Small Dosimeter based on Timepix device for ISS

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Work carried out within the Medipix Collaboration

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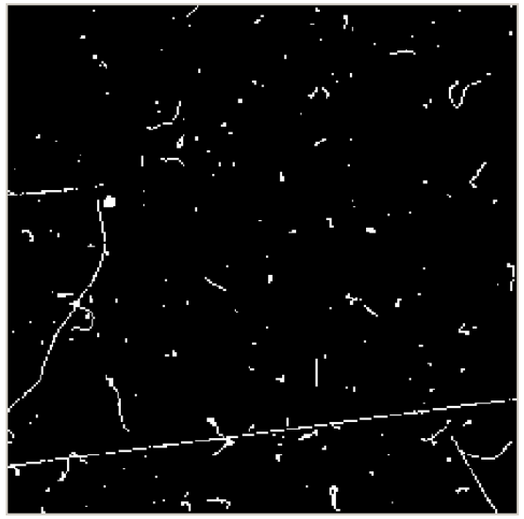
Outline

- Introduction
- Timepix Dosimeter for ISS
- Control software
  - Data analysis
  - Frame Rate Algorithm
- Testing of the software
- Summary

Introduction

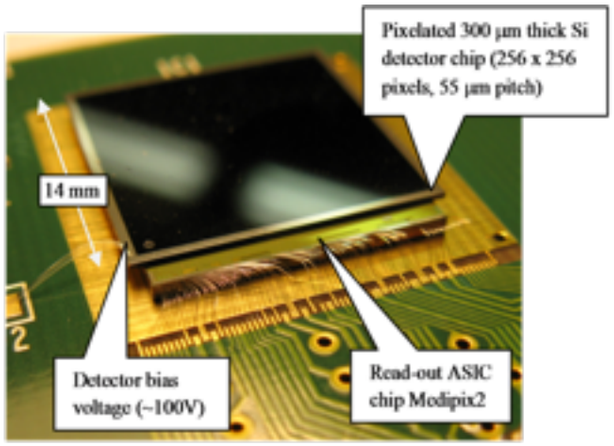
- **Space:** energetic and complex radiation field
- Most of the dose comes from interaction of **heavy ions, protons**
- Standard detection methods fail

- As a result, more complex analysis of radiation environment needed
- Important to distinguish different particles:
  - measuring a **tracks** of particles
  - measuring their deposited **energy**



Timepix

- posses suitable properties for measurements of this type
- positive sensitive pixelated detector
- 300 µm thick sensor, 256x256 µm, 55 µm pitch
- Measure position and charge deposited (ToT mode)
- After calibration, deposited energy can be determined



Timepix Dosimeter for ISS

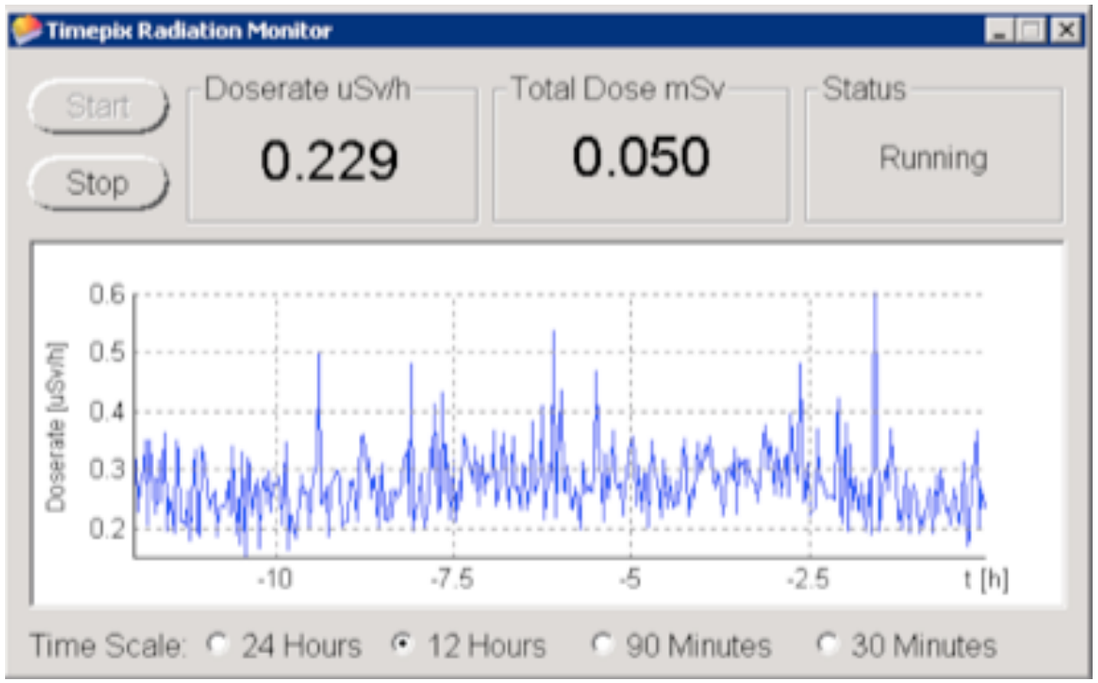
- Project of IEAP, UH and NASA
- Application of Timepix as dosimeter for ISS

AIMS:

- Show that it is possible to use Timepix as dosimeter in Space
- Show online equivalent dose rate
- Measure data in space environment and use them for further analysis and algorithm improvements

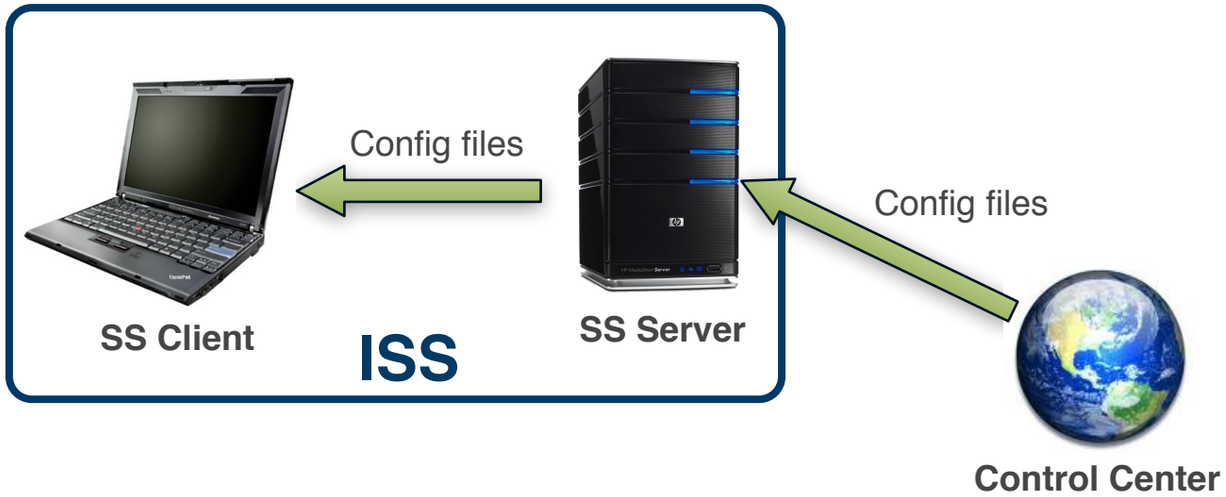
Software & Hardware

- Modified USB Lite interface -> Timepix + USB A connector
- Special version of Pixelman software -> Dosimetric plugin
- Fully automatic control of acquisition
- Online data analysis (Frame Analysis)
- Automatic adjustment of meas. parameters (Frame Rate Algorithm)
- Automatic error-recovery (e.g. device disconnected)
- Simple GUI
- Highly configurable



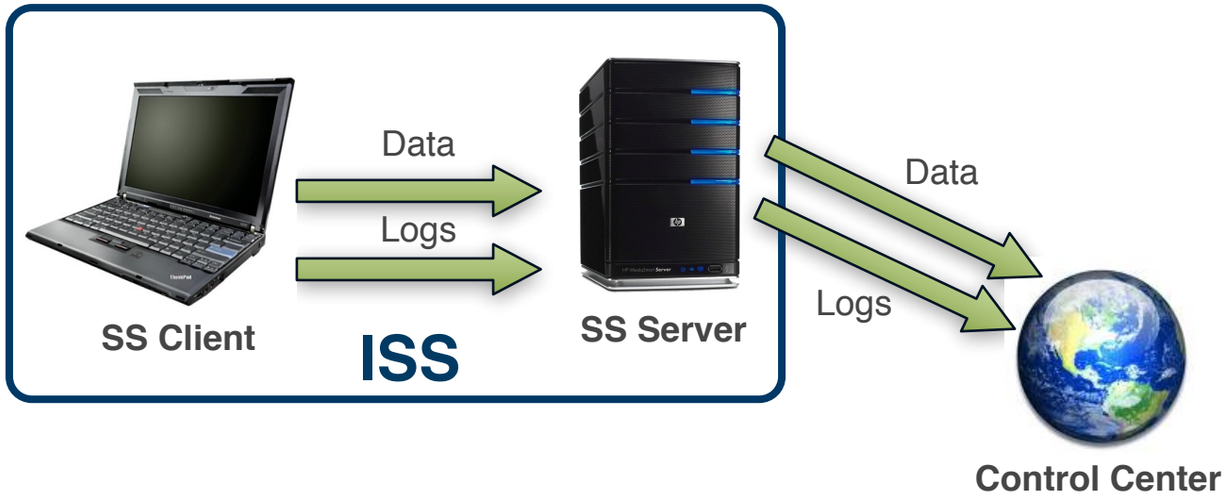
Remote configuration of the software

- No interaction from crew required (except from start / stop)
- Need to change parameters remotely from Earth
- Software is highly configurable (over **170 parameters**)
- Configuration files uploaded to SS Server
- Dosimeter plugin downloads automatically configuration files from server and applies new configuration



Saving data and log files

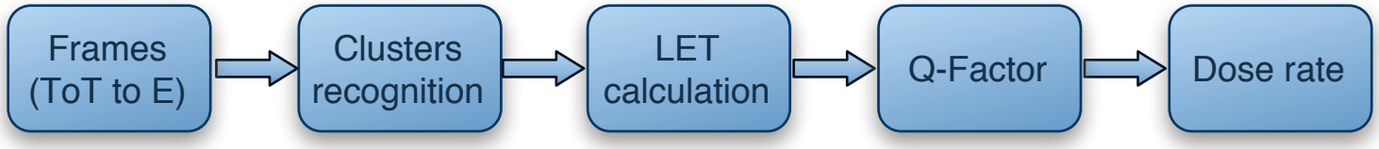
- Data, log files and analysis results are saved (cached) on the Client
- They are copied to the Server in configurable time intervals and deleted from the Client
- From the Server they can be downloaded to Earth
- Software offers several levels of debugging messages - for adjusting parameters of analysis



Data Analysis

Data analysis

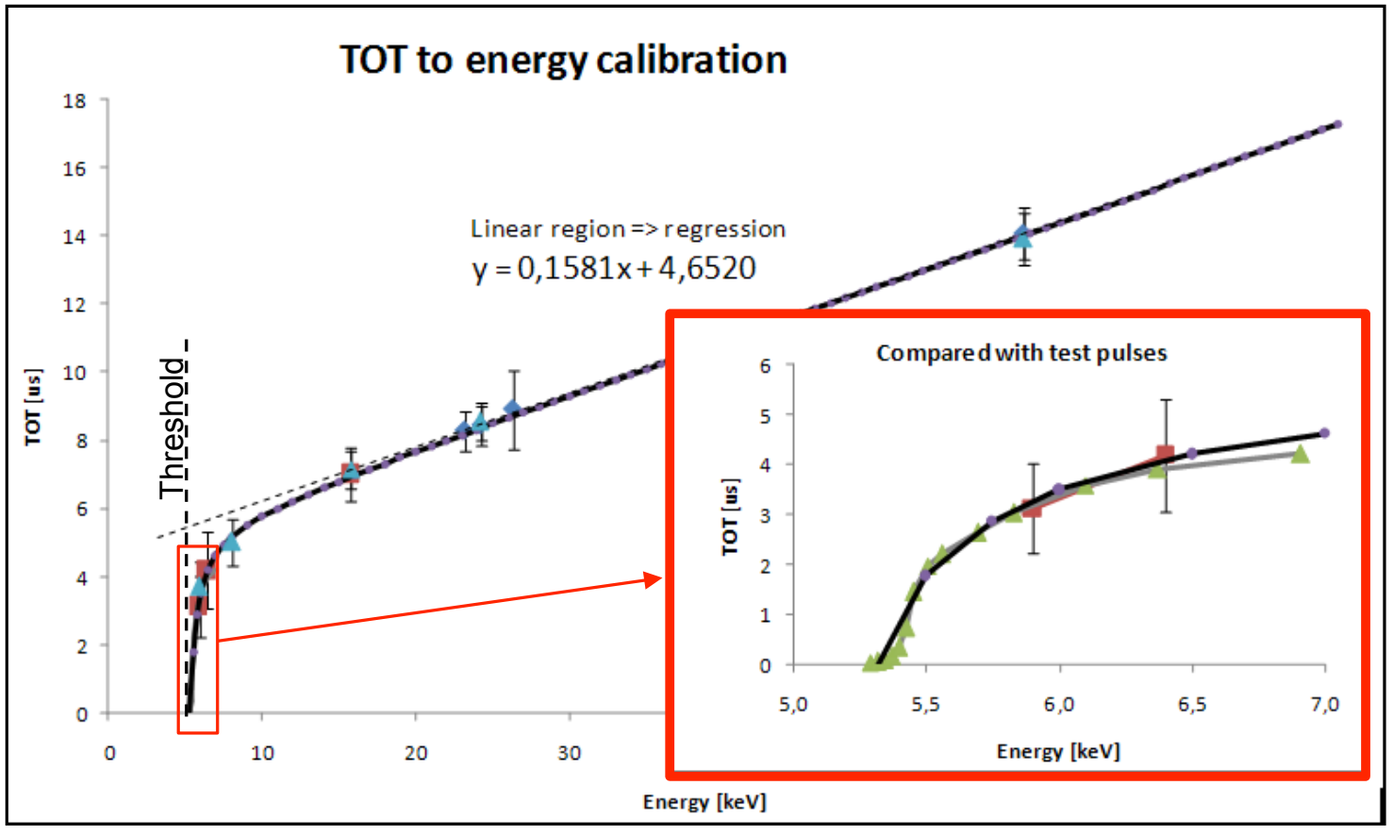
- Software analyzes acquired frames in order to get:
  - **Equivalent dose rate [µS/h]**
  - **Total cumulated equivalent dose [mSv]**
- To calculate the dose equivalent, particle types have to be recognized
- Each type of incident radiation is given “quality factor” (Relative Biological Effectiveness)
- For heavy ions tracks, this quality factor is dependent on LET

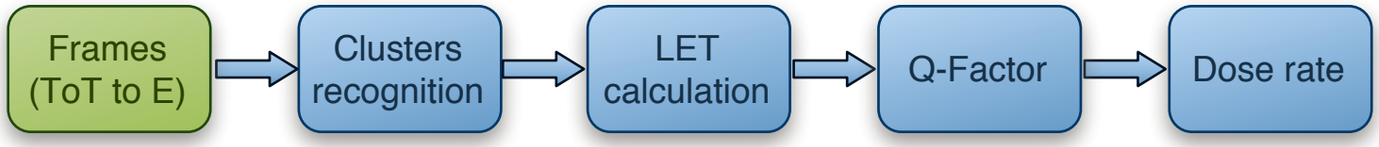


ToT to Energy (Timepix calibration)

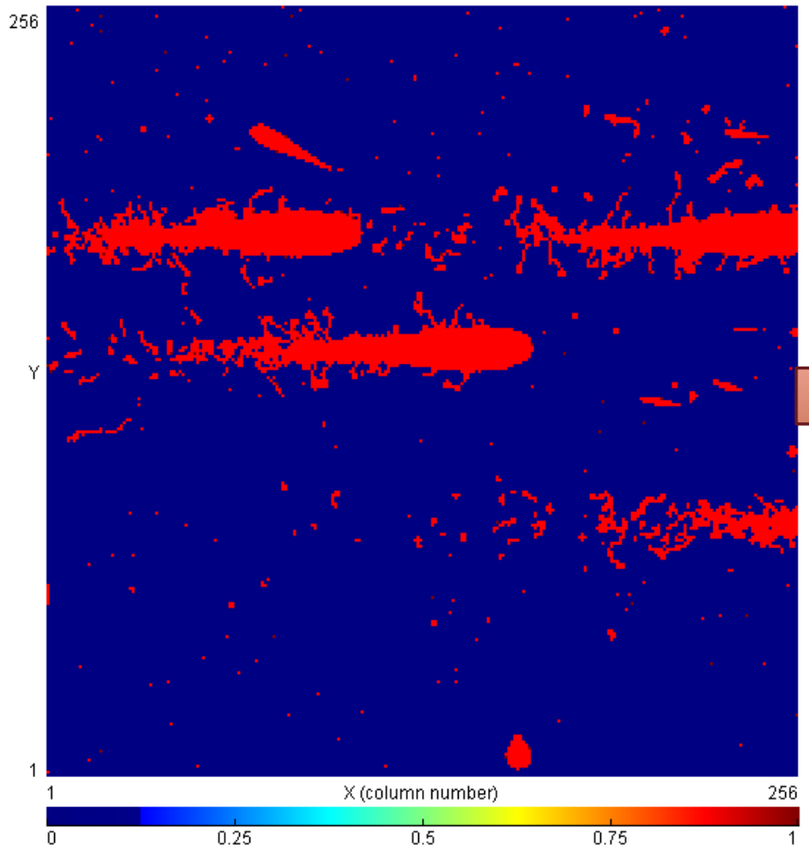
$$f(x) = ax + b - \frac{c}{x - t}$$

a,b – linear regression in high energy range
c – curvature
t – threshold

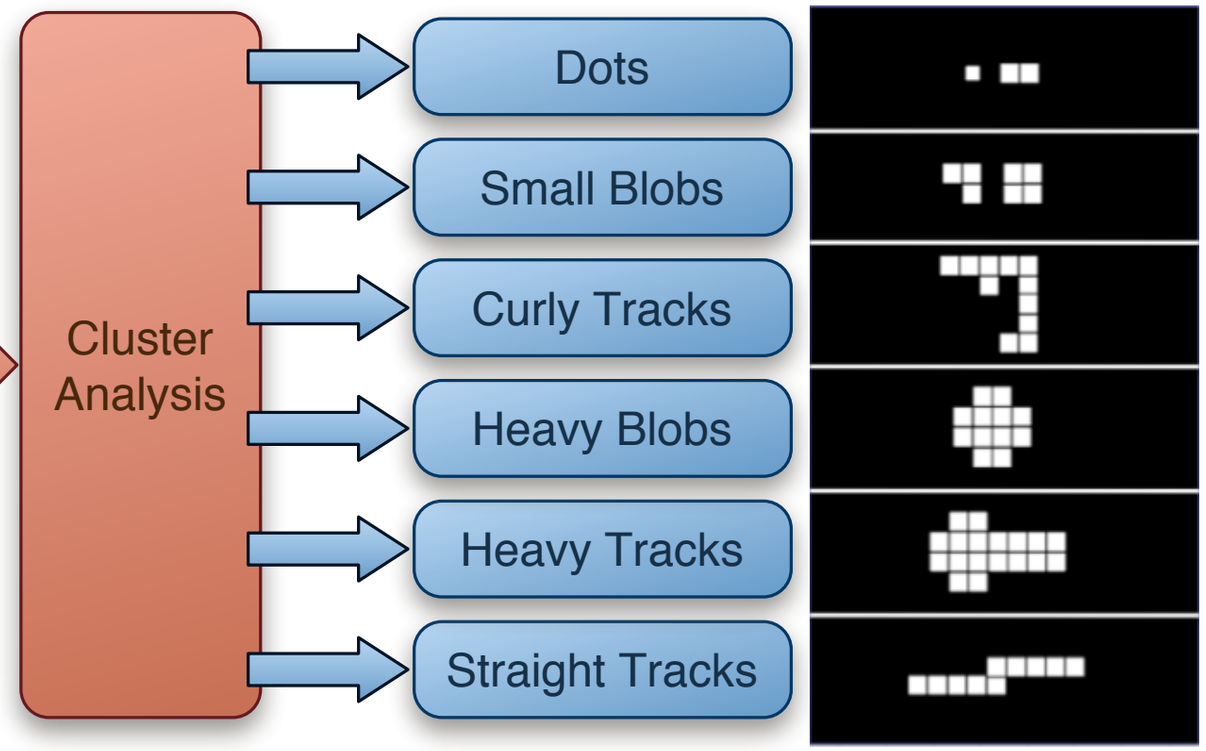




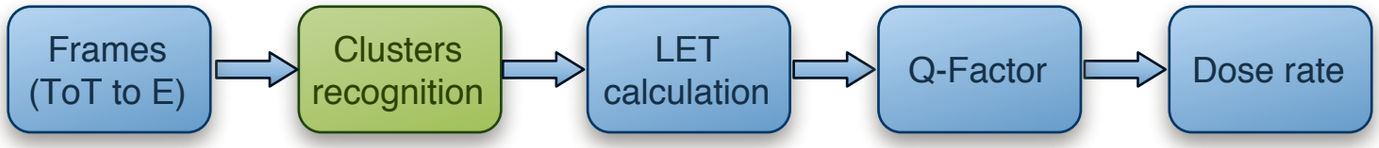
Cluster Analysis



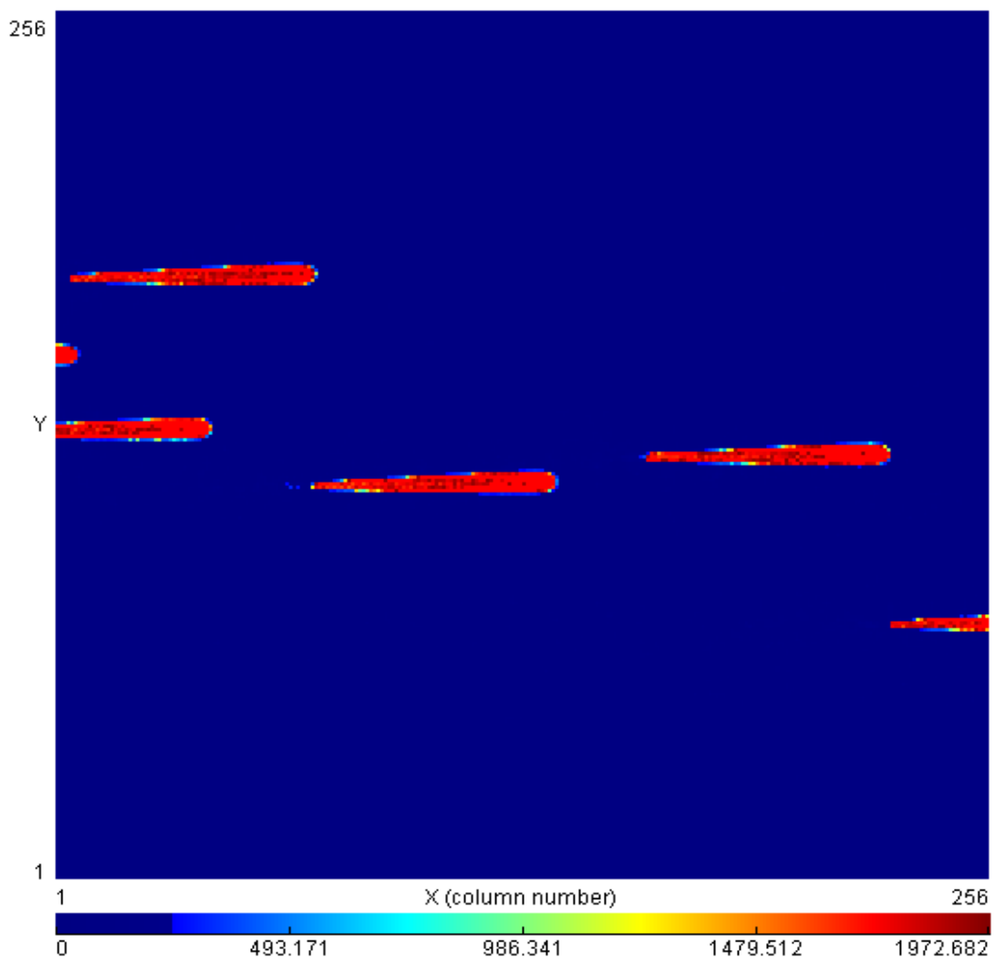
Frame containing 400 MeV 56Fe, 85°, measured at HIMAC, Japan

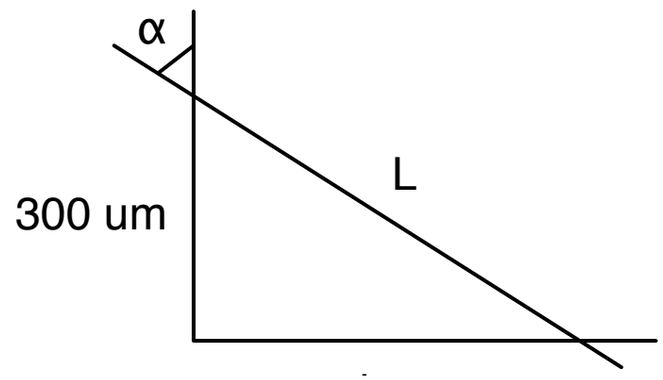


Cluster analysis algorithm is successfully working in ATLAS-MPX network



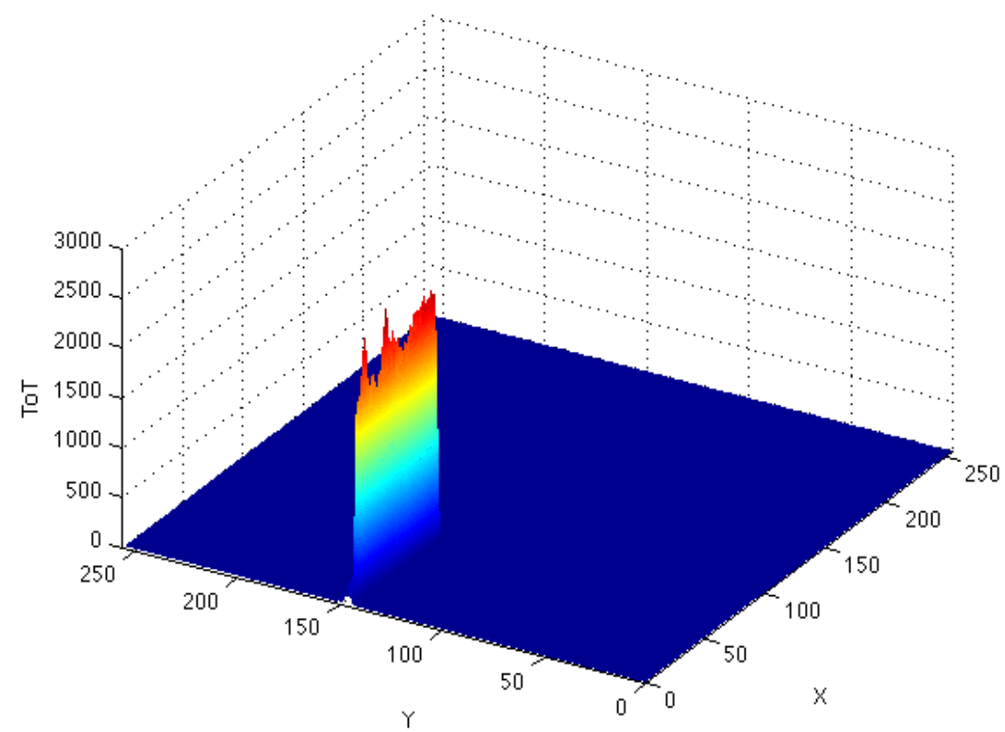
Calculation of LET





$$L = \sqrt{l^2 + 300^2}$$

$$LET = \frac{E}{L}$$



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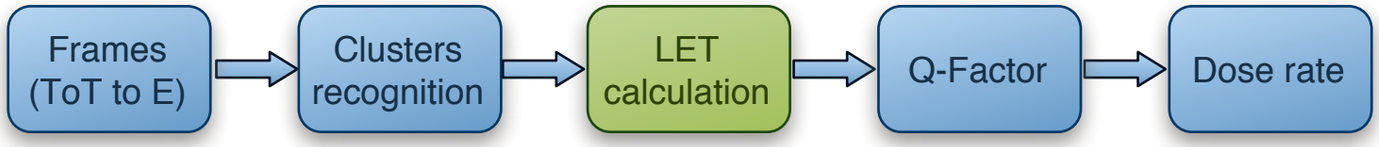

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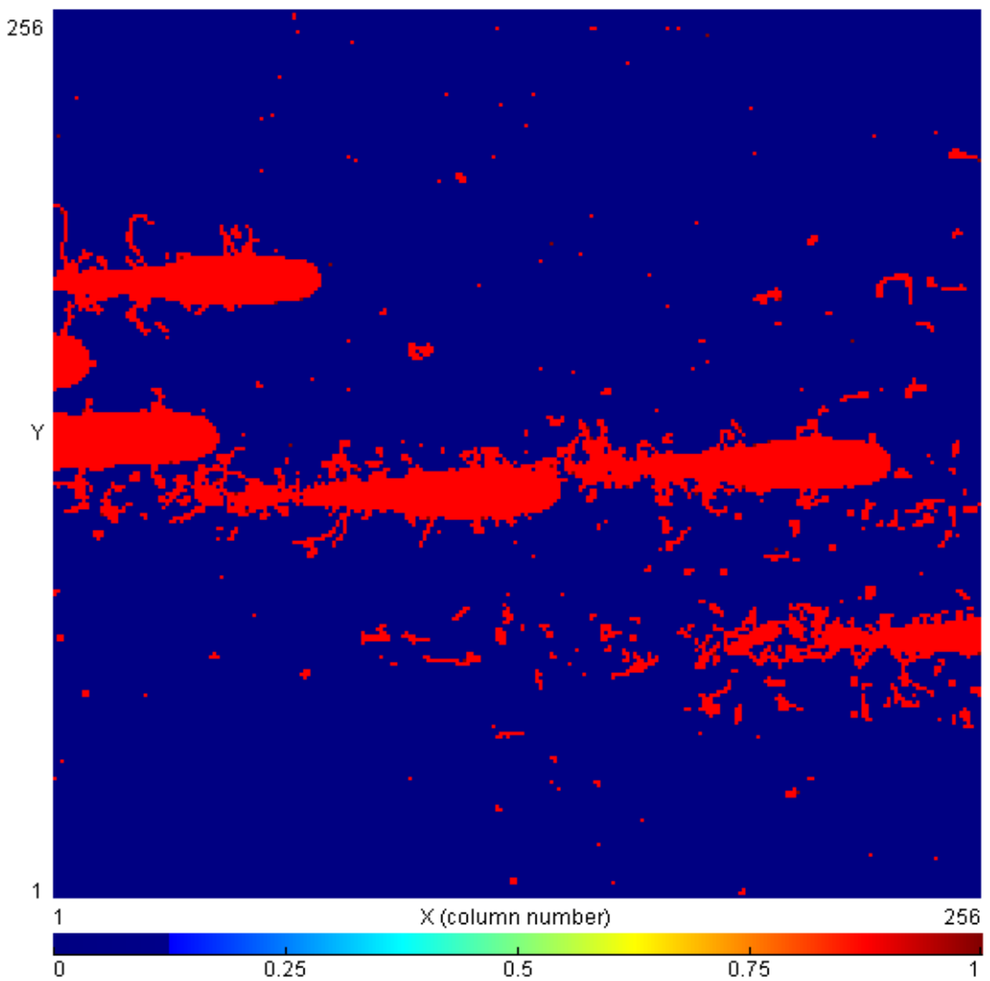
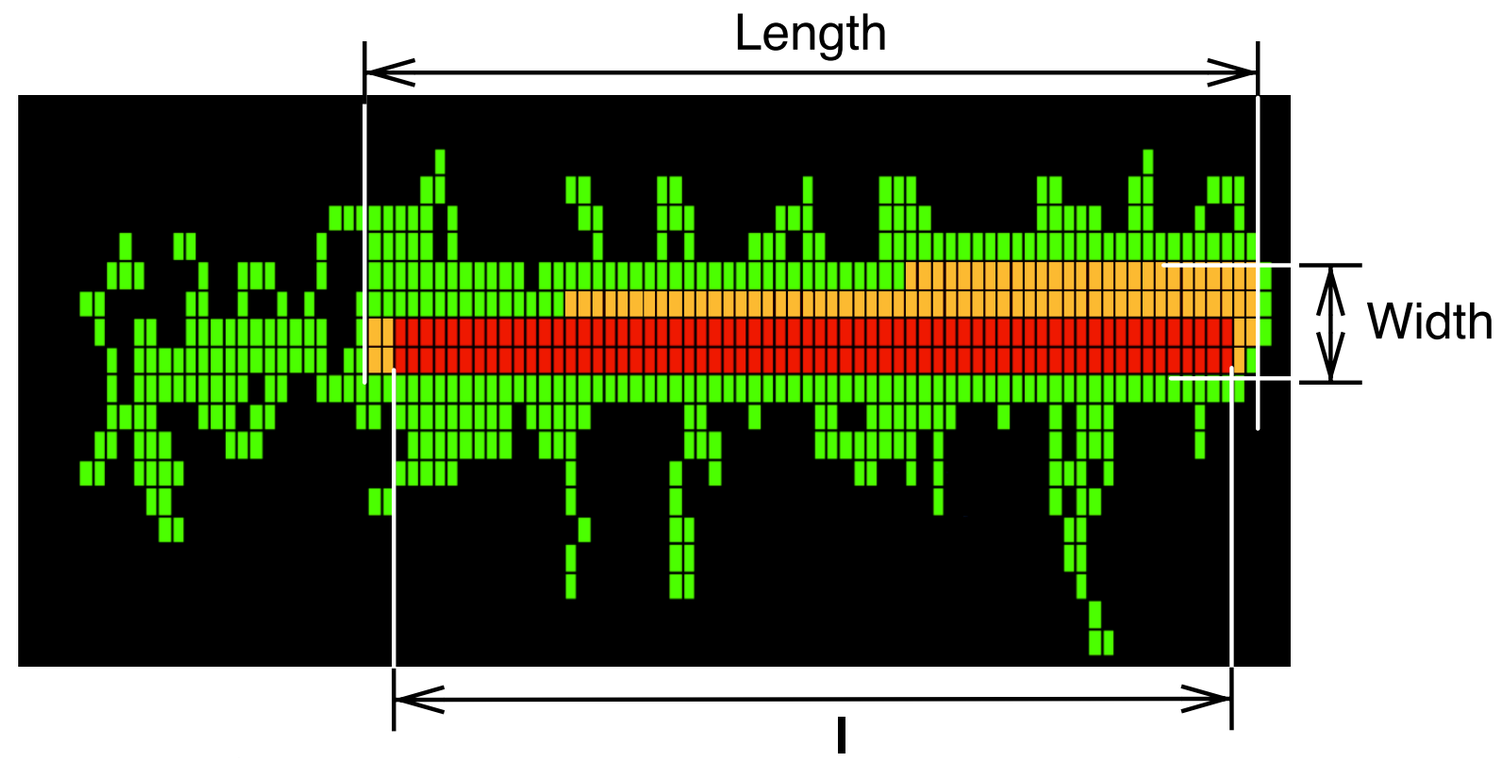
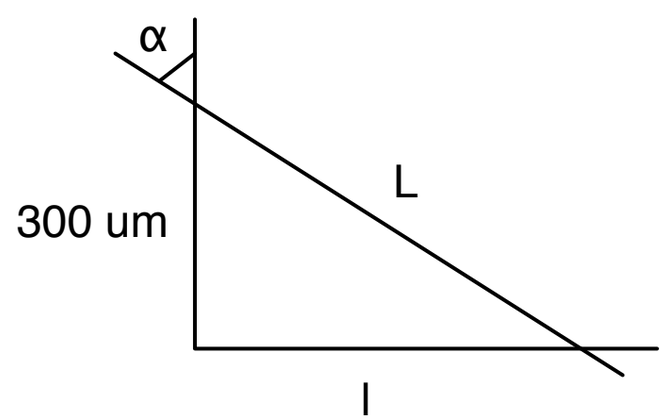


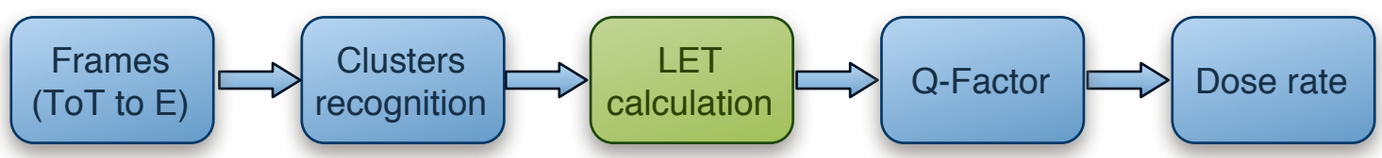




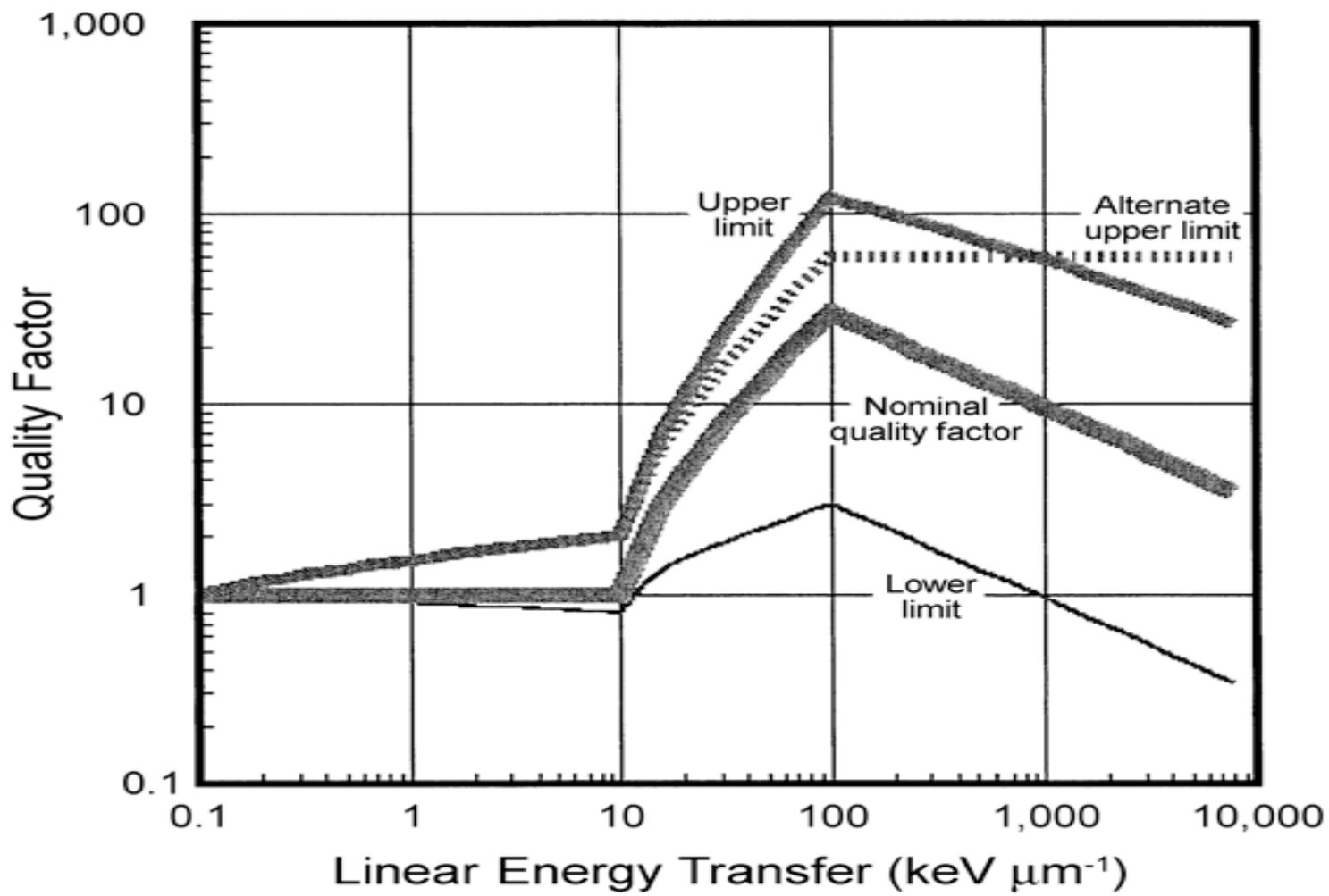
$$l = Length - Width$$

$$L = \sqrt{l^2 + 300^2}$$

$$LET = \frac{E}{L}$$



Quality Factor

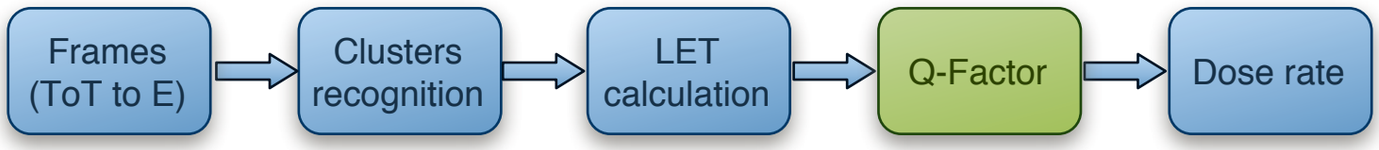


- QF ~ 1, LET < 10 keV
- QF ~ 1, LET > 1 MeV

For 300 µm Si:

- QF ~ 1, LET < 3 MeV
- QF ~ 1, LET > 300 MeV

Quality Factor as a function of LET as proposed in National Council on Radiation Protection and Measurements (NCRP) 153 (2008). Values based on long-term risks (e.g. cancer)



Dose Equivalent Calculation

Si Detector Layer Issues:

Volume = 3.0×10^{-2} cm x 1.408^2 cm^2 = 5.947×10^{-2} cm^3

Si density = 2.3212

Si Detector Mass = 0.138 g

Si to H2O = 1.114

Measured Energy Conversion for Dose Purposes

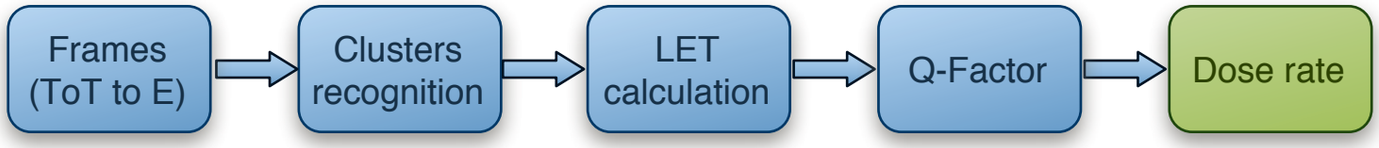
KeV/g in H2O = (1.114/0.138) x $E_{Timepix}$ = 8.072 x $E_{Timepix}$

Total Dose Equivalent in Sv (As Well As Dose in Gy)

D = H = 8.072 x $E_{Timepix}$ KeV/g / 6.24 x 1012 KeV/Sv g

D = H = 1.29×10^{-6} x $E_{Timepix}$ [µSv]

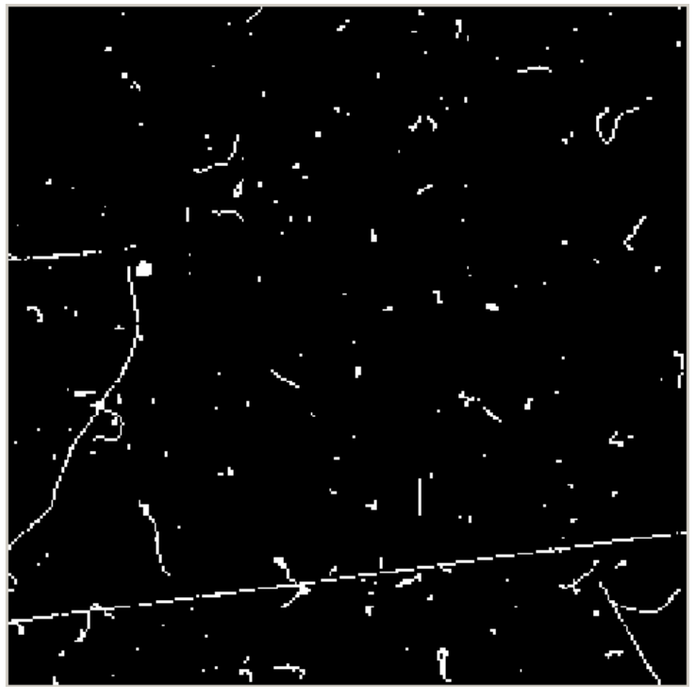
Doserate = D / acqtime [µSv/s]



Frame Rate Algorithm

Cluster overlapping

- With higher radiation intensities and constant acquisition time
  - => frame occupancy increases
  - => clusters overlap
  - => cluster analysis cannot recognize single clusters
- Solution:
  - Acquisition time has to be changed automatically in order to adapt to radiation conditions



Frame Rate Algorithm

- Automatically adjusts acquisition time to radiation conditions
- Algorithm decides according to several criteria (sub-routines):
  - Pixel count
  - Delta pixel count (4 frames)
  - Pixel volume
  - Cluster count
  - Delta cluster count (4 frames)
  - Cluster type
  - XY Grid
- Each sub-routine and all parameters are configurable from a file

Software Testing

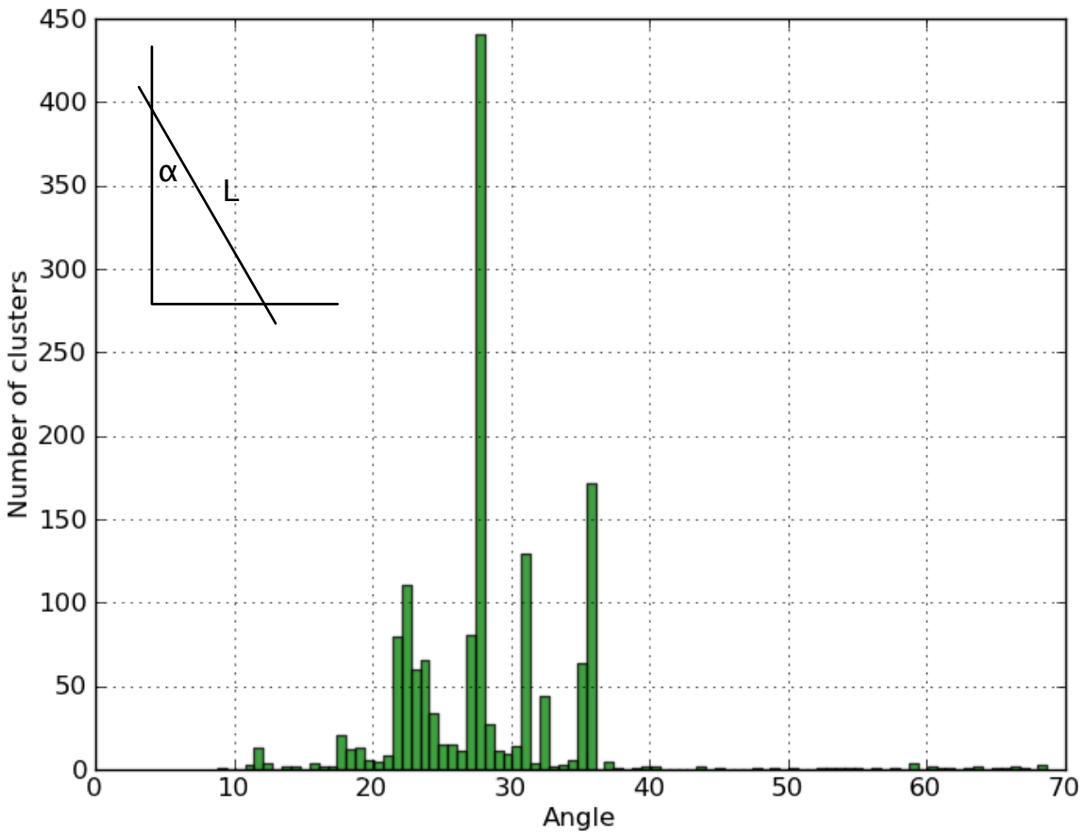
Software Testing

- **Frame Analysis Algorithm** was tested:
  - on data from HIMAC, JAPAN
  - in NASA Space Radiation Laboratory at Brookhaven, USA
- For different angles: 30, 60, 75, 85

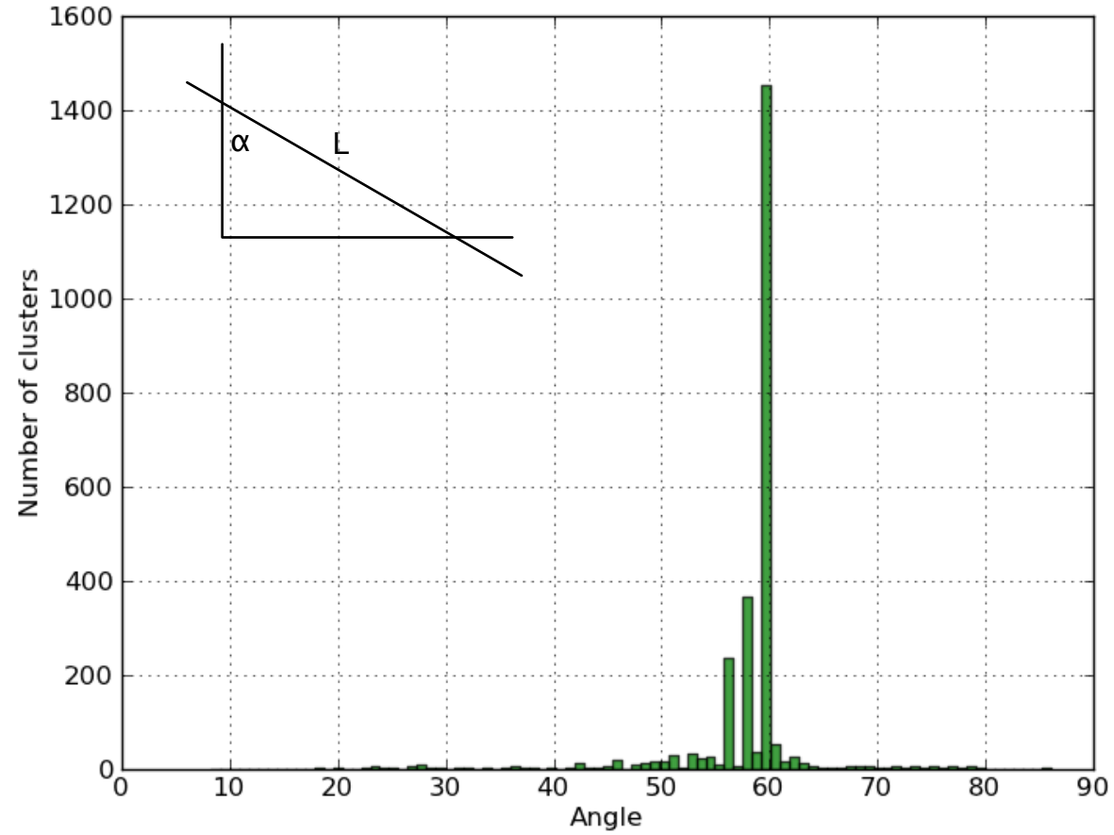
- **Frame Rate Algorithm** was tested:
  - on X-ray tube with different intensities (current)

Angle & LET Calculation Evaluation

30°



60°

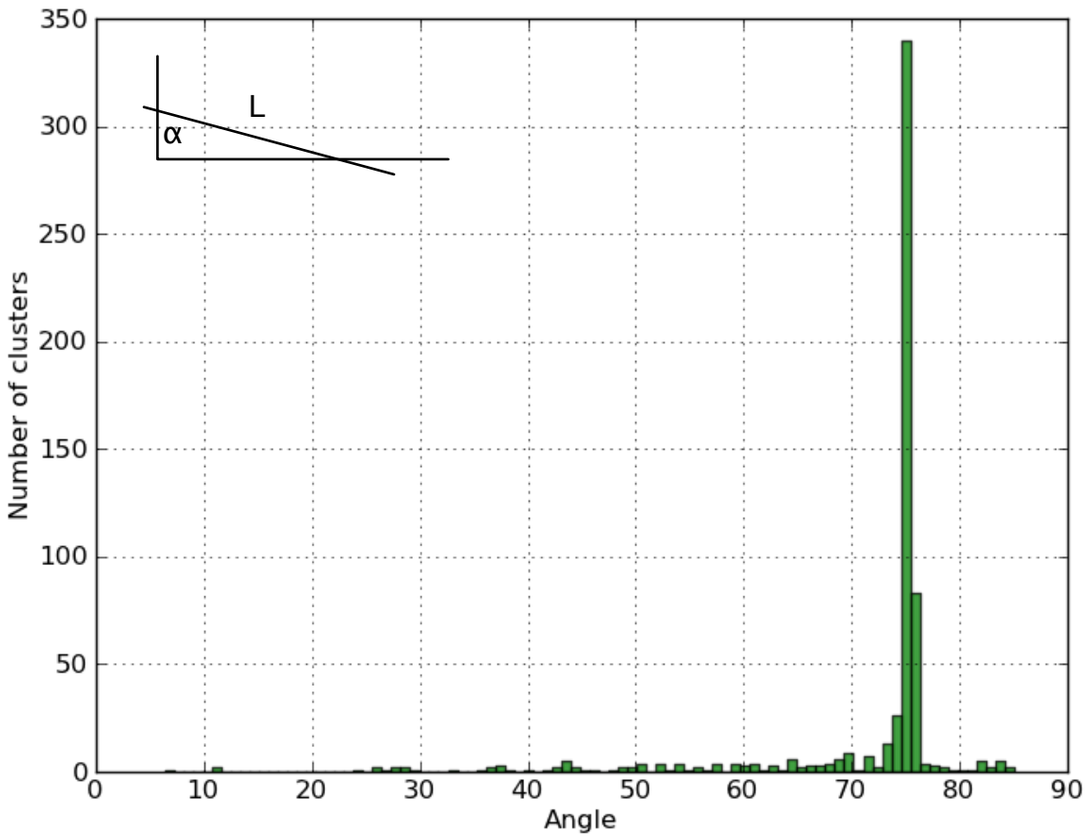


Angle	30°
Average angle	28.25°
Std. dev. angle	0.37 %
Std. dev. LET	0.07 %

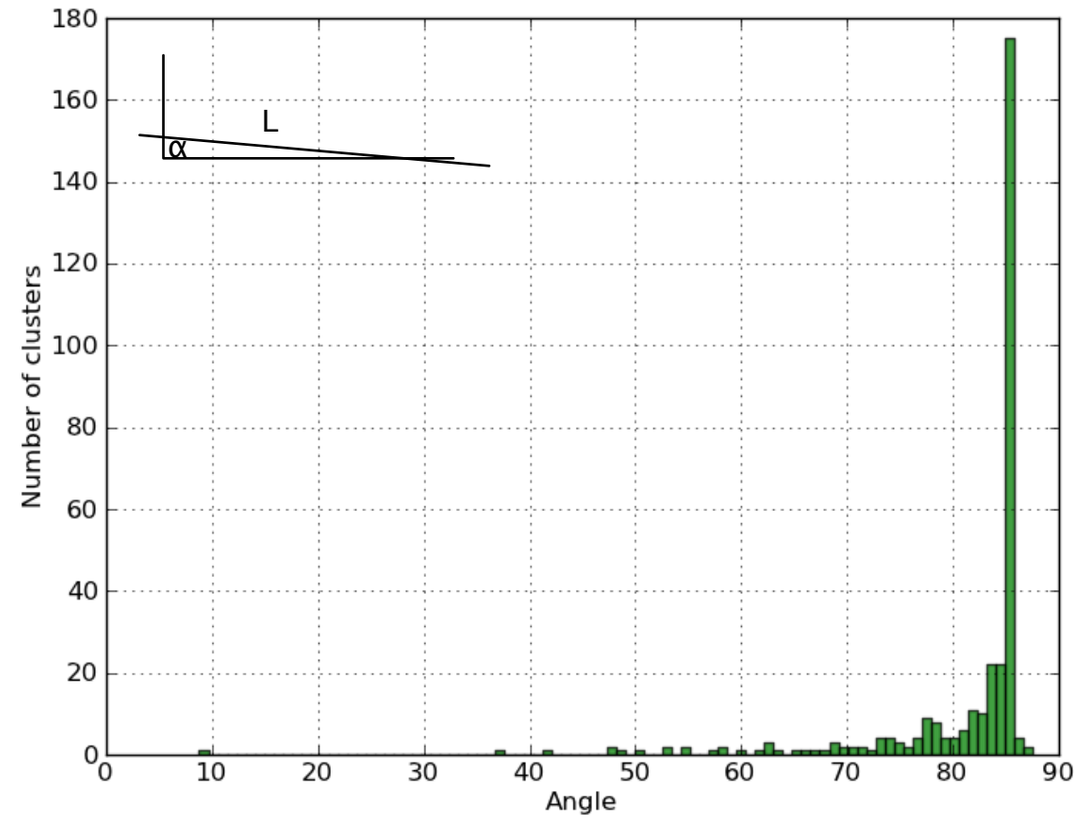
Angle	60°
Average angle	57.91°
Std. dev. angle	0.06 %
Std. dev. LET	0.02 %

Angle & LET Calculation Evaluation

75°



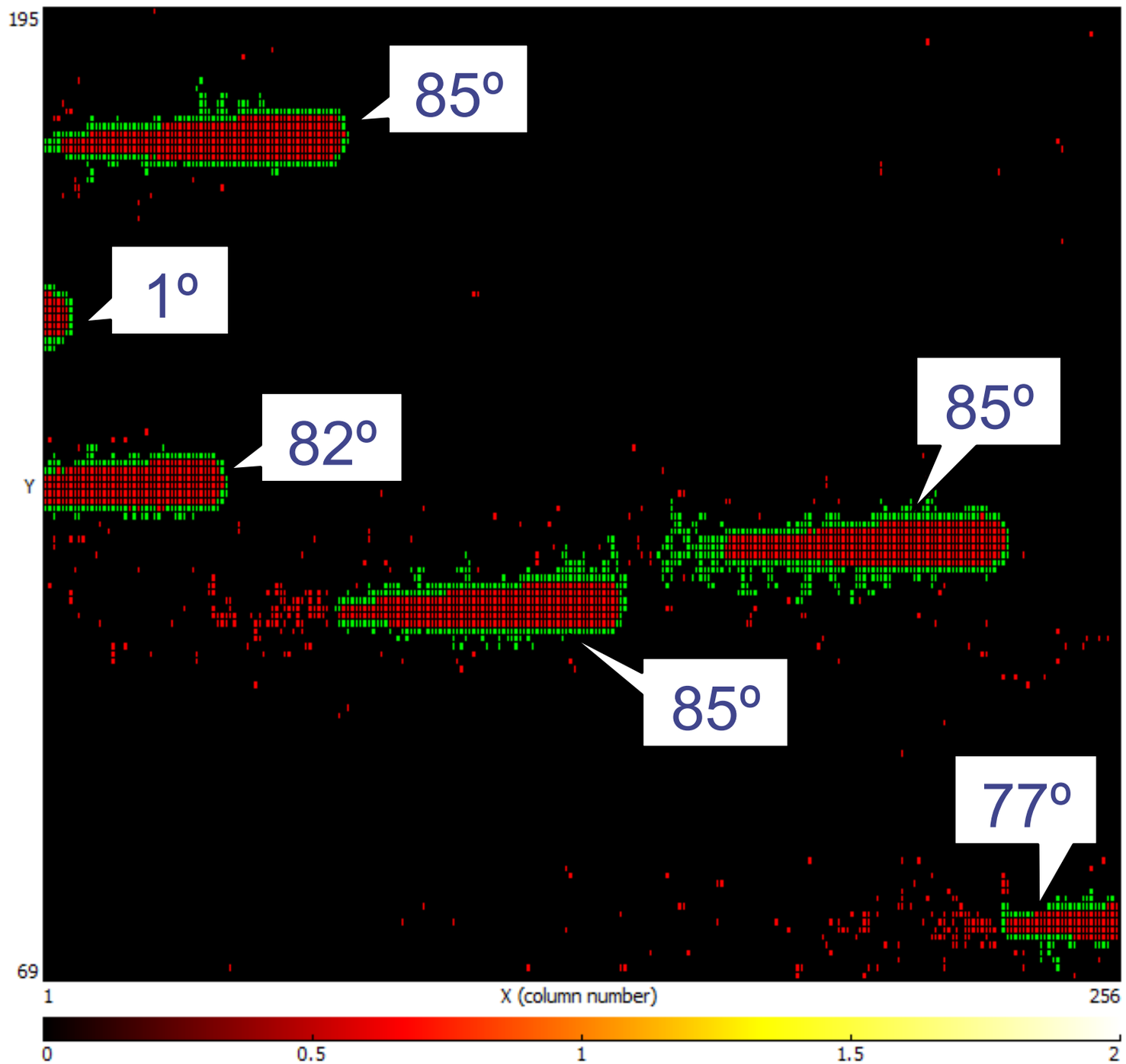
85°



Angle	75°
Average angle	71.4°
Std. dev. angle	0.21 %
Std. dev. LET	0.22 %

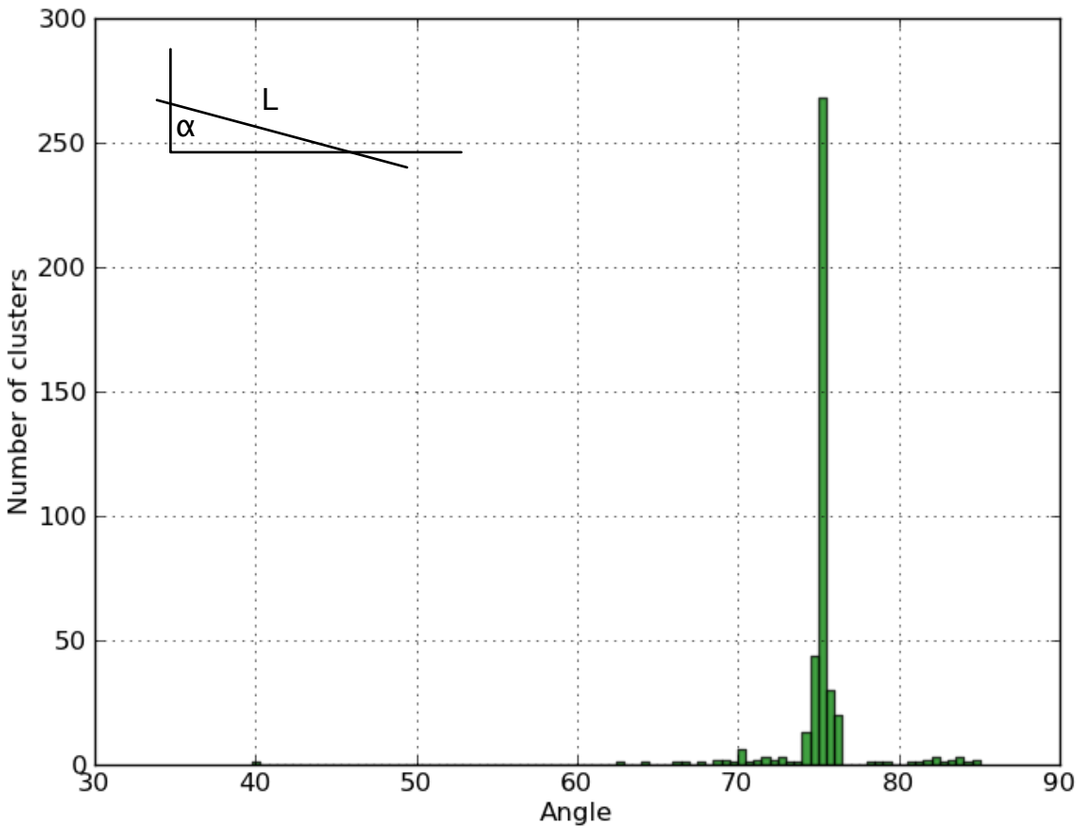
Angle	85°
Average angle	81.1°
Std. dev. angle	0.29 %
Std. dev. LET	1.63 %

Partial Clusters Issue

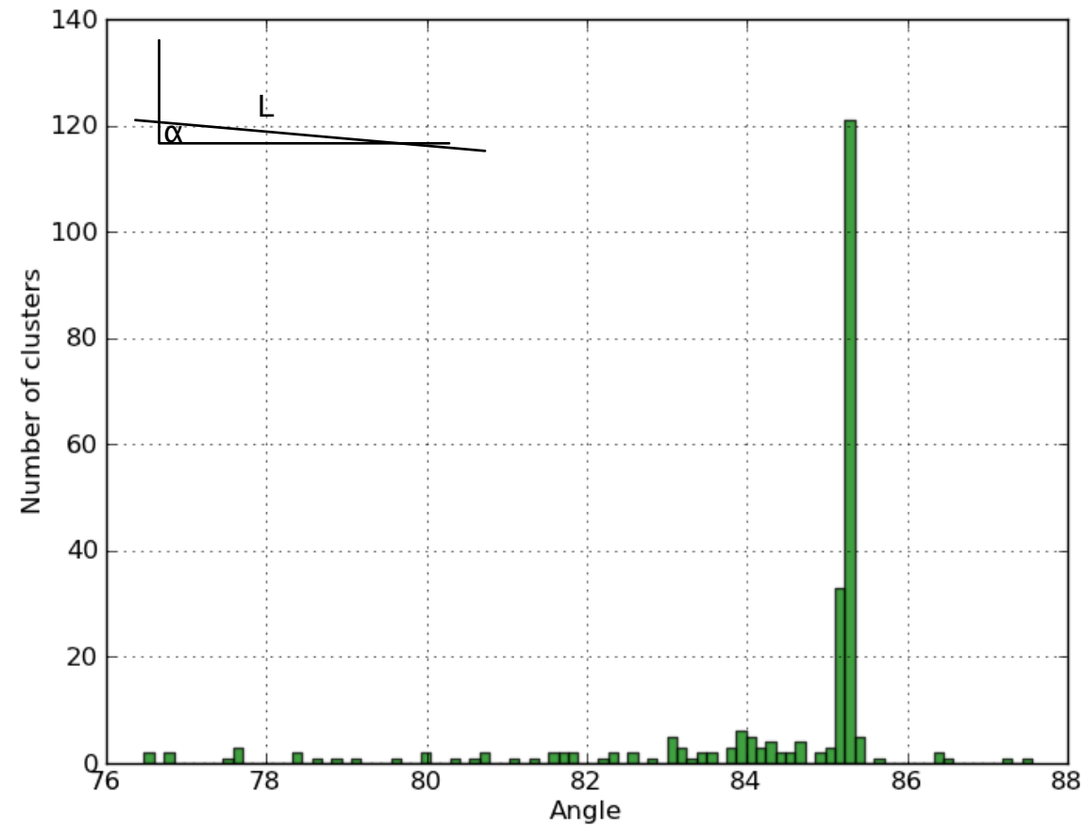


Angle & LET Calculation Evaluation

75°



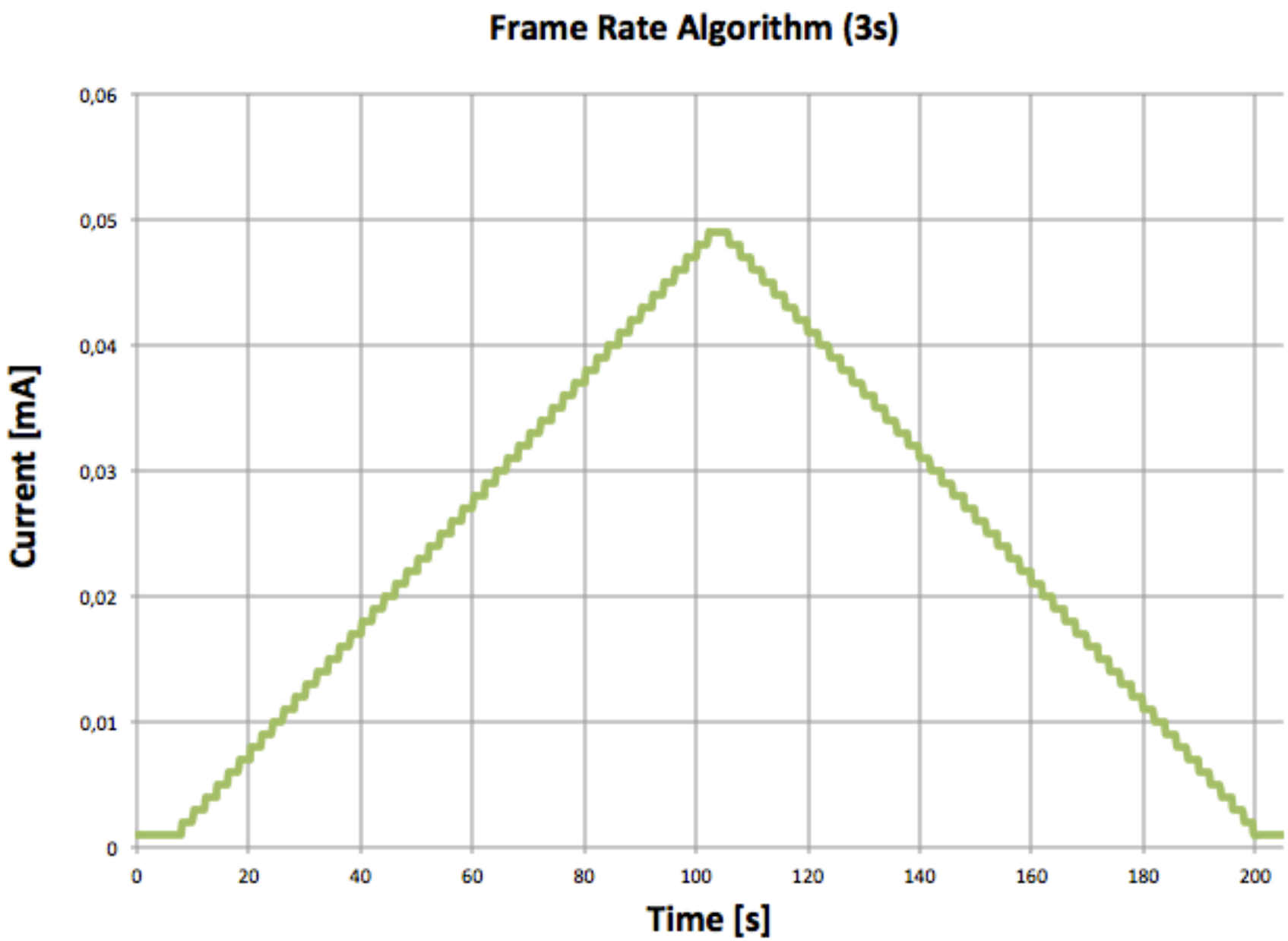
85°



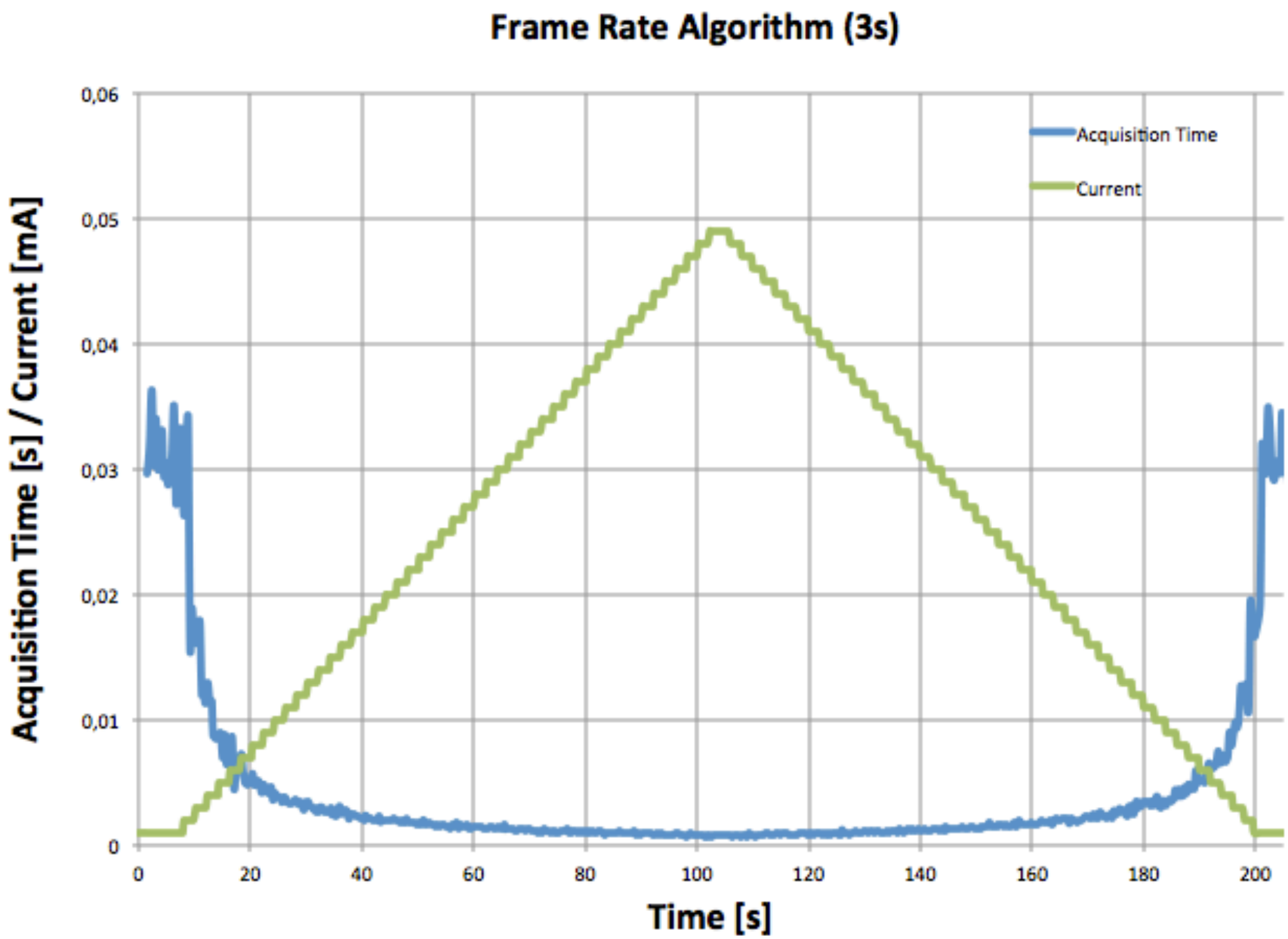
Angle	75°
Average angle	75.1°
Std angle	0.01 %
Std LET	0.02 %

Angle	85°
Average angle	84.3°
Std angle	0.08 %
Std LET	0.79 %

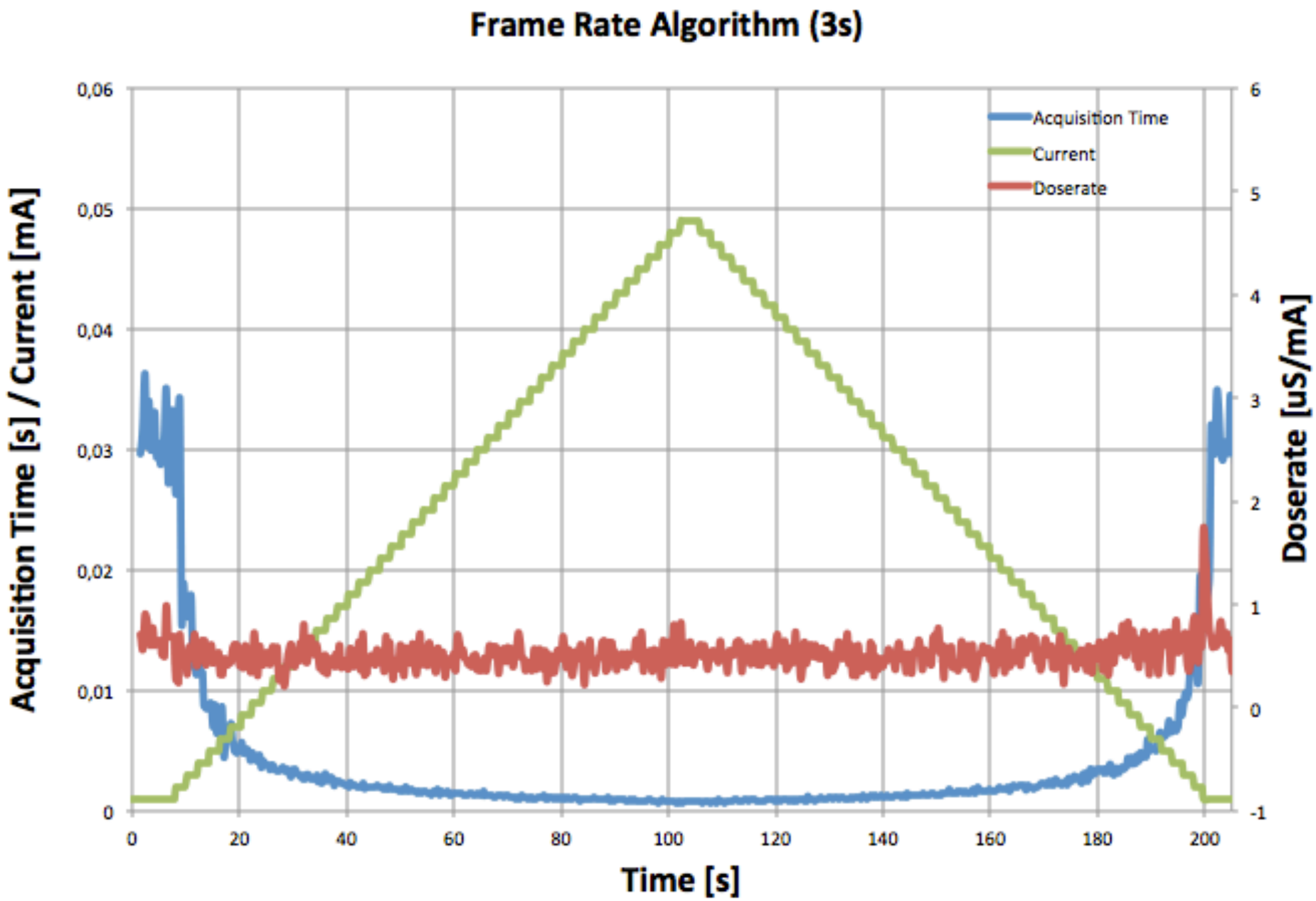
FRA Testing with X-Ray tube



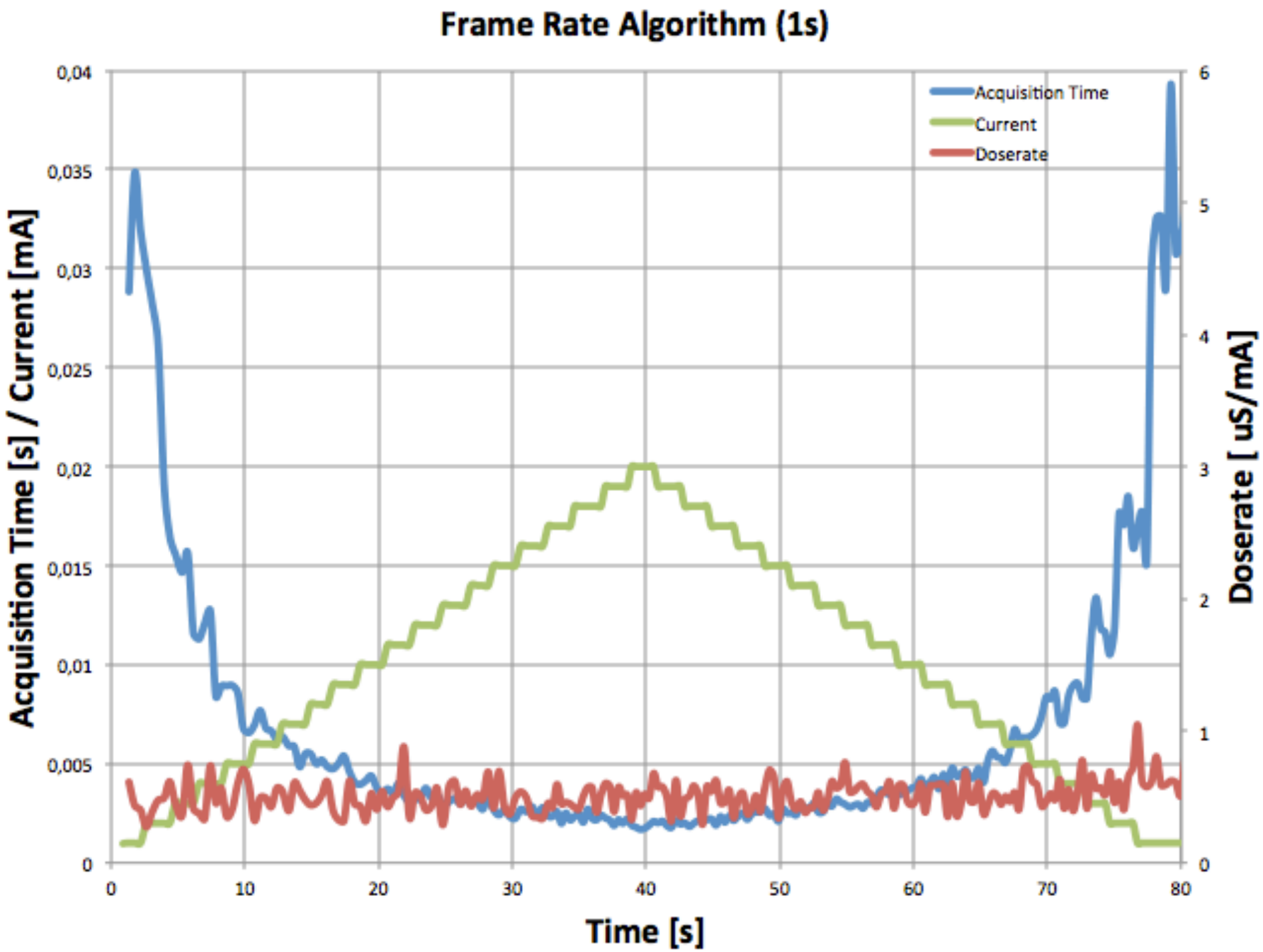
FRA Testing with X-Ray tube



FRA Testing with X-Ray tube



FRA Testing with X-Ray tube



Summary

- Timepix detector can be used for dosimetric measurements in ISS
- The software was tested at accelerators and it is working as expected
- The software is currently being evaluated at NASA
- Data measured in ISS will be used for further analysis and improvements of the software
- The software and hardware will be evaluated during a mission on ISS towards end of year 2011
- Patent application pending for use of Medipix for quantum dosimetry
- Patent pending for the frame rate algorithm

Thank you for your attention