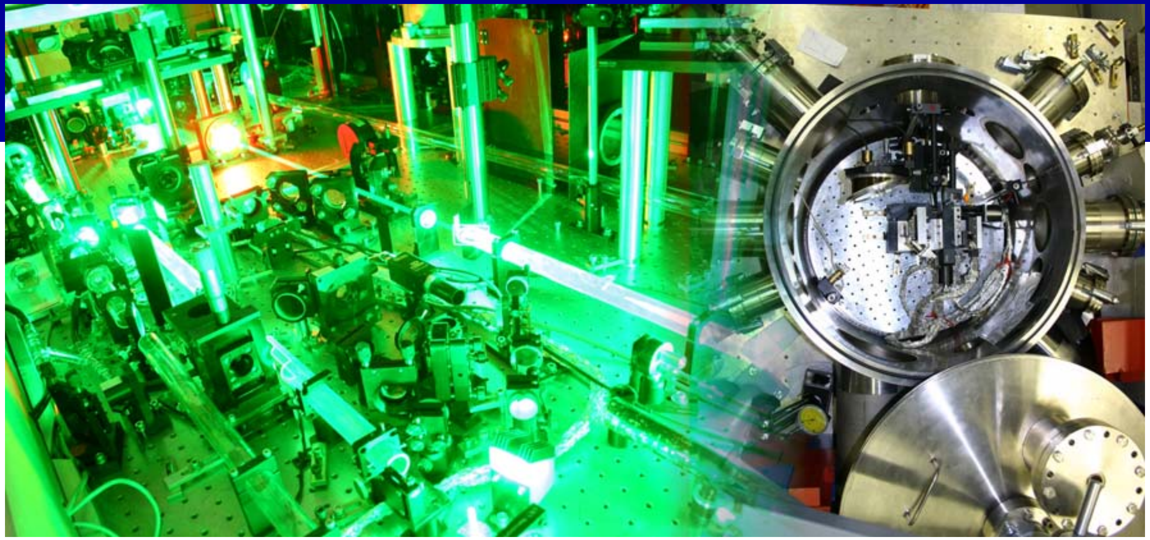
Laser-plasma acceleration of quasi-monoenergetic protons from microstructured targets



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Institut für Optik und Quantenelektronik, Friedrich-Schiller-Universität Jena

Timur Esirkepov, JAERI, Kyoto

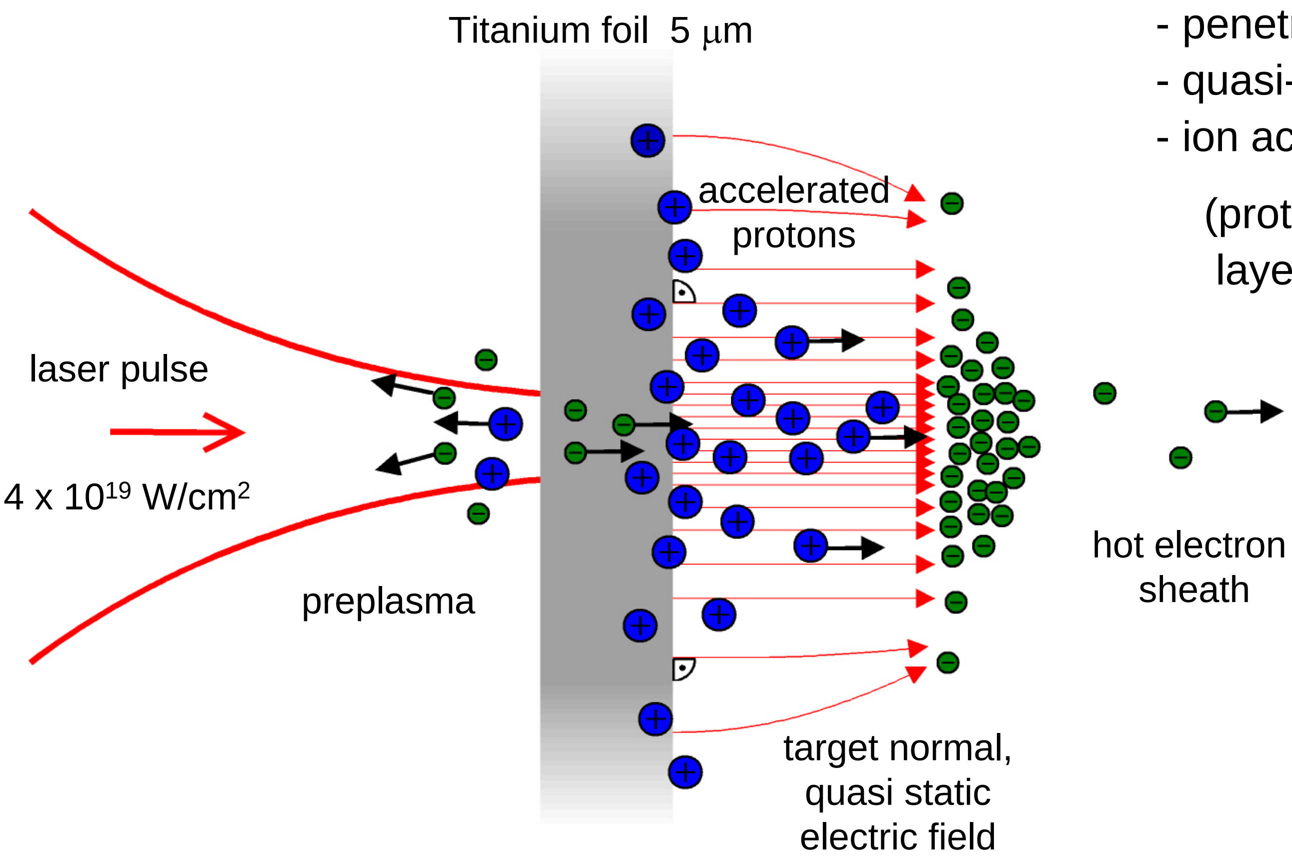
Ken Ledingham, University of Strathclyde, Glasgow

Target Normal Sheath Acceleration

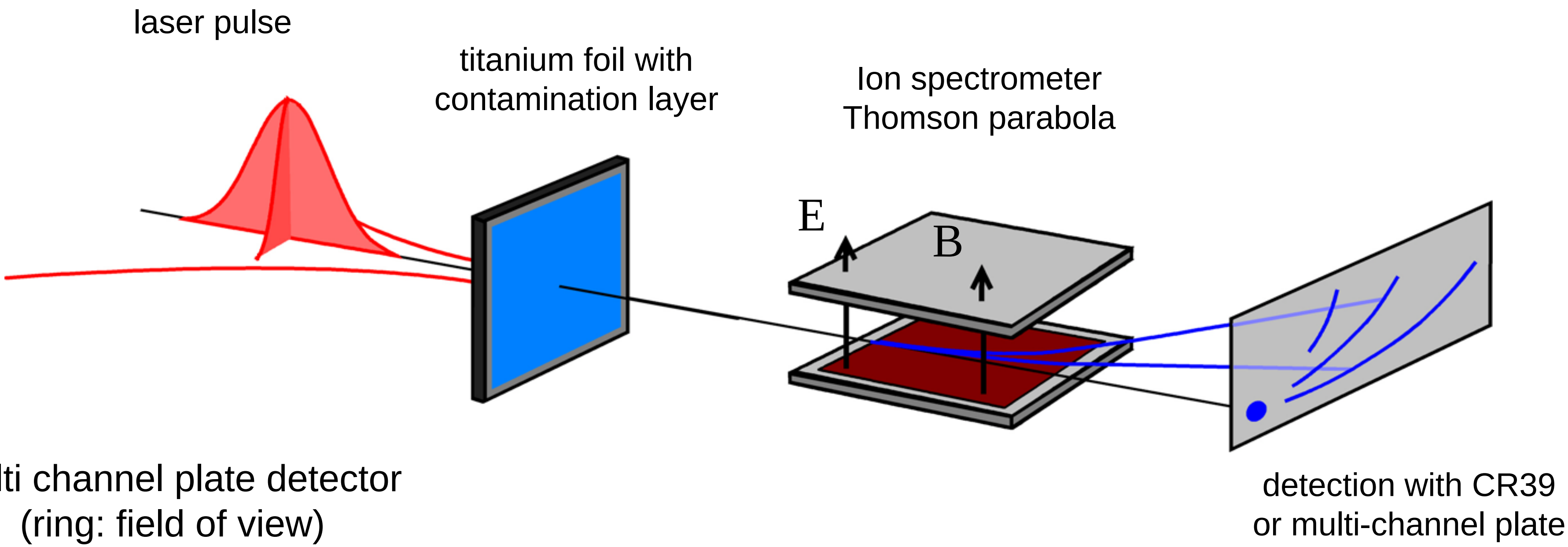
mechanism:

- laser on thin metal foil
- electron acceleration into target
- penetration through target
- quasi-static field on the back
- ion acceleration from the back

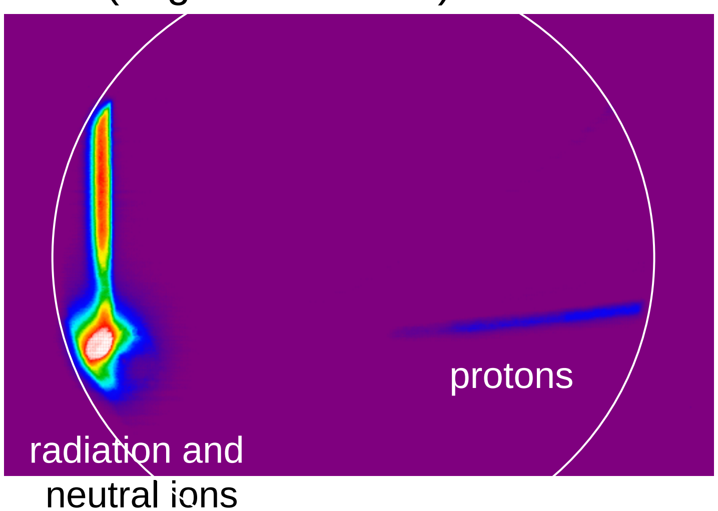
(protons from contamination layer on the foil surface)



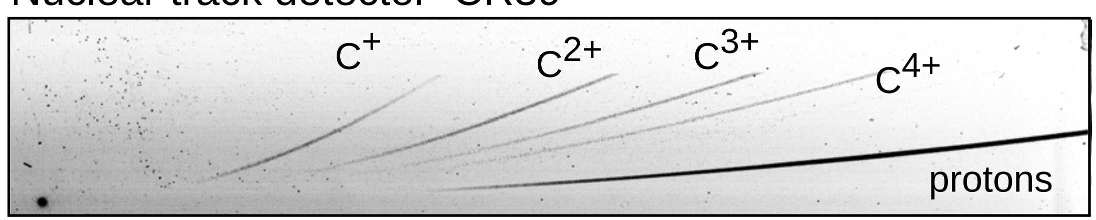
Detection of Laser Accelerated Ions



Multi channel plate detector
(ring: field of view)

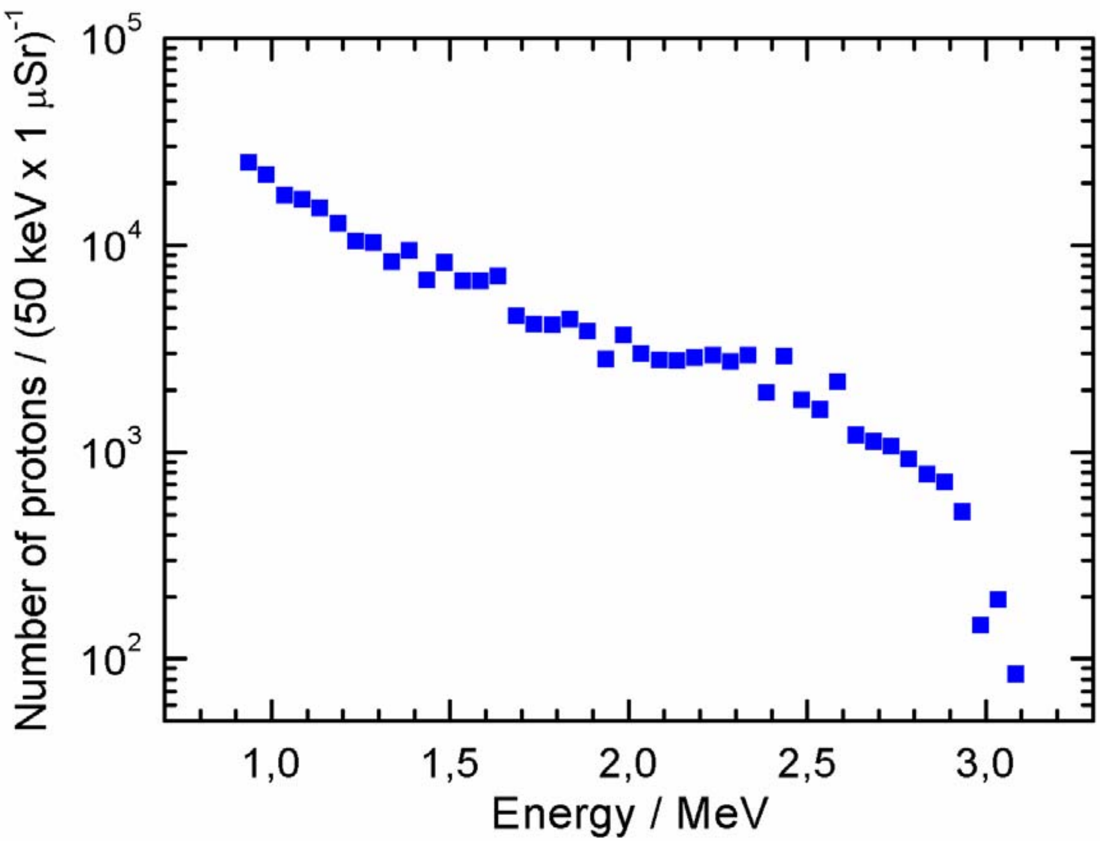


Nuclear track detector CR39



radiation and
neutral ions

Spectrum of laser accelerated protons

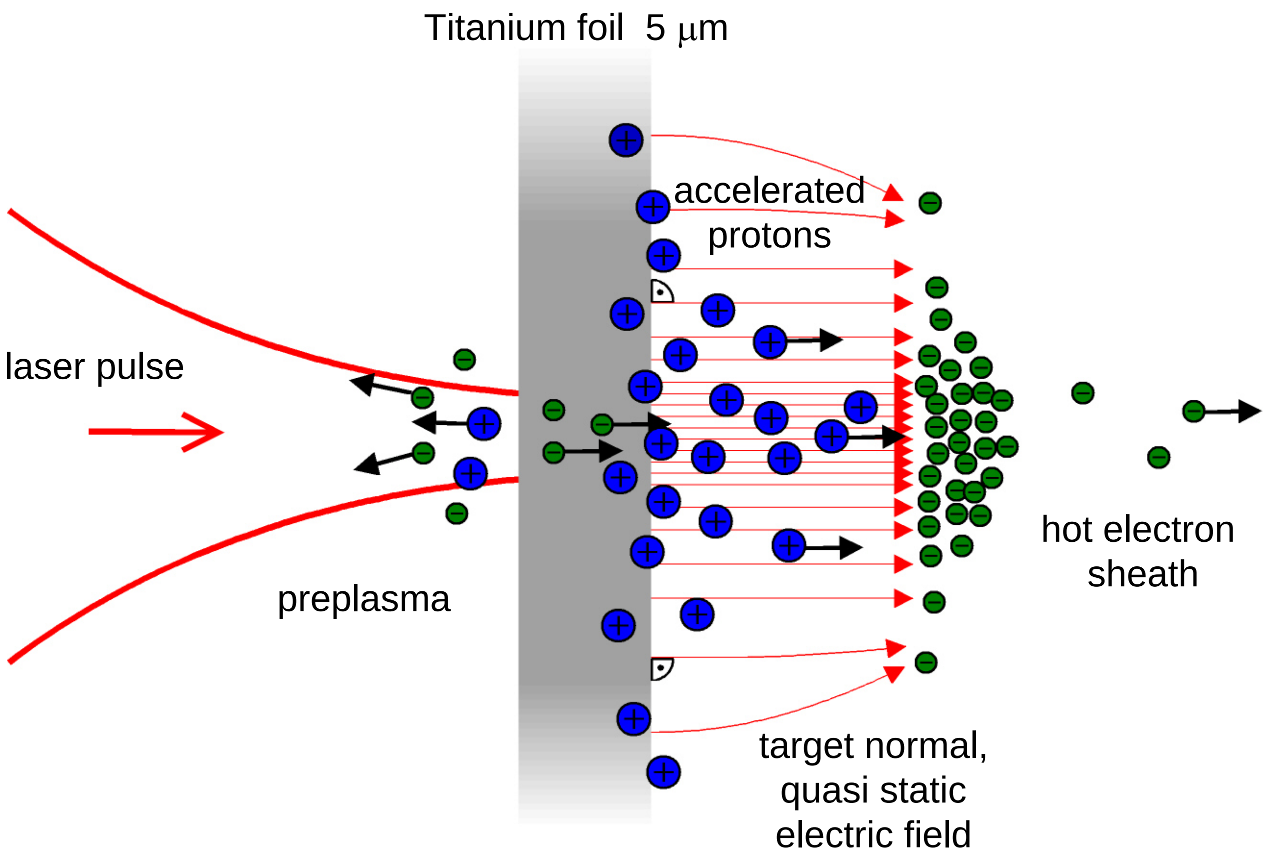


laser pulse 1 J in 100 fs,
4 x 10^{19} W/cm^2
(table top laser)

broad energy distribution, ultrashort pulses (ps)

low transversal and longitudinal emittance
due to cold ions, small source size and short acceleration period

The Route to Narrow Energy Distribution



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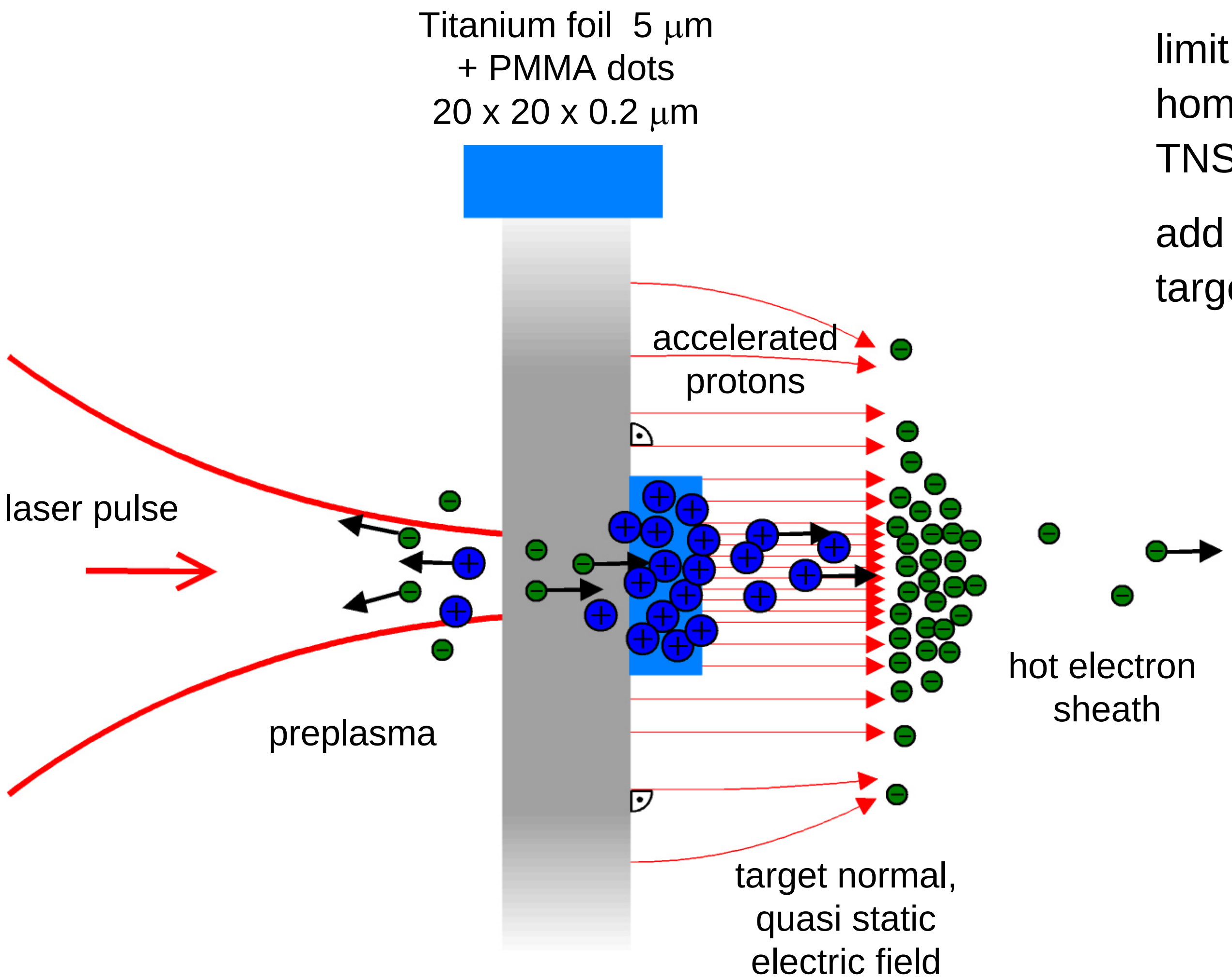
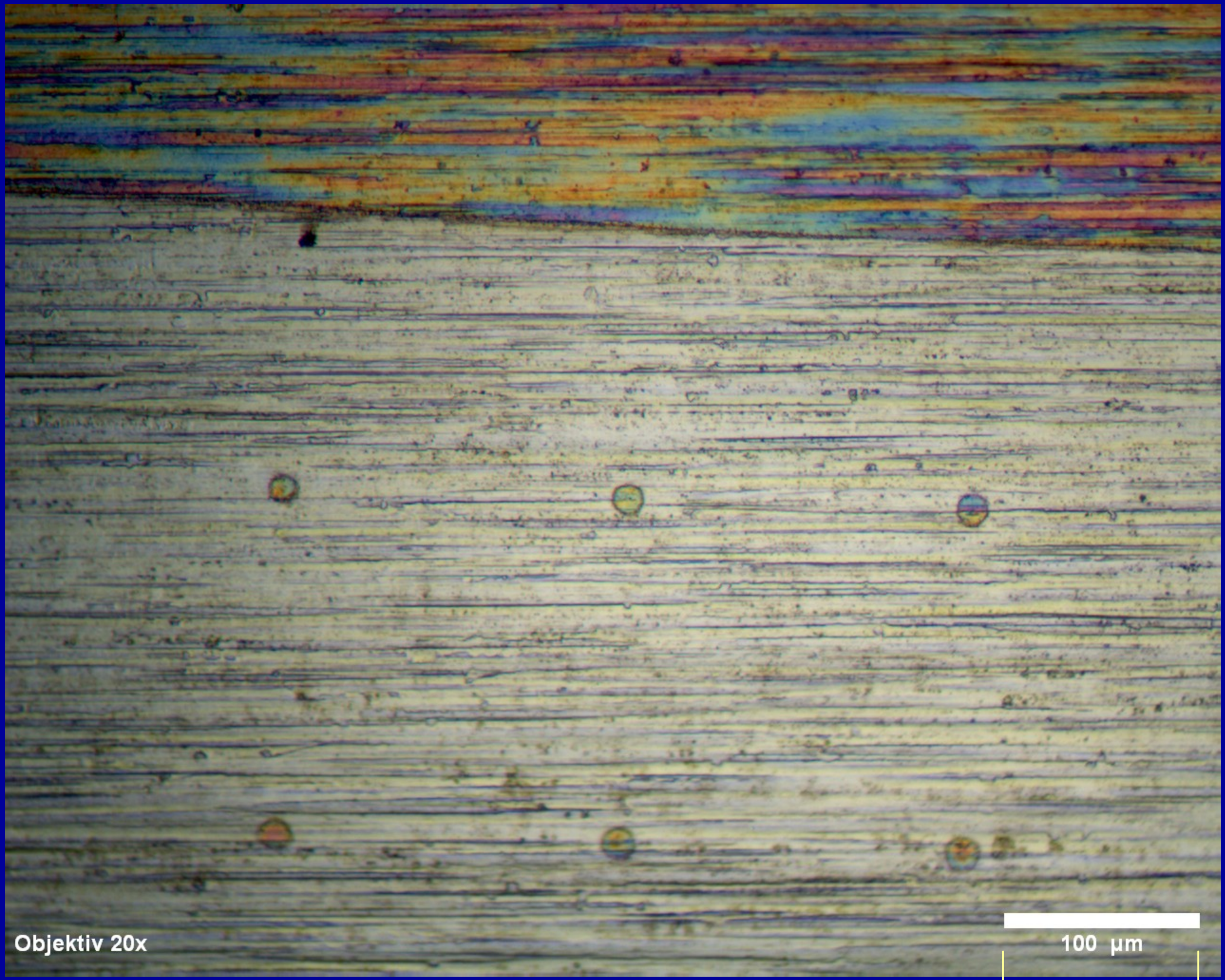


limit the proton layer to the nearly homogeneous central part of the TNSA field:

add a proton rich dot on the target back surface

Titanium Foil Target with PMMA Dots



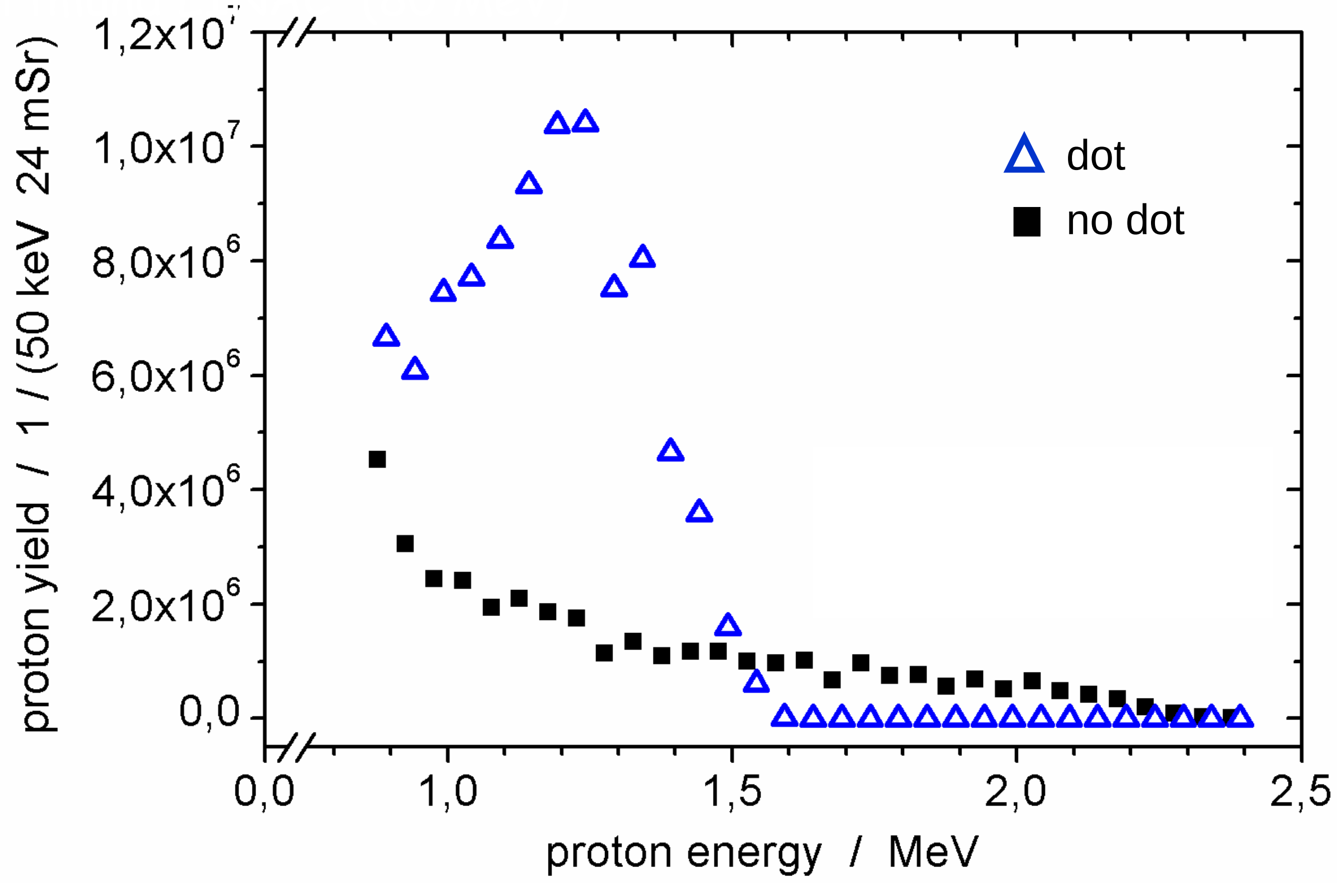
200 nm PMMA

bare titanium

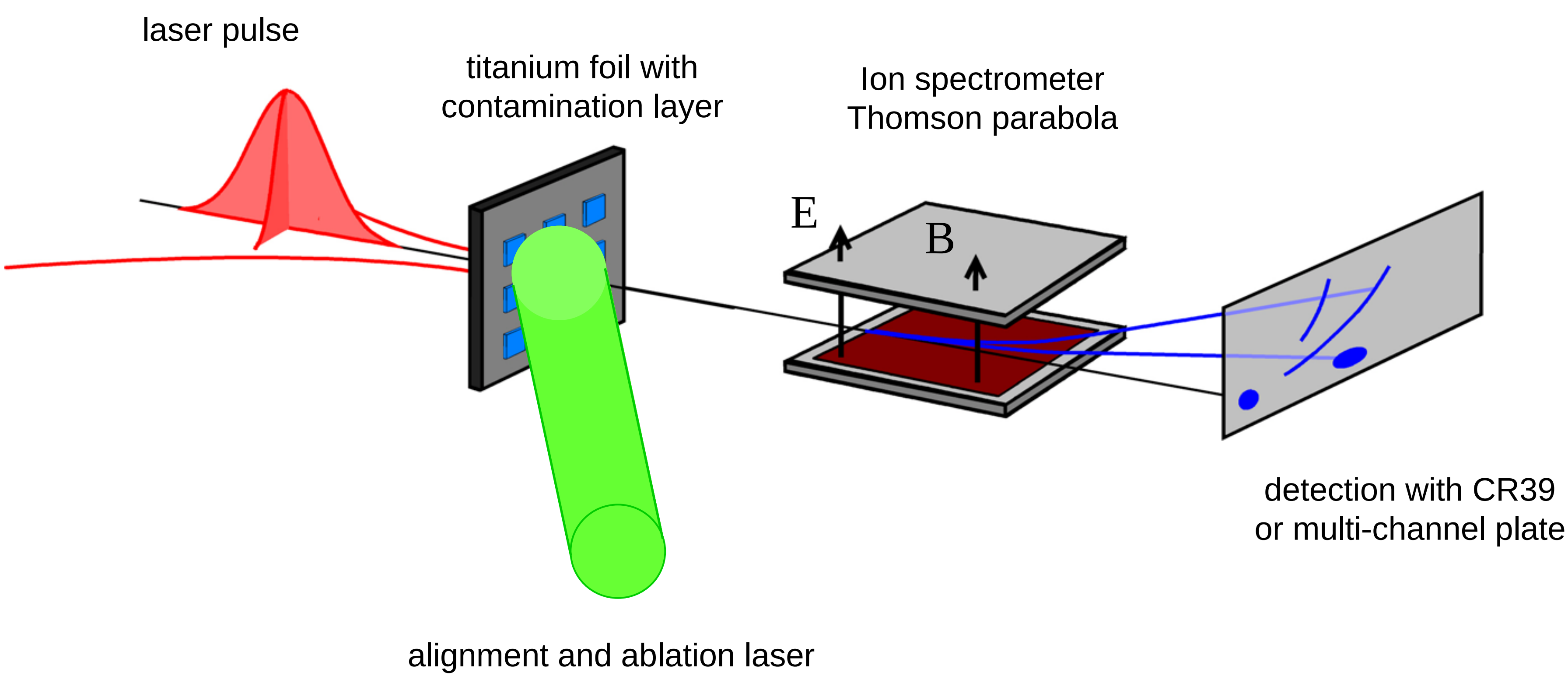
PMMA dot

100 µm

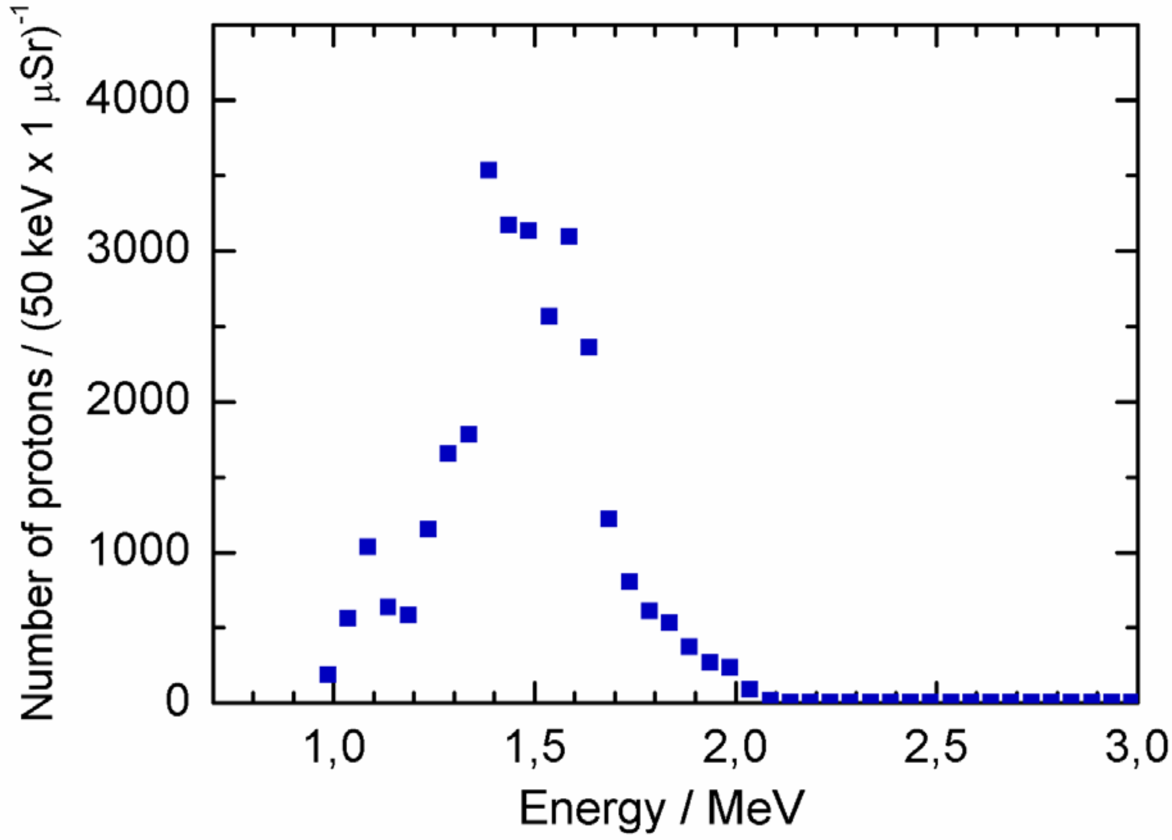
Proton Spectrum with and without Proton Rich Dots



Alignment and Ablation of Contamination Layer



Proton Spectrum after Ablation of Contamination Protons



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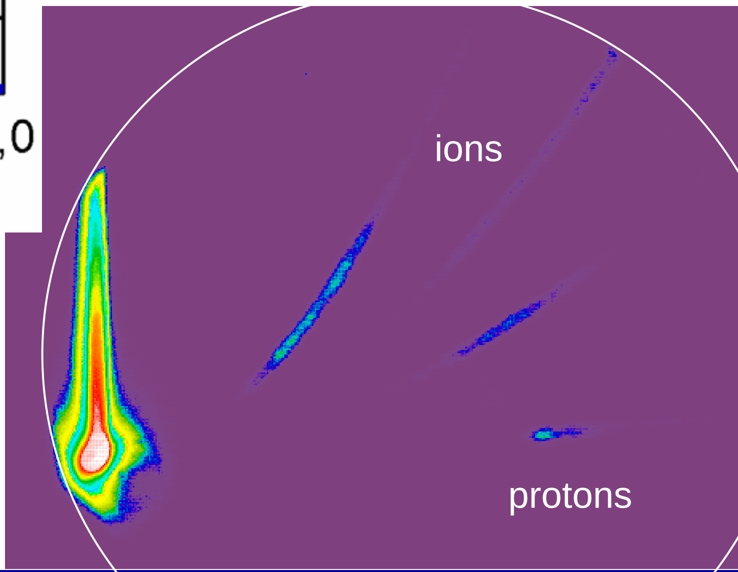
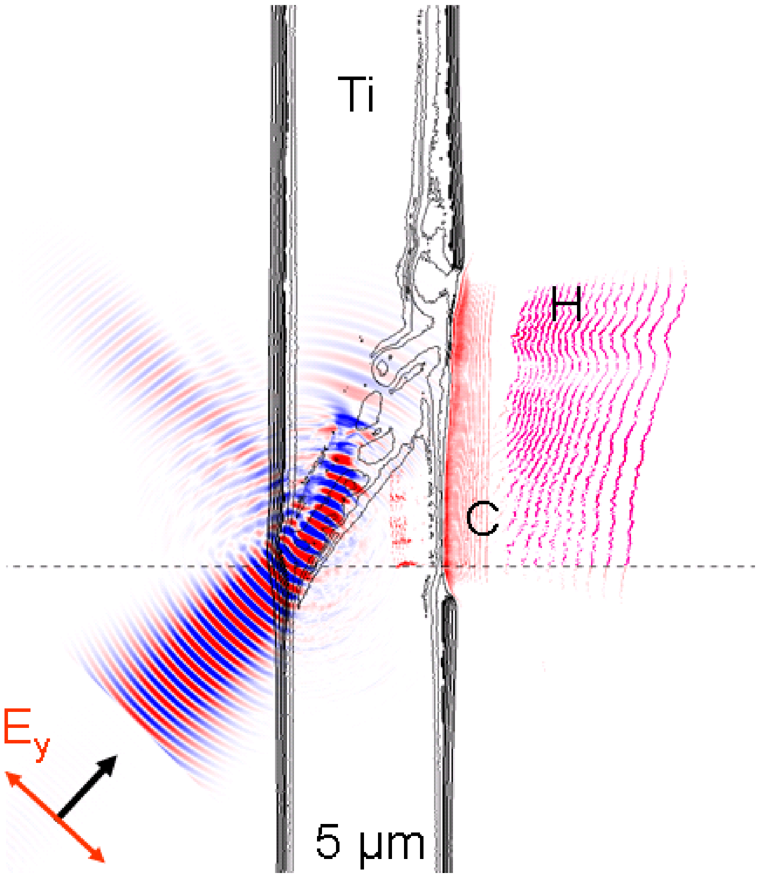
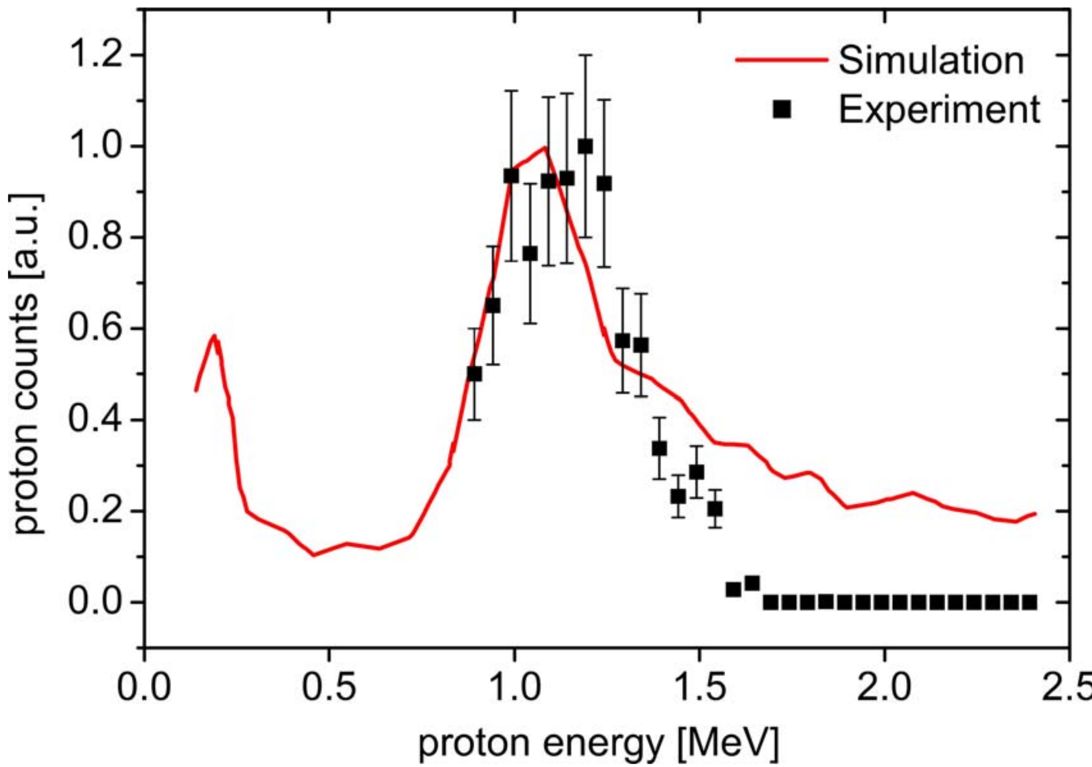


2 D particle in Cell Simulation of Proton Acceleration

2D-PIC simulation by T. Esirkepov for following conditions :

$I_L = 3 \times 10^{19}$ W/cm², 5 µm Ti-foil + 0.5 µm PMMA dot (20×20) µm²





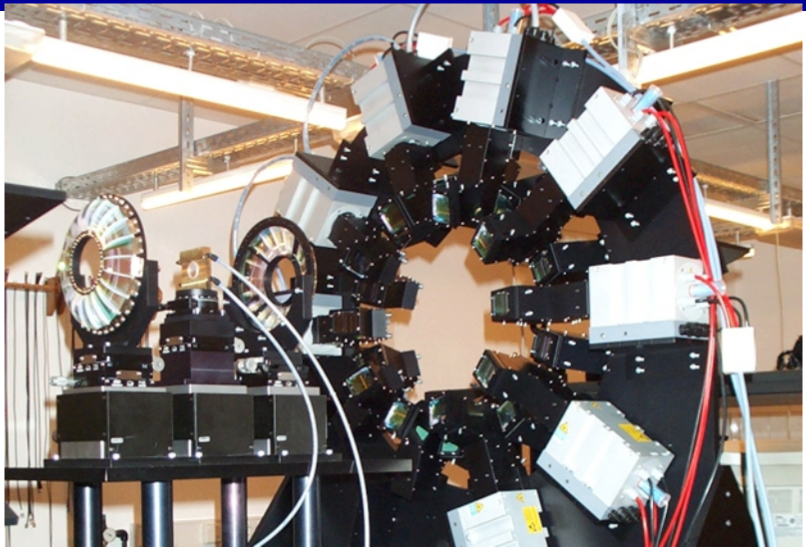
Petawatt Scaling

POLARIS laser system:

- Petawatt laser available in Jena by 2008 (diode pumped Yb^{3+}:Glass)
- 4 out of 5 amplification stages realized including mosaic compressor (8 J,150 fs)

→

$I_{POLARIS} = 10^{21}$ W/cm² @ 0.1 Hz
(E = 150 J, λ = 1042 nm, τ = 150 fs)



2D-PIC simulation for ***POLARIS***-scenario:
$I_L = 10^{21}$ W/cm²,
5 µm Ti-foil + 0.1 µm PMMA dot (Ø 2.5 µm)

→

8×10^8 protons at
$E = 173\,\mathrm{MeV}$ with
$\Delta E/E \sim 1\%$

Hein *et al.* Diode-pumped chirped pulse amplication to the joule level. *Applied Physics B* **79**, 419 (2004)

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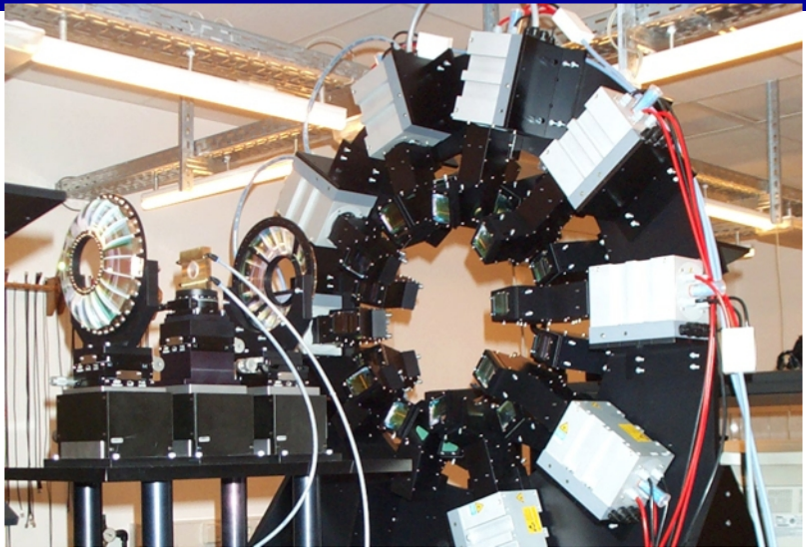

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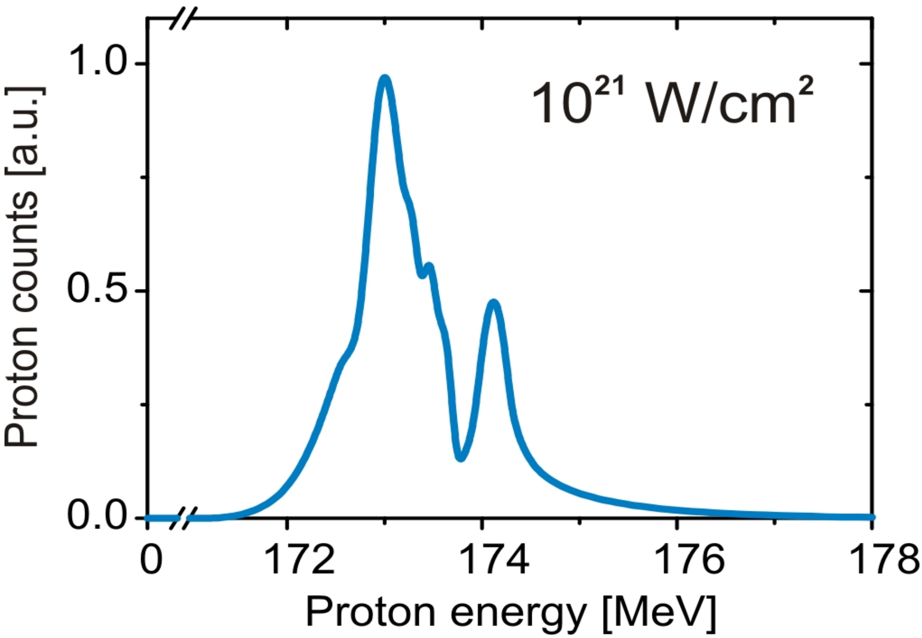
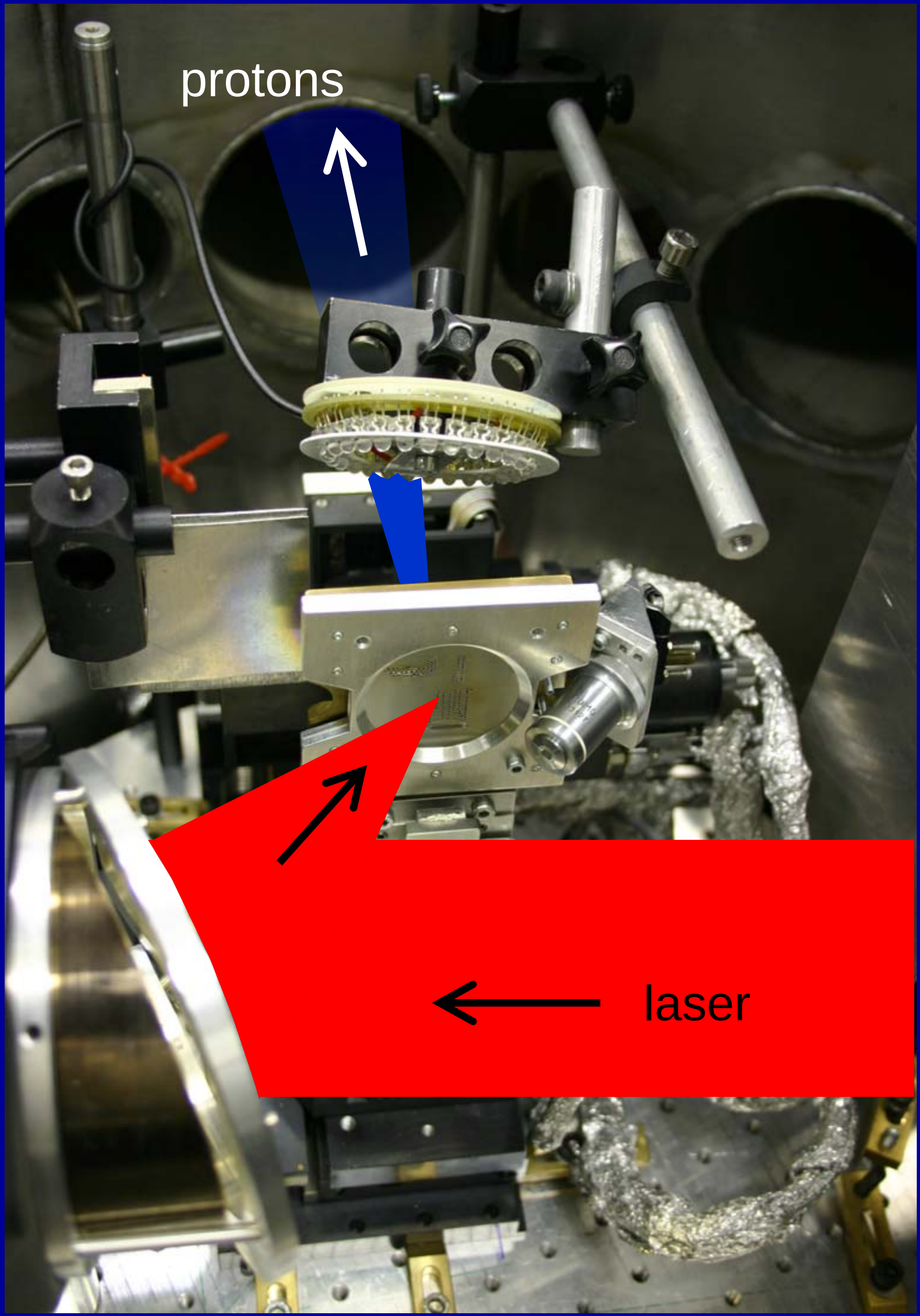


Proton acceleration

charge nC; duration ps;
low transverse emittance
todays energy: MeV
todays energy spread: 10%

near future (next laser generation)
200 MeV, 1%



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todays energy: MeV
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200 MeV, 1%

applications and future:

ultrafast proton shadowgraphy of hot and dense plasmas

low emittance, short pulse ion injectors

nuclear reactions with ultrashort particle and x-ray/gamma-ray pulses
nuclear physics in high external fields ?
generation of neutron rich nuclei ?

tomorrows medical applications
isotope production and irradiation of tissue ?