Bundesministerium
für Bildung
und Forschung

On the Phase Front of Neutron Detection

The CASCADE Project

DPG Tagung Darmstadt HK 70.6 - 18. März 2016

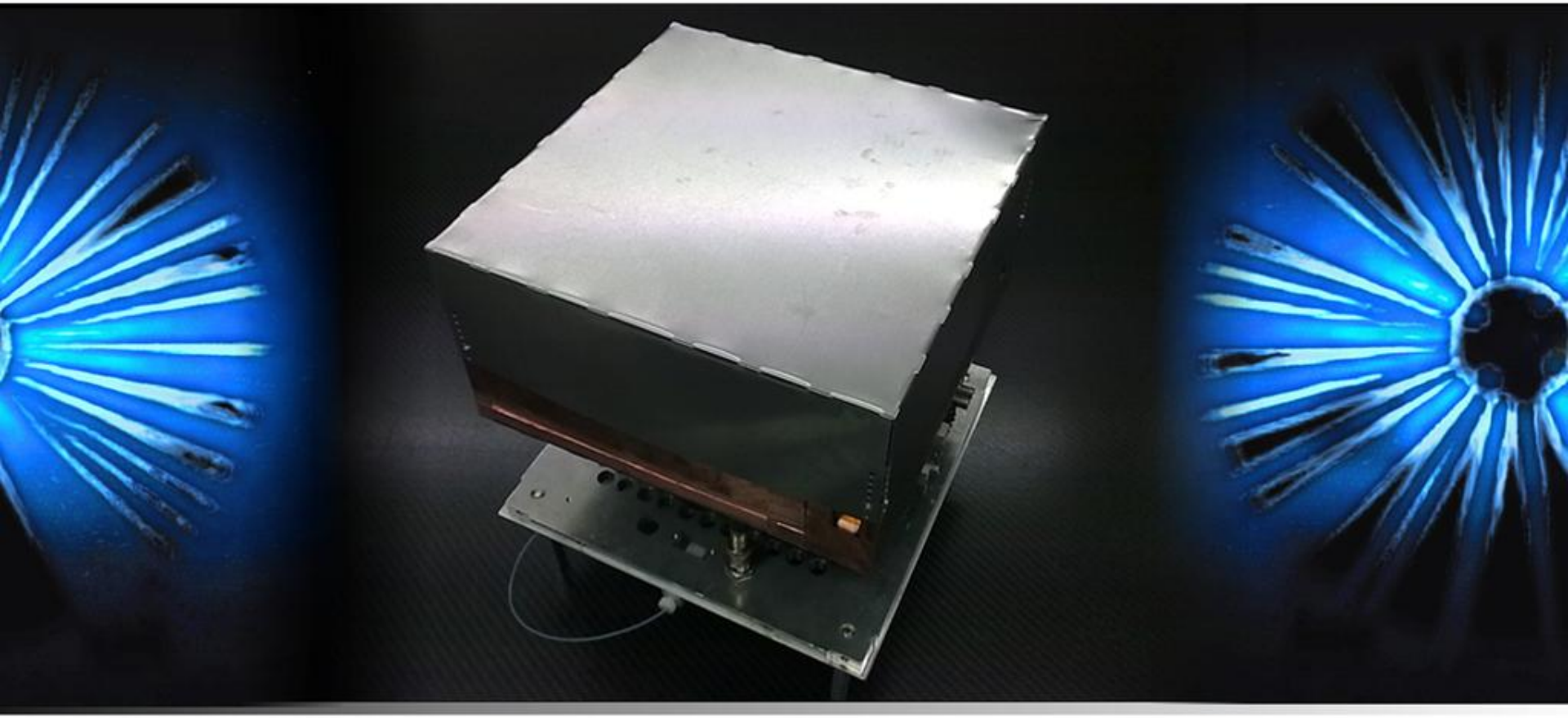
Physikalisches Institut

Ruprecht-Karls-Universität Heidelberg

Markus Köhli

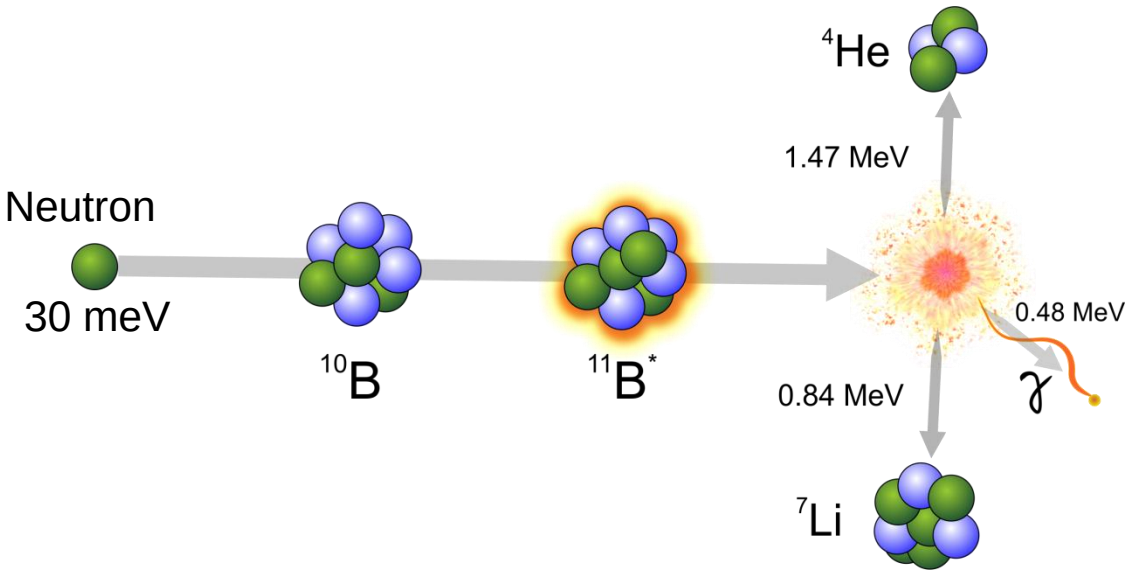
U. Schmidt

ANP-PAT

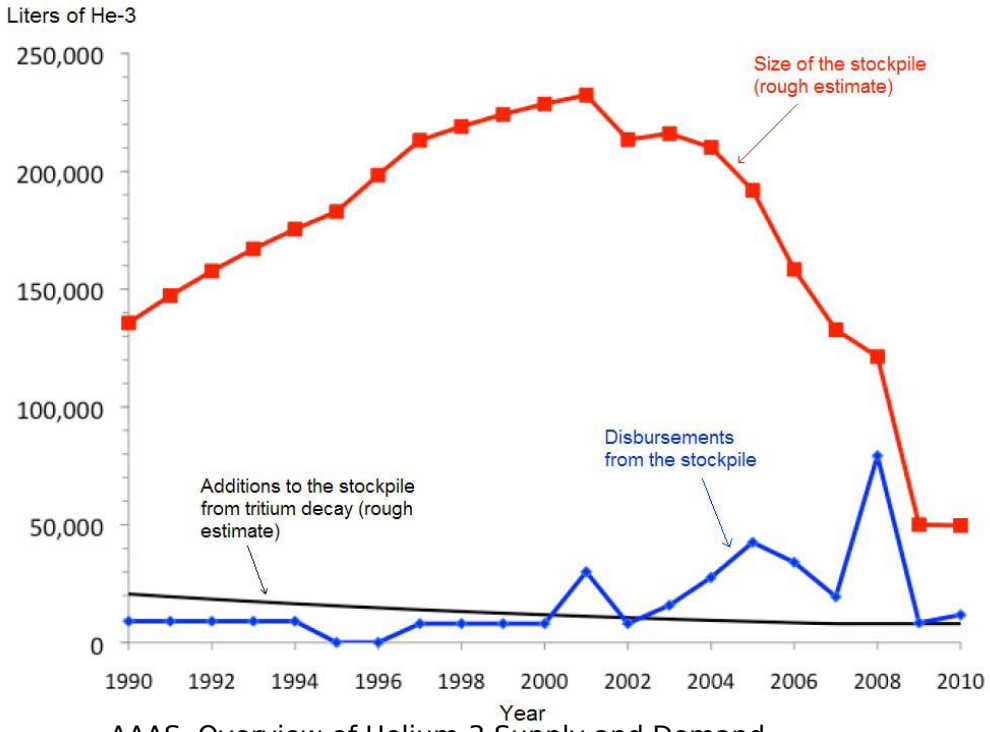


Neutron Capture

Element	Reaction	CS at 25.2 meV
^{3}He	^{3}He+n$\rightarrow$ ^{3}H+764 keV	5327 b
^{6}Li	^{6}Li+n$\rightarrow$ ^{3}H+α + 4.78 MeV	940 b
^{10}B	^{10}B+n$\rightarrow$ ^{7}Li+α + 2.79 MeV (6.4 %)	3837 b
	^{10}B+n$\rightarrow$ ^{7}Li+γ + α + 2.31 MeV (93.6 %)	



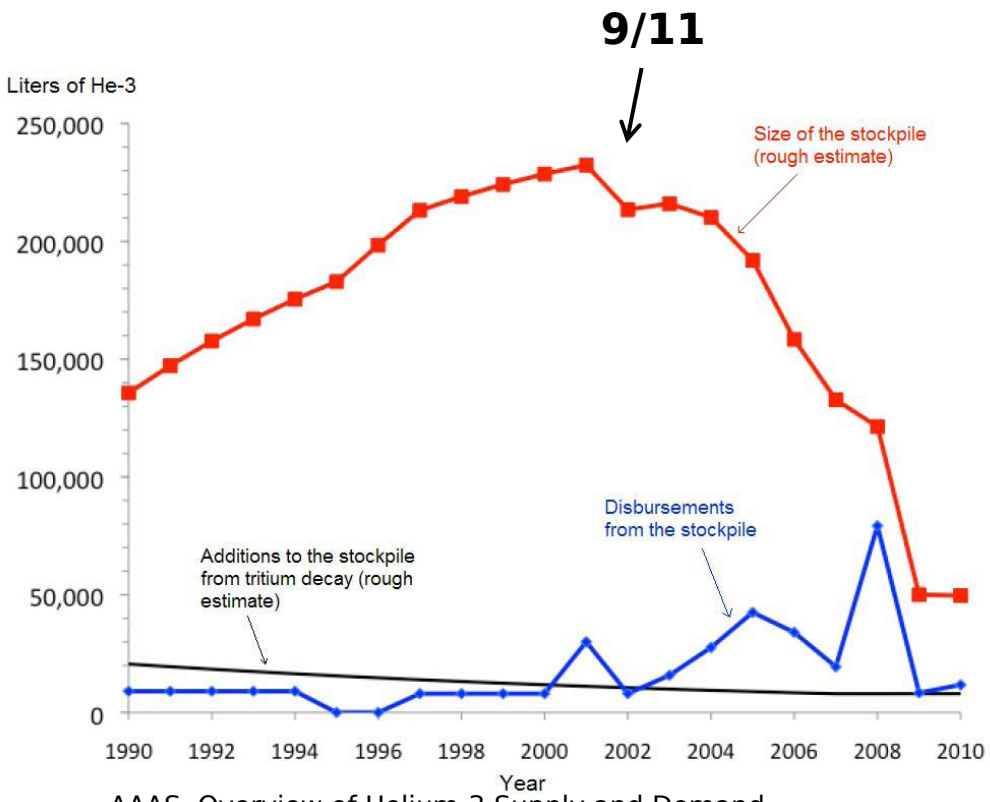
The Helium-3 Crisis



AAAS, Overview of Helium-3 Supply and Demand

[1] http://www.saphymo.com/photos/ecatalogue/116-2/access-control-clearance-monitors-rcp-radiological-control-for-pedestrian.jpg
[2] http://cits.uga.edu/uploads/1540compass/1540images/_compass750/RPM1.jpg

The Helium-3 Crisis



AAAS, Overview of Helium-3 Supply and Demand

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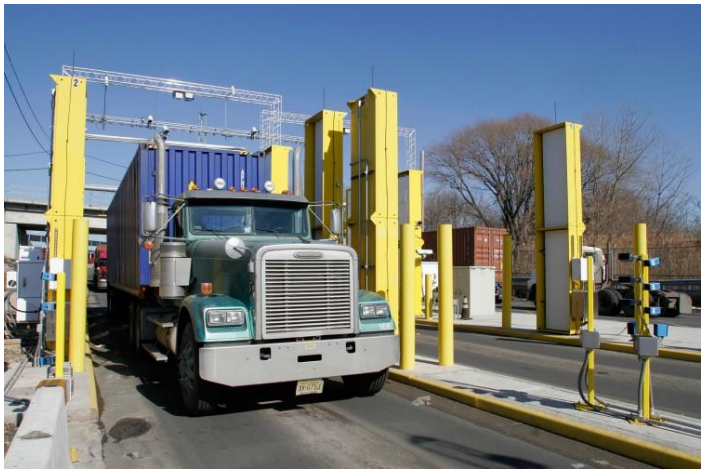

[2]

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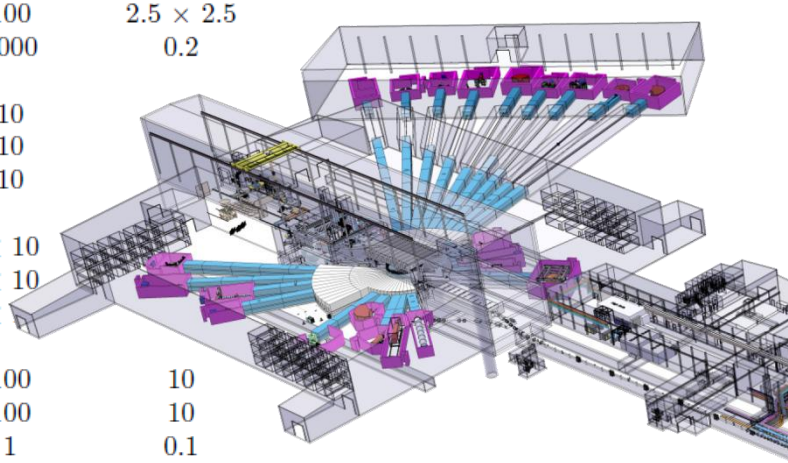
[2] http://cits.uga.edu/uploads/1540compass/1540images/_compass750/RPM1.jpg

ESS Instrumentation

Instrument	Detector area [m^2]	Wavelength range [Å]	Time resolution [μs]	Spatial resolution [mm]
Multi-purpose imaging	0.5	1 - 20	1	0.001 - 0.5
General purpose polarised SANS	5	4 - 20	100	10
Broad-band small sample SANS	14	2 - 20	100	1
Surface scattering	5	4 - 20	100	10
Horizontal reflectometer	0.5	5 - 30	100	1
Vertical reflectometer	0.5	5 - 30	100	1
Thermal powder diffractometer	20	0.6 - 6	< 10	2×2
Bi-spectral powder diffractometer	20	0.8 - 10	< 10	2.5×2.5
Pulsed monochromatic powder diffractom.	4	0.6 - 5	< 100	2×5
Material science & engineering diffractom.	10	0.5 - 5	10	2
Extreme conditions instrument	10	1 - 10	< 10	3×5
Single crystal magnetism diffractometer	6	0.8 - 10	100	2.5×2.5
Macromolecular diffractometer	1	1.5 - 3.3	1000	0.2
Cold chopper spectrometer	80	1 - 20	10	
Bi-spectral chopper spectrometer	50	0.8 - 20	10	
Thermal chopper spectrometer	50	0.6 - 4	10	
Cold crystal-analyser spectrometer	1	2 - 8	< 10	
Vibrational spectroscopy	1	0.4 - 5	< 10	
Backscattering spectrometer	0.3	2 - 8	$<$	
High-resolution spin echo	0.3	4 - 25	100	10
Wide-angle spin echo	3	2 - 15	100	10
Fundamental & particle physics	0.5	5 - 30	1	0.1
Total	**282.6**			



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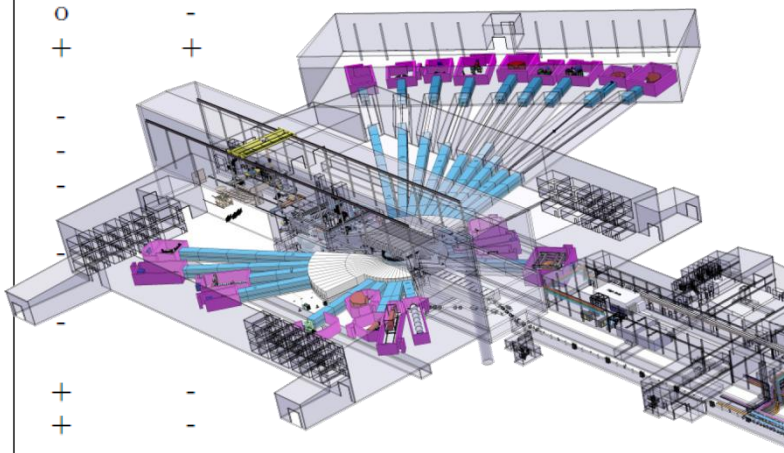
ESS Instrumentation

Instrument	Detector technology						
	^{10}B thin films		Scintillators		^{3}He	Micropattern	
	⊥	∥	WSF	Anger		Rate	Resolution
Multi-purpose imaging	-	-	-	-	-	o	+
General purpose polarised SANS	o	+	-	+	o	+	-
Broad-band small-sample SANS	o	+	-	+	-	+	-
Surface scattering	o	+	-	+	o	+	-
Horizontal reflectometer	-	o	-	+	+	o	-
Vertical reflectometer	-	o	-	+	+	o	-
Thermal powder diffractometer	o	+	+	-	-	o	-
Bi-spectral powder diffractometer	o	+	+	-	-	o	-
P-M powder diffractometer	o	+	+	-	-	o	-
MS engineering diffractometer	o	+	+	-	-	o	-
Extreme conditions diffractometer	o	+	+	-	-	o	-
Single crystal diffractometer	o	+	+	-	-	o	-
Macromolecular diffractometer	-	o	o	o	-	+	+
Cold chopper spectrometer	+	o	o	-	-	-	
Bi-spectral chopper spectrometer	+	+	o	-	-	-	
Thermal chopper spectrometer	+	+	+	-	-	-	
Cold crystal analyser spectrometer	-	o	-	+	+	-	
Vibrational spectrometer	-	o	-	o	+	-	
Backscattering spectrometer	-	o	-	+	+	-	
High-resolution spin echo	-	o	-	o	+	+	-
Wide-angle spin echo	-	o	-	o	+	+	-
Fundamental & particle physics	-	-	-	-	+	+	+



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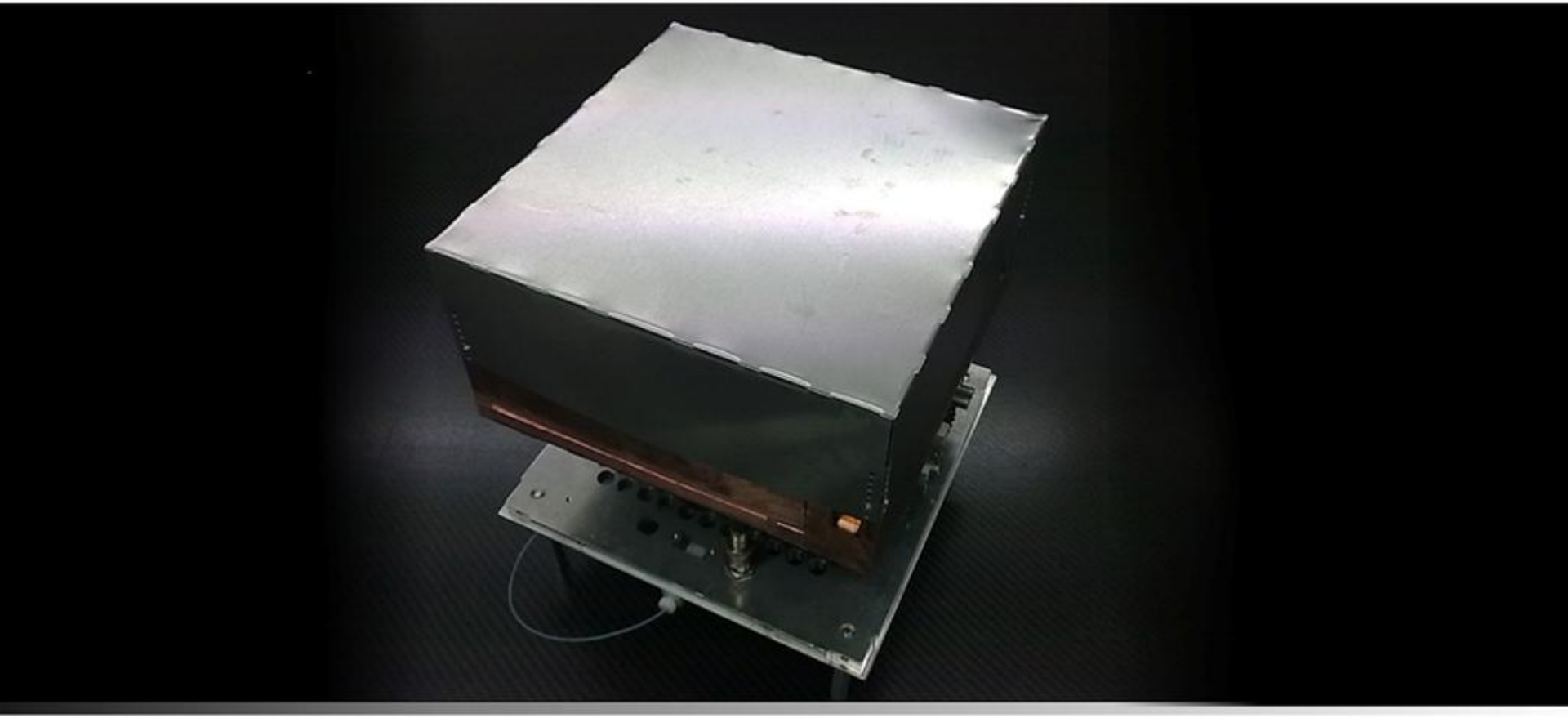
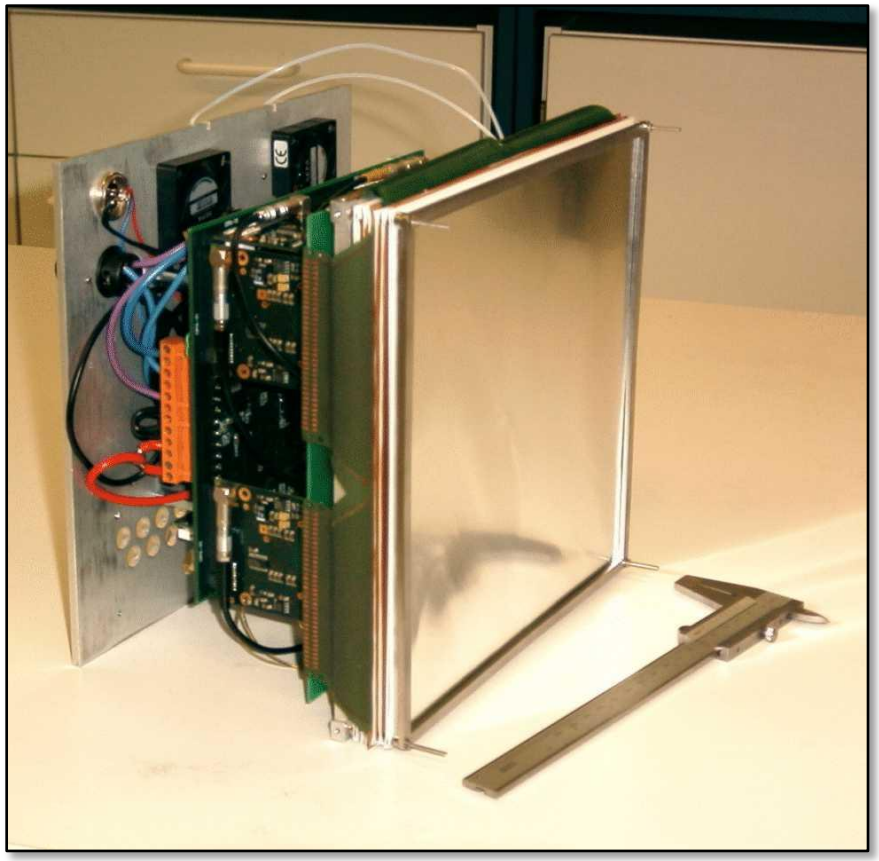
The Detector



The CASCADE Detector

CASCADE detector without housing



The CASCADE Detector

Active Detection Volume

6 layers of Boron-10

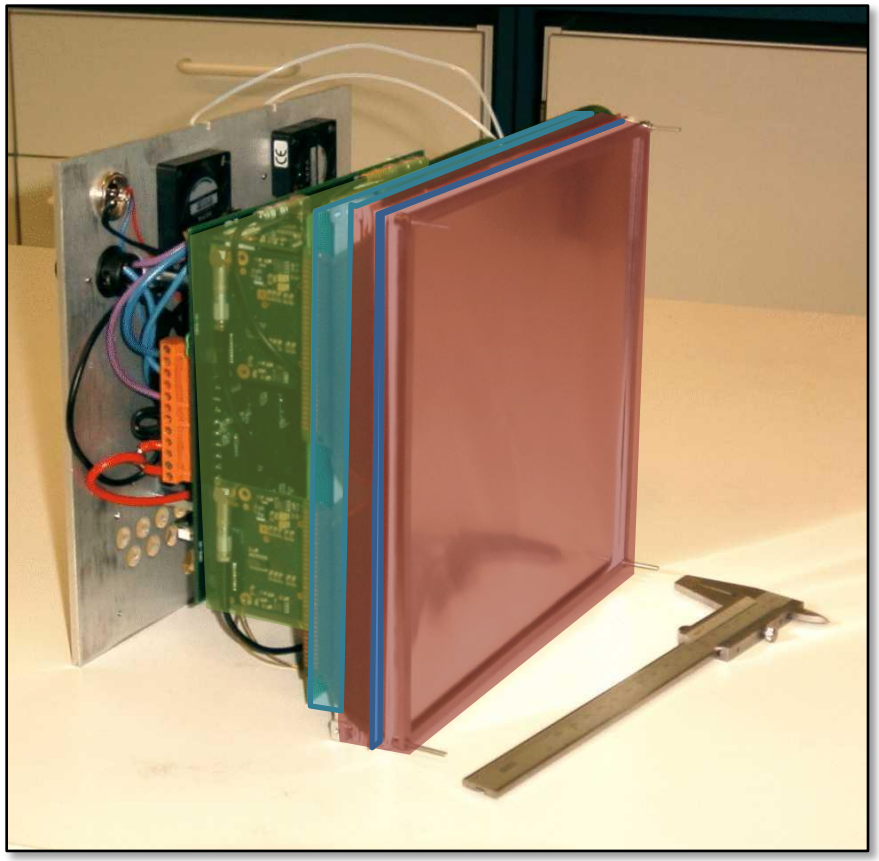
Readout

128x128 crossed stripes @ 1.56 mm

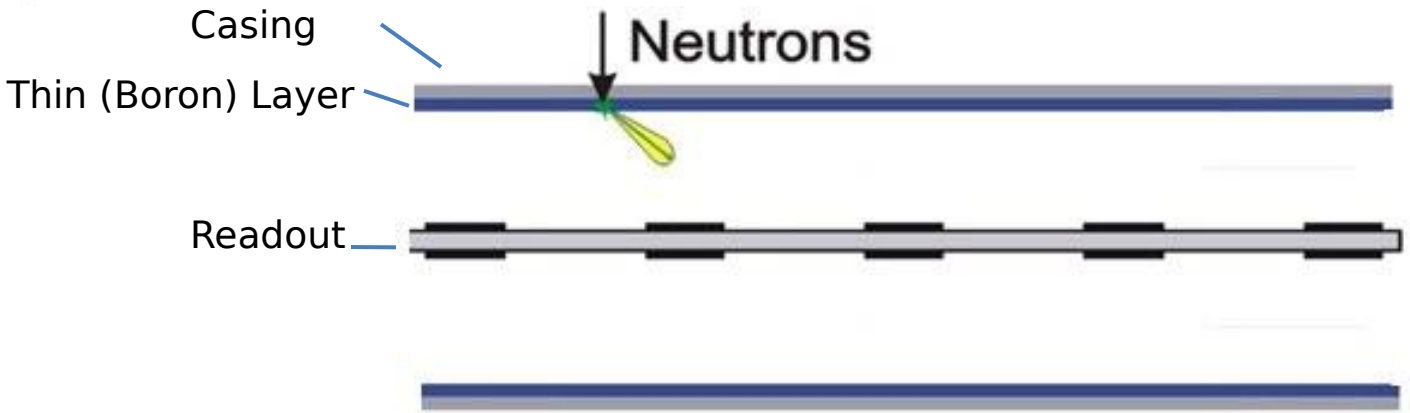
Electronics

5x CIPix 64ch @ FPGA 10 MHz

CASCADE detector without housing



The CASCADE Concept



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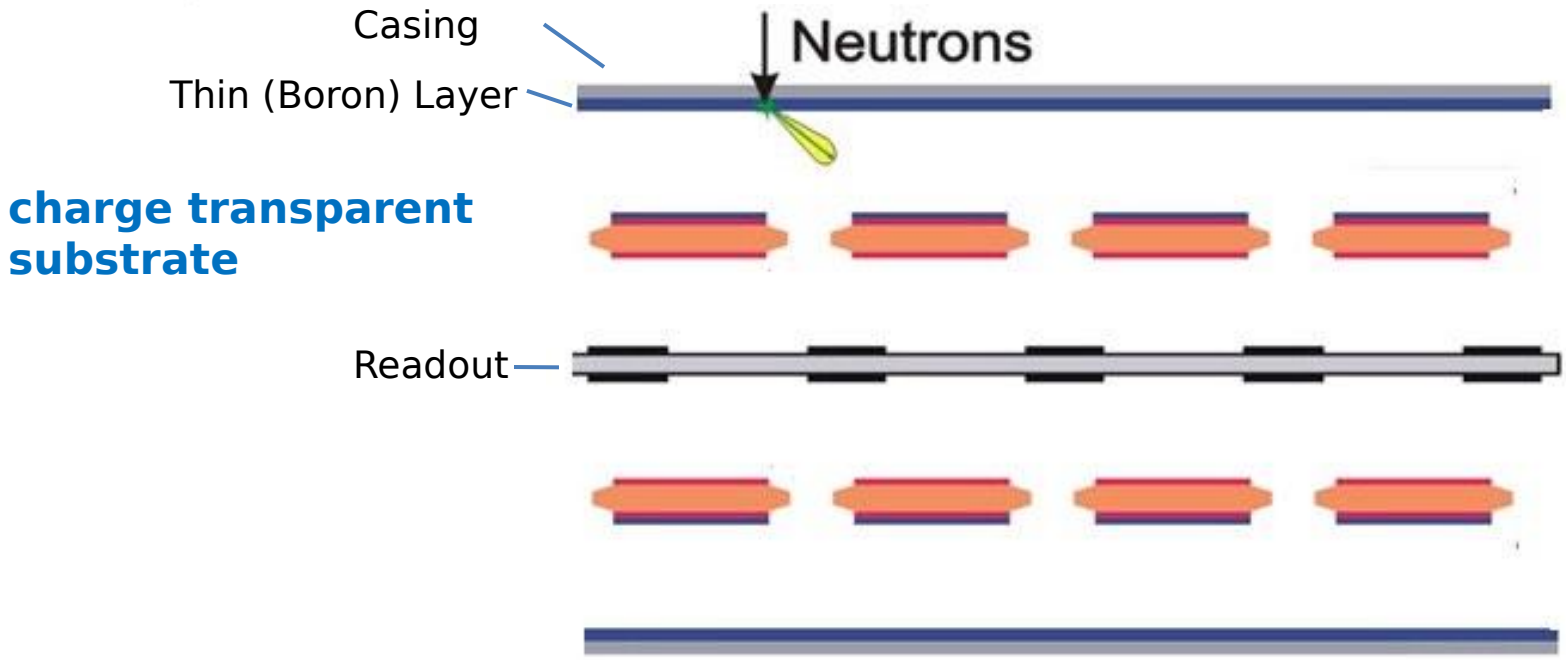

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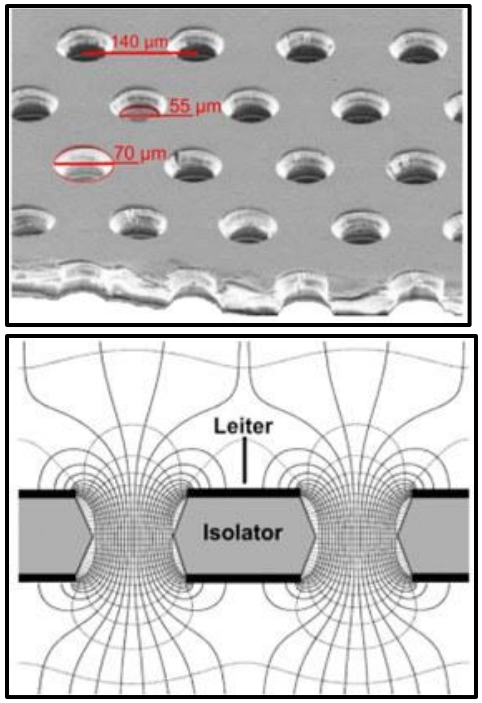
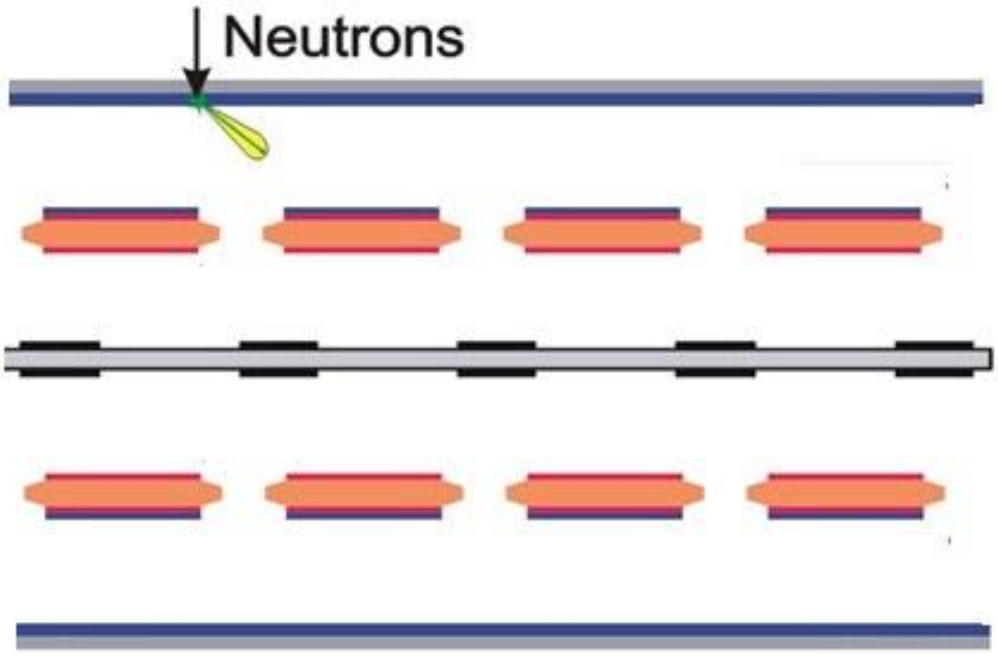


GEM
(Gas Electron Multiplier foil)



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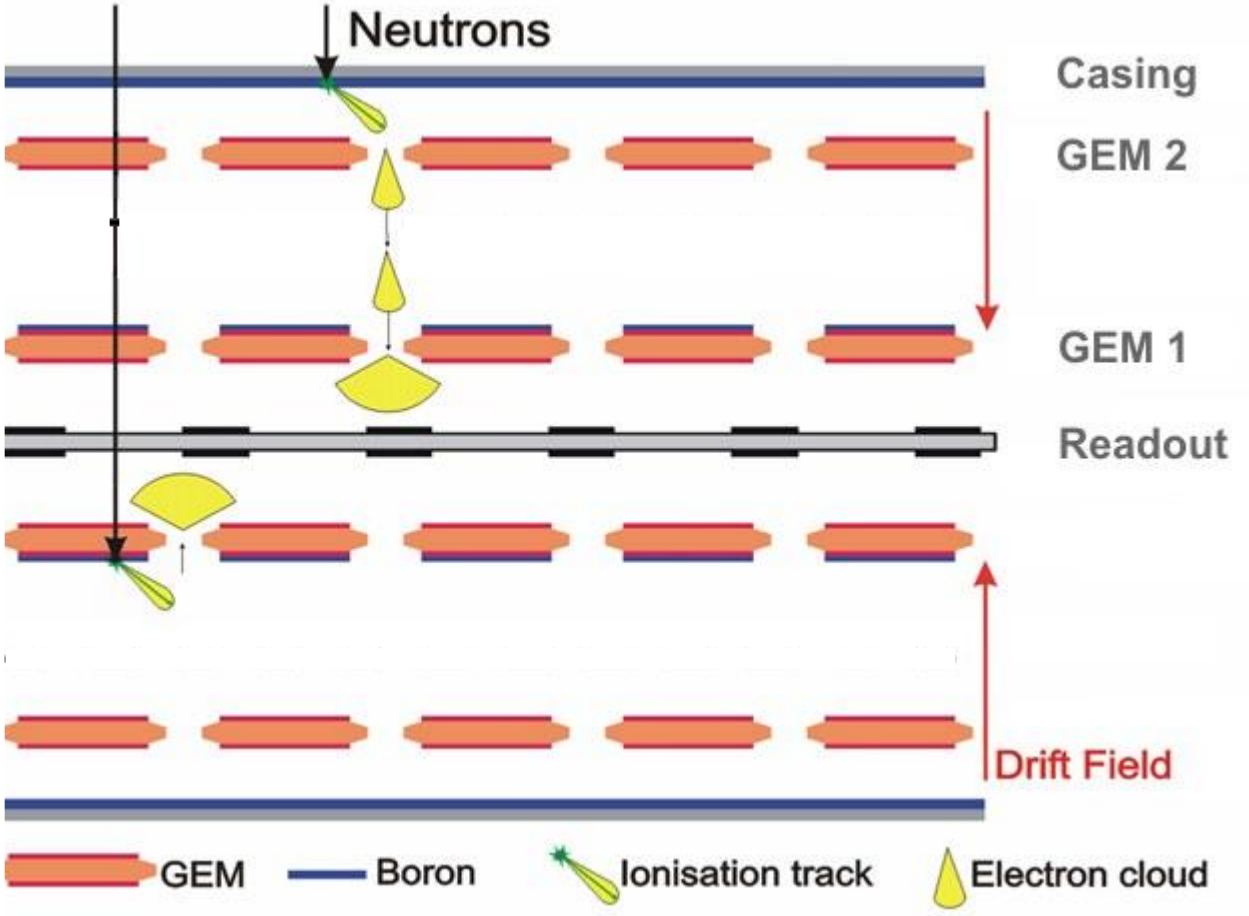

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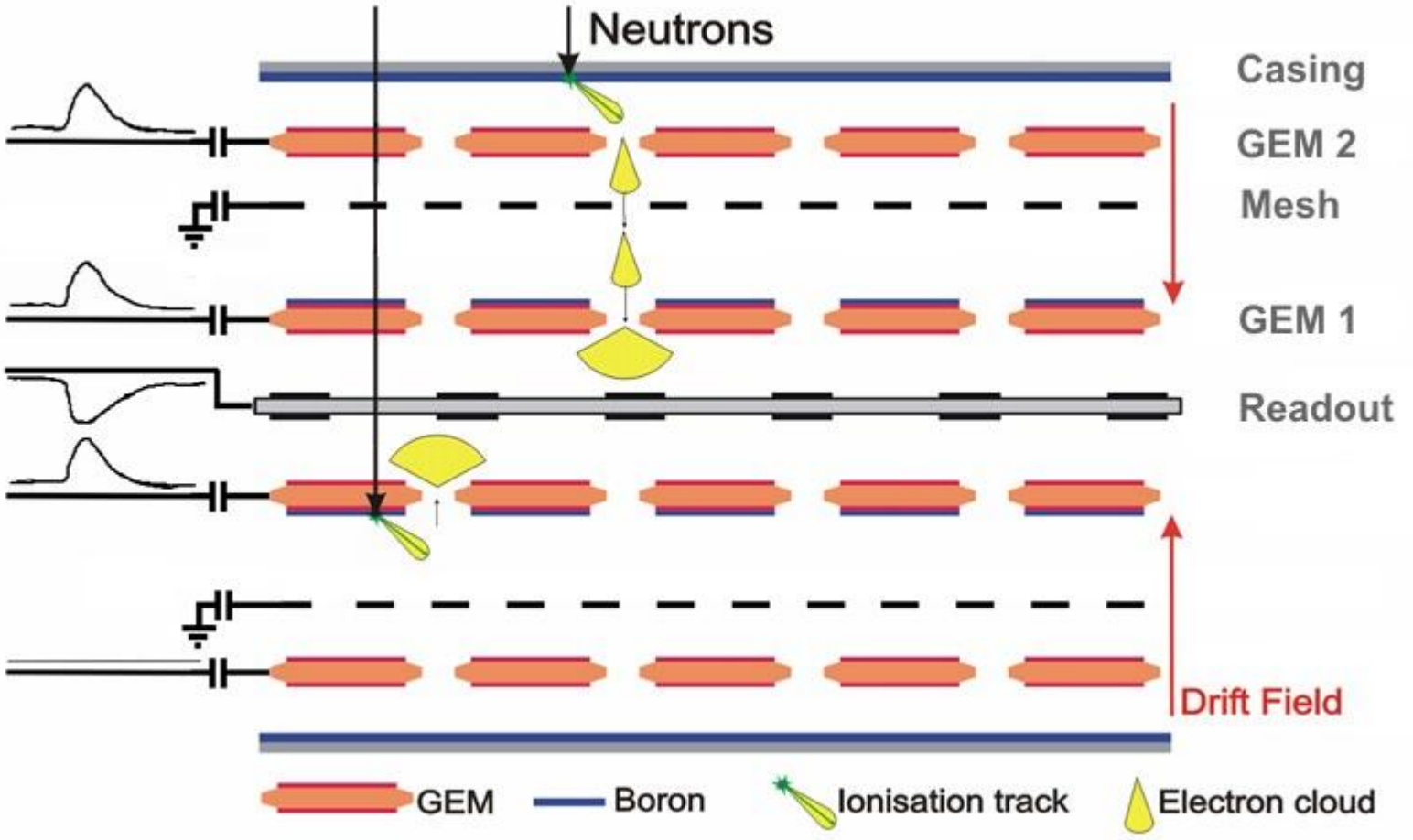

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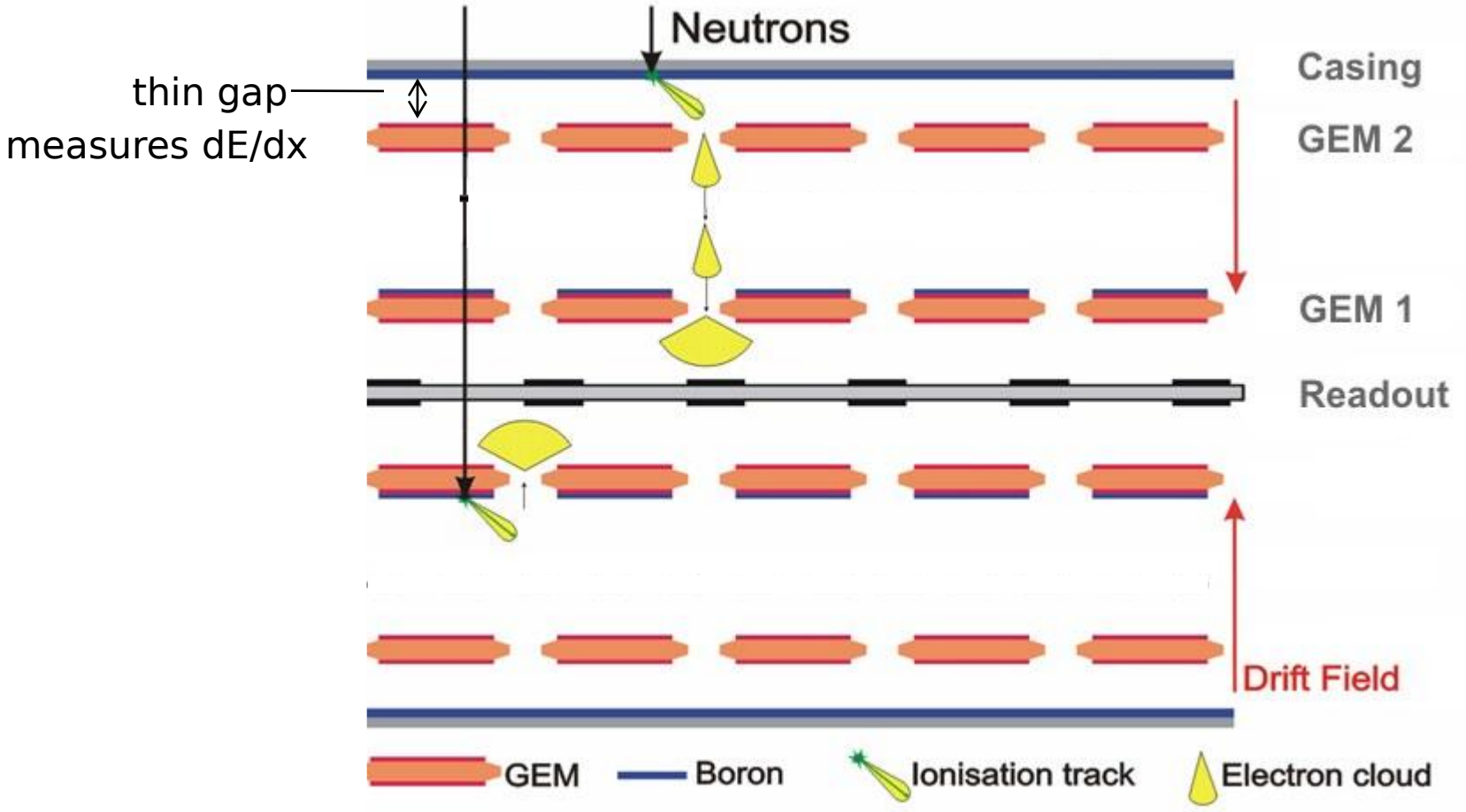
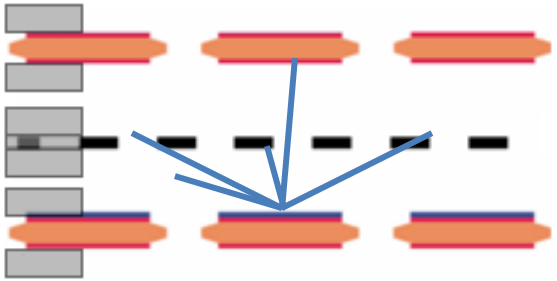


Signals in the Detector



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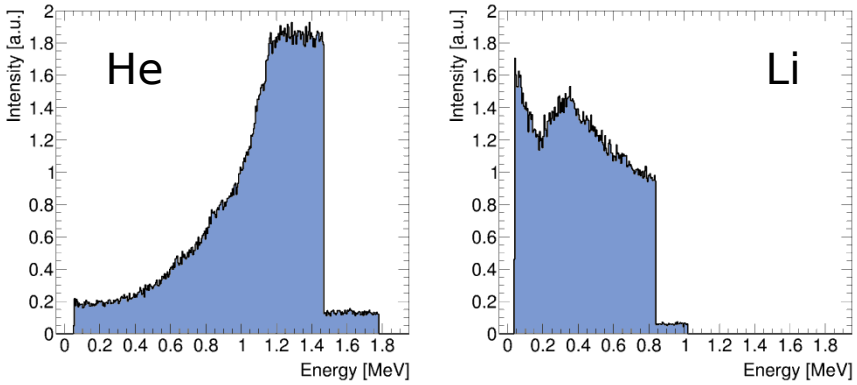

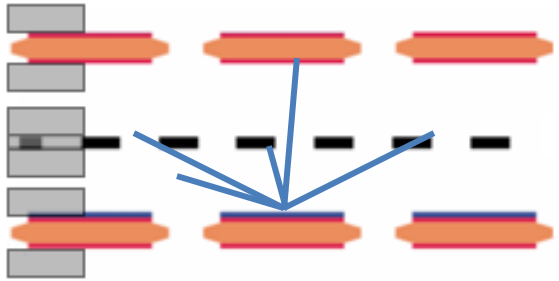

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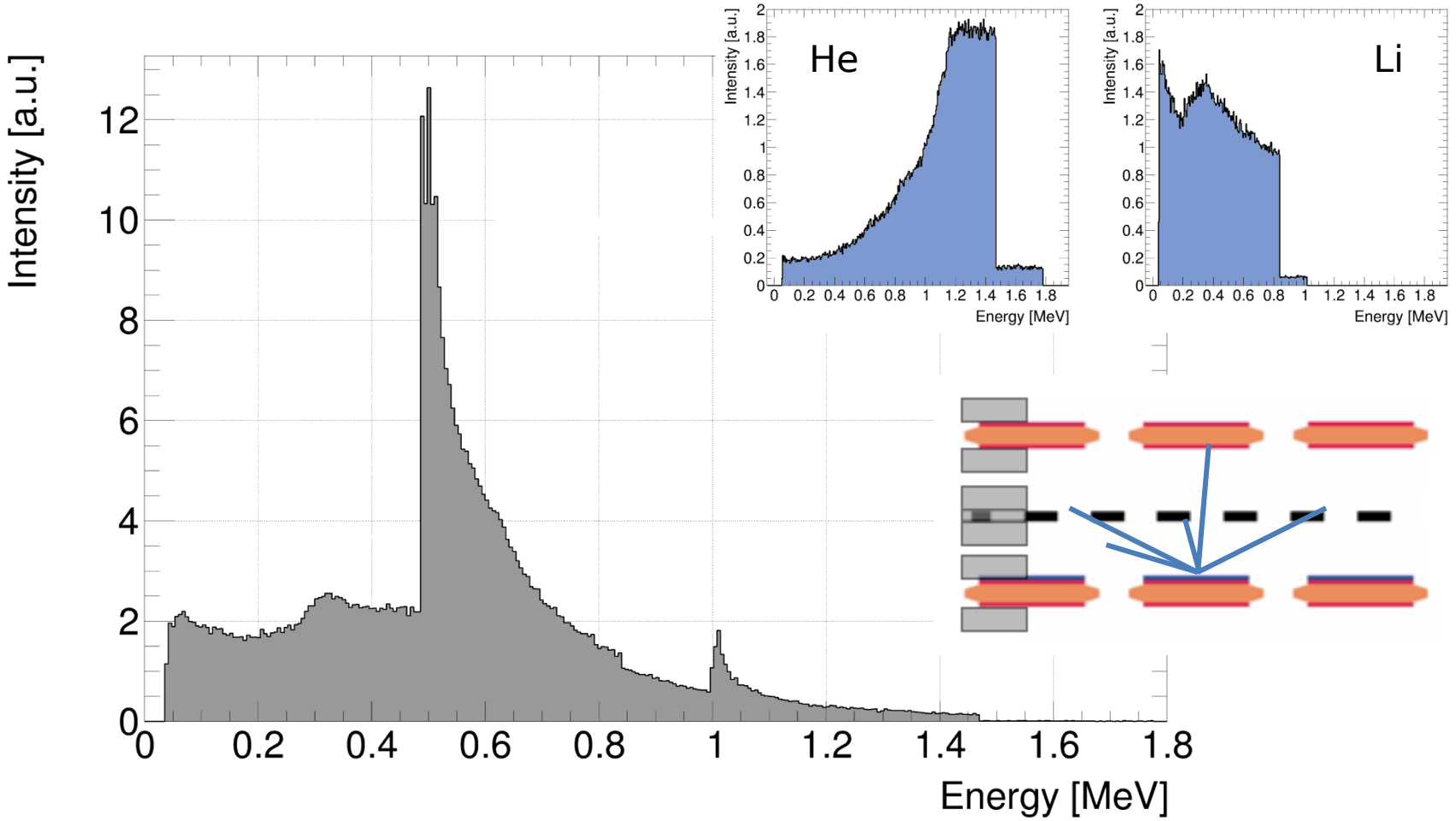

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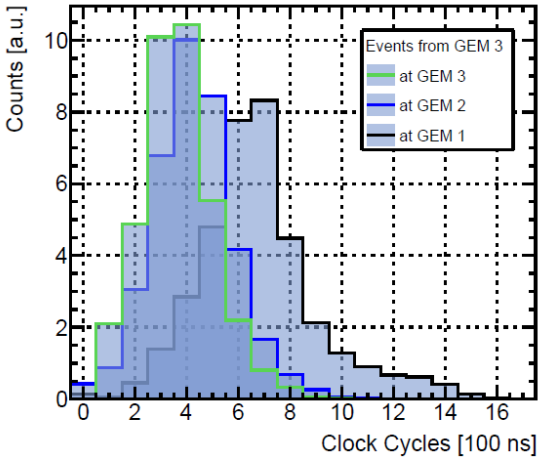

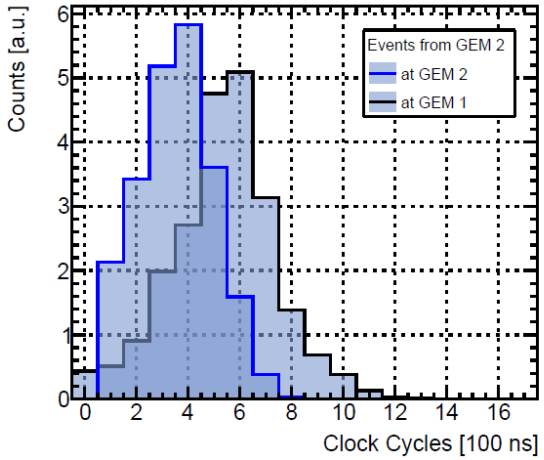

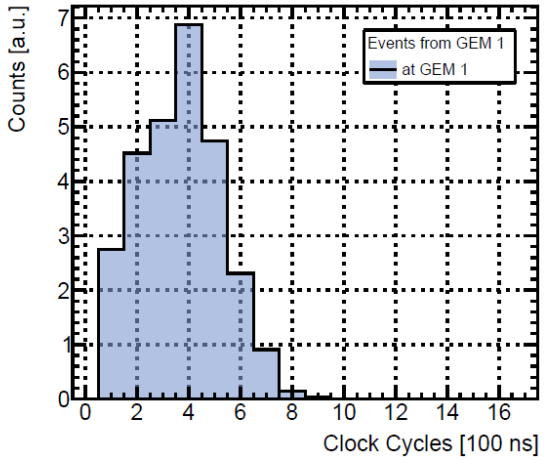

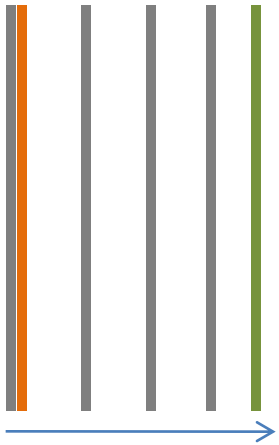

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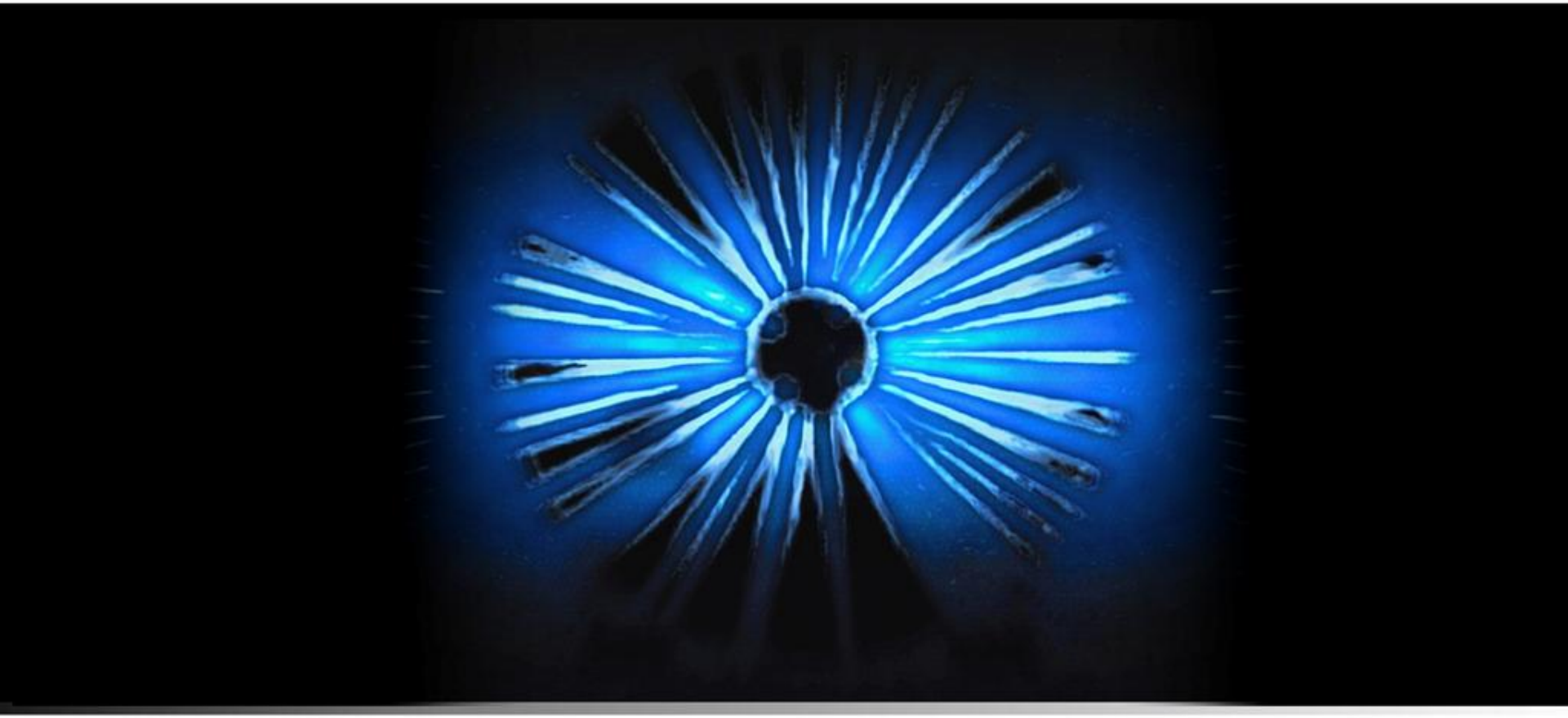
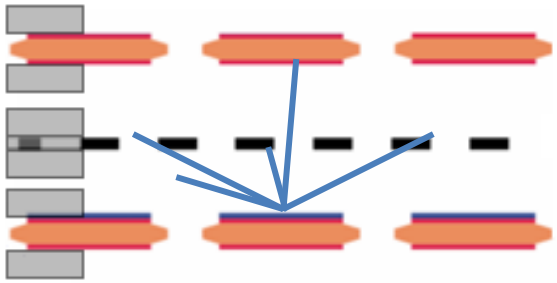
Characterization Measurements



Spatial Resolution



Spatial resolution: 2.4 mm FWHM

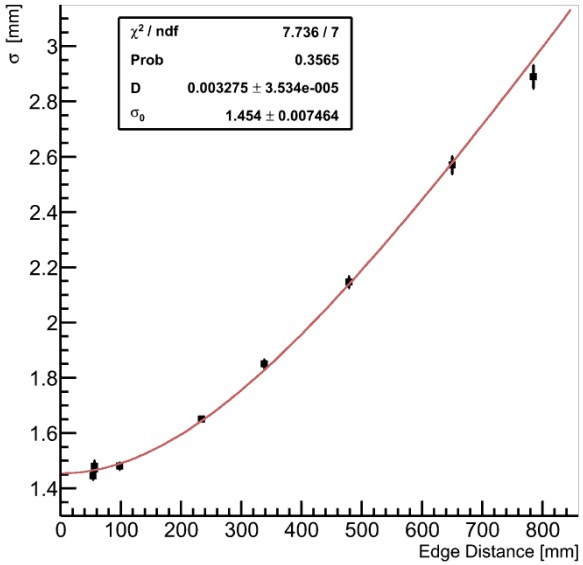
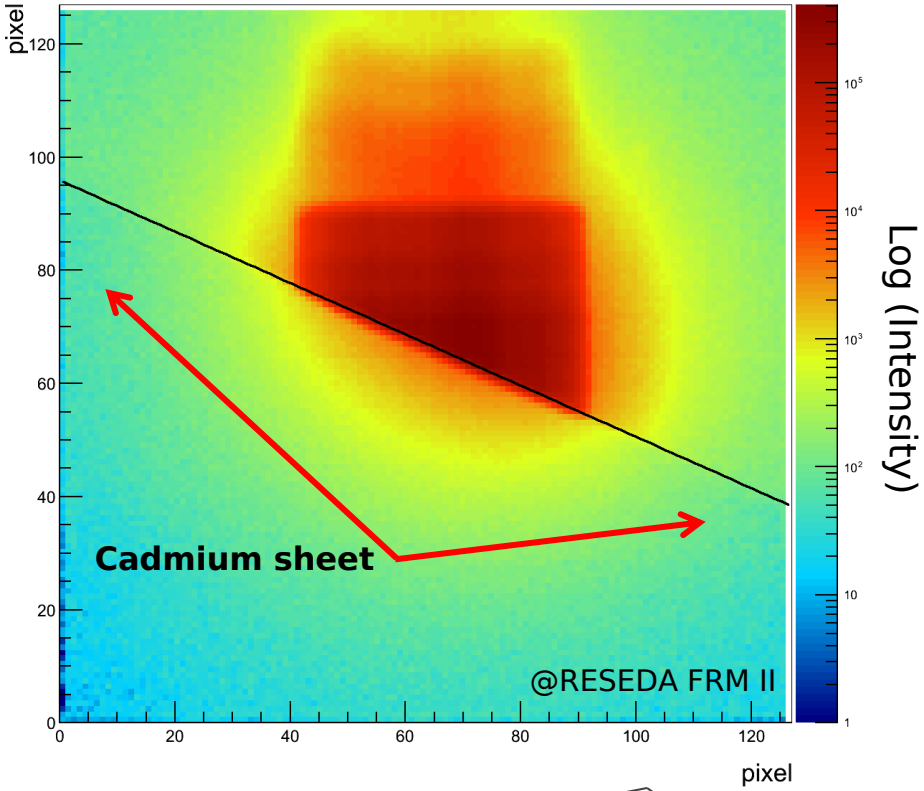
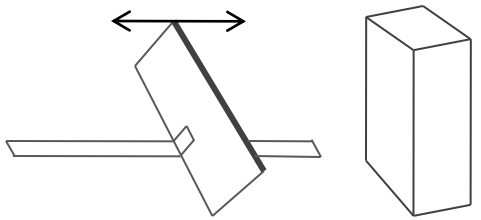


Image of a cold neutron beam (after guide)

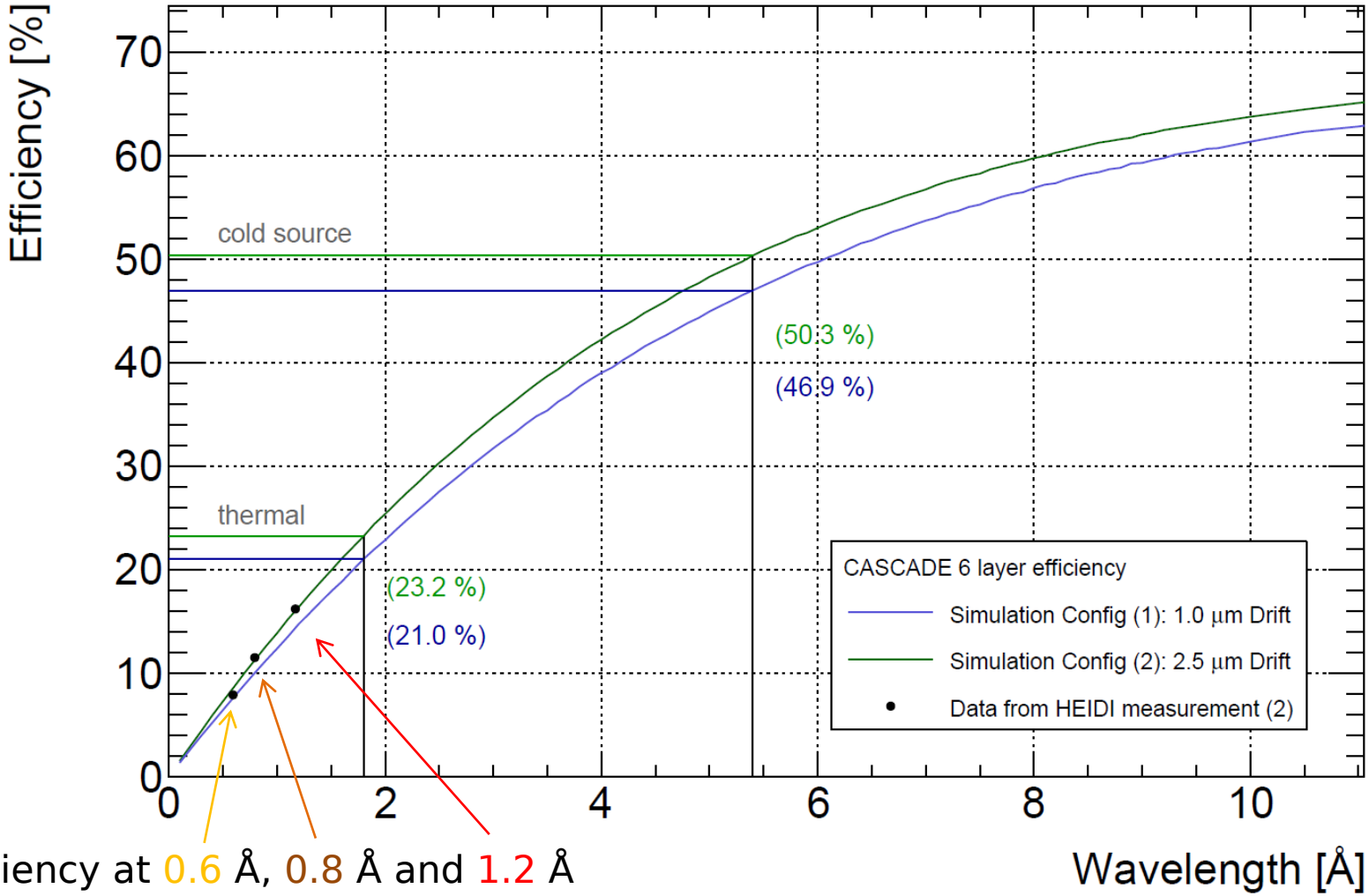




Detection Efficiency

1.5 – 0.8 – 1.0 – 1.0 – 0.8 – x

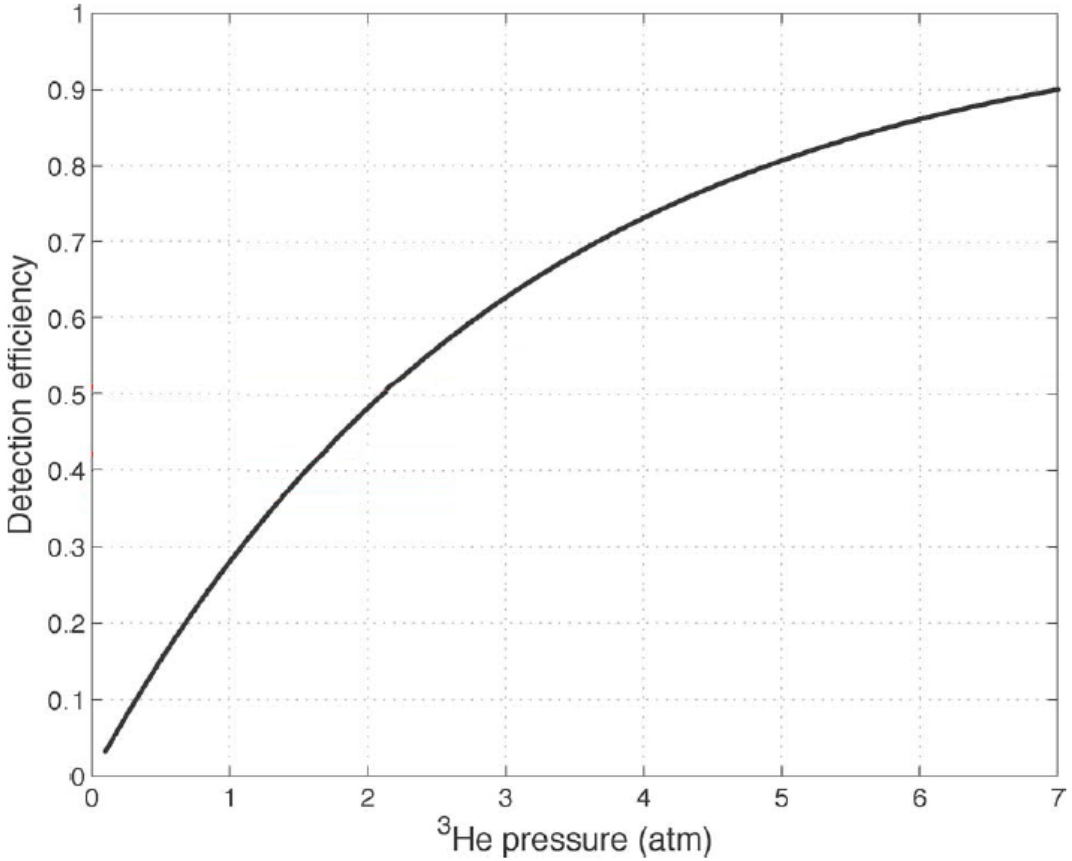
Simulation of the 2D efficiency and data of 0.6 Å, 0.8 Å and 1.2 Å



Efficiency at 0.6 Å, 0.8 Å and 1.2 Å

Detection Efficiency

Comparison of the efficiency to a Helium-3 tube



J. L. Lacy et al., "The Evolution of Neutron Straw Detector -Applications in Homeland Security", IEEE Transactions on Nucl. Science, 60,2,2013

Fig. 7. Intrinsic thermal neutron efficiency of a 2.92 cm (1.15in) ^{3}He tube as a function of gas pressure. The horizontal lines mark the efficiency calculated by (3),

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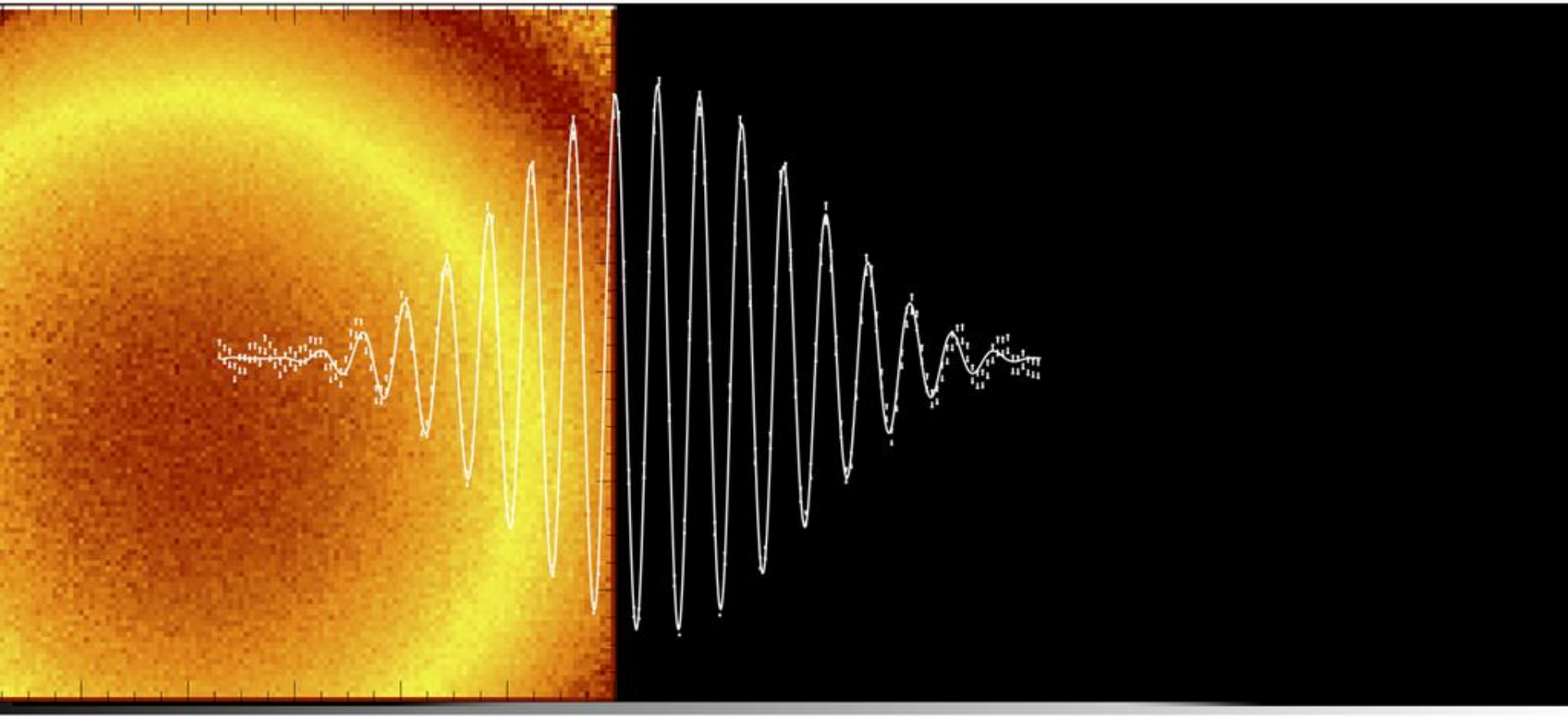
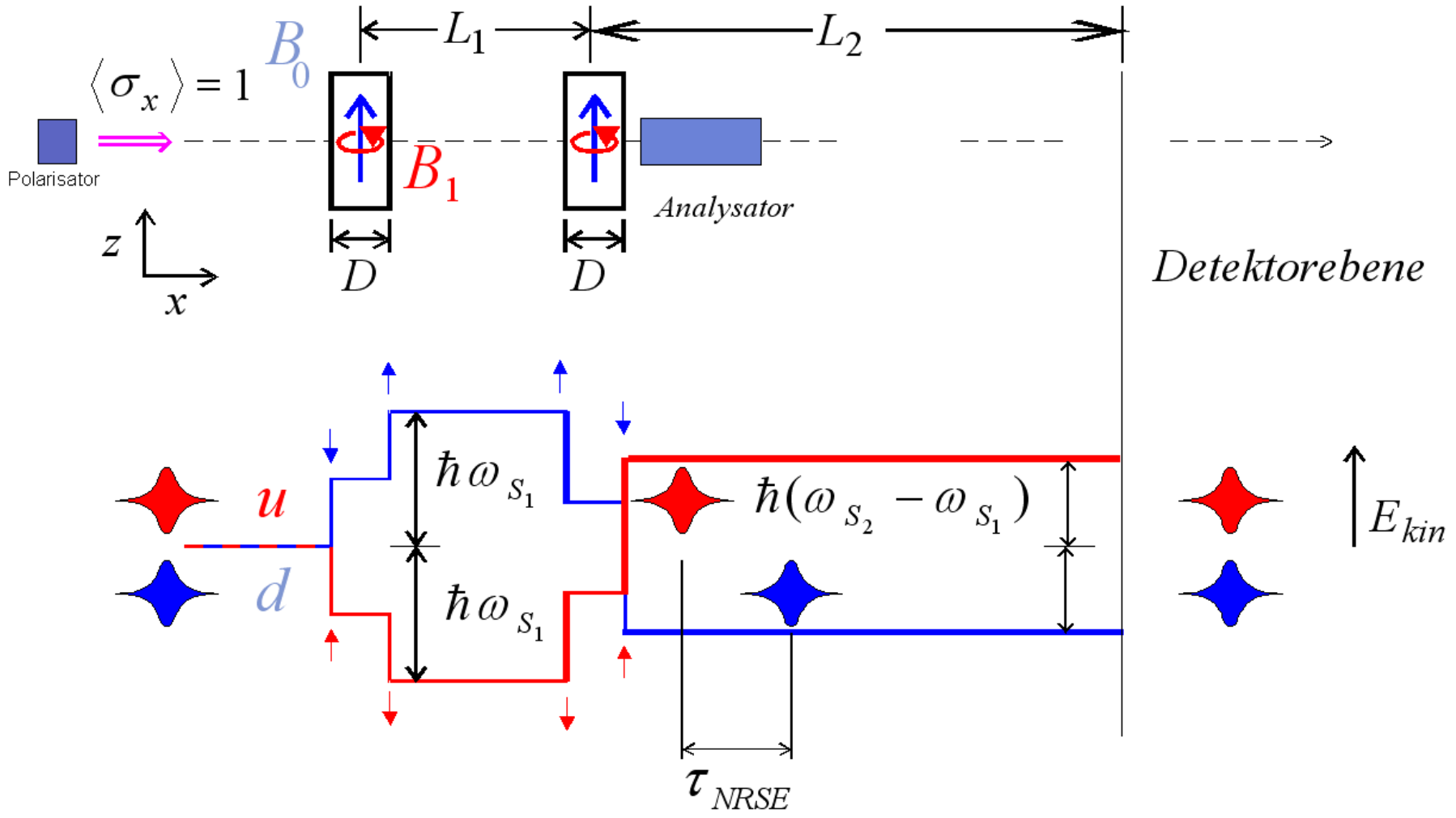
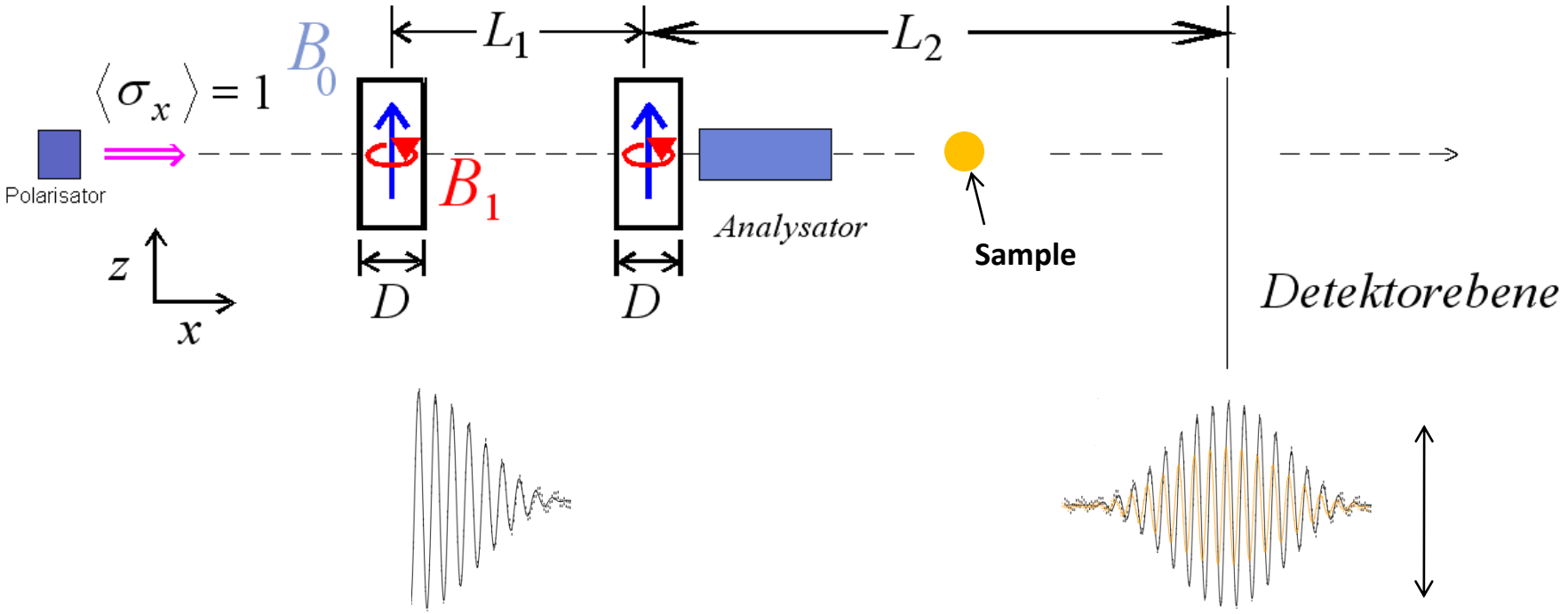
Spin Echo



Spin Echo - MIEZE

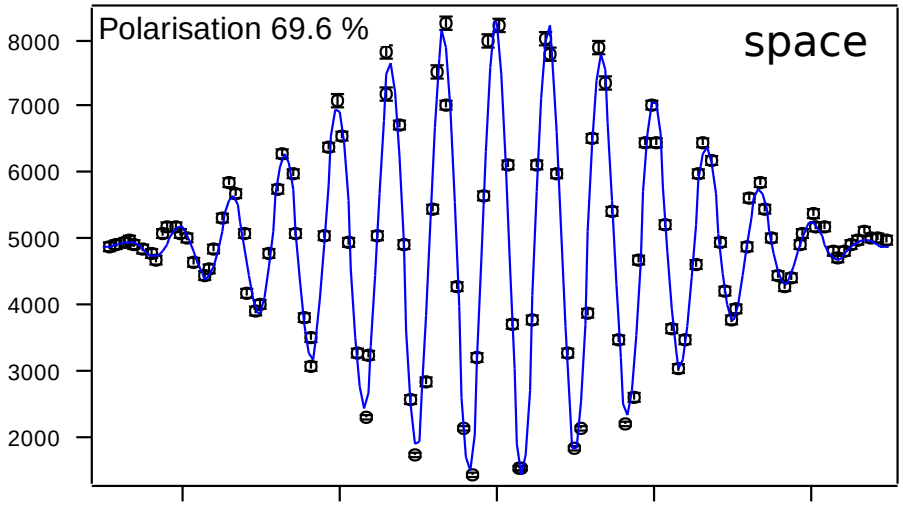


Spin Echo - MIEZE

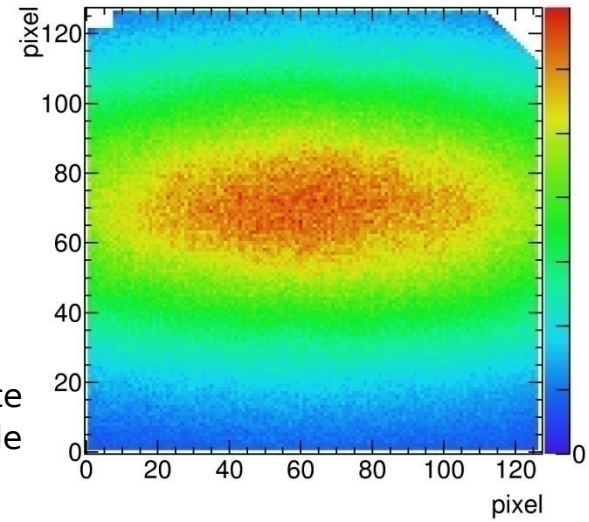


Spin Echo Measurements

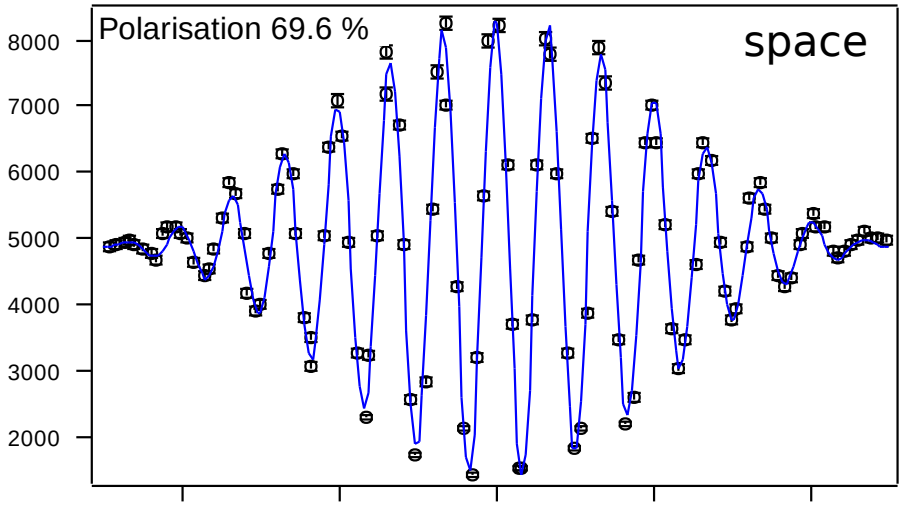
RESEDA, FRMII: spectrometer arms
3 – 15 Å @ 11% FWHM



Spin Echo Measurements

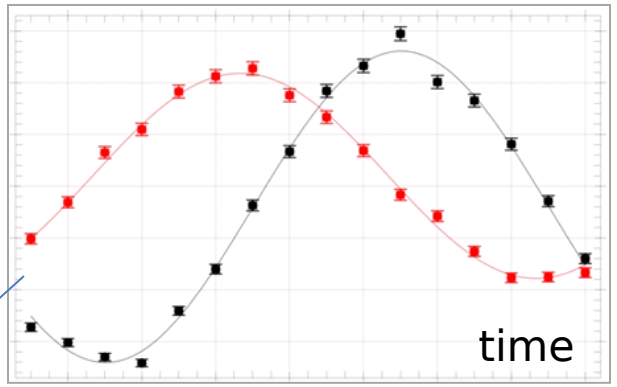


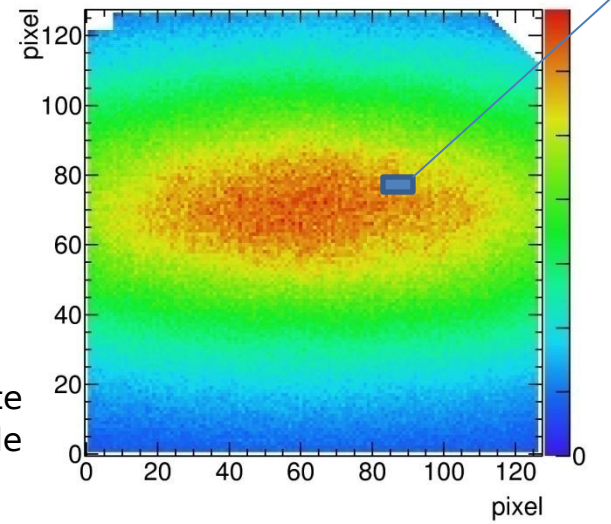
Graphite Sample



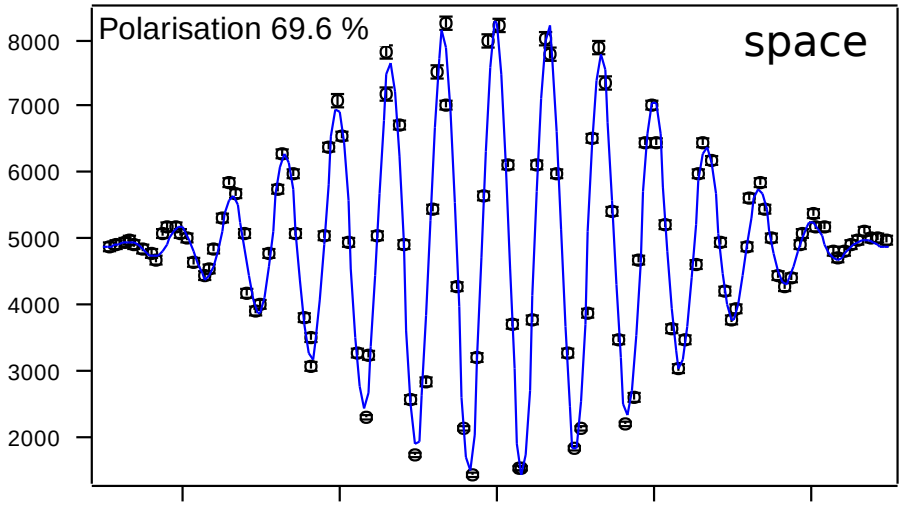
Typical Spin Echo group

Spin Echo Measurements



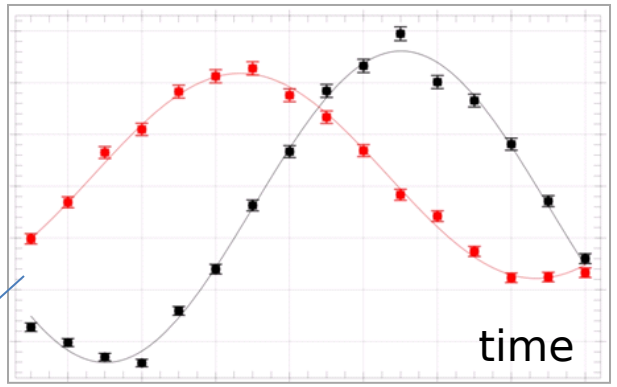


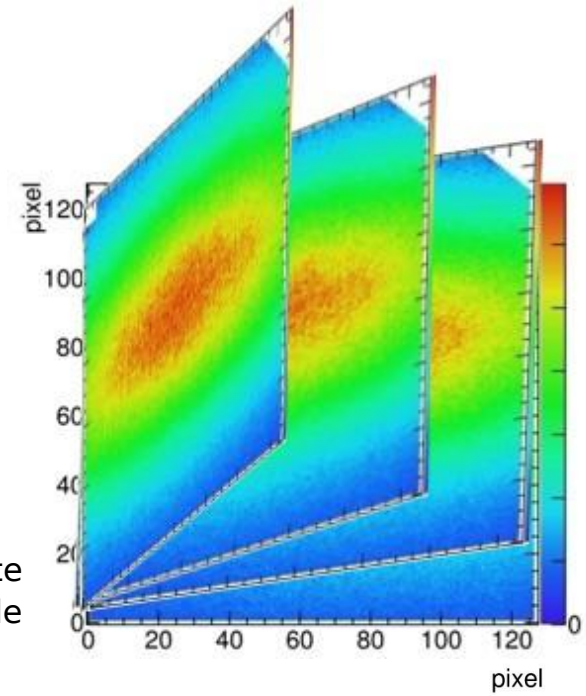
Graphite Sample



Typical Spin Echo group

Spin Echo Measurements





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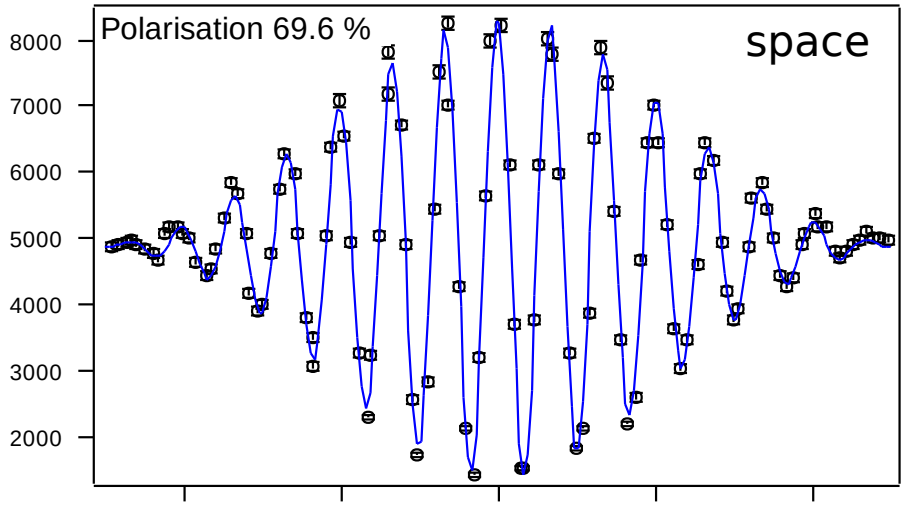
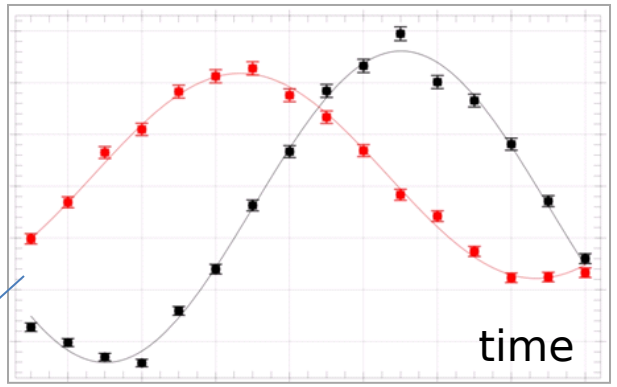
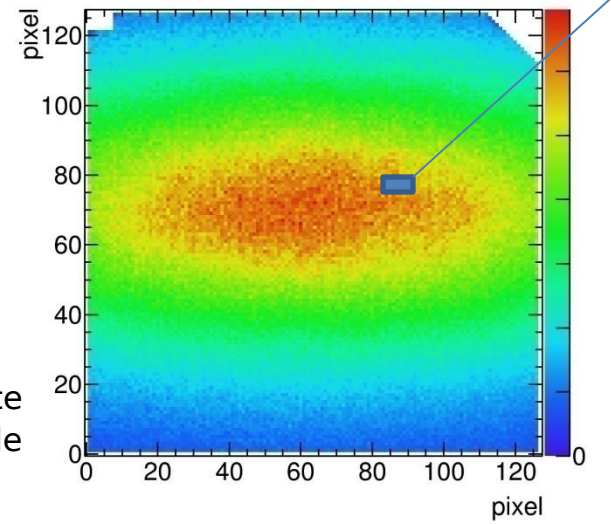


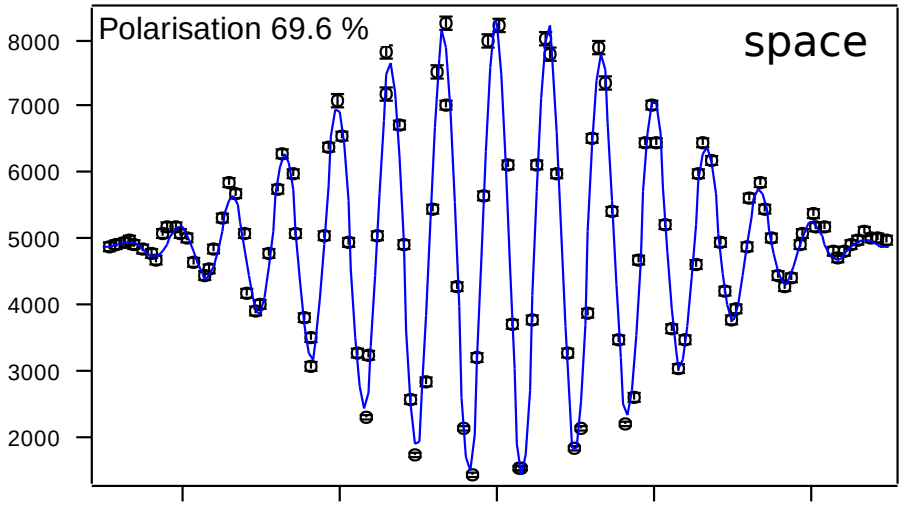
Typical Spin Echo group

Spin Echo Measurements



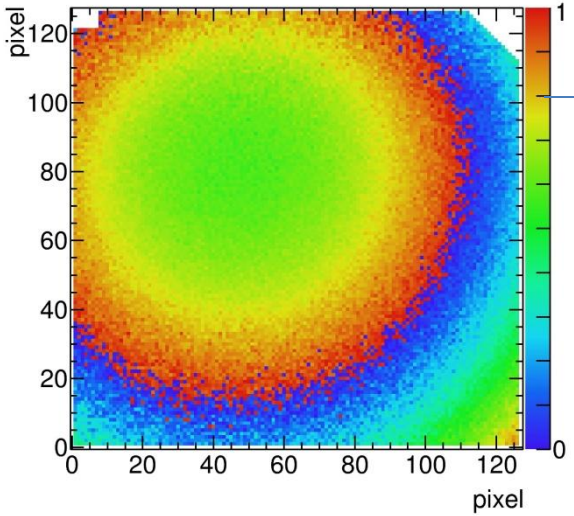


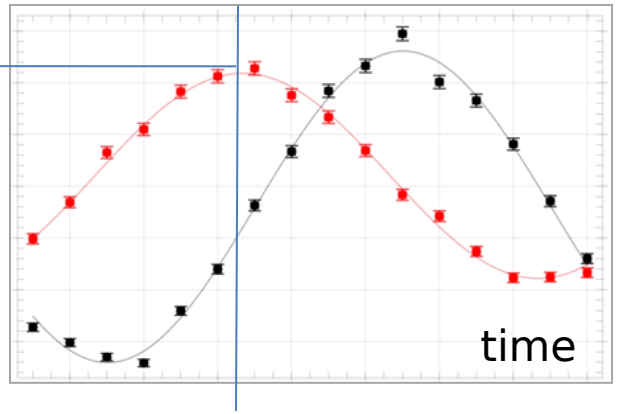
Graphite Sample

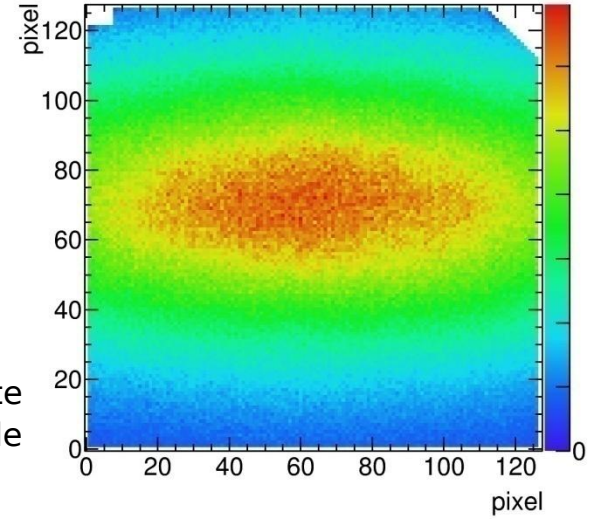


Typical Spin Echo group

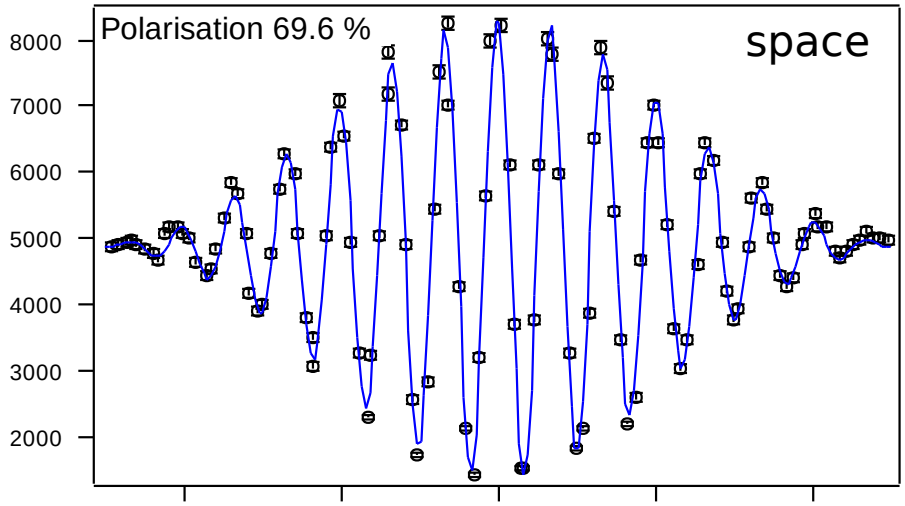
Spin Echo Measurements





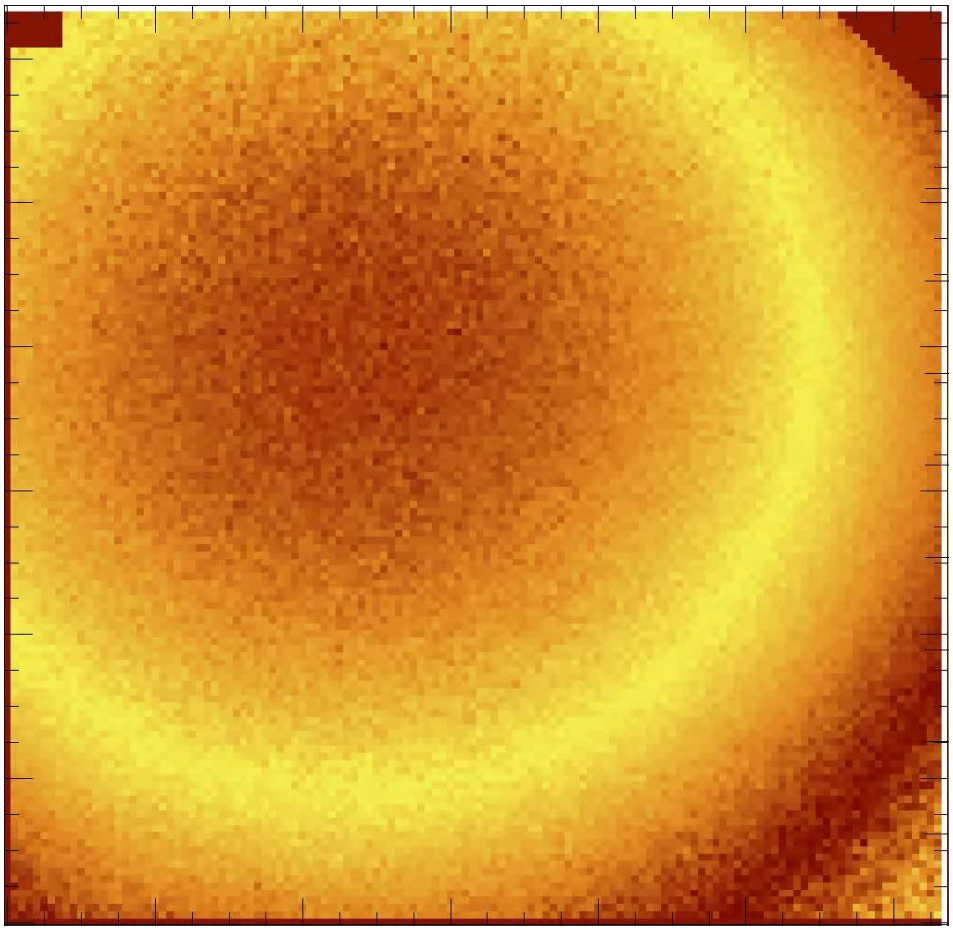


Graphite Sample

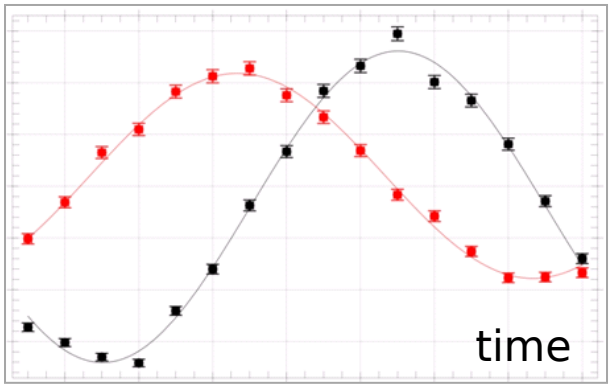


Typical Spin Echo group

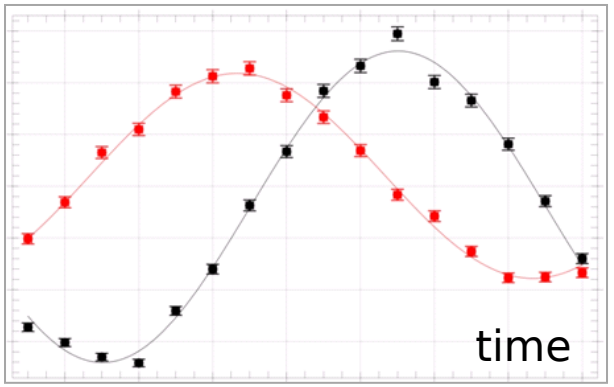
Spin Echo Measurements

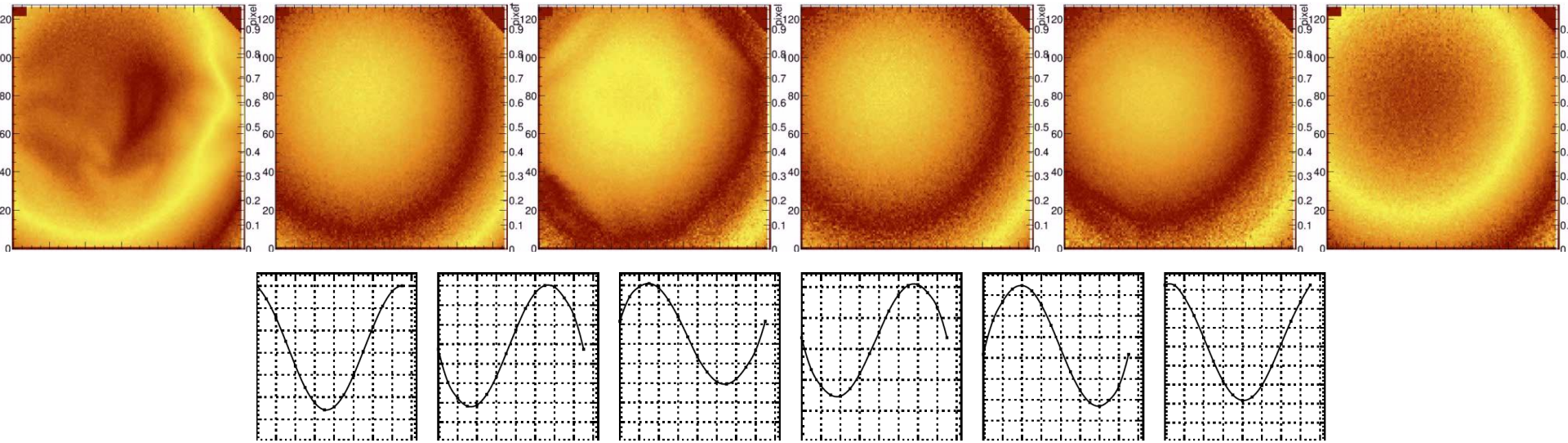


100 kHz x16

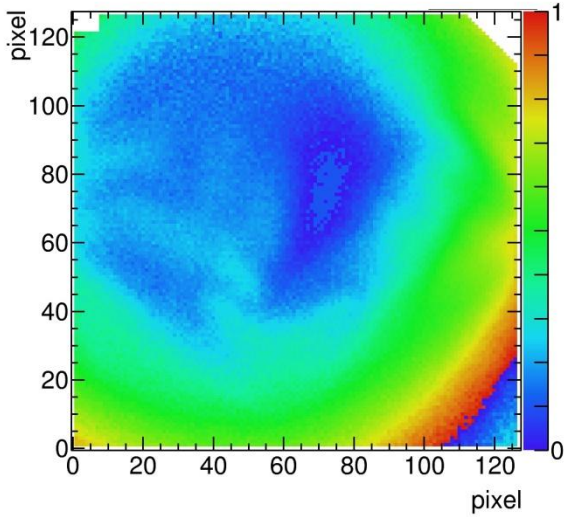


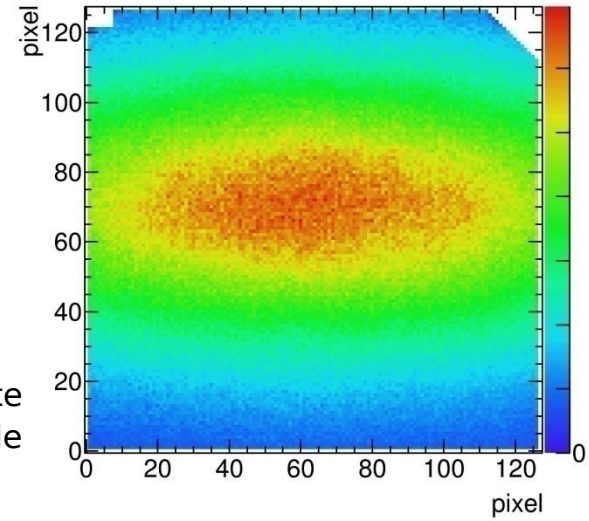
Spin Echo Measurements



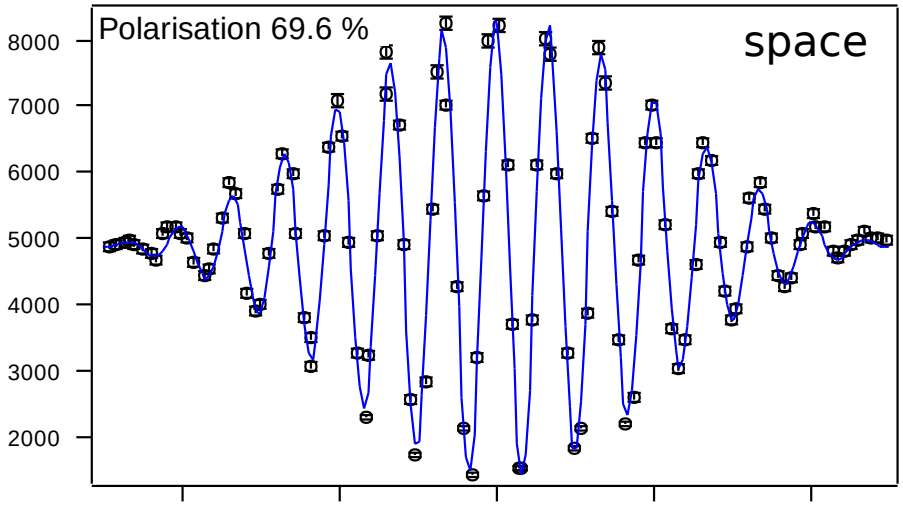


Spin Echo Measurements



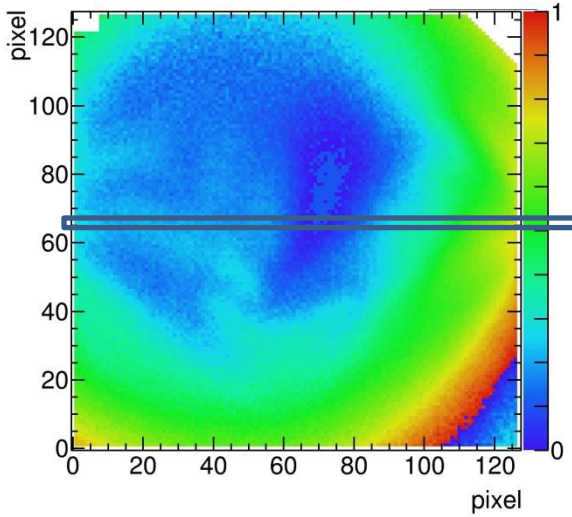


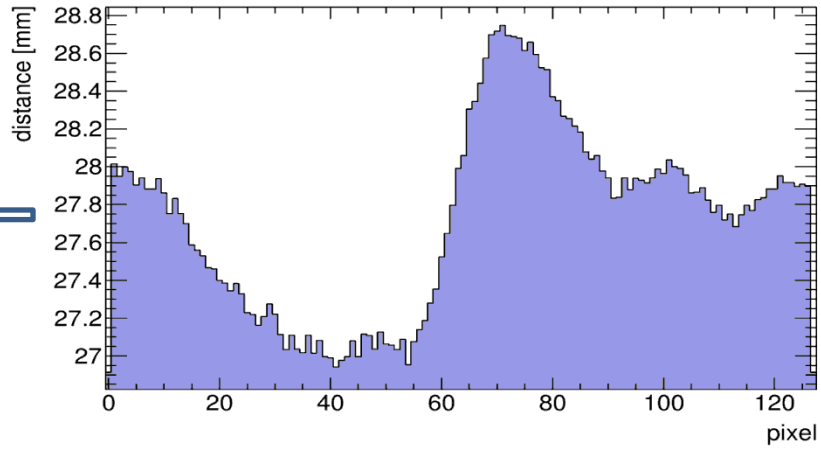
Graphite Sample

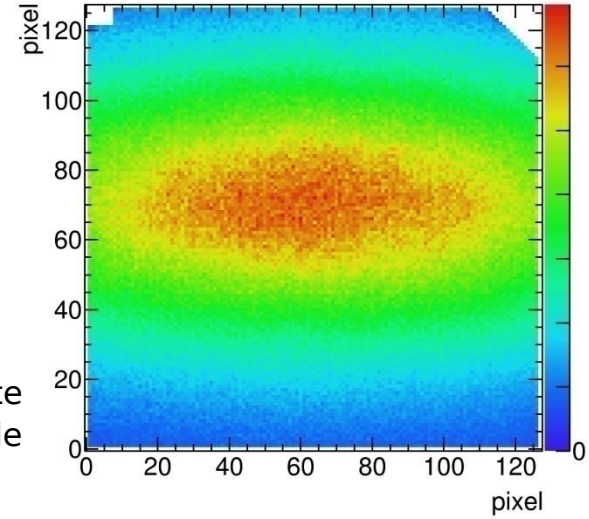


Typical Spin Echo group

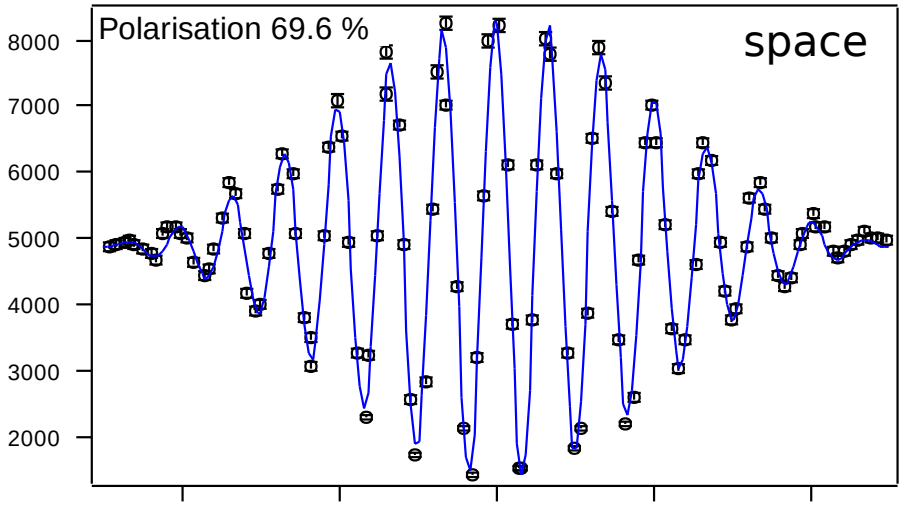
Spin Echo Measurements







Graphite Sample

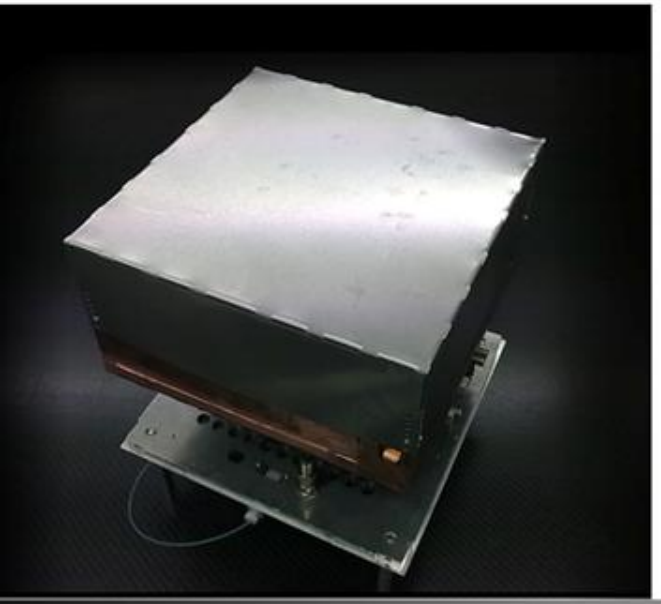


Typical Spin Echo group

CASCADE

Boron-10 technology

a high rate, spatially and time resolved detector for Spin Echo applications



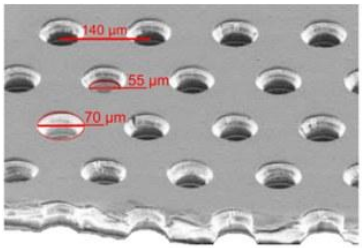
- conversion layer identification
- high TOF resolution (100 ns readout)
- 2.4 mm FWHM spatial resolution
- 2 MHz rate capability
- 21% thermal neutron efficiency @ 6 layers

Outlook

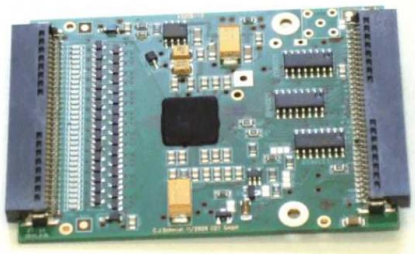
CASCADE

Technology available in 2000

GEM



Multichannel ASIC



Outlook

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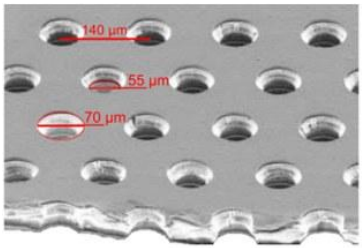
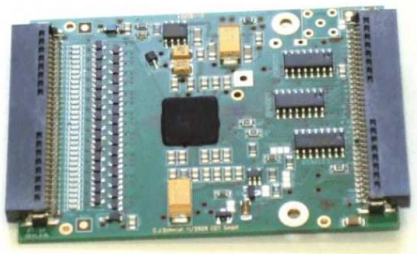
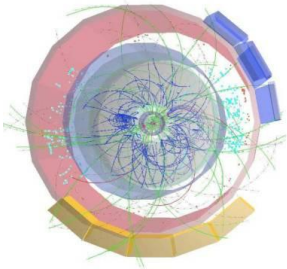


Multichannel ASIC

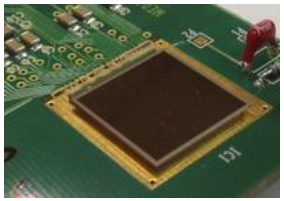


New Project

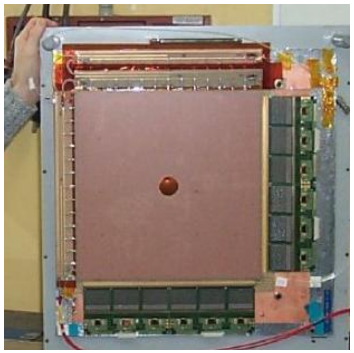
Technology available in 2015



TPC



TimePix

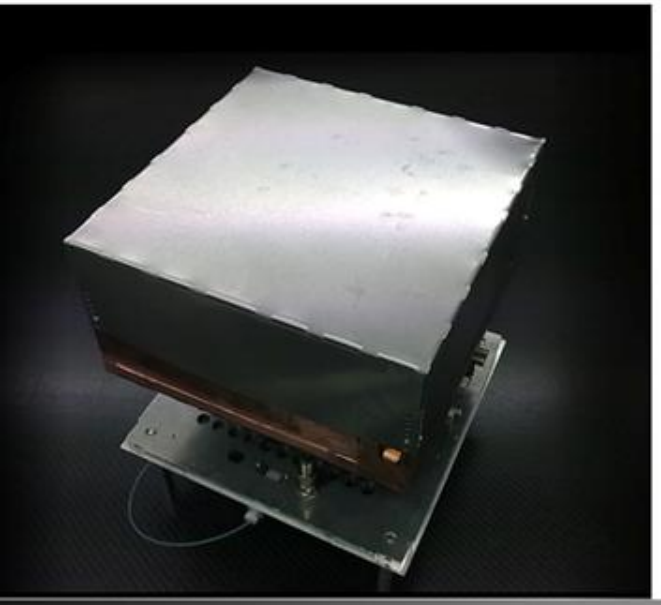


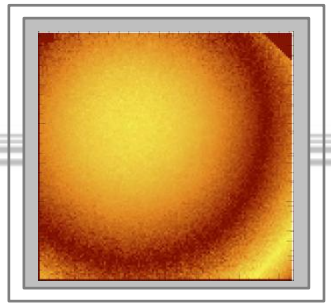
VMM ASIC

CASCADE

Boron-10 technology

a high rate, spatially and time resolved detector for Spin Echo applications





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