

# In-kind detector activity @ HZG for the ESS detector group (plans and detector capabilities)

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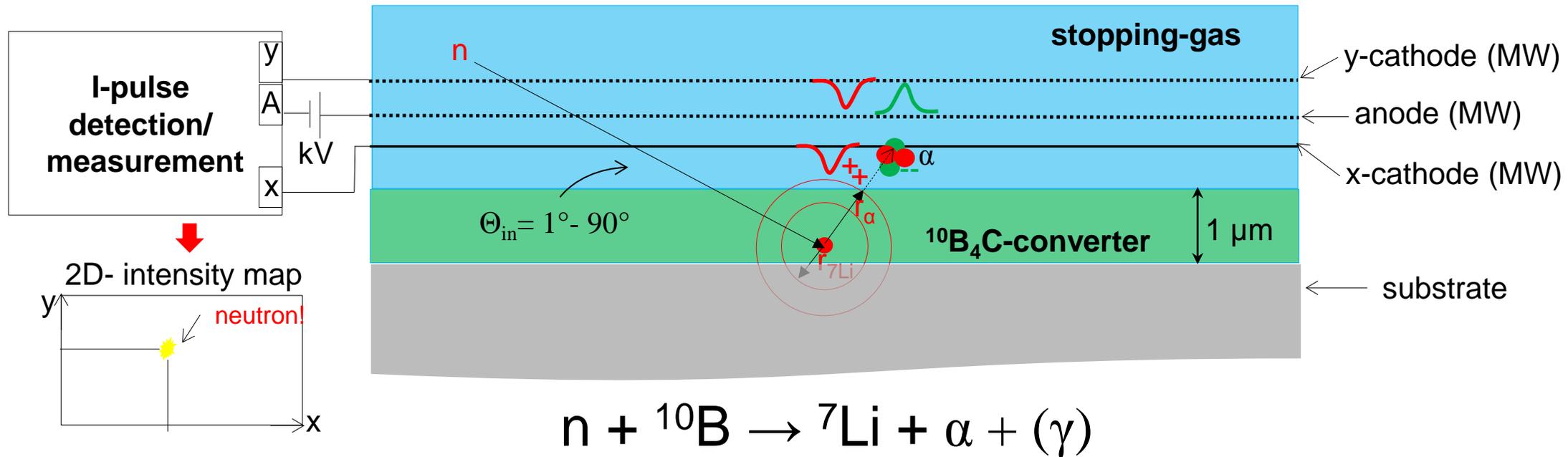
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IKON 10, 2016, 18<sup>th</sup> February, Düsseldorf

- short intro:  $^{10}\text{B}_4\text{C}$  coating based neutron detectors
- Results from previous projects
- Milestones for the proposed project (Am-CLD)
- Summary

# Gaseous MWPC driven by $^{10}\text{B}_4\text{C}$ neutron converter and delay-line



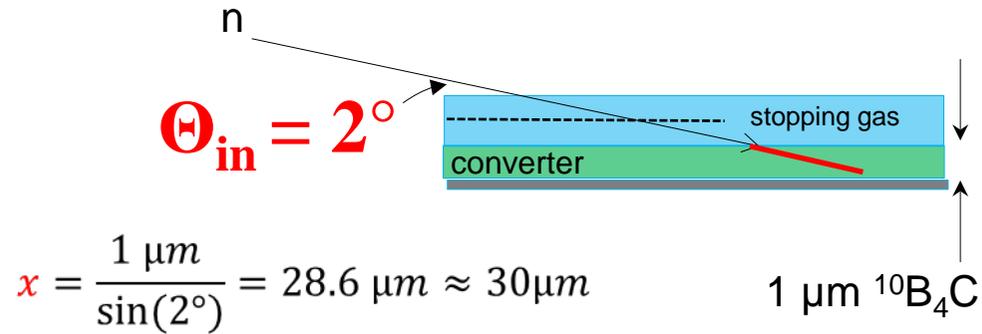
- i) penetration length in  $^{10}\text{B}$  before absorption/capture for thermal – cold neutrons: **32  $\mu\text{m}$  - 12  $\mu\text{m}$**
- ii) ion range for  $\alpha$ -particle: **3.2-3.9  $\mu\text{m}$**  and for  ${}^7\text{Li}$  particle: **1.5 – 1.7  $\mu\text{m}$**  in  $^{10}\text{B}_4\text{C}^{+,++}$

+ J. P. Biersack and L. Haggmark, Nucl. Instr. and Meth. 174, 257, (1980)

\*\*J. F. Ziegler, J. P. Biersack and U. Littmark, "The Stopping and Range of Ions in Solids", Pergamon Press, New York, (1985)

- iii) ion range for  $\alpha$ -particle: **2-3 mm** and for  ${}^7\text{Li}$  particle: **1 – 1.5 mm** in 1 bar  $\text{CF}_4$

## A1-CLD (Absorption in 1 Layer Conversion Detector):

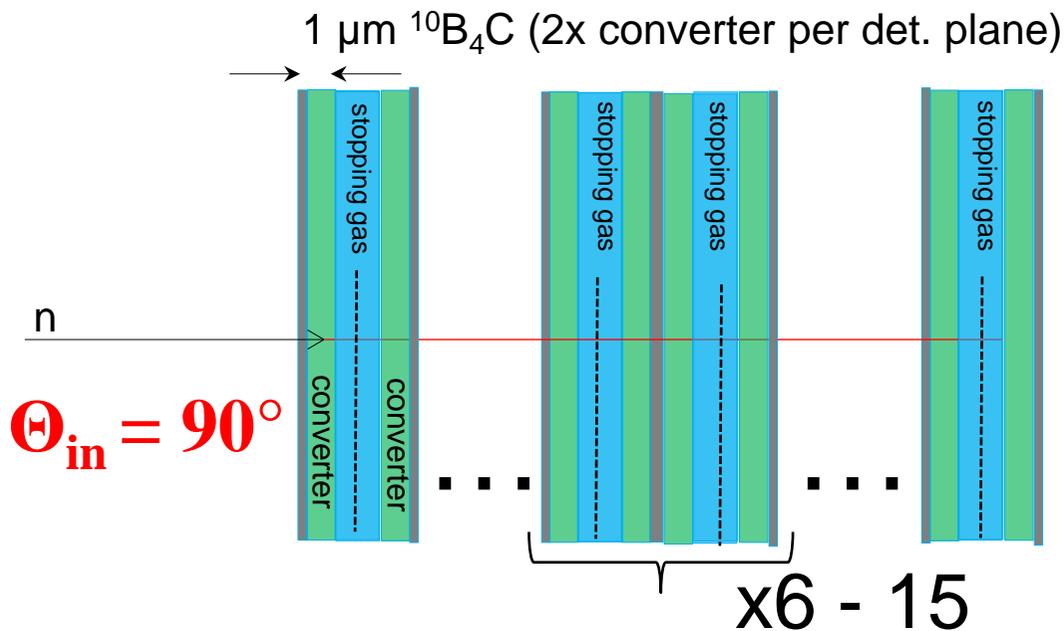


$^{10}\text{B}$  abs. length: **32  $\mu\text{m}$  - 12  $\mu\text{m}$**   
ion range: **3.9-1.5  $\mu\text{m}$**

- high conversion efficiency (++)
- position resolution: sub-mm! (++)
- fixed detector-sample distance (o)

good for SANS, HR-diffraction, (well collimated beam)

## Am-CLD (Absorption in multiple Conversion Detector):



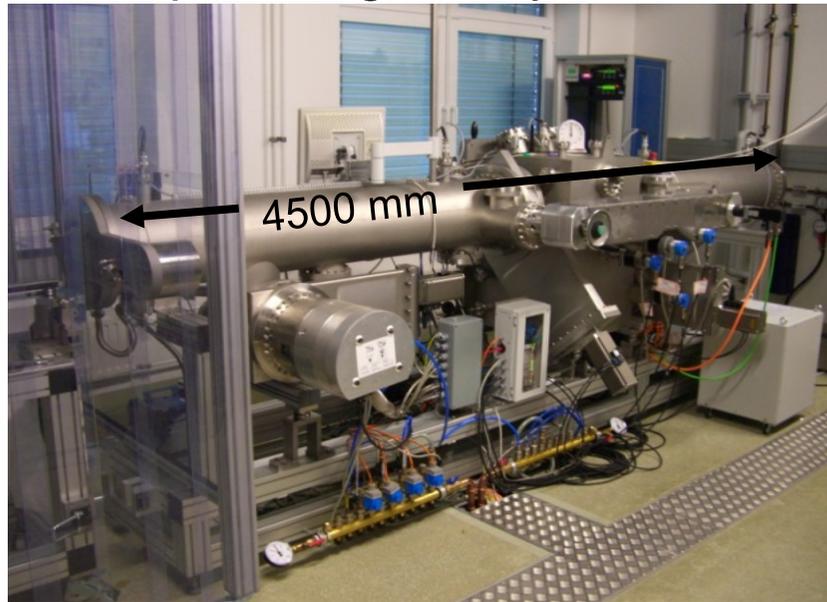
- position resolution: wire pitch mm (+)
- variable detector-sample distance (++)
- variable converter layer thickness (++)\*

good for diffraction, SANS, beam monitor

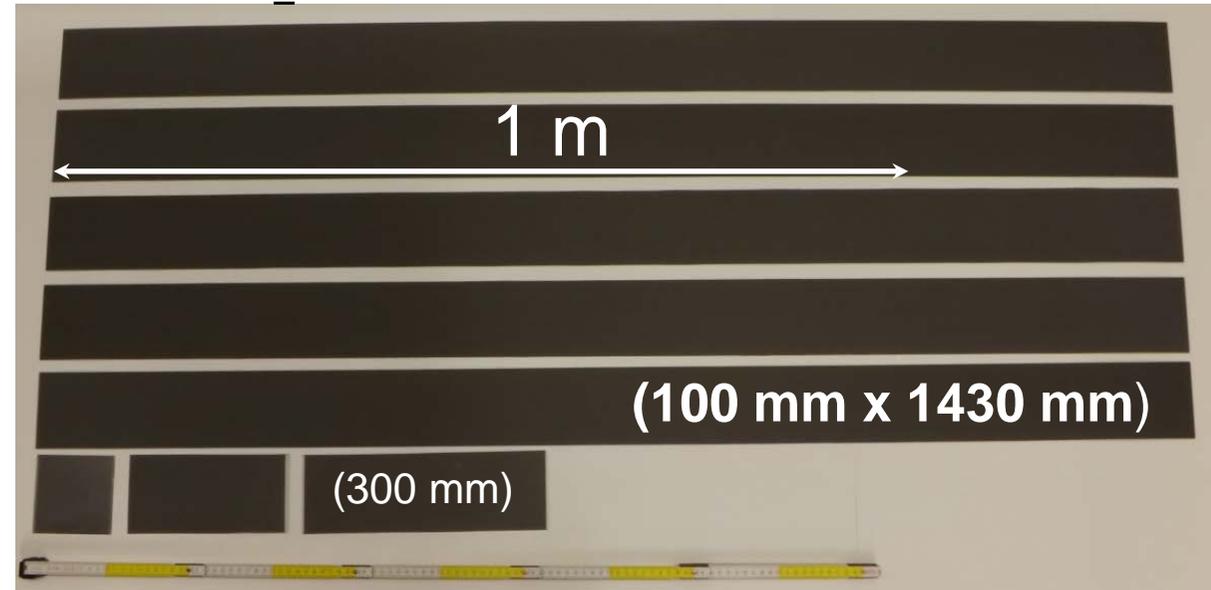
\*F. Piscitelli and P. Van Esch JINST 8, P04020, 2013

# $^{10}\text{B}_4\text{C}$ -conversion coatings

## HZG sputtering facility:

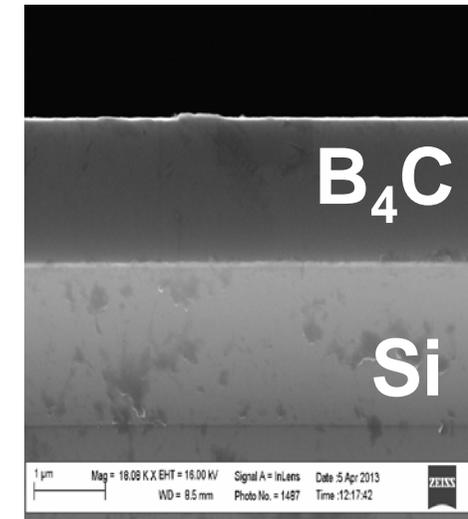
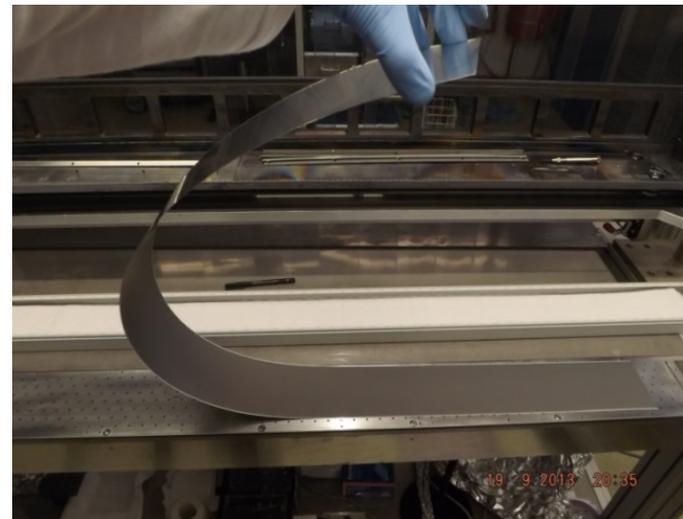


## 1.2 $\mu\text{m}$ $^{10}\text{B}_4\text{C}$ coatings on 0.3 mm Al:

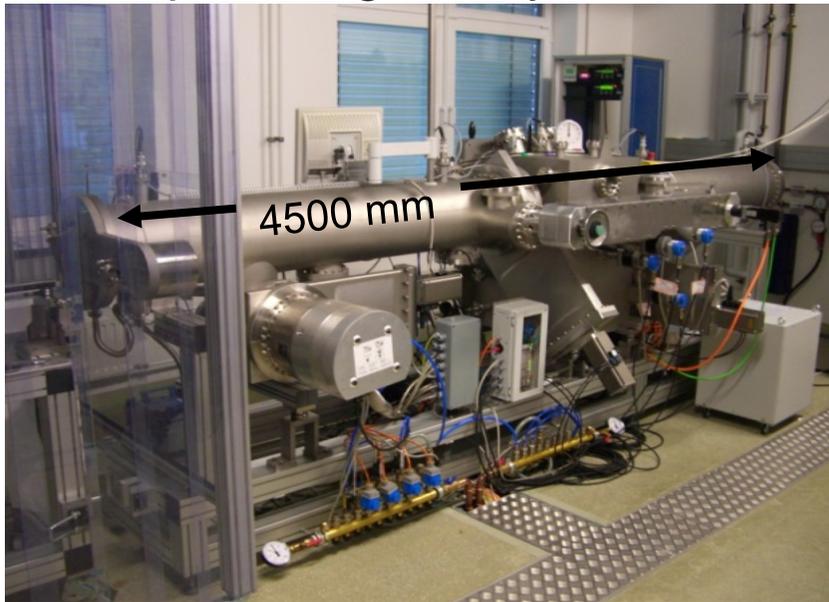


## coating characteristics:

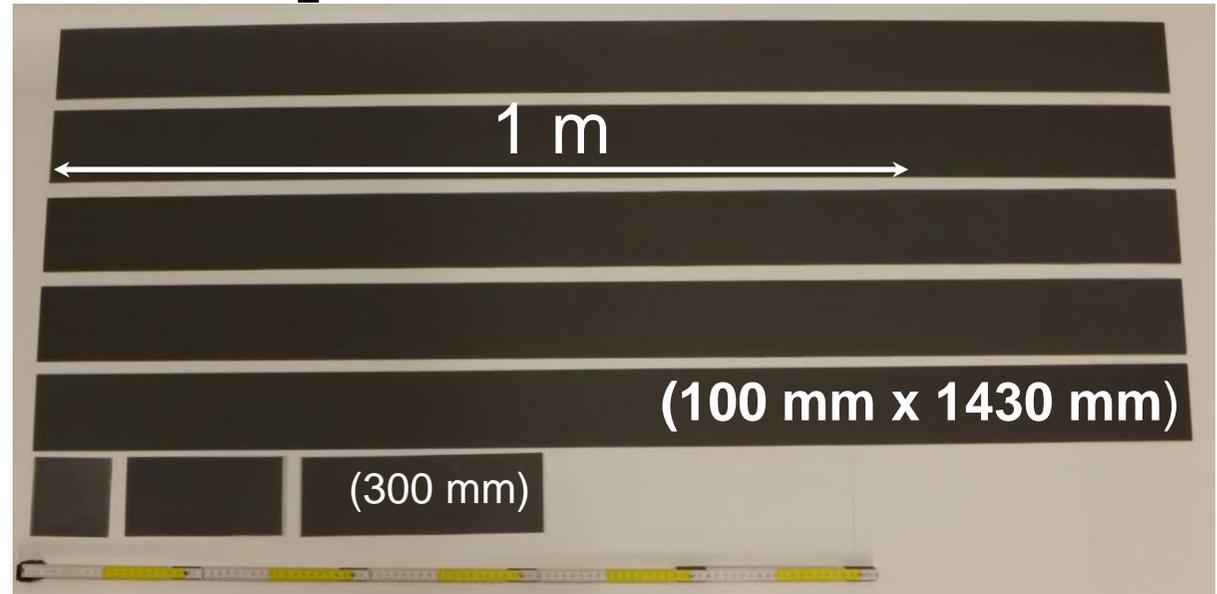
- amorphous, highly adhesive, almost lit. density
- highly flexible converters
- Hydrogen content: below **0.3 %**
- High neutron efficiency



## HZG sputtering facility:

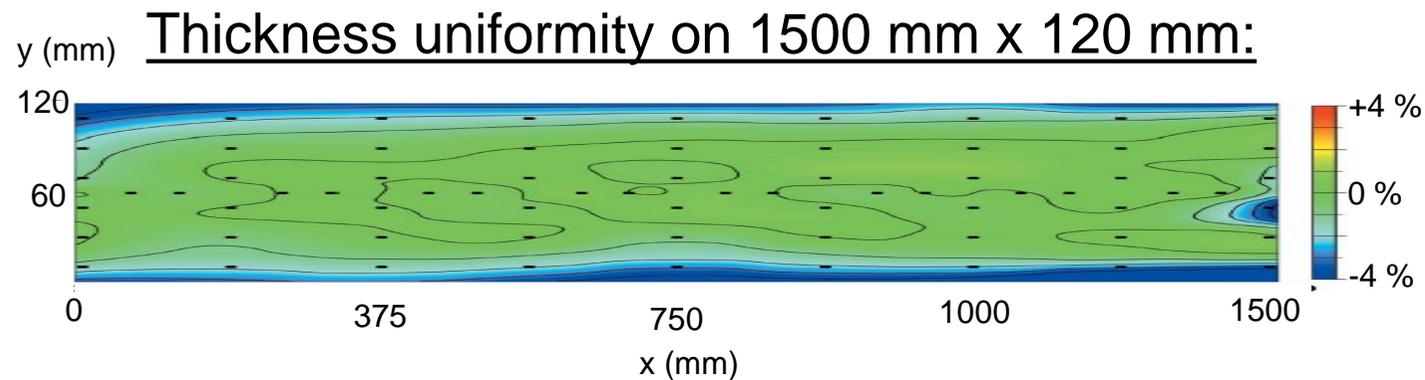


## 1.2 $\mu\text{m}$ $^{10}\text{B}_4\text{C}$ coatings on 0.3 mm Al:



## coating characteristics:

- highly uniform on 100 mm x 1500 mm **< 4 %**
- application also for X-ray mirrors at sync. sources w-w.
- content of residual gases (O, N, Ar,...) **< 2%**

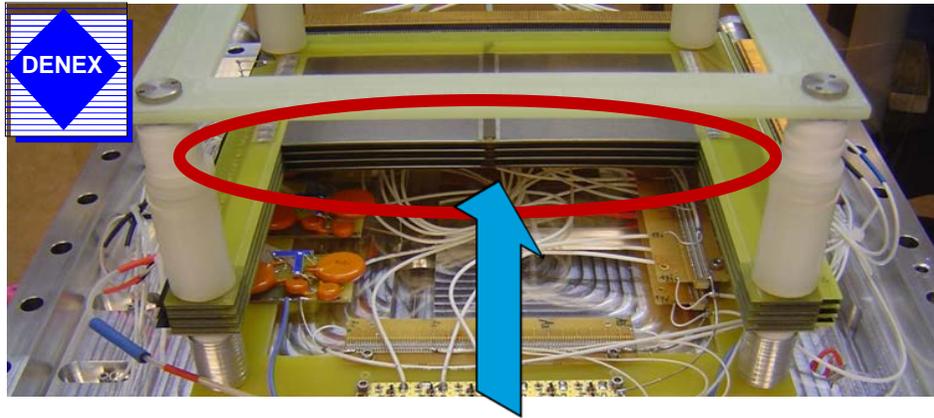


-M. Störmer, F. Siewert and H. Sinn, *J. Synchrotron Rad.*, **23**, 50-58 (2016)

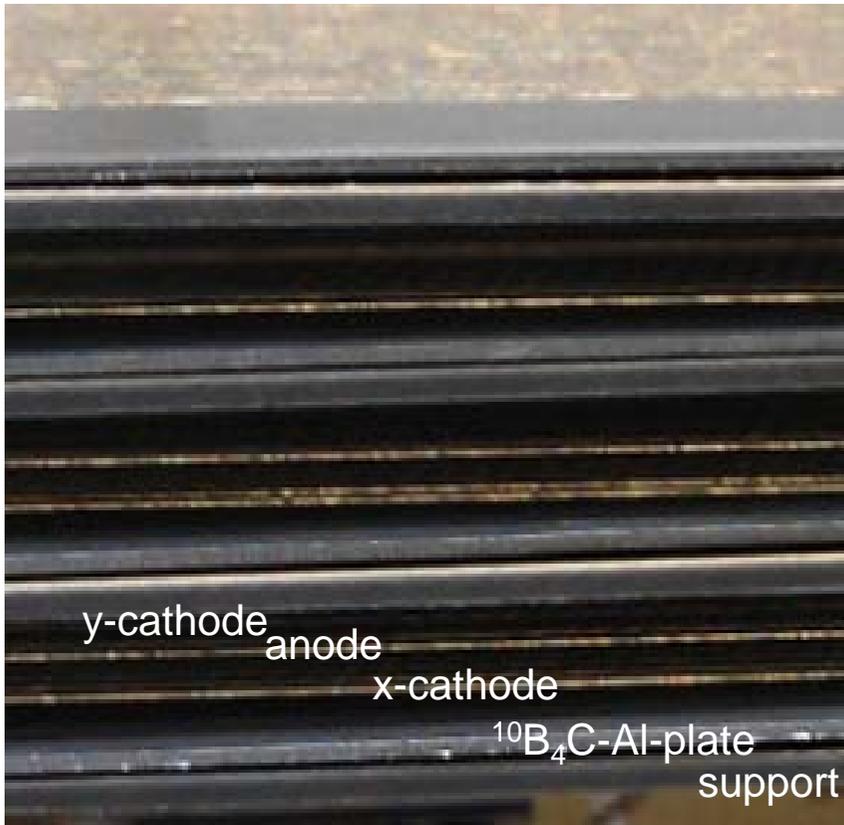
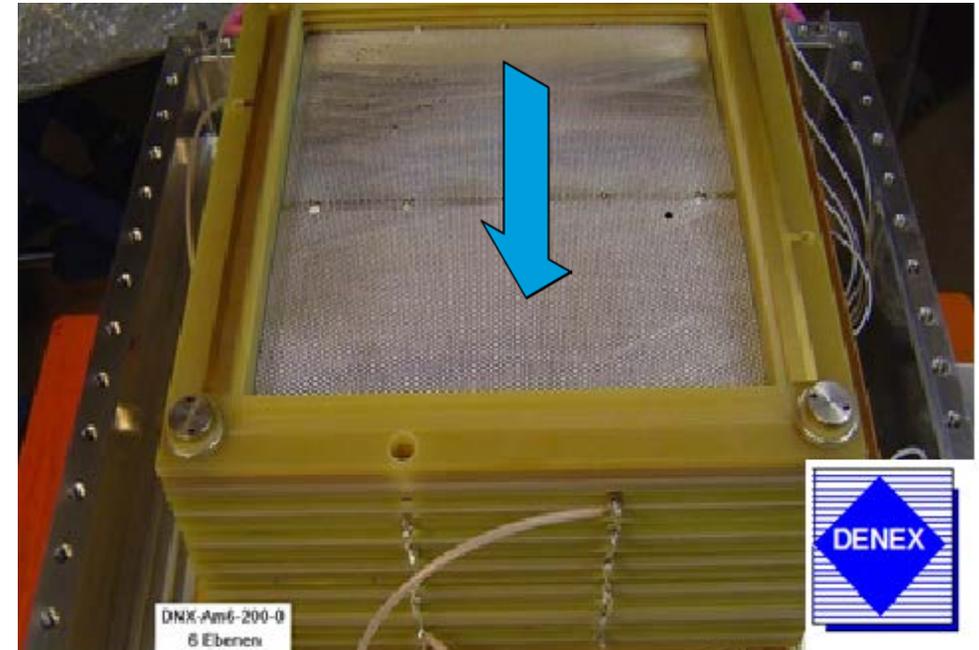
# Performance of A1- and Am-CLD

# Inside view in the A1- and Am-CLD prototype detectors (200 mm)

A1-CLD detector inside:

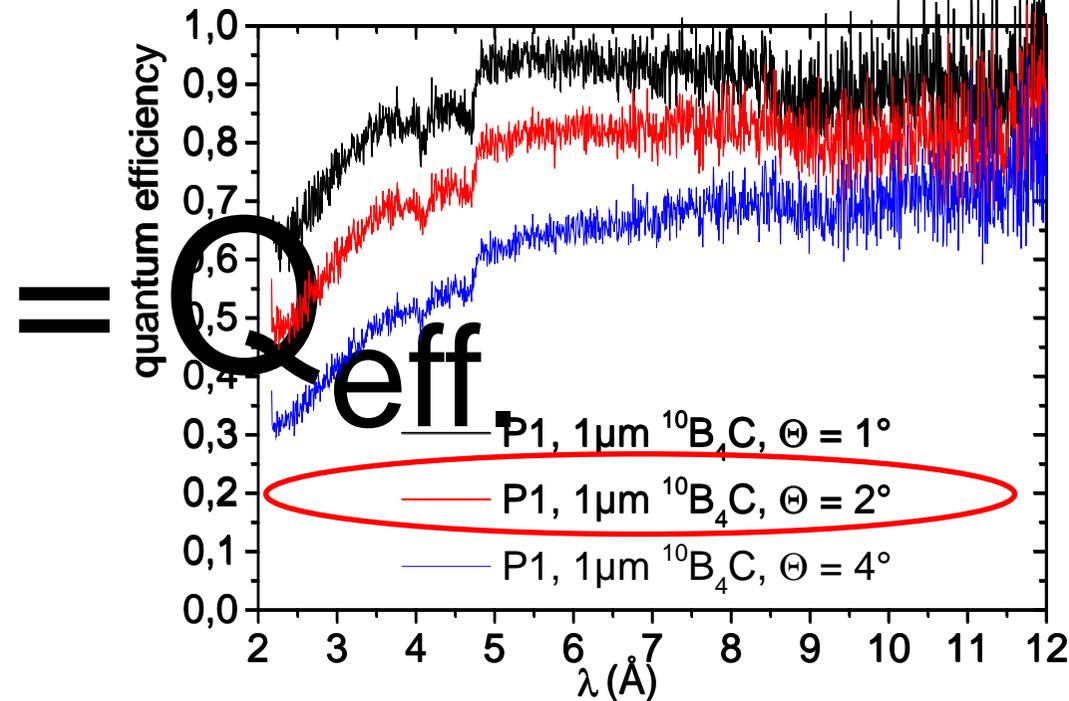
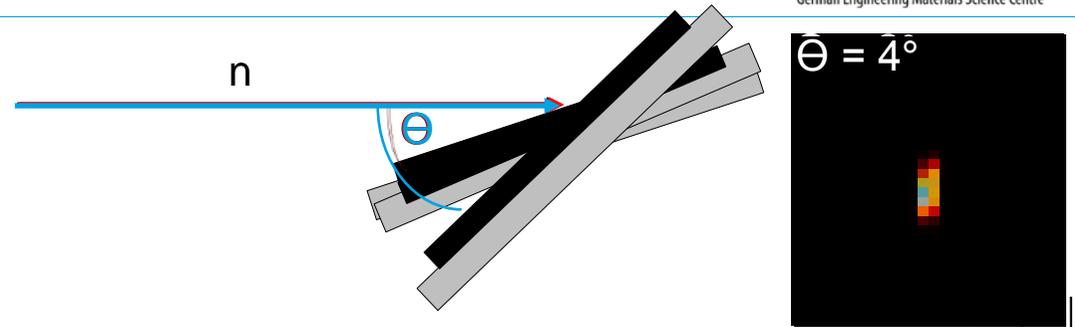
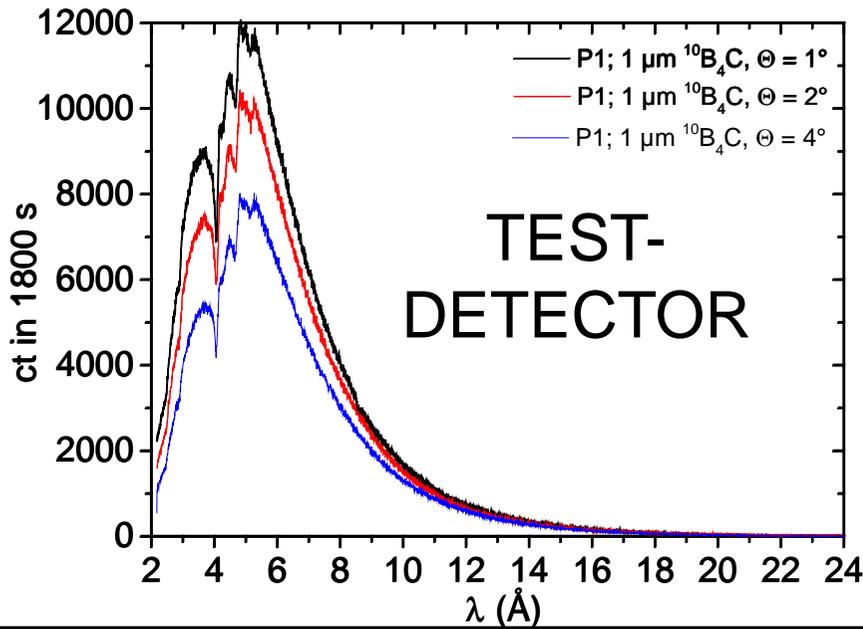


Am-CLD detector inside:



one partial detector plane (about 9 mm!)

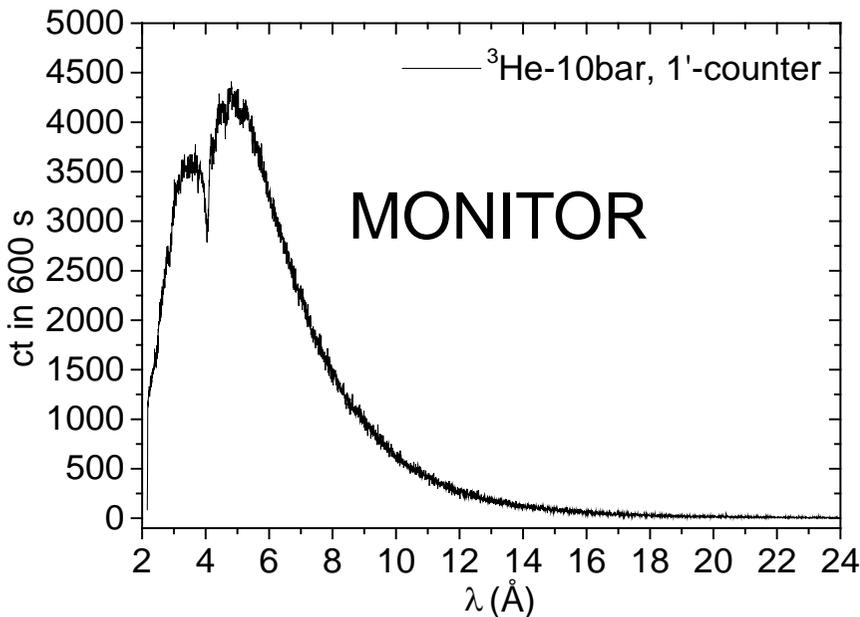
# Rel. quantum efficiency of 1 $\mu\text{m}$ $^{10}\text{B}_4\text{C}$ in the A1-CLD detector



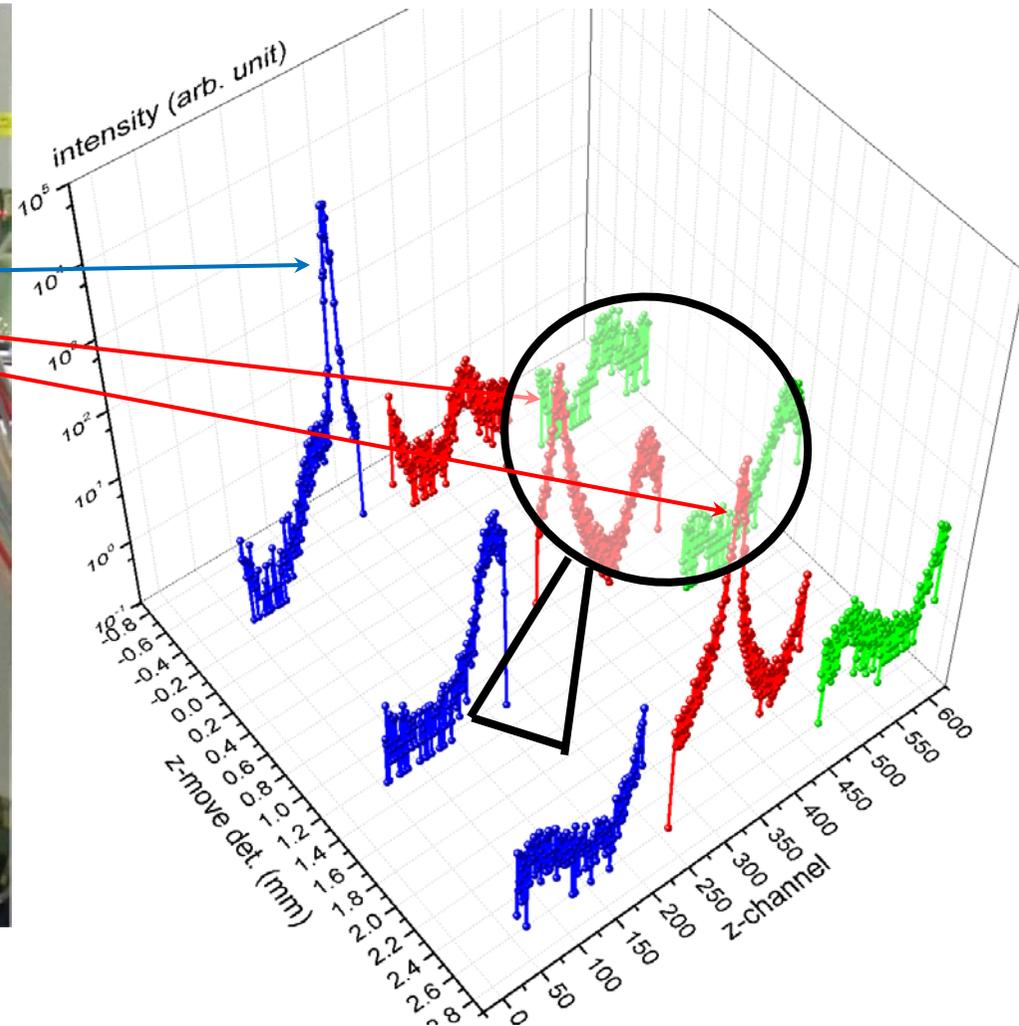
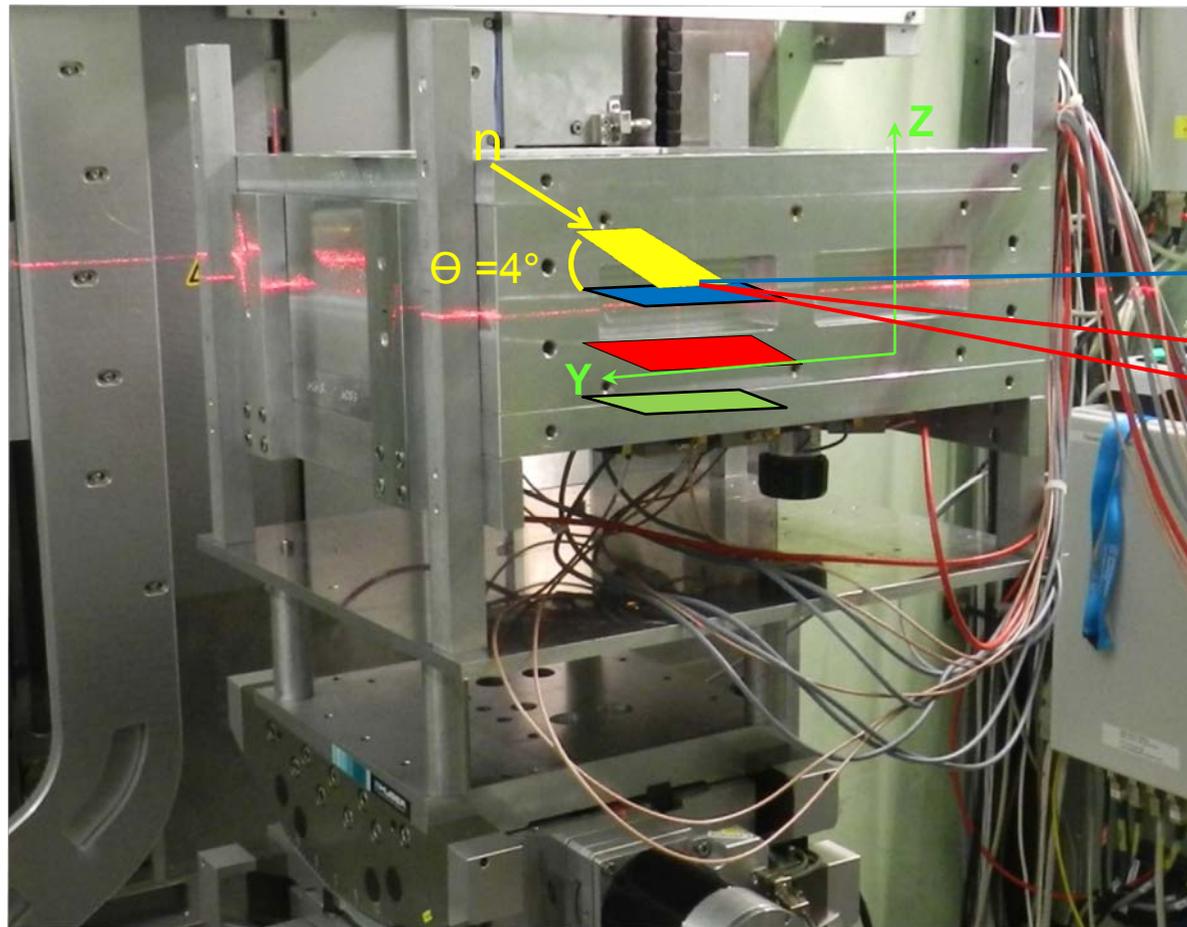
- $\Theta = 2^\circ$  is a good compromise eff.  $\leftrightarrow$  tech. feasibility
- rel.  $Q_{\text{eff}}$  of up to 85 % of a  $^3\text{He}$  counter tube

**measured @ REFSANS (MLZ)!**

**3x**

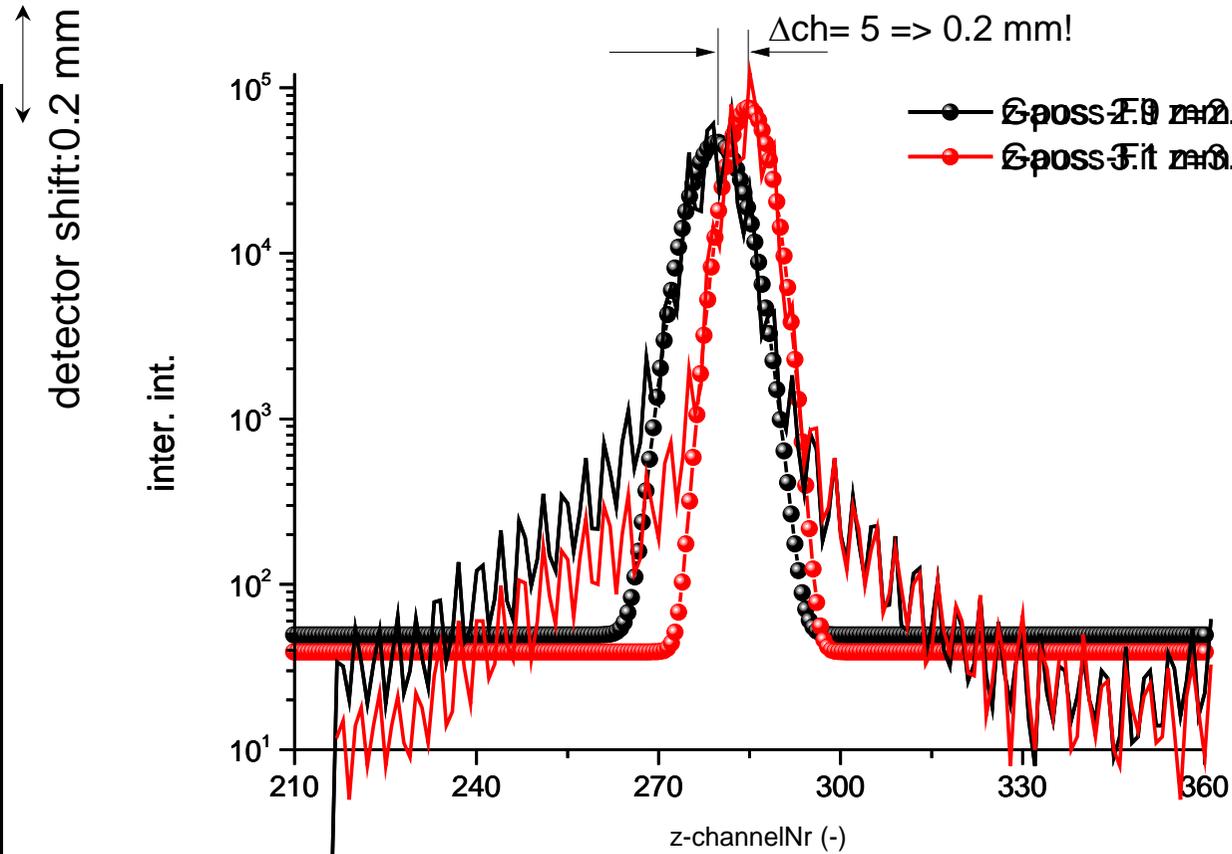
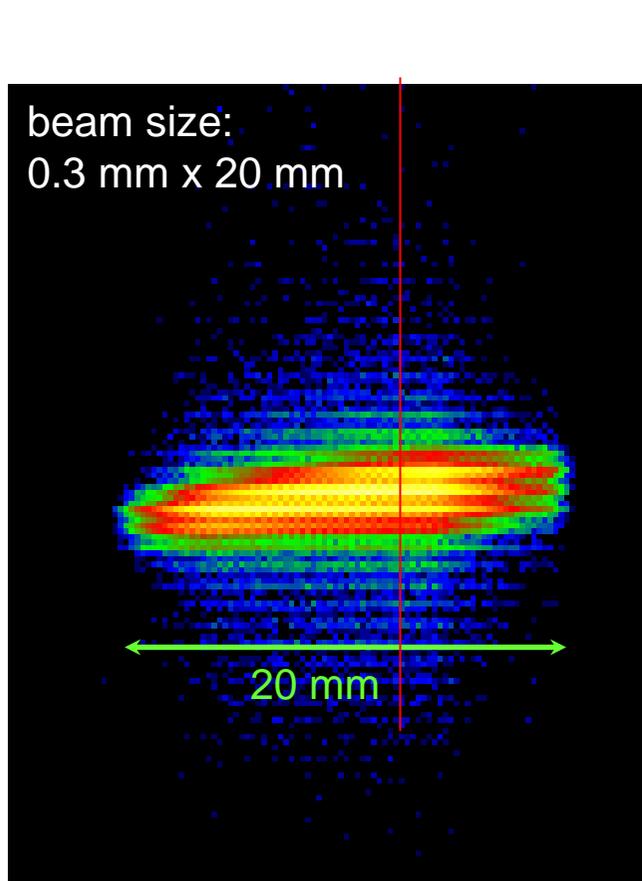


# Position detection by the A1-CLD detector



**measured @ REFSANS (MLZ)!**

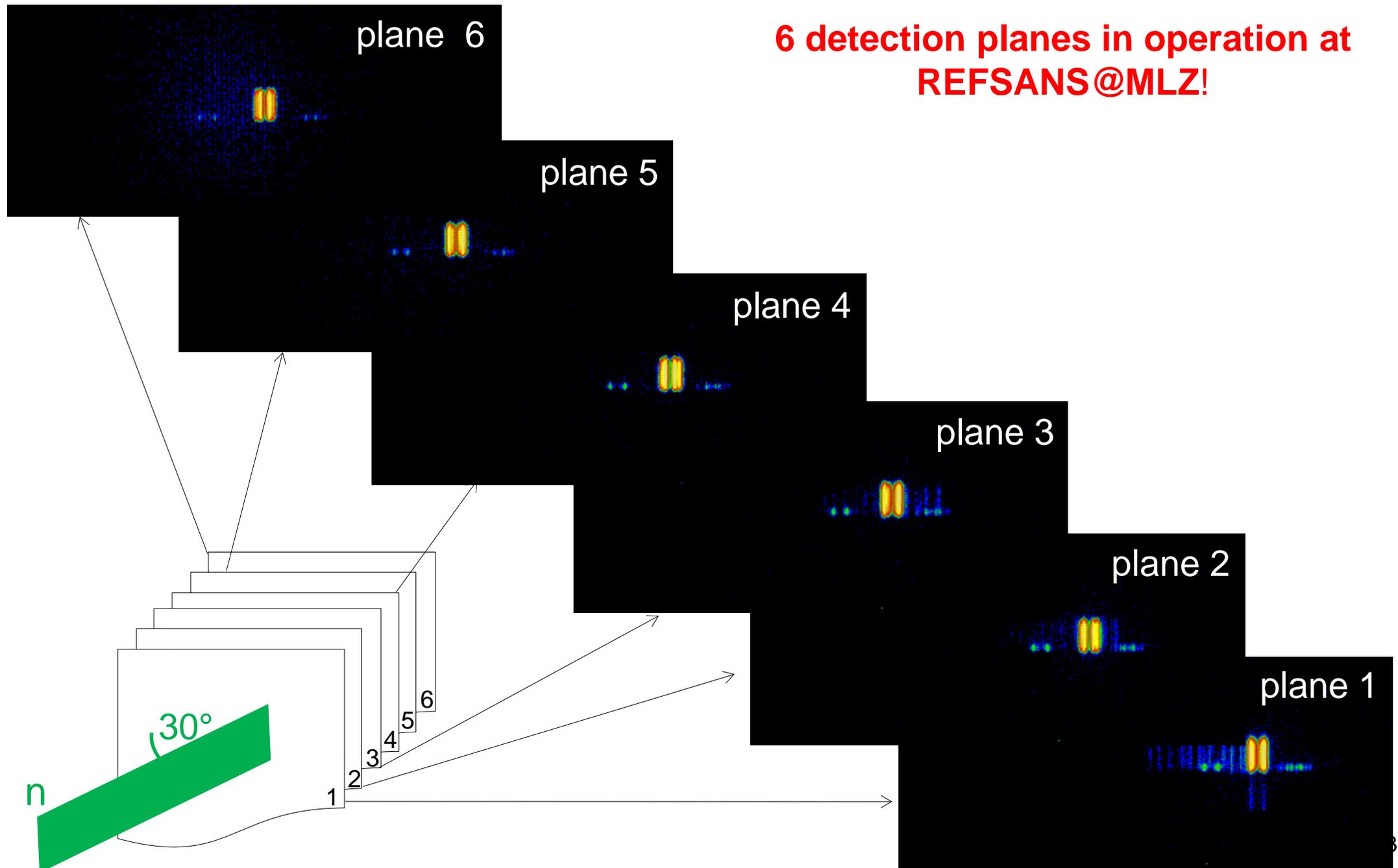
# High position precision of the A1-CLD detector concept



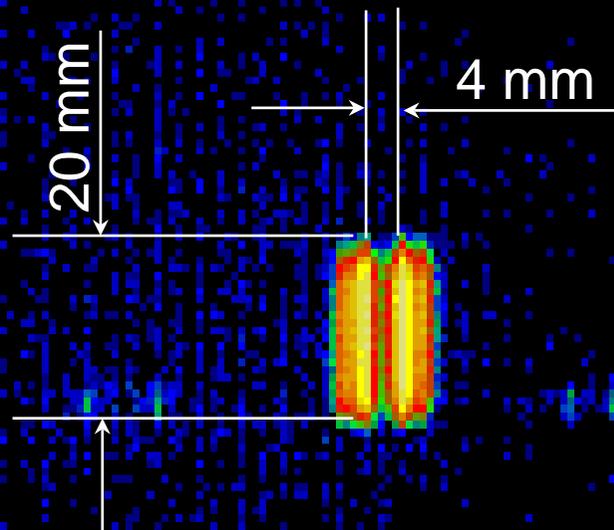
**$\Rightarrow$  position resolution  $< 0.1 \text{ mm}$   
for direction parallel to the converter plane normal!**

# Position resolution of the Am-CLD detector concept

**6 detection planes in operation at REFSANS@MLZ!**



plane 6



Position resolution  $< 4$  mm

# Milestones for the proposed project (Am-CLD)

# Am-CLD demonstrator detector for Diffraction (500 mm x 700 mm)

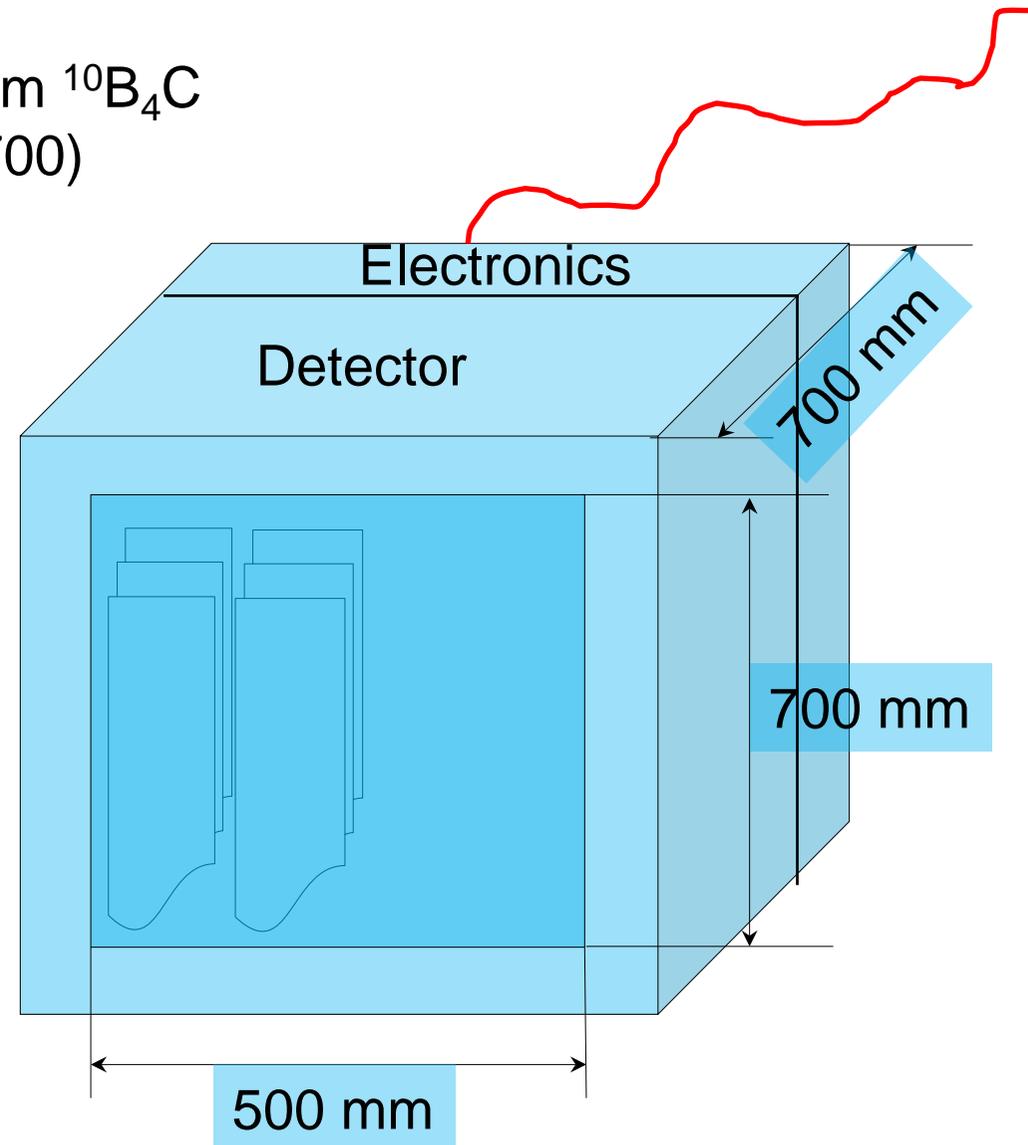
-Large housing allows for stepwise growing of the Am-detector to the final stage.

## Stage 1: (2015-2017)

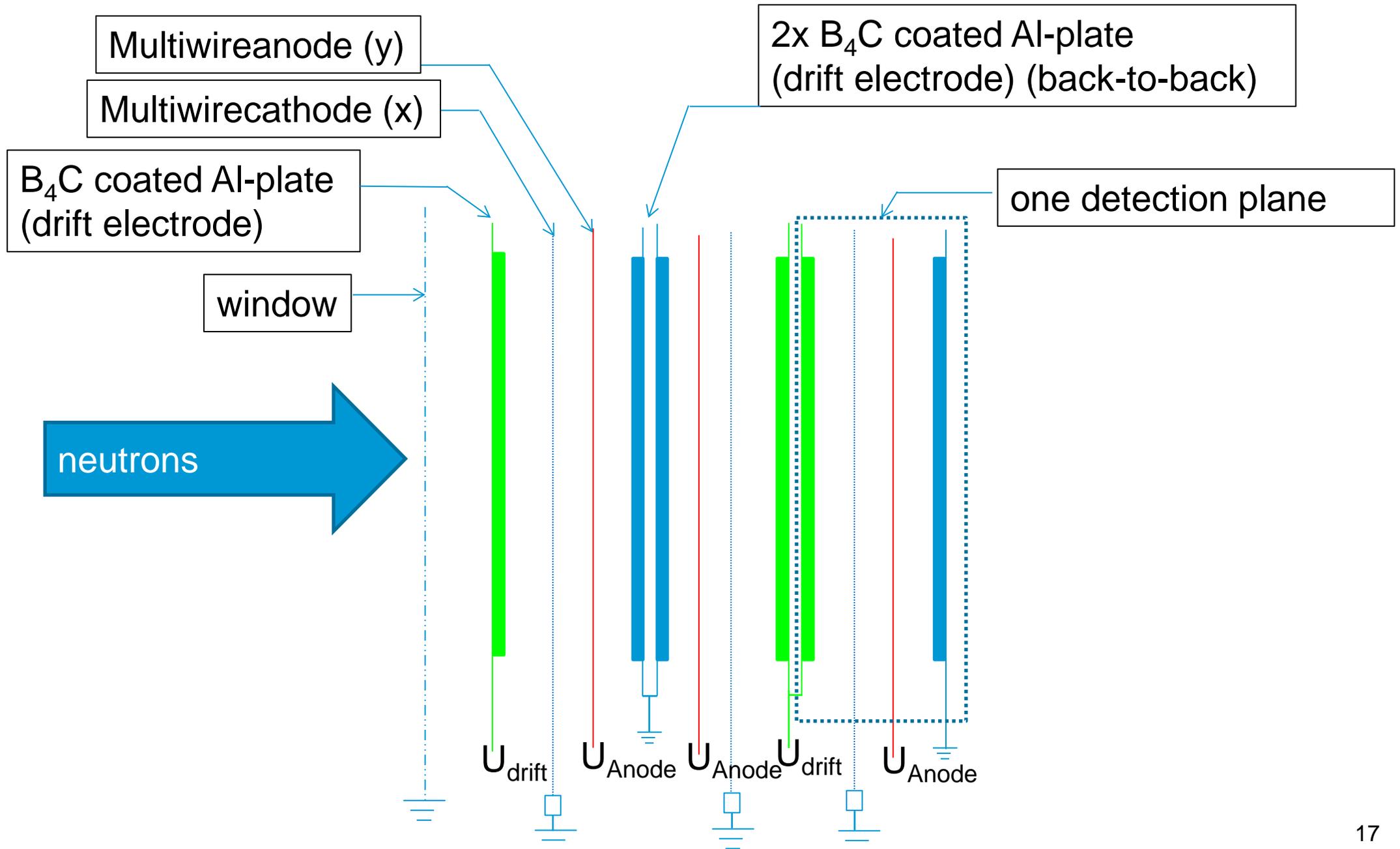
- 30 x (100 mm x 700 mm) converter  $1.2 \mu\text{m } ^{10}\text{B}_4\text{C}$
- Am-CLD with 3 detection planes (500 x 700)
- tests at **HZB, Rez** with neutrons:

## Challenges:

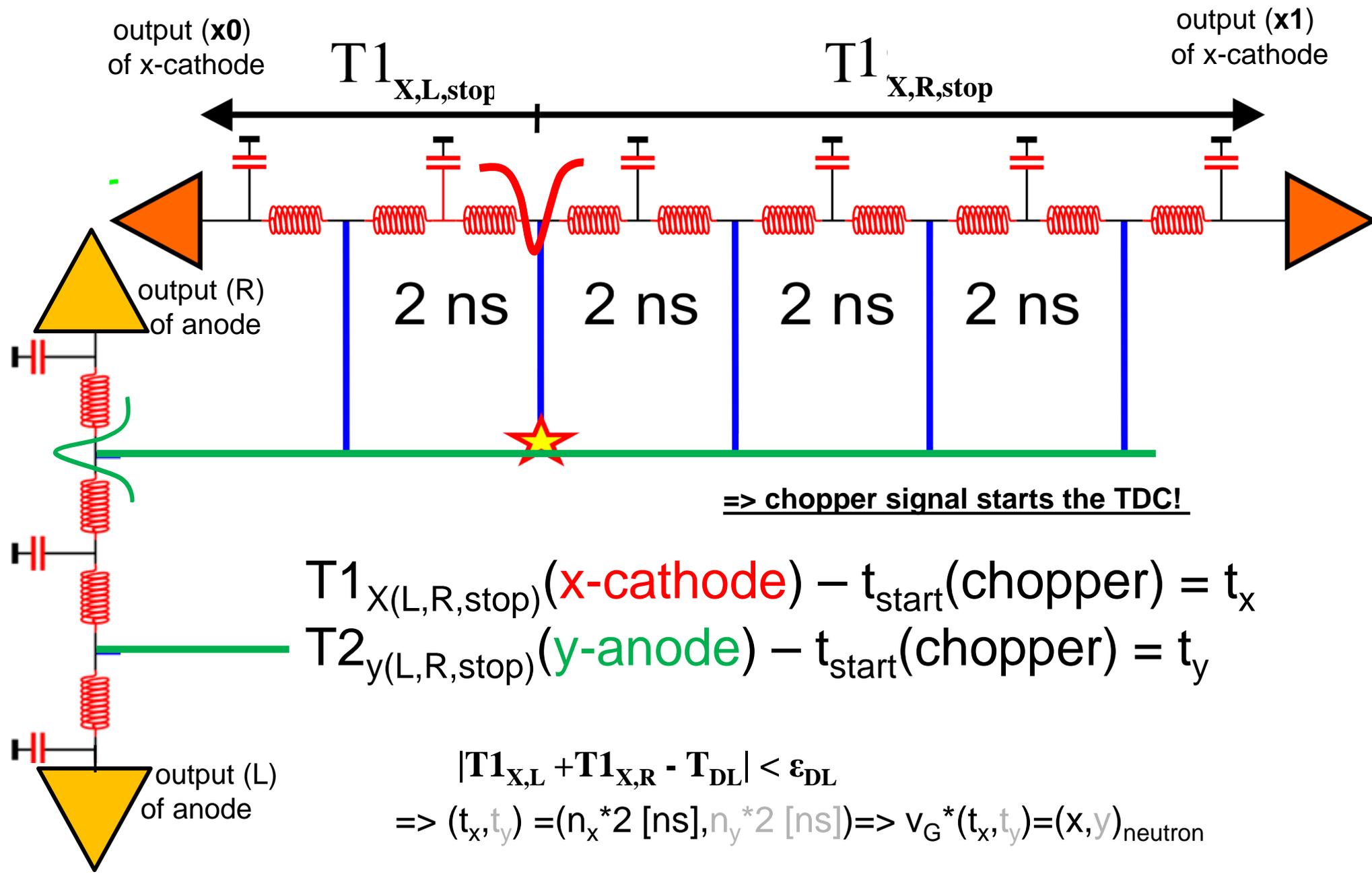
- 1) mech. support of converter planes
- 2) minimize dead zones between converters
- 3) minimization of detection plane depth (T resolution, parallaxe eff., housing Vol.)
- 4) read-out: electronics, software
- 5) Background



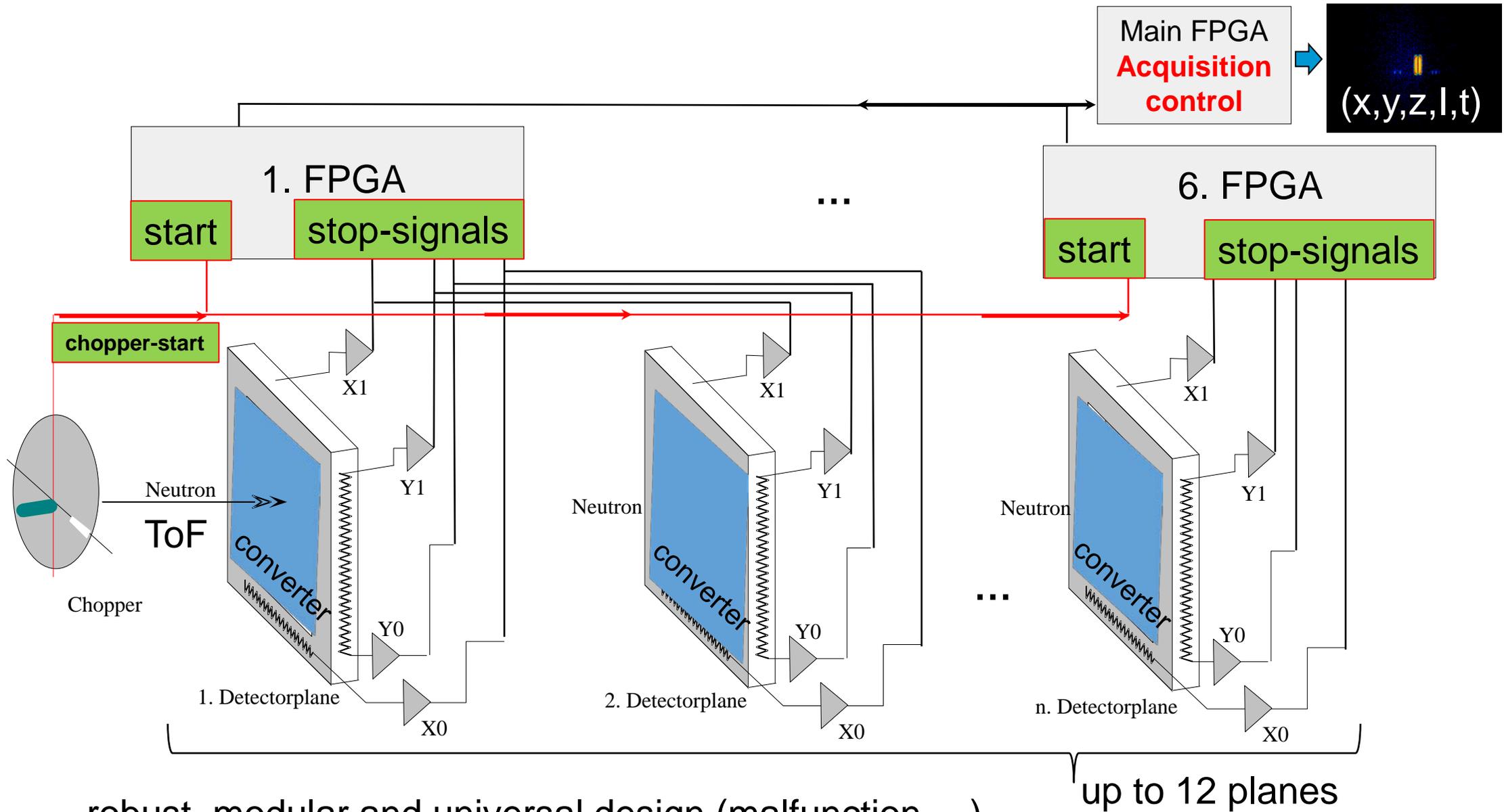
# Electrode set up of Am-CLD



# Position Encoding by delay line: chopper start (ToF-mode)



# Software TDC read out on FPGA



- robust, modular and universal design (malfunction,...)
- high position resolution/efficiency

# Performance of envisaged TDC read-out schema

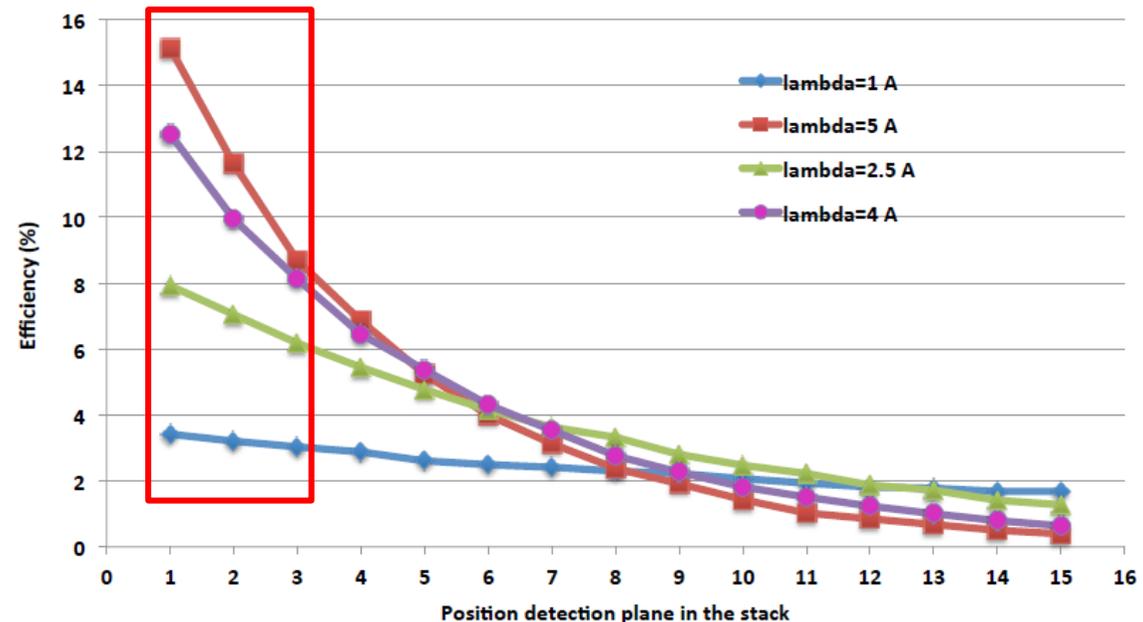
- $[4(\text{EL}) \times 3(\text{PL})] \times 2(\text{CFD} + \text{ToT}) + 1(\text{Ch.})$  TDCs (in time sampling mode) written on two FPGA (for 3 detection planes)
- 96 + x time channels should detect 20-30 ns wide falling and 30-40 ns wide rising edges of n-pulses (12 planes Am-CLD)
- Time stamps per plane for one event:  
 $[4(x, y) + \text{max. } 1(\text{ch.})] \times 2(\text{f/r}) \times 2(\text{ToT}) =$   
 max. 20 stamps in max. 64 bit string
- $4(\text{EL}) \times 2(\text{ED}) \times 2(\text{CFD} + \text{ToT}) \times (\text{Nr. PL}) \times (8\text{Byte})$ :  
 $\Rightarrow$  Data rate: < 128 Byte x event rate = data stream per plane
- max. Data rate at max. count rate (170 kHz per plane!):  
 a) 3 planes: about 65 MB/s  
 b) 12 planes: about 261 MB/s

more at poster: “Readout-Electronics for Delay-Line Detectors with  $^{10}\text{B}_4\text{C}$  Converters”

# Expected performance for Am-CLD (3 planes)

- ToF-Timing resolution: 1  $\mu$ s (limit geo.) - 1 ns (limit ele.) (spectroscopy, spin echo)
- Position resolution: 2 mm x 5 mm
- Rate capability: ave. 170 kHz per plane  $\Rightarrow$  global: 3 x 170 kHz  $\Rightarrow$  (12 planes): 2 MHz
- Data stream at highest rate: 65 MB/s (3 planes); 261 MB/s (12 planes)
- Efficiency: 10 – 36 % at 1- 5  $\text{\AA}$

Efficiency per detection plane for a stack of 15 double-sided coated  $^{10}\text{B}_4\text{C}$  layers, 1.2  $\mu\text{m}$ .

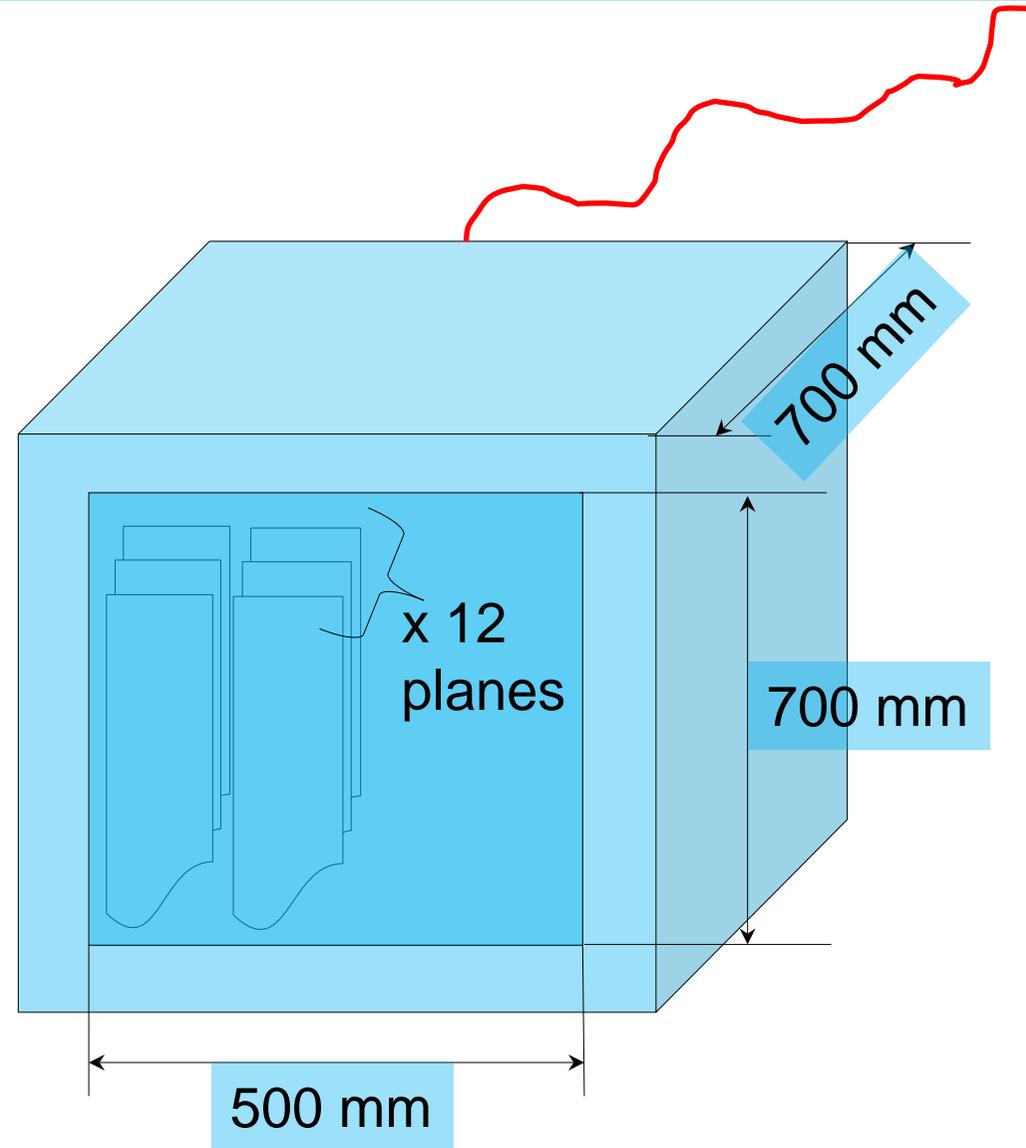
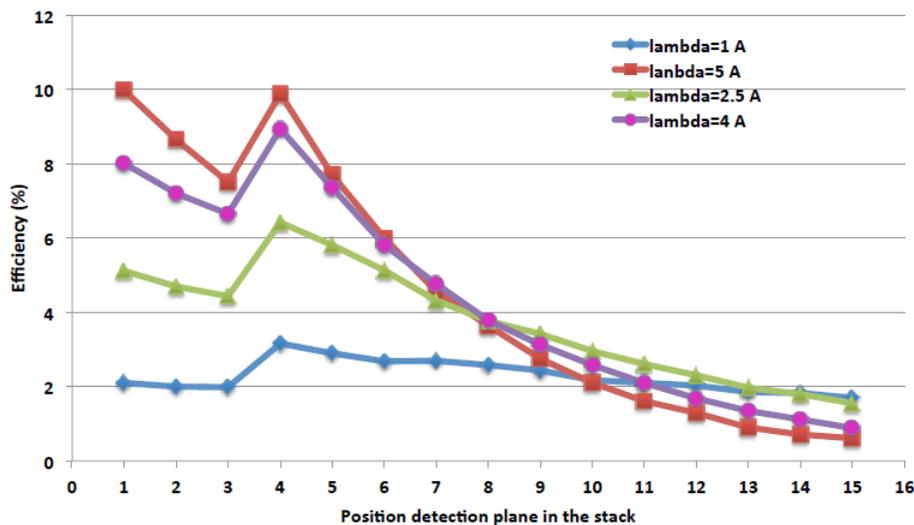


# Am-CLD demonstrator detector for Diffraction (500 mm x 700 mm)

## Stage 2: (after 2017)

- 150 x (100 mm x 700 mm) converter
- Am-CLD with 12 detection planes (500 x 700)
- tests at **HZB/REZ/ESS** with neutrons:
  - 1) amount of coatings Link.  $\leftrightarrow$  HZG
  - 2) read-out: electronics, software
  - 3) thicknessprofil
  - 4) Background

Efficiency for a stack with 3 x double-sided coated with 0.6 um + 12 x double-sided coated with 1.2 um.



## Time line of the Am/A1-CLD

x/2016 – x+2/2016: coating of the unfinished 8x(500 mm x 700 mm) and 31x(100 mm x 200 mm) converter elements

x/2016 – x+3/2016: Coating tests in high neutron flux

x/2016 – x+3/2016: Development/fabrication of trigger board/s

x/2016 – x+4/2016: programming of TDC read-out on FPGA for one 2D-plane

x/2016 – x+3/2016: fabrication of housing and first partial detector (500 mm x 700 mm)

x/2016 – x+2/2016: pre-characterization, Neutron tests at beamlines (also A1), data eva.

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x/2017 – x+4/2017: programming of TDC read-out on FPGA for x-2D-plane

x/2017 – x+4/2017: fabrication additional x-2D-planes in the detector housing

x/2017 – x+5/2017: pre-characterization, Neutron tests at beamlines (also A1), data eva.

x/2017 – x+2/2017: reports, publication

# Summary

- well performing A1 and Am-CLD presented
- High quality coating process on large size substrates is manifested (papers, patent pending)
- proposed future activity established on solid, results.
- mechanical engineering challenges in the up-scaling of the detector present.
- Size and position resolution of proposed Am-CLD detector meets request of diffraction beamlines @ ESS
- envisaged TDC read-out schema copes for 2 MHz global count rate at an high detection efficiency and at a moderate data stream.
- The read-out hardware is for A1-CLD and Am-CLD identic. “One for all”

Thank you for your attention!