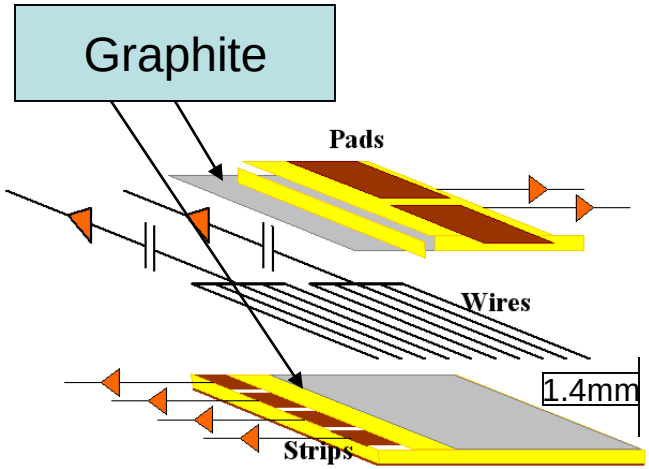
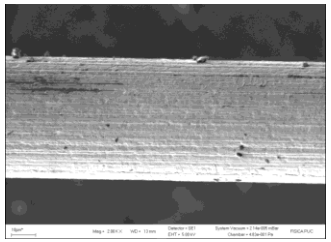
Experience with large area Resistive coating

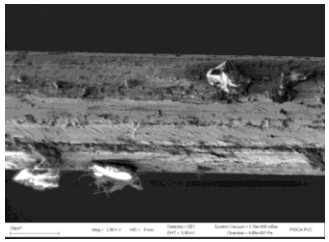
- Short introduction to TGC technology.
- Why resistive coating ?
- Potential pitfalls:
  - Quality of the material
  - Contacts to the outside
  - Uniformity
- How to apply the material.
- What is the optimal resistivity?
- Achieved uniformity.
- Conclusions.

Short Introduction to TGC's

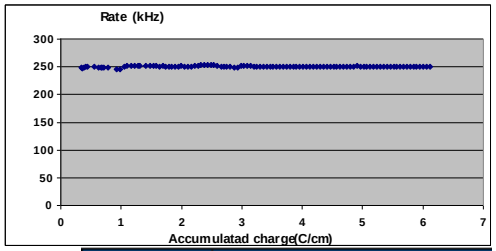
- CSC-like structure, except that anode-to-cathode distance=1.4mm, while anode-to-anode distance=1.8mm.
- Anode wires sandwiched between 2 high resistive layers.
- Readout behind resistive layers (strips, pads) or anodes.
- Operating voltage: 2.9-3.0 KVolts.
- Gas: CO2-n Pentane (55%-45%): n Pentane increases the ionization, while absorbing the photons in the avalanche.
  - This provides high gain, without sparks.
  - N-Pentane acts also as cleaning agent (no major wire deposits after 6 Coulomb/cm).
  - For a small volume, one can afford to use flammable gas, and take precautions for leaks. C-H3 chains provide a good quencher, and avoids other problems.

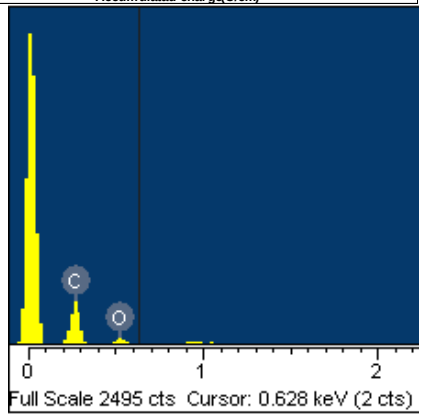






Wires in non-irradiated
And
Irradiated areas





Large number of TGC's have been constructed

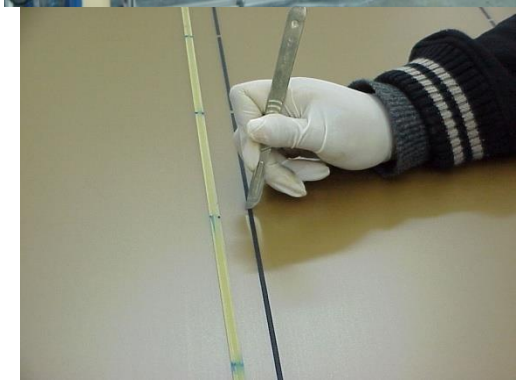
- 4,000 large area TGC's have been constructed.
- They provide the End-Cap MUON trigger of the ATLAS MUON Spectrometer (as well as the azimuthal Coordinate for tracking).
- 350,000 electronic channels
- Many steps of QA/QC in the production procedure.
- The majority of the chambers were irradiated for 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.

Why resistive coating ?

- Having a high resistivity cathode reduces any damage that could be caused by sparking.
- By putting the readout layer behind a thin (100µm-1.4mm) G-10 layer, using standard multi-layer PC procedures, one obtains a smooth cathode surface.
- The transparency of the resistive layer is proportional to R*C (i.e. the surface resistivity X the capacitance to the readout pattern).
  - For low-rates, one can use high-resistivity material and place the readout pattern far from the cathode surface.
  - For high rates, one needs to reduce the gap between the readout pattern and the cathode to a minimum, to have a low resistivity layer.
- With a highly quenching gas, there are no problems of space-charge limitations (one can have local rates measured in KHz/mm^2), however high rates on a large surface reduces the operating voltage far from the ground contacts, therefore leading to non-uniform gain.
  - Increase the number of ground contacts and make sure that the surface resistivity matches the detector rates.

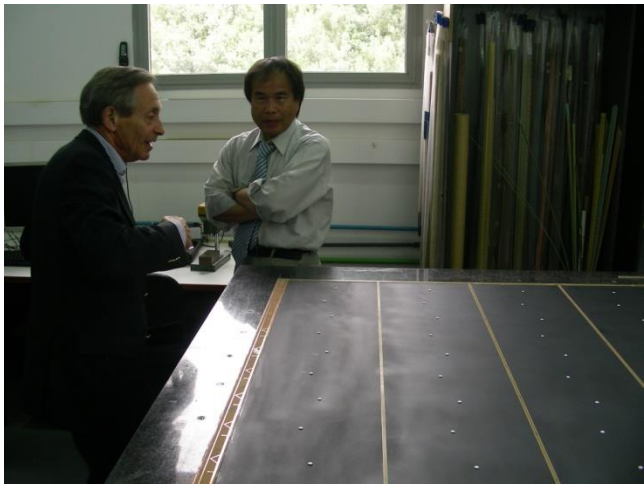
Potential pitfalls

- Quality of the material:
  - The Pre-Preg material on which the resistive coating will be applied has to be smooth, but porous.
  - It is very important that during the multi-layer fabrication (press), the relevant surface has been covered with Tedler paper.
- Conditions for coating:
  - It is very important to control the conditions for applying the coating (low humidity <40%) and well defined temperature. At Weizmann, a special room has been instrumented for this purpose.
- Quality of the coating:
  - The firms that produce the coating material (an admixture of graphite and glue), are not interested in the surface resistivity. Any new batch has to be controlled for the final surface resistivity by using testing samples.
  - During the coating process, some dust particles can be attached. It is crucial to perform a polishing procedure, after the coating material has cured.
  - The coating gun has to be cleaned after each application, to obtain a uniform coating.
- Avoid any contact between glue and the coated surface. This changes the local resistivity.
- Contacts to ground:
  - Various ways of providing contacts to the ground have been tried. Most of them change (conductive glues, Ag compounds, etc) change the conductive properties with time. ATLAS solution: many Cu strips making contact by pressure. Future solution: Cu contact attached by press during multi-layer fabrication.



Type of coating material

- Different coating materials have been used:
  - For OPAL, DAG504, aerosol spray:
    - Problem: the material was not very reproducible in terms of resistivity, but some of the producers (UK instead of NL) contained some oil component (mainly used as lubricant)
    - The material could be easily damaged (scratch).
    - It needed an ageing process to work with n-Pentane.
  - For ATLAS, use 2 component product:
    - Kontakt Chemie; CRC Industries, Deutchland GMBH: Graphit33 + Plastik70.
    - Using 2 components, allows to achieve the needed resistivity.
    - The coating is of very high quality and cannot be mechnically damaged (no scratches).
    - The coating does not need to any ageing process.

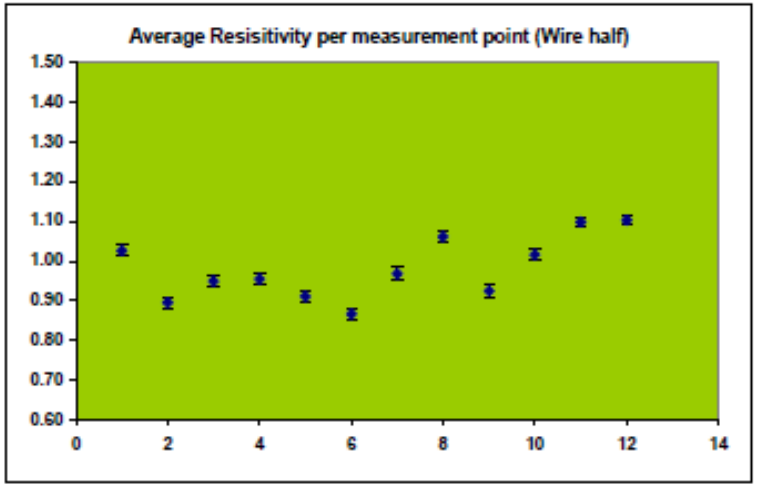


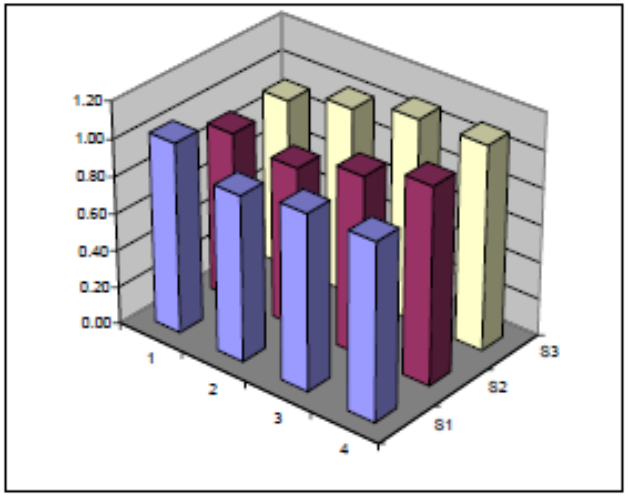
How to apply the Coating

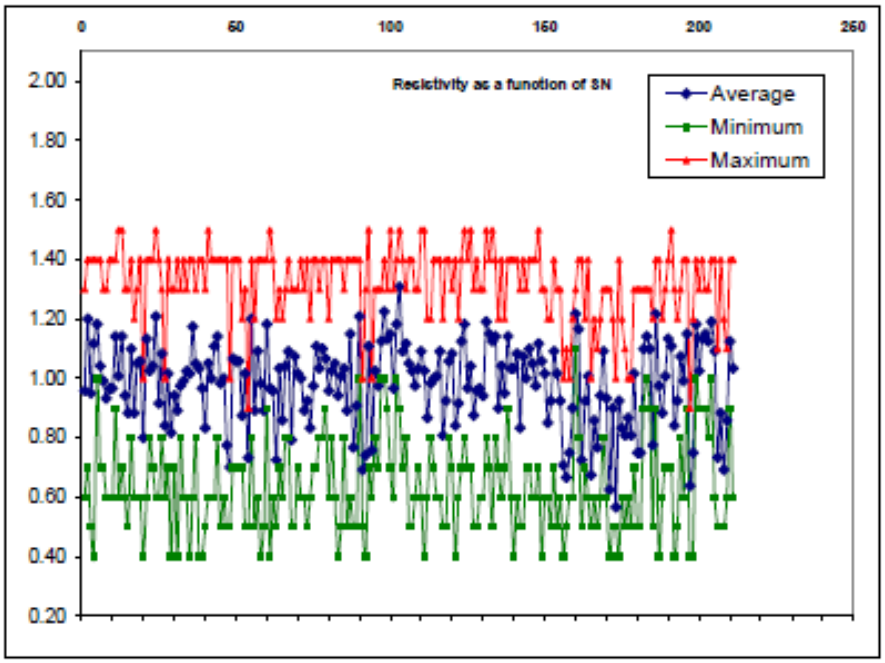
What is the optimal resistivity

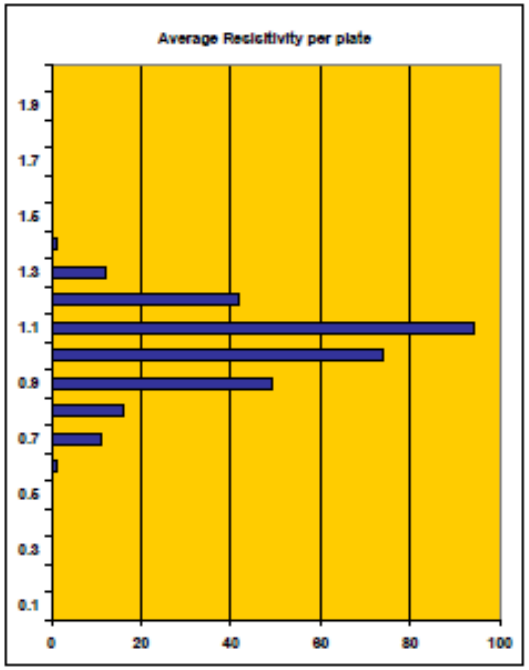
- For ATLAS:
  - In the low rate region, we have used 1MOhm/□. This provides for the same capacitance, narrow space signals (less cross-talk between strips)
  - In the high rate region (rapidity >1.92), we have used 0.5MOhm/□. This permits to have a low voltage drop up to 1KHz/cm² over the full surface.
- For SLHC (10KHz/cm²), one has to change the capacitance, by placing the strips 100µm from the resistive coating (instead of 1.4mm), which allows to decrease the resistivity to 40KOhm/□.
- The lower the resistivity, the more uniform the resistivity.

Achieved Uniformity for High Resistivity

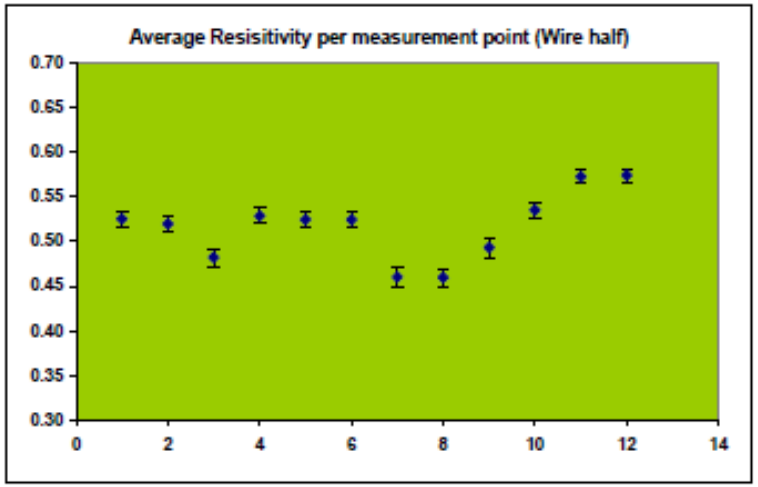


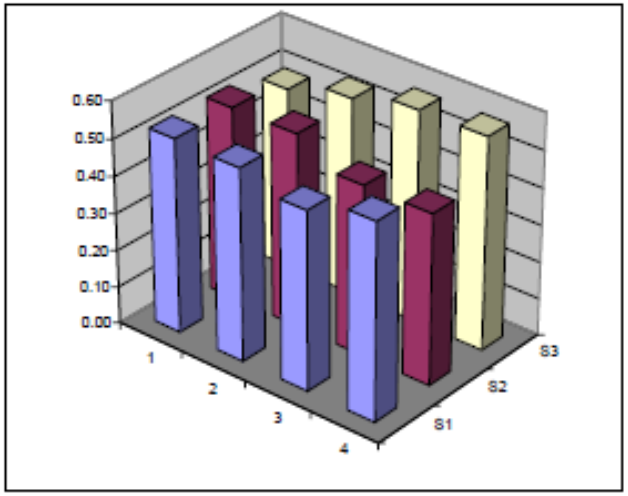


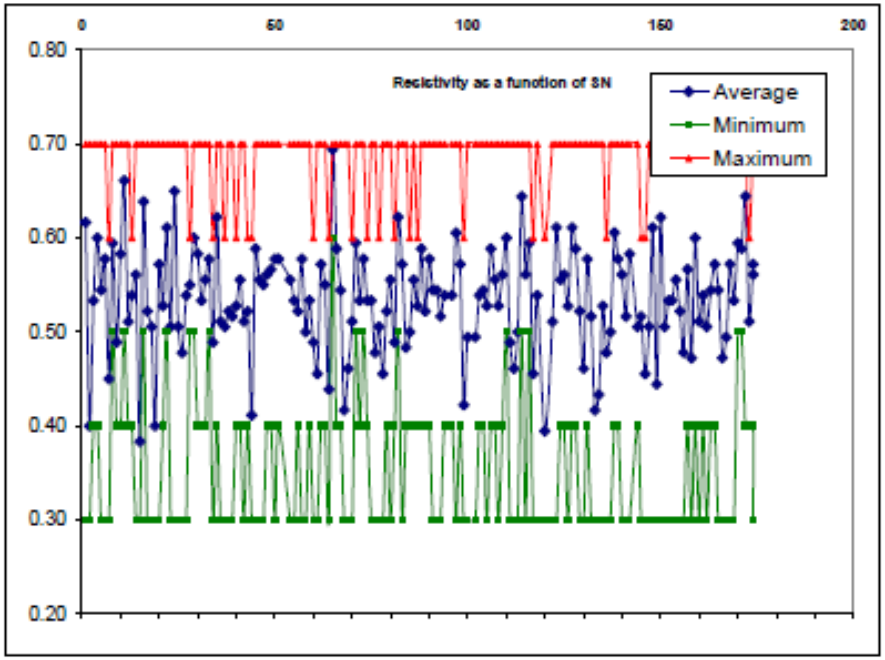


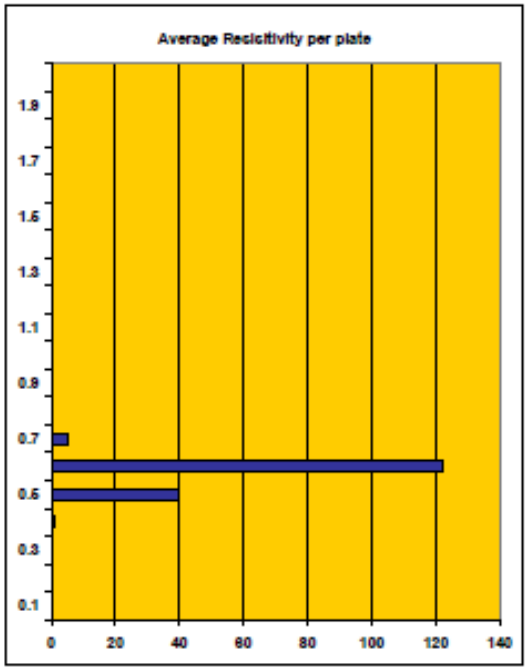


Achieved Uniformity for Low Resistivity









Potential problems

Resistive cathodes have many advantages, however there are a number of pitfalls:

- Avoid any not connected resistive islands (I do not have a picture), although the lack will do some connection (high resistivity), this will lead to sparks at high rates.

- Avoid not connected edges in the electric field (use in a show for Lab students; where sparks occur in the edge of the resistive layer).

-Make sure that you have as good as possible connection on most of the perimeter of the resistive layer, since this will influence the Voltage drop at high rate.

Conclusions

- Resistive coating provides a good way to obtain a smooth cathode surface.
- Resistive coating provides an excellent protection against sparks and other incidents.
- Resistive coating for large surface detectors requires a lot of care in the optimization of the resistivity and the contacts to the ground.
- Providers of resistive coating material do not care about its resistivity performance of the material, it needs constant control of its quality.
- The coating has to be apply under well defined conditions of temperature and humidity.
- When applying on large surfaces, it is crucial to polish the surfaces and control the uniformity of the resistive layer.
- The contact to the outside ground is not trivial, and needs a lot of care.
- When properly done, resistive coating provides a good solution for large area detectors.