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DRAFT

Quality Assurance

for ATLAS MDT Chamber Construction

Task Owner QA/QC Procedures

Description of the Quality Assurance Procedures for the Construction of the Monitored Drift Tube chambers for the ATLAS muon spectrometer.

Table 1: Quality control tests of drift tube materials at the chamber production sites

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Aluminum tube				
Visual inspection of inside and outside	no obvious defects or holes, proper cleaning, deburring, straightness, bar code, packing	reject tube, notify supplier	central	1: sample test/box 2: every tube before wiring
Outer diameter envelope, from 8 points on circumference	29970 − 15 μm	reject box	central	sample test/box
Wall thickness, at 8 points on circumference	100 − 30 μm	reject box	central	sample test/box
Length L	L − 0.5 mm ($L \leq$ 1 m) L − 0.7 mm ($L >$ 1 m)	reject box	central	sample test/box
Straightness	insertion in jig without difficulties	reject tube, notify supplier	central	sample test/box
Wire				
Visual inspection	no defects of gold-plating, proper cleaning, no kinks	reject spool	central	1: first meters and every 100 m per spool under microscope, 2: inspection during wiring
Endplug				
Visual inspection	proper cleaning and no obvious defects of plastic, O-rings, wire locator, Al reference surface, crimp tube	reject endplug, notify supplier	central	1: sample test/batch 2: each endplug before wiring
Outer diameter envelope, from 8 points on circumference **(optional)**	30020 − 10 μm	reject batch	central	sample test/batch
Wire locator outer diamter	within tolerance	reject batch	central	sample test/batch

Table 3: Quality control tests of drift tubes at the chamber production sites

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Drift tube				
Visual inspection	no obvious damage of tube or endplug, no visible defects of tube and wire crimp, tube correctly sealed	reject tube, adjust wiring station	local	each tube after wiring, before chamber assembly
Aluminum tube outer diameter envelope in endplug region	less than 30.020 mm	adjust wiring setup	local	sample test/day after wiring
Length L	$L - 0.5$ mm at $20 - 1^\circ$ C	reject drift tube, adjust wiring station	local	1: sample test/day 2: each tube on chamber assembly jig
Relative azimutal orientation of endplugs	-10 mrad	reject drift tube, adjust wiring station	local	1: sample test/day 2: each tube on chamber assembly jig
Straightness	insertion in jig without difficulties	reject drift tube	local	1: sample test/day 2: each drift tube during chamber assembly
Ground contact resistance	less than 100 mΩ	repeat laser welding	local	1: sample test/day 2: monitoring of selected tubes over time

Table 3: Quality control tests for all drift tubes at the chamber production sites

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Drift tube				
Room temperature	20 ± 2° C	adjust	local	during tube tests
Relative humidity (optional)			local	monitoring
Temperature of tube	20 ± 1° C	adjust temperature or tension	local	during tube assembly
Temperature of tube	known within ±1° C	repeat measurement	central	during wire tension measurement
Wire tension (oscillation frequency)	within ±5% of the nominal value at 20 ± 1° C	reject drift tube	central	1: shortly after tube wiring 2: after min. two months, before assembly
Wire location at the tube ends	within ±25 μm of the center of the endplug ref. surface in y and z	reject drift tube, inspect endplugs and wiring station	central	sample test on day of wiring, tube held as in assembly jig, incl. test of coaxiality of endplugs, measurements at 0 and 180°
Gas pressure test at 3 bar overpressure	no obvious leaks	reject drift tube, inspect endplugs, adjust wiring station	local	
Gas leak rate at 2 bar overpressure	less than 10^{-8} bar l/s	reject drift tube, inspect endplugs, adjust wiring station	central	after pressure test
HV stability test: leakage current	less than 2 nA/m	reject drift tube, inspect endplugs, tubes, wire	central	with Ar:CO_2 (93:7) at 3 bar and 3100 V
HV stability test: cosmic count rate (optional)	within $\pm 3\sigma$ of nominal value	reject drift tube, inspect endplugs, tube, wire	central	with Ar:CO_2 (93:7) at 3 bar and 3100 V

Table 4: Drift-tube test equipment at the production sites

Site	Wire tension (osz. frequency)	Wire position	Leak rate (whole tube)	HV test (leakage current)	HV test (cosmic rate)
Freiburg	Excitation in B-field	Brandeis X-ray system	Leak detector with single-tube containers	HV system with pA-meter	yes
LMU/MPI (accept. test) **NTU Athens**	CAEN SY502 meter, excitation in B-field CAEN SY502 meter, excitation in B-field	Brandeis X-ray system, MPI jig Brandeis X-ray system	Pressure rise in evacuated volume at endplug (8 tubes sim.) Leak detector, single-tube container	HV system with 1 nA sensitivity As Pavia (single-tube)	BNL preamp., shaper
Univ. Athens	as NTU Athens (after module 0)				
Thessaloniki (accept. test)	excitation in B-field			CAEN SY127 (10 channels), 1 nA sensitivity HV system	
Frascati	Electrostatic excit., multi-channel system, integration with leak test	Electromagnetic, as Pavia/Rome	Helium leak detector, 30 single-tube containers	CAEN SY527 (96 channel) 1 nA sensitivity HV system, integration with leak test	Yes
Cosenza	CAEN SY502 meter, excitation in B-field integration with leak test	Electromagnetic, as Pavia/Rome	As Pavia, automatic control system	CAEN SY527 (96 channel) 1 nA sensitivity HV system, integration with leak test	
Pavia	As Rome	Electromagnetic (EMMI)	Argon mass spectrometer, 10 single-tube containers (commercial system)	HV system (10 channels) with pA-meter, integration with leak test	
Rome	Excitation in B-field, multi-channel	Electromagnetic (EMMI)	As Frascati or Pavia,	As Pavia	
NIKHEF	Mechanical excitation, piezo-electric measurement	Electromagnetic, as Pavia/Rome	Helium leak detector, multi-tube container	Multi-channel HV system, integration with leak test	Yes
Dubna (also for MPI)	Excitation in B-field, meter custom design	Brandeis X-ray system, MPI jig	Helium mass spectrometer, multi/single-tube containers	CAEN SY527 (96 channel) 1 nA sensitivity HV system	BNL preamp., shaper
Protvino	Excitation in B-field, meter custom design	Brandeis X-ray system	Mass spectrometer		
Boston	Excitation in B-field, meter custom design	Brandeis X-ray system	Mass spectrometer, multi-tube container	Multi-channel HV system, integration with leak test	Yes
Michigan	As Seattle	Electromagnetic, as Pavia/Rome	Helium leak tester, evacuated volume at end-plug and moving along tube	Multi-channel HV system	
Seattle	Excitation in B-field, meter custom design	Electromagnetic, as Pavia/Rome	As Michigan	As Michigan	

Table 5: Quality control tests during chamber assembly.

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Environment				
Room temperature	20 ± 1.5 C	adjust	local	before glueing
Relative humidity	50 ± 10 %	adjust	local	before glueing
Atmospheric pressure (optional)			local	monitoring
Temperature of chamber	20 ± 0.5° C	adjust	local	uniform, before glueing
Temperature of jigging	20 ± 0.5° C	adjust	local	uniform, before glueing
Temperature difference chamber–jigging	< 0.2° C	adjust	local	during glueing
Spacer assembly				
Glue gaps between tube layer on combs and cross plates	200 – 1000 μm	adjust	local	both orientations of cross plates around z-axis
On-chamber gas system				
Leak rate	less than 10^{-8} bar l/s	repair	local	of preassembled gas manifolds
Flow rate/tube	to be specified	repair		for preassembled gas manifolds

Table 6: Quality control tests during chamber assembly (cont.)

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Assembly of tube layers				
Vacuum suction underpressure	at nominal value	adjust	local	tube positioning on combs during glueing
Horizontal gaps between tubes	not more than two adjacent tube walls touching, no adjacent endplugs touching	relocate drift tubes	local	before glueing
Height of endplug reference surfaces	within ±10 μm of nominal value in y	relocate drift tubes	local	before glueing
Stability of in-plane monitor readings (image displacement)	within ±10 μm of nominal value in y and z	adjust	central	after each glueing step (definition of zero of in-plane monitors), after correction for middle
Sphere locations	within ±10 μm of nominal value in y and z	adjust	local	before each glueing step, with sphere and in-plane monitors
Outer cross plate sags on the assembly table **(optional)**	zero within ±10 μm	adjust	local	before glueing of a layer, measured with temporary cross plate sag monitors
Middle cross plate sag on the assembly table **(optional)**	zero within ±20 μm	adjust	local	before glueing of a layer, measured with in-plane monitors plus outer cross plate sag correction
Alignment Platforms				
Angular alignment of axial/praxial platforms	within ±50 μrad, ±200 μrad, ±50 μrad around x-, y-, z-axes with chamber coord. axes, orthog. ±100 μrad · cross plate length	store data	central	after each glueing step (initially); includes accuracy of rec. of thermal and gravitational deformations with in-plane system
Angular alignment of projective platforms	within ±200 μrad, ±50 μrad, ±50 μrad around x-, y-, z-axes with chamber coordinate axes	store data	central	includes accuracy of rec. of thermal and gravitational deformations with in-plane system

Table 7: Quality control tests of all assembled chambers at the production sites

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Mechanical Tests				
Sag of chamber with kinematical supports before sag compensation		store data	central	φ readings of in-plane monitors
Sag of chamber on kinematical supports after sag compensation	within $-20\,\mu$ of wire sag	adjust sag compensation until tolerance reached, store data	central	φ readings of in-plane monitors
Deformation of cross plates on kinematical support **(recommended for BM, BO)**	$< 20\,\mu m$	store data	central	with temporary cross plate sag monitors and FEA model

Table 8: Quality control tests of all assembled chambers at the production sites (cont.)

Test	Acceptance criteria	Reaction if failed	Data base	Comment
Operation Tests				
Gas pressure test at 3 bar overpressure	test done, no obvious leaks	repair gas manifold, repair/disconnect faulty tubes, store ID	central	
Gas leak rate at 2 bar overpressure	less than 2×10^{-8} bar l/s per tube	repair gas manifold, repair/disconnect faulty tubes, store ID	central	after pressure test
HV stability: leakage current	less than 2 nA/m ≈ 5 nA per channel	replace electronics boards; identify, sputter/disconnect faulty drift tubes, store ID	central	with installed electronics boards, baseline gas at 3 bar and nominal and 2× nominal gas gain
HV stability: cosmic count rate **(optional)**	within $\pm 3\sigma$ of nominal value	identify noisy channels, store ID	local	with installed electronics boards, baseline gas at 3 bar and nominal gas gain
Operation in cosmic ray test stand	evaluation of performance: noise level, efficiency, random rate, max. drift time, resolution vs. r, uniformity, local wire displacement, stable performance of all channels over 1–2 weeks	make chamber operational, store ID of faulty tubes	local	with test electronics, baseline gas at 3 bar and nominal gas gain
Wire location measurement with cosmic rays **(optional)**	no systematic deviations from expected wire grid	store wire location data incl. meas. errors, adjust assembly tooling in case of deviations	central	track reconstruction in cosmic ray tower

Table 9: Quality control tests of all assembled chambers after transport to CERN and during storage

Test	Acceptance criteria	Reaction on failure	Data base	Comment
Visual inspection	no visible damage	perform possible repairs, mark chamber for X-ray tomograph and full leak test		acceptance test after transport to CERN
Gas leak rate at 3 bar	less than 2×10^{-8} bar l/s per tube	repair gas manifold, repair/disconnect faulty tubes, store ID	central	1: full leak test for one chamber per transport to CERN (acceptance test) or if visible damage of chamber 2: monitoring of pressure (at known temperature) over storage time
HV stability: leakage current	less than 5 nA/channel	replace electronics boards; identify, disconnect faulty tubes, store ID	central	after mounting of final electronics, with baseline gas at 3 bar and nominal and 2× nominal gas gain
Operating test	evaluation of performance: pulser test (correct connections), signals from all channels, noise level, random rate, uniformity	replace electronics, make chamber operational	local	after mounting of final electronics, with baseline gas at 3 bar and nominal operating conditions

Table 10: Quality control tests of selected chambers from each production site after transport to CERN and during storage

Test	Acceptance criteria	Reaction on failure	Data base	Comment
Wire location measurement with X-ray tomograph (incl. location of wire on the alignm. platforms)	−20 μm rms in y and z with respect to the expected wire grid	store wire location data and chamber ID, adjust assembly tooling in case of deviations, measure chambers since problem first detected	central	1: sample test/production site 2: for chambers with expected mechanical problems
Wire tension (osc. frequency)	within −5% of the nominal value at given temperature	store data, notify production sites, measure other chambers	central	for one chamber/production site at regular intervals over storage time (temperature meas. to −1° C)
Tube ground contact resistance	less than 100 mΩ	store data, notify production sites, measure other chambers	central	for one chamber/production site at regular intervals over storage time