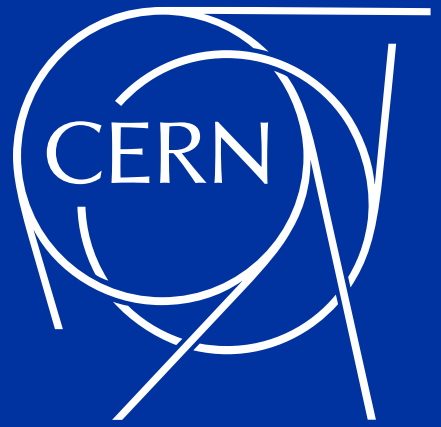
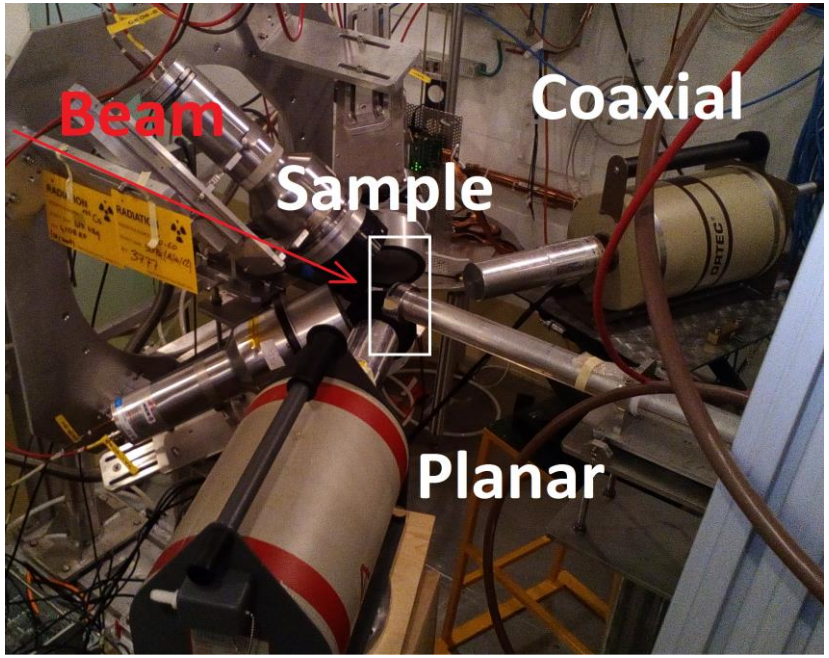


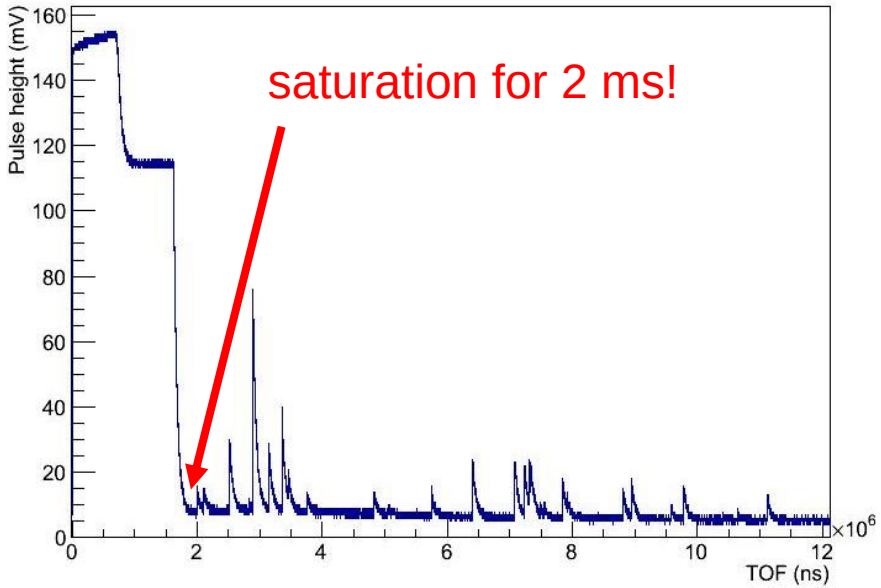
Development of HPGe detectors for (n,xn) measurements at n_TOF

M. Bacak (CERN)
on behalf of the team

Motivation and project description

- **Technology development for prompt gamma ray spectroscopy at n_TOF**
  - NTUA (GR), IFIN-HH (RO), UoI (GR), PSI (CH), …
  - (n,n‘), (n,2n), (n,xg), fission g-rays, …
  - 4 Tests (2012-2017) with commercial detectors
- **Principal goal: development of HPGe electronics permitting such measurements at n_TOF EAR1**
  - n_TOF EAR1 @ ~185 m flight path
    ~$3x10^5$ n/pulse (~$6x10^4$ n/s) for E_n = 1-100 MeV (1.4-14 μs TOF)
  - Full waveform digitization for post processing
  - **Challenge**: **intense gamma flash** blinding the detector for milliseconds (= ~eV)
    - Energy deposition of several GeV/100ns
    - Modification of the preamp circuit to allow gating the flash



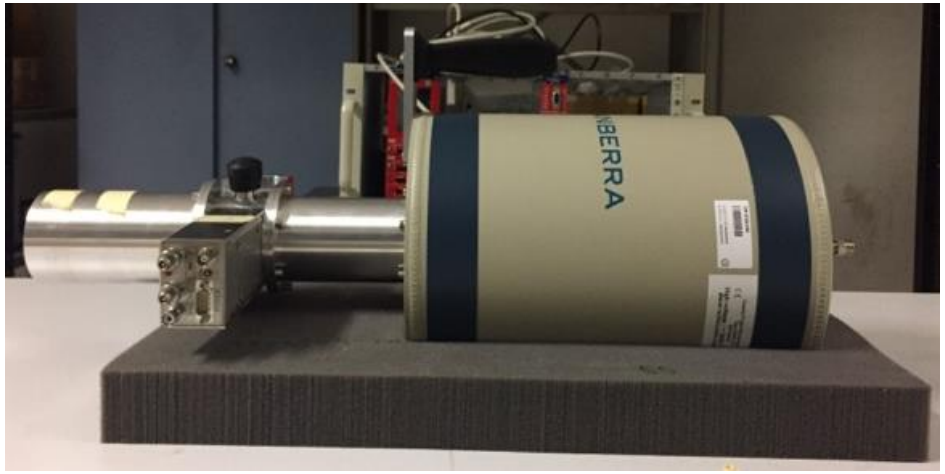


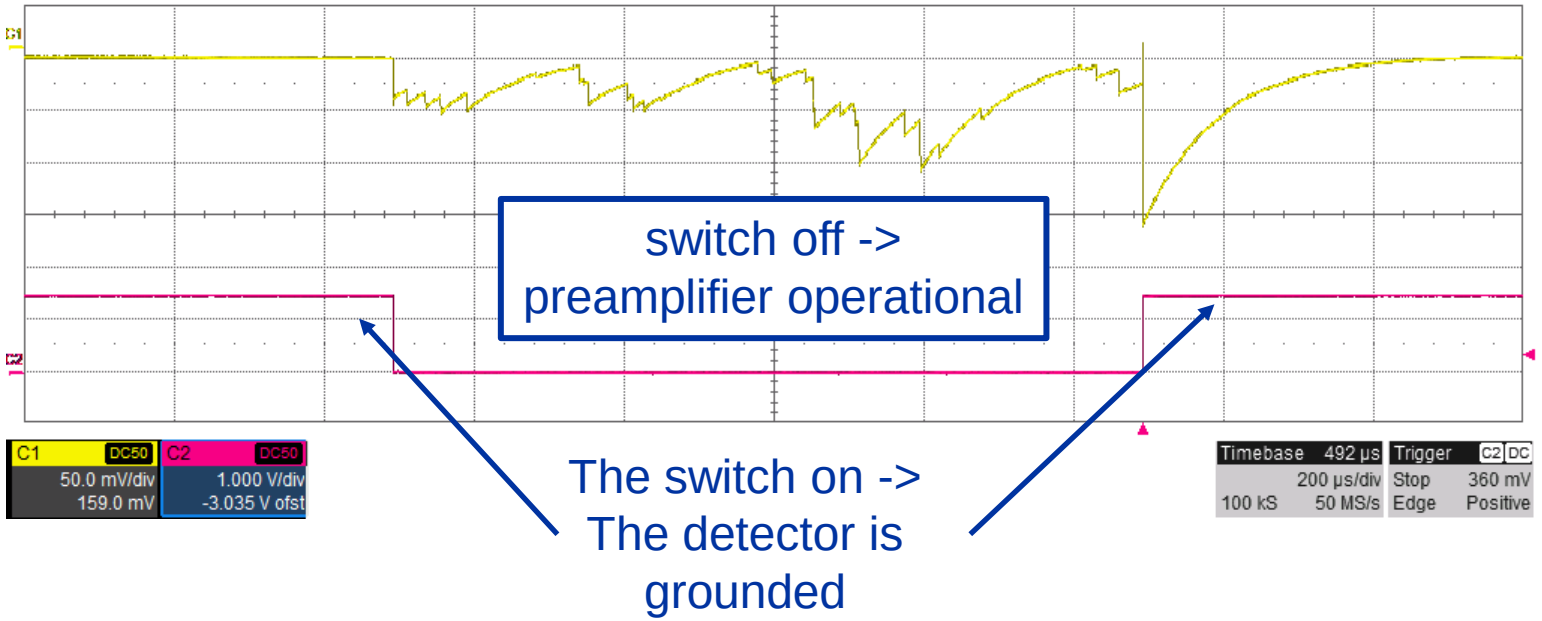
Development & first tests I

- **Detector developed with Mirion/Canberra**
  - **Transistor Reset Preamplifier (TRP)** - feedback capacitor discharged to ground by means of a transistor switch connected to a FET gate (“SWITCH”) – in the warm preamp of the HPGe

https://doi.org/10.1016/j.nima.2021.165297

- **2018 detector delivered just before LS2 @ CERN (shutdown till 2021)**
  - p-type HPGe, 26% rel. efficiency, LN cooled
  - **Tested & characterized in lab**



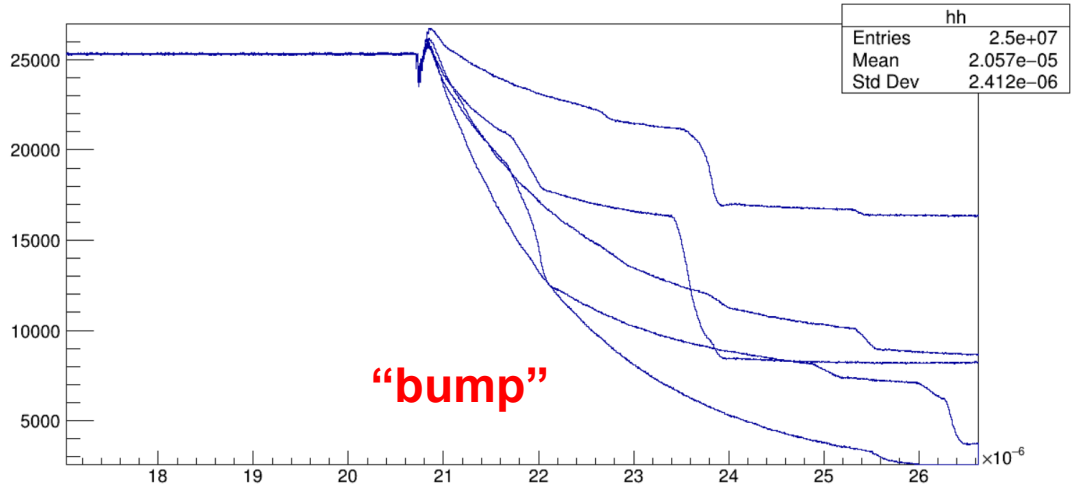


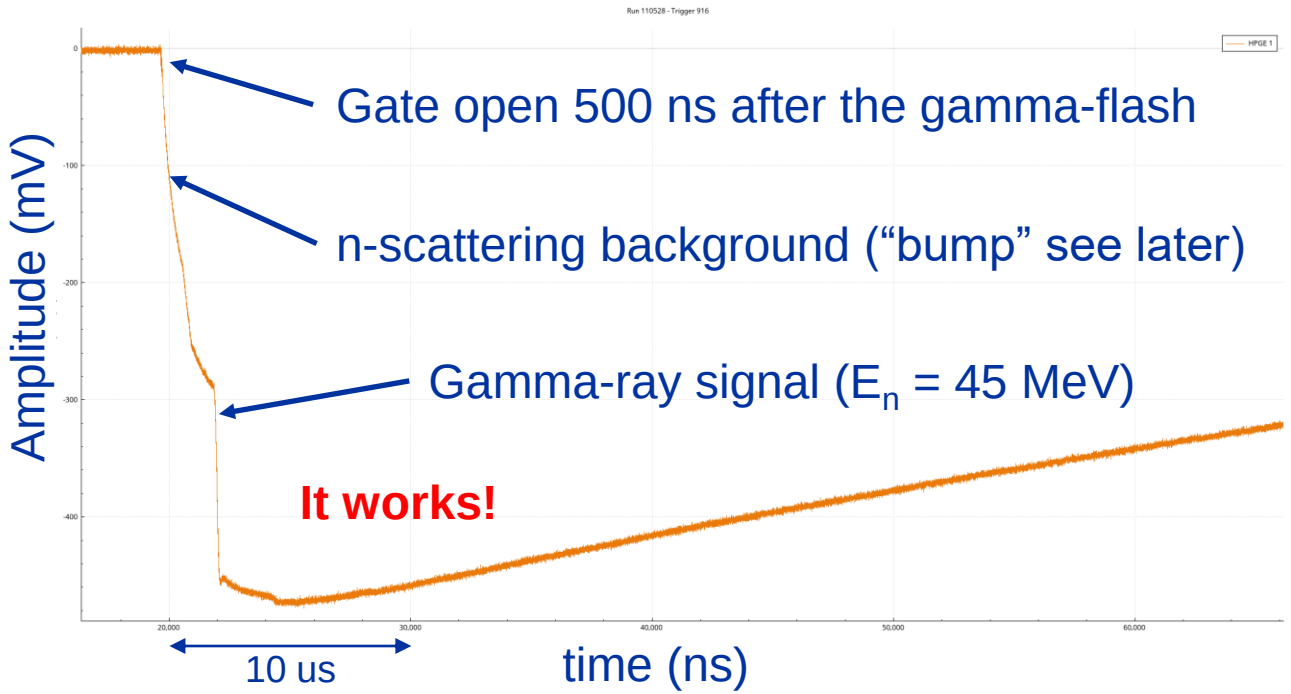
Development & first tests II

- **Detector developed with Mirion/Canberra**
  - **Transistor Reset Preamplifier (TRP)** - feedback capacitor discharged to ground by means of a transistor switch connected to a FET gate (“SWITCH”) – in the warm preamp of the HPGe

https://doi.org/10.1016/j.nima.2021.165297

- **2018 detector delivered just before LS2 @ CERN (shutdown till 2021)**
  - p-type HPGe, 26% rel. efficiency, LN cooled
  - Tested & characterized in lab
  - **Short beam time before shutdown**

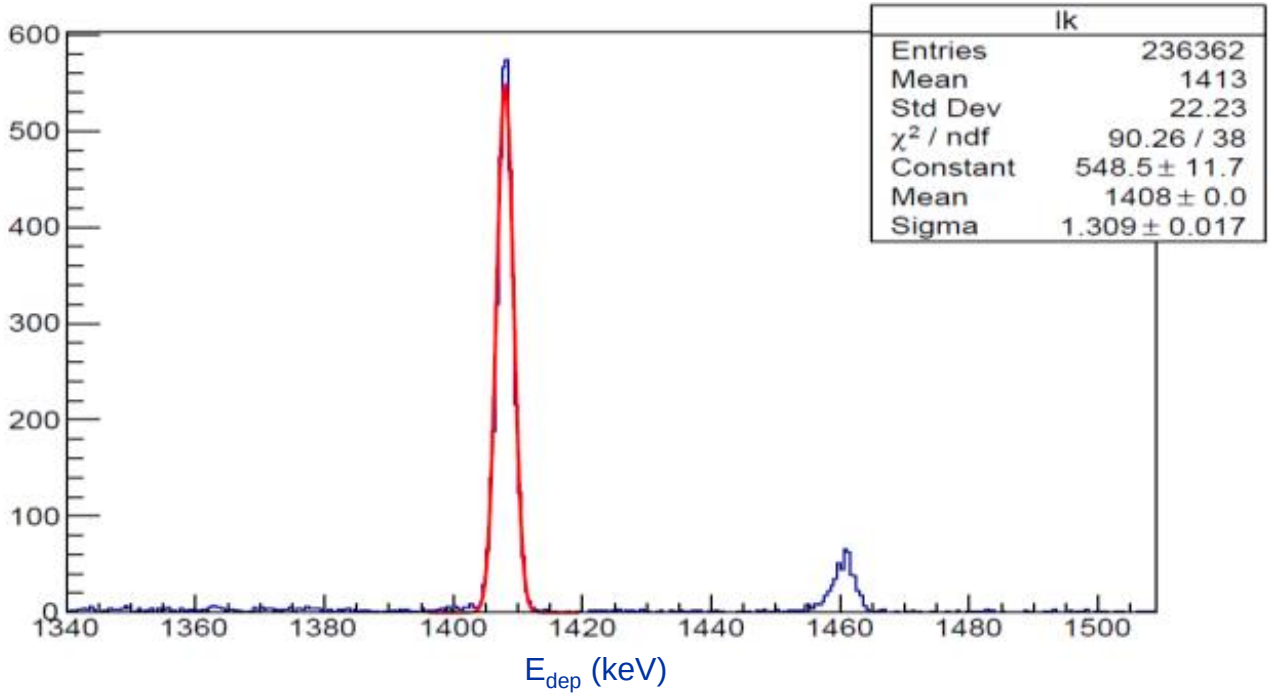


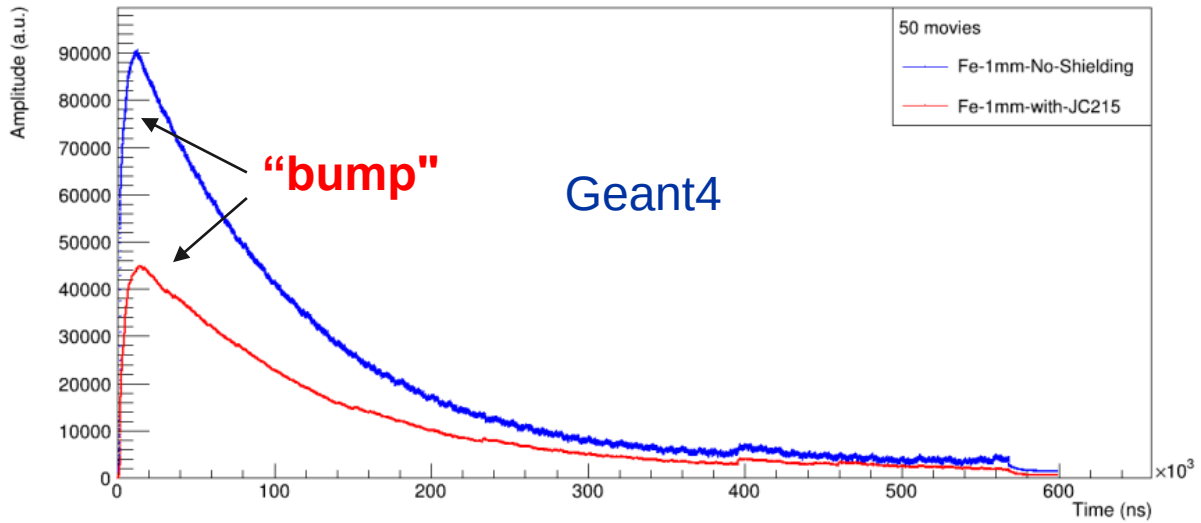


Pulse Shape Analysis

- **Beam off (calibration sources)**
  - Trapezoidal filter https://doi.org/10.1016/j.nima.2007.05.231
  - Digital FWHM 3.1 keV @ 1408 keV
  - Analog (MCA) 2.8 keV @ 1408 keV
- **Beam on**
  - Challenge due to moving baseline induced by (n,el) in the crystal
  - Simulations nicely reproduce the average shape of this “bump”
    - Simulate n_TOF neutron pulses & averaging
    - Sadly not useful for treating beam data

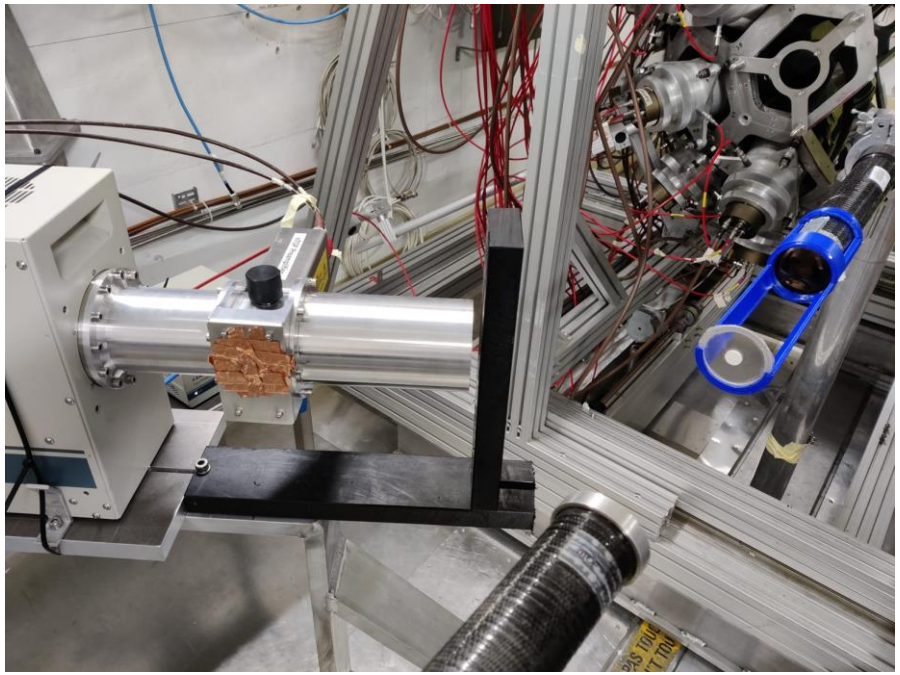
[1] E. Stamati Thesis
[2] https://doi.org/10.12681/hnpsanp.5153

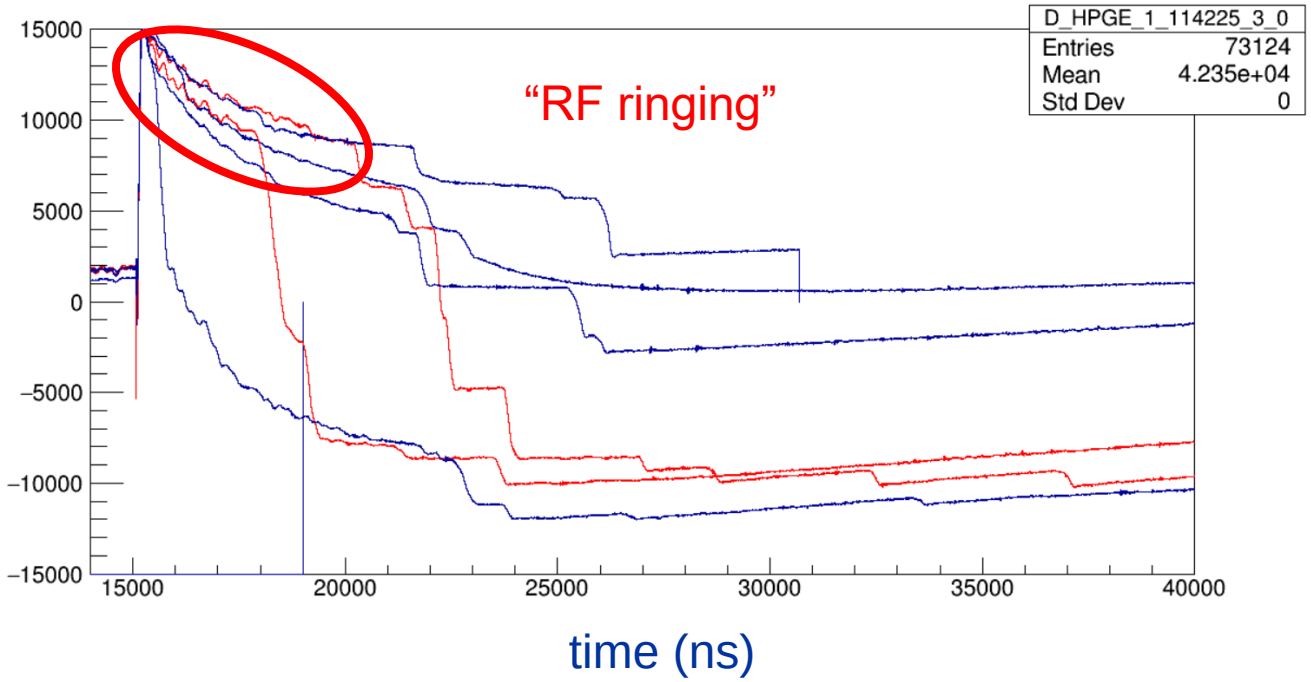




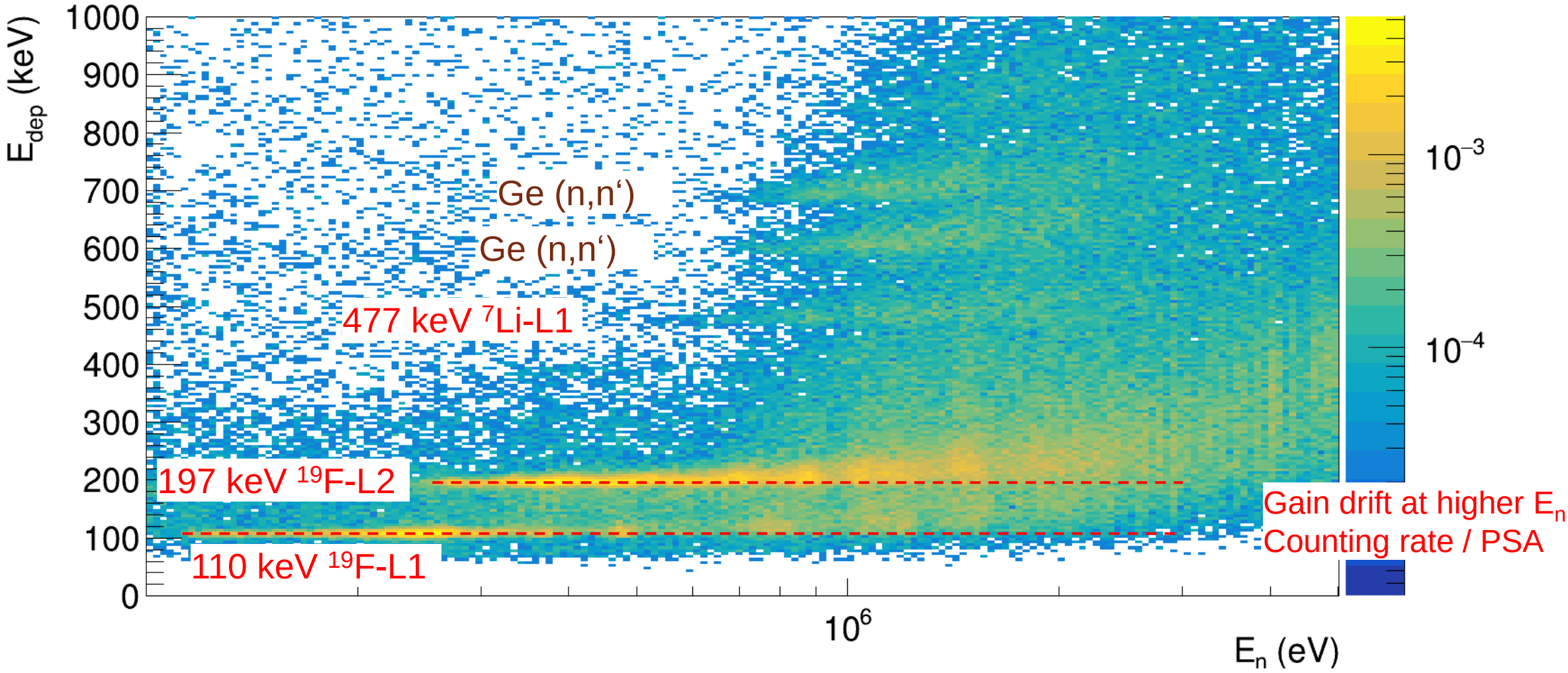
Beam data

- **Short run (2023)**
  - ^{7}Li(n,n‘)L1 with Eγ = 477.61 keV
  - ^{19}F(n,n‘)L1 with Eγ = 109.89 keV
  - ^{19}F(n,n‘)L2 with Eγ = 197.14 keV (89 ns)
  - ^{56}Fe(n,n‘)L1 with Eγ = 846.78 keV

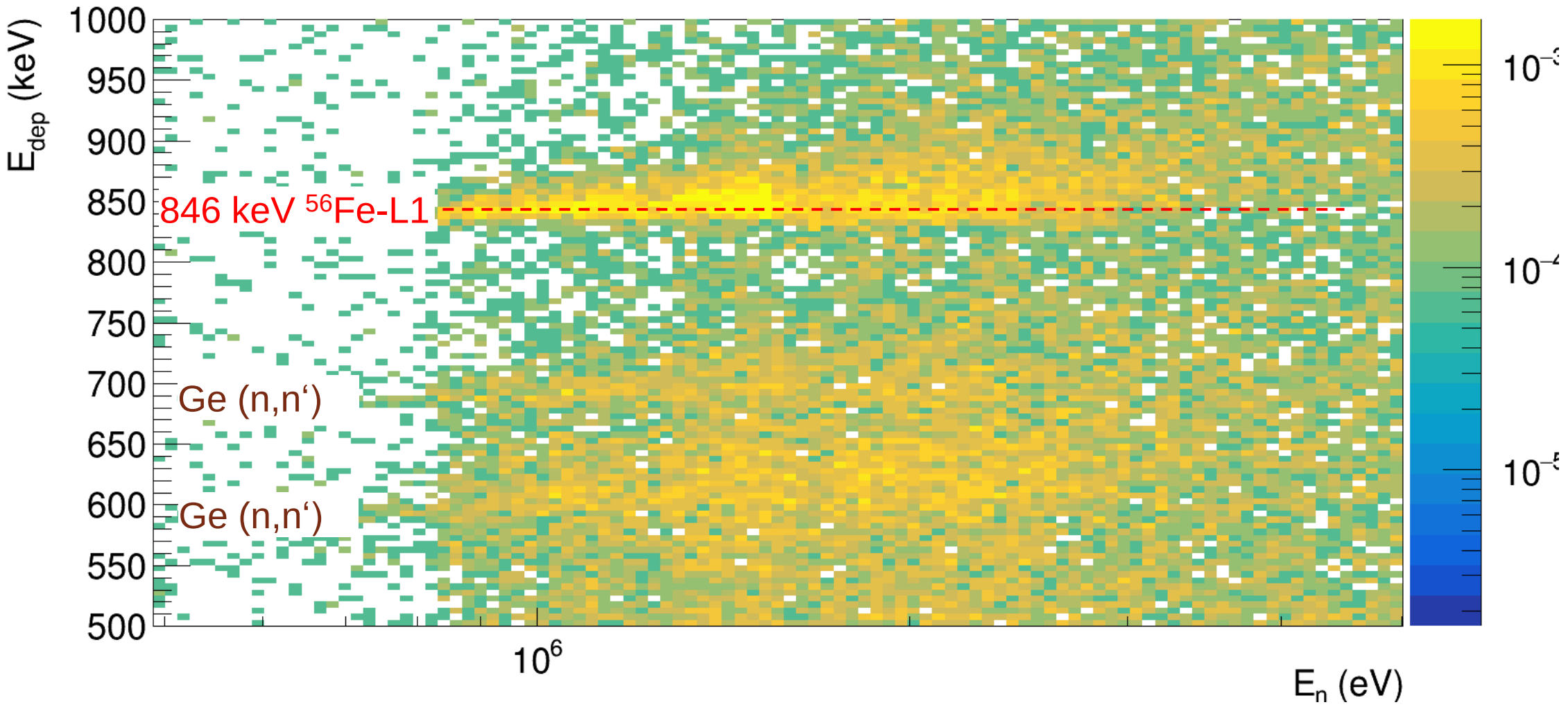




Beam data – LiF



Beam data – ^{56}Fe



Summary & Outlook

- **Successful project – first measurement of (n,inel) at n_TOF**
  - ✓ Detector/electronics designed and tested – principle works with HPGe detectors
  - ✓ First beam tests in 2018 before LS2 (bump) & full characterization in 2019
  - ✓ Further modifications to preamp and cooling system 2019-2022
  - ✓ Dedicated measurement setup in 2023 CERN-INTC-I-230 – ^{56}Fe and ^{7}Li^{19}F data under analysis
    - RF ringing issue
    - Data analysis challenging – publication of proof-of-principle pending
- **Future:**
  - Hardware modifications: RF shielding / switch into cold part of HPGe
  - Development of dedicated and more advanced pulse shape analysis routine using ML
  - Follow-up as part of a MSCA fellowship (2024-2026)

Thanks!

Michael Bacak
michael.bacak@cern.ch