GE Oil & Gas – Reuter-Stokes

GE Reuter-Stokes

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Our People - Twinsburg, OH Facility

- OSHA VPP Star
- GE eCO2 certified
- HealthAhead
- ISO 9001
- 10 CFR 50 App B
- ASME Sec III
- 200 EEs
- Non-union
- 163'000 ft^2
- 100 acres

Reuter-Stokes key milestones

1956 – Reuter-Stokes founded

1984 – Reuter-Stokes acquired by GE

2001 – Tensor (Oil & Gas exploration products) acquired by GE

2008 – $^{3}_{2}$He shortage

2010 – Commercial $^{3}_{2}$He available

2010 – Reuter-Stokes launches $^{10}_{5}$B lined proportional counter

2011 – Reuter-Stokes investigates $^{10}_{5}$B for safeguards

Reuter Stokes Measurement Solutions

Technologies for Harsh Environments

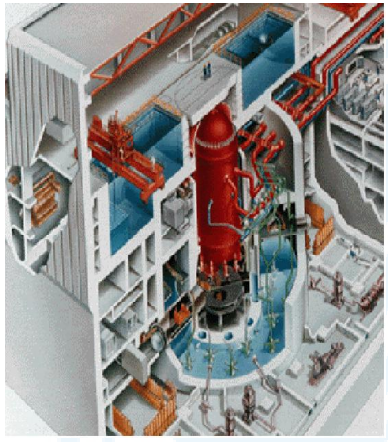
Nuclear Instrumentation

Neutron Monitoring

In-core power monitoring

Ex-core power monitoring

Gamma Thermometer



Radiation Measurements

Homeland Security

Safeguards

Scattering

Environmental monitoring

^{3}He recycling

Drilling Tools

^{3}He Detectors

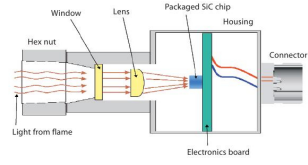
Oil exploration

Geo-steering

Turbine Instruments

Flame detection sensor

- SiC technologies



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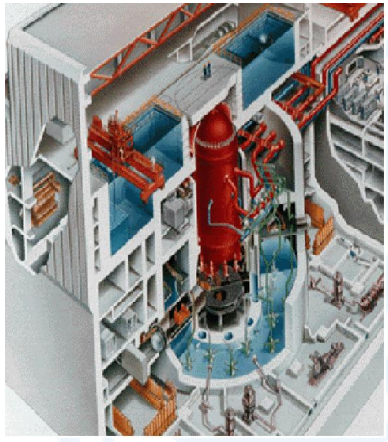

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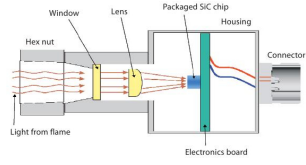

Radiation Measurement Solutions

60 Years of Experience

- Over 10,000 neutron counter designs manufactured
- ^{3}He gas-filled detectors – multiple designs
- ^{10}B lined detectors – reactor power monitoring
- BF_3 gas-filled detectors
- High pressure ion chamber
- Scintillator packaging for harsh environments (O&G)
- ^{3}He recovery and purification

Core Competencies

- Harsh Environment Packaging
- Handling Sensitive Materials
- Radiation Detection
- Precision Fabrication
- Product Testing & Modeling

RS Skills

- Brazing, welding
- Long lived
- Integrated electronics

- Radioactive Sources
- Hygroscopic materials
- NRC compliance / DOT shipping regulations

- neutron
- γ radiation
- Ultraviolet

- Thin metal welding
- Coatings – electroplating and boron
- thin wire and cable processing

- Environmental testing
- Position calibration
- Monte Carlo simulation

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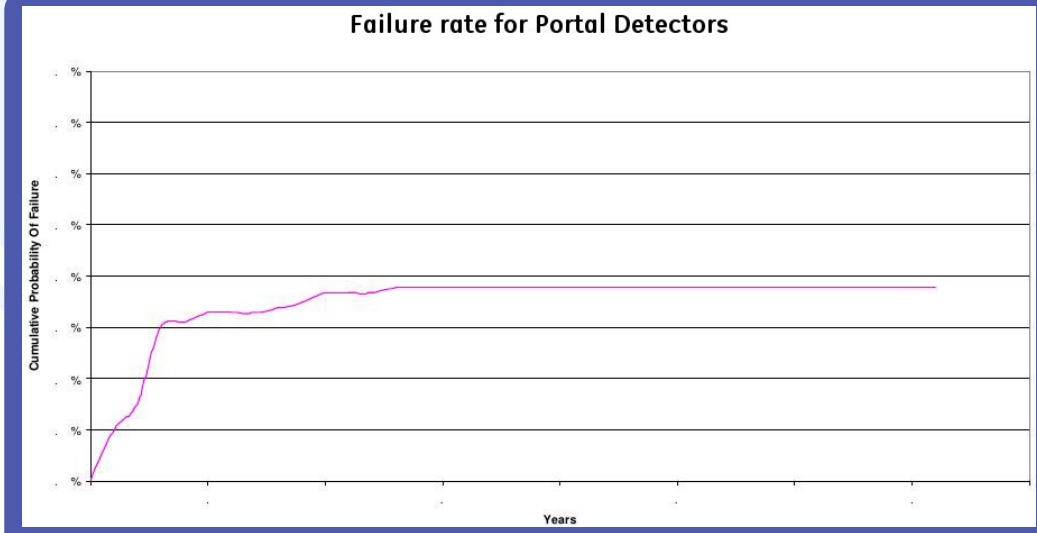
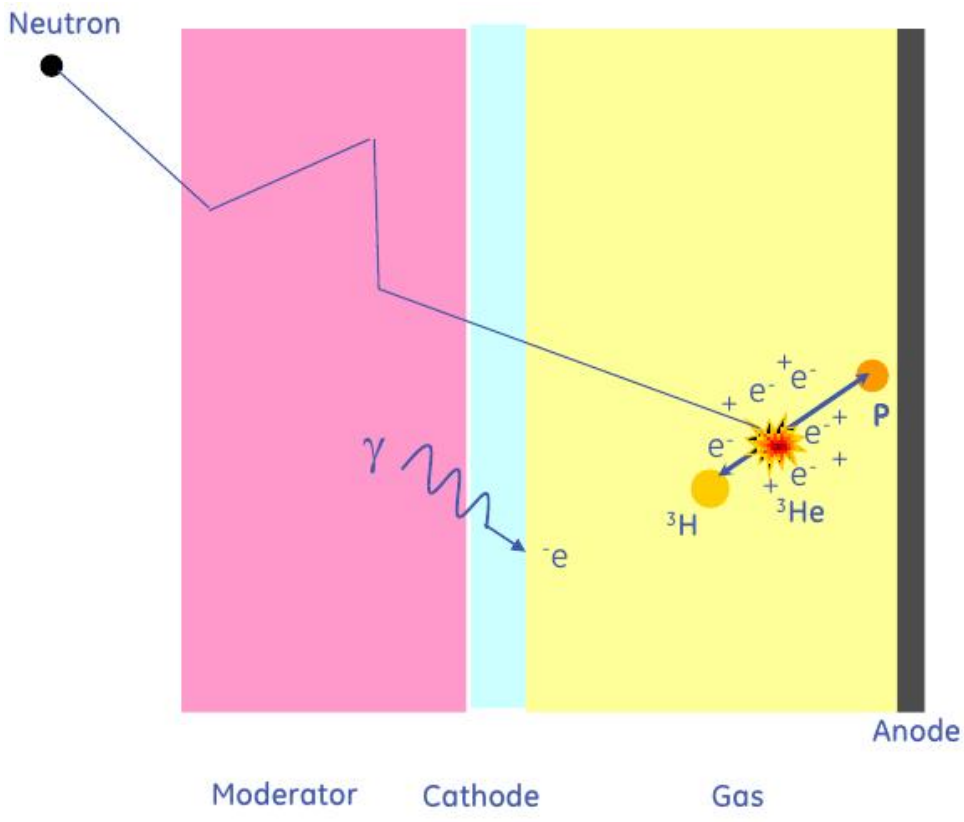


MTBF: 832 years

- Monte Carlo simulation

$^3_2$He Detector



Detector: Construction

- Metallic outer housing
- Small diameter anode
- Proportional fill gas
- Welded and brazed construction
- Optimized ^{3}He pressure for desired efficiency
- Optimized size for instrument applications

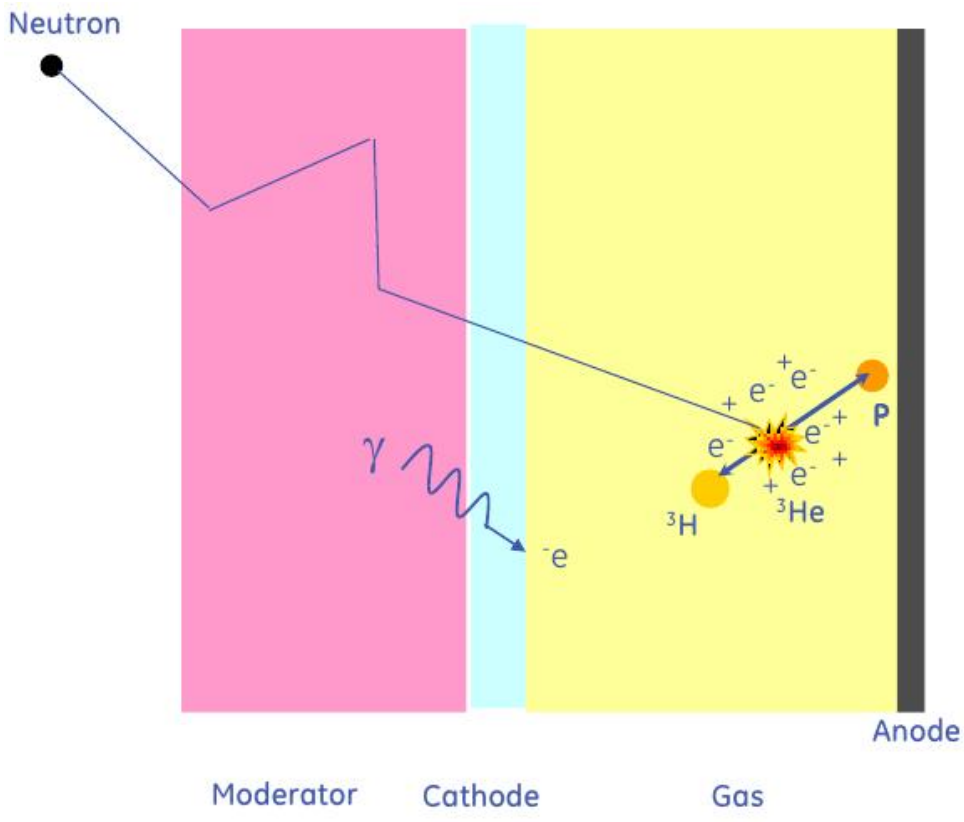
Operation:

- Well understood principles
- Neutron captured by ^{3}He nucleus
- Gamma response primarily from interaction with detector wall
- Charge sensitive electronics
- Well defined spectrum

$$^3_2He +^1_0 n \longrightarrow^3_1 H(0.191\,\text{MeV}) +^1_1 p(0.573\,\text{MeV})$$

$$\alpha = 5330\text{barns at } 0.025\,\text{eV}$$

$^3_2$He Detector



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GE Measurement & Control – $^3_2$He Detectors

Available Sizes

Detector Diameter:

- ↳ from 8mm
- ↳ up to 5 inches ($\sim$ 11cm)

Detector sizes (active length):

- ↳ 8 mm $\rightarrow$ up to 41 inches
- ↳ $\frac{1}{2}$ inch $\rightarrow$ up to 44 inches
- ↳ 1 inch $\rightarrow$ up to 150 inches

Aluminum: $\min_{\varnothing} = \frac{1}{2}$"

Fill pressure

0.1 atm $\leqslant$ **stainless steel** $\leqslant$ 30 atm

The maximum fill pressure for **aluminum** is 15 bar.

For shipping purposes, all detectors must be certified up to $4\times$ the fill pressure.

Materials of construction

Stainless steel:

- ↳ Background: $2.9 \times 10^{-4}\ \frac{\text{cps}}{\text{cm}^2}$

Aluminum:

- ↳ Background: $2.9 \times 10^{-3}\ \frac{\text{cps}}{\text{cm}^2}$

Detector Type

- ↳ Proportional Counter
- ↳ PSD

Connector

- ↳ Vacuum Couplings
- ↳ straight or right angle connector
- ↳ HN, MHV, SHV, Lead wire

Every detector is custom made

NeuAcq® Overview

Introduction and History
System Overview
8-pack Overview
Networking Standards
Communication Protocols

NeuAcq® Overview

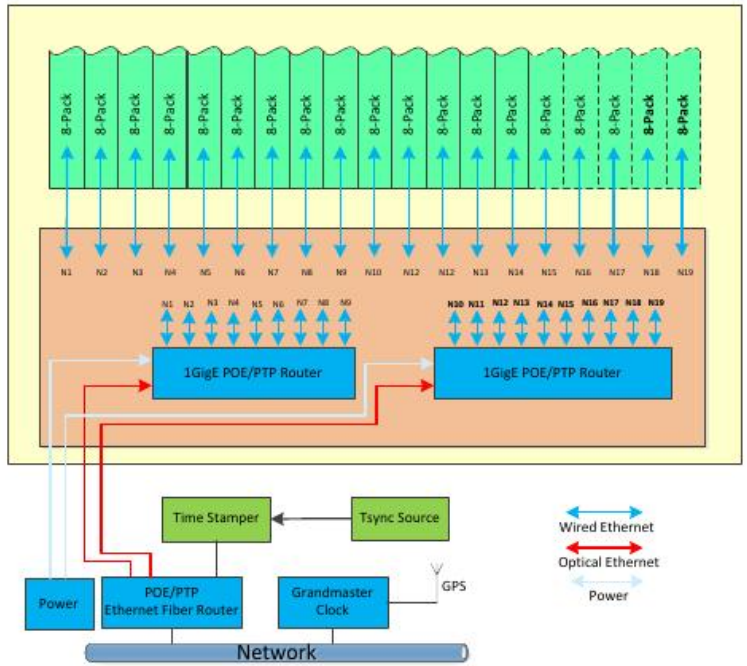
Introduction and History

- 2007 GE's Reuter-Stokes licensed electronics from SNS,
- Based on non-proprietary, existing network standards,
  - ↳ achieve higher data rates,
  - ↳ improved reliability,
  - ↳ significant simplification in the overall system interconnections and cables, and
  - ↳ off the shelf network devices.

NeuAcq® Overview

System Overview

- Fully scalable system and electronics
- blue components ⇒ off-the-shelf
  - ↳ mitigated obsolescence
- Network Routers
  - ↳ IEEE 1588-2008 PTP,
  - ↳ IEEE 802.3af POE,
  - ↳ No. of routers depends on system size.
- Power ⇒ PoE
- Grandmaster clock
  - ↳ time base for the PTP functionality,
  - ↳ typically uses a GPS clock.
- Timestamper
  - ↳ provided by GE,
  - ↳ external synchronization for ToF,
  - ↳ absolute time measurement,
  - ↳ version of the RSPP



imagination at work

NeuAcq® Overview

- $^{3}_{2}$He PSD,
  - ↳ charge division,
  - ↳ various detector lengths, diameter, and sensitivity.
- Decoupling Capacitors,
  - ↳ HV isolation, while passing pulses
- Preamplifiers,
- ADCs,
  - ↳ very fast and highly accurate,
  - ↳ digitizing pulses at 10^7 samples/s.
- Platform Processor,
  - ↳ RSPP ⇒ FPGA and ARM processor.
- Waveform Digitization can compensate:
  - ↳ baseline drift,
  - ↳ detection of multiple pusles, and
  - ↳ γ/neutron discrimination.

NeuAcq® Overview

- POE,
  - ↳ IEEE-802.3.at-2009 (POE+)
  - ↳ up to 25.5 W for 48-44 VDC range,
  - ↳ no need for extra power cable,
  - ↳ power isolated ⇒ minimize ground loop issues
- PTP,
  - ↳ very accurate and stable timestamp over Ethernet,
  - ↳ GPS based grandmaster clock,
  - ↳ absolute time stamping.
- TCP,
  - ↳ all event data,
  - ↳ guaranteed correct data delivery,
  - ↳ tests with 1GB Ethernet $\Rightarrow 6 \times 10^6 \frac{\text{events}}{\text{second}}$,
  - ↳ higher rates could be achieved with faster network.
- UDP.
  - ↳ discover mechanism ⇒ which modules are on network,
  - ↳ could be eliminated with static IP address.

NeuAcq® Overview

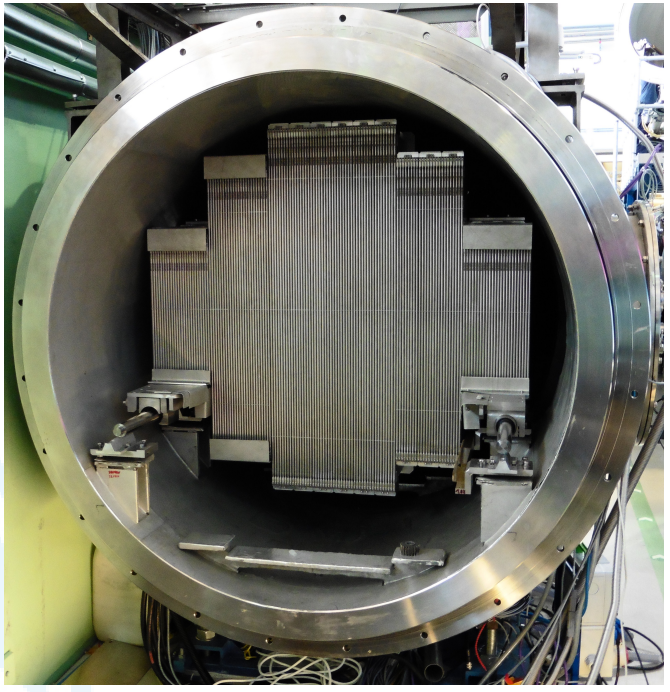
Introduction and History
System Overview
8-pack Overview
Networking Standards
Communication Protocols

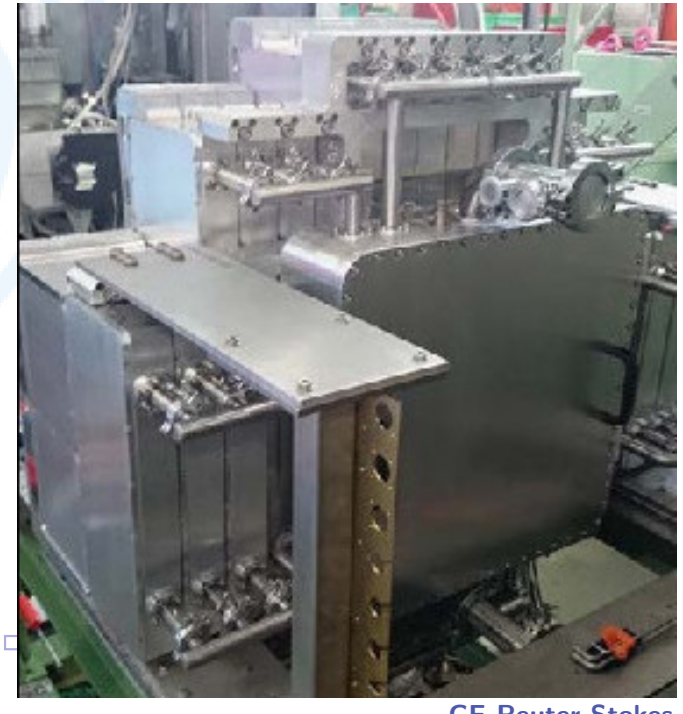
Compatible with:

- EPICS
- ADARA

GE's Reuter-Stokes partnership with JCNS–KWS-2

- Development of Multi-MHz detector array, in partnership with JCNS
  - ↳ 18 × 8-pack of three (3) different length,
  - ↳ 2 × GB routers,
  - ↳ Grandmaster clock,
  - ↳ timestampers, and
  - ↳ mounting frame





http://www.fz-juelich.de/SharedDocs/Meldungen/JCNS/EN/2015/2015-11-06-SANS-2-Detector.html

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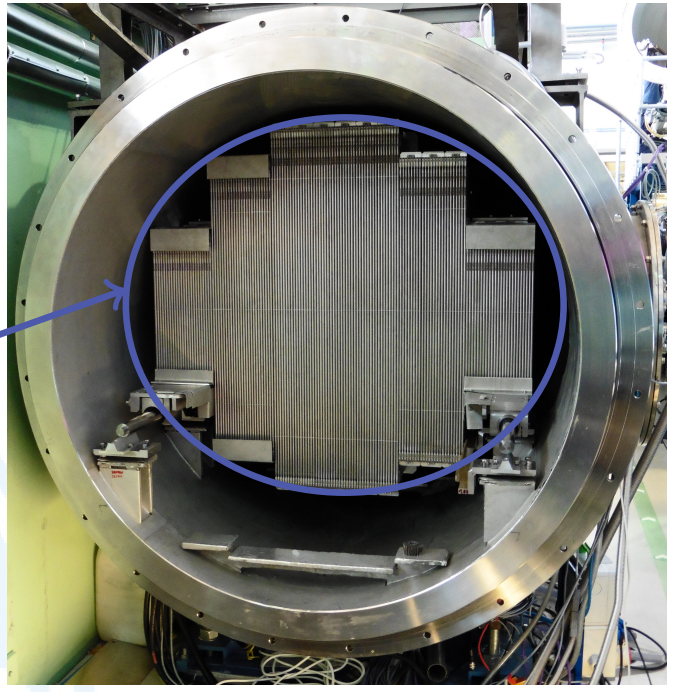

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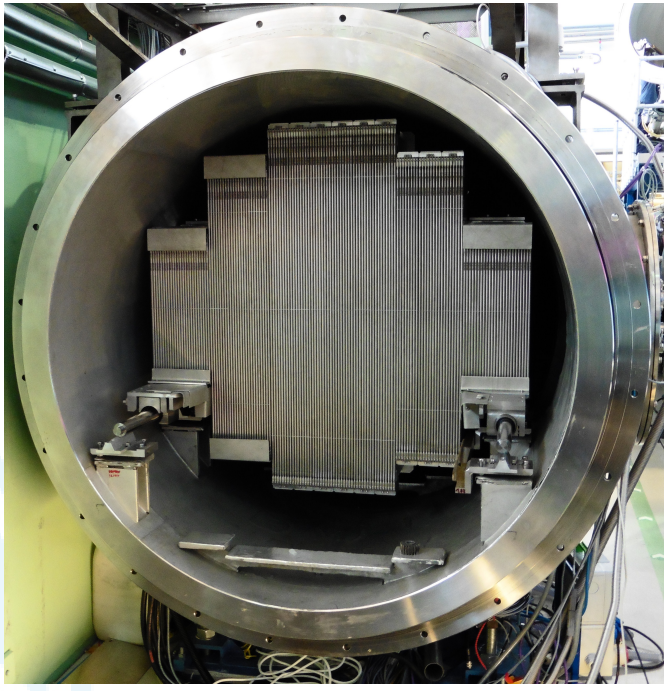
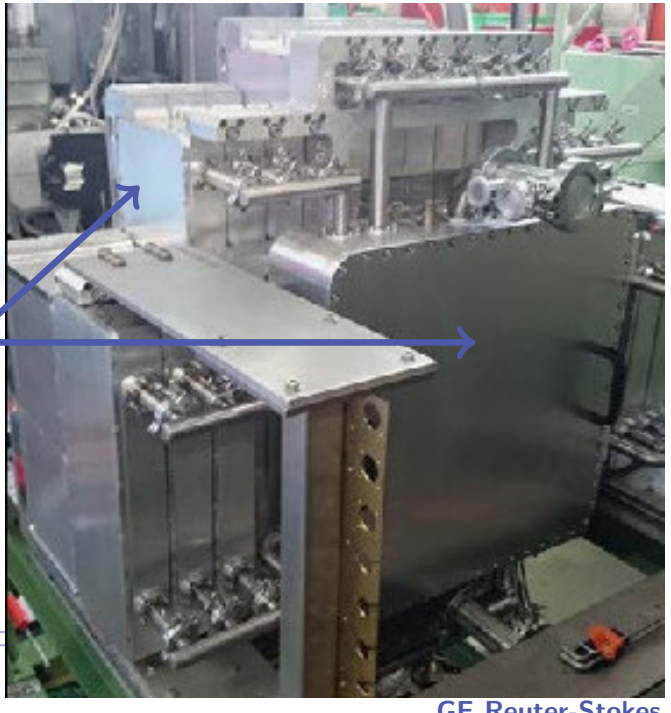
GE's Reuter-Stokes partnership with JCNS–KWS-2

System Characteristics

- 0.9m^2 array of 8mm $^3_2$He detectors
  ↳ $\eta \sim 85\%$ for 5Å
- dead-time constant of 25ns
- count rate as high as 5MHz with 10% dead-time
- $25\times$ improvement compared to old detector

To improve the read-out characteristics and reduce noise, the electronics is mounted in a closed container at the rear of the detector.





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GE's Reuter-Stokes partnership with JCNS–KWS-2

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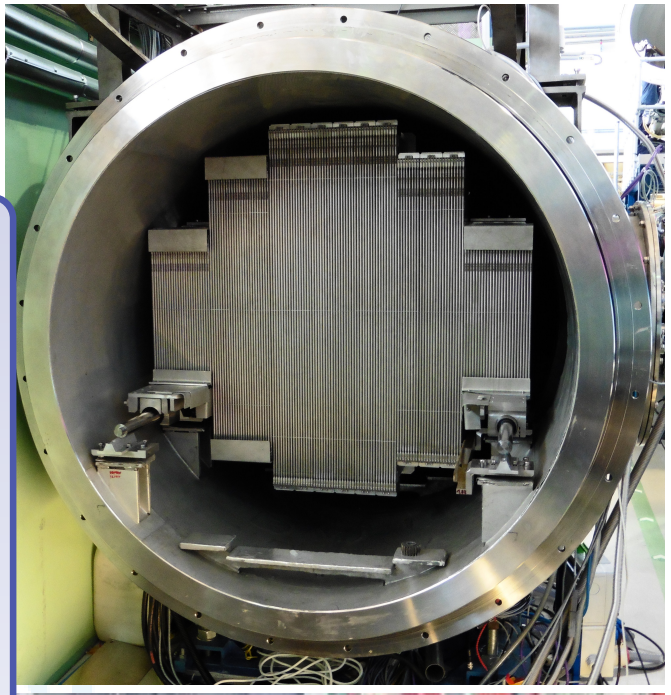
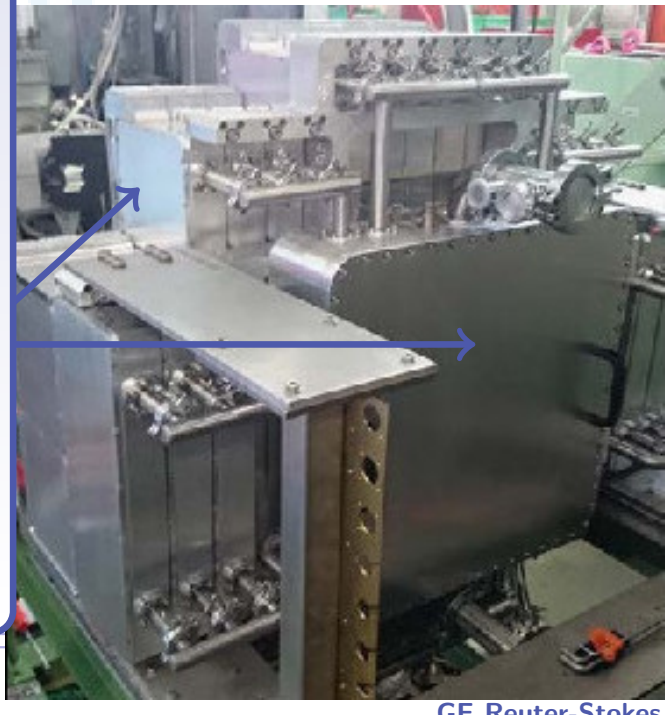
GE Reuter-Stokes measurement solutions

- individual He-3 detectors
- individual B-10 detectors
- individual B-10+ detectors
- detector array, with mounting frame
- NeuAcq® data acquisition electronics

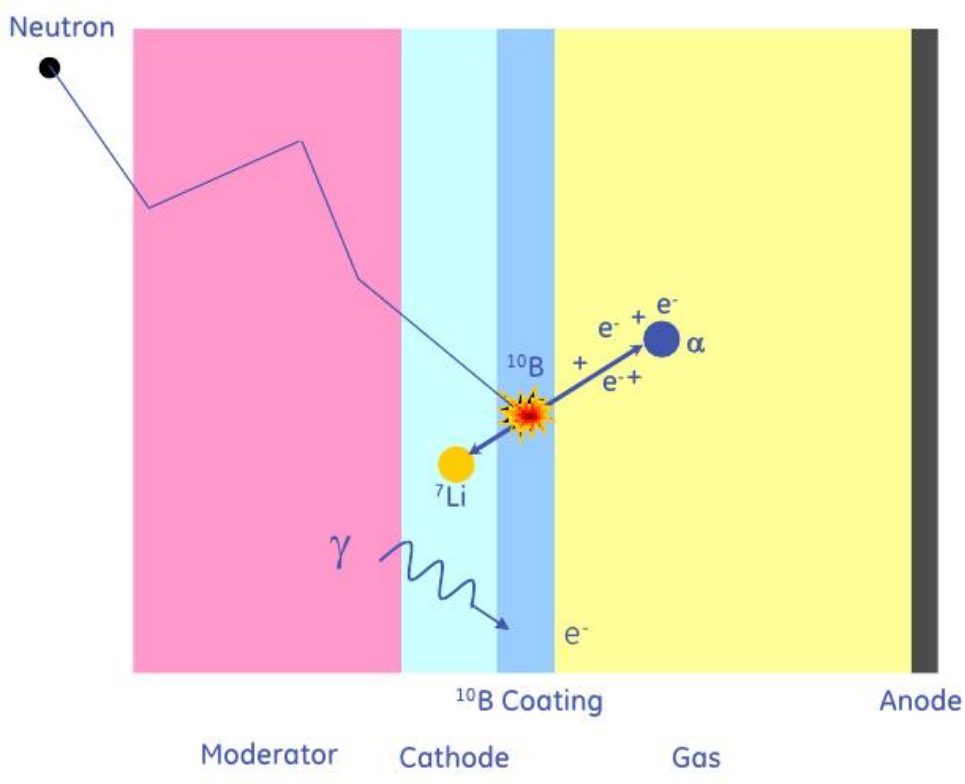
GE's Reuter-Stokes can assist for your measurement solution, from individual detectors to turnkey solutions.





http://www
2015-11-06

$^{10}_{5}$B Detector



$$n + {}^{10}B \rightarrow \alpha + {}^{7}Li(4\%)$$

$$n + {}^{10}B \rightarrow \alpha + {}^{7}Li^{*}(96\%) + 0.49\,\text{MeV}$$

$$\sigma = 3840\text{barns} \; @ \; 0.025\,\text{eV}$$

Detector: Construction similar to ^{3}He

- Metallic outer housing
- Small diameter anode
- Proportional fill gas
- Welded and brazed construction

$^{10}_{5}$B Lining: organic formulation

- Thin layer on internal shell
- Optimize coating thickness
- Use boron enriched in $^{10}_{5}$B isotope

Operation: new design

- Same physics principles as $^{3}_{2}$He
- Charge sensitive electronics
- Well defined spectrum
- Validated through use in nuclear reactor instrumentation

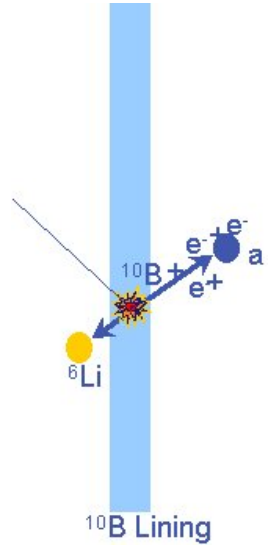
$^{10}_{5}$B Detector

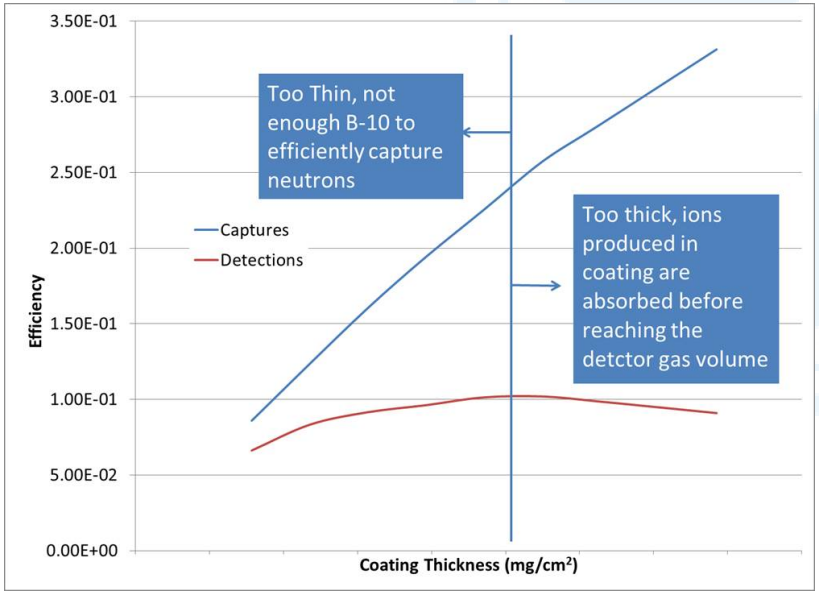
$^{10}_{5}$B Coating Optimization

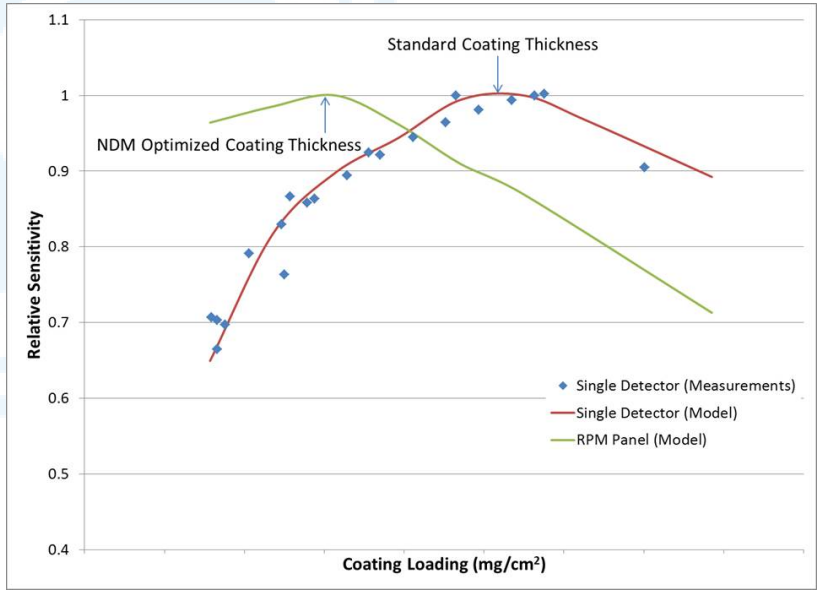
Thickness: optimize neutron counting

Too thin: fewer neutron reactions/higher probability of reaction products escaping into detector volume

Too thick: more neutron reactions/reaction products absorbed in lining





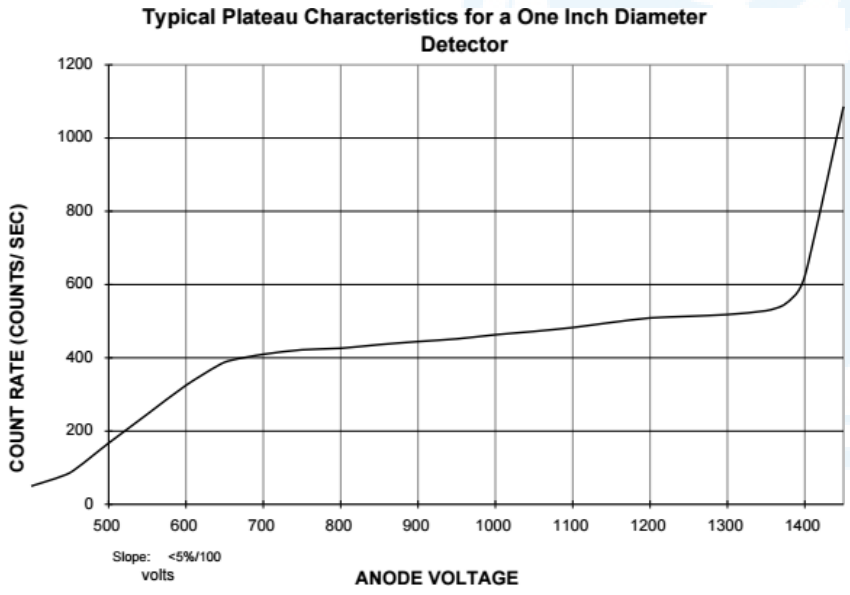


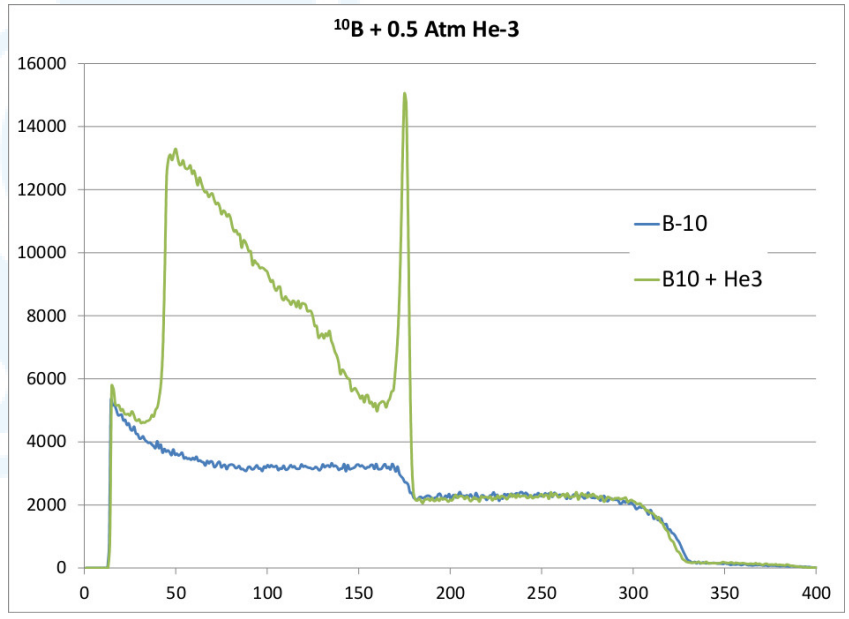
B10Plus+® Neutron Detector

How does it work?

B10Plus+® is :

GERS $^{10}_{5}$B lined proportional counter incorporates a small amount of $^{3}_{2}$He = boost neutron sensitivity





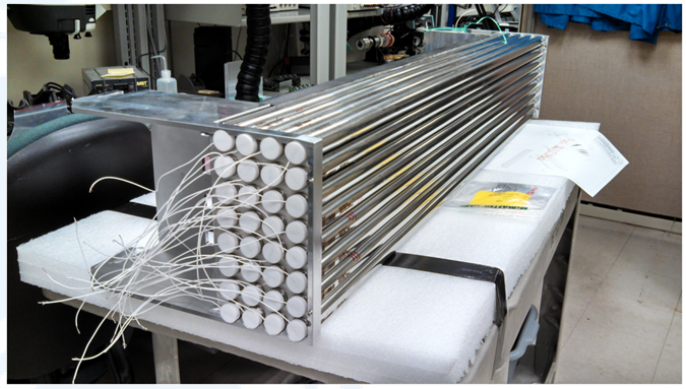
B10Plus+ “Superpack”

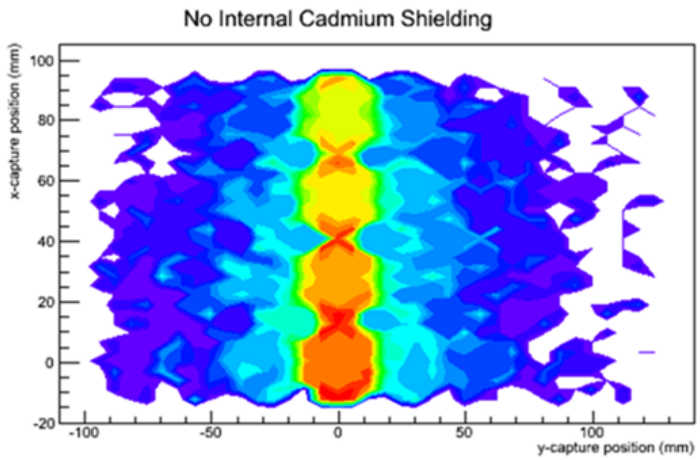
B-10 lined detector + $\frac{1}{2}$atm ^{3}He

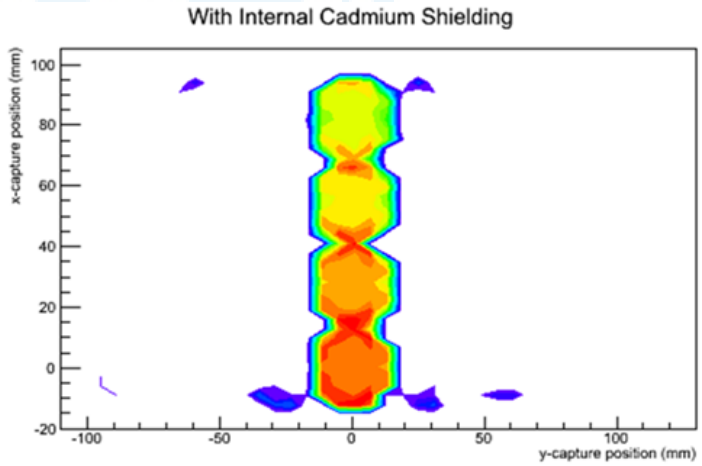
4 rows deep

Optimized design using GEANT4

- ↳ Coating thickness
- ↳ Gas fill composition
- ↳ Inter-column shielding







45.4% absolute efficiency (PuBe source, 25 mm collimator) equivalent to 3 atm He-3 8-pack

GERS outlook

Gamma Scintillator Packages for downhole operation

$CeBr_3$ crystals

NeuAcq® upgrade

↳ higher count rate capability

↳ more channels per plateform processor ⇒ cheaper system

change in GE philosophy

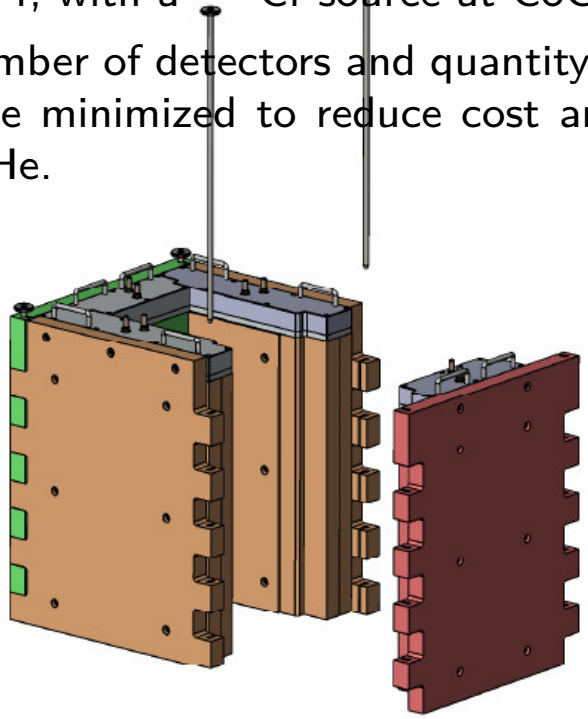
↳ possibility to lease larger system from GE's Reuter-Stokes

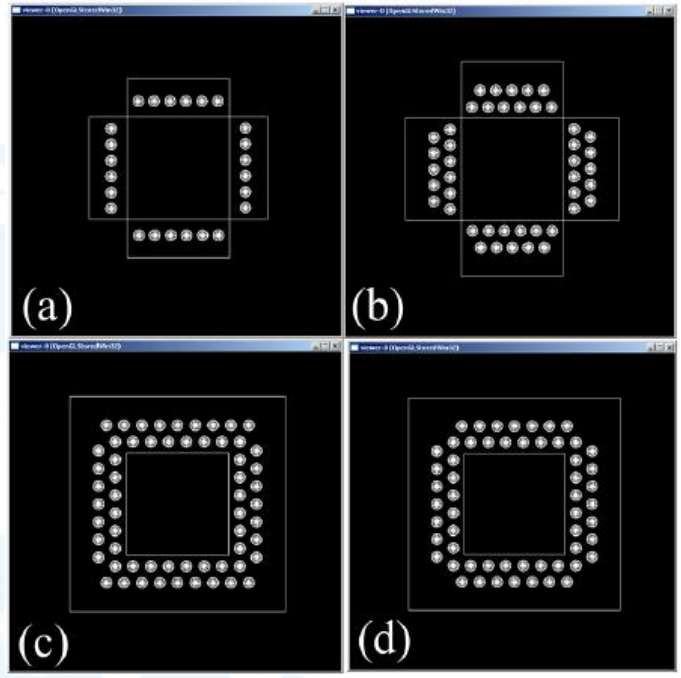
GE's Reuter-Stokes recognizes the need for better position resolution in scattering detector arrays

Neutron Coincidence Counter

B10Plus+® UNCL

- Four footprints were considered,
- Cavity dimensions configured for PWR fuel rod bundles ($23.4cm \times 23.4cm$).
- 85 configurations were simulated using GEANT4, with a ^{252}Cf source at CoG,
- The number of detectors and quantity of $^{3}_{2}$He gas were minimized to reduce cost and conserve $^{3}_{2}$He.





(a) existing UNCL design.

(b) based on the UNCL, with up to 2 additional rows of detectors.

(c) and (d) are designed to maximize the number of detectors nearest the cavity.

Neu

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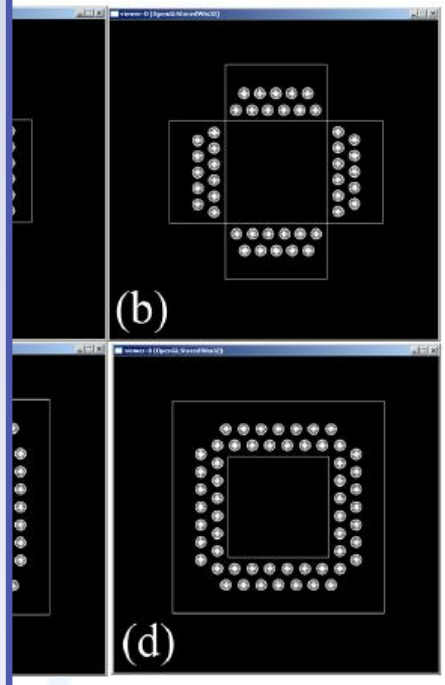
Variables in GEANT4 simulations

- Detector diameter
  - ↳ 25 mm – 28.6 mm
  - ↳ **25mm**
- Moderator thickness
  - ↳ 9 mm – 14 mm
  - ↳ **14mm**
- Thickness of moderator in front of first row
  - ↳ 6.35 mm – 19.1 mm
  - ↳ **12.7mm**
- Thickness of moderator between rows
  - ↳ 6.35 mm – 12.7 mm
  - ↳ **12.7mm**
- Active length
  - ↳ 14 inch – 24 inch
  - ↳ **18 inch**
- $^{3}_{2}$He partial pressure
  - ↳ 0 atm – 1 atm
  - ↳ 0.5 atm (inner row), 0.25 atm (outer row), 4.9 litres total
- $^{10}_{5}$B coating loading
  - ↳ 0.1 mg/cm^2 – 0.55 mg/cm^2
  - ↳ **0.24 mg/cm^2**



UNCL design.

on the UNCL, with
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are designed to max-
number of detectors
cavity.

GE imagination at work