Bundesministerium
für Bildung
und Forschung

High Resolution Neutron Detection by the µTPC method

DPG Bochum 2018
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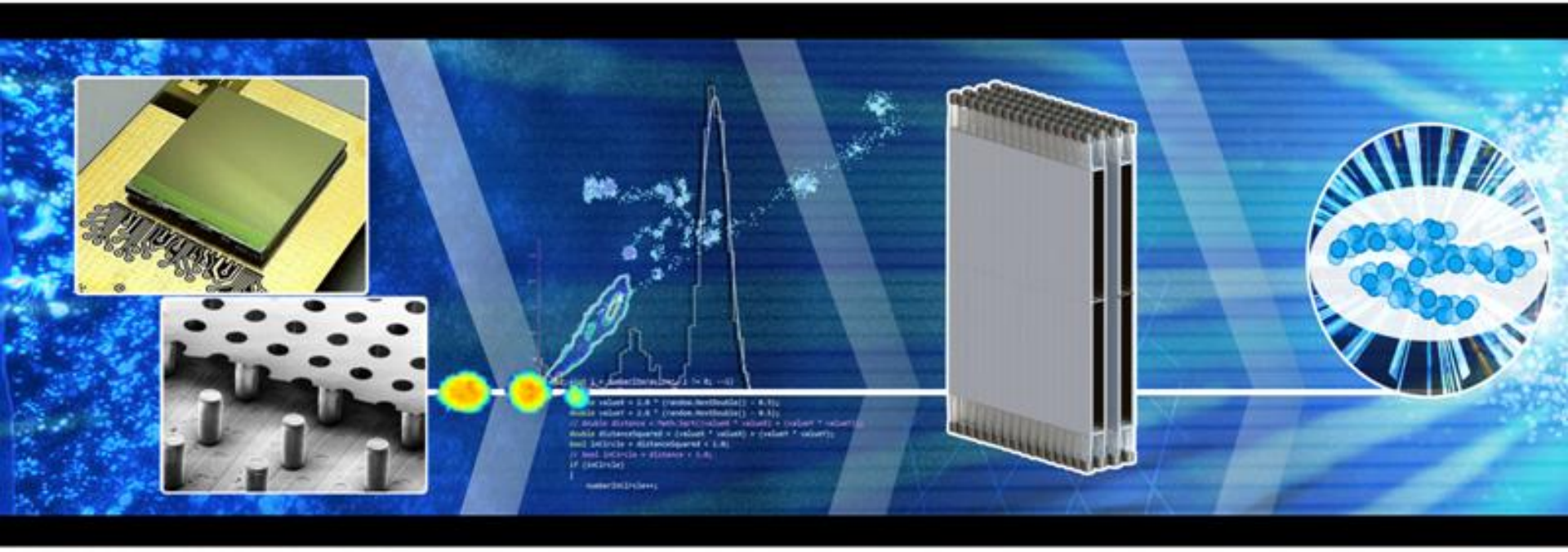
universitätbonn

Physikalisches Institut (LCTPC)
Rheinische
Friedrich-Wilhelms-Universität
Bonn

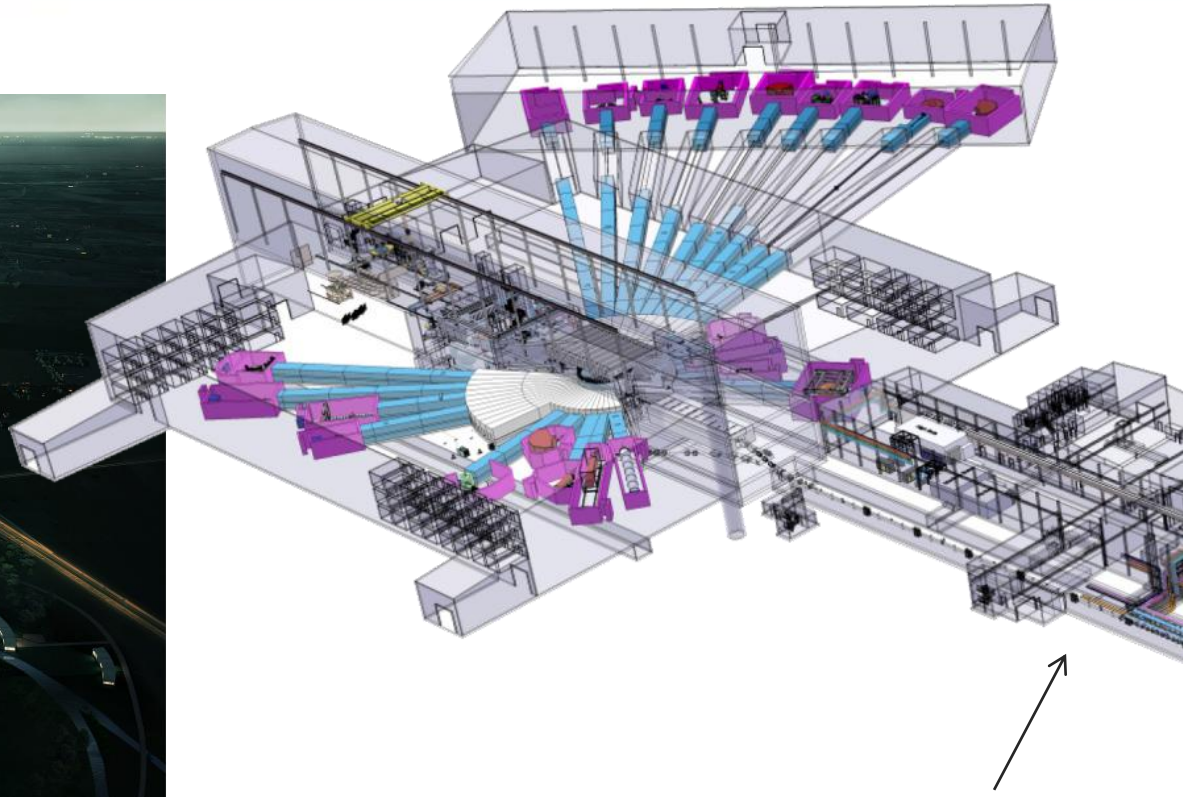
Markus Köhli

T. Wagner, F. Schmidt, J. Kaminski, K. Desch



ESS Neutron Scattering Facility

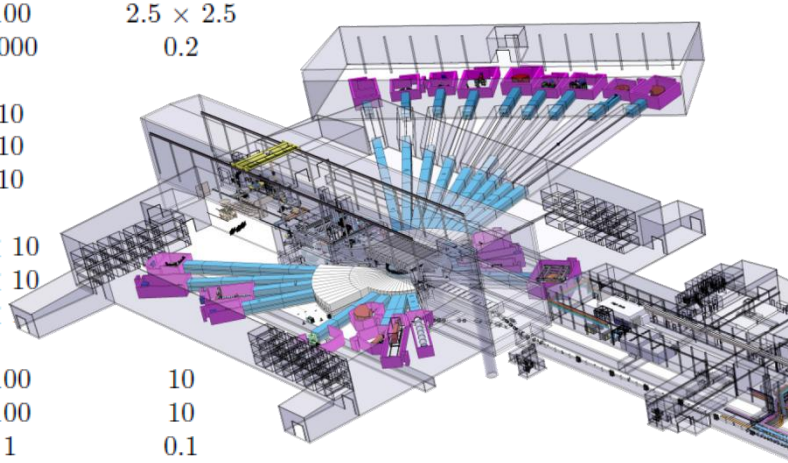
ESS TDR 2013
Lund, Sweden



Linear Accelerator
2 GeV
3 ms Pulse
62.5 mA

ESS Instrumentation

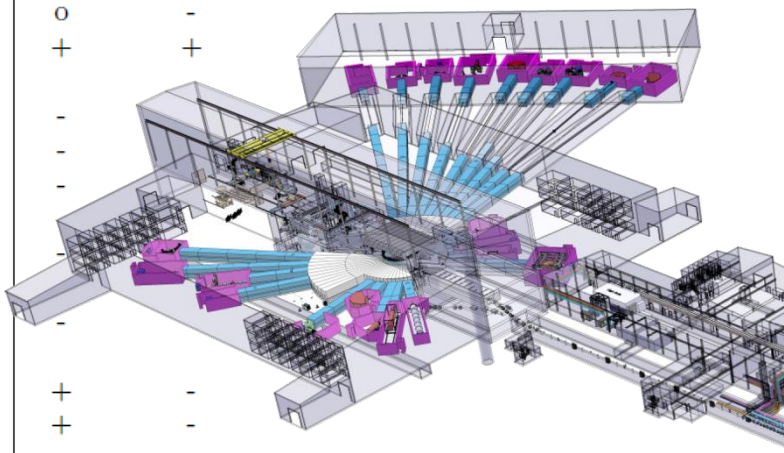
Instrument	Detector area [m^2]	Wavelength range [Å]	Time resolution [μs]	Spatial resolution [mm]
Multi-purpose imaging	0.5	1 - 20	1	0.001 - 0.5
General purpose polarised SANS	5	4 - 20	100	10
Broad-band small sample SANS	14	2 - 20	100	1
Surface scattering	5	4 - 20	100	10
Horizontal reflectometer	0.5	5 - 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**			



ESS TDR 2013

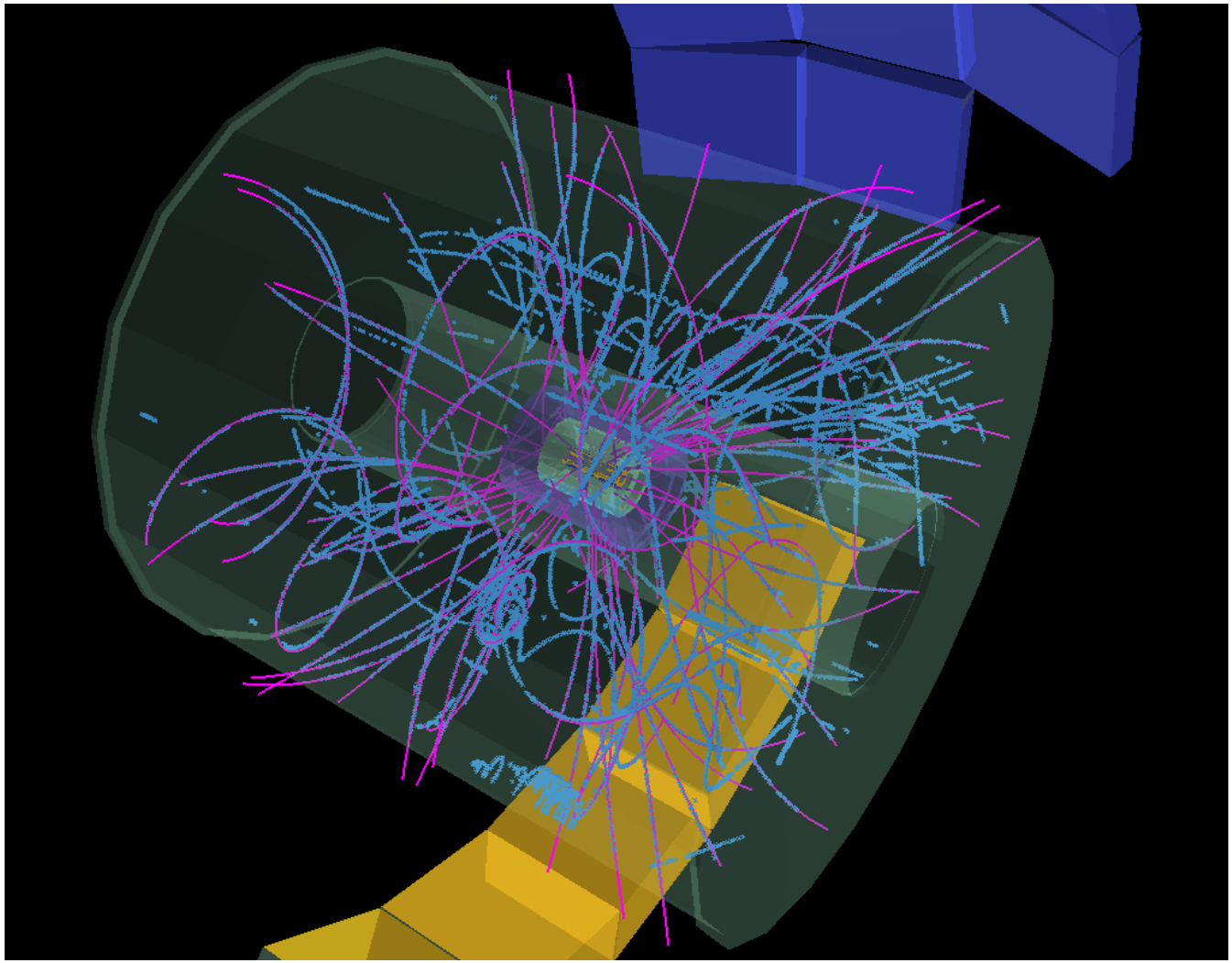
ESS Instrumentation

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	-	-	-	-	+	+	+



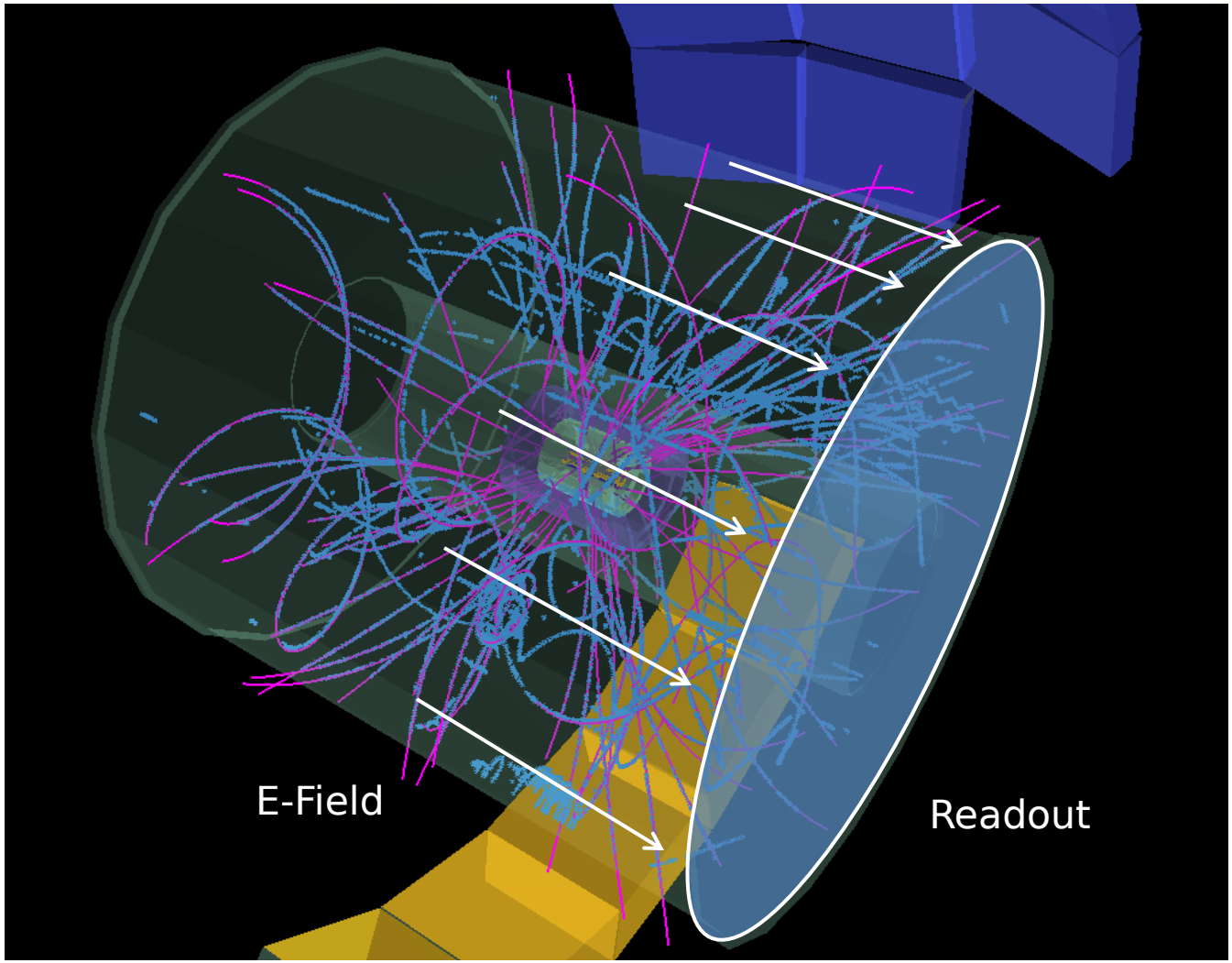
ESS TDR 2013

The Time Projection Chamber



[1] http://www-alice.gsi.de

The Time Projection Chamber



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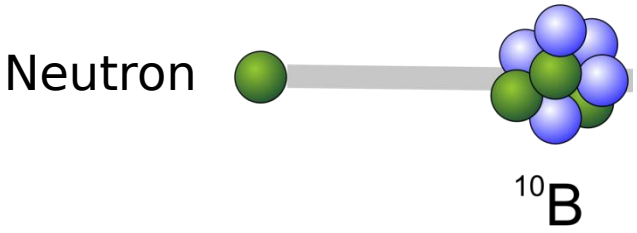
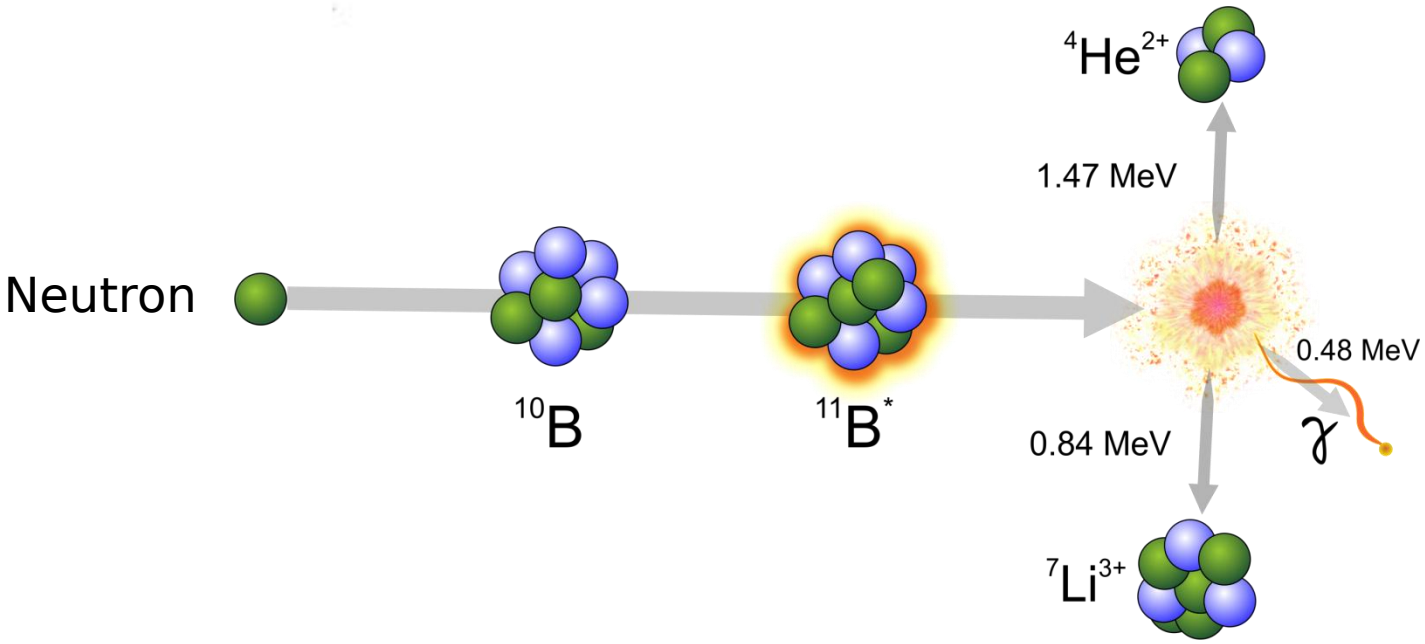
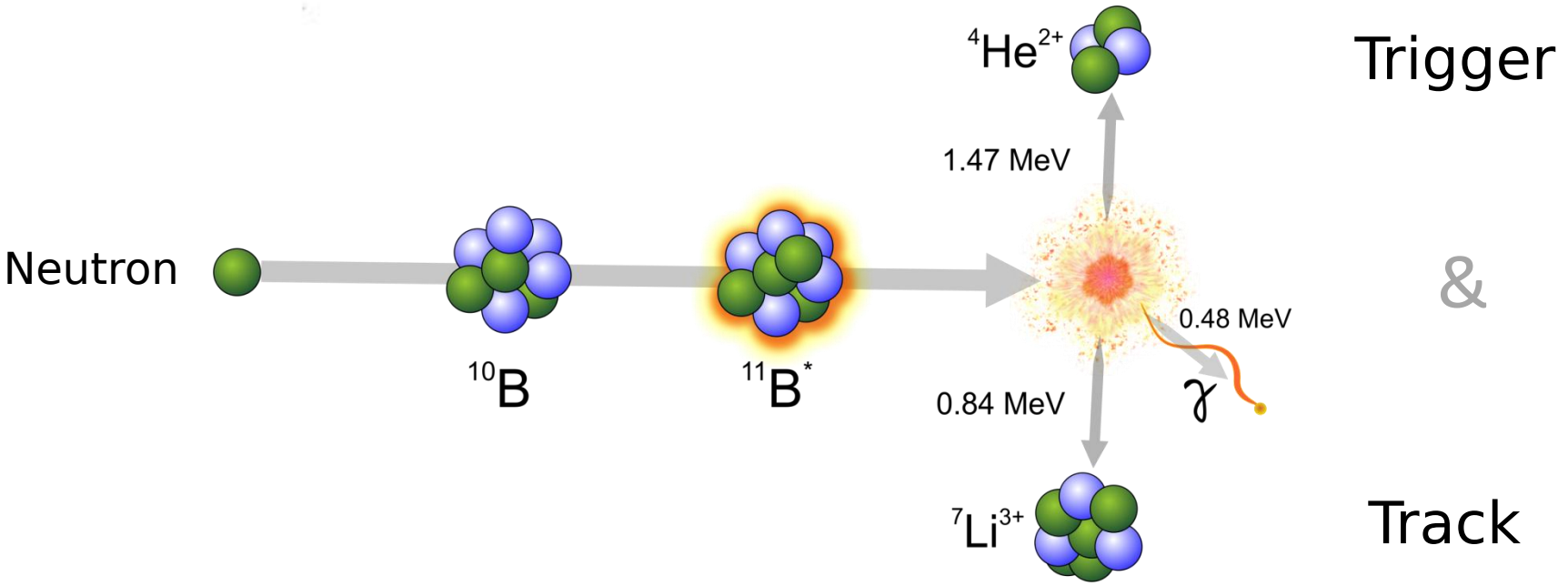
The Neutron TPC Trigger



The Neutron TPC Trigger



The Neutron TPC Trigger



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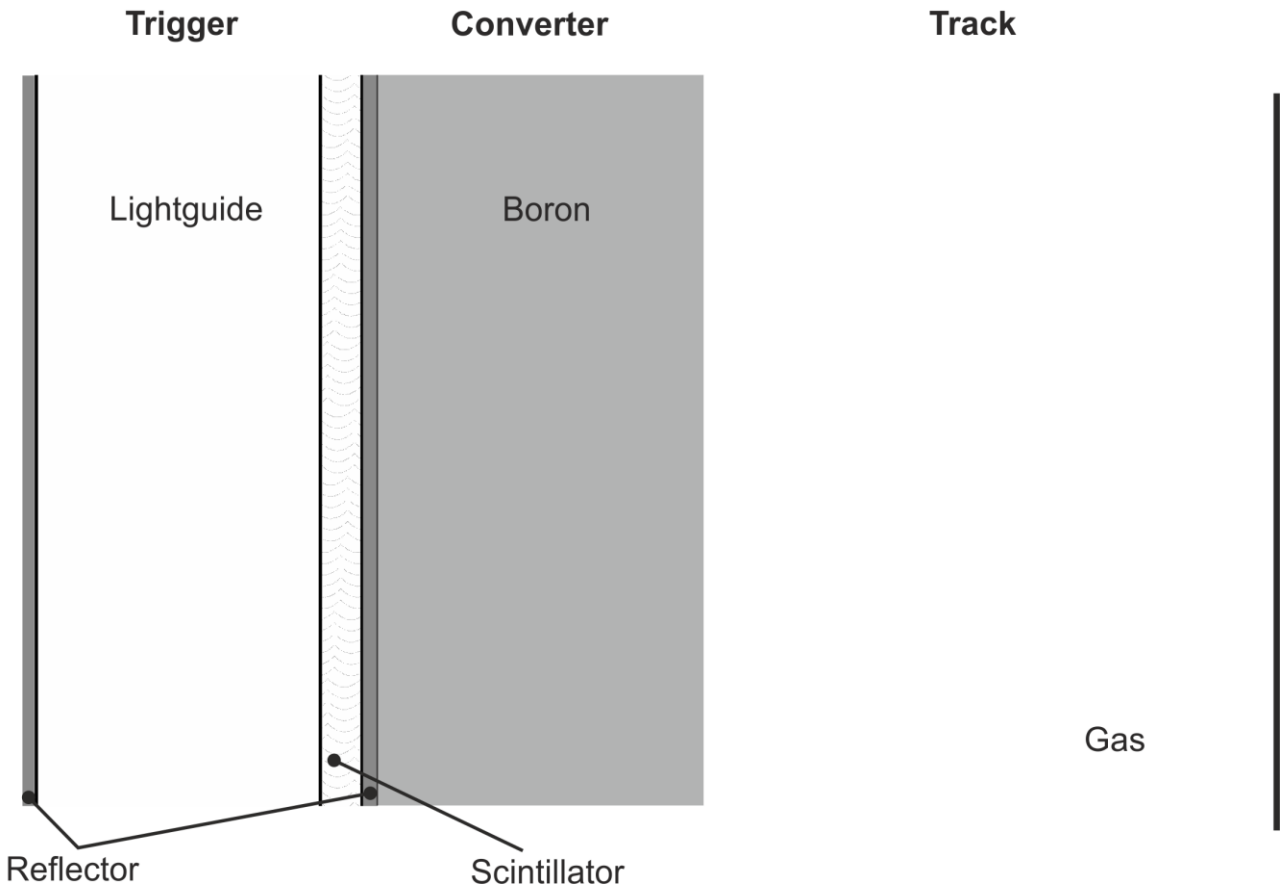

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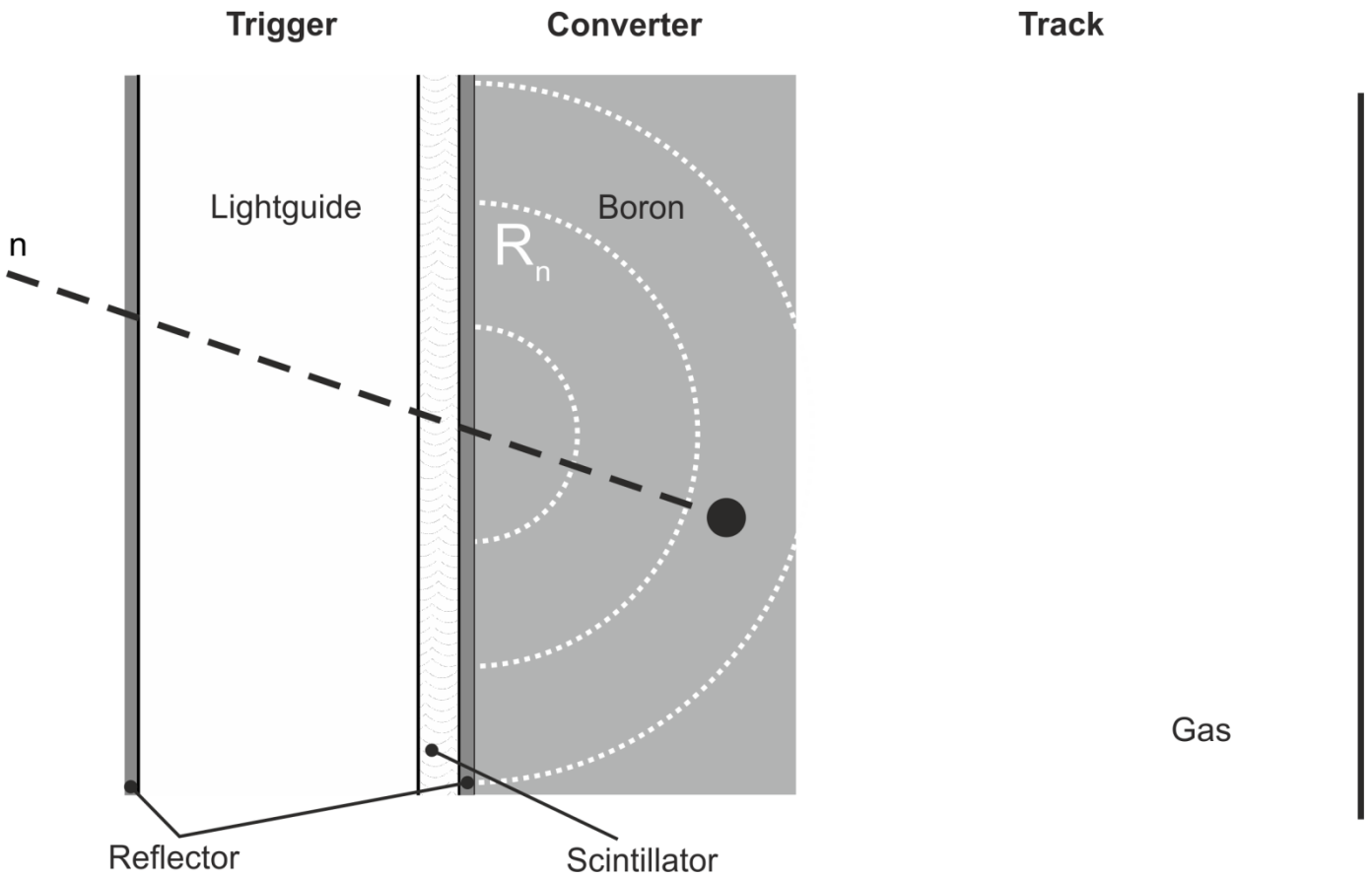
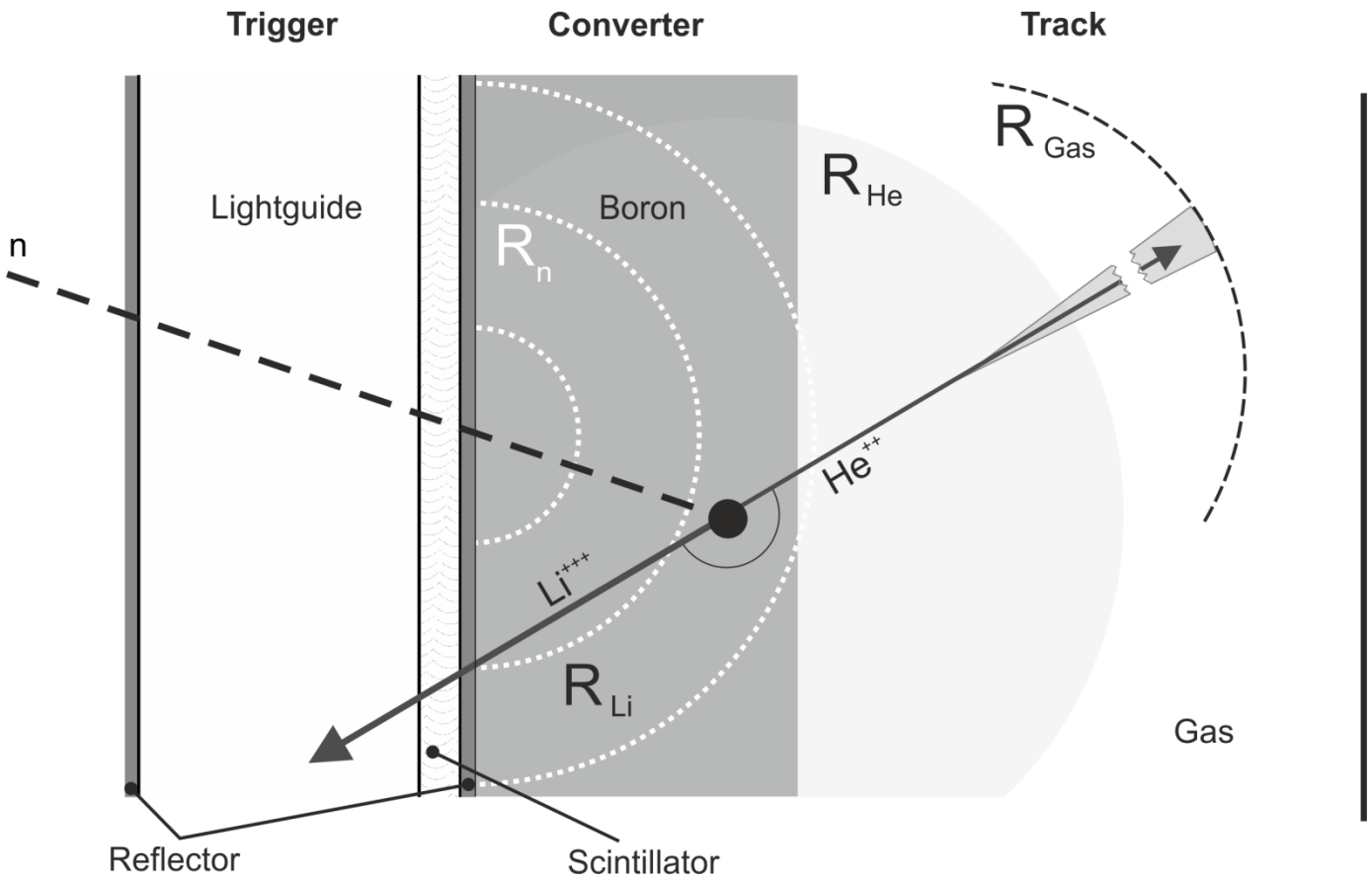
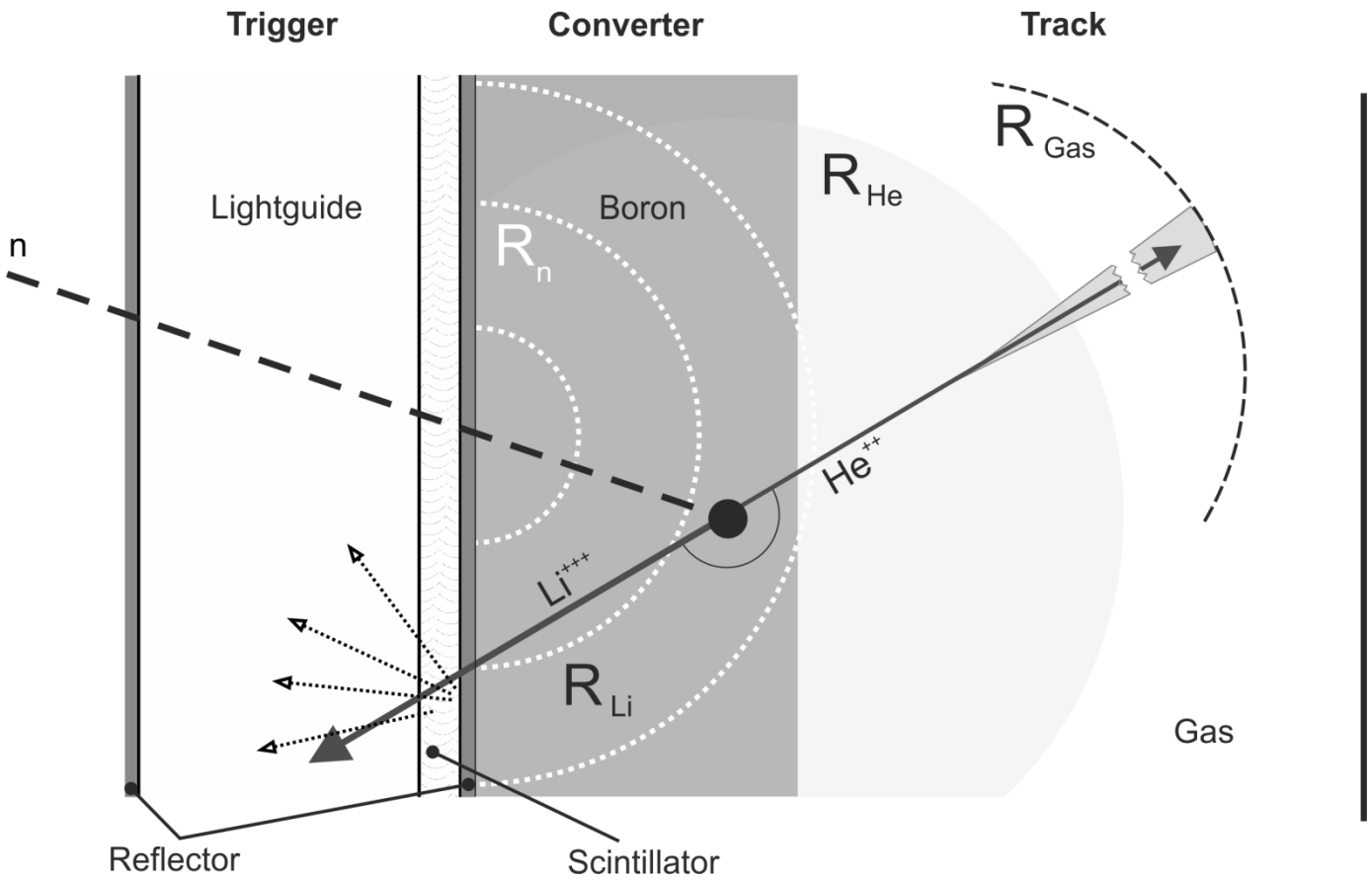


The Neutron TPC

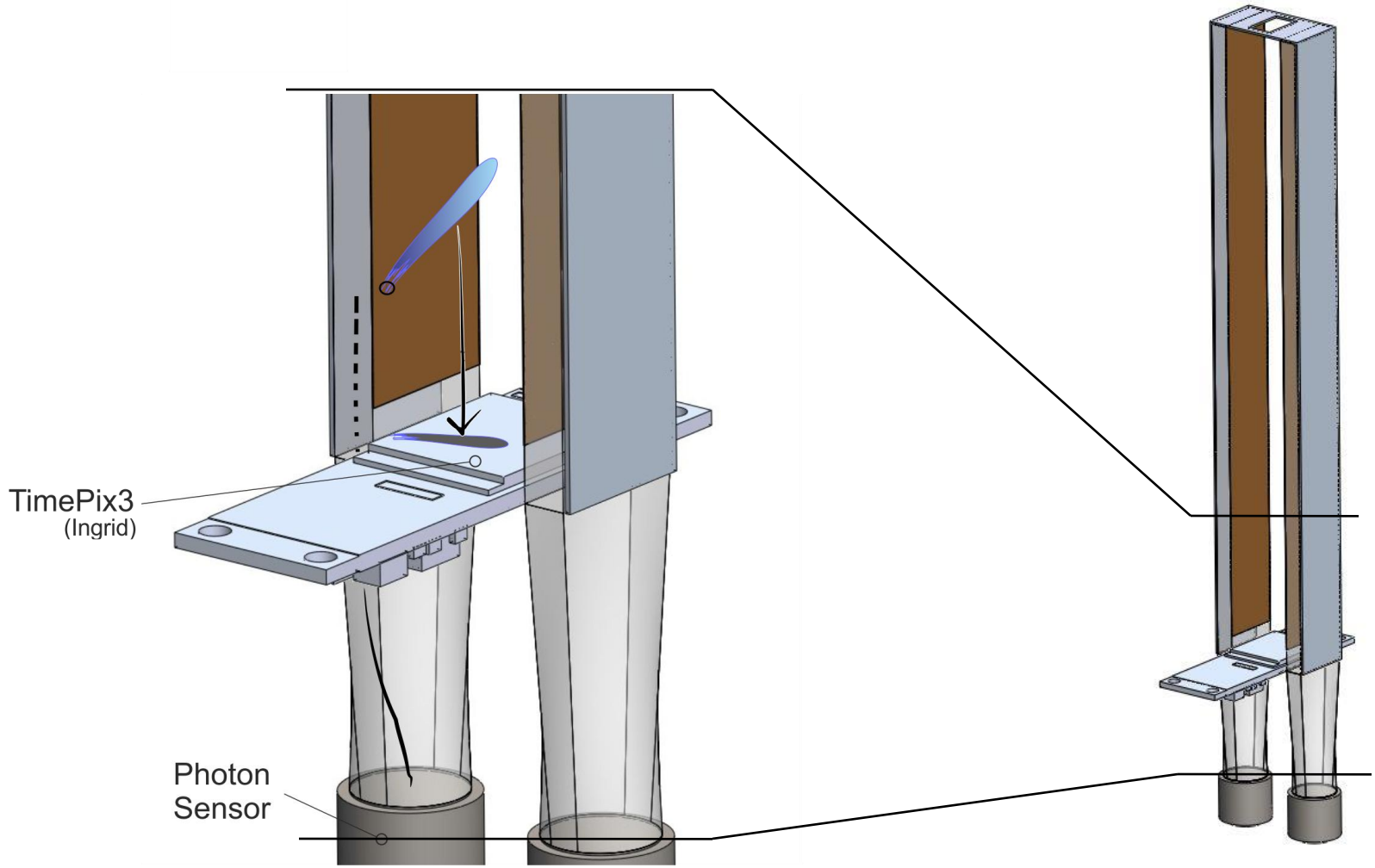


The Neutron TPC

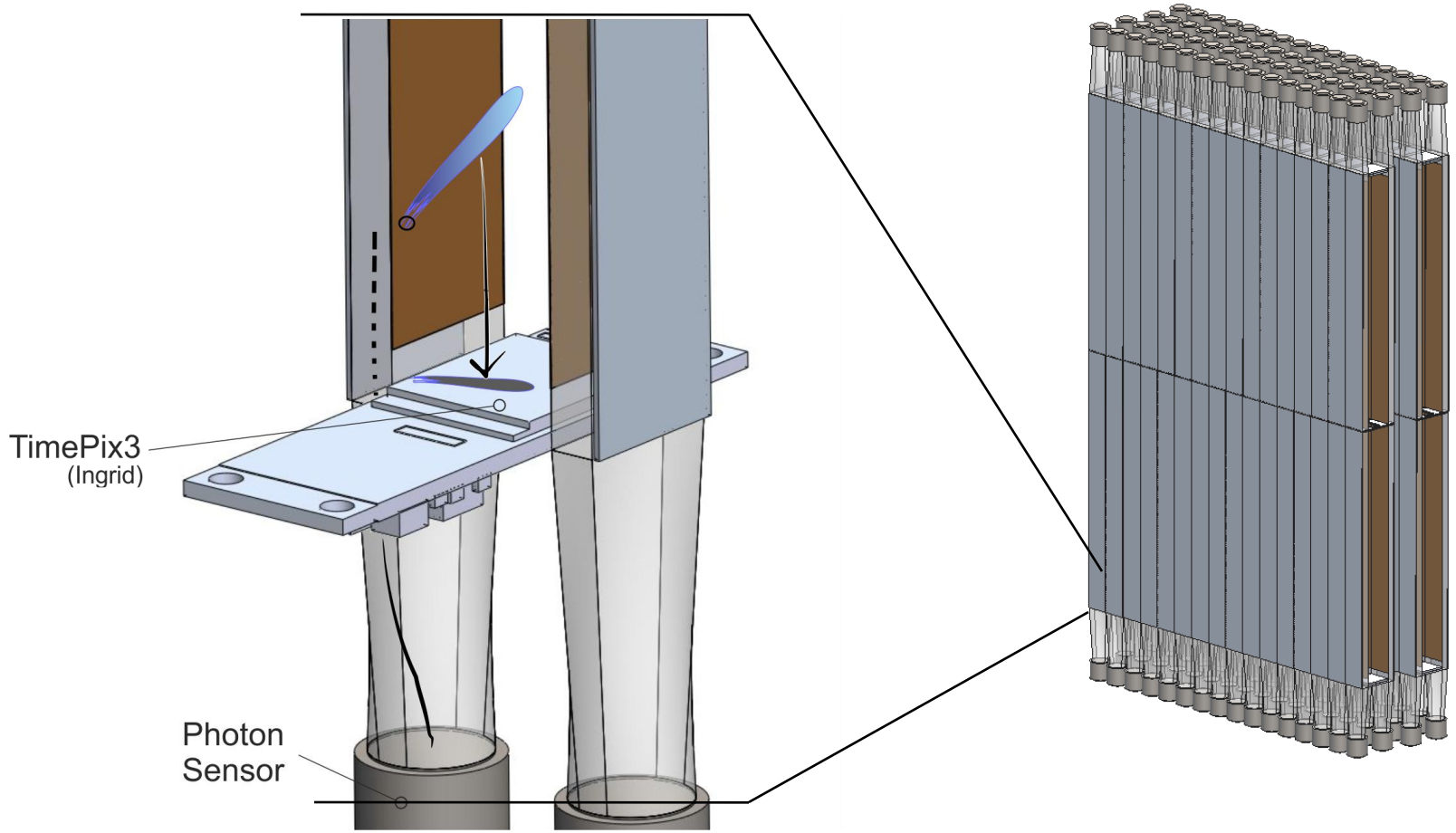


The Detector

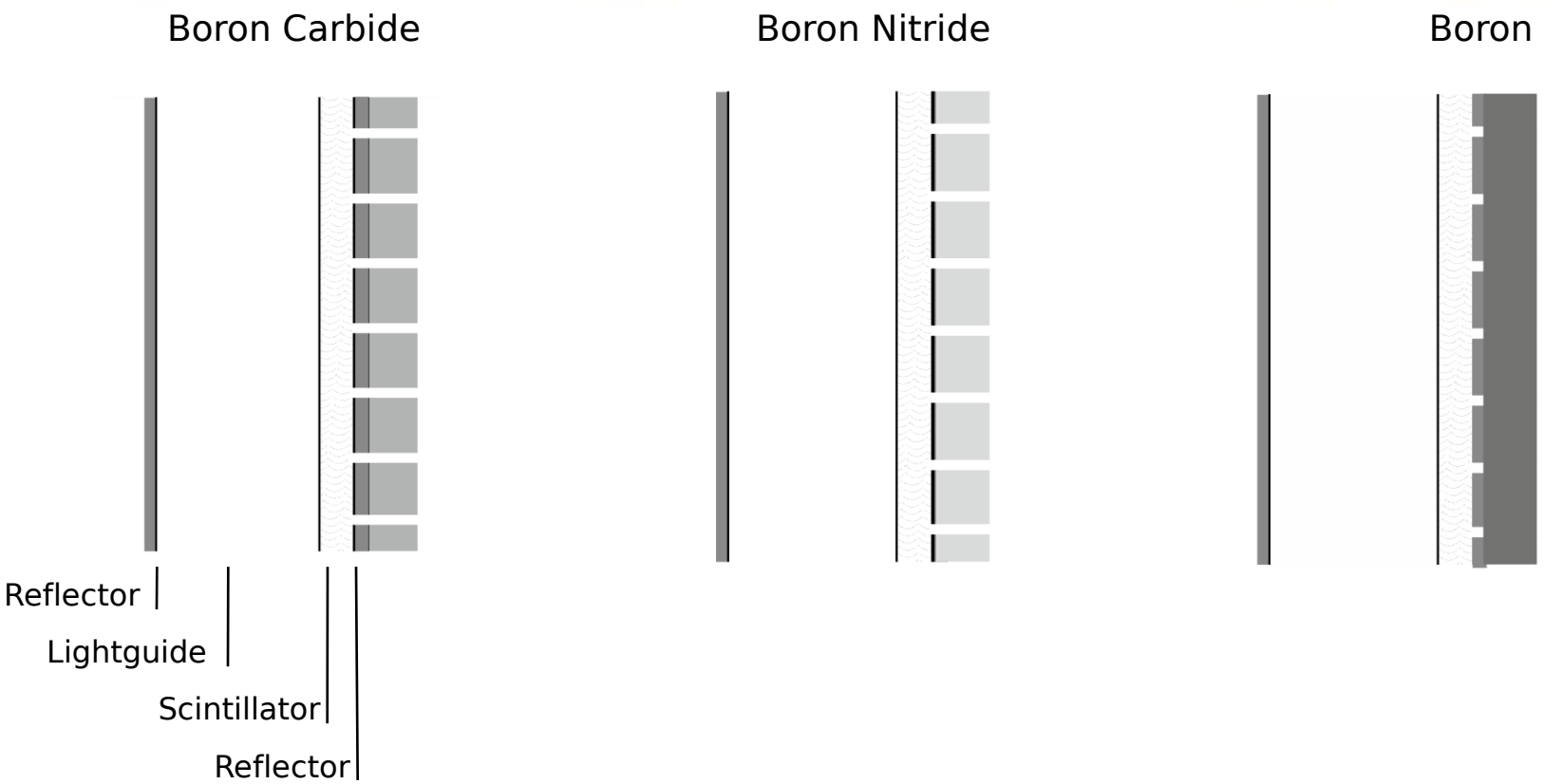
The Neutron TPC



The Neutron TPC: BODELAIRE

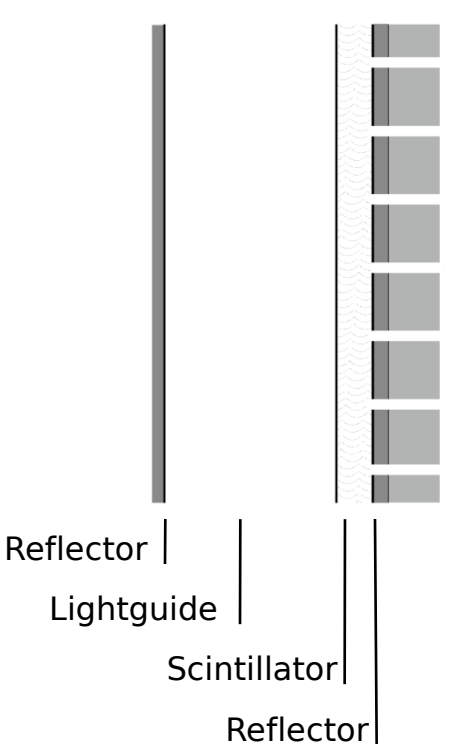


Field Cage Design

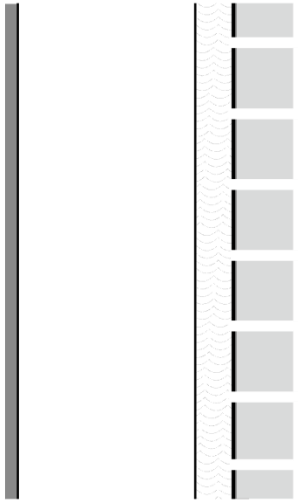


Field Cage Design

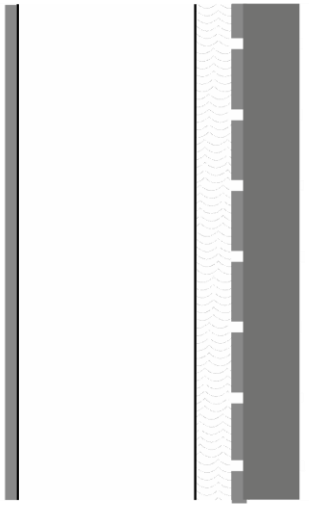
Boron Carbide



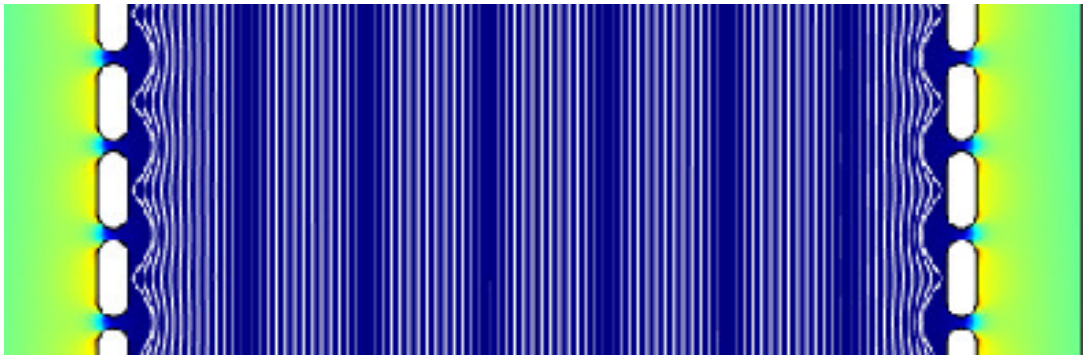
Boron Nitride



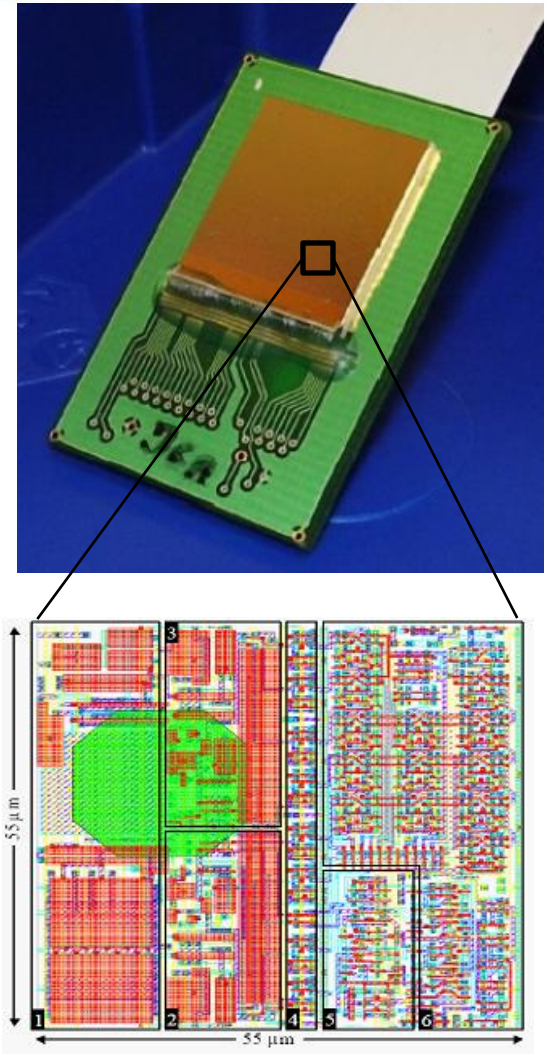
Boron



Simulation: Electric Field Homogeneity



The TimePix Chip



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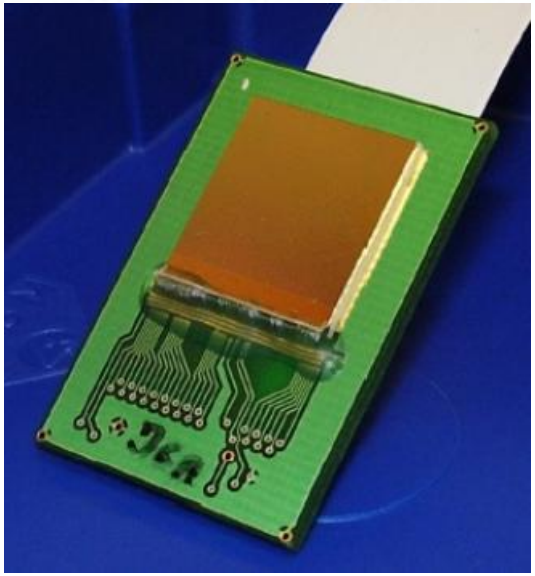

- 256 × 256 pixels @ 55 × 55 µm²
- 1.4 × 1.4 cm²
- 40 MHz clock
- ENC ca. 90 e^-

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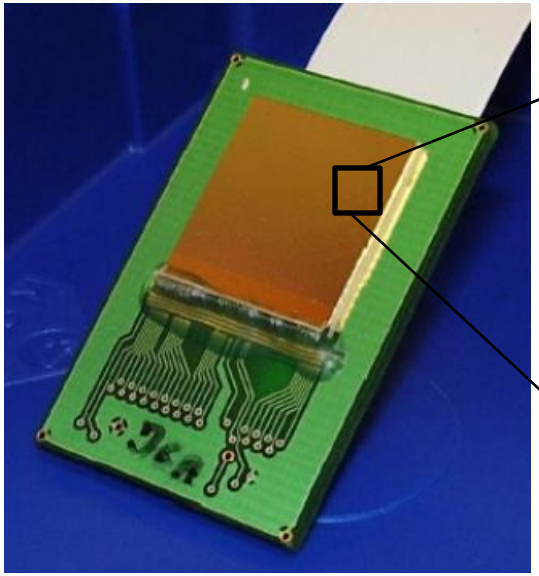

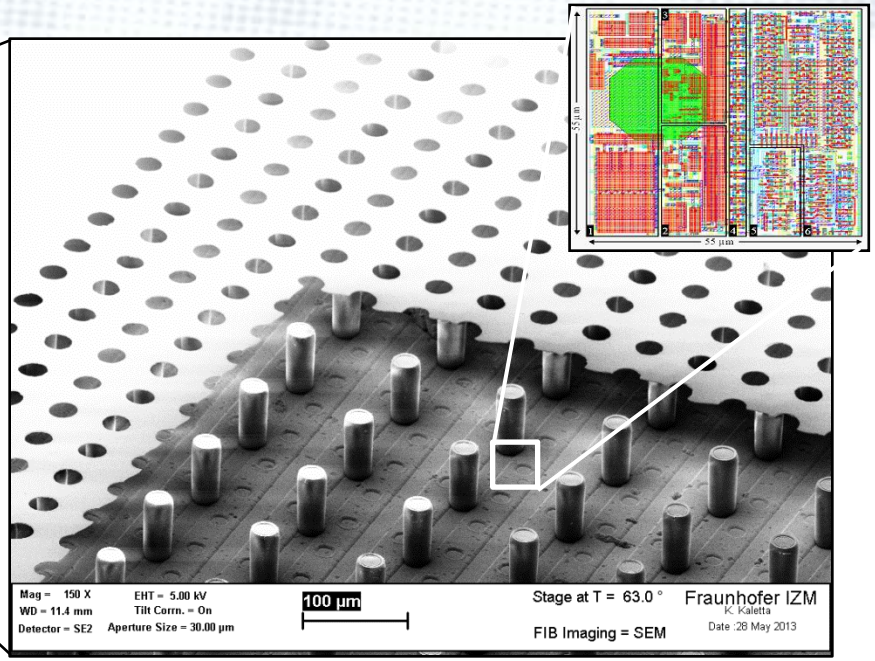

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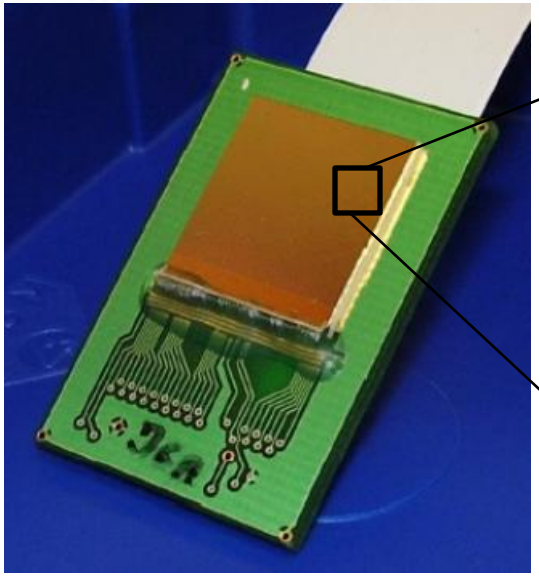

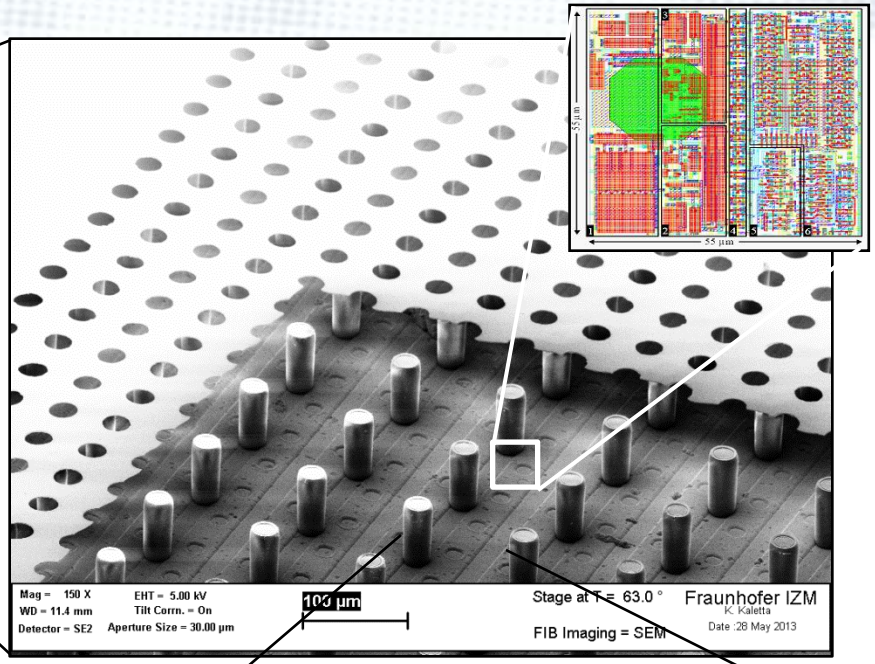

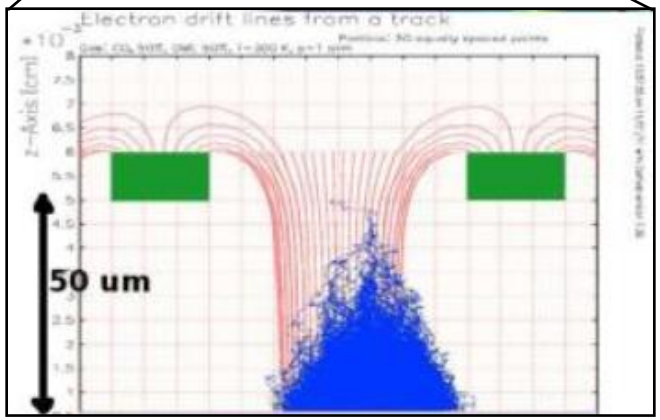

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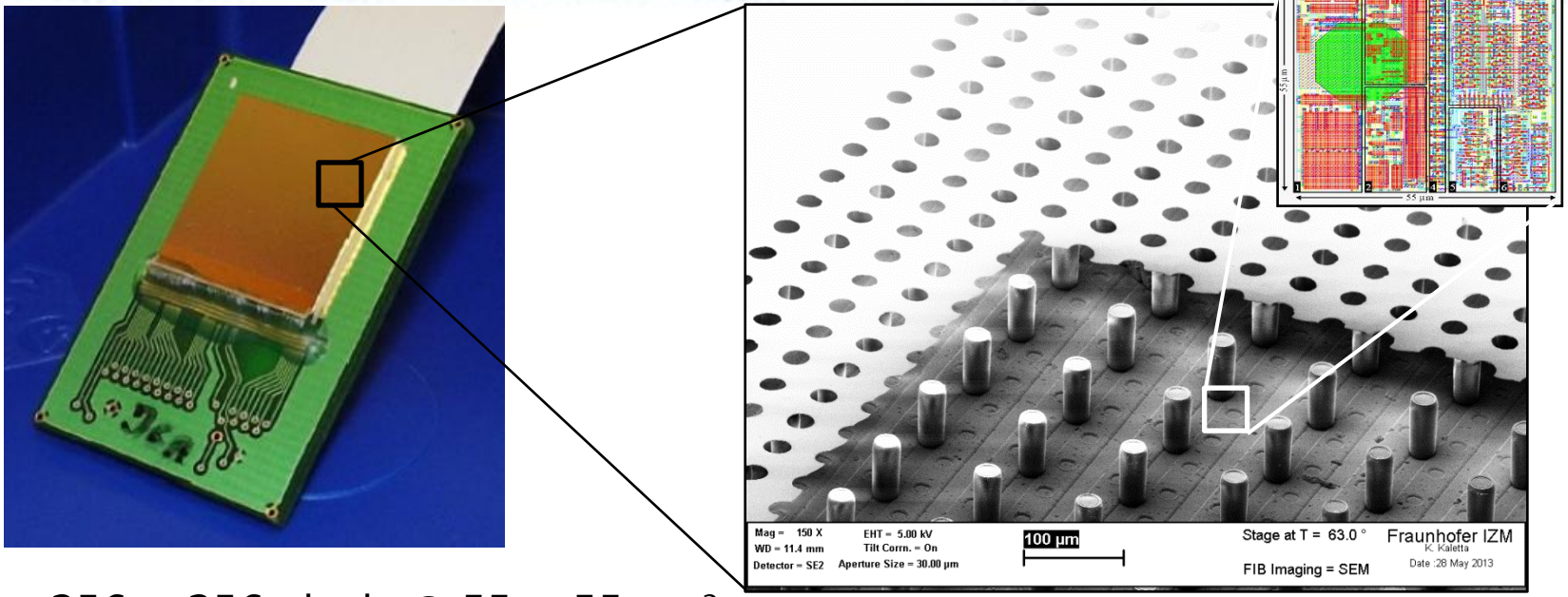

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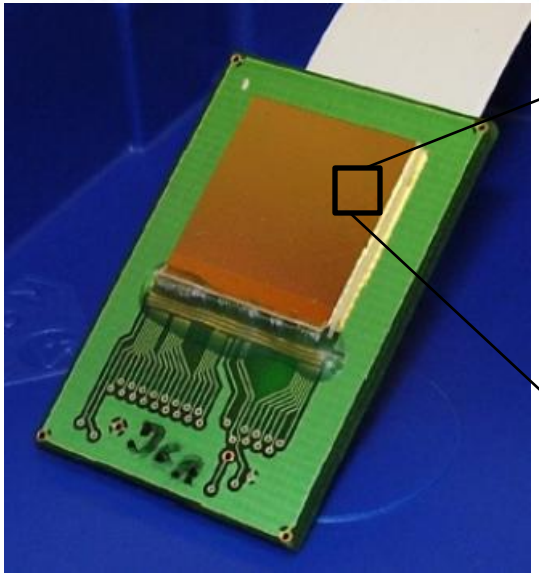
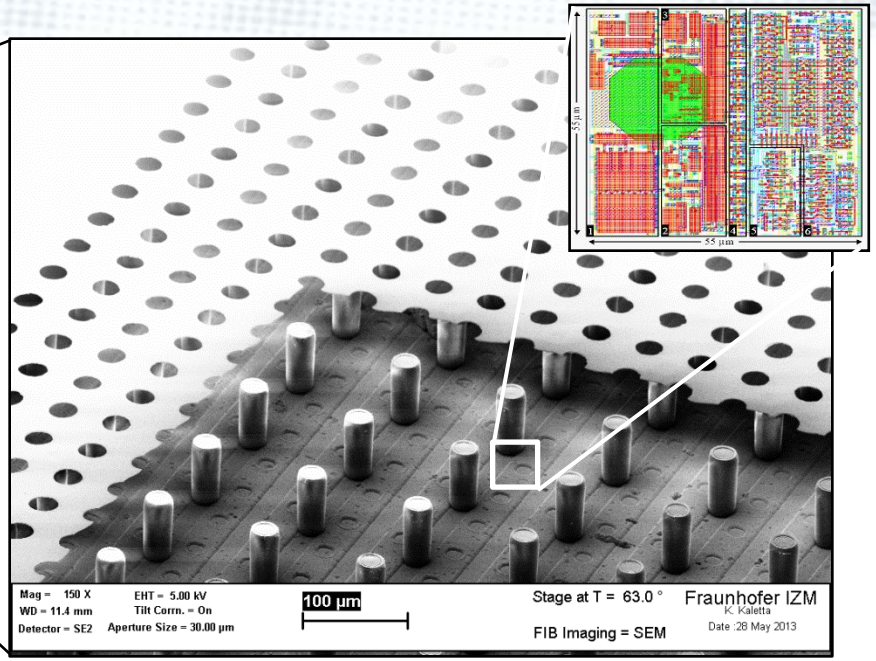
Modes:
- Time Over Threshold (TOT)
- Time of Arrival (ToA)
- Hit Counter

The TimePix Chip





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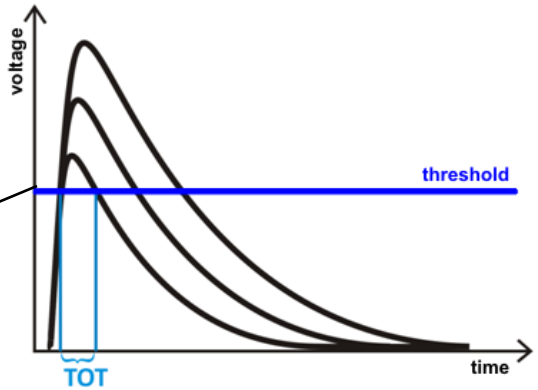
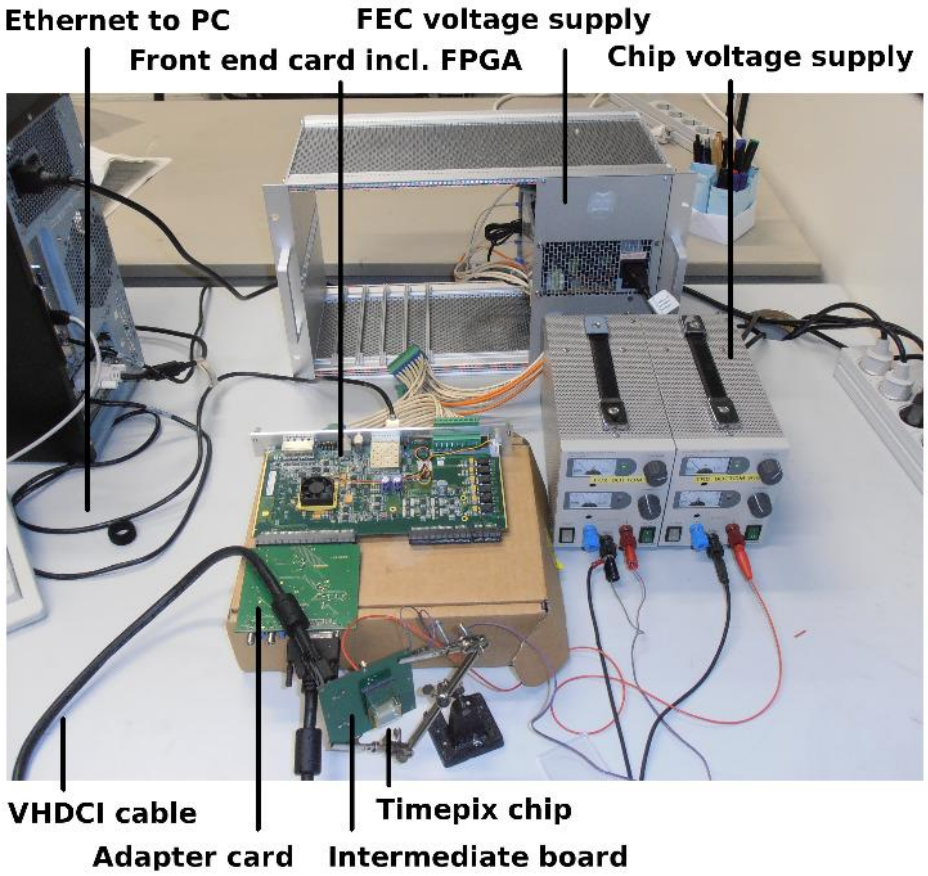
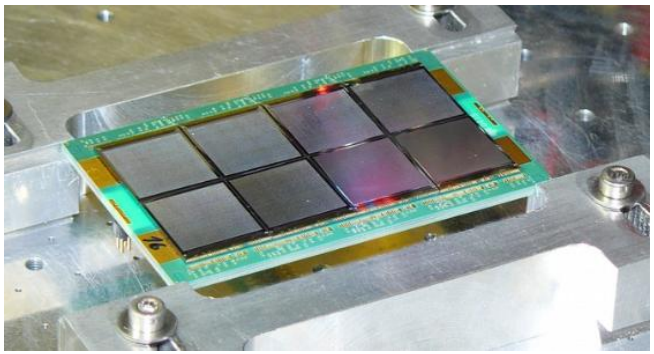


TimePix Readout System

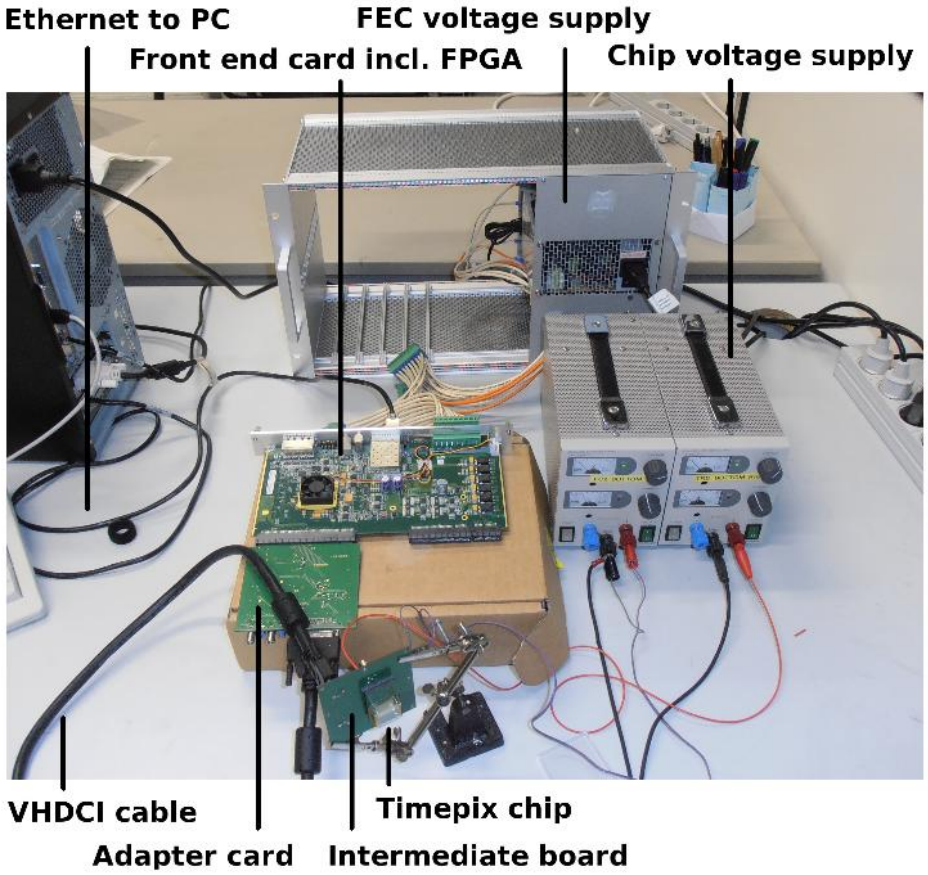


Octoboard:

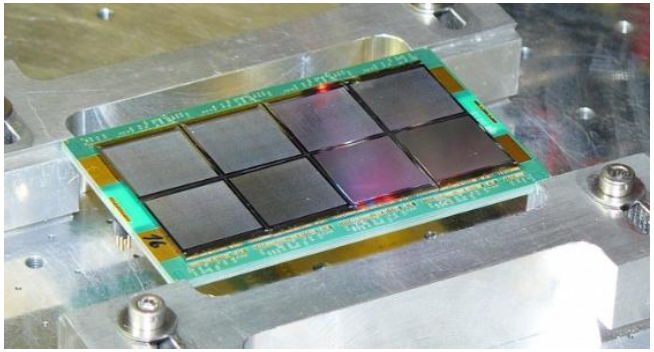


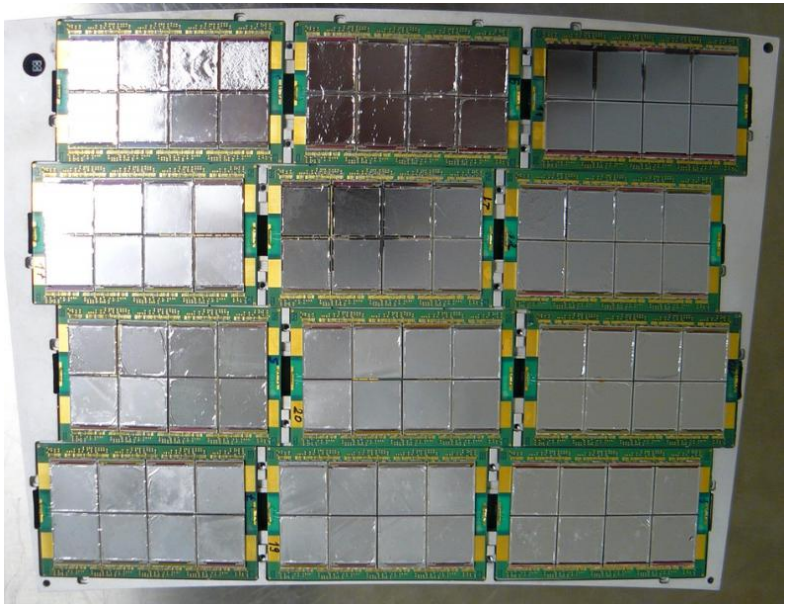
[1] M. Lupberger, The Pixel-TPC – A feasibility study, Thesis 2016
[2] H. Muller, RD51 SRS Status December 2016, CERN

TimePix Readout System



Octoboard:





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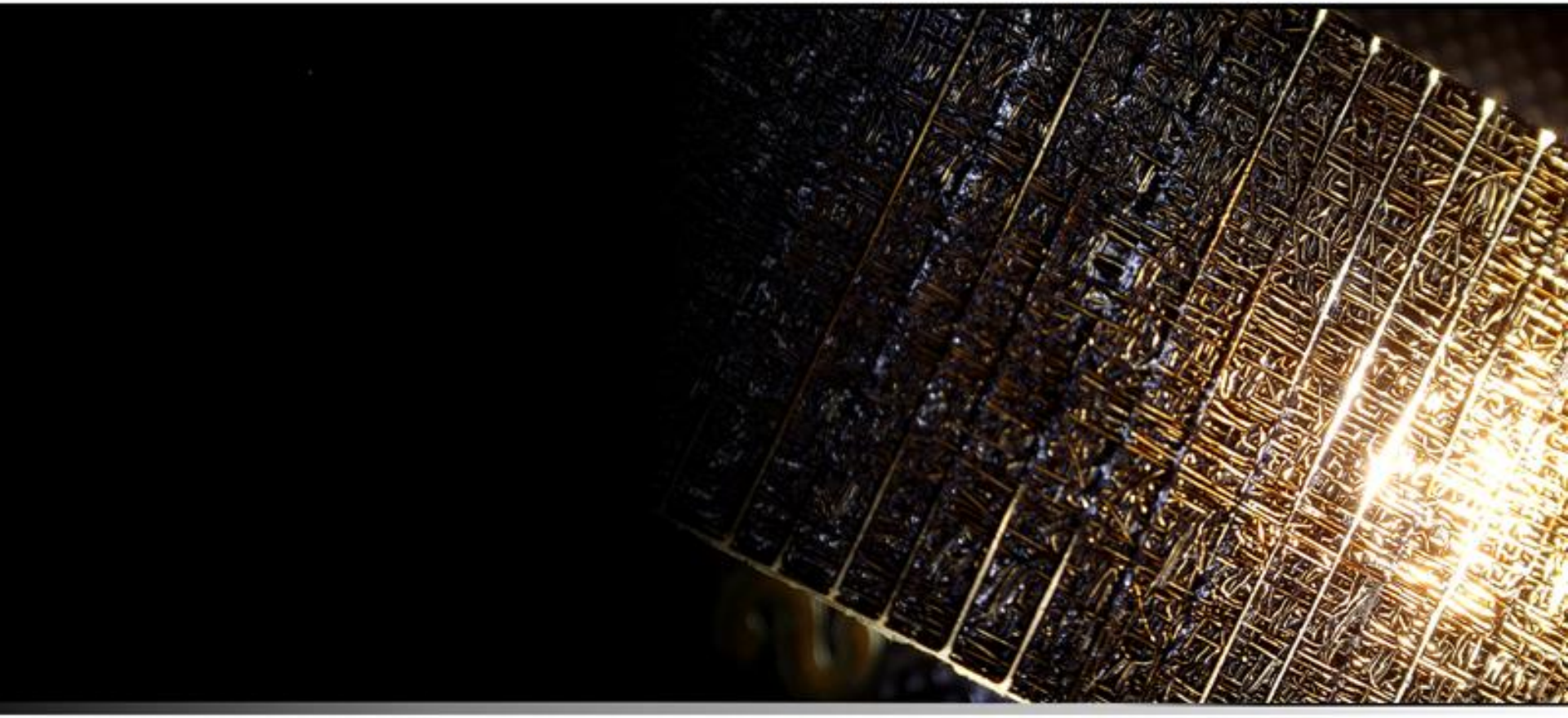
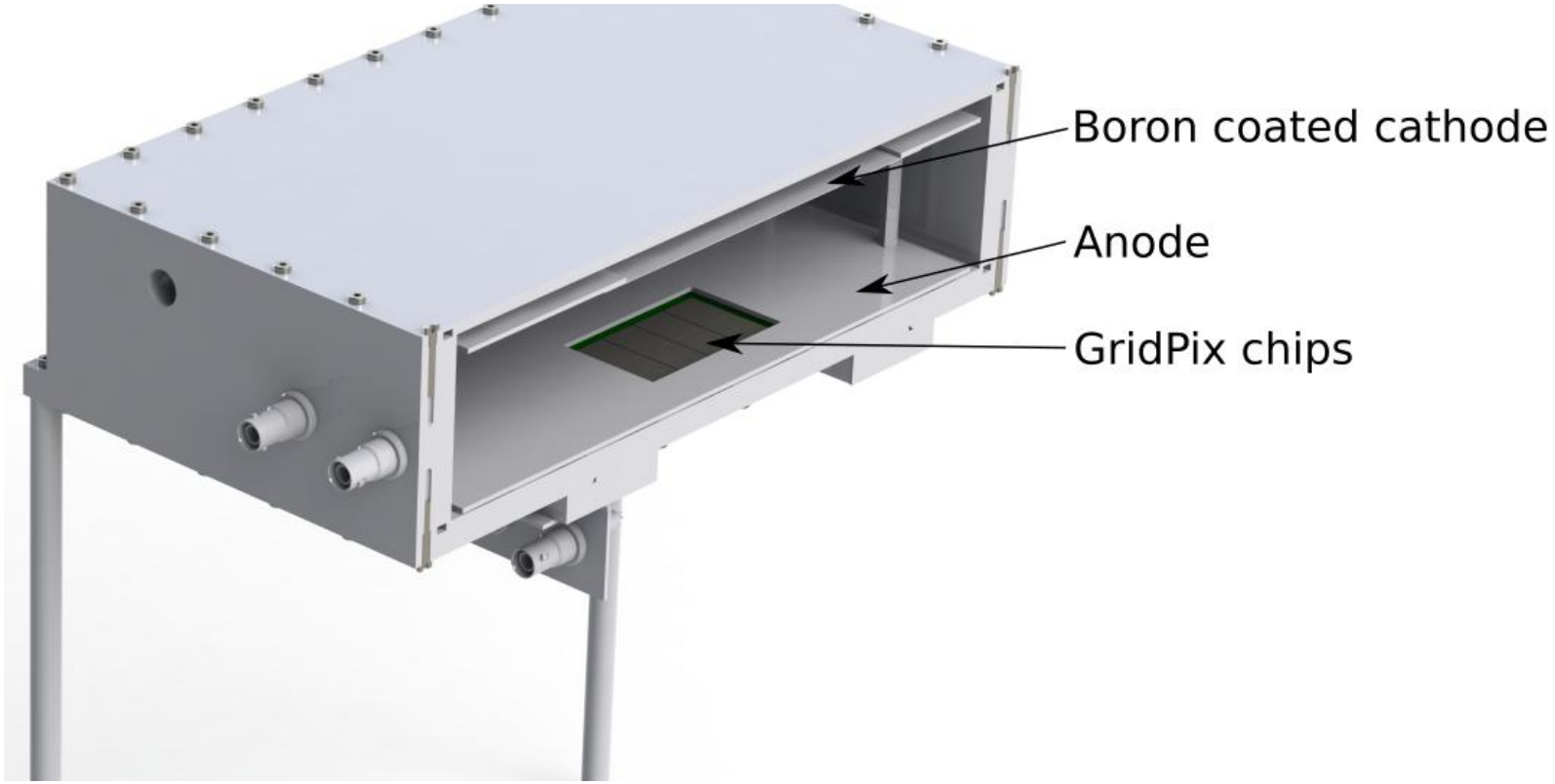
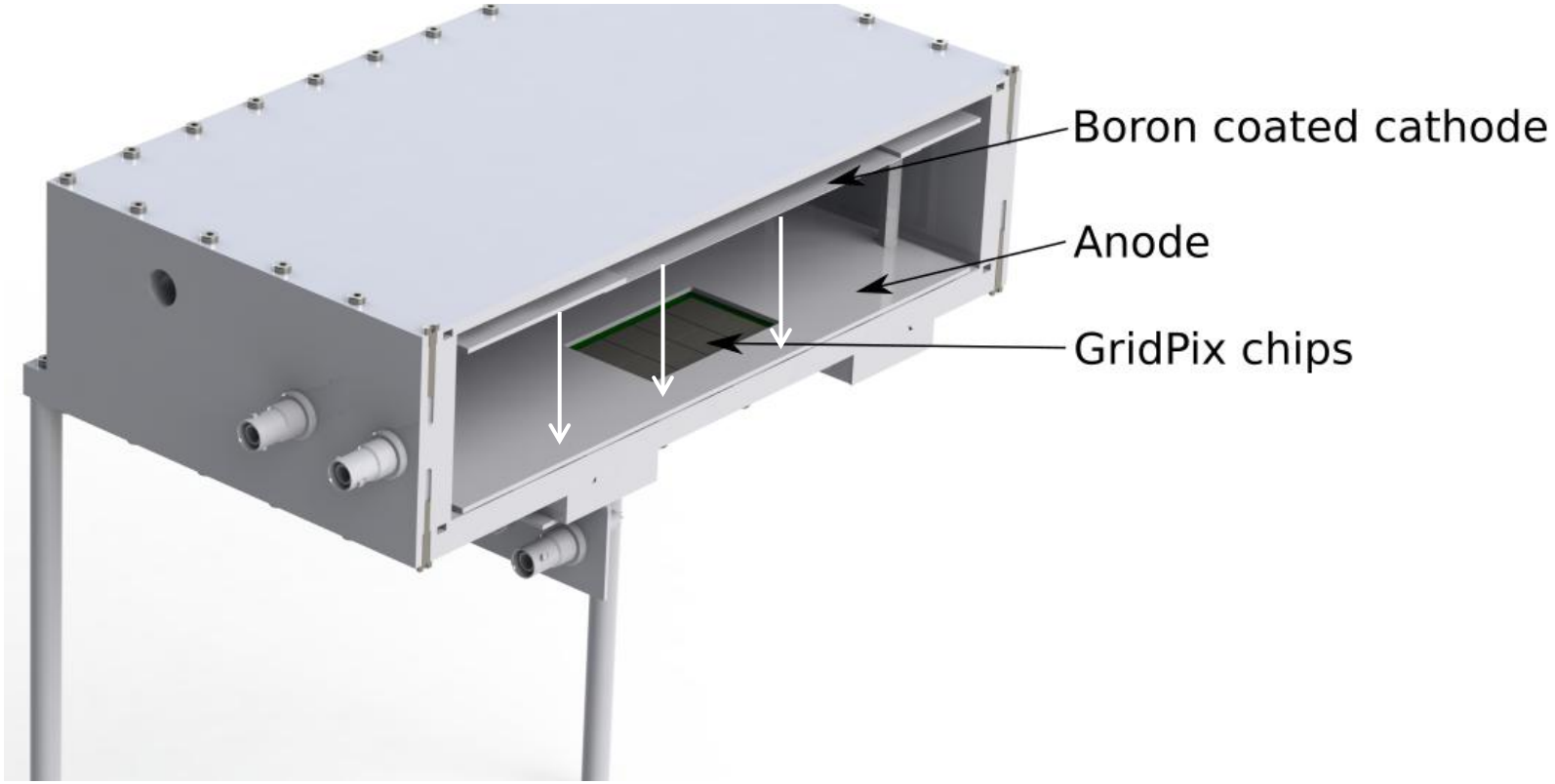
Detecting Neutrons



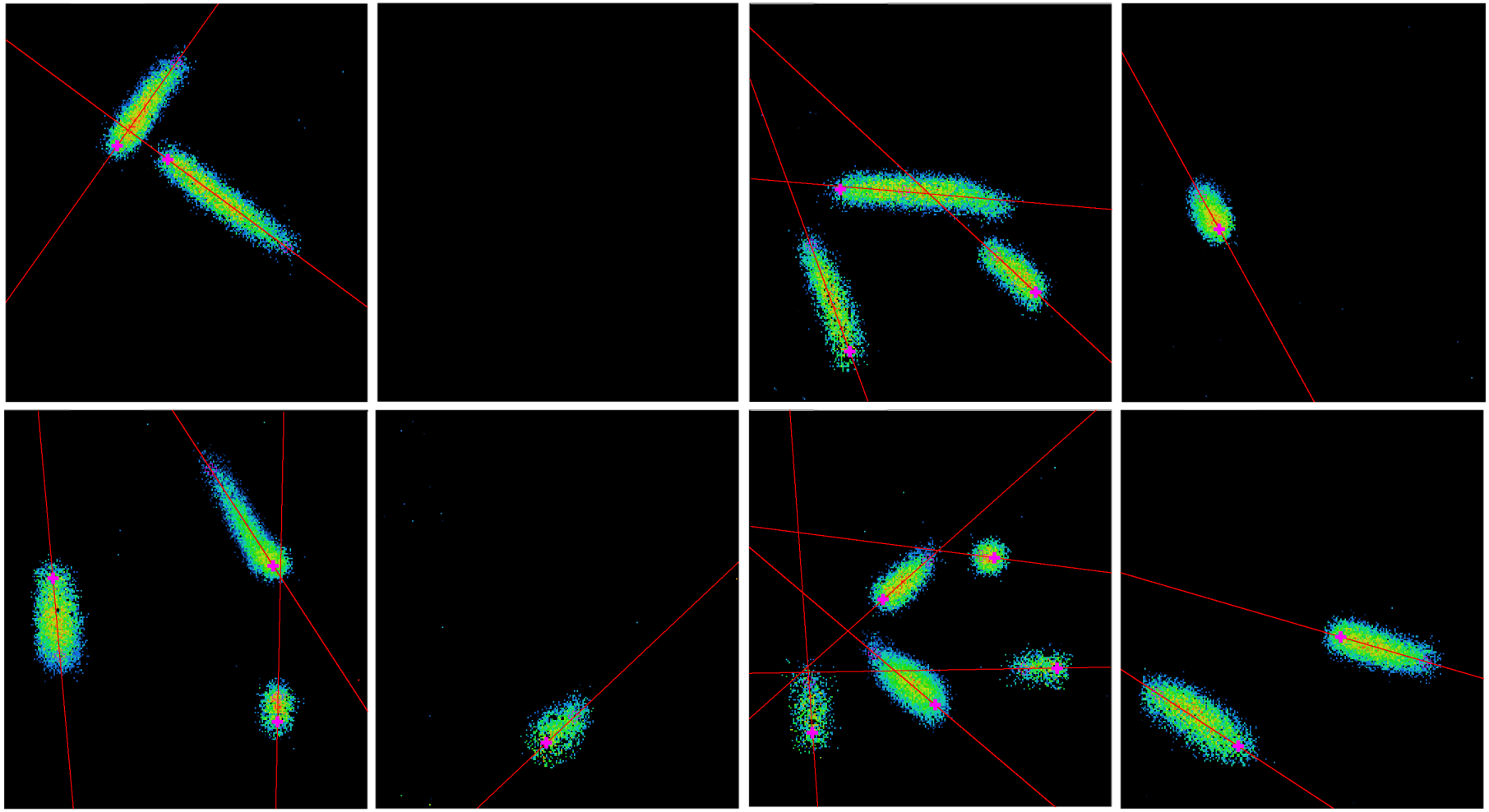
Test Detector



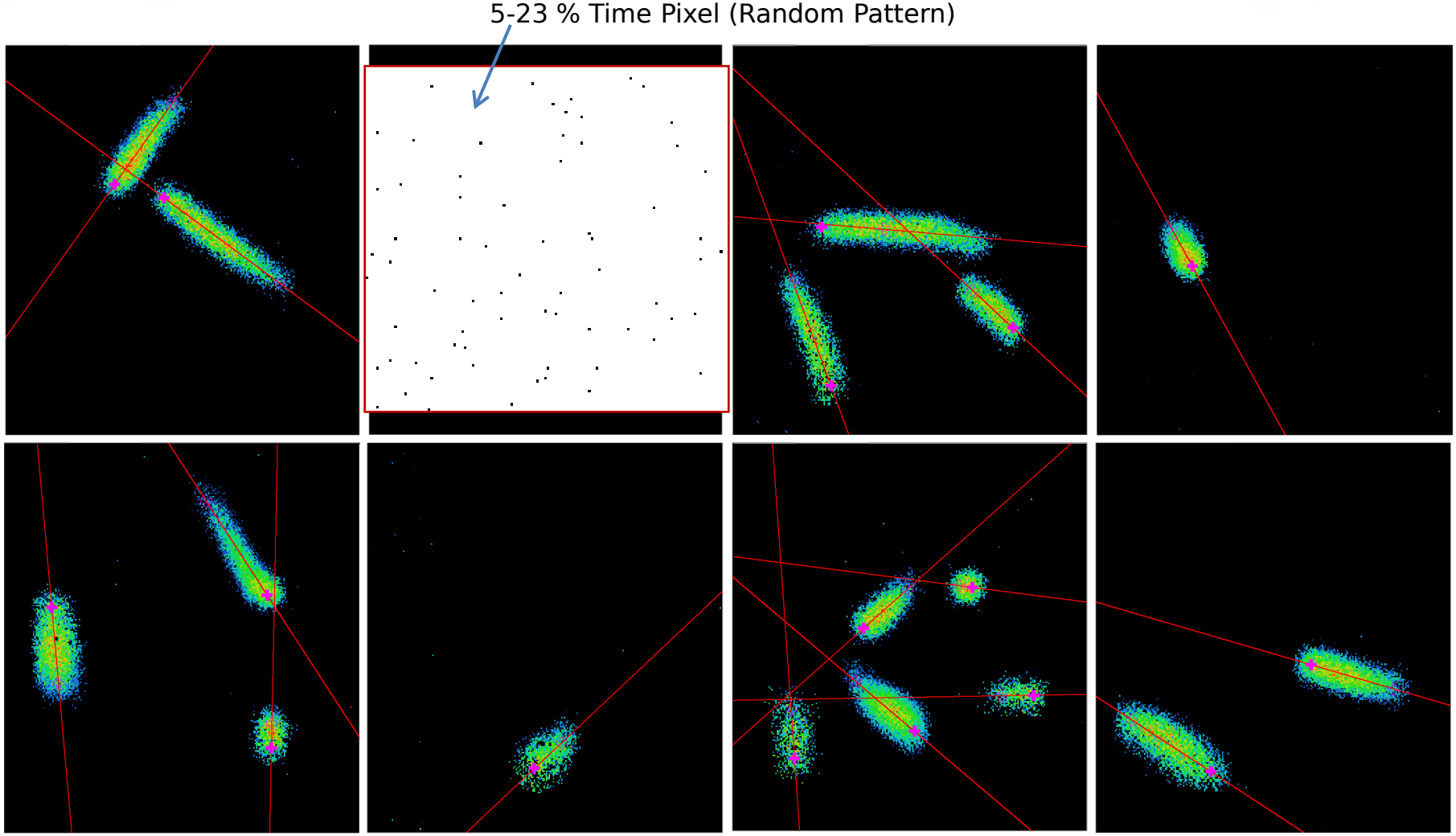
Test Detector



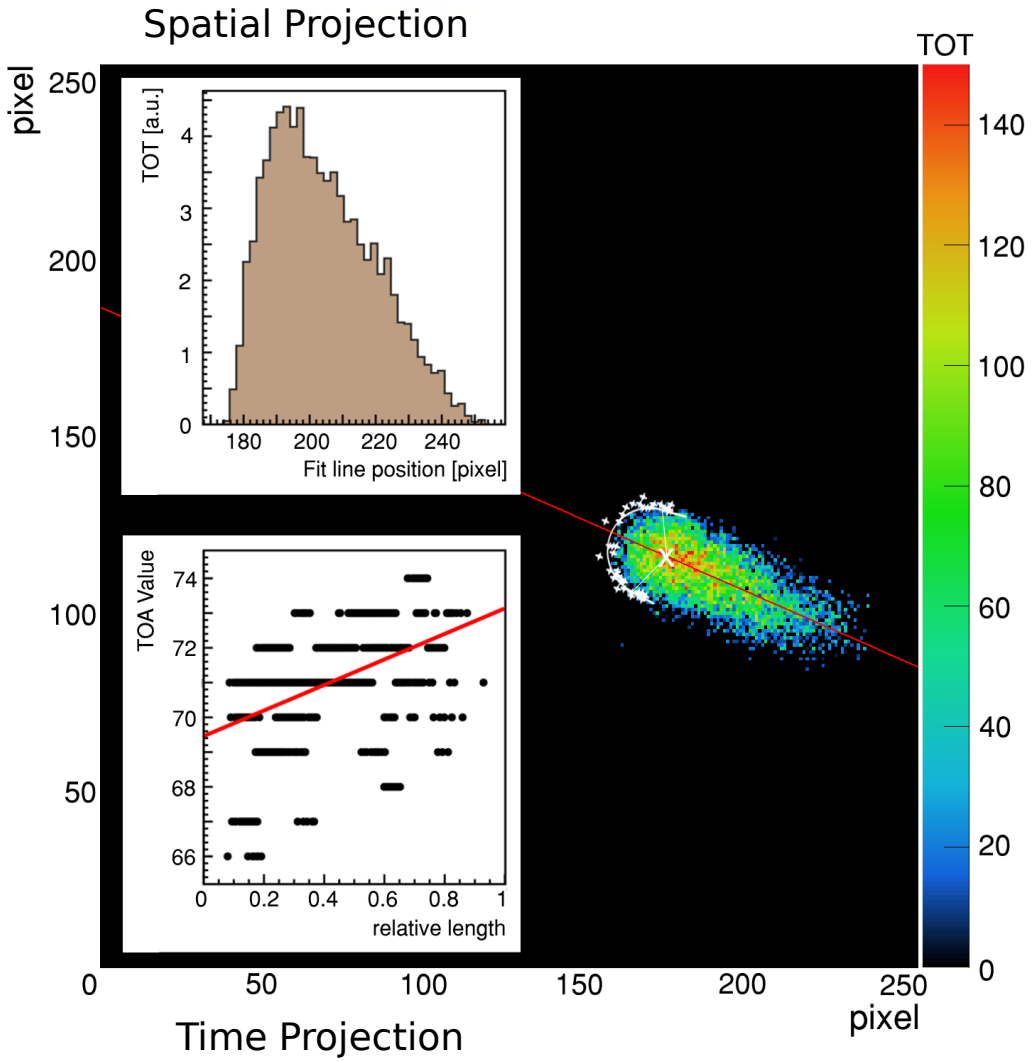
Neutron Conversion Tracks



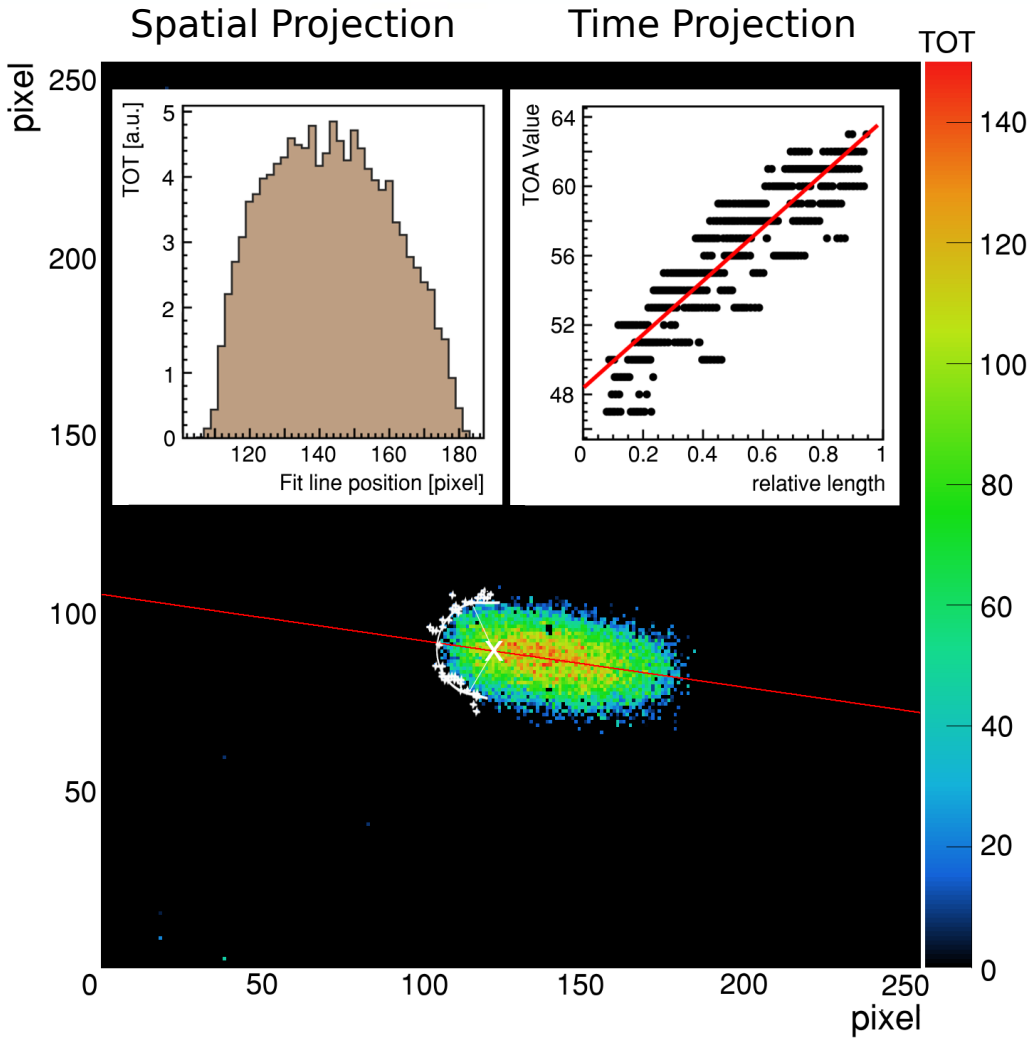
Neutron Conversion Tracks



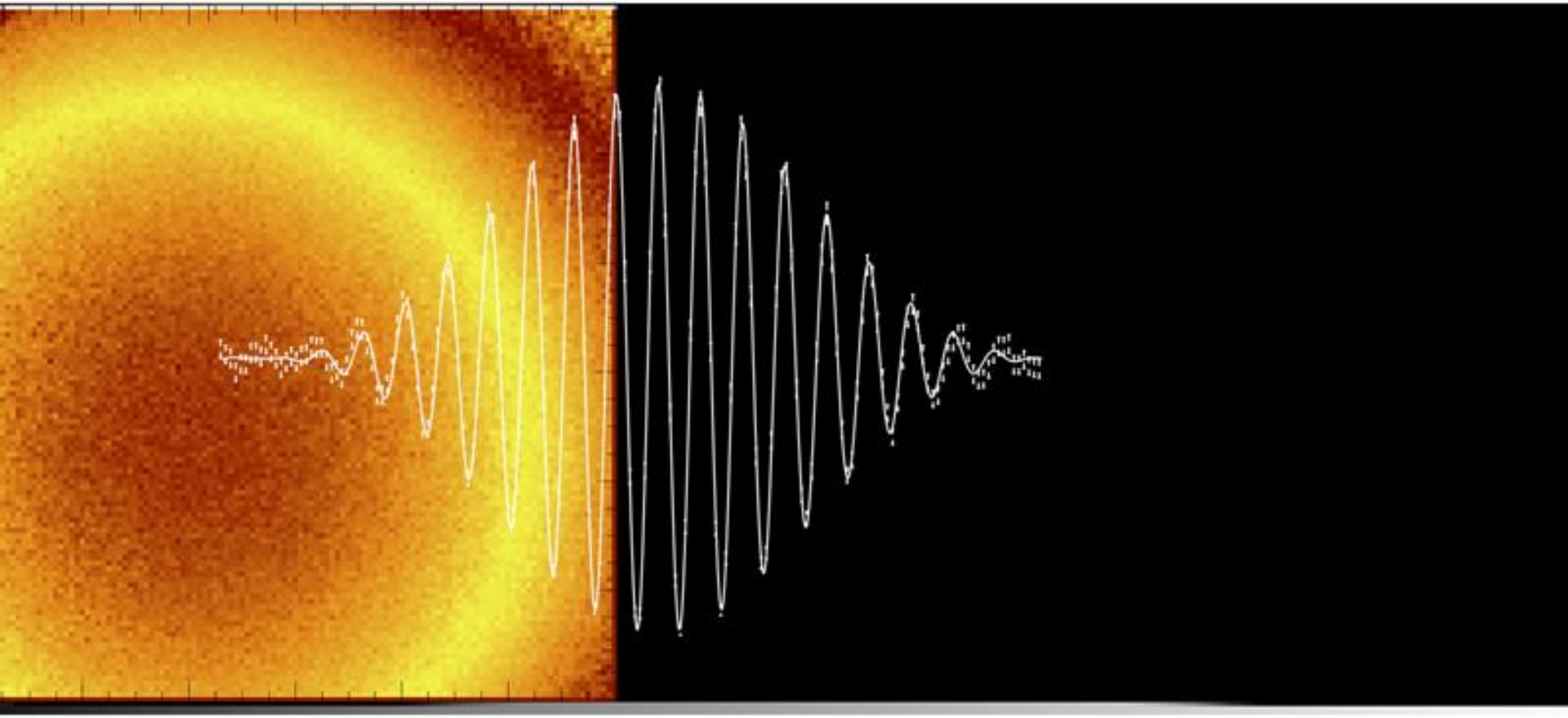
Event Example: Lithium



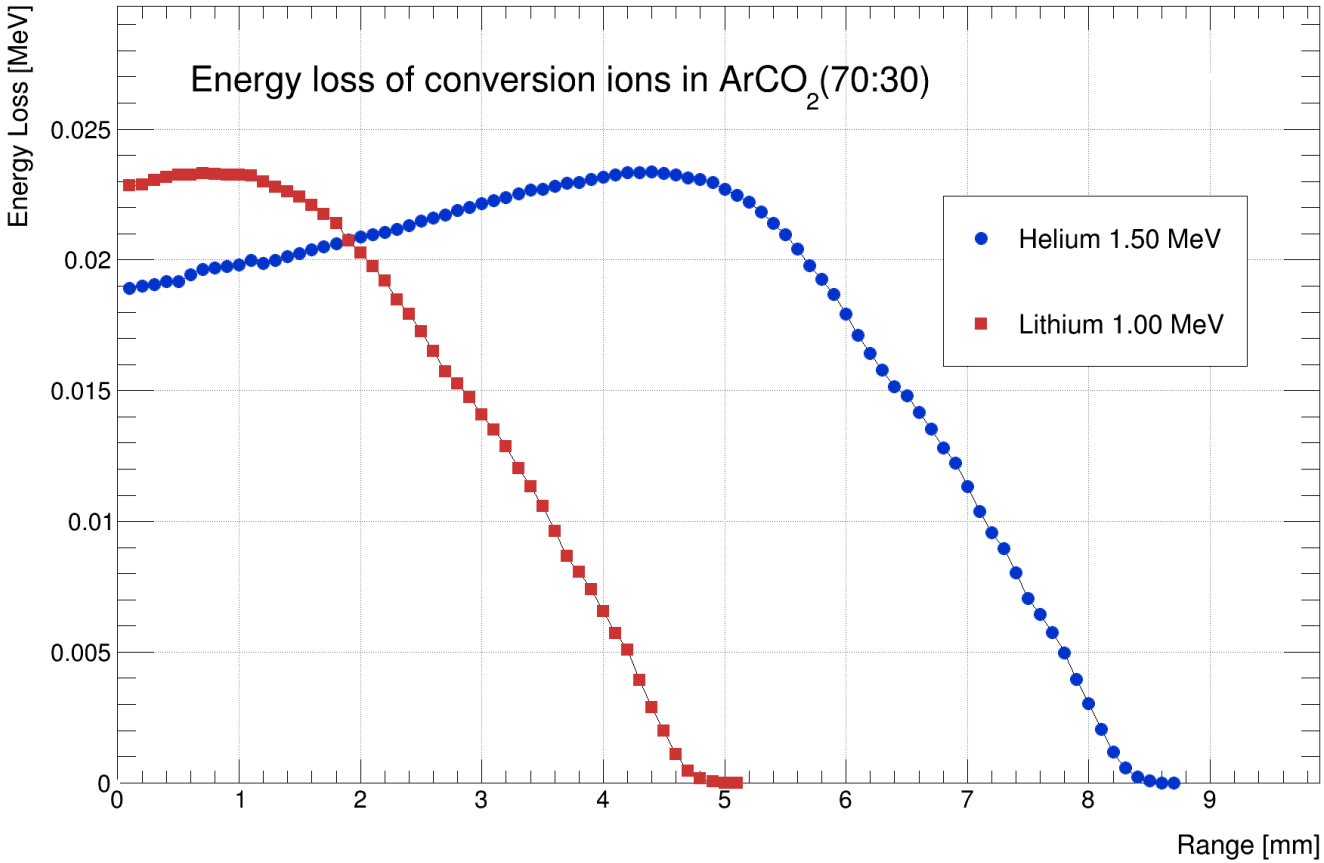
Event Example: Helium



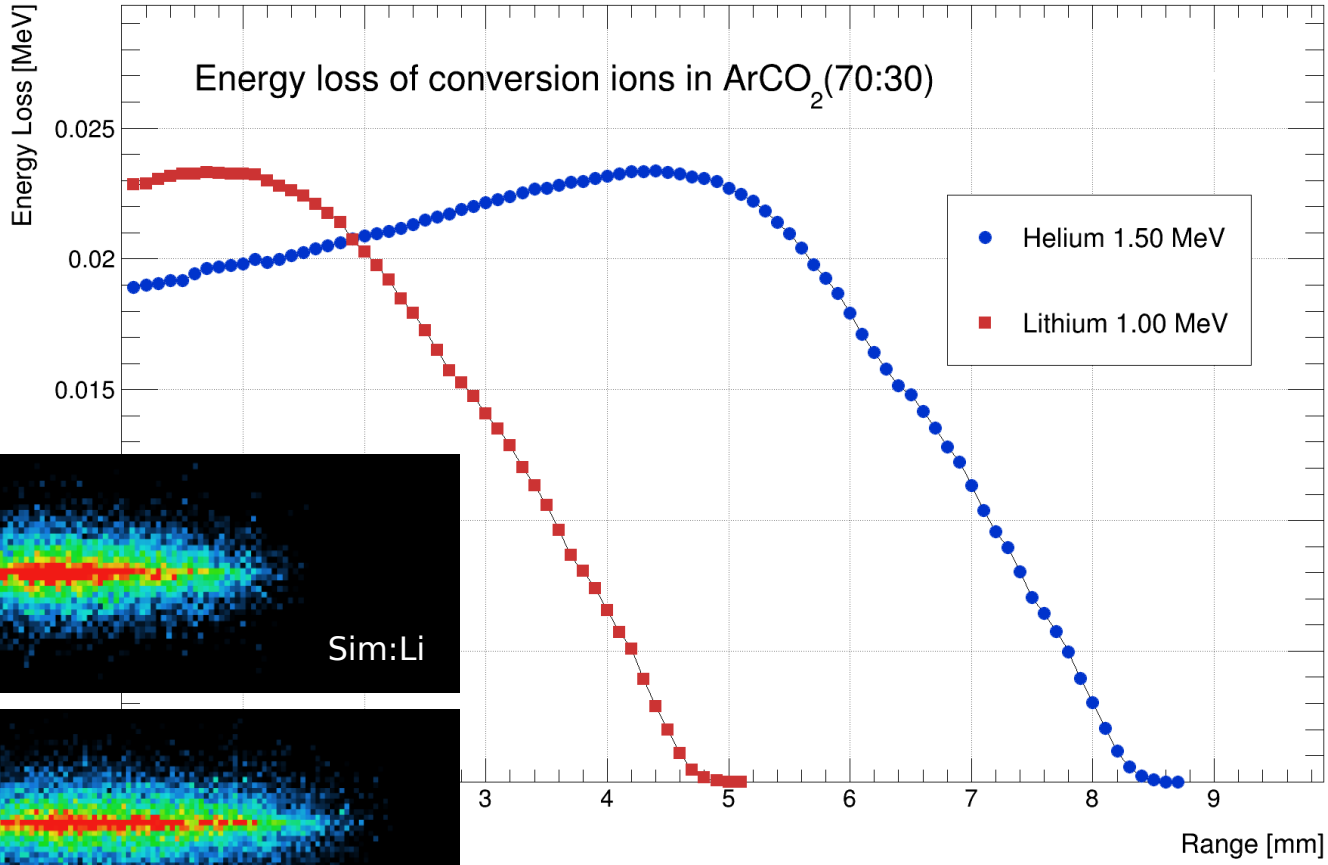
Analysis and Results



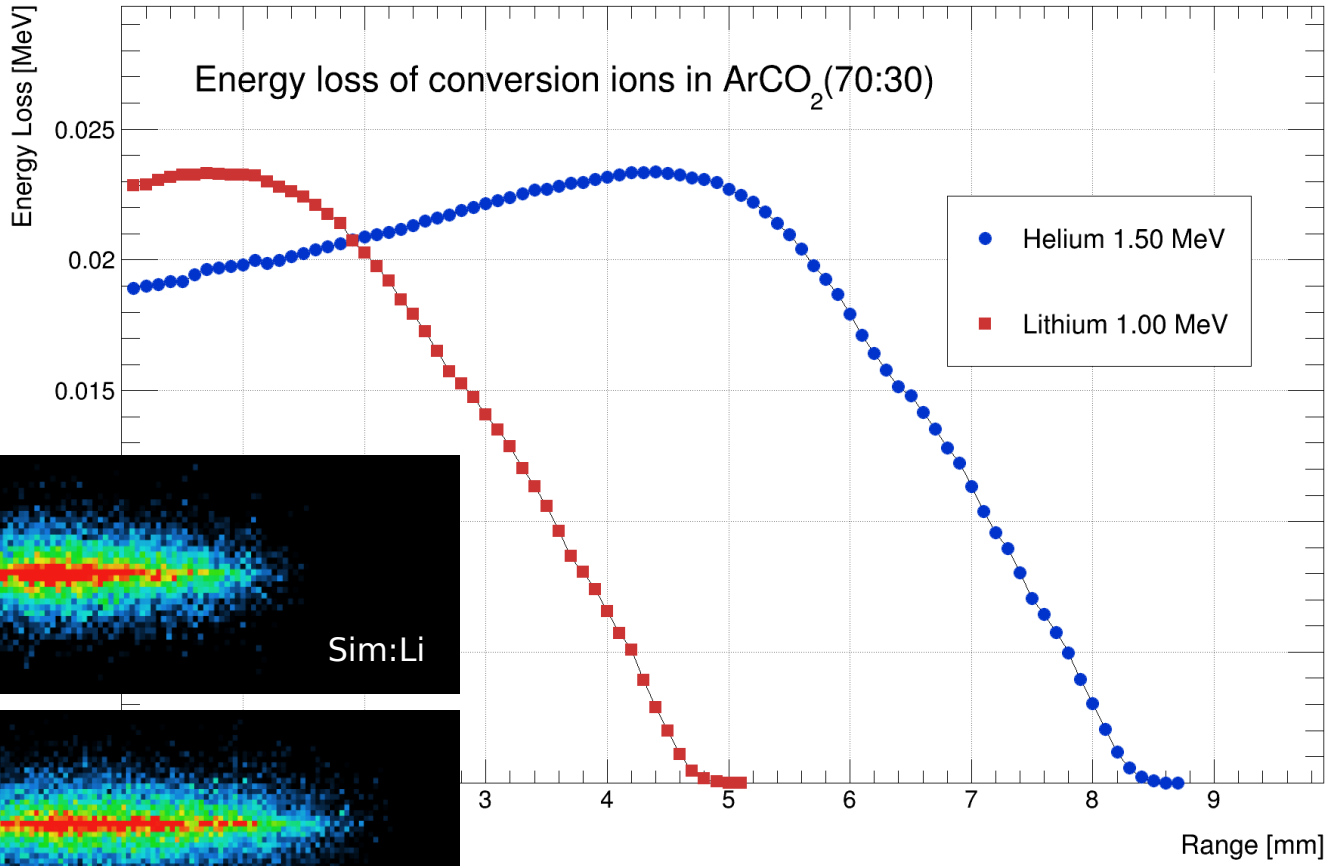
Energy Loss in Gas



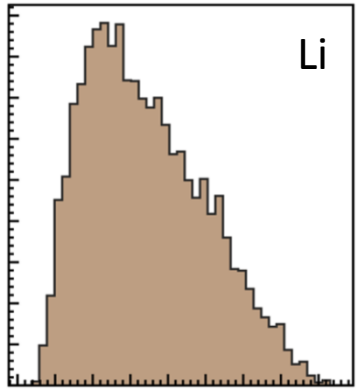
Energy Loss in Gas

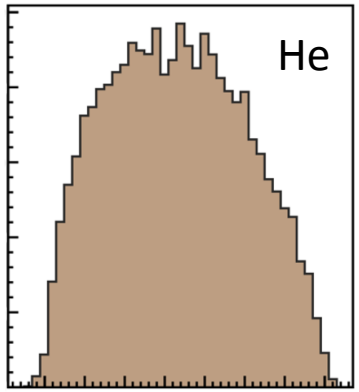


Energy Loss in Gas



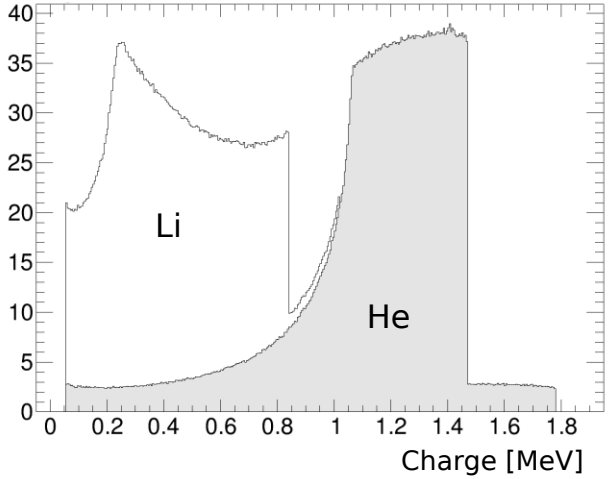
Spatial Projection

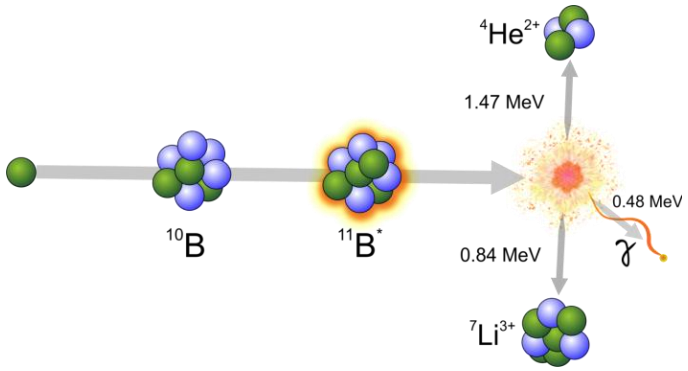




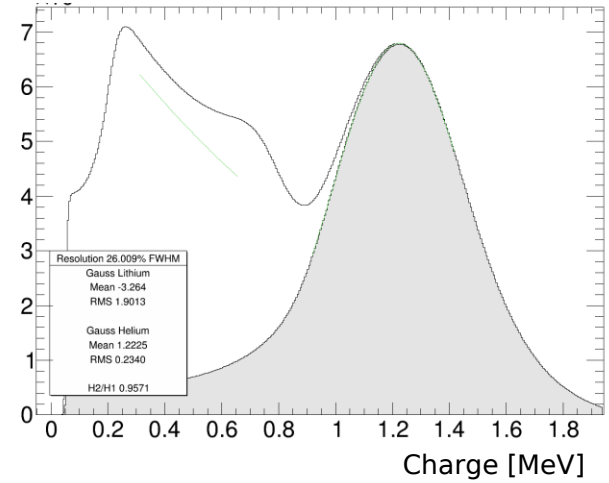
Energy Spectrum

Simulation: 1 µm Layer of Boron



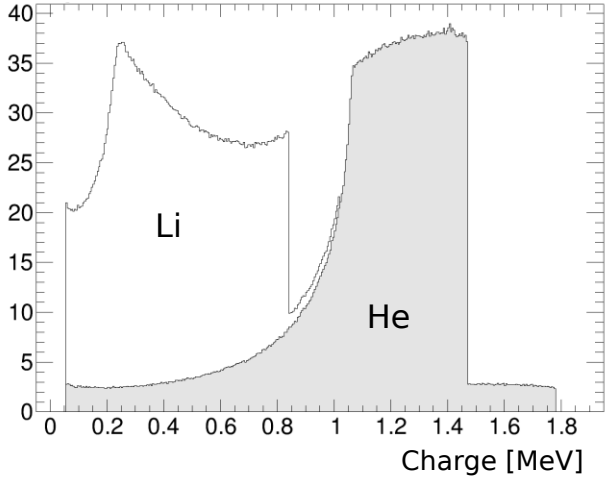


Folded with 25 % FWHM



Energy Spectrum

Simulation: 1 µm Layer of Boron



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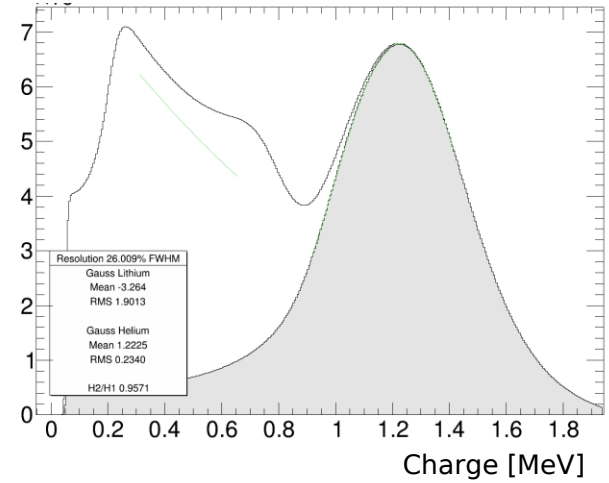
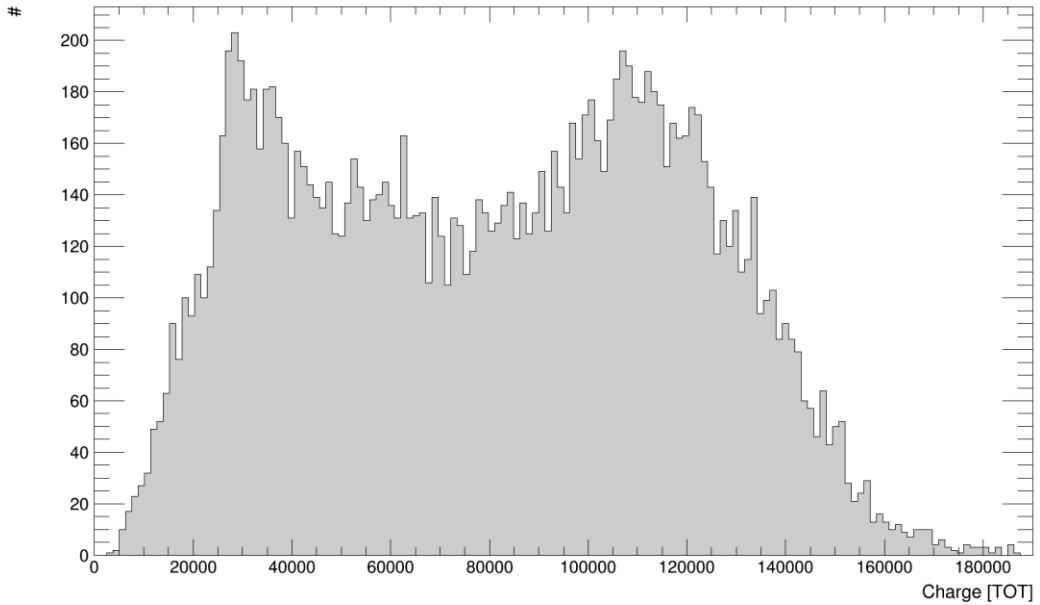
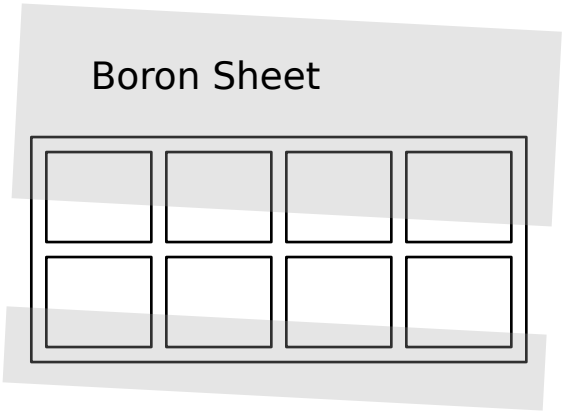


TOT Spectrum (fiducialized)



Spatial Resolution



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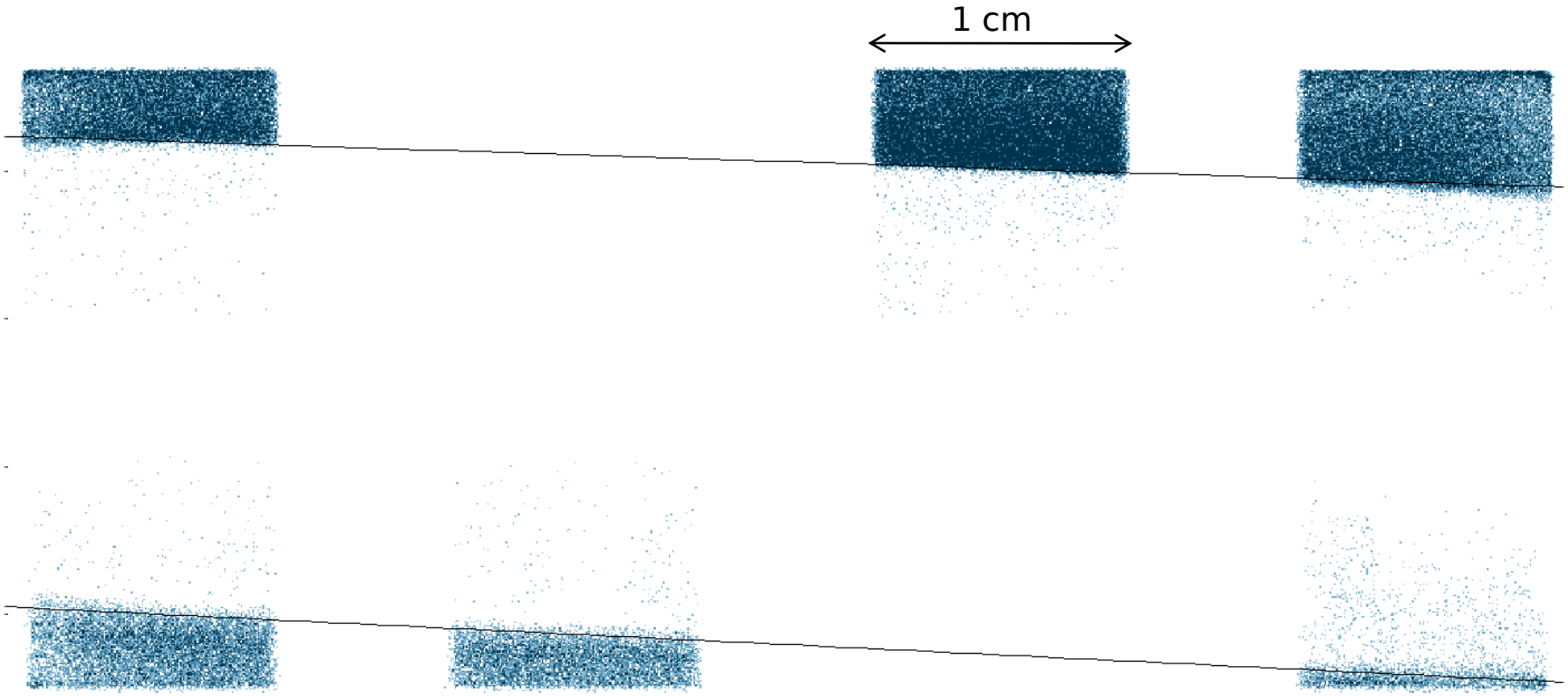
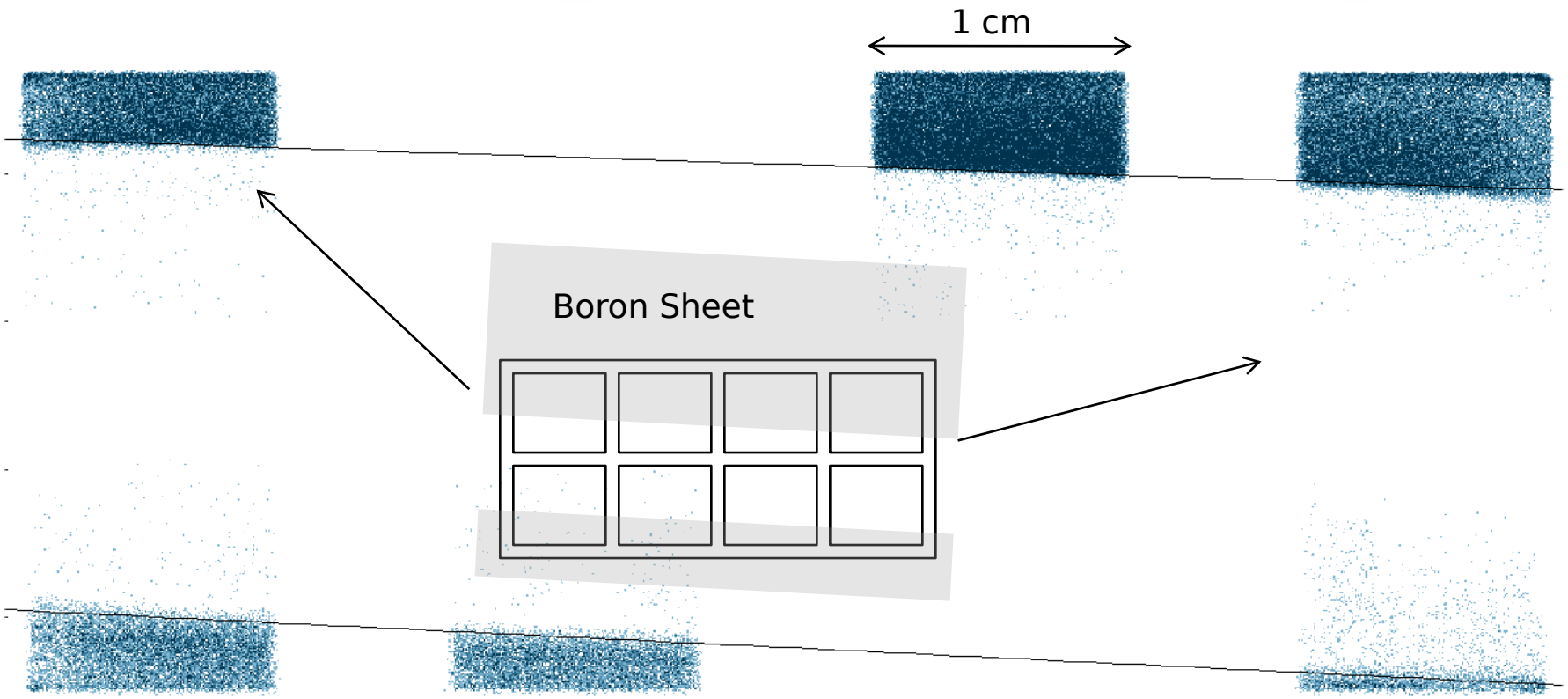
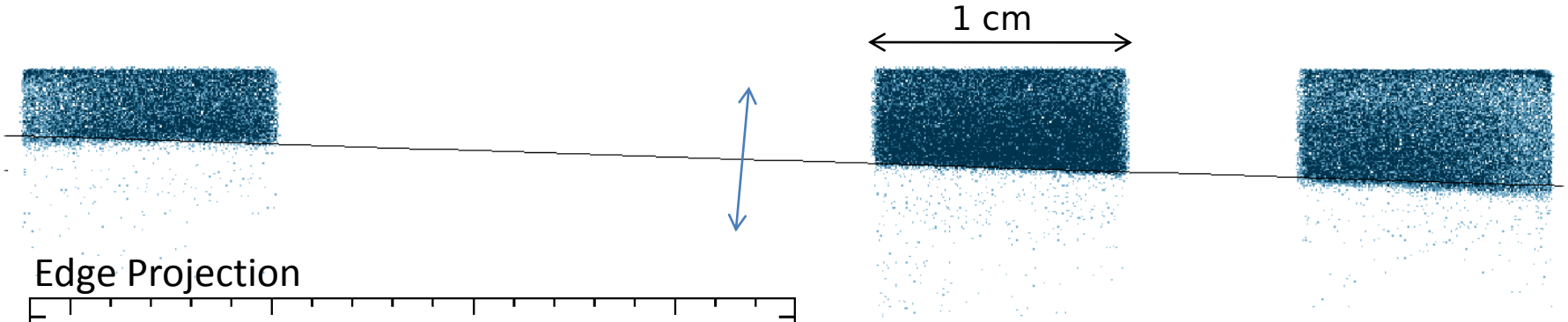


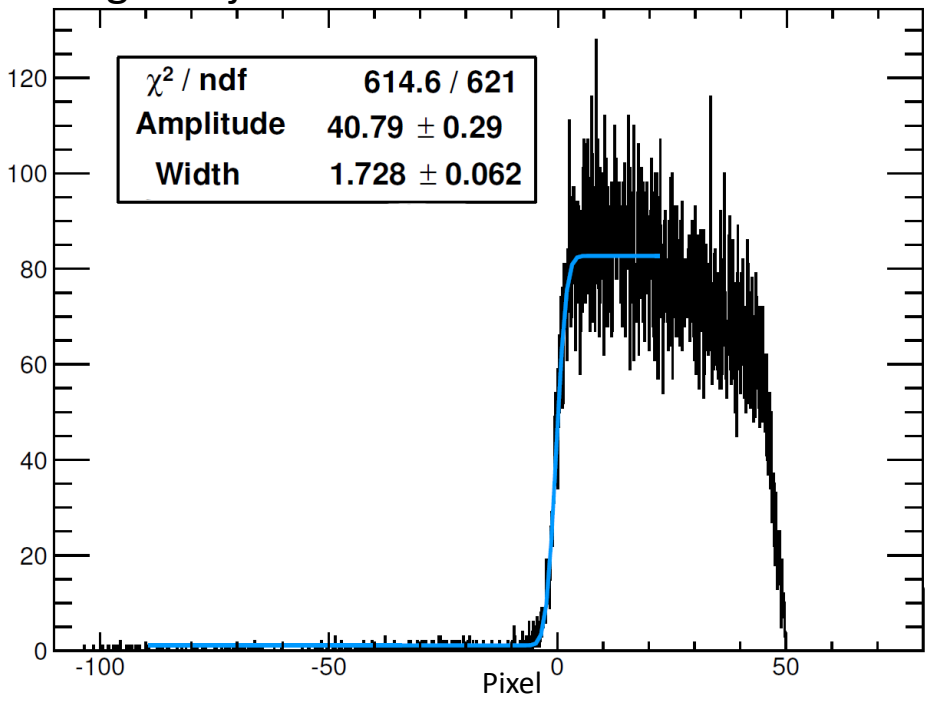
Spatial Resolution



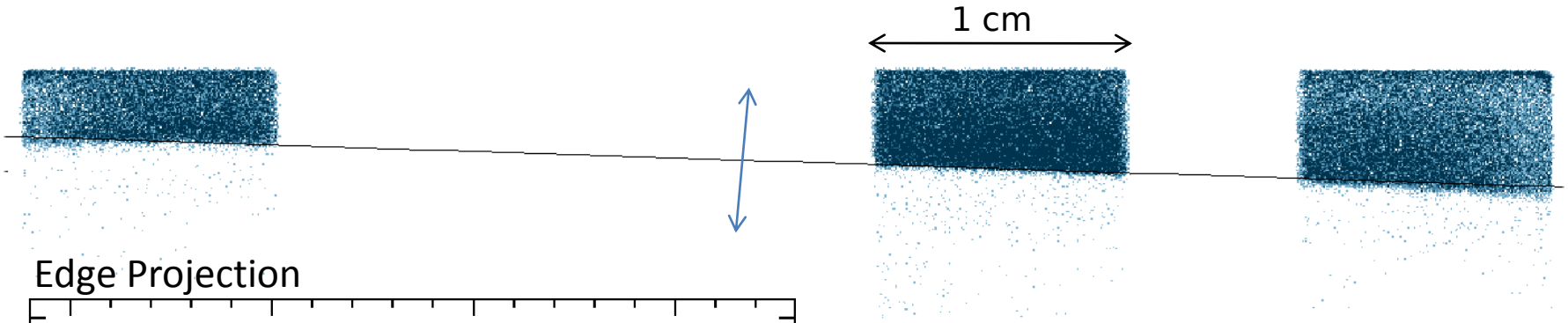
Spatial Resolution



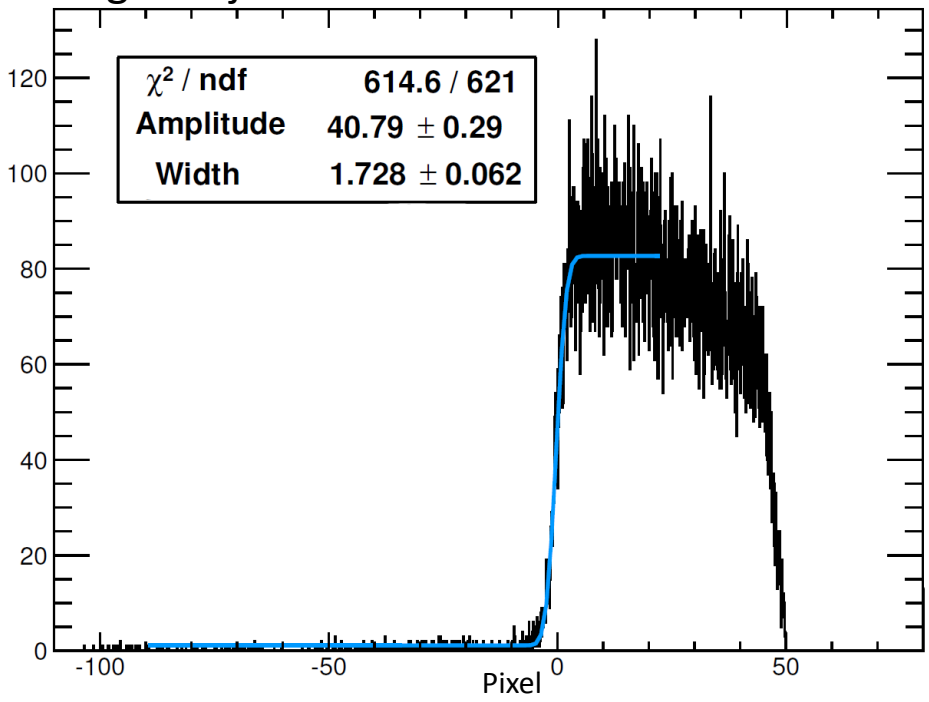
Edge Projection



Spatial Resolution



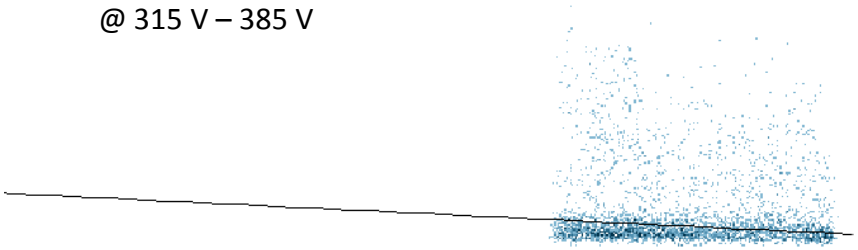
Edge Projection



Spatial Resolution σ

(95 +/- 4) µm

@ 315 V – 385 V



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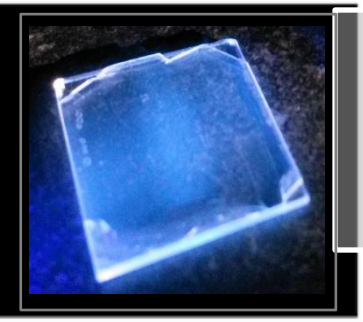

High Resolution Neutron Detection

The Neutron Time Projection Chamber

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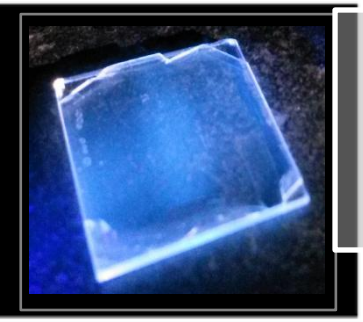

High Resolution Neutron Detection

The Neutron Time Projection Chamber

- Trigger & Track Principle

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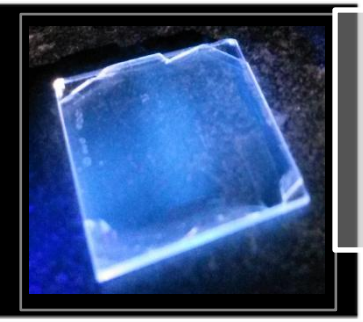

High Resolution Neutron Detection

The Neutron Time Projection Chamber

- Trigger & Track Principle
  - Using both conversion products

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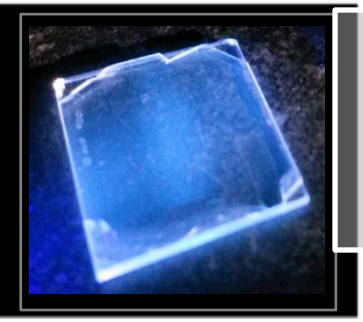

High Resolution Neutron Detection

The Neutron Time Projection Chamber

- Trigger & Track Principle
  - Using both conversion products
  - Combination of gaseous tracking detector [TimePix] and a photo sensitive detector [SiPMs]

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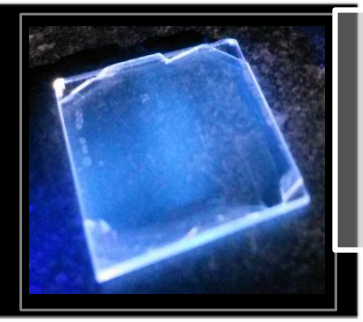

High Resolution Neutron Detection

The Neutron Time Projection Chamber

- Trigger & Track Principle
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  - Combination of gaseous tracking detector [TimePix] and a photo sensitive detector [SiPMs]
  - [Spatial Resolution σ (95 +/- 4) µm]

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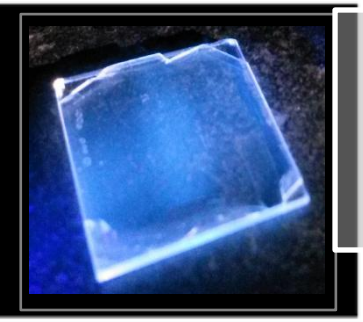

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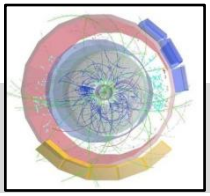

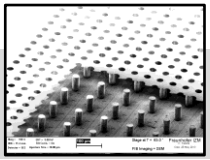

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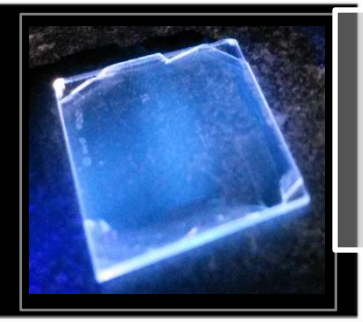

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