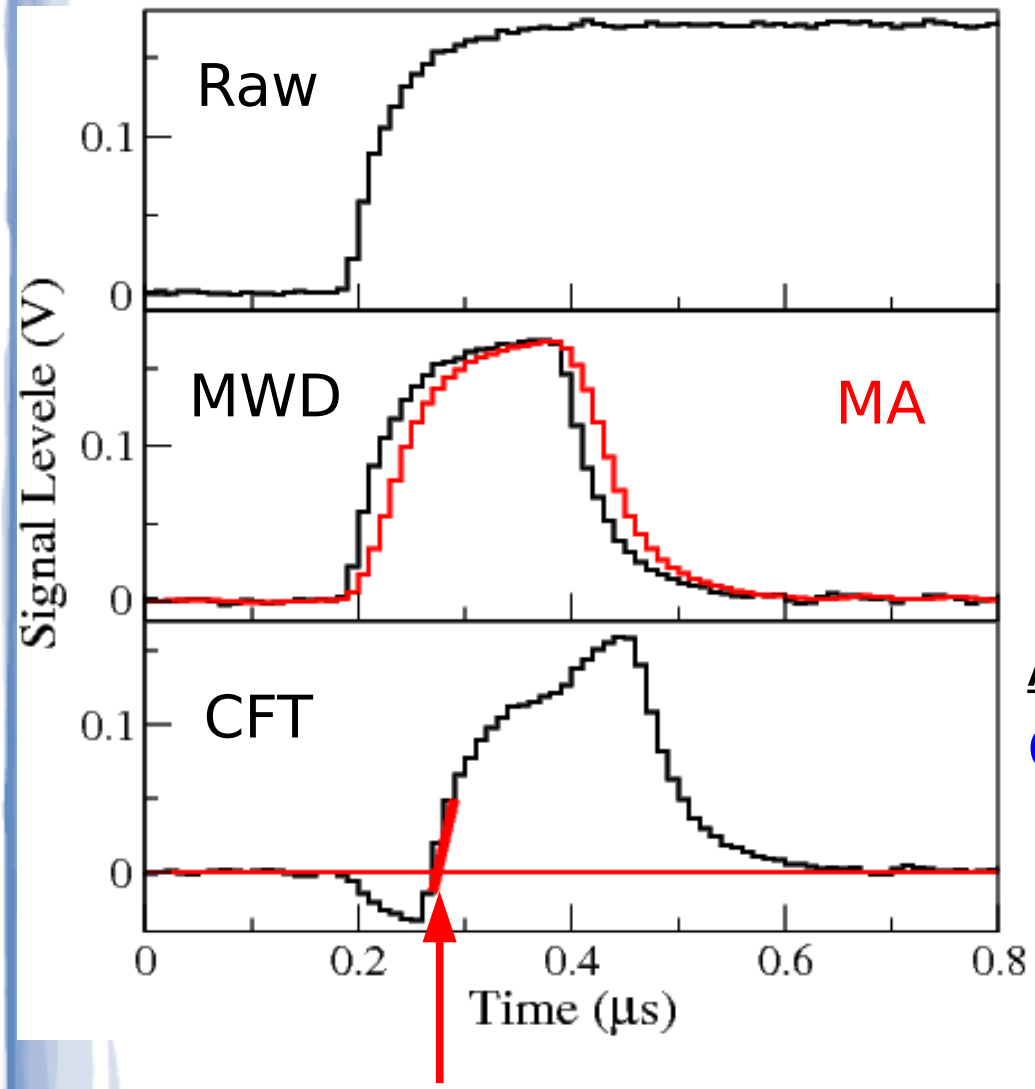
Optimization of the Constant-Fraction Timing Method for the EMC

M. Kavatsyuk, M. Lopateguie, E. Guliyev, M. Hevinga, P.J.J. Lemmens, H. Löhner, T.P. Poelman, G. Tambave

for the PANDA collaboration

KVI, University of Groningen, Groningen, The Netherlands

Constant-Fraction Timing



Time stamp: zero-crossing (linear regression)

Moving Window Deconvolution (MWD) and Moving Average (MA) filtering

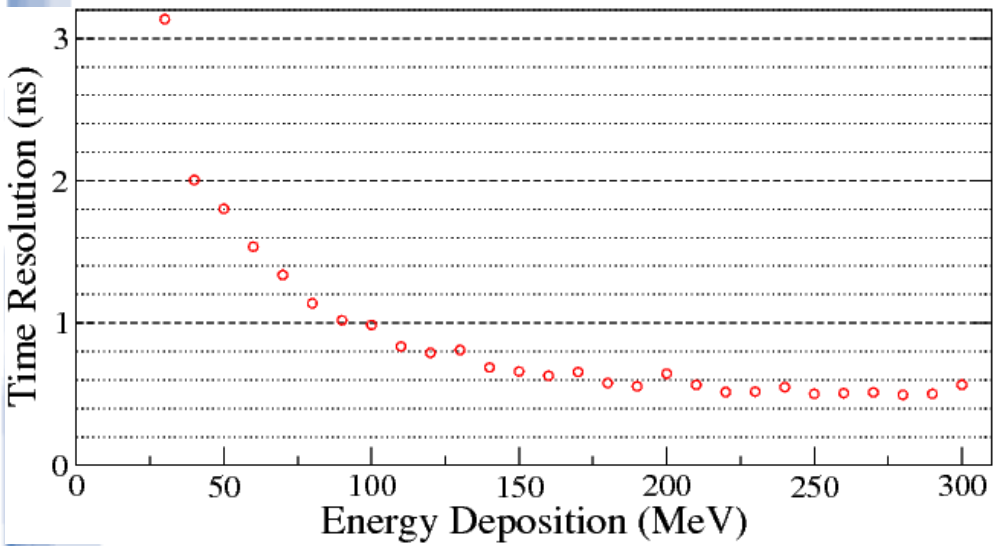
<u>Analogue-like implementation:</u>

CFT(n) = MWD(n-*d*) – *R*·MWD(n)

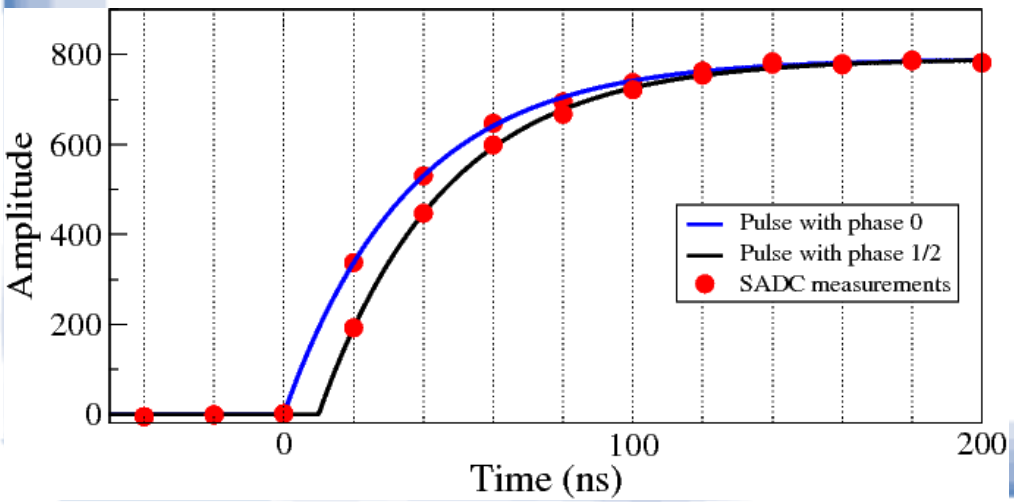
- Delay *d* = signal rise time
- Fraction *R* – to select most linear part of the signal leading edge
- *N* – number for the linear regression
- Symmetry against zero level

Time-Resolution Measurement with SADC

Time resolution for the Proto60

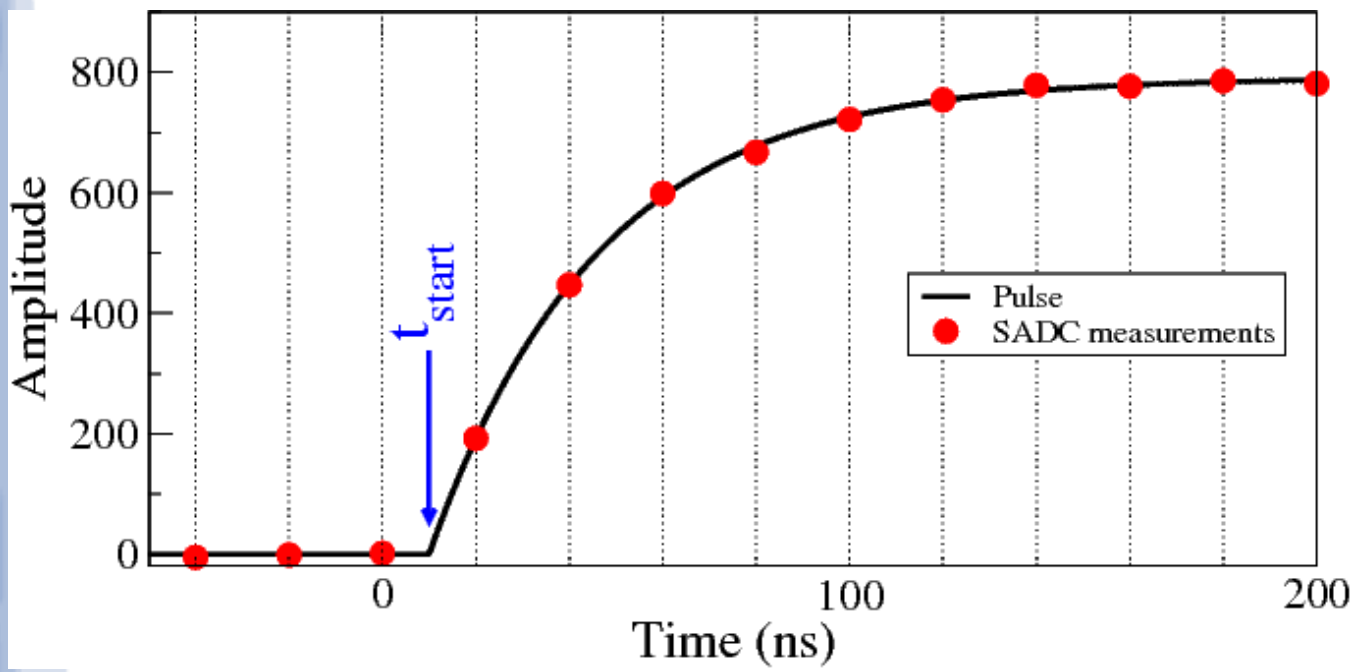


Definition of the pulse phase



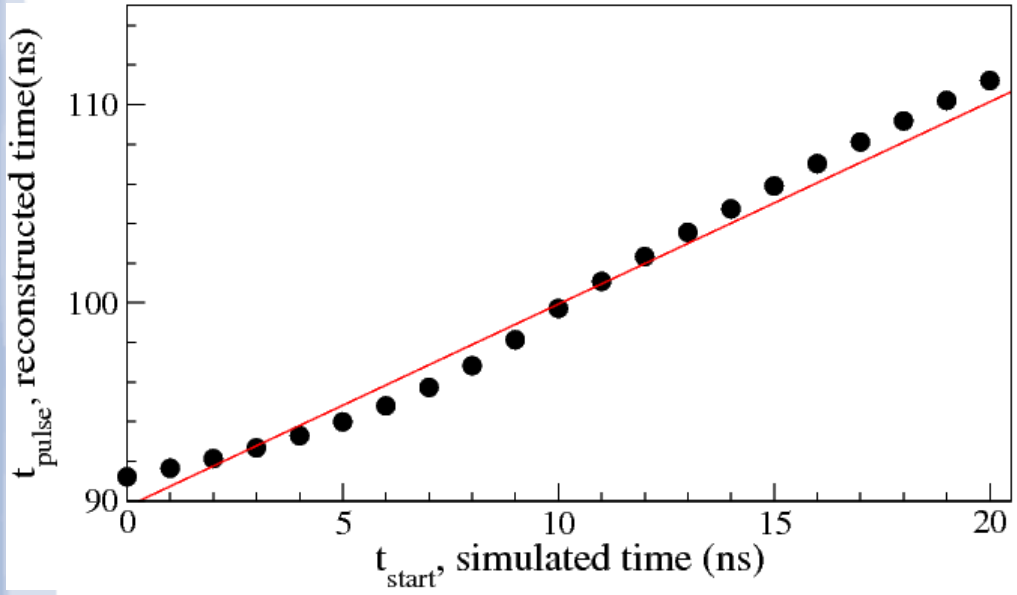
- Time resolution is deduced from the Δt measurements between two crystals
- Different SADC channels have same clock – The phase of two digitised signals is the same
- The Δt measurements are not affected in the case if timing method has non-linear response on the pulse phase
- Special investigations of the linearity of the pulse-phase response has to be performed

Definitions
Simulation



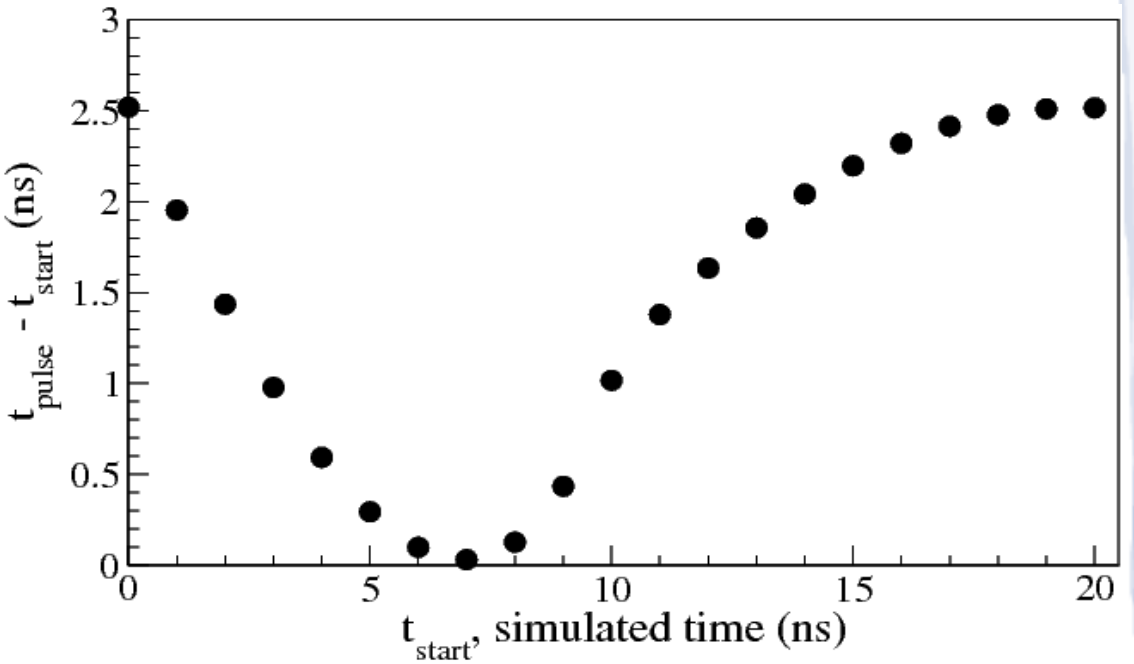
- t_{start} – starting time of the simulated pulse
- t_{pulse} – recovered time-stamp
- t_{start}-t_{pulse} distribution for different phases – measure of the linearity of the timing-algorithm response

Pulse-Phase Linearity
Simulation (50 MHz SADC rate)



Ratio of CFT is optimized for the narrowest Δt distribution for pulses with same phase

- Deviation of the time-stamp is in order of few ns!
- Shape of the deviation curve does not depend on the amplitude



Pulse-Phase Linearity
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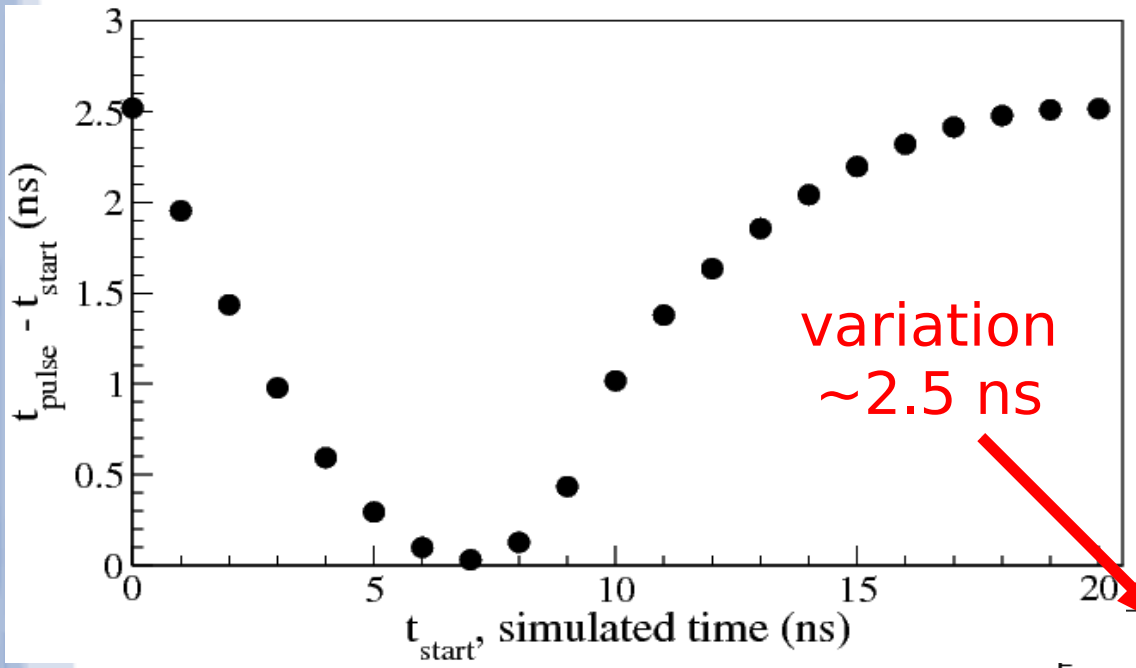
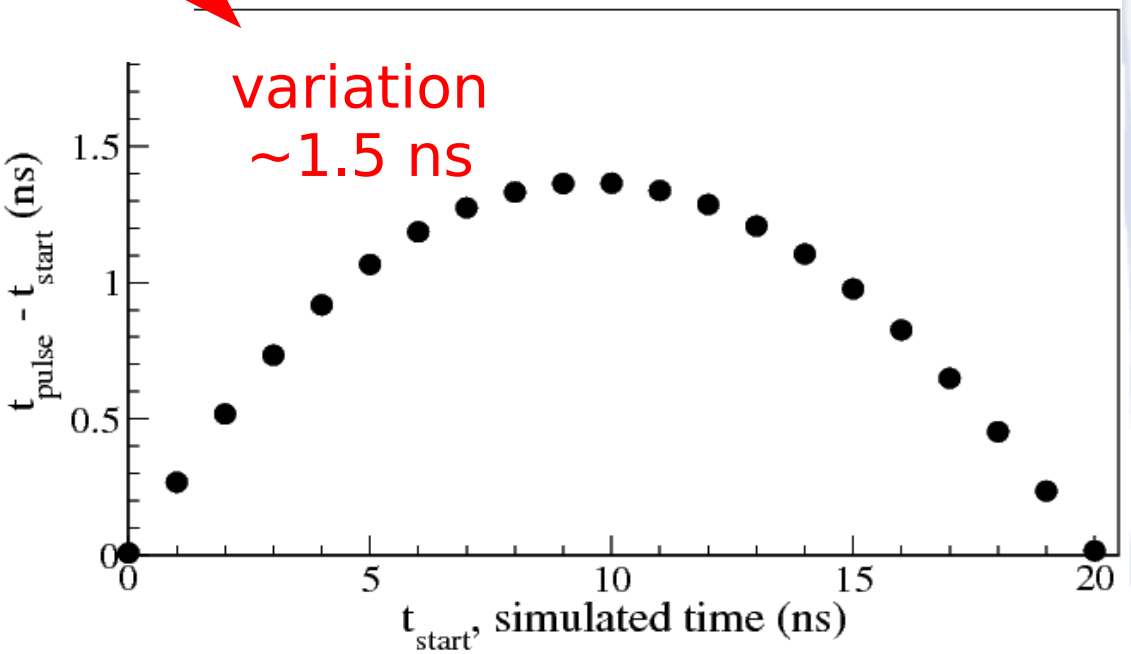
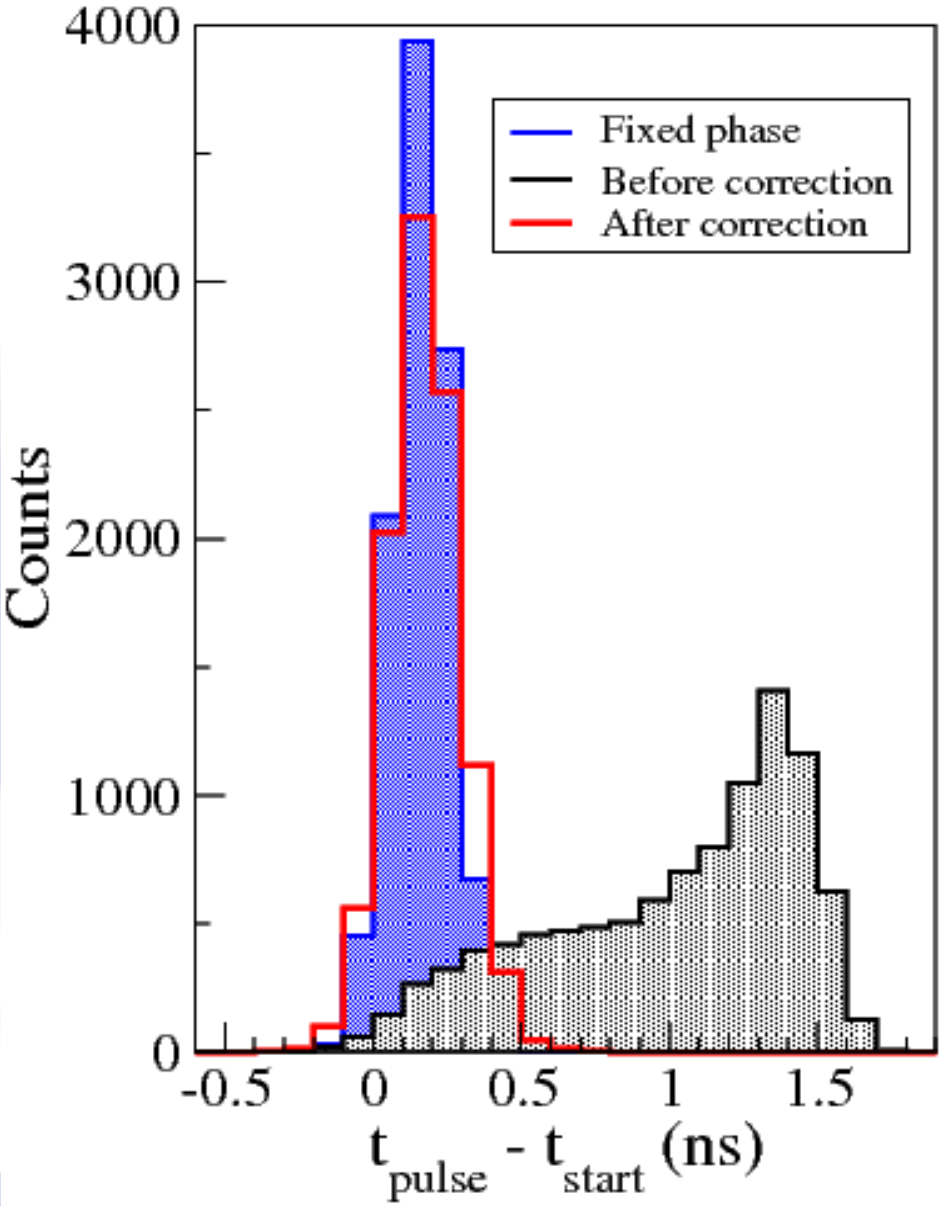


Optimization of CFT Ratio allows to reduce the variation and symmetrize the shape of the variation dependence on the phase

- Symmetric and "simple" shape of the variation dependence allows to make corrections
- As input parameter for the correction the detected phase may be used

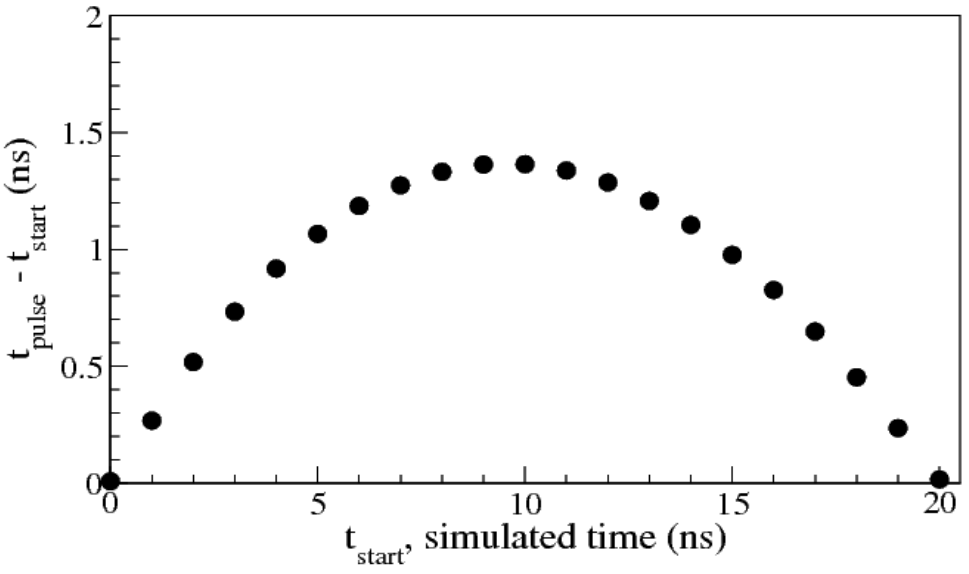


Pulse-Phase Linearity
Simulation (50 MHz SADC rate)



Distribution of t_{pulse}-t_{start} obtained for random t_{start} values

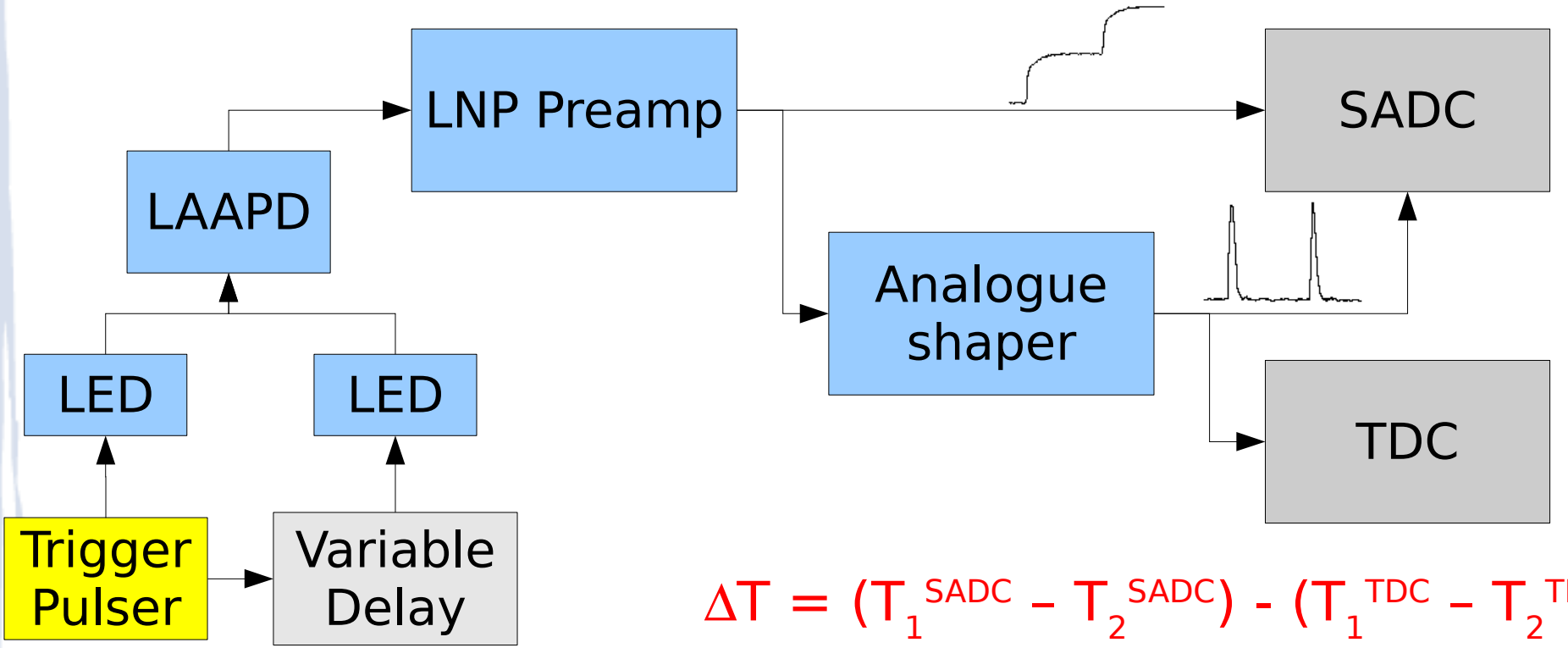
Applied event-by event correction deduced from the deviation curve



Cross-Check of the Pulse-Phase Linearity

- **Computer simulations**
  - Used pulse-shape and noise level is determined from the Proto60 data
  - Data-analysis procedure same as for SADC data

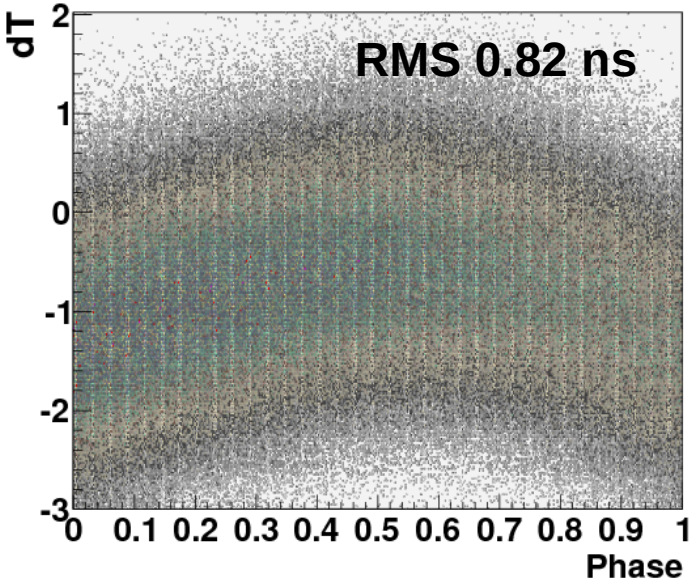
- **Test measurements with LED light pulser**

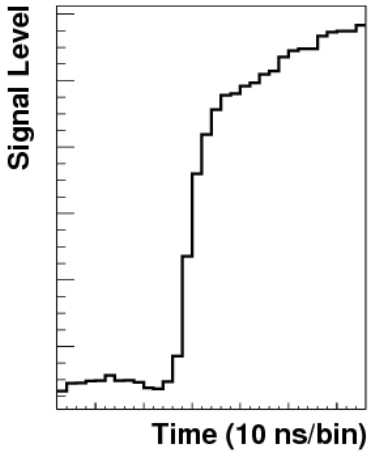


$$\Delta T = (T_1^{SADC} - T_2^{SADC}) - (T_1^{TDC} - T_2^{TDC})$$

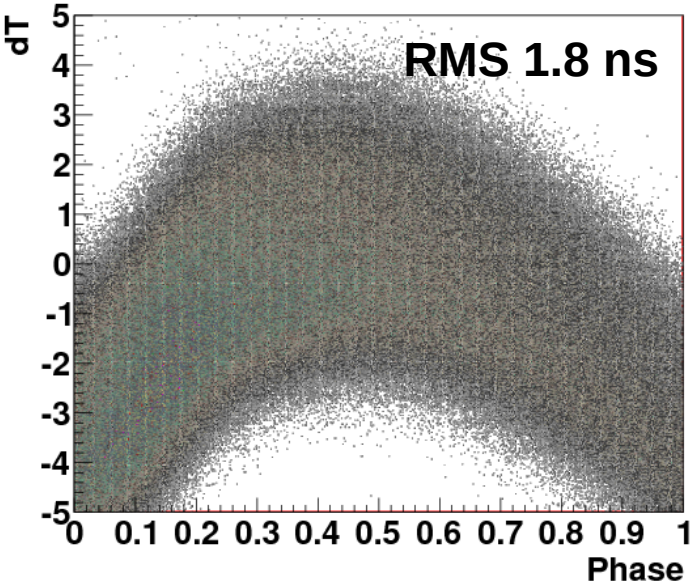
Pulse-Phase Linearity
LNP Preamplifier

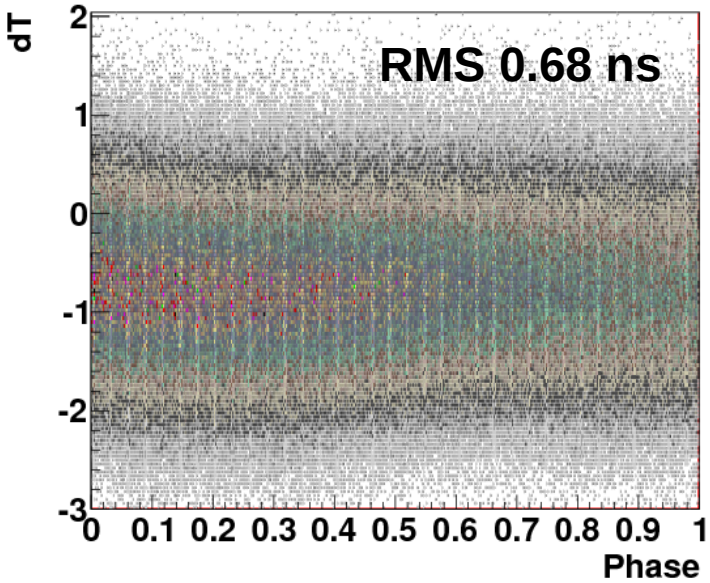
100 MHz

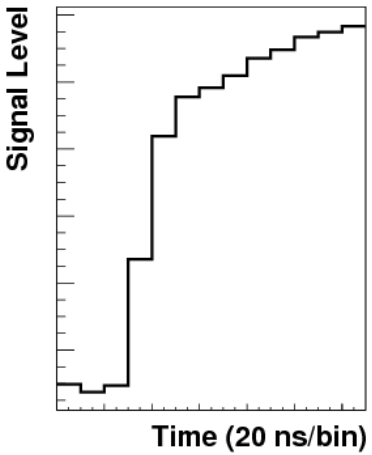


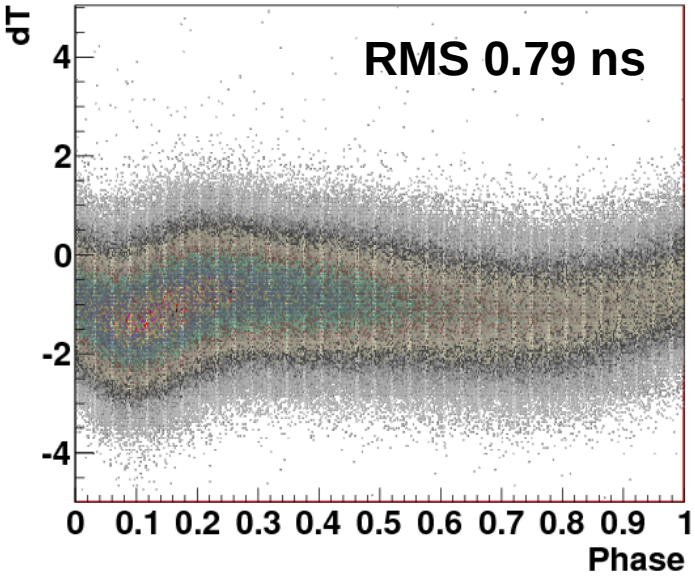


50 MHz



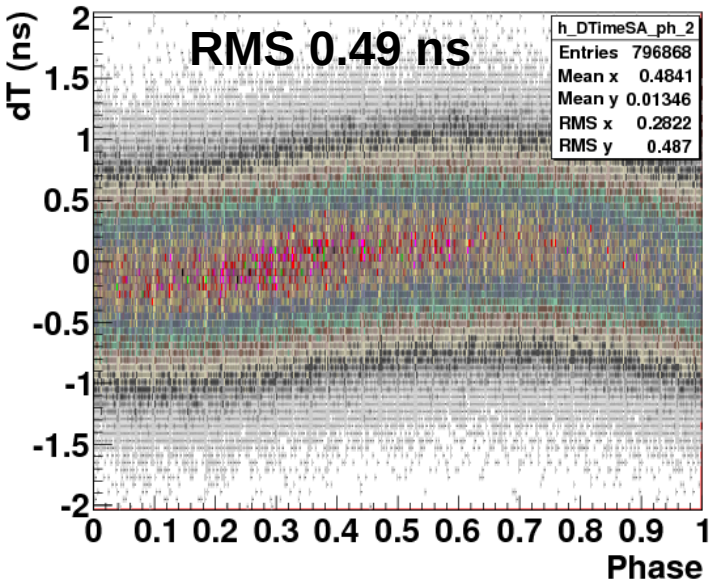


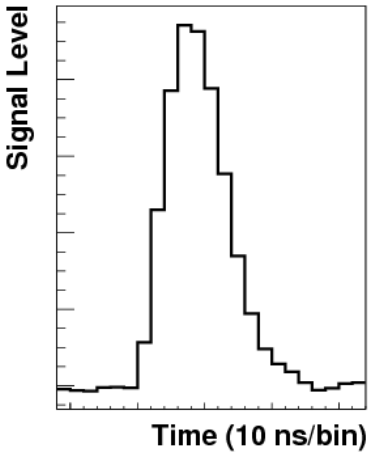




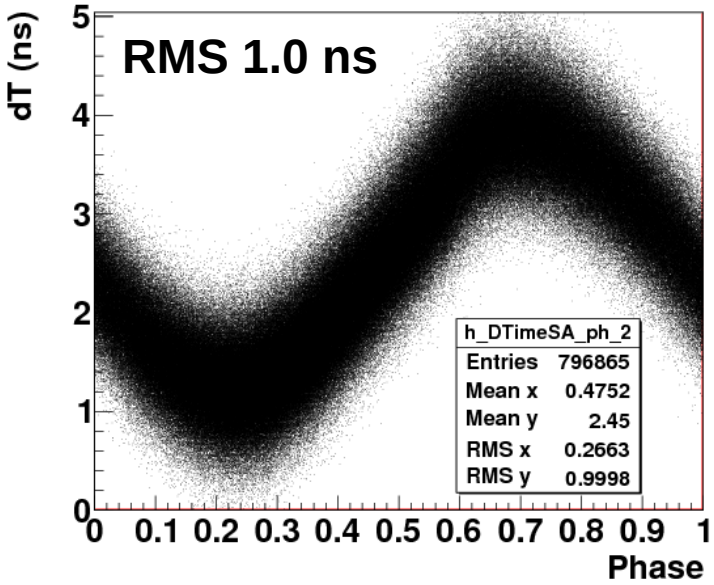
Pulse-Phase Linearity
LNP Preamplifier

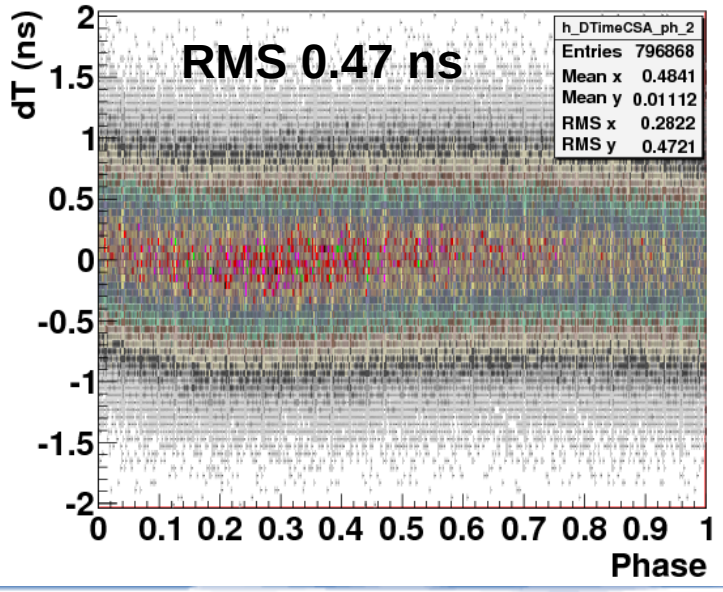
100 MHz

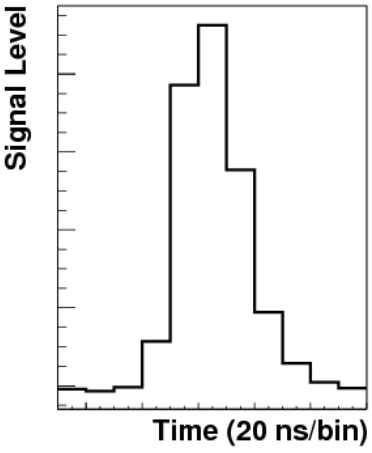


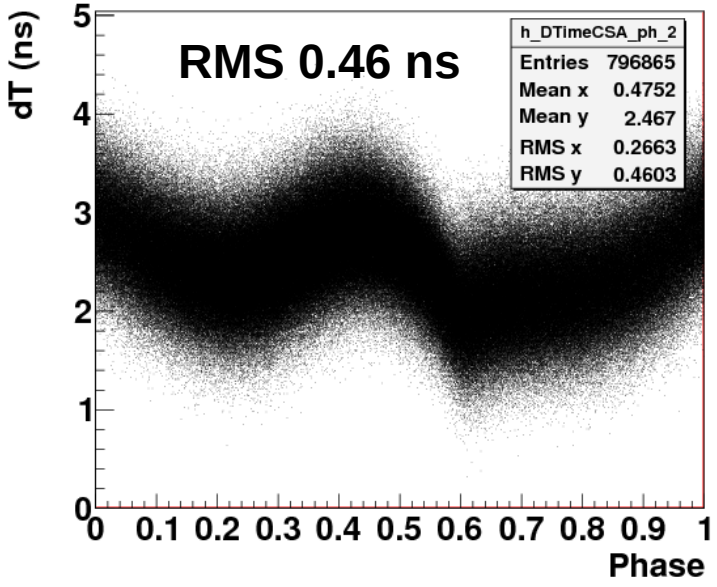


50 MHz









Summary

- The digital implementation of the Constant-Fraction Timing-method produces results with much higher precision than the SADC sampling rate
- The CTF response for digitized pulses is non-linear
- The CFT non-linearity increases at lower SADC sampling rates
- The CFT non-linearity can be minimized by the selection of CFT-ratio parameter and almost completely compensated with 2nd – 3d ordr polynomial correction (50 MHz – 25 MHz SADC sampling rate)

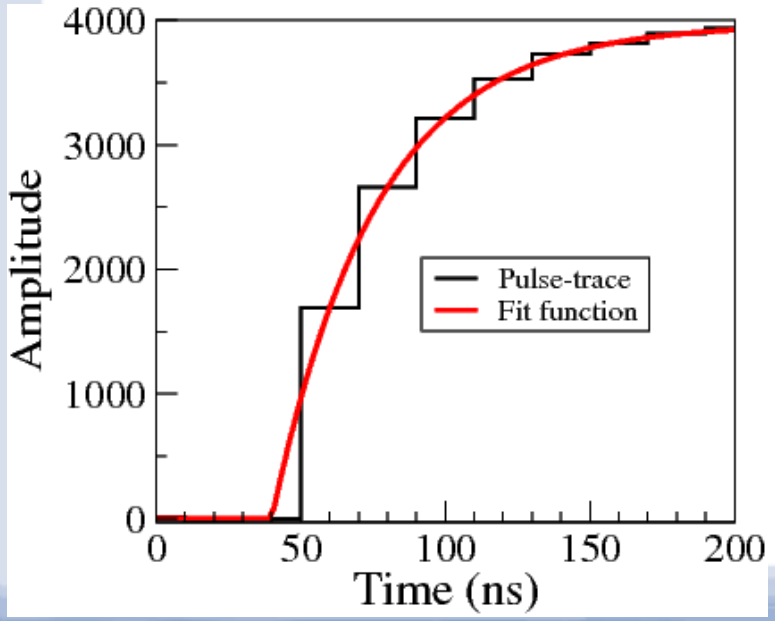
- The non-linear CFT response can not be seen with correlated signals having constant delay (like Proto60 data)

Fitting of The Pulse
Simulation (50 MHz SADC rate)

Time information can be obtained from the pulse-shape fit:

- Fitting raw data after preamplifier (FIT-RAW) (possible only for pulses separated in time more than 200 μs)
- Fitting rising edge of the MWD-filtered pulse (FIT-MWD)

Fitting rising edge of the MWD-filtered pulse



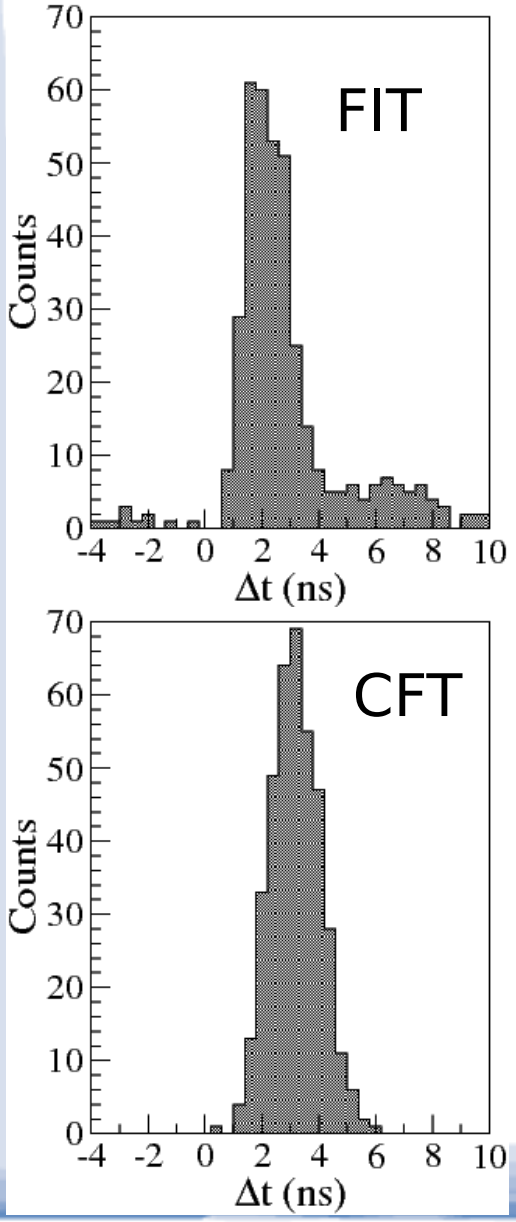
Time-resolution for 500 MeV pulse:

- FIT-RAW 70 ps
- FIT-MWD 100 ps
- CFT 450 ps
- CFT correced 120 ps

Corrected CFT method provides only 20% worse time resolution in comparison with the (practically) best-possible method while saving a lot of computational power

Fitting of The Pulse Proto60 data

Time difference distributions



Measurement conditions:

- Beam between two crystals
- Only events with about same energy deposition in both crystals are selected
- Time resolution estimated per crystal ($RMS_{\Delta T}/\sqrt{2}$)

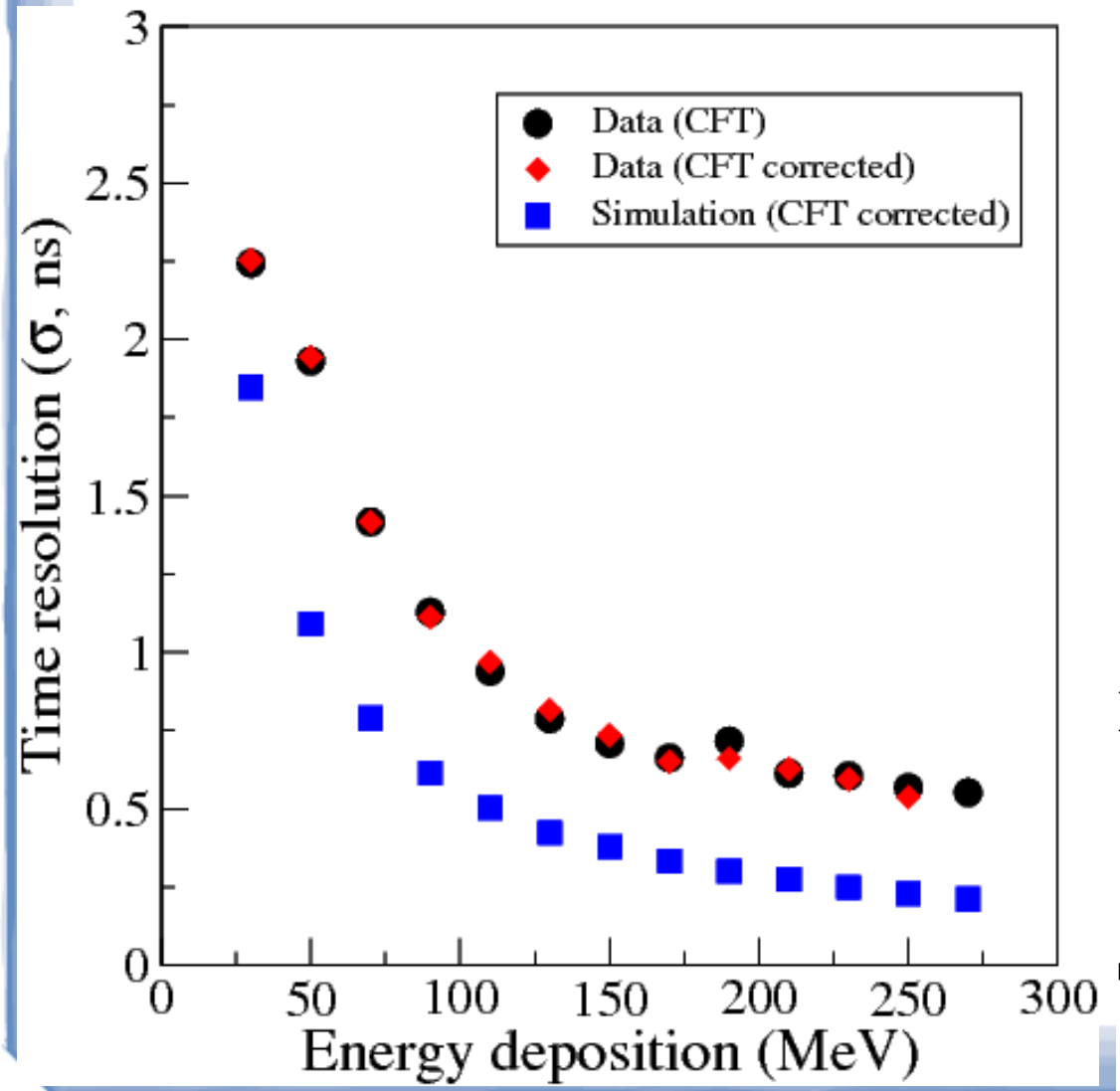
Time-resolution for about 280 MeV energy deposition:

- FIT-MWD 550 ps
- CFT corrected 610 ps

CFT provides only 10% worth time resolution while being more faster and robust

CF Timing: Simulation vs Experiment

Time resolution for the Proto60



Simulation predicts much better time resolution than experiment. Possible reasons:

- Noise (taken into account properly)
- Pulse-shape variations?

Leading-edge raising-constant measured for Proto60