Detection developments at n_TOF

a quick tour through the challenges and n_TOF solutions to (n,) measurements*

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NSTAPP - Neutrons in Science, Technology and Applications

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Detection developments at n_TOF

The reaction channels

(n,f)

(n,γ)

(n,chp)

The challenges

Day-to-Day cross sections measurement

Dealing with high radioactivity

Pushing the high E_n limits

Others ...

The n_TOF solutions!

Disclaimer:

- No time to include every single detector system
- No space to include the corresponding references
- Limited to detection systems. Analysis methods and techniques not covered

Every detector is connected to the n_TOF DAQ

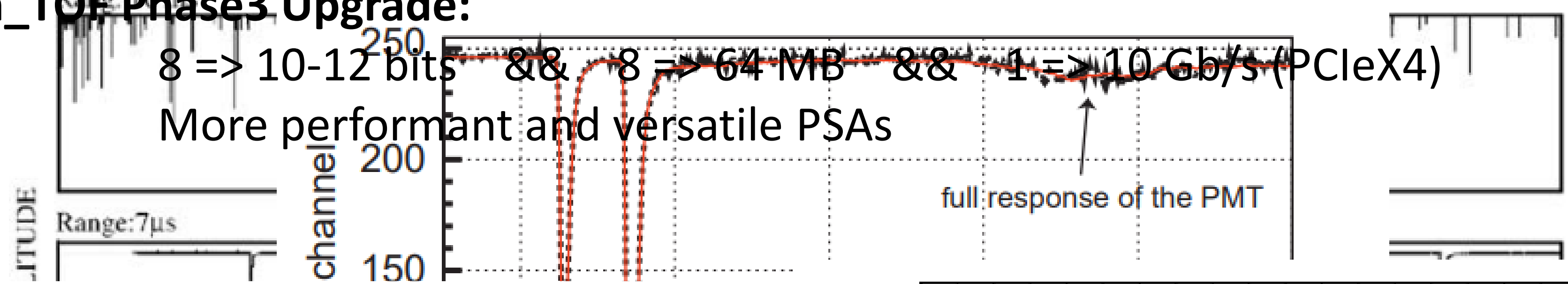
n_TOF Phase 1: <u>one of the firsts of its kind</u>

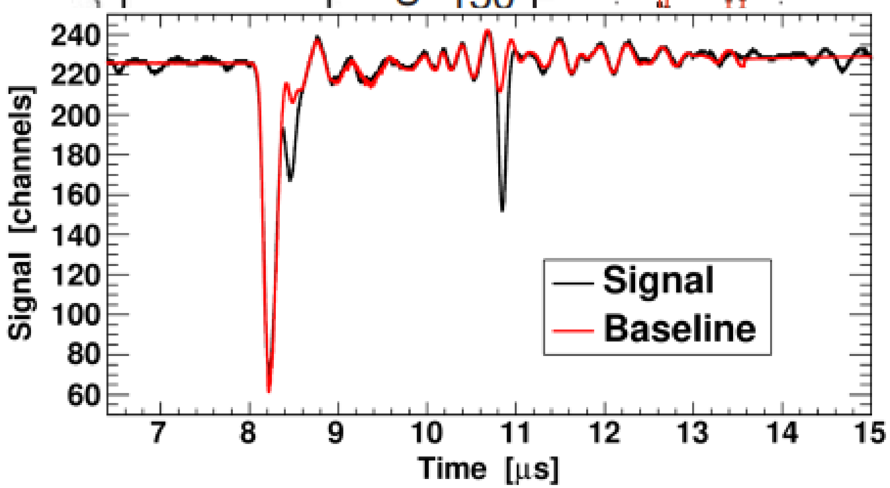
~54 flash-ADC (FADC) channels with 8-bit and 1 GS/s with 8 MB memory

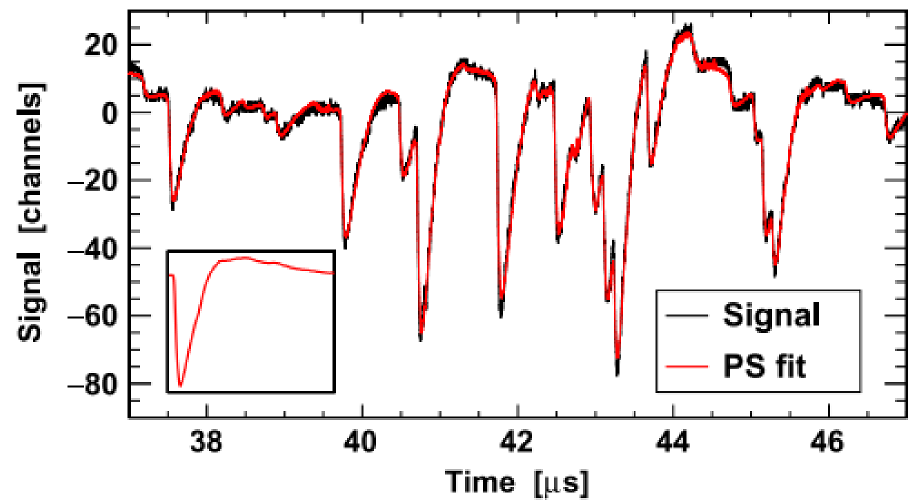
Digitized movies stored permanently (CASTOR) for offline Pulse Shape Analysis (PSA)

n_TOF Phase3 Upgrade:

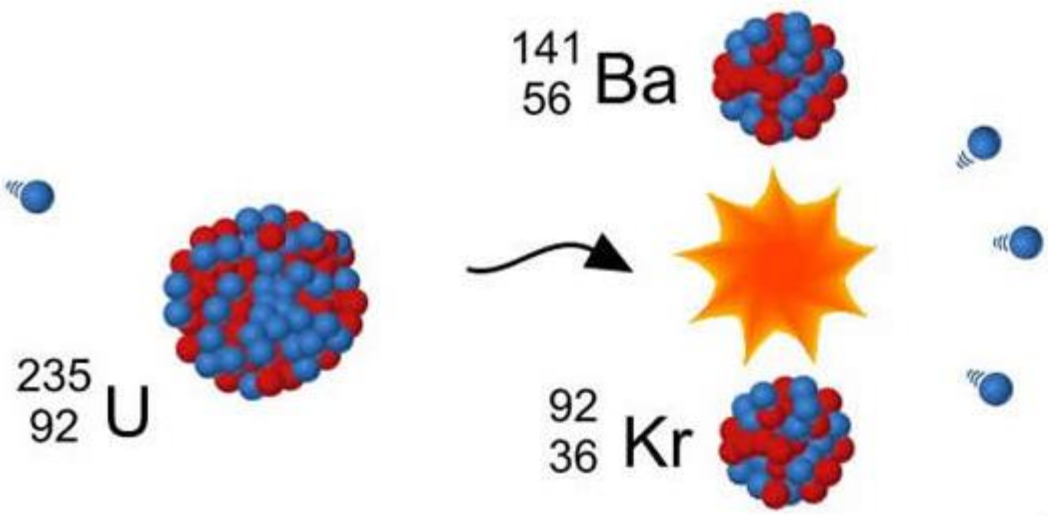
- 8 => 10-12 bits && 8 => 64 MB && 1 => 10 Gb/s (PCIeX4)
- More performant and versatile PSAs







(n,f)
challenges and (n_TOF) solutions

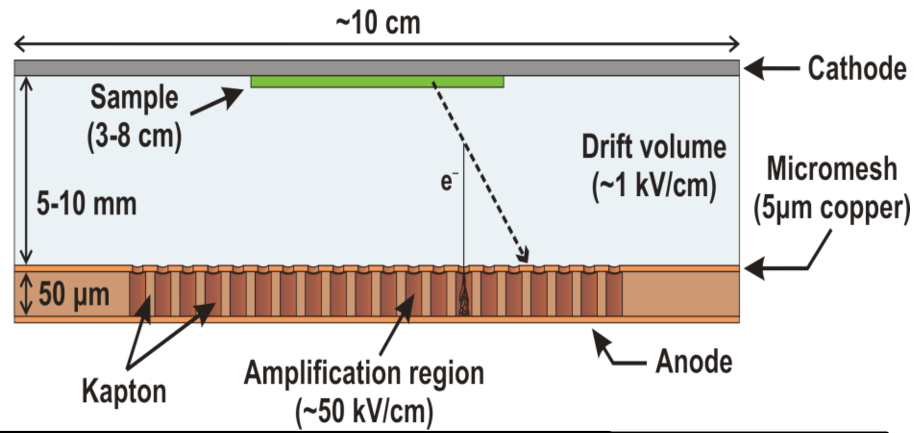


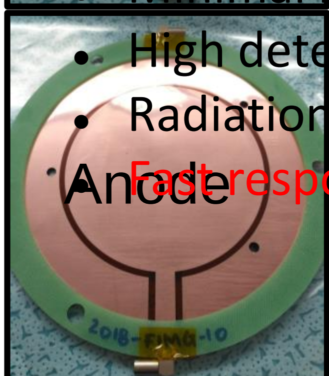
Current day-to-day fission cross sections

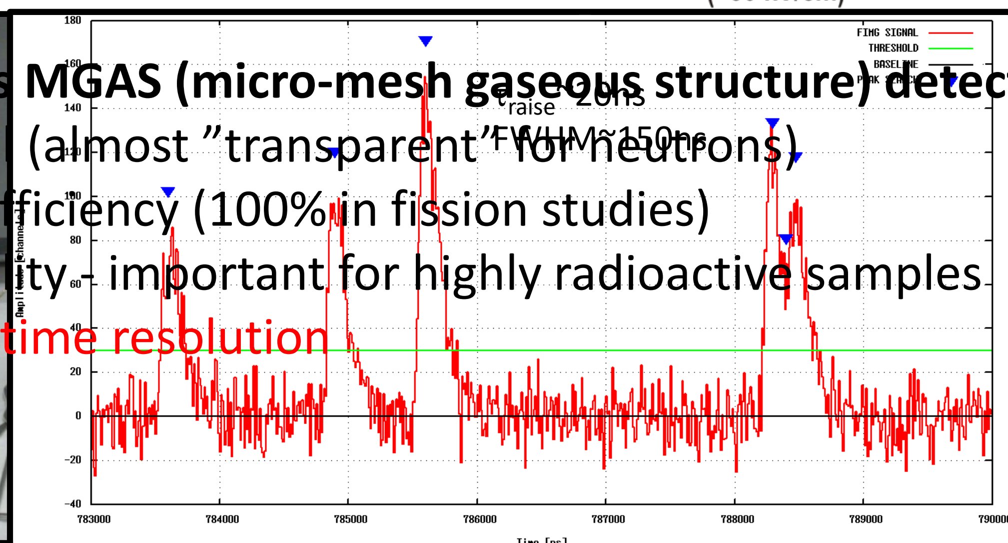
The challenge

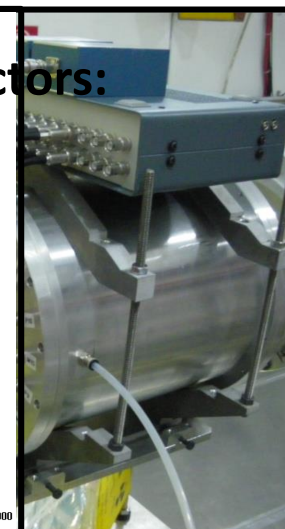
Need of a stable, robust, easy to use/analyze fission detector [for σ(n,f) and beam monitoring]

The n_TOF solution









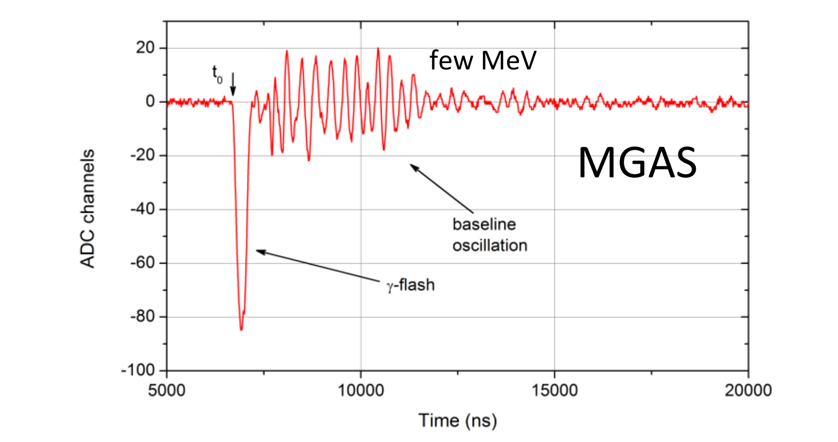
n_TOF Micromegas MGAS (micro-mesh gaseous structure) detectors:

- Minimal material (almost "transparent" for neutrons)
- High detection efficiency (100% in fission studies)
- Radiation durability - important for highly radioactive samples
- Fast response & time resolution

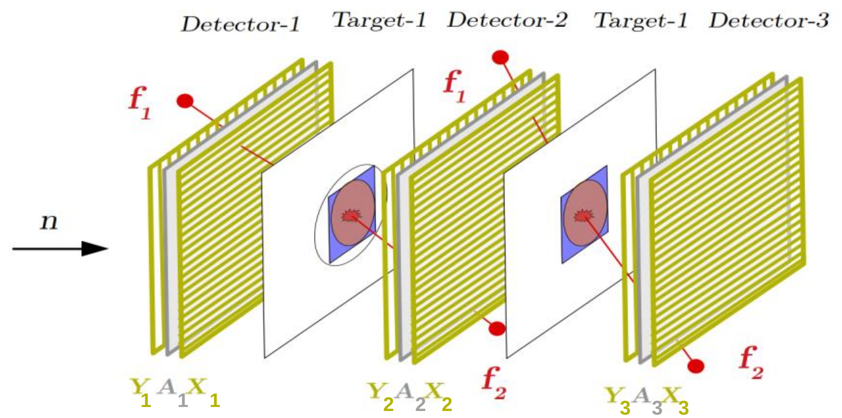
***MGAS*@n_TOF ===> Beam monitoring with ^{235}U(n,f) + σ(n,f) of ^{230}Th, ^{240,242}Pu + ...**

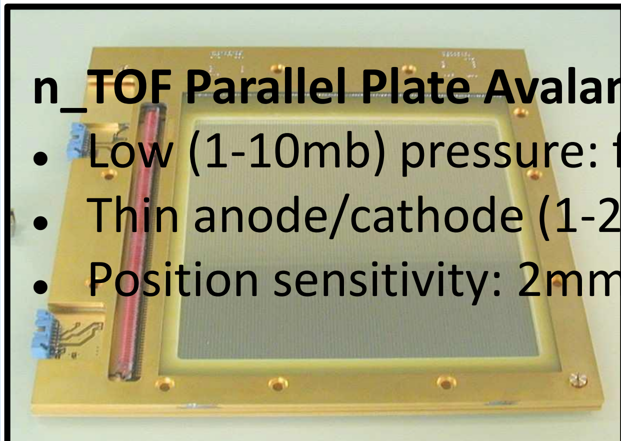
Pushing the high E_n limit

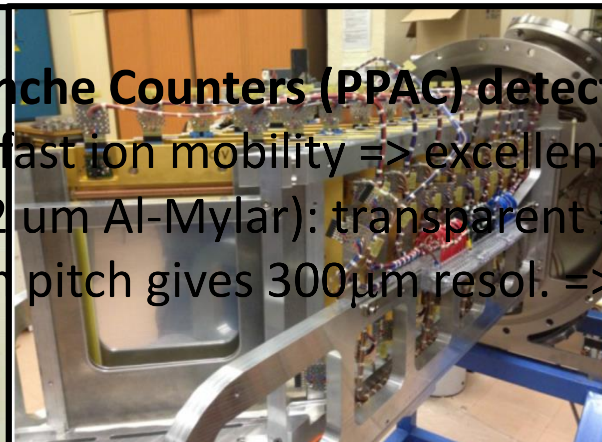
The challenge

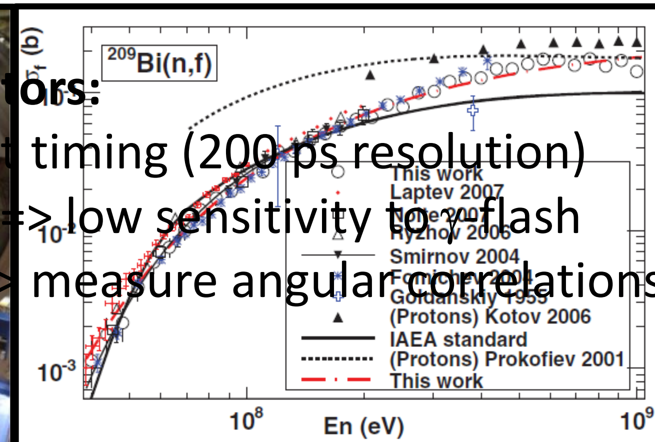


The n_TOF solution









n_TOF Parallel Plate Avalanche Counters (PPAC) detectors:

- Low (1-10mb) pressure: fast ion mobility => excellent timing (200 ps resolution)
- Thin anode/cathode (1-2 um Al-Mylar): transparent => low sensitivity to γ-flash
- Position sensitivity: 2mm pitch gives 300μm resol. => measure angular correlations

PPAC@n_TOF ===> Beam monitoring + σ(n,f) and ang. corr. of ^{nat}Pb, ^{209}Bi, ^{233}U, ^{232}Th (1 GeV!)

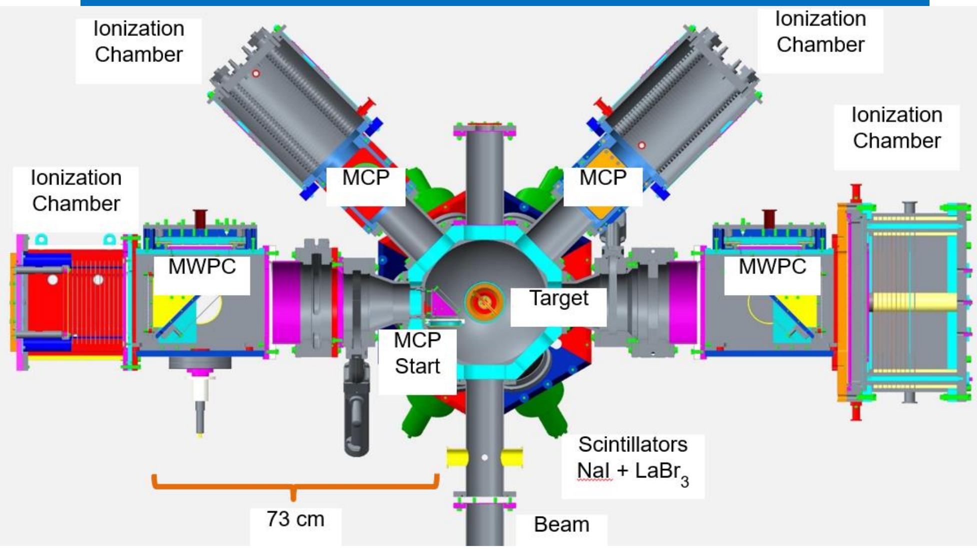
Seeing all fission observables simultaneosuly

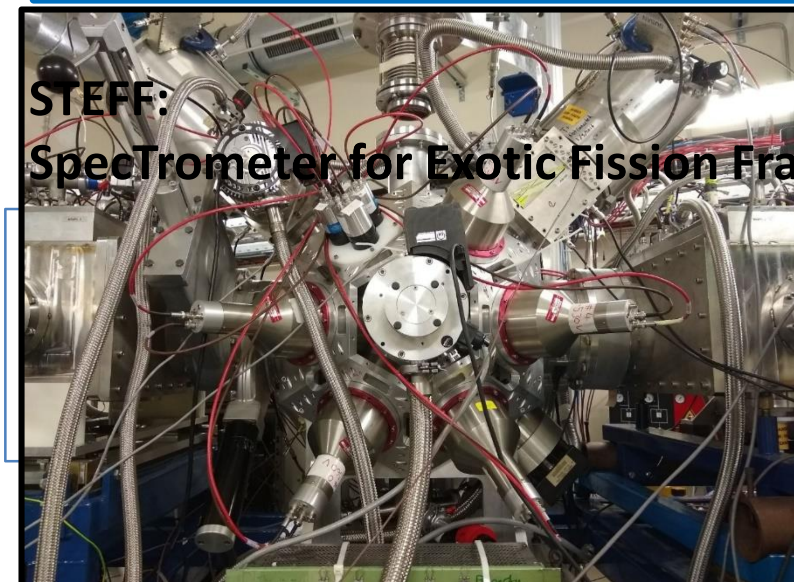
The challenge

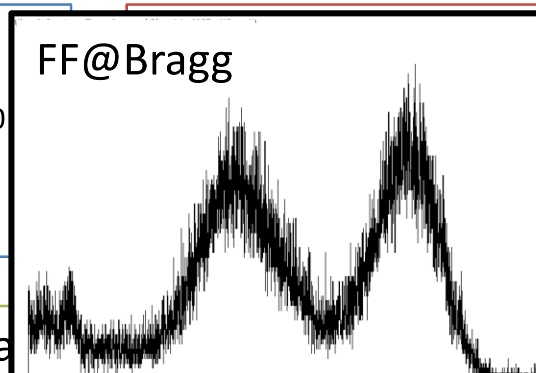
Fission is very rich in observables!

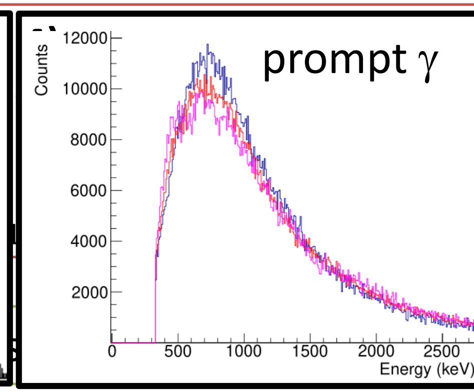
- Fission fragments:
  - A and Z yields
- Prompt emission of:
  - gammas: energy and multiplicity
  - neutrons: multiplicity (Nubar)

The n_TOF solution









STEFF@n_TOF ===> ^{235}U and ^{239}Pu experiments

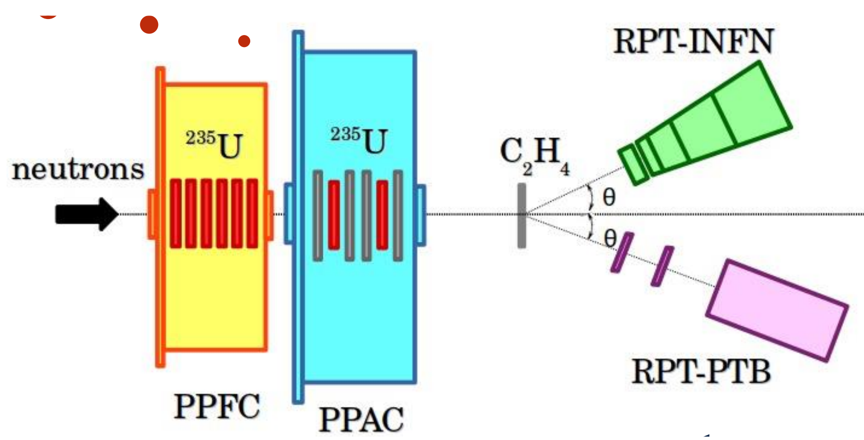
Measuring relative to $^{1}H(n,p)$ at high E_n

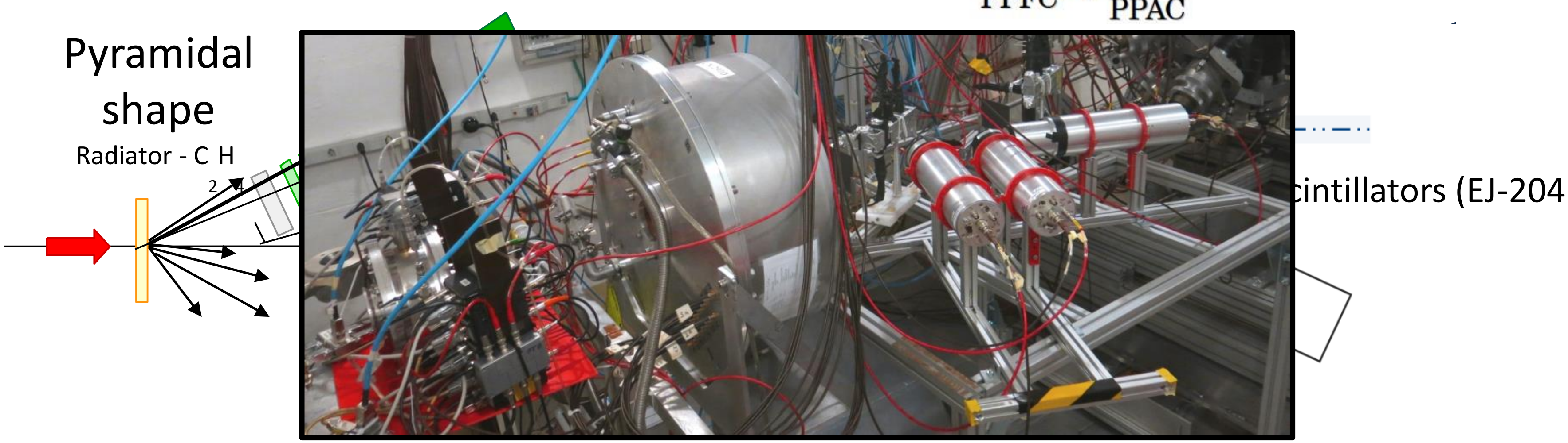
The challenge

$^{235}U(n,f)$ standard only up to 200 MeV,

- how can it be extended above 20 MeV? masure abve 200 MeV

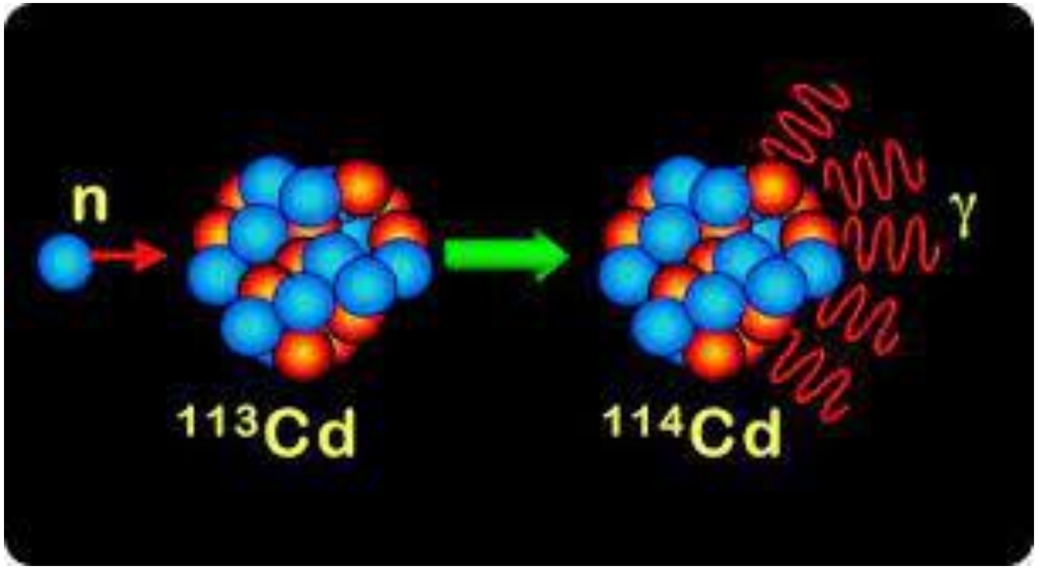
The n_TOF solution (II)





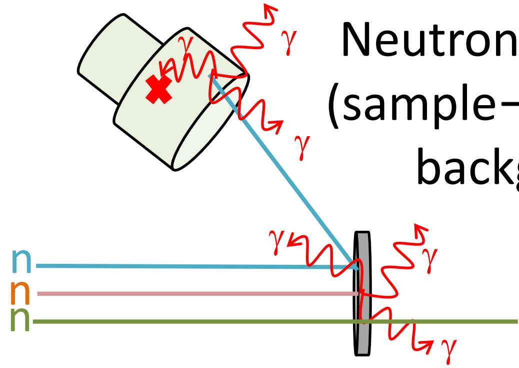
PRT@n_TOF: *$^{235}U(n,f)$ combined with PPAC*

(n,γ)
challenges and (n_TOF) solutions

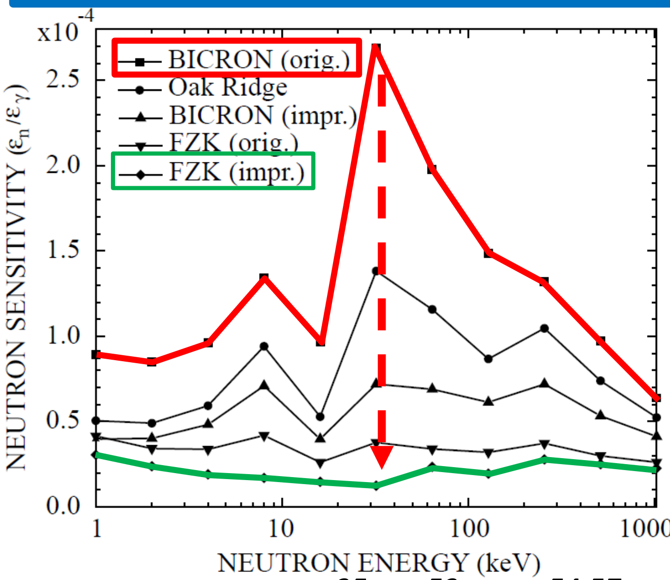


Neutron sensitivity

The challenge

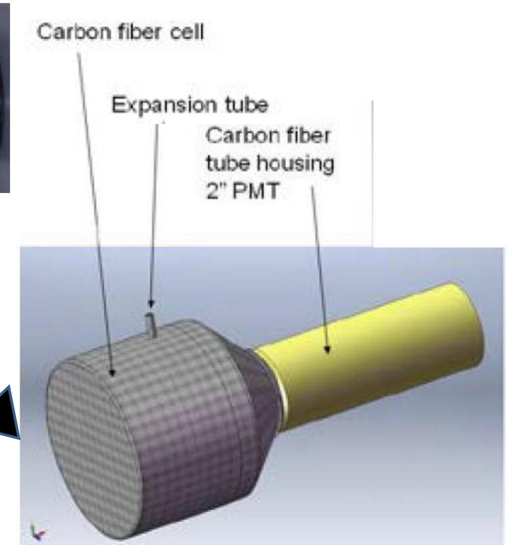


Neutron scattering (sample→ detector) background



The n_TOF solution

Al/SS→Carbon Fiber



Total Energy Detectors (TED):

Condition I: Low efficiency detectors $\varepsilon_{\gamma i} << 1$

Condition II: The efficiency is proportional to E_γ (by means of the ¿accurate? PWHT)

$$\varepsilon_c = k \sum_{i=1} E_{\gamma i} = kE_c$$

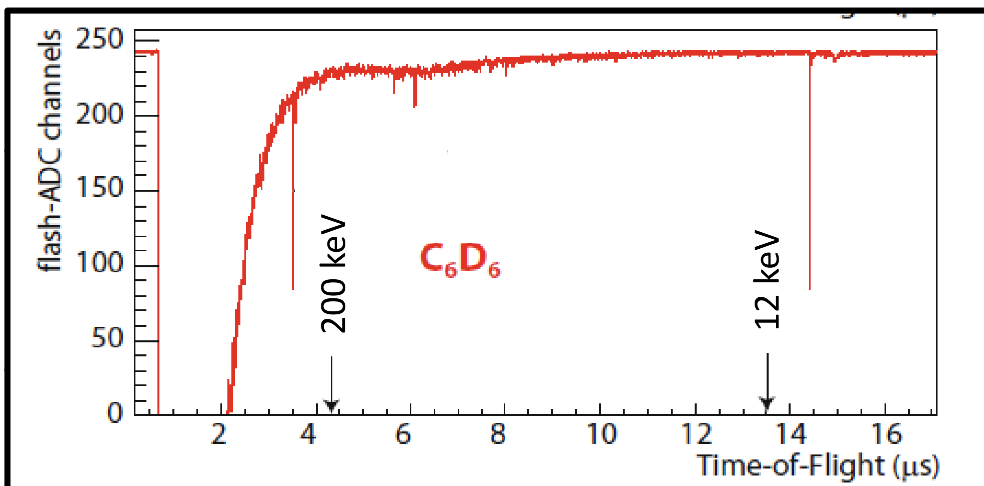
C6D6@n_TOF: *^{35}Cl, ^{53}Mn, ^{54,57}Fe, ^{58}Zn, ^{62,63}Ni, ^{90,91,92,93,94,96}Zr, ^{69,71}Ga, ^{72,74,76}Ge, ^{80}Se, ^{89}Y, ^{88}Sr, ^{140}Ce, ^{147}Pm, ^{171}Tm, ^{203,204}Tl, ^{204,206,207}Pb, ^{209}Bi, ^{236,238}U, ^{242}Pu, ^{244,246}Cm*

Pushing the high E_n limit (@EAR2?)

The challenge

The upper E_n limit for (n,γ) at EAR2 is due to:

- High counting rate
- Huge g-flash



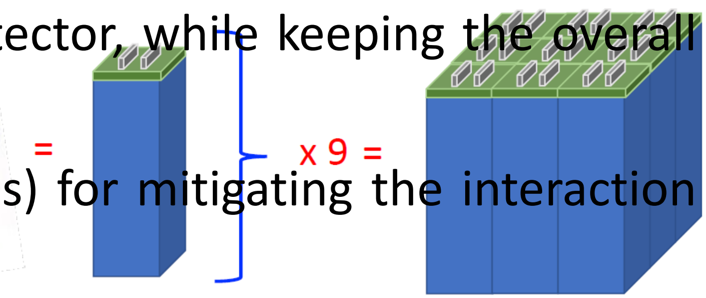
The n_TOF solution

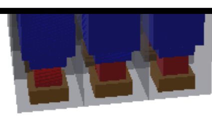
D)

ergy deposition due to the flash

etector, while keeping the overall

Ms) for mitigating the interaction





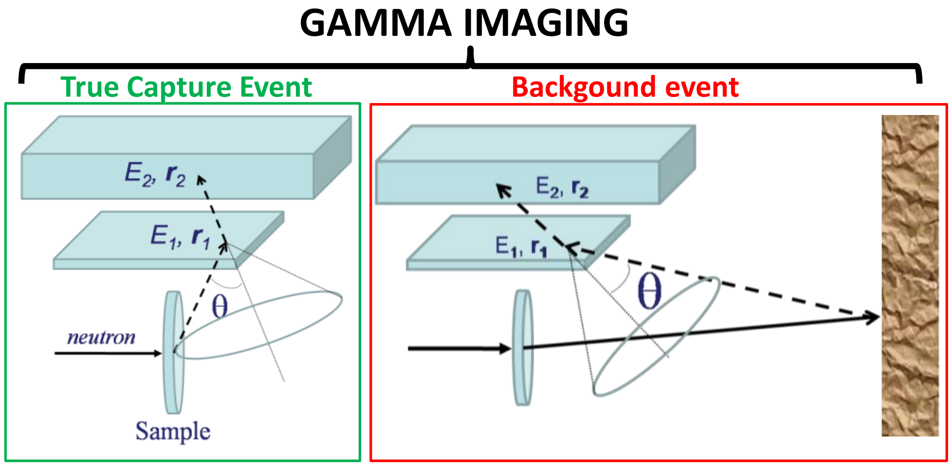
***sTED**@n_TOF ===> beam tests ongoing*

Low signal to background cases

The challenge

Everything but γ-rays from the sample is background!

The n_TOF solution



Total **I** -ray **imagi**

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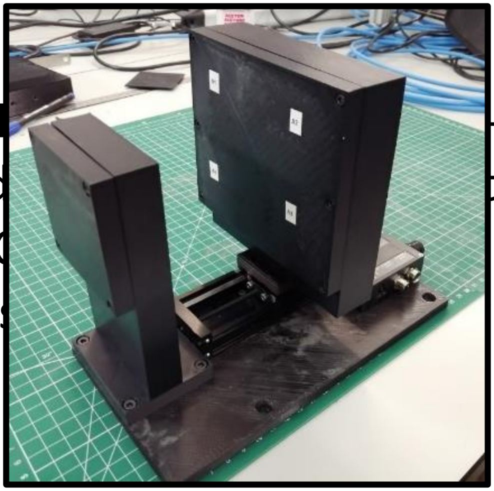
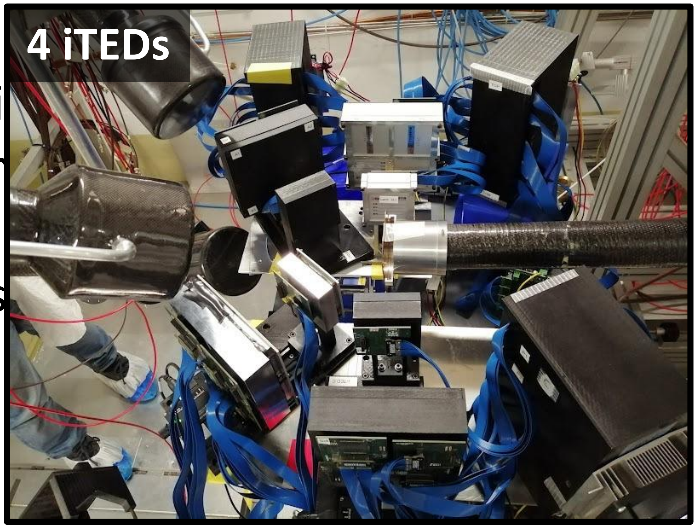




***iTED**@n_TOF: tests at EAR1 and EAR2, ^{79}Se in 2022*

Unstable isotopes: low-mass & high-activity

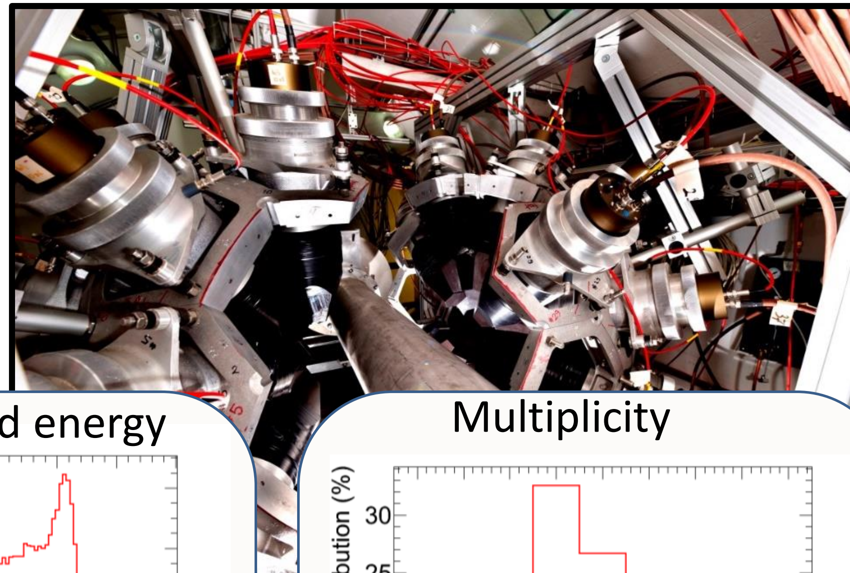
The challenge

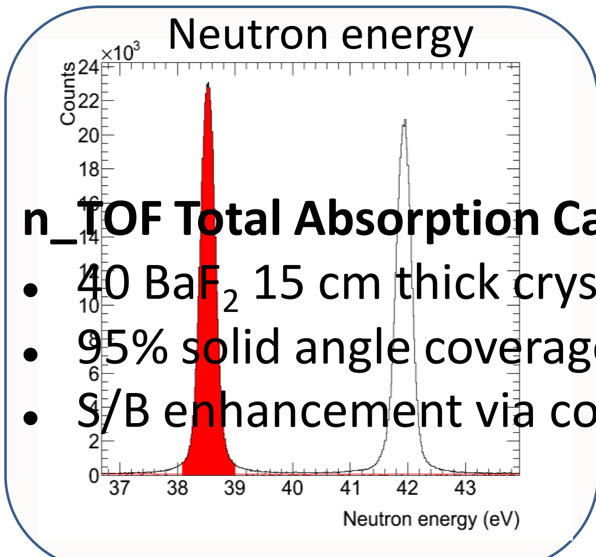
Activity and limited mass of the radioactive isotopes of interest in nuclear technology (*actinides*) and astrophysics (*branching points*).

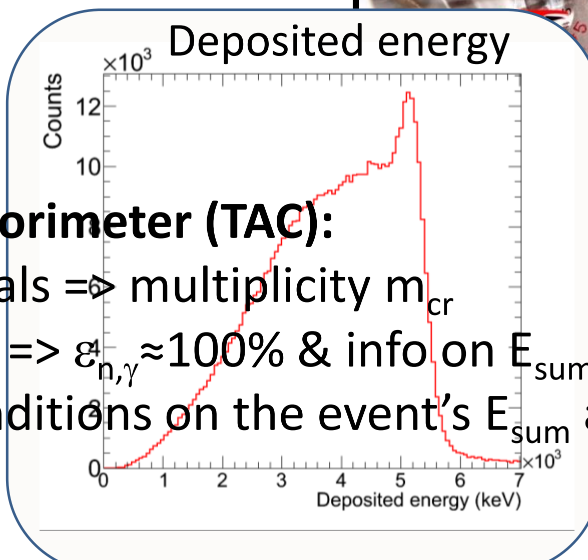
=> Require **high efficiency**

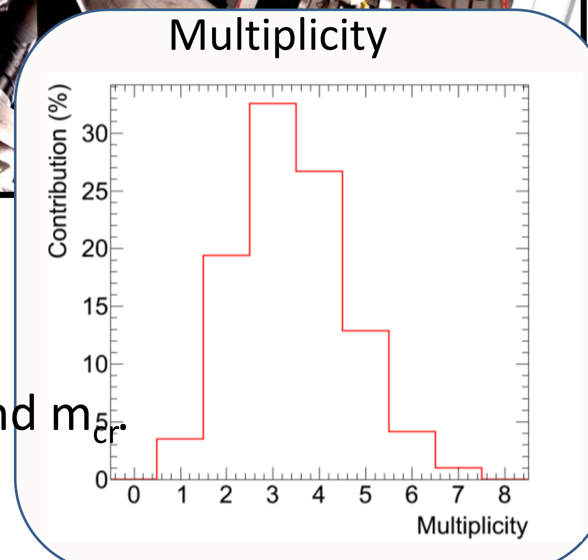
=> Require **background reduction**

The n_TOF solution









n_TOF Total Absorption Calorimeter (TAC):

- 40 BaF_2 15 cm thick crystals => multiplicity m_{cr}
- 95% solid angle coverage => $\varepsilon_{n,\gamma}$≈100% & info on E_{sum}
- S/B enhancement via conditions on the event's E_{sum} and m_{cr}.

TAC@n_TOF: $^{233, 234, 238}$U, ^{237}Np, ^{240}Pu, ^{241,243}Am

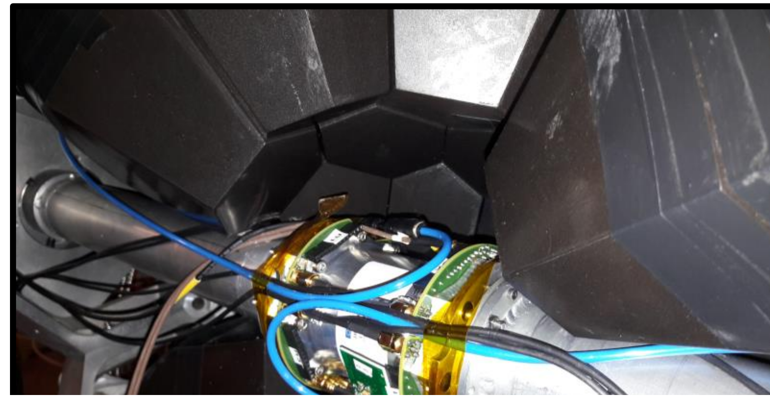
Fission background

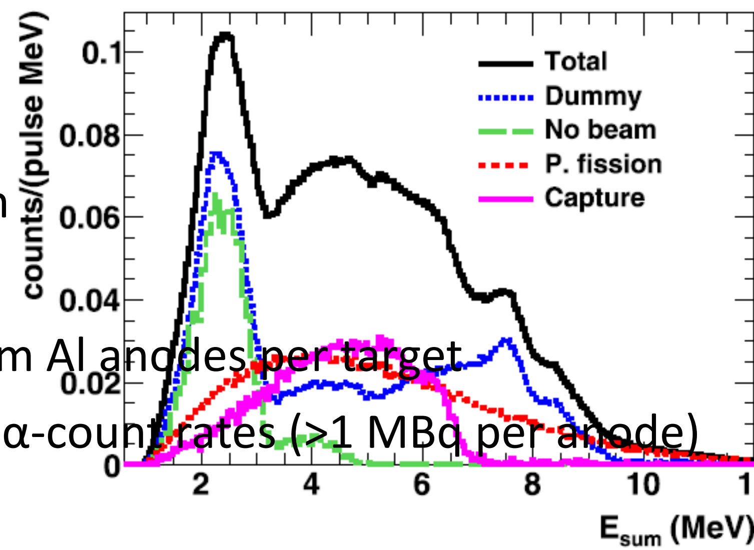
The challenge

Fission competes with capture, with more and more energetic γ-rays emitted in fission than in capture.

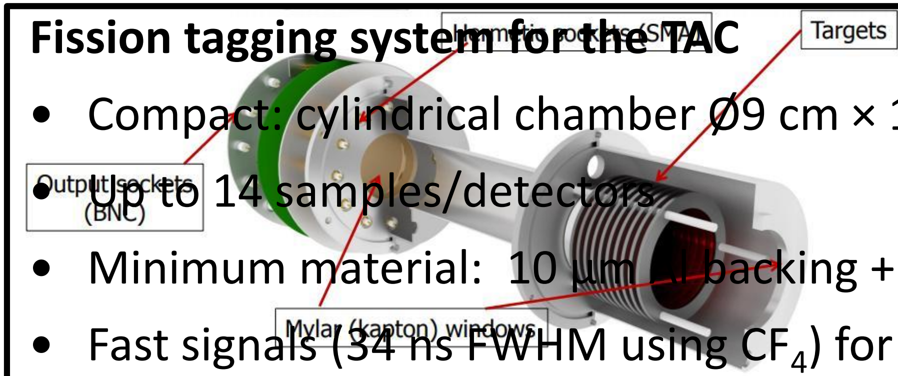
=> γ-ray background from fission

The n_TOF solution





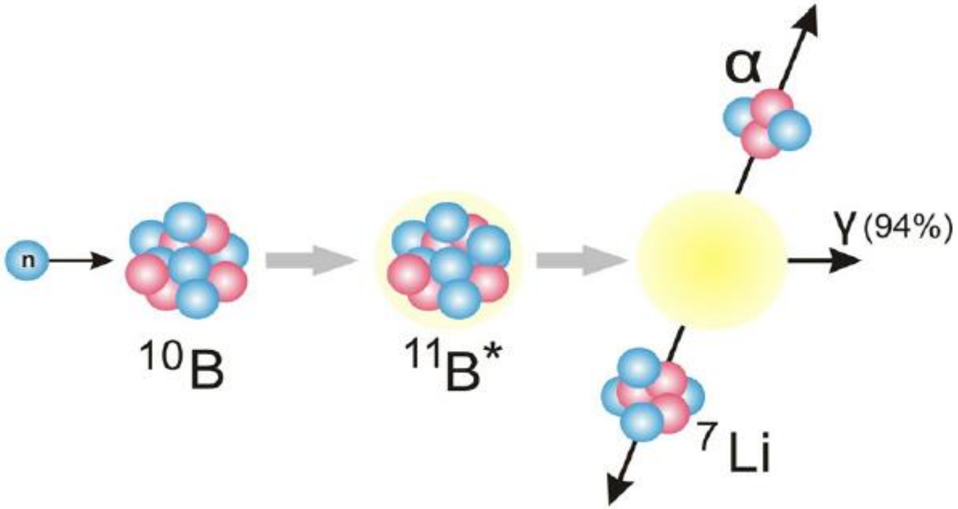
Fission tagging system for the TAC



- Compact: cylindrical chamber Ø9 cm × 12 cm
- Up to 14 samples/detectors
- Minimum material: 10 µm Al backing + 20 µm Al anodes per target
- Fast signals (34 ns FWHM using CF_4) for high α-count rates (>1 MBq per anode)

TAC@n_TOF: ^{233}U, ^{235}U and, soon, ^{239}Pu

(n,chp)
challenges and (n_TOF) solutions

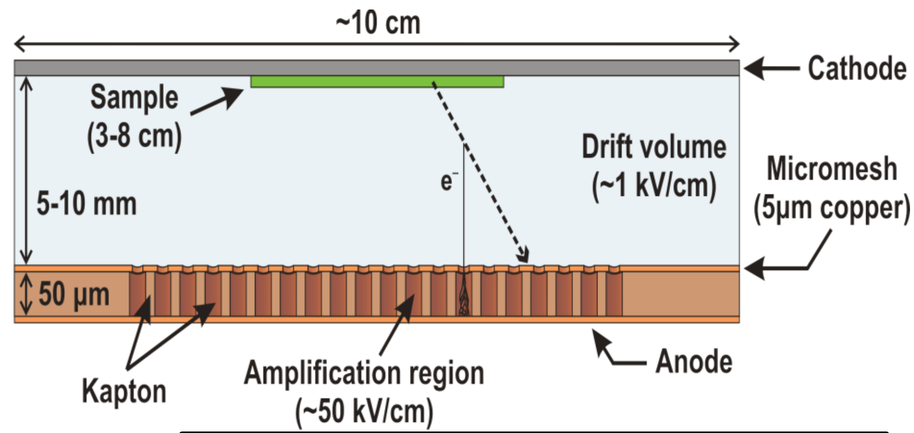


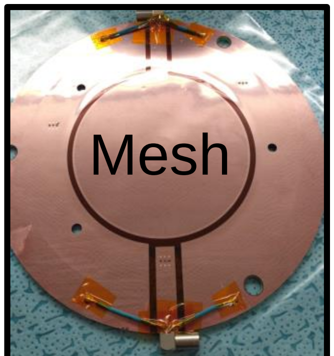
Day-to-day (n,chp) cross sections

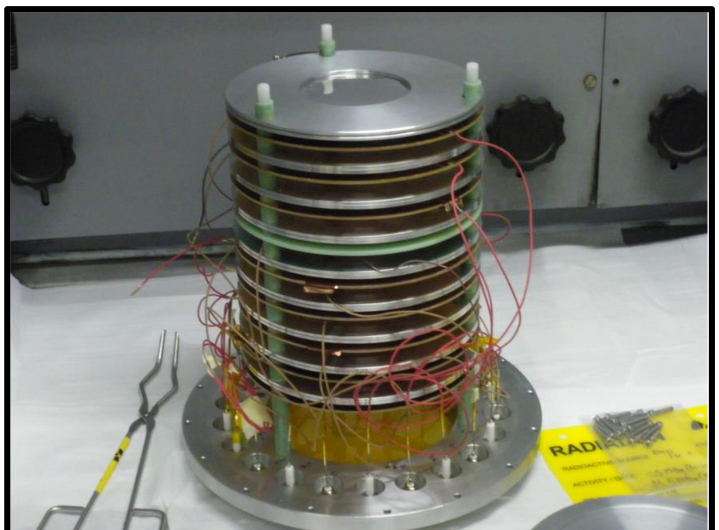
The challenge

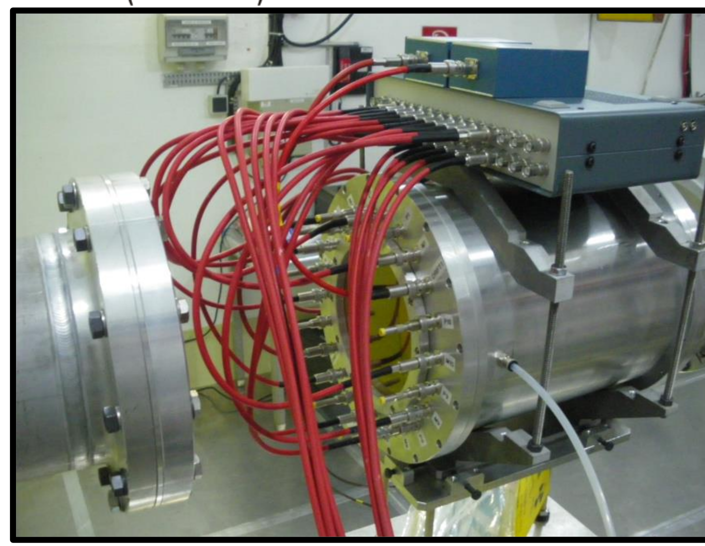
Need of a stable, robust, easy to use/analyze detector for σ(n,p/α/t) and beam monitoring]

The n_TOF solution





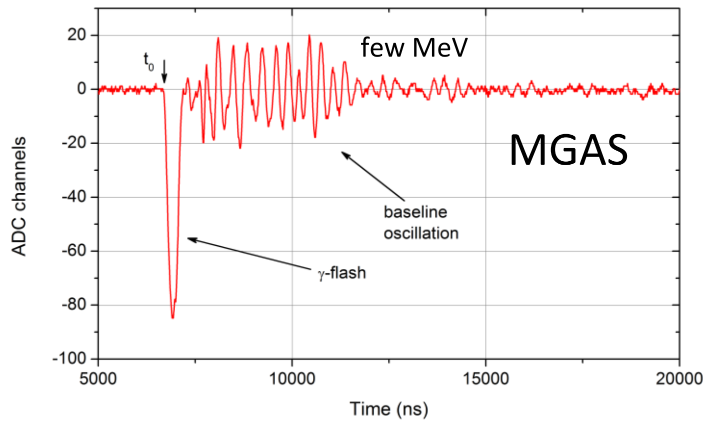




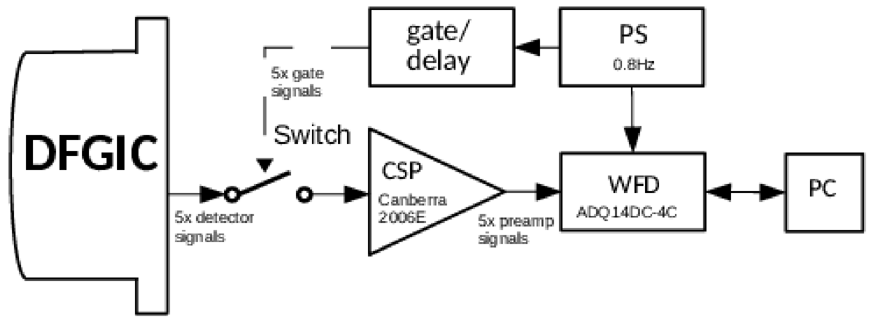
***MGAS**@n_TOF ===> Beam monitoring with* ^{10}*B(n,*α*) +* σ *of* ^{14}*N(n,p),* ^{33}*S(n,*α*),* ^{35}*Cl(n,p)*

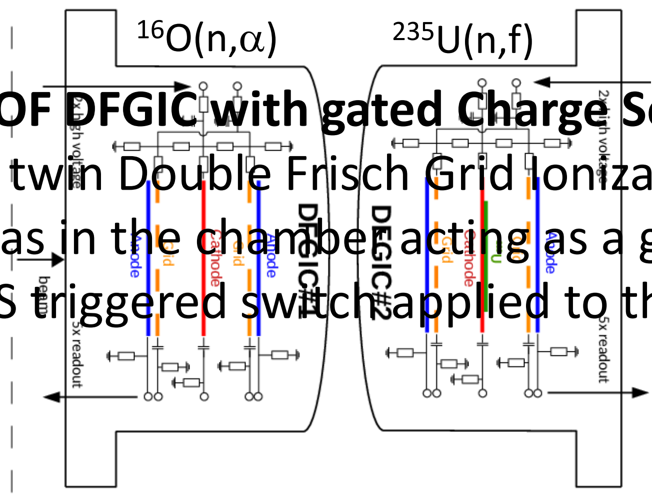
Pushing the high E_n limit

The challenge



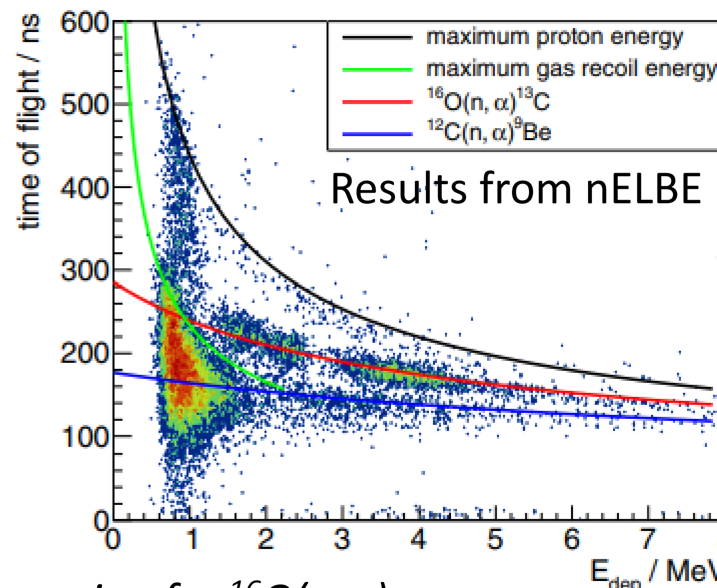
The n_TOF solution





n_TOF DFGIC with gated Charge Sensitive Pr

- A twin Double Frisch Grid Ionization Cham
- Gas in the chamber acting as a gaseous ^{16}C
- PS triggered switch applied to the CSP



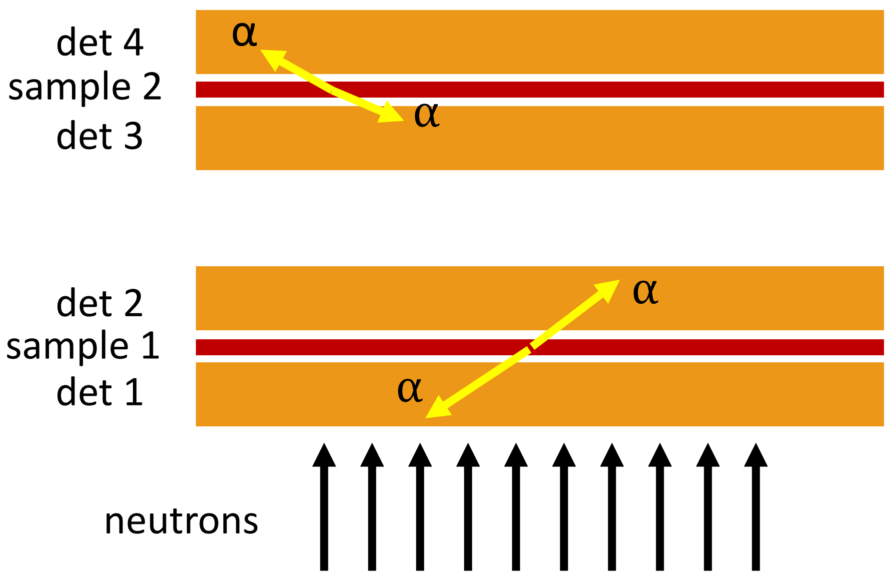
***Gated DFGIC**@n_TOF: tests ongoing for $^{16}O(n,\alpha)$*

Dealing with high radioactivity in (n,α/p)

The challenge

Dealing with the activity from GBq targets.

Discriminate background ^{7}Be γ and ^{7}Be(n,p)



Silicon detectors in the neutron beam

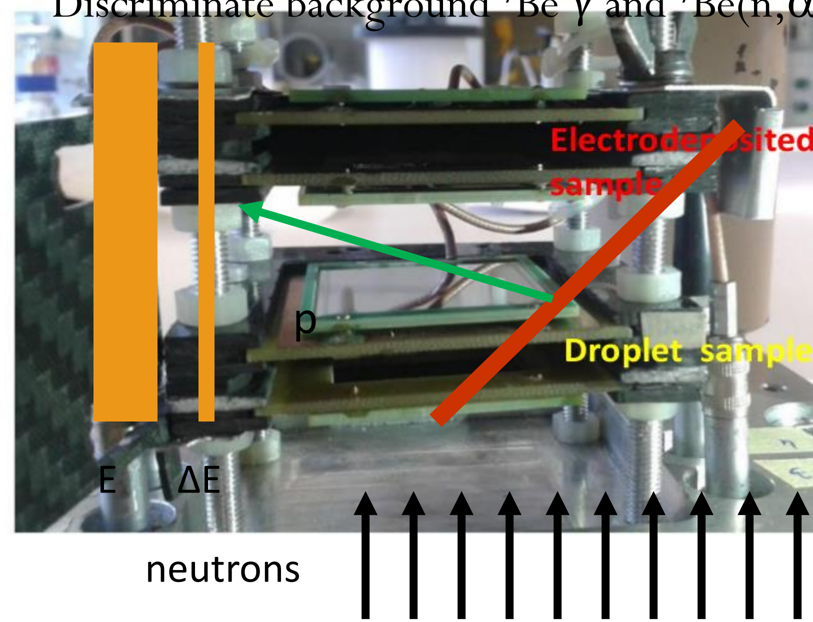
3x3 cm^{2} active area, 140 μm thickness

2 ^{7}Be targets with ~18 GBq each (~1.4 μg)

The n_TOF solution

=> Unambiguous identification of the reaction products.

Discriminate background ^{7}Be γ and ^{7}Be(n,α)



Silicon detectors OFF the neutron beam

3x3 cm^{2} active area, 20 and 140 μm thickness

^{7}Be target with ~1 GBq each (~0.1 μg)

Summary

*Not exhaustive