Frontend Electronics for high-precision single photo-electron timing

Matteo Cardinali

on behalf of the PANDA Cherenkov Group

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JOHANNES GUTENBERG UNIVERSITÄT MAINZ

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

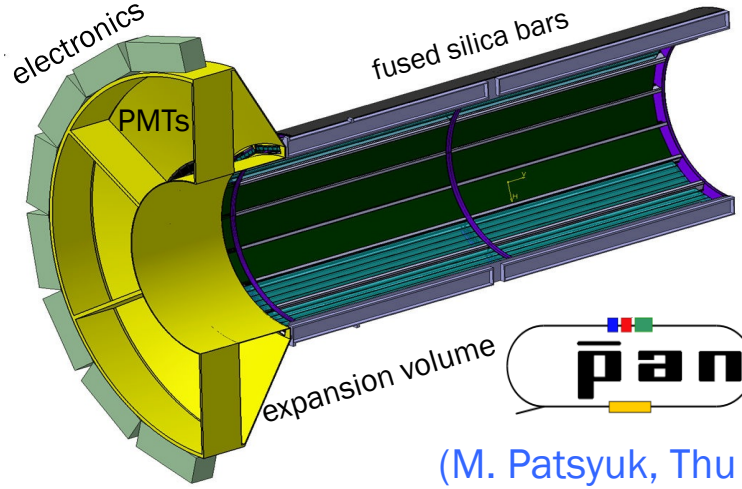
HELMHOLTZ GEMEINSCHAFT

Helmholtz-Institut Mainz

Three Wishes

Challenging electronics R&D for the
PANDA Barrel DIRC

(Detection of Internally Reflected Cherenkov light)



(M. Patsyuk, Thu 16)

Keypoints:
- imaging & time of propagation
- compact & low power consumption
- high count rate per channel

Three Wishes

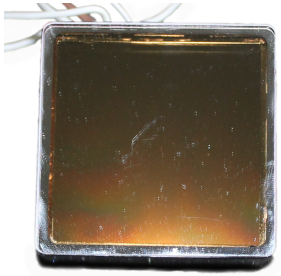
1) Large number of channels (15.000 ch)

2) Fast (50-100 kHz/ch, interaction rate up to 50 MHz)

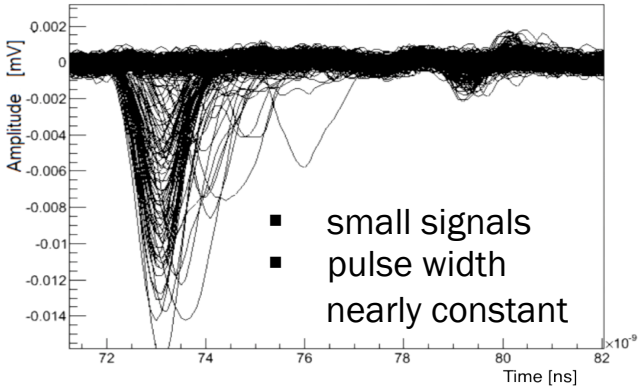
3) High Resolution ($\sigma_{\text{Single Photo-Electron}}$<100 ps)

FEE Design

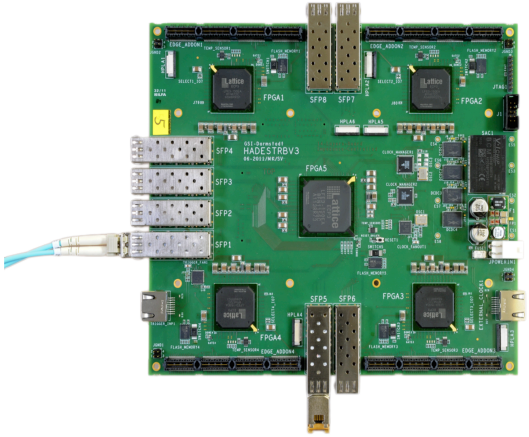
- Micro-Channel Plate PMTs (MCP)



  - Photonis XP85012 (64 ch);
  - typical gain 6 x 10^5;
  - rise time 0.6 ns;
  - timing resolution ~40 ps (SPE).



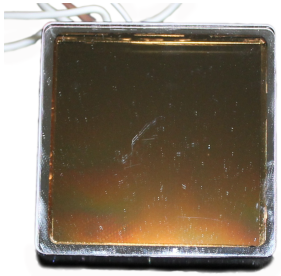
- TDC Readout Board v3 (TRB3)



  - developed in GSI;
  - 4 FPGAs programmed as TDC (64 ch each);
  - 10 ps RMS time precision;
  - 700 kHz max data readout trigger rate;
  - 67 MHz max hit rate;
  - LVDS input.

FEE Design

- Micro-Channel Plate PMTs (MCP)



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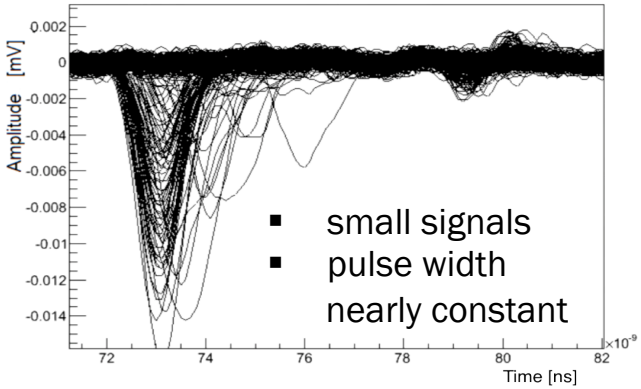

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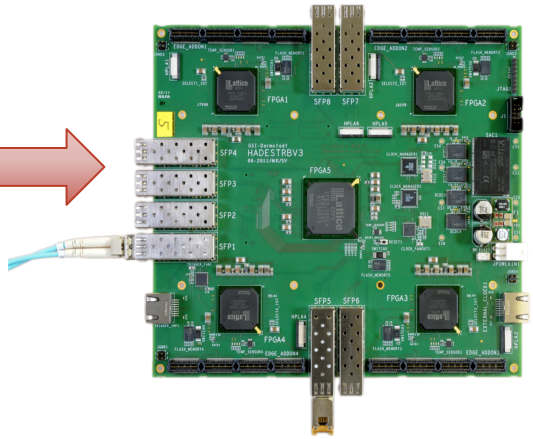

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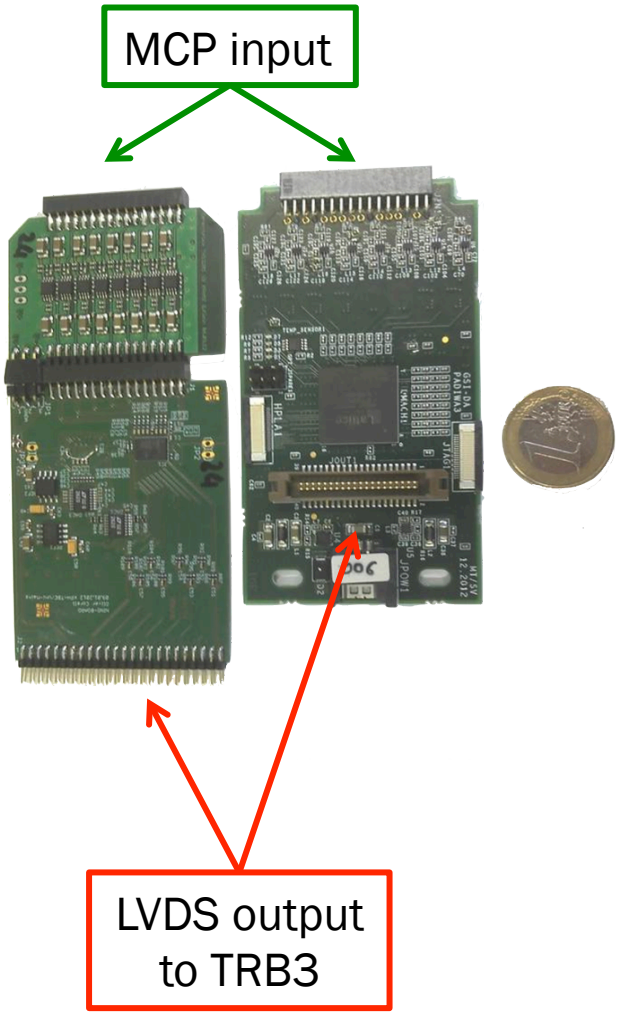
- 4 FPGAs programmed as TDC (64 ch each);
- 10 ps RMS time precision;
- 700 kHz max data readout trigger rate;
- 67 MHz max hit rate;
- LVDS input.

FEE Design

NINO card:

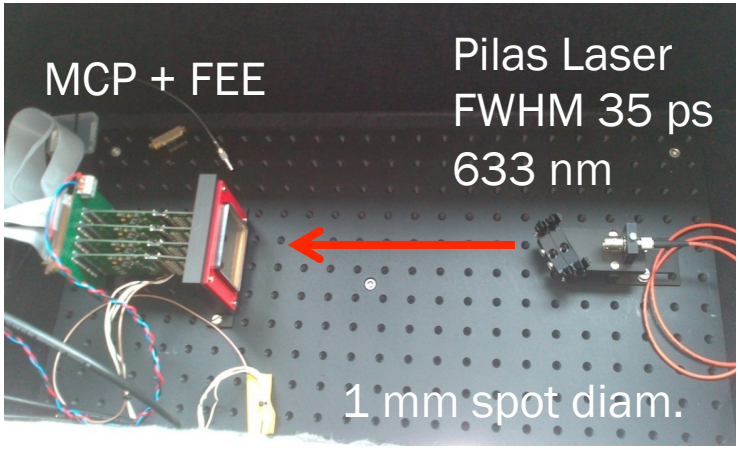
- modular design;
  - pre-amplifier card (x10, up to ~1.8 GHz);
  - discriminator card with NINO ASIC (from ALICE);
- 160 mW/ch;
- *Time over Threshold.*



PADIWA card:

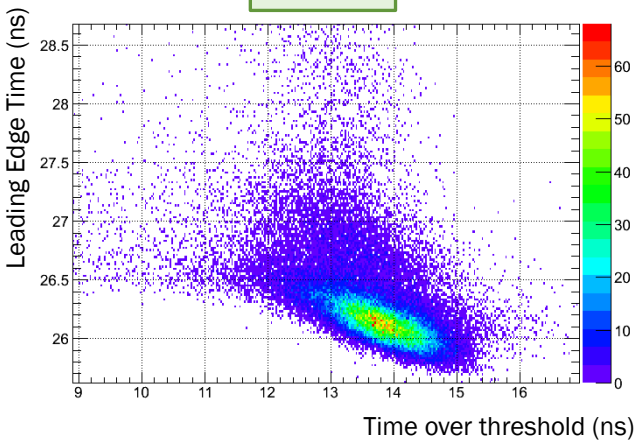
- pre-amplifiers (x10, up to ~2.2 GHz);
- FPGA discriminator (reprogrammable);
- 80 mW/ch;
- *Time over Threshold.*

Laser Characterisation



- Realistic condition (~0.3 γ/event);
- threshold behaviour;
- time walk correction.

NINO



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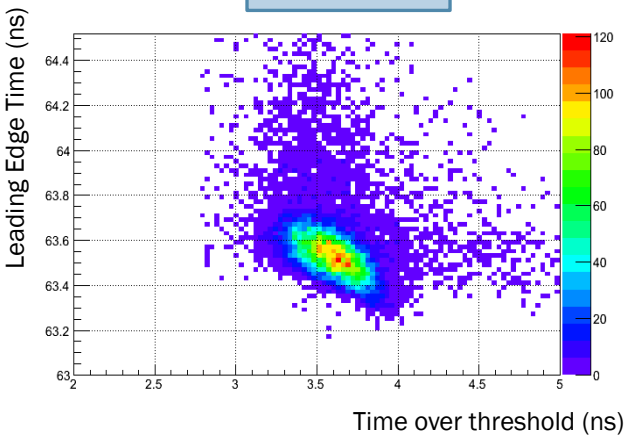

correction: $t_{corr} = t_{meas} - m \cdot (\mathrm{ToT}) + q$

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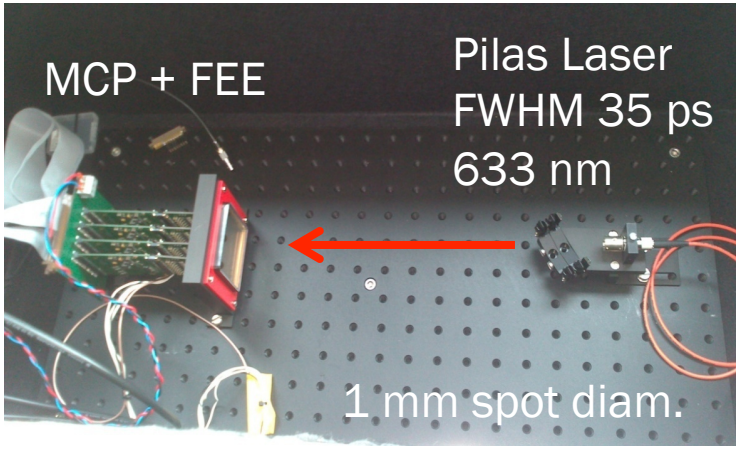

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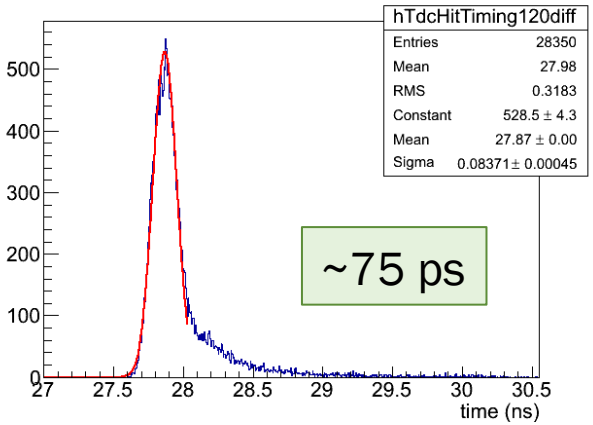

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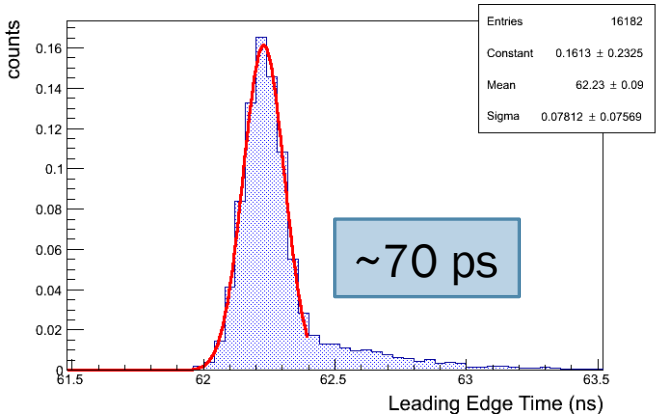
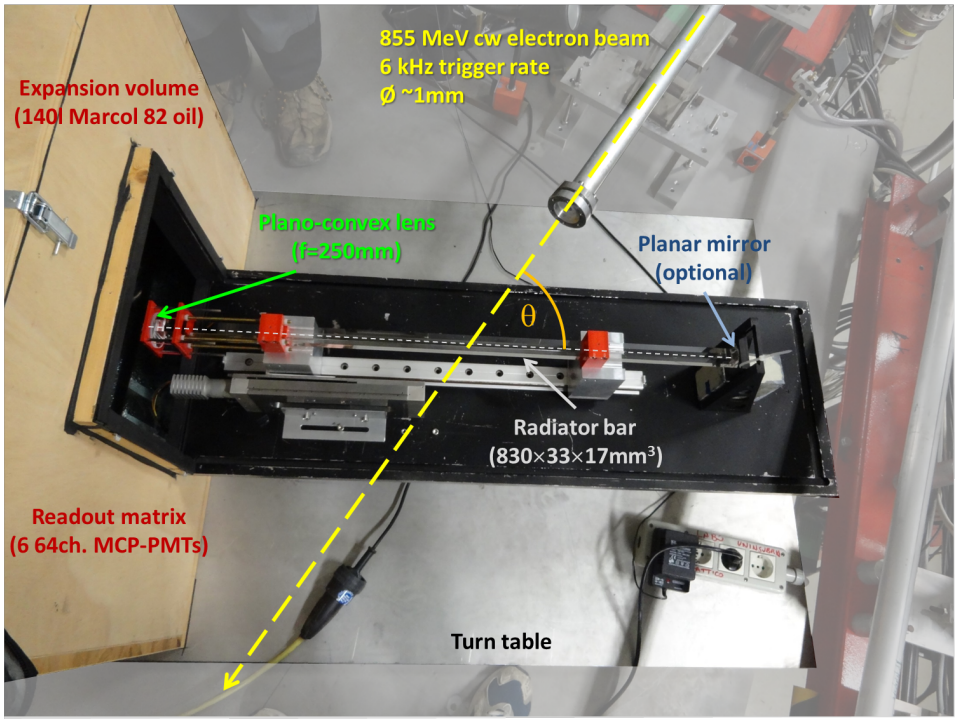
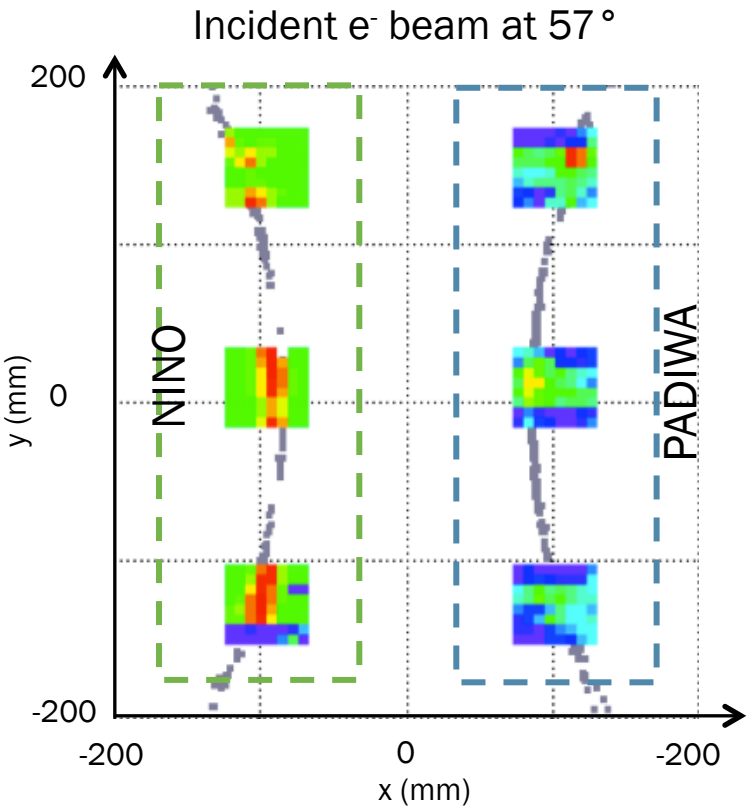


correction: $t_{corr} = t_{meas} - m \cdot (\mathrm{ToT}) + q$

Test Experiment

- 2013, **MAMI**, 855 MeV e^- beam
  - NINO & PADIWA;
  - up to 6 MCPs;
  - 384 readout channels;
  - 2-3 detected photons per event.

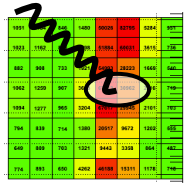




- Clear Cherenkov pattern (expecially for NINO FEE);
- Padiwa issue (now solved).

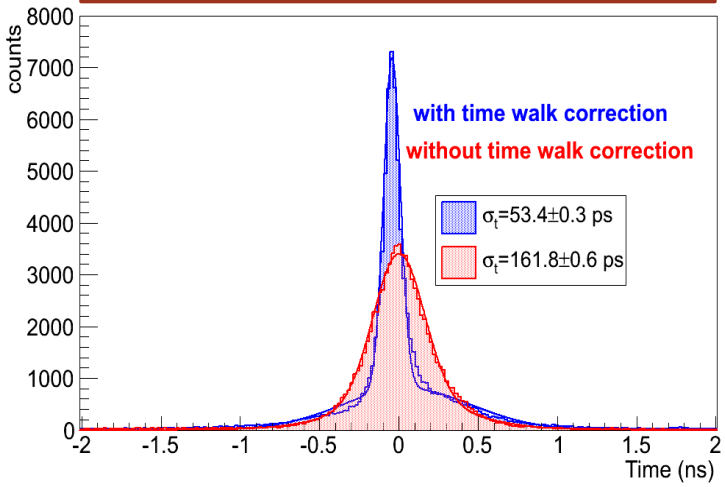
FEE Timing Resolution

- Studies performed for NINO cards;
- charge sharing between neighbouring pixels (single photo-electron);
- time walk correction validated;

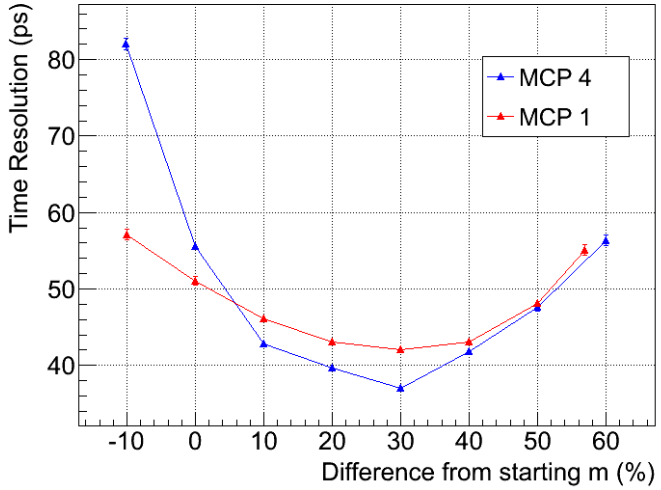


$$t_{corr} = t_{meas} - m \cdot (\mathrm{ToT}) + q$$

Coefficient from laser characterisation



Optimisation of parameters

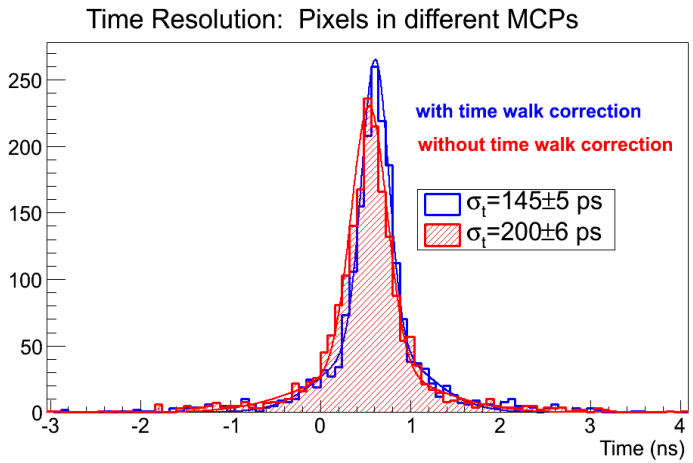


- timing resolution (*NINO card* + *TRB3*) ~ 40 ps.

Timing Resolution

- Timing resolution of the entire prototype:

- optimised walk correction;



$$\sigma_{total} = \frac{\sigma_{fit}}{\sqrt{2}} \approx 100 \text{ ps}$$

Timing Resolution

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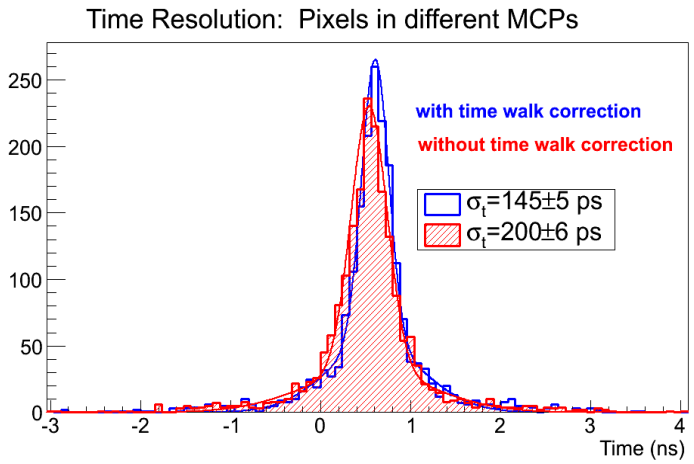
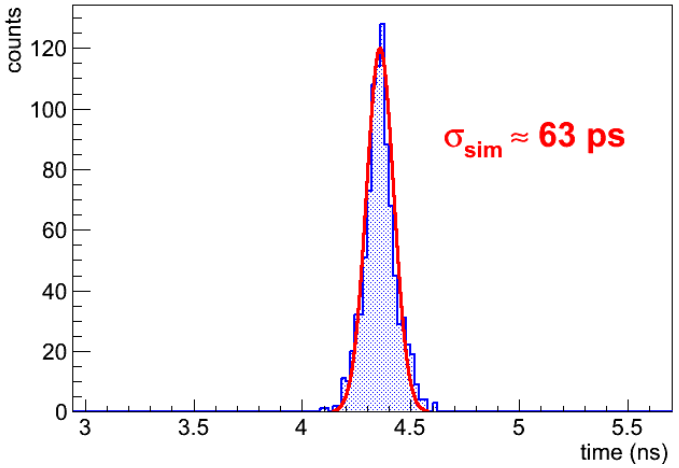


$$\sigma_{total} = \frac{\sigma_{fit}}{\sqrt{2}} \approx 100 \text{ ps}$$

- Simulation of propagation time;



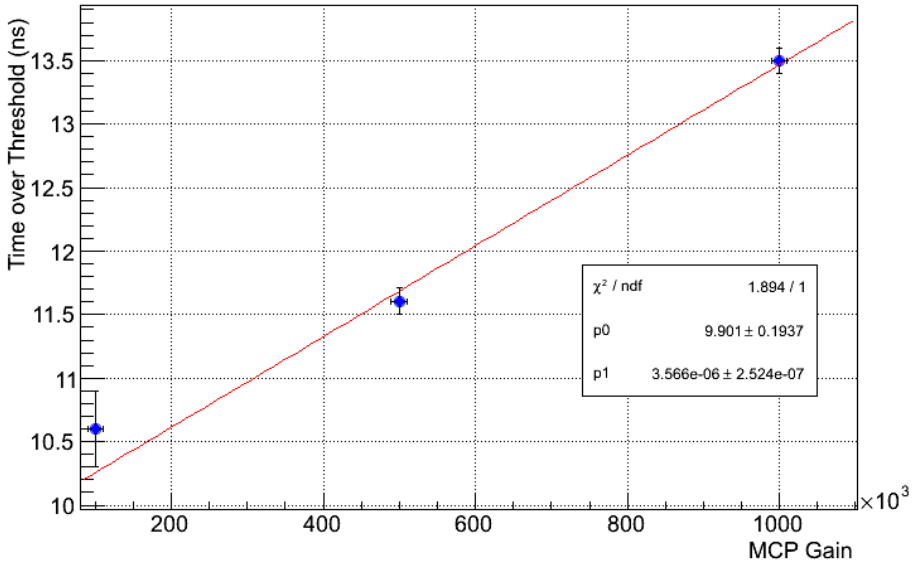
$$\sigma_{prop} \sim \sqrt{\sigma^2_{total} - (40 \text{ ps})^2_{FEE} - (40 \text{ ps})^2_{MCP}}$$

$$\sigma_{prop} \sim 82 \text{ ps}$$

- around $\sqrt{82^2 - 63^2} \approx 50\text{ps}$ from the sync. time of TRBs.

Global performances – gain studies

- 1 x 10^6 has been used for the test experiment;
- can we use a smaller gain?

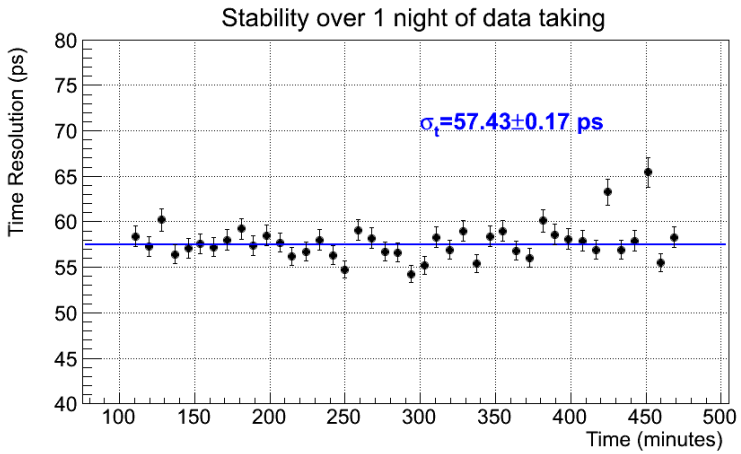


Gain	Timing Resolution	
	not corrected	corrected
1 x 10^5	~190 ps	~180 ps
5 x 10^5	~175 ps	~130 ps
1 x 10^6	~161 ps	~40 ps

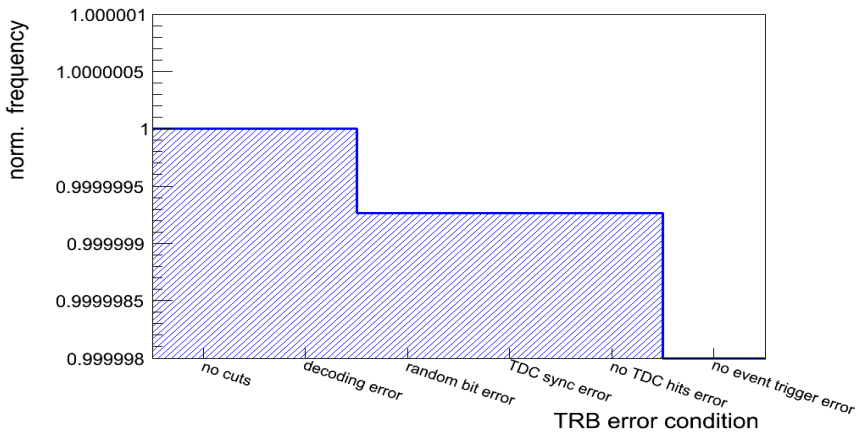
- Clear correlation between gain and time over threshold;
- the corrected timing resolution gets significantly worse (walk correction needs to be adapted).

Global performances – stability

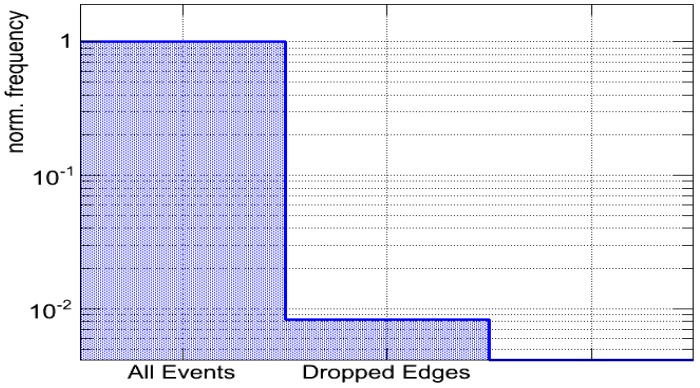
- Timing performances stable over extended period;



- less than 1 in a million events lost by TRB;



- lost hits in less than 1% of the events;



Wishes Fulfilled

- ✓ TRB3 provides a stable DAQ system and high precision TDC;
- ✓ time-over-threshold is sufficient for walk correction;
- ✓ excellent timing (σ_t<100 ps);
- ✓ both FEE cards meet PANDA requirements.

What's next?

- Test experiment at GSI of novel designs for DIRC (summer 2014);
  - PADIWA readout
  - large TRB3 readout
  - analysis ongoing
- Systematic gain studies;
- Fast start counter development
  - systematic studies of sync. time