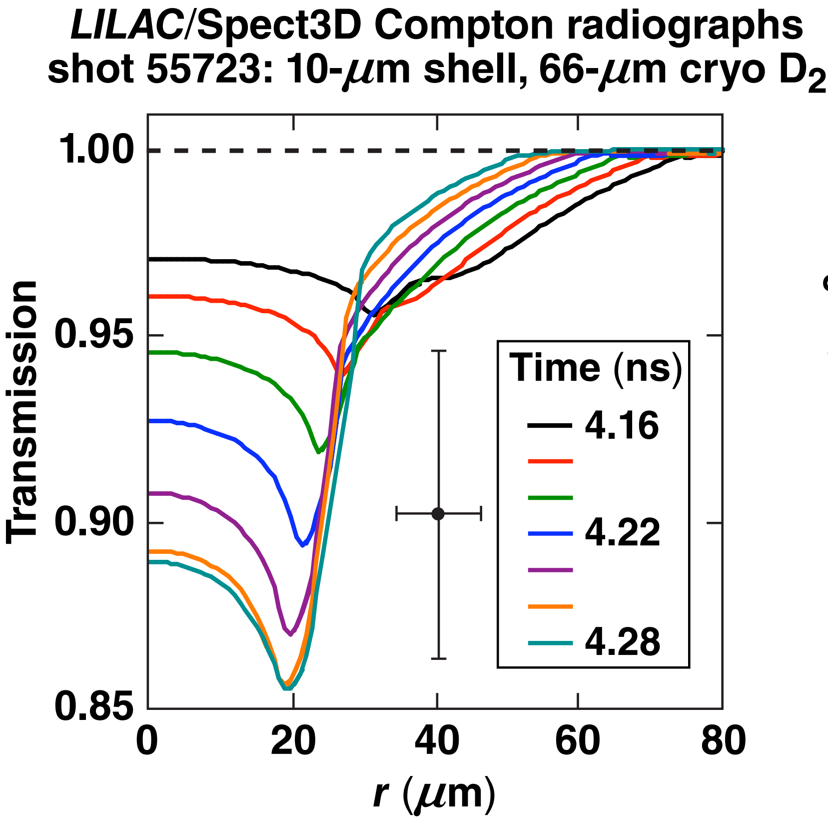
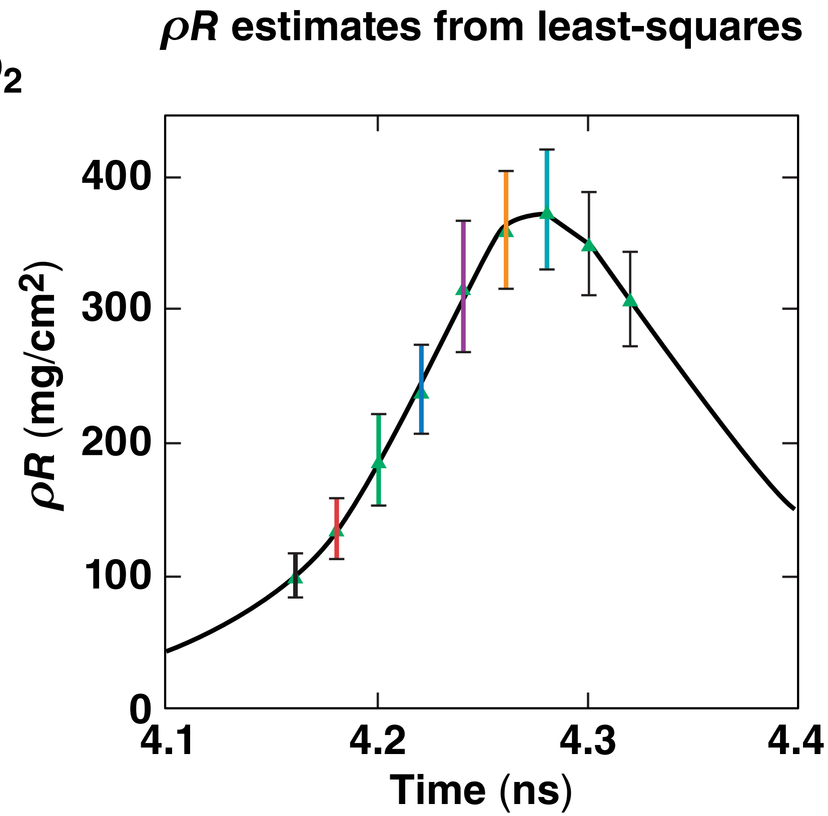
Compton Radiography of Cryogenic Implosions on OMEGA





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Summary

Compton radiography of cryogenic implosions on OMEGA promises to be a precise diagnostic of areal density

- Compton radiography offers advantages over soft x-ray radiography, including absence of background and composition independence
- Even with low radiograph contrast, covariance analysis based on a homogeneous shell model gives statistically significant average-areal-density estimates
- Application of this fitting model to simulated cryogenic-implosion data gives areal-density estimates that are accurate as well as precise

Collaborators

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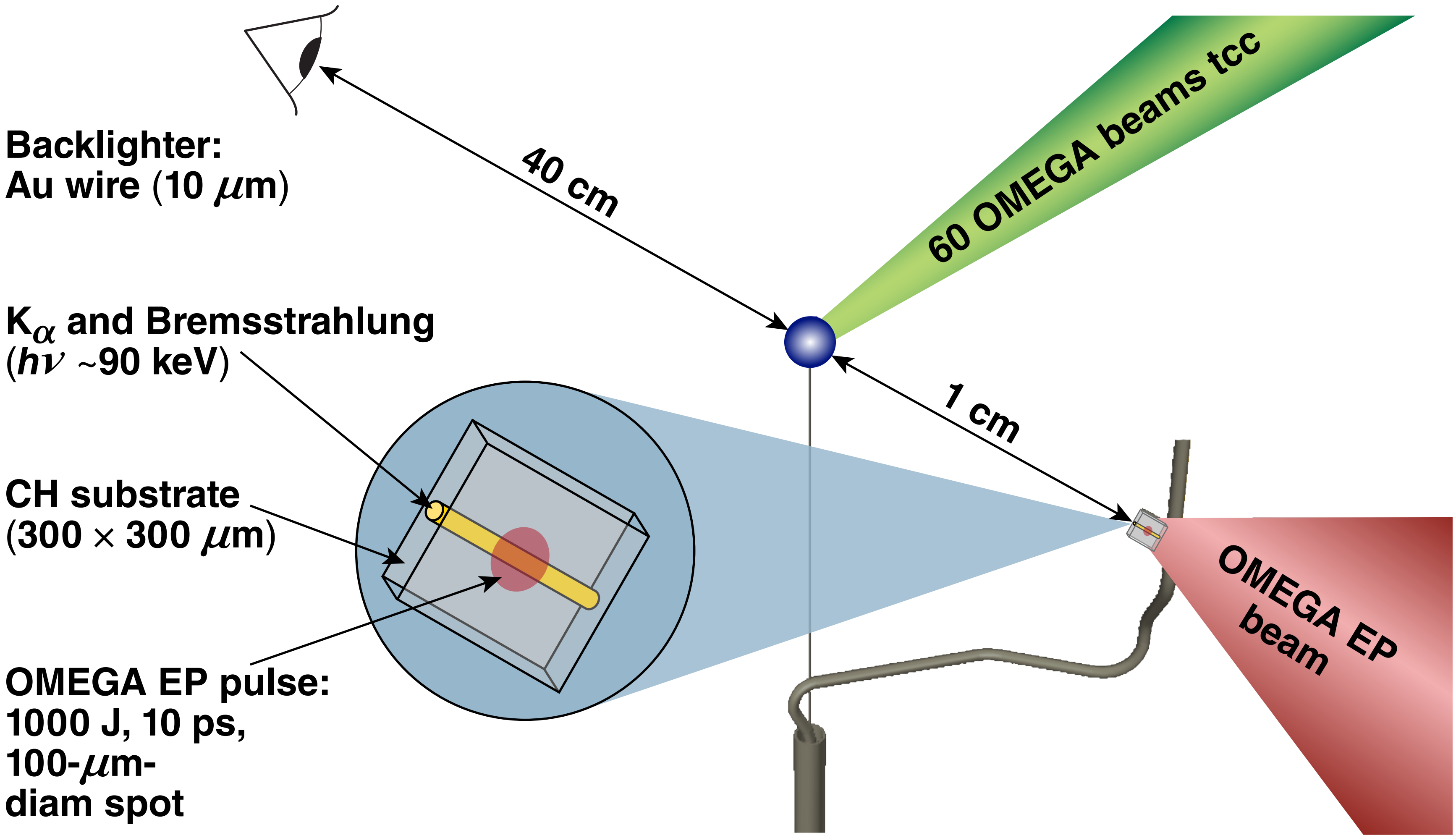
†LLE Summer High School Research Program (2010).
*Talk Q13.00004

We are developing Compton radiography for cryogenic implosions on OMEGA



TC9042

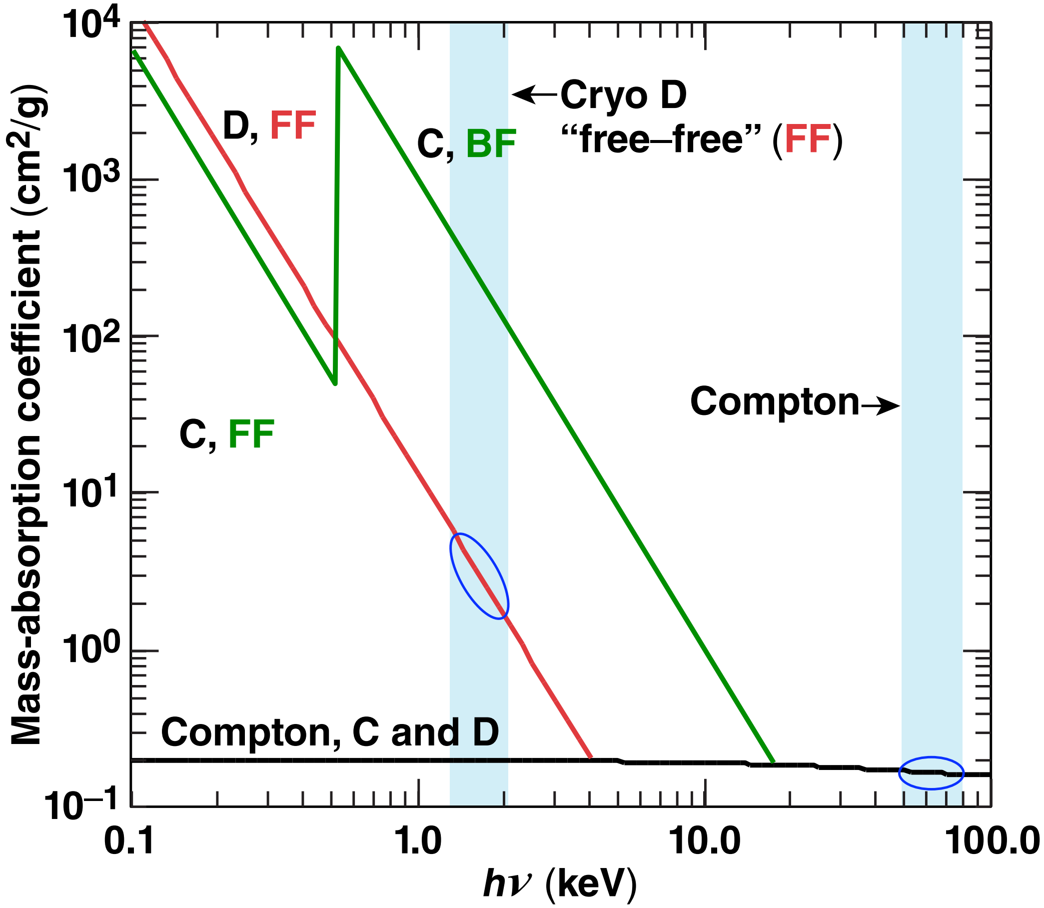
The development of Compton radiography on OMEGA is motivated by several factors

- High resolution (~10 μm) is obtained with point-projection backlighting[1,2]
- Radiography at hard x-ray energies (~90 keV) is free of background from self-emission
- In soft x-ray radiography, the free–free (FF) opacity of cryogenic hydrogen can be overwhelmed by trace contamination due to mix

R. Tommasini *et al*.[2] have been developing Compton radiography on OMEGA.

[1] H.-S. Park *et al*., Phys. Plasmas 13, 056309 (2006); R. Tommasini *et al*., Rev. Sci. Instrum. 79, 10E901 (2008).
[2] R. Tommasini (Q13.00004).

The properties of the different absorption and scattering mechanisms distinguish the radiography methods



Deuterium

ρ = 3 g/cm^3
kT = 25 eV

Carbon

ρ = 0.5 g/cm^3
kT = 100 eV

- Free–free (FF) and bound–free (BF) have strong material and spectral (ν^{-3}) dependence
- Compton scatter "opacity" depends weakly on composition (~Z/A) and the backlight spectrum

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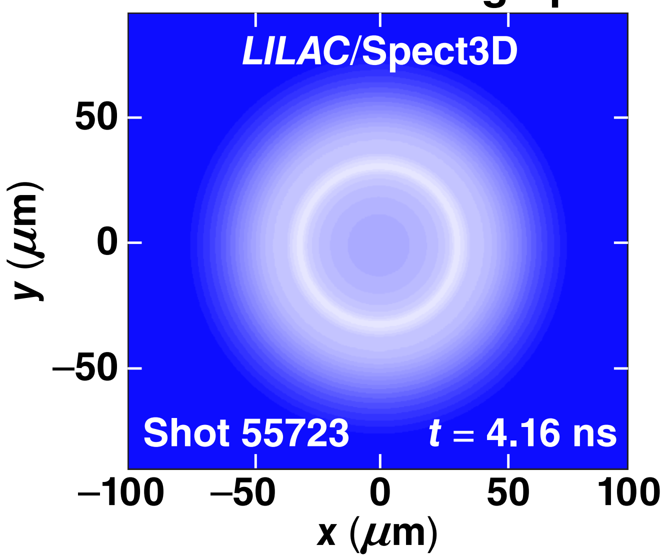
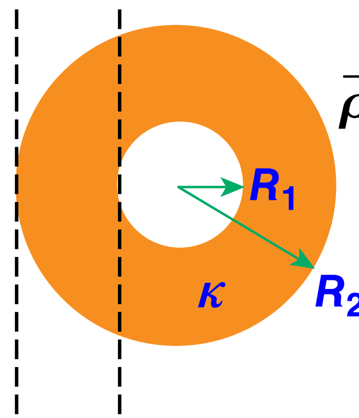
The shell ρR can be estimated by fitting a three-parameter shell model to the radiographic data

Simulated radiograph

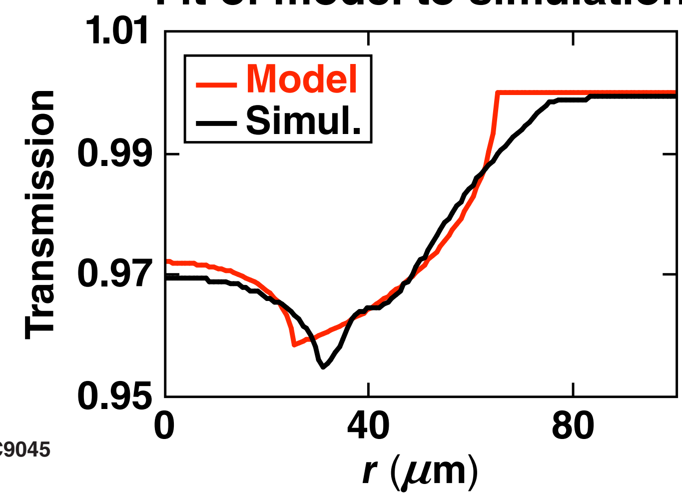


Homogeneous shell model and its radiograph

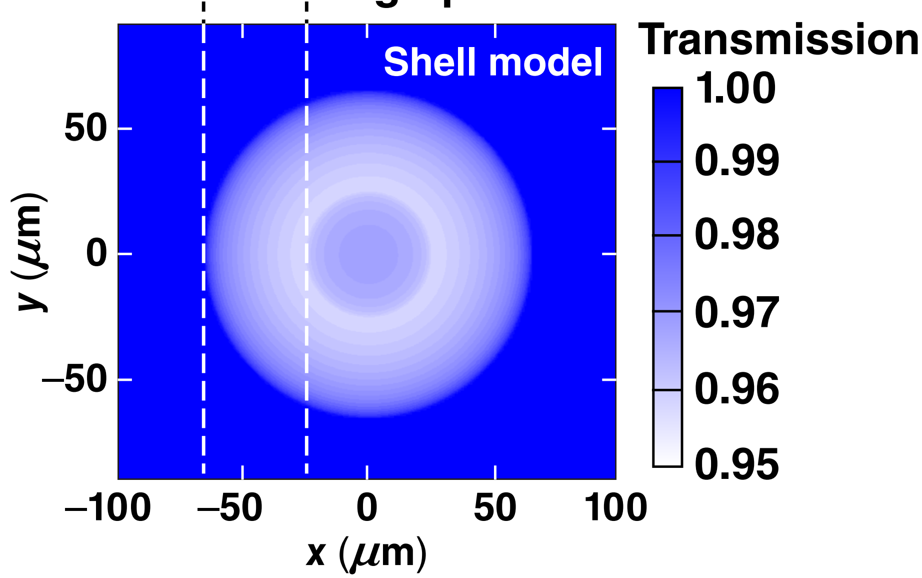


$$\overline{\rho R} = \frac{m_{\mathrm{I}}}{Z\sigma_{\mathrm{KN}}}\kappa(R_2 - R_1)$$

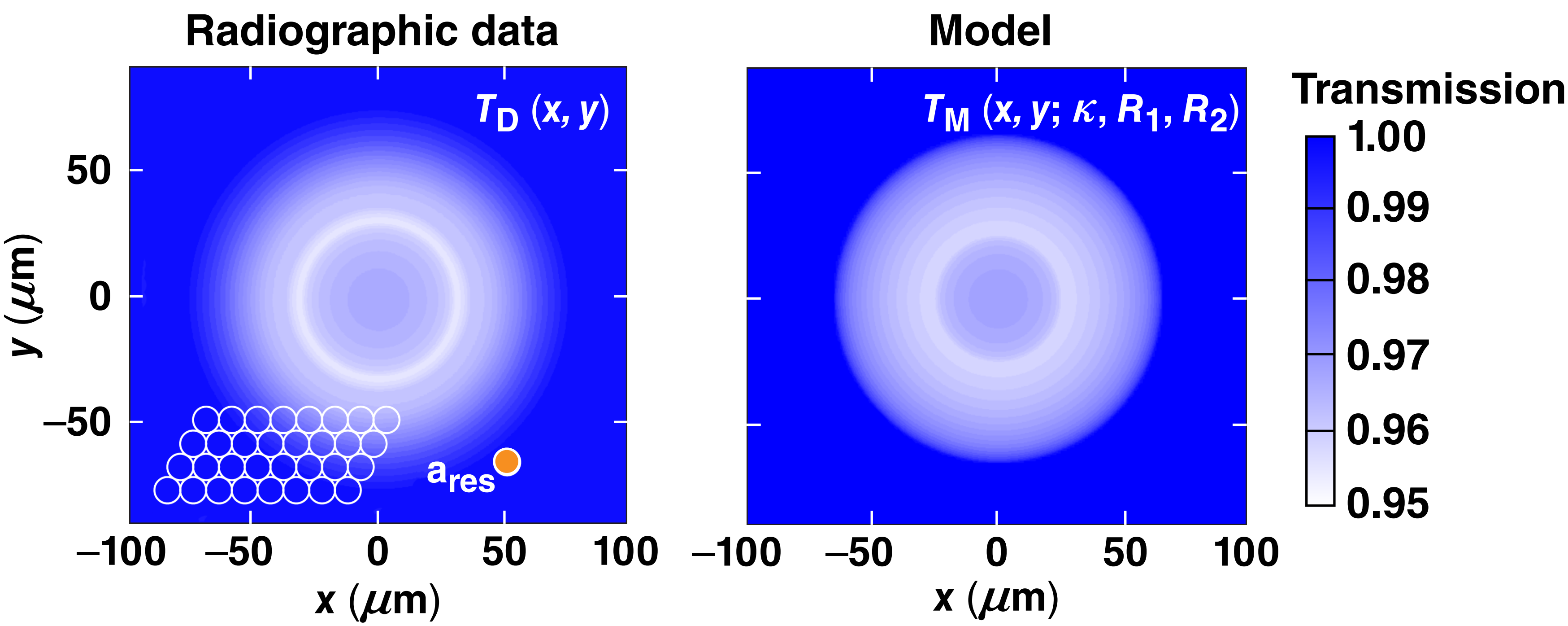
Fit of model to simulation



Model radiograph



The least-squares fitting process begins by characterizing the radiographic transmission data



- Assume statistically independent transmission measurements distributed uniformly, one per resolution area: $a_{res} \approx \pi r_{BL}^2$
- Measurement variance: σ_T
- Find the κ, R_1, and R_2 values that minimize $\chi^2 = \sum_i \frac{(T_D - T_M)^2}{\sigma_T^2}$

TC9047a

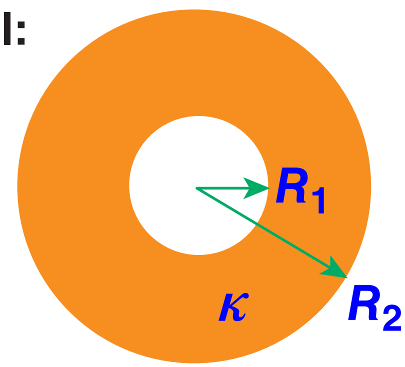
The variances of the parameter estimates are obtained from the least-squares fitting process

Minimize $\chi^2 = \sum_i \frac{(T_D - T_M)^2}{\sigma_T^2}$

Measurement variance: σ_T

Resolution area: $a_{res} \approx \pi r_{BL}^2$

Model:



$T_M(x, y; \kappa, R_1, R_2)$ and $\frac{\partial T_M(x, y; \kappa, R_1, R_2)}{\partial p_k}$

where $p_k = \{\kappa, R_1, R_2\}$

The covariance matrix gives the variances of the parameter estimates.

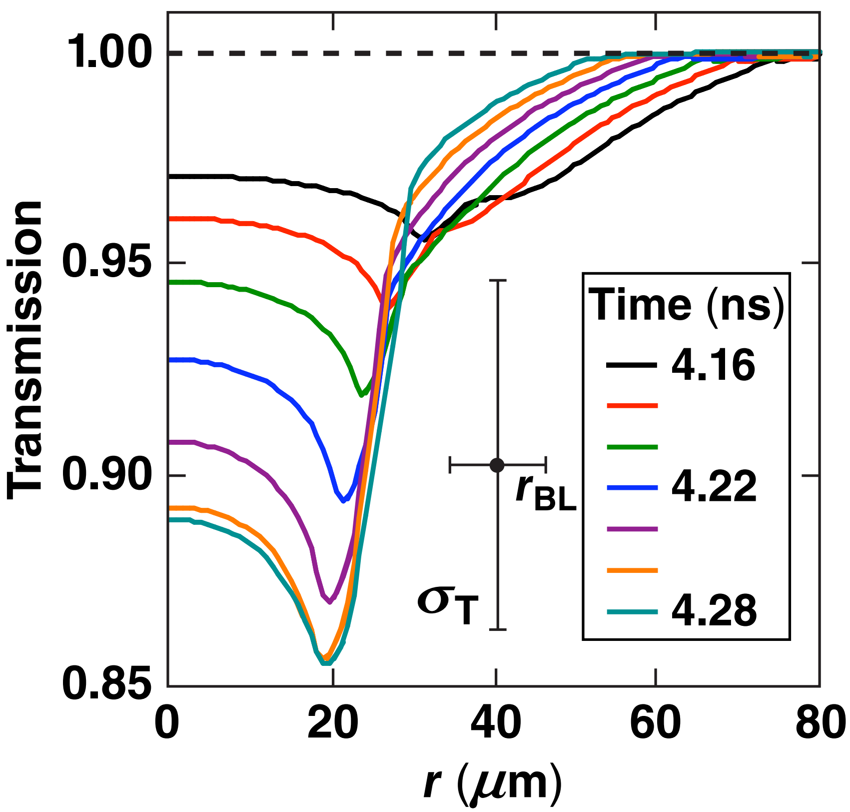
$$\sigma_k^2 = \langle \delta p_k \delta p_k \rangle, \text{ where } \langle \delta p_k \delta p_l \rangle = \left[\sum_i \frac{1}{\sigma_T^2} \left(\frac{\partial T_M}{\partial p_k} \right) \otimes \left(\frac{\partial T_M}{\partial p_l} \right) \right]^{-1}$$

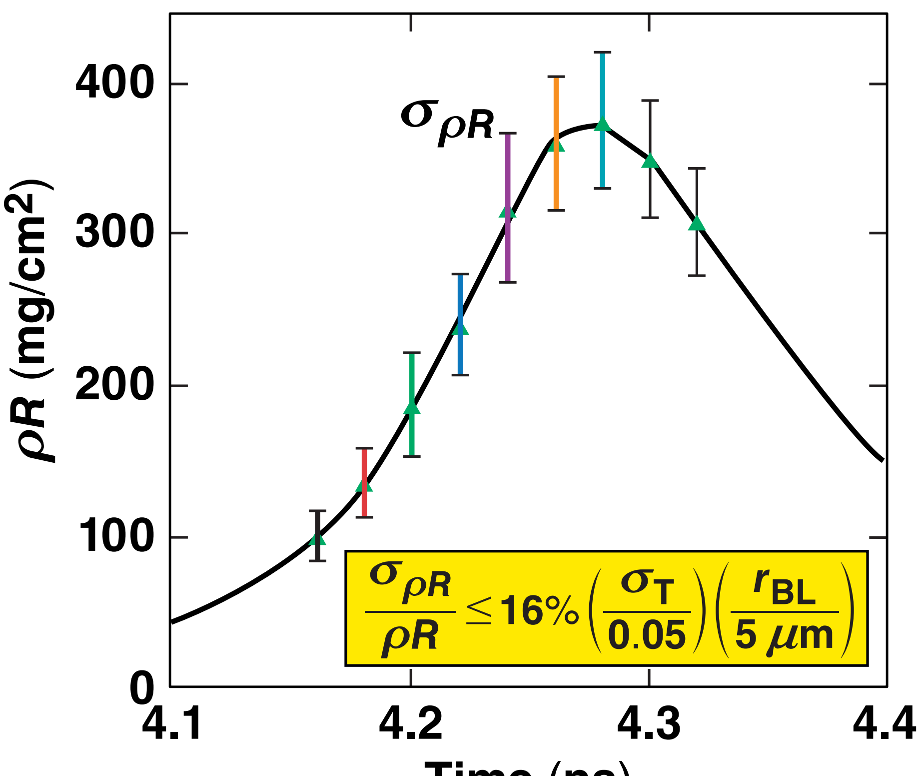
Scaling: $\sigma_k^2 \sim \sigma_T^2 / N$, $N \sim \pi R_2^2 / a_{res}$, $\boxed{\sigma_k \sim \sigma_T (r_{BL}/R_2)}$

TC9047

Analysis of *LILAC*/Spect3D simulated data in terms of the homogeneous shell model gives accurate ρR results

- *LILAC*/Spect3D*–simulated Compton radiographs
- Analysis with nominal measurement error $\sigma_T = 0.05$ and a resolution area of radius $r_{BL} = 5\ \mu m$





TC9046

*Prism Computational Sciences, Inc., Madison, WI.

Summary/Conclusions

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