Options for the Placement of the STT Front-End Electronics and the Selection of Transmission Cables and Consequences for the Time Resolution

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Main options for read-out of the STT:

The Krakow ASIC

To be installed inside PANDA

The Jülich Fast Flash-ADC sytem

All electronics outside PANDA:

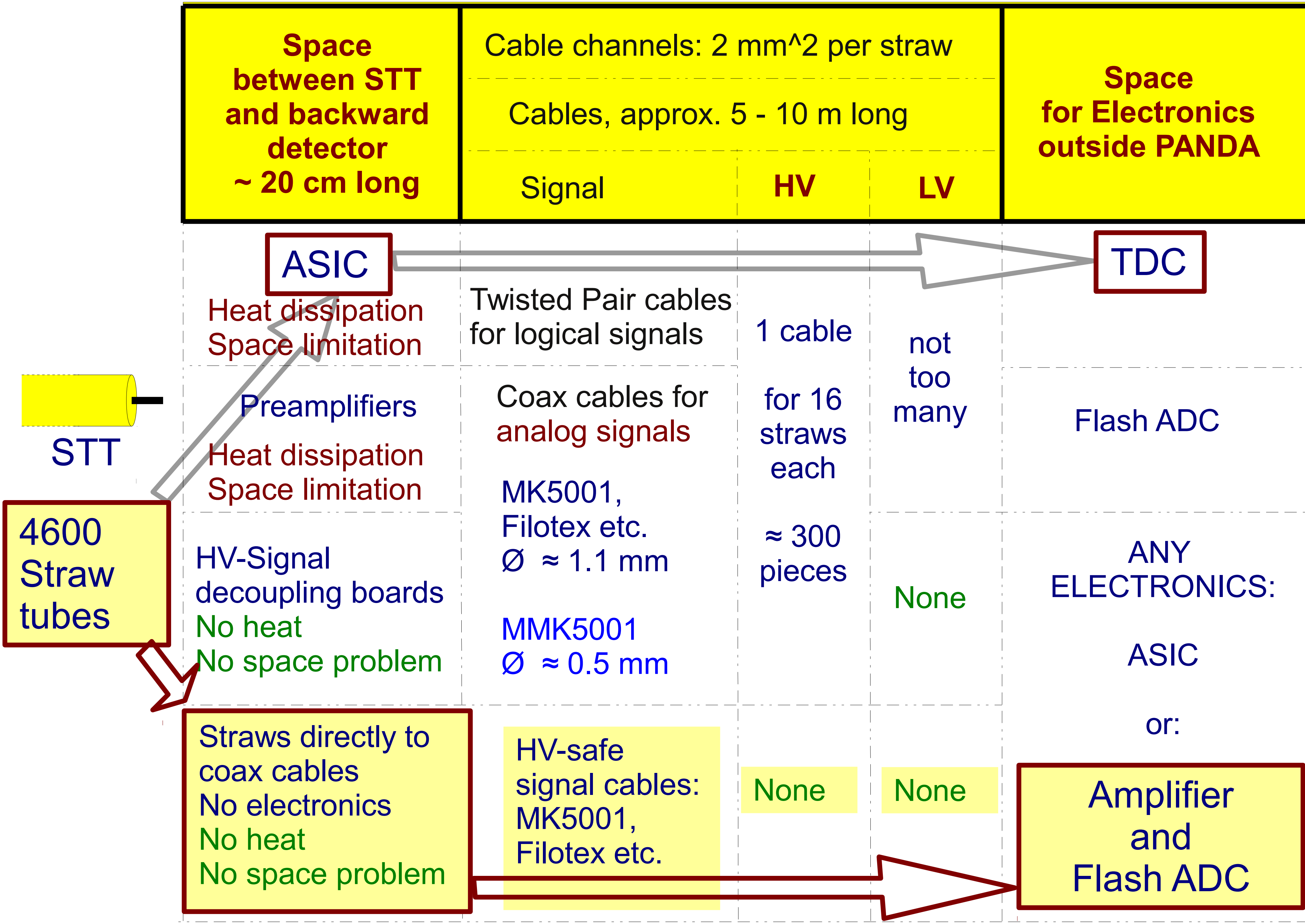
Time and charge information from real-time signal analysis

Does electronics significantly limit the time resolution of the straw detector ?

Experimental techniques:

No complex tracking experiment

Electronical time uncertainty estimated from noise and signal shape



Space between STT and backward detector ~ 20 cm long
Cable channels: 2 mm^2 per straw
Cables, approx. 5 - 10 m long
Signal
HV
LV
Space for Electronics outside PANDA
ASIC
TDC
Heat dissipation
Space limitation
Twisted Pair cables for logical signals
1 cable
for 16 straws each
≈ 300 pieces
not too many
STT
Preamplifiers
Heat dissipation
Space limitation
Coax cables for analog signals
MK5001, Filotex etc.
Ø ≈ 1.1 mm
MMK5001
Ø ≈ 0.5 mm
Flash ADC
4600 Straw tubes
HV-Signal decoupling boards
No heat
No space problem
None
ANY ELECTRONICS:
ASIC
or:
Straws directly to coax cables
No electronics
No heat
No space problem
HV-safe signal cables: MK5001, Filotex etc.
None
None
Amplifier and Flash ADC

Requirement and specifications as given in the TDR

- Single-hit spatial resolution in x and y: < 150 µm
  (Assuming linear relationship and max. drift time of 200 ns: Time resolution << 6 ns)

- ASIC (TDR): 1-2 ns

- TDC resolution: 1 ns

- Gas amplification max. $5*10^4$ for limitation of ageing
  (This poses also a limit for the time resolution)

Conditions during the measurements

- A single straw tube

- 80% Ar, 20% CO_2

- HV = 2000 V

- Gas amplification
  derived from fast Fe-55 signal component ~ $2*10^4$
  including ion tail ~ $8*10^4$

- Source of events: Mainly Fe-55 Scaling to Cosmics and Sr-90 signals

Electronic equipment

- TRA16 current amplifier (Working horse during our previous in-beam measurements):

Input impedance	= 96 Ω (to be optimized for cables)
Current gain	= 380
Bandwidth	= 60 MHz
Rise time for delta pulses	= 5 ns
Peaking time	= 8 ns
RMS noise voltage	= 2.5 mV
ENC	= 5600 e-

- Fast amplifier (275 MHz bandwidth) for exploring the limits of the detector

- 200 MHz digital oscilloscope

Measurements

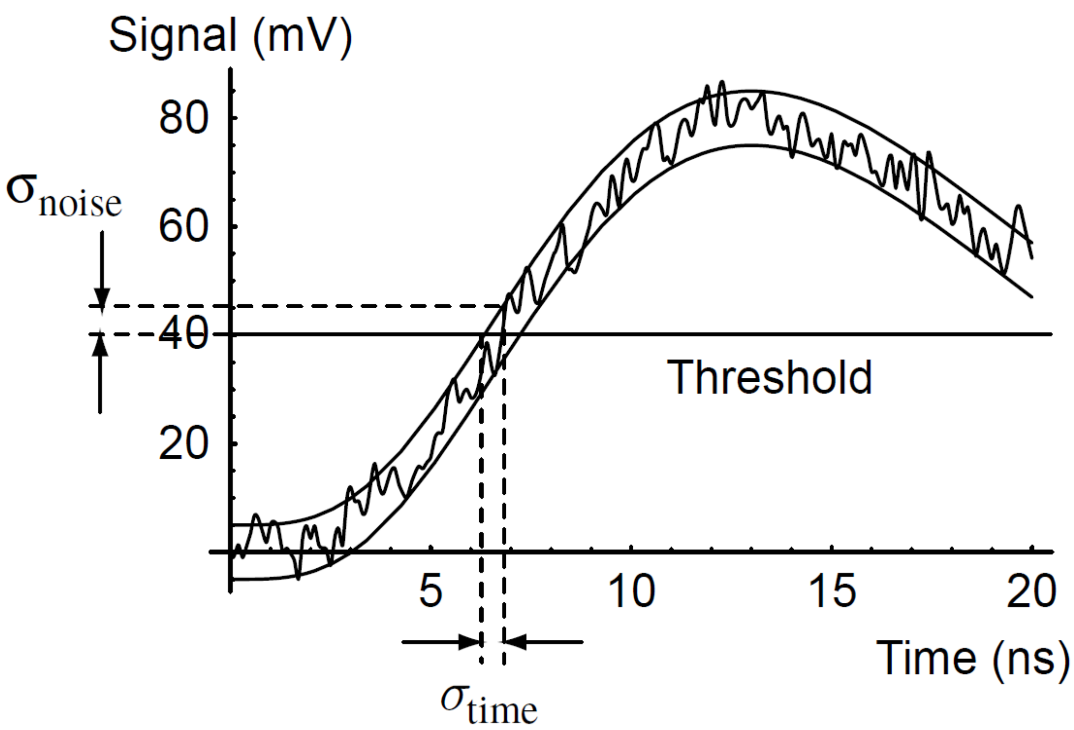
- Signals and noise voltage
  - Transmission of initial signals through long, thin cables
  - The role of impedance matching between straw and amplifier

- Electromagnetic interference
  - This appears often unexpectedly and spoils the detector performance

What do we learn from the signal shape and the noise magnitude ?

The uncertainty of the determination of the arrival time of a signal is limted by the slope of the leading edge and the noise voltage:

$$\sigma_{time} = \sigma_{noise} / dV/dt$$

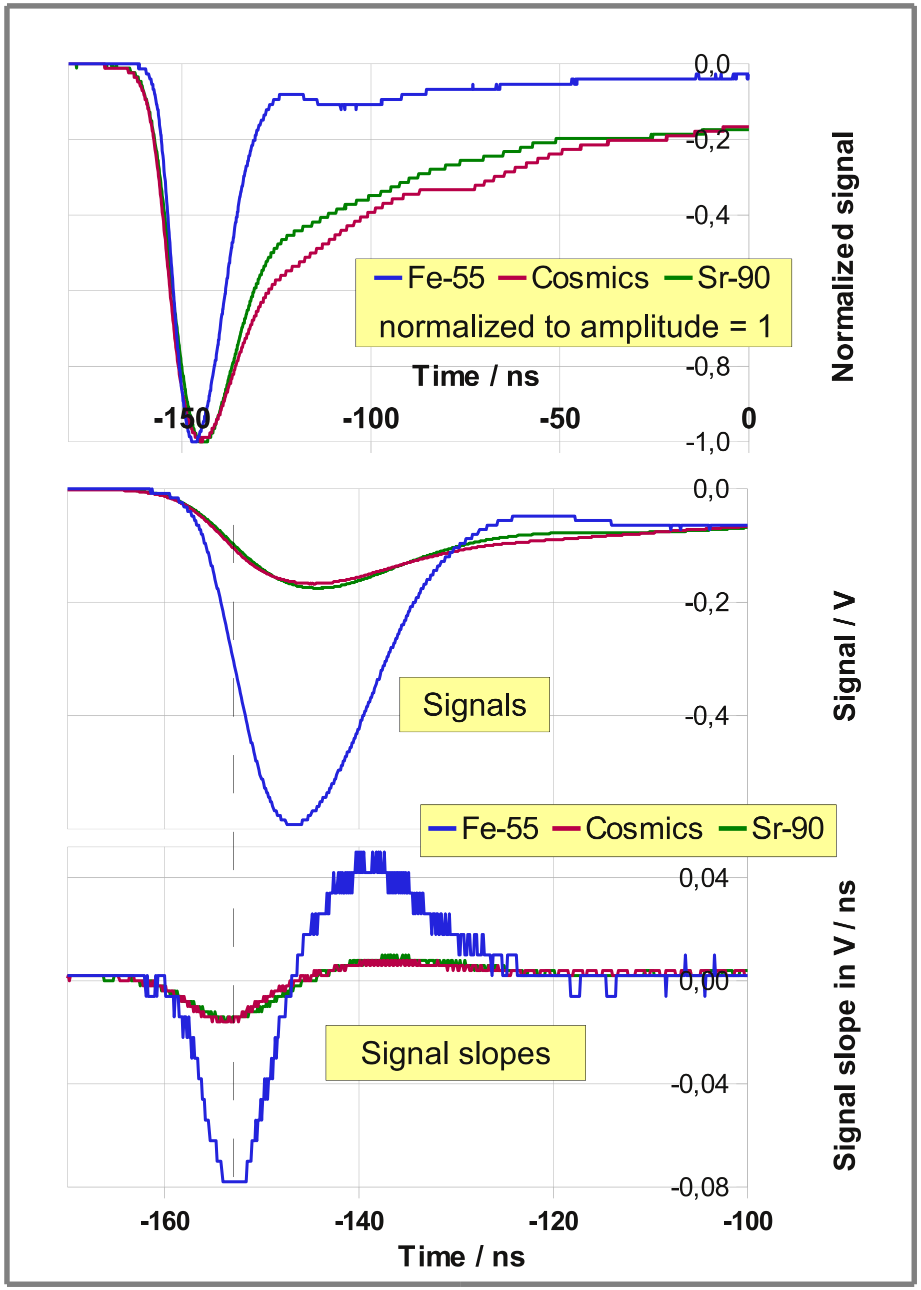


This noise is an intrinsic feature of the system.

Not to be confused with induced parasitic signals (EMI, see later).
These have to be reduced with technical measures.

Fixed-number statements about the resolution of a timing system are not possible
The timing resolution is usually strongly amplitude dependent

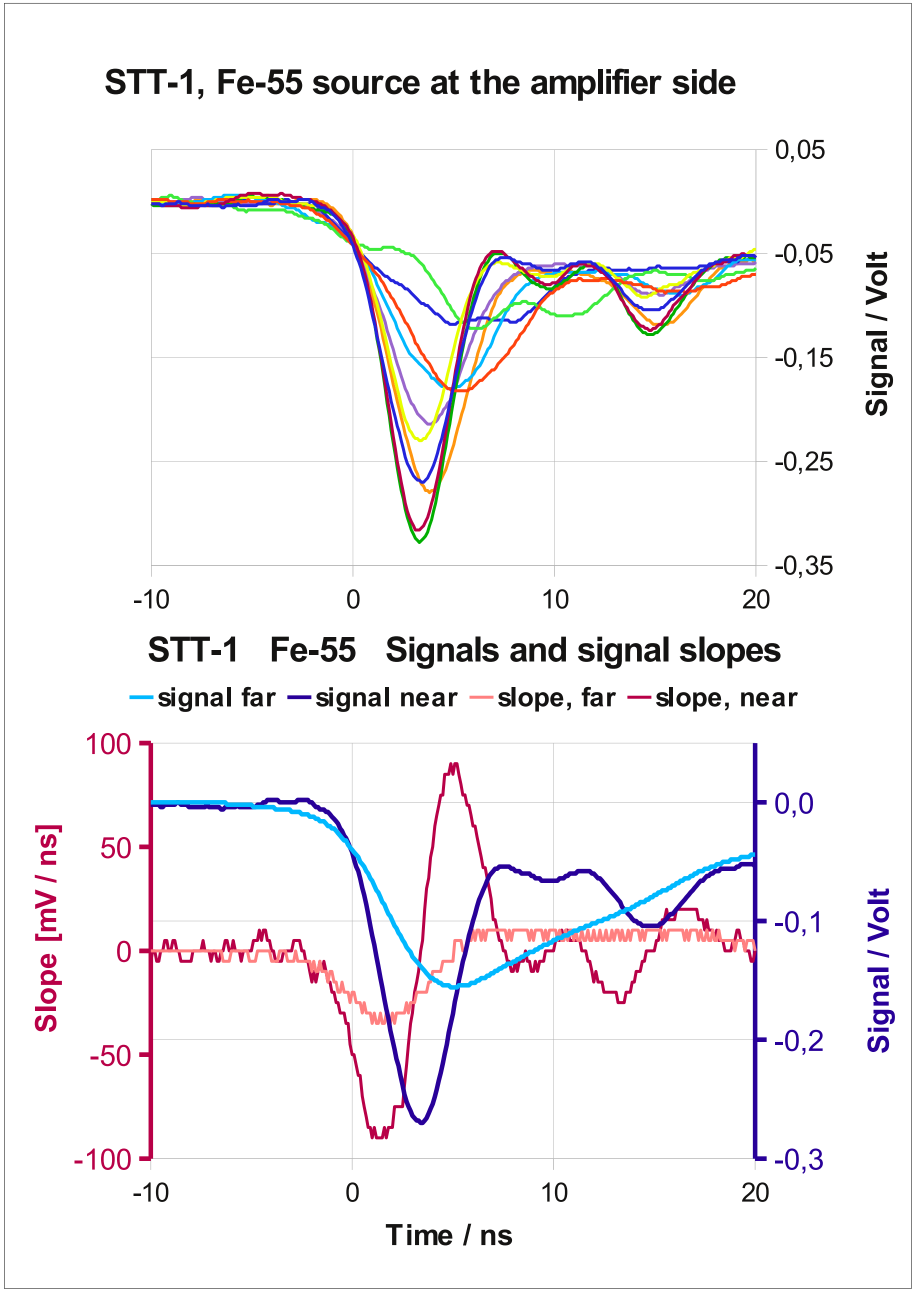
Fe-55 signals as a model for average pulse parameters of track signals



Signals averaged over 128 events

	Amplit. [mV]	Slope [mV / ns]	Time uncertainty [ns]
RMS noise	3.5		
Fe-55	590	80	0.044
Cosmics	168	18	0.19
Sr-90	176	18	0.19

How fast do amplifiers have to be ?
The only application of a very fast (275 MHz bandwidth) amplifier



- Fe-55: Absorption of 6 keV x-rays
- Well localized cluster of ~ 200 electrons.
- A single signal component is expected

<u>Measured signal rise times / ns:</u>

near end 5.7 ± 2.7
far end 6.5 ± 2.7
Amplifier response < 1.3 ns

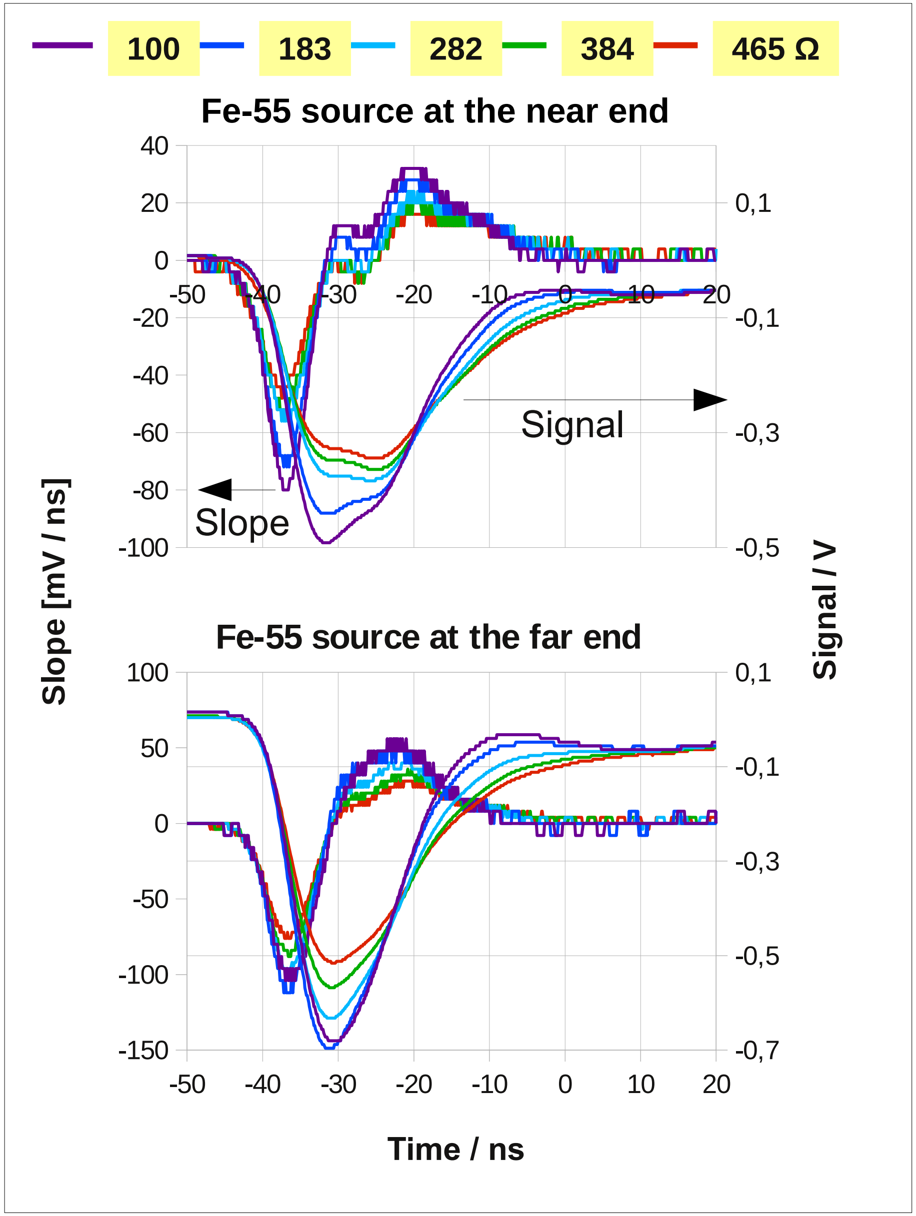
<u>Conclusions:</u>

Signal shapes are defined by
- the physics of signal generation
- signal damping during passage of the straw
- amplifiers need not be very fast

<u>Estimated time uncertainty:</u>

Source position: far end 91 ps
(near end 36 ps)
(with RMS noise voltage = 3.2 mV)

Impedance matching between straw and amplifier input



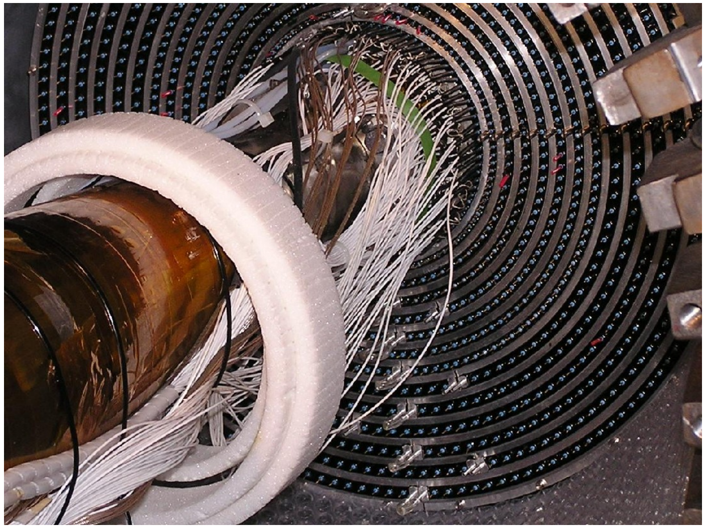
- Standard 60 MHz amplifier used from now on
- Straw impedance ~ 373 Ω
- Resistors placed between Straw and amplifier
- Source: Fe-55

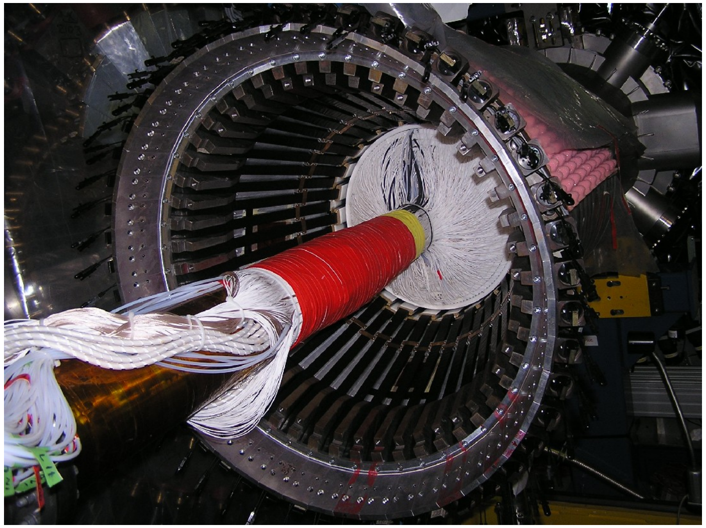
- Largest amplitudes and signal slopes
  Without impedance matching
- No effect on the noise voltage
  sigma-V = 3.5 +/- 0.1 mV
- Best values for the time uncertainty:
  near end: **44 ps**
  far end: **31 ps**

WASA: Common cables for signals & HV

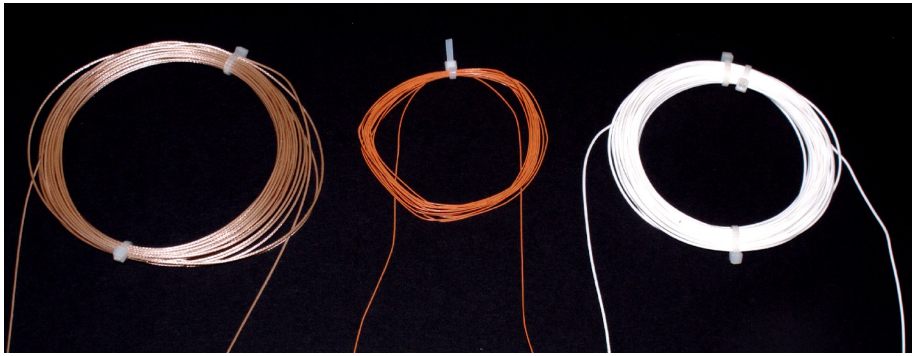
PANDA: Cables candidates investigated

Cables plugged directly onto straw pins
Cable type: Filotex 75 Ω
1.2 mm Ø
5 m long

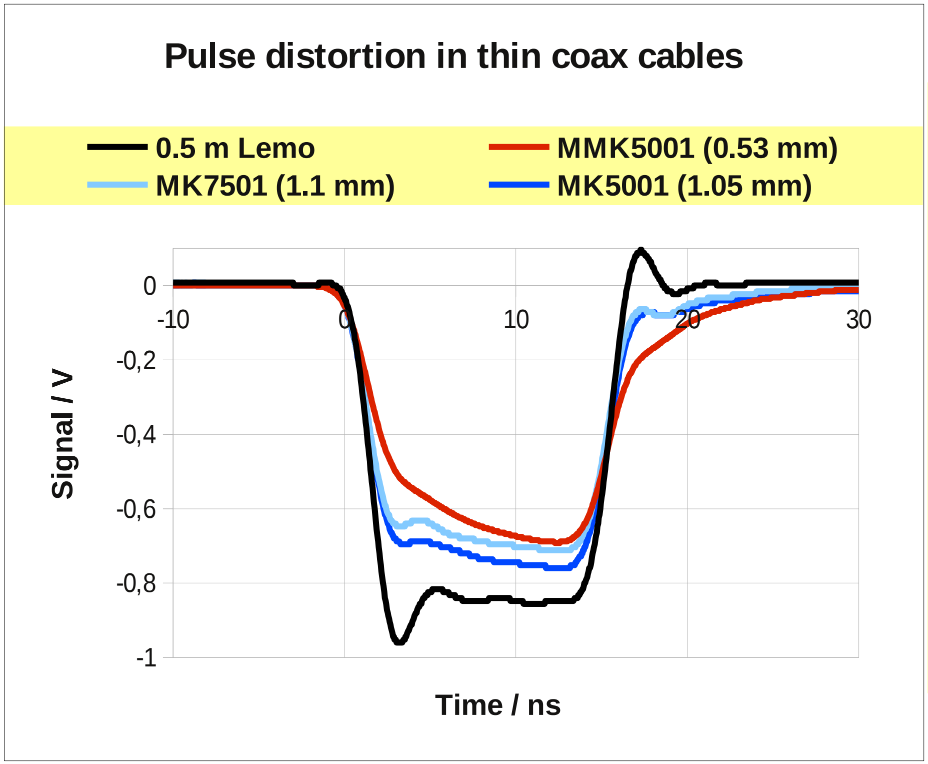




MK5001	**MMK5001**	**MK7501**
1.05 mm	0.53 mm	1.1 mm
HV test at factory:		
1000 V	----------	1000 V



Standard NIM signals transmitted through thin and very thin cables



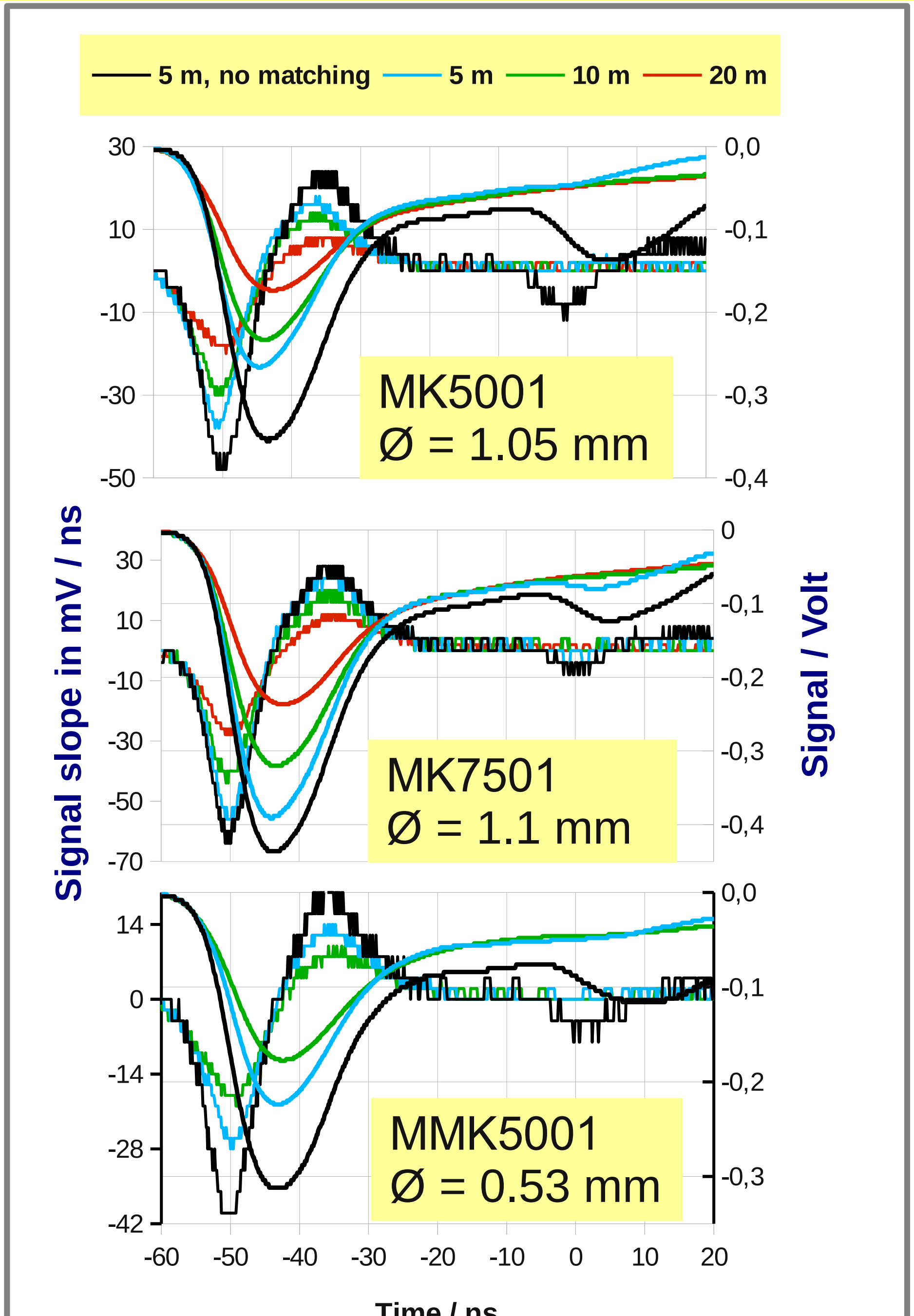
Length of cables:
Lemo 0.5 m
thin cables 5 m

Conclusion:

~ 1.1 mm cables: ~ 20% amplitude reduction
0.53 mm cable: ~ 30 % amplitude reduction, less steep

Rise times still shorter than in initial straw signal

Signal transmission through long, thin cables



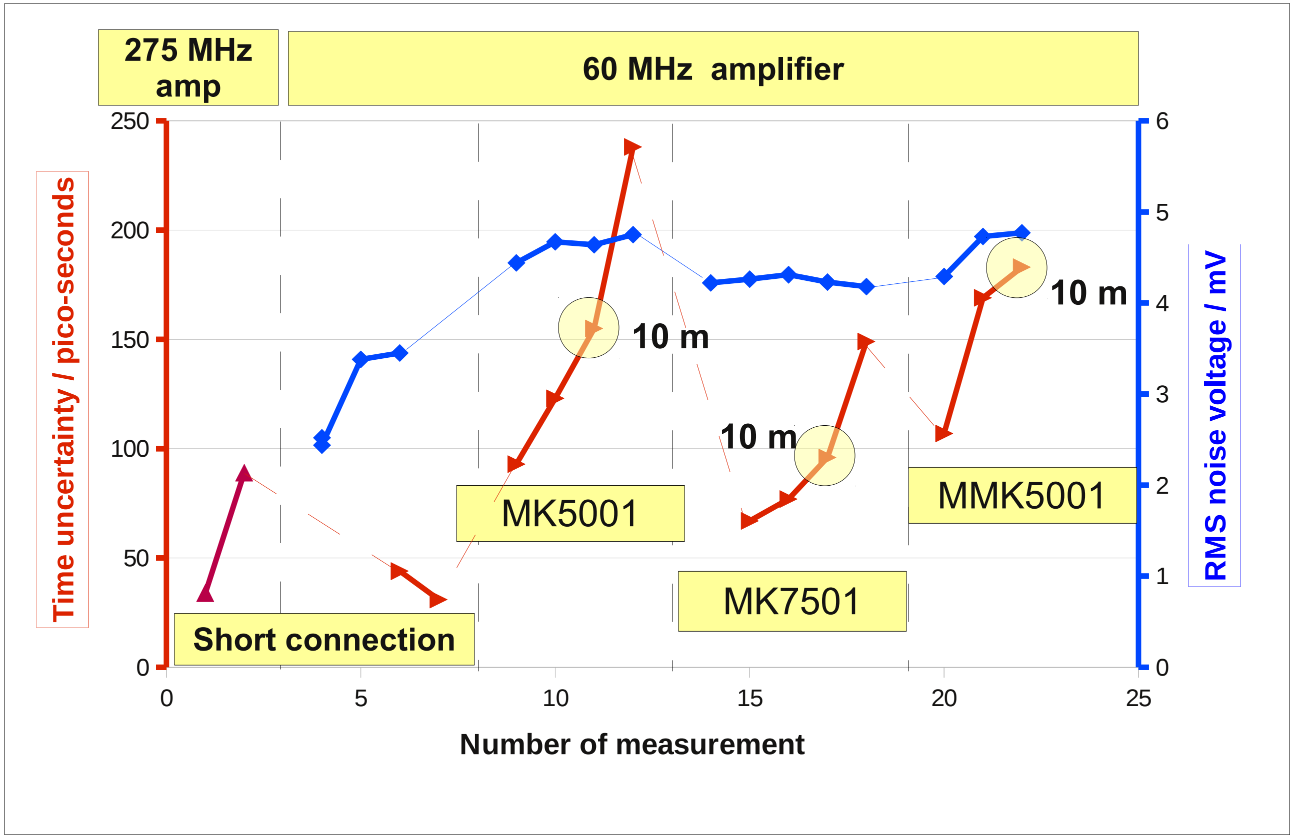
Fe-55 signals

Cables 5; 10 and 20 m long
placed between straw and amplifier

Importance of impedance matching at the amplifier input: see reflections

Solution with shunt resistor is temporary:
Amplifier with optimized
input impedance
will improve signal

Estimated electronical time uncertainty



Fe-55	short connection	44 ps
Sr-90 or cosmics	Normalization: * 4.4	190
Reduction of gas amplification	(from $8*10^4$ to $5*10^4$)	**300 ps (= minimum for any timing technique)**

These estimates are based on the assumption that
- timing is derived from the steepest slope
- there is no walk due to leading-edge timing etc.

These aspects are treated in the DAQ digital pulse processing; see talk of Ljuba Jokhovets

Sr-90 or cosmics	thin cable,	10 m long	**680 ps**	(corresponds to 23 μm)

Another kind of „noise“: Electromagnetic interference in radiation detectors

This can be avoided !

Critical points:

- ground connection between detector and amplifier
- sensitivity along the whole straw

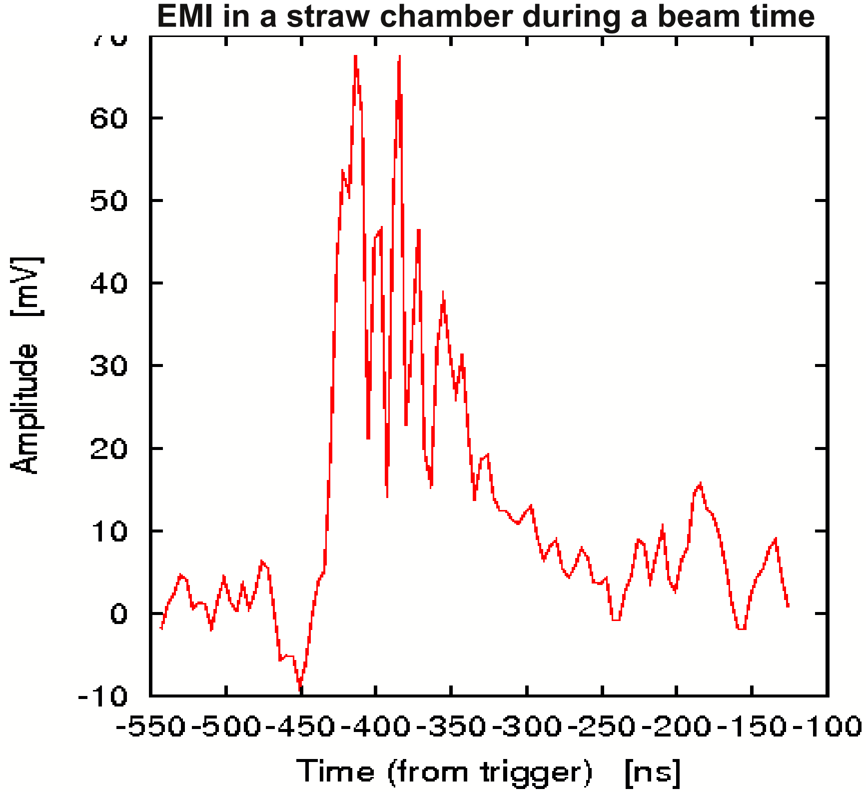
Sources:

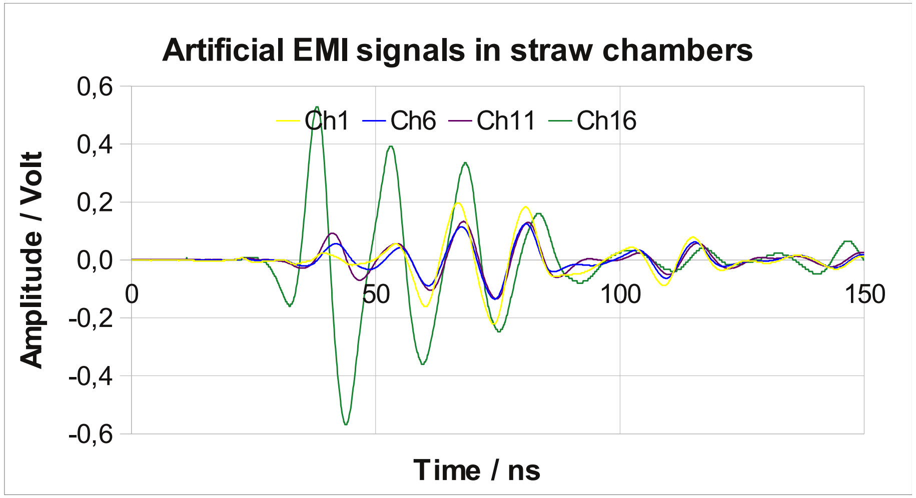
- Often unknow
- All powerful electrical devices
- Signal cables with logical signals (twisted pair and also coax)
- Clock signals of on-board electronics
- HV power supplies
- Worst case: coincident parasitic signals, e.g from photomultipliers

Countermeasures:

- a common shielding covering straws and electronics
- grounding
- identify source and render it harmless
- be patient

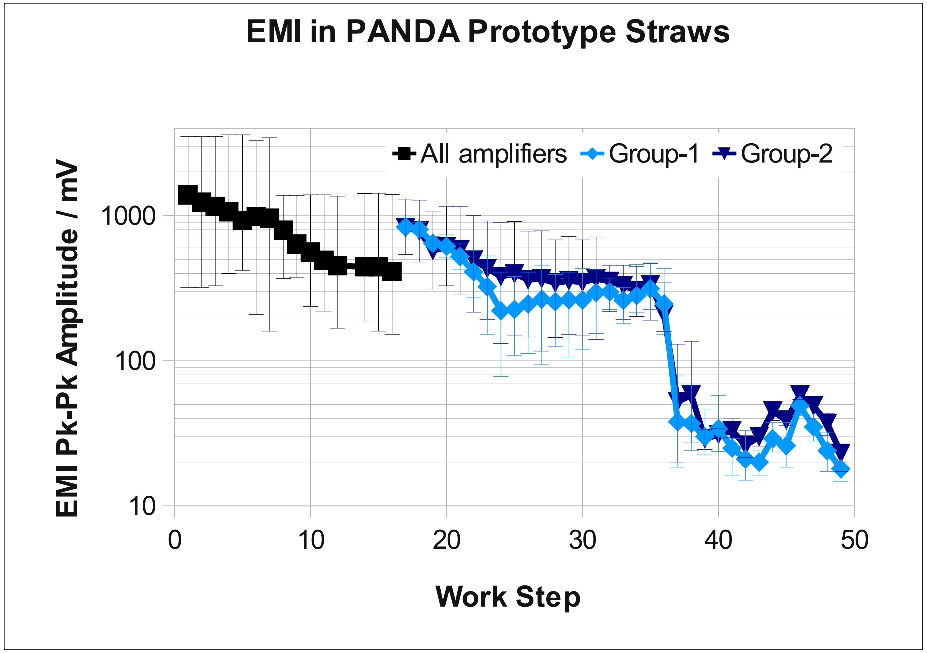
Parasitic signals in straw chambers





Application of counter measures:

- Shielding of straws, cables and electronics with 6 µm Al-foil
- Ground connection via wide Cu foils



Do we know anything about EMI inside PANDA ?

(PMs, signal cables, clock signals, HV harmonics)

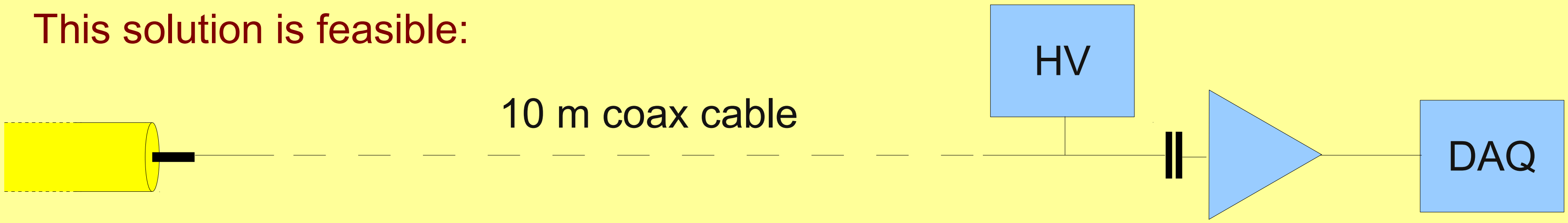
Recommendation:

- Shielding of the whole STT with a tight jacket of Mylar + Al
- Electronics and the body of the STT on the same ground

A significant reduction of parasitic amplitudes happens only when the last hole in the shielding is closed

Summary

- Initial straw signals are not extremely fast
  - Thin cables make only moderate signal deterioration
- Impedance matching
  - Not needed between the straws and the cables
  - It must be precise at the amplifier input
- Time uncertainty of 680 ps expected for MIPs with 10 m thin transmission cable
- Sielding of the whole STT and the cables against EMI is necessary
- This solution is feasible:



Near Future Strategy

Amplifier:
- Design of an optimized version of the amplifier currently in use starting Nov 2013
- longer integration
- reduced power consumption, reduced range of output voltage
- adjustable impedance matching for straws and cables

Cables:
- Large-scale in-beam tests with STT
- No strong effect on time resolution expected; it may not be significant

Flash ADC system:
- Talk of Ljuba Jokhovets
- new design, more compact

Measure time resolution as directly as possible
(with tracking experiments we are usually not sensitive enough):
- Deduce a precise trigger signal from straw signals
- Check the contribution of all major electronical ingredients

Realistic larger-scale setup for in-beam test in 2014
- with almost final amplifier
- with long cables