The research of large area ⁿMCP detector

@ *Tsinghua University*

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UCANS V

5th International Meeting of Union for Compact Accelerator - Driven Neutron Sources

outline

✓

1. Why MCP?
2. MCP ➡ ^{n}MCP
3. Setup of the ^{n}MCP neutron detector
4. Experimental evaluation
5. Summary

Why MCP?

Gaseous detector : $^{10}BF_3$ or ^{3}He

? Number density: $10^{19}/cm^3$ per atm

? **efficiency**

✓ Increasing volume

✓ Increasing pressure

? $^{10}BF_3$ <1bar, eletronegativity

☹ **Spatial resolution**

? $Range_{charged\ particles@gas}$: **1~10mm**

Solid detector:

Number density: $10^{21\sim22}/cm^3$

✓ **efficiency**

? Charged particles production

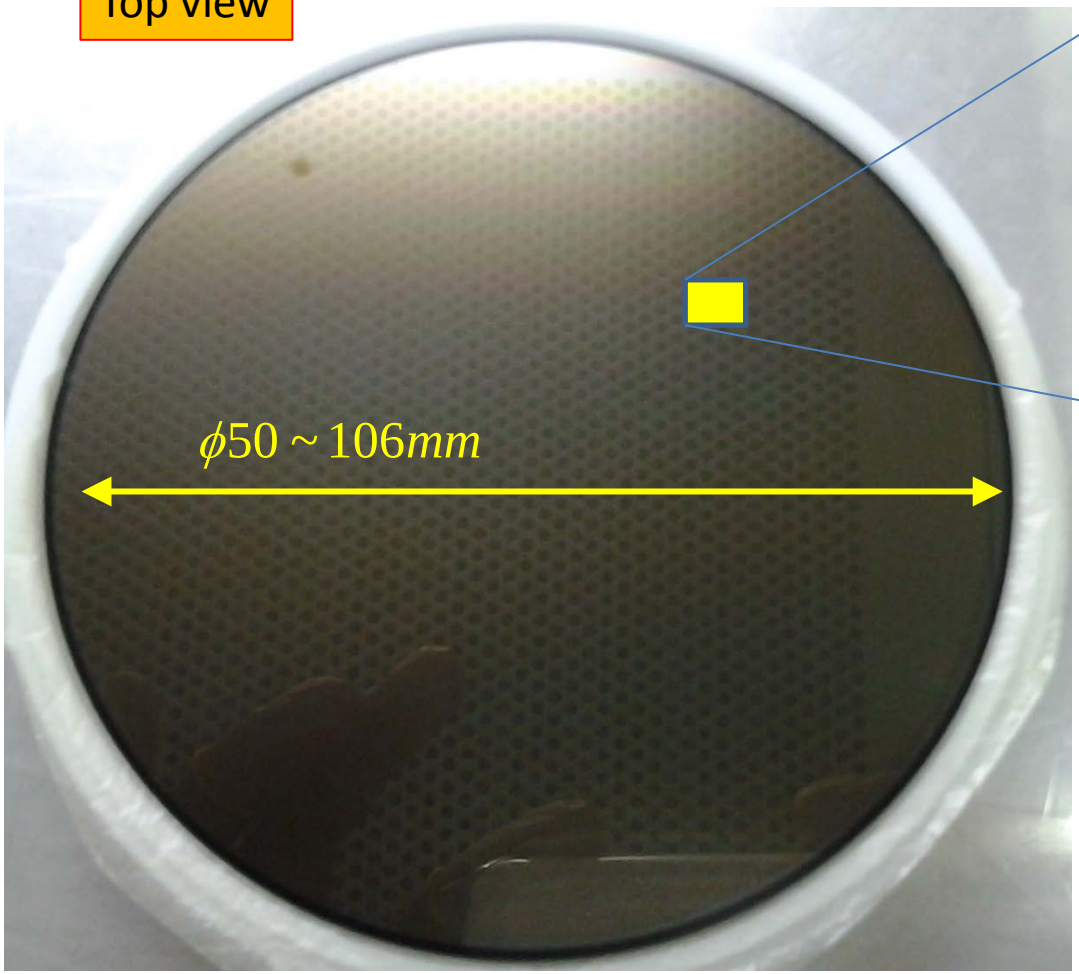
? Escape of charged particles

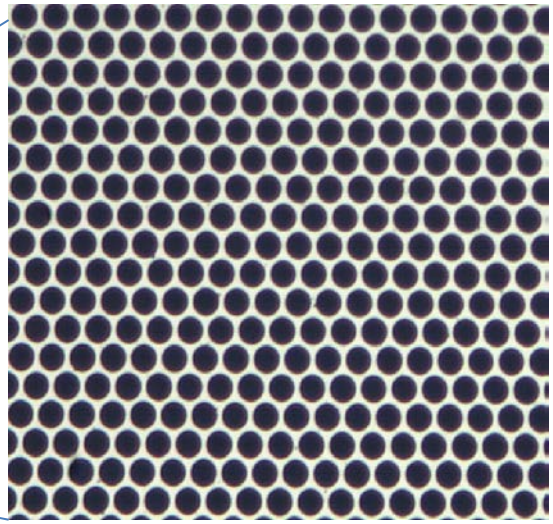
✓ **Spatial resolution**

✓ $Range_{charged\ particles@solid}$: **1~10μm**

Micro Channel Plate

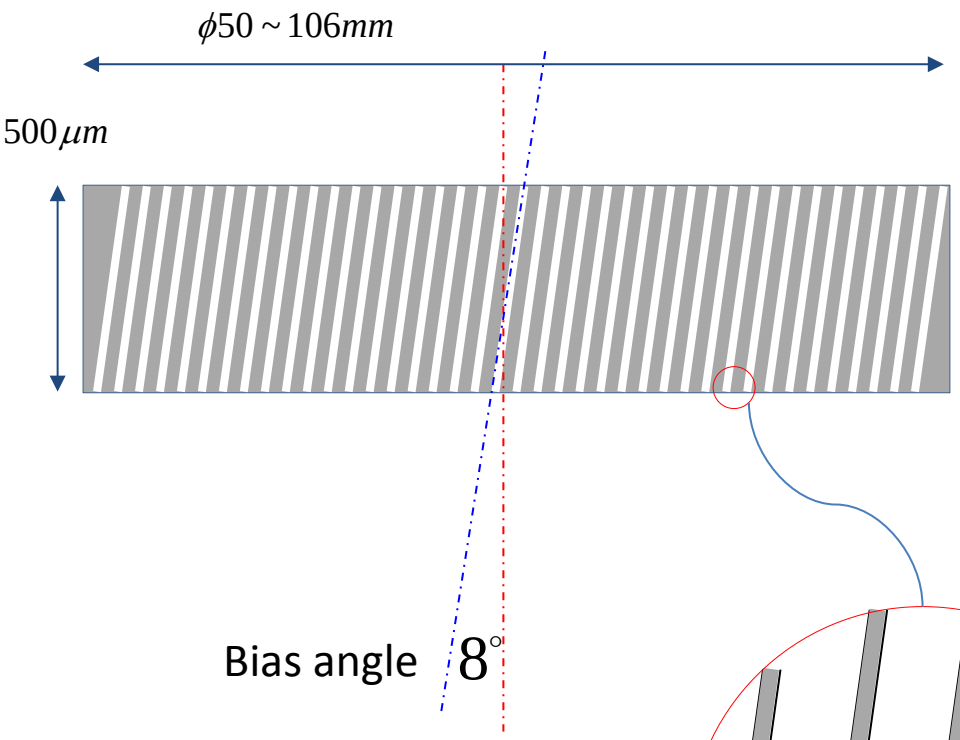
Top view

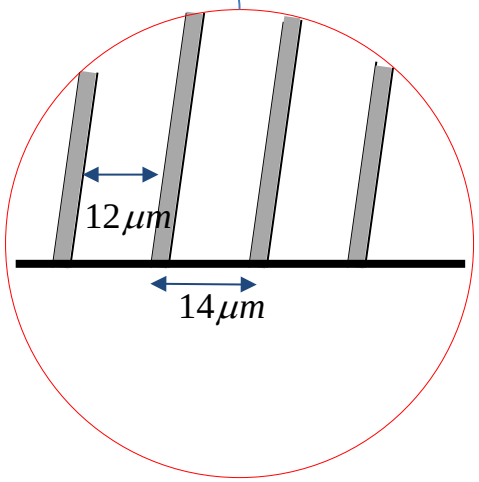




The common MCP

section view





	Density: 3.4g/cm^3
	Weight%
SiO_2	**%
Na_2O	**%
BaO	**%
PbO	**%
Bi_2O_3	**%
K_2O	**%

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MCP ➡ nMCP

? There is **no neutron sensitive nuclide** in common MCP

- Cross section: barns @ 25.3meV
- ^{28}Si: 2.2
- ^{23}Na: 3.9
- ^{137}Ba: 9.8
- ^{138}Ba: 4.5
- ^{207}Pb: 11.5
- ^{208}Pb: 11.4
- ^{209}Bi: 9.4
- ^{39}K : 4.38

➢ ***Neutron sensitive material* should be introduced into the glass of MCP at first.**

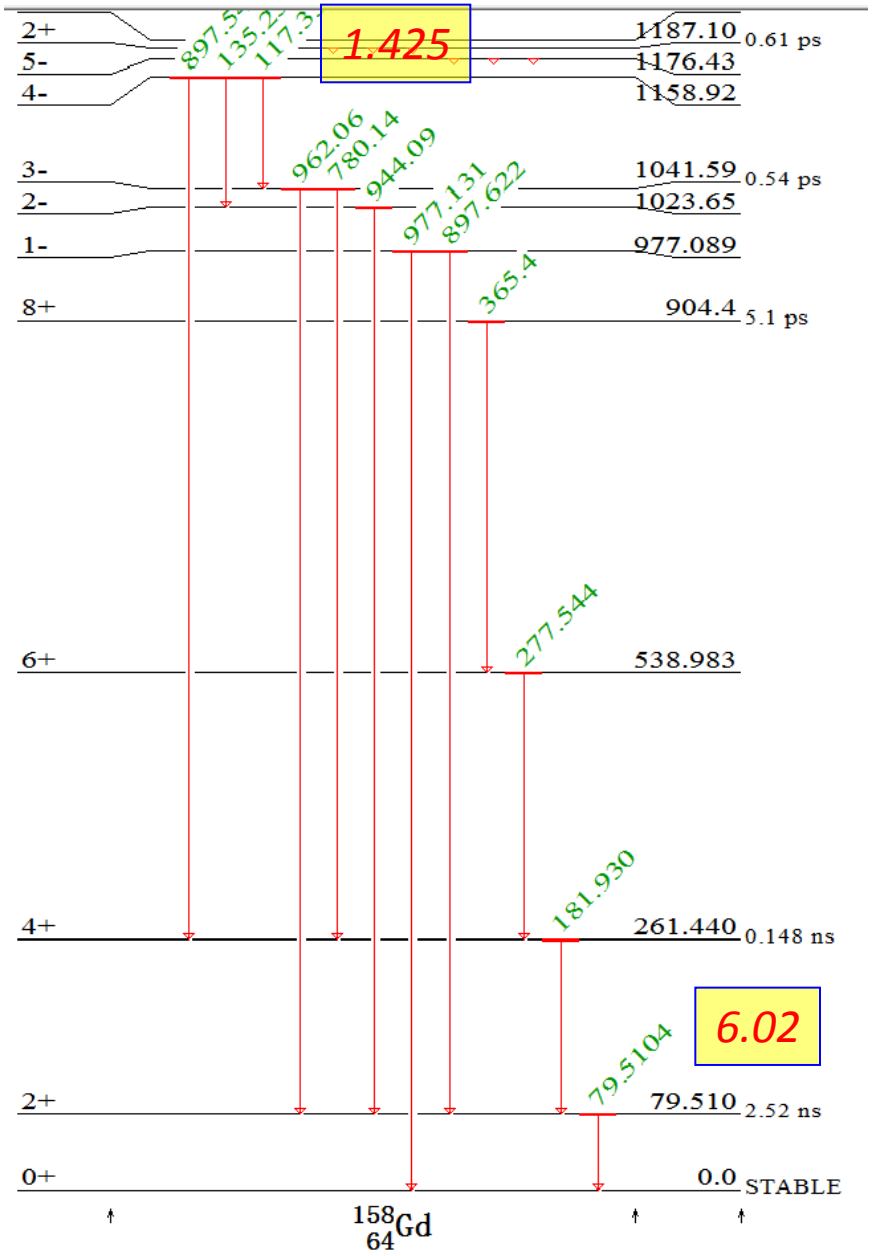
✓ **Large** neutron absorption cross section

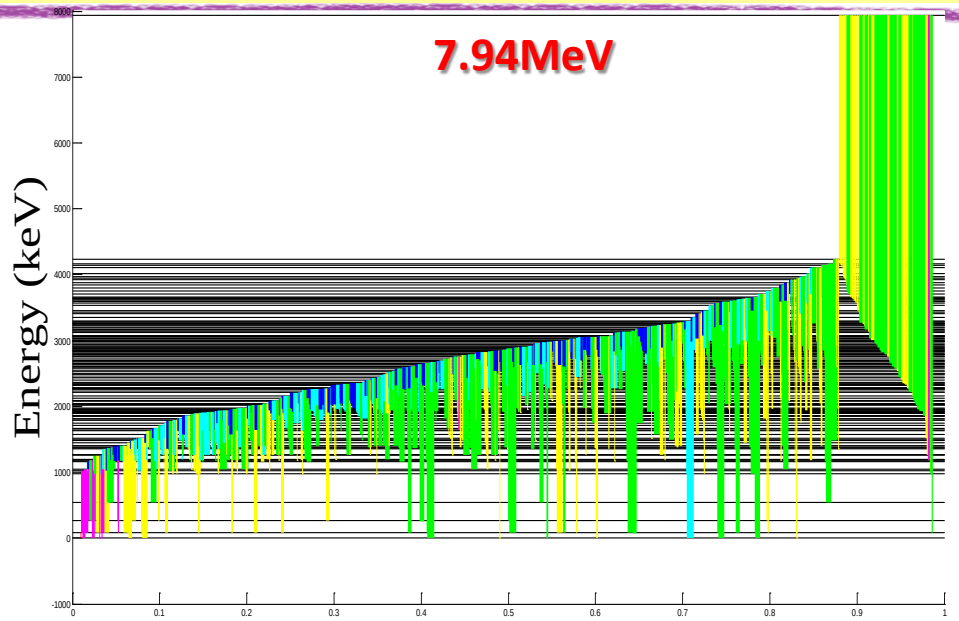
✓ Energetic **charged** particles emission

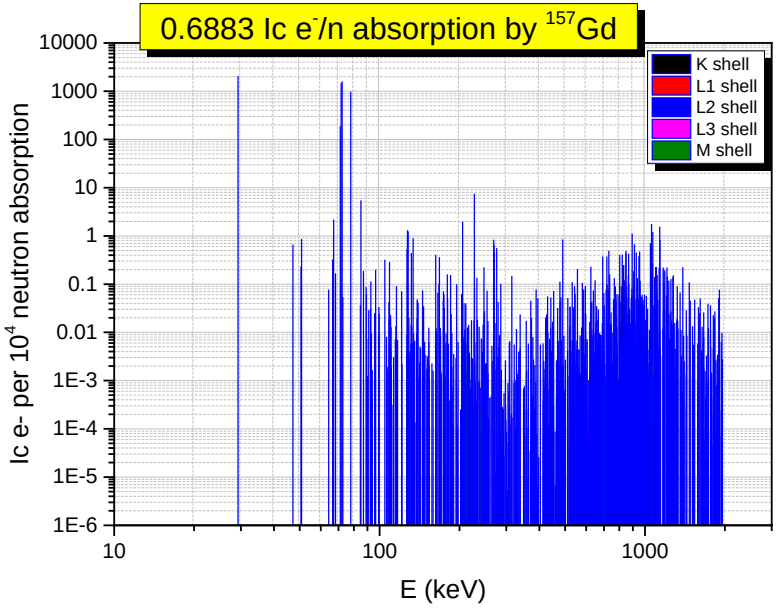
✓ High **abundance** or easily to be enriched

- Cross section: barns @ 25.3meV
  - **^{3}He: 5333**
  - **^{6}Li: 940**
  - **^{10}B: 3842**
  - **^{155}Gd: 60740**
  - **^{157}Gd: 252928**

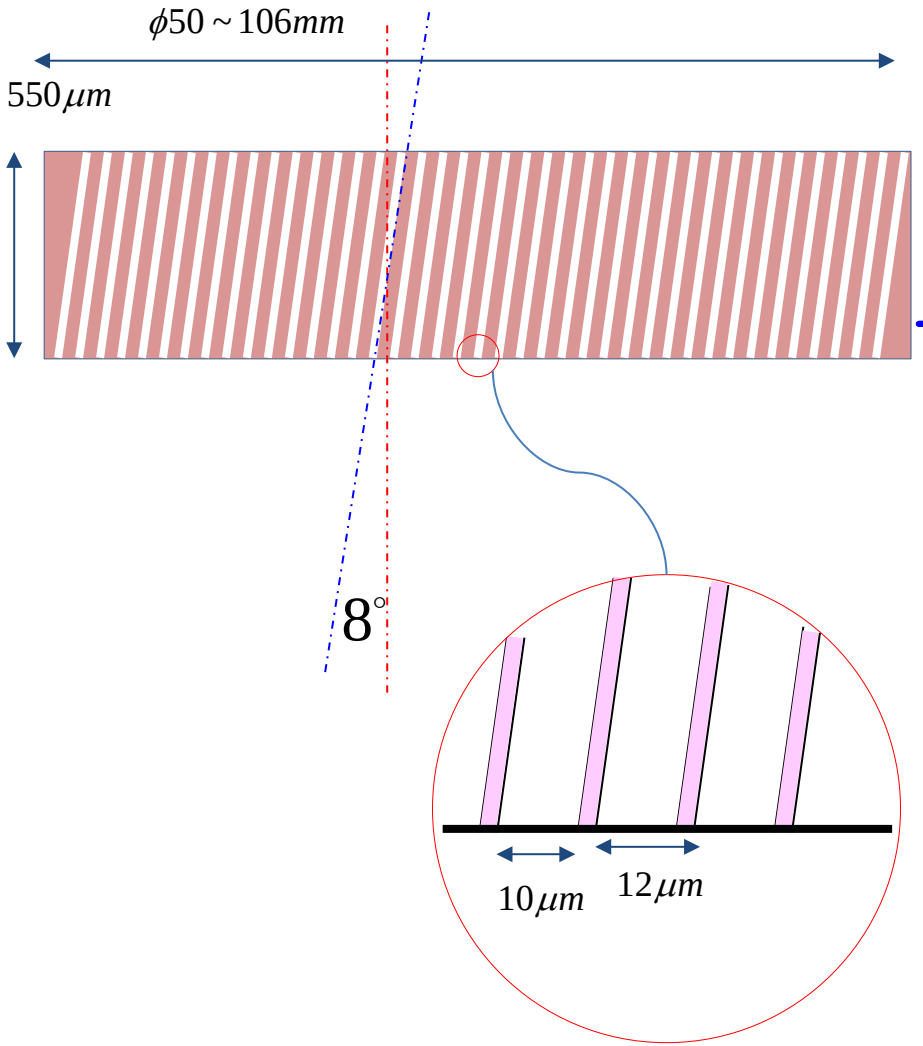
^{155,157}Gd(n,γe) ^{156,158}Gd







^{n}MCP: The neutron sensitive MCP



	Density: 4.2g/cm^3
	weight%
SiO_2	**%
Na_2O	**%
Cs_2O	**%
BaO	**%
$^{nat}Gd_2O_3$	9.90%
PbO	**%
Bi_2O_3	**%
TiO_2	**%

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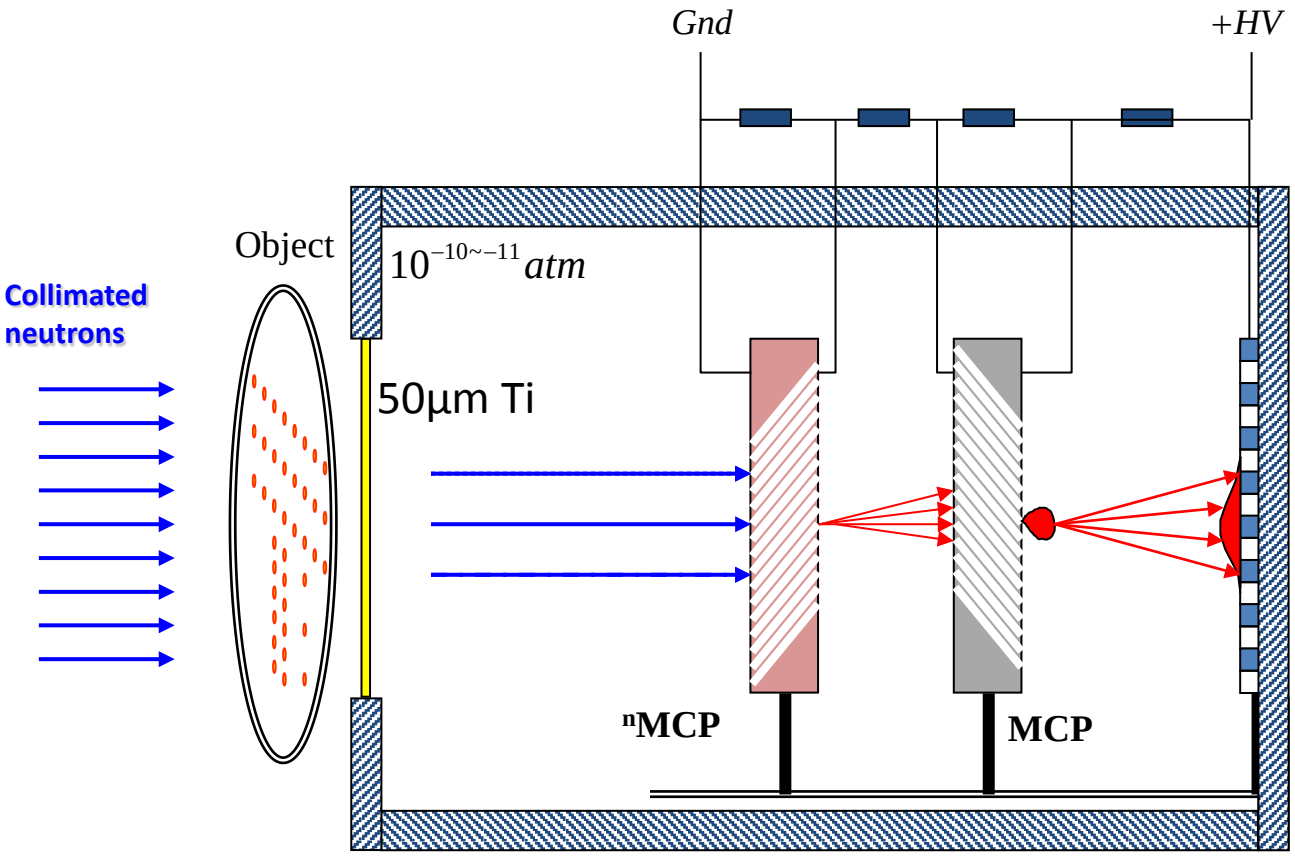
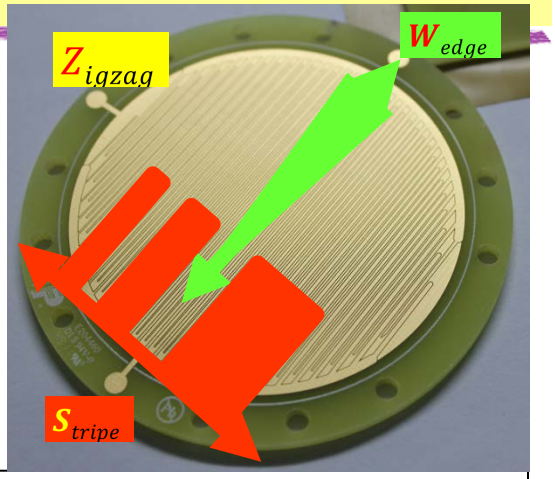
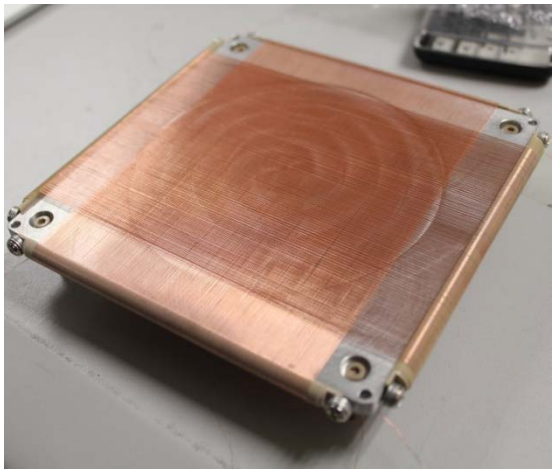
The geometry of the MCP detector



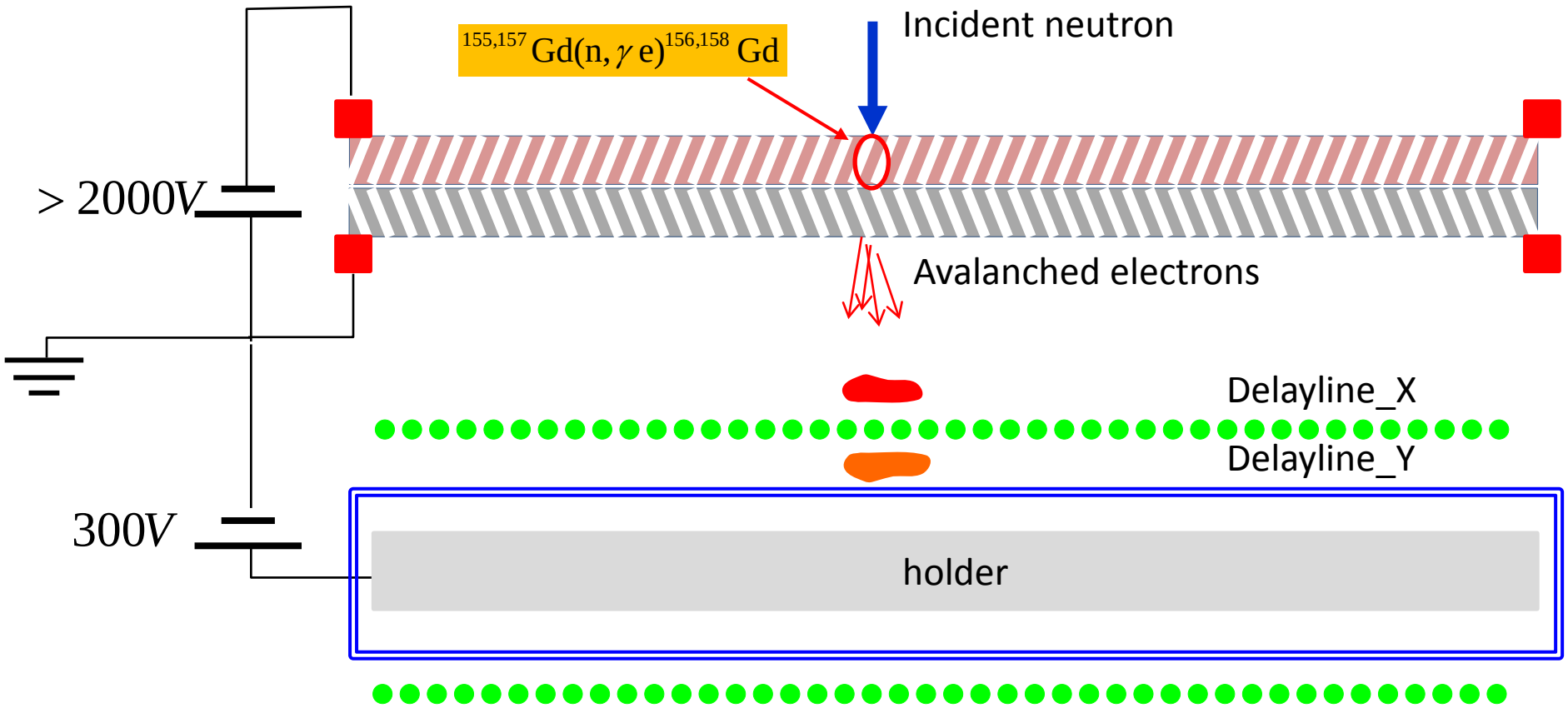


Anode:

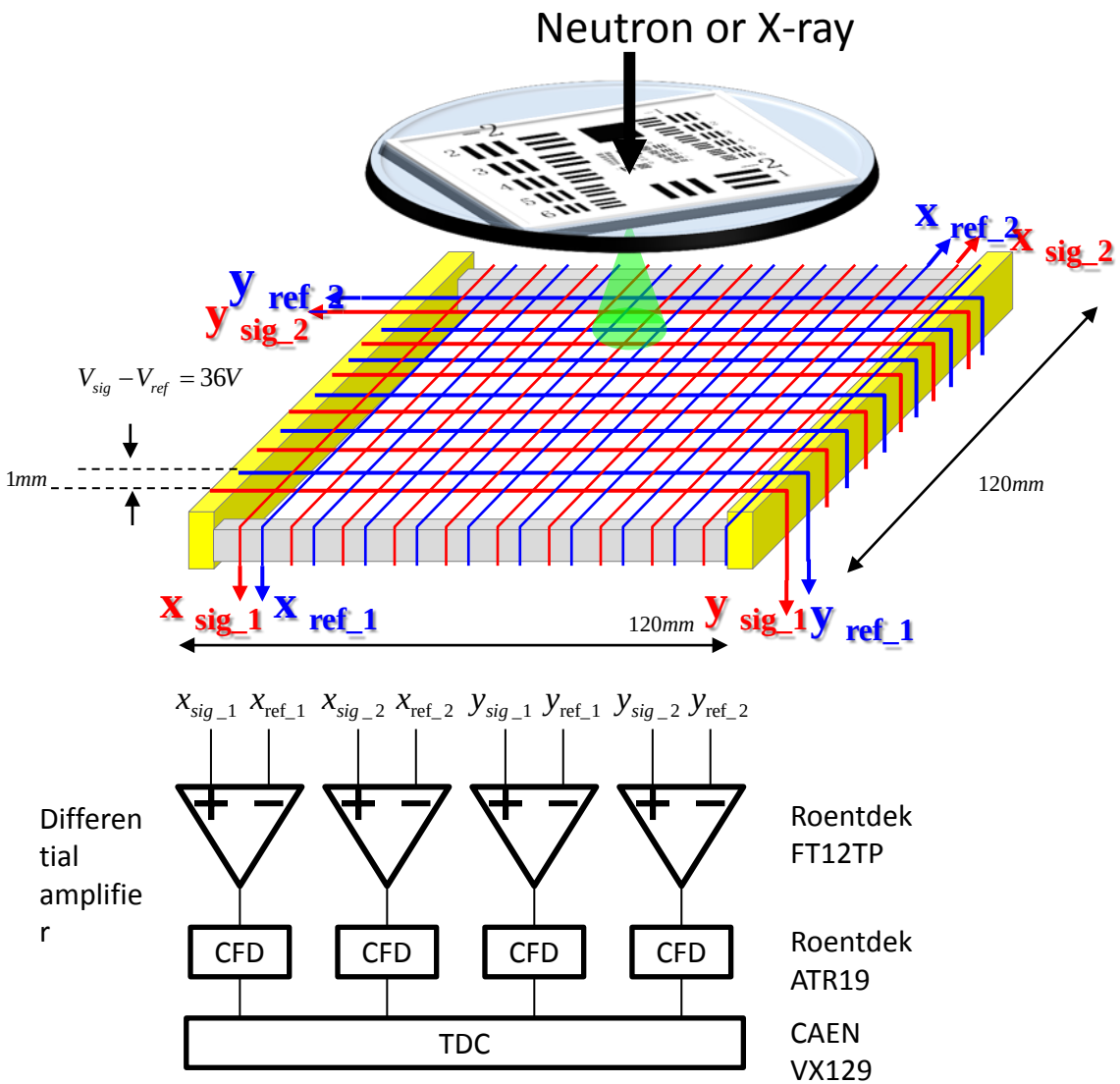
- **WSA**
  - ✓ Good for small MCP
  - ? Spatial resolution is bad for large MCP
- **Delay line**

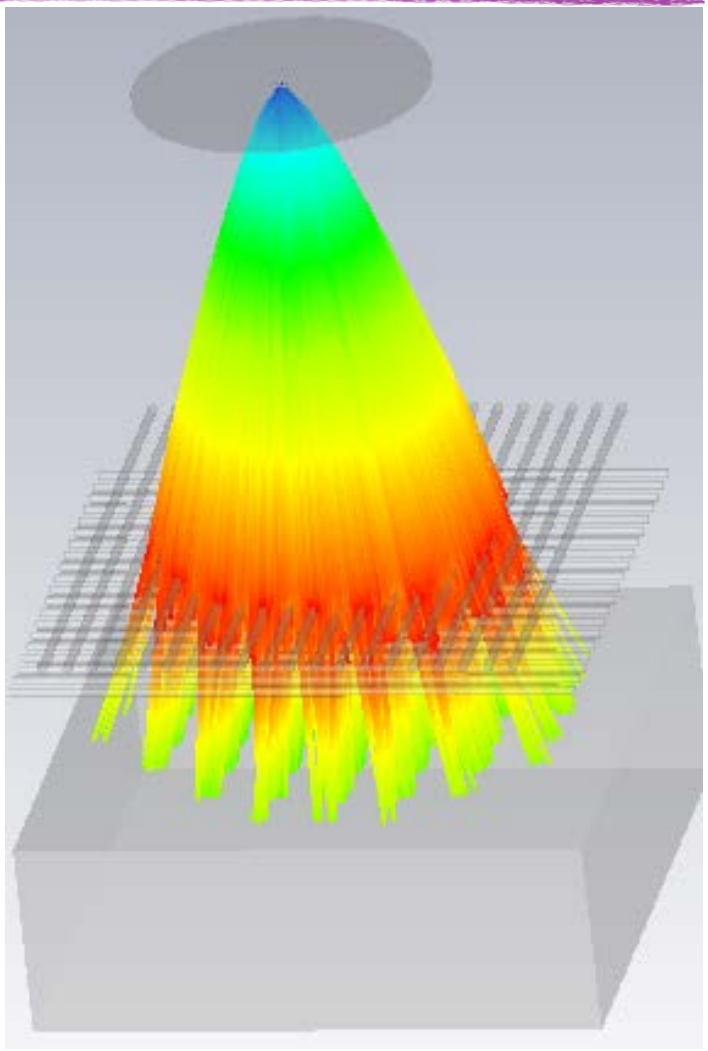


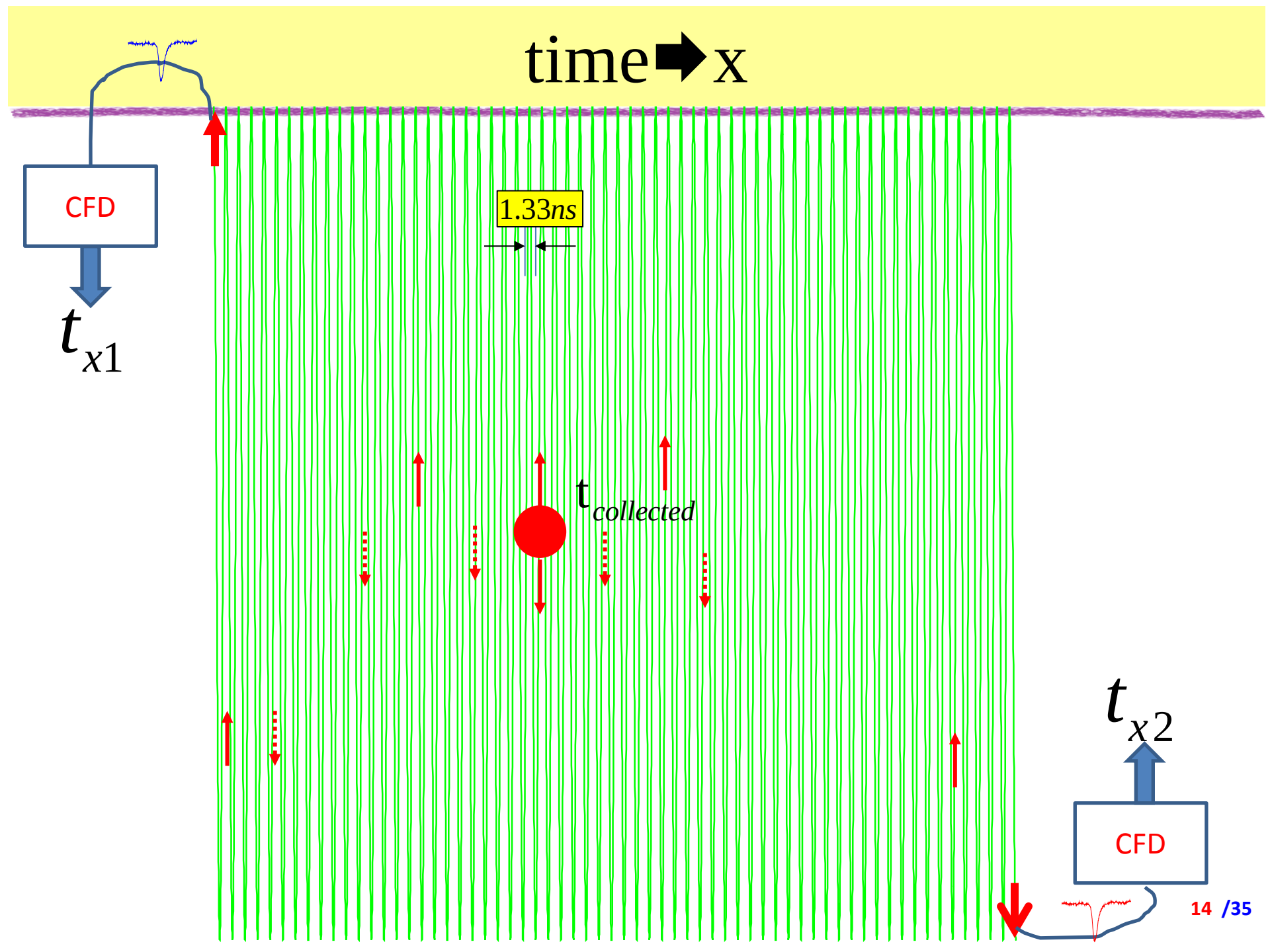
Neutron ➡ IC e⁻ ➡ electron cloud ➡ signals



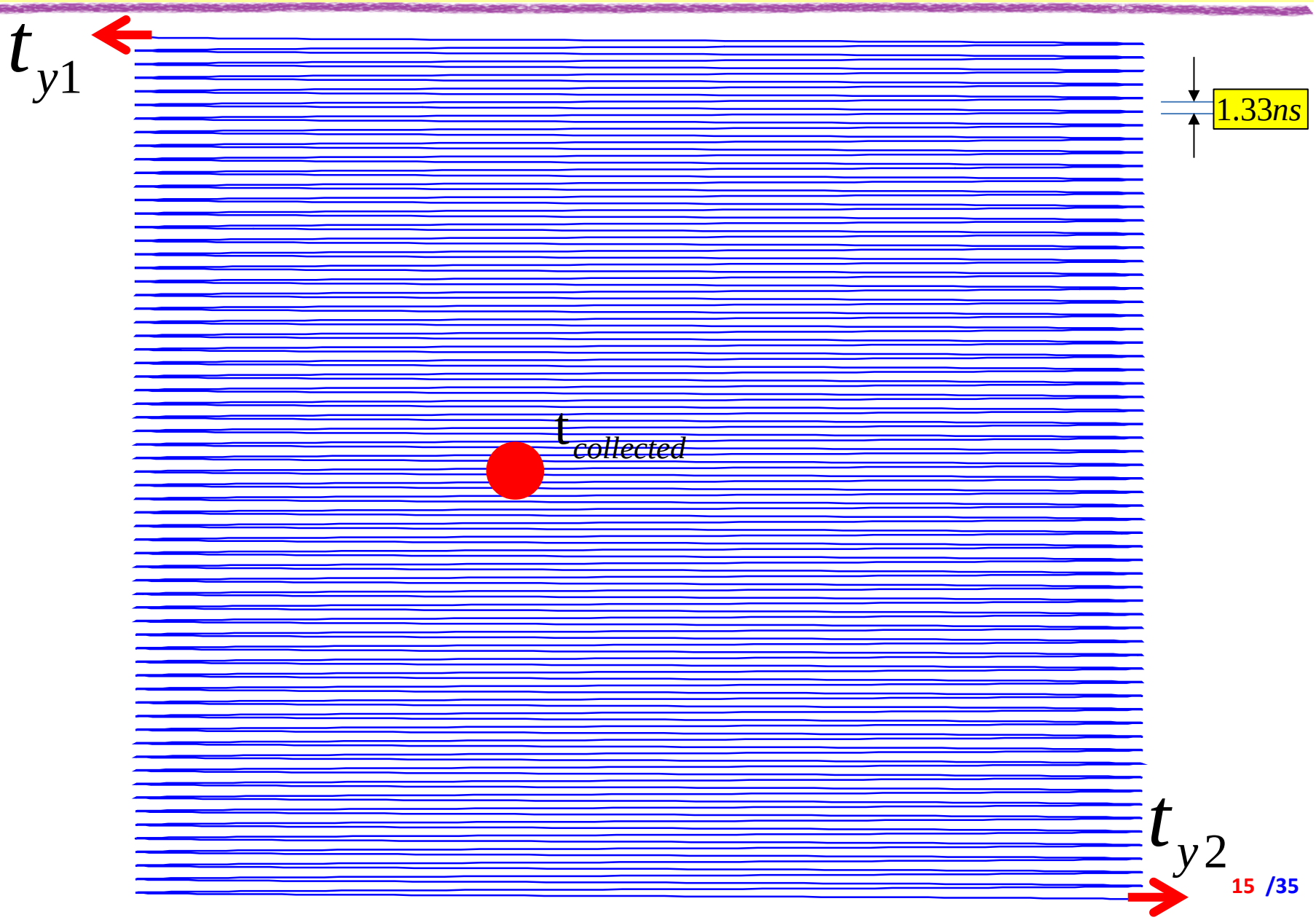
Details of the delay-line readout



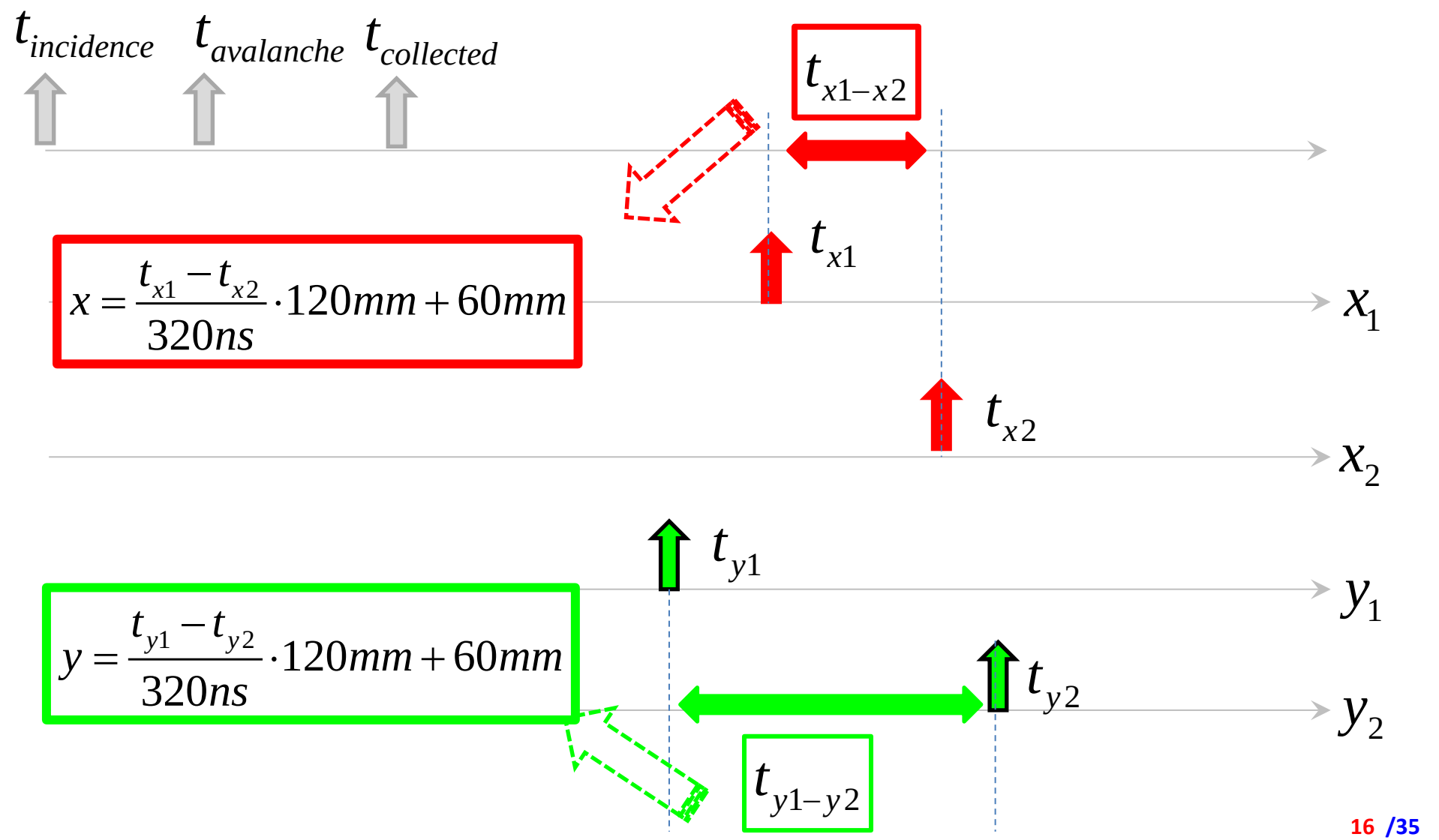



time ➡ x
CFD
t_{x1}
1.33ns
$t_{collected}$
t_{x2}
CFD

time➡y



The sequence of time signals



outline

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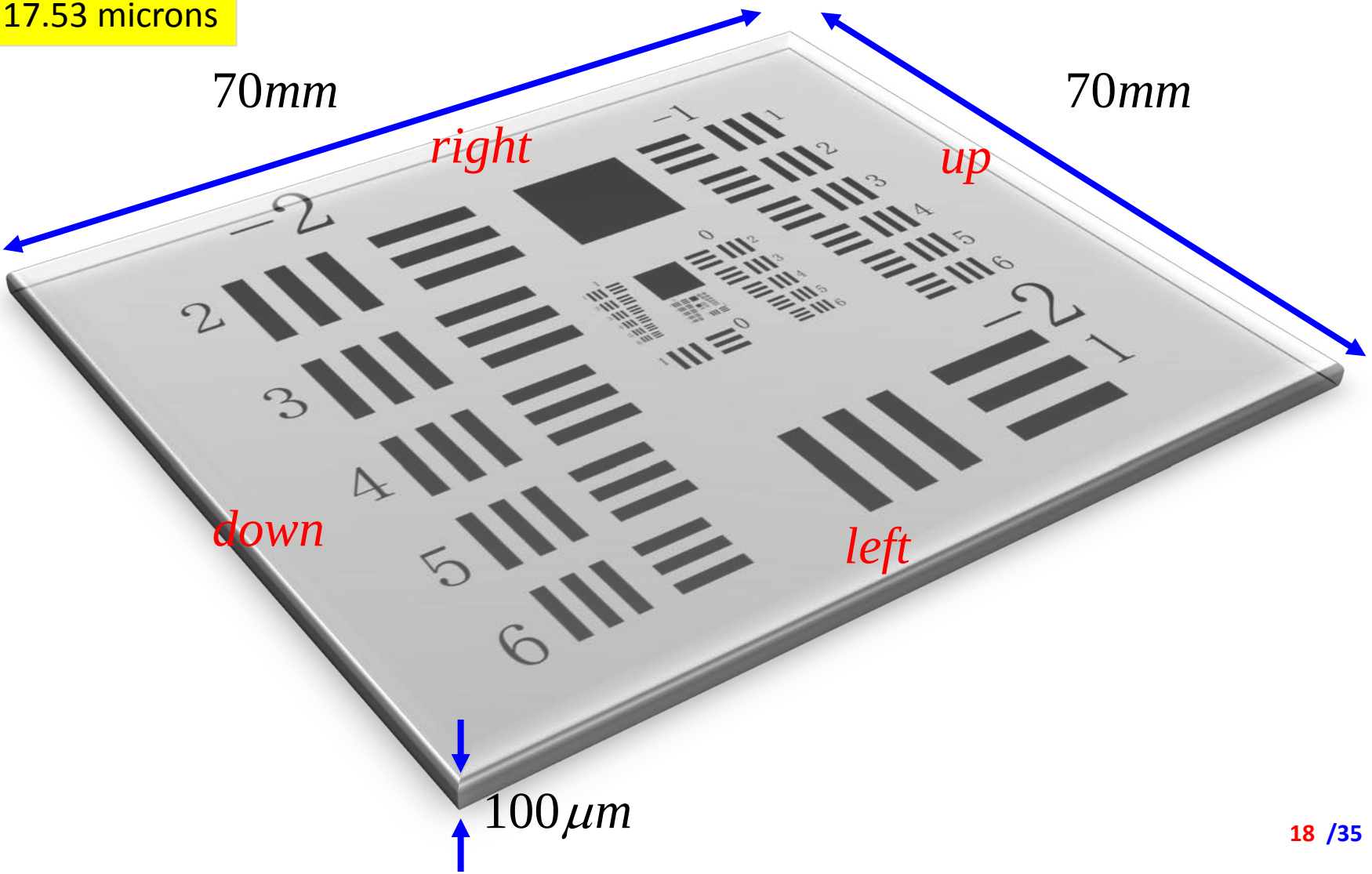
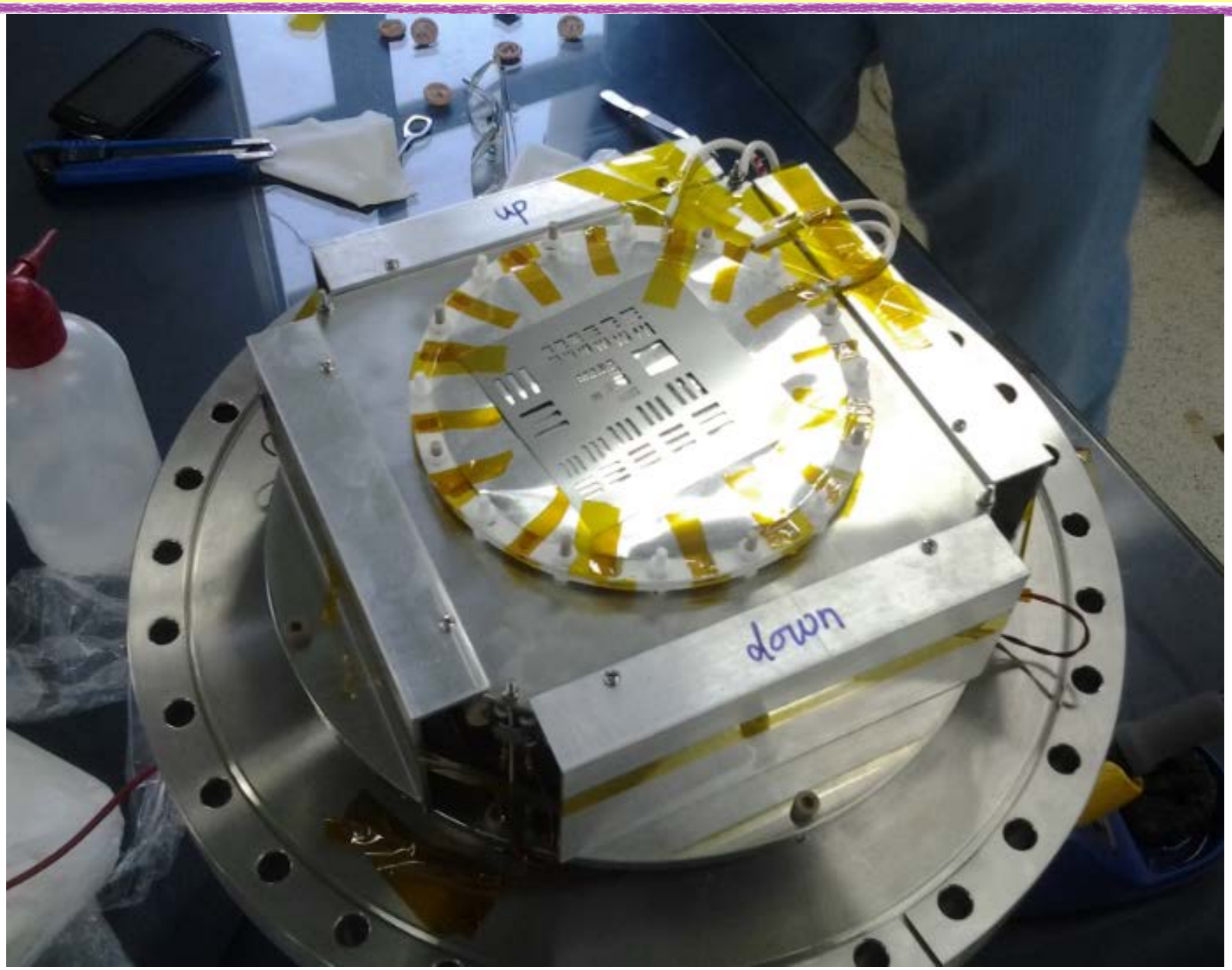
Gd mask: USAF 1951

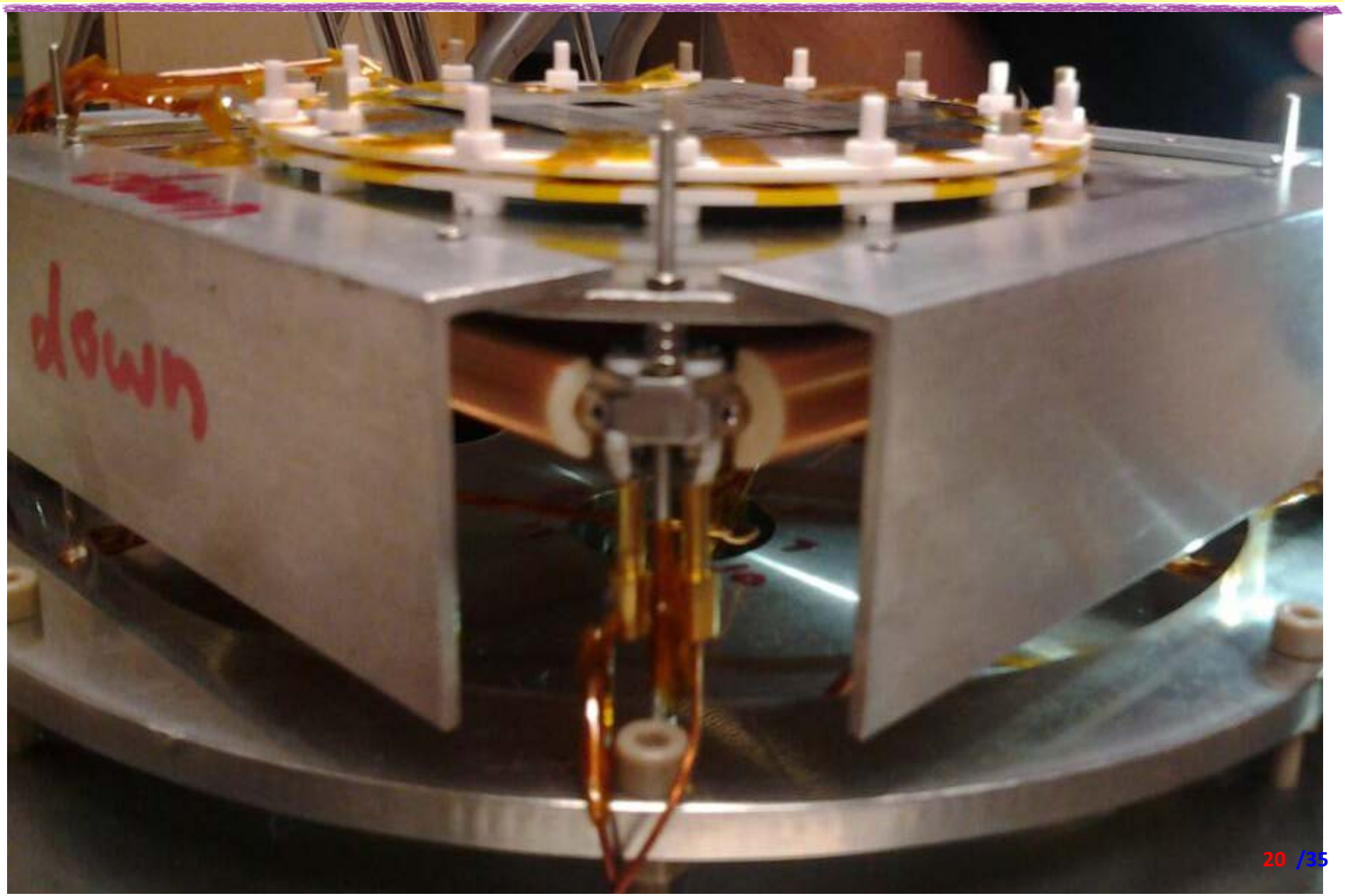
Line pairs:
Max: 2 millimeters
Min: 17.53 microns



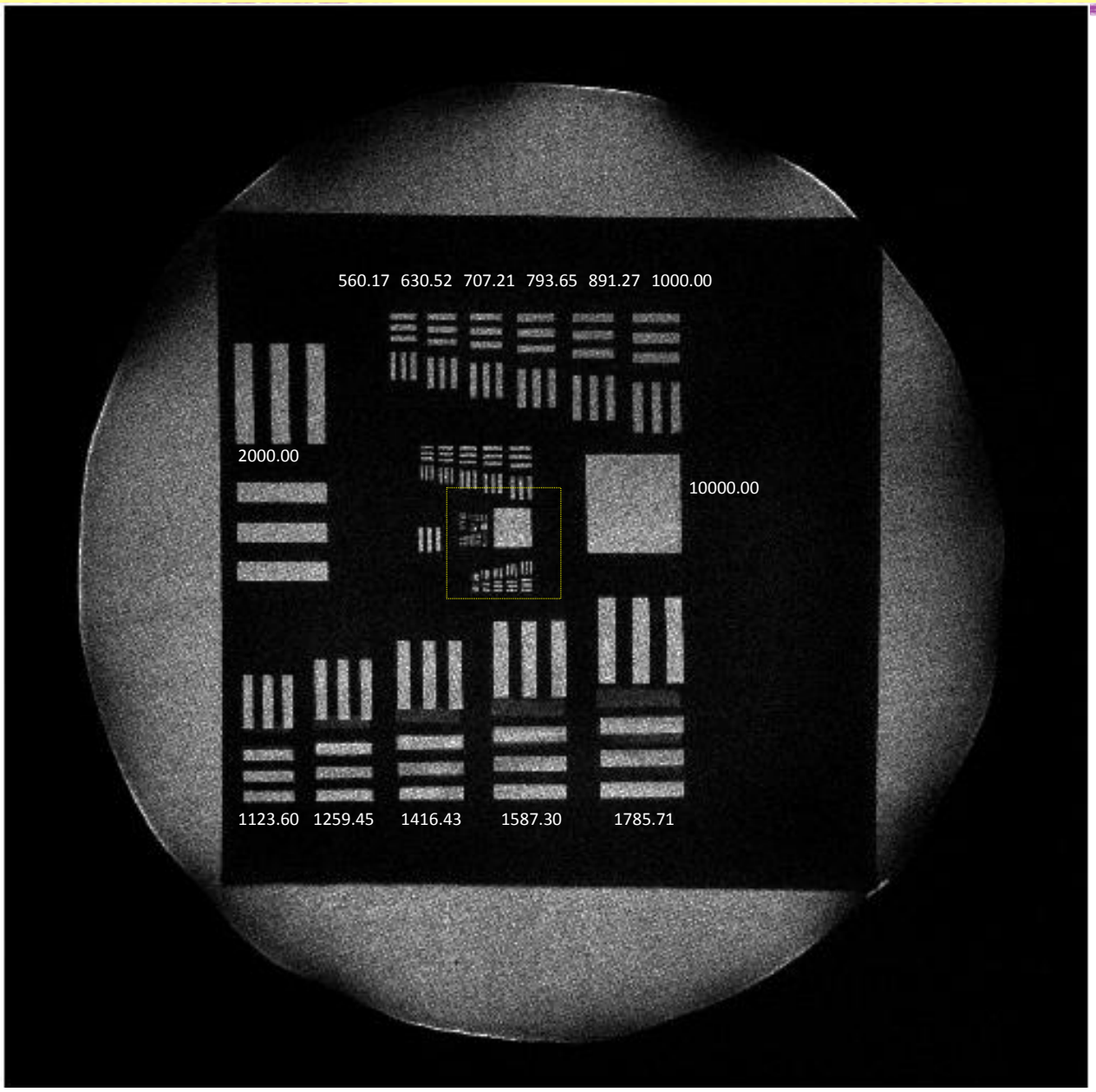
106mm MCP detector with delayline readout



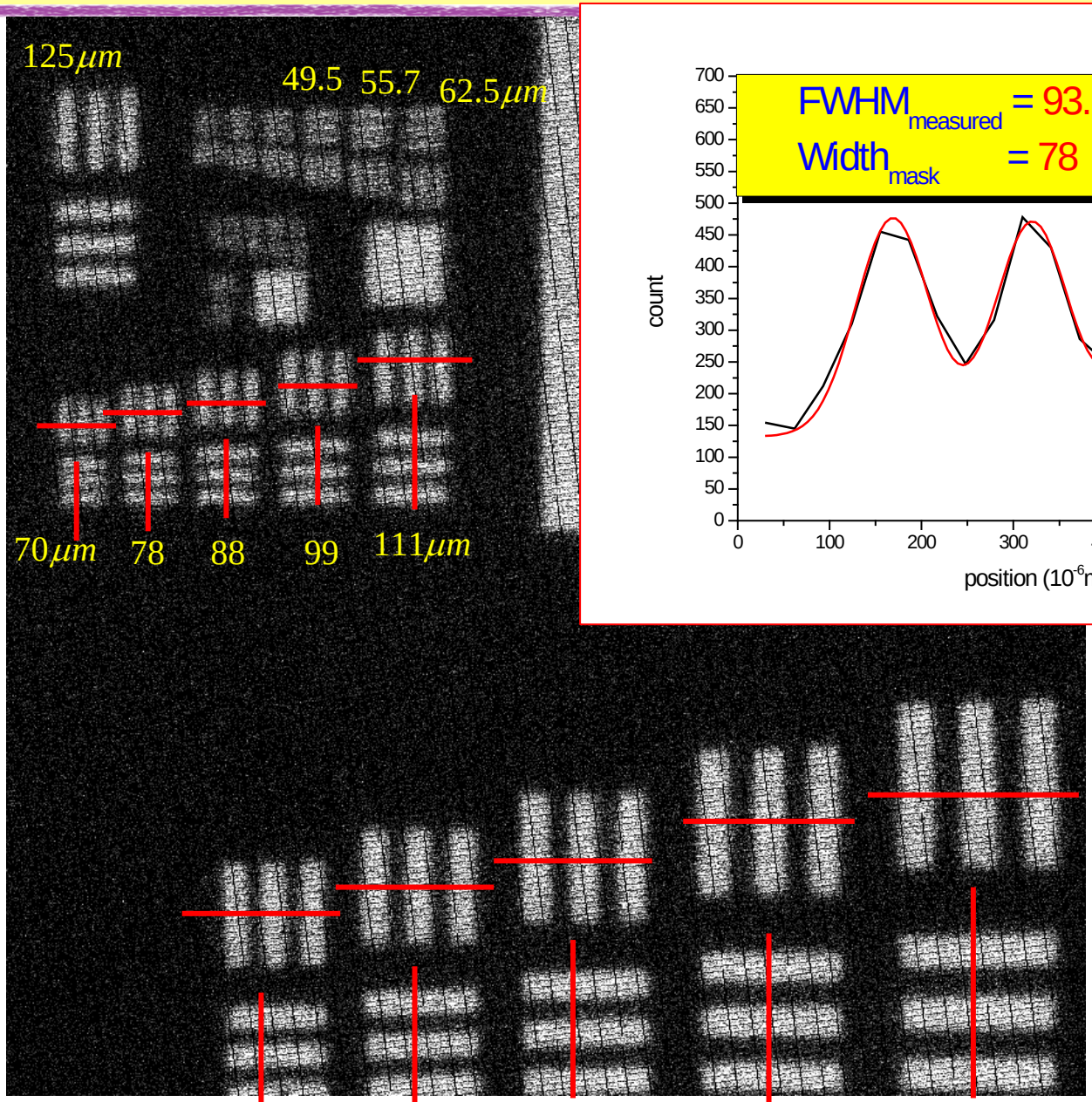
^{n}MCP+MCP



15kV X-ray image

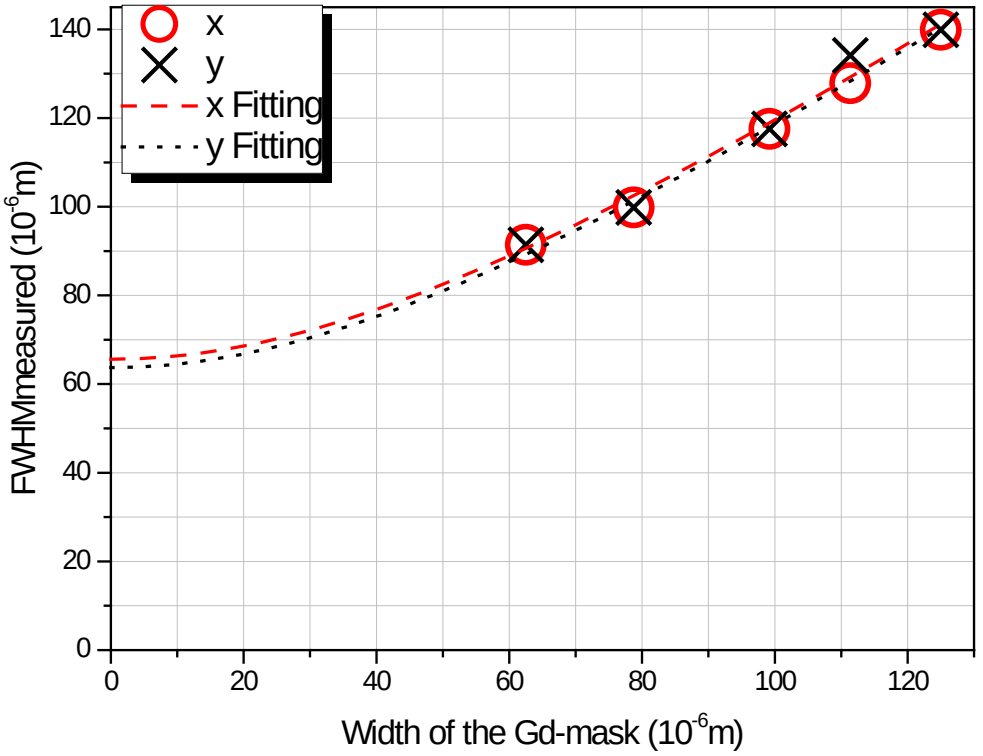


15 kV X-ray image in detail



$FWHM_{measured}$ vs $Width_{mask}$

$$FWHM^2_{measured} = Width^2_{mask} + FWHM^2_{det}$$



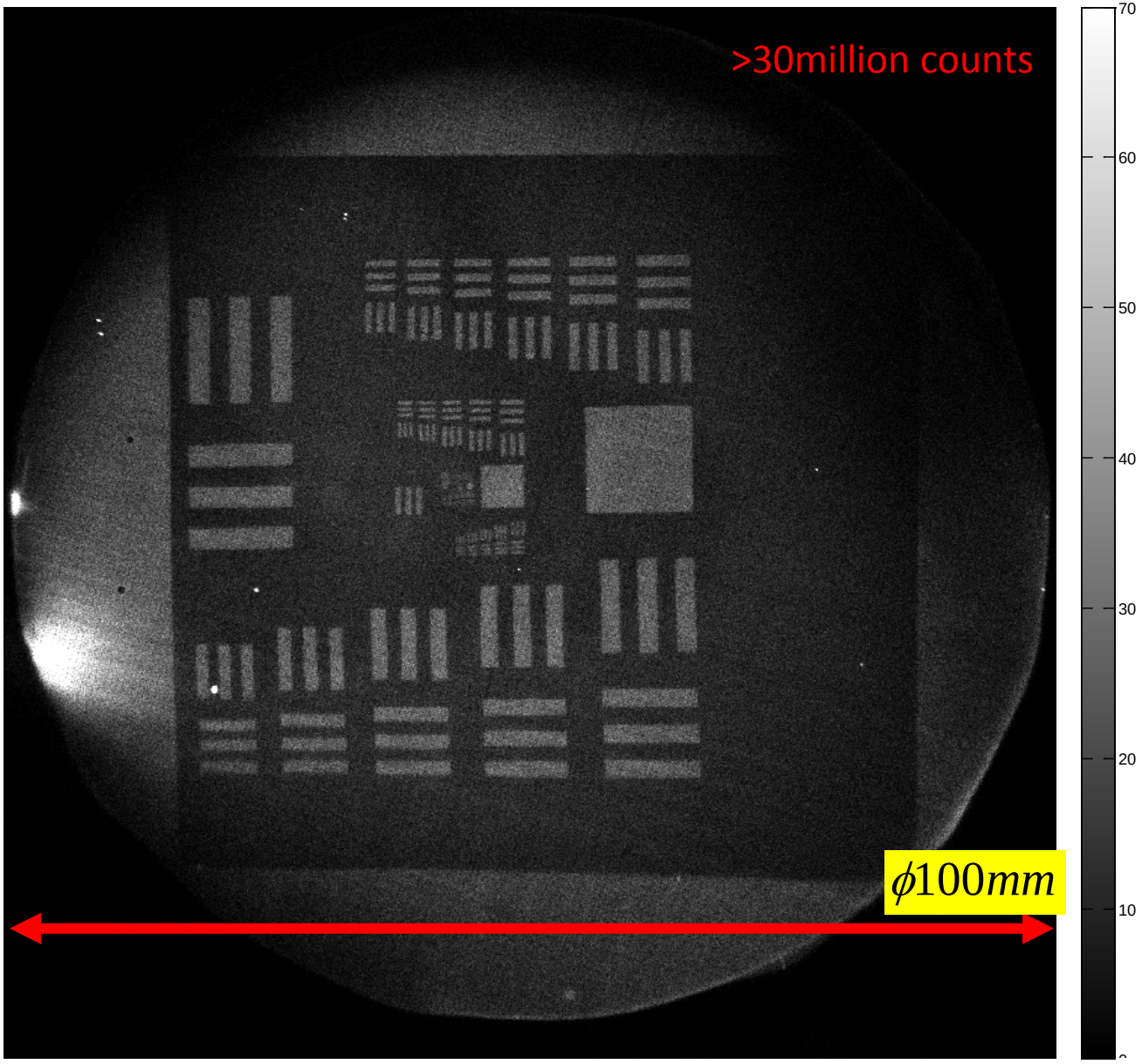
Intrinsic spatial resolution of the detector

$$FWHM_{det\_x} = 65.6\,\mu m$$

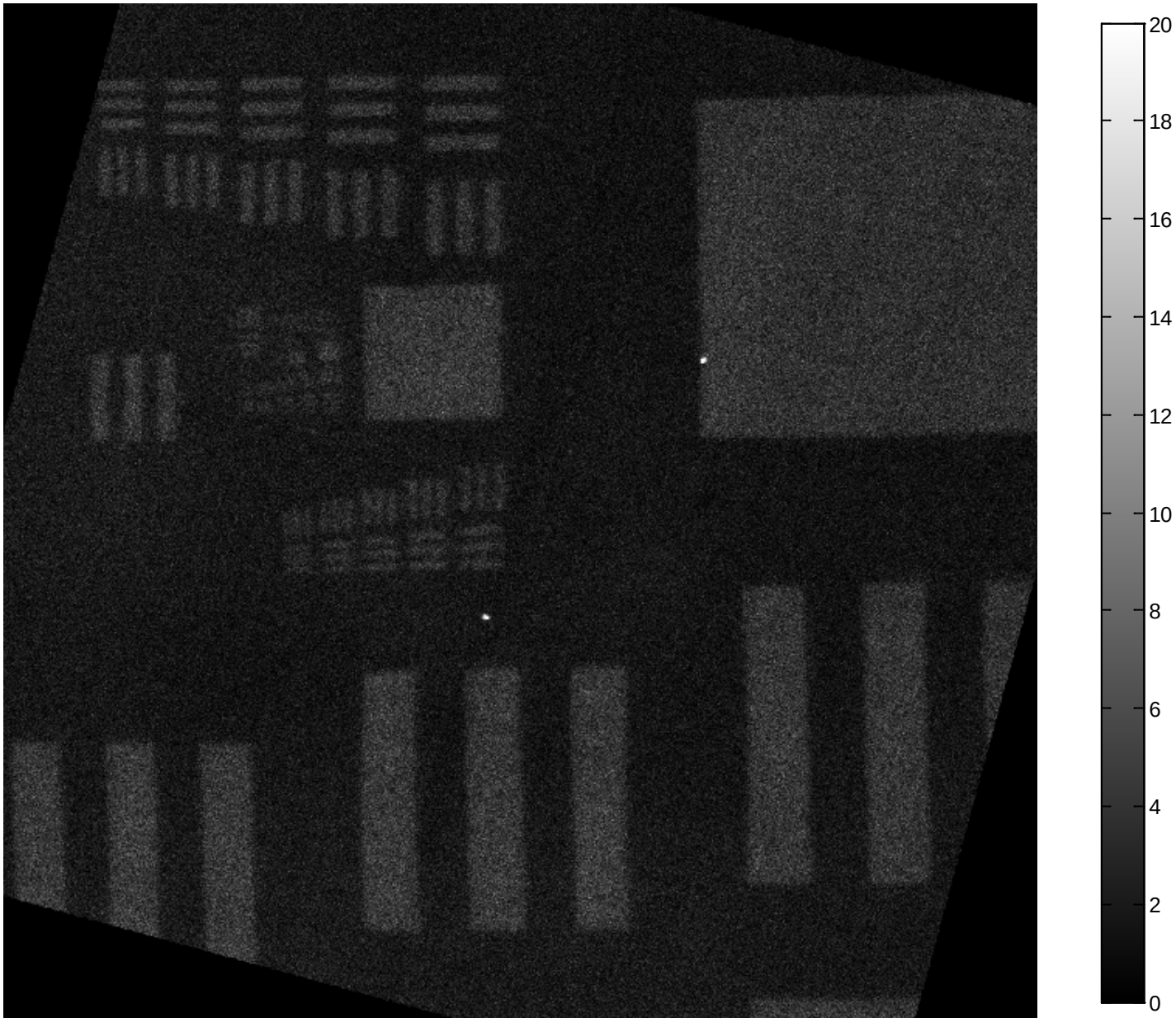
$$FWHM_{det\_y} = 63.7\,\mu m$$

Neutron experiments @ CPHS

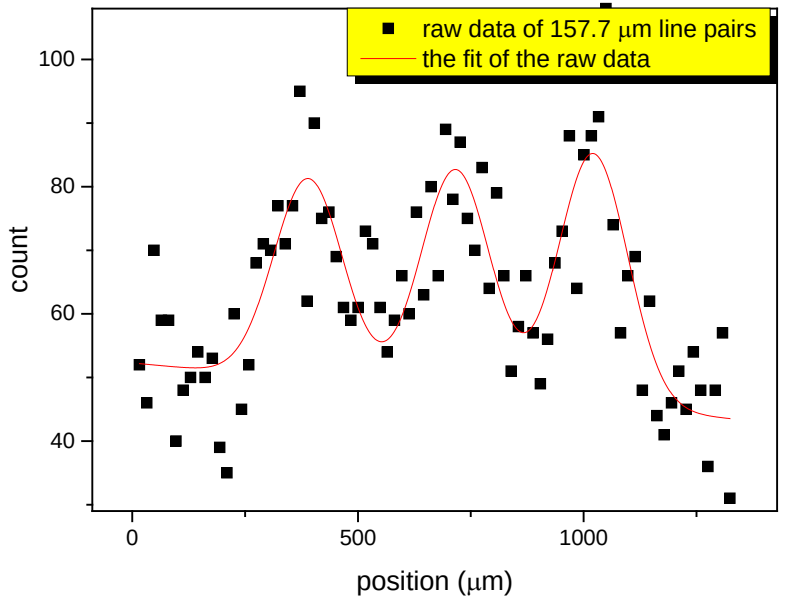
neutron image @ CPHS



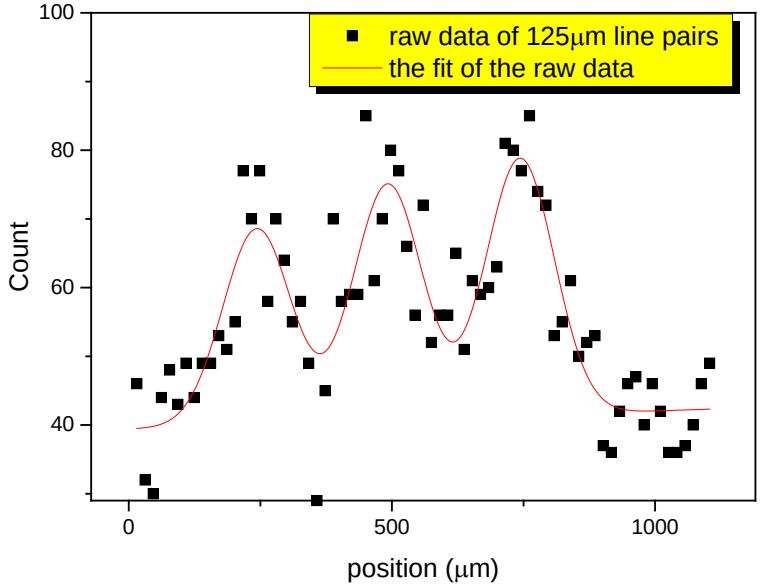
Neutron image in detail



The spatial resolution of neutron image

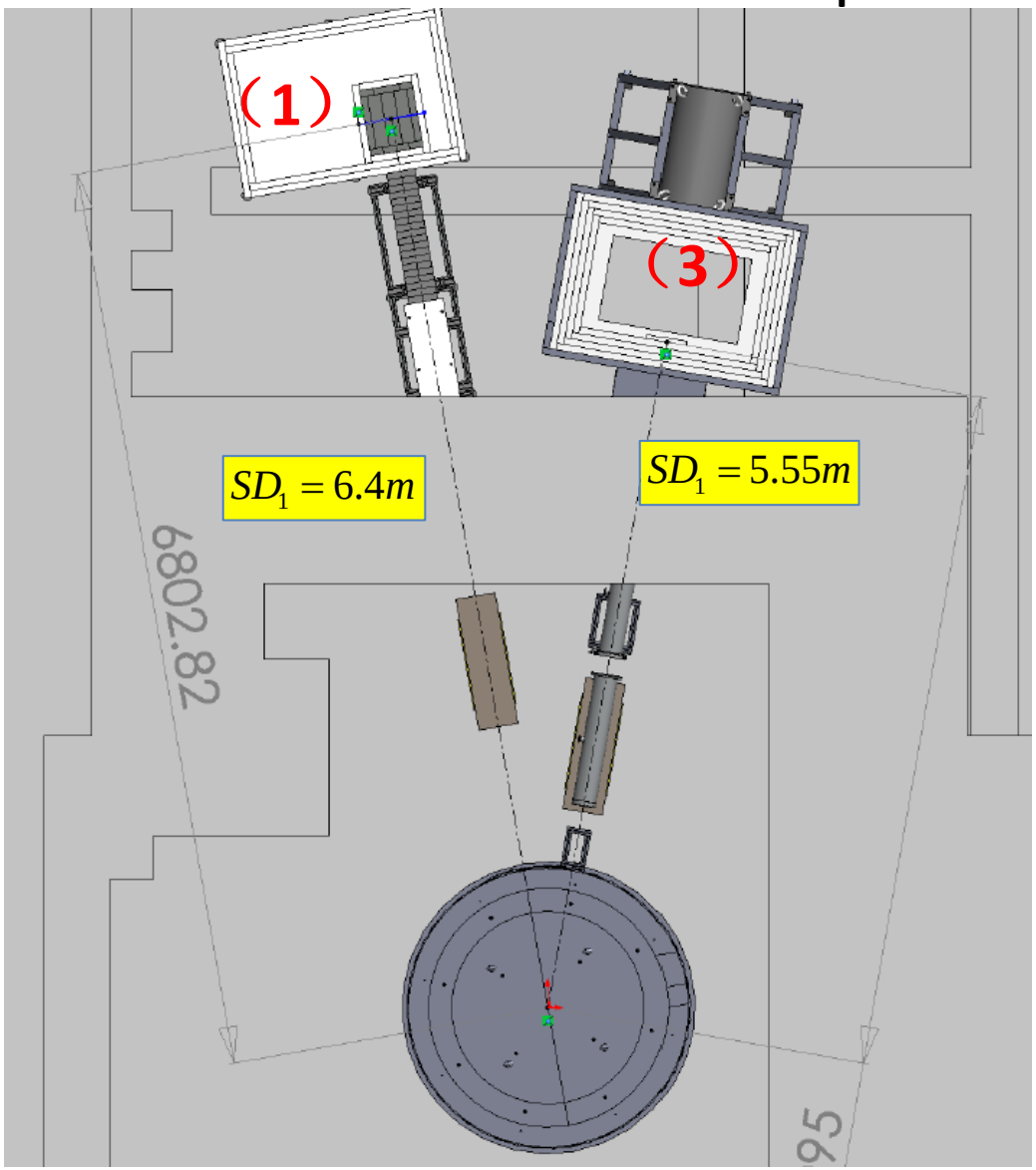


$$FWHM_{detector} = \sqrt{180.95^2 - 157.7^2} = 88.7\,\mu m$$



$$FWHM_{detector} = \sqrt{153.01^2 - 125^2} = 88.2\,\mu m$$

The detection efficiency

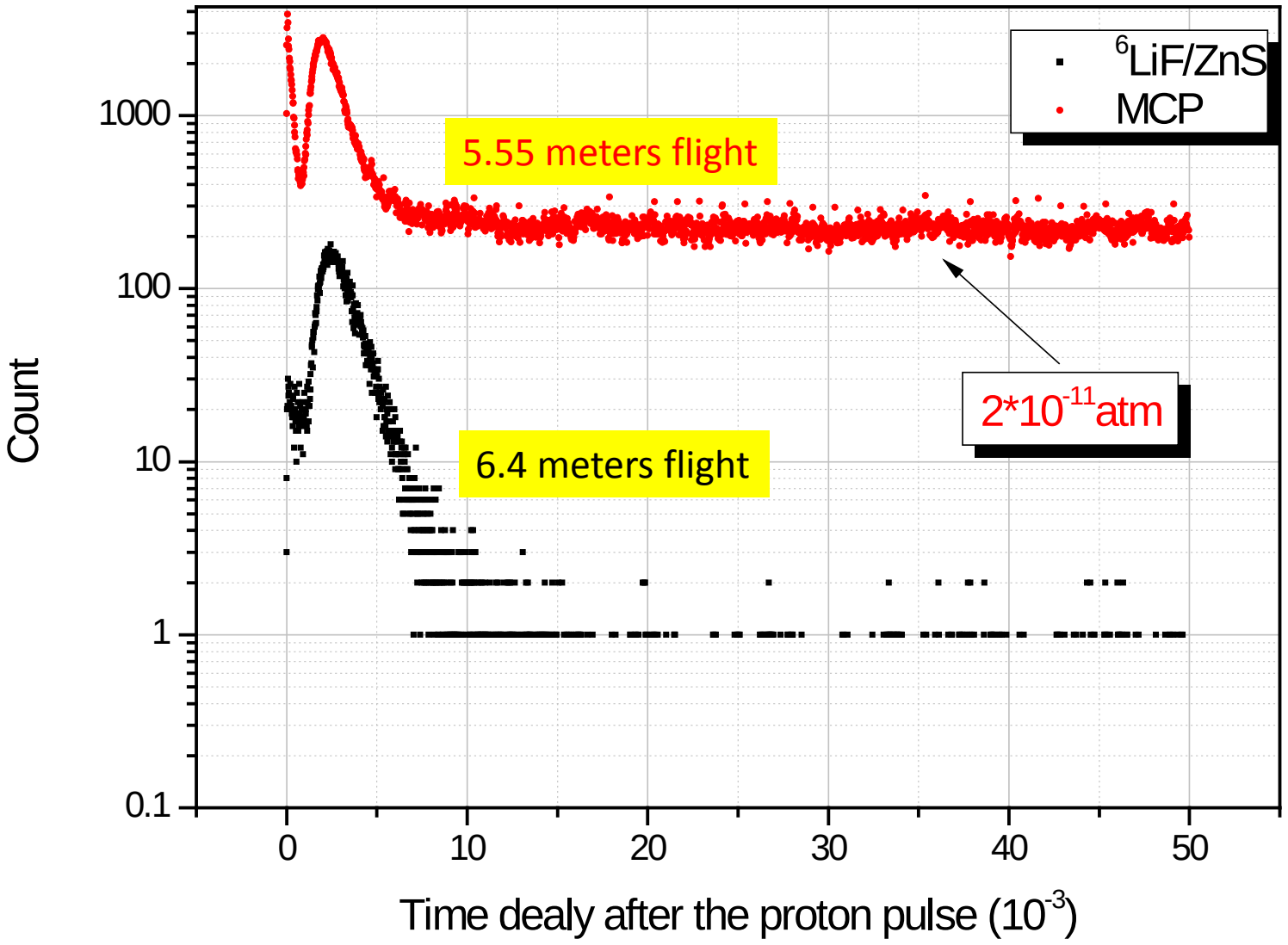


Geometry factor Dead time

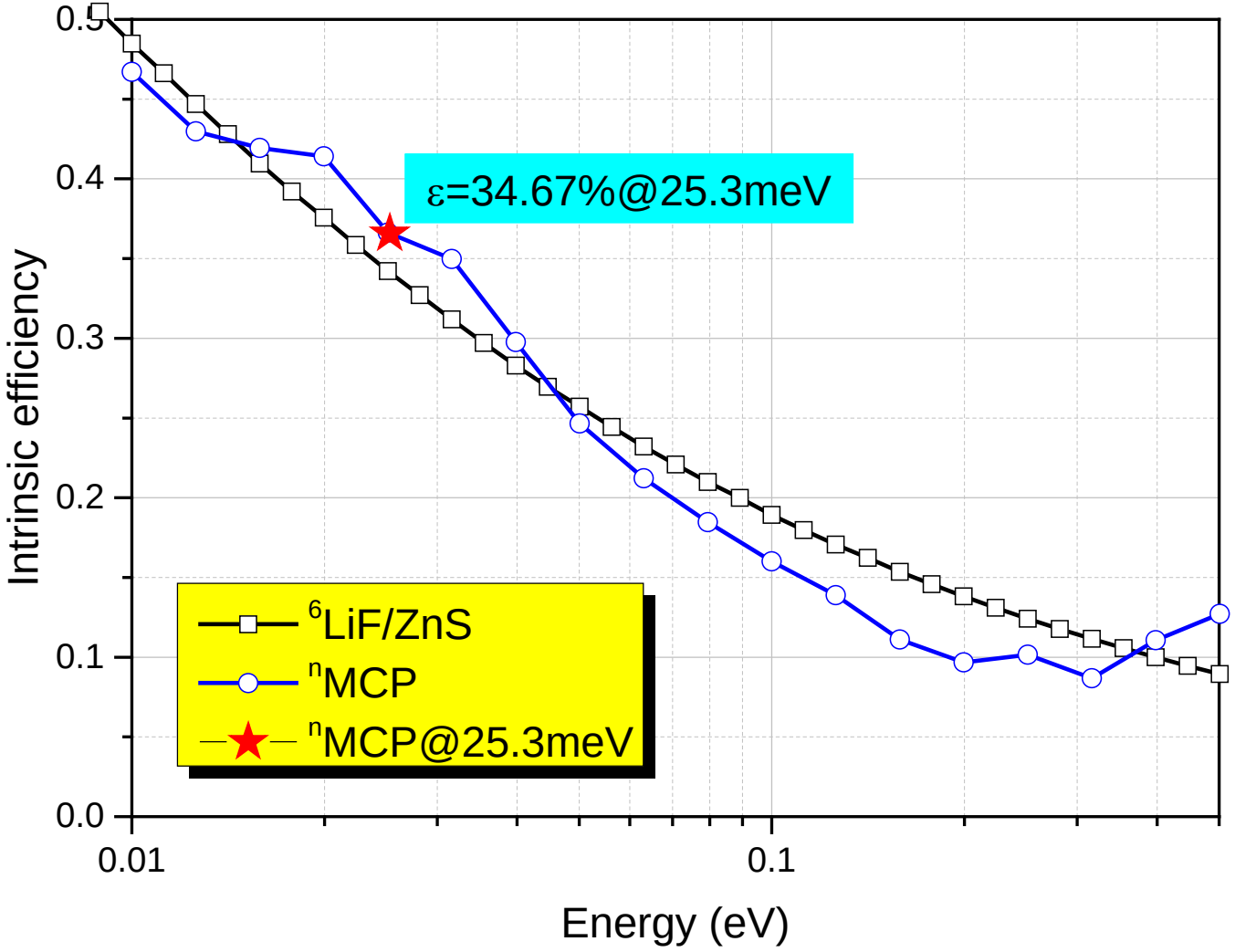
$$\frac{n_3}{n_1} = \frac{\varepsilon_3}{\varepsilon_1} \cdot \left(\frac{SD_1}{SD_3}\right)^2 \cdot \frac{S_3}{S_1} \cdot \frac{f_{\tau 3}}{f_{\tau 1}}$$

$$\varepsilon_3 = \varepsilon_1 \cdot \frac{n_3}{n_1} \cdot \left(\frac{SD_3}{SD_1}\right)^2 \cdot \frac{S_1}{S_3}$$

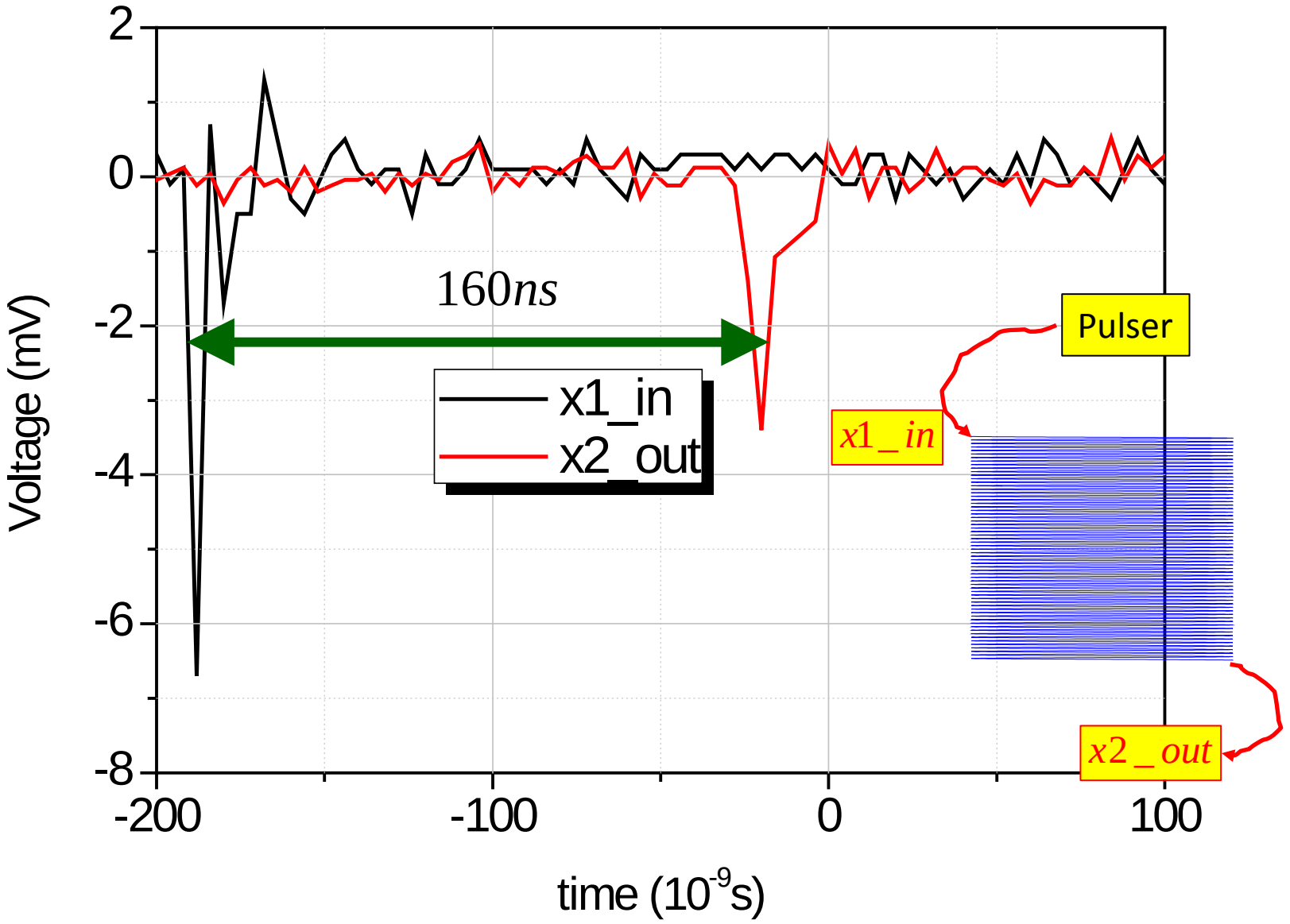
TOF : ^{6}LiF/ZnS & MCP



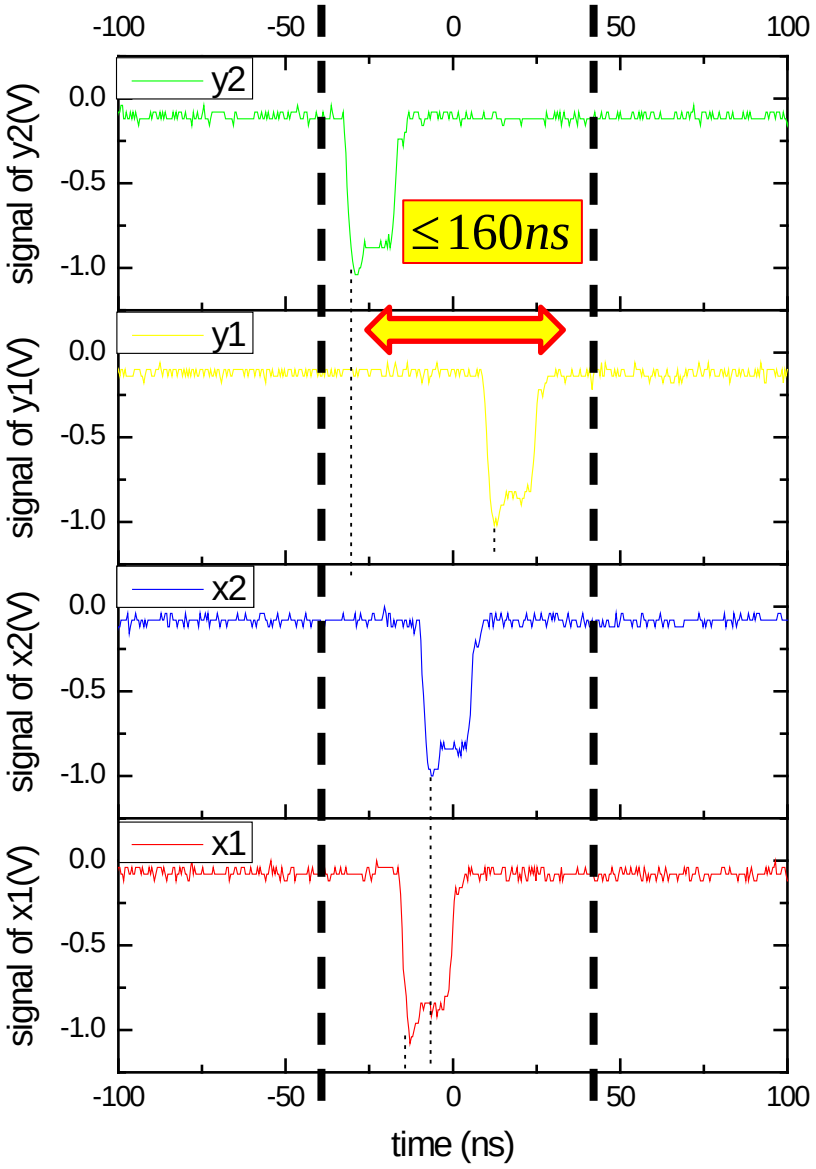
The efficiency



The throughput analysis

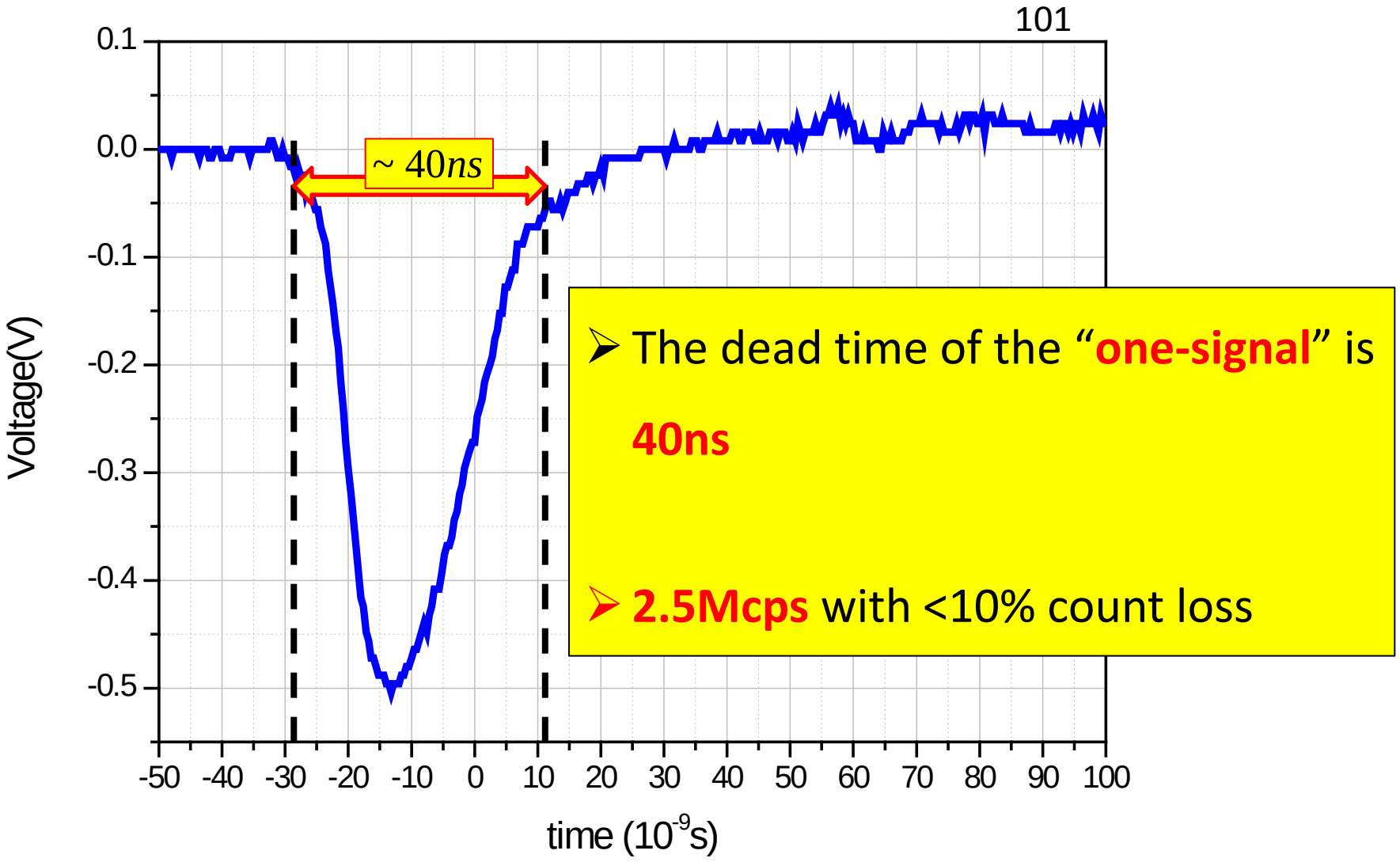


The time signals after CFD



- The dead time of the "**four-signal-group**" is **<160ns**
- **624kcps** with <10% count loss

the “monitor” signal before CFD



- The dead time of the “**one-signal**” is **40ns**
- **2.5Mcps** with <10% count loss

5.Summary

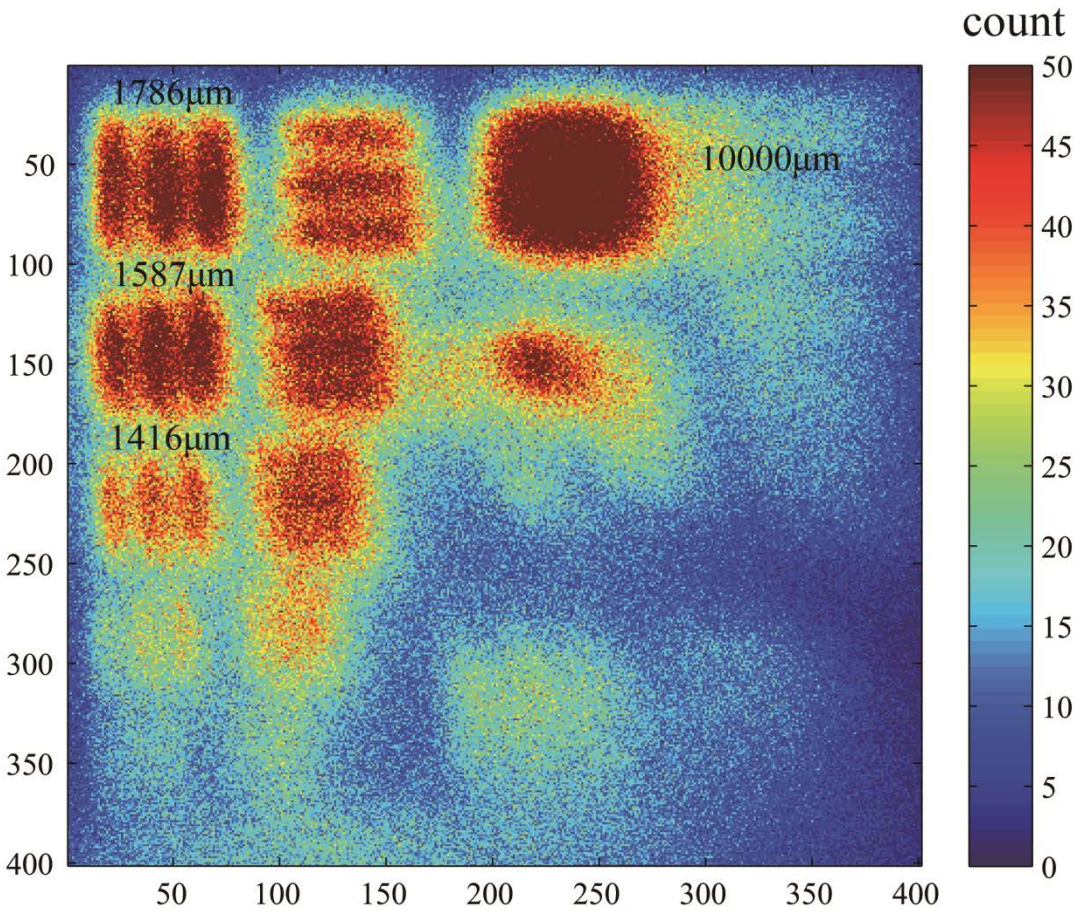
- The ^{nat}Gd doped ^{n}MCP neutron detector has been realized @ Tsinghua:
  - Sensitive Area: *100mm diameter*
  - Spatial resolution: *<100microns*
  - Detection efficiency: *>30%@1.8Å*
  - Throughput : *0.64~2.5Mcps*
- The efficiency could be enhanced with ^{nat}Gd coating

Thank you

&

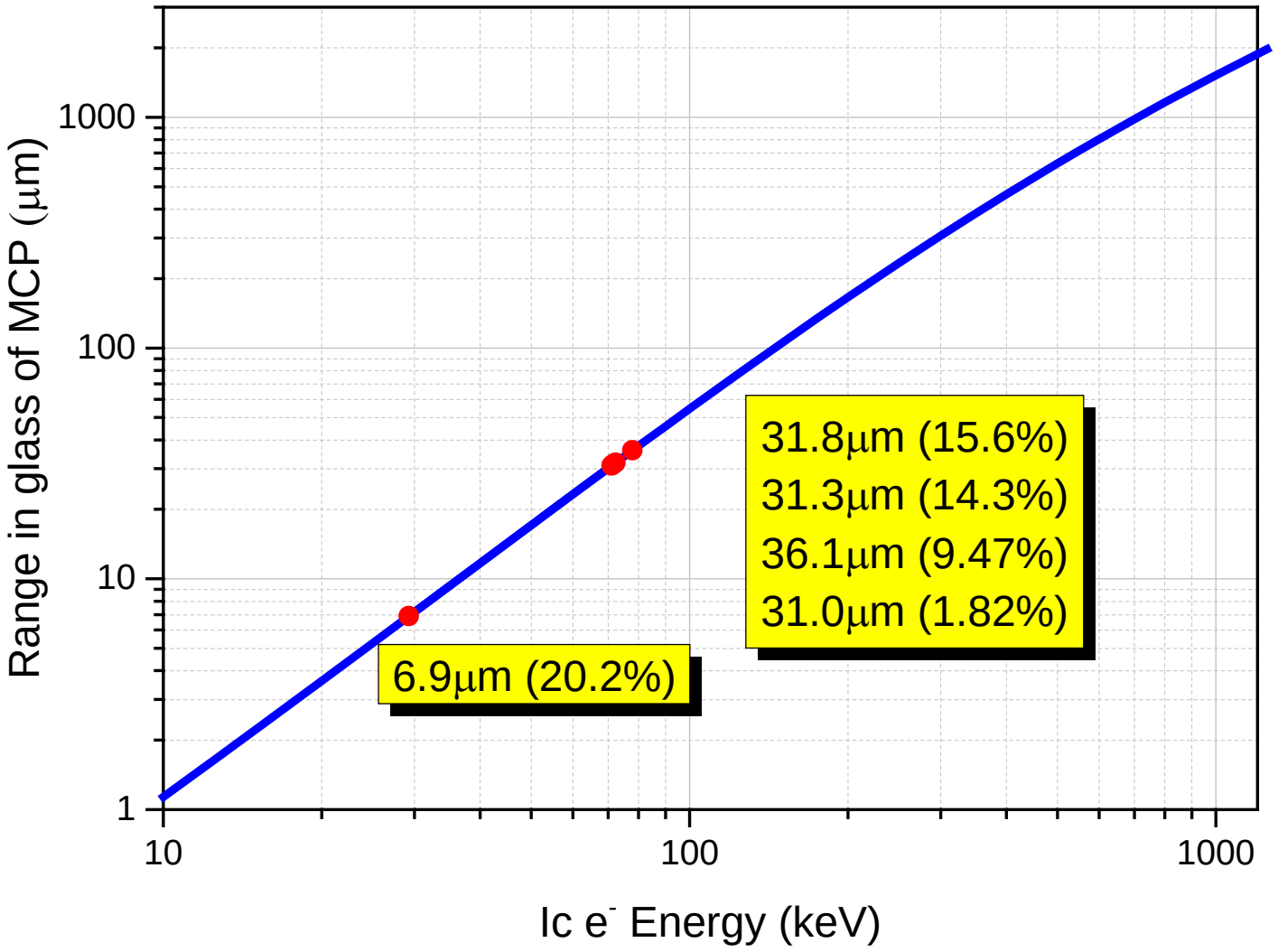
questions?

WSA

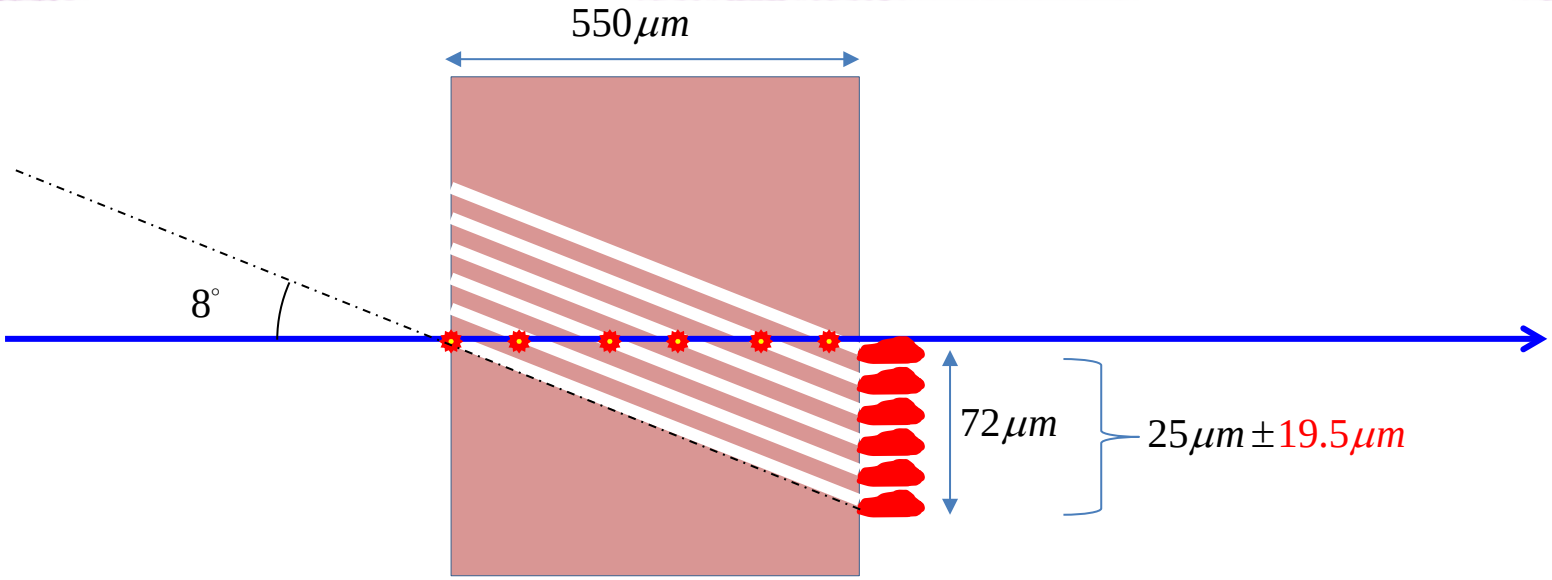


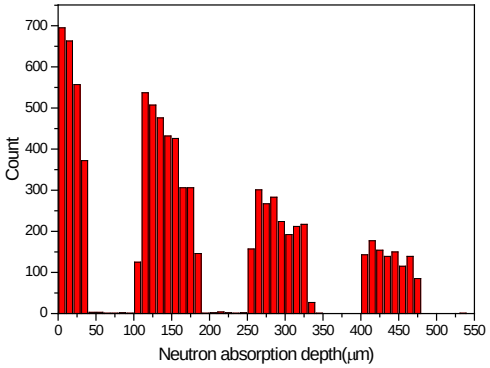
$$FWHM_{x,y} = 2.355 \cdot \frac{ENC}{Q_{\max}} \cdot D_{WSA} = 2.355 \cdot \frac{Q_0}{Q_{\max}} \cdot D_{WSA} + 2.355 \cdot \frac{k \cdot \pi}{4} \cdot \frac{D_{WSA}^3}{Q_{\max}}$$

The range of Ic e- in MCP



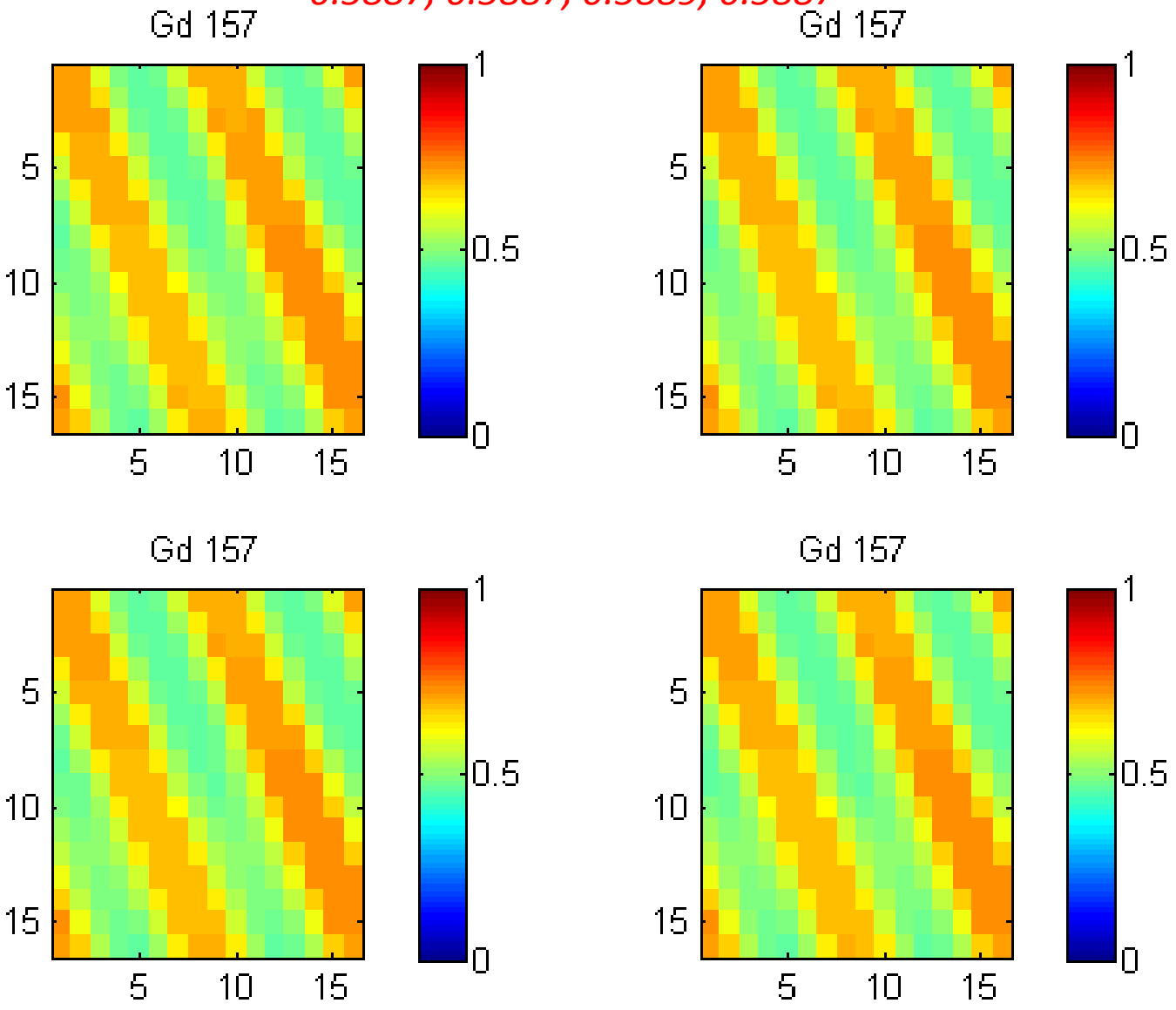
A neutron can penetrates several pores





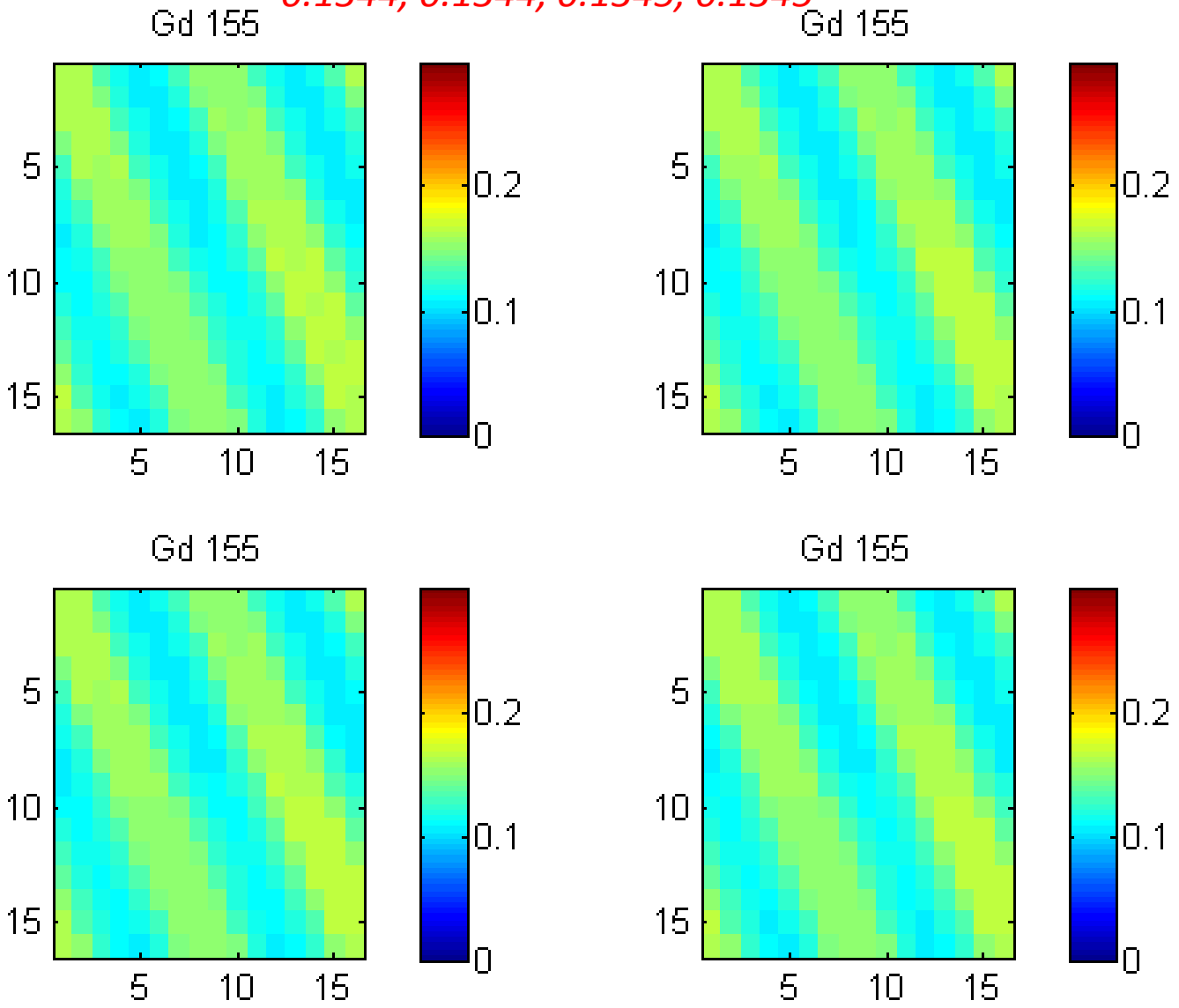
Neutron absorption by ^{157}Gd

0.5887, 0.5887, 0.5889, 0.5887

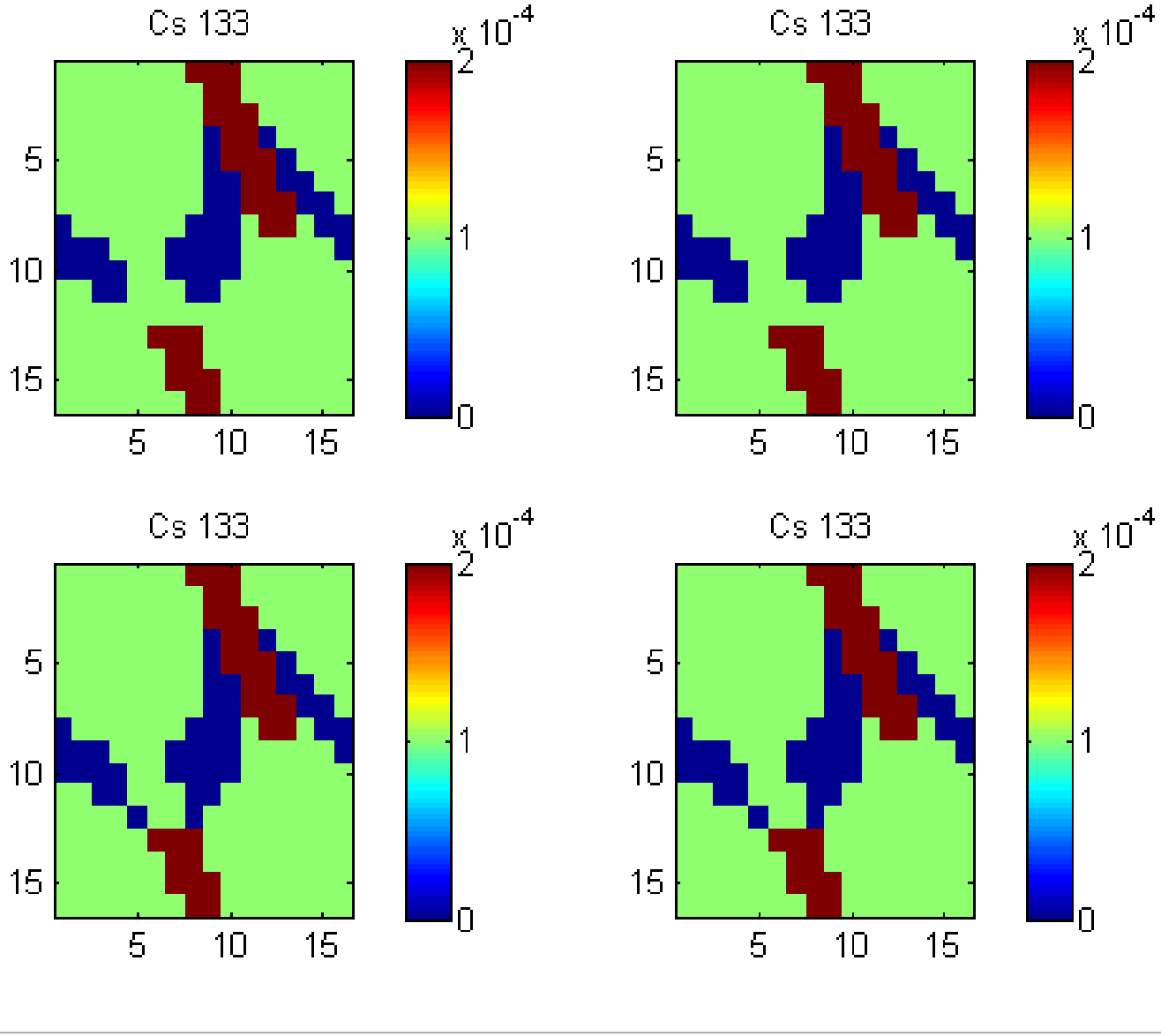


Neutron absorption by ^{155}Gd

0.1344, 0.1344, 0.1345, 0.1345



Neutron absorption by ^{133}Cs



Neutron experiment@CIAE