



detect and identify

Measurement of Tritium in Helium

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**22nd Annual Air Monitoring Users Group (AMUG) Meeting
Palace Station Hotel, Las Vegas, Nevada, USA, 5th May 2010**

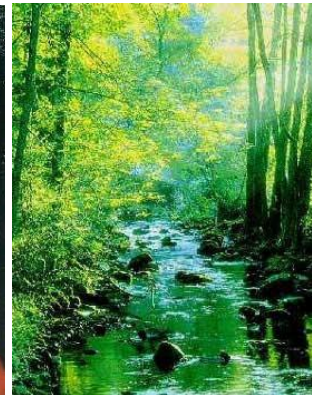
Overview

- ▶ Introduction
- ▶ New Physics at CERN
 - ▶ Large Hadron Collider LHC
 - ▶ Cryogenic System
- ▶ Tritium in Helium Measurement
 - ▶ Concept
 - ▶ Monitor Berthold LB110
 - ▶ Calibration
 - ▶ Minimum Detectable Activity Concentrations
 - ▶ Regulations



Berthold Technologies in Bad Wildbad

- ▶ German Manufacturer of instruments for
 - ▶ Industrial Process Control
 - ▶ Bioanalytics
 - ▶ Radiation Protection
- ▶ Nicely located in the Black Forest (close to Karlsruhe)
- ▶ Since more than 60 years reliable products
MADE IN GERMANY



Large Hadron Collider at CERN Geneva

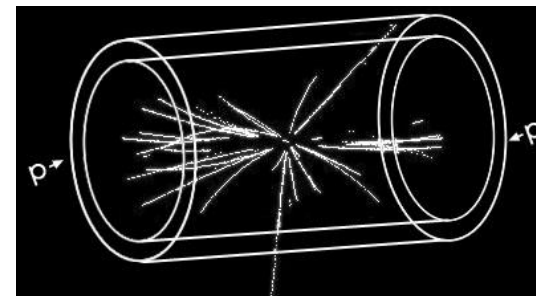
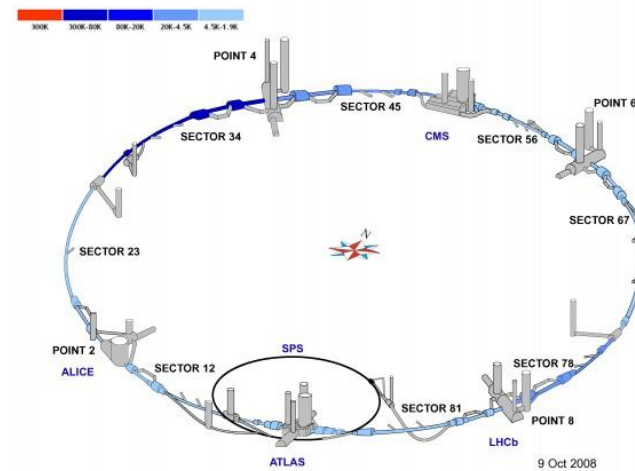
- ▶ LHC was designed to collide two counter rotating beams of protons or heavy ions
- ▶ p-p collisions at 7 TeV/per beam
- ▶ 1232 supraconducting dipoles on 27 km circumference
- ▶ 1st operation started in September 2008





Detectors at the Large Hadron Collider

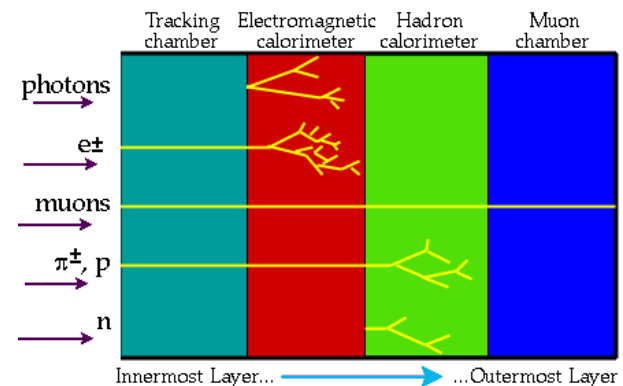
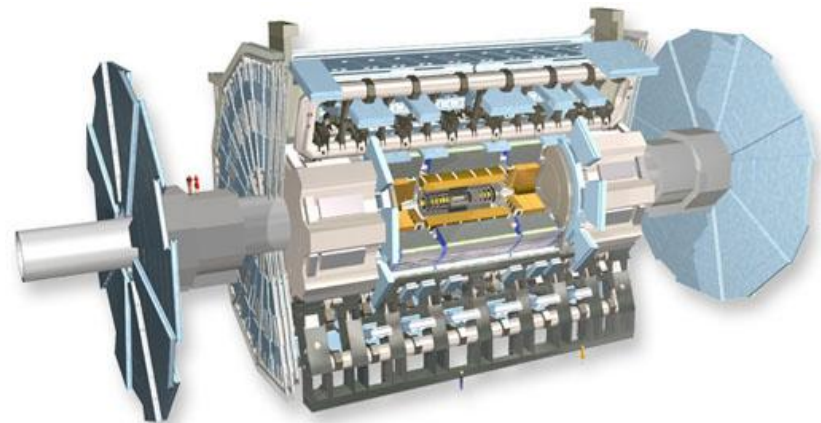
- ▶ ALICE (Heavy Ion Physics)
- ▶ ATLAS (Higgs-Particle)
- ▶ CMS (Calorimeter for γ high E)
- ▶ LHCb (CP-Violation)





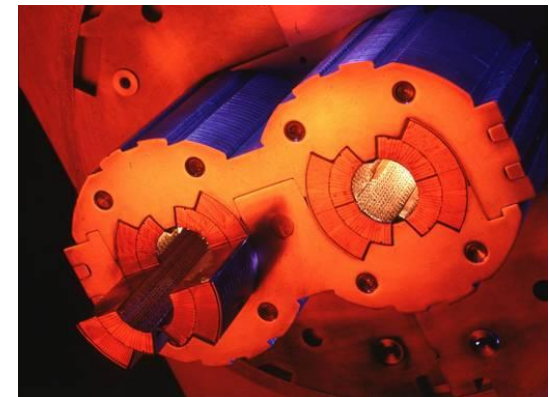
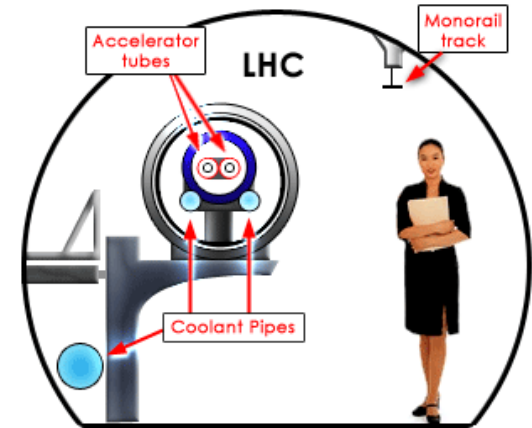
ATLAS Detector at the LHC

- ▶ General purpose detector
 - 46 x 25 x 25 m³ (L x W x H)
 - 7000 tons weight
- ▶ Detector components
 - ▶ Inner tracker (semiconductor pixel, silicon microstrip, straws)
 - ▶ Calorimeter (sensors liquid argon & plastic scint in metal plates)
 - ▶ Muon Spectrometer (large straws)
 - ▶ Magnet System
 - ▶ Trigger System
 - ▶ Data Acquisition System
 - ▶ Computing System
- ▶ 1700 scientists from 159 institutes in 37 countries



Magnets at LHC

- ▶ 1232 Superconducting dipole magnets
- ▶ cooled down to 1.9°K (liquid helium)
- ▶ 11.700 Ampere
- ▶ 8.4 Tesla
- ▶ Length: 14.3 m
- ▶ Weight: 35 tons
- ▶ Cost: 0.5 Mio. CHF

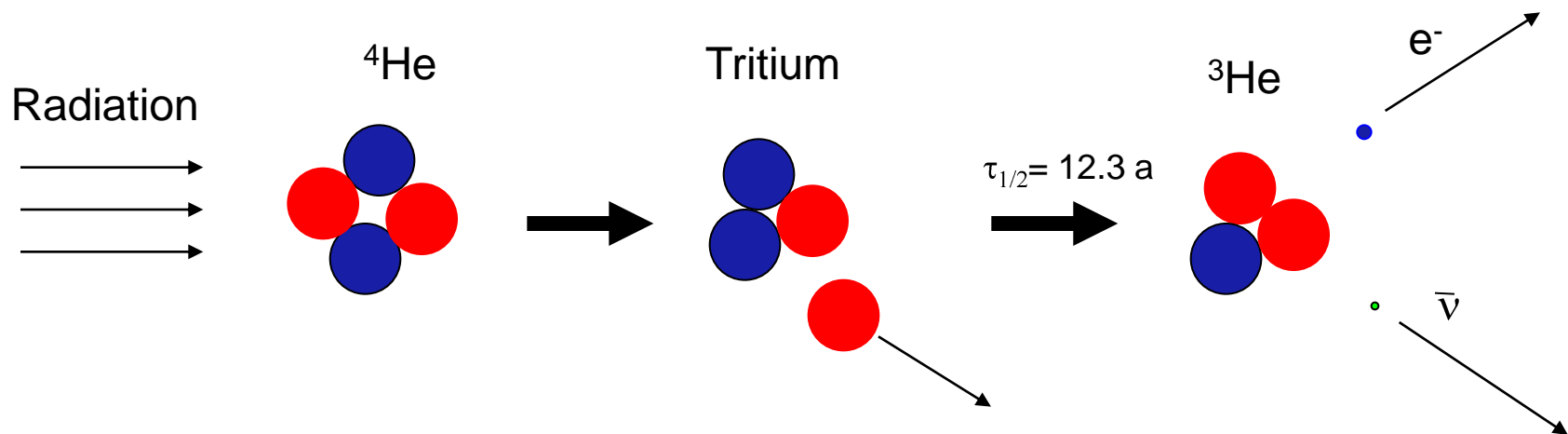




Helium Cooling System

- ▶ Total mass of helium in operating conditions
 - ▶ 15 tons per sector
 - ▶ 120 tons total in the eight LHC sectors
- ▶ Helium storage capacity
 - ▶ 27 tons liquid in helium dewars
 - ▶ 50 tons gaseous at ambient temperature
- ▶ Liquid helium from the CERN liquid storage is taken by external suppliers and returned to CERN on request
- ▶ The helium shall not be contaminated with radionuclides exceeding exemption / clearance levels

Production & Decay of Tritium in Helium



Estimated total annual Tritium activation: 3.7 GBq

Tritium Monitor LB 110 (P10)



- ▶ Proportional counter (1.3 liter)
- ▶ 1 : 4 mixing ratio air/counting gas P10
- ▶ 0.260 liter sensitive volume
- ▶ 1.25 liter/min flow
- ▶ Tritium counting efficiency 55%
- ▶ Calibration factor
7 kBq/m³ per cps
- ▶ Background rate in tritium
channel 1 to 3 cps
- ▶ Risetime discrimination against
external gamma radiation

Tritium Monitor LB 110 (P10)

▶ Minimum detectable activities

- ▶ 5400 Bq/m³ within 30 s
- ▶ 3800 Bq/m³ within 60 s
- ▶ 1200 Bq/m³ within 10 min
- ▶ 500 Bq/m³ within 1 h
- ▶ 100 Bq/m³ within 24 h

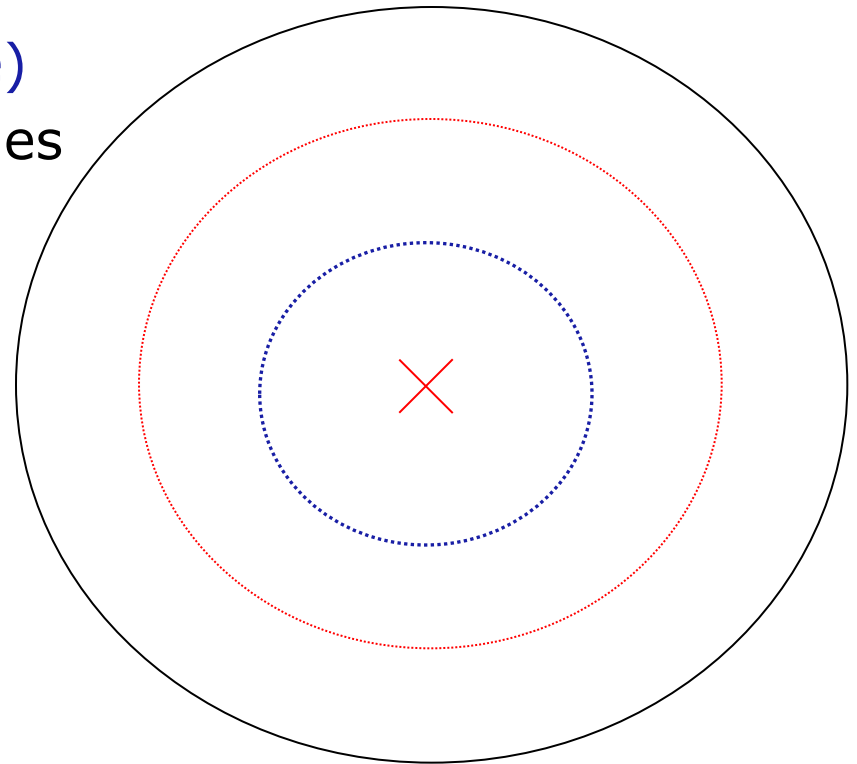
▶ Spillover

- ▶ 5% – 7% for ¹³⁷Cs
- ▶ 3% – 5% for ⁸⁵Kr
- ▶ 23% – 25% for ¹⁴C



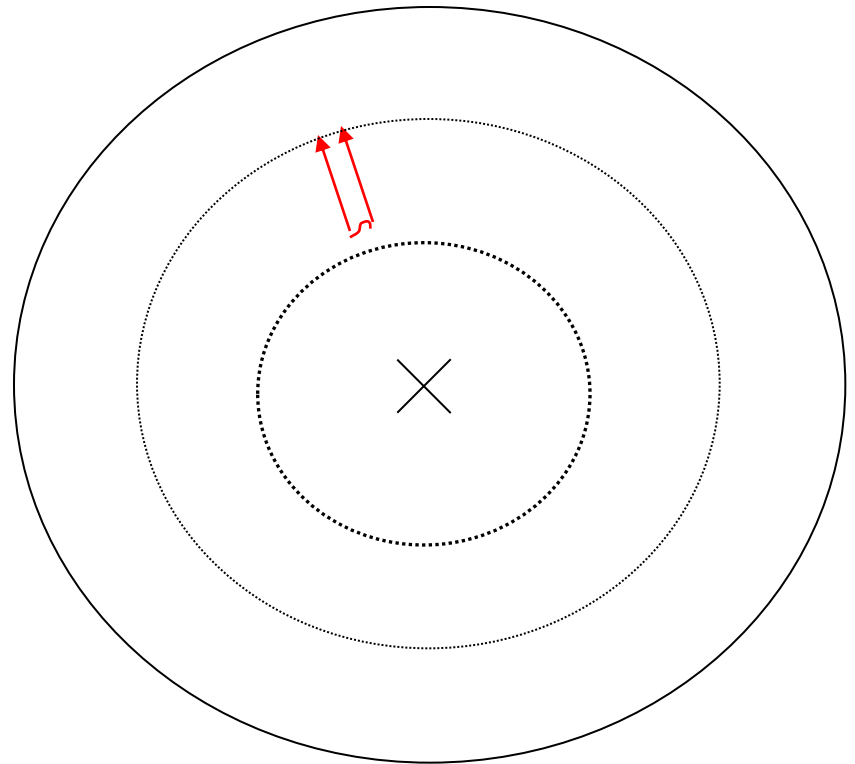
Design of Tritium Monitor LB 110

- ▶ Proportional counter tube
- ▶ Detector housing (cathode)
- ▶ Principal layout of electrodes
 - ▶ Outer anode plane (20 wires)
 - ▶ Inner cathode plane (40 rods)
 - ▶ central anode wire
- ▶ HV on anodes, virtual ground on cathodes, anode readout



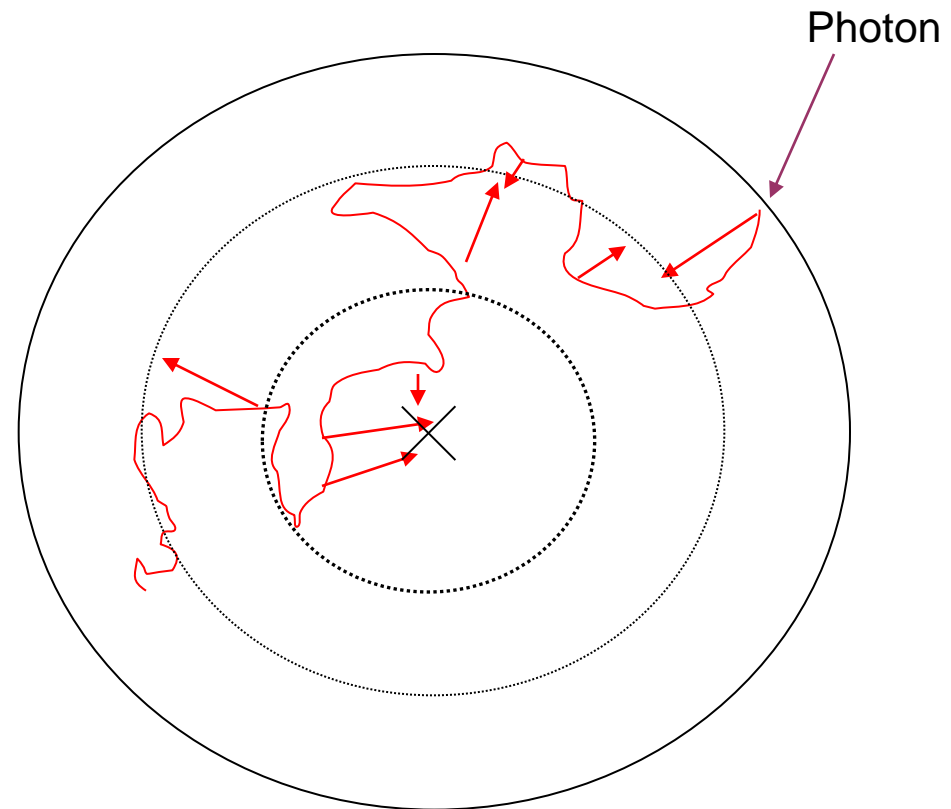
Primary Ionization Tritium Event

- ▶ Track of a low energy beta particle from a tritium decay
- ▶ Primary ionization along the track
- ▶ Primary electrons are drifting towards anode wires
- ▶ Drift ranges are approximately equal
- ▶ All charges are arriving at nearly the same time
- ▶ Fast rise time of signal



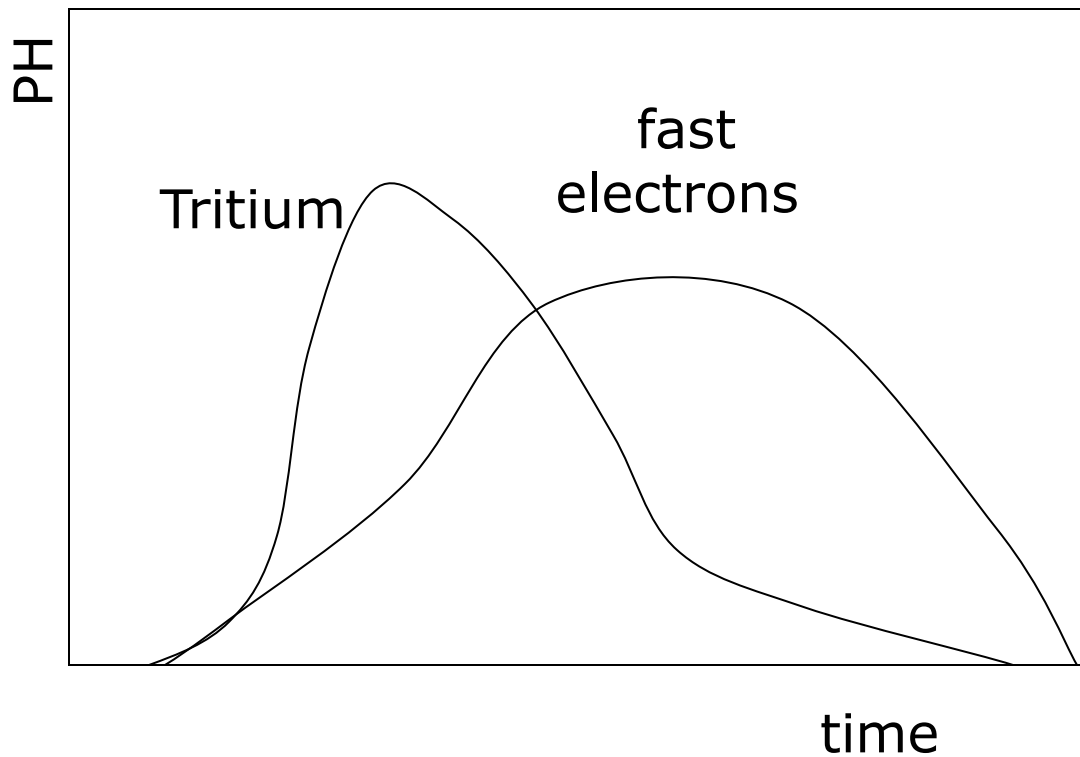
Primary Ionisation Cs-137 Event

- ▶ Track of a fast electron in the detector volume
- ▶ Primary ionization along the track
- ▶ Primary electrons are drifting towards anode wires
- ▶ Drift distances are very different
- ▶ There are very short and very long drift times
- ▶ Slow rise time of the signal



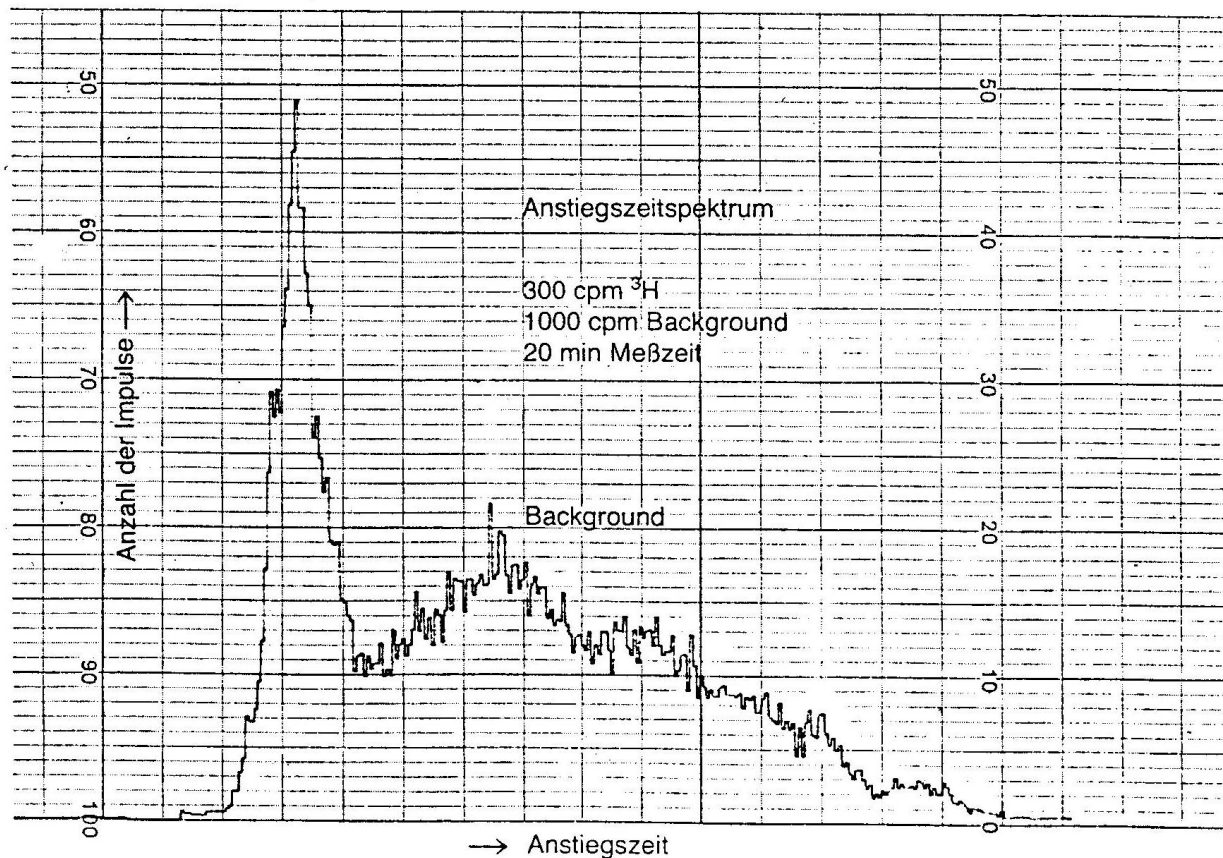


Tritium Rise Time Discrimination





Rise times of anode signals



National Physical Laboratory - NPL

- ▶ National Metrological Institute of the UK
- ▶ one of the UK's leading science & research facilities
- ▶ a world-leading centre of excellence in developing and applying the most accurate standards, science and technology available
- ▶ Ionising radiation science areas
 - ▶ Dosimetry
 - ▶ Neutron Metrology
 - ▶ Radioactivity



Tritium in Helium Calibration Procedure

- ▶ LB 110 attached to NPL tritium calibration rig
- ▶ Monitor and rig were pre-filled and gases mixed
 - ▶ Helium at a nominal pressure 33.3 kPa
 - ▶ P10 gas (90% Argon, 10% Methane) was then admitted to the system until pressure reached a nominal 100.7 kPa
- ▶ A vessel previously filled with standardised tritium in hydrogen was opened to the rig
- ▶ The tritium gas had been previously standardised in a manner traceable to national standards of radioactivity
- ▶ the gases were then mixed using the rig circulation pump until homogeneity was achieved



Tritium in Helium Calibration Procedure

- ▶ The addition of tritiated hydrogen made no significant difference to the overall pressure within the system
- ▶ The monitor's gas mixing equipment was not used during the calibration procedure
- ▶ The monitor's response to tritium in this atmosphere was recorded
- ▶ The tritium activity concentrations are expressed as the total activity of tritium divided by the total volume of hydrogen and helium in the rig
- ▶ The reported uncertainties are based on standard uncertainties multiplied by a coverage factor $k=2$, which provides a level of confidence of approximately 95%

Tritium in Helium Calibration



- ▶ Tritium calibration performed by Hilary Philipps / NPL & Alfred Klett Nov. 18-19 and Nov. 24-25, 2009
- ▶ NPL calibration rig (on the right)
- ▶ Berthold Tritium Monitor LB 110 (on the left)



The Monitor under Calibration



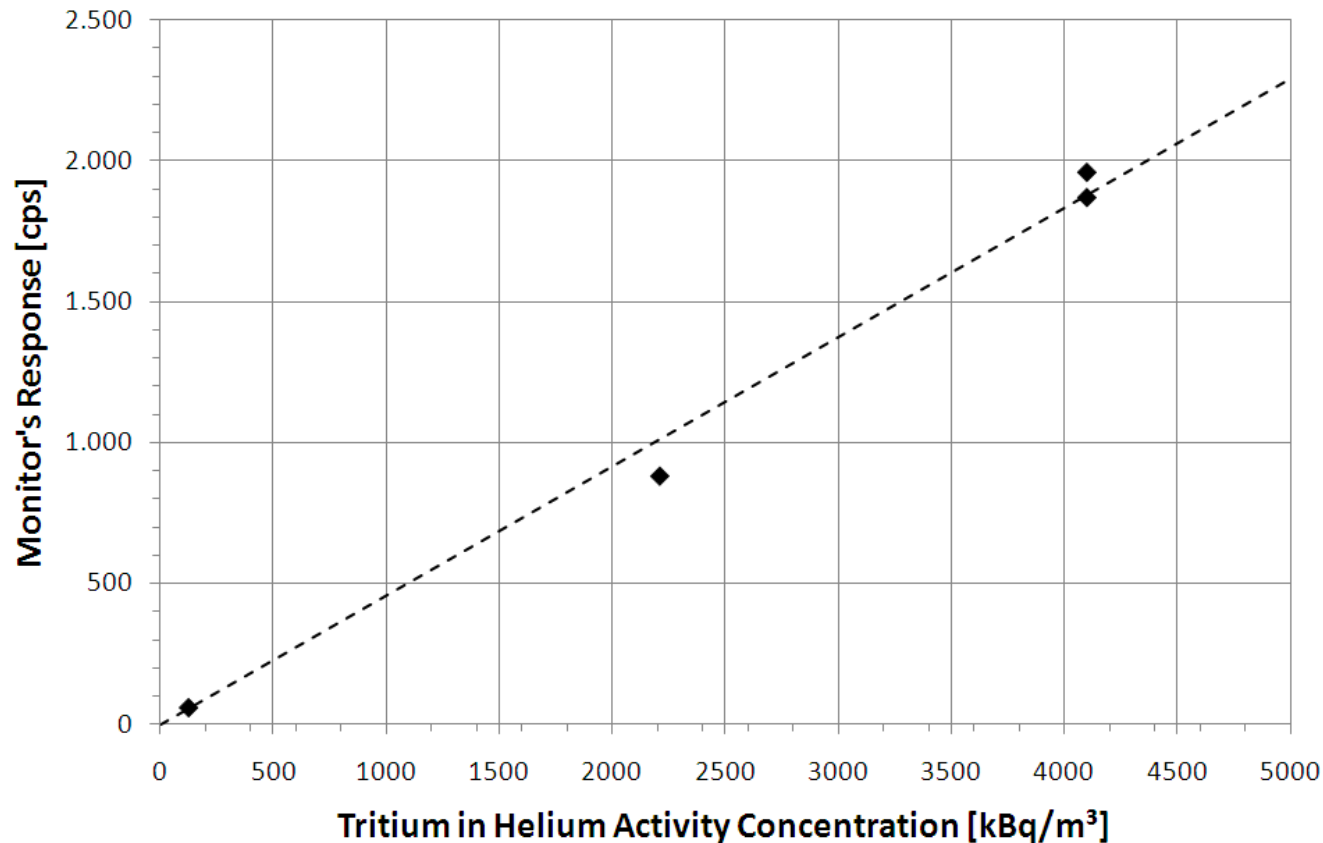


NPL Calibration Rig

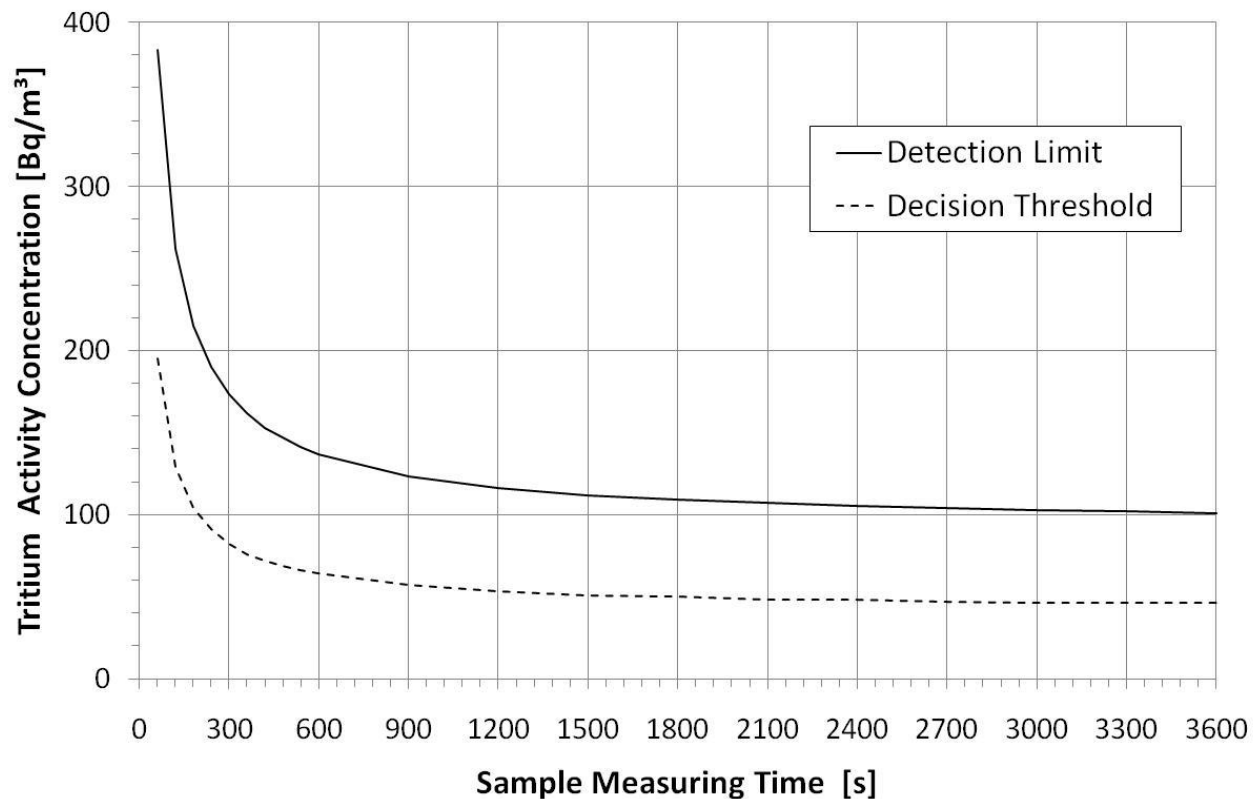




Tritium in Helium Calibration Results



MDA & Decision Threshold



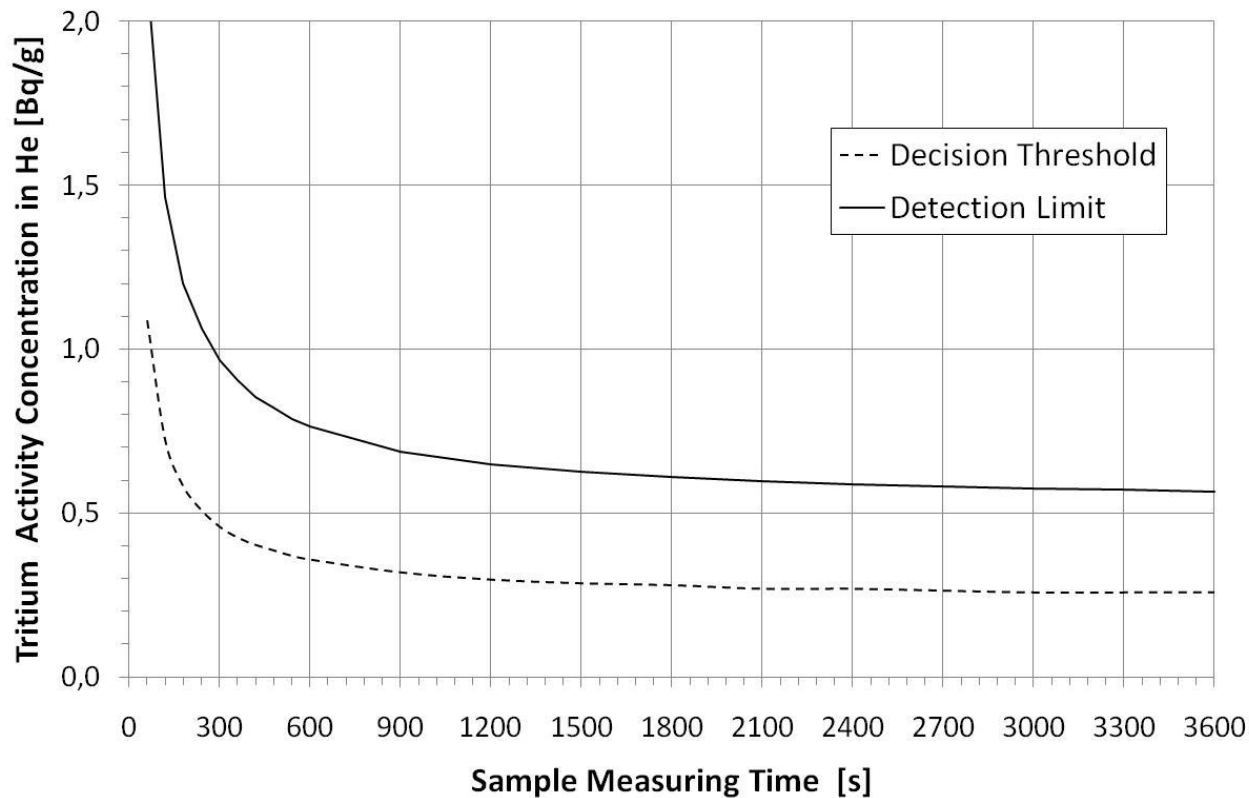
calculated according
to ISO 11929-1:2000

600 s measuring time
background

5% error probability
for errors of the 1st
and 2nd type



MDA & Decision Threshold



calculated according to ISO 11929-1:2000

600 s measuring time background

5% error probability for errors of the 1st and 2nd type

Tritium in Helium Calibration Summary

Quantity	Value	Unit
Monitor's Response to Tritium	0,458	cps / (kBq/m ³)
Calibration Factor	2,18	kBq/m ³ per cps
Background Counting Rate	0.78	cps
Minimum Detectable Activities with $T_{\text{bgd}} = T_{\text{sample}} = 600\text{s}$		
MDA Volumetric Activity Concentration	137	Bq/m ³
MDA Mass Activity Concentration	0,7	Bq/g

Tritium Regulations

- ▶ IAEA Safety Guide No. RS-G-1.7 100 Bq/g
- ▶ CERN's clearance & exemption limits
 - ▶ activity concentration 200 Bq/g
 - ▶ total activity release 200 kBq
- ▶ Germany's tritium limits
 - ▶ exemption 1000 kBq/g
 - ▶ clearance 1000 Bq/g



References

- 1) Operating Manual Tritium Monitor LB 110
Berthold Technologies Ident. No.: 80872 BA2, Rev. 02, May 20, 2009
- 2) National Physical Laboratory NPL, Calibration Certificate, Berthold Type LB 110
S/N 6010, Reference: 2009100203 , February 10, 2010, Teddington, UK
- 3) IAEA, Application of the Concepts of Exclusion, Exemption and Clearance
IAEA Safety Guide No. RS-G-1.7, Vienna, Austria, August 2004