Gossip ageing studies

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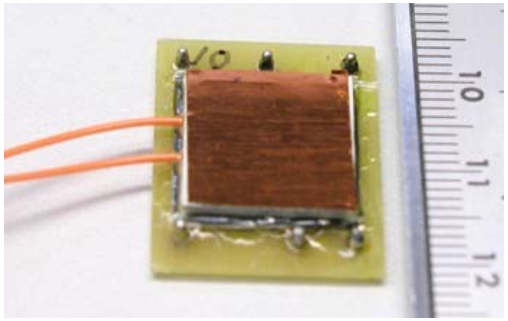


- Ageing gaseous detectors
- Ageing dummy Gossip using ^{90}Sr source
- Ageing SiProt using ^{90}Sr source
- Ageing induced by UV light

Micro pattern gas detectors (RD51) workshop
Nikhef, April 16 - 18, 2008

Gaseous detector ageing

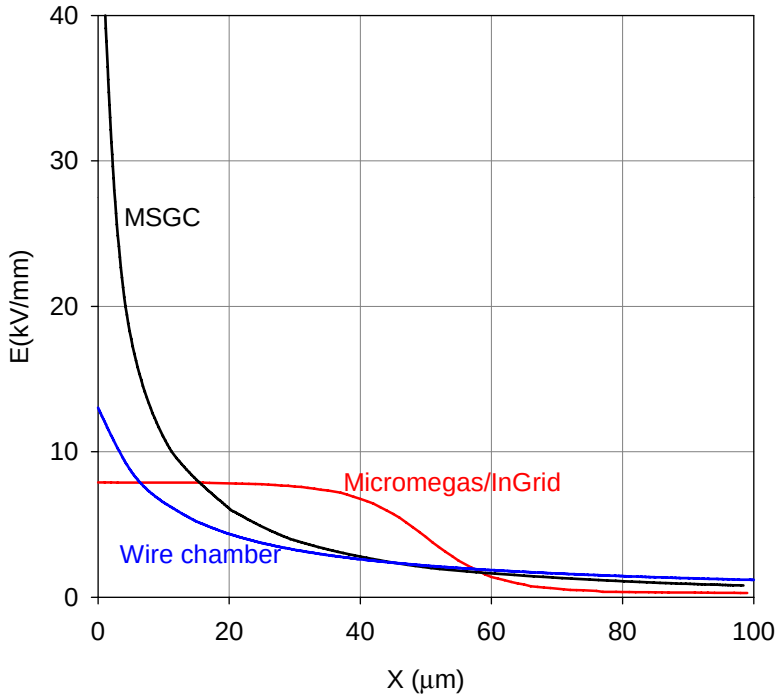
- No ageing of the ionising medium
  - Gas permanently renewed
- Ageing of electrode material, support structure or services
  - In most cases not the first concern

- Ageing of gaseous detectors normally from a **remainder** on the anode deposited by the hot avalanche
  - Homogeneous soft insulating layer
  - Crumbly layer
  - Spikes
  - ……
- Leading to
  - Decay of gas gain
  - Broadening of the charge signal distribution
  - HV instability
- Ageing by remainder on the anode directly linked to ionisation in the chamber gas
- => ageing studies of gaseous detectors may be exclusively done by inducing ionisation

Dependence on electrode geometry

- Crucial is the **field strength** in the vicinity of the anode
- High field => high avalanche temperature
  - Production of radicals
  - Dissociating organic molecules
  - => deposit on the anode
- Electrical field near anode for different detector technologies
  - MSGC: very high
  - Wire chamber: moderate
  - Micromegas/InGrid: comparatively low
  - GEM: high at edges of the hole
- Additional effect: magnitude anode surface
  - MSGC: very small (edge of anode strip)
  - Wire chamber: quite small
  - Micromegas/InGrid: large
  - GEM: avalanche not in vicinity of anode

Field strength (E) along the central drift path (X) to the anode for three different electrode geometries



Nature of the deposits

- No single compound in the gas is known to cause (deposit) ageing
  - Si-oil from bubbler has NOT been identified as ageing causing compound
- Hydrocarbons are more prone causing ageing than CO_2, CF_4
- Deposits often contain Si and/or C
- One of the ageing mechanisms: in hydrocarbons (from fossile oil), a C may be replaced by Si:
  - SiH_4, $CSiH_6$, C_2SiH_8
- Not exclusively by the avalanche
  - ionising radiation may create radicals as well in the gas and at the detector walls

Possible ionisation sources for ageing studies

- PS beam at CERN
  - ☺ Best radiation test
  - ☺ Mip ionisation profile (24 GeV/c p)
    Average rate **3 - 9 GHz/cm^2**
    - ☹ but current during spill order of magnitude higher **(> 50 GHz/cm^2)**
      - Can Gossip handle this??
  - ☹ Running a testbeam experiment is time and money consuming
  - ☹ Tight time schedules

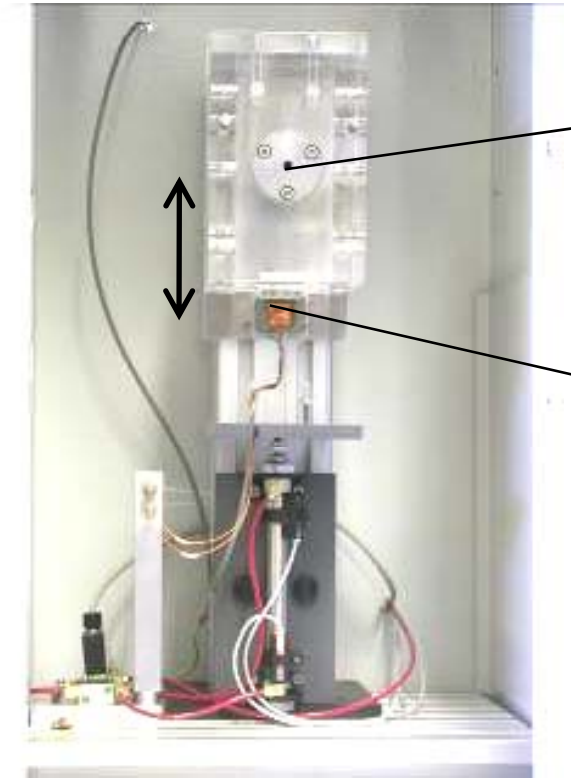
- Powerful (5 GBq) ^{90}Sr source at Nikhef
  Up to ~ **1.5 GHz/cm^2** continuously
  - ☺ Rate still OK for Gossip
  - ☺ Mip ionisation profile (1 – 2 MeV/c e$^-$)
  - simulating b-layer environment
  - ☺ Always available
  - ☹ Not ultimate radiation test

Reference: pixel b-layer at SLHC
- rate up to **0.4 GHz/cm^2**
- dose up to **10^{16} cm^{-2}**
- mostly hadrons: p, π in GeV range (mips)
- γ (MeV - GeV range)
- n (MeV range)

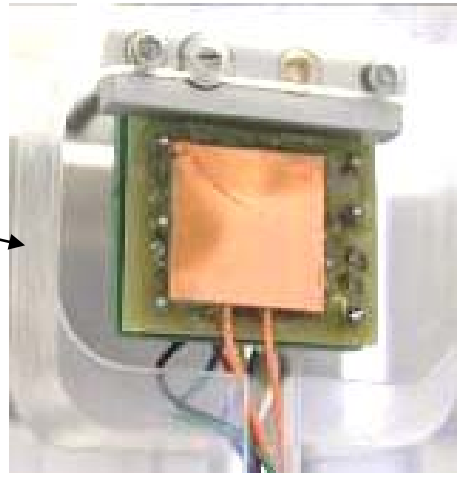
- UV light source at Nikhef (Harry van der Graaf)
  - ☺ Continuous operation
  - ☺ Easy in use (no personal danger)
  - ☹ Different ionisation profile
    - individual photoelectrons mainly liberated from metal surfaces

Irradiation facility with 5 GBq source

- Remote controlled irradiation stage
  - Sample can be moved in and out by pneumatic piston
  - => separating induced signal from background signal



source

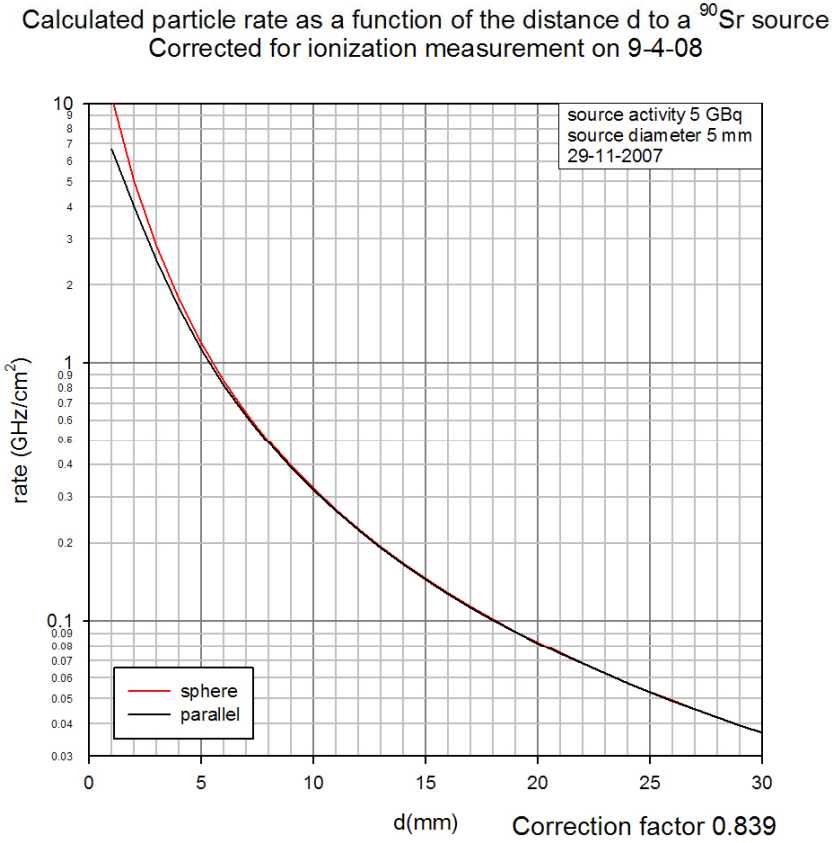


Ageing sample

^{90}Sr source at Nikhef

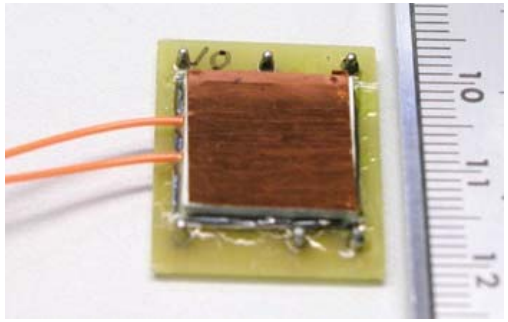
- 5GBq ^{90}Sr
  - 1 – 2 Mev e$^-$ simulating mips
- Rate calibrated with ionisation chamber
- Distance sample to source 4.7 mm =>
  - 1.33 GHz/cm^2 (sphere)
  - 1.25 GHz/cm^2 (parallel surface)
- => 1.15*10^{14} mips/cm^2/day in bulk material

- **SLHC aim: 10^{16} mips/cm^2 for the ATLAS b-layer**

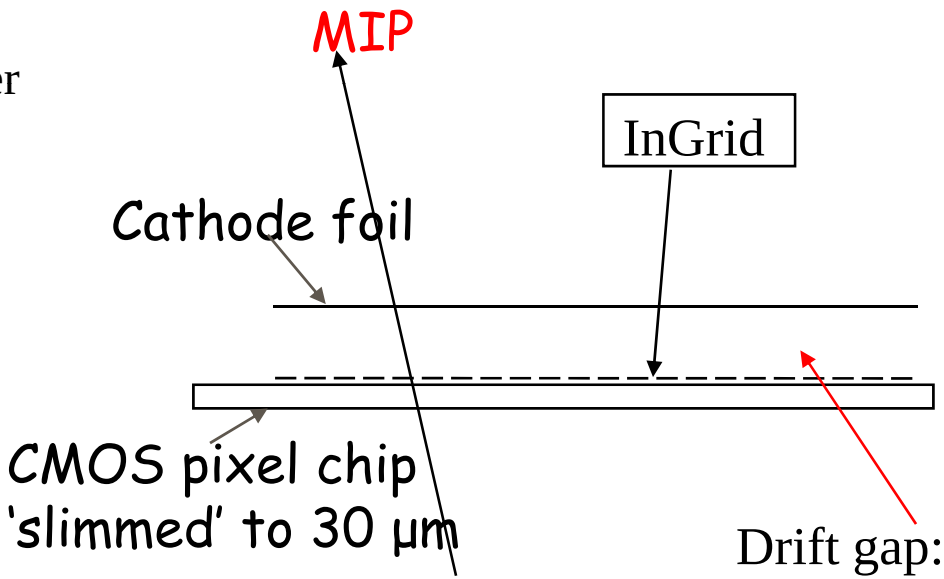


What is Gossip?

- Gaseous pixel detector
- Slimmed silicon pixel chip
- Short drift distance
  - 1.2 mm
- => high rate capabilities (GHz/cm^2 region)
- Good position resolution expected (low diffusion)
- => suited for SLHC b-layer
- Aim for G = 1000



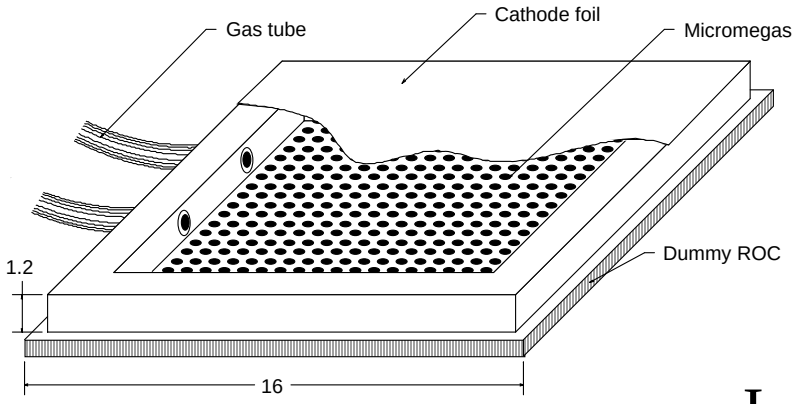
Gossip prototype

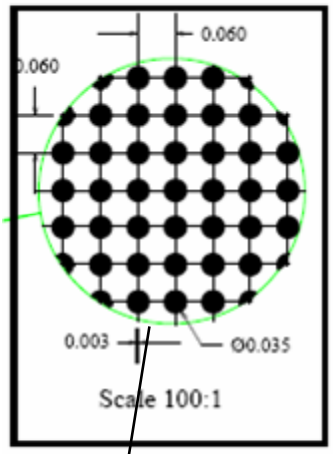


- Thickness gas layer marginal
- => limited by efficiency requirements

GOSSIP: Gas On Slimmed SIlicon Pixels

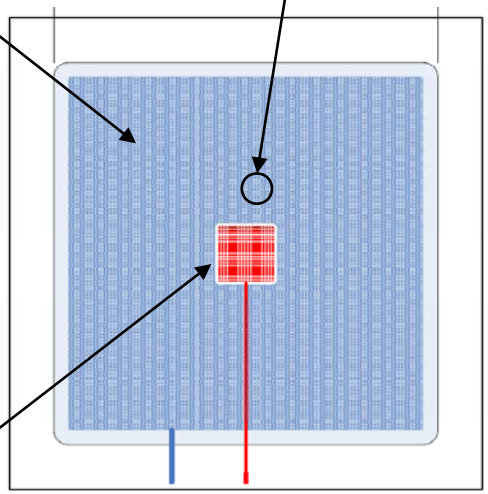
Dummy detector for GOSSIP ageing studies





- Dummy glass ROC
- Circular pads on 60 µm pitch
- Drift volume 13 x 13 mm, 1.24 +/- 0.01 mm high
- Centre signal electrode: 2 x 2 mm structure of 1089 pads (red)
  - => Final detection volume is a block of 2 x 2 x 1.2 mm
- Gas gain by Micromegas
- Closed gas volume of 210 µl
- Gas flow ~ 0.5 l/h
  - => more than 2000 volume exchanges/hour

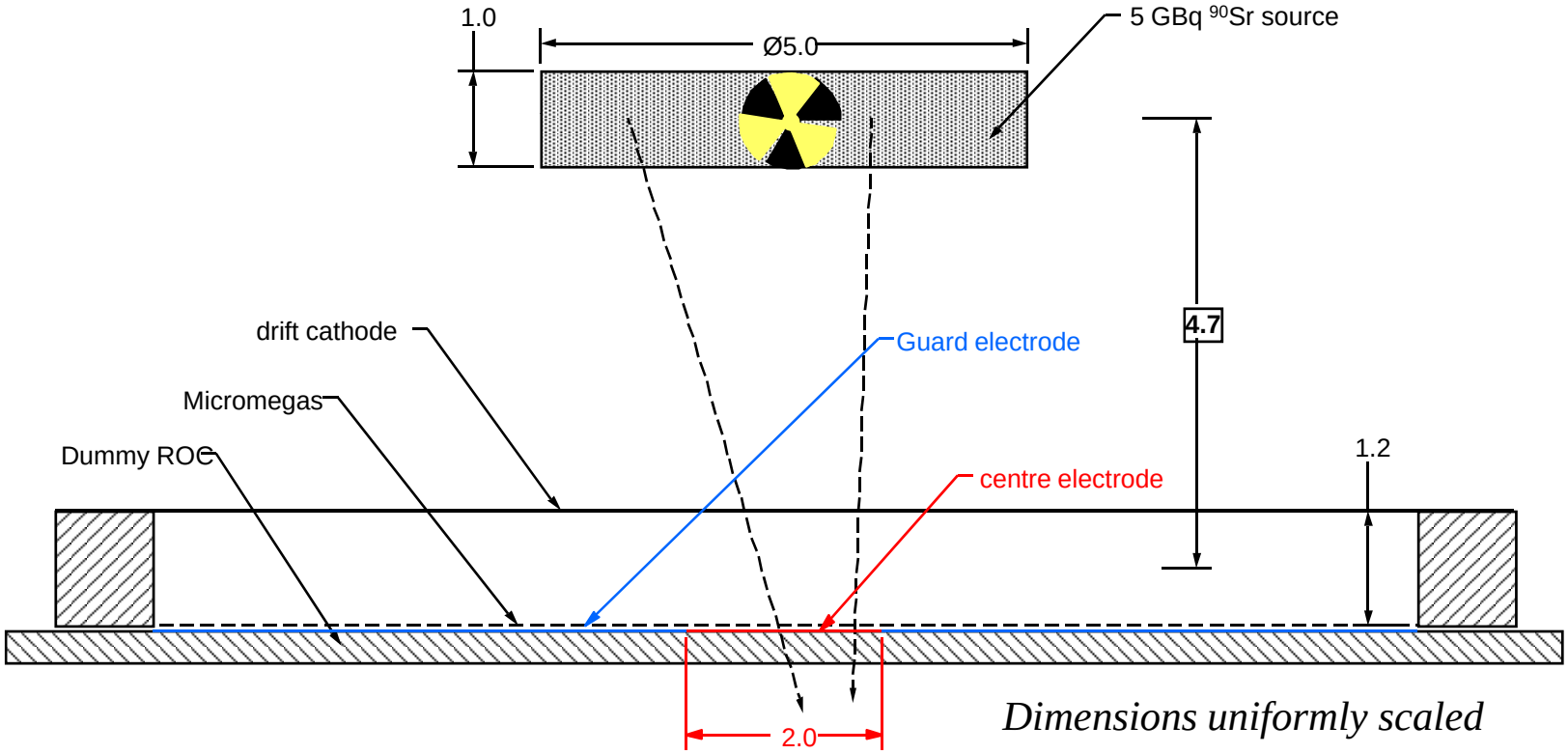
I_{guard} electrode



I_{centre} electrode

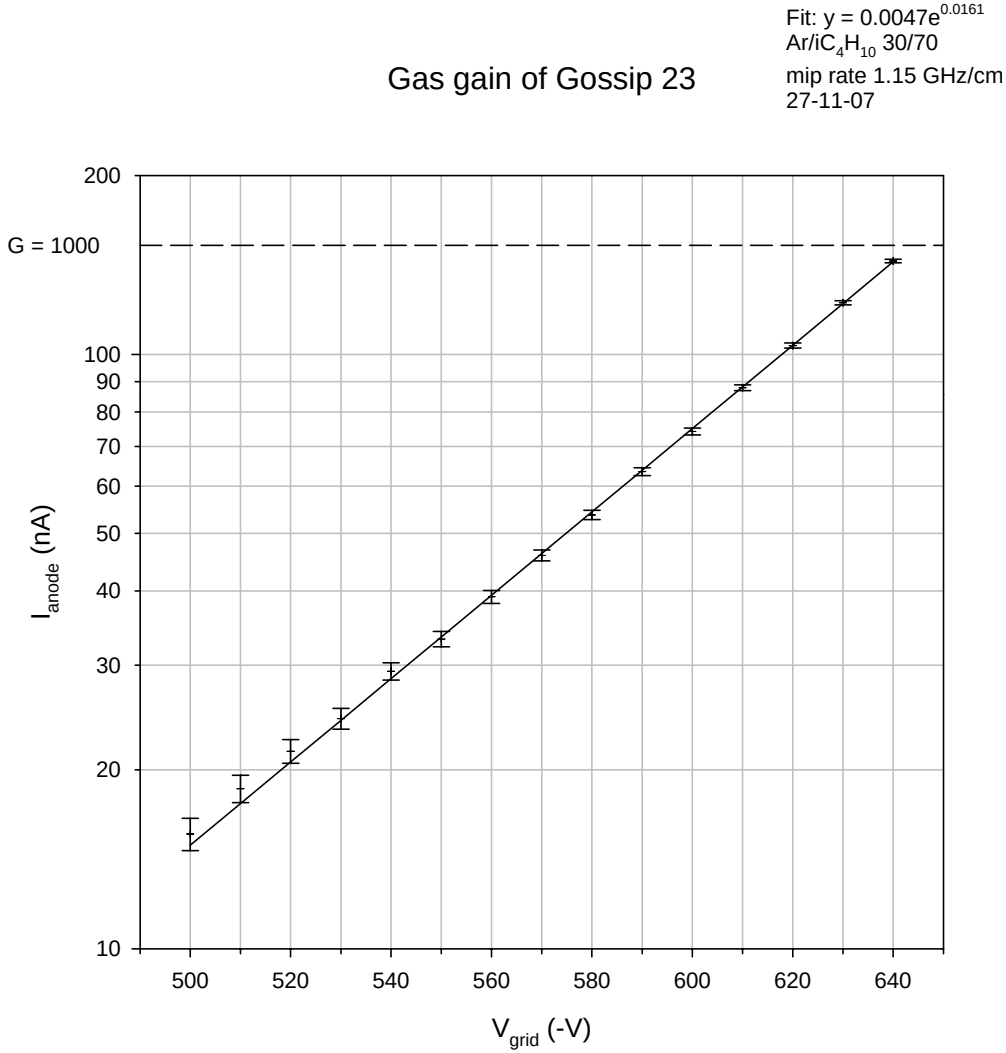
Source geometry during irradiation

- Distance centre source to centre drift volume 4.7 mm
- Homogeneous irradiation of centre electrode



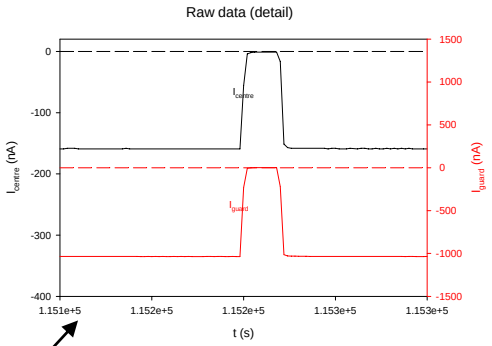
Rate dependence

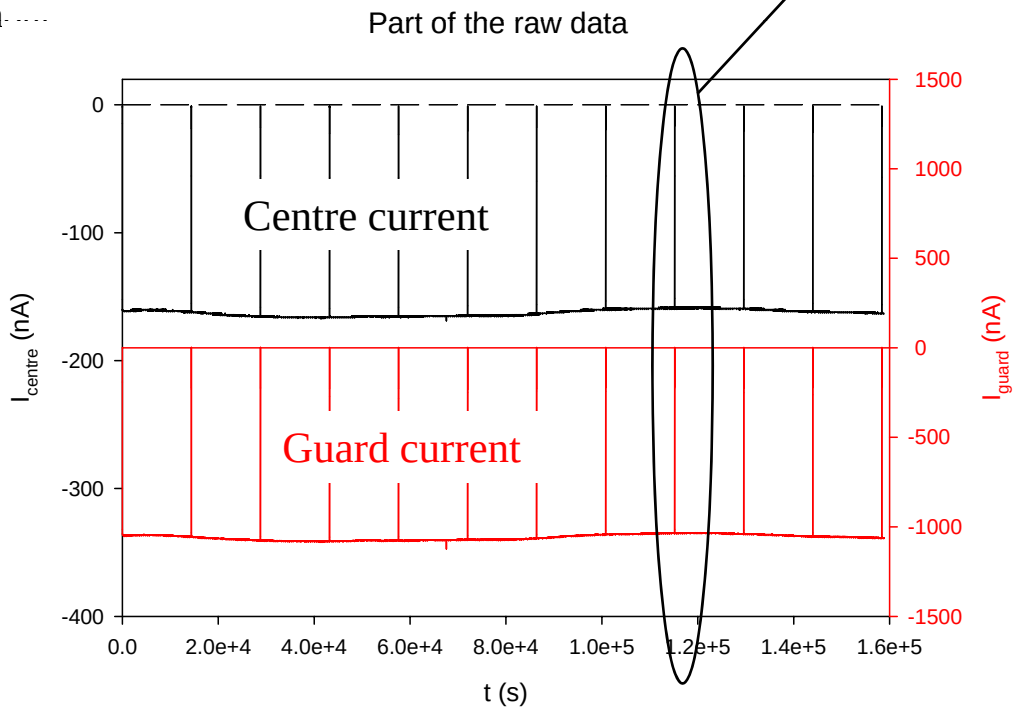
- Gas: Ar/iC_4H_{10} 70/30
- Rate 1.33 GHz/cm^2
- Rate dependence investigated by gain curve
- No sign of saturation until gain = 900



Ageing method

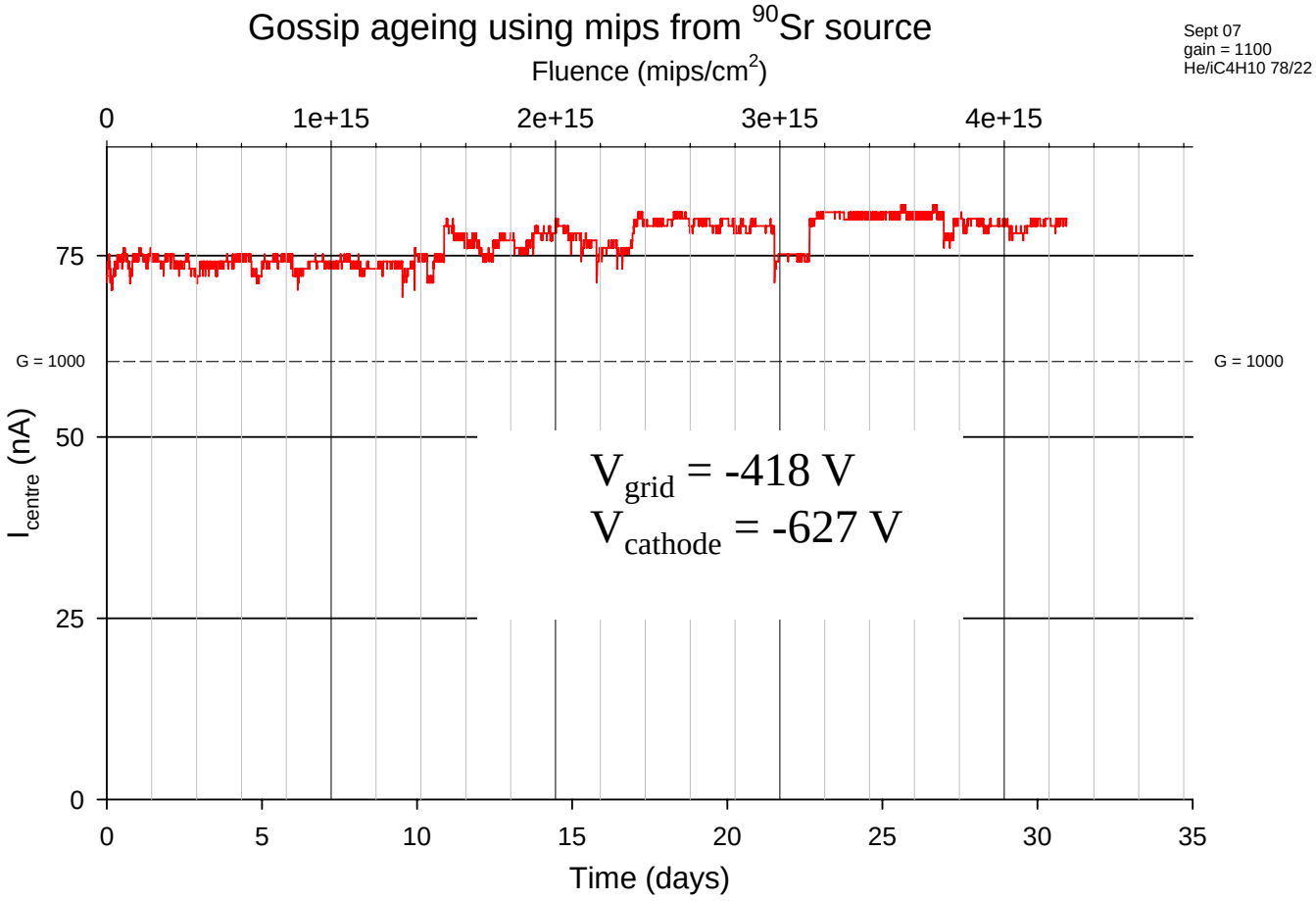
- Two gas mixtures tested so far
  - Gossip21: **He/iC_4H_{10} 78/22**
  - Gossip23: **Ar/iC_4H_{10} 70/30**
- Data taking every 2s
- Background current periodically measured for reference
  - 20 s per 4 h





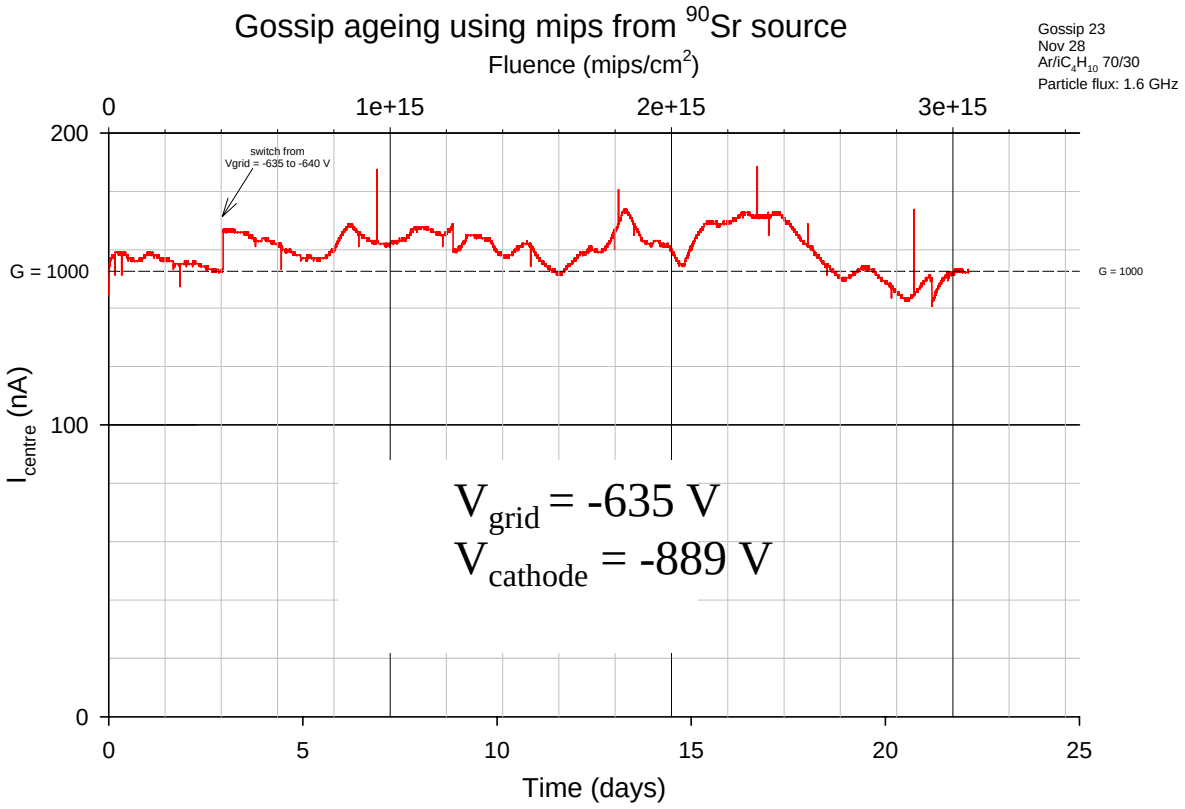
Gossip21: He/iC_4H_{10} 78/22

- ☺ No sign of decay of gas gain
- Instabilities
  - partly caused by variations in temperature and pressure?
- ☹ But measurement had to be terminated because of increased sensitivity for HV trips
- Tripping induced by radiation



Gossip23: Ar/iC$_4$H$_{10}$ 78/22

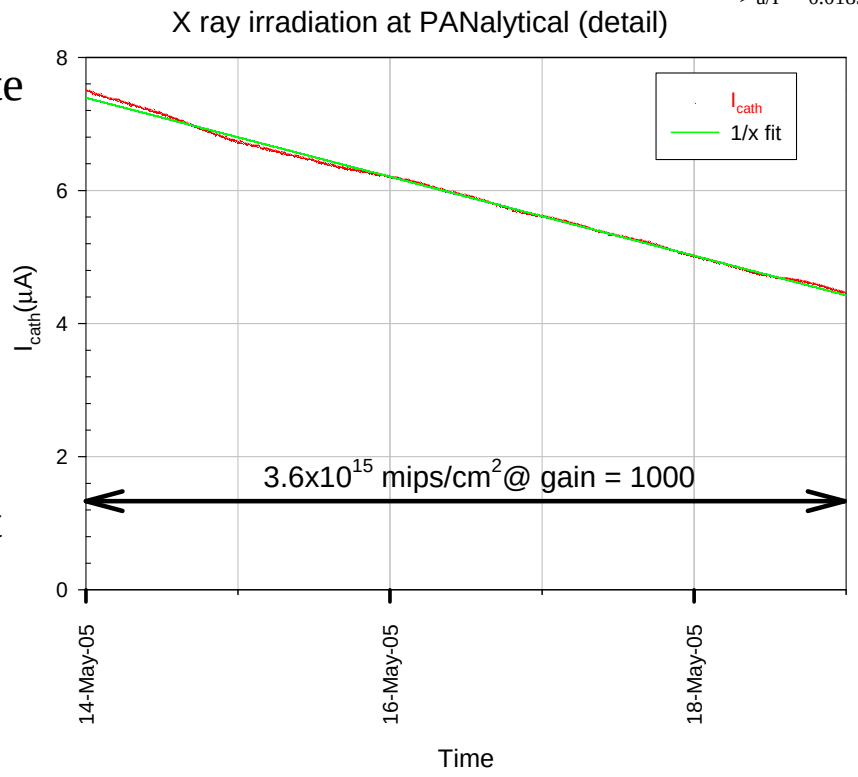
- More fluctuation but no significant indication for decay of gas gain
- Trip (I_{guard} > 2 µA) at about once a week
- Again measurement had to be terminated after 22 days because of increased sensitivity for tripping



Comparison to earlier measurement

- 8.04 keV X-rays at Panalytical
- Here **40% reduction in gain** but **no tripping problems**
- Using X rays instead of MIPs?
- Anode: solid aluminium plate instead of small pads glass ROC?
- Gas: Ar/$\mathbf{CH_4}$ 90/10 vs Ar or He / $\mathbf{iC_4H_{10}}$ mixtures?
- At Panalytical ~ 5x higher charge rate?
- Much lower gas refreshment rate
- Other reasons???

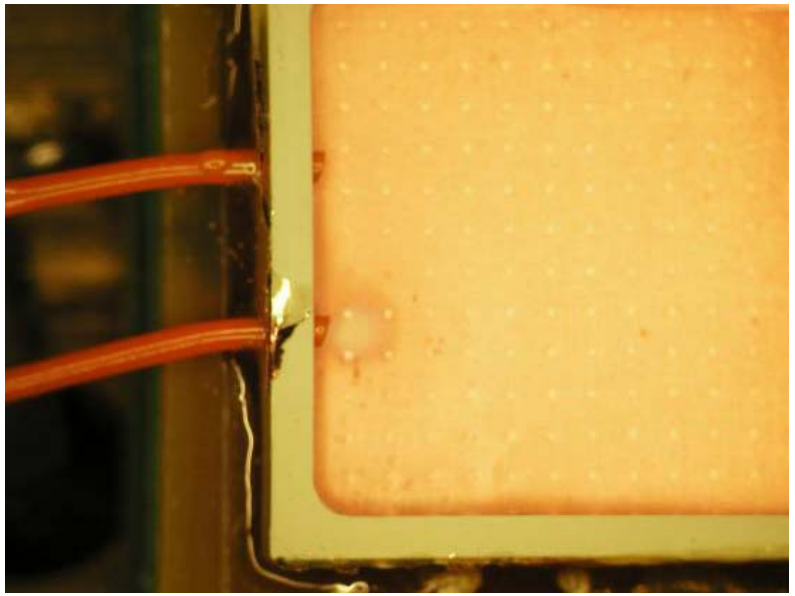
Linear fit
$I = I^0 + a.t$
a = -0.5932
$\Rightarrow a/I^2 = 0.0183$



av current = 5.9 μA
=> total charge deposited
= 5.9*3600*24*4
= 2.55 C
surface 0.49 cm^2
=> 5.2 C/cm^2
assume: drift distance 1 mm
Ar/CH4 having $9e^-$/mm
=> 1 mip = $9*1000*1.6*10^{-19}$
= $1.44\ 10^{-15}$C
deposited charge corresponds to
$3.6\ 10^{15}$ mips/cm^2

Examining Gossip21 after irradiation

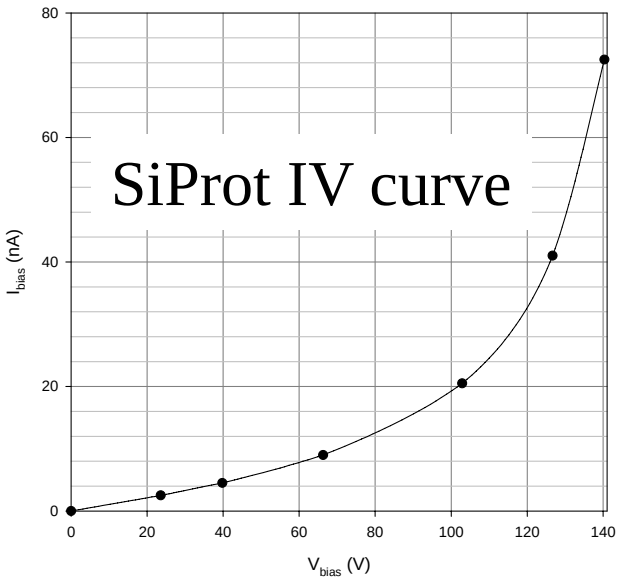
- Field foil removed
- Coloured spot **on top** of Micromegas near one of the gas pipes
  - Probably inlet
- When removing Micromegas no other pollutions/damages found
  - Dummy ROC and Micromegas were still clean
- => no visual cause for HV tripping traced



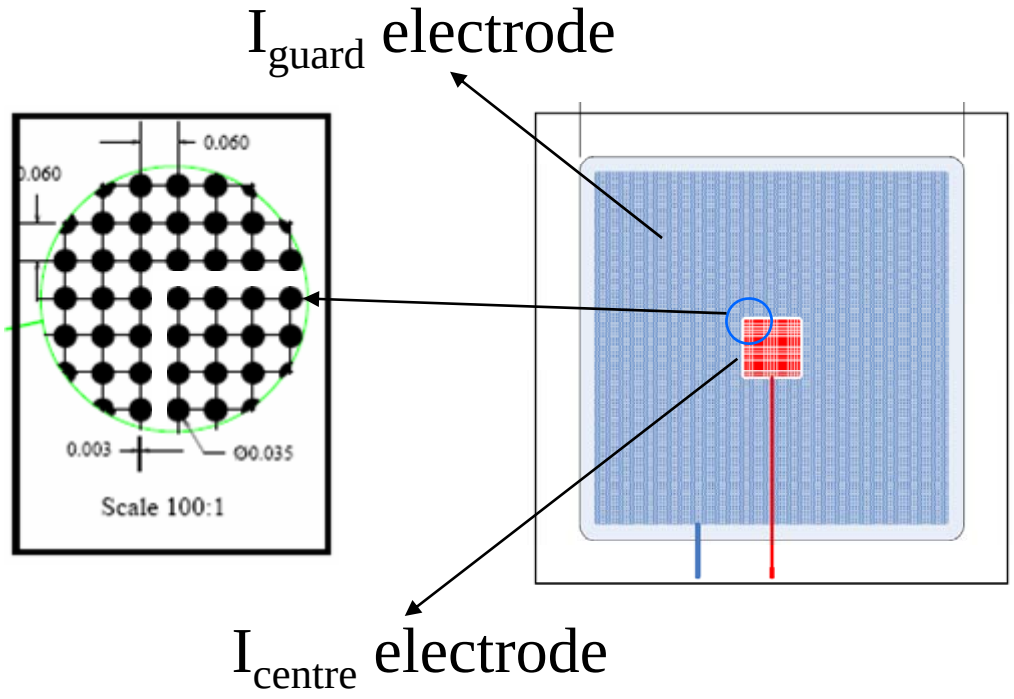
SiProt ageing test

- SiProt: amorphous silicon layer to protect the ROC against discharges
- Dummy glass ROC fully covered with 20 µm SiProt layer
- Guard electrode set on +5V
- Measuring leakage current on centre electrode
- => bulk resistance SiProt layer measured parallel across 8 mm length

Bias current from voltage across a SiProt layer



voltage set between centre electrode and guard electrode of the SiProt1 glass ageing substrate 28-2-2008



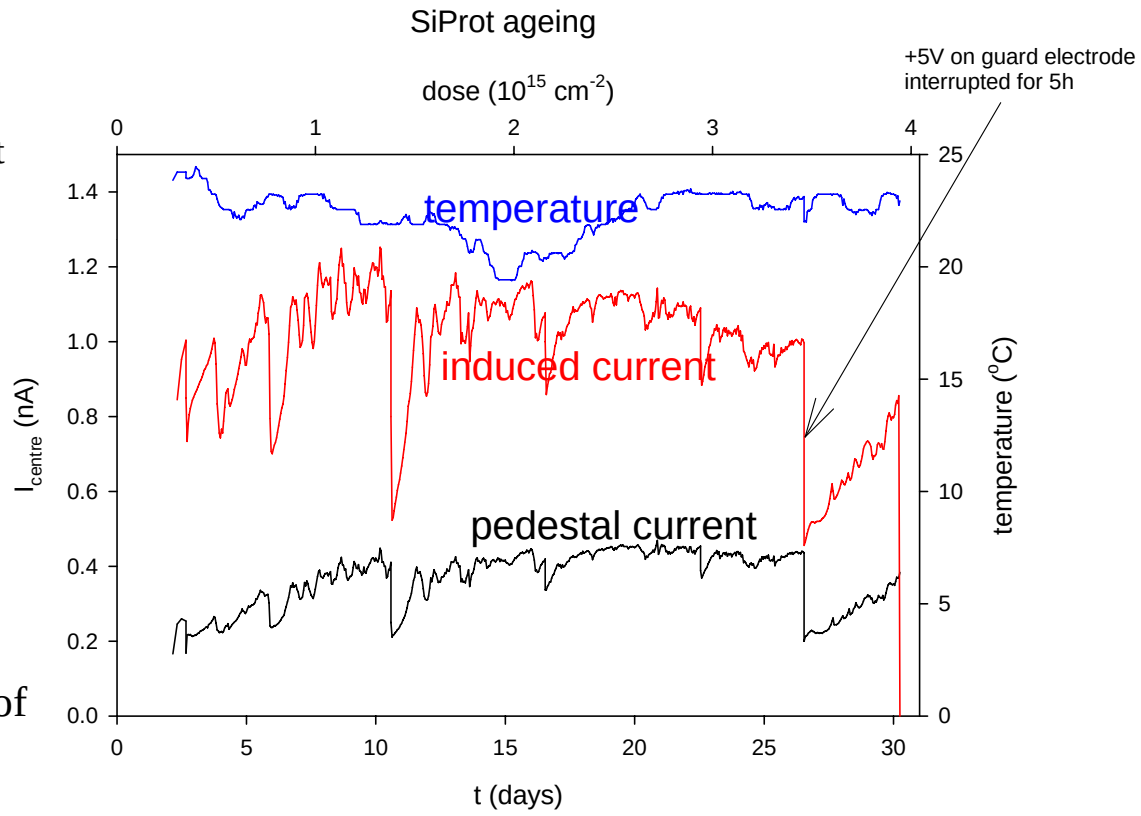
Measured resistance 2 – 10 GΩ
=> bulk resistance ~ 0.5 – 2.5 10^9 Ωcm
2.6 - 13 10^{11} Ω between two pads
(just OK for b-layer SLHC)

SiProt current at 5V during mip irradiation

- SiProt conductivity shows unstable behaviour
  - Variations within factor ~2 from average
- Induced current not exceptionally high
  - Not much effect expected at SLHC rate (0.4 instead of 1.15 GHz)
- Also long term effects
  - Increase of current over a period of several days
- But no significant effects on the operation and protection of the ROC expected
- Until 4 x 10^{15} mips/cm^2 no ageing observed

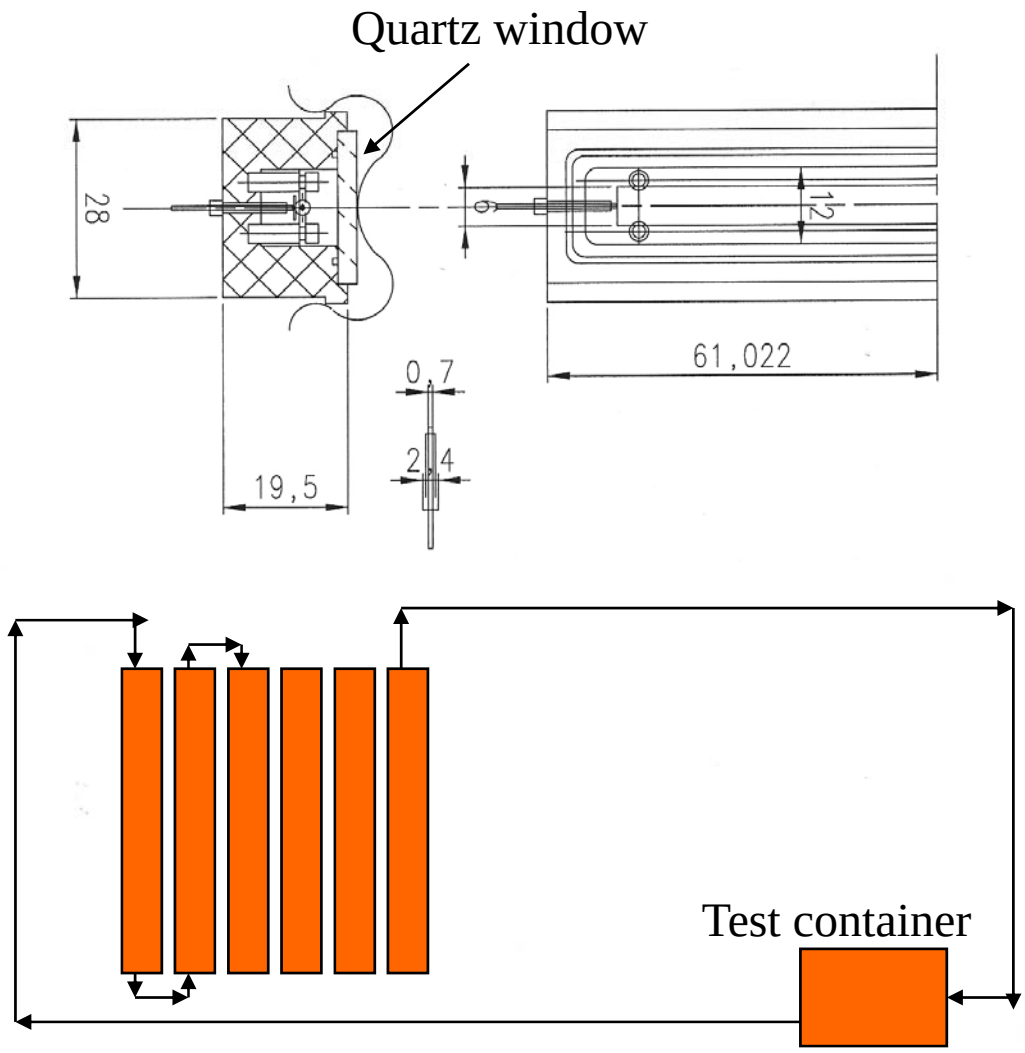
Sample: SiProt1 glass aging substrate
covered with 20 μm SiProt
Guard electrode set at + 5V
Current measured at centre electrode

8-4-2008



Ageing test chamber with ionisation by UV light

- Initiated by Harry van der Graaf
- Long, thin chambers from clean materials
  - SS
  - glass
  - ceramics
  - No plastics, epoxies
- Closed loop gas system
- Gas gain by InGrid structure
- Inserting suspicious material in test container
- Possible purification of the gas by avalanches
  - Downstream chambers have less ageing (LHC-b experience)
- Still in development



Conclusions

- For the Gossip prototypes we do not see the common ageing behaviour of gaseous detectors
  - ☺ No significant decrease of gas gain even at a high dose
  - ☹ But for iC_4H_{10} mixtures deterioration of HV stability
  - Not in agreement with earlier X-ray CH_4 test for unknown reasons
  - Will continue tests with other quenchers
    - CO_2
    - DME
    - CH_4
  - Verification required with other kinds of irradiation (hadrons, γ, n)

- SiProt ageing looks promising
  - No significant effect observed until $4 * 10^{15}$ cm^{-2}
  - Protection and ROC operation remain intact
  - To be repeated with neutrons

- UV light ageing
  - Convenient experimenting
  - Easy way tracing ageing compounds