EUROPEAN SPALLATION SOURCE

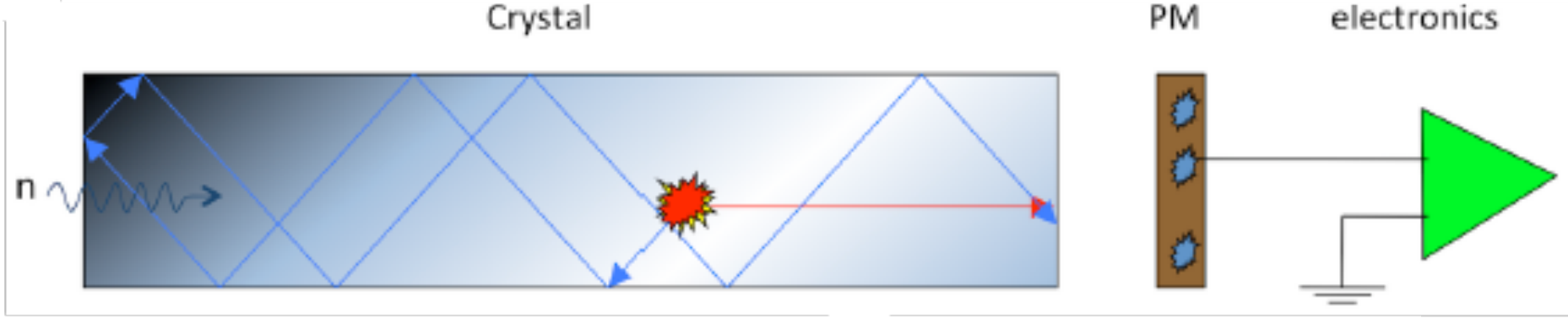
LSS Detector update

Dorothea Pfeiffer on behalf on the ESS detector group

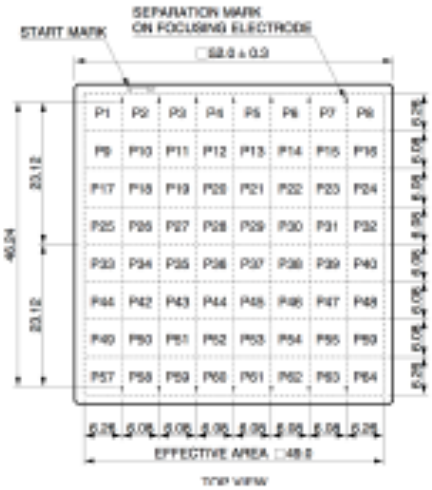
Thanks to G. Croci and F. Piscitelli for their slides

Detectors for SKADI: SoNDe grant

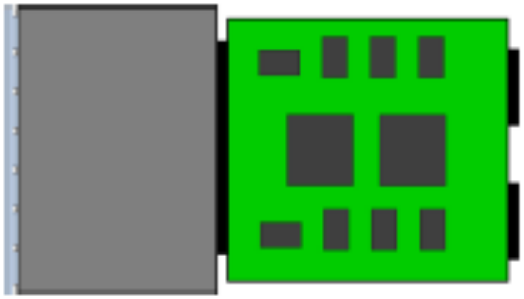
- SKADI SANS instrument needs detectors which can take higher rates than existing Anger Cameras
- H2020 4MEUR Grant: Julich + LLB + IDEAS(NO) + Lund U +ESS
- See Sebastian Jaksch's talk this afternoon in the detector session



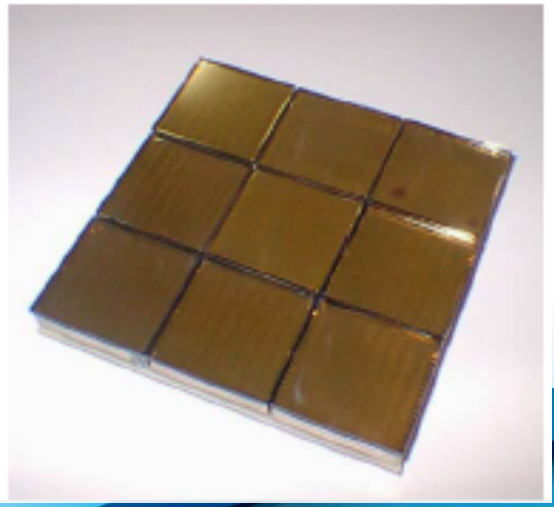
a)



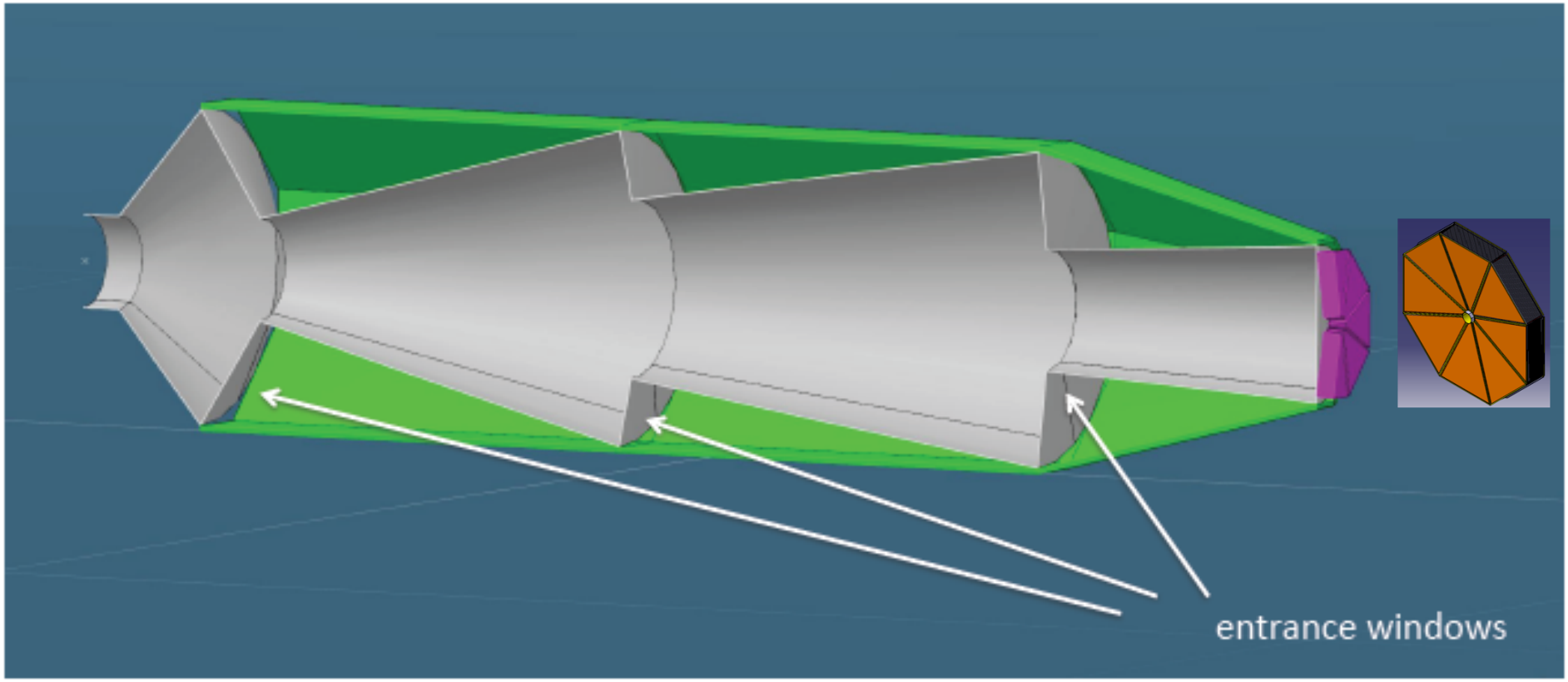
b)



c)

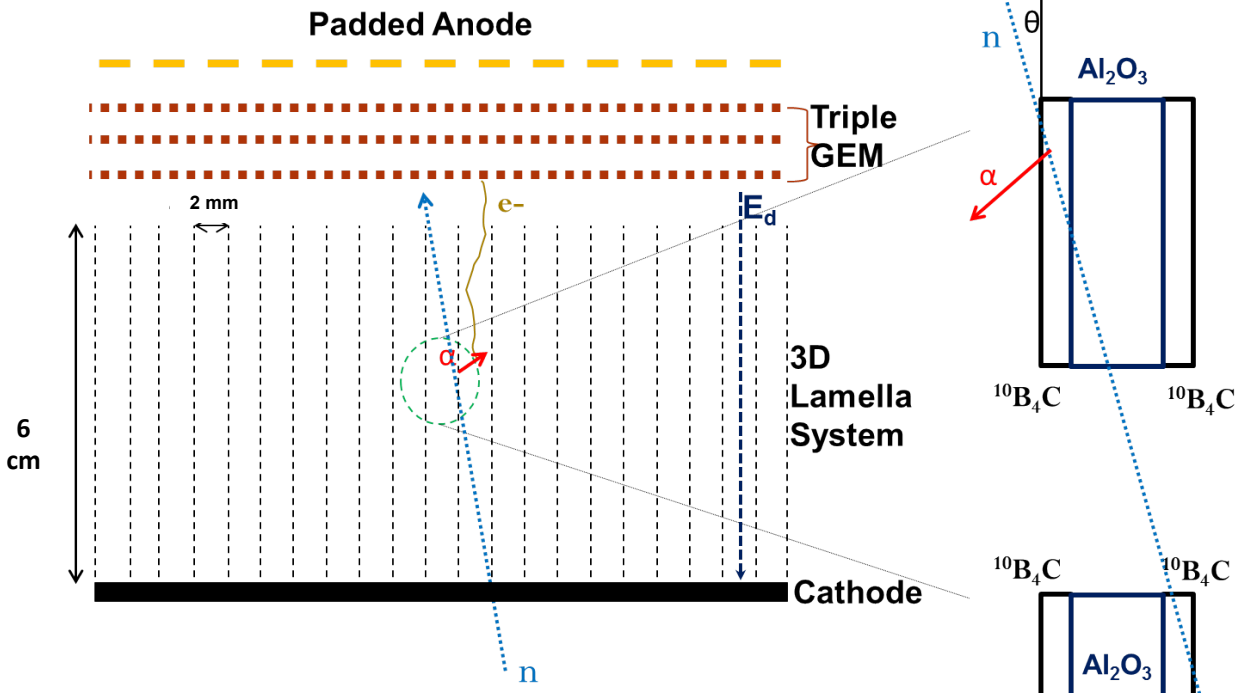


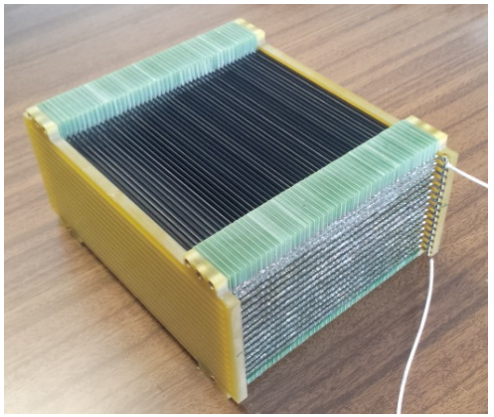
LOKI detectors

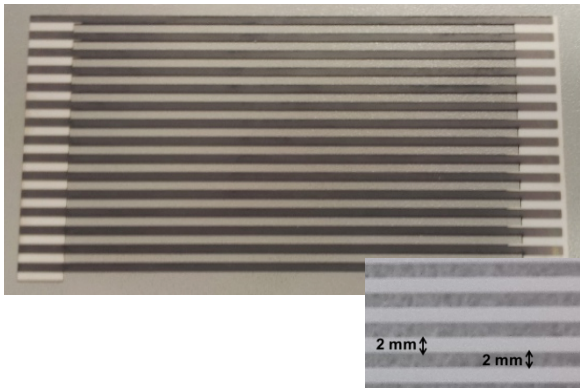


For further information, please refer to the poster by G. Groci et al.

Boron Array Neutron Detector (BAND) - GEM

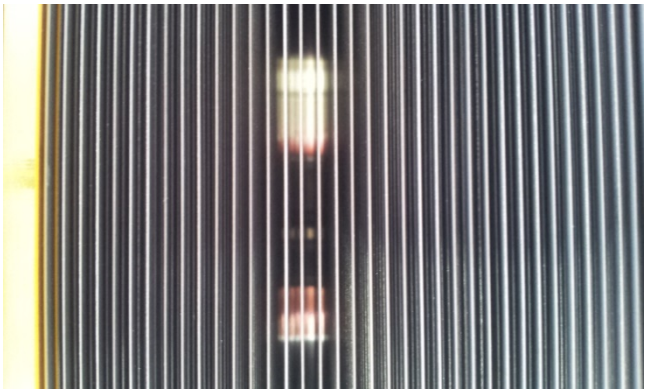


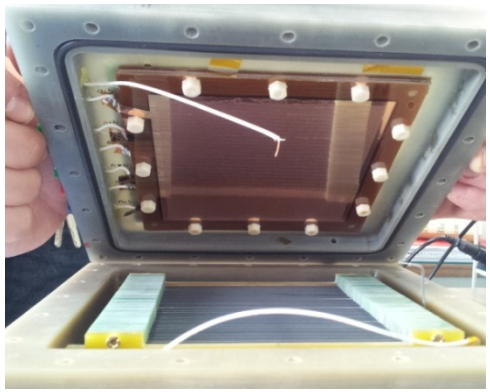


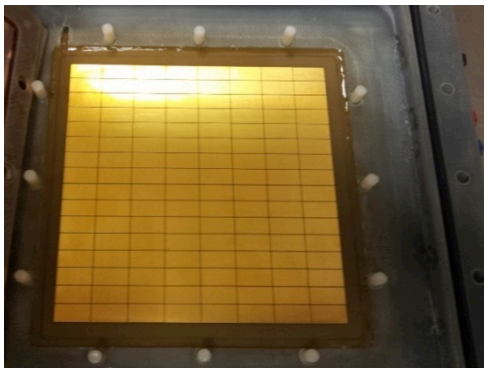


Lamellas coated on both sides with $^{10}B_4C$

Using low θ values (few degs) the path of the neutron inside the B_4C is increased → Higher efficiency when detector is inclined



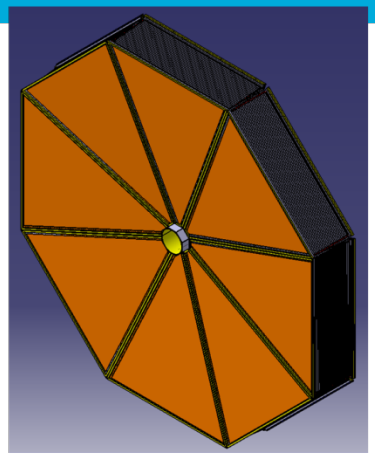


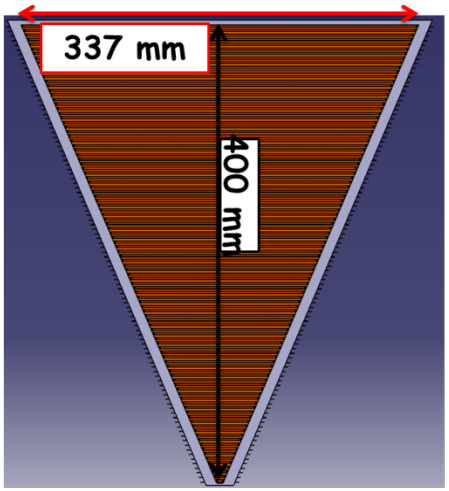


BandGEM Demonstrator Design 1/2

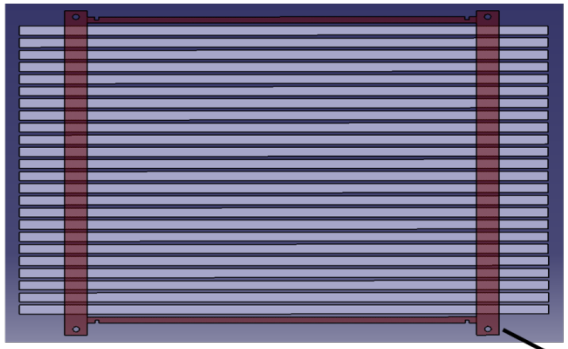
EUROPEAN SPALLATION SOURCE

LOKI rear detector UMBRELLA

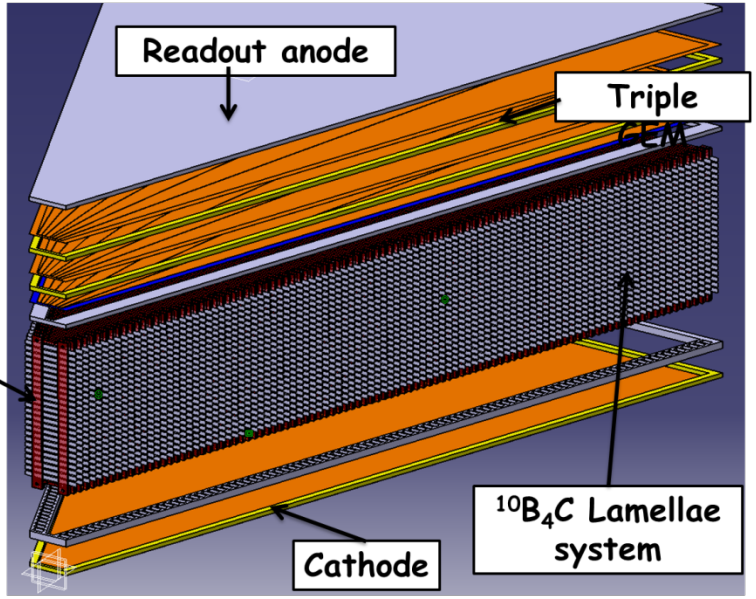




Detector Top and Exploded view – 3D Cathode



One Lamella element: 24 Al strips coated by 1 µm 10B4C on both sides



Geometrical dimension of the demonstrator defined in order to equip all the rear area by using 8 modules

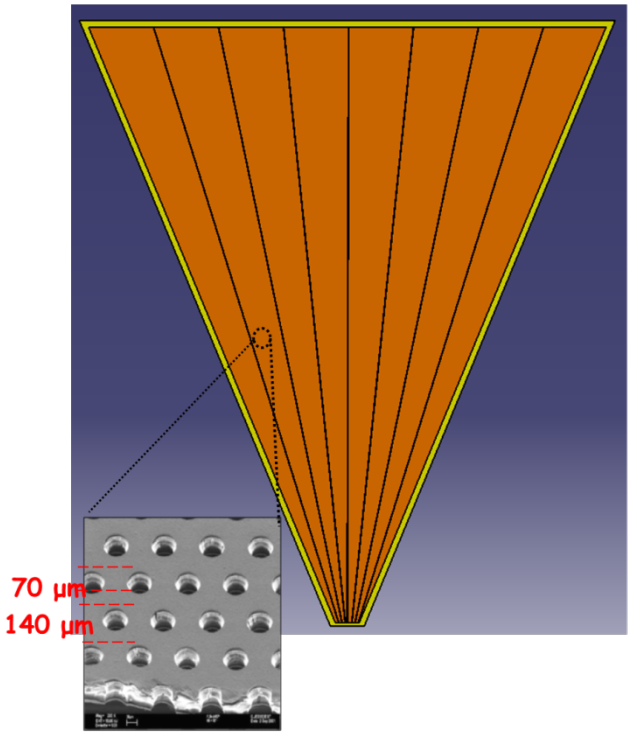
Total of 100 lamellas (separated by 4 mm gap) are foreseen to realize the demonstrator

Tilting the detector by few degrees ensures high detection efficiency

BandGEM Demonstrator Design 2/2

EUROPEAN SPALLATION SOURCE

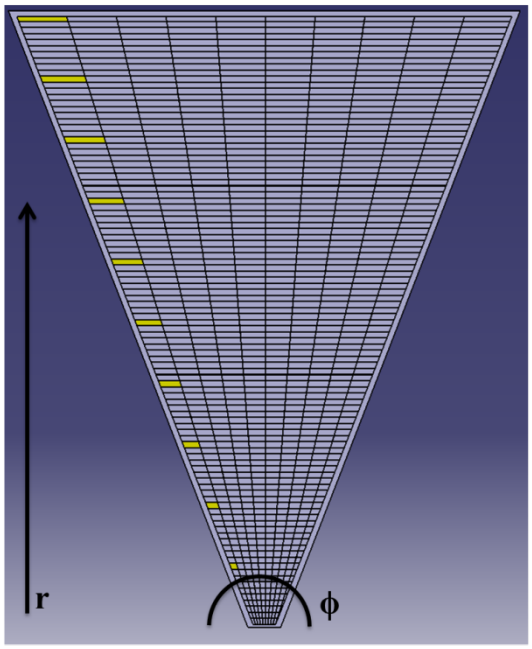
GEM Foils



Charge amplification structure.

Multi-GEM based detectors provide a gain of about 10^2 (in this case), with a negligible discharge probability.

Anodic Pads



Localization performed recording the charge reaching a suitably padded readout board.

Preliminary design: 1000 pads with a constant dimension of 4 mm along the r-axis

	Prototype - Achieved	Demonstrator - Simulated
Lamella Distance	2 mm	4 mm
B_4C/empty ratio on lamellas	1	3
Full Lamella System lenght	6 cm	9 cm
Lamella Thickeness	250 µm	100 µm
Lamella Material	Aluminium Oxide	Aluminium/Titanium
Optimal tilt angle	7 degrees	2.4 degrees
Pulse Height Threshold	70 keV	100 keV
Cathode geometry	10x10 cm2 - Square	Trapezoidal
Count Rate Capability	10 MHz/cm^2	12 MHz/cm^2
Gamma Ray Sensitivity	$5*10^{-5}$	10^{-7}
Measured Efficiency @ 1.5 Å	18.5%	//
Expected Efficiency @ 2.0 Å	//	37%
Expected Efficiency @ 6 Å	//	55%
Expected Efficiency @ 12 Å	//	61%
Resolution FWHM @ 2,6,12 Å	//	5.5 – 6 mm
Front-end ASIC	CARIOCA – 8 channels/chip	GEMINI – 16 channels/chip

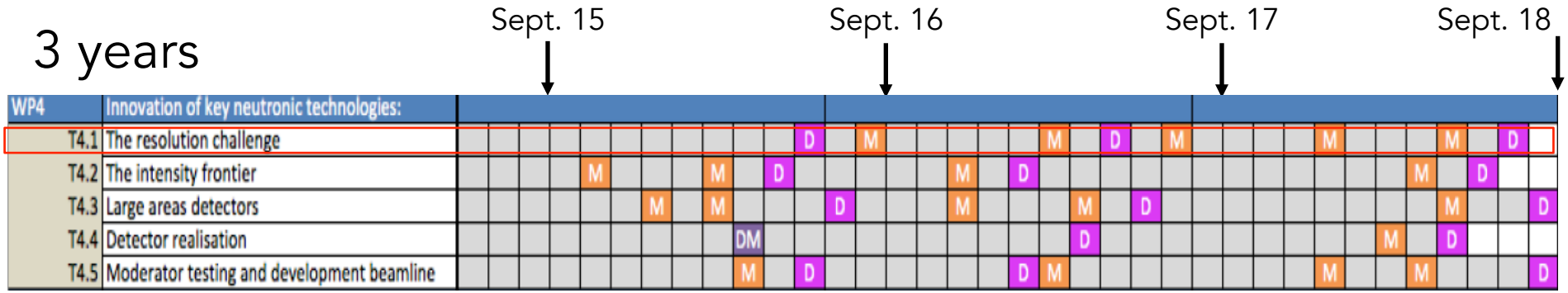
Performance: Prototype and Demonstrator

NMX detectors

Task 4.1 Neutron Detectors – The Resolution Challenge

The key objective of WP4 is the technological evolution of neutron detectors in terms of resolution, intensity and dimensions.

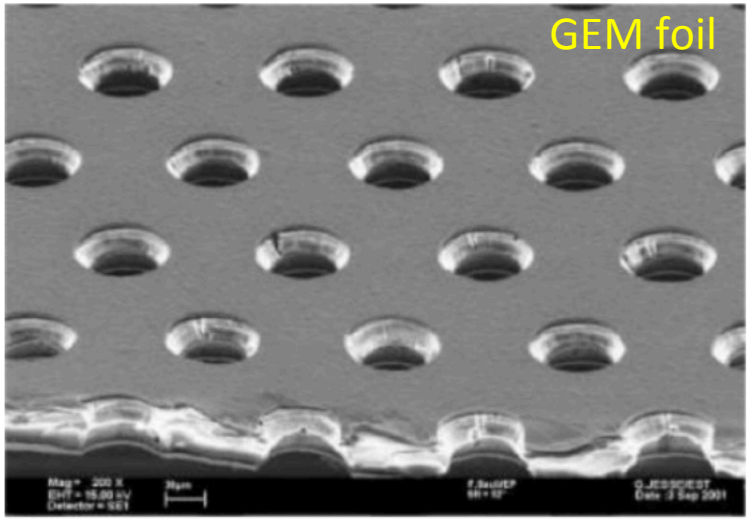
3 years

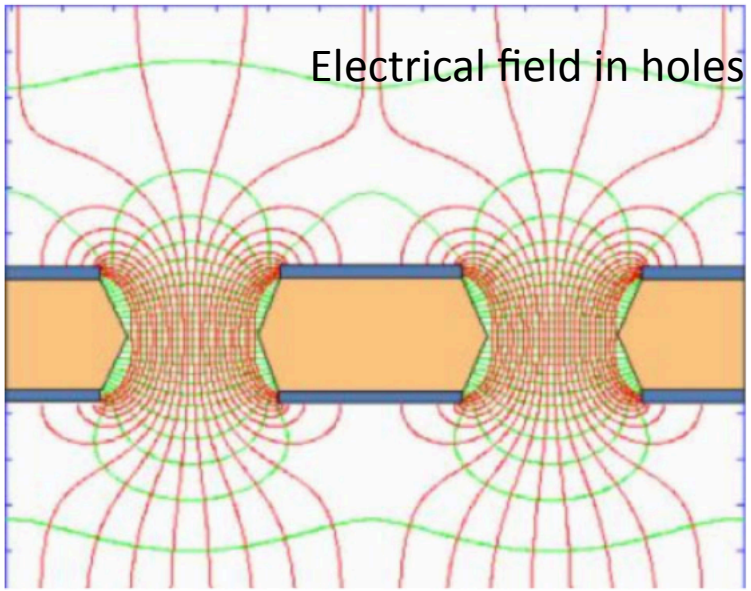


Requirements and challenges

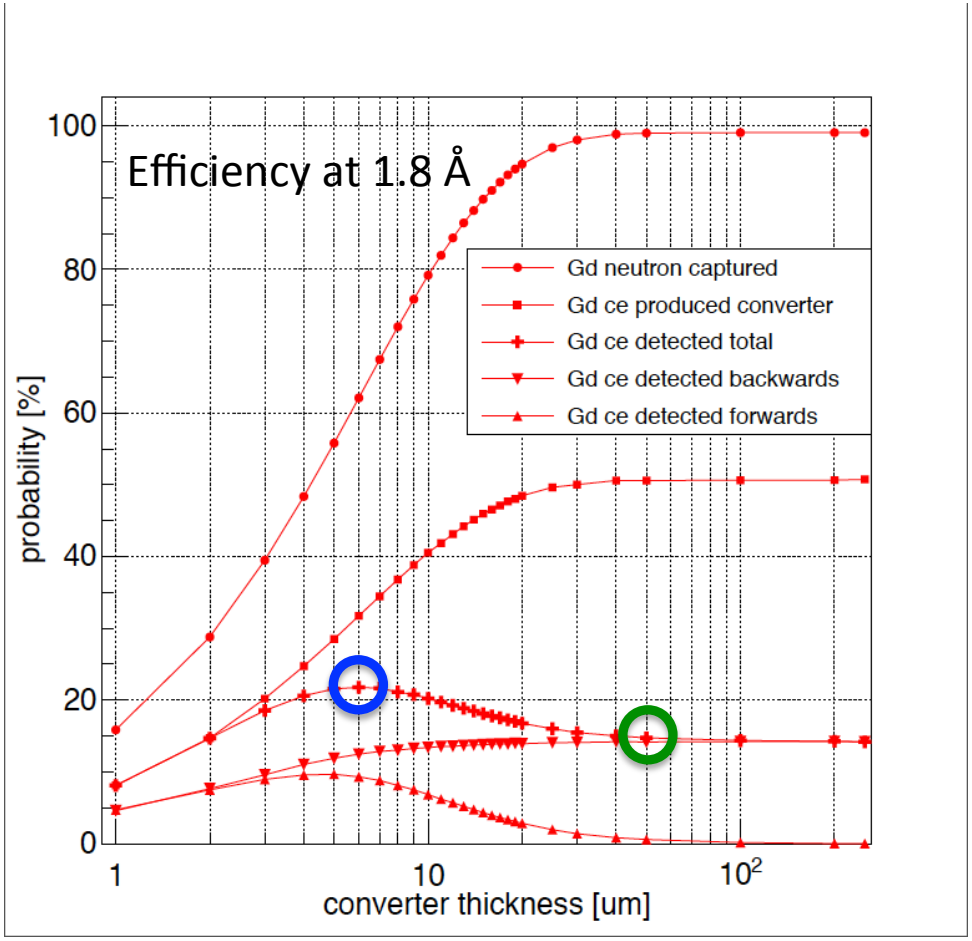
- 200 µm position resolution (beyond state of art for time resolved neutron detectors)
- High rate requirements with up to MHz/cm^2
- High gain stability and count rate stability
- Mechanical robustness (detectors mounted on freely movable robotic arms)
- Reasonable gamma suppression

=> Gd-GEM detector





Natural Gadolinium converters



Baseline: Backwards and forwards mode. Optimum thickness 6 um, thinnest available foil 10um:

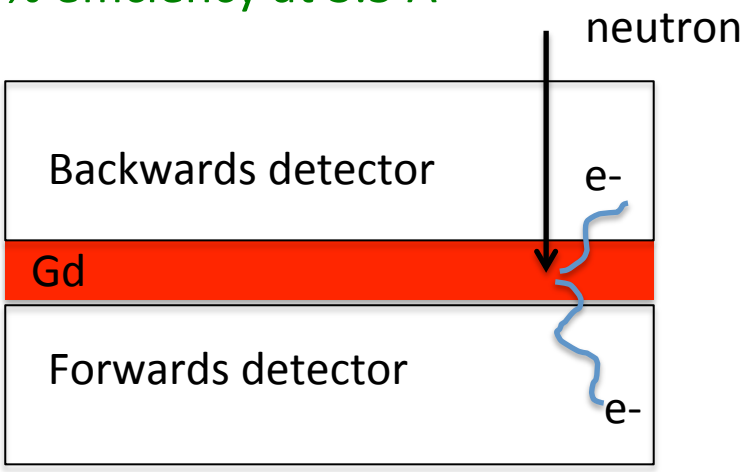
20% efficiency at 1.8 A

28% efficiency at 3.5 A

Alternative: Backwards mode, one detector: Optimum thickness >=50 um

14% efficiency at 1.8 A

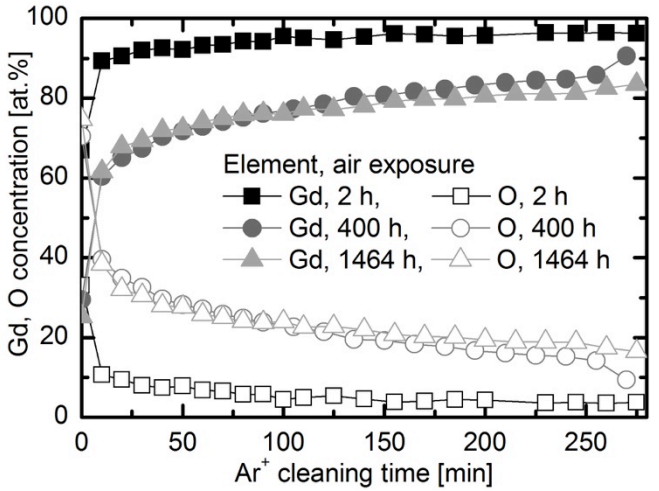
20% efficiency at 3.5 A

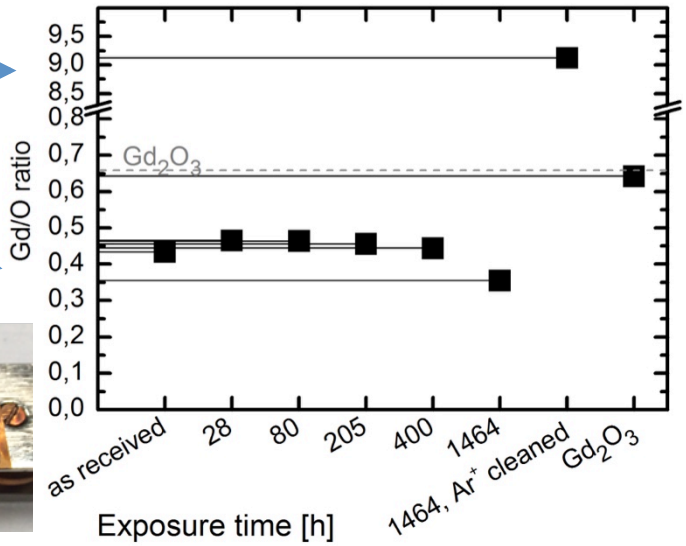


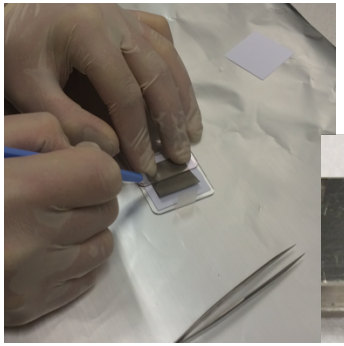
Upgrade with 157 Gd: up to 38% efficiency at 1.8 A and 42% efficiency at 3.5 A

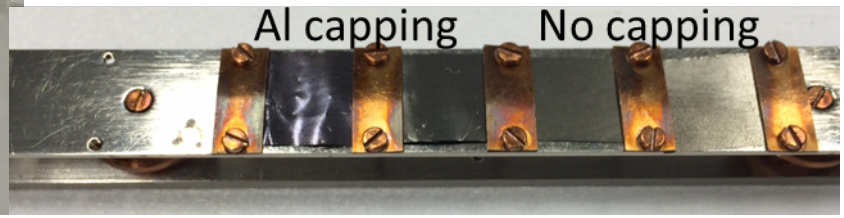
Capping layer for Gd foil not needed

- XPS measurements w/o Al capping layer
  - no benefit with Al capping
  - capping process “adds” O
  - foils are stable
  - GdO layer with O surplus builds up but does not grow significantly



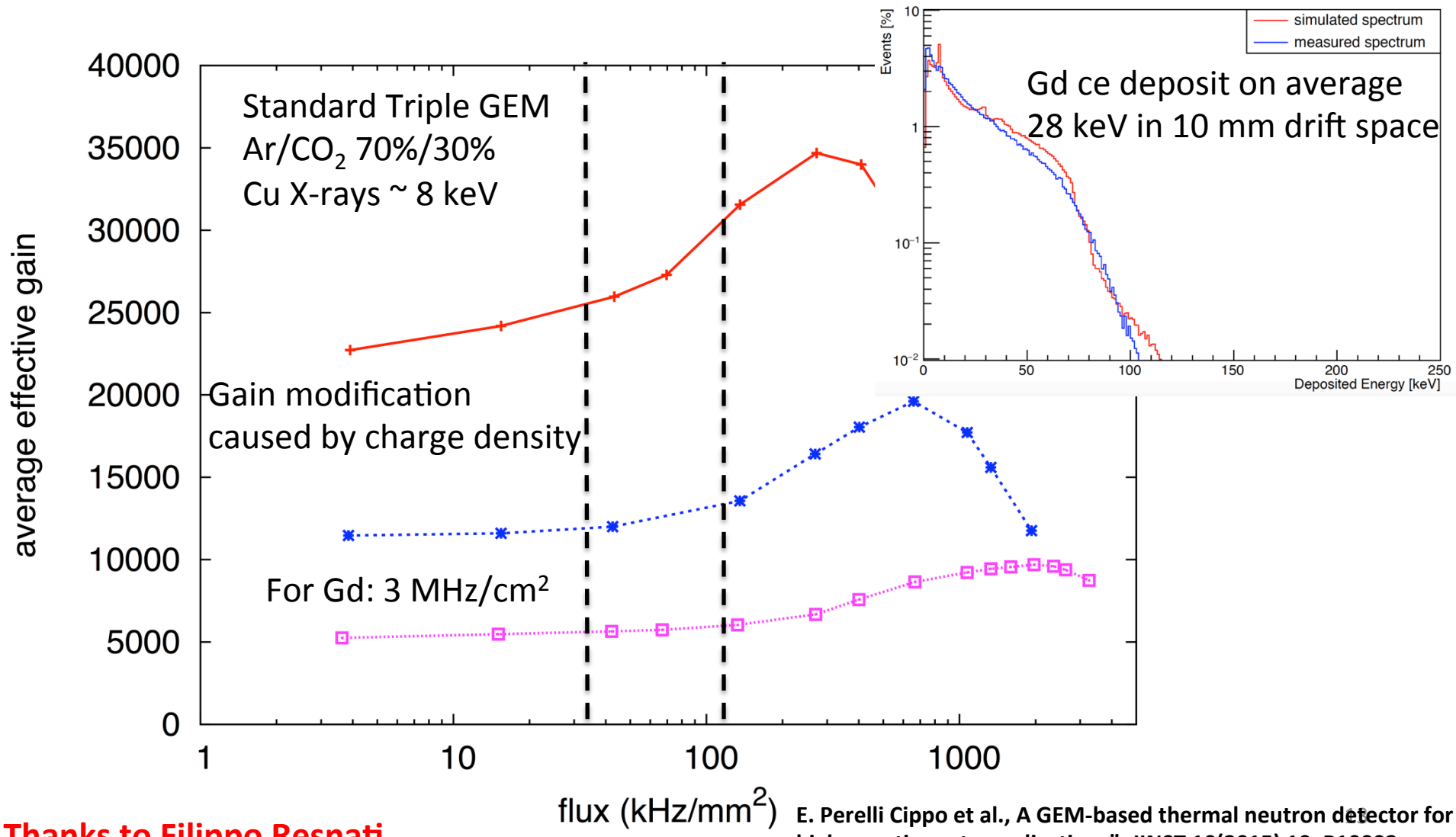






Thanks to Susann Schmidt

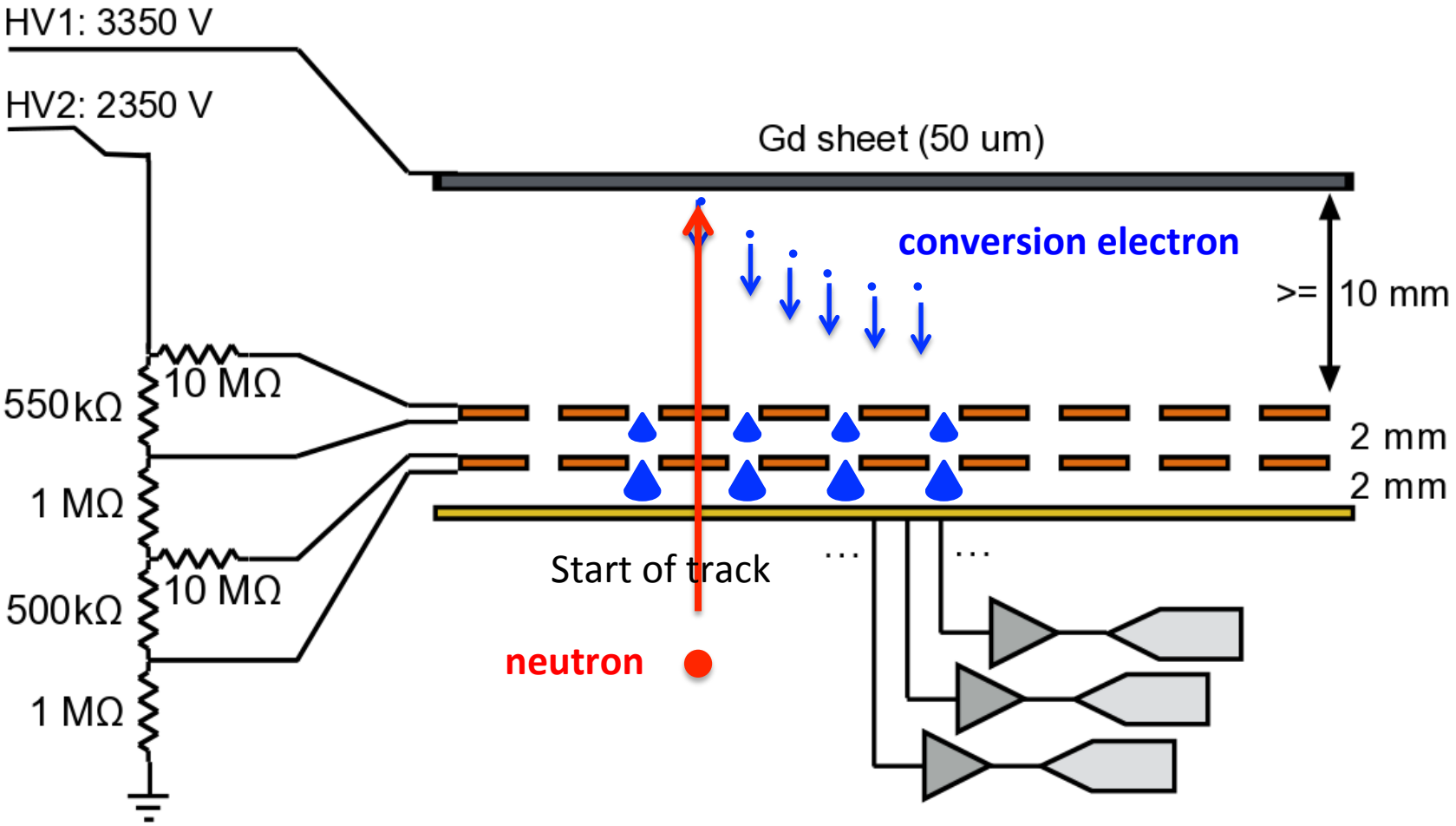
GEM Rate capabilities with Gd



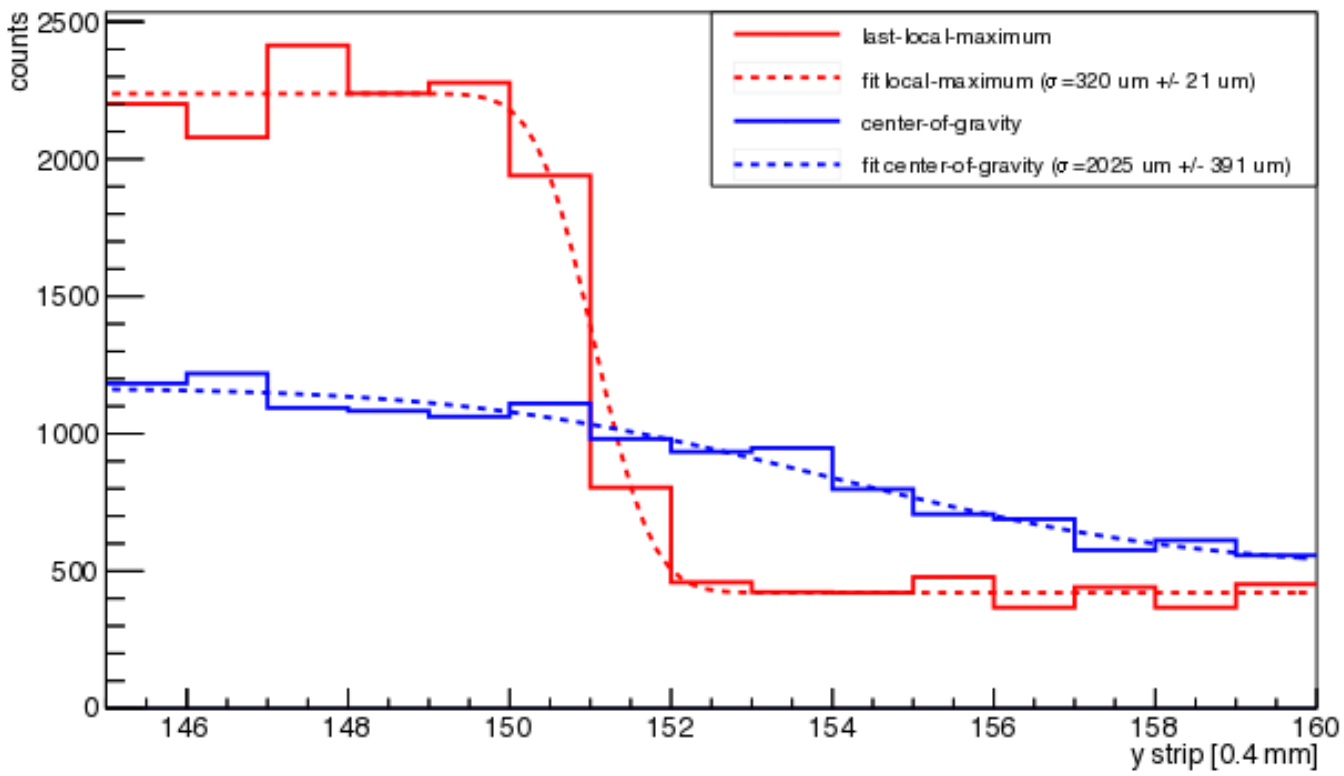
Thanks to Filippo Resnati

E. Perelli Cippo et al., A GEM-based thermal neutron detector for high counting rate applications", JINST 10(2015) 10, P10003

Gd-GEM backwards setup

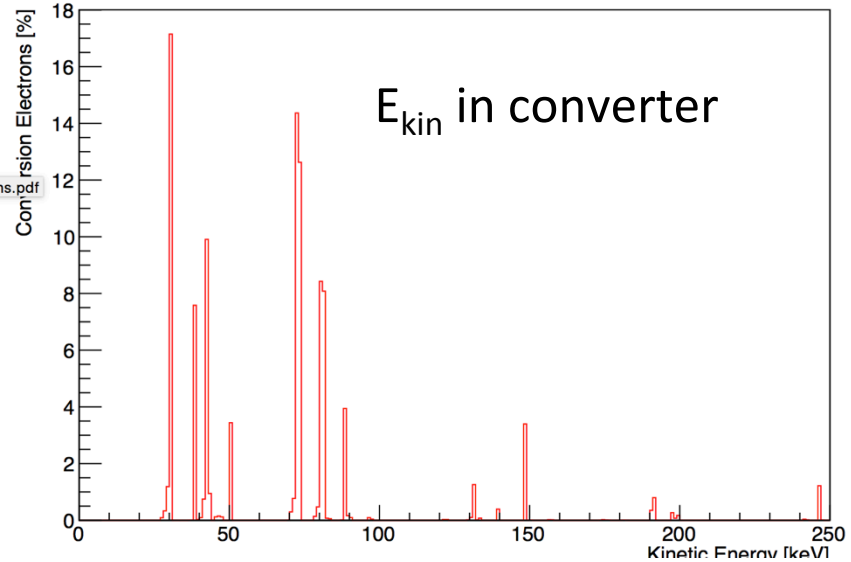


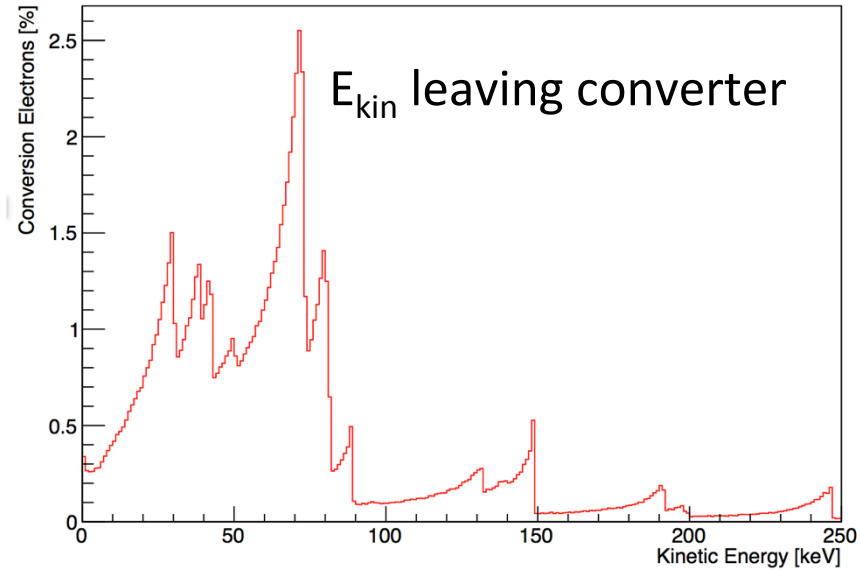
Position resolution

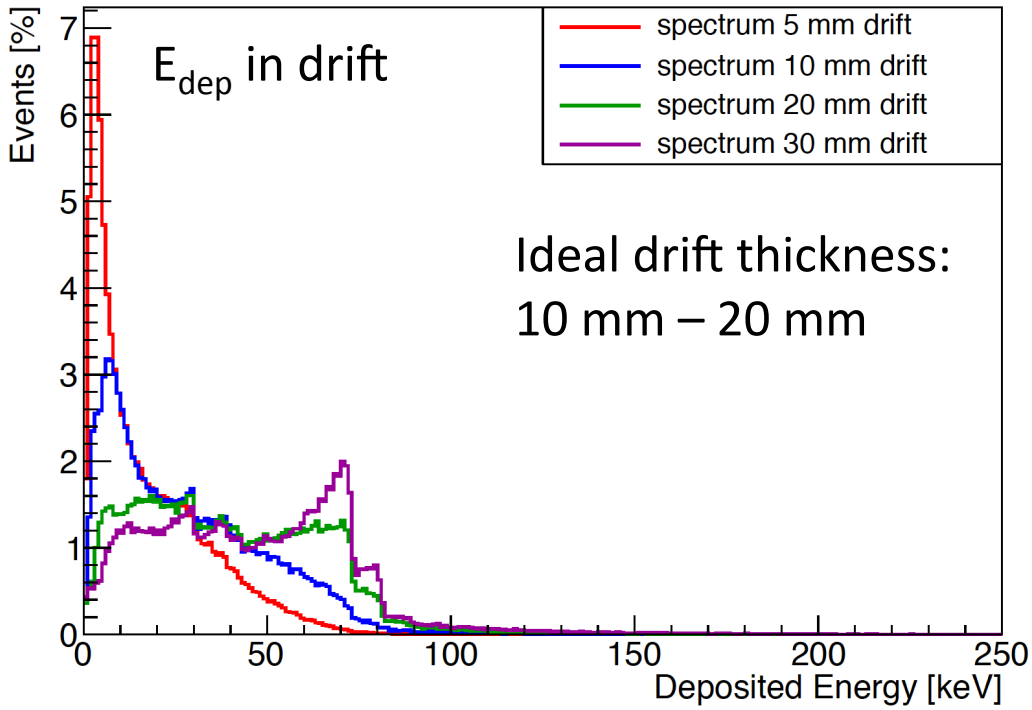


- Intrinsic position resolution: σ <= 400 um
- Scales with strip width (200 um strips possible)

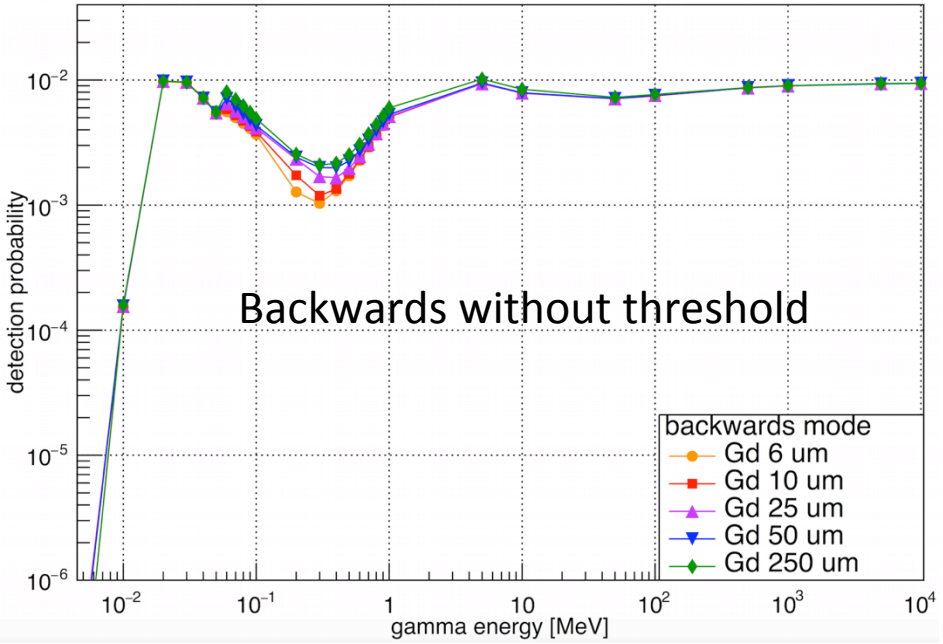
Optimum drift size of Gd-GEM

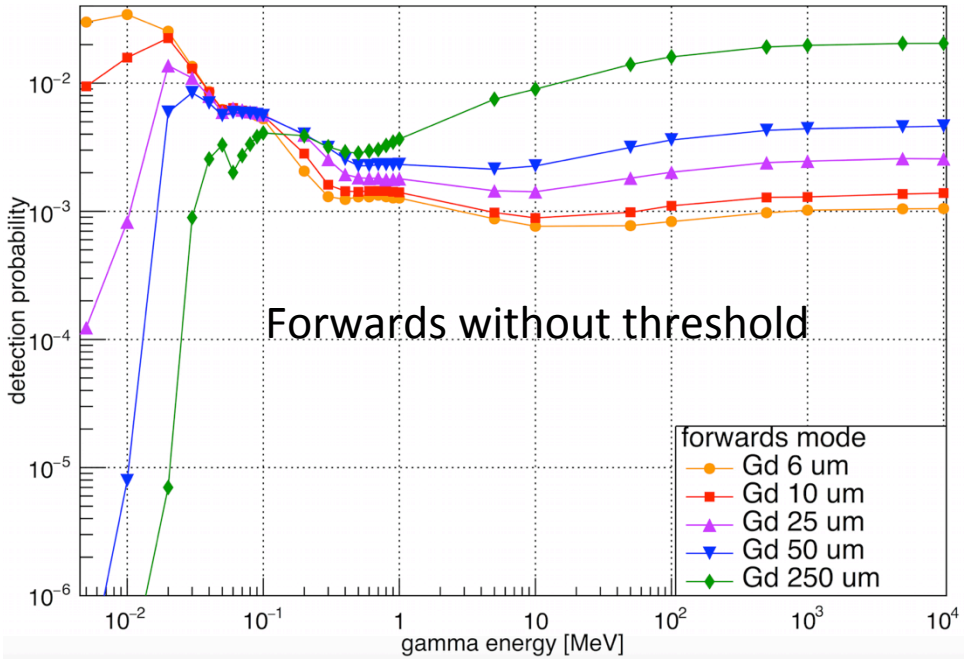






Simulated and measured gamma sensitivity in 10 mm drift





Measured values 250 um Gd and 3 keV threshold

backwards

6E-03 241 Am 59.5 keV gamma

2E-03 22 Na 511 keV/1274.5 keV gamma

forwards

1E-03 241 Am 59.5 keV gamma

2E-03 Na 511 keV/1274.5 keV gamma

Neutron and gamma sensitivity of 50 um Gd in backwards configuration

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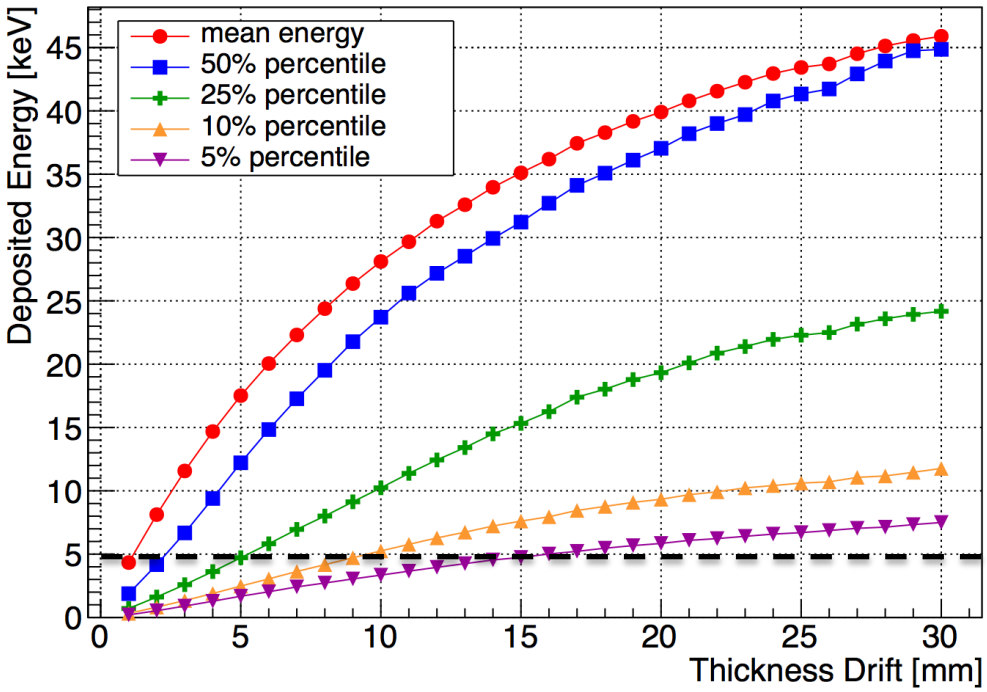
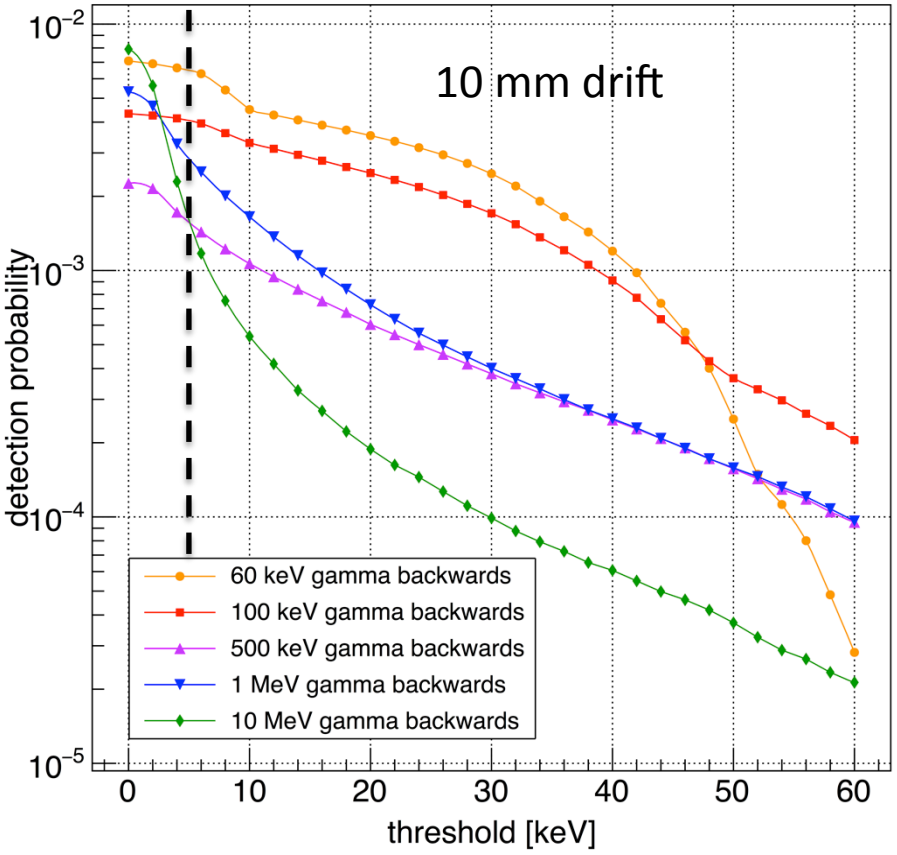
Neutrons



Gammas

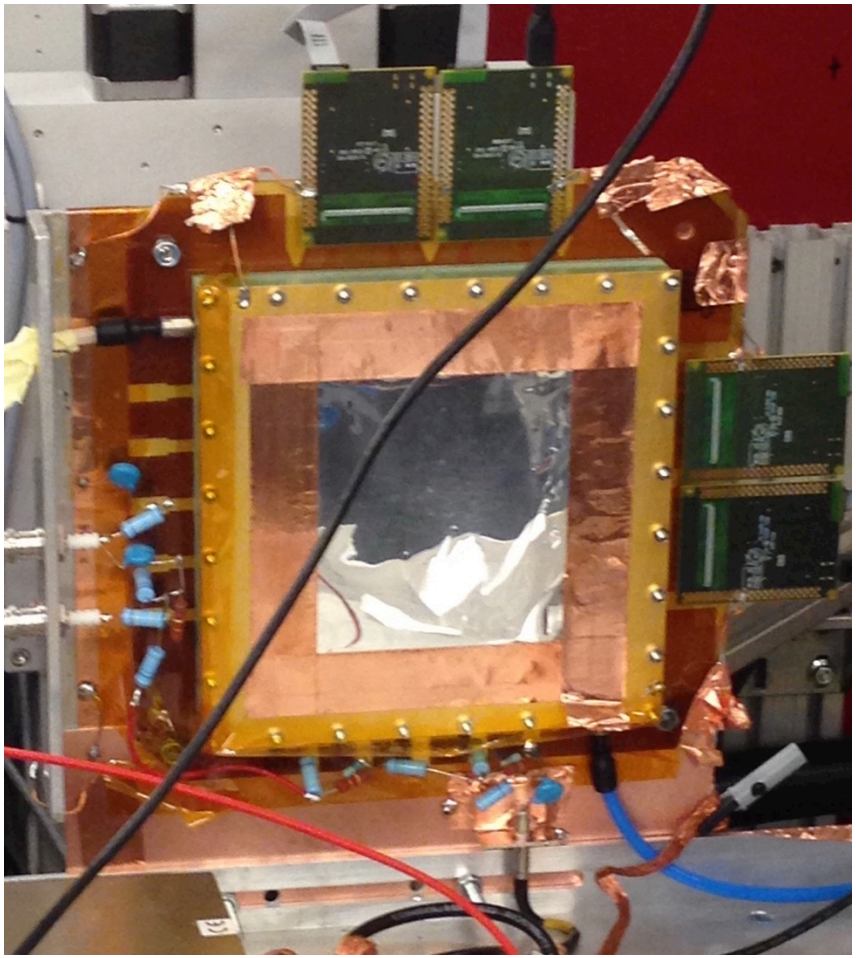


Depending on threshold and gamma energy, gamma sensitivity around 10^{-3}

Results from 2015

- **Gd-GEM detector works**
- Detection efficiency (2 Å neutrons) is with 12% as expected from simulations (without scattering 15%)
- Tracking of electrons works
- Intrinsic position resolution of σ <400µm (relates directly to 400 µm strip pitch)
- With smaller pitch σ = 200 µm achievable
- Fast readout electronics are under development, VMM2 being tested at the moment
- Gamma sensitivity with reasonable energy threshold around 10^{-3}, 50 keV – 500 keV gammas are the biggest problem since their energy deposit is identical to the Gd conversion electrons

Gd-GEM Outlook for 2016



- Further study gamma sensitivity
- Determine optimum drift thickness
- Study stability with 2 GEM foils
- Evaluate low scatter readout material
- Study smaller strip pitch
- Build 10cm x 10 cm prototype to participate in neutron scatter experiment to show performance

Freia, (Frejya, Freyia, Frøya, Frøjya, and Freja) in Old Norse the "Lady", one of the Vanir gods, rules over the heavenly afterlife field Fólkvangr and there receives half of those that die in battle.

FREIA – a reflectometer for kinetics and liquid surfaces

Swiss-Danish ESS
instrumentation consortium

Jochen Stahn
Marité Cardenas
Ursula B. Hansen

ESS SAC Meeting
21. 05. 2014, Lund

Estia

a

focusing reflectometer for small samples

based on the

Selene guide concept

BrightnESS

EUROPEAN SPALLATION SOURCE

BNC Budapest Neutron Centre

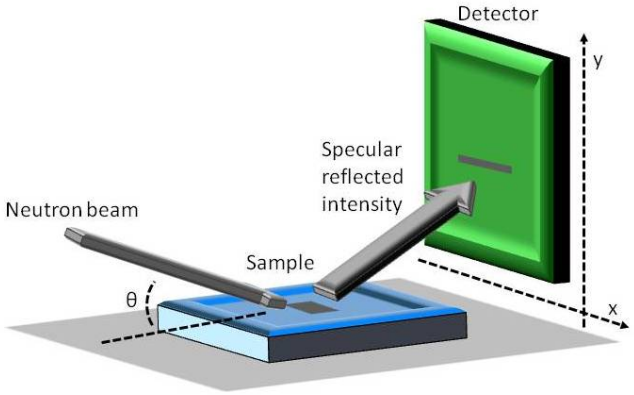
Wigner

LUND UNIVERSITY

NEUTRONS FOR SCIENCE

Reflectometry at ESS: FREIA and ESTIA

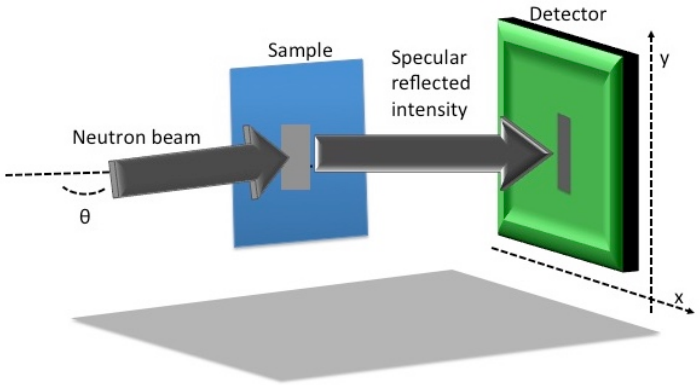
FREIA



Horizontal Reflectometer
(FREIA)

Suitable for liquids
(limited angular range)

Estia



Vertical Reflectometer
(ESTIA)

Not suitable for liquids
More versatile
(wide angle range)

Task 4.2 Neutron Detectors – The Intensity Frontier

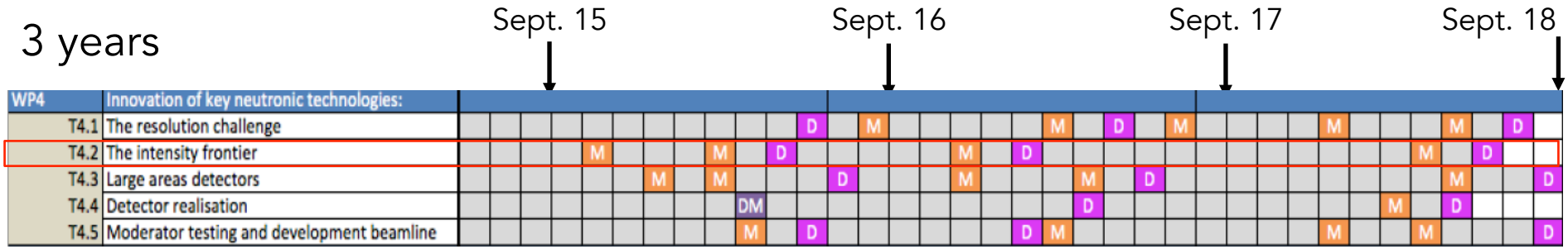
The key objective of WP4 is the technological evolution of neutron detectors in terms of resolution, intensity and dimensions.

Lund University

Wigner Research Institute

Budapest Neutron Centre

3 years



Deliverable

Milestone

The Multi-Blade project

concept introduced in 2005

NEUTRONS FOR SCIENCE

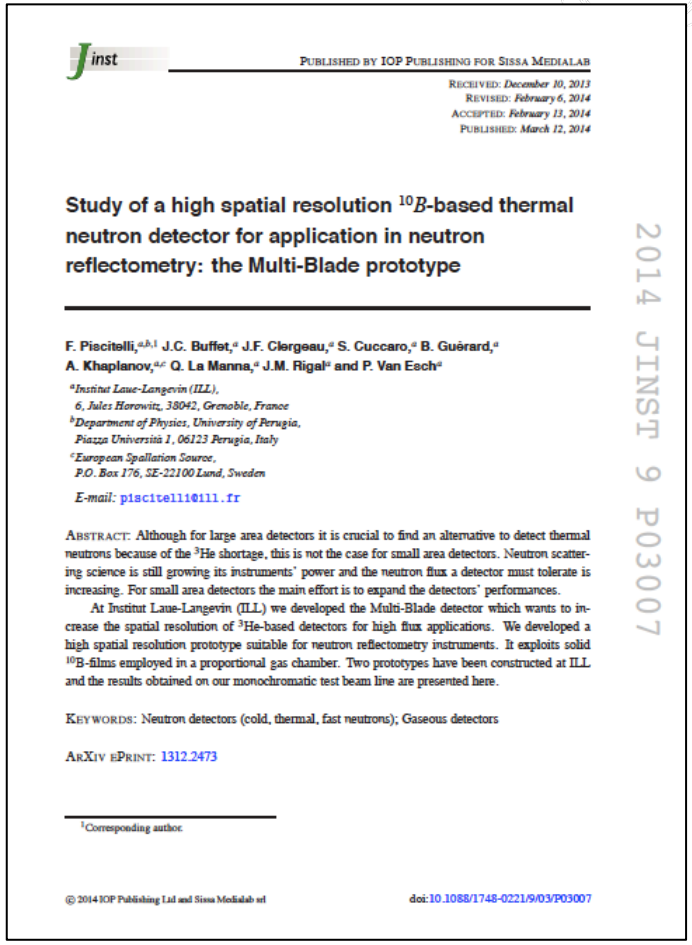
Institut Laue-Langevin

proof of concept in 2012

NEUTRONS FOR SCIENCE

Institut Laue-Langevin

University of Perugia



JINST

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Study of a high spatial resolution ^{10}B-based thermal neutron detector for application in neutron reflectometry: the Multi-Blade prototype

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ABSTRACT: Although for large area detectors it is crucial to find an alternative to detect thermal neutrons because of the ^{3}He shortage, this is not the case for small area detectors. Neutron scattering science is still growing its instruments' power and the neutron flux a detector must tolerate is increasing. For small area detectors the main effort is to expand the detectors' performances.

At Institut Laue-Langevin (ILL) we developed the Multi-Blade detector which wants to increase the spatial resolution of ^{3}He-based detectors for high flux applications. We developed a high spatial resolution prototype suitable for neutron reflectometry instruments. It exploits solid ^{10}B-films employed in a proportional gas chamber. Two prototypes have been constructed at ILL and the results obtained on our monochromatic test beam line are presented here.

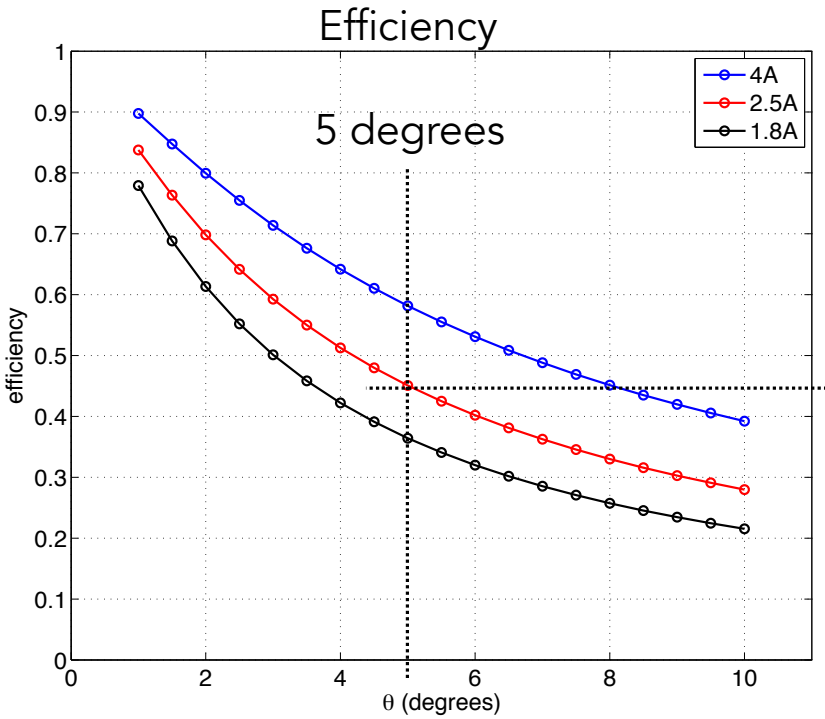
KEYWORDS: Neutron detectors (cold, thermal, fast neutrons); Gaseous detectors

ARXIV EPRINT: 1312.2473

[1] Corresponding author.

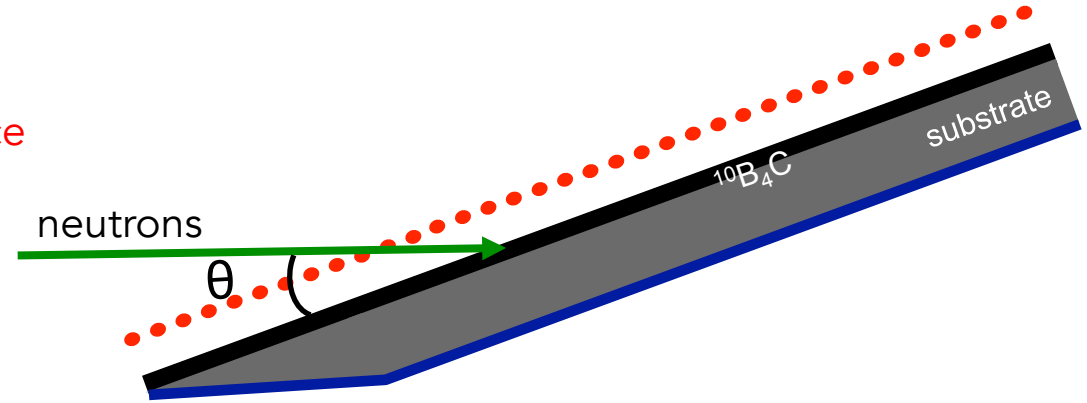
doi:10.1088/1748-0221/9/03/P03007

2014 JINST 9 P03007



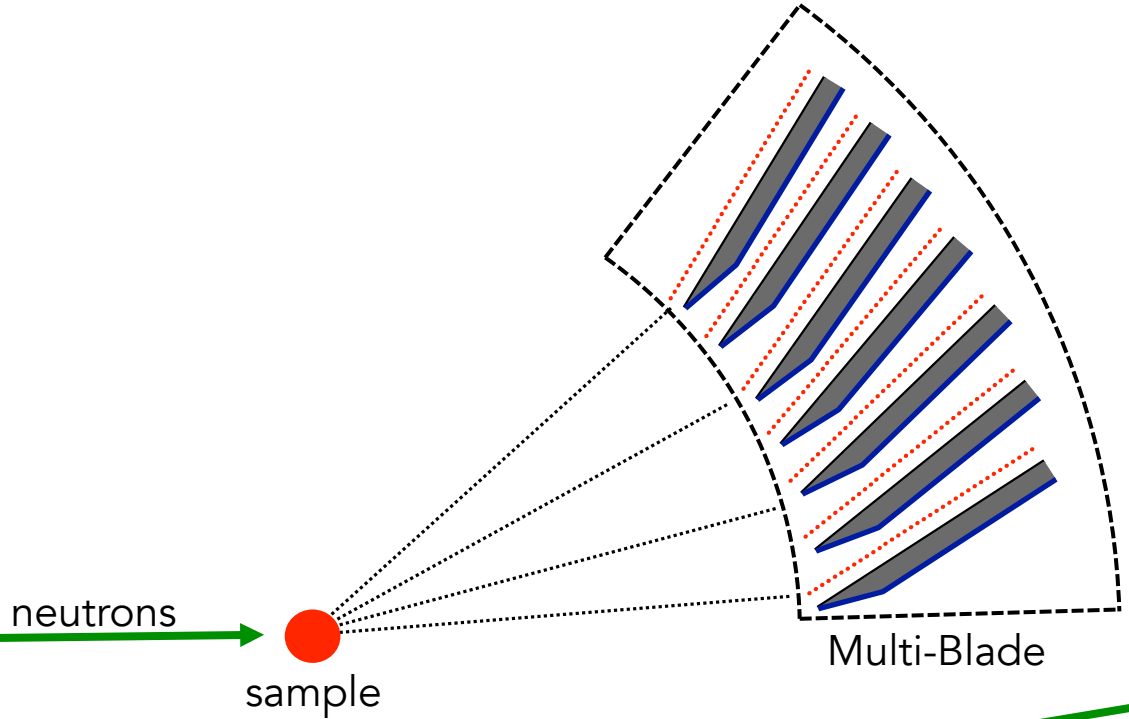
Efficiency 45% at 2.5Å
A single Boron layer inclined at 5 degrees

The intensity is spread over a wider surface
(5 degrees = factor x10)

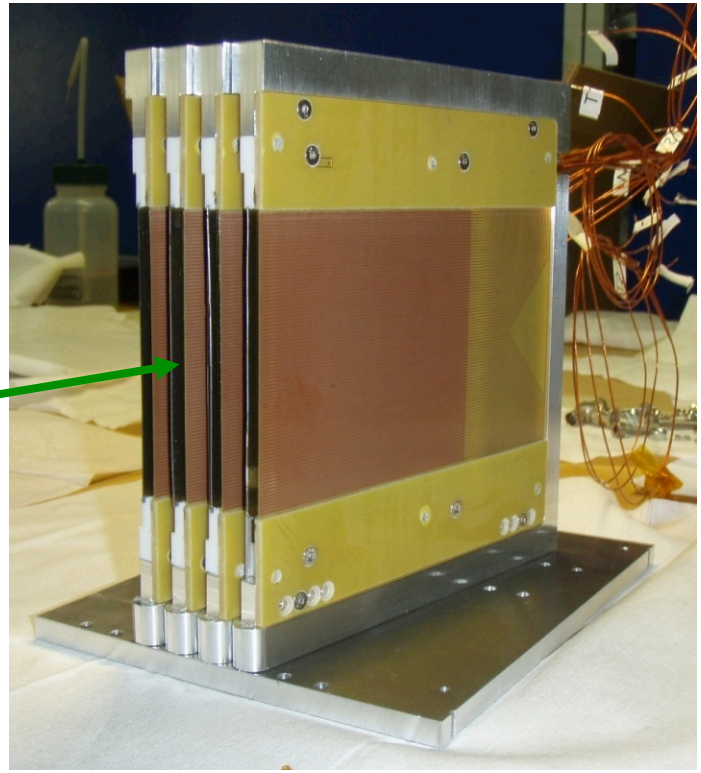


4 cassette demonstrator:

proof of concept in 2012



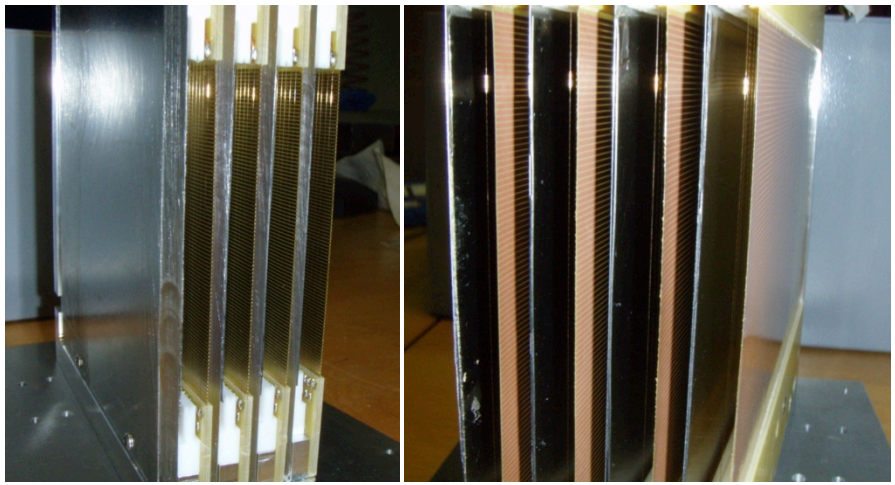
neutrons
hit the layers at 5°

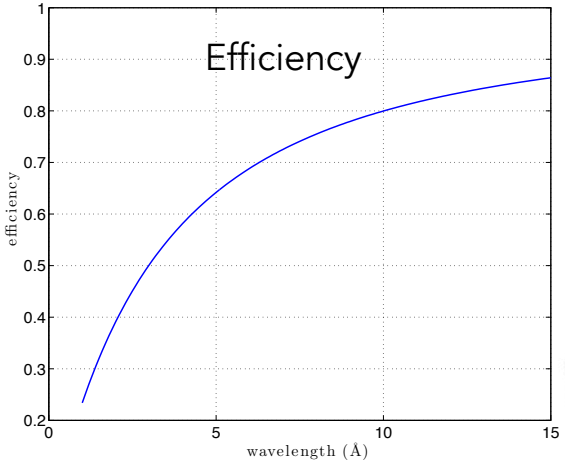


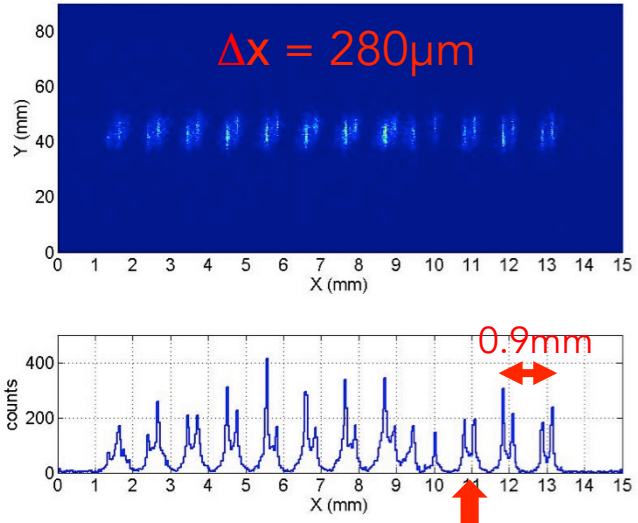
4 cassette demonstrator:

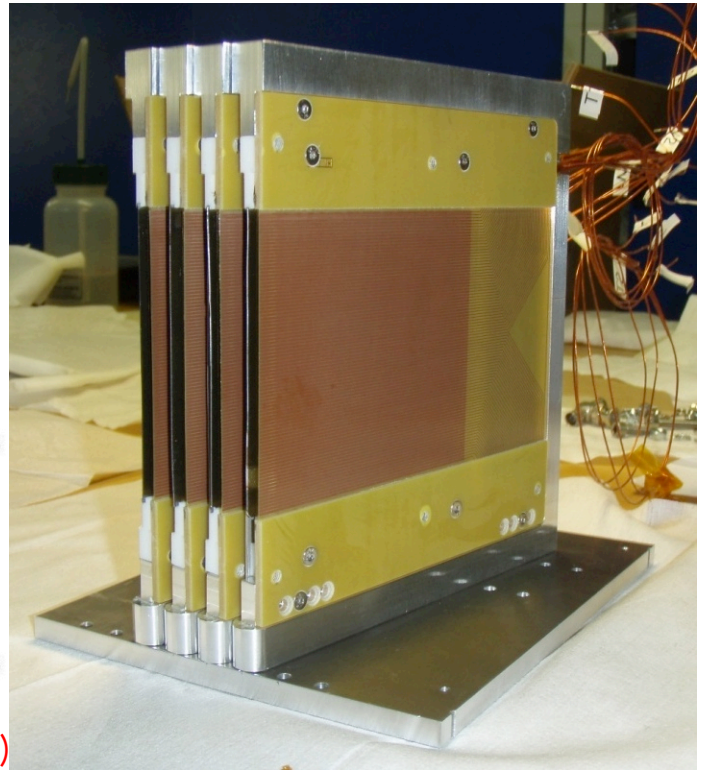
Results:

- Measured Efficiency 45% at 2.5Å
- Spatial Resolution 4mm x 280µm
- Counting rate capability ~5000 n/s/mm^2 at 2.5Å (limited by the electronics)
- Atmospheric pressure operation (thin vessel window, low scattering) (cost effective materials)









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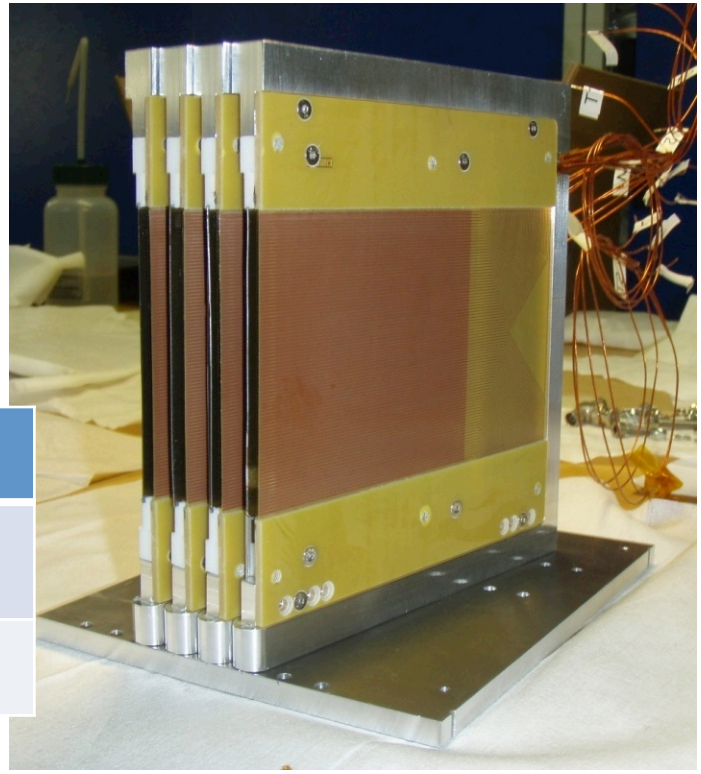

The ESS requirements

	FREIA	Estia	
Max local rate	10^5 n/s/Å/mm^2	• Conventional refl. • High intensity mode	10^5 n/s/Å/mm^2 10^4 n/s/Å/mm^2
Spatial resolution	4mm x 1mm	4mm x 0.5mm	

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x10

x20

x300

The state of the art

Instrument	Facility	techn.	area ($mm \times mm$)	spatial res. ($mm \times mm$)	efficiency	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
FIGARO [9]	ILL	^{3}He	512×256	$\sim 2 \times 7.5$	$\sim 63\%$ @ 2.5Å $\sim 90\%$ @ 10Å $\sim 80\%$ @ 30Å	$3 \cdot 10^7$	230
SuperADAM [11]	ILL	^{3}He	300×300	2.8×2.8	76% @ 4.4Å	$2 \cdot 10^5$	-
REFSANS [12]	FRM2	^{3}He	500×500	$\sim 2 \times 2$	58% @ 10Å $\geq 50\% \in [5, 18]$Å	$2.2 \cdot 10^5$	300
INTER [13]	ISIS	^{3}He,^{6}Li	200×200	$\sim 1 \times 1$	-	-	-
POLREF [14, 15]	ISIS	^{3}He	200×200	$\leq 1 \times 1$	-	-	-
BIOREF [16]	HZB	^{3}He	300×300	2×3	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
MR	SNS	^{3}He	210×180	1.5×1.5	-	-	-
Platypus [17]	OPAL	^{3}He	500×250	1.2×1.2	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
SOFIA [18, 19]	J-PARC	^{3}He ^{6}Li	128×128 256×256	2×2 4×4	- -	- -	300 300

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Next demonstrator:

- Counting rate capability
- Overlap and uniformity

The ESS requirements

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Spatial resolution	4mm x 1mm	4mm x 0.5mm	

Next demonstrator (9 cassettes):

- Counting rate capability
- Overlap and uniformity

BrightnESS

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- Build technology prototype
- Tests at both beam line and Reflectometry beam line

LUND UNIVERSITY

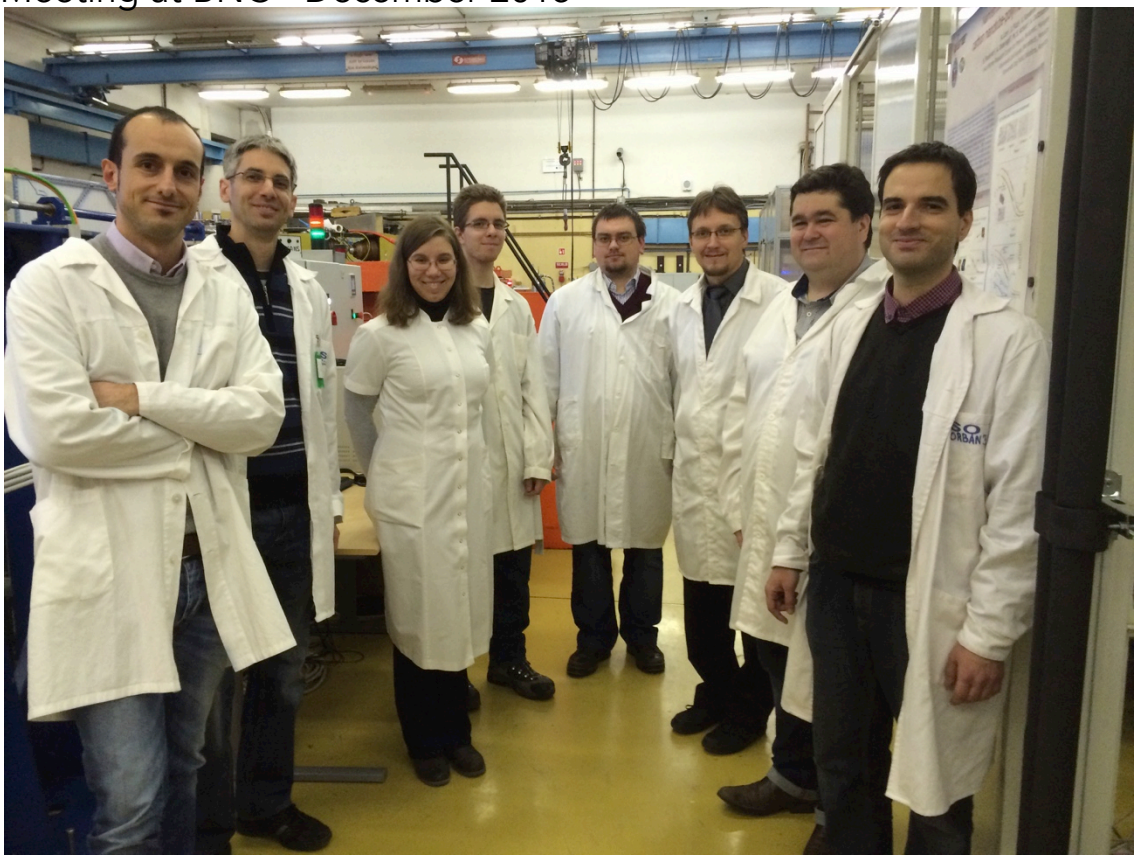
- Electric filed modeling
- Testing and availability of beam line
- Build technology prototype
- Data analysis

Wigner

- Detailed GEANT4 on detector performance

All three partners will work together on the final detector for the ESS Reflectometers

Meeting at BNC - December 2015



Francesco Piscitelli
Tibor Zsíros
Eszter Dian
Péter Pázmándi
Gábor Kiss
Dezső Varga
Richard Hall-Wilton
János Orbán

BrightnESS
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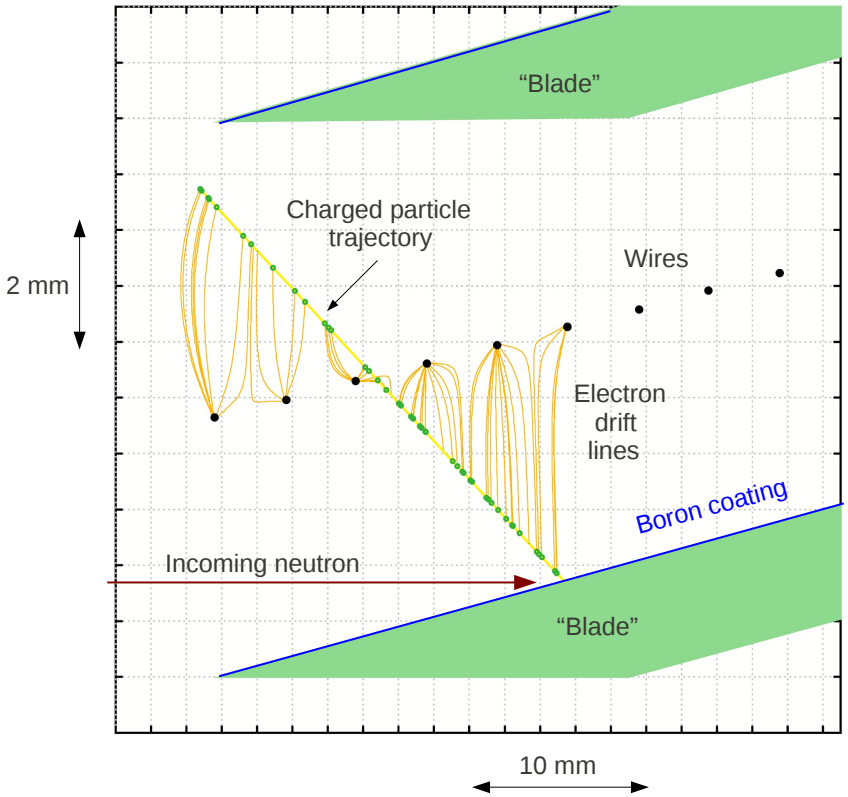
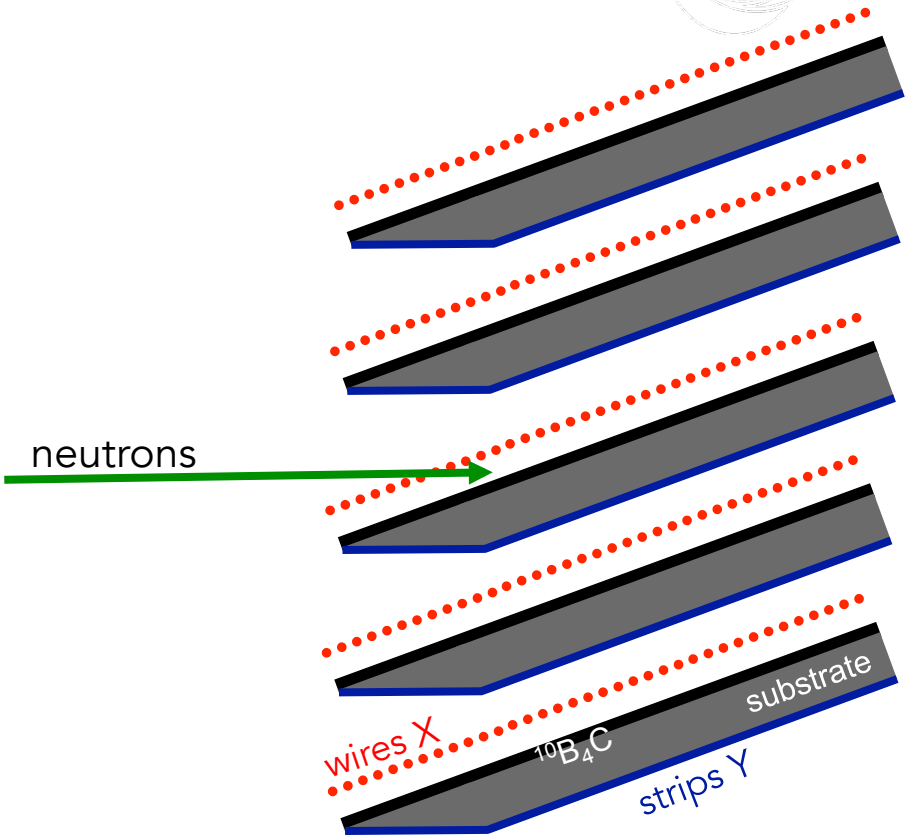
LUND UNIVERSITY

Wigner Research Institute

Budapest Neutron Centre

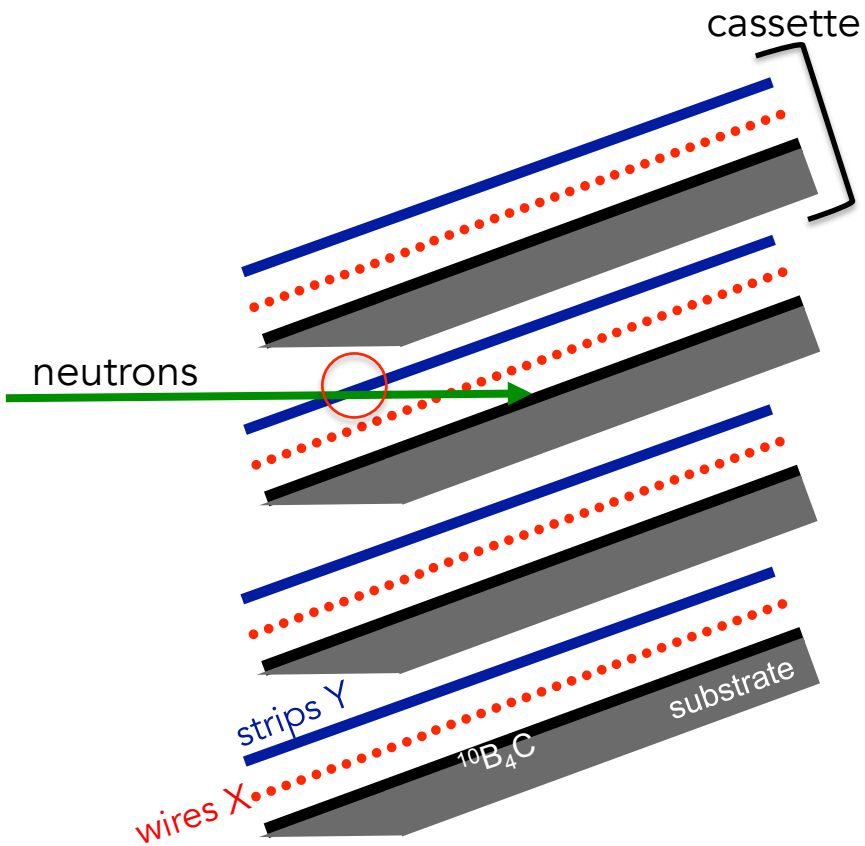
Electric field modeling

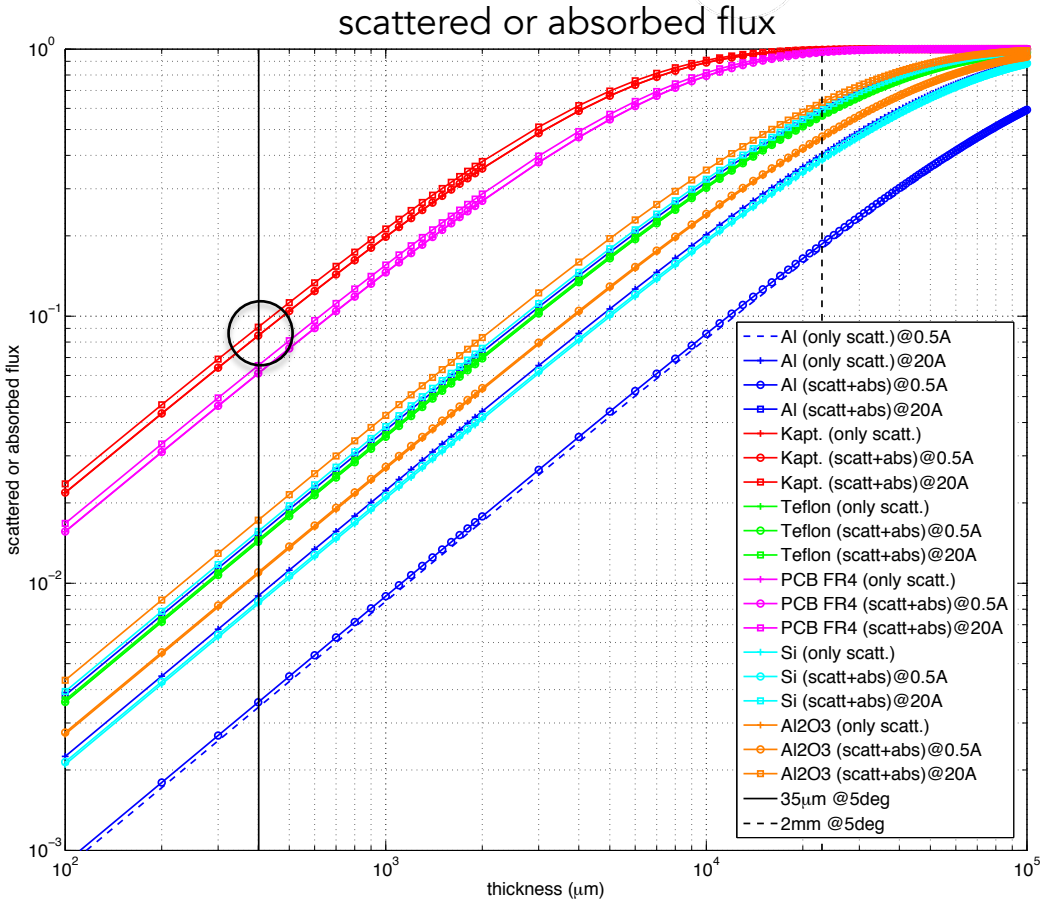




Materials evaluation

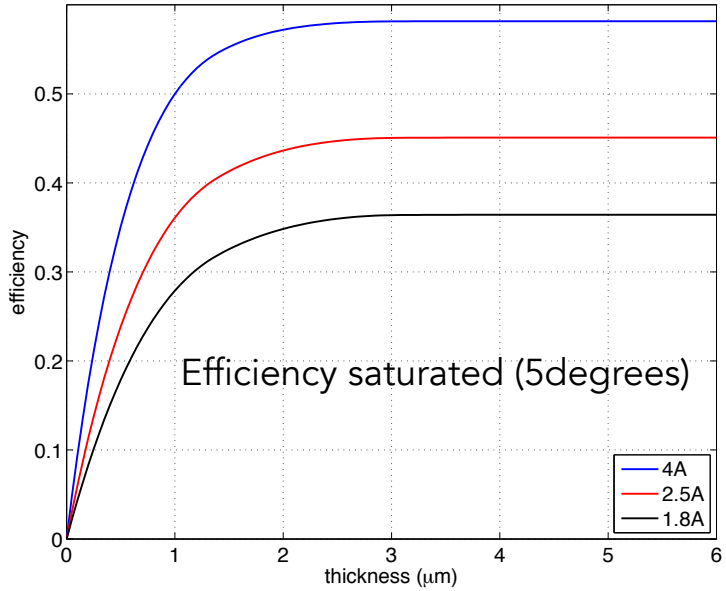
Old Design



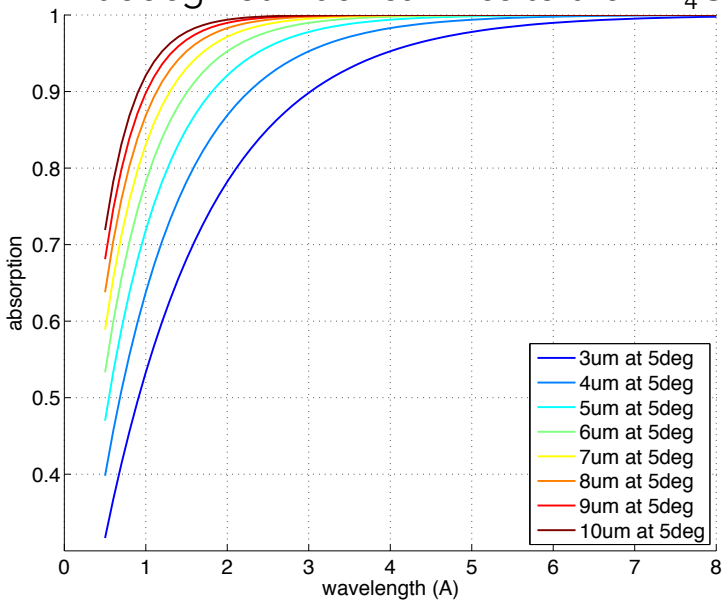


Any material holding the strips at 5deg scatters too much!

Materials evaluation

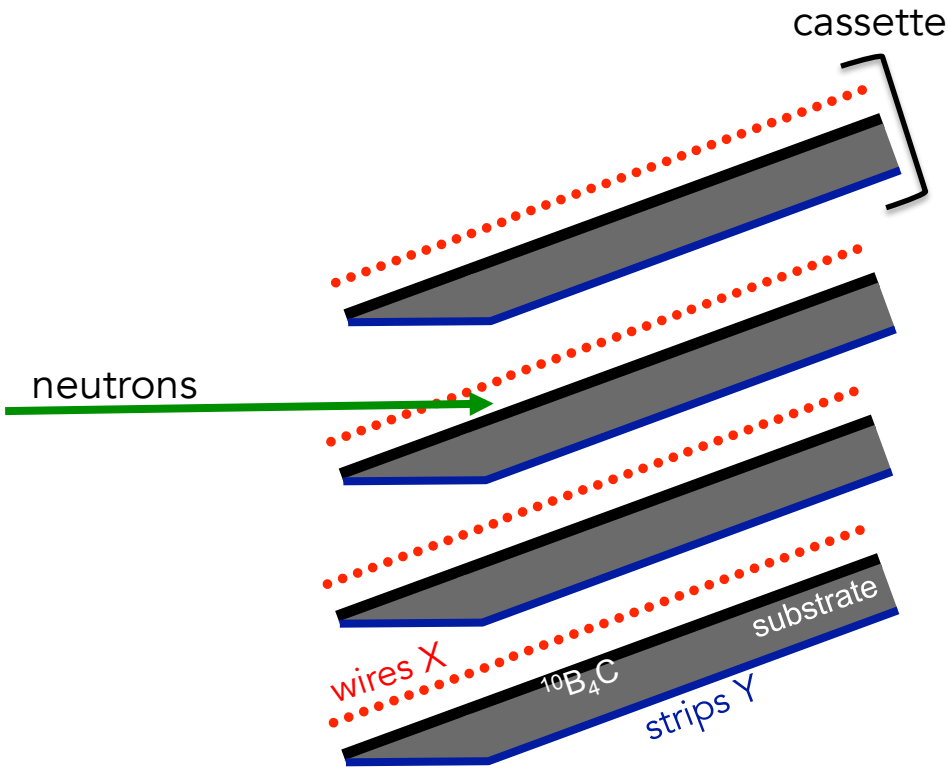


At 5deg not much survives to the $^{10}B_4C$



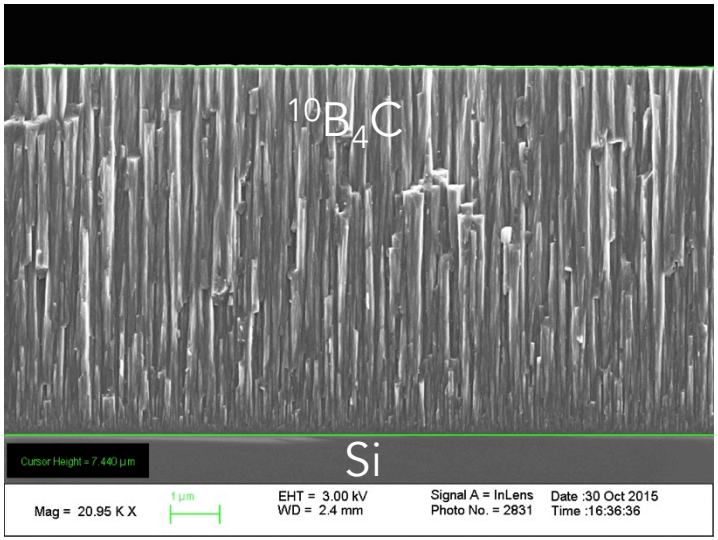
New Design

- Substrate as thick as necessary
- Kapton (strips) shielded by $^{10}B_4C$



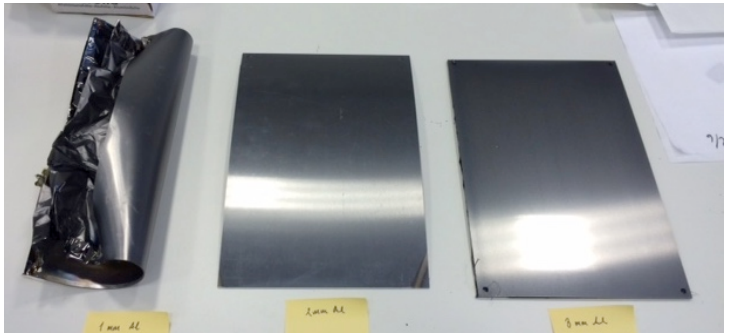
Materials evaluation

Planarity is an issue on large surfaces

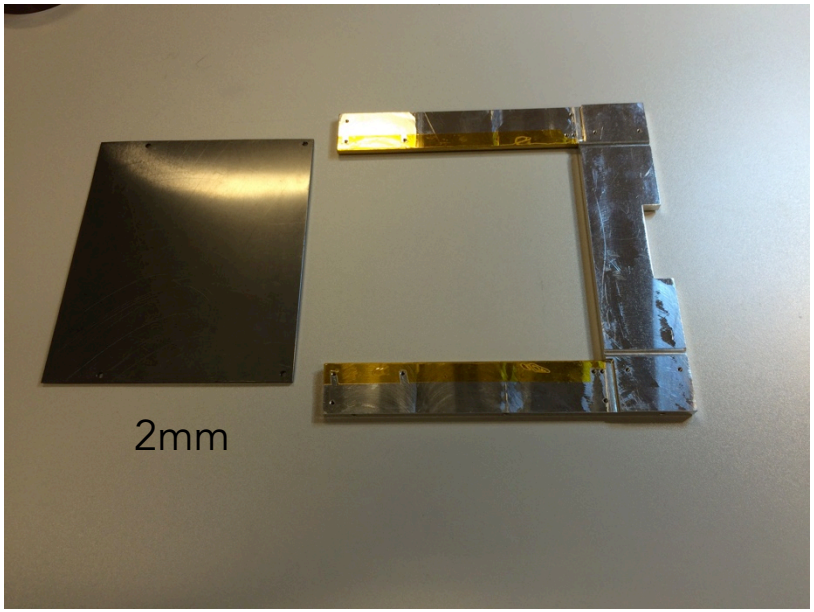


~7 µm single-side

200x300mm^2 Al-plates single-side coated



1mm 2mm 3mm

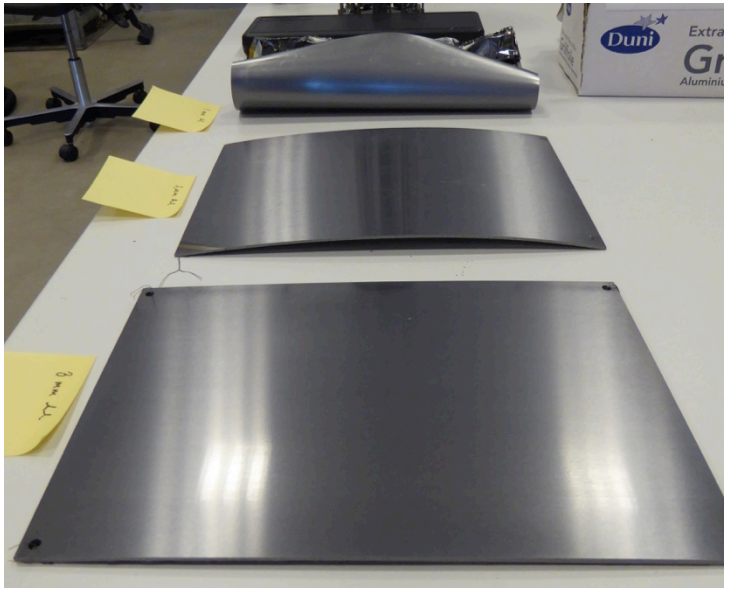


2mm

1mm

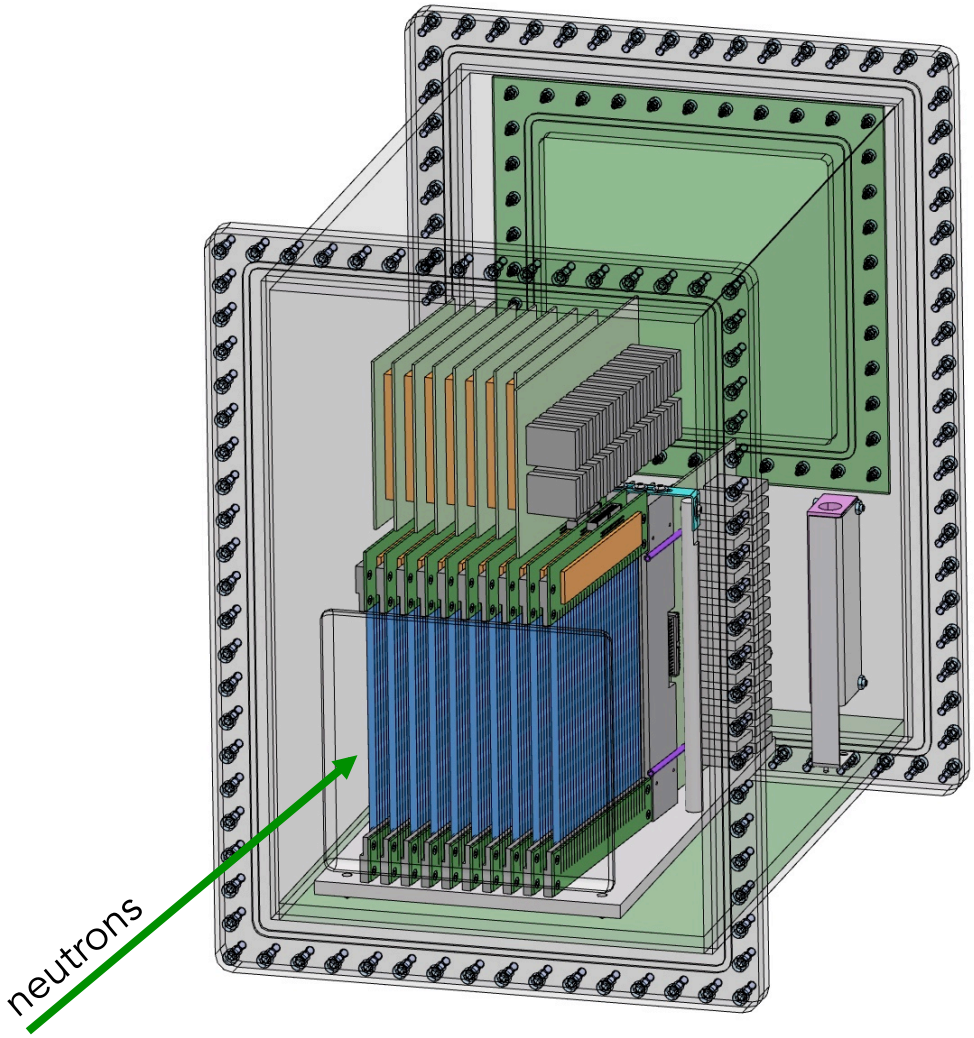
2mm

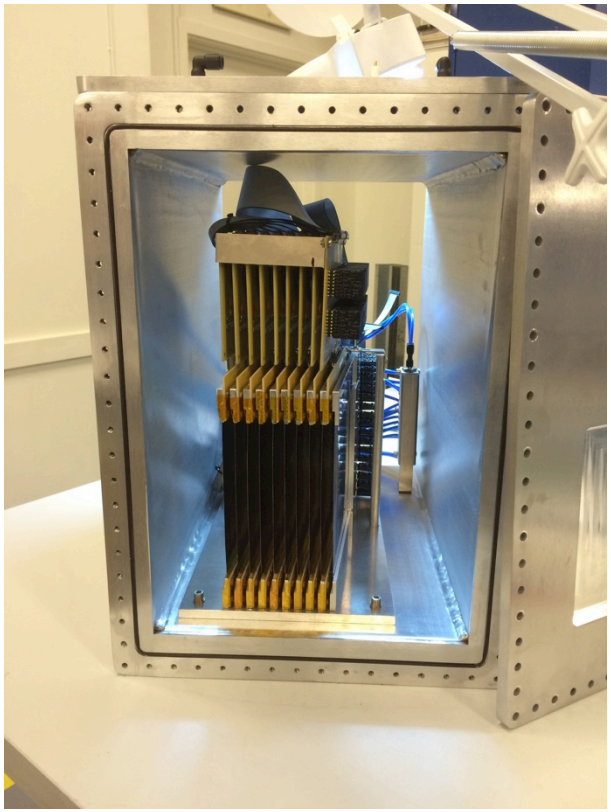
3mm

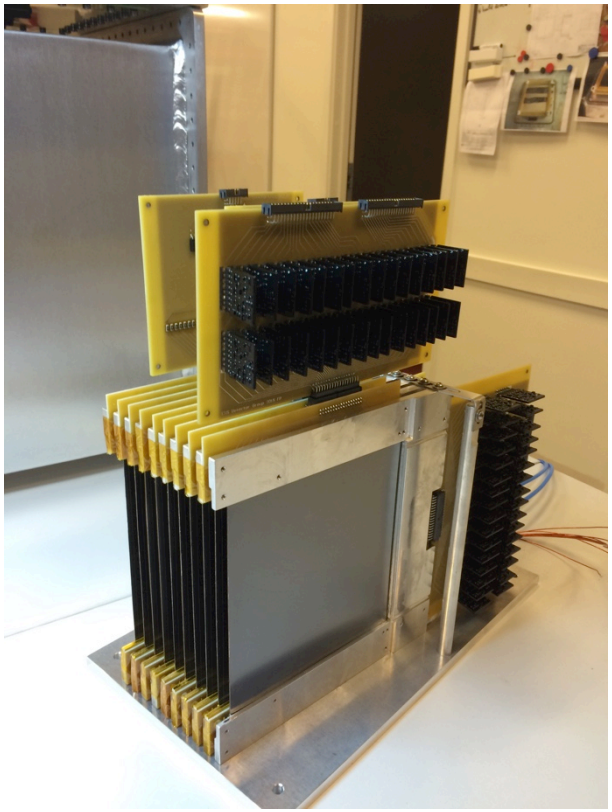


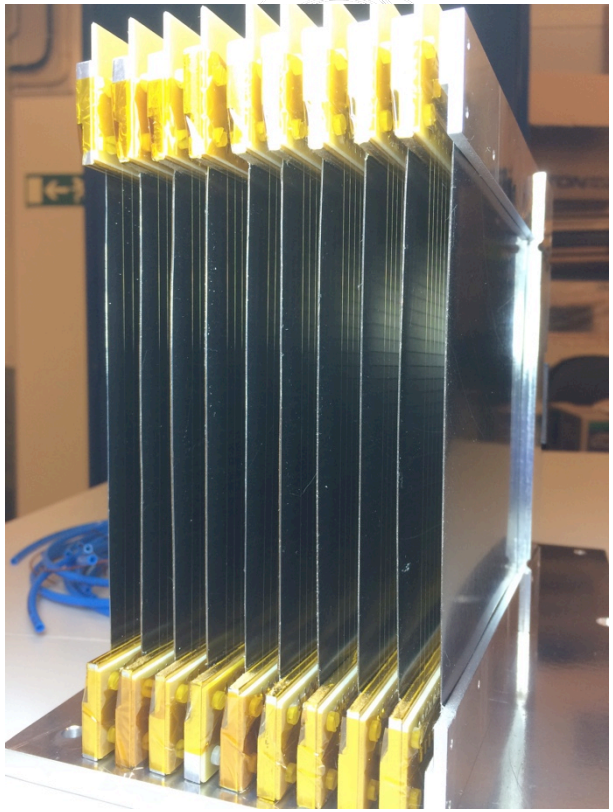
Multi-Blade mechanical design

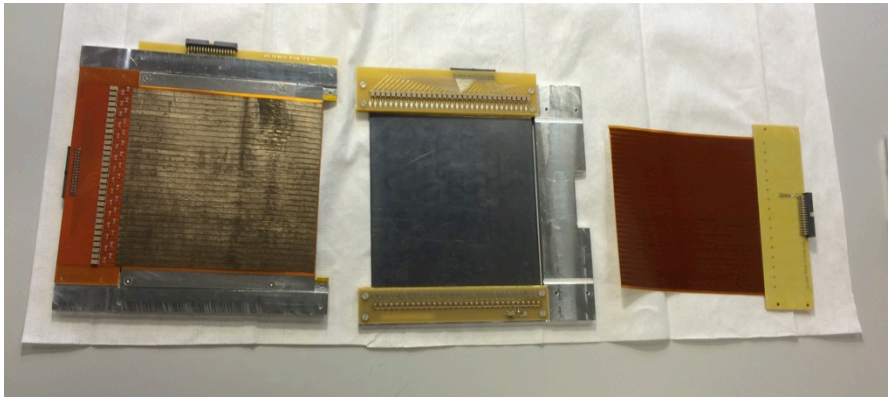
10x10cm^2 demonstrator





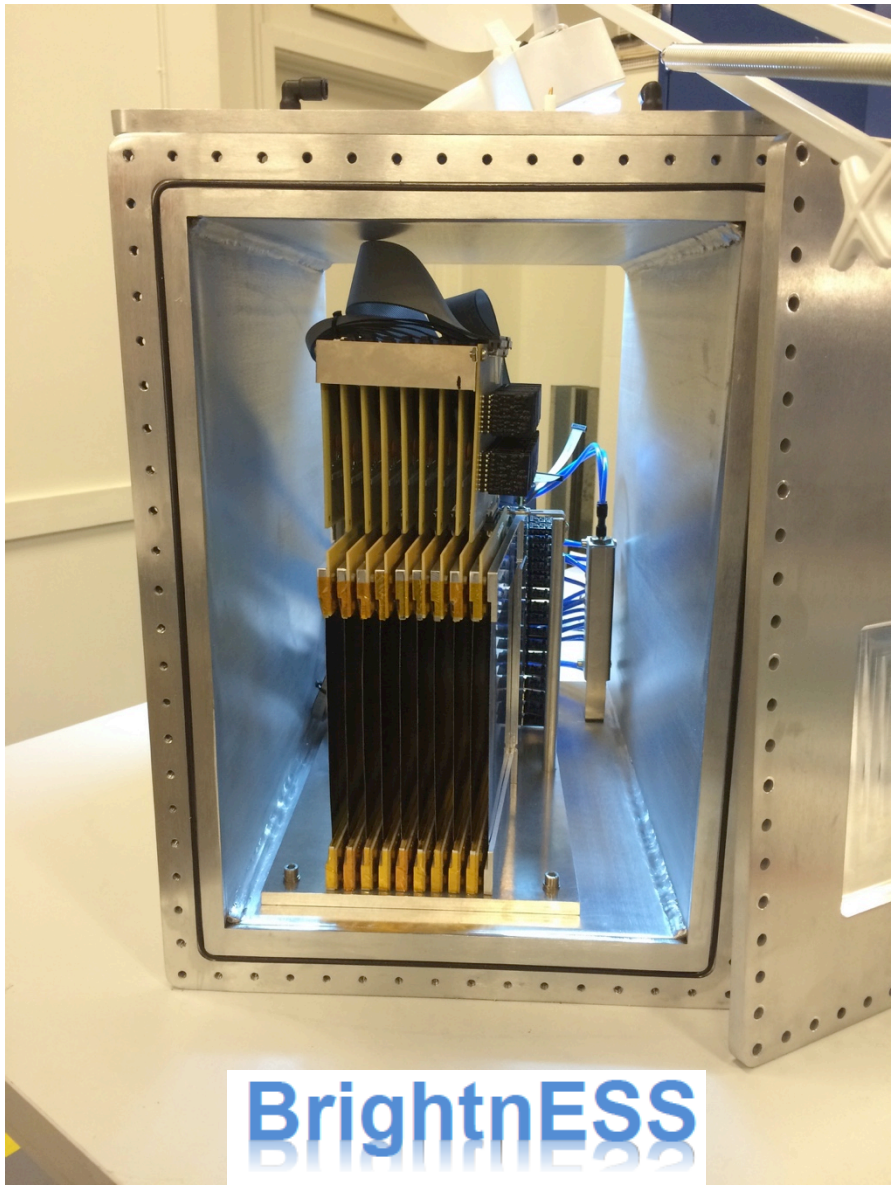






Assembly completed in December 2015

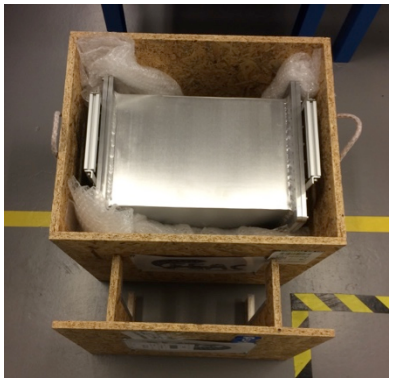
1 blade area: ~120x120 mm^2
9 cassettes (10 blades)
Coating area: ~ 10x120x120 mm^2 (single side)
Detector active area: ~10x9x120mm^2=90x120mm^2

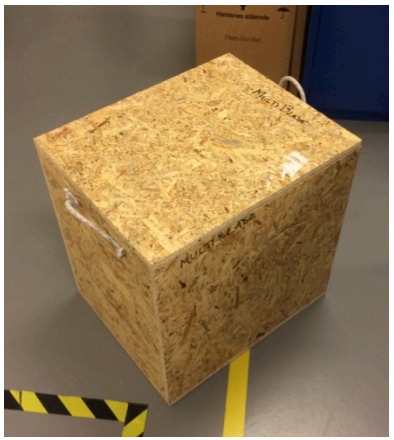


Demonstrator ready!

Tests to come:

- SF (Lund University) - Now
- BNC (Budapest) - February
- Real instrument - …





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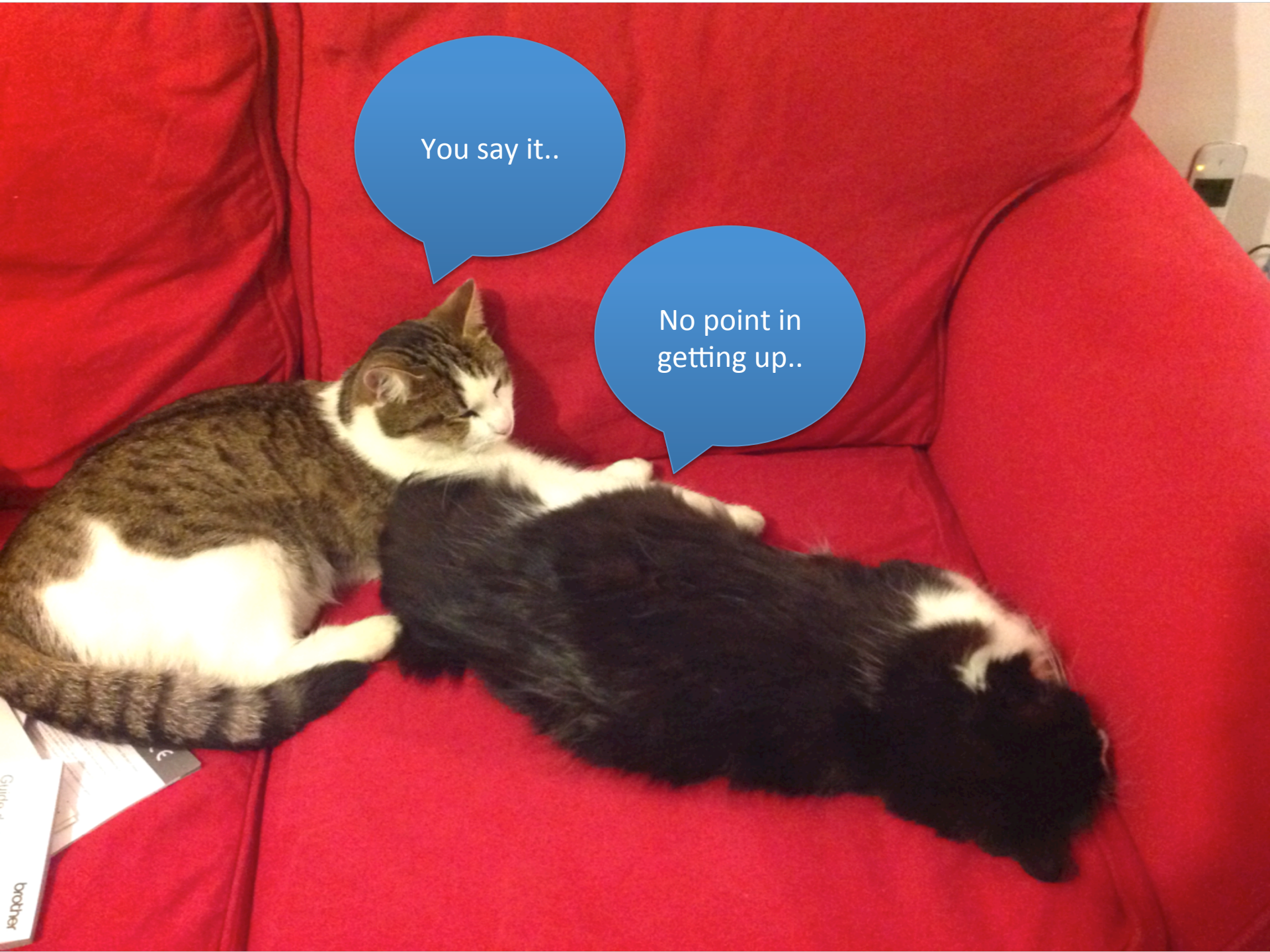
Thank you for your attention !


You say it..
No point in getting up..
brother