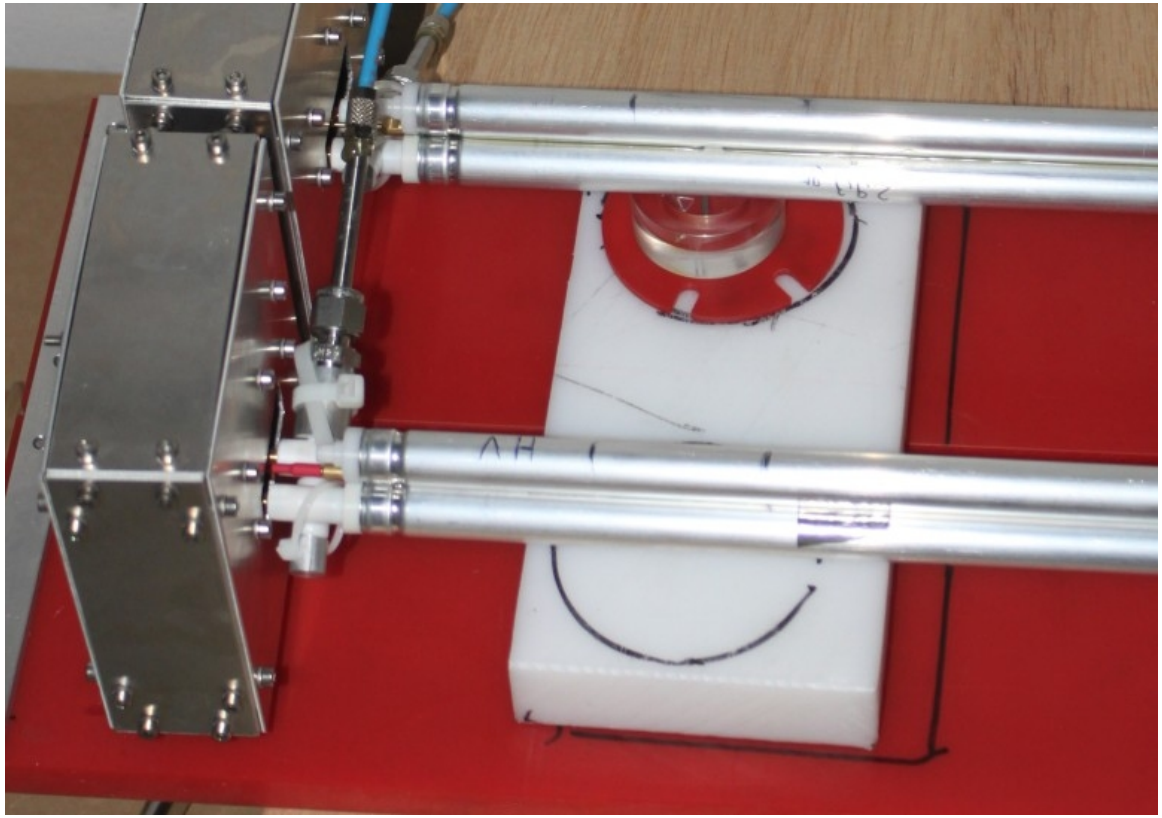
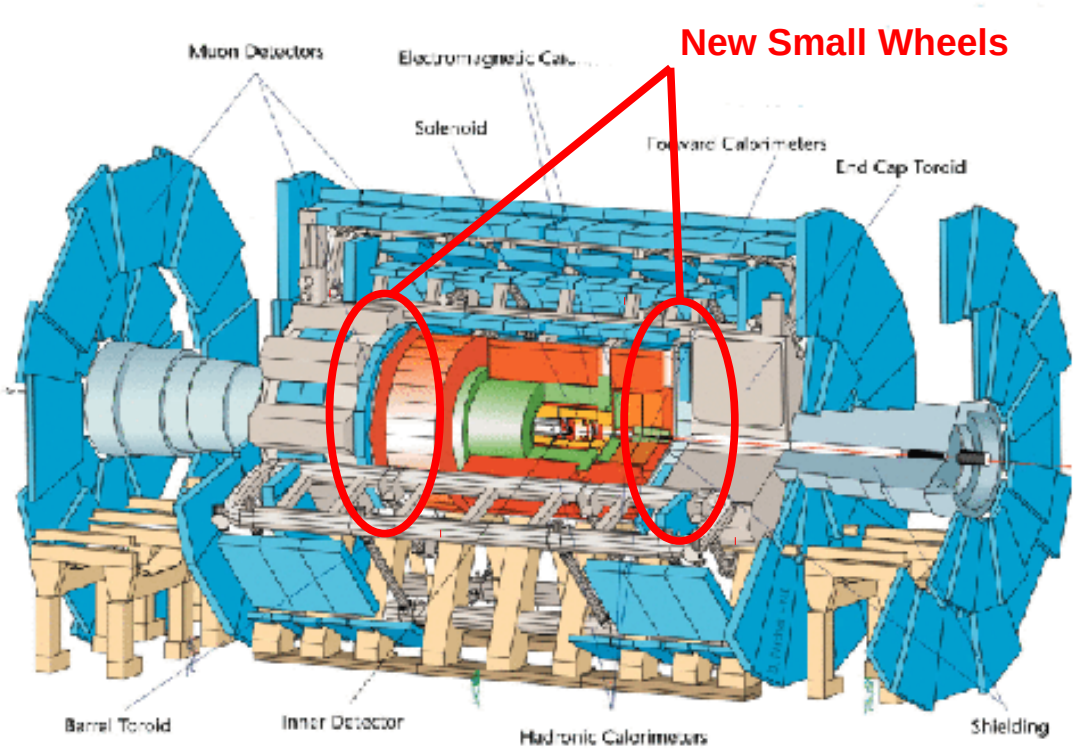
Long Term Irradiation Study of sMDT Drift Tubes Using Beta-Electrons From a Sr90 Source Accumulating 60 C Per Wire

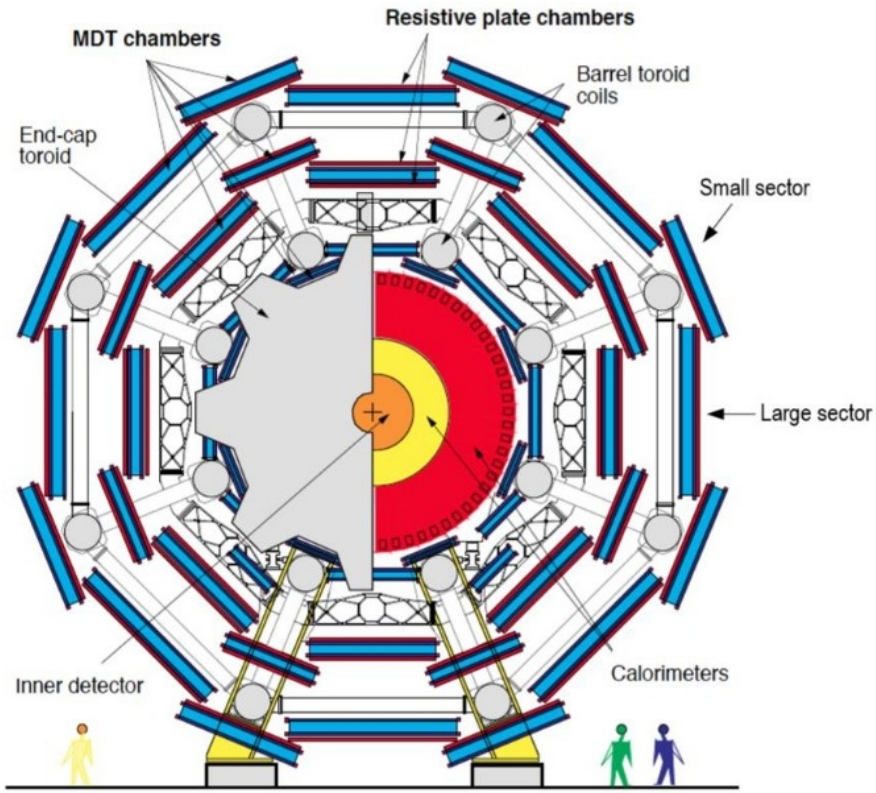


3rd International Conference on
Detector Stability and Aging Phenomena in Gaseous Detectors
CERN, 8. Nov. 2023

Ralf Hertenberger, LMU München for MPI-LMU collaboration

ATLAS MDT Drift Tubes D = 30 mm: Precision Muon Tracking





old new

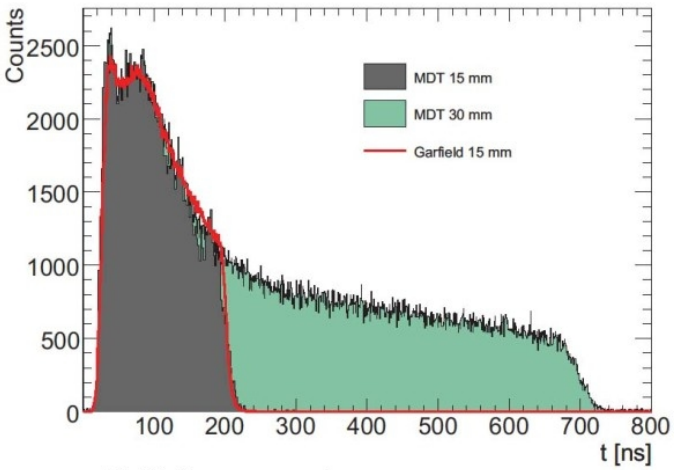
MDT D=30mm

sMDT D=15mm

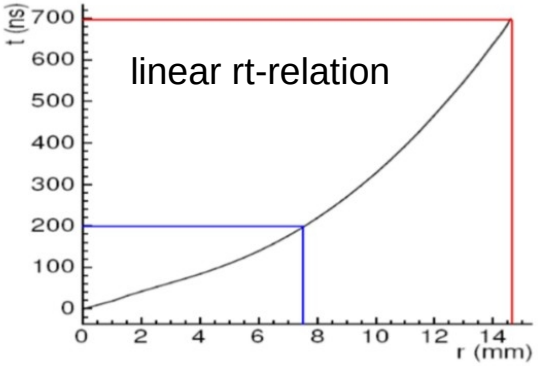
MDT 30 mm: Monitored Drift Tube chambers are used for precision tracking in the ATLAS muon system

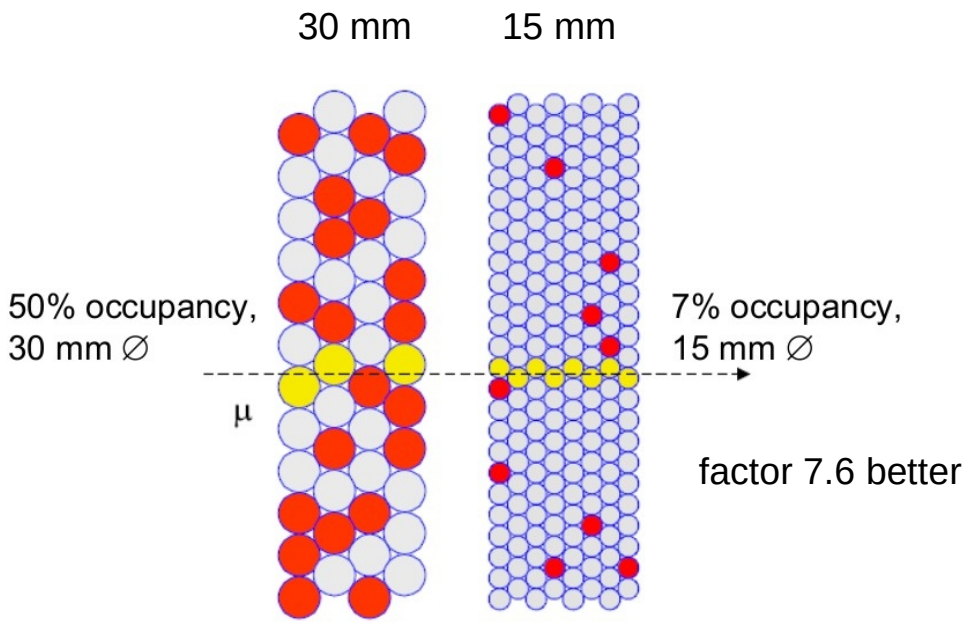
2010: proposal to build NSWs from sMDT for HL-LHC: 7.5 x 10^{34} 1/cm^2 s
Ar:CO2 93:7 3 bar
2730 V GG: 20000

Basic Idea of Improvement: Drift Tubes D=15mm <-> D=30mm



Drift time spectra





occupancy improvement:

3.8 x shorter drift-time
2 x smaller cross section

=> 7.6 x reduction

less gain loss by space charge:

8.7 x smaller gain loss

=> new long term stability test using ^{90}Sr with Q_{acq} > 6 C/cm

Observed Ageing Phenomena at ATLAS MDT Drift Tubes D=3cm

Freiburg group (LS Herten):

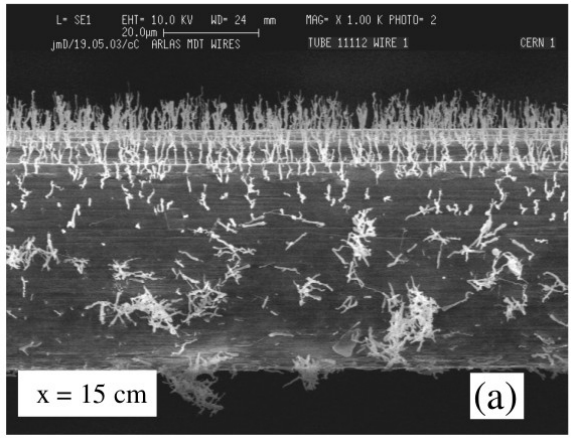
M. Kollefrath **NIM A 419 (1998) p351**

Ar:**CH4**:N2	91:**5**:4 Vol%	aging after **80 mC/cm** hydro-carbonic deposits on the anode wire steady deterioration of detector performance
Ar:**CH4:**N2**:**CO2	94:**3**:2:1 Vol%	no reduction in performance up to **0.6 C/cm** with water or ethanol addition
Ar:CO2	80:20 Vol%	no ageing observed up to **0.6 C/cm**

S. Zimmermann PHD Thesis 2004

ageing introduced by **silicone pollution** in the drift gas
the anode wire acts as pollution filter
the silicone is trapped **within the first 50 cm** of the anode wire
=>build-up of **whiskers**

no aging using clean **Ar:CO2 93:7 Vol%**
=> requirement: no pollutions !



Investigated Ar:CO2 Gas Mixtures for ATLAS MDT Drift Tubes of D=3cm

1998 - 2004

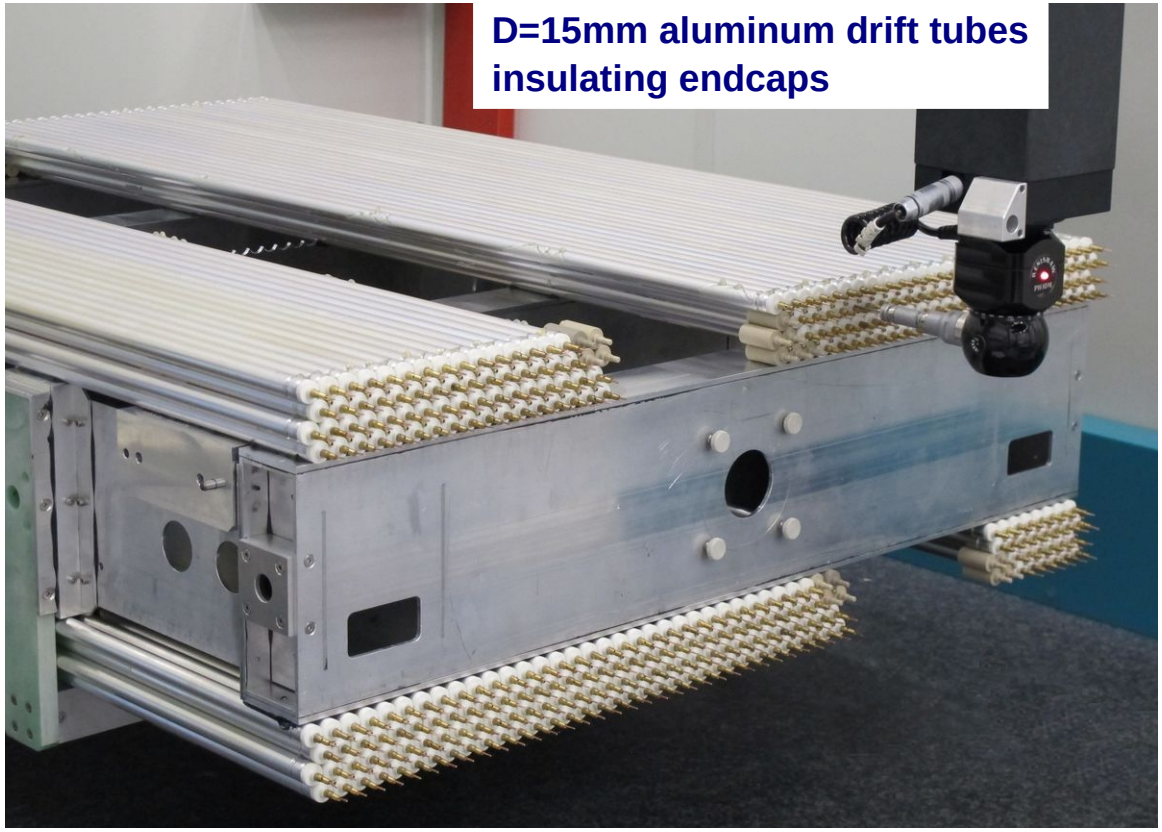
no aging of 3 cm MDT tubes was observed using **Ar:CO2** gas mixtures
93:7 Vol% and
80:20 Vol%
at accumulated charges up to few C/cm
legacy requirement for ATLAS: **0.6 C/cm** (2000)

the requirement for the inner radius of the New Small Wheel (2010)
was a **factor 10 higher** (HL-LHC)

this drove the new study of the Ar:CO2 gas mixture
Ar:CO2 93:7 Vol%
to a factor 10 higher accumulated charges: **6 C/cm**

ATLAS sMDT Muon-Drift-Chamber

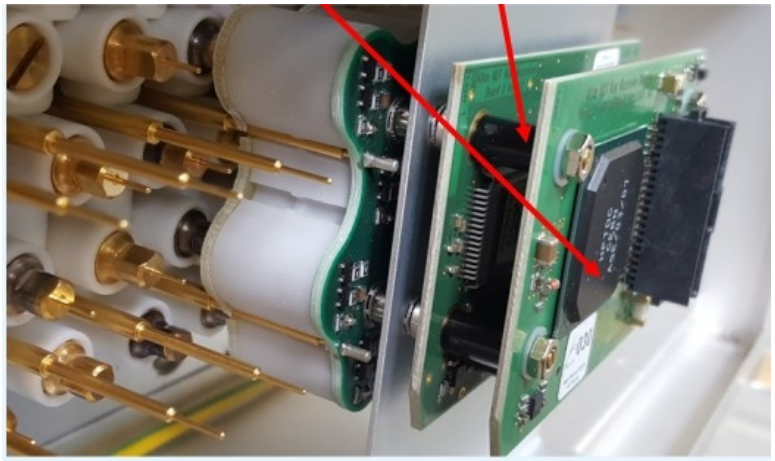
no aging is expected from the material cocktail

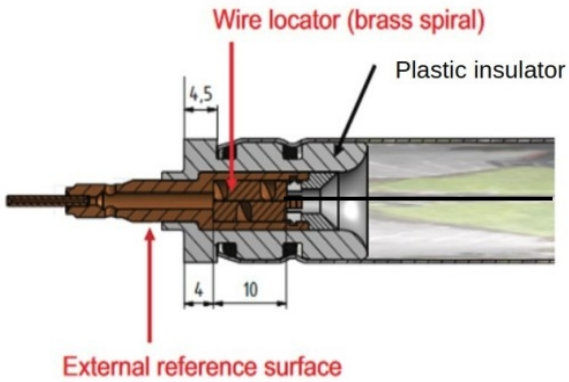


D=15mm aluminum drift tubes
insulating endcaps

gas inlet distri-bution

o-ring sealed



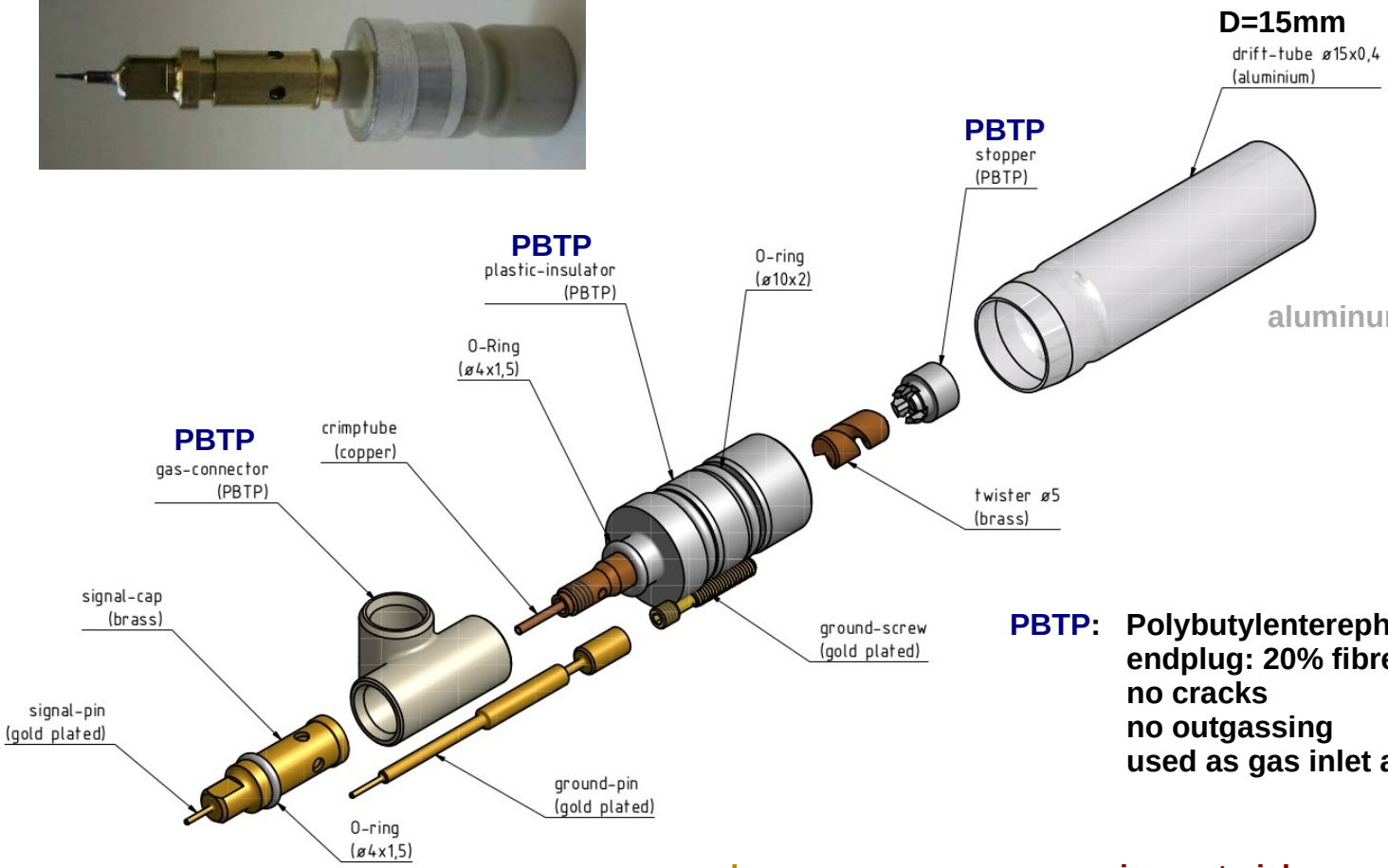


D=50µm
gold-plated
tungsten wire

capacitive hedgehog cards
ASD amplifier shaper discriminator board
TDC board
gold plated signal and grounding pins

ATLAS sMDT Muon-Drift-Tube

D=15mm 0.4mm wall thickness



aluminum: etched and Surtec coated protective coating
=> cleaning
conductive surfaces

PBTP: Polybutylenterephtalat
endplug: 20% fibreglas reinforcement
no cracks
no outgassing
used as gas inlet at MDT chambers

brass, copper: non ageing materials

wire: gold plated tungsten wire D=50µm
signal-cap: brass, gold plated signal pin

o-rings: EPDM, no grease or sealant

no aging (outgasing) is expected to be created by these materials ✔

^{90}Sr Beta Source Characteristics

decay	β- endp. energy	half life	range	energy loss [keV]
^{90}Sr -> ^{90}Y	0.546 MeV e^-	28.8 a	R = 0.8 mm in Al	100 17.0 in Ar
^{90}Y -> ^{90}Zr	2.282 MeV e^-	64.1 h	R = 5.1 mm in Al	200 11.7
				500 8.7
			0.3 MeV e^- : R = 0.4 mm in Al	1000 8.2
			wall thickness of	1500 8.3
			sMDT tube	2000 8.5
			ΔE(Al) ≈ 180 keV	ΔE(Ar) ≈ 9 keV

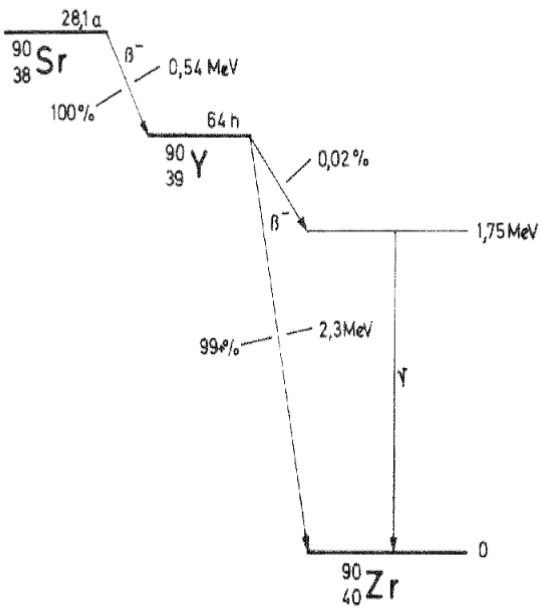


Abb.1: Zerfallsschema von ^{90}Sr/^{90}Y

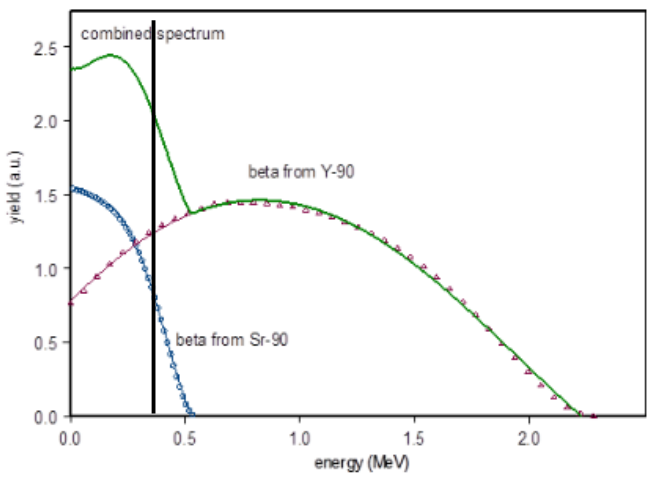


Figure 1: β spectrum of ^{90}Sr and the daughter nucleus ^{90}Y.

QSA GLOBAL

QSA Global GmbH
Gieselweg 1
38110 Braunschweig
Postfach 11 37
38001 Braunschweig
Germany
Tel. +49 5307 932-0
Fax +49 5307 932-194

Eingegangen am
10. Juli 2006
Beschleunigerlabor

CERTIFICATE

No. 100787 – OG 701

for a Sealed Radioactive Source

28 June 2006

Source Type: Reference Source

Product code	SIFB10090
Drawing	VZ-2931-001
Source no.	OG 701
Nuclide/s	Strontium-90

Measurement Data

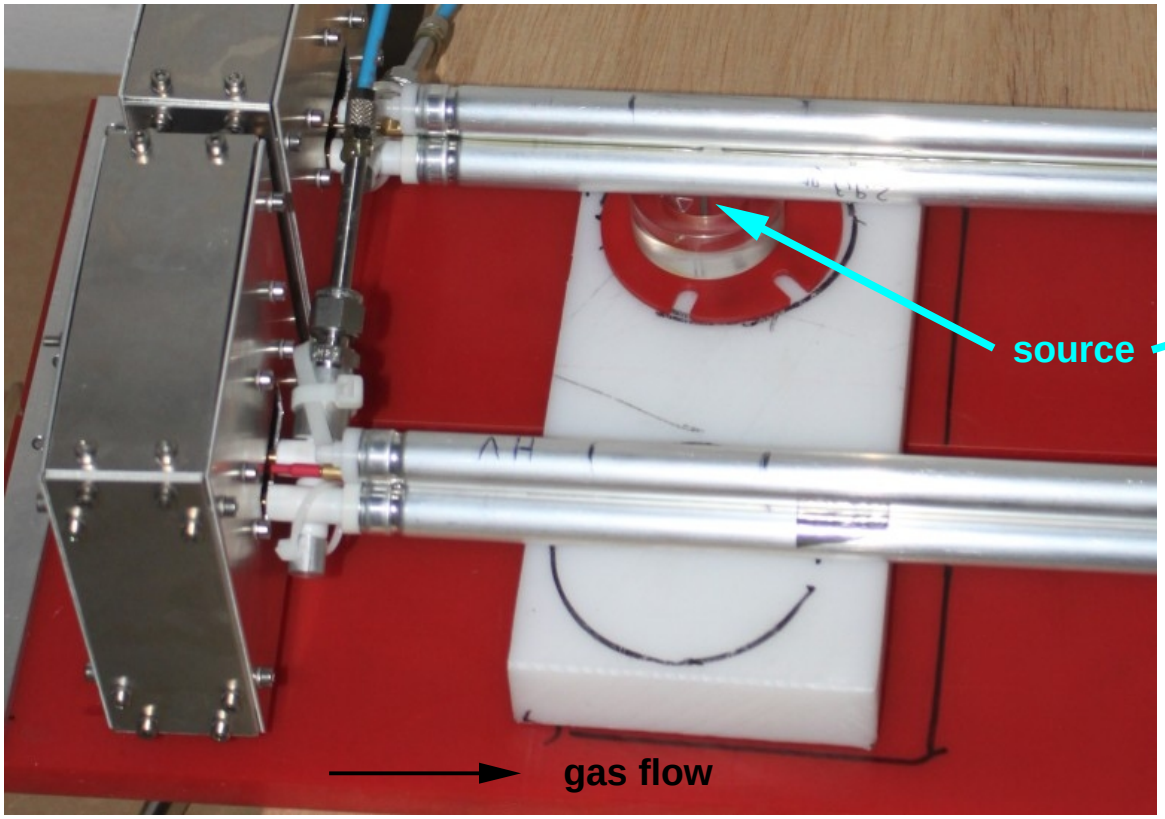
Activity	244 MBq
Uncertainty*	5 %
Reference date	23.06.06 at 12:00 GMT
Traceability*	Defined on page 2
Radioactive impurities	Related to Sr-90 (equal 100 %) the following radioactive impurities were

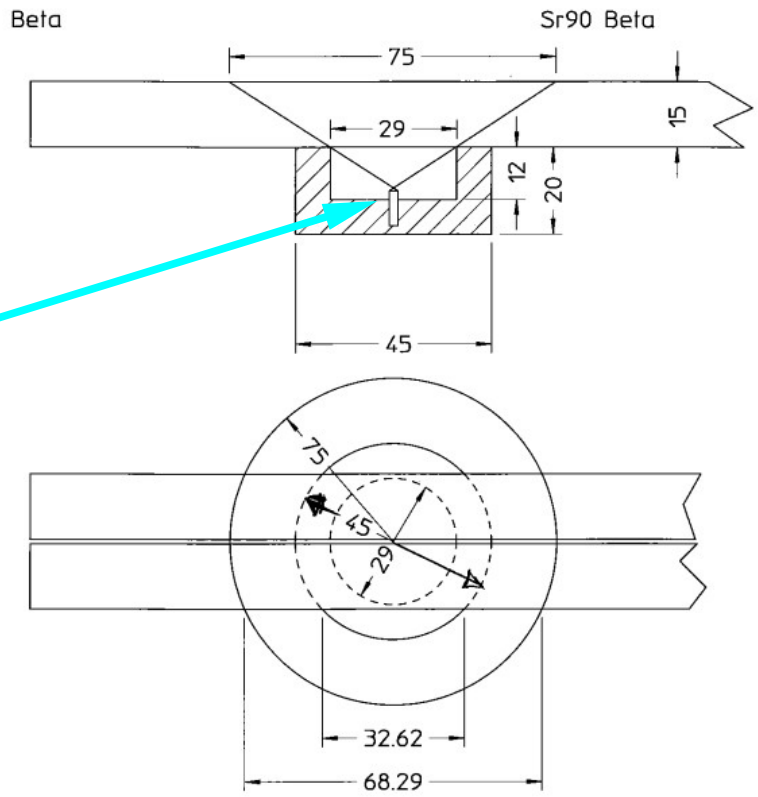
213 MBq

^{90}Y betas contribute, most ^{90}Sr betas stop in aluminum tube

^{90}Sr Irradiation Setup

stainless steel gas inlet, 3cm plastic for insulation





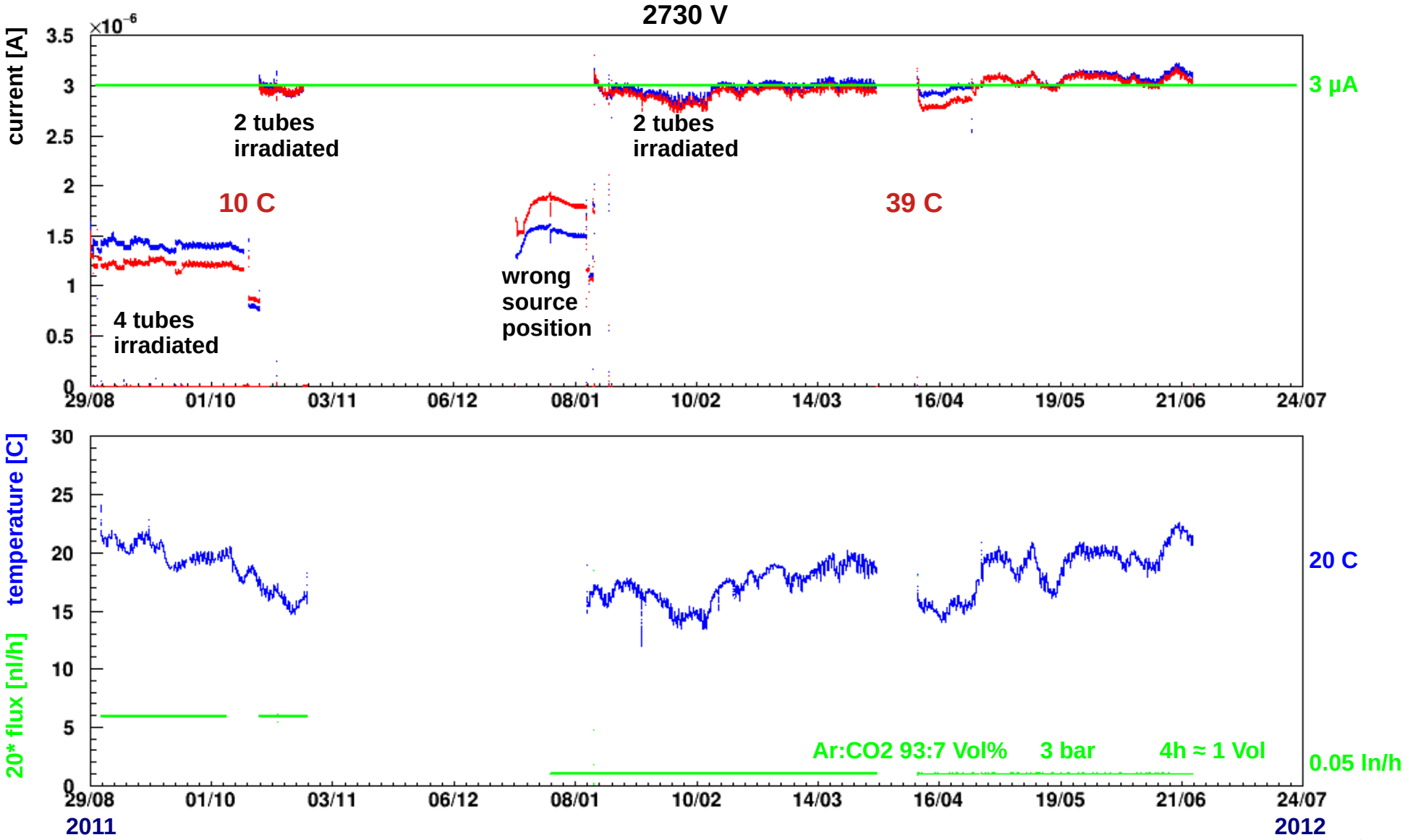
3 periods of measurements:

2011 irradiation of 4 tubes
2012 irradiation of 2 tubes optimized
2013 irradiation of PBTP endplugs + tube

basic idea:

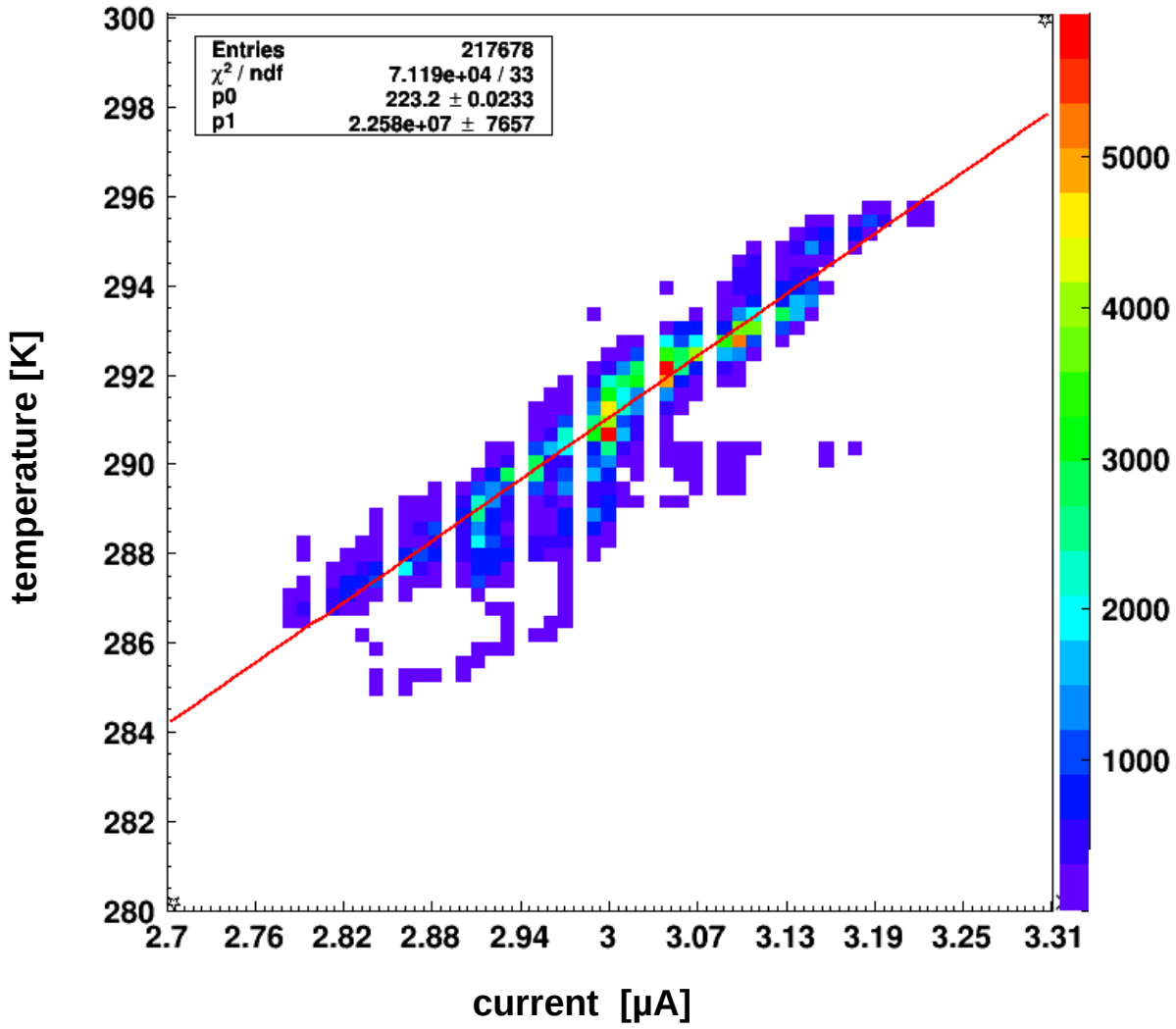
keep HV, gas-flow and pressure const.
HV: 2730 V GG: 20000
1 year measurement
monitor I and T

Anode Currents Induced by the Beta Irradiation 2011 and 2012



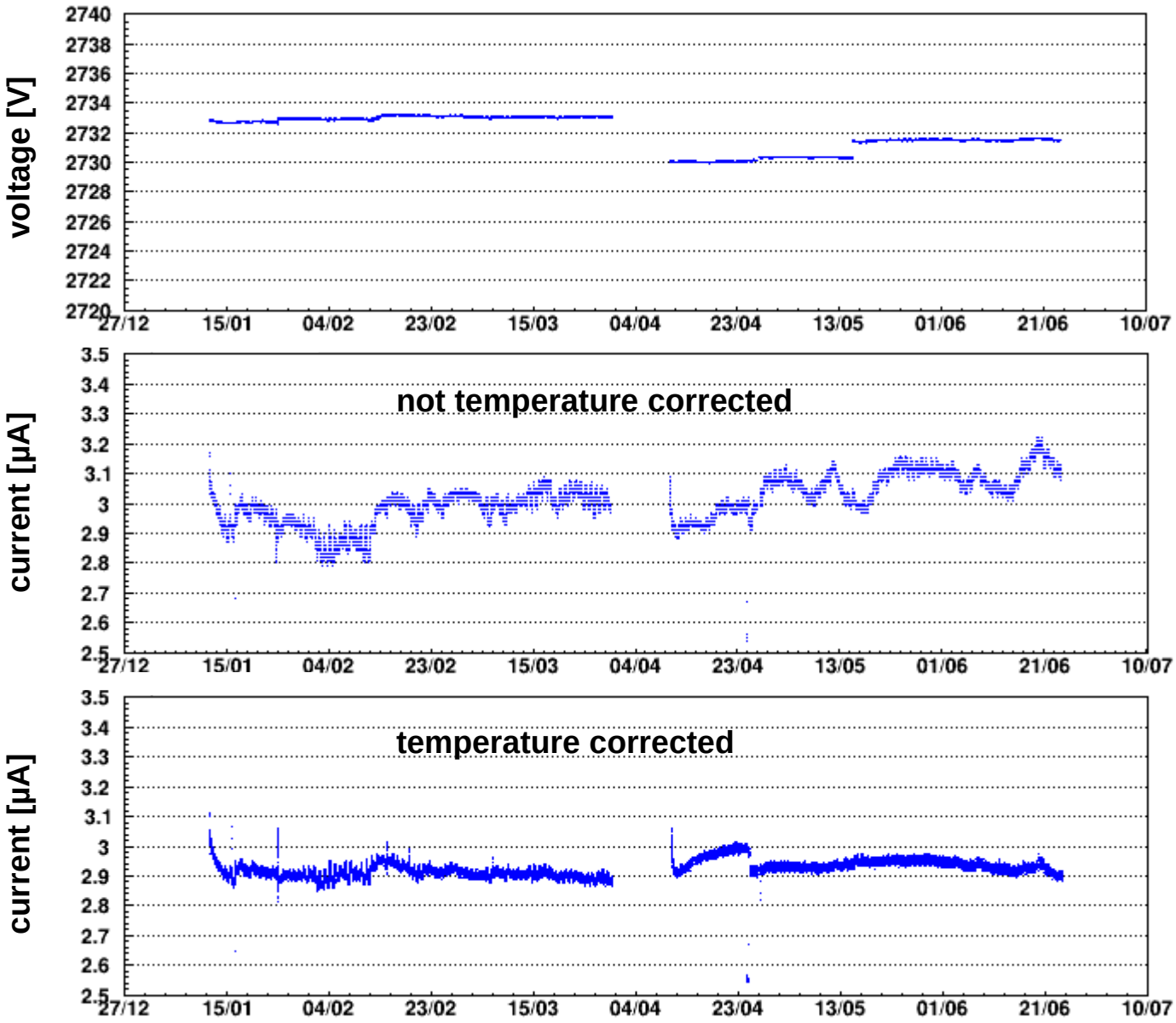
no indication of decreasing currents, currents scale with T ✔

Current – Temperature - Relation



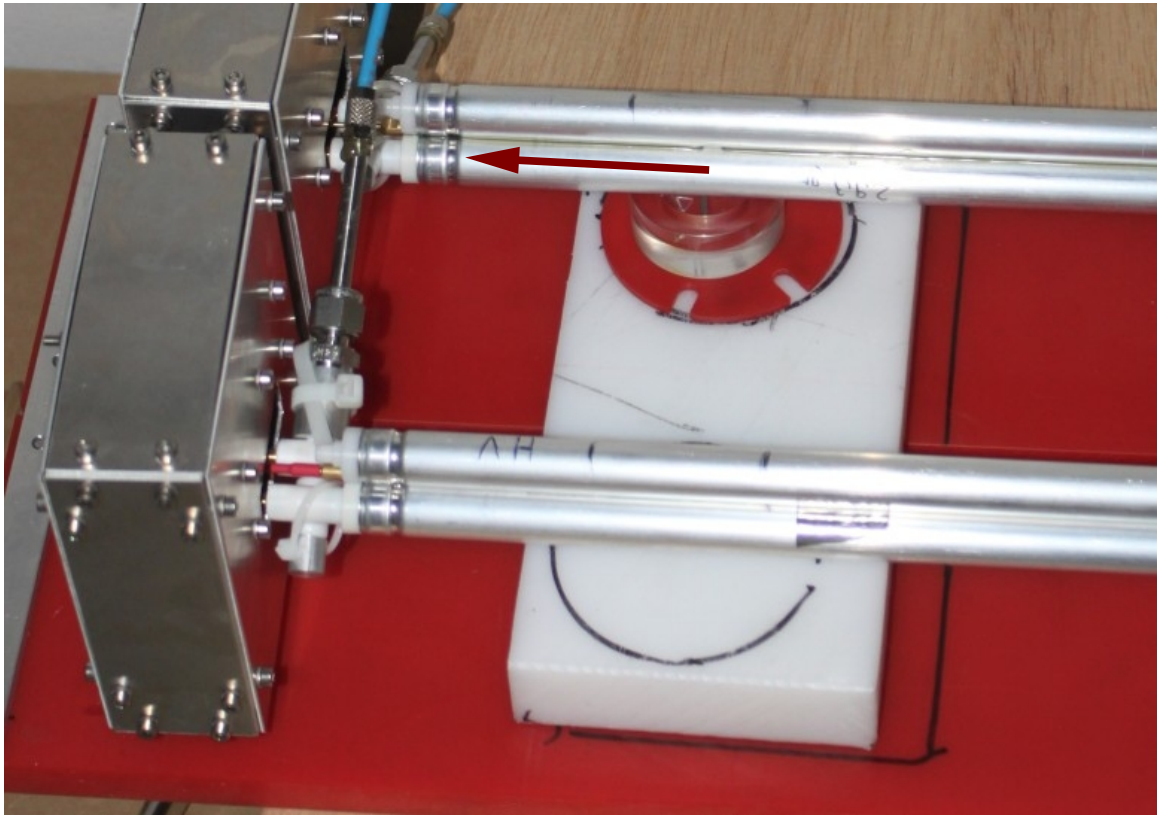
a linear fit will be used to correct the T dependence

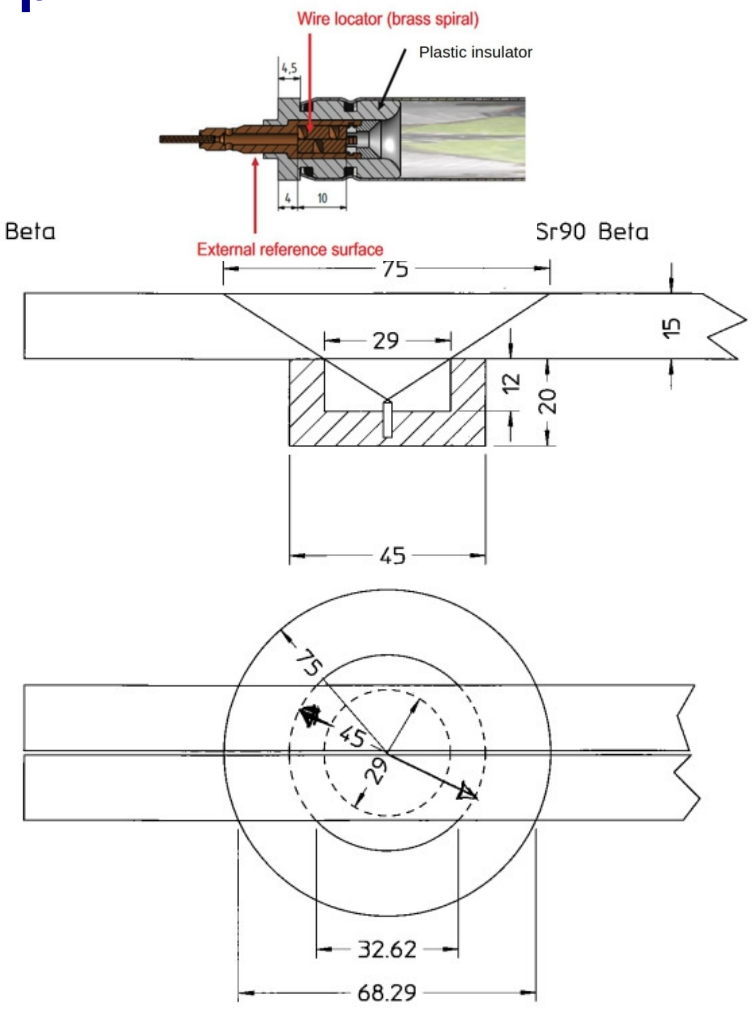
Current Corrected by Temperature



temperature correction works => almost constant current
no decline in current intensity ✔

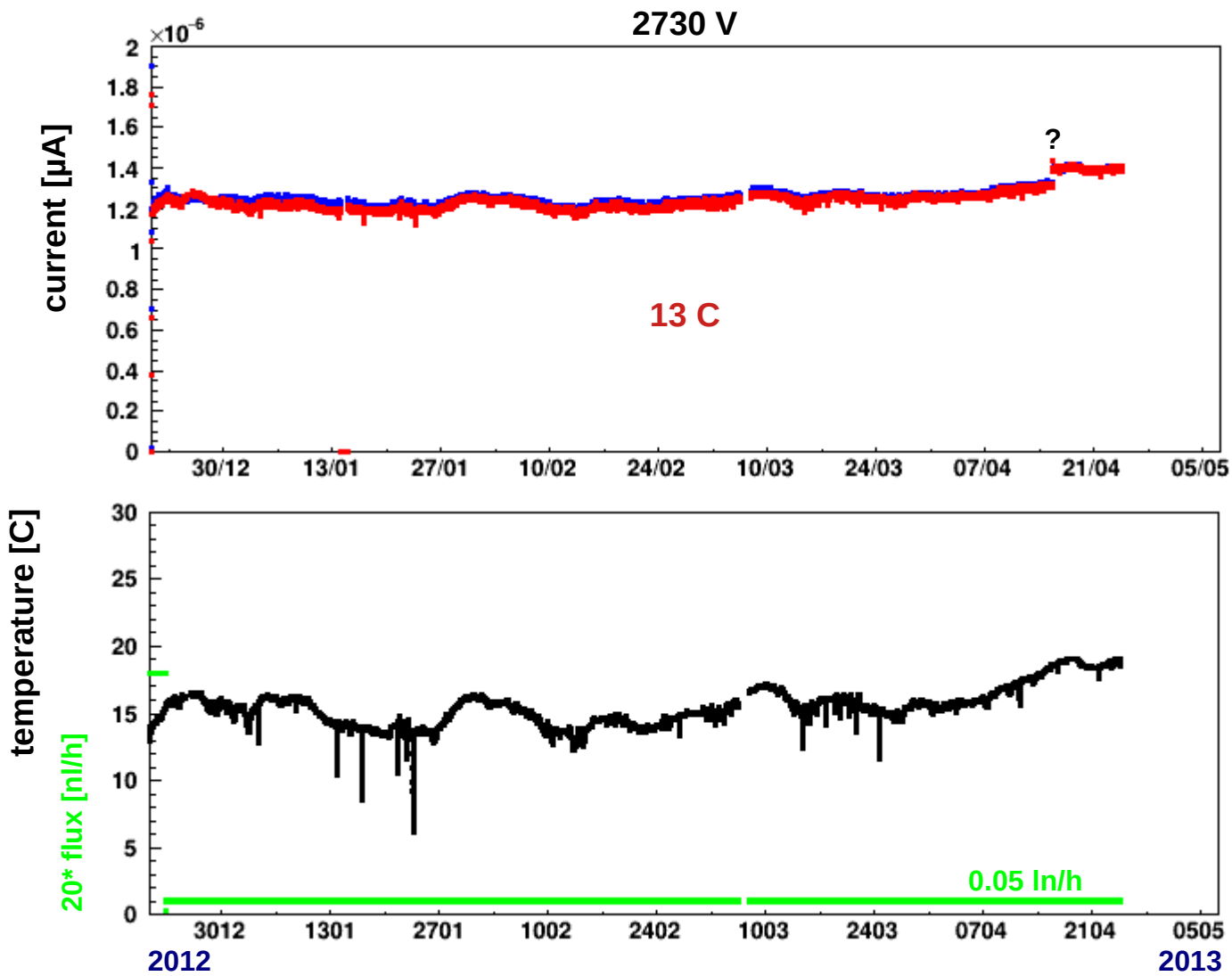
^{90}Sr Irradiation Setup





2013 irradiation of PBTP endplugs + tube
shift of source position in 2013

Anode Currents Induced by the Beta Irradiation in 2013



no indication of decreasing currents, currents scale with T ✔
no irradiation induced outgassing of the endplug

Accumulated Charges

	curr	acc. Q	Q/cm	location	int.act.length
2011:	1.4 μA	10 C	3.1 C/cm	tube	1 cm
2012:	3.0 μA	39 C	12.2 C/cm	tube	1 cm
2013:	1.3 μA	13 C	2.0 C/cm	tube	1 cm
sum:		62 C	19.3 C/cm	tube	
		17 C	≈5.0 C/cm	endplug	(estimate)

✔

Summary

- 2 sMDT tubes were irradiated using a 90Sr beta- source

- Ar:CO2 93:7 Vol% was used as counting gas

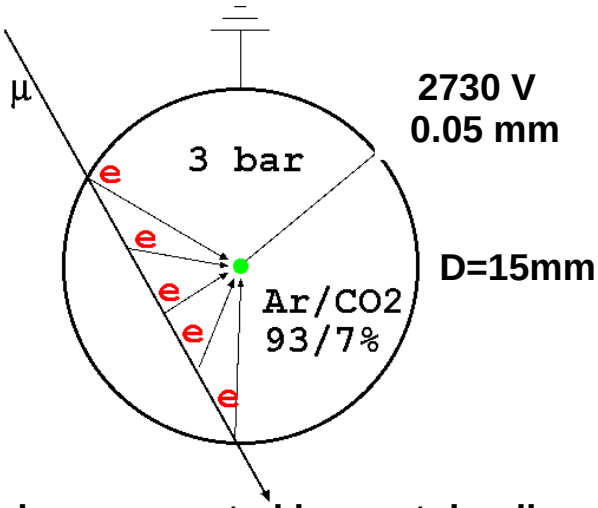
- more than 60 C were accumulated per tube
  this corresponds to almost 20 C/cm ✔
  this is 3 * higher than the ATLAS HL-LHC requirement of 6 C/cm

- the endplug was irradiated by ≈ 5 C/cm
  no outgassing or deterioration of the gas was observed ✔
  no cracks were observed

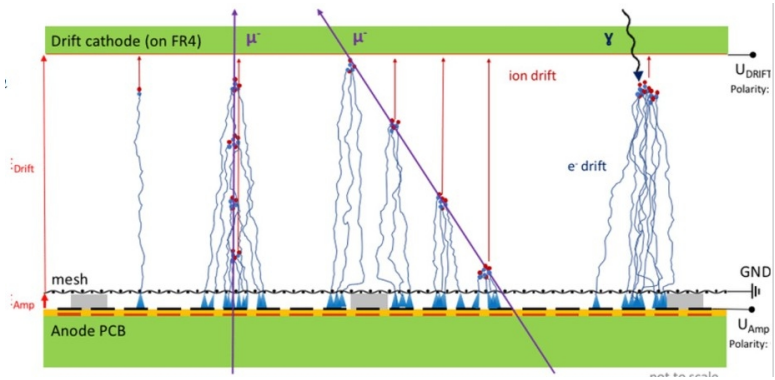
- no sign of deterioration in performance was observed ✔

- the observed anode currents scale with temperature fluctuations as expected
  no decrease in performance was observed ✔

Difference Between Wire-Detectors and Planar Detectors



MM: Ar:CO2:C4H10 93:5:2 Vol% 0.02 C/cm^2



wire: all charges created in one tube diameter
are concentrated along the wire on 0.05 mm

inhomogeneous electric field
=> acceleration of el. dipoles

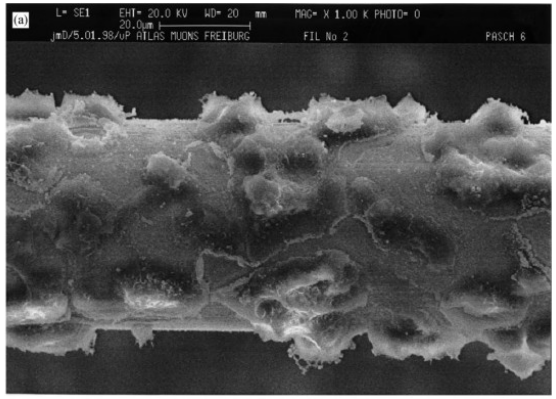
C-H mixtures show ageing
Ar:CO2 mixtures do not age

planar structure: each event covers only an
area of ≈ 2 mm^2
no big concentration of long chain molecules

homogeneous el. field, no acceleration of
electric dipoles

no loss in performance at use of C4H10
@ 0.35 C/cm2
a heavily discharging region was investigated
using SEM, no aging was observed

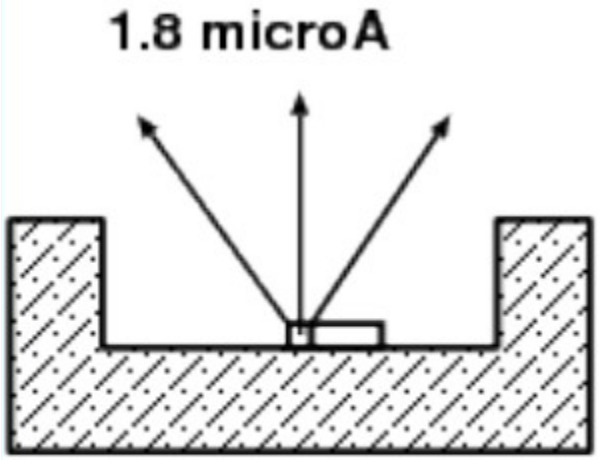
no whiskers or hairs were observed on the
surface of the resistive strips
a pretty rough surface by construction



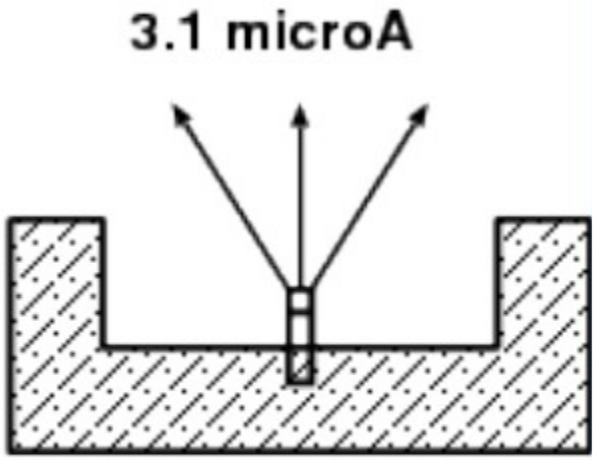
C-deposit on an anode wire
after 0.12 C/cm
Ar:CH4:N2:CO2 94:3:2:1

M.Kollefrath et al NIMA 419 p351

Backup



Konfiguration 1



Konfiguration 2

Estimate of the Gas-Gain During the Irradiation

interacting fraction **0.093**

strenght of the source: 244 Mbq, 5.6 y = 213 MBq
0.776 is part of the spectrum > 300 keV
0.776 * 213 = **165 MBq**

beta electrons: **$1.53 * 10^7$** betas/s create **3 µA** detector current

av. excitation energy: 27 eV
9 keV average energy loss per beta, see estar/NIST

=> 9000/27 = **333** e^- produced by 1 beta

=> **$1.9 * 10^{13}$** e^-/s / **$5 * 10^9$** = 4000

=> gas-gain of 4000 is factor 5 below 20000

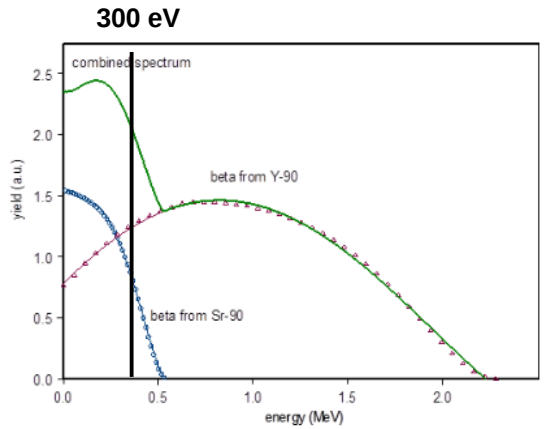
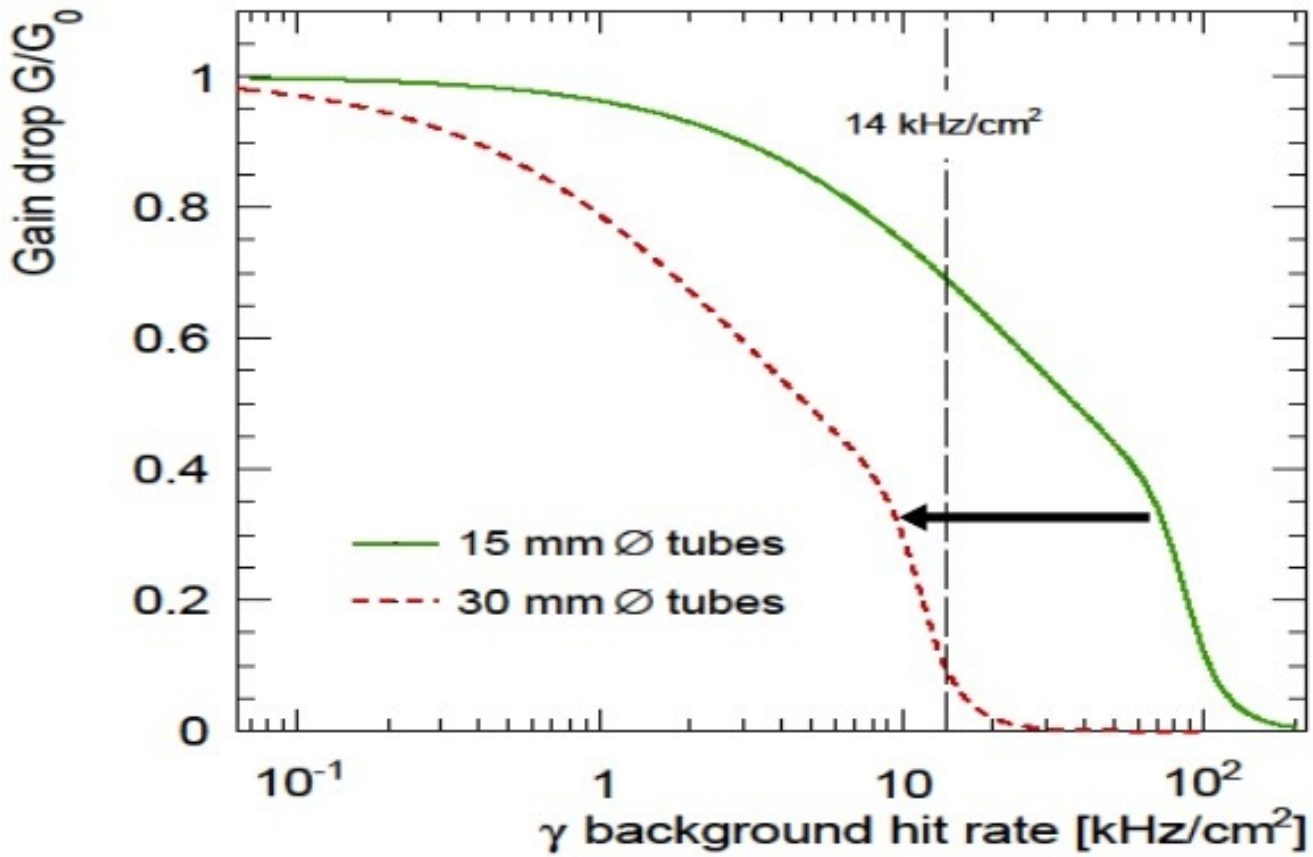


Figure 1: β spectrum of ^{90}Sr and the daughter nucleus ^{90}Y.


Gain drop G/G0
1
0.8
0.6
0.4
0.2
0
14 kHz/cm2
15 mm ∅ tubes
30 mm ∅ tubes
10-1
1
10
102
γ background hit rate [kHz/cm2]