Performance of the ATLAS Precision Muon Chambers under LHC Opertating Conditions

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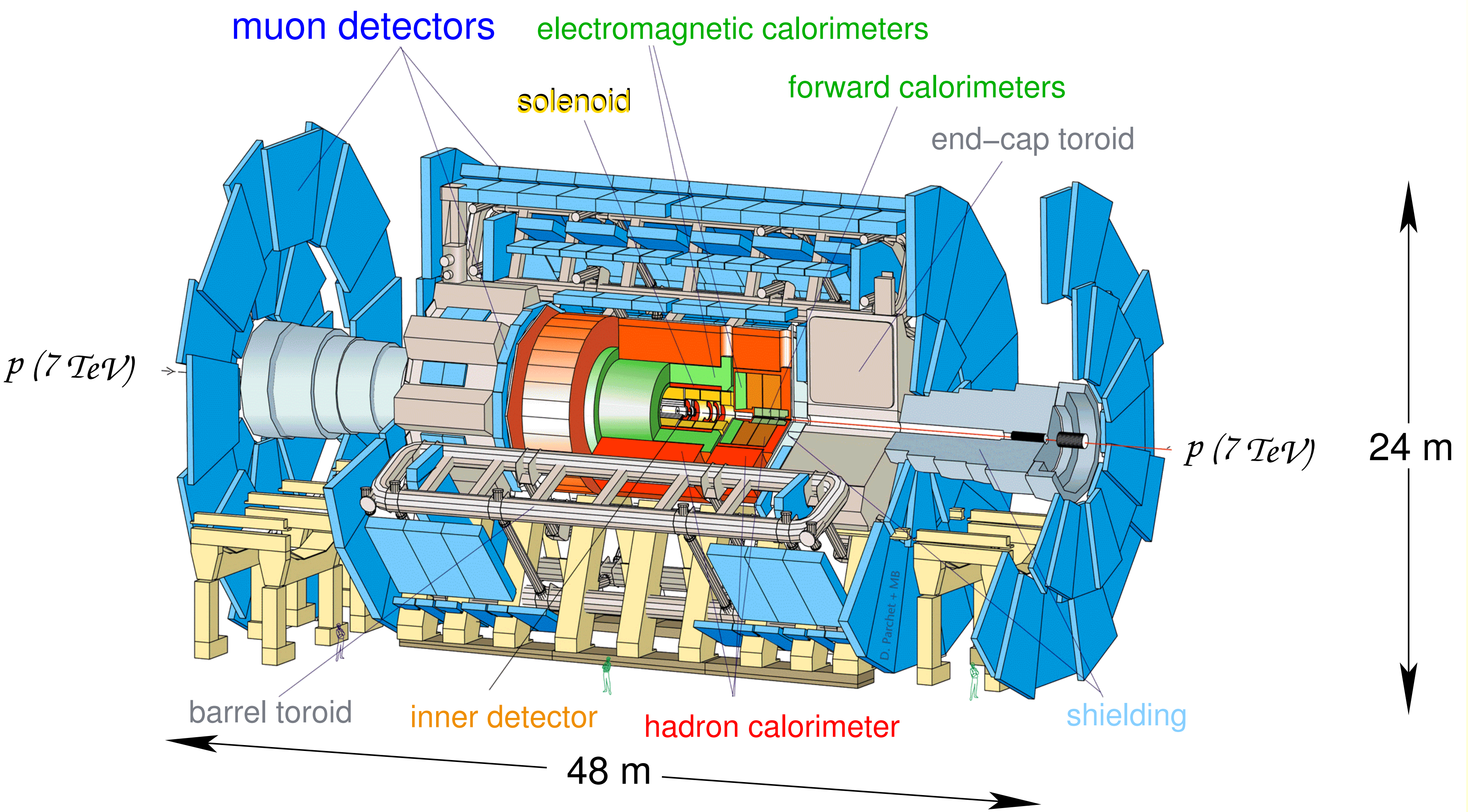
9th Pisa Meeting on Advanced Detectors:
Frontier Detectors for Frontier Physics
25.05.–31.05.2003

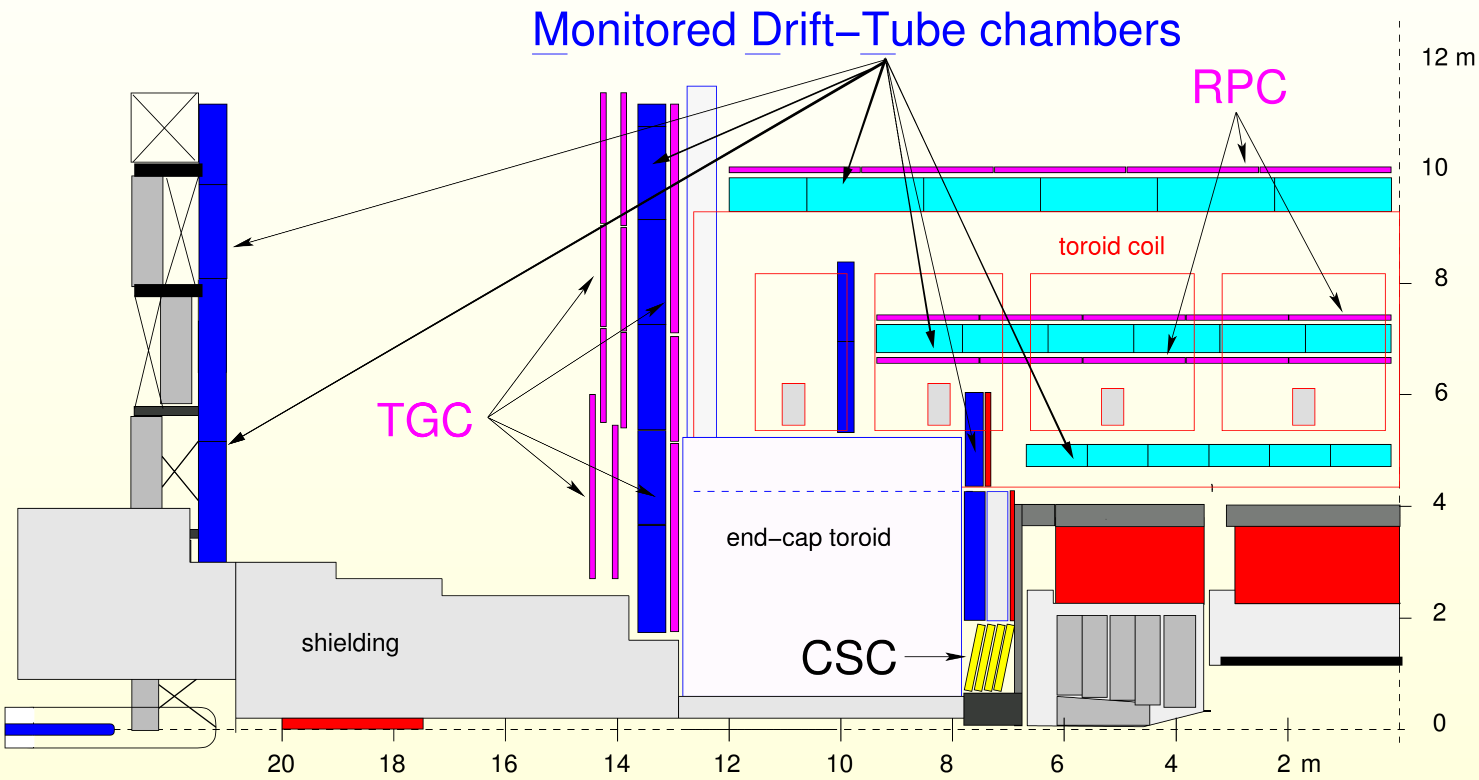
Outline

1. The ATLAS detector and its muon spectrometer.
2. Monitored drift-tube chambers as precision tracking detectors.
3. Background conditions in the muon spectrometer.
4. Spatial resolution of drift tubes at the ATLAS background.
5. Single-tube and tracking efficiencies at the ATLAS background.
6. Summary.

THE ATLAS DETECTOR



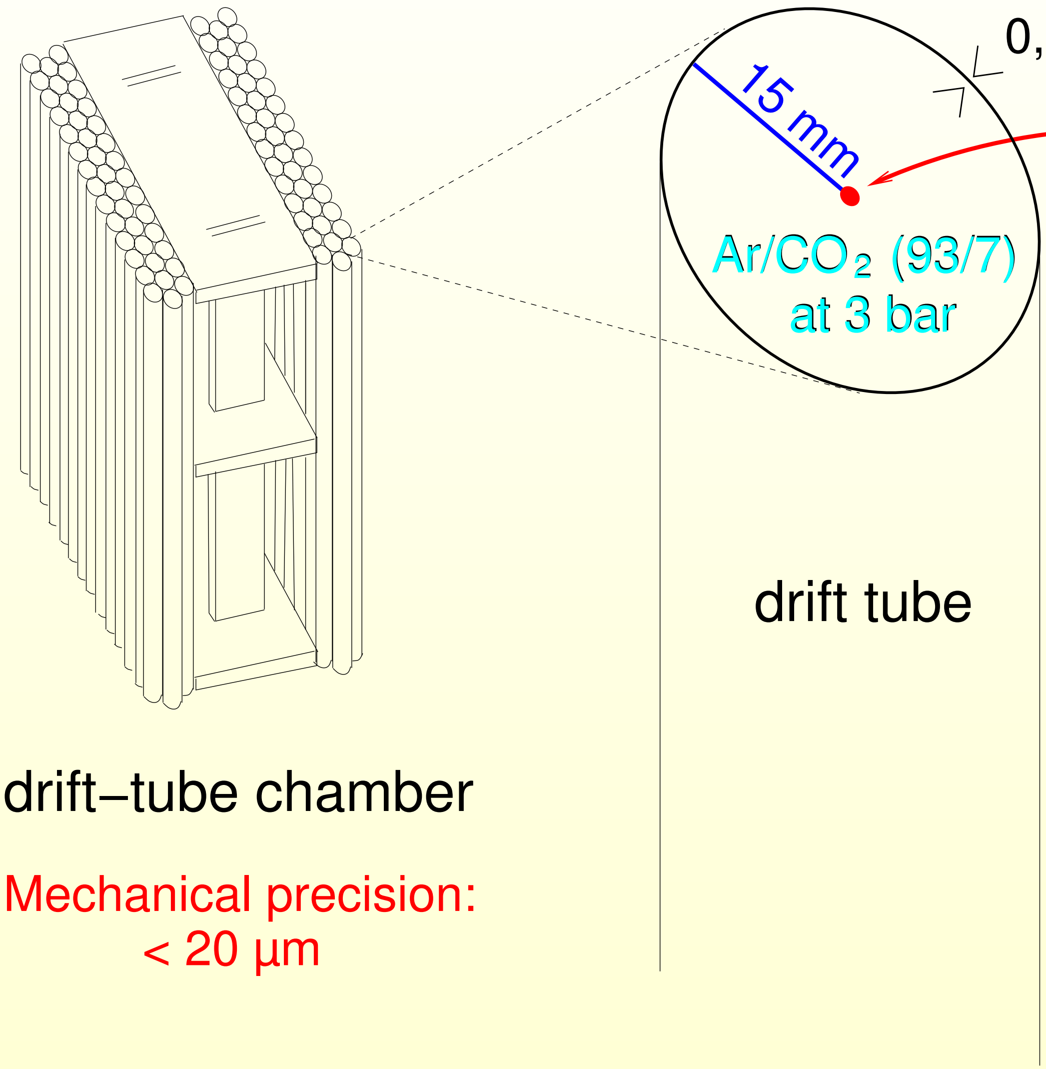
The ATLAS Muon Spectrometer



- Average magnetic field: 0.4 T.
- Fast trigger chambers: TGC, RPC.
- High resolution tracking detectors: CSC, MDT.

⋆ Accurate reconstruction of the muon momentum (3% accuracy).

Monitored Drift-Tube Chambers



50 µm W–Re wire
at 3080 V,

gas gain: $2 \cdot 10^4$,

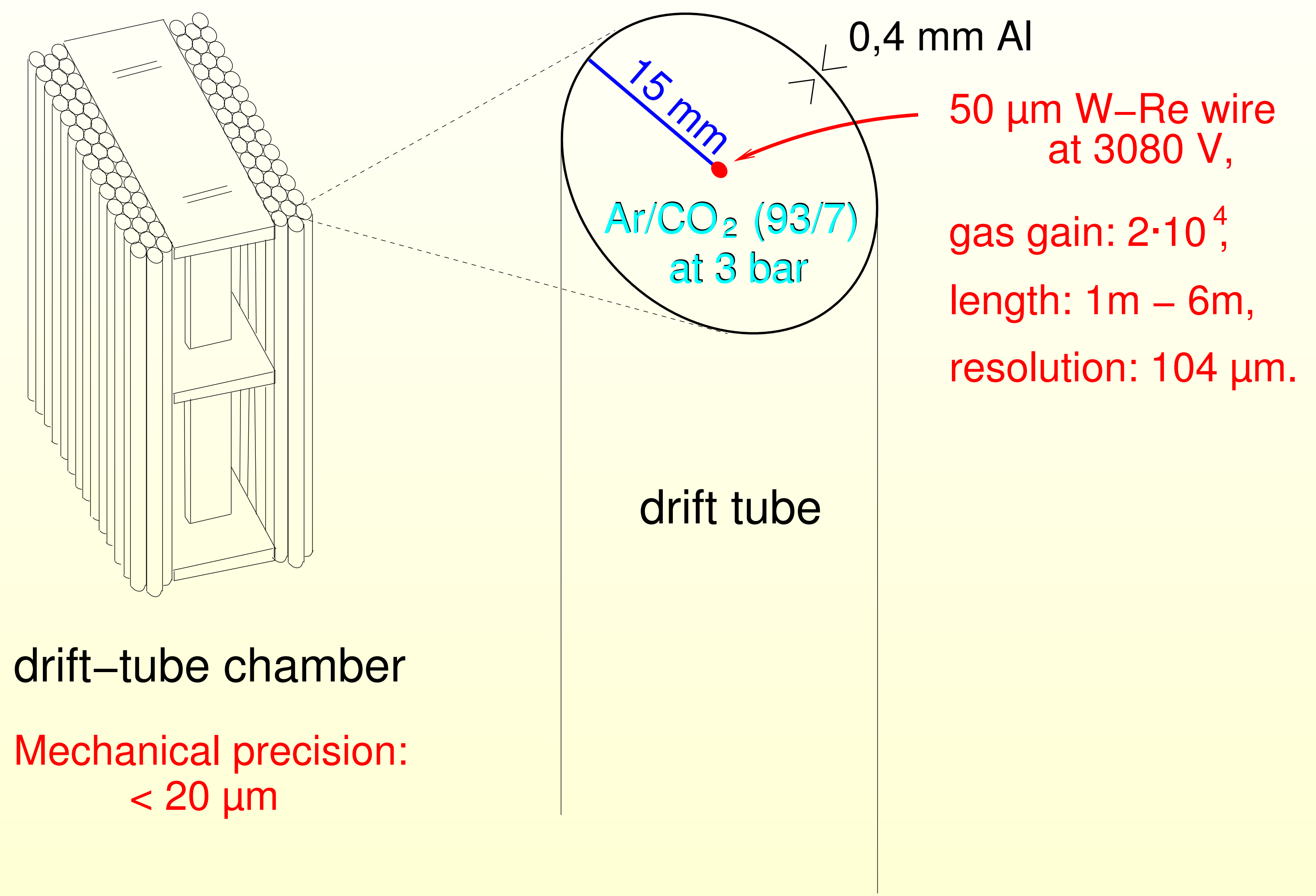
length: 1m – 6m,

resolution: 104 µm.

drift–tube chamber

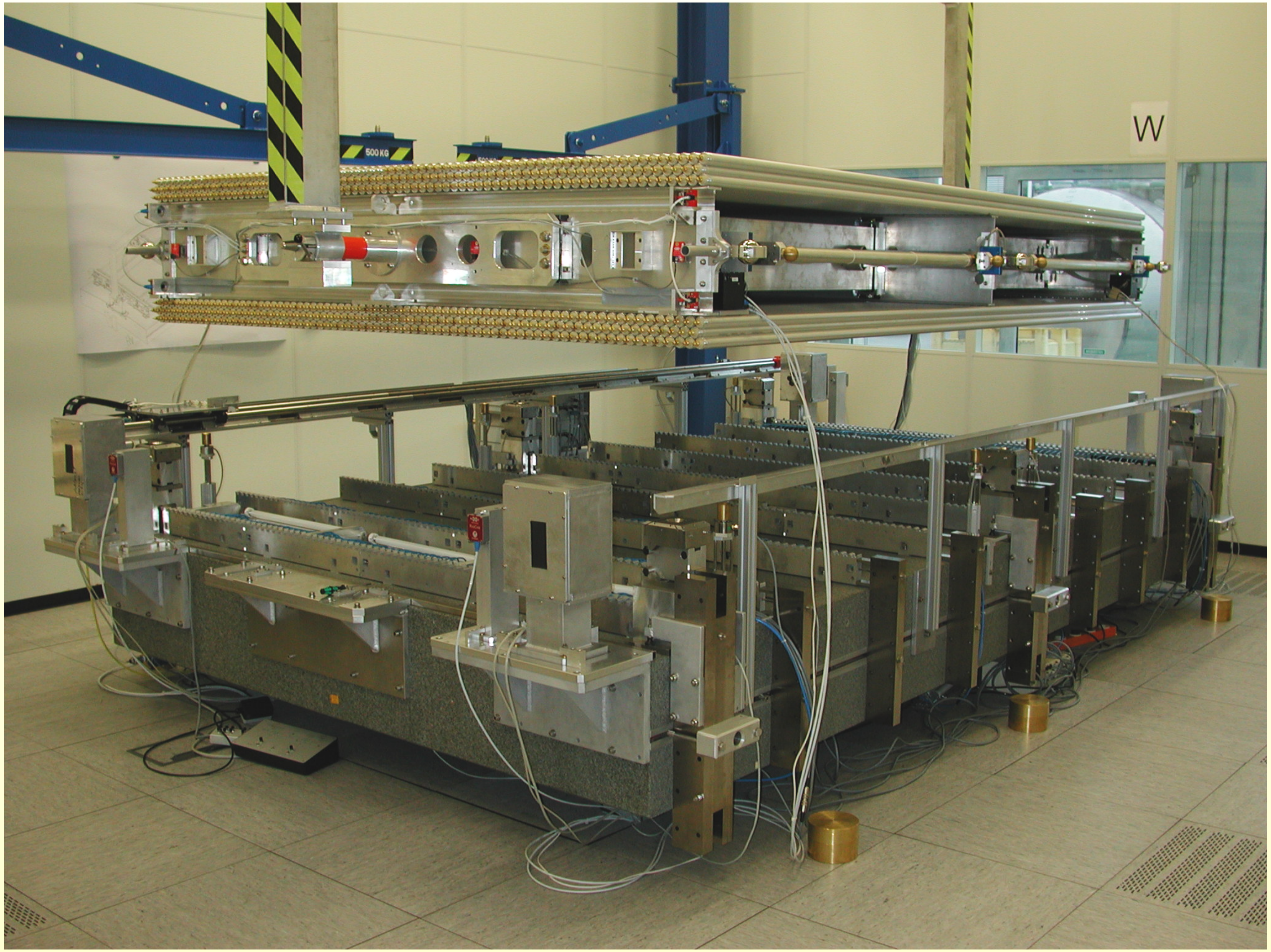
Mechanical precision:
< 20 µm

Monitored Drift-Tube Chambers

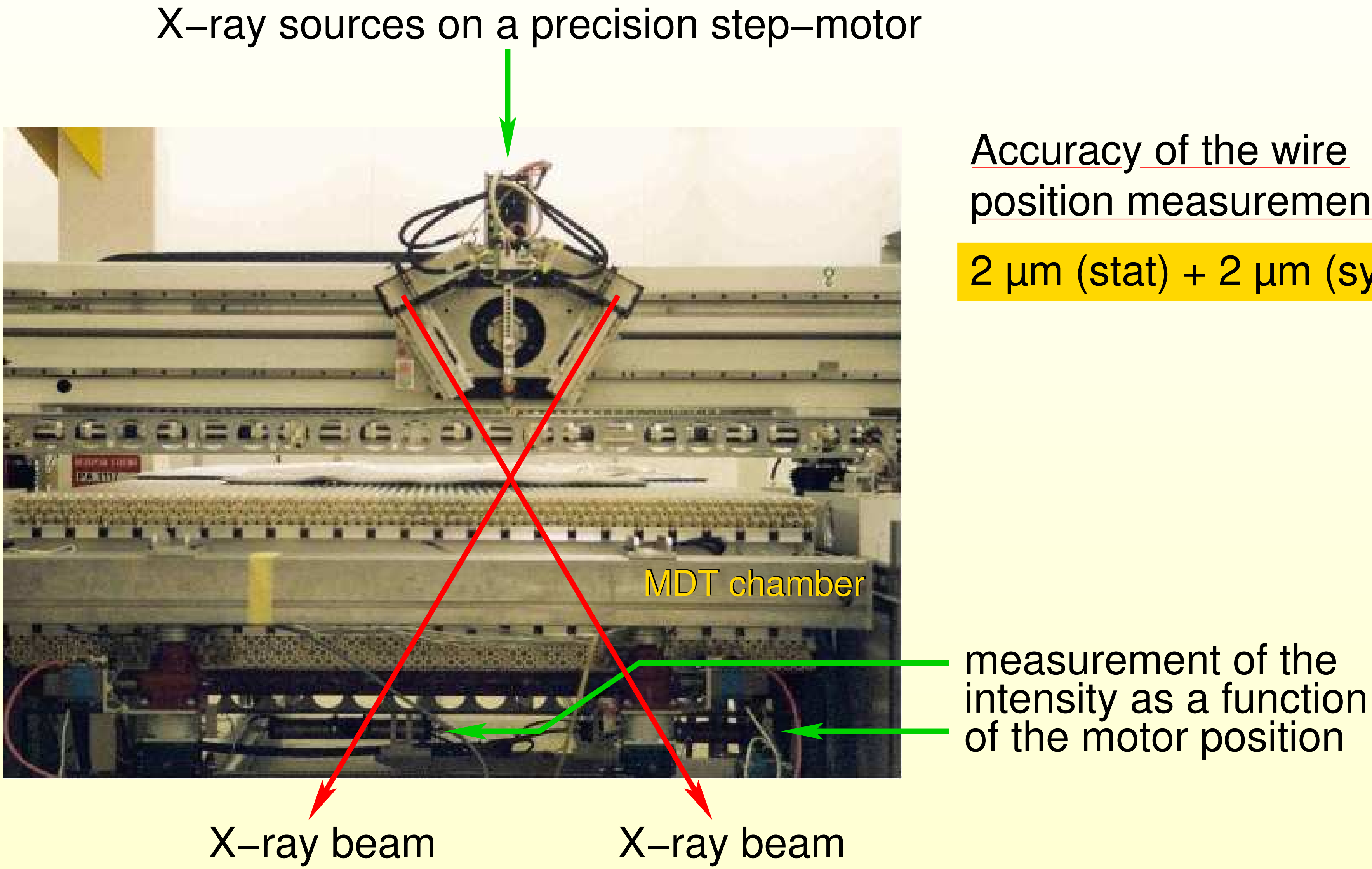


1200 chambers (350 000 tubes in total) must built for ATLAS.

Picture from the Chamber Assembly



Quality Control by X-Ray Tomography

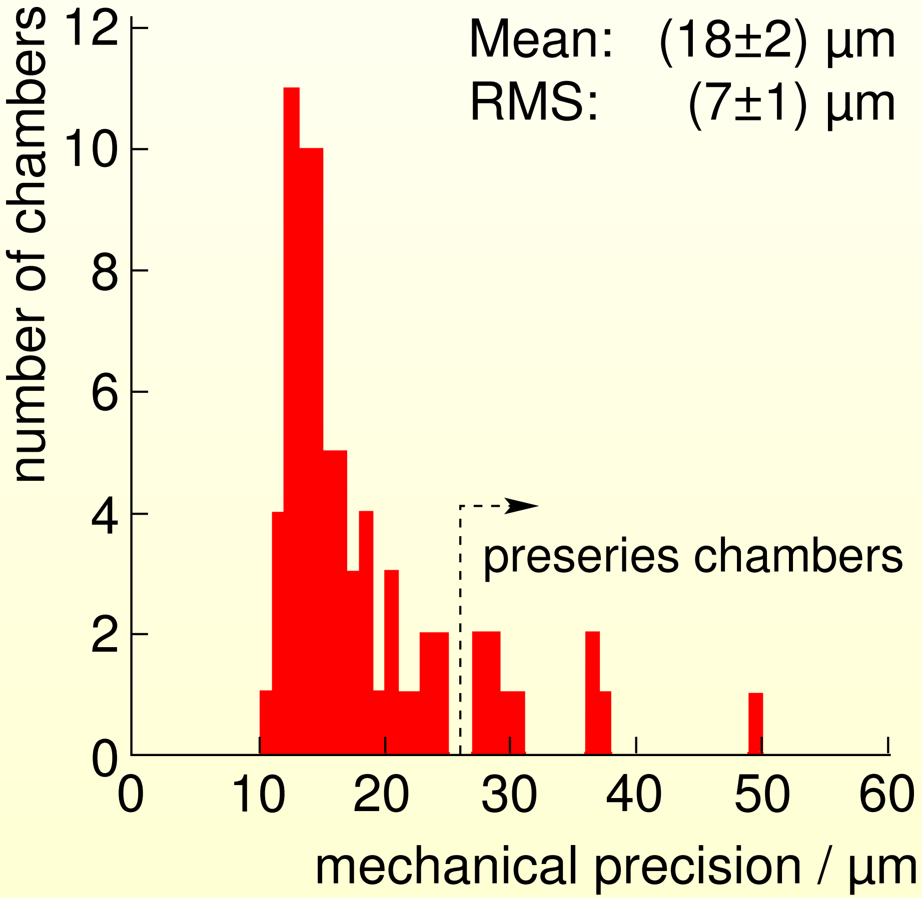


Accuracy of the wire position measurement:

2 µm (stat) + 2 µm (syst).

Results of the X-Ray Tomography

75 of 650 chambers produced at 13 different sites have been tested.



Mechanical chamber precision:
15 μm.

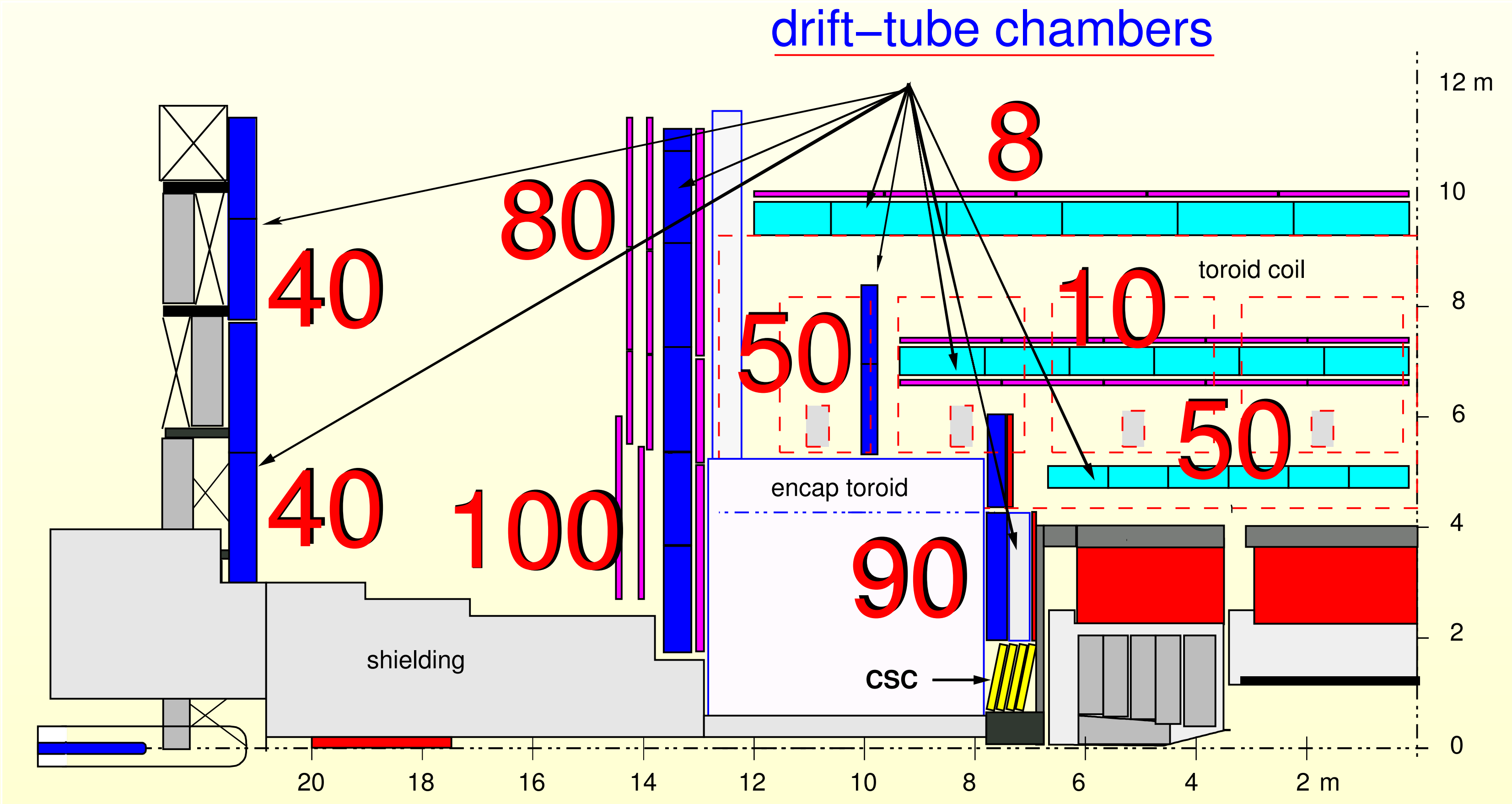
Further details on the chamber assembly and the X-ray tomography in the poster session:

H. Kroha et al. Large Scale Production and Tests of Precision Drift Tube Chambers for the ATLAS Muon Spectrometer.

S. Schuh. A high precision X-ray Tomograph for quality control of the ATLAS Muon Monitored Drift Tube Chambers.

Background Conditions

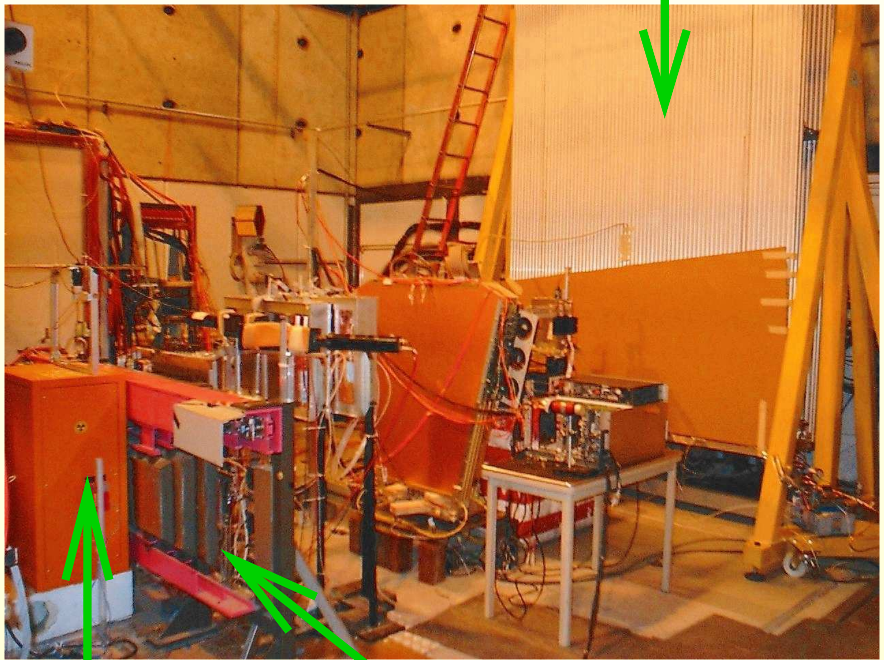
Neutron and Photon Background Counting Rates ($s^{-1}cm^{-2}$)

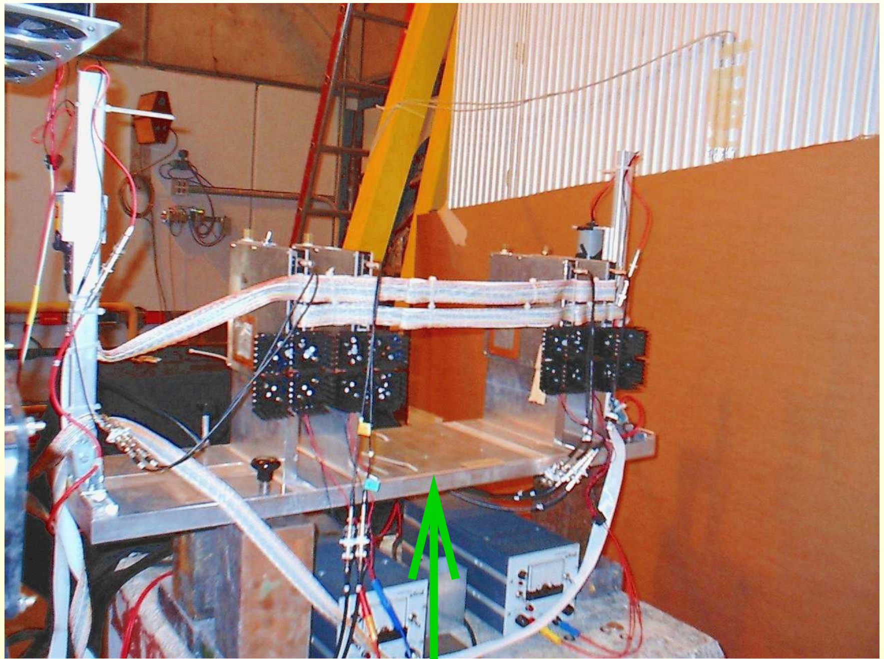


Spatial Resolution of Drift Tubes

Experimental Set-up at CERN's Gamma Irradiation Facility

MDT chamber
with 4 m long tubes





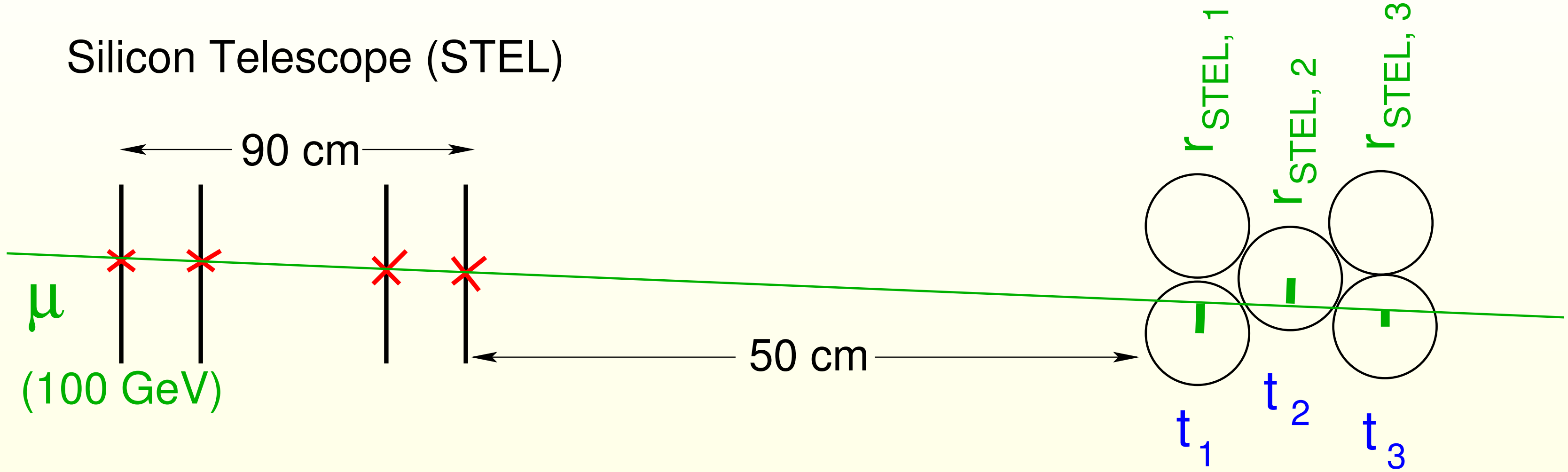
740 GBq
Cs137 source

movable lead filters
for rate adjustment

four–layer silicon tracking detector

Second such measurement. First mesurement: M. Aleksa et al., NIM A 446 (2000) 435.

Strategy of the Analysis



Reconstruction of the
muon trajectory
from the
hits in the silicon telescope

Extrapolation of the trajectory into
the 1st triple layer of the chamber

↓

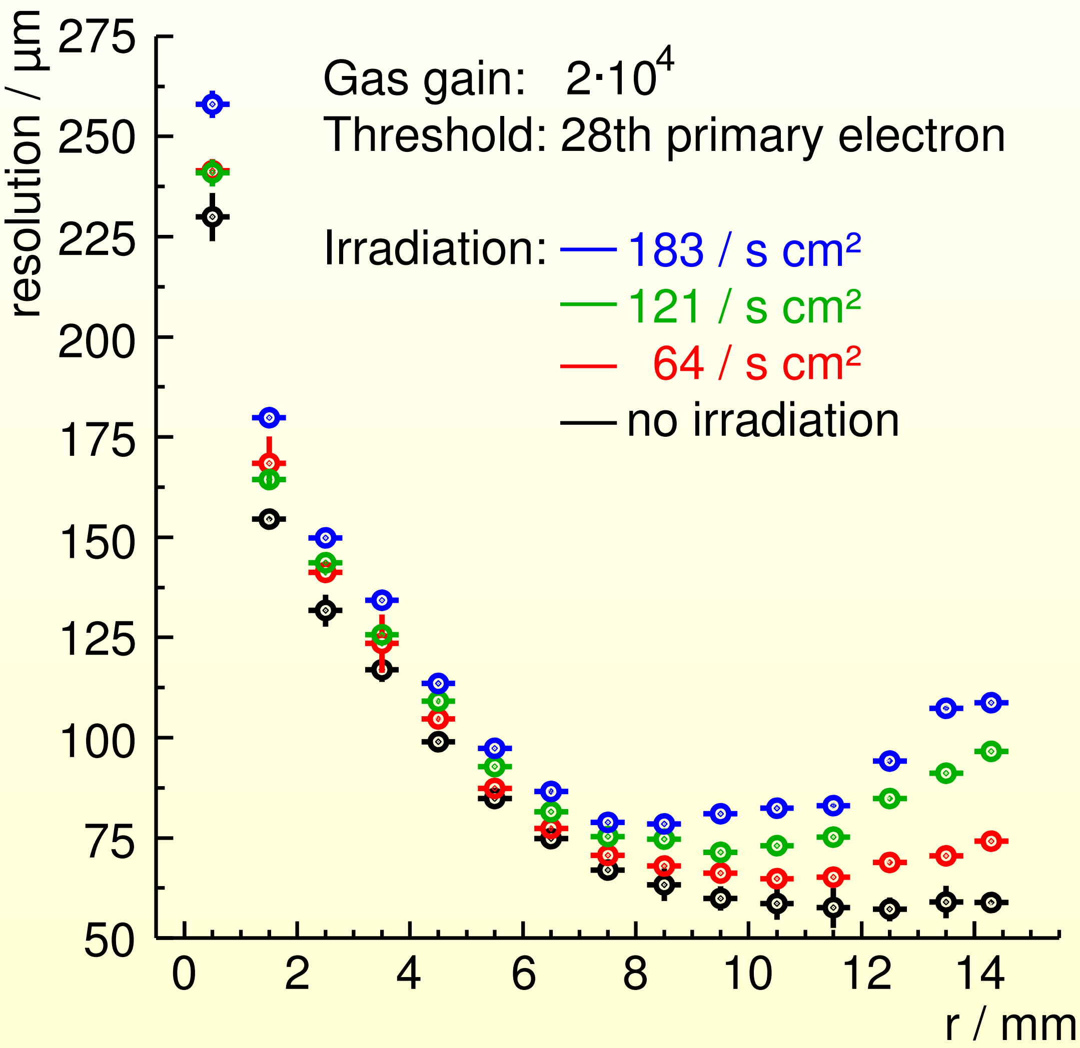
Track distance $r_{STEL,k}$
(accuracy: 20 μm)

↓

$r_{STEL,k}$ vs t_k →
space-to-drift-time relationship $r(t)$

$\sqrt{Var(r(t) - r_{STEL})}$ as a function of r_{STEL} is the single-tube resolution $\sigma(r)$.

Rate Dependence of the Single-Tube Resolution

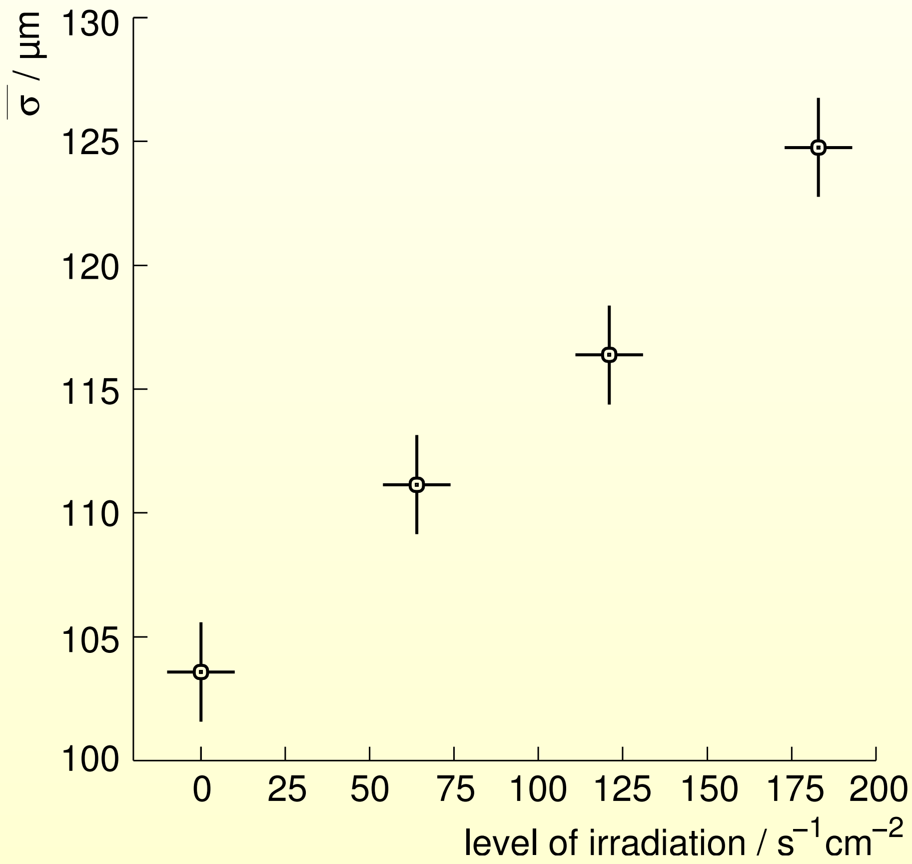


degradation due to the
space charge effect

Average Single-Tube Resolutions

Average single-tube resolution:

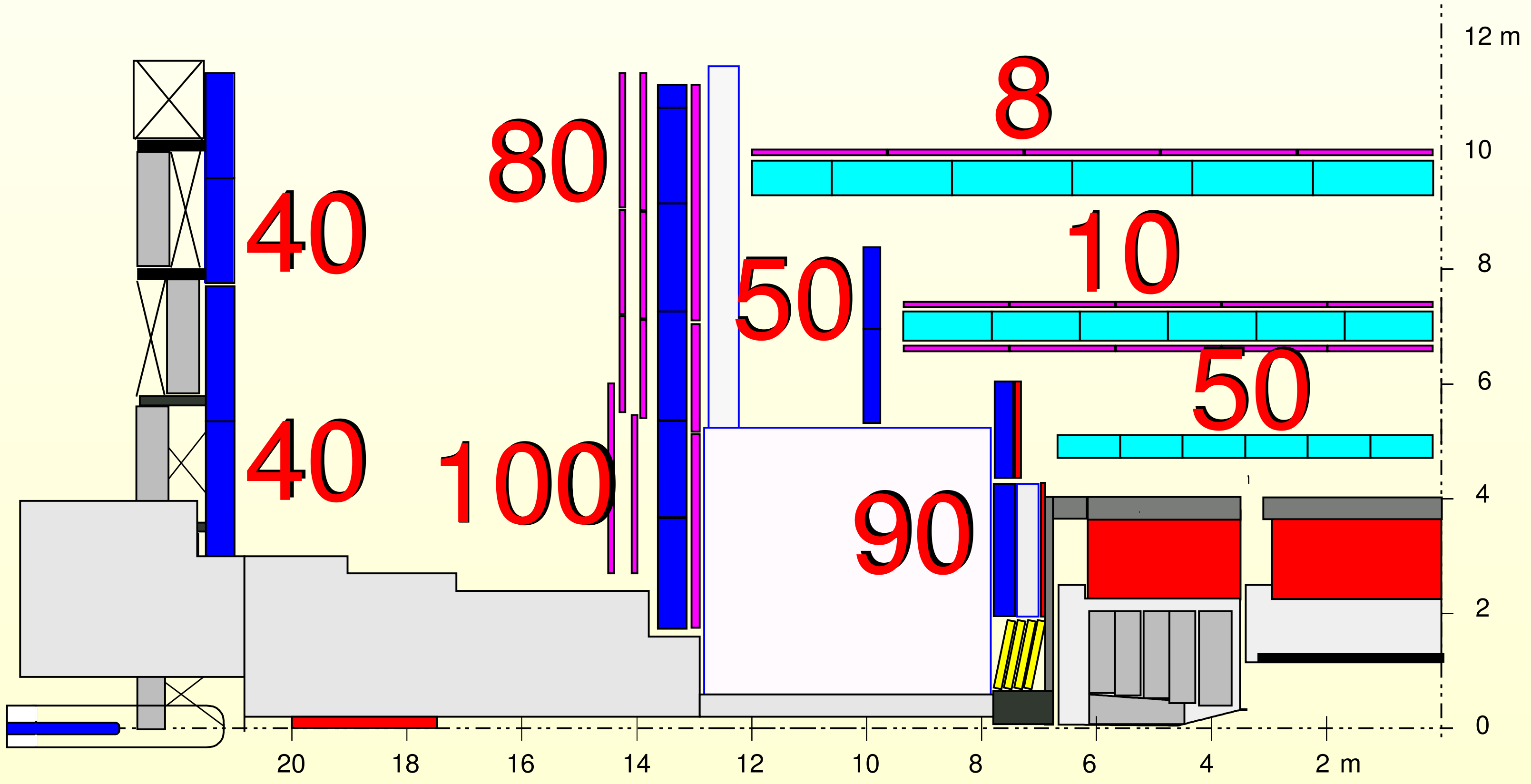
$$\bar{\sigma} := \sqrt{\frac{1}{14.6\ \text{mm}} \int_0^{14.6\ \text{mm}} \sigma^2(r) dr}$$



Good spatial resolution even at a high level of irradiation!

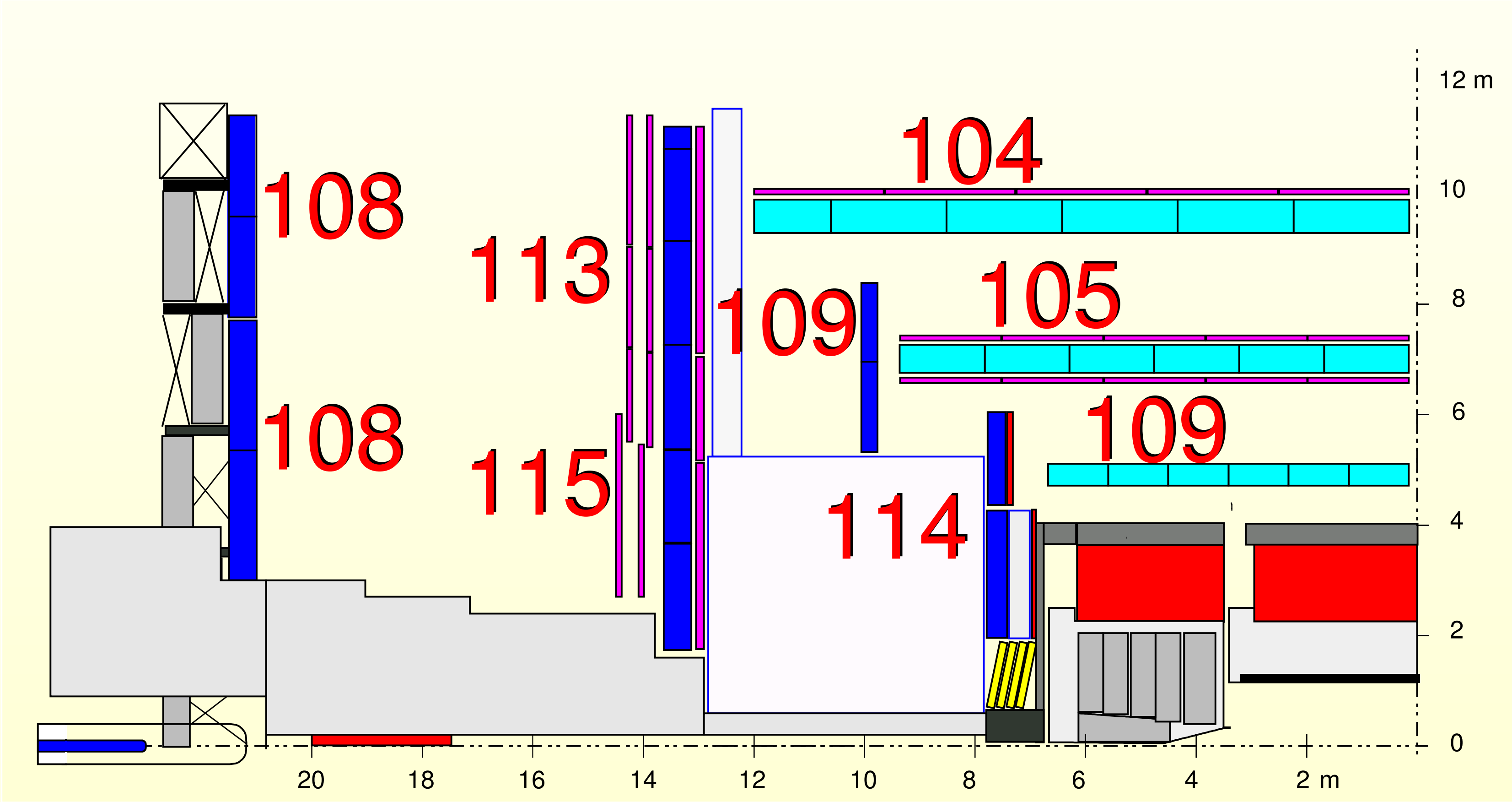
Spatial Resolution under Irradiation – Summary

Neutron and Photon Background Counting Rates ($s^{-1}cm^{-2}$)



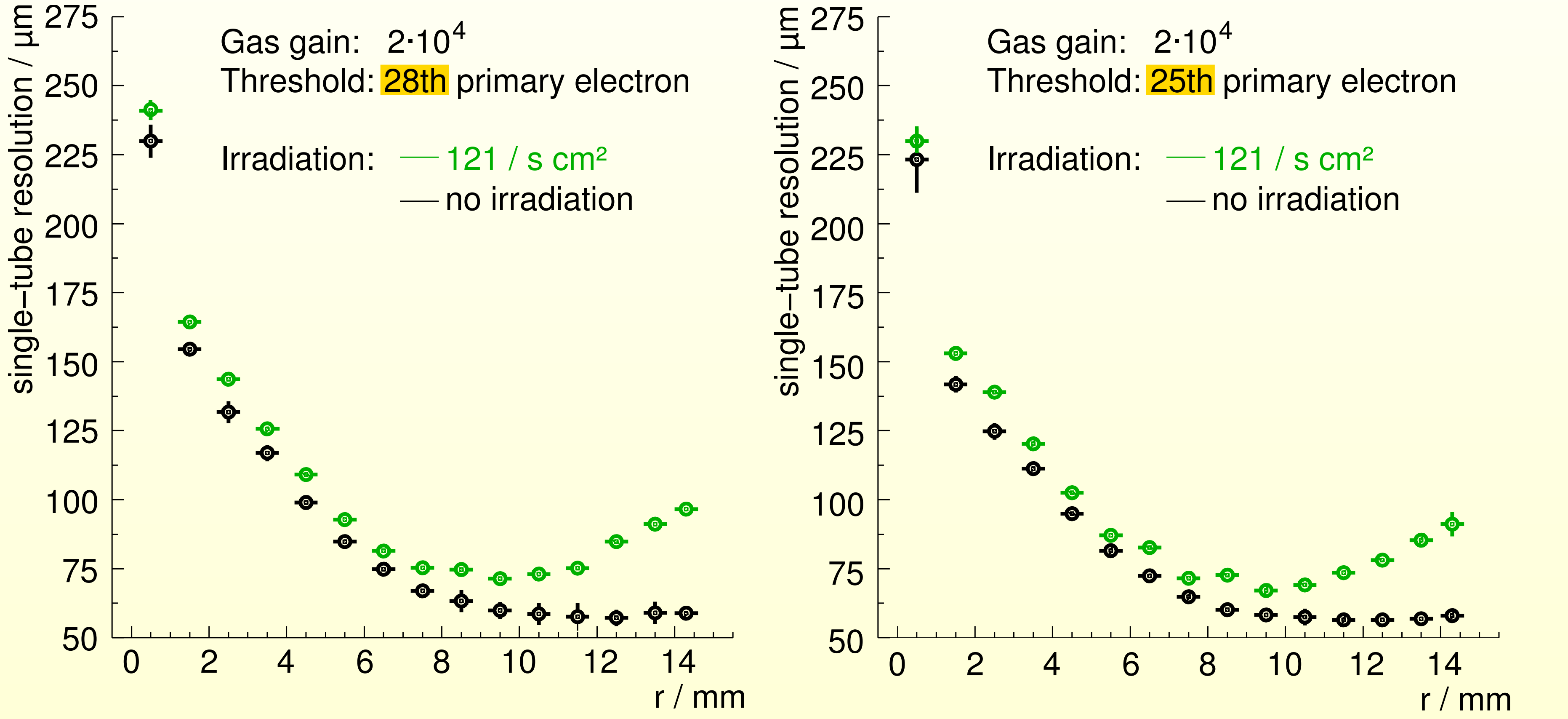
Spatial Resolution under Irradiation – Summary

Average Single-Tube Resolution (μm)



Ways of Improving the Spatial Resolution

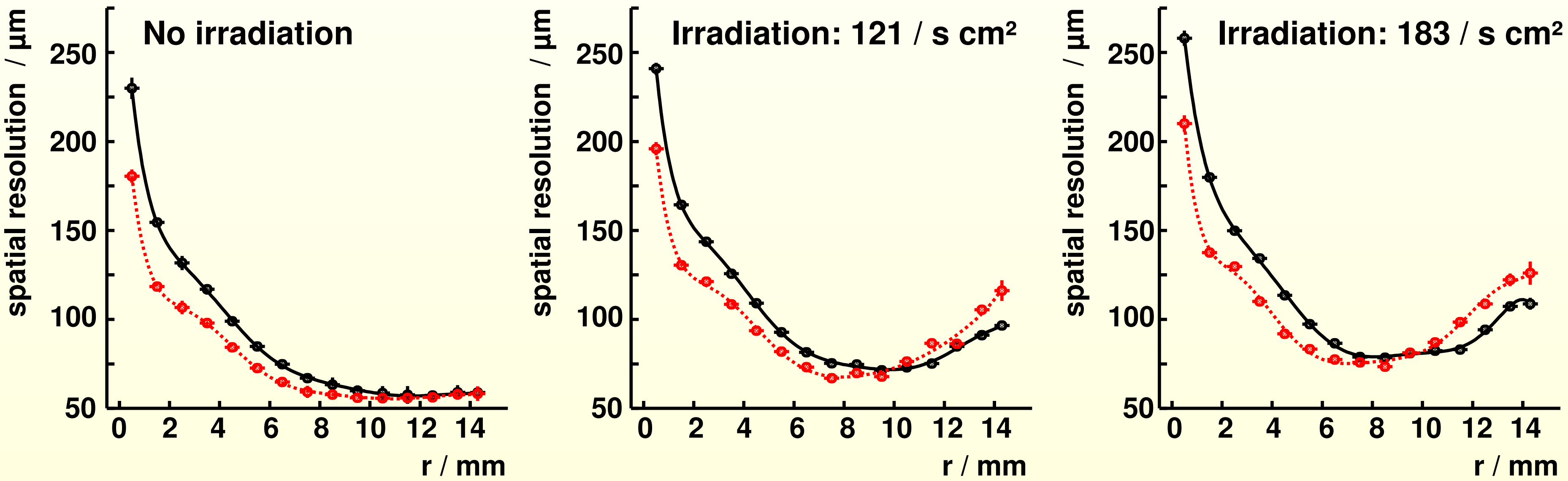
a) Improving the resolution by lowering the discriminator threshold.



The average resolution is improved by 5 μm at the lower threshold.

Ways of Improving the Spatial Resolution

b) Improving the resolution by increasing the gas gain.

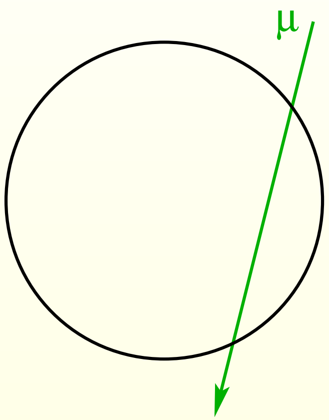


	No irradiation	Irradiation: 121 / s cm²	Irradiation: 183 / s cm²
Single–tube resolutions:			
Gas gain. $2\cdot10^4$:	104 µm	116 µm	125 µm
Gas gain. $4\cdot10^4$:	87 µm	105 µm	114 µm
Difference:	17 µm	11 µm	11 µm

The space-charge effect compensates the gain in resolution.

Single-Tube and Tracking Efficiencies

Single-Tube Efficiency



First possibility :

The tube traversed by the muon has detected a hit.

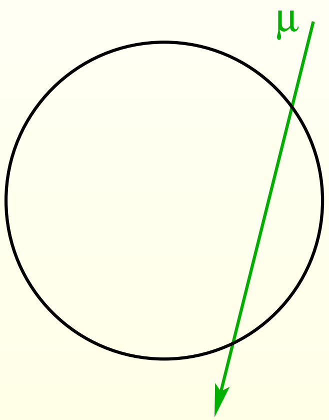
$\longrightarrow$ The tube is efficient.

Second possibility :

The tube traversed by the muon has detected no hit.

$\longrightarrow$ The tube is not efficient.

Single-Tube Efficiency



First possibility :

The tube traversed by the muon has detected a hit.

$\longrightarrow$ The tube is efficient.

Second possibility :

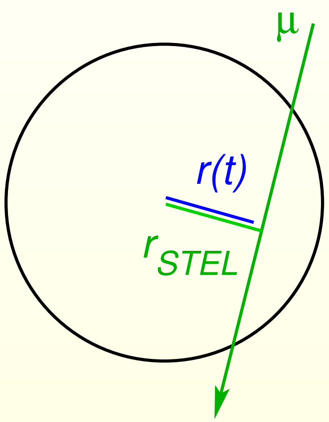
The tube traversed by the muon has detected no hit.

$\longrightarrow$ The tube is not efficient.

Irradiation ($s^{-1}cm^{-2}$)	Irradiation in kHz per tube	Efficiency
none	0	0.9970 ± 0.0002
63 $s^{-1}cm^{-2}$	73	0.9962 ± 0.0002
121 $s^{-1}cm^{-2}$	138	0.9960 ± 0.0002
183 $s^{-1}cm^{-2}$	209	0.9955 ± 0.0003

High efficiency also at high rates!

PROBABILITY $\epsilon_{3\sigma}$ FOR A CORRECT HIT



First possibility :

$$|r_{STEL} - r(t)| \leq 3\sigma(r_{STEL})$$

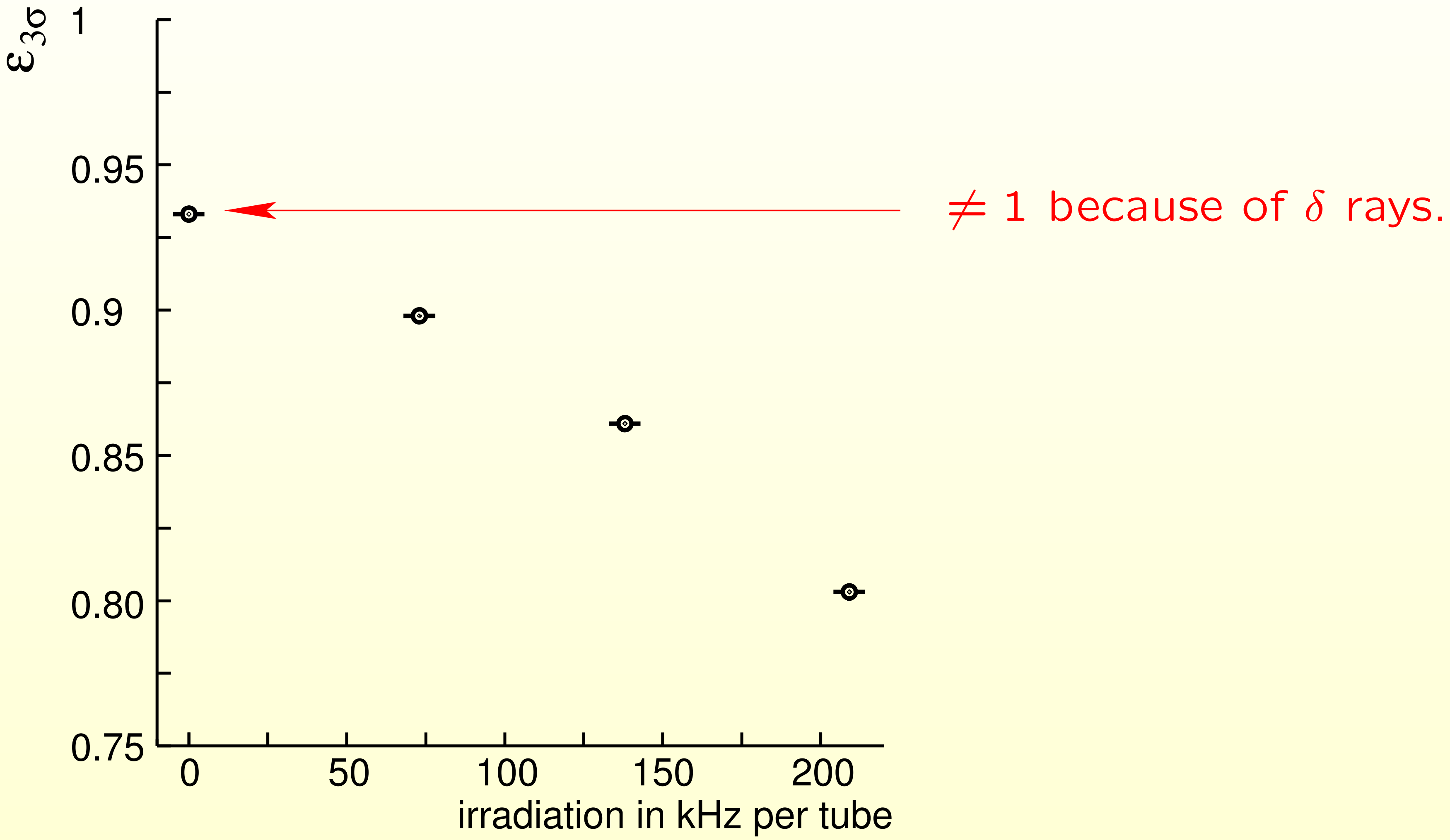
$\longrightarrow$ The hit is correct.

Second possibility :

$$|r_{STEL} - r(t)| > 3\sigma(r_{STEL})$$

$\longrightarrow$ The hit is wrong.

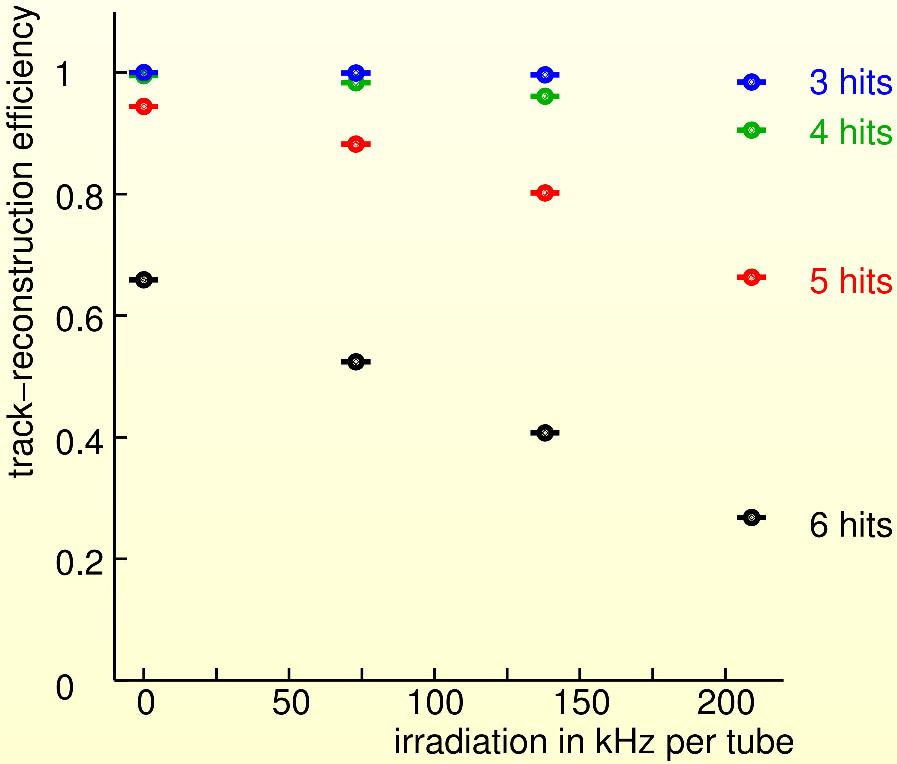
PROBABILITY $\epsilon_{3\sigma}$ FOR A CORRECT HIT



Track-Reconstruction Efficiency

Track-reconstruction efficiency for a track with at least k hits:

$$\sum_{l=k}^{6} \binom{6}{l} \epsilon_{3\sigma}^{l} \cdot (1-\epsilon_{3\sigma})^{6-l}.$$



Efficient tracking will be possible also at high levels of γ irradiation!

SUMMARY

1. Monitored drift-tube chambers are the heart of the precision detector in the ATLAS muon spectrometer.
   (a) Their mechanical precision is 15 μm.
   (b) The spatial resolution of their tubes is less than 104 μm.
2. In the ATLAS muon spectrometer, these chambers will experience background counting rates of up to 100 $s^{-1}cm^2$.
3. Under these conditions the average single-tube resolution will be degraded by less than 10 μm only.
4. Efficient track reconstruction under LHC operating conditions has been demonstrated.