

A Modular Control System for Treating Moving Targets with Scanned Ion Beams: Design, Development, and Preliminary Test Results

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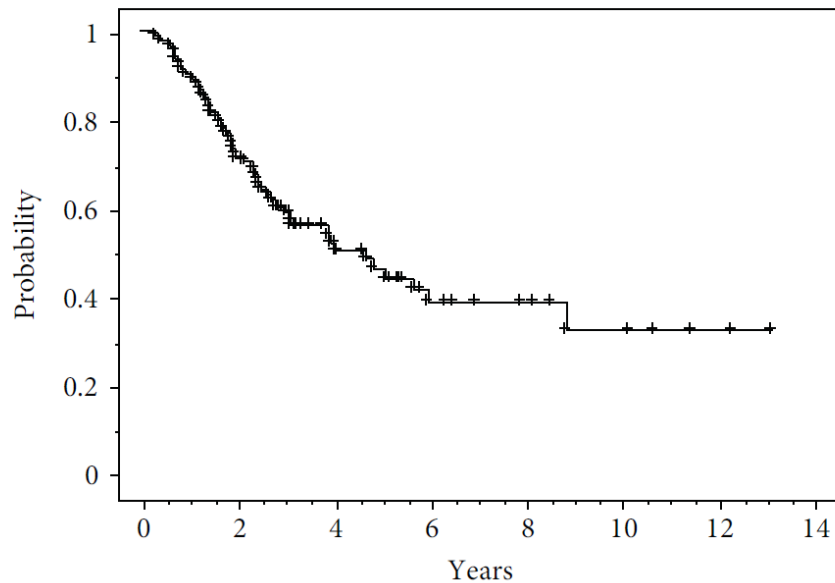
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265.

Lung cancer has the **lowest** 5 year survival rate.

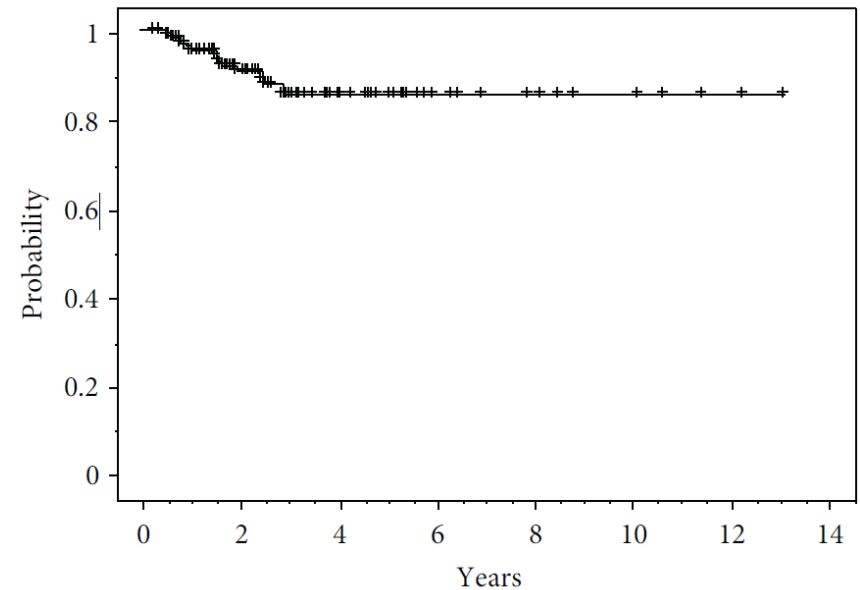


Source: Lung Cancer Alliance

Overall Survival Rates

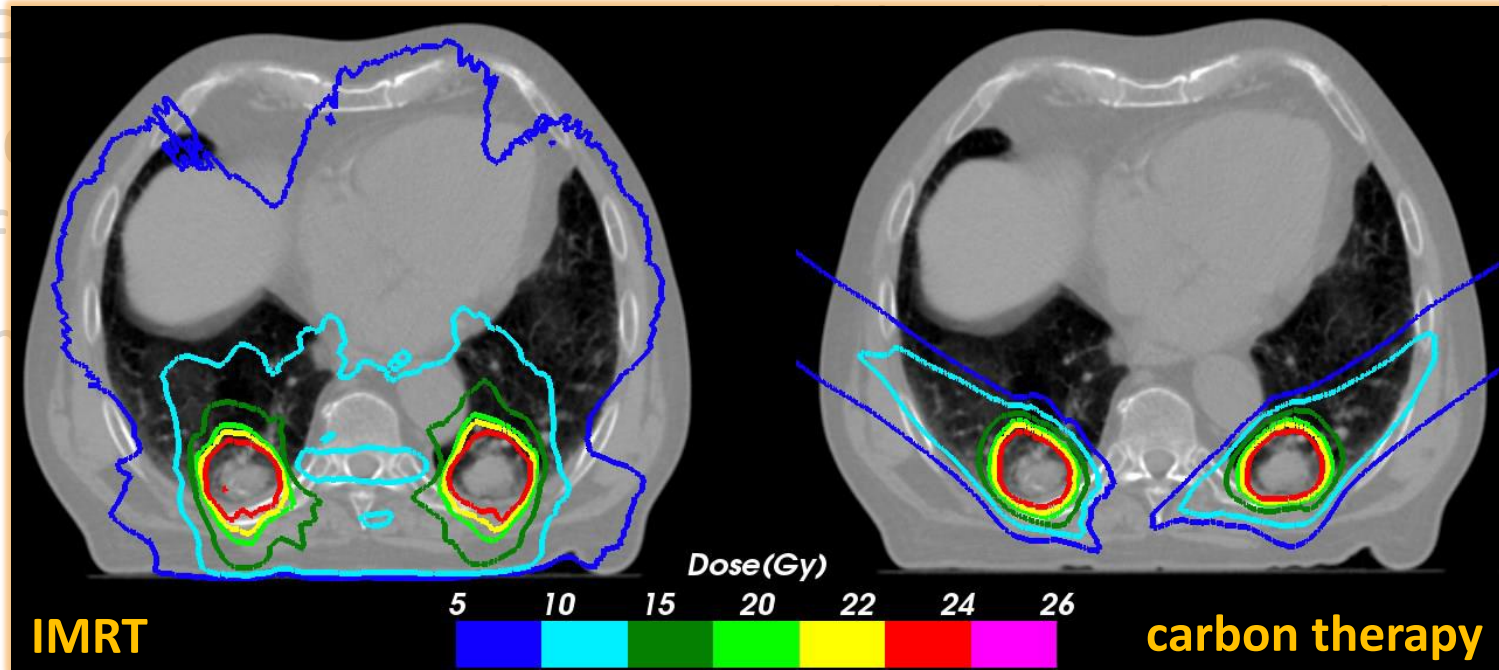


Local Control Rates



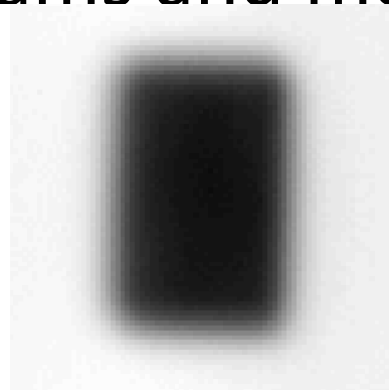
(Nakajima M et al 2013)

- Scanned particle therapy has potential for dose escalation while sparing healthy tissue

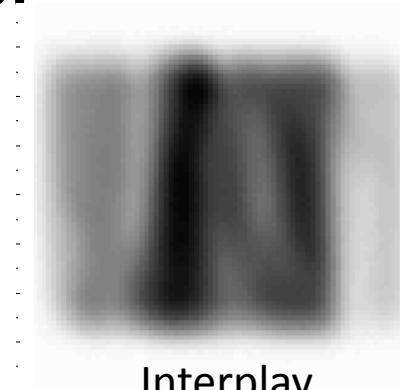


(courtesy of Anderle K)

- Scanned particle beam therapy has the potential for dose escalation while sparing healthy tissue
- But requires a practicable solution to adverse effects from **interplay** between moving ion beams and moving tumors.



Static



Interplay

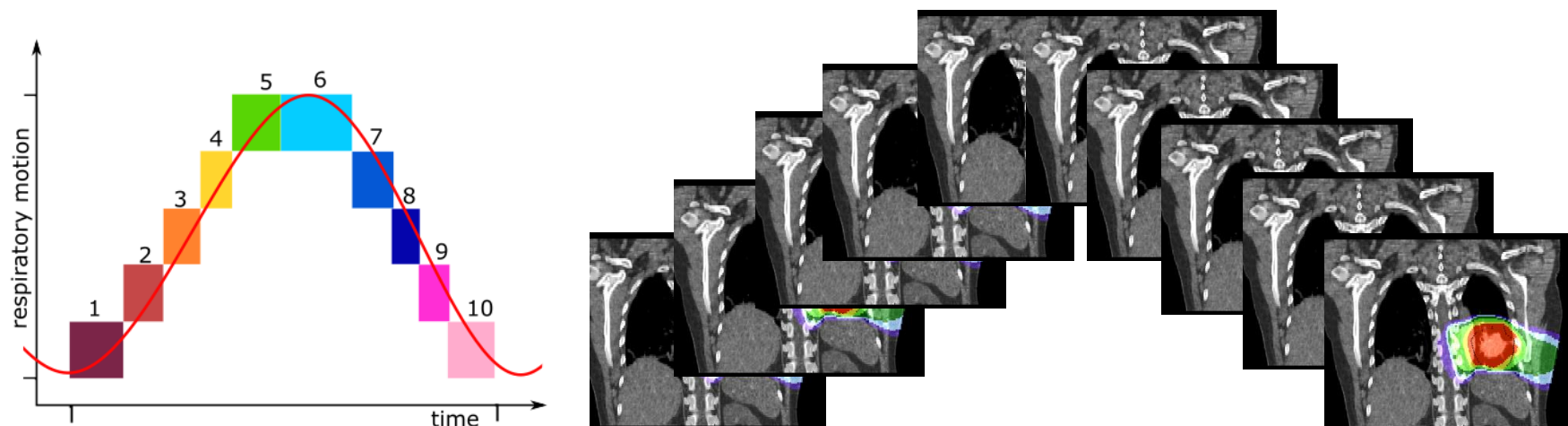
- Scanned particle beam therapy has the potential for sparing healthy tissue
- But requires careful planning to avoid adverse effects from beam range straggling and interplay



Static

Interplay

- Many motion compensation methods
- Designed conformal treatment plans and dose delivery method
- TPS already available (TRiP4D)

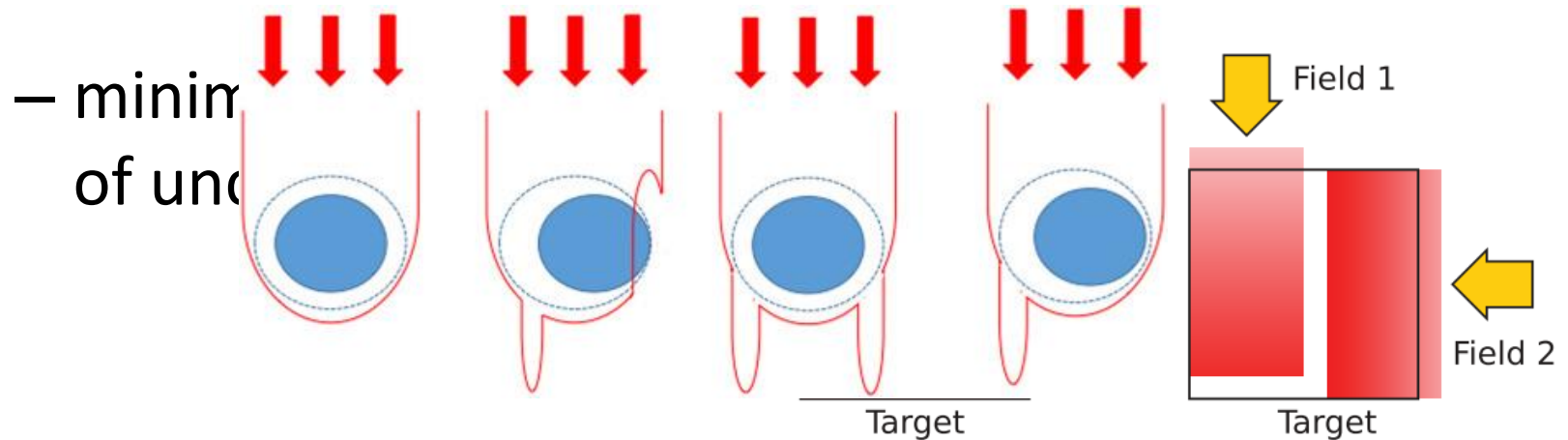


- Library of plans

4DCT

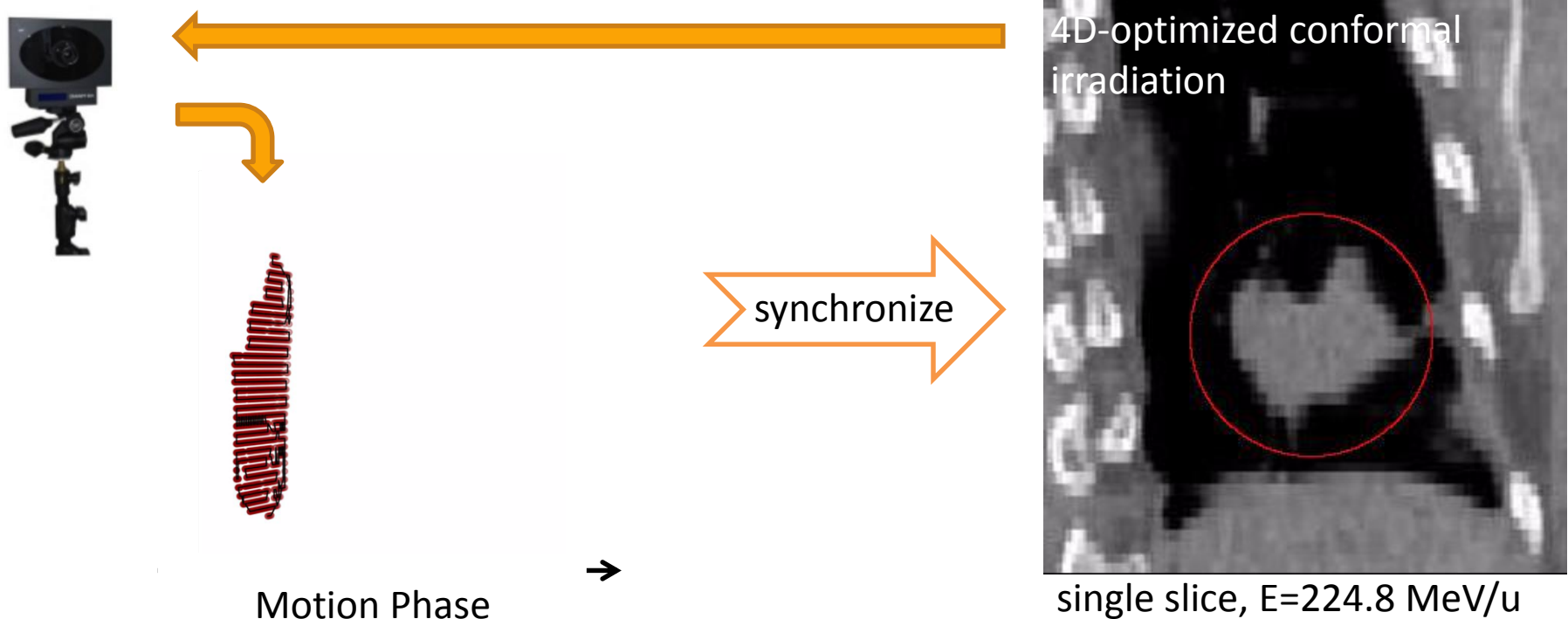


- robust 4D-optimization
 - worst case cost function to minimize the dose distribution degradation from patient positioning shifts and tumour depth uncertainties

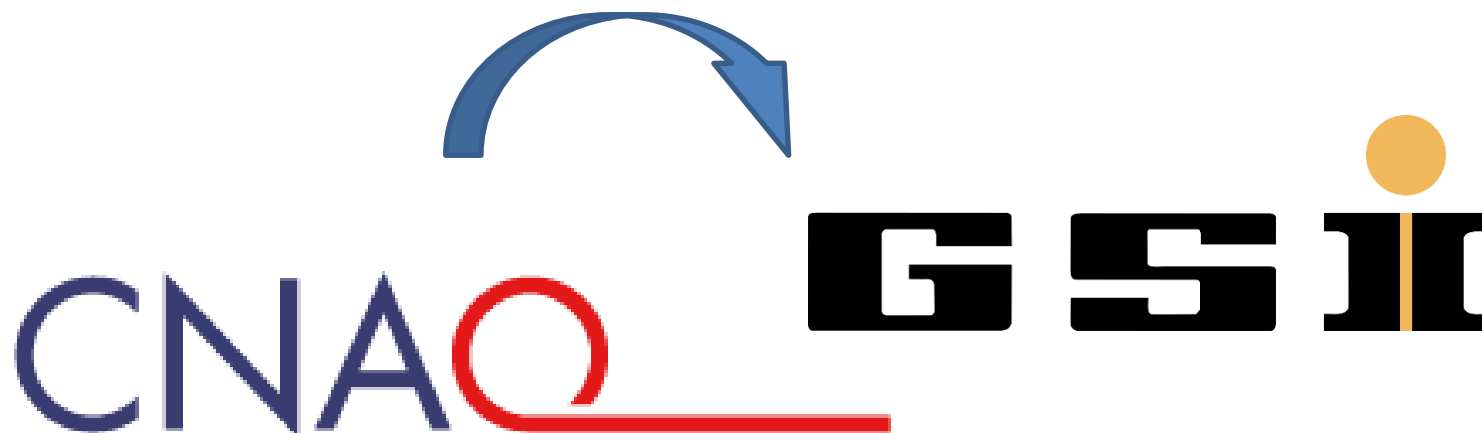


(Wolf M, 2018)

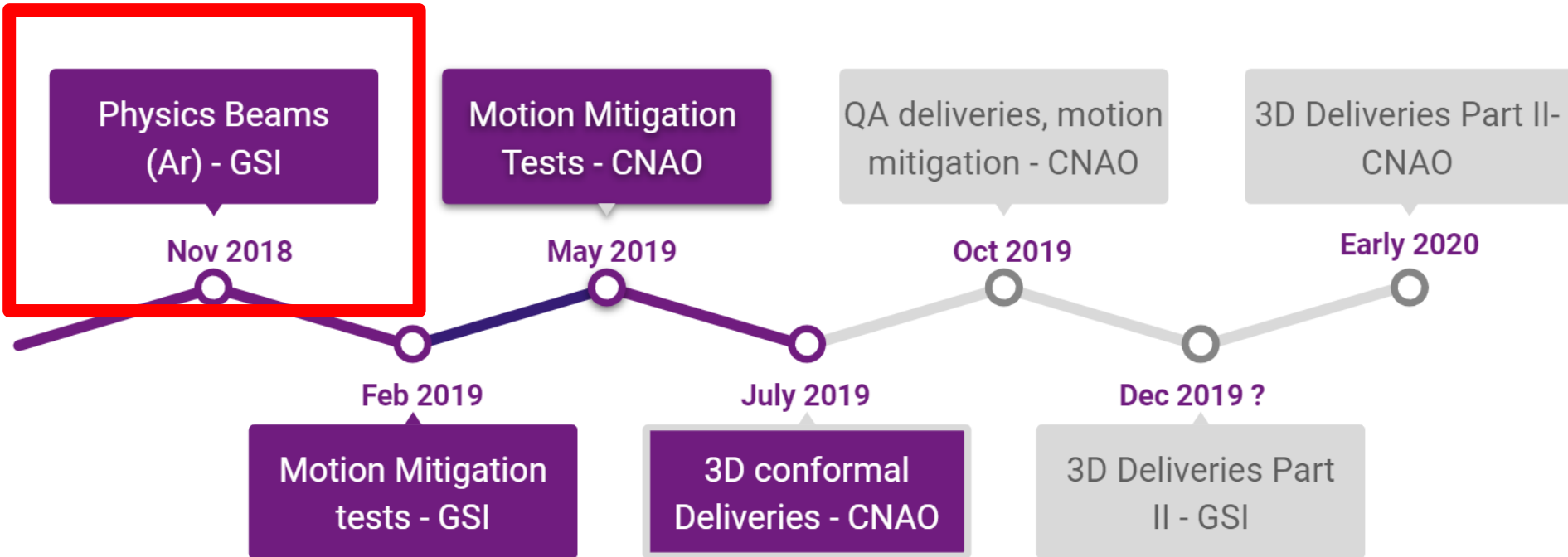
- treatment delivery:
 - library is sent to motion-synchronized DDS
 - MMS detects motion, directs sub-plan switching



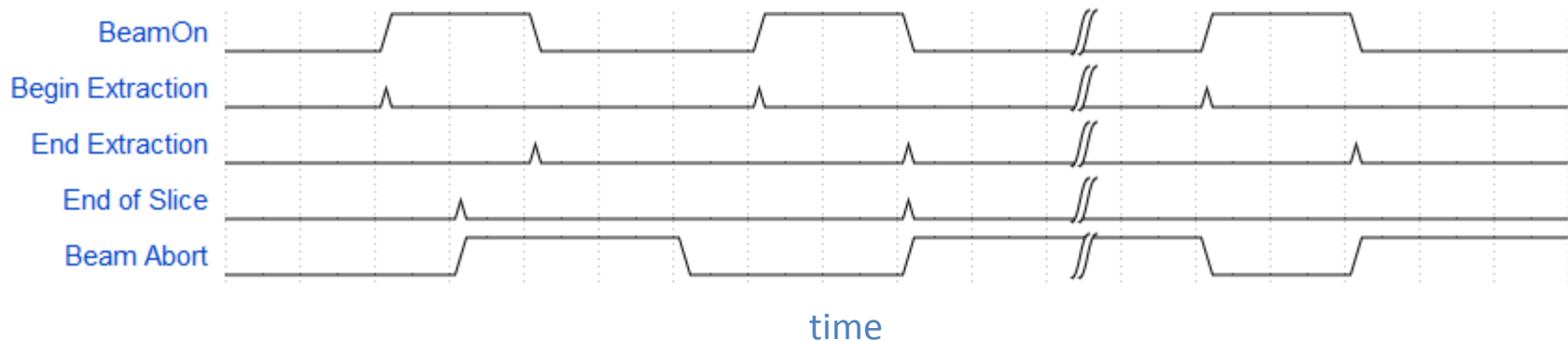
- A motion-synchronized dose delivery system (M-DDS) was designed, developed and tested at GSI and CNAO.



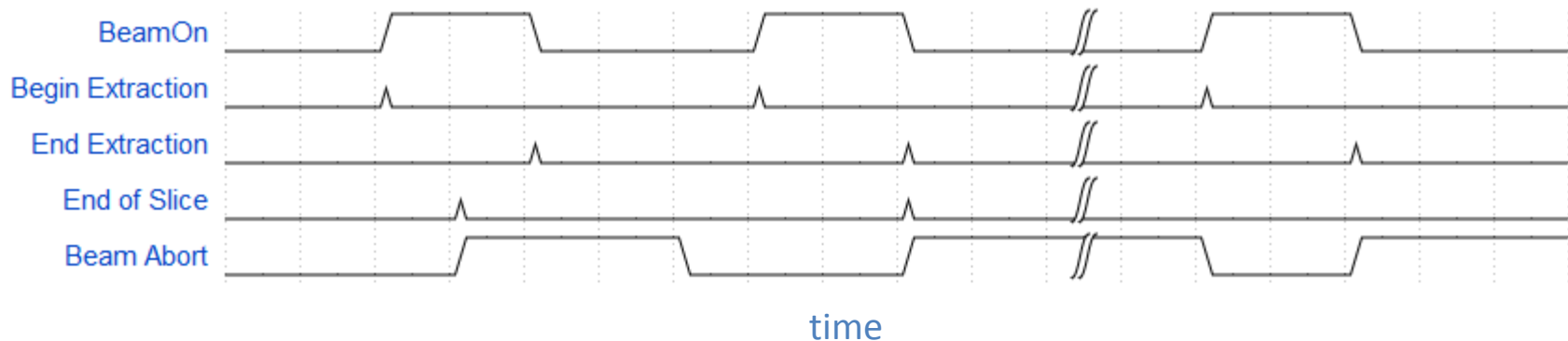
Experiment timeline



- transmission, reception, timing, and synchronization of signals used by each subsystem
- Integration testing: delivering test plans

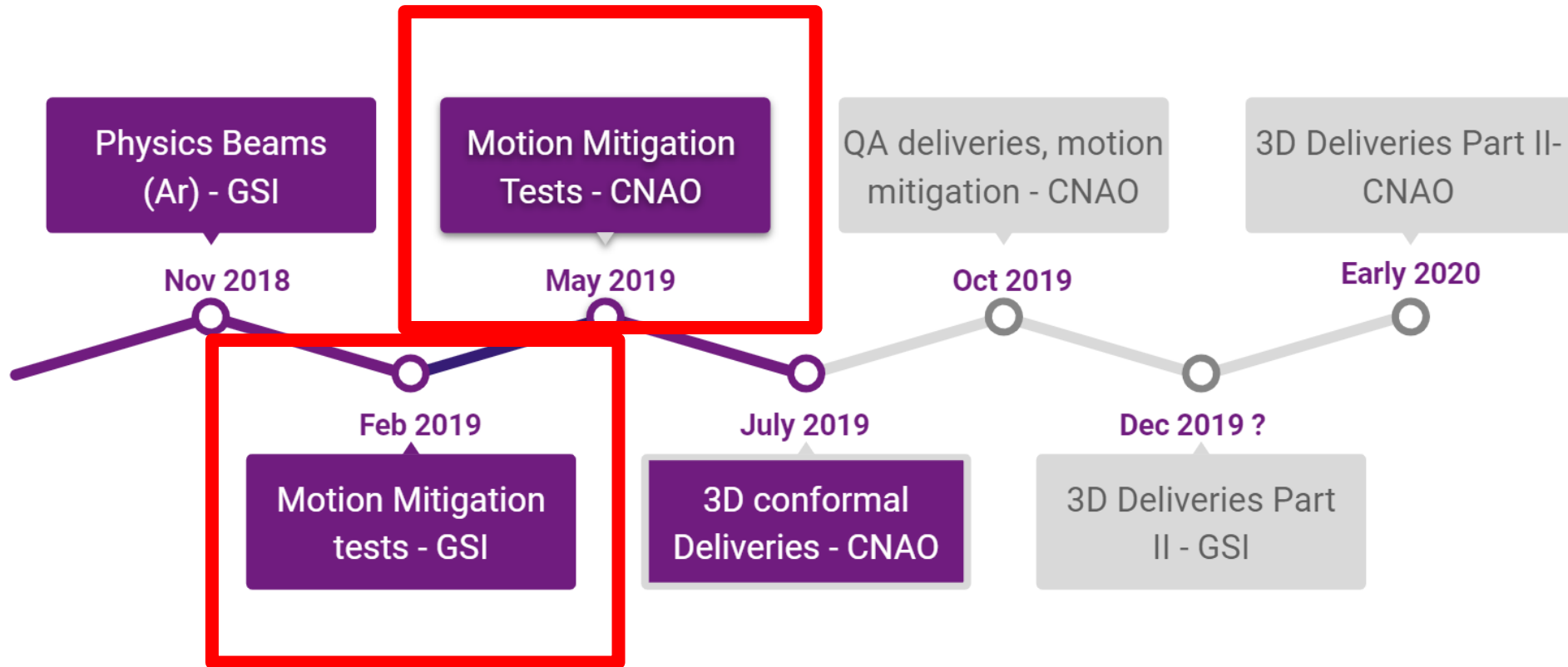


- transmission, reception, timing, and synchronization of signals used by each subsystem
- Integration testing: delivering test plans



Confirm that the implemented dose delivery system, which synchronizes the motion of tumors and scanned ion beams can irradiate tumors safely and with dosimetric accuracy, while sparing surrounding healthy tissues.

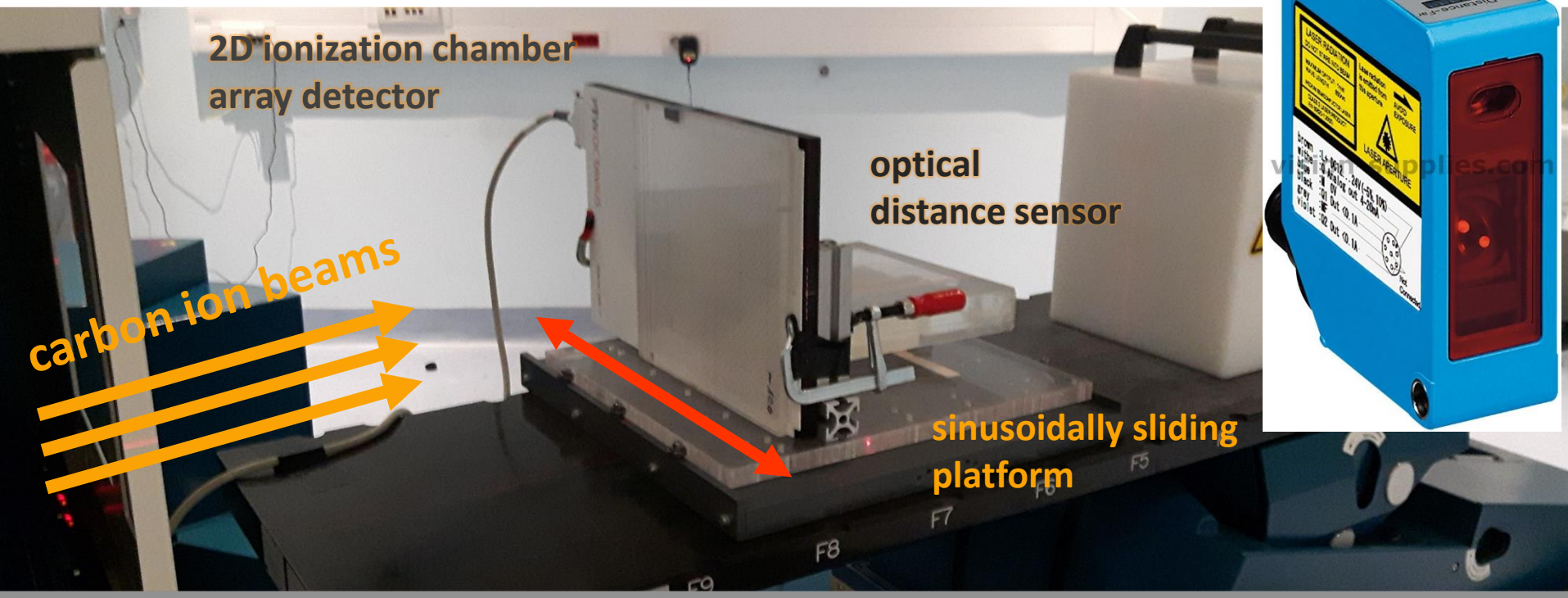
Experiment timeline



- Continued safety for clinical prototype
- Gating tests
- CNAO: Complete beam disruption with chopper magnet
- GSI: Residual intensities $\sim 10\%$ of full intensity

Delivery set-up

- 2D and 3D geometries – squares, outlines, lines, cubes, ellipses
- 20 mm and 40 mm horizontal motion
- uncompensated, 3, 6, 10 motion phases



- Preliminary results have validated the basic functionality and feasibility of the implemented motion mitigation strategy.
- 3D conformal irradiations successfully delivered

Thank you!



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Christoph Sauter
Chrstitoph Schuy
Uli Weber
Berdt Voss
Timo Steinsberger

Marco Donetti
Medical physics staff



The results presented here are based on the experiment SBIO, which was performed at the GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt (Germany) in the frame of FAIR Phase-0.



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