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FLUKA validation of MONET code for dose calculation in Hadrontherapy

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FLUKA for Hadrontherapy

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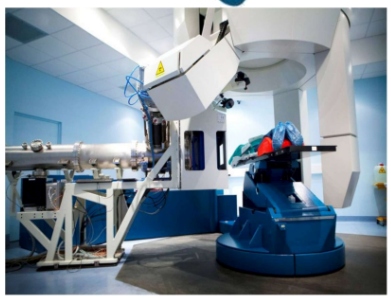
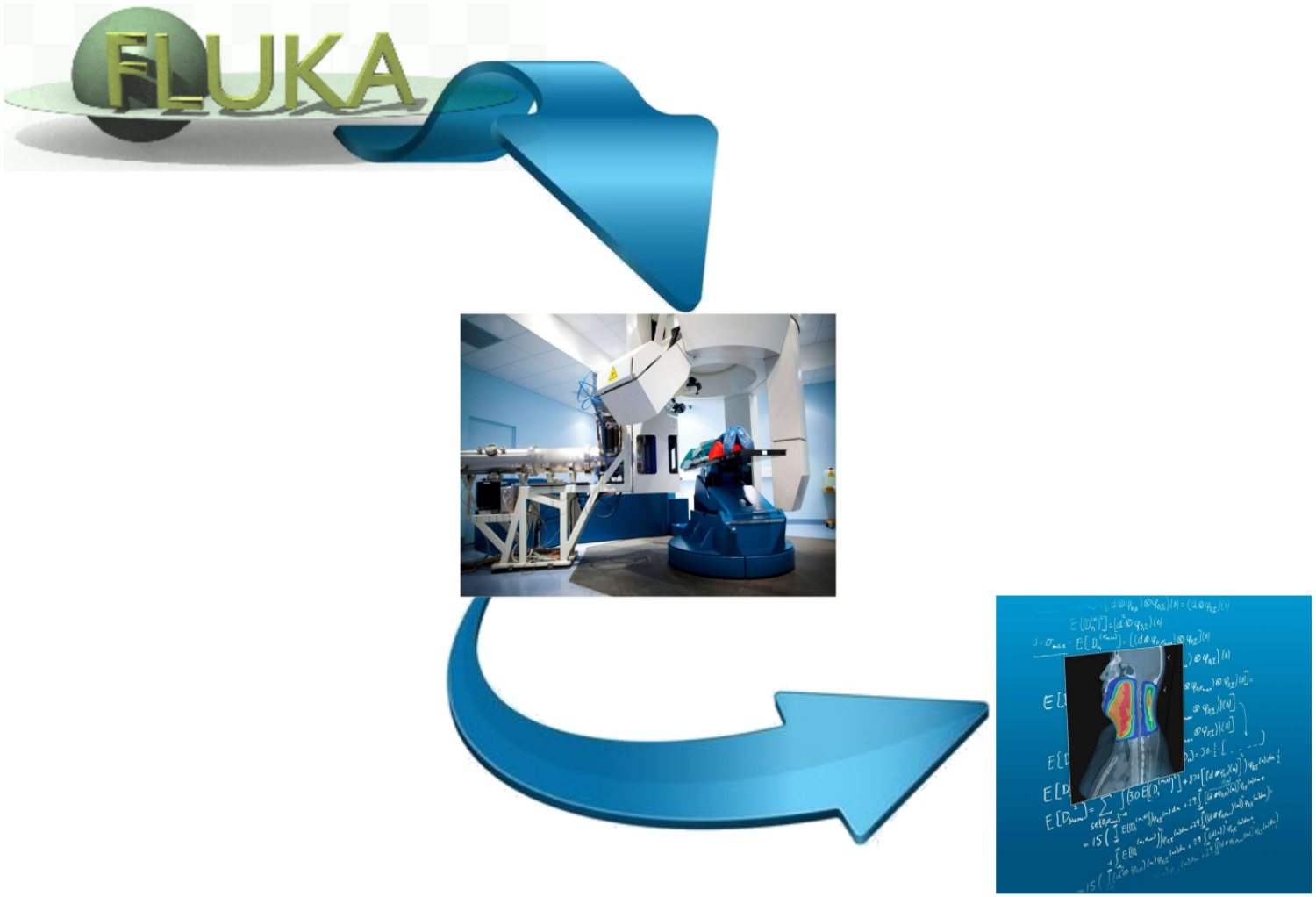
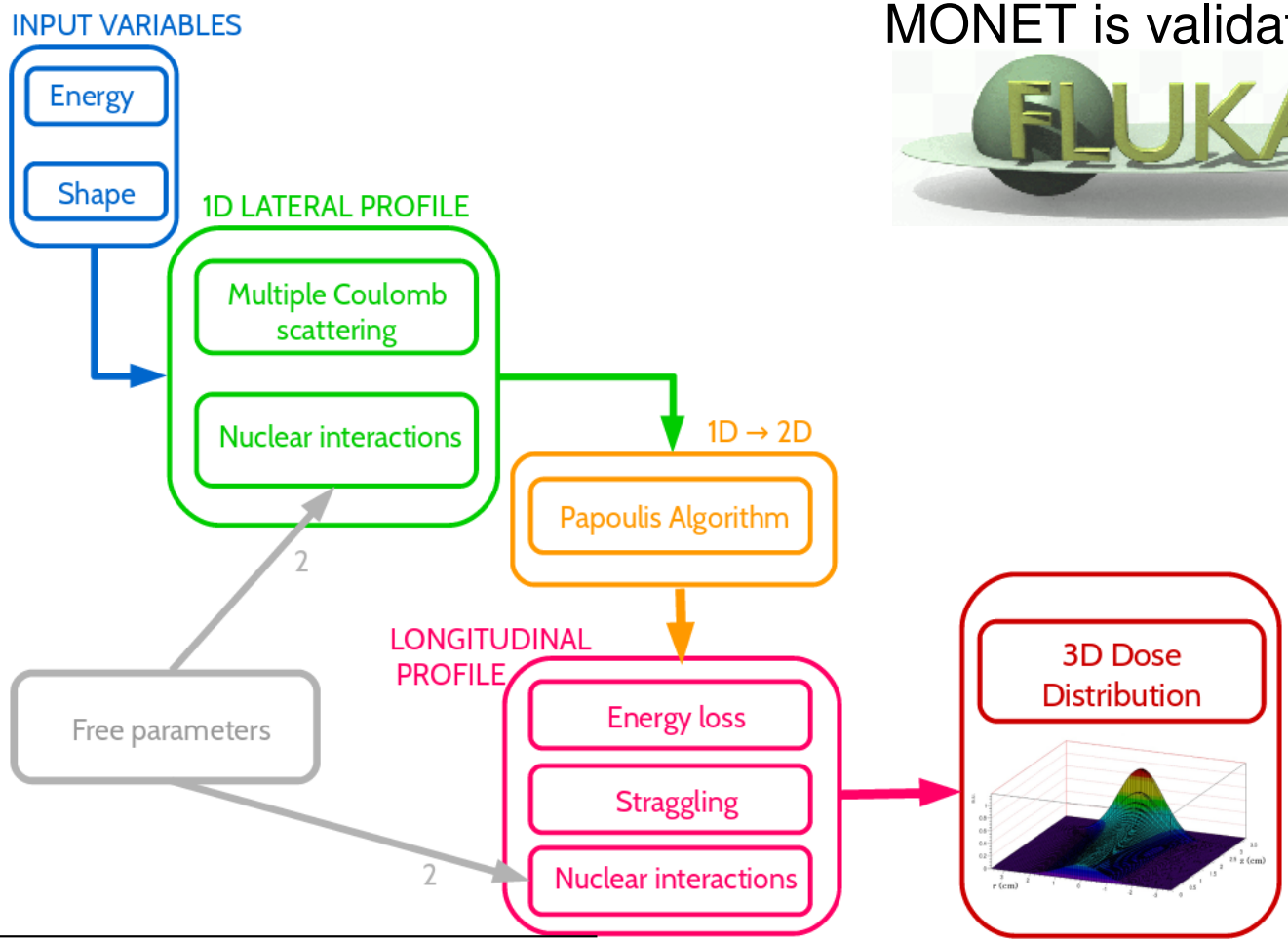


FLUKA for Hadrontherapy



MONET
MOdel of ioN dosE for Therapy

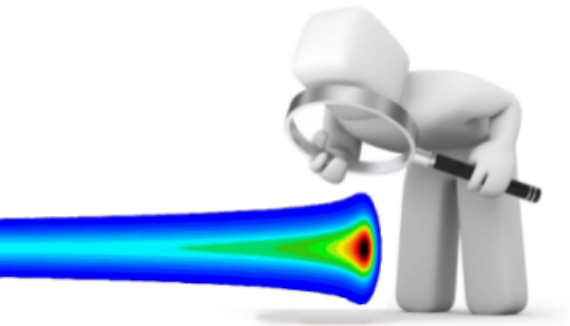
MONET is a fast and accurate model for the computation of the energy deposition of **protons and ^4He ions** in water [1].



MONET is validated with

[1] Embriaco et al. 2017 *Physica Medica* **38** 66-75

The role of FLUKA simulation



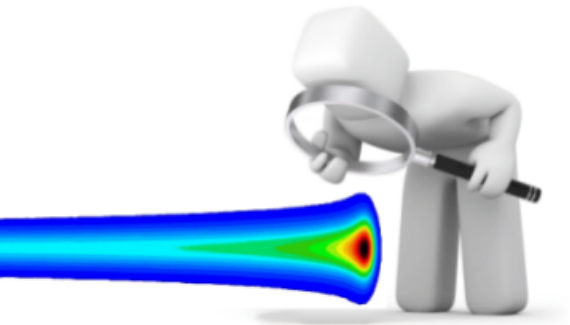
Nuclear interaction:

- Lateral profile: Cauchy Lorentz
- Longitudinal profile: Linear parametrization

Attenuation of ^4He ions:

We have evaluated the decrease of fluence as a function of depth for each energy analyzed.

The role of FLUKA simulation



Nuclear interaction:

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Attenuation of ^4He ions:

We have evaluated the decrease of fluence as a function of depth for each energy analyzed.

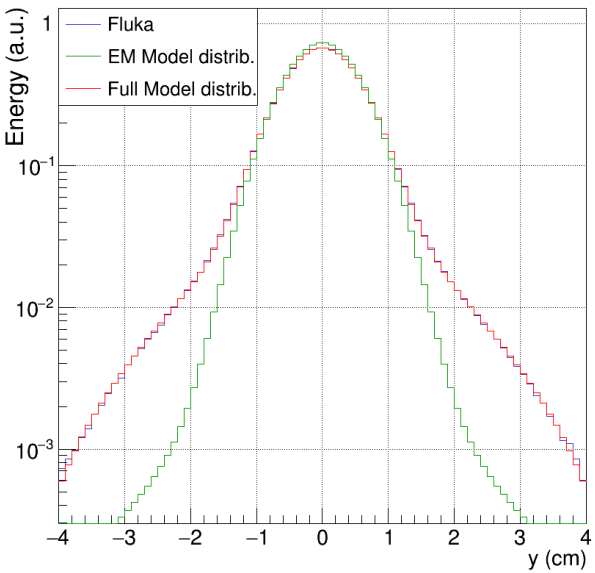
After the implementation of MONET, the results of the code are compared with FLUKA simulations.

Lateral profile

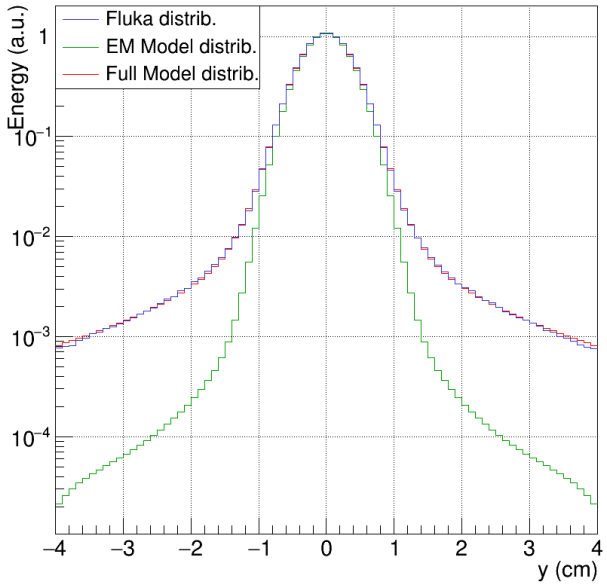
The lateral distribution is calculated as the sum of **multiple Coulomb scattering** and **nuclear interactions**[1] [2]:

$$f_x(x) = W_p f_M(x) + (1 - W_p)\frac{t(x)}{\int t(u)\mathrm{d}u}$$

Protons of 150 MeV at z=15 cm



[4] *He* ions of 150 MeV/u at z=15 cm



[2] Bellinzona et al. 2016 *Physics in Medicine and Biology* **61** N102

[3] Embriaco et al. 2017 *Physica Medica* **40** 51–58

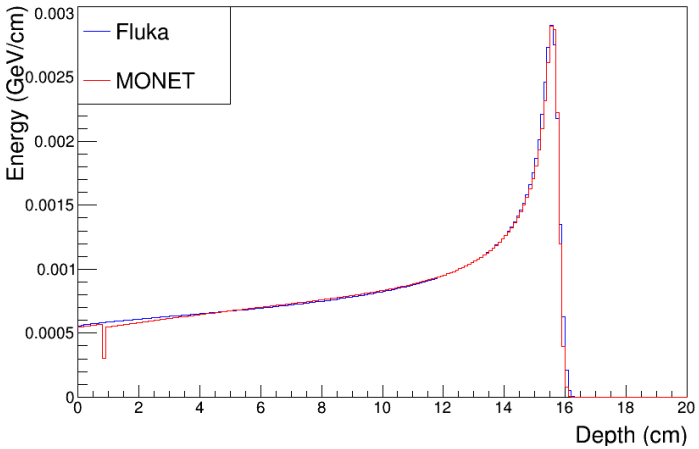
Longitudinal profile

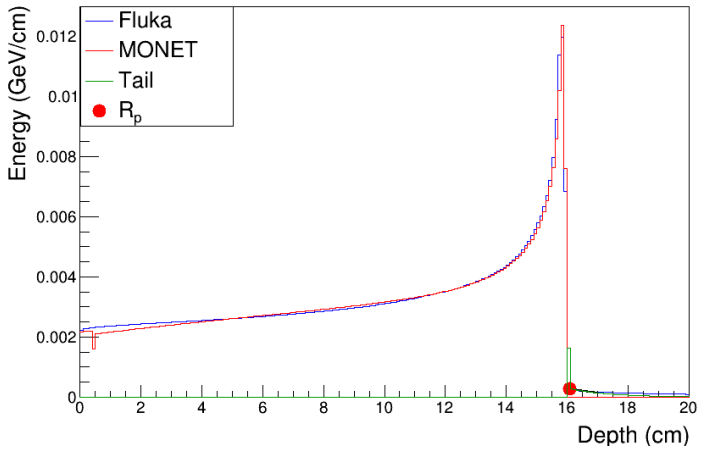
The longitudinal profile is evaluated by the sum of **average energy loss, straggling and nuclear interactions** [1] [4]:

$$f_z(z) = W_p \hat{E}_K(z) + (1 - W_p) E_N(z)$$

where $E_N(z)$ is a **linear parametrization** for the nuclear contribution:

$$E_N(z) = az + b$$





Protons and ^4He ions of 150 MeV/u.

[1] Embriaco et al. 2017 *Physica Medica* **38** 66-75

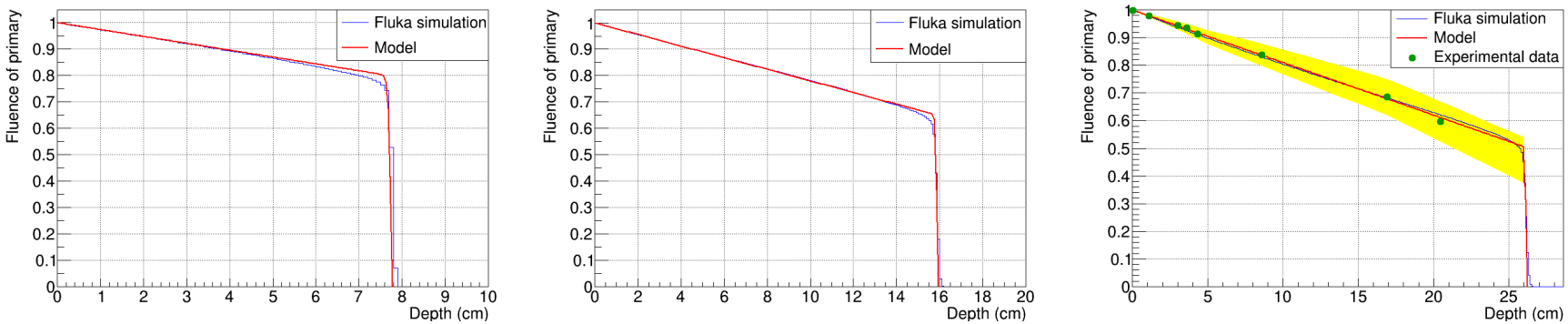
[4] Carlsson et al. 1997 *Physics in Medicine and Biology* **42** 1033-1053

Attenuation of ^4He ions

For **protons beams**, the fluence is evaluated using the **Ulmer relation**[5].

The attenuation curves of ^4He ions are fitted using an **error function multiplied by a linear parametrization**[6]:

$$W_p = (\alpha z + \beta) \times \text{erf}\left(\frac{R - z}{\gamma}\right)$$



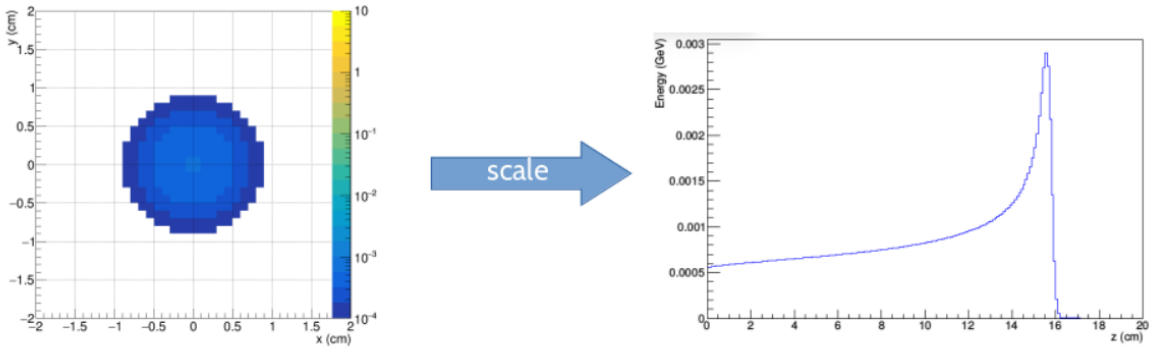
The energy analyzed are left: E=100 MeV/u, middle: E=150 MeV/u and right: E=200 MeV/u.
For energy of 200 MeV/u, the experimental data[7] are added for the validation of the curve.

[5] Ulmer 2007 *Rad. Phys. and Chem.* **76** 1089

[6] Embriaco, A model for the fast and accurate dose evaluation in hadrontherapy, *PhD thesis*

[7] Rovituso et al. 2017 *Physics in Medicine and Biology* **62**(4):1310

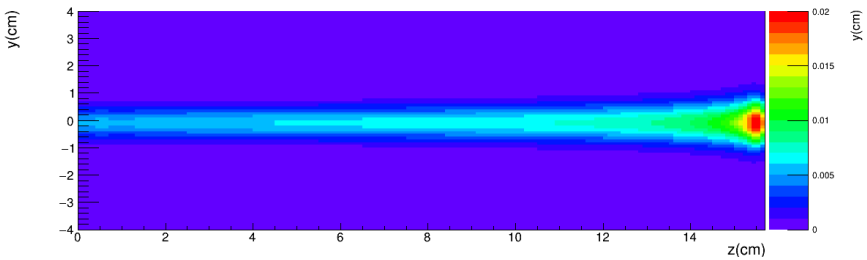
3-dimensional dose distribution

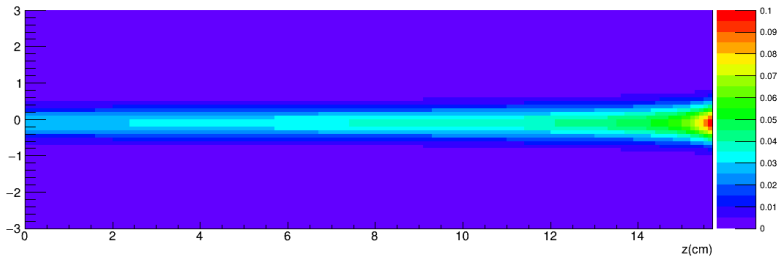


$$D(x,y,z) = f(z)f(r)$$

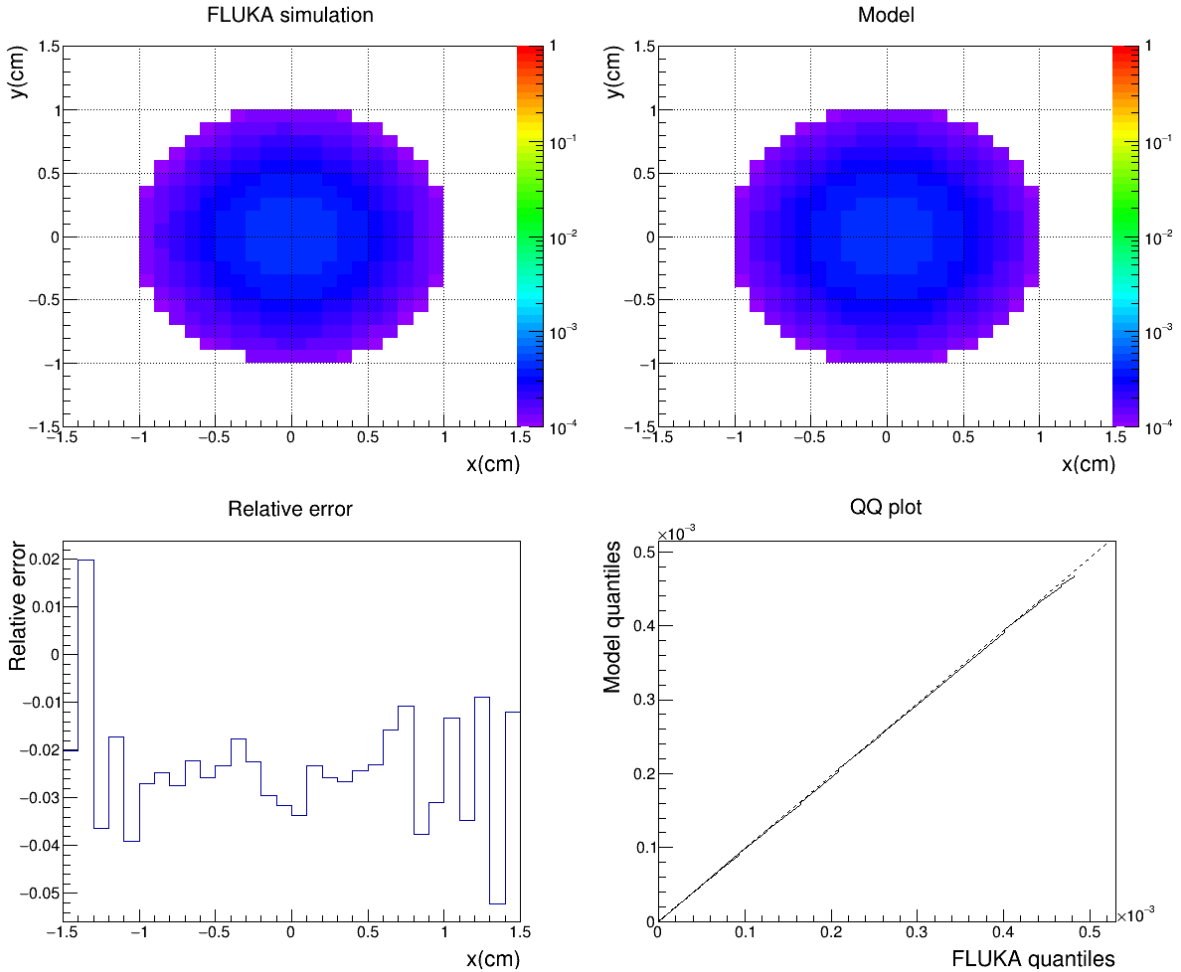
Protons of 150 MeV

^{4}*He* ions of 150 MeV/u





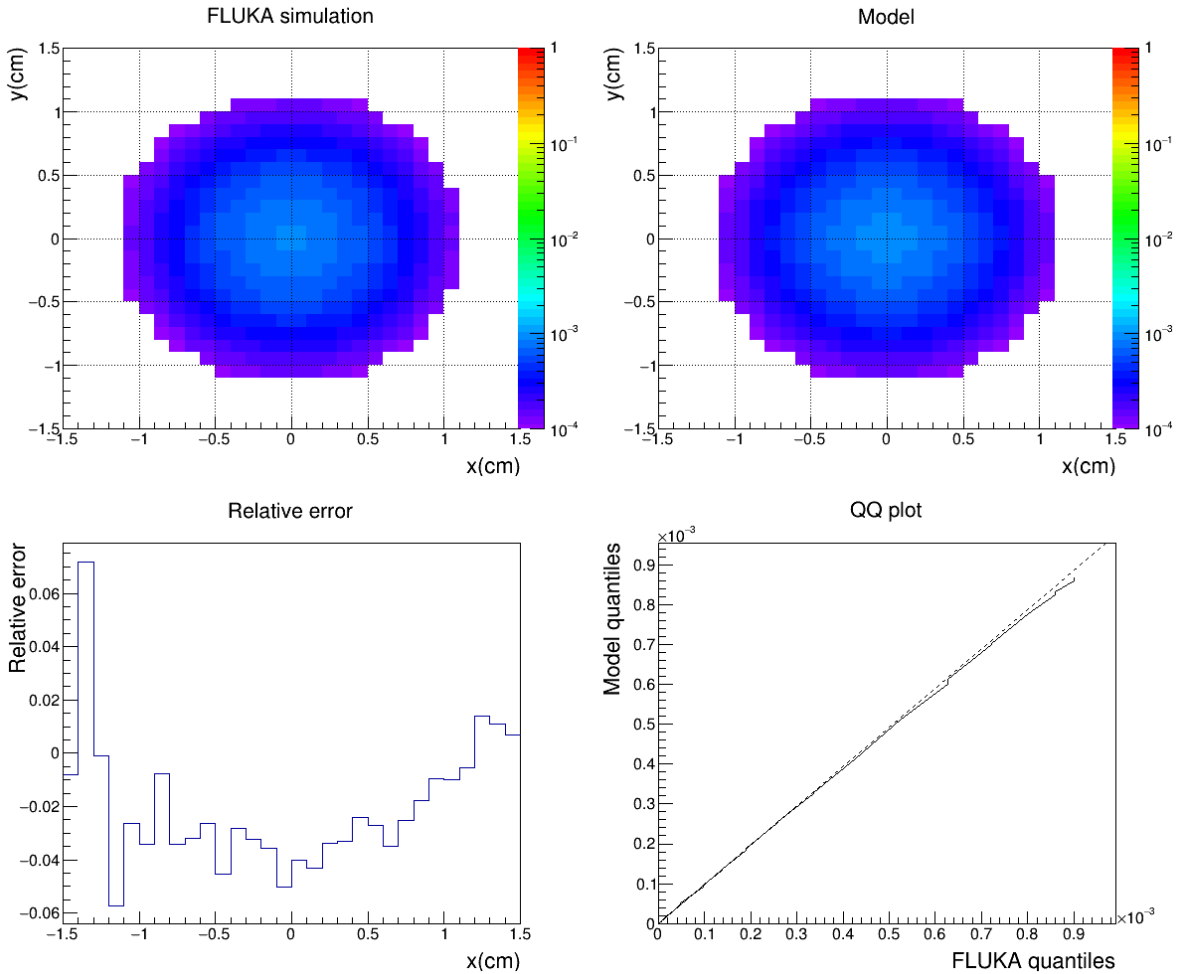
Proton Single Gaussian beam



Energy 100 MeV at depth z=4 cm (Bragg peak at 7.8 cm).

[1] Embriaco et al. 2017 *Physica Medica* **38** 66-75

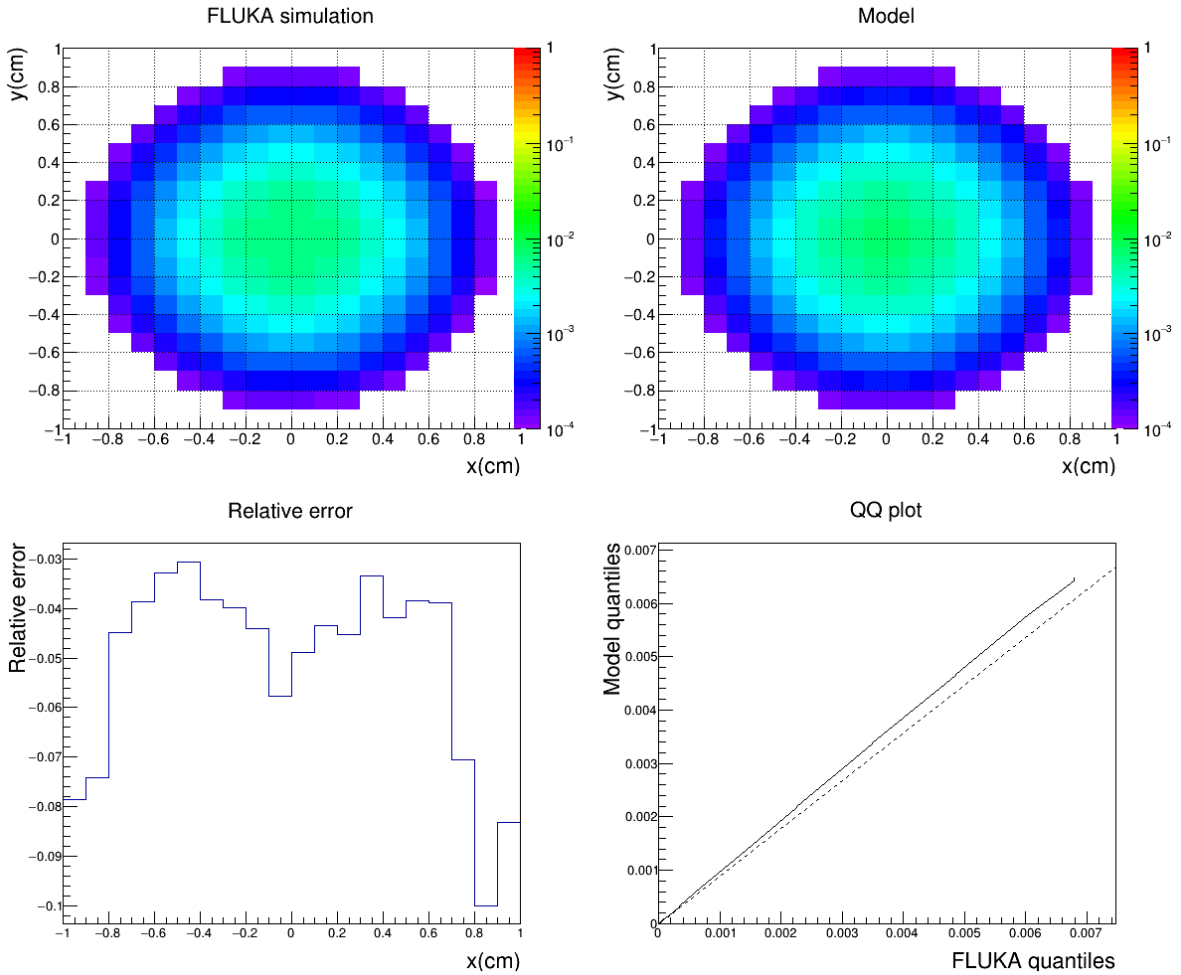
Proton Single Gaussian beam



Energy 150 MeV at depth z=15 cm (Bragg peak at 15.8 cm).

[1] Embriaco et al. 2017 *Physica Medica* **38** 66-75

^{4}*He* Single Gaussian beam



Energy 100 MeV/u at depth z=4 cm (Bragg peak at 7.8 cm).

[6] Embriaco, A model for the fast and accurate dose evaluation in hadrontherapy, *PhD thesis*

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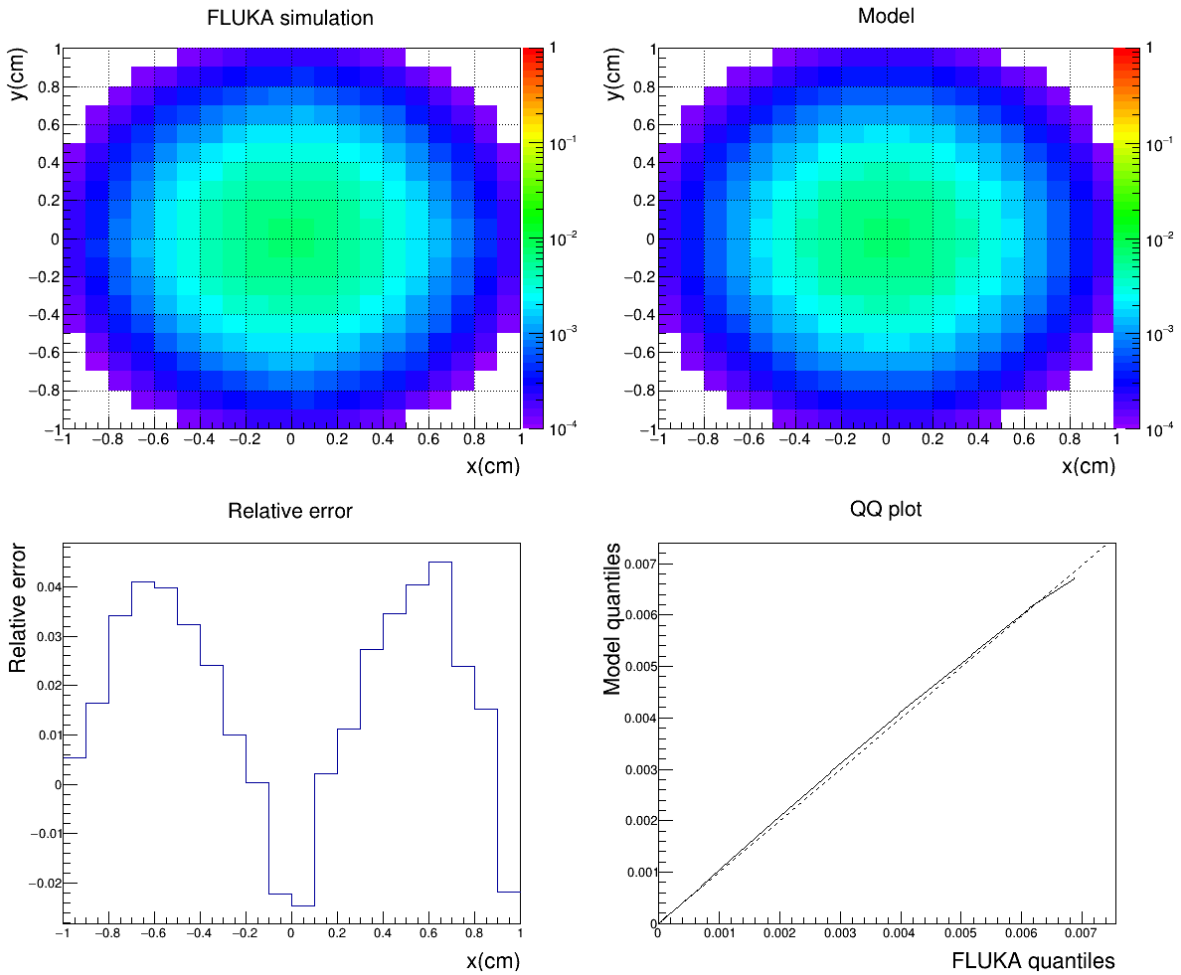
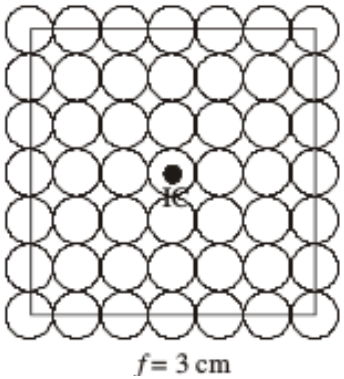


Energy 150 MeV/u at depth z=15 cm (Bragg peak at 15.9 cm).

[6] Embriaco, A model for the fast and accurate dose evaluation in hadrontherapy, *PhD thesis*

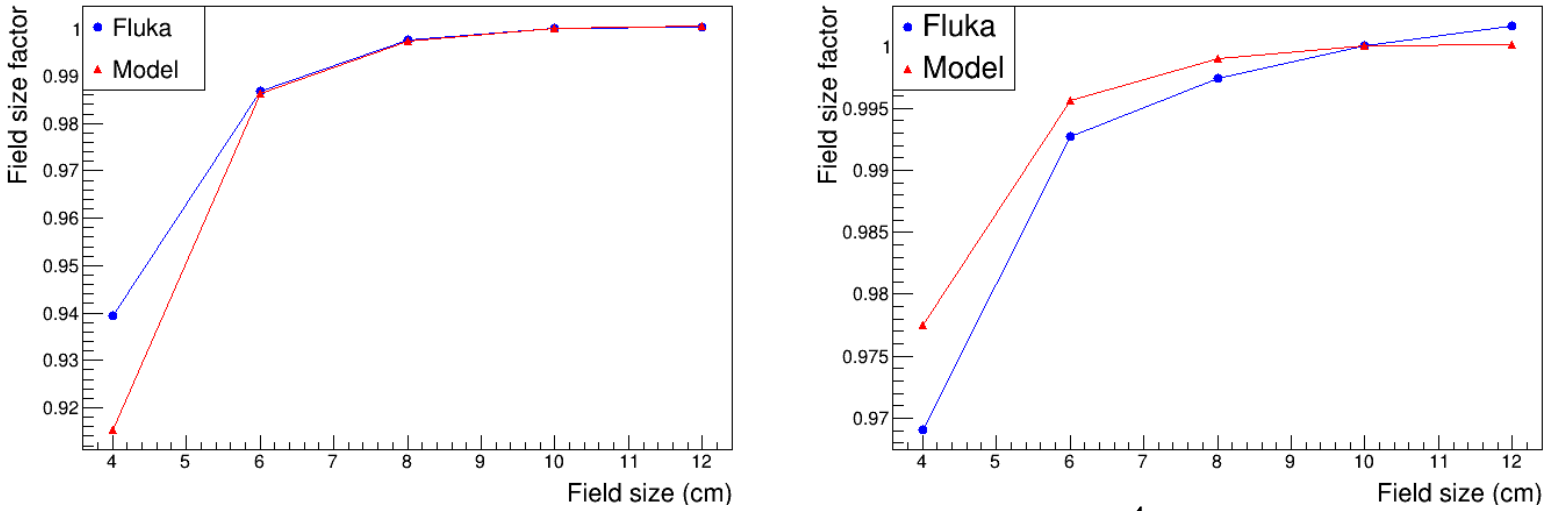
Field size factor test



The field size factor is defined as:

$$FSF(f) = \frac{D_f}{D_{10}}$$

where f assumes the values $4, 6, 8, 10, 12$ cm.



Field size factor at energy 150 MeV at z=15 cm for protons (left) and ^4He ions (right).

[1] Embriaco et al. 2017 *Physica Medica* **38** 66-75

[6] Embriaco, A model for the fast and accurate dose evaluation in hadrontherapy, *PhD thesis*

Conclusion

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FUTURE
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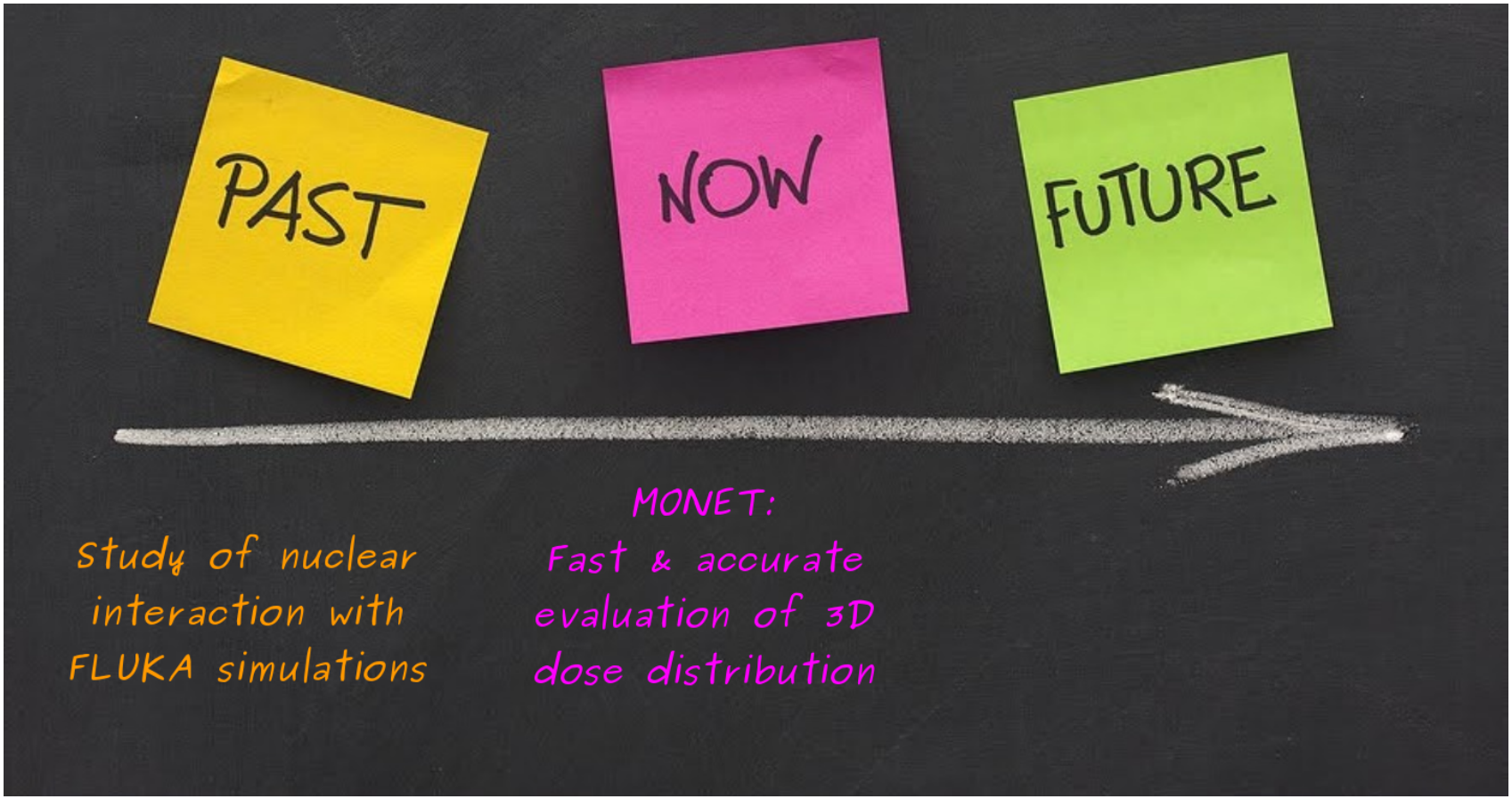
Conclusion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MONET:
Fast & accurate evaluation of 3D dose distribution

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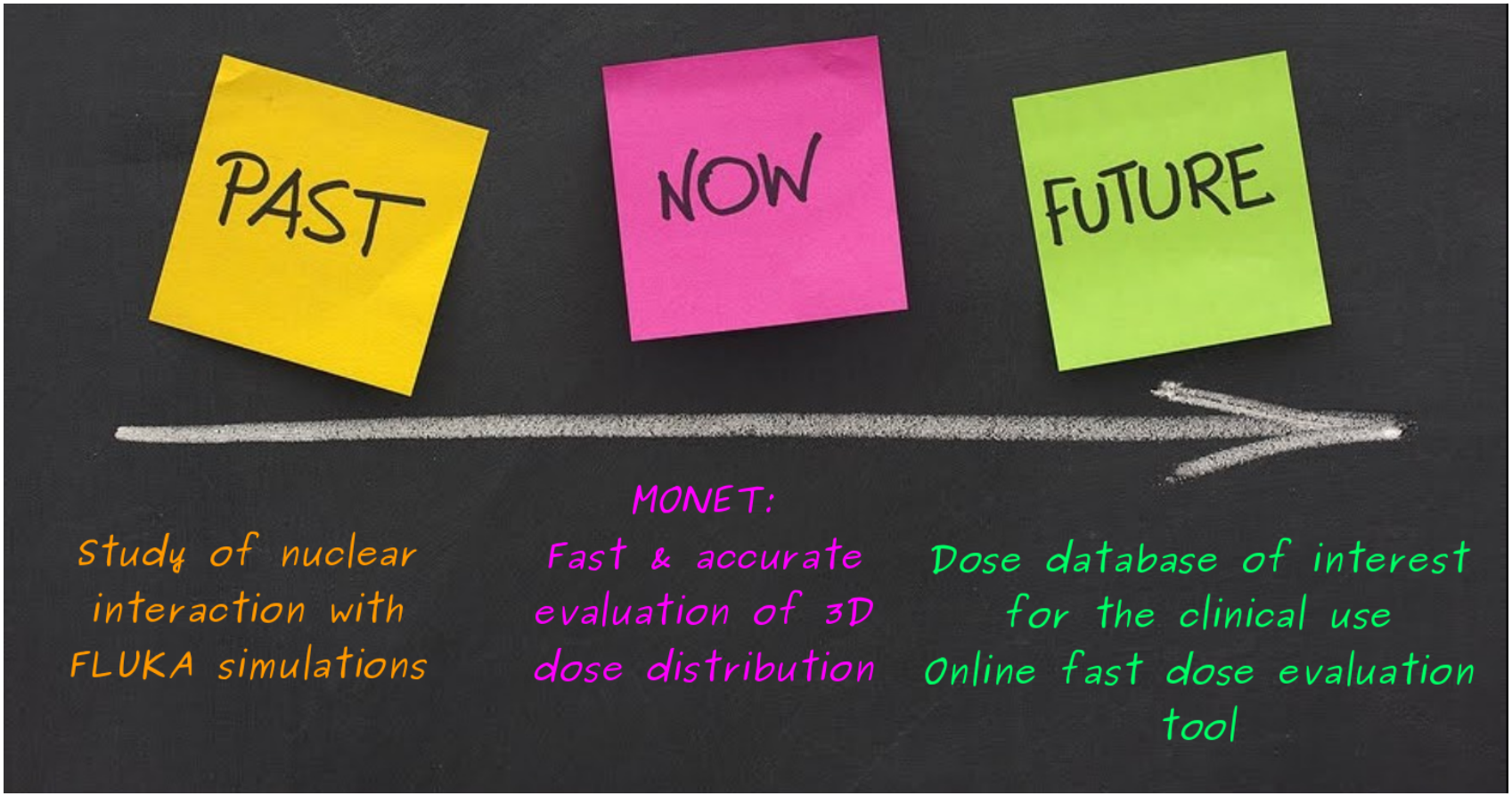
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FUTURE
Study of nuclear interaction with FLUKA simulations
MONET:
Fast & accurate evaluation of 3D dose distribution
Dose database of interest for the clinical use
Online fast dose evaluation tool