Tantalum shock-released from 2 MBars to 0.78 MBars in lithium fluoride lands on the reflected Hugoniot within 0.2 percent

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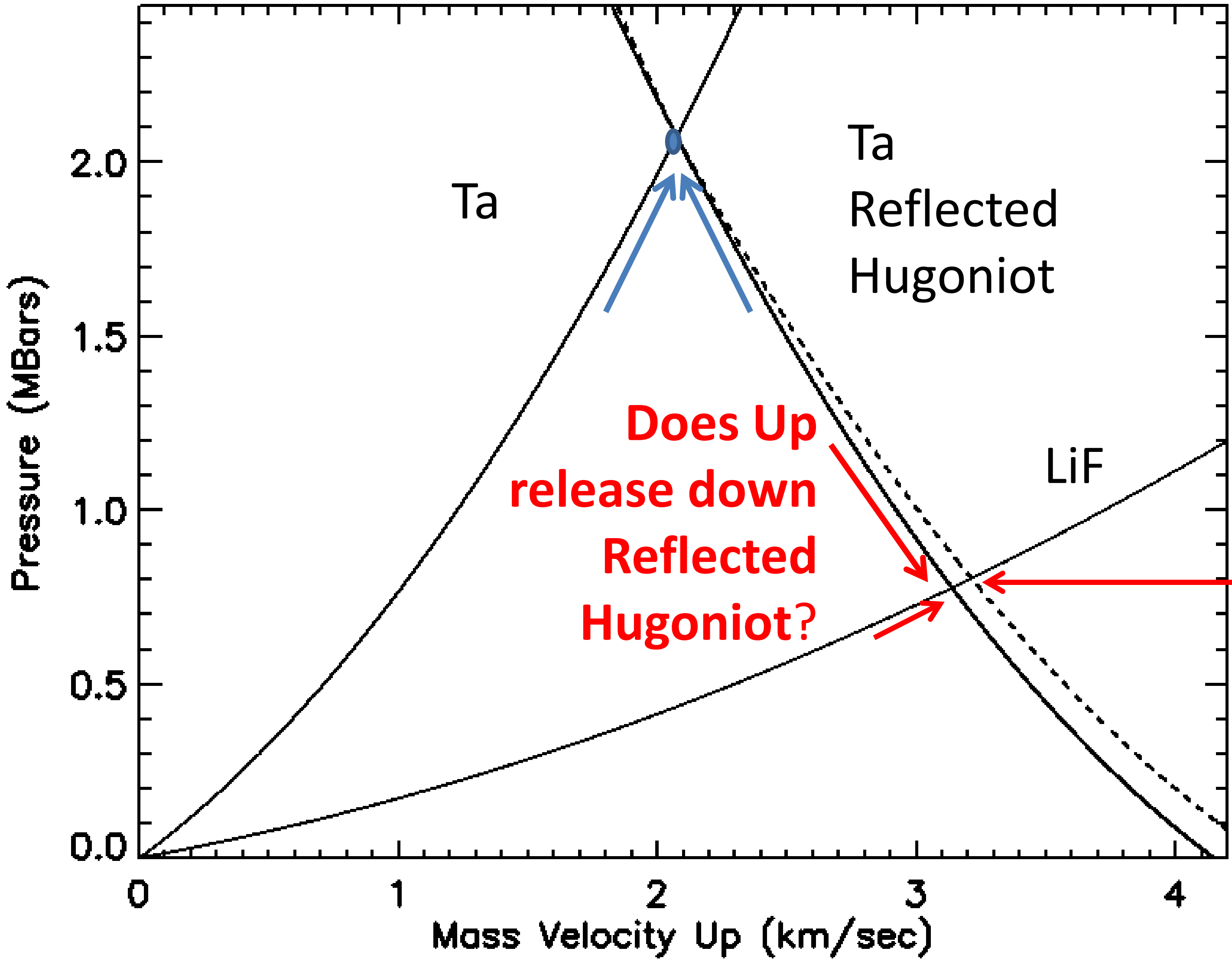
References

1. S. P. Marsh, "LASL Shock Hugoniot Data", Los Alamos Series on Dynamic Material Properties (1980).
2. A. C. Mitchell and W. J. Nellis, "Shock compression of aluminum, copper, and tantalum", J. Appl. Phys. 52(5), May 1981
3. N. C. Holmes, J. A. Moriarty, G. R. Gathers, and W. J. Nellis, "The equation of state of platinum to 660 GPa (6.6 Mbar)" J. Appl. Phys. 66, 2962 (1989).
4. B. J. Jensen, D. B. Holtkamp, and P. A. Rigg, D. H. Dolan, "Accuracy limits and window corrections for photonic Doppler velocimetry", J. Appl. Phys. 101, 013523 (2007).
5. P. A. Rigg, M. D. Knudson,2 R. J. Scharff, R. S. Hixson, "Determining the refractive index of shocked [100] lithium fluoride to the limit of transmissibility", (in press June 2014)

Impedance Matching and Pressure Standards are used to Determine Velocities, Densities and Pressures



Or
is there a
measurable
thermal
expansion
on
release?

Can we perform a Ta -> Ta-LiF experiment and observe deviations from the reflected-Hugoniot on release?

Where is the uncertainty in Up lowest?

There are Two Hugoniot-Uncertainty Representations:

C-error polynomial in Up:

[1] A. C. Mitchell and W. J. Nellis, 1981

[2] Holmes, Moriarty, Gathers, and Nellis 1989

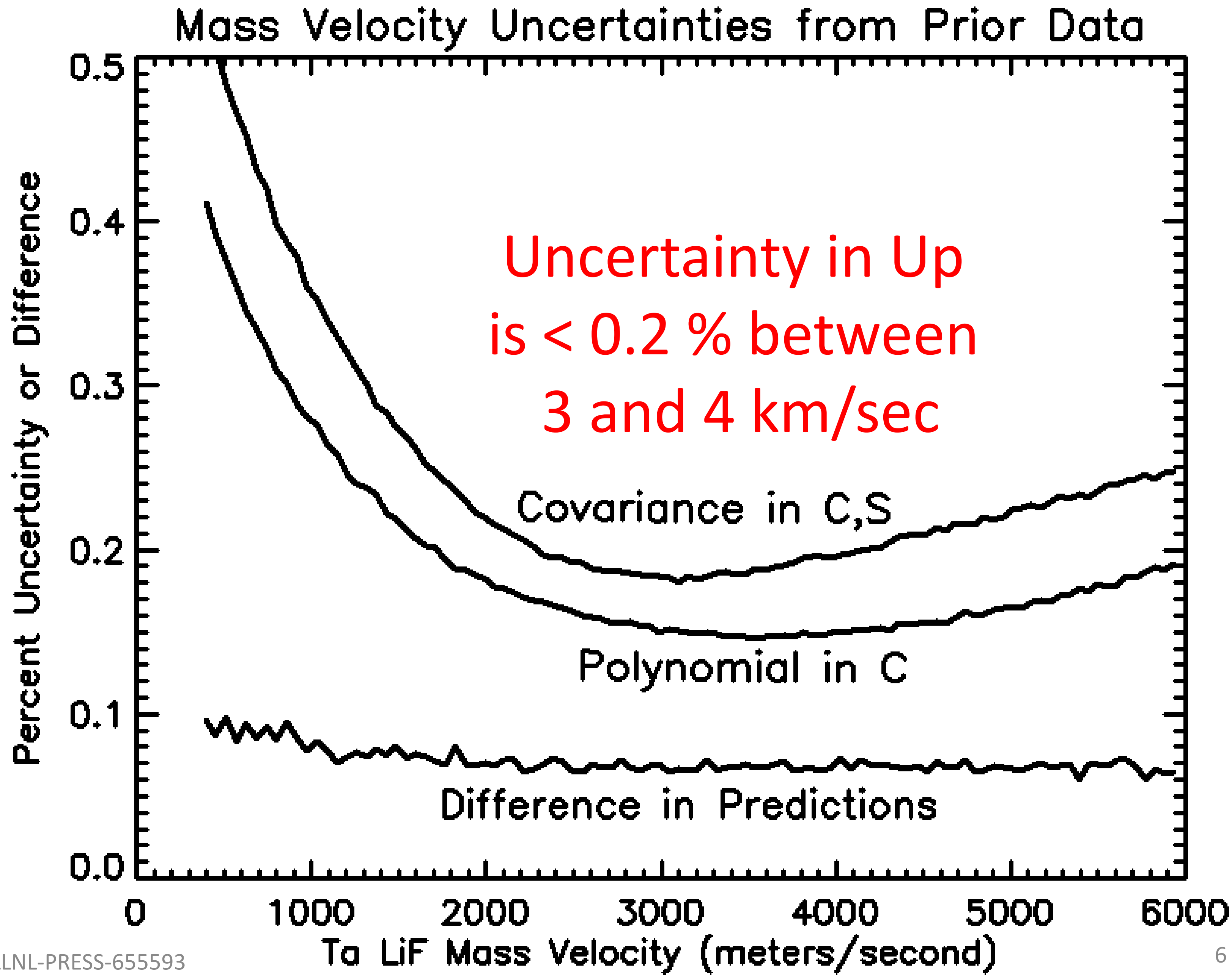
Covariance in C, S:

[3] Rigg, Knudson, Scharff, Hixson 2014

Hugoniots	from [2, 6] with polynomial one-sigma uncertainties in C				from [3] with covariance one-sigma uncertainties in C, S			
Ta	C	[2]	3291.	m/s	C	[3]	3315.	m/s
	S		1.308		S		1.300	
	A_0	[1, 5]	23.65	m/s	$\sigma_C^{\ 2}$	[3]	879.10	$(m/s)^2$
	A_1		-0.01437		$\sigma_S^{\ 2}$		1.8701e-4	
	A_2		3.67E-6	s/m	$\sigma_{CS}^{\ 2}$		-0.38046	m/s
LiF	C	[6]	5150.	m/s	C	[3]	5215.	m/s
	S		1.35	m/s	S		1.351	
	A_0	[1, 5]	31.48	m/s	$\sigma_C^{\ 2}$	[3]	2350.99	$(m/s)^2$
	A_1		-1.62769E-2		$\sigma_S^{\ 2}$		6.4093e-4	
	A_2		3.7040E-6	s/m	$\sigma_{CS}^{\ 2}$		-1.01165	m/s

[4] $U_s = C + SU_p$ [5] $\sigma_C = A_0 + A_1 U_p + A_2 U_p^{\ 2}$ [6] Based on data in Marsh 1980

Ta:LiF Release



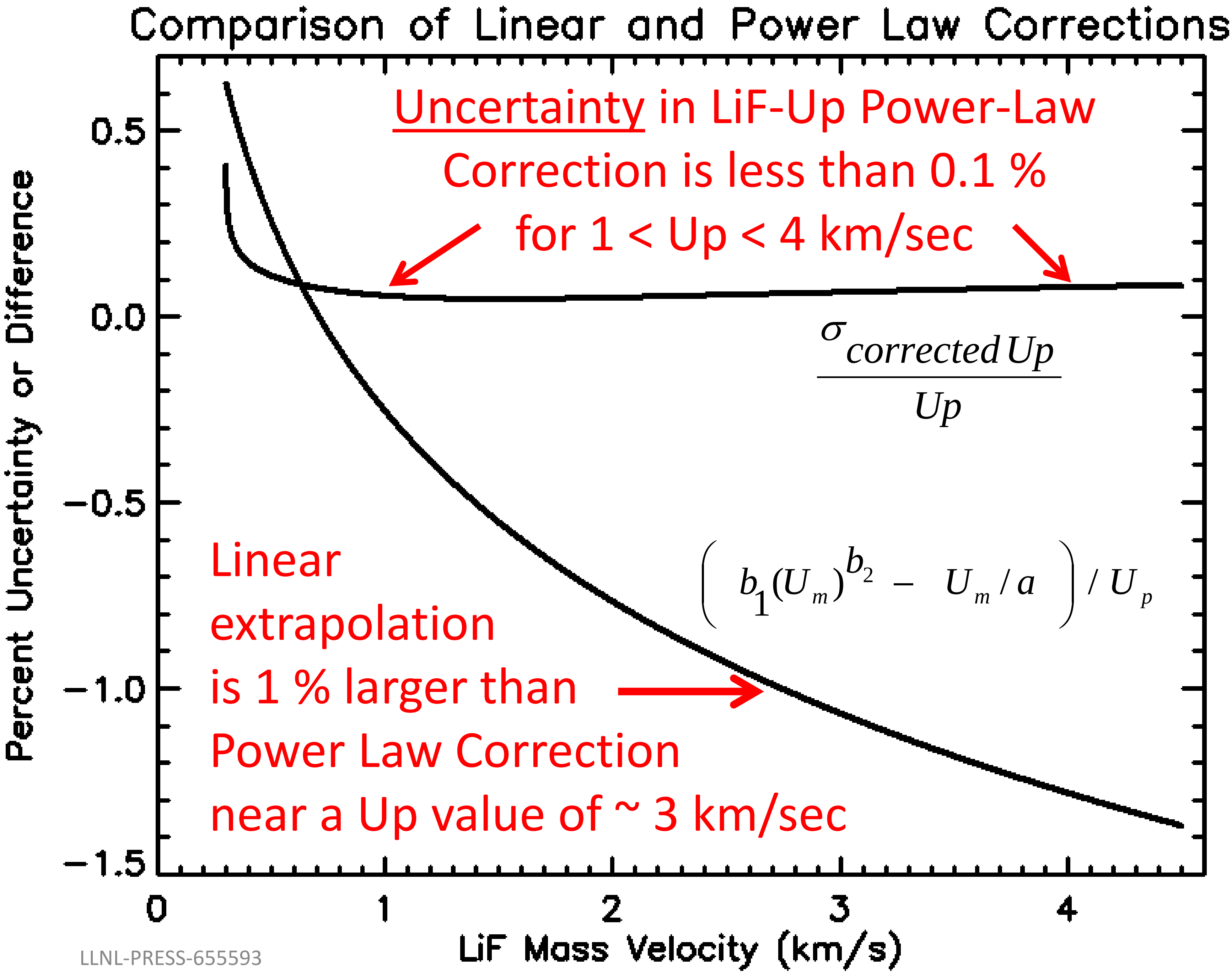
There are Two Velocity Correction Methods

Linear approximation for low velocities (0.47 to 0.9 km/sec):

B. J. Jensen, D. B. Holtkamp, and P. A. Rigg, D. H. Dolan, "Accuracy limits and window corrections for photonic Doppler velocimetry", J. Appl. Phys. 101, 013523 (2007).

Power law method based on 13 points between 0.47 and 4.5 km/sec:

P. A. Rigg, M. D. Knudson, R. J. Scharff, R. S. Hixson, "Determining the refractive index of shocked [100] lithium fluoride to the limit of transmissibility", (in press June 2014)


Comparison of Linear and Power Law Corrections
Uncertainty in LiF-Up Power-Law
Correction is less than 0.1 %
for 1 < Up < 4 km/sec
$\frac{\sigma_{corrected\,Up}}{Up}$
Linear
extrapolation
is 1 % larger than
Power Law Correction
near a Up value of ~ 3 km/sec
$\left(b_1 (U_m)^{b_2} - U_m / a \right) / U_p$
Percent Uncertainty or Difference
0.5
0.0
−0.5
−1.0
−1.5
0
1
2
3
4
LiF Mass Velocity (km/s)

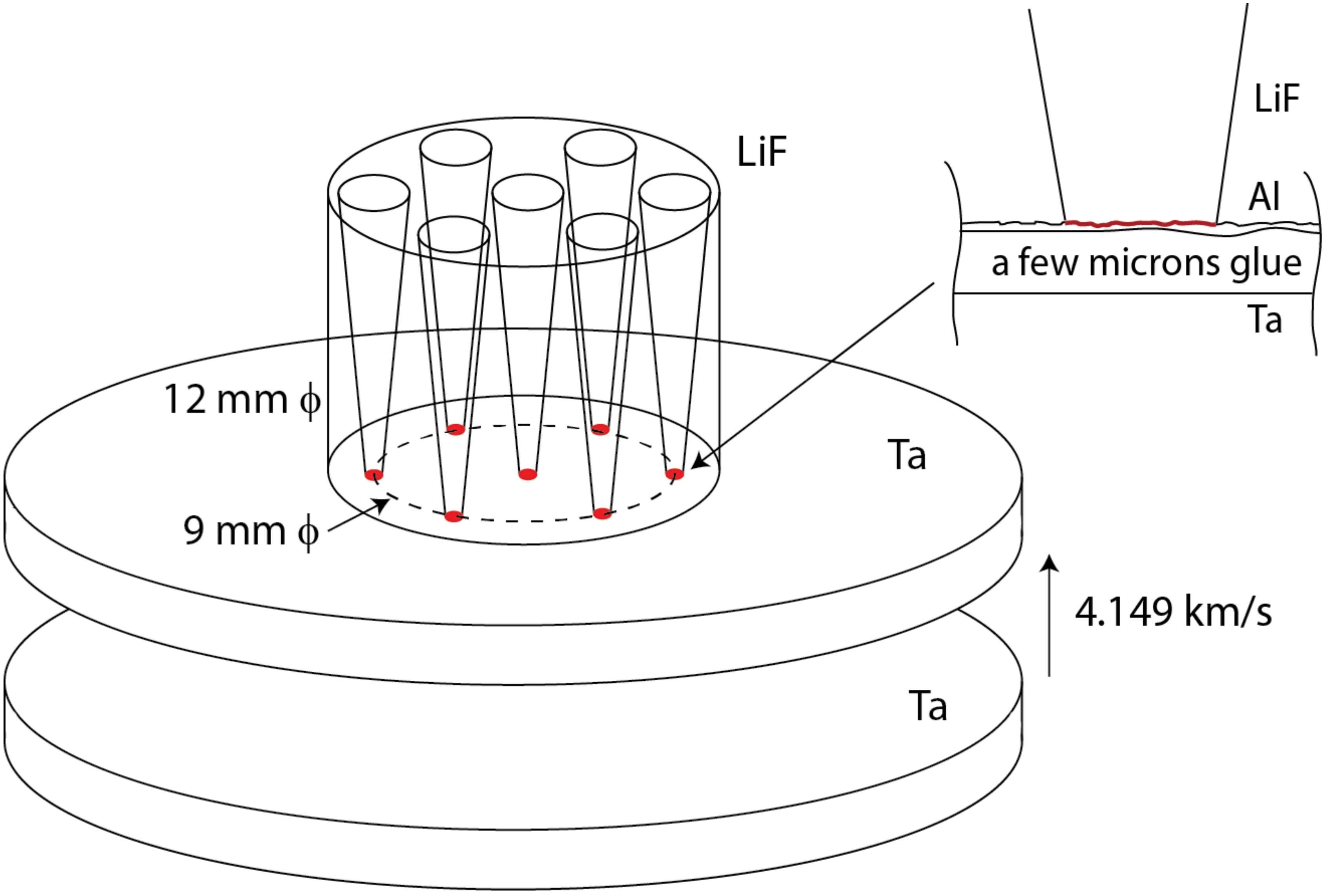
For Ta impacting Ta-LiF with release
Up = 3.1 km/sec, these quantities are no larger than 0.18 %:

- the difference in predicted Up's,
- uncertainties in predicted Up,
- and uncertainty in corrected Up with power law correction.

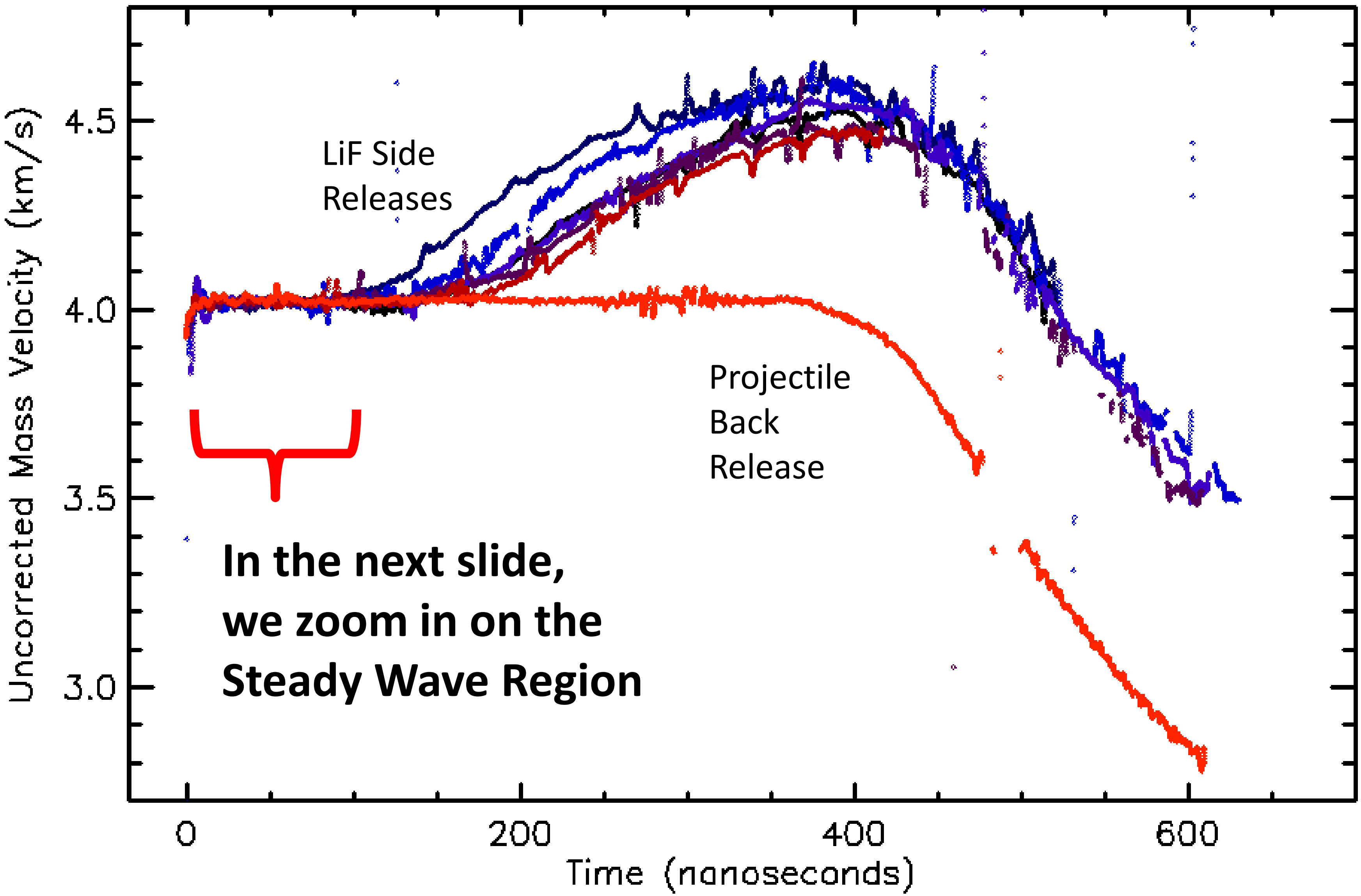
We performed an impact experiment with Ta impacting Ta-LiF and used PDV to observe Up near 3.136 km/sec with these parameters:

Impactor velocity	**4.149**	**km/sec**	**0.1 %**	**Measured**
Impactor density	16.6409	gm/cc	0.1 %	Measured
Base density	16.6440	gm/cc	0.1%	Measured
LiF density	2.640	gm/cc	0.2 %	Literature
LiF purity	99.99%			Procurement spec
Laser wavelength	1550.297	nm	10^{-6}	Measured
Laser linewidth	< 7.5	MHz		Measured
Sample rate	50	Gsamples/s		Calibrated
Gaussian Window	2.04	ns FWHM		

We collected PDV data from seven identical channels

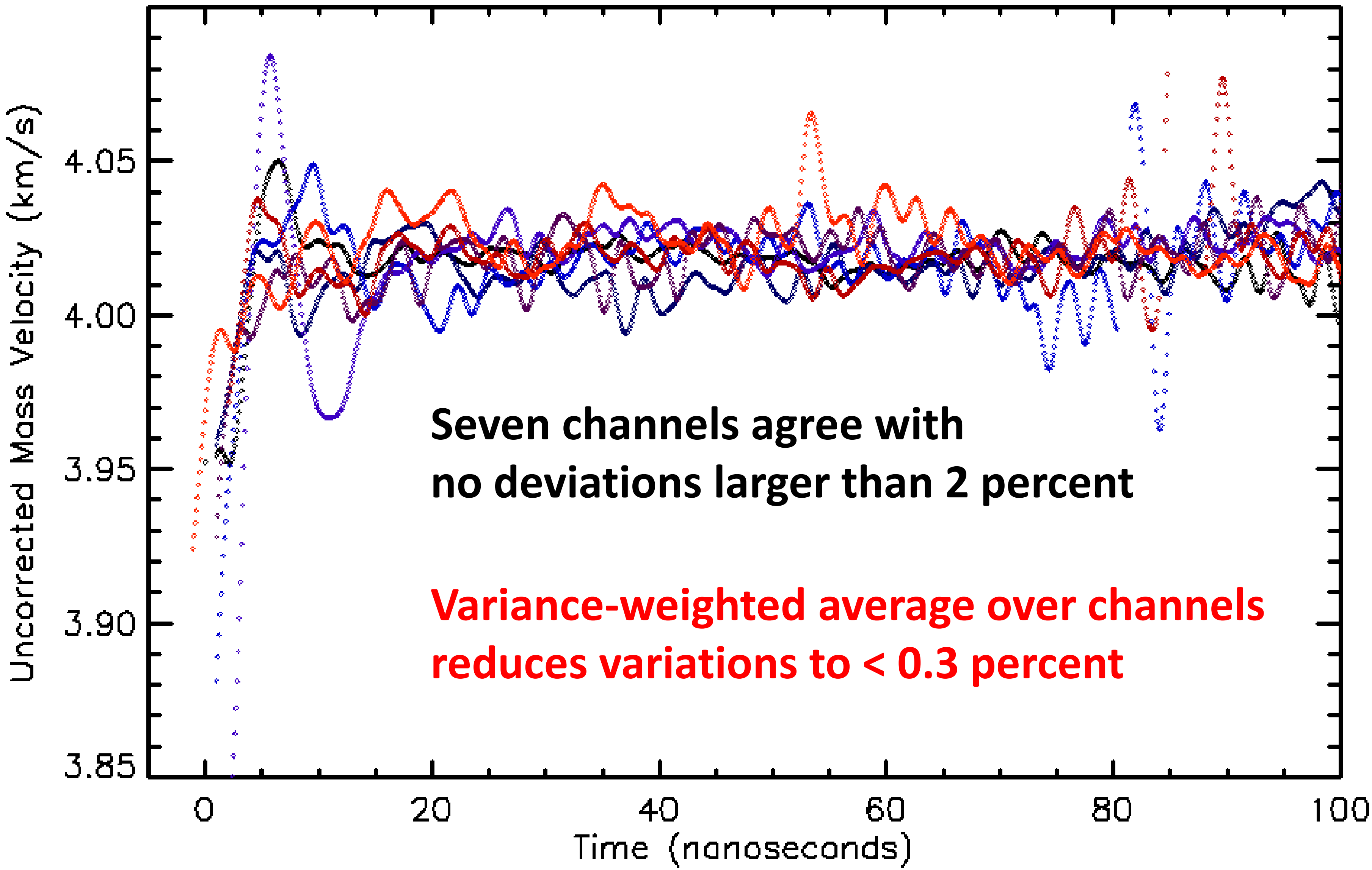


Uncorrected Mass Velocities for Ta -> Ta:LiF at 4.149 km/sec



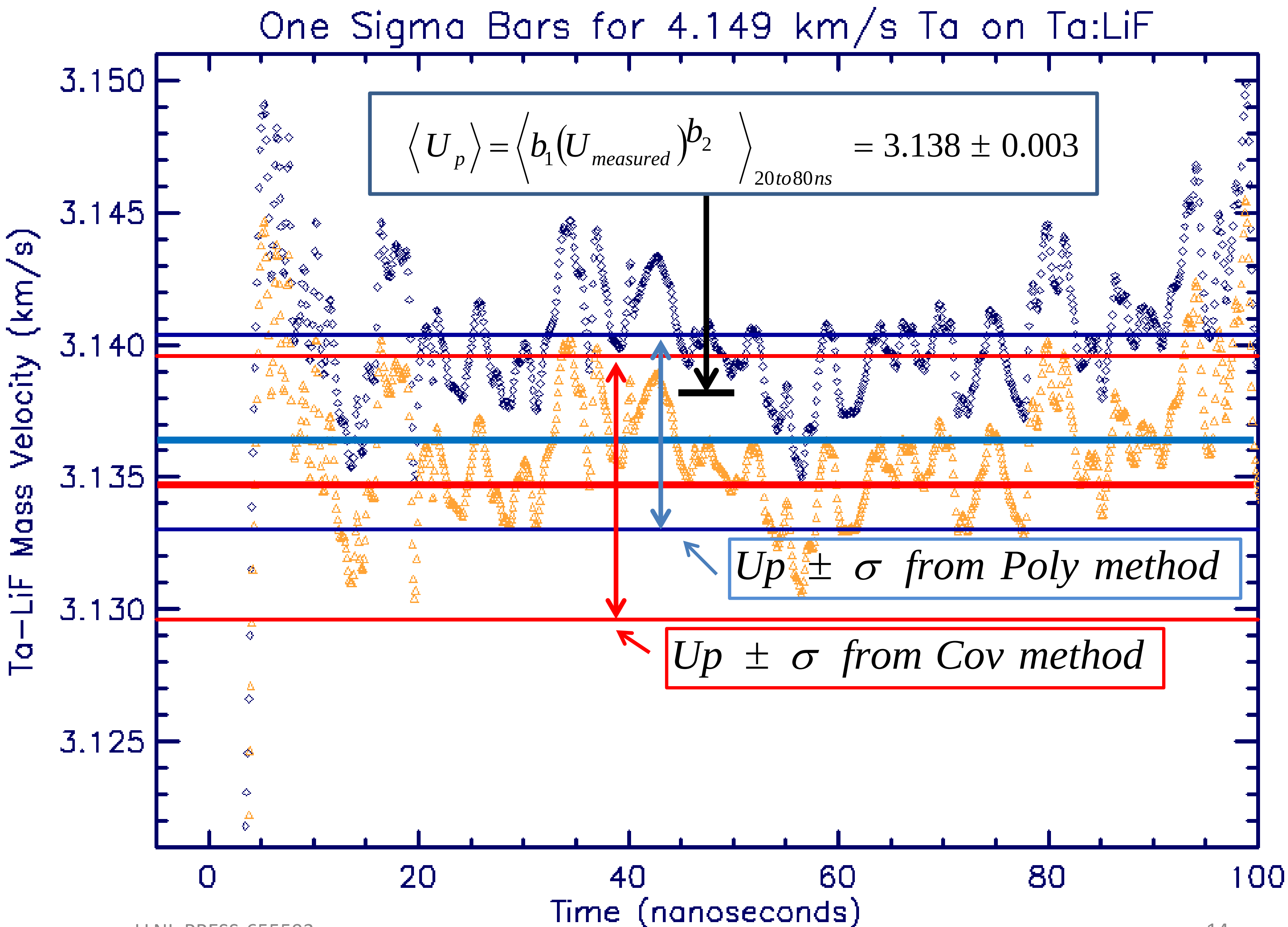
In the next slide, we zoom in on the Steady Wave Region

Uncorrected Mass Velocities for Ta -> Ta:LiF at 4.149 km/sec



Seven channels agree with no deviations larger than 2 percent

Variance-weighted average over channels reduces variations to < 0.3 percent


One Sigma Bars for 4.149 km/s Ta on Ta:LiF
$\langle U_p \rangle = \langle b_1 (U_{measured})^{b_2} \rangle_{20 to 80 ns} = 3.138 \pm 0.003$
Up ± σ from Poly method
Up ± σ from Cov method
Ta–LiF Mass Velocity (km/s)
Time (nanoseconds)
3.150
3.145
3.140
3.135
3.130
3.125
0
20
40
60
80
100

RESULTS	Up (km/s)	Sigma Up (km/s)	Percent
1980, 1981 1989 EOS	3.136	0.004	0.12
2014 EOS	3.135	0.005	0.16
Power Law	3.138	0.003	0.09

CONCLUSIONS:

With no additional corrections, the predicted Up from prior shock-wave measurements and power-law corrected PDV agree within one standard deviation.

The release in tantalum from 2 Mbars to 0.78 Mbars
lands on the tantalum reflected Hugoniot within 0.2 %