LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

RADART

RAdiation **D**osimetry to **A**dvance **R**adio**T**herapy

Total FTE=10.7 (Researchers=2.4)

7 Researchers
8 PhD students
6 MSc students
3 Undergraduate students/Trainees
8 External collaborators

6+2 Articles in int. journals
1 LIP students note
1 Int. Oral presentations
2 Int. Poster presentations
2 PhD + **1** MSc thesis finished

SPOF array for high-res. dosimetry

- **New project SciMinT:** *Development of a real-time dosimeter for MBRT based on the SPOF array concept.*

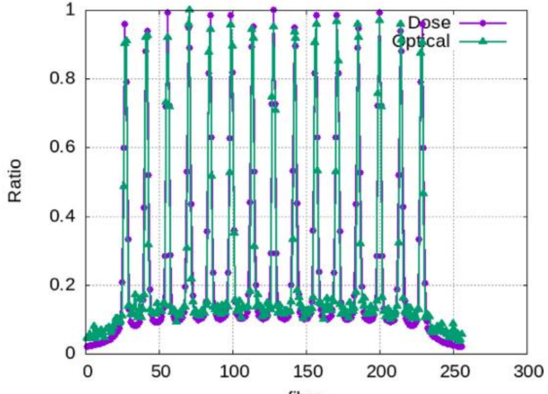
- **Detector requirements:**

  - High spatial resolution (250-500 μm);
  - Lateral fields spanning several cm;
  - High signal frequencies (> 30 MHz/channel) ⇒ **Dedicated electronics**
  - Radiation hardness;
  - Good physical durability;
  - Portability ⇒ redesign to a compact detector.

- **Project funded** (~60 k€) by FCT (2024.17923.PEX)

  - Collaboration with HollandPTC Protonen Therapie Centrum

FLUKA simulations



D. Guerreiro et al, RPC224 (2024)

Materials for micro- and nanodosimetry

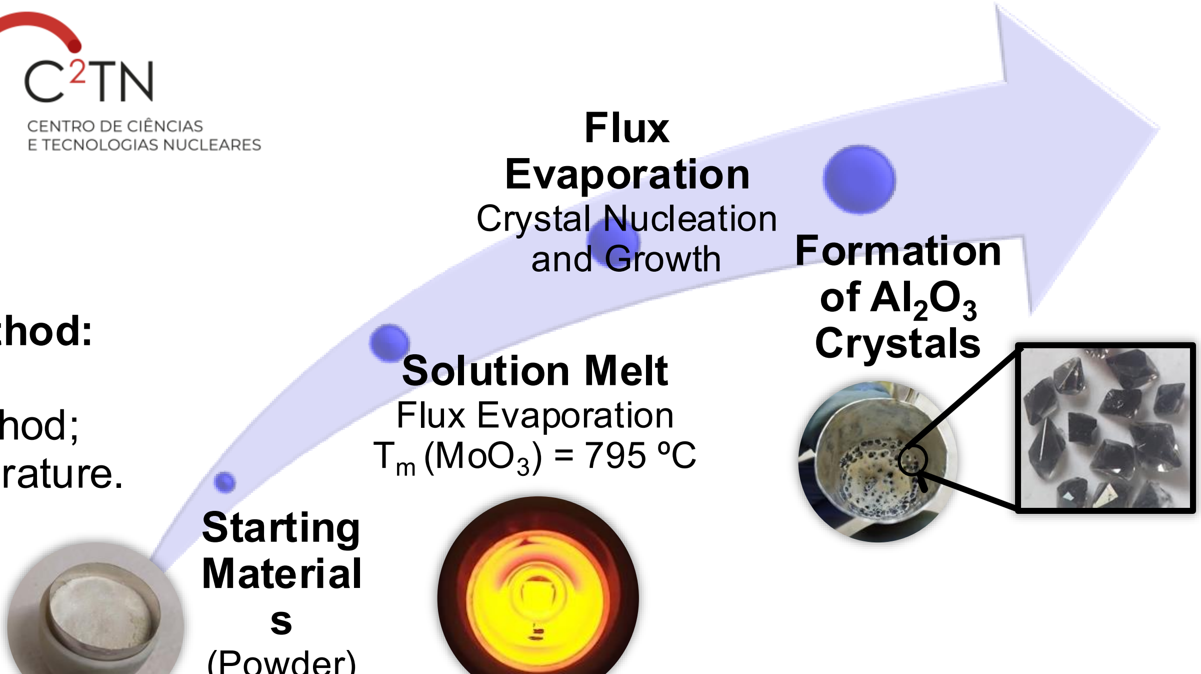
- **LUMIDOS project** (~50 k€) is ongoing (2023.15783.PEX): *Development of a new method to produce FNTDs based on alumina crystals.*

  ➢Collaboration with C²TN CENTRO DE CIÊNCIAS E TECNOLOGIAS NUCLEARES

- **Flux Evaporation Method:**

  ➢More accessible method;
  ➢Lower melting temperature.

  ⇒ **Cheaper**

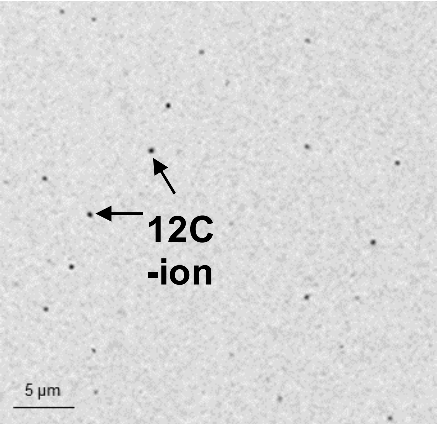


C. Rodrigues et al, SSS160 (2025)

Materials for micro- and nanodosimetry

- **First carbon irradiation tests at** HIT dkfz.
- C. Rodrigues delivered her PhD. Thesis. ⇒ **Waiting defence.**
- **Application to neutron detection** using HDPE as a converter:
  - Test irradiations with na AmBe source at Politecnico de Milano by the master student G. Rigolizzo in March 2026.

Flux-grown Al_2O_3 (F995)
$E(^{12}C)$ = 176.56 MeV/u
Fluence = $3 \times 10^5\ cm^{-2}$



- **SHIELD project** submitted to FCT **(~250 k€):** *Sustainable High-efficiency Electrospun nanofibers for Large area optically stimulated luminescence Dosimetry.*

- **PATHFINDER project** to be submitted: *Large Area High Granularity OSL Dosimetry for Advanced RT beam delivery.*

Modelling radiobiological effects ~~of NPs~~ in targeted RT

- J. Antunes delivered her thesis. ⇒ **Defence scheduled to May 19, 2026.**

- **Cell.DOT project** (~250 k€ total, ~70 k€ for LIP/RADART) is currently ongoing: *Studying the biophysical effects of targeted radiation therapy using 2D and 3D cell models.*

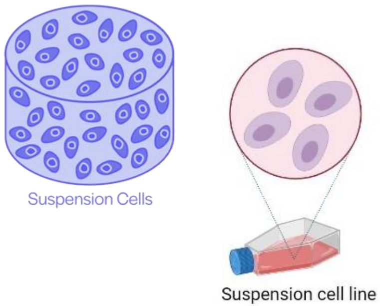
    - Use of advanced imaging tools to improve the accuracy of biological effect data;
    - Simulation of nanodosimetric patterns and ROS production;
    - Translation of these patterns into observed biological effects.

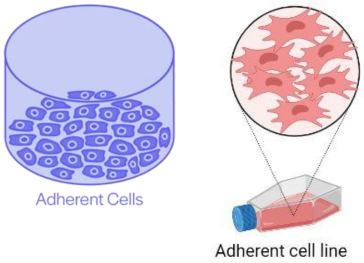
- Collaboration with

C²TN CENTRO DE CIÊNCIAS E TECNOLOGIAS NUCLEARES
iBB Institute for Bioengineering and Biosciences
UNIVERSIDADE D COIMBRA
P.PORTO

Modelling radiobiological effects ~~of NPs~~ in targeted RT

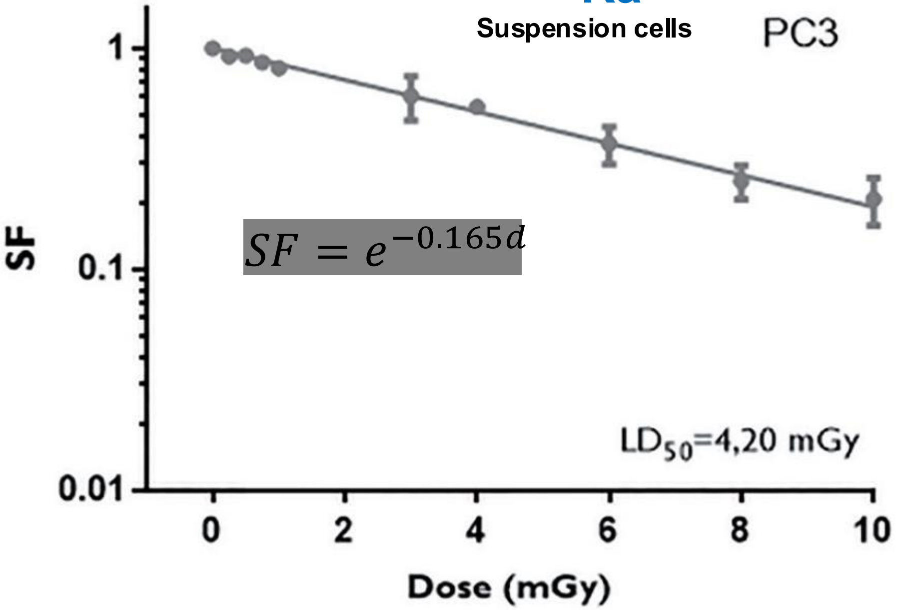
- Can we predict the response of one culture type (suspension or adherent) using data from the other?





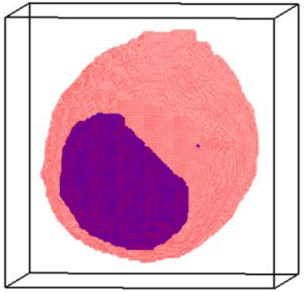
^{223}Ra

Suspension cells



$$SF = e^{-0.165d}$$

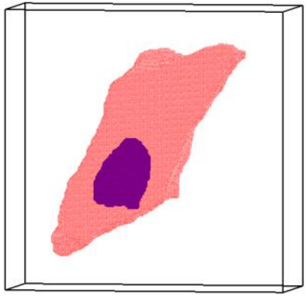
Modelling radiobiological effects ~~of NPs~~ in targeted RT

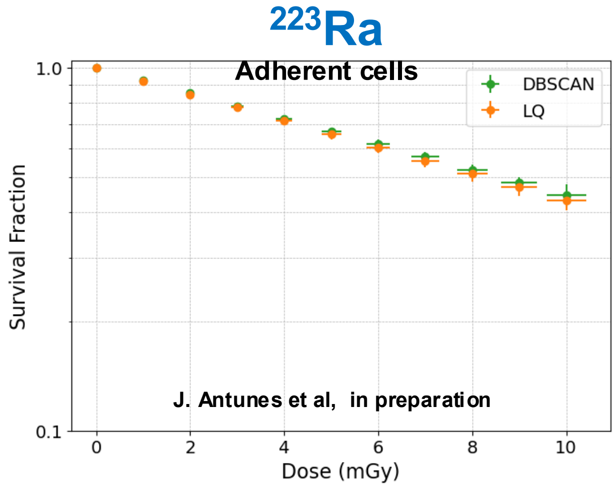


- Geometries reconstructed from **confocal microscopy.**

- MC simulations with TOPAS-nBio +

➢**LQ model** ⇒ needs expt .data for each cell culture;
➢**BDSCAN scorer** (SSB and DSB) ⇒ can use the data from one cell culture to predict the other.





LabExpoRad integration into RADART

- From 2026 the LabExpoRad group will be integrated in RADART.
- LabExpoRad: *Establishing sensitive biological models for radon toxicity.*
- **Paradigm shift**:

2025: Environmental baseline	
Model	Plant systems
Biomarkers	Morphological growth, phenolic compoud fluctuations
Goal	Ecotoxicology and environmetla radiobiology

⇒

2026: Translational health	
Model	Human cellular model
Biomarkers	Mitochondrial DNA damage, targeted cytotoxicity, genotoxicity
Goal	Elucidating indirect oxidative stress mechanism in human cells.

➢ Advancing from environmental radiobiology towards human-centred translational radiobiology

SWOT

Strengths

- High-expertise
- Collaborations with national and international research groups
- Financial support from the LUMIDOS, Cell.DOT, and SciMinT projects

Weaknesses

- Heavy teaching and administrative workload for senior researchers
- Lack of long-term resources to retain early-career researchers

Threats

- No dedicated PhD program
- Increasing trend among M.Sc. students to enroll in universities abroad
- A couple of senior researchers are expected to retire within the next 2–3 years

Opportunities

- More than 10 new PT centres in Spain and one in Porto, Portugal
- Attract students from abroad
- Integration of the LabExpoRad group
- A new senior researcher from Rio de Janeiro may join the team

Backup slides

Luminescence Dosimetry for radiobiology

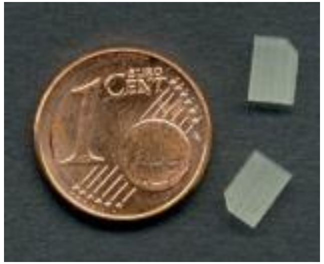
Optically Stimulated Luminiscence (OSL)

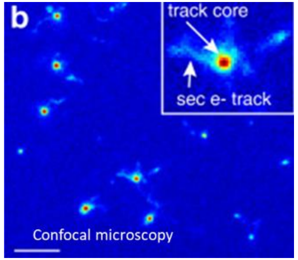
RM133 (2020)

J. Christiense et al, PMB66 (2021)

Fluorescent Nuclear Tracking Detector (FNTD)

- 3D particles interaction mapping with excellent resolution (nm)
- **Al_2O_3:C,Mg** crystals ⇒ **Dosimetry of heavy particles**
  - No saturation (LET ≤ 1800 keV/µm)
  - No processing prior to readout
  - Limited sensitivity for low-LET radiation

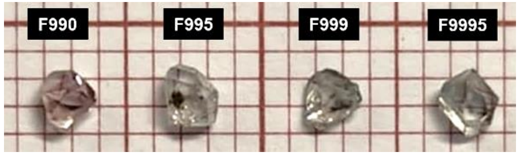


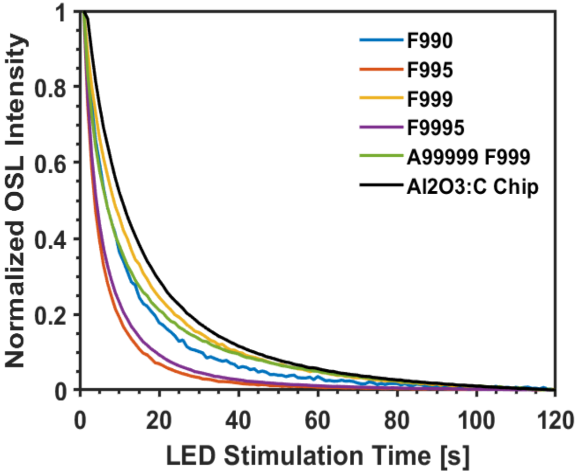


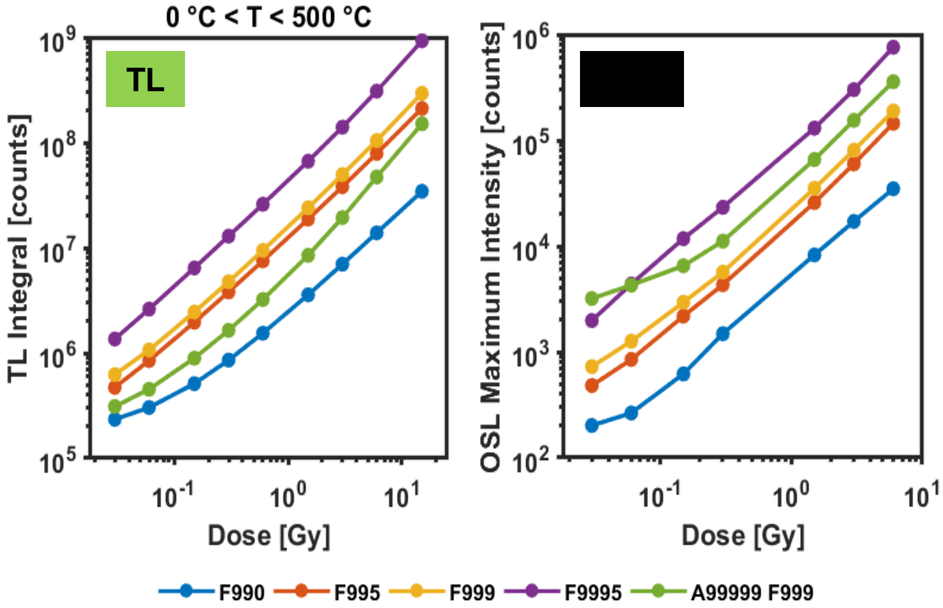
M. Niklas et al, RO8 (2013)

M. Akselrod et al, NIMB247 (2006), RM46 (2011), RM133 (2020)

Influence of flux purity on luminescence



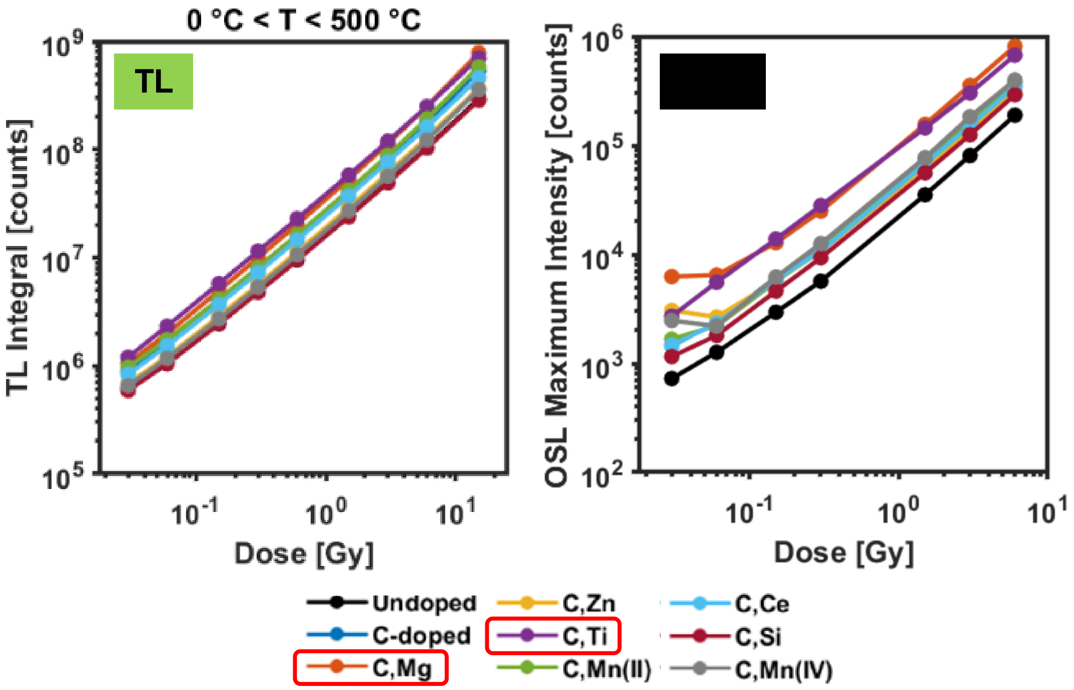




- 99.5 % purity flux produces crystals with fastest decay

- TL and OSL strongly correlates with MoO_3 flux purity

Influence of dopping



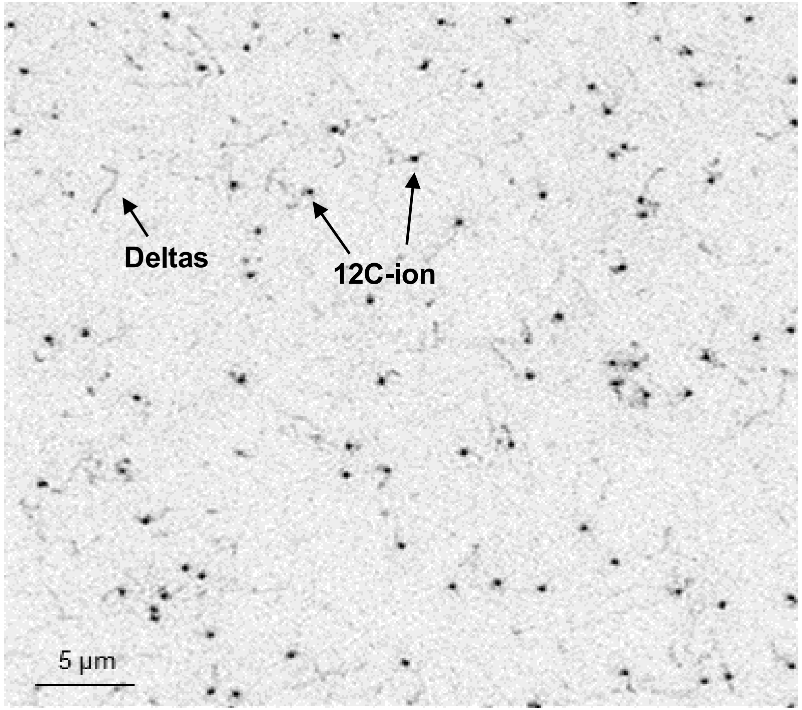
- Doping improved TL and OSL responses, outperforming F999

First irradiation tests

Al_2O_3:C,Mg LANDAUER

$E(^{12}C)$ = 118.52 MeV/u

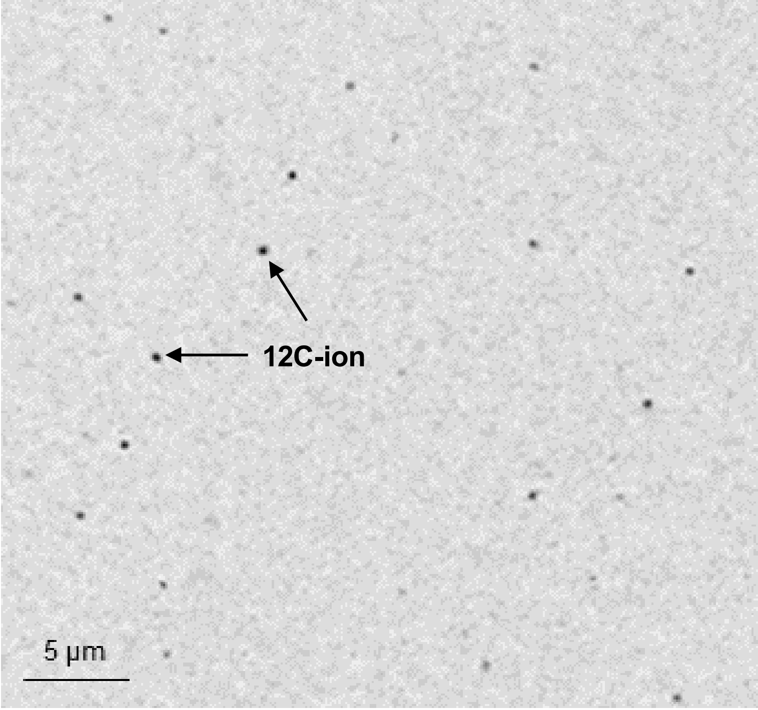
Fluence = 2 × 10^6 cm^{-2}



Flux-grown Al_2O_3 (F995)

$E(^{12}C)$ = 176.56 MeV/u

Fluence = 3 × 10^5 cm^{-2}



DBSCAN scorer

```
# DBSCAN configuration parameters
d:Sc/DBSCAN/MinimumDistanceForDSB        = 3.2 nm
u:Sc/DBSCAN/SampleHitsWithProbability    = 0.16
d:Sc/DBSCAN/LowerEnergyForSamplingSSB    = 5.0 eV
d:Sc/DBSCAN/UpperEnergyForSamplingSSB    = 37.5 eV
i:Sc/DBSCAN/MinimumNumberofSSBtoFormDSB  = 2
```

1. Record ionization events from MC simulation

Collect the 3D spatial coordinates of all ionization events occurring within the sensitive volume from individual particle tracks.

2. Apply energy-based probability filter

Assign a damage probability to each ionization event based on its deposited energy;
This models the likelihood that an energy deposition can initiate DNA damage.

3. Apply SPointsProb filter

From the remaining events, randomly accept each with a fixed probability (SPointsProb = 0.16);
This accounts for the chance that an ionization event actually reaches and affects DNA, either directly or via free radicals.

4. Run DBSCAN algorithm

DBSCAN groups the filtered events into clusters of dense energy deposition.

5. Extract cluster-level metrics

Cluster size (Number of ionization events inside each cluster) and cluster weight.

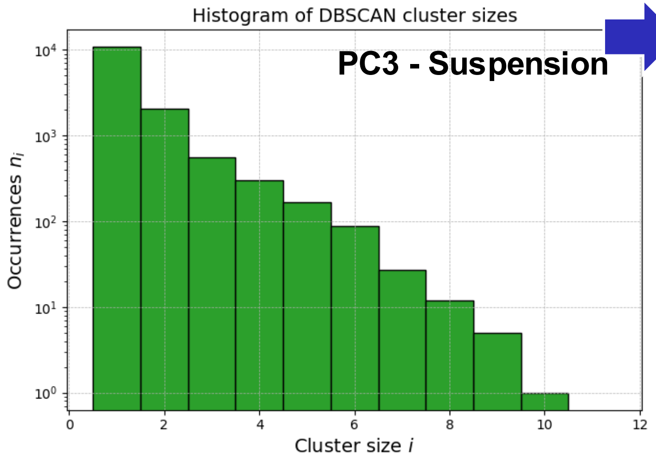
6. Classify DNA damage in SSB or DSB

Survival Fraction from DBSCAN

$$SF = \exp(-N_{lethal}) \qquad N_{lethal} = \sum n_i w_i \qquad w_i = k i^{\gamma}$$

$n_i \rightarrow$ number of clusters with size i

k and $\gamma \rightarrow$ free parameters, determined by fitting the model to experimental data.



$k = 0.8$
$\gamma = 3.74$

Apply the model to the MC data obtained using the **adherent** cell model