Irradiation Response of Straw Drift Tubes

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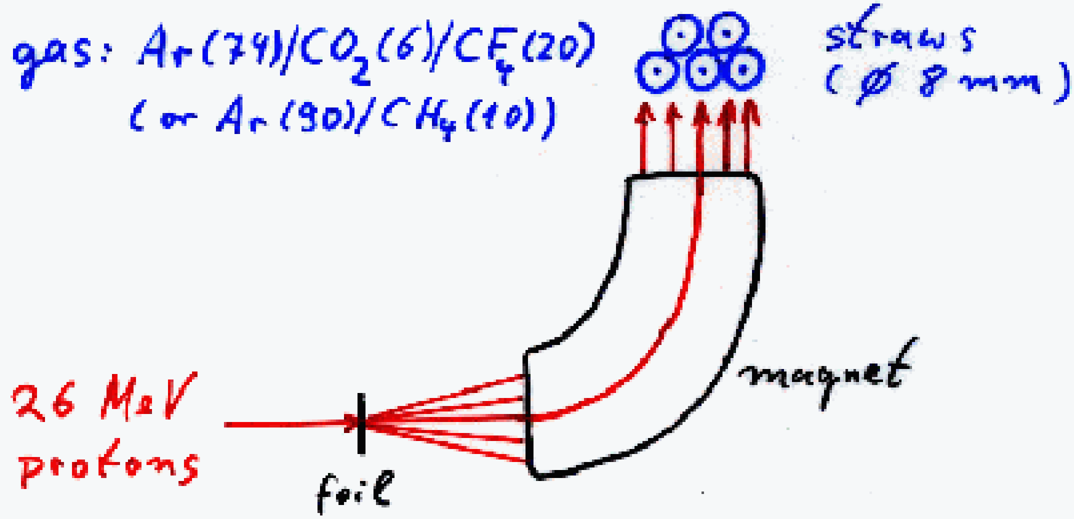
Aging tests for the large-area tracking system of the COMPASS experiment (CERN).

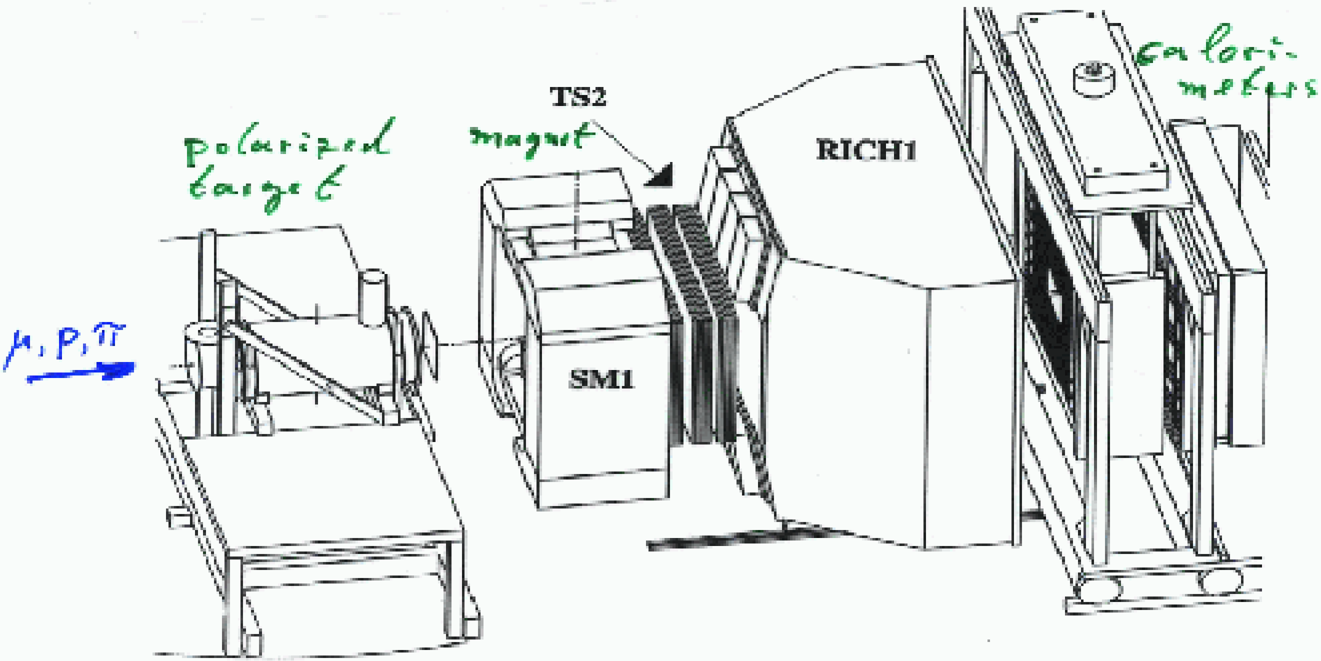


[$\langle \Delta E/\text{straw} \rangle$ = 16 keV (700 e^-)

$\longleftrightarrow$ for 100 GeV μ's : 2.3 keV (100 e^-)]

COMPASS Experiment at CERN

first stage magnetic spectrometer:

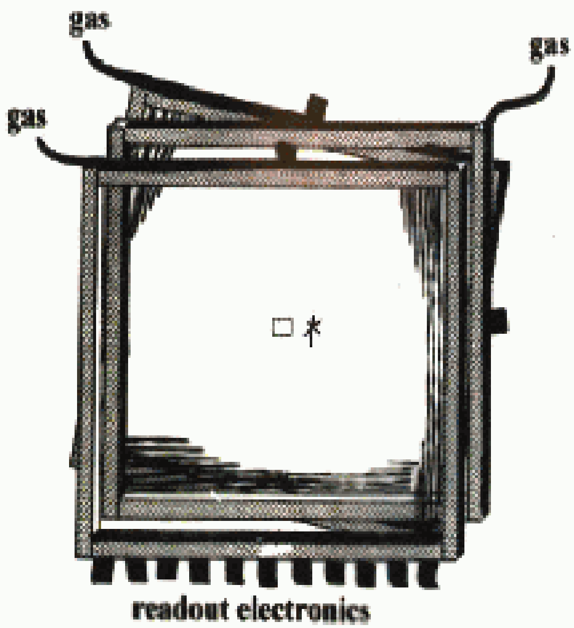


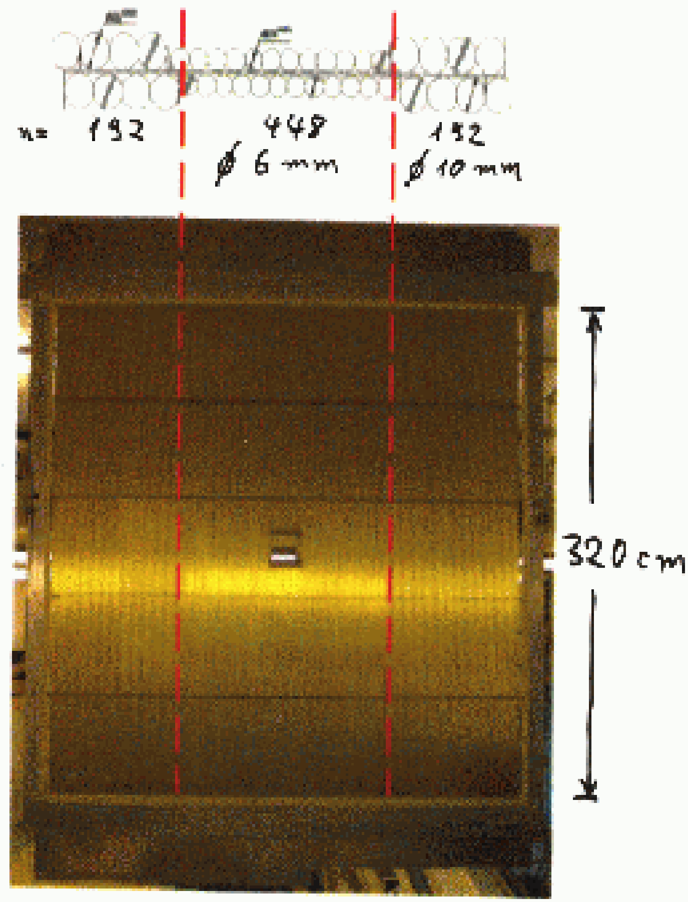
$I_\mu = 100$ MHz , $I_p = 50$ MHz , $I_\pi = 5$ MHz
(μ halo at 10 cm from axis $5 \cdot 10^4$ Hz/cm²)

tracking station TS2 :
18 double layers of straws → 13 800 straws,
length 3.2–3.7 m , Ø 6 and 10 mm
(built in Dubna by Pechekhonov et al.)

|| 4 (20) years , gas gain 10^5 ($2 \cdot 10^4$) } **1.1 C/cm** in inner μ halo ||

One submodule (out of 6) of the COMPASS large area tracking station

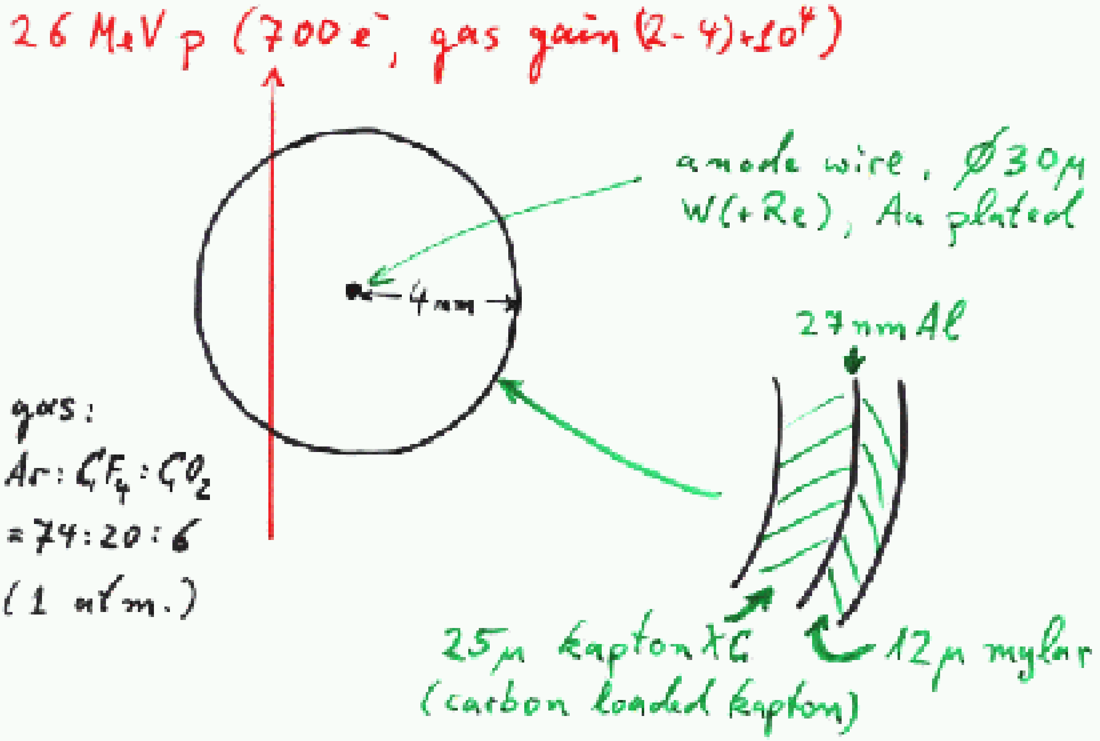




3 double layers of straws

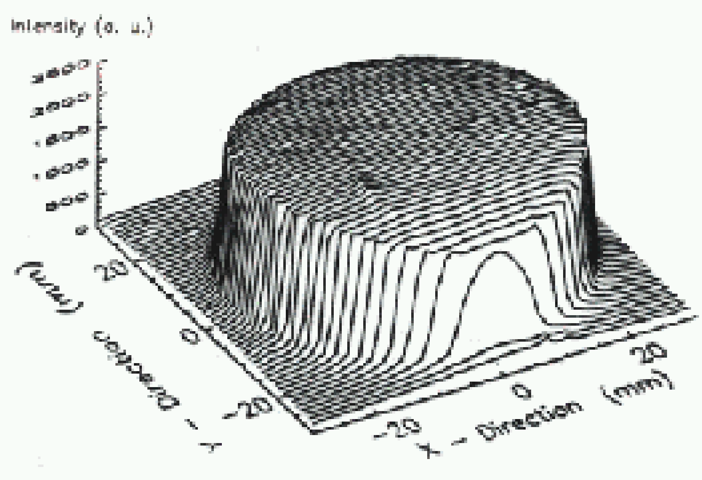
* 16cm x 23cm physical hole

Irradiation Experiments



Variable proton flux (measured with scintillator + ionization chamber), typical $(2-4)10^6$ Hz/mm².

Homogeneous radiation field:

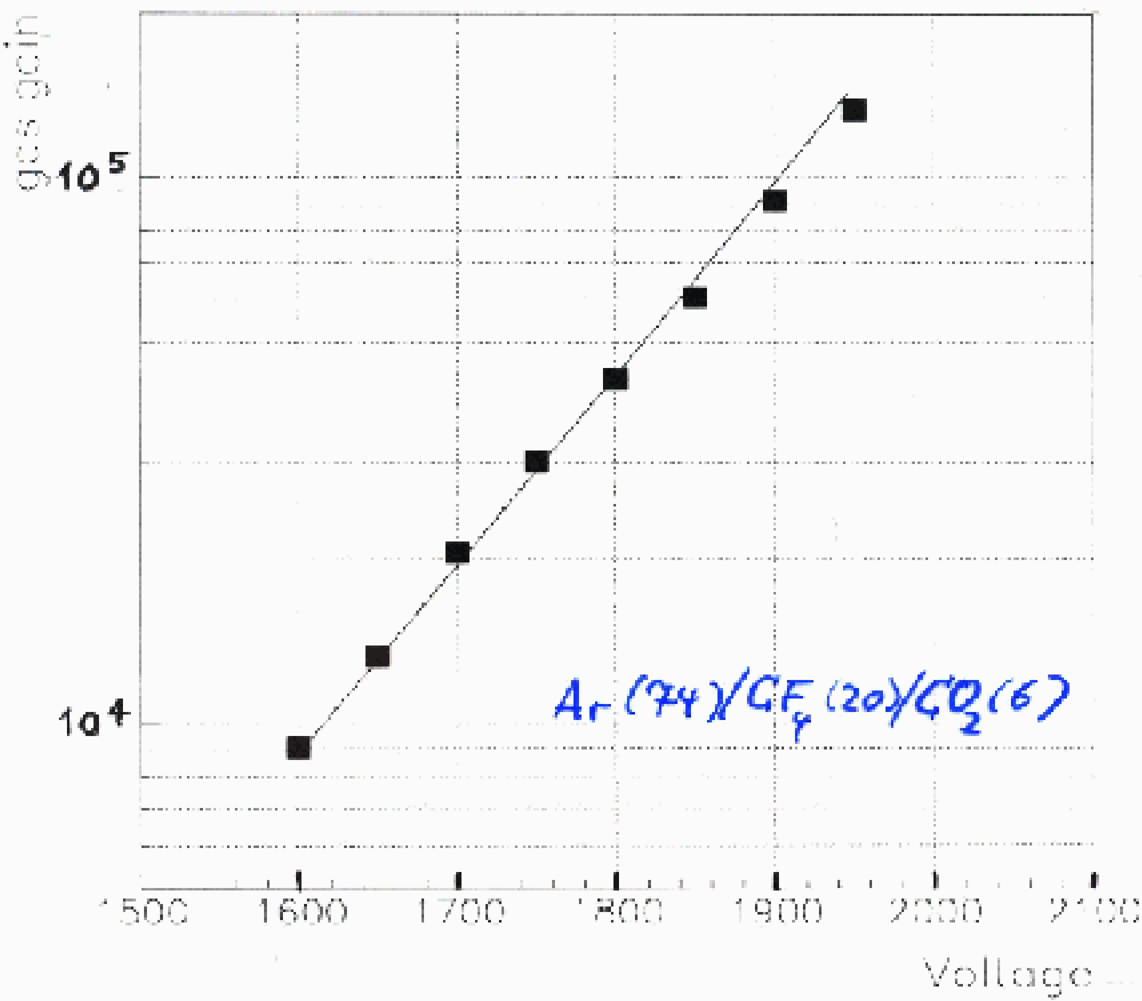


Gas Gain

$$G = \frac{\int I_{Anode} \cdot dt}{\int (flux \cdot irradiated\,area) \cdot \frac{Q_{primary}}{event} \cdot dt}$$

low → no space charge effects

40mm · 8mm



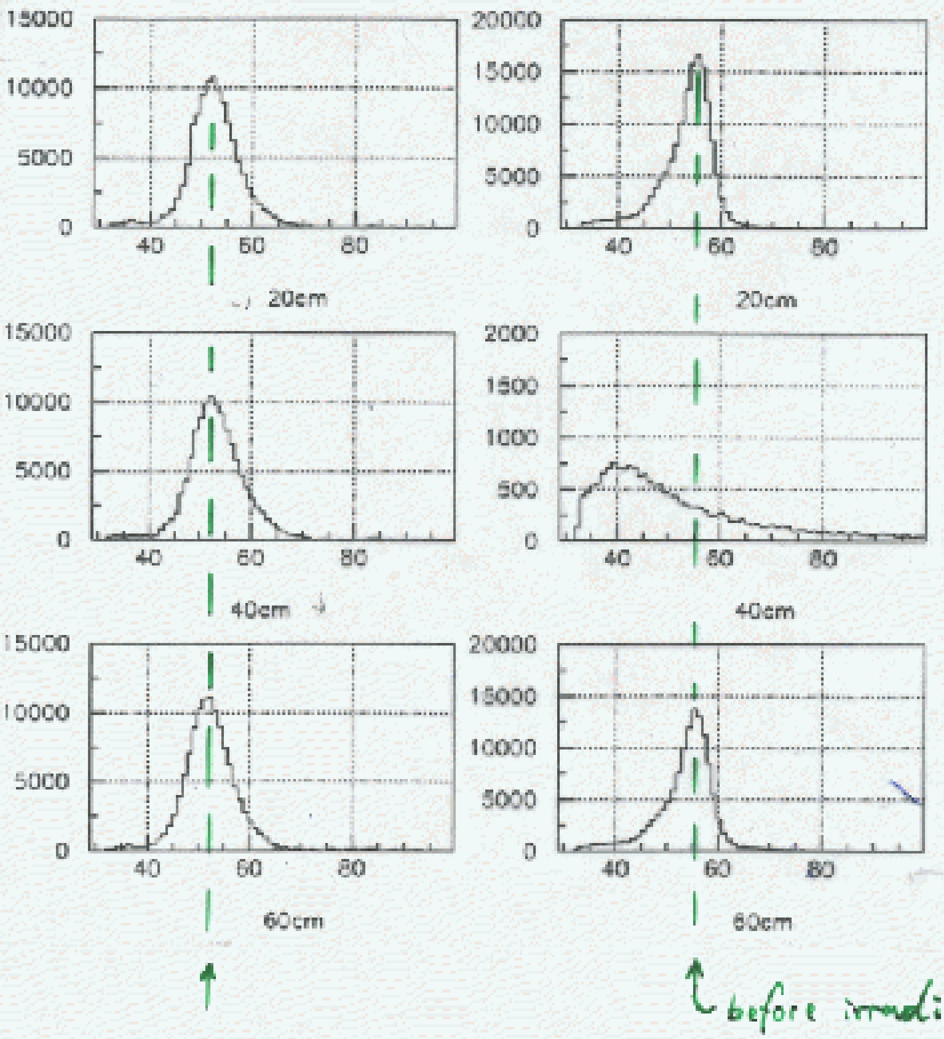
Aging Effects

consistent results from 2 independent irradiation experiments, each with 3 straw detectors and collected charge 1.1 C/cm.

a) gain loss ΔG

pulse height spectrum for ^{55}Fe (5.9 keV)

$Ar/CF_4/CO_2$, 2000 V | $Ar(90)/CH_4(10)$, 1600 V



out of beam

in beam

out of beam

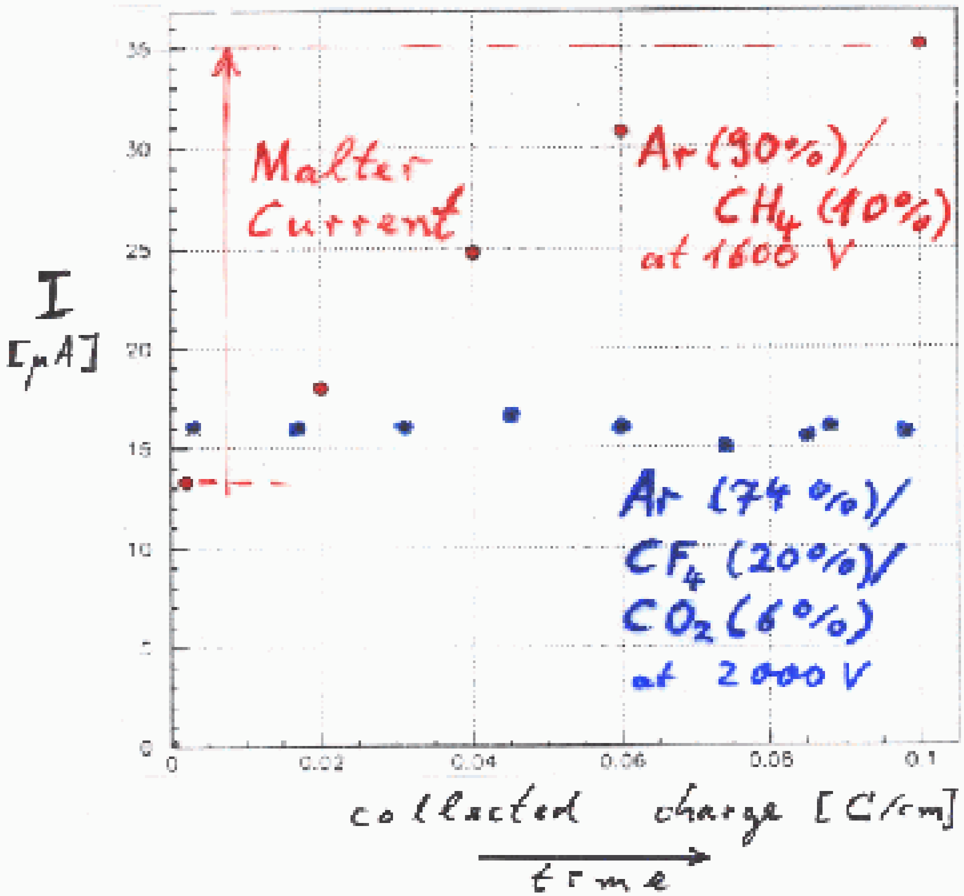
before irradiation

$$\frac{\Delta G}{G} / \frac{Q}{e} \lesssim 1\% / (C/cm) \text{ for } Ar/CF_4/CO_2$$

$$= 23\% \quad " \quad " \quad Ar/CH_4$$

b) Malter current

current I during irradiation with protons of constant flux $\dot{\Phi} = 1.7 \cdot 10^7 / (cm^2 s)$



$Ar/CF_4/CO_2$:

No significant Malter current up to a collected charge $Q/\ell = 1.1$ C/cm

selfsustained Malter current I_M for Ar/CH_4:

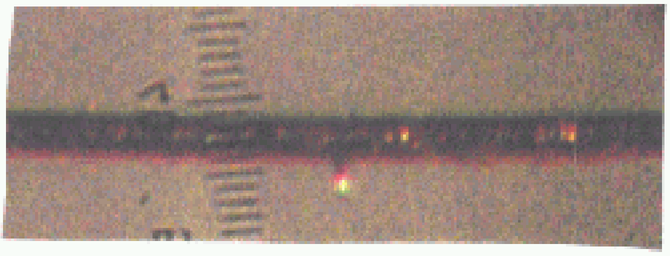
beam off — voltage off — voltage on ⟶

$I_M \approx 0$, back to maximum in 120 min

c) surface material modifications

$Ar(90)/CH_4(10)$:

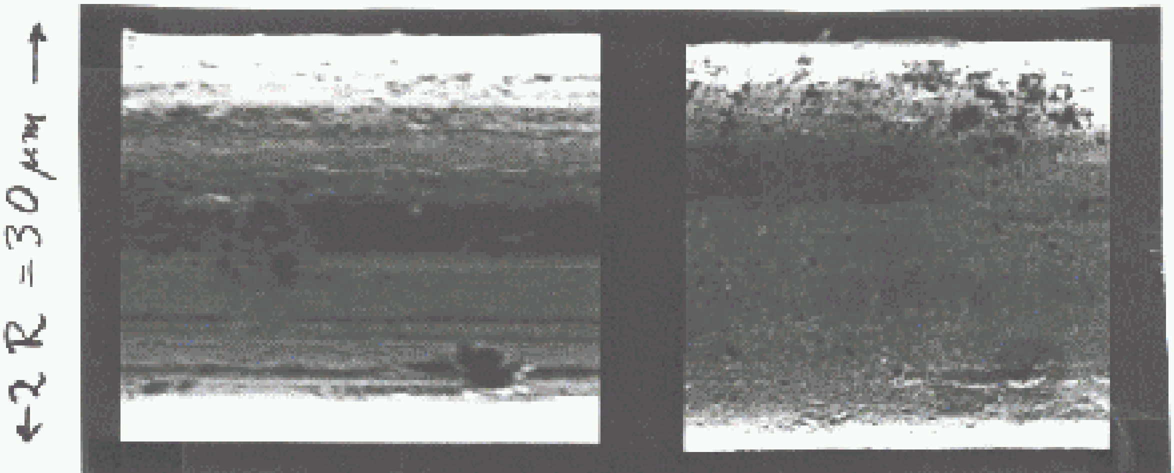
light microscope:
inhomogeneous layers + needles ($\sim 20\,\mu m$) on anode and cathode,
rings and droplets on anode.



$Ar(74)/CF_4(20)/CO_2(6)$

light microscope: nothing on cathode, dark, redish pigmentation of anode wire.

scanning electron microscope:
scaly deposit on anode wire, $\Delta R \lesssim 0.1\,\mu m$

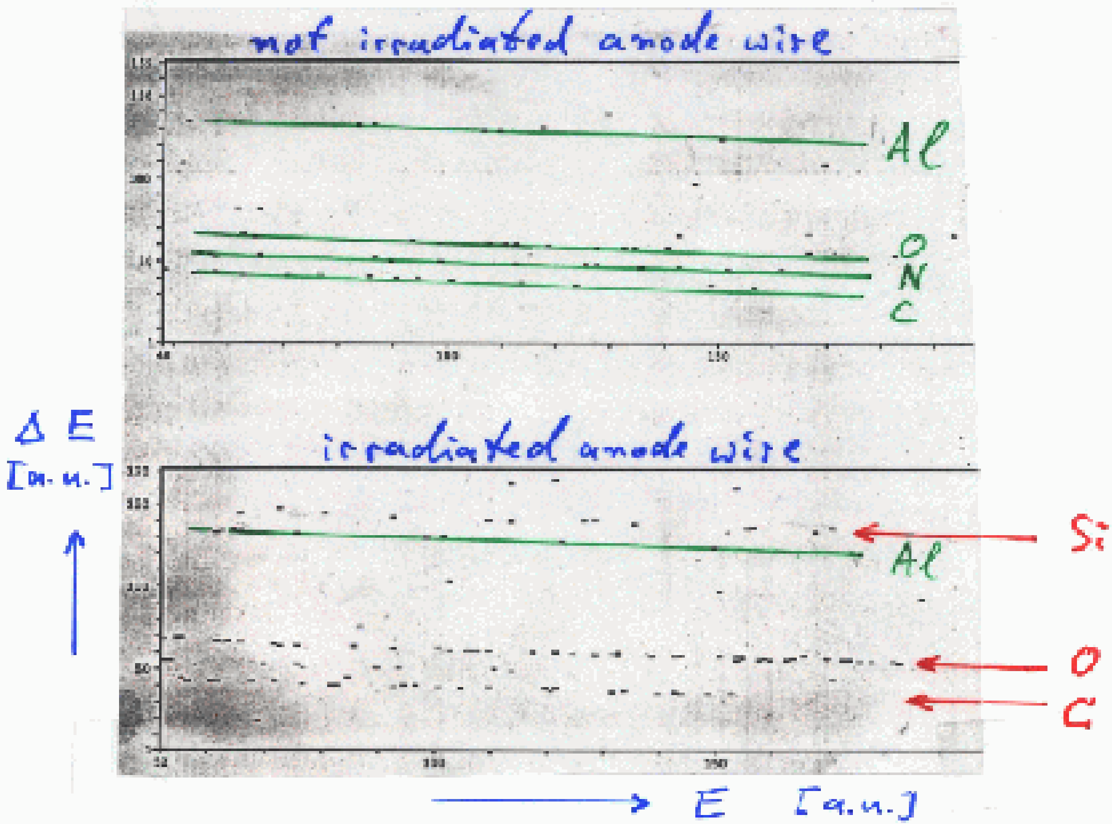


not irradiated irradiated

elastic recoil detection analysis (ERDA):

method: 200 MeV Au ions from Munich Tandem accelerator, detection of recoils with ionization chamber at $\theta_{lab} = 37°$

result: enhancement of C, O, and Si on surface of anode wire



Main Conclusion

Straw drift tubes made from Kapton XC, operated with Ar(74)/CF_4(20)/CO_2(6), show

- no significant change of gas gain and dark current
- tolerable small modification of the anode wire surface

after collection of 1.1 C/cm.