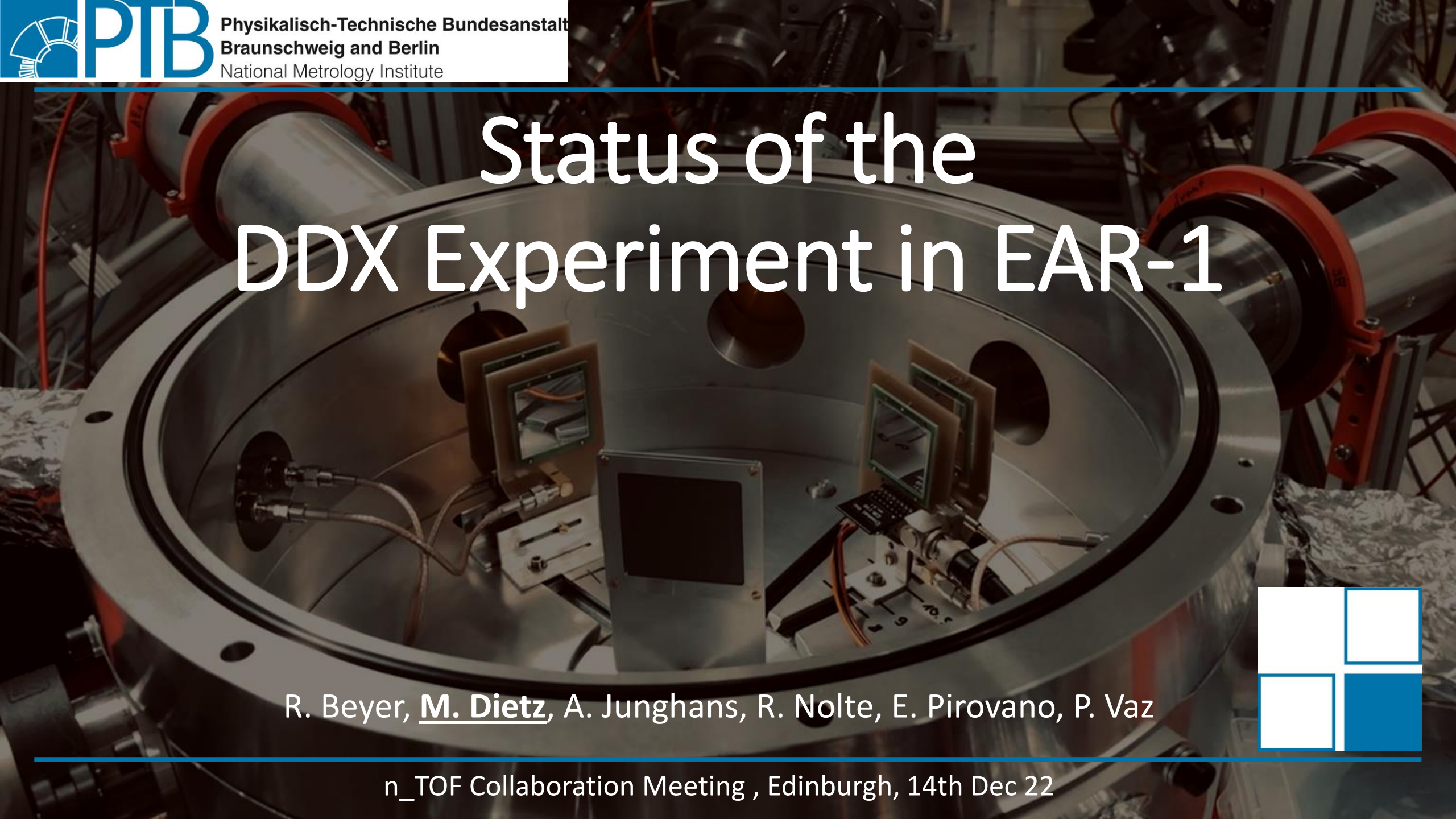
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Status of the DDX Experiment in EAR-1



R. Beyer, **M. Dietz**, A. Junghans, R. Nolte, E. Pirovano, P. Vaz

n_TOF Collaboration Meeting , Edinburgh, 14th Dec 22

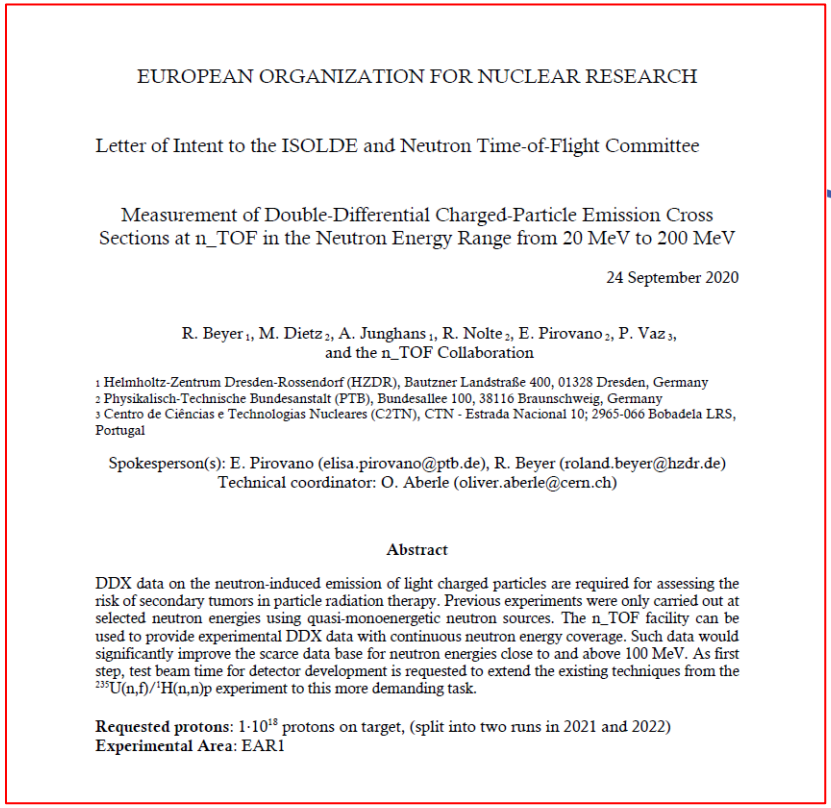
Outline

- Motivation & Objectives

- DDX Test 1: 9th to 12th May ´22
- Learnings I
- Improvements

- DDX Test 2: 16th – 23th Nov ´22
- Learning II

- Carbon Data
- Summary & Outlook



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Committee

Measurement of Double-Differential Charged-Particle Emission Cross Sections at n_TOF in the Neutron Energy Range from 20 MeV to 200 MeV

24 September 2020

R. Beyer [1], M. Dietz [2], A. Junghans [1], R. Nolte [2], E. Pirovano [2], P. Vaz [3], and the n_TOF Collaboration

[1] Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Bautzner Landstraße 400, 01328 Dresden, Germany
[2] Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany
[3] Centro de Ciências e Tecnologias Nucleares (C2TN), CTN - Estrada Nacional 10; 2965-066 Bobadela LRS, Portugal

Spokesperson(s): E. Pirovano (elisa.pirovano@ptb.de), R. Beyer (roland.beyer@hzdr.de)
Technical coordinator: O. Aberle (oliver.aberle@cern.ch)

Abstract

DDX data on the neutron-induced emission of light charged particles are required for assessing the risk of secondary tumors in particle radiation therapy. Previous experiments were only carried out at selected neutron energies using quasi-monoenergetic neutron sources. The n_TOF facility can be used to provide experimental DDX data with continuous neutron energy coverage. Such data would significantly improve the scarce data base for neutron energies close to and above 100 MeV. As first step, test beam time for detector development is requested to extend the existing techniques from the ^{235}U(n,f)/^{1}H(n,n)p experiment to this more demanding task.

Requested protons: $1 \cdot 10^{18}$ protons on target, (split into two runs in 2021 and 2022)
Experimental Area: EAR1

Neutron-induced emission of light charged particles at 100-200 MeV

High-energy secondary neutrons produced

- in hadron therapy: E_n up to 200/400 MeV for proton/carbon beams
- by cosmic radiation: E_n up to GeV

Absorbed dose calculations require

- DDX data for (n, px) (n, dx) (n, αx) …
- for tissue constituents (C, N, O,..)
- Particularly important for young patient of radiation therapy!

Present situation:

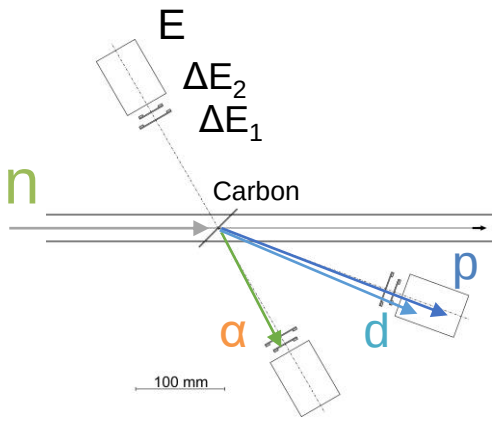
- Only few data for the emission of hydrogen and helium ions above 50 MeV
- Modelling of composite ejectiles is challenging

DDX test experiments @ nTOF – May + Nov 2022

- **Prototyp**: Measurement of the **D**ouble-**D**ifferential Cross Section of Neutron-Induced Charged-Particle Emission of Carbon above 100 MeV
- DDX Principle: **^{12}C(n,lcp x)** --- **l**ight **c**harged **p**article: p,d,t,^{3}He,α
- <u>Objectives:</u>

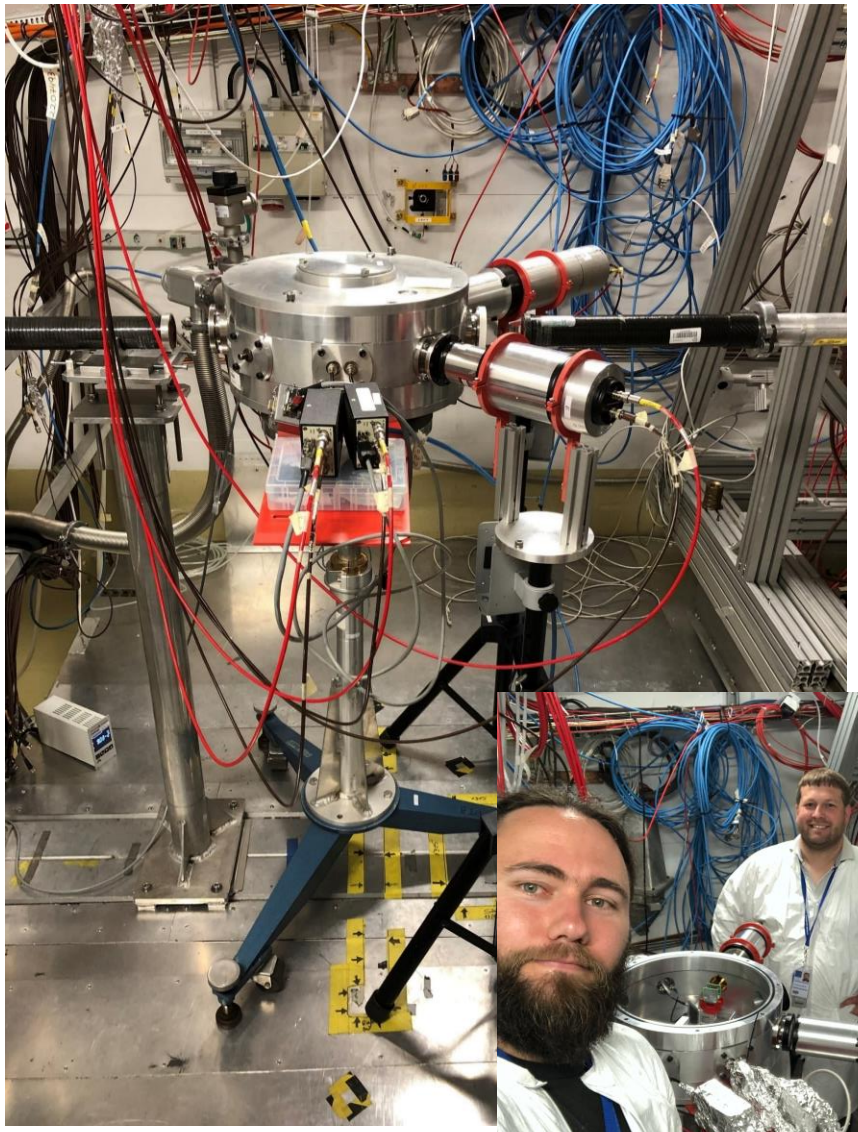
  TEST 1:
  - Response to the g-flash?? Switch device needed?
  - Maximum neutron energy detectable?
  - Mechanical setup? Alignment?

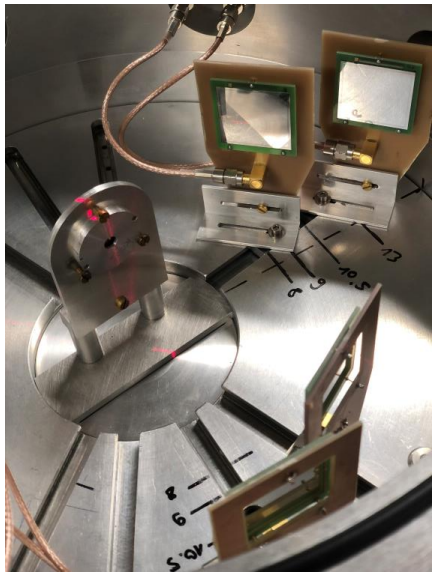
  TEST 2:
  - **Improve RINGING problem**
    - Find solutions
  - Collect Statistics for proposal (DE-DE-plots)

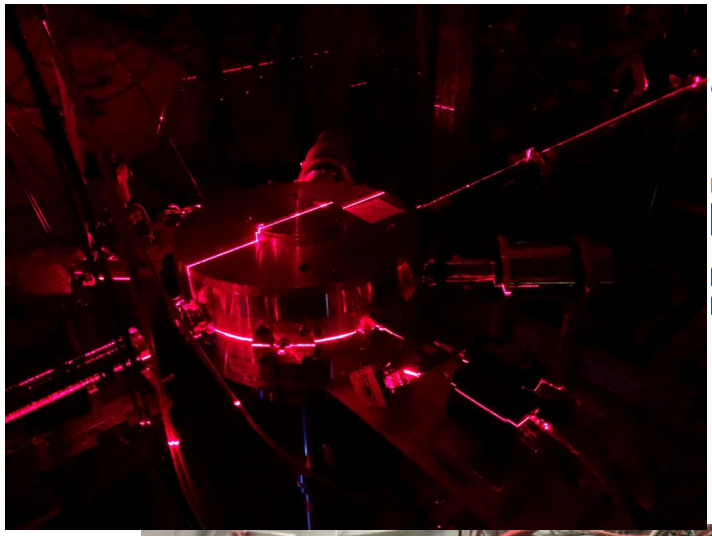


- <u>Procedure:</u>
  - Try different detector configurations (Si diodes + CeBr / plastic scintillator)
  - 2 sample-types with different thickness
    - PE (1mm or 2.3mm)
    - C (0.125mm – 1.5mm)

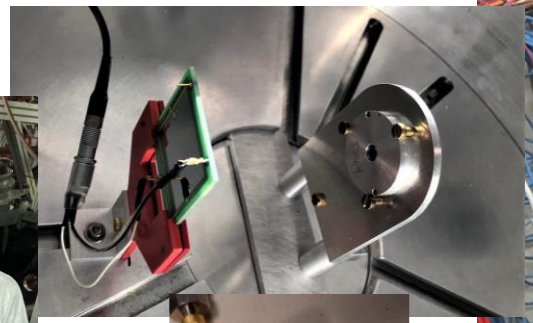
DDX test experiments @ nTOF – May + Nov 2022

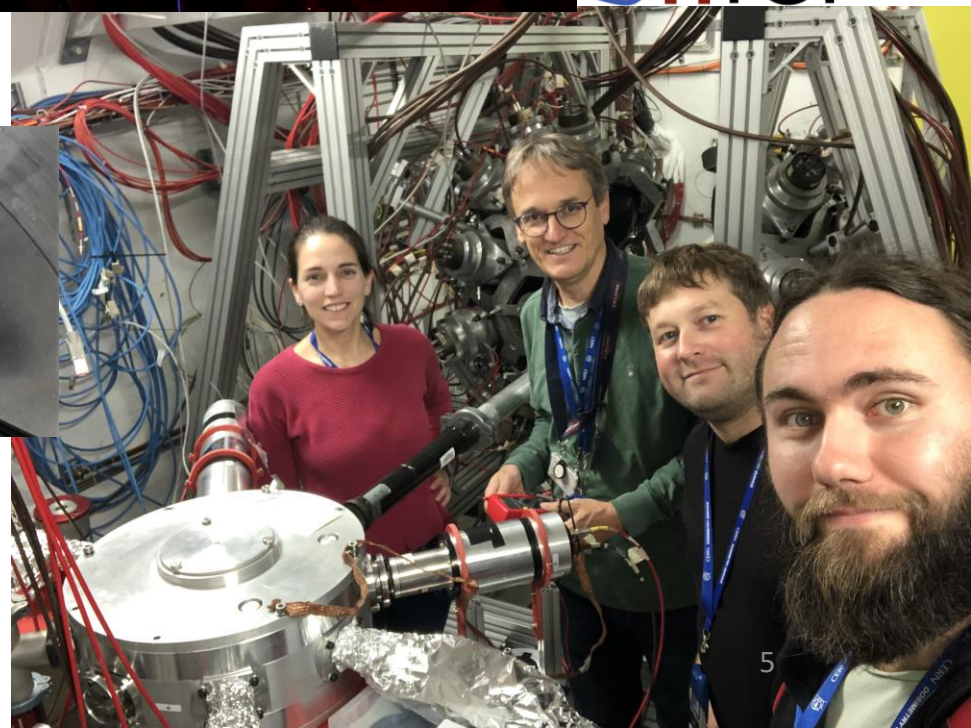




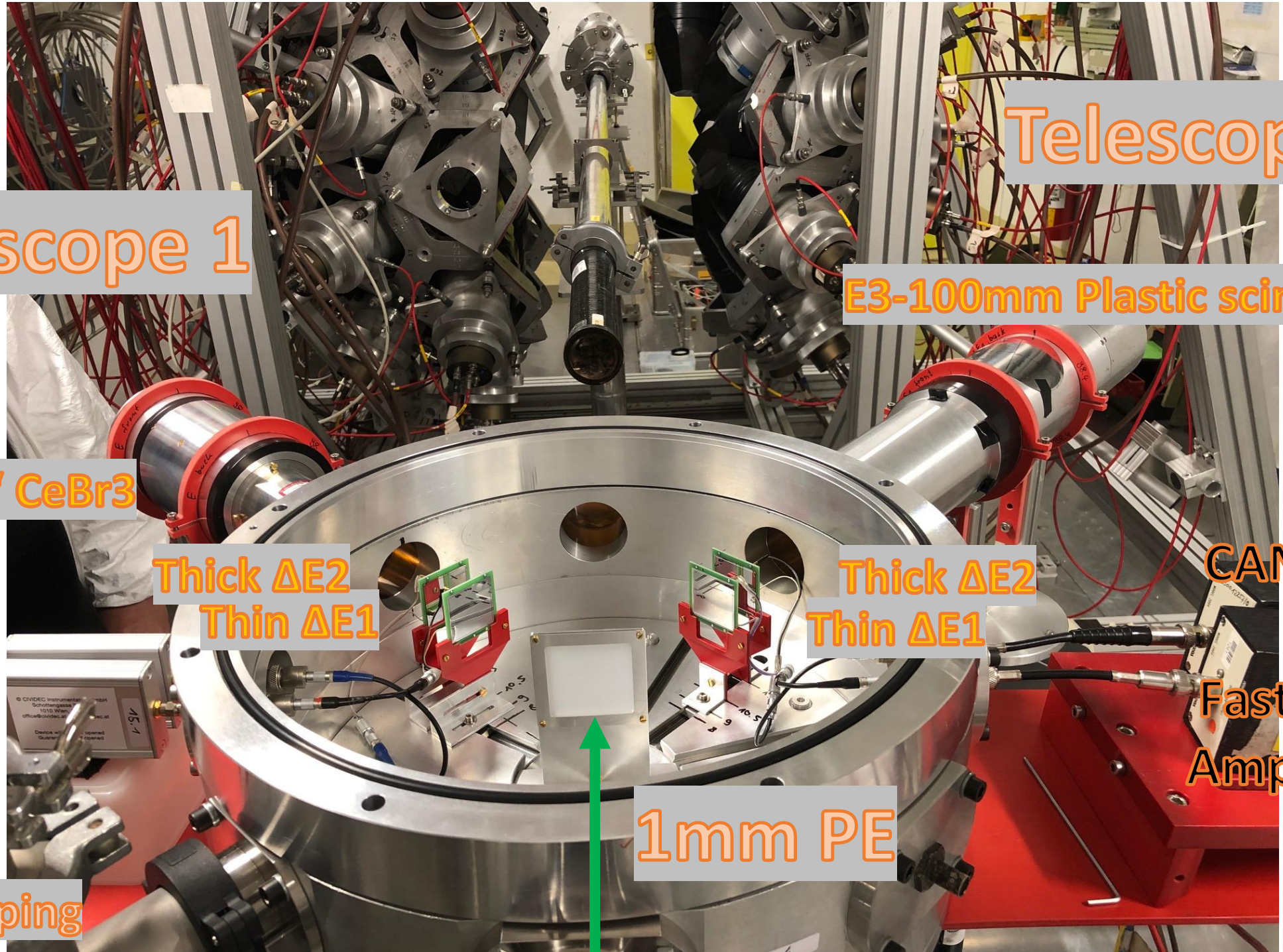


Setup, Calibration, Alignment, Switch device…



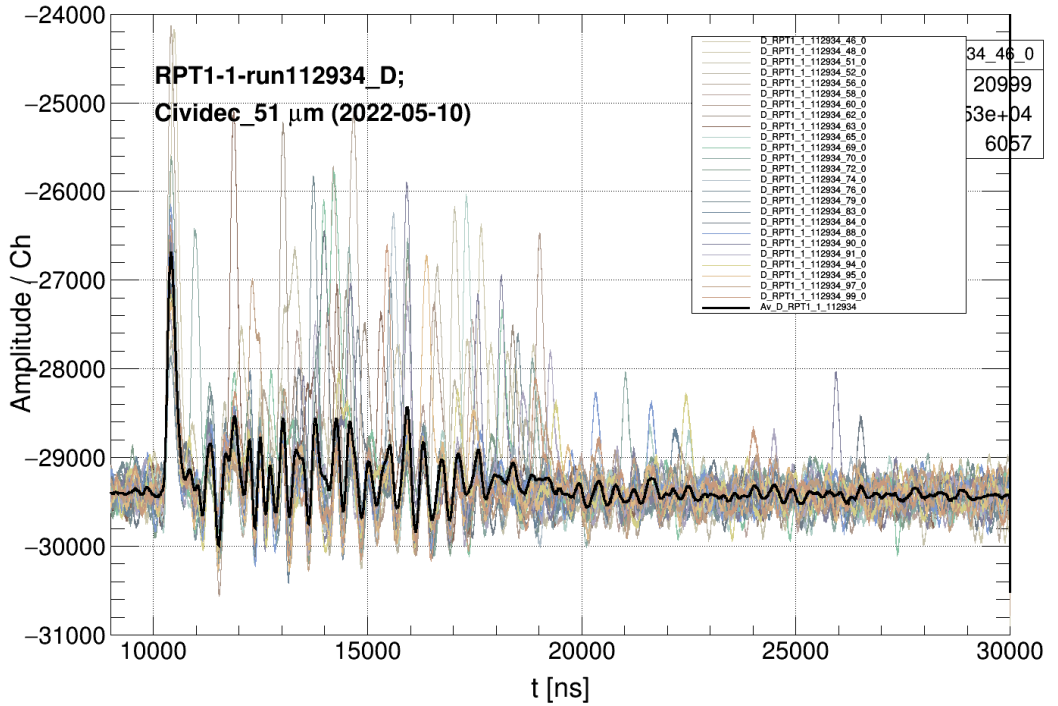


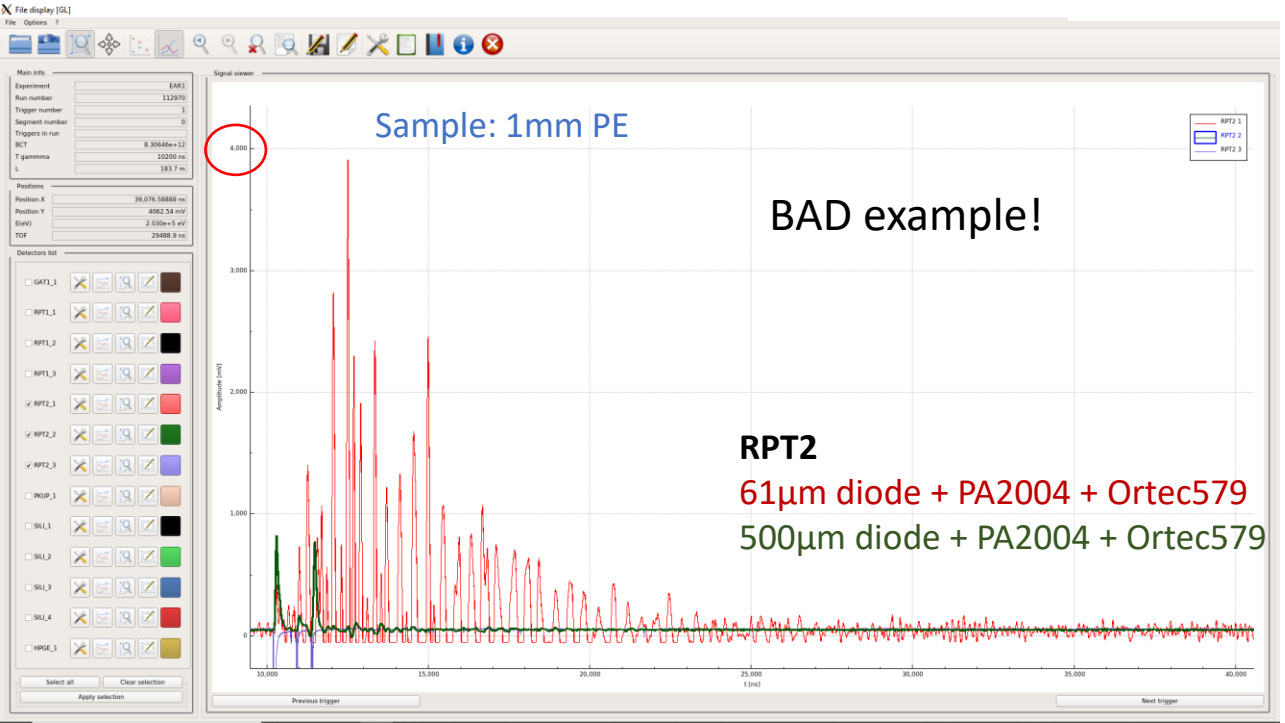
SETUP
May 22

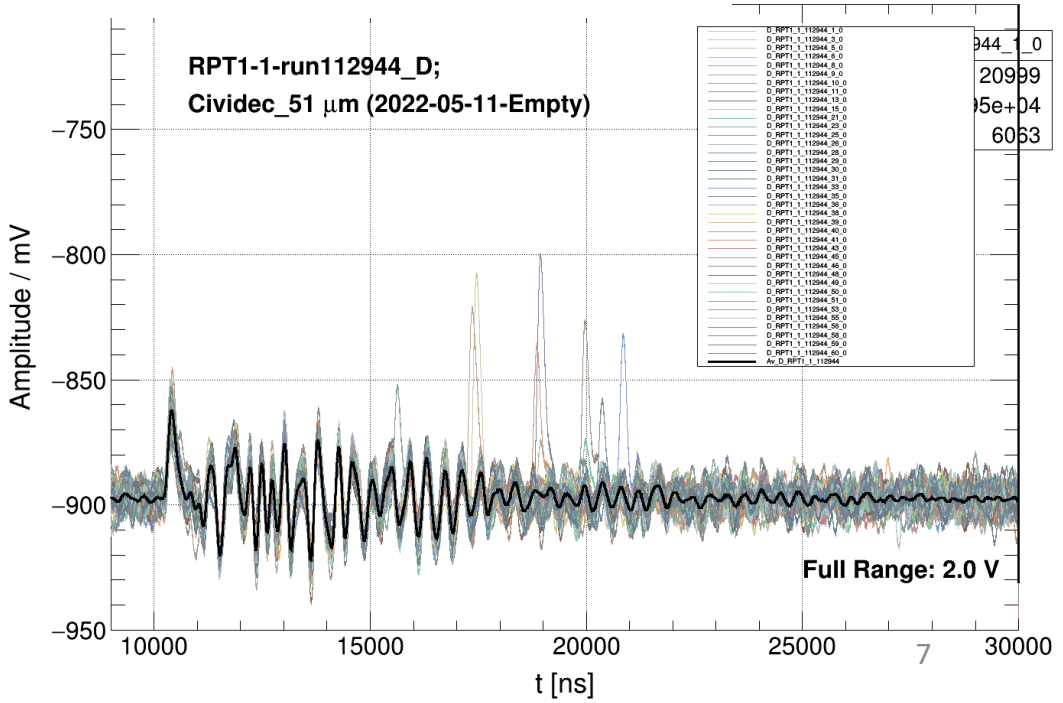

Telescope 1
Telescope 2
E3-100mm Plastic scintillator
E3-3“ CeBr3
Thick ΔE2
Thin ΔE1
Thick ΔE2
Thin ΔE1
Cividecs
CAN2004
+
Fast Filter
Amps (FFA)
1mm PE
Pumping

Waveforms I (May)

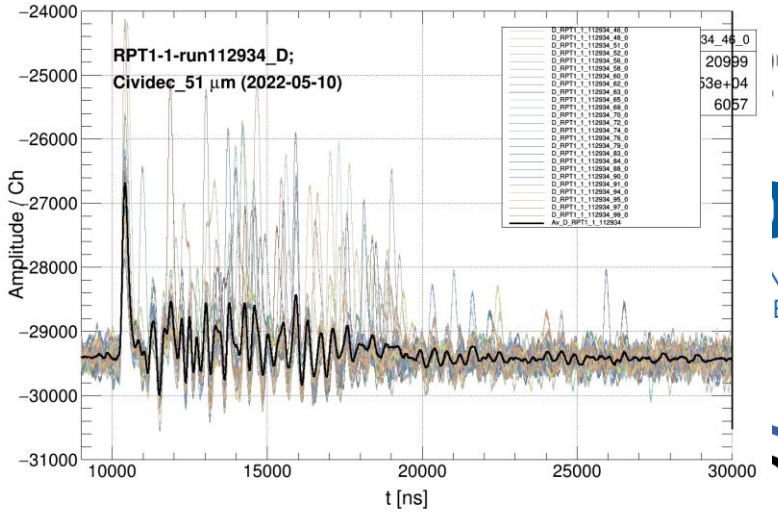
- Tried out different configurations
  (Cividec, Canberra2004, Switch w Cremat, …)
- RINGING
  =>Oscillations with different amplitude, similar patterns, independent of samples







Main Challenges



- g-flash is quite moderate, no switch needed
- RINGING ⇔ EM-interference:
  - Beam-induced issue results in a ringing baseline; esp. ~10µs after g-flash === MeV neutron region
  - Critical if Ringing ~> Signal
  - Frequency estimate: 3-5 MHz
  - Appears in differential experimental setups (detectors, amps, …)

- Unclear where interference enters signal chain
  - Inside chamber (beam) or preamps/connectors (bunker)?

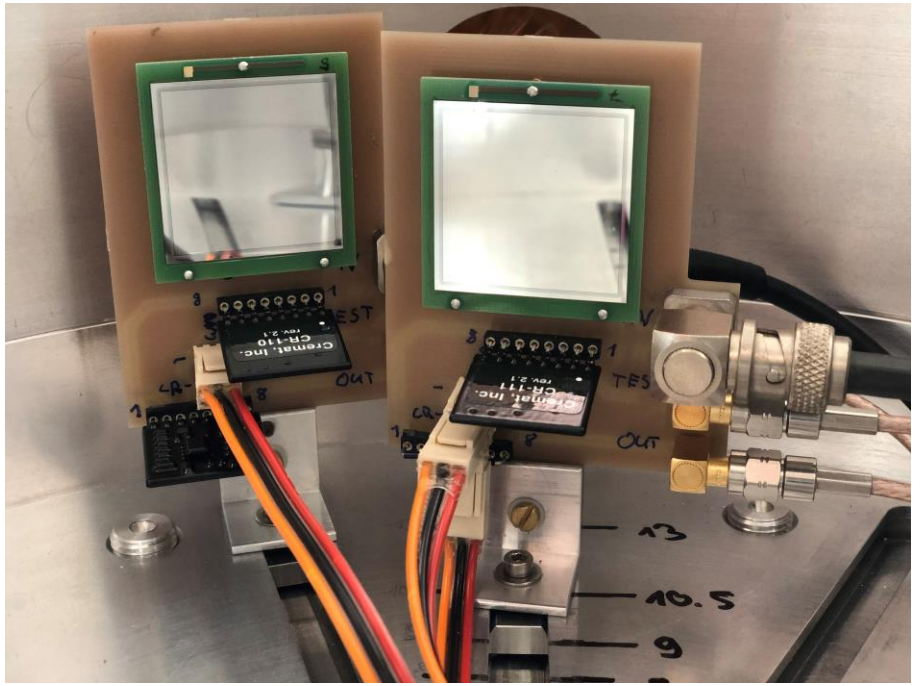
→ Temporary solution: Baseline reconstruction

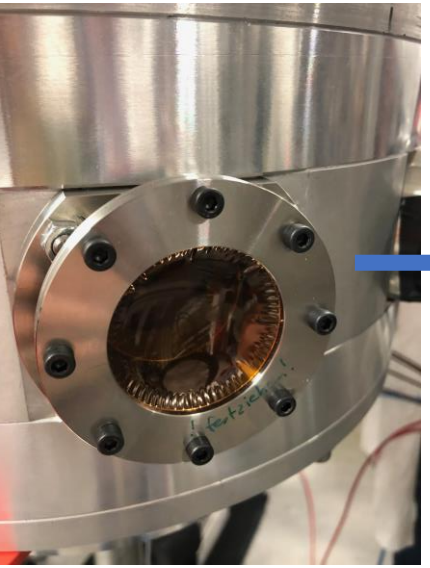
Talk @ Impedance WG CERN, Aug ´22:
Ringing Problems at high En @ n_TOF EAR1

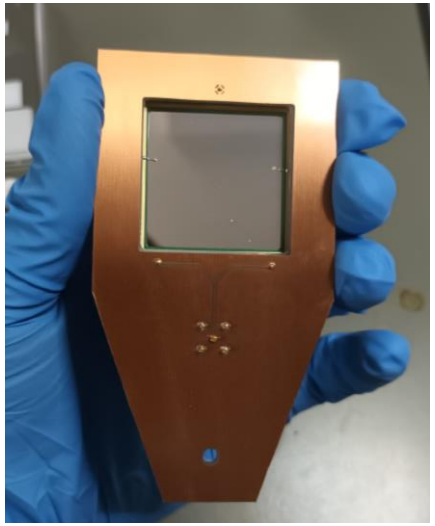
→ First Antenna Measurement during Nov. DDX beam time

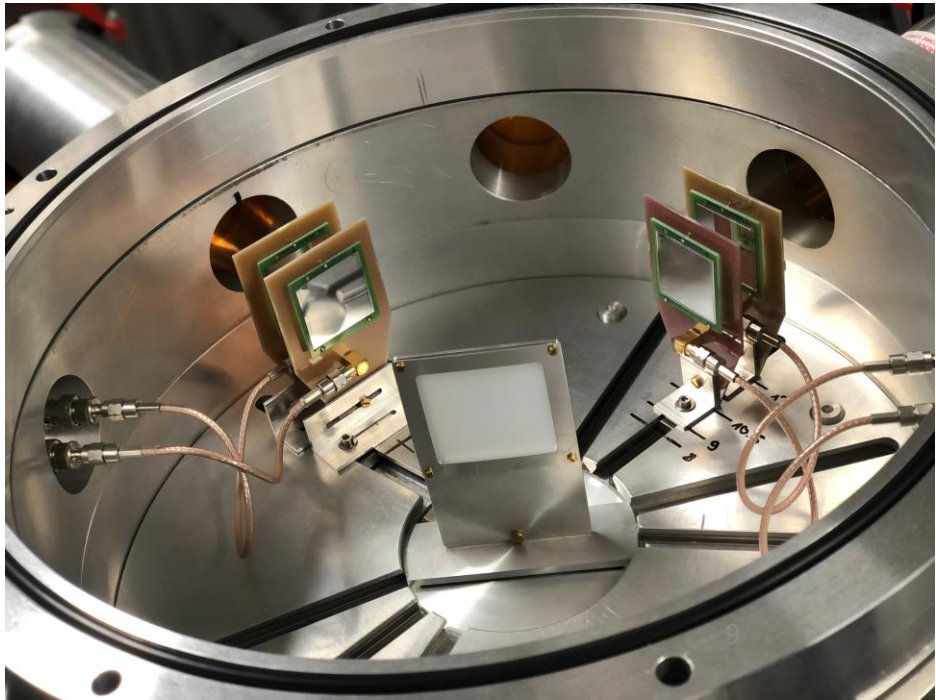
3 Main Improvements

- Aluminium shielding (100-200µm) of kapton windows (RF-tight)
- SMA cabling inside chamber
- New diode holder with option for preamp inside

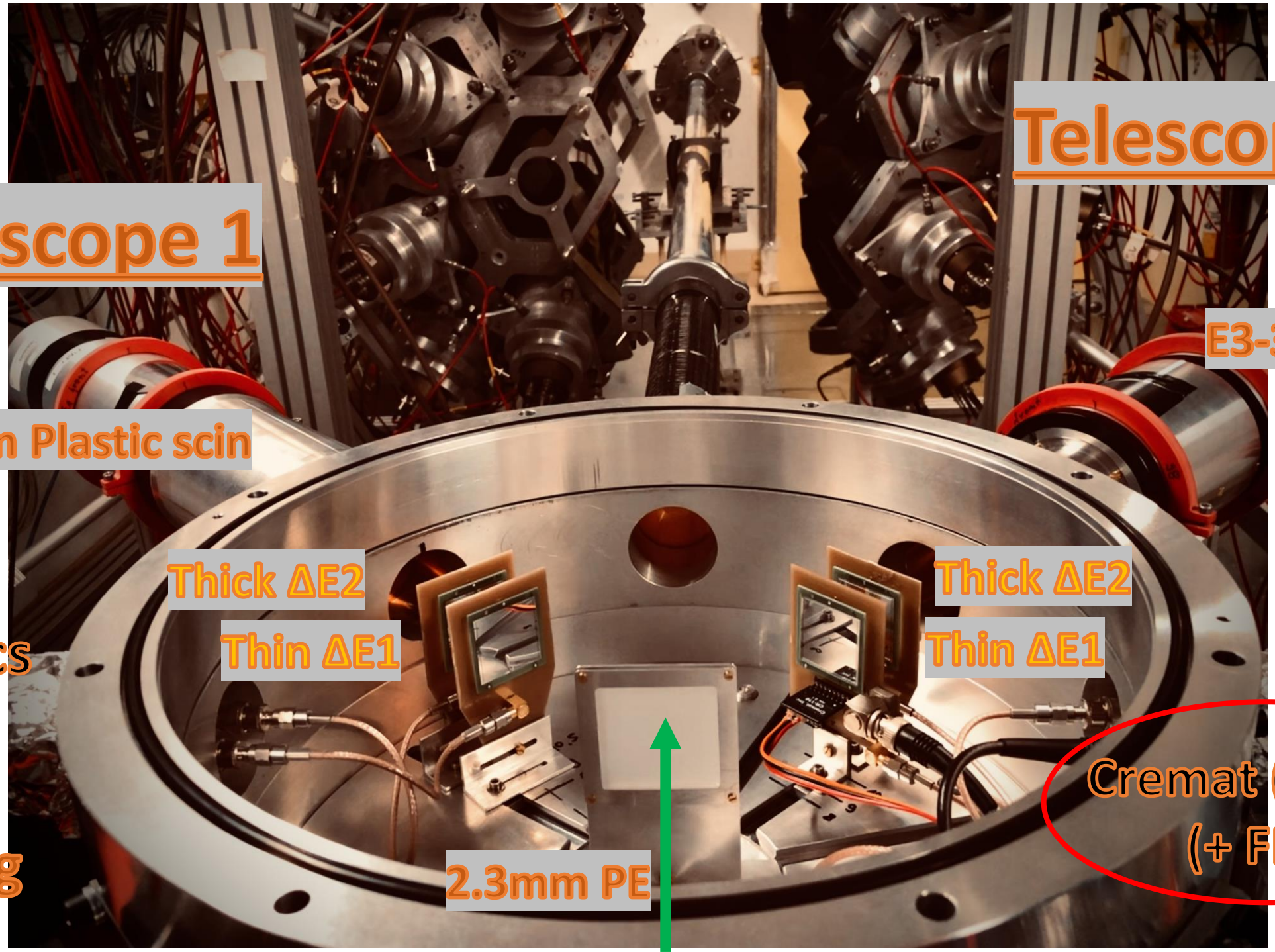








SETUP
Nov 22

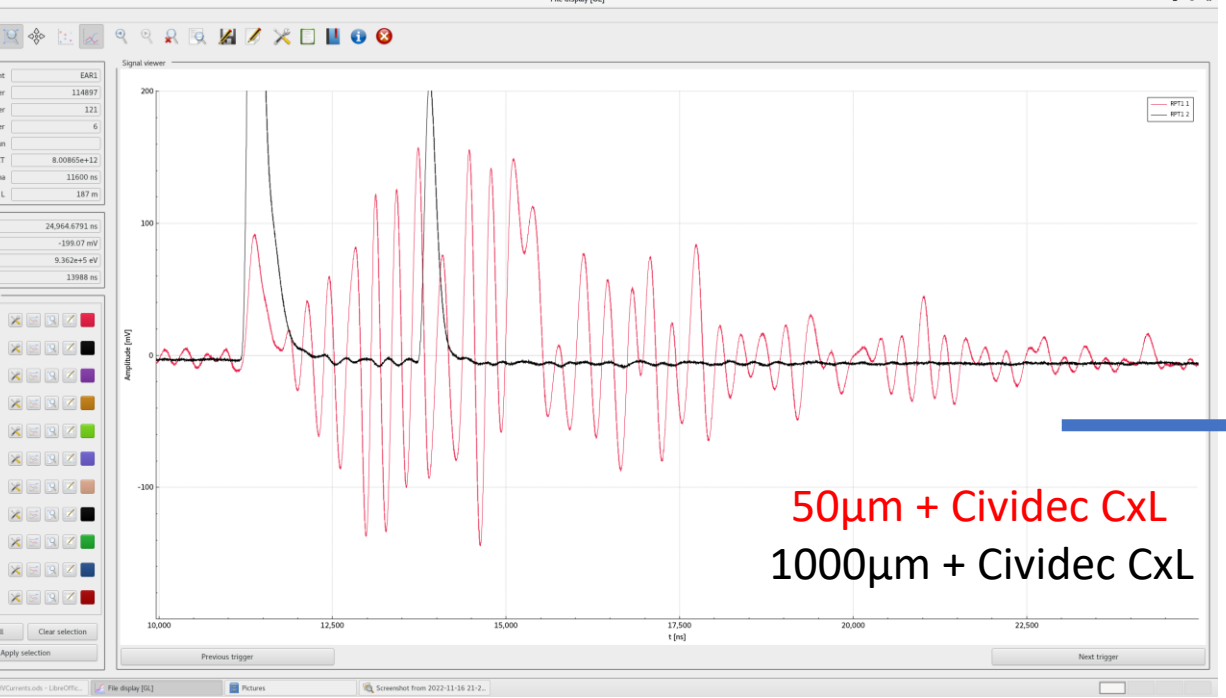


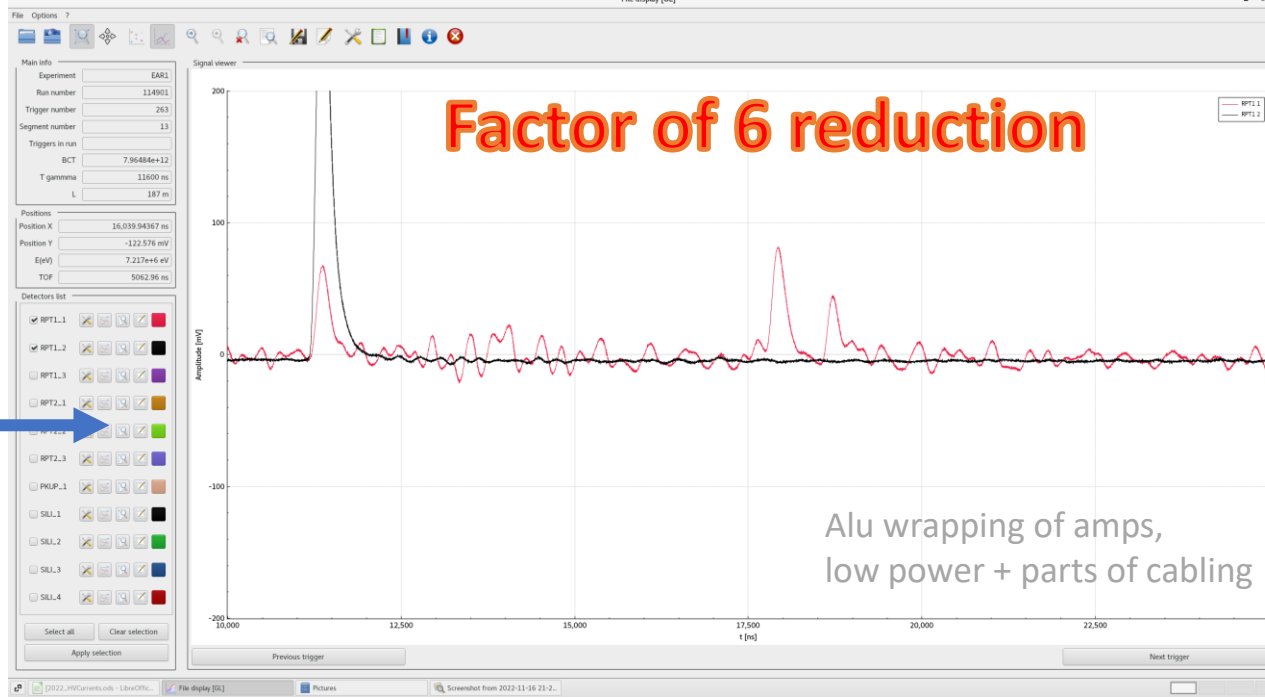
Cividecs

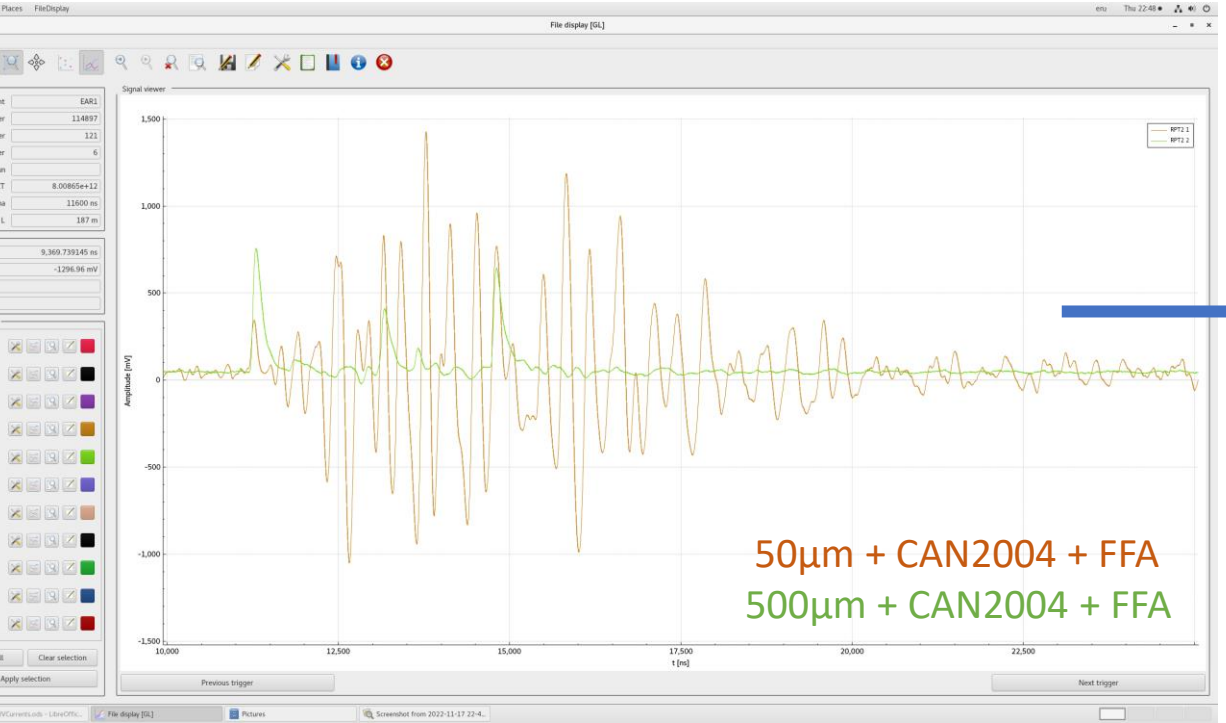
PA2004
+ FFA

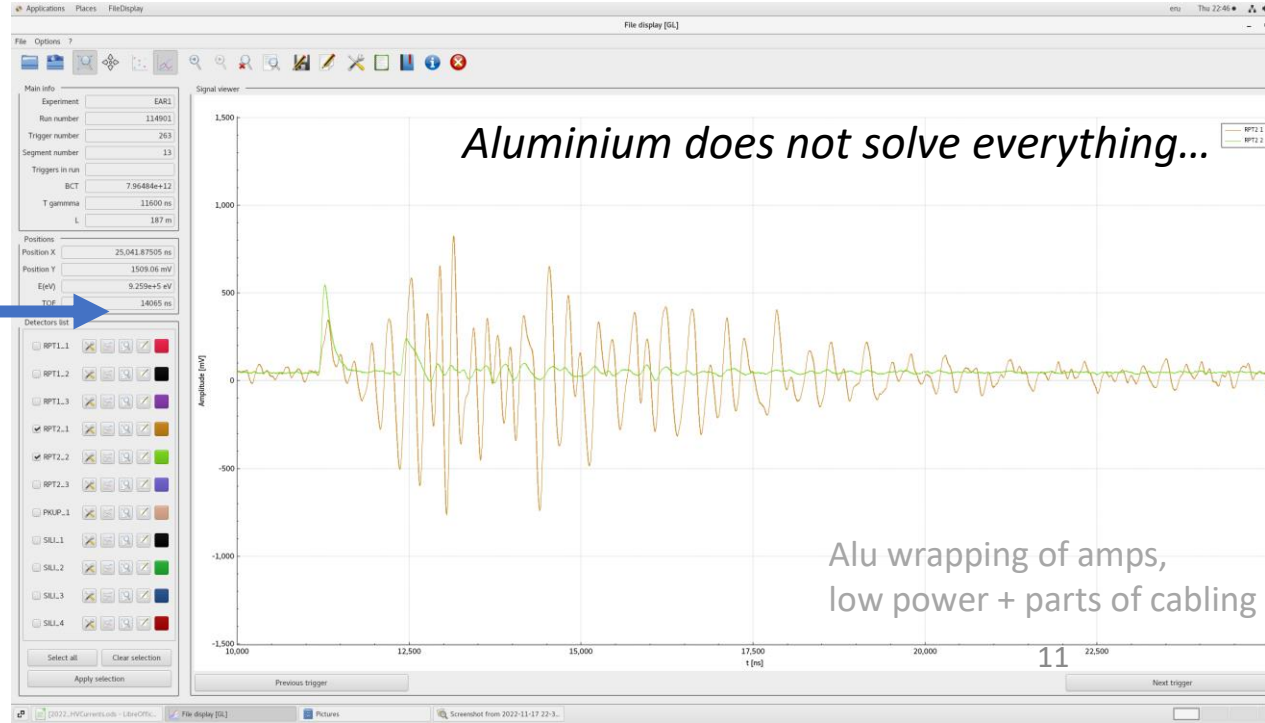
Cremat (inside)
(+ FFA)

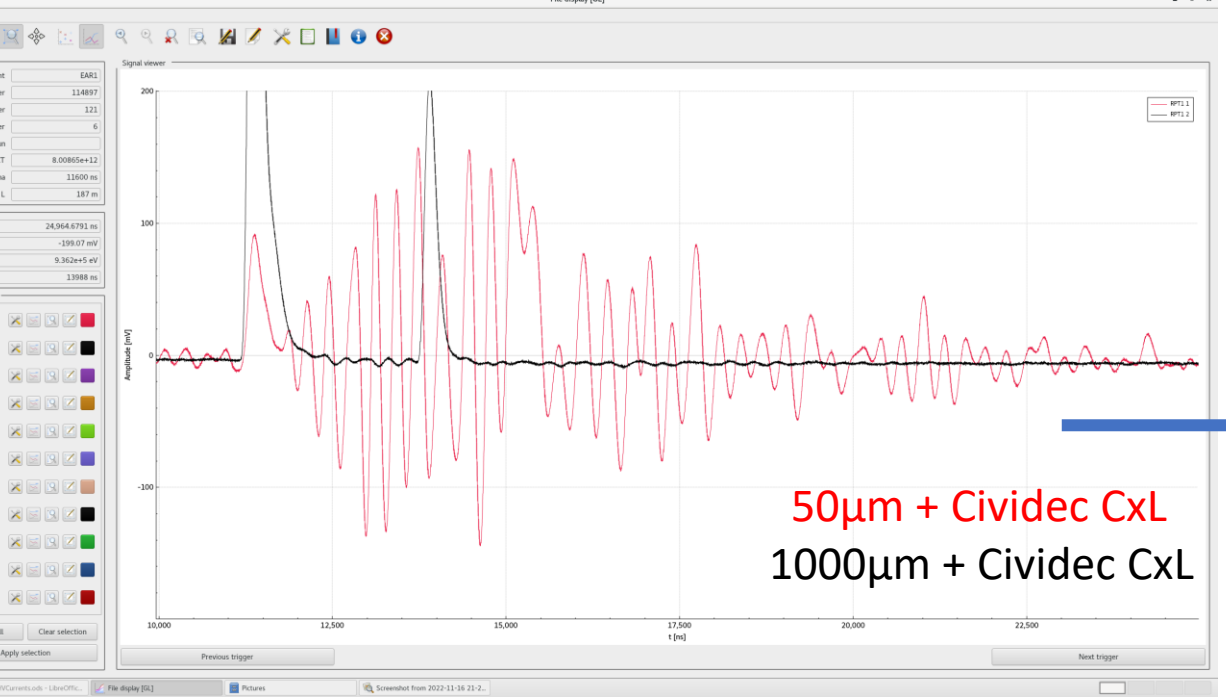
Pumping
downstairs

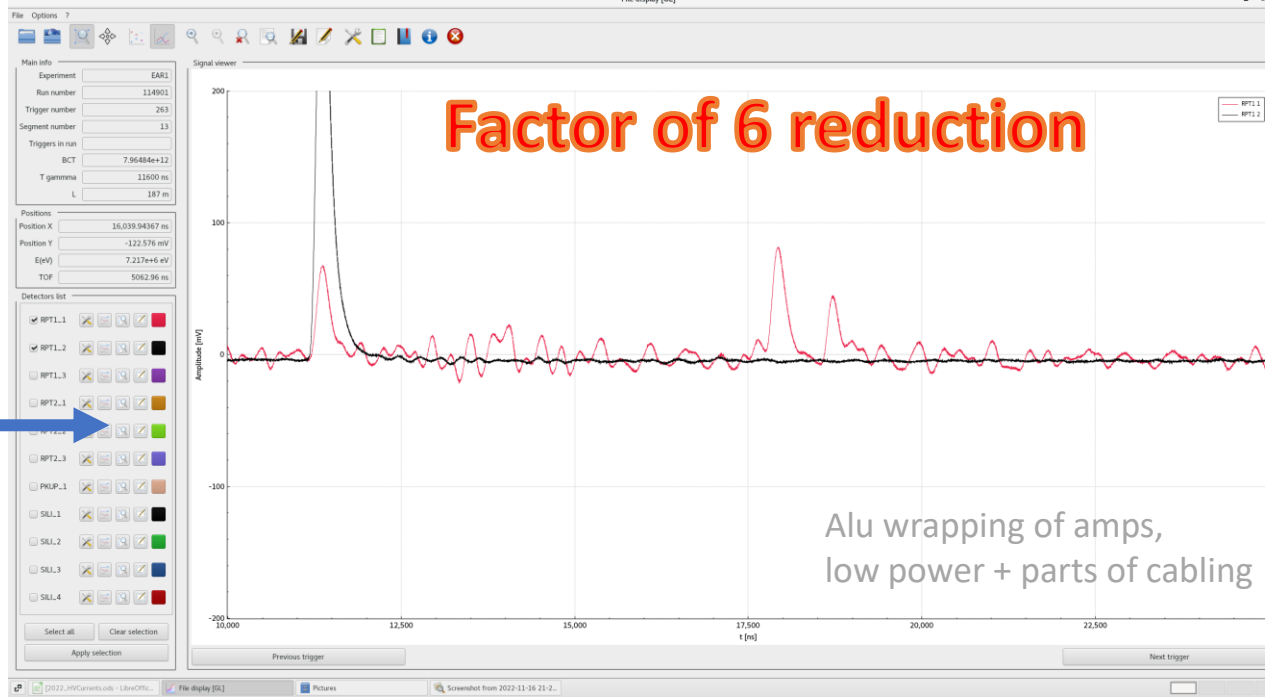

50µm + Cividec CxL
1000µm + Cividec CxL


Factor of 6 reduction
Alu wrapping of amps,
low power + parts of cabling


50µm + CAN2004 + FFA
500µm + CAN2004 + FFA


Aluminium does not solve everything…
Alu wrapping of amps,
low power + parts of cabling


50µm + Cividec CxL
1000µm + Cividec CxL


Factor of 6 reduction
Alu wrapping of amps,
low power + parts of cabling

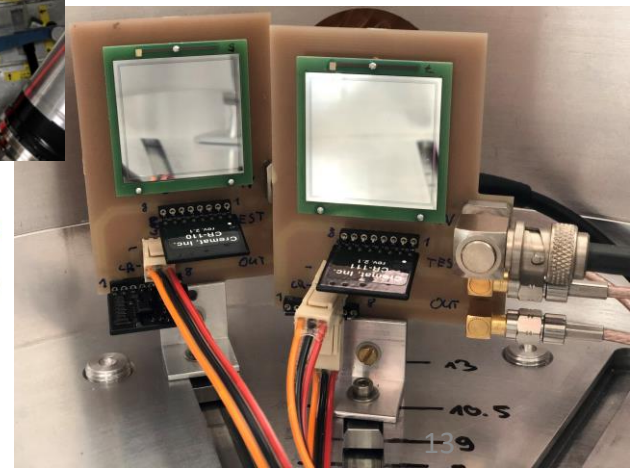

50µm + CAN2004 + FFA
500µm + CAN2004 + FFA


Preamp inside
50µm + Cremat110 + FFA
500µm + Mesytec + FFA

Learning II (Nov 2022)

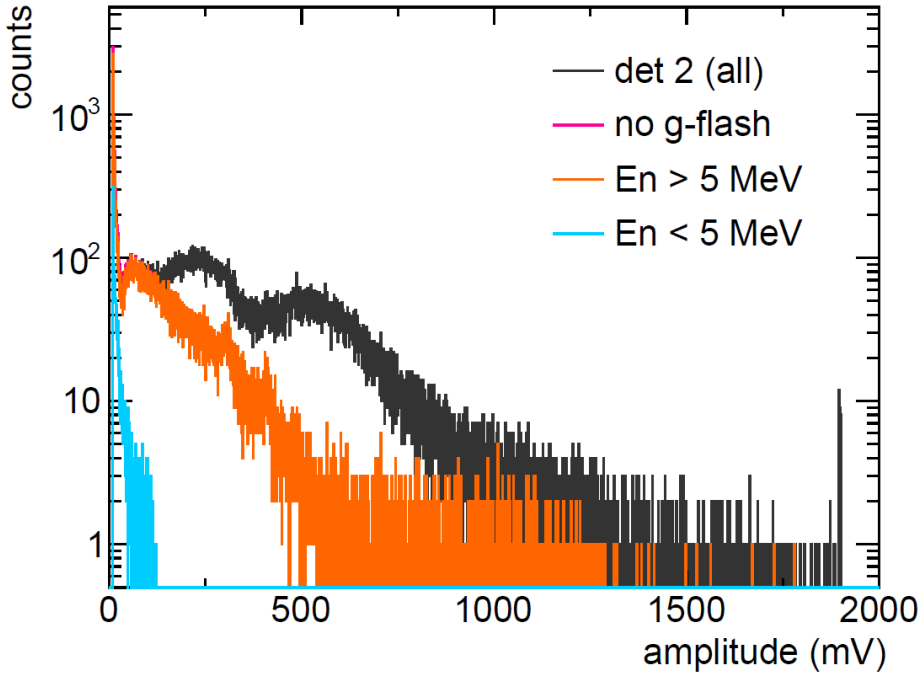
- Proper shielding of (pre)amplifier + cable connection is needed
- RF-tight chamber through Alu + Kapton windows
- Preamp inside the vacuum chamber is shielded best
- Grounding of plastic scintillator improved baseline

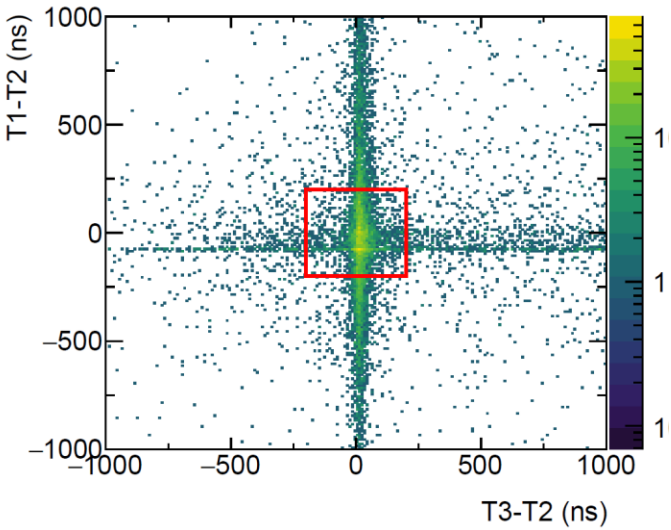
- Things that did not work / improve:
  - Capacitance-matched preamps (thin Si ~2nF) like: Ortec 142B or 142C, Mesytec MPR-1,
  - Re-wrapping with Aluminium
  - Turning diode (direction of ground)



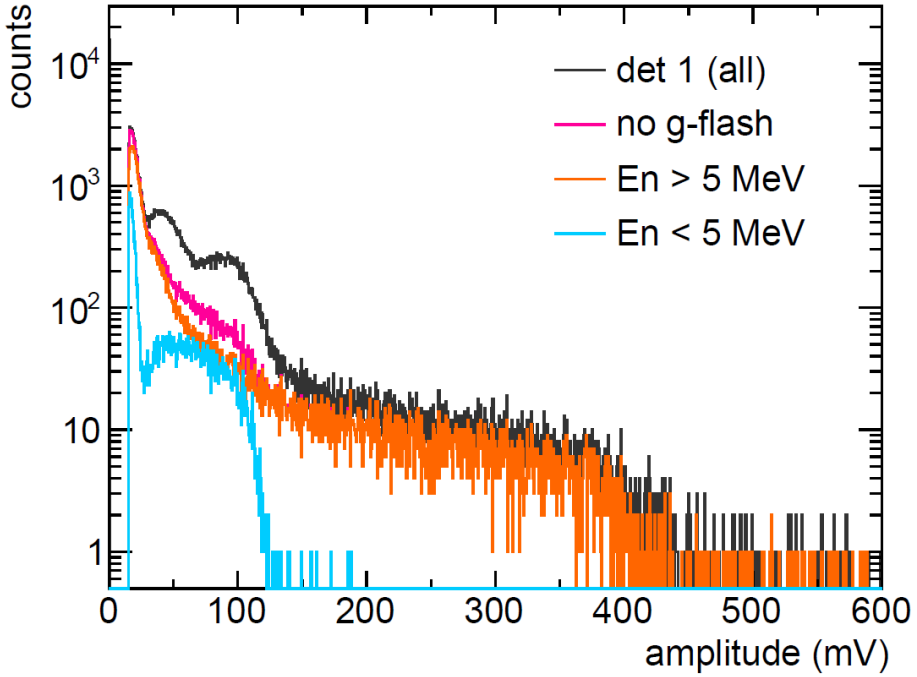
Carbon Data Tele1

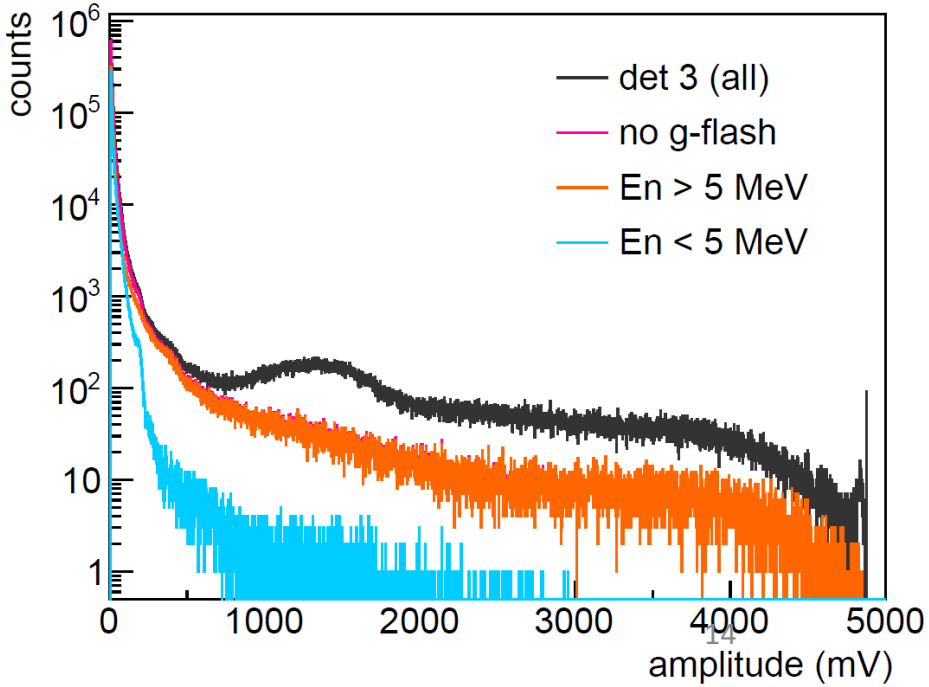
- Cividec gain for thin diode not matched yet
- G-flash hardly saturates full range
- Clear coincidence pattern





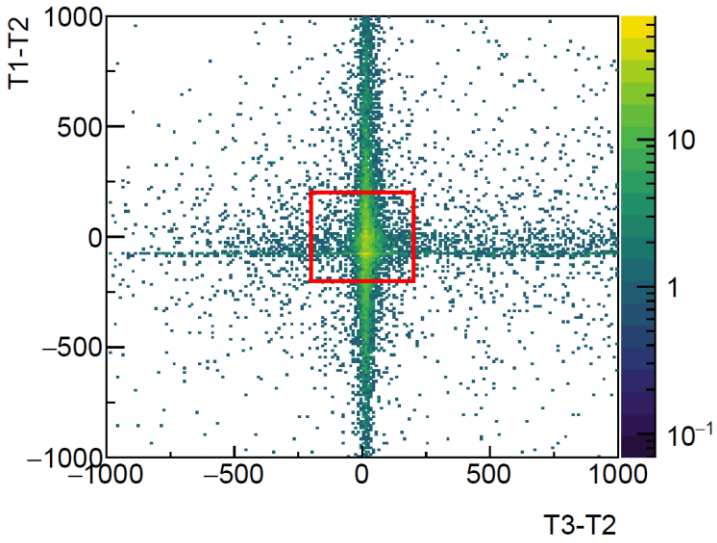
DE1: 51µm + Cividec
DE2: 1043µm+Cividec
DE3: Plastic(150mm)

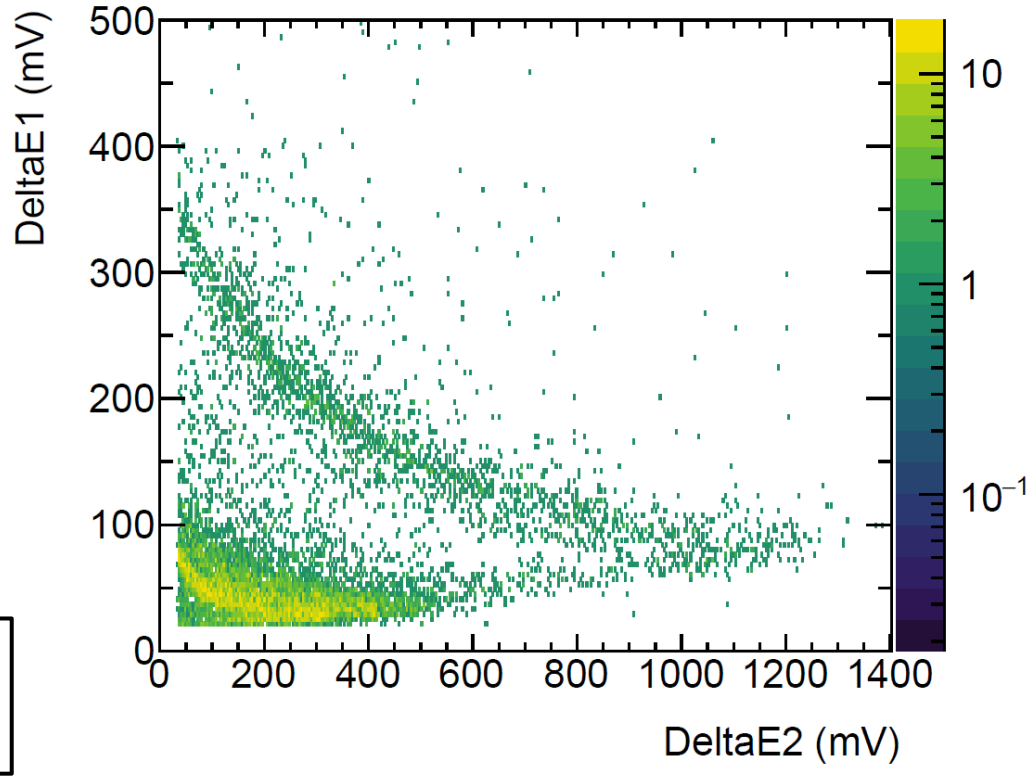


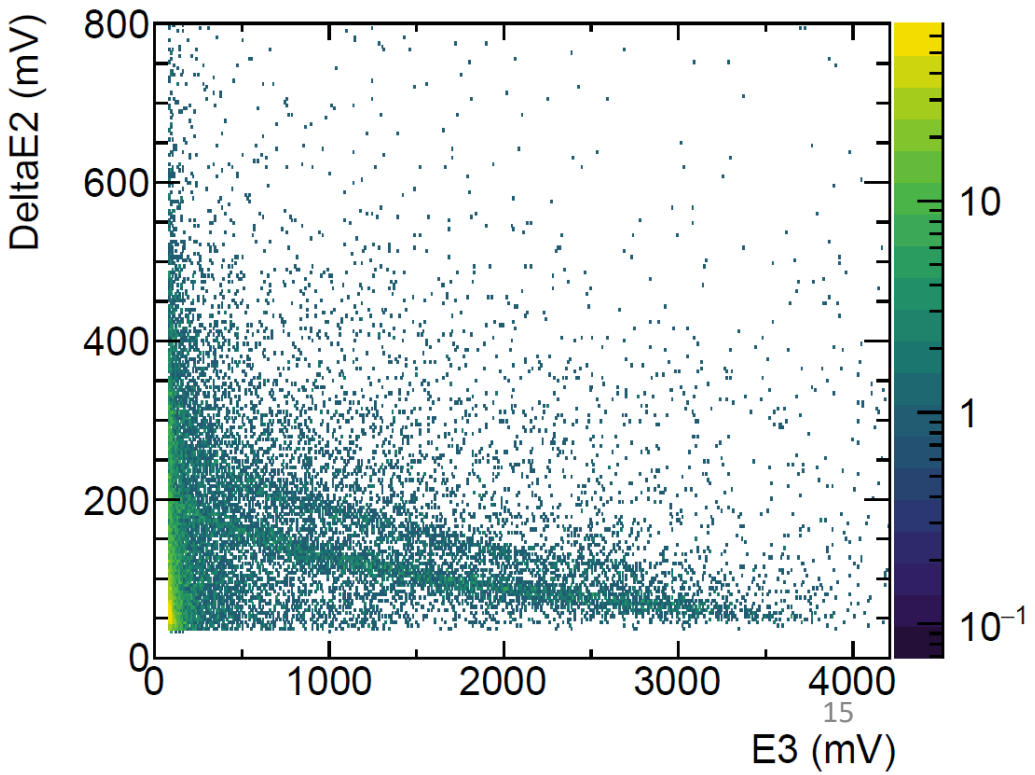


Carbon Data Telescope 1

- Clear coincidence pattern
- Particle separation possible (H-He; p-d)







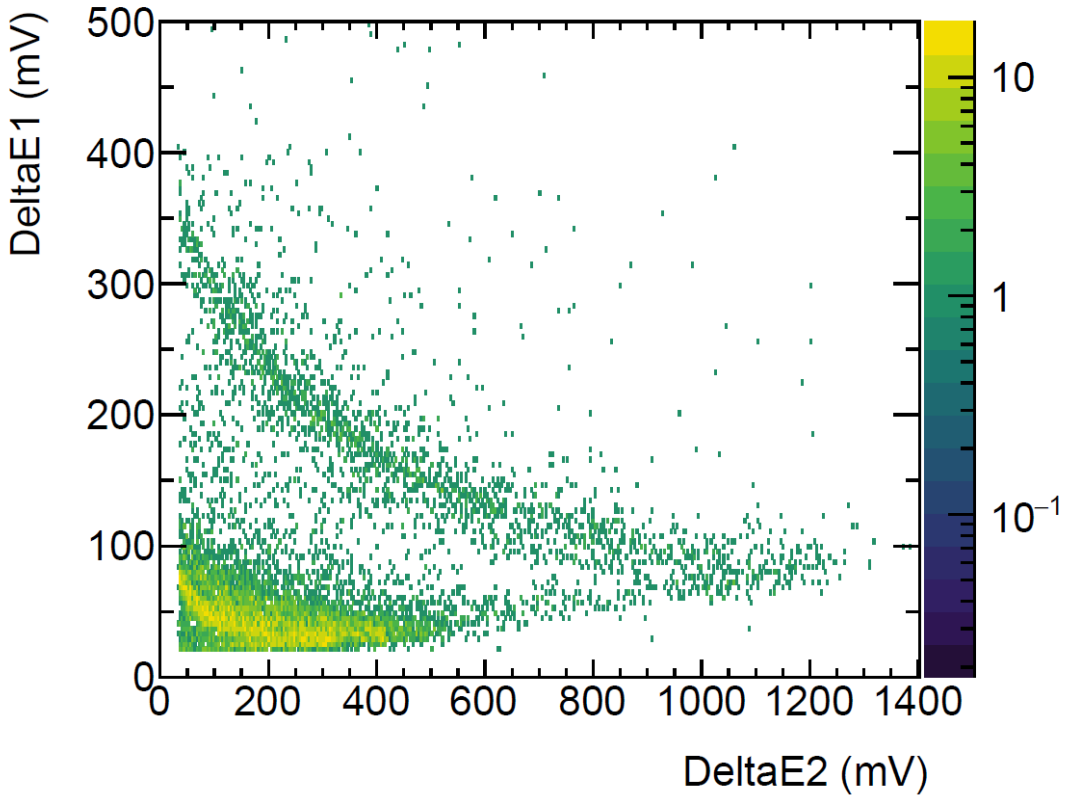
DE1: 51µm + Cividec
DE2: 1043µm+Cividec
DE3: Plastic(150mm)

Carbon Data Tele1 vs Tele 2

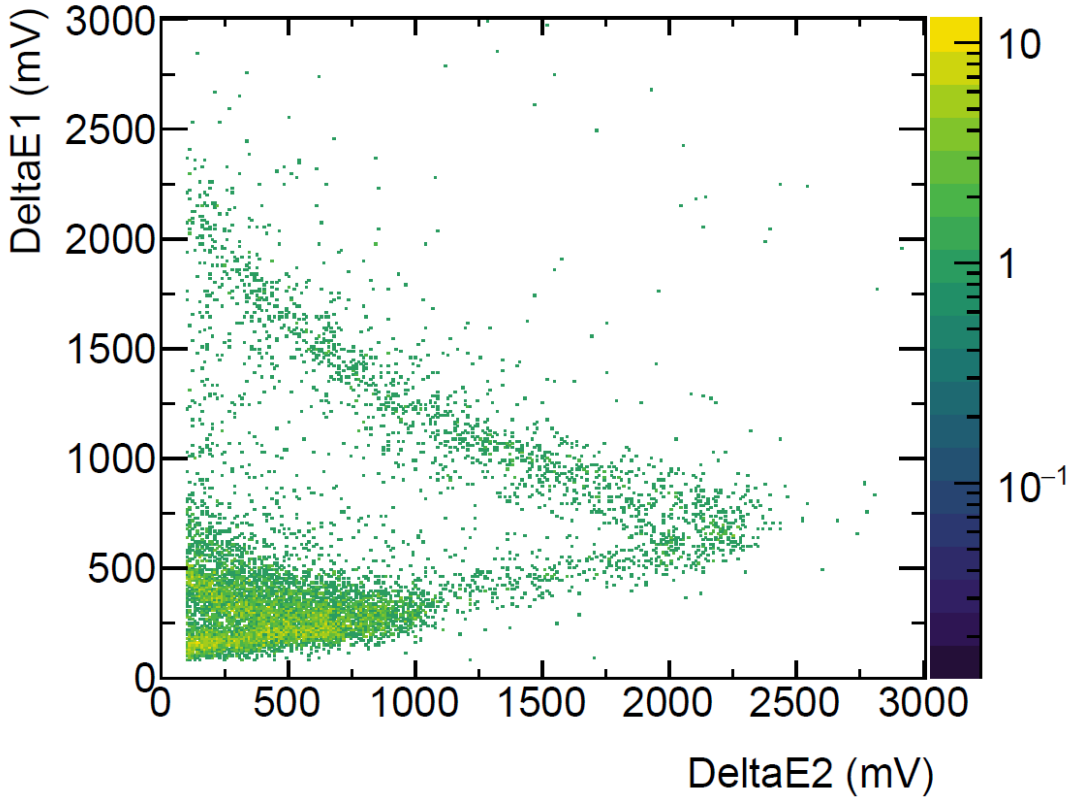
- Clear coincidence pattern with both: Cividec or Cremat
- Particle separation possible (H-He)

DE1: 51µm + Cividec
DE2: 1043µm+Cividec

Cividecs



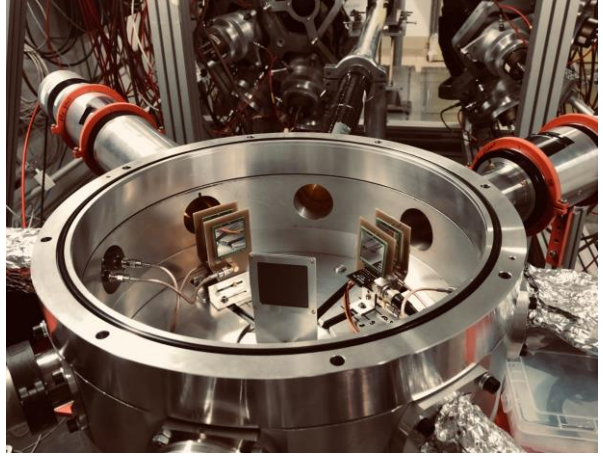
Cremat + Can2004

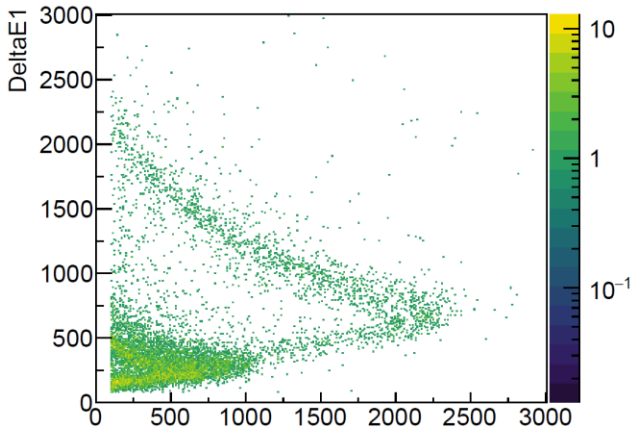


DE1: 49µm
+ Cremat
CR110+FFA
DE2: 507µm
+ Can2004
+ FFA

Summary + Outlook

- Two working telescopes with wrapped Cividecs and Cremat preamp inside shielded vacuum chamber
- Ringing is under control or managable -> Further investigation
- Particle identification seems possible

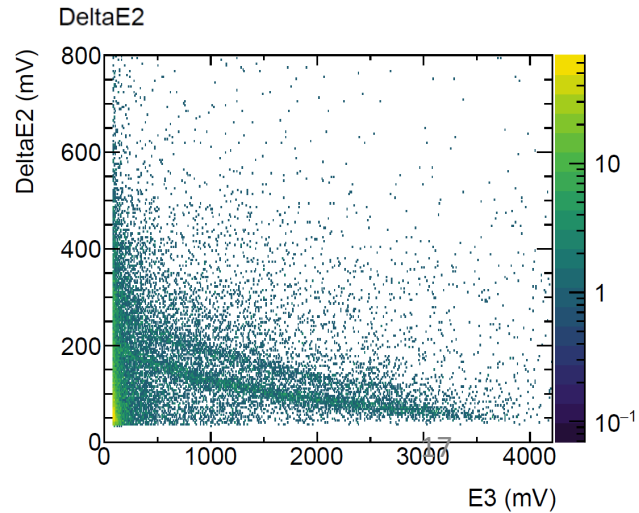




Cremat preamp inside + plastic scintillator

Outlook:

- Baseline reconstructed PSA needed
- Implement energy calibration
- Further analysis ongoing to check detector resolution +…
- Planning of final experiment (DDX Proposal 2023)



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- HZDR colleagues
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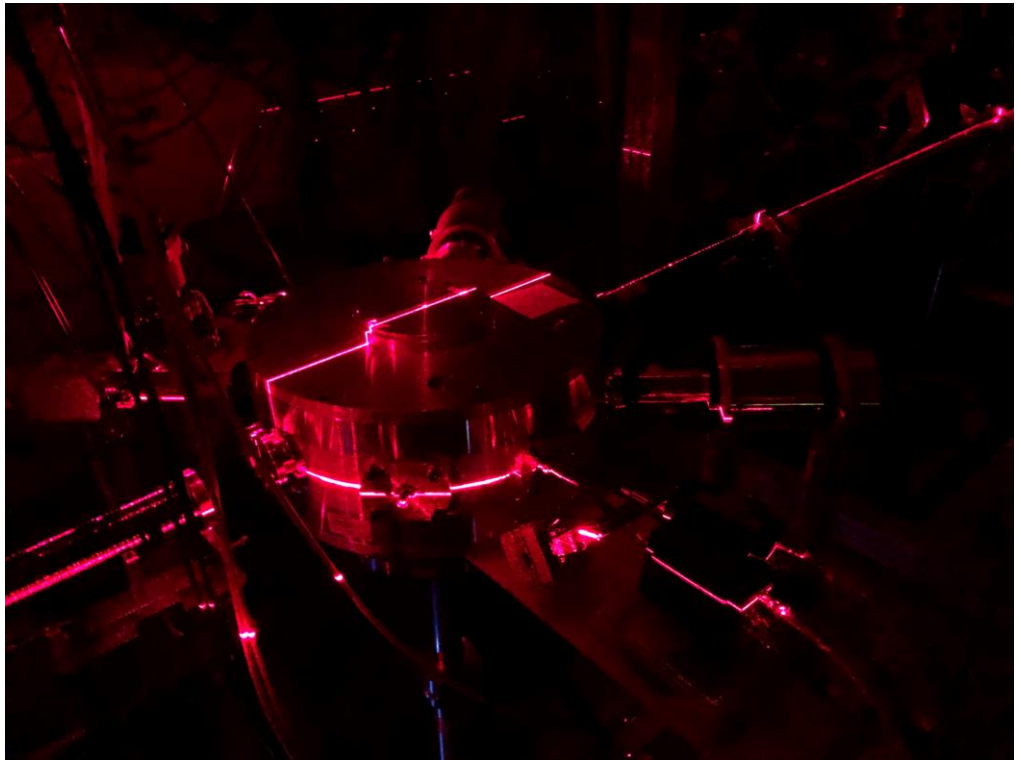
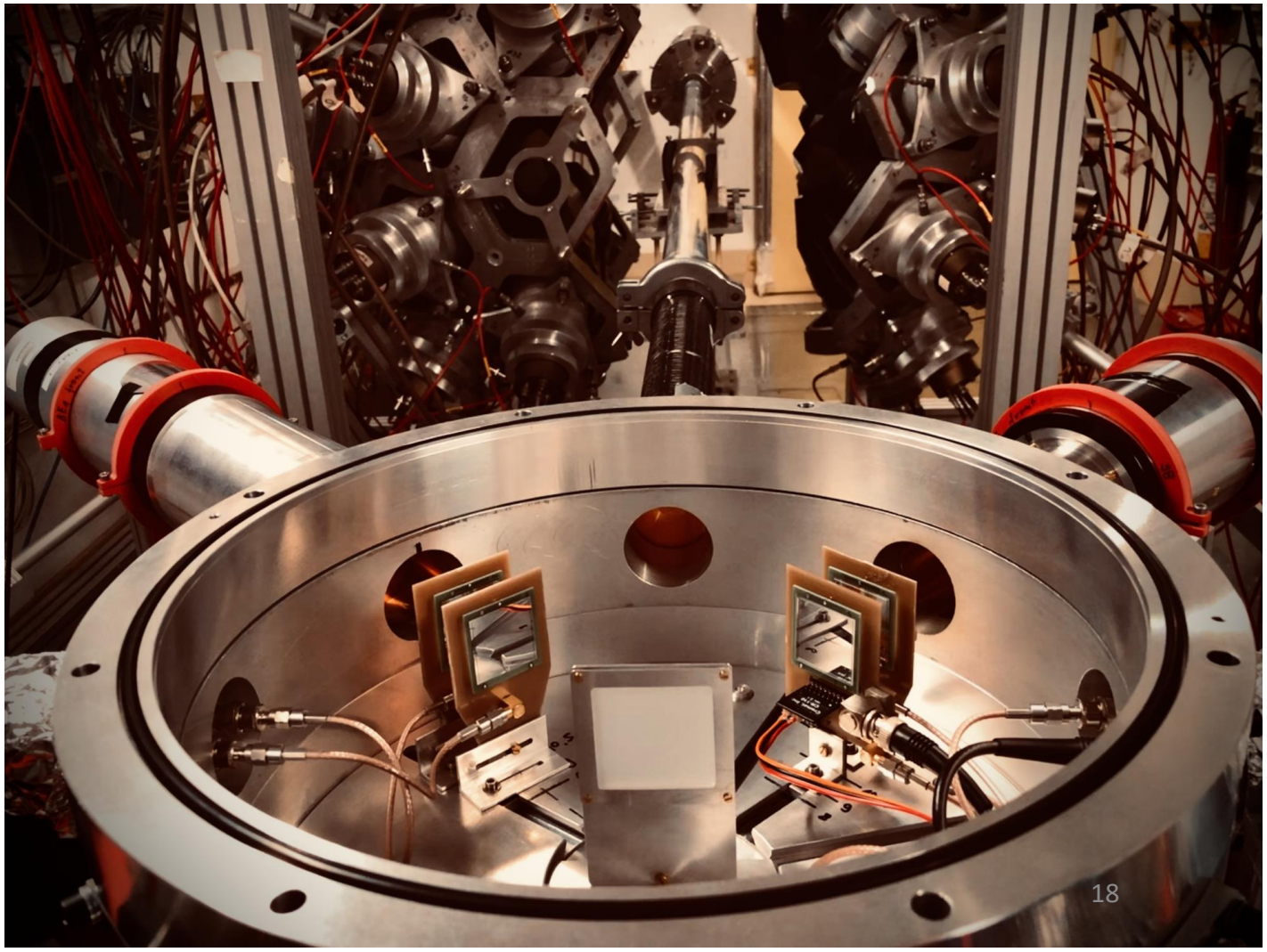
- PTB Workshop and electricians
- Local team
- Shifters
- RP (PTB + CERN)

THANK YOU!





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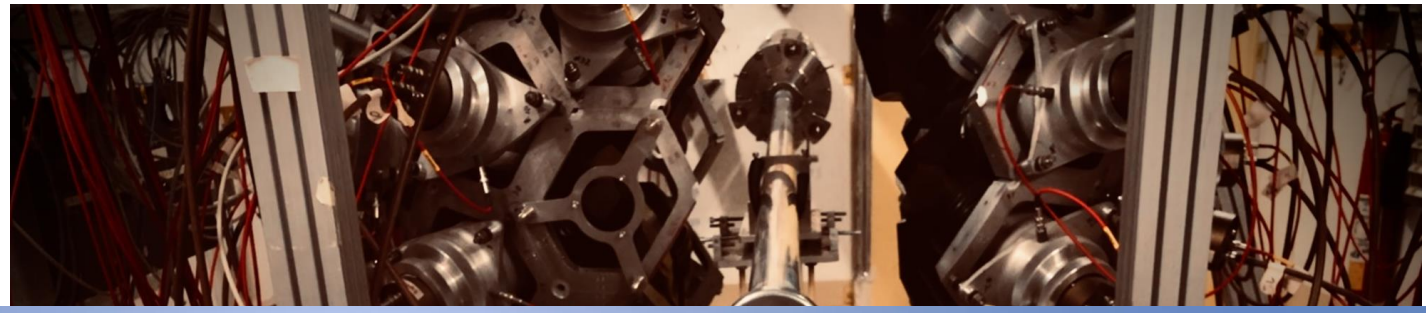
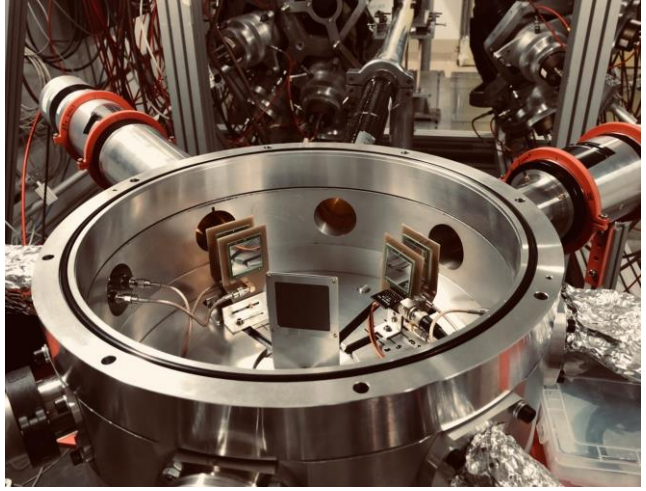


Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
Bundesallee 100
38116 Braunschweig

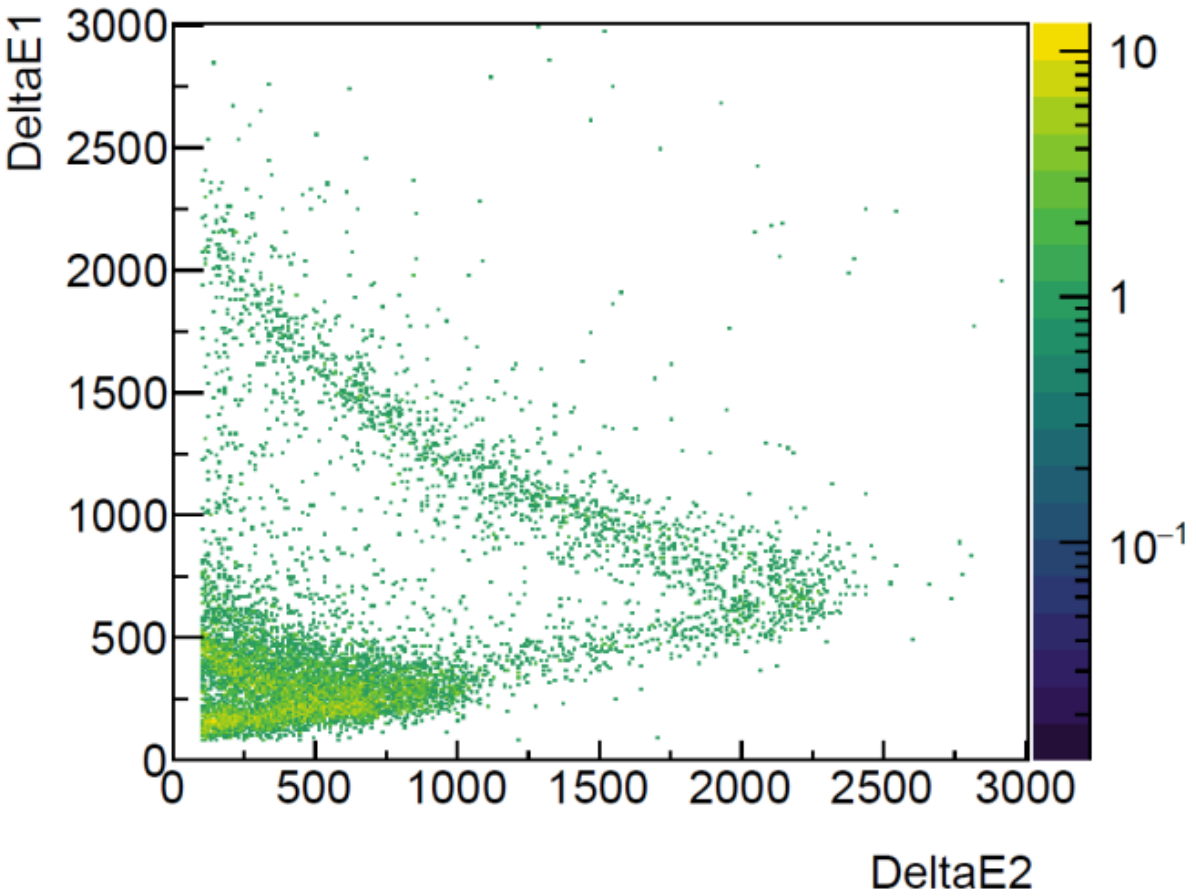
Mirco Dietz
Telefon: +49531 592-6425
E-Mail: mirco.dietz@ptb.de
www.ptb.de

APPENDIX / EXTRA SLIDES

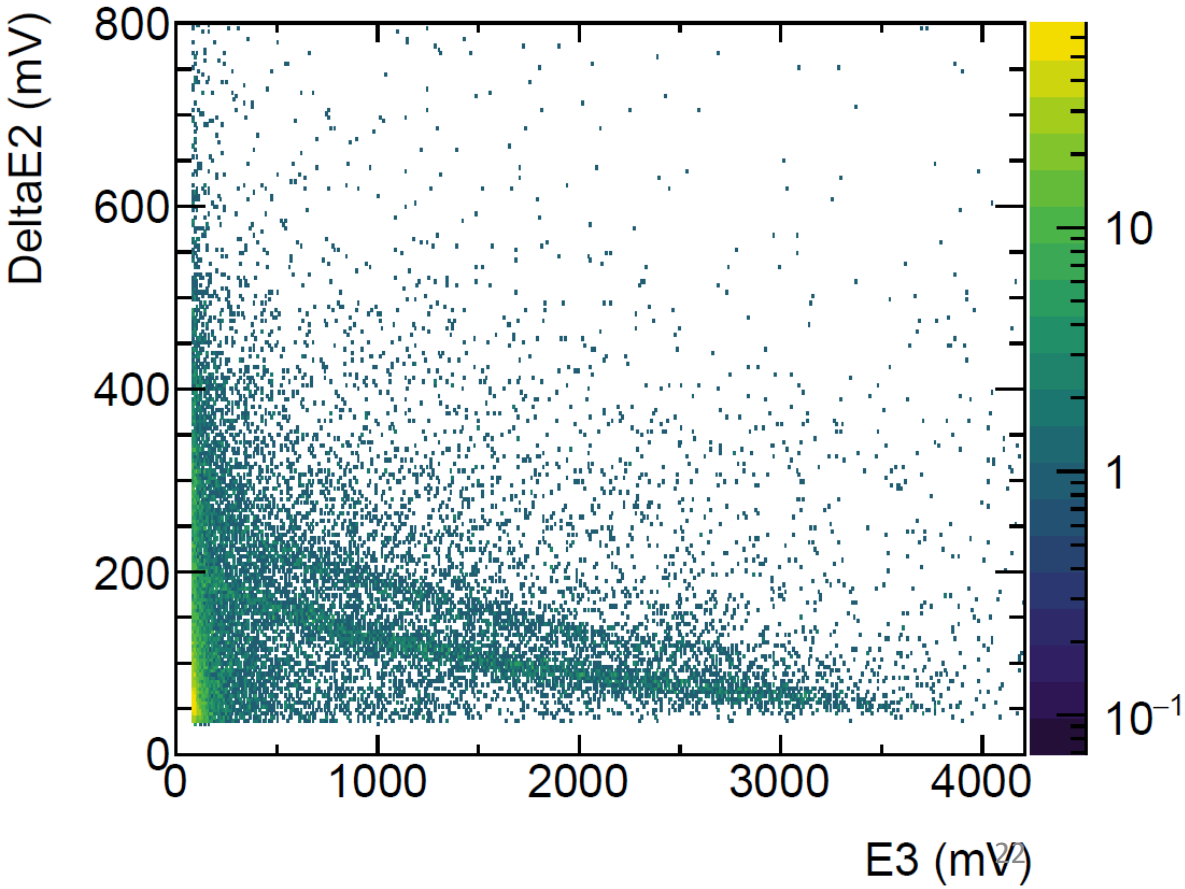
(Best)Carbon Data



Cremat preamp inside!

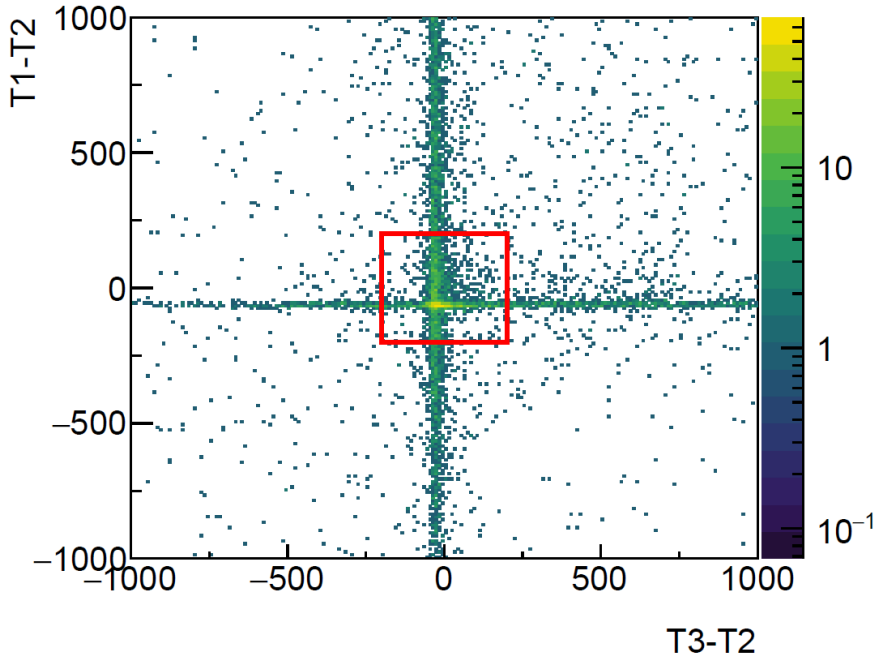


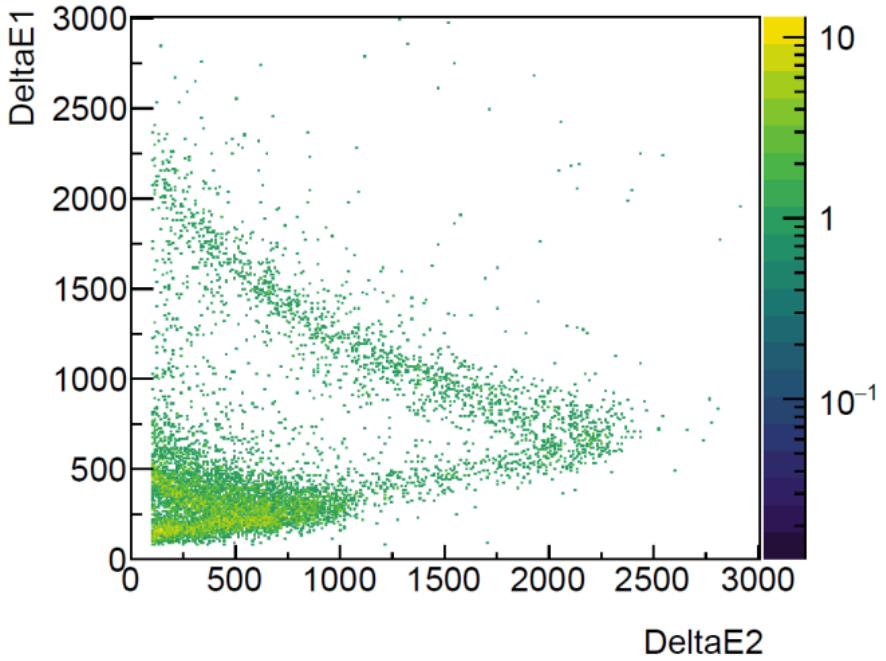
150mm Plastic scintillator

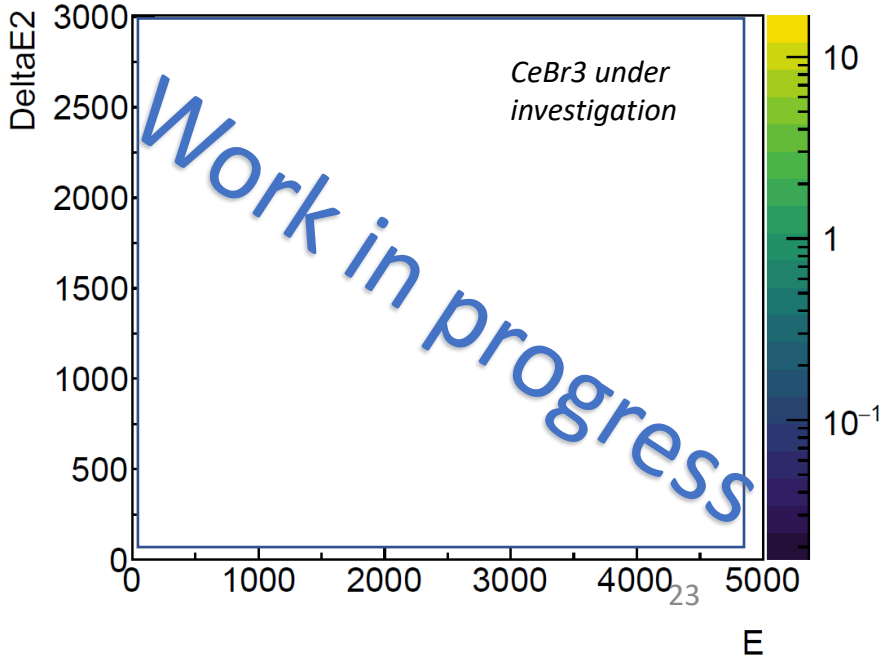


Carbon Data Tele2

- Clear coincidence pattern
- Particle separation possible (H-He)



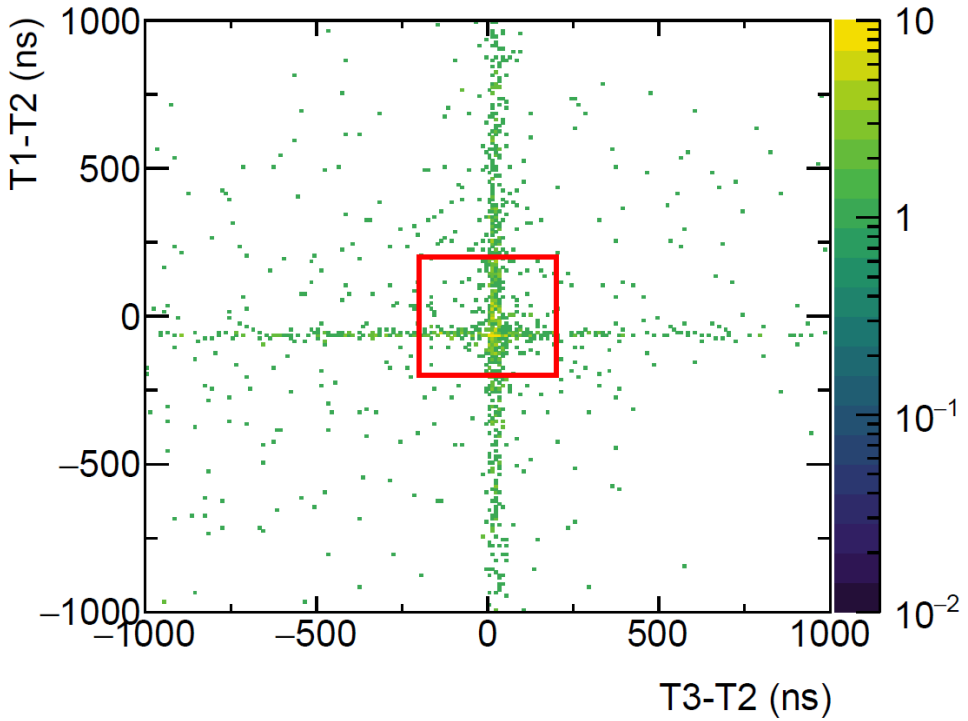


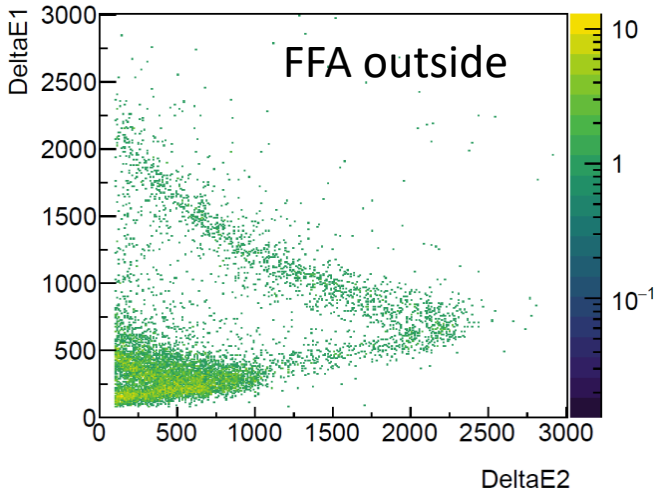


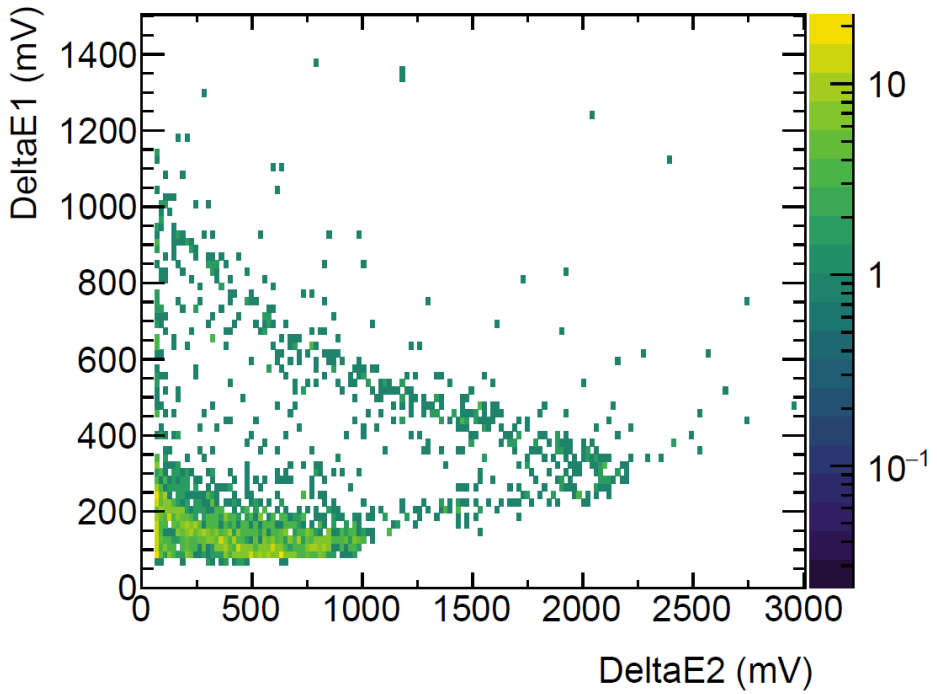
DE1: 49µm + Cremat110+FFA
DE2: 507µm+ Can2004 + FFA
DE3: 3“ CeBr3

Carbon Data Tele2 with Shaper inside

- Clear coincidence pattern
- Particle separation possible (H-He but less gain $_{(1/2)}$ and less statistics



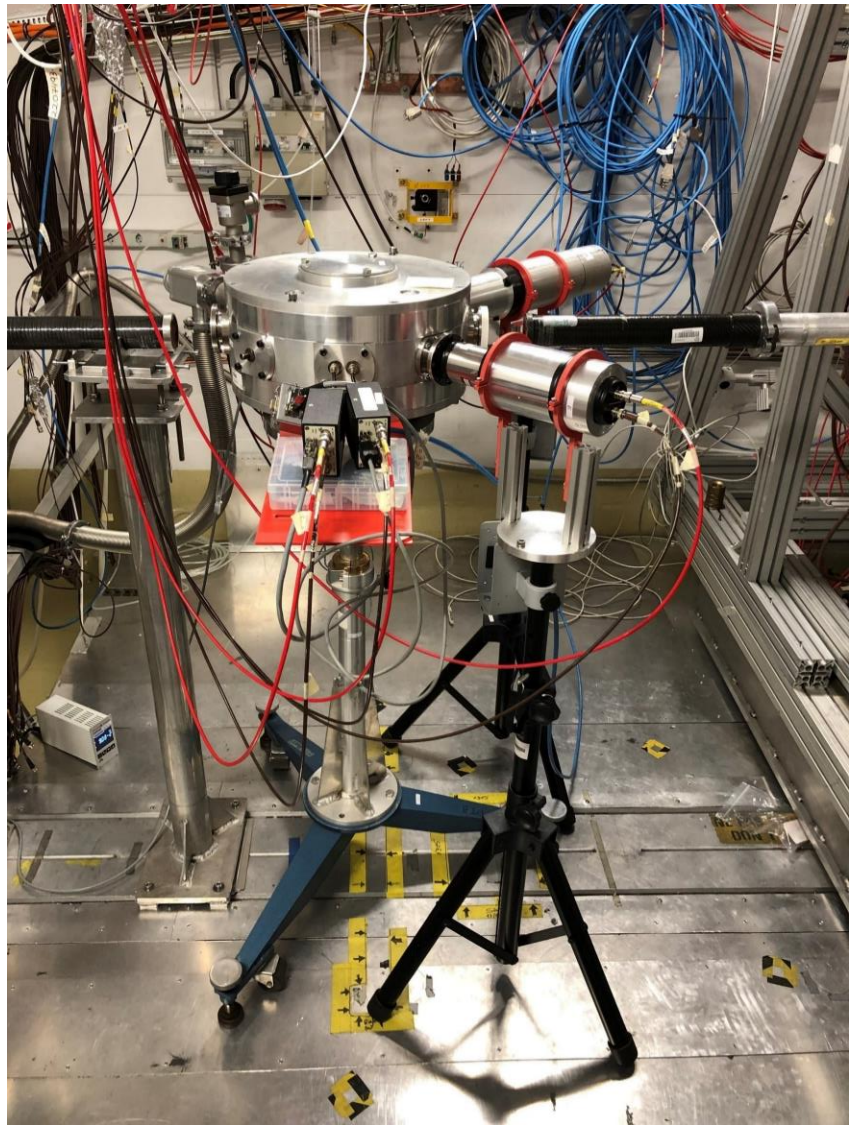


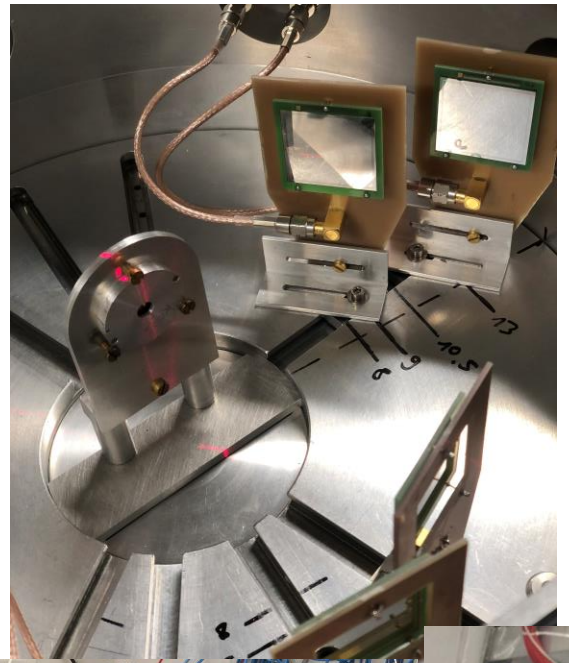


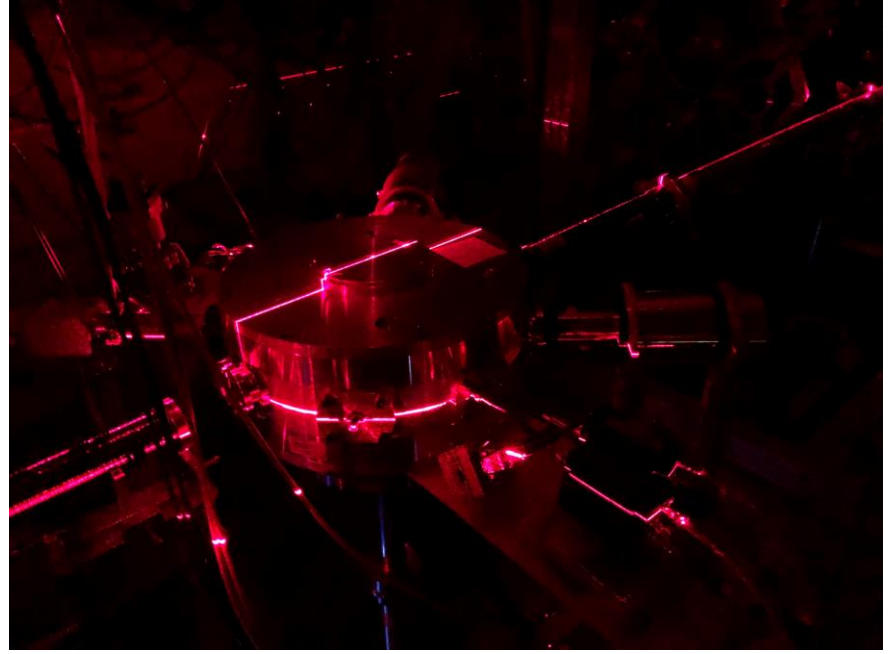
Cremat CR200 shaper inside (over 1 night), rebinned

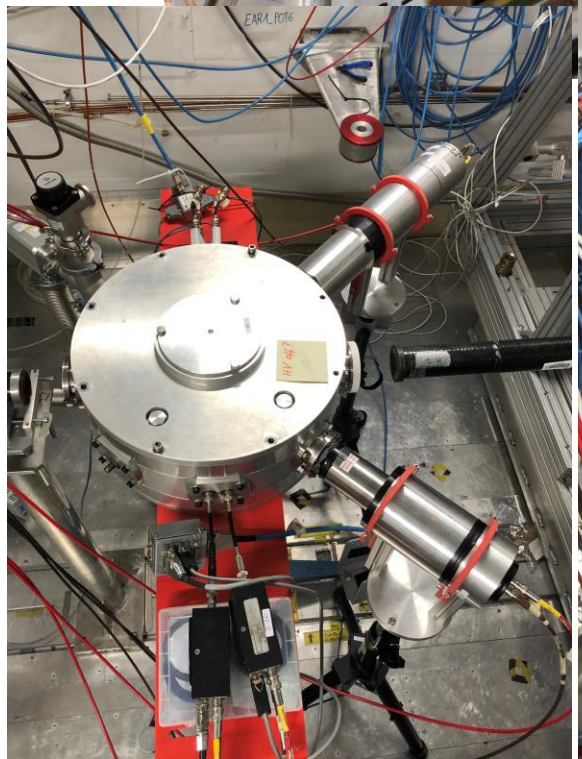
DE1: 49µm + Cremat110+FFA/Cr200
DE2: 507µm+ Can2004 + FFA
DE3: 3“ CeBr3

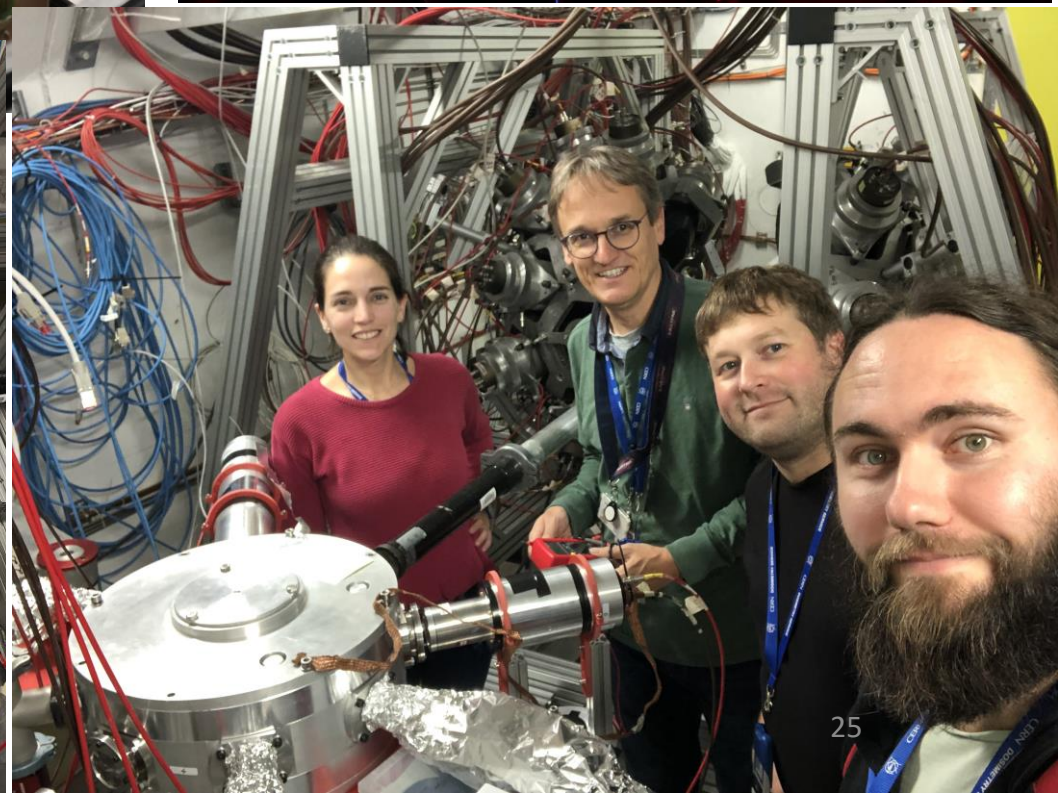
Setup @ n_TOF











Summary May ´22 --- Detector Configurations

DDX Confi-guration	RPT1_1	RPT1_2	RPT1_3	RPT2_1	RPT2_2	RPT2_3	SAMPLE	Files / Comments
Config 1 (9/5)	50µm-Civ#032	1000µm-Civ#033	CeBr3_880V	XXX (not working)	500-PA2004-FFA (13.2)	Plastic100_1680V	1mm PE	112898 – 112902.
Config 2 cal	50-Cividec#032	1000-Cividec#033	CeBr3_990V	**50-PA2004_FFA(13.1)**	500-PA2004-FFA (13.2)	Plastic100_1680V	3A-RPT1 3A-RPT2	112906-112908,112924 112910-112911, 112917-112918
Config 2 (10/5)	50-Cividec#032	1000-Cividec#033	CeBr3_990V	50-PA2004_FFA(13.1)	500-PA2004-FFA (13.2)	Plastic100_1680V	1mm PE 1mm C	112934 112935-112940
Config 3 cal (11/5)	50-**Cremat-TFA**	1000-**Cremat-Shaper**	CeBr3_1300V	**60**-PA2004_FFA(13.1)	500-PA2004-FFA(13.2)	Plastic100_1680V	3A-RPT1 3A-RPT2_1	112950-112951 112948
Config 3 (11/5)	50-**Cremat-TFA**	1000-**Cremat-Shaper**	CeBr3_1300V	**60**-PA2004_FFA(13.1)	500-PA2004-FFA(13.2)	Plastic100_1680V	1mmPe noSw 1mmPE Sw 1mmPE + Pb	112964 112965-112970 112971
Config 3 PA (11/5)	**50-Cremat**	**1000-Cremat**	CeBr3_1300V	**60-PA2004**	**500-PA2004**	Plastic100_1680V	1mm PE 1mm PE Sw	112972-112975 112976
Config 4 (11/5)	50-Cremat-Shaper	1000-Cremat-TFA	CeBr3_1300V	**60-Cividec#032**	500-PA2004-FFA(13.2)	Plastic100_1680V	1mm PE Empty 1mm C	112977-112981, 112984 112985-112986 112987-11988
Config 5 (12/5)	50-Cremat-Shaper	1000-Cremat-TFA	CeBr3_1300V	60-Cividec#032	**CAN500**-PA2004-FFA(13.2)	Plastic100_1680V	207Bi 1mm C	112989-112993 112994-113000
Config 5 cal (13/5)	50-Cremat-Shaper	1000-Cremat-TFA	CeBr3_1300V	60-Cividec#032	**CAN500**-PA2004-FFA(13.2)	Plastic100_1680V	3A-RPT1 3A-RPT2	113006 113008

Grounding of Plastic scintillator (Nov 2022)