Experimental Studies of Ion interactions in Plasmas: collisional and collisionless ion energy transfer

S. N. Chen

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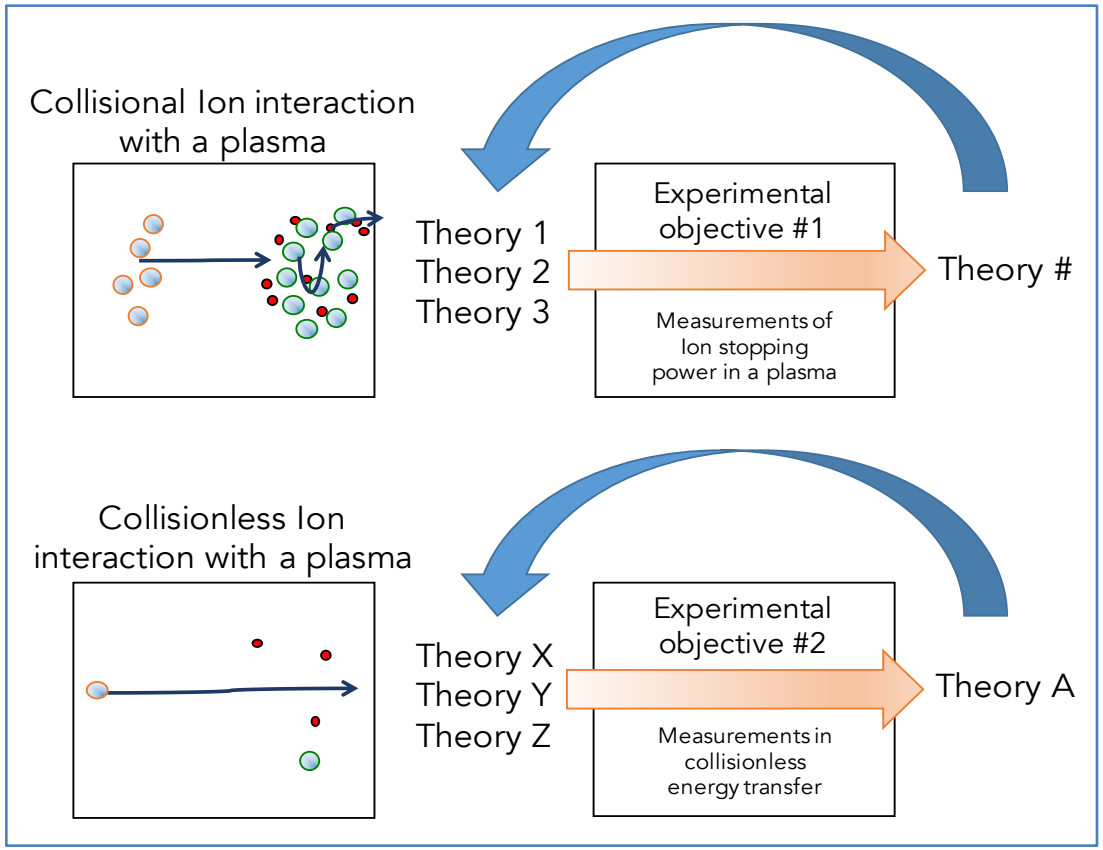
What do we know about ion energy transfer in a plasma ?

- Collisional: “Stopping power”
- Collisionless: wave creation and instabilities



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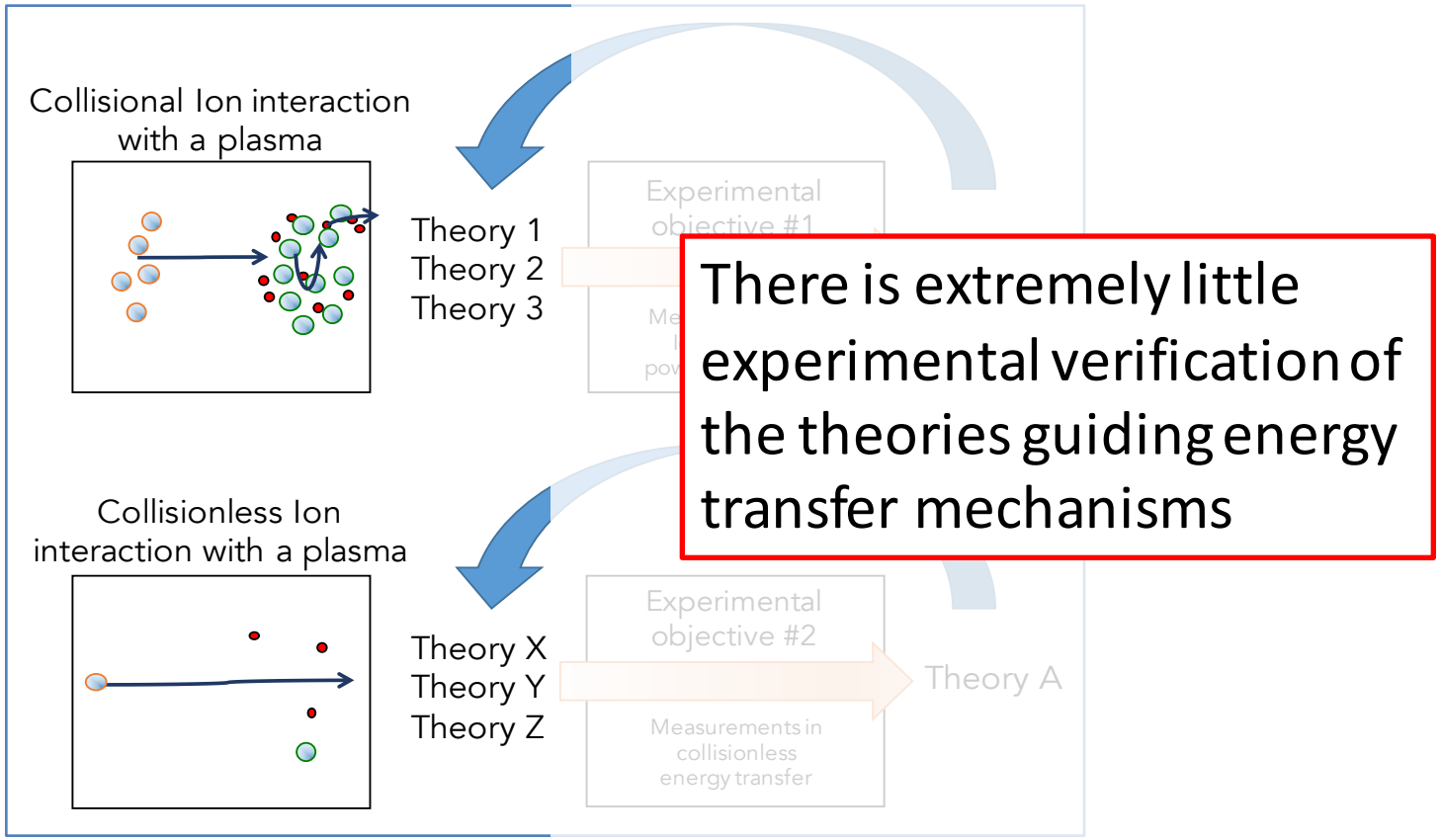
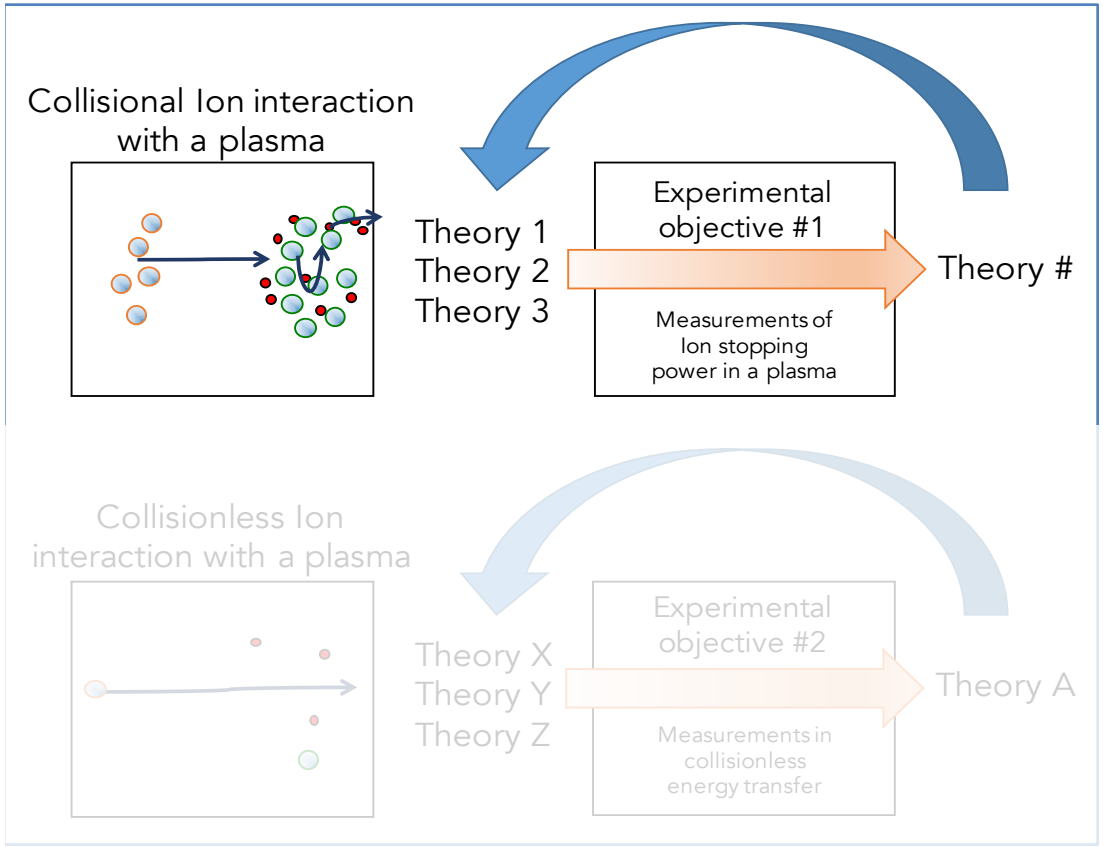


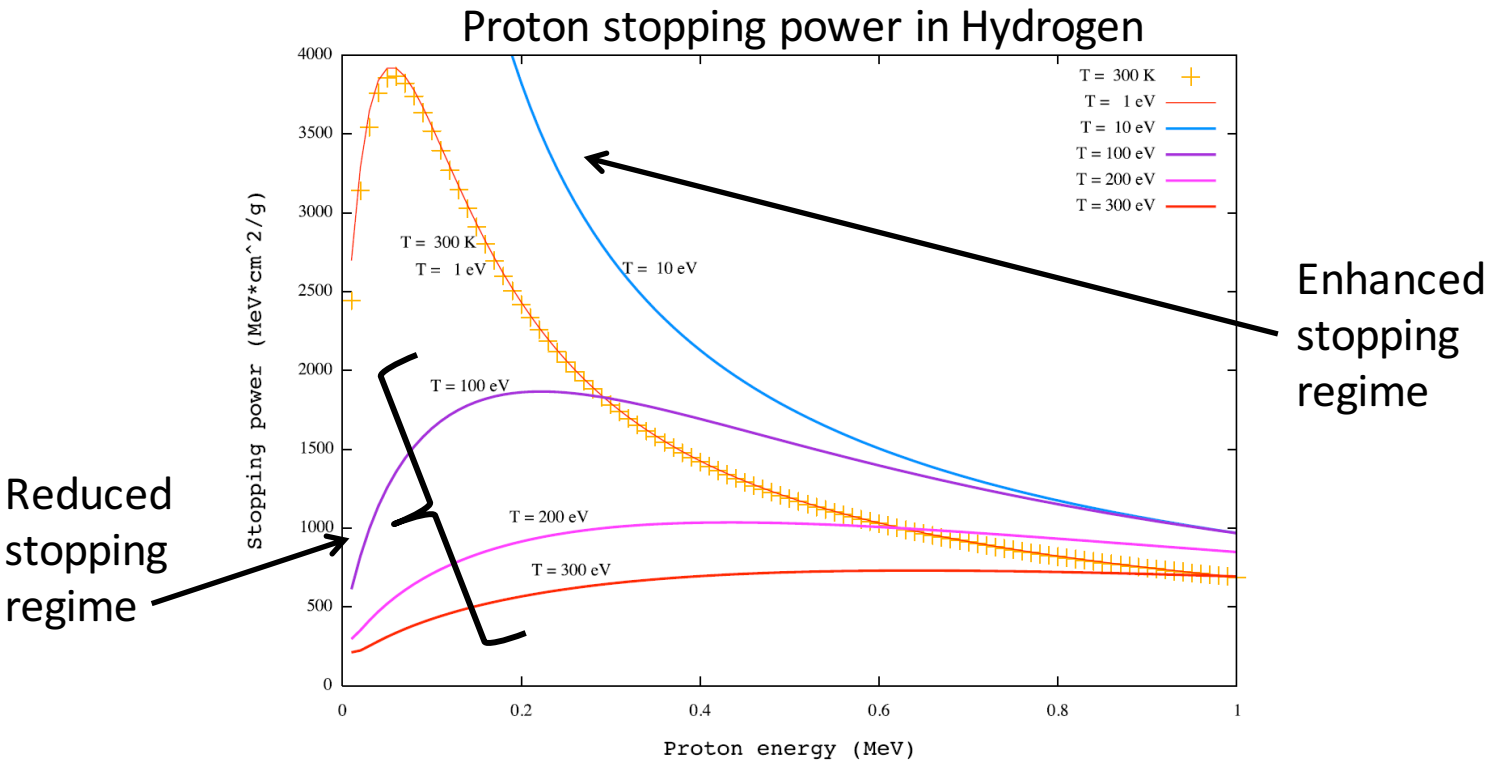
Why do we want to know about collisional energy transfer (stopping power) ?



- Stopping power in Solids and Gases are widely available – PSTAR & SRIM
- Interest picked up with laser based Inertial Confinement Fusion (ICF)
  - Heavy Ion Fusion, Proton Fast Ignition, etc.
  - All simulations rely on unverified theoretical models
- Stellar physics
  - Re-heating due to fusion products

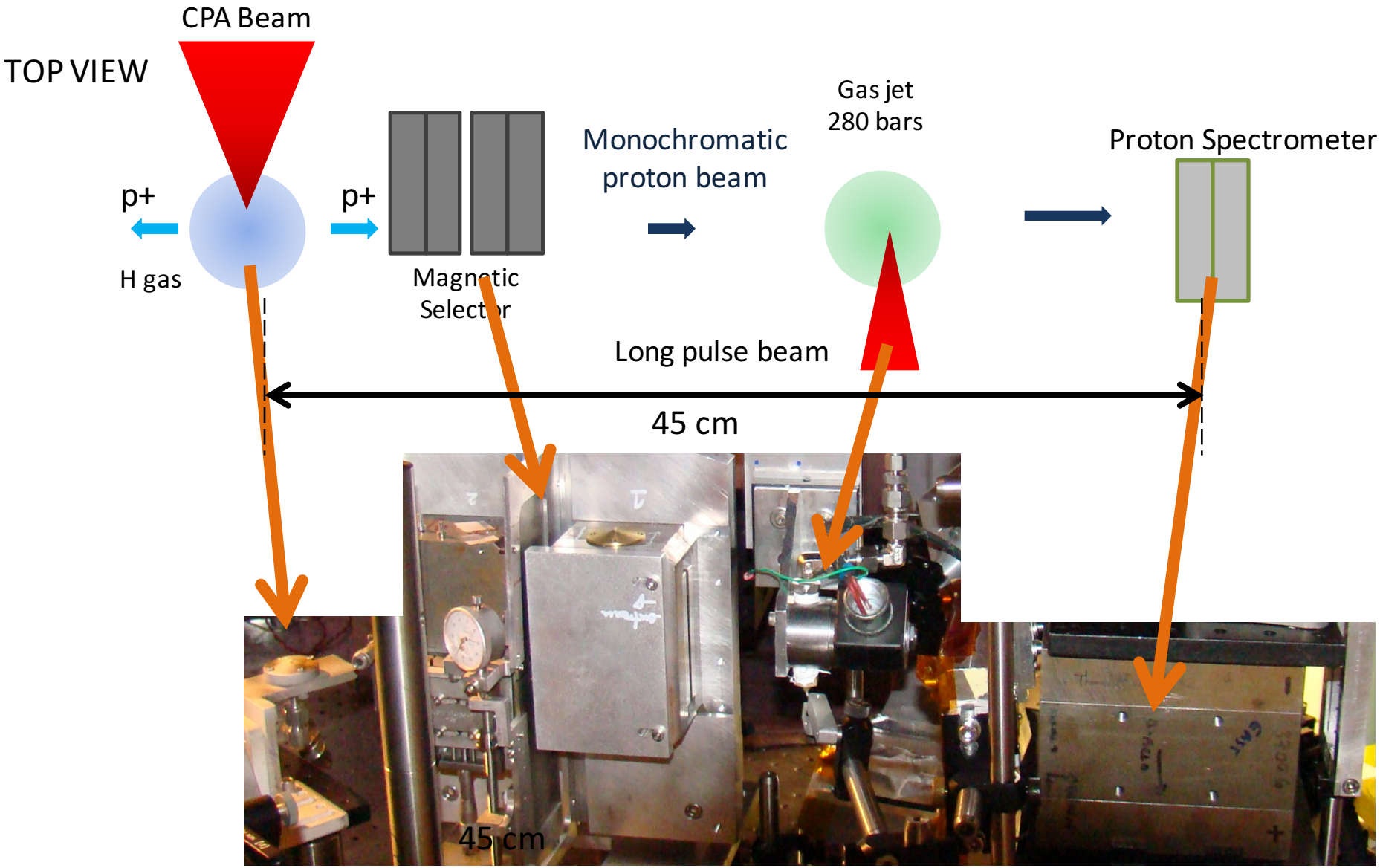
- Ideally, one would need a picosecond beam since the plasma is evolving hydrodynamically – nanosecond timescale

Ion stopping power in with a plasma

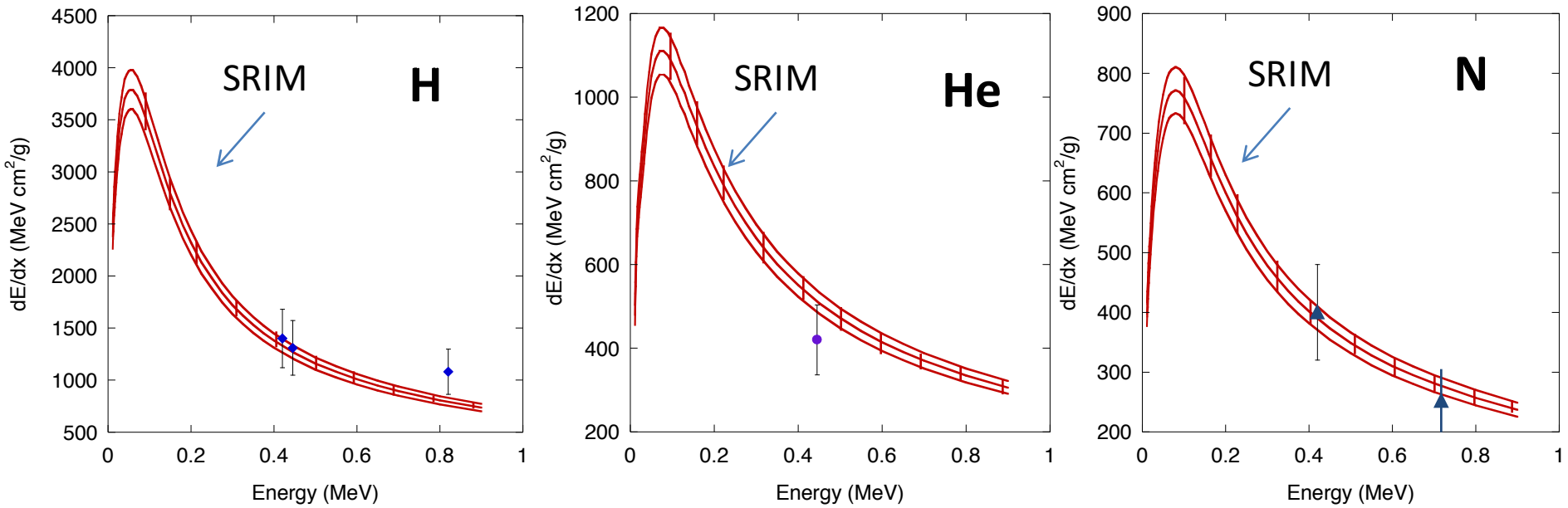


S. Atzeni
2-D DEUD hydrodnamic code

First experiments performed at ELFIE and Titan/JLF



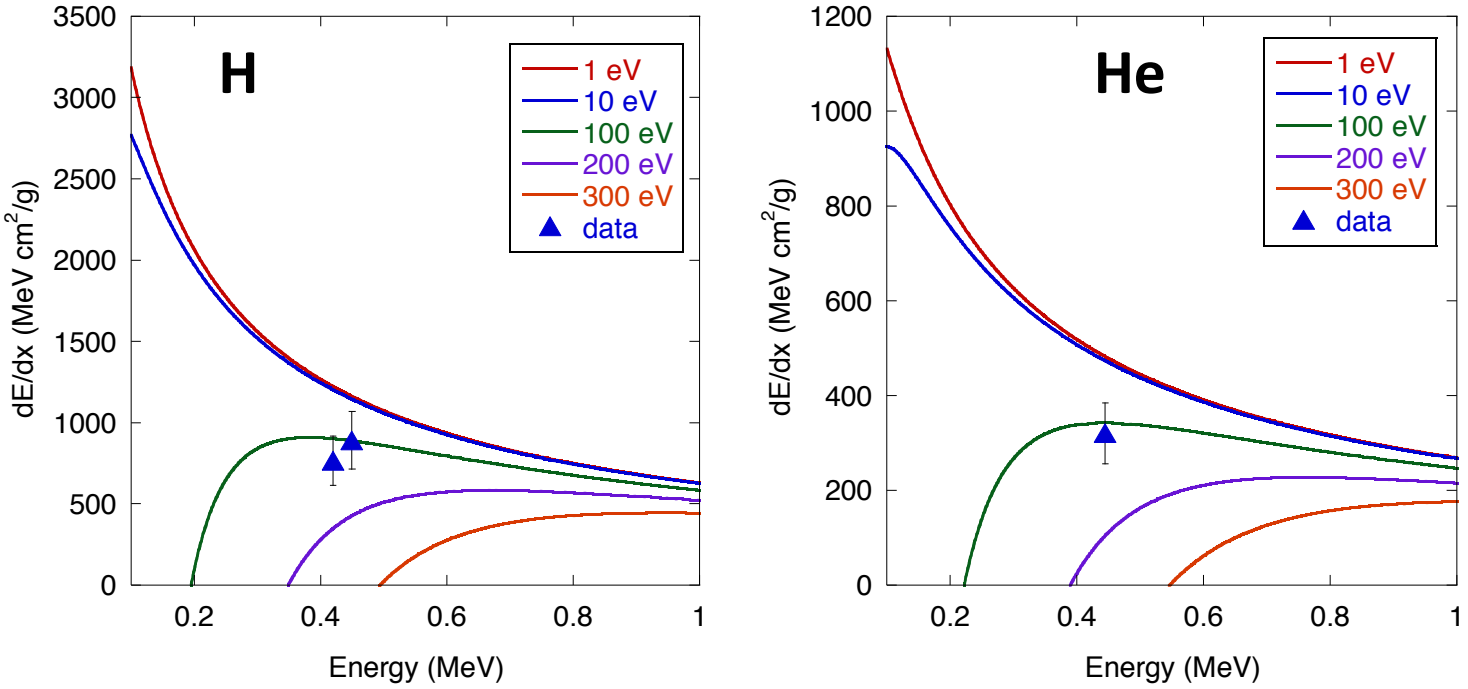
Proton stopping through cold gas



S. N. Chen, et al. NIMA **740**, 105 (2014)

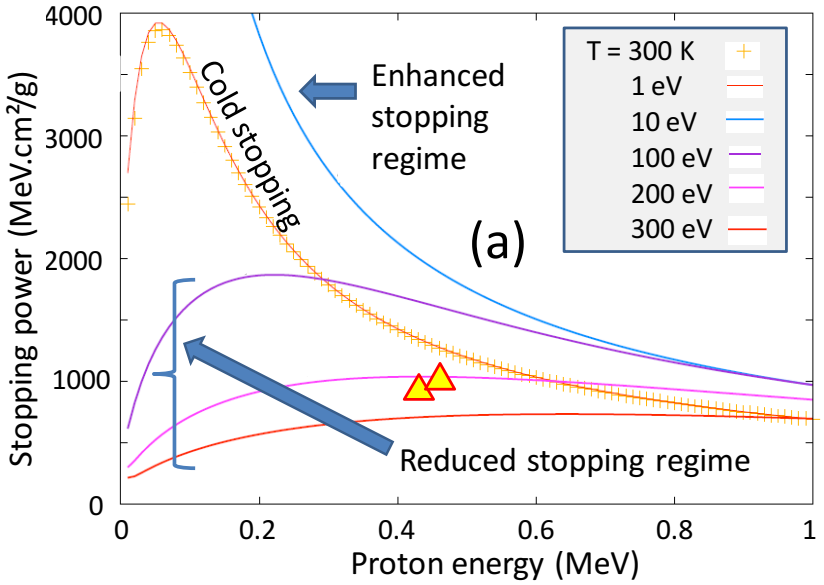
Proton stopping through fully ionized gas - reduced stopping regime

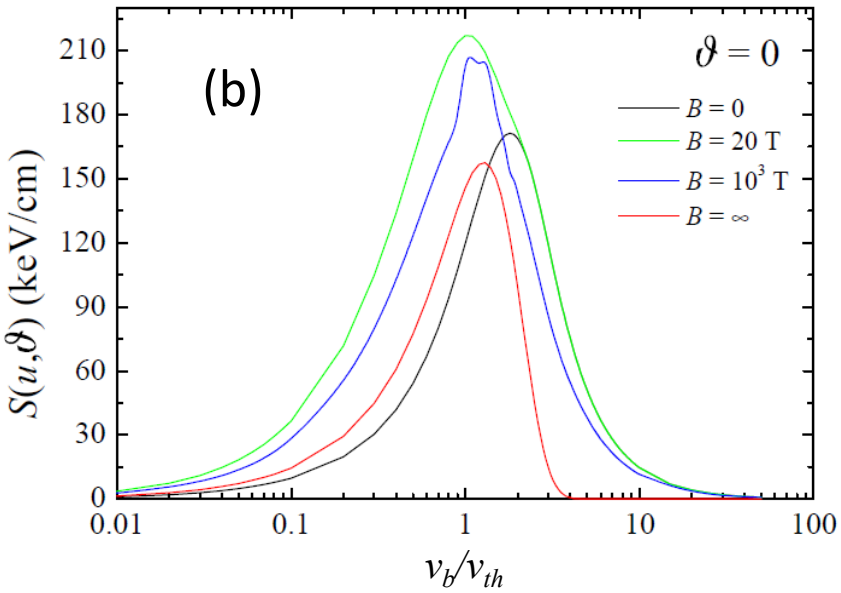
30 J long pulse beam



What's next ?

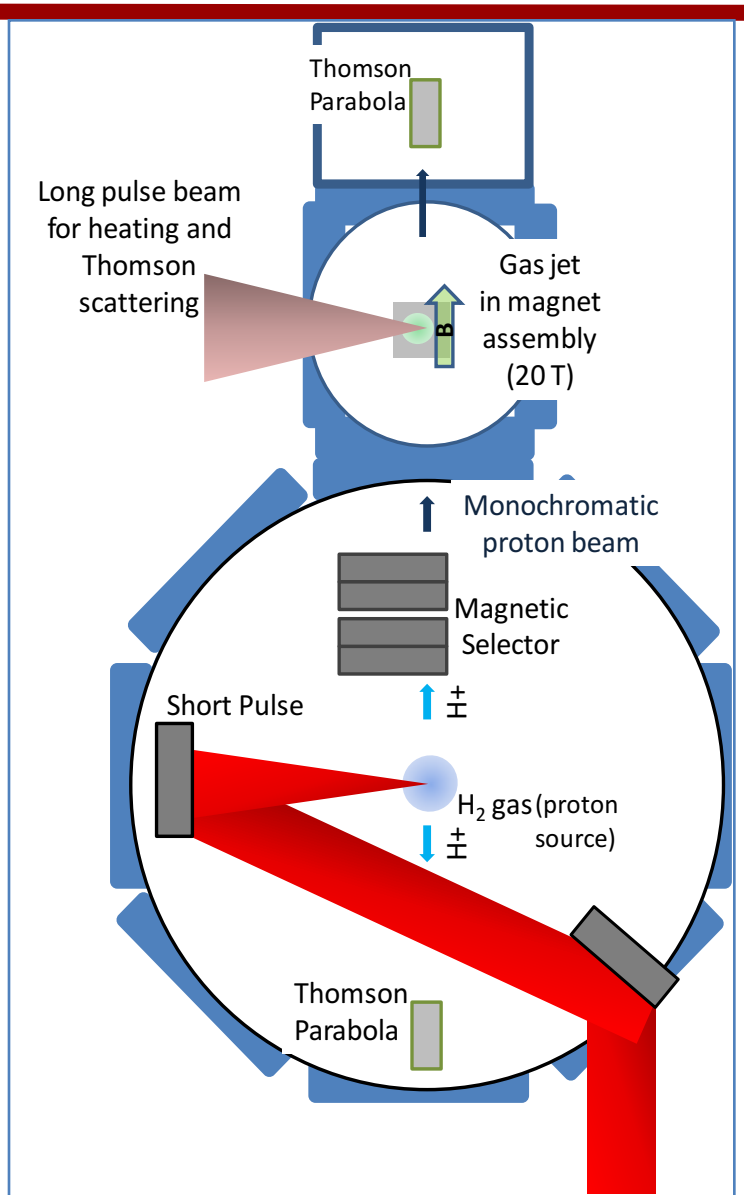
Proton stopping power in Hydrogen



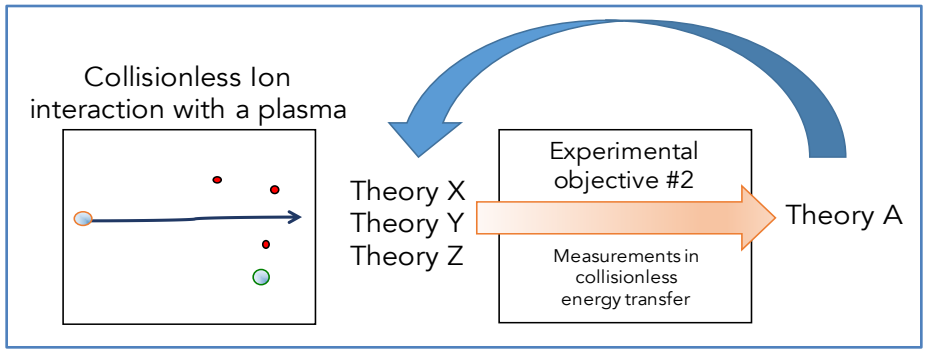


S. Atzeni, U. of Rome
2-D DEUD hydrodnamic code

Simulation done by C. Deutsch, LGPG


Thomson
Parabola
Long pulse beam
for heating and
Thomson
scattering
B
Gas jet
in magnet
assembly
(20 T)
Monochromatic
proton beam
Magnetic
Selector
Short Pulse
H2 gas (proton
source)
Thomson
Parabola

Why do we want to know about collisionless energy transfer ?

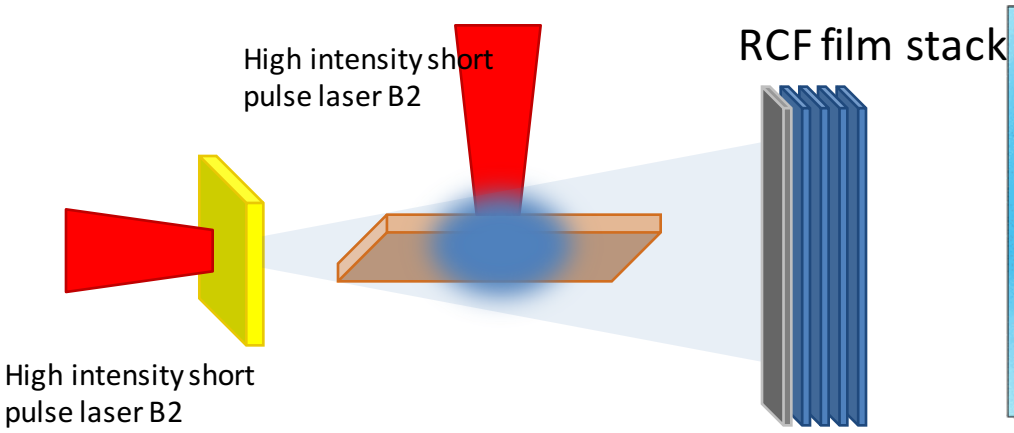


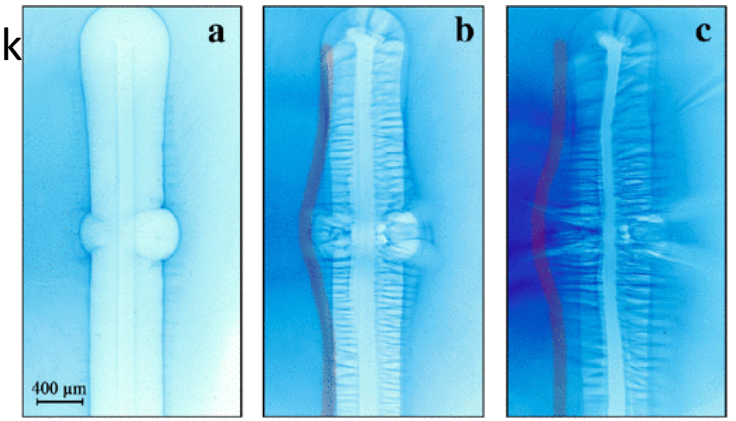
- ICF - wall design of the experimental chamber
- Cosmic Ray transport
- Space weather
- Precursor to Collisionless shocks

- Very little is verified in the field of ion transport since tests need high density beams
- High density beams are needed to trigger instabilities quickly
- Plasma machines have been used in the past, but beam densities are very low

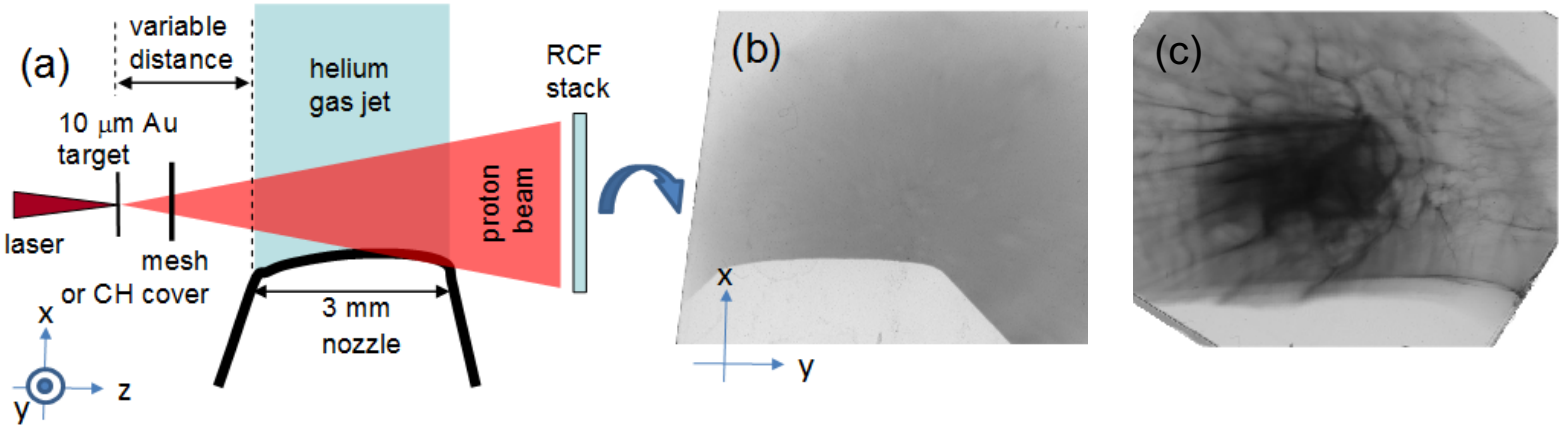
Collisionless interactions between electron and ion beams with a plasma

- High density electron and proton beams with MeV energy, so instabilities can be easily triggered

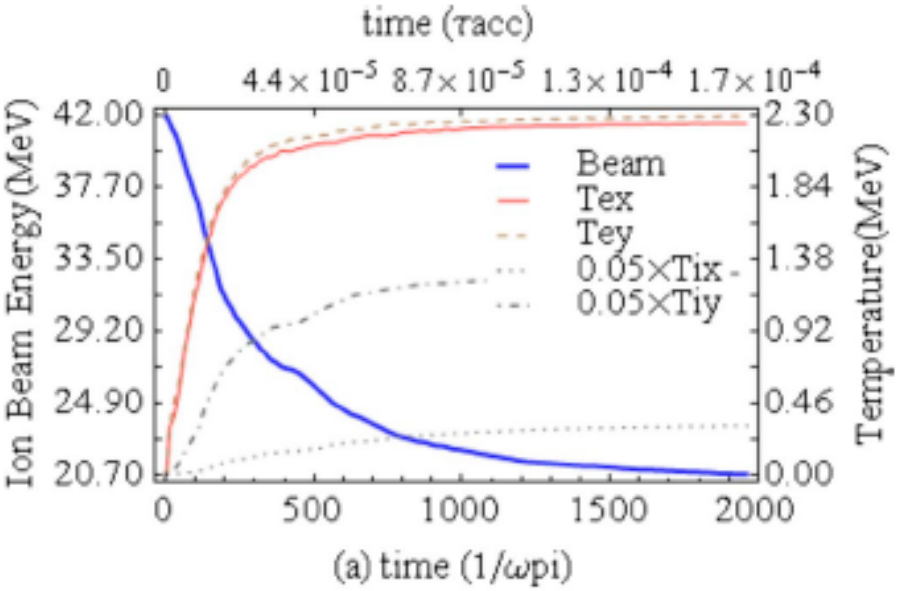


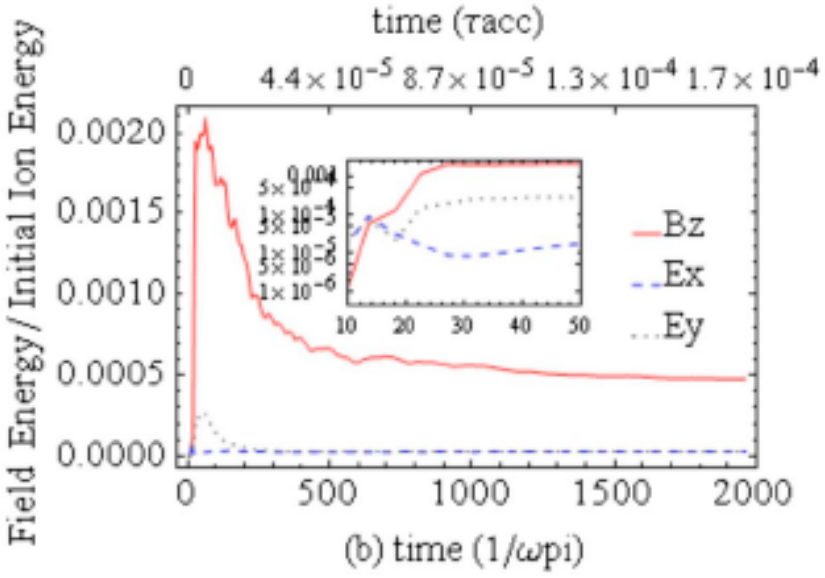


K. Quinn, et al., Phys. Rev. Lett. 108, 135001 (2012)



What are the simulations telling us



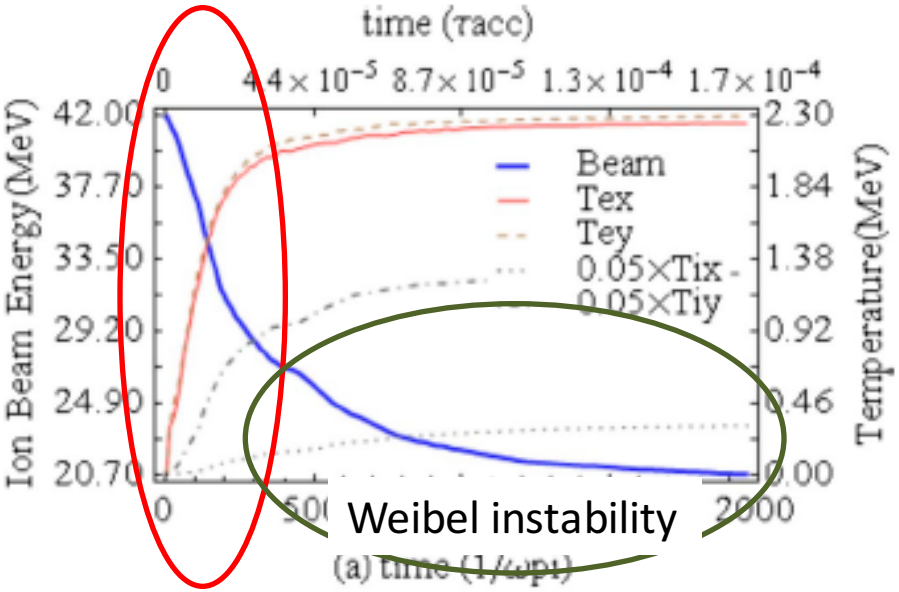


J. Park, et al., Physics of Plasmas (1994-present) 17 , 022901 (2010)

Energy transferred can vary by more than 50% depending on the model used

What are the simulations telling us

TS instability



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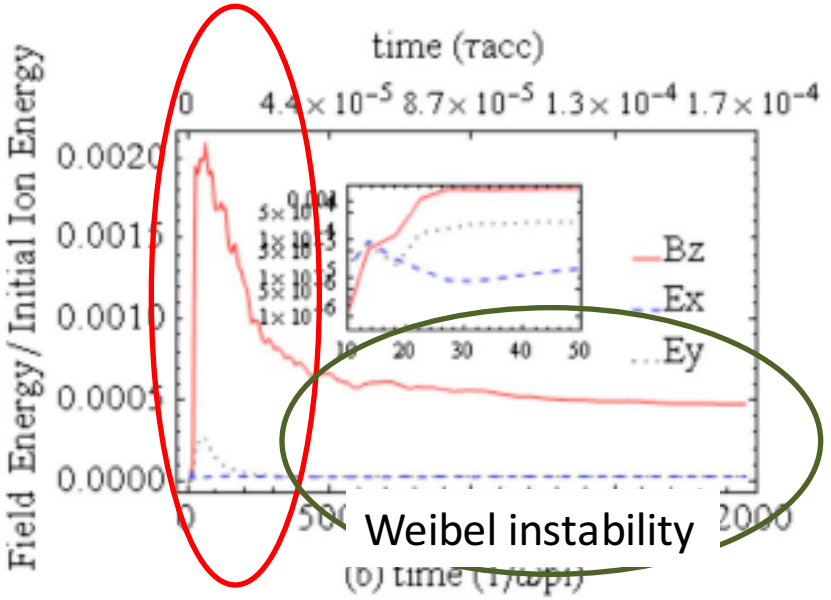

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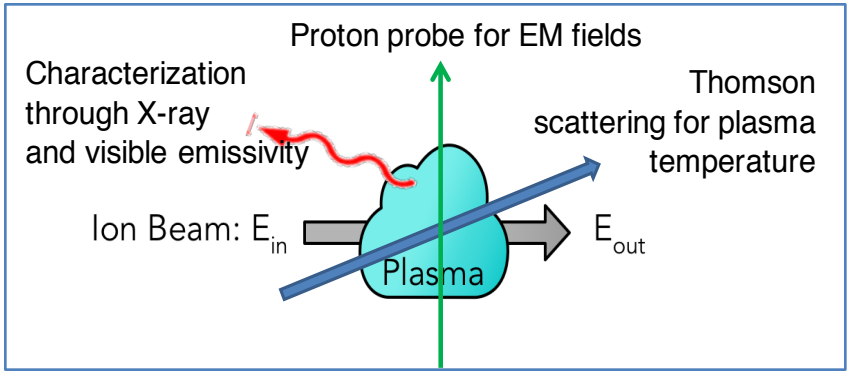
Energy transferred can vary by more than 50% depending on the model used

Need: Multiple laser beams and high energy ion beams with high particle density

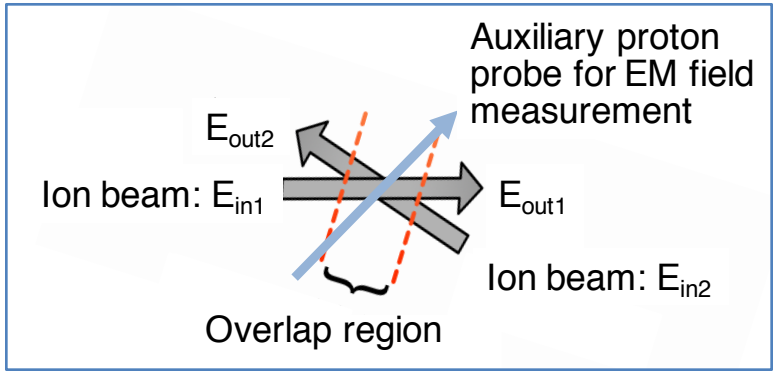
Ion beam interaction with a hot plasma

$v_b >> v_{th}$

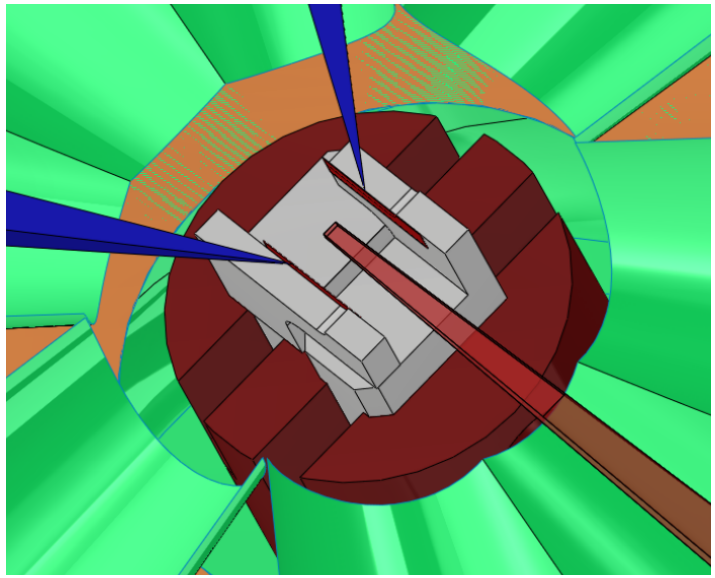


Counter-streaming ion beams

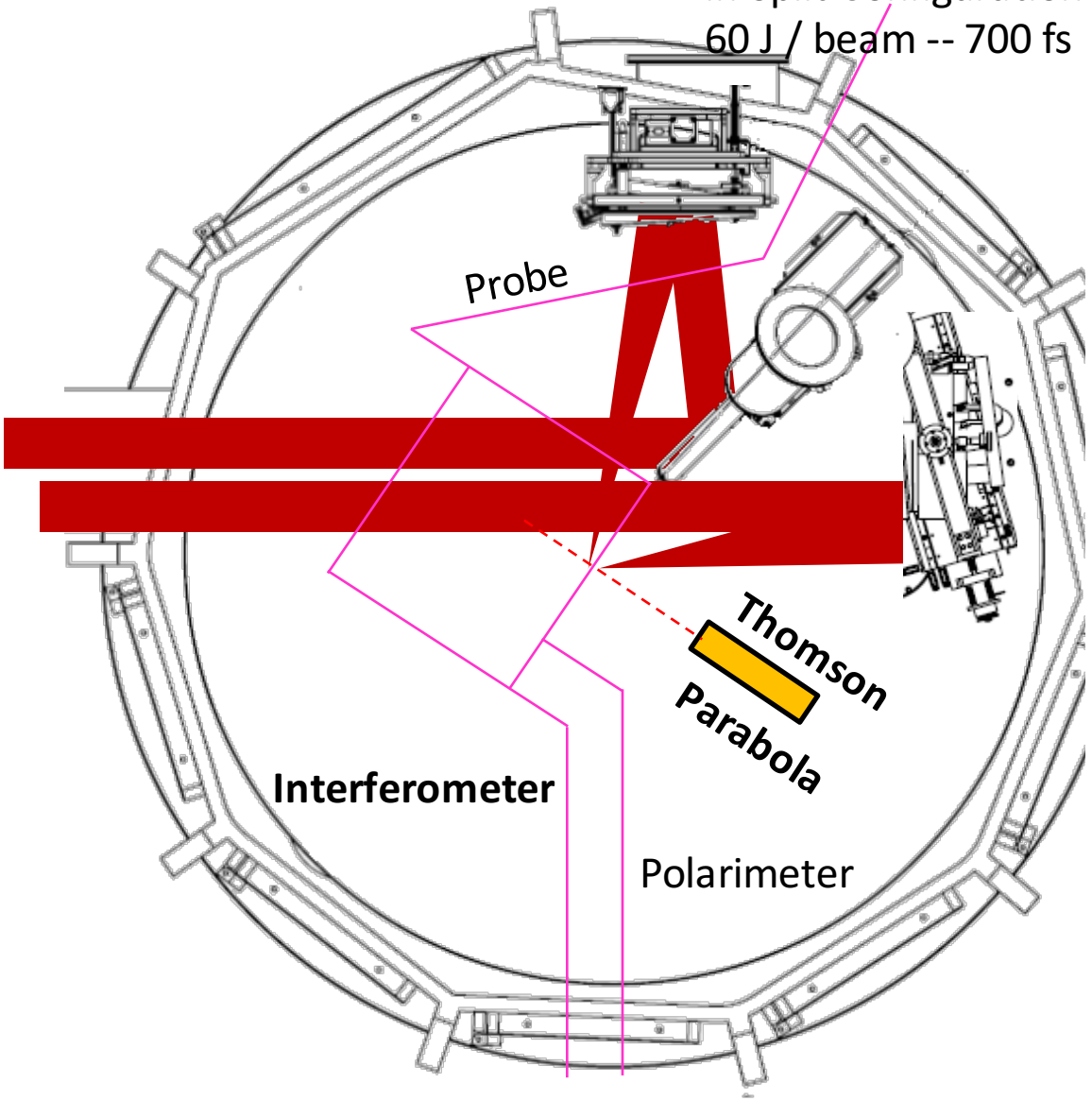
$v_{b1} = -v_{b2}$



The Titan Laser in Split Configuration Provides Double TNSA beam Production



Titan Laser
in Split Configuration
60 J / beam -- 700 fs



Apollon with the multiple high intensity beams is the ideal facility to perform experiments

- Experimental verification of the predicted stopping power of protons in a plasma
- Study collisionless ion energy transfer mechanism to a plasma through instabilities on the way to studying collisionless shocks in the future

- Apollon offers
  - Multiple beams
  - High power/intensity = high density/energy ion beams
  - Versatile experimental chamber
  - High rep-rate