Numerical Modeling of PCCI Combustion

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PCCI = Premixed Charge Compression Ignition

Combustion regime in between Mixing-Controlled Diesel ignition and truly homogeneous HCCI

Stratification can exist but fuel-air mixing and ignition are distinct independent processes, like HCCI combustion

Not constrained to be fully homogeneous

Representative of port-injection, early direct injection

Chemical kinetics dominates autoignition in HCCI and PCCI engines

Advantage:

Well validated detailed chemical kinetic mechanisms available to predict autoignition for many fuels

Disadvantage:

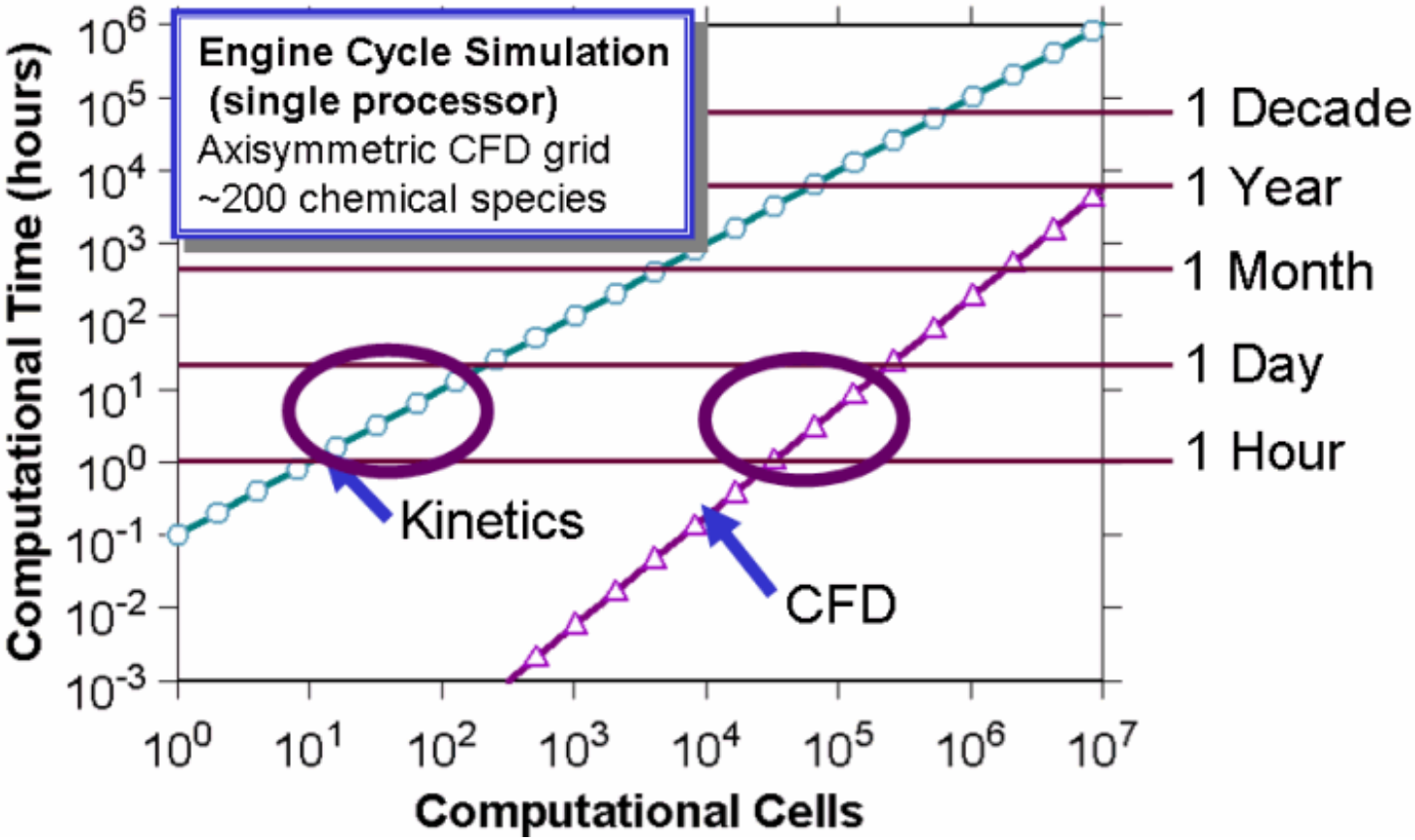
Solutions chemical kinetic systems are computationally intensive

High resolution CFD with detailed chemistry at every grid point exceeds capability of today's computers

Possible Approaches:

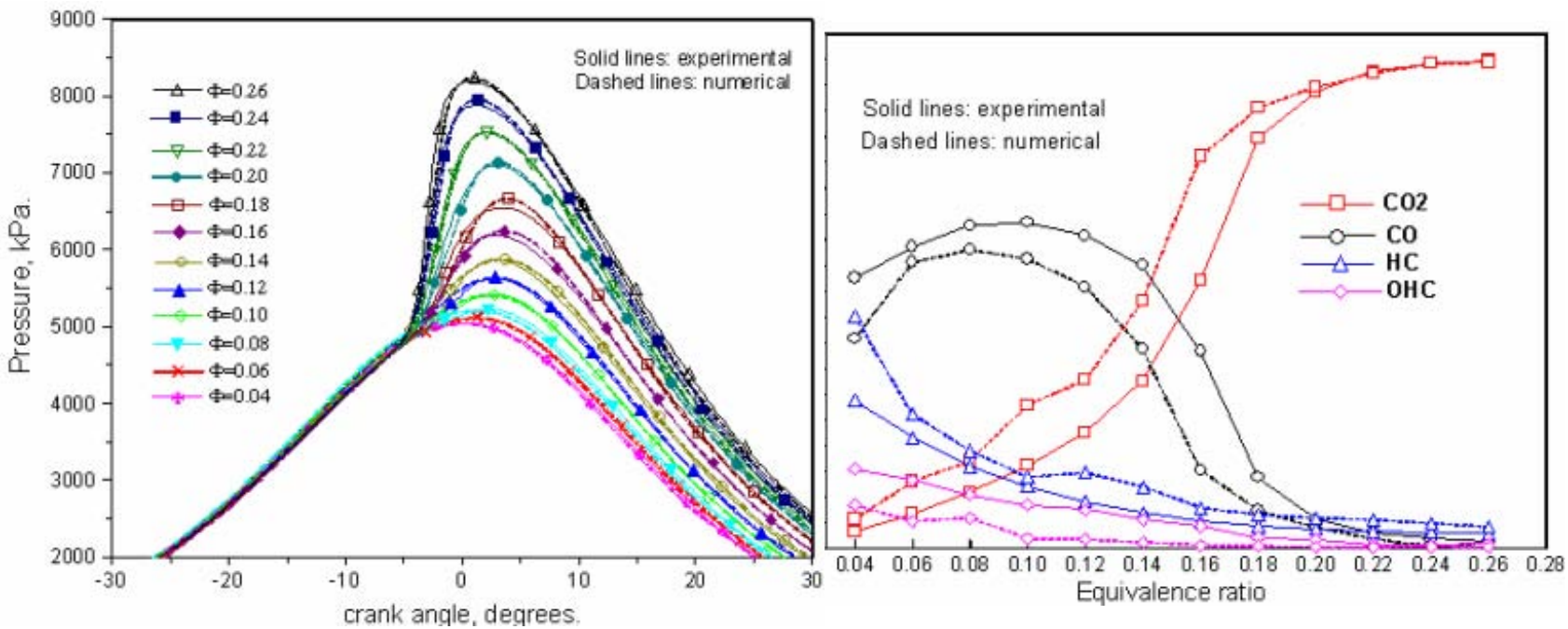
Few grid points for CFD and Chemistry

Many grid points for CFD, a few grid points for chemistry (Our approach)
- works when chemistry and turbulence weakly interact (e.g., HCCI)



For truly homogeneous "HCCI" engines we have developed method to accurately predict multidimensional combustion

Uses high resolution CFD and detailed chemical kinetics in a computationally efficient manner

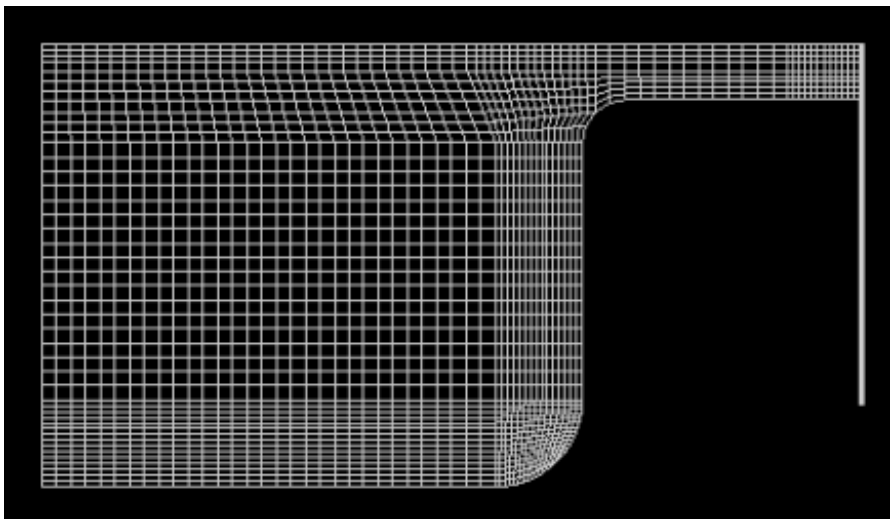


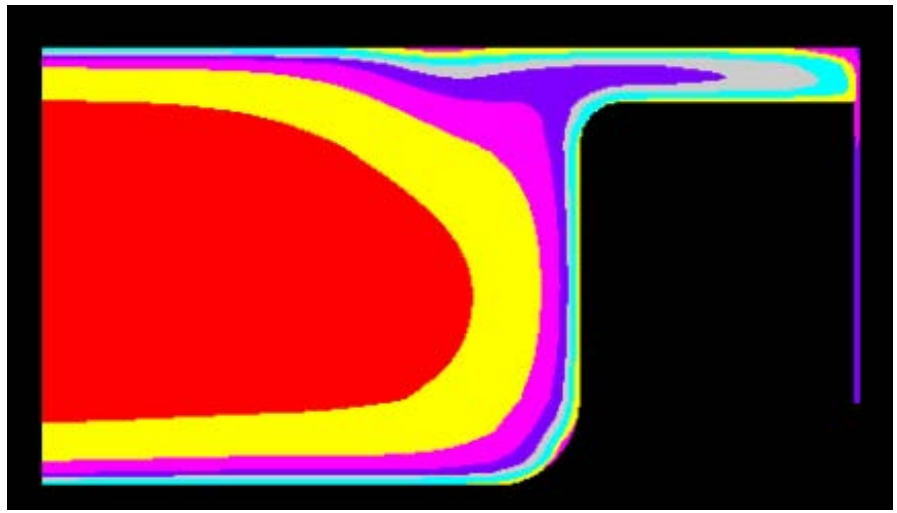
But great interest in partially stratified "HCCI" for better control and higher power output (PCCI)

Simulation of PCCI systems: Developing new fully integrated KIVA and detailed chemical kinetics model

High resolution CFD solver handles mixing, advection and diffusion

Chemistry handled by multi-zone detailed kinetics solver





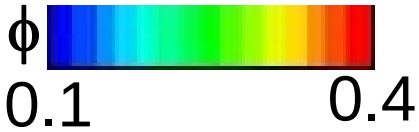
Solutions are mapped back and forth between solvers throughout the cycle

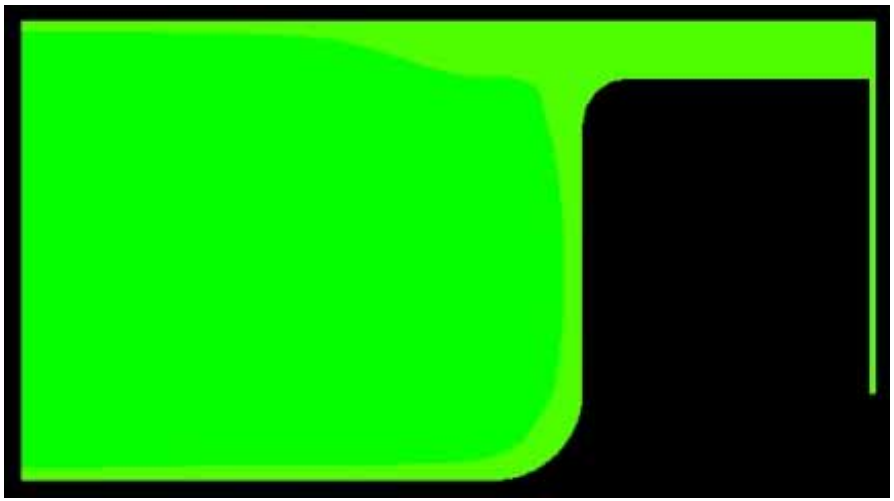
Effective, but greater complexity from the mapping between back and forth between the models

We are studying effect of stratification on PCCI combustion with a gasoline-like fuel (isooctane)

Example: Homogeneous versus mild stratification (biased towards centerline of combustion chamber)

IVC temperature, pressure, overall equivalence ratio the same



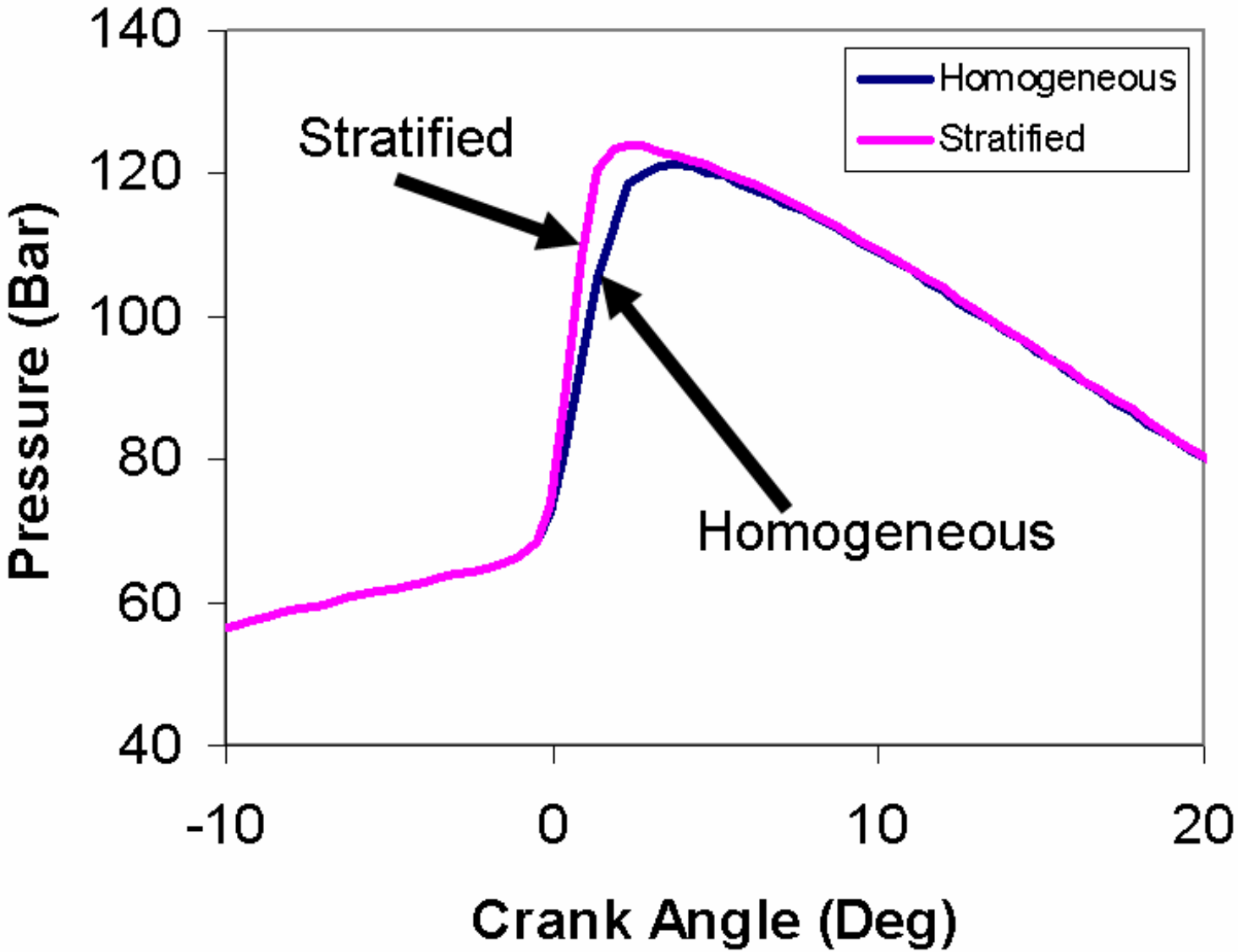


Homogeneous (ϕ=0.35)

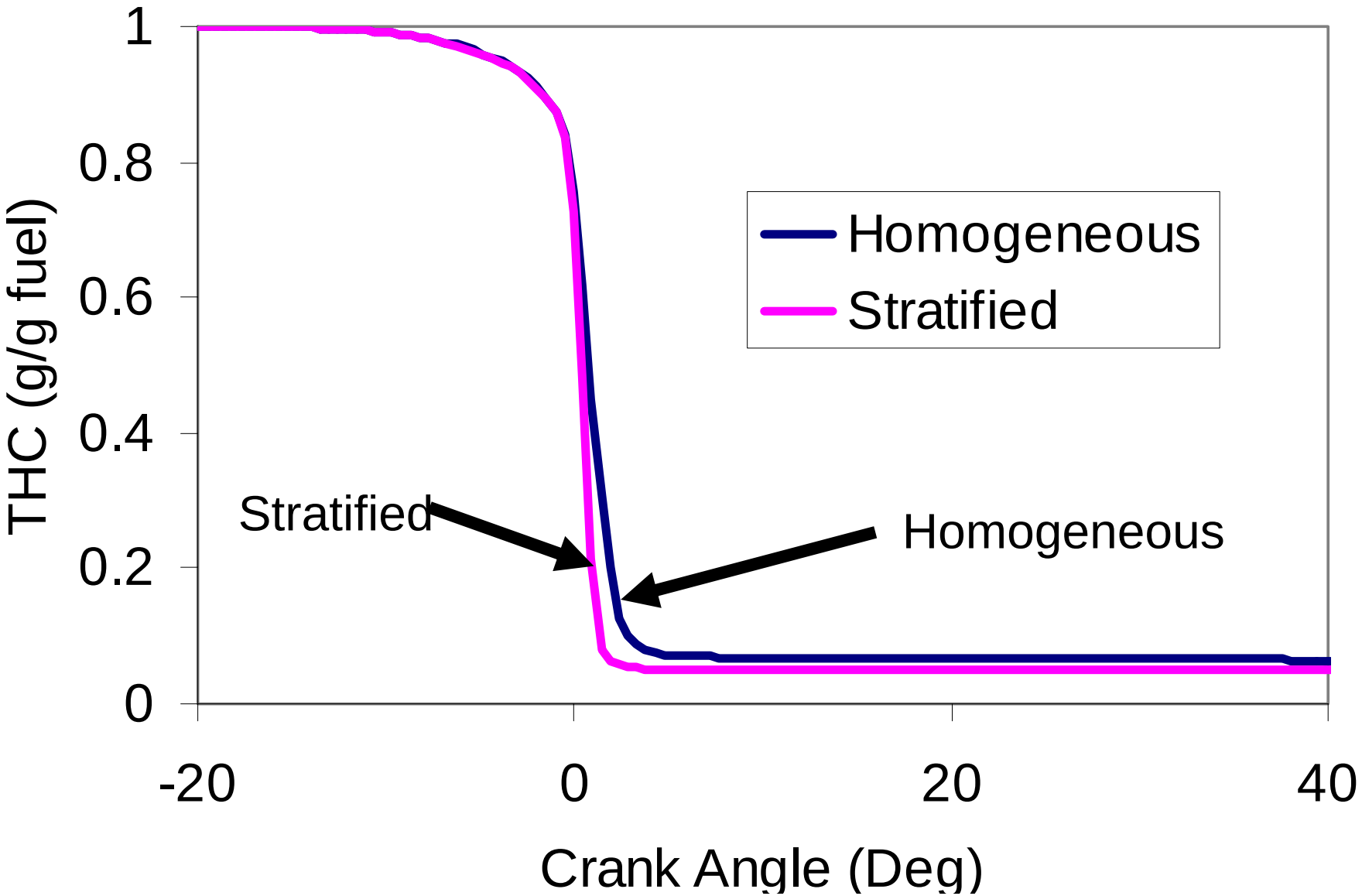
"Mildly" Stratified (ϕ=0.15-0.45)

CA = -10°

Combustion timing appears not significantly affected by stratification, but some affect on rate of combustion



Total Hydrocarbon Emissions reduced with less fuel trapped in crevices



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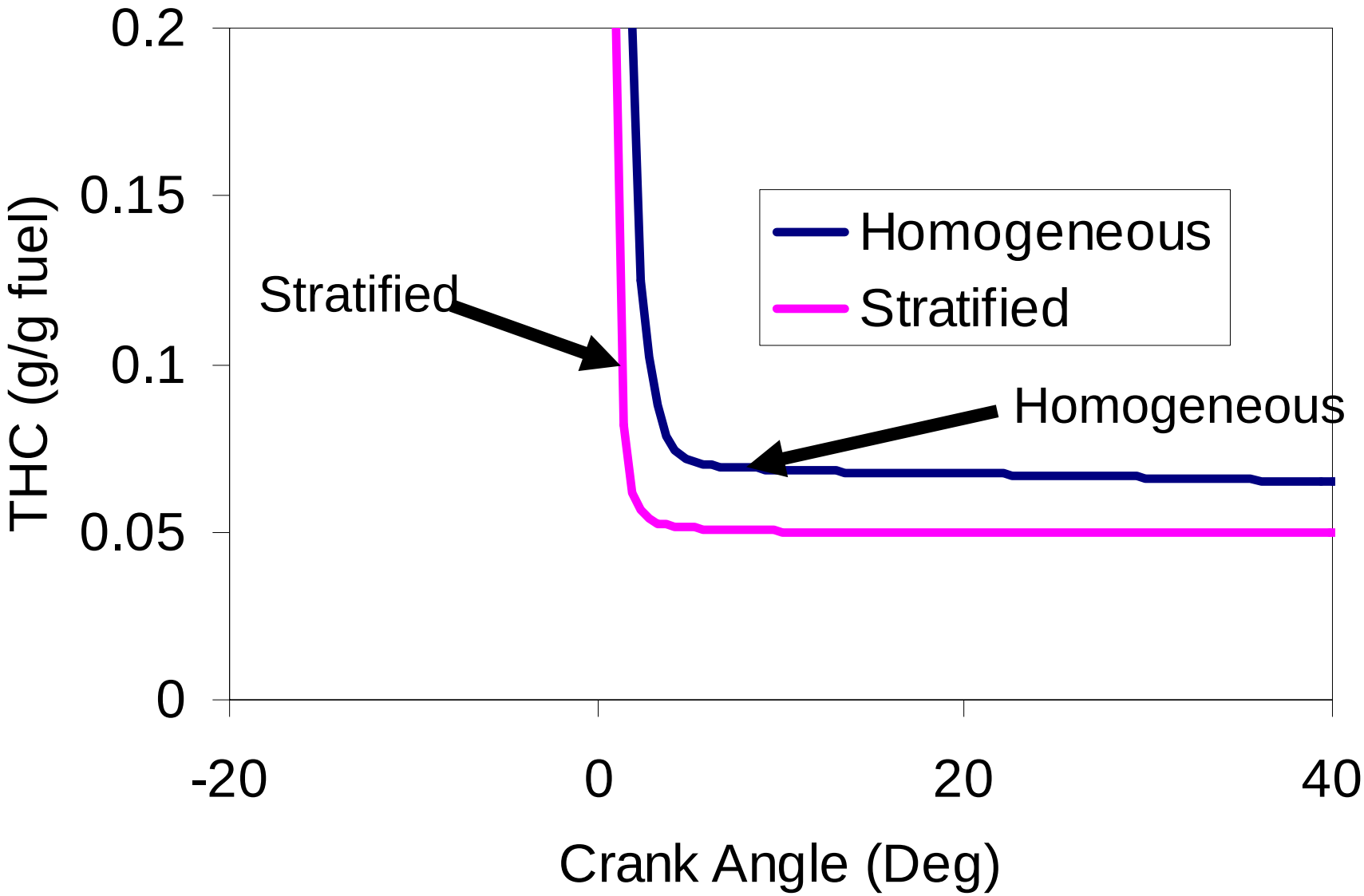
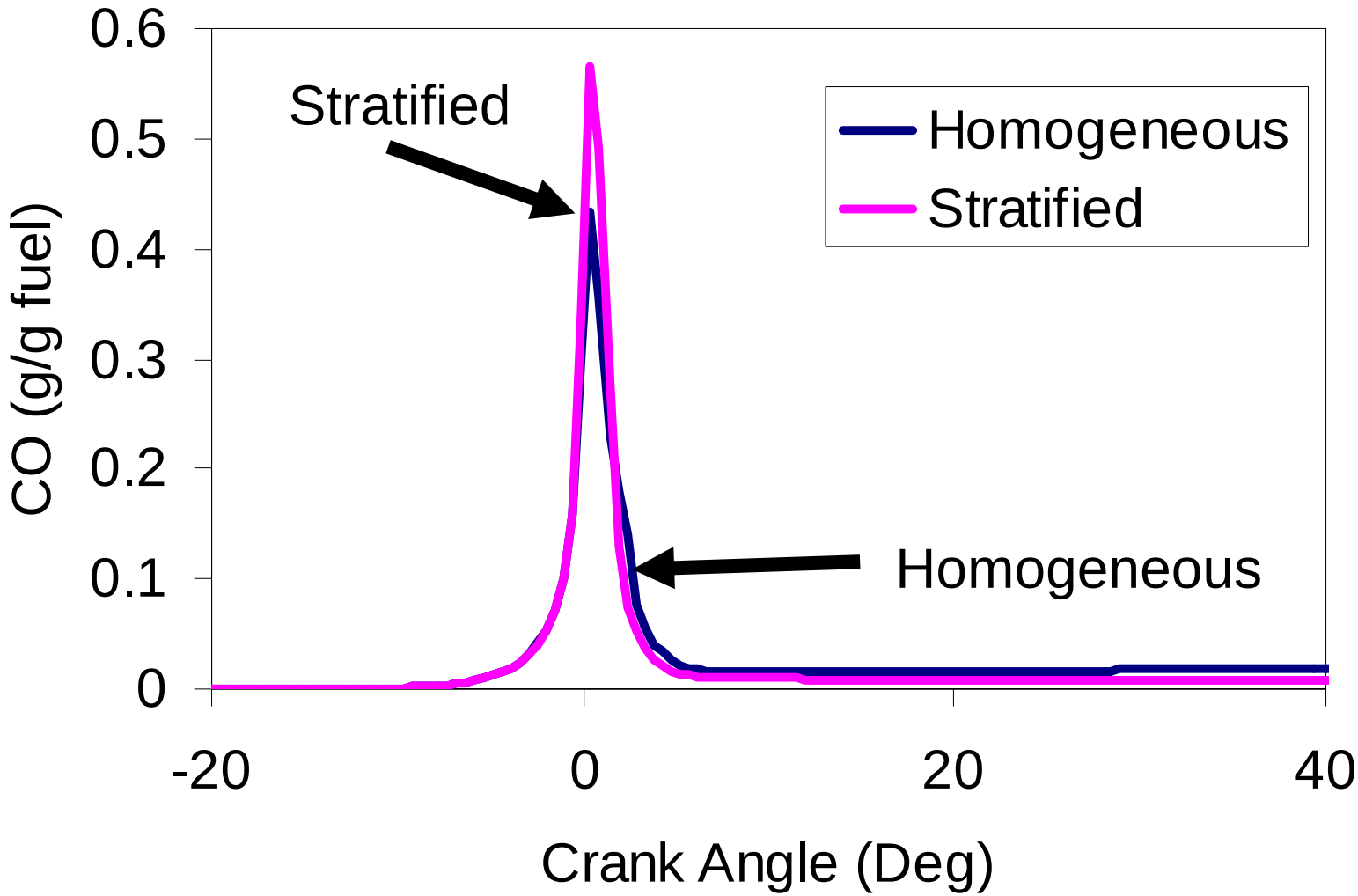


Exhaust CO also lower for stratified case, more complete combustion as more fuel starts in hotter regions



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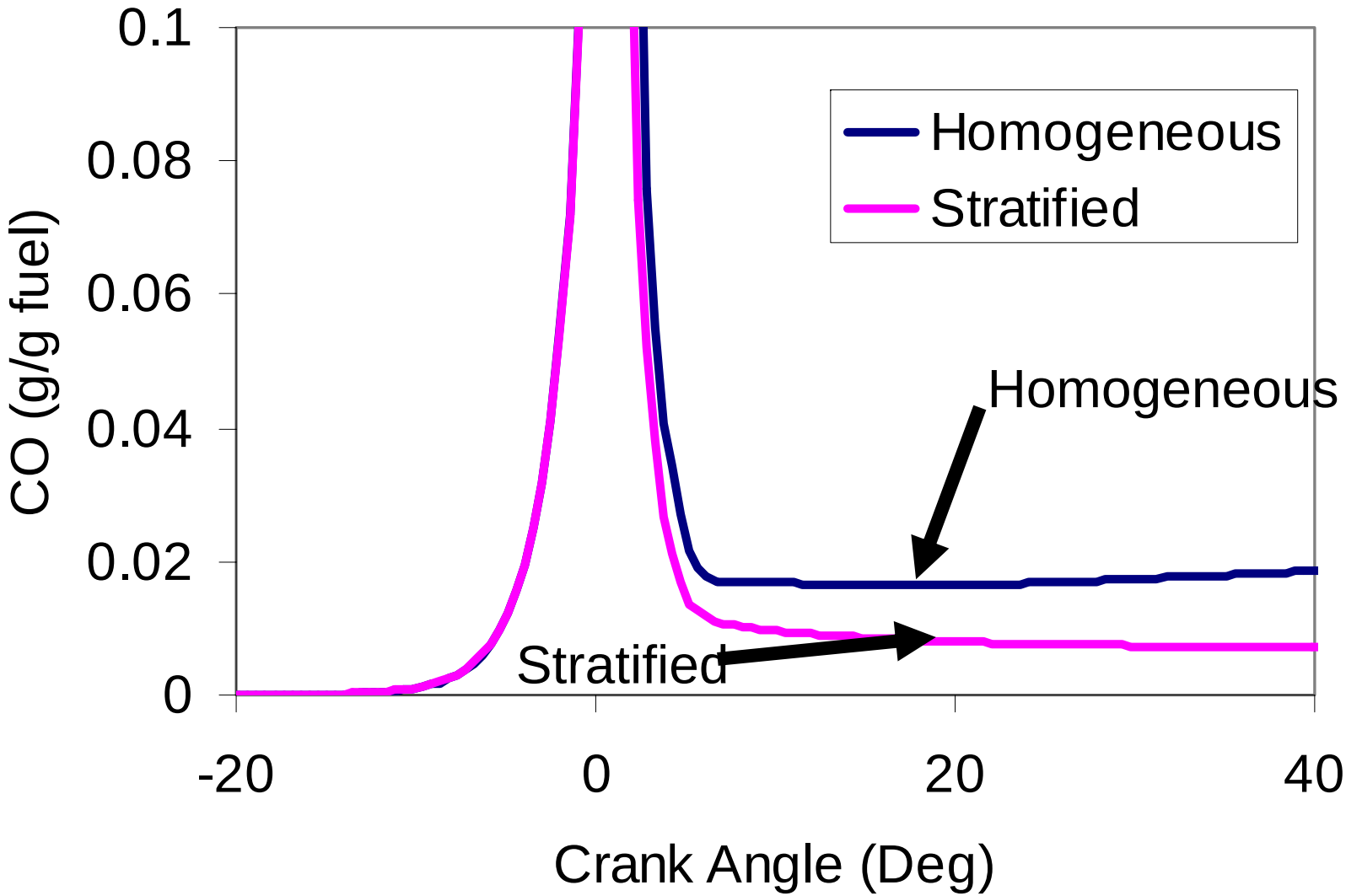
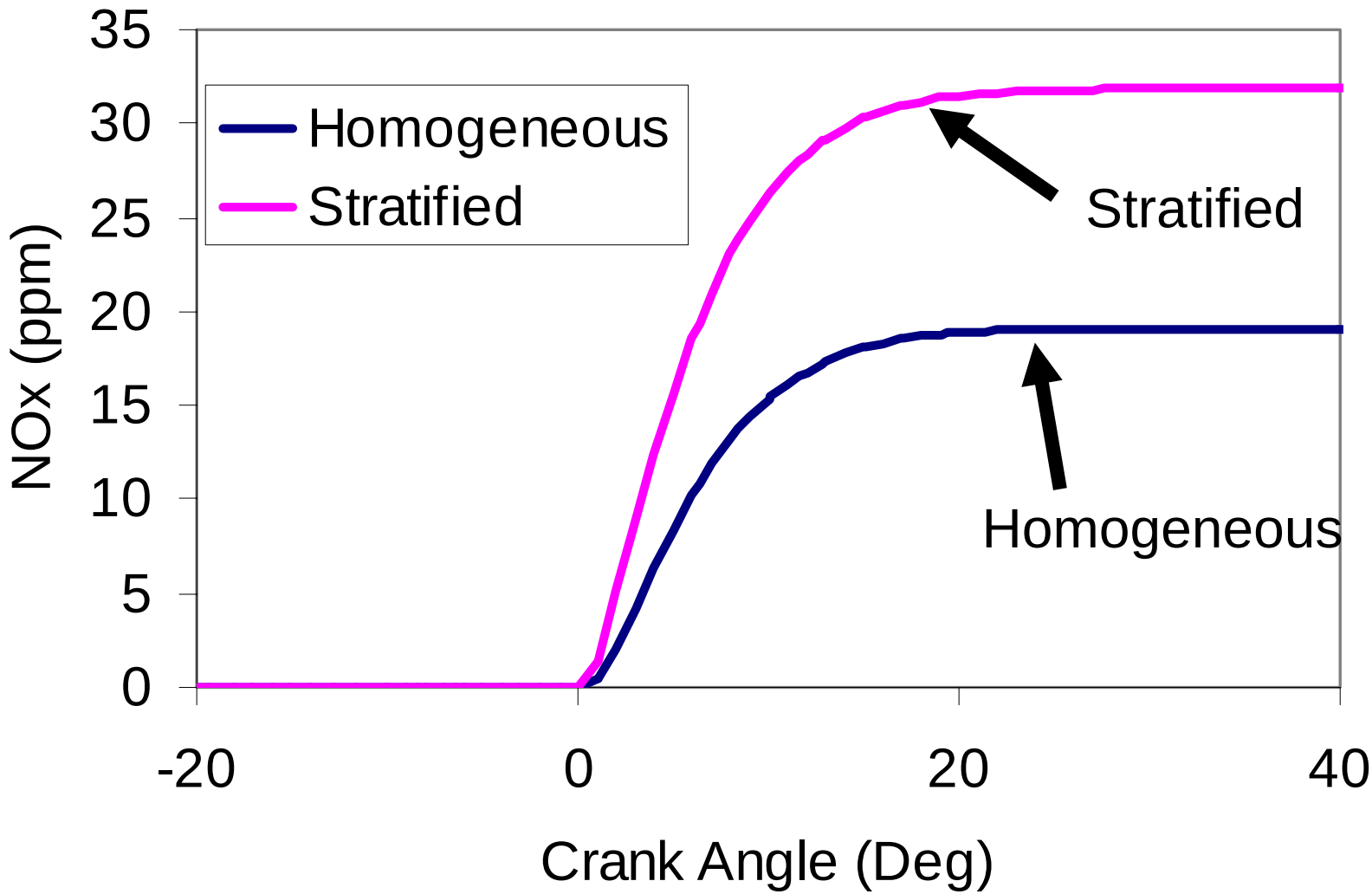
In homogeneous cases much CO is formed as fuel ejects from crevice during expansion, stratification reduces

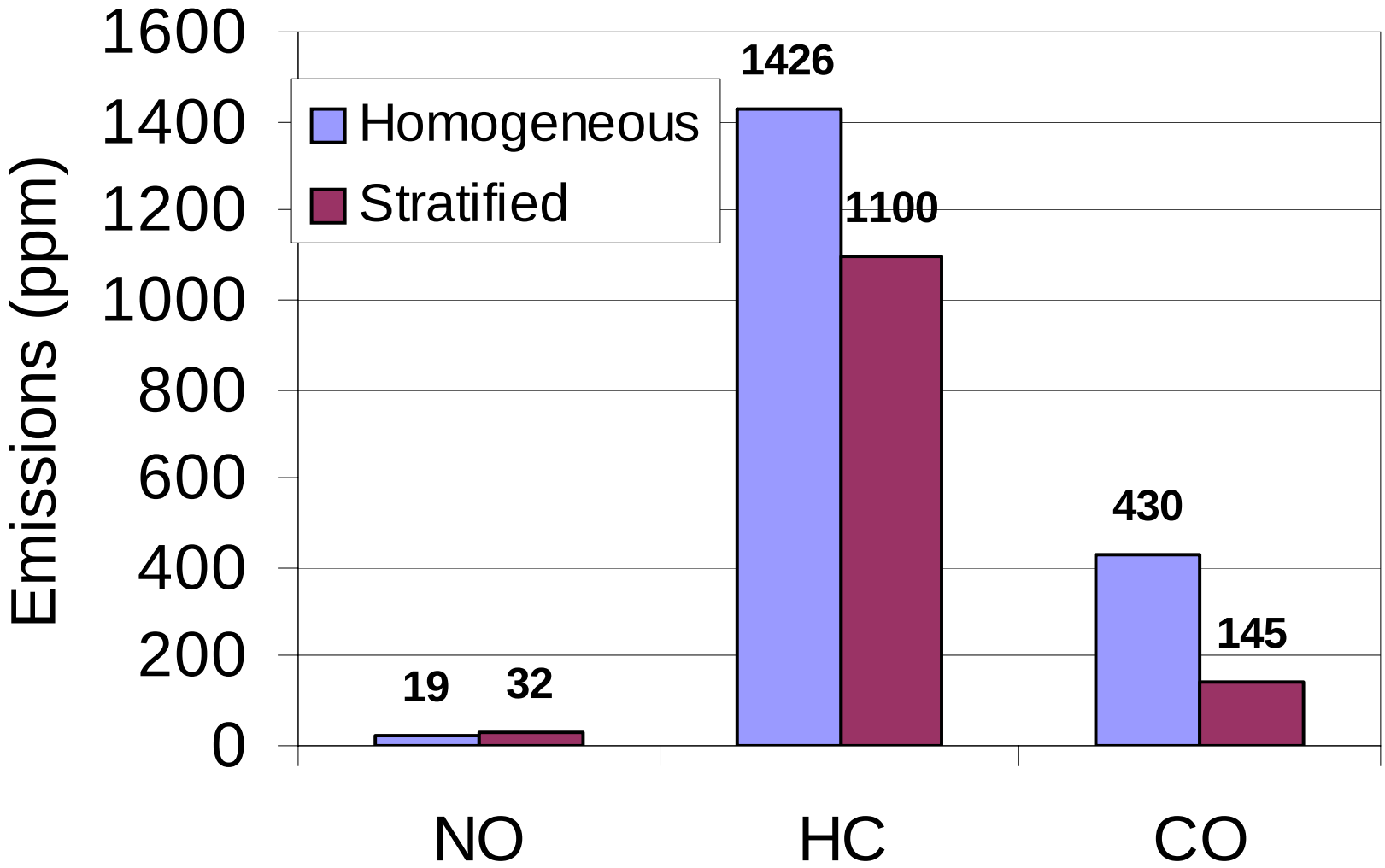


Higher peak cylinder temperatures will promote higher NOx emissions

But may be possible to operate more stably with later combustion timing using stratification, mitigating NOx



These results suggest possible beneficial effects on HC and CO emissions from stratification



Conclusions

Computationally efficient CFD + detailed kinetics approach can simulate non-homogeneous HCCI-like combustion

Even mild stratification may have beneficial impact on THC and CO emissions but care must be taken to prevent increase of NOx

Future work will explore impact of stratification on emissions and operating range

IVC Axisymmetric KIVA3V used to predict temperature distribution during homogeneous compression