Characterization and development of Parallel Plate Avalanche Counters for ion detection

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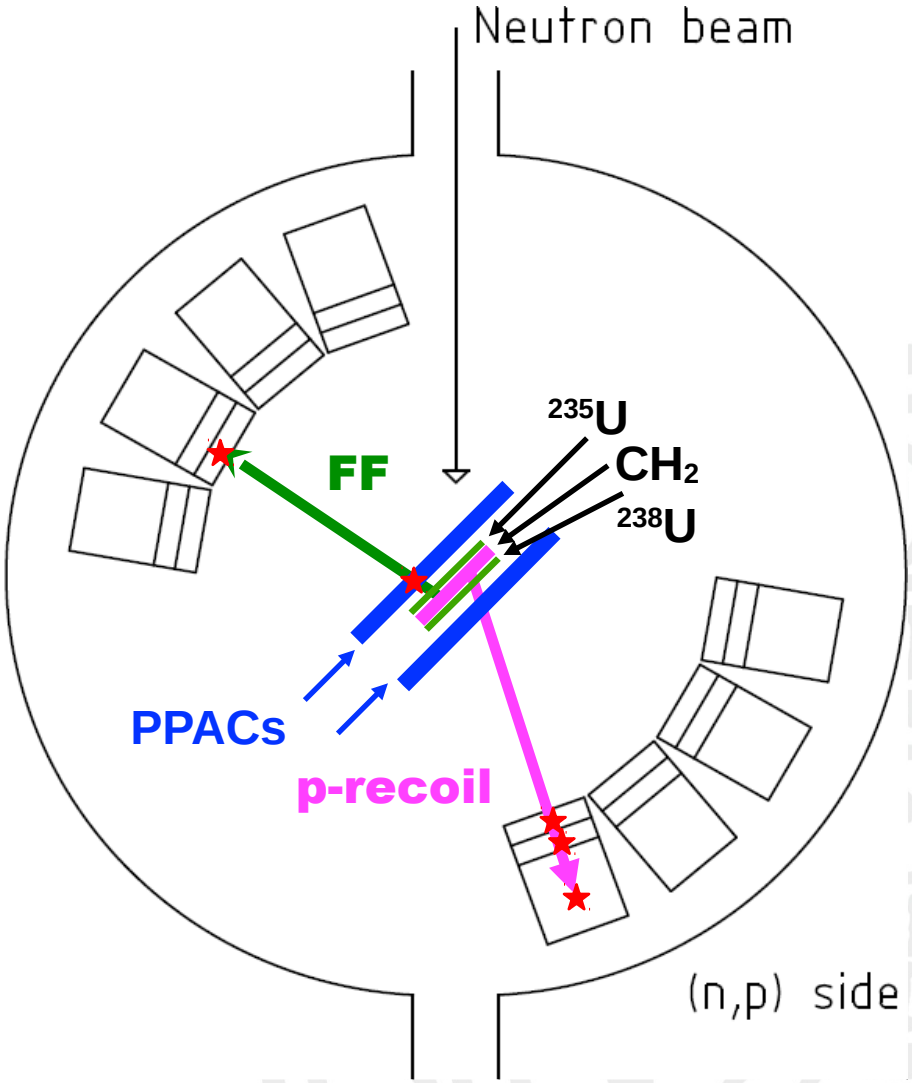
Upgrade of the Medley setup

- Simultaneous study of $^{235}U(n,f)$ and $^{238}U(n,f)$ cross sections versus np scattering.
- Three targets at a time:

$$^{238}U + CH_2 + ^{235}U$$

- Timing detectors **(PPACs)** will be used to determine the neutron energy by the time of flight (TOF).



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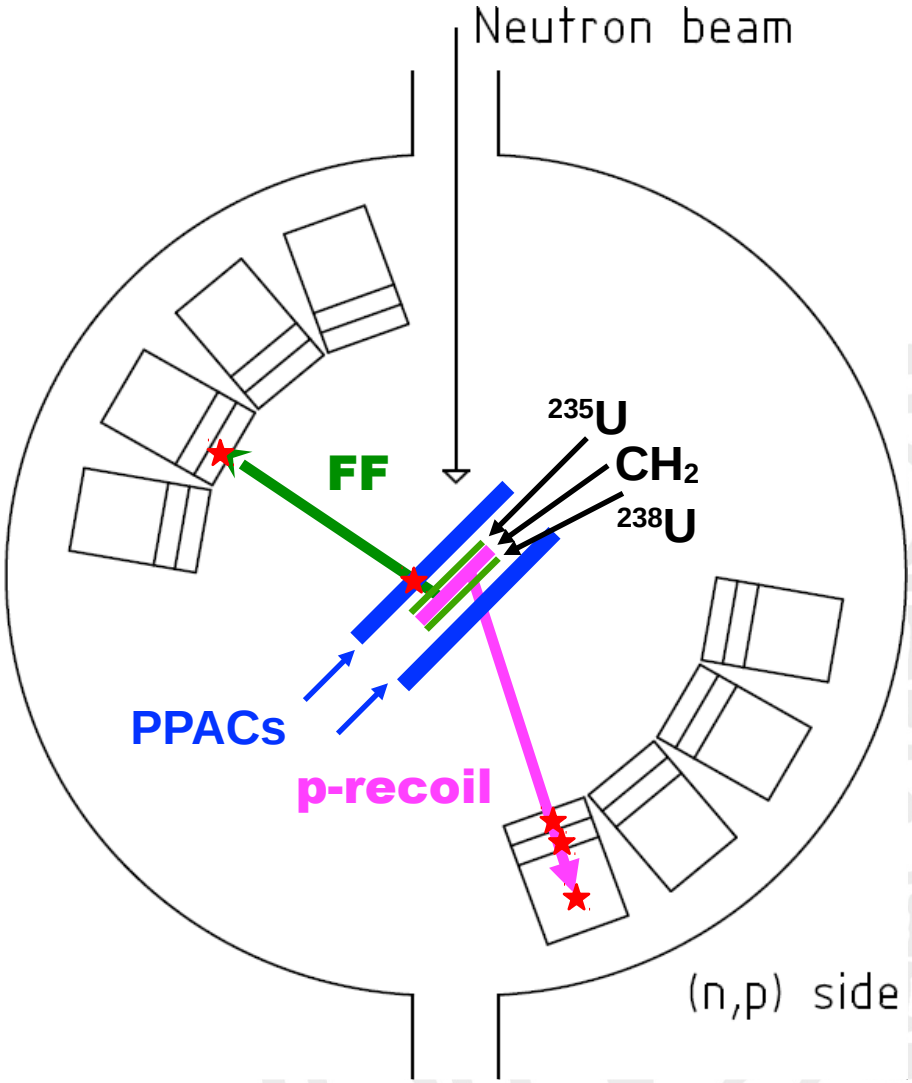

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Two types of events:

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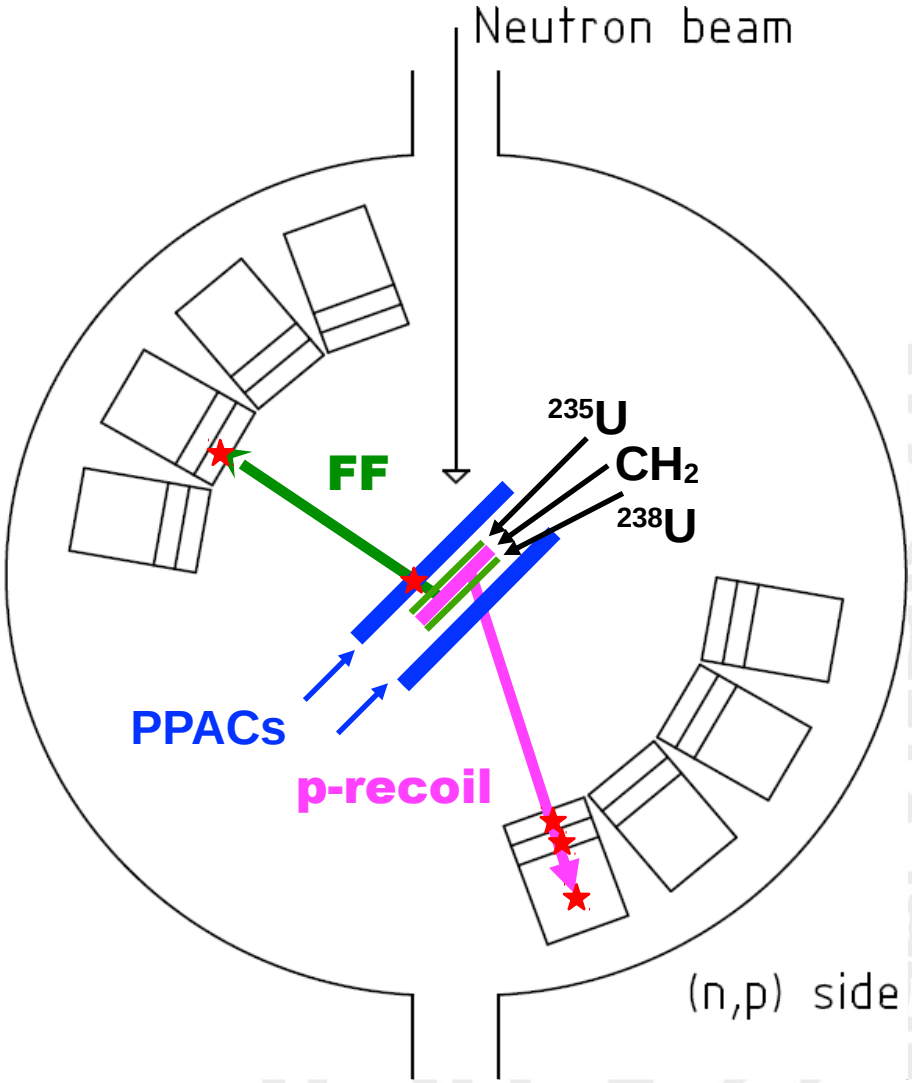
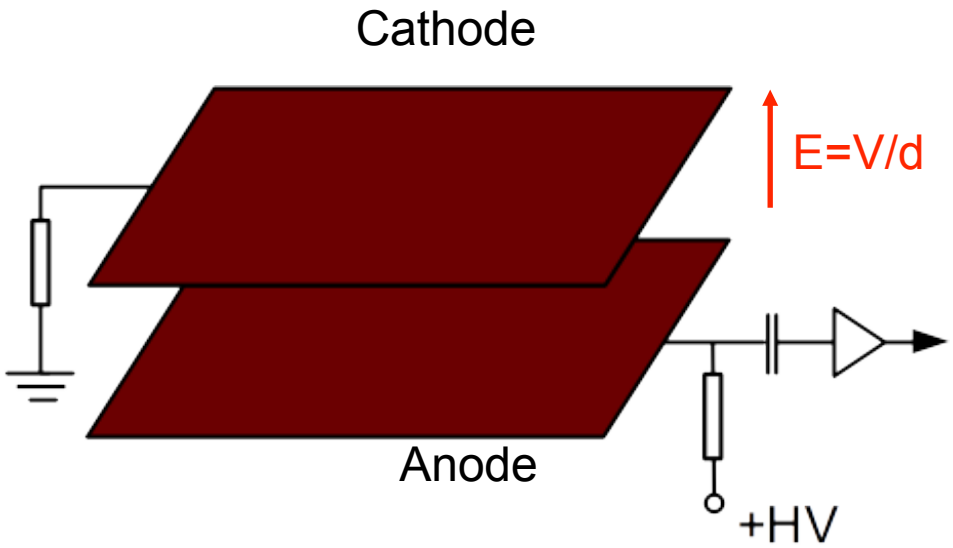
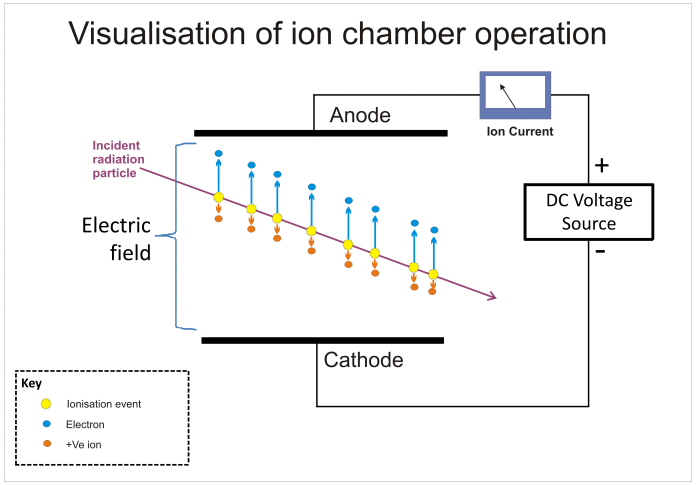
- **Proton recoil from H(n,n) in CH_2:** Identification at the forward telescopes.



PPAC
Parallel Plate Avalanche Counter





Bottom figure by Dougsim - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=22422020

- Low-pressure gas ionization chamber.
- C_3F_8 at a few mbar.
- High detection efficiency of fission fragments.
- Very thin mylar electrodes (~ μm)
- Nearly insensitive to gammas and neutrons.
- Time resolution ~ 1 ns or lower
- Poor energy resolution ~20 %

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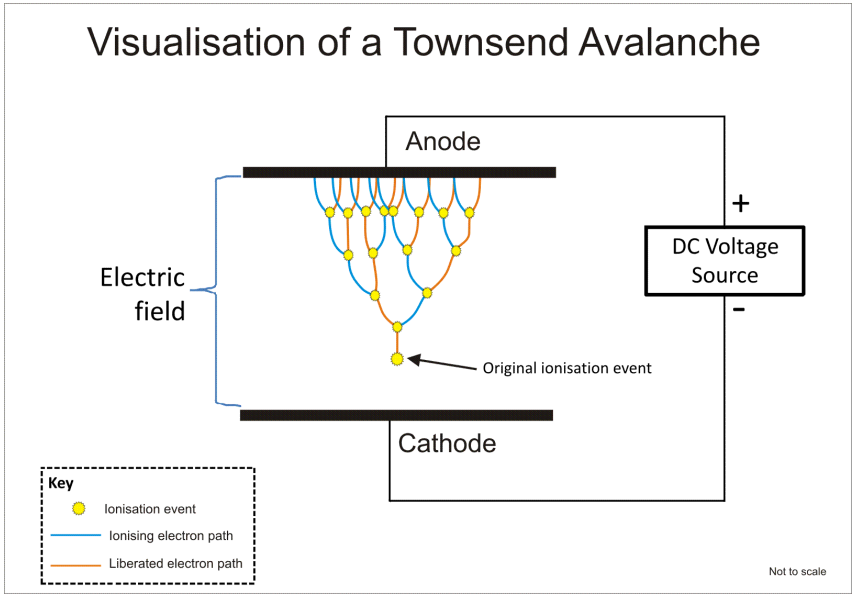
Parallel Plate Avalanche Counter



$$N = N_0 M = N_0 \frac{\exp(\alpha d) - 1}{\alpha d}$$

$$\frac{\alpha}{p} = A \exp(-Bp/E),$$

$$N_{V=const.} = C_1 \exp(C_2 p)$$
$$N_{p=const.} = C_3 \exp(C_4 V)$$

$$\alpha d \approx C_2 * p + C_4 * V$$

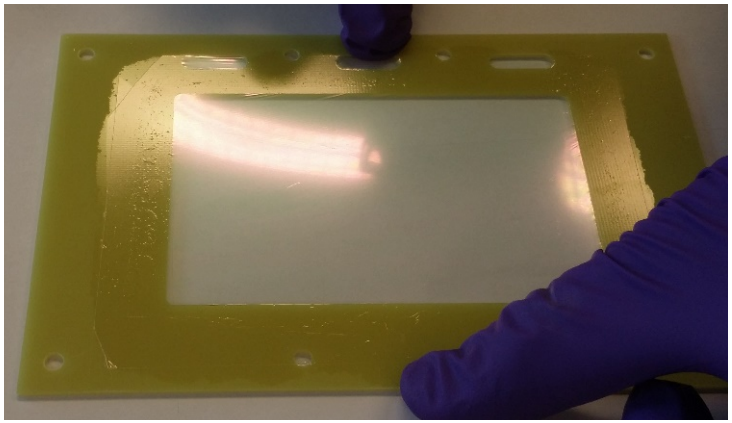
Brunner et al., NIM154,159(1978)

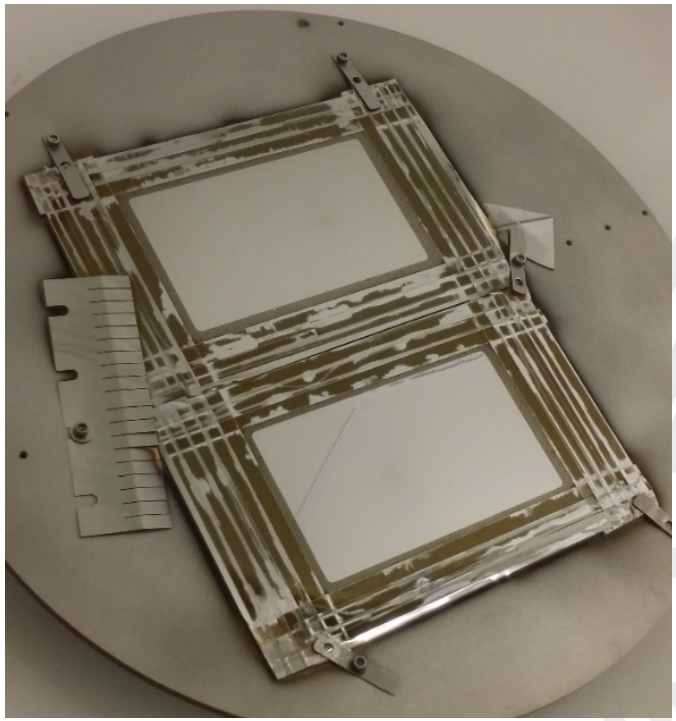
N: amplified number of electrons
N_0: initial number of electrons
M: gas amplification factor
α: 1st TC
d: gap of electrodes
p: gas pressure
E: electric field
V: bias voltage
A, B: gas coefficient
C_*: coefficient

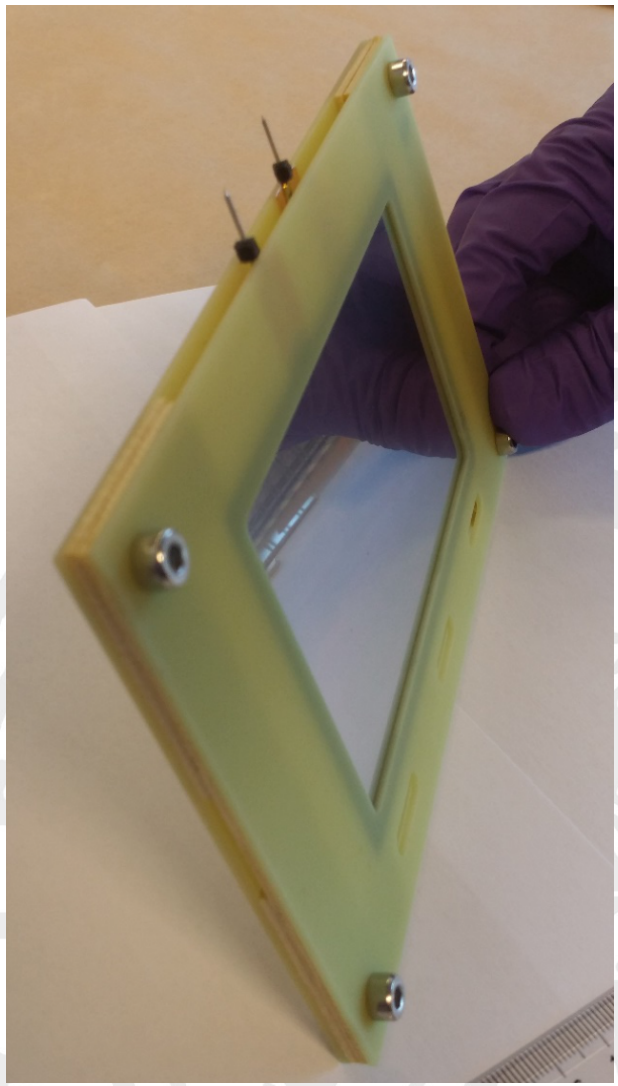
Fig. by Dougsim - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=22286660

Mounting of a PPAC prototype

- PPACs developed and built at our lab.
- Single-gap PPAC, to be used for timing.
- In steps:
  - Mylar film mounted on frames
  - Aluminium evaporation
  - Final assembly



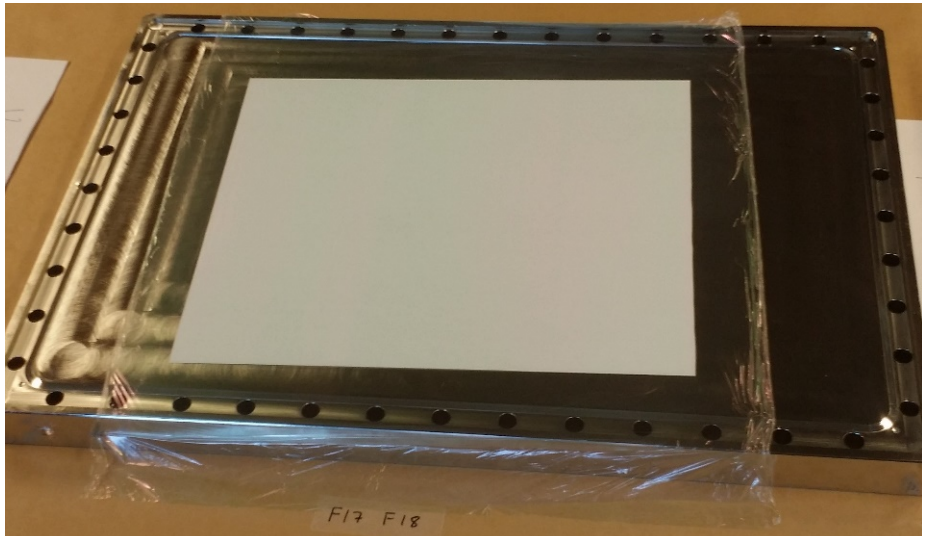


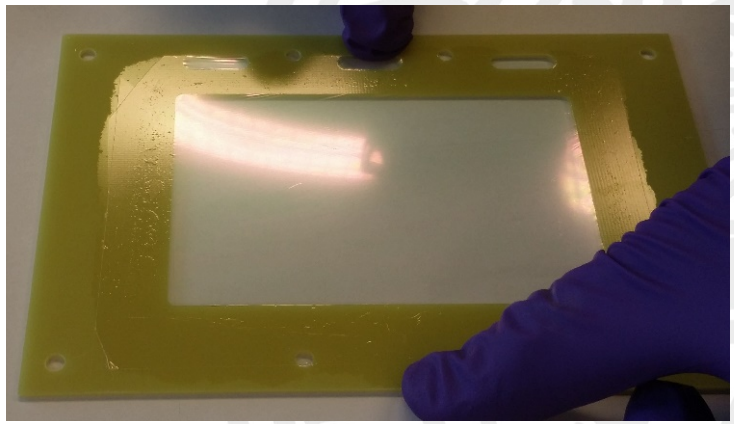


M. Carlsson, Master thesis (2018)

Mounting of a PPAC prototype

- A PPAC is made out of several 1.6 mm thick FR-4 fiberglass plates.
  - **Two** plates for the electrodes, with outer dimensions: 160x100 mm² and with a window: 100x60 mm².
  - **Extra** plates as spacers, to get a gap of 3.2 mm.
- 0.9 μm mylar film stretched and glued to the frame.





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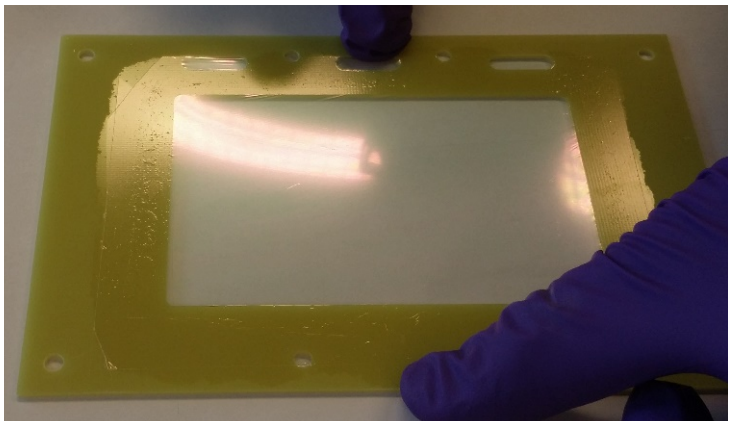
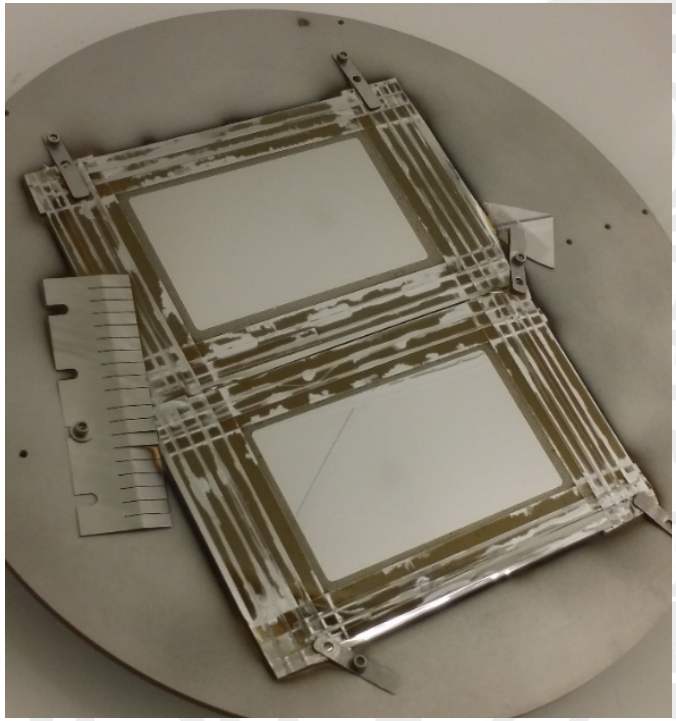
Mounting of a PPAC prototype

- Aluminium is evaporated on the mylar at MSL (MicroStructure-Lab at Ångstrom, Uppsala Univ.)
- Nominal specifications:
  - 40 nm aluminium
  - 1.5 Ω/□ sheet resistance
- Thickness measurements (profiler).
- Conductivity checks (4-point probe).





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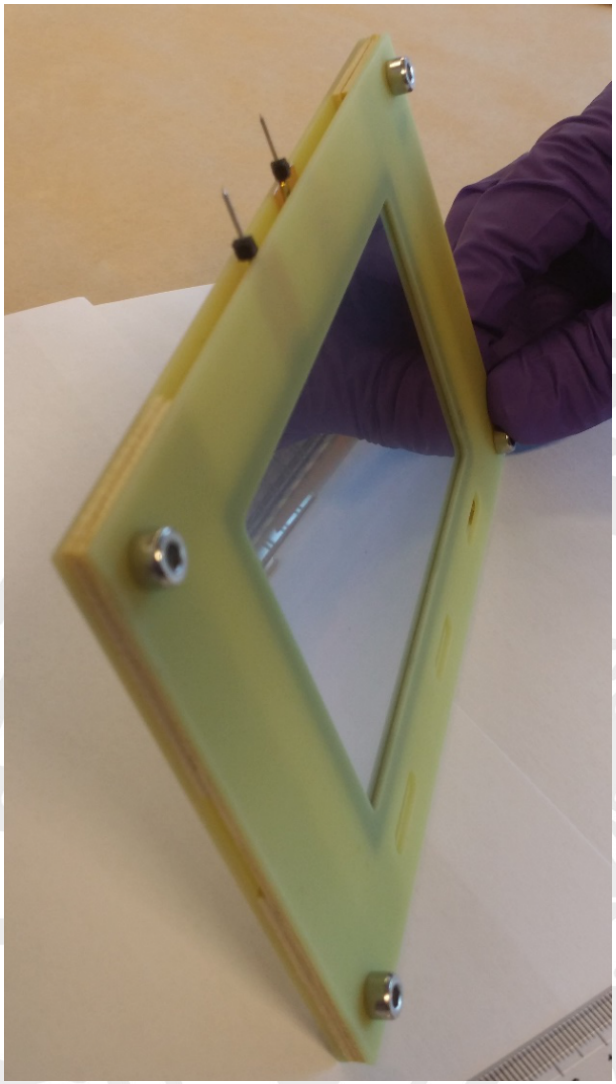
Mounting of a PPAC prototype

- Electrical connections to the electrodes:
  - Solder connectors on copper tape.
  - Conductive epoxy.
- Several working prototypes were prepared and tested, but...
-
  - … after a few months, connections were degraded and become unstable.



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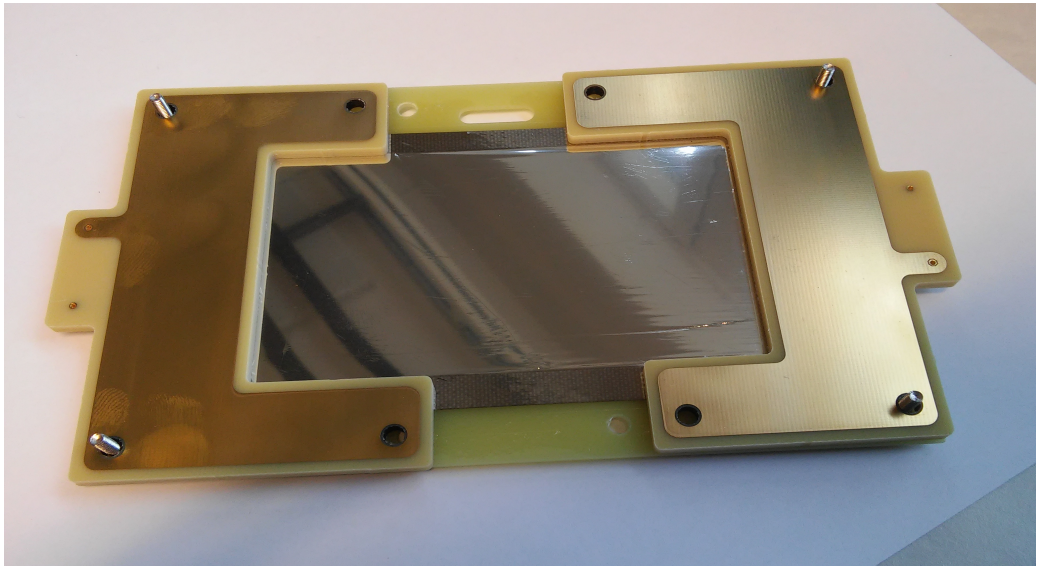
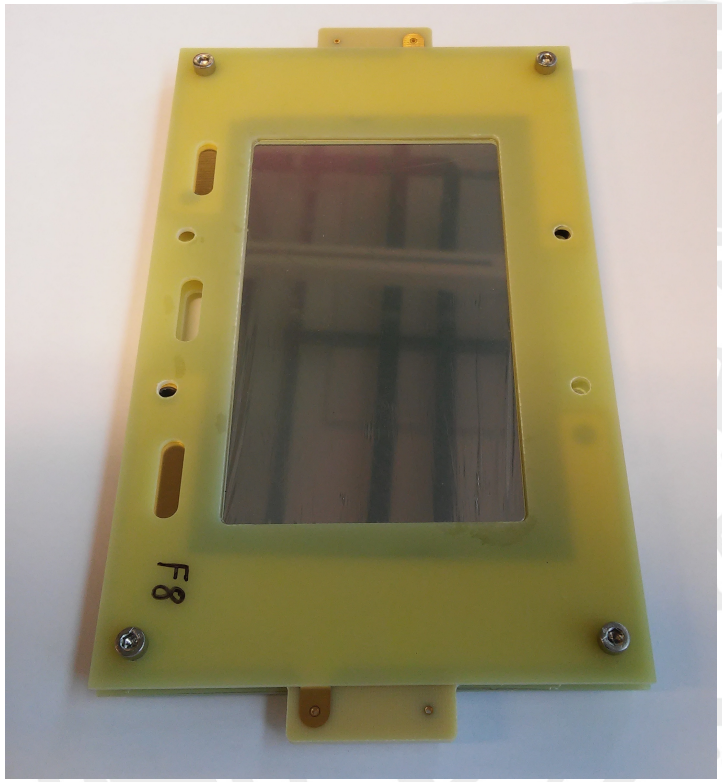
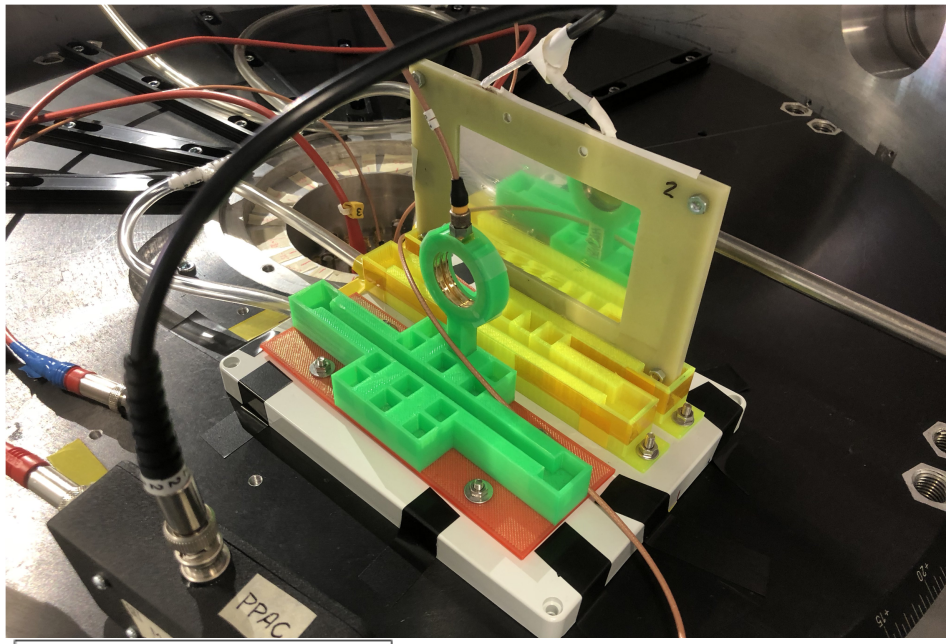
Mounting of a PPAC prototype

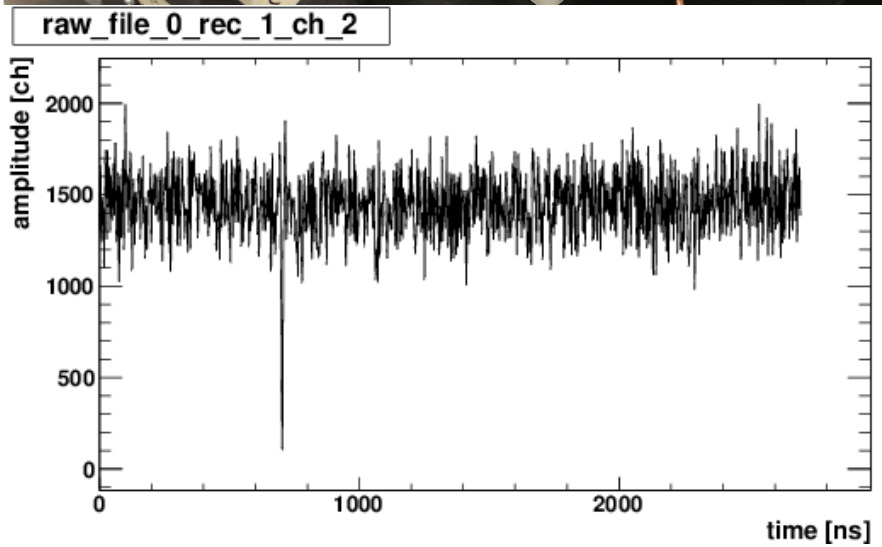
- New solution for the connections (currently under investigation):
  - Connectors integrated in the spacers.
  - Metalized (Ni/Au) spacers connected to aluminized electrodes by mechanical pressure.





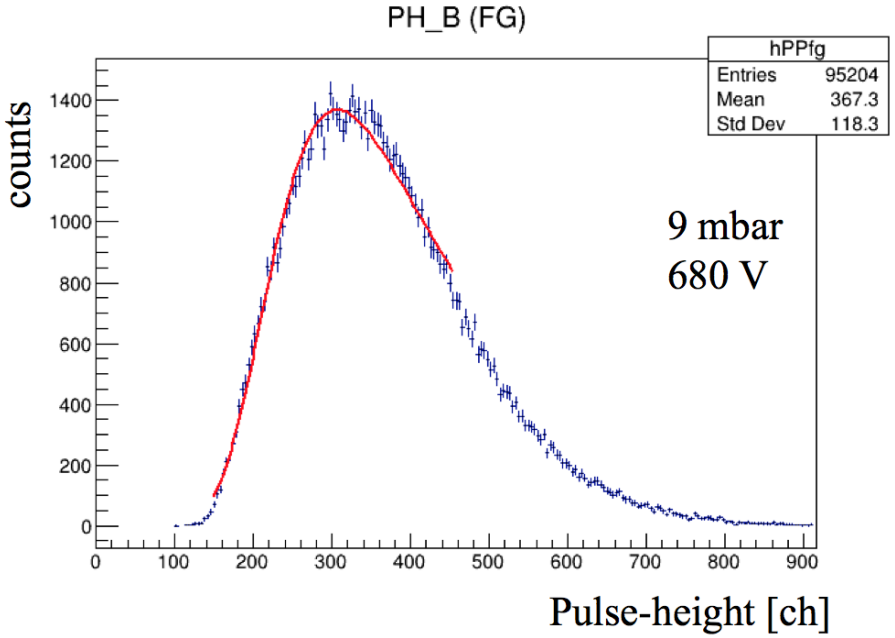
Experimental tests





- Tests done inside a vacuum-tight chamber, filled with C3F8 gas at a few mbar.
- Detection of:
  - α particles from ^{241}Am.
  - FF (and α) from ^{252}Cf.
- A Silicon detector is used as a monitor.

Experimental tests



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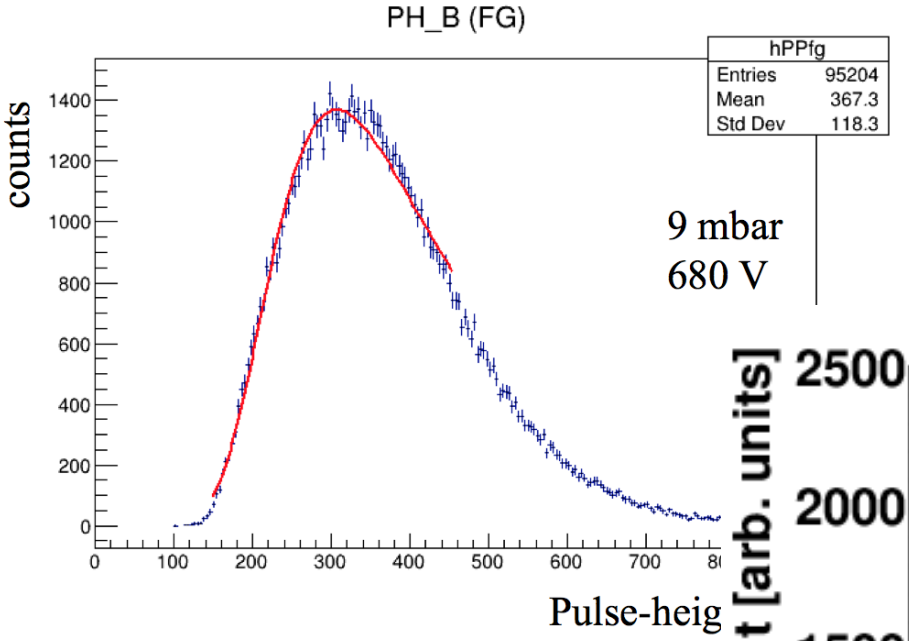

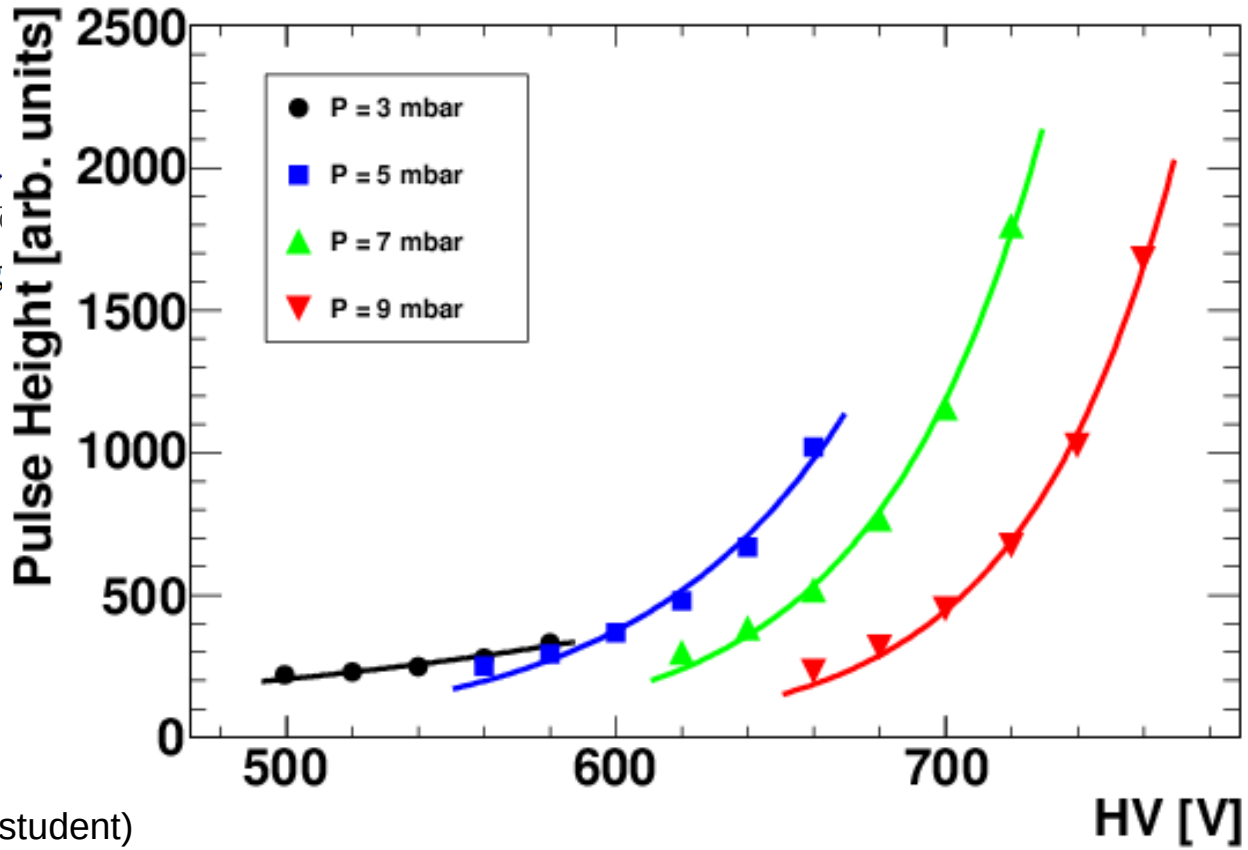

Data collected by K. Nakano (visiting Ph.D. student)

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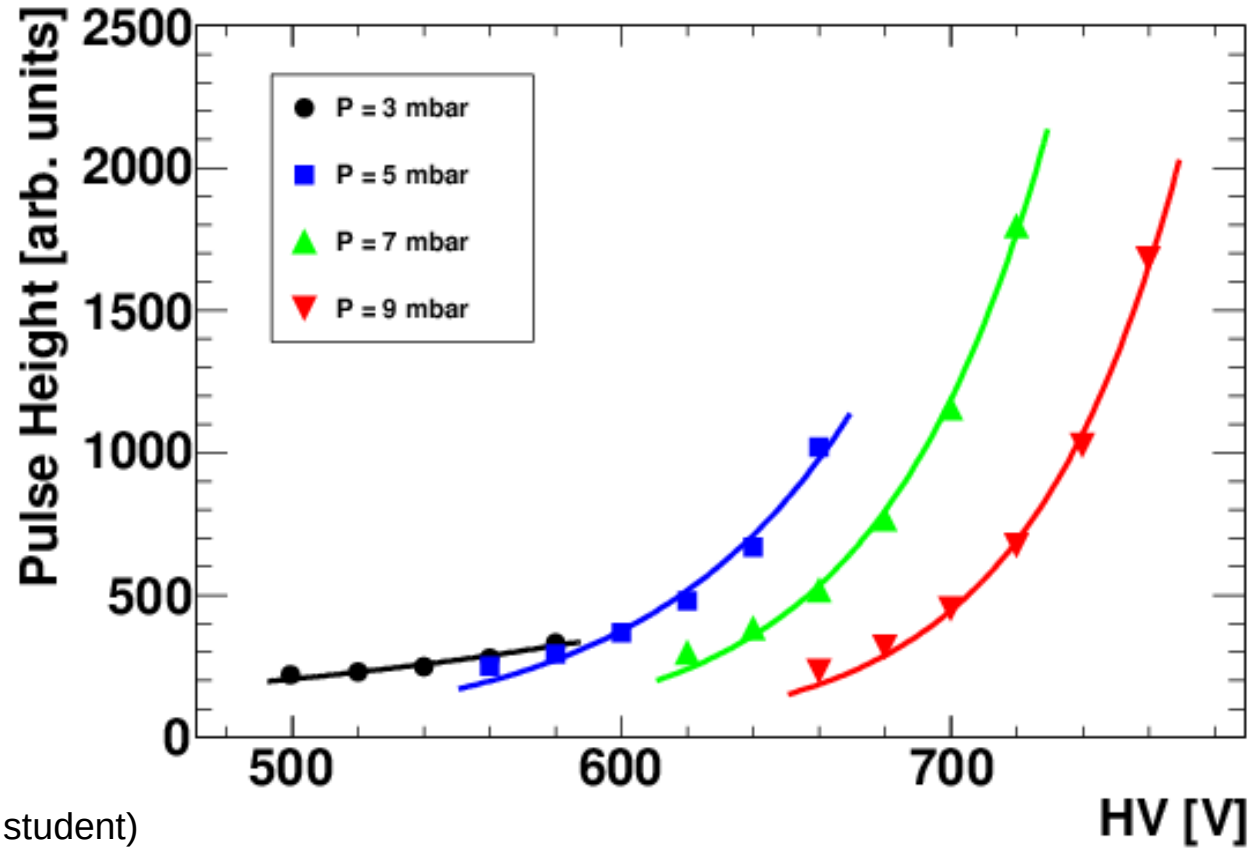
$$N_{V=Const.} = C_1 \exp(C_2 p)$$
$$N_{p=Const.} = C_3 \exp(C_4 V)$$

$$\alpha d \approx C_2 * p + C_4 * V$$

P [mbar]	C_4 [V^{-1}]
5	0.016
7	0.002
9	0.022



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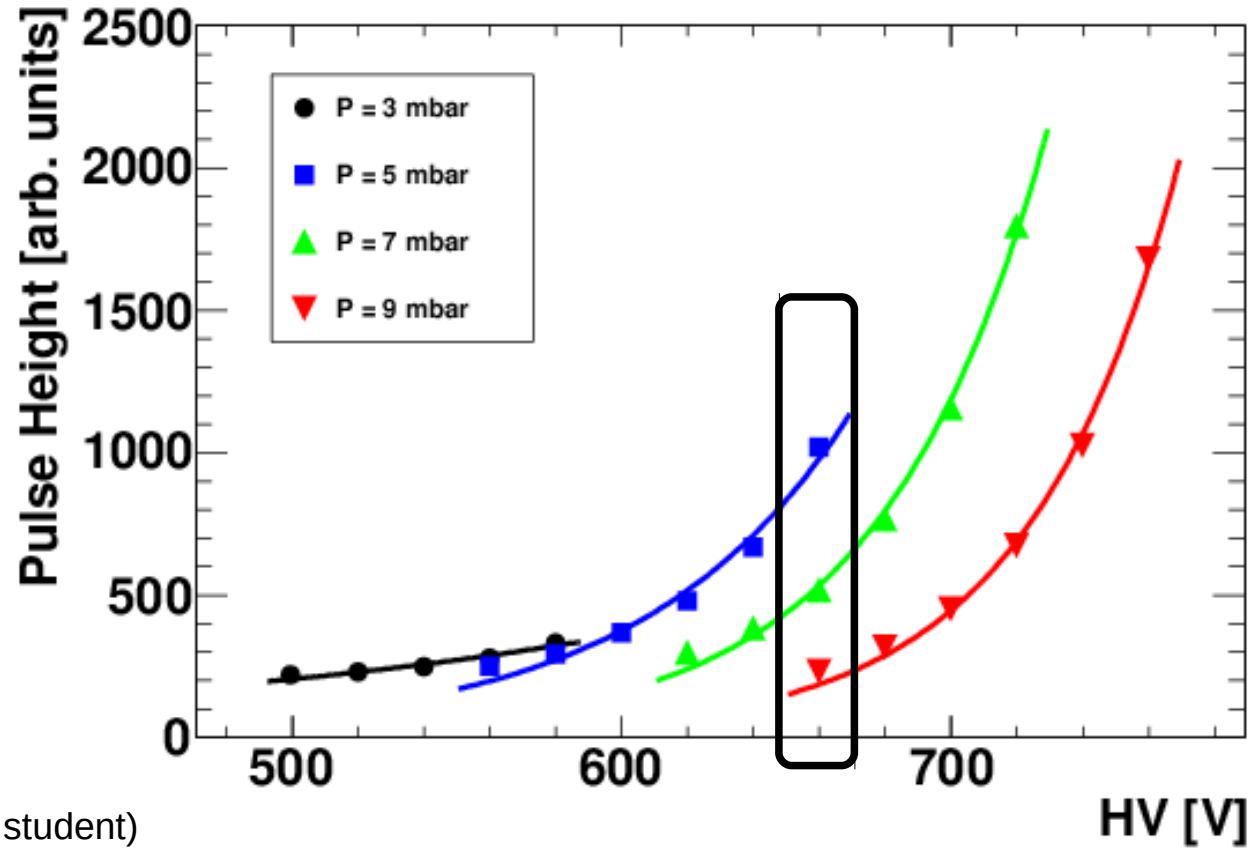

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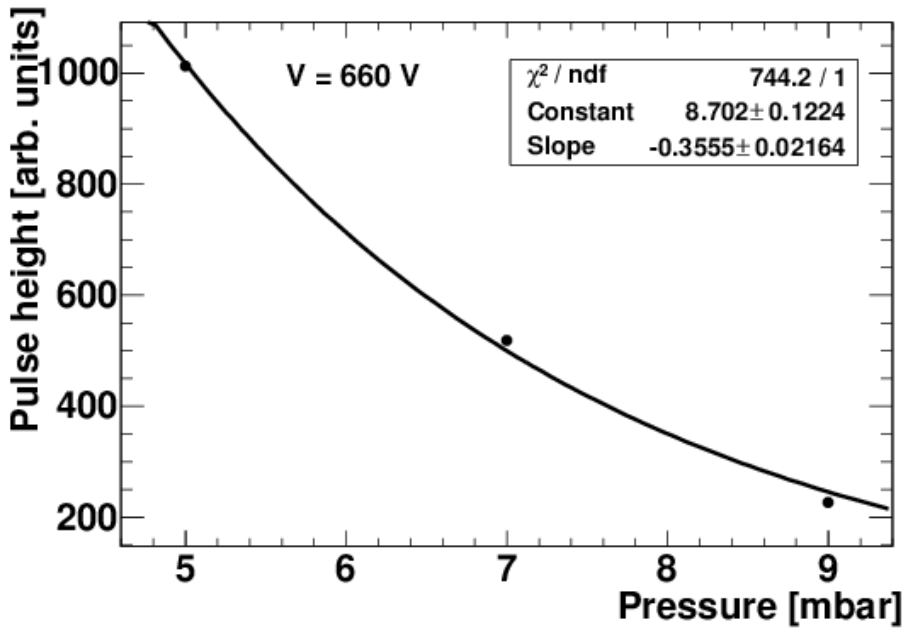

V [V]	C_2 [mbar^{-1}]
660	-0.355

P [mbar]	V [V]	S [V/mm/mbar]	αd [adim]	α/p [1/mm/mbar]	α [1/mm^{-1}]
5	660	41.25	8.78	0.55	**2.74**
7	660	29.46	10.71	0.48	**3.35**
9	660	22.92	11.23	0.40	**3.51**

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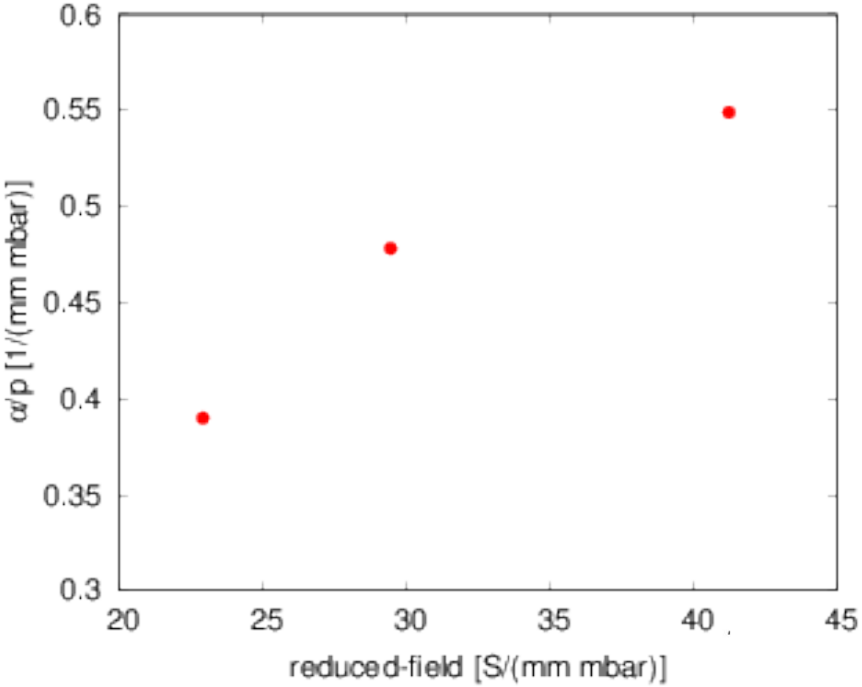

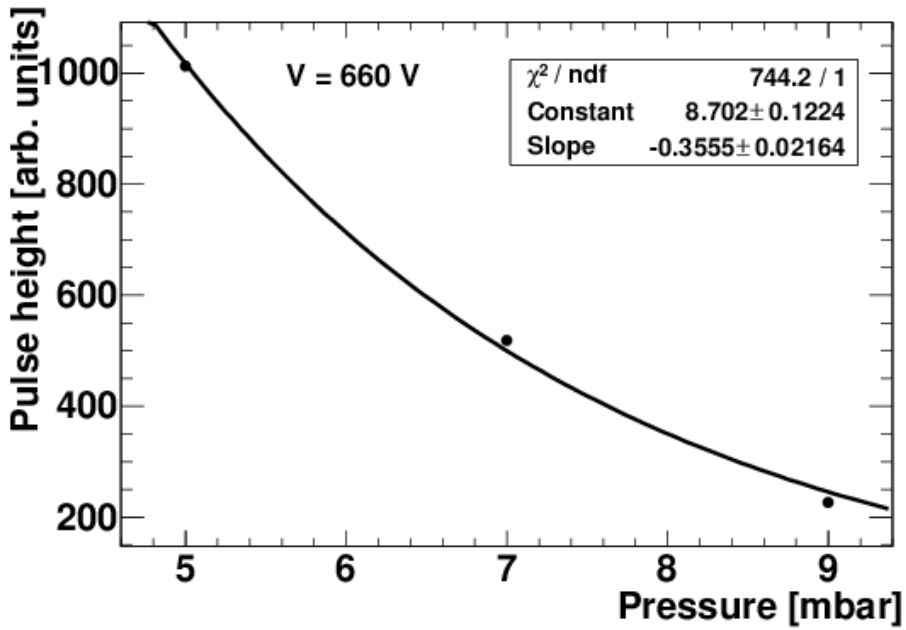

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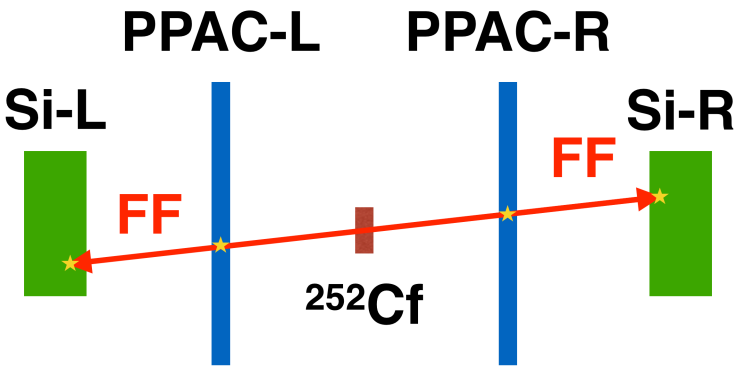
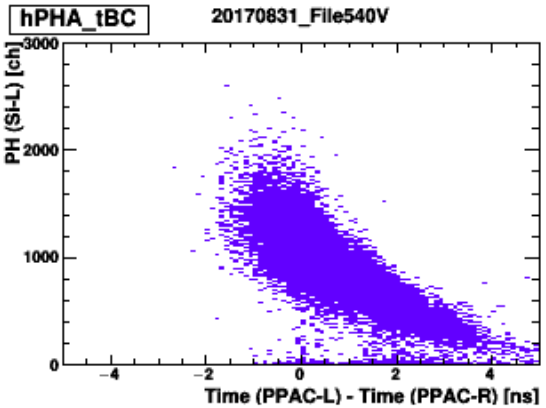
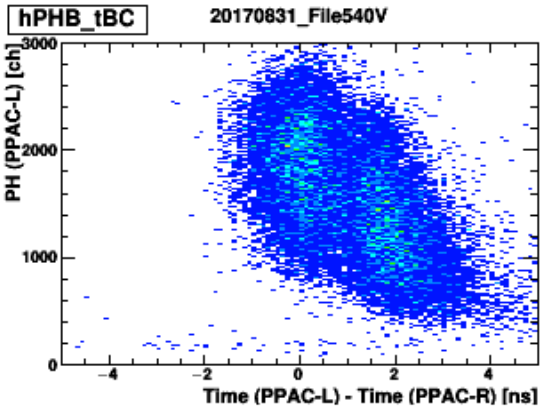
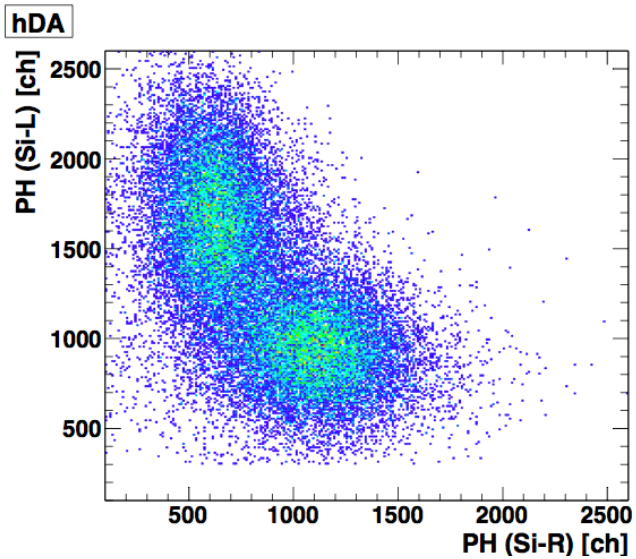
Detection of fission fragments using PPACs

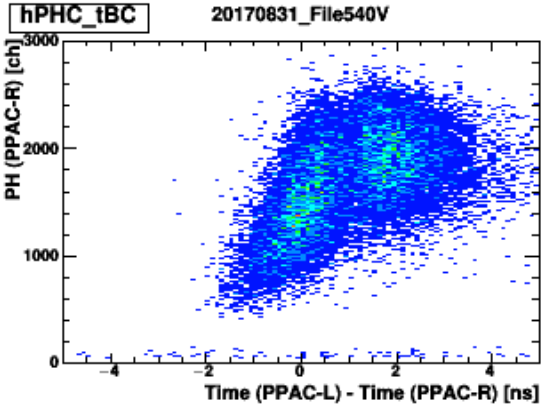
- Detection, in coincidence, of both fission fragments from ^{252}Cf(sf).
- Silicon detectors used as monitors of the PPACs.

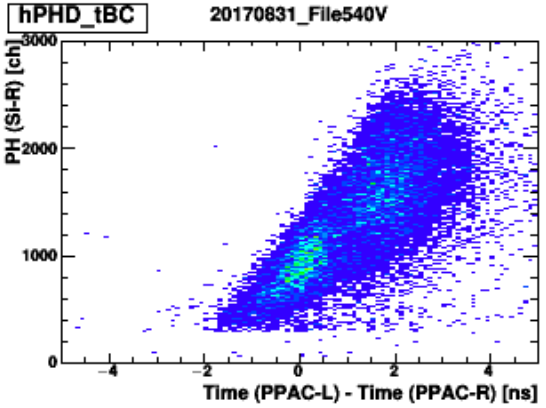








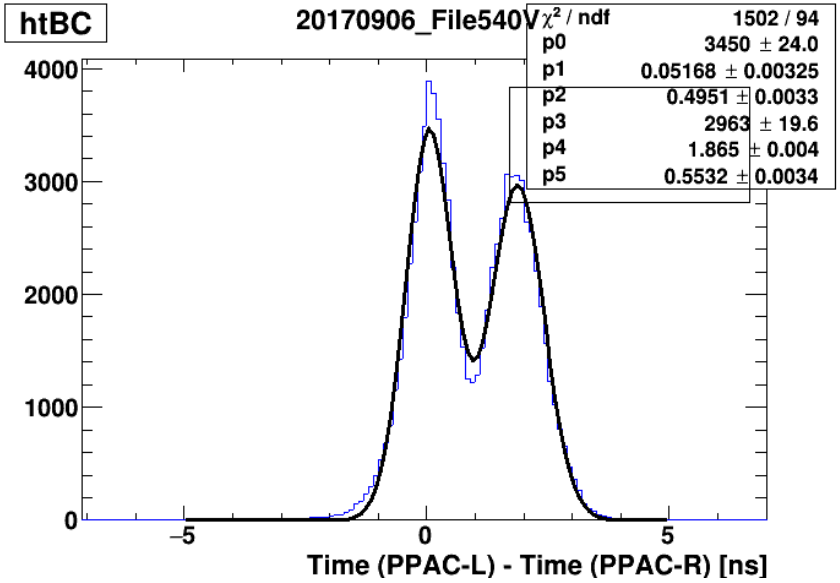


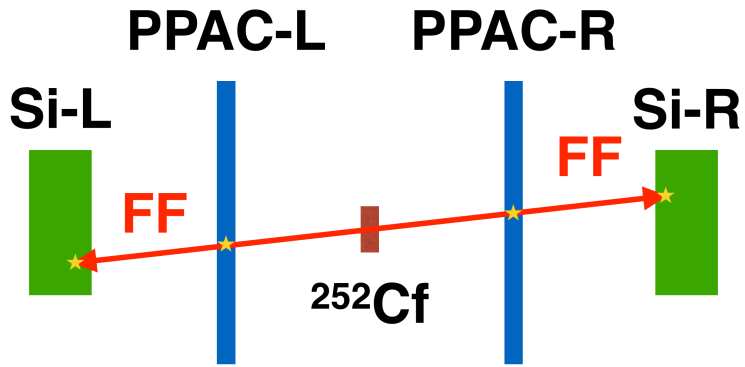


D. Tarrío, FIESTA 2017 school and workshop, Santa Fe (USA) 2017

Time resolution

- Detection, in coincidence, of both fission fragments from ^{252}Cf(sf).
- Alpha particles from 241Am are also used (not shown here).
- Silicon detectors used as monitors of the PPACs.





Time resolution: ~1.2 ns (from the fit).
After discounting the spread in time of the fission fragments, time resolution is ~ 1 ns.

Summary

- PPAC (Parallel Plate Avalanche Counter) is a suitable instrument to detect fission fragments and alpha particles in neutron-induced reactions.
- Our group is interested in **measurements of nuclear data** (neutron-induced reactions), and PPACs will open new possibilities.
- To be used at the upcoming **Neutrons For Science (NFS) facility at GANIL**, and at other facilities.
- **Ongoing development** of PPACs for fission fragment and alpha detection:
  - Improvement of the construction process.
  - Experimental studies on their capabilities (time resolution, efficiency, etc).
  - Analysis of the PPAC performance based on theoretical models.
  - … and more to be done.
- **We are open to new applications and interested groups are welcome to contact us!**

UPPSALA UNIVERSITET

Thank you for your attention

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