Beam-Target Interaction for Heavy Ion Fusion

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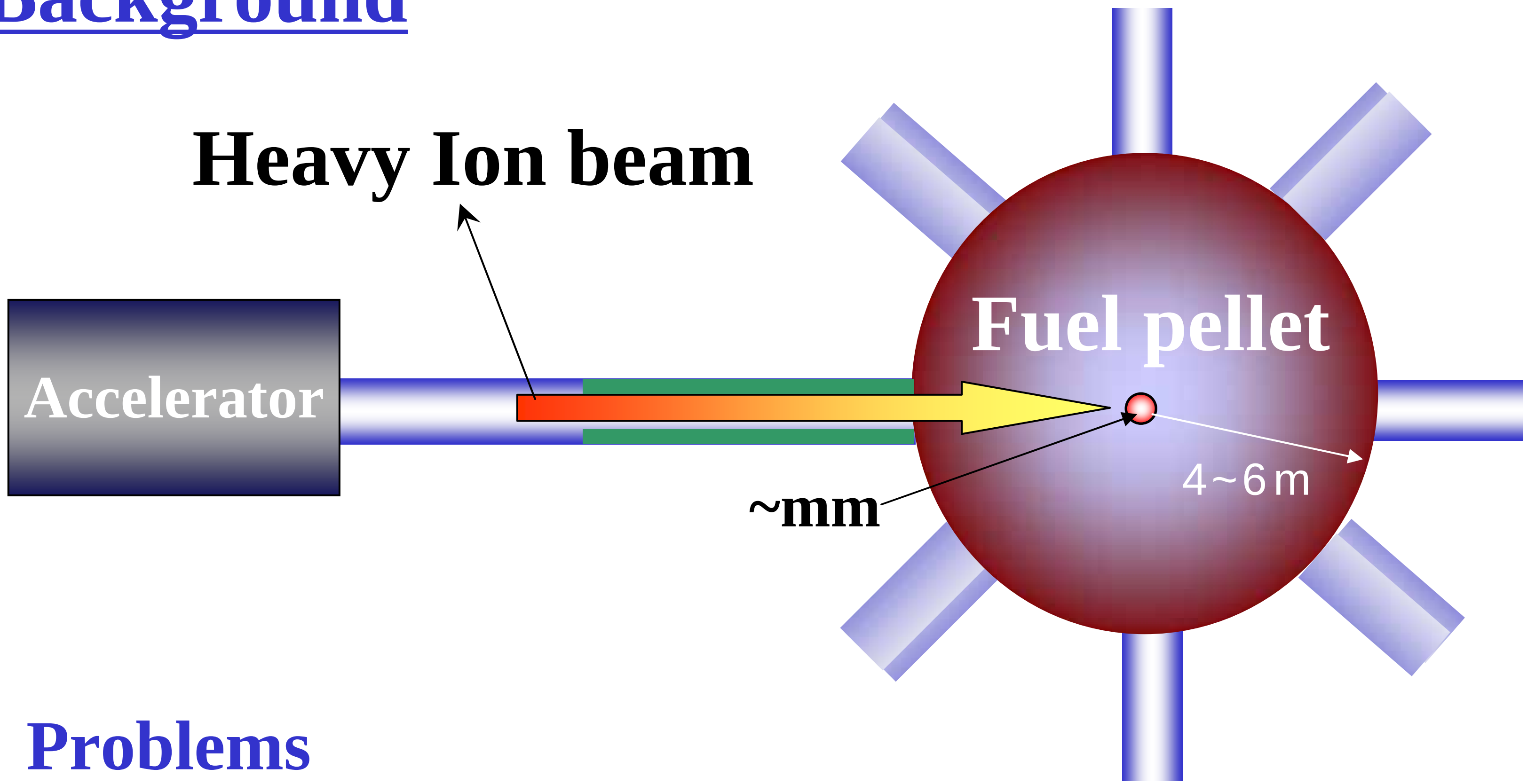
Contents

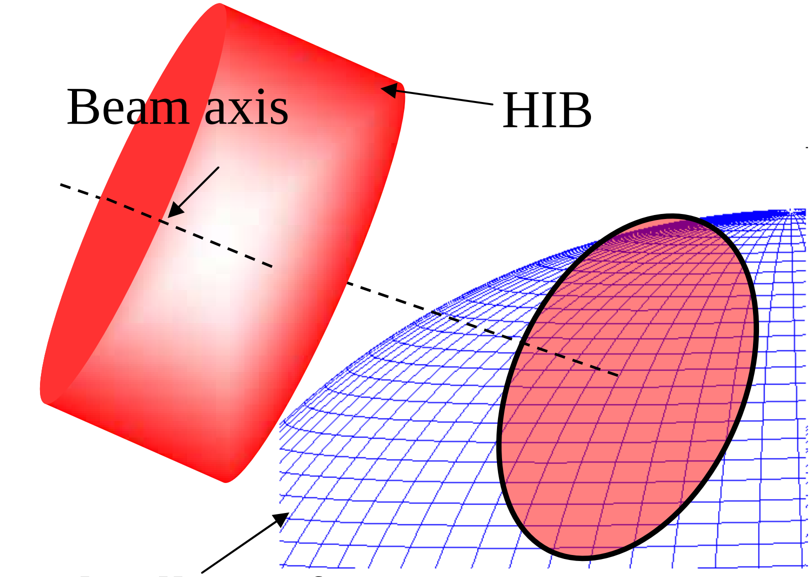
Background

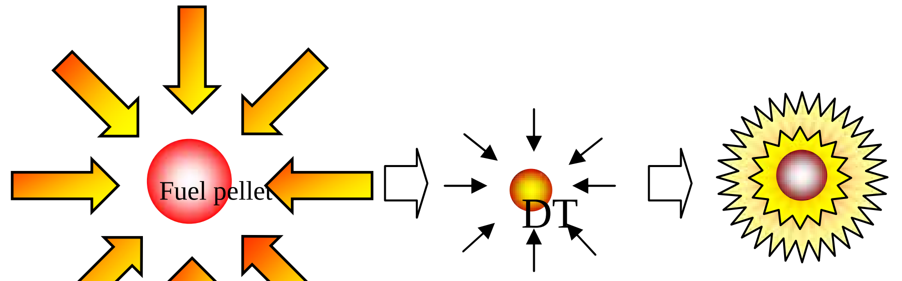


Problems

*Beam Accelerator (Scale, Cost, etc..)
*Physics of Intense Beam (Bunching, Emittance growth, etc..)
*Beam Final Transport (Stable transportation, Interaction with gas, etc..)
*Beam-Target Interaction
*Analysis of Target-Plasma Hydrodynamics
etc..

Purposes





$$D + T \Rightarrow {}^{4}_{2}He + {}^{1}_{0}n + 17.6\,MeV$$

Effective Implosion

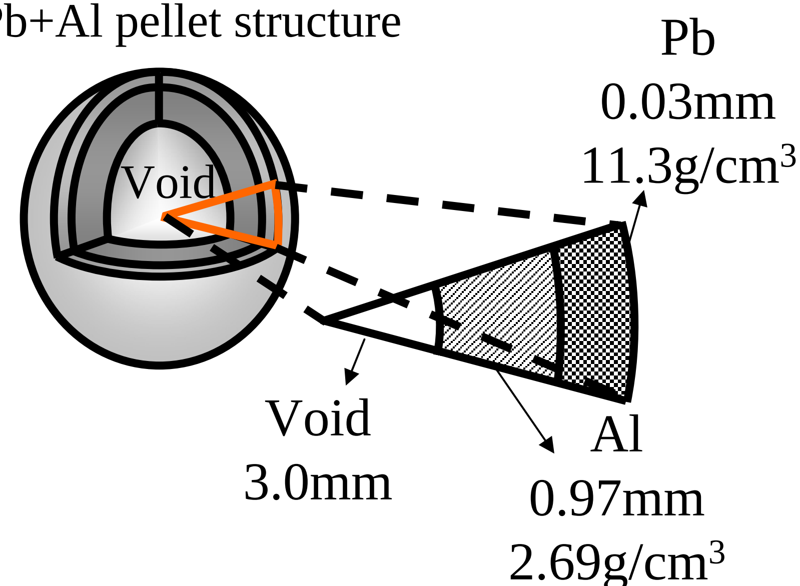
Non-uniformity (< few %)

*Calculation of deposition energy on a fuel target

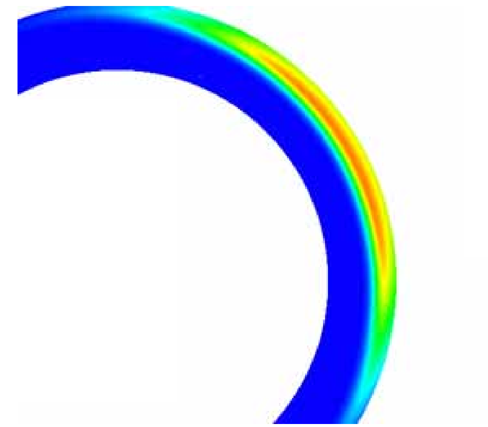
*Development of 3D-implosion code

Simulation Model

Pb+Al pellet structure



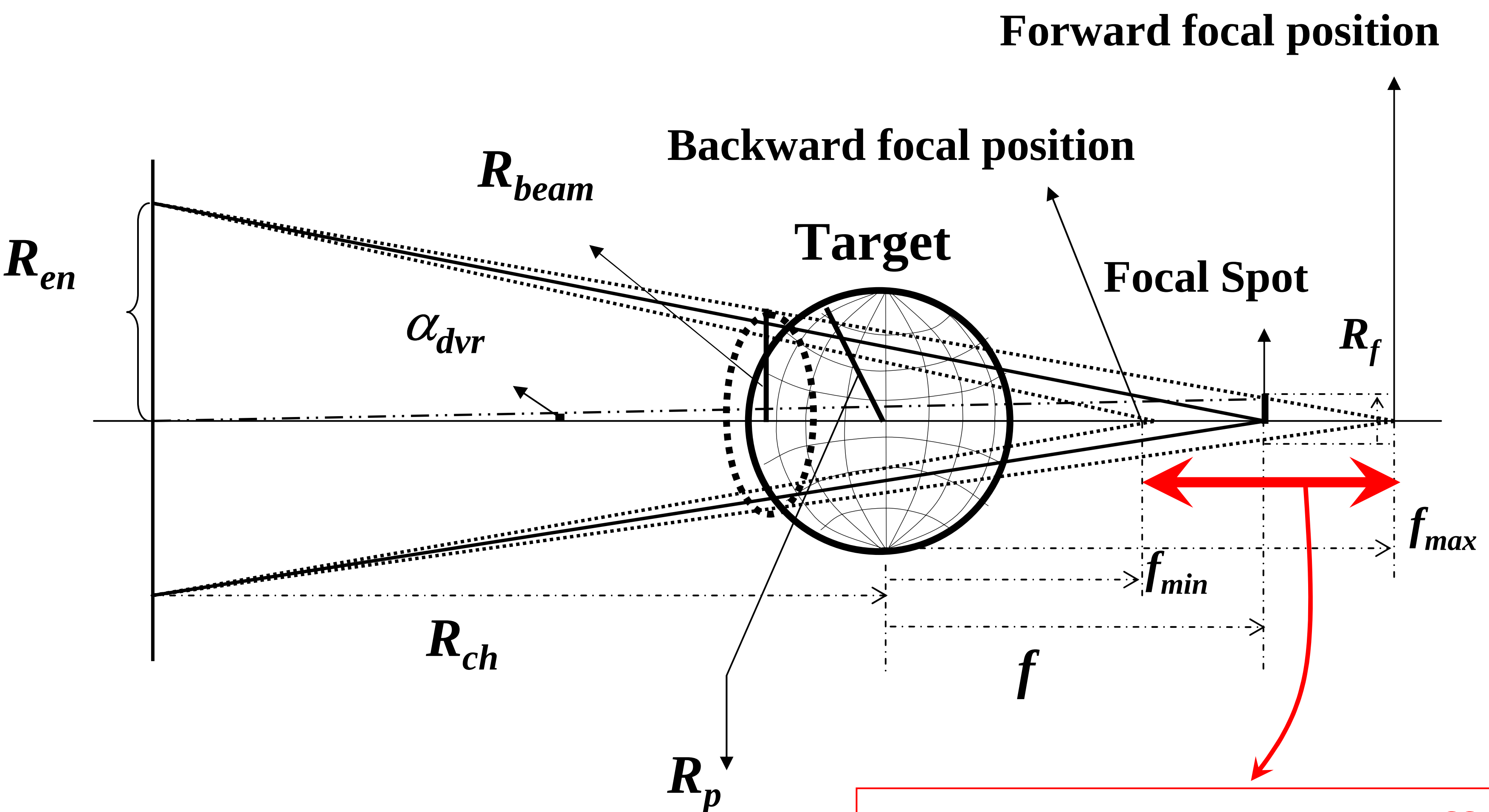
Deposition energy from 1 Beam



Beam parameter

*Heavy ion beam:	Pb^+
*Particle energy:	8GeV
*Beam temperature:	100MeV
*Transverse beam emittance:	5.0 mm mard
*Beam number density:	1.3×10^{11} 1/cc
*Beam number:	12,20,32,60,92,120
*Beam distribution:	Gaussian

HIB transverse emittance



Include the Emittance Effect by changing the Focal Spot

Non-uniformity

$$\sigma_{\mathrm{RMS}} = \sum_{i}^{n_r} w_i \sigma_i$$

$$\sigma_{RMSi} = \frac{1}{\langle E \rangle_i} \sqrt{\frac{\sum_{j}^{n_\theta} \sum_{k}^{n_\phi} \left(\langle E \rangle_i - E_{ijk} \right)^2}{n_\theta n_\phi}}$$

$$w_i = \frac{E_i}{E}$$

σ_{rms}:root mean square(RMS) non-uniformity

σ_i:non-uniformity at a surface

$\langle E_i \rangle$:mean deposition energy at a surface

E_{ijk}:deposition energy at each point

n_r, n_θ, n_ϕ:each mesh number

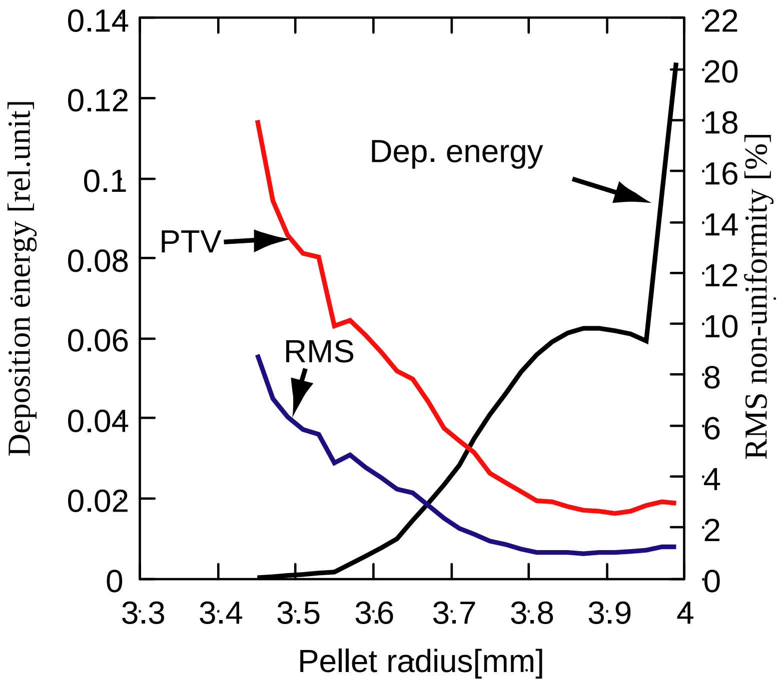
E:total deposition energy

E_i:total deposition energy at a surface

w_i:weight function include the Bragg peak effect

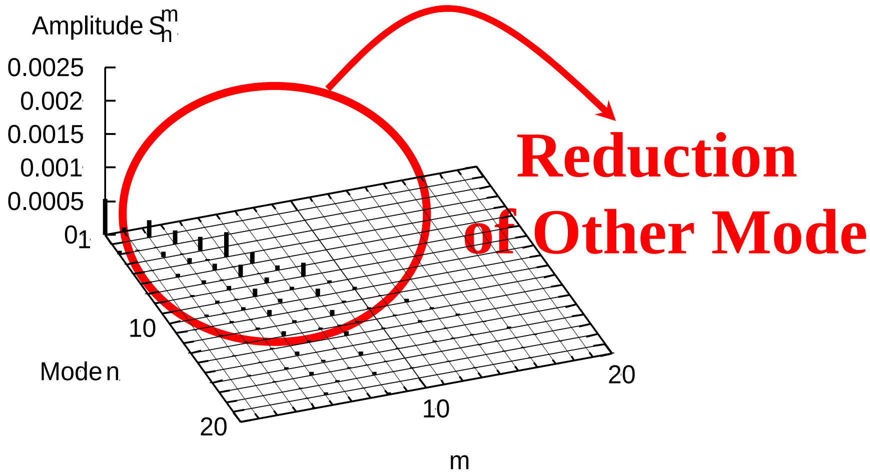
Simulation Results

32-beam system

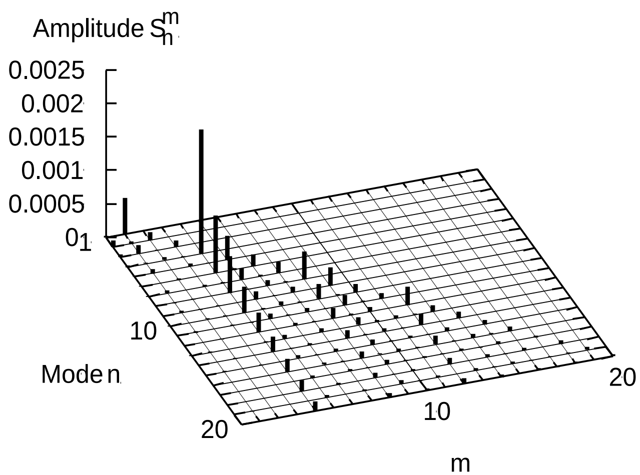


$$\sigma_{rms} = 1.86\,\%$$

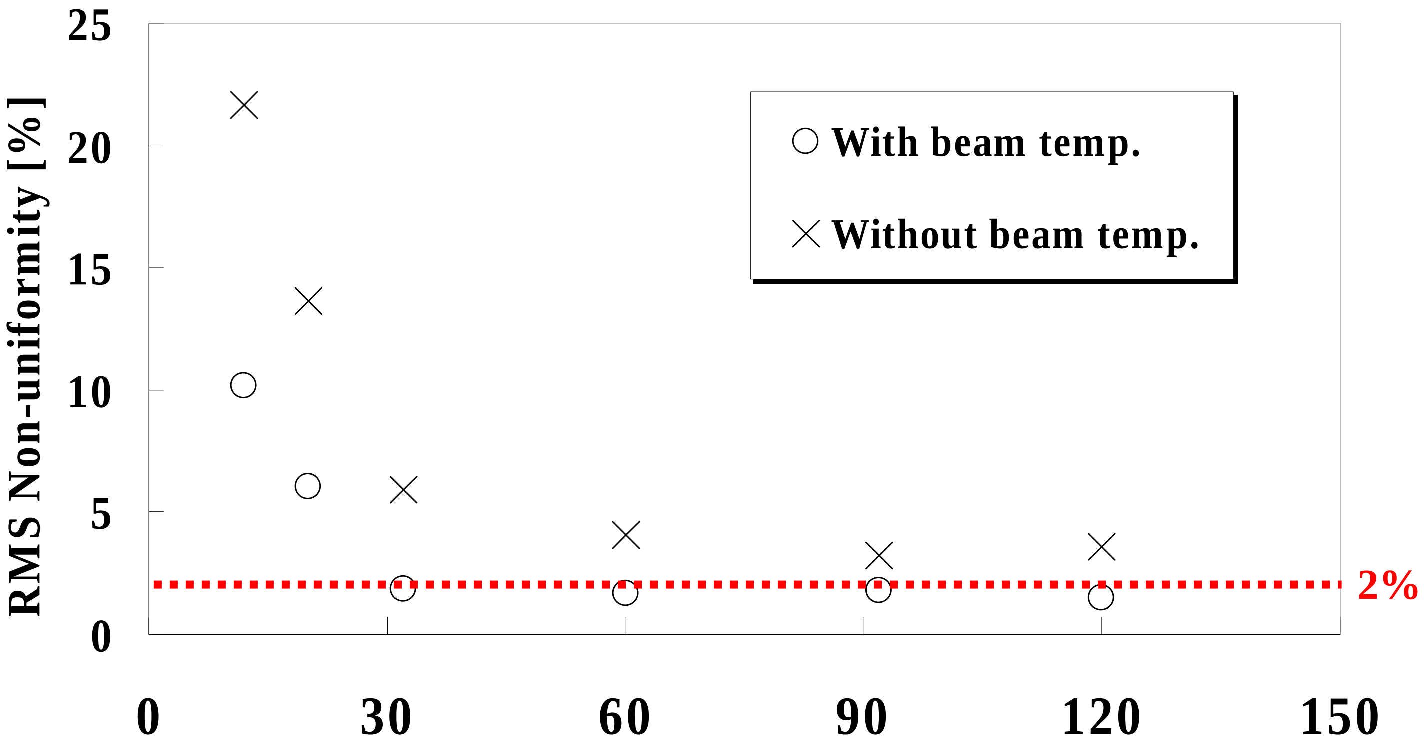
@Bragg peak layer



Global



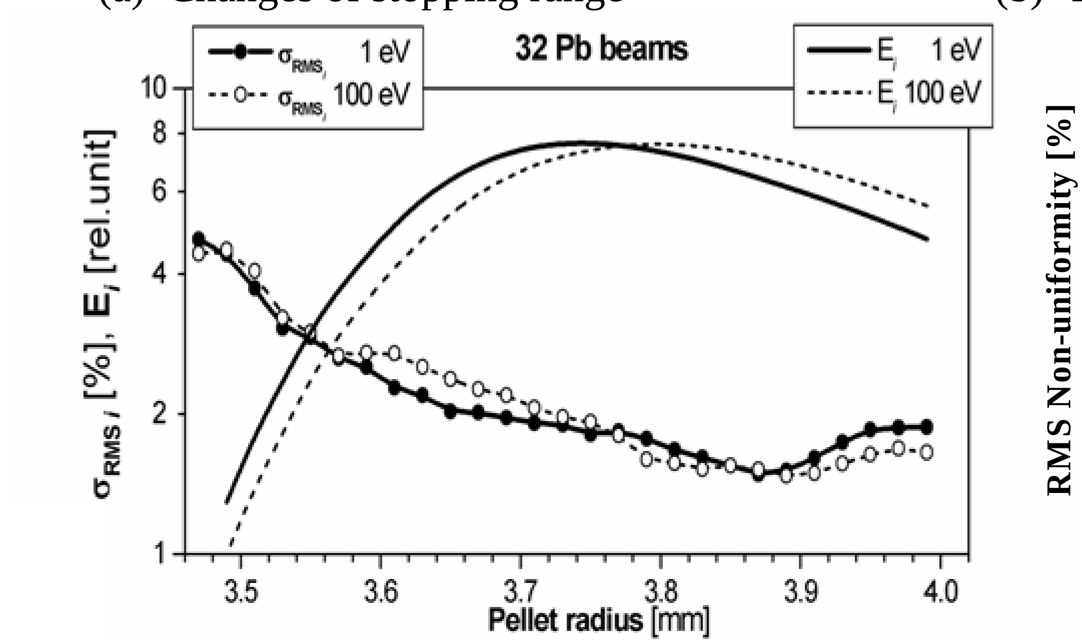
Effect of HIB Number



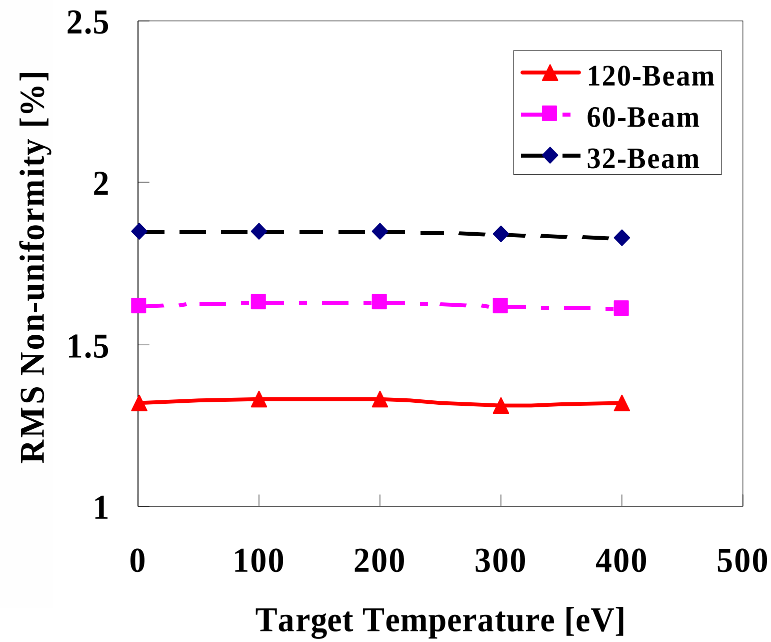
At least 32 beams are effective

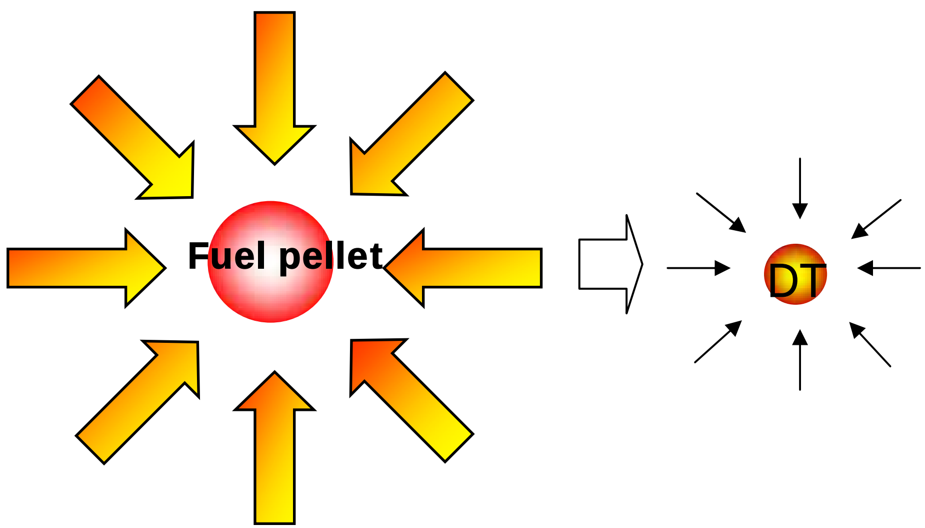
Effect of Target Temperature

(a) Changes of stopping range



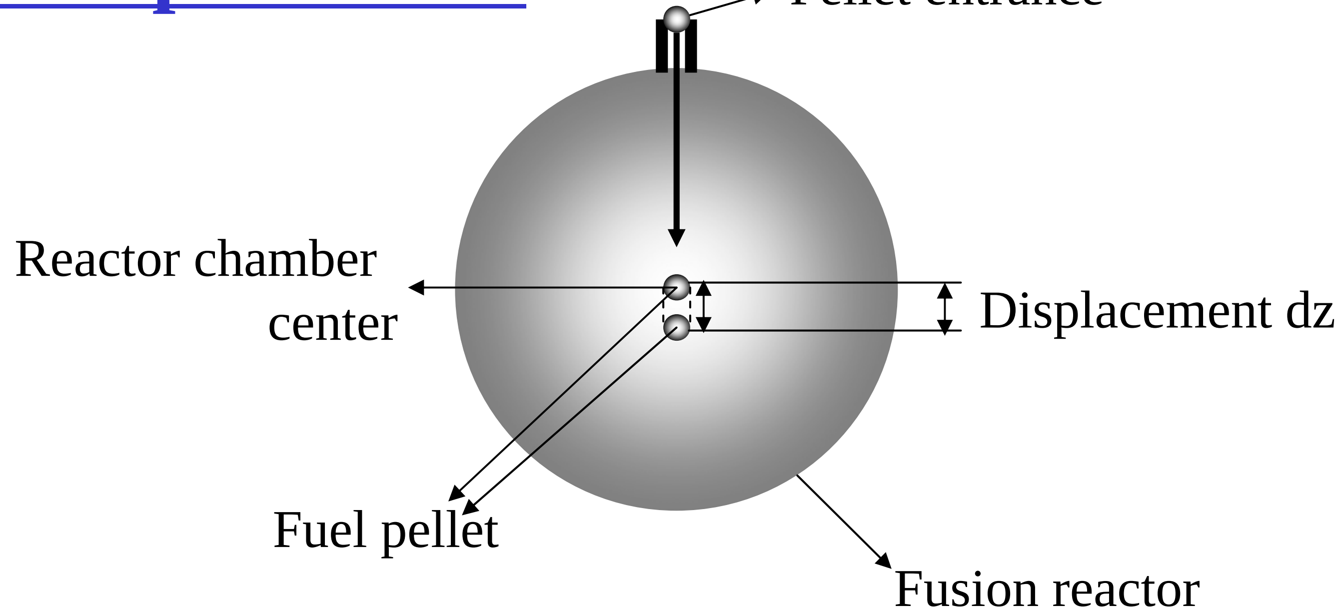
(b) Target temperature v.s. RMS non-uniformity

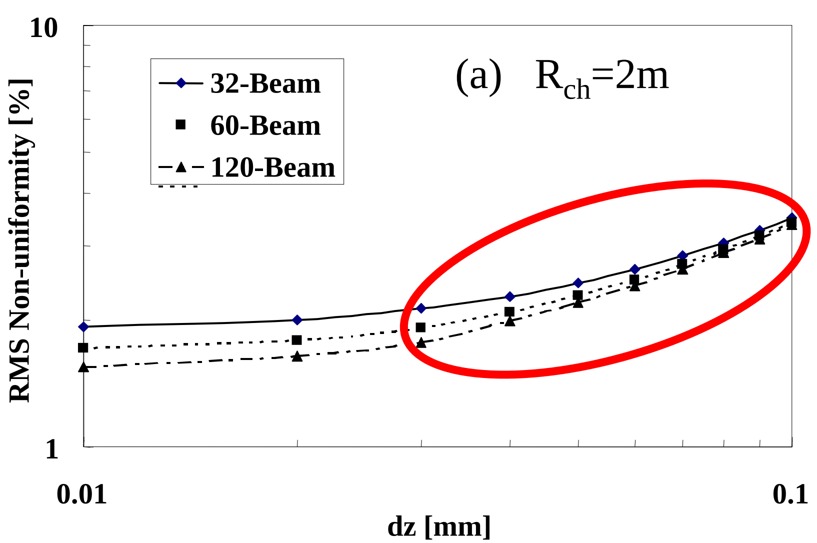


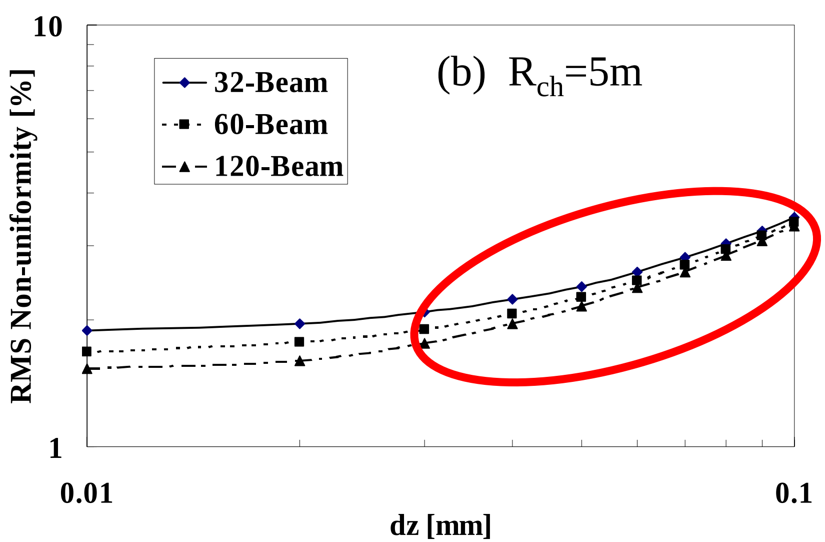


HIB illumination non-uniformity is kept low
during the HIB pulse duration

Pellet Displacement

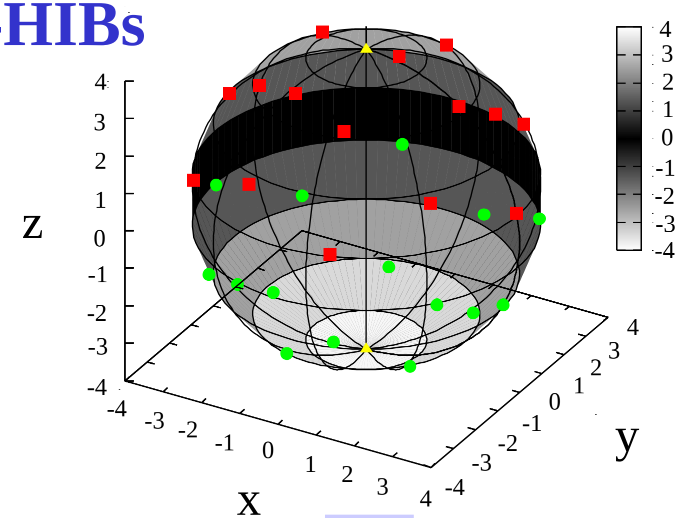






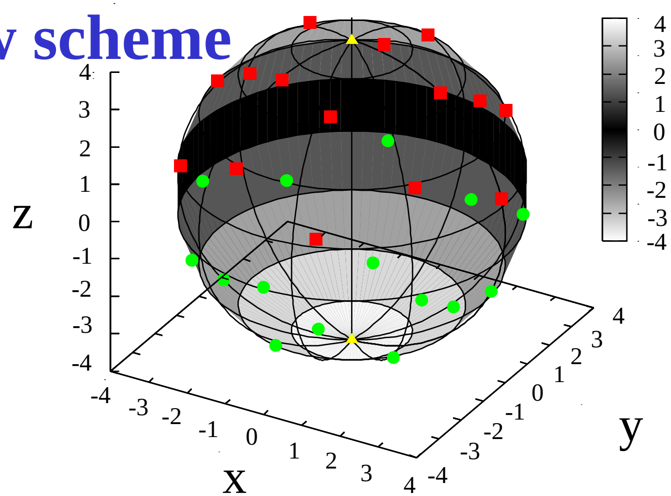
Reduce the Non-uniformity for the Pellet Displacement

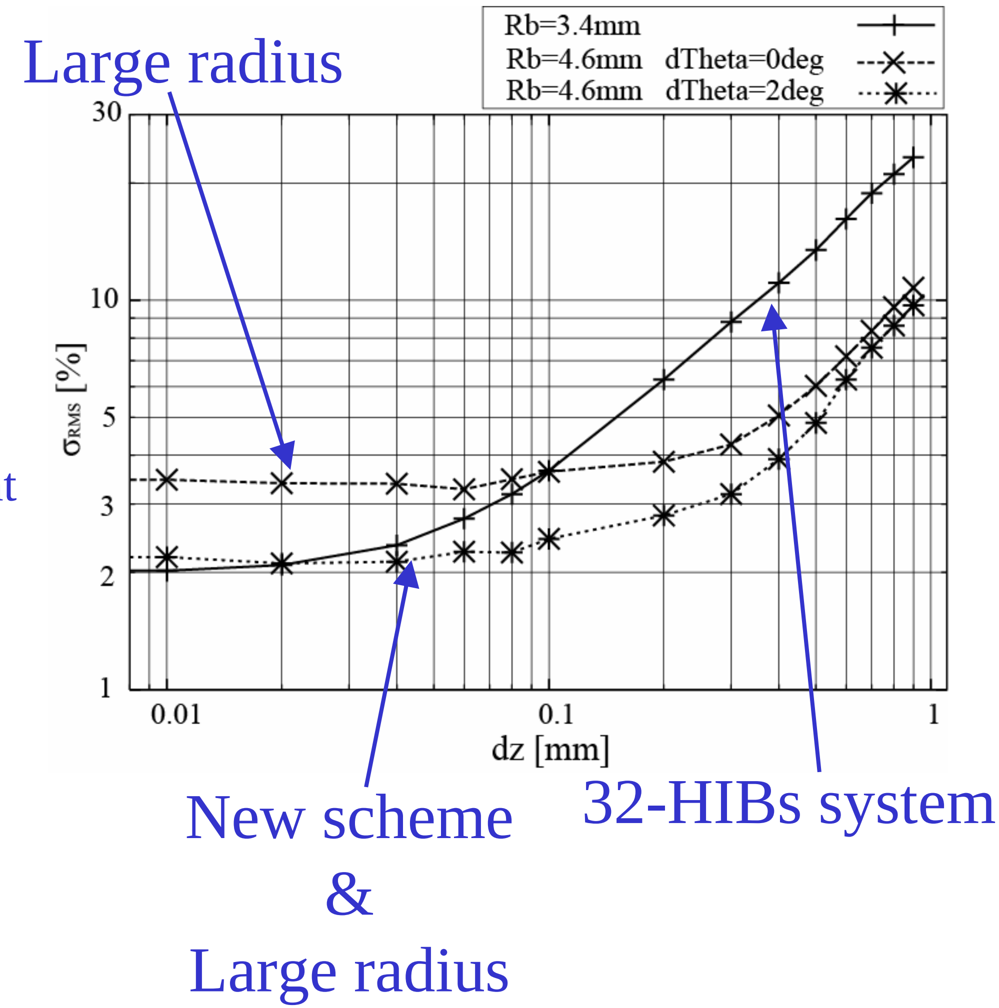
32-HIBs



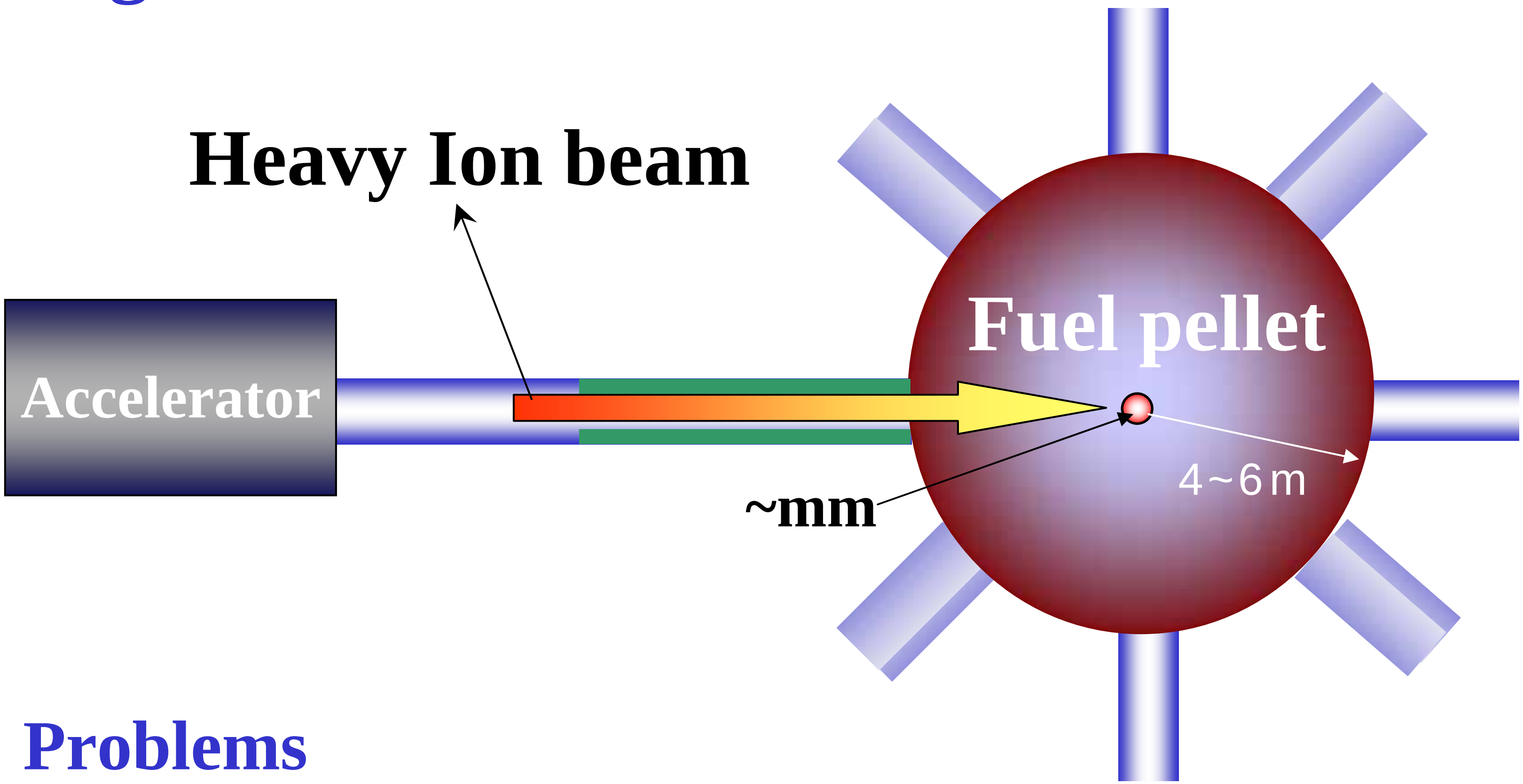
Displace the HIB illumination point
for the theta-direction (2 deg.)

New scheme





Background2



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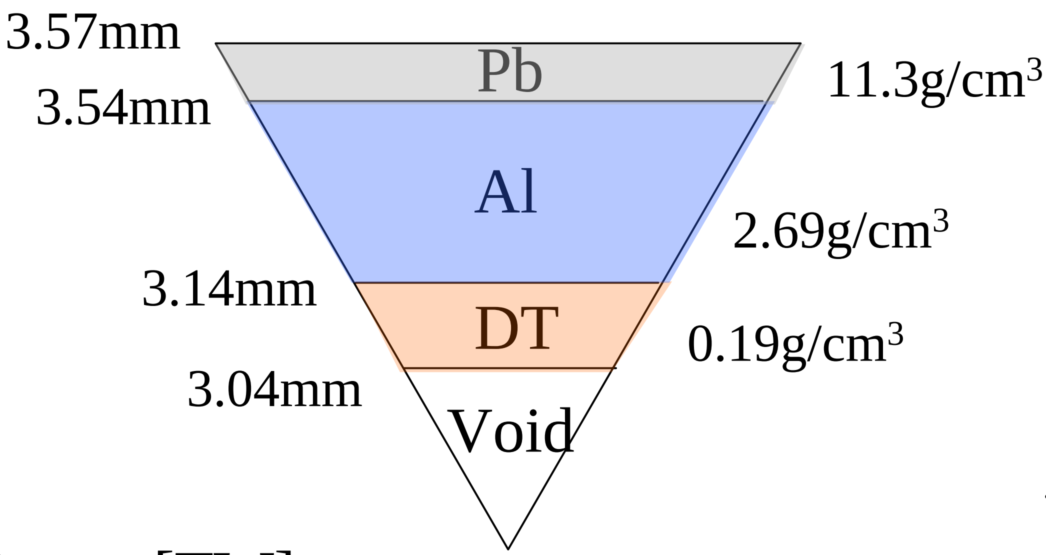
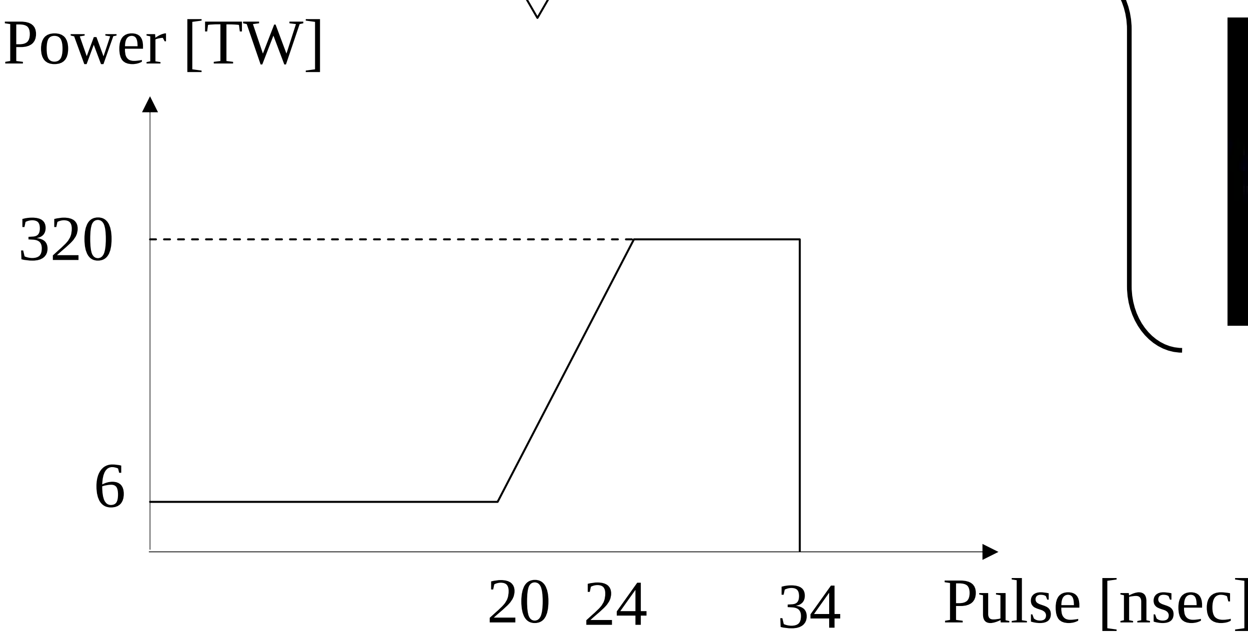
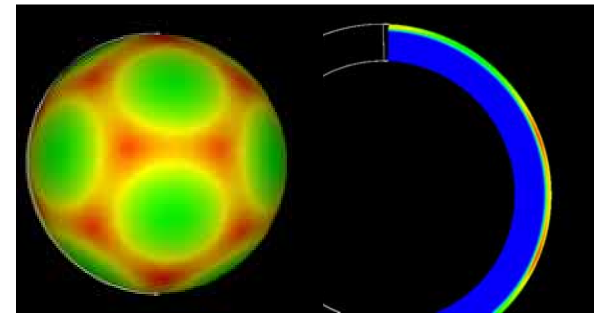
Initial Condition

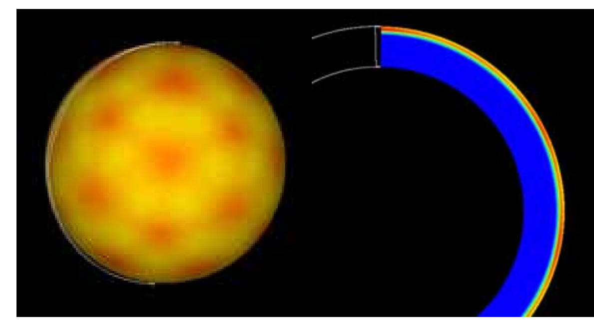




Illumination Pattern

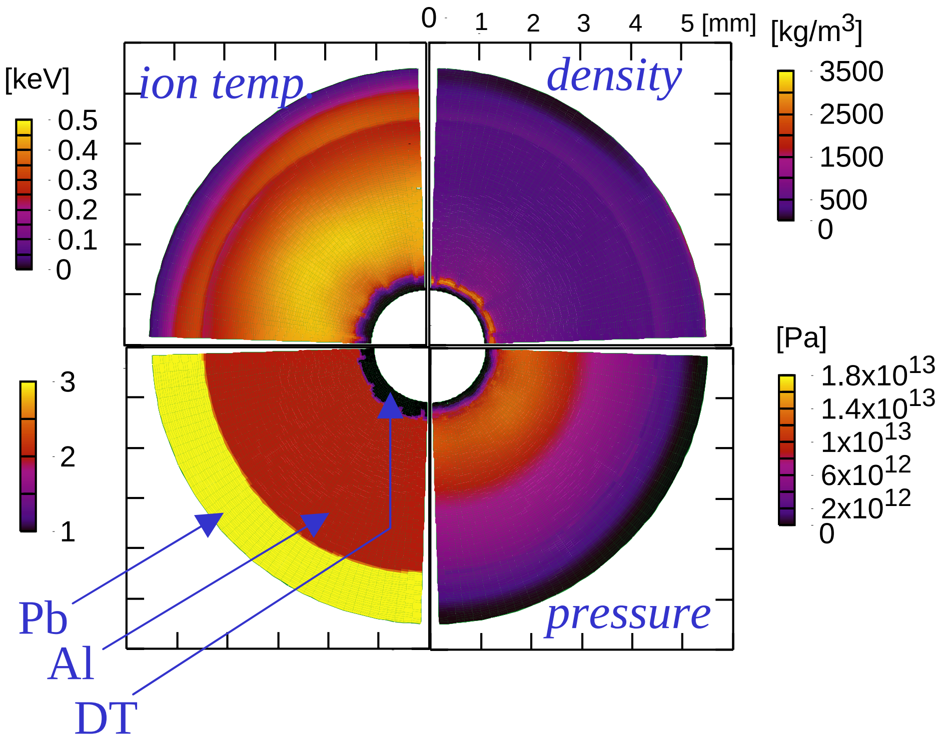


12-HIBs system

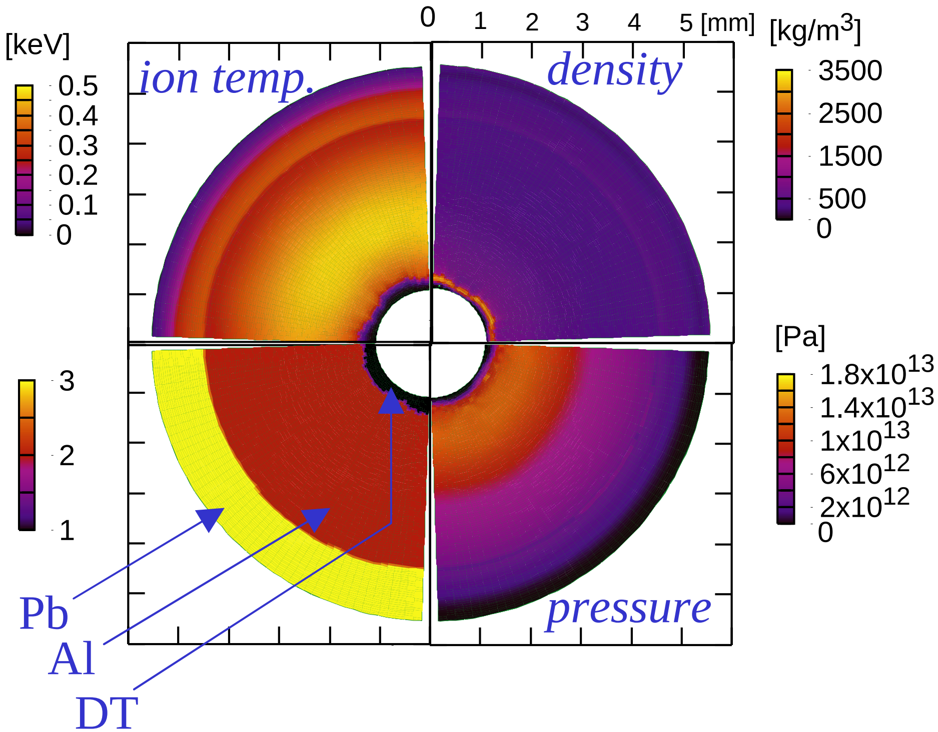


32-HIBs system

Preliminary results

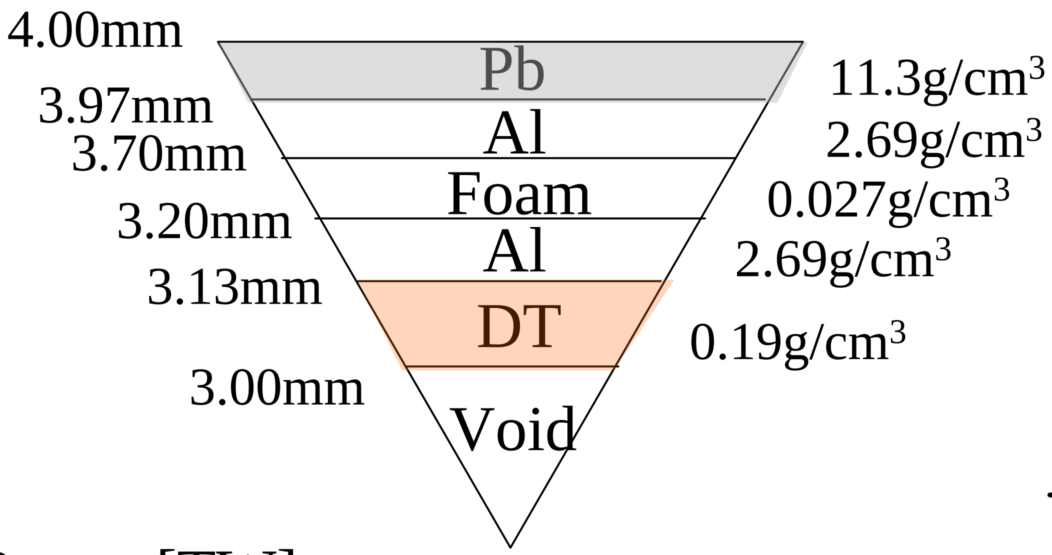


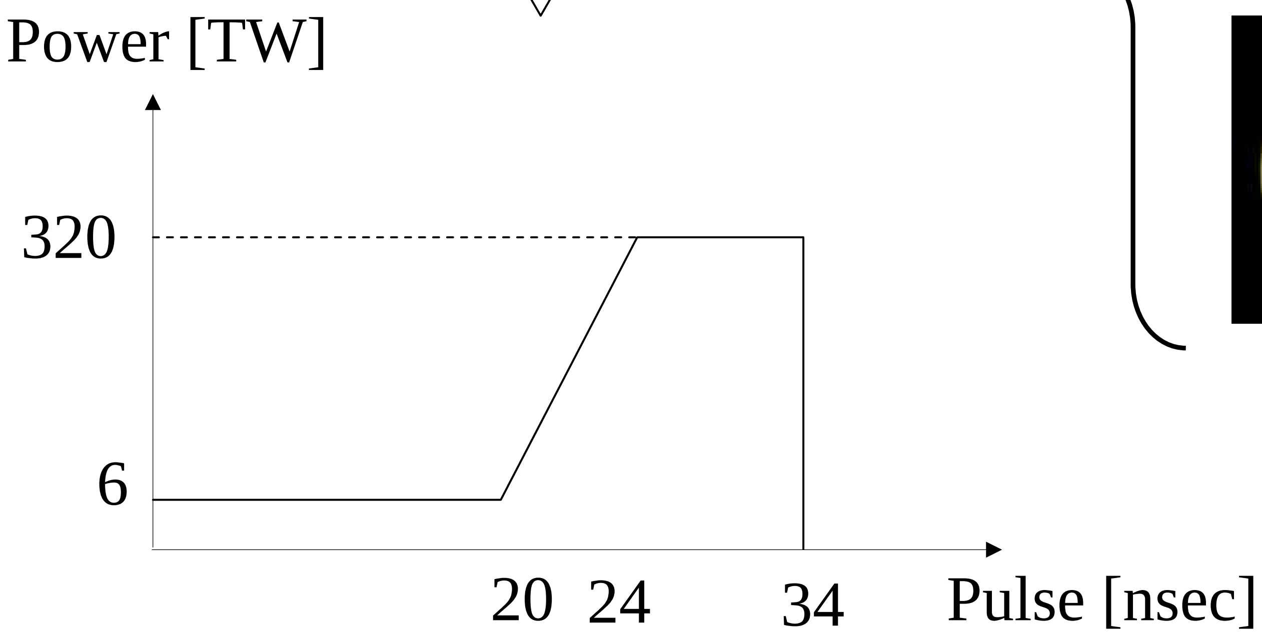
12-HIBs@32nsec



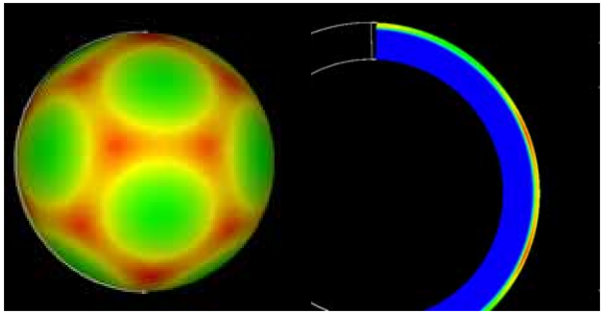
32-HIBs@32nsec

Initial Condition2

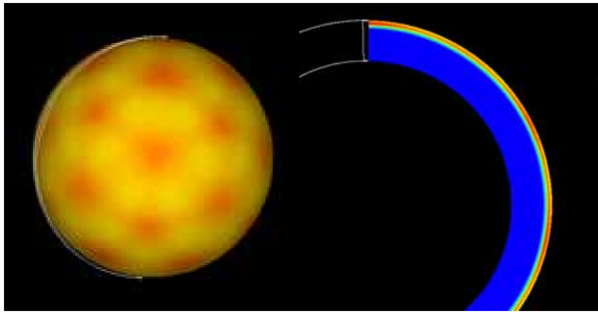




Illumination Pattern

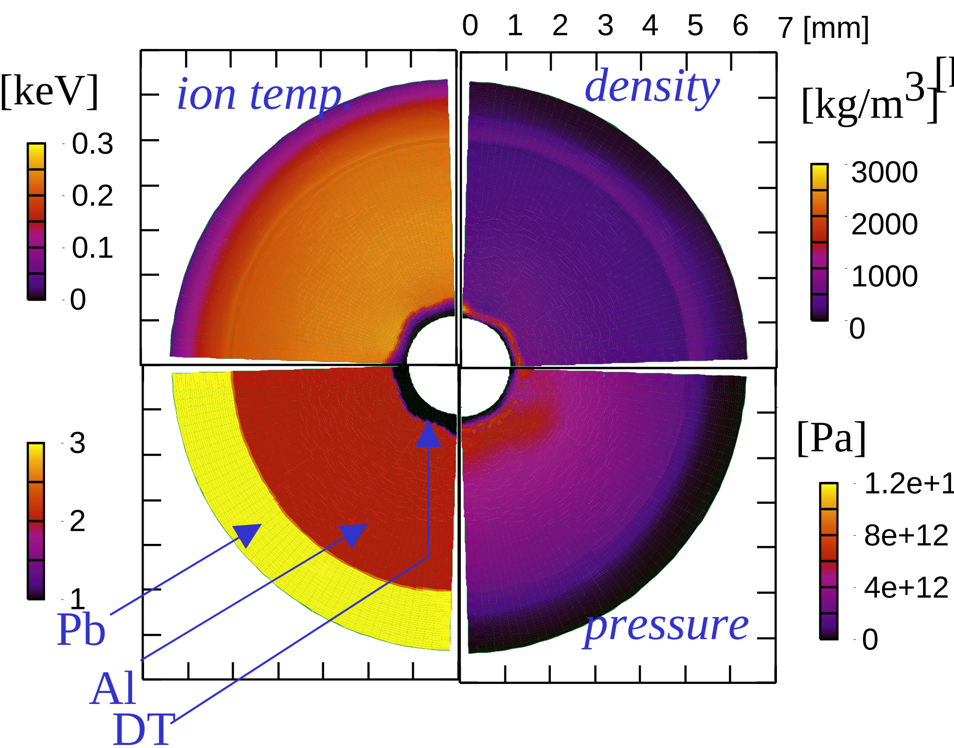


12-HIBs system

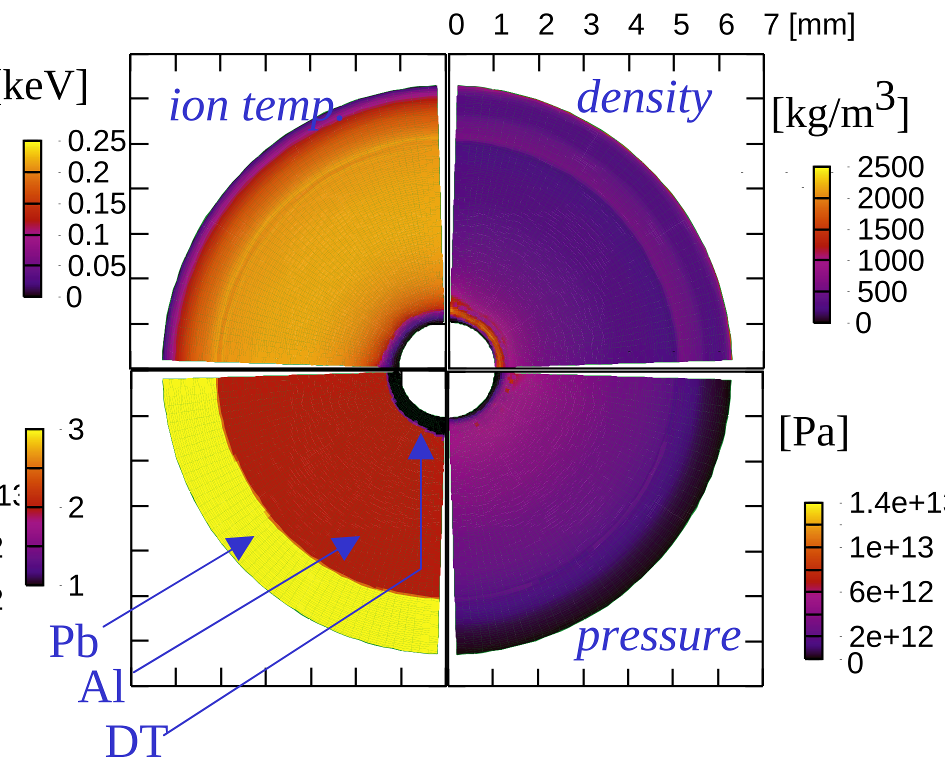


32-HIBs system

Preliminary results



12-HIBs@36nsec



32-HIBs@36nsec

Summary

- HIB illumination non-uniformity can be smoothed due to the beam temperature and emittance
- HIB illumination non-uniformity is kept low during the HIB pulse duration onto a direct-driven pellet in ICF
- The non-uniformity is reduced by changing the illumination pattern for the pellet displacement
- In the case of the large non-uniformity (12-HIBs system), our implosion code works well
- The implosion non-uniformity is suppressed by foam layer

Future Subject

- Find a optimum parameters (HIB pulse, target structure, etc..) to effective implosion