CDT
Cascade Detector Technologies GmbH
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69123 Heidelberg, Germany
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The ^{10}B-based Jalousie Neutron Detector

ICON-10, Düsseldorf, 18.02.2016

Christian J. Schmidt

CDT

Our solution for POWTEX (FRM-II) as alternative for ^{3}He-filled PSD counter tubes

POWTEX

Project leader:
Andreas Houben
RWTH Aachen

JARA Jülich Aachen Research Alliance

JÜLICH FORSCHUNGSZENTRUM

RWTH AACHEN

JCNS
ZAT, ZEL

Solid state and quantum chemistry

Texture analysis

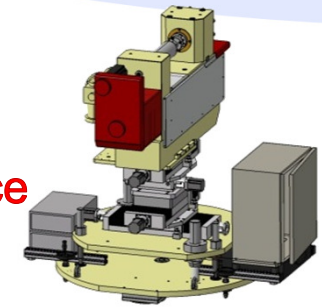
Bundesministerium für Bildung und Forschung

Verbundforschung

High pressure station SAPHiR

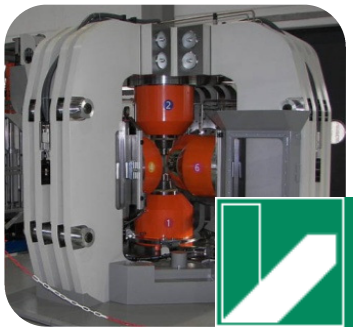
Jens Walter

Christian Randau



GZG Geowissenschaftliches Zentrum Göttingen

Geo-Science University Göttingen



Nico Walte

UNIVERSITÄT BAYREUTH

H. Conrad, Th. Brückel, W. Schäfer, J. Voigt, *J. Appl. Cryst.* **41.**, 836 (2008).
A. Houben, W. Schweika, Th. Brückel, R. Dronskowski, *Nucl. Instr. and Meth. A* **680**, 124 (2012).

CDT GmbH contracted by RWTH Aachen for concept, design and realization at FRM II, cooperation with FZJ/JCNS through JARA

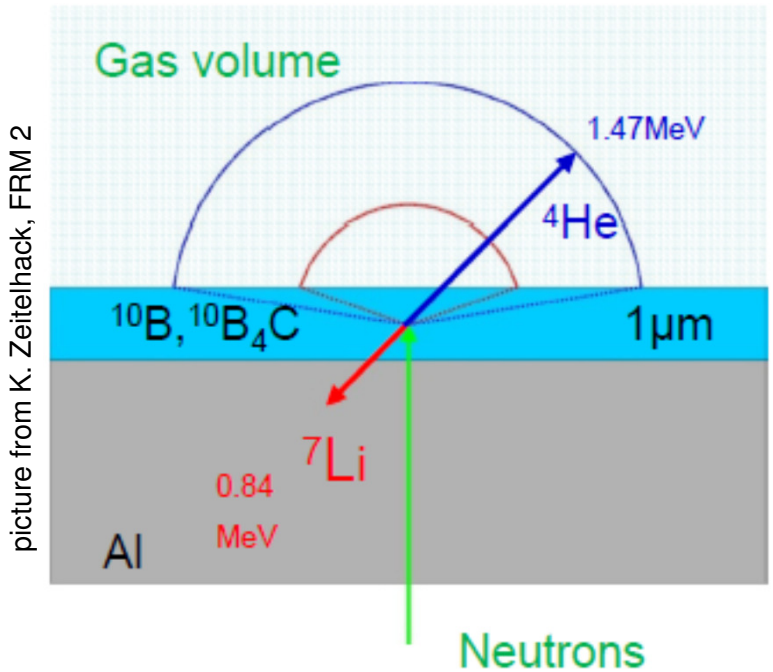
Neutron detection with ^{10}B converters

$^{10}B + n \rightarrow {}^{7}Li\ (1.02\ MeV) + \alpha\ (1.78\ MeV)$ (6%)

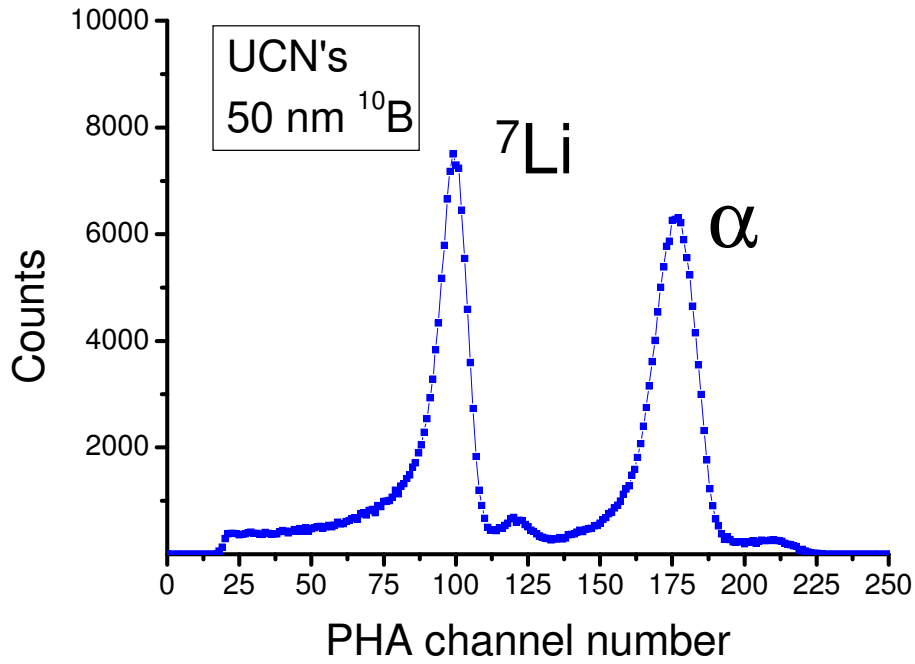
$\rightarrow {}^{7}Li\ (0.84 MeV) + \alpha\ (1.47\ MeV) + \gamma\ (0.48\ MeV)$ (94%)

3838 b (1.8 A)

- ^{10}B and $^{10}B_4C$ are stable, inert (compared to BF_3) and non hygroscopic (as e.g. Li, BF_3)
- > 96% enriched ^{10}B available (large industrial demands for ^{11}B)
- large charge-signal inside detector
- Ranges of α (3.14 µm) and ^{7}Li (1.53 µm) limit single layer detection efficiency to ~ 5% for thermal neutrons at vertical incidence

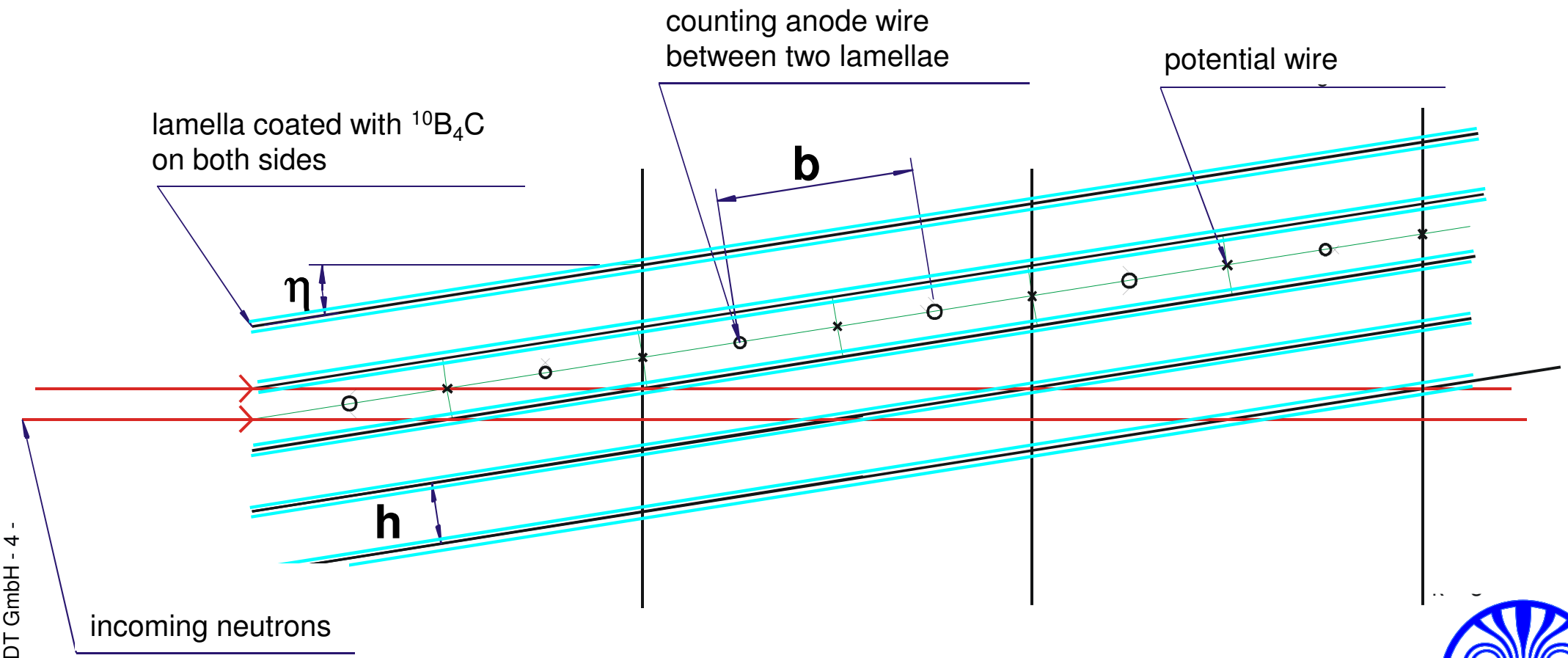


picture from K. Zeitelhack, FRM 2



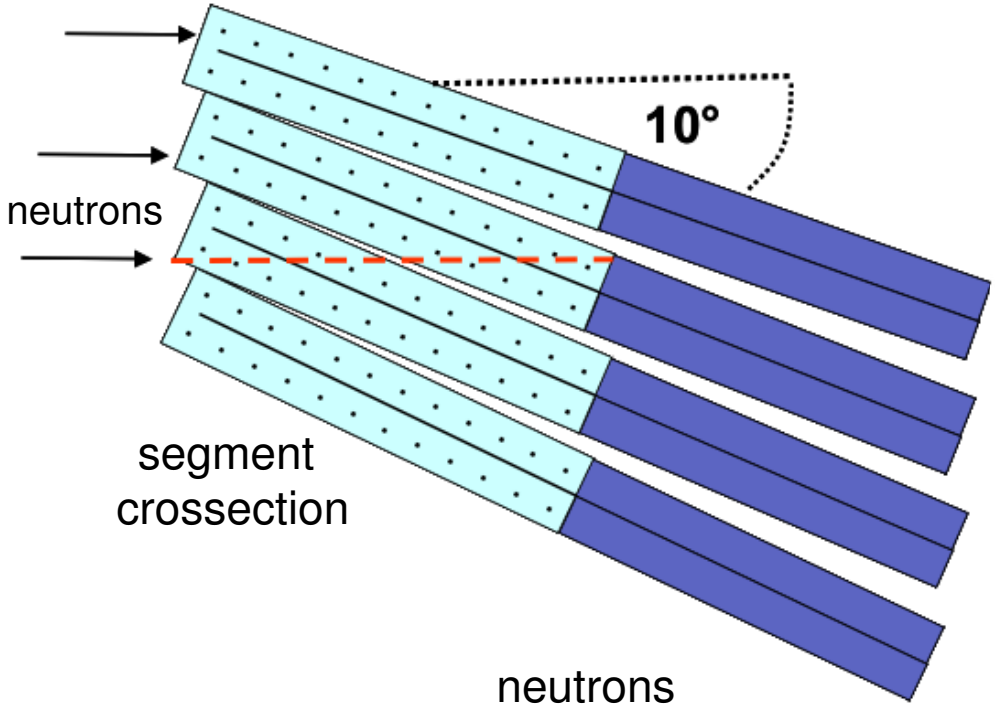
Jalousie: Detector Concept – neutrons at scraping incidence

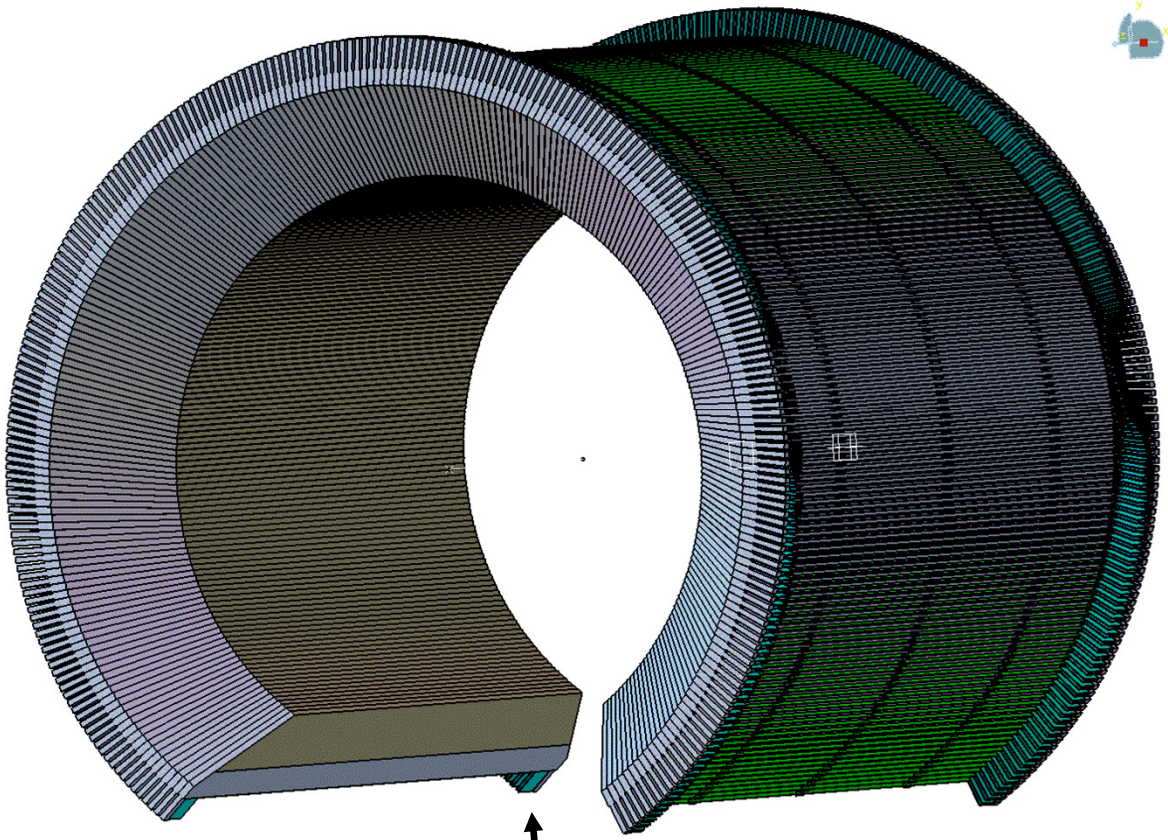
^{10}B-coated lamellae inclined to incoming neutron intensity at an angle of $\eta = 10°$

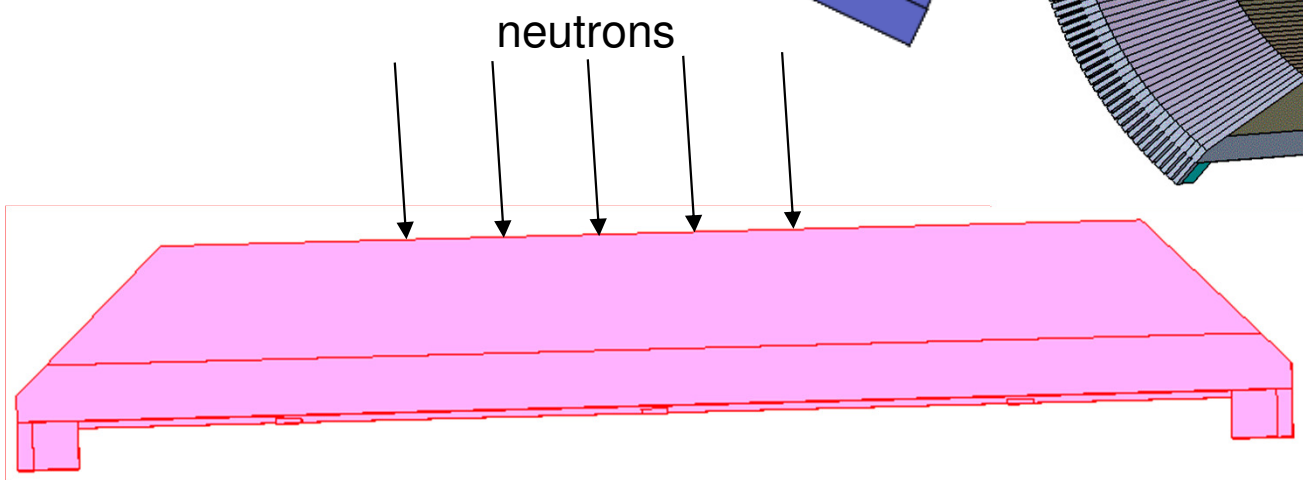


realized depth: 8 Boron/B_4C layers

Jalousie: Modular and Segmented for POWTEX Cylinder







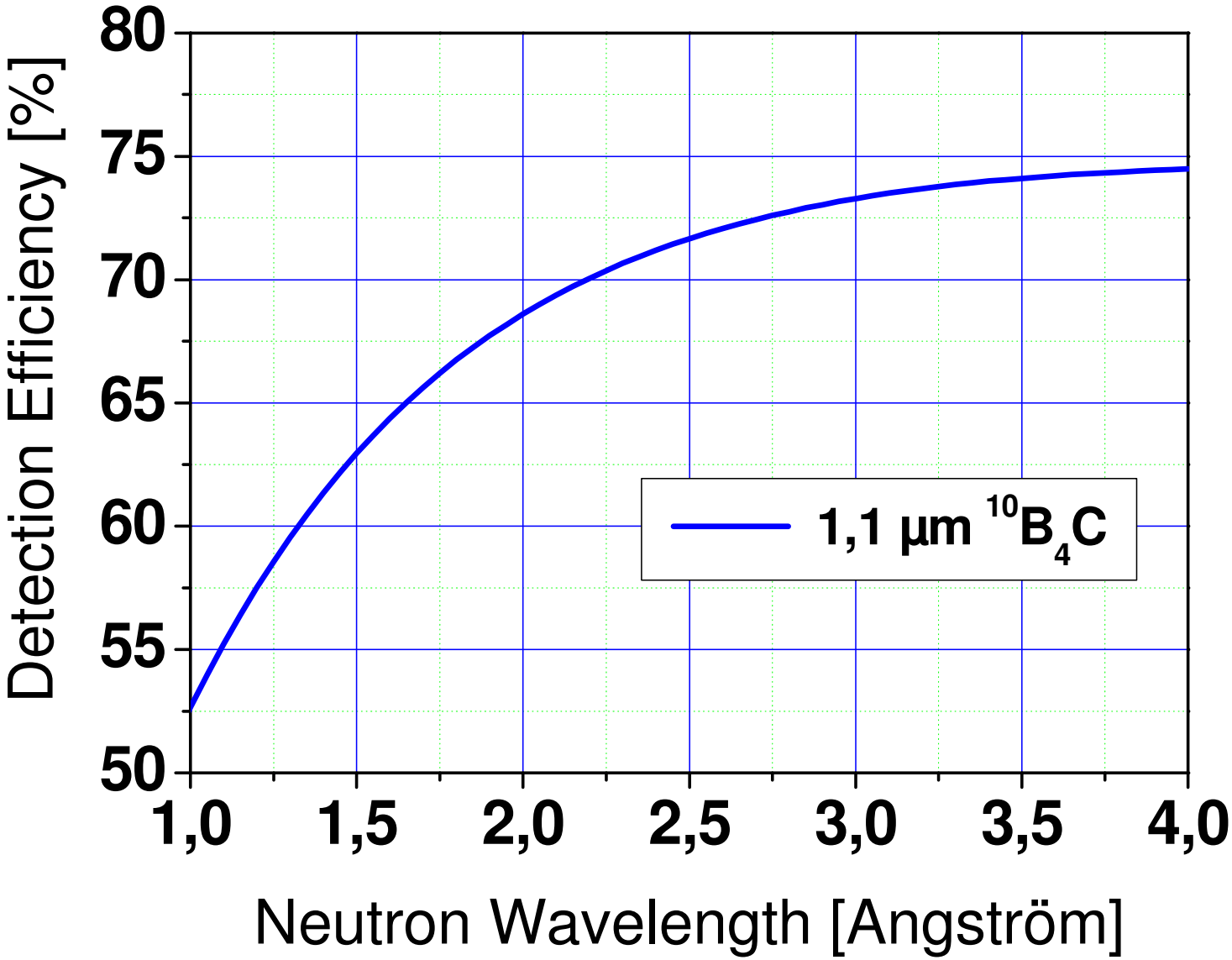
segment side view, 1,6m active length

240 segments
1,14° coverage each segm.
cylinder inner radius: 80cm

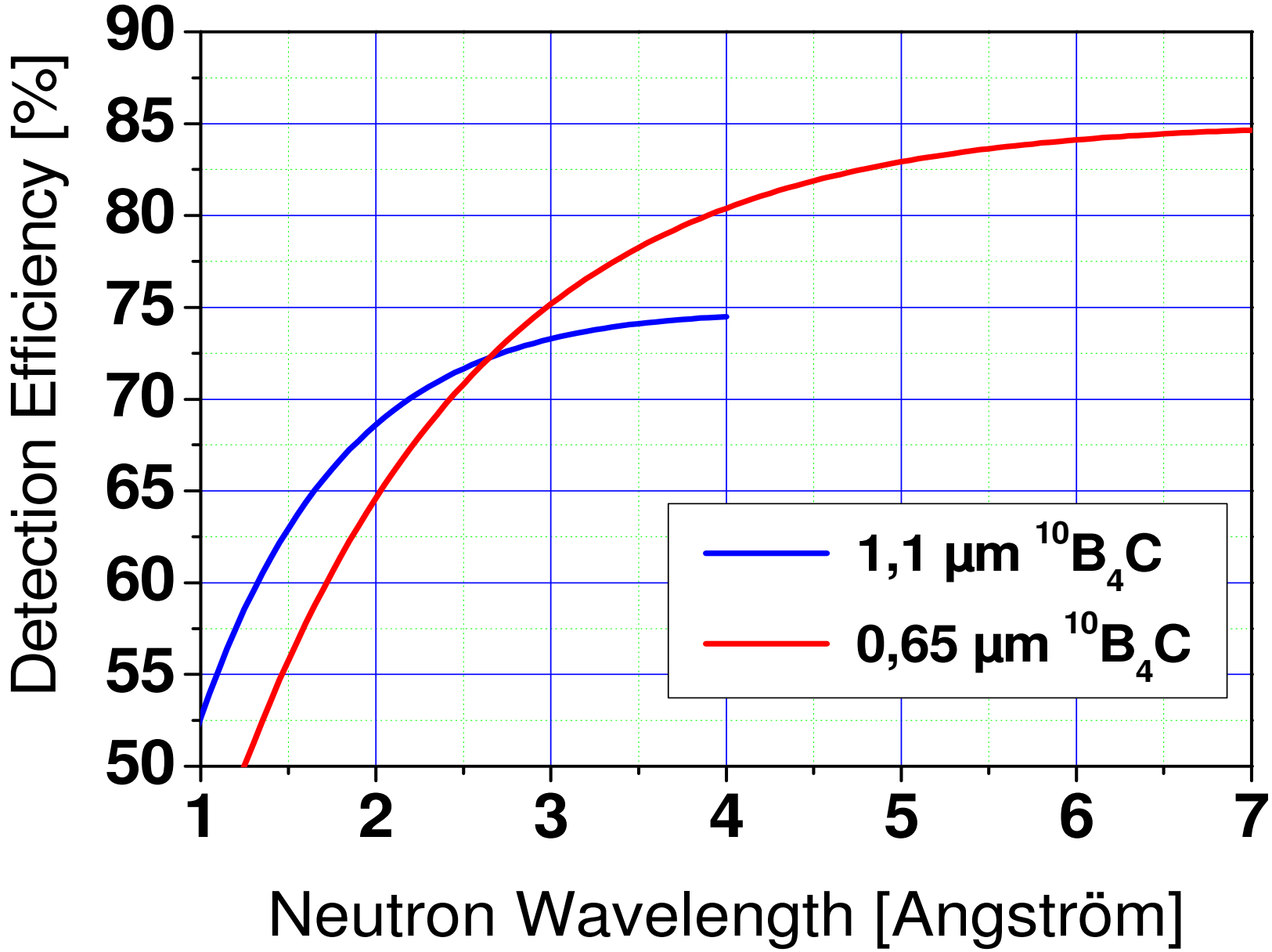
All-active detector entrance area, no blind areas !

Projected Detection Efficiency

Efficiency as function of wavelength, η = 10°, 8 $^{10}B_4C$ layers

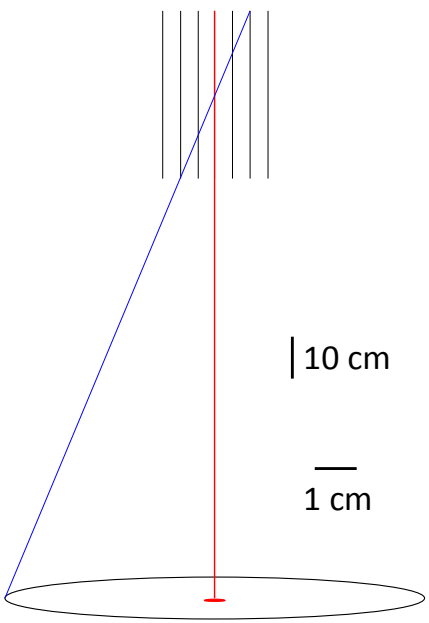


Efficiency may be optimized for the application

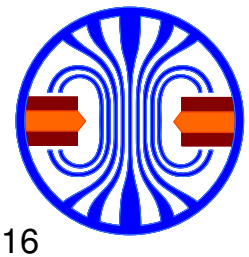


From Area- to Volume-Sensitivity

- POWTEX → Volume detector with VOXELs
  - born to cumulate detection efficiency → competitive to ^{3}He
  - enhancement in rate capability even with wire-chamber tech.
  - operation at ambient pressure → close to complete coverage, no pressure tanks
  - enhancement in point density
    → in depth voxels not aligned!
  - advanced options in background analysis
    → e.g. stray reflected rays
    → *intrinsic collimation*



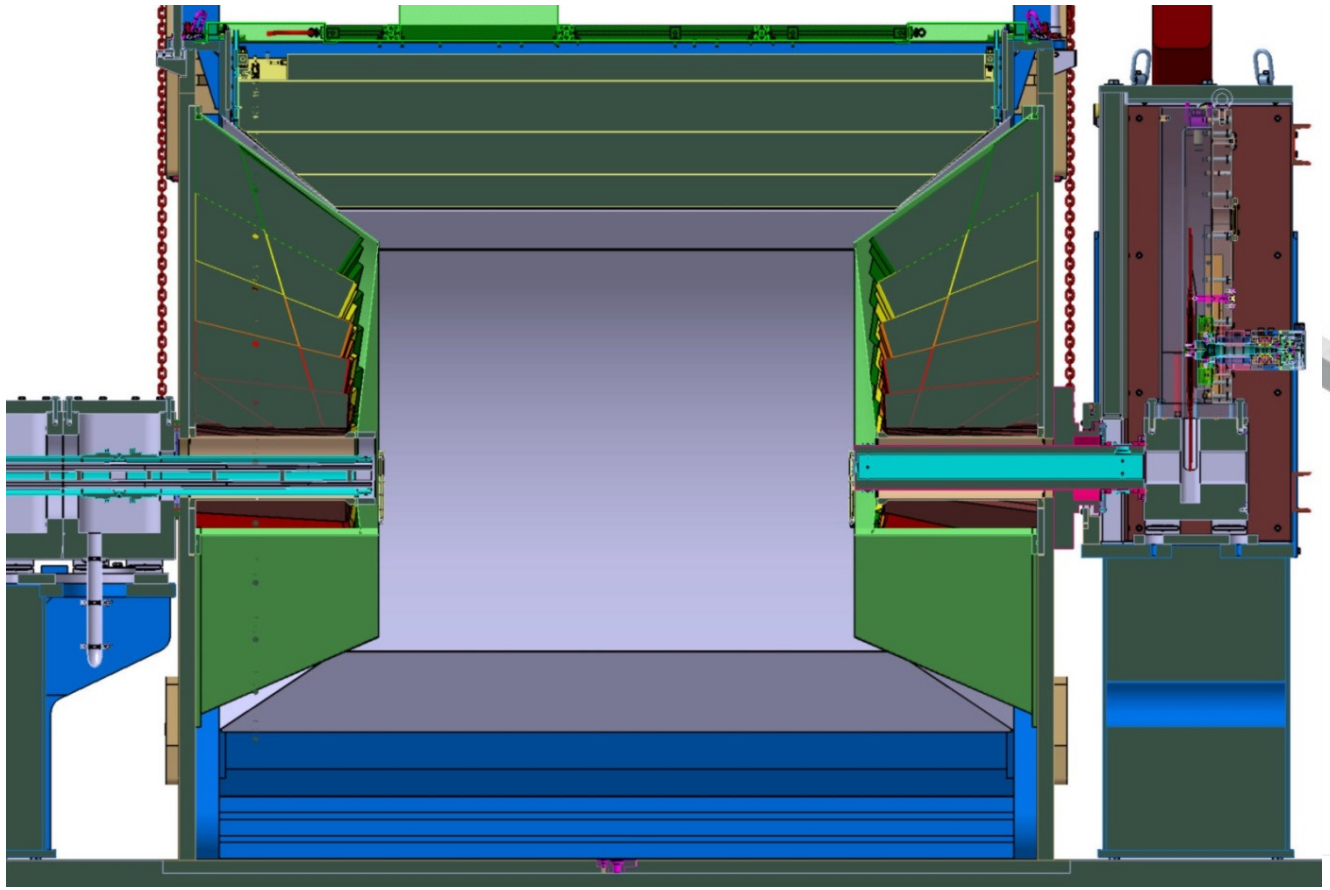
picture from W. Schweika, FZJ



POWTEX Instrument, Towards 4π-Coverage

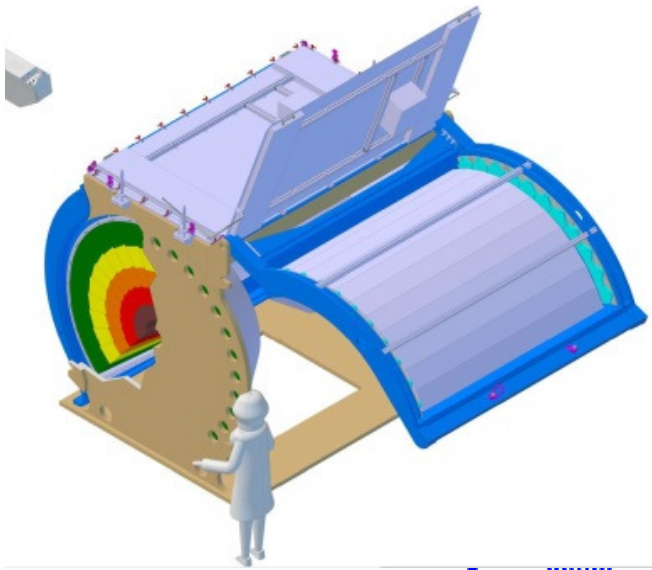
- Cylinder jacket coverage 274°, 240 segments
- Two end-caps, φ-coverage 276° each
- No coverage on bottom → sample instrumentation
- 2 Mio. active Voxels, 60.000 analog ASIC r/o channels

POWTEX



9 sqm detector area

overall blind area < 5,8%



Realization of POWTEX-Jalousie at FRM II

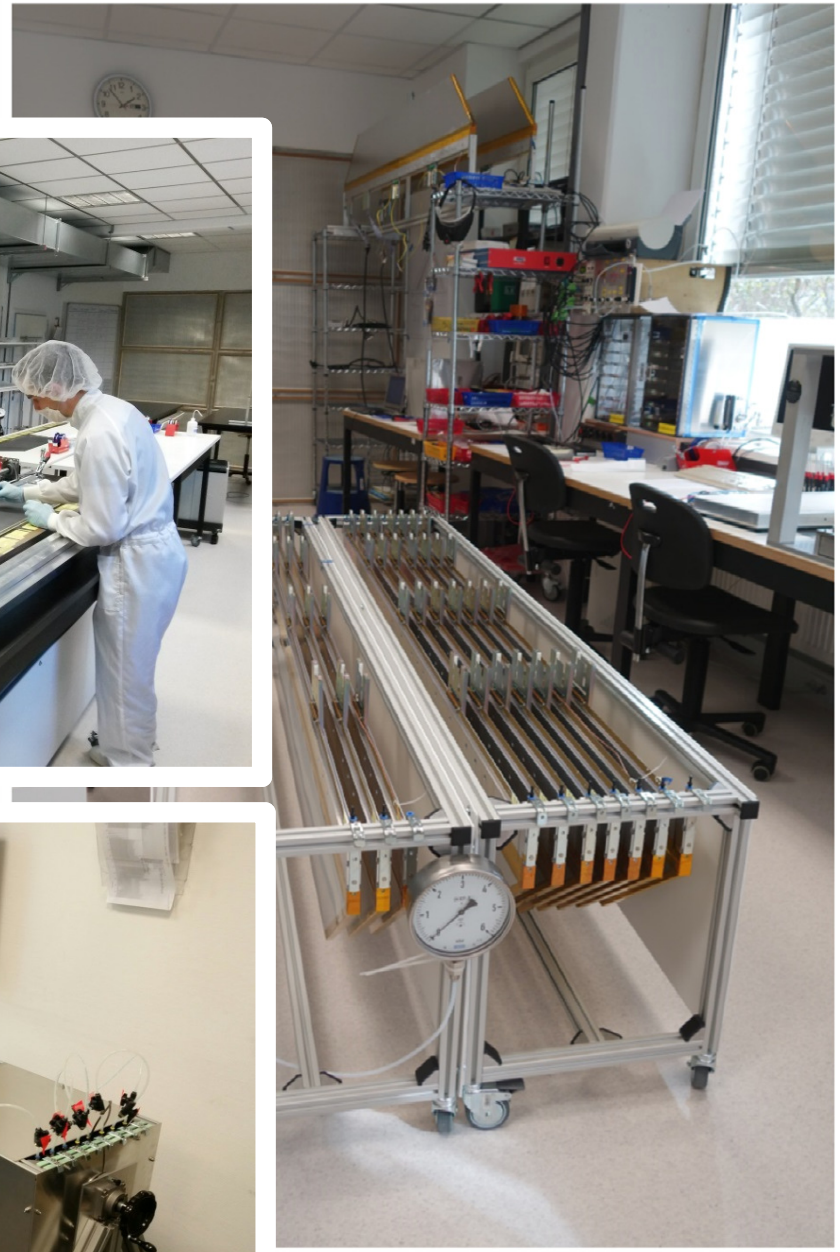
- **Jalousie was elaborated in two prototyping iterations.**

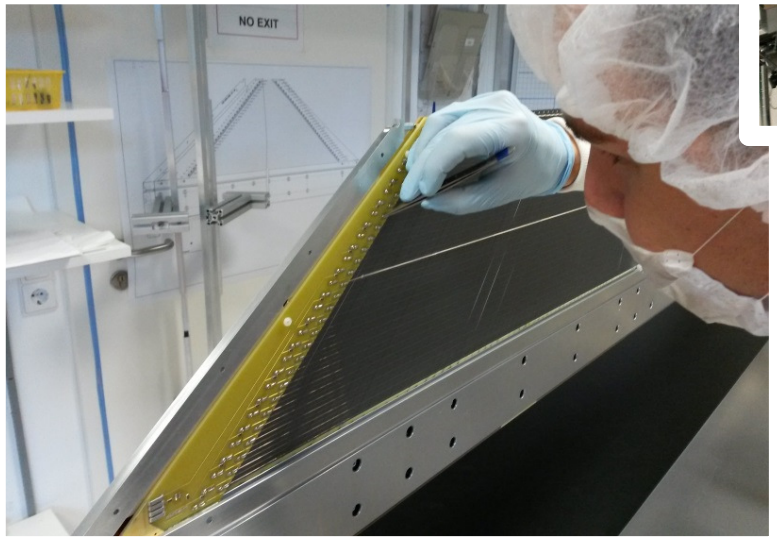
module pair at HEIDI (FRM II)

- **Third iteration: Production pre-series (12 segments).**
- **Serial Production ongoing:**
  - **66/240 segments assembled (28%).**
  - **60% coating done (~400 m²).**
  - **all electronics manufactured.**
  - **2 to 3 segments per week.**

Detector Segments in Production at CDT GmbH

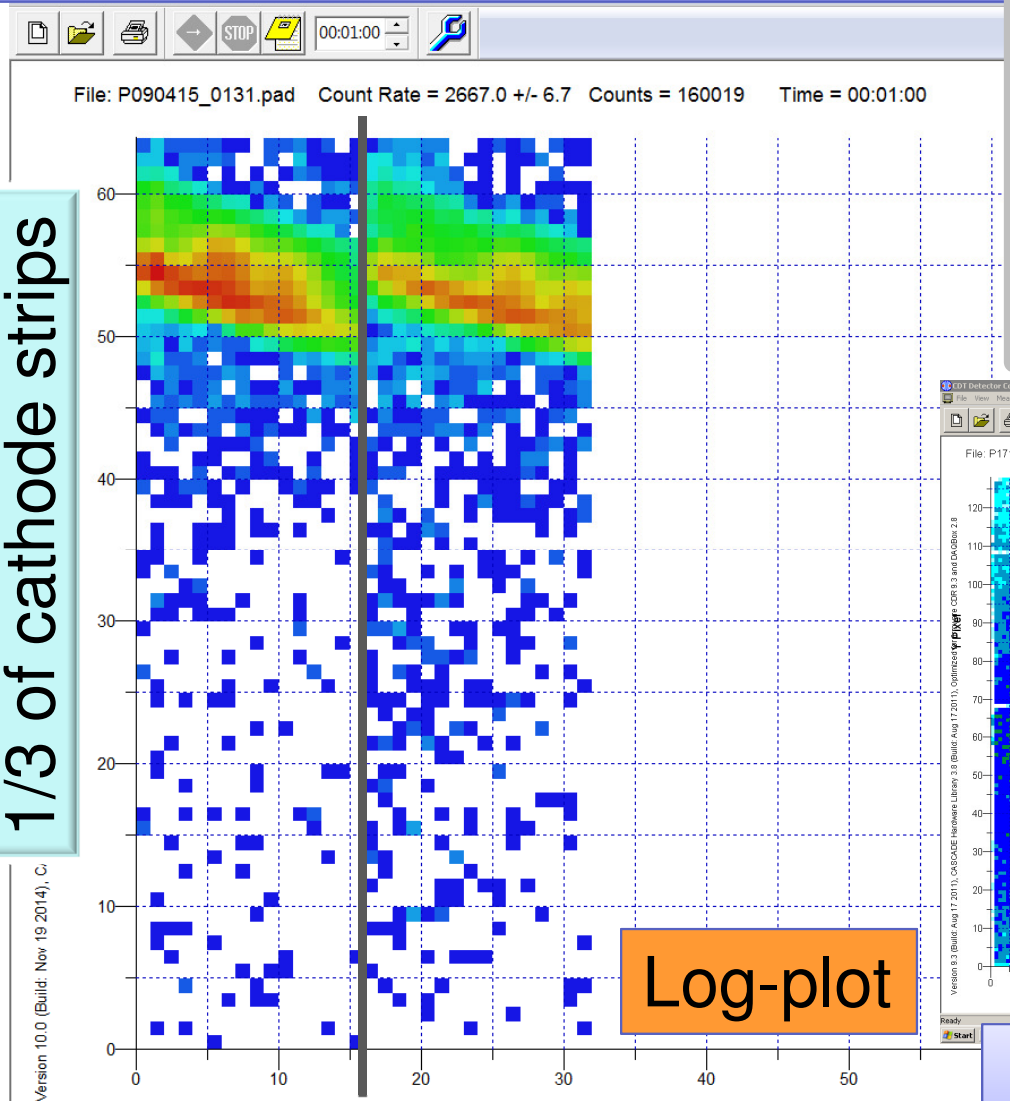
current capacity:
3 segments per week





Measurements at Triga Reactor Mainz

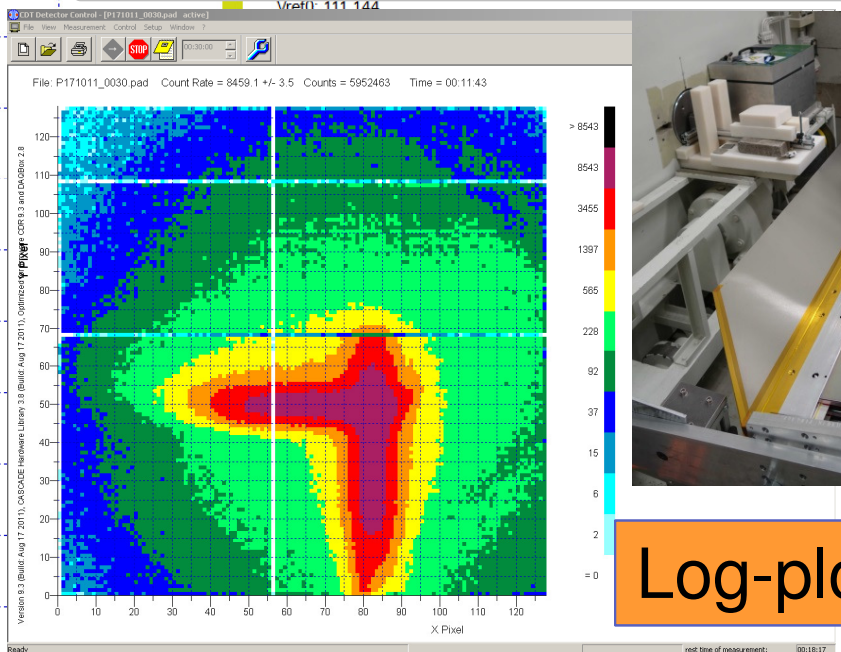
Slit-collimated Beam onto Jalousie segment at 10°
(both wire planes shown side by side)

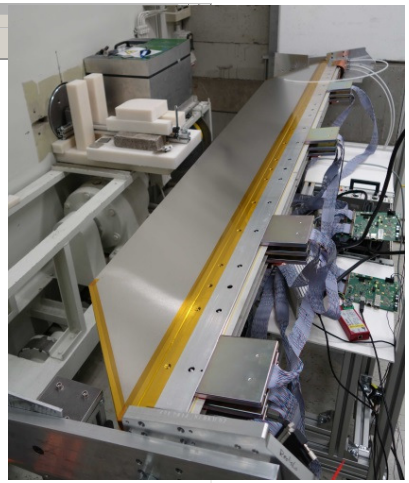


1/3 of cathode strips

Log-plot

#1 wire plane #2





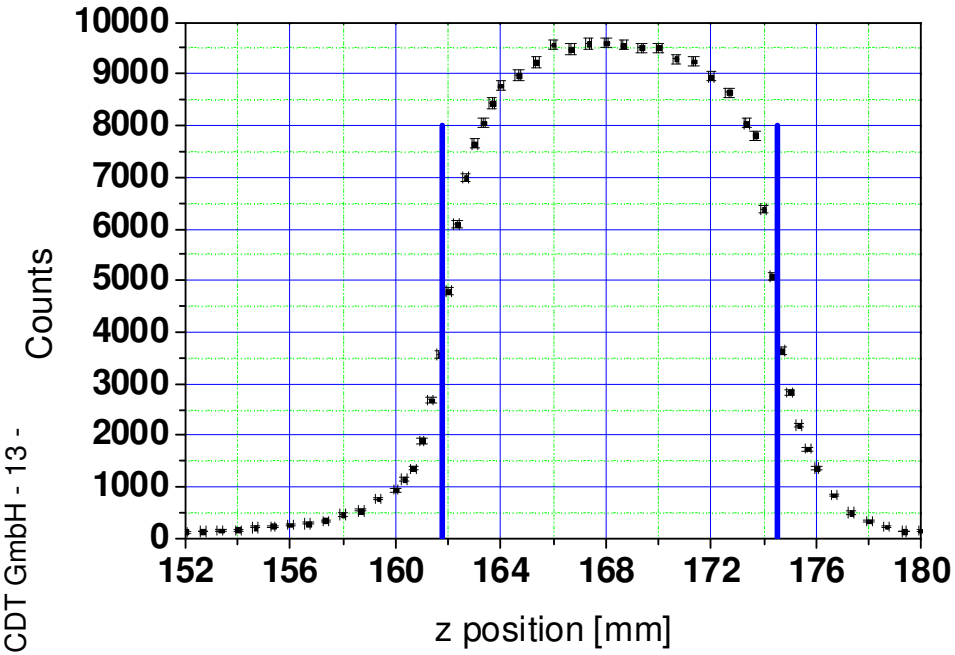
Log-plot

Uncollimated beam profile measured with CASCADE 2D-200

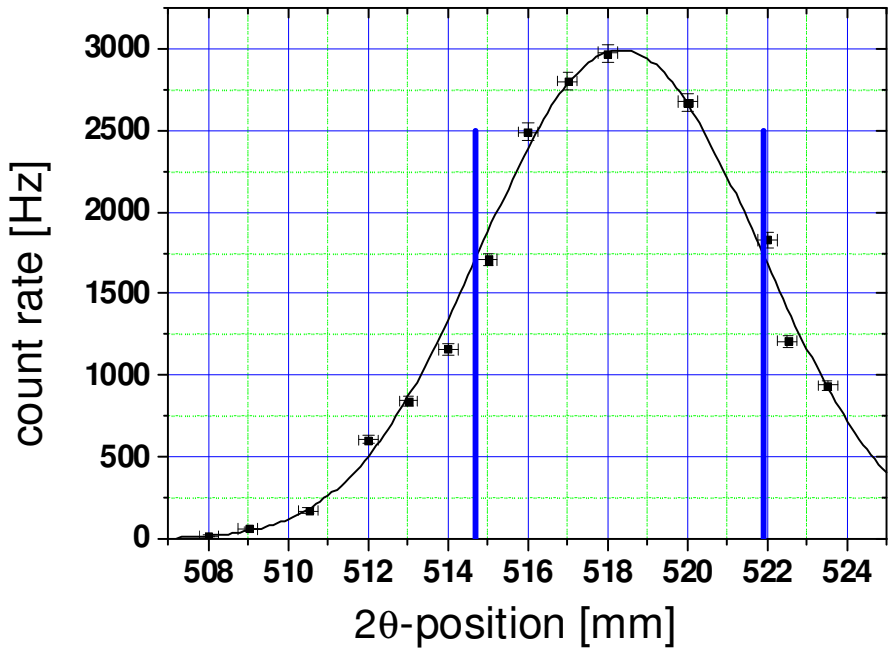
Measurements at Triga Reactor Mainz, Prototype II

collimated beam:
width 0,5mm in detector

Resolution scan across anode wires



Resolution scan across cathode strips

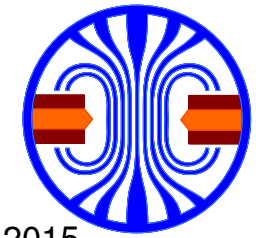


measured resolution: $\Delta 2\theta$ = 0,38° FWHM

Jalousie Specifications to meet POWTEX Needs

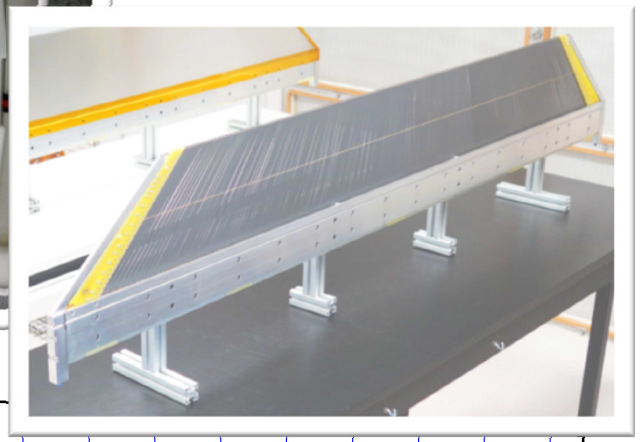
Parameter	Design	Value
Accumulated detection efficiency	■ 8 boron layers ■ inclined at 10°	**> 52% (1.0 Å)** **> 65% (1.8 Å)** **> 72% (2.5 Å)**
spatial resolution (2D) (at ambient counting gas pressure) 3D in depth → TOF	■ width of cathode readout strip $\Delta 2\theta = 0{,}469°$ ~ 6 mm ■ lamellae height h = 7,9 mm at window corresp. to $\Delta\varphi = 0{,}566°$	**resolution in 2θ:** **0,38° (FWHM)** **resolution in φ:** **0,665° (FWHM)**
TOF resolution	Anode spacing b = 15,6 mm	**2,7 – 6,9 µs (FWHM)**
Count rate per segment	limited by coincident read-out of cathode and anode	**2MHz @ 10% dead time**
Count rate per readout ch	limited by ASIC shaping time constant	**333kHz @ 10% dead time**

- **Very low γ-background:** Low-Z converter material ^{10}B, alpha versus e-ionization density
- **Long term stability** due to continuous purge of cheap counting gas through detector.

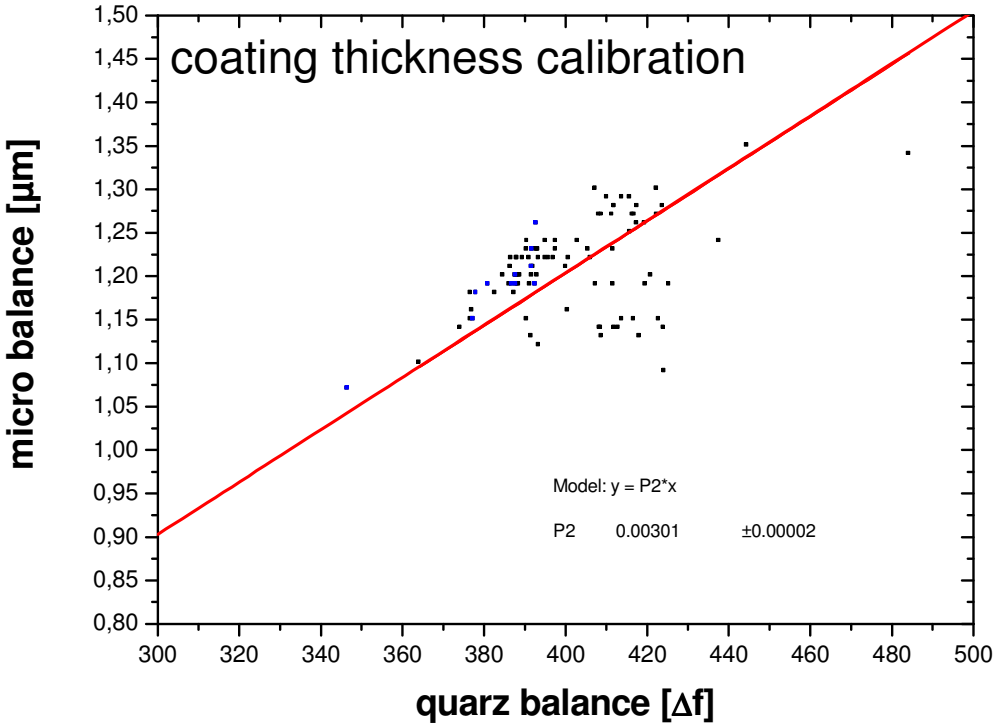


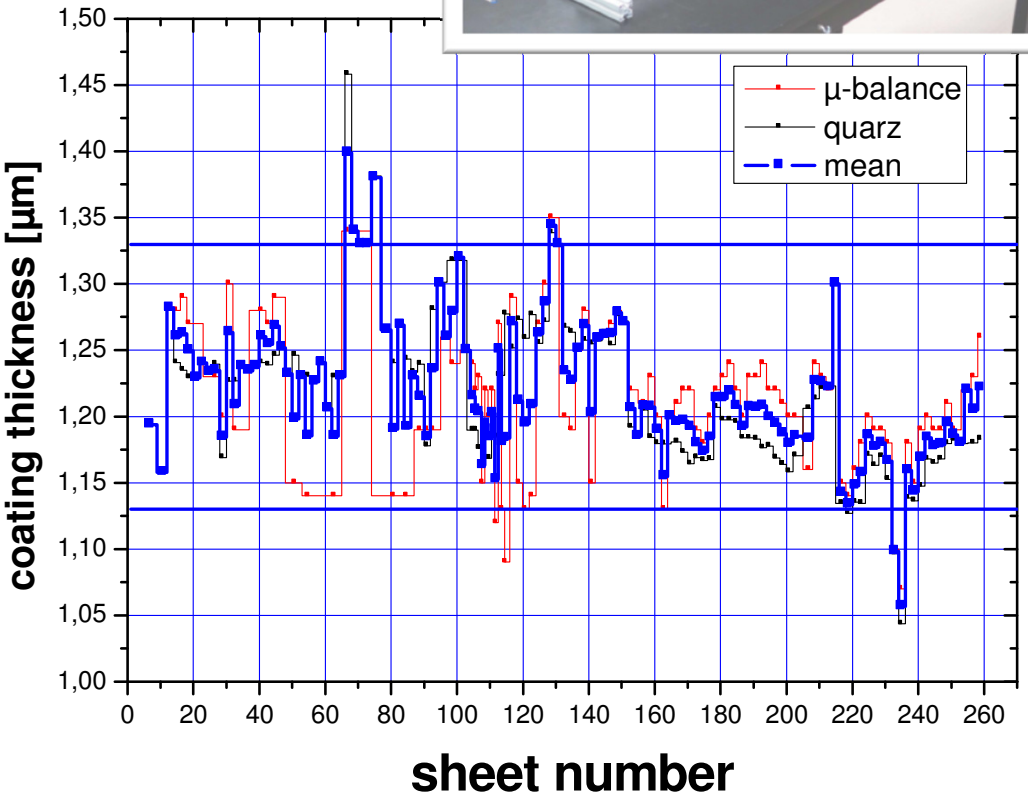
$^{10}B_4C$ Coating for POWTEX

400 m² coated ~ 60% of total area (700 m²)



cathodes coated by
Fraunhofer Institut IST

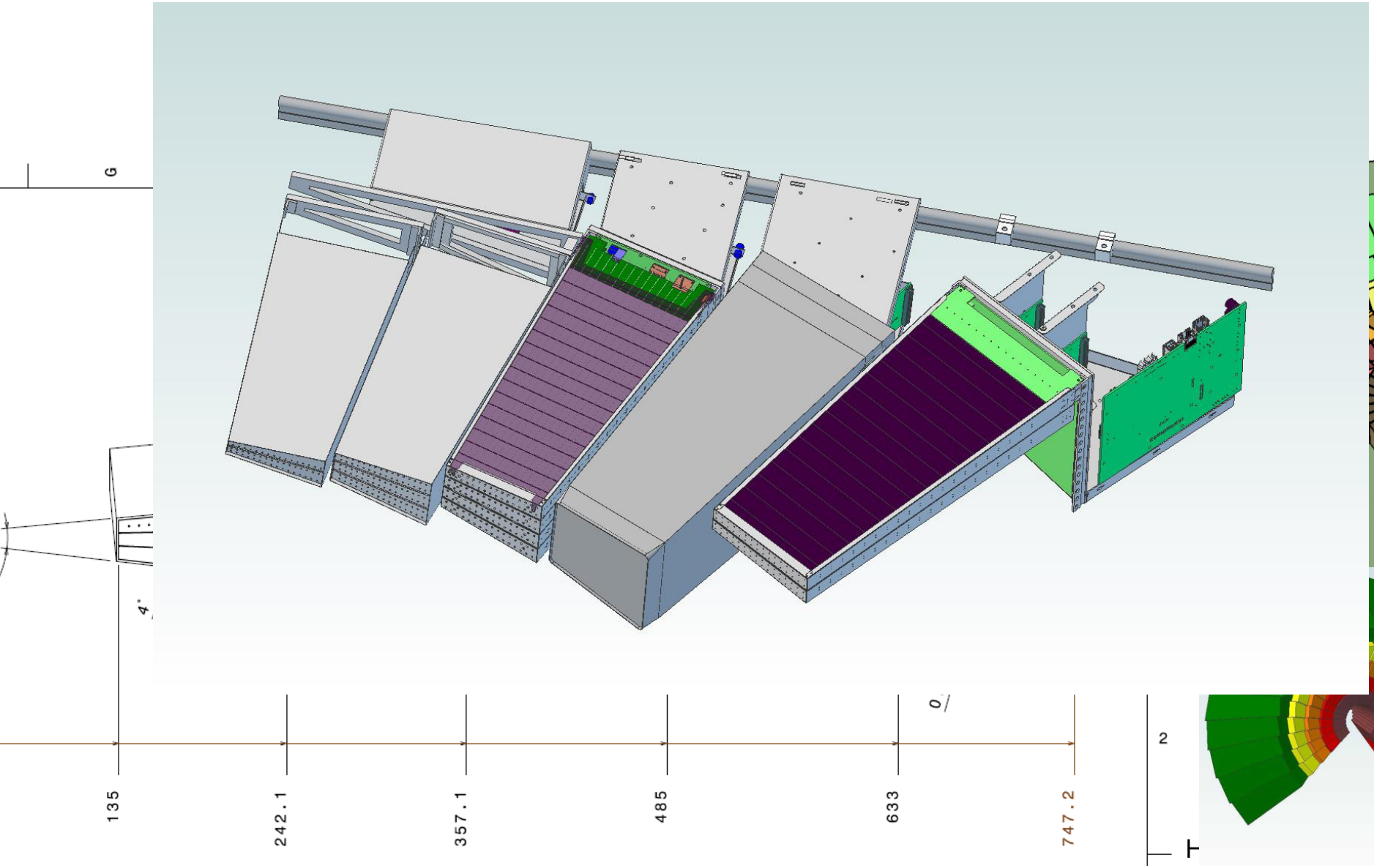


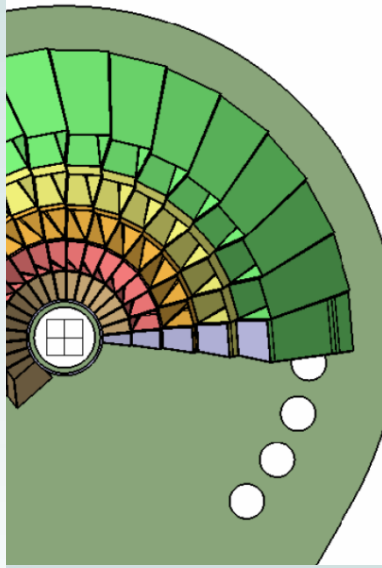


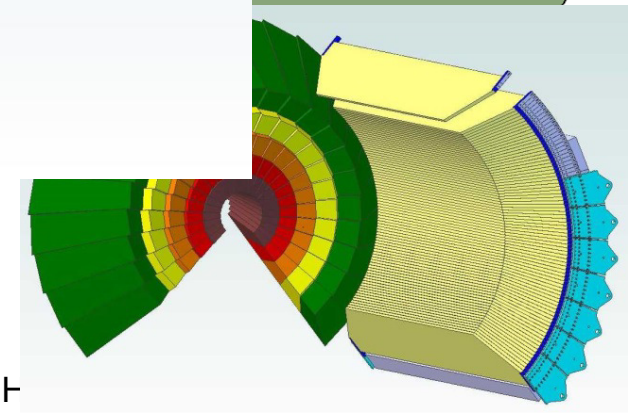
Coating at S-DH
our neighbor and expert in
neutron guides

POWTEX End-Cap, anode-wires oriented to sample

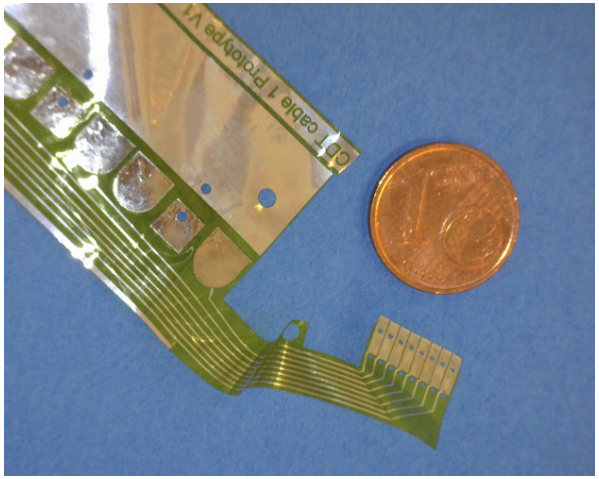
- End-cap engineering design and prototyping ongoing
  - 12°-Segment substructured in 5 submodules







POWTEX End-Cap



- Prototyping of sub-module 3 ongoing

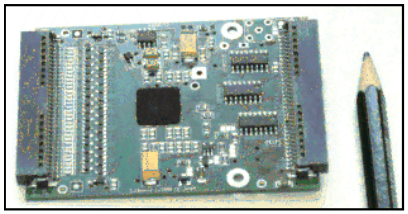
  Challenges:
  - 3D-Structure
  - Sealed Aluminum housing
  - Assembly procedures
  - Interconnect electrodes → Ukrainean Micro Cable Experts LTU:
    Aluminum leads on 10µm polyimide substrate

- Production pre-series (four 12°-segments)
- Serial production in 2016/17 (additional 42 segments)

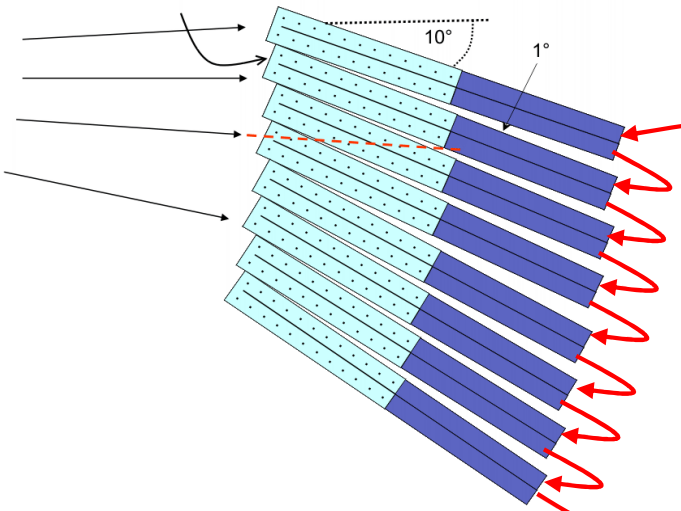
POWTEX project finalization in late spring 2017

Electronic Signal-Readout and DAQ

- 60.000 individual channels with CIPix-1.1 readout ASIC



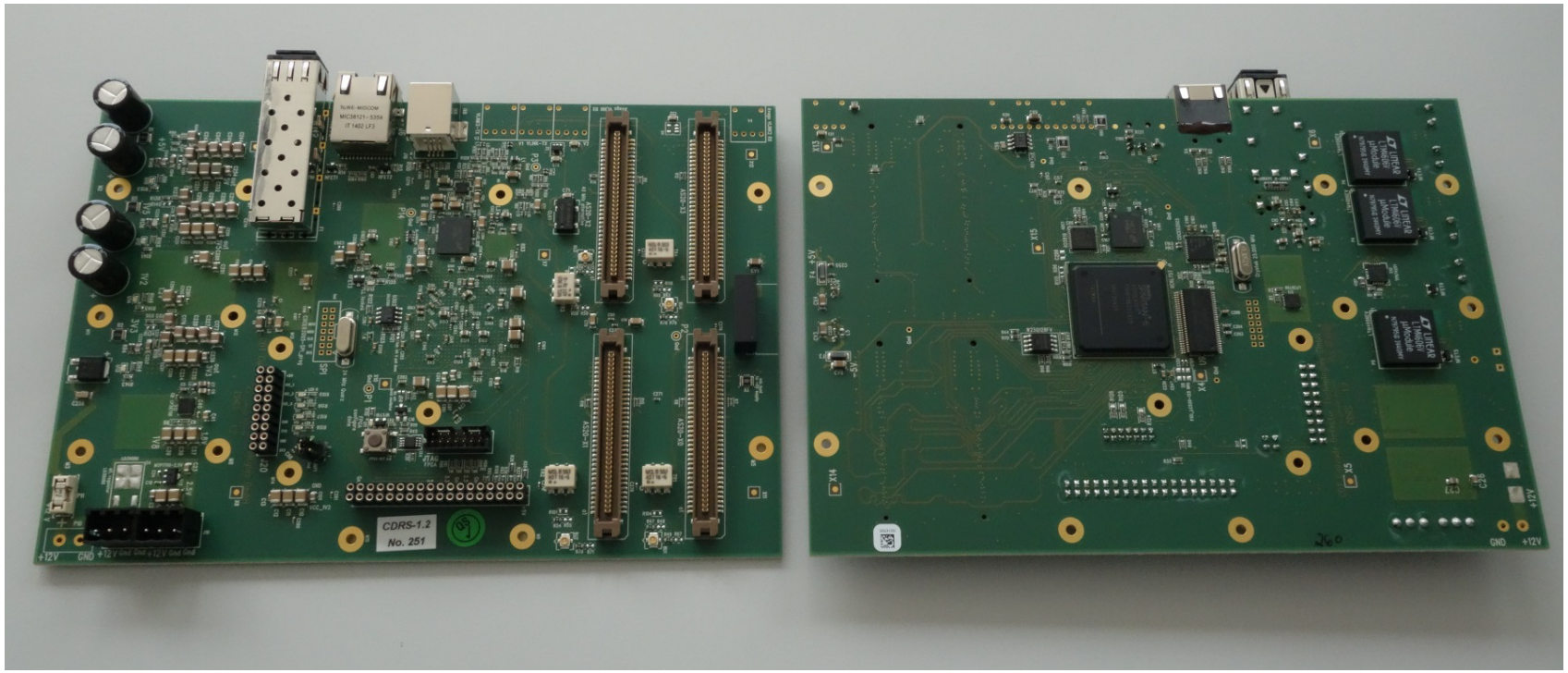
- Position and event reconstruction via coincidence identification in local, module based FPGA, 2 Mio. volume elements (VOXELs)
- Data readout through daisy-chained GBit optical link (Struck SIS1104)
  - One GBit optical link transmits 12,8 Mio. **event mode data** elements per second (64 Bit per event defined for POWTEX).
  - Data aggregation onto few GBit links
  - Bandwidth focusing through Token Ring



Token Ring

SIS1104 PCI Express Quad Optical Link Card
(640MByte/sec)

CDRS: 256-channel read-out for POWTEX, 2D-200 or 2D-300 GEM detector



- Spartan-6 FPGA
- opt. Gbit interface
- 4-fold CIPix-ASIC interface
- Clock recovery and synchronisation to global time
- 4ch ADC (60 MHz, 10 bit)
  → pulse height analysis
- DDR-RAM on board
- LVDS interface
- Avago opt. I/O interface
- Digital-IO diagnostic sensor interface
- 48V power distribution ring (galvanically decoupled)

System capability and scalability of CDRS

- Token-Ring readout along the daisy chain
  → distribute bandwidth where it is needed

- Star-shaped clock distribution and backup communications channel

- System precautionary previsions:
  - Twofold access concept for firmware in-system upgrade
  - Guaranteed access even with faulty firmware installed
  - Three-fold clocking means
  - Two-fold controls access

CDT
CASCADE Detector Technologies GmbH

- Neutron Detectors
- Readout Electronics
- Complete Systems
  - ^{10}B Coatings

CDT

since 2006

a university spin-off dedicated to neutron detector technology

CDT GmbH
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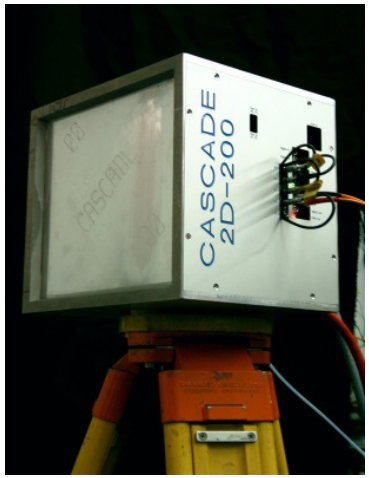
69123 Heidelberg
Germany

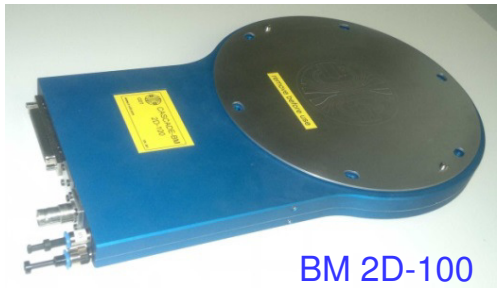
www.n-cdt.com

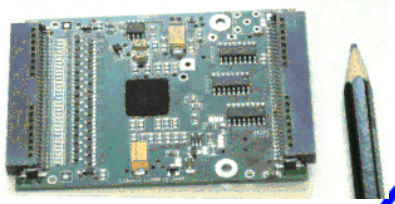
CDT CASCADE Detector Technologies GmbH

- Founded in 2006 as spin-off of Physikalisches Institut Heidelberg
- Focus: ^{10}**B based area detectors for thermal and cold neutrons as complete system solutions with electronics and software**



  - JALOUSIE detector, the alternative for ^{3}He PSDs
    large areas, medium resolution → POWTEX and DREAM
  - CASCADE 2D-200 – high rates GEM-based solution with extraordenary contrast of 10^5. → expansion to 2D-300 (300 x 300mm^2)
  - CASCADE-MIEZE – special variation to resolve 1MHz intensity variations
  - CASCADE-BM position sensitive Beam Monitors
  - UCN detectors
  - ASIC and FPGA-based multi-channel readout electronics


BM 2D-100



- Customers: FRM-II, FZJ, ESS, PSI, ILL, KIT (IBR-II), IHEP (CSNS, China), KEK & JAEA (Japan) via REPIC, KACST (Saudi Arabia),

CDT Business Resources

- Equity capital:
  currently ~ (200 + 100) TEuro

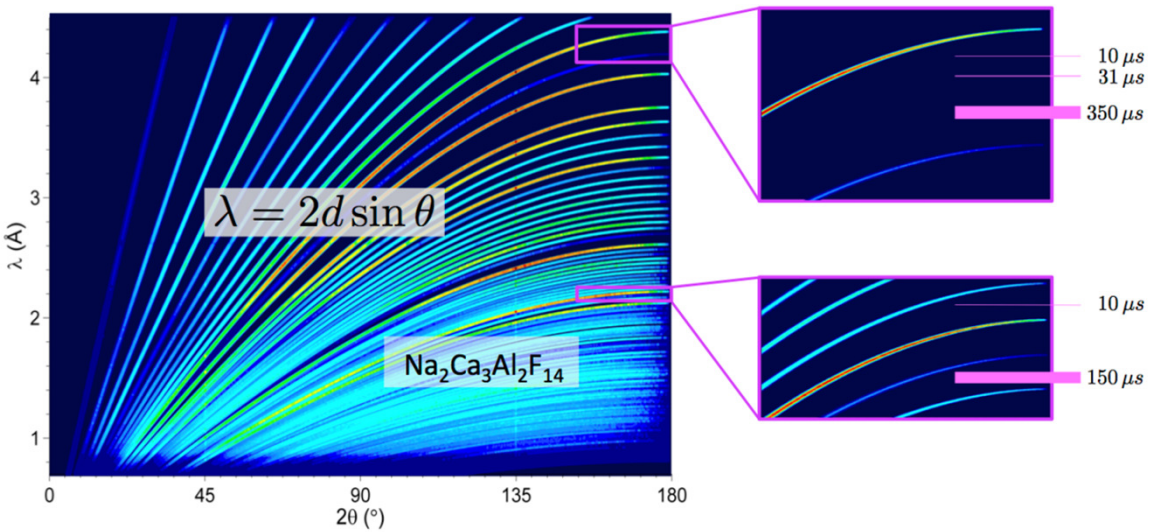
- Current human resources:
  12 FTE with additional ext. engineering capacities, further buildup ongoing

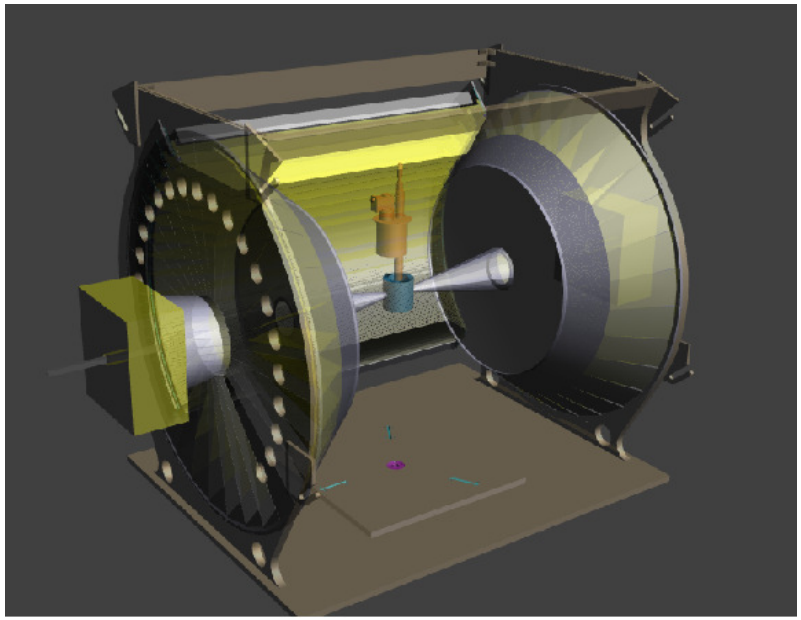
- Company premises: 840 m^2
  lab-, production- and office space,
  additional new clean-room in preparation (20 m x 8 m)

- High throughput, large area $^{10}B_4C$ coating facility at hand (~ 2 m^2/day)
  (cooperation with S-DH), metallic Boron coating

The ESS-Instrument DREAM is Exciting!

- Perfect in timing for production-resources availability
- Engineering, assembly and QA procedures are running smoothly
- DREAM-like larger coating area needs are feasible (3,6m x 0,8m)





- CDT-team would love to get engaged!