CONCEPTUAL DESIGN OF A SPECTROSCOPY-TYPE NON-ROTATING GANTRY SYSTEM

PTCOG-AO 2025

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Background

Visualization of an IMPT and PAT Planning

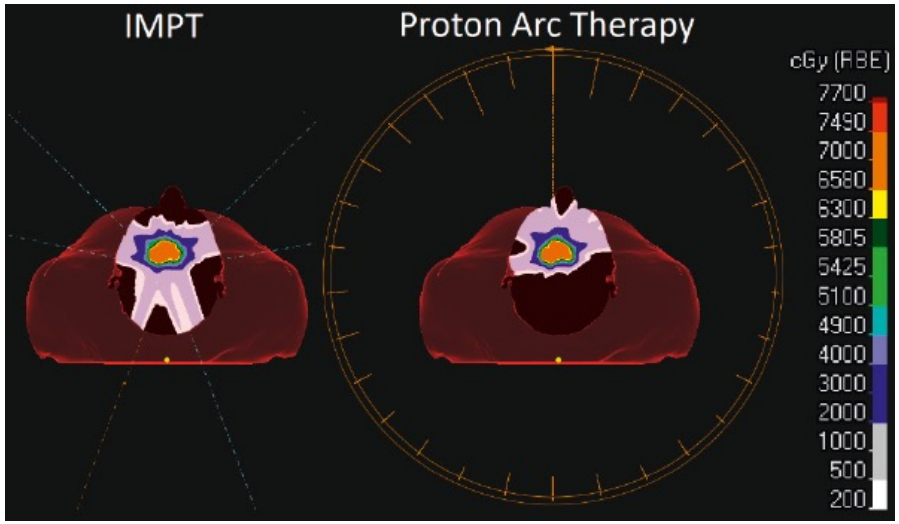


Figure reproduced from Jong, B.A.: Proton arc therapy: technical feasibility and clinical benefit in head and neck. cancer treatment. PhD thesis, University of Groningen, Groningen, The Netherlands (2025). https://doi.org/10.33612/diss.1220534045

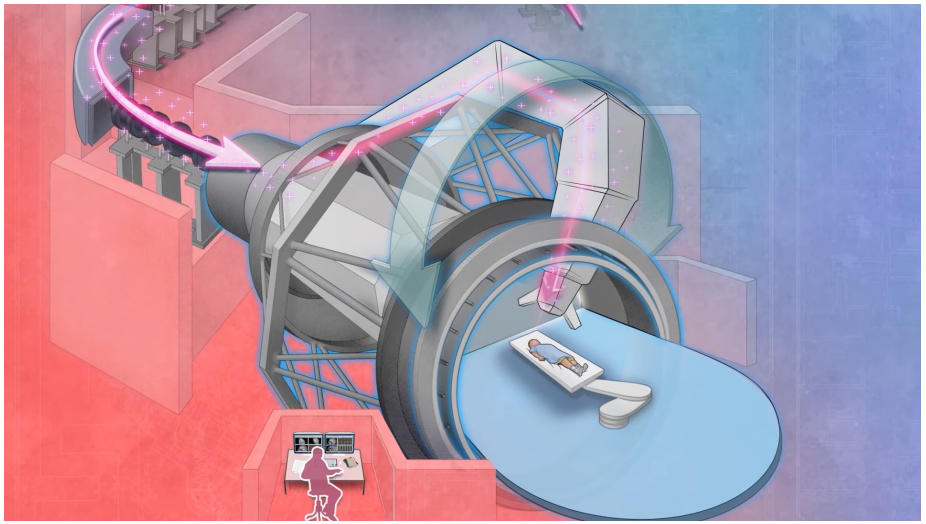
Multiple Treatment Angles

↓ Provide

- **Better dose distribution on target**
- **Better protection of normal tissue**

Generally Realized with

Rotating Gantry System



- An internal diameter of 8~12 m, total diameter of **15~20 m**
- Generally, mechanical system **restricts available treatment angles** to several ones
- **Change of Treatment angles takes time**, especially challenging in PAT

↓

Compactness & continuous treatment angles and rapid change are desired

IMPT: Intensity Modulated Proton Therapy
PAT: Proton Arc Therapy

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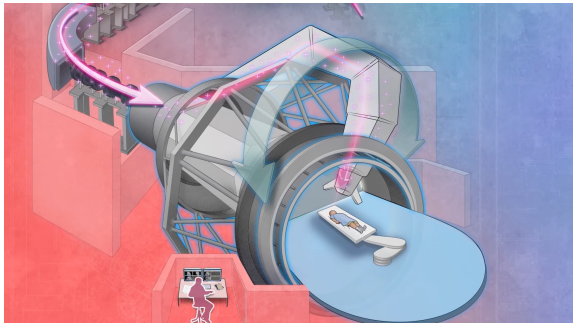
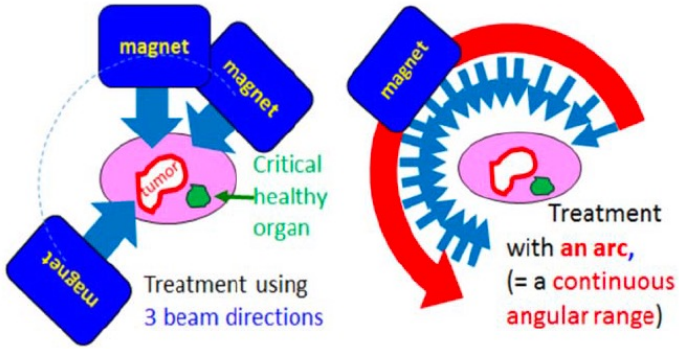
Purpose

Conventional Rotating Gantry System





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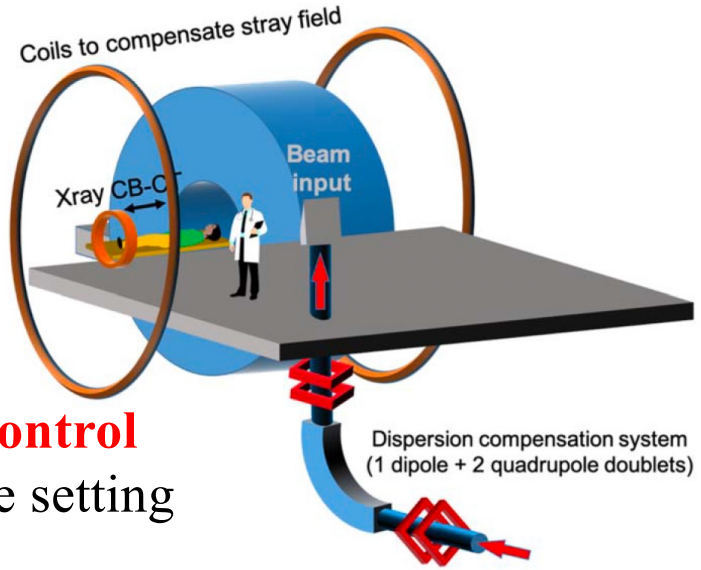
A static beam delivery device for fast scanning proton arc-therapy. *Physics in Medicine & Biology 66(5), 055018 (2021)* https://doi.org/10.1088/1361-6560/abe02b

Instead of rotation

Dynamic magnetic-field control
for treatment angle setting

Spectroscopy-type Non-rotating Gantry System



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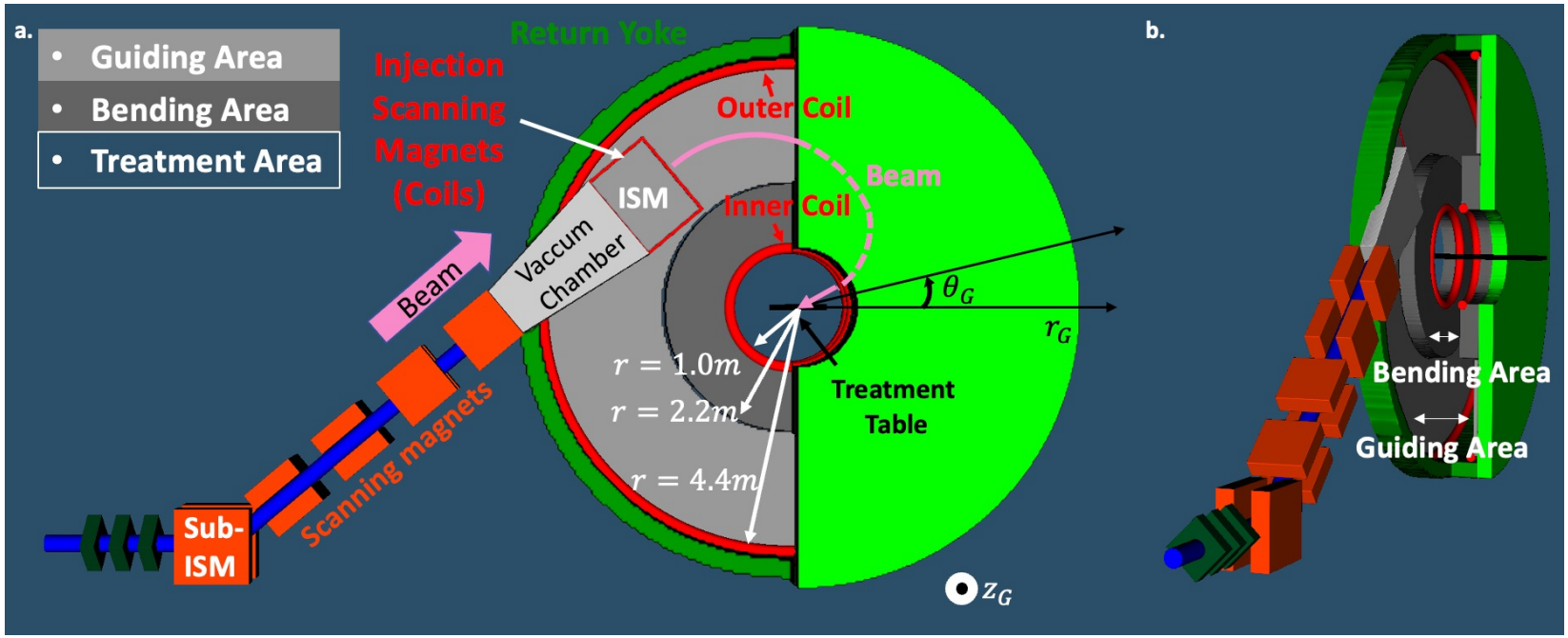
Design Methodology



- **Outer Coils:** Excite magnetic field in both Bending Area and Guiding Area
- **Inner Coils:** Create a magnetic free area for treatment
- **Magnet Poles:** Adjust the magnetic field strength rate in Bending Area and Guiding Area
  $2G_B$: **Pole Gap** in B Field
  $2G_G$: **Pole Gap** in G Field
- **ISM** (Injection Scanning Magnets): Set the treatment angle

Methodology

Magnetic Field Simulation @Opera3D
↓
3D Field Profile (B_r, B_θ, B_z)
↓
Beam Transport Evaluation
↓
Field Parameter Optimization
↑

Beam Transport Evaluation

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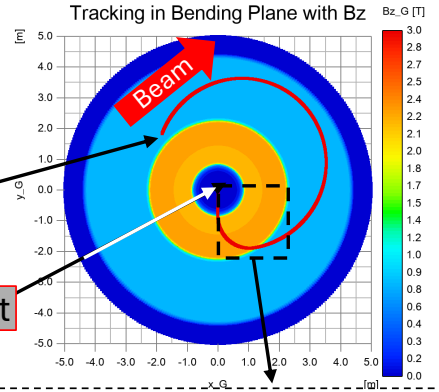
A Beam Trajectory for 180 Treatment in Simulated Magnetic Field B_z@Opera3D

From the Exit of ISM

Target



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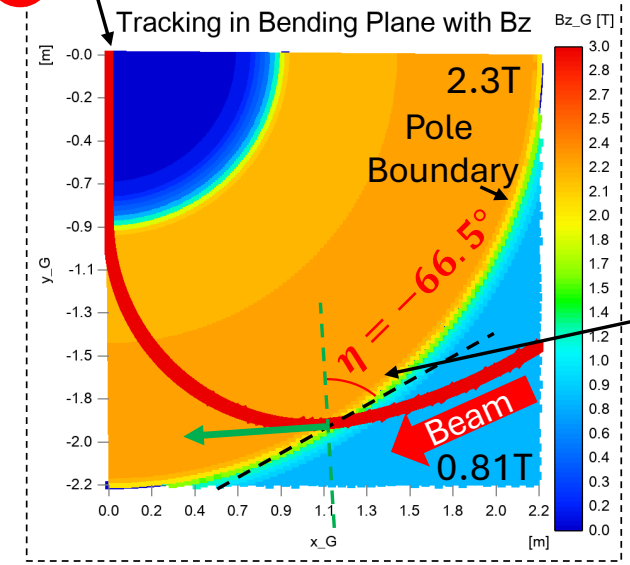


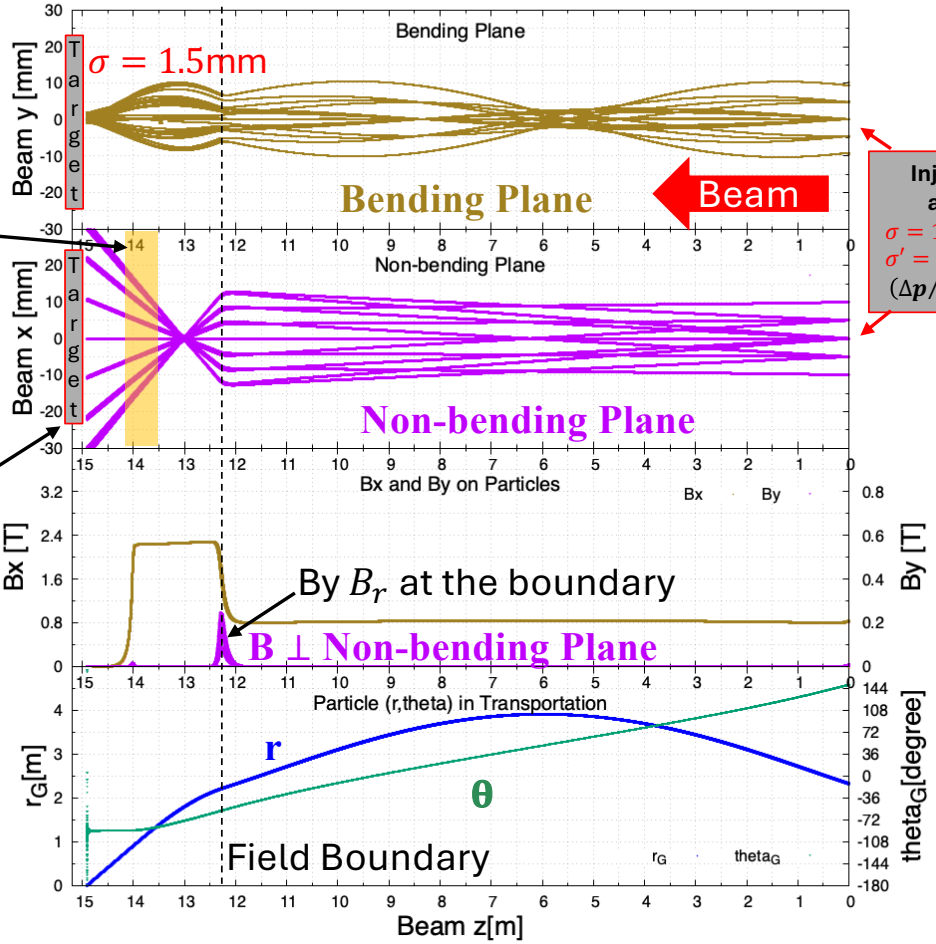
D Challenge in Transverse Optics

How to refocus to the target in this area?

Overfocus on target $\sigma = 32.3$mm

Large $|\eta|$ and σ at the boundary

B Particle Tracking Result



Injection at ISM
$\sigma = 10.0$mm
$\sigma' = 1.0$mrad
$(\Delta p/p_0)_0 = 0$

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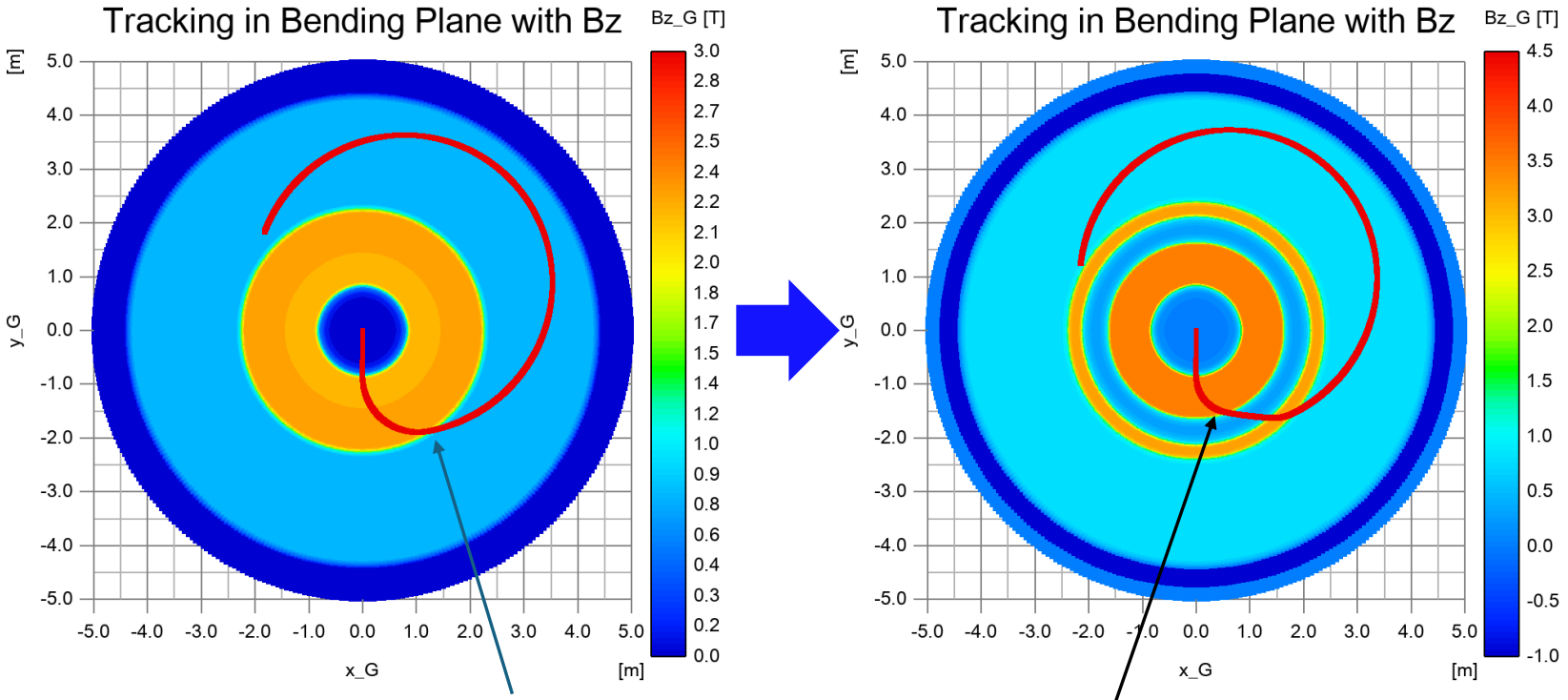
Radially Varying Field



Overfucsing at the boudnary
in non-bending plane

B_r component at the boundary
→ 2nd TIME FOCUSING
to the target

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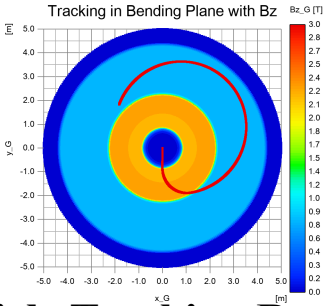
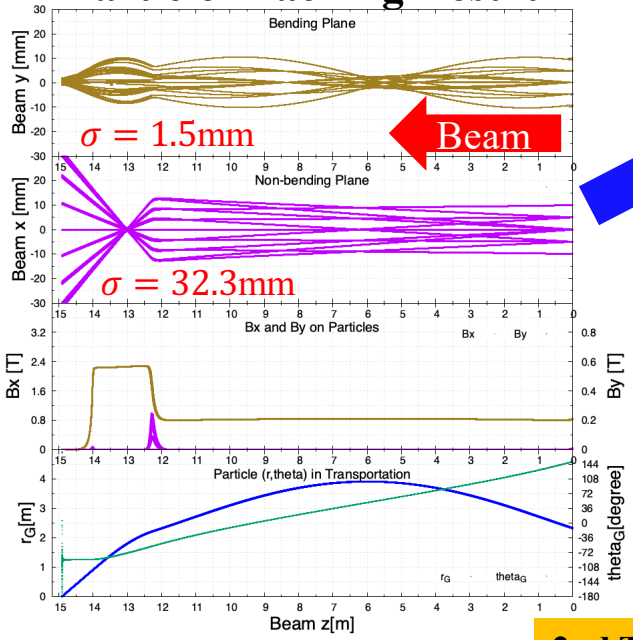
Radially Varying Field

Previous Field

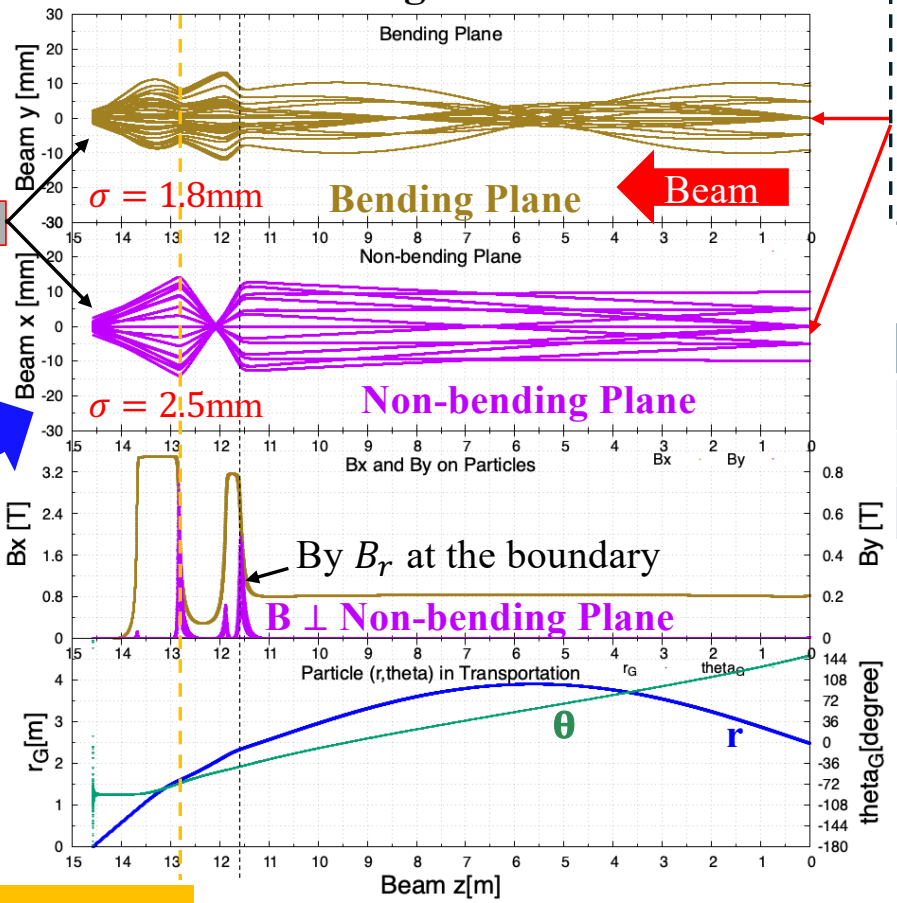


Particle Tracking Result

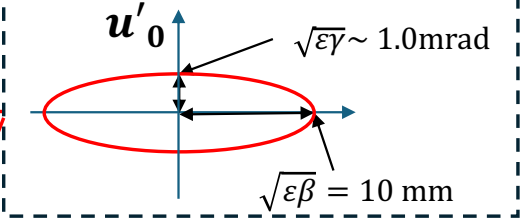


Particle Tracking Result with RVF

Target

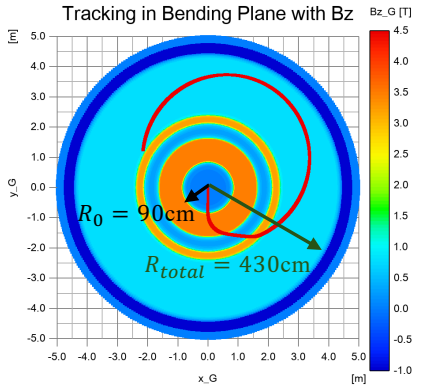


Same Initial Phase Space



RVF Parameters for 230MeV Proton

RVF	Radius [cm]	B_z [T]
R1	90~158	3.5
R2	158~218	0.3
R3	218~230	3.2



2nd Time Focusing

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Beam Size for Other Treatmnet Angles

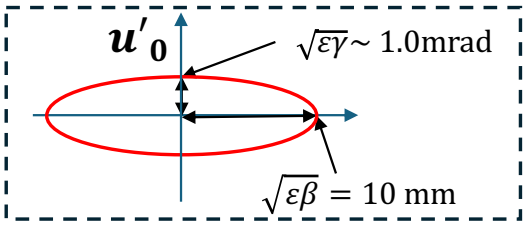
No Radially Varying Field

On-target Beam Spot Size		
Treatment Angle	**Non-bending** Plane [mm]	**Bending** Plane [mm]
180°	32.3	1.5
135°	30.1	2.5
90°	26.7	4.1
45°	27.1	3.7
0°	27.0	1.4

With Radially Varying Field

On-target Beam Spot Size		
Treatment Angle	**Non-bending** Plane [mm]	**Bending** Plane [mm]
180°	2.5	1.8
135°	1.3	2.5
90°	1.4	4.8
45°	1.7	3.0
0°	1.9	1.3

Initial Phase Space
at the exit of ISM



Next Step:
compensate angle dependency
of beam size

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SUMMARY

- Spectroscopy-type **non-rotating gantry** system is potentially capable of realizing
  1. **compactness**
  2. **continous & rapid change of treatment angle in 180 degree range**

- For monochromatic beam, transverse plane **focusing challenge is sovled with a RVF (Radially Varying Field)**

- Next step:
  1. Compensate angle dependency of on-target beam size in transverse plane
  2. Optimize beam transport for chromatic beam

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