H2 Test Beam 1st→7th July 2015: LYSO crystals + NINO readout

Fast Timing meeting

November 13th, 2015

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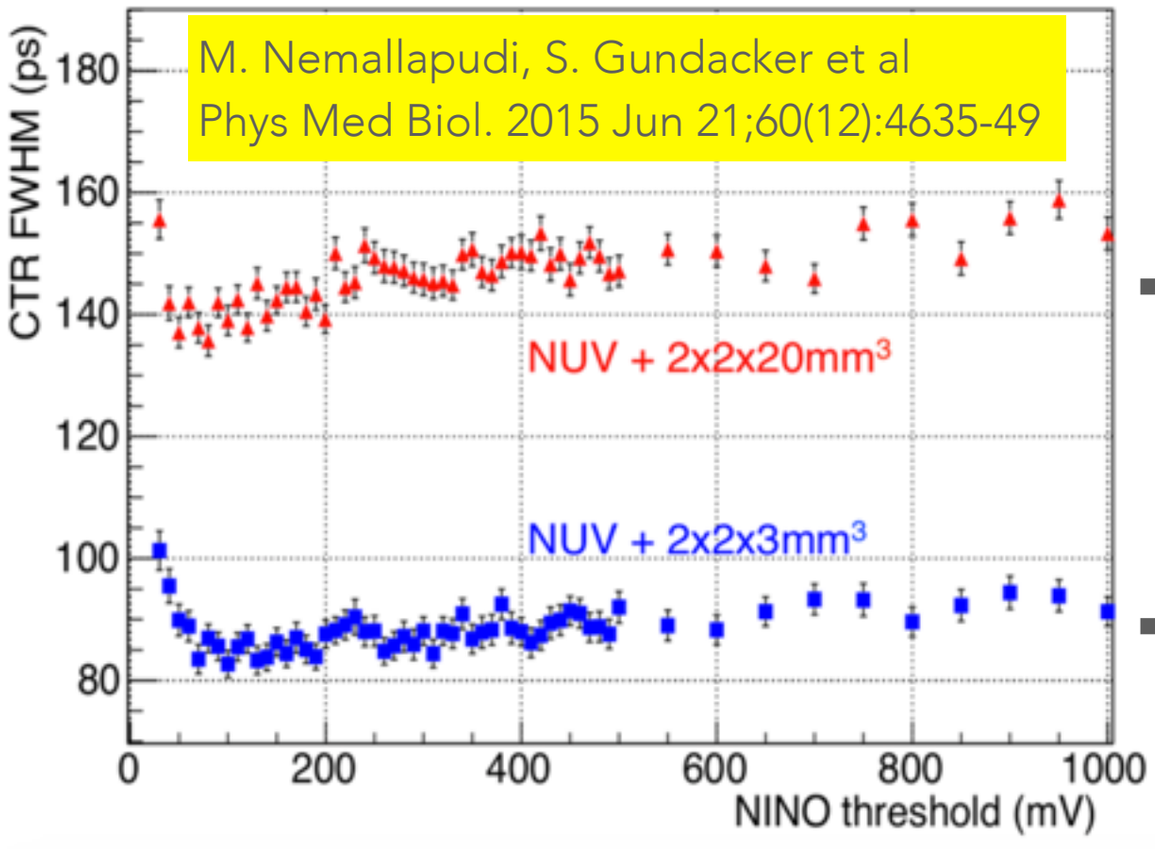
Introduction

- Since several years, intensive **R&D** activity at Lab27 on **crystal timing** for **TOF-PET**

measurements done at CERN
LSO:Ce:Ca crystal - **FBK NUV** SiPMs used

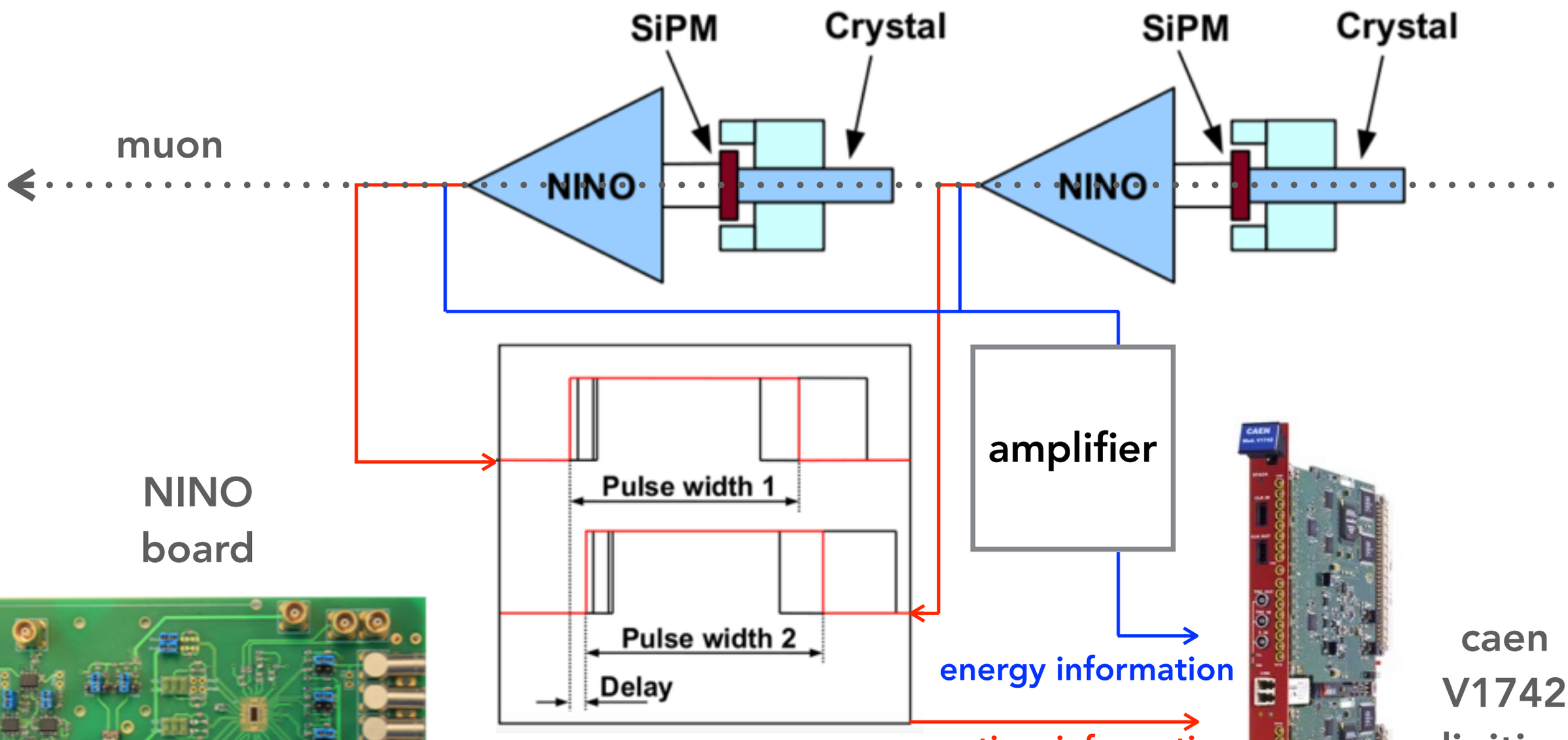


CTR of 140 ps FWHM
(σ_{CTR} = 60 ps, σ_{single} = 42 ps)
➡ 20 mm long crystal

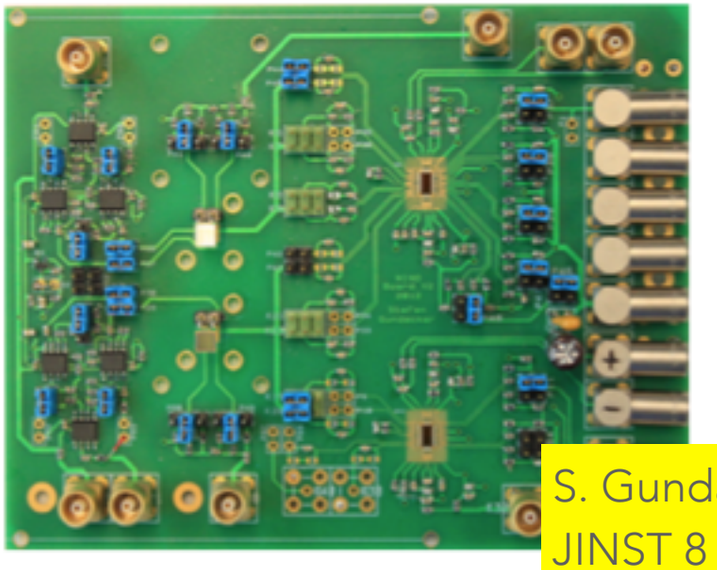
CTR of 85 ps FWHM
(σ_{CTR} = 36 ps, σ_{single} = 25 ps)
➡ 3 mm long crystal

- In the plot, 2x2x3 cm^3 crystals used. Recently, same CTR measured for 2x2x5 cm^3 + new generation of SiPM (**NUV-HD**) ⇒ used for TB

Measurement setup



NINO
board

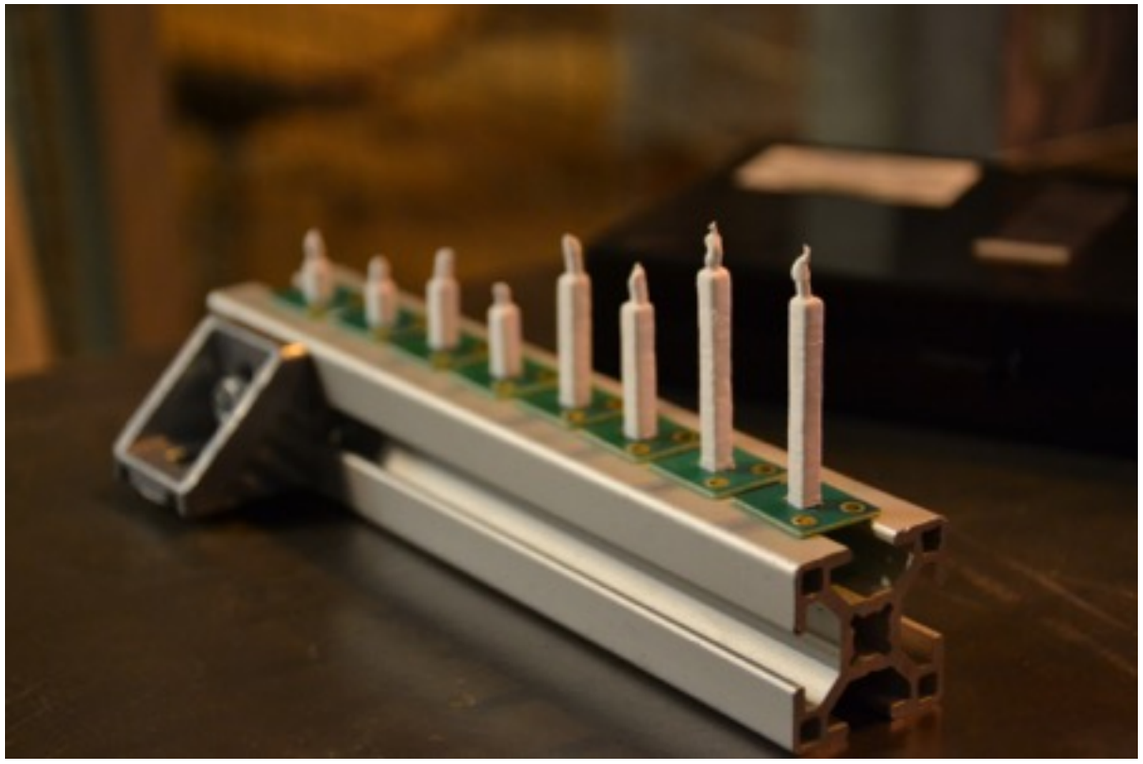


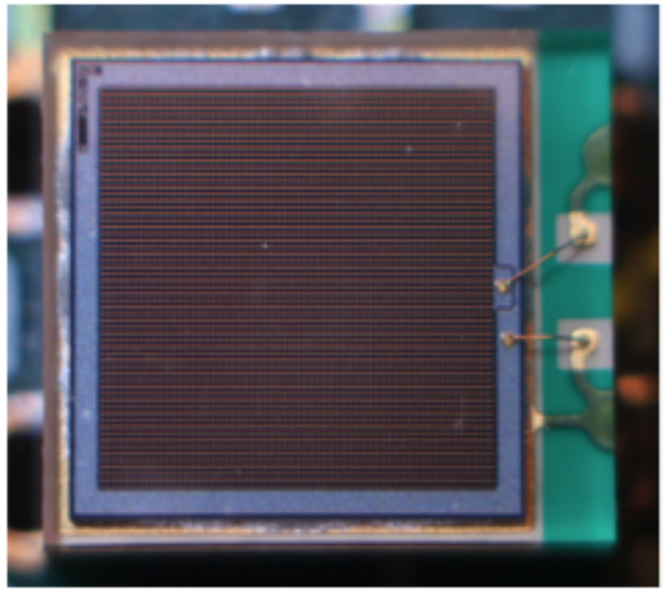
S. Gundacker et al,
JINST 8 P07014 2013

caen
V1742
digitizer

Crystals and photodetectors

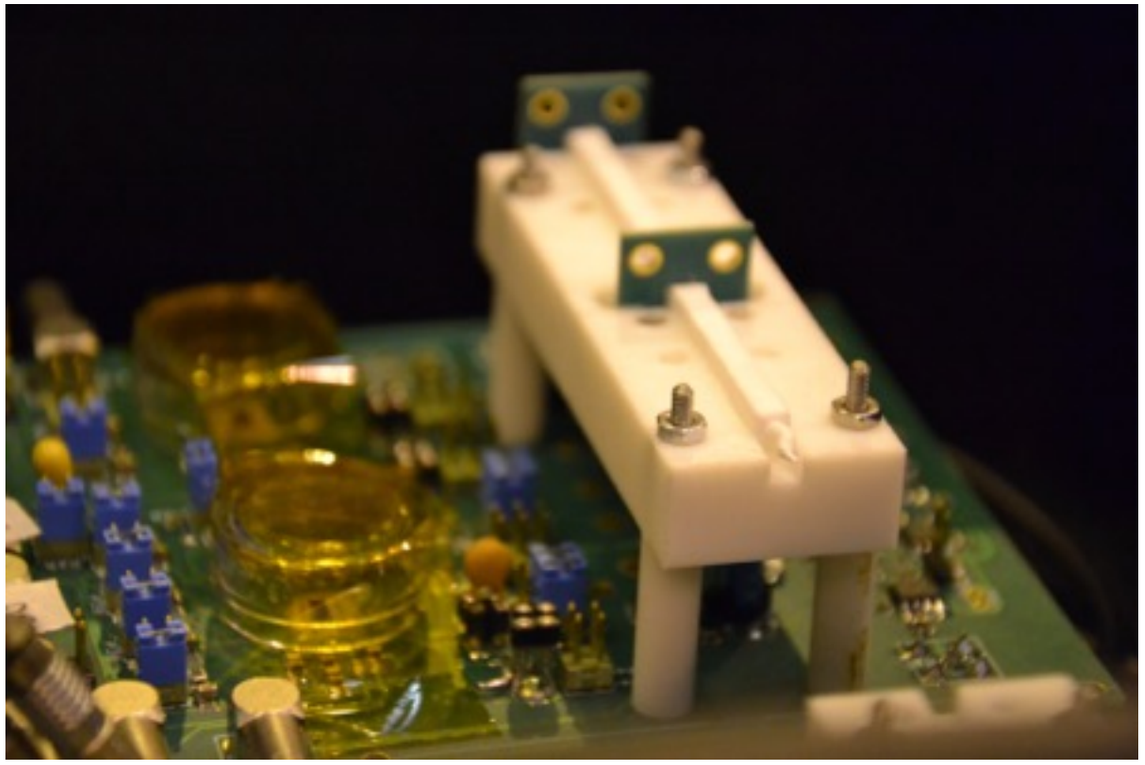
- 1st configuration:
  - couples of **LYSO:Ce crystals** (*CPI*), dimensions **3×3×L mm³**, **L=5,10,20,30 mm**
  - Crystals coupled to **3×3 mm² SiPM** (Hamamatsu TSV MPPC), 50 µm SPAD (3600 SPADs)
  - SiPMs connected to the board through ~5 cm long wires

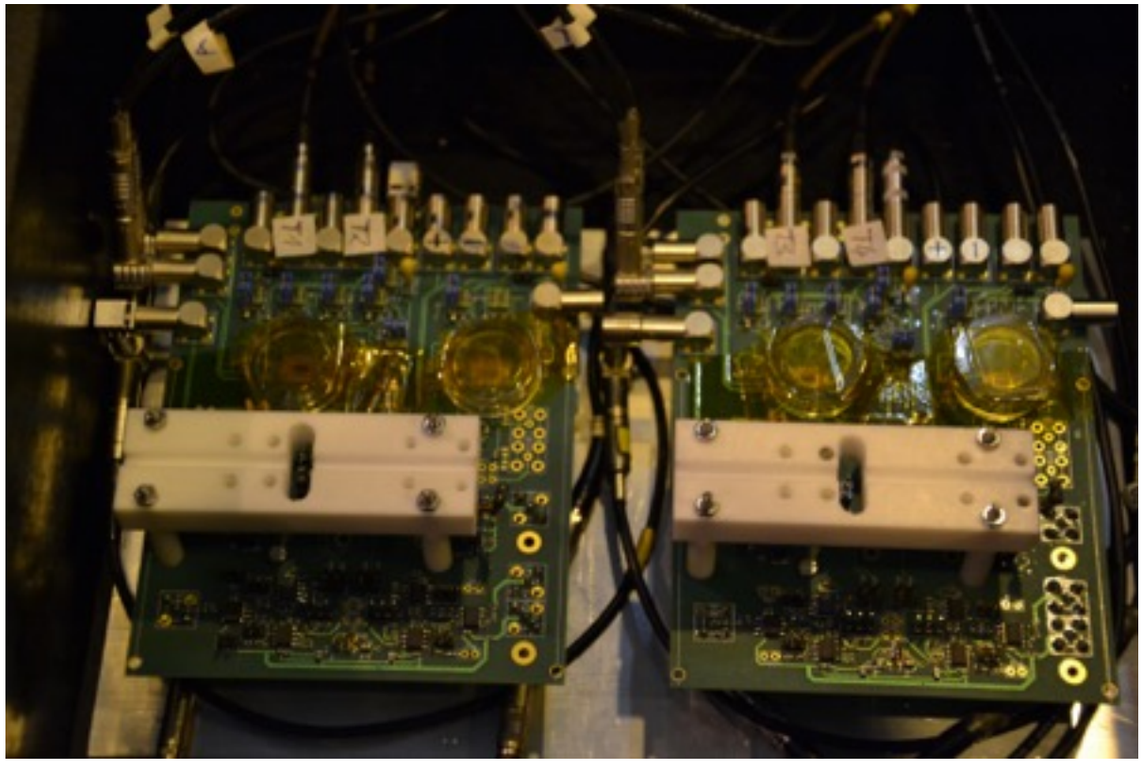




- 2nd configuration:
  - couples of **LSO:Ce:Ca crystals** (*Agile*), dimensions **2×2×5 mm³**
  - Crystals coupled to **4×4 mm² SiPM** (FBK NUV-HD), 25 µm SPAD (6400 eff. SPADs)
  - SiPMs directly connected to the board

Final setup in H2

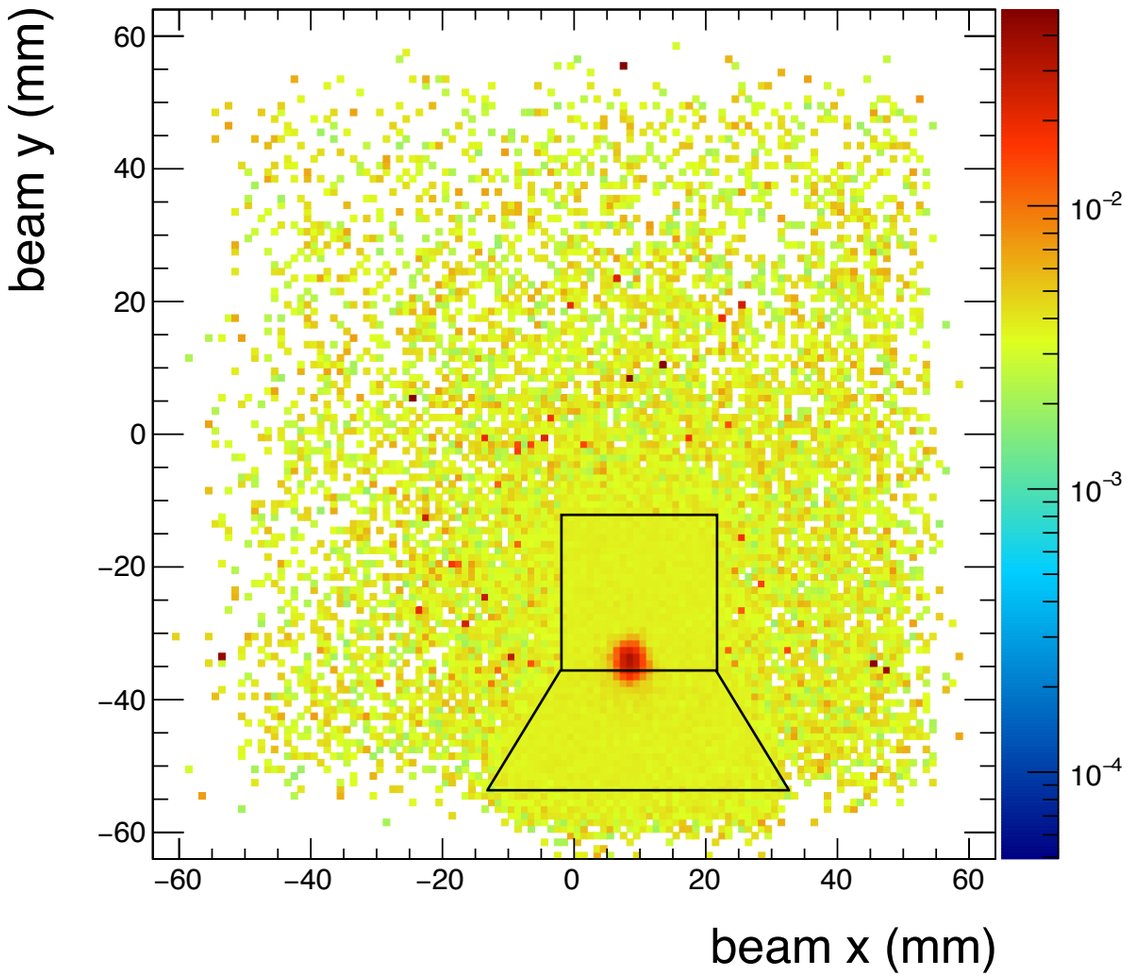


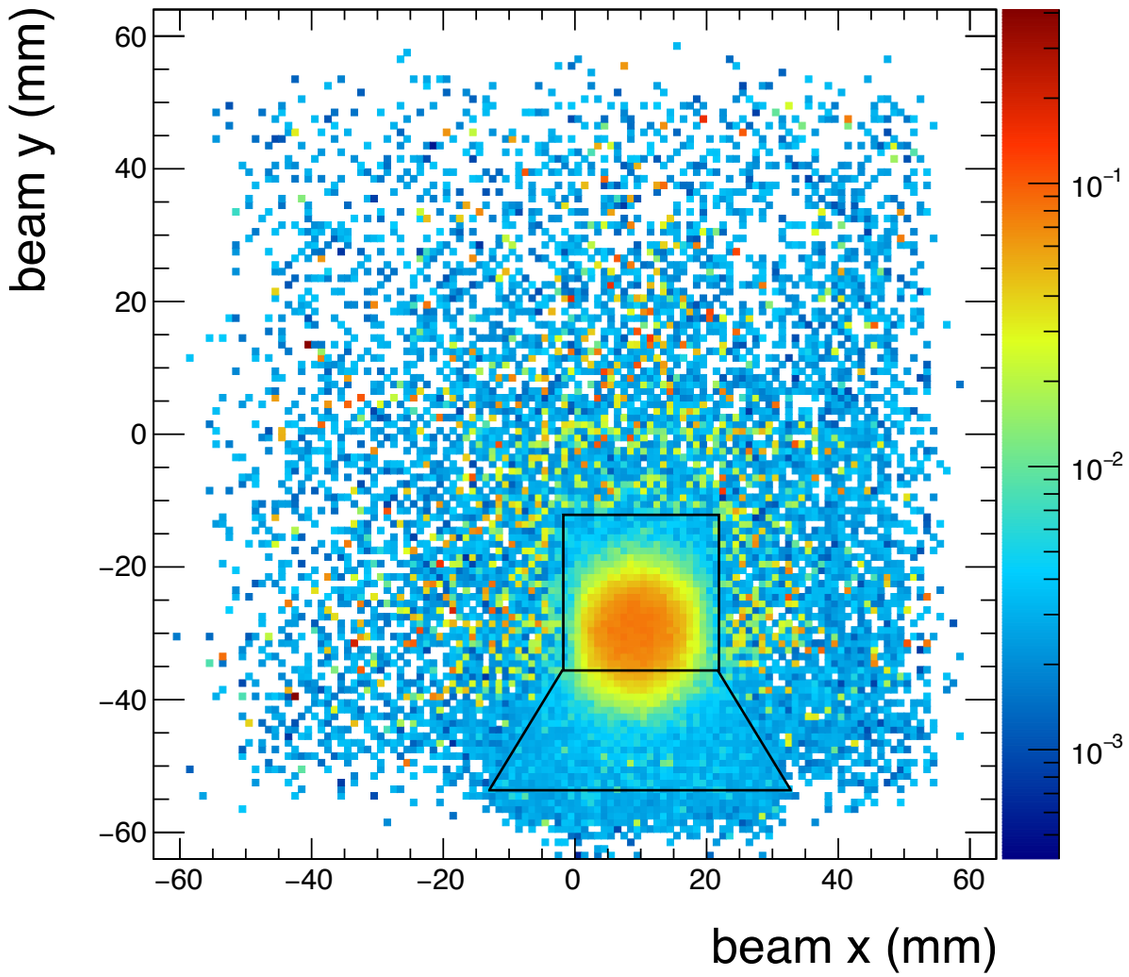


- took data during the **biggest heat wave ever** recorded in Geneva
  - temp. on the experimental table was measured **~27—29° C** (also during night)
  - not the best conditions for the measurement:
    - » **SiPM performance suboptimal** (higher dark count rate, breakdown voltage variations, etc.)
    - » optical coupling unstable (**glue was melting**)

Alignment and trigger

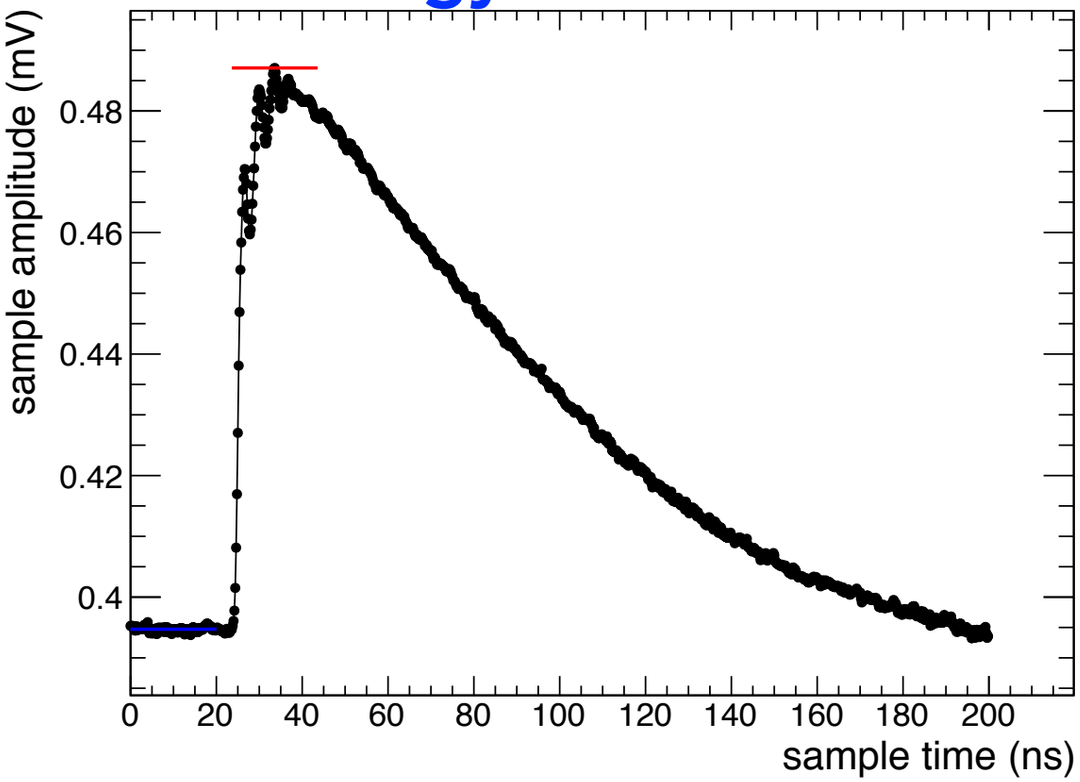
- Using a **20×20 mm² plastic scintillator** (+ scintillating/Cherenkov-producing light guide) as a trigger
  - **excellent alignment** between crystal setup and iMCP setup (ruler-made!)
  - can compare **crystal-to-crystal** and **crystal-to-MCP**



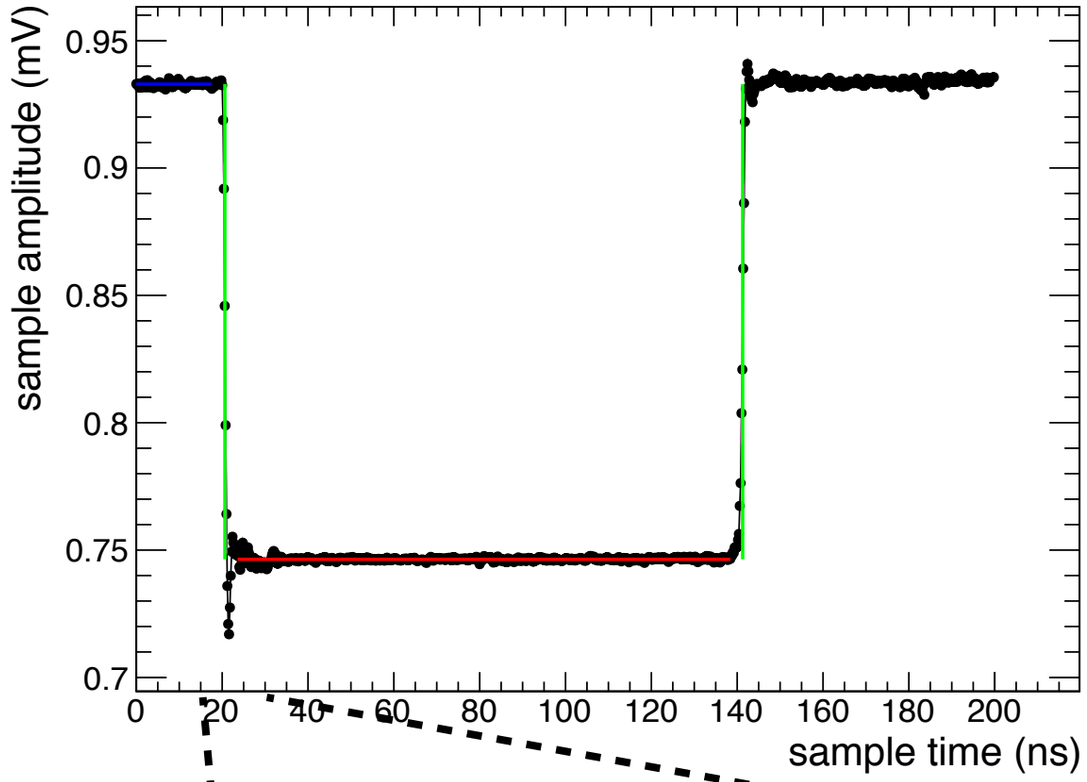


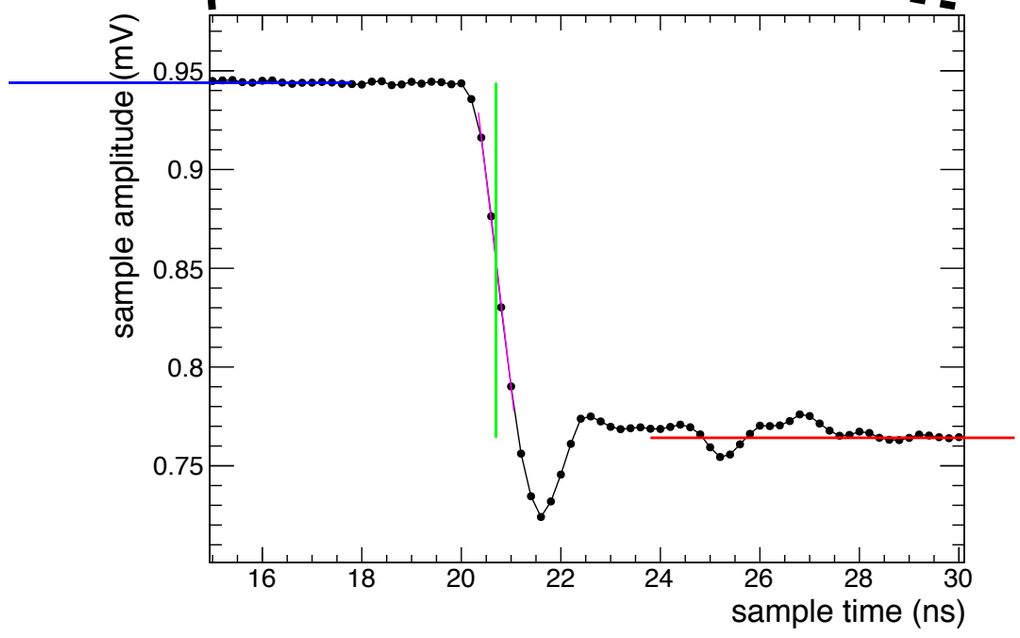
Crystal pulse reconstruction

energy information



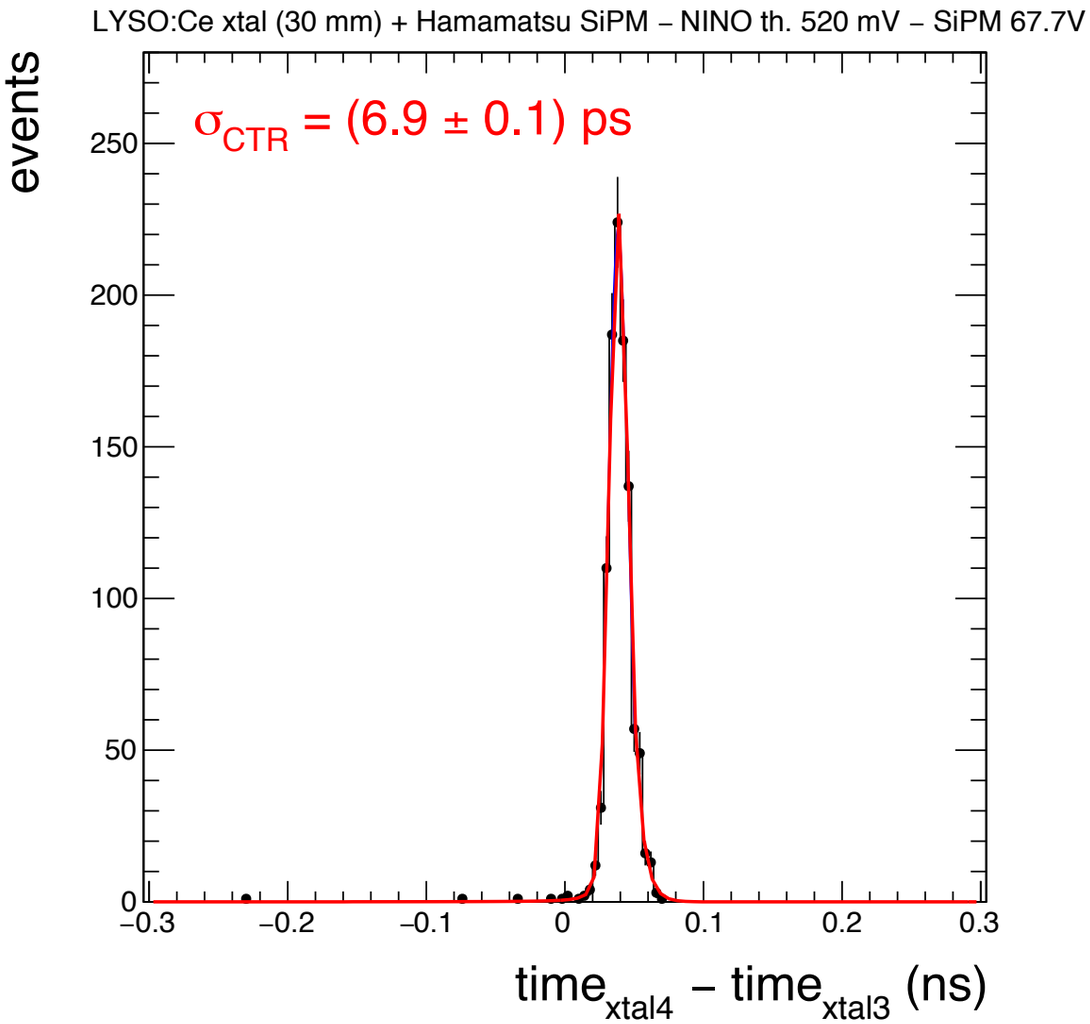
time information





Intrinsic performance of the system

- The **signal** from **one** crystal+SiPM was **split into 2 NINO input** channels
- All subsequent steps remained unchanged
  - testing the intrinsic performance of NINO + acquisition system (digitization)



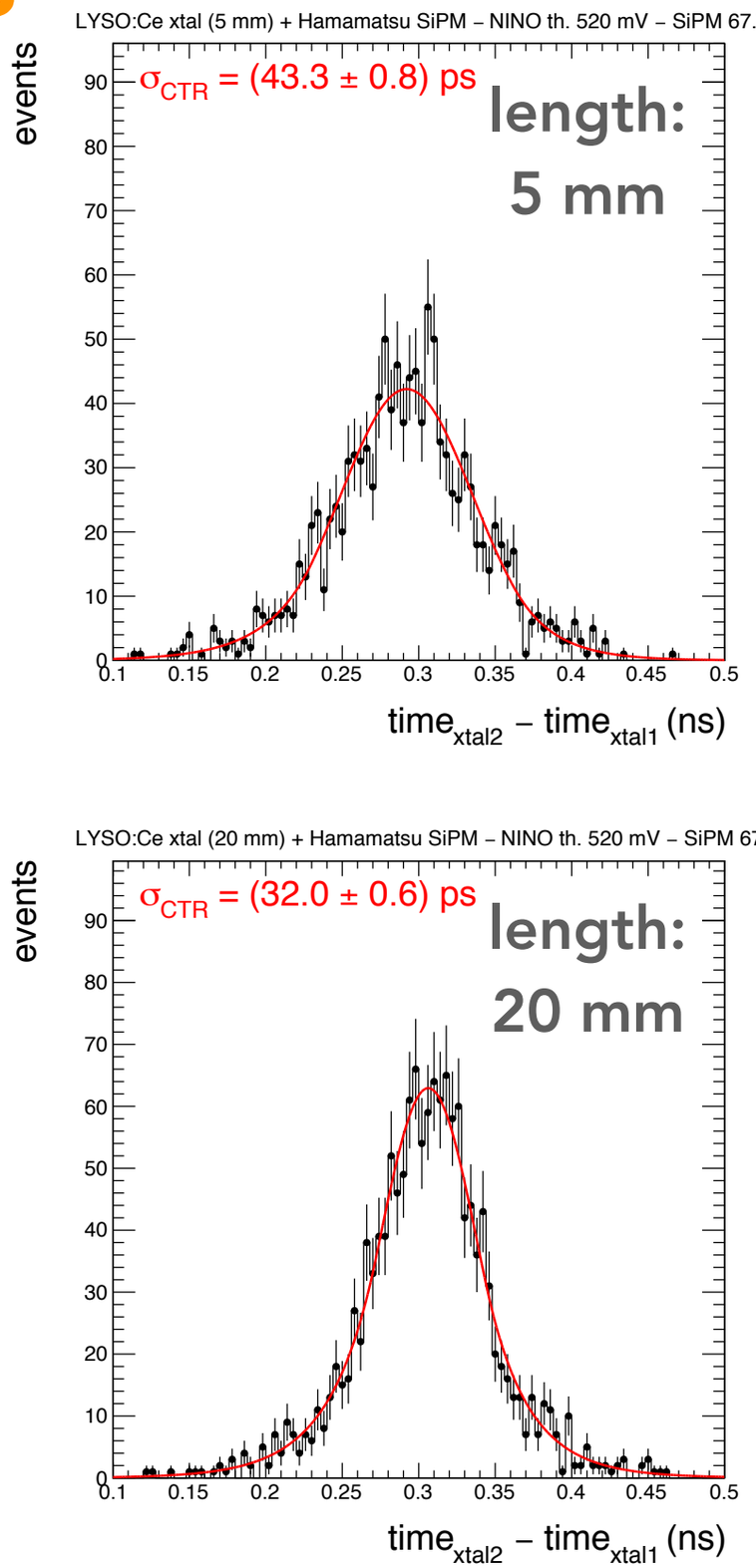
- Measuring **~7 ps** of intrinsic resolution
  - same results obtained by other independent measurements
    - » e.g. Adi measured 7 ps with DRS4, on whose chip the Caen V1742 digitizer is based)
  - small contribution to the timing measurements to follow

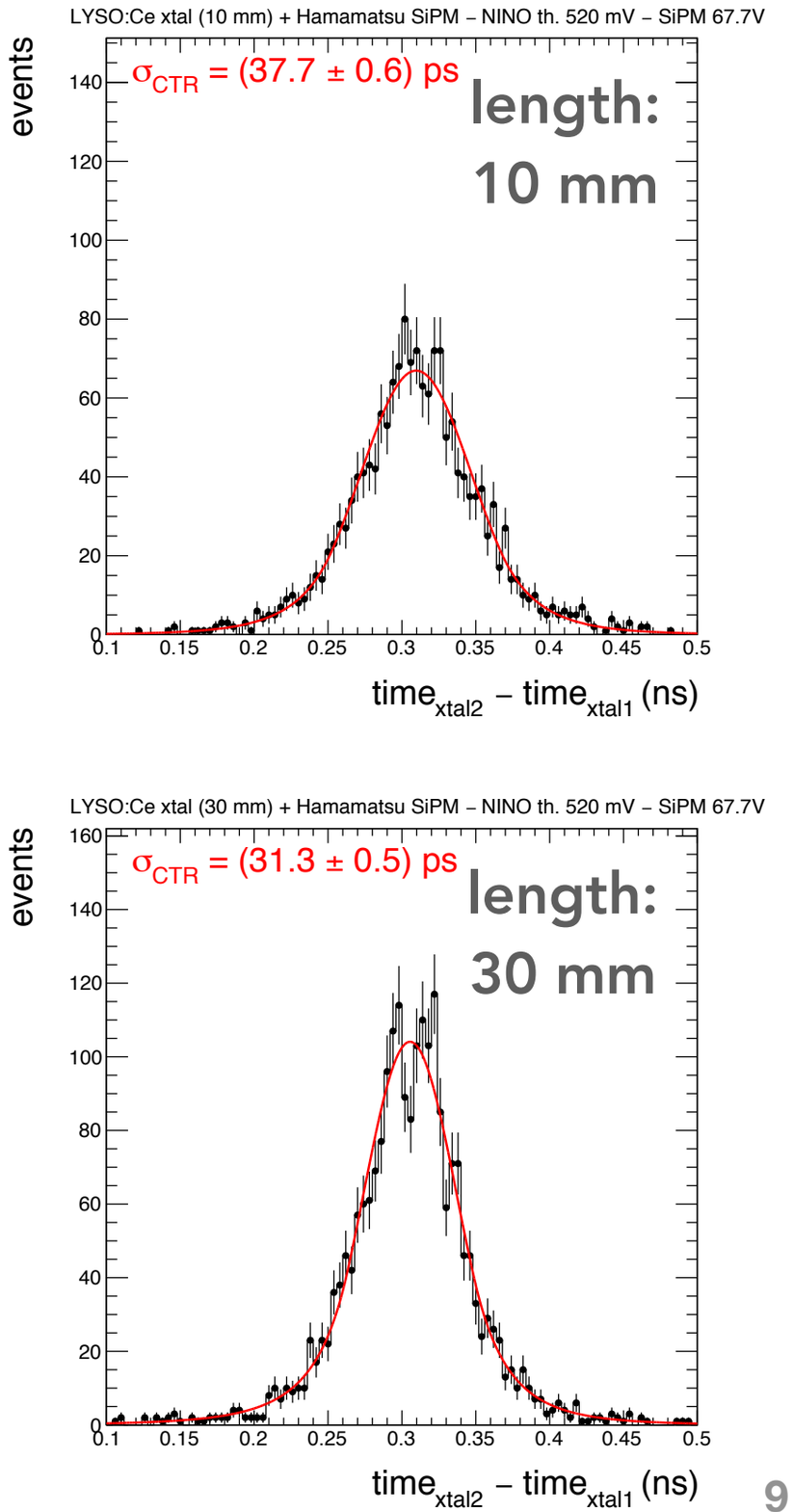
LYSO:Ce + Hamamatsu TSV SiPM timing measurements

- We measure **σ_{CTR} ~ 32 ps** for long crystals (above 20 mm)

- This means (assuming the two crystals are the same)

  σ_{single} ~ 23 ps

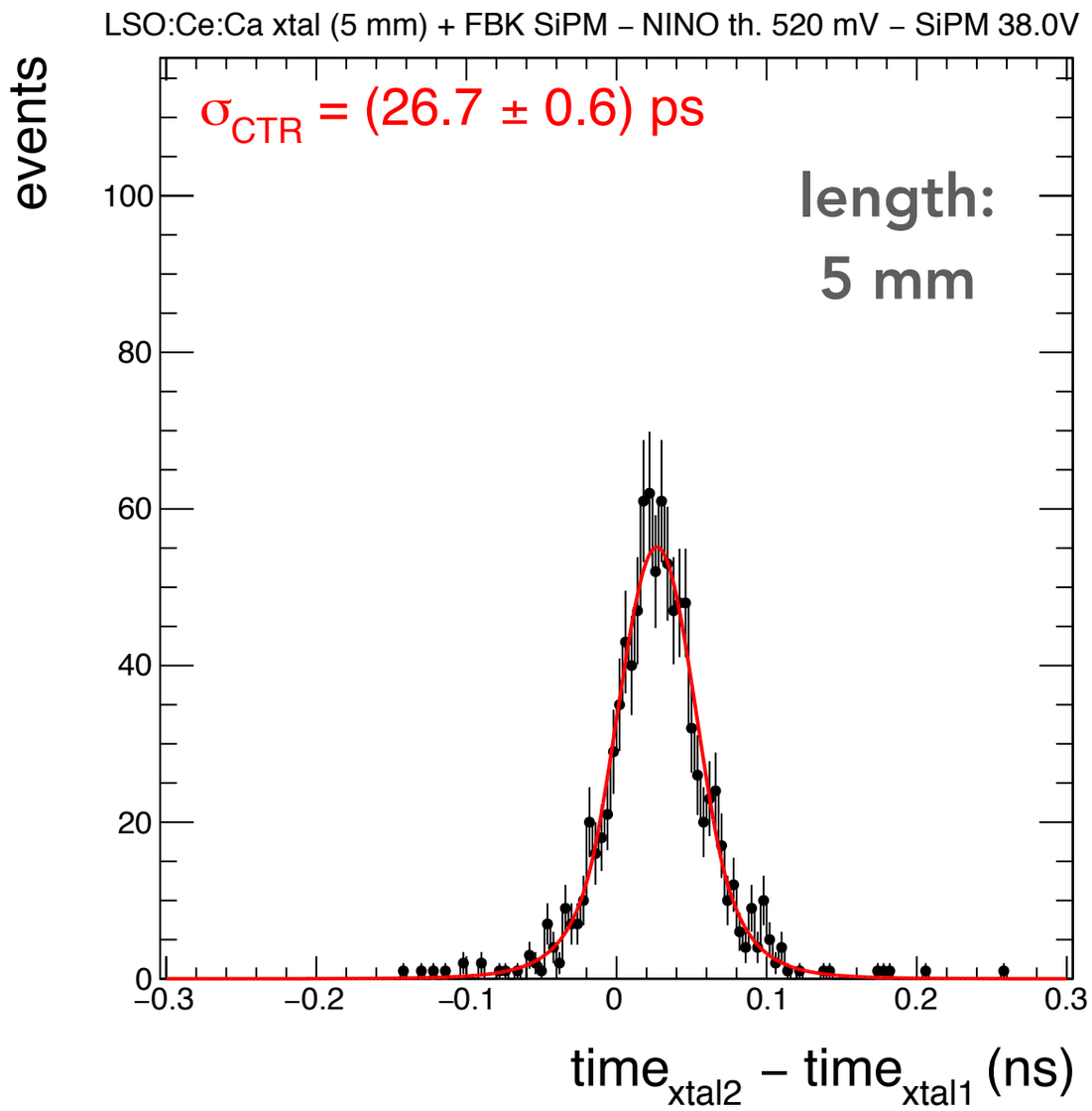




LSO:Ce:Ca + FBK NUV SiPM timing measurements

- We measure **σ_{CTR} ~ 27 ps** for 5 mm crystals

- This means (assuming the two crystals are the same)
  σ_{single} ~ 19 ps

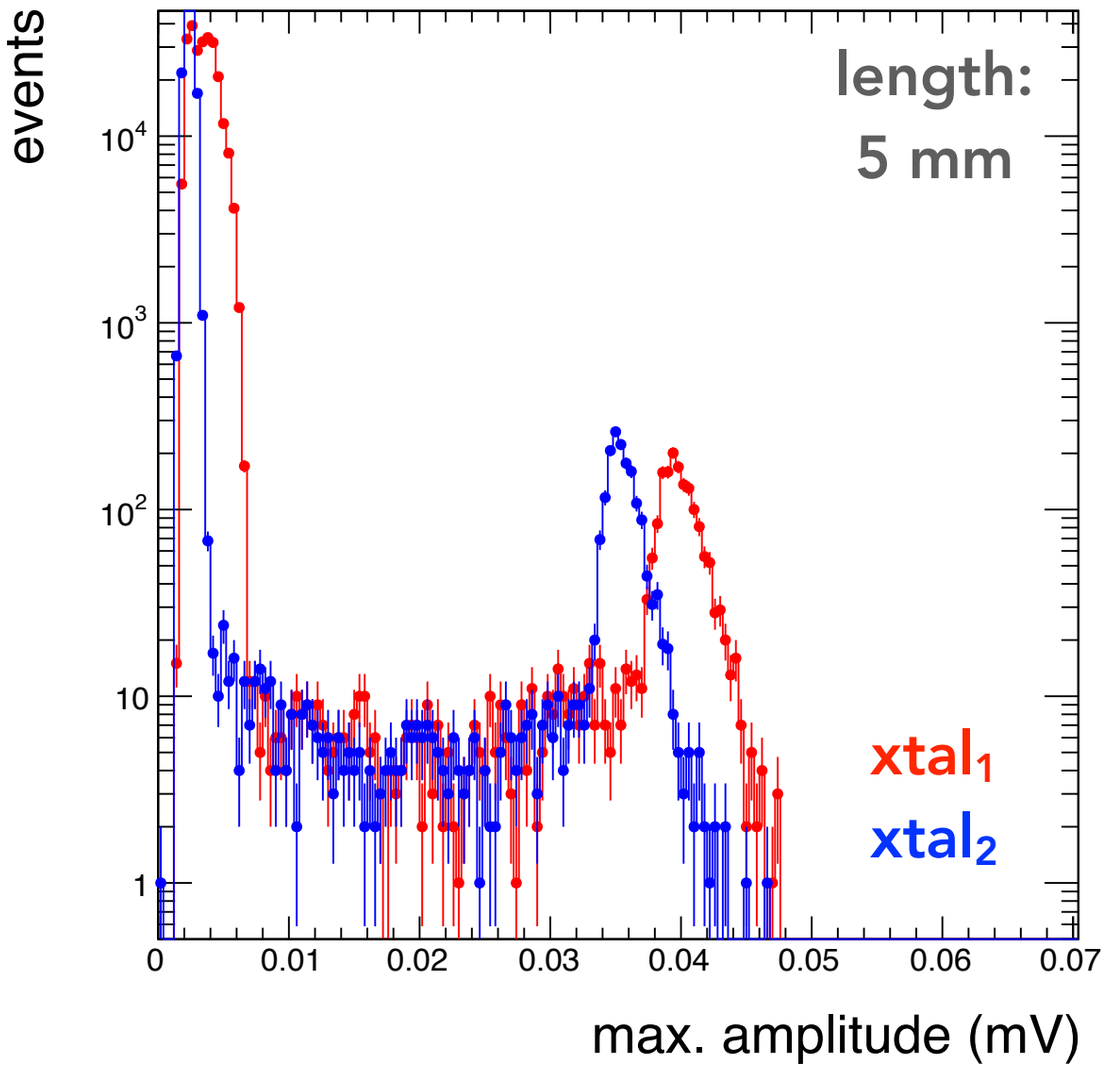


New: observed CTR dependence with signal amplitude

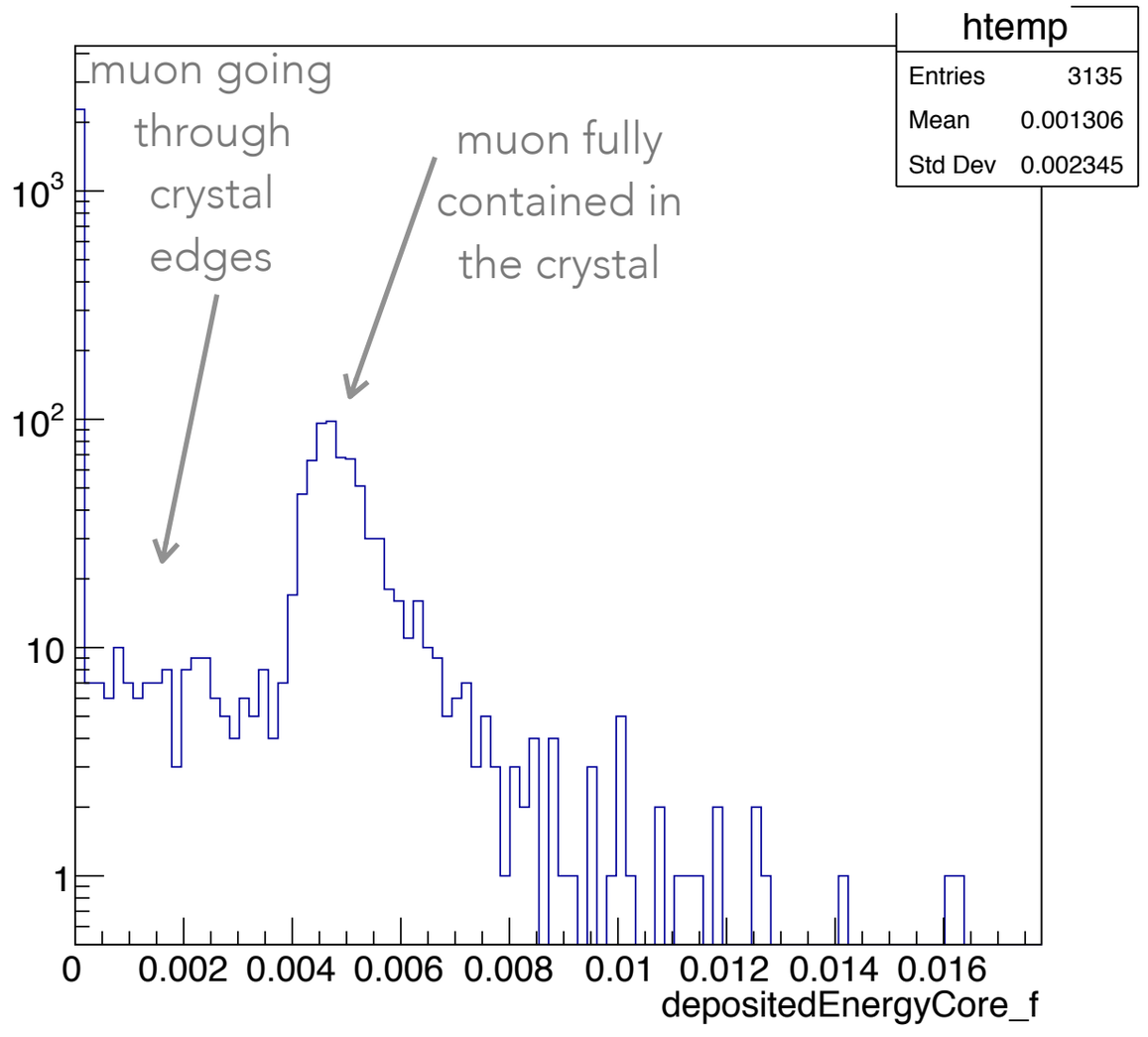
- A typical SiPM amplitude spectrum:

simulation (by Marco):
5 mm crystal, 150 GeV muon beam with 2° divergence

data



simulation

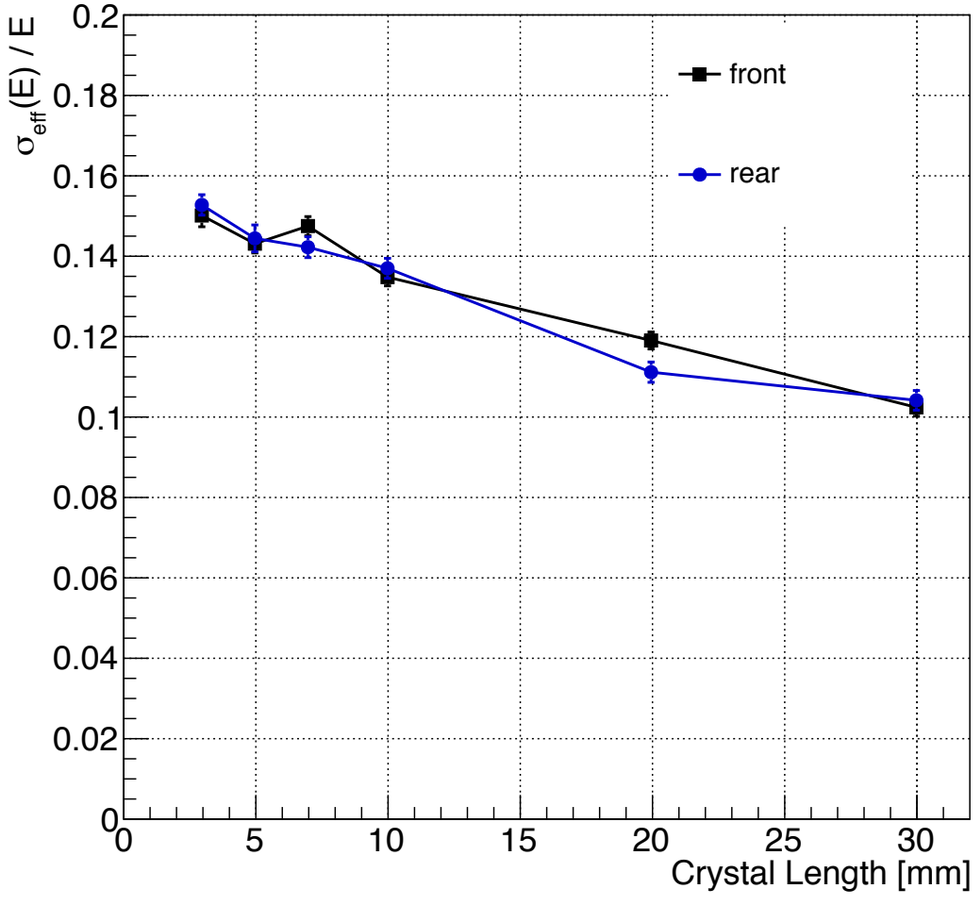


New: observed CTR dependence with signal amplitude

- Intrinsic energy deposition spread:
  - non negligible Landau fluctuations

simulation (by Marco):
relative width of the mip peak varies between ~15% (for short crystals) to ~10% (for long crystals)

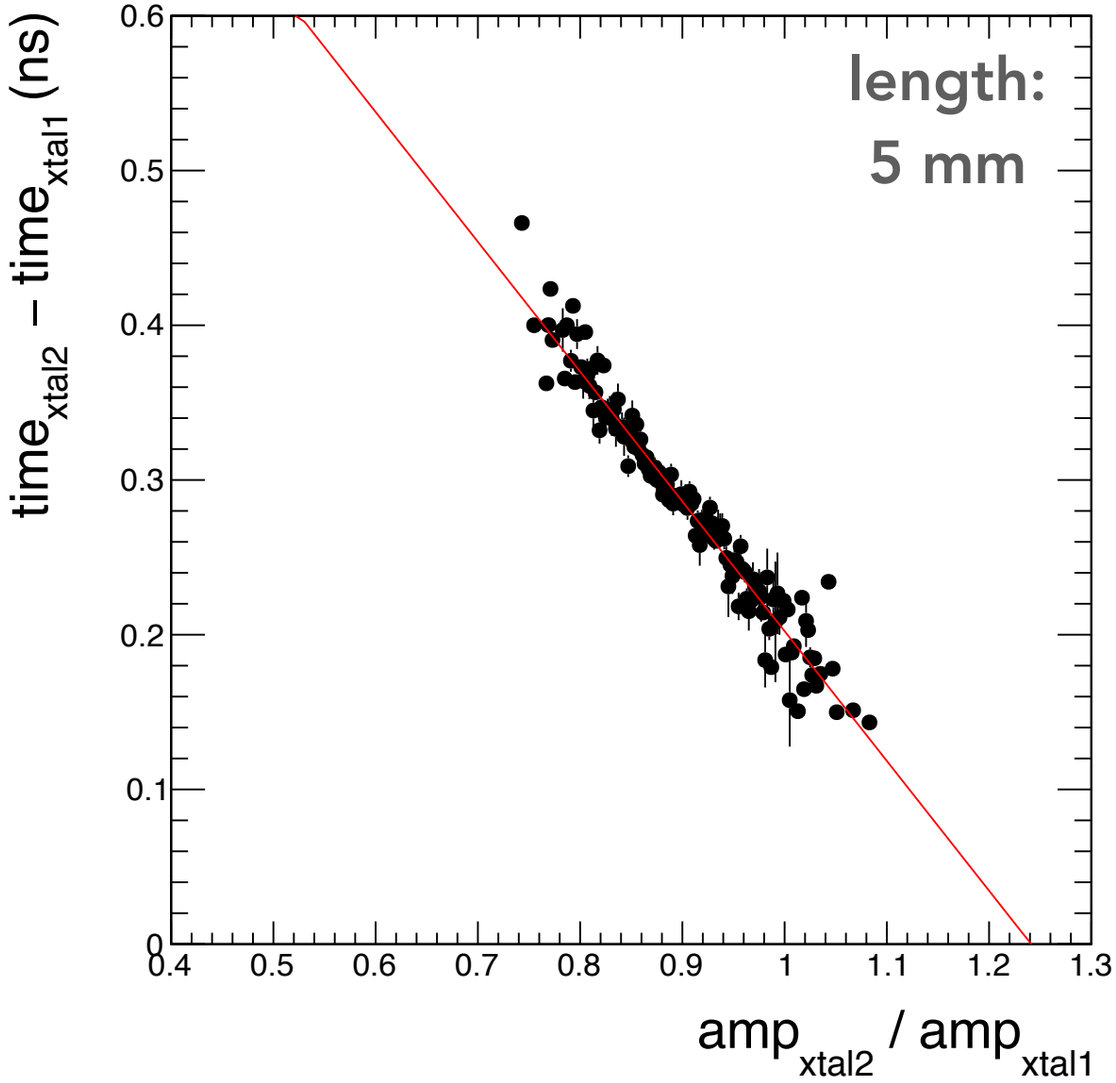
simulation



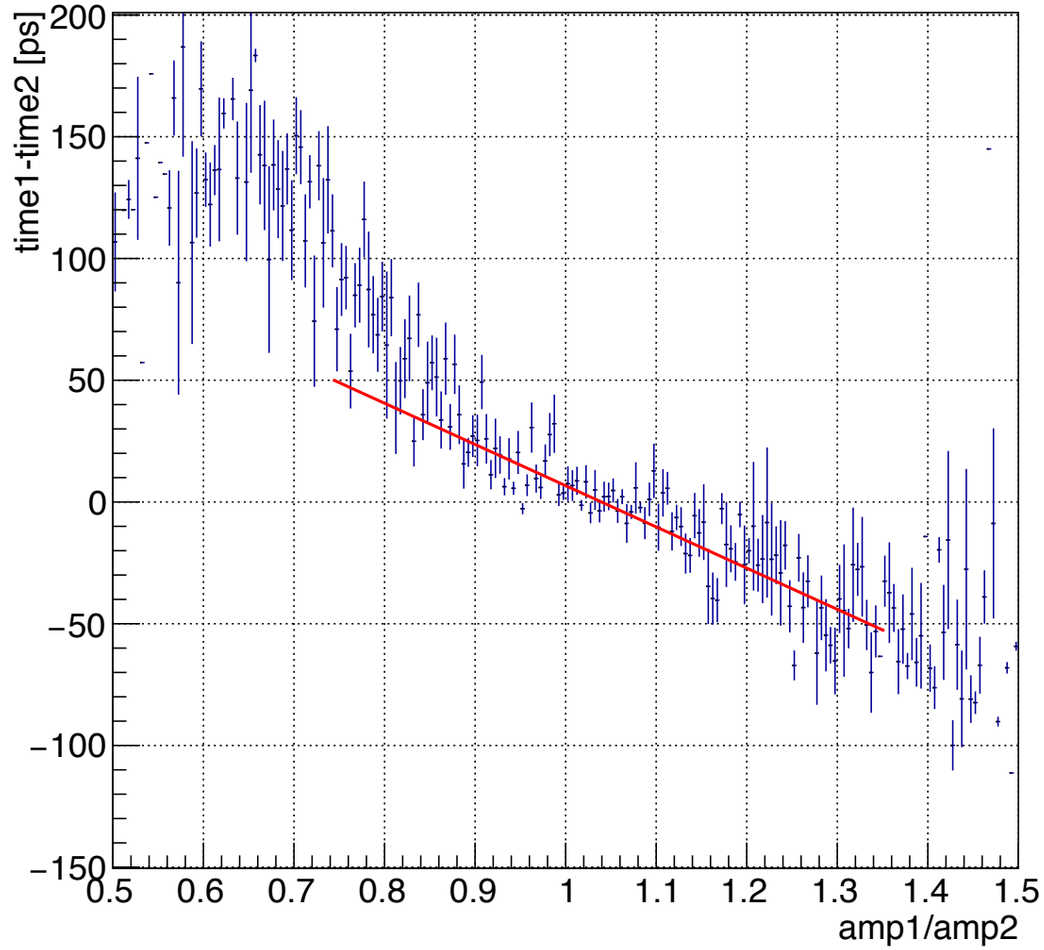
New: observed CTR dependence with signal amplitude

- Amplitude walk effect from NINO leading edge discriminator:
  - dependence maximized using **amp_{xtal2} / amp_{xtal1} ratio**

data



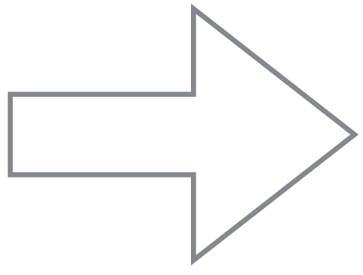
simulation

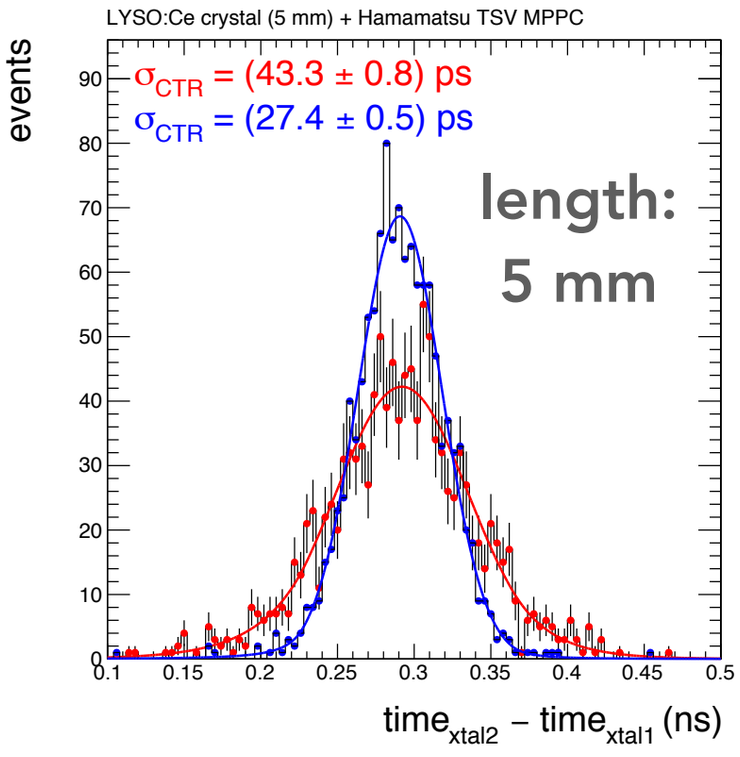


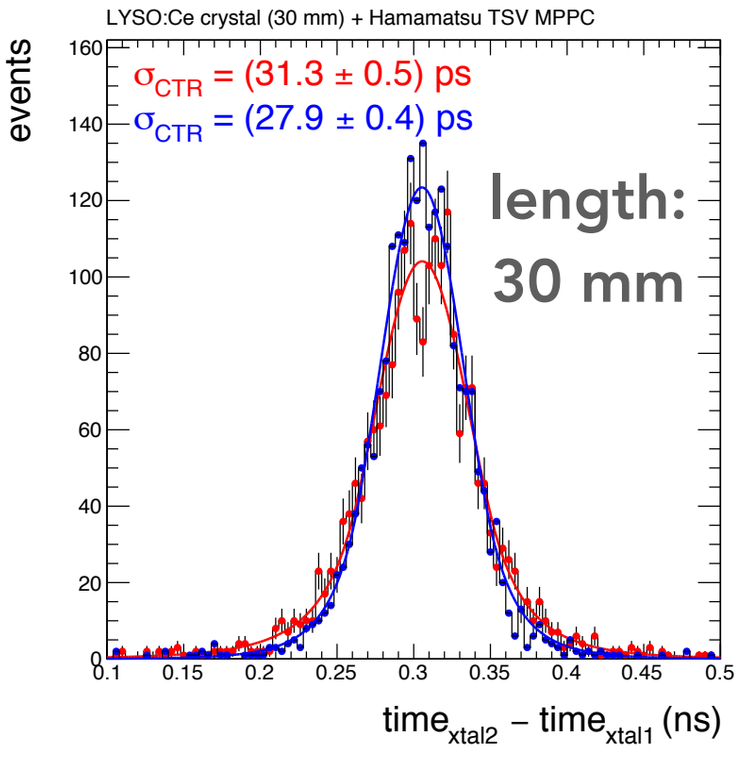
New: observed CTR dependence with signal amplitude

- Amplitude walk effect from NINO leading edge discriminator:
  - dependence maximized using **amp_{xtal2} / amp_{xtal1} ratio**

- Can **compute correction** and apply it to the measured CTR





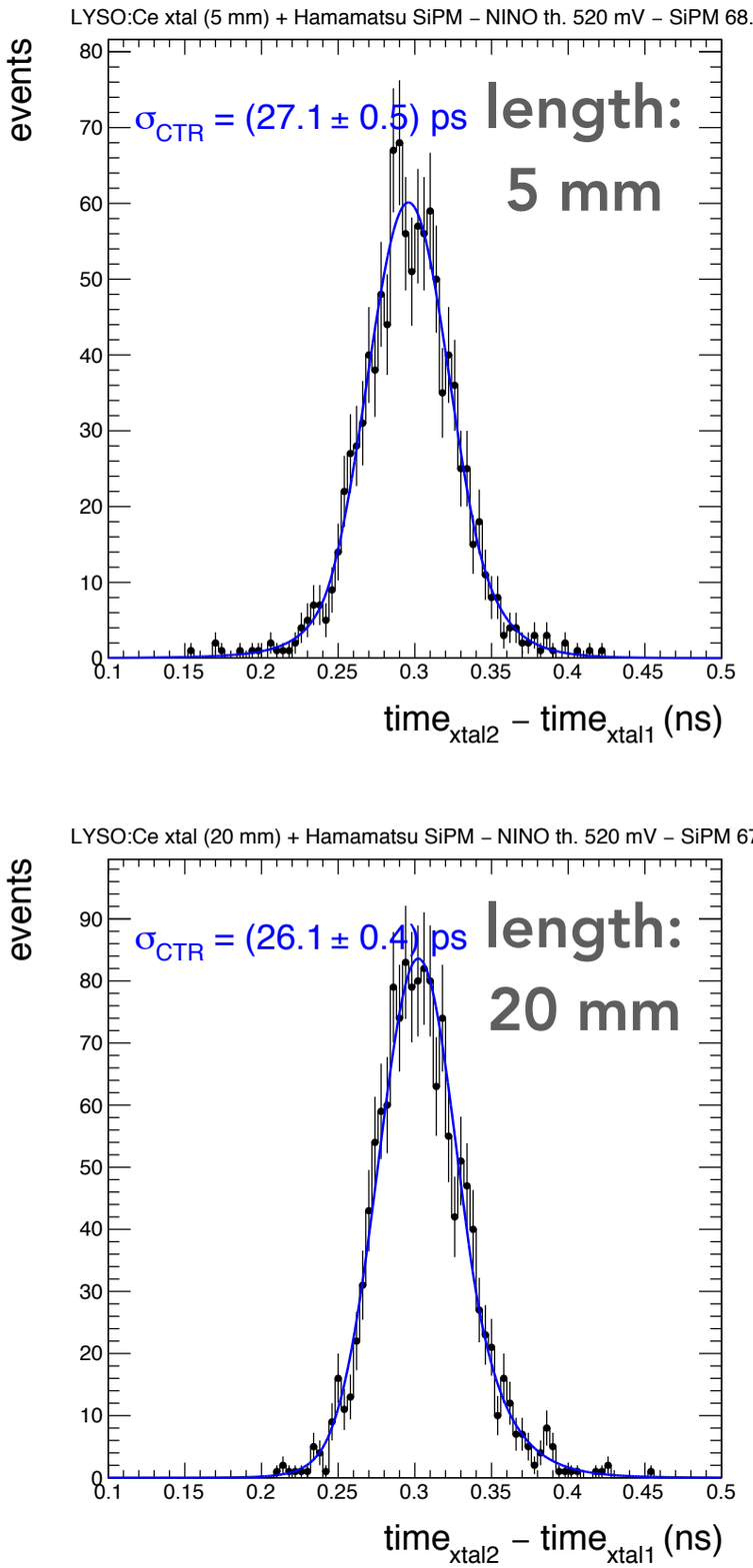


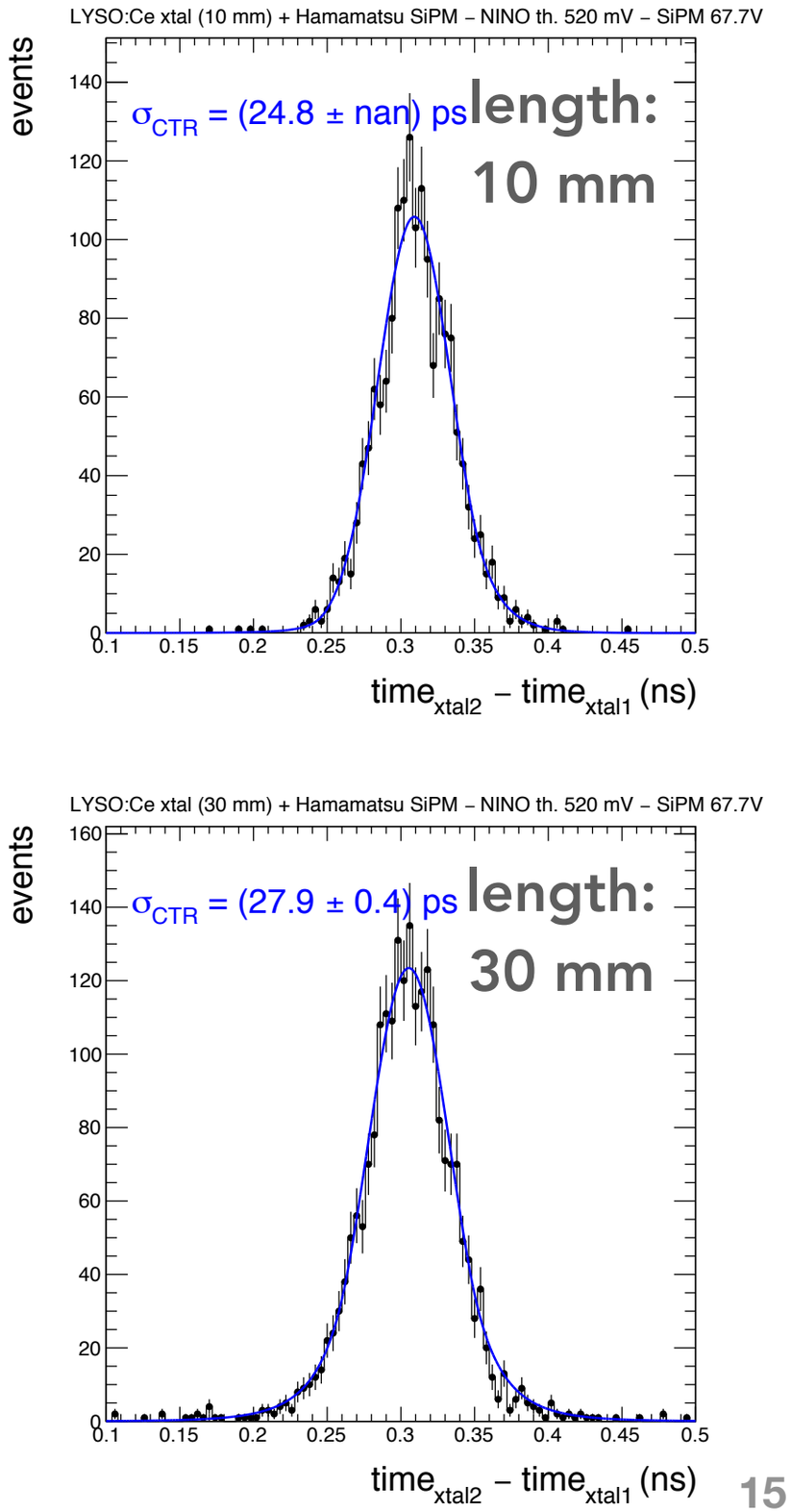
LYSO:Ce + Hamamatsu TSV SiPM timing measurements - **Amplitude walk correction**

- We measure **σ_{CTR} ~ 26 ps** for all crystal lengths

- This means (assuming the two crystals are the same)

  σ_{single} ~ 18 ps

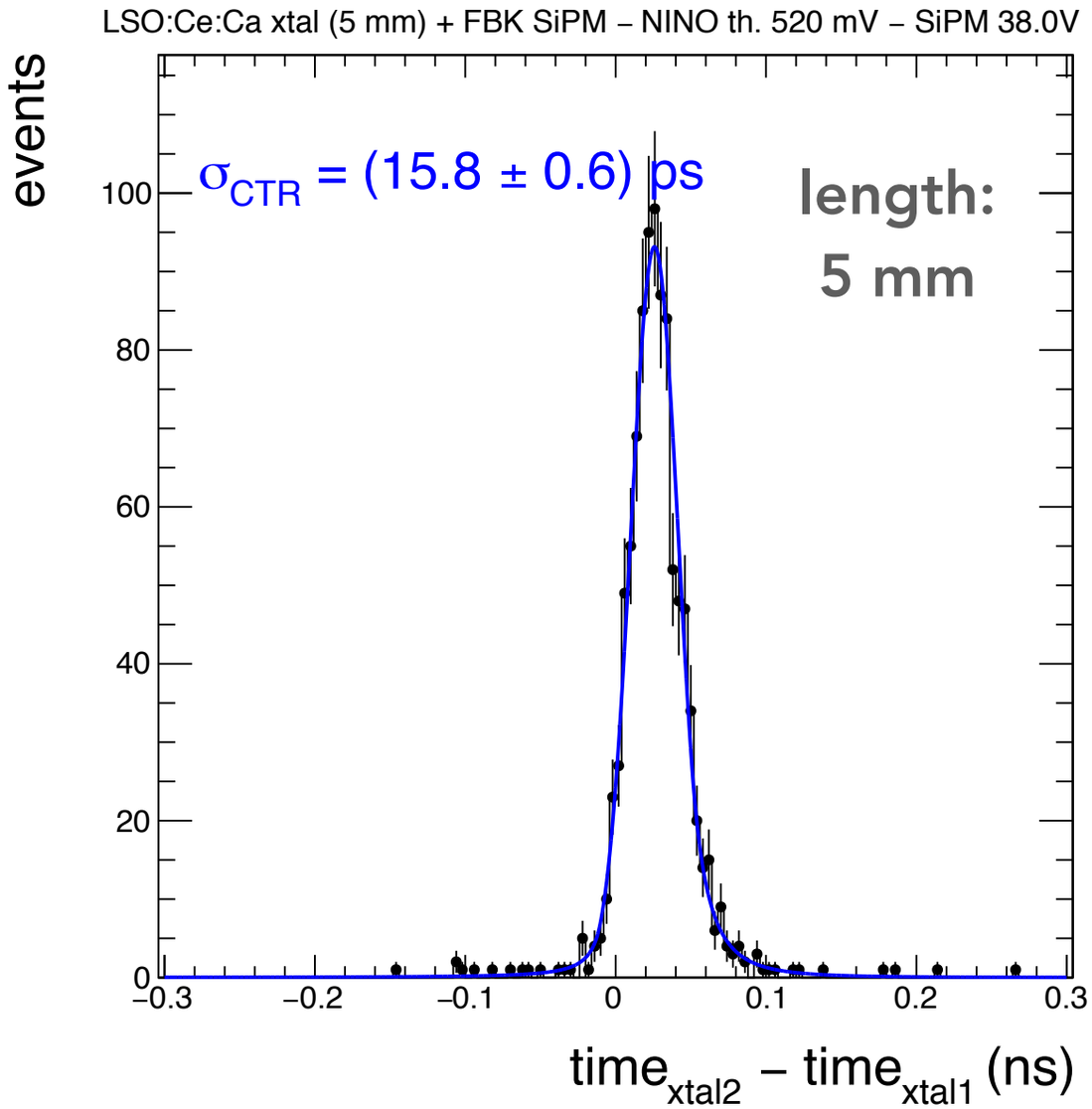




LSO:Ce:Ca + FBK NUV SiPM timing measurements - **Amplitude walk correction**

- We measure **σ_{CTR} ~ 16 ps** for 5 mm crystals

- This means (assuming the two crystals are the same) **σ_{single} ~ 11 ps**



Conclusions

- **Crystal+SiPM** system (raw — no corrections applied):
  - shows to be **100% efficient** to the passage of mips (by construction)
  - allows for **~32 ps** of CTR with mips and LYSO:Ce + Hamamatsu TSV MPPC
  - allows for **~27 ps** of CTR with mips and LSO:Ce:Ca + FBK SiPM

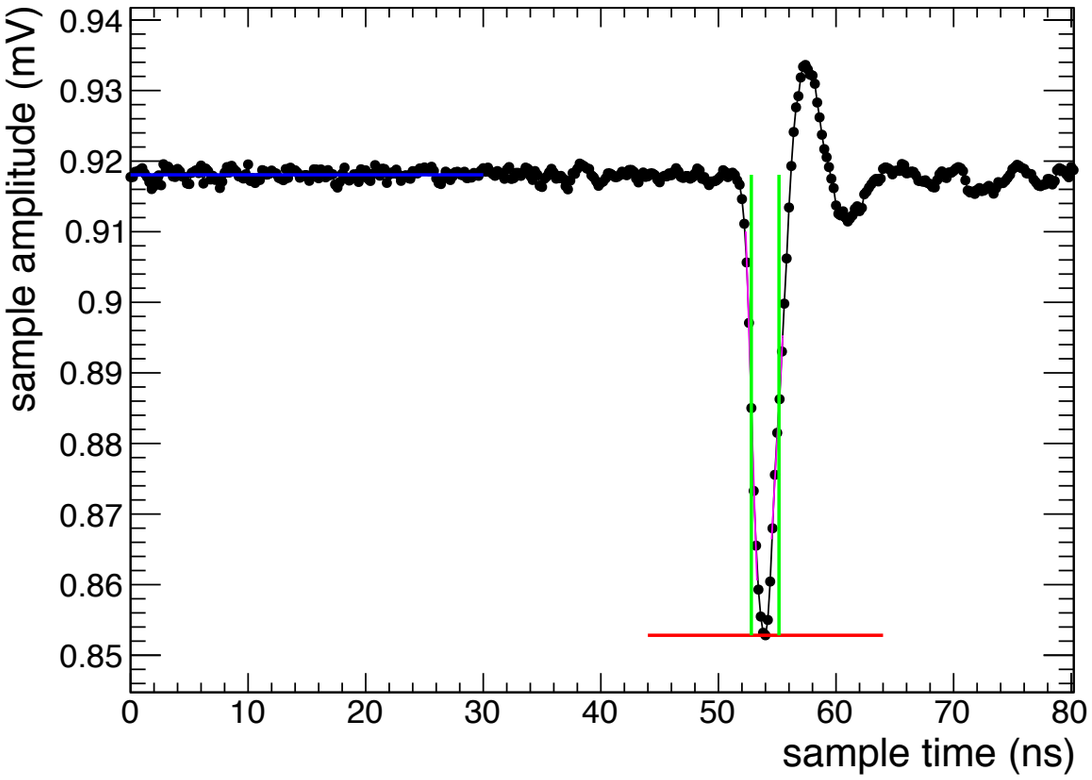
- After **amplitude walk correction**:
  - for LYSO:Ce + Hamamatsu TSV MPPC a roughly constant CTR of **~26 ps** is measured
    - » could be saturating due to noise pickup from long cables used to connect SiPM to NINO
  - for LSO:Ce:Ca + FBK NUV-HD SiPM a CTR of **~16 ps** is measured
    - » measured CTR roughly scales with energy compared to 511 keV gamma (**16 ps** vs. **36 ps /√(5 MeV / 511 keV) ~ 12 ps**)

- With LSO:Ce:Ca + FBK NUV-HD + amplitude walk correction, the **timing resolution of the single device is at the level of 11 ps!**

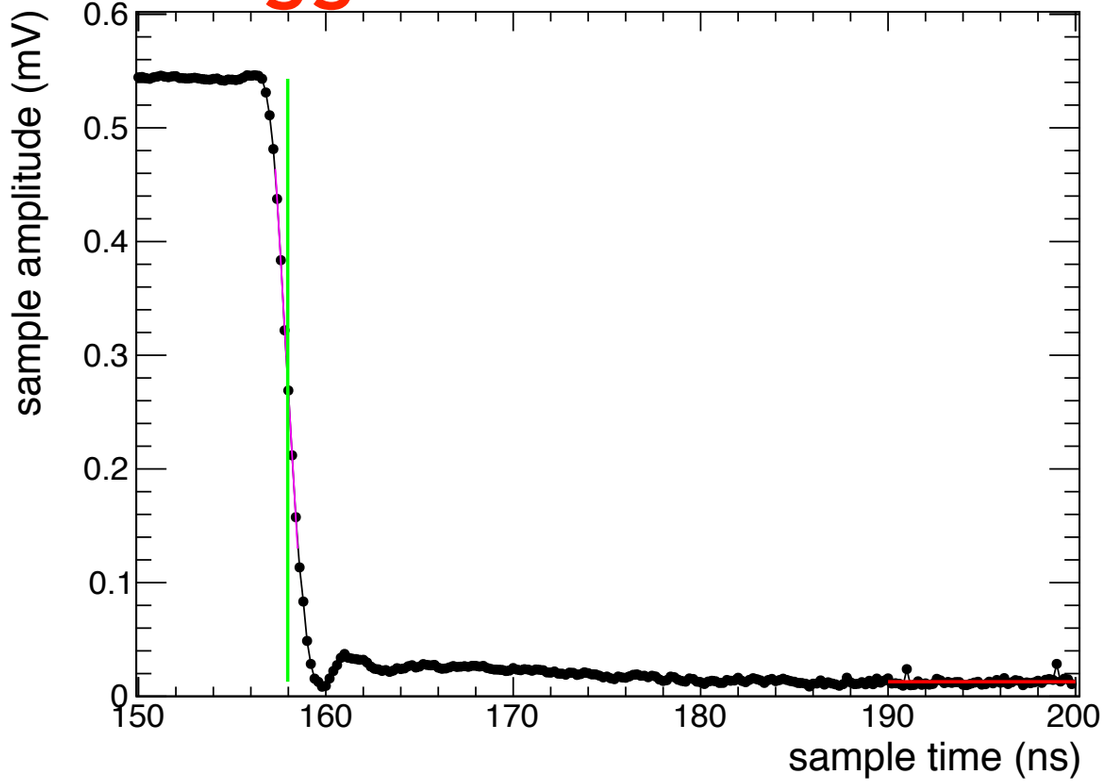
Bonus slides

MCP pulse reconstruction

MCP time information



Trigger time information



- NB: MCP (ch.0) and crystals were on **different channel groups** on the digitizer
  - clock distribution can vary between the two groups
  - use the **digitized trigger information** to correct for this effect