Neutron irradiation test on ATLAS MDT chambers

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Summary

- ATLAS experiment at LHC & MDT chambers
- Background in ATLAS
- Test strategy
- Experimental setup
- Analysis results
- Conclusions

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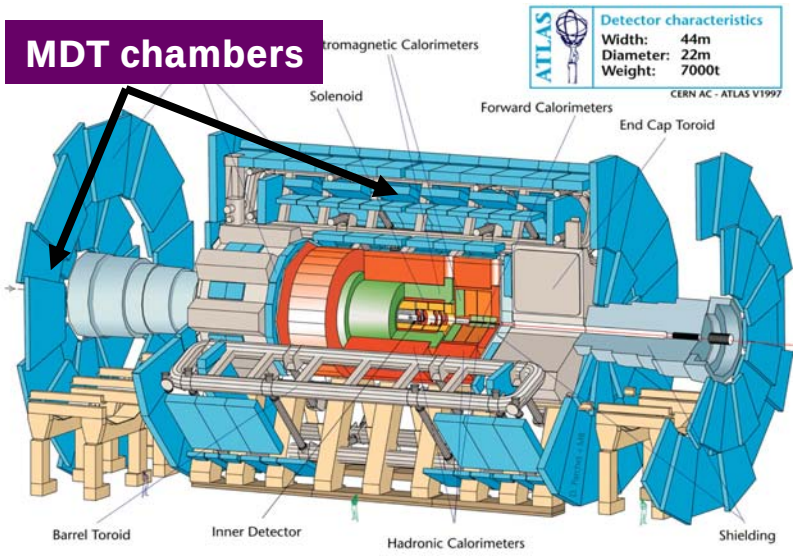
ATLAS & MDT chambers

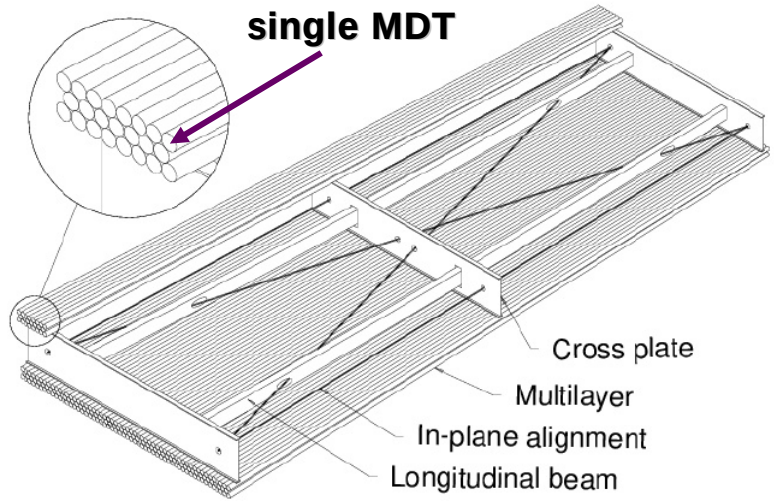


ATLAS is one of the 4 experiments under construction at LHC.

It features a stand-alone Muon Spectrometer with toroidal magnetic field:
$\Delta p_t / p_t < 10\%$ **up to 1 TeV**

MDT and CSC (precision chambers)

RPC and TGC (trigger devices)



Monitored Drift Tube Chambers

Al tubes 30 mm in diameter,
50 μm W-Re wire

Ar-CO_2 (93:7) at 3 bar absolute

HV=3080 V, gas gain=$2 \cdot 10^4$

Muons crossing the tubes produce ions – electrons pair.

e^- drift toward the anode wire in a measured drift time.

Time information provides muon position.

Neutron irradiation test on ATLAS MDT chambers

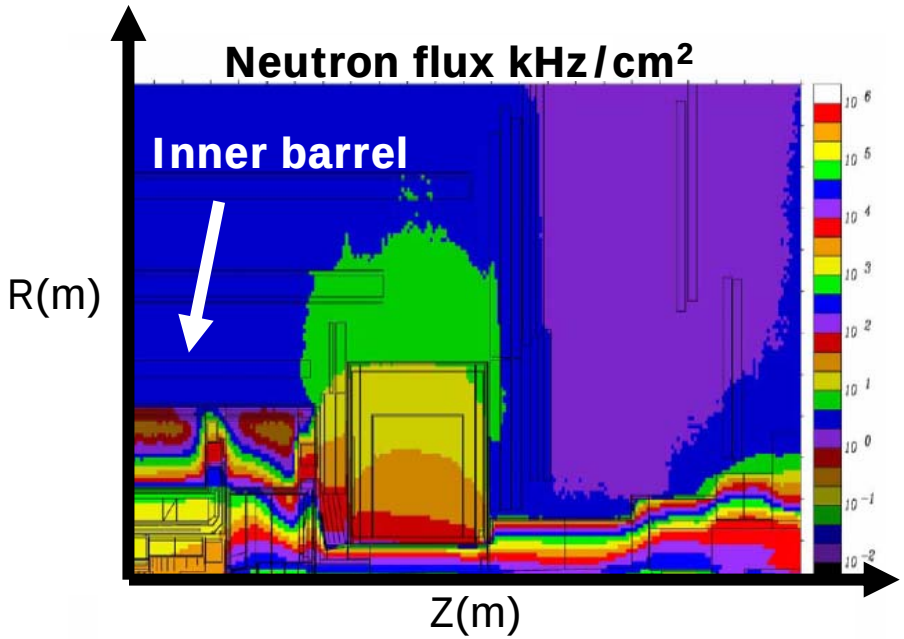
Background in the ATLAS muon spectrometer

- Low energy secondary particles from hadrons interactions with calorimeters and shields, uncorrelated to primary p-p collisions
- Total flux ~ 5 kHz/cm^2 (safety factor 5 applied)
  - Neutron flux ~ **3.45 kHz/cm^2**
- Max count rate 500 Hz/cm^2
- MDT sensitivity to neutrons = 5 ·10^{-4} (energy range 10^{-2} - 10 MeV)
- Neutrons in 10 years of ATLAS operation = **3.45 ·10^{11} n/cm^2** (Inner Barrel region)

L=10^{34} cm^{-2} s^{-1}

Fluxes (kHz/cm^2)

Neutrons	Photons
3.45	**1.20**



Neutron irradiation test on ATLAS MDT chambers

Test strategy

- MDT chambers have to operate in the harsh LHC background for at least 10 years
- Foreseen an upgrade for S-LHC (luminosity 10 times higher)

Test performed @ ENEA Casaccia Research Center (Rome, Italy)

1. July 2005:

   2 MDT bundles under **photon irradiation** at Calliope facility (4.8 C/cm ~ **80 ATLAS years**)

   G.Avolio et al., Monitored Drift Tubes aging under intensive gamma irradiation, Nuclear Instruments and Methods in Physics Research A (2006), doi:10.1016/j.nima.2006.08.059

2. September 2005:

   one of the Calliope bundles under **neutron irradiation** at Tapiro reactor ($1.32 \cdot 10^{12}$ n/cm^2 ~ **40 ATLAS years**)

TAPIRO nuclear reactor

TAPIRO is a copper reflected fast neutron source at the Enea Casaccia research center

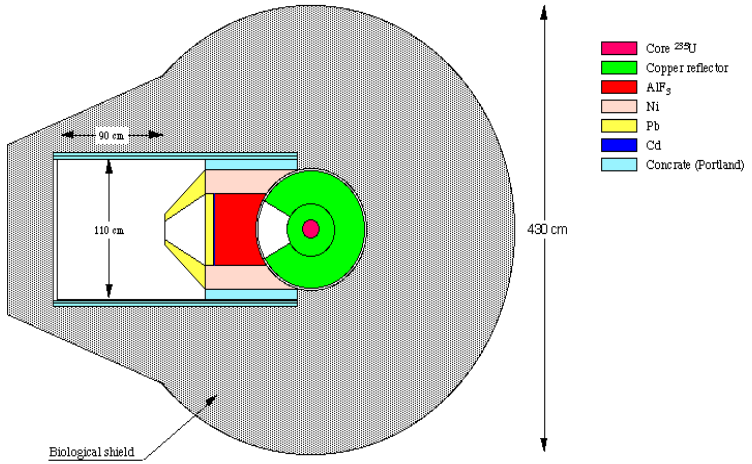
A cylindrical core (U 98.5%,Mo 1.5%) with fully enriched 93.5% ^{235}U

Neutron flux at the reactor core 2.2×10^{12} n/cm^2/s at the maximum thermal power (5kW).

Experimental setup hosted in the thermal column
(110 cm x 110 cm x 160 cm)

Neutron energy range between 10^{-4} and 10 MeV with a **broad peak around 1 MeV**

Horizontal cross-section of the Tapiro nuclear reactor



Neutron irradiation test on ATLAS MDT chambers

Experimental setup @ TAPIRO

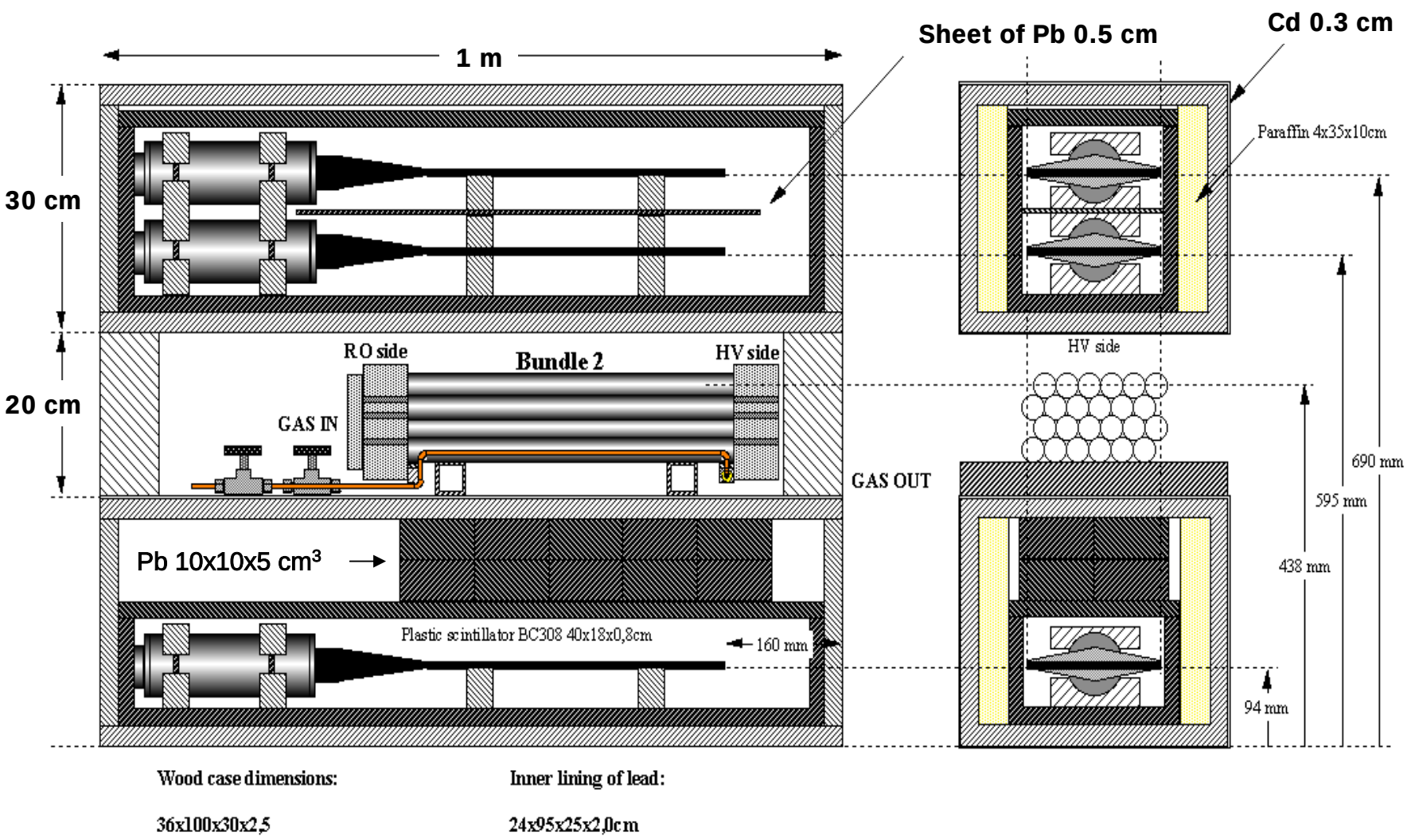
Test detector:
6x4 drift tubes, 47cm long, built and tested following the standard ATLAS wiring and quality control procedures

Gas:
Ar-CO_2 (93:7) supplied through the ATLAS standard distribution system

Front-end elx:
front-end chip (ASD) containing the TDC (for drift times) and the Wilkinson ADC (for charge measurements)

Cosmic ray trigger:
coincidence of 3 scintillator counters.
Borum powder and Cadmium foils increase neutron shielding and photomultiplicity

Experimental setup @ TAPIRO



Wood case dimensions:

36x100x30x2,5

Inner lining of lead:

24x95x25x2,0cm

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Test goals

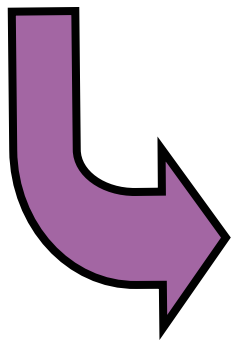
Study MDT behaviour:

- at high background rates

  Cosmic data acquired during irradiation @ reactor thermal power between 50-100 mW, corresponding to **3.3 – 10 kHz/cm^2** (~ ATLAS-like neutron flux)

- after intensive irradiation

  Cosmic data acquired after irradiation @ thermal power between 100-400 W, corresponding to an overall integrated flux of **1.32·10^{12} n/cm^2** (~ 40 ATLAS years)



- Final MDT electronics robustness
- Material durability
- Gain drop
- Single tube efficiency
- Tracking performances

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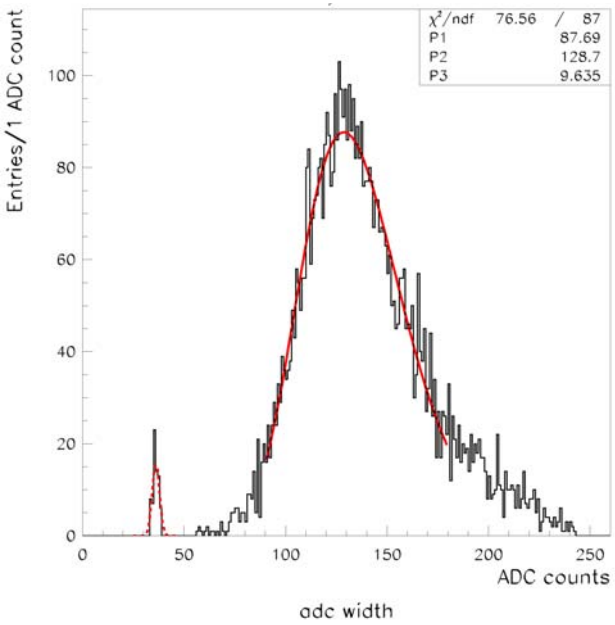
High rate studies: ADC analysis

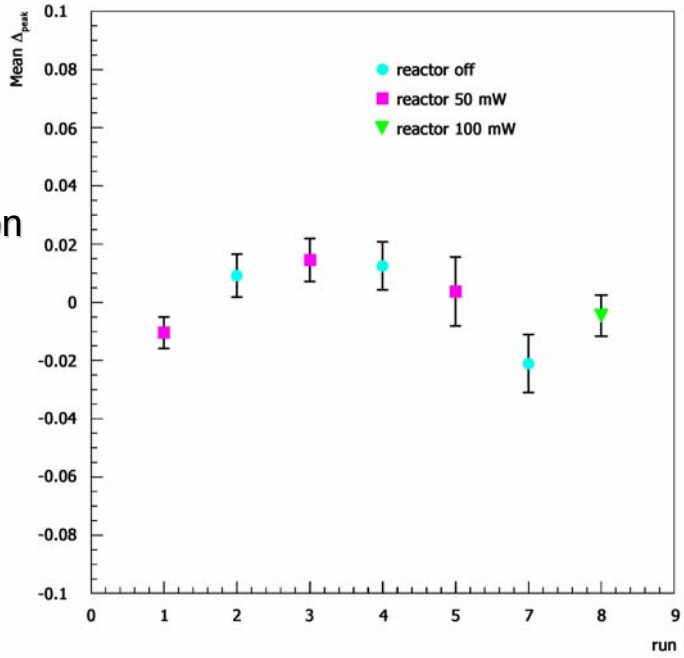


Typical ADC spectrum.

Fitted with empirical function

$$f(x) = p_1 \cdot \exp\left(-\frac{(x-p_2)^2}{x \cdot p_3}\right)$$

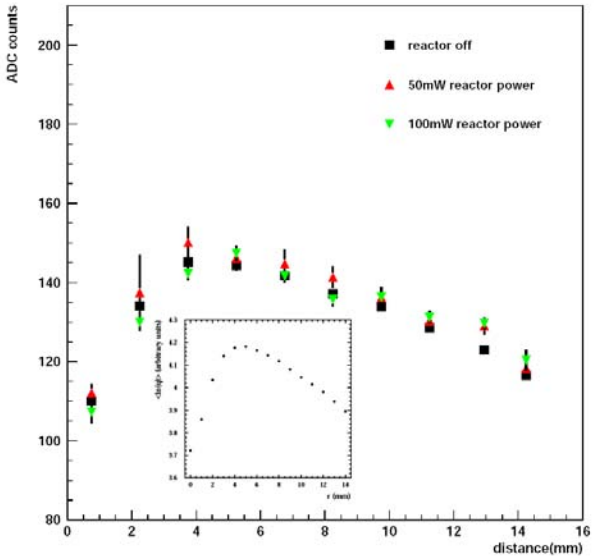
Peak abscissa (p_2) gives information on integrated charge and gas gain



Peak abscissa vs drift radius

Typical trend for Ar-CO_2 mixture, as simulated with GARFIELD.

No performance deterioration at high rates

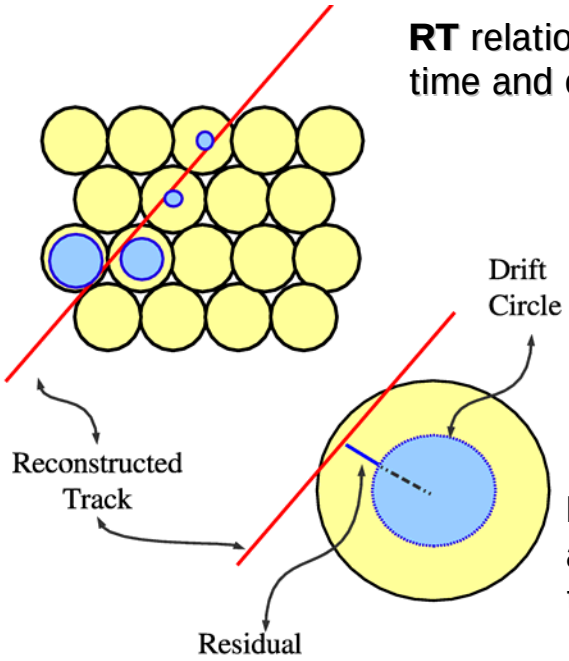


Mean variation of peak with respect to reference run.

No systematic effects are visible within 1σ.

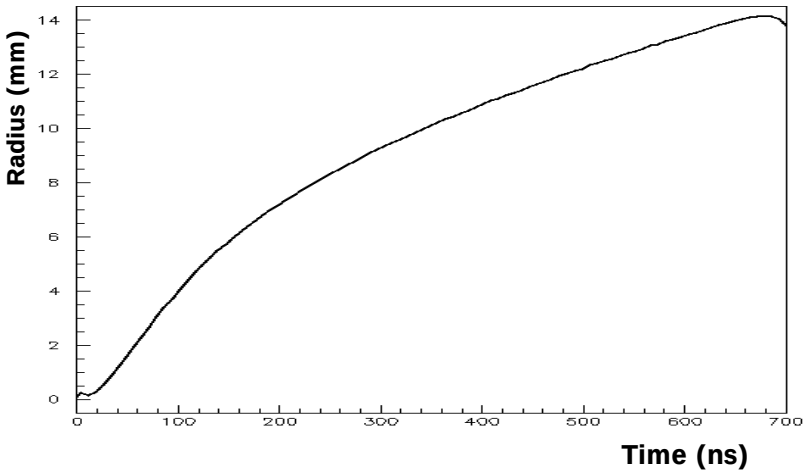
No gain loss in high rate environment (within **±2%**)

High rate studies: RT relations



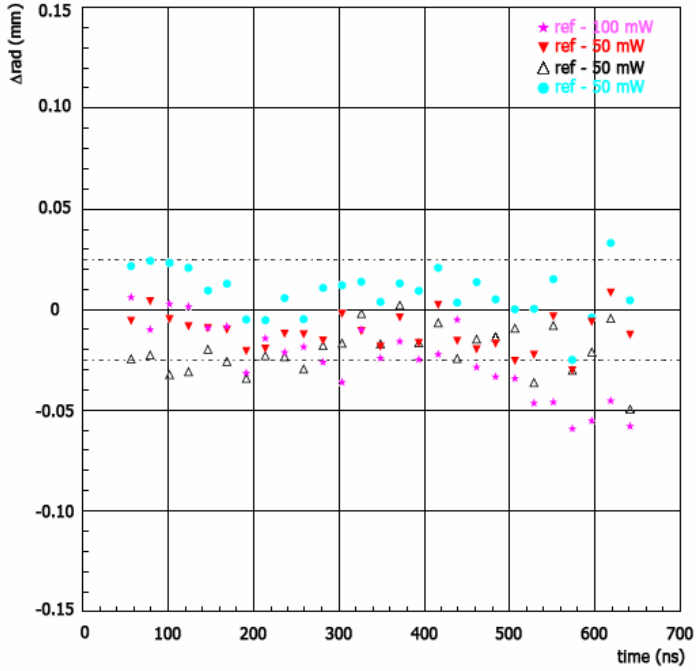
RT relation between measured time and extrapolated drift radius

RTs calculated by iterative autocalibration procedure through **CALIB** package



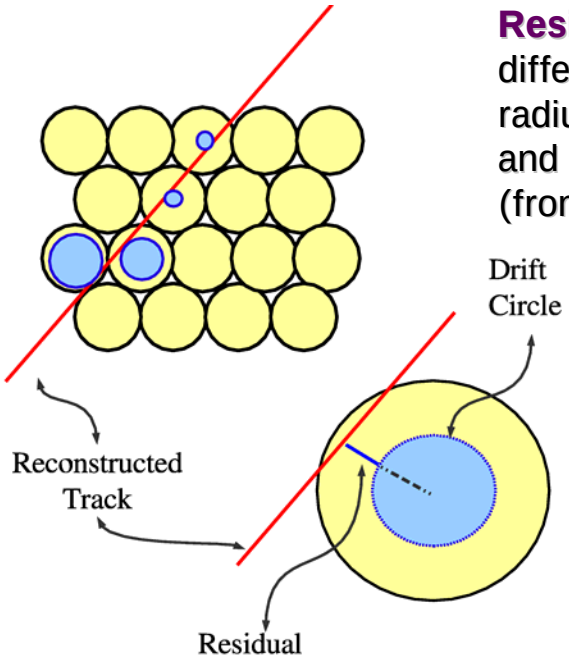
RTs calculated for each daily run with source on

RTs compared to reference run: differences within ±25 μm

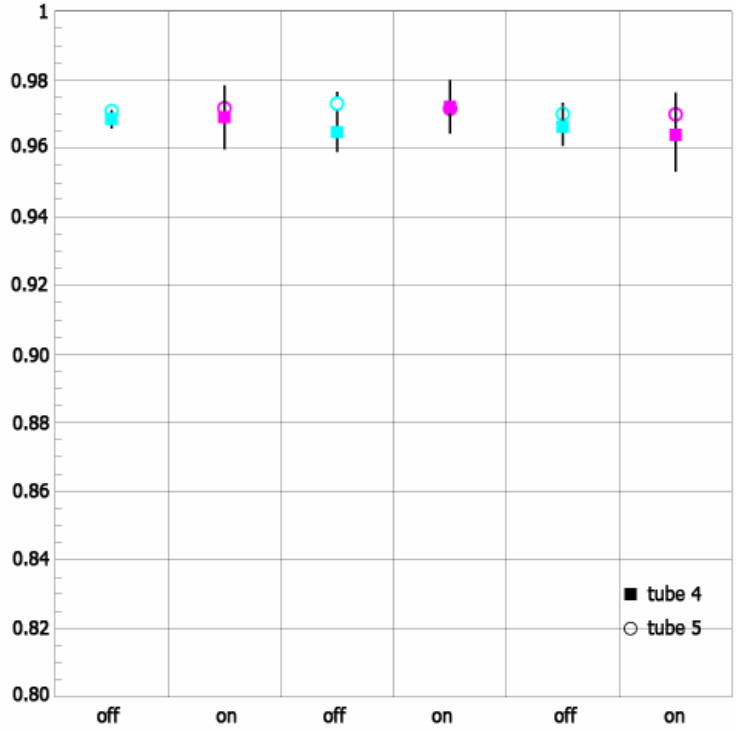


Pattern recognition still possible under ATLAS-like neutron fluxes.

High rate studies: efficiency



Residual:
difference between measured radius (drift circle) and extrapolated radius (from reconstructed track)



Hardware efficiency:
possibility to register a hit in the tube, irrespective of measured time

5σ efficiency:
a track is reconstructed on 3 tubes and extrapolated on the 4th.
Hit on 4th tube is accepted if residuals are lower than 5 times the spatial resolution

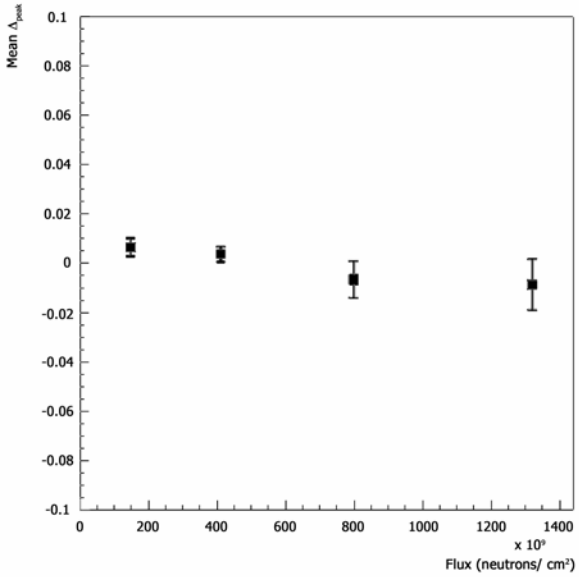
Single tube 5s efficiency calculated for each run.

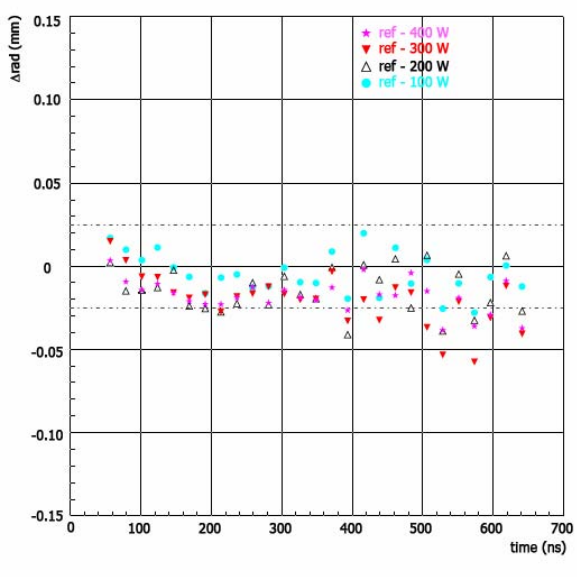
Cosmic runs and **high rate runs** are compared.

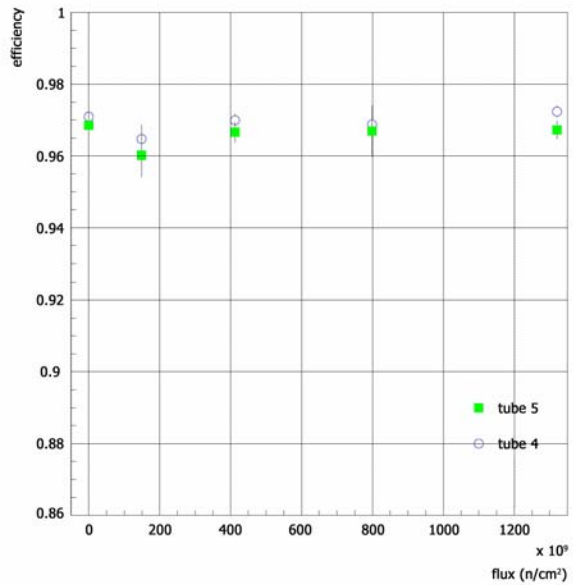
No efficiency variation.
Stable around 97%.

Neutron irradiation test on ATLAS MDT chambers

Aging studies







Mean variation of peak
with respect to reference run.

Values compatible within 1σ

No gain loss after massive neutron irradiation.

RTs calculated for 4 different integrated flux runs.

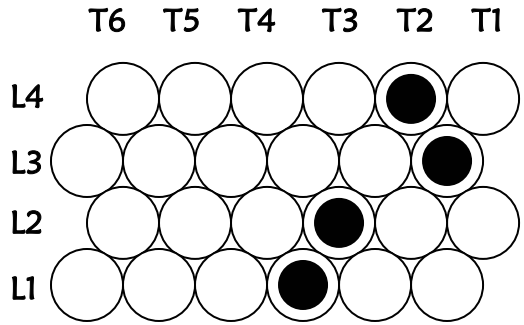
Comparable to reference runs within ±25 μm.

No degradation of track fit quality after intensive irradiation

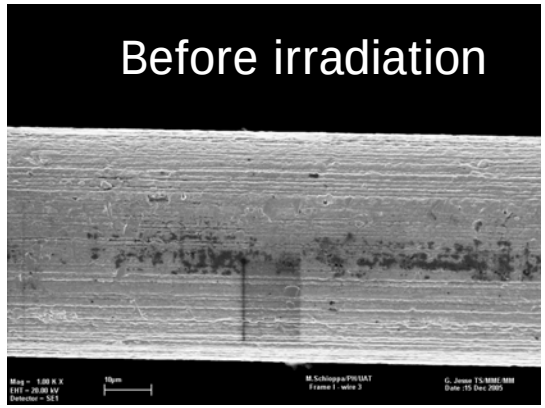
5s efficiency

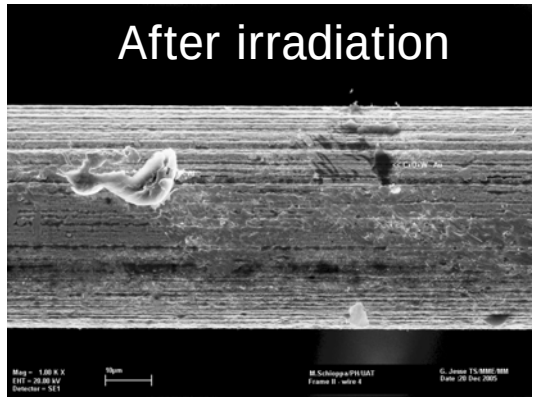
Values are stable around 97% within statistical errors during the overall data taking

SEM & EDX analysis



- After irradiation **4** wires (in different position in the serial triplet) analyzed by SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive X-ray)
- 3 samples (4 cm) for each tube: gas inlet side, gas outlet side, middle
- Reference samples: 3 x 4cm wires from the same spool
- Irradiated wires show the same pollution detected on the reference ones





Conclusions

- Intensive neutron and photon irradiation test was performed on final MDT-like test chambers.

  After overall accumulated charge (**4.8 C/cm**) and neutron flux (**$1.32*10^{12}$ n/cm^2**)

- good electronics response
- no gas leak observed: stable behaviour of o-rings, end-plugs, gas distribution elements
- no damage evidences from chemical analysis on wires

- no gain drop observed from ADC studies
- negligible variation of drift properties from RT studies
- no reconstruction efficiency loss

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Backup slides

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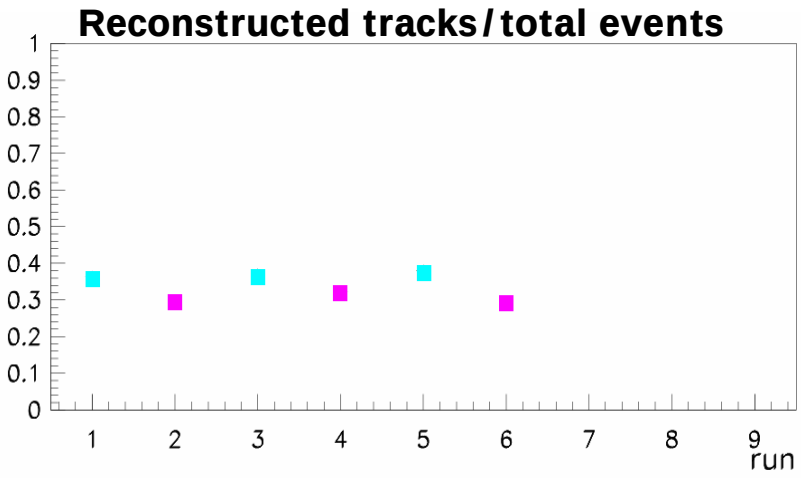
Backup



Source off runs

Source on runs