Photo electron yield and pulse shape measurements with LArGe@MPIK

A.Smolnikov, M. Bernabe-Heider, P.Peiffer,
S.Schoenert, S.Vasiliev

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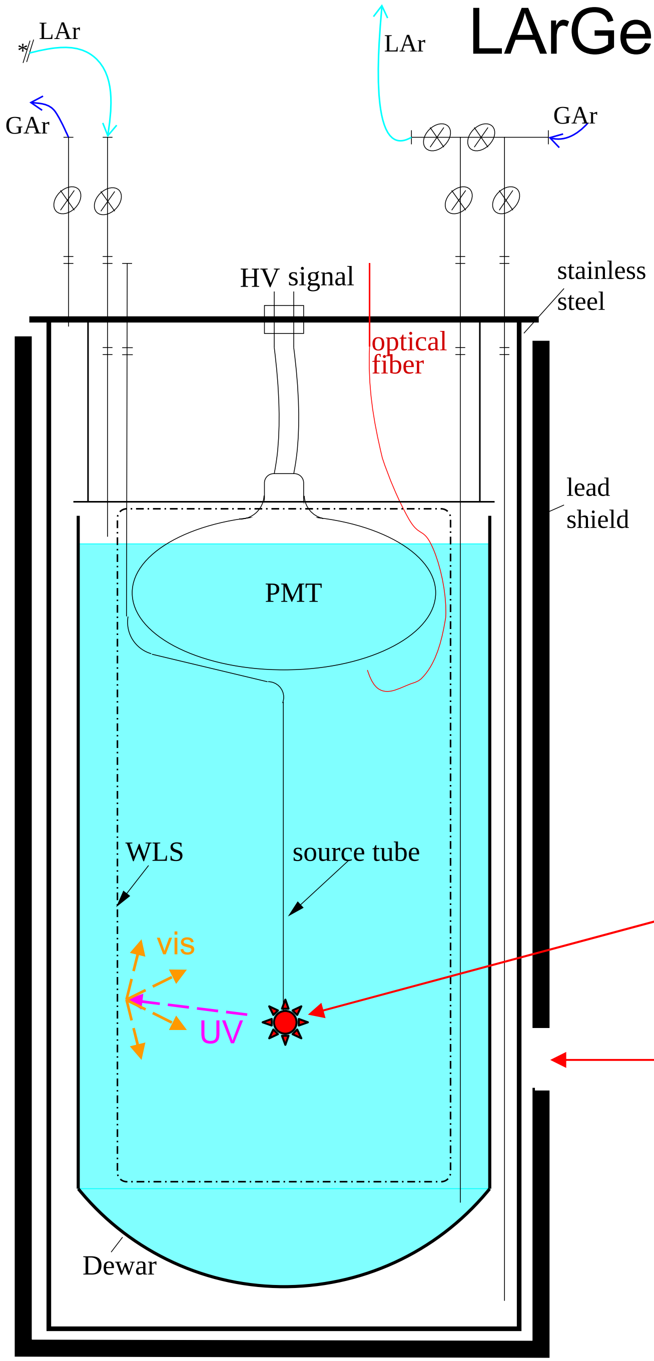
Outline

- Motivation
- Experimental setup
  - System description
  - DAQ
- Improving the photo electron yield
  - Coating the VM2000 reflecting foil
  - Photo electron yield
  - Pulse hight spectra from γ sources
- Pulse shape discrimination
  - γ-sources
  - AmBe neutron source
- Outlook

Motivation

- Improved photo electron yield
  - →Lower threshold
  - →Compensate shadowing effects
  - →Investigate pulse shapes at lower energy
- WARP: 3000 pe/MeV possible
- Pulse shape analysis
  - →Tag neutrons
  - →Tolerate higher background rates (e.g. ^{39}Ar)
- Dark Matter ??

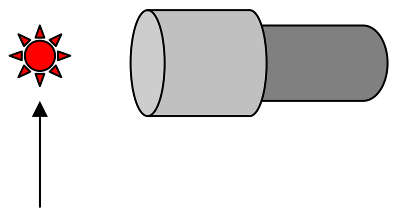
LArGe@MPI-K: Schematic system description



- Dewar ∅29 cm, h=65 cm
- Light detection: WLS (VM2000 + PST/TPB)
  + PMT(8“, ETL 9357-KFLB)
- Active volume ∅20 cm, h=43 cm
  ≈ 19 kg LAr
- Shielding: 5 cm lead
  +15 mwe underground

Measurements:

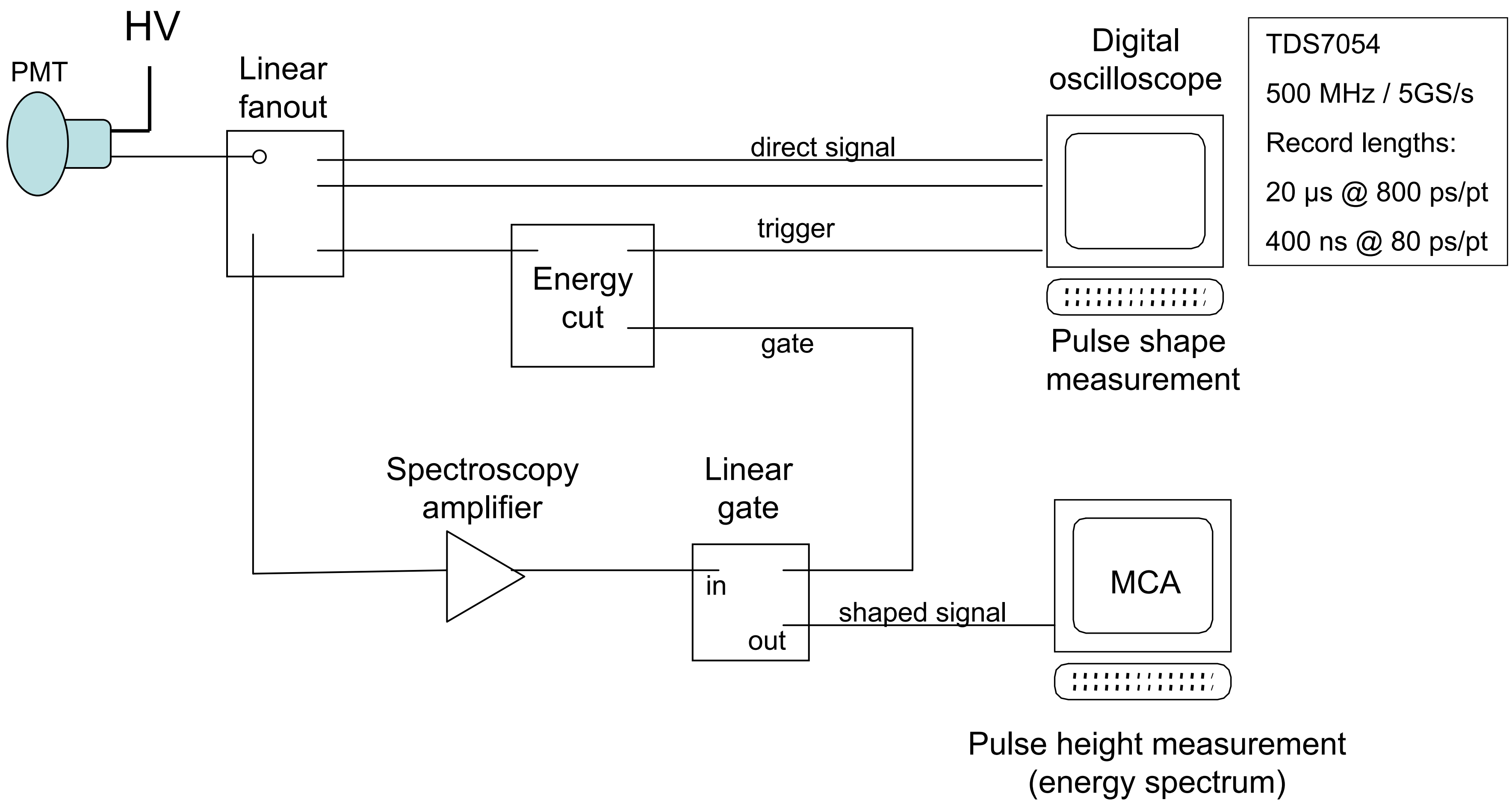
Internal source



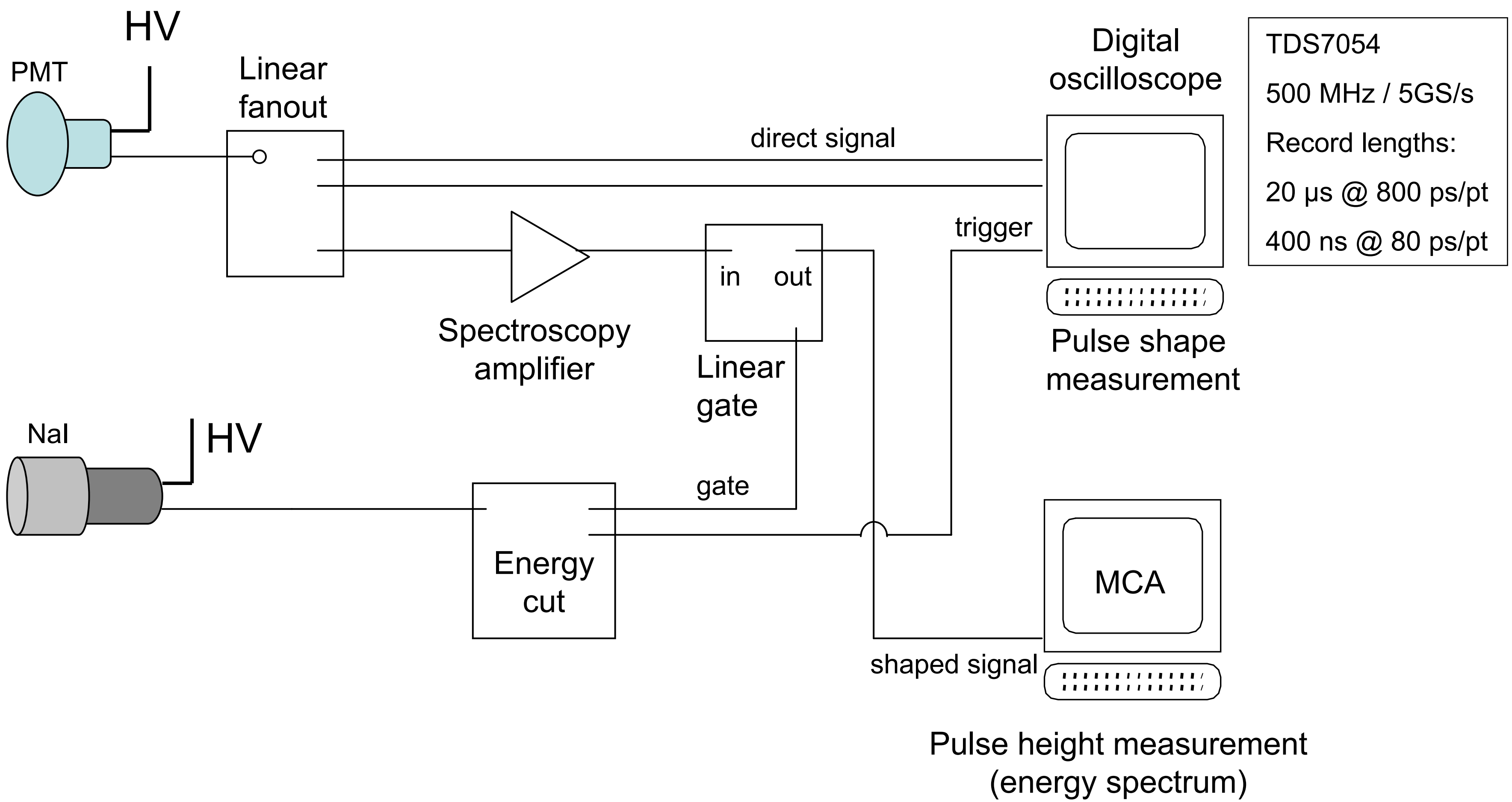
NaI – detector
For coincidence measurement

External source

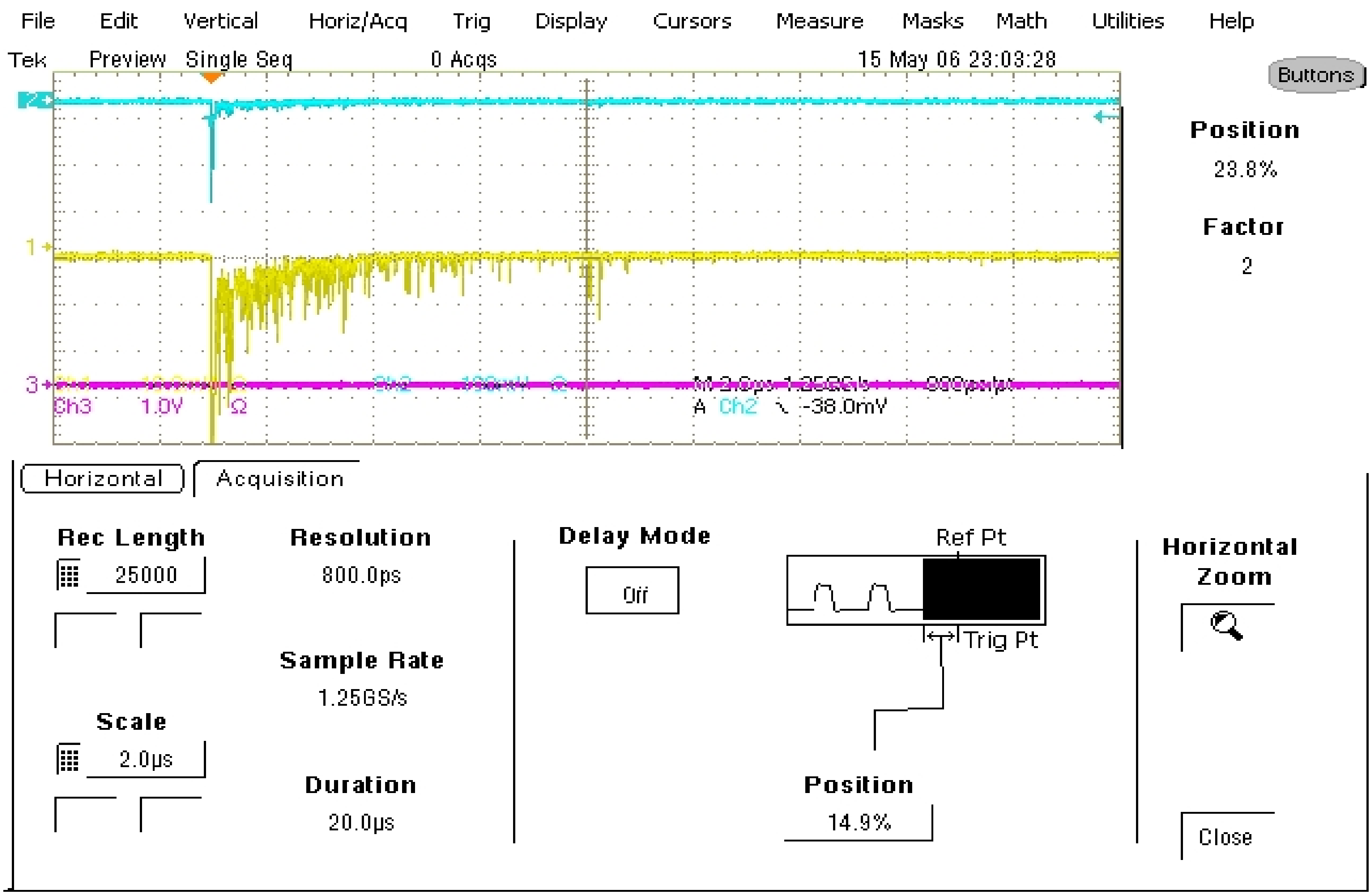
Electronic readout (single channel)



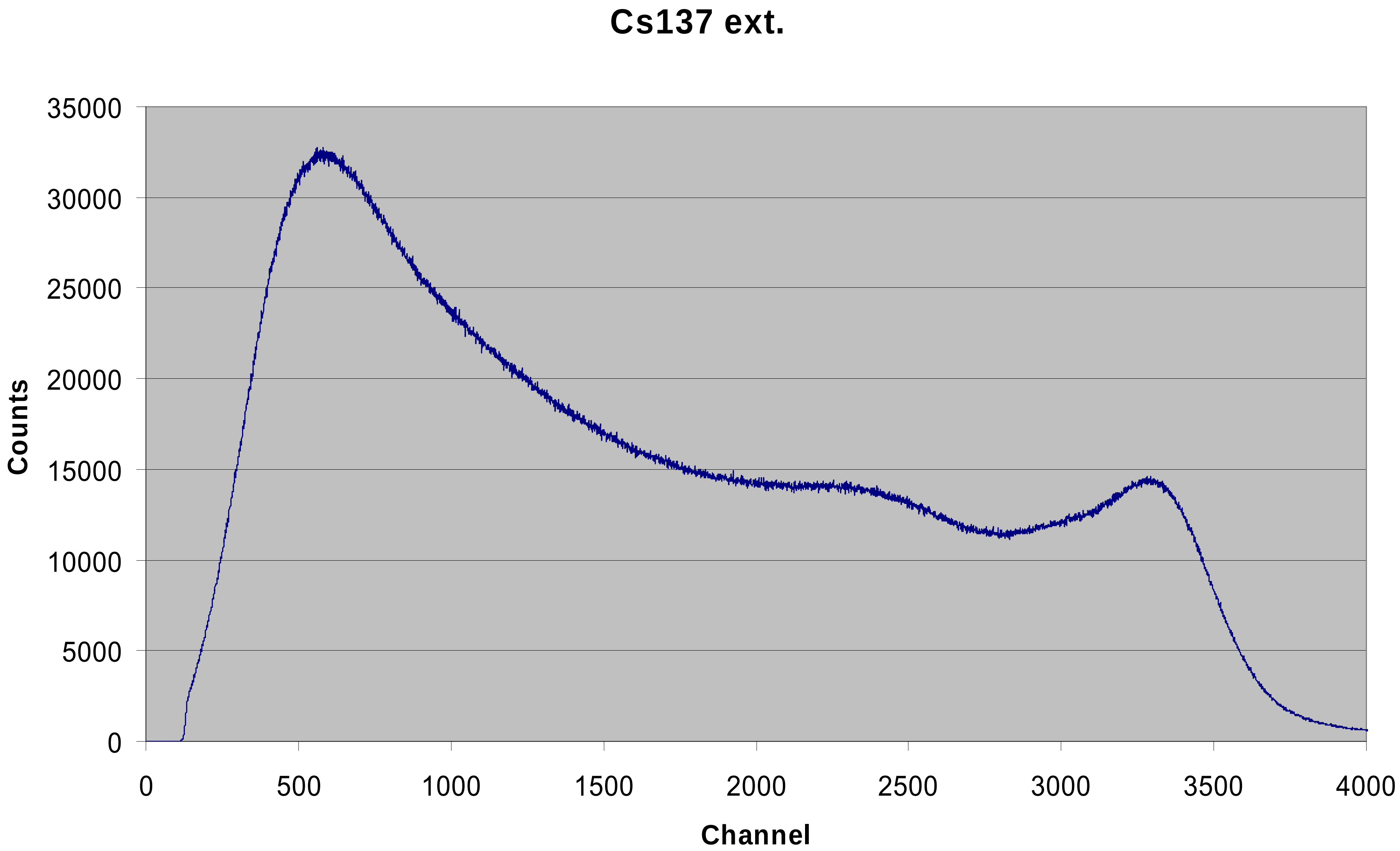
Electronic readout (coincidence setup)



Example: digital oscilloscope pulse



Example: MCA spectrum



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- Pulse shape discrimination
  - γ-sources
  - External AmBe neutron source
  - Internal ^{222}Rn

Coating the VM2000 foil

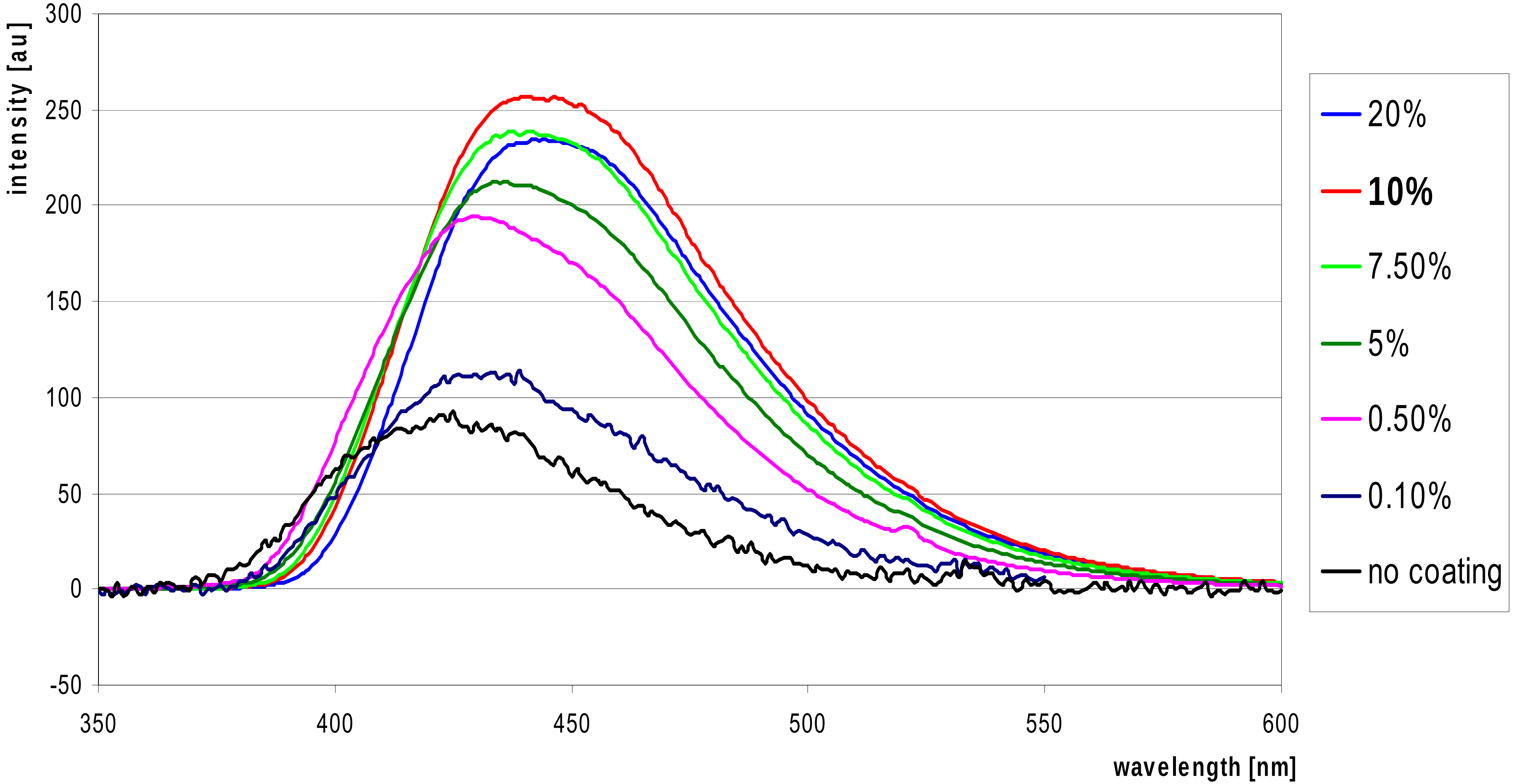
- *Status:* (407±10) pe/MeV VM2000 w/o fluor
- *Goal:* further improve light yield with additional fluor
- *Past experience:* pure TPB coating improves light-yield,
  but deteriorates over time + reduces reflectivity
  →polymer matrix doped with fluor

- *Matrix material tested:* **PST (polystyrene)** + PVT
- PST emission max.: λ=335 nm, absorption max.: λ=260 nm
- Thickness of PST layer on VM2000: ~2.5 μm

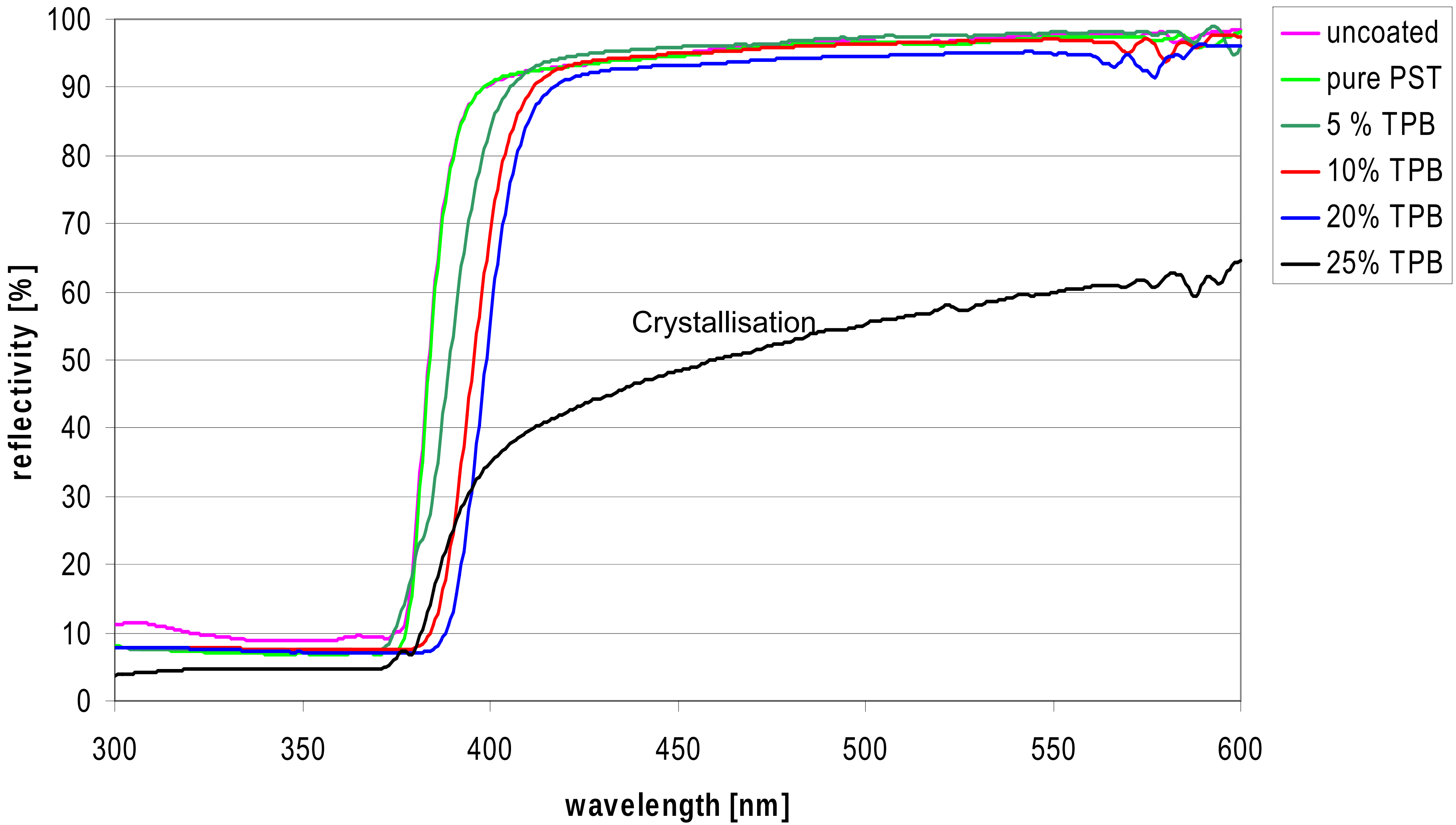
- *Fluors tested:* **TPB** (tetra-phenyl-buthadiene), PMP, TFPB

Best performance (so far): TPB in PST
TPB absorption max. at λ = 345 nm → good overlap
Emission maximum at λ = 450 nm

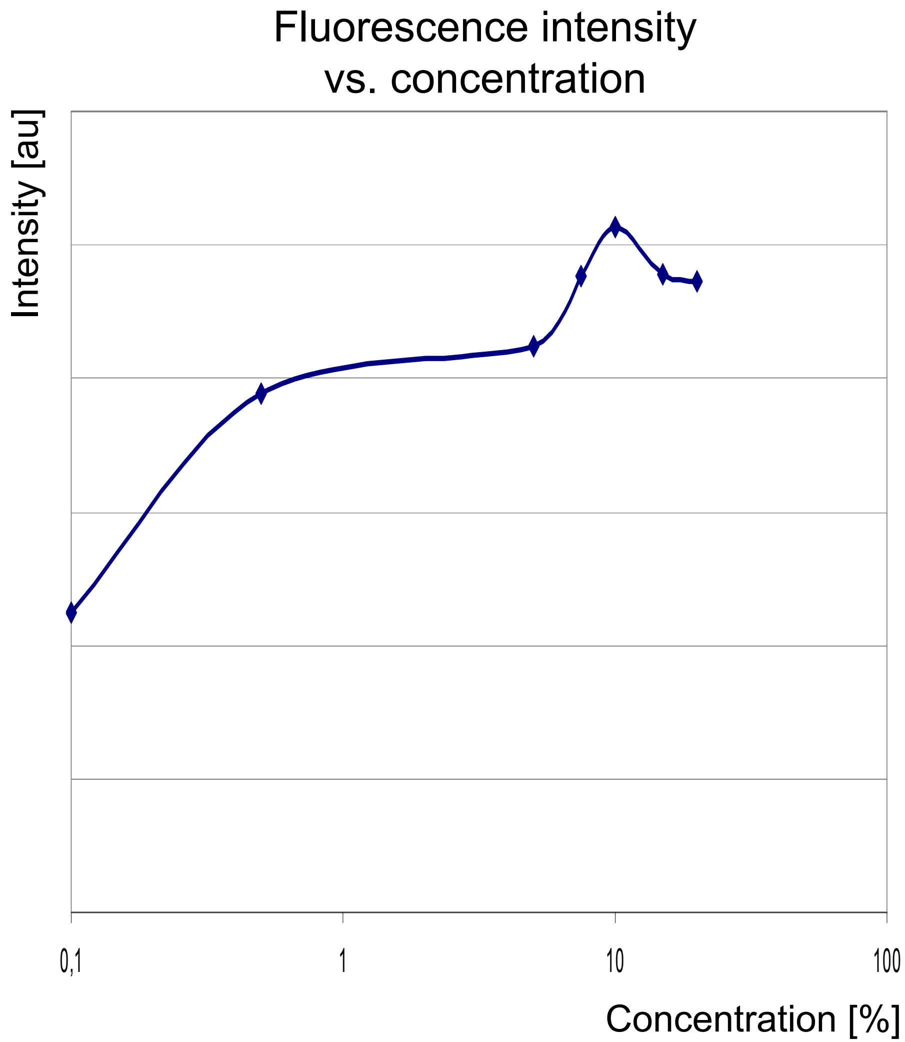
Fluorescence spectra with different concentrations of TPB in PST



Specular reflectivity for different concentrations of TPB in PST



Properties of PST+TPB coating at different concentrations



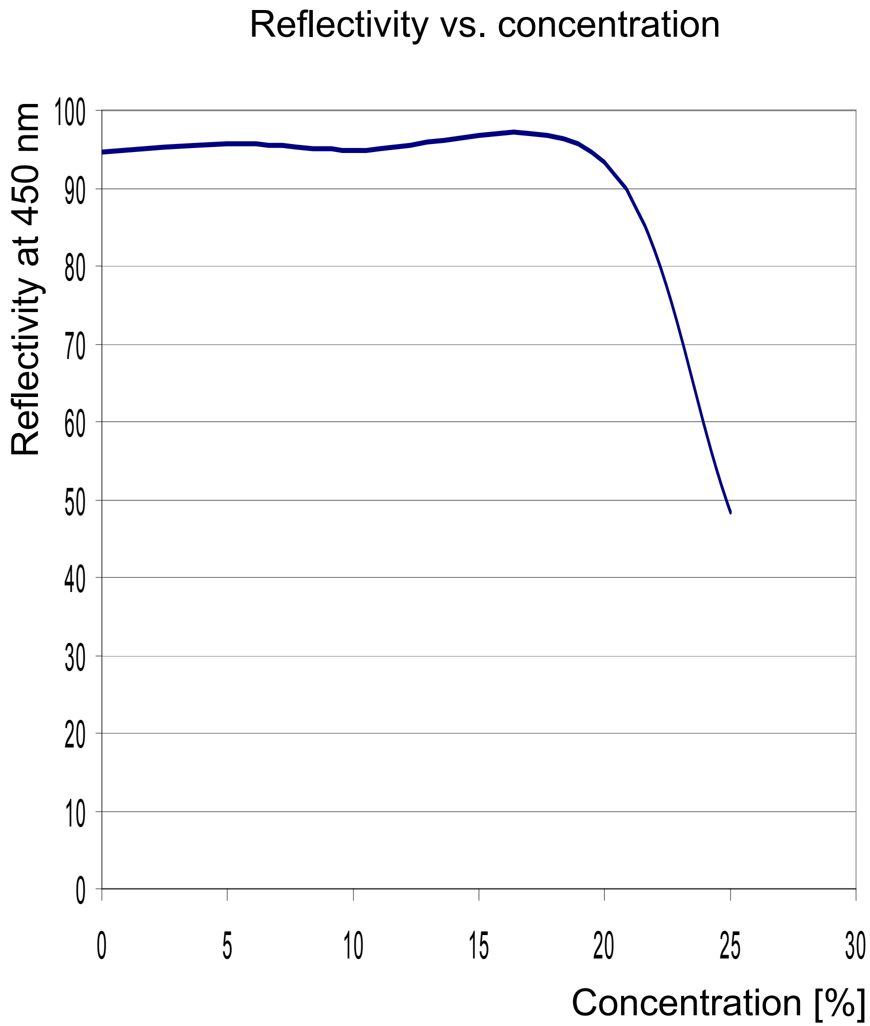
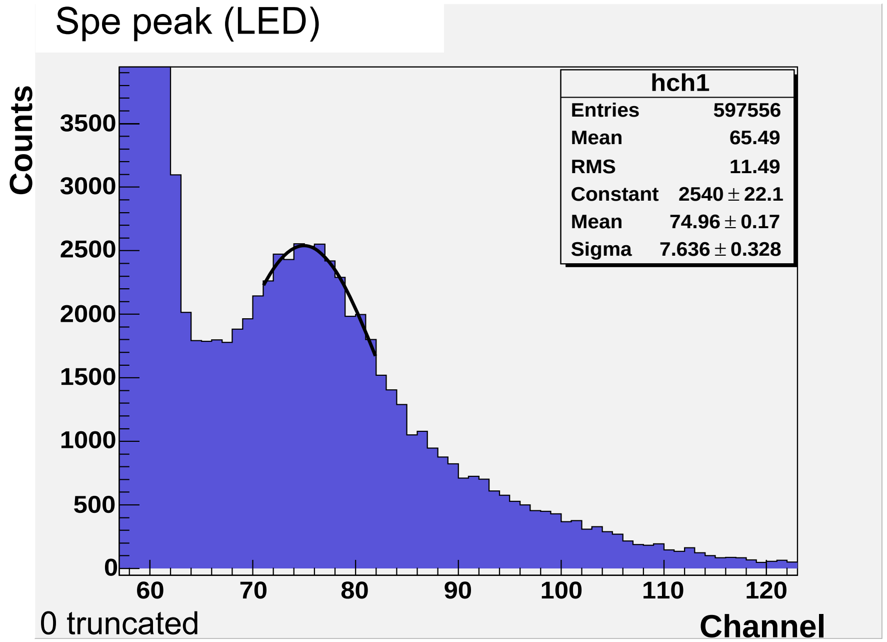
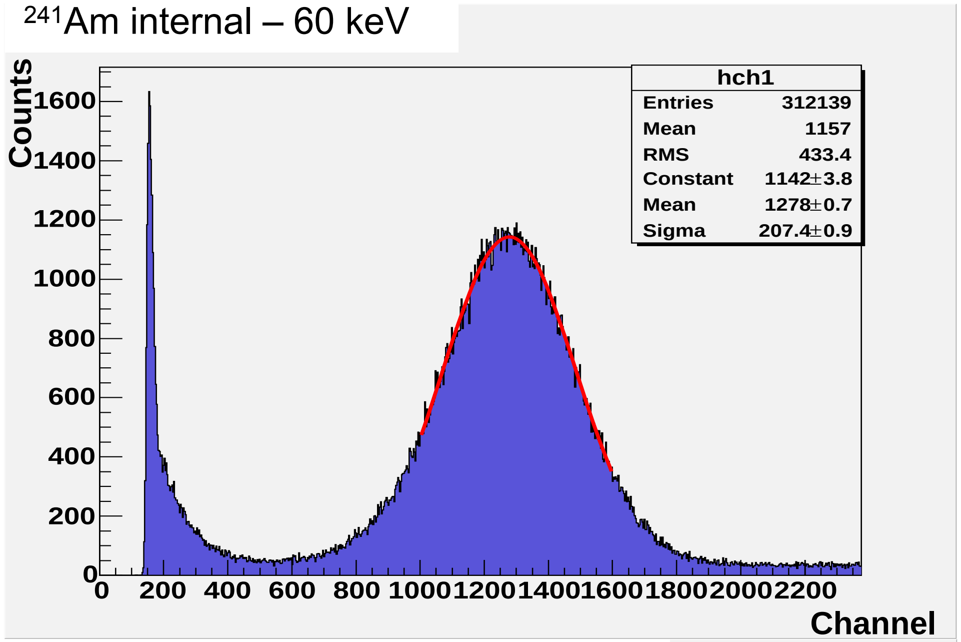
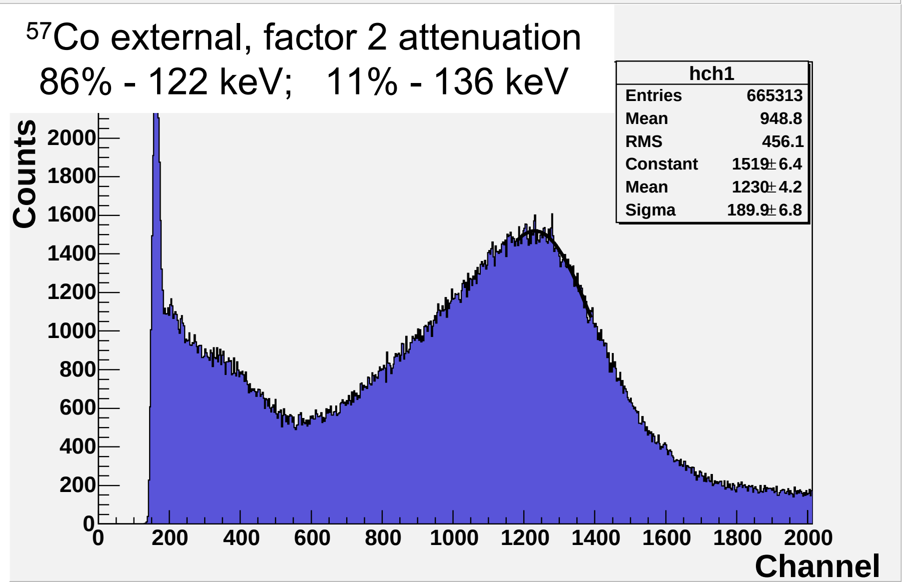


Photo-electron yield

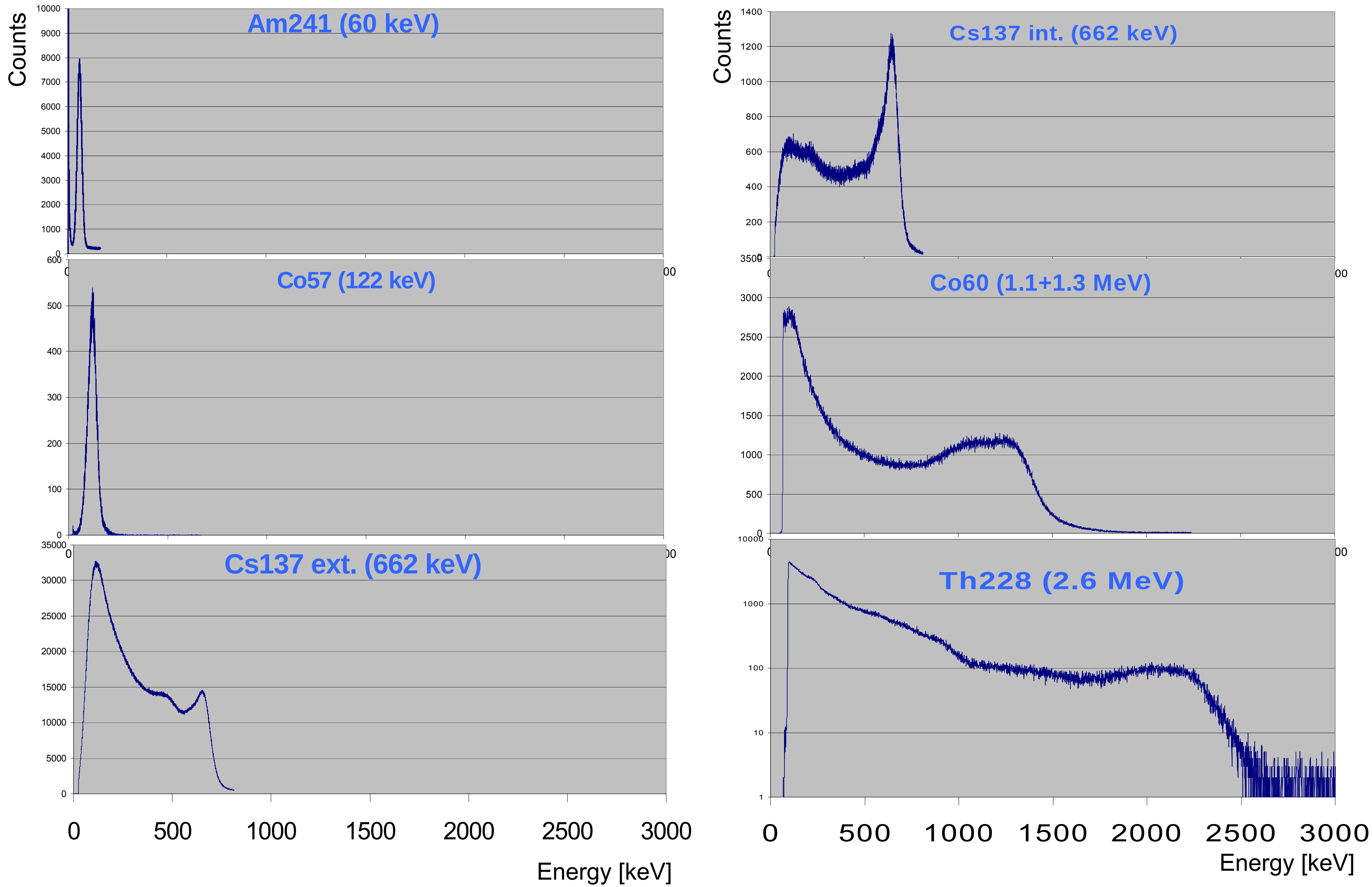




- Spe peak at ch 75 ± 0.5, pedestal at ch 56
  - → 19 ± 0.5 channels / photo electron
- ^{241}Am (γ - 60 keV) at ch 1278 ± 1
  - → (1072 ± 28) pe/MeV
- ^{57}Co at ch 1230 ± 4 (x2 attenuated)
  - → (1037 ± 50) pe/MeV
- Mean **(1055 ± 28)** pe/MeV



LAr scintillation energy spectra



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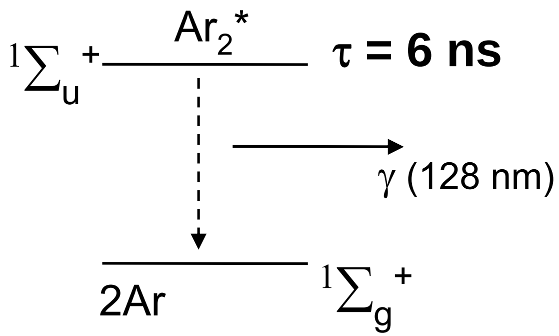
  - External AmBe neutron source
  - Internal ^{222}Rn as α-source

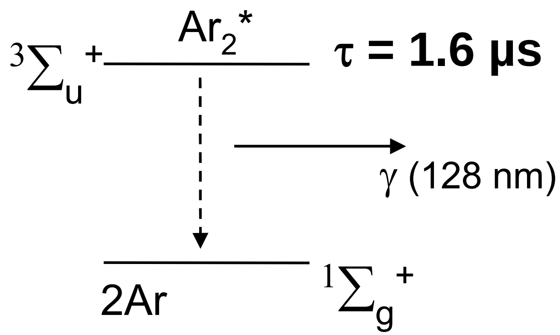
LAr scintillation pulse shape discrimination principle

Excimer creation:

$Ar^{*}+Ar \rightarrow Ar_2^{*}$ or $Ar^{+}+Ar \rightarrow Ar_2^{+}$ and $Ar_2^{+}+e \rightarrow Ar_2^{*}$

De-excitation:





Population depends on ionisation density

Ratio singlet/triplet emission (I1/I2)*:

electrons / γ's : **0.3** α's : **1,3** fission fragments/nuclei : **3**

* Hitachi et al. Phys.Rev.B 27(9):5279, 1983

Part II

Neutron measurements with LAr set up

Two AmBe neutron sources:
2 x 10^3 n/sec and 2 x 10^5 n/sec

✂(5.48 MeV) + ^{9}Be = ^{13*}C → ^{12}C + n + 11.18 MeV

^{12}C + n + 6.73 MeV + ☎ (4.45 MeV)

for 2 neutrons ~ 1 ☎ (4.45 MeV)

rewriting of eq. (5) in terms of E_n:

$$F(E_n) = \sigma(E_n) \frac{4\pi}{E_n(\theta=0) - E_n(\theta=\pi)} \frac{\Delta E_2}{\varepsilon} \quad (6)$$

where $E_n(\theta=0)$ and $E_n(\theta=\pi)$ are the maximum and

much higher. In case of ^{226}Ra only a 50% contribution of ^{210}Po has been assumed because of the growth of ^{210}Pb. This nuclide has a half-life of 22 y and the 50% contribution therefore corresponds to a source which has been encapsulated 22 y ago, probably a realistic age for the ^{226}Ra–Be(α, n) sources in use today.

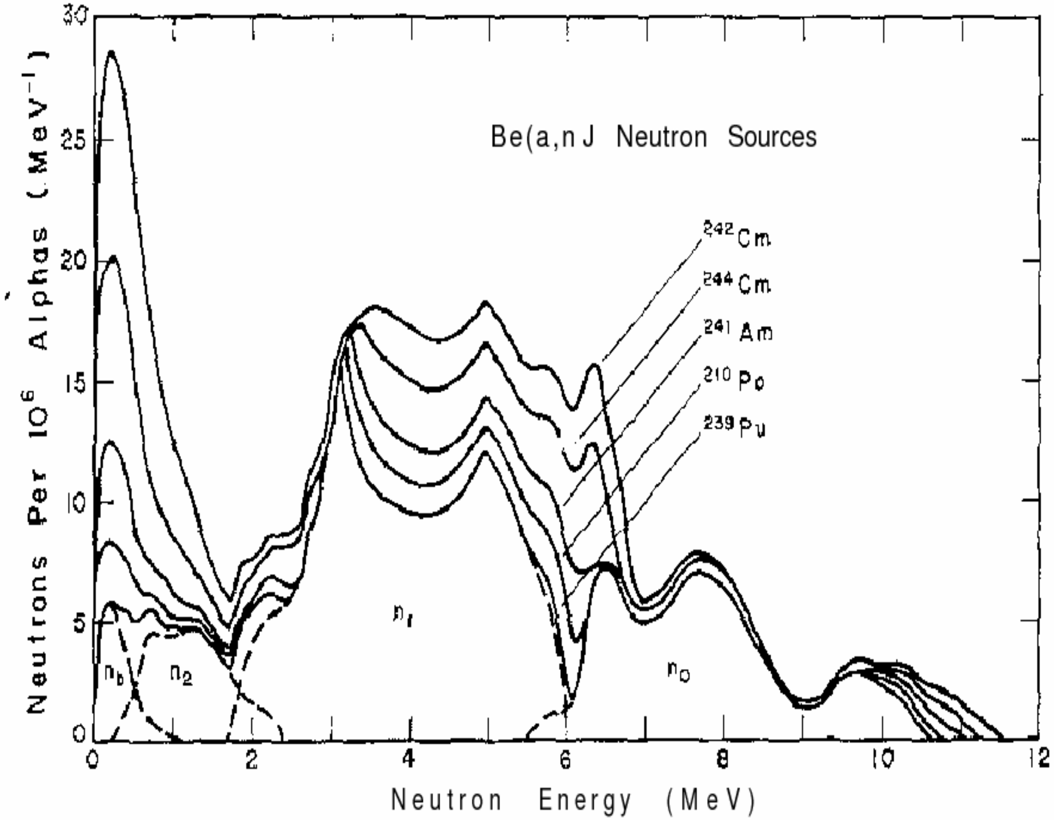
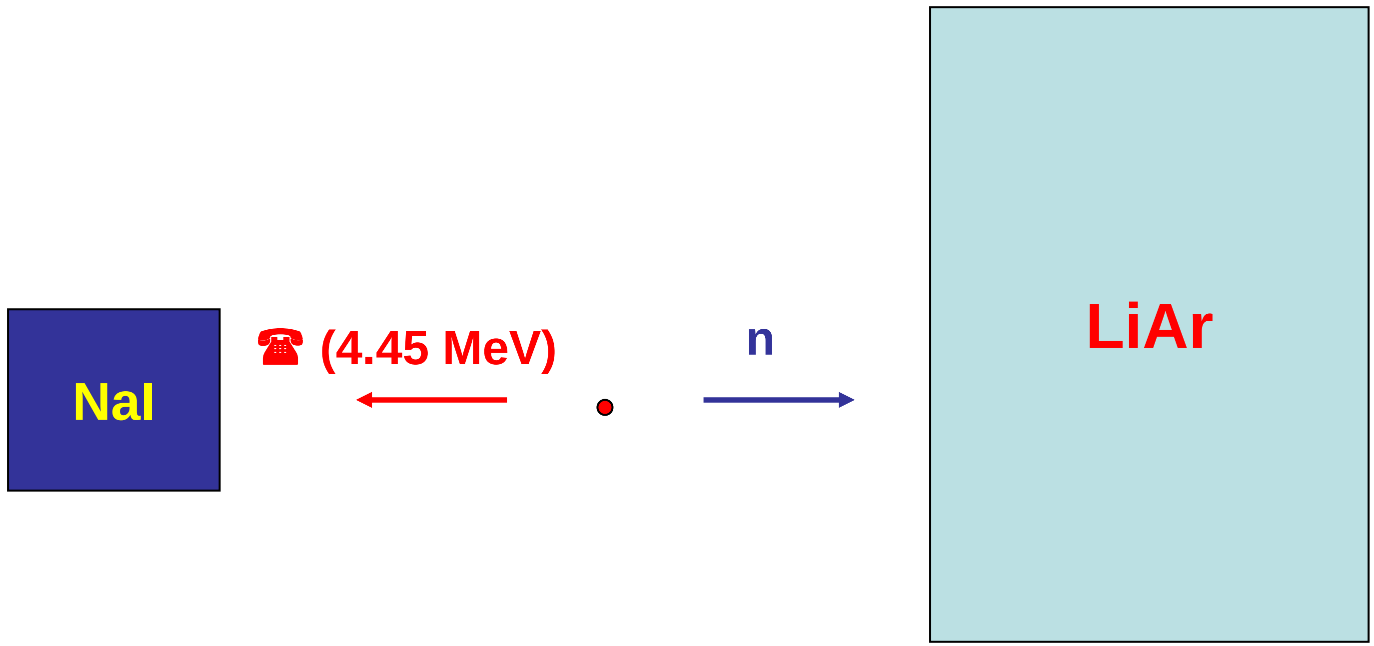
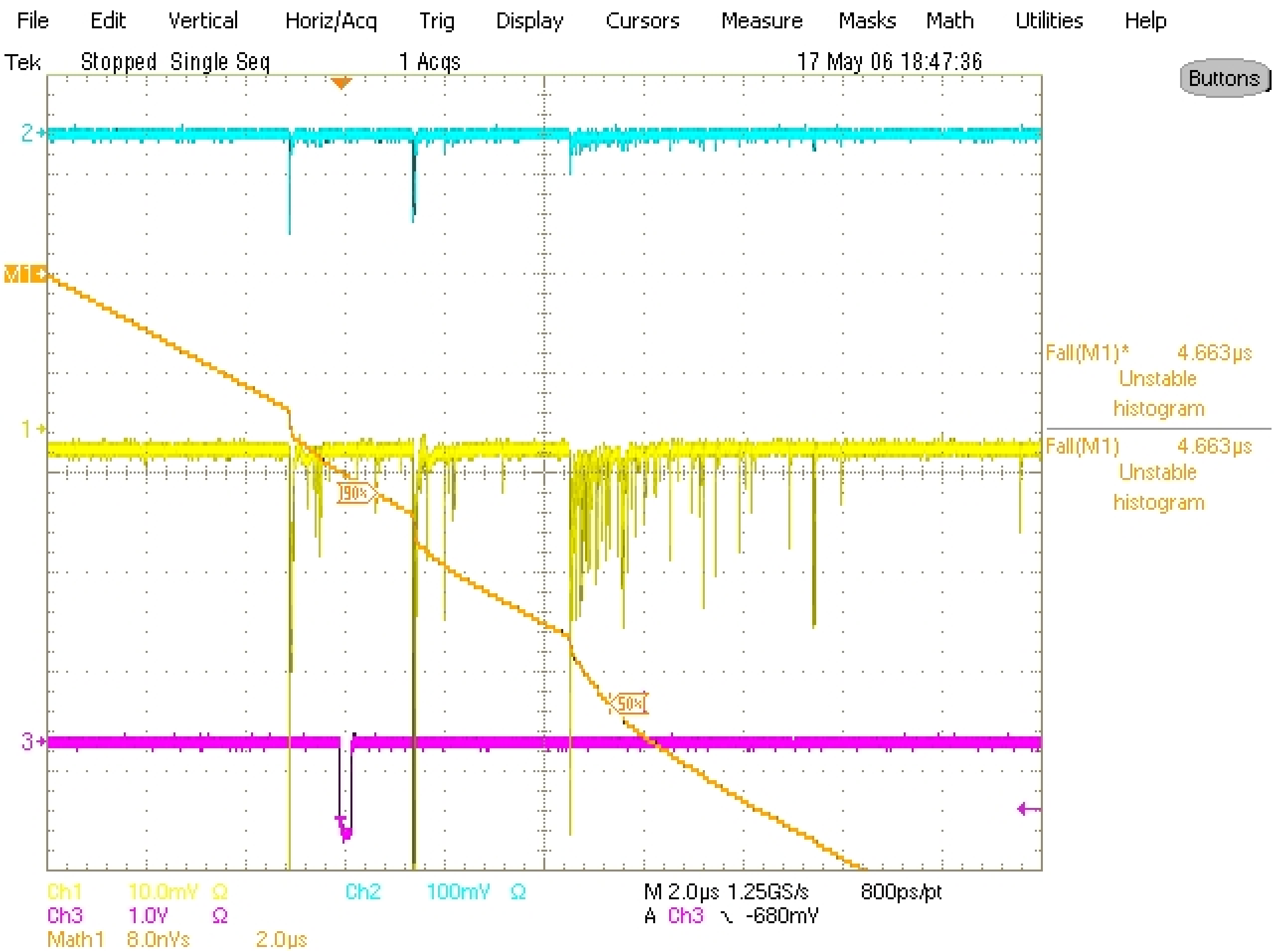


Fig. 3, Neutron source spectra. The separation of the individual neutron groups is illustrated, for the ^{S39}Pu-Be O,n) spectrum.


NaI
☎ (4.45 MeV)
n
LiAr



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Buttons
2
M1
1
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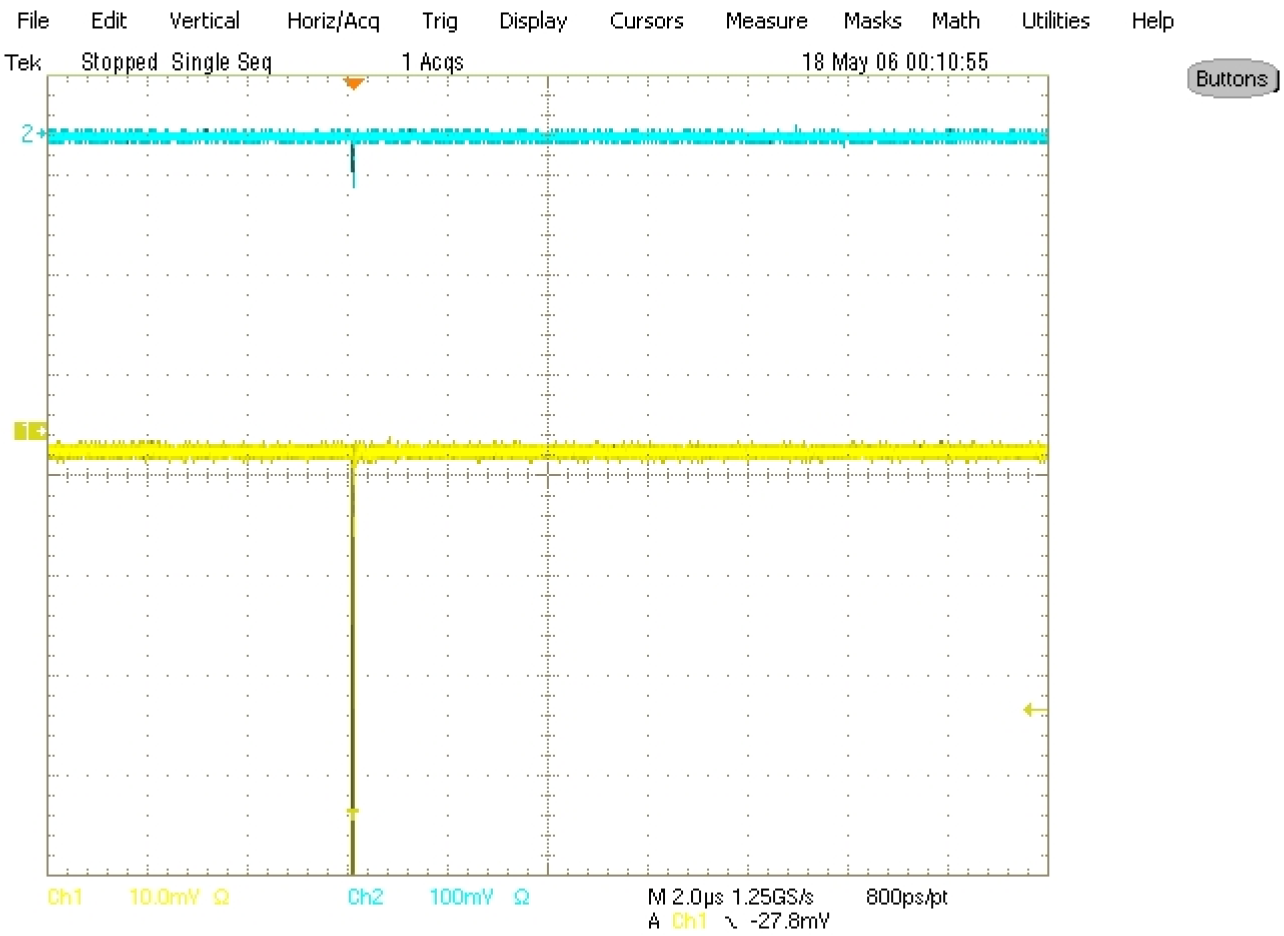
Fall(M1)* 4.663µs
Unstable
histogram
Fall(M1) 4.663µs
Unstable
histogram
Ch1 10.0mV Ω
Ch2 100mV Ω
Ch3 1.0V Ω
Math1 8.0nVs 2.0µs
M 2.0µs 1.25GS/s 800ps/pt
A Ch3 ⤥ -680mV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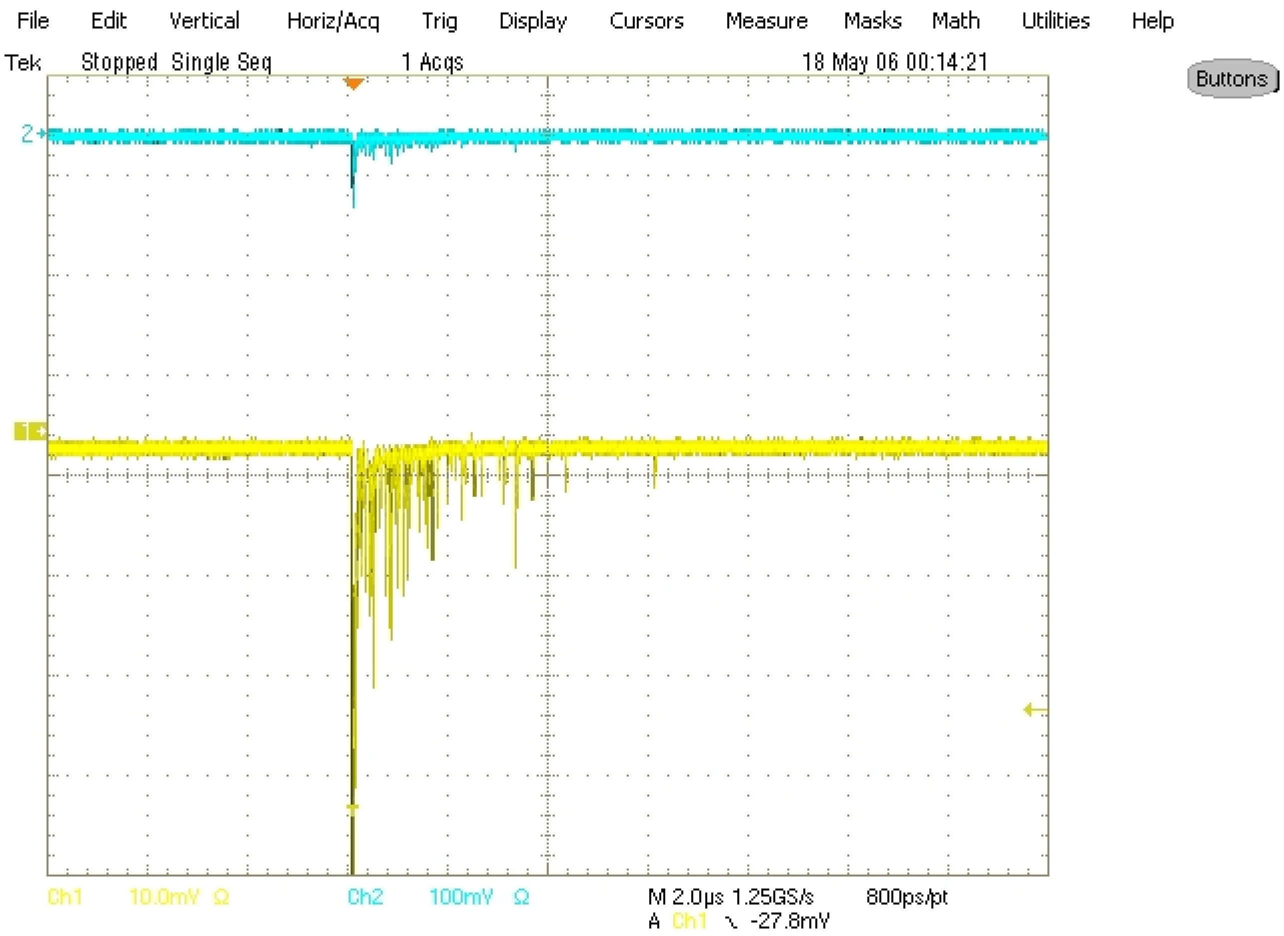
Ch2 100mV Ω
M 2.0µs 1.25GS/s 800ps/pt
A Ch1 ↘ -27.8mV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Buttons
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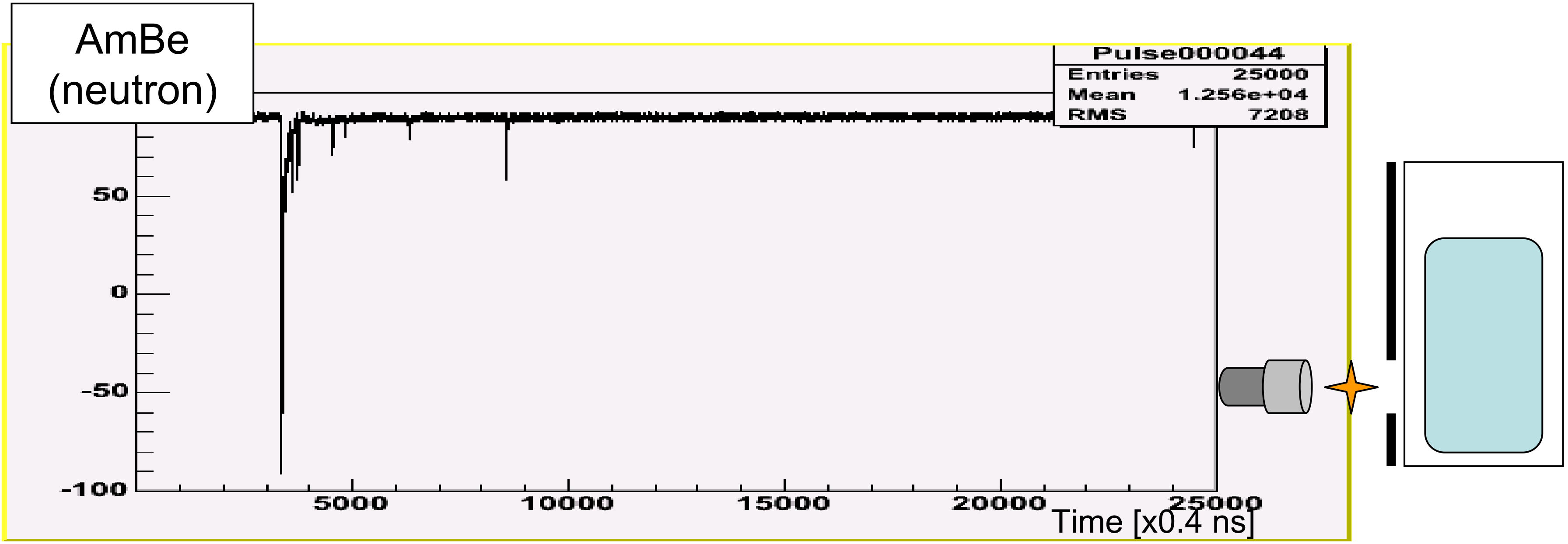
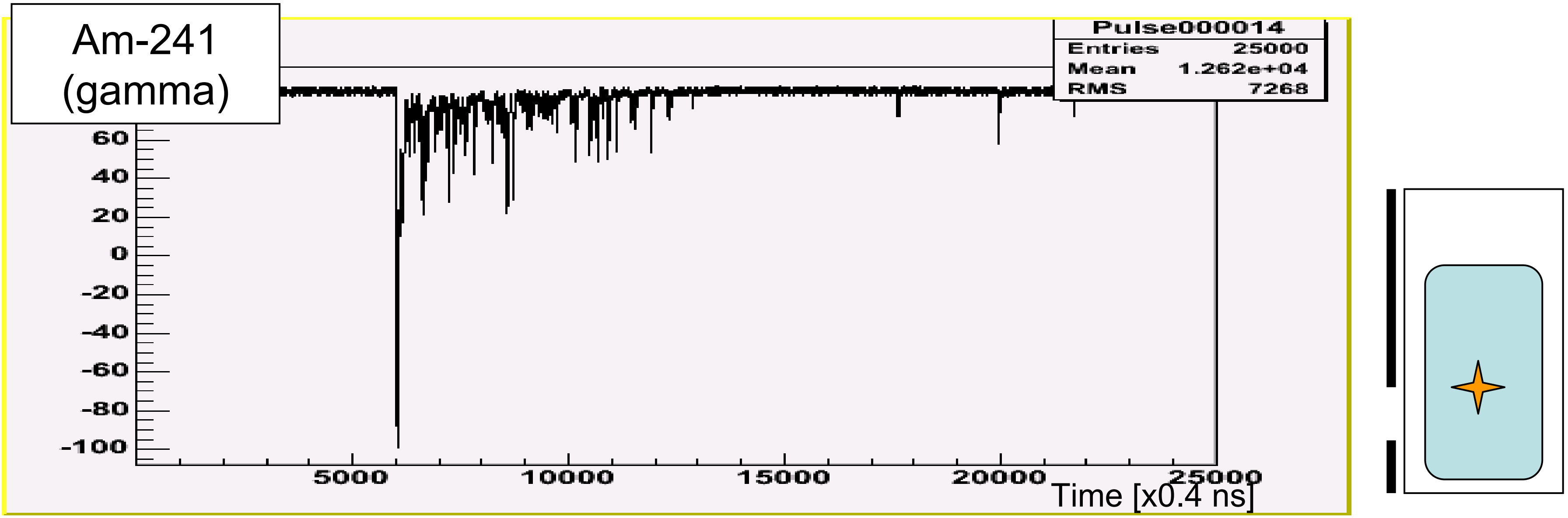
Ch2 100mV Ω
M 2.0µs 1.25GS/s 800ps/pt
A Ch1 -27.8mV

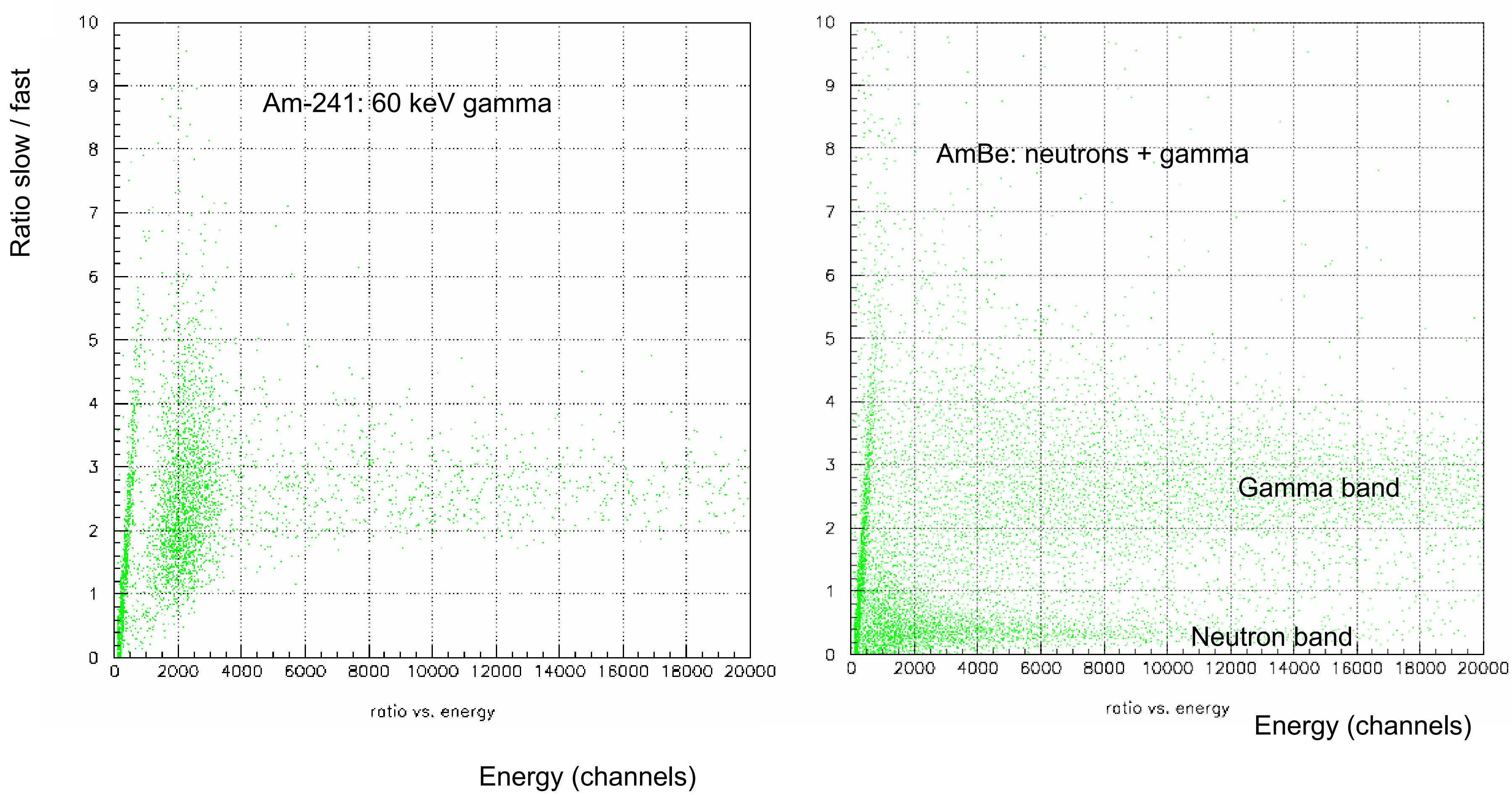
Pulse shapes γ vs. n





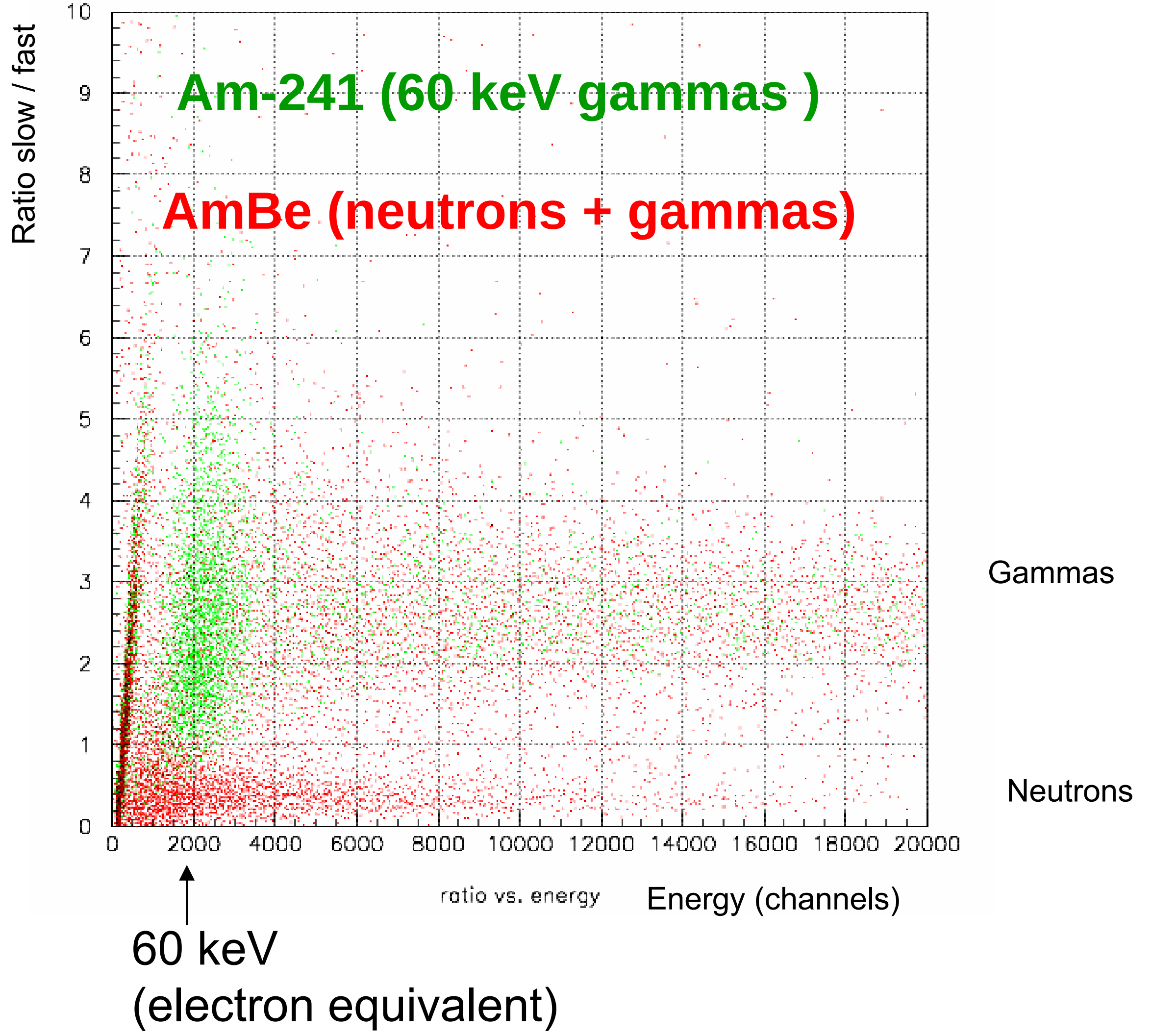
γ vs. n – scatter plot

(Preliminary analysis)



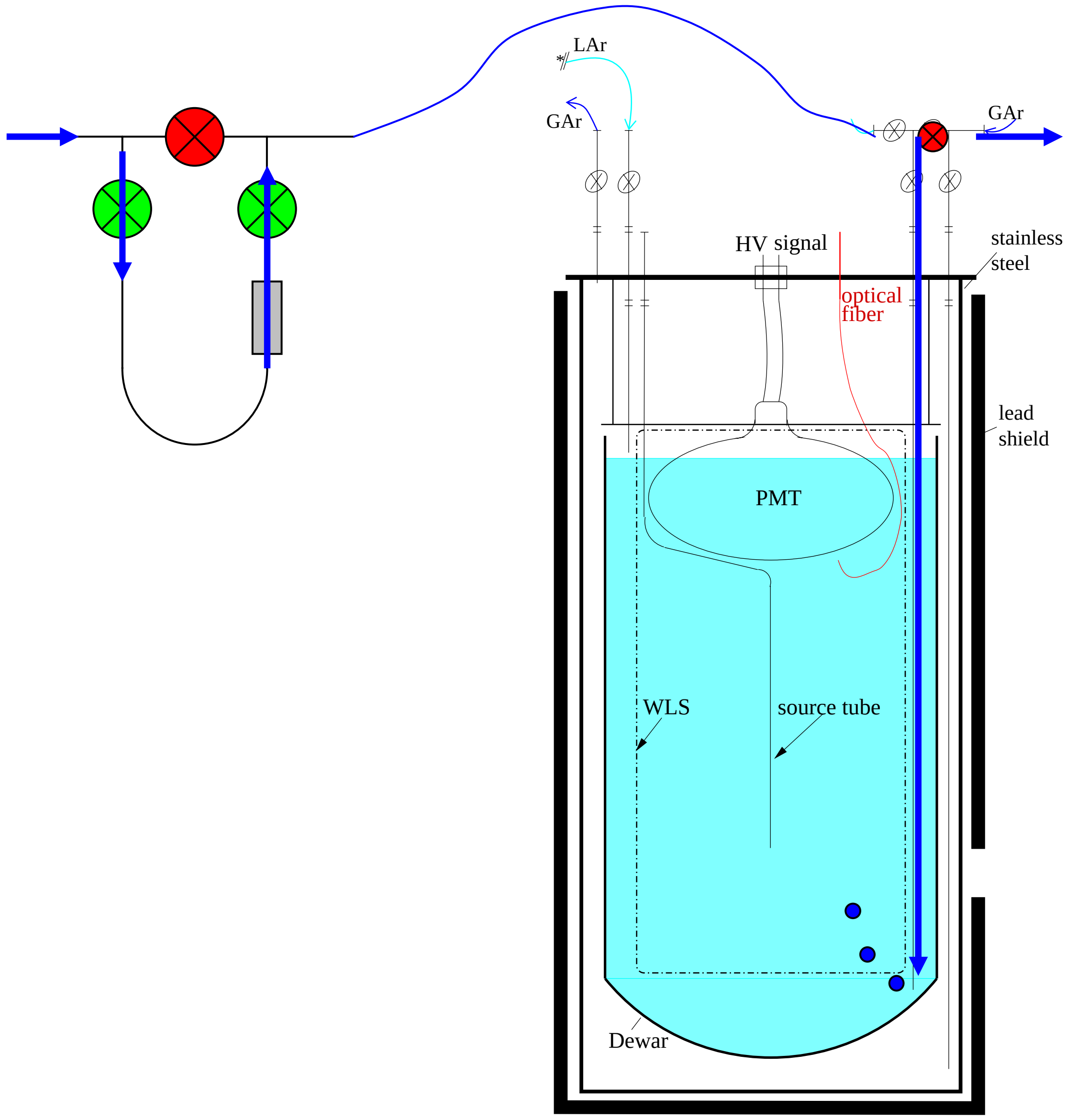
Pulse shape discrimination: neutrons vs. gammas

(Preliminary analysis)

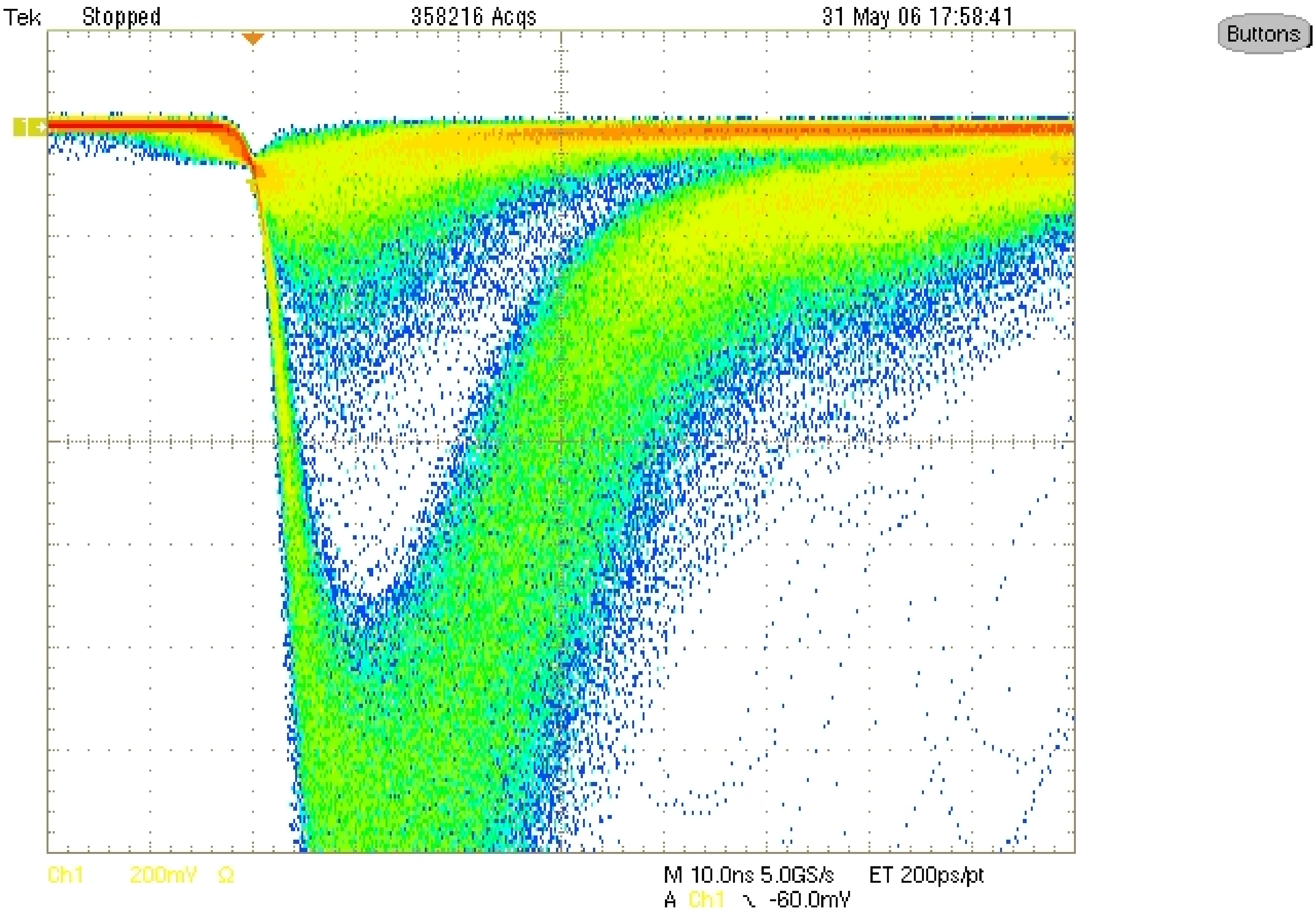


Adding Radon

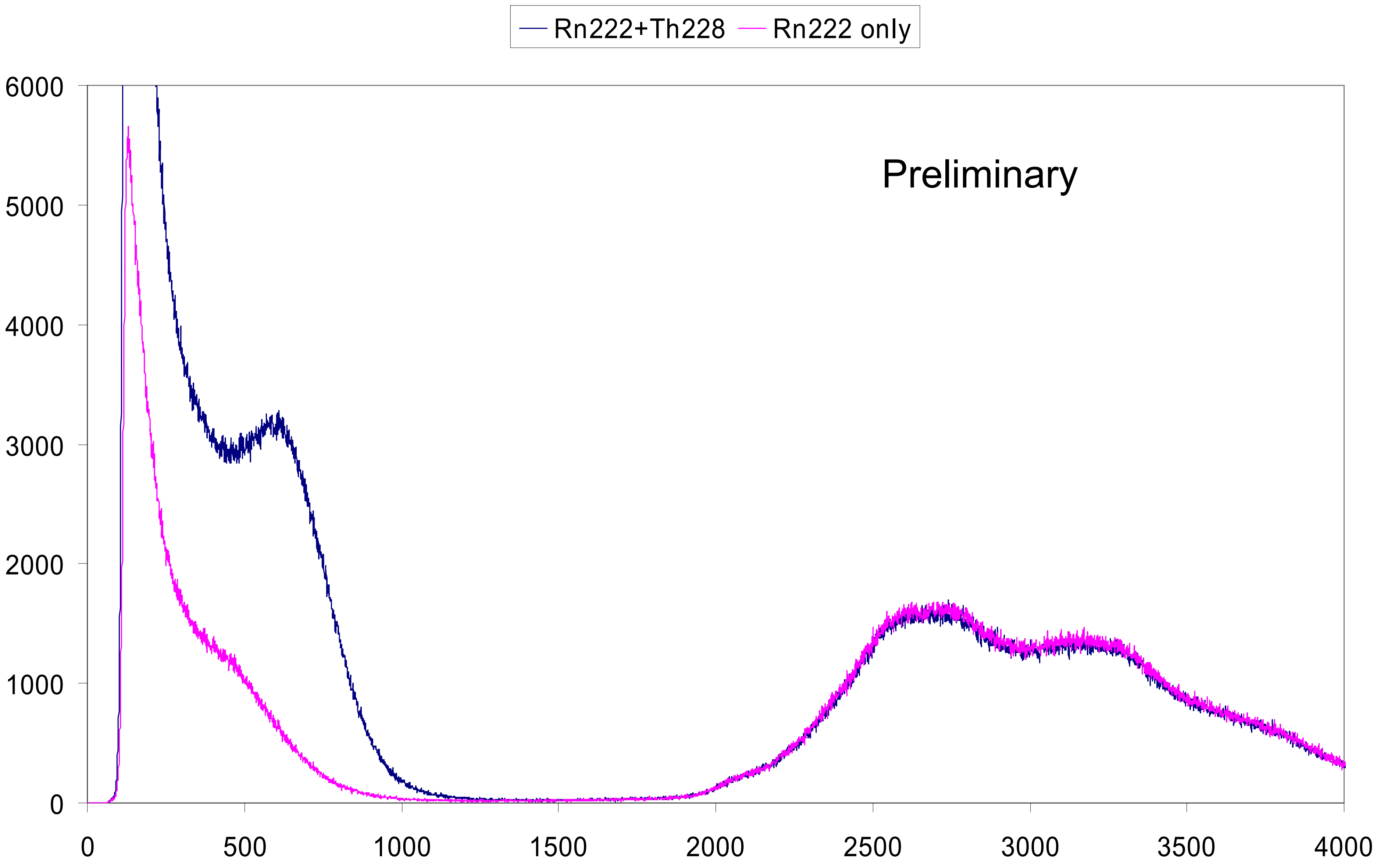
1. Freezing ^{222}Rn onto a charcoal trap.
2. Connecting the trap to the sytem
3. Flushing the tubes
4. Flushing GAr through the trap into the LAr
5. Warming the trap to release ^{222}Rn



^{222}Rn + ^{60}Co pulses



$^{222}Rn + ^{228}Th$ spectrum



Next steps

- Added ^{222}Rn
  - preliminary: apparently no alpha quenching
  - Bi-Po-tagging to select α / β+γ
- Refined pulse shape data analysis
- Pulse-shape libraries from α's

Conclusions

- Coating the VM2000 foil with PST + TPB: high light yield + excellent specular reflectivity
- light yield improved to ~1 pe/keV
- Excellent pulse shape discrimination at low energies (60 keV) achieved
- LAr spiked Rn by bubbling (preliminary: no α-quenching observed)

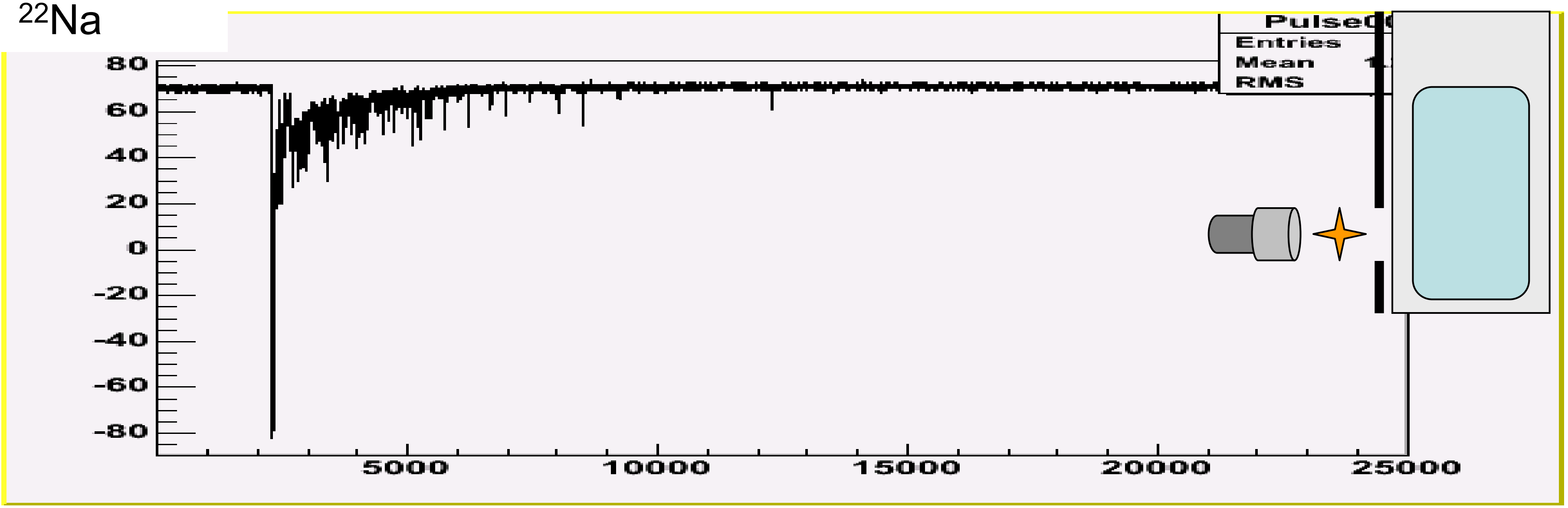
Conclusion of the Conclusions

- It was shown that the LAr scintillator is a powerful tool to be used in GERDA as:

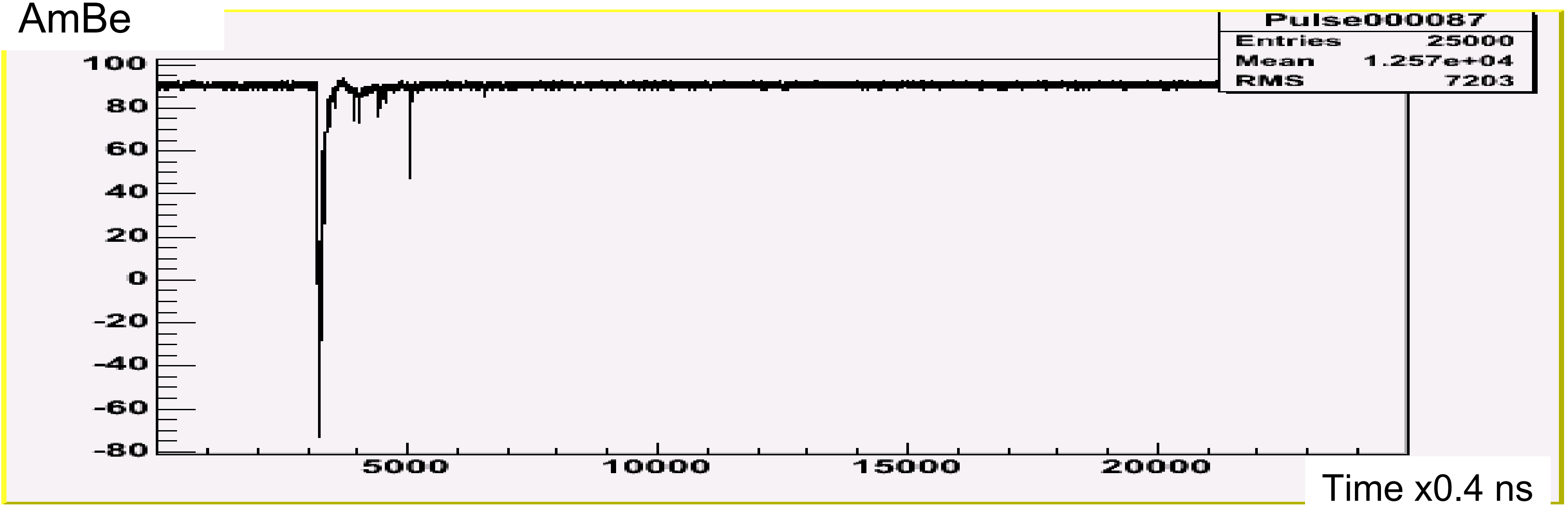
1. Gamma spectrometer with large active volume (for direct measurement of gamma background inside the GERDA facility)
2. Large volume Neutron detector (spectrometer) (for direct measurement of neutron background and neutron – gamma delayed (anti-) coincidence inside the GERDA facility)
3. Radon detector (alpha-spectrometer) (for direct monitor of Radon (Thoron) inside the GERDA facility)

Pulse shapes γ vs. n

^{22}Na



AmBe



Time x0.4 ns