EP-DT
Detector Technologies

# Towards a 60 x 60 cm$^2$ demonstrator for the NMX instrument at the European Spallation Source ERIC

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# Outline

The European Spallation Source ERIC

The NMX instrument

Quasi-Laue TOF diffractometry

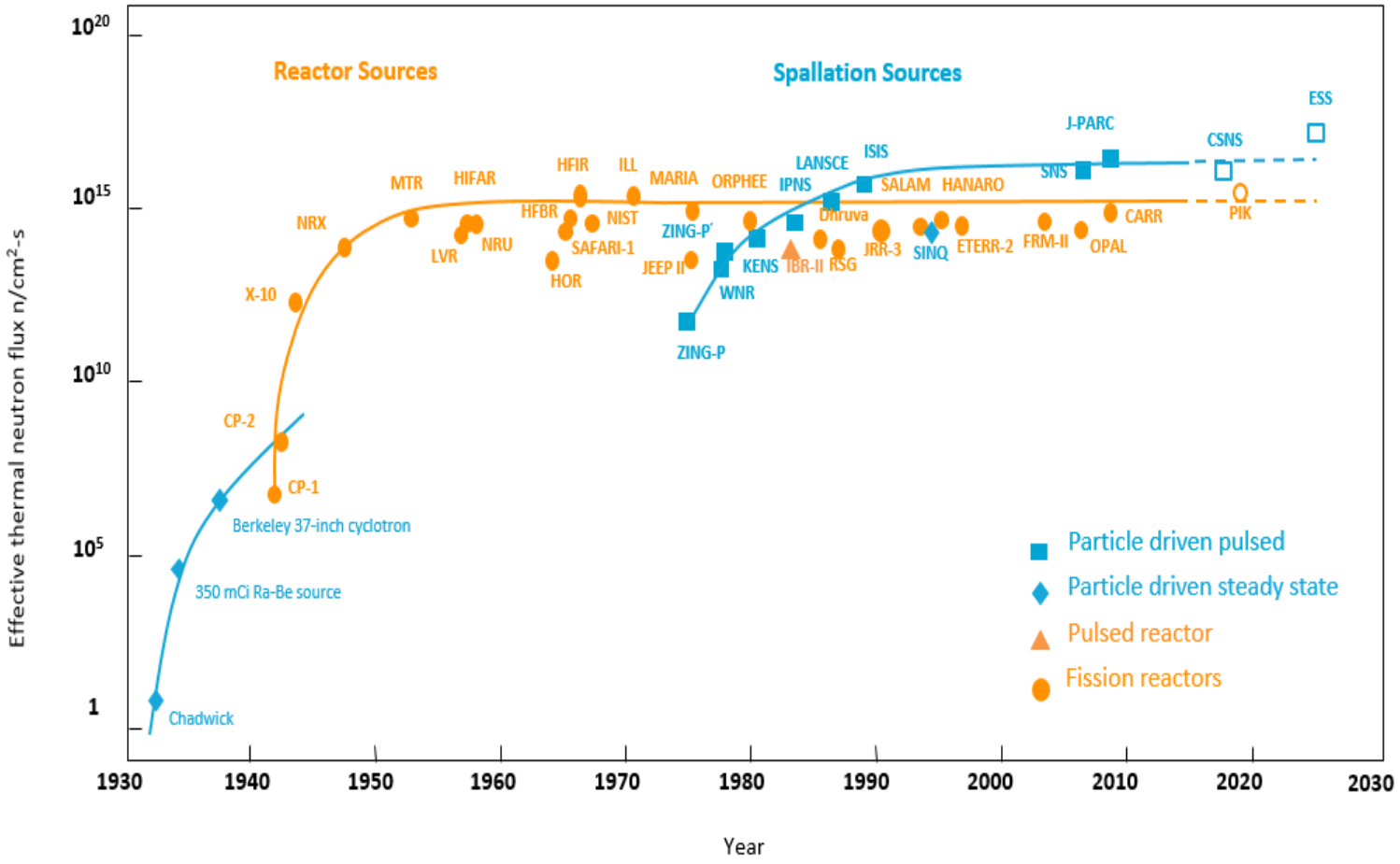
Detector baseline

Current status of detector demonstrator prototype

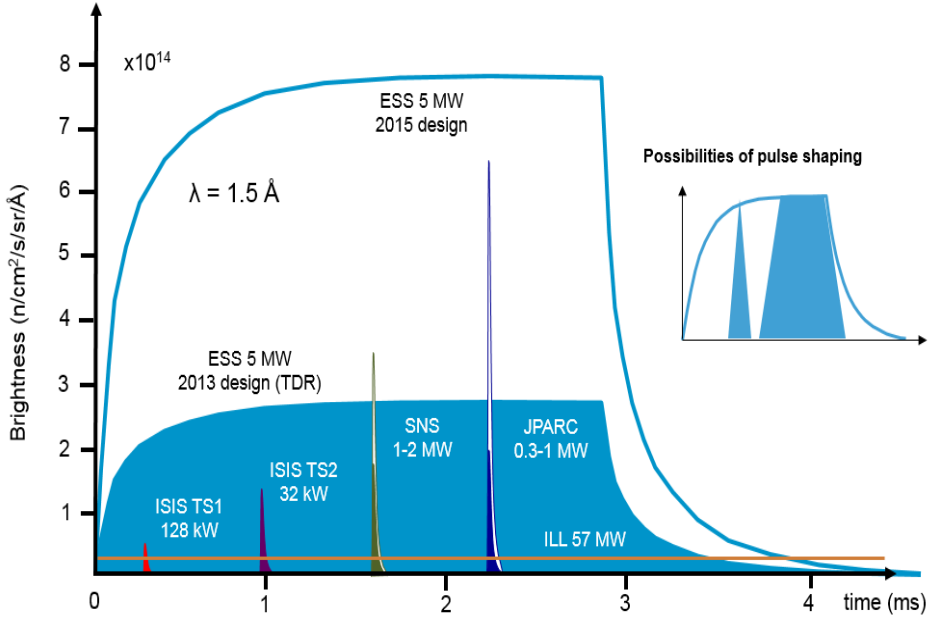
Conclusions and outlook

# The European Spallation Source
## Campus and surroundings

# The European Spallation Source
## Performance

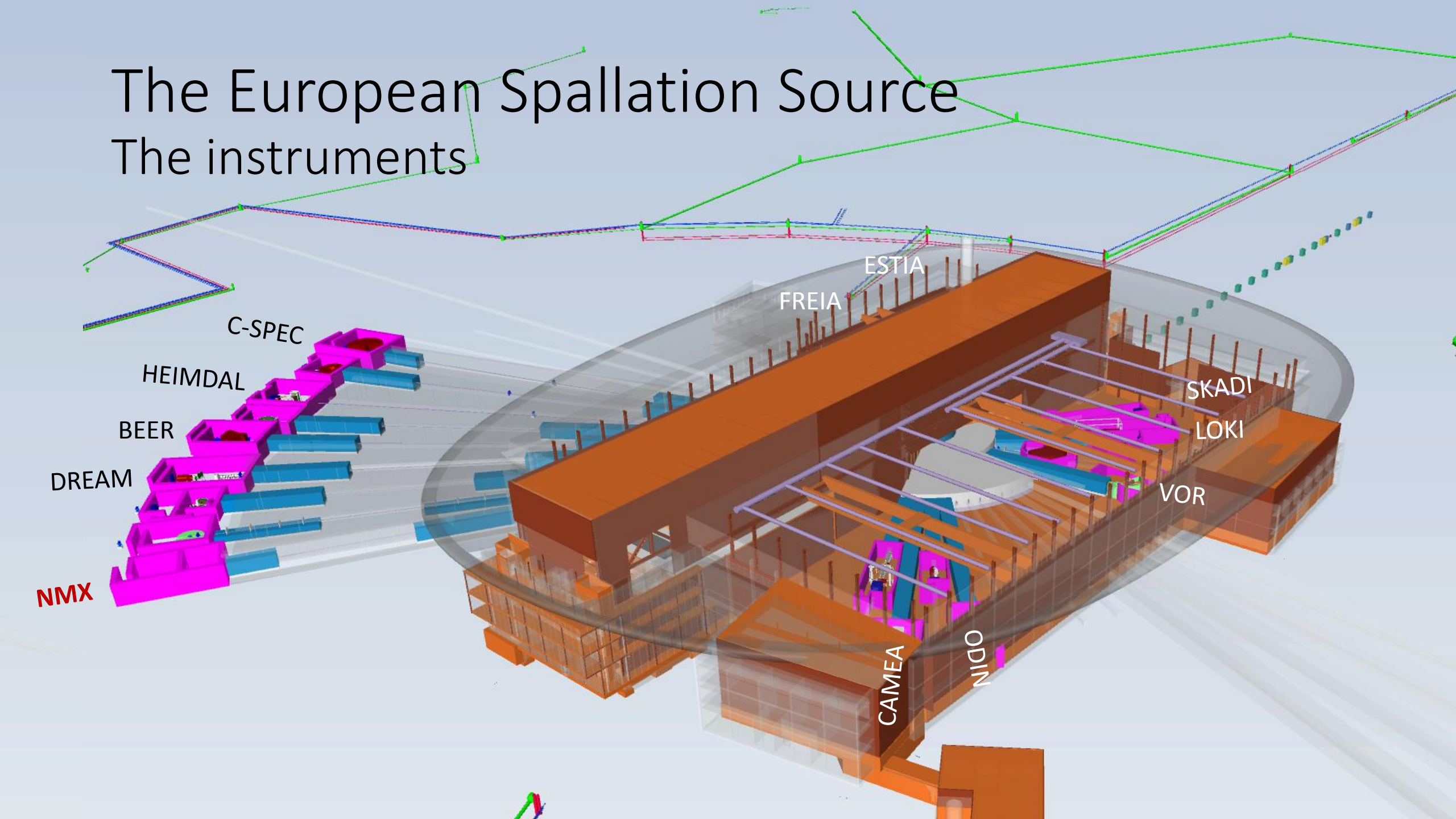



(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)



# The European Spallation Source

## The instruments



# The NMX instrument

## Neutron macromolecular crystallography

Determinate structures of proteins, location of hydrogen atoms

Optimised for small samples and large unit cells

Time-of-flight (TOF) quasi-Laue diffractometer

Wavelength band from 1.8 Å to 3.55 Å (6.49 to 25.25 meV)

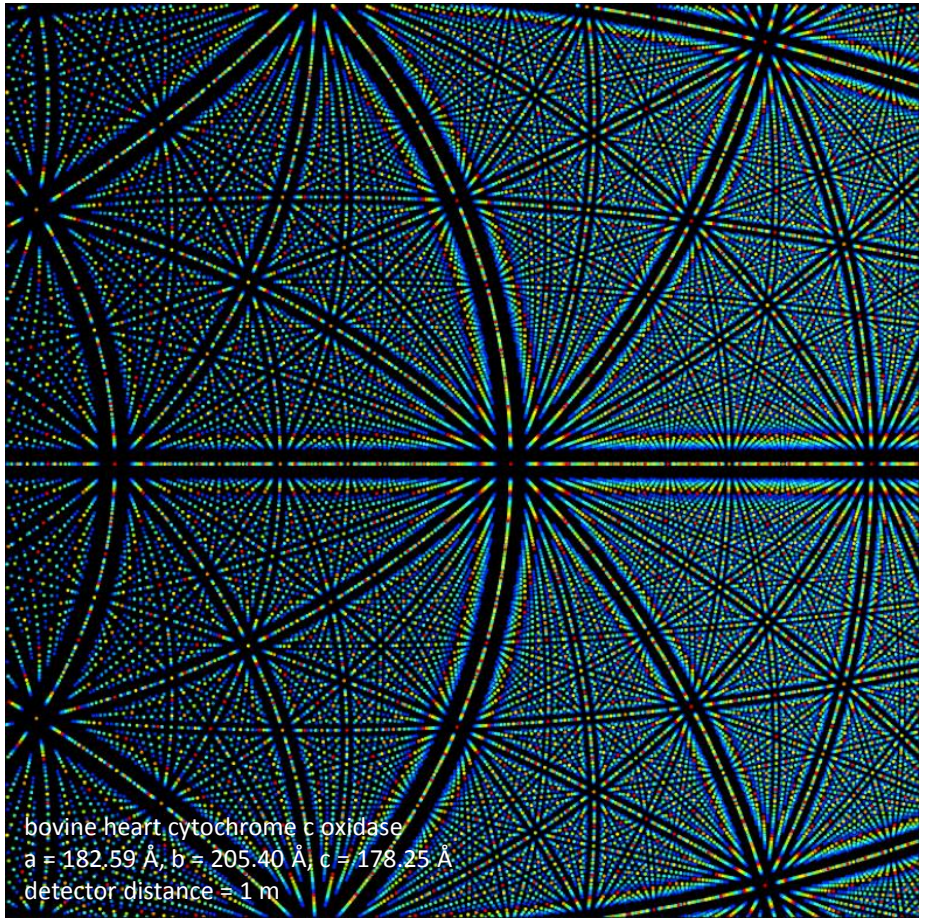
$2 \cdot 10^9$ n/s on $5 \times 5$ mm$^2$ sample (~ 3 kHz n/cm$^2$ on detector)

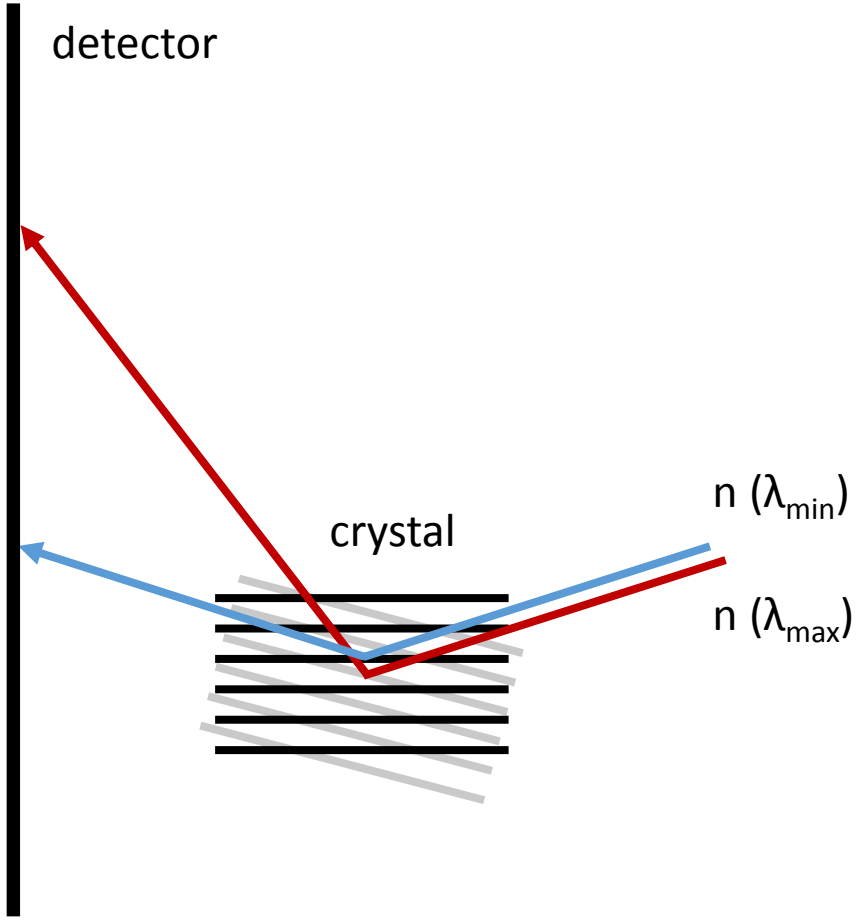
Approx. 0.8 m$^2$ detector active area

No fixed instrument geometry

# Quasi-Laue Time-Of-Flight Diffractometry

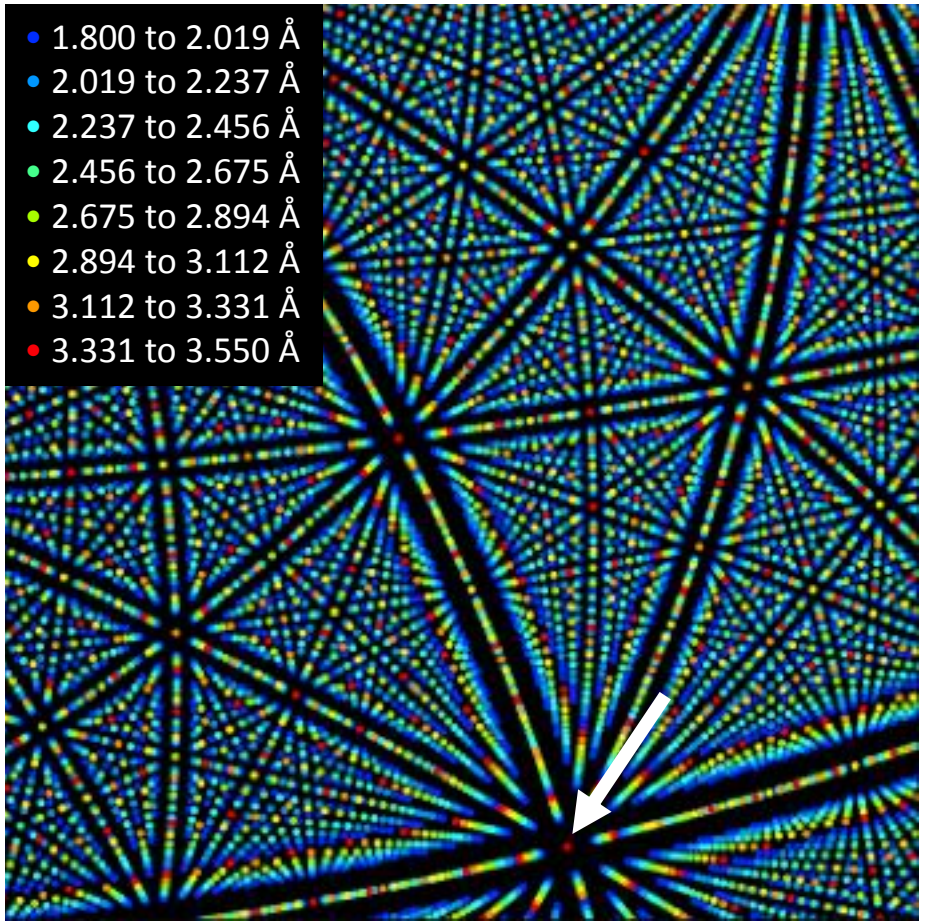
## Principle and example diffraction pattern

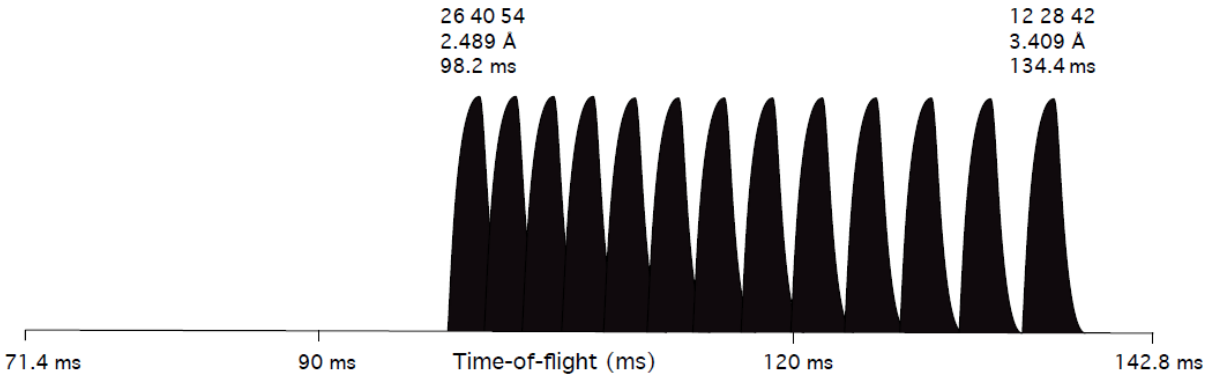


# Quasi-Laue Time-Of-Flight Diffractometry

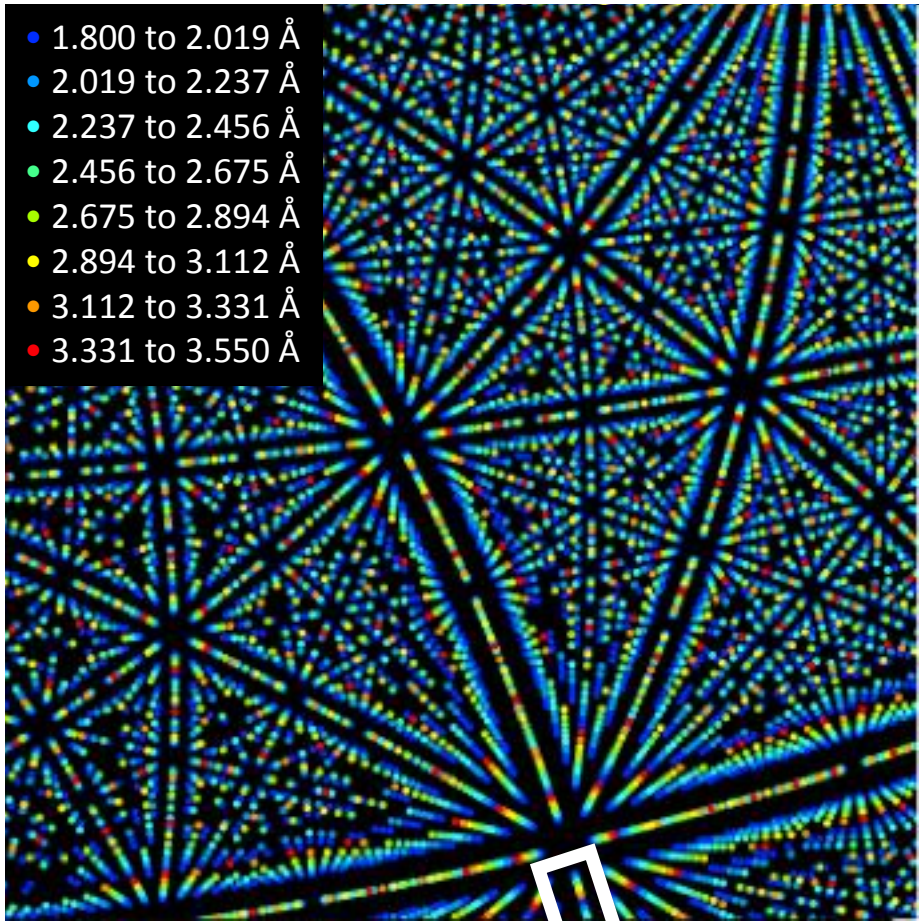
## Separation of harmonic reflections

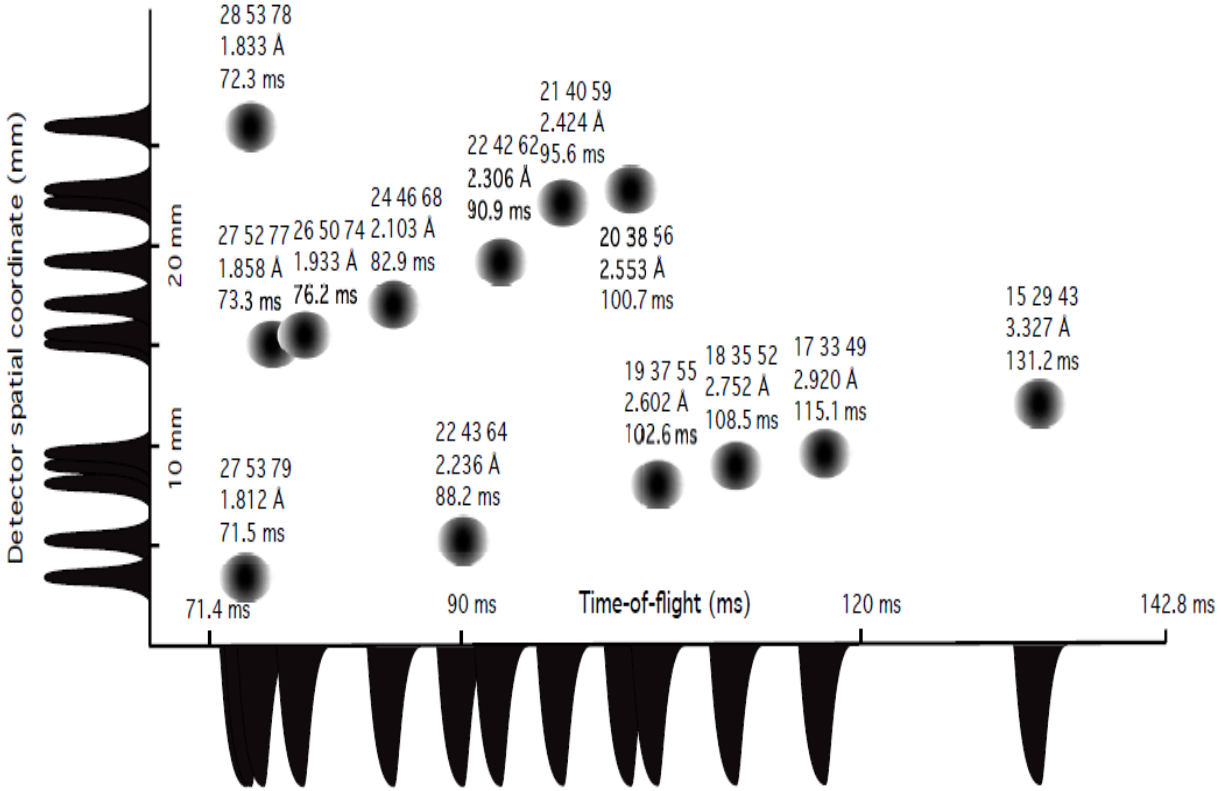


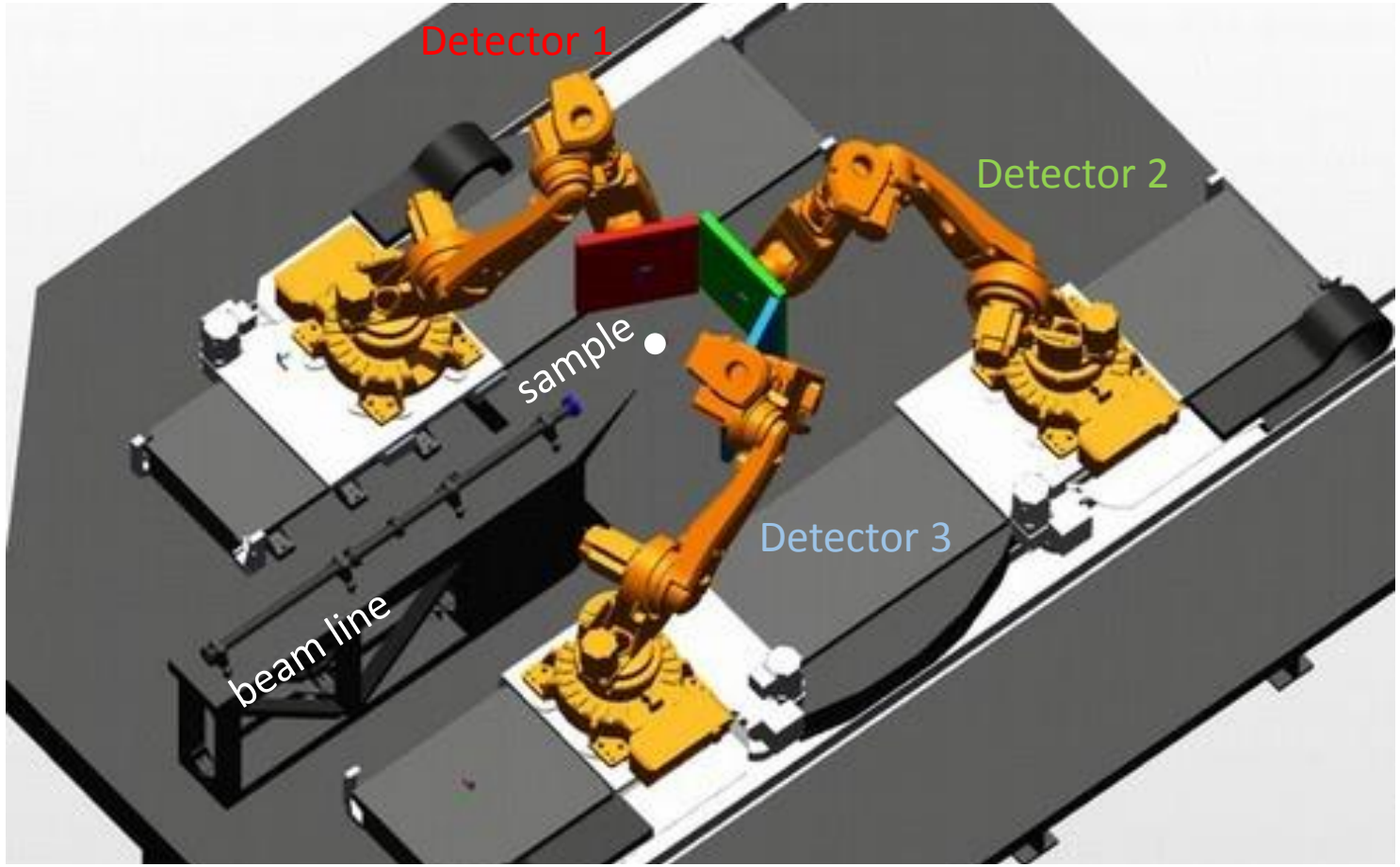
# Quasi-Laue Time-Of-Flight Diffractometry

## Separation of spatial reflections



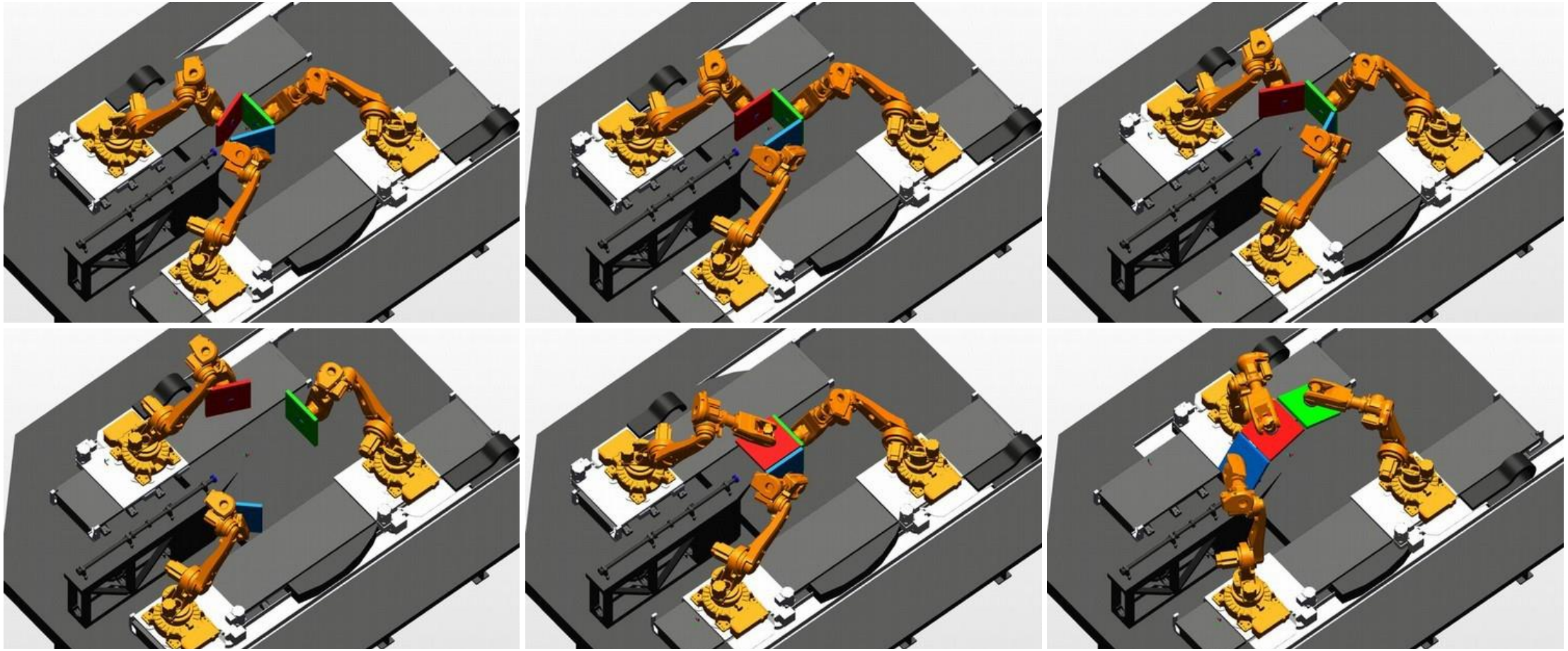



# The NMX instrument
## No fixed detector geometry




Detector Positioning System for ESS NMX, Final Design Report, J.-L. Ferrer

# The NMX instrument
## No fixed detector geometry



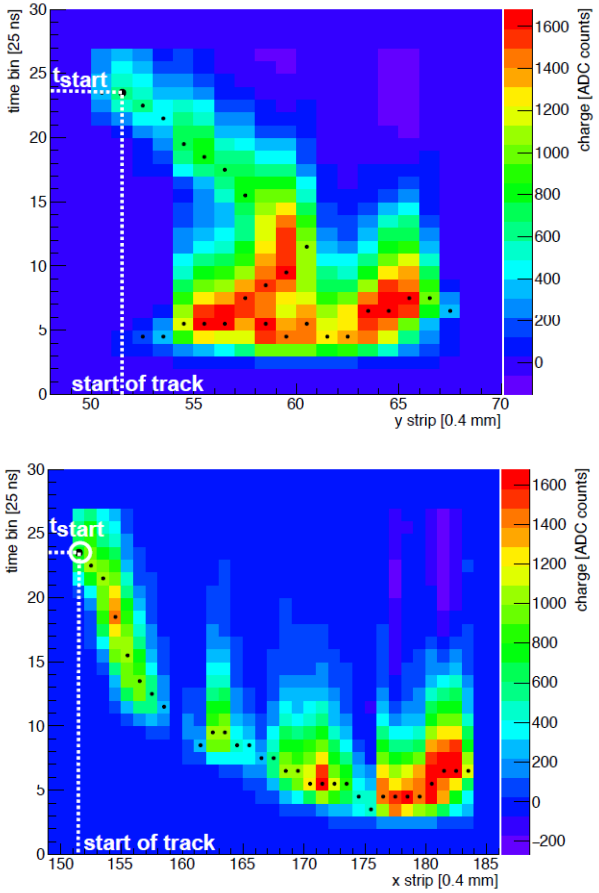
# NMX detector baseline

Triple-GEM detector in Ar/$CO_2$ 70:30 gas mixture

Natural (enriched) gadolinium cathode
Neutron detection efficiency <14% (<31%)

Backward configuration: neutrons pass full detector volume before reaching cathode

Hit position reconstructed with µTPC method



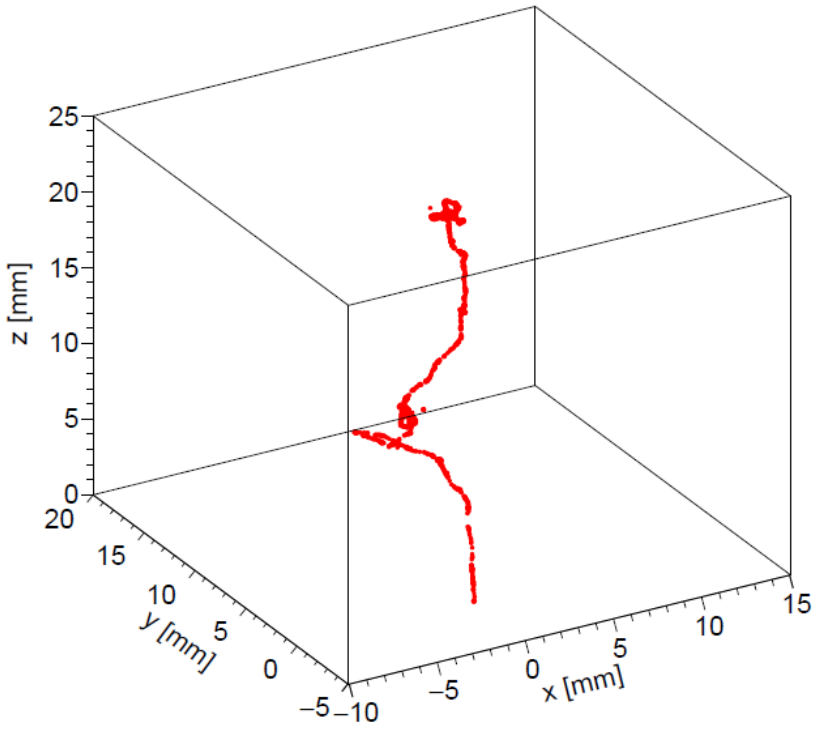
# NMX detector baseline

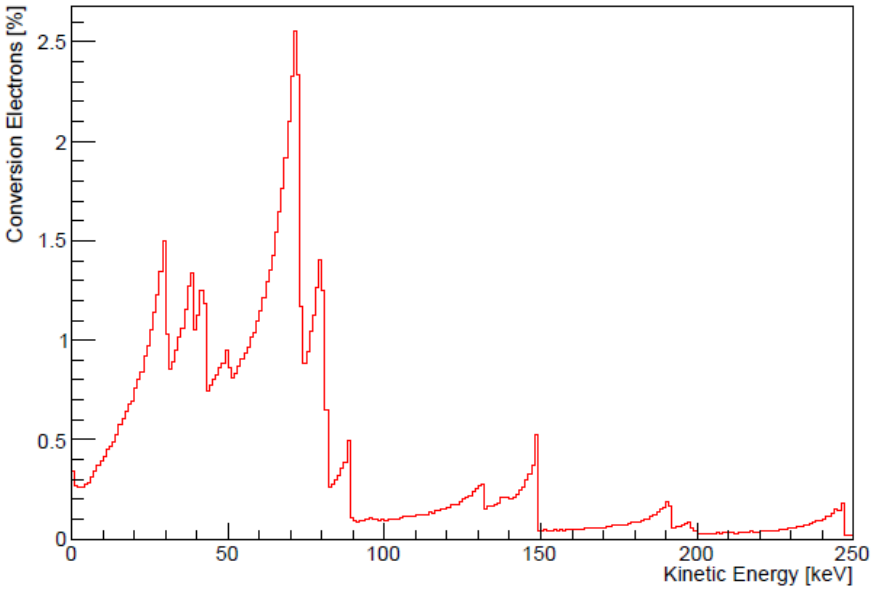
## Drift length

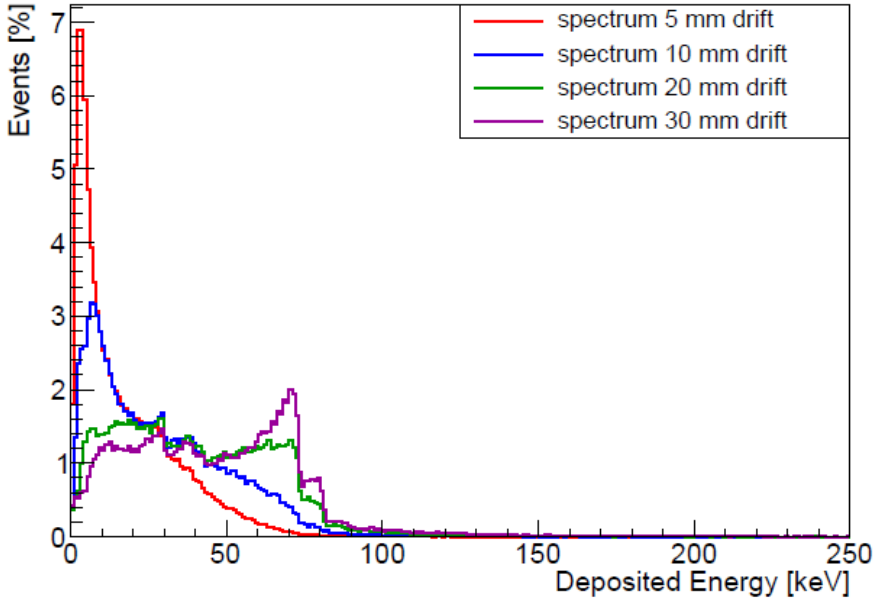
Conversion electrons with energy 10 to 250 keV

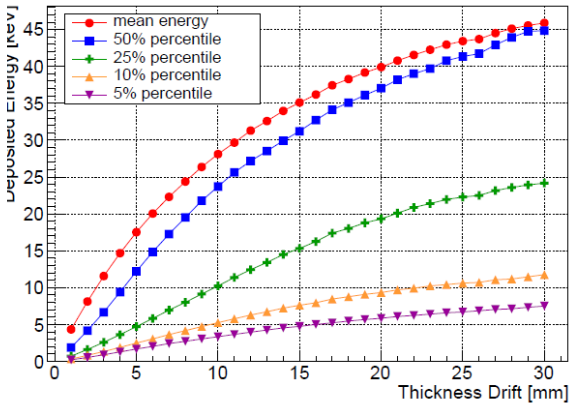
Should be fully contained in drift volume

10 mm drift length is sufficient to contain electrons with energies up to 30 keV



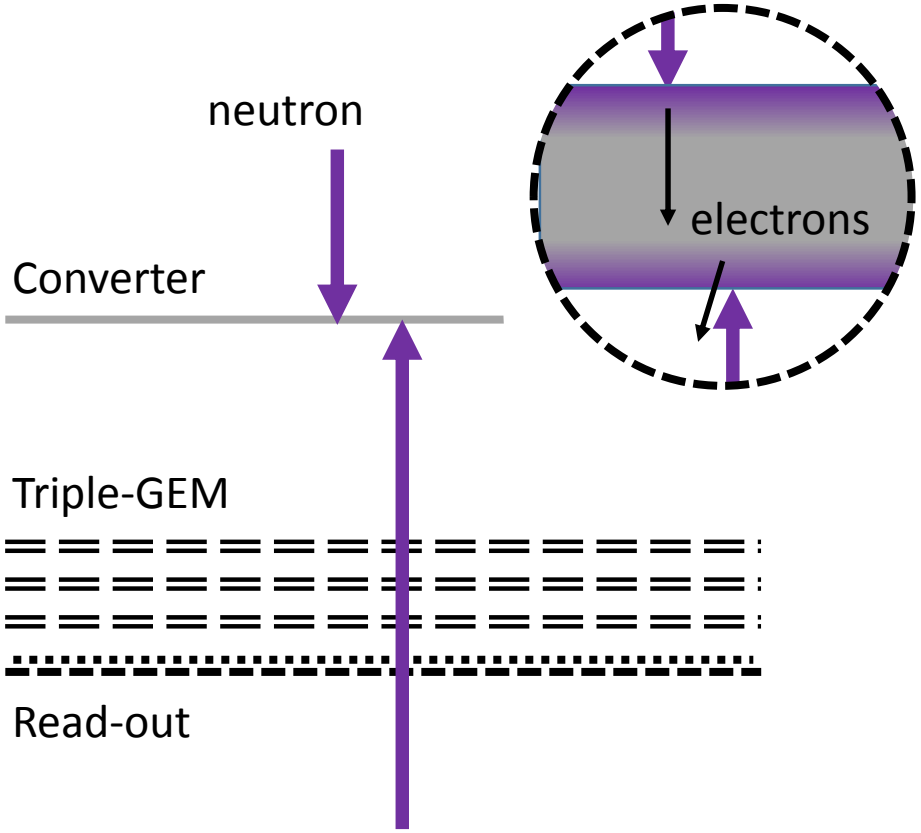



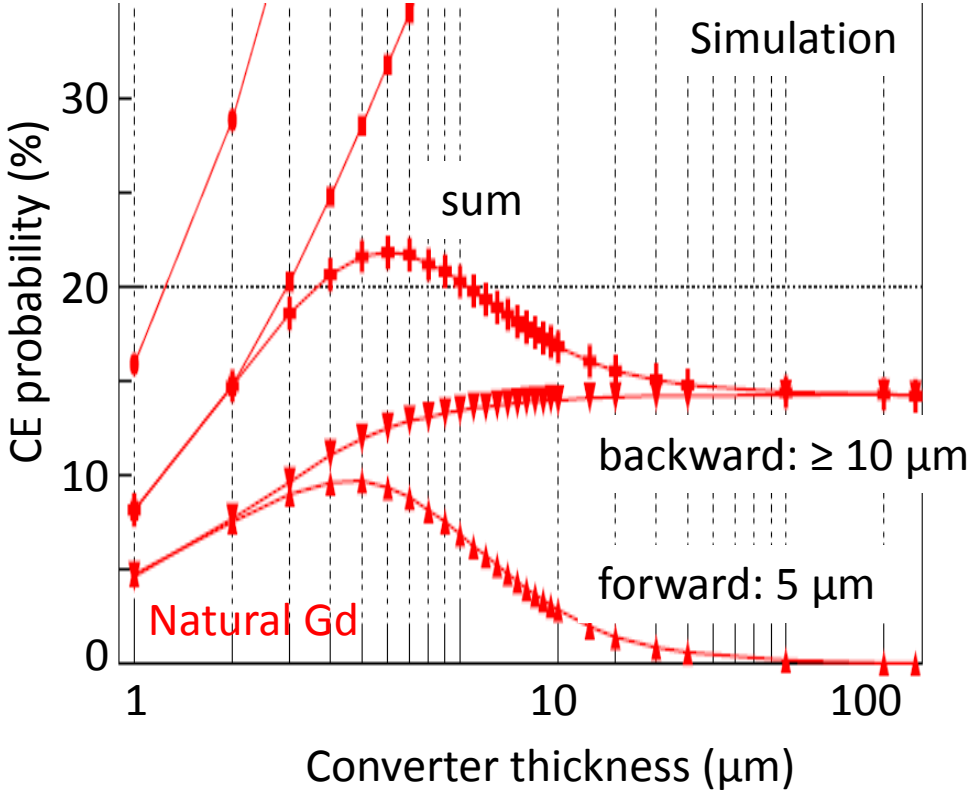



# NMX detector baseline

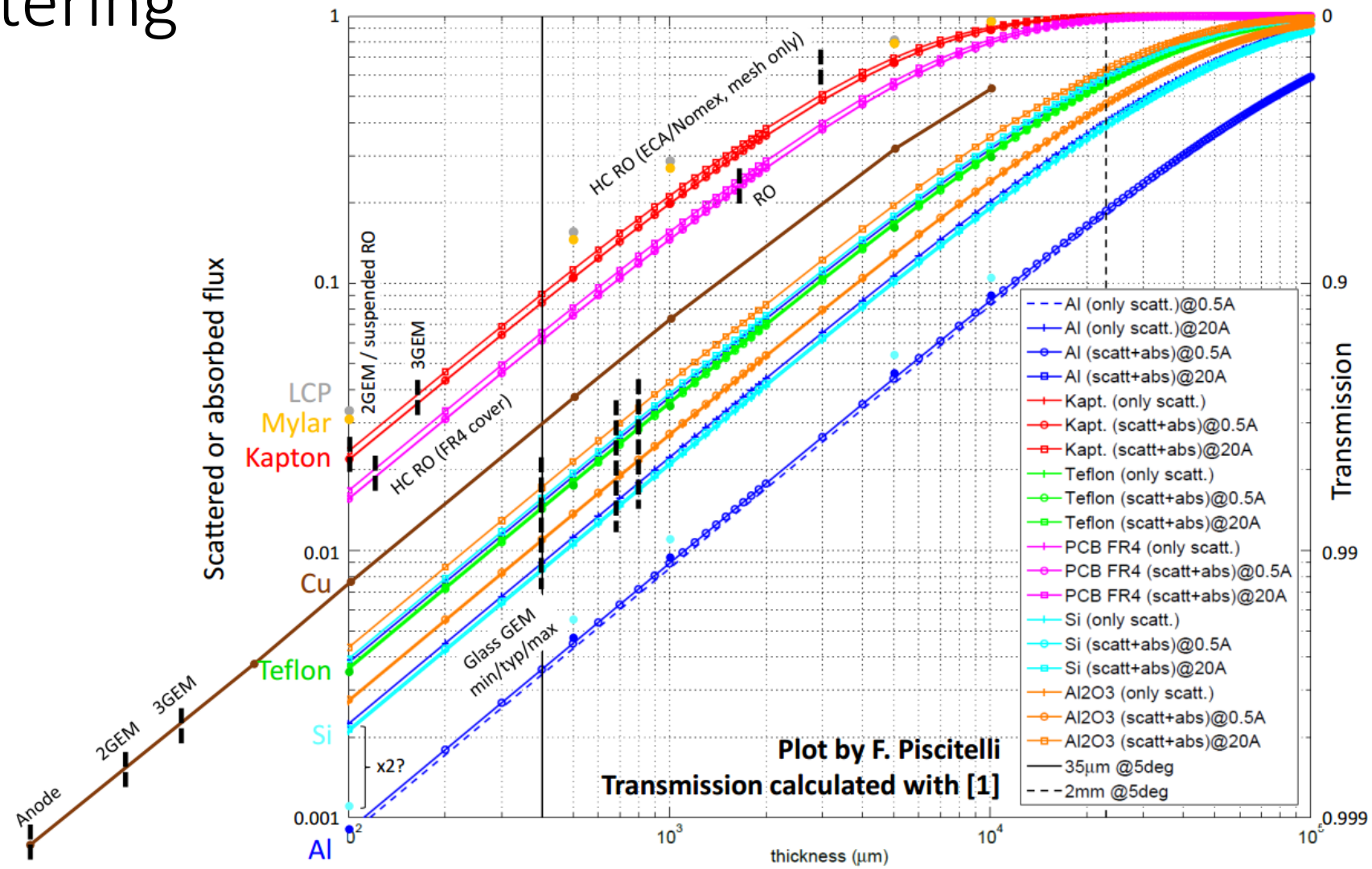
## Forward vs. backward configuration



# NMX detector baseline

## Scattering



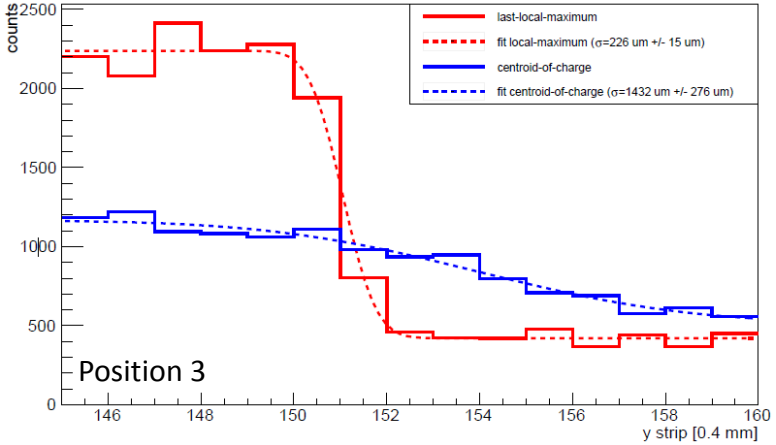

[1] https://webapps.frm2.tum.de/intranet/neutroncalc/

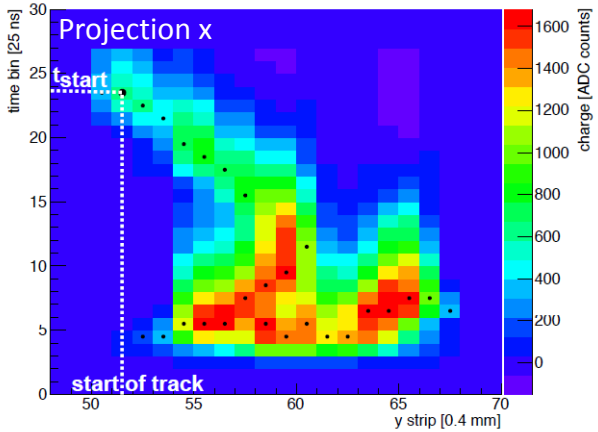
# NMX detector baseline

## Position resolution

200 µm or better

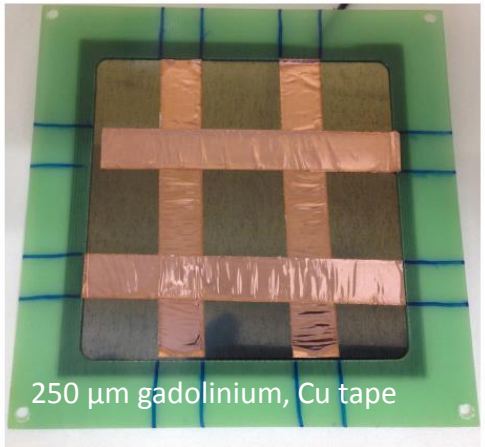
µTPC method improves position resolution considerably

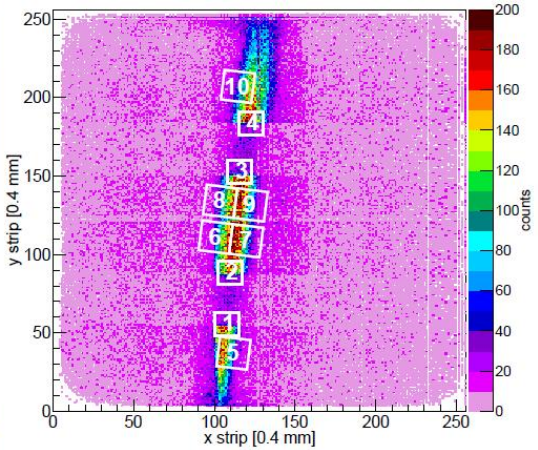


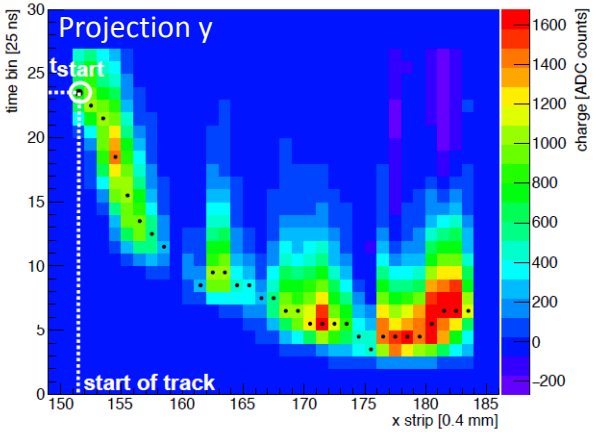




Not yet there but close

Study with mask this summer

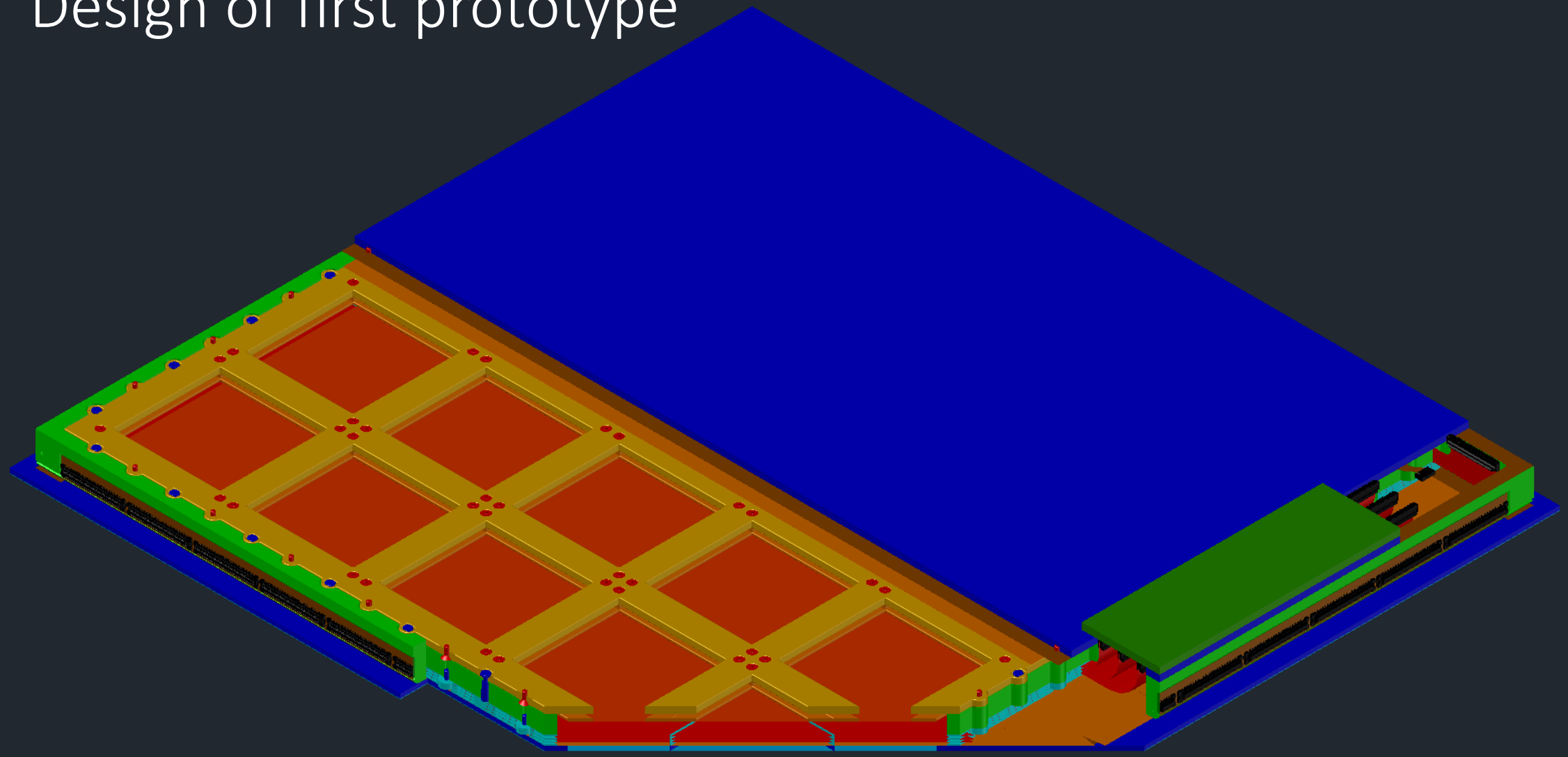


# The NMX detector demonstrator

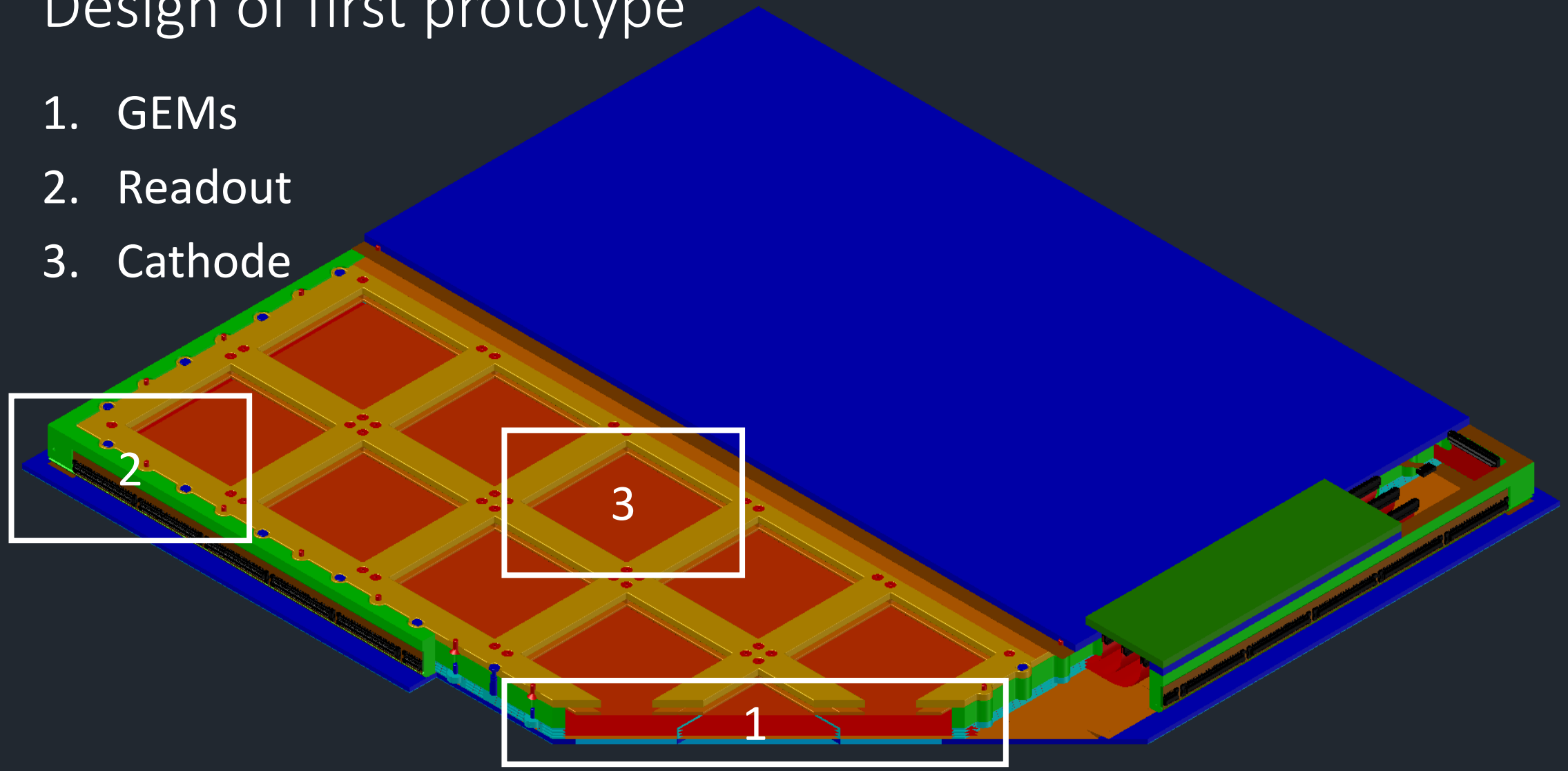
## Design of first prototype



# The NMX detector demonstrator

## Design of first prototype

1. GEMs
2. Readout
3. Cathode



# The NMX detector demonstrator

## Design of first prototype

**Detector**

Triple-GEM with active area of 51.22 x 51.22 $cm^2$
10 mm drift gap with field cage, other gaps 2 mm

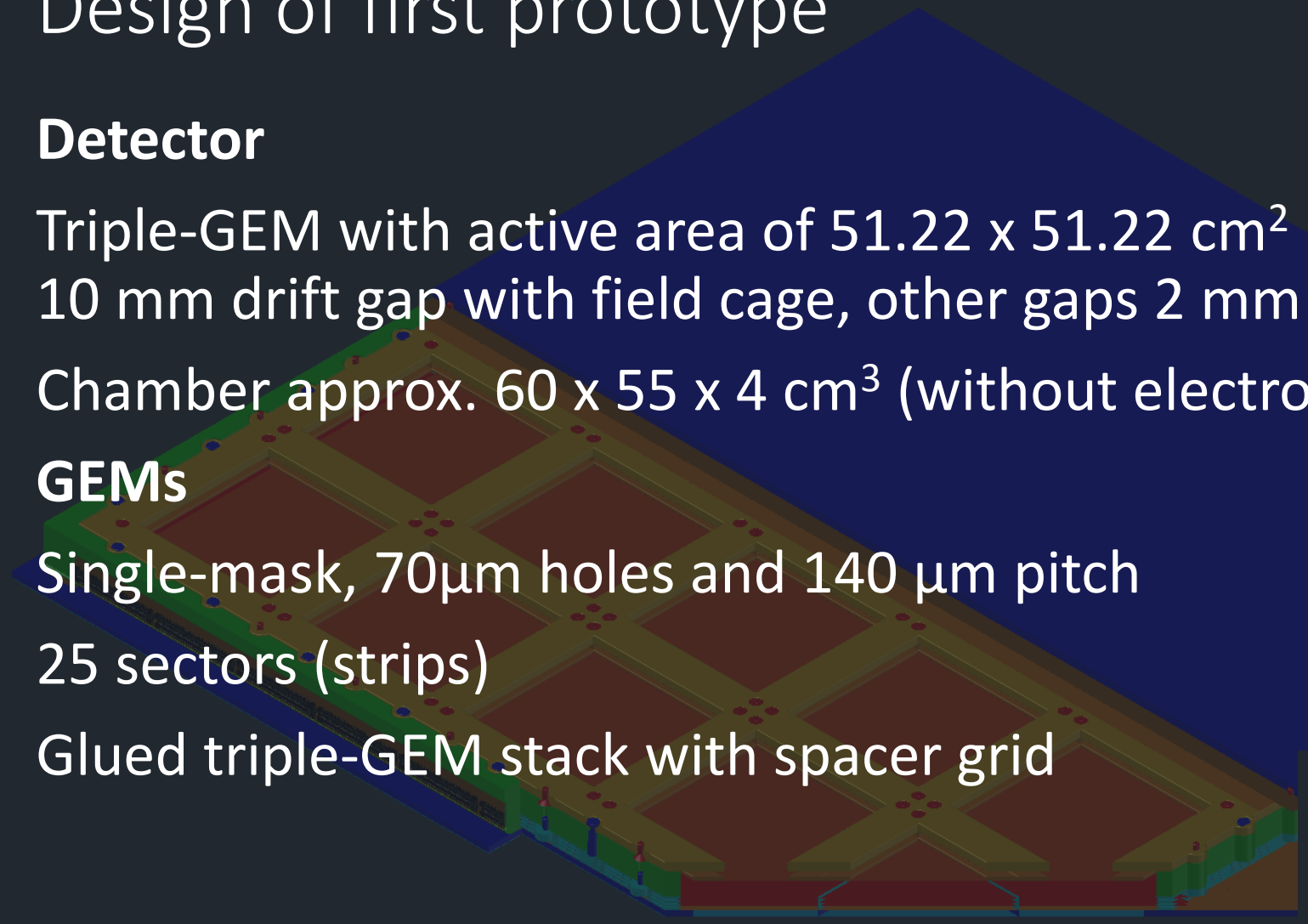
Chamber approx. 60 x 55 x 4 $cm^3$ (without electronics)

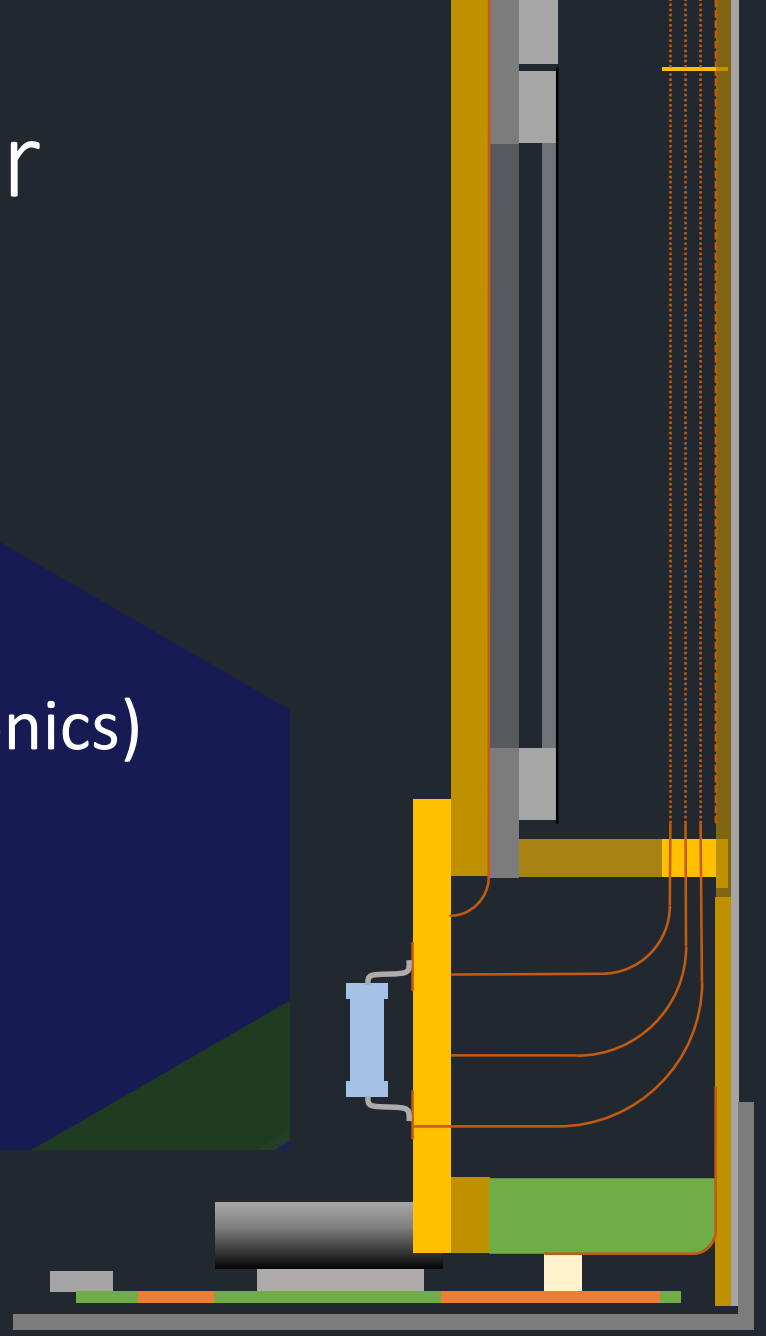
**GEMs**

Single-mask, 70µm holes and 140 µm pitch

25 sectors (strips)

Glued triple-GEM stack with spacer grid





# The NMX detector demonstrator

## Design of first prototype

**Readout**

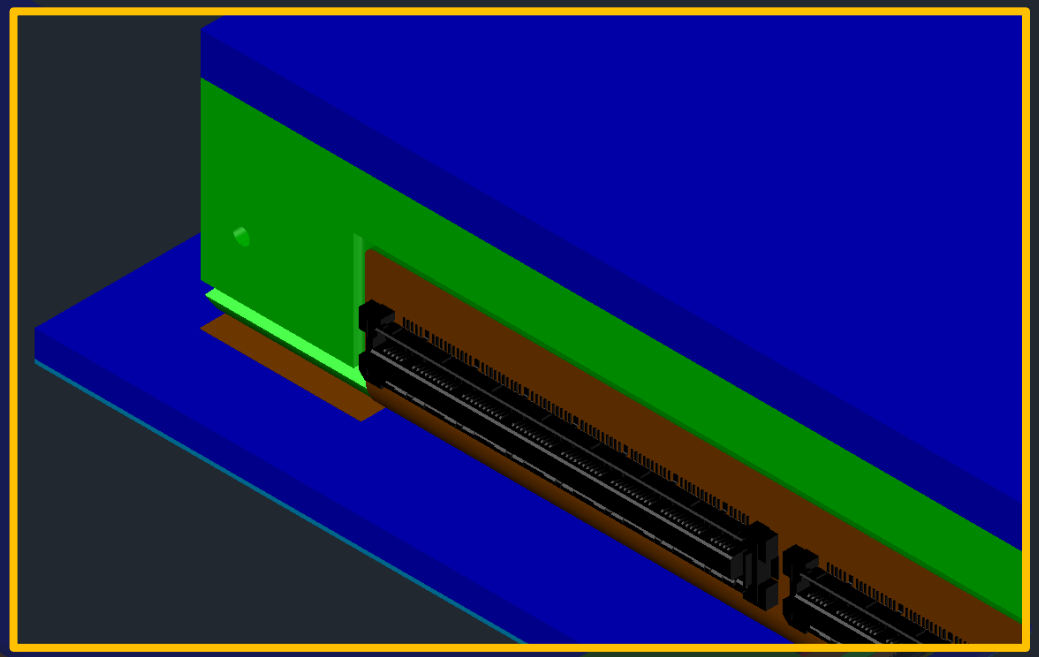
Four 25.6 x 25.6 $cm^2$ sectors

x/y Cartesian strips, 400 µm pitch
640 channels / coordinate / module

Strips read out by **VMM3 and SRS**
(see M. Lupberger's talk)

Passive cooling of VMMs

No material behind readout



# The NMX detector demonstrator

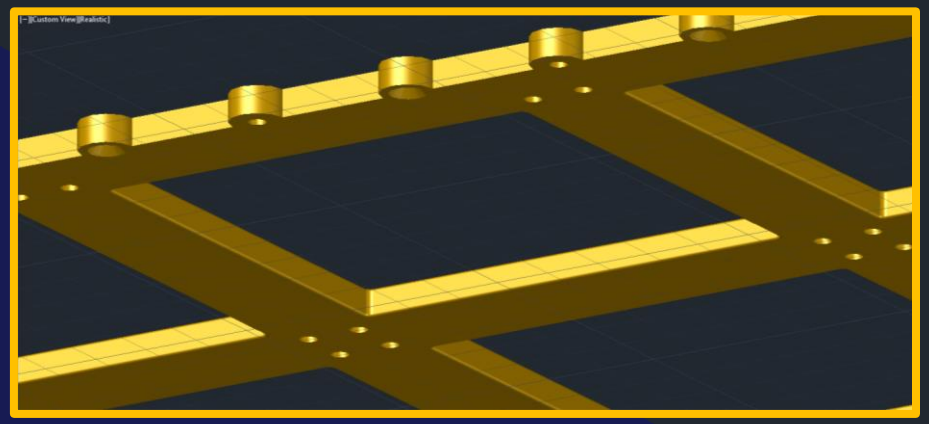
## Design of first prototype

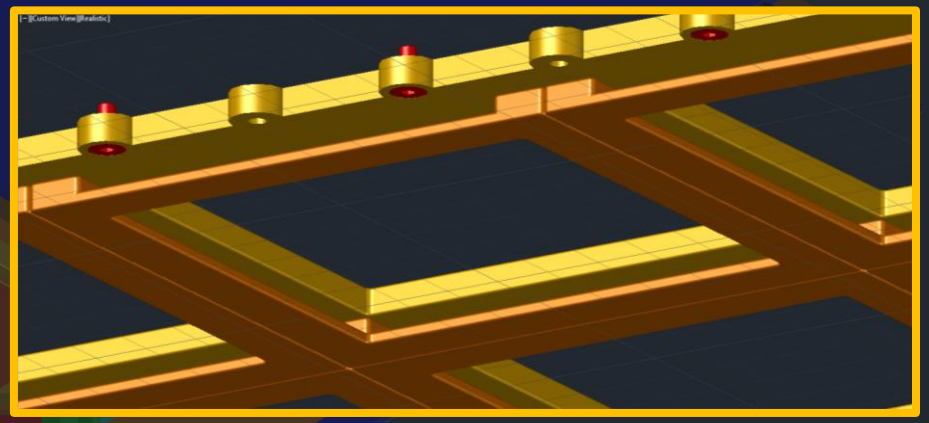
**Cathode**

Natural gadolinium, 25 µm thick

Design already foreseen for possible upgrade to enriched Gd-157 (ongoing study)

Assembled from 25 individual gadolinium foils on aluminium frames
Costs: 2k$ / foil (>12 k$ for Gd-157)



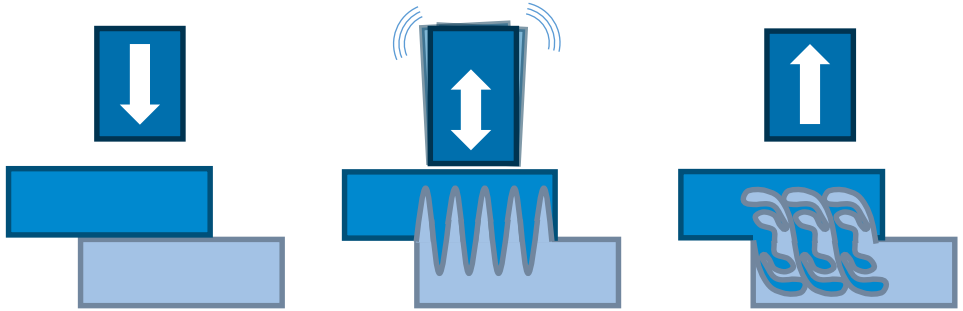


# Ultrasonic welding
## of gadolinium cathodes

### Principle

Ultrasonic acoustic vibrations + pressure

Molecules of one material diffuse into other material

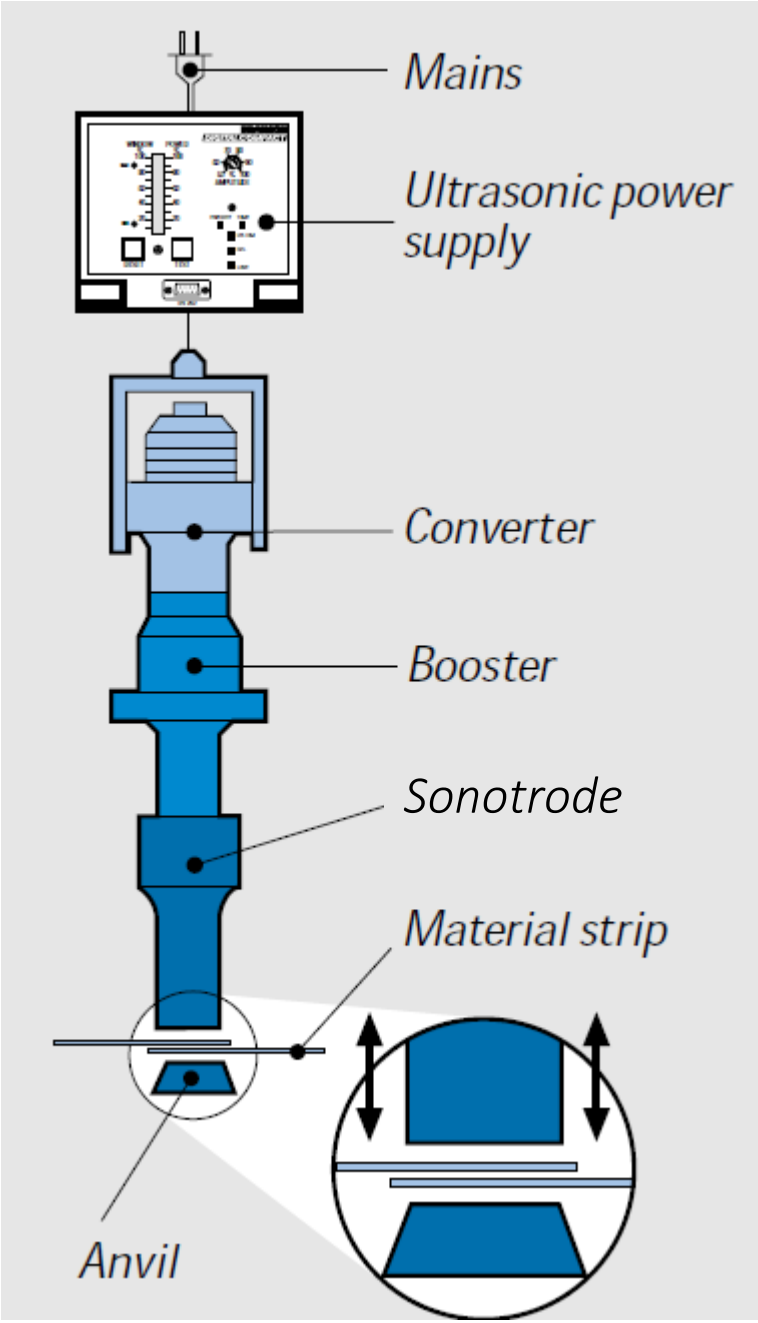


### Advantages

Joining of dissimilar materials

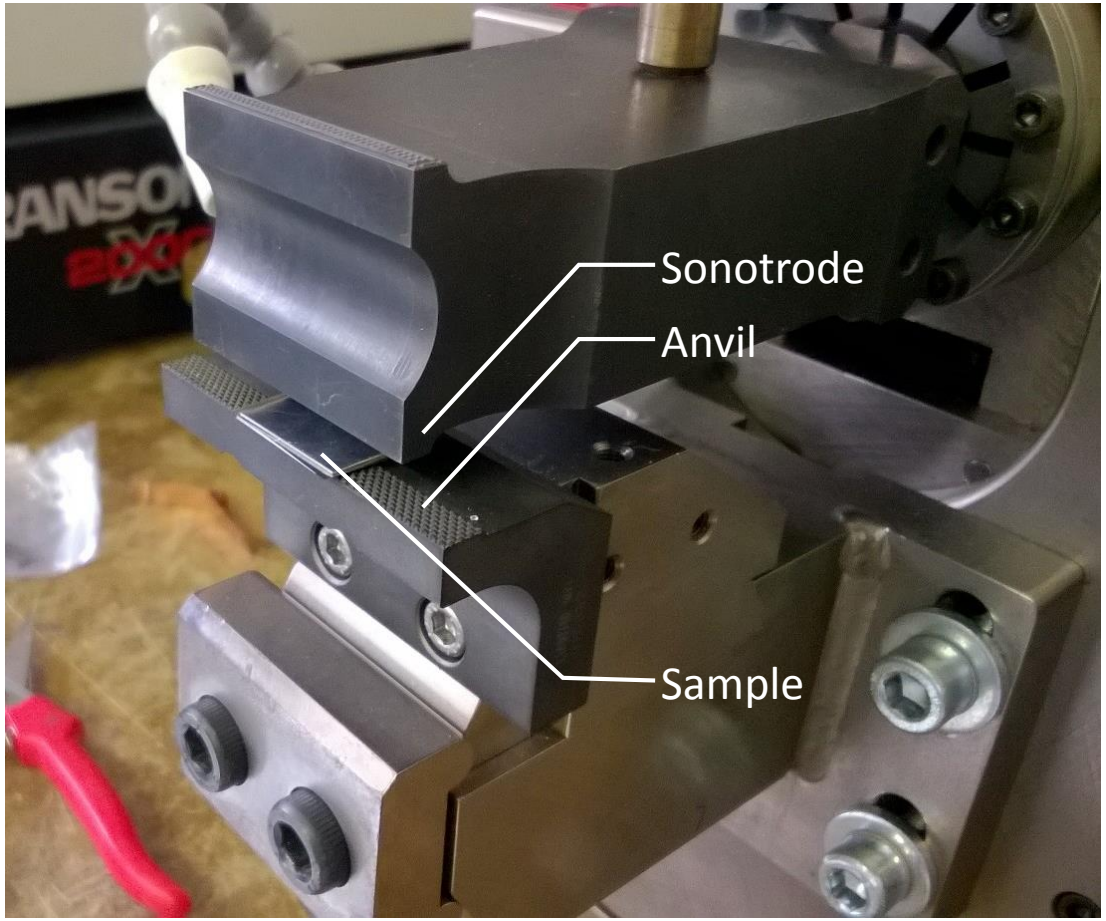
Precise and clean welds

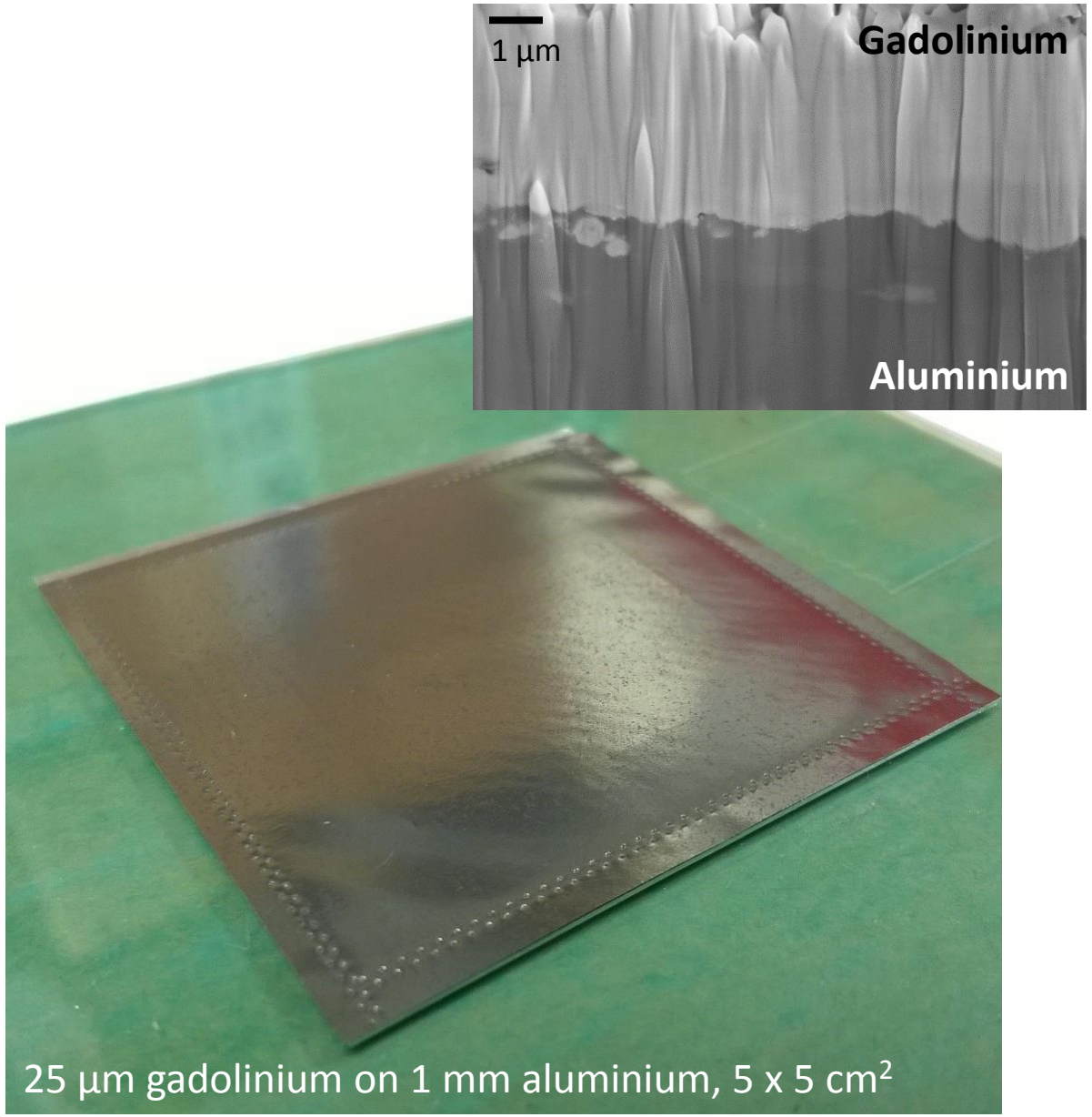
**Electrical and mechanical stability**




http://textinfo.wordpress.com/2013/04/11/ultrasonic-technology-in-nonwoven-and-textile-industry/

# Ultrasonic welding
## of gadolinium cathodes

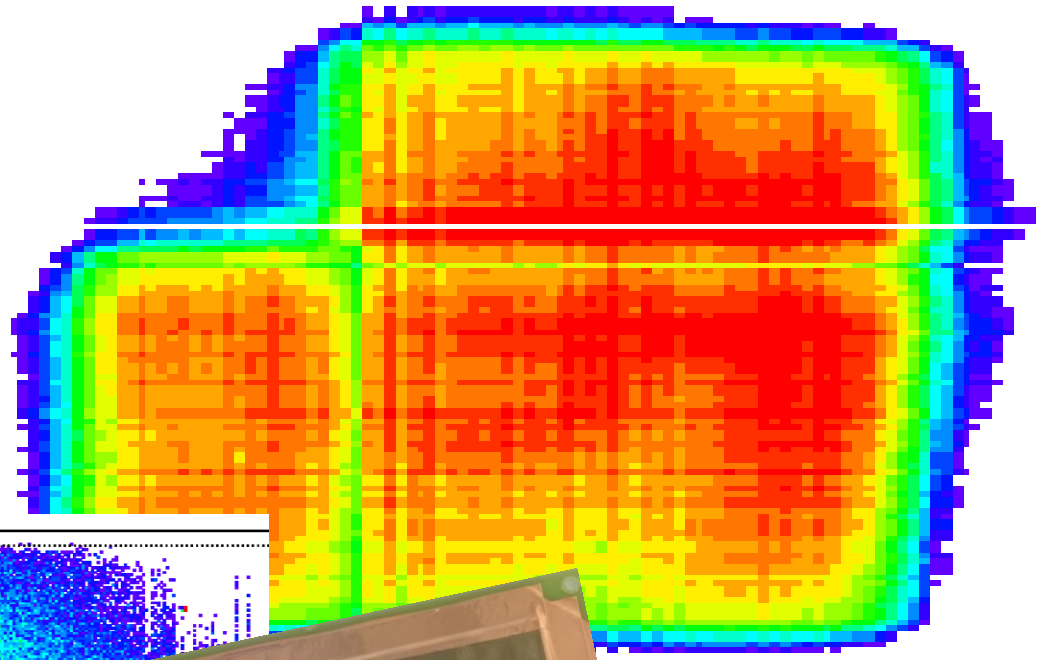


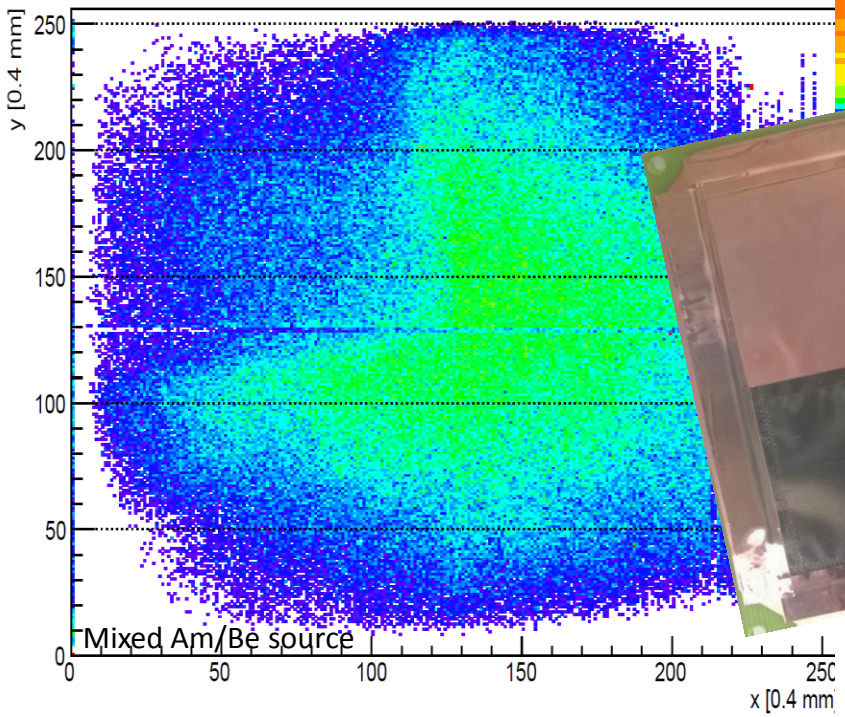
# Ultrasonic welding
## of gadolinium cathodes

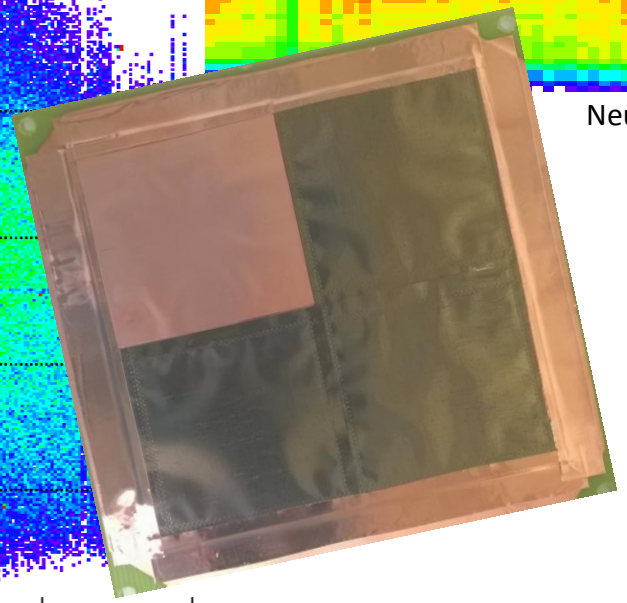
Measurement with segmented cathode (3x Gd, 1x Cu)

Welding pattern not visible with current settings but will be studied in greater detail



Neutron beam at IFE Norway



# Conclusions
## and outlook

NMX instrument will be first instrument without fixed geometry
Three fully integrated and moveable detector units

Close to requirement of 200 µm spatial resolution
Studies with slit mask ongoing

VMM readout will be capable of handling the high neutron flux
(see M. Lupberger's talk)

First gadolinium cathodes produced with ultrasonic welding
Possibility to upgrade to enriched Gd-157 currently studied

Detector design ready and currently reviewed
Production of components will start in July
First prototype will be ready by end of October