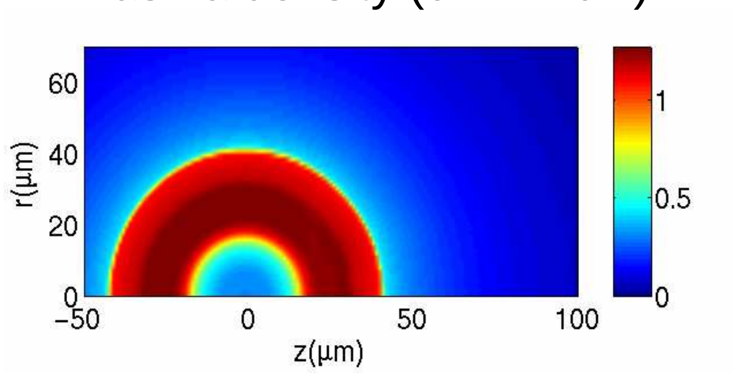
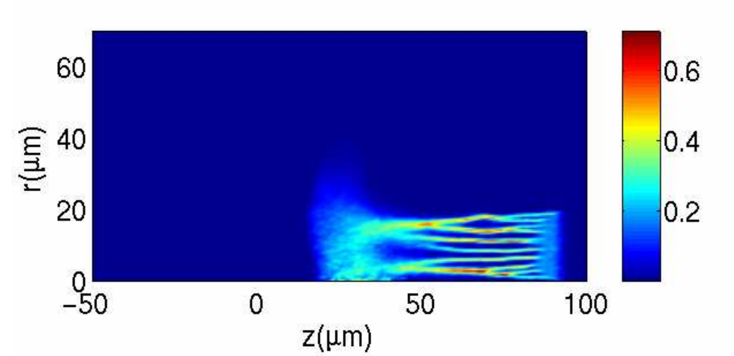
Fluid+PIC Integrated Simulations Using LSP+DRACO

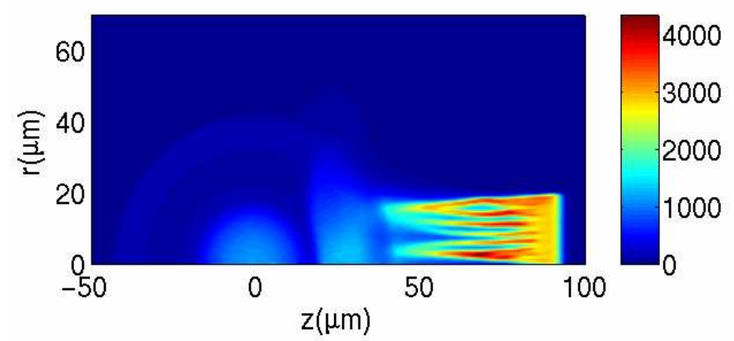
Plasma density (cm^{-3}×10^{26})



Hot electron density (cm^{-3}×10^{23})



Plasma electron temperature (eV)



300 kJ fuel assembly
2MeV, r_0=20μm e-beam, t=1ps

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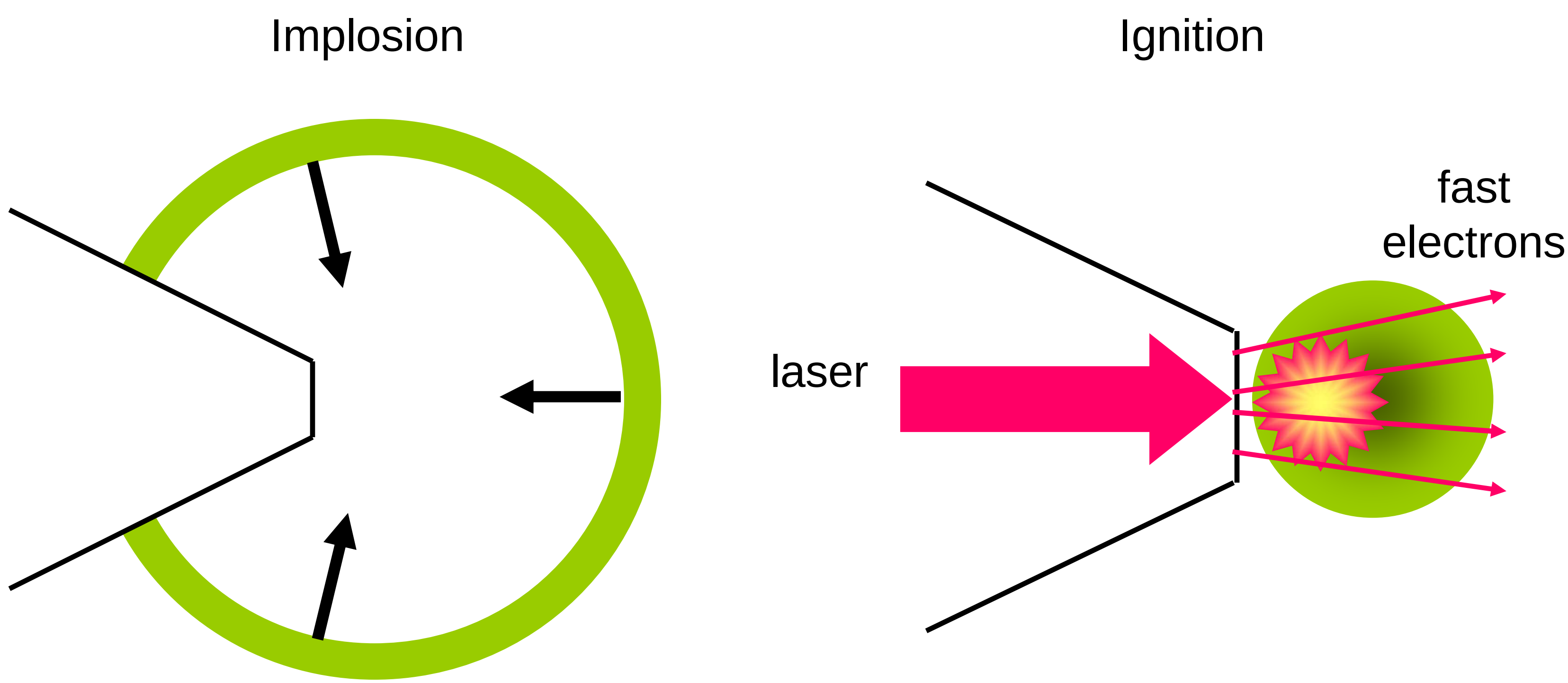
Summary

We have coupled the hybrid-PIC code LSP[1] and the fluid code DRACO[2] to perform an integrated fast-ignition simulation

- LSP[1] is used to simulate the transport of hot electrons in the dense plasma of fast-ignition targets
- DRACO[2] is used to simulate the implosion, ignition and burn
- Test integrated simulations show resistive filamentation, blooming and straggling of fast electrons and ignition by a 20 kJ, 2MeV monoenergetic electron beam
- We plan to simulate the whole fast-ignition experiment when the cone-in-shell target capability will be available in DRACO (under development, Ken Anderson)
- Similar projects are under development at LLNL and ILE (Osaka University, Japan)

[1] D. R. Welch *et al*., Phys. Plasmas **13**, 063105 (2006)
[2] P. B. Radha *et al*., Phys. Plasmas **12**, 056307 (2005)

We plan to simulate the whole fast ignition experiment including implosion of cone-in-shell targets and transport of hot electrons from the inner cone surface to the dense core.



The generation of hot electrons by a PW laser pulse will probably be described based on the results obtained by others (Sentoku, Wilks)

In the integrated simulation we use LSP to simulate the hot electron transport and energy deposition and use DRACO to simulate the target hydrodynamics, ignition and burn

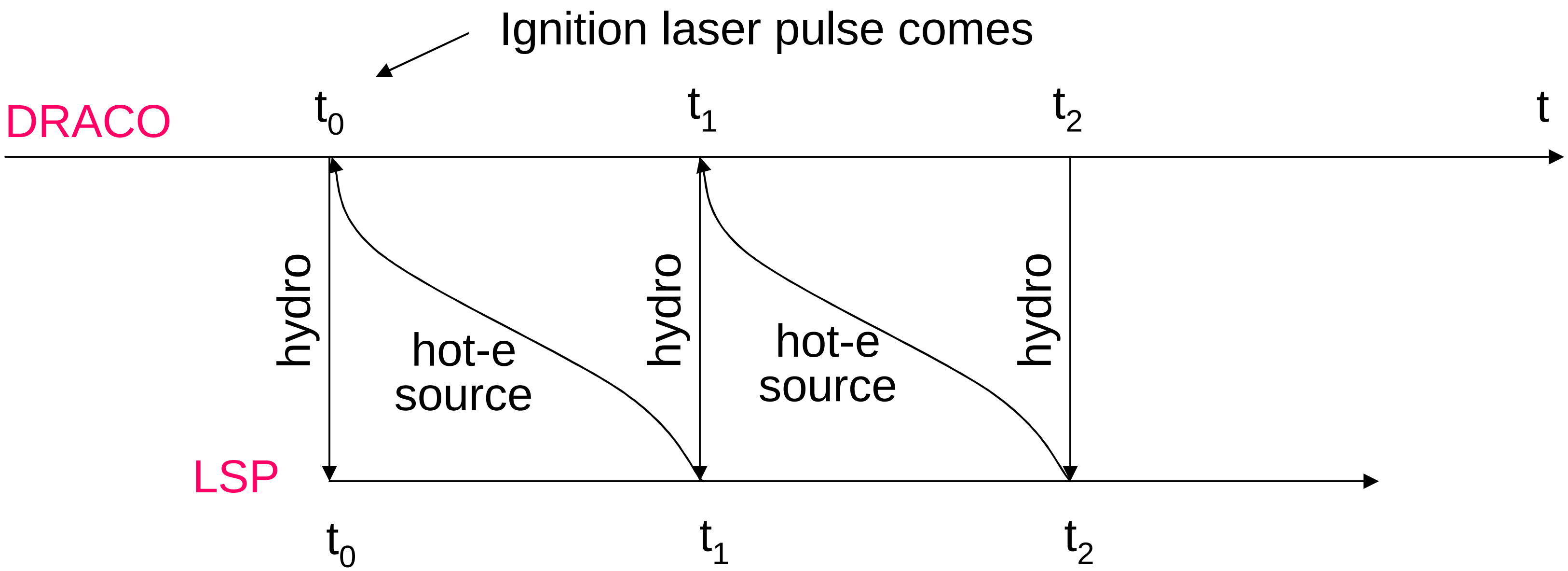
DRACO:

- 2-D cylindrically symmetric hydrodynamic code
- includes all the necessary physics required to simulate ignition and burn of the imploded capsules
- does not simulate the hot electron transport and energy deposition

LSP:

- 2-D/3-D implicit hybrid-PIC code
- implicit solution for the electro-magnetic fields and implicit particle push
- hybrid fluid-kinetic description for plasma electrons
- intra- and inter- species collisions based on Spitzer rates (have been corrected to include relativistic effects)
- does not simulate fusion reactions and α-particle transport
- uses ideal gas equation of state

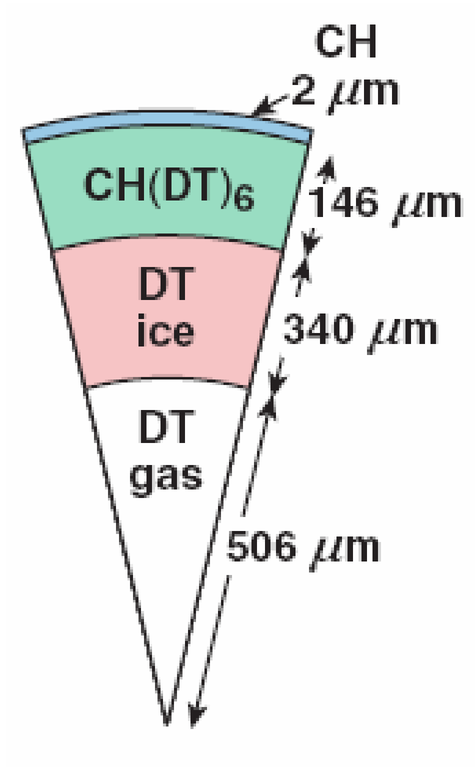
In the integrated simulation LSP is used to generate hot electrons source term in the temperature equation solved by DRACO

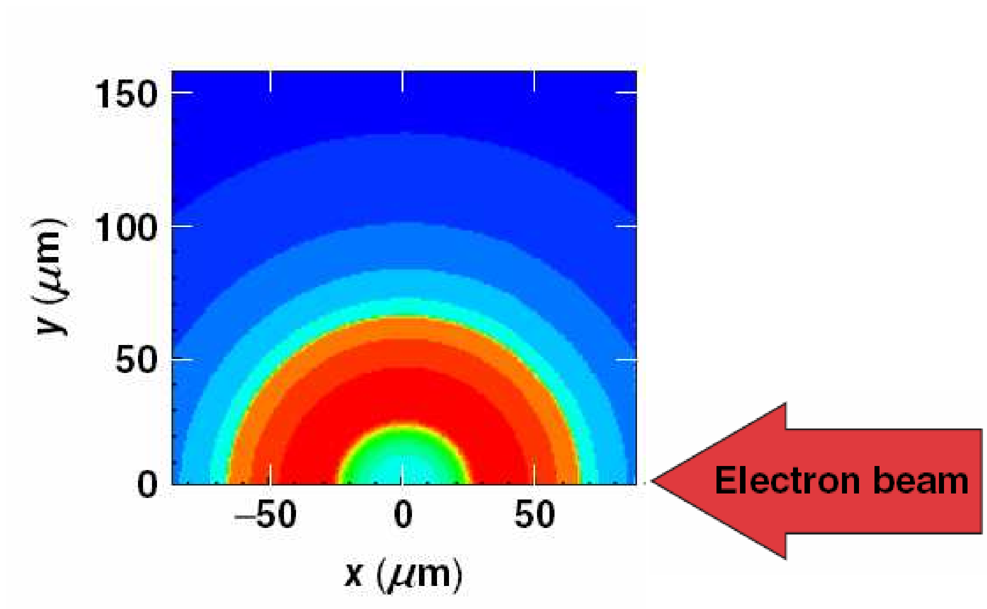


- LSP generates the time history of hot electron energy deposition in plasma to be used in DRACO
- Hydrodynamic profiles in LSP: electron and ion temperatures, densities and velocities are periodically updated according to DRACO results (fluid species). Electro-magnetic fields and hot electron distributions (kinetic species) are not changed.
- In LSP multiple species are used for hot electrons with different energies to model the energy dependence of the stopping power and scattering coefficients

In the test simulation an imploded optimized fast-ignition target[1] is heated by a 2MeV, r_0=20μm electron beam

300 kJ fuel assembly





Collimated monoenergetic (E_e=2MeV) e-beam with the radius r_0=20μm

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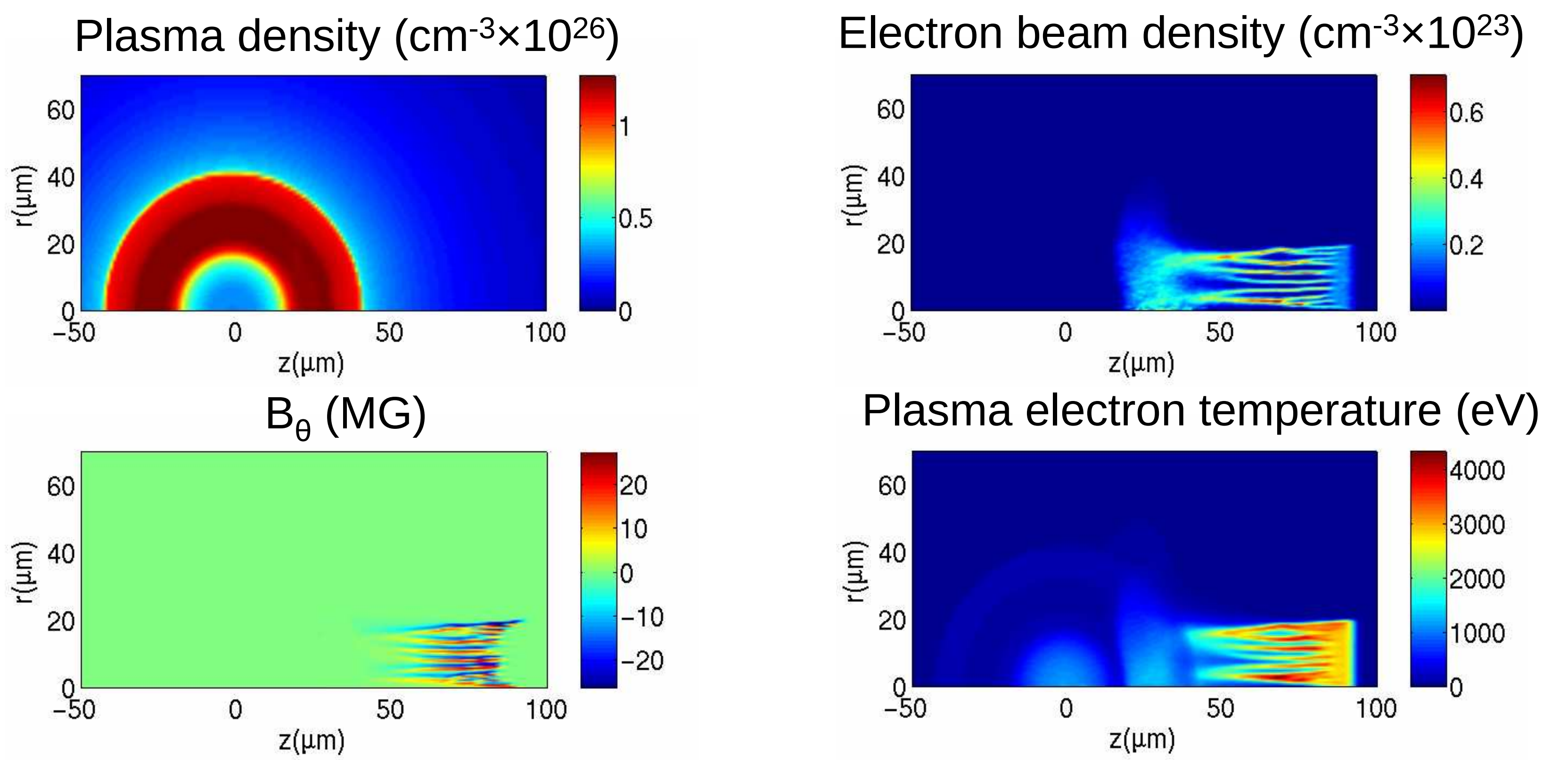
[1] R. Betti and C. Zhou, Phys. Plasmas **12**, 110702 (2005)

LSP simulations predict resistive filamentation of the e-beam[1,2]

Snapshots at t=1ps after the beginning of e-beam:

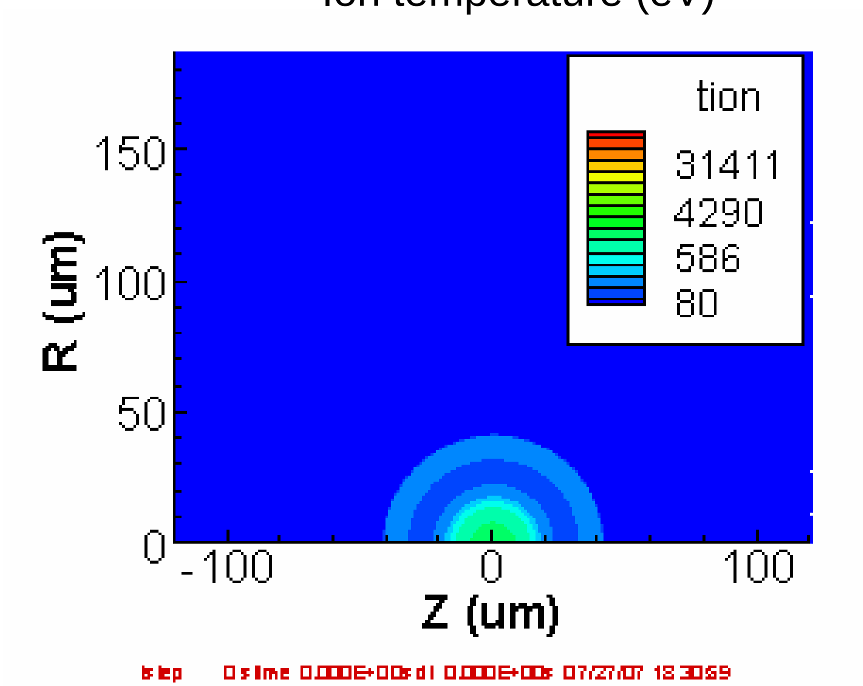


[1] L. Gremillet *et al.,* Phys. Plasmas **9**, 914 (2002)
[2] J. J. Honrubia and J. Meyer-ter-Vehn, Nucl. Fusion **46**, L25 (2006)

Ignition is triggered by a 20kJ e-beam in the integrated simulation

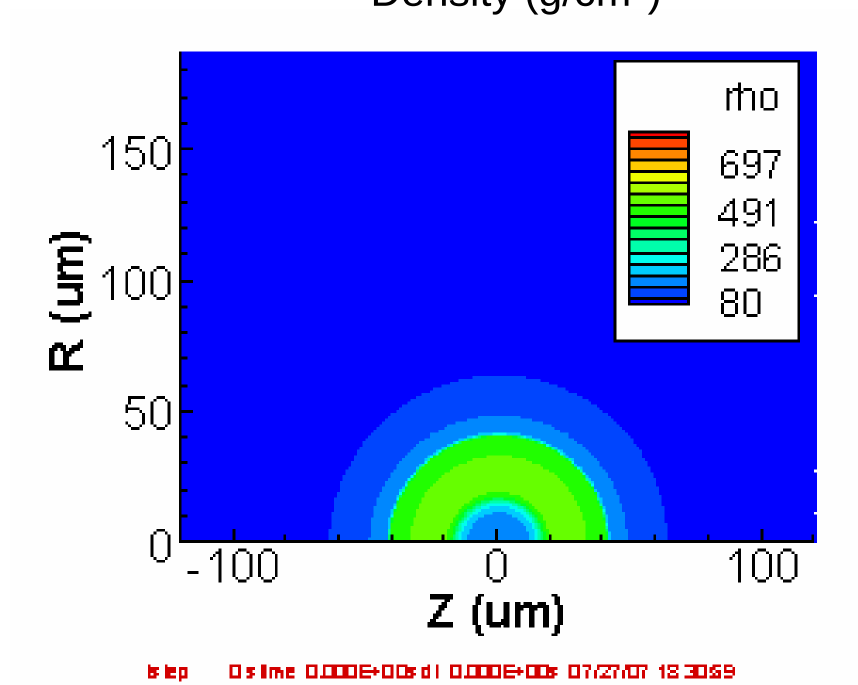
300 kJ fuel assembly

Ion temperature (eV)



300 kJ fuel assembly

Density (g/cm^3)



Previous DRACO simulations[1] using a simplified hot-electron transport model[2] (straight-line electron trajectories, no blooming and straggling) predicted a minimum ignition energy of 16.25 kJ for the same target and electron beam

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[1] A. A. Solodov, R. Betti, J. A. Delettrez, and C. D. Zhou, Phys. Plasmas **14**, 062701 (2007)

[2] C. K. Li and R. D. Petrasso, Phys. Rev. E **70**, 067401 (2004)

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