Simulation and Detection of Helical Ion-Paths in a small Cyclotron

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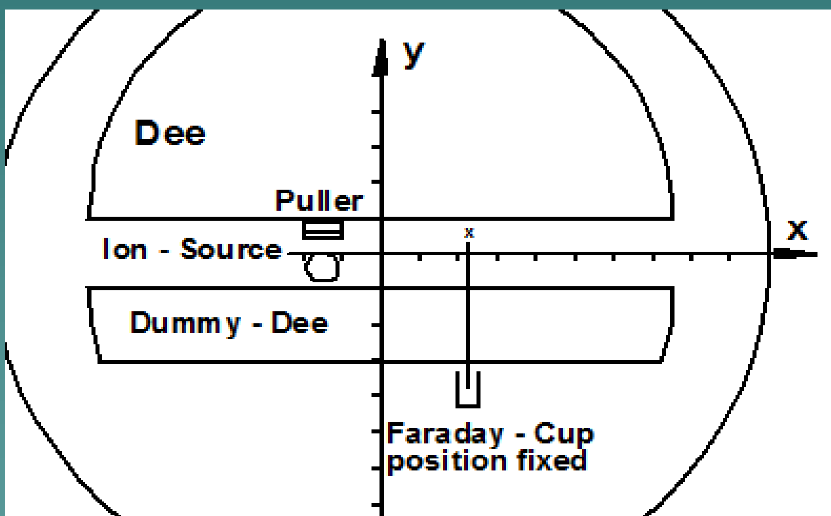
Overview

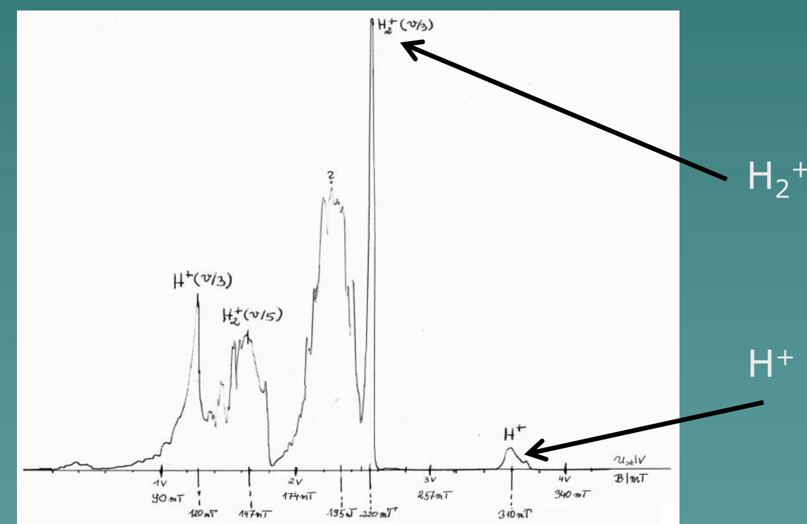
- History and development of the project COLUMBUS
- Fundamentals of the simulation of the acceleration process
- Relevance and Limits

COLUMBUS - a small Cyclotron for School- and Teaching - Purposes

- Start in 2012
- Presented on the Cyclotrons 2013 in Vancouver
- First Beam in 2014
- Workshops since 2015

Experiment: Intensity vs Magnetic field

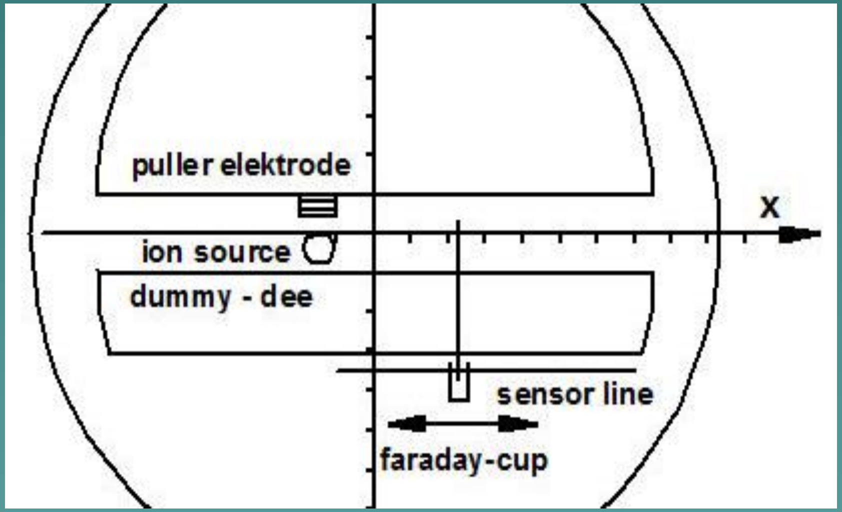


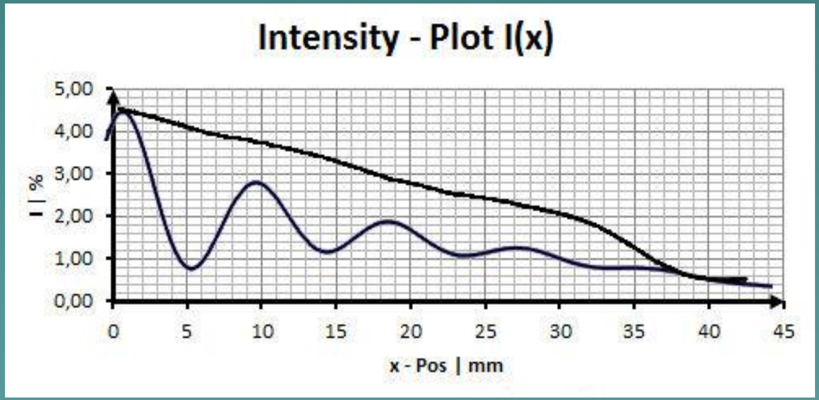


fixed: position of the detector

variable: magnetic field

Experiment: Intensity vs x-Position





variable: position of the detector

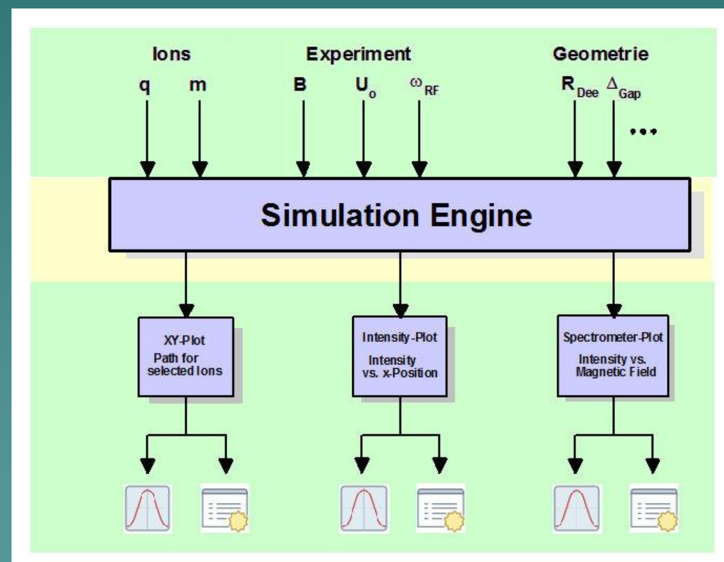
fixed: magnetic field

The Structure of the Simulation

Input - Layer

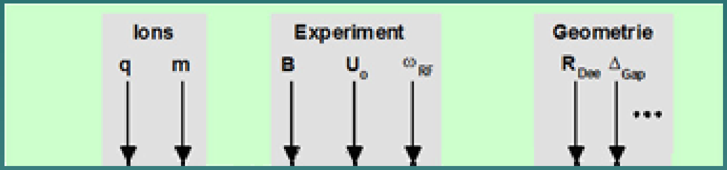
Simulation - Layer

Presentation - Layer

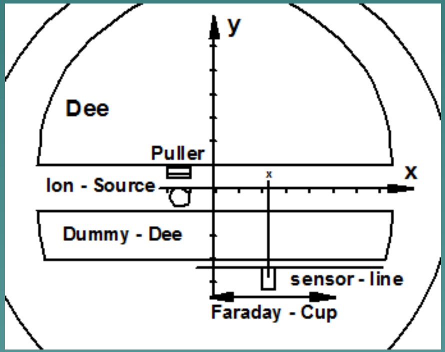


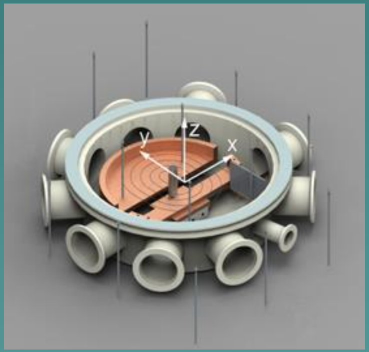
The Input - Layer

Parameter:



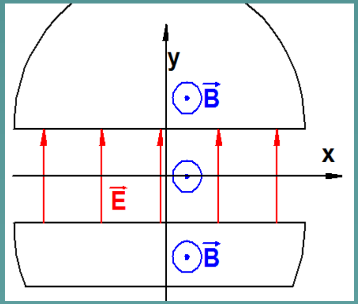
Coordinate System:





The Fields:

$$\vec{E} = \begin{pmatrix} 0 \\ \hat{E} \cdot \cos(\omega_{RF} \cdot t - \varphi) \\ 0 \end{pmatrix}$$



$$\vec{B} = \begin{pmatrix} 0 \\ 0 \\ B_z \end{pmatrix}$$

The Simulation - Layer

Simulation Engine

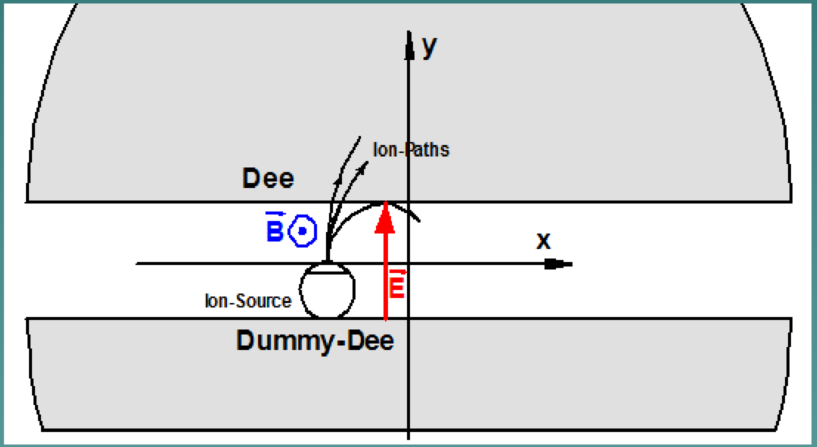
The Acceleration - Phase:

$$m \cdot \vec{a} = m \cdot \ddot{\vec{x}} = \sum \vec{F} = \vec{F}_C + \vec{F}_L =$$

$$= q \cdot \vec{E} + q \cdot \left(\vec{v} \, x \, \vec{B} \right) = q \cdot \left(\vec{E} + \vec{v} \, x \, \vec{B} \right)$$

$$\ddot{x} = \frac{q}{m} \cdot \dot{y} \cdot B_z = \dot{y} \cdot \omega_{ZF} \qquad with \quad \omega_{ZF} = \frac{q}{m} B_z$$

$$\ddot{y} = \frac{q}{m} \cdot E_y - \frac{q}{m} \cdot B_z \cdot \dot{x} = \frac{q}{m} \cdot E_y - \omega_{ZF} \cdot \dot{x}$$



The Simulation - Layer

Simulation Engine

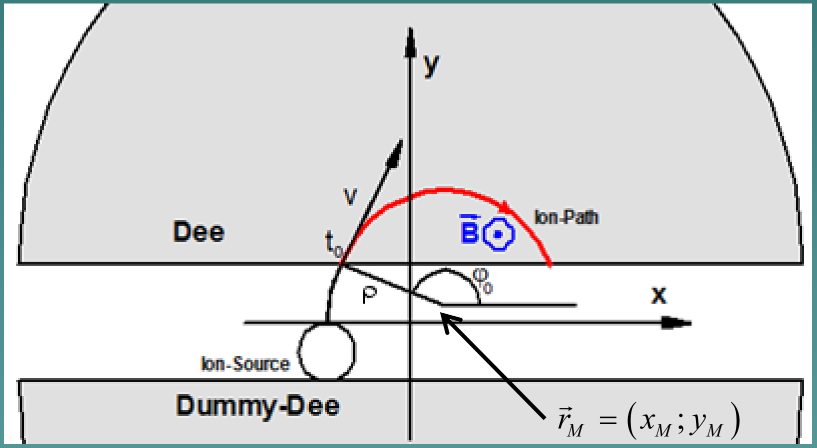
The Deflection - Phase:

$$x(t) = \rho \cdot \cos\left(\varphi_0 - \omega_{ZF} \cdot [t - t_o]\right) + x_M$$

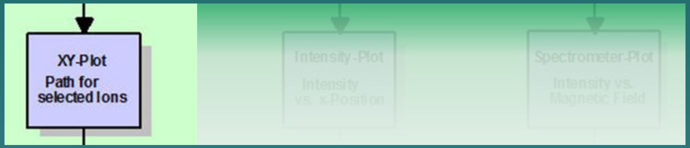
$$y(t) = \rho \cdot \sin\left(\varphi_o - \omega_{ZF} \cdot [t - t_o]\right) + y_M$$

$$\rho = \sqrt{\frac{v_{xo}^2 + v_{yo}^2}{\omega_{ZF}^2}}$$

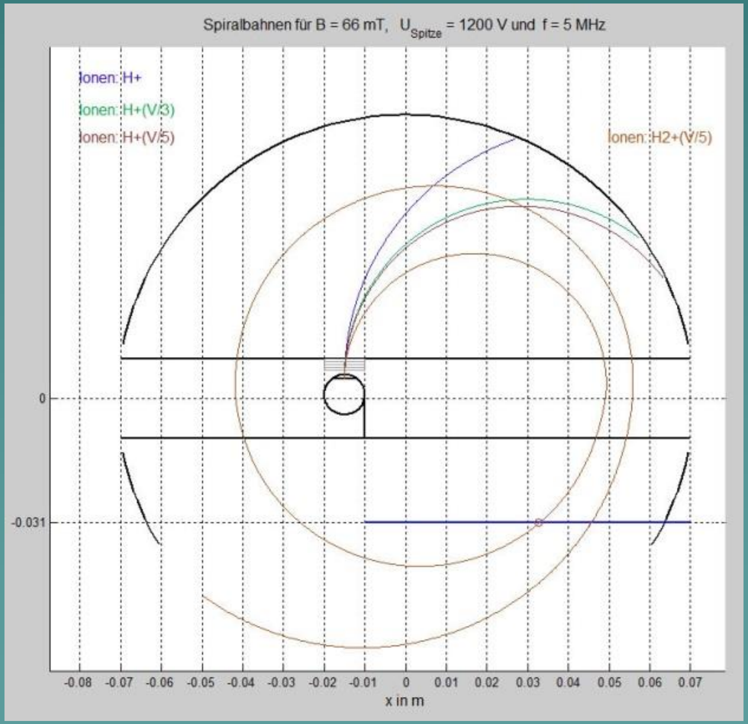
$$\varphi_o = \frac{\pi}{2} + \arctan\left(\frac{v_{yo}}{v_{xo}}\right)$$

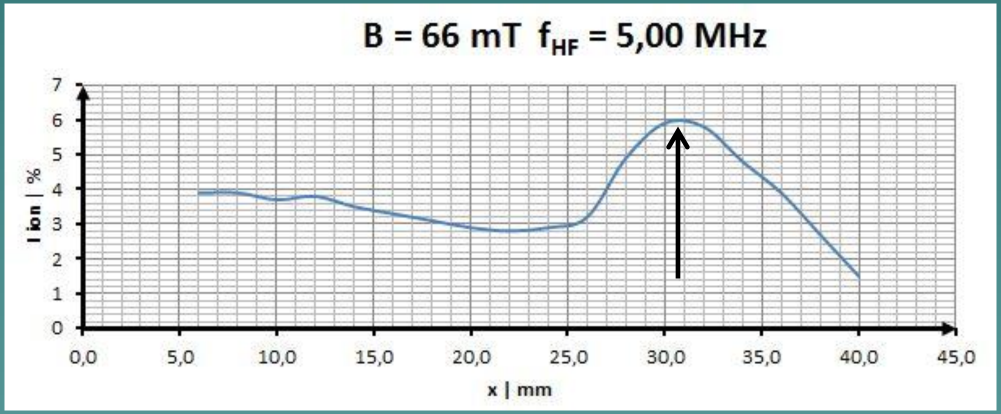


The Presentation - Layer

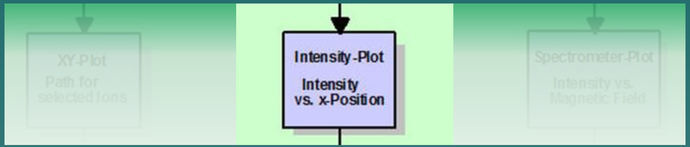


The XY - Plot:

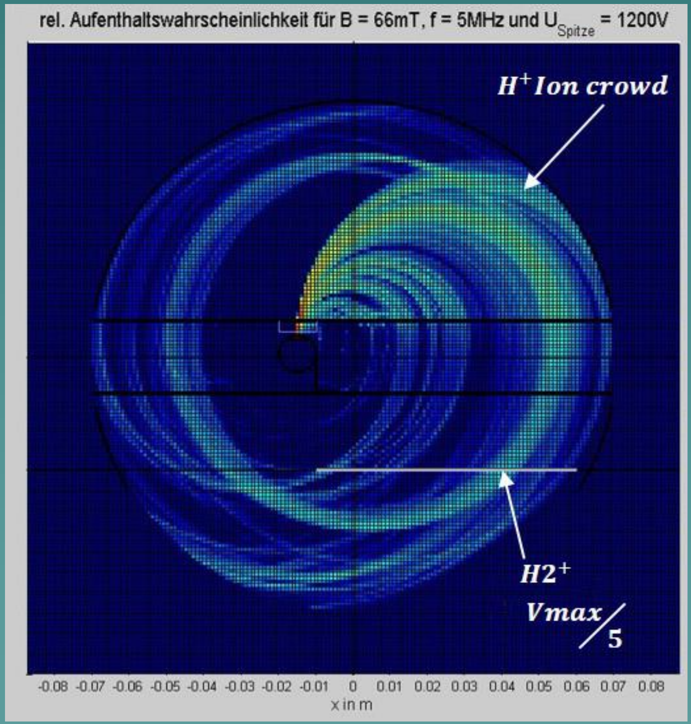


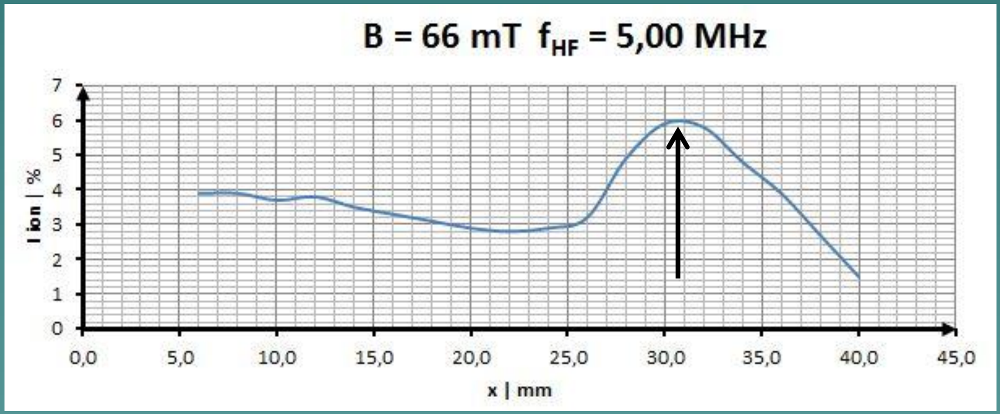


The Presentation - Layer

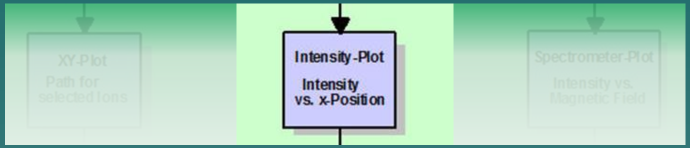


The Intensity - Plot:

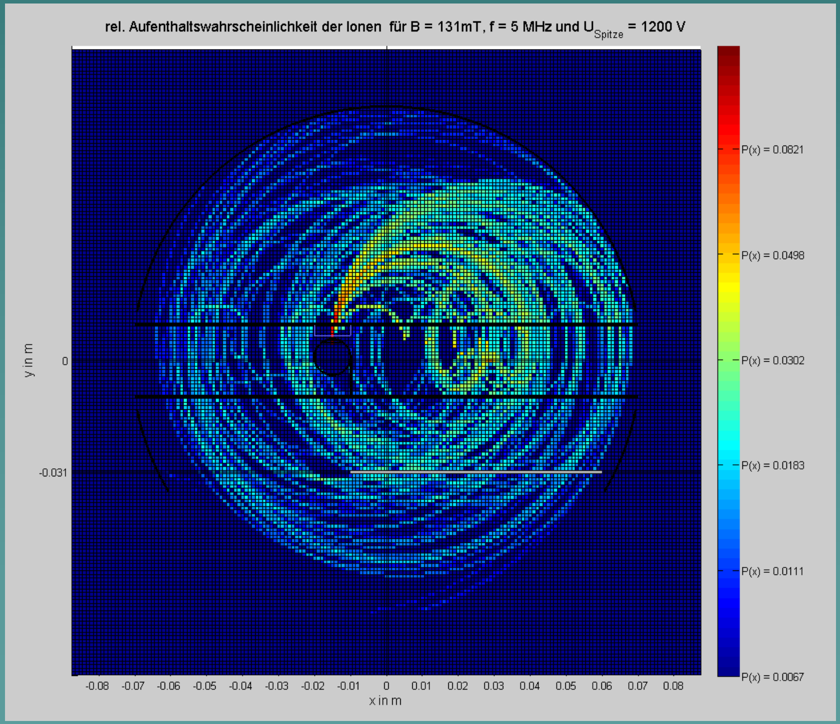


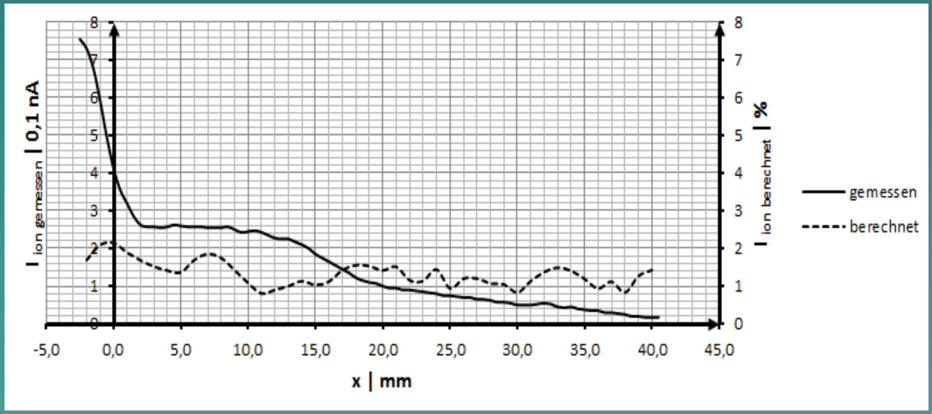


The Presentation - Layer



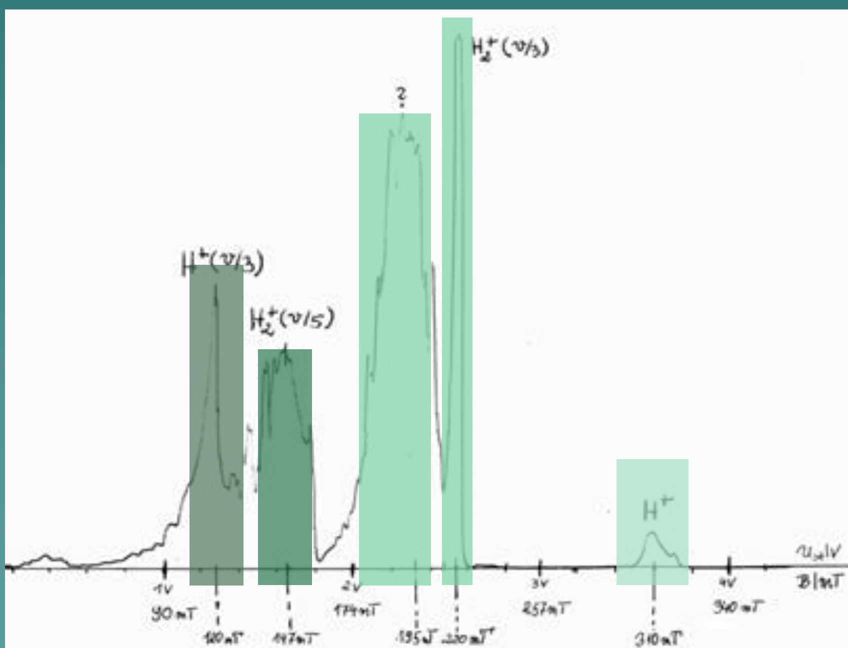
The Intensity - Plot:

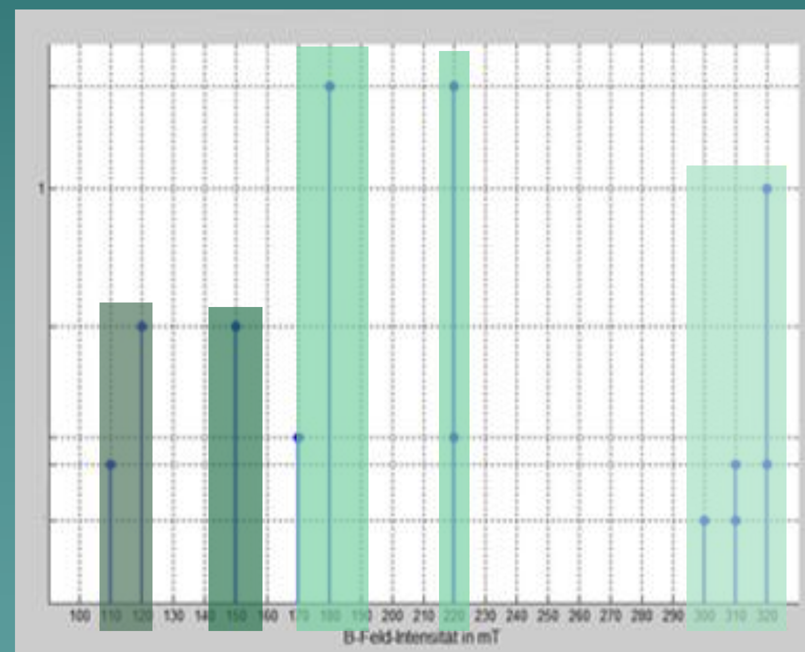




The Presentation - Layer

The Spectrometer - Plot:





Conclusion:

good at qualitative analysis:

- good idea of ion-paths
- explication of intensity

careful with quantitative predictions:

- non constant ion beam from the ion-source
- loss of particles during the acceleration process
- measuring inaccuracy of the parameters

Thank you
for
your attention