A Scintillator-Based Range Telescope for Proton Therapy

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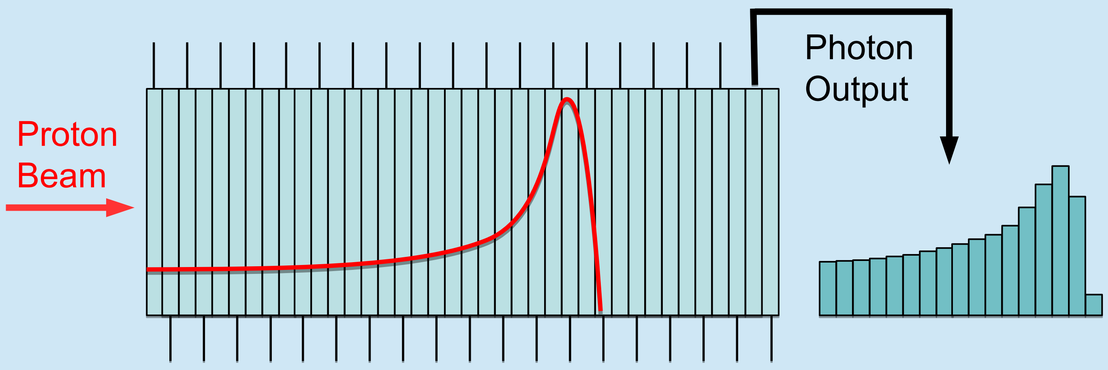
Abstract

A detector is under development to improve the accuracy and reduce the measurement time for proton energy measurements in proton therapy using an adapted calorimeter module that was designed for the SuperNEMO high energy physics experiment. A potential layout of a range telescope is presented. In addition, a method to retrieve proton range from quenched scintillation photon output is proposed.

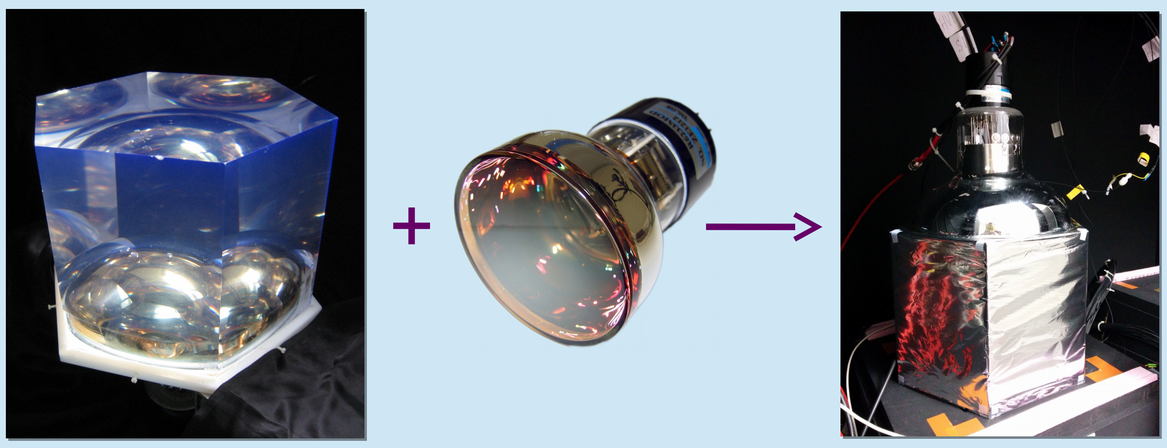
Concept

In order to measure the range/energy of a proton beam, a scintillator block will be cut in segments, called sheets. Each sheet will be read out individually. The resulting photon output allows to measure proton range.



The SuperNEMO* Optical Module

PVT Scintillator + High Quantum Efficiency PMT, wrapped in reflective material:



Advantages:

- High light output
- Fast response time (ns)
- Compact
- Cheap
- PVT scintillator is water equivalent

Disadvantages:

- Radiation hardness?
- Quenching (SOLUTION PROPOSED)

Applications in Proton Therapy

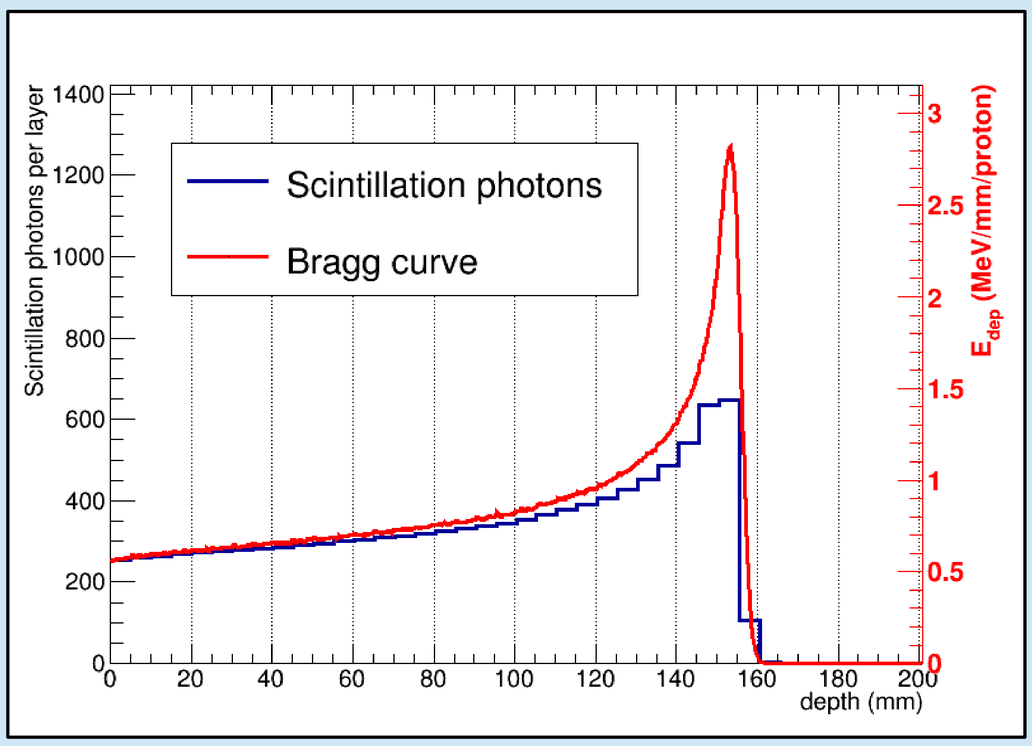
Quality Assurance (QA): Significantly reduce time and cost of regular QA procedure in proton therapy centres.

Proton Computed Tomography (pCT): Provide the energy measurement stage of a pCT in order to reduce treatment planning uncertainties.

Fast Treatment Plan Verification: Deliver the prescribed treatment plan to the range telescope for plan verification.

Quenching

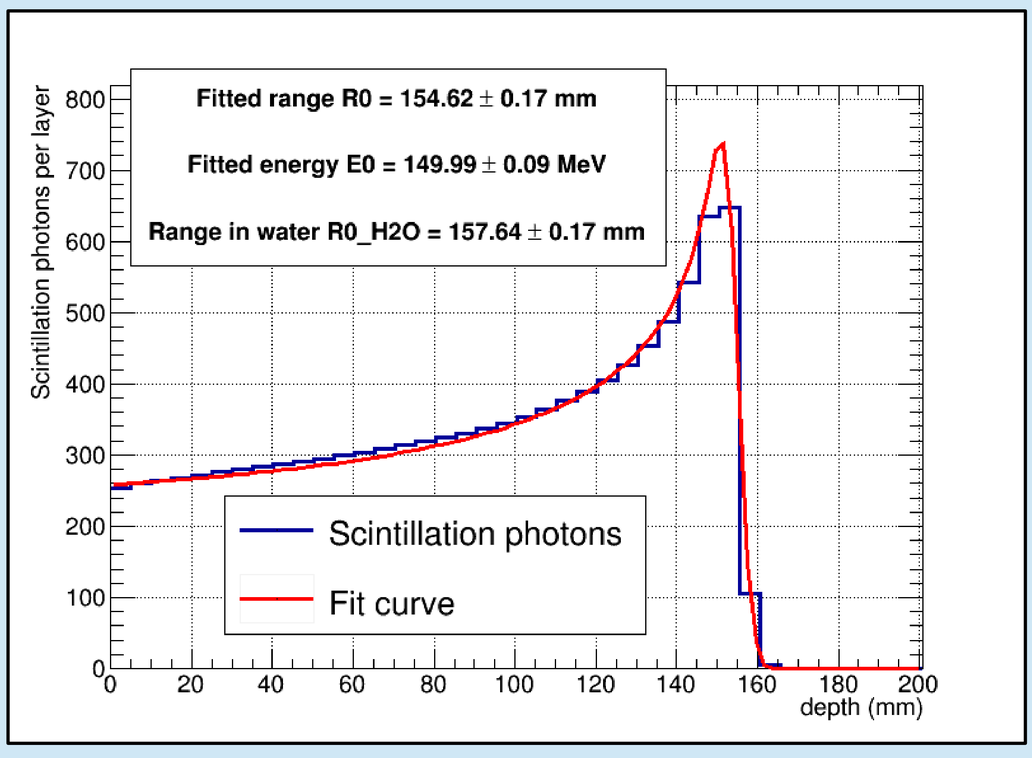
The scintillation light yield from ionizing radiation with high dE/dx undergoes quenching which is described by Birk's law**.



GEANT4 simulation of the Bragg curve and the scintillation light output in a range telescope with 5mm thick scintillator sheets for a proton beam of 150MeV.

Measure Proton Range

An analytical model of a quenched Bragg curve*** has been developed to fit the scintillation light output. The model has three parameters; one parameter is the mean proton range in the scintillator which can be converted to proton energy and the corresponding range in water.



Fit to a GEANT4 simulation of the light output in a range telescope with 5mm thick scintillator sheets for a proton beam of 150MeV.

References

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** Birks, J.B. *Scintillations from Organic Crystals: Specific Fluorescence and Relative Response to Different Radiations*. Proc. Phys. Soc. A64: 874. (1951)

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