LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

CHAIR OF MEDICAL PHYSICS
MUNICH-CENTRE FOR ADVANCED PHOTONICS

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Swift Ion Bunch Acceleration by High Power Laser Pulses

CHANNELING 2016

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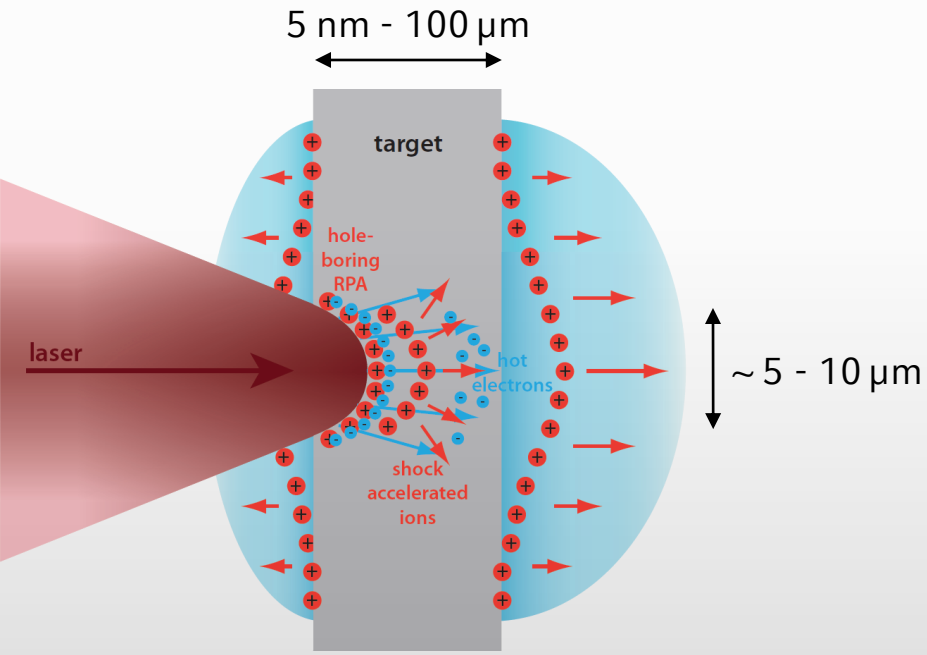
Laser-driven Ion (LION) Acceleration



A. Henig, Advanced Approaches to High Intensity Laser-Driven Ion Acceleration. PhD Thesis, LMU Munich (2010)

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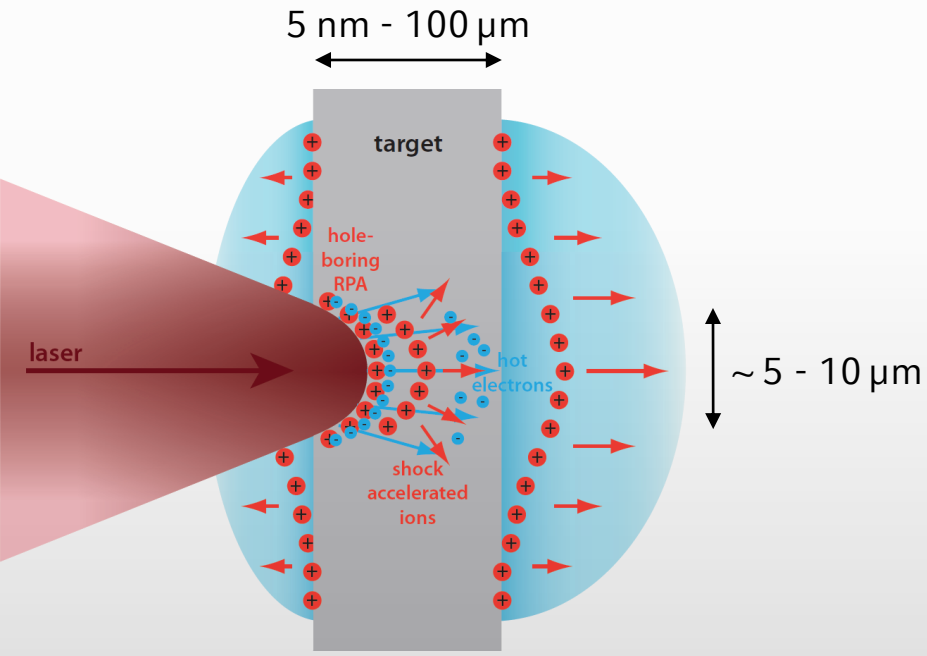

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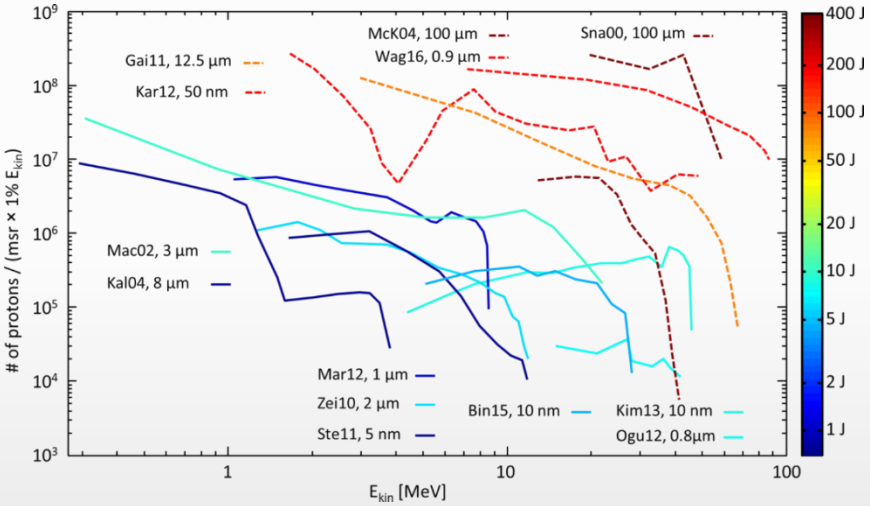
- Broad energy spread (up to 100 %)
- Very short (ps) bunch durations
- Micron source size
- Large angular divergence (up to tens of degrees)
- Small emittance
- Mixed radiation field (ions, electrons, x-rays, neutrons, …)

Laser Development Promises Higher LION Energies



J. Schreiber, P. R. Bolton, K. Parodi. Rev. Sci. Instrum. 87, 071101 (2016)

- Up to 10^8 $\frac{\text{protons}}{mrs \times 1\%\, E_{\text{kin}}}$ → high density ion bunches: 1.3 x 10^{14} $\frac{\text{protons}}{cm^2 \times ps}$

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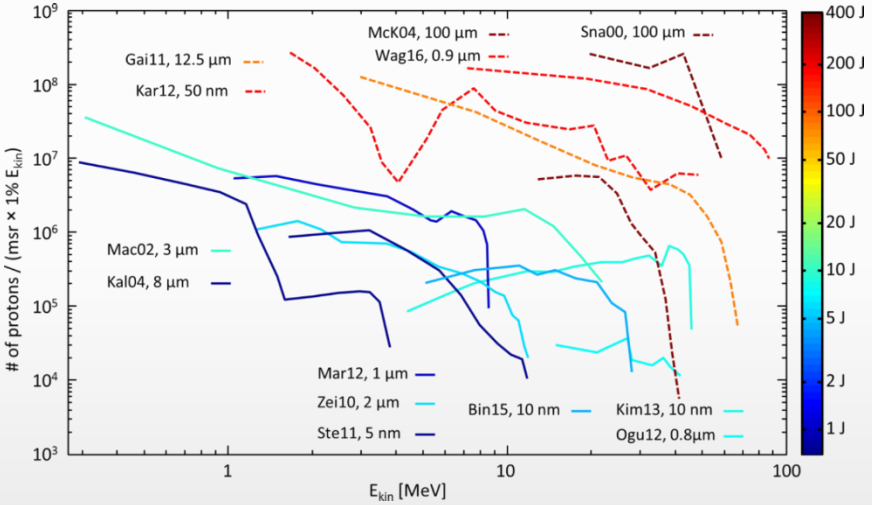

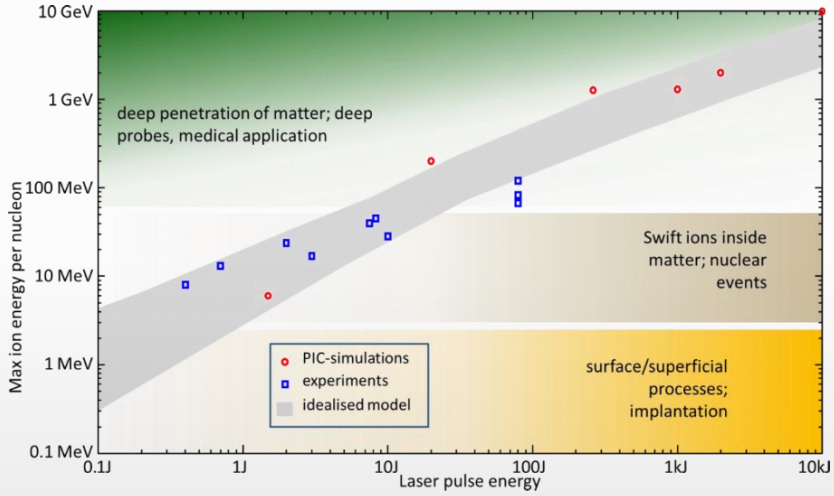

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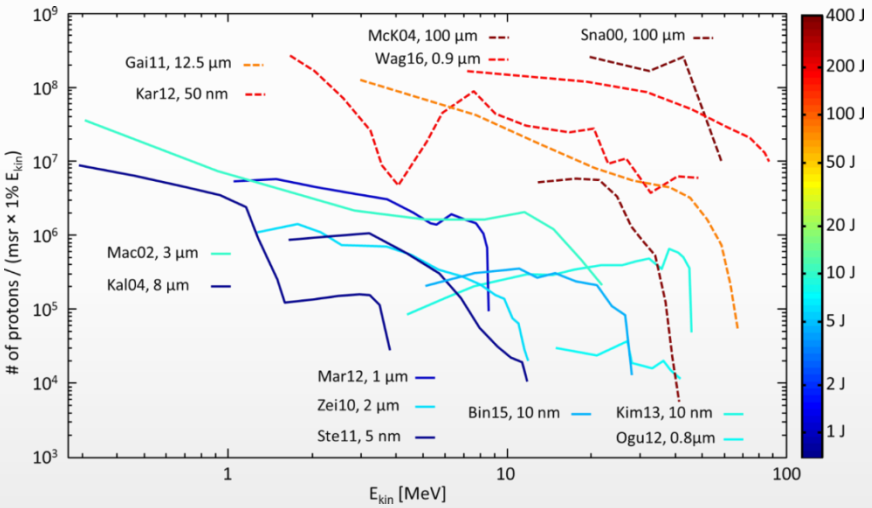

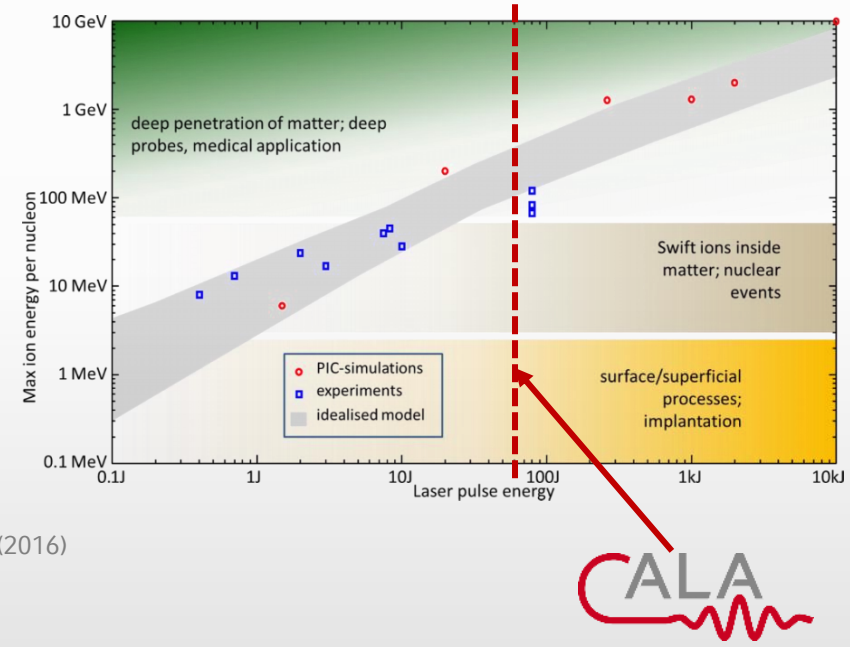

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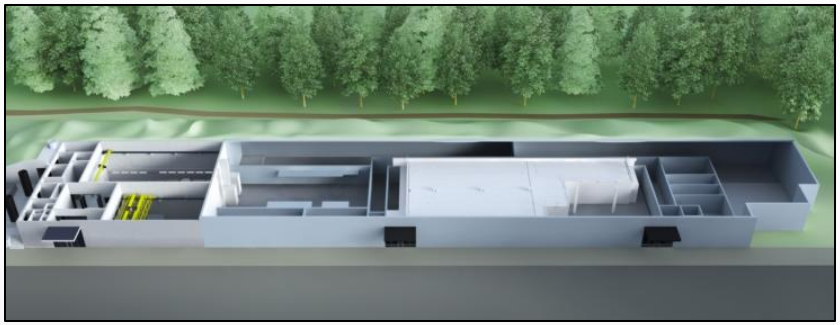
CALA – Centre for Advanced Laser Applications

ATLAS 3000 Laser System:

- 3 PW Ti:sapphire laser
- 60 J pulse energy
- 20 fs pulse duration
- 1 Hz repetition rate



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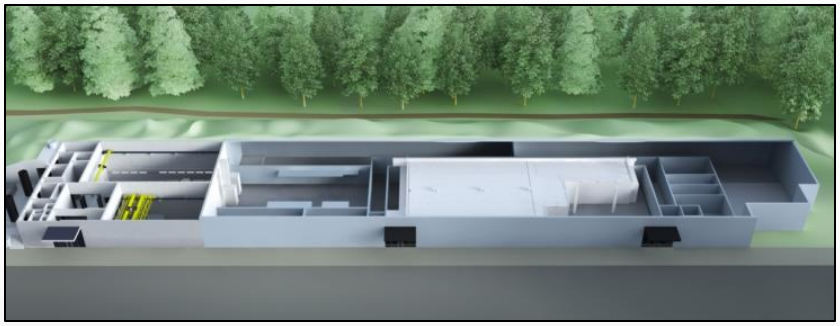
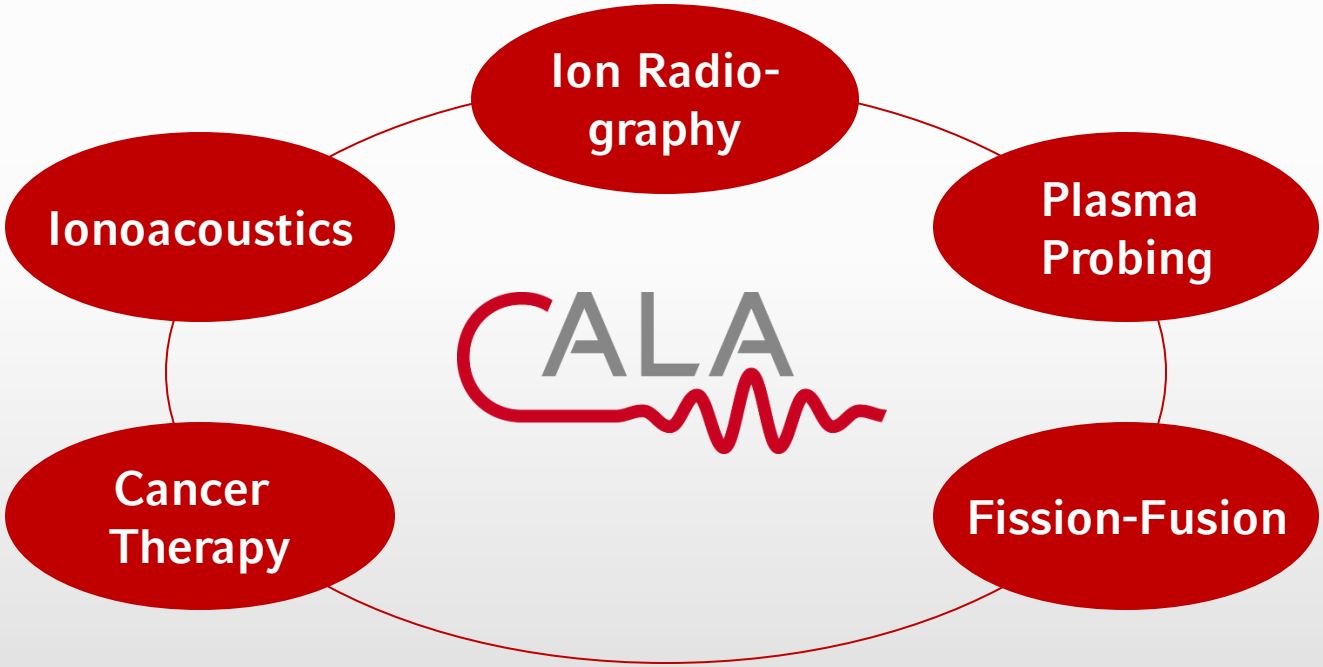


eli delivery consortium – Extreme Light Infrastructure (ELI)

http://www.eli-beams.eu/

- ELI Beamlines (Czech Republic), ELI Nuclear Physics (Romania), ELI Attosecond (Hungary)
- Several 1 – 10 PW laser systems
- Research topics: Particle acceleration, novel x-ray sources, nuclear physics, ultrashort light sources, …

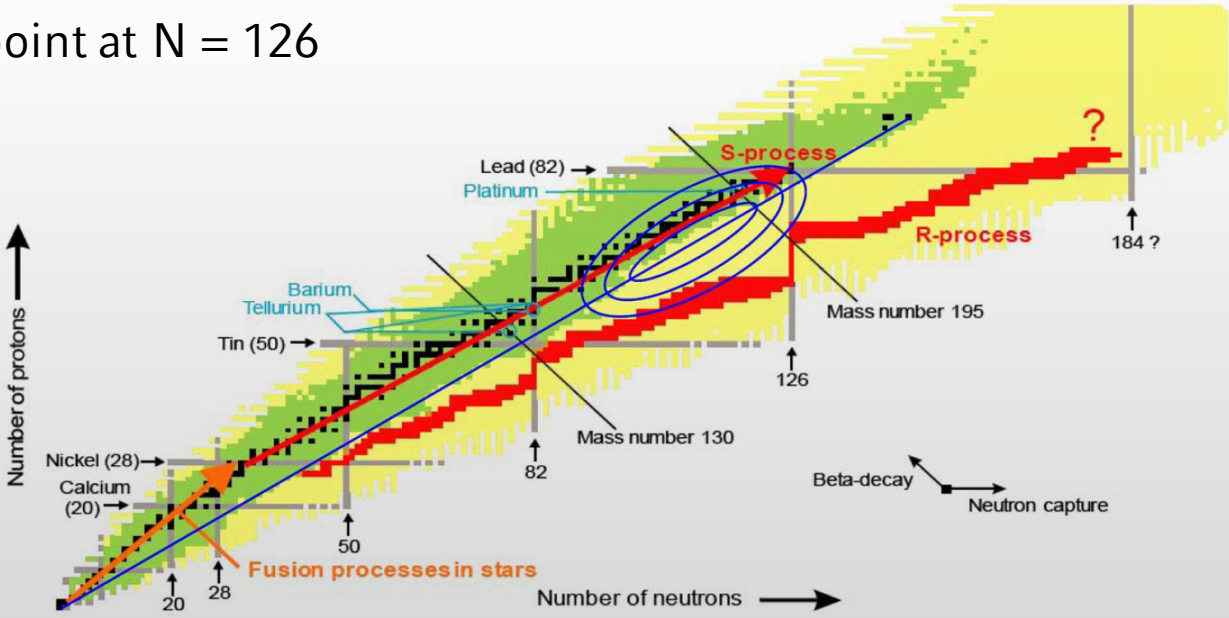
LION Applications



Fission-Fusion Mechanism

Question: How were the heavy elements made?

- rapid neutron capture process (r-process)
- investigation of nuclear properties of ~ 1000 neutron-rich isotopes needed
- bottleneck: waiting point at N = 126



D. Habs, P. G. Thirolf et al. Appl. Phys. B 103, 471 (2011)

Fission-Fusion Mechanism

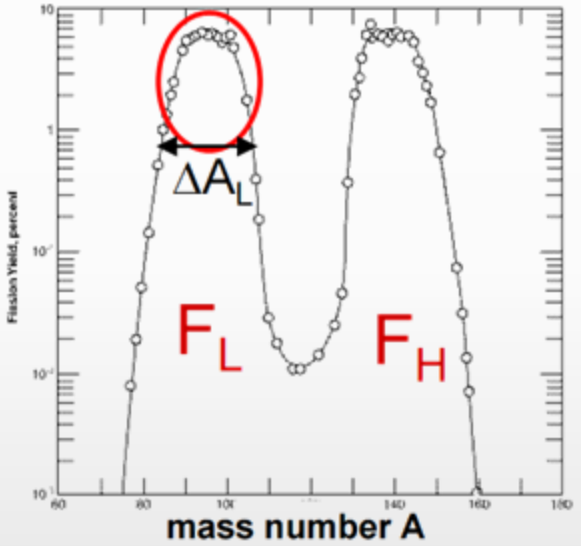
1. **Fission:**

   ^{232}Th fissions into light and heavy fission products

   $\langle A_L \rangle \sim 91$, $\Delta A_{L,FWHM} \sim 14$ amu

   $\Delta A_{L,10\,\%} \sim 22$ amu

   $\langle Z_L \rangle \sim 37.5$

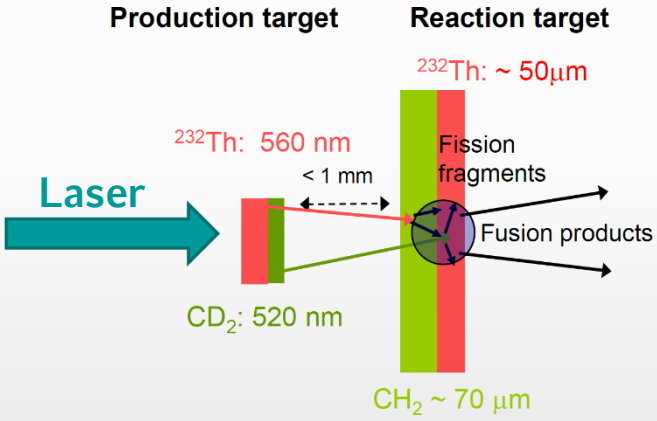


2. **Fusion:**

   light fission fragments fuse ⟶ isotopes near N = 126 achievable

Fission-Fusion Mechanism

Why can LION acceleration potentially contribute?



- CD_2 induces fission in Th target
- CH_2 induces fission in Th beam
- fusion of light fission fragments

➢ high (solid-state like) density of accelerated ion beam

Fission-Fusion Mechanism

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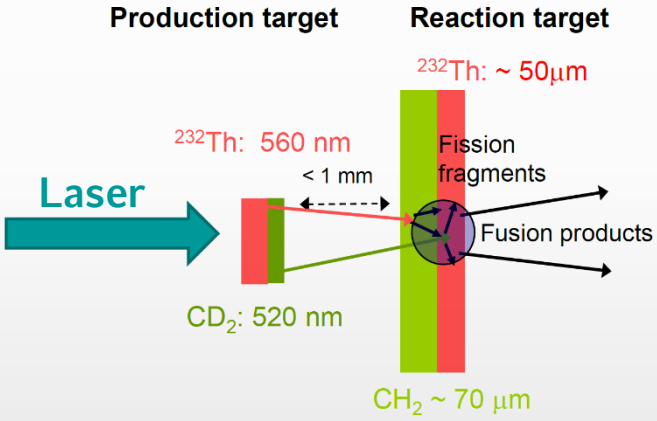
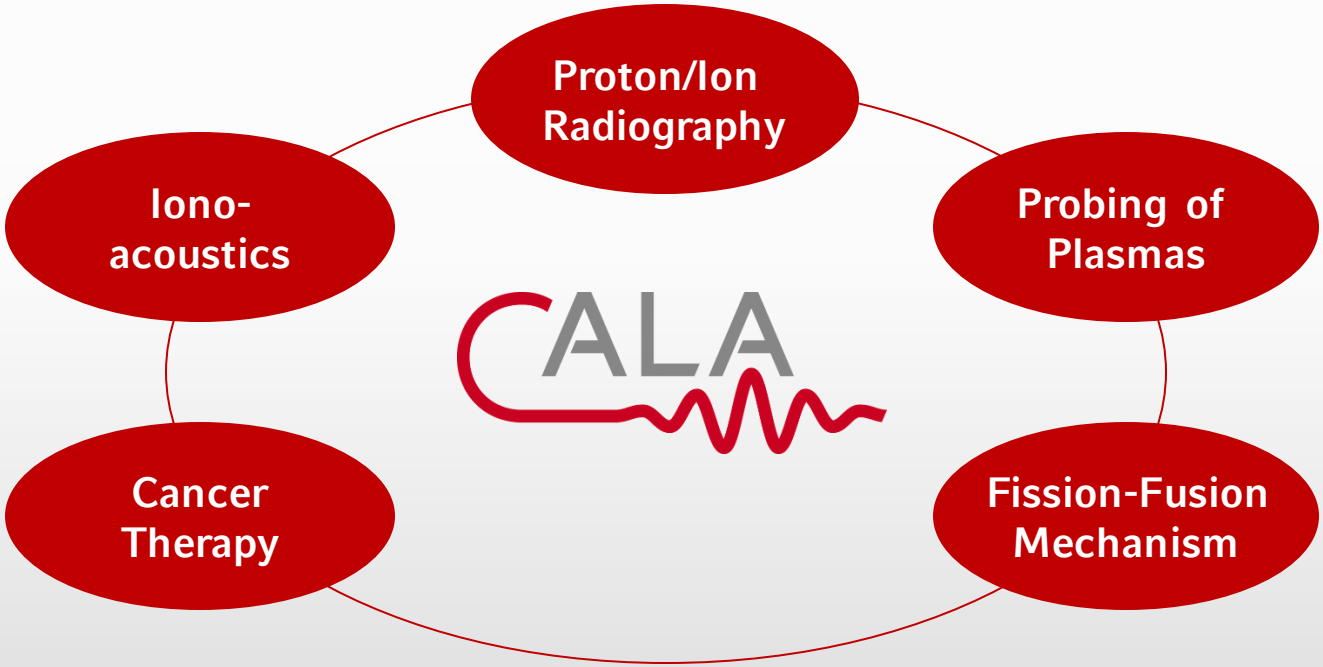


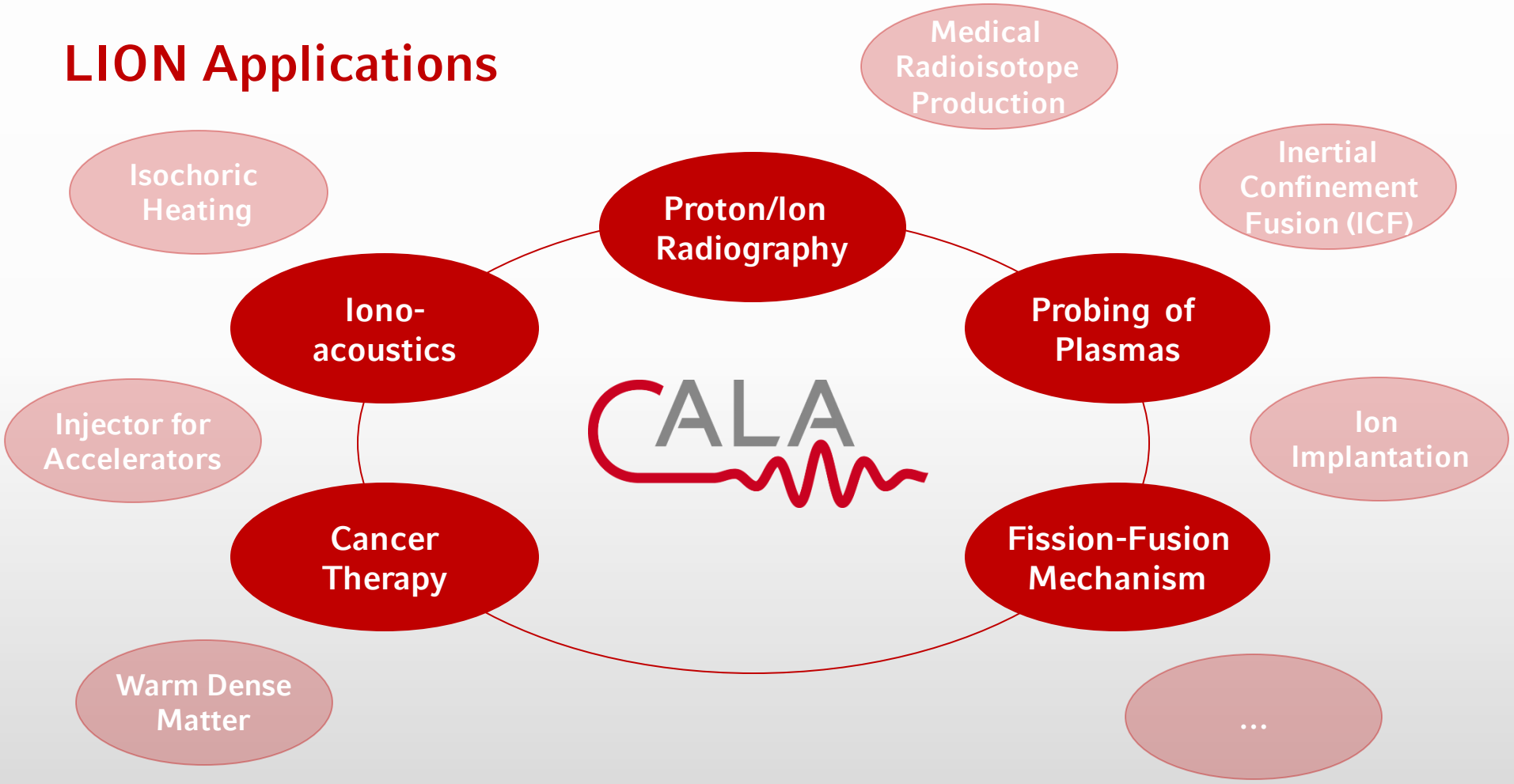
- CD_2 induces fission in Th target
- CH_2 induces fission in Th beam
- fusion of light fission fragments

- high (solid-state like) density of accelerated ion beam
- potential reduction of stopping power („snowplough effect“)
- thick reaction targets and much increased fusion probability

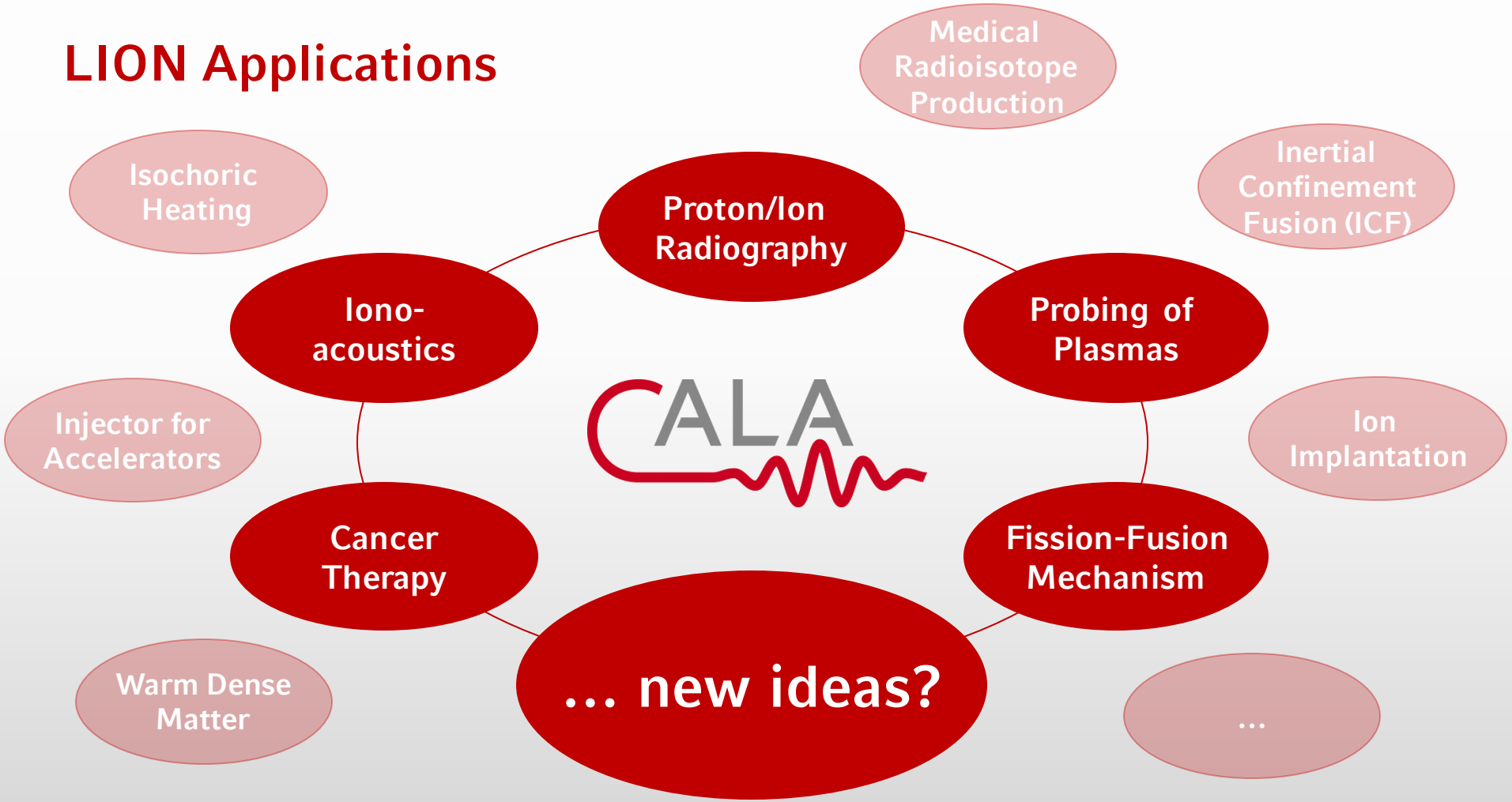
LION Applications



LION Applications



LION Applications



Take Home …

- **Laser-driven ion acceleration provides a unique particle source:**
  - *Micron source size* and *large divergence angles*
  - *Broad energy spectrum* and *ps bunch durations*
  - *High peak current*
  - …
- **Various applications**
  - *Medical physics* (Cancer therapy, radiography, …)
  - *Nuclear physics* (Fission-Fusion, ICF, …)
  - *Material Science* (Ion implantation, …)
  - …
- **Centre for Advanced Laser Applications (CALA) near Munich**

… and we are always interested in new applications!

Thank you for your attention!

LEX Photonics

CALA

Bundesministerium für Bildung und Forschung