Compact Cancer Killers —
Simulating Next-Generation Laser-Driven Ion Accelerators

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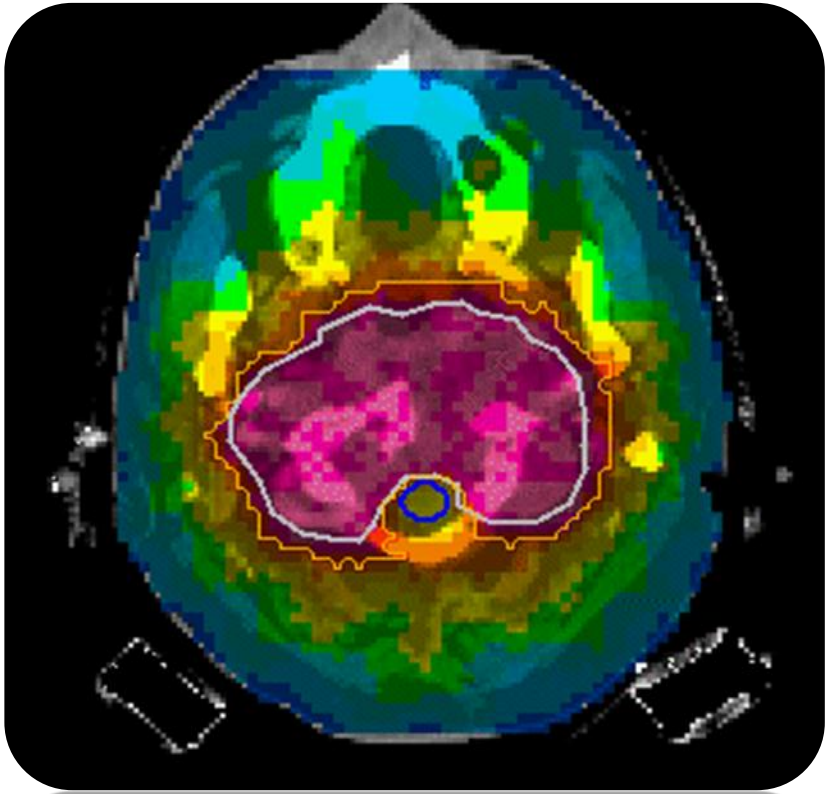
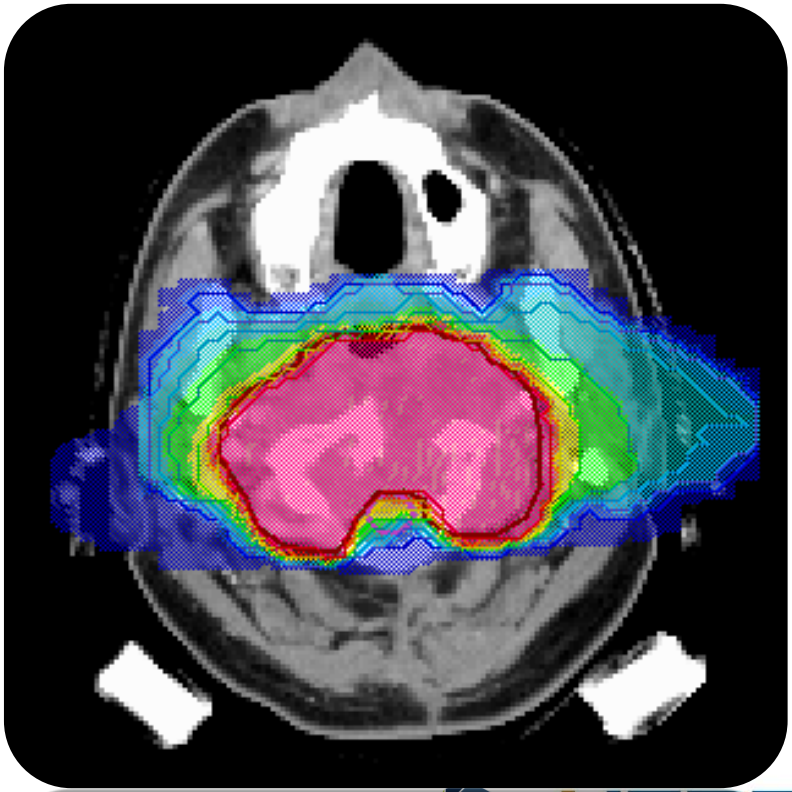
Radiation Tumor Therapy with Beams of Ions



8 X-Ray Beams



2 Ion Beams

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Oncoray @ Dresden

Oncoray is the
German National Center for
Translational Cancer Research

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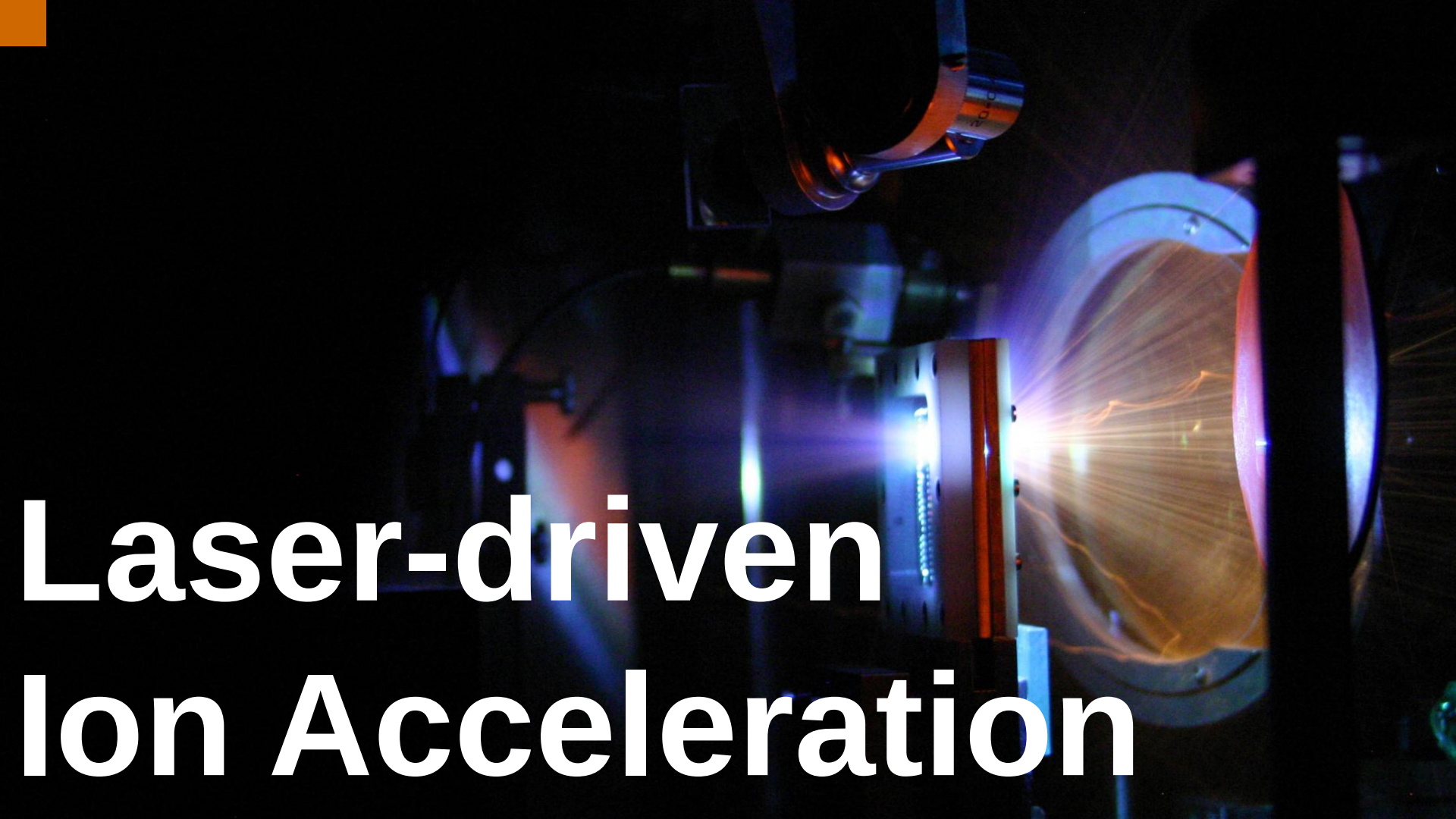
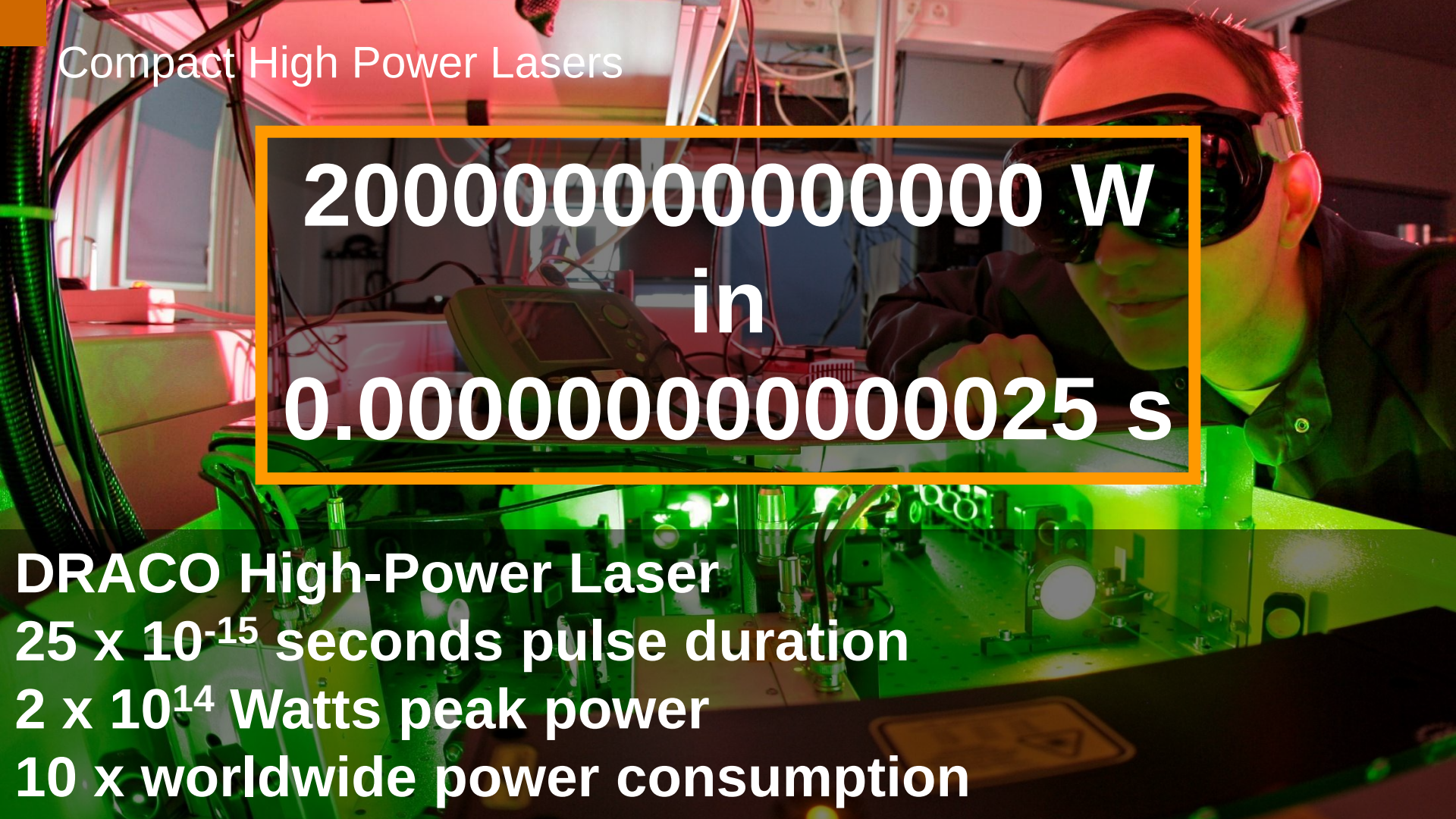
Can we make this compact & affordable?



Laser-driven Ion Acceleration

Compact High Power Lasers

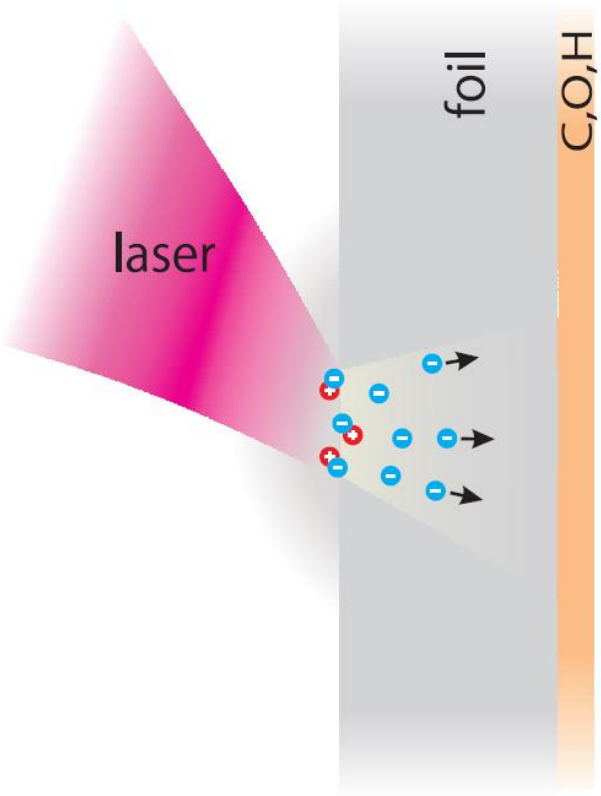


200000000000000 W
in
0.000000000000025 s

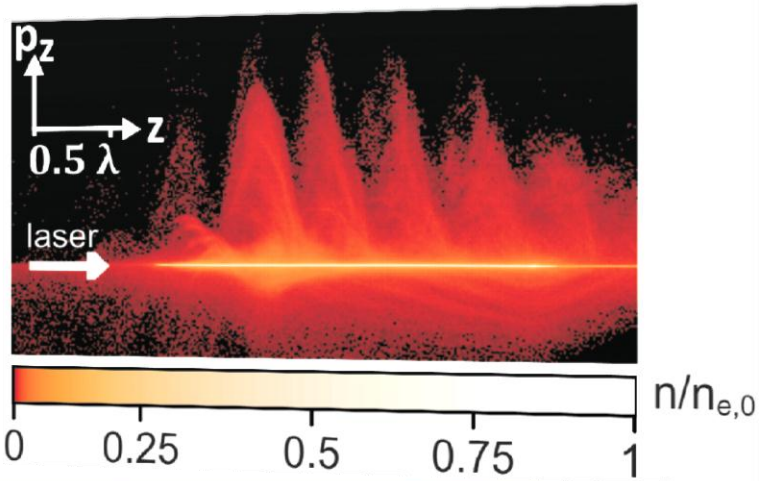
DRACO High-Power Laser
25 x 10^{-15} seconds pulse duration
2 x 10^{14} Watts peak power
10 x worldwide power consumption

How does one accelerate Ions with Lasers?

The Working Horse – Target Normal Sheath Acceleration



- Laser ionizes target front side up to critical density
- Electrons accelerated by laser force in bunches (10-100 fs time scale)



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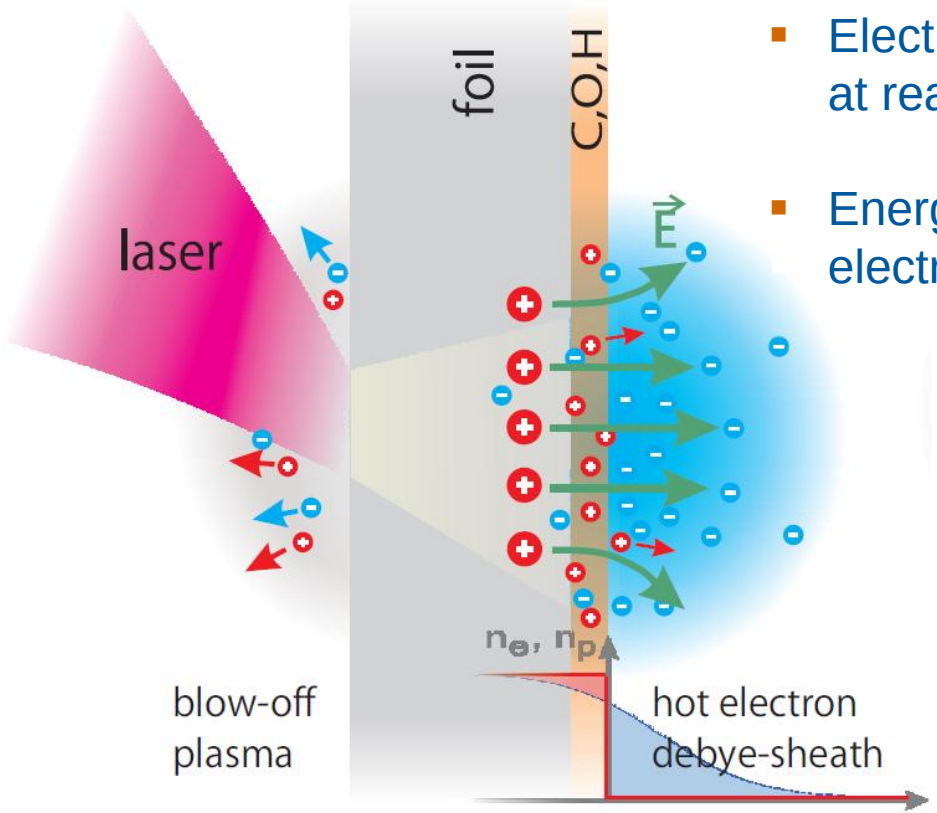
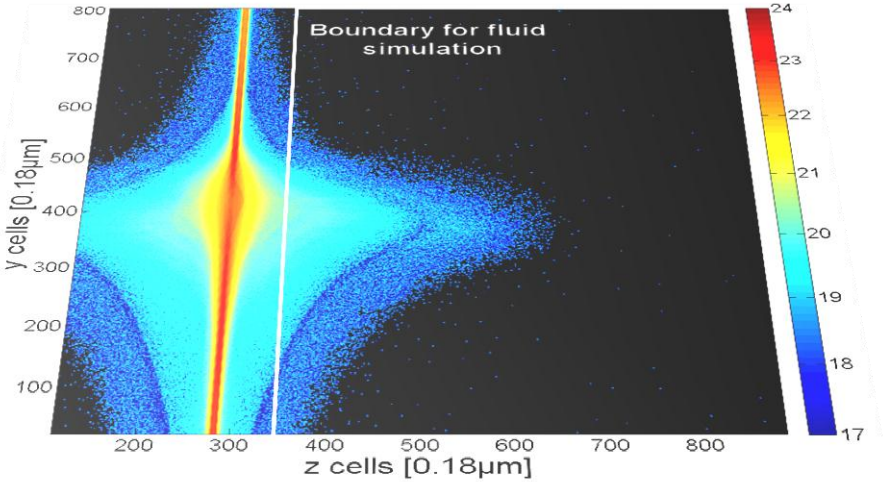
The Working Horse – Target Normal Sheath Acceleration



- Electrons form sheath at rear surface
- Energy transfer from electrons to ions



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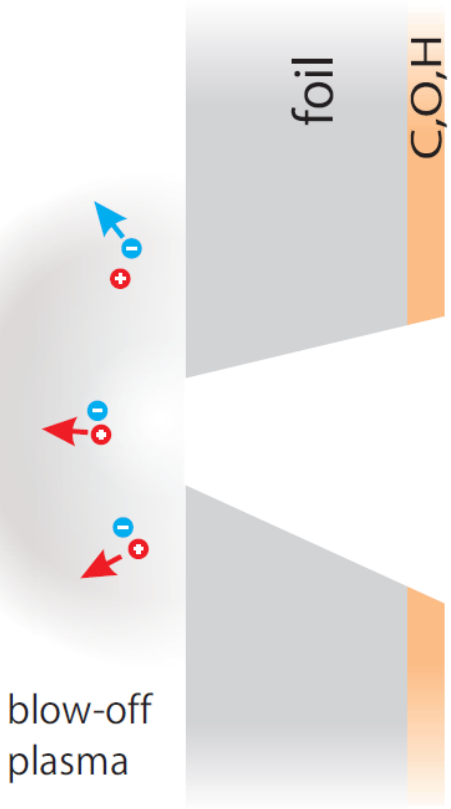
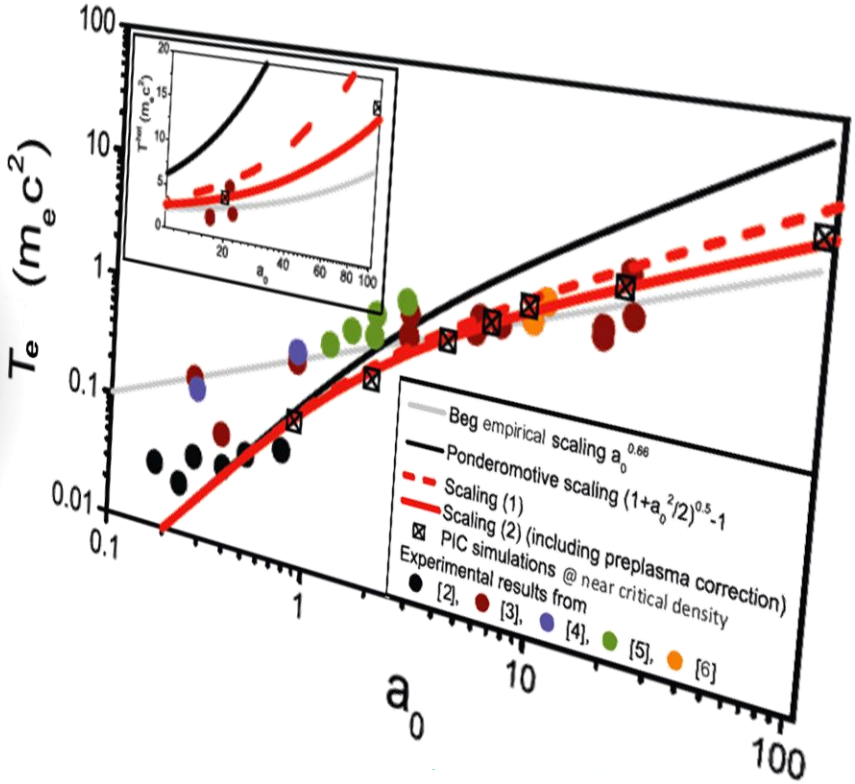
The Working Horse – Target Normal Sheath Acceleration





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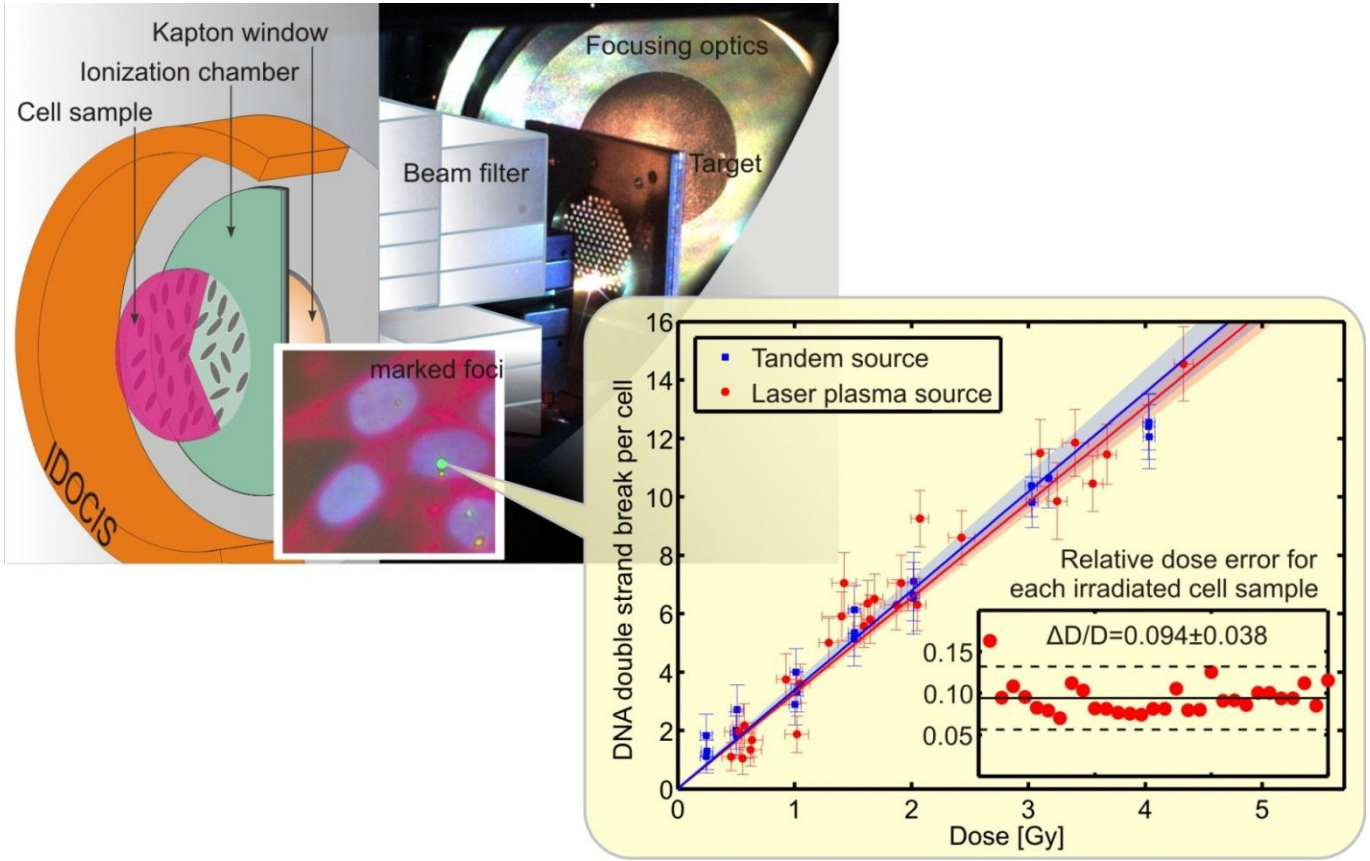
First dose-controlled Laser-Proton-Irradiation of Cancer Cells



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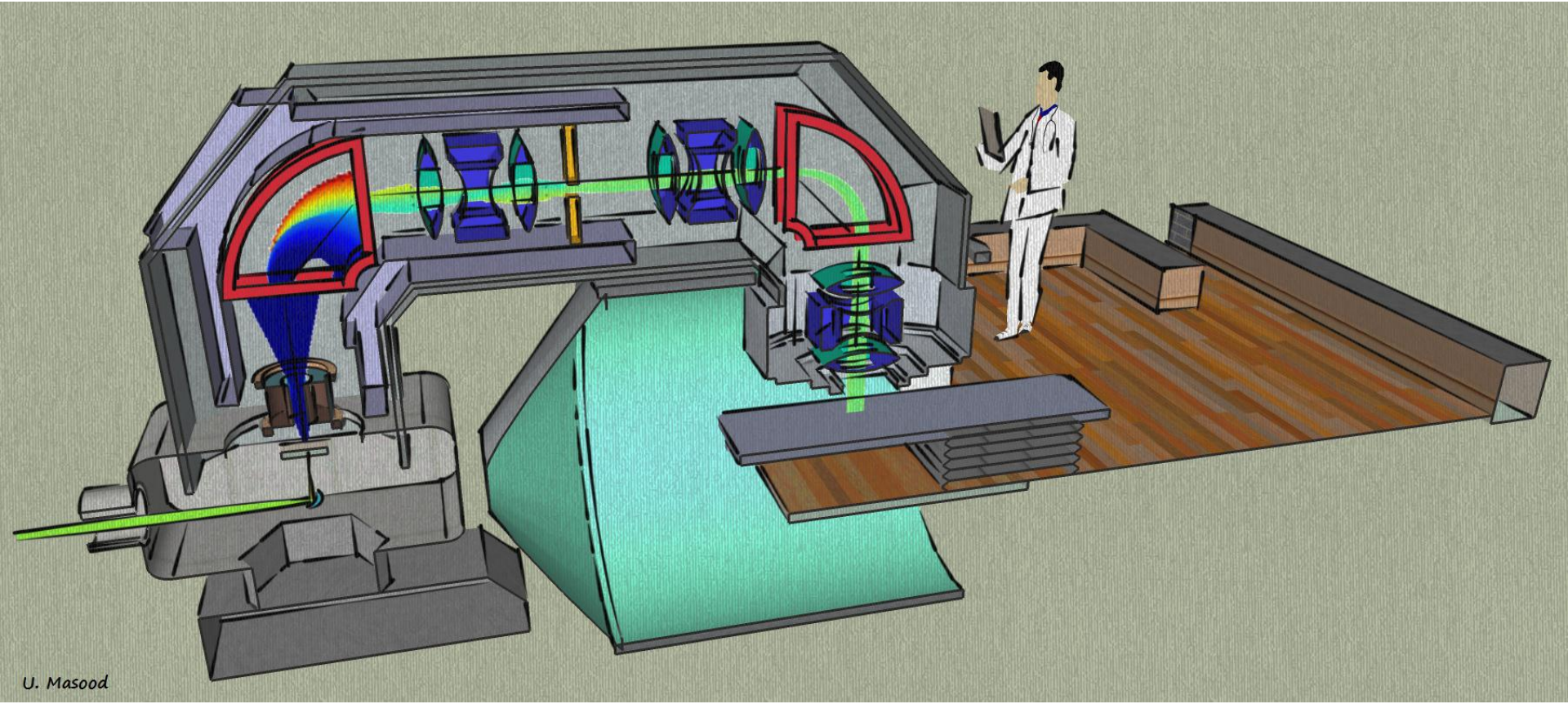
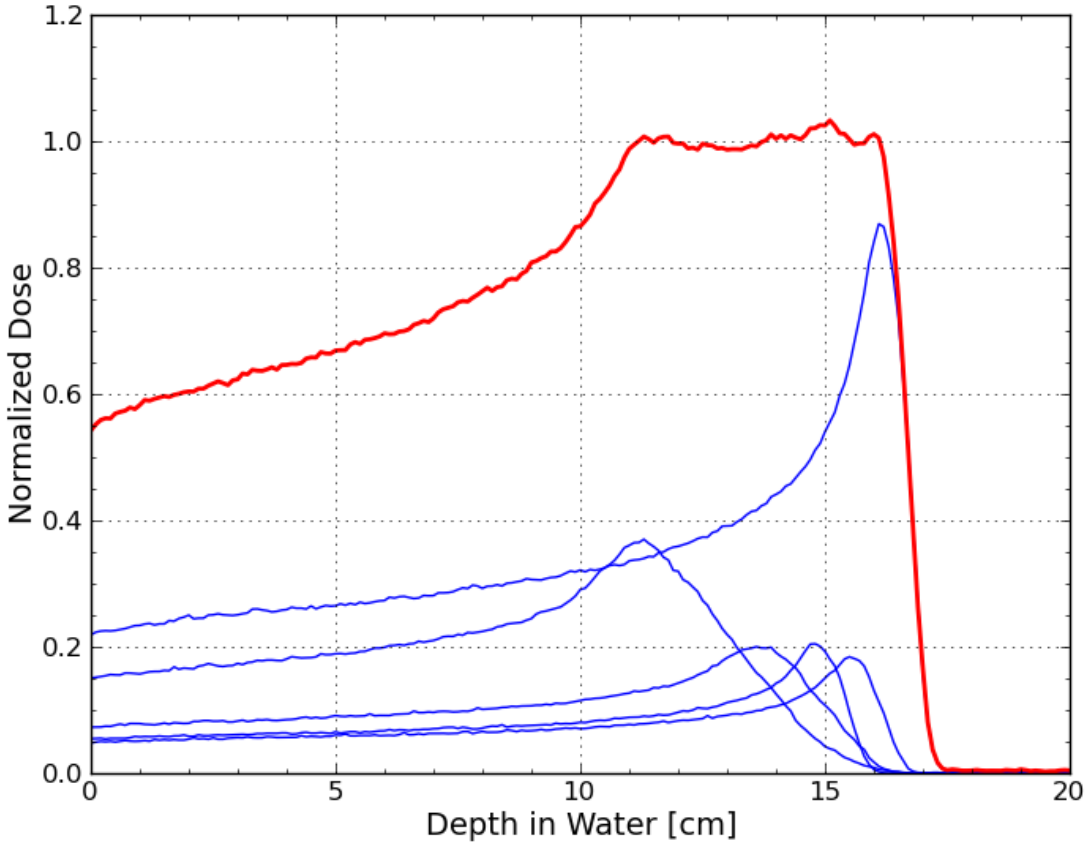
A compact, isochronous Gantry using Pulsed Magnets

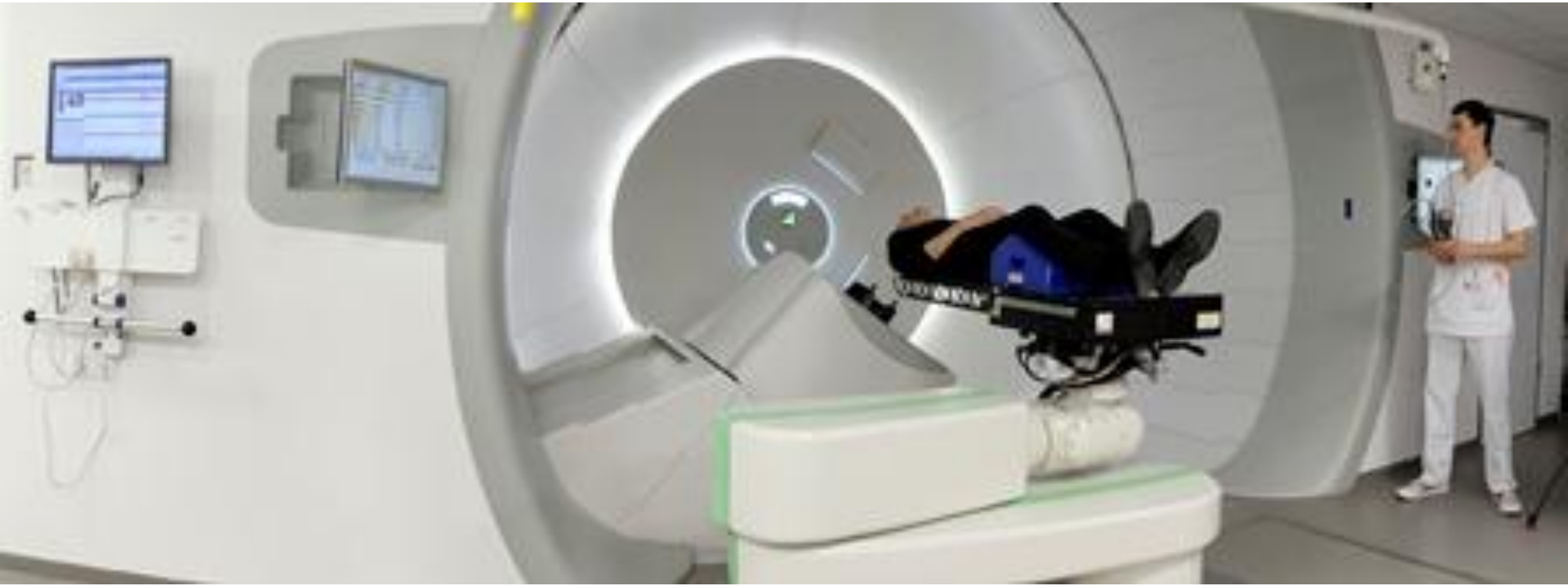


Spread-out Bragg-Peak Irradiation with Broad Energy Beams



The flatter the dose plateau,
the better the dose control

In Reality, this will look nicer

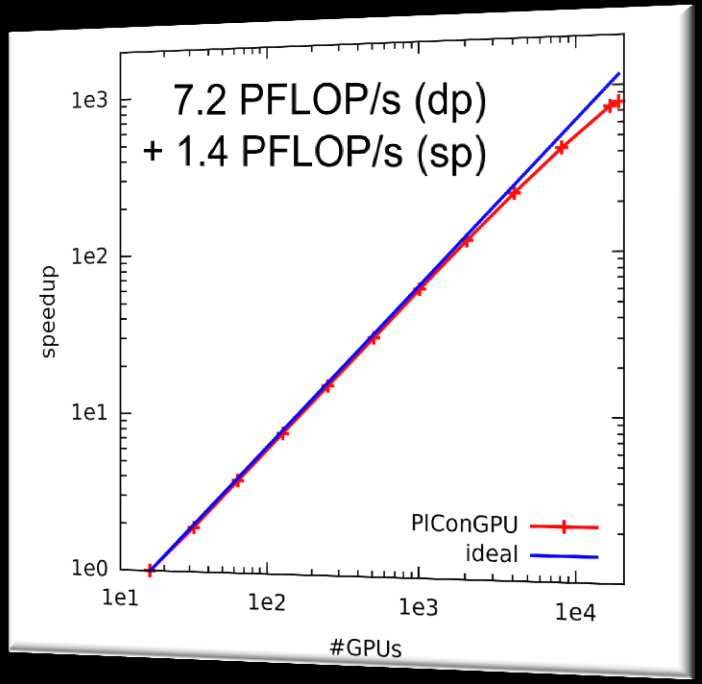


Yes, we can (probably)

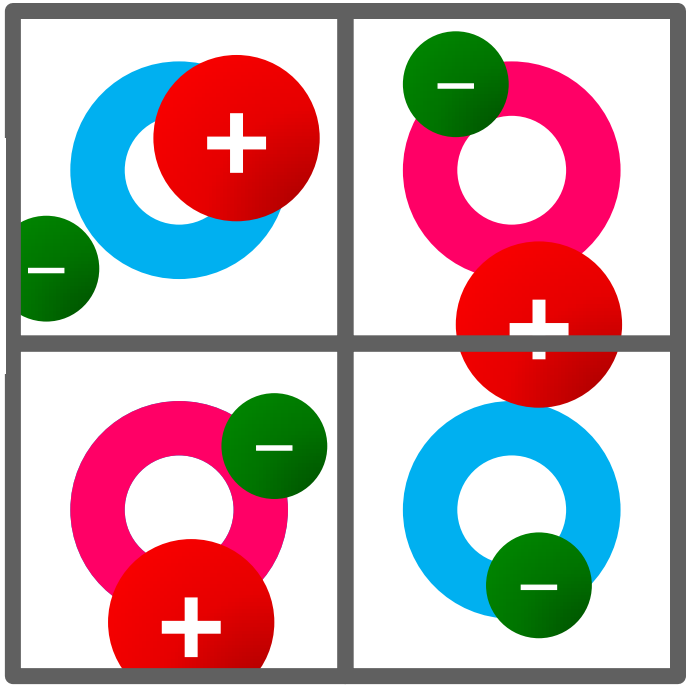
So, what do you do with GPUs?

PIConGPU

- 3D3V Particle-in-Cell Code
- Fully GPU-accelerated C++
- Open Source
- See picongpu.hzdr.de



Plasma Simulation using the Particle-in-Cell Technique



Field Domain **Particle Domain**

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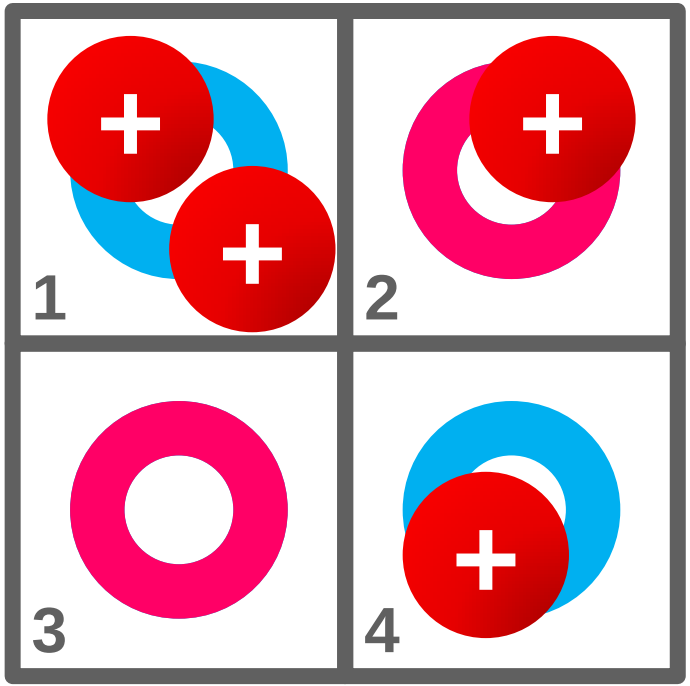
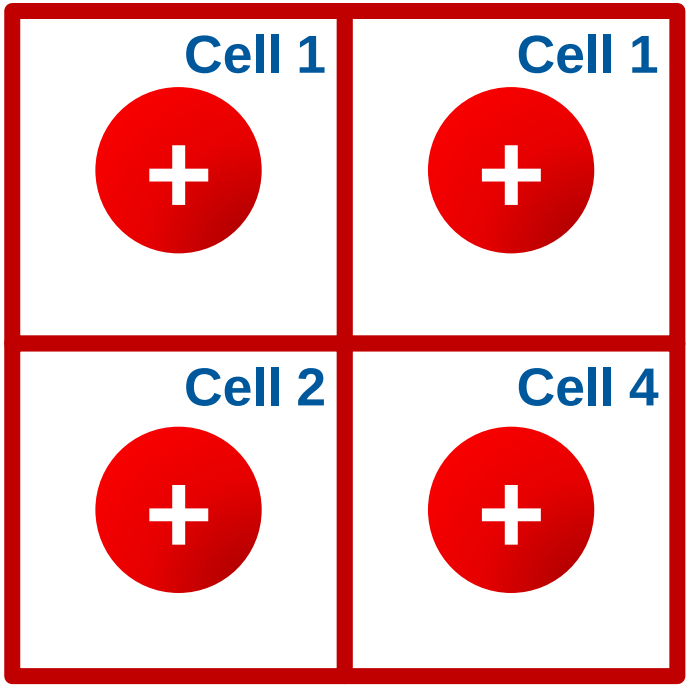
Creating vectorized Data Structures for Particles and Fields





Field Domain **Particle Domain**

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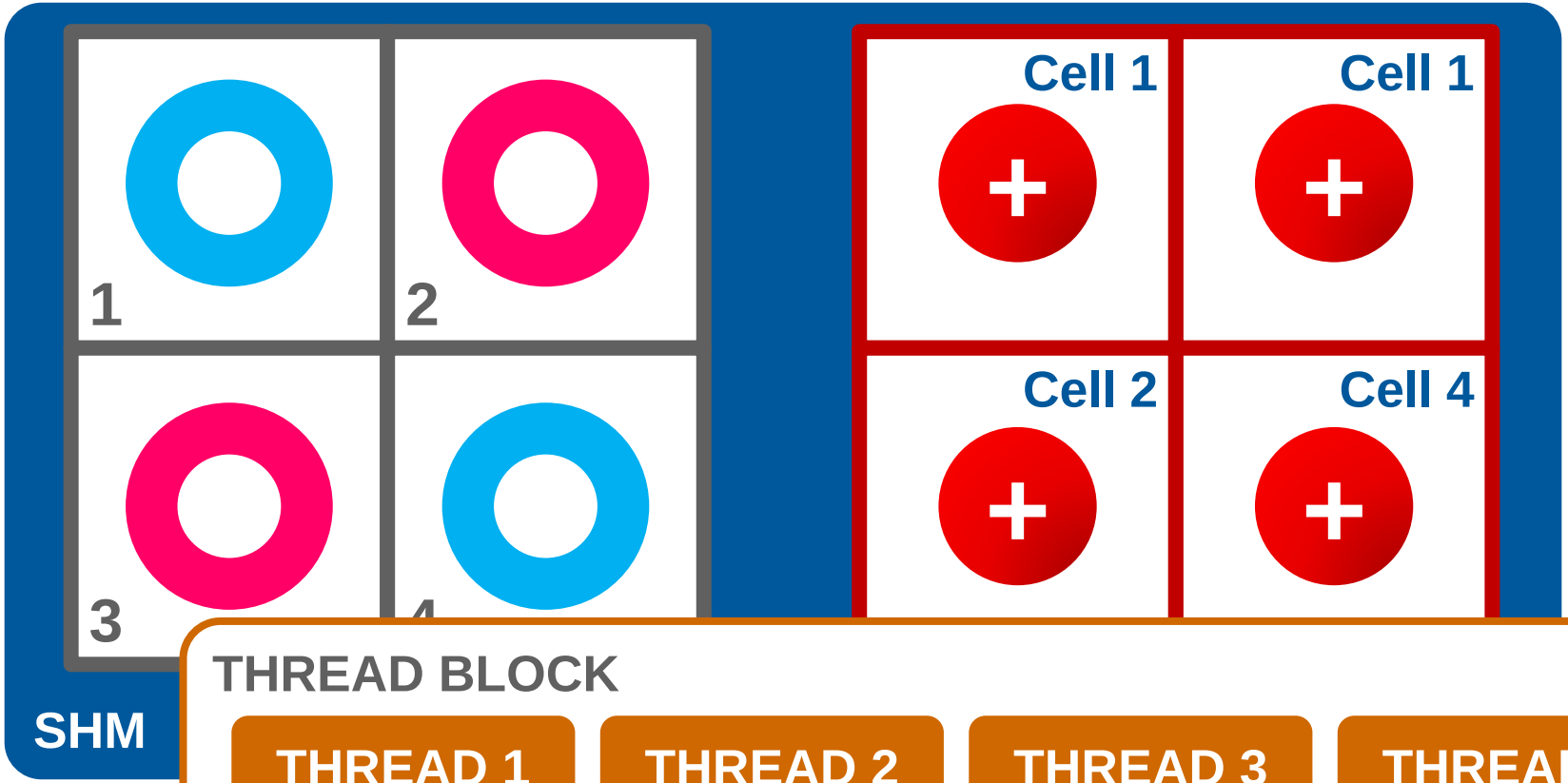
Thread-wise Operations on Fields and Particles in Shared Memory



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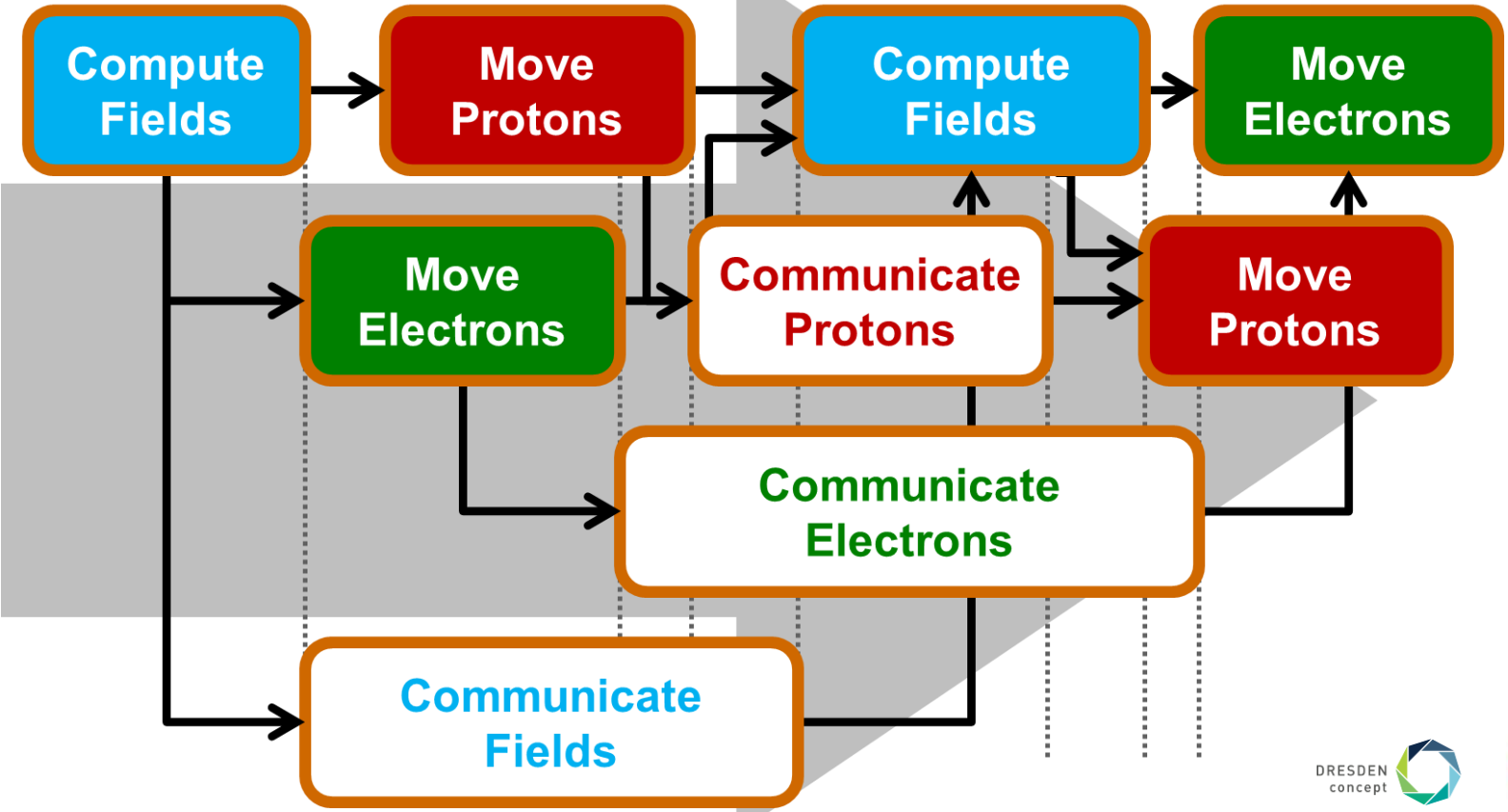
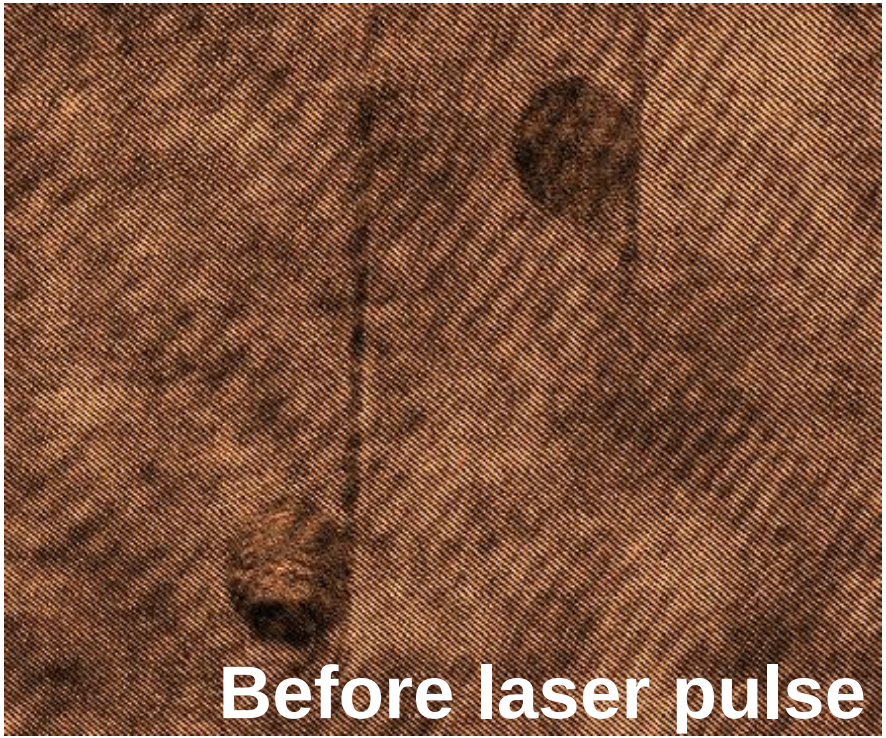
Task-Parallel Execution of Kernels + Asynchronous Communication

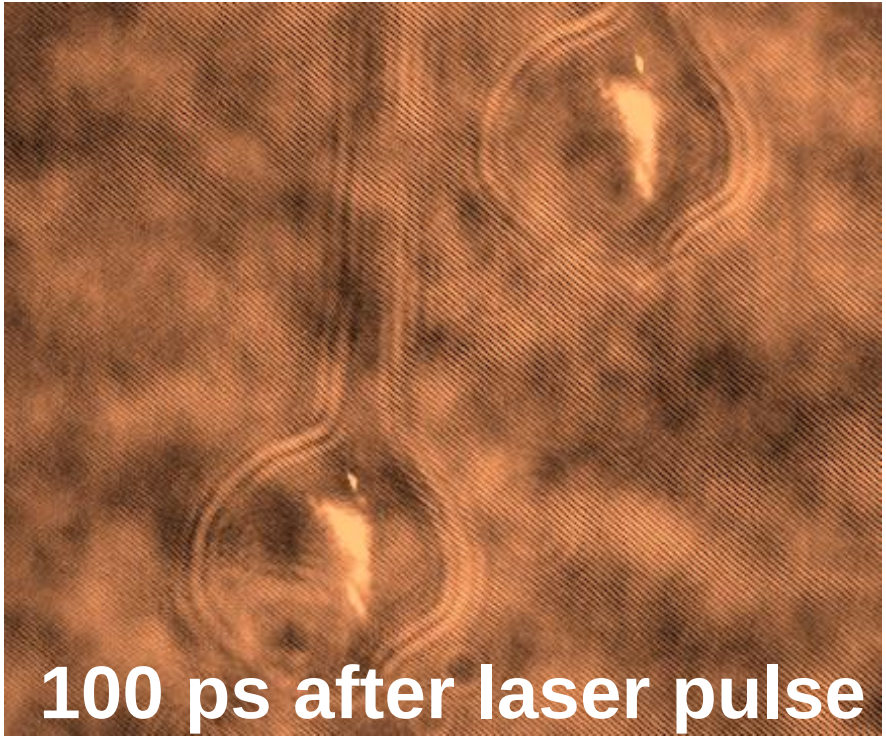



GPU-only code!

Does it work?

Targets must be held by „something“





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Sometimes, you just need a little force…

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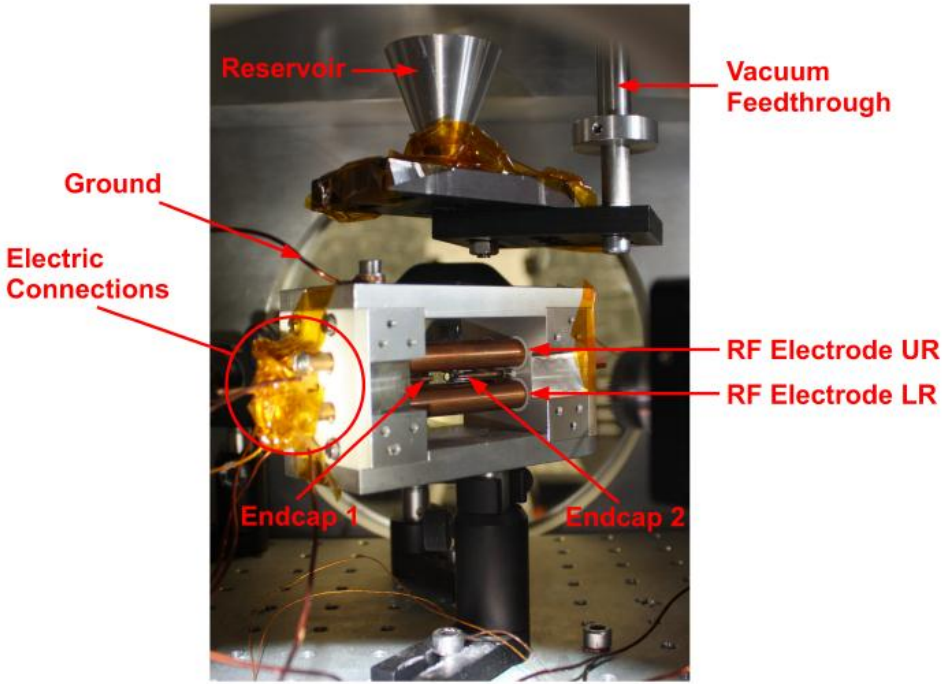
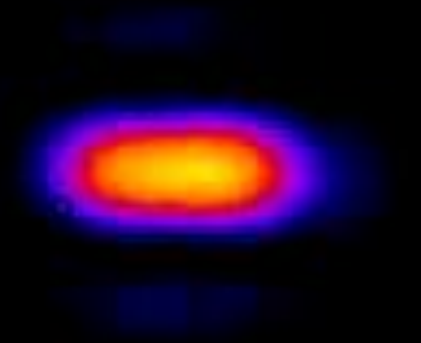
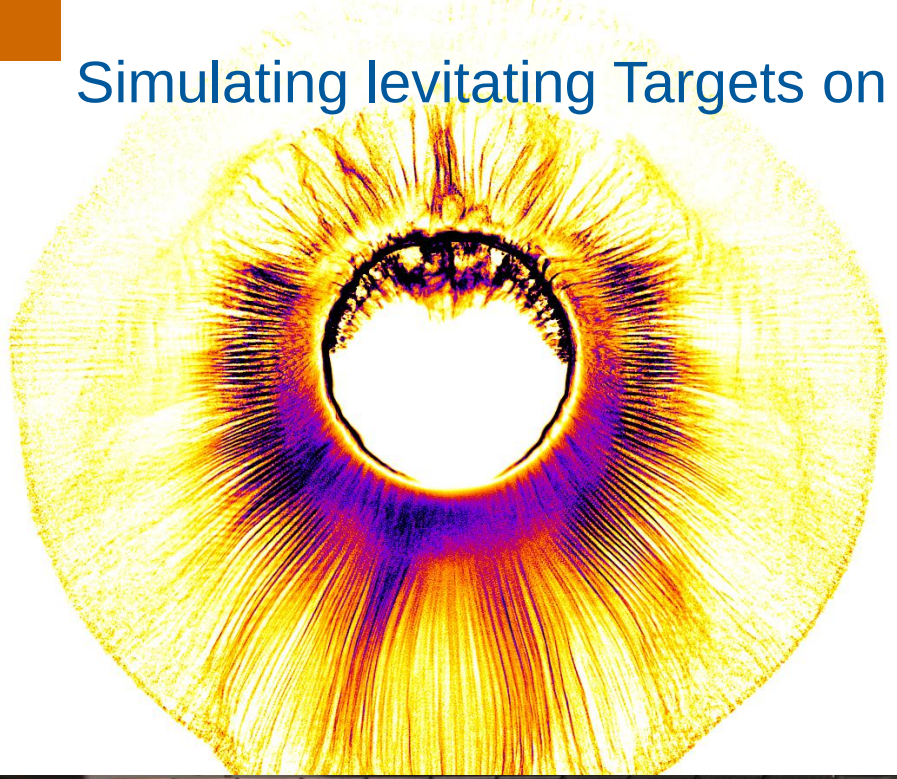


Levitating Targets in a Paul Traps



100µm

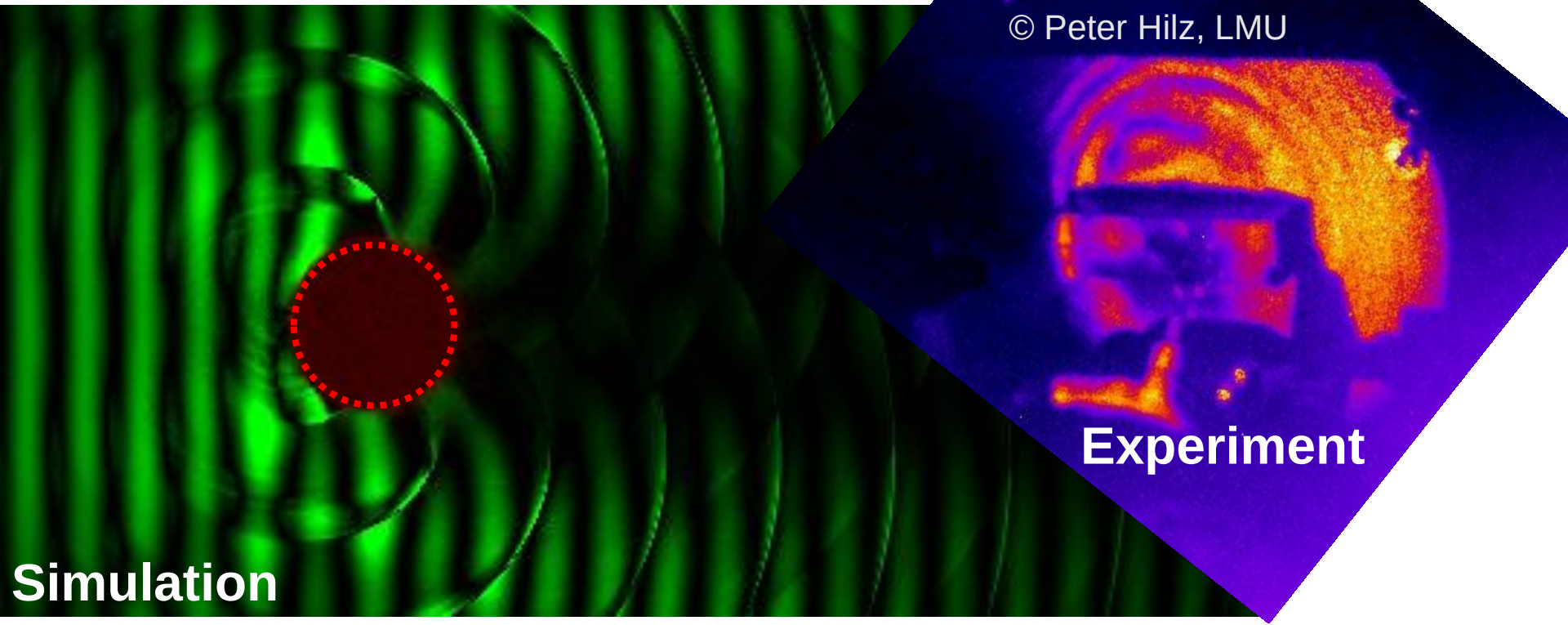
Simulating levitating Targets on TITAN

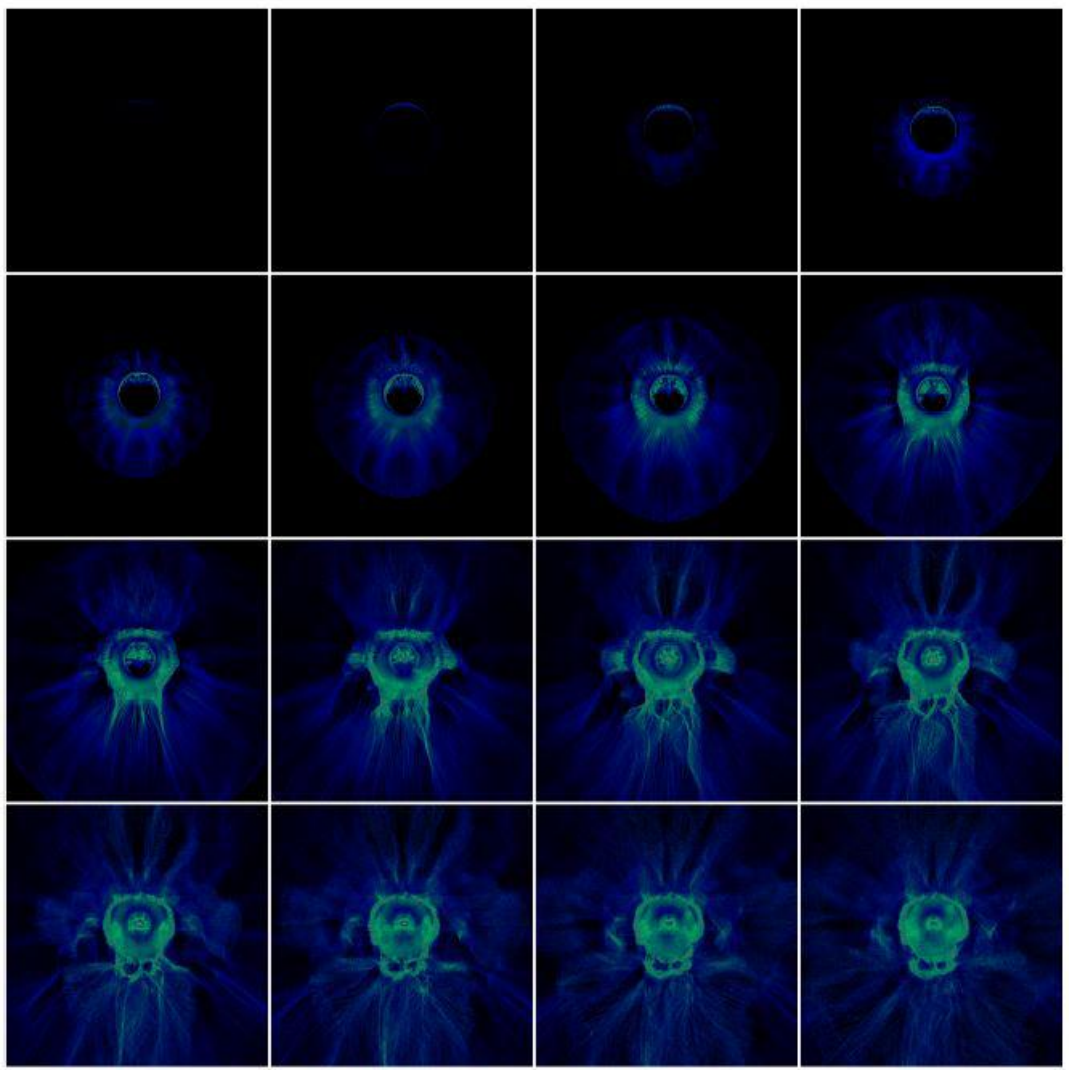


PIConGPU

- Five 3D Simulations (+many 2D)
- 100 n_c, resolving λ_{plasma}
- 1 ps duration @ as resolution
- ORNL INCITE Highlight

Validation – Diffraction of Laser on Target





Thank you!