High energy heavy-ion timing with polycrystalline Diamond Detectors

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Thanks to M. Freer, D. Parker and the staff at the Birmingham cyclotron accelerator facility and Physics department.

Many thanks also to G. Strudwick and P. Veeramani (Surrey) for support during the initial stages of the project.

- **Timing for Lycca**
- **Sample fabrication & detector tests at the Birmingham cyclotron**
- **Digital pulse shape analysis**
- **Initial tests at GSI**
- **Conclusion and future plans**

Lund York Cologne Calorimeter (Lycca)

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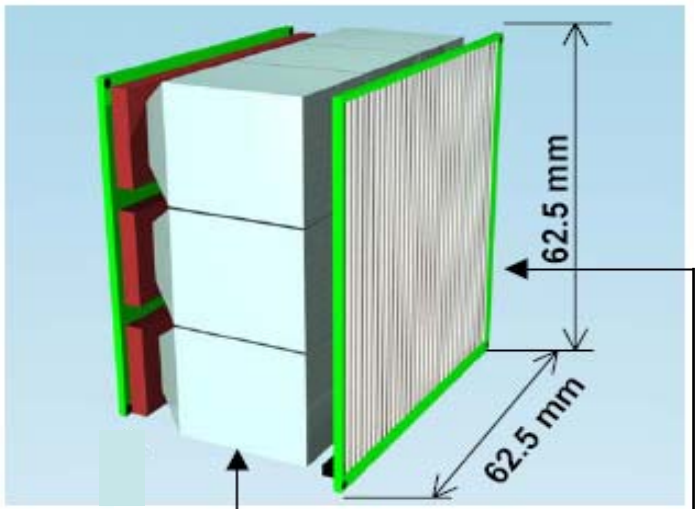
- **Part of the HISPEC at FAIR**
  - **high resolution gamma ray spectroscopy**
  - **Final particle identification and tracking**

    ⟹ **Lycca detector array**



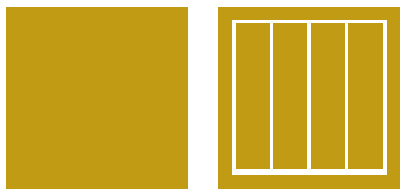
Each Lycca module:
9 detectors with
(2 x 2) cm^2 area

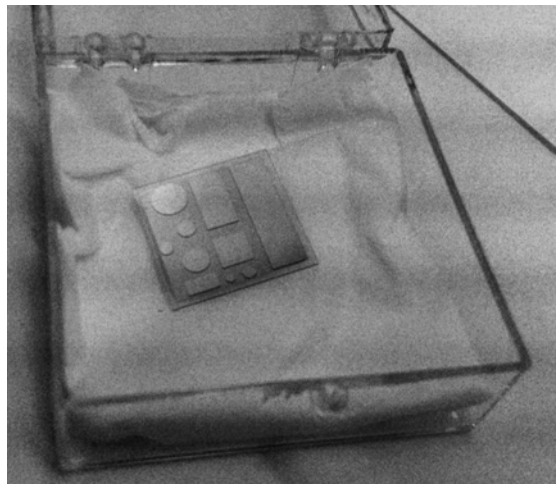
Timing detectors - TOF
Plastic or pc diamond

Sample fabrication

- Electronic grade (20 x 20 x 0.3) mm^3 polycrystalline diamond (DDL)

- Electrode layout determined by shadow masks or Photolithography
  - 1 side planar
  - 1 side patterned (sizes, shapes, guard ring…), maximum pad size (18 x 4.5) mm^2

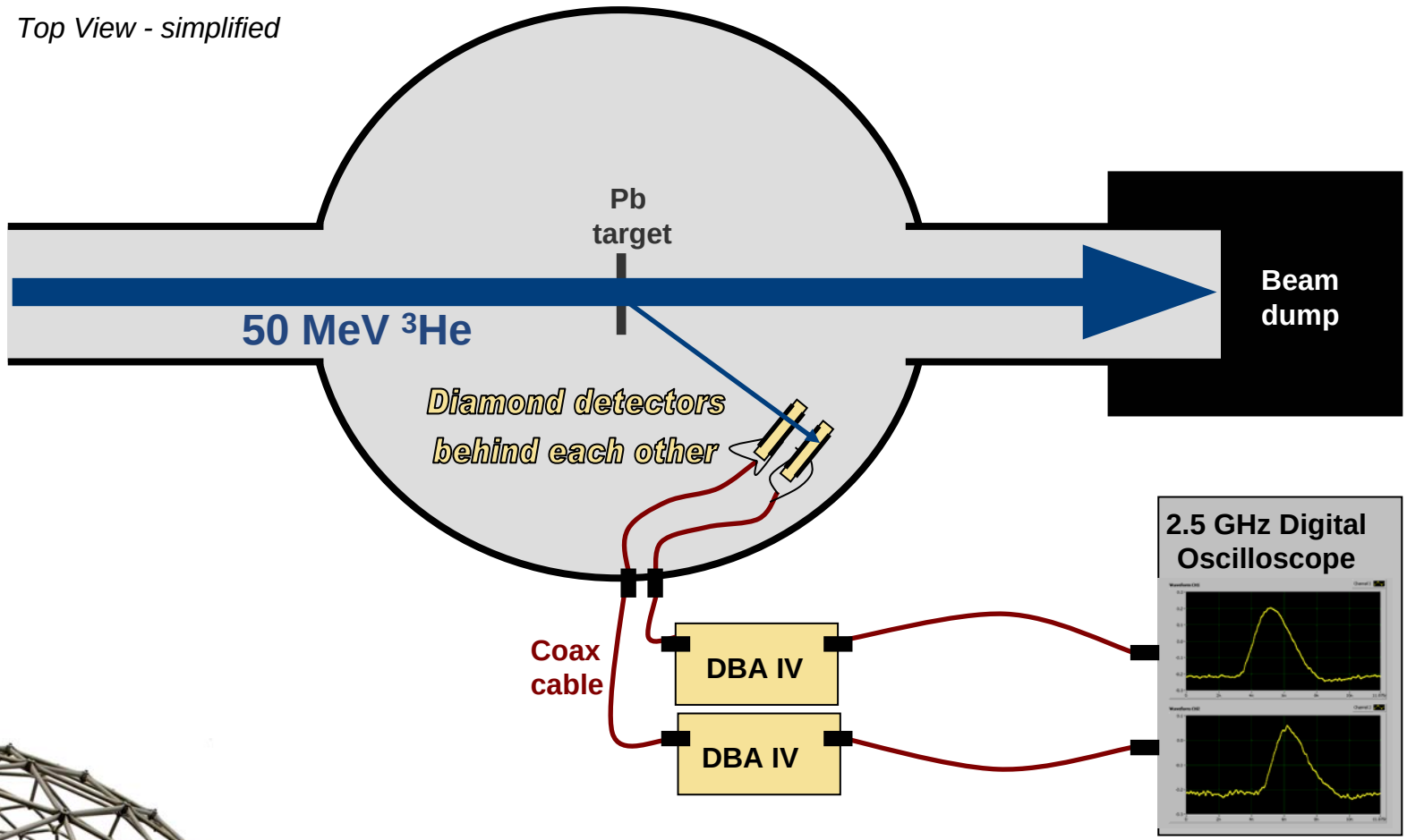




- Electrode deposition by thermal evaporation or sputtering of typically 100 nm metal (Al, Au, Au/Pd)

- Mounting of samples on PCB – top contacts with wire bonds or silver paste

Set-up at the Birmingham Medical Physics Cyclotron



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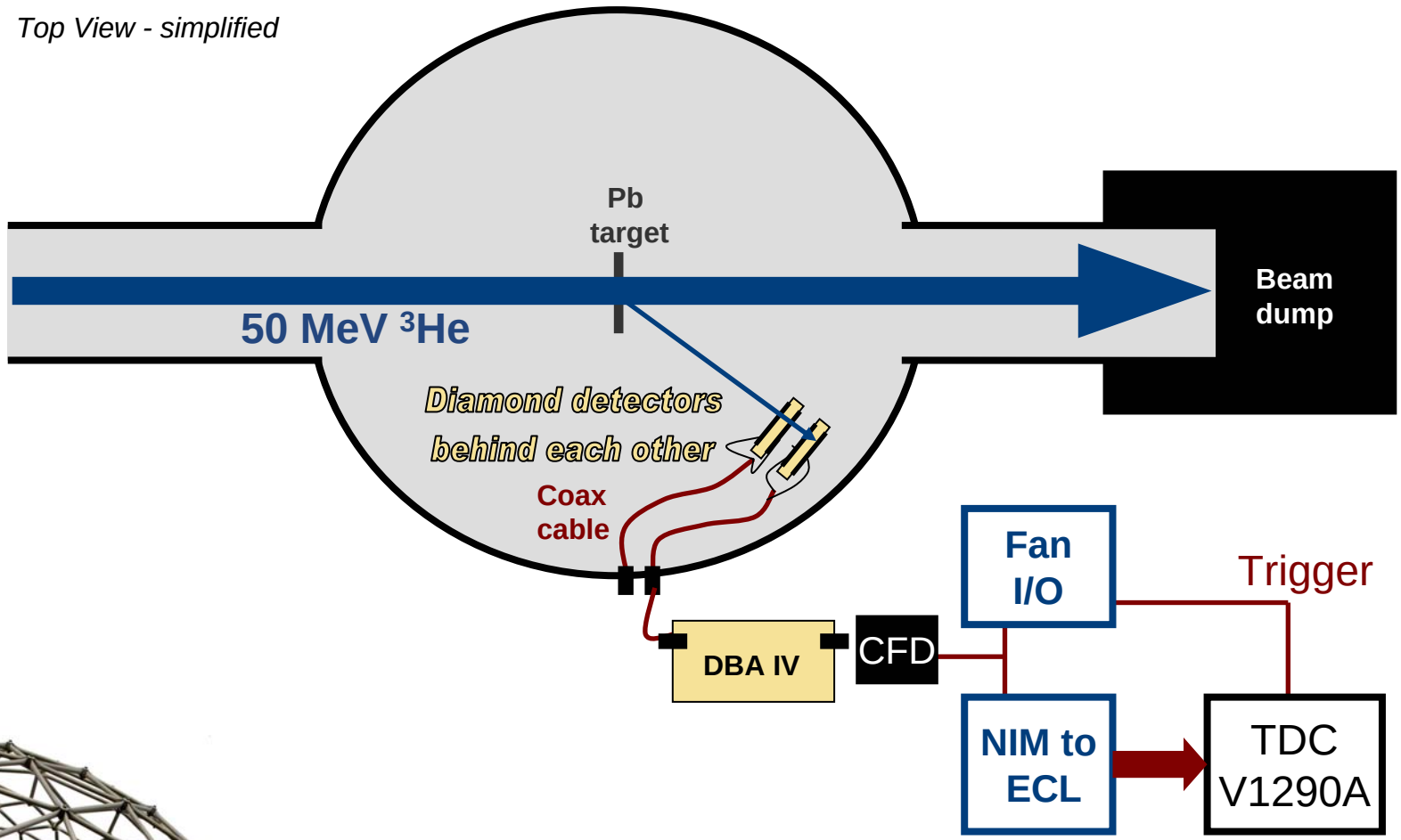

Single pulse analysis: pulse risetime I

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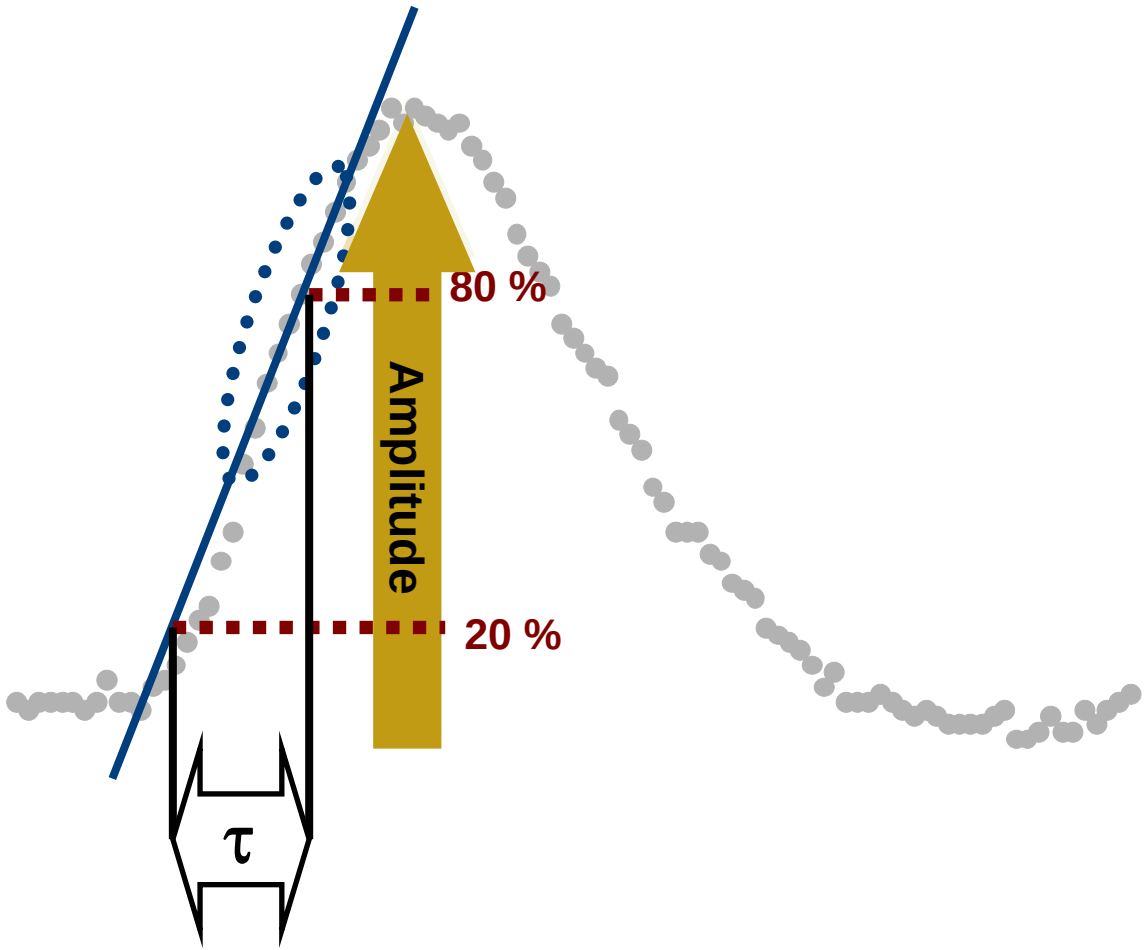
Interpolation of the rising gradient



Single pulse analysis: pulse risetime II

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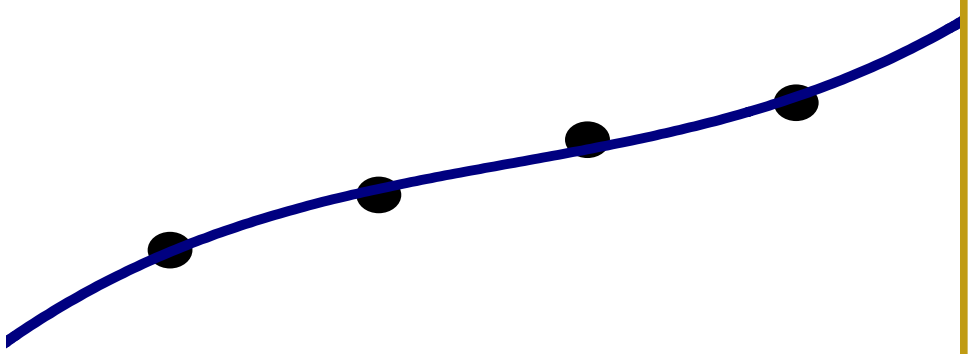
Smoothing the raw pulse shape using a “point by point” cubic interpolation

Use 4 consecutive points for fitting

$$A(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3$$



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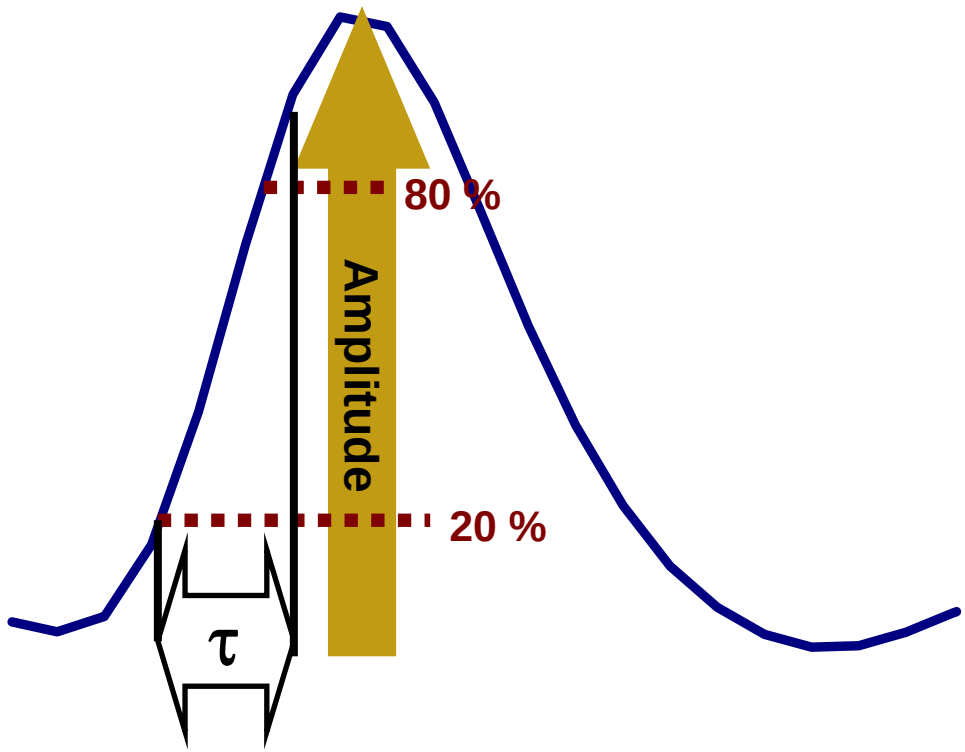
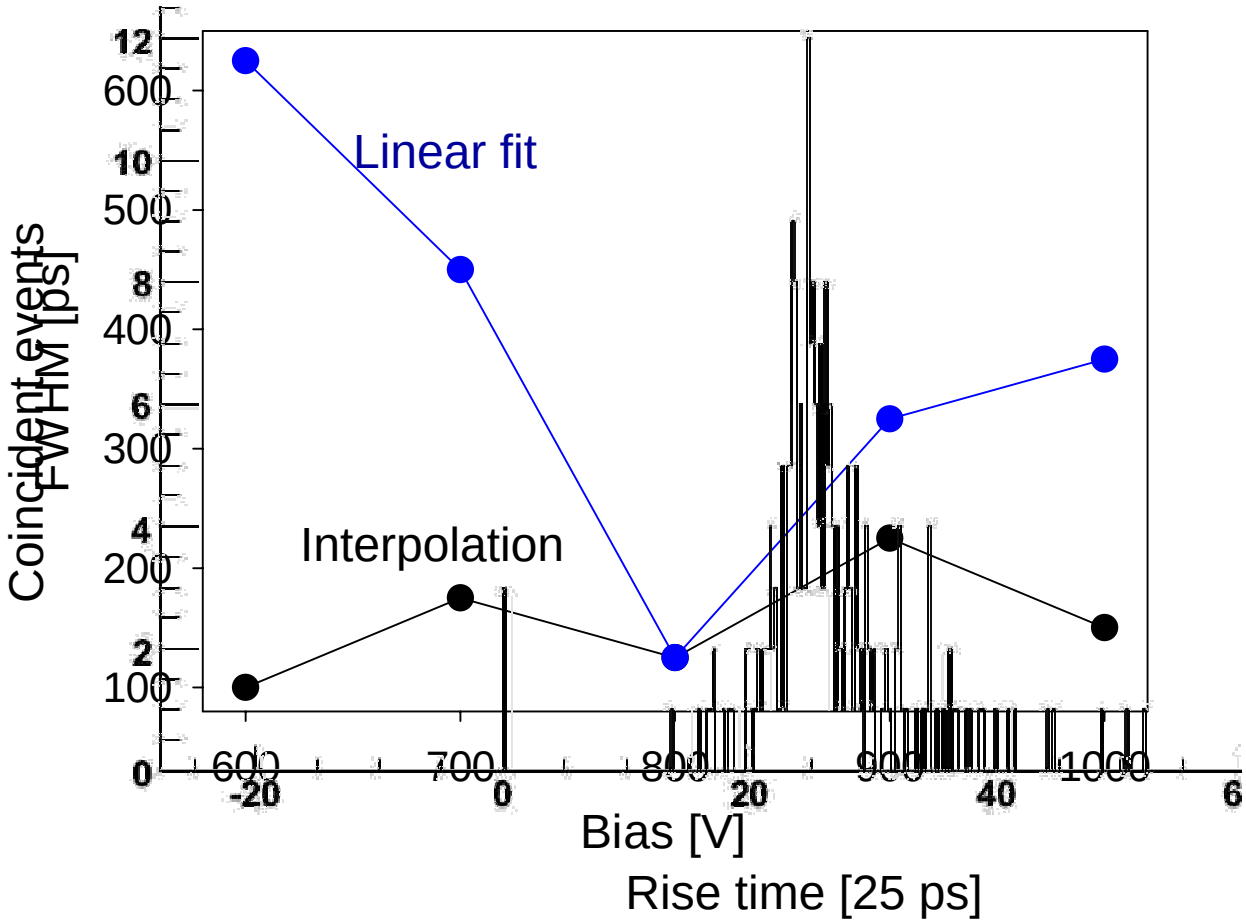
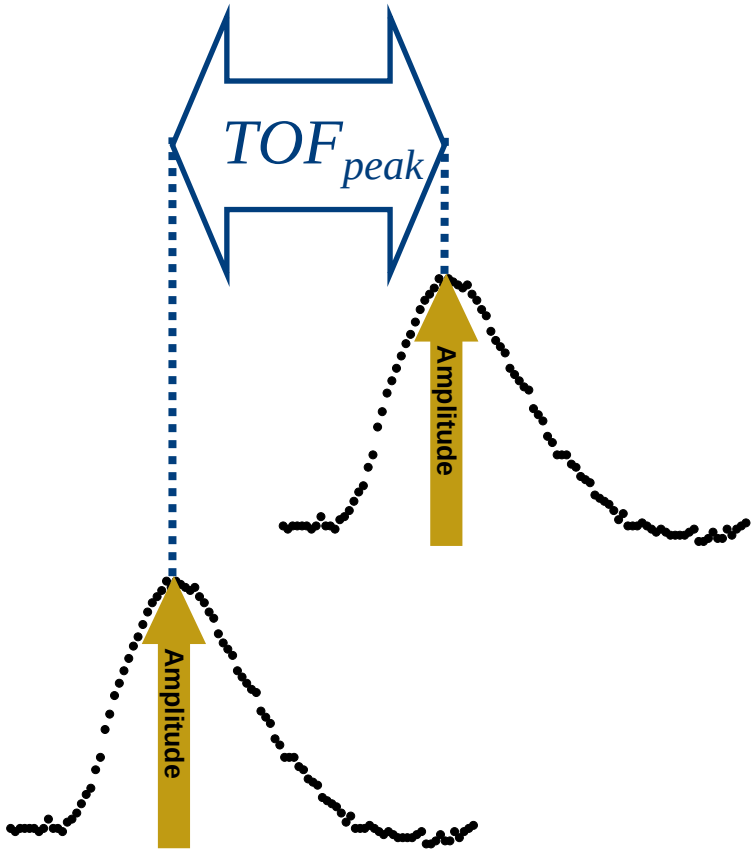


Results:


Linear fit
Interpolation
FWHM [ps]
Coincident events
Bias [V]
Rise time [25 ps]
12
600
10
500
8
400
6
300
4
200
2
100
0
600
700
800
900
1000
-20
0
20
40
6

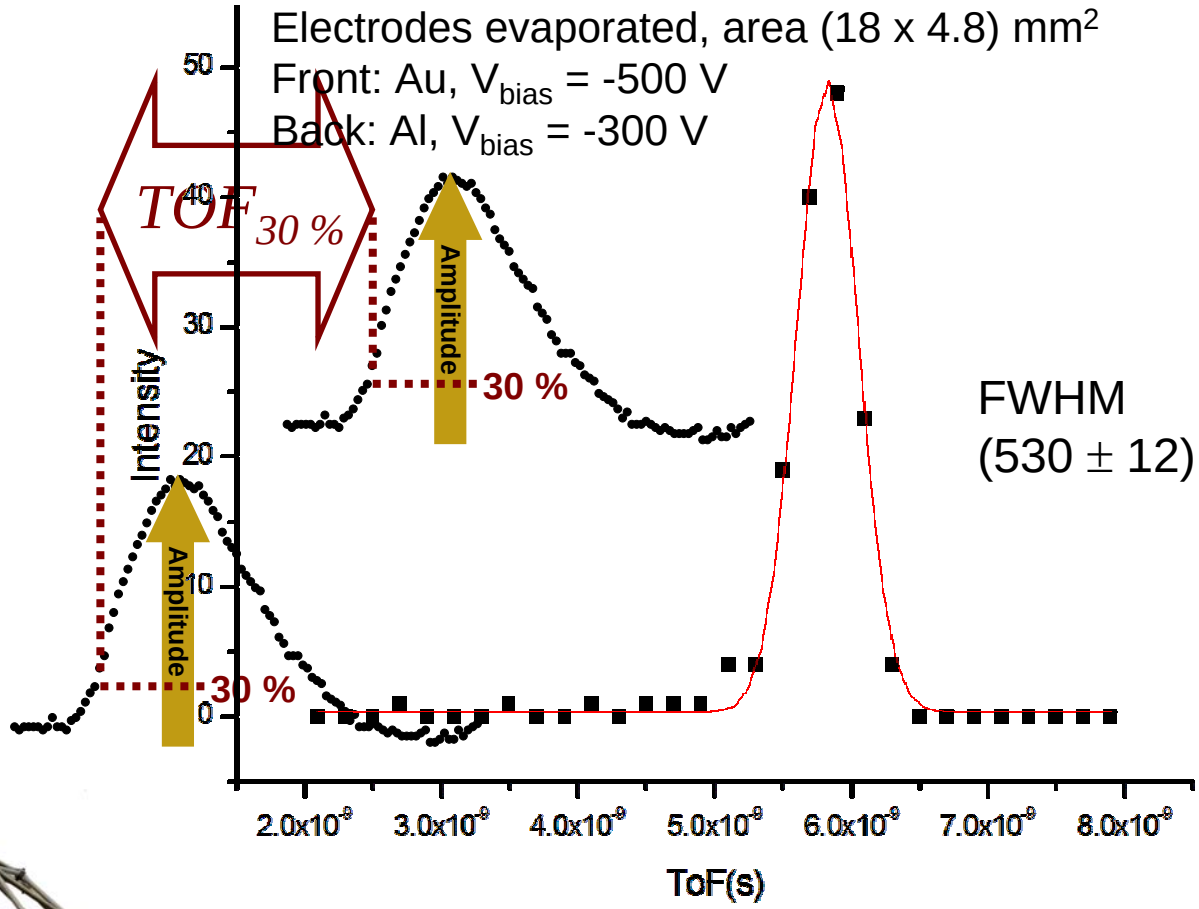
Analysis coincidence data

Method I: Peak to Peak time



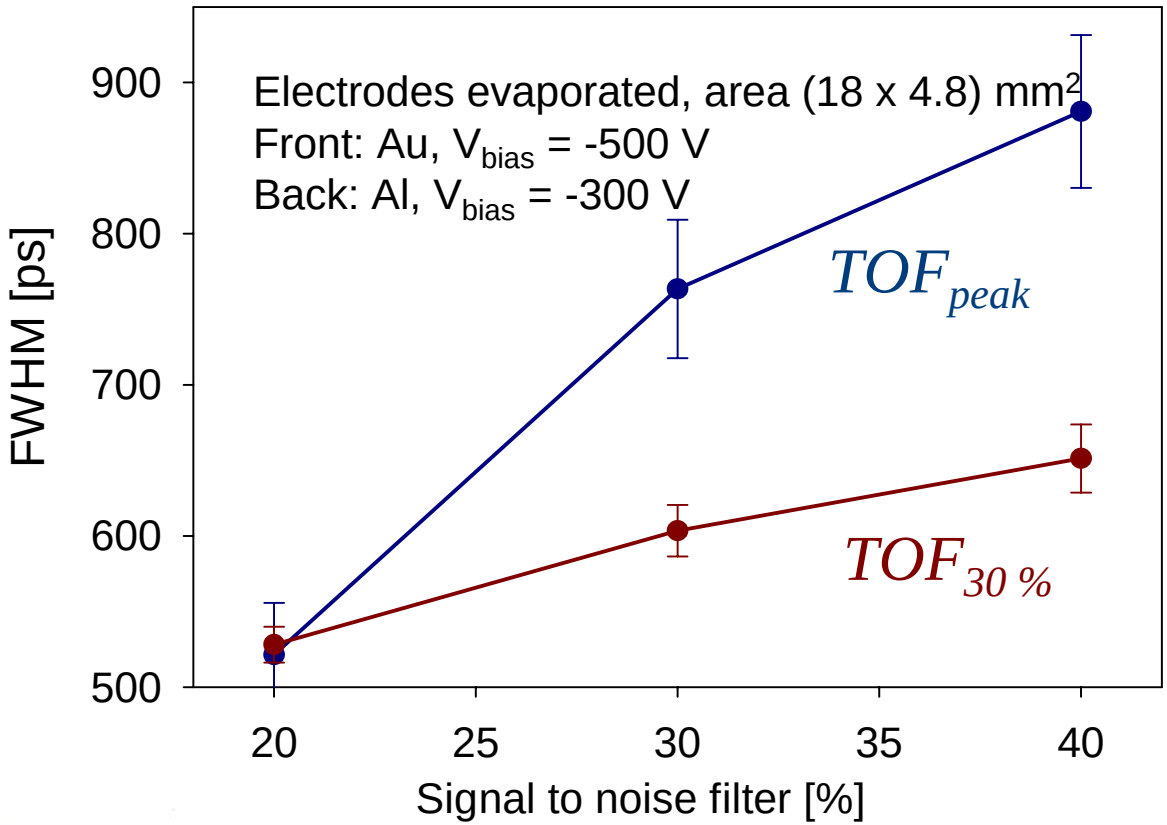
Analysis coincidence data

Method II: Fixed threshold (relative to amplitude):



FWHM
(530 ± 12) ps

Comparison of method I and II



Better signal to noise

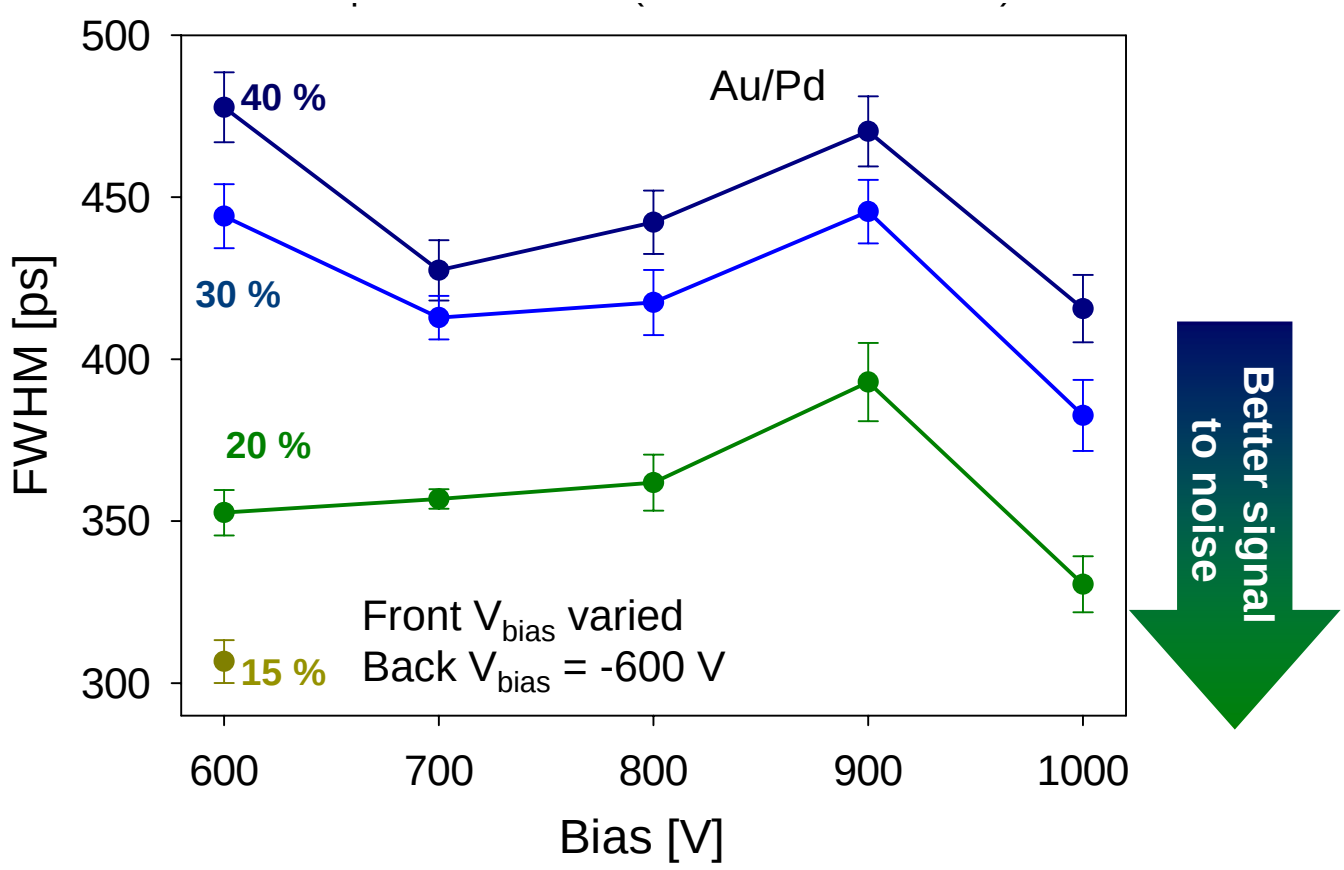
The time resolution improves, if only "large" signals are considered in both cases.

$TOF_{30\%}$ results in

- narrower TOF histograms
- better defined peaks/fits

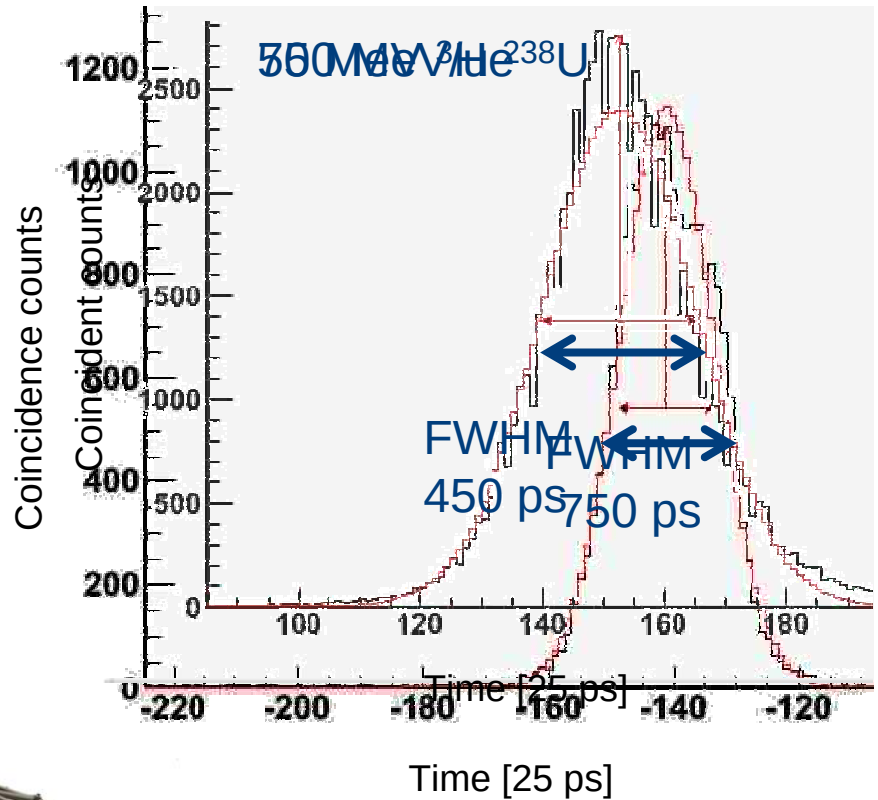
Influence of bias voltage $TOF_{30\%}$

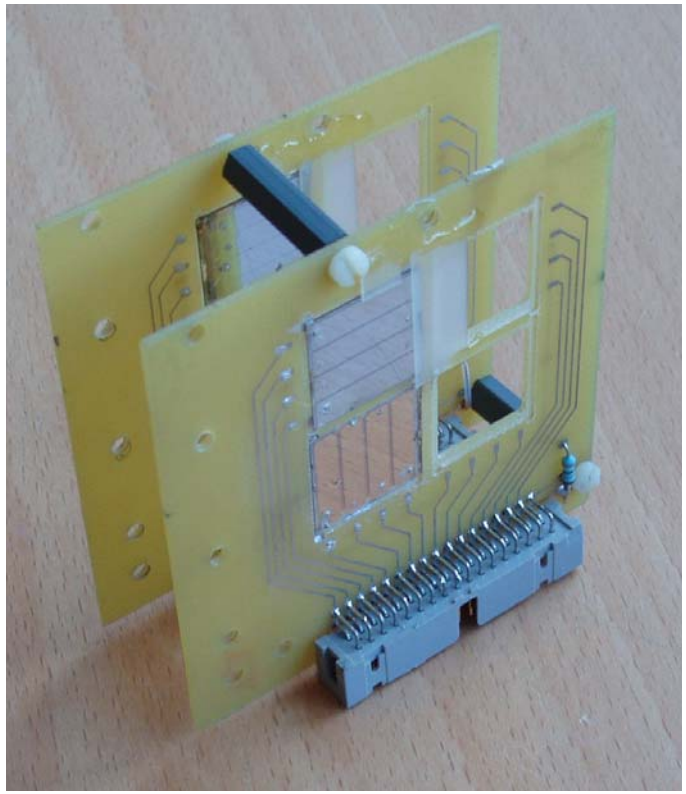
No clear improvement with increasing bias voltage



Coincidence data

Au/Pd pair, V_{bias} +300 V



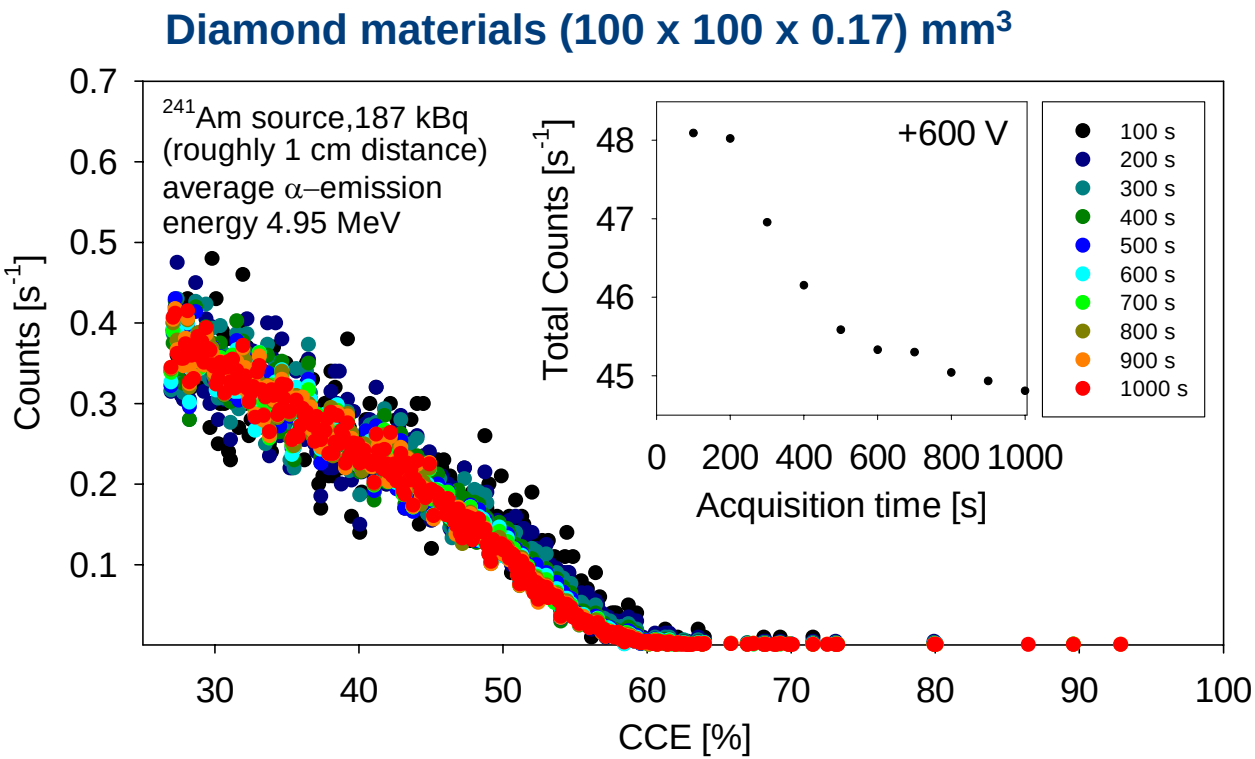


Larger signal amplitude improve the performance

Electronic noise needs optimising

Alternative material

- Diamond materials
- Thermal grade pc



Conclusion & Outlook

- We successfully fabricated and tested prototype detectors
  - Individual rise times decreases with voltage at “low” bias (<1.3 $V\mu m^{-1}$) and appears constant above.
  - Time resolution in coincidence measurements remains constant at high V_{bias}.
  - The time resolution improves with signal amplitude

- Future
  - Investigate the effect of electrode size and contact fabrication systematically
  - Study time resolution of alternative materials
  - Optimise data acquisition and noise performance