Ageing studies for the Straw Tube detectors in the LHCb outer tracking system

Sebastian Bachmann
University of Heidelberg
Germany

On behalf of the LHCb outer tracker collaboration

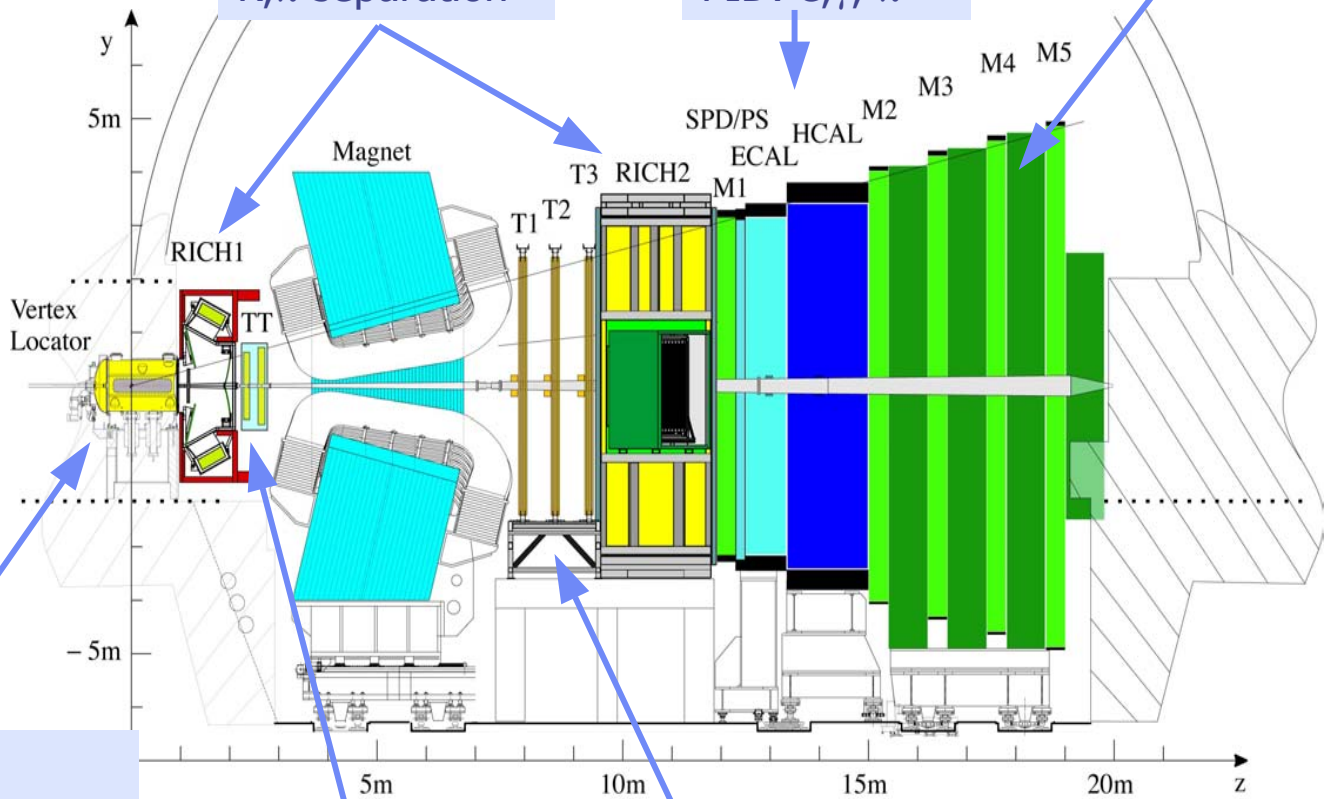
The LHCb experiment

Particle ID:

RICHES: PID
K,π separation

Calorimeters:
PID: e,γ, π^0

Muon System



Tracking system:

VELO:
• primary +displaced vertex
• impact parameter

Trigger Tracker:
p for trigger

Tracking Stations:
p of charged particles

Outer tracker: demands

1. Measurement of momentum
   ($\delta p/p = 0.4\%$ @ 20GeV)
   ➔ $\sigma_x < 200\mu m$

2. LHC bunch structure
   ➔ fast charge collection

3. LHC environment
   ➔ rate capability (~400kHz/cm²)
   ageing resistance up to 2C/cm
   (~10 years at LHCb)

4. Pattern recognition
   ➔ Occupancy < 7%

Outer tracker: parameters

3 stations (6m x 5m)

4 planes per station (X/U/V/X)

2 layers of straw tubes per plane

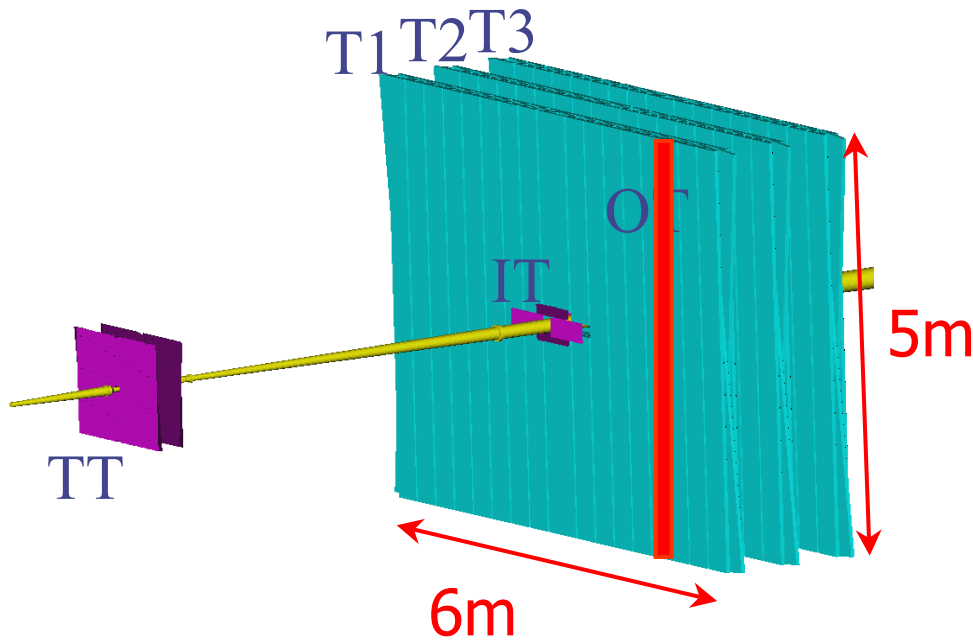
➔ 55.000 straw tubes

137.5 km of straw tubes

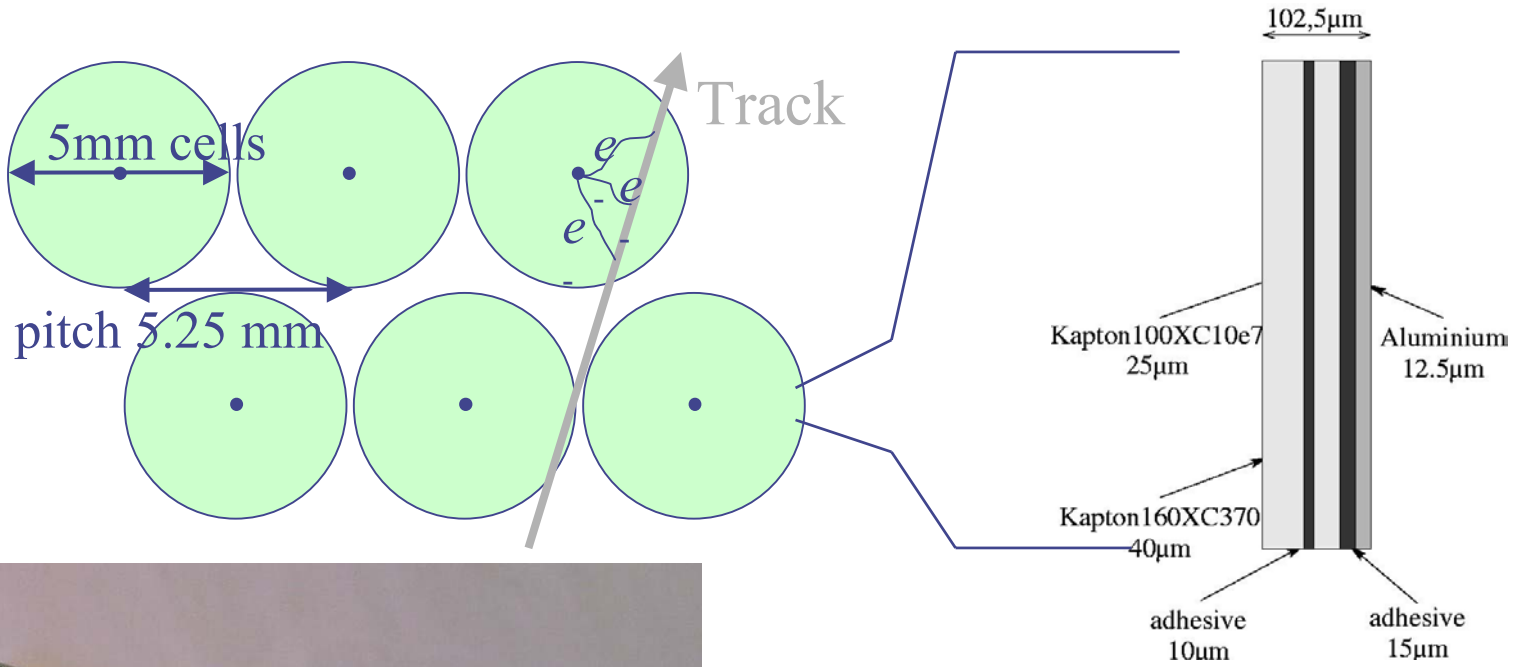
➔ modular design

264 modules of 5 m x 0.34 m

256 straws of 2.5 m



Detector technology: straw tubes

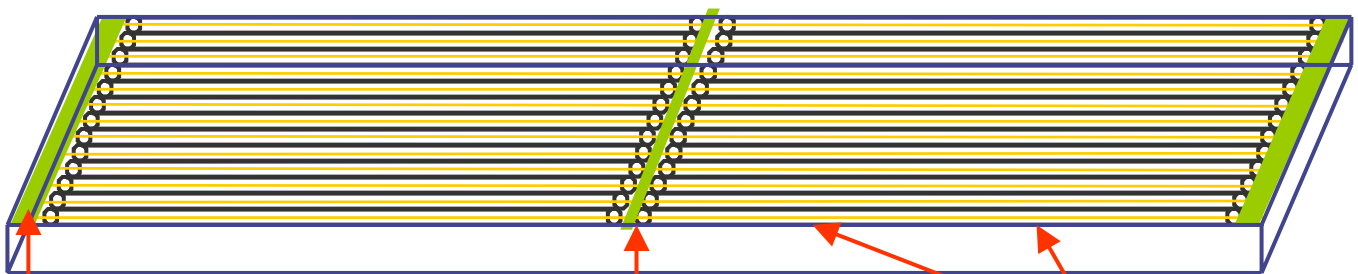


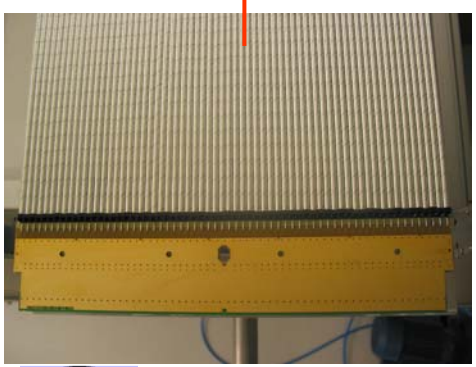
- Inner winding (cathode):
  Kapton XC
- Outer winding:
  Kapton/Aluminium-laminate
  (25µm) (12.5 µm)

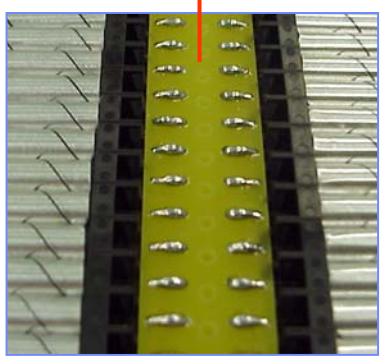
Detector modules I

A. Half modules (one straw layer):

1. Rohacel panels with CF skins, covered with Kapton/Al-laminat
2. PCB‘s
3. Straws
4. wires



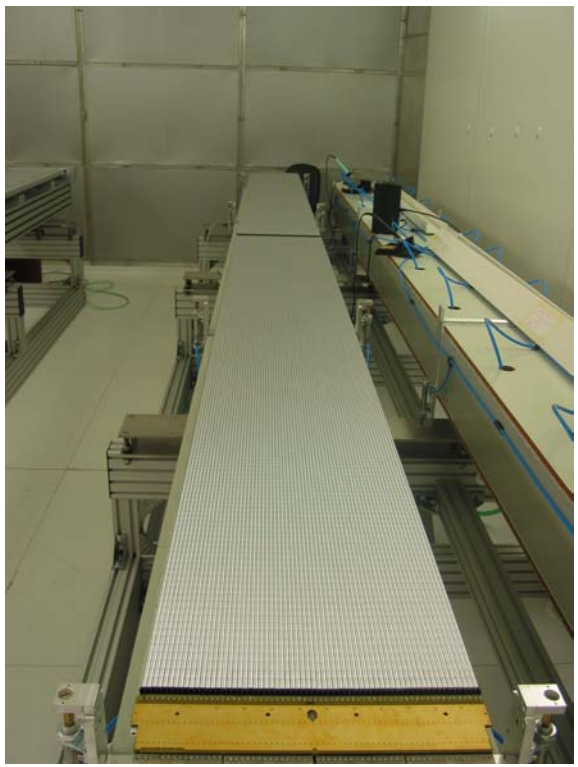




Wire locator (2x per straw) and endpieces

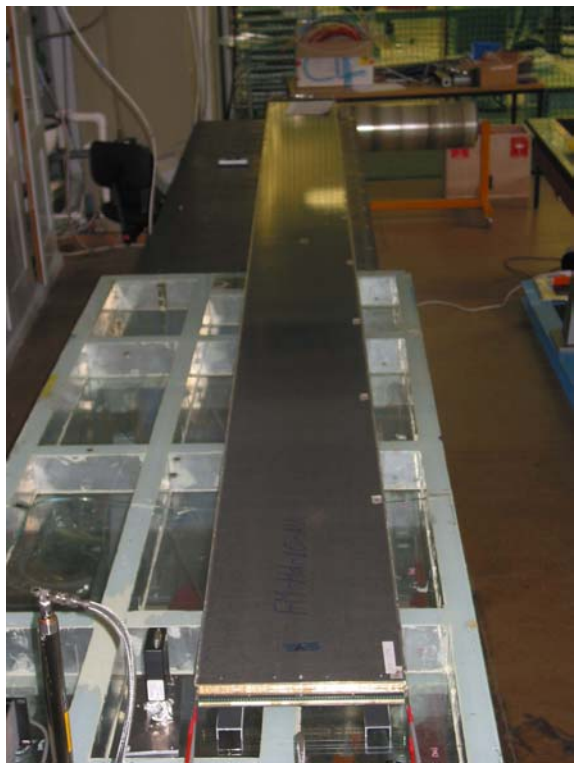
Detector modules II

Two half modules (see last slide)
+ side walls



gluing

Full module



Materials in contact with gas

Material	Used for	Approved by	LHCb test result
Straws	Cathode		o.k.
25 µm Au plated tungsten wire (CFW)	Anode	Hera-B OT	o.k.
PCB	HV feed through	Hera-B OT	o.k.
solder tin	solder wires	Hera-B OT	o.k.
Noryl	Wire locator, endpieces	Atlas TRT	o.k.
Araldite 103+HY991	seal modules	CERN/GDD, Atlas TRT	o.k.
Kapton-Al laminate	Seal sandwich panels		o.k.

Choice of the counting gas

Requirements to the counting gas

1) fast
2) good position resolution
3) no aging

$Ar + CO_2 + \overset{? \quad ?}{CF_4}$
$\underset{? \quad ?}{}$

Usage of CF_4:

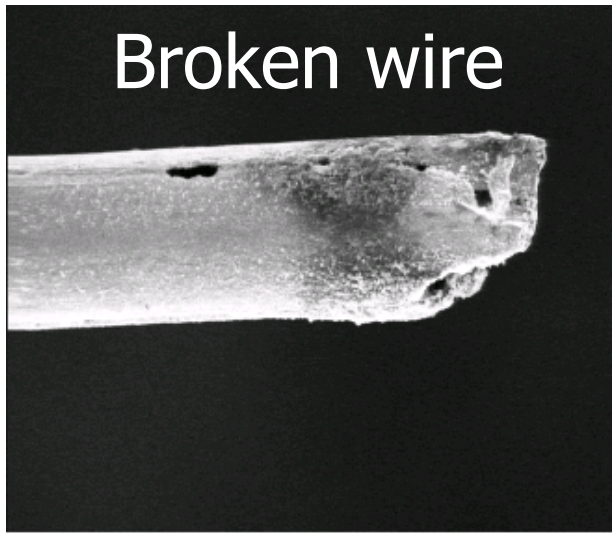
Pro: fast

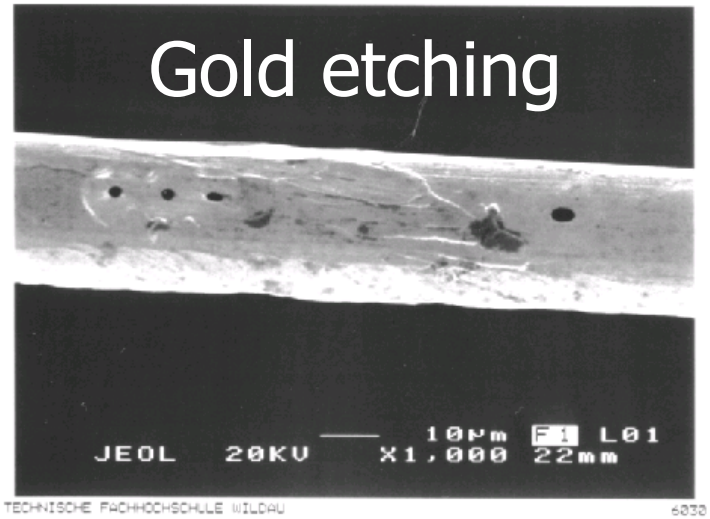
Contra: electronegative

➔ degradation of resolution

??? Impact on aging ???

Wire breaking in gases with CF_4



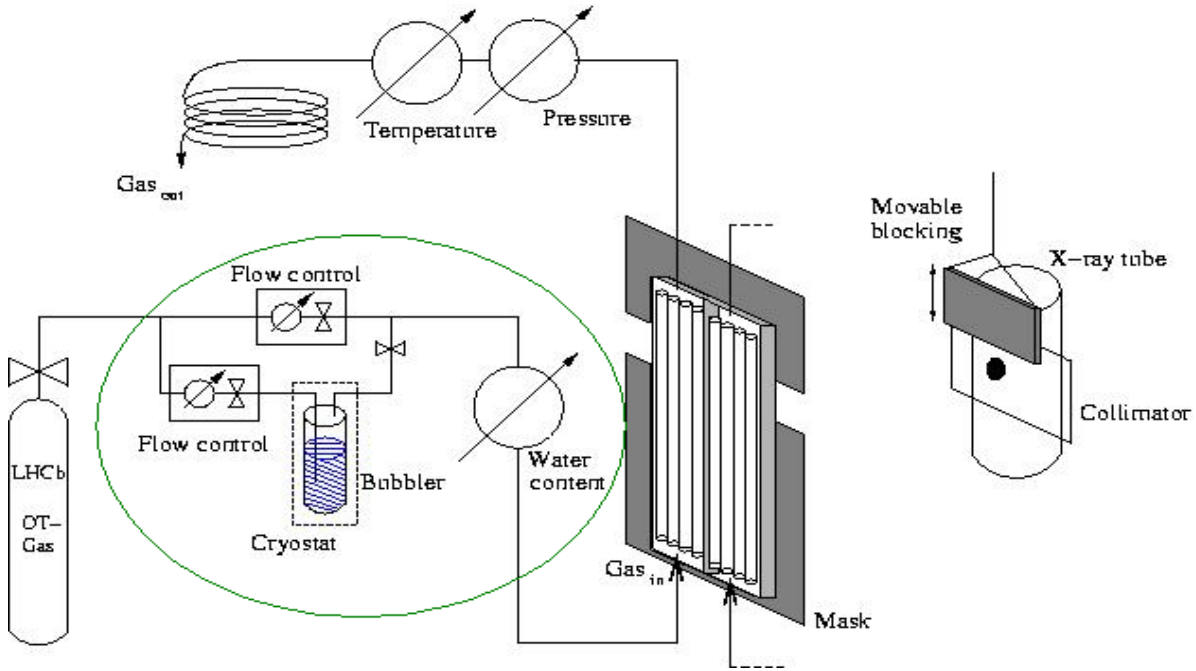


- repeatedly observed breaking anode wires in irradiated regions.
- wires irradiated in CF_4 showed indications for wire etching
- never observed wire breaking in Ar/CO_2

Systematic study with X-rays to compare Ar/CO_2 (70/30) vs. $Ar/CO_2/CF_4$ (75/10/15)

X-ray tests

Set-up:

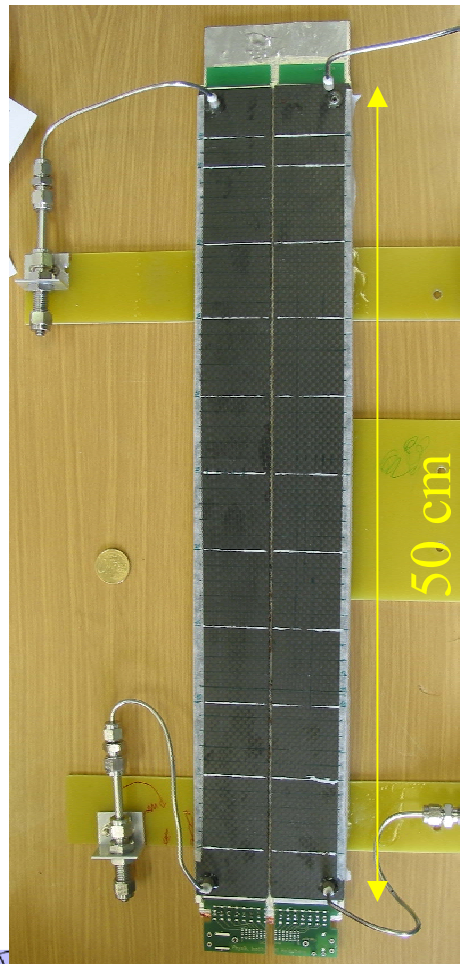


Standard procedure:

1. Before irradiation: Measure gain along wire
2. Monitor gain during irradiation
3. Monitor gain of reference wire
4. After irradiation:
   - remeasure gain along wire
   - optical inspection of wire
   - inspection of wire by means of SEM and EDX

Operating conditions

Ar/CO_2 $Ar/CO_2/CF_4$



Double chamber:

- test both gases at same time
- final materials

Parameters:

HV: Ar/CO2 (70/30): 1520V

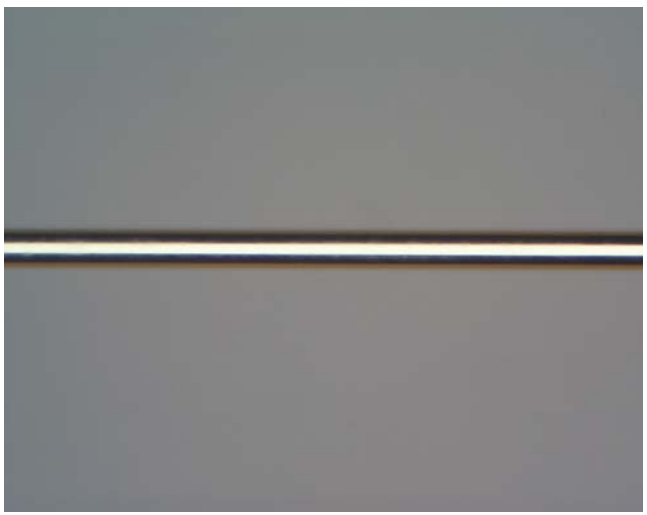
Ar/CO2/CF4 (75/10/15): 1550V

gas gain: 28000 (550 kHz)

40000 (low rate)

Results for Ar/CO_2

Optical inspection of wires after 1C/cm



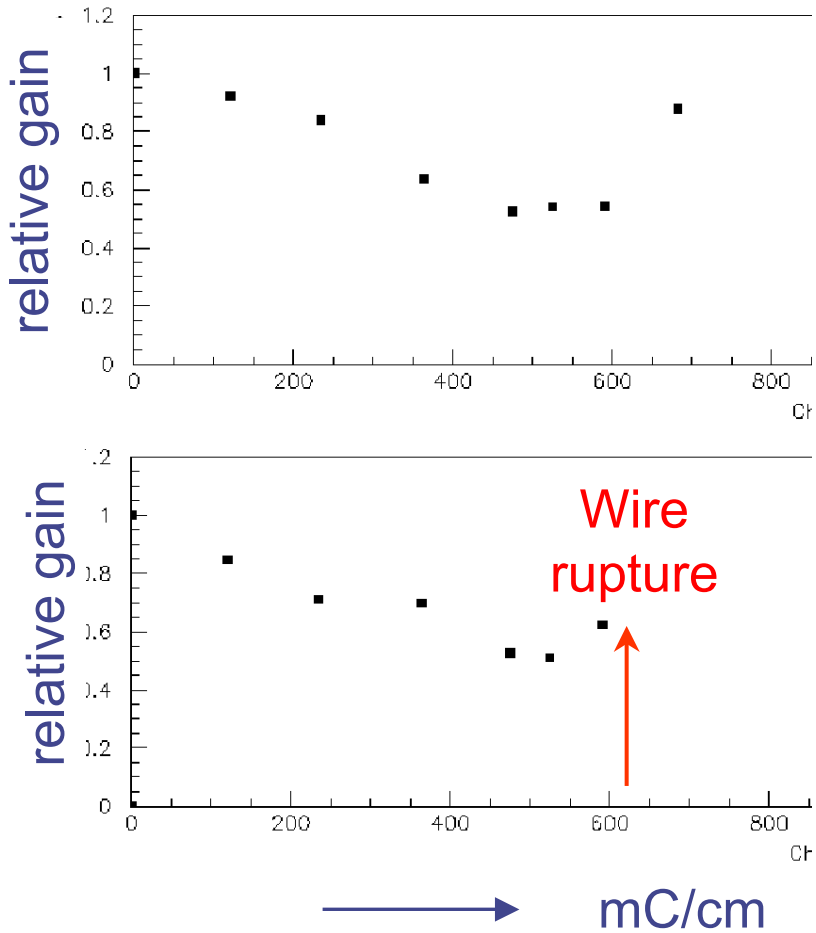
- no gain loss
- no degradation of resolution
- no polymerisation (EDX)

Validation of system

Results for $Ar/CO_2/CF_4$

Same test conditions as for Ar/CO_2 mixture:

- wire rupture after 0.6 C/cm !
- gain loss, not restricted to irradiated area
- degradation of resolution
- strong carbon and oxygen deposits
- no Si-pollutions observed



Summary of X-ray tests with $Ar/CO_2/CF_4$

# straws	Q_{int} [C/cm]	Irrad. length [cm]	acc. factor	gas flow [vol/h]	Irrad. of wire locator?	Water content [ppm]	Effects observed
1	2,8	4	6-14	1	no	<50	C deposits
2	0,7-1,4	4	10-20	1	no	<50	gain loss
2	1,7-2,5	4	30-45	1	no	<50	C deposits wire rupture
2	1,8-2,2	4	32-34	2	no	<50	gain loss C and O deposits
2	1,7-2,3	4	32-38	3,5	no	500	gain loss C and O deposits
2	1,7-2,3	4	32-34	2	no	3500	wire etching
2	0,6-0,9	4	40-50	1,4	Yes	<50	gain loss + wire ruptures
4	0,7-1,1	4	40-45	1,4	no	<50	gain loss + wire rupture C and O deposits
2	1,1	8-10	45	1,4	yes	<50	gain loss C and O deposits
2	0,5-0,7	10	40	1,4	no	<50	gain loss + wire ruptures C and O deposits

Final choice of counting gas

$Ar/CO_2/CF_4$ (75/10/15):

Long term operation in a large system risky

abandoned

Ar/CO_2 (70/30):

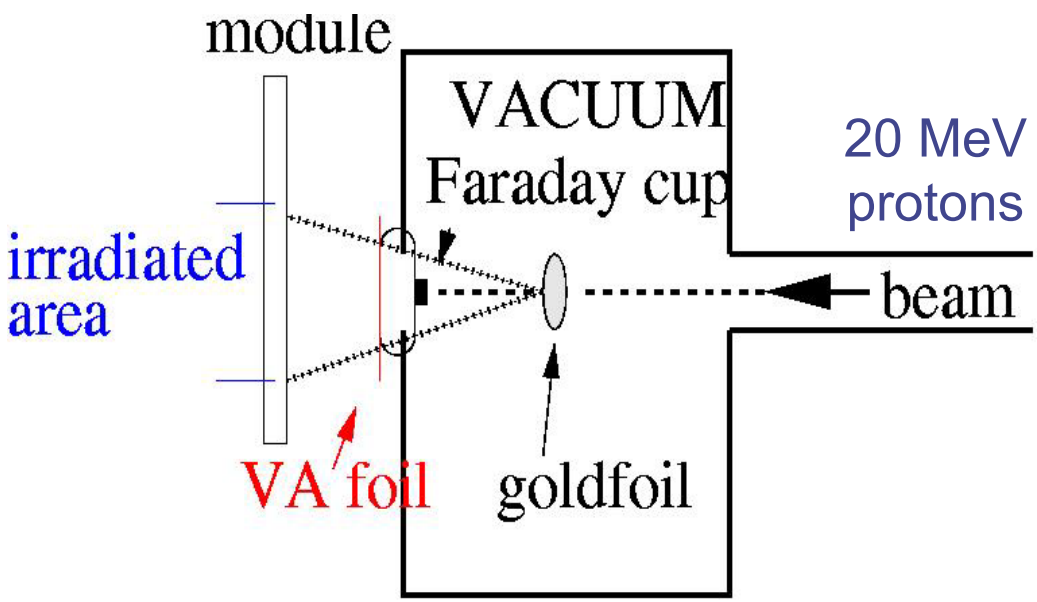
Slower charge collection, but no major impact on physics performance

baseline gas mixture

Tests with low energetic protons

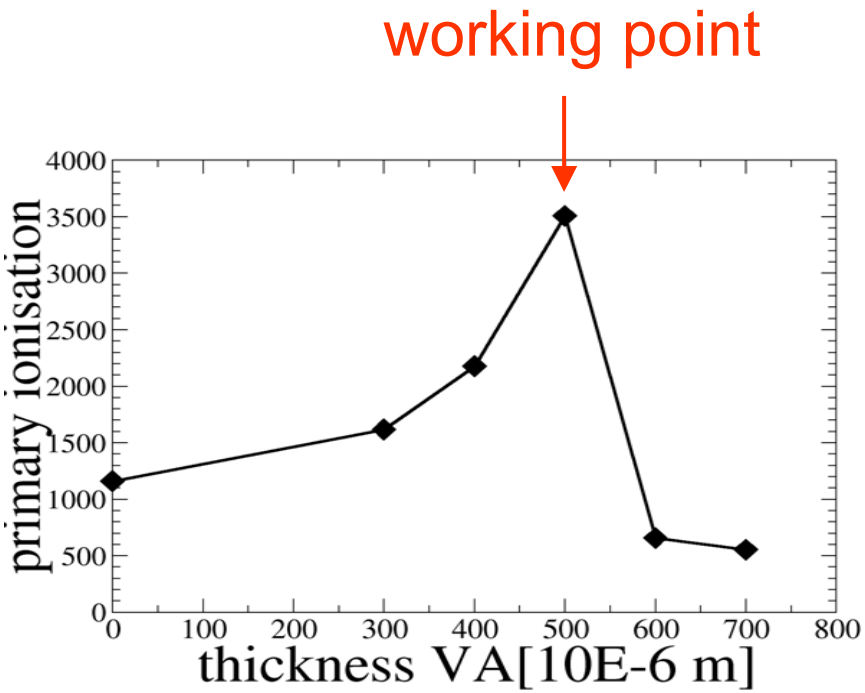
Aim: Validate cathode, i.e. straw tube materials
Search for unwanted effects,
e.g. Malter effect

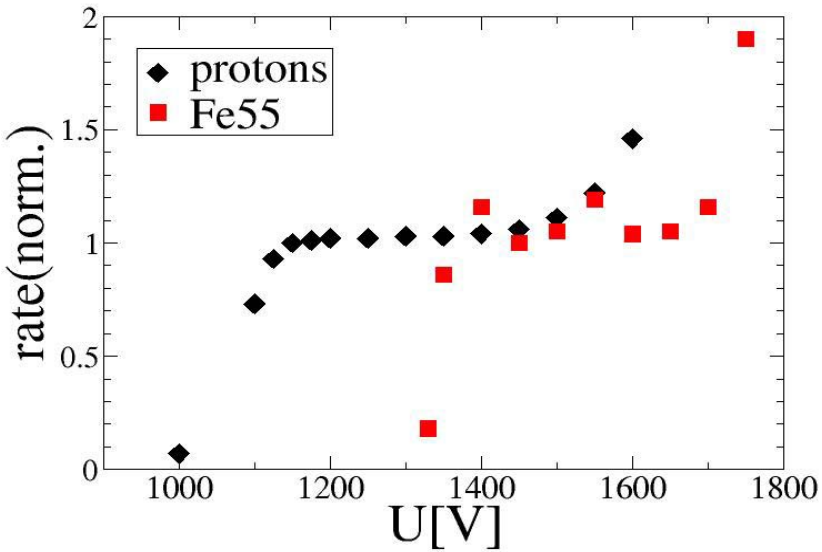
Set-up:
Optimized to maximize
- primary ionisation
- irradiated area



Primary ionisation of protons

Thickness of VA foil adjusted to Bragg peak
→ maximum primary ionisation

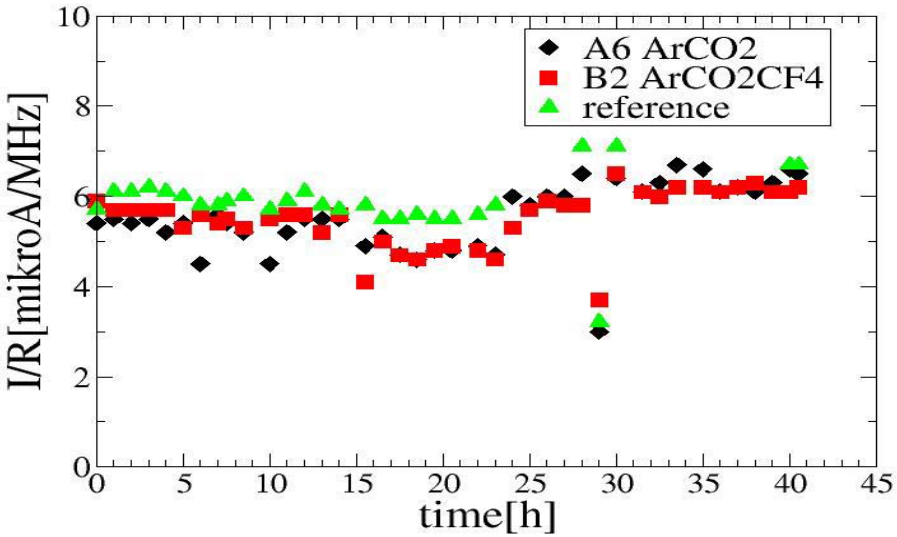




Primary ionsation: up to 1600 MIP‘s,
average 100 MIP‘s

Results

Stability of gain:



Integrated charge:
0.6C/cm
(~3 years at LHCb)

- no gain loss
- no Malter effect observed
- first streamers observed at gain 6×10^5

Outlook

- Detector design has been validated in many aging tests with X-rays and low energetic protons.

- Ar/CO_2 (70/30) chosen as counting gas

- Final tests with detectors build from materials taken out of the production are on the way with
  - lower acceleration factor (~10)
  - larger irradiated area (~50cm)