PROTON ENERGY SCAN

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RADIATION DAMAGE

- Because SiPMs detect single charge carriers -> radiation damage.
- Effect of radiation on silicon detectors -> depends on various factors:
  - type of radiation;
  - the energy of the particles;
  - the radiation dose;
  - the duration of exposure.
- 2 categories of radiation-induced damage: bulk damage due to loss of non-ionizing energy (NIEL) and surface damage due to loss of ionizing energy (IEL).
- Bulk damage is induced mainly by high-energy particles (protons, pions, electrons and photons) and neutrons. Defects are due to the interaction between the particles and the material lattice atoms.
- The Non Ionizing Energy Loss (NIEL) scaling hypothesis was introduced to compare the displacement damage of several particles.
- Different particles -> different interactions -> different damage.

Energy scan

- Radiation damage from hadronic particles at fixed temperatures.
- TIFPA facility in Trento : irradiation at different energies and fixed fluence, $10^9\,\frac{p}{cm^2}$;
- For the energy scan: “solid water”*.

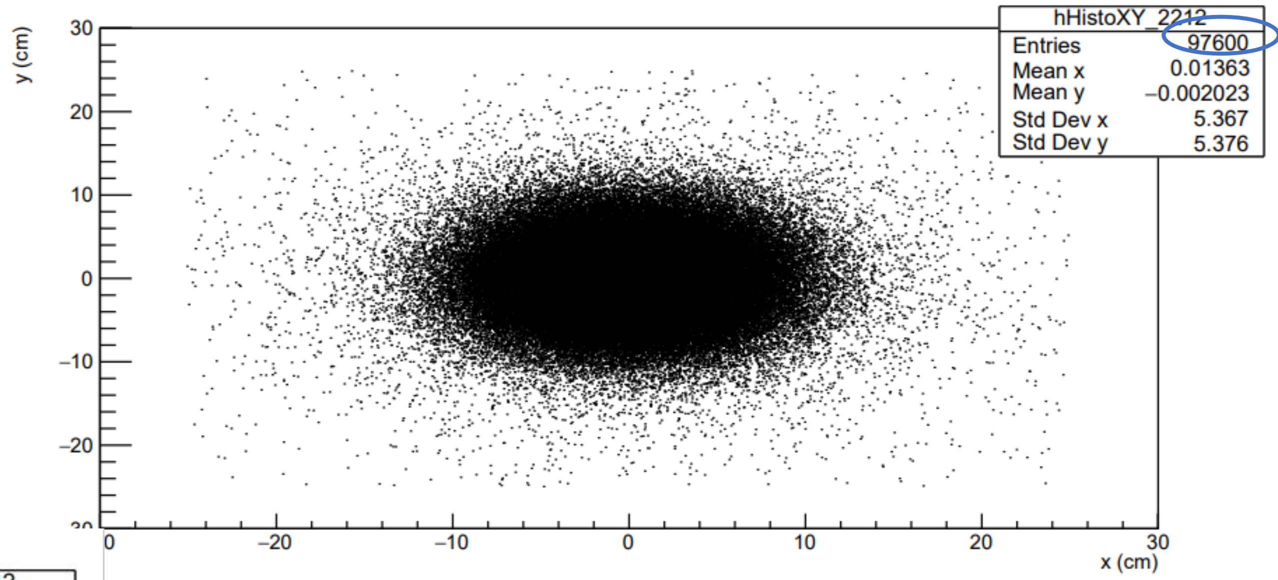
# Board	Energy scan (MeV)	RW3 thickness (mm)
5	138	0
6	75	88 ± 1
8	45	116 ± 1
9	25	127 ± 1
10	18	131 ± 1

*IBA Solid Plate Phantom (**RW3**).

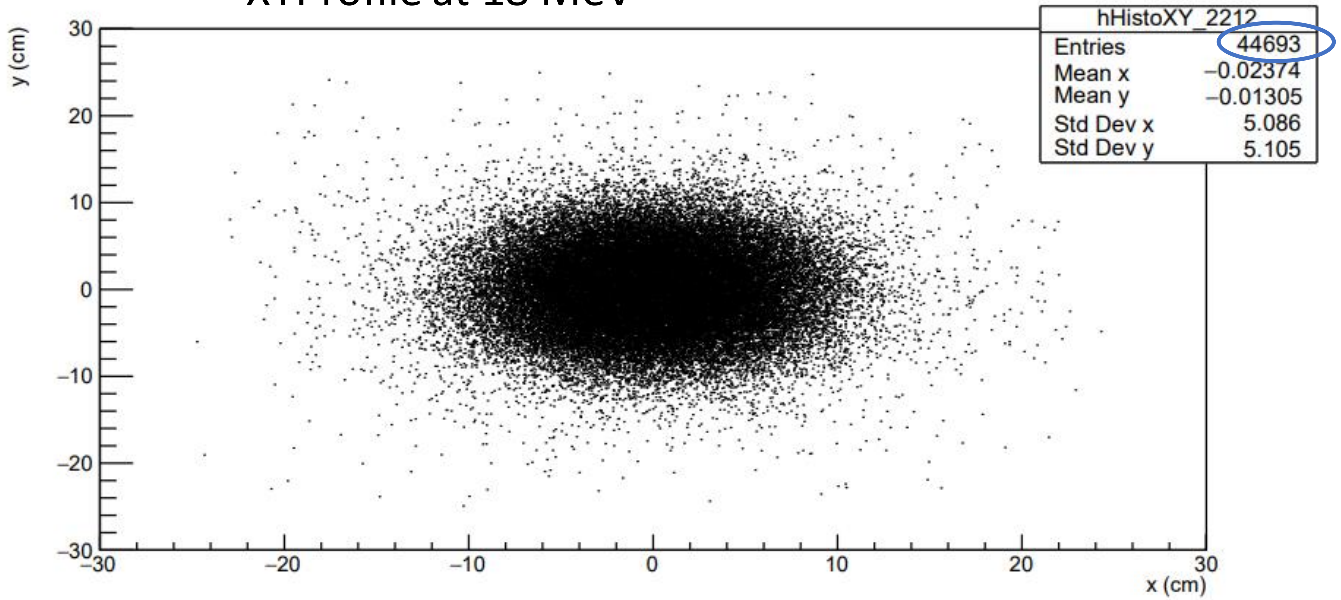
Energy scan

- ❑ How does the fluence change in relation to the degrader used? How efficient was the degrader?
- ❑ From simulation files→ Efficiency degraders ε
- ❑ Normalization at 138 MeV.

XYProfile at 138 MeV



XYProfile at 18 MeV



Energy scan

- The hardness factor k is useful for comparing the displacement damage produced by different particles with the damage that would be produced by neutrons of 1 MeV and the same fluence.

$$k = \frac{D_{particle}}{D_n\left(1 \text{ MeV n}_{eq}\right)} = \frac{D_{particle}}{95 \text{ MeV mb}}$$

$$\kappa = \frac{\int D(E)\,\phi(E)\,dE}{D(E_n = 1MeV) \cdot \int \phi(E)\,dE}. \qquad (3.3)$$

Here $D(E_n = 1\,\text{MeV})$ is set to 95 MeVmb [AST93] to assure the independence of different calculations from the used binning of the spectra. The equivalent 1 MeV neutron fluence Φ_{eq} can be calculated by

$$\Phi_{eq} = \kappa\,\Phi = \kappa \int \phi(E)\,dE. \qquad (3.4)$$

- Evaluation of the hardness k factor* from tables in:

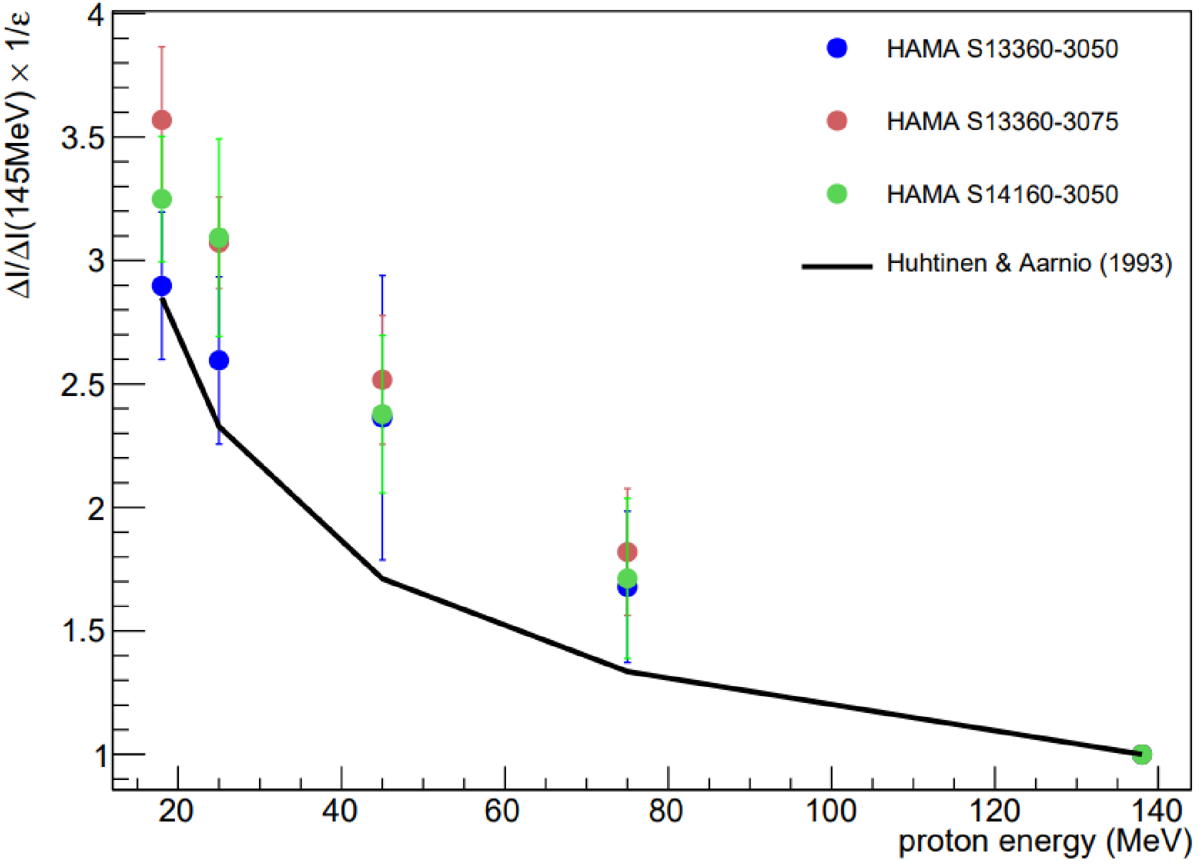
  http://rd50.web.cern.ch/NIEL/default.html

Energy scan

- Evaluation of: $\frac{\Delta I}{\Delta I(138\ MeV)}\frac{1}{\varepsilon}$

  where $\Delta I = I_{irr} - I_{noirr}$ at 3V overvoltage, ε efficienciency.

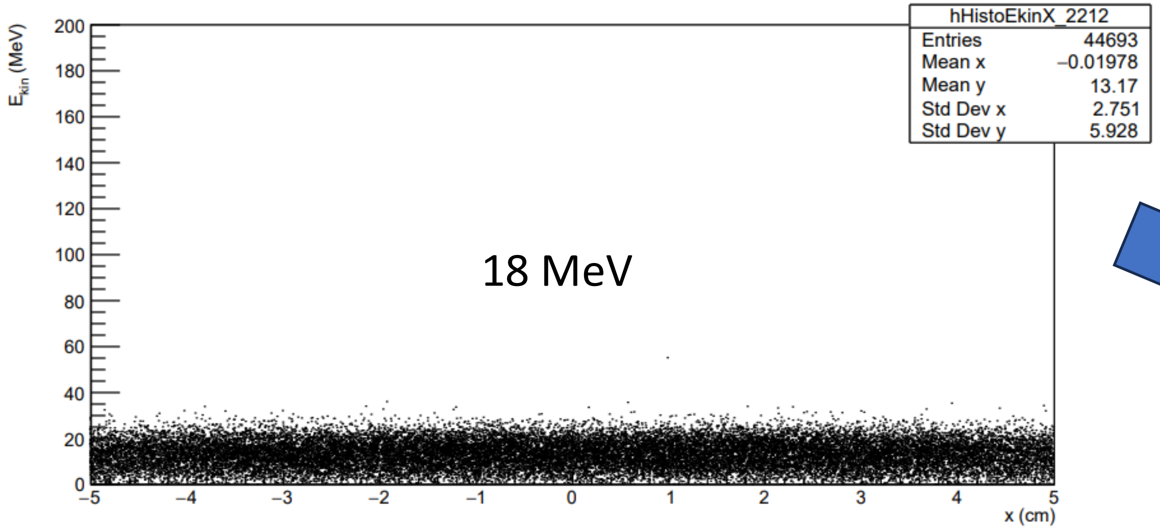
- Comparison with k factor → It tells us how the damage for protons changes, damage at 18 MeV compared to damage at 138 MeV.

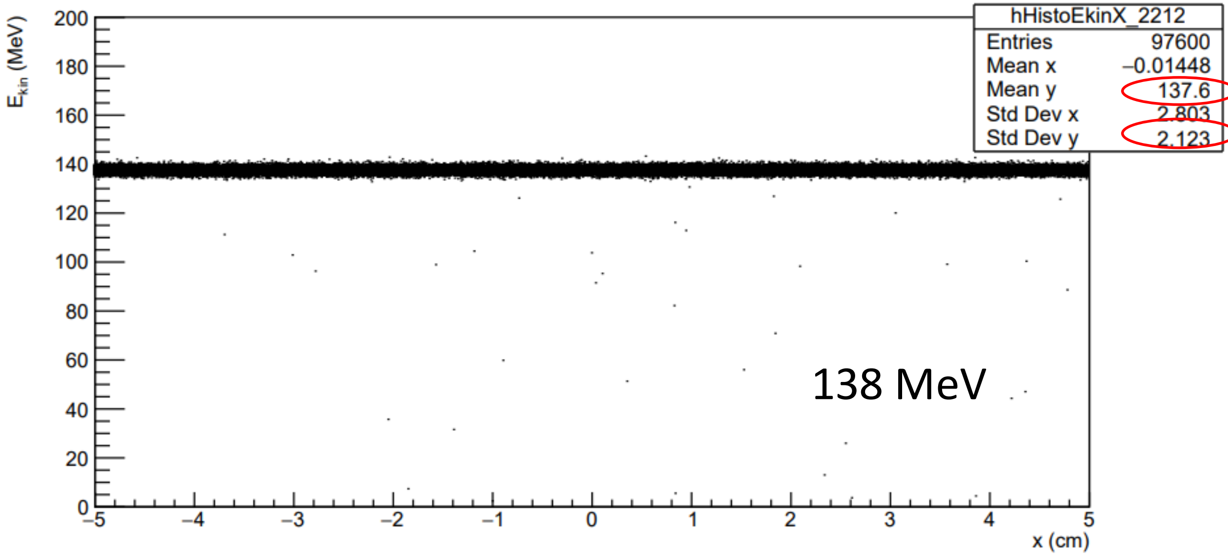


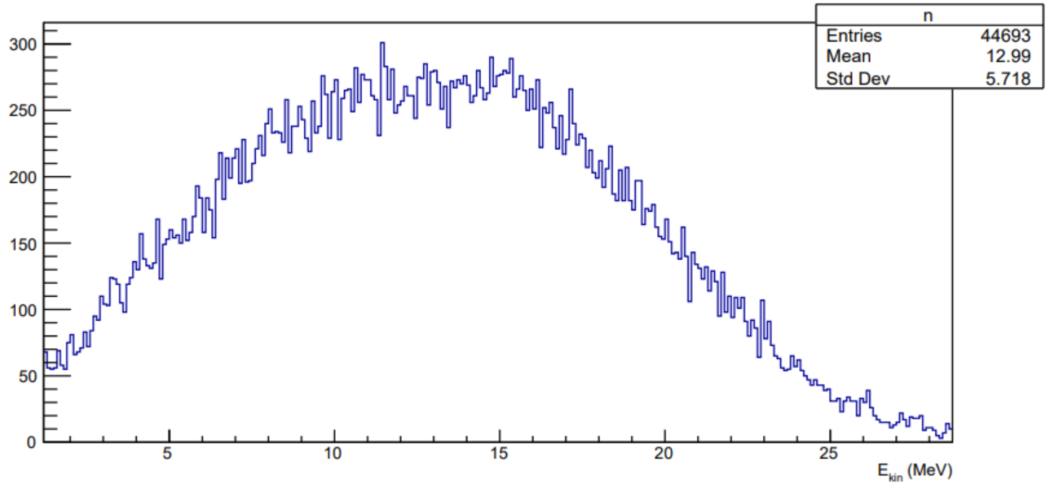
- Energy used: 138 MeV, 75 MeV, 45 MeV, 25 MeV, 18 MeV.

Energy scan

- Simulation -> energy band.
- The spread increases as the energy decreases (increase in degrader thickness).



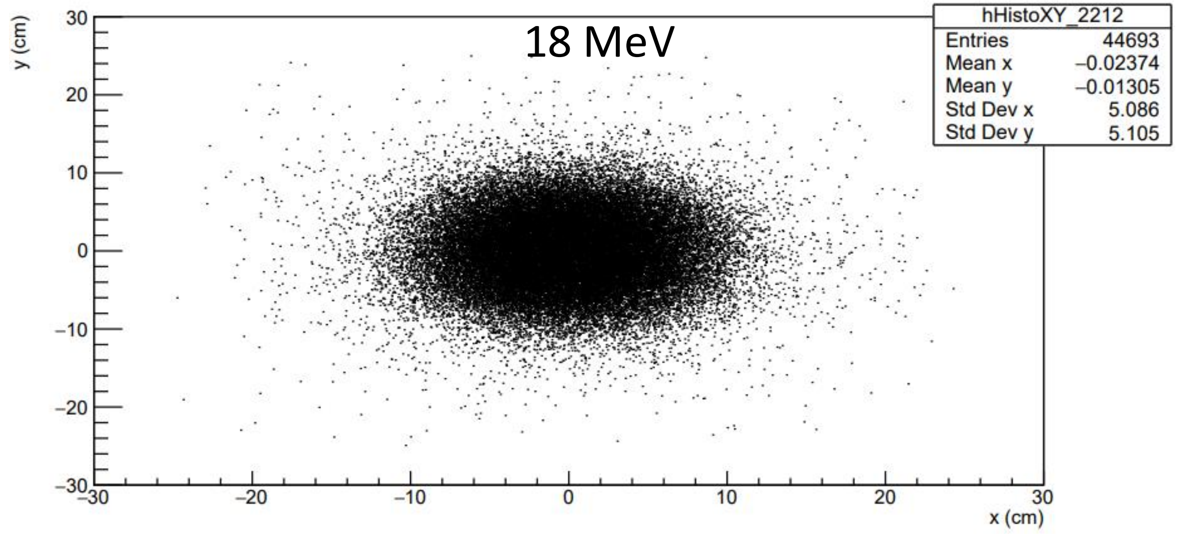


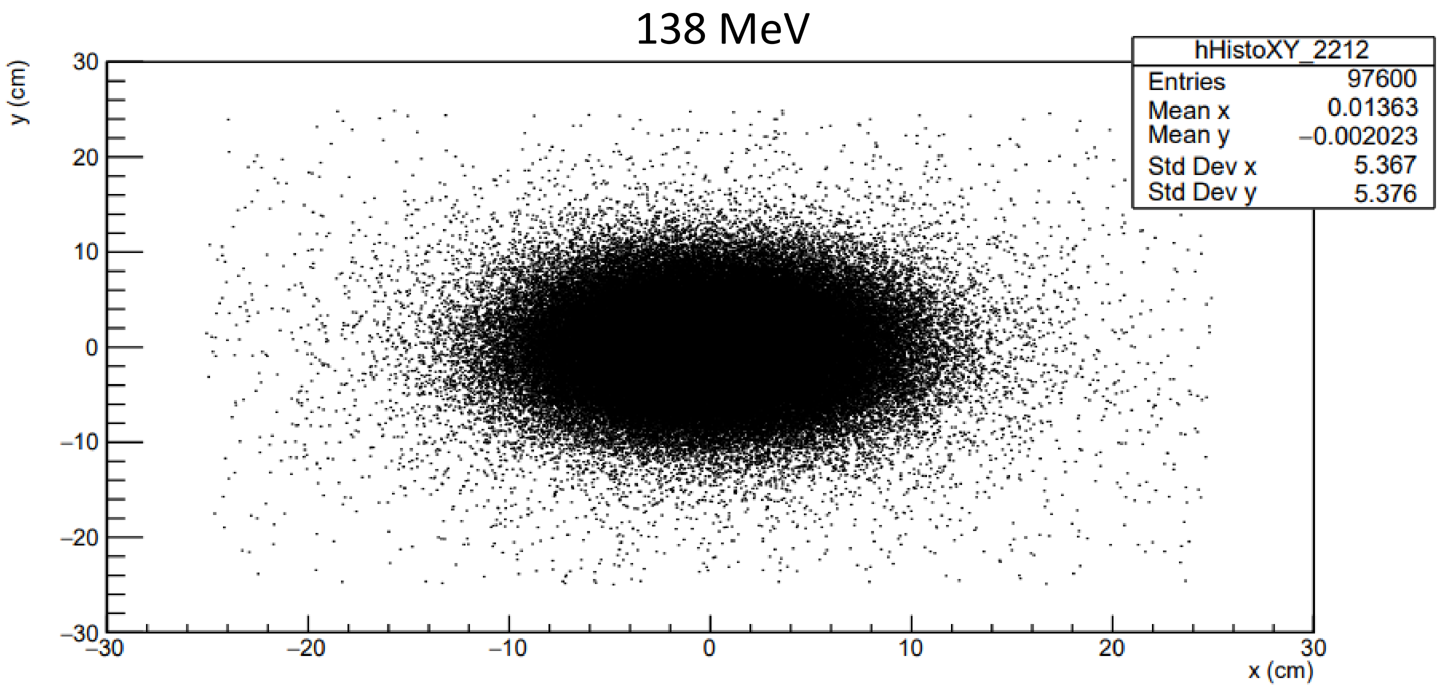


- Uncertainty on energy -> uncertainty on k factor -> uncertainty on damage -> beam not perfectly monochromatic

Energy scan

- ❑ Simulations -> XY plane distribution of protons.
- ❑ Does the proton distribution at 0mm≠ distribution at 131mm?
- ❑ Does the degrader change the distribution?



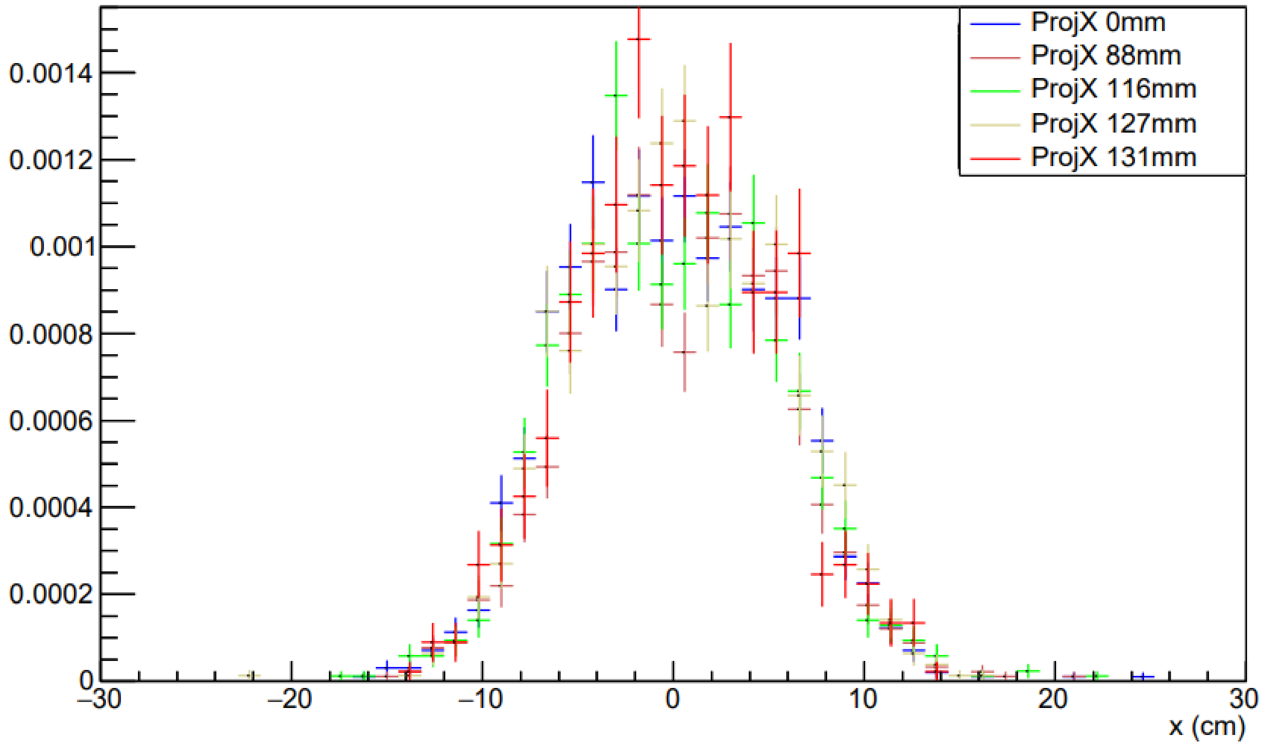


- ❑ Expectations: at 131 mm -> wider distribution than distribution at 0 mm -> Proton scattering.

Energy scan

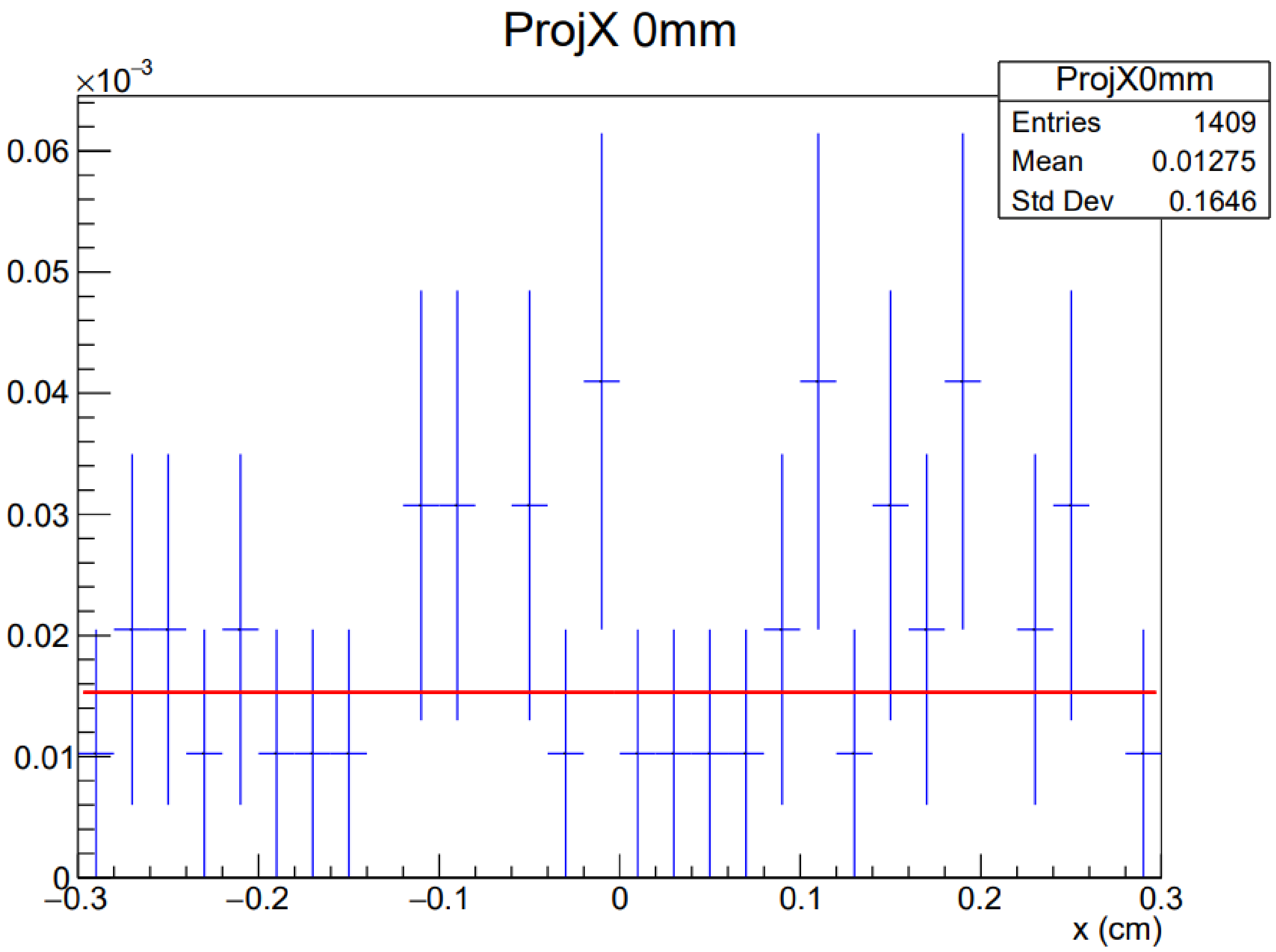
- ❑ **Comparison of distributions in X for a narrow range of Y [-1, 1] mm.**
- ❑ **Distributions -> overlapping.**

- ❑ **REMEMBER:**
  - **0 mm-> 138 MeV;**
  - **88 mm -> 75 MeV;**
  - **116 mm -> 45 MeV;**
  - **127 mm -> 25 MeV;**
  - **131 mm -> 18 MeV.**



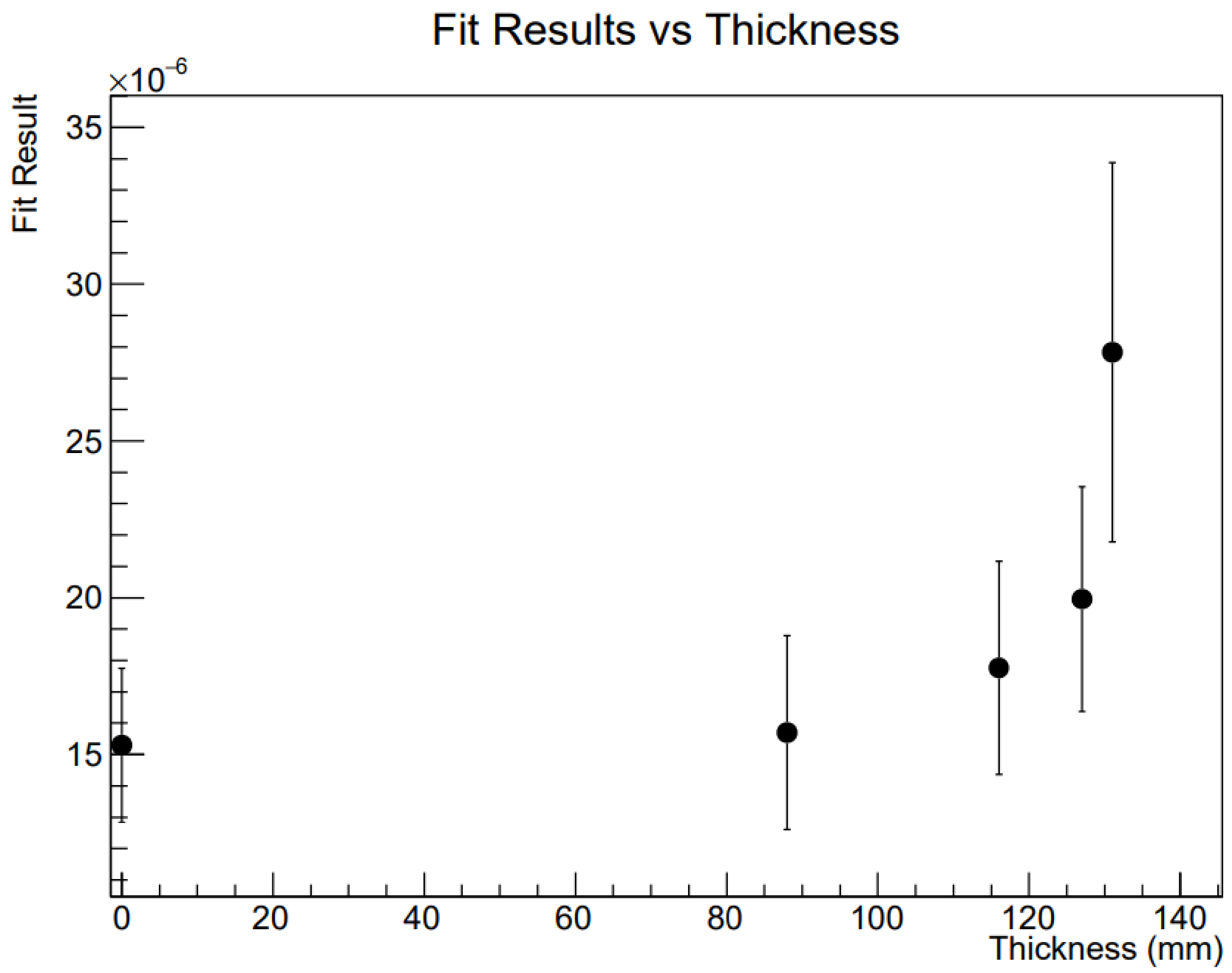
Energy scan

- If we look at the central plateau, for eac
  distribution, in the region X = [-3,3]mm.
- Fit with a pol0.



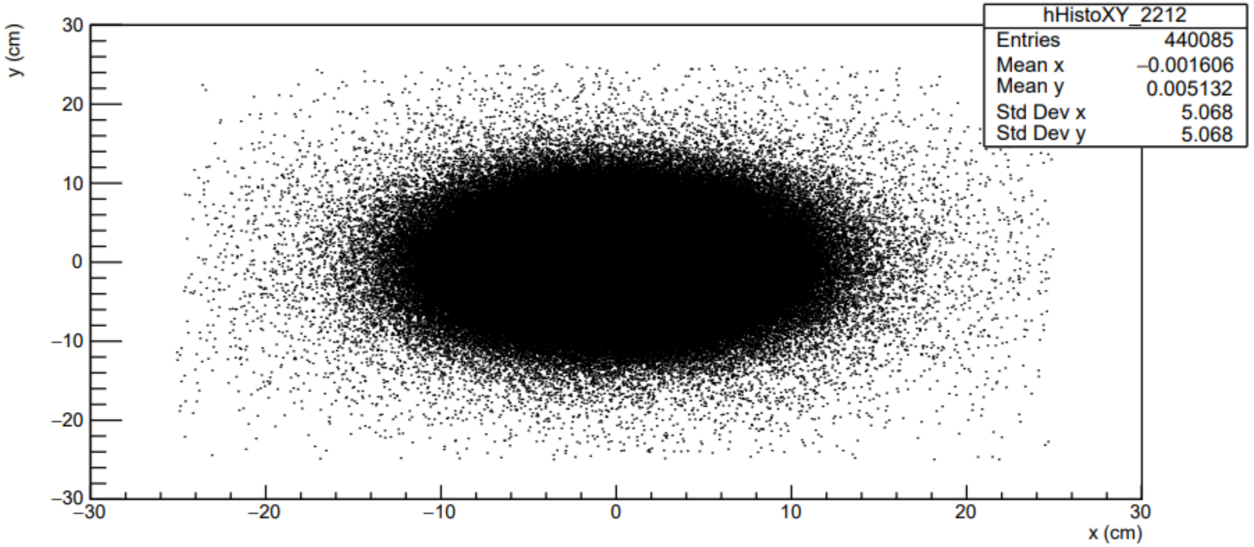
Energy scan

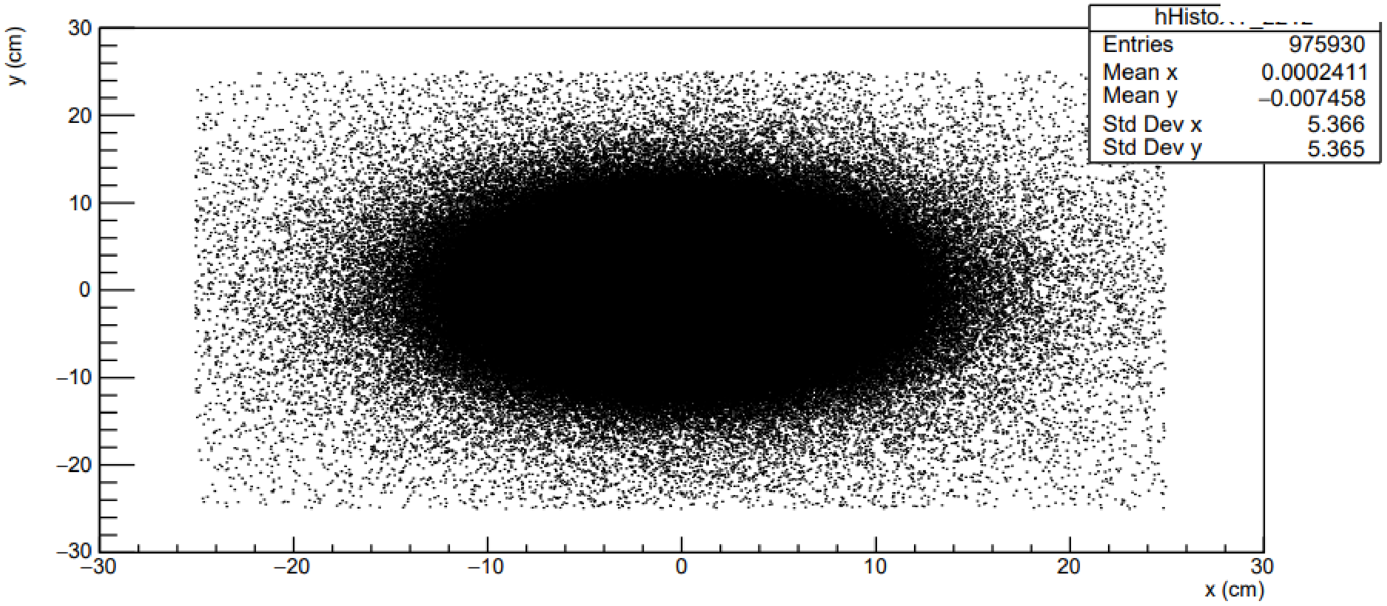
- **Fit results vs degrader thickness.**



Energy scan

- Let's increase the statistics.

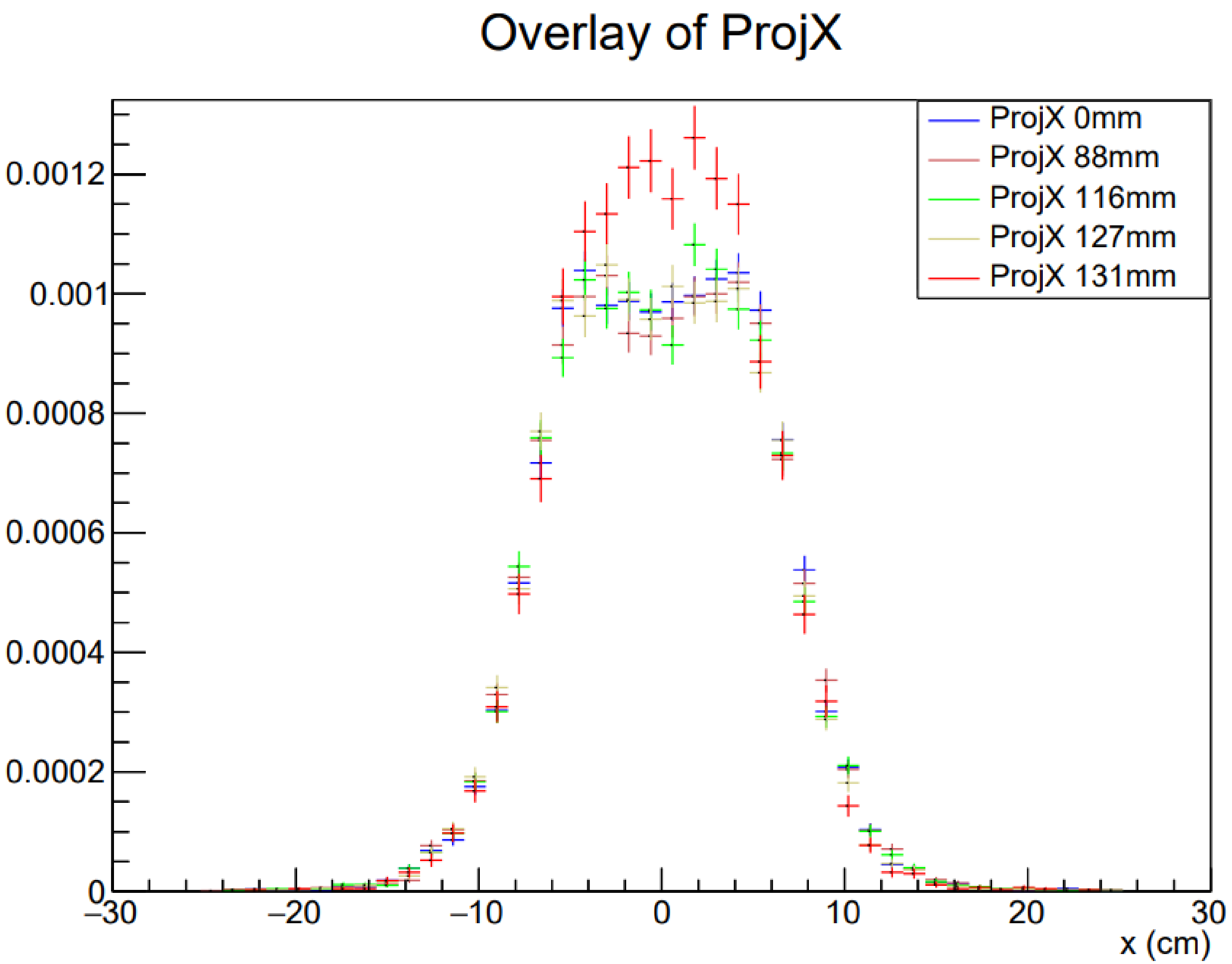




- Expectations: smaller fit errors.

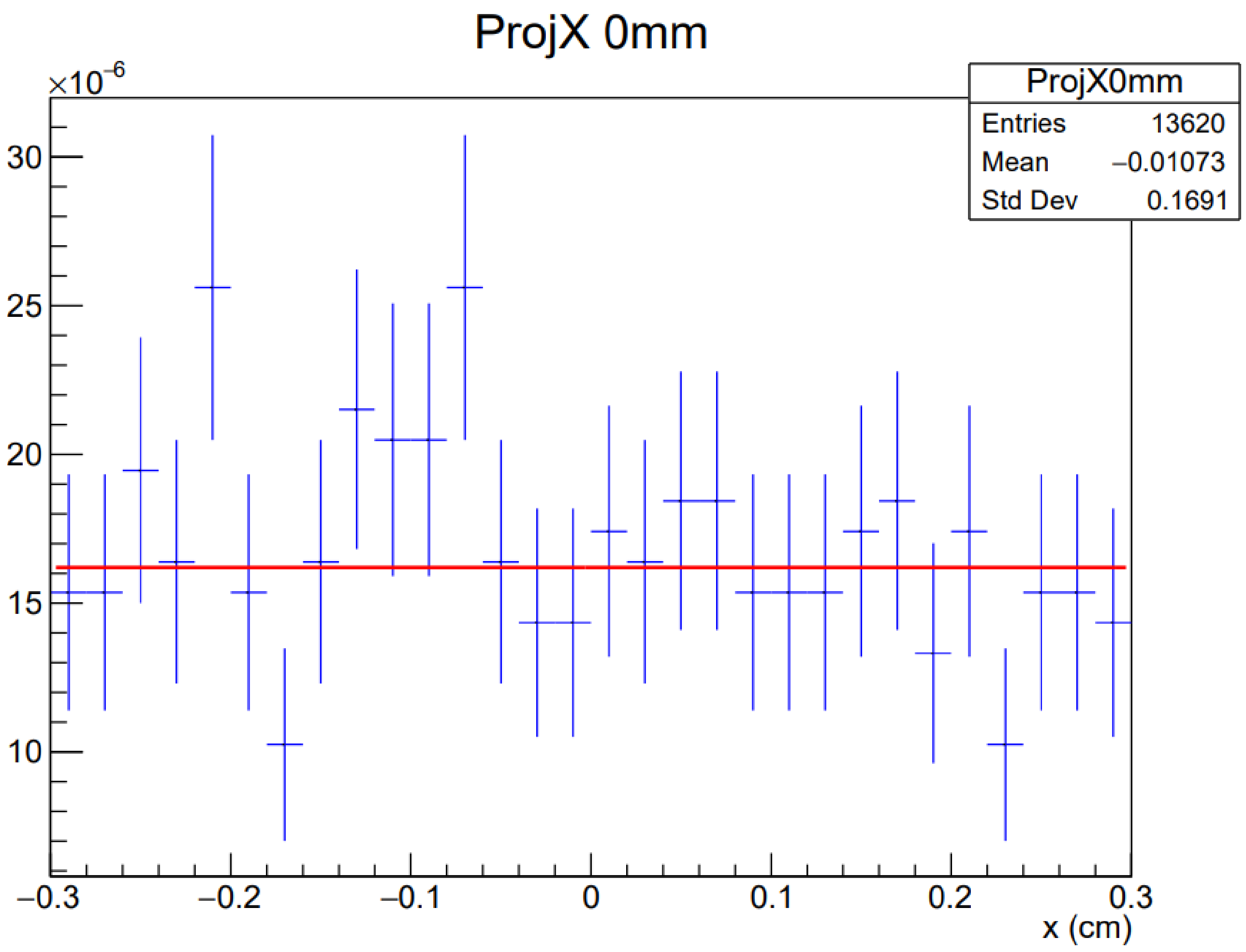
Energy scan

- **Comparison of distributions in X for a narrow range of Y [-1, 1] mm.**



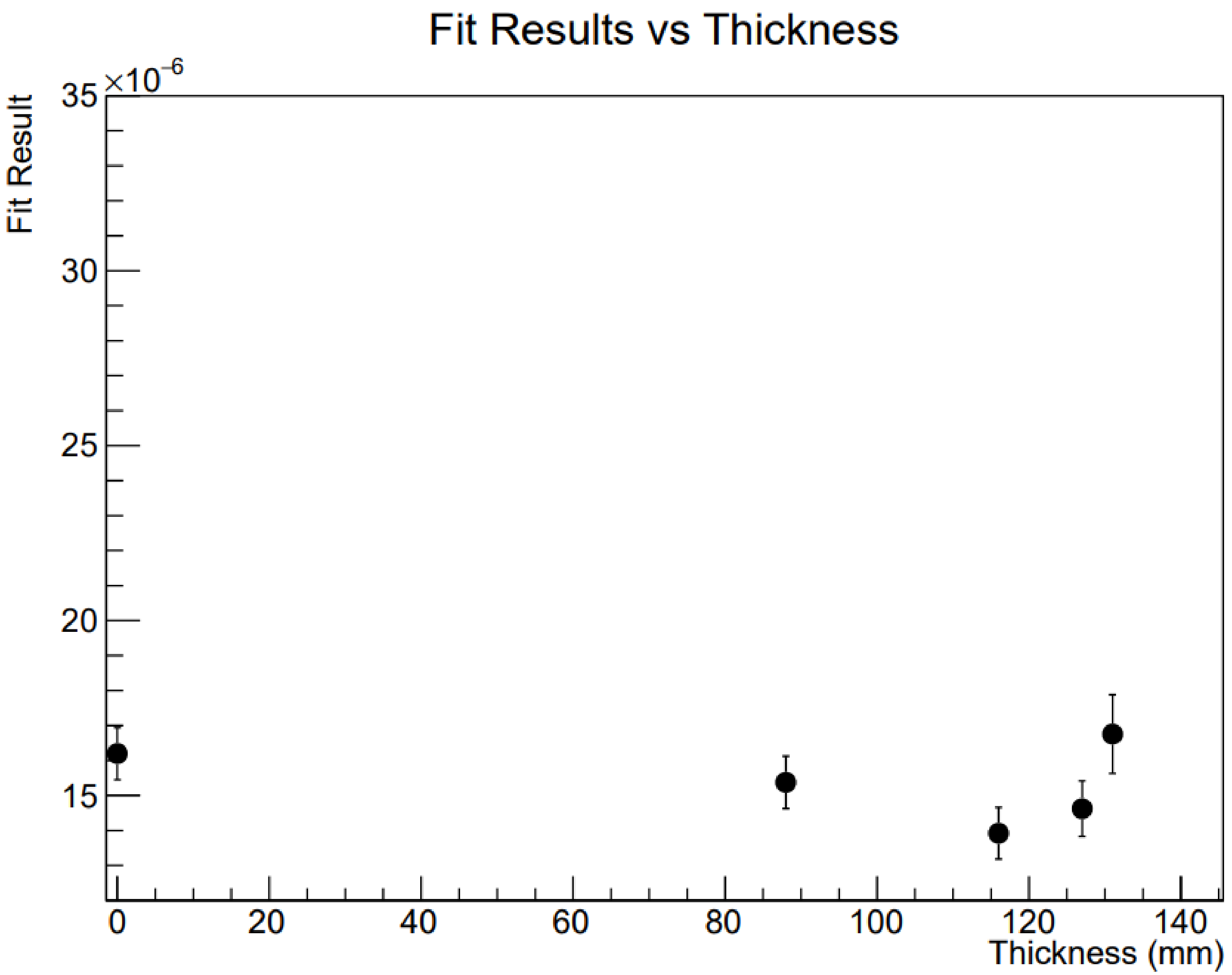
Energy scan

- **If we look at the central plateau, for each distribution, in the region X = [-3,3]mm.**
- **Fit with a pol0.**



Energy scan

- **Fit results vs degrader thickness.**



Conclusion

- We have seen how to compare the radiation damage of our sensors with the theoretical damage curve.
- We examined the simulation of the Xy profile of the beam looking for a crucial role of the degraders in lowering the energy, looking for evidence of proton scattering in the proton distribution.
- We have seen that at the increasing of the energy we have no longer a monochromatic beam, so we have to take into account this in the comparison with k factor.

THANKS!