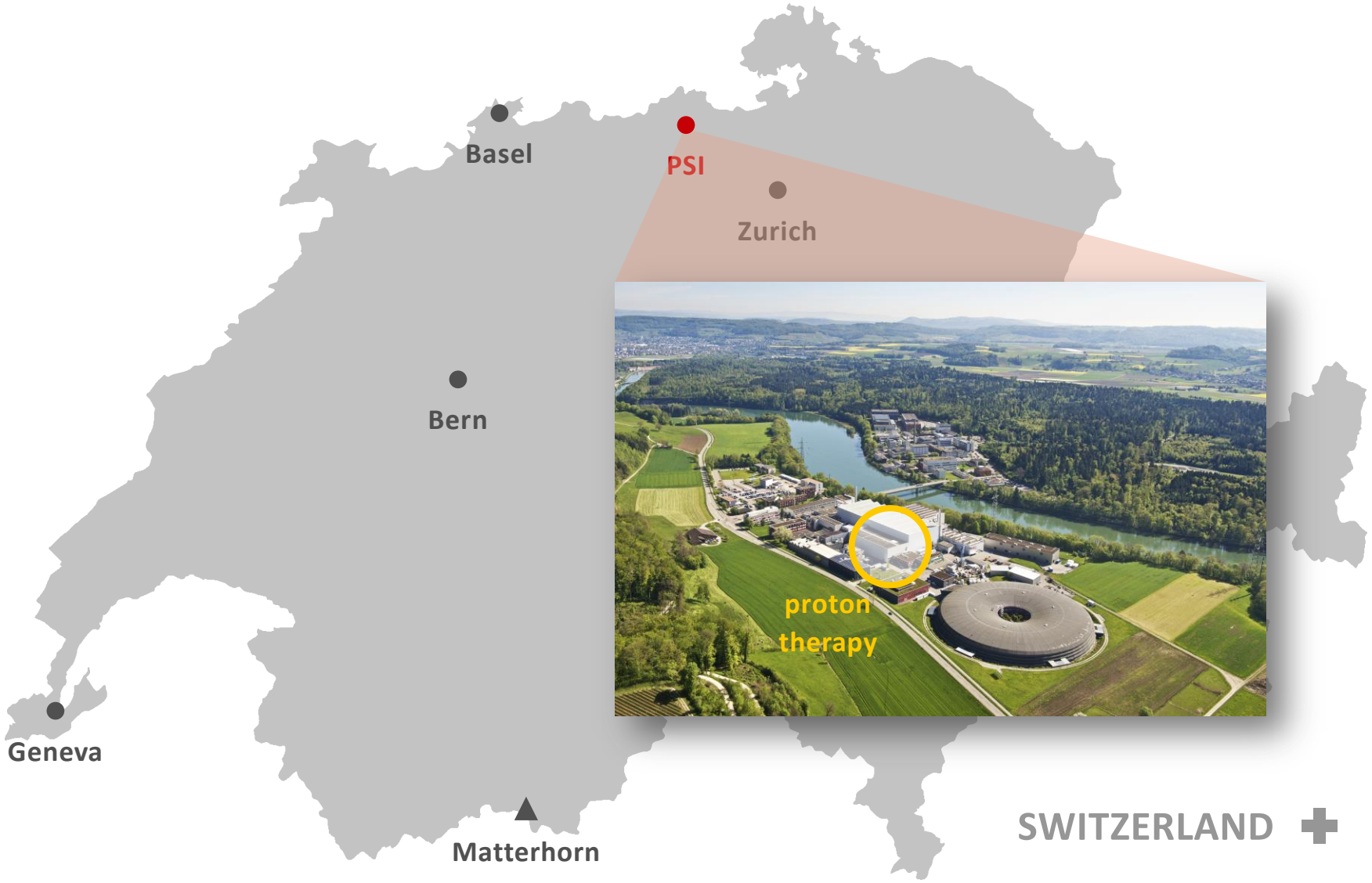
PAUL SCHERRER INSTITUT

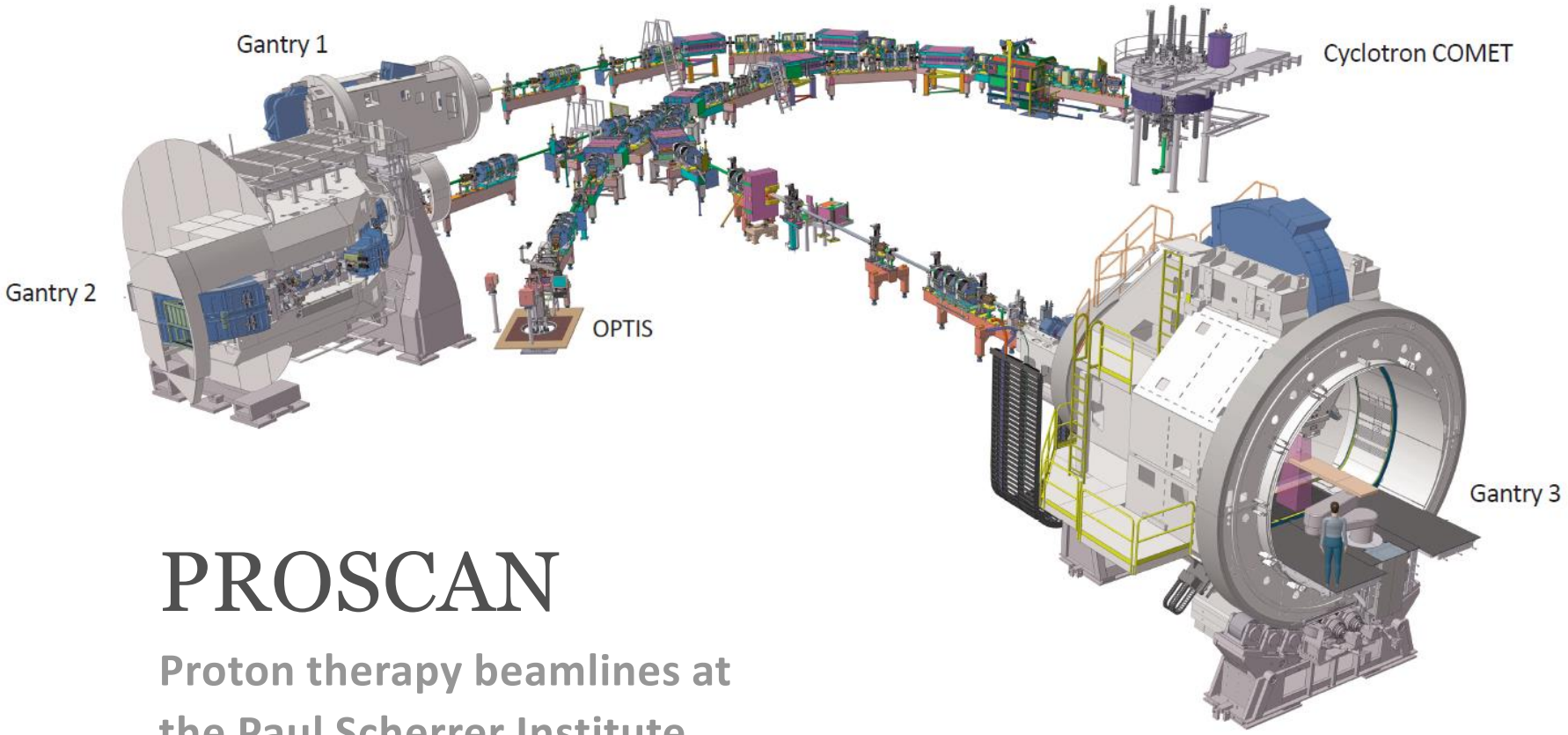
PSI

Klimpki *et al.* :: Center for Proton Therapy :: Paul Scherrer Institute

A real-time beam monitoring system for highly dynamic irradiations in scanned proton therapy

16th ICALEPCS | THCPA06 | Barcelona, Spain | October 12, 2017


Basel
PSI
Zurich
Bern
proton
therapy
Geneva
Matterhorn
SWITZERLAND



PROSCAN

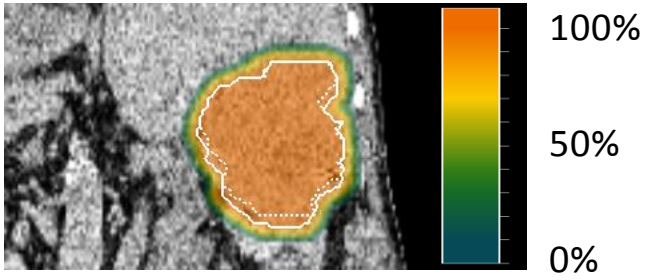
Proton therapy beamlines at the Paul Scherrer Institute

Latest developments

Fast irradiations on Gantry 2

Clinical example

- liver tumor (460 cm^3)
- single field (0.6 Gy)



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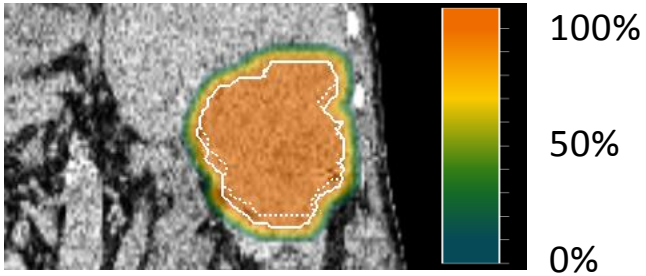
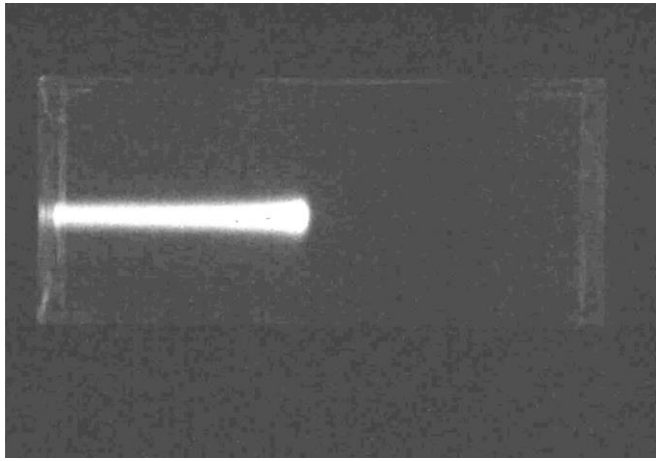
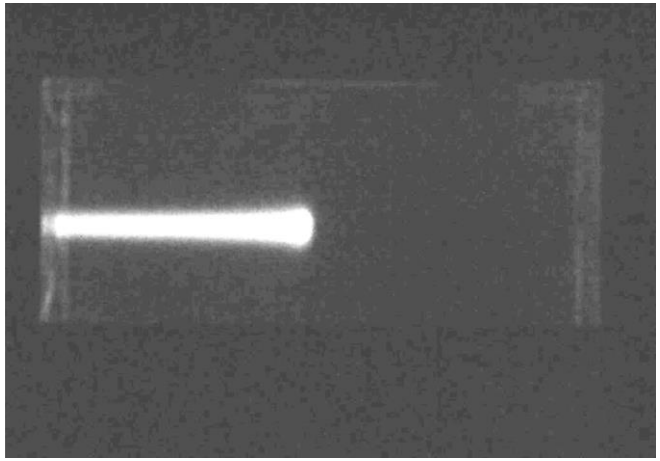


conventional 52 sec.



accelerated 26 sec.



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Clinical example

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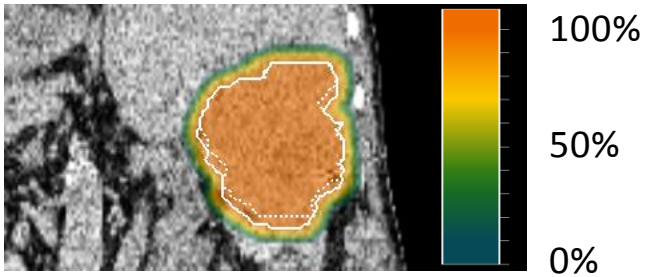


conventional 52 sec.

treating patients since Nov. 2011

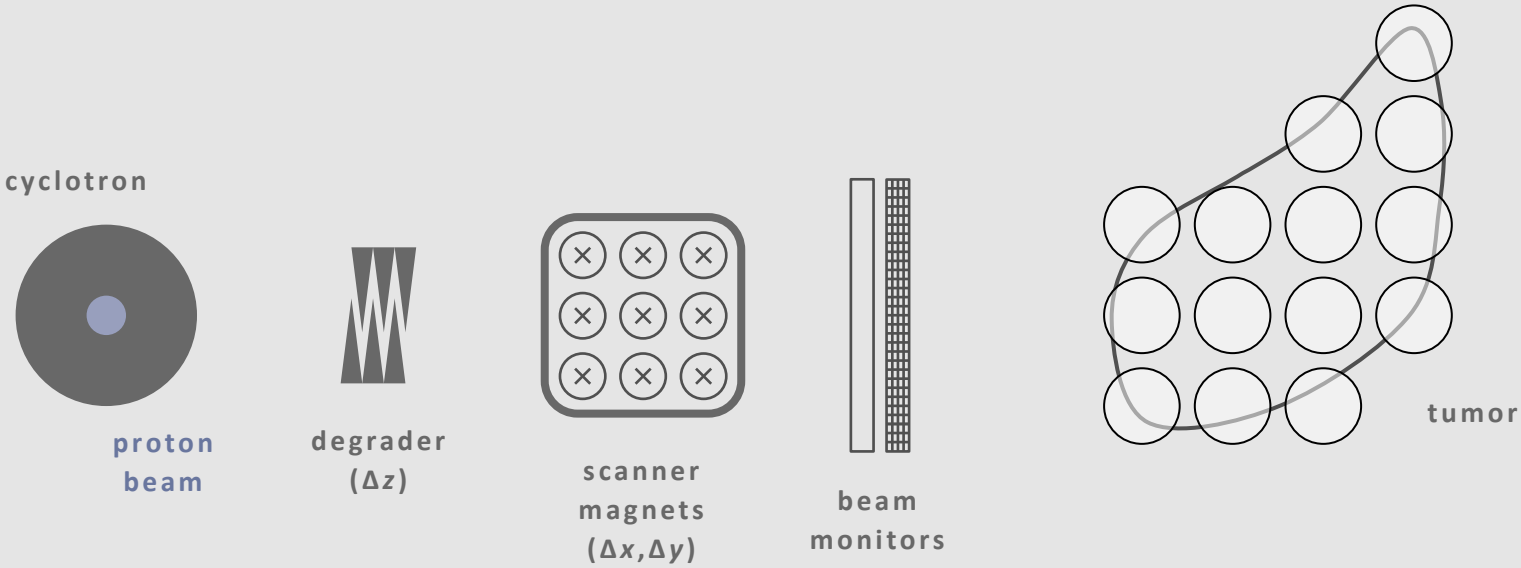
accelerated 26 sec.

***not** treating patients yet*

speed

Conventional irradiations on Gantry 2

→ ‘Step-and-shoot’ irradiations



Conventional irradiations on Gantry 2

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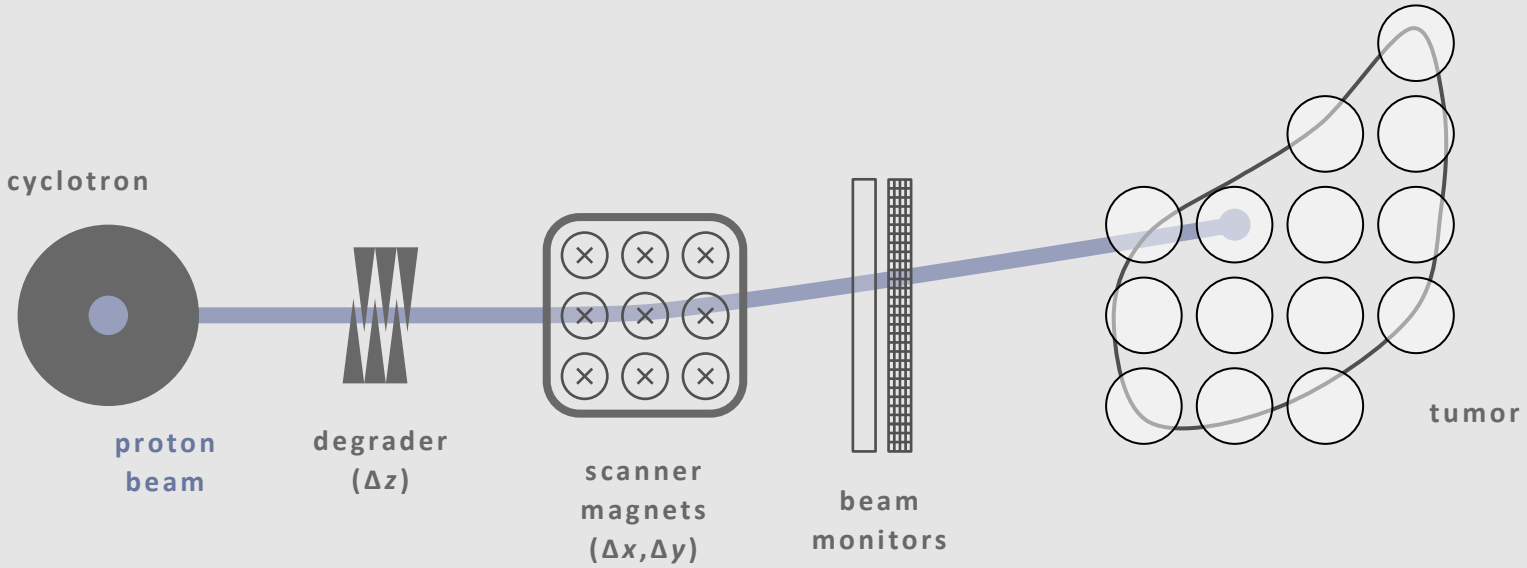

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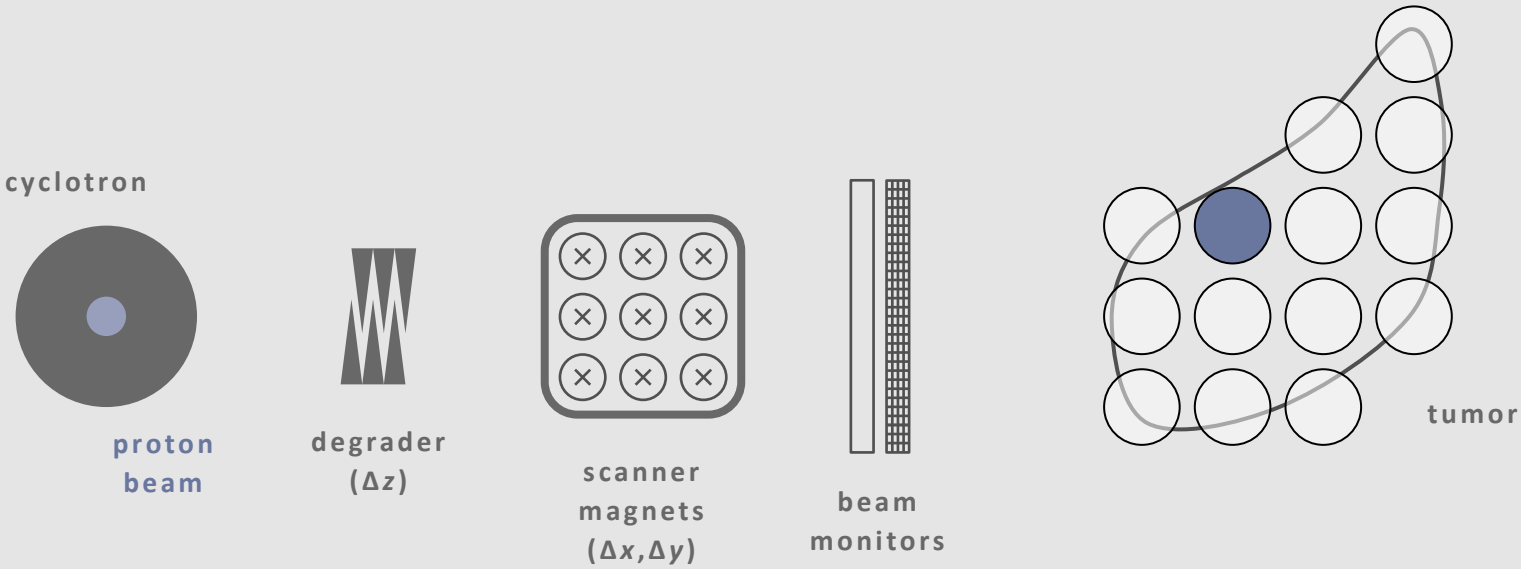

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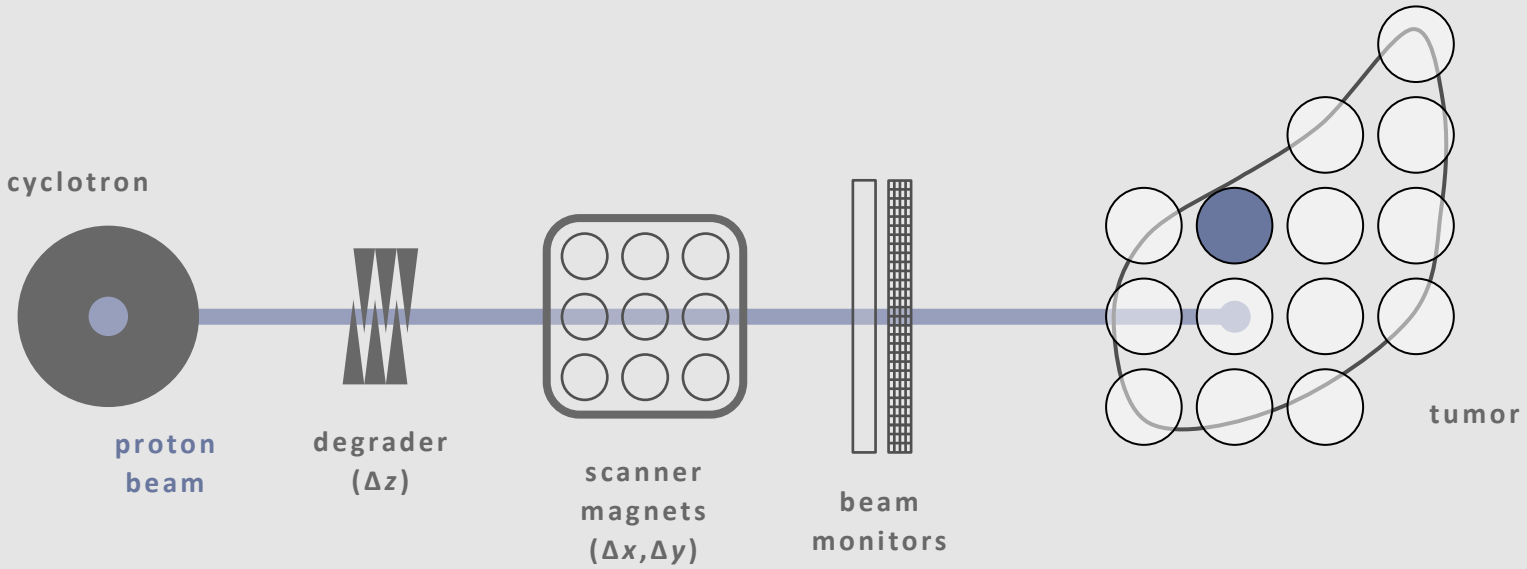

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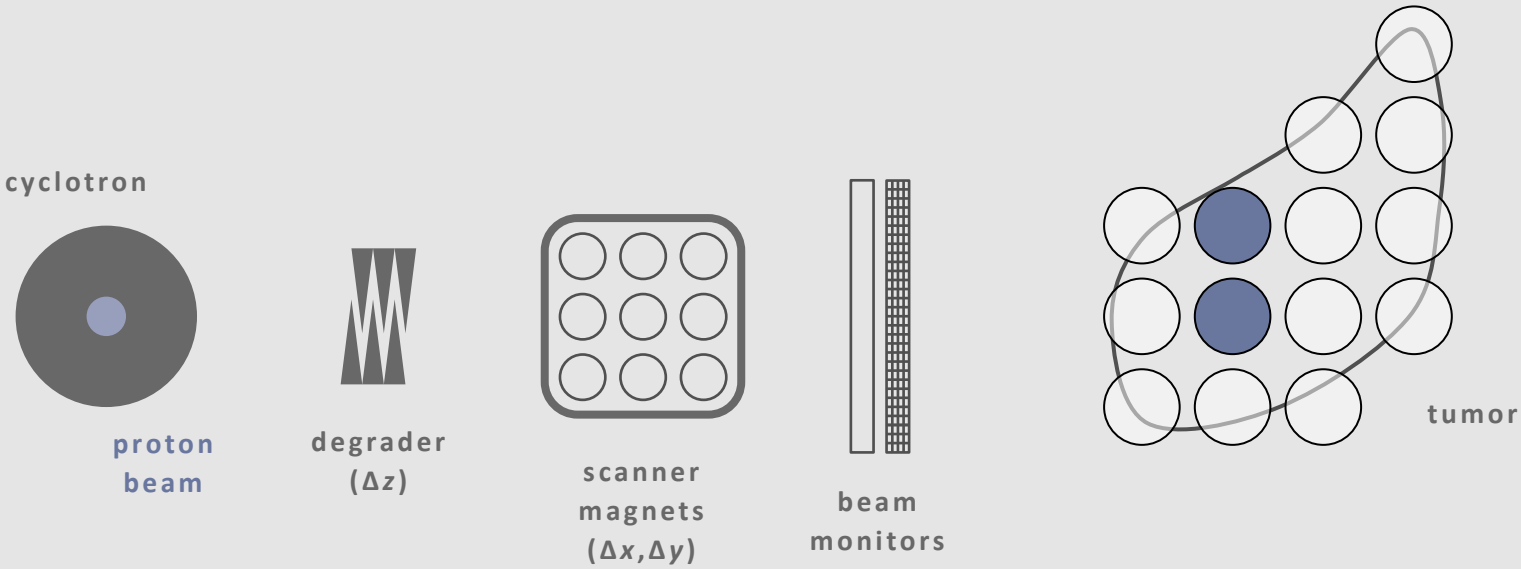

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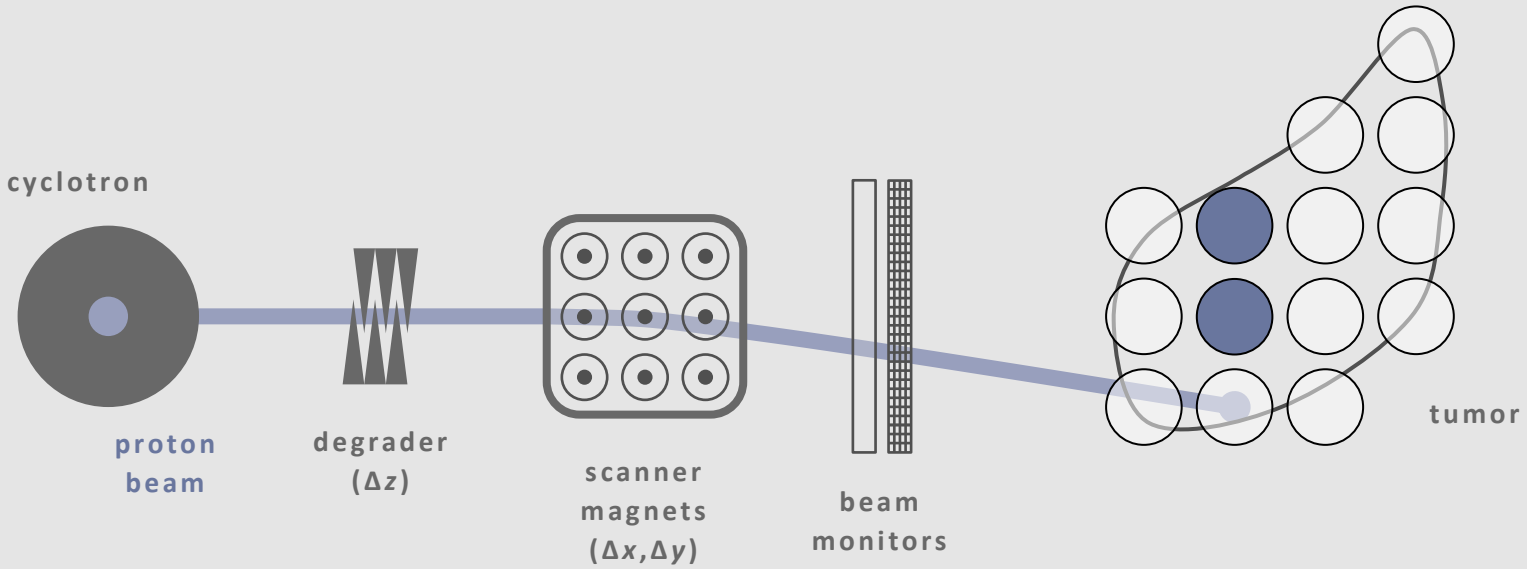

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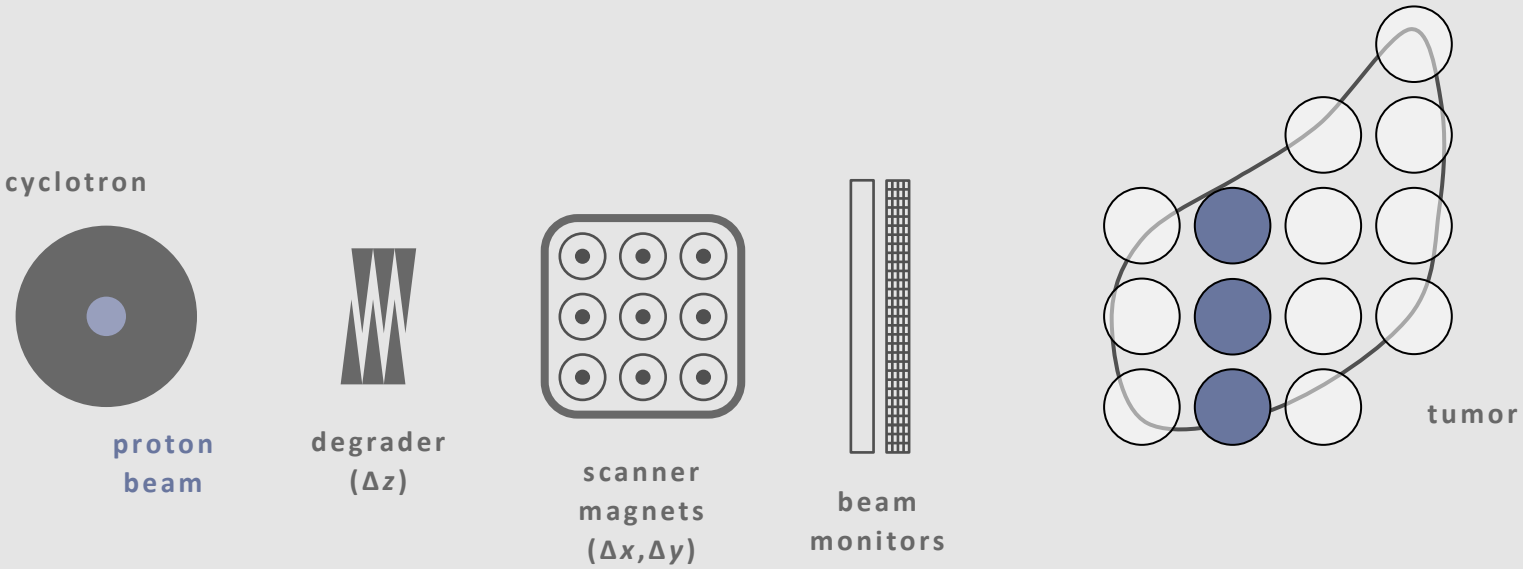

Conventional irradiations on Gantry 2

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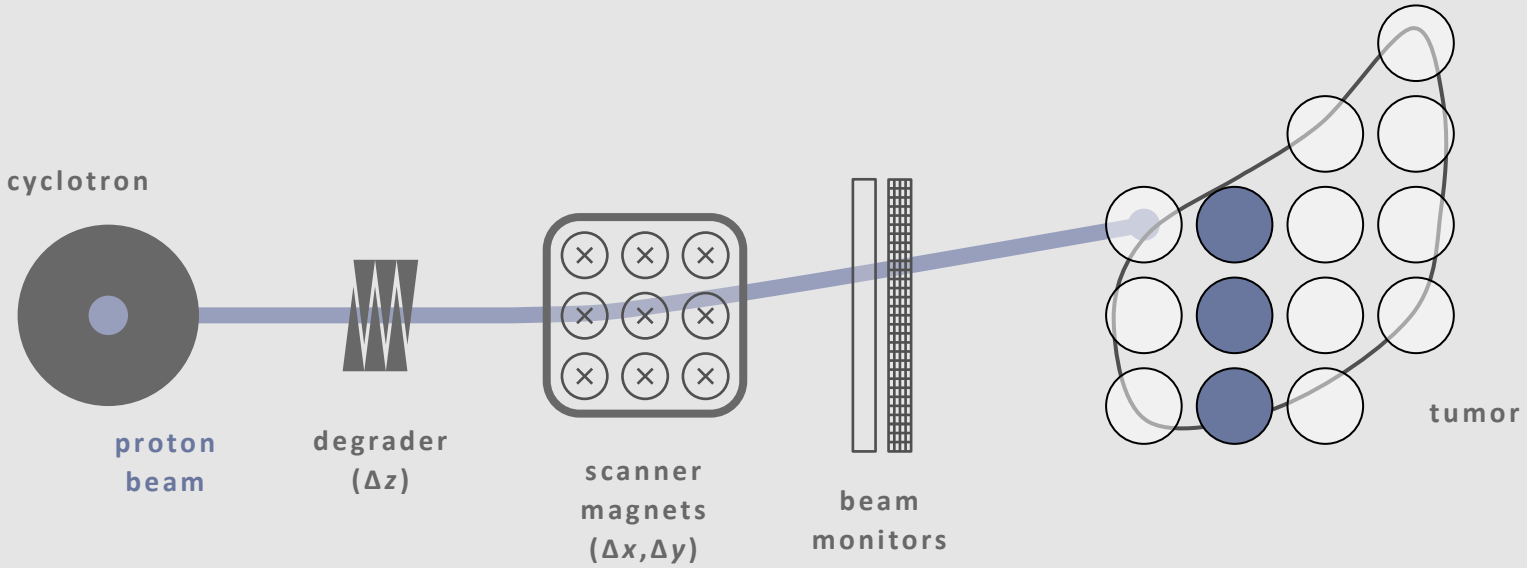

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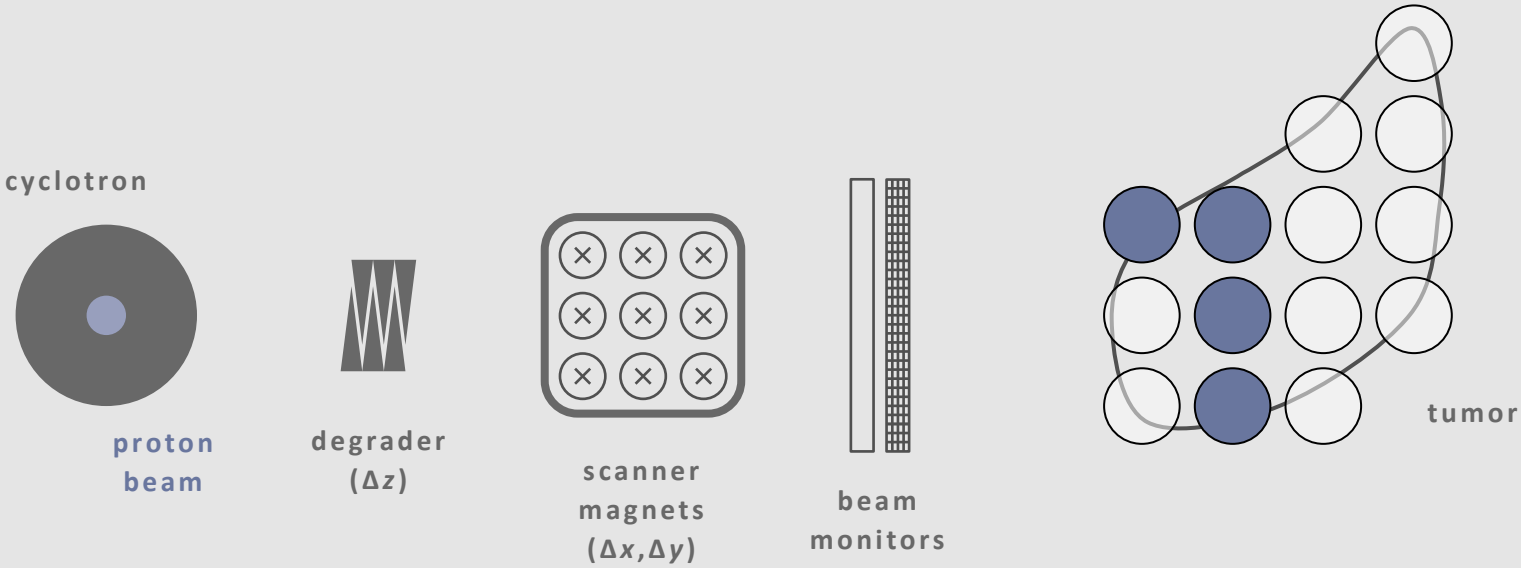

Conventional irradiations on Gantry 2

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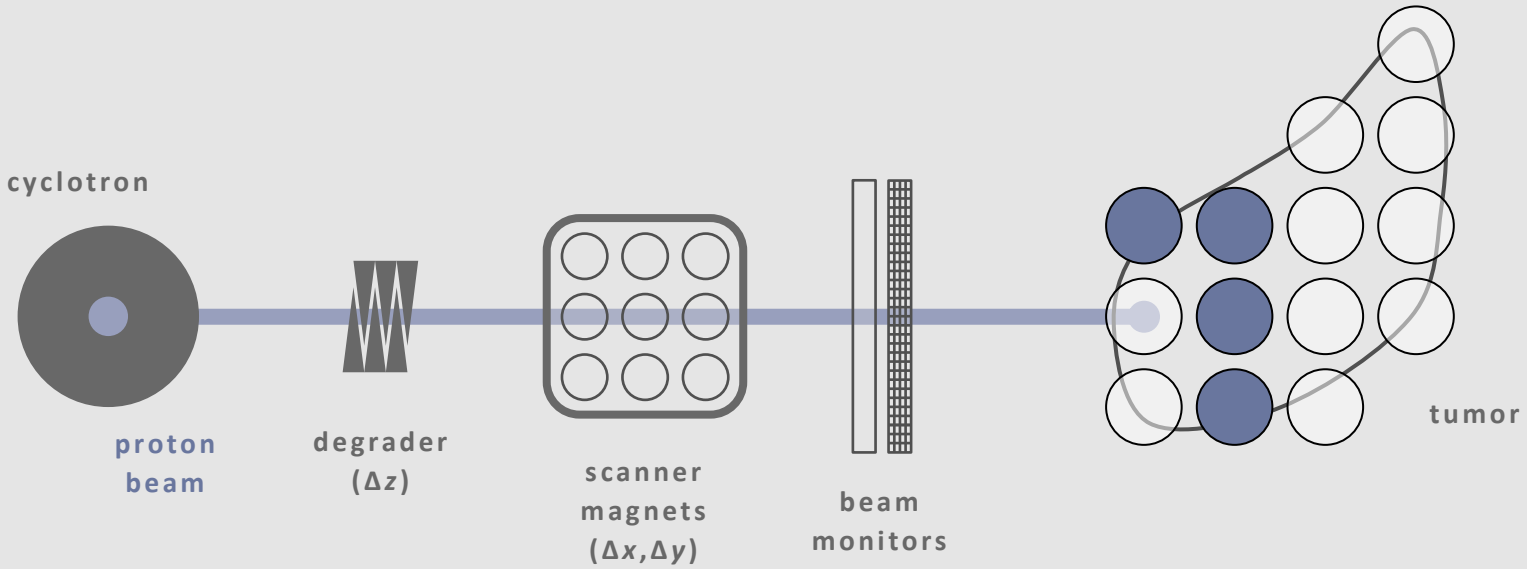

Conventional irradiations on Gantry 2

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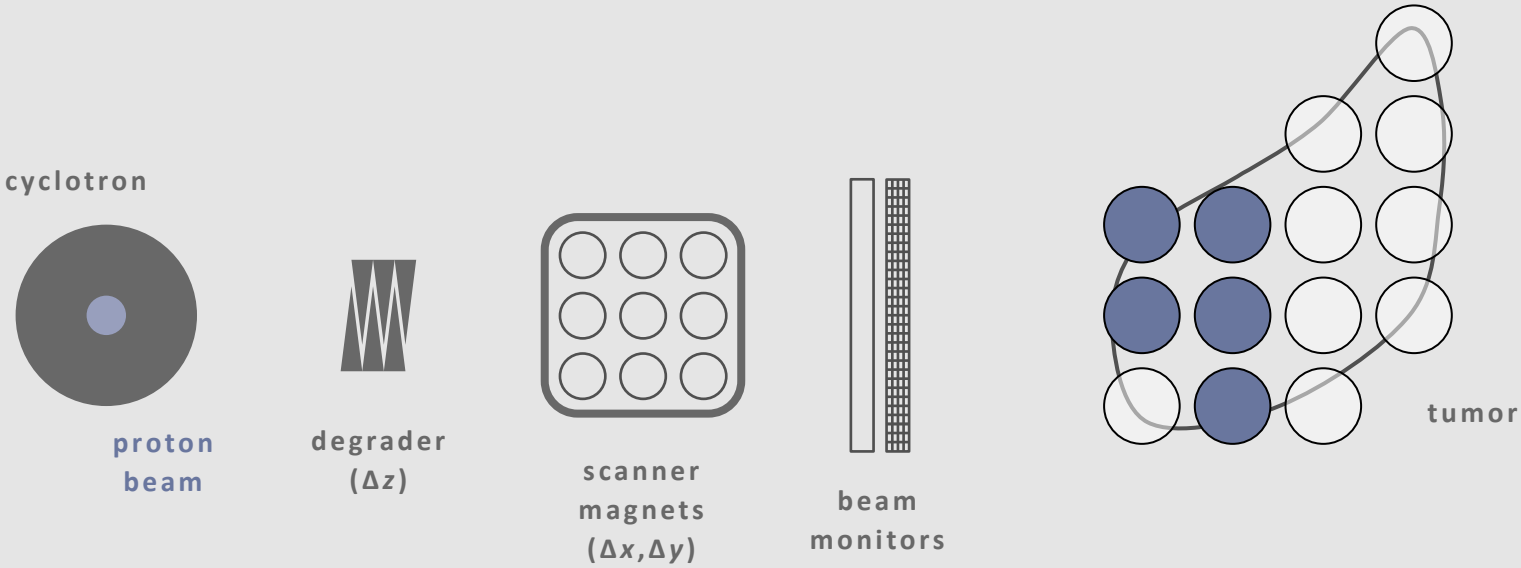

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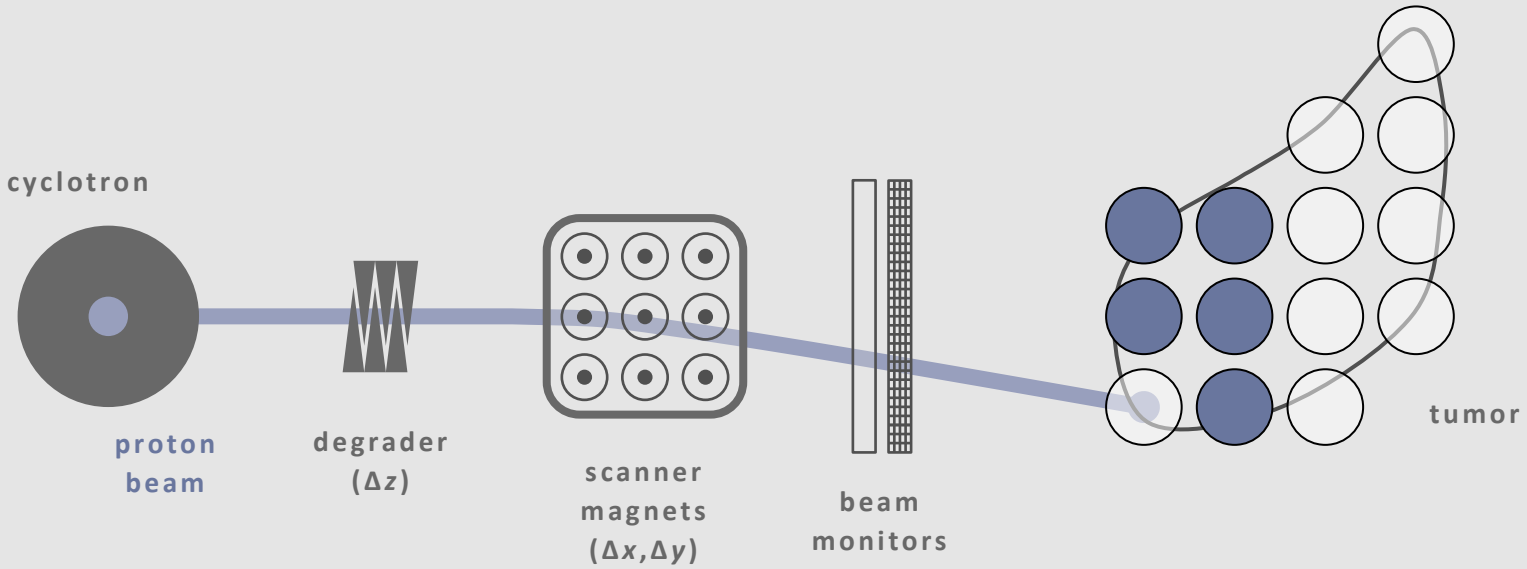

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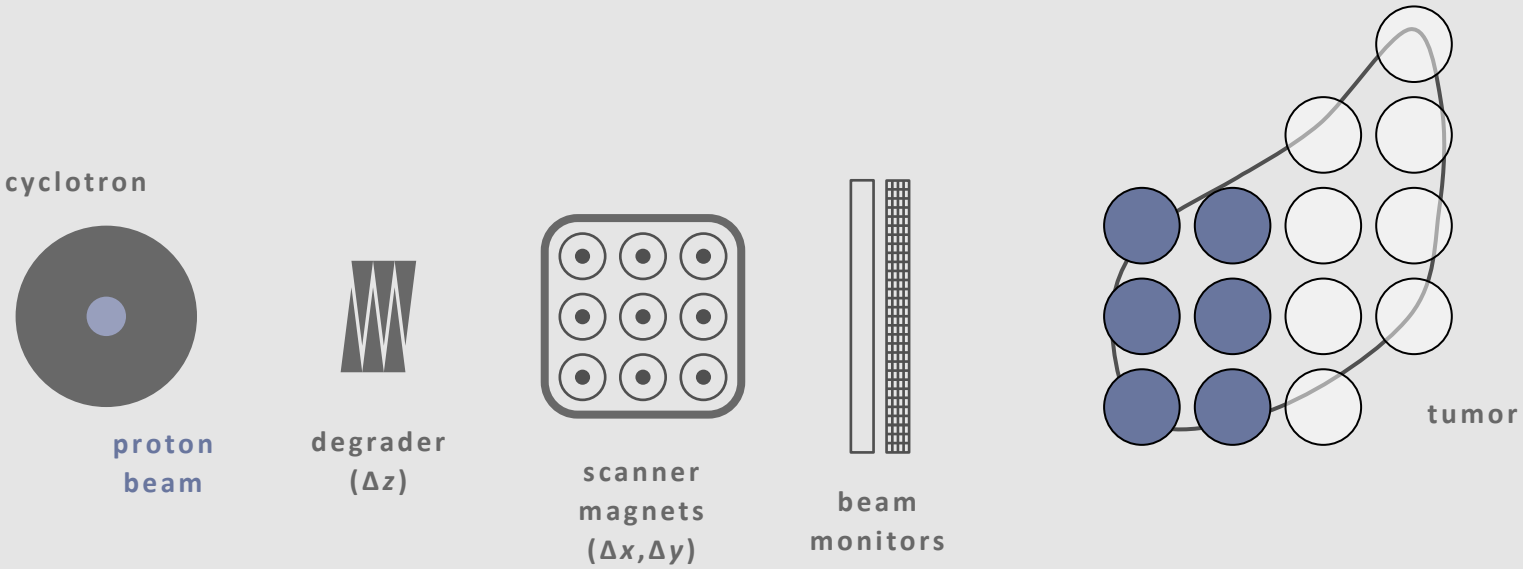
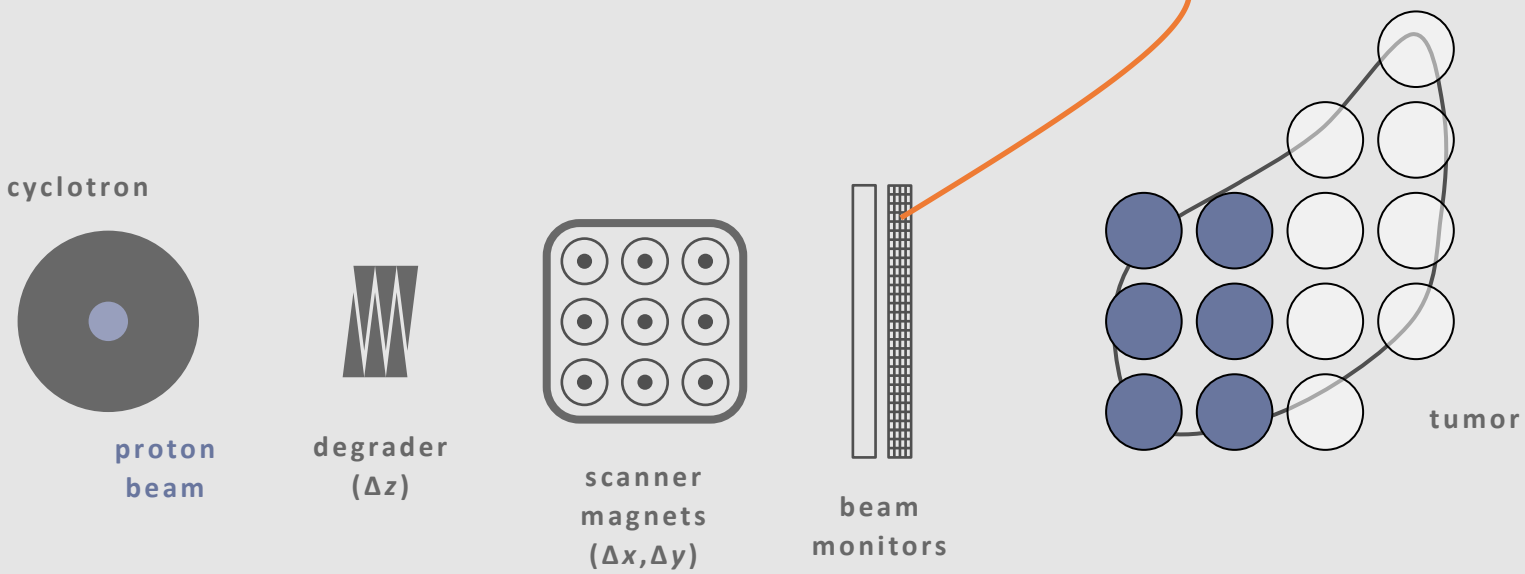


Conventional irradiations on Gantry 2

→ ‘Step-and-shoot’ irradiations

← Cyclic monitoring (after every spot)

- position within tolerance (± 1.5 mm)

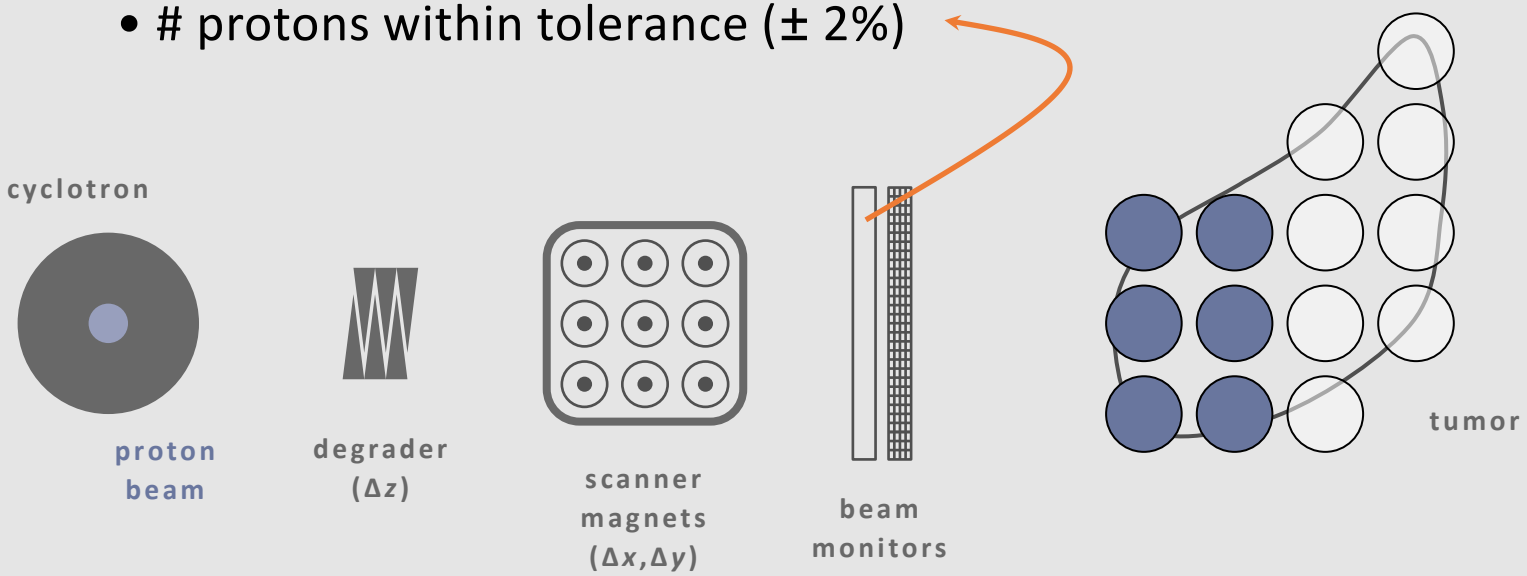


Conventional irradiations on Gantry 2

→ 'Step-and-shoot' irradiations

← Cyclic monitoring (after every spot)

- position within tolerance (± 1.5 mm)
- # protons within tolerance (± 2%)



Conventional irradiations on Gantry 2

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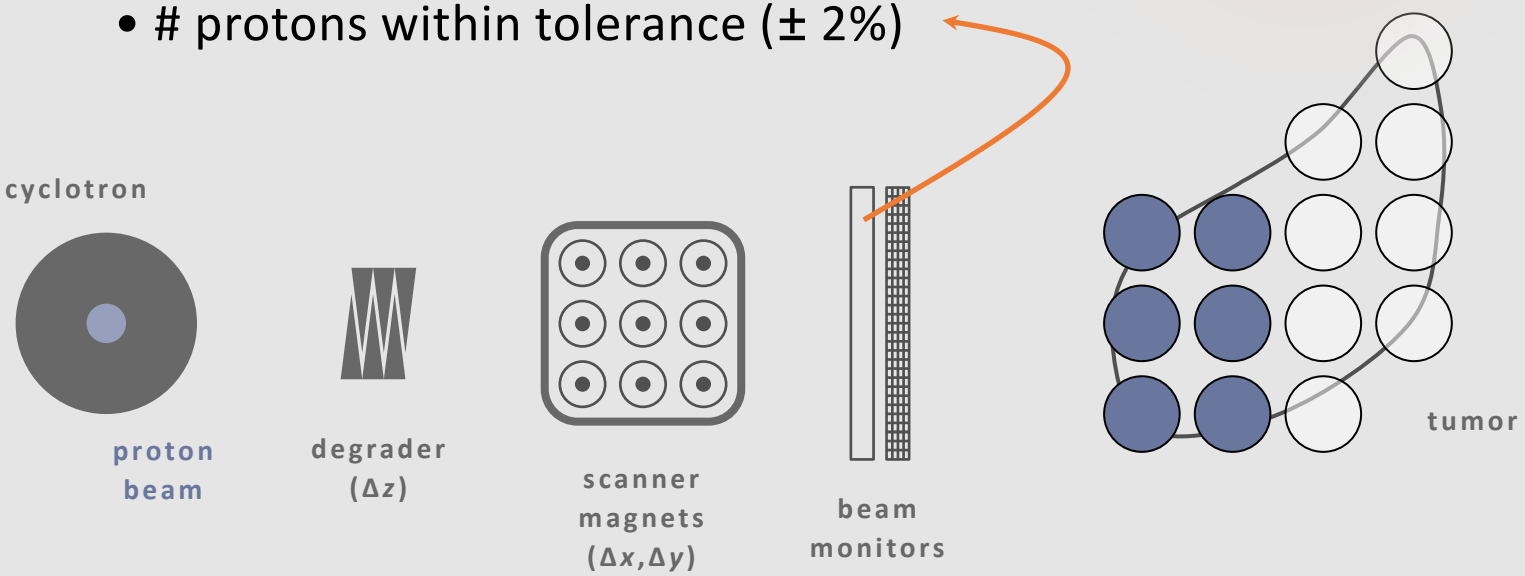
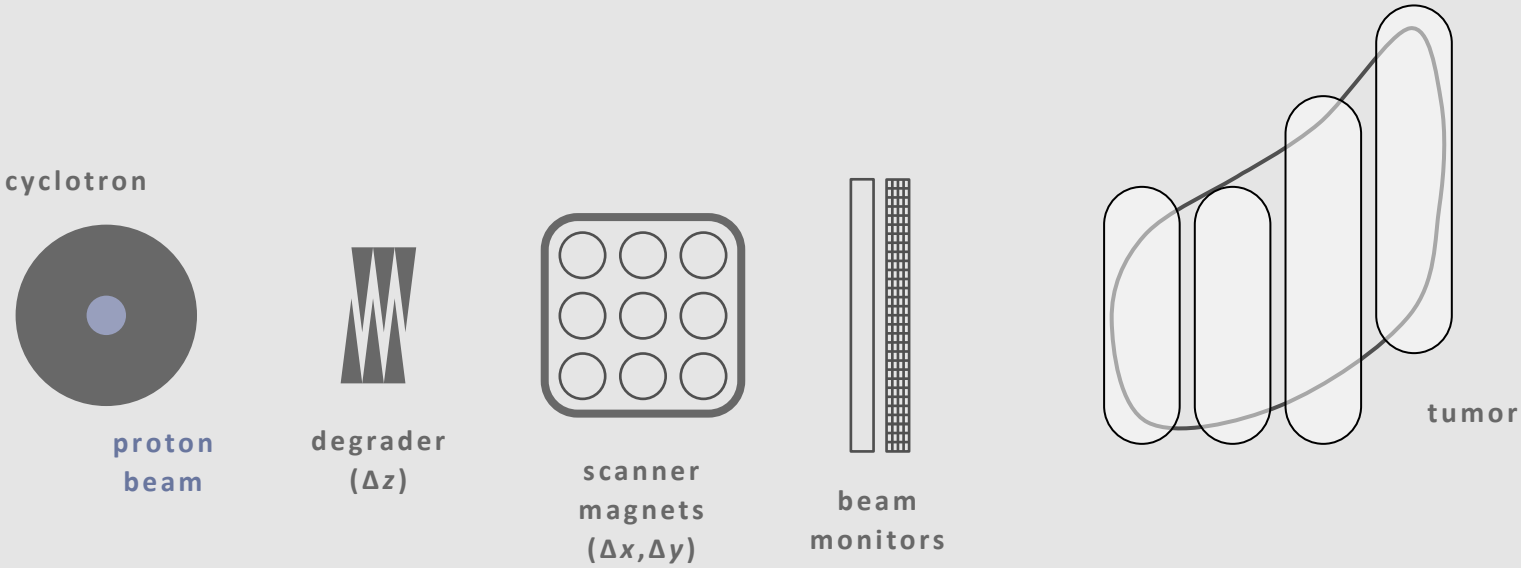
DRAWBACK

rather 'slow'



Accelerated irradiations on Gantry 2

→ **Continuous** irradiations



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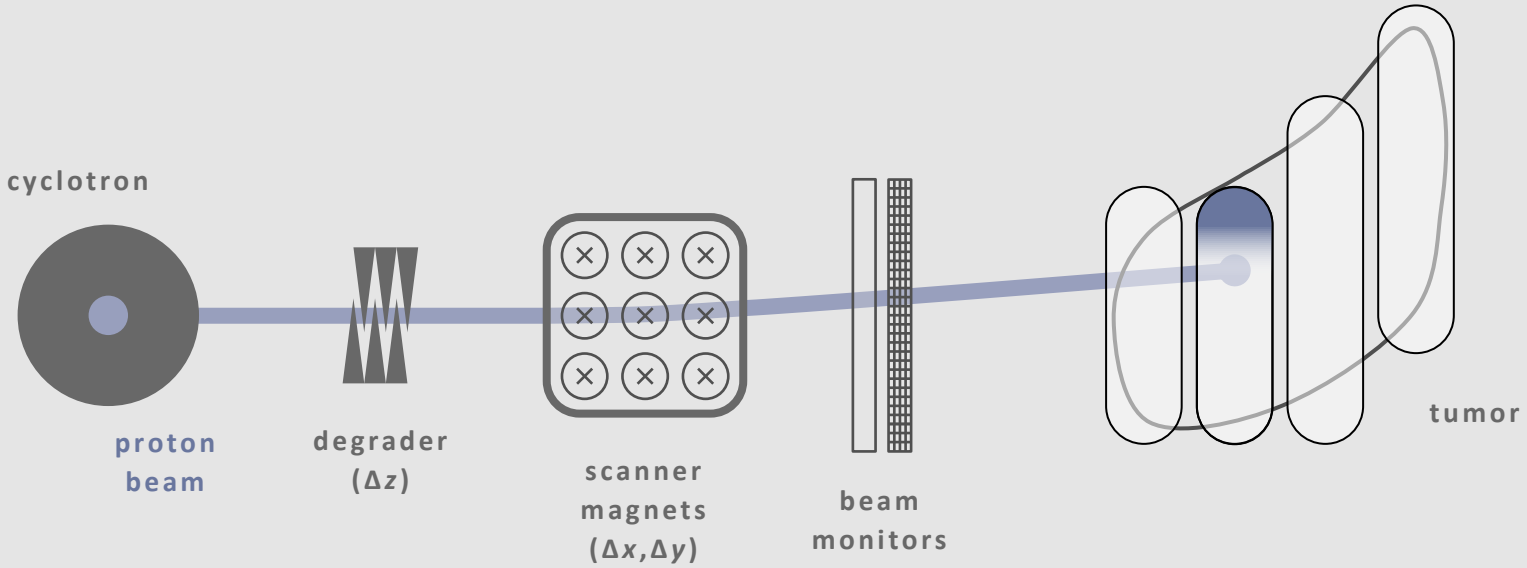

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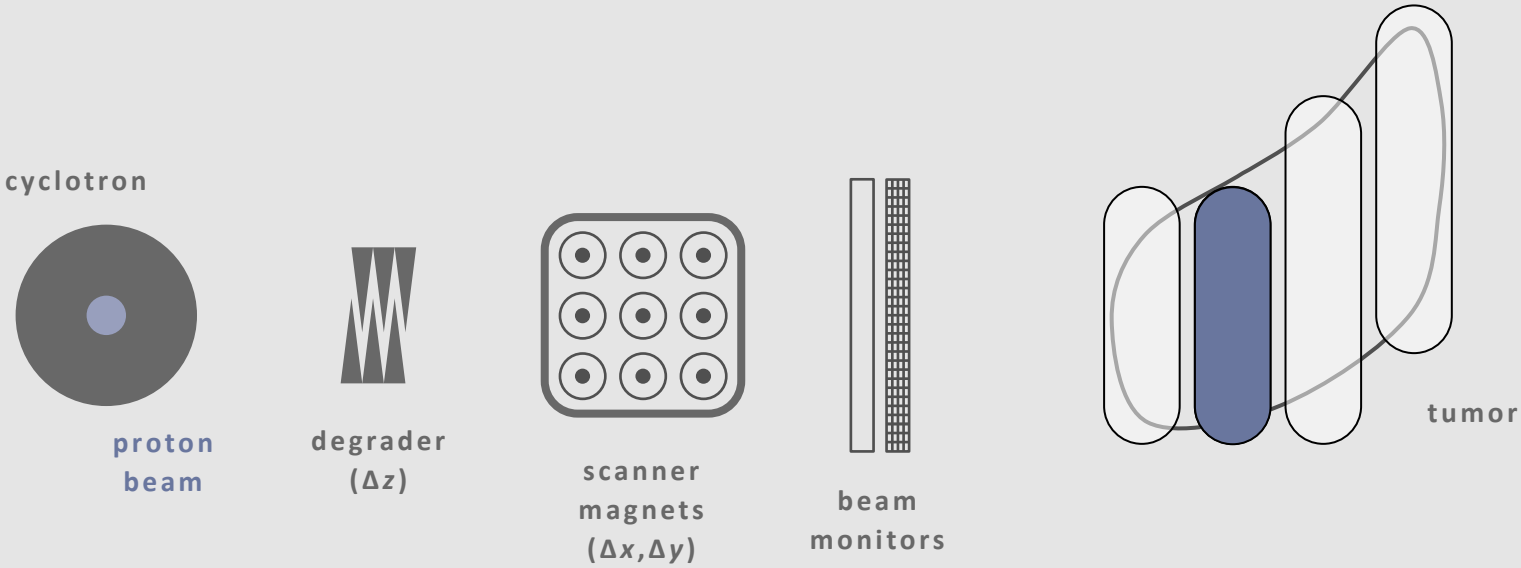

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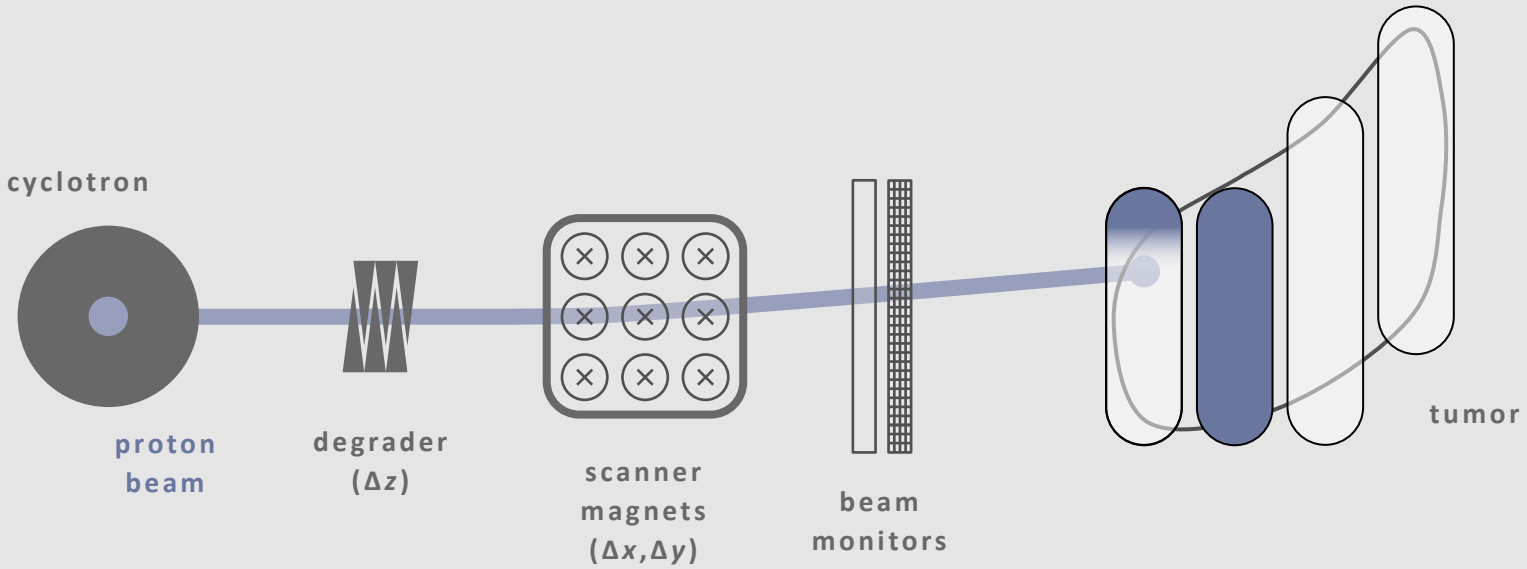

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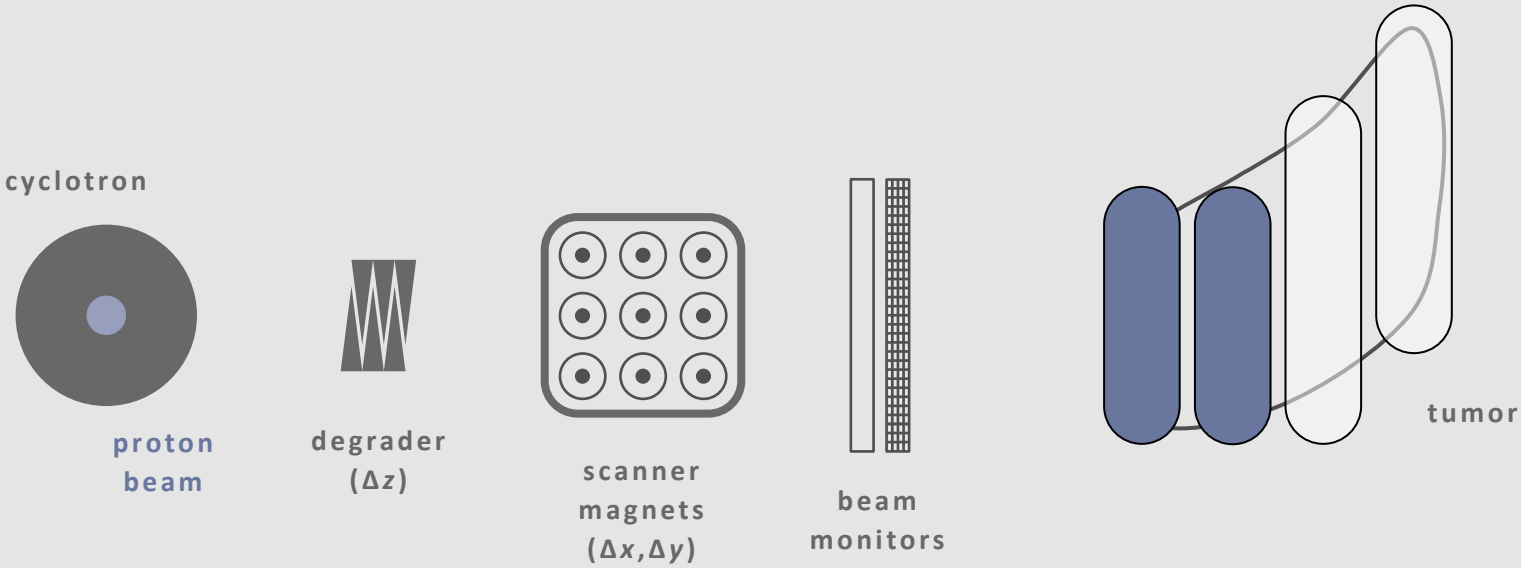

Accelerated irradiations on Gantry 2

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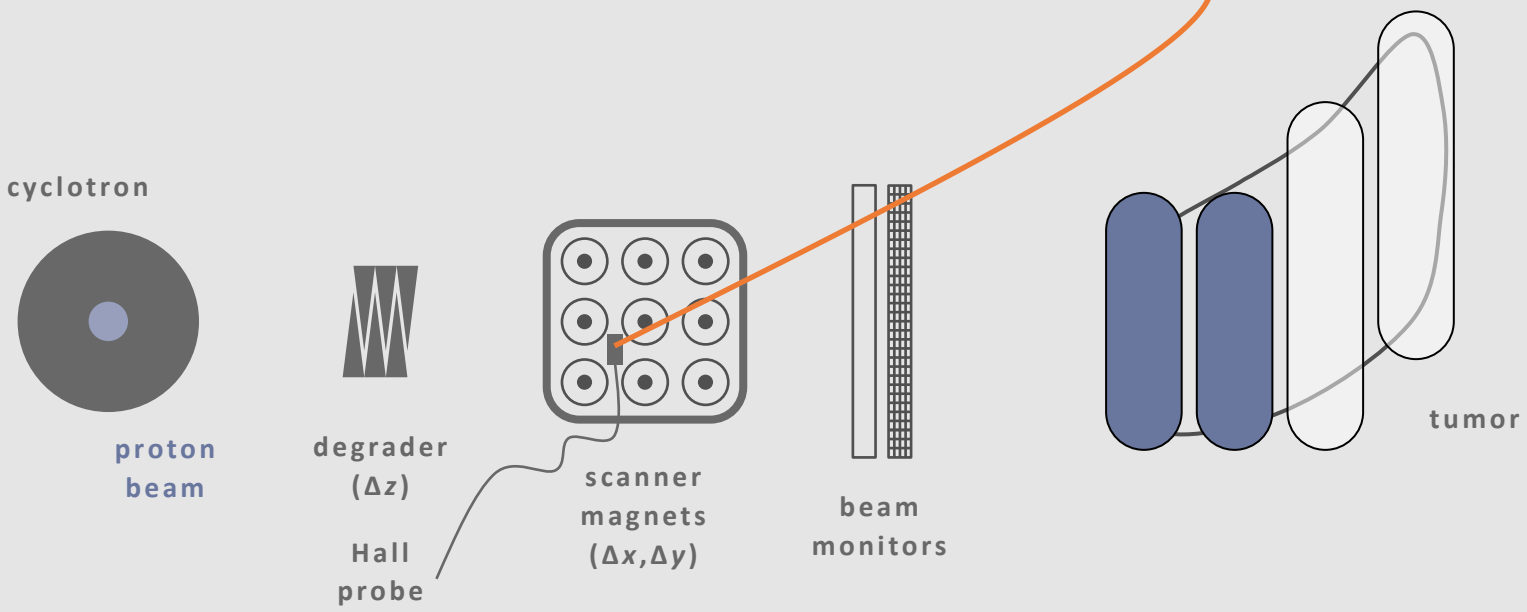
← **Real-time** monitoring (every 10 µs)

- position within tolerance (± 1.5 mm)

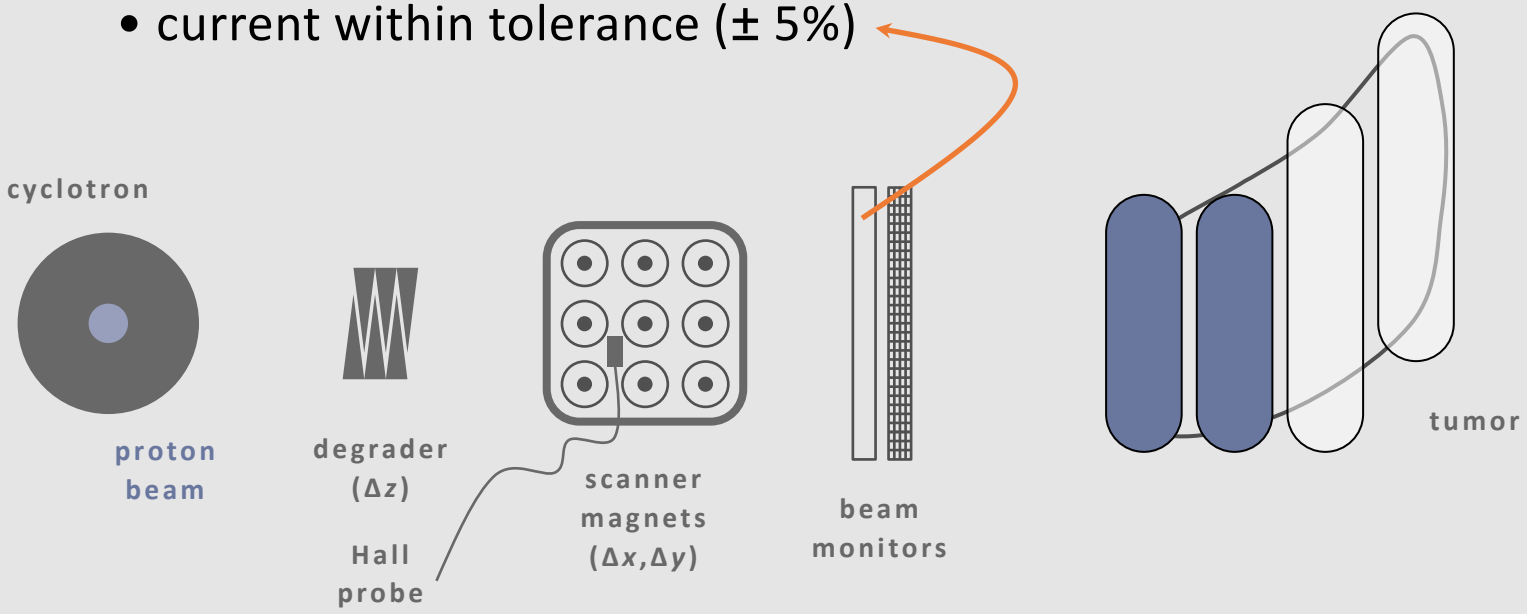


Accelerated irradiations on Gantry 2

→ **Continuous** irradiations

← **Real-time** monitoring (every 10 µs)

- position within tolerance (± 1.5 mm)
- current within tolerance (± 5%)



Accelerated irradiations on Gantry 2

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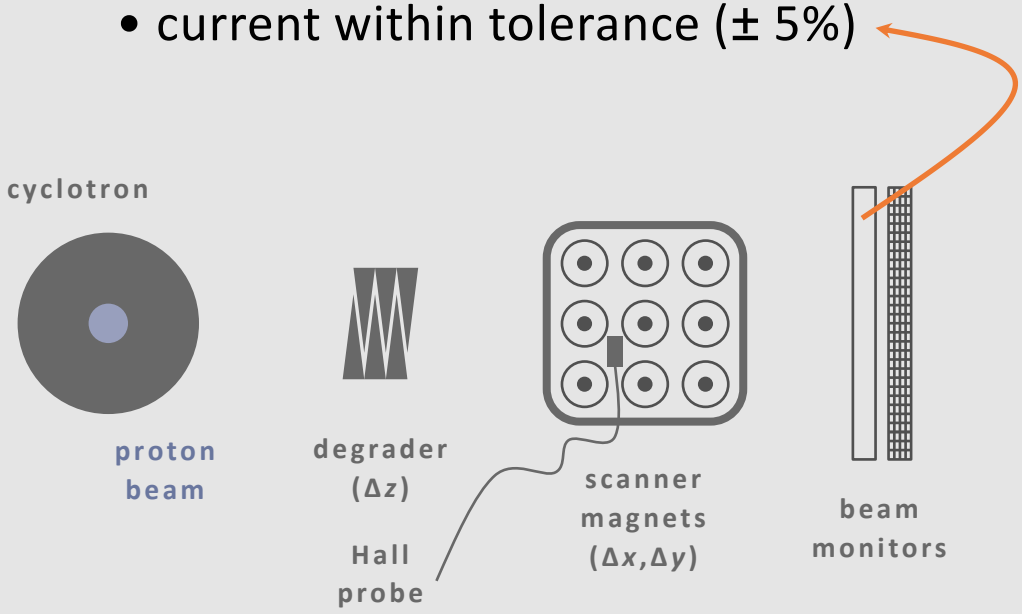
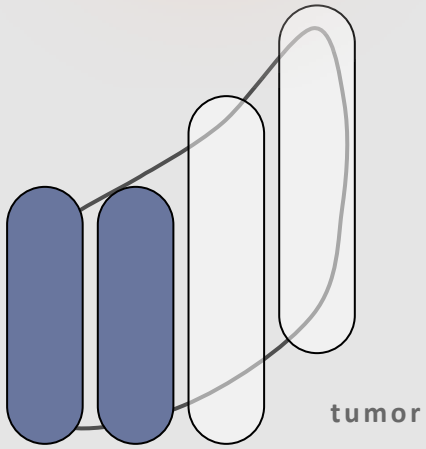
CHALLENGE

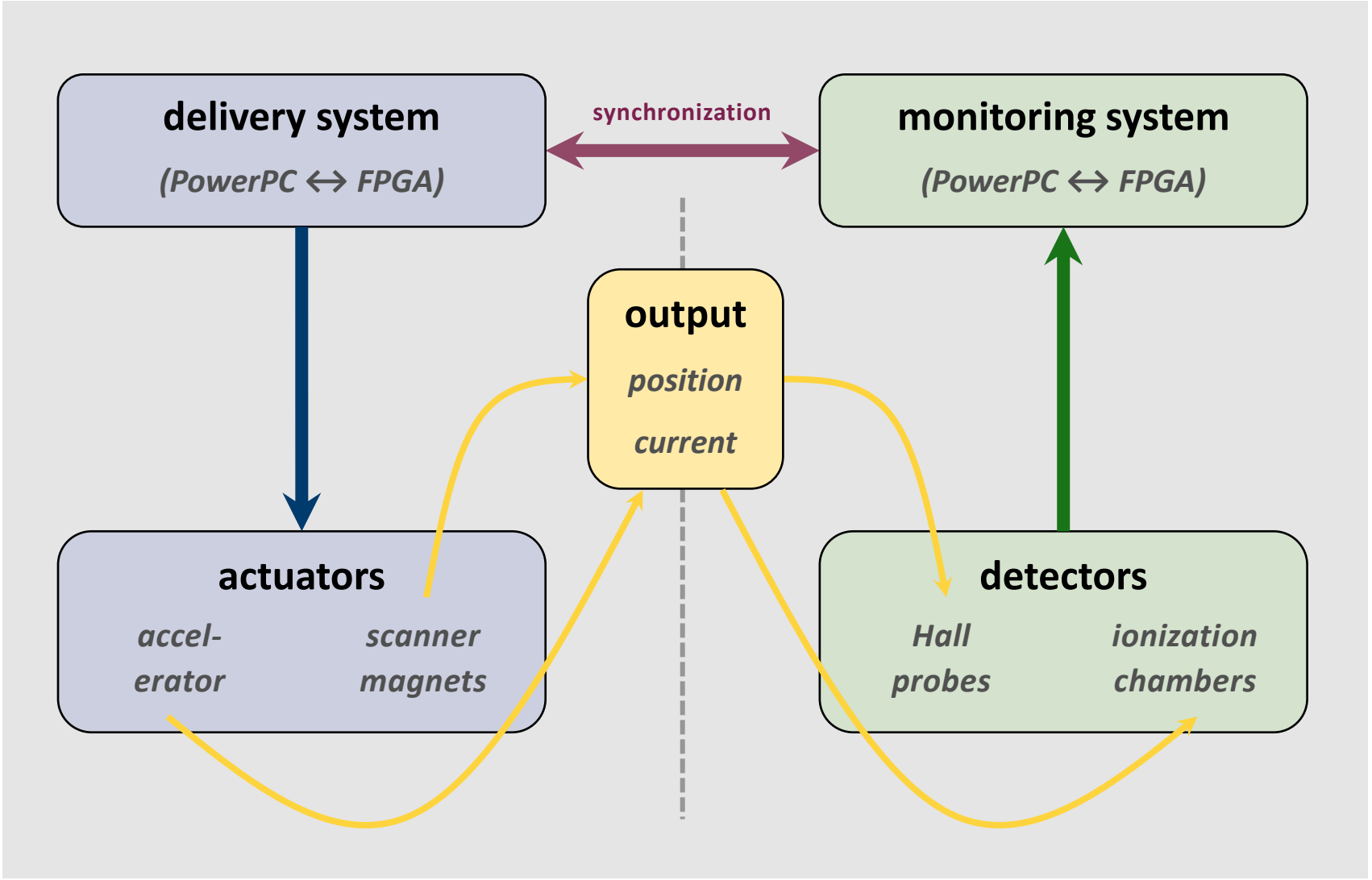
highly dynamic





safety

Independent beam delivery and monitoring

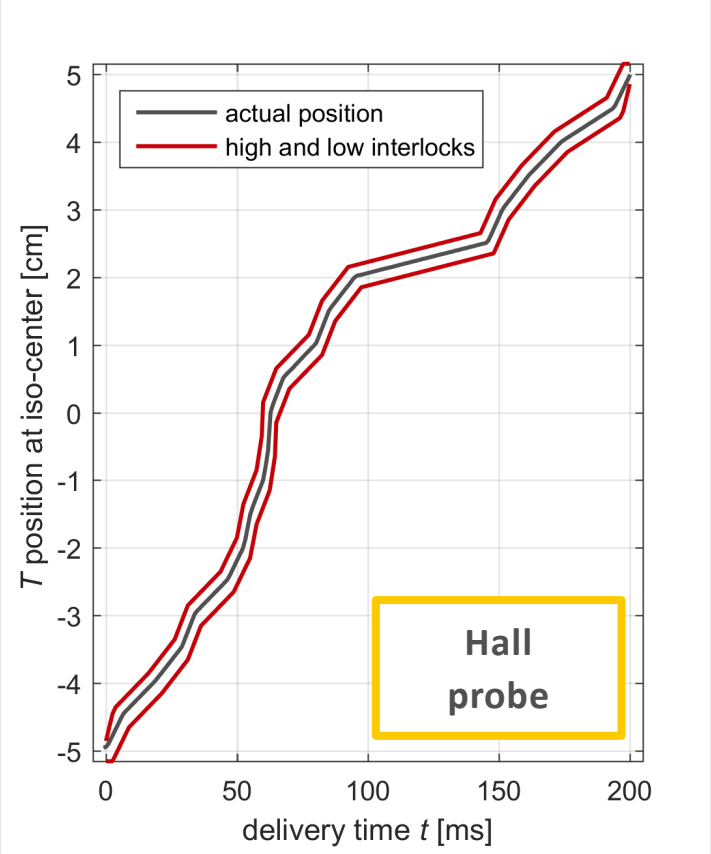


Time-driven beam delivery I

Position and current control based on trajectory tables:

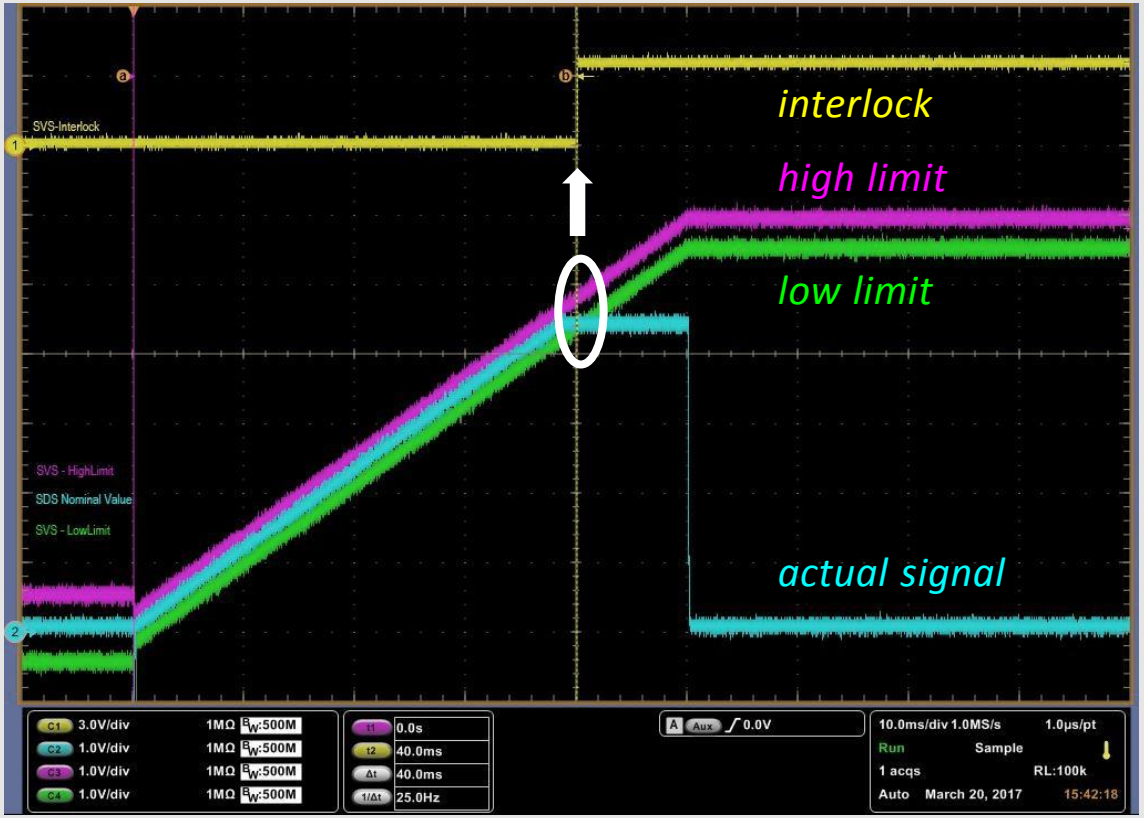
beam position

time [ms]	position [cm]
0	– 5
40	– 3
60	0
100	+ 2
150	+ 3
200	+ 5



Beam position interlock

Response of our test system to tolerance violations

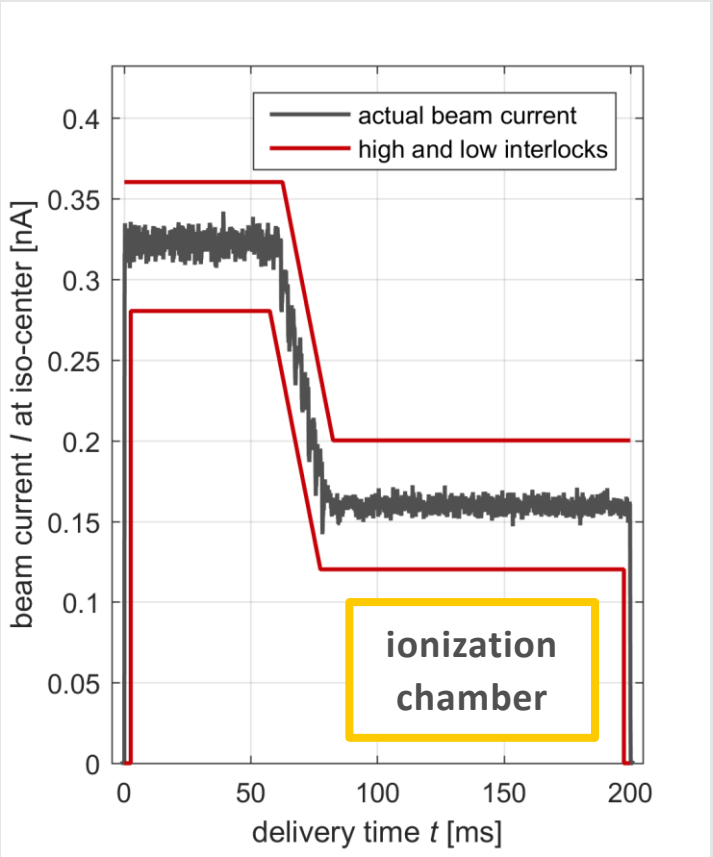


Time-driven beam delivery II

Position and current control based on trajectory tables:

beam current

time [ms]	current [nA]
0	0.0
1	0.3
60	0.3
80	0.2
199	0.2
200	0.0



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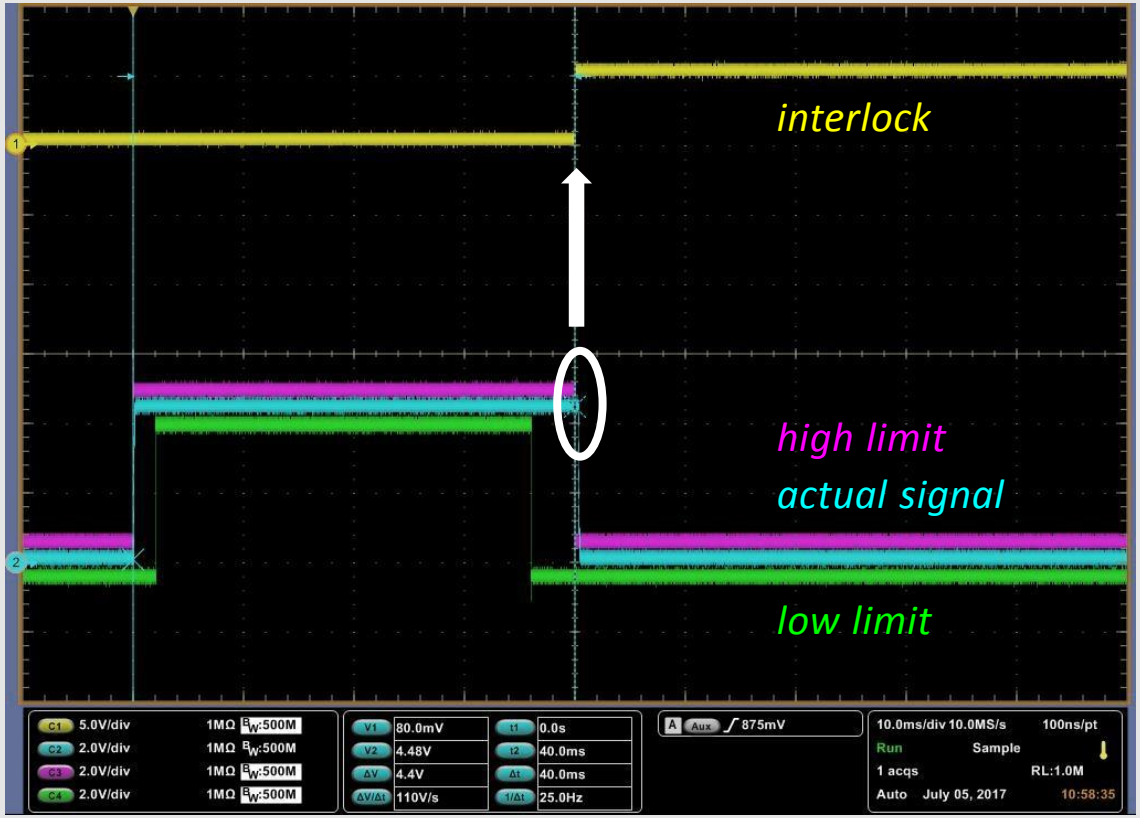

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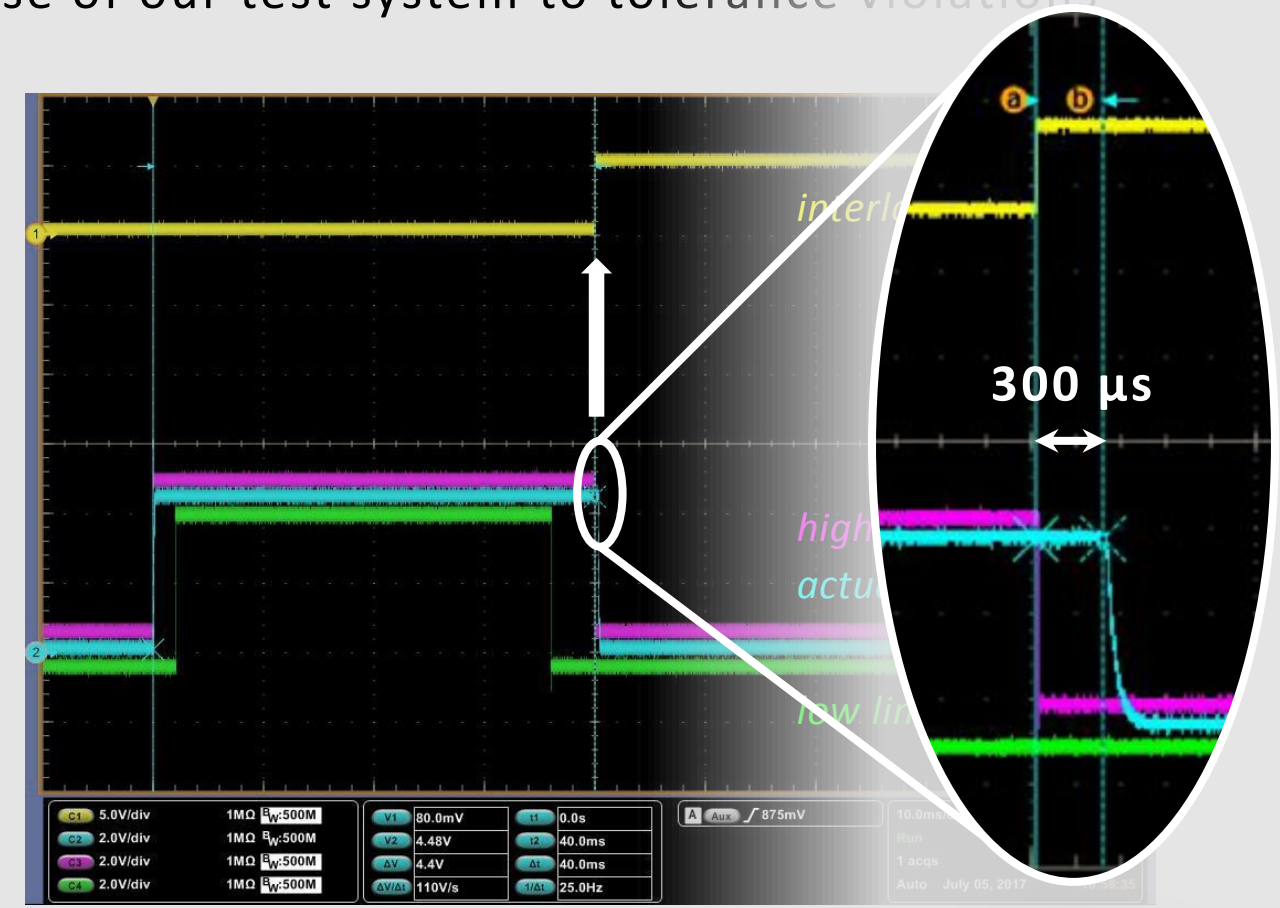

Summary

- First implementation of real-time beam monitoring on a proton therapy beamline

  position: indirect supervision via Hall probes in beam-scanning magnets

  current: direct supervision via ionization chambers at the end of the beamline

- Identical monitoring devices for conventional and accelerated scanning mode

- *Ongoing*: testing of error scenarios and interlock resumption strategies

Thank you for your attention!

Special thanks to my supervisors Prof. Lomax, Dr. Meer & Dr. Psoroulas and the entire line scanning team.

This work is supported by the Giuliana and Giorgio Stefanini Foundation.