Ionisation of a single nanoparticle by heavy Cosmic Rays
NanoCR experiment

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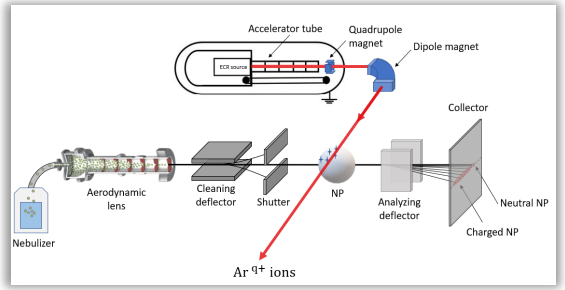
Outline

- Scientific Motivation
- Experimental Set-up
- Data reduction
- Results
- Conclusion

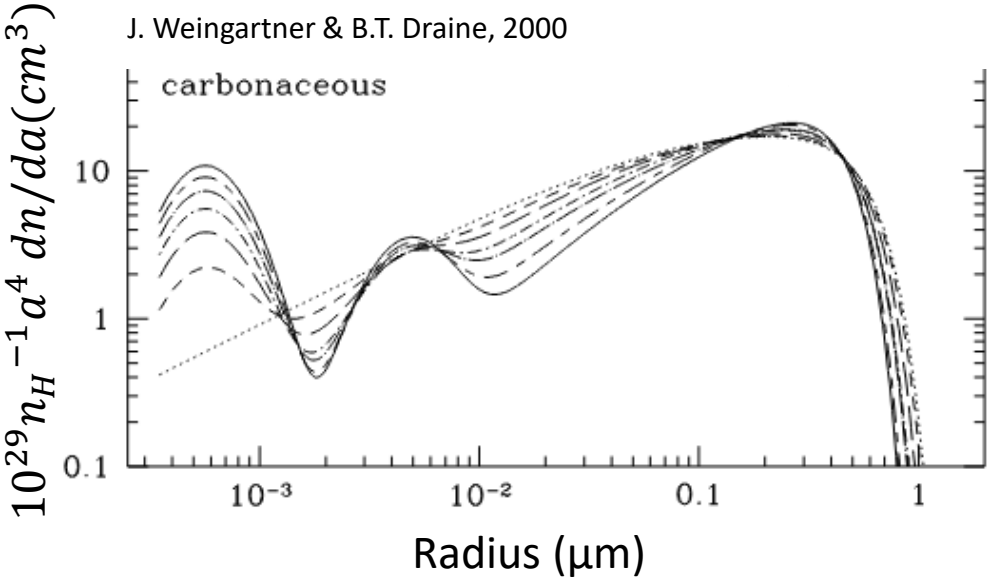


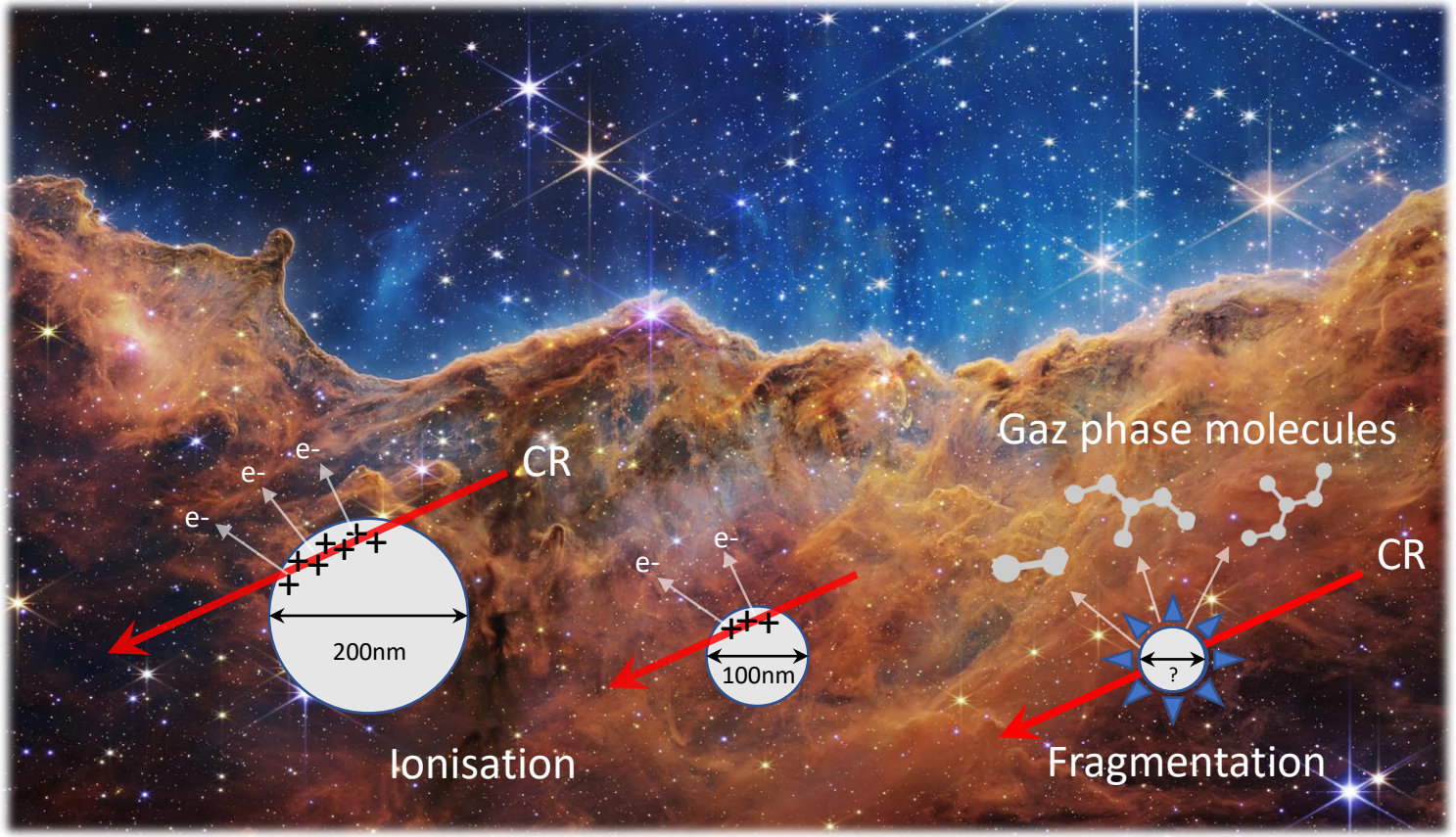
Astrochemistry in the Interstellar Medium

- Gaz (H, He) & Dust (C, Si)
- Chemical Reactions
- UV irradiation
- Cosmic Rays :

Particle Rays Eliciting Fragmentation in Organic Units

J. Weingartner & B.T. Draine, 2000





Cosmic Ray / Interstellar dust interaction scheme
Cosmic Cliffs, NASA, ESA, CSA, and STScI

Complex molecules in space ?

Physics Inputs

H gas density

Ionisation rate

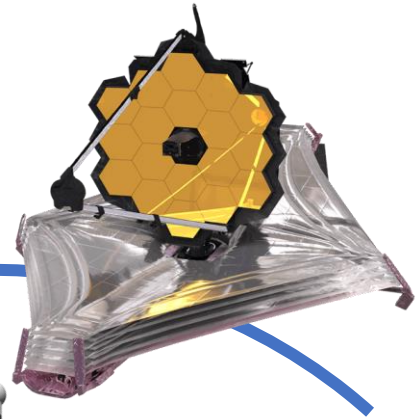
Cosmic Ray Spectrum

Cross section

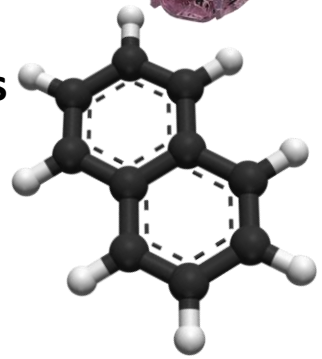
Dust size distribution

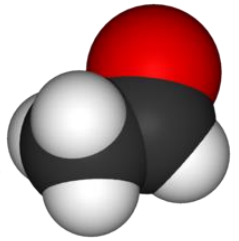
Fragmentation size limit ??

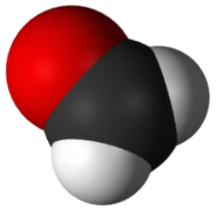
Astrochemistry simulations

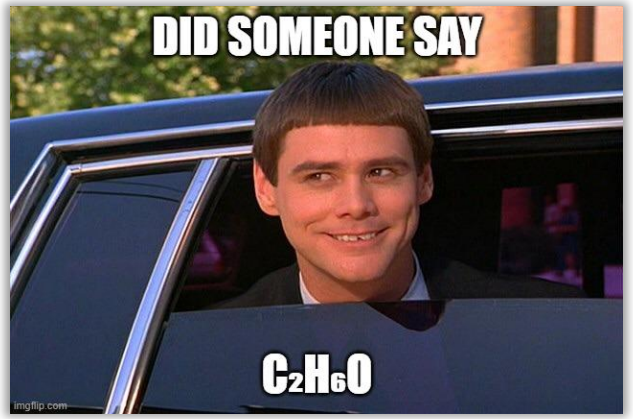


Observed Molecules









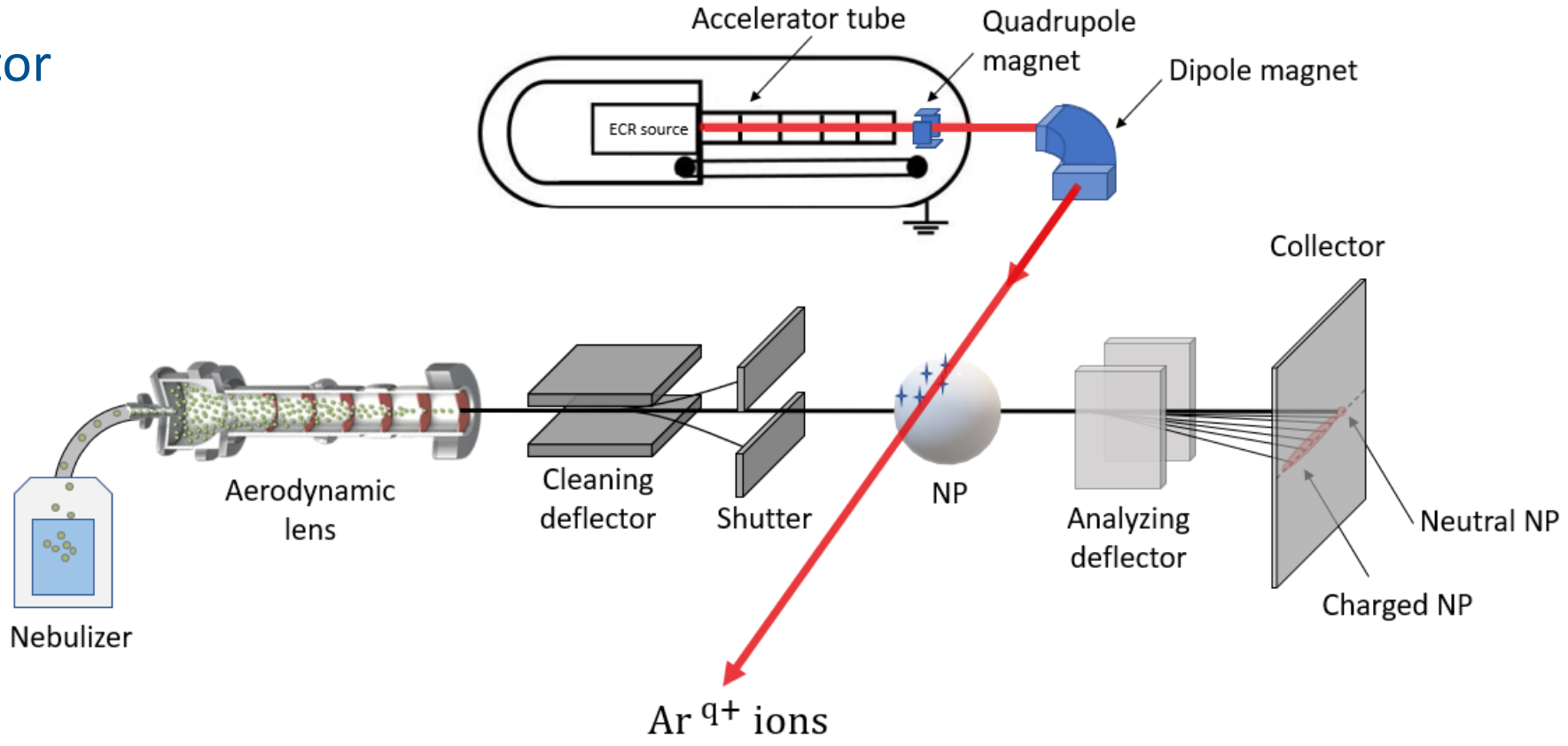
Experimental Set-up : NanoCR

- Cosmic Rays :

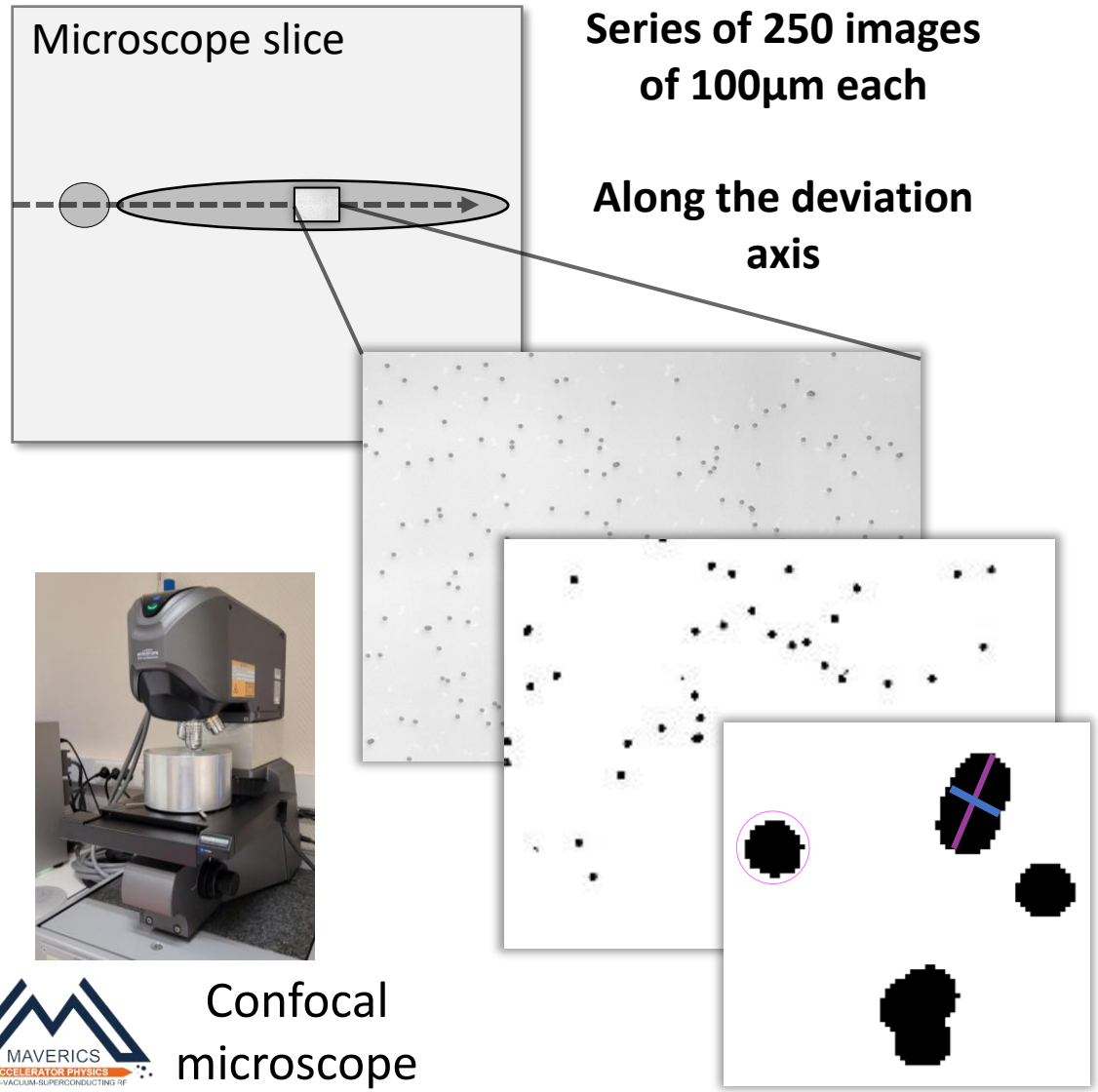
Argon ions produced by
4 MV electrostatic accelerator

- Dust Grains:

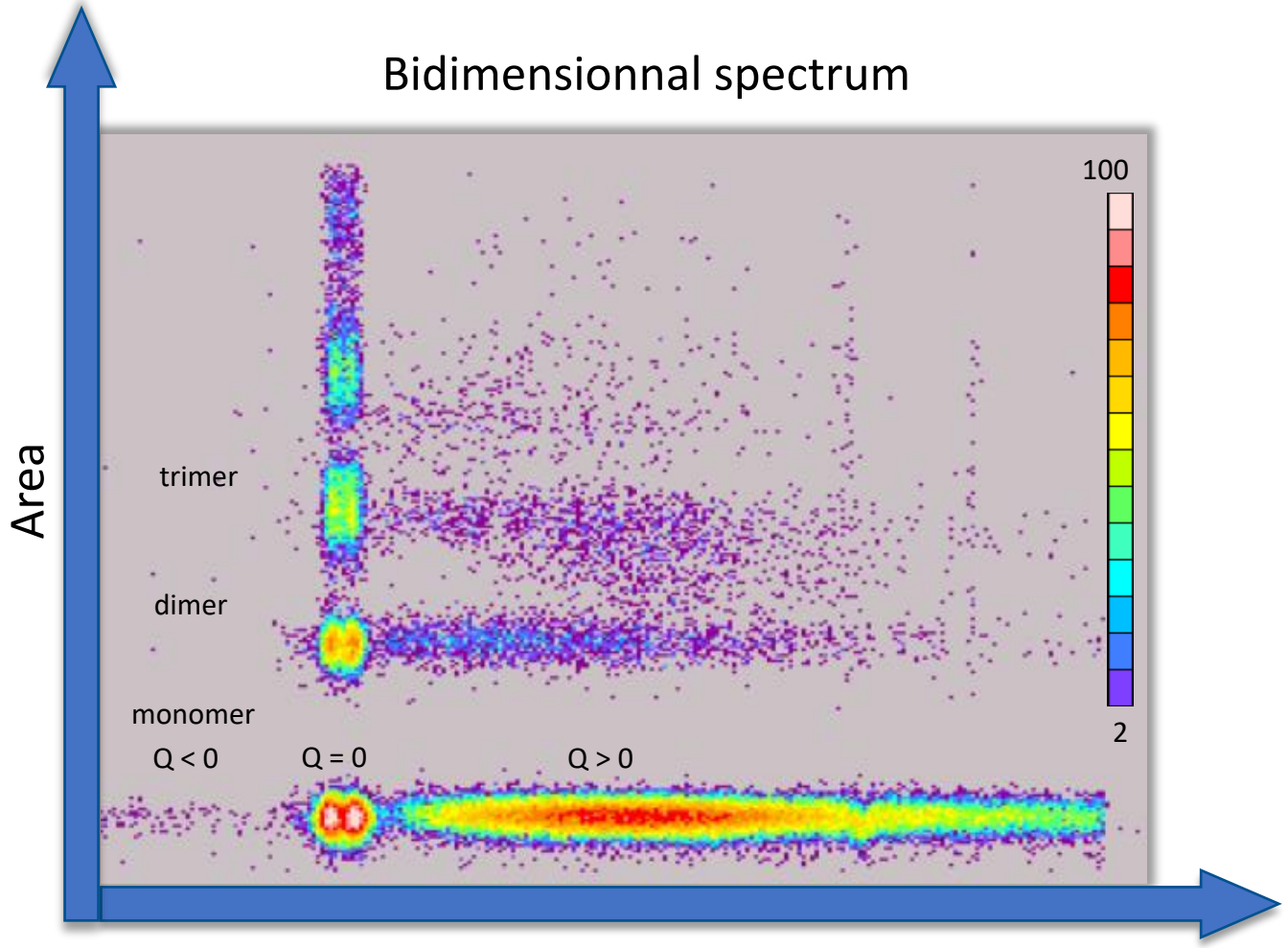
100nm radius Polystyrene
Monodisperse
Nanoparticles



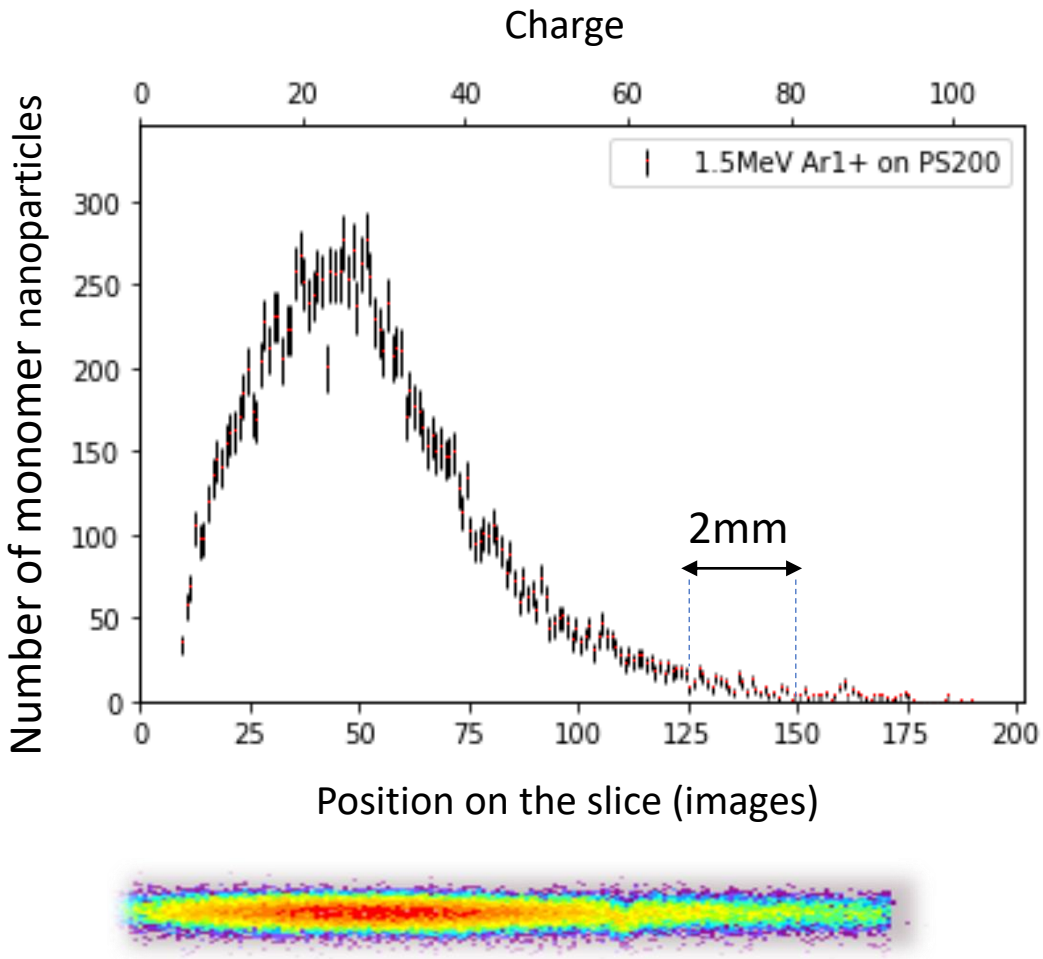
Experimental Set-up : Microscope

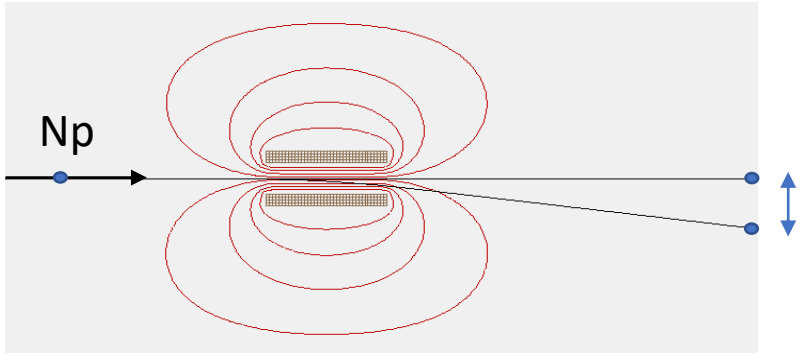


Confocal microscope



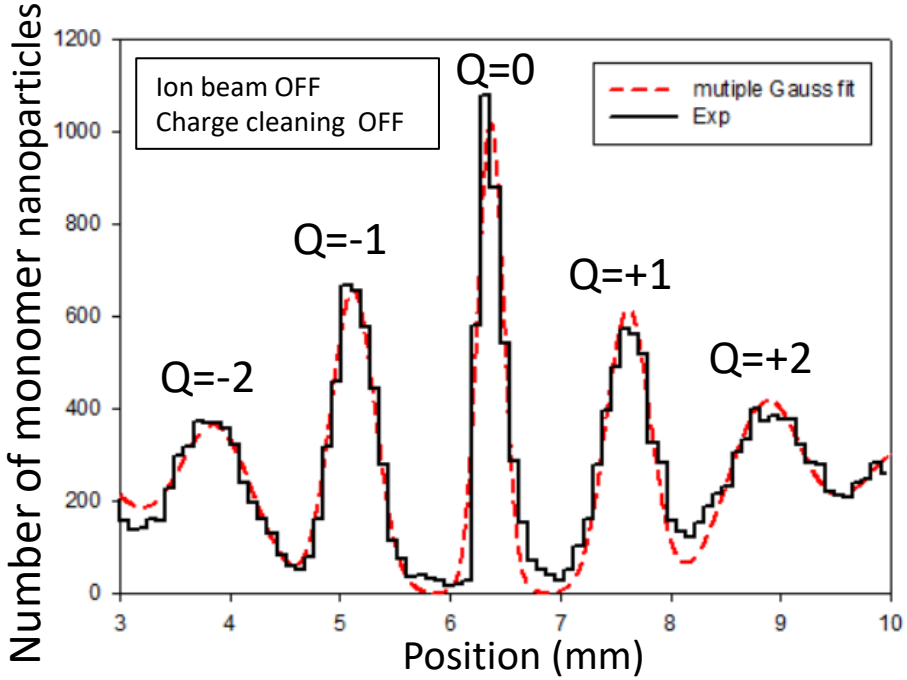
Data reduction : System Response





Analyzing deflector
SIMION scheme

$$\Delta x = q \times \alpha$$

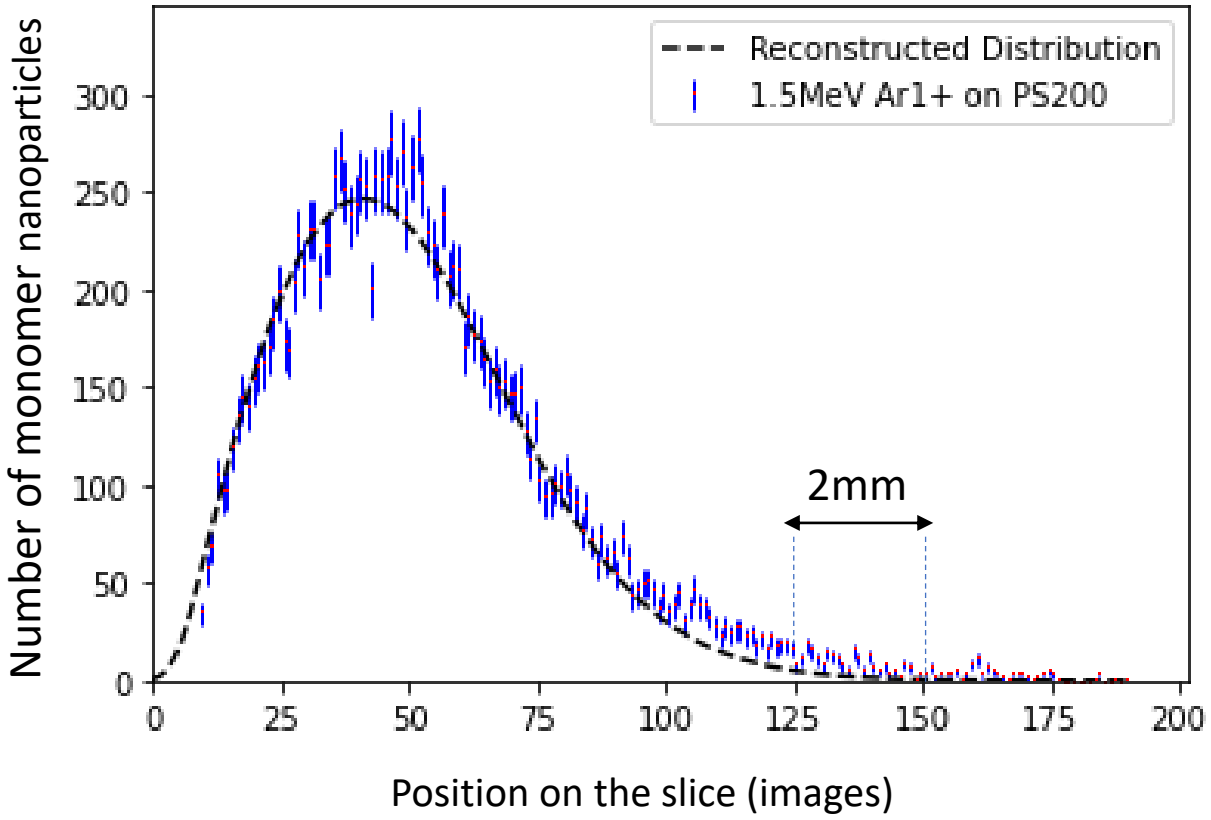


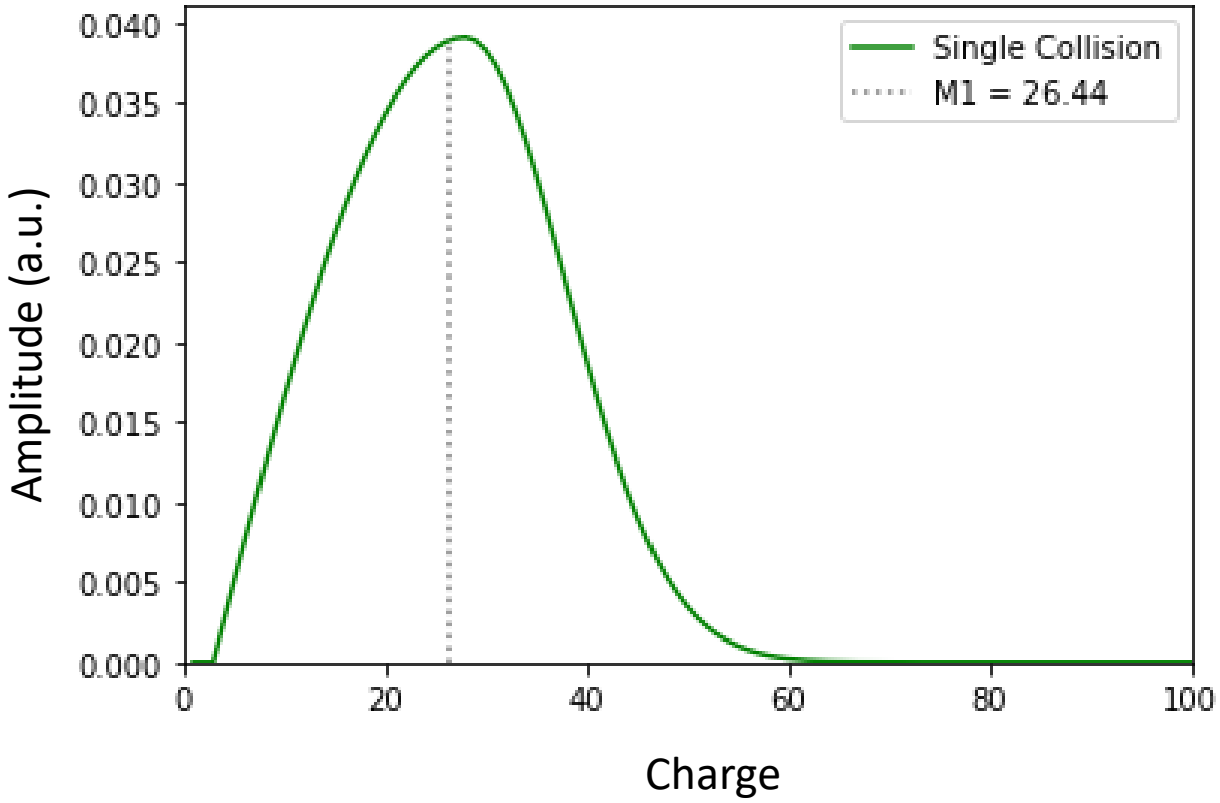
$$\sigma_q = \sqrt{\sigma_0^2 + (q \times \sigma_E)^2}$$

$$R(q, x_q, \sigma_q) = \sum_q \frac{1}{\sqrt{2\pi}\sigma_q} e^{-\frac{(x-x_q)^2}{2\sigma_q^2}}$$

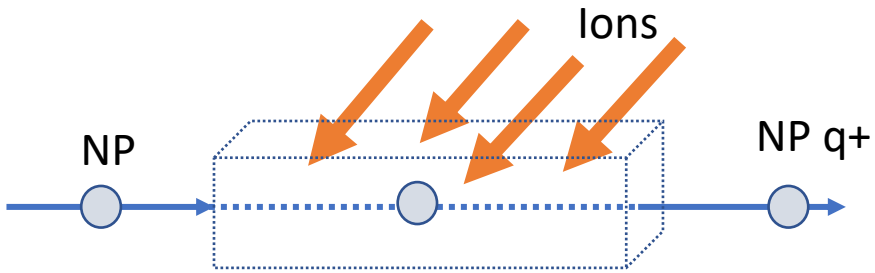
Data reduction : Reconstruction method

$$\text{Minimization}\ [\ \text{Exp}(x) - \sum_{q>0} D(q) * R(q, x_q, \sigma_q)\ ]$$

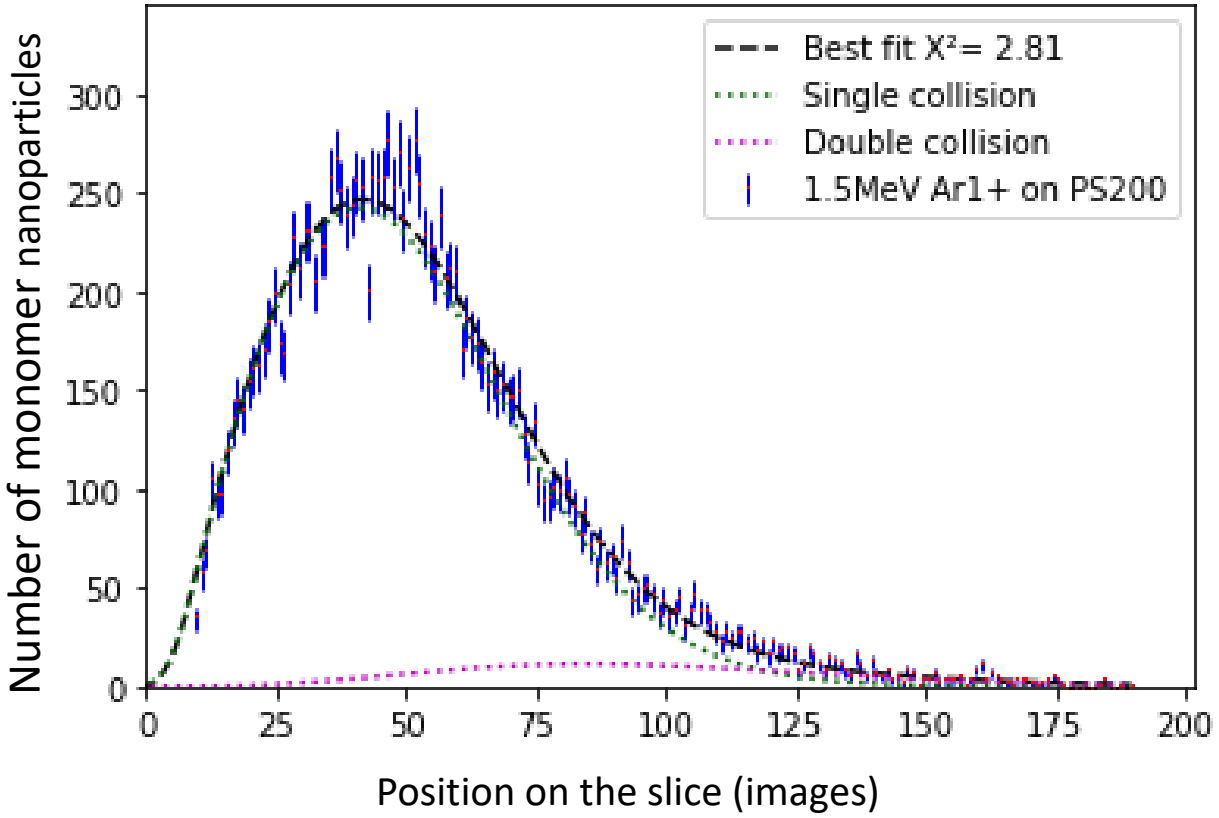


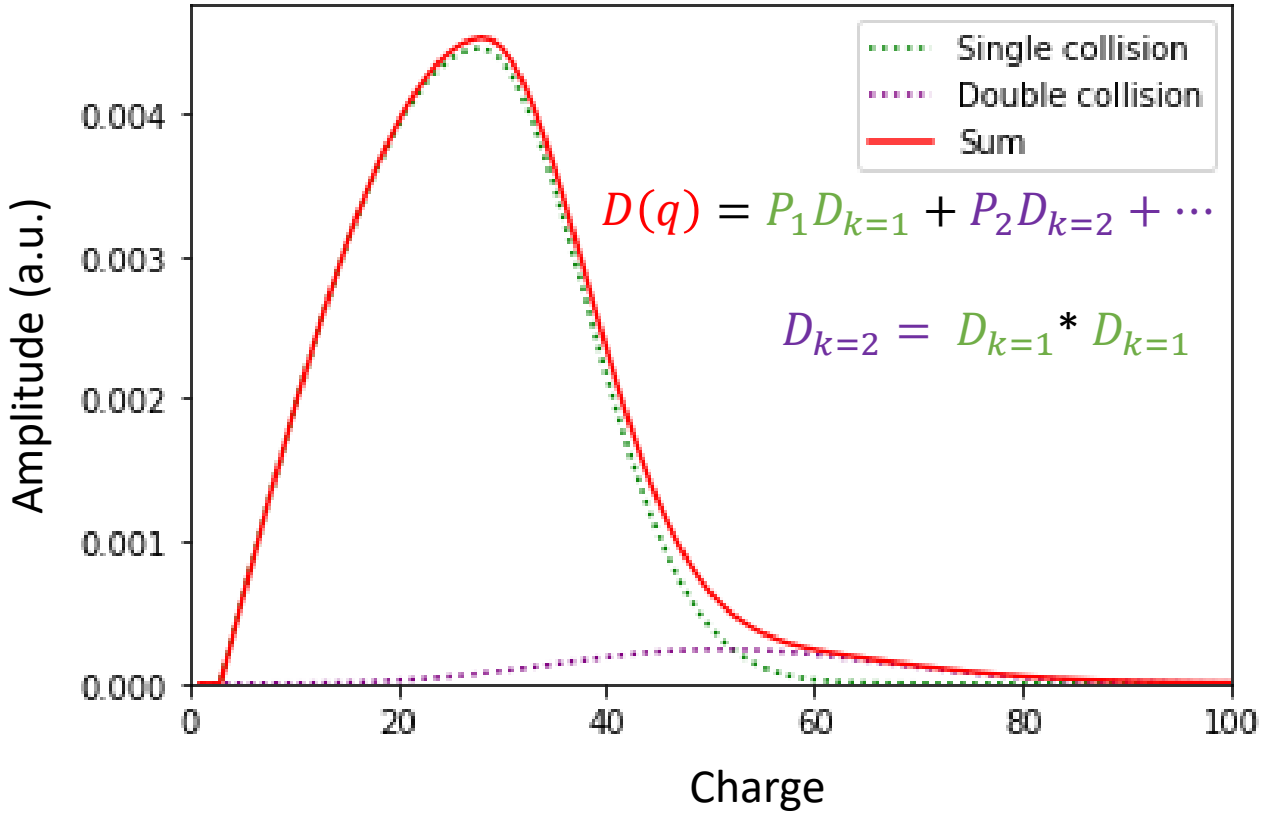


Data reduction : Multiple Collision

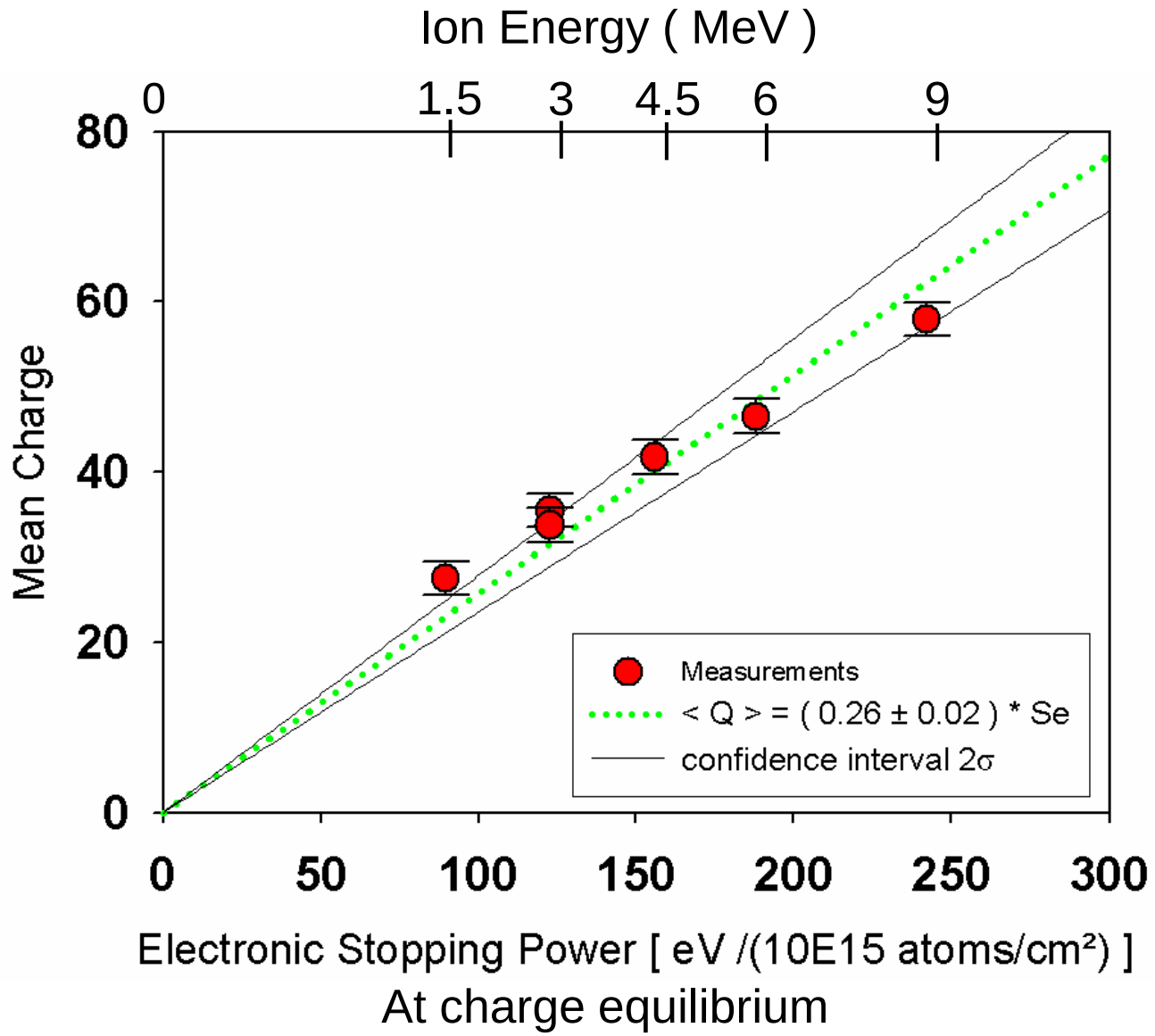


Poisson's Law : $P_k = \frac{\lambda^k}{k!} \times e^{-\lambda}$





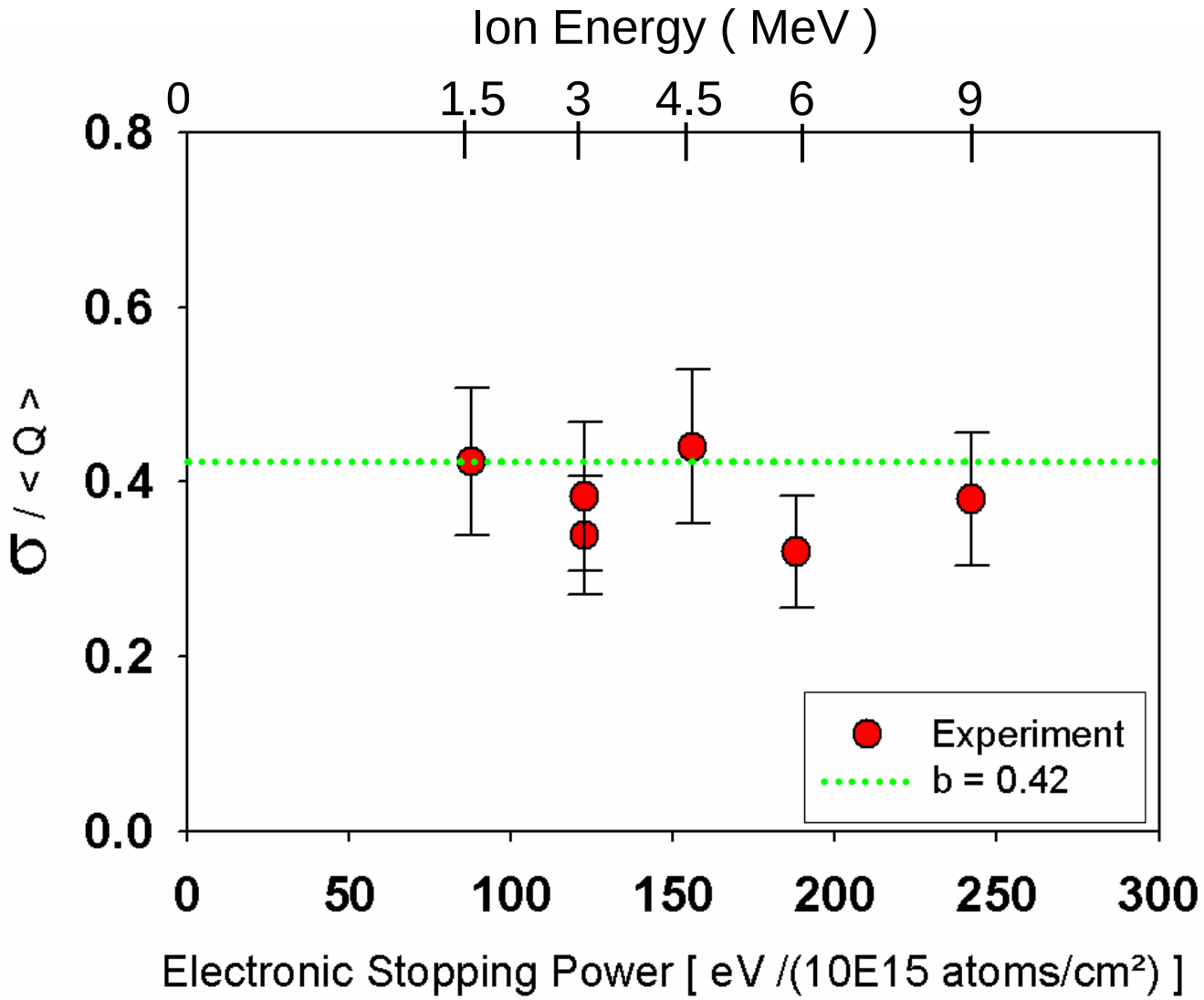
Results : Mean Charge



Analysis of Single Collision Charge Distribution for each beam energy

Mean charge is linear with the electronic stopping power

Results : Distribution Shape

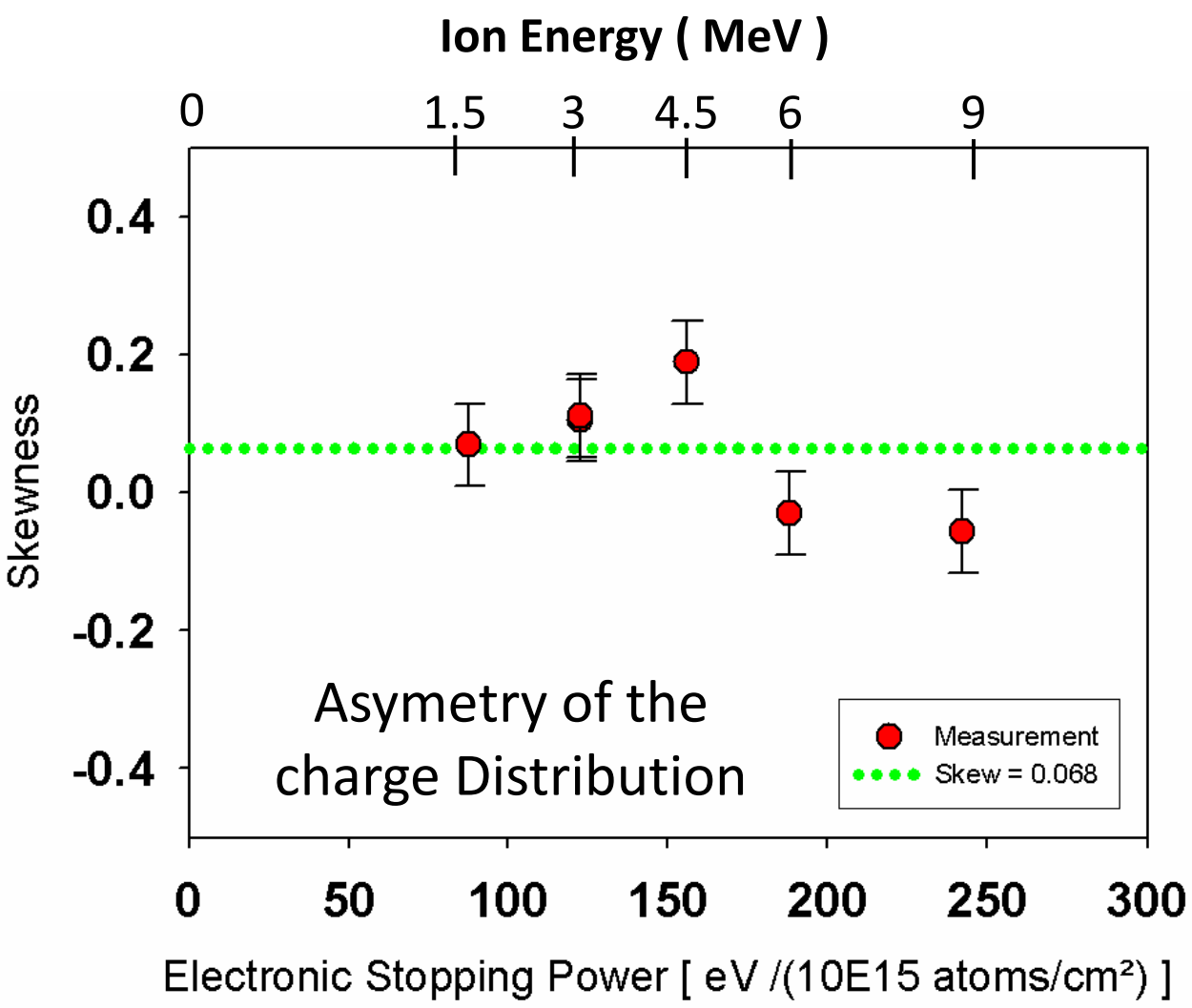


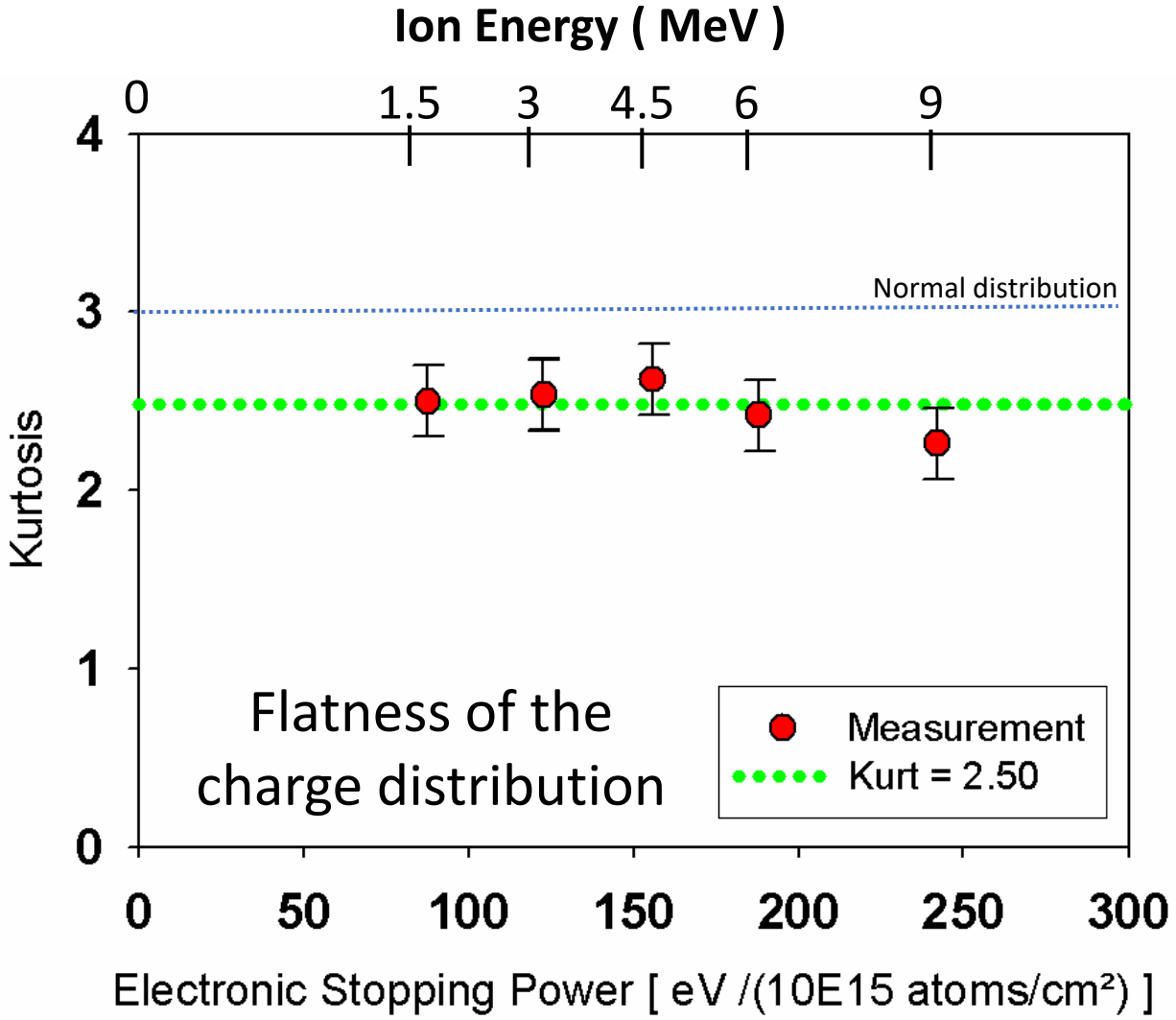
$$\sigma = \sqrt{M2}$$

M2 is the 2nd order moment of the distribution (width)

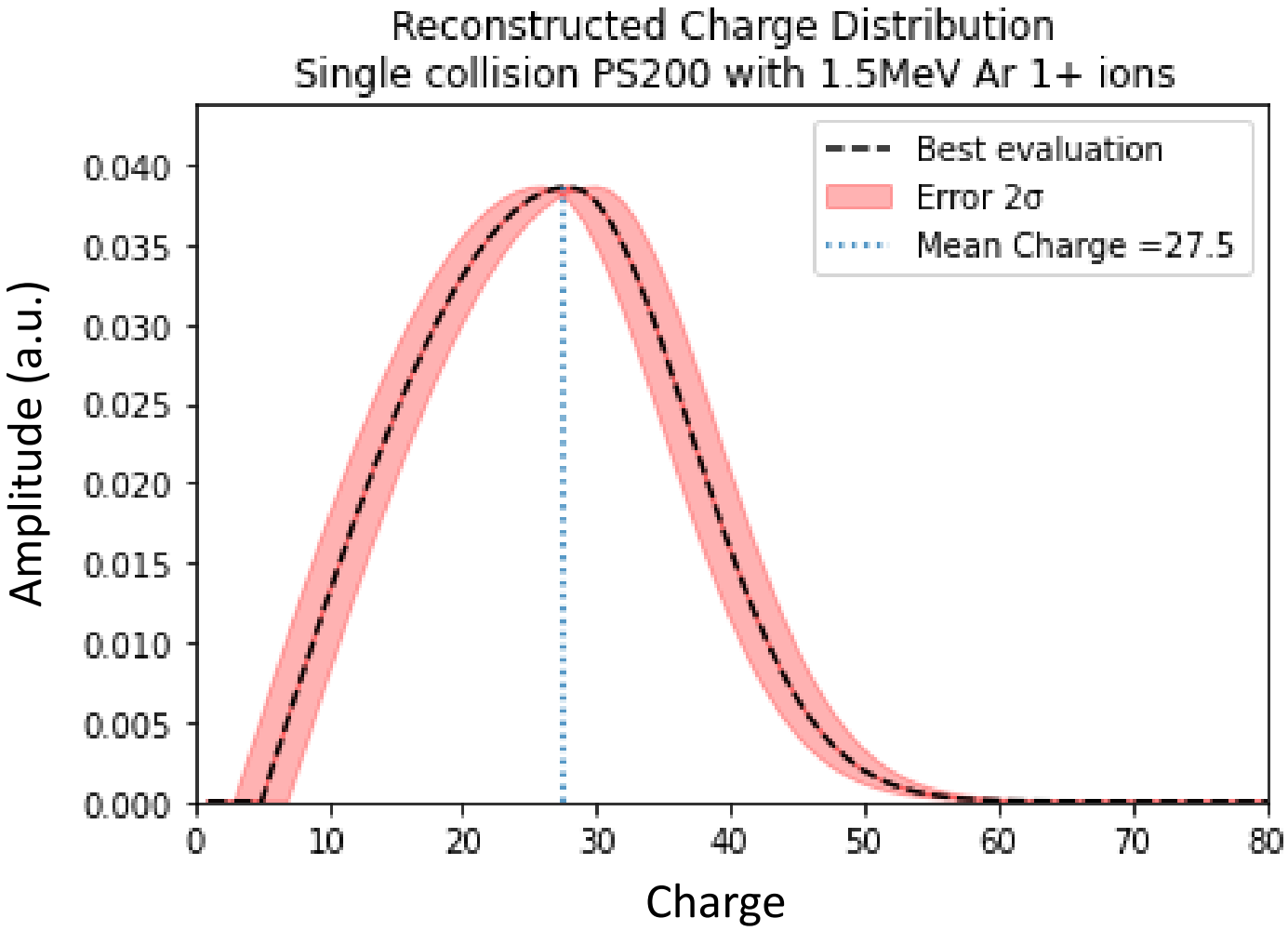
Stay constant with the Electronic stopping power

Results : Distribution Shape





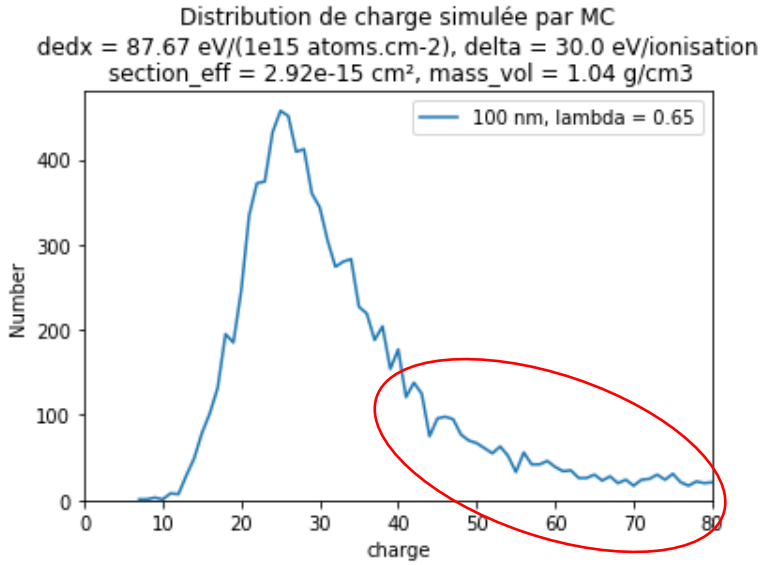
Results : Generic shape

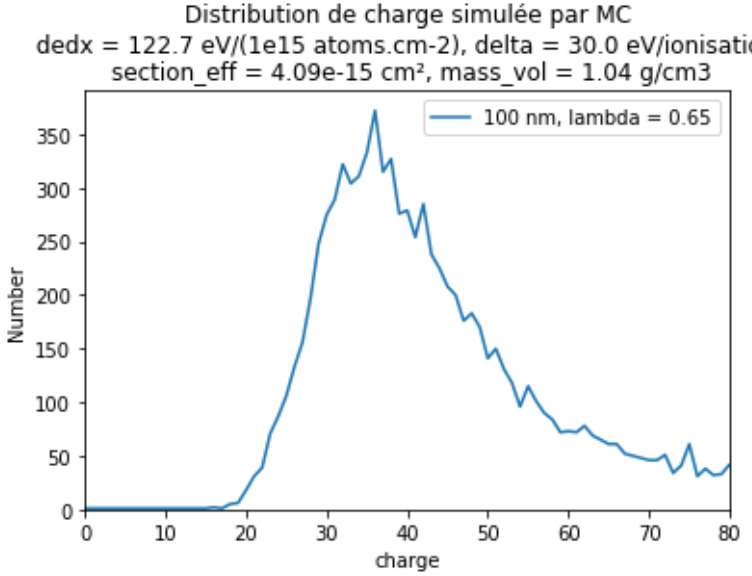


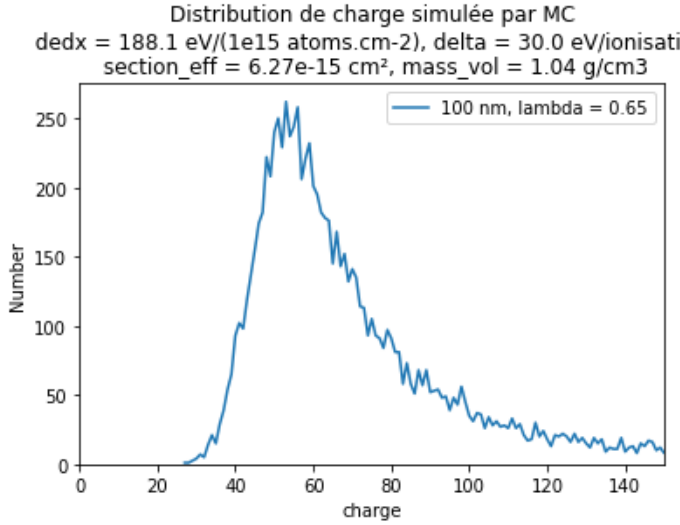
Single collision distribution
Generic shape

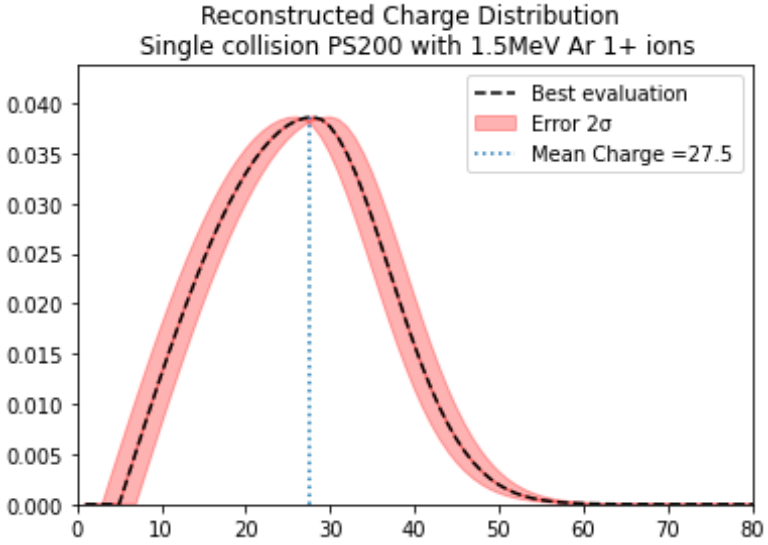
Near Gaussian ;
Little tail for high charge
Rough cut at low charge

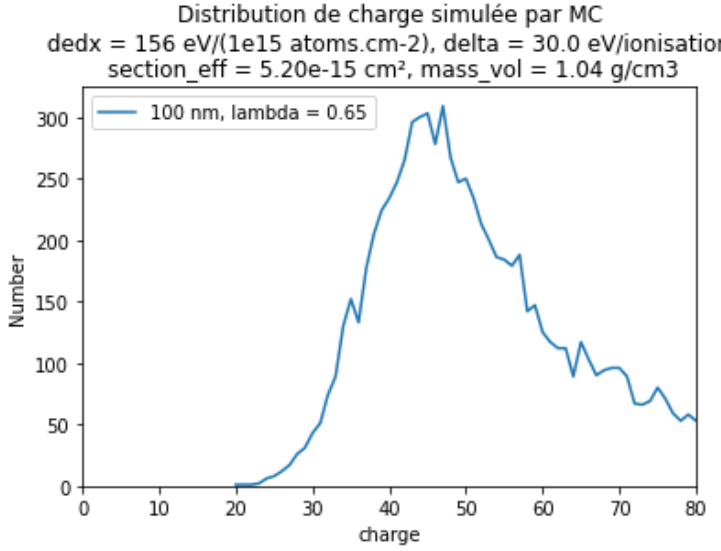
MC Simulation

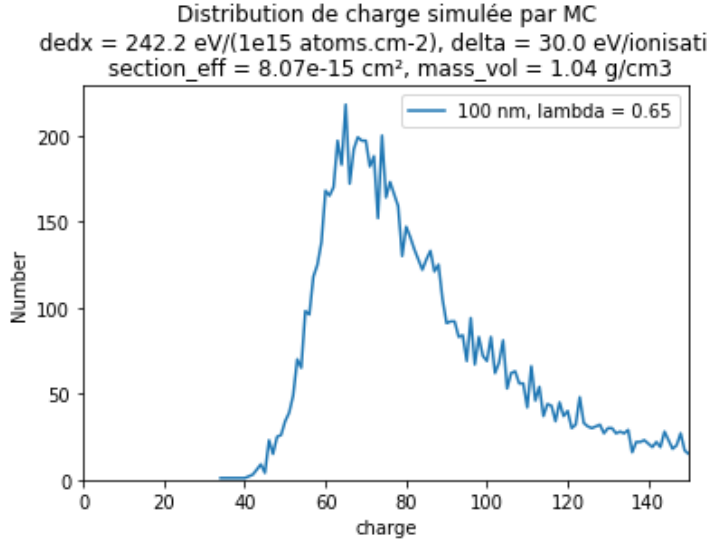












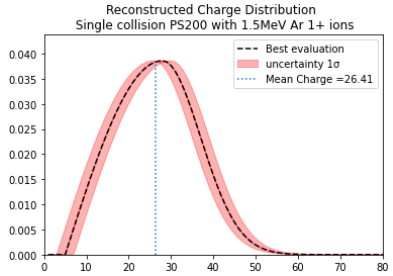
Conclusion

For now :

First view of Single Collision Charge Distribution

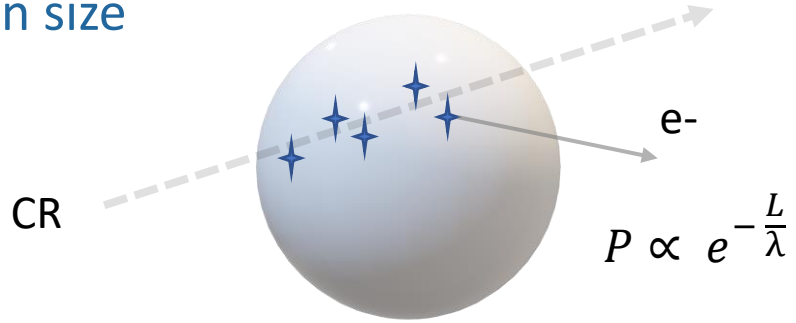
Mean charge grows linearly with Stopping power ; shape is roughly the same

Results obtained from 1.5 – 9MeV Ar ions on PS200 experiments

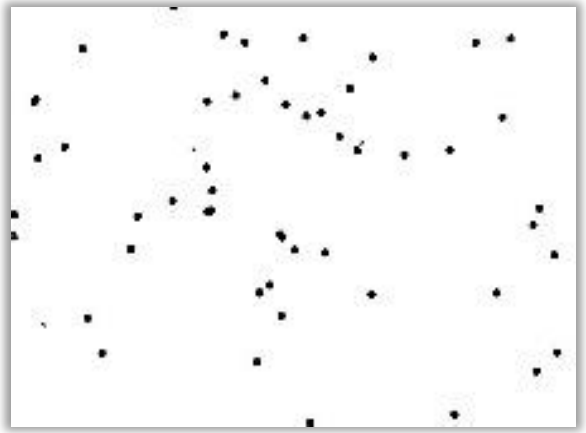


To do:

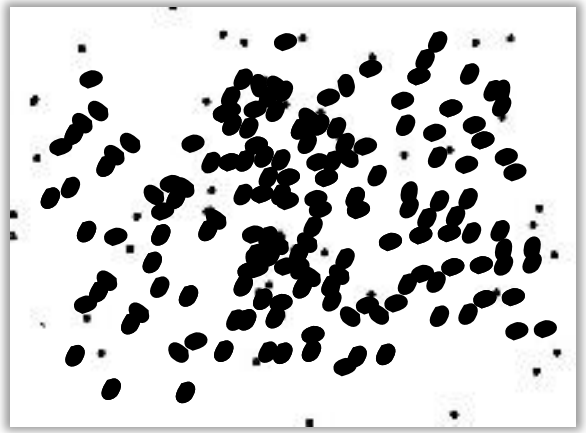
- Make a Dust/CR interaction model that reproduce the Data. MC v1.0 done.
- Compute Ionisation cross-section of dust grains for an associated grain size distribution
- Compute Ionisation rate of dust grains
- Next run on different size maybe Si



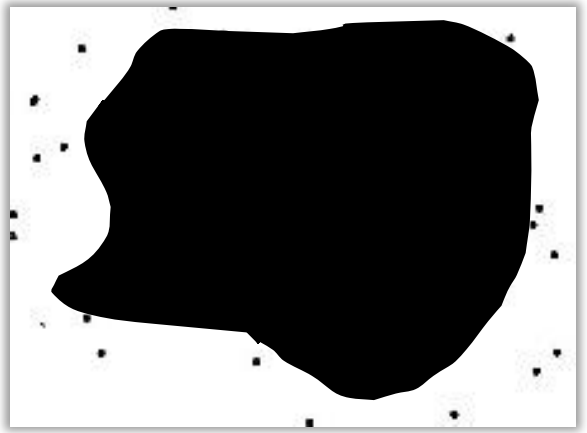
Thank you for your attention



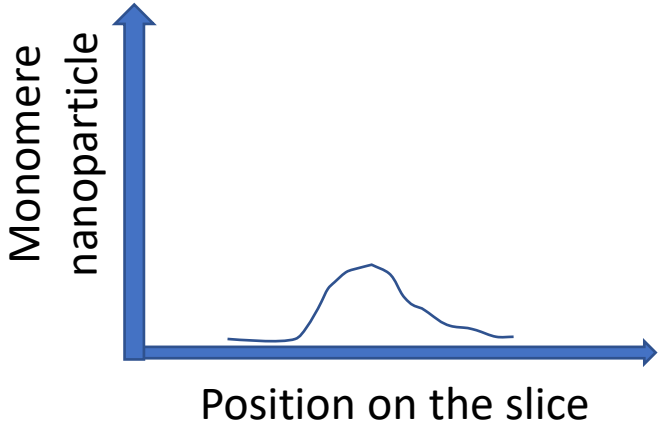
Enough statistics
N~50

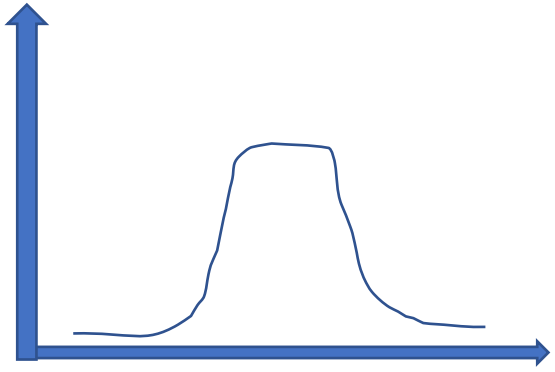


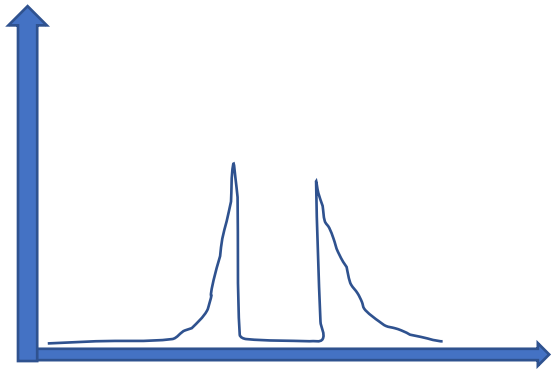
Piling up !
N~70??



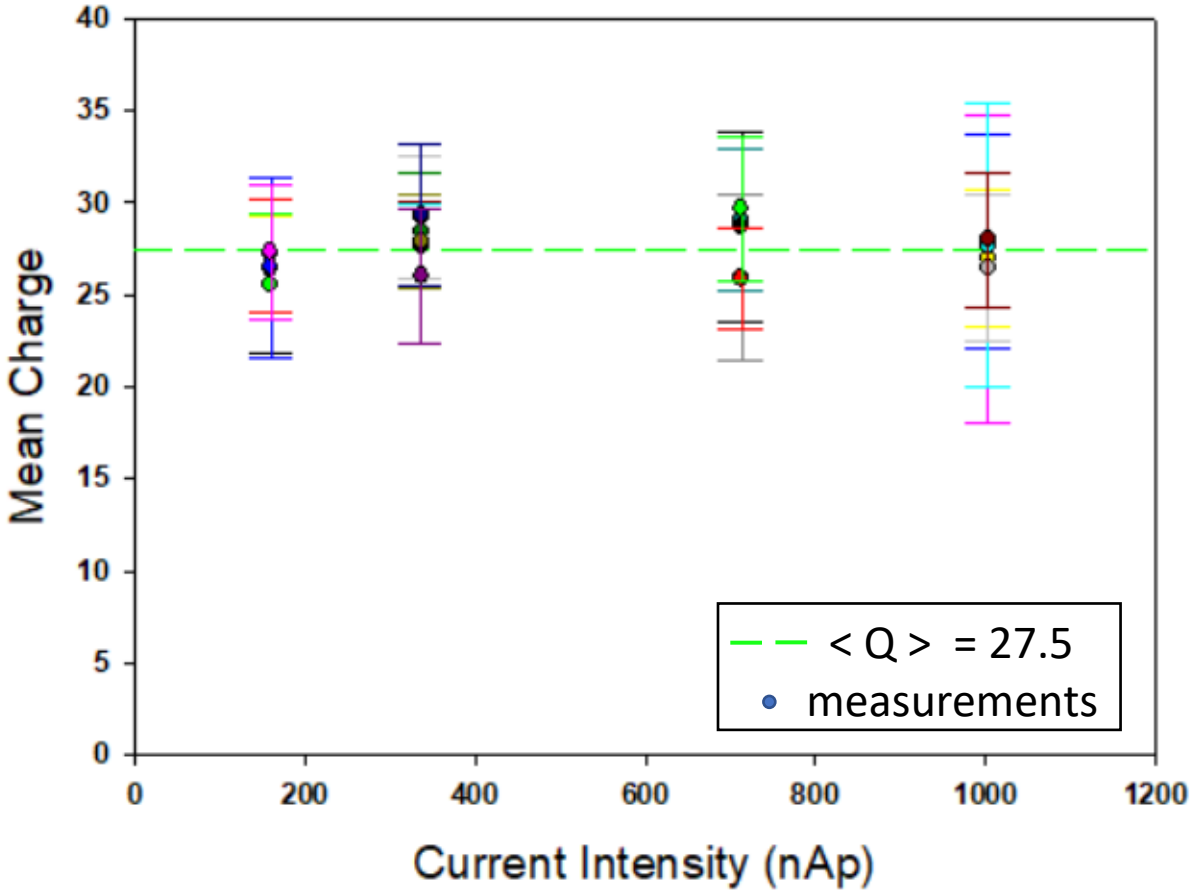
Nice crust…
N=NaN

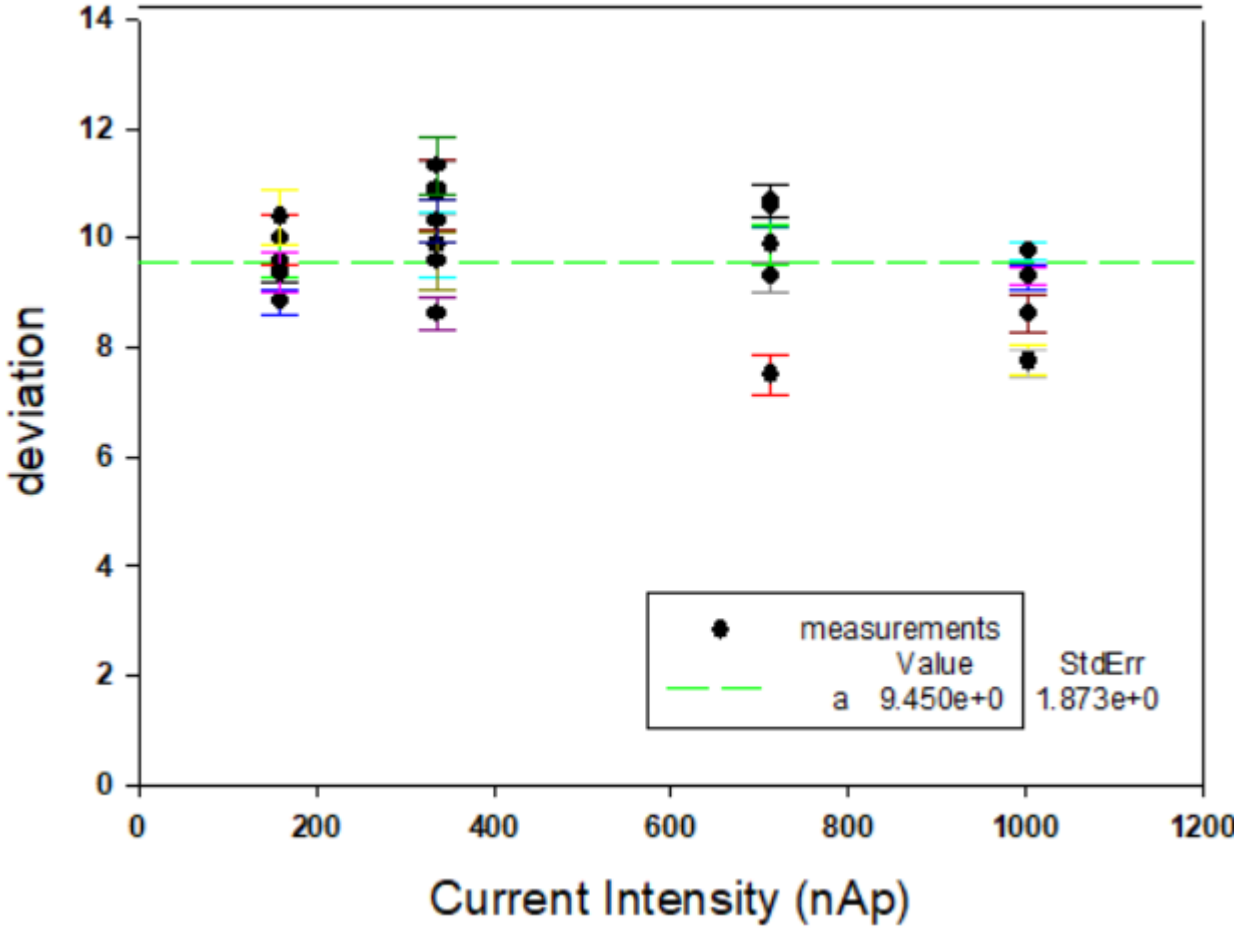




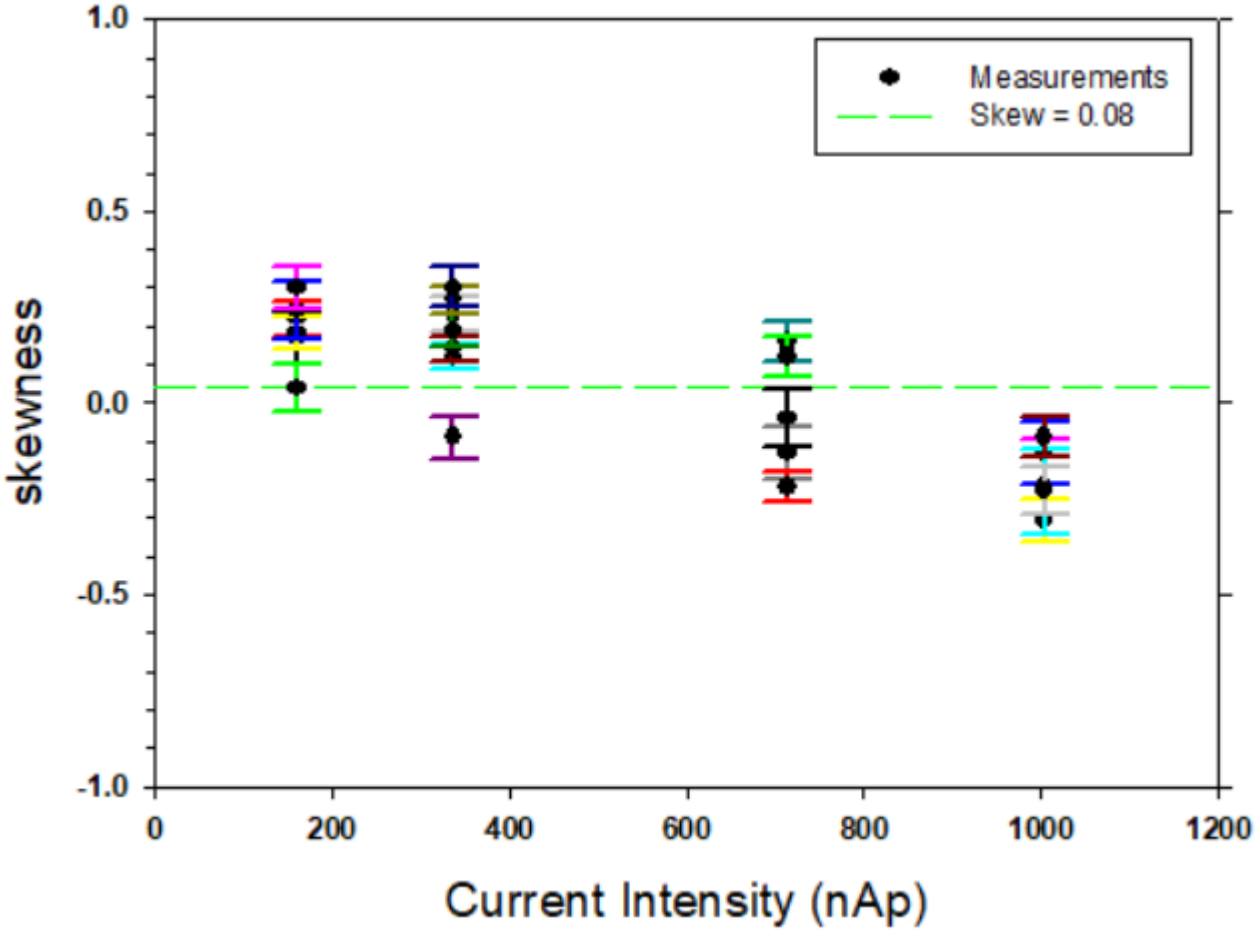


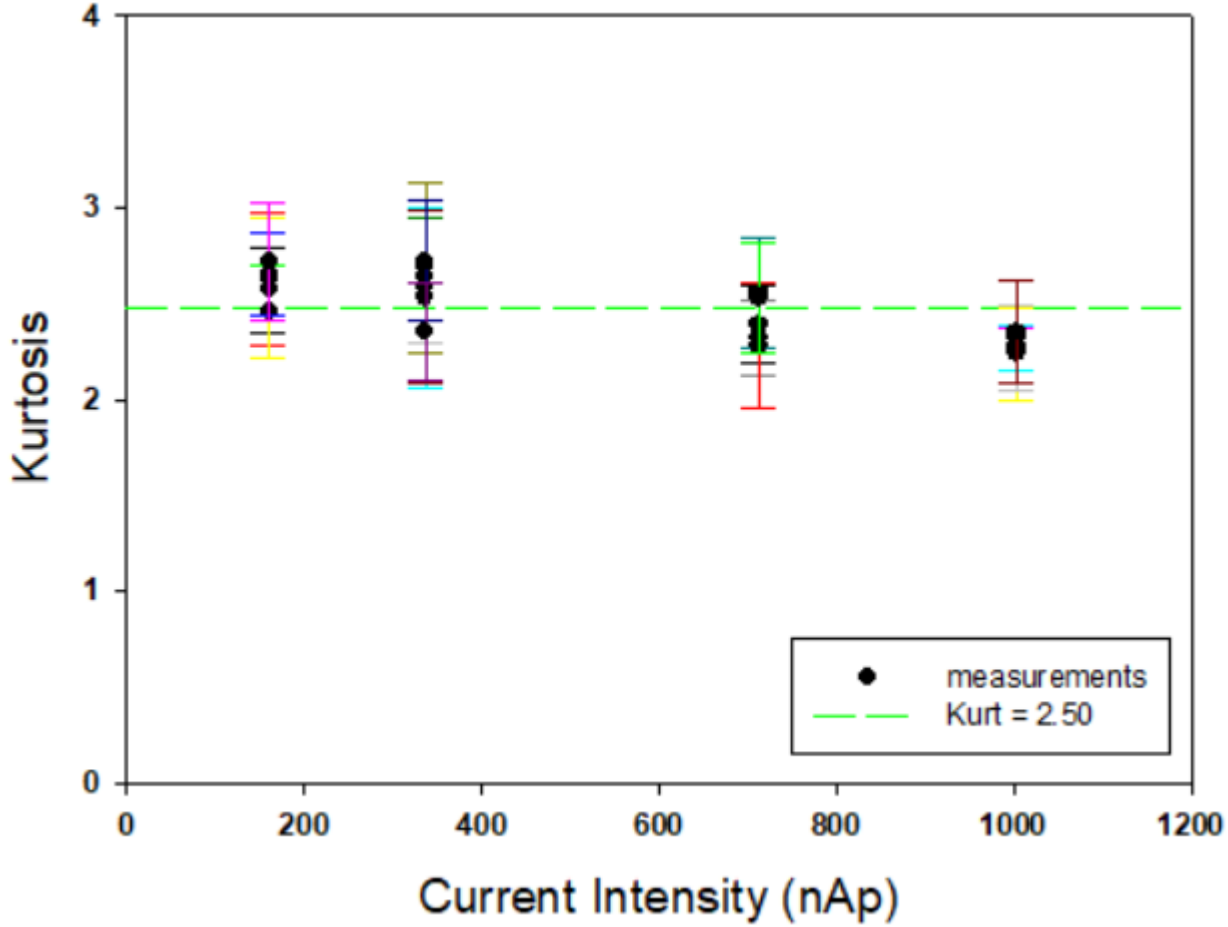
Mean charge and shape with the current



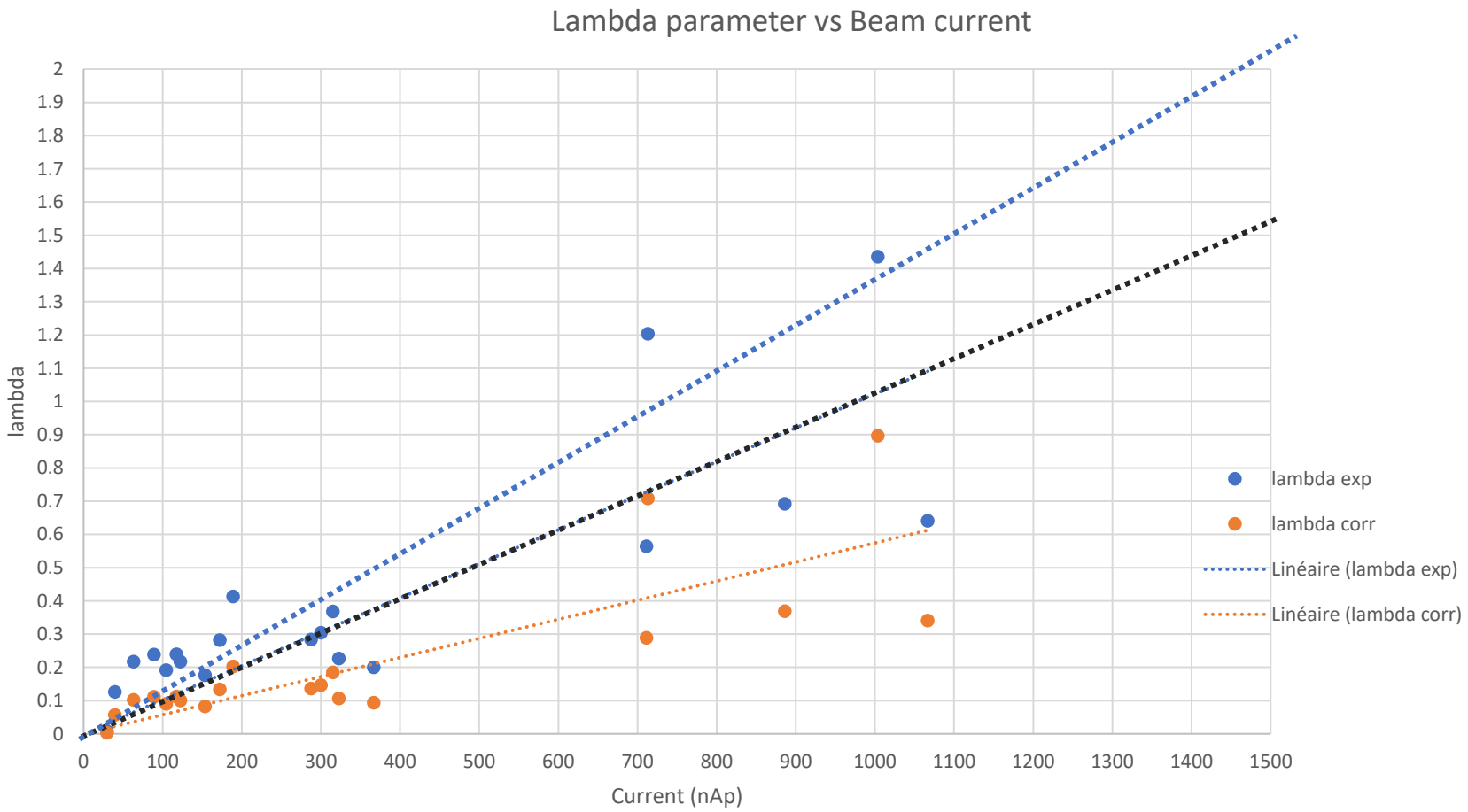


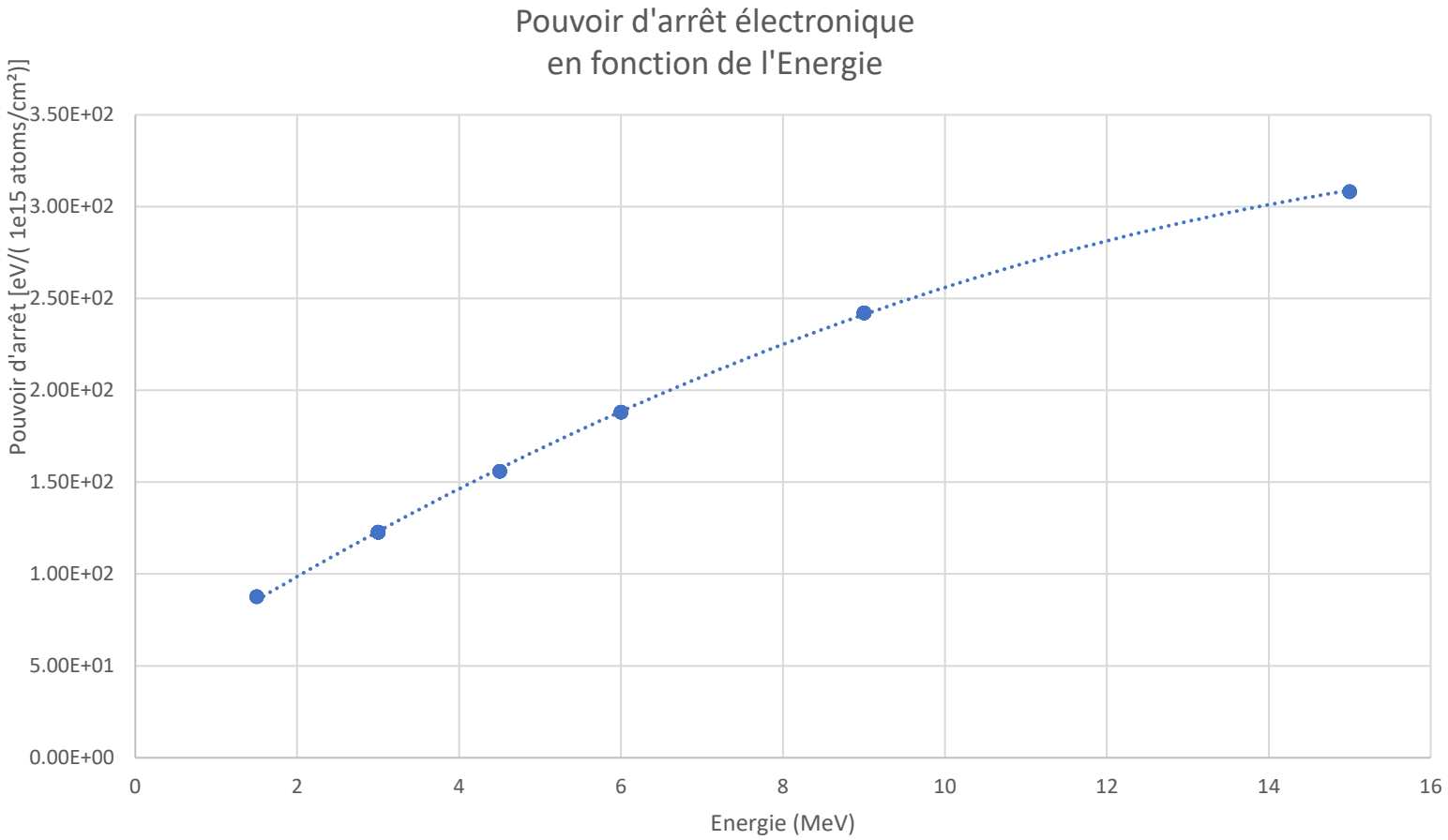
Annexes & references



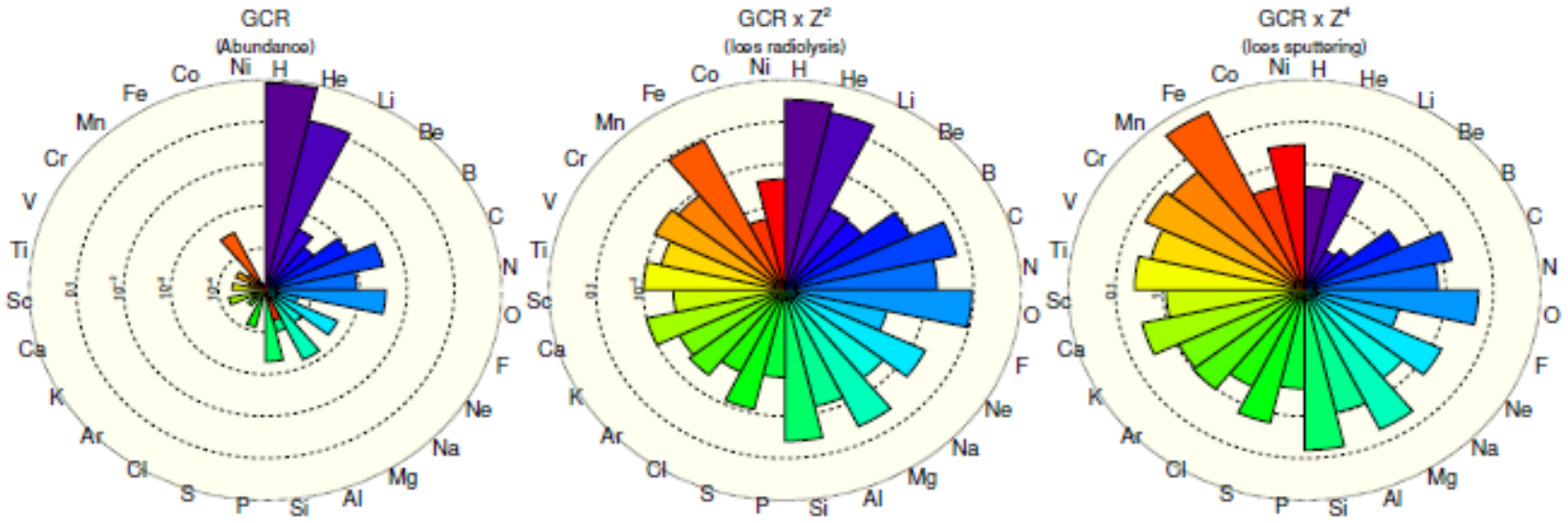


Annexes & references




Pouvoir d'arrêt électronique
en fonction de l'Energie
Pouvoir d'arrêt [eV/(1e15 atoms/cm²)]
3.50E+02
3.00E+02
2.50E+02
2.00E+02
1.50E+02
1.00E+02
5.00E+01
0.00E+00
0
2
4
6
8
10
12
14
16
Energie (MeV)

A&A 671, A156 (2023)



Cosmic ray abundances; E. Dartois & al (2023)