# Using $K_\alpha$ images to characterize pre-plasma and electron refluxing in intense laser experiments

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# Motivation

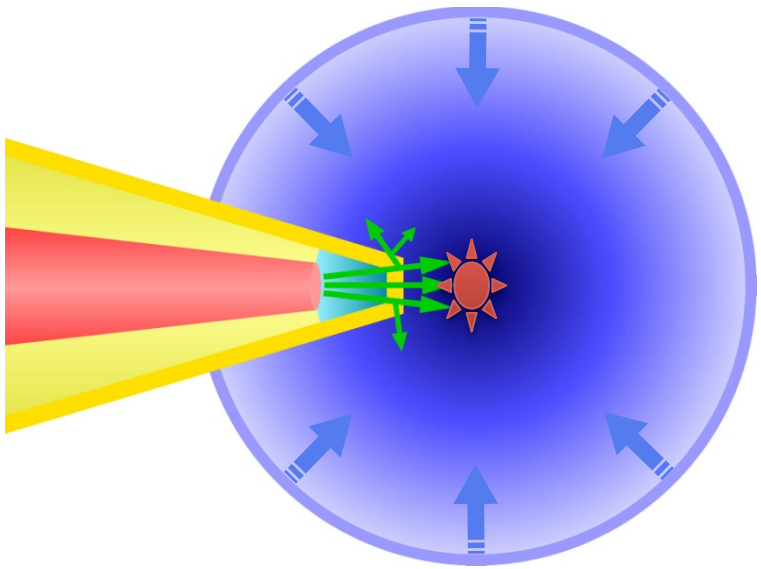
- Angular distribution of laser generated hot electrons is crucial.
- Recent experimental measures of the divergence vary widely.
- $K_\alpha$ imaging is a primary experimental measure.
- PIC simulations tend to indicate a large *intrinsic* divergence in the LPI region ($\Theta_{1/2}$ = 50-60°).

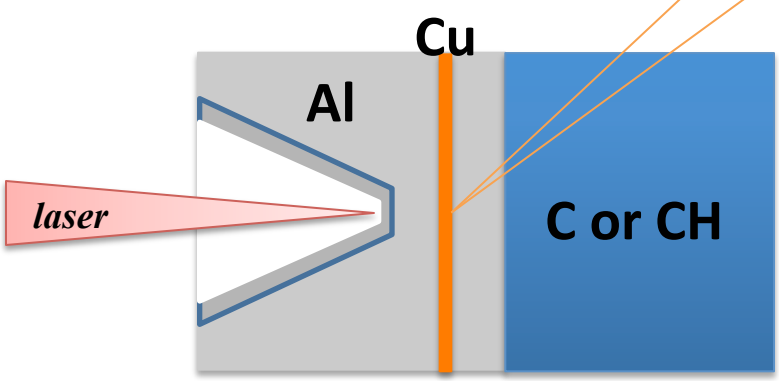
**This talk will show how a large intrinsic electron divergence can result in varying divergences as measured by $K_\alpha$ imaging.**

# We've shot slabs and buried cone targets

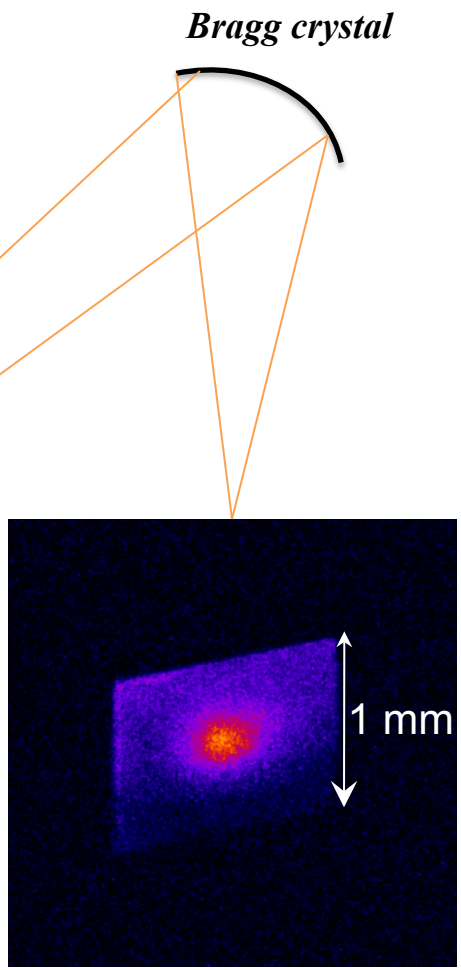
DEPARTMENT OF PHYSICS

## Cone-guided Fast Ignition:





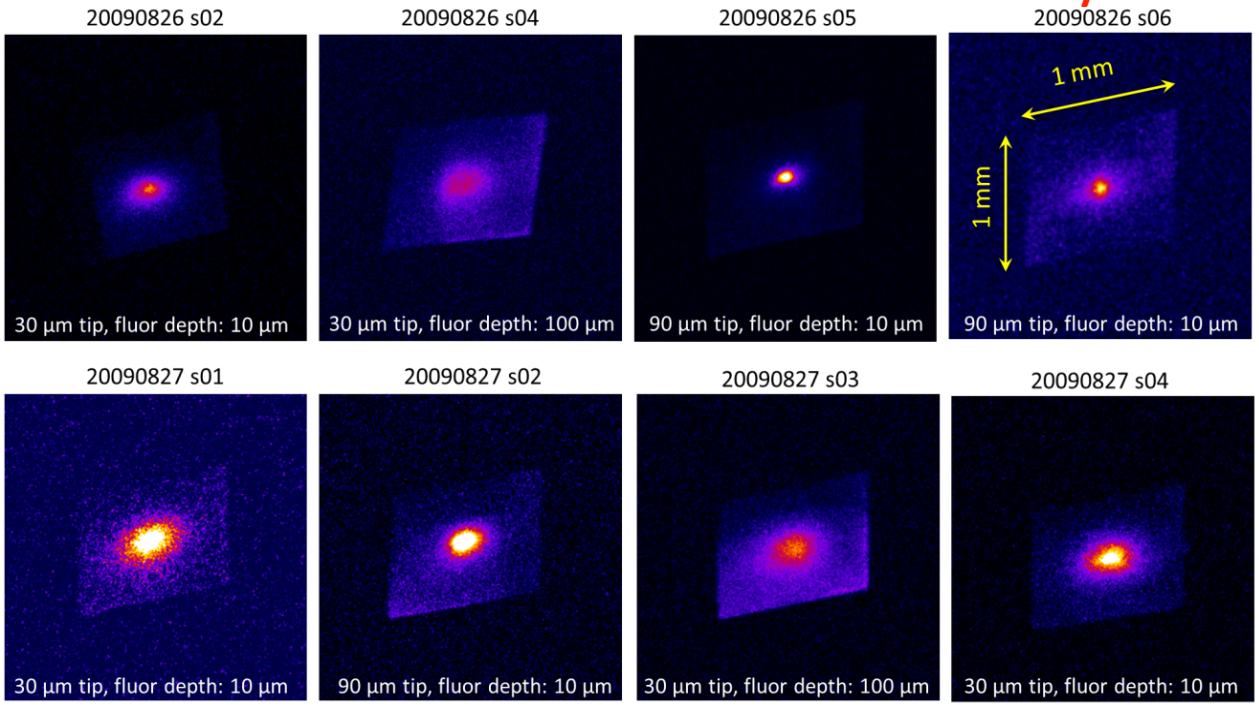

*Buried cone target with a Get-Lost Layer (GLL)*




*$K_\alpha$ image of a buried cone target*

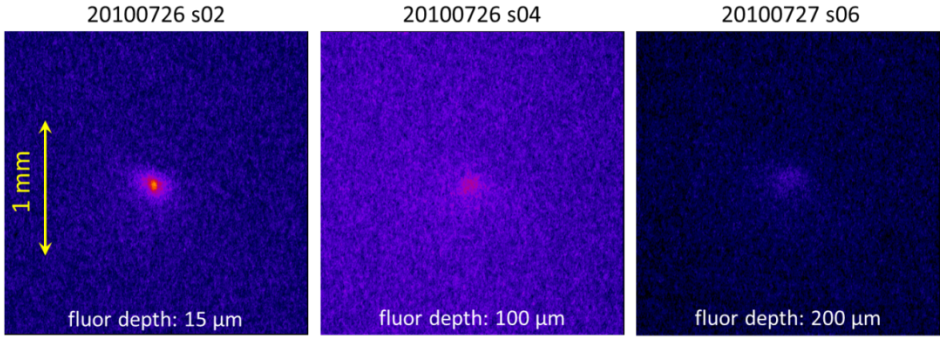
# Recent Titan Results: $K_\alpha$ imaging

## 2009 Run: Buried Cone Results. $\Theta_{1/2}$ = 40-45°




Detector used:
X-ray CCD

## 2010 Run: Buried Cones Results. $\Theta_{1/2}$ = 12-15°




Detector used:
Image Plates

# Simulation setup for the 2009 experiment

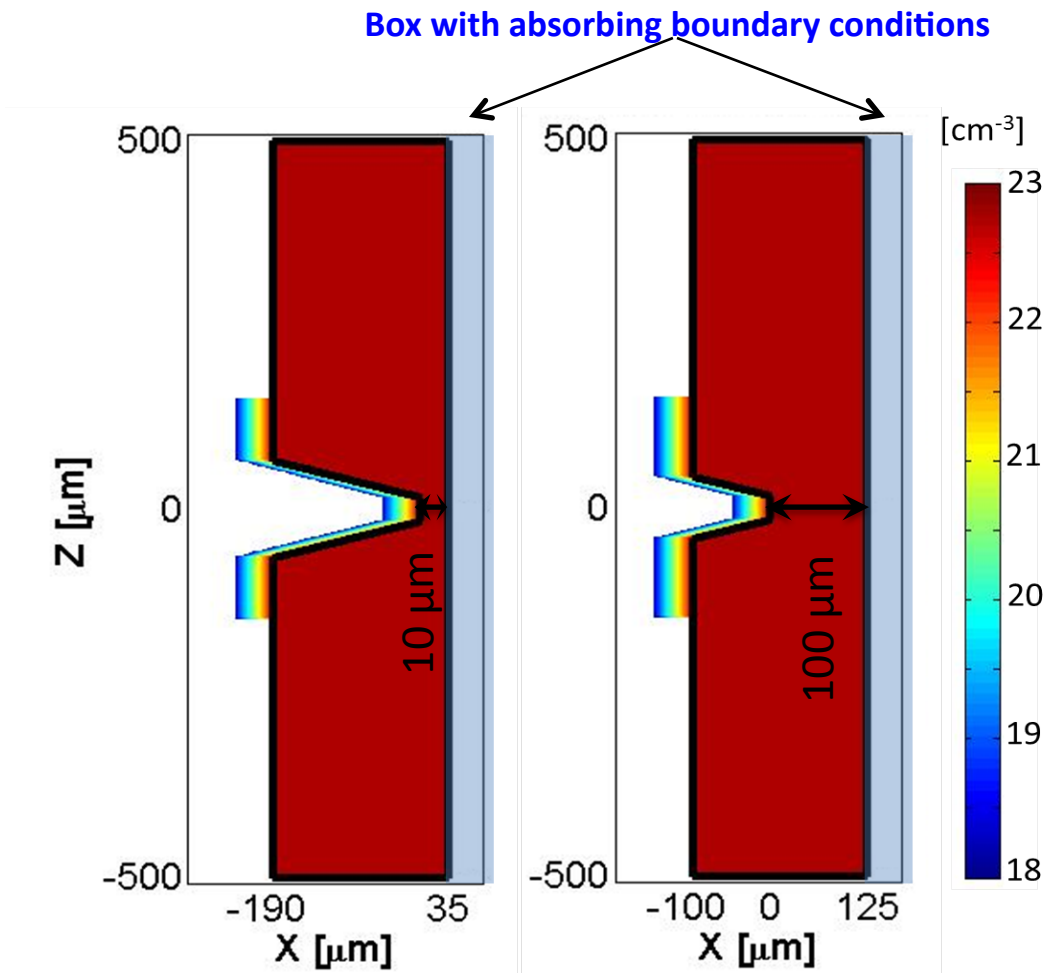
Fully kinetic simulations, using modified PIC code LSP

**(1) TARGET**
Buried cone target
(30° cone angle)
Exponential preplasma

**(2) GRID**
2D Cartesian (XZ)
Cell size: from λ/8 to λ

**(3) LASER**
λ= 1 μm
I=1 x $10^{20}$ W/cm$^2$
$w_o$ = 7 $\mu$m
sine$^2$ envelope w/
τ = 700 *fs*
propagates along +x
z-polarized

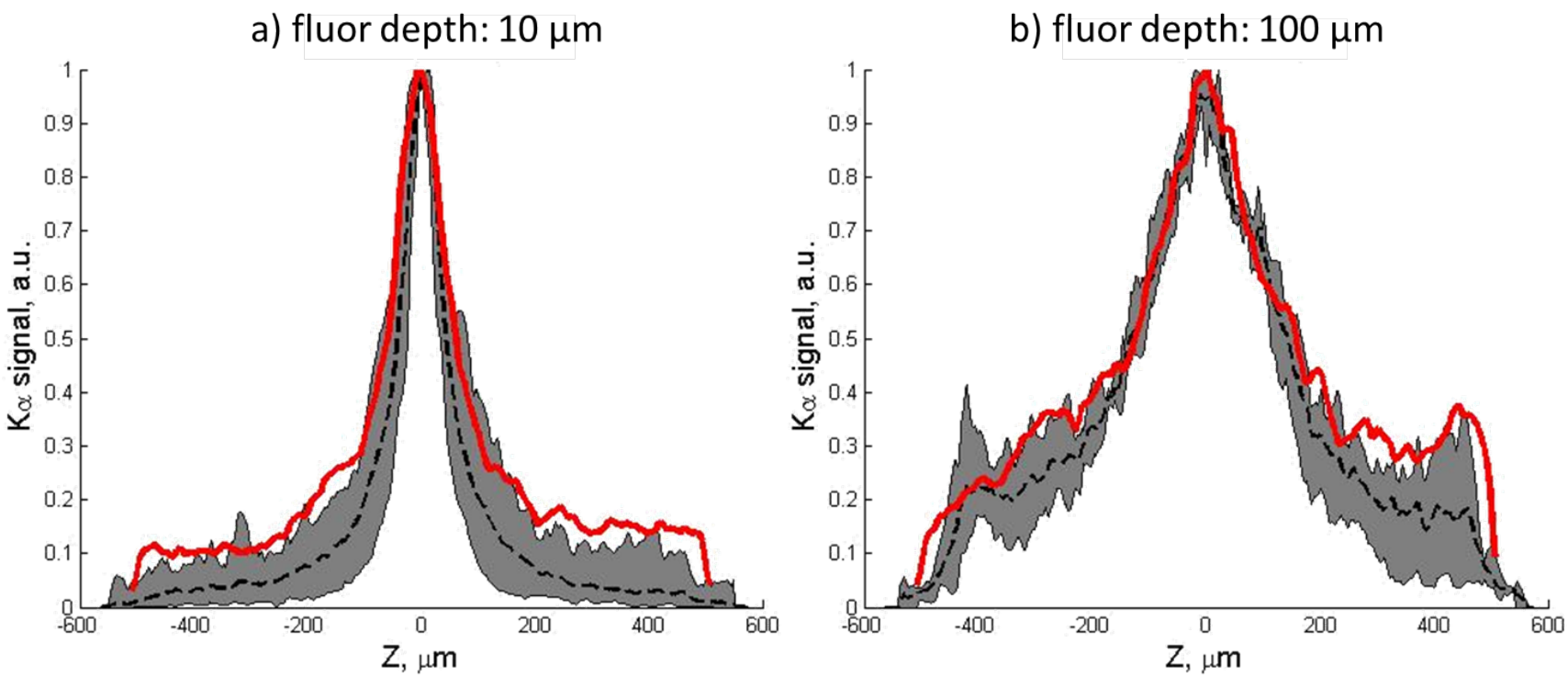
**(4) RUN DURATION**
~20 ps
with Δt=30 timesteps/optical cycle




Preplasma scale length is the only free parameter

# Simulation vs. 2009 Experiment: L = 5 μm

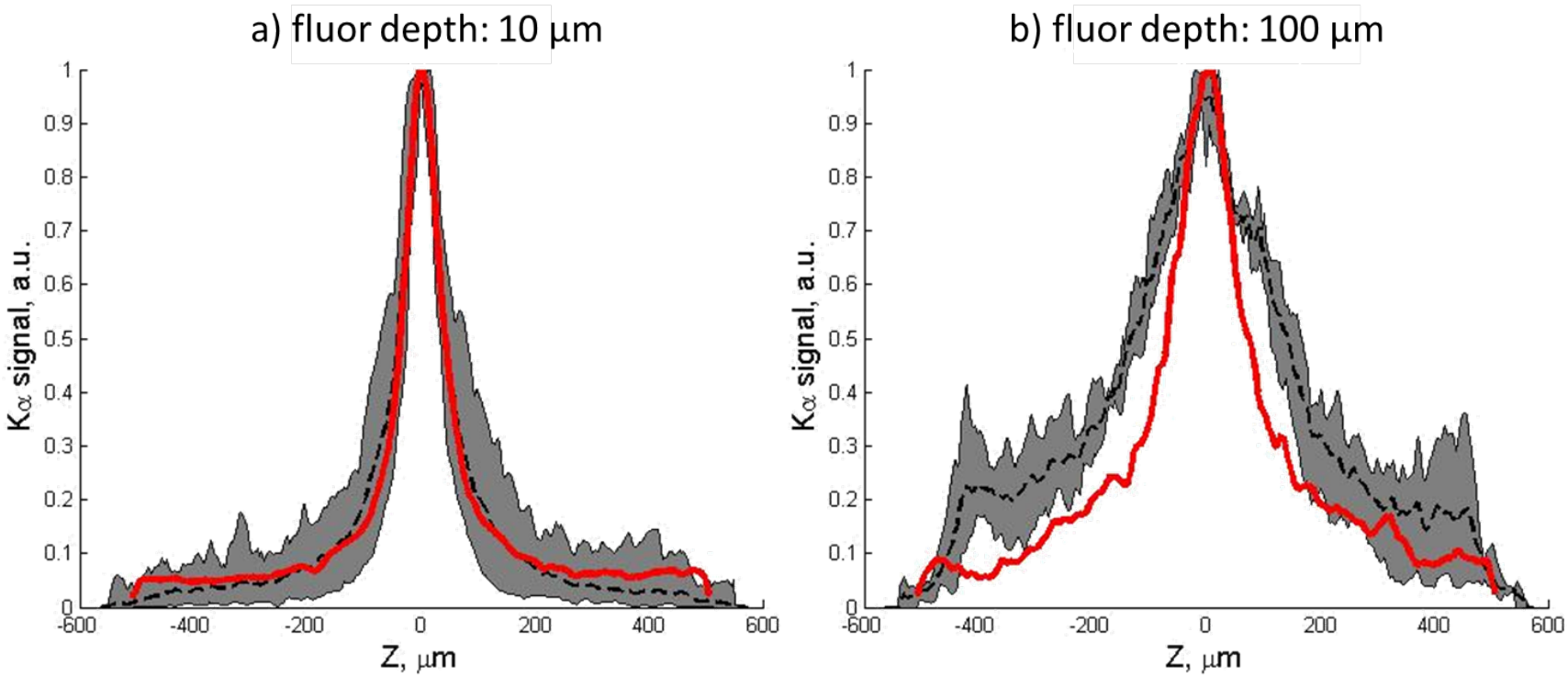
Red – simulation
Grey - experiment




Preplasma scale length L=5 μm

# Simulation vs. 2009 Experiment: L = 2.5 µm

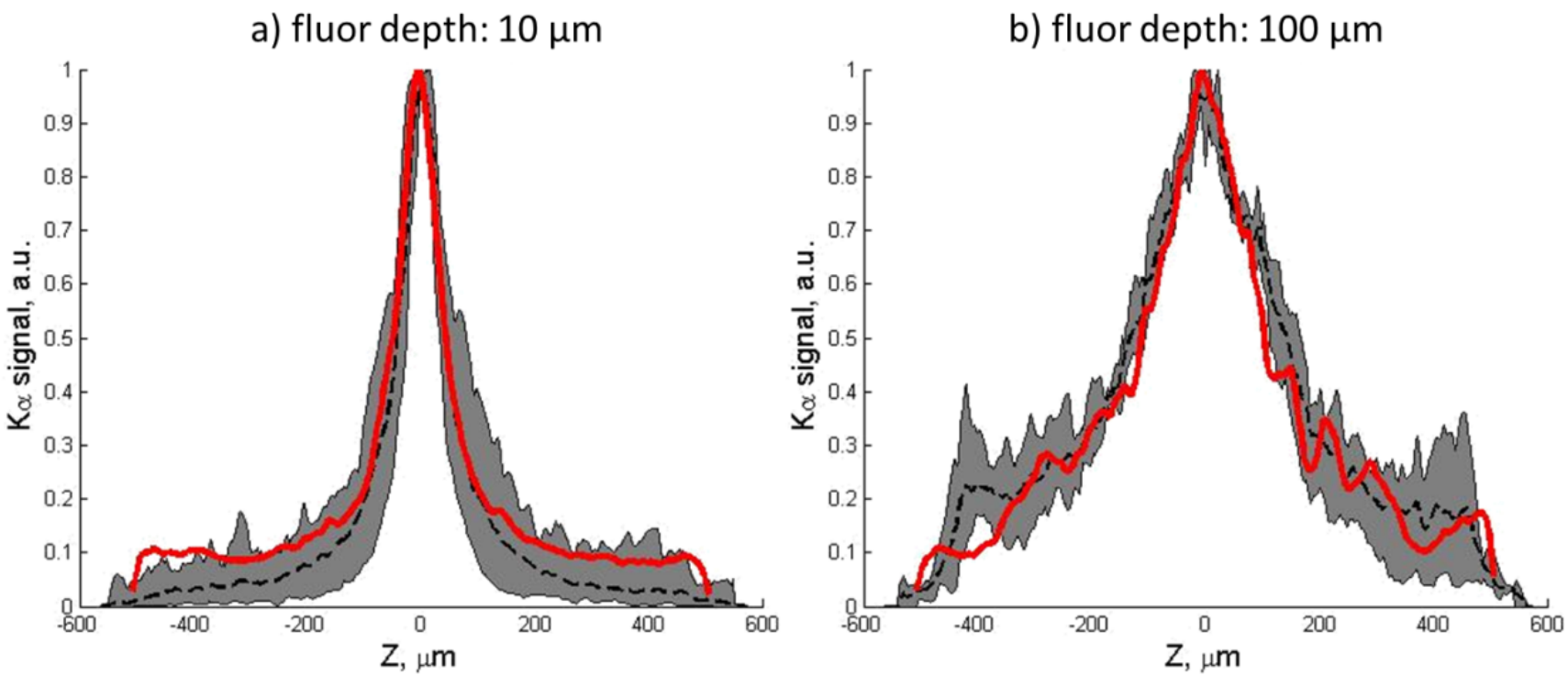
Red – simulation
Grey - experiment




Preplasma scale length L=2.5 µm

# Simulation vs. 2009 Experiment: L = 3.75 µm

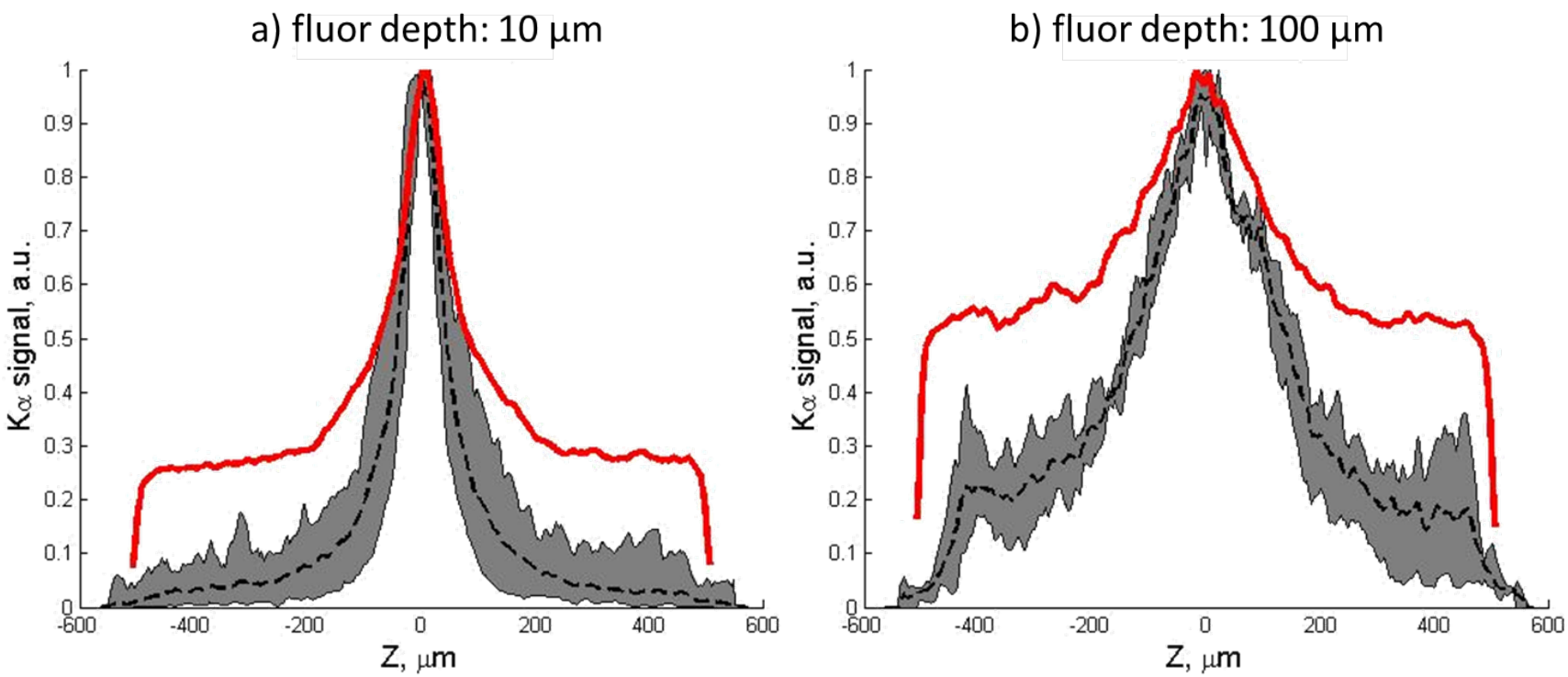
Red – simulation
Grey - experiment




Preplasma scale length L=3.75 µm

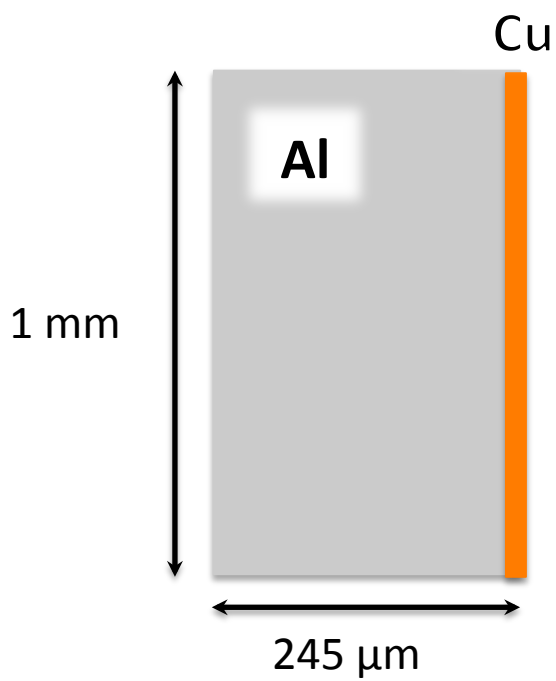
# Effect of the Get Lost Layer

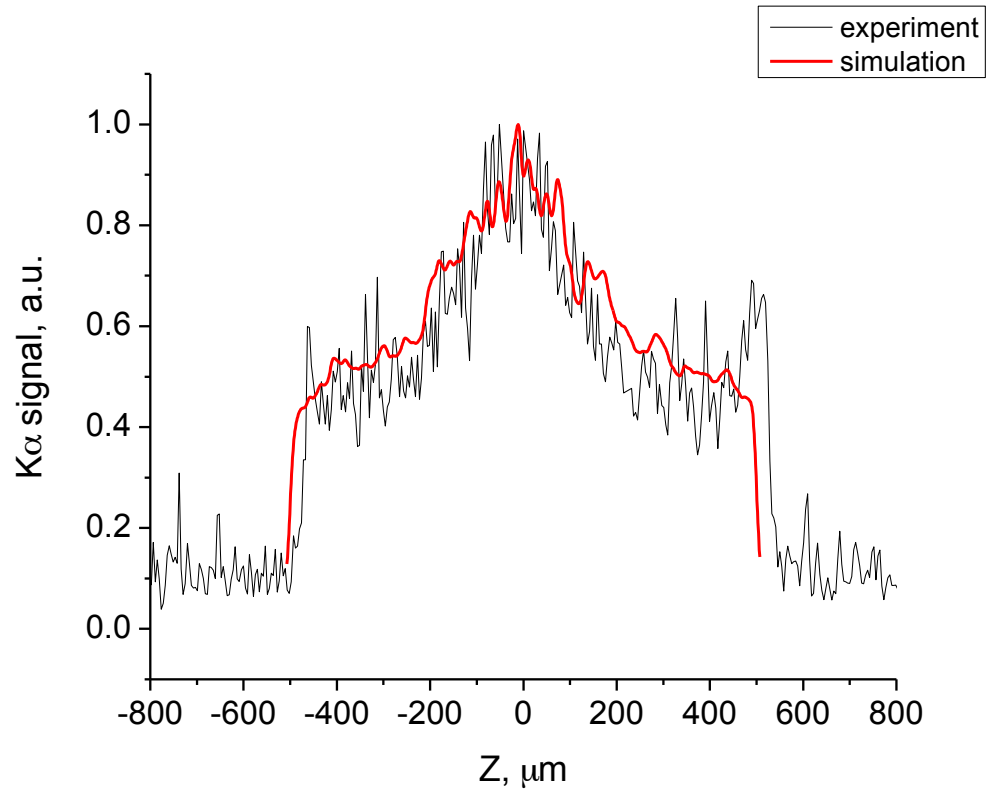
Red – simulation
Grey - experiment




Preplasma scale length L=3.75 µm (no GLL)

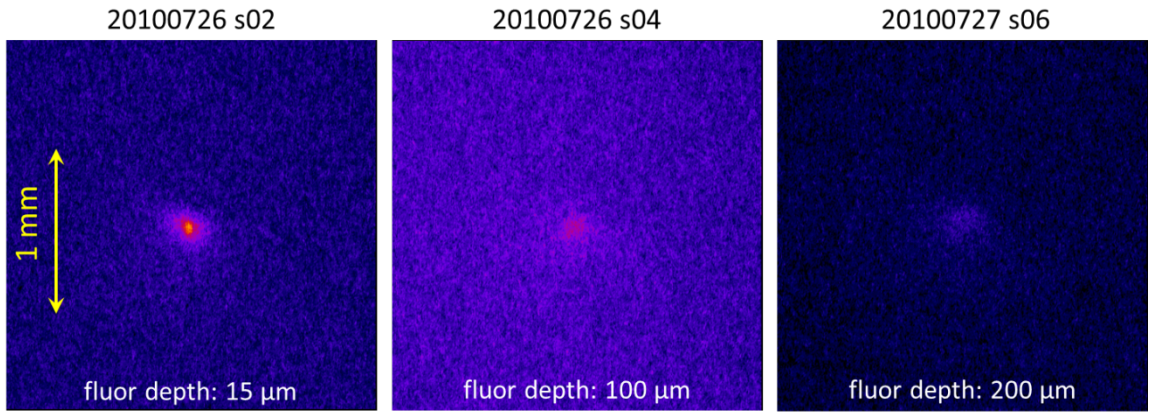
# Simulation vs. experiment for a slab with no GLL



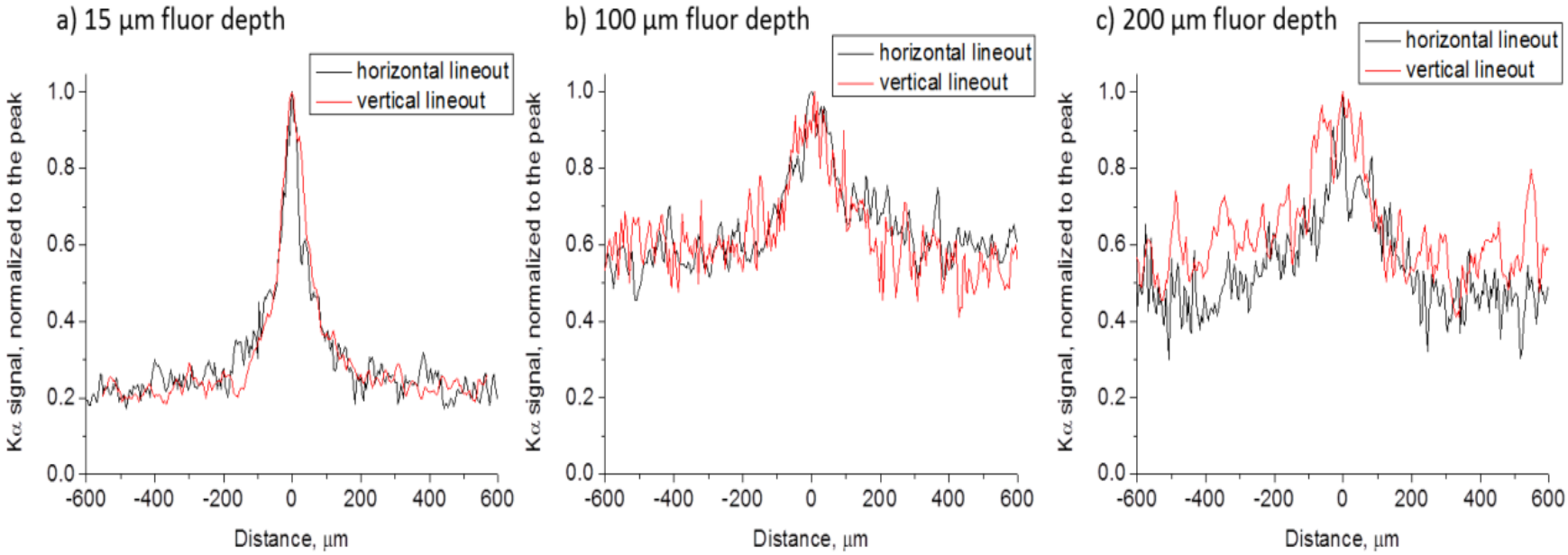




Slab target, no GLL

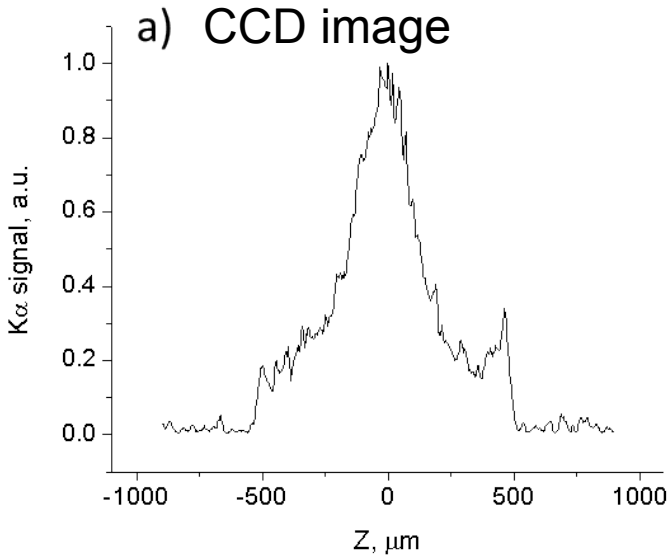
# Experimental results for 2010 experiment

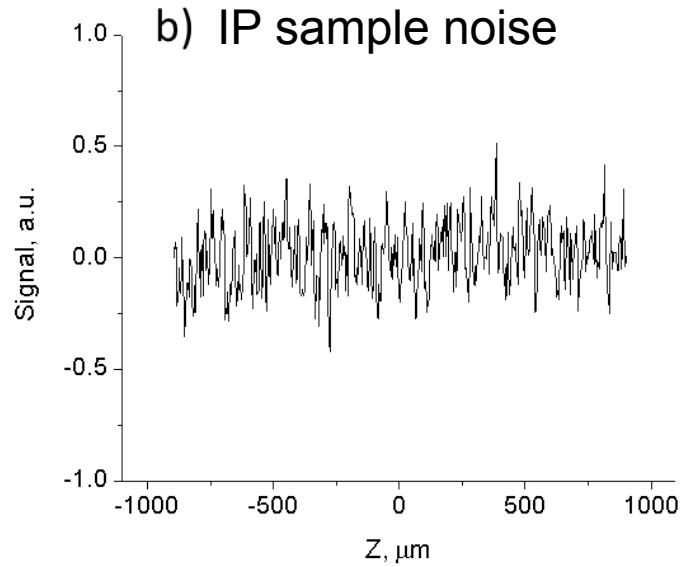


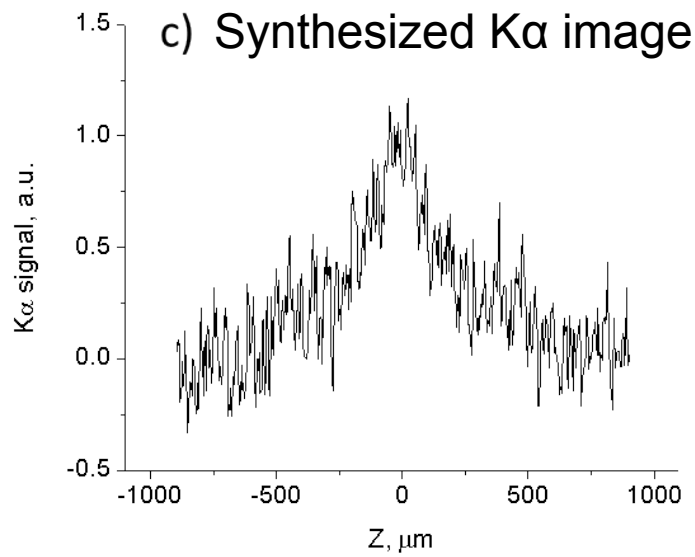

$\theta_{1/2}$ = 12-15°



# Noise issue in IP-based images



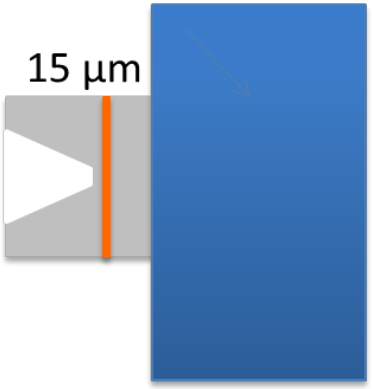



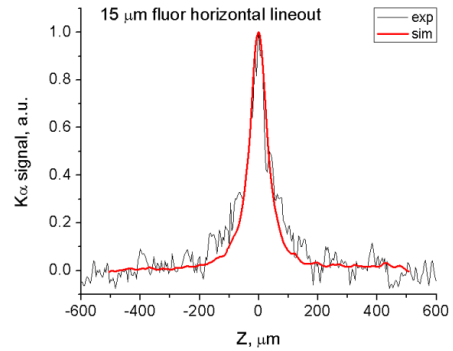



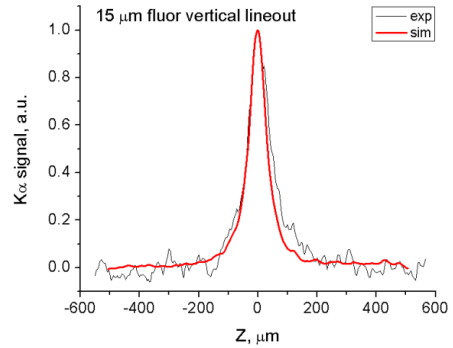

This is what we would have measured in 2009, had we had used image plates.

Note, the pedestal is hidden!

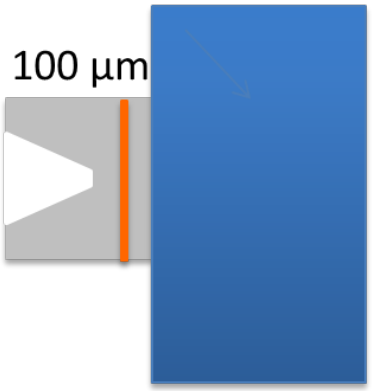
# Simulations for 2010 experiment

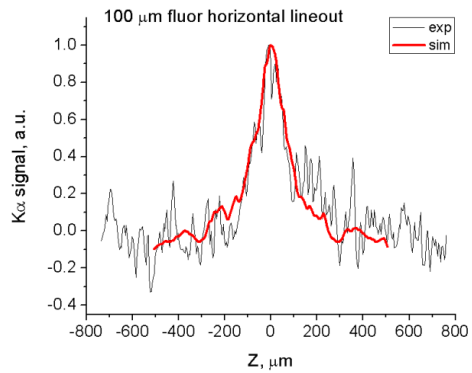


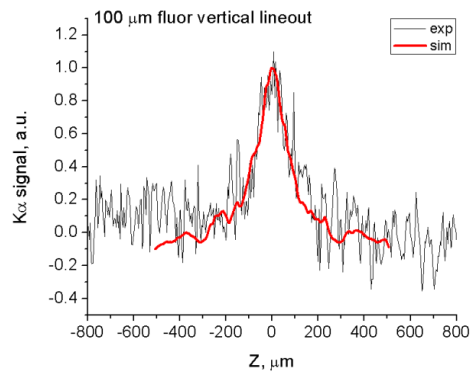



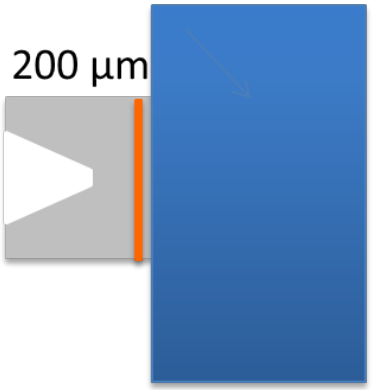

Red – simulation
Grey - experiment

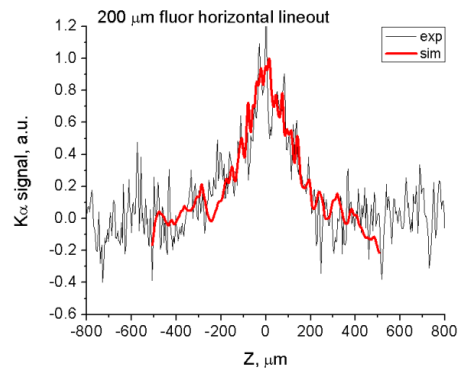


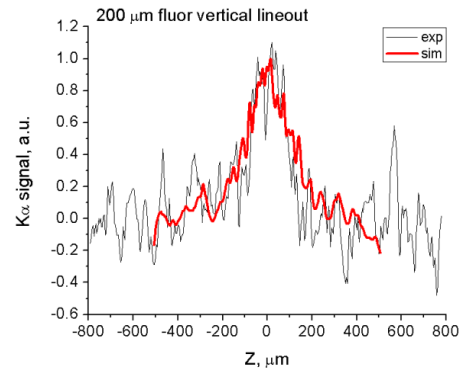



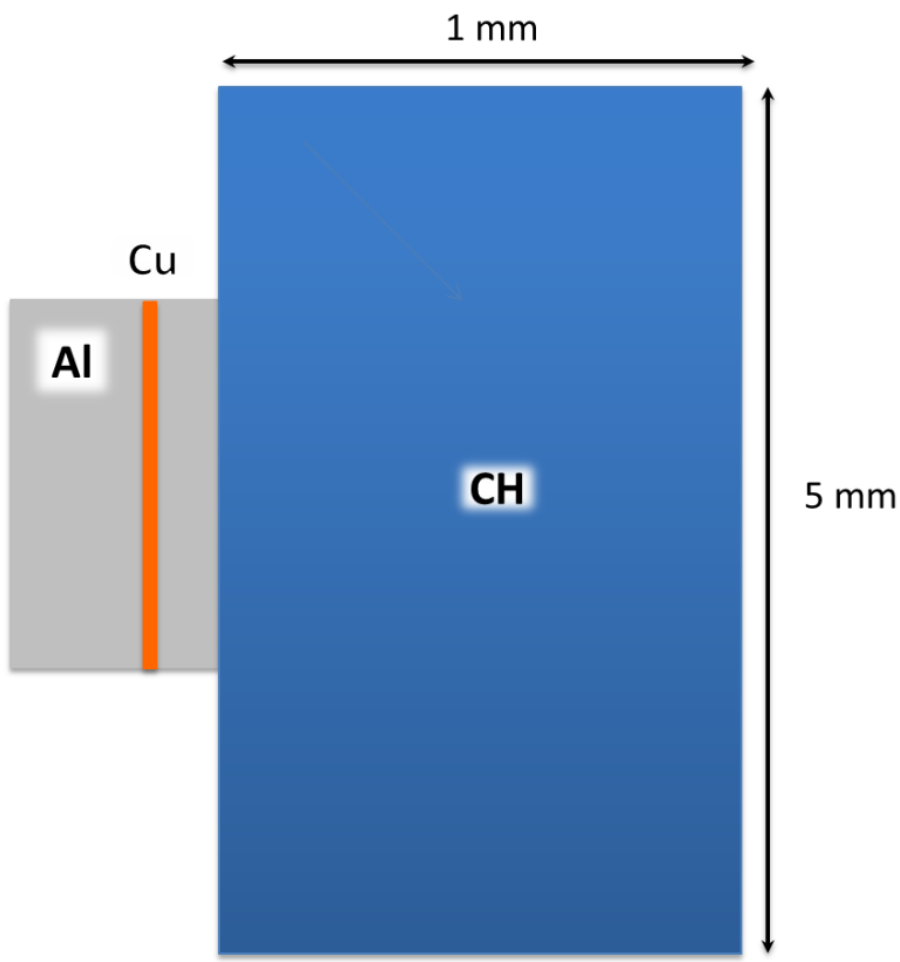

Preplasma scale length: L=2.5 µm



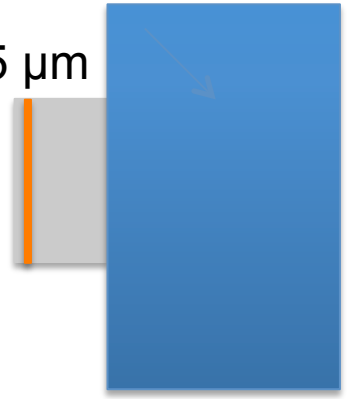



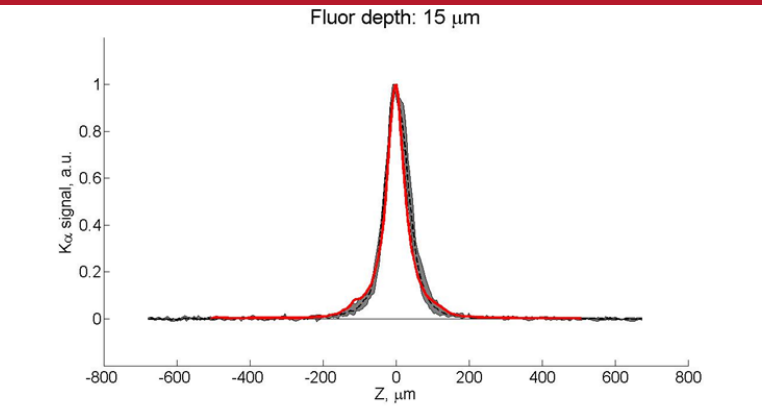
# Slab targets with GLL



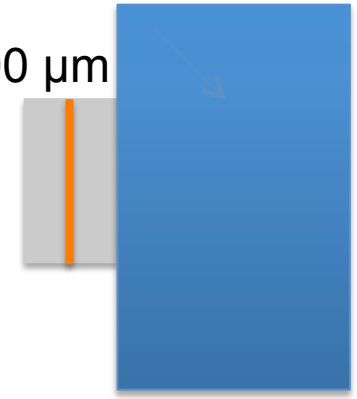
# Slab results

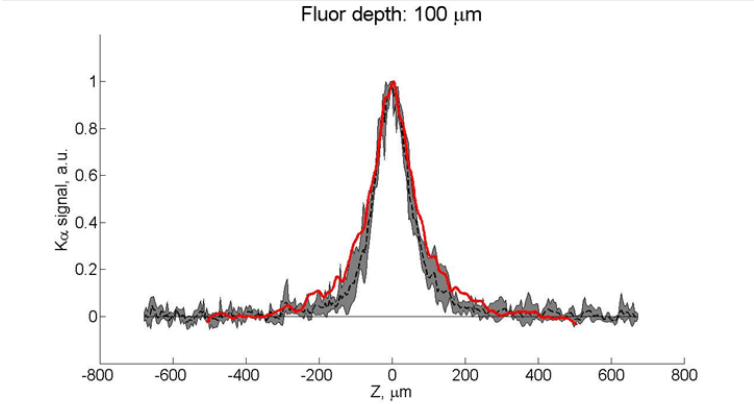
15 µm



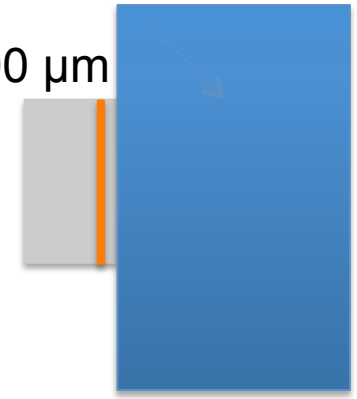


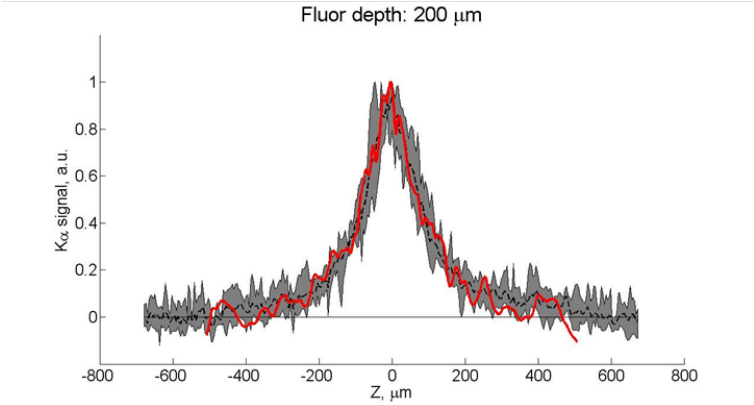

100 µm






200 µm






Red – simulation
Grey - experiment

Preplasma scale length: L=1.75 µm

# Summary

- Good match between experiment and simulation.
- Wide range of targets using data collected with 2 different detector types over 2 years.

We find that $K_\alpha$ images

- provide a poor measure of intrinsic divergence.
- yield a bulk divergence angle that is low compared to intrinsic.
- can characterize the pre-plasma near the critical surface.
- can be used to check the performance of GLL's.

**$K_\alpha$ images can still be used to benchmark PIC codes from which the intrinsic divergence can be determined.**

Thank you!