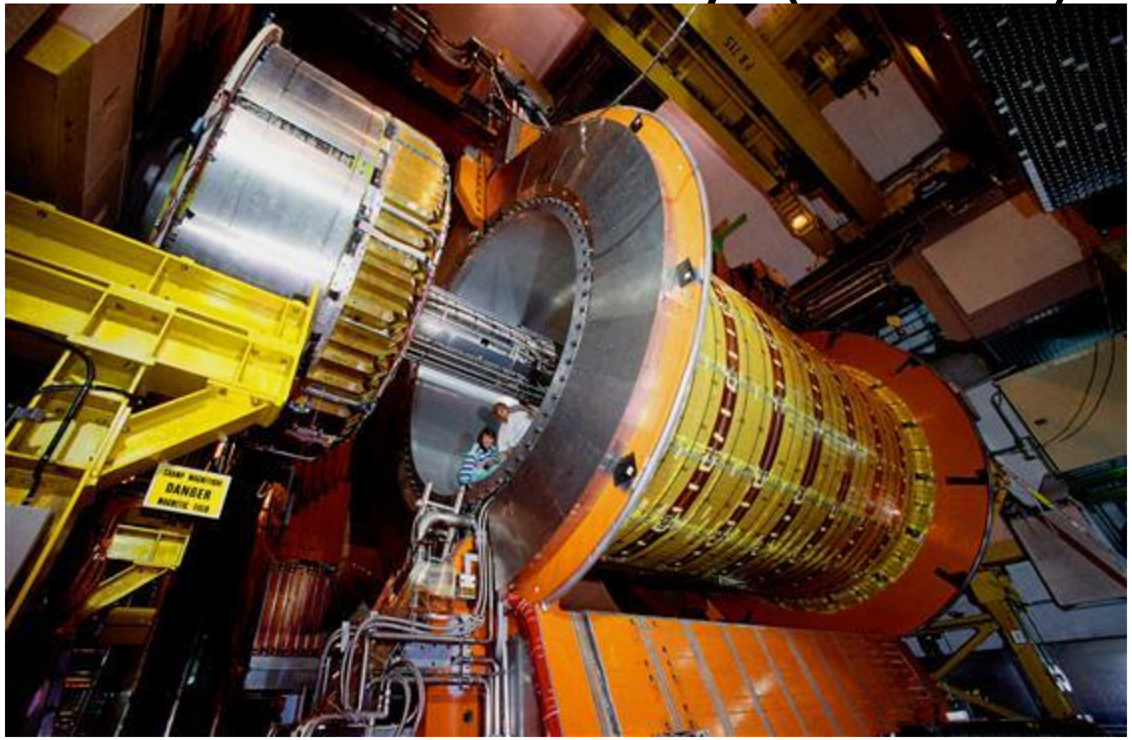
TGC's ageing experience

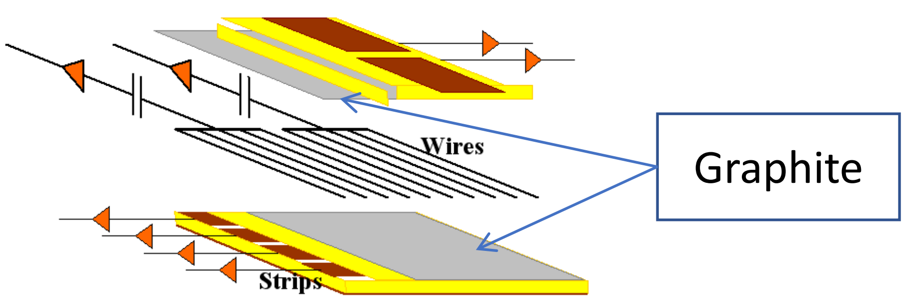
- Description of the TGC's detectors
- Critical points regarding electric field
- Ageing tests
- Past and future experiences
- Experience in the ATLAS Big Wheels, regarding ageing
- Construction issues that lead to ageing effects
- Conclusions

First use was in calorimetry (OPAL)



- 400 detectors were made that run for 11 years (~2% failure rate).
- Important to operate in a quasi-saturated mode to count particles in a hadronic shower and avoid large fluctuations.
- Used gas is CO_2(55%) n-pentane(45%)

Large number of TGC's have been constructed



- 4,000 large area TGC's have been constructed.
- They provide the End-Cap MUON trigger of the ATLAS MUON Spectrometer (as well as the azimuthal Coordinate for tracking).
- 350,000 electronic channels
- Many steps of QA/QC in the production procedure.
- The majority of the chambers were irradiated for 1/2hr with a 3KCu CO(60) source, to find any possible defect:
  - Defects are mainly due to irregularities in the surface:
    - Drops of glue will charge-up and produce sparks.
    - Bad contacts to graphite.
    - Hairs from non-properly coated G-10 material.
- With 8,000 large area cathodes, one acquires lots of experience on potential problems.

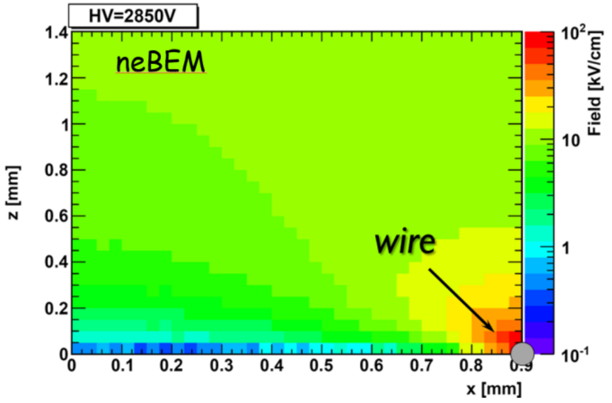
Characteristics of the TGCs

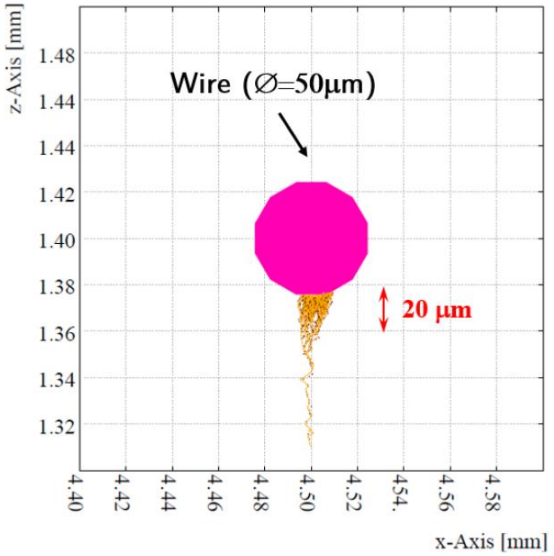
Make the gas gap as small as possible to avoid low energy particles stopping in the gas (Bragg peak)

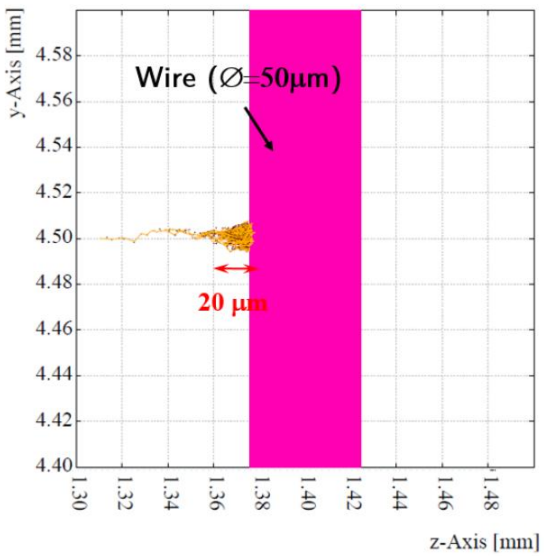
Have a high field close to the wire, to avoid sensitivity to the gap spacing.

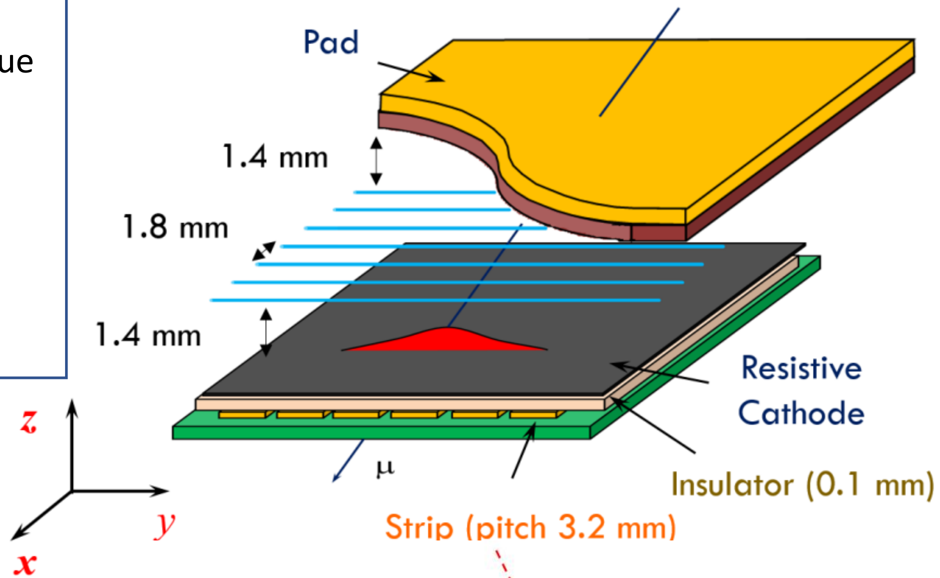
Use a resistive uniform cathode to avoid sparks due to non-uniformities.

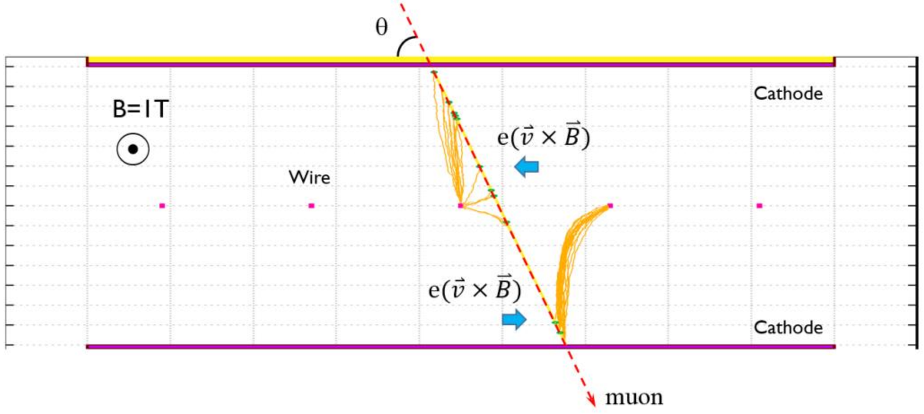
Use a gas with high ionization to obtain many ionization clusters for MIP's
CO_2 (55%) n-Pentane (45%)





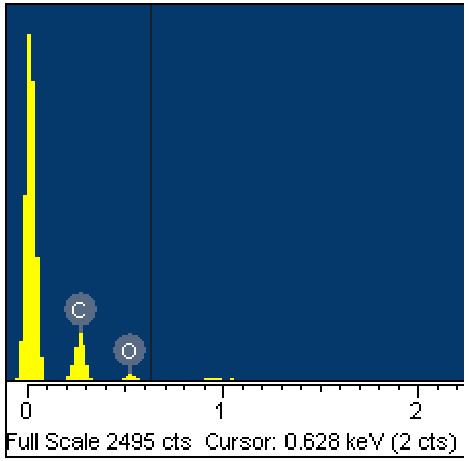




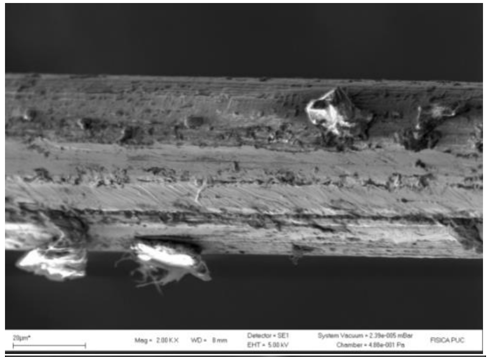


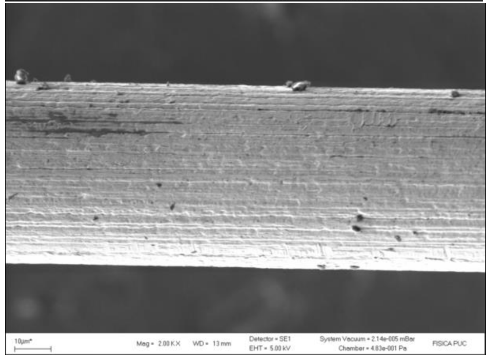
Aging tests

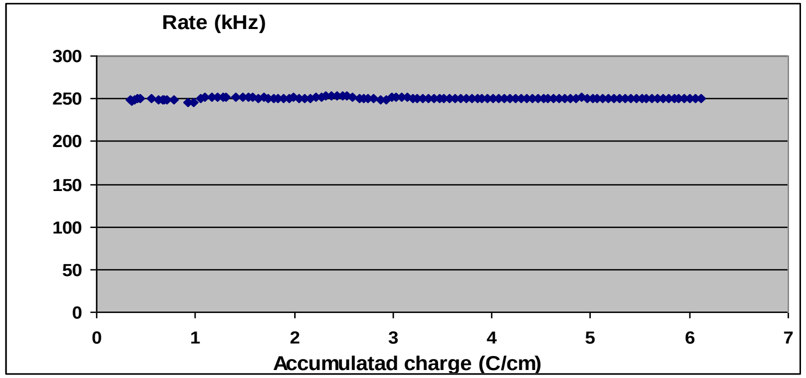
- 10 small chambers (10X10cm²) were irradiated for various periods of time, and their current followed through the irradiation time.
- A small chamber has accumulated 6 Coulomb/cm, without any deterioration= 20 years at SLHC with safety factor 5.
- Anode and cathodes were analyzed for deposits in Chile.
- The deposits in the wires are very small, since the n-pentane is a very strong cleaning agent, but the problem is that this cleaning effect will also affect cathode graphite repairs that were not properly done, in the long-term.

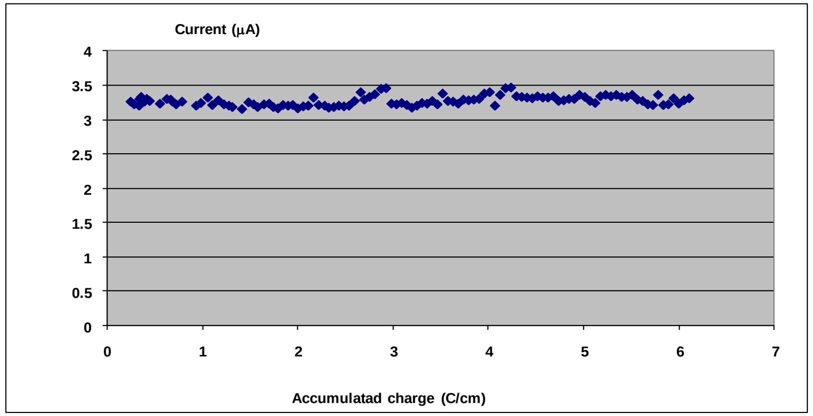


Deposits due mainly to Carbon and Oxygen







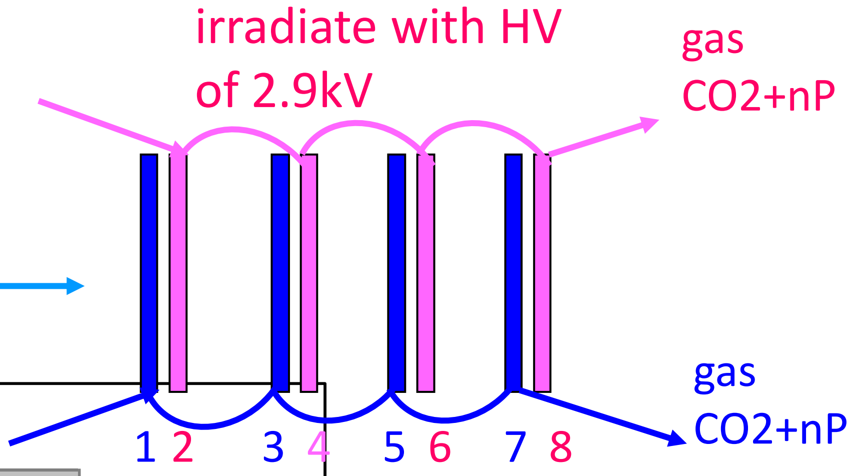


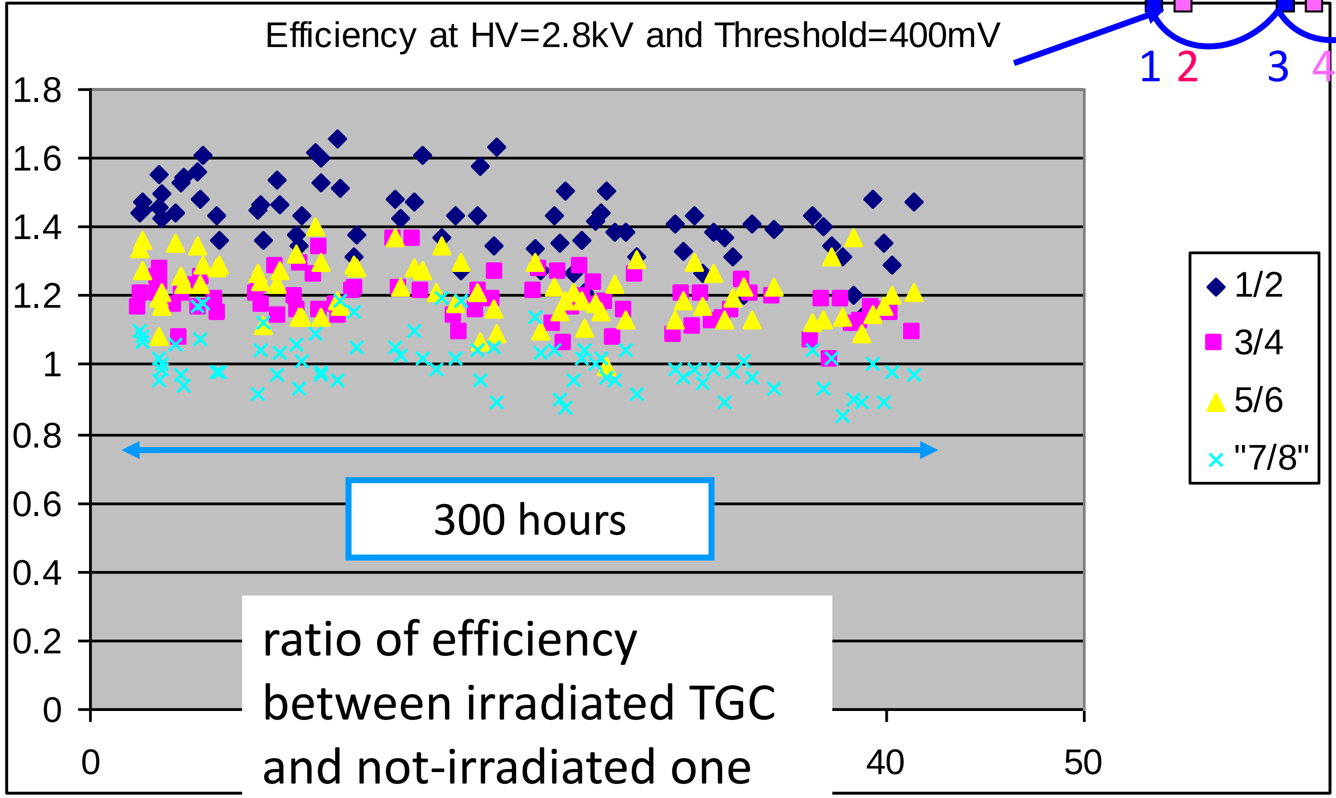
Worries about complex molecules in gases

- TGC's uses n-pentane in its gas mixture, could it be a gas deterioration while going from 1 chambers to the other under radiation?
- Use 3 K-Cu Co(60) source and irradiate 4 chambers simultaneously and 4 chambers without irradiation but with same gas for comparison.

QA with high-radiation gamma-ray flux (2)

irradiate gamma-ray from Co60 (300 hours, 3000Hz/cm2). accumulated charge corresponds to 3 yrs of operation in ATLAS



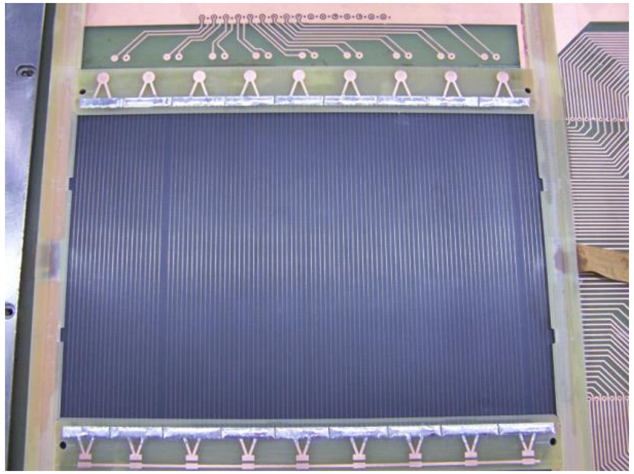


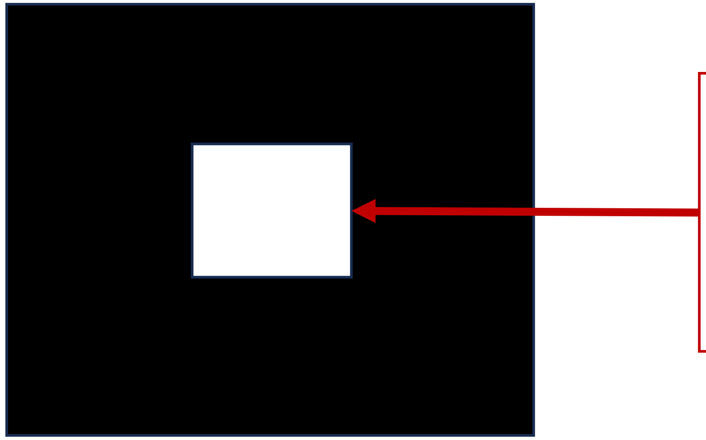
- no degradation of efficiency
- no effect of gas decomposition even in the last chamber

Possible pitfalls

With an electric field of 2.1kV/mm be careful on conductive edges

Cover cathode

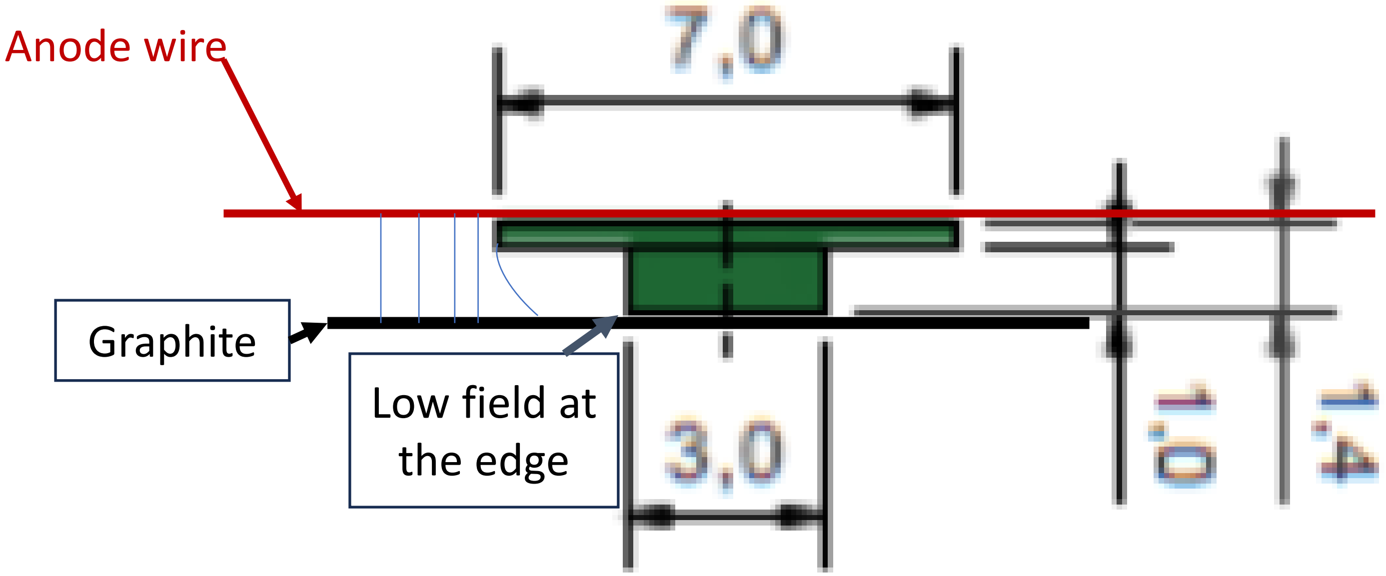




Concentration of the electric field lines=> continuous sparking along the edges under irradiation

Cover cathode with graphite at ground

But also the edges of the graphite play a role need to reduce the electric field at the edge

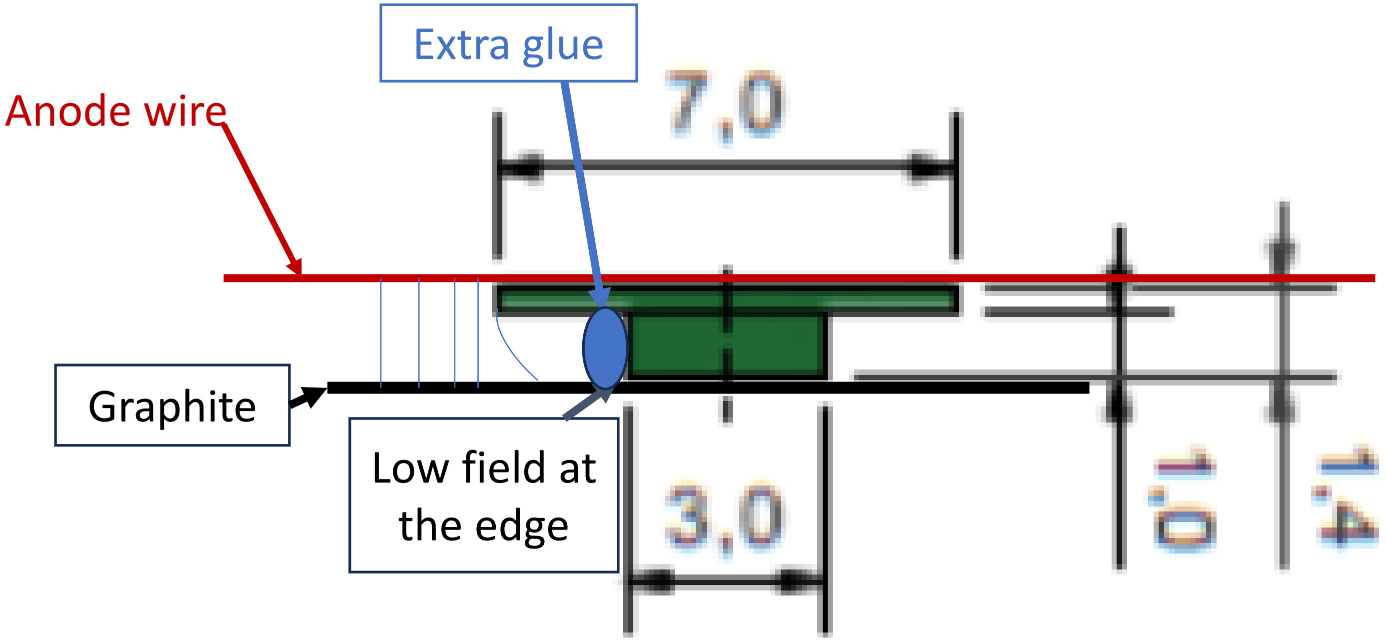


But if there is extra glue at the leg of the support, long term problems occur

Long term problems occur due to:

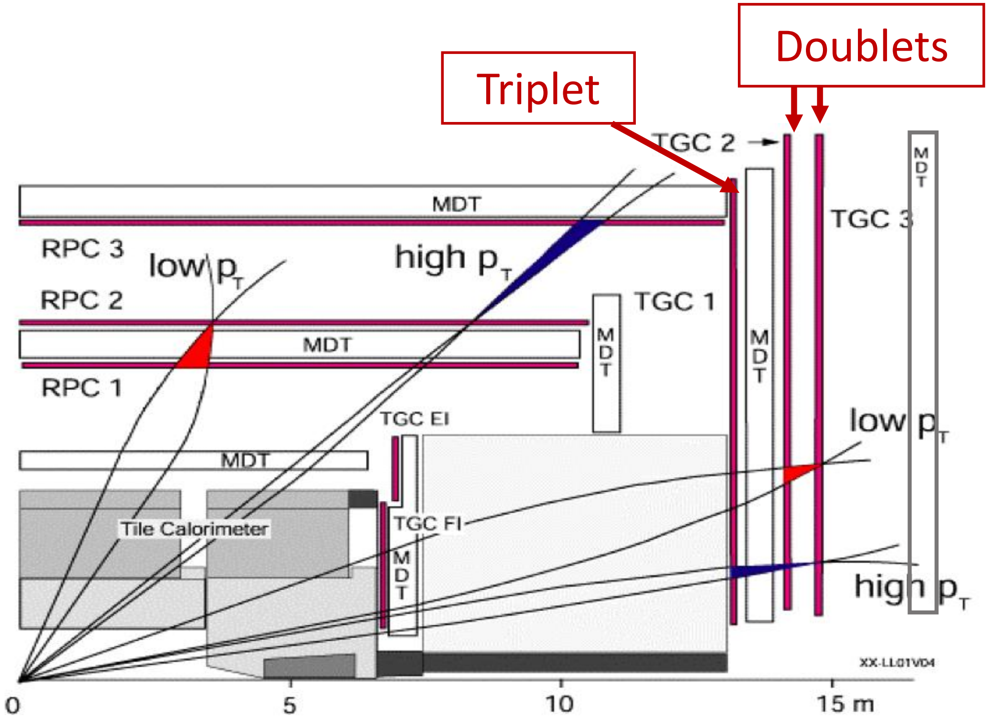
Charge up of the glue=>spark

Glue dissolves some of the graphite, leading to continuous sparking
Also glue deposited on the graphite charges up and sparks with time,



The above issues will be discussed later and have no connection to ageing, but just mistakes in the construction

Use of TGC’s in ATLAS as a trigger device



- Front plane contains 3 TGC layers, back 2 planes contain 2 TGC layers each.
- A cone is open around the hit point in the last 2 planes for an infinite momentum μ, the size of the cone is inversely proportional to the μ momentum.
- A coincidence 3-out-of-4 is made within the corresponding cone in the back layer, to match a

  2-out-of-3 coincidence in the front layer

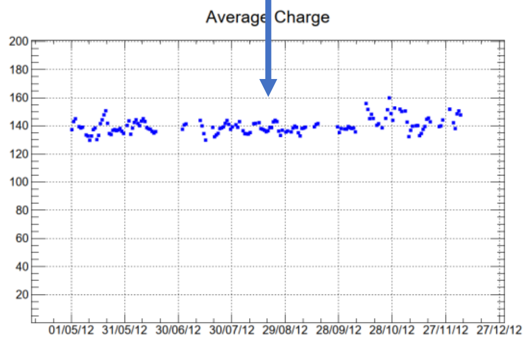
Past and future experiences using TGC’s

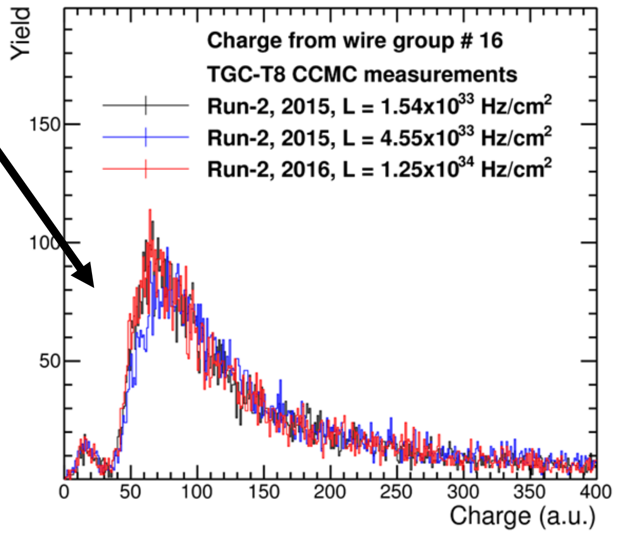
- It is very hard to trace the behavior of detectors over many years, in particular, taking into account running conditions variations.
- Use MIP’s to follow changes by using an independent system on EVERY DETECTOR PLANE in a limited area and pointing towards the interaction point.

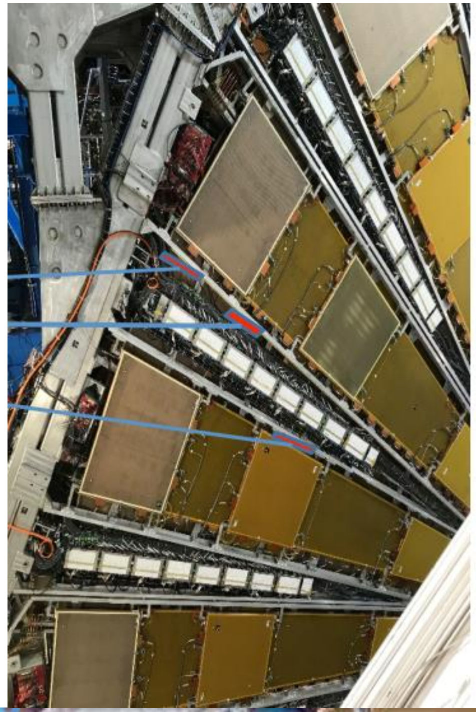
Charge monitor arrangement to follow charged deposited by MIP's

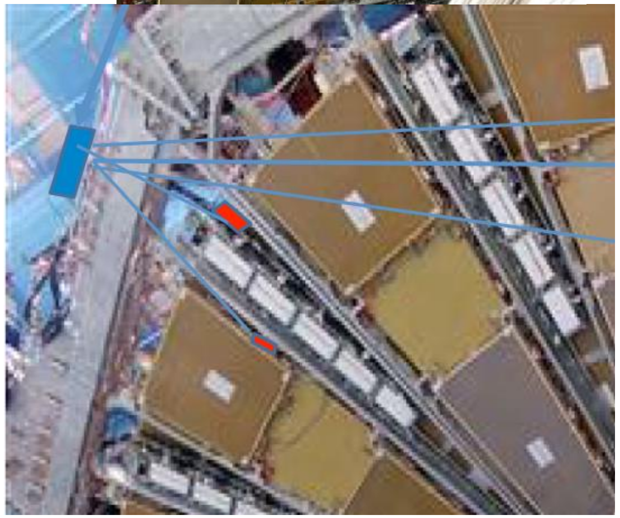
- For triplets (doublets), use an analog output for a group of wires, triggered by a coincdence of 2-out-3 (3-out-4) of a pointing group and read the integrated charge.
- Keep track of the average and RMS value of each measurement.

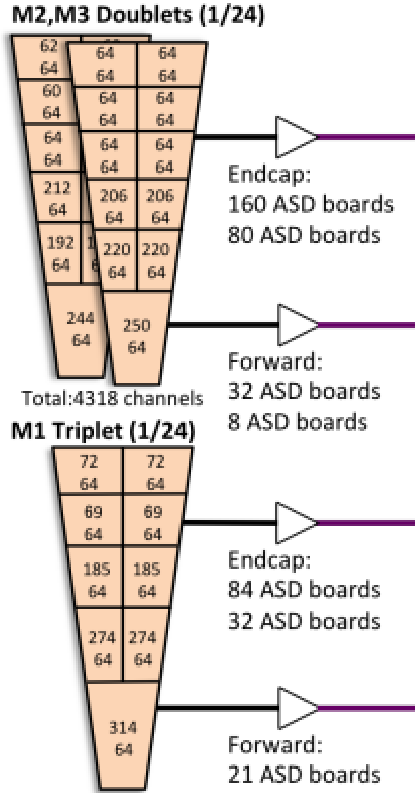
Typical charge spectra for one channel as a function of the instantaneous Luminosity
And its average variations



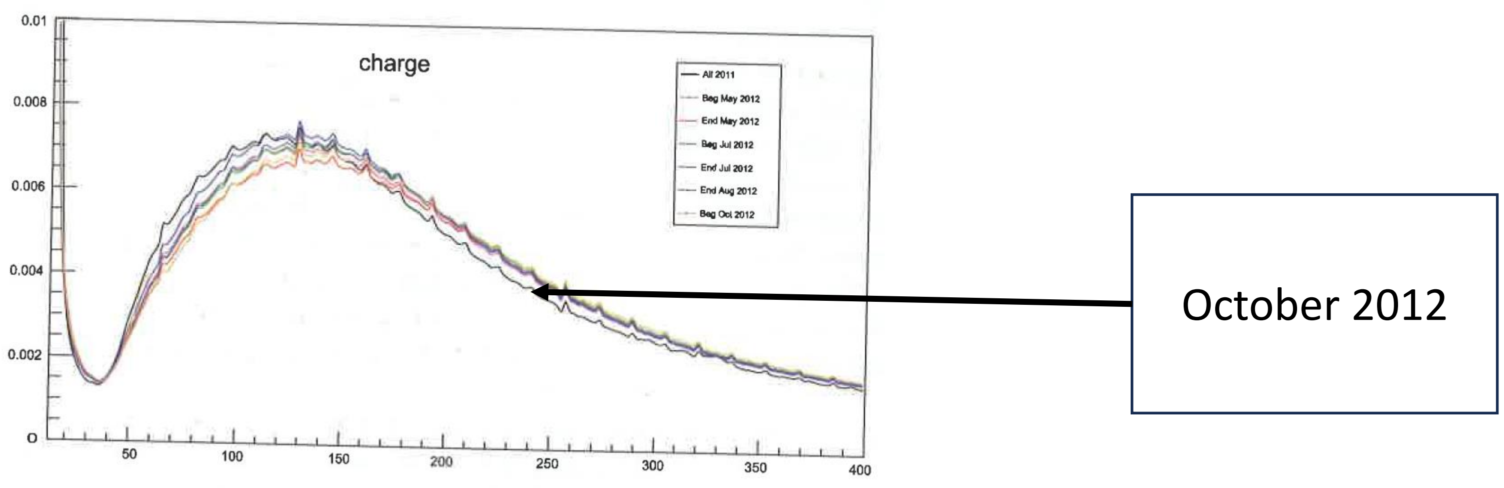






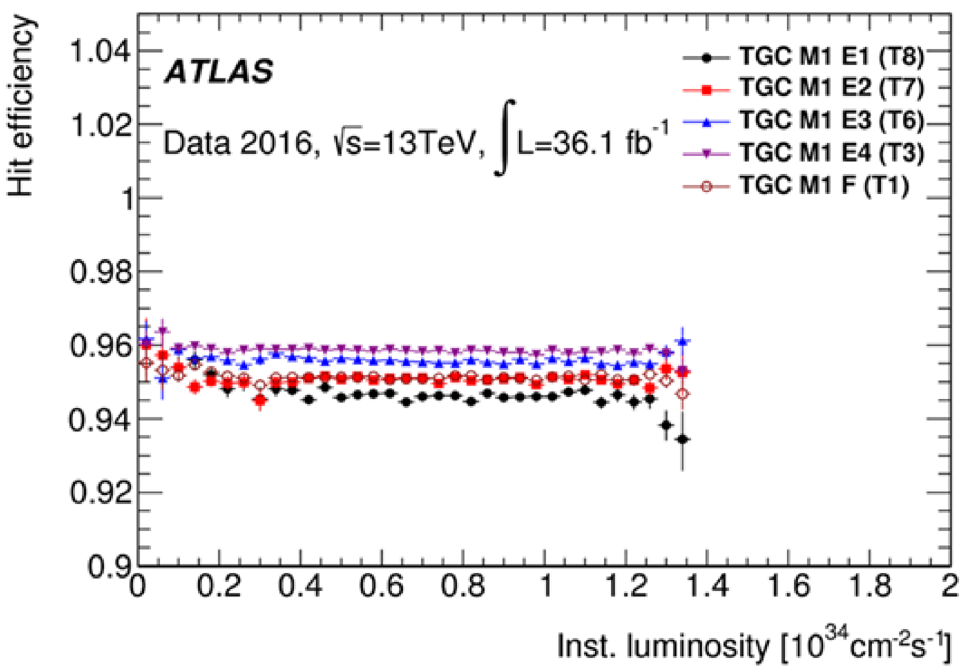


Also by comparing average distributions for 1278 planes (one side) one can see no changes, except October 2012



- Do not blame everything on ageing
  - The small diminution in the MIP charge was accompanied by a large number of HV tripping chambers.
  - The try to overcome the problem; gas flow was increased to further delude any contaminant.
  - Problem was traced (Roberto) to a different n-pentane supplier that was using different stainless-steel containers.
  - The n-pentane is a very good cleaning agent, but it also cleans the rests of the welding materials.

After replacing the filling tanks (without any welding), the issue was solved at all Luminosities

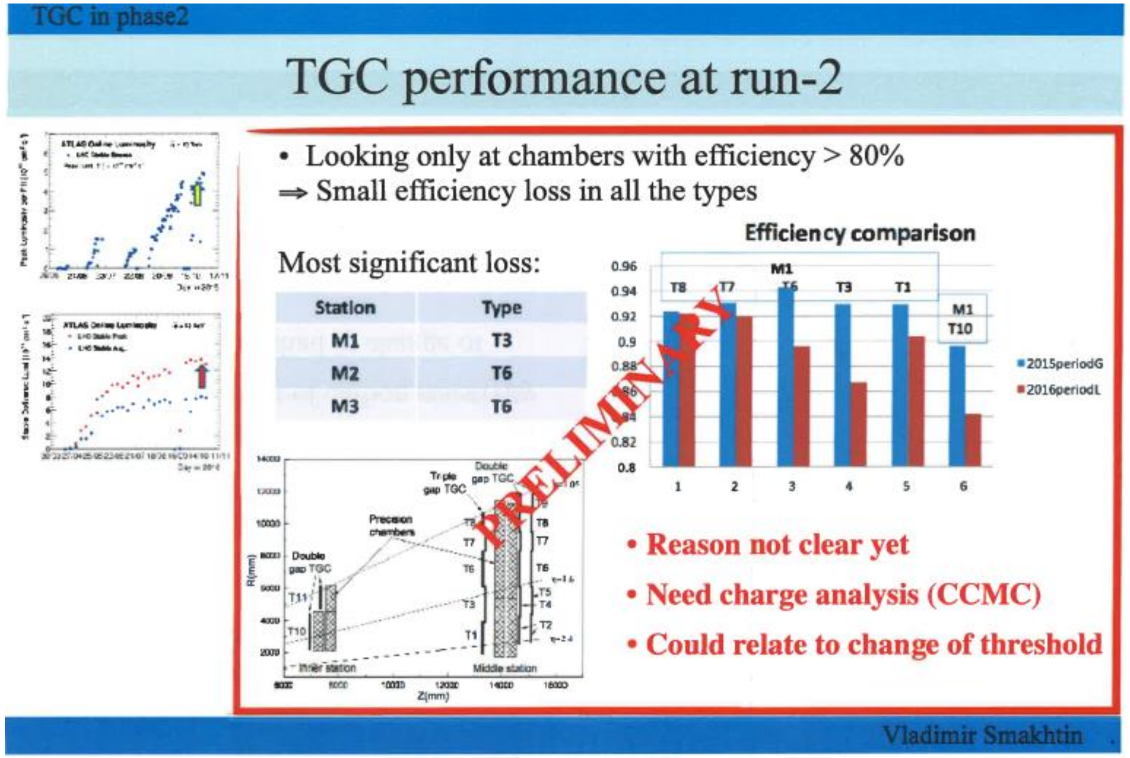


- Do not blame on ageing any change that you do not understand
- It is crucial to have responsible people that follow changes (Roberto and Gas Group) in the systems over long time periods.

Do not blame on ageing any observed phenomena, without understanding the data being used

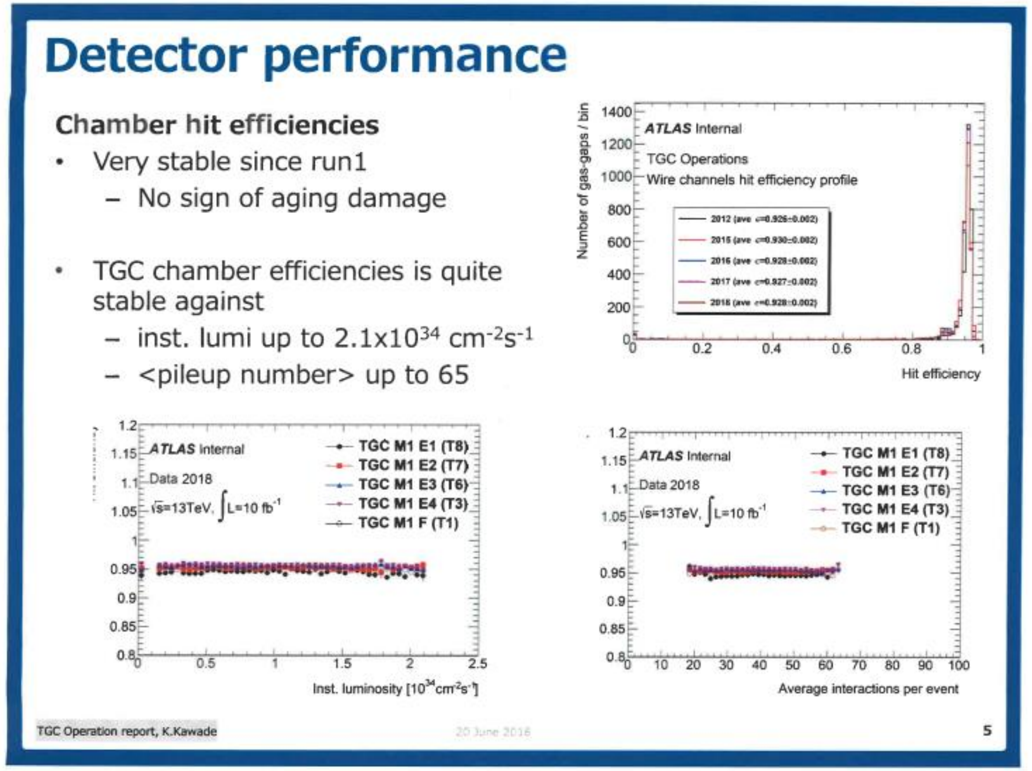
higher luminosity leads to a higher contamination of low energy particles from material in front

Analysis of data without momentum cut, leading to wrong conclusion in eff.

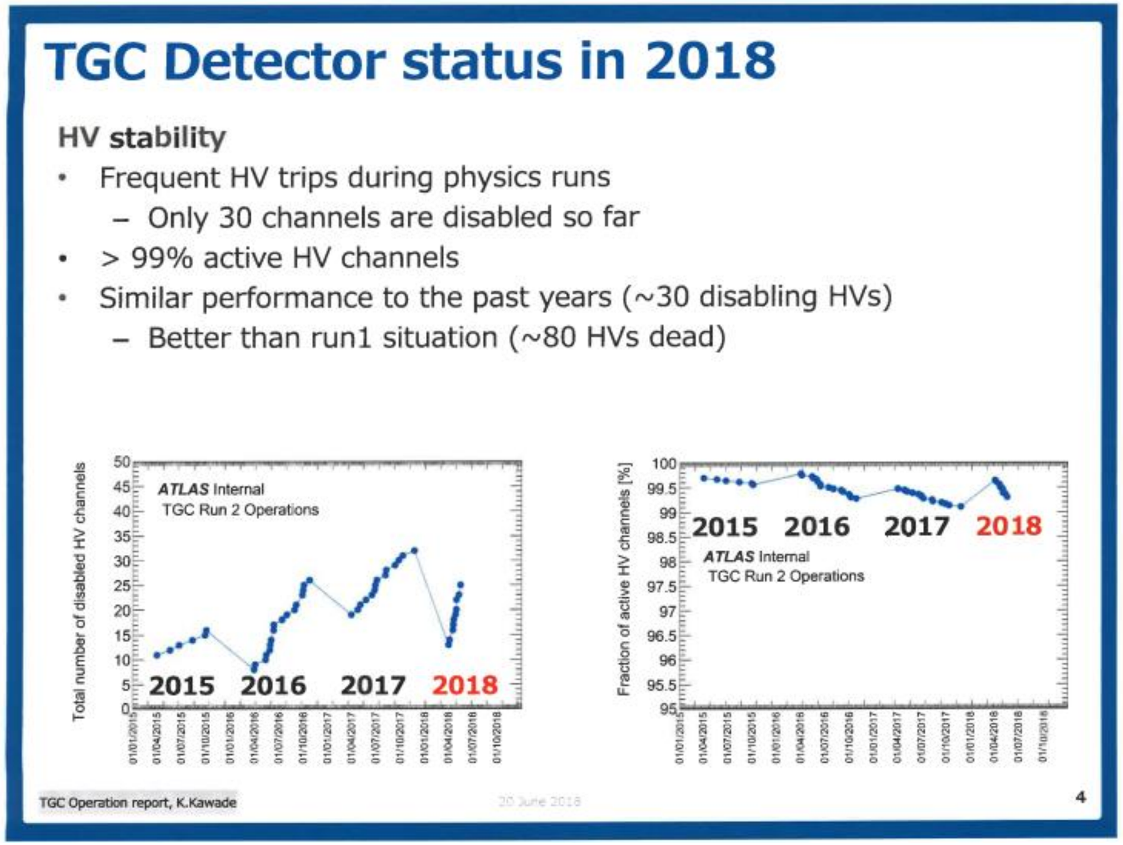


Analysis of data using momentum cut.

No change in detector efficiency from 2012-2018



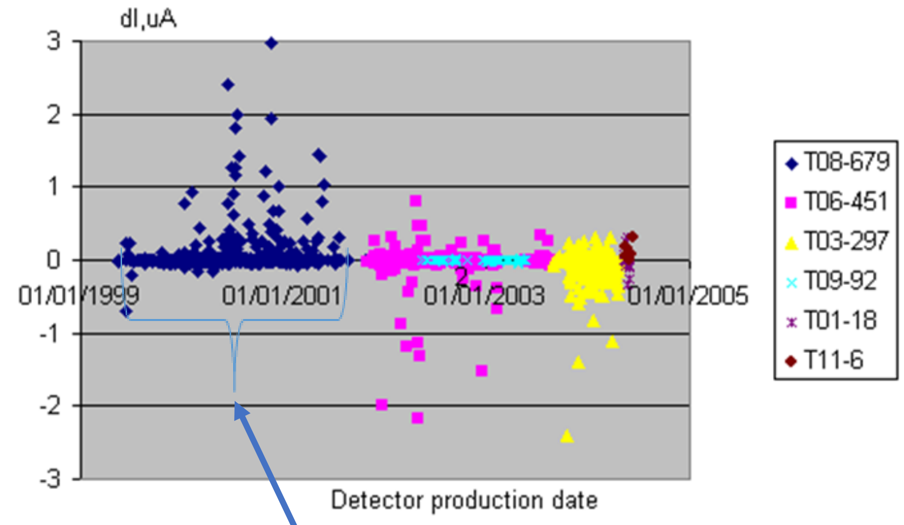
Operational HV issues throughout the years



- The strong cleaning effects of n-pentane lead with time to the formation of small bridges of graphite in places where corrections were not properly done, as well as rests of glue with graphite, that charged up with time, leading to HV shorts.
- 35% of these bridges could be burned in an atmosphere of pure CO2, while other detectors had to be exchanged.
- These procedure allowed to keep the system operational since 2008 with a high efficiency.
- But most of these issues could be partially predicted from the start

sTGC tests with Co(60) 2000Ci source

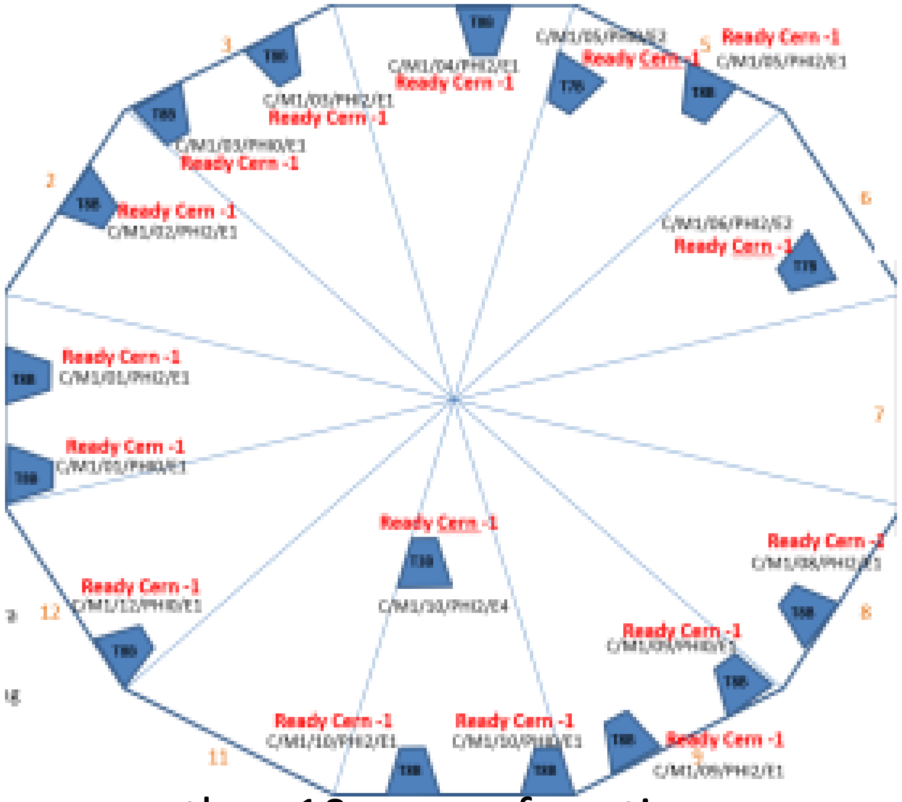
- All Israeli produced triplet detectors were fully irradiated with a strong Co(60) for 1/2hr at a rate of 100Hz/cm² and then the current was compared to the initial current imposing a cut on the difference of 1μA (graphite and glue related problems were found in the rejected detectors).
- A high level technician (Boris) was put in charge of the clean room, where detectors are closed, to ensure that any defect is either properly cured or cathode is replaced.
- Following this changed, all detectors were irradiated with a rate of 200-3000Hz/cm², with requirement cut at 0.5μA.



TGC tests: first set of chambers tested at 1/3 of the rate=>change person in charge of clean room to ensure good quality detectors.

Crucial to have competent people to check every step in the detector construction

The issues for the detectors to be replaced clearly not related to irradiation but to quality in the construction



- Detectors to be replaced after more than 10 years of continuous operation are the ones that were the least exposed to radiation.
- There is no replacement for a highly qualified technical personnel with understanding of the physical meaning of every step in the detector production. This requires experience and feeling.

Conclusions

- There are no signs of TGC detector ageing for TGC's that were installed and in operation since 2008 to 2023.
- One has to be very careful with replacement materials on all aspects (including materials for replacement detectors) since although the name might be the same, but place of fabrication might not, and every new batch needs to be qualified. However the people that have the knowledge to perform the qualification are slowly disappearing.
- It is very hard and it is becoming harder and harder to have competent technical staff to produce good detectors, and in particular, one should not give up on stringent QA tests.
- Running such a complex system is life-time job, where the meaning of RESPONSIBILITY and CREDIBILITYbut in a new scientific world, they have lost their importance an POLITICAL LEADERSHIP with responsibility laying in a task-force are the new scientific values.