The X-ray scanning technique application for sTGC detectors quality control

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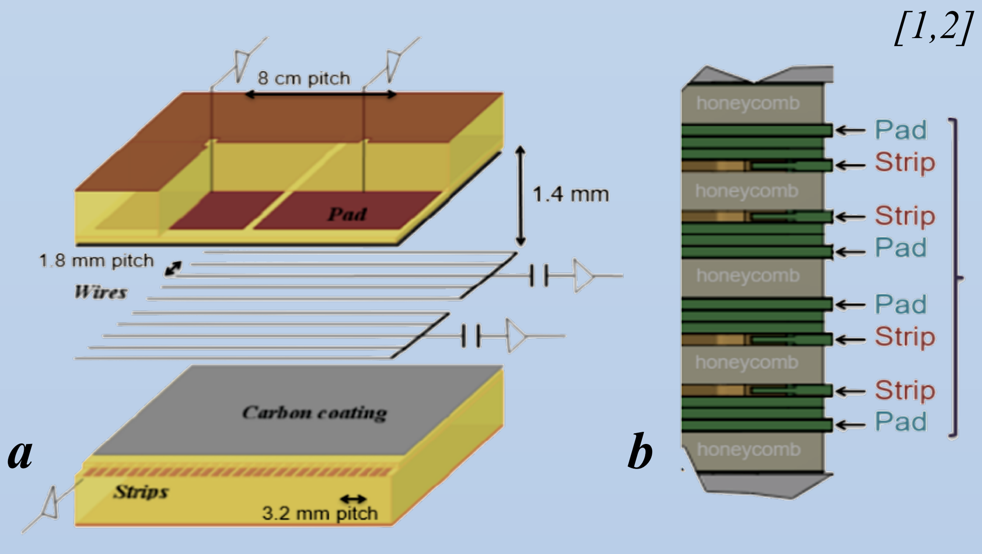
Abstract

The gas detectors operated under harsh radiation conditions, like the one foreseen at the HL-LHC, must fulfill a list of stringent quality control criteria. Based on current response, the X-ray scanning technique has been developed for detection of various defects prior to the installation of readout electronics. The later usually happens at the last stage of detector assembly. Thus, it allows testing the quality of the chambers, identified defects and when possible fix them already at an early stage.

sTGC detectors

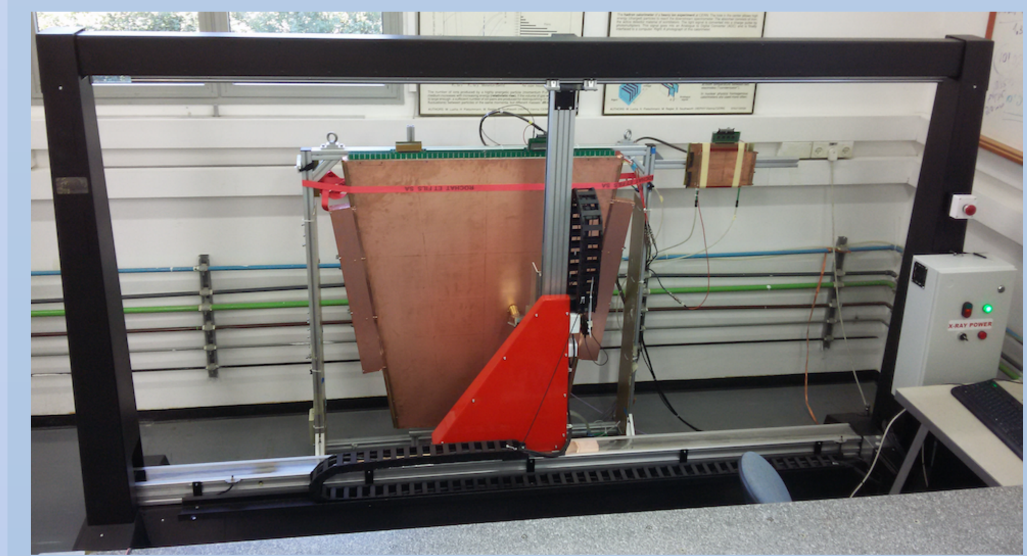
Operational gas: *CO2 / n-pentane mixture, 55% / 45%*
Operational voltage: *2.9 kV*
Anode wires: *50 µm diameter gold plated tungsten*
Wire pitch: *1.8 mm*
Gap thickness: *1.4 mm*
Cathode plane: *100 or 200 FR4 with graphite-epoxy coating with R = 100 or 200 kΩ/□ (at the air on inner/outer layer, respectively)*
Electrodes: *strips (precise tracking) and pads (triggering "3 of 4 in quad")*

[1,2]



a *- The schematic diagram of the sTGC structure*
b *- the cross section of a quadruplet, the 4 layers of sTGCs*

X-ray scanner



X-ray scanner in Weizmann Institute of Science

- XY machine
- HV supply CAEN NDT1471
- X-ray tube Amptek mini-X with collimators
- PC
- QScanner software *[3]*

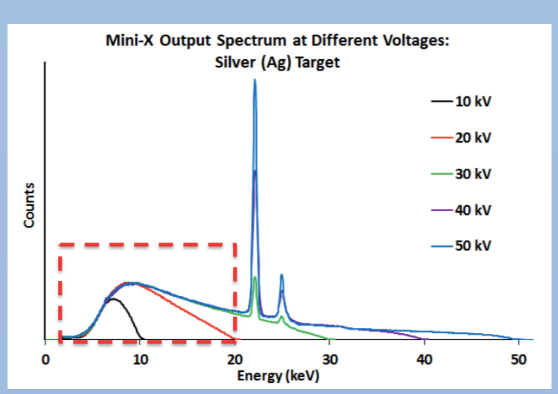
- The X-ray scanner was designed for sTGC gas gain mapping and defect search by current response *without readout electronics*
- The scanning procedure allows to obtain current response mapping of the sTGC
- Precision scans with narrow slit collimator allow to observe strip and wire structure
- Various types of defects are observed: "hotspots", cathode strip defects, wire defects
- Step-by-step (long but precise) and continuous (quick) data taking *[4]*

X-ray scanning modes and absorbers

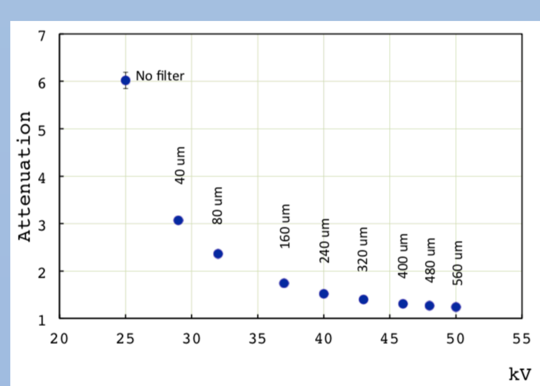
Playing with X-ray spectra we are making the method sensitive to the defects and insensitive to cathode board trace lines, voltage drops and number of layers

High energy high intensity mode (50kV, 75uA):
- *+ Burning down dust-like defects*
- *+ Up to 4 layers through*
- *- Voltage drop at the first layer*
- *- Insensitive to gap thickness*

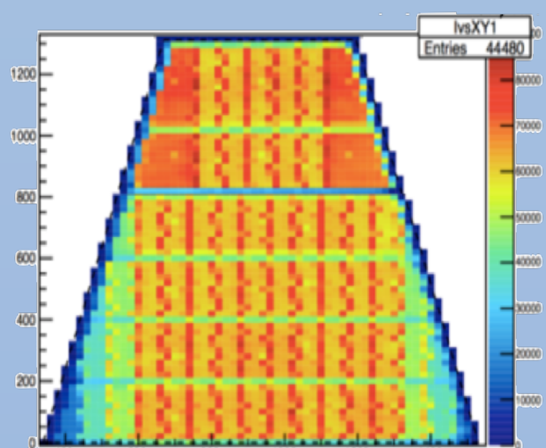
Low energy low intensity mode (25kV, 5uA):
- *+ Sensitive to the gap thickness uniformity*
- *- Applicable for single layer only*
- *- Very sensitive to copper trace lines*
- *- Scan from the strip side only*



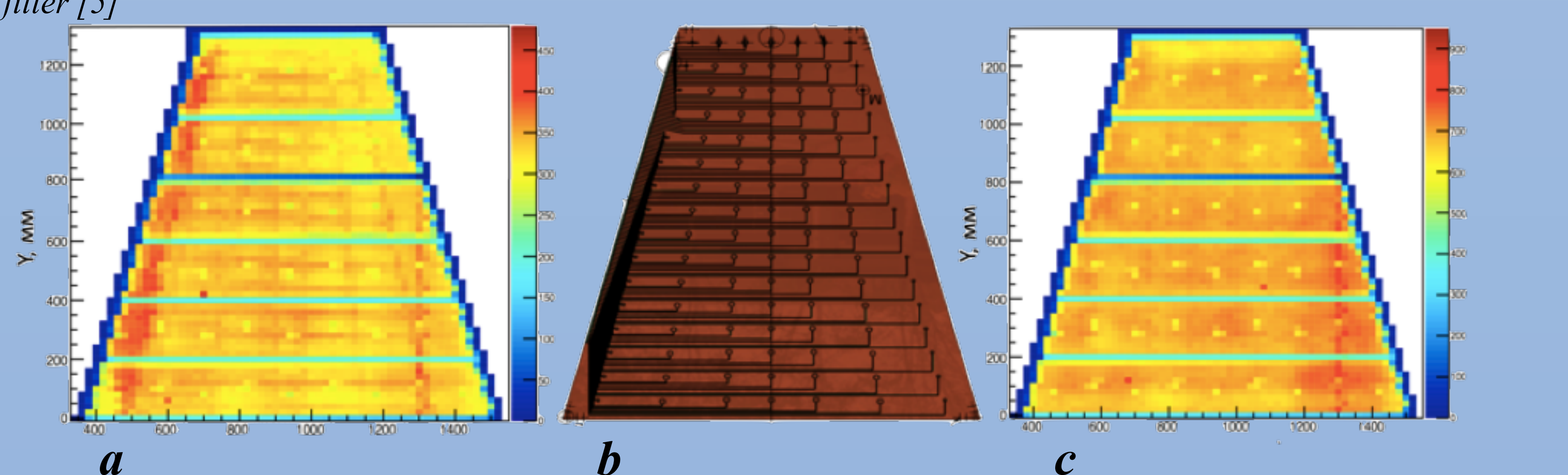
The Amptek Mini-X X-ray tube emission spectra. The area marked with red dashed line indicates the region being absorbed with copper filter [5]



Current attenuation graph with different copper filters vs voltage. The signal amplitude remains the same.



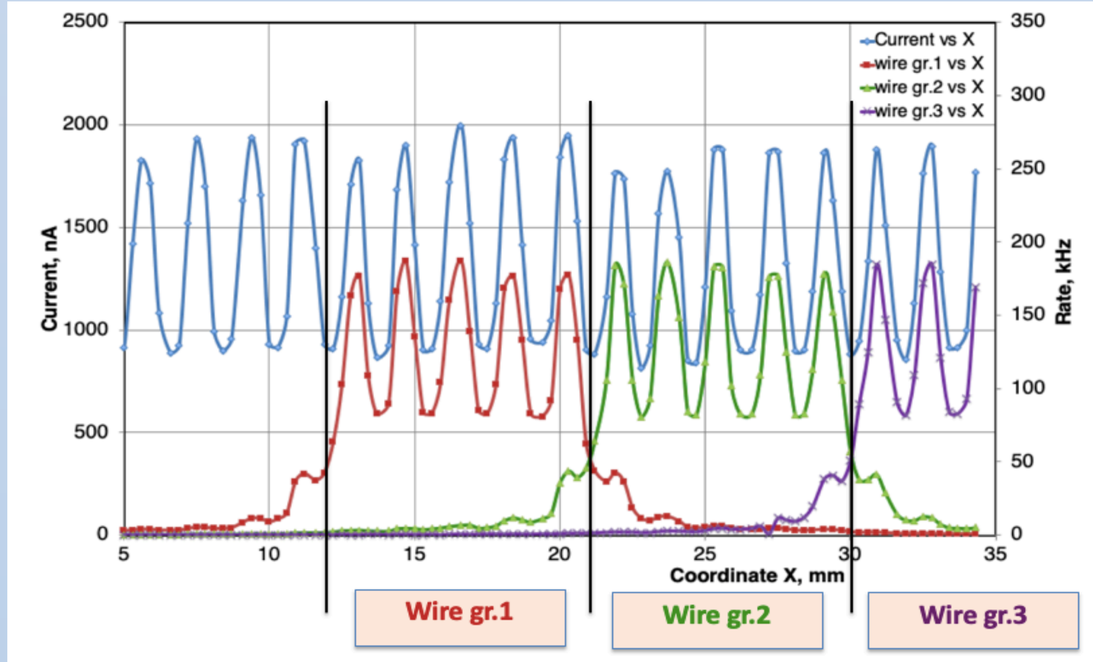
Voltage drop during the scan at High intensity mode (50 kV, 75uA)



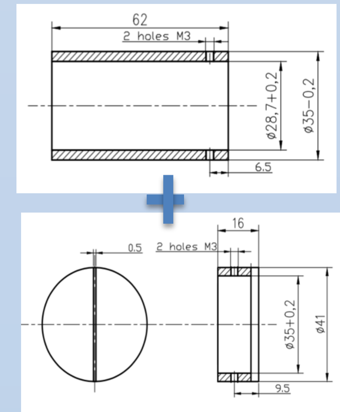
sTGC current maps for the same layer: ***a*** *– from Pad side at 25 kV and 5 uA without filter;* ***b*** *– trace lines scheme for the pad cathode board;* ***c*** *– from Pad side at 50 kV and 5 uA with 560um copper filter*

By tuning the X-ray energy and absorber thickness we move spectra to the transparency window for copper. The X-ray tube parameters of 50 kV, 5 uA & 560 um copper filter are found to be the best for the pad side scanning. The method is suitable for scanning doublets or singlets from both sides

Precise scans with slit collimator

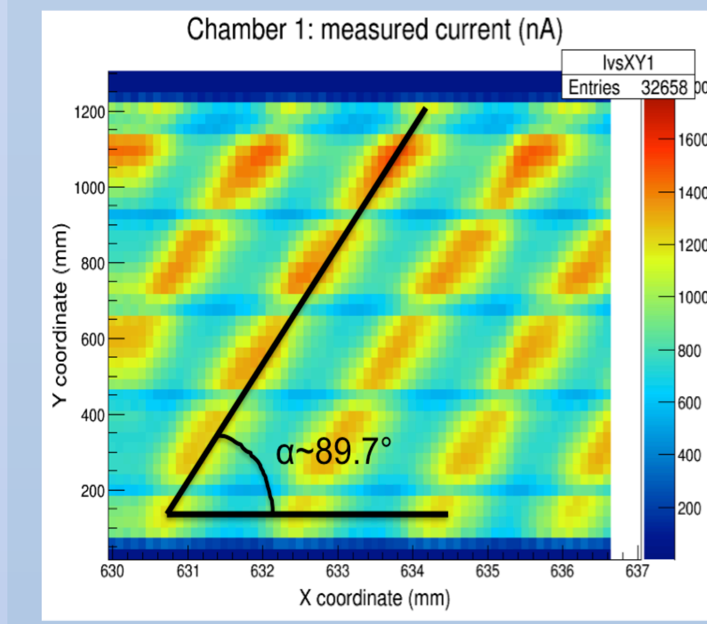


Chamber current and rate from 3 consequent wire groups vs X coordinate

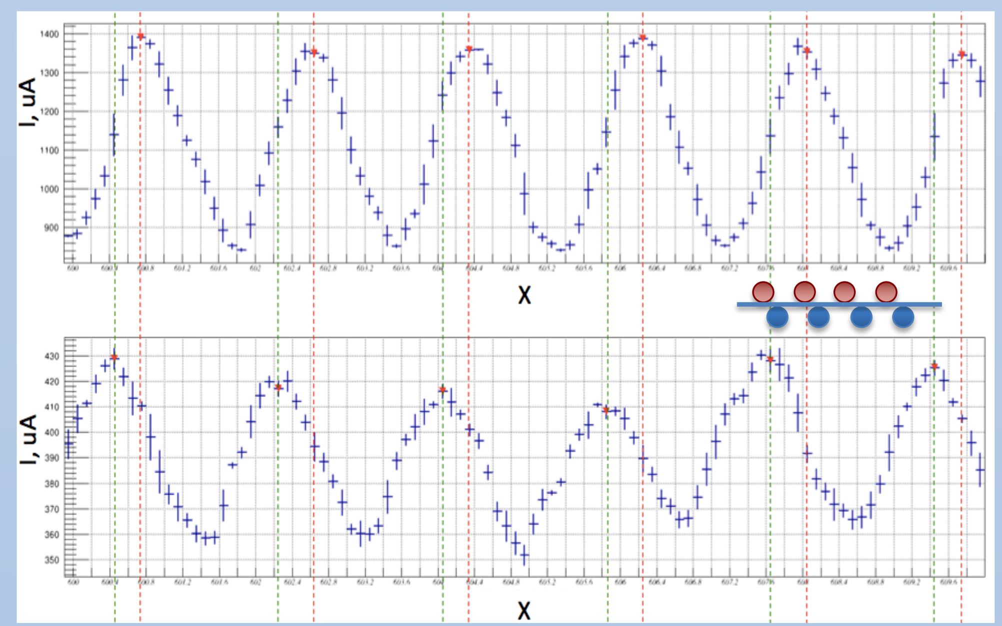


Tube and slit collimators combination used for precise measurements

- We made a precise scan with a slit collimator with simultaneous rate measurements from single wire groups (5 wires in a group). X-ray parameters: 50 kV, 75 uA;
- Current peak corresponds to the fact that the X-ray flux hits the wire;
- Current valley corresponds to the fact that the X-ray flux hits in between the wires;
- This result displays that the photoelectric effect is the dominant process in X-ray scanning



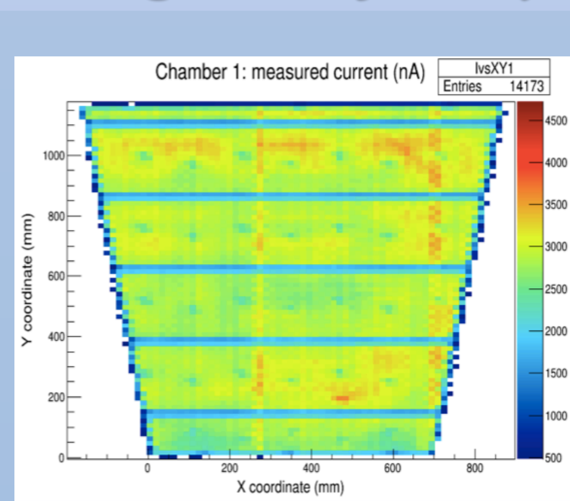
Mapping of scanner and sTGC misalignment. The scan area is 1250x7mm²



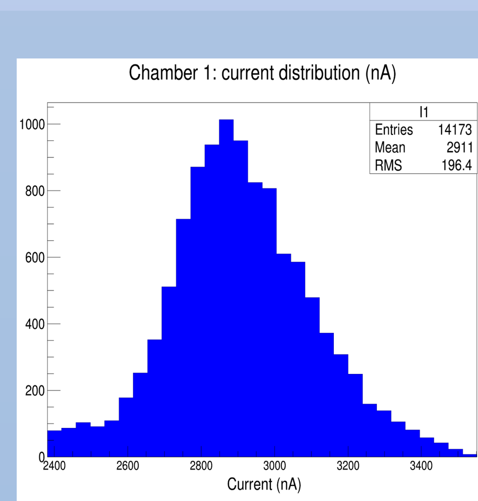
Current distribution for 2 simultaneously irradiated layers of the sTGC quadruplet prototype. Peaks correspond to single wires. The layer-to-layer shift here is ~0.3-0.4 mm while pitch is exactly 1.8mm

- We are able to study wire angular and layer-to-layer alignment with slit collimator [4];
- The doublets are designed with layer-to layer shifted wires, and X-ray scanner is a powerful tool for wire alignment check without any readout electronics.

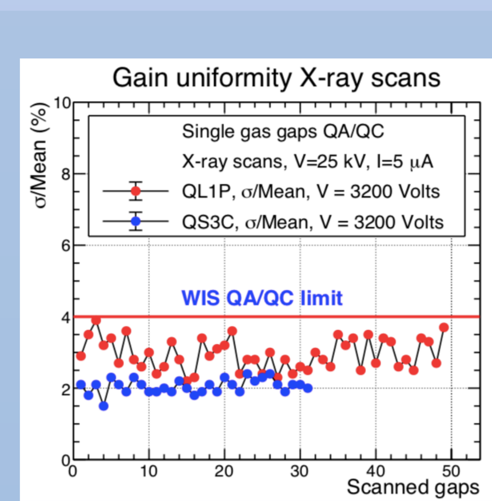
Gas gain uniformity



Single gap current map example



Current distribution for the single gap

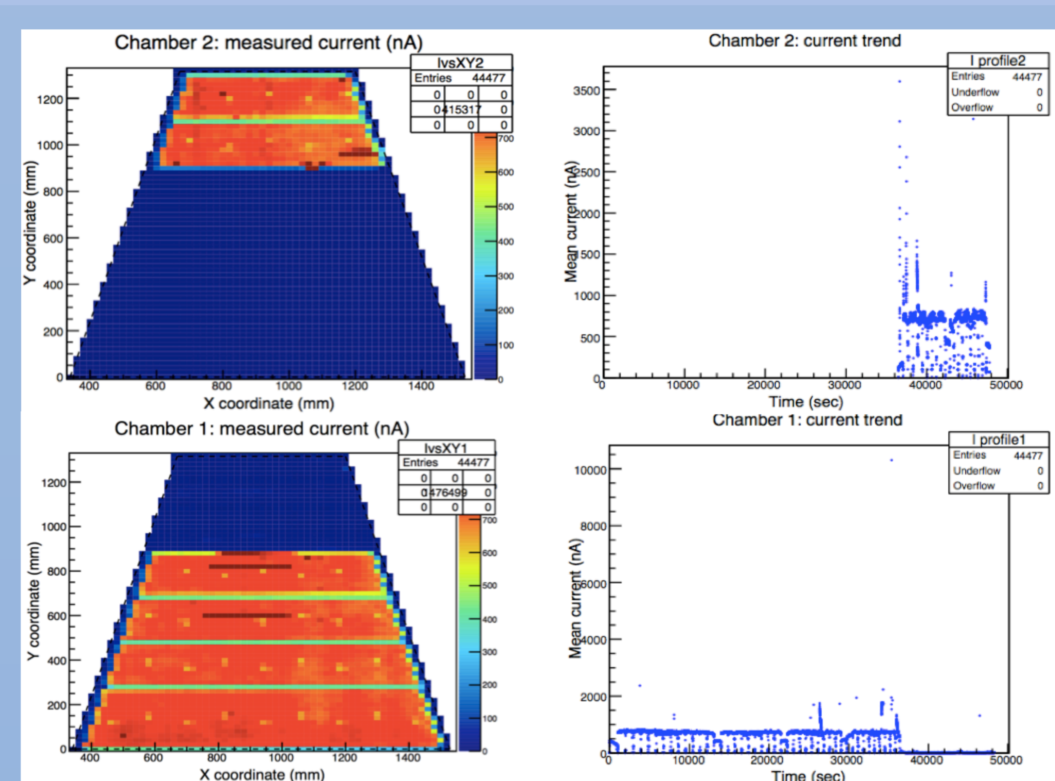


Gas gain uniformity parameter for production gaps at WIS

- For the production of the single gaps, the gas gain uniformity is being checked in low energy mode under 3200V;
- Current distributions is a standard function of the QScanner software;
- It is important to remove zero areas, edges, wire supports and buttons from the current distribution;
- At Weizmann Institute production site, the criteria for single gap rejection is **σ**/mean<4%.

Hotspot search

- The most important defect for the production detectors are hotspots – local discharges under X-ray irradiation;
- The first scan should cover the full area with square collimator (20x20 mm) or round collimator (d=30 mm);
- The scanning mode with 5s stop is optimal for current measurement is necessary due to current stabilization and to exclude single accidental discharges;
- The scan can be repeated locally around the hotspot for several times for the problem identification or for burning down the defect caused the discharge.



The first scan of the production singlet. The chamber electrically divided into two and connected to different HV channels. Dark red stripes correspond to hotspots. The current trend function allows to evaluate the amplitude of the discharge.

Conclusions

- The X-ray scanner is a powerful tool for QA/QC of the sTGC chambers without electronics;
- The method provides information on the detector internal structure, alignment and defects;
- We suggest some basic principles of the QA/QC based on wide research and production experience.

References

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5. http://amptek.com/products/mini-x-ray-tube/#6

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