

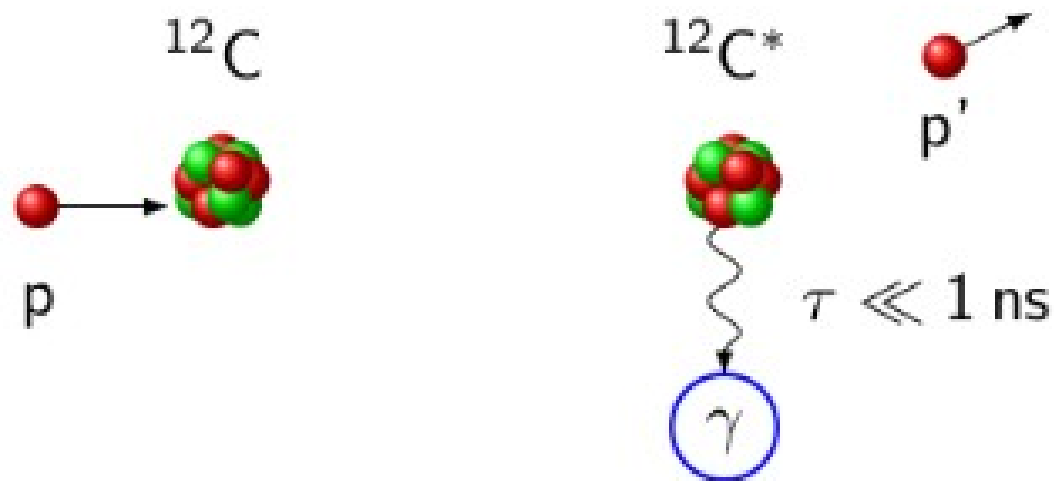


# Operating a fast scintillator coupled to a PMT at 10 Mcps for proton therapy

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# Prompt gamma-rays for proton range verification

- 150 MeV protons used for cancer treatment
- Micropulse frequency: 106 MHz (9.4 ns)
- Protons per micropulse:  $\sim 100$  (2 nA)
- $1e10$  protons / s  $\rightarrow$   $1e9$  gammas / s
- Gamma origin correlated to proton range



# Compact approach

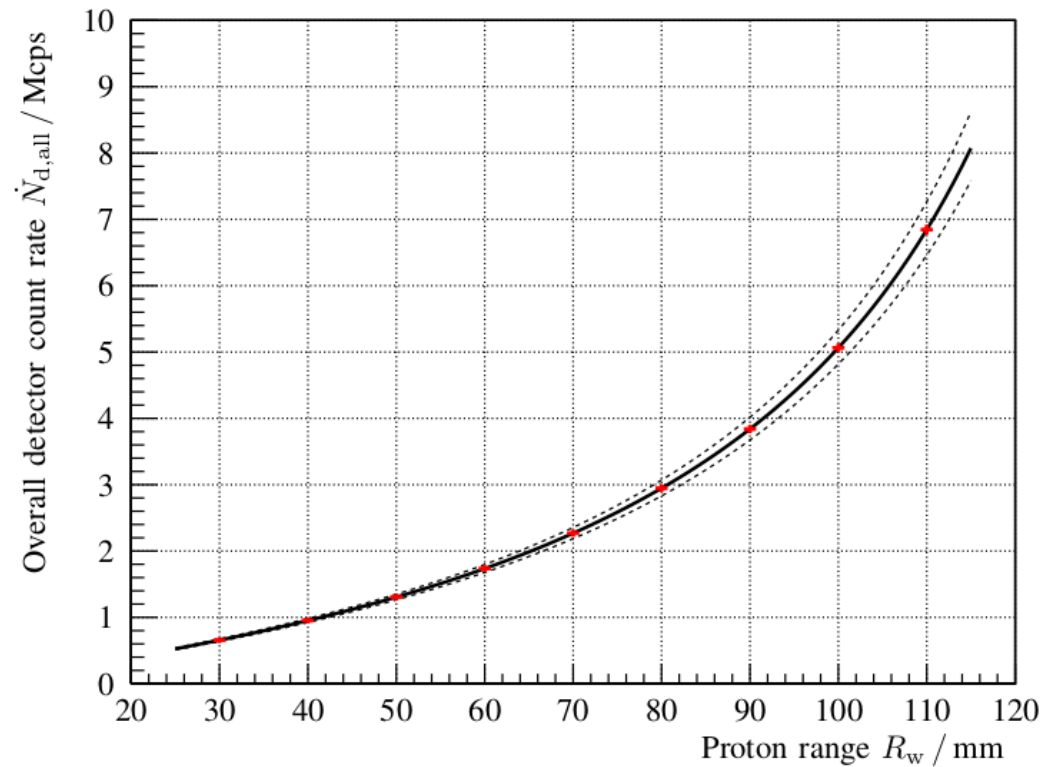
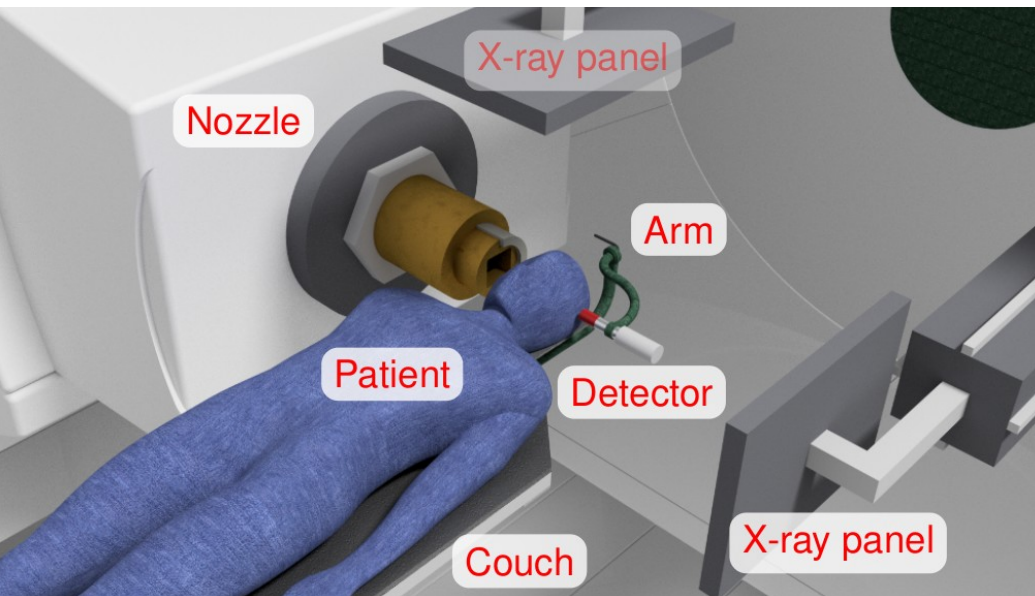
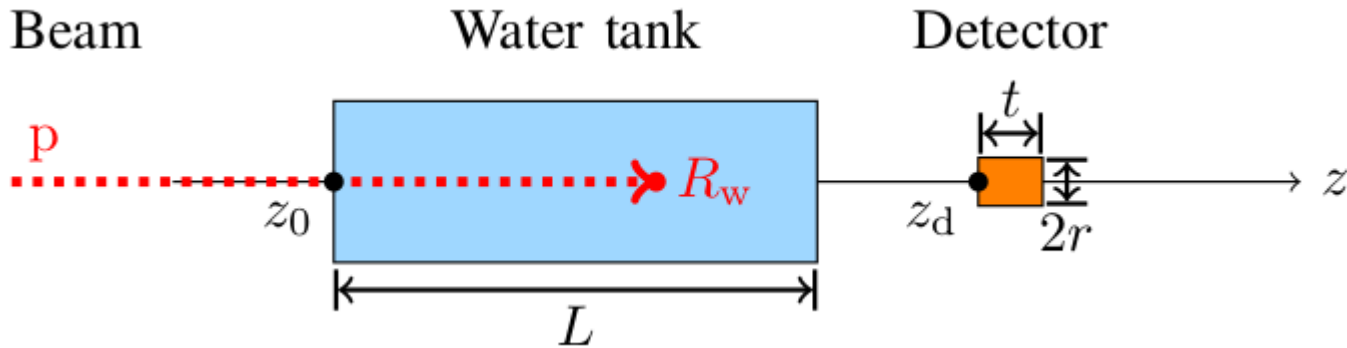
- As small as possible gamma detector to facilitate integration in the treatment room, even if we lose a bit of accuracy.
- <http://dx.doi.org/10.1109/TRPMS.2019.2930362>

## Compact Method for Proton Range Verification Based on Coaxial Prompt Gamma-Ray Monitoring: a Theoretical Study

F. Hueso-González and T. Bortfeld

*Special Issue on Particle Therapy*

# The physics

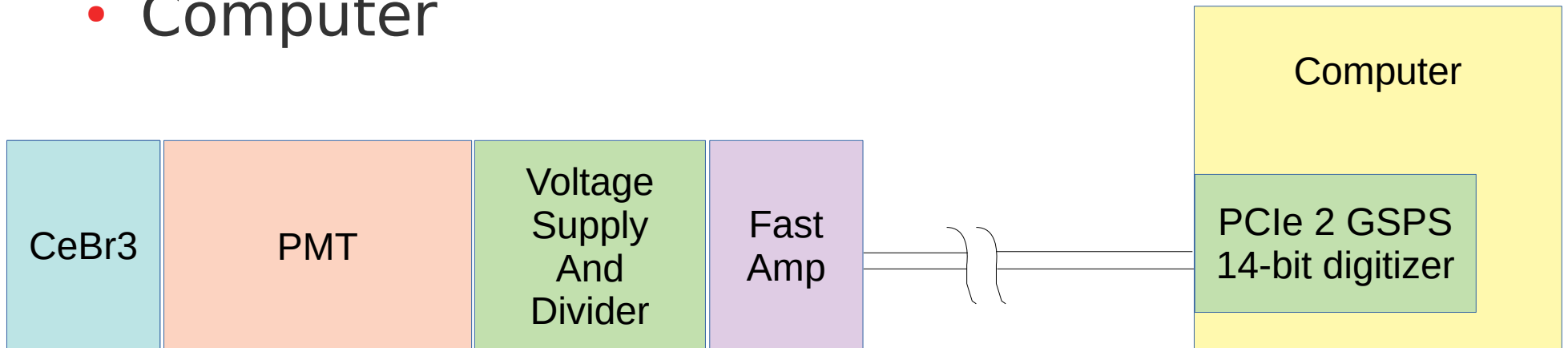


# Clinical conditions

- **$1e9$   $\gamma/s$** , but only during **10 ms** (beam spot)
- It is essential to detect as many of them for detecting treatment delivery errors with statistical significance !
- A fast data acquisition system **without dead time** and **with pile-up recovery** is needed
- A **fast scintillator** and robust PMT **voltage divider** is required for coping with the high count rates up to  **$1e7 / s$**

# Current roadmap

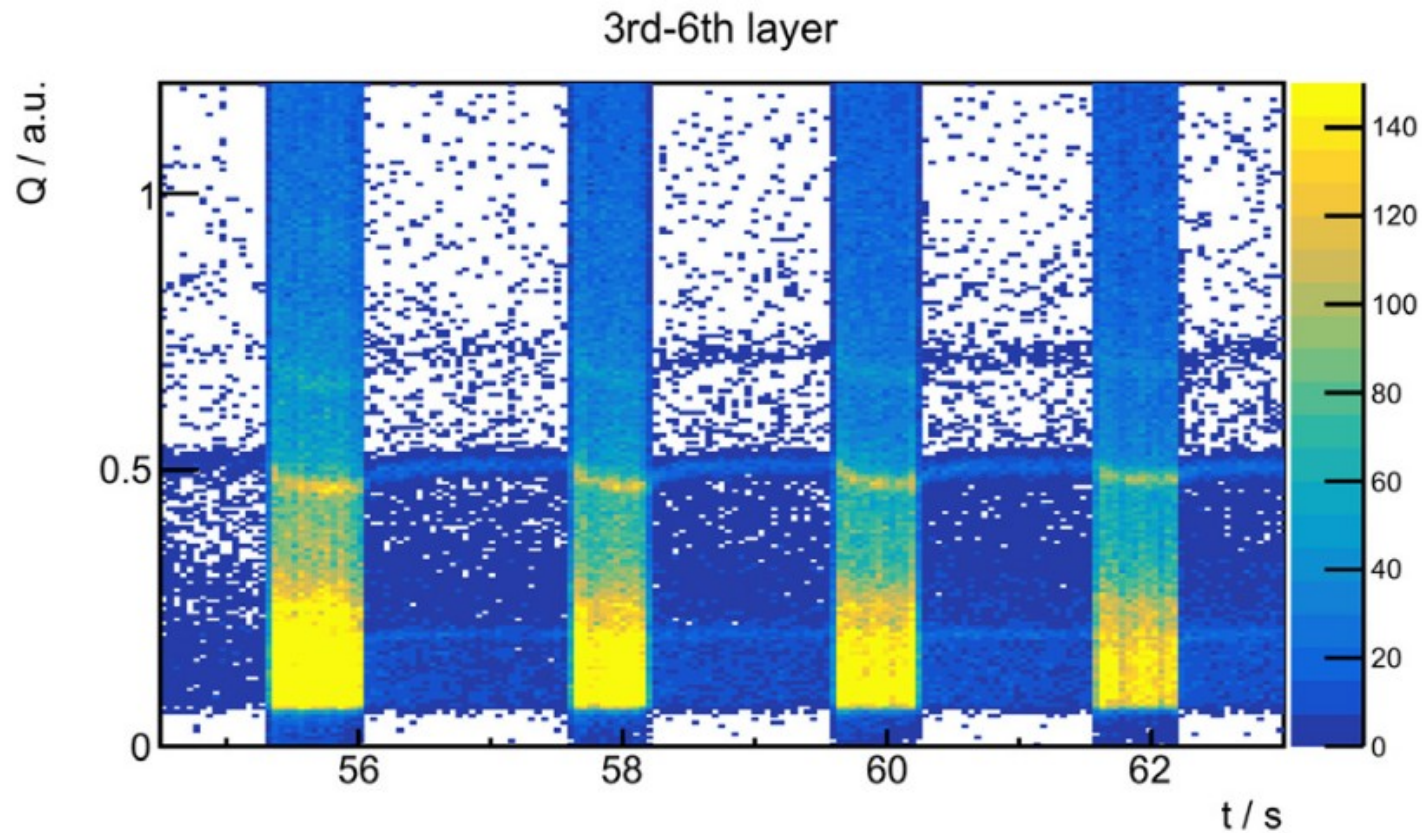
- CeBr3 1" x 1" crystal
- Hamamatsu PMT R13408-100
- Voltage divider circuit
- Fast amplifier
- 14-bit 2 GSPS digitizer PCIe Gen3x8 card
- Computer



# PMT Voltage divider

The problem: PMT gain (inter-dynode voltage) is not constant with load

→ The PMT amplifies 'less' when count rate increases (non-linear response)



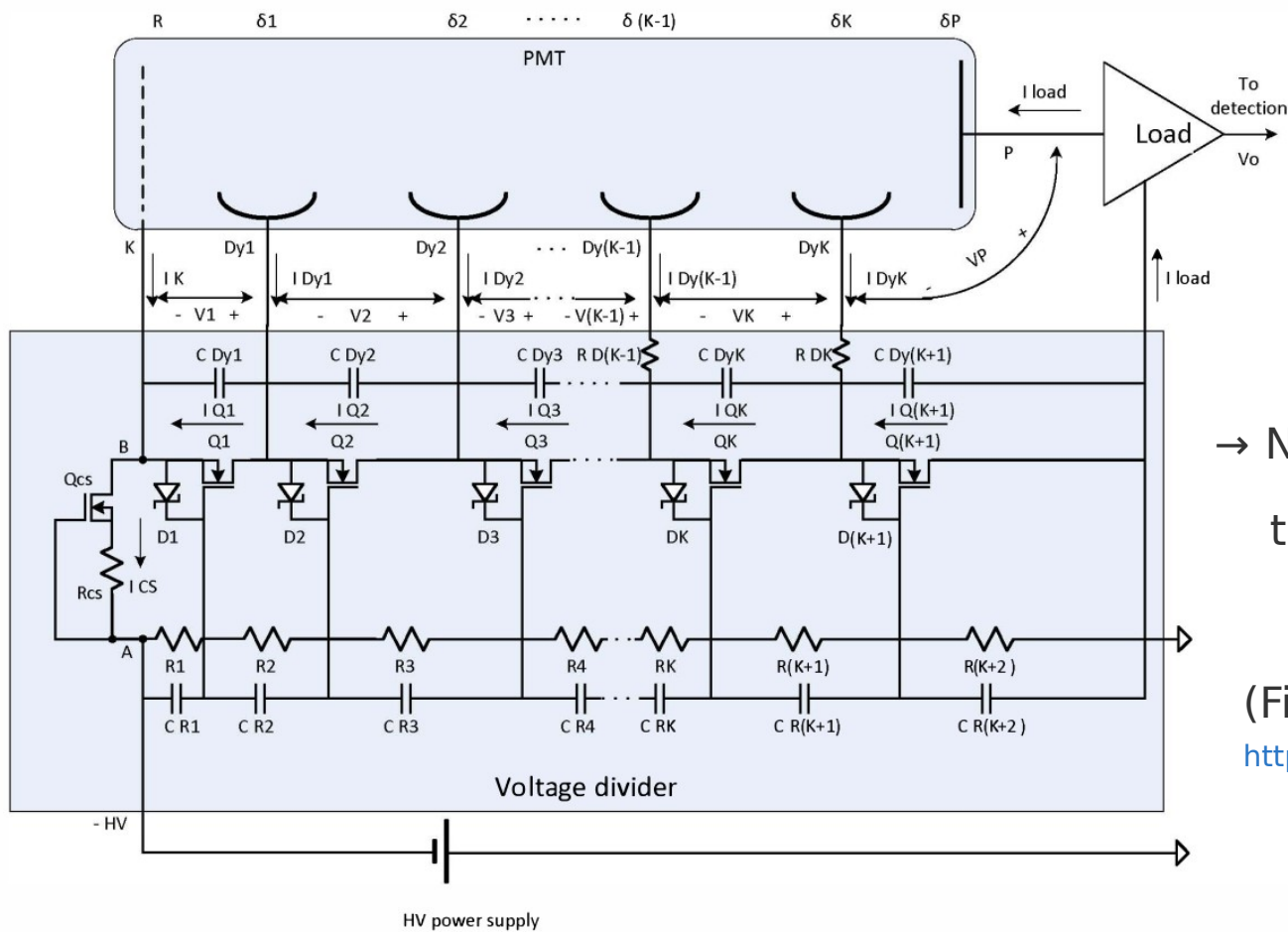
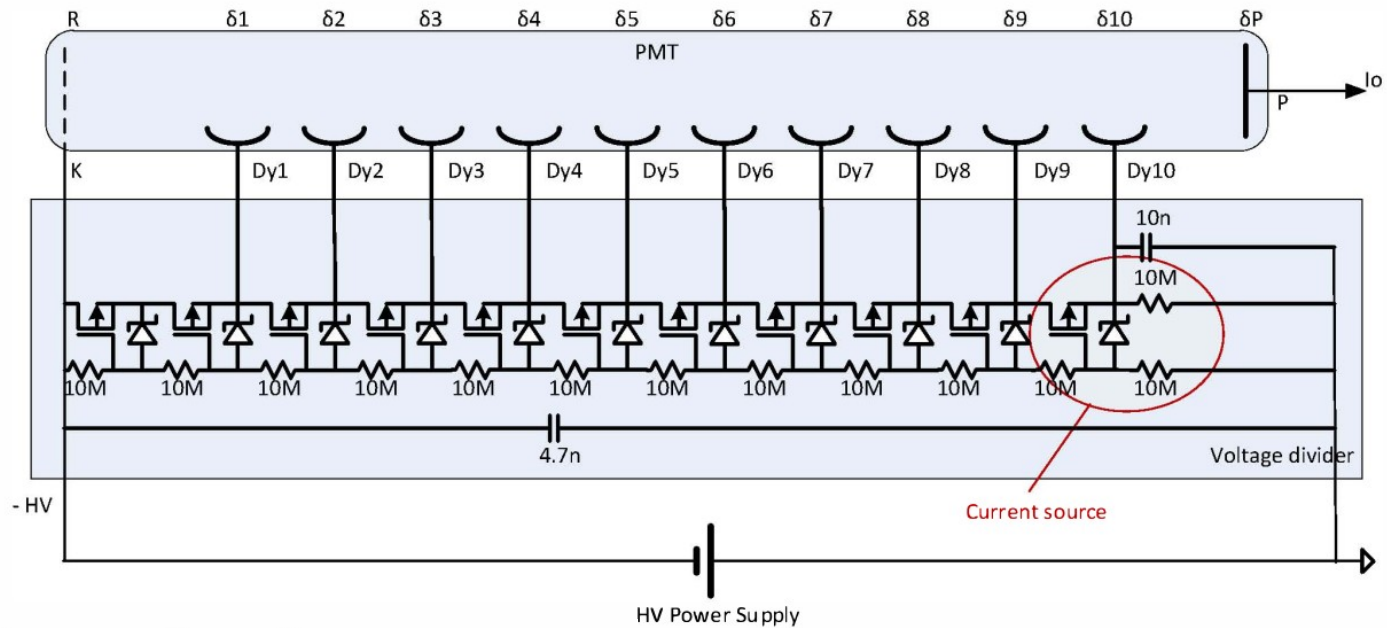
Pausch et al 2020 <https://doi.org/10.1016/j.nima.2018.09.062>



# Divider

Solutions under study:

- ET Enterprises
- Fully Active Voltage Divider



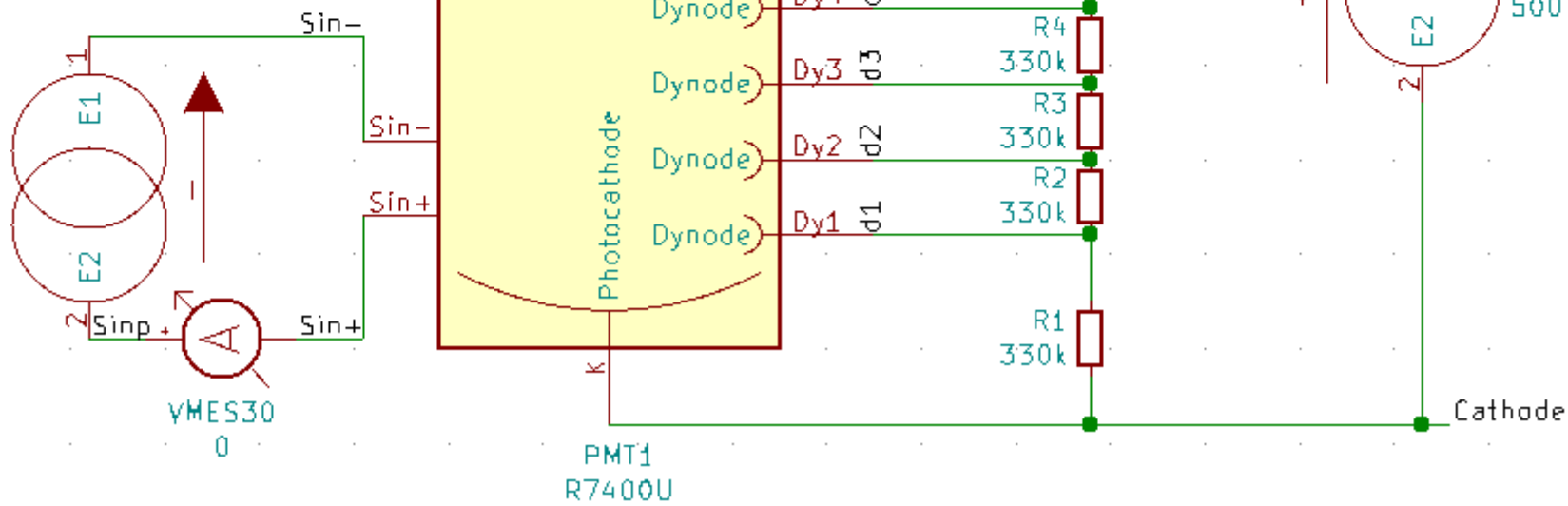
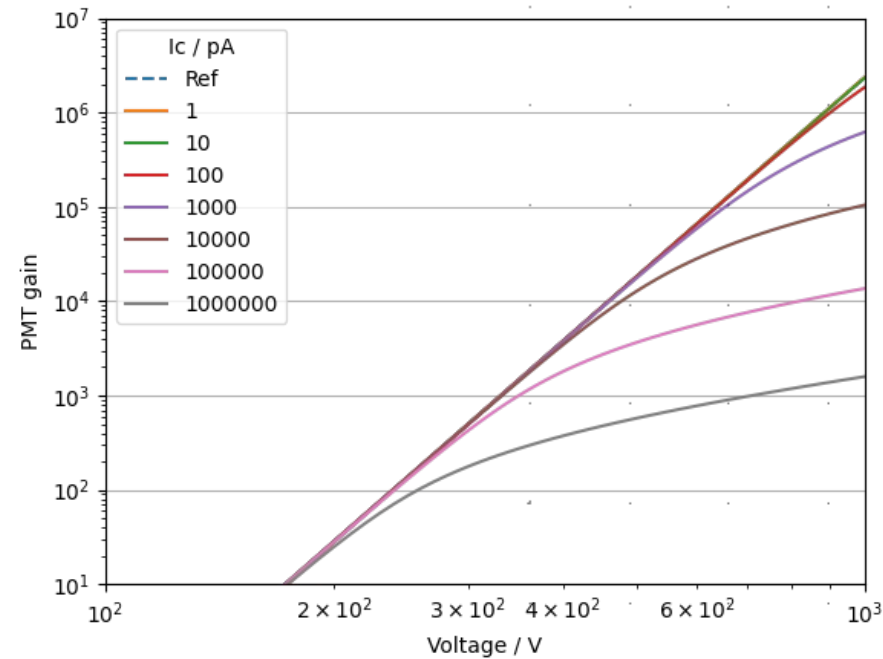
→ NGSPICE simulation / optimization  
to achieve linearity up to 10 Mcps

(Figures from Heifets et al 2012)

<https://patents.google.com/patent/US8921756>

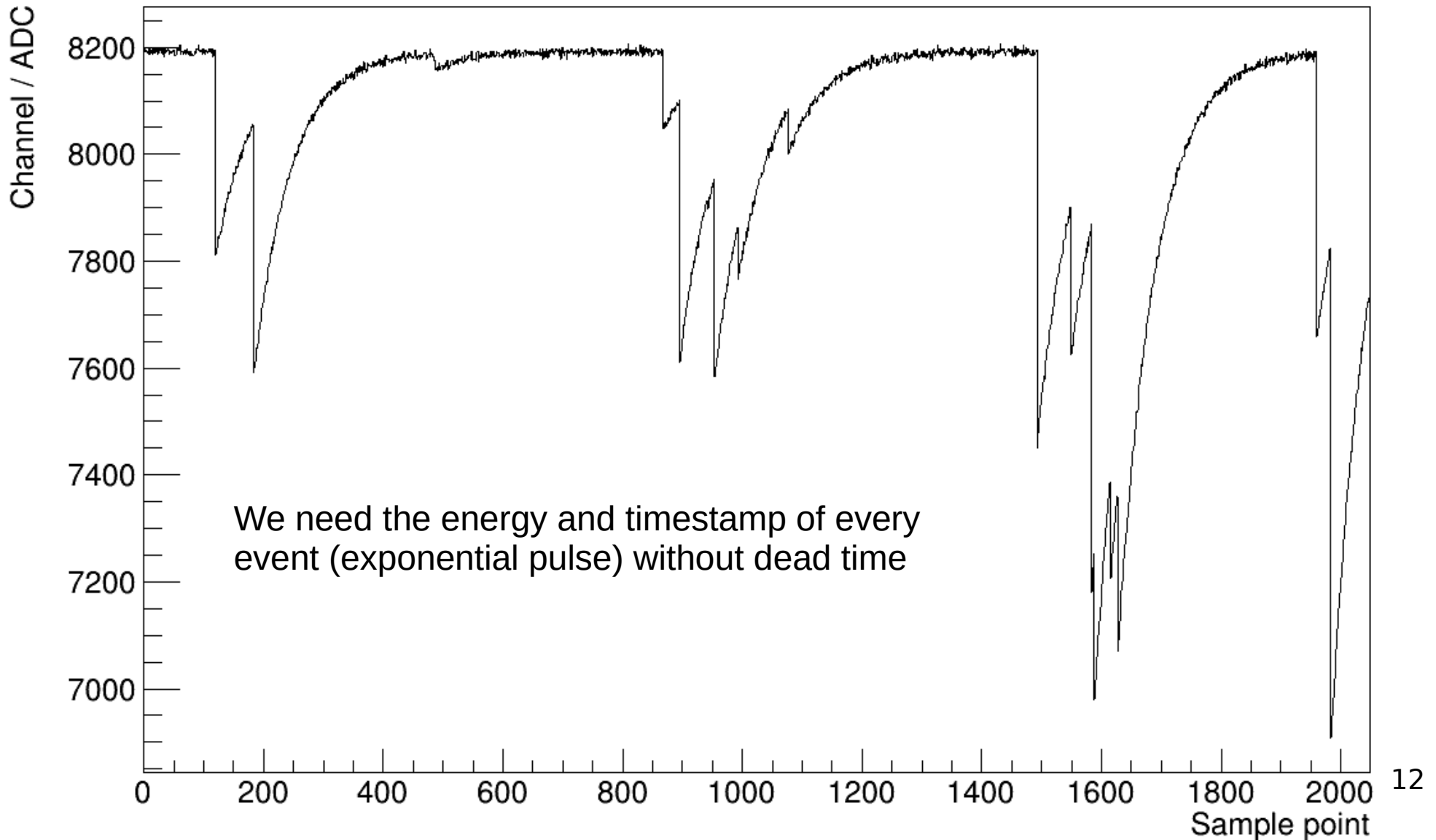


# Divider linearity



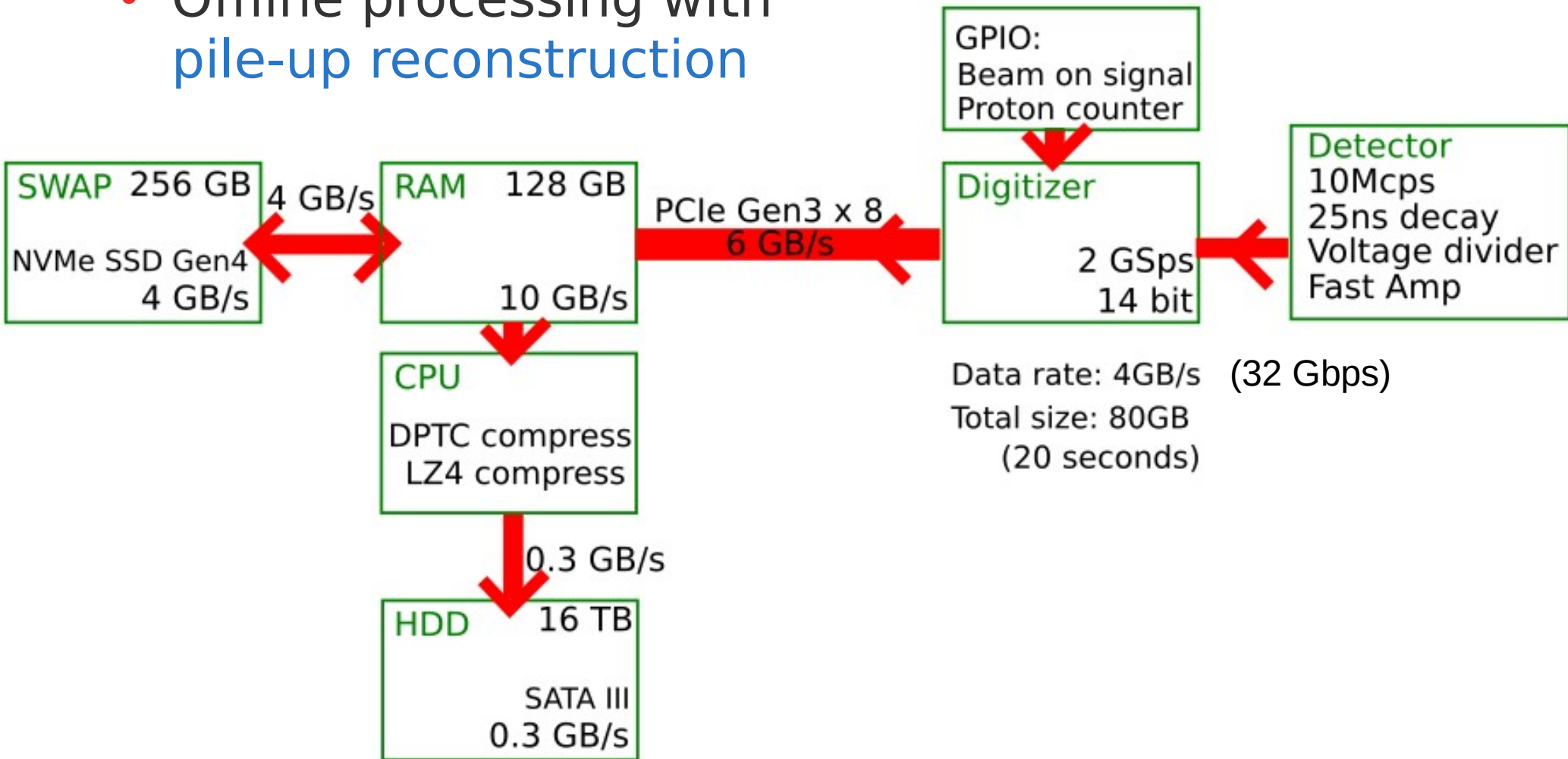
# Digitizer and acquisition

- At 10 Mcps and 2 GSPS, we expect:



# Continuous streaming

- Continuous streaming of full waveform from ring buffer during measurement (~20 s)
- Offline processing with **pile-up reconstruction**



# Outlook

- Detector, PMT → ordered
- Digitizer, Computer → quoting stage
- Voltage divider circuit → under study
- First tests with a GBq source are envisioned

