EP-DT
Detector Technologies

Current status of the
NMX Zita detector prototype v0

P. Thuiner

on behalf of the CERN GDD group

Outline
What is part of this talk

The European Spallation Source ERIC

The NMX instrument: Overview

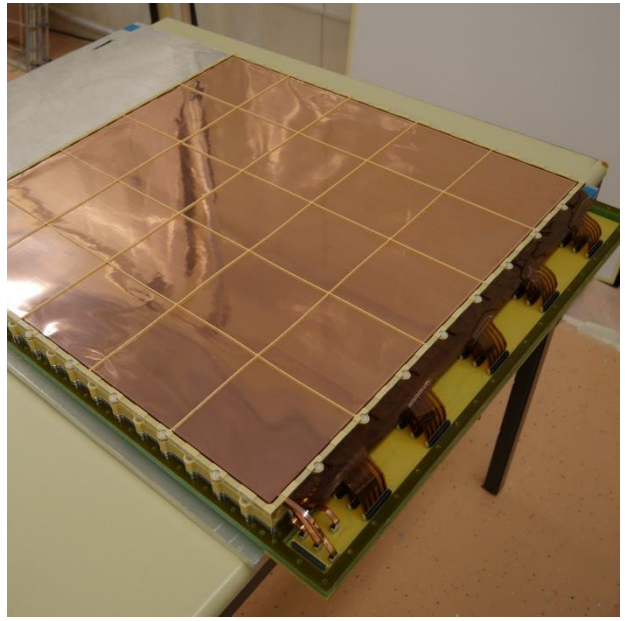
Zita: Demonstrator prototype v0

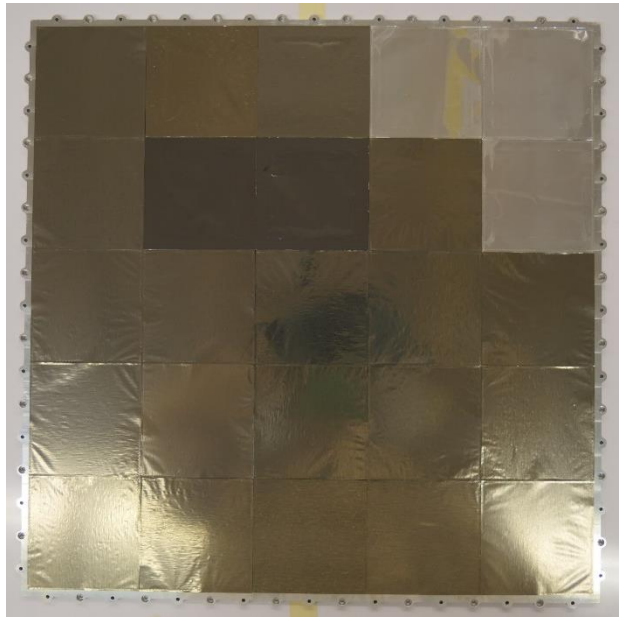
First tests

Conclusions

Outlook

Not part of talk:
Results with 10 x 10 cm² prototype (rate, resolution, efficiency, diffraction patterns,...)





The European Spallation Source

Campus and surroundings

https://europeanspallationsource.se/sites/default/files/images/media/2017-08/ESS_BIG_VIEW.jpg

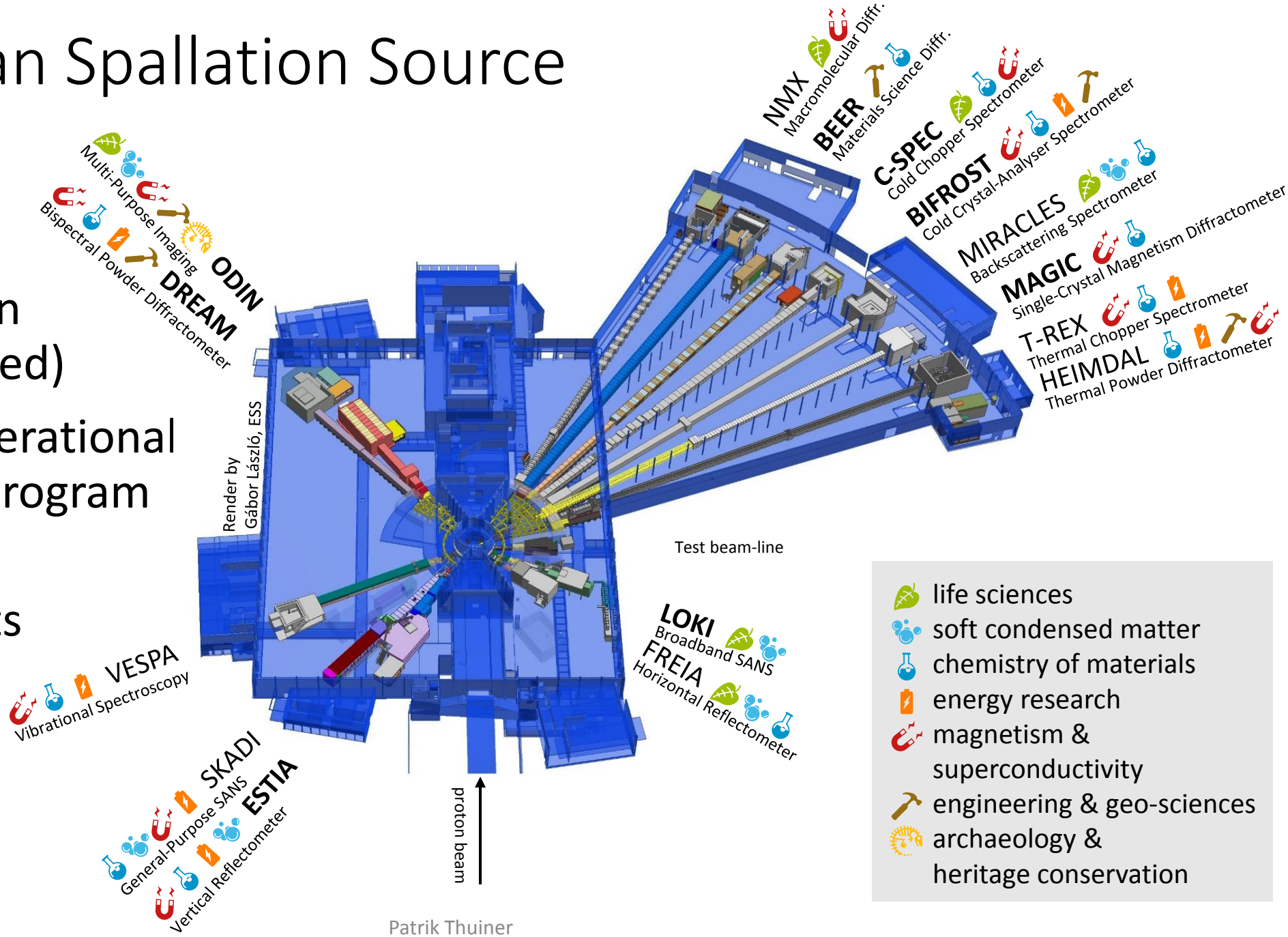
The European Spallation Source

Instruments

15 instruments currently foreseen (22 initially planned)

8 instruments operational for start of user program (August 2023)

Other instruments as possible backups in case of major delays



The NMX instrument

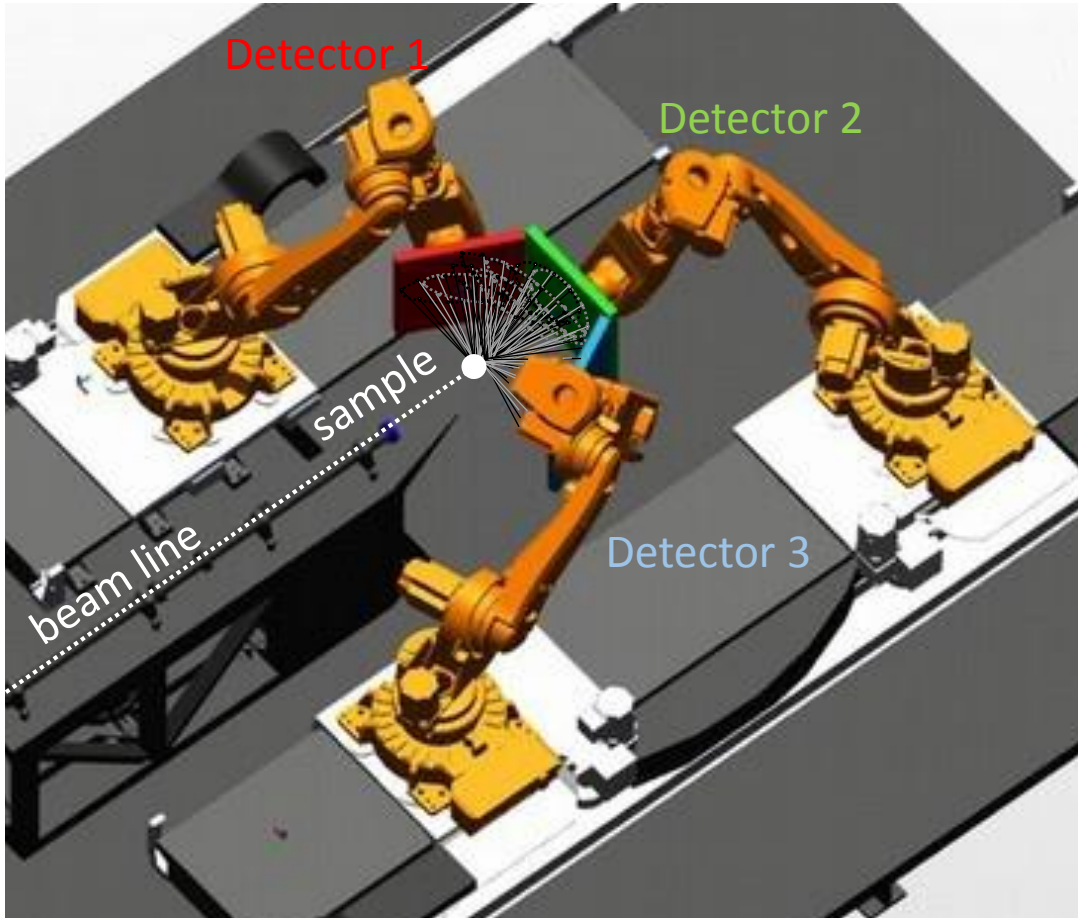
Neutron macromolecular diffractometer

Structure determination of **biological macromolecules** by crystallography

Locates **hydrogen atoms** relevant for the function of the macromolecule

Needed: high rate capabilities, good detection efficiency, position & time resolution

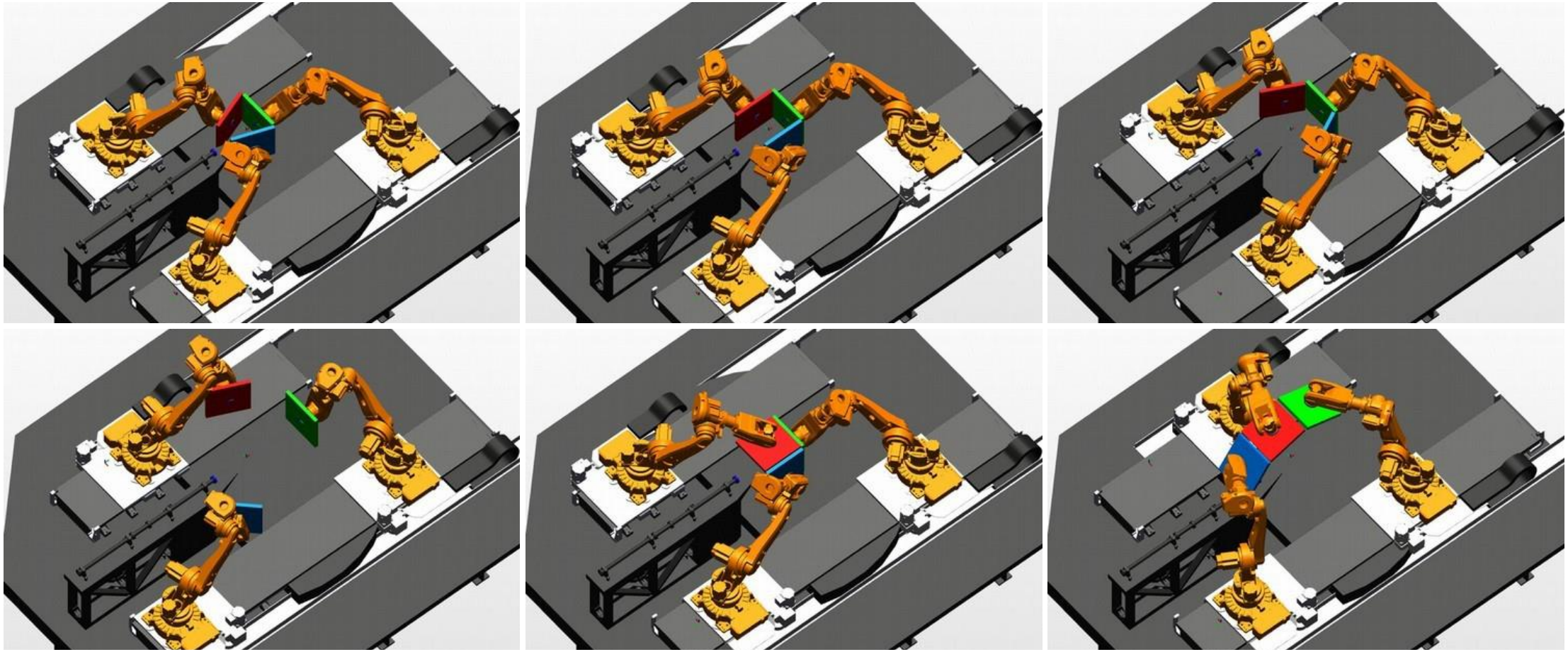
Physics **demonstrator** build at **CERN GDD** facilities as part of BrightnESS project within Horizon 2020



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

The NMX instrument

No fixed detector geometry



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

The NMX instrument
Detector baseline

Triple-GEM detector with **natural gadolinium cathode** as neutron converter

Active **detector area 50 x 50 cm²**, divided into four segments

GEM foils glued onto **frames, spacers in active area** to keep gap length

Minimised distance GEM – detector edge on three sides

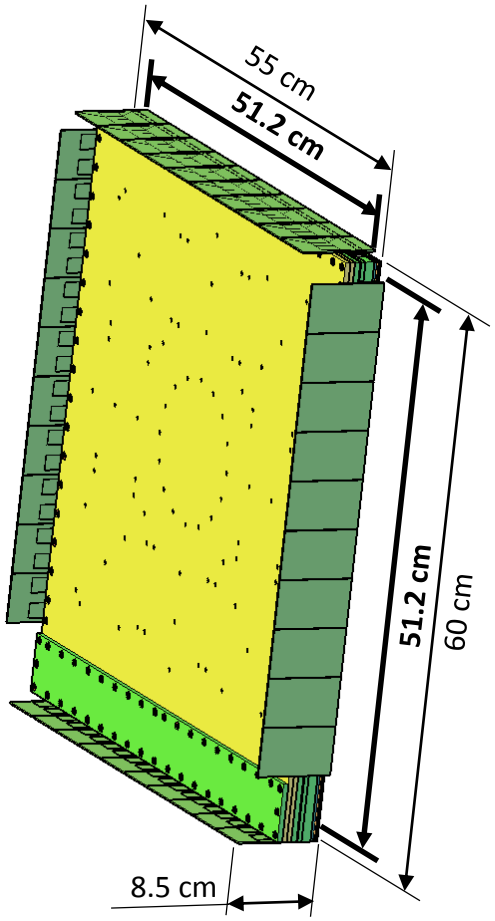
Very low material budget readout

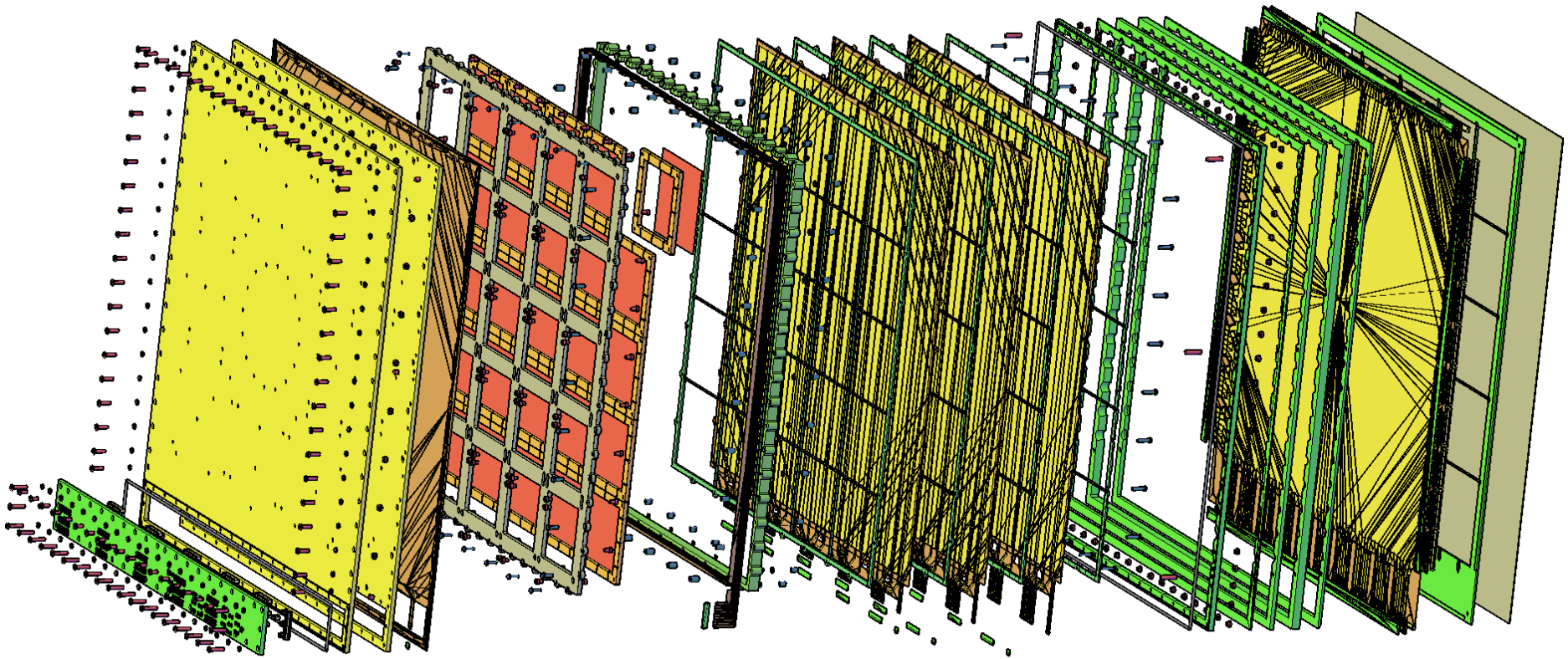
Cartesian **2D strip readout**, 400 µm strip pitch (standard size)

5 VMM3a hybrids per coordinate per module
total of **40 VMM3a hybrids** read **5120 strips**

µTPC method as readout technique

NMX demonstrator prototype v0 “Zita”
911+ pieces of fun





shielding and cables not shown

NMX demonstrator prototype v0 “Zita”
Why so complicated?

Detector moves

Dead area between three detectors to be minimized

→stretching as in CMS GEM upgrade doesn’t work

} GEM spacers “edgeless” design w/ perpendicular VMM hybrids

Gadolinium as neutron converter

→ can’t be sputtered

→ foils can’t be larger than ~ 100 cm², can‘t be glued

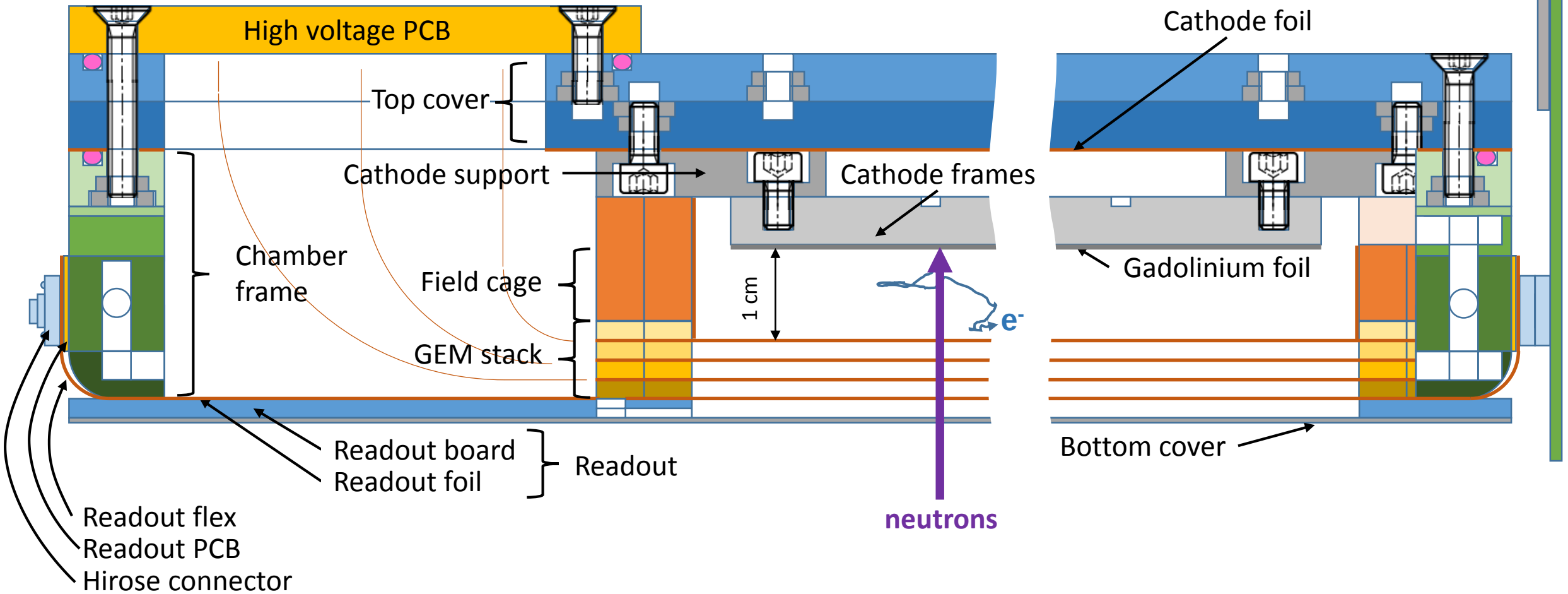
} cathode assembly 25x segments

Neutron scattering

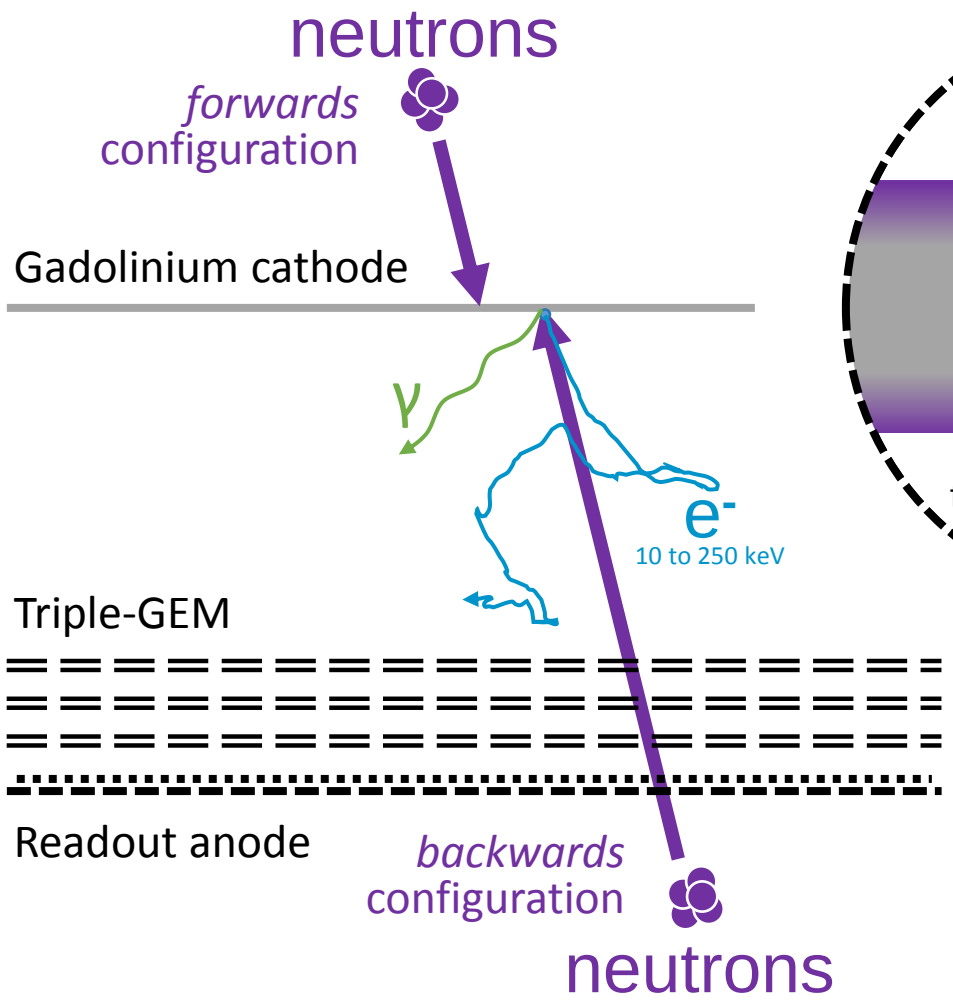
→ low material budget readout

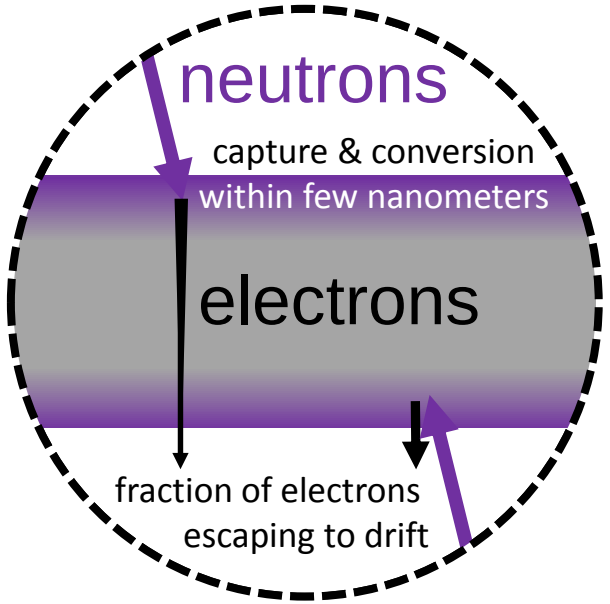
} metal window

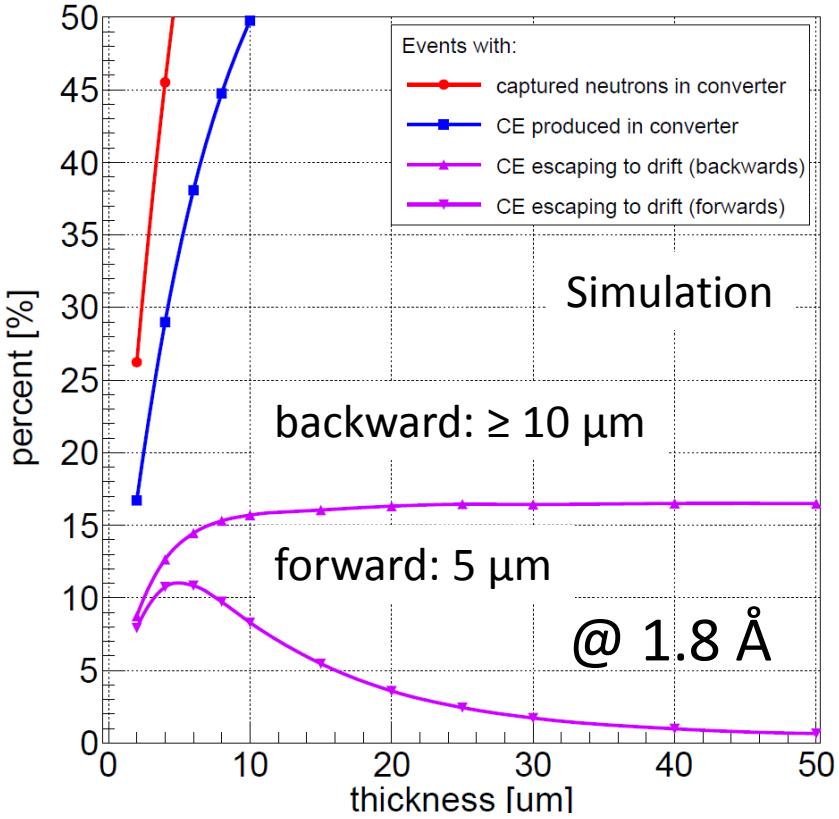
NMX demonstrator prototype v0 “Zita”
Cross section

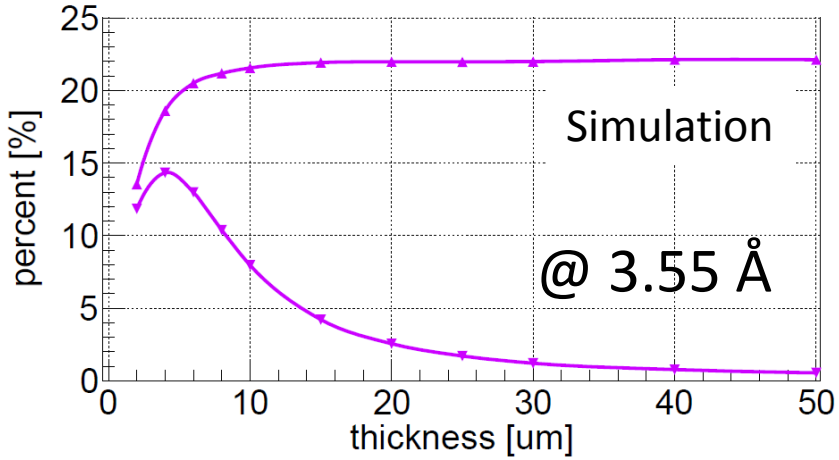


Gadolinium cathode
Theory









Simulations by D. Pfeiffer, ESS

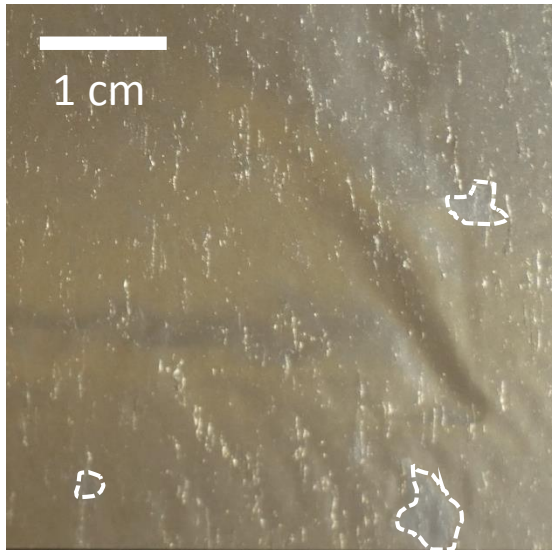
Gadolinium cathode
Assembly

Gadolinium **can't be sputtered** to uniform **thickness > few µm**

Gadolinium **can be rolled** to uniform **thickness > 10 µm**

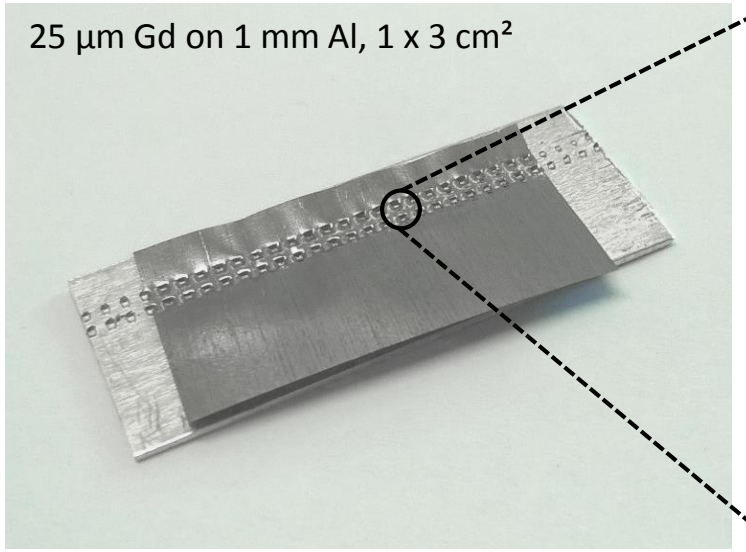
Gadolinium **can't be rolled** to **area > O(10 cm x 10 cm)**

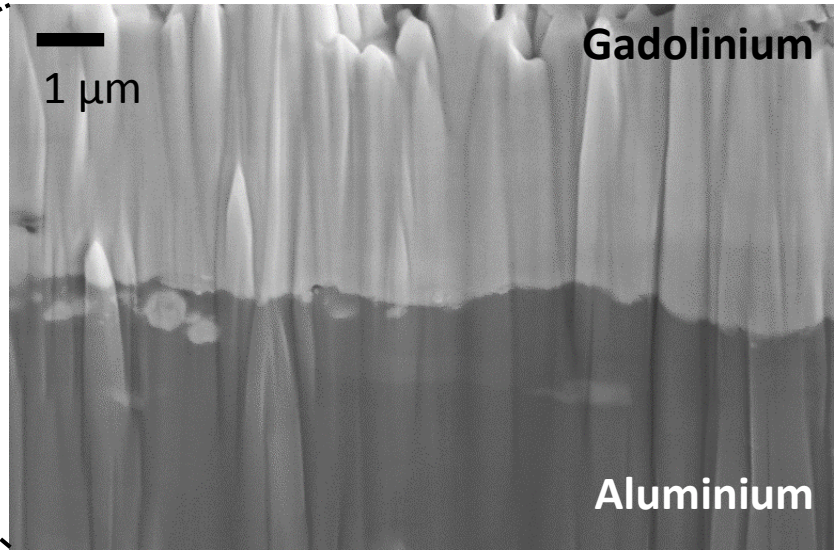
Some assembly required



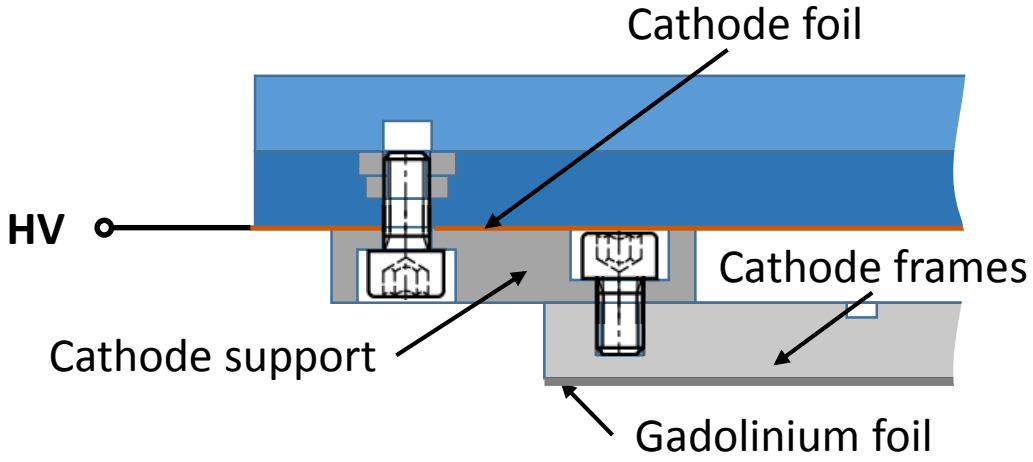
Gluing

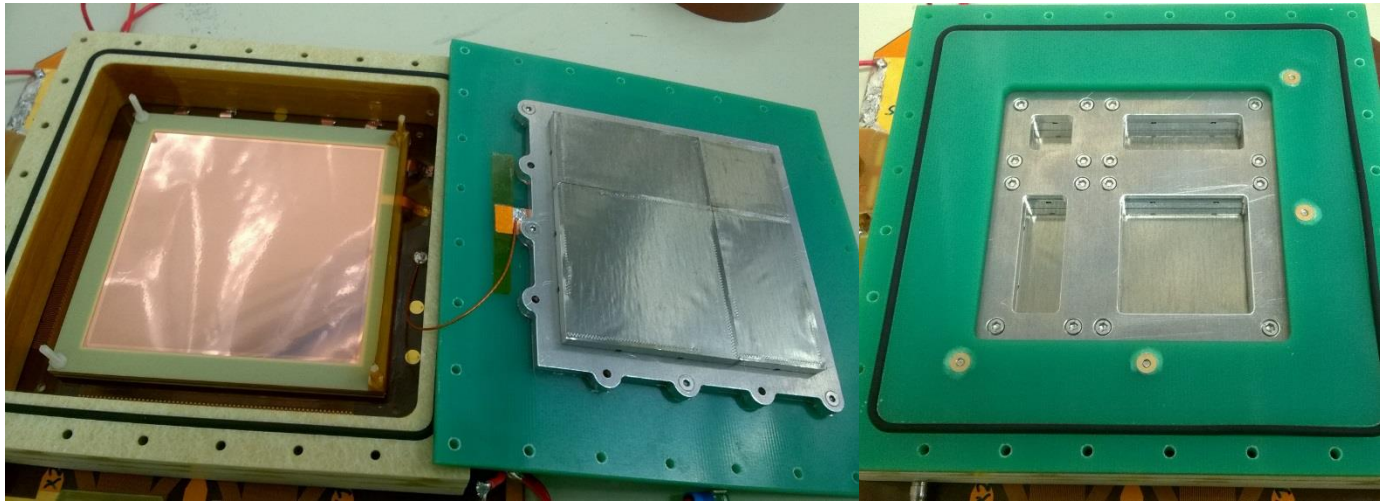
Welding

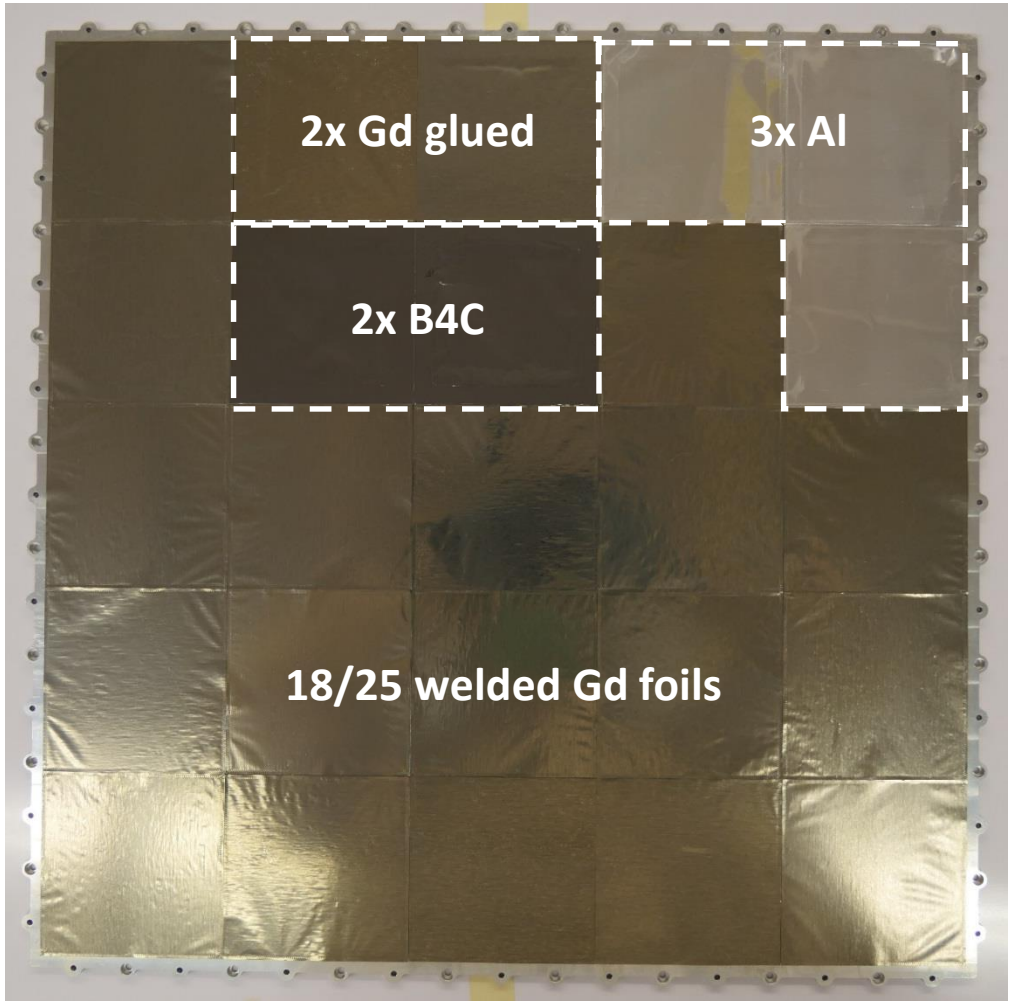




Gadolinium cathode
Assembly







GEM foils
and assembly of GEM stack

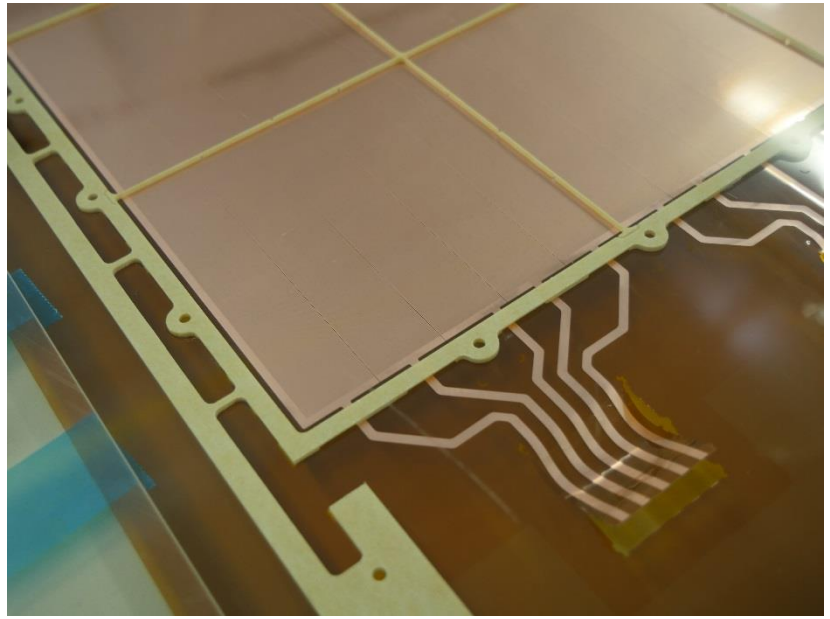
Active area of **51.2 cm x 51.2 cm**

GEM top segmented into
25 strips of 2 cm x 51.2 cm

GEM bottom not segmented

Spacer frame **every 10 cm**

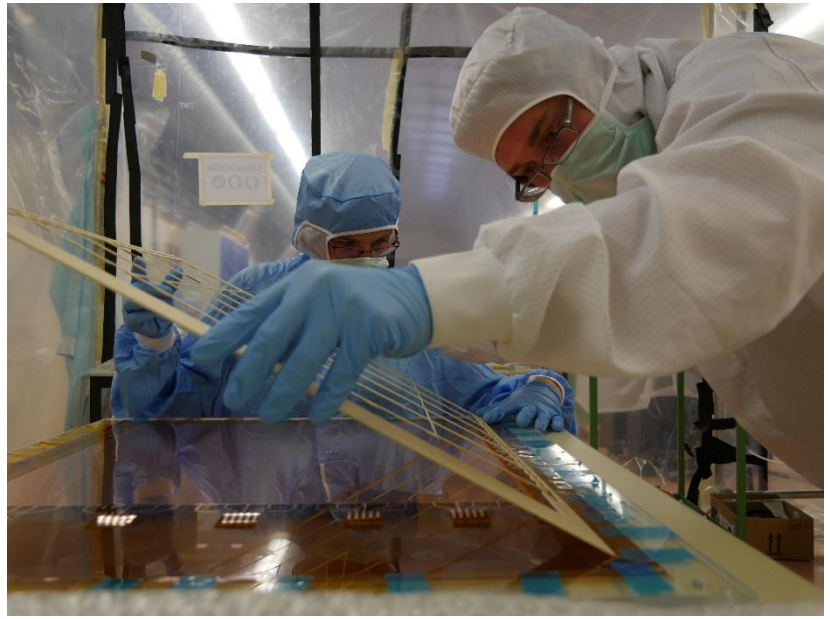
Additional **spacer on top of GEM 1** since detector will also be **operated upside down**

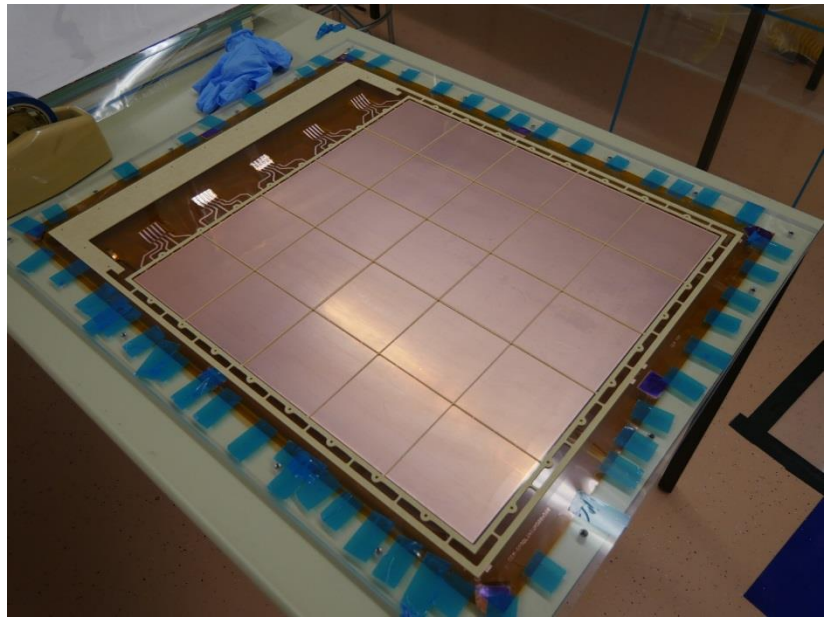


GEM foils
and assembly of GEM stack

GEM **stretched at room temperature** with tape and glued to frame

Supporting frame around GEM frame during stretching





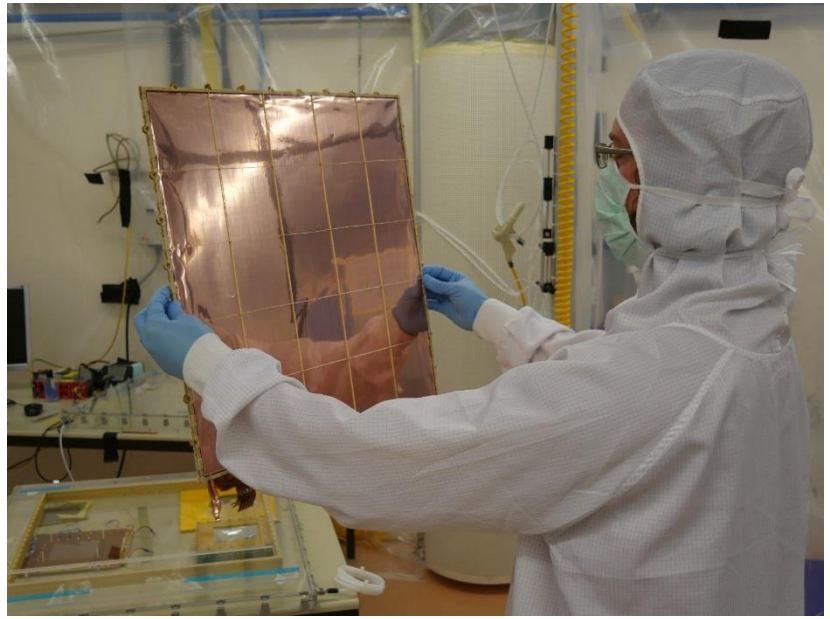
GEM foils
and assembly of GEM stack

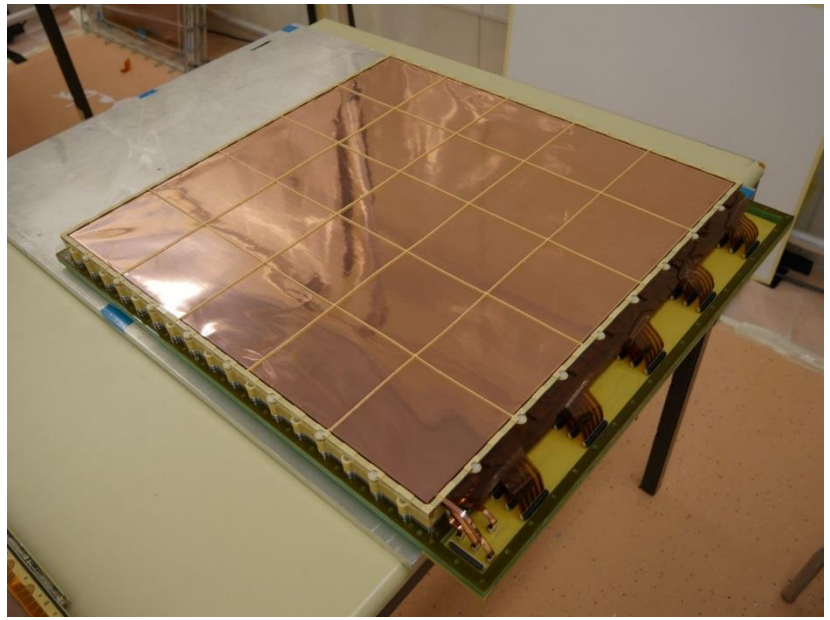
Supporting frame **removed after full assembly** of stack

GEM stack **screwed into place** and connected to **HV feed-throughs** with **ZIF connectors**

HV test of each individual after assembly (stability, discharges, …)

All GEMs worked fine
(one sector on GEM 1 ~60 nA leakage current after two weeks of testing)

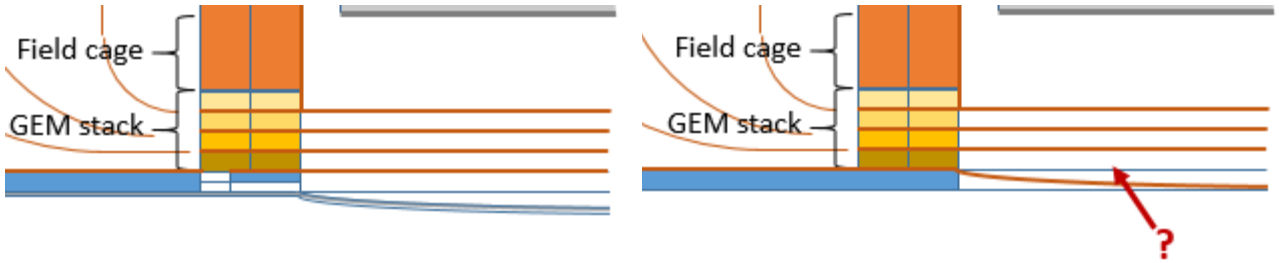




Readout board
and detector chamber

Hollow readout with **pressure equalisation**

Low material budget readout

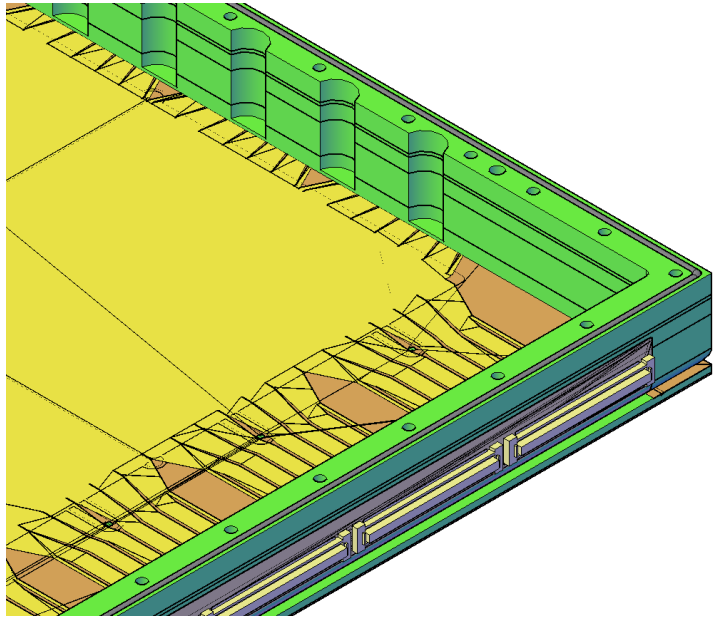


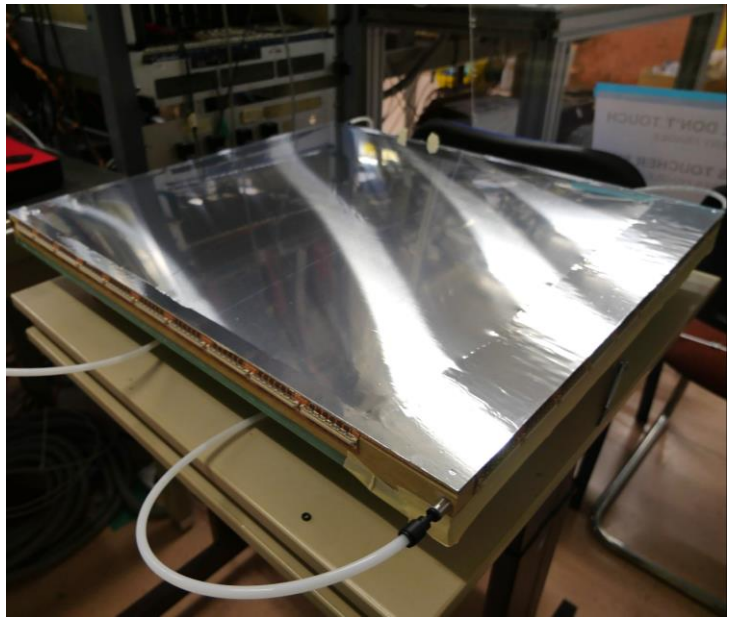
Readout in four quarters **read from all four sides**

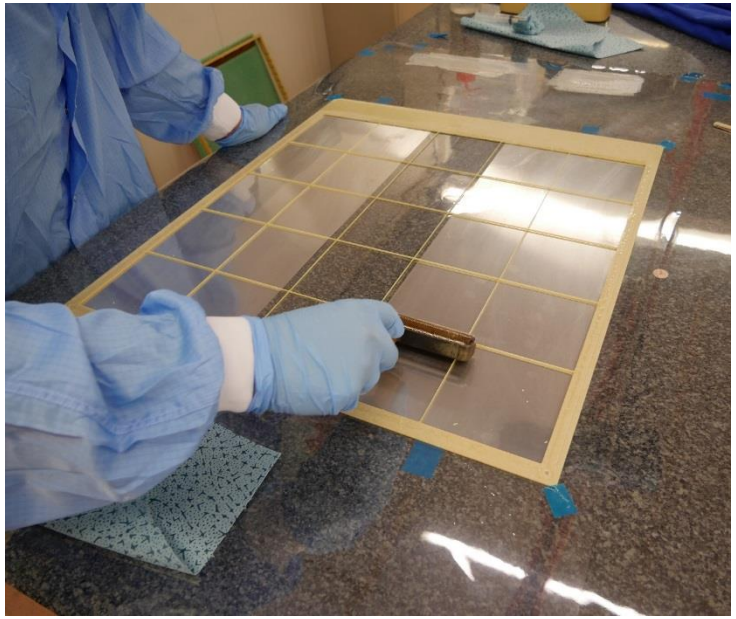
VMM3a **hybrids perpendicular to readout** plane

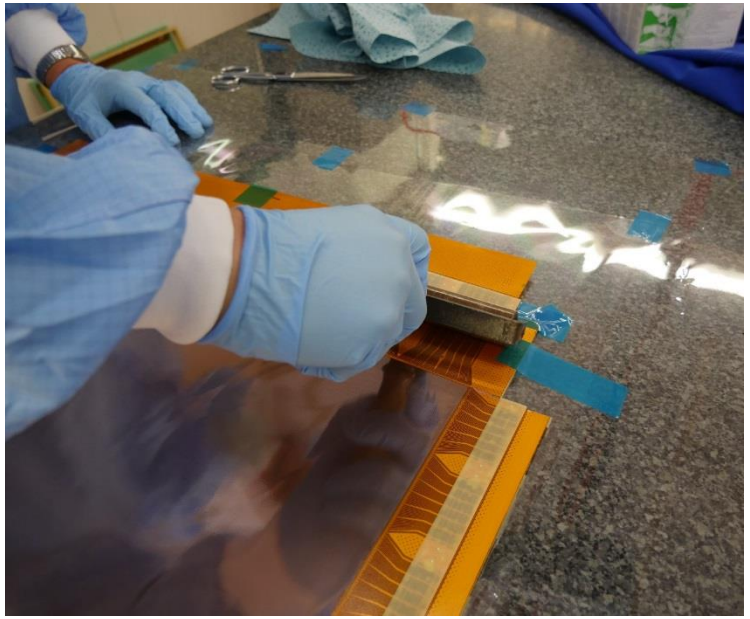
→ needs to be folded around detector edge

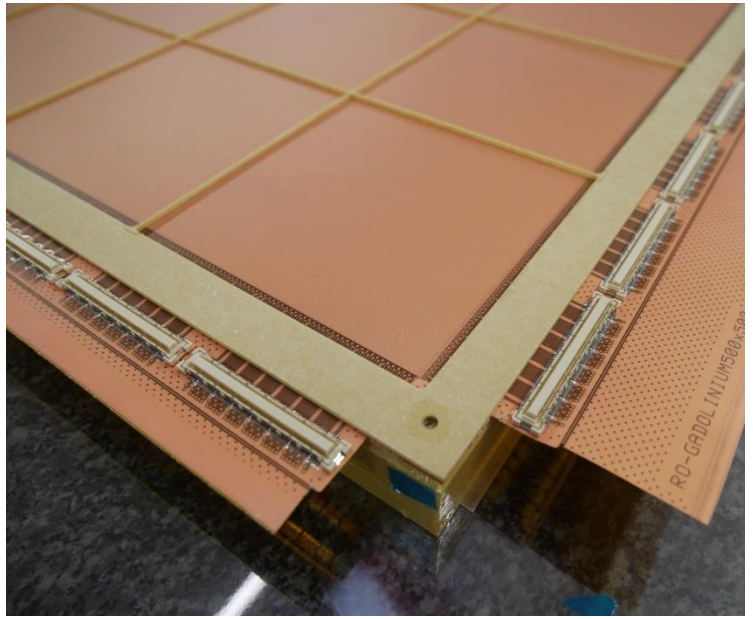
New 140 Pin **Hirose connectors**

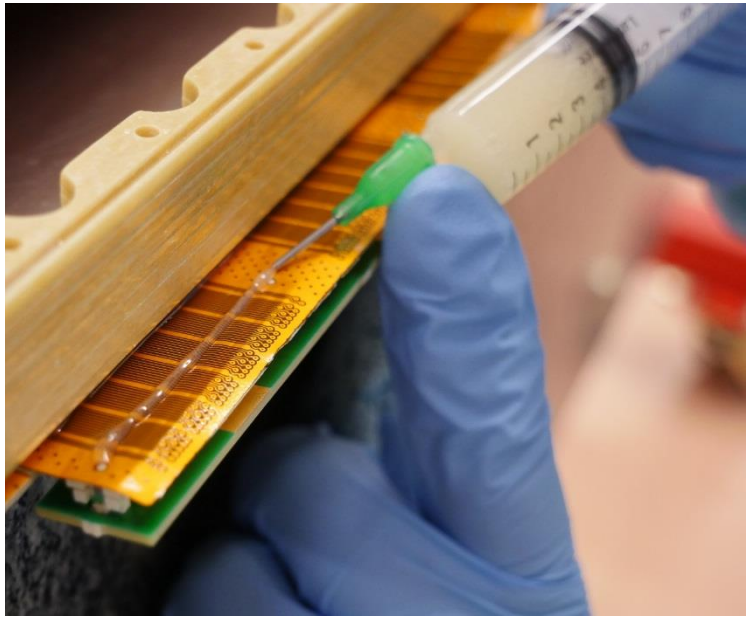


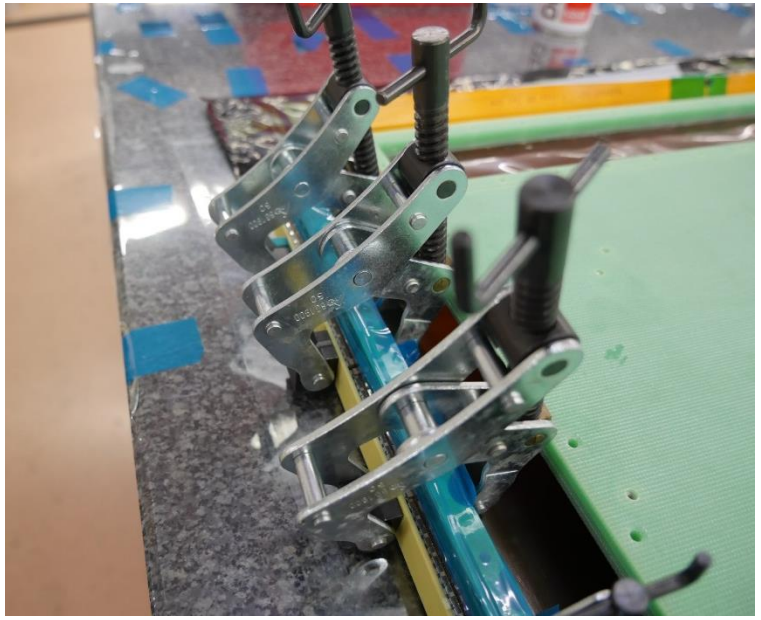












Readout board
Test of readout strips

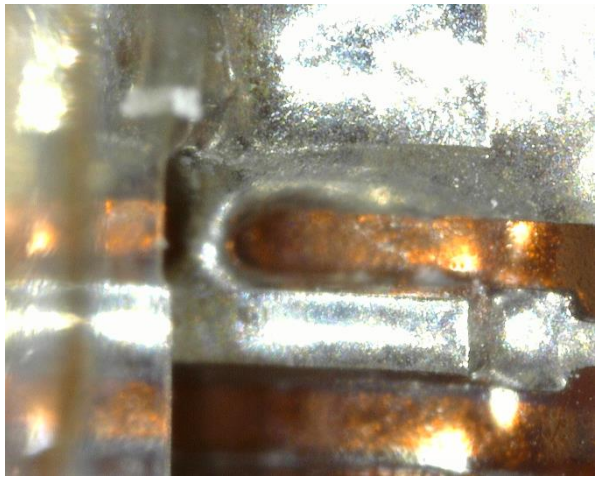
Readout strips tested with help of CMS GEM team (Michele Bianco and **Saleem Khan Lohani**)

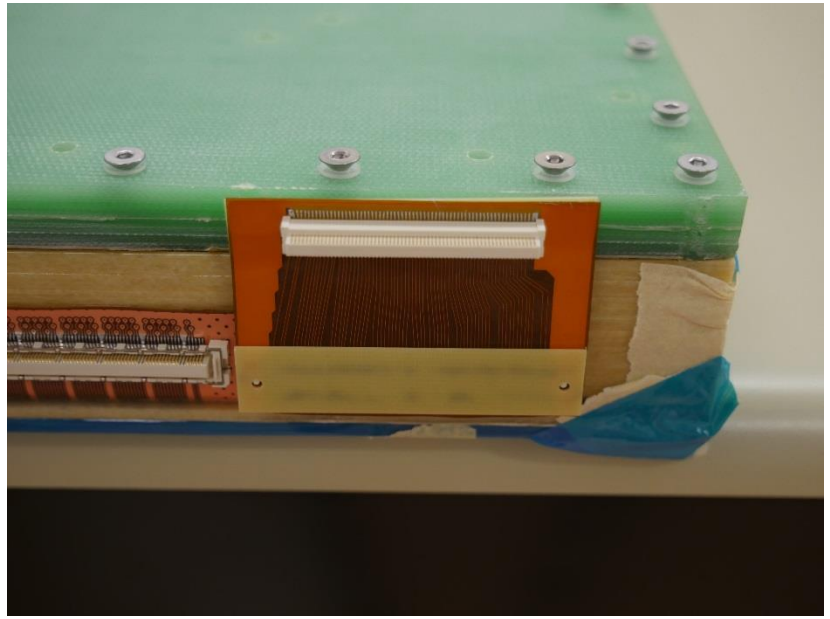
Short between strips only, **no capacitance**

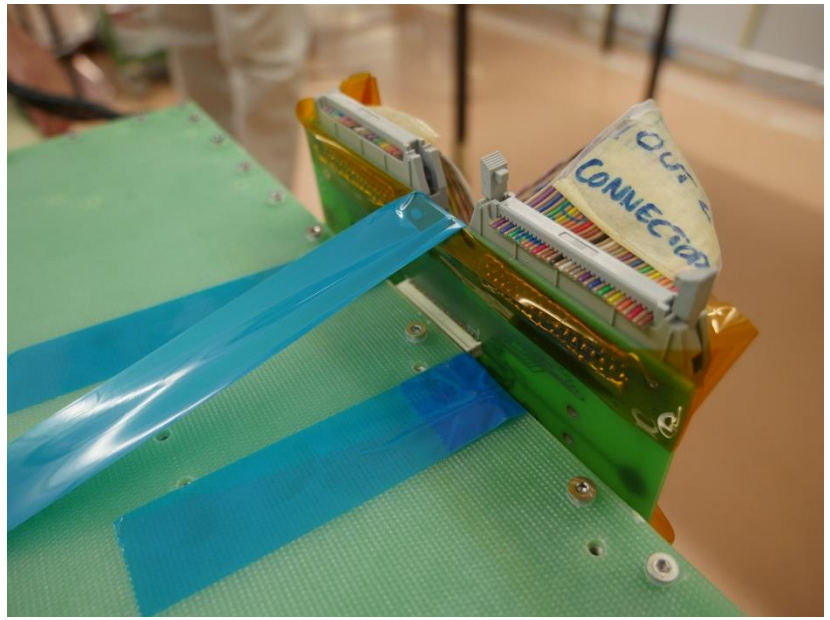
Adapter old Panasonic **to new** Hirose connector

GND pins of new connector **tested manually**

→ 3/5120 pins shorted to GND pins







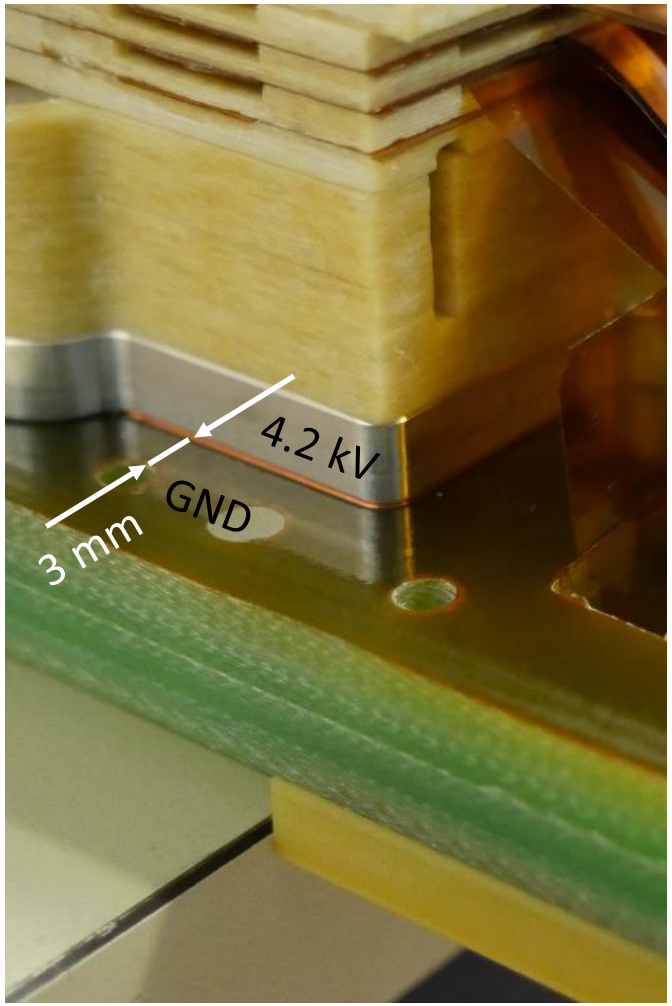
NMX demonstrator prototype v0
Test of assembled detector

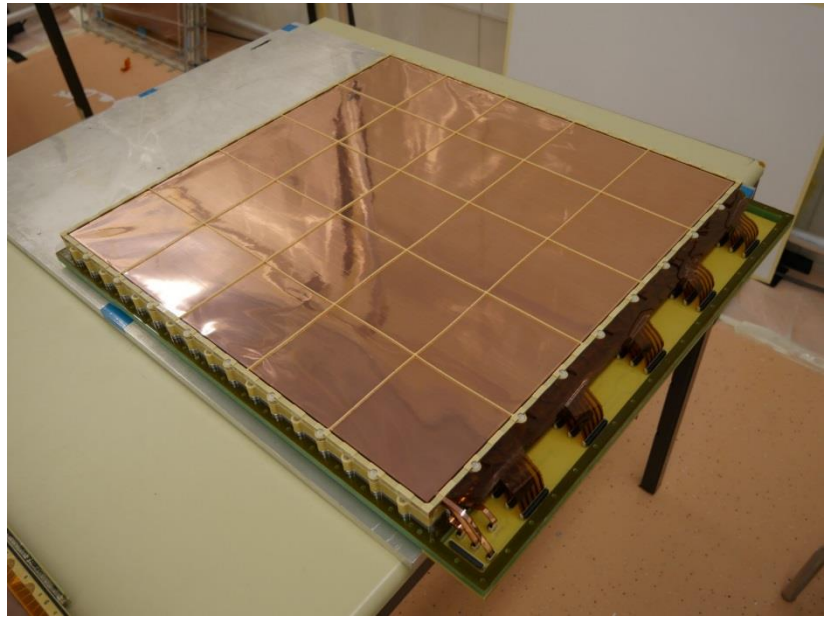
Detector can’t reach operating voltage of 4.2 kV on C

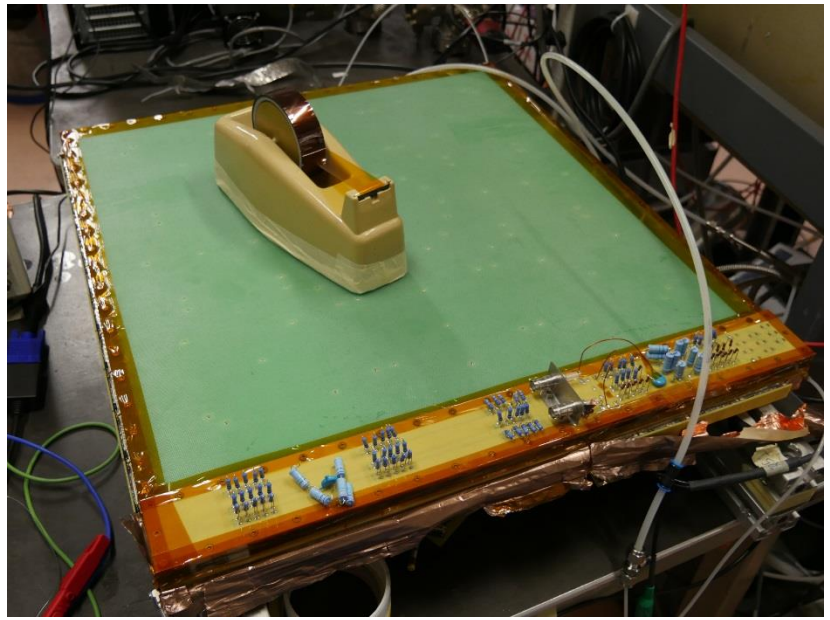
Discharges to ?

Only discharges if detector fully wrapped in Cu foil and Cu tape

→ HV clearing between cathode and chamber screws not large enough







NMX demonstrator prototype v0 “Zita”
Tests with radioactive source and x-ray

Detector **runs stably** at gain < 10k for several hours

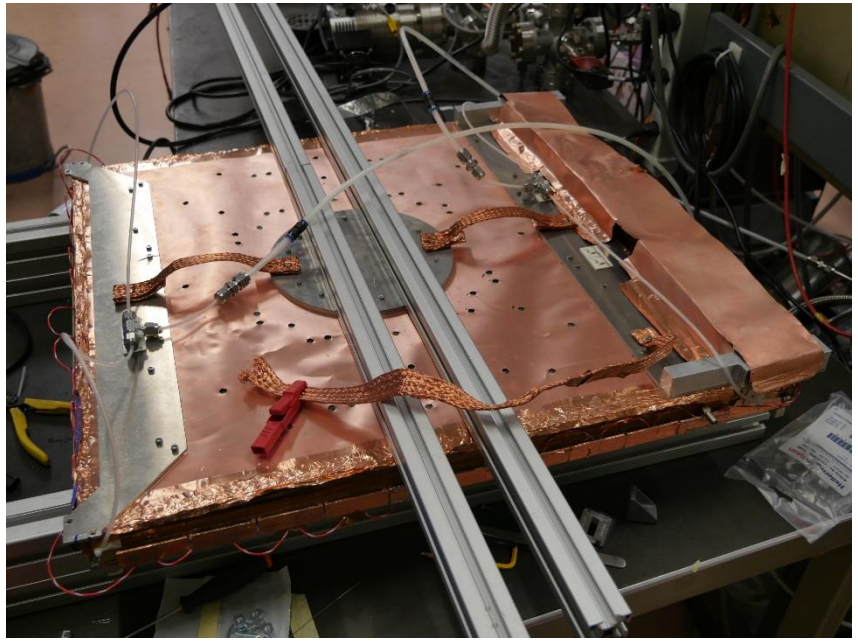
Discharges every other minute, **no trip**, currently investigated

Induced current from Ag x-ray tube and
Sr-90 visible in both anode and GEM 3 bottom

Unsolved so far:

Detector picks up a lot of noise → signal can’t be read, interaction rate can’t be estimated

Investigated with help of ATLAS in GDD lab



Conclusions & outlook
NMX @ CERN

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

Detector (almost) fully **assembled**

Problems with **S/N ratio**

Discharges not understood yet

Once problems with S/N understood:
Gain uniformity measurements for **different detector angles**

Conclusions & outlook
NMX @ ESS

Until January 2019:

Detector operation at CERN GDD

From March 2019:

Detector and assembly tools moved to ESS Utgård

Measurements at Lund University source facility

Measurements at CERN GDD to be discussed

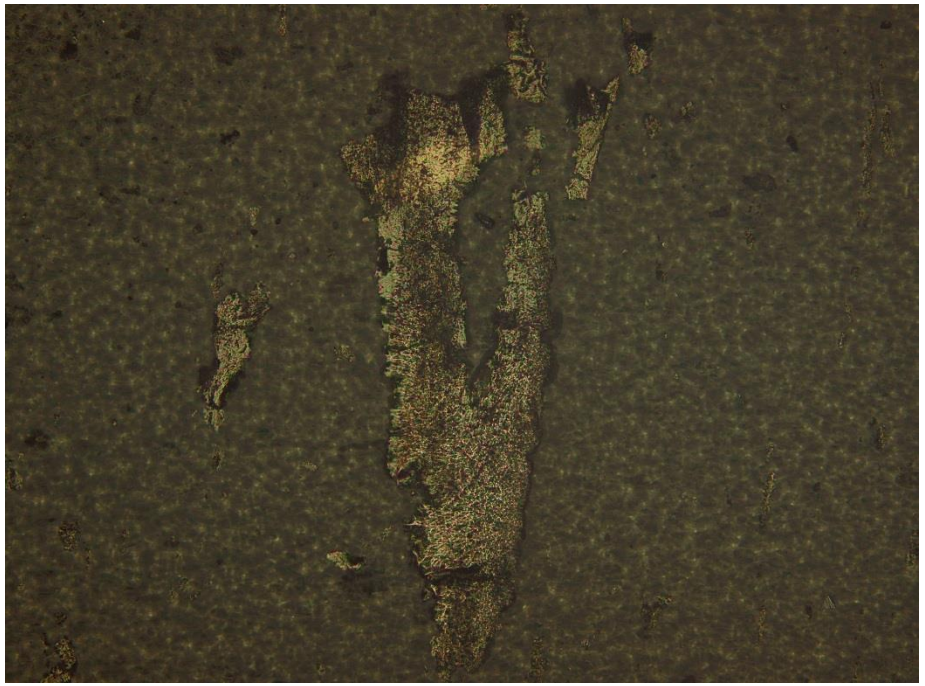
Changes for next prototype v1 “Otto” already under development

Backup

Gadolinium foils
Issues with Gd flakes and Gd oxide

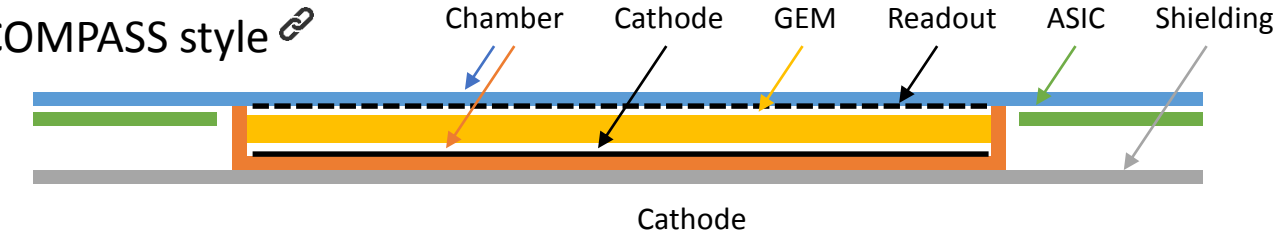
Right: Gd flakes from bad production of foils

Bottom: Gd oxide flake on tape



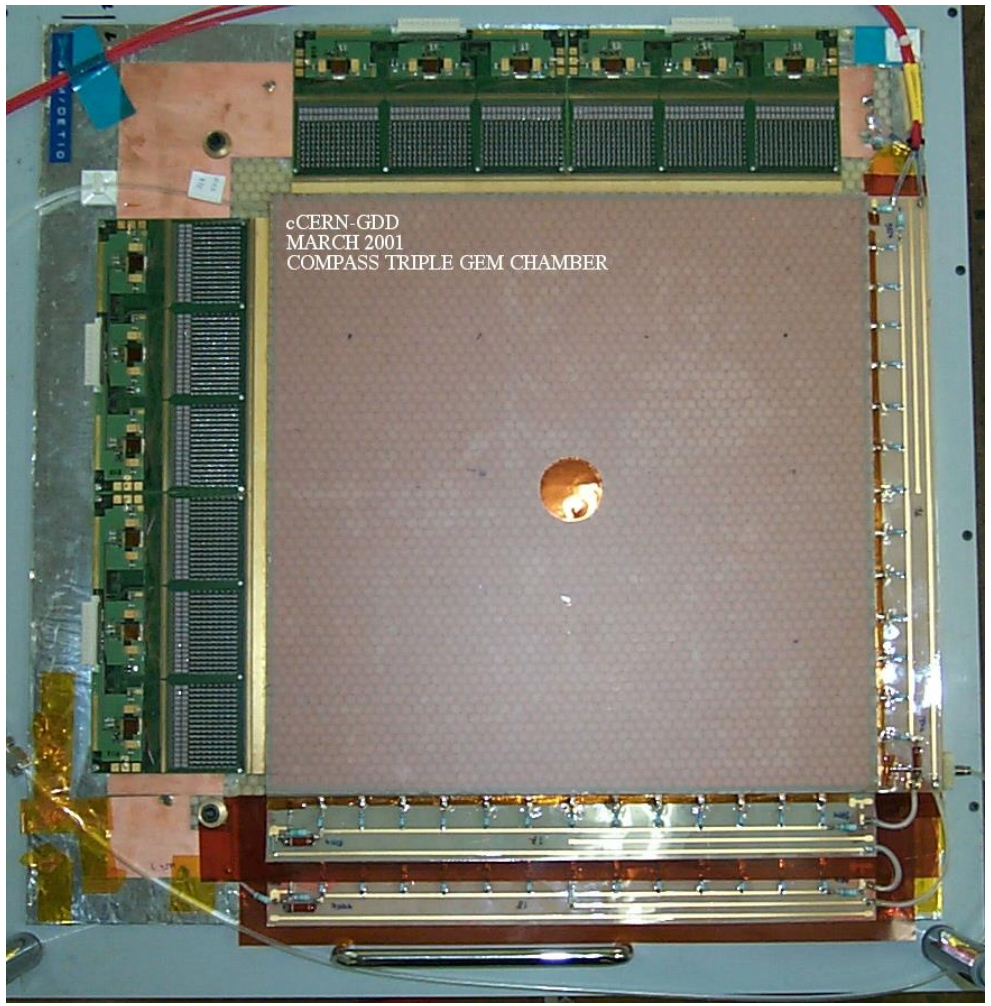
NMX demonstrator prototype v0 “Zita”
Design challenges

COMPASS style



CMS style

NXM style



Detector mounted to robotic arm
and services mounted to detector

Weight-bearing top stack

Cathode, field cage and GEMs
mounted onto support structure
fixed to detector cover
Each part interchangeable

GEM frames and detector frame optimized for
minimum area and maximum stability

Bottom stack

Hollow frame behind readout
strips with equalized pressure
Reduced scattering, flat readout

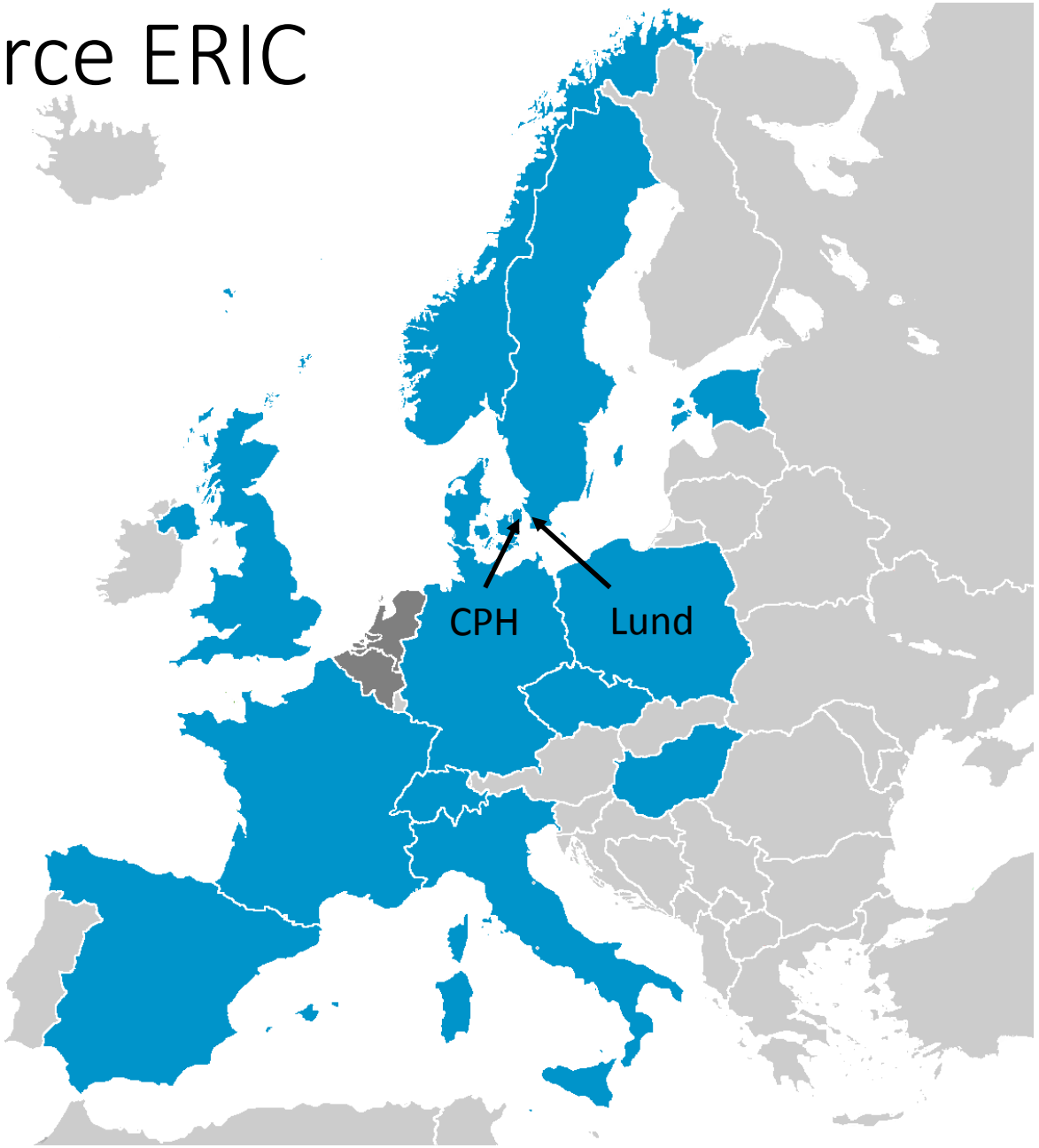
The European Spallation Source ERIC
Overview

Multi-disciplinary research centre based on world's most powerful neutron source

Pan-European project hosted by Sweden and Denmark

Research facility currently under construction in Lund (Sweden)

Data Management and Software Centre located in Copenhagen (Denmark)



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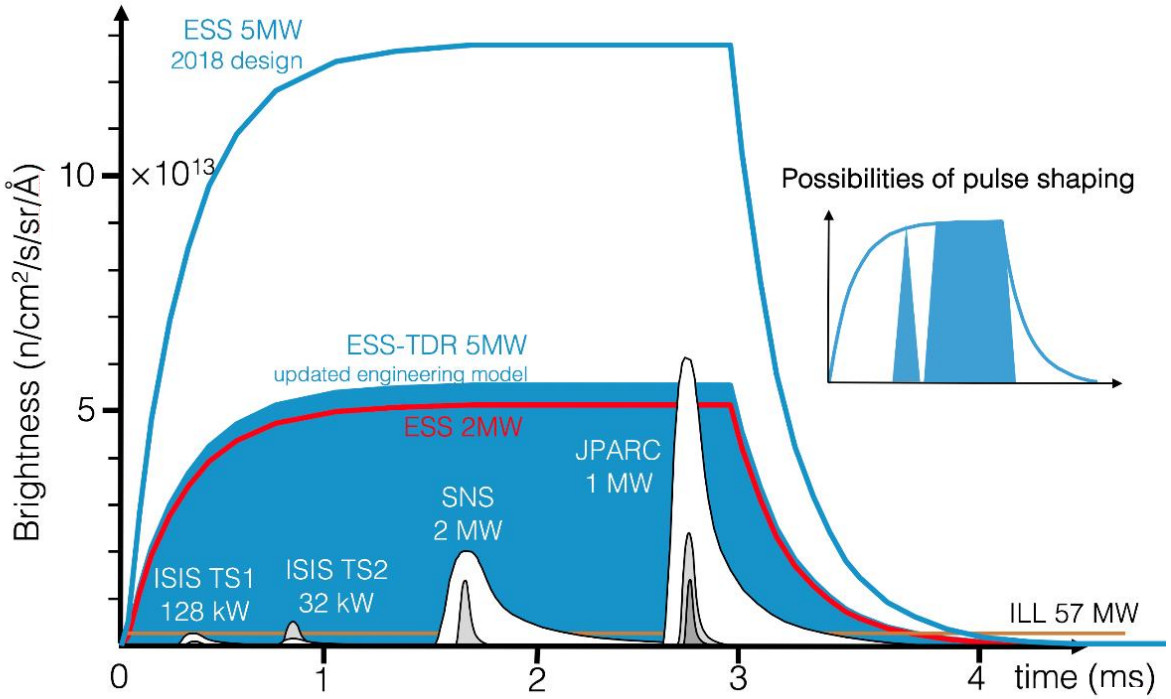

Modified from https://europeanspallationsource.se/ess-mandate