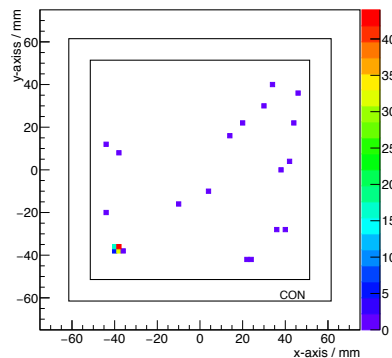
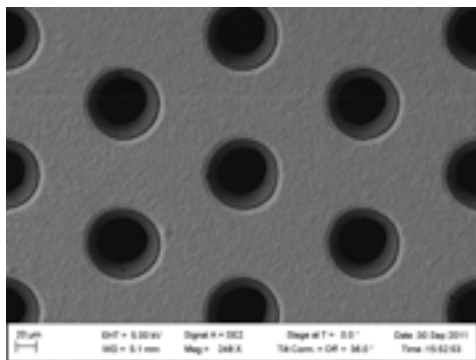


Development of a Spark Detection System (SDS)

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Rheinische Friedrich-Wilhelms Universität Bonn
Helmholtz-Institut für Strahlen- und Kernphysik (HISKP)



Motivation:

- Identify GEM foils with multiple sparks at the same position and document them
- Define criteria to accept/reject foils depending on their sparking behaviour
- Comparison with I_{leak} measurements
- Identify spots to be cross-checked with optical scans

Realisation:

- Camera surveillance
- Metal box enclosure:
 - Fixed camera position
 - Optical black box to guarantee constant light environment
 - Electric shielding (More important for the parallel I_{leak} measurements)
- Sparks are detected by values over threshold on differences for consecutive frames
- Detection algorithm using OpenCV realised in LabVIEW - interaction with other QA procedures (I_{leak})



J. Merlin (CMS), RD51 Meeting Munich, <https://indico.cern.ch/event/709670/contributions/3008626/>
 "Effect of discharges on GEM detectors - Single Hole Setup"

simplified schematics

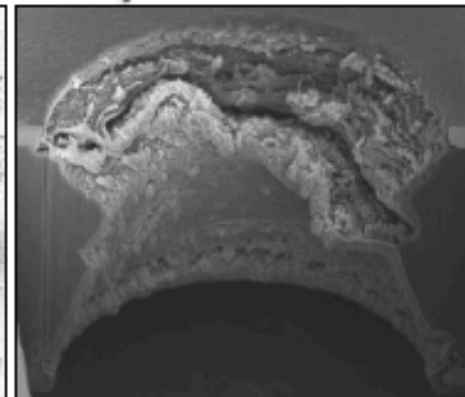
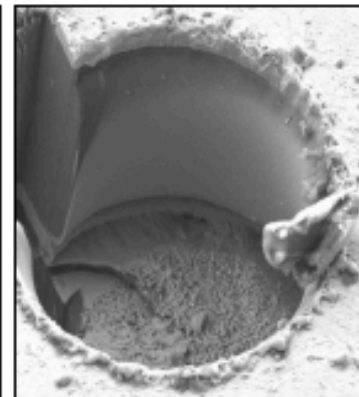
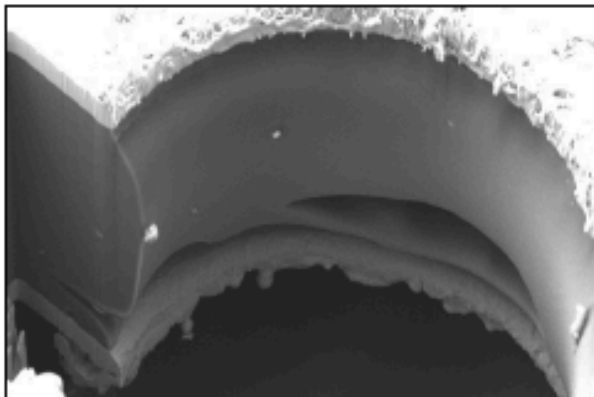
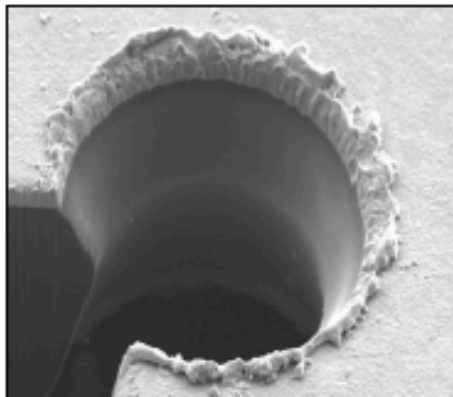


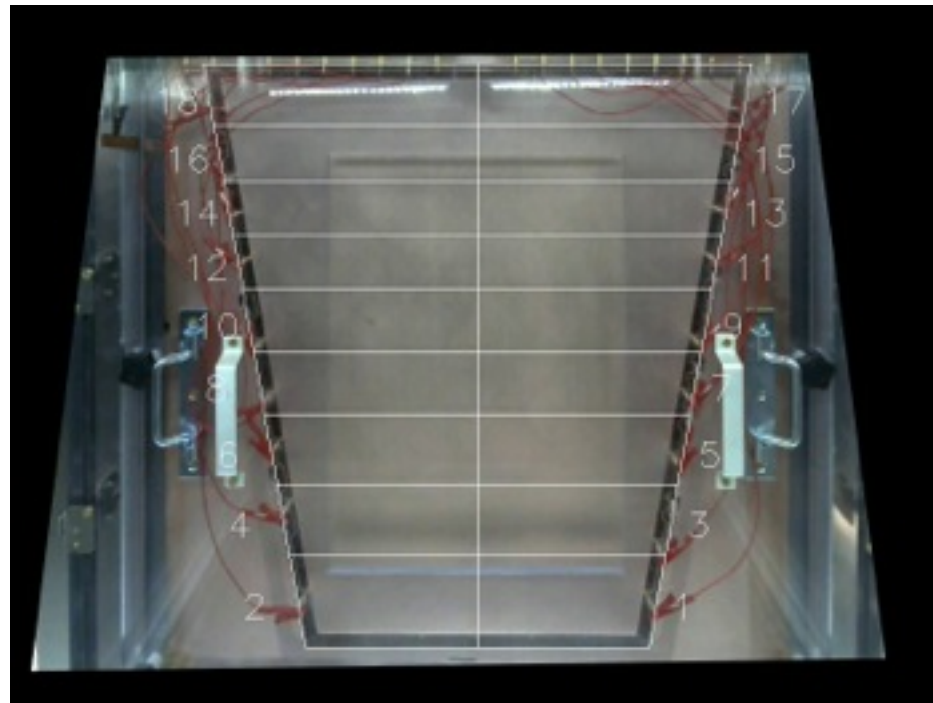
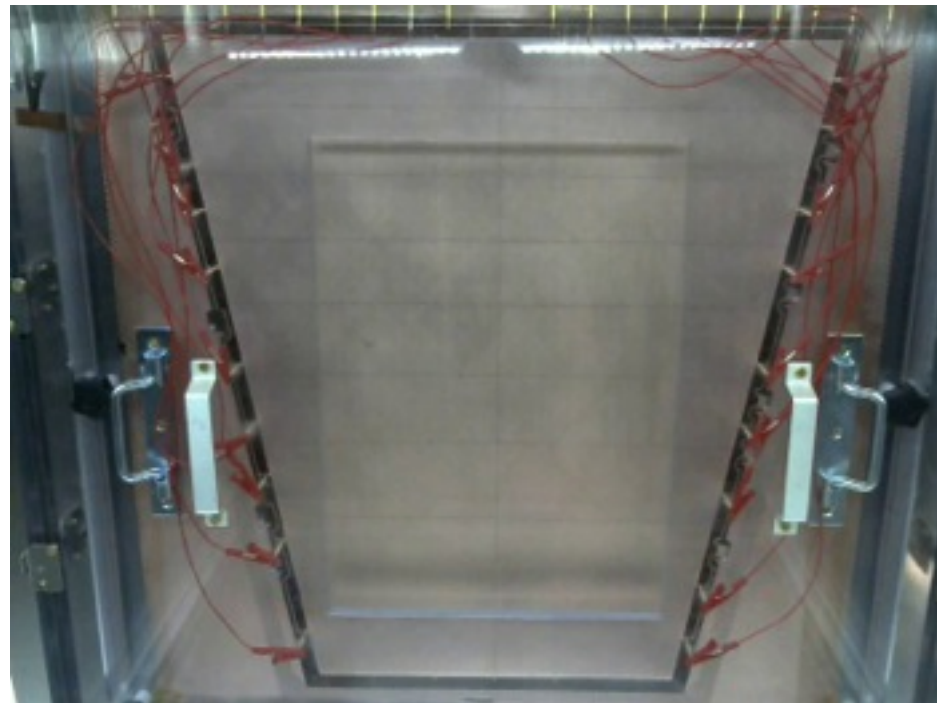
"Slow Ramp-UP" Phase:
 - Progressive and uniform surface etching
 - Clean internal surface

"Fast Discharging" Phase:
 - Creation of cavities and defect on internal PI surface

"Slow Discharging" Phase:
 - Attenuation of cavities and defect due to uniform surface etching

"Shorted" Phase:
 - Strong irregularities and defects

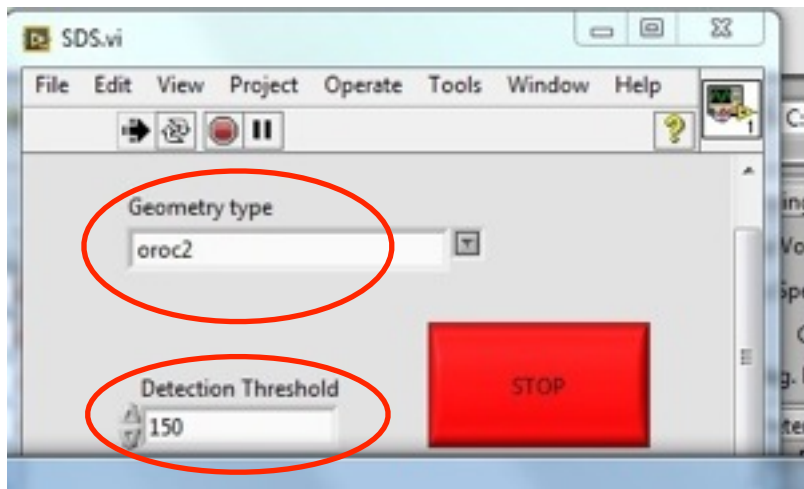




- Camera view tilted → corrected by perspective transformation using the GEMs edge point as reference (user input)
- GEM geometries available so far
 - 10x10 cm²
 - IROC, OROC I, II, III



Labview control software for SDS



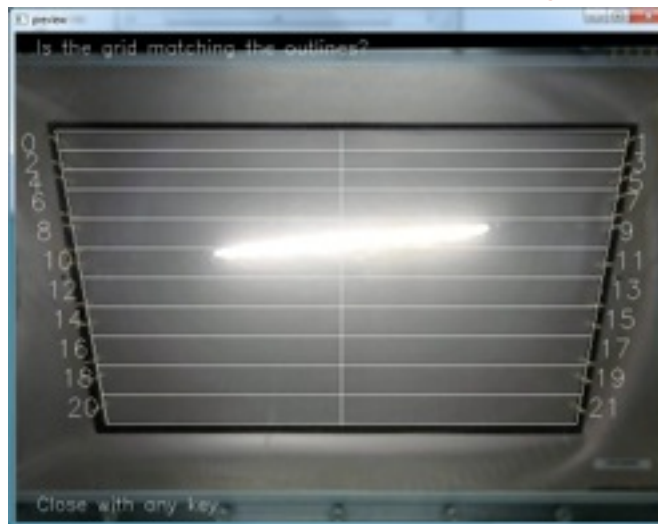
1. Control if the whole GEM is in the optical range of the camera



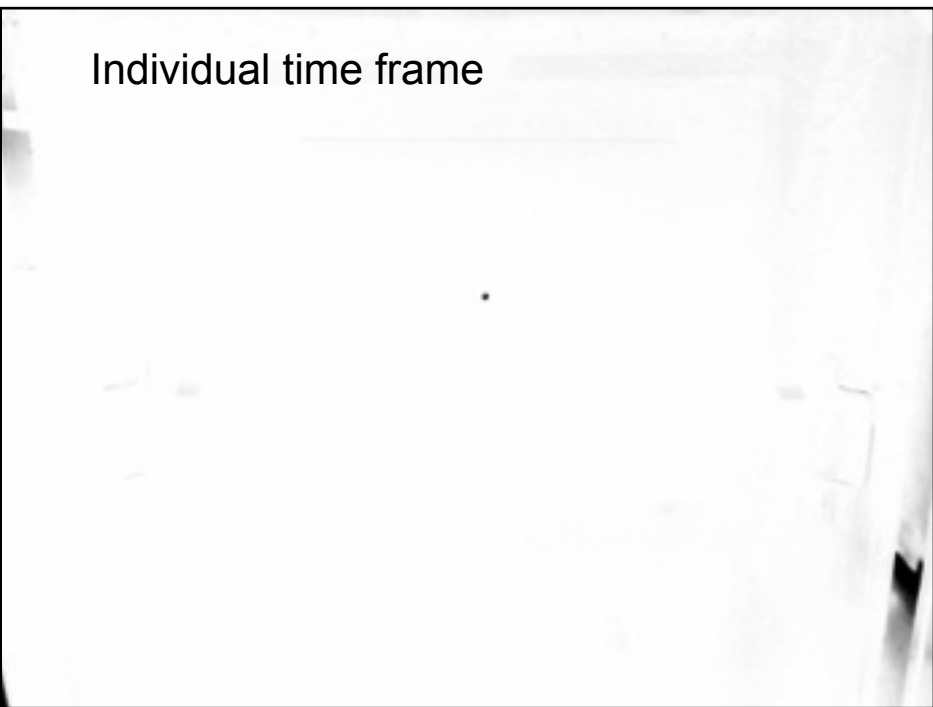
2. Set the edges of the GEM foil (user input)



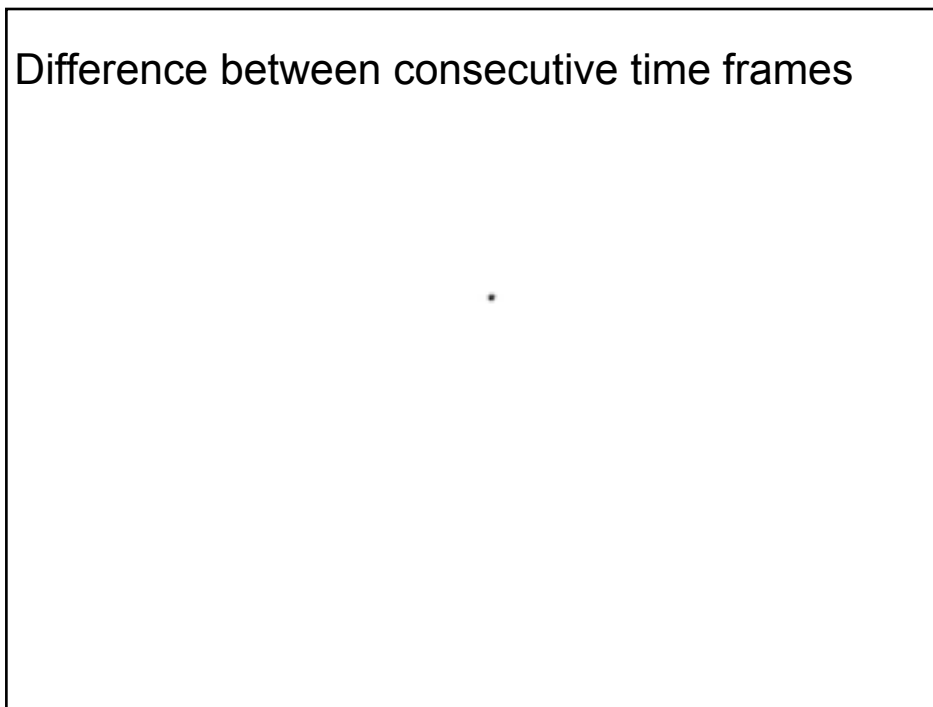
3. Coordinate transformation / segmentation



Individual time frame

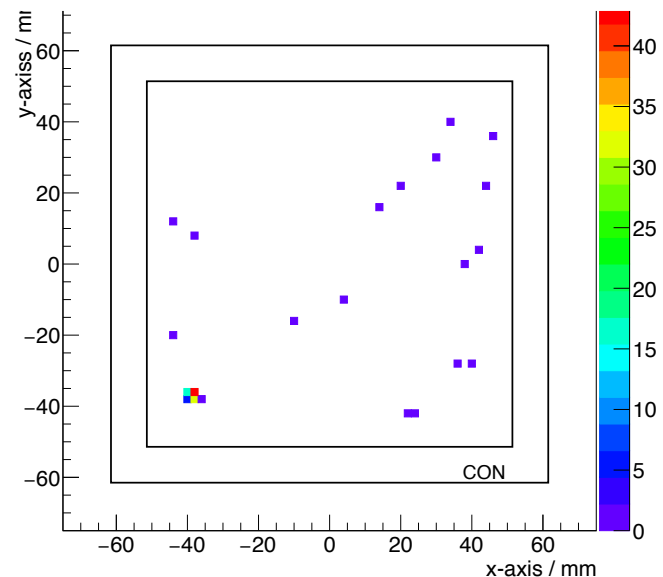
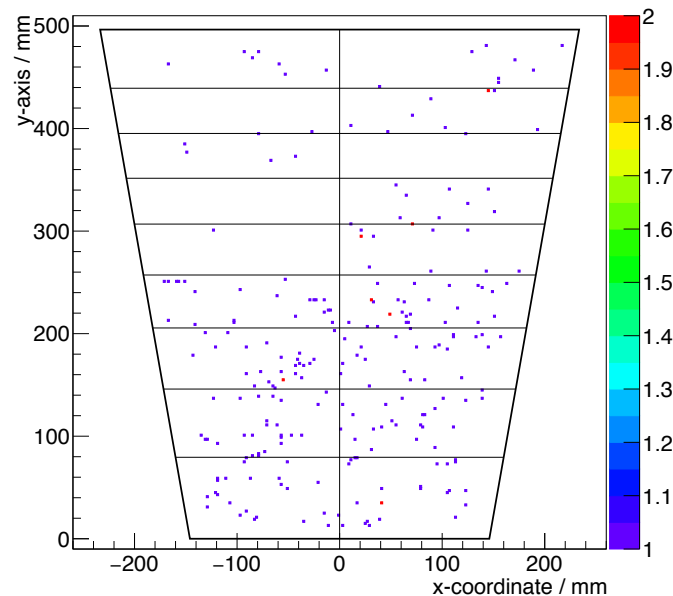


Difference between consecutive time frames



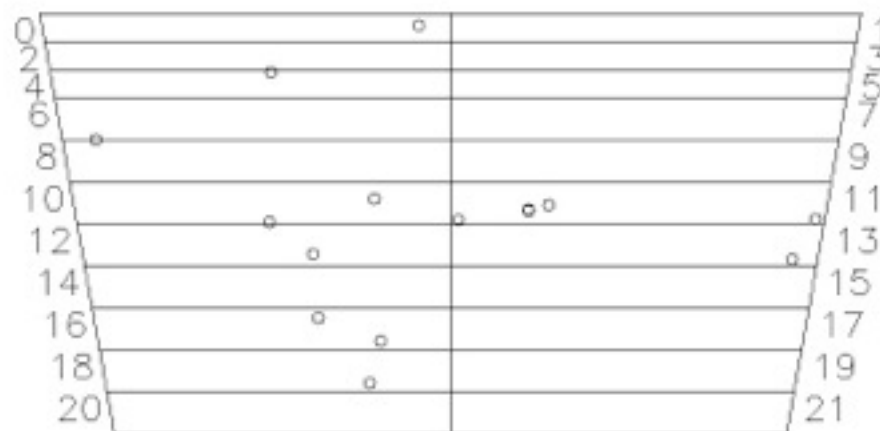
First measurements:

- 10x10 cm² and IROC GEM foils from R&D phase
- Spark maps contain time of the spark and position (to correlate power supply trip or spikes in I_{leak} measurements)
- Efficiency of spark detection SDS compared to spark detection by power supply $\sim 99\%$, but power supply can not detect multi sparks happening at the same time
- Video for cross-check
- Position resolution ~ 1 mm
- Example IROC: Uniform spark distribution
- Example 10x10 cm² GEM; Constant sparking at fixed position
- Allows correlation to HD scans



C:\Users\gem\Desktop\Data\SparkFct_Humidity\PP-O2-G2-05\LeakageMeasurements\T40\01-PP-O2-G2-05_sparkmap.txt

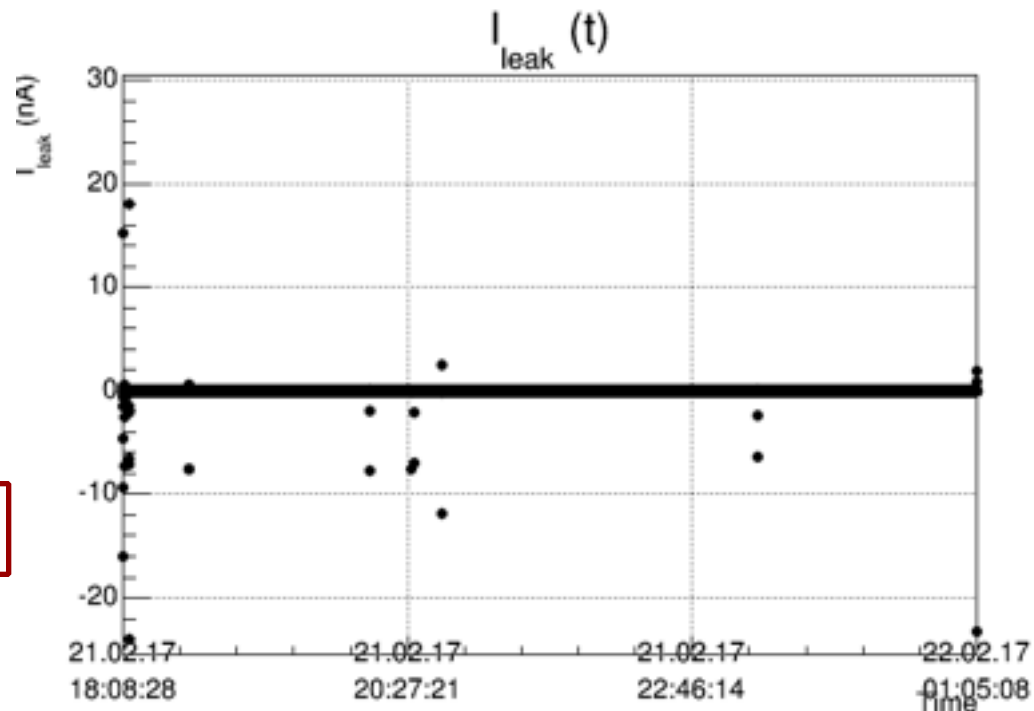
| Day | Month | Year | Hour | Minute | Second | x-coordinate transformed | y-coordinate transformed |
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|
| 21 | 2 | 2017 | 18 | 8 | 33 | 373.301 | 130.367 |
| 21 | 2 | 2017 | 18 | 8 | 33 | 693.749 | 331.877 |
| 21 | 2 | 2017 | 18 | 8 | 34 | 287.673 | 381.851 |
| 21 | 2 | 2017 | 18 | 8 | 43 | 407.507 | 297.534 |
| 21 | 2 | 2017 | 18 | 9 | 12 | 340.496 | 401.087 |
| 21 | 2 | 2017 | 18 | 11 | 24 | 96.0689 | 228.802 |
| 21 | 2 | 2017 | 18 | 11 | 41 | 335.132 | 279.294 |
| 21 | 2 | 2017 | 18 | 40 | 32 | 713.066 | 296.623 |
| 21 | 2 | 2017 | 20 | 8 | 45 | 331.041 | 437.896 |
| 21 | 2 | 2017 | 20 | 29 | 19 | 246.106 | 170.805 |
| 21 | 2 | 2017 | 20 | 30 | 29 | 484.311 | 284.91 |
| 21 | 2 | 2017 | 20 | 43 | 40 | 245.773 | 299.952 |
| 21 | 2 | 2017 | 23 | 17 | 54 | 282.429 | 326.604 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.328 | 289.159 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.45 | 288.578 |



- Sparks do not only appear in the very first minutes/seconds according to long term measurements

C:\Users\gem\Desktop\Data\SparkFct_Humidity\PP-O2-G2-05\LeakageMeasurements\T40\01-PP-O2-G2-05_sparkmap.txt

| Day | Month | Year | Hour | Minute | Second | x-coordinate transformed | y-coordinate transformed |
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|
| 21 | 2 | 2017 | 18 | 8 | 33 | 373.301 | 130.367 |
| 21 | 2 | 2017 | 18 | 8 | 33 | 693.749 | 331.877 |
| 21 | 2 | 2017 | 18 | 8 | 34 | 287.673 | 381.851 |
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| 21 | 2 | 2017 | 18 | 11 | 24 | 96.0689 | 228.802 |
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| 21 | 2 | 2017 | 18 | 40 | 32 | 713.066 | 296.623 |
| 21 | 2 | 2017 | 20 | 8 | 45 | 331.041 | 437.896 |
| 21 | 2 | 2017 | 20 | 29 | 19 | 246.106 | 170.805 |
| 21 | 2 | 2017 | 20 | 30 | 29 | 484.311 | 284.91 |
| 21 | 2 | 2017 | 20 | 43 | 40 | 245.773 | 299.952 |
| 21 | 2 | 2017 | 23 | 17 | 54 | 282.429 | 326.604 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.328 | 289.159 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.45 | 288.578 |

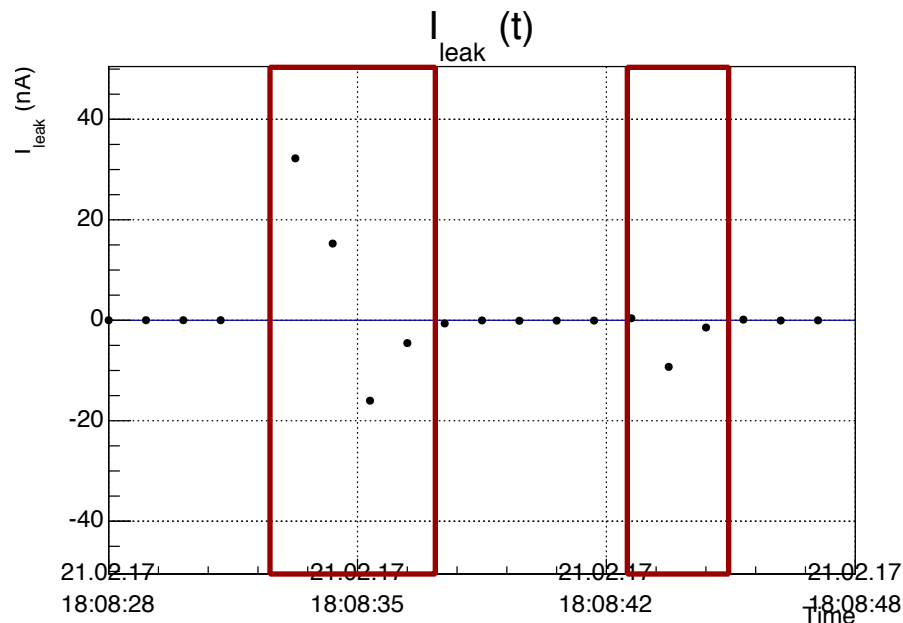


- Sparks do not only appear in the very first minutes/seconds according to long term measurements

C:\Users\gem\Desktop\Data\SparkFct_Humidity\PP-O2-G2-05\LeakageMeasurements\T40\01-PP-O2-G2-05_sparkmap.txt

| Day | Month | Year | Hour | Minute | Second | x-coordinate transformed | y-coordinate transformed |
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|

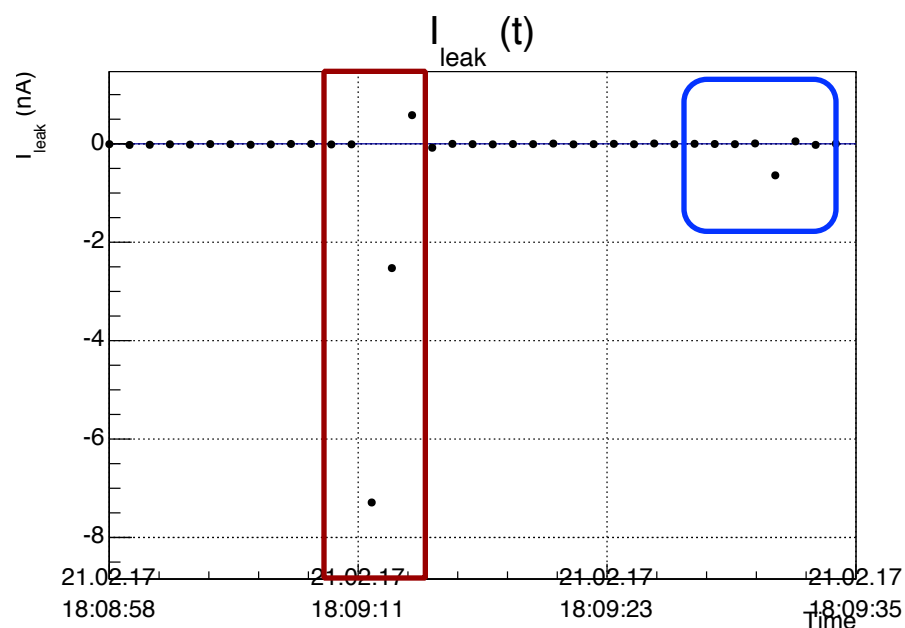
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|----|---|------|----|----|----|---------|---------|
| 21 | 2 | 2017 | 18 | 8 | 33 | 373.301 | 130.367 |
| 21 | 2 | 2017 | 18 | 8 | 33 | 693.749 | 331.877 |
| 21 | 2 | 2017 | 18 | 8 | 34 | 287.673 | 381.851 |
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| 21 | 2 | 2017 | 18 | 11 | 41 | 335.132 | 279.294 |
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| 21 | 2 | 2017 | 20 | 29 | 19 | 246.106 | 170.805 |
| 21 | 2 | 2017 | 20 | 30 | 29 | 484.311 | 284.91 |
| 21 | 2 | 2017 | 20 | 43 | 40 | 245.773 | 299.952 |
| 21 | 2 | 2017 | 23 | 17 | 54 | 282.429 | 326.604 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.328 | 289.159 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.45 | 288.578 |



- Sparks do not only appear in the very first minutes/seconds according to long term measurements
- Optical SDS can locate exact position and total number of sparks

C:\Users\gem\Desktop\Data\SparkFct_Humidity\PP-O2-G2-05\LeakageMeasurements\T40\01-PP-O2-G2-05_sparkmap.txt

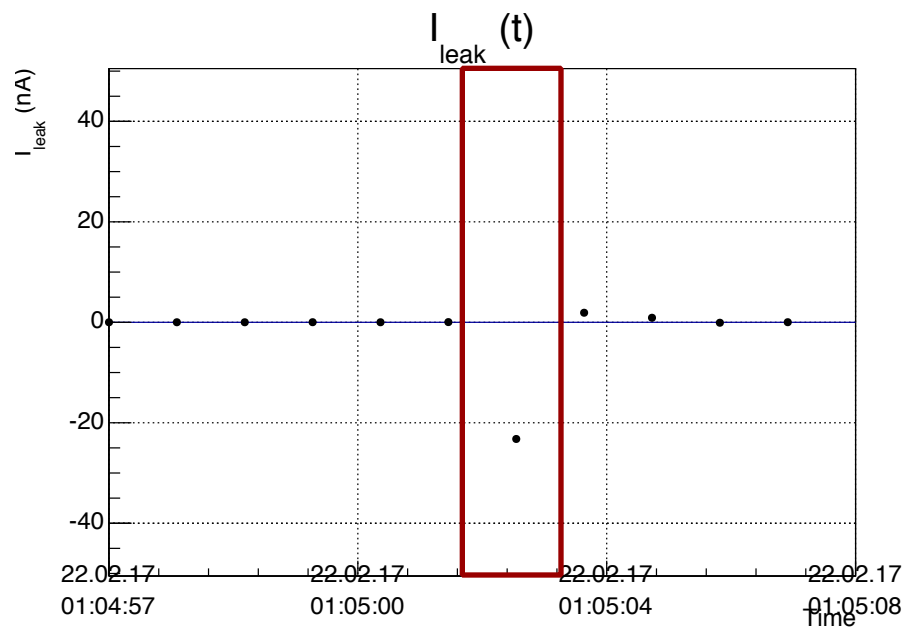
| Day | Month | Year | Hour | Minute | Second | x-coordinate transformed | y-coordinate transformed |
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|
| 21 | 2 | 2017 | 18 | 8 | 33 | 373.301 | 130.367 |
| 21 | 2 | 2017 | 18 | 8 | 33 | 693.749 | 331.877 |
| 21 | 2 | 2017 | 18 | 8 | 34 | 287.673 | 381.851 |
| 21 | 2 | 2017 | 18 | 8 | 43 | 407.507 | 297.534 |
| 21 | 2 | 2017 | 18 | 9 | 12 | 340.496 | 401.087 |
| 21 | 2 | 2017 | 18 | 11 | 24 | 96.0689 | 228.802 |
| 21 | 2 | 2017 | 18 | 11 | 41 | 335.132 | 279.294 |
| 21 | 2 | 2017 | 18 | 40 | 32 | 713.066 | 296.623 |
| 21 | 2 | 2017 | 20 | 8 | 45 | 331.041 | 437.896 |
| 21 | 2 | 2017 | 20 | 29 | 19 | 246.106 | 170.805 |
| 21 | 2 | 2017 | 20 | 30 | 29 | 484.311 | 284.91 |
| 21 | 2 | 2017 | 20 | 43 | 40 | 245.773 | 299.952 |
| 21 | 2 | 2017 | 23 | 17 | 54 | 282.429 | 326.604 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.328 | 289.159 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.45 | 288.578 |



- Sparks do not only appear in the very first minutes/seconds according to long term measurements
- Optical SDS can locate exact position and total number of sparks
- Not all peaks seem to be sparks

C:\Users\gem\Desktop\Data\SparkFct_Humidity\PP-O2-G2-05\LeakageMeasurements\T40\01-PP-O2-G2-05_sparkmap.txt

| Day | Month | Year | Hour | Minute | Second | x-coordinate transformed | y-coordinate transformed |
|-----|-------|------|------|--------|--------|--------------------------|--------------------------|
| 21 | 2 | 2017 | 18 | 8 | 33 | 373.301 | 130.367 |
| 21 | 2 | 2017 | 18 | 8 | 33 | 693.749 | 331.877 |
| 21 | 2 | 2017 | 18 | 8 | 34 | 287.673 | 381.851 |
| 21 | 2 | 2017 | 18 | 8 | 43 | 407.507 | 297.534 |
| 21 | 2 | 2017 | 18 | 9 | 12 | 340.496 | 401.087 |
| 21 | 2 | 2017 | 18 | 11 | 24 | 96.0689 | 228.802 |
| 21 | 2 | 2017 | 18 | 11 | 41 | 335.132 | 279.294 |
| 21 | 2 | 2017 | 18 | 40 | 32 | 713.066 | 296.623 |
| 21 | 2 | 2017 | 20 | 8 | 45 | 331.041 | 437.896 |
| 21 | 2 | 2017 | 20 | 29 | 19 | 246.106 | 170.805 |
| 21 | 2 | 2017 | 20 | 30 | 29 | 484.311 | 284.91 |
| 21 | 2 | 2017 | 20 | 43 | 40 | 245.773 | 299.952 |
| 21 | 2 | 2017 | 23 | 17 | 54 | 282.429 | 326.604 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.328 | 289.159 |
| 22 | 2 | 2017 | 1 | 5 | 2 | 467.45 | 288.578 |



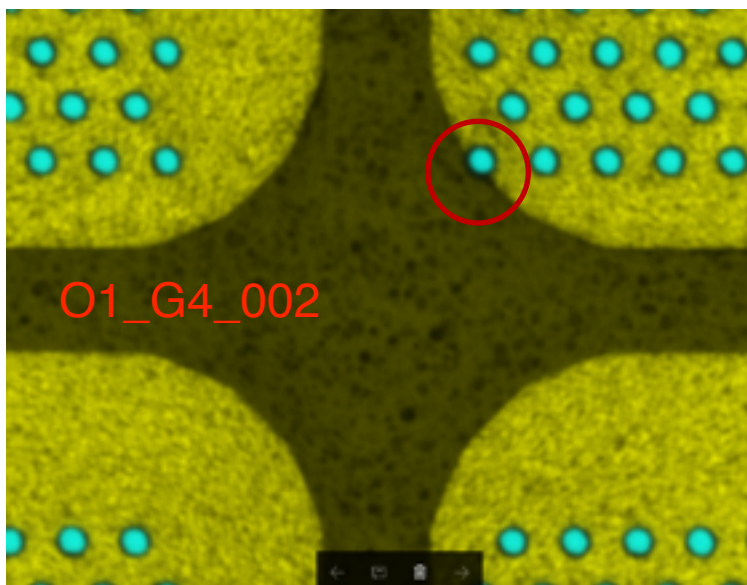
- Sparks do not only appear in the very first minutes/seconds according to long term measurements
- Optical SDS can locate exact position and total number of sparks
- Not all peaks seem to be sparks



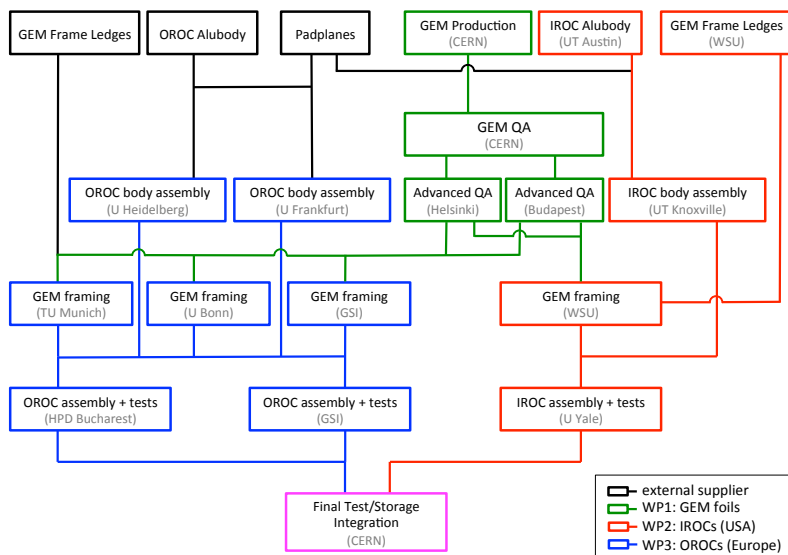
Spark Detection System (SDS)



- Evaluation of SDS- I_{leak} behaviour was done
- If sparks are optical visible I_{leak} was well above 1-2 nA
- Spark detection in the database (I_{leak} above threshold) was tuned to count this kind of sparks
- Small spike in I_{leak} might come also from other source (especially if no shielding of the HV-Box)

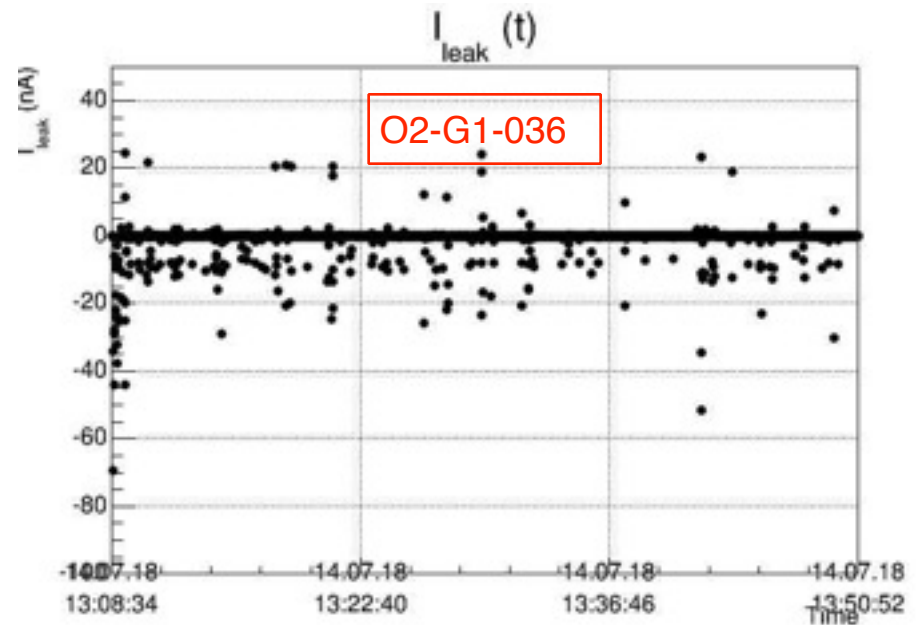
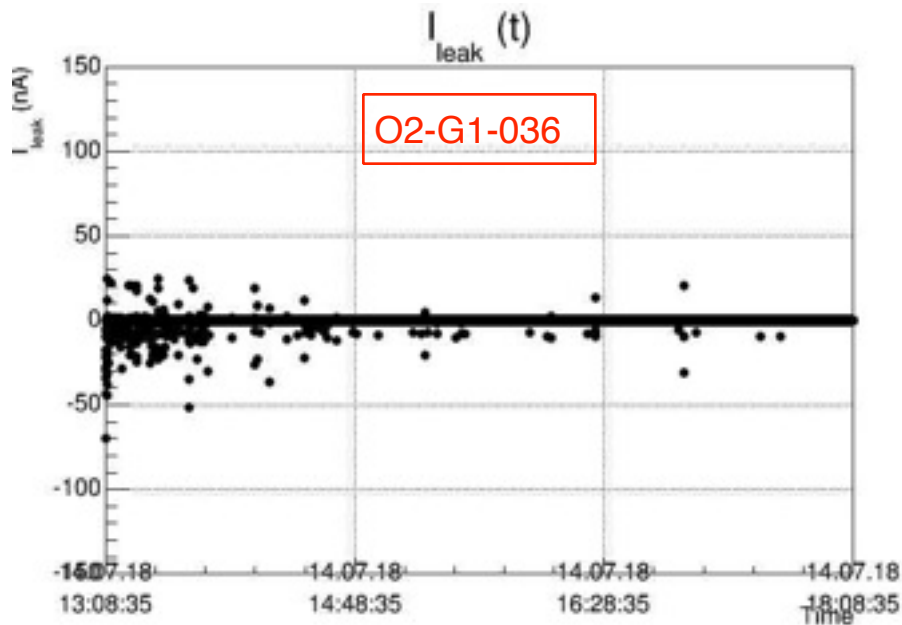


- Cut holes GEM foils are foils with a hole in metal and apical
- Earlier studies (when GEM was a novel technique) showed an increase sparking behaviour of such foils
- Since then tremendous increase of production quality and methods,
- but impact of cut holes still not fully understood
- First GEMs with such defects were rejected in the ALICE QA.
- Later: new policy was to test GEM foils with holes on metal and apical at 550 V in N₂ (normally I_{leak} done at 500 V in N₂)
- Now at the end of production long term I_{leak} measurements done at framing centres





I_{leak} (long term)



- O2-G1-036 (FU@550V) has been long term tested (5h)
- The main amount of sparks happened in the first ~ 1h
- Afterwards long periods without any sparks (although it never did stop completely)

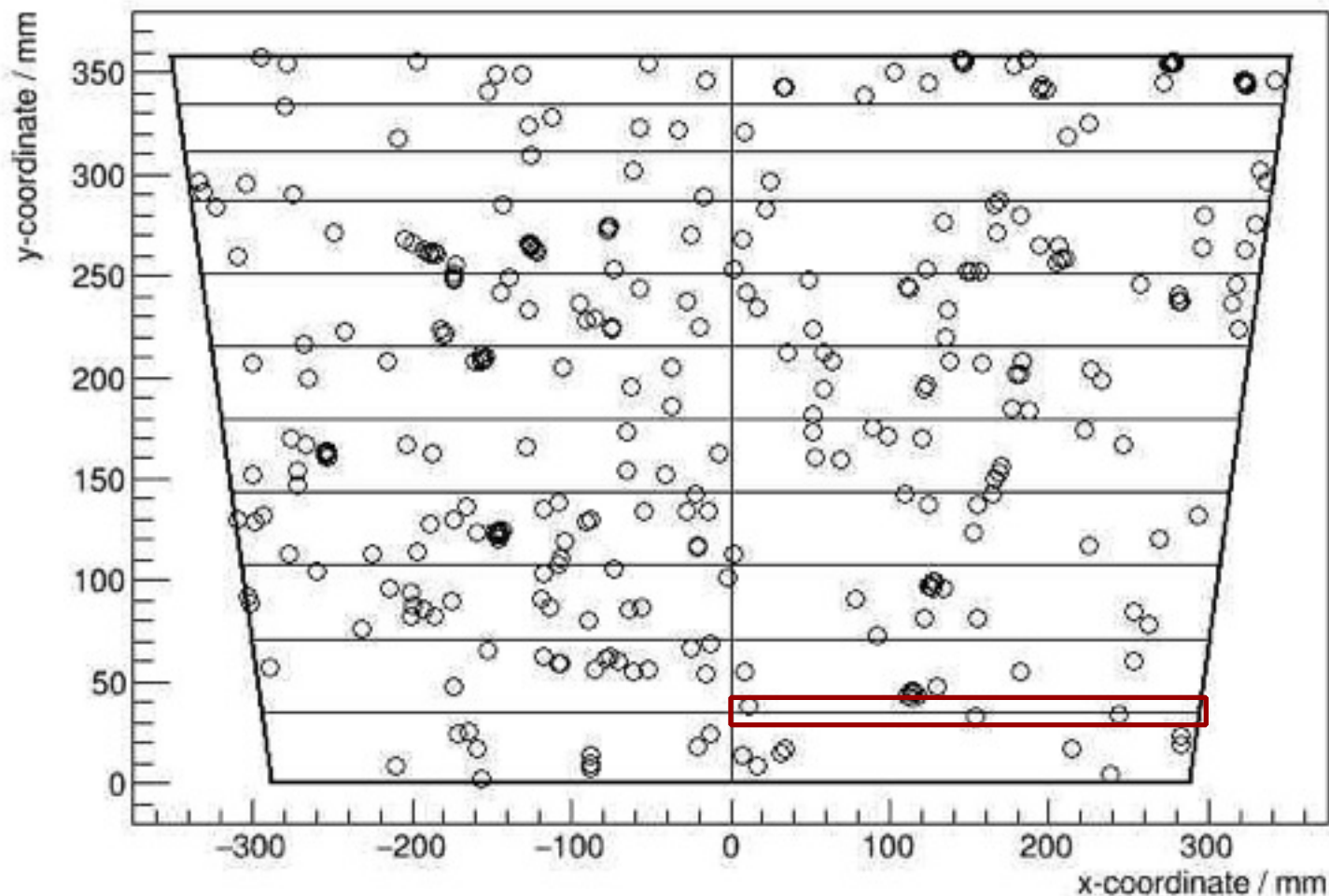


Spark Detection System (SDS)



O2-G1-036 threshold = 0, Entries 346

Sparkmap OROC2

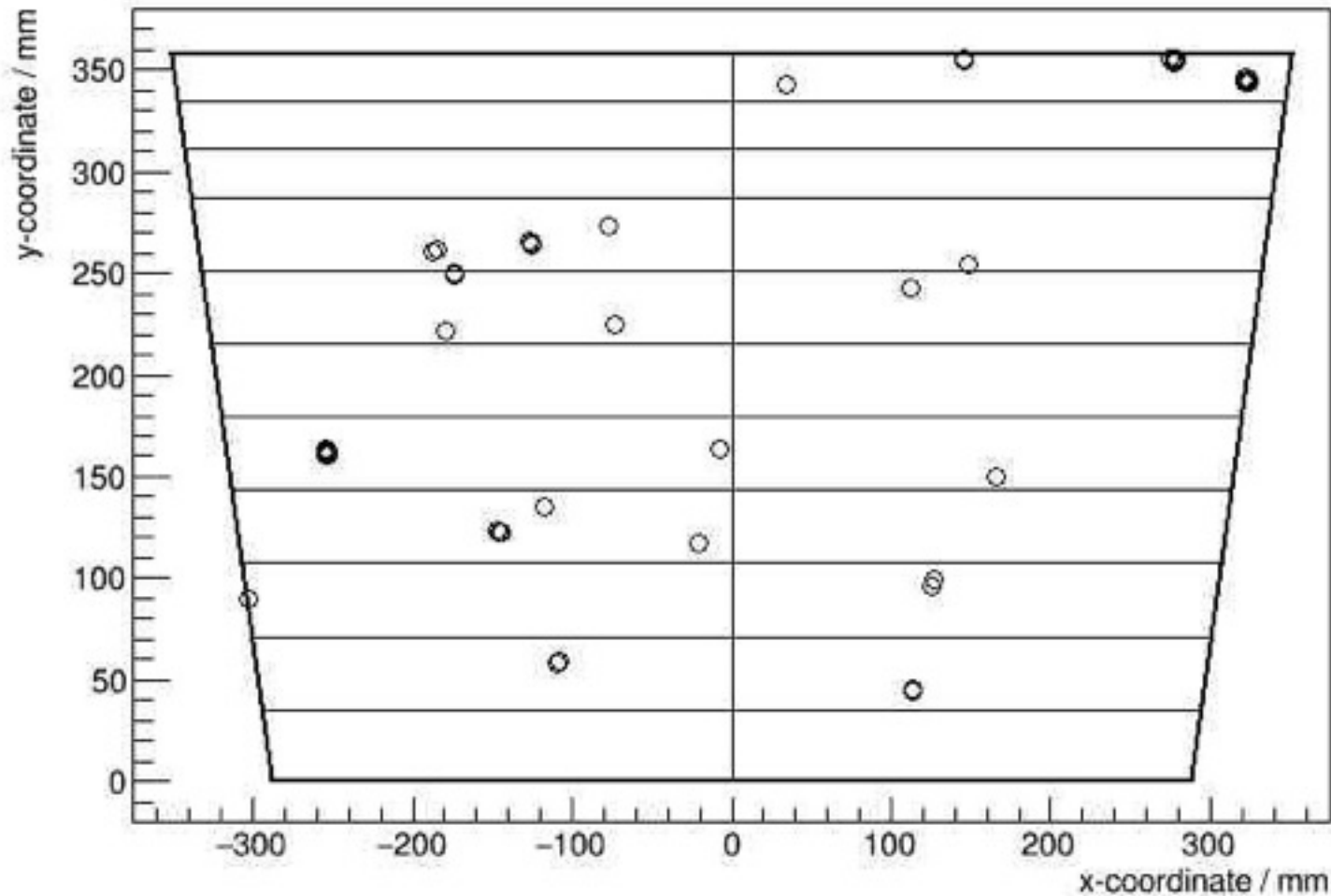




Spark Detection System (SDS)

O2-G1-036 threshold = 1, 22 Spark Positions

Sparkmap OROC2

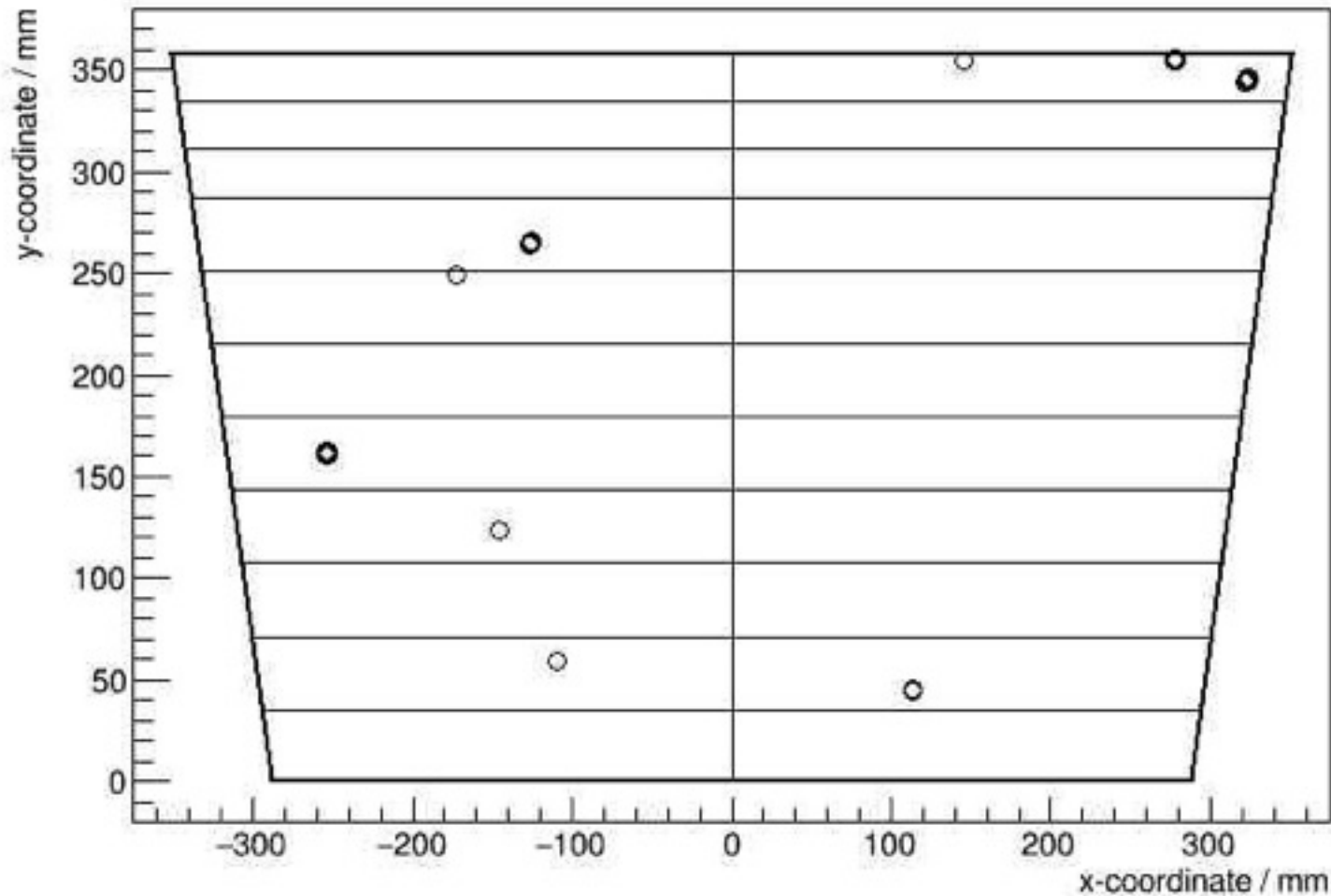




Spark Detection System (SDS)

O2-G1-036 threshold = 2, 9 Spark Positions

Sparkmap OROC2

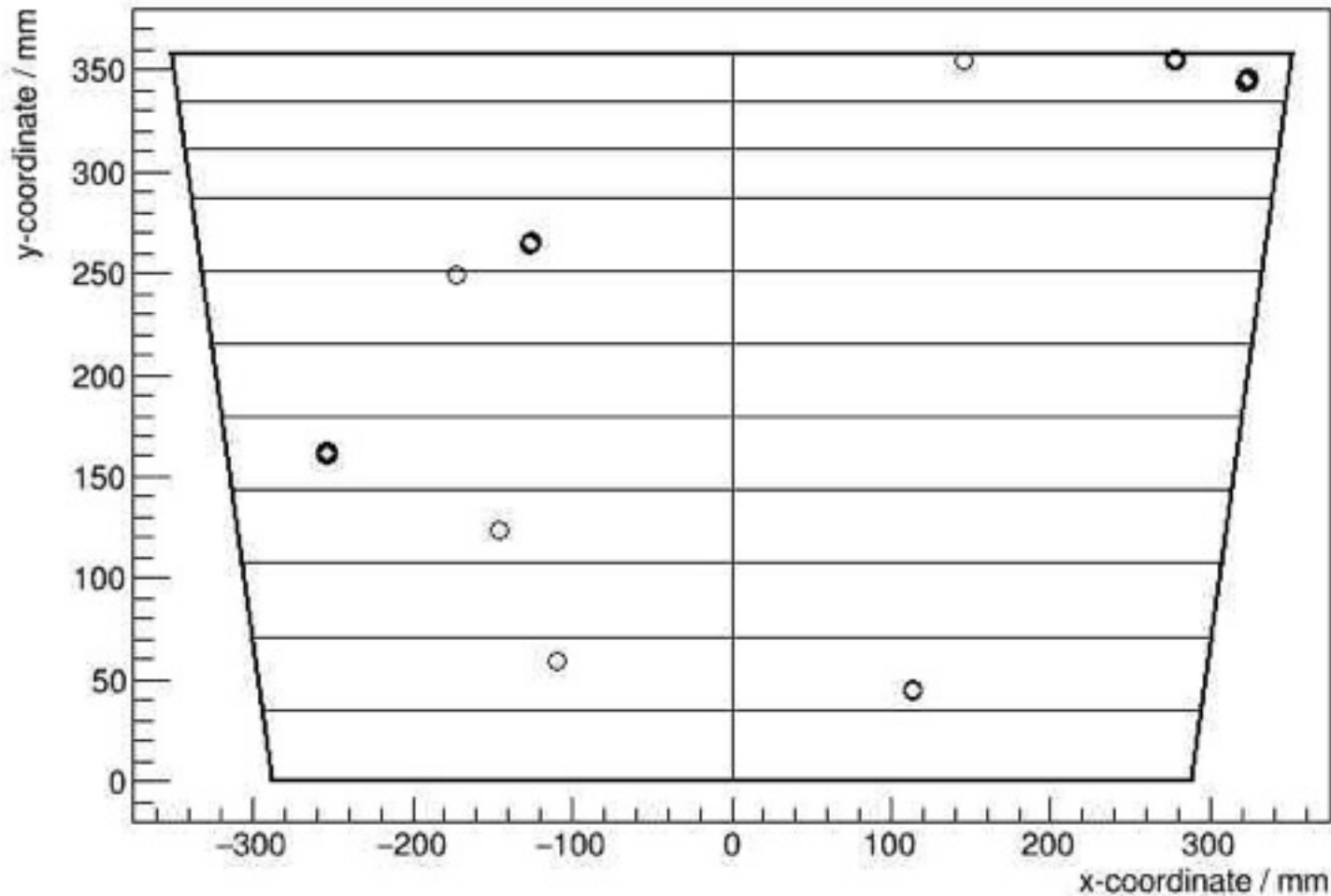




Spark Detection System (SDS)

O2-G1-036 threshold = 3, 9 Spark Positions

Sparkmap OROC2

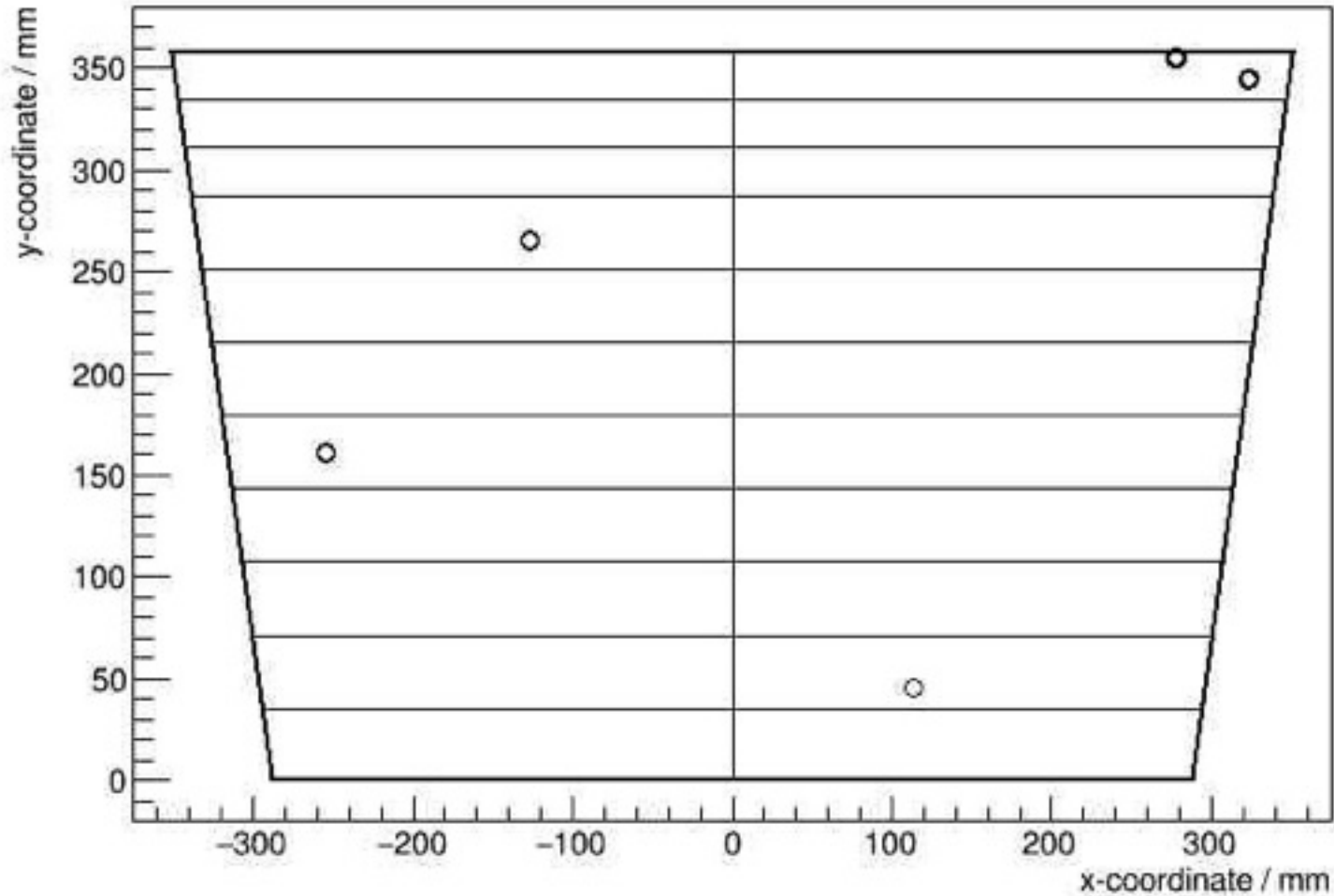




Spark Detection System (SDS)

O2-G1-036 threshold = 4, 5 Spark Positions

Sparkmap OROC2



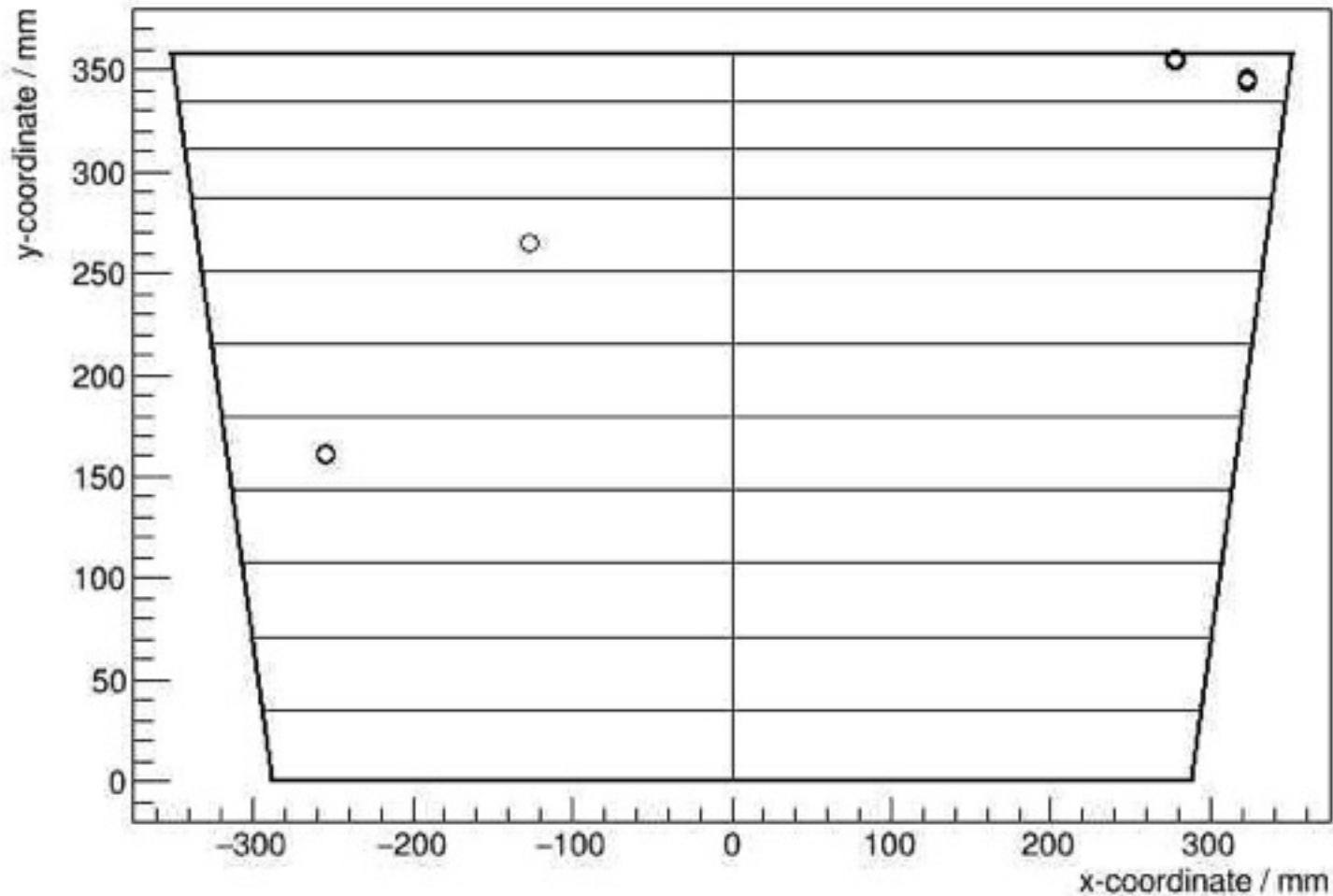


Spark Detection System (SDS)



O2-G1-036 threshold = 5, 4 Spark Positions

Sparkmap OROC2

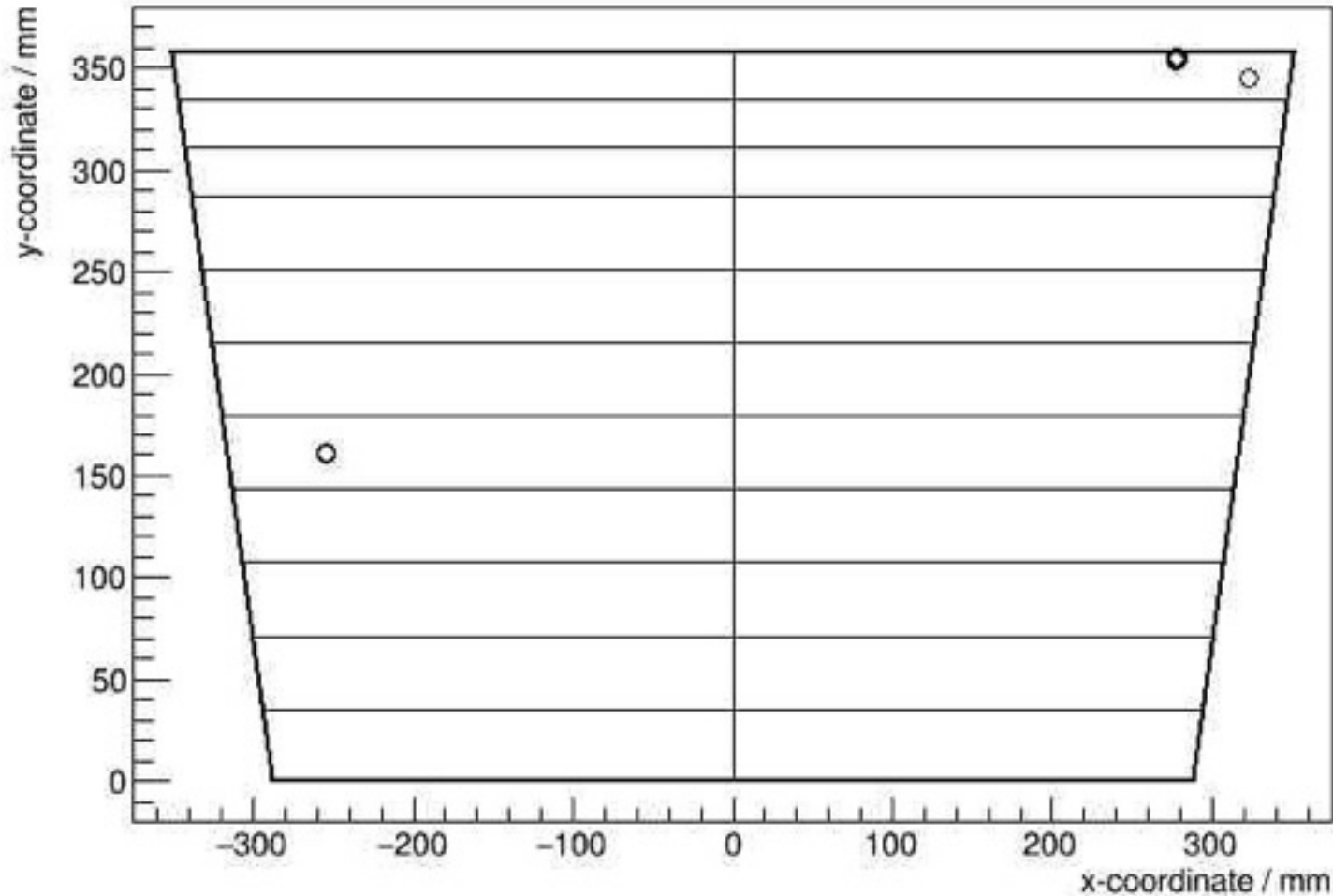




Spark Detection System (SDS)

O2-G1-036 threshold = 6, 3 Spark Positions

Sparkmap OROC2



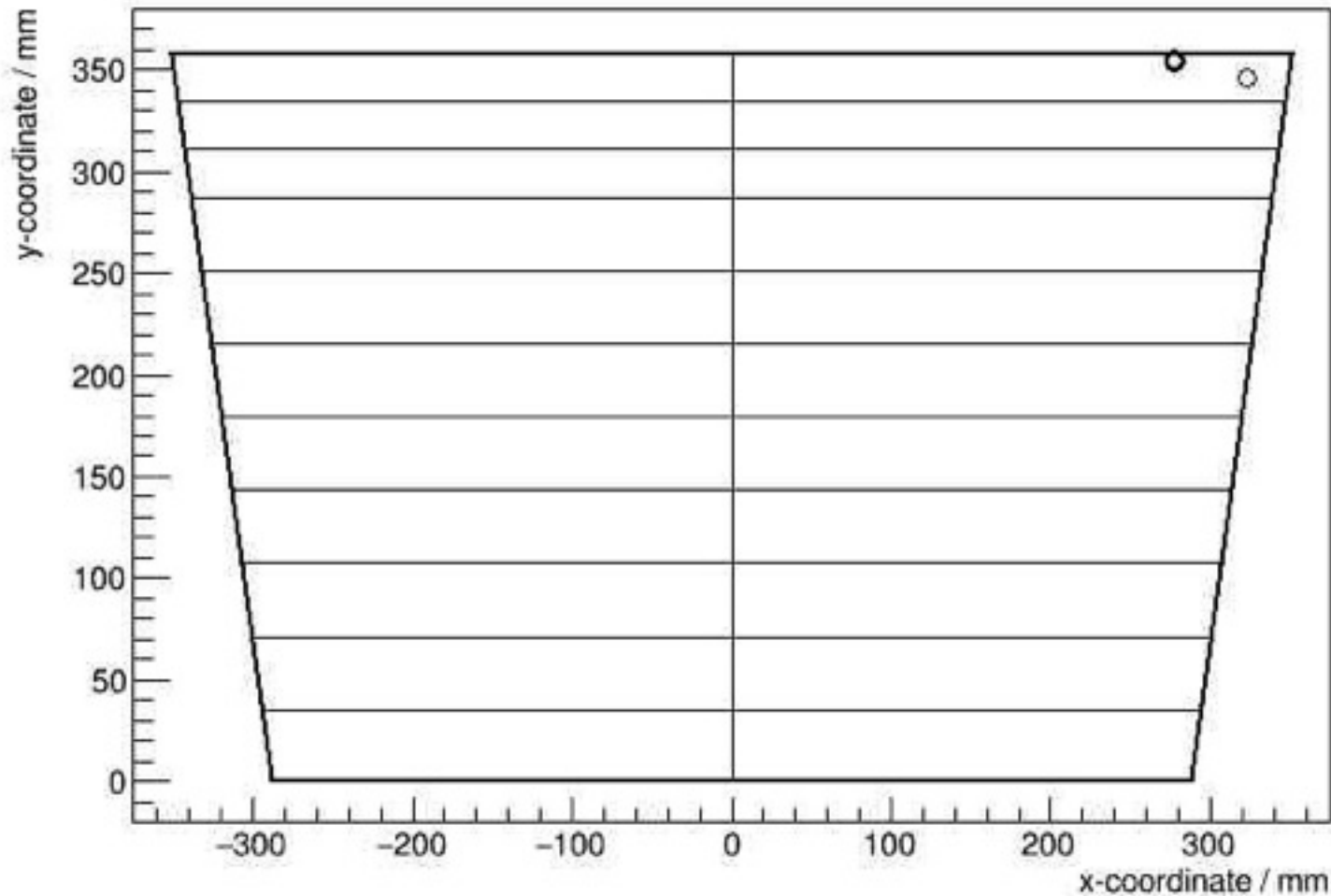


Spark Detection System (SDS)

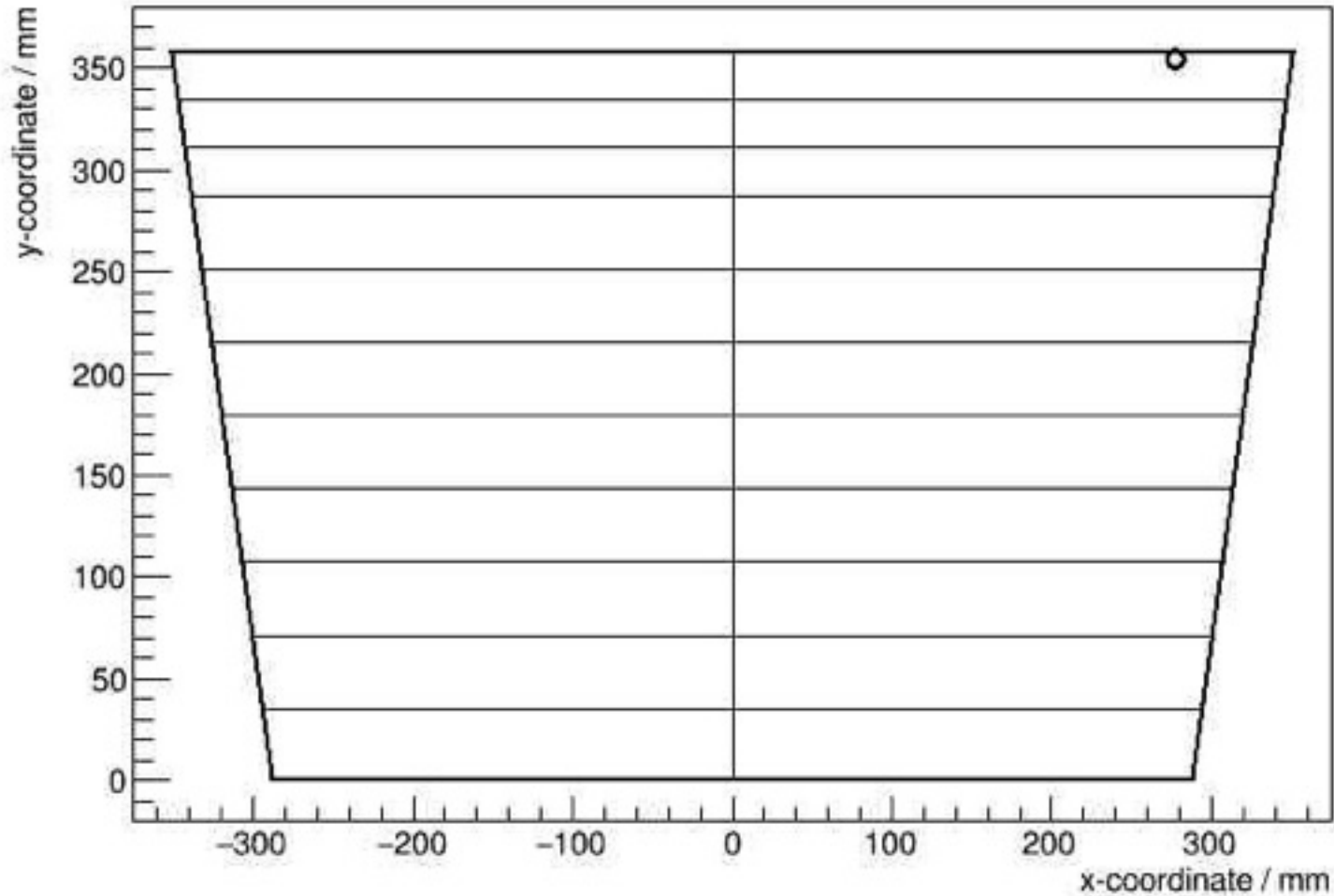


O2-G1-036 threshold = 8, 2 Spark Positions

Sparkmap OROC2



O2-G1-036 threshold = 9, 1 Spark Position Sparkmap OROC2

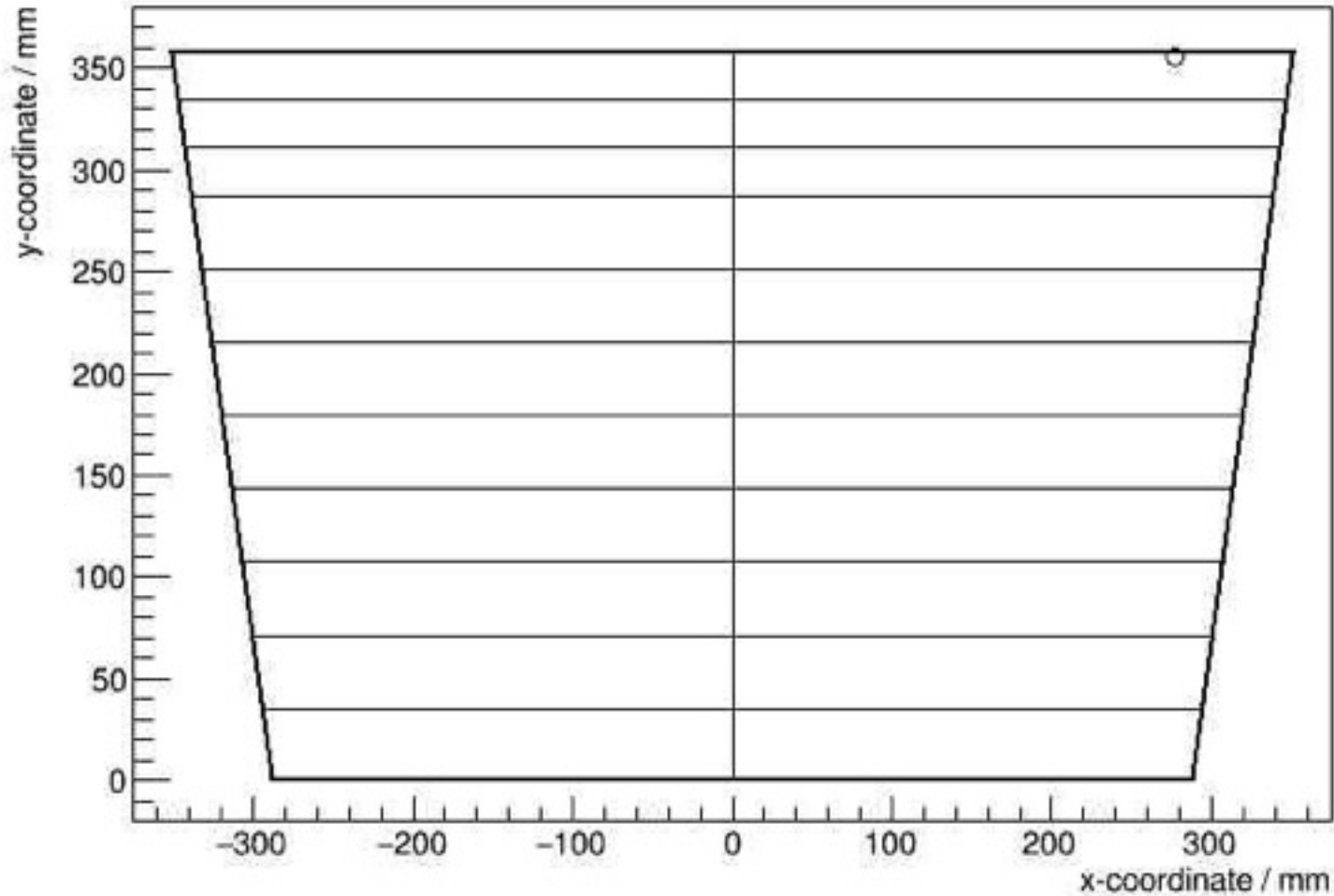


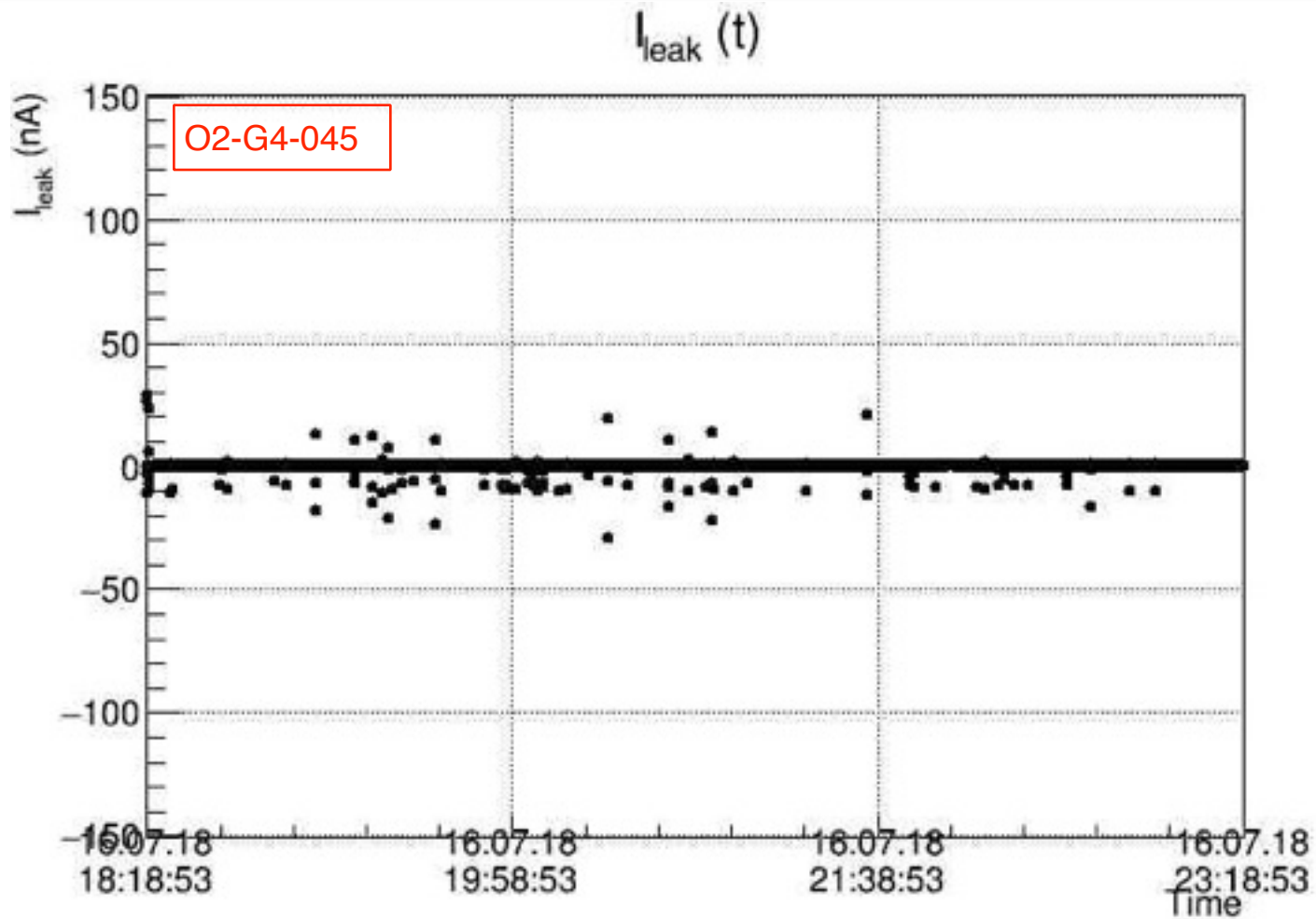


Spark Detection System (SDS)

O2-G1-036 threshold = 17, 1 Spark Position

Sparkmap OROC2





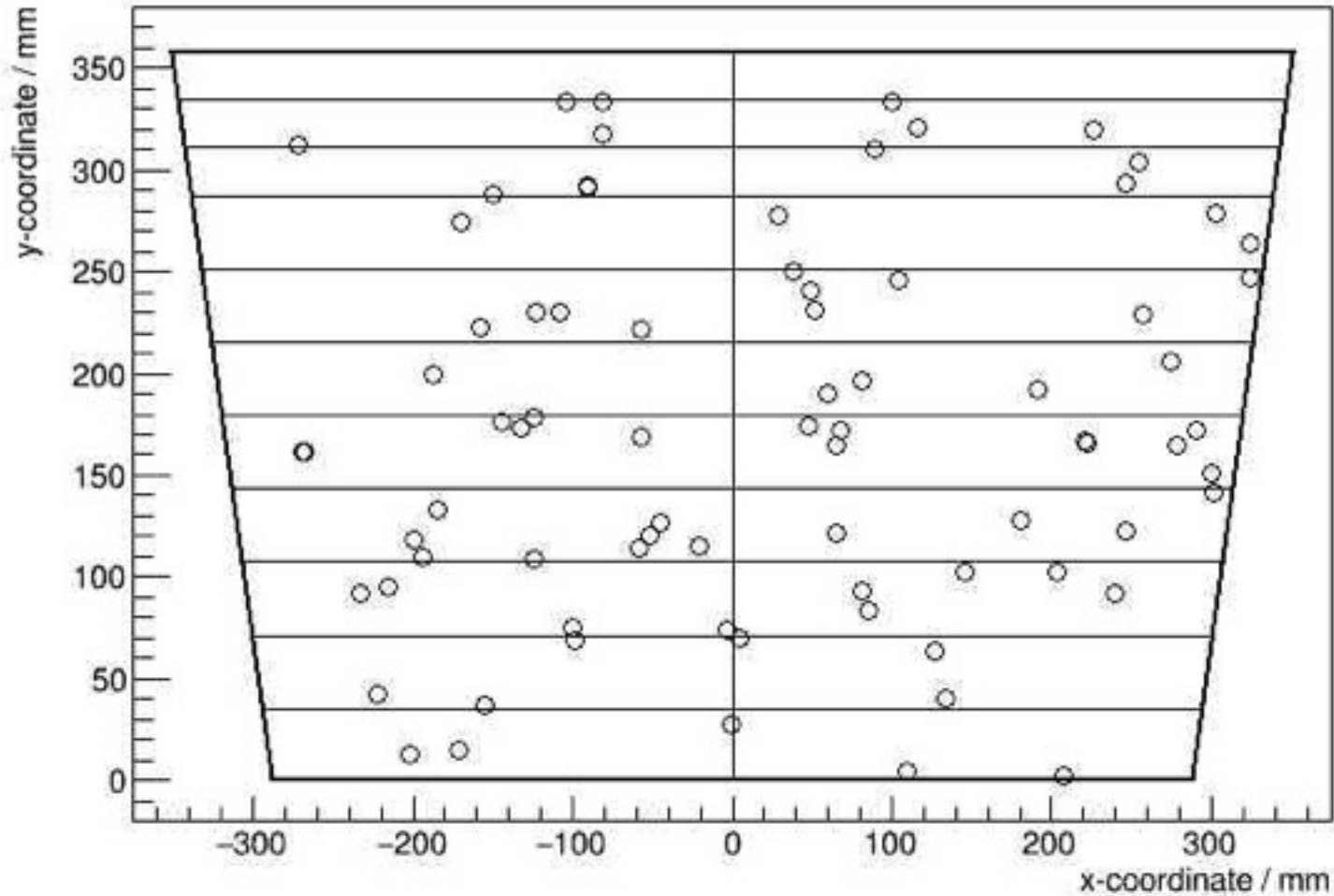
- O2-G4-045 (Standard@500V) has been long term tested (5h)
- The sparks happen all over the 5h



Spark Detection System (SDS)

O2-G4-045 threshold = 0, Entries 77

Sparkmap OROC2

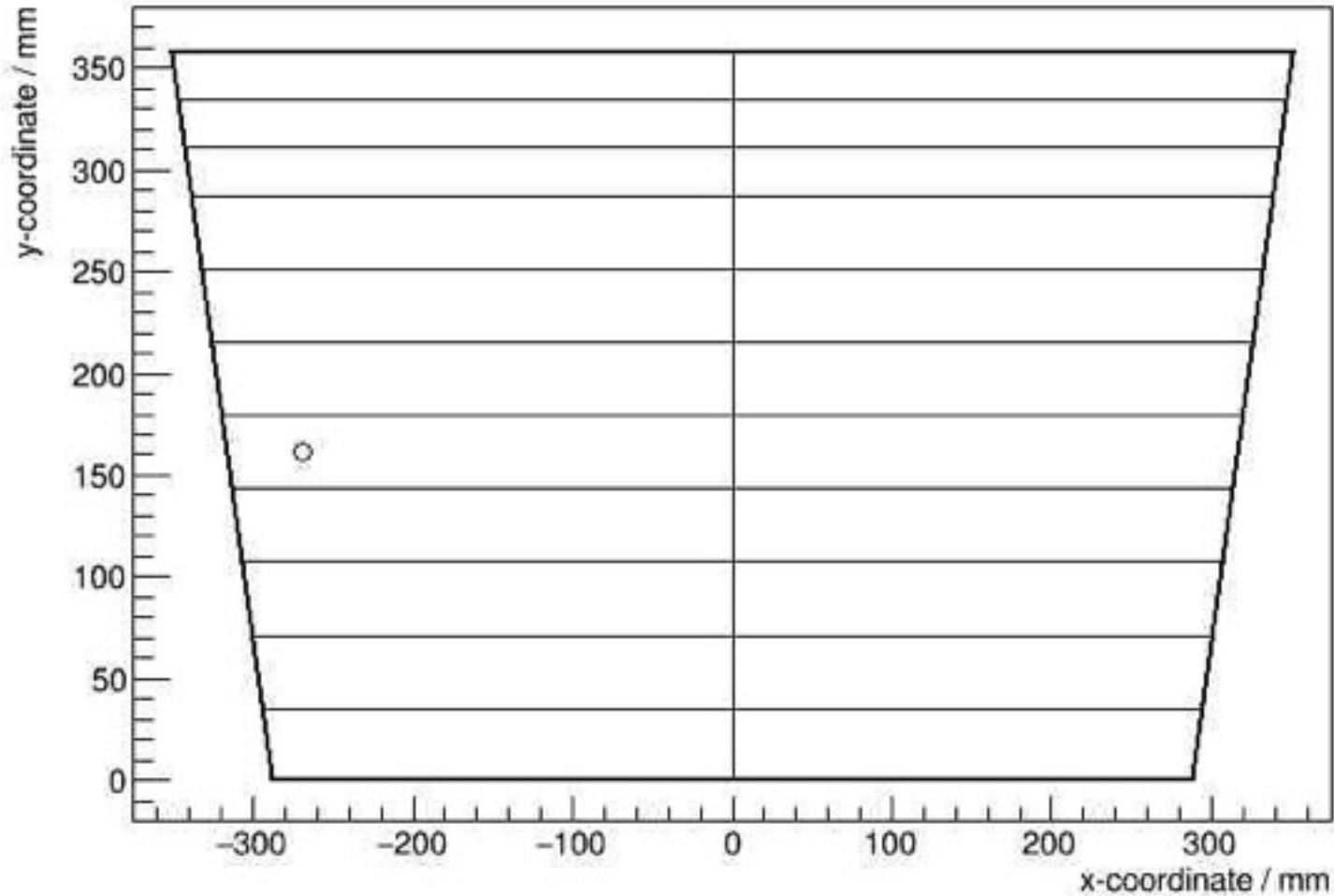




Spark Detection System (SDS)

O2-G4-045 threshold = 1, Entries 77

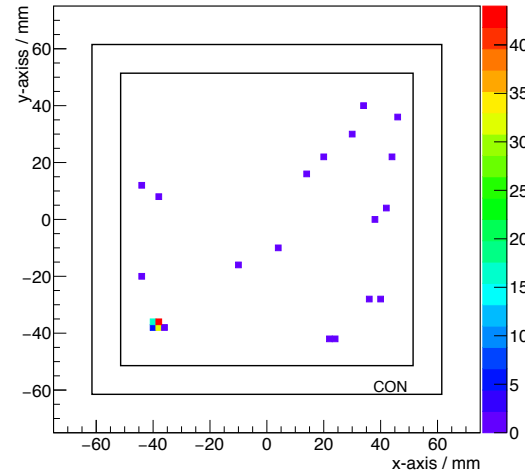
Sparkmap OROC2



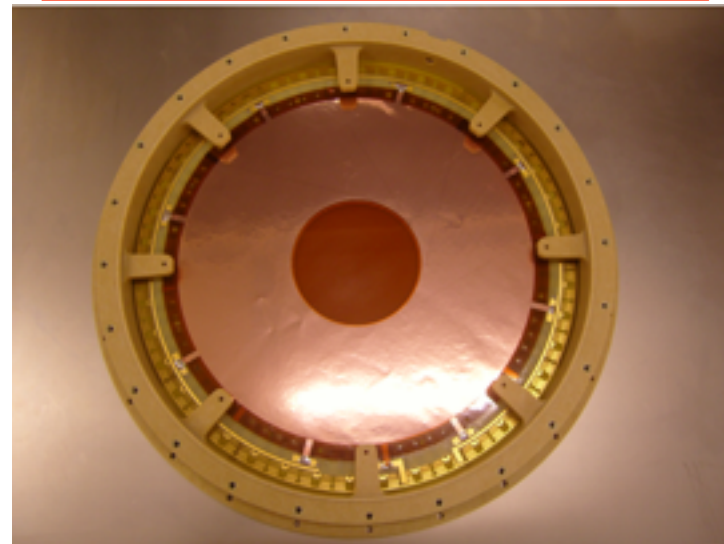
- Spark Detection System is a tool to effectively identify sparks (especially for long-term measurements)
- So far a low number of GEMs have been rejected because of sparks at the same position
- Investigate all our spark measurements (ALICE GEM production database)
 - Where do the sparks occur (are segment boundaries preferred)?
 - Are the cut holes correlated to the spark position?
 - How do the sparking spots look like ? Can they be correlated by HD scans
- Repeat study with cut hole GEM foils (the original 15) to see if single cut holes trigger sparks
- Implement also other GEM geometries (GEM TPC Bonn used in FOPI/CB ELSA)



Thanks for your attention



to be implemented



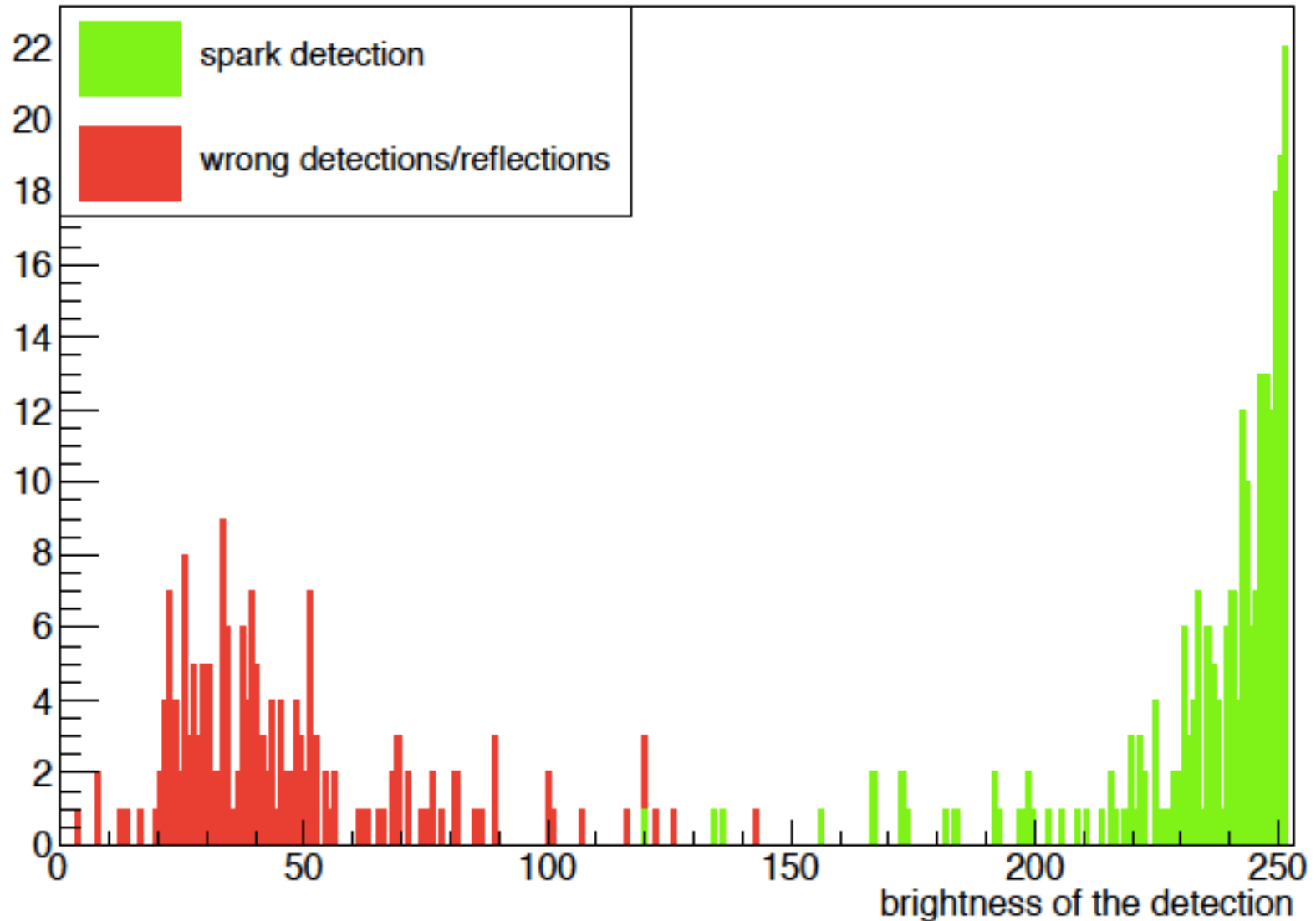
+ ?



Backup

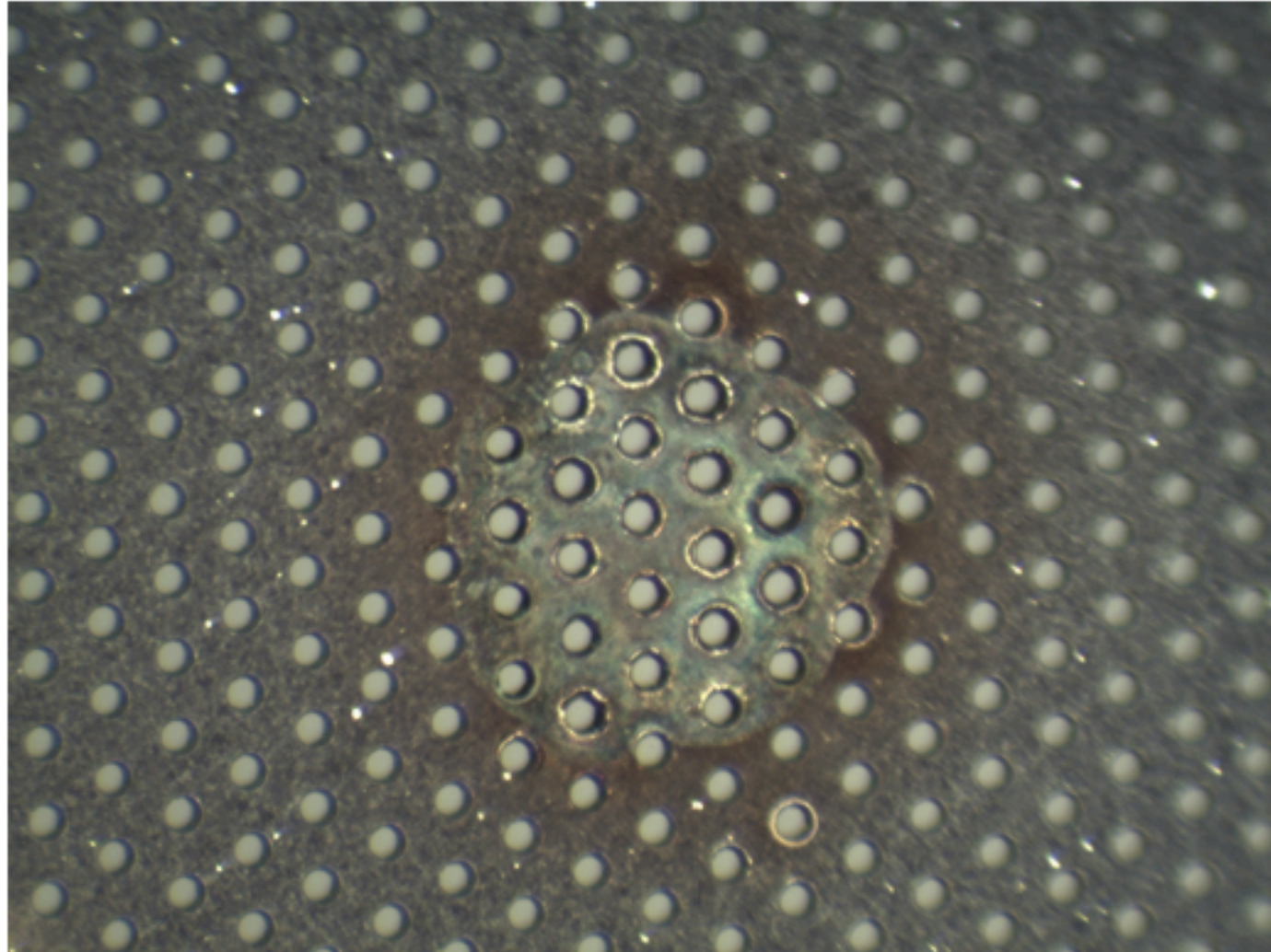


Determination of correct threshold





Spark Marks

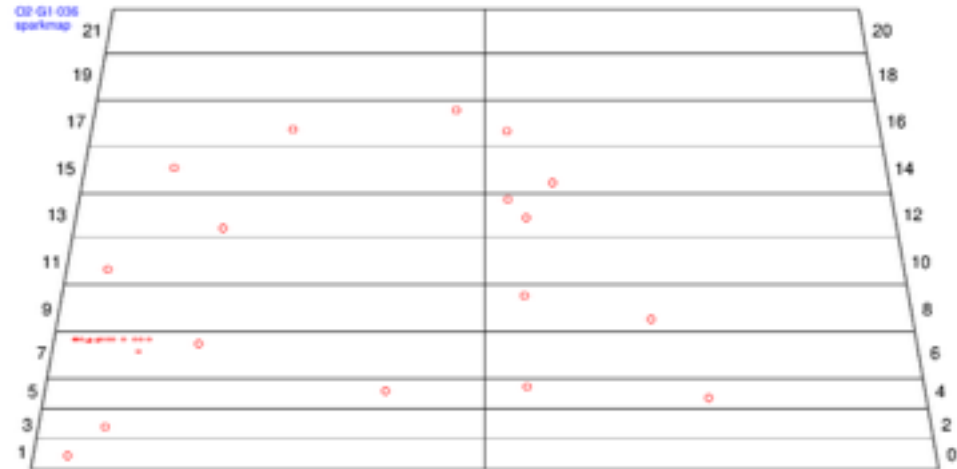
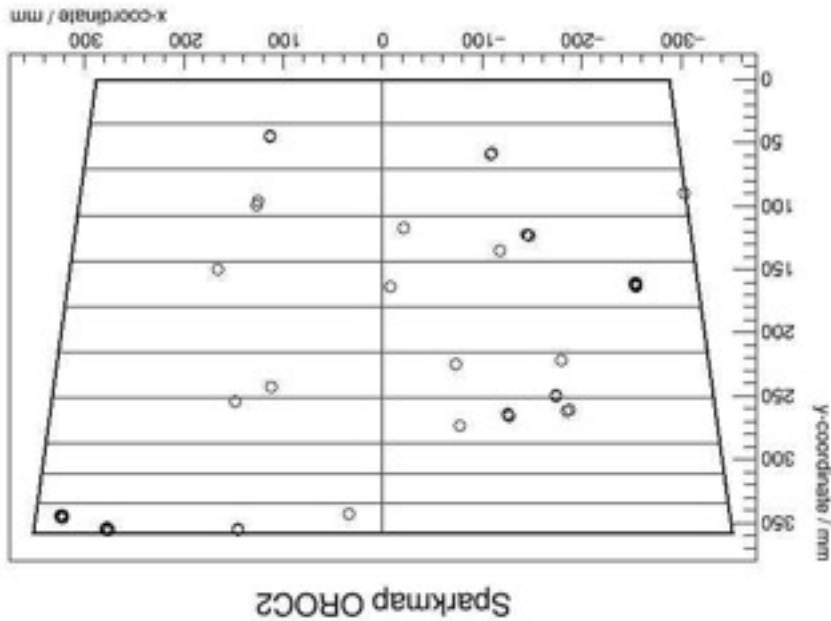




Shift due to Macrolon plate



O2-G1-036 threshold = 1, Entries 346





Spark Detection System (SDS)



O2-G1-036 threshold = 17, 1 Spark Position

