SHARP A compact focusing system for medical applications using a diverging plasma lens

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SHARP is tackling

Design and tests of **strongly converging** & **compact final focus optics**

- Application: **Precise** irradiation for **radiotherapy**, with **low doses to surrounding off-target tissues**
- Goal: Fast precision **3D spot scanning**

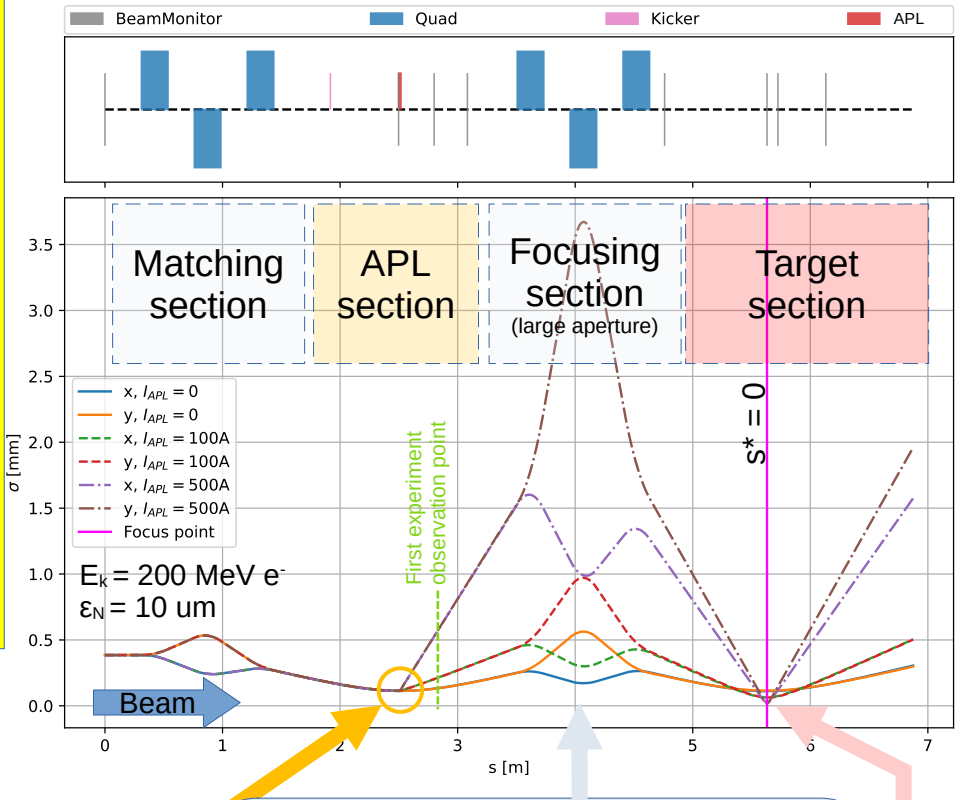
With this, we will also study:

- Dosimetry performance of strongly converging optics for e^- & p^+
- Emittance preservation from plasma wakefields in APLs
- Generation of non-gaussian beam profiles at target

Finally we will design an insertable proton minibeam platform for pre-clinical research @ Oslo Proton Therapy Center

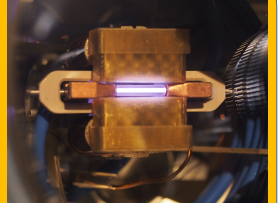
References:

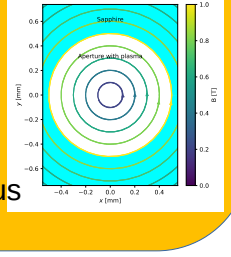
- E. Rød-Lindberg, "Compact final focus for particle therapy", MSc thesis, 2025
- F. Reaz et al, "Sharp dose profiles for high precision proton therapy using strongly focused proton beams", Sci Rep. 2022



Diverging Active Plasma Lens

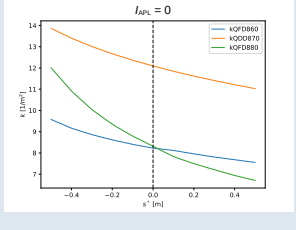
- **Linear active plasma lens**
  - Uniform current density
  - Same focusing force in both planes (x & y)
- Reverse the polarity to **defocus** the beam
- => Enhanced β at focus quads
- Moderate APL gradients needed
  - 100 A gives 80 T/m or 120/m² at E_k = 200 MeV, r=0.5 mm
- **Less disruption of the beam** & **more compact** vs. other means of β enhancement before final focus
- **Focal spot symmetric in x/y**





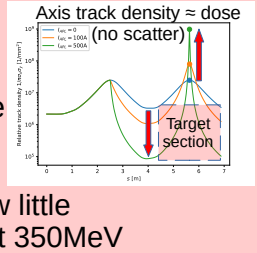
(Re-)Focusing with Quads

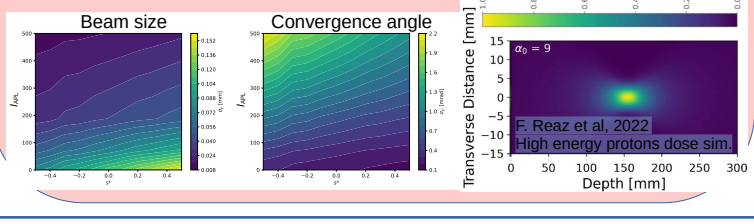
- Receives diverging beam with enhanced β from APL section
- Can vary focus point over some range
- Large initial β leads to small β* and large convergence angle
- Slightly different magnet strengths for I_{APL}>0



Sharply converging beam

- Higher I_{APL} and/or smaller s* => sharper convergence, to smaller focus point
  - Diminishes the off-target dose
- Expect the effect to be partially preserved with scattering
  - Simulations with protons show little degradation from scattering at 350MeV

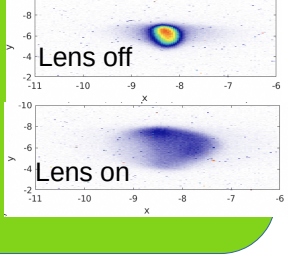




First test at CLEAR

- Observed beam profile 30 cm after APL,before focusing quads
- Compared beam profile lens on (≲1 kA) vs. lens off
- Observed gradual increase in σ when increasing I_{APL}
- No focusing section at that time
- Plan to follow up in 2025

From E. Lindberg, 2025
(note: Screen calibration uncertain)



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https://www.mn.uio.no/fysikk/english/research/projects/sharp-particle-accelerator-precision-focus-system-medical-applications/index.html

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