

# Initial Characterization of the First CSPEC Detector Module



William Saenz-Arevalo  
on behalf of the SDN groupe at ILL

Gaseous detector workshop  
6 - 7 May 2026, Modane

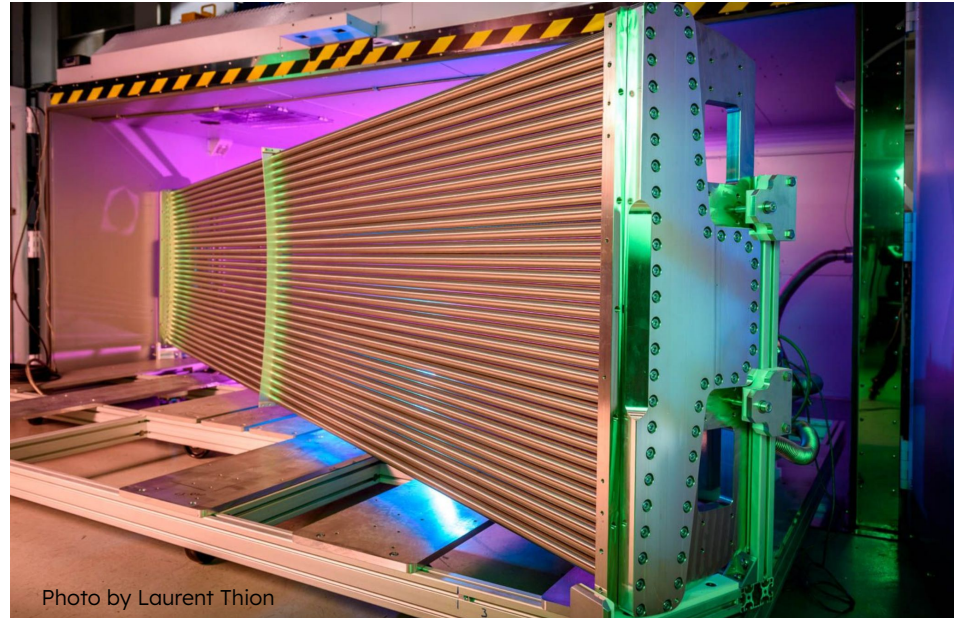


Photo by Laurent Thion

# Outline

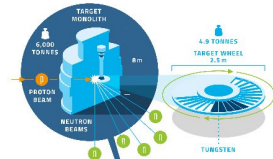
- Introduction to the CSPEC instrument at ESS
- Multitube technology at ILL
- CSPEC detector
  - Conceptual design
  - Commissioning of 1st module
  - Preliminary performance tests
- Overview

# ESS - A new source of neutrons

- European Spallation Source @ Lund, Sweden
- Linac accelerators for proton beam at 2 GeV
- Neutrons from spallation of proton against tungsten target

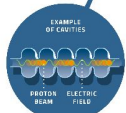
1 Protons are generated in the ion source

3 The protons strike the target and high-energy neutrons are released



5 When the neutrons arrive at the instruments, researchers use them to examine matter down to the atomic level

2 Cavities accelerate the protons to 96% of the speed of light

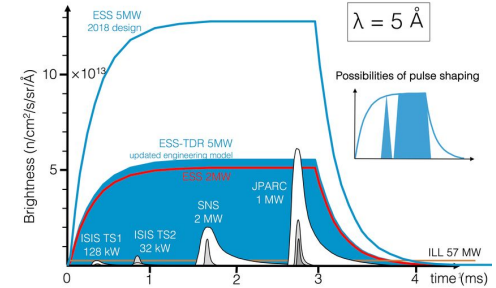


4 The neutrons are slowed down and sent down neutron guides to the instruments

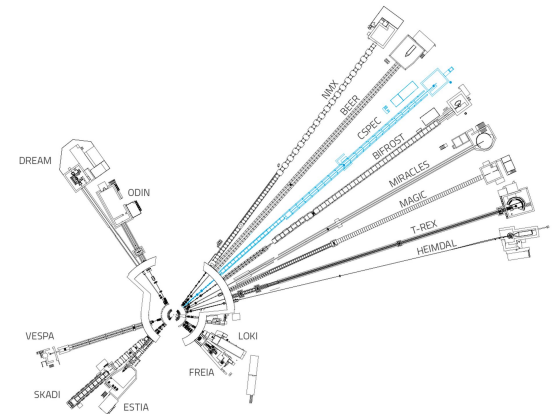


6 All the data is sent to the Data Management and Software Centre in Copenhagen to be stored, managed and analysed with the researchers

- Few ms pulsed neutron beam

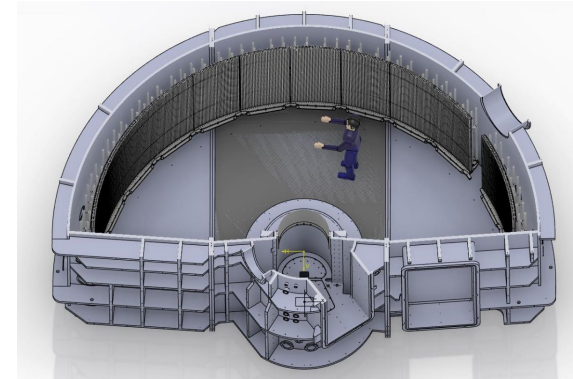
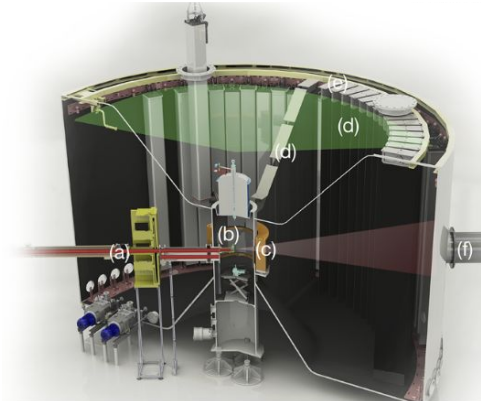
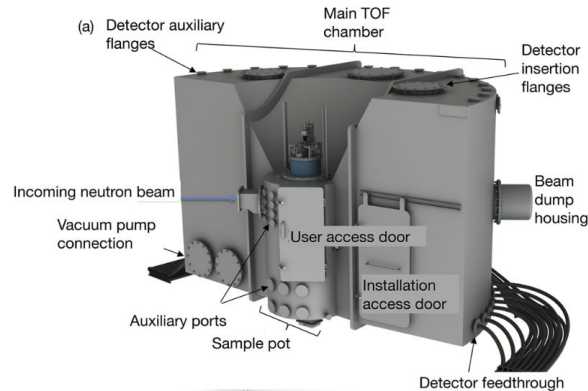


- 15 instruments (8 at ~ 150 m from the source)



# CSPEC instrument

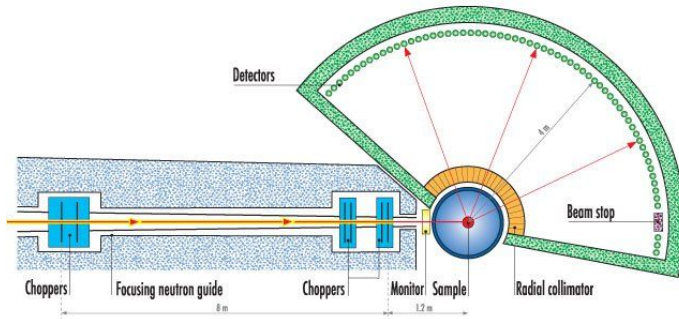
- Cold Chopper Spectrometer → Inelastic neutron scattering (angle, energy) → Dynamic behaviour in materials
  - Angle determined from position sensitive detectors
  - Energy determined from time-of-flight TOF
- Detector requirements:
  - High uniformity of response,
  - High neutron counting efficiency
  - Low gamma-sensitivity



# ILL's experience in $^3\text{He}$ TOF detectors

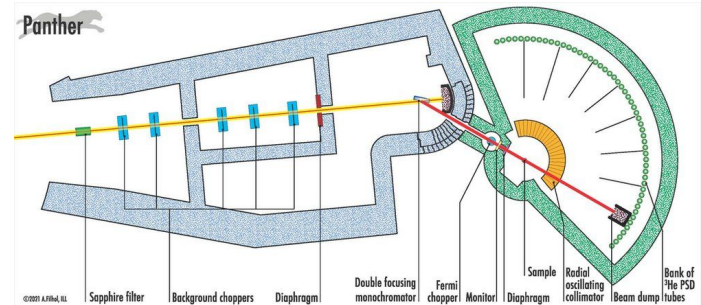
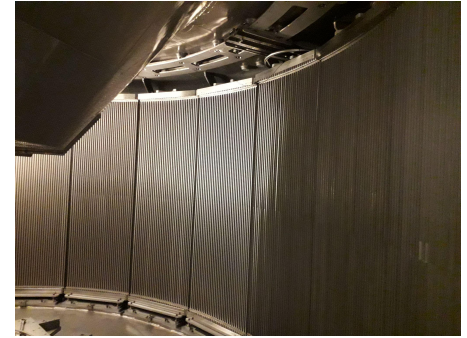
## IN5

- Gas: 4.75 bar  $^3\text{He}$  + 1.25 bar  $\text{CF}_4$
- 12 modules of 32 tubes each
- Flight path: 4 m
- Detection height: 3 m
- Operational since 2008



## PANTHER

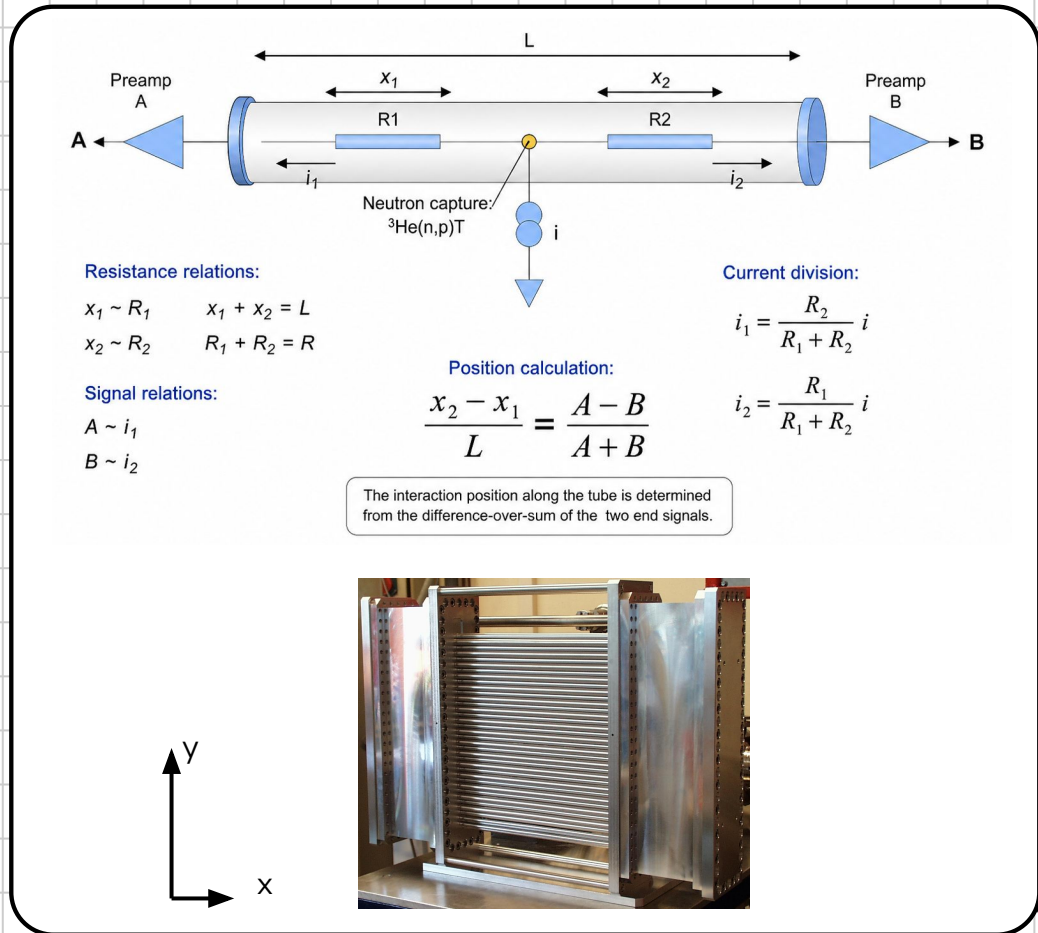
- Gas: 10 bar  $^3\text{He}$
- 9 modules of 32 tubes each
- Flight path: 2.5 m
- Detection height: 2 m
- Operational since 2020



# Multitubes technology

- Gaseous detector
  - $^3\text{He}$  → neutron absorber
  - Ar/CF<sub>4</sub> → ionization
  - CO<sub>2</sub> → quenching
- 2D dimensional reconstruction of neutron absorption position from charge division
 

(X, Y) → ( interaction position, tube number )
- Position resolution determined by
  - X → SNR, proton-tritium COG, ionization track topologies....
  - Y → Fixed to tube-to-tube separation

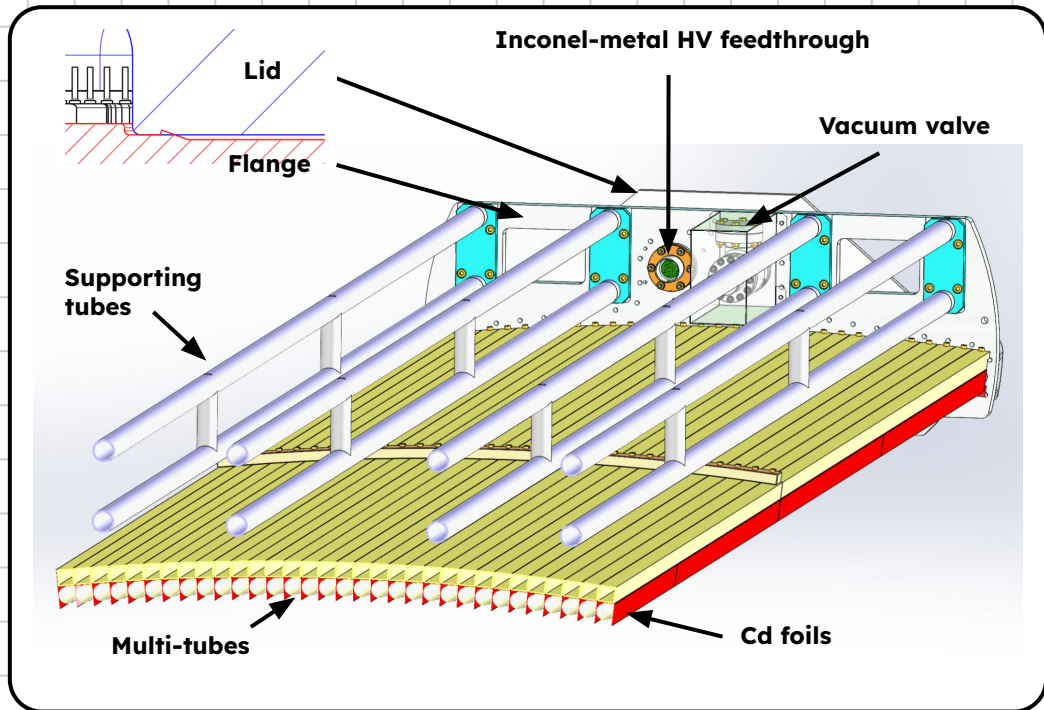
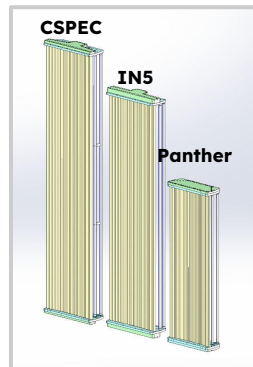
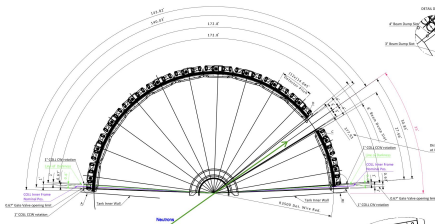
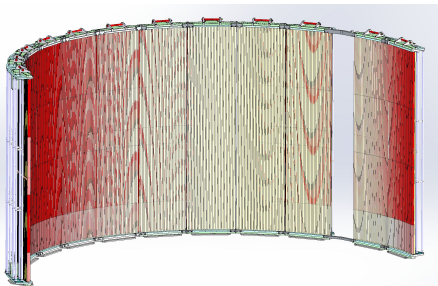


# Multitubes Modules for CSPEC

- 12 isolated modules of 32 tubes each
- Tubes: 3.5 m length, 2.54 cm  $\varnothing$  (56 L per module)
- 25  $\mu\text{m}$   $\varnothing$  stainless steel anode wire
- Gas pressure: 4 bar 3He + 1 bar Ar/CO<sub>2</sub>
- Vacuum tightness from knife-edge seals
- Cadmium foils for crosstalk suppression
- Weight (per module) ~ 500 kg

Main challenges:

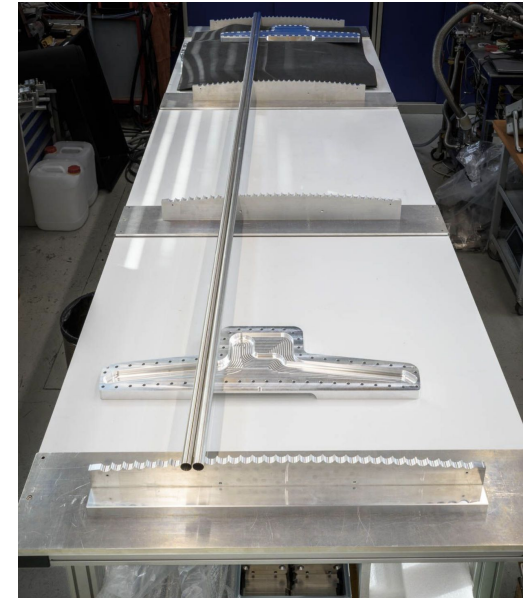
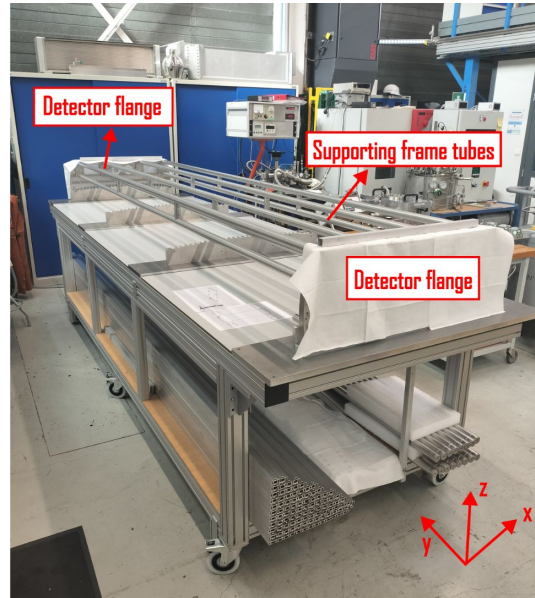
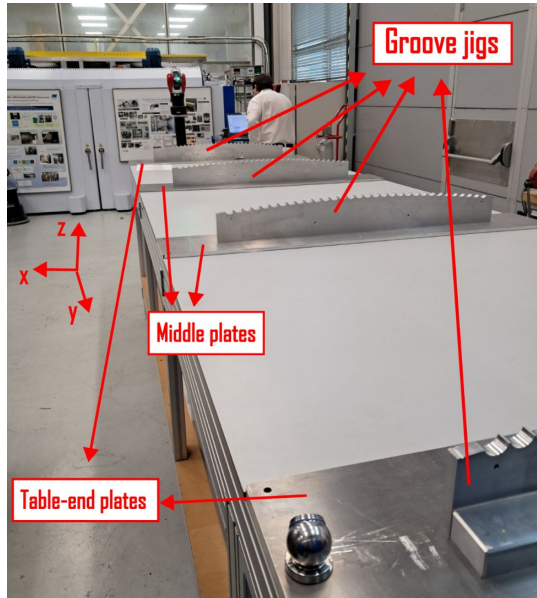
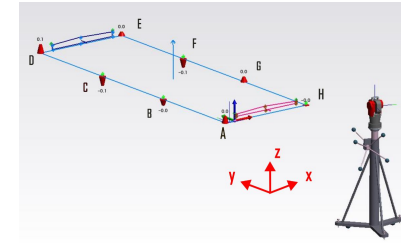
- Counting uniformity along tubes: variations < 5%
- High counting: 50 kHz/tube
- Stable detection efficiency: leaks < 0.01 mbar/day



# Commissioning of 1st CSPEC detector module

# Welding table and frame module installation

- 3D laser tracker of welding table before and after placing module frame
- Adjustment of table legs to achieve deviations  $< 0.1$  mm
- Metrology of table kept unchanged for 12 modules production



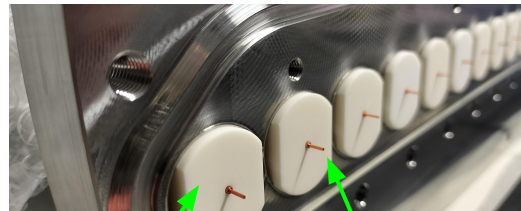
# Tubes welding → Wire insertion → HV PCB installation



**Automatic welder  
(power and rotating speed pretuned)**



**Stainless steel 304  
wire**

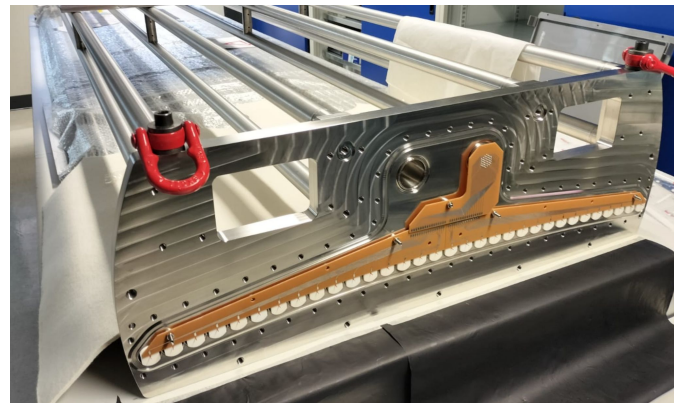


**Insulating end  
caps**

**Copper crimping  
tubes**



**Polyimide (Kapton) flex-rigid circuit**



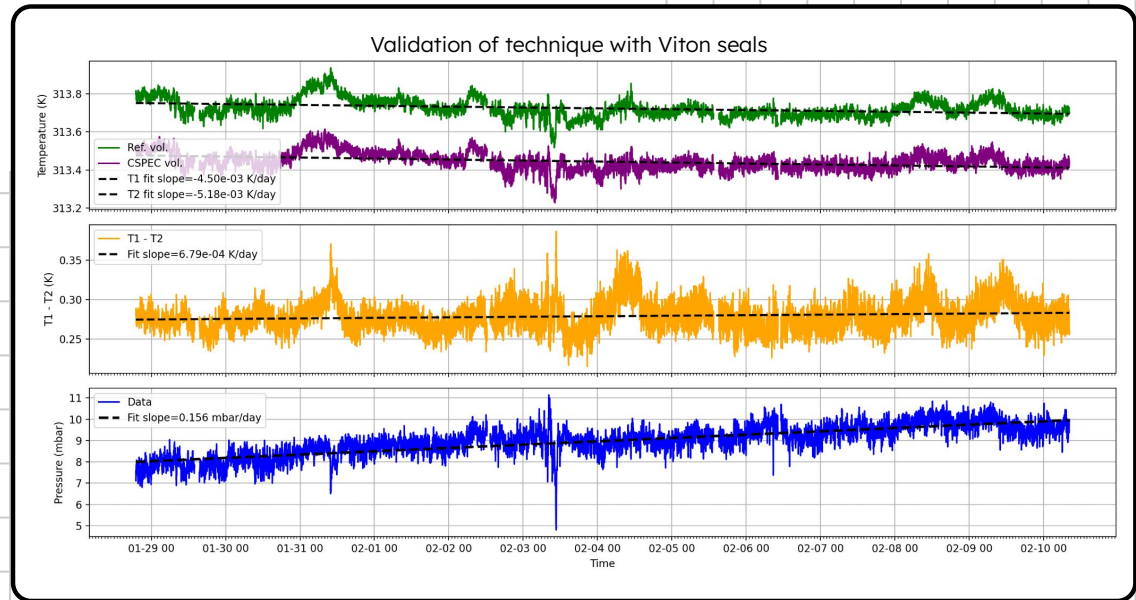
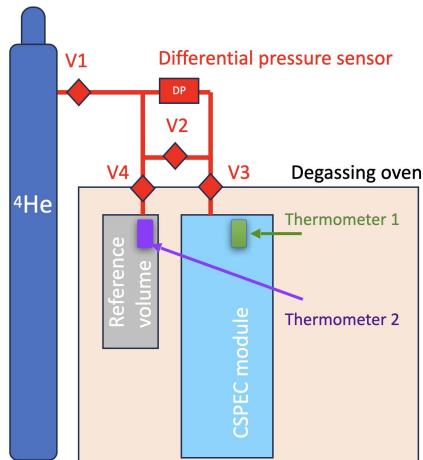
# Pumping → Vacuum tightness → Degassing

- $10^{-7}$  mbar reached a couple of hours after first pumping
- $4\text{He}$  sniffing with large flow next to flange joints (no signal visible on mass spectrometer)
- While pumping, module baking at  $100\text{ }^{\circ}\text{C}$  during 2 weeks



# Overpressure tightness

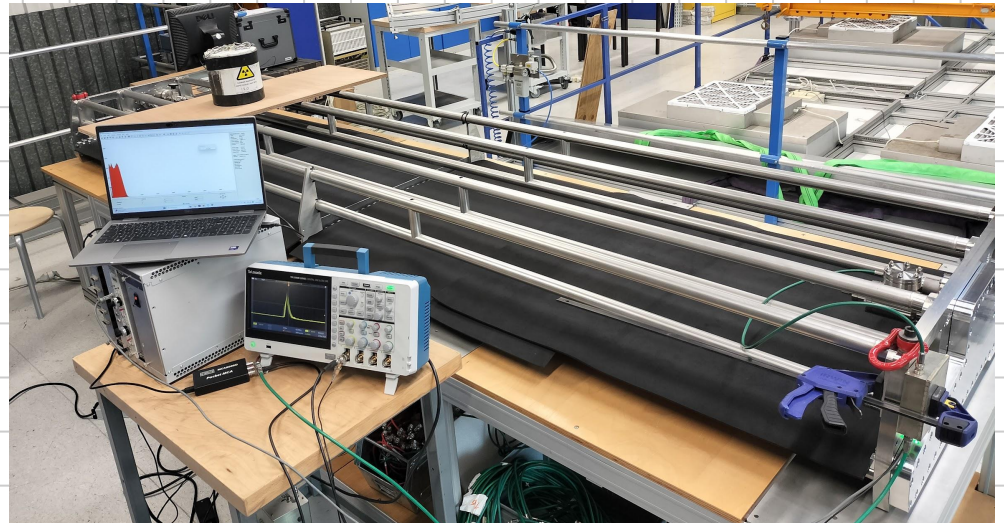
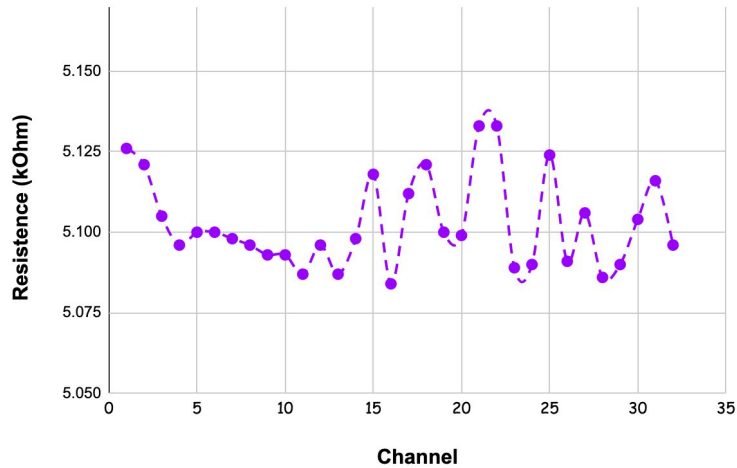
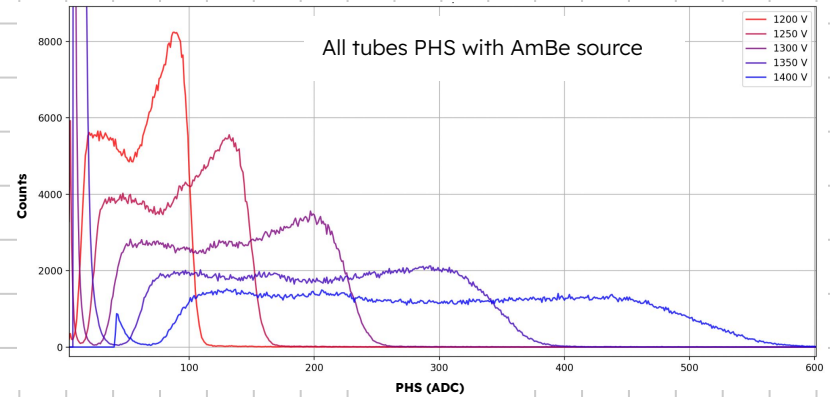
- Technique: differential pressure monitoring
  - Thermally controlled vessel (degassing oven)
  - Differential pressure sensor between CSPEC and reference volume
  - Thermometers attached to CSPEC and reference volume (PT100)
  - Valve V1: Common gas filling of both volumes (currently  $^4\text{He}$  but final gas mixture later on)
  - Valve V2: Allow gas flow from bottle to CSPEC
  - Valve V3: Isolation of CSPEC module
  - Valve V4: Isolation of reference module



# Preliminary performance tests of 1st module

# Preliminary tests at the workshop area

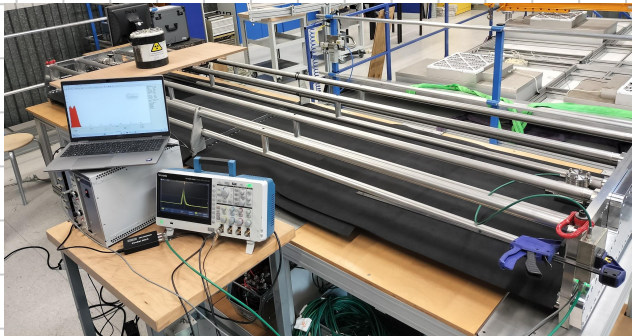
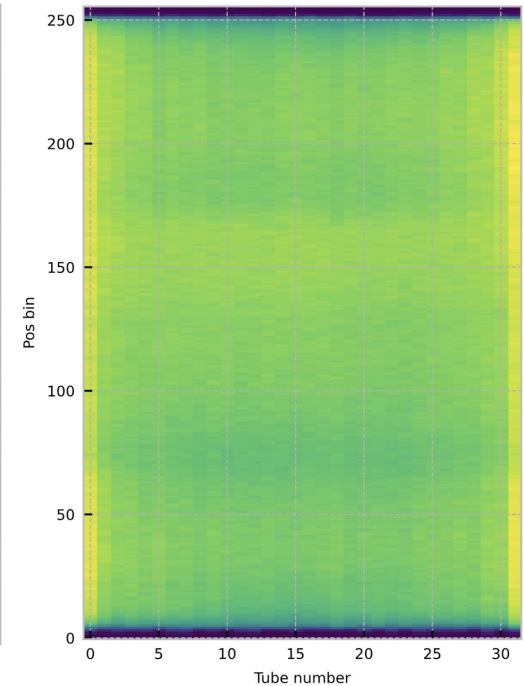
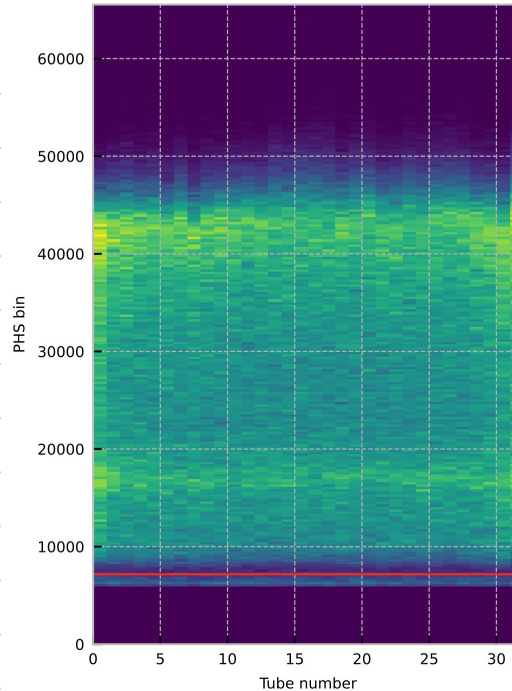
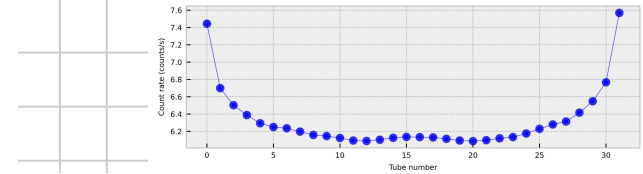
- $^3\text{He}$  (3 bar) + Ar (0.95 bar) +  $\text{CO}_2$  (0.05 bar)
- Protocolary check of electric resistance (per tube)
- AmBe source for HV tuning



# Preliminary tests at the workshop area

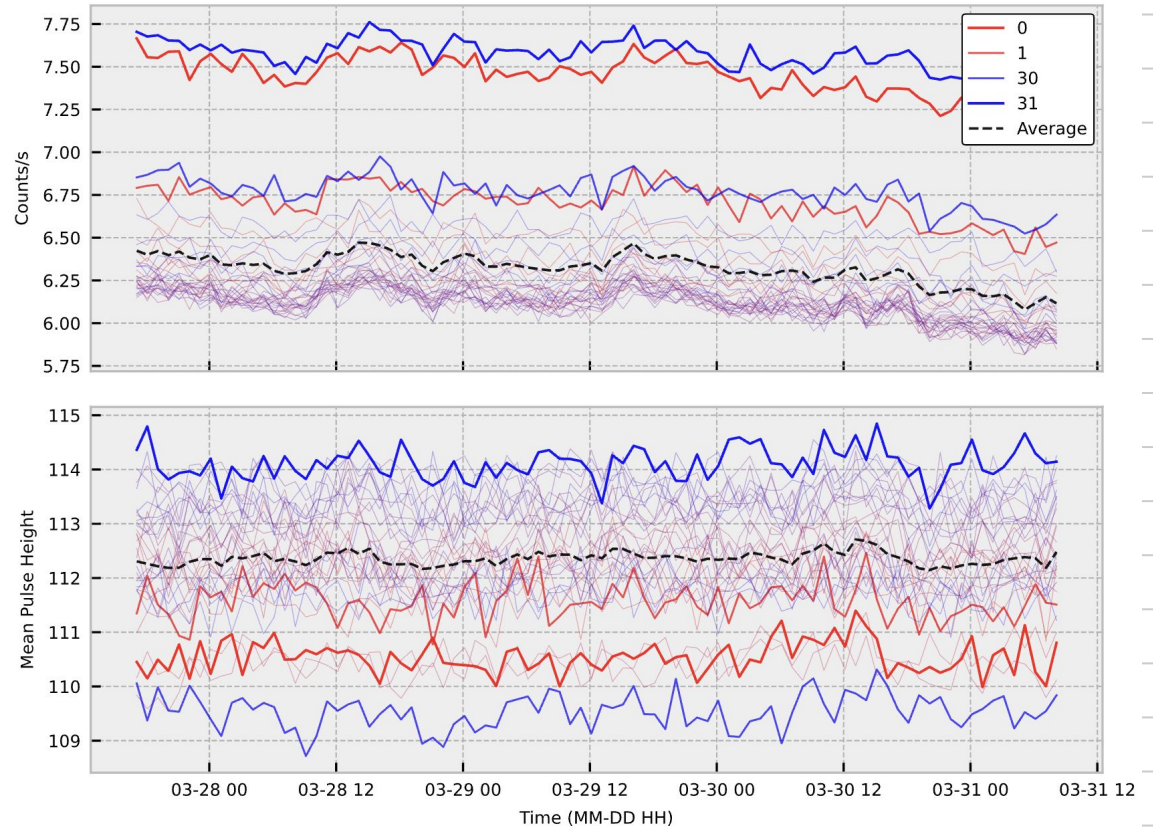
Data acquisition from background measurement (ground level)

- Left: Pulse Height Spectra (PHS) vs tube number
- Right: Reconstructed position image (pos =  $A/(A+B)$ )
  - Negligible sparking rate on edges



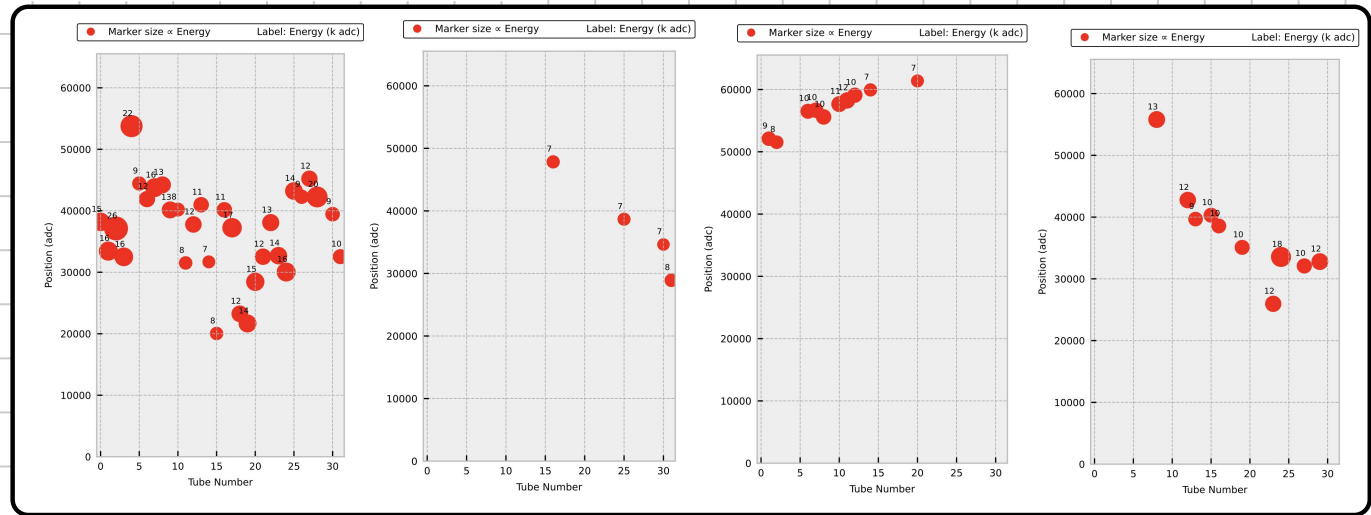
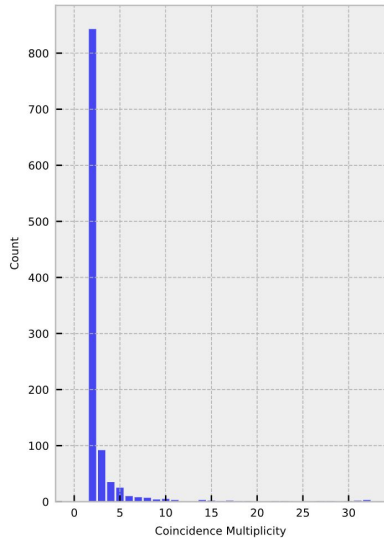
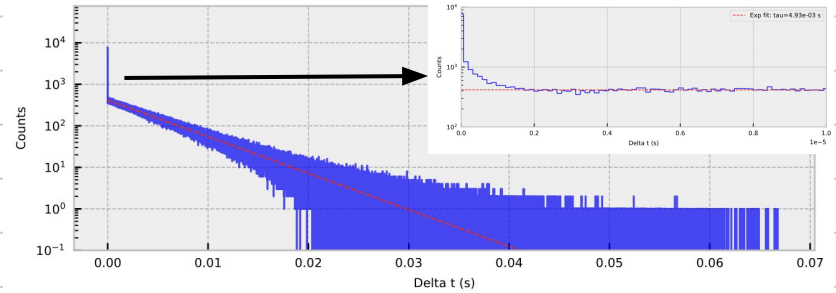
# Stability measurements

- Background data over a weekend (one point every hour)
- Counting stability dominated by environment factor
- Gain (mean pulse height) stability ~ 1%



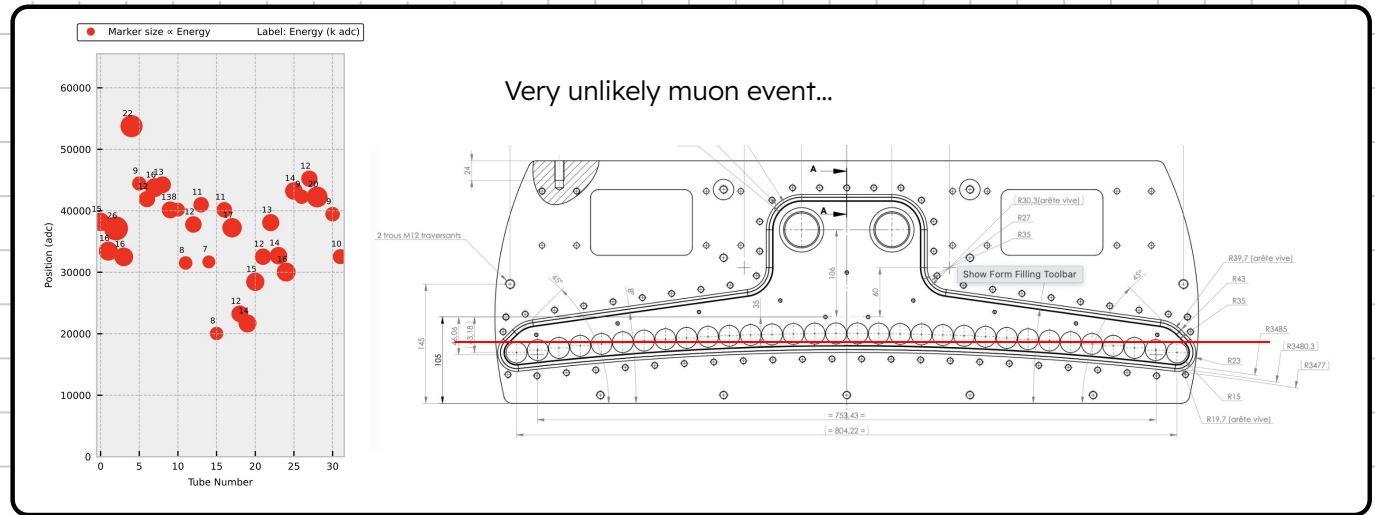
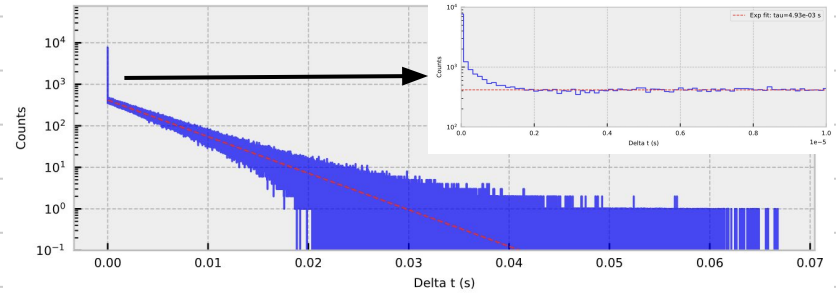
# Background time analysis

- List mode acquisition allows recording A, B and t of each detection
- Delta t: time separation between events
- Coincidences cut on events with Delta t < 2 us
- Tube multiplicity of coincidence events decays rapidly but is non zero for 32!



# Background time analysis

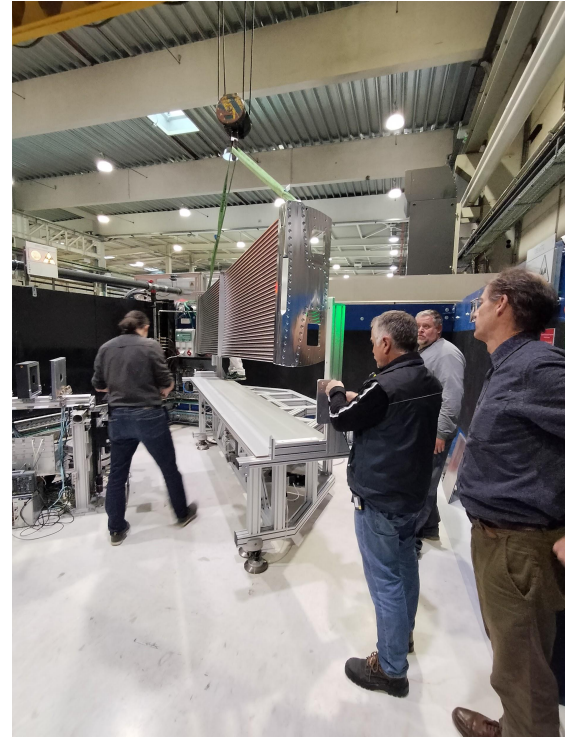
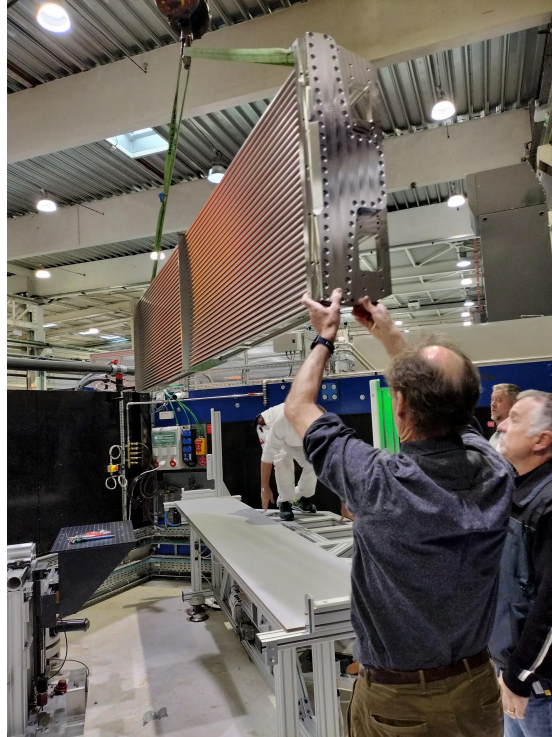
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- Looking for candidates...



# Performance tests at CT2 beam line

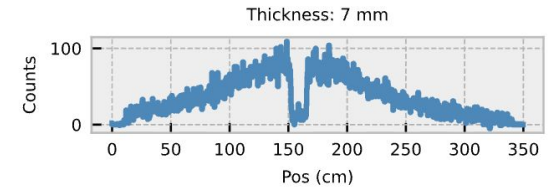
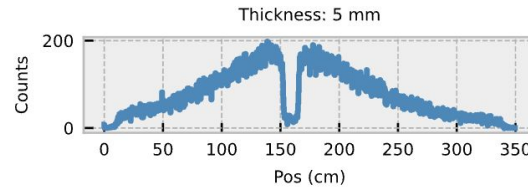
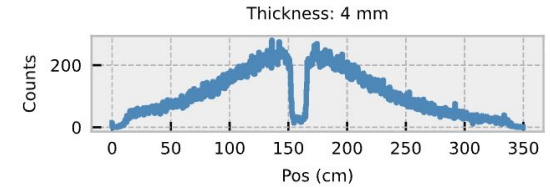
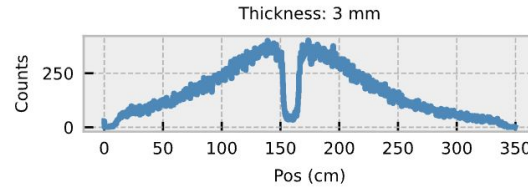
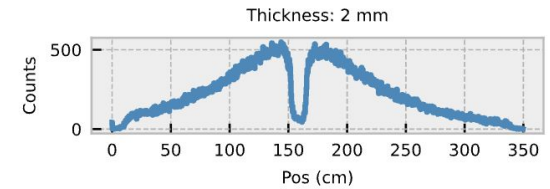
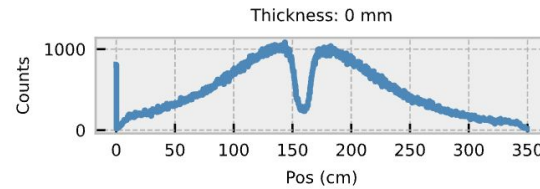
# Transport between workshop and beam line CT2

(end of March 2026)



# Counting linearity on a single tube

- Maximization of beam spreading to cover the full detector
- Reading of 4 channels only to avoid dead time from signal processing of DAQ
- Operation conditions:
  - HV: 1550 V
  - Shaping time: 1.1  $\mu$ s
  - Attenuating plexiglass from 0 to 9 mm
  - 10 s runs
  - Background subtraction

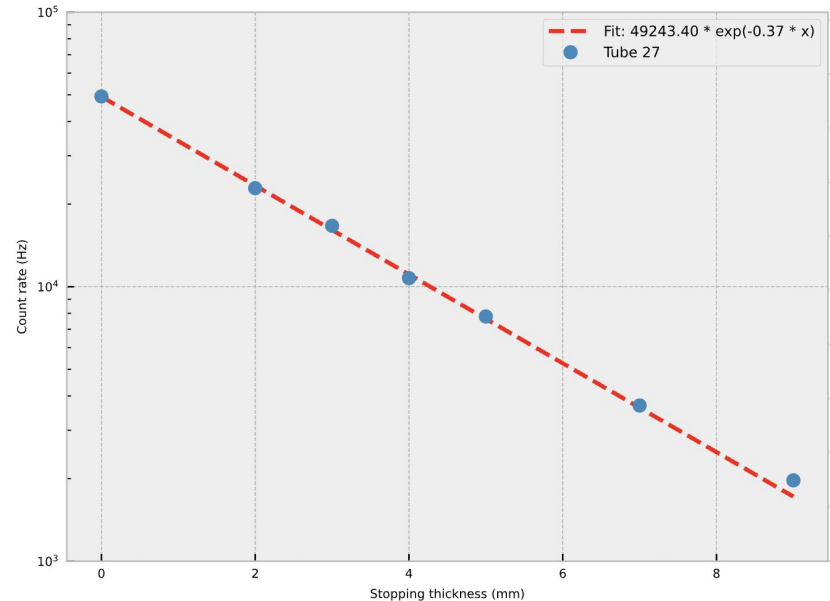
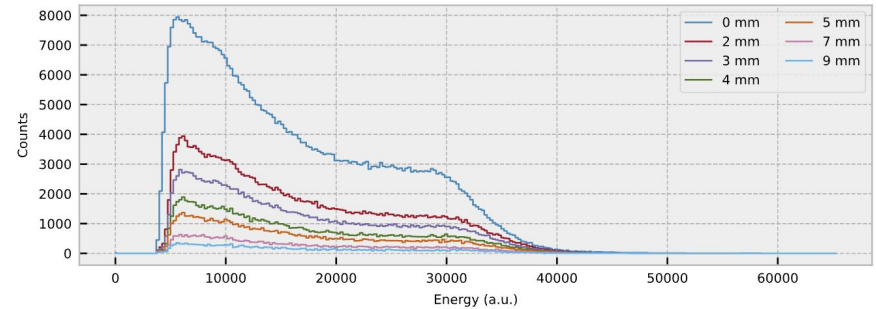


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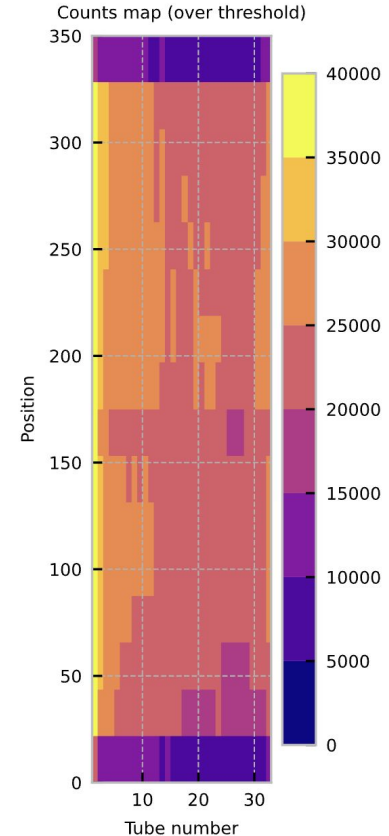
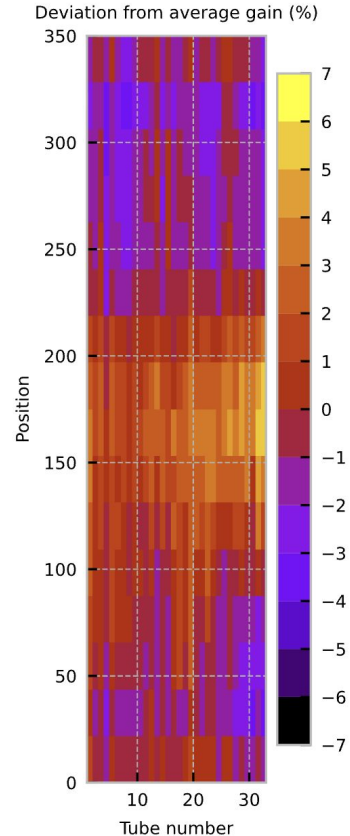
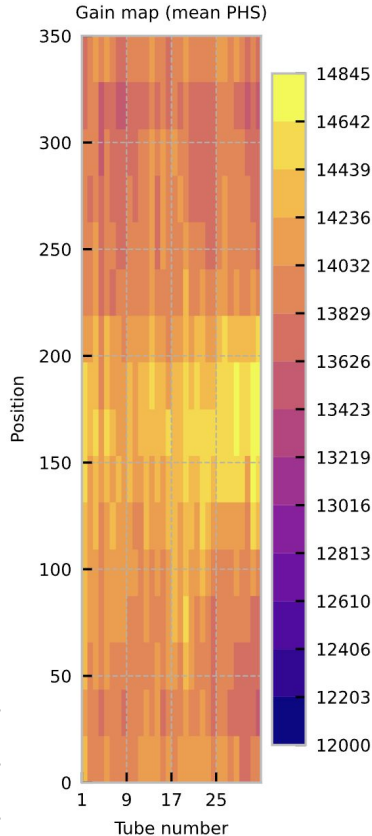
## Results:

- No deformation of energy spectra at high counting
- No deviation from exponential behavior up to 50 kHz  
(Specifications in contract: max count rate 50 kHz per tube)

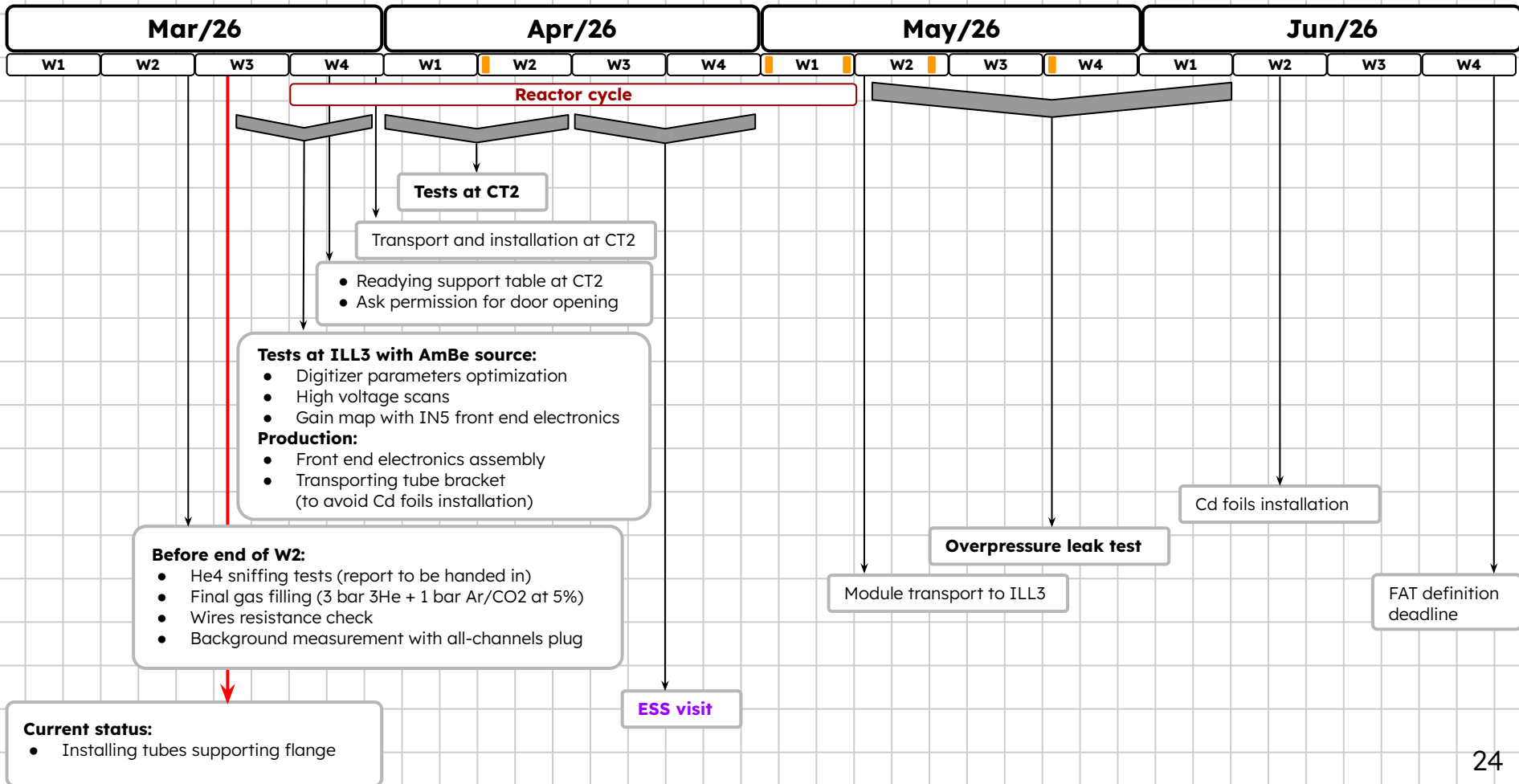


# Gain uniformity map

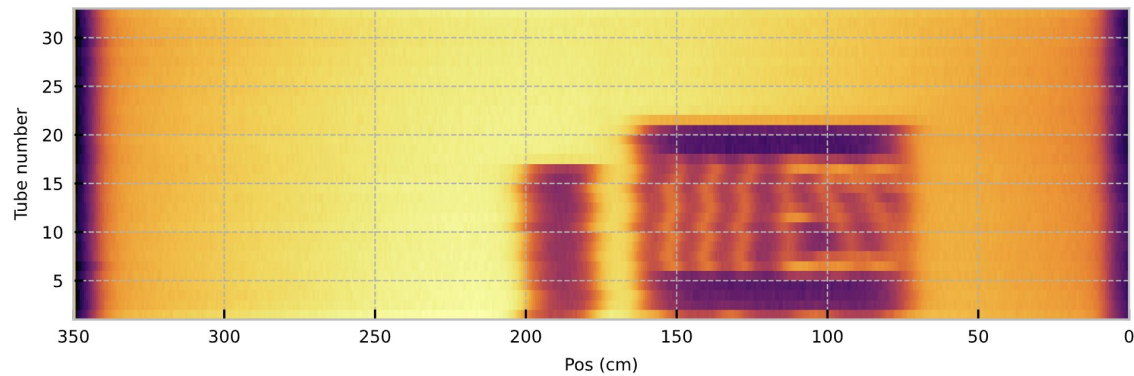
- Operation conditions:
  - HV: 1500 V
  - Shaping time: 1.1 us
- Plots:
  - Left: absolute commuted gain
  - Middle: Gain deviations from average
  - Right: Counts per pixel (to control enough statistics for gain calculation)
- Gain deviations across full detector  $< 6\%$   
(FAT requires deviations  $< 5\%$ , which will be reached once Cd bars are mounted)



# Overview

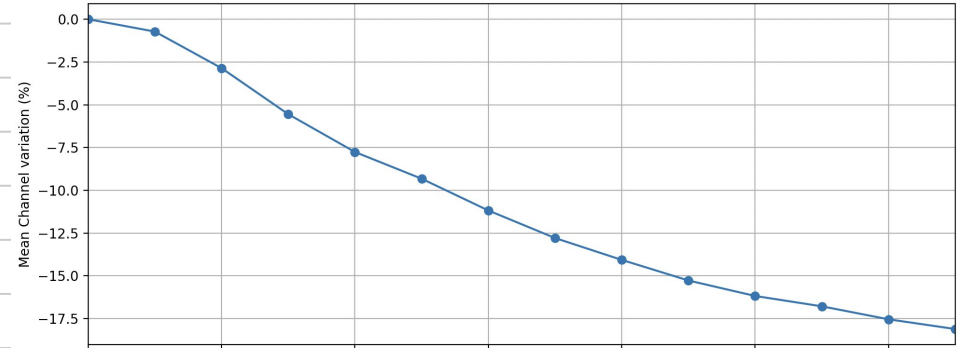
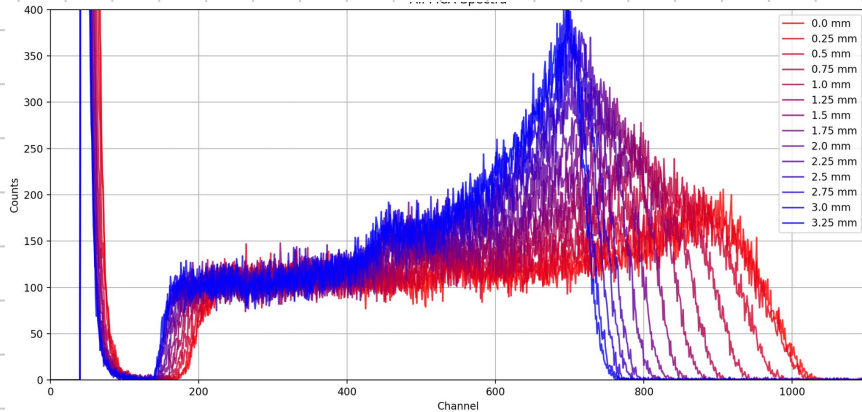


# Thank you



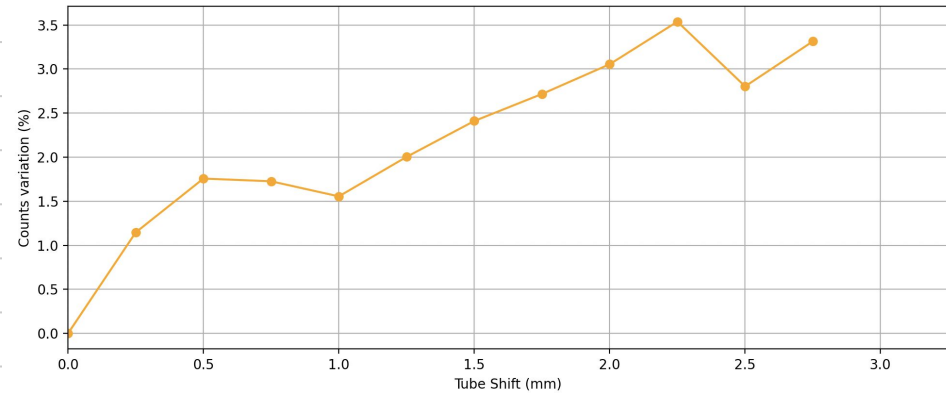
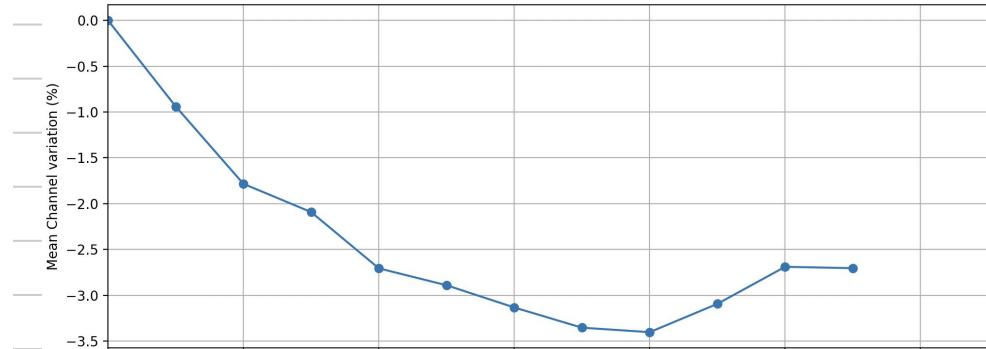
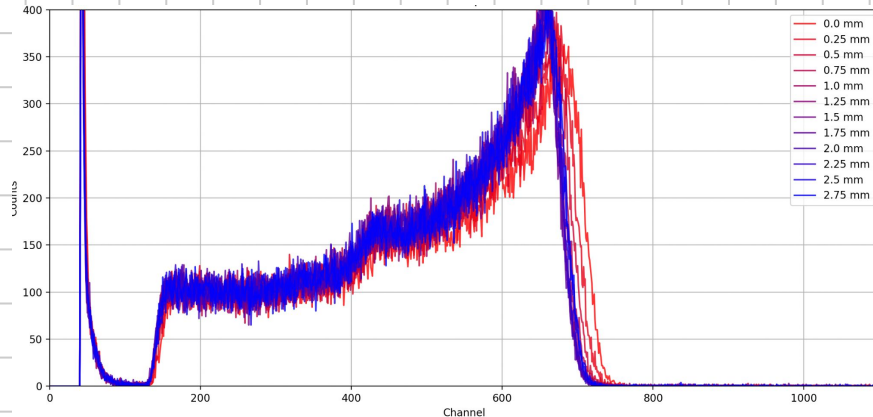
# Spectra vs Tube shifting

- **Setup:** No alignment (Friday, 20th March)
- **Spacers:** from 0 to 3.25 mm on tube #1
- **Amplifier:** 3V/pC, 3 us
- **Results after shifting 3.25 mm:**
  - ~20 % drop of the gain (mean channel)
  - ~3 % raise of counts



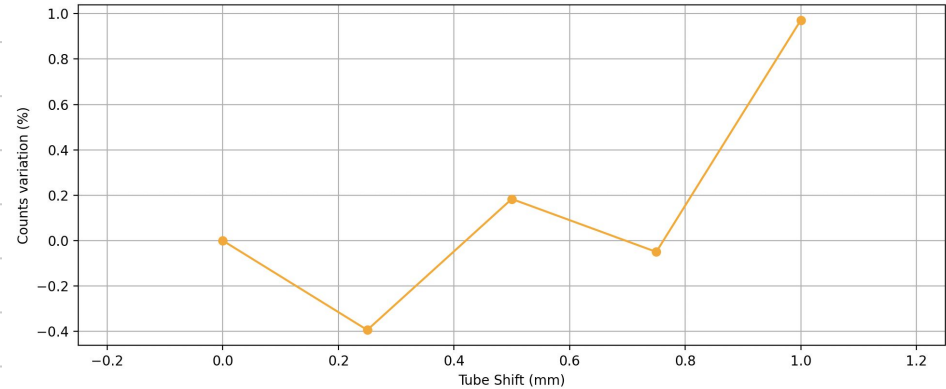
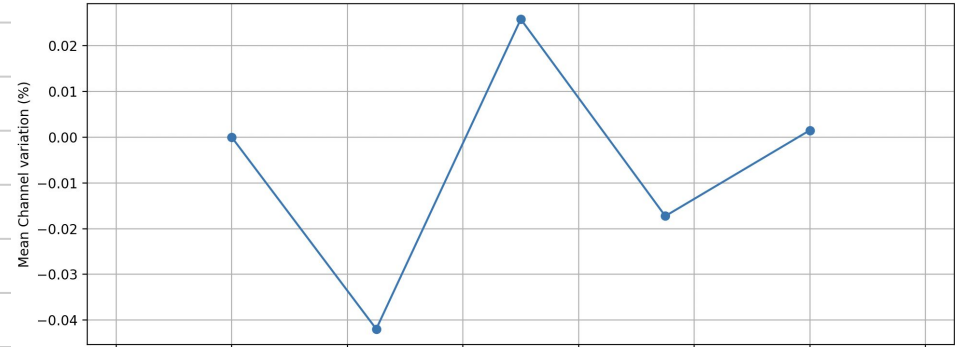
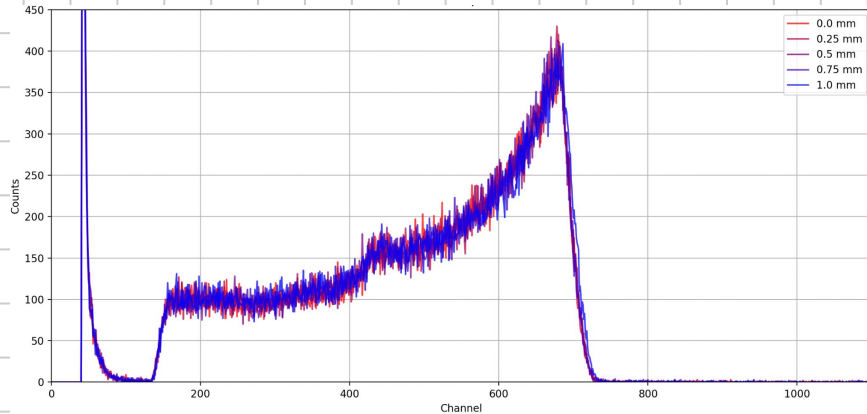
# Spectra vs Tube shifting

- **Setup:** global alignment of middle piece (monday, 23rd March)
- **Spacers:** from 0 to 2.75 mm on tube #1
- **Amplificator:** 3V/pC, 3 us
- **Results:**
  - Reduced gain variation: ~3 %
  - Minimal gain (best alignment) with 2 mm spacers
  - Same ~3 % raise of counts as on Friday



# Spectra vs Tube shifting

- **Setup:** global alignment of middle piece (Tuesday, 24rd March)
  - Additional 1.5 mm shift of middle piece
- **Spacers:** from 0 to 1 mm on tube #1
- **Amplificator:** 3V/pC, 3 us
- **Results:**
  - Largely reduced gain variation



# Spectra vs Tube shifting

- **Setup:** global alignment of middle piece (Tuesday, 24rd March)
  - Additional 1.5 mm shift of middle piece
- **Spacers:** from 0 to 3 mm on tube #1
- **Amplificator:** 1V/pC, 1.4 us
- **Results:**
  - Reduced gain variation: ~1.5 %
  - Minimal gain (best alignment) with 1 mm spacers
  - Same ~3 % raise of counts as on Friday

