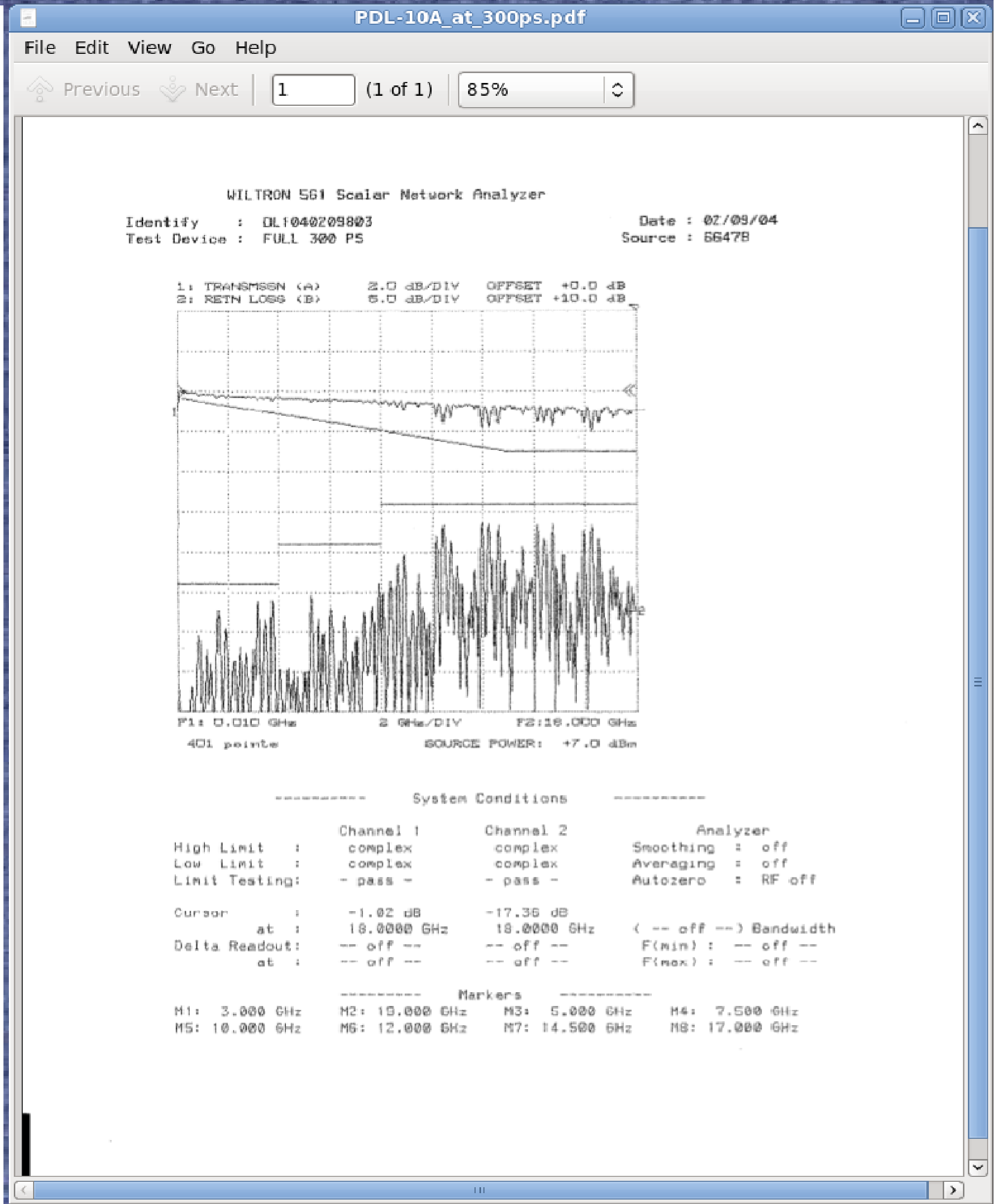
In the standard set-up (series connected), two identical 312.5 ps electro-mechanical trombone sections are connected in series via a short semi-rigid coaxial cable on the front panel. The Series Connected configuration provides a full delay extension range of 625 ps with 0.50 ps resolution.

The PDL-10A is fully programmable via GPIB (IEEE488.2 protocol) interface or via a MicroTerminal (MT-1A).

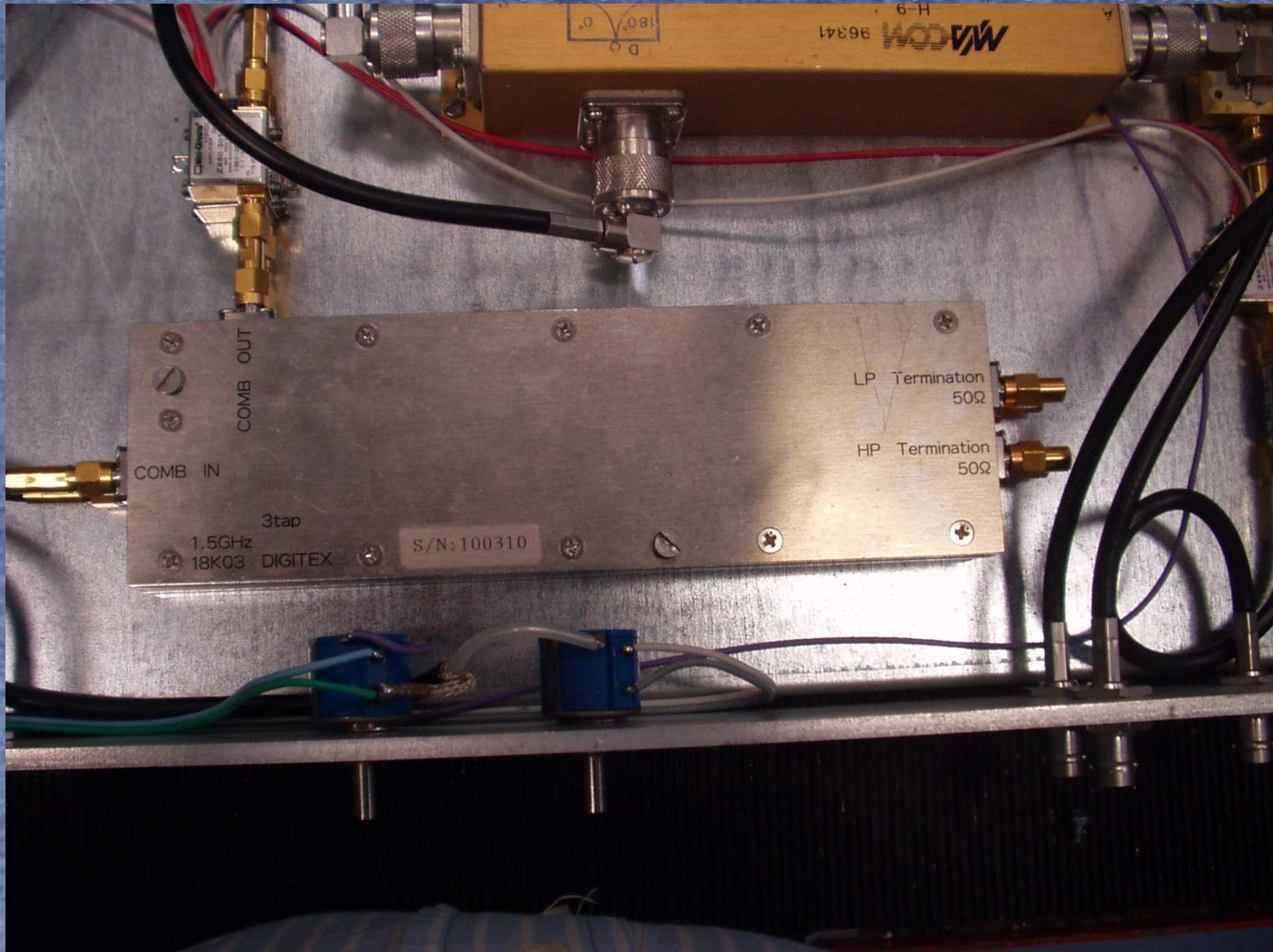
At 18 Ghz, the frequency roll-off is typically less than 1.0 dB.

Colby 10A

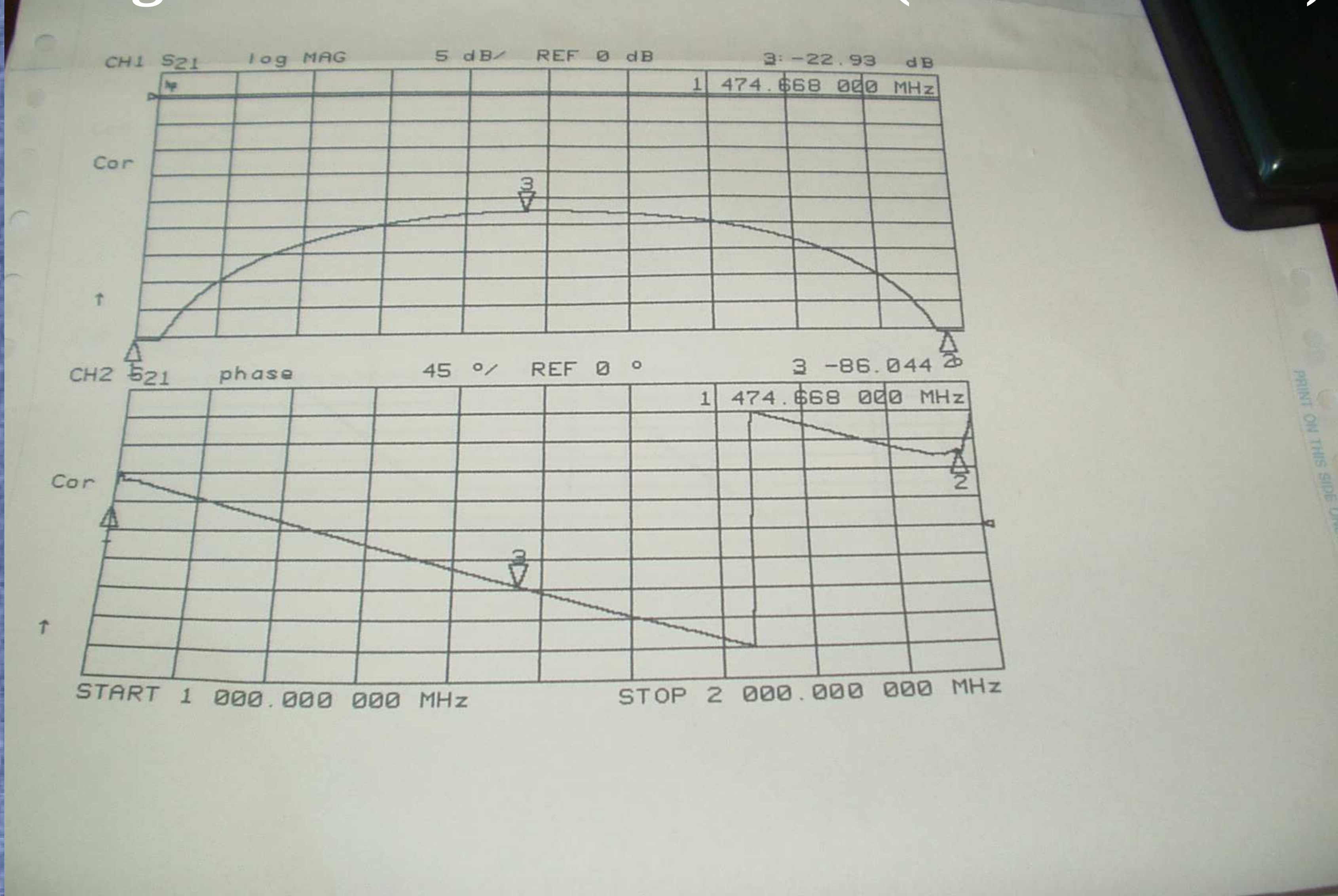



PDL-10A_at_300ps.pdf
File Edit View Go Help
Previous Next 1 (1 of 1) 85%
WILTRON 561 Scalar Network Analyzer
Identify : DL1040209803
Test Device : FULL 300 PS
Date : 02/09/04
Source : 6647B
1: TRANSMSSN (A) 2.0 dB/DIV OFFSET +0.0 dB
2: RETN LOSS (B) 5.0 dB/DIV OFFSET +10.0 dB
F1: 0.010 GHz 2 GHz/DIV F2:18.000 GHz
401 points SOURCE POWER: +7.0 dBm
System Conditions
Channel 1 Channel 2 Analyzer
High Limit : complex complex Smoothing : off
Low Limit : complex complex Averaging : off
Limit Testing: - pass - - pass - Autozero : RF off
Cursor : -1.02 dB -17.36 dB
at : 18.0000 GHz 18.0000 GHz (-- off --) Bandwidth
Delta Readout: -- off -- -- off -- F(min) : -- off --
at : -- off -- -- off -- F(max) : -- off --
Markers
M1: 3.000 GHz M2: 15.000 GHz M3: 5.000 GHz M4: 7.500 GHz
M5: 10.000 GHz M6: 12.000 GHz M7: 14.500 GHz M8: 17.000 GHz

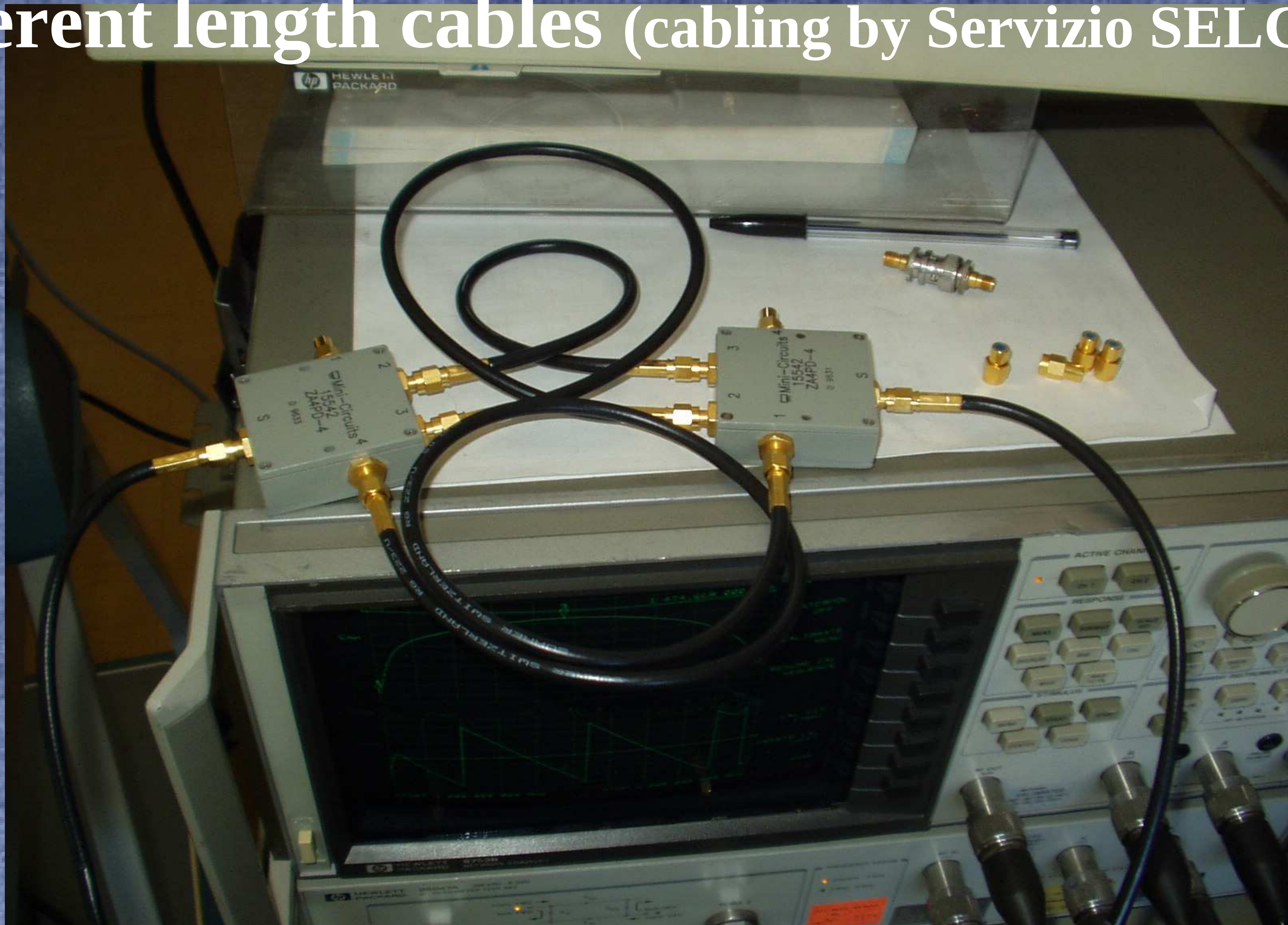
The core of the front end is the comb filter, a sophisticated, custom device, done by fabricating a special pcb using Duroid as dielectric(ε_r=2.9). The filter can replicate the bunch signals with the goal to send them to a RF mixer for detection.



The “pcb” comb filter has very high attenuation (~23dB) and, added to the cable attenuation, it makes too small signals to have adequate SNR & dynamic range for the tests at DAFNE (fall 2012 runs).

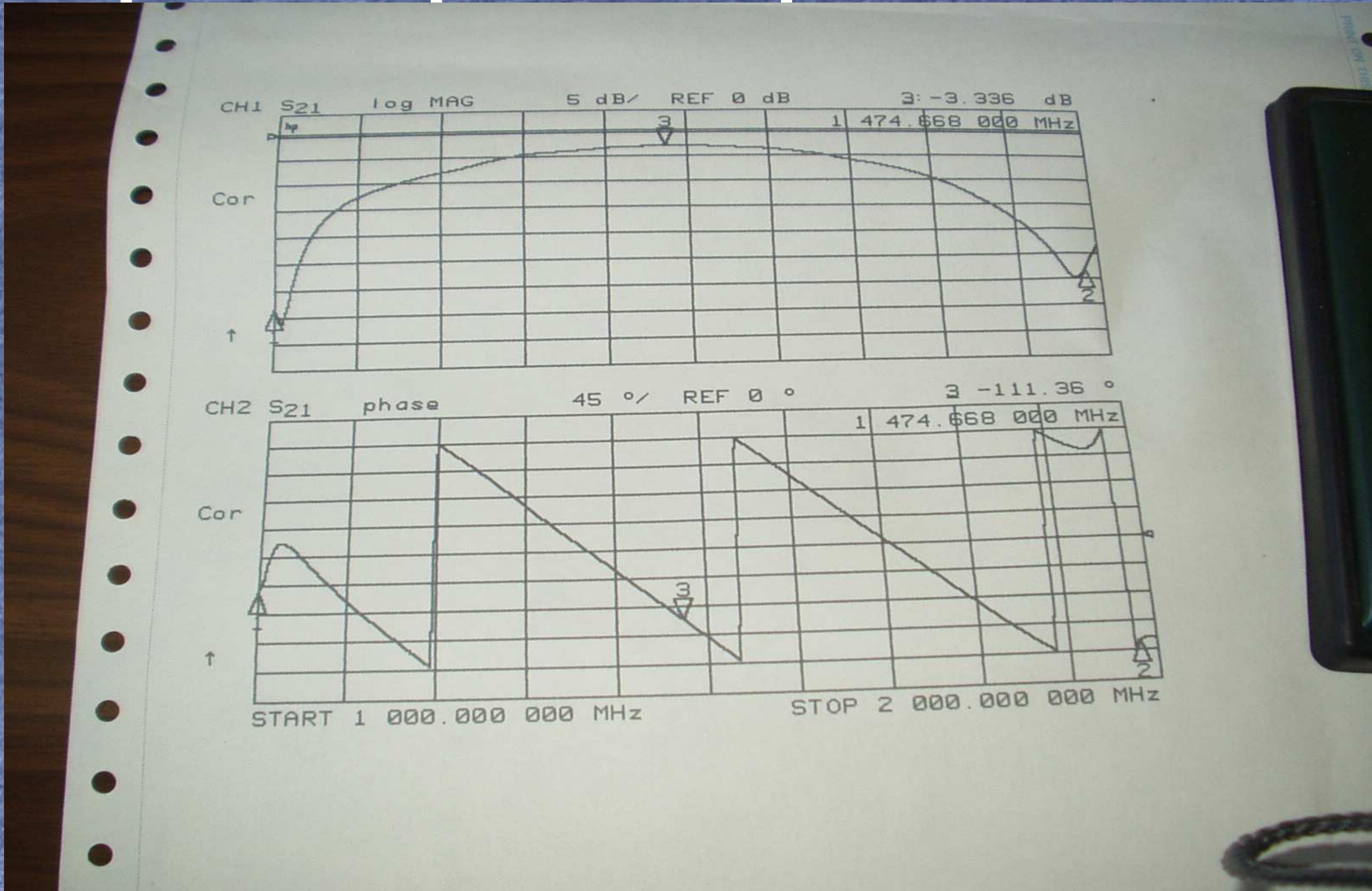


Another type of comb filter is now under test. This uses two 4-ways splitters to replicate bunch signals at 4*RF by implementing different length cables (cabling by Servizio SELCED).

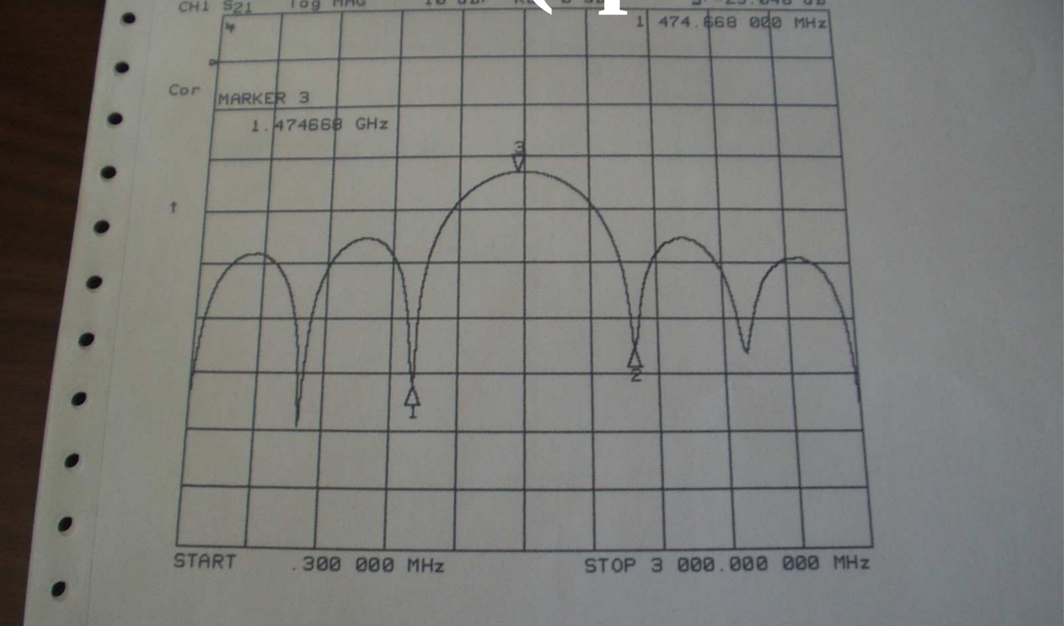


In the picture: 3 cables with different length to make $n*\Delta T=n*(1/RF/4)=n*678$ ps skews, with $n=0,1,2$

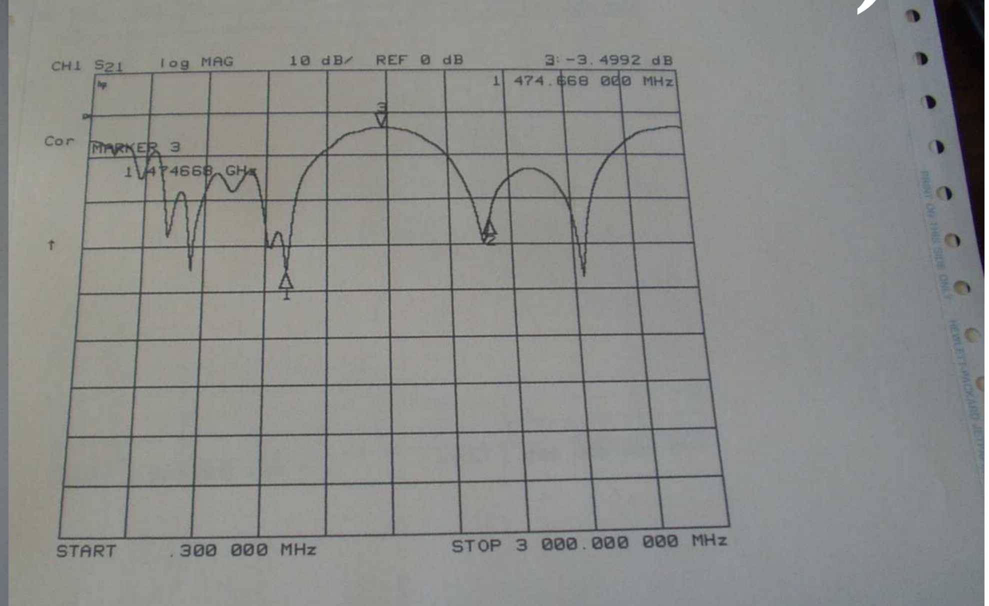
Attenuation is only 3.3 dB ! The magnitude response has the same shape of the previous “pcb” comb filter



Nevertheless, outside the main lobe, “pcb” comb filter transfer function is much more clean than with the other method (splitter-combiner comb filter)



Comb filter
(magnitude vs. frequency)



Two splitters with cables
(magnitude vs. frequency)

But signal detection is done by a mixer with 4*RF as LO so we don't care!

After frequency domain plots, time domain measurements have be done

To have a bunch signal simulator we need a device to transform a simple pulse from the usual pulse function made by a signal generator to the derivative shape that we get from a pickup. To do this, we use an inverting splitter followed by two different delayed paths, followed by a non-inverting combiner.

300 ps rise time for the bunch pulse emulator.

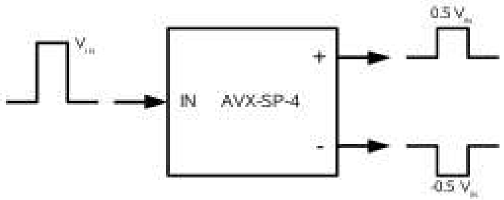
For a preliminary test is enough fast but it's far from the real case

AVTECH

AVX-SP AND AVX-CP SERIES

0° AND 180° POWER SPLITTERS
AND 0° POWER COMBINERS
FOR NANOSECOND PULSES

AVX-SP SERIES
0° AND 180° NANOSECOND PULSE POWER SPLITTERS



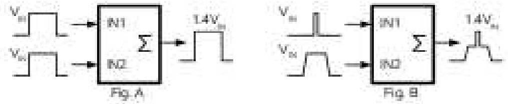
The AVX-SP series of pulse splitters provides two outputs which are either both in-phase with the input signal (0° and 0°, non-inverted), or with one output non-inverted and with one output inverted (0° and 180°). The function of an inverting pulse splitter is illustrated above. A positive input pulse is split into one positive output pulse and one negative output pulse. The output voltage magnitudes are each equal to one-half the input magnitude. Output relative magnitudes and delays are closely matched and stable. The 300 ps rise time AVX-SP-1 and AVX-SP-2 are designed for use with nanosecond speed laboratory pulse generators or with Avtech units such as the AVI and AVL series. The 60 ps rise time AVX-SP-3 and AVX-SP-4 models are intended for use with sub-nanosecond laboratory pulse generators and with Avtech AVH, AVP, AVM and AVN series units. Inverting power splitters may also be used as inverting transformers (with 50% loss of amplitude) if the non-inverting output is terminated in fifty Ohms.

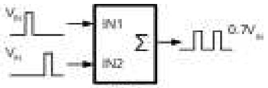
AVX-SP models are not reversible - that is, they can not be used as power combiners. See the AVX-CP series for applications requiring pulse power combiners.

Model:	AVX-SP-1	AVX-SP-2	AVX-SP-3	AVX-SP-4
Output A:	non-inverted			
Output B:	non-inverted	inverted	non-inverted	inverted
Rise time: (20%-80%)	≤ 300 ps		≤ 60 ps	
Droop (max.):	10% for PW = 100 ns		10% for PW = 10 ns	
PW (maximum):	100 ns		10 ns	
Input and load impedance:	50 Ohms			
Maximum input voltage:	350 V		30 V	
Maximum average power:	1/2 W		1/4 W	
Amplitude match:	± 2% (Output A to Output B)			
Delay match:	± 10 ps (Output A to Output B)			
Connectors:	SMA			
Size: (H x W x D)	38 × 28 × 23 mm (1.5" × 1.1" × 0.9")			
Chassis material:	cast aluminum, blue enamel			

AVX-SP-4

AVX-CP SERIES
0° NANOSECOND PULSE POWER COMBINERS





The AVX-CP series of pulse combiners can be used to add together two pulse signals. They can also be used in reverse, to split a signal input pulse into two identical outputs with 70% of the original amplitude.

When used to sum two unity amplitude inputs, the combiners will yield an output equal to about 1.4 times the input amplitude. The basic summing action of an AVX-CP series power combiner is illustrated in Figure A above. Other possible applications for pulse power combiners are illustrated in Figures B and C. Figure B demonstrates how a relatively fast narrow pulse can be superimposed on a wider pedestal base pulse while Figure C illustrates how two input pulse lines can be combined onto a single line.

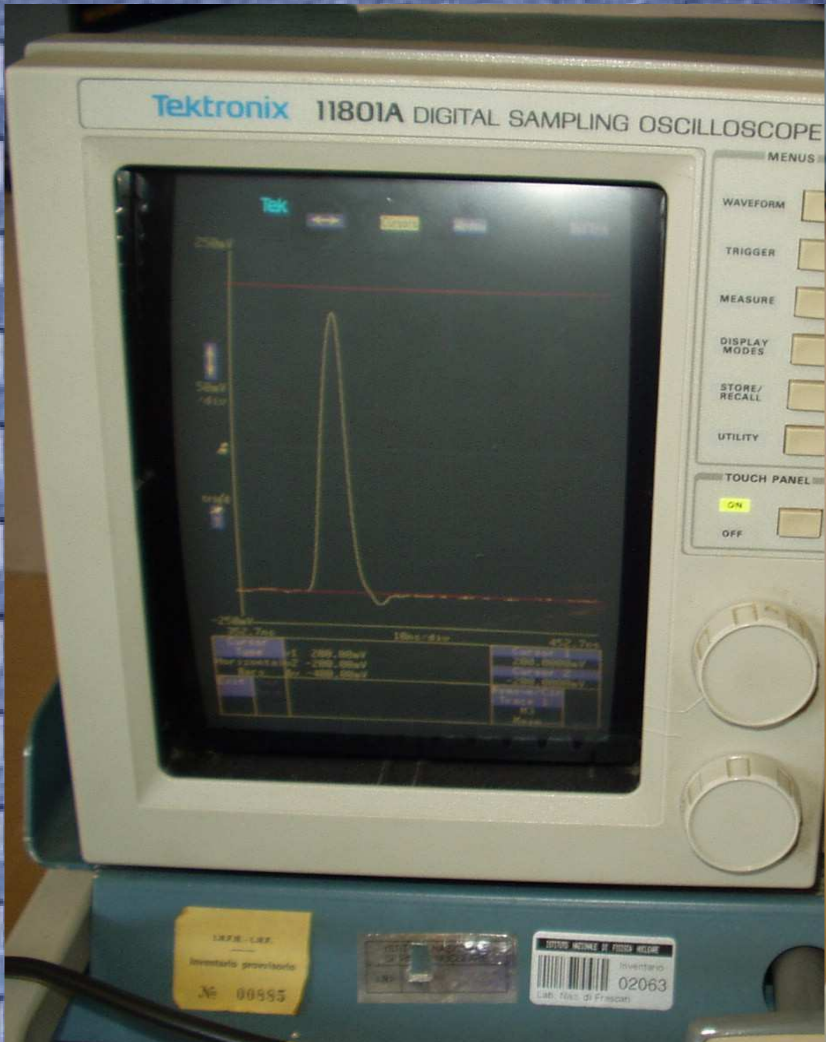
For a 100 ns pulse width, model AVX-CP-1 is rated for a maximum input voltage of 5V, the AVX-CP-2 is rated at 20V, the AVX-CP-3 is rated at 70V, and the AVX-CP-4 is rated at 350V. In all cases (except for the AVX-CP-4) the maximum voltage can be increased if the maximum pulse width is reduced. All models require 50 Ohm terminations.

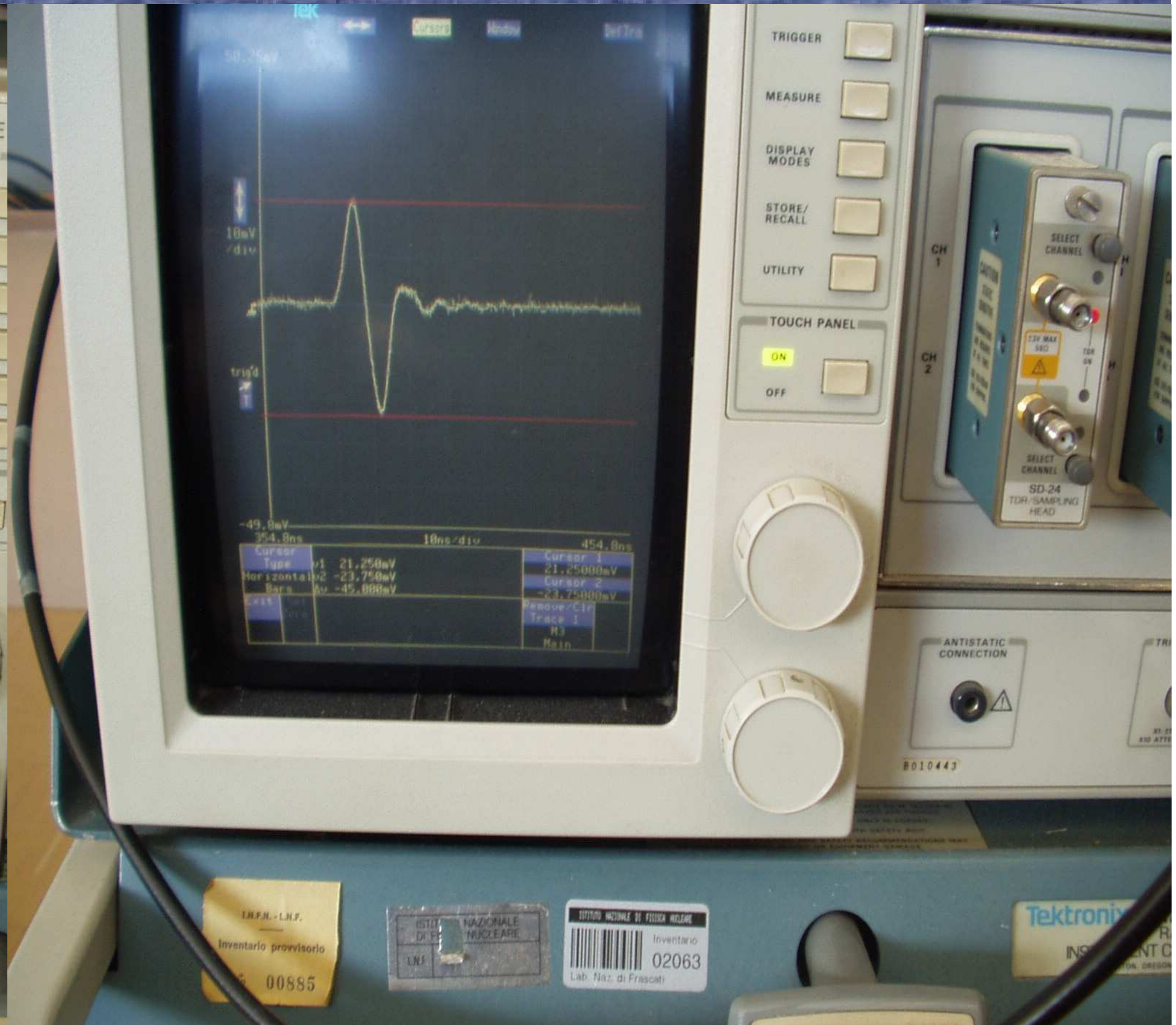
Model:	AVX-CP-1	AVX-CP-2	AVX-CP-3	AVX-CP-4
Maximum input voltage:	40 V	60 V	150 V	350 V
Maximum pulse width at a given amplitude[1]:	100ns / 5V 75ns / 10V 60ns / 40V	200ns / 10V 100ns / 20V 50ns / 60V	250ns / 20V 100ns / 70V 50ns / 150V	600ns / 20V 350ns / 100V 100ns / 350V
Rise time: (20%-80%)	≤ 300 ps	≤ 1 ns	≤ 0.5 ns	≤ 1 ns
Maximum average power:	1/4 W	1/4 W	1/2 W	1 W
Input and load impedance:	50 Ohms			
Droop:	≤ 10% (at max input)			
Connectors:	SMA			
Size: (H x W x D)	36 × 28 × 59 mm (1.4" x 1.1" x 2.3")			
Chassis material:	cast aluminum, blue enamel			

1) As determined using synchronous, equal amplitude pulses applied to both inputs.

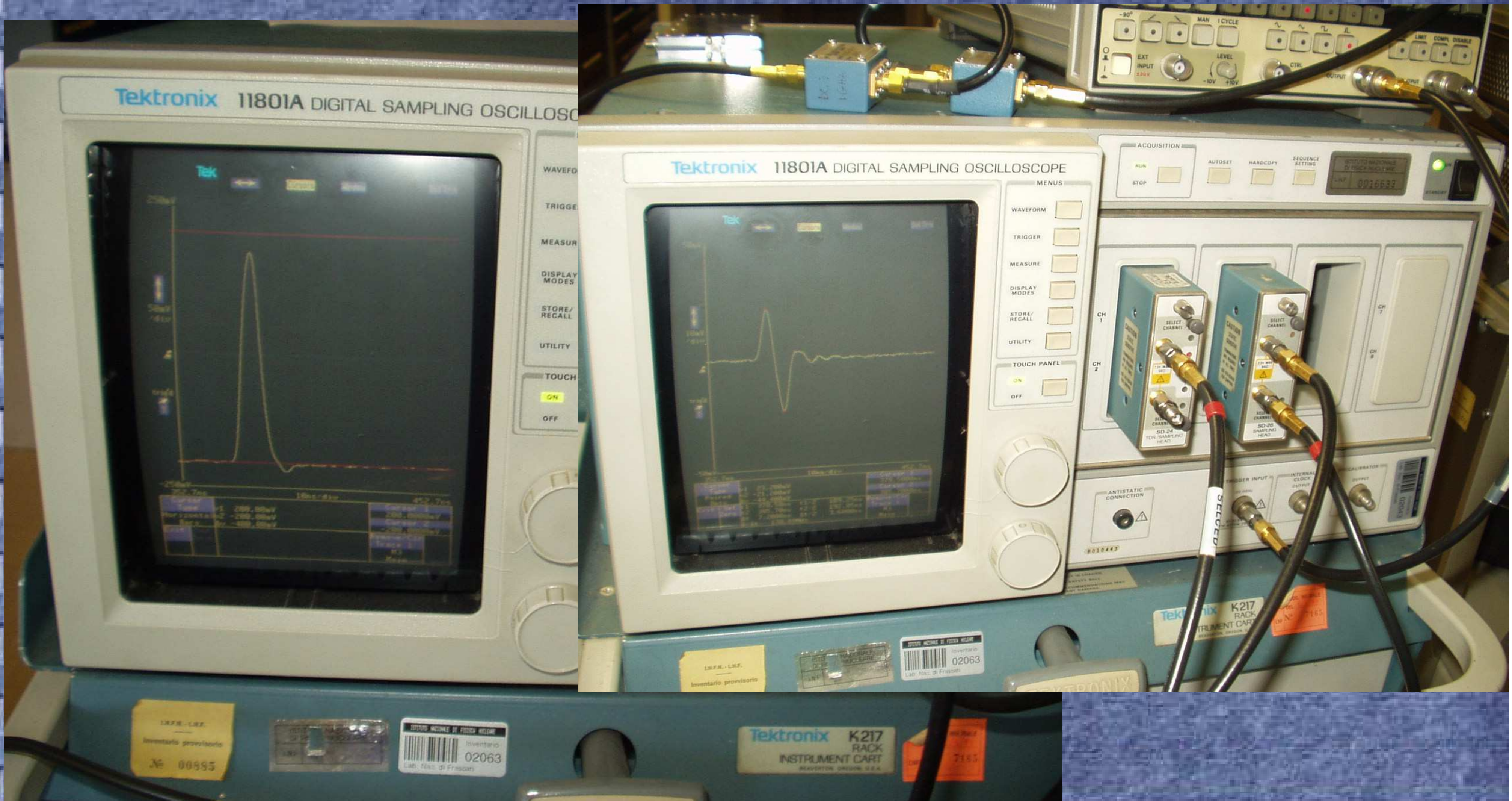
AVX-CP-1

This is what we get: we pass from a 400mVpp pulse to a 44mVpp (-19dB) derivative shape typical of a button



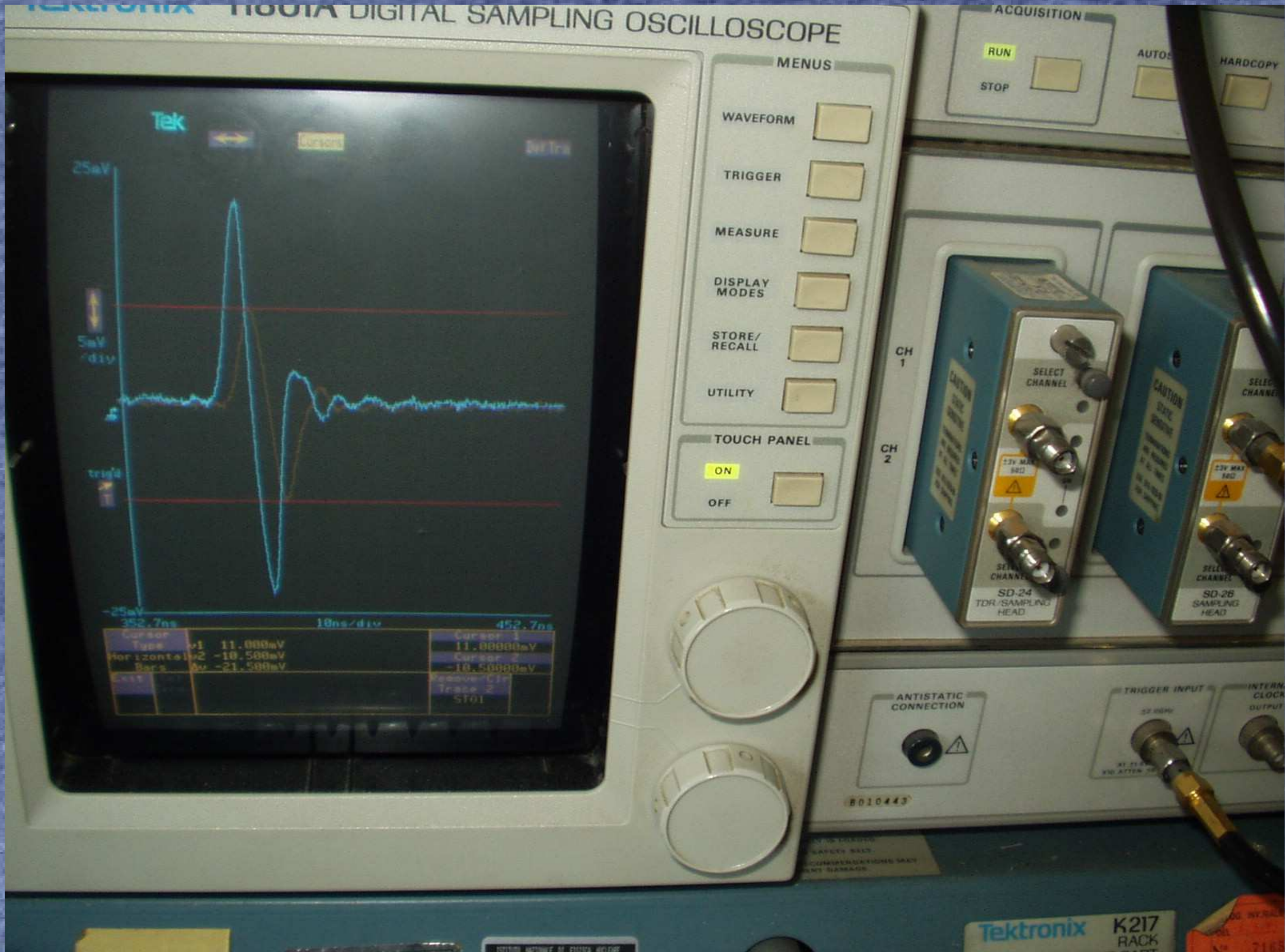


From the rise time point of view , this parameter is dominated by the function generator rise time (4.5ns) ...so we cannot see the 3 replicas of the bunch because they are too close (spaced by 678 ps)



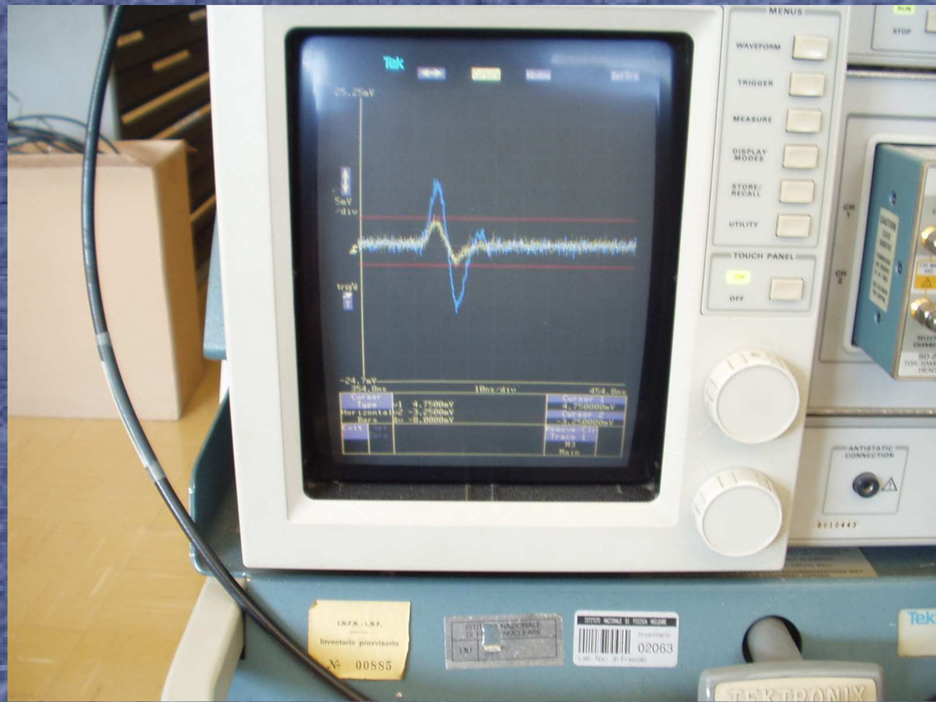
To evaluate better the "pcb" comb filter behavior just to consider this example: a pulse of 400mV passing through the comb filter is reduced to 2.5 mV; this clarify the difficulty to manage so small signals in a very noisy area

In time domain the 44mVpp pulse passing through the new filter became 22mVpp even if this value is given by the envelope of the 3 pulses that will be separated in the real case (much shorter rise time)



Indeed disconnecting 1 cable we get ~15mVpp pulse (from 22Vpp with 3 cables)

And disconnecting 2 cables, we get ~8mVpp pulse that still is much larger that use the first method ("pcb" comb filter) !



Front end conclusion

The insertion of extremely precise trombone lines with digital control and of a different type of comb filter with much less attenuation should have a positive impact to understand the front end behavior with high and low current beams.

Probably the insertion of more diagnostic points in the circuit would help to speed up the FE tuning.

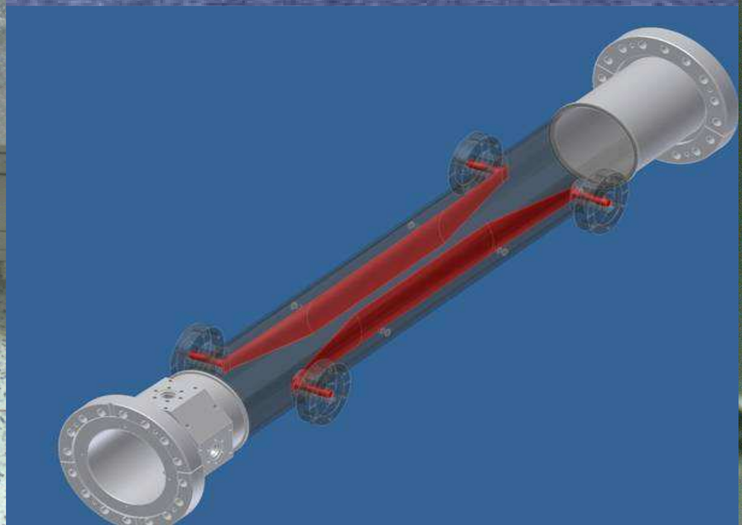
Horizontal kicker

- A new horizontal kicker (design by D.Alesini, A.Zolla & G.Fontana) has been installed in DAFNE e- main ring having:

➢ Tapered and double length striplines;

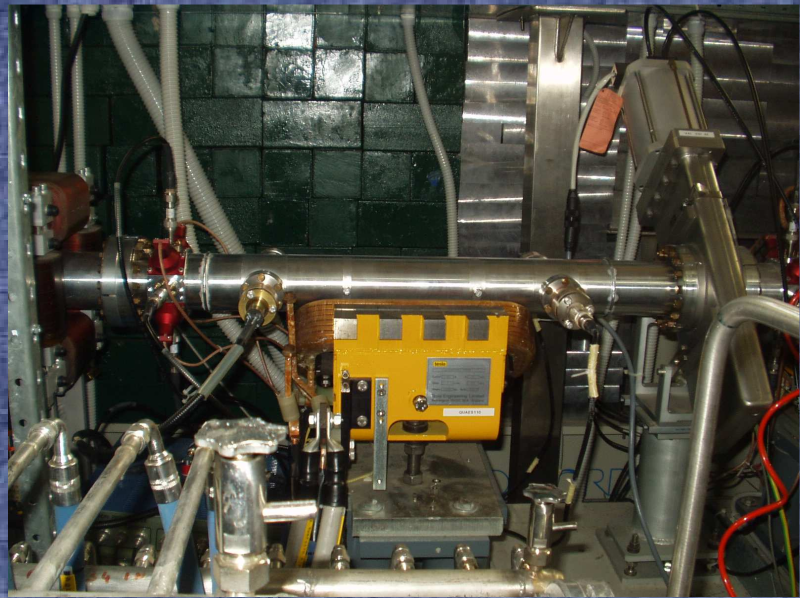
➢ reduced stripline separation in the horizontal plane (88 mm -> 60 mm);

➢ much better shunt impedance.



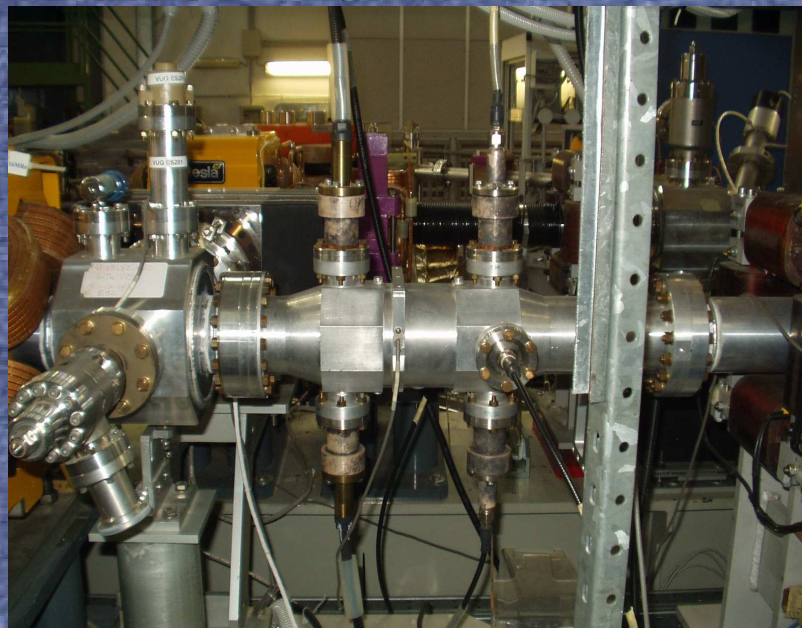
Transverse feedback kickers

e- horizontal kicker =>



As it's possible to see in the pictures the new horizontal kicker is much longer than the vertical one.

e- vertical kicker =>



Remote signal/clock jitter stability

- In DAFNE e- transverse feedbacks, during the past operations, “long term” signal/clock drift of the order of ~ 180 ps had been observed.

- During spring 2013 DAFNE shutdown, thermal control has been installed by Servizio Fluidi in the room hosting the electronic equipments of the e- transverse feedback in order to avoid or to limit timing fluctuations.

The other topics

I. 12-bit (transverse) and 8-bit (longitudinal) FPGA based processing unit are running very efficiently with a new EPICS operator interface and a complete compatibility with the well consolidated bunch-by-bunch diagnostic tools based on MATLAB

II. the simplified (no QPSK modulation) longitudinal back end is running well up to the achieved top beam current (1.4 A), still waiting for a definitive test and acceptance

Conclusion

- DAFNE is extremely useful to test innovative ideas for bunch-by-bunch feedback systems for future circular colliders as Tau-Charm.
- With the next DAFNE run (starting next September) important conclusions are expected on the feedback performance.
- If DAFNE would have a smaller emittance, the tests would go even more in depth. (This is a DAFNE limit!)
- Possible new tests at SuperKekB next year (?) or in a low emittance accelerator (ESRF?, Diamond?) could give more information to further feedback improvements