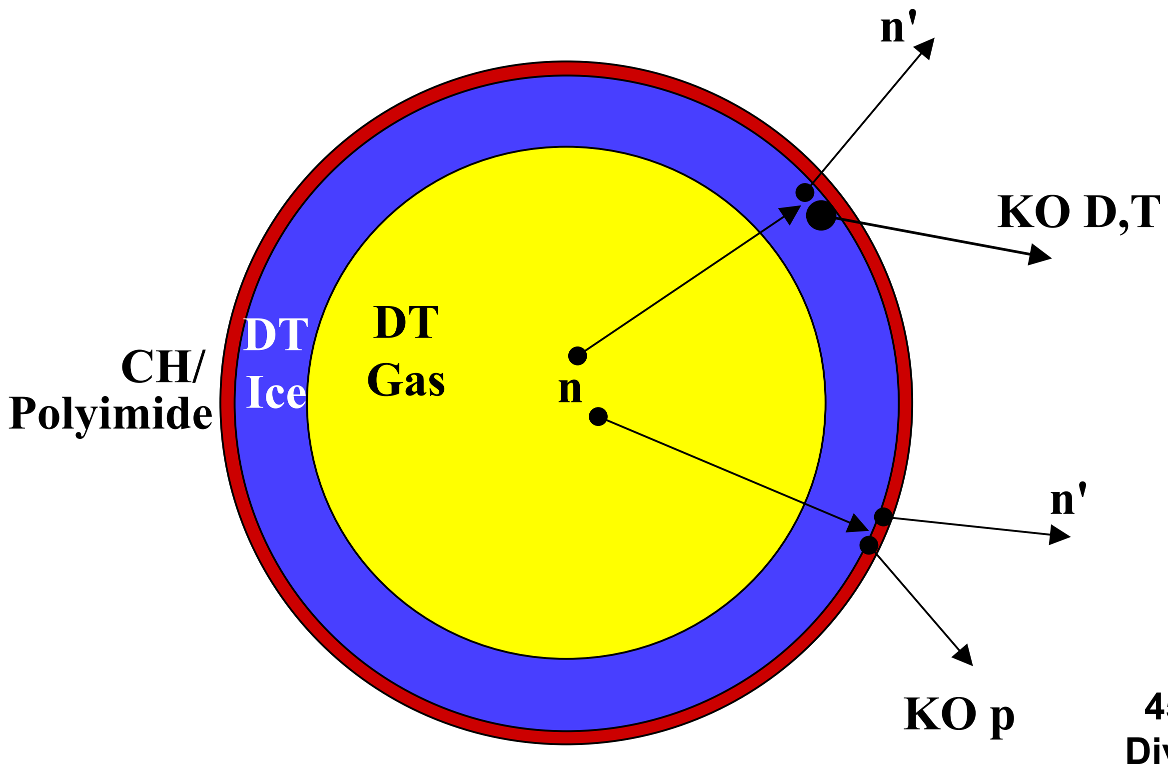
Diagnosing DT Cryogenic Fizzles at the NIF:

Using Charged-Particle Spectrometer (CPS) Measurements of Knock-on D, T, & p and Magnetic Recoil Spectrometer (MRS) Measurements of Down-scattered Neutrons



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Summary

- The ablator areal density ($\rho R_{ablator}$) of DT cryogenic capsules at the NIF can be characterized using charged-particle spectrometry of knock-on (KO) particles

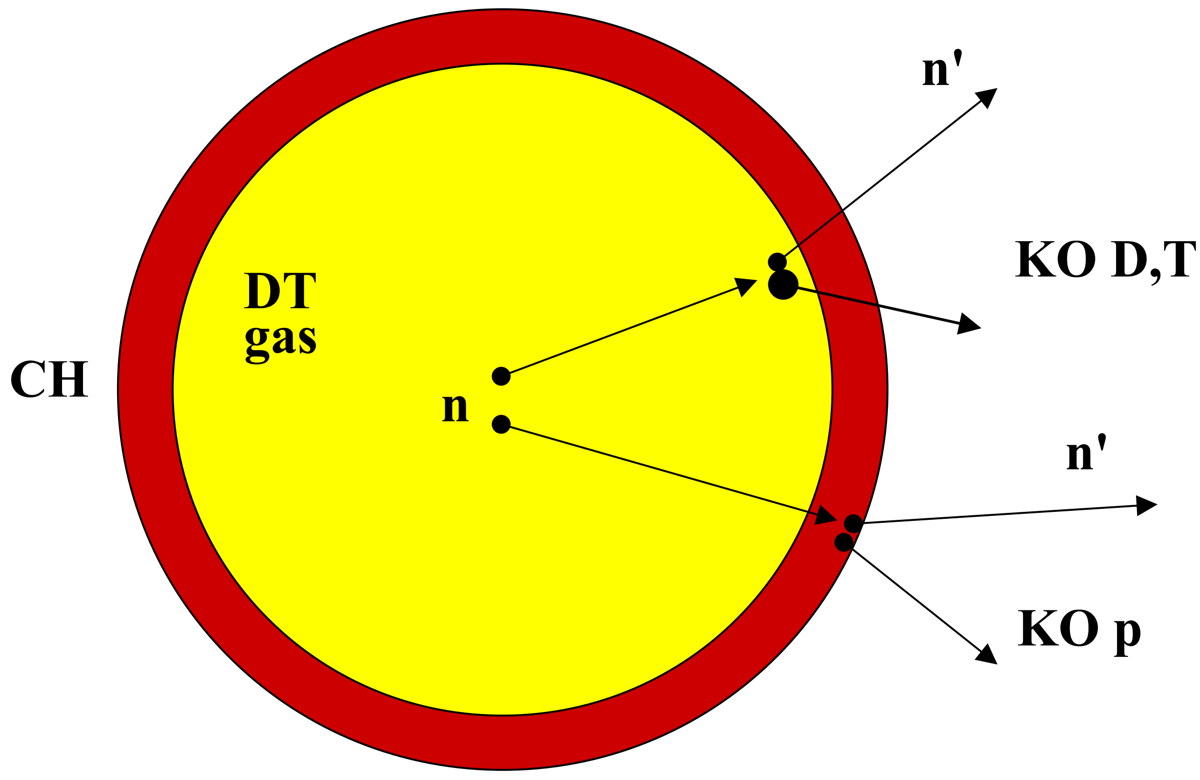
- An accurate determination of the total areal density (ρR_{total}) of these same capsules can be obtained from the MRS through spectral measurements of down-scattered primary neutrons

- Combining the information obtained from these two techniques, failure modes can be diagnosed

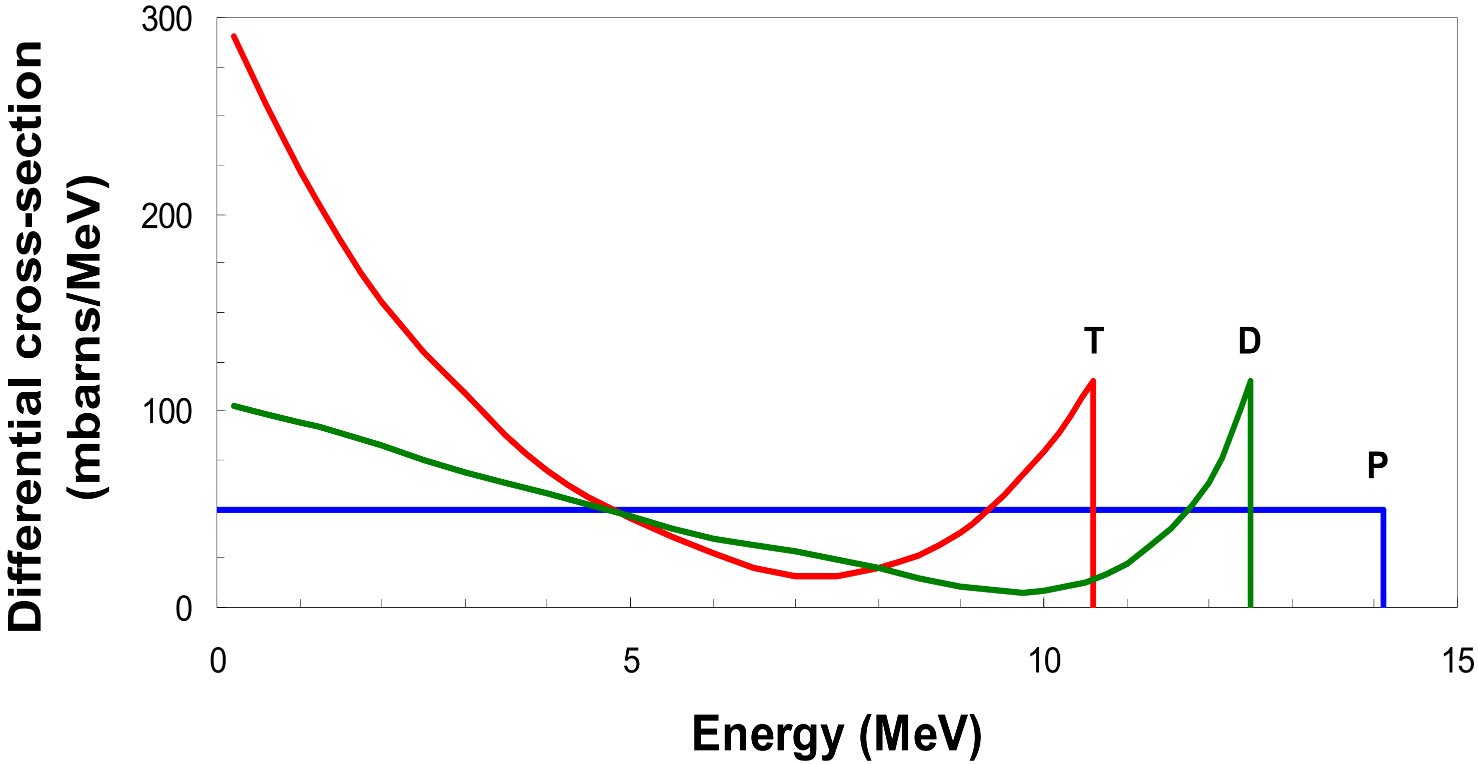
Outline

- CPS for KO spectrometry
  - Measurement
  - Diagnosing capsules at OMEGA
  - Diagnosing $\rho R_{ablator}$ at the NIF
- MRS for neutron spectrometry
  - Measurement
  - Diagnosing ρR_{total} at the NIF
- Simultaneous use of CPSs and the MRS to elucidate the physics behind fizzles at the NIF

Knock-ons are fuel and shell ions which are elastically scattered by DT neutrons

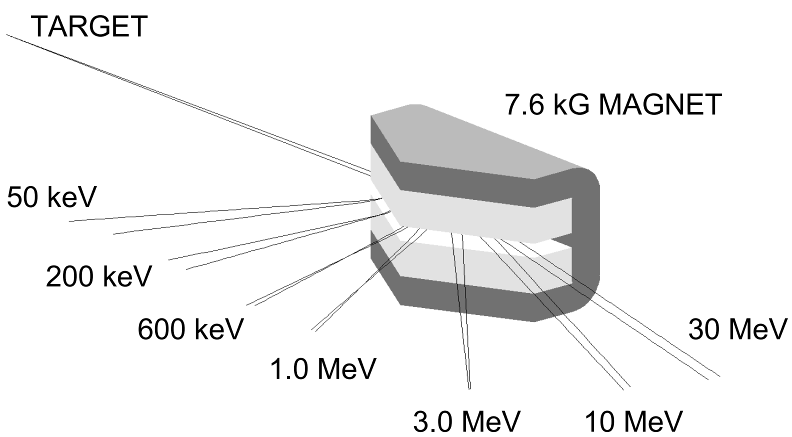


KO birth spectra are defined by the differential cross-section for neutron scattering off each particle type



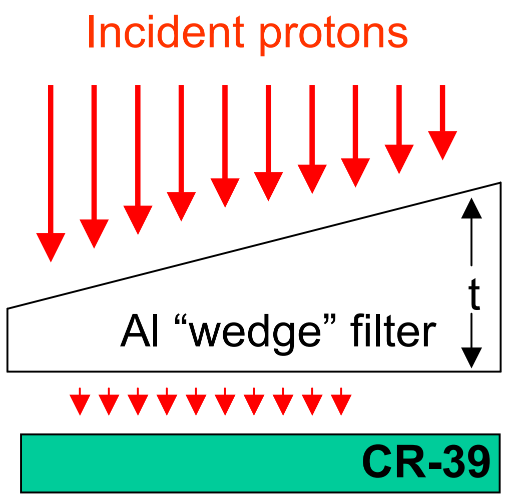
Two types of charged-particle spectrometers are used for measurements of KO spectra

Magnet-based Spectrometers (CPSs)



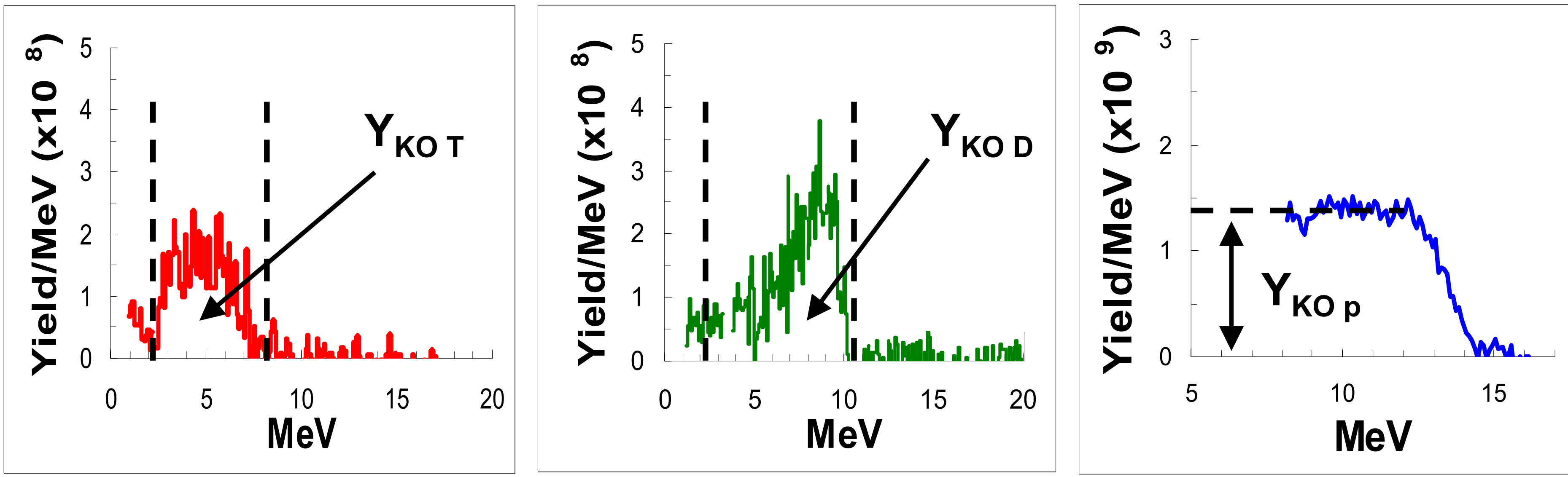
Particle energies identified from trajectories.

"Wedge-Range-Filter" Spectrometers (WRFs)



Particle energies identified from local thickness t and diameter of etched proton tracks in CR-39.

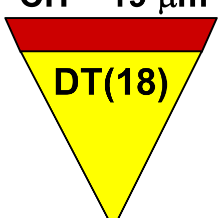
$\rho R_{ablator}$ is determined from the KO p yield, while ρR_{fuel} is determined from the KO D or T yield



$$\rho R_{fuel} \propto Y_{KO\ D,T} / (\sigma^{eff}_{D,T}\ Y_{1n})$$

$$\rho R_{ablator} \propto Y_{KO\ p} / (\sigma^{eff}_{p}\ Y_{1n})$$

CH ~ 19 μm



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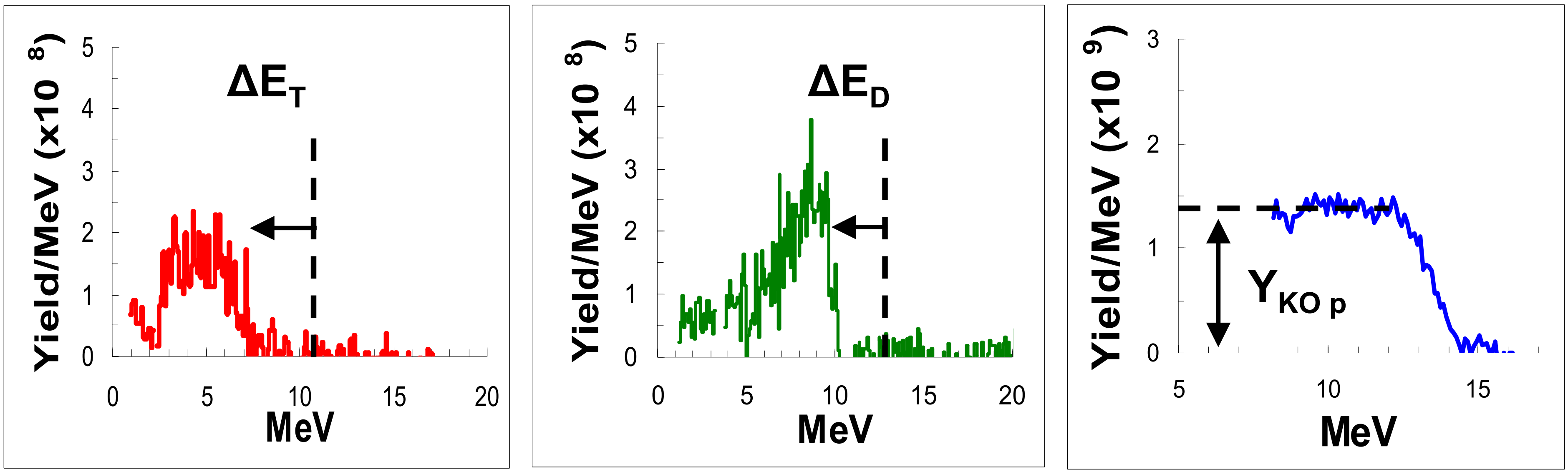
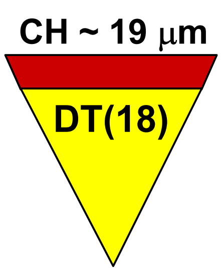
ρR_{total} is inferred from the downshift of the KO D or T and, together with KO p data, ρR_{fuel} is determined



$$\rho R_{fuel} = \rho R_{total} - \rho R_{ablator}$$



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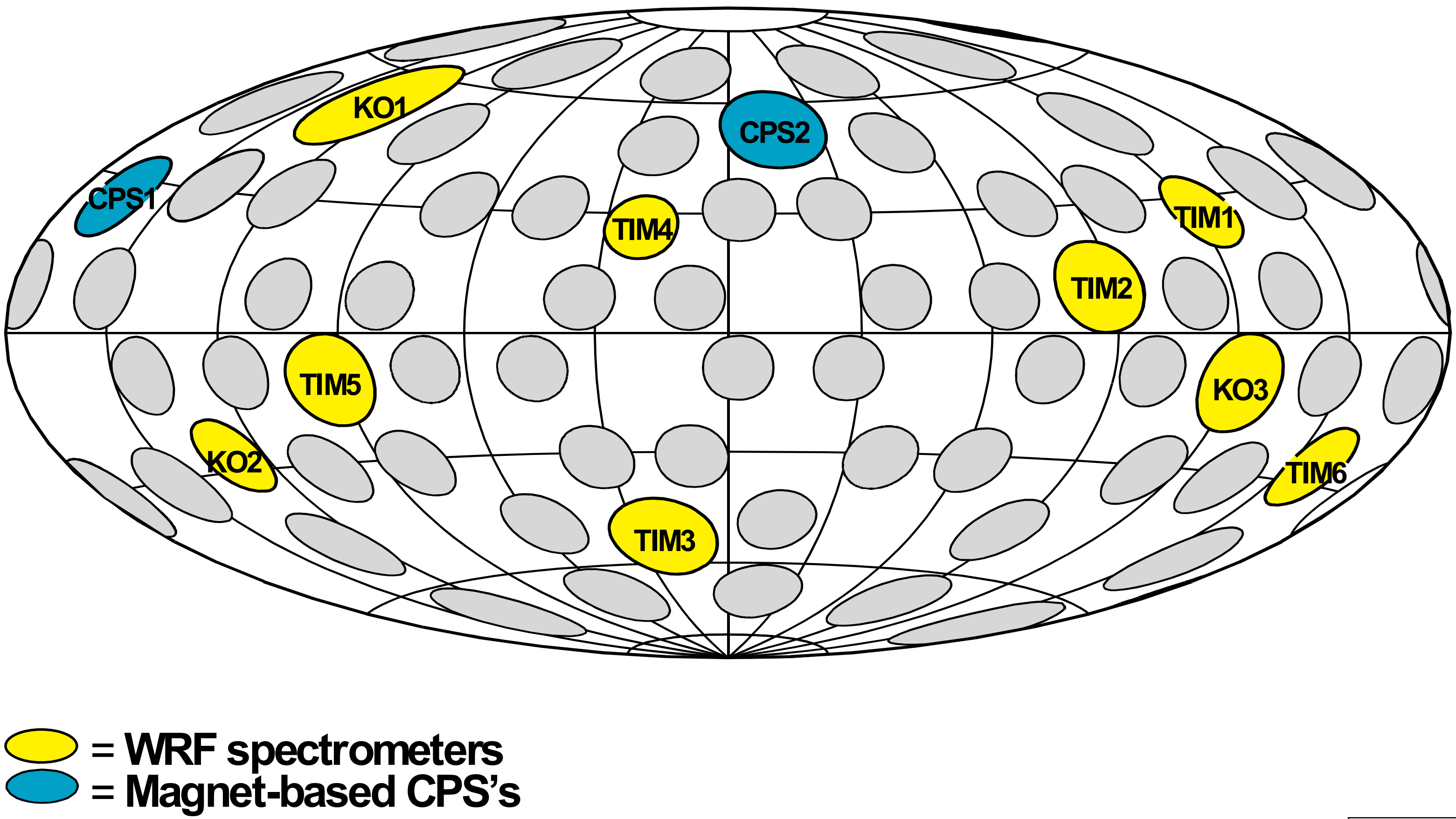
$\rho R_{ablator}$ asymmetries are studied using simultaneous measurements of multiple KO p spectra

OMEGA target chamber



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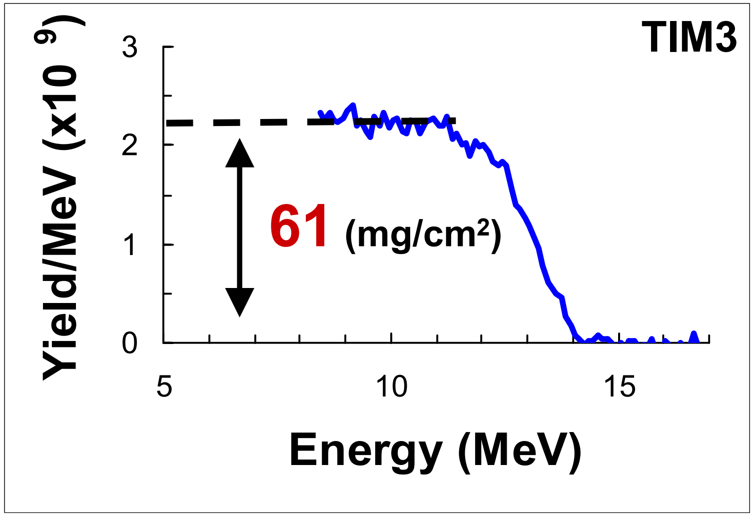
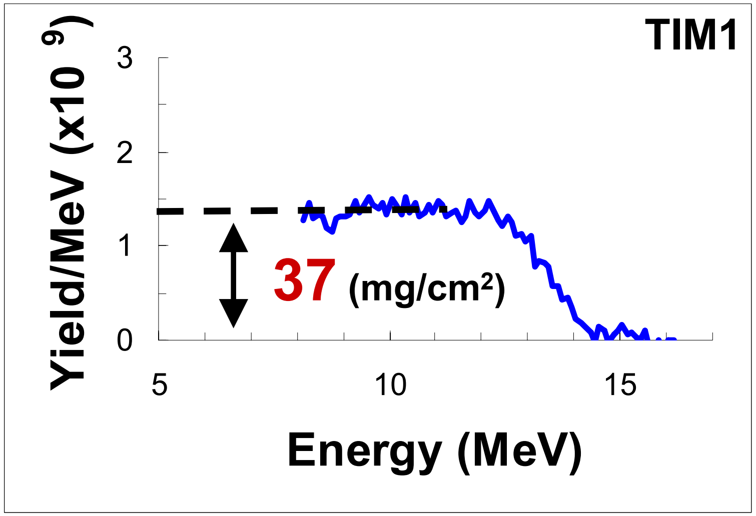
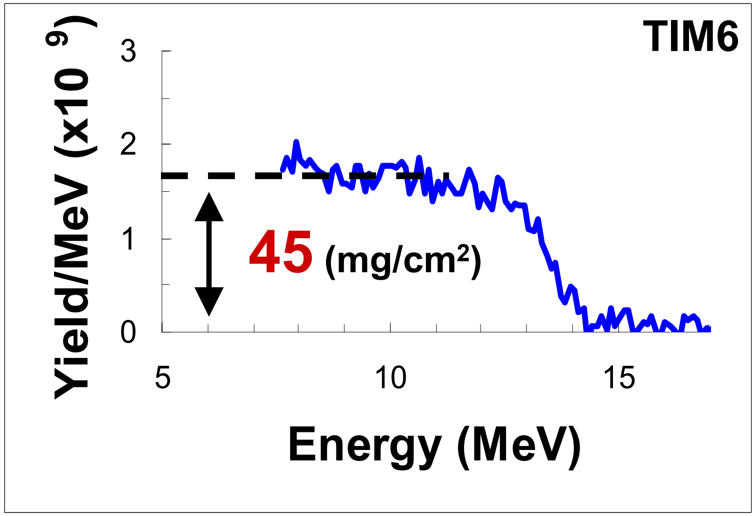
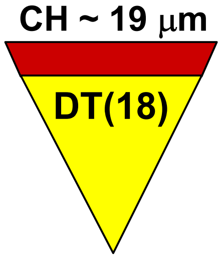
$\rho R_{ablator}$ asymmetries are studied using simultaneous measurements of multiple KO p spectra









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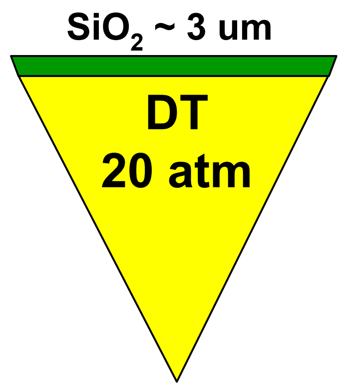
The KO D & T spectra extend to their theoretical maximum energies if little ablator remains at bang time



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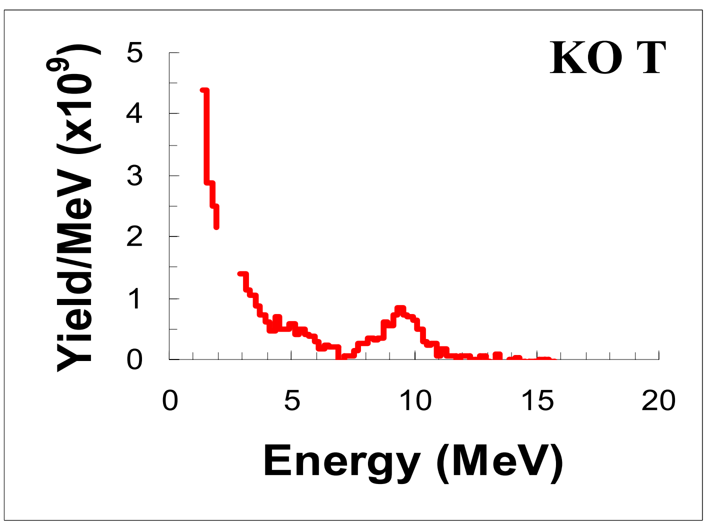
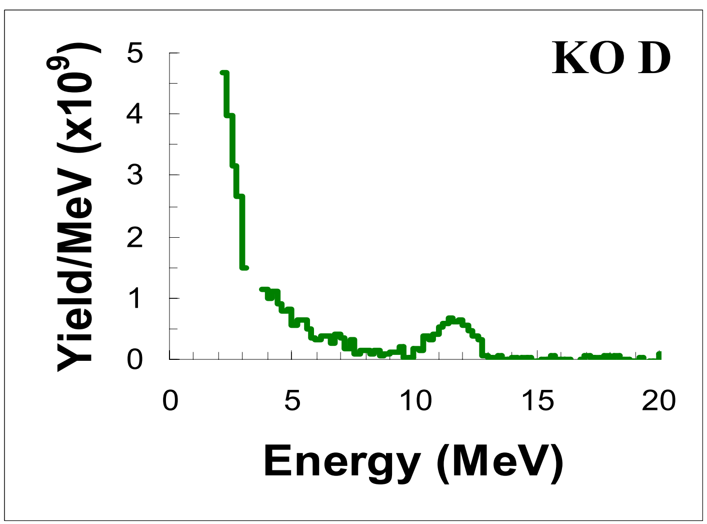
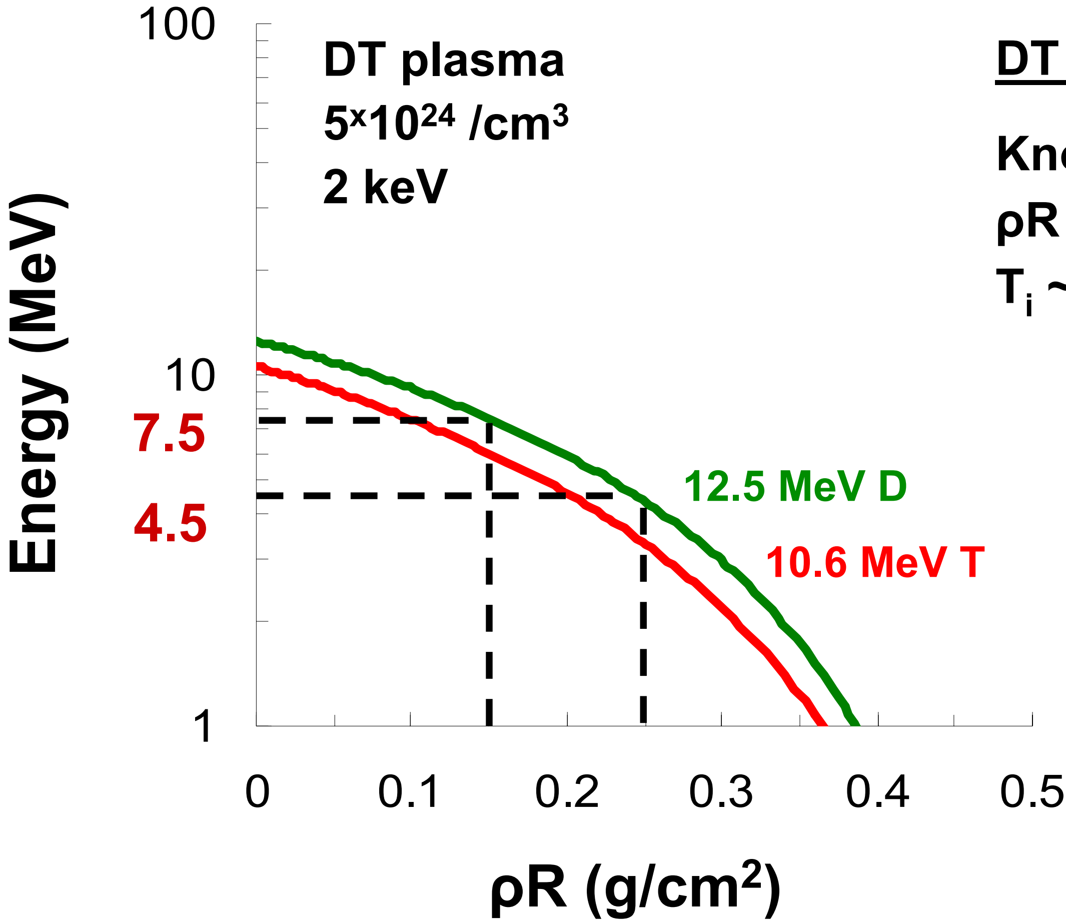




KO D will escape OMEGA cryogenic capsules with energies high enough to provide ρR measurements



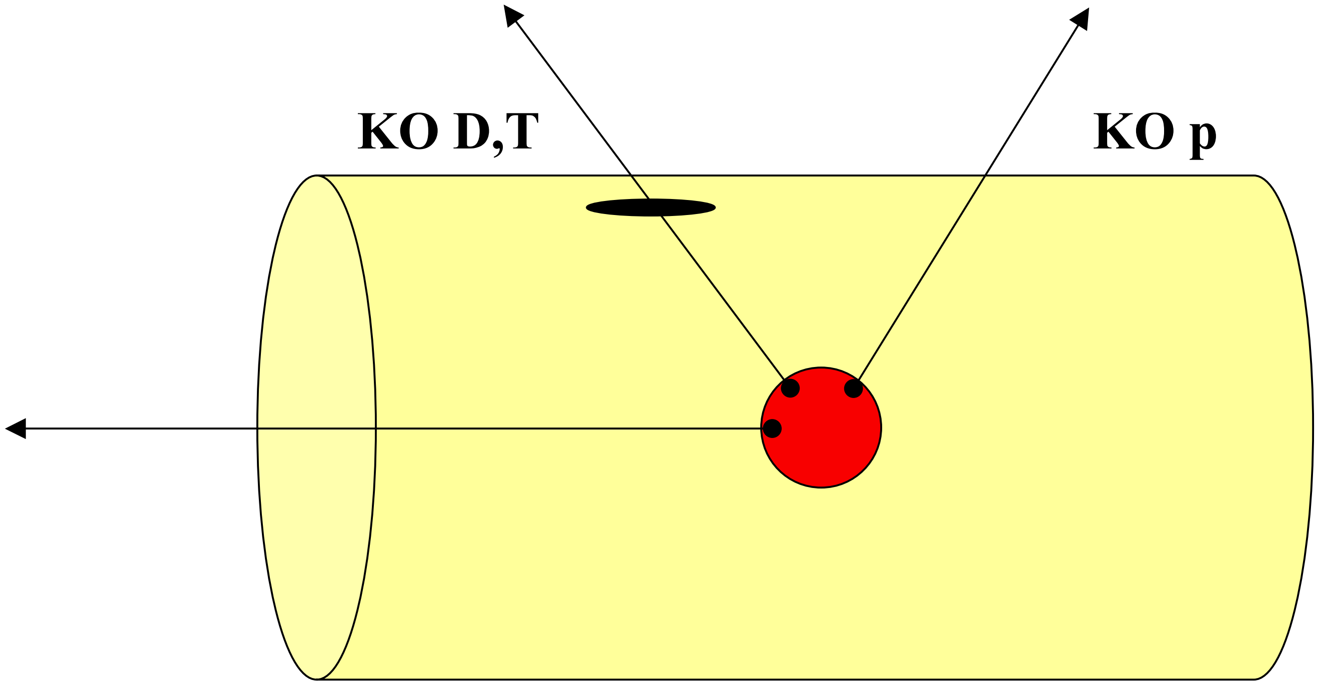
DT cryogenic targets:

Knock-on yields ≥ 2×10^{11}
ρR ~ 150-250 mg/cm²
T_i ~ 2-4 keV

KO spectrometry can be implemented on NIF indirect drive implosions

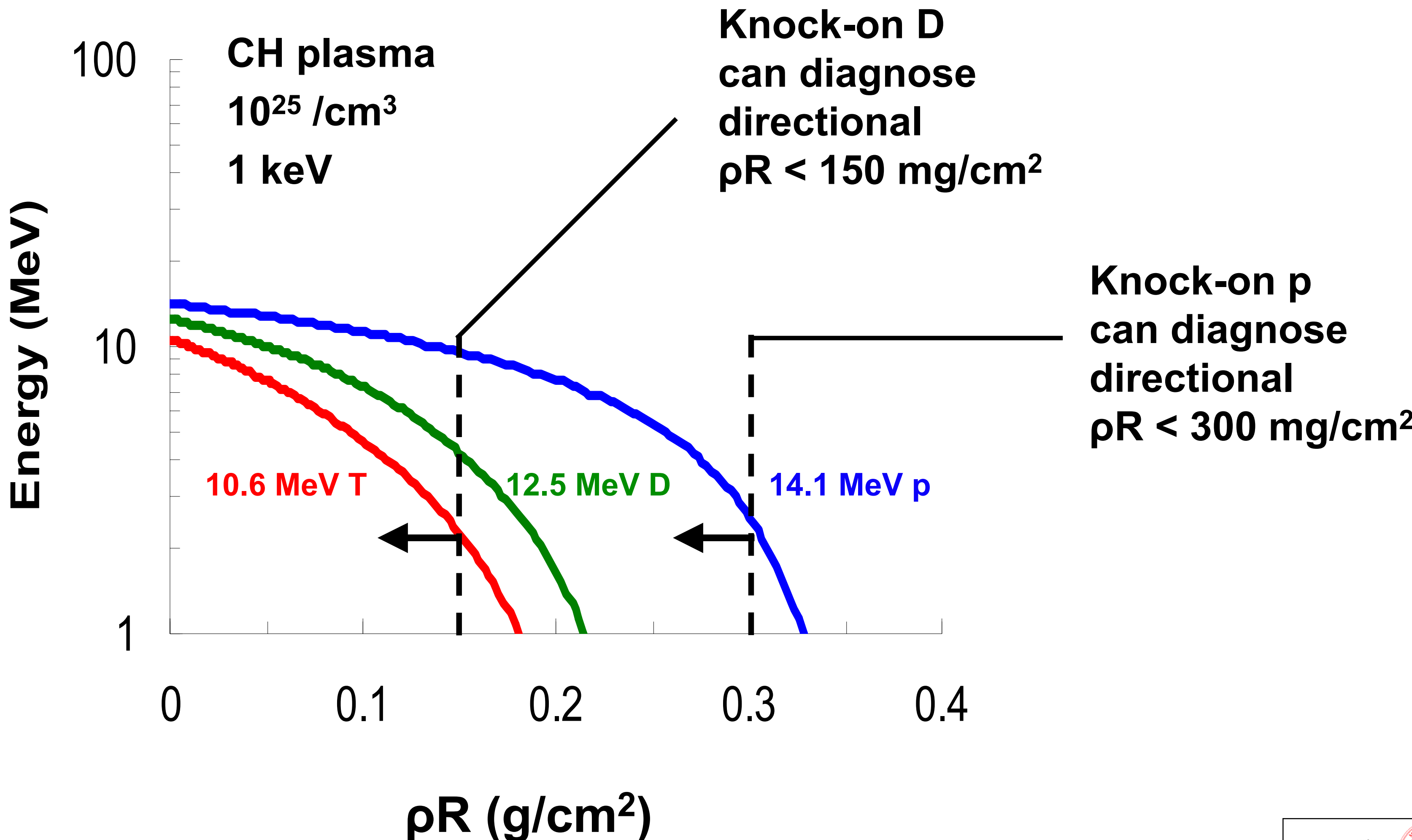
KO D & T can be detected through a diagnostic hole

KO protons of interest easily penetrate the capsule and hohlraum*

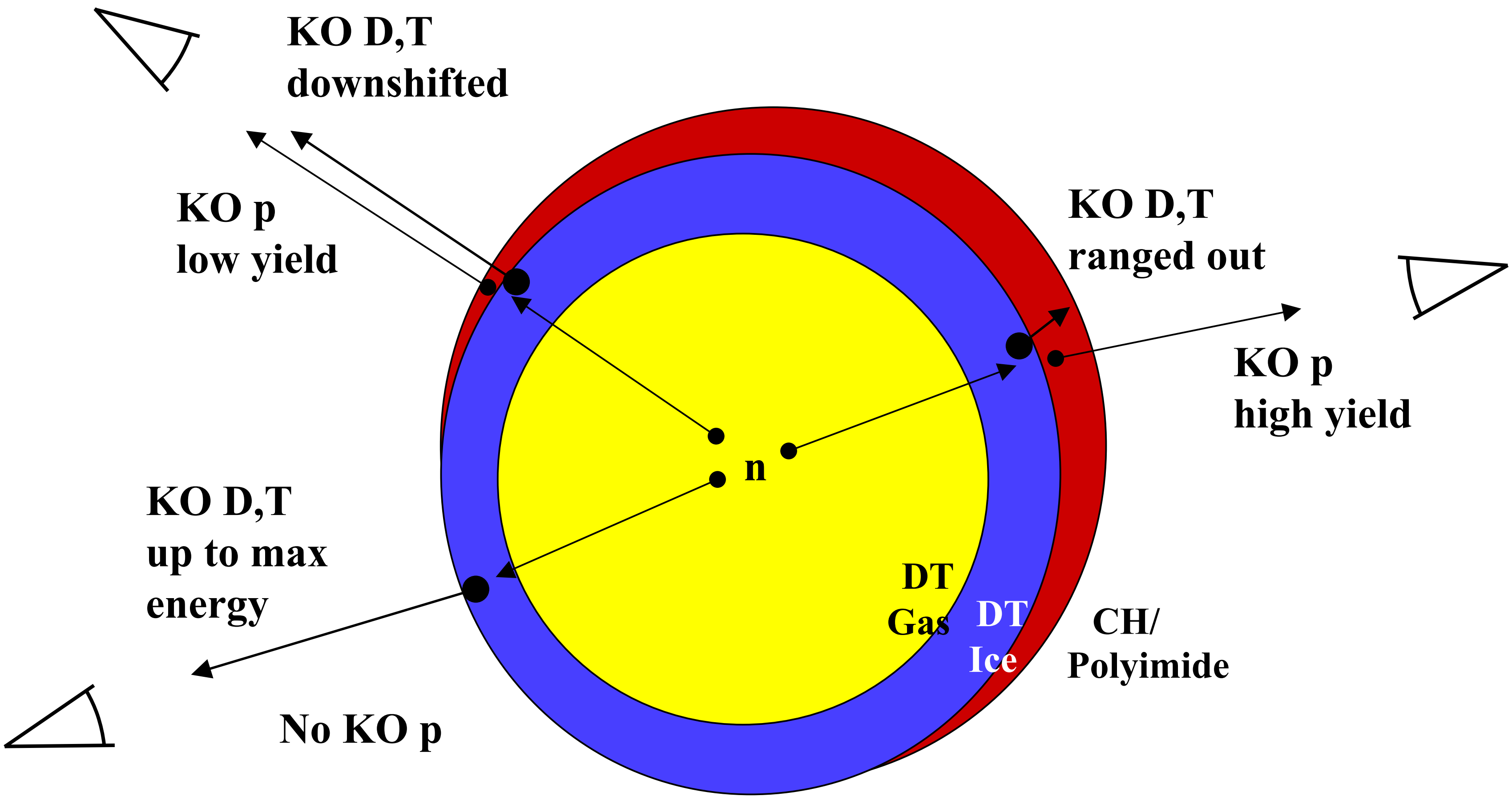


*C.K. Li et al. CO2.012

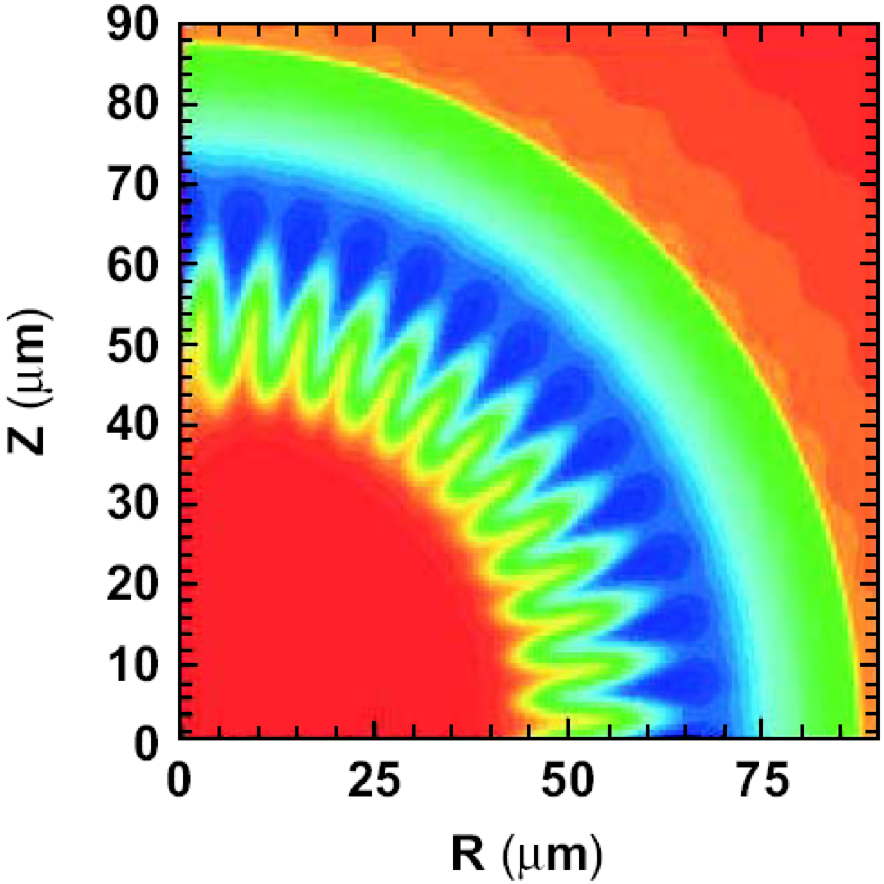
For many NIF failure modes, KO D, T, & p can characterize $\rho R_{ablator}$



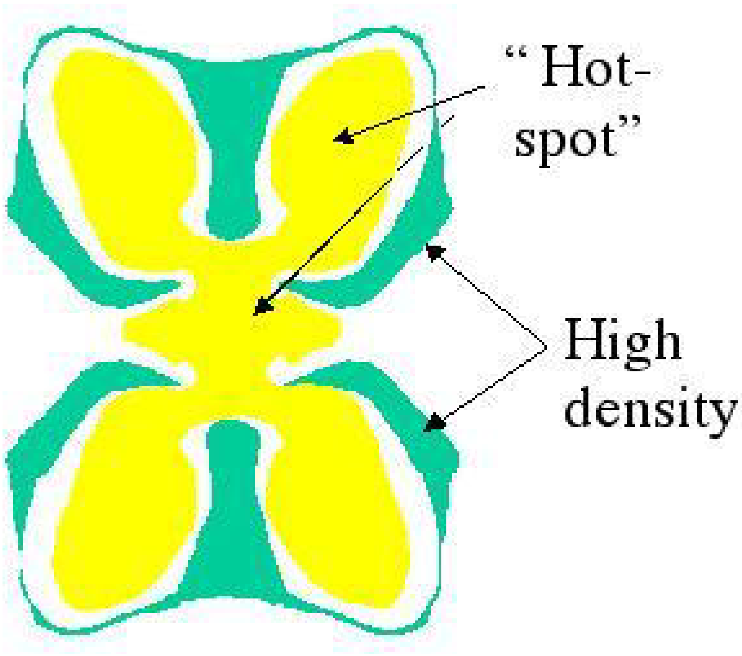
Asymmetries in $\rho R_{ablator}$ can be identified and quantified with KO spectra



Knock-ons can help to distinguish drive asymmetry from mix for NIF fizzles



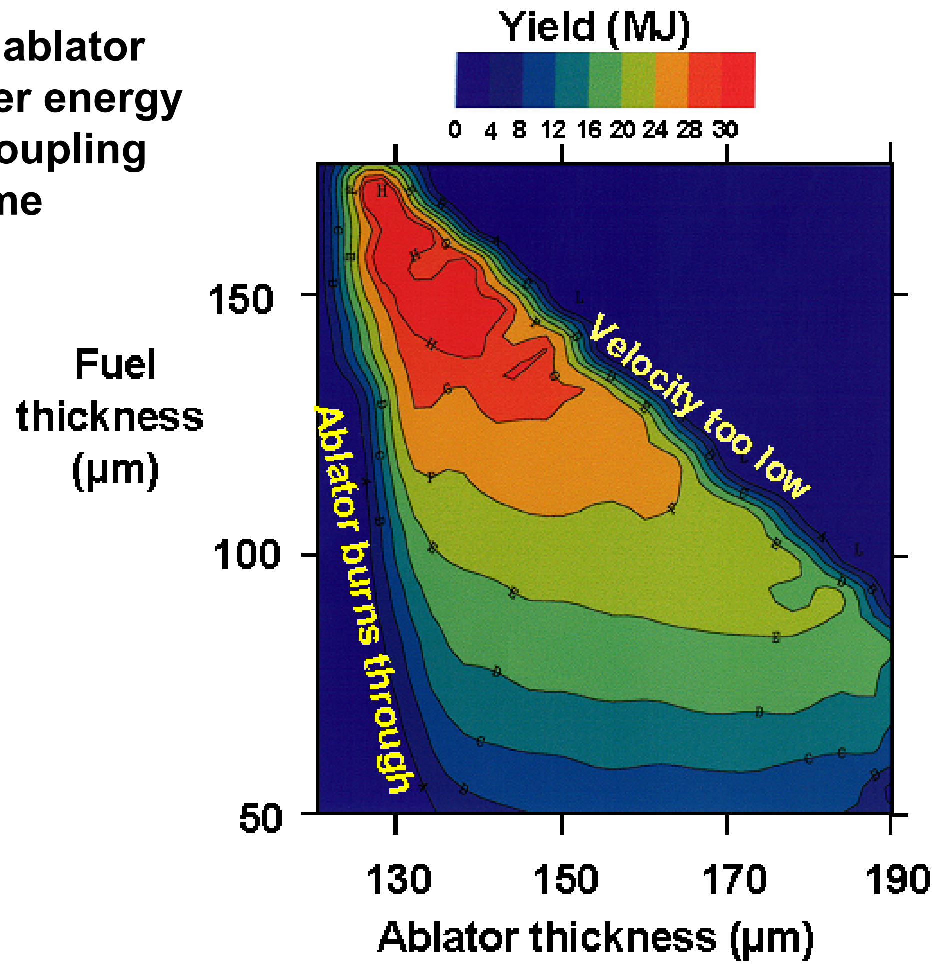
R. Betti (LLE)



S. Haan (LLNL)

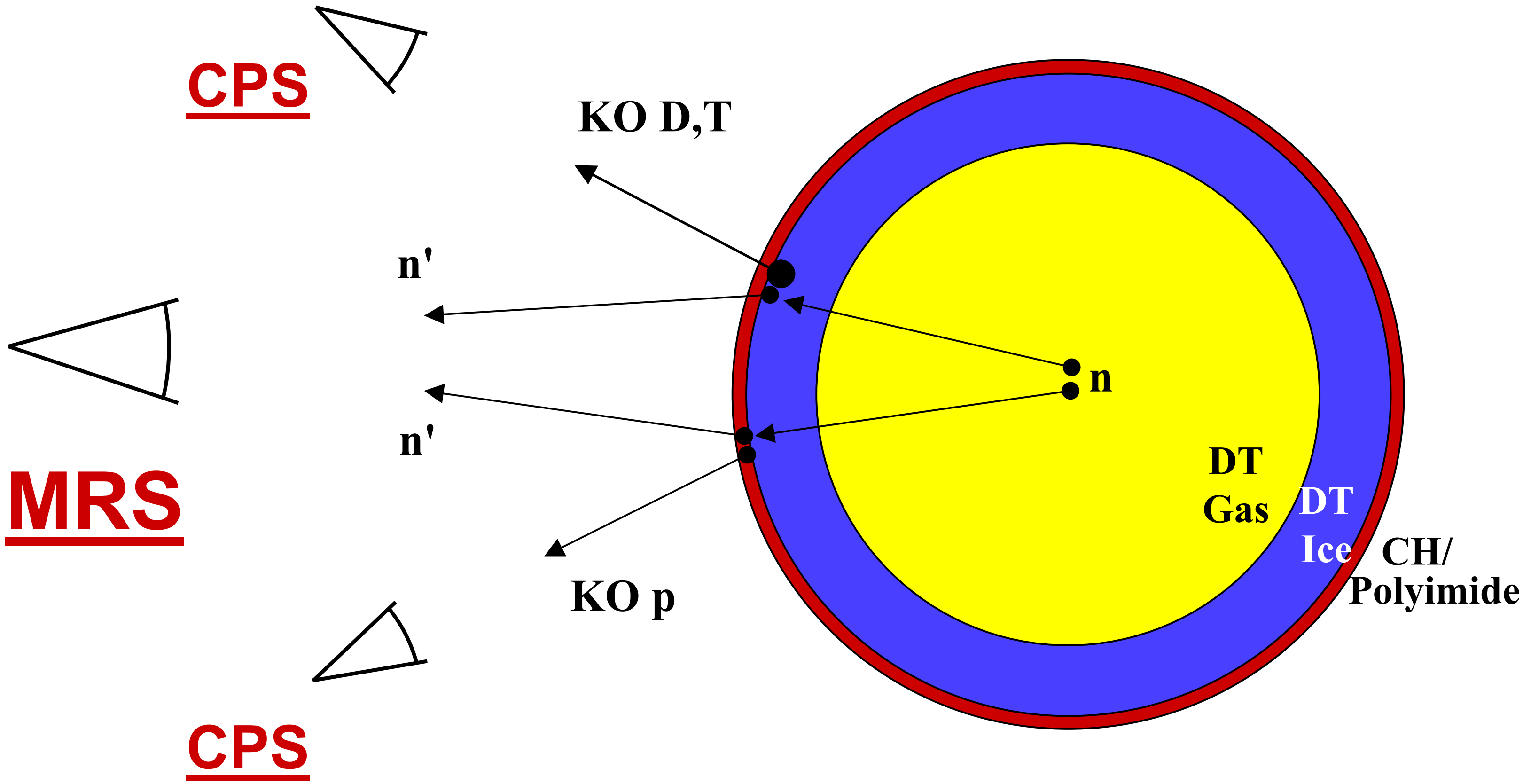
For the NIF, both $\rho R_{ablator}$ and ρR_{fuel} will directly reflect the quality an implosion

Polyimide ablator
1.3 MJ laser energy
Nominal coupling
Ignition time



Calculated by M. Hermann (LLNL)

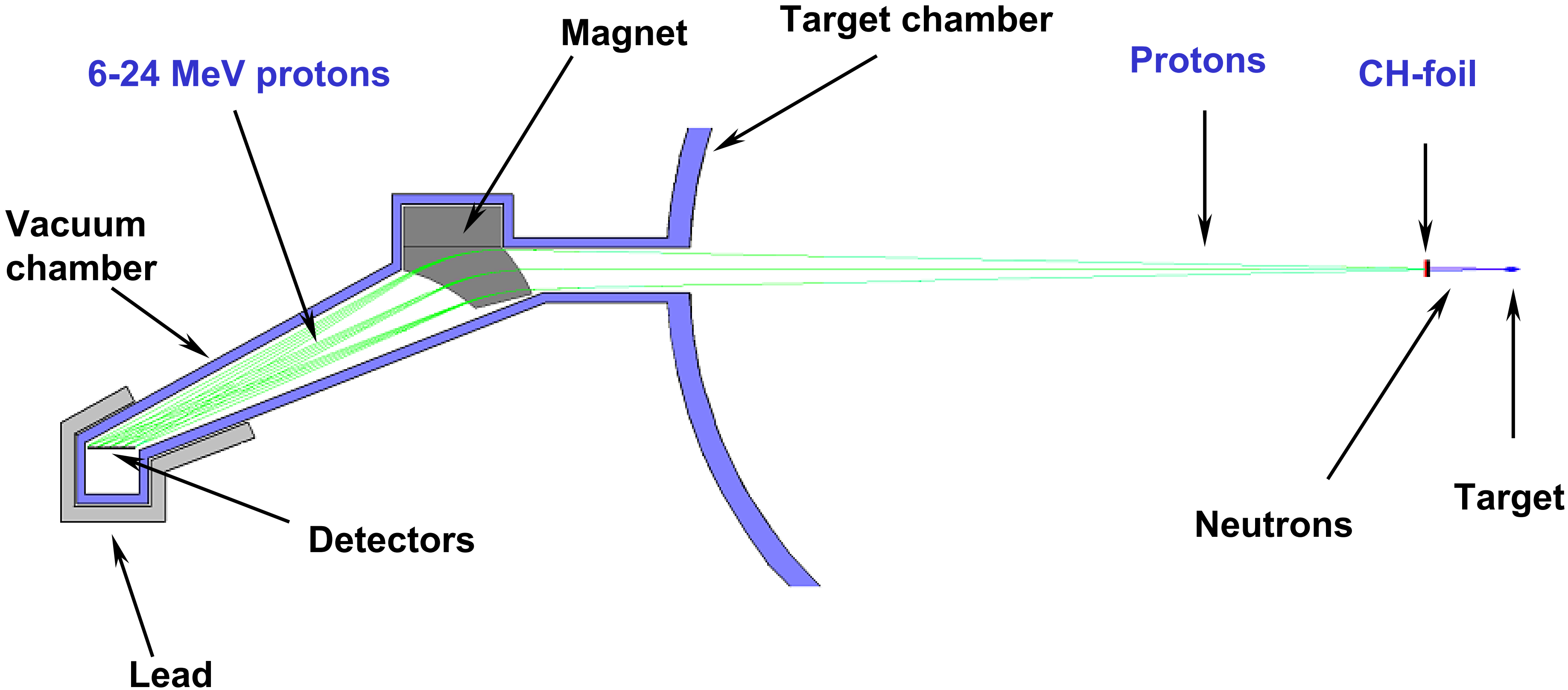
The ρR_{fuel} of NIF fizzles can be inferred from MRS* measurements along with CPS data



$$\rho R_{fuel} = \rho R_{total} - \rho R_{ablator}$$

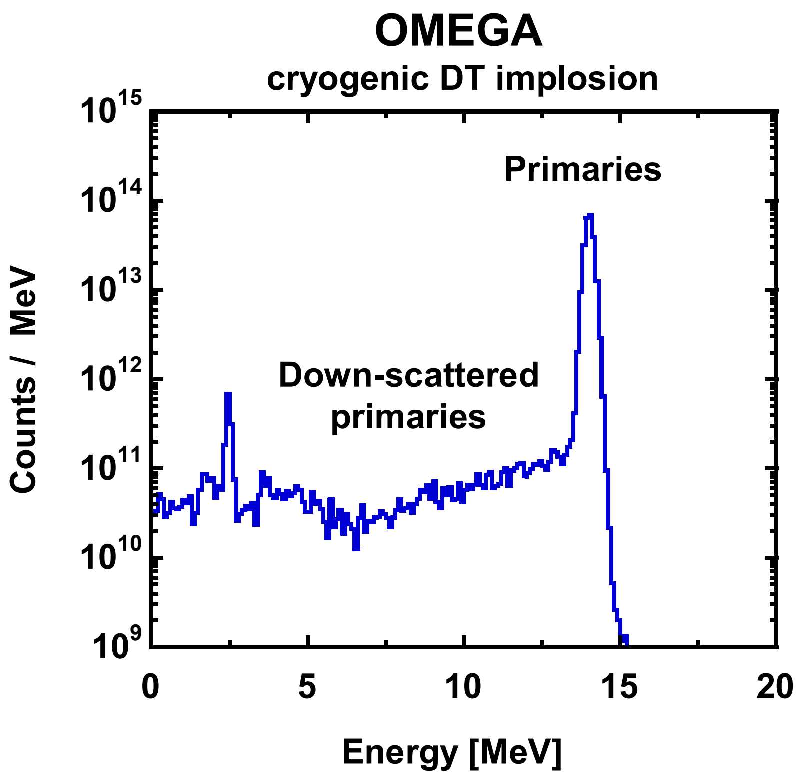
*J. A. Frenje et al. QP1.153

The MRS will reconstruct the down-scattered neutron spectrum to infer ρR_{total}



MRS principle

The yield of down-scattered neutrons ($Y_{n'}$) is directly proportional to ρR_{total}

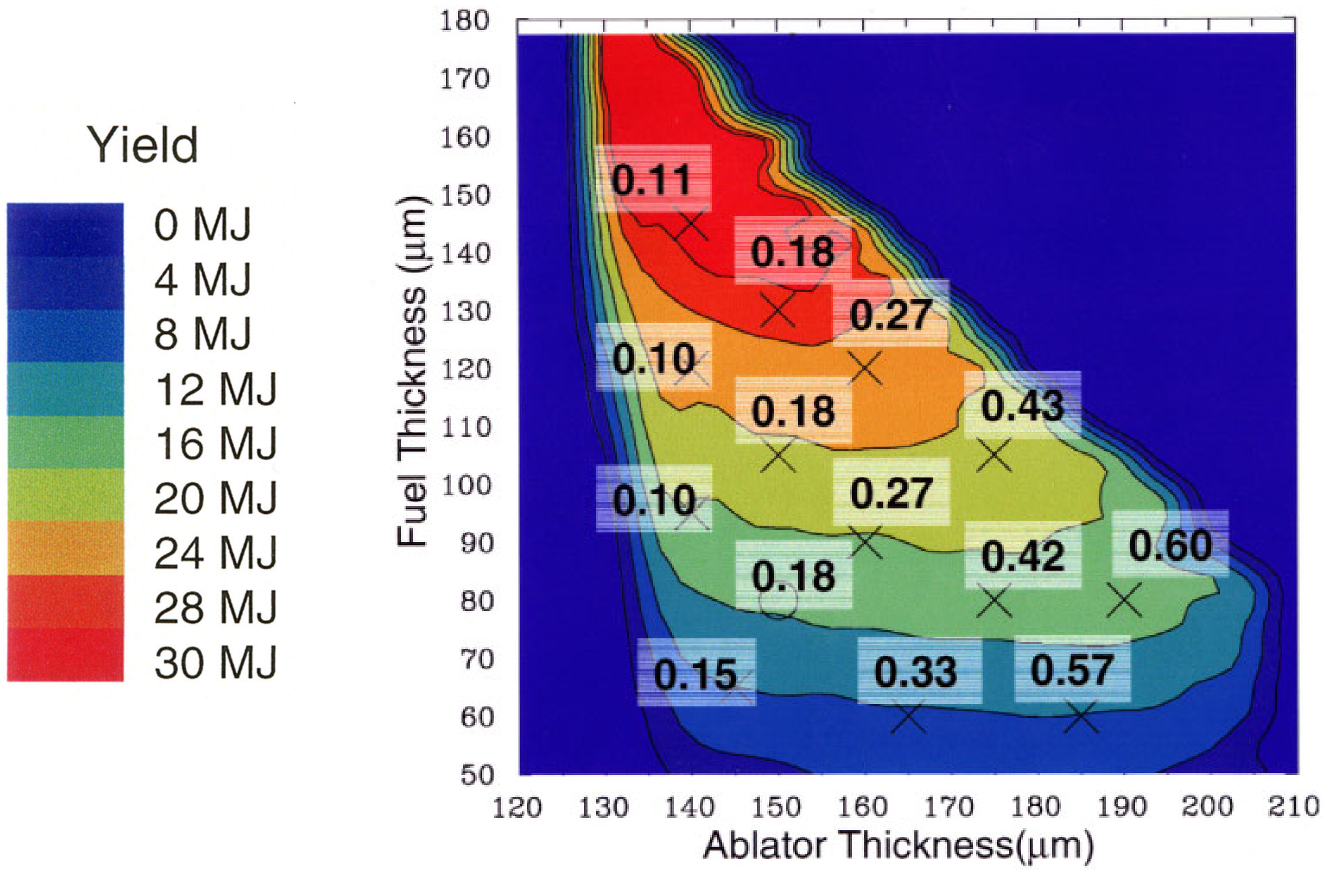


Calculated by S. Hatchett (LLNL)

$$Y_{n'} \propto (\sigma_D + \sigma_T + \sigma_C + \sigma_p)\, \rho R_{total}\, Y_{1n}$$

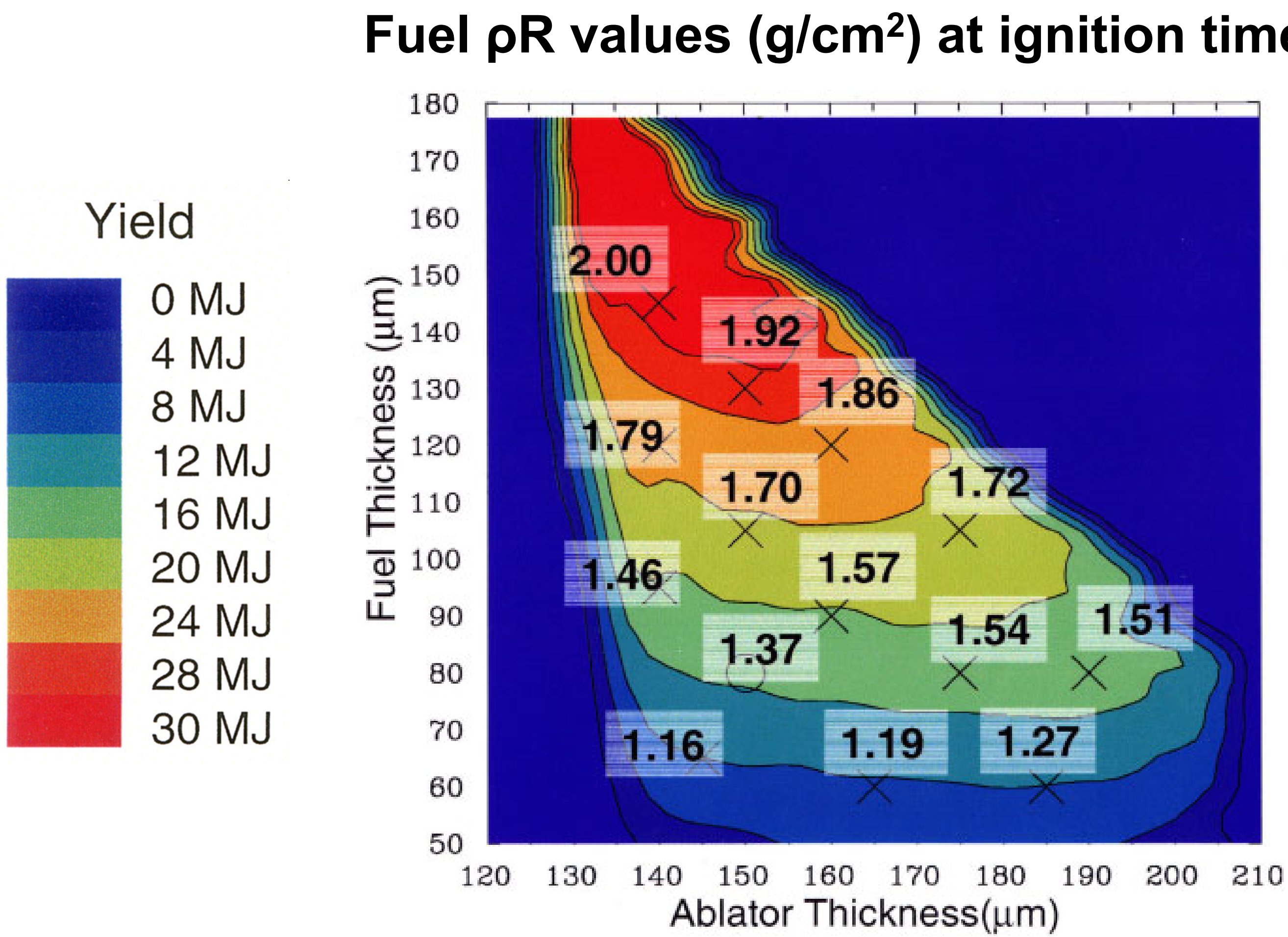
The $\rho R_{ablator}$ of many NIF fizzles can be inferred from CPS measurements

Ablator ρR values (g/cm²) at ignition time



Calculated by M. Hermann (LLNL)

The ρR_{fuel} of NIF fizzles can be inferred from MRS measurements along with CPS data



Calculated by M. Hermann (LLNL)

Together, CPS and MRS can uniquely determine where an implosion lies in this parameter space.

This information will help to diagnose failure modes on the NIF.

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