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ENEA C.R. Frascati

FAST DIGITIZING TECHNIQUES APPLIED TO SCINTILLATION DETECTORS

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INTRODUCTION

NEUTRON/GAMMA DETECTION

- organic scintillators (such as NE213 or stilbene), due to their ***n/γ*** pulse shape discrimination properties, are used for neutron (**n**) and gamma-ray (**γ**) detection in mixed ***n/γ*** fields
- applications: fusion devices, accelerators, high energy physics experiments, neutron source metrology

PROBLEM

- need of **high count rate dynamic range WITH n/γ pulse shape discrimination**

SOLUTION

- **fast digitizers** for direct sampling of pulses from scintillator + PMT system

ADVANTAGES

- **post-experiment signal data reprocessing**
- **real-time control applications**

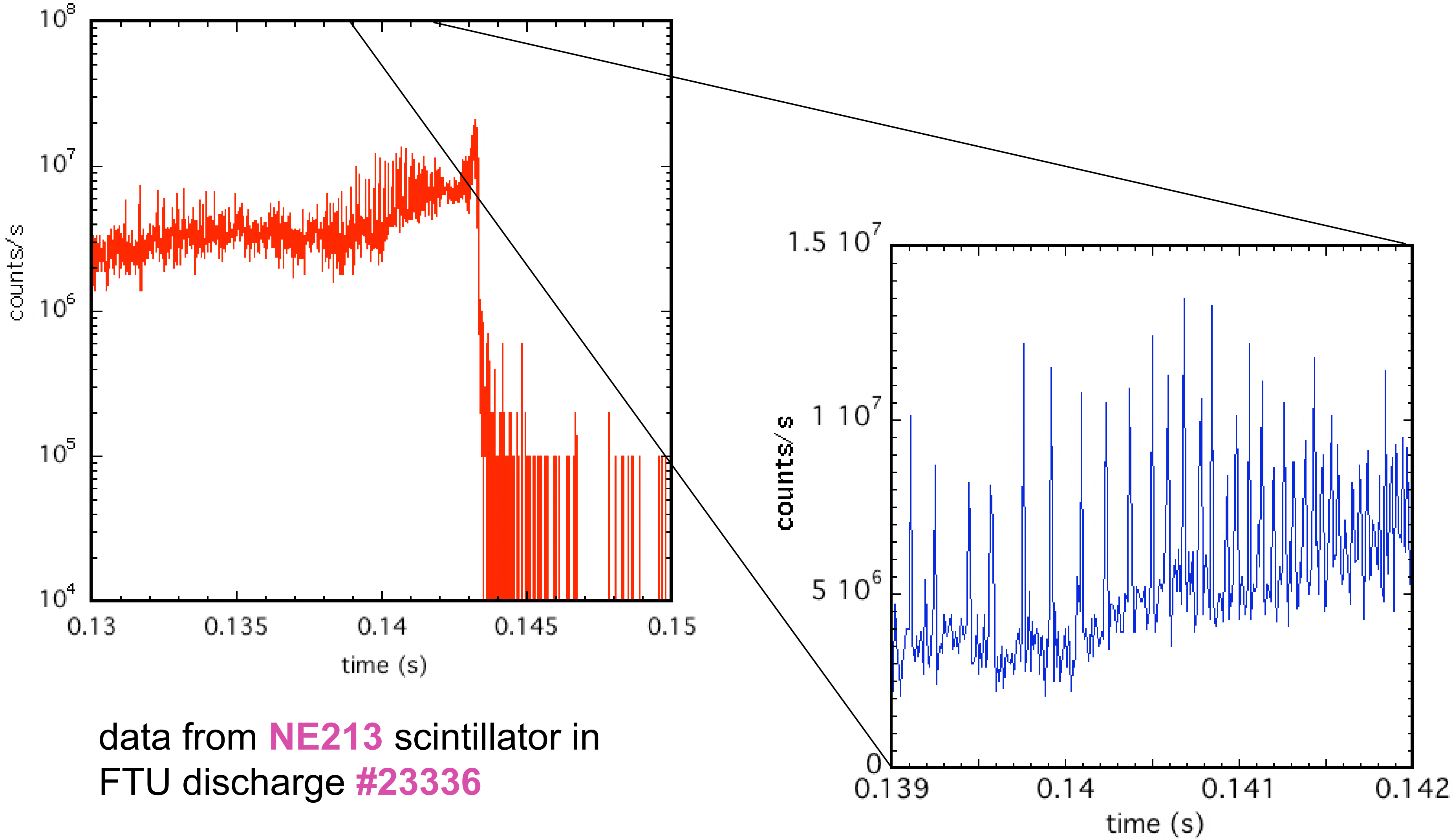
DIGITAL SAMPLING

hardware features

- *digitizer*: A/D transient recorder (Stratecic Test model UF.3025)
- *sampling*: **12-bit 200 MHz** (1 channel) or **12-bit 100 MHz** (2 channels)
- *memory*: **256 MSamples** on board
- *bus:* **PCI**
- *computer*: ADM Athlon XP **1.8 GHz** / **512 MB RAM**
- direct digitization of photomultiplier (PMT) anode signal
- *coupling*: **DC**
- *input impedence*: **50 Ohm** / **1 MOhm**
- *trigger input*: **standard TTL**
- *input signal*: up to **± 5 V**

HIGH COUNT RATE

radiation emission related to fast plasma phaenomena from Frascati Tokamak Upgrade (FTU)

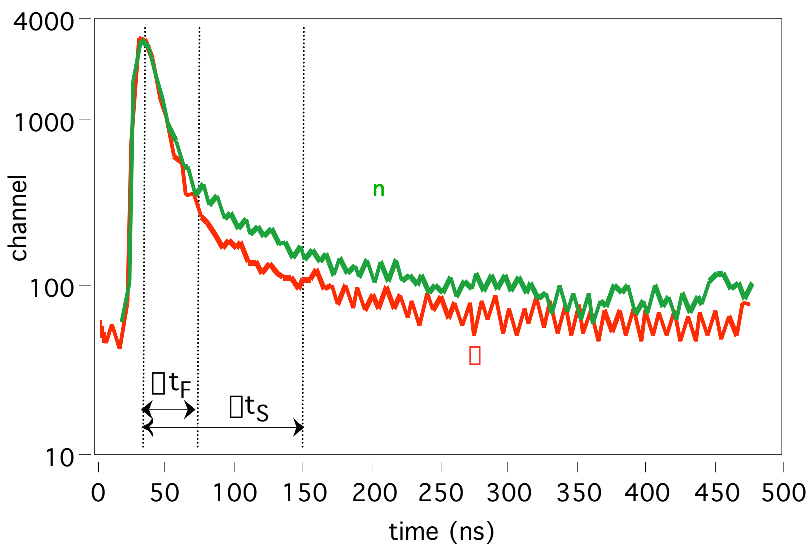


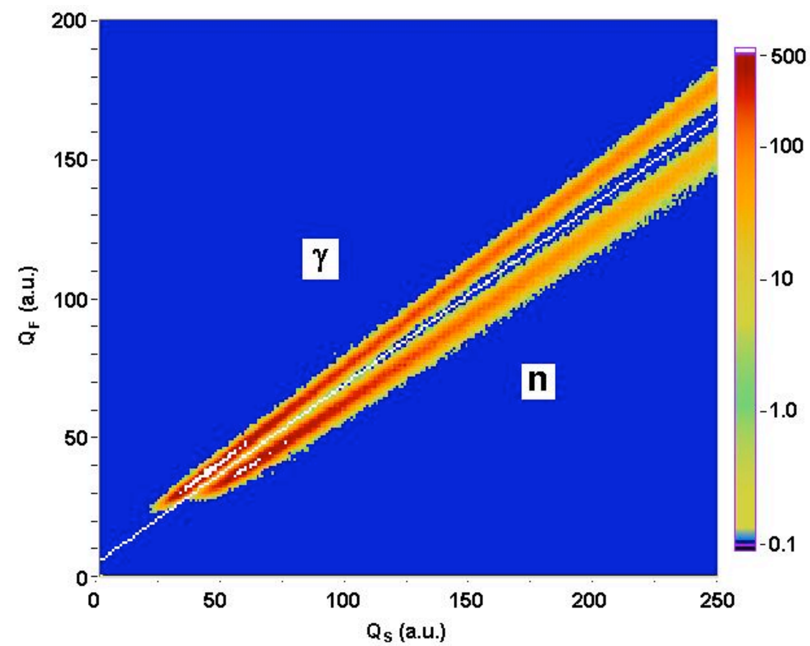
data from **NE213** scintillator in
FTU discharge **#23336**

DIGITAL PULSE SHAPE DISCRIMINATION

analysis of digitized pulses through dedicated LabVIEW software

- reduction of low frequency noise
- pulse peak identification above preset threshold
- pulse re-organization in windows of fixed length (range: **32÷96 samples**)
- pile-up identification and evaluation of **single** and **pile-up** count rates





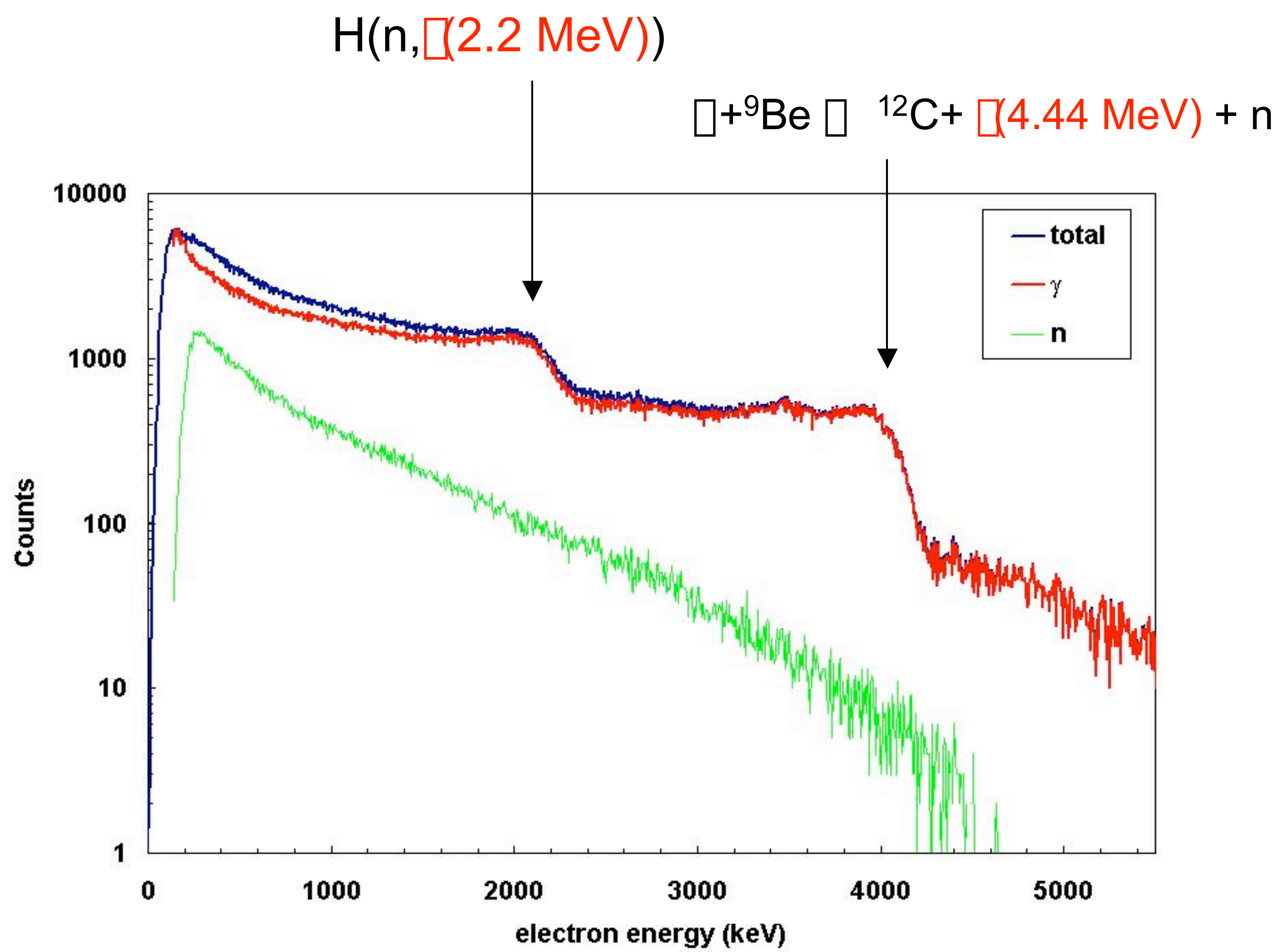
n/γ discrimination using the **charge comparison method**: each pulse is integrated in two time windows starting from the peak of the pulse (typically Δt_F =25 ns and Δt_S =120 ns). Q_S/Q_F ratio (charges integrated during Δt_S and Δt_F) provides the indication whether a neutron or a γ-ray event has taken place.

PULSE HEIGHT ANALYSIS

simultaneous n and γ pulse height spectra

- each pulse is integrated in a time window lasting 150 ns ÷ 325 ns from the beginning of the pulse

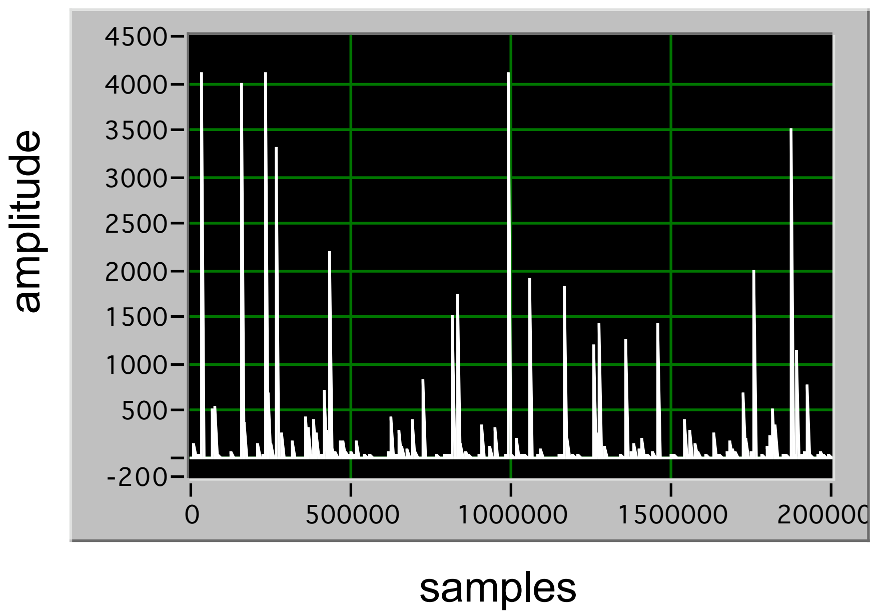
stilbene scintillator:
pulse height spectra from AmBe source in polyethylene shielding



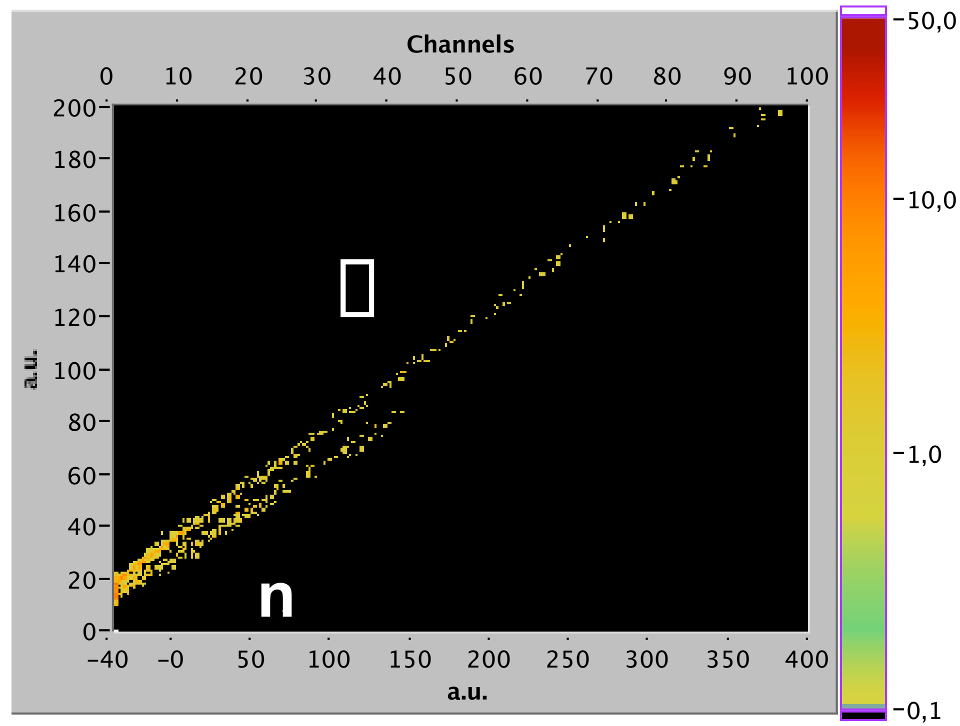
CONTINUOUS ACQUISITION

256 MSamples on board memory allows continuous acquisition for a total time duration ***~1.3 s***

- all pulses are acquired regardless of amplitude
- full pulse processing via software



detail of 1 ms of train of pulses

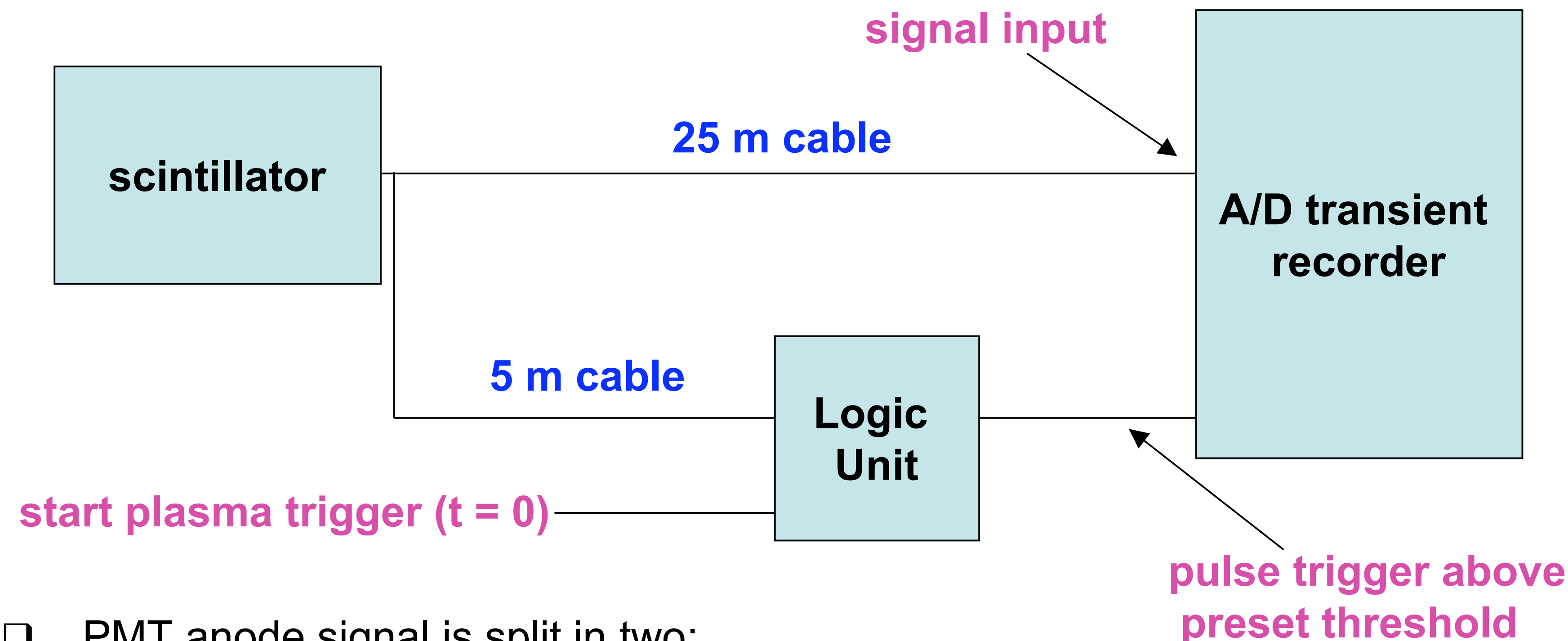


n/□separation

FTU deuterium plasma discharge **#25536**

NON-CONTINUOUS ACQUISITION

for acquisitions ***over 1.3 s*** *alternative scheme in which only triggered pulses are acquired for a preset number of samples*



- PMT anode signal is split in two:
  1. for pulse triggering
  2. for pulse digital acquisition (*suitably delayed*)

- **pulse trigger** is associated with a **time stamp** marking the beginning of each pulse event.

NON-CONTINUOUS ACQUISITION

main characteristics and options of non-continuous acquisition system

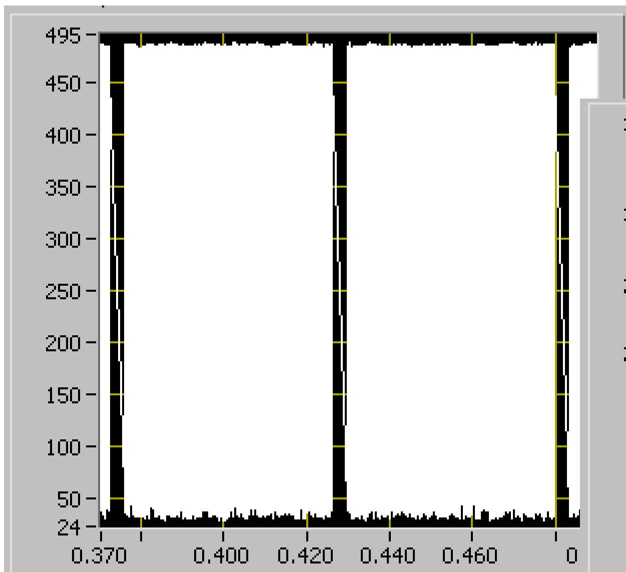
- 12-bit adc @ 200MHz sampling rate
- **time stamp** associated with each pulse
- **multiple recording mode**
  - external trigger signal is used and several triggered pulses can be recorded without restarting the hardware
  - data reading and storage to PC is performed after preset **acquisition buffer** is full
- **non-continuous acquisition**
  - no pulse acquisition during data transfer/storage
  - no loss of pulses (above preset trigger threshold) during **acquisition buffer**
- programmable **acquisition buffer** size and **postrigger count**
- programmable **total acquisition time duration** up to **40 s**

NON-CONTINUOUS ACQUISITION

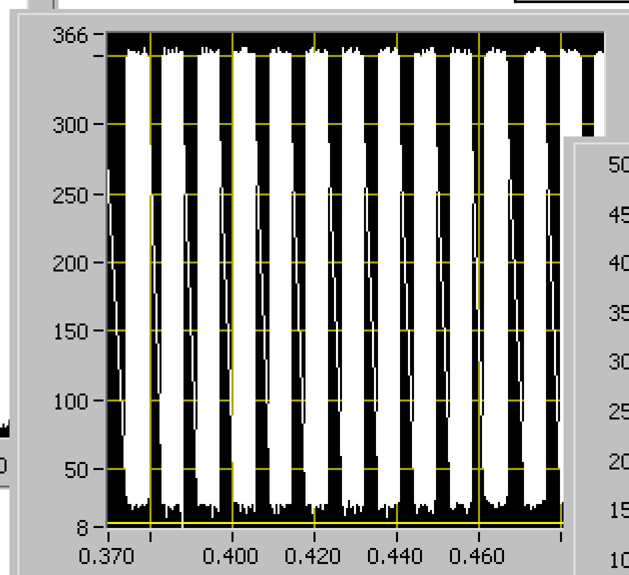
characterization of data transfer/storage duty cycle

- optimum **acquisition buffer** length: 16 kbyte
- tests performed with pulse generator up to 400 kHz pulse rate
- each buffer contains 512 pulses

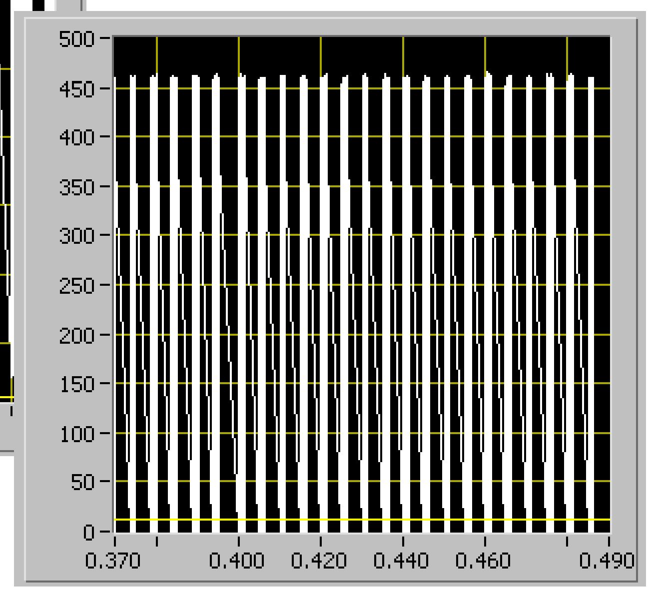
pulse rate (KHz)	acquisition buffer (ms)	transfer/ storage gap (ms)
10	50	4
100	5	4
300	2	4
400	1.5	4



10 kHz



100 kHz

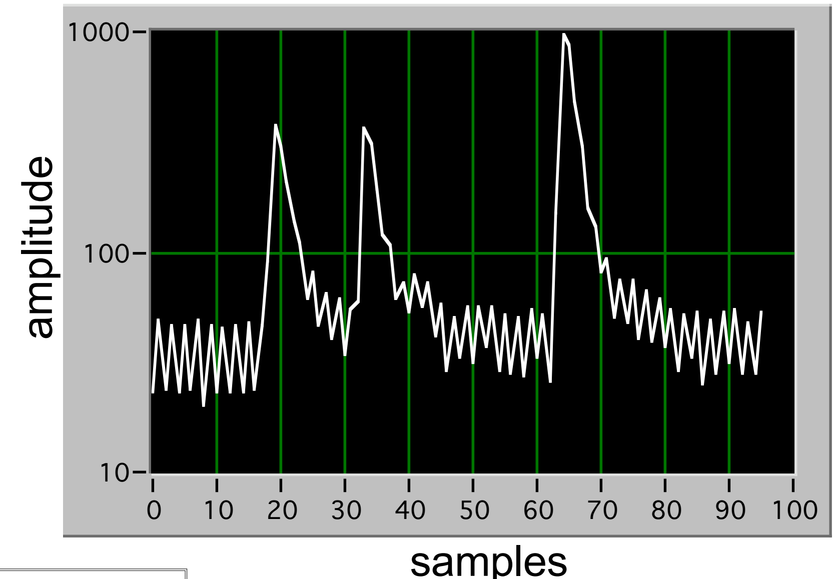


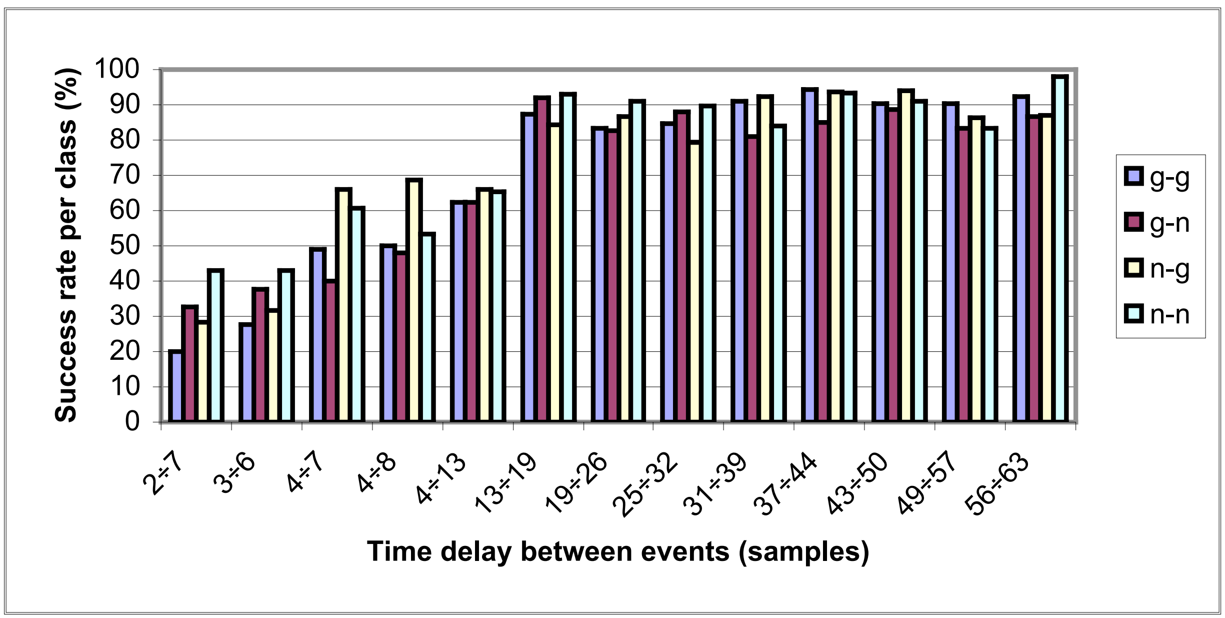
400 kHz

PILE-UP TREATMENT

preliminary work on recognition of neutron and γ pulses in pile-ups

- use of neural network techniques
- test with experimental **n** and **γ** pulses mounted for simulating pile-ups with different time delay
- encouraging results: achievable count rate with **n/γ discrimination ~ 10 MHz**
- needs to be demonstrated for experimental pile-up measurements





1 sample = 5 ns

CONCLUSIONS AND FUTURE ACTIONS

summary

- A/D 200 MHz transient recorders enable simultaneous **neutron/γ-ray spectroscopy** and **counting in high count rate regime (MHz range)** in experimental conditions (tokamak plasmas)

- performance:
  - short duration acquisitions (≤ 1.3 s): no loss of pulses in continuous mode
  - long duration acquisitions (≤ 40 s): partial loss of pulses in non-continuous acquisition mode

- pile-up software treatment investigated

future actions

- improvement of fast transient recorder hardware:
  - extension of lossless acquisition to longer time (100 s) durations
  - 14-bit resolution

- further software development for data analysis

- application to other types of radiation detectors