



# BLIN4

4th Beam Line and INstrumentation Workshop



**POLITECNICO**  
MILANO 1863

DIPARTIMENTO DI ENERGIA



ERC-2014-CoG No. 647554

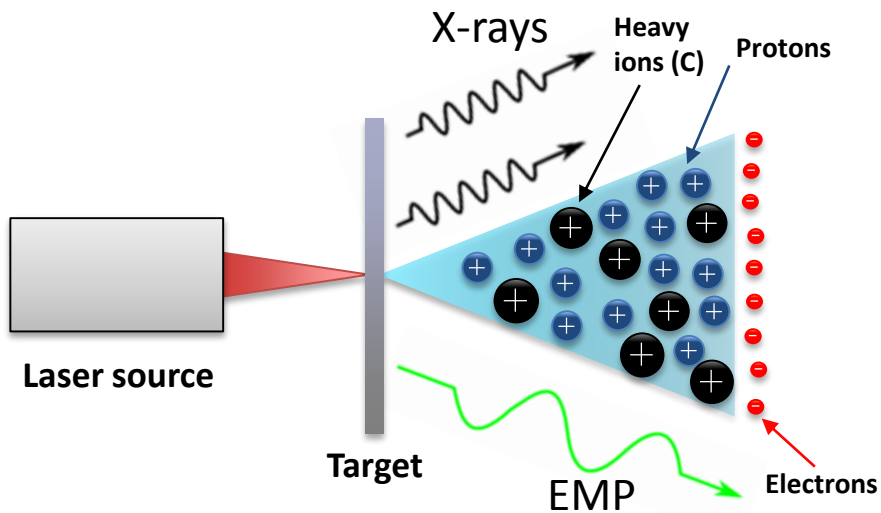
**ENSURE**

## **Laser-driven proton beam diagnostic: feasibility study of a novel technique and possible applications**

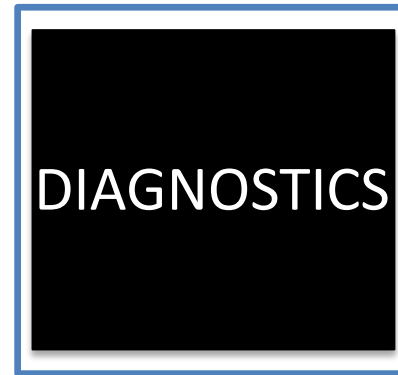
Davide Vavassori

29/06/2020

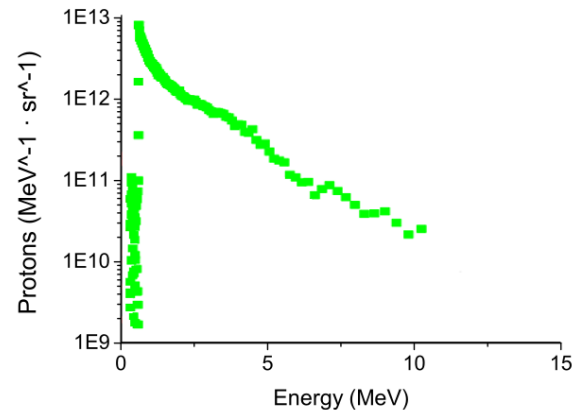
# LASER DRIVEN PROTON BEAM DIAGNOSTICS



- Reliable data
- Maximum energy ~ 10 MeV (required for several potential applications)
- High repetition rate



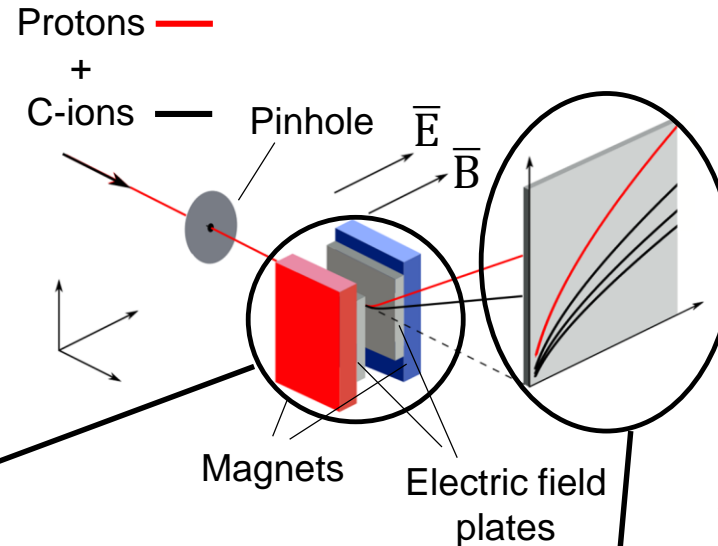
- Real-time energy spectrum measurement
- Discriminate ion species
- Low background sensitivity
- EMP resistant
- No saturation



[C. Zulick *et al.*, Appl. Phys. Lett. 102, 2013]

# TPS AND LIMITATIONS

- Discriminates ion species
- Removes electrons
- Provides energy resolved distribution
- Needs position sensitive detector



Deviation between nominal and effective fields (fringe fields)

[P. Bolton *et al.*, Phys. Med. 30, 2013]

[F. Treffert *et al.*, Rev. Sci. Instrum. 89, 2018]

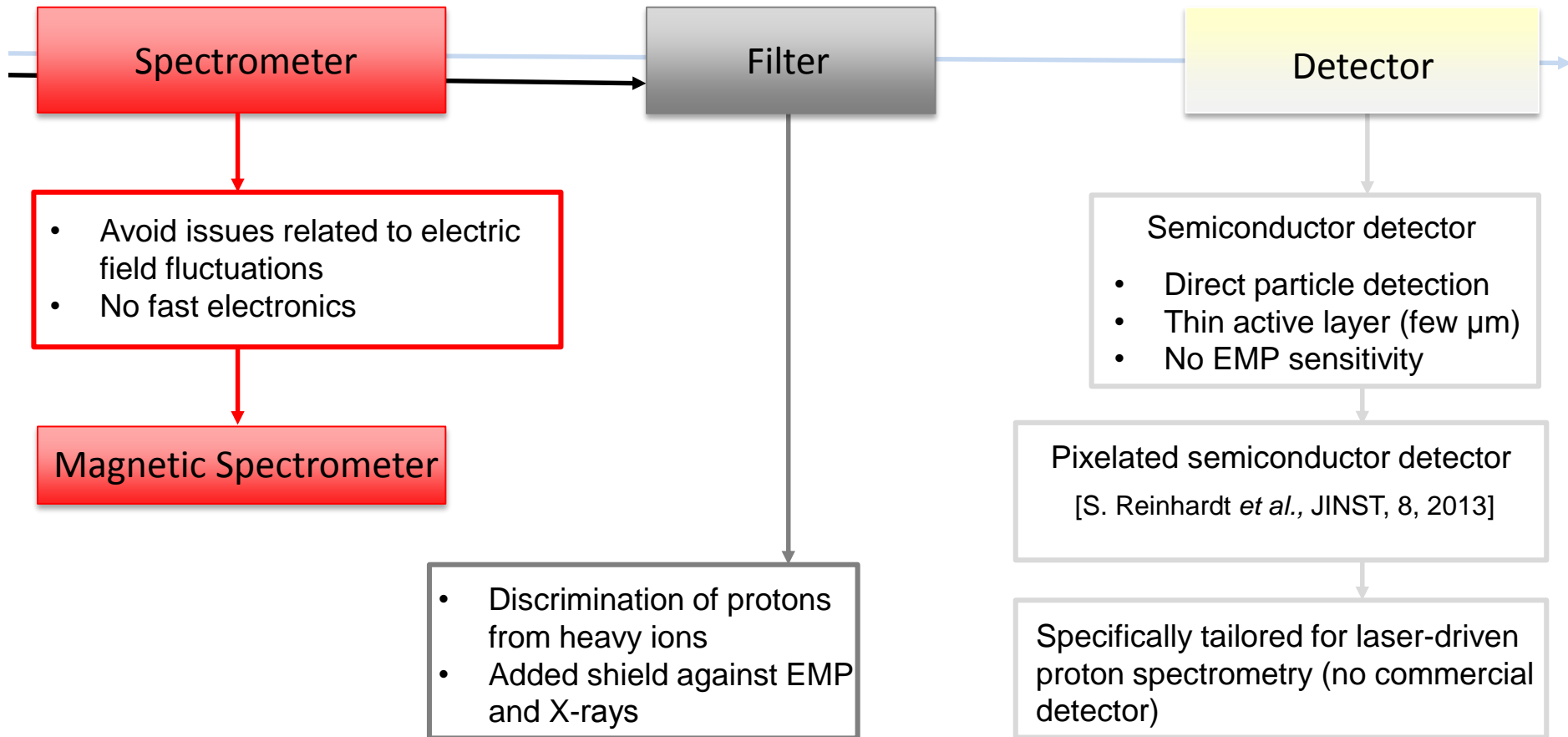
Effective magnetic field constant, while effective electric field fluctuates

Problems related to calibration of the energy-position relationship

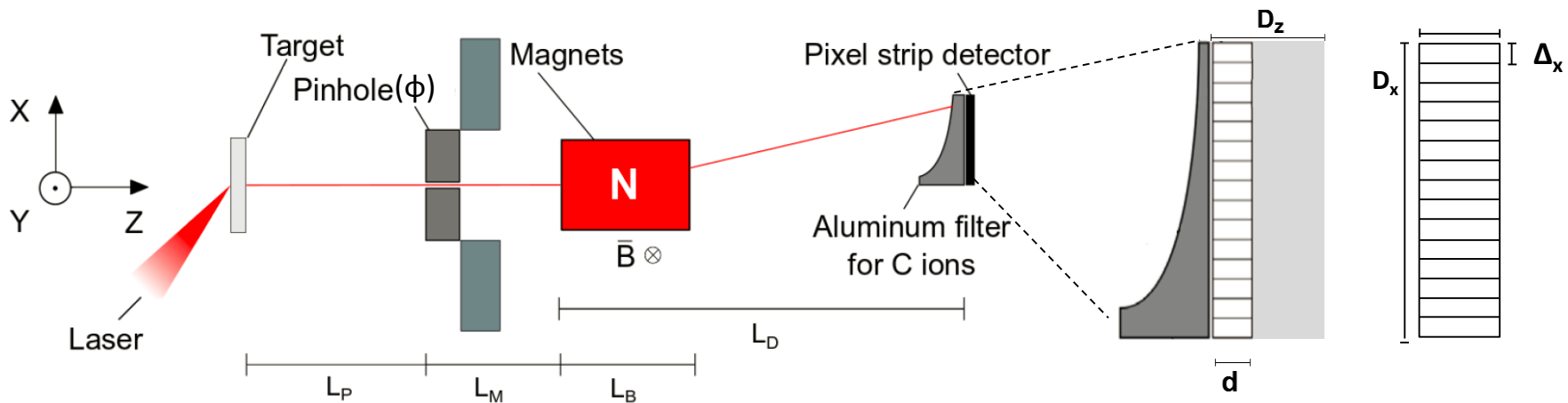
Microchannel plate + phosphor screen

- Saturation issues
- Complex and uncertain **absolute calibration**

# IMPROVEMENTS FOR THE DETECTION SYSTEM



# PROPOSED DETECTION SYSTEM



## THEORETICAL STUDY

- Develop a solid theoretical basis
- Study the feasibility of the reconstruction technique

Analytical model of the detection system

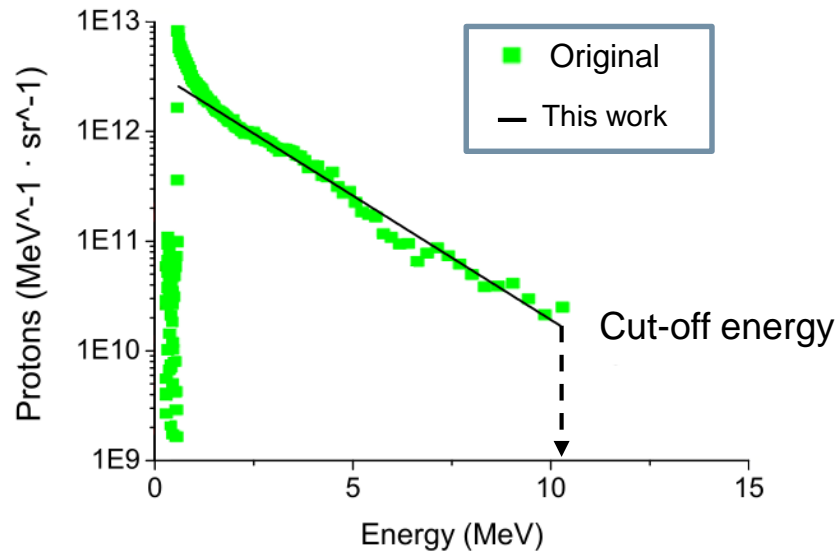
Transport inside the MS

Detection stage

Monte Carlo simulations (FLUKA)

# DETECTION SYSTEM SIMULATIONS

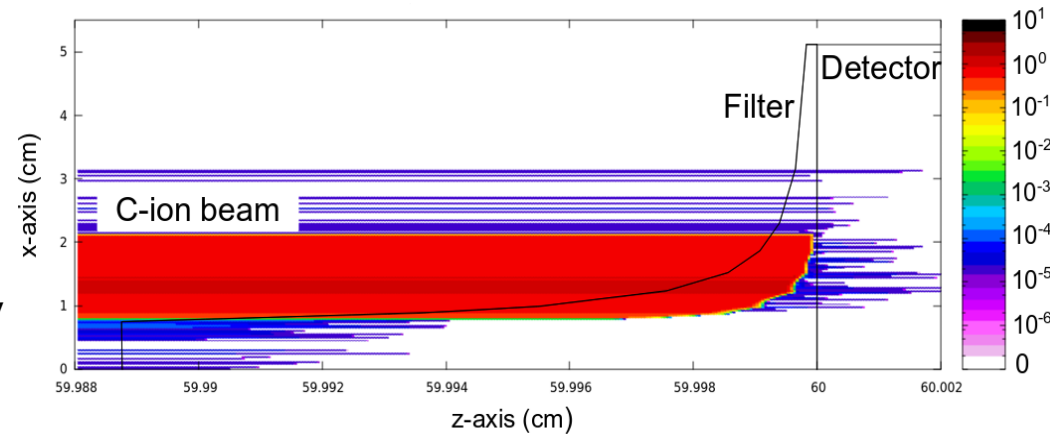
## MODELING OF THE PROTON SPECTRUM



- Quasi-exponential trend
- Maximum energy ~ 10 MeV

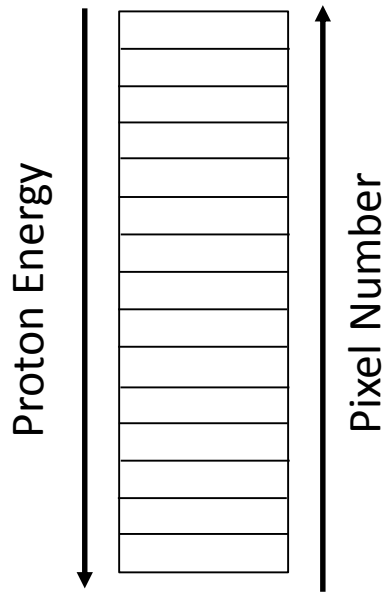
Implemented as the source spectrum in FLUKA

## MODELING OF THE FILTER



- Filter thickness profile derived analytically (1.7-115  $\mu\text{m}$ )
- Implemented complex filter profile in FLUKA
- Tested with non monochromatic C-ion beam

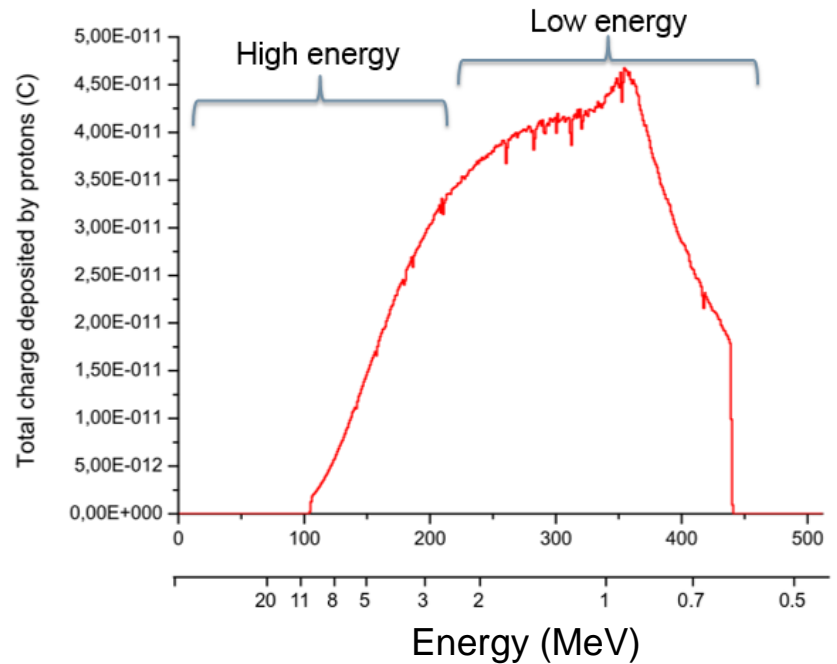
# STEP 1: EVALUATION OF THE PROTON ENERGY AND MEASUREMENT OF THE TOTAL CHARGE DEPOSITED BY PROTONS



## Derived analytically

- Energy bin is assigned to each pixel
- Each pixel integrates total deposited charge

Determination of **proton energy**



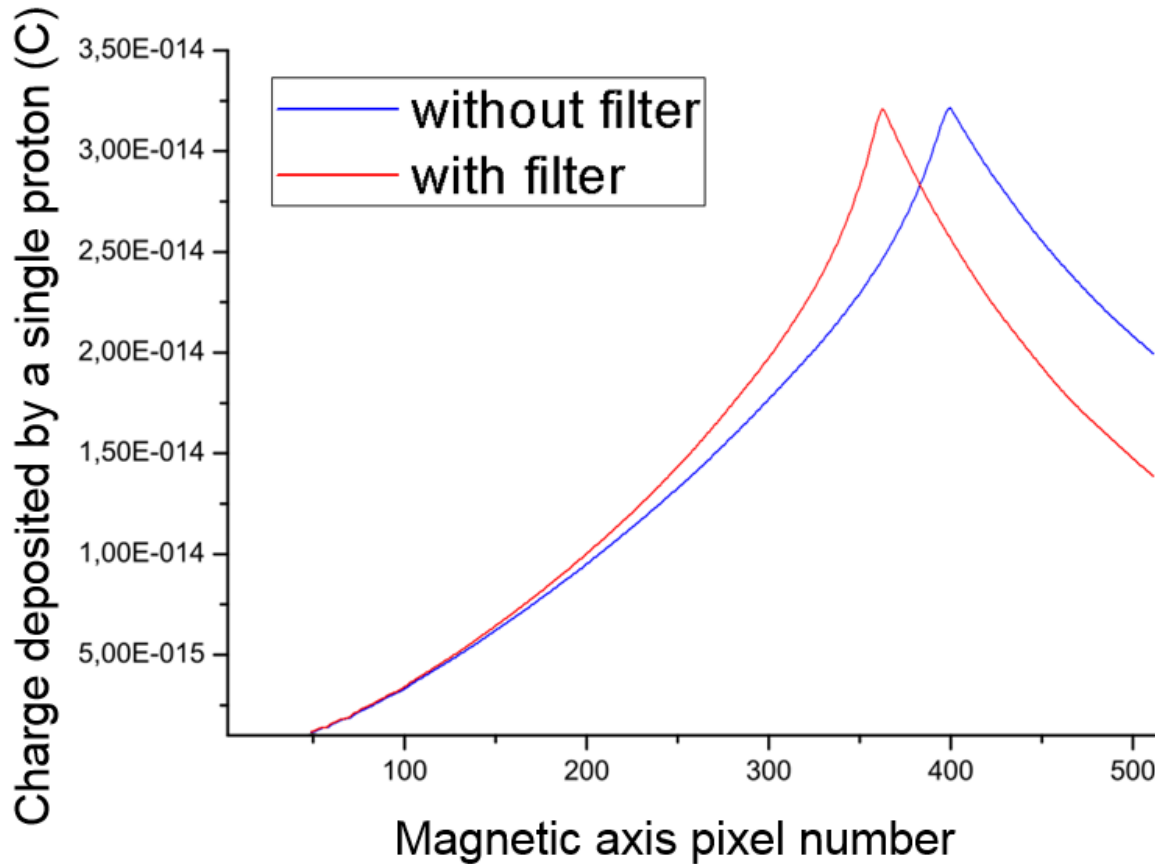
## Derived numerically

- It is the quantity that would be measured in an experiment
- Gradient in deposited charge over the whole spectrum

**Solution:**  
Front-end electronics modulated along the magnetic axis

Determination of the **total charge**

# STEP 2: MEAN CHARGE DEPOSITED BY A SINGLE PROTON EVENT IN EACH PIXEL



## Analytical part

- SRIM software was employed

## Numerical part

- Simulations performed on single pixels
- Introduces particle straggling

Dividing the total charge by the single proton charge  $\longrightarrow$  **Number of protons**



# STEP 3: RECONSTRUCTED PROTON SPECTRUM

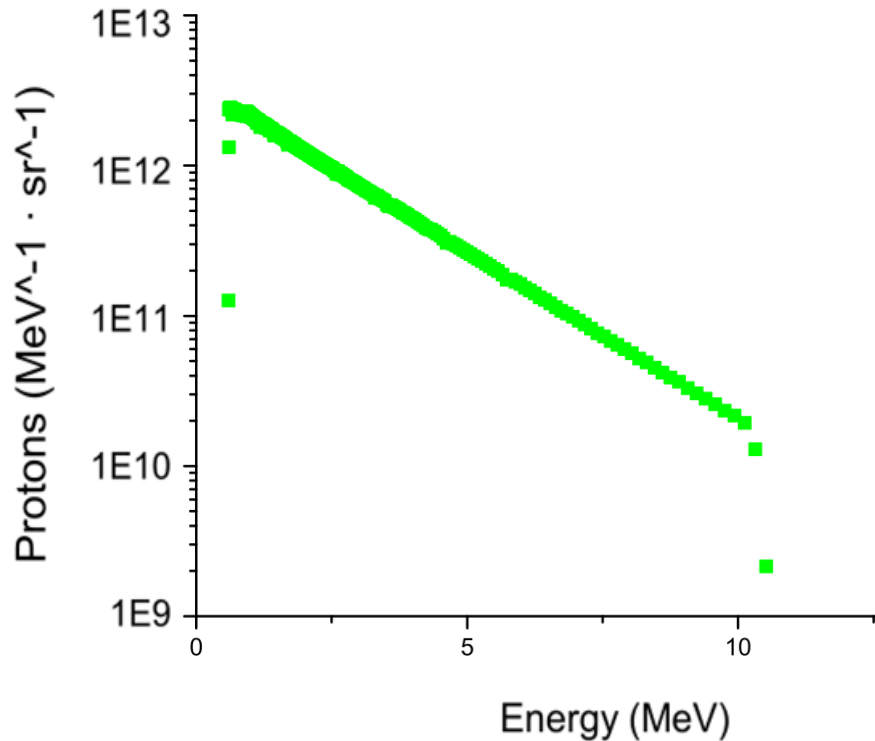
Combining the information obtained in the different previous steps, the proton spectrum can be reconstructed



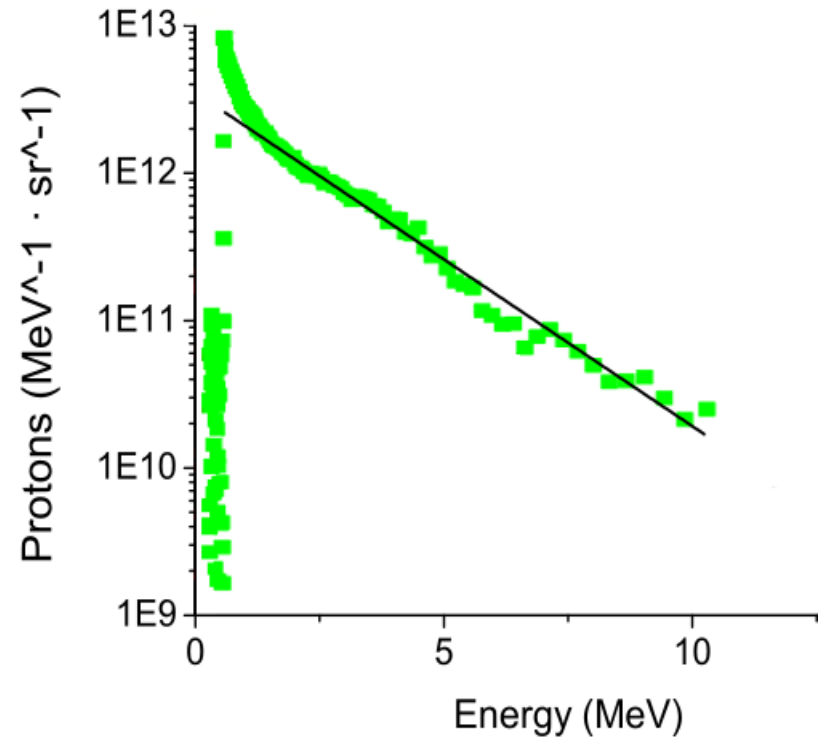
✓ Shows **theoretical feasibility**

[G. Milluzzo *et al.*, Rev. Sci. Instrum., 90, 2019]

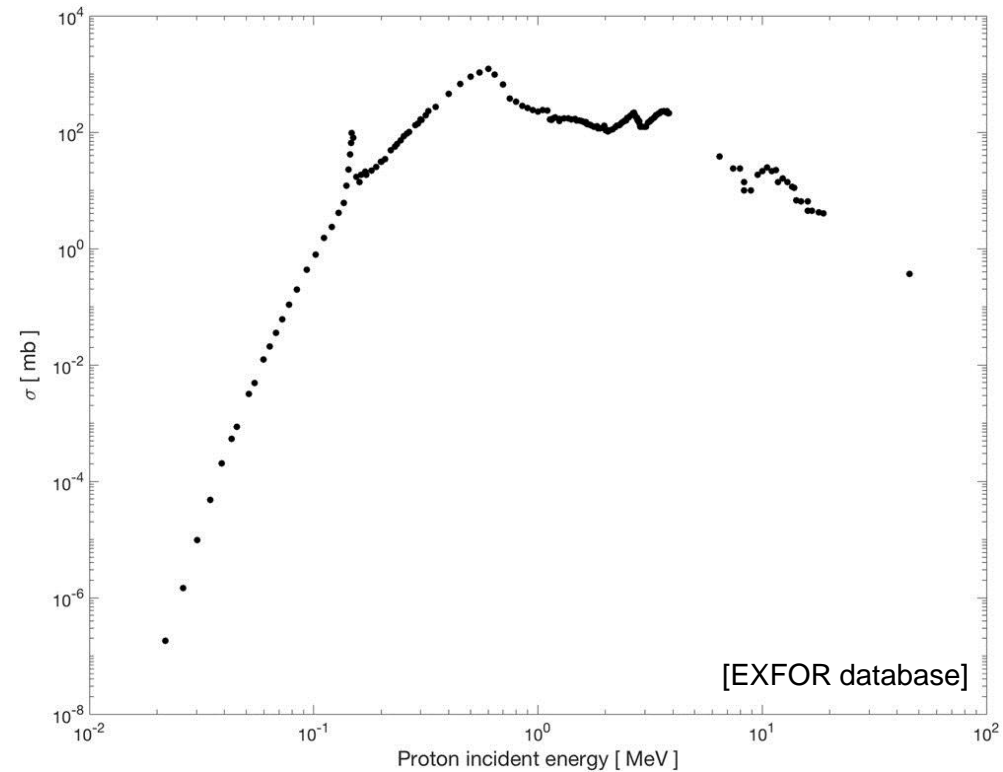
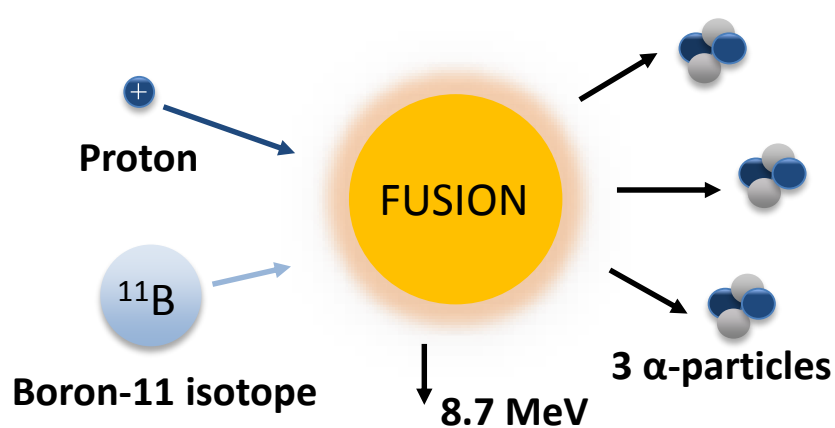
## Reconstructed



## Original



# APPLICATIONS OF THE PROPOSED DETECTION SYSTEM : STUDY OF NUCLEAR REACTIONS



- Energy applications

[H. Hora *et al.*, Laser Part. Beams 33, 2015]

- Medical applications

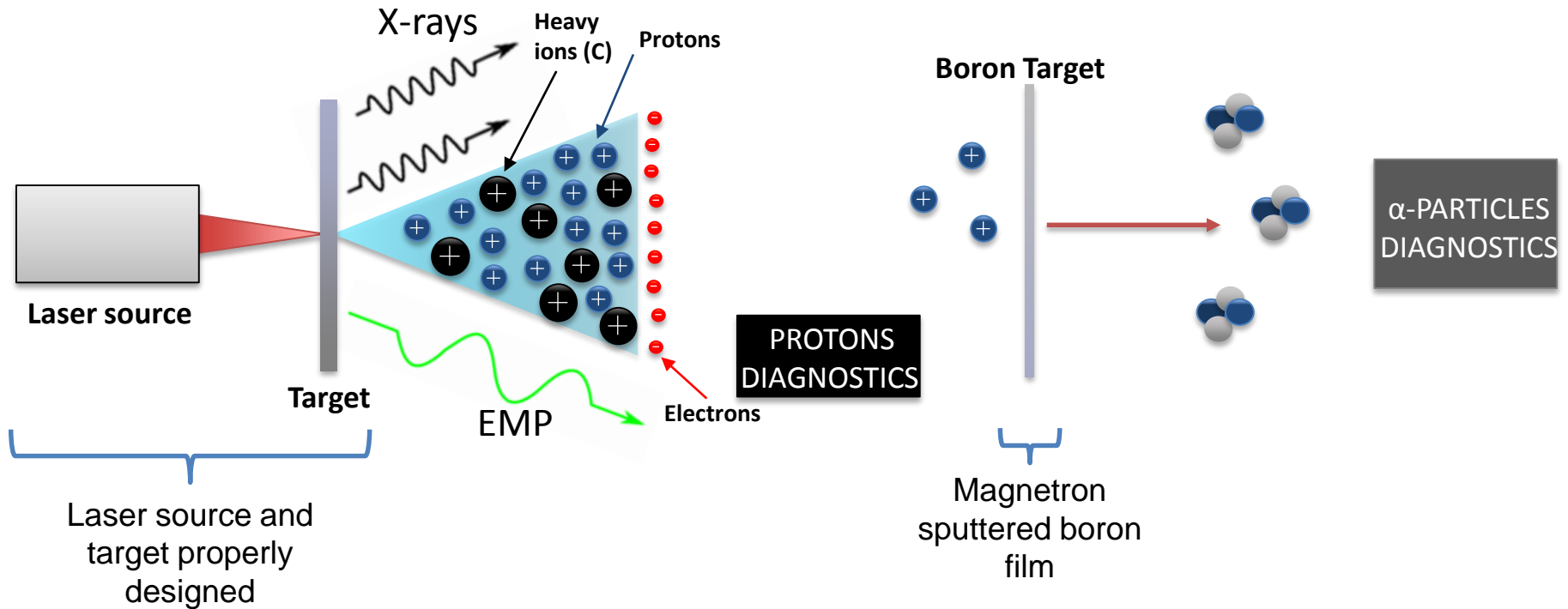
[G. A. P. Cirrone *et al.*, Sci. Rep. 8, 2018]

[NEPTUNE project (INFN)]

→ Main resonance peak occurring approximately at 670 keV proton energy ( $\sigma \approx 1.2$  barn)

→ Further studies on the reaction cross section are needed

# APPLICATIONS OF THE PROPOSED DETECTION SYSTEM : STUDY OF PROTON-BORON REACTION



Exponential trend of laser-driven proton energy could be beneficial to study the reaction

- Proton energy is well characterized
- Proton number is well characterized

More in-depth study of the reaction

# CONCLUSION AND FUTURE PERSPECTIVES

## CONCLUSIONS

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- An alternative laser-driven proton beam diagnostic has been proposed and it has been studied combining an analytical model and numerical simulations.
- The detection system has a properly designed filter (selection stage).
- Presence of a modular front-end electronics, but no fast electronics.
- The theoretical feasibility of the reconstruction technique was demonstrated.

## PERSPECTIVES

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- Analytical model can be used to analyze future experimental data and to design a real spectrometer.
- Experiments involving irradiation of a prototype system, based on a detector with a small number of pixels in a well-defined geometry, are needed.
- Realization of the proposed laser-driven proton beam diagnostic.
- Application in experiments requiring precise beam characterization.

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**ENSURE**

**Thank you for your kind attention!**