



GTR 7 Informal Working Group
February 28 – March 1 2011
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GTR7-06-03



Rear Impact Dummy Biofidelity

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Objectives & Tasks

- **Evaluate biofidelity of available RIDs (BioRID, RID3D, HyIII)**
 - Choose biofidelity test condition
 - Develop experimental seat for rear impact sled testing
 - Conduct sled tests
 - PMHS (Post-Mortem Human Subjects)
 - Dummies (BioRID II, RID3D, Hybrid III)
 - Assess biofidelity and repeatability of dummies
- **Investigate the mechanism of injury**
 - Develop and validate 3-D cervical spine kinematic instrumentation
 - Identify injurious kinematics (if possible)
- **Choose appropriate dummy & injury criterion**
 - Assess efficacy of various ICs (if possible)



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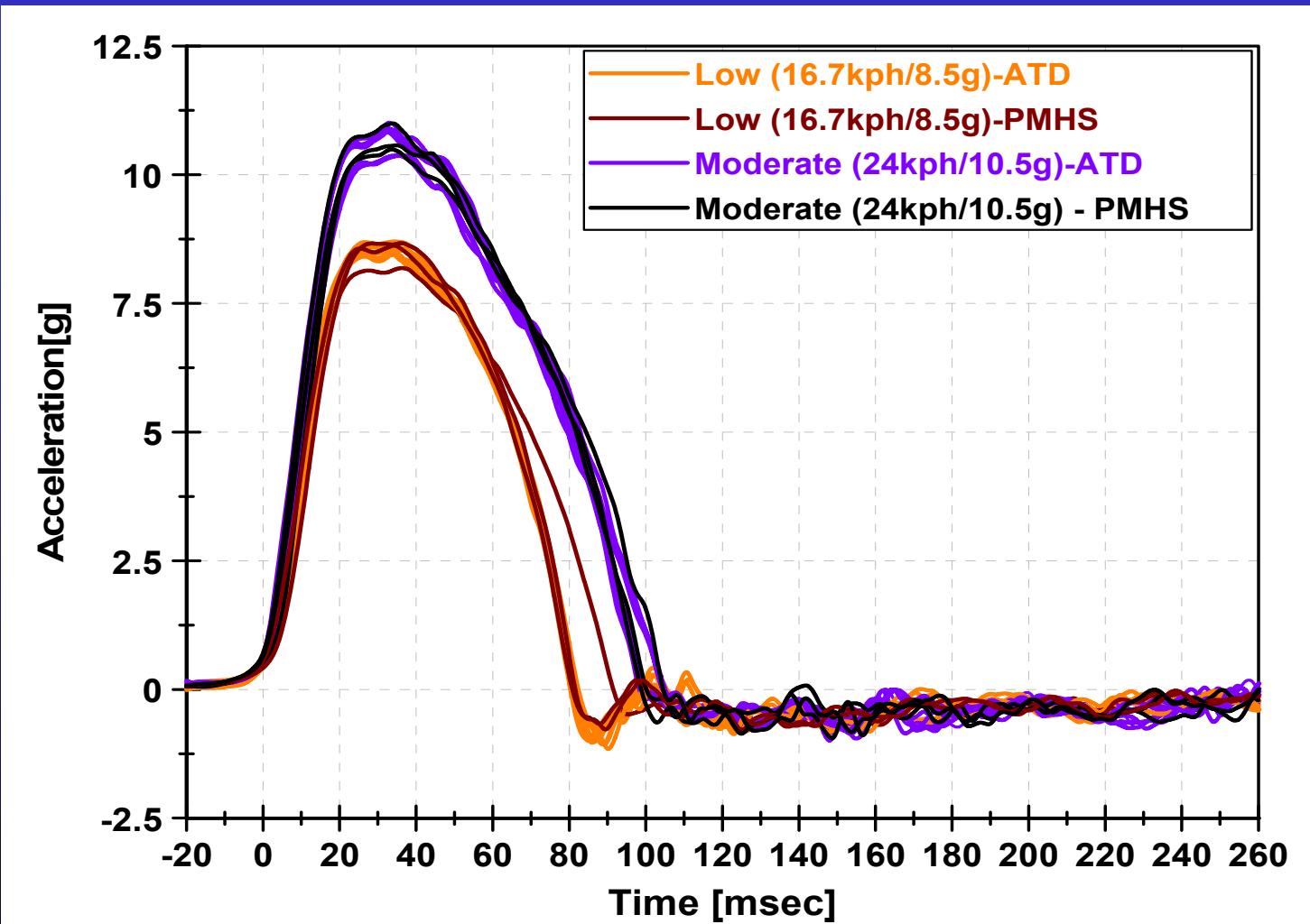


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Pulses: Low & Moderate speed





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Experimental Seat

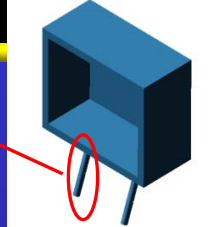
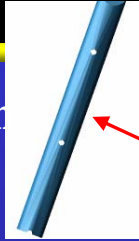
- **Design goals for experimental seat:**
 - Repeatable & Reproducible
 - Two seats side-by-side
 - Capable of measuring/evaluating external biofidelity
 - 6 load cells in seat back
 - 4 load cells in seat pan
 - 4 load cells in head restraint
 - Able to match the ‘yielding’ seat back motion of a typical OEM seat
 - Durable and Reusable
 - Withstand multiple tests without degradation in response



Experimental Seat

Head restraint

Diameter :17 mm



Mass : 5.5 kg

Seat

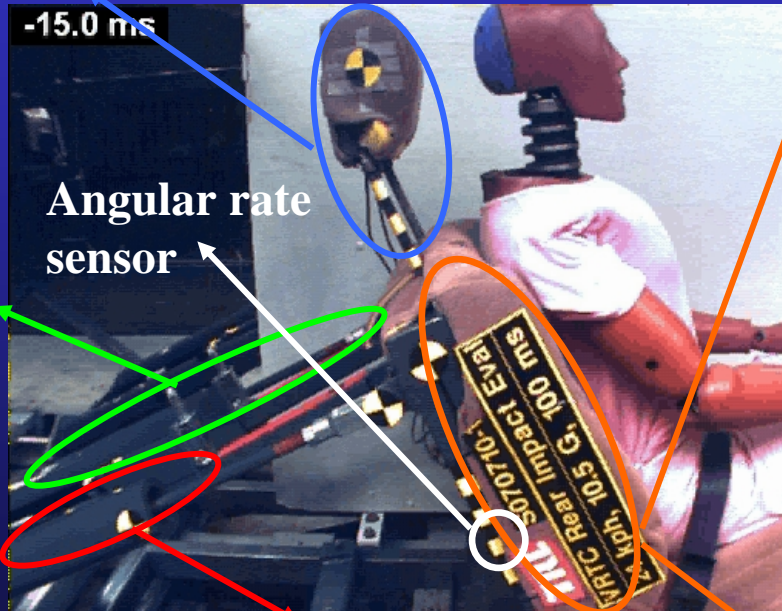
-Mass: 30 kg

-Padding / cushions /
seat cover of 1999
Toyota Camry seat

Damper

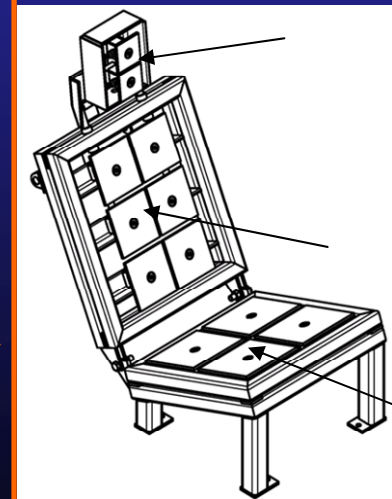


One-way damper (x2)



Angular rate
sensor

Seat instrumentation



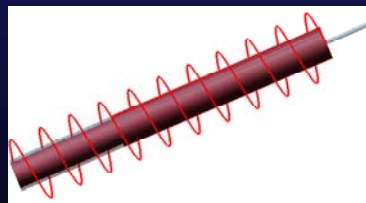
HR LCs

SB LCs

SP LCs

Spring

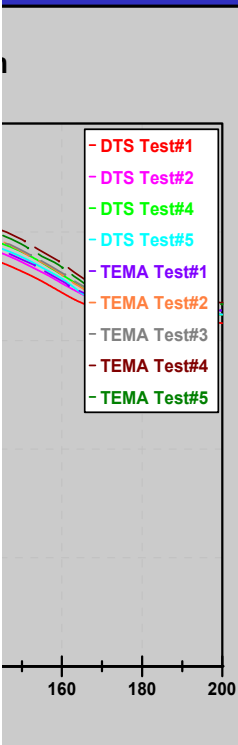
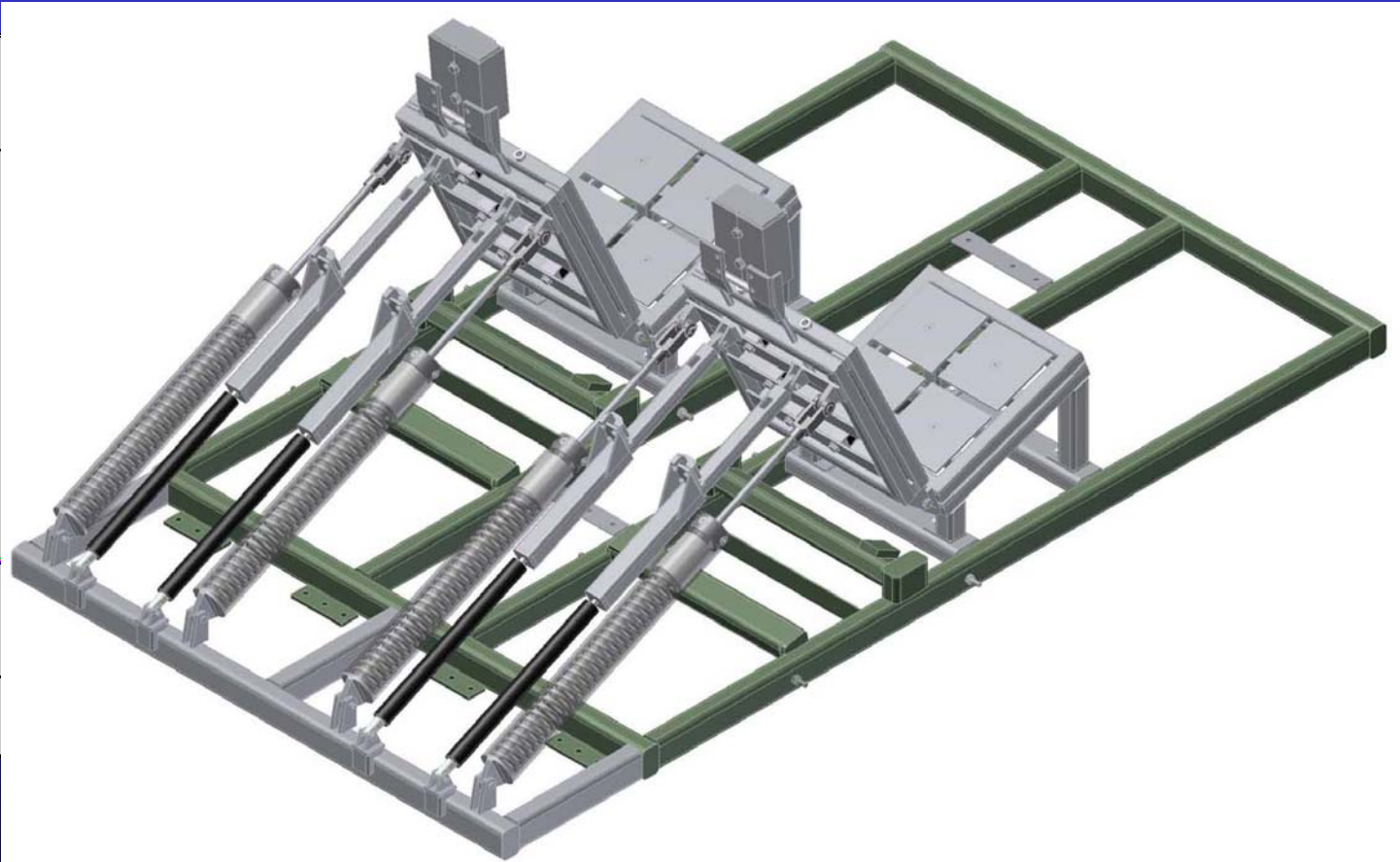
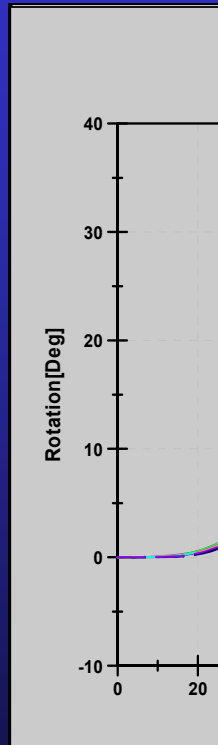
Stiffness:
13500 N/m
(x2)





Experimental Seat

■ R&R → Steel Ballast:



Repeatability (passenger): CV = 2.7 % (DTS); CV = 2.7 % (Video)
Reproducibility: CV = 3.0 % (DTS); CV = 3.0 % (Video)



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Test Matrix

Three repeats at each speed

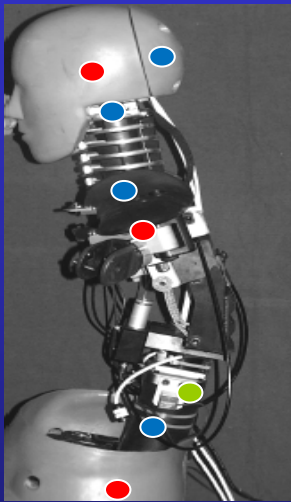
Dummies			
Test Number	Test Speed	Driver Side Dummy	Passenger Side Dummy
1	L	Hybrid III 50 th	BioRID II
2	L	Hybrid III 50 th	BioRID II
3	L	RID3D	BioRID II
4	L	RID3D	BioRID II
5	L	RID3D	Hybrid III 50 th
6	M	RID3D	Hybrid III 50 th
7	M	RID3D	Hybrid III 50 th
8	M	RID3D	BioRID II
9	M	RID3D	BioRID II
10	M	Hybrid III 50 th	BioRID II

7 PMHS at each speed

PMHS		
Test Number	Test Speed	Driver Side Dummy
1	M	PMHS 01
2	L (4)	PMHS 02
3	L/M	PMHS 03
4	L/M	PMHS 04
5	L/M	PMHS 05
6	L/M	PMHS 06
7	L/M	PMHS 07
8	L/M	PMHS 08



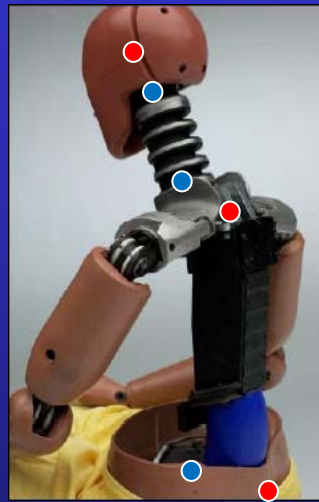
Internal Biofidelity Measures



<RID3D>

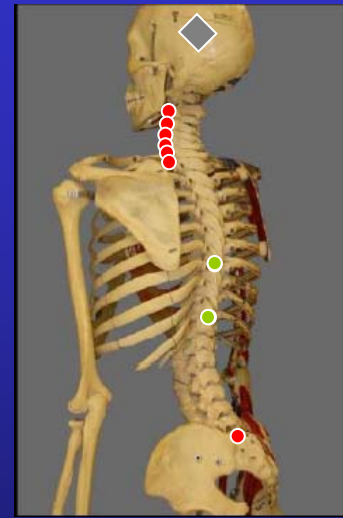
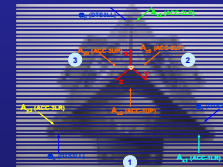


<BioRID II>



<Hybrid III>

- Accelerometers (x, z)
- Accelerometers (x, z) & angular rate sensor (y)
- Load cell
- ◆ Aluminum tetrahedron
 - 9au
 - 3a ω
 - 6a ω



<PMHS>

	RID 3D	BioRID II	Hybrid III	PMHS
Head	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	6a ω
T1	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)
T8	None	Two Acc (x, z)	None	Two Acc (x, z)
T12	Two Acc (x, z)	None	None	Two Acc (x, z)
L1	None	Two Acc (x, z)	None	Two Acc (x, z)
Pelvis	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)	Two Acc (x, z) One ARS (y)

	RID 3D	BioRID II	Hybrid III	PMHS
Skull Cap	Fx, Fz	Fx, Fz	None	None
Upper neck	Fx, Fz, My	Fx, Fz, My	Fx, Fz, My	None
Lower neck	Fx, Fz, My	Fx, Fz, My	Fx, Fz, My	None
Lumbar	Fx, Fz, My	Fx, Fz, My	Fx, Fz, My	None
Muscle Substitute (front)	None	Fx	None	None
Muscle Substitute (rear)	None	Fx	None	None



Sled Tests

Low Speed (8.5 g, 16.7 kph FMVSS 202)

BioRID II



Hybrid III



RID3D



PMHS 01





Sled Tests

Moderate Speed (10.5 g, 24.0 kph)

BioRID II



Hybrid III



RID3D



PMHS01





Methodology

- **Create Biomechanical Targets from PMHS data**
 - Calculate mean and standard deviation curves
 - Phase shift optimally aligned (Donnelly & Moorhouse, 2010)
- **Calculate ATD mean curves**
- **Calculate biofidelity ranking**
 - Updated NHTSA Biofidelity Ranking System
- **Calculate Repeatability**
 - Peak %CV
 - Average time-based %CV

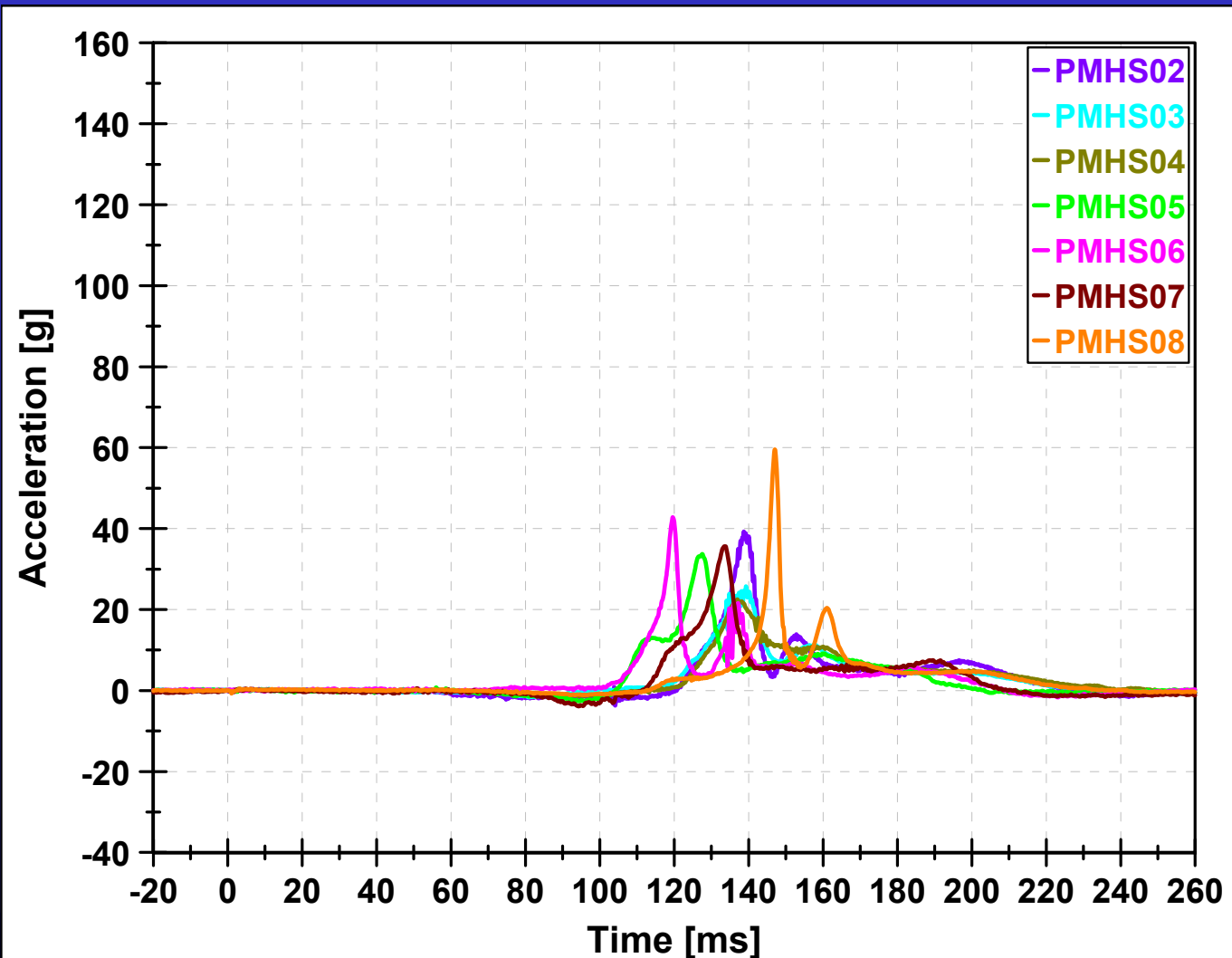


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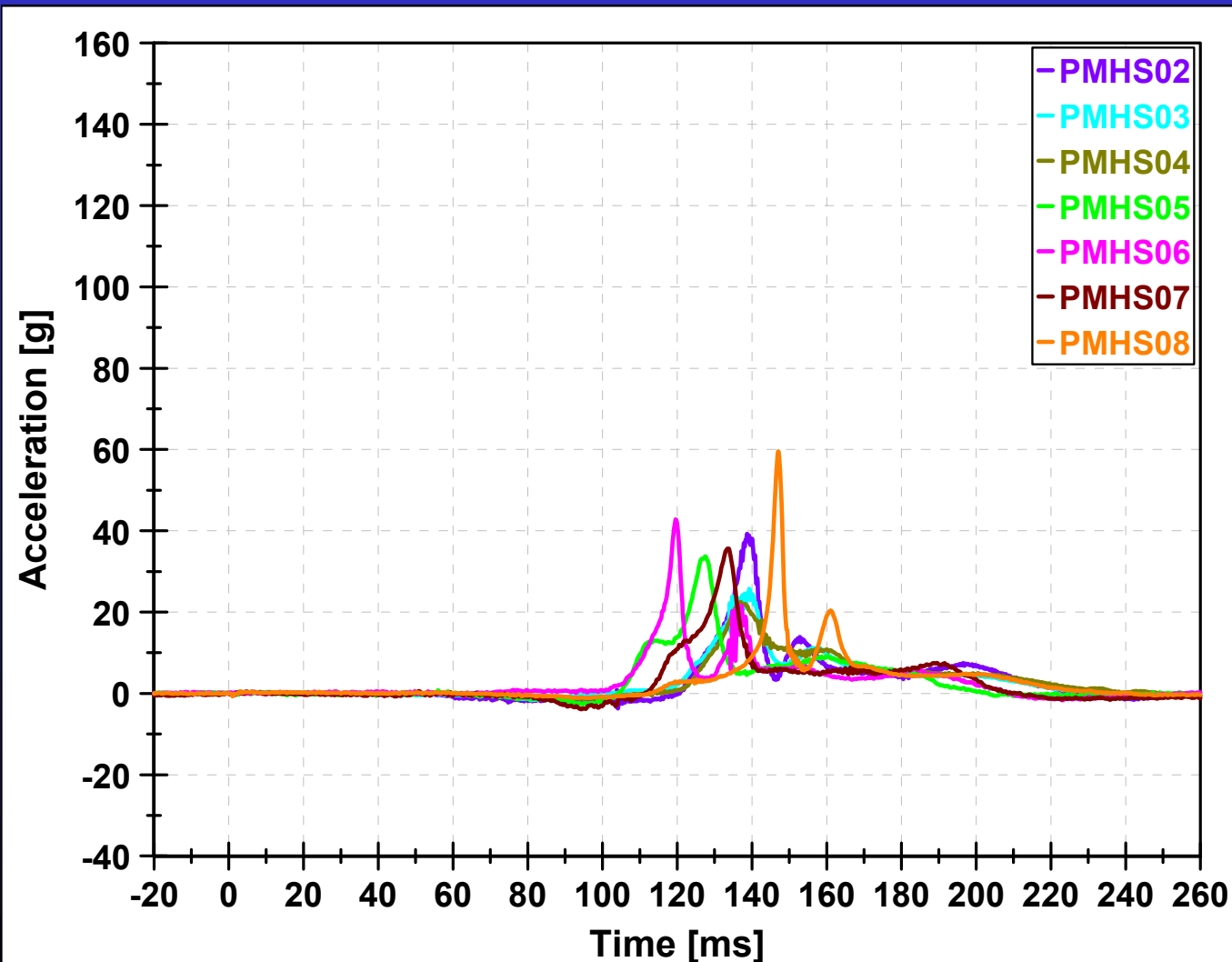


Methodology (Phase Alignment)



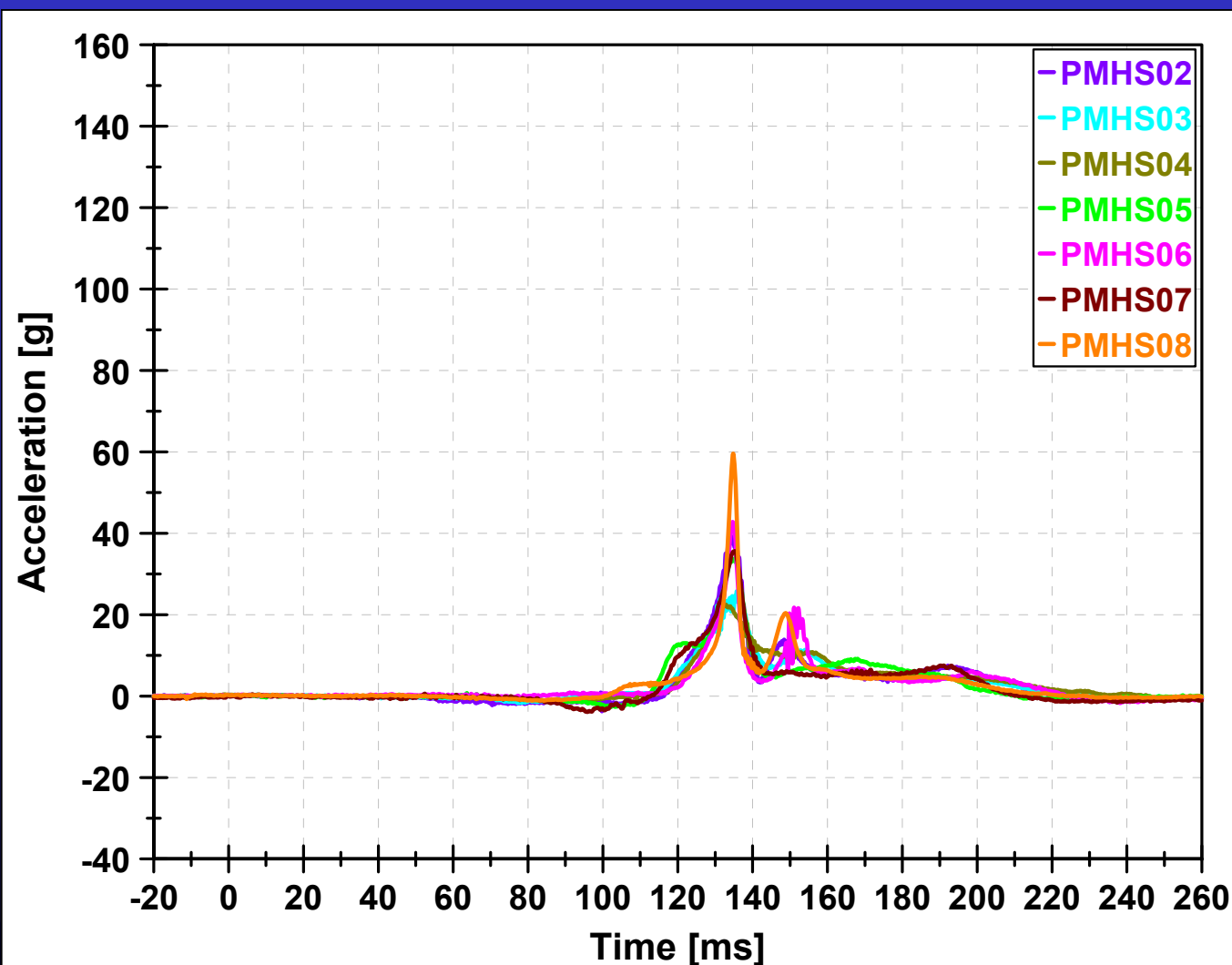


Methodology (Phase Alignment)





Methodology (Phase Alignment)





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 - Peak %CV
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Methodology (Biofidelity)

- **Biomechanical Target**
 - Mean PMHS response \pm one standard deviation
- **NHTSA Bio Rank (Rhule et al., 2002, 2009)**

$$B = \frac{\sum_{j=1}^m \left(V_j \times \left(\frac{\sum_{k=1}^n \sqrt{R_{j,k}}}{n} \right) \right)}{\sum_{j=1}^m V_j}$$

B = biofidelity rank

V = test condition weight

**R = response measurement comparison value
(DCV/CCV)**

j = test condition

k = response measurement

m = # of test conditions

**n = # of response measurements per test
condition**



Methodology (Biofidelity)

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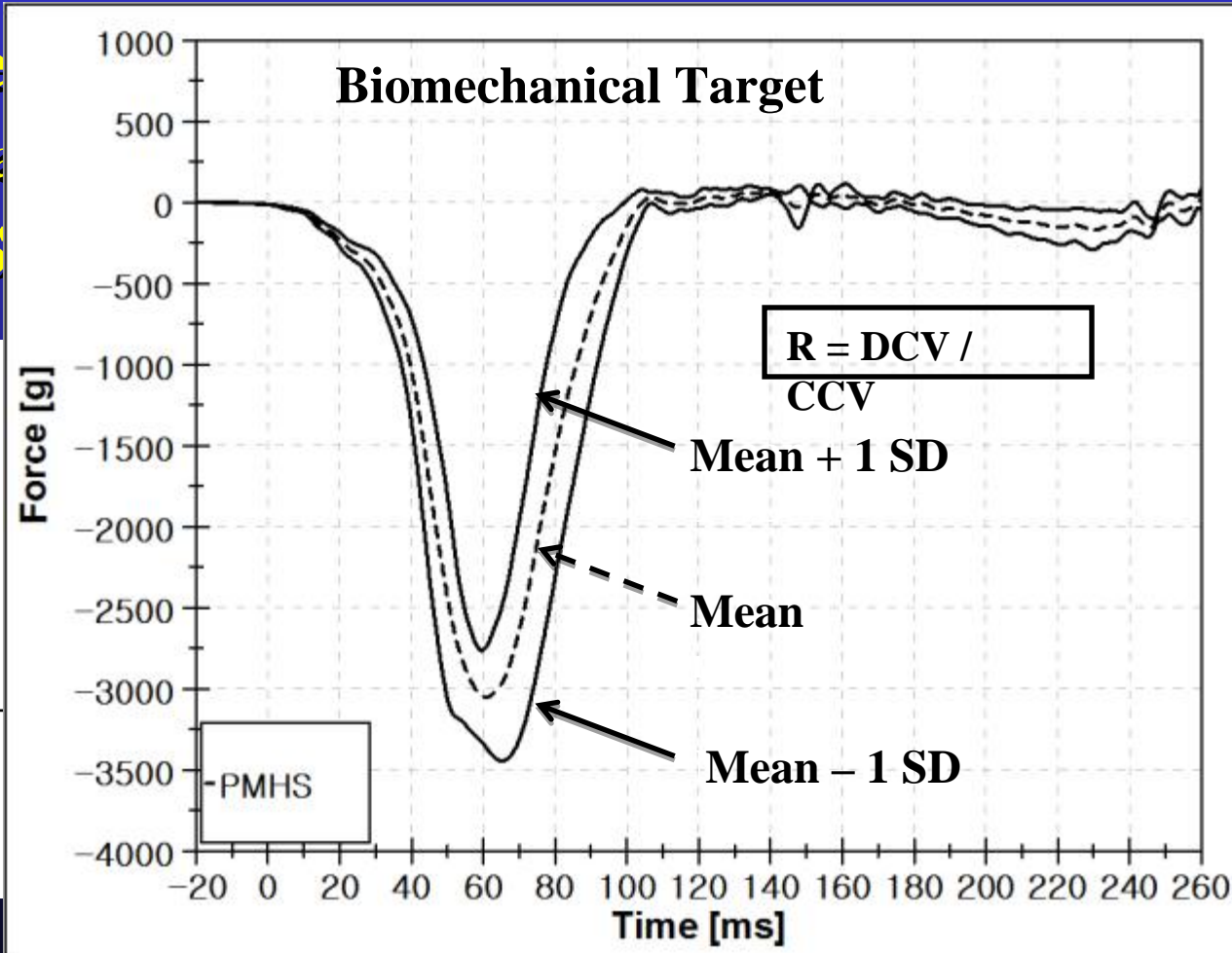
m = # of test conditions

n = # of response measurements per test condition



Methodology (Biofidelity)

- Biomechanical Target
- Mean
- NHTSA



$$B = \frac{\sum_{j=1}^m}{\dots}$$

Comparison value

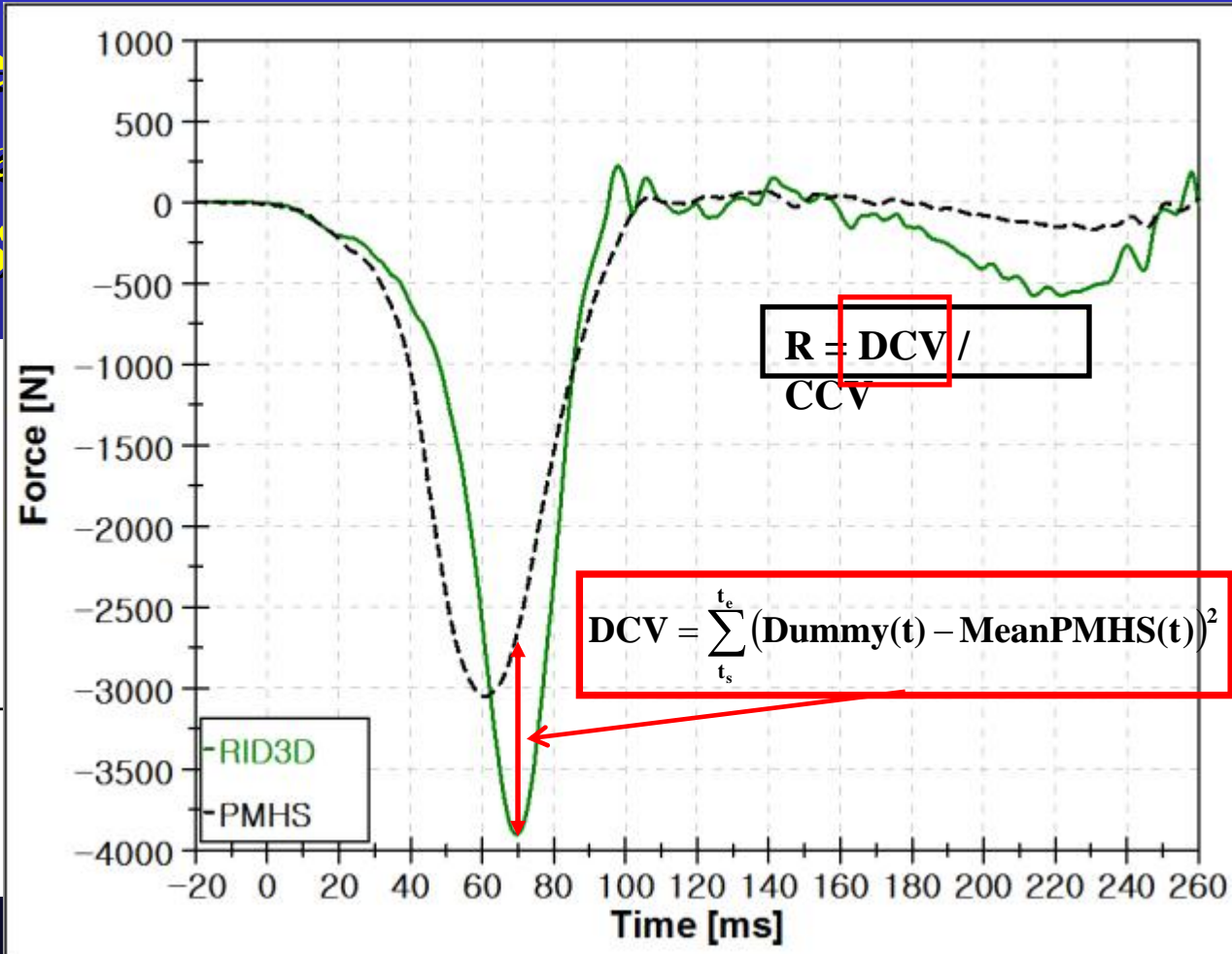
Test



Methodology (Biofidelity)

- Biomechanics
- Measurement
- NHTSA

$$B = \frac{1}{m} \sum_{j=1}^m$$



Comparison value

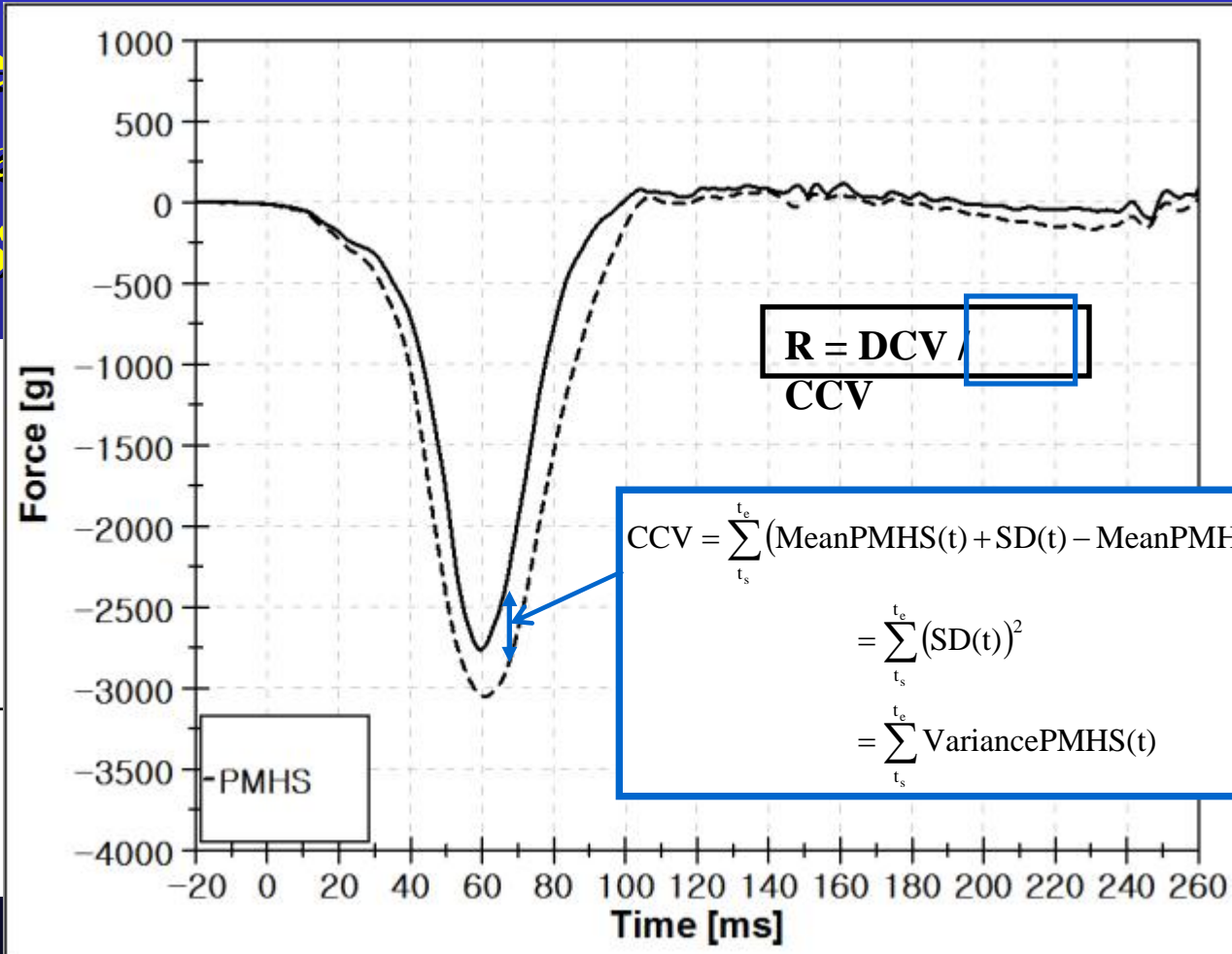
Crash test



Methodology (Biofidelity)

- Biomechanics
- Measurement
- NHTSA

$$B = \frac{1}{m} \sum_{j=1}^m$$



value

st



Methodology (Biofidelity)

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Methodology (Repeatability)

- **Peak analysis** (Rhule 2005)
 - **Coefficient of variation**

R&R rating	C.V. %
Excellent	0 to 5
Good	>5 to 8
Acceptable	>8 to 10
Poor	>10

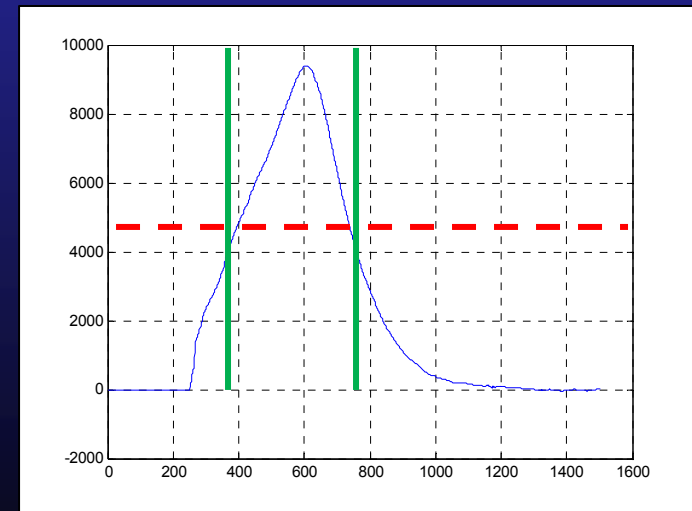


Methodology (Repeatability)

- **Peak analysis** (Rhule 2005)
 - Coefficient of variation

- **Time based analysis** (J Shaw 2006)
 - Average C.V. across time
 - Upper 50% only

R&R rating	C.V. %
Excellent	0 to 5
Good	>5 to 8
Acceptable	>8 to 10
Poor	>10





External Biofidelity Parameters

Measured Signals

- SB Upper Left
- SB Upper Right
- SB Center Left
- SB Center Right
- SB Lower Left
- SB Lower Right
- SP Rear Left
- SP Rear Right
- SP Front Left
- SP Front Right
- HR Contact Time
- HR Fx Top
- HR Fx Bottom
- HR Fz Left
- HR Fz Right
- Lap Belt Tension



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- SP Rear Right
- SP Front Left
- SP Front Right
- HR Contact Time
- HR Fx Top
- HR Fx Bottom
- HR Fz Left
- HR Fz Right
- Lap Belt Tension

Included in BioRank

- Sum SB Total
- Sum SP Total
- HR Contact Time
- Sum HR Fx
- Sum HR Fz



Internal Biofidelity Parameters

Measured Signals

- Head Acc x
- Head Acc z
- Head Ang Vy
- T1 Acc x
- T1 Acc z
- T1 Ang Vy
- T8 Acc x
- T8 Acc z
- T12 Acc x
- T12 Acc z
- Pelvis Acc x
- Pelvis Acc z
- Pelvis Ang Vy



Internal Biofidelity Parameters

Measured Signals

- Head Acc x
- Head Acc z
- Head Ang Vy
- T1 Acc x
- T1 Acc z
- T1 Ang Vy
- T8 Acc x
- T8 Acc z
- T12 Acc x
- T12 Acc z
- Pelvis Acc x
- Pelvis Acc z
- Pelvis Ang Vy

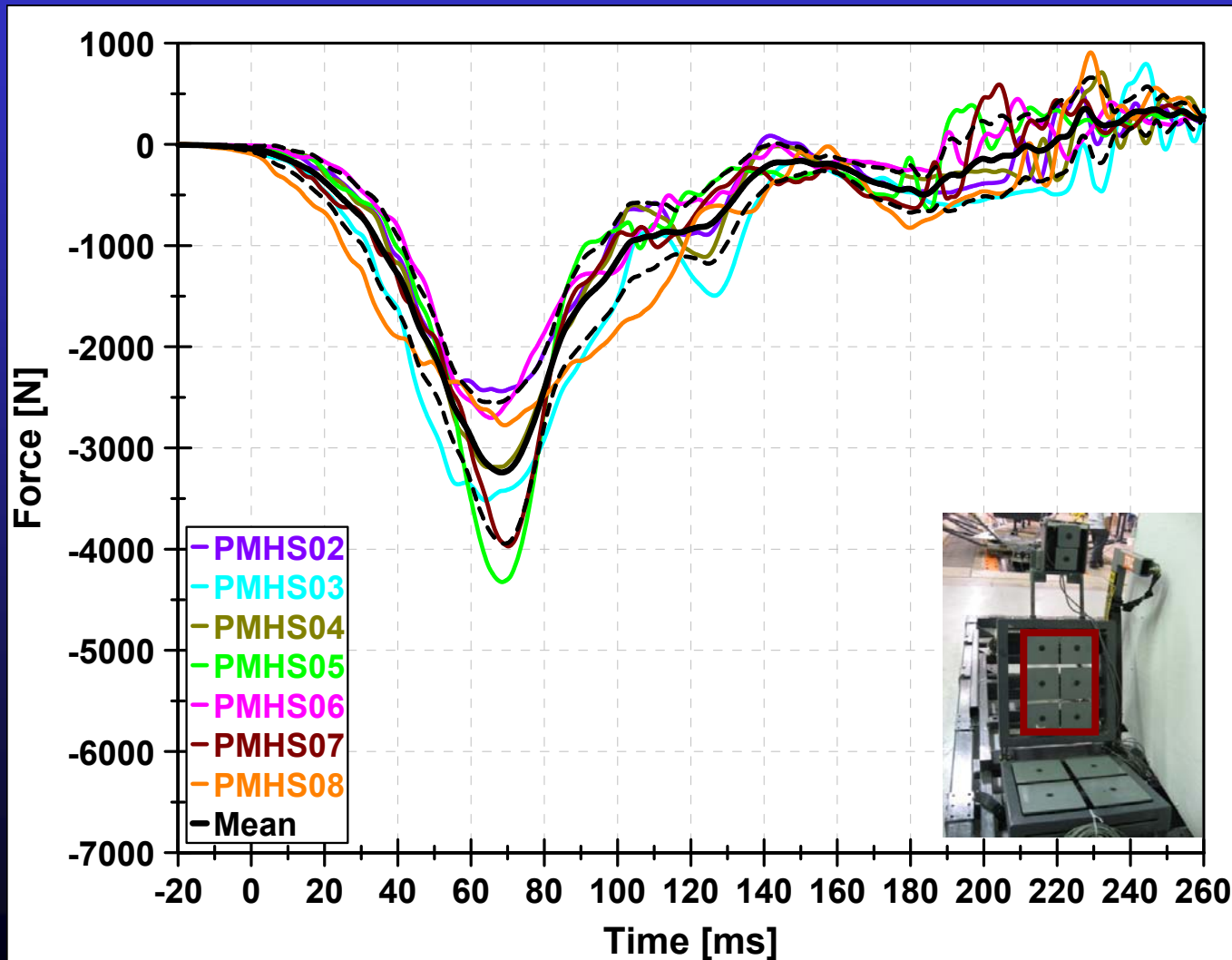
Included in BioRank

- Head Acc Res
- Head Rotation
- T1 Acc Res
- T1 Rotation
- T8 Acc Res
- T12 Acc Res
- Pelvis Acc Res
- Pelvis Rotation
- HIC
- Head to T1
Rotation



External Biofidelity

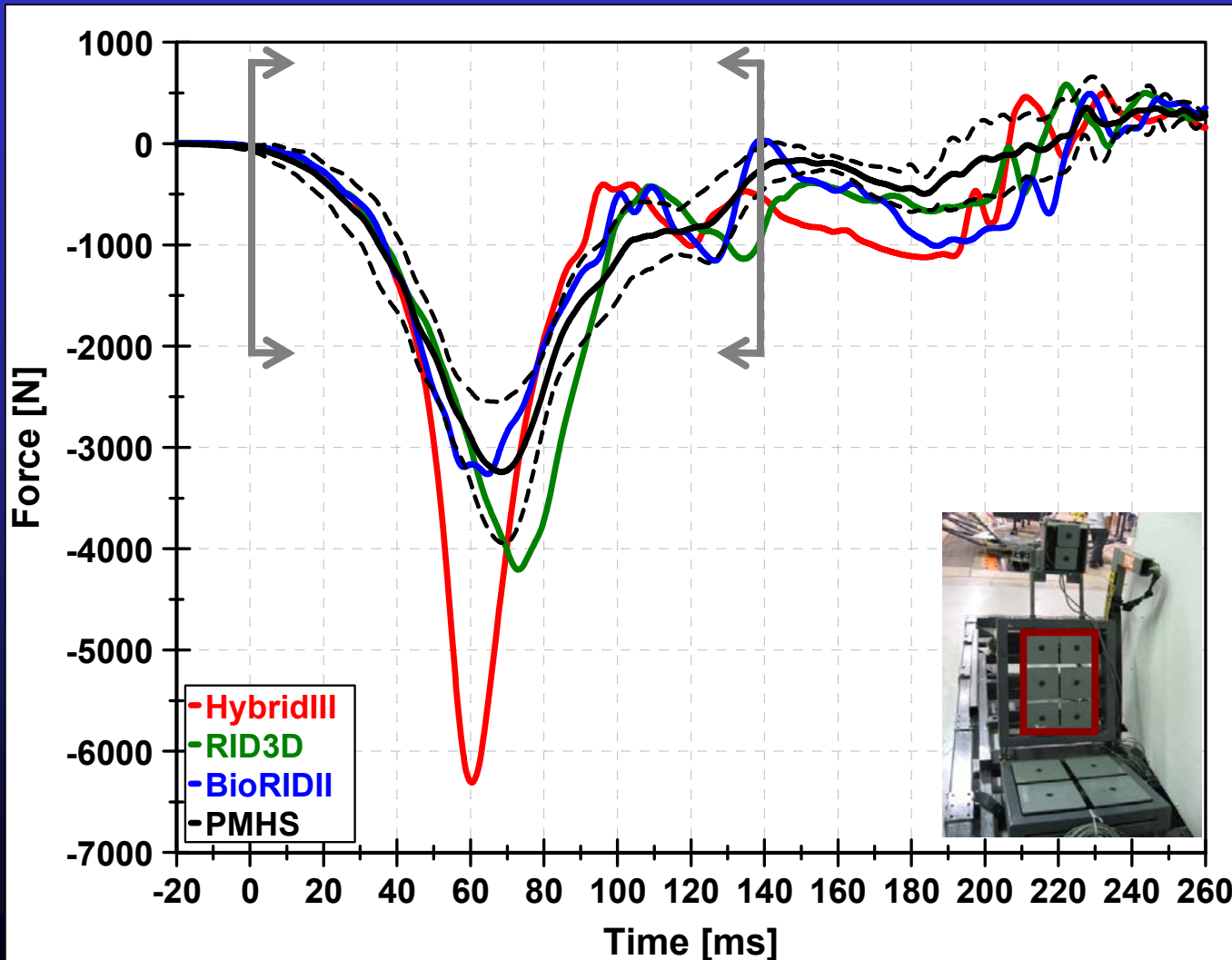
Low Speed – Total Seat Back Load





External Biofidelity

Low Speed – Total Seat Back Load

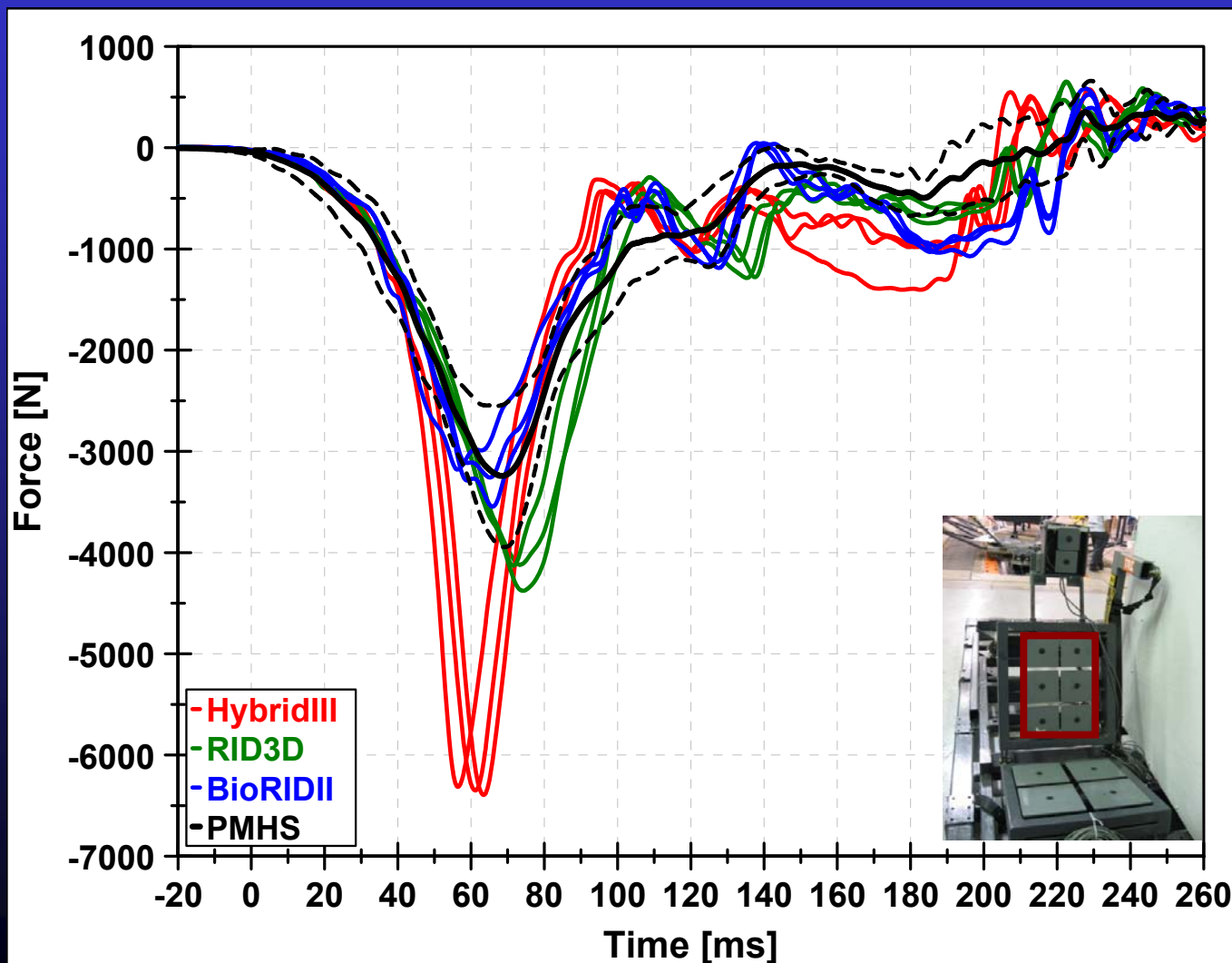


\sqrt{R}
2.61
1.34
0.73



External Biofidelity

Low Speed – Total Seat Back Load

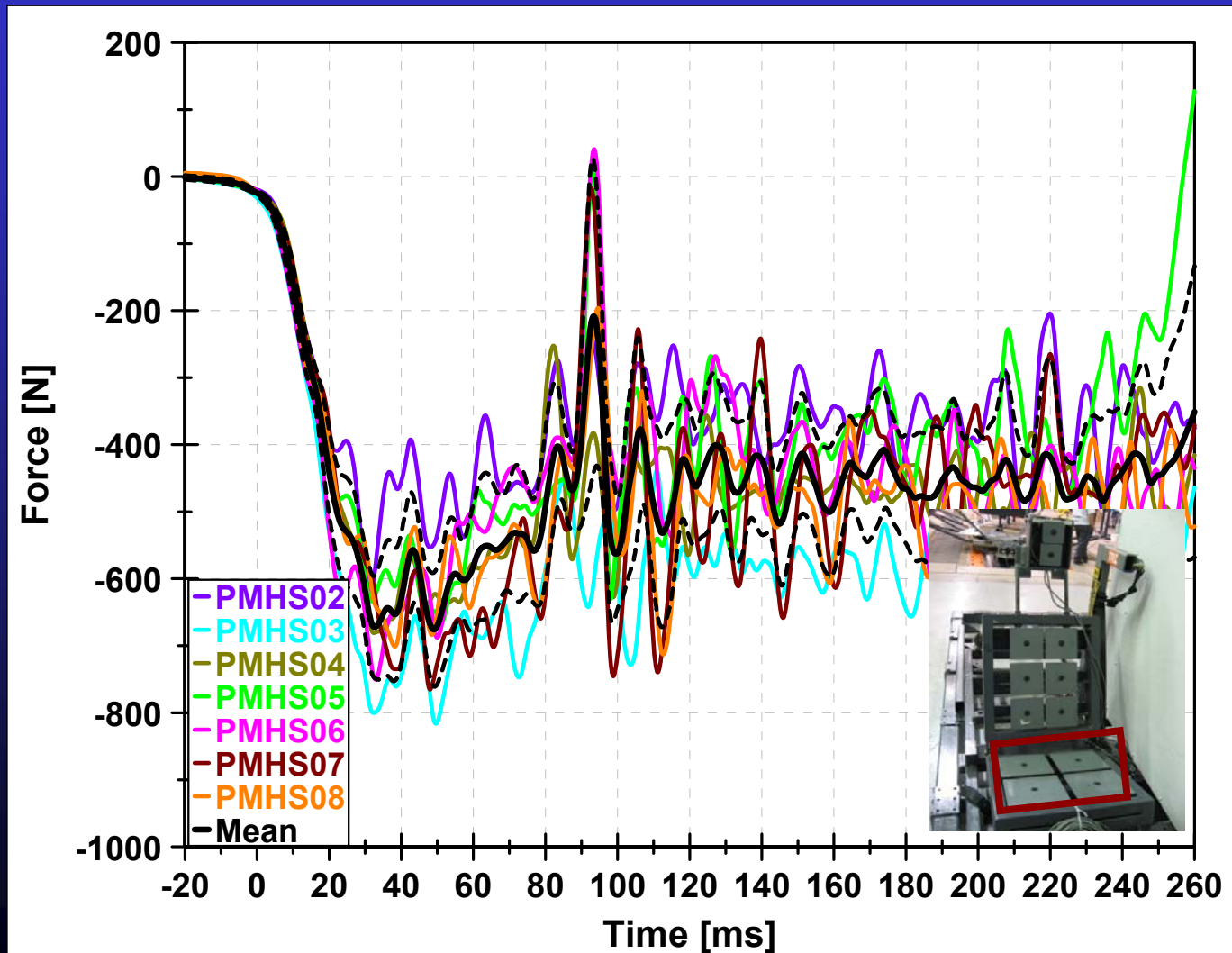


%CV (Peak)	%CV (Avg)
0.6	2.8
3.5	5.9
5.8	5.5



External Biofidelity

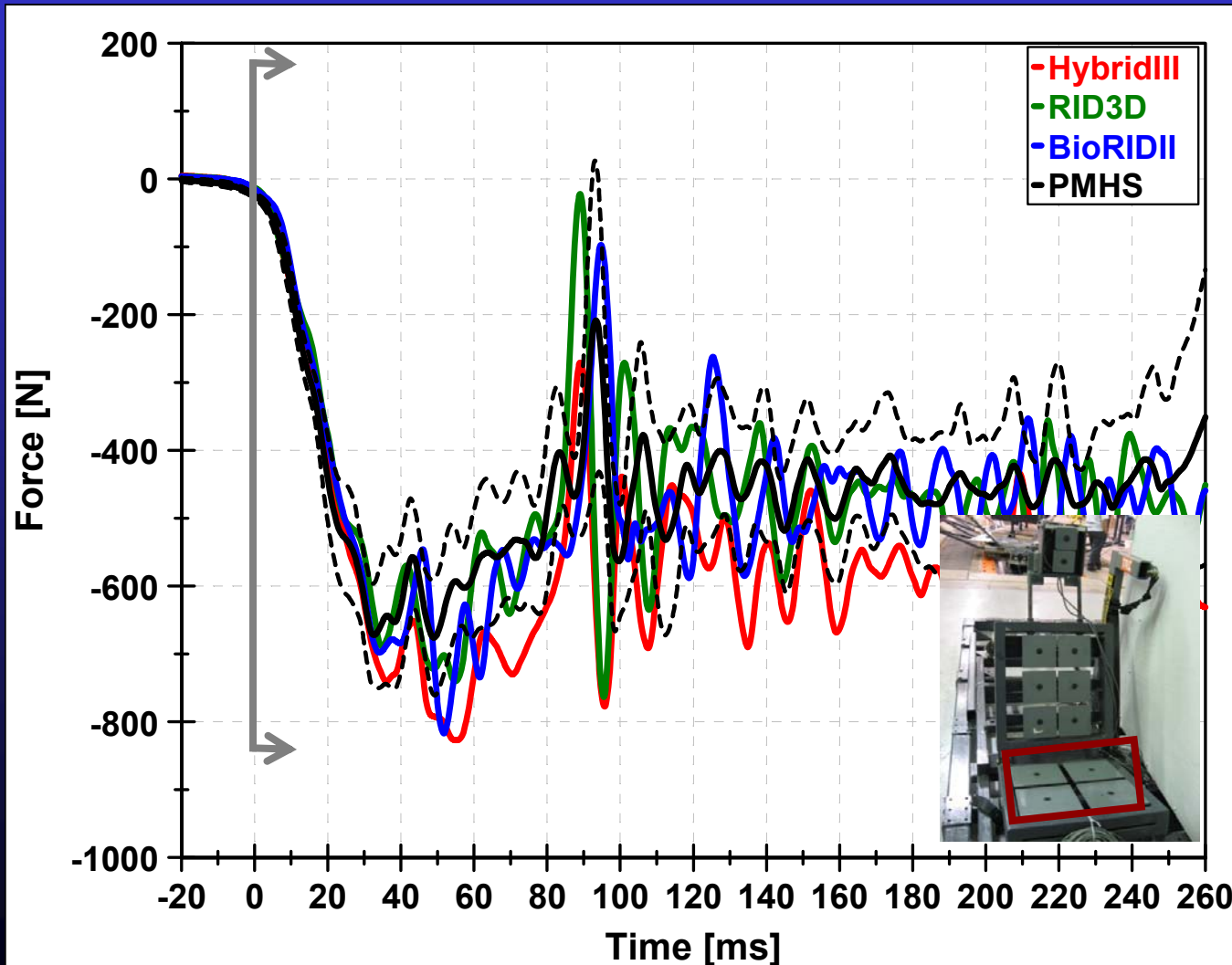
Low Speed – Total Seat Pan Load





External Biofidelity

Low Speed – Total Seat Pan Load

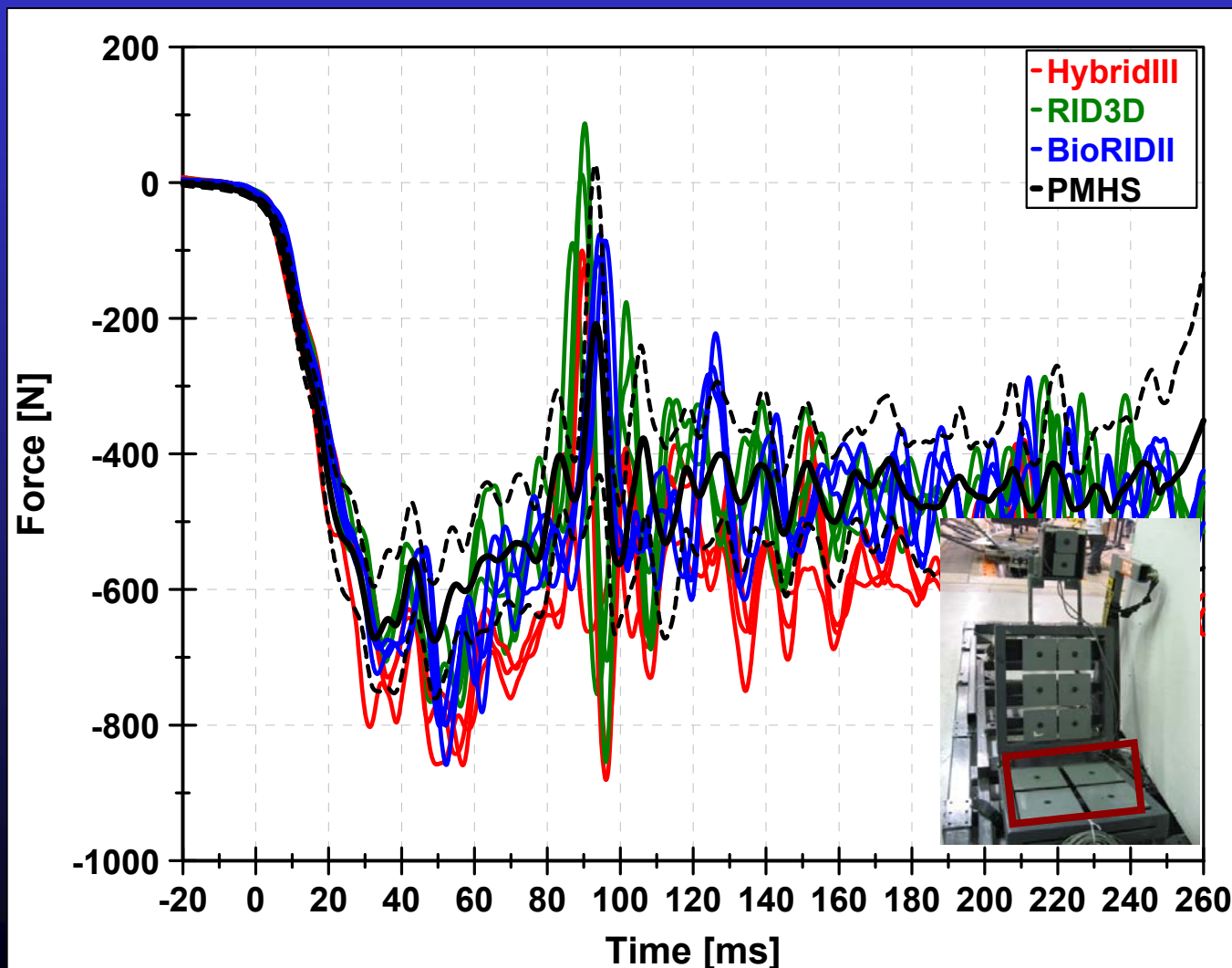


\sqrt{R}
1.45
0.99
0.77



External Biofidelity

Low Speed – Total Seat Pan Load



%CV (Peak)	%CV (Avg)
1.5	6.5
7.7	7.5
4.1	5.3



External Biofidelity

Low Speed – HR Contact Time

HR Contact Time (Low Speed)

	HybridIII	RID3D	BioRIDII
PMHS 113.0 ± 7.4 ms	107.2	121.4	112.4
	108.1	119.3	115.8
	110.1	123.4	117.6
Mean	108.5	121.4	115.3

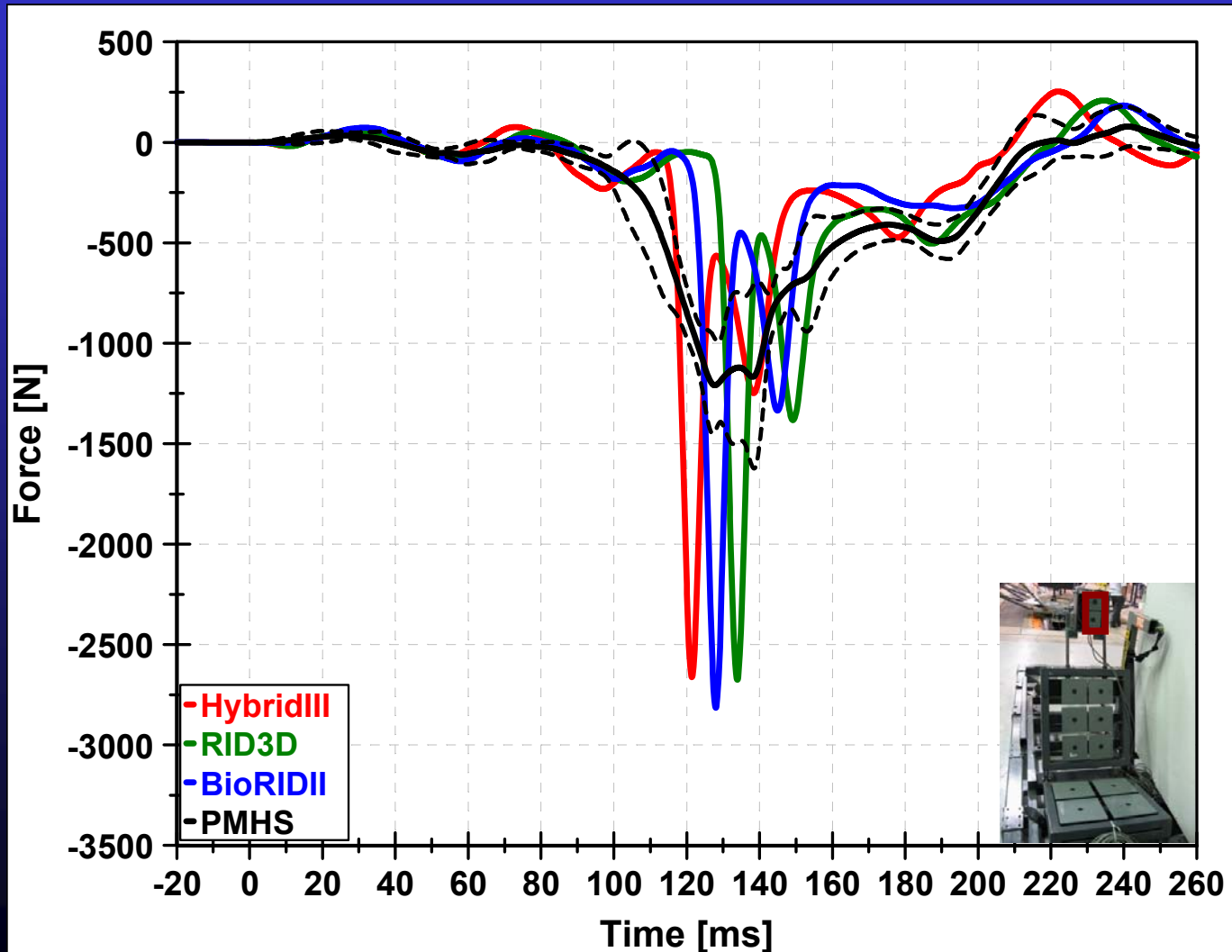
HR Contact Time (Low Speed)

	HybridIII	RID3D	BioRIDII
\sqrt{R}	0.38	1.29	0.10
Peak C.V.	1.4	1.7	2.3



External Biofidelity

Low Speed – Total HR Load (Front)

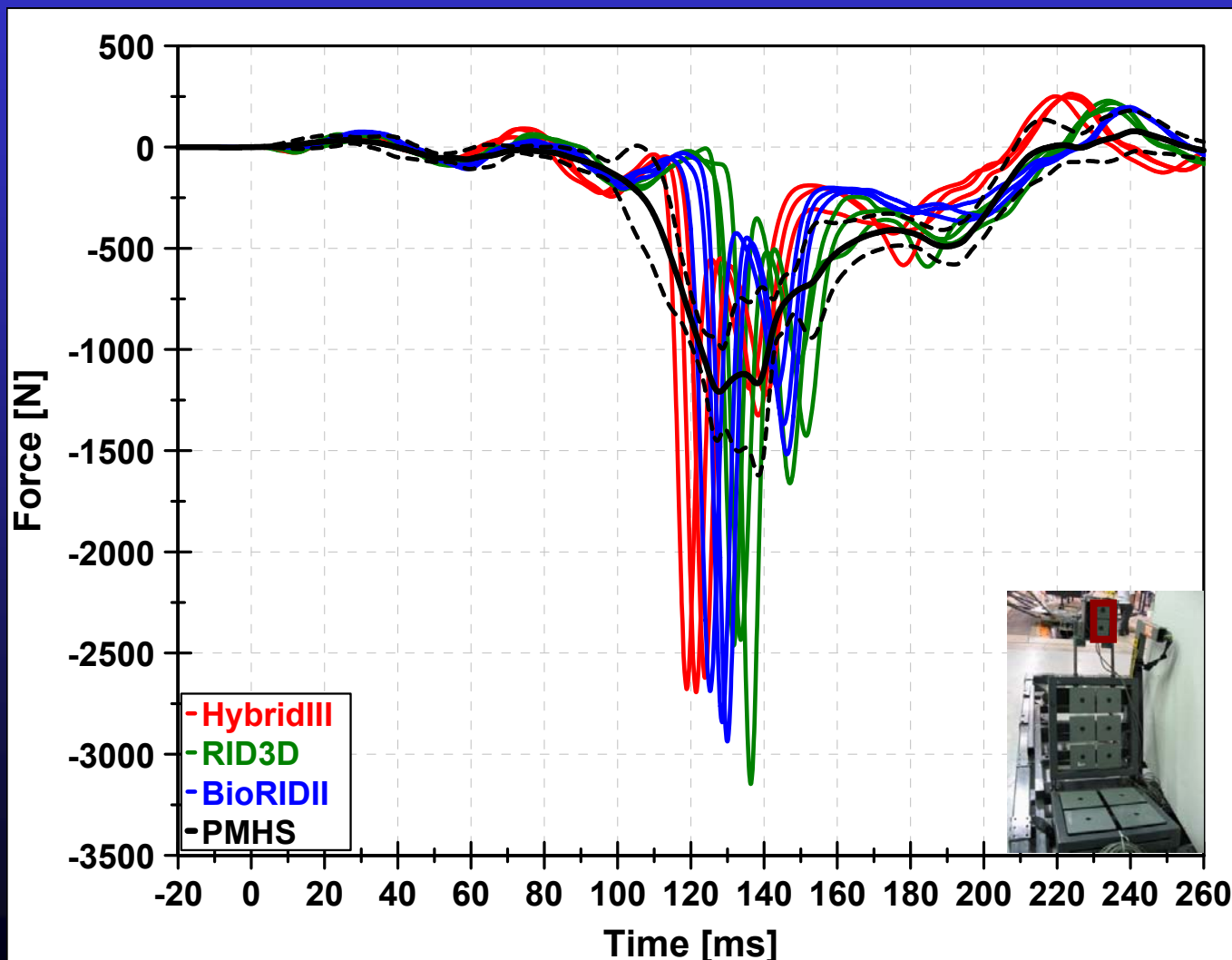


\sqrt{R}
2.01
2.31
2.09



External Biofidelity

Low Speed – Total HR Load (Front)



%CV (Peak)	%CV (Avg)
1.4	3.3
15.0	14.2
4.5	5.8



External Biofidelity

Low Speed Results

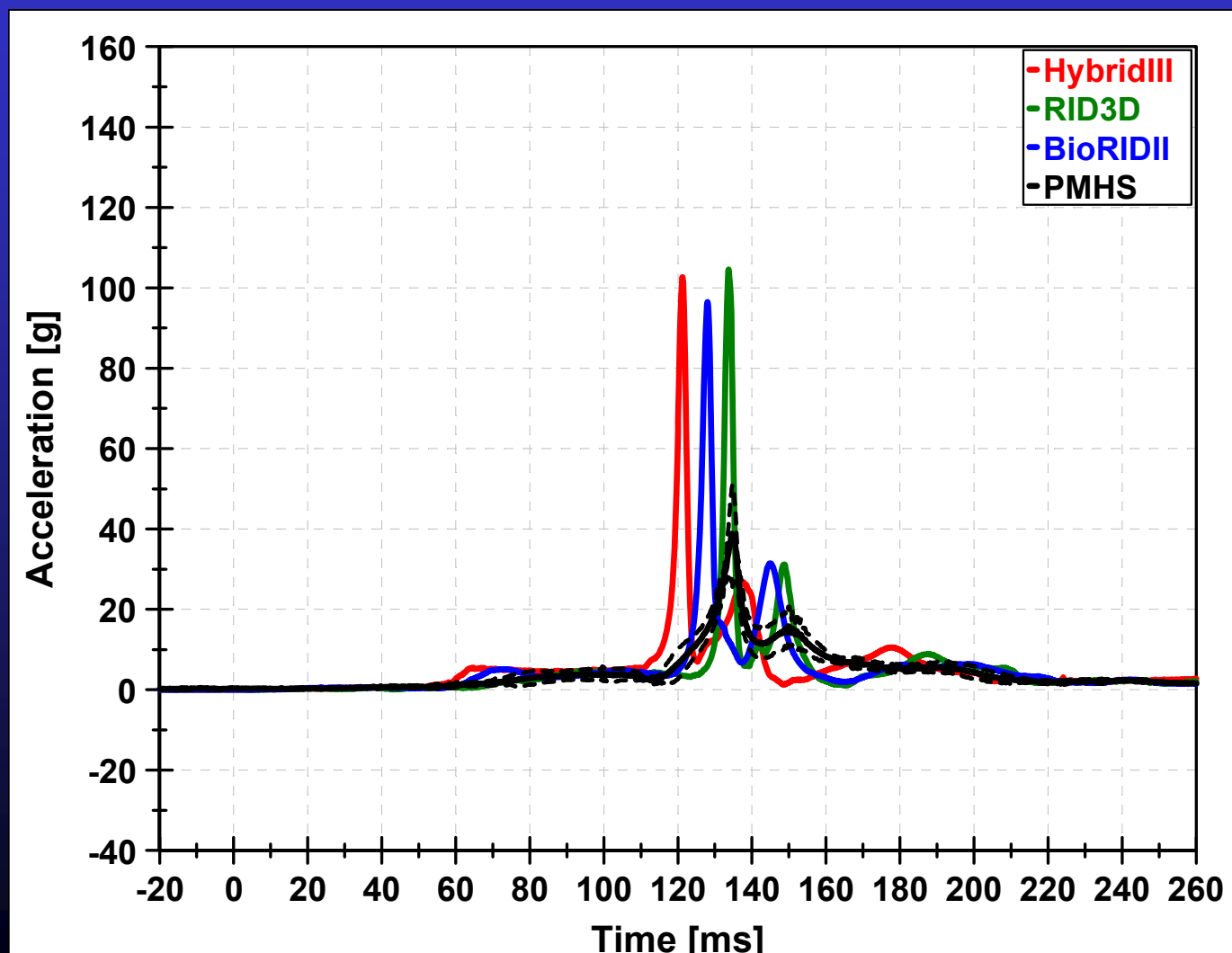
External Biofidelity (Low Speed)

	HybridIII	RID3D	BioRIDII
	\sqrt{R}		
Sum SB Total	2.61	1.34	0.73
Sum SP Total	1.45	0.99	0.77
HR Contact Time	0.38	1.29	0.10
Sum HR Fx	2.01	2.31	2.09
Sum HR Fz	N/A	N/A	N/A
Mean	1.61	1.48	0.92



Internal Biofidelity

Low Speed – Head Acceleration (Resultant)

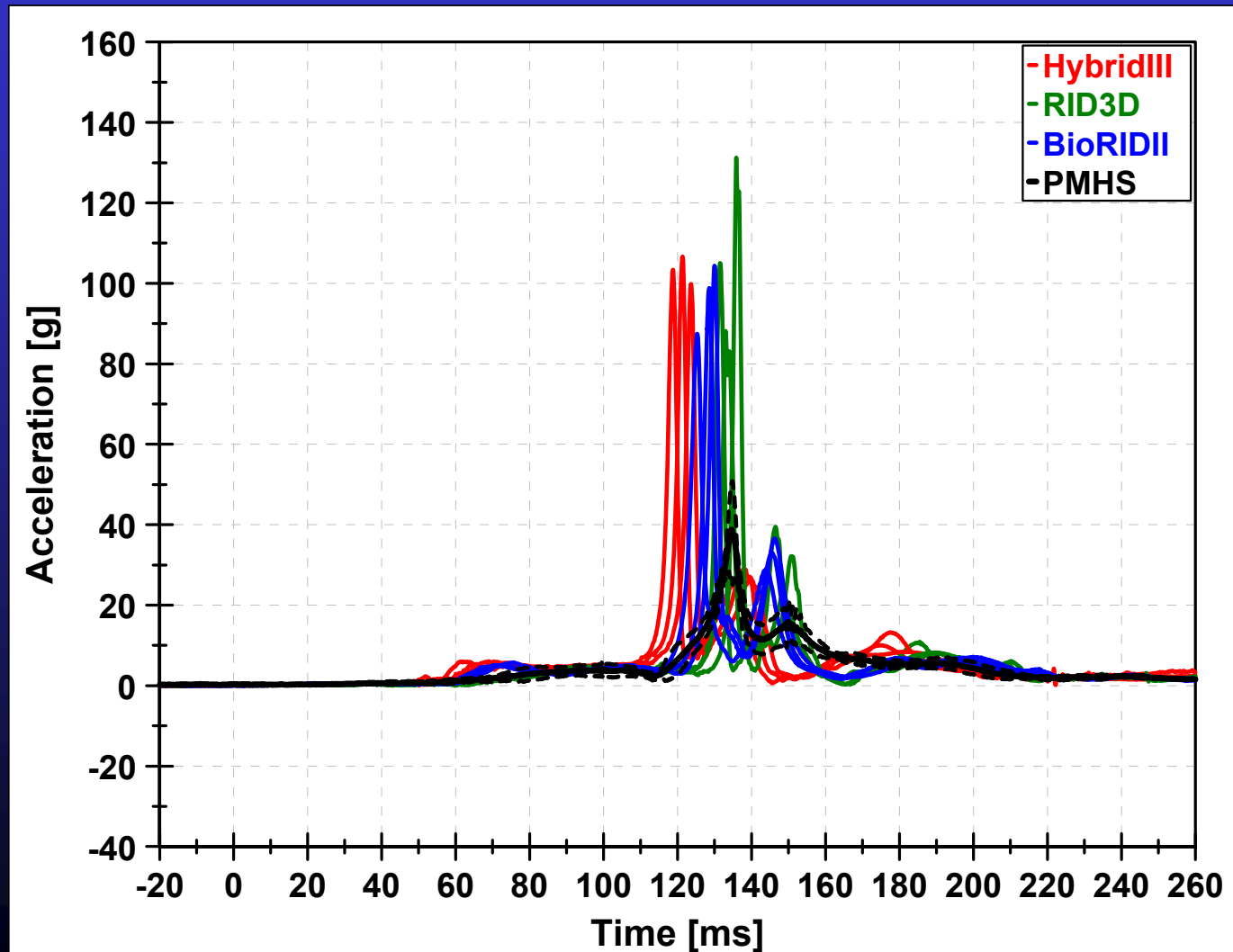


\sqrt{R}
5.09
3.54
4.58



Internal Biofidelity

Low Speed – Head Acceleration (Resultant)

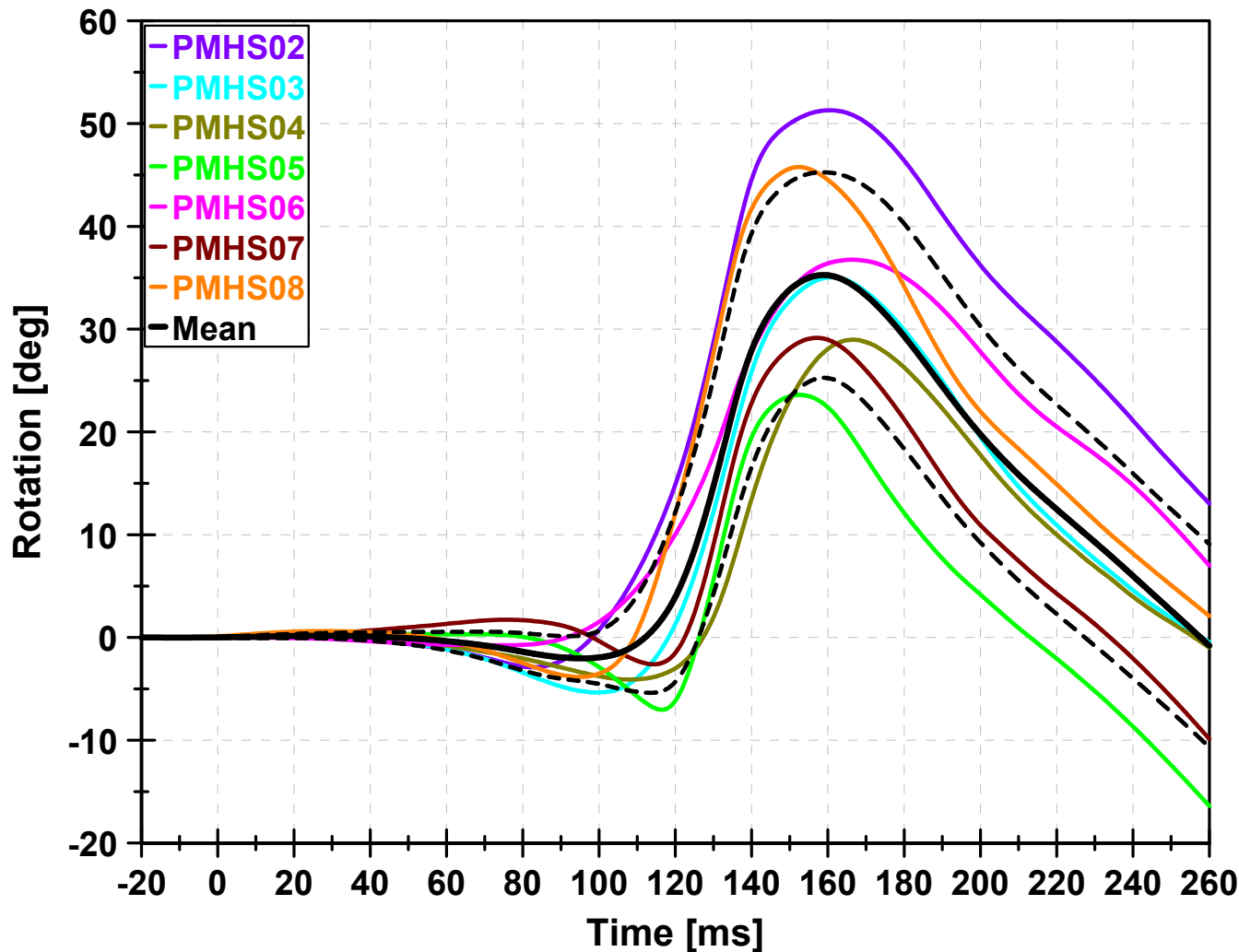


%CV (Peak)	%CV (Avg)
3.2	3.3
20.1	14.2
8.9	5.8



Internal Biofidelity

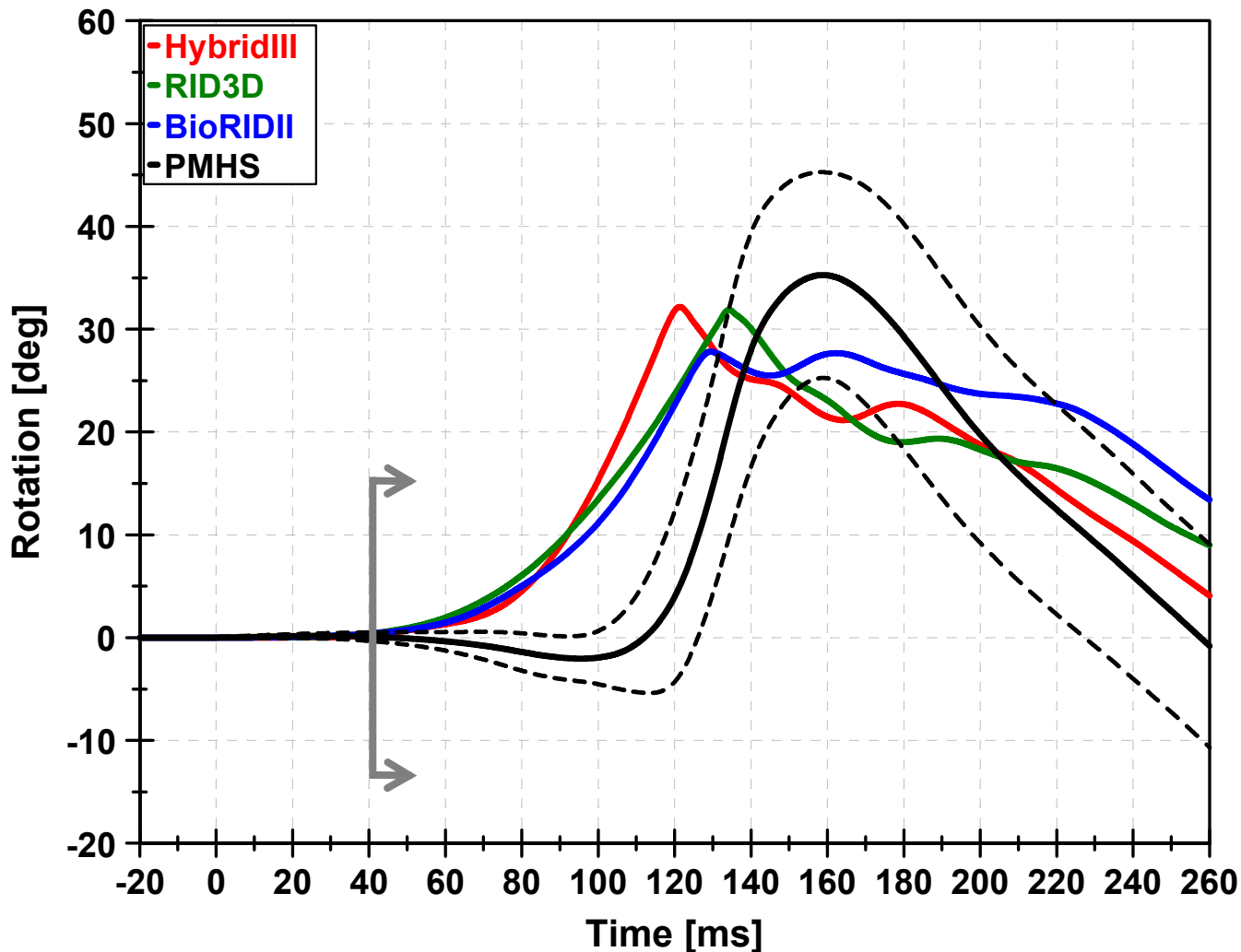
Low Speed – Head Rotation





Internal Biofidelity

Low Speed – Head Rotation

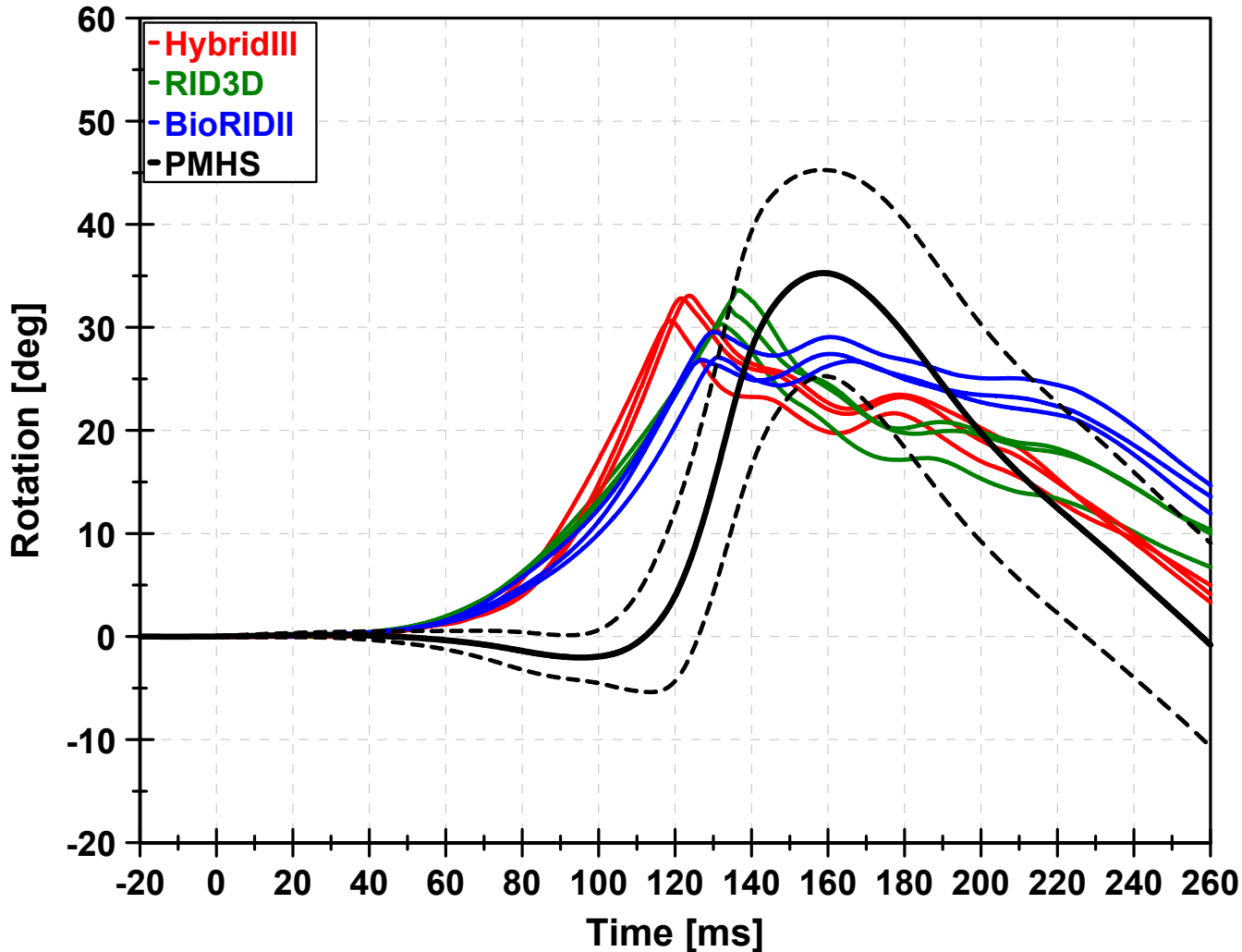


\sqrt{R}
1.32
1.23
1.19



Internal Biofidelity

Low Speed – Head Rotation

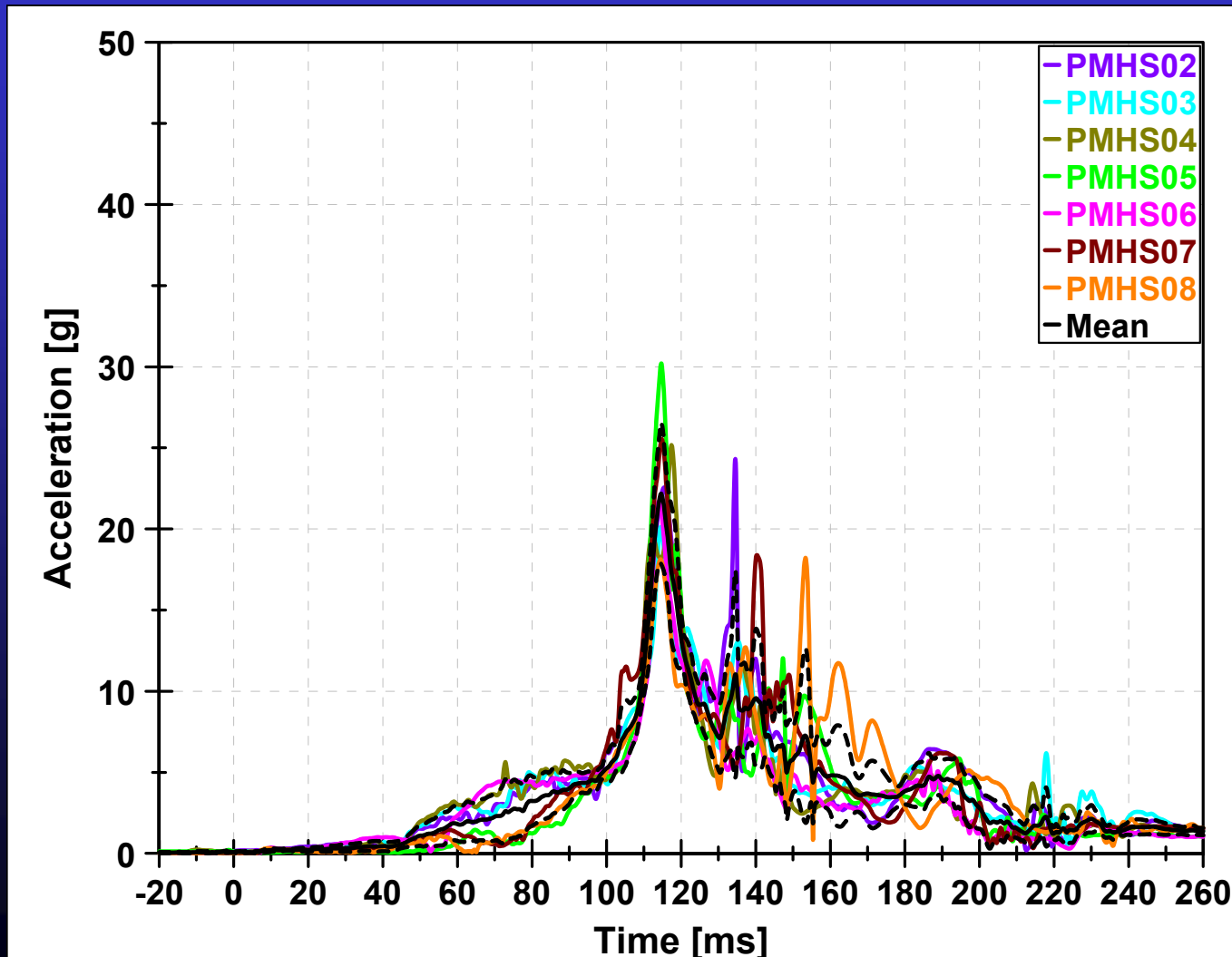


%CV (Peak)	%CV (Avg)
4.1	5.0
5.2	8.3
4.8	6.3



Internal Biofidelity

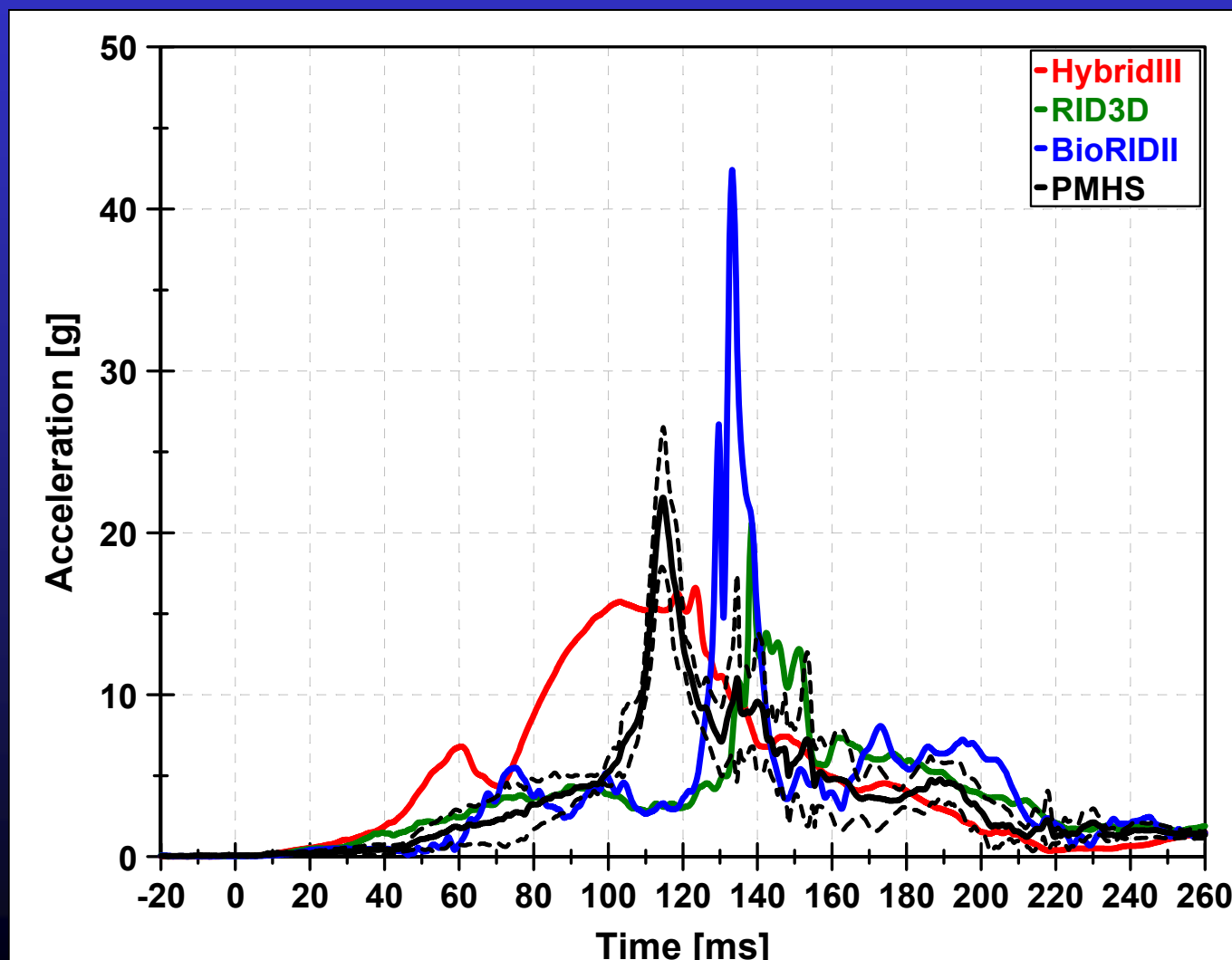
Low Speed – T1 Acceleration (Resultant)





Internal Biofidelity

Low Speed – T1 Acceleration (Resultant)

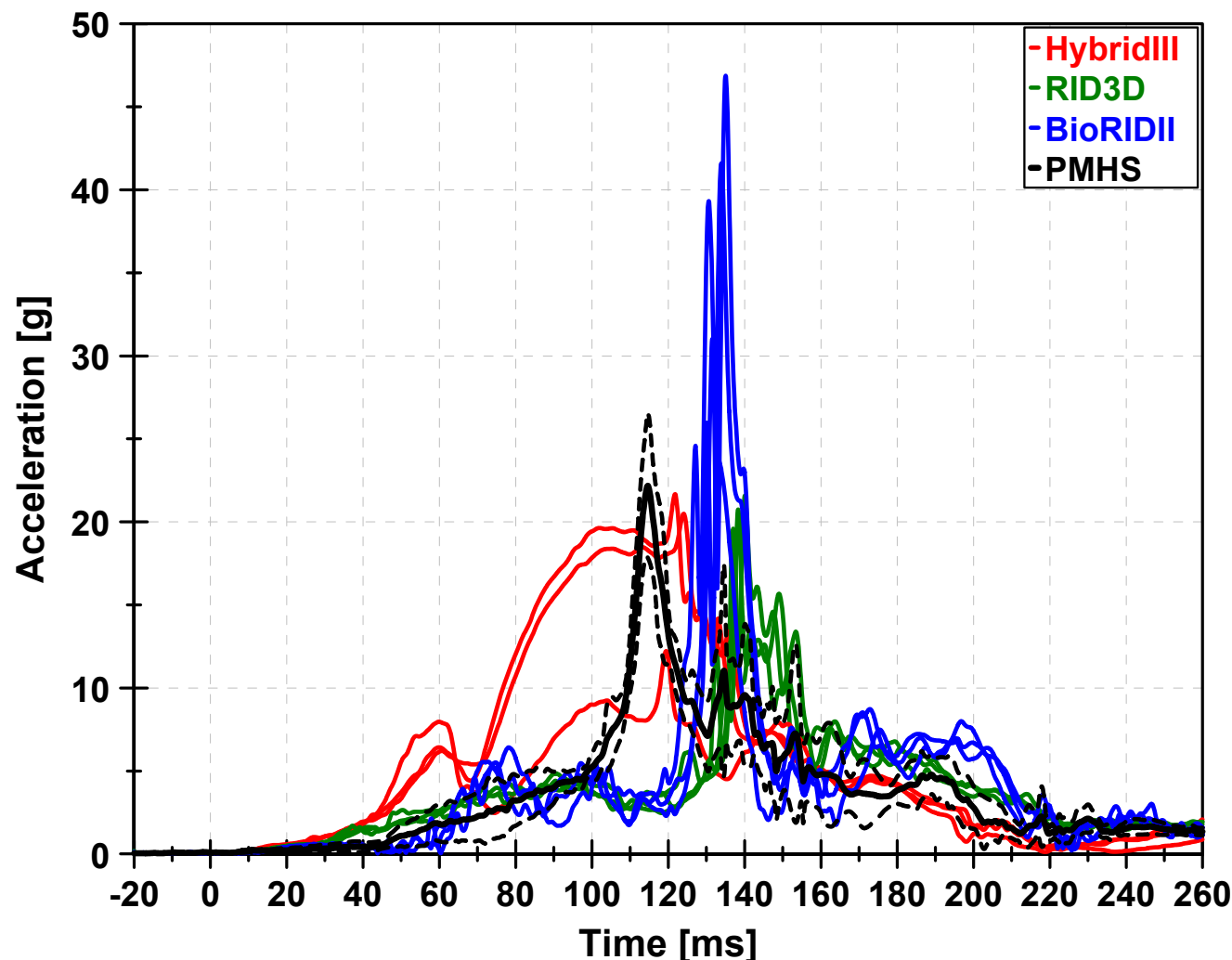


\sqrt{R}
2.24
2.39
3.32



Internal Biofidelity

Low Speed – T1 Acceleration (Resultant)

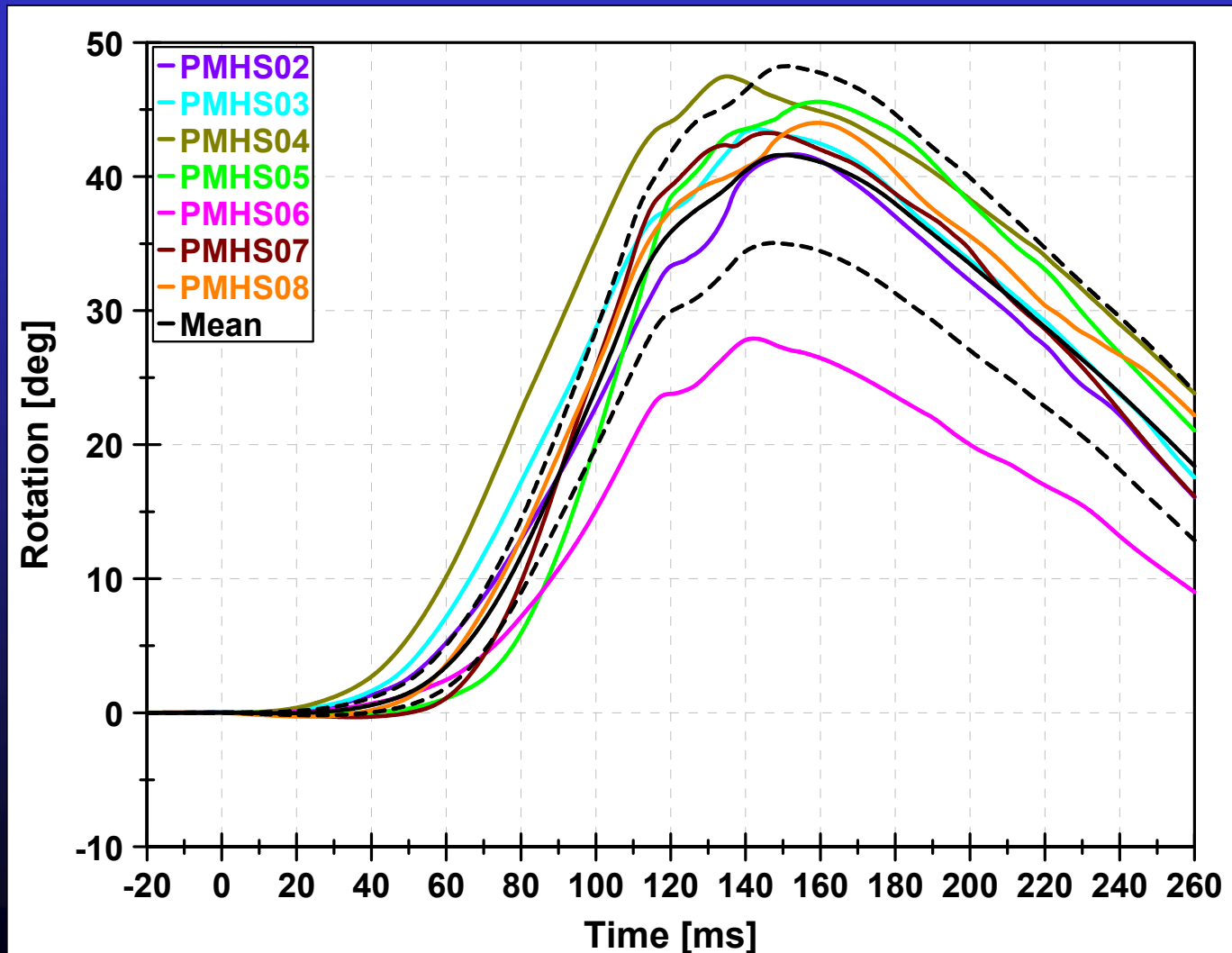


%CV (Peak)	%CV (Avg)
28.4	39.4
4.8	30.5
9.1	12.2



Internal Biofidelity

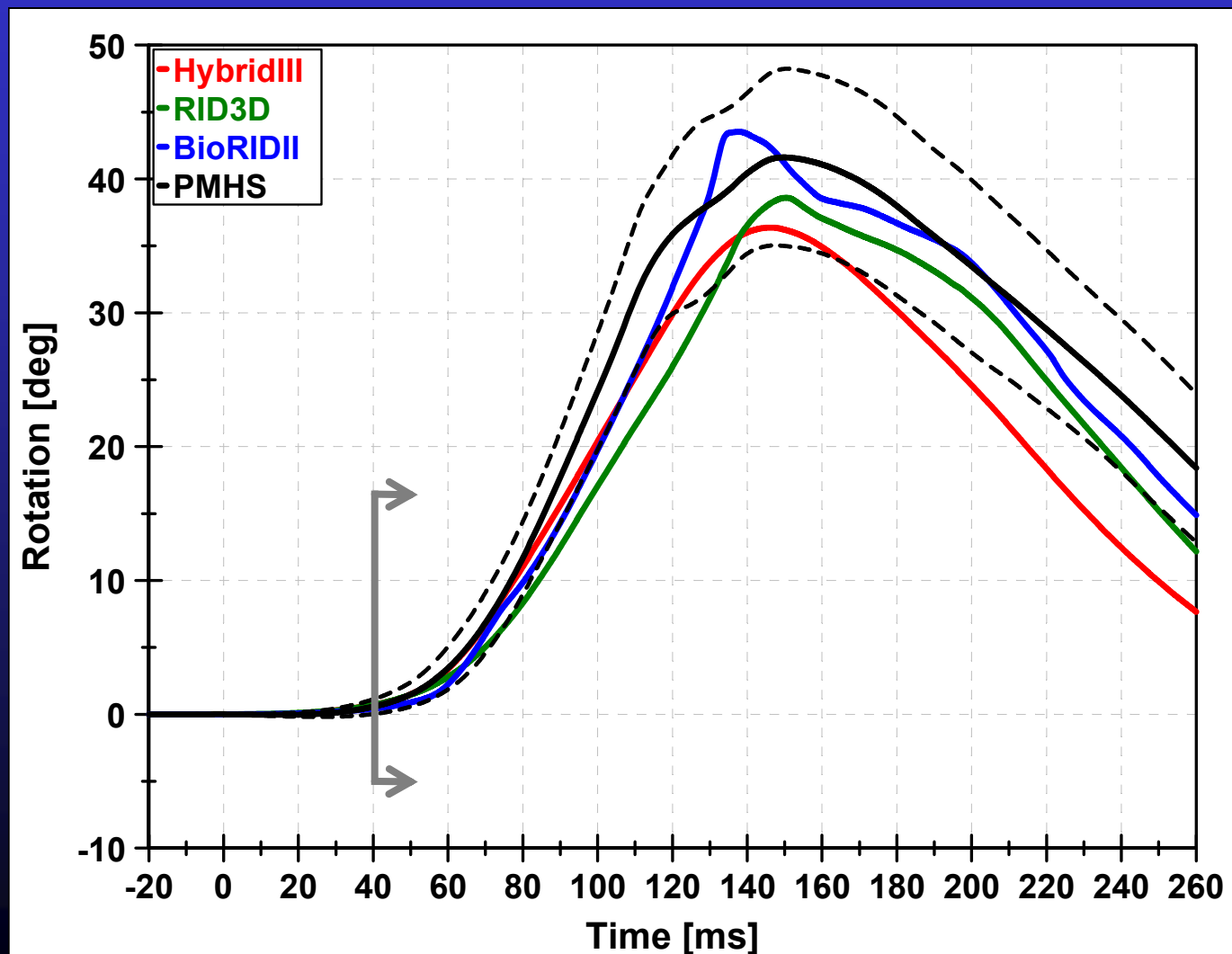
Low Speed – T1 Rotation





Internal Biofidelity

Low Speed – T1 Rotation

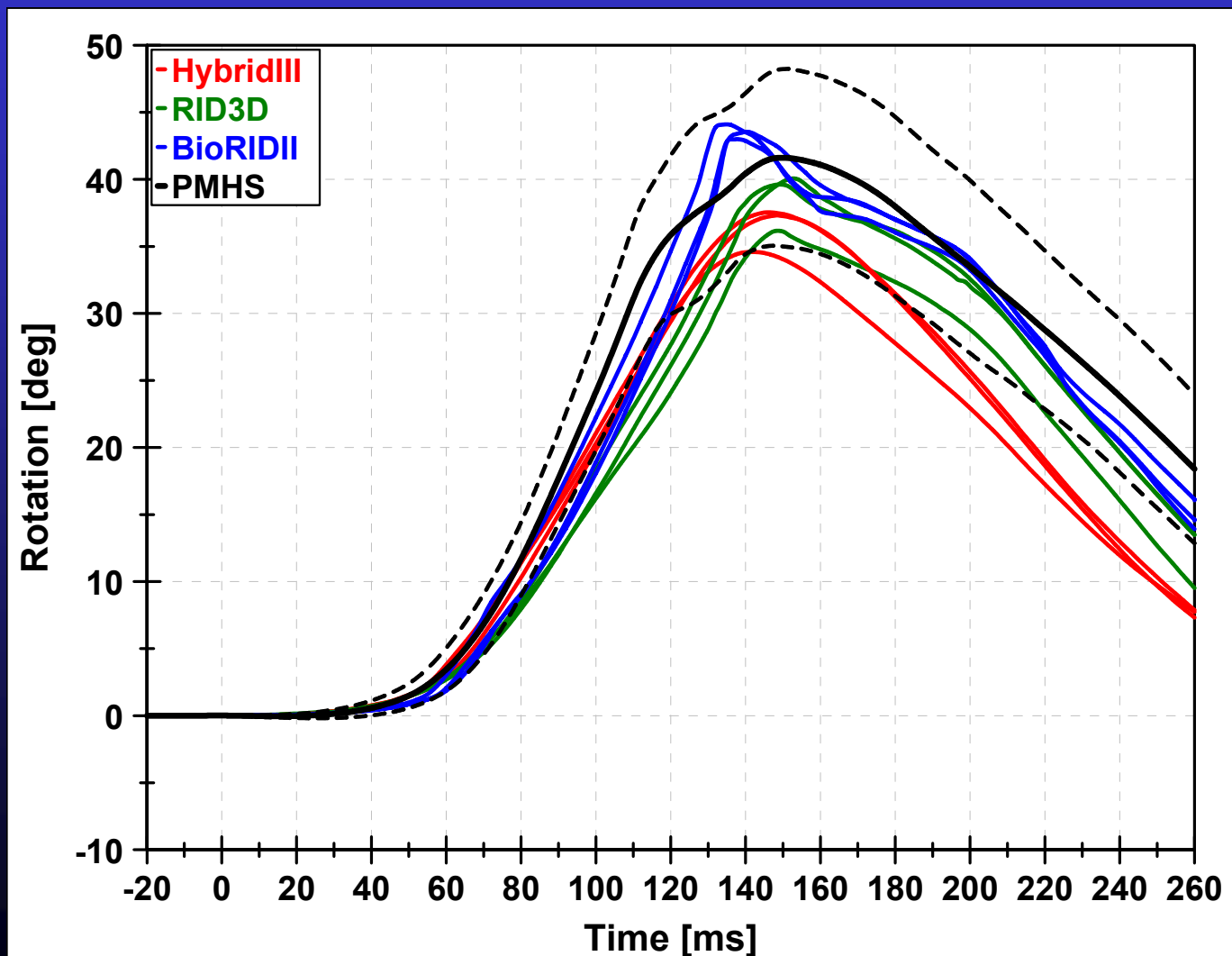


\sqrt{R}
1.31
0.92
0.48



Internal Biofidelity

Low Speed – T1 Rotation

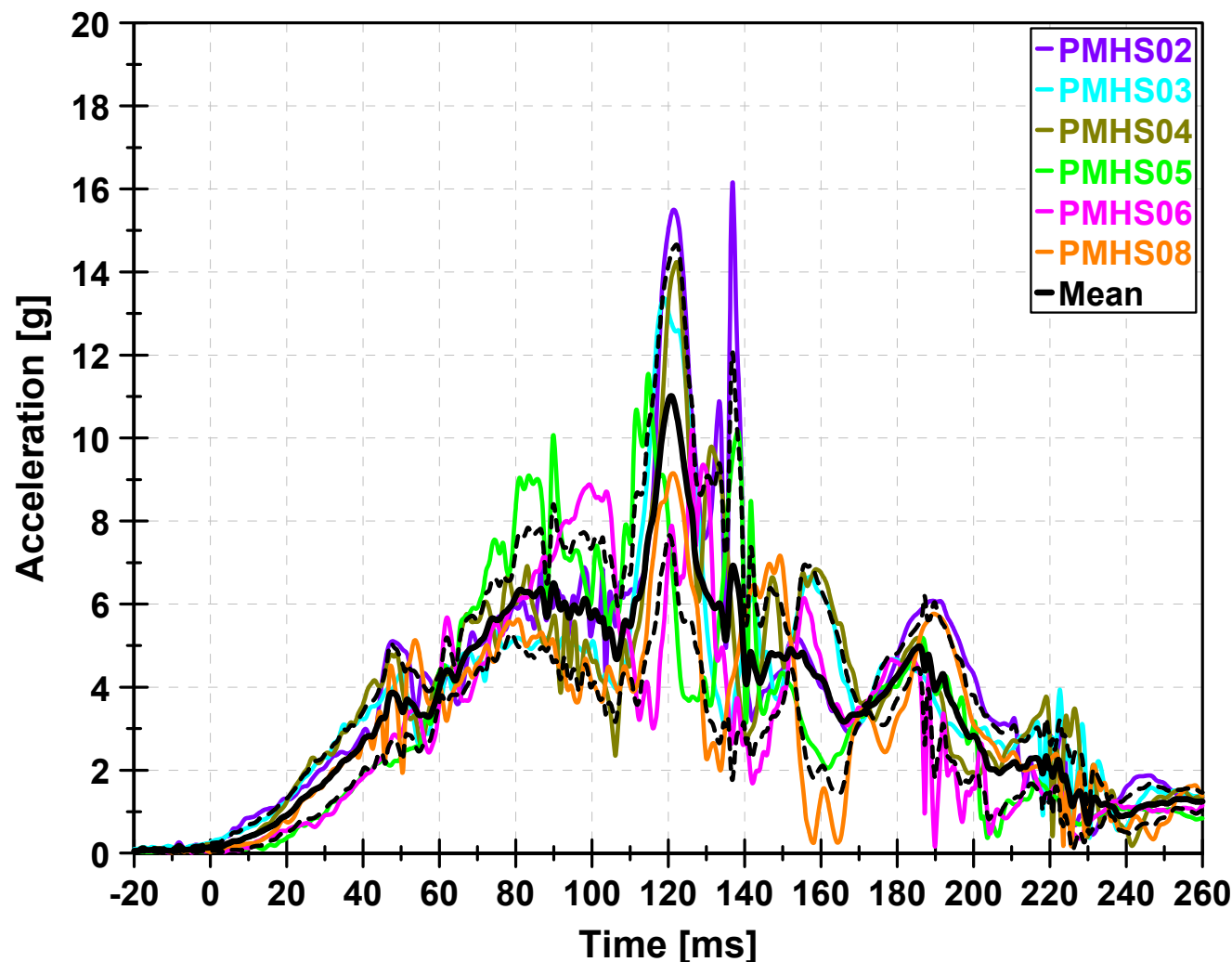


%CV (Peak)	%CV (Avg)
4.5	5.0
5.5	6.5
1.3	2.6



Internal Biofidelity

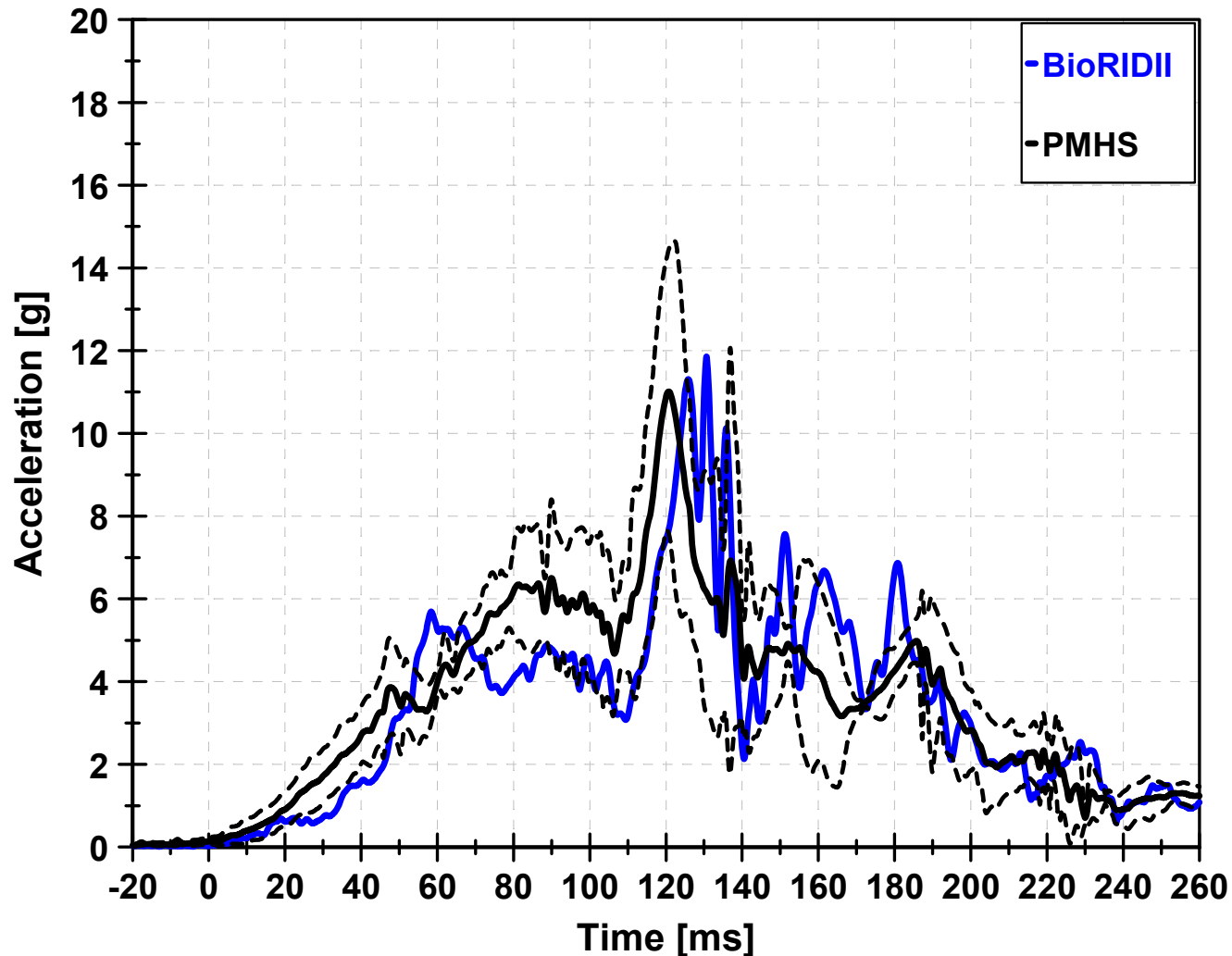
Low Speed – T8 Acceleration (Resultant)





Internal Biofidelity

Low Speed – T8 Acceleration (Resultant)

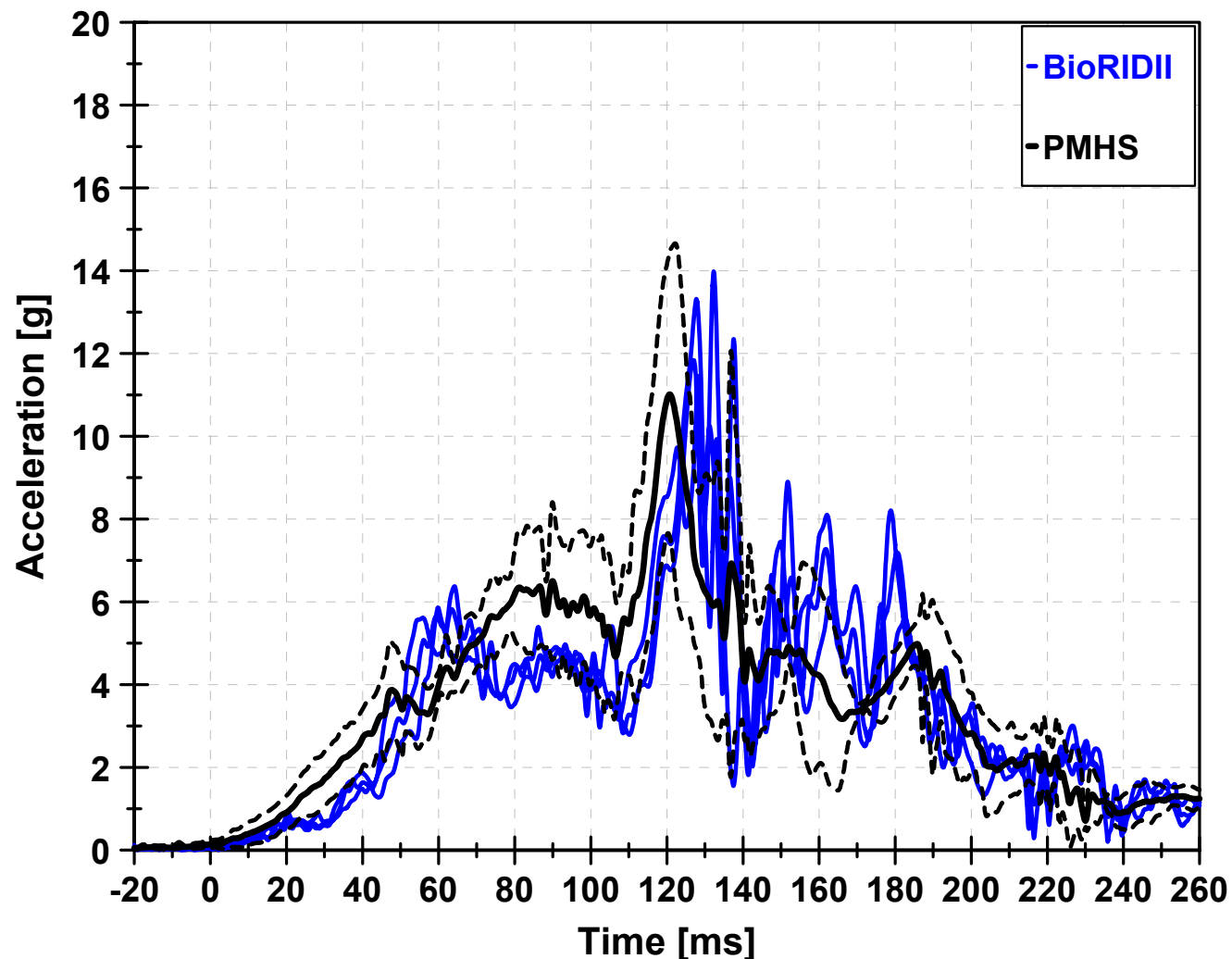


\sqrt{R}
N/A
N/A
1.00



Internal Biofidelity

Low Speed – T8 Acceleration (Resultant)

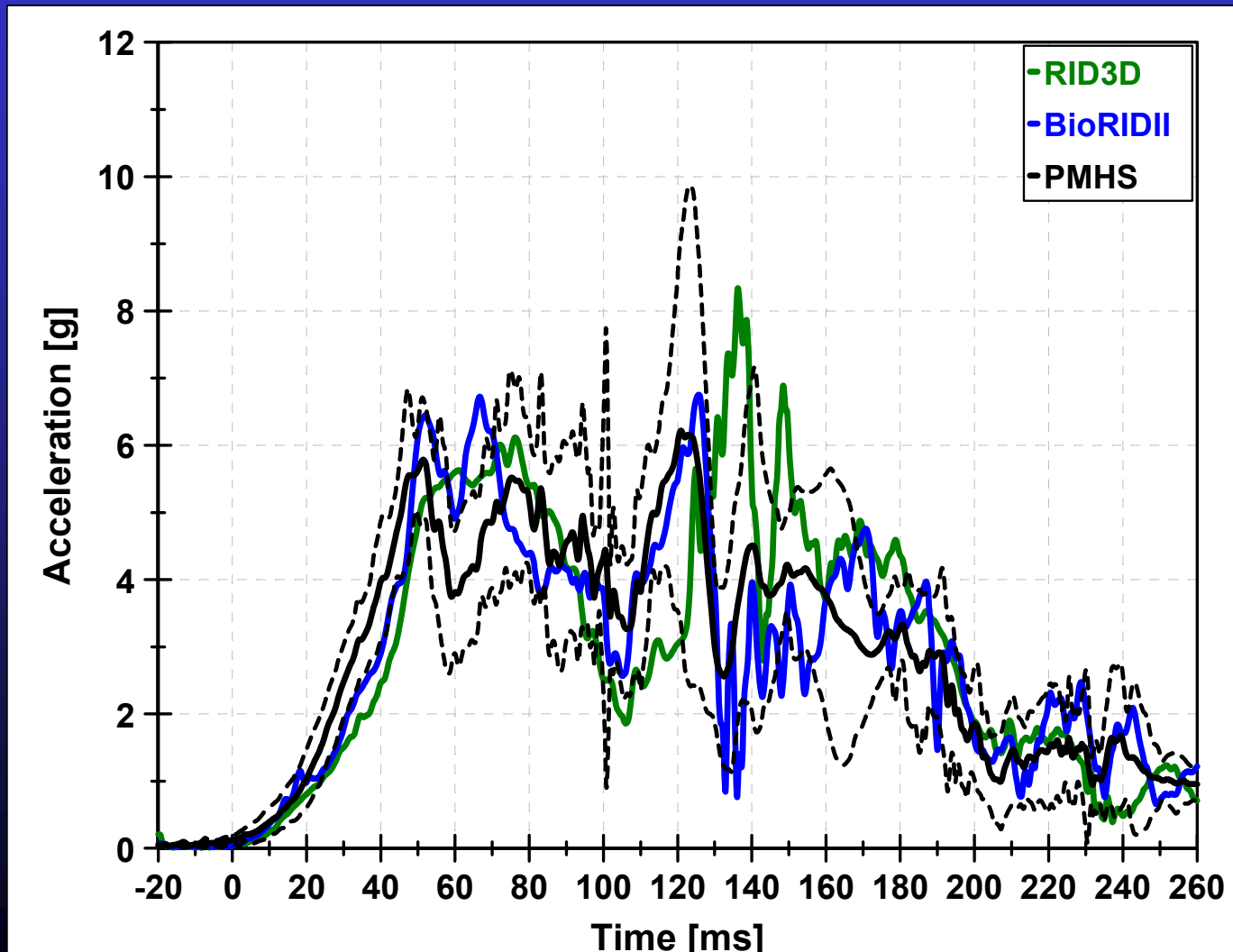


%CV (Peak)	%CV (Avg)
N/A	N/A
N/A	N/A
11.0	12.5



Internal Biofidelity

Low Speed – T12/L1 Acceleration (Resultant)

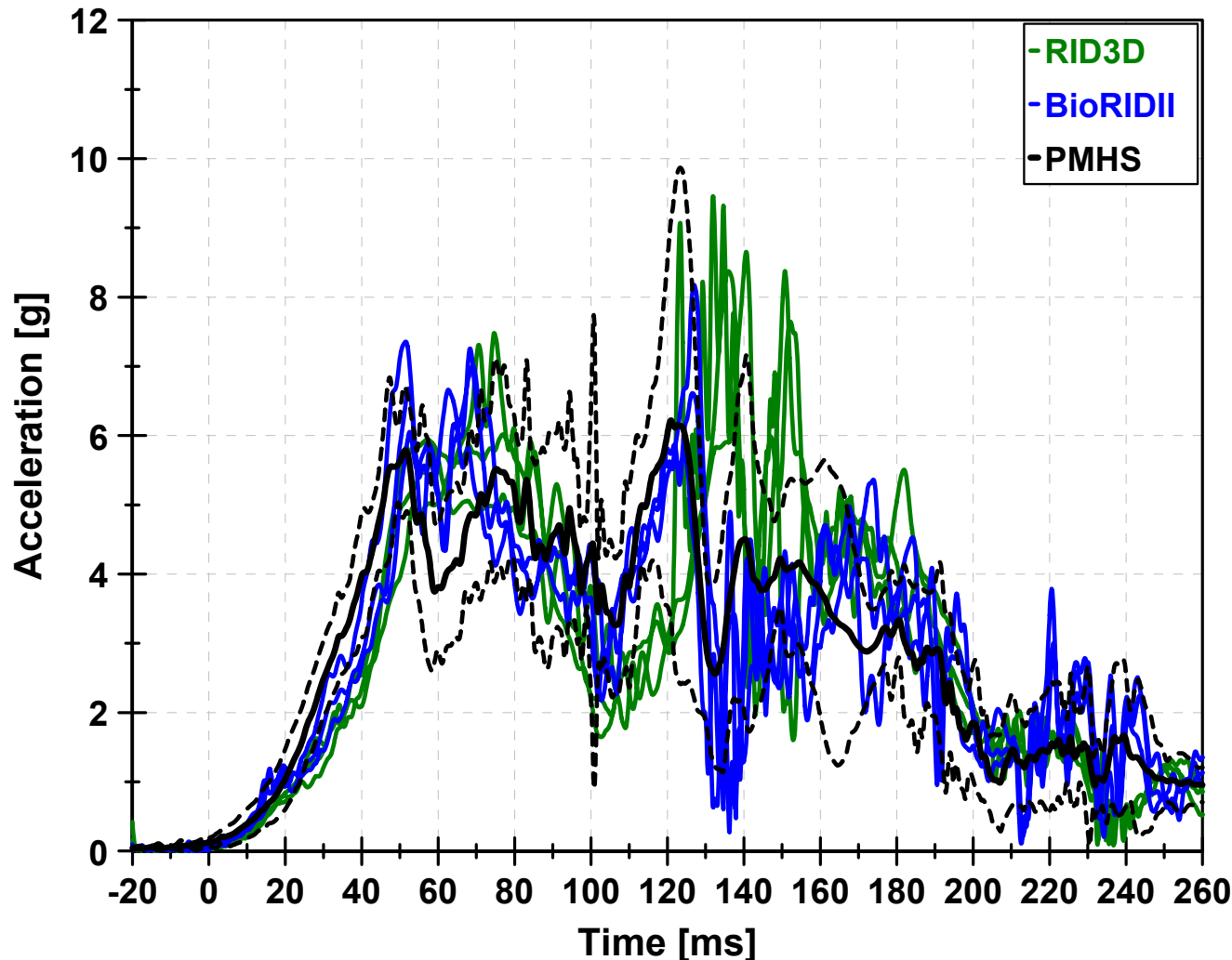


\sqrt{R}
N/A
1.04
0.67



Internal Biofidelity

Low Speed – T12/L1 Acceleration (Resultant)

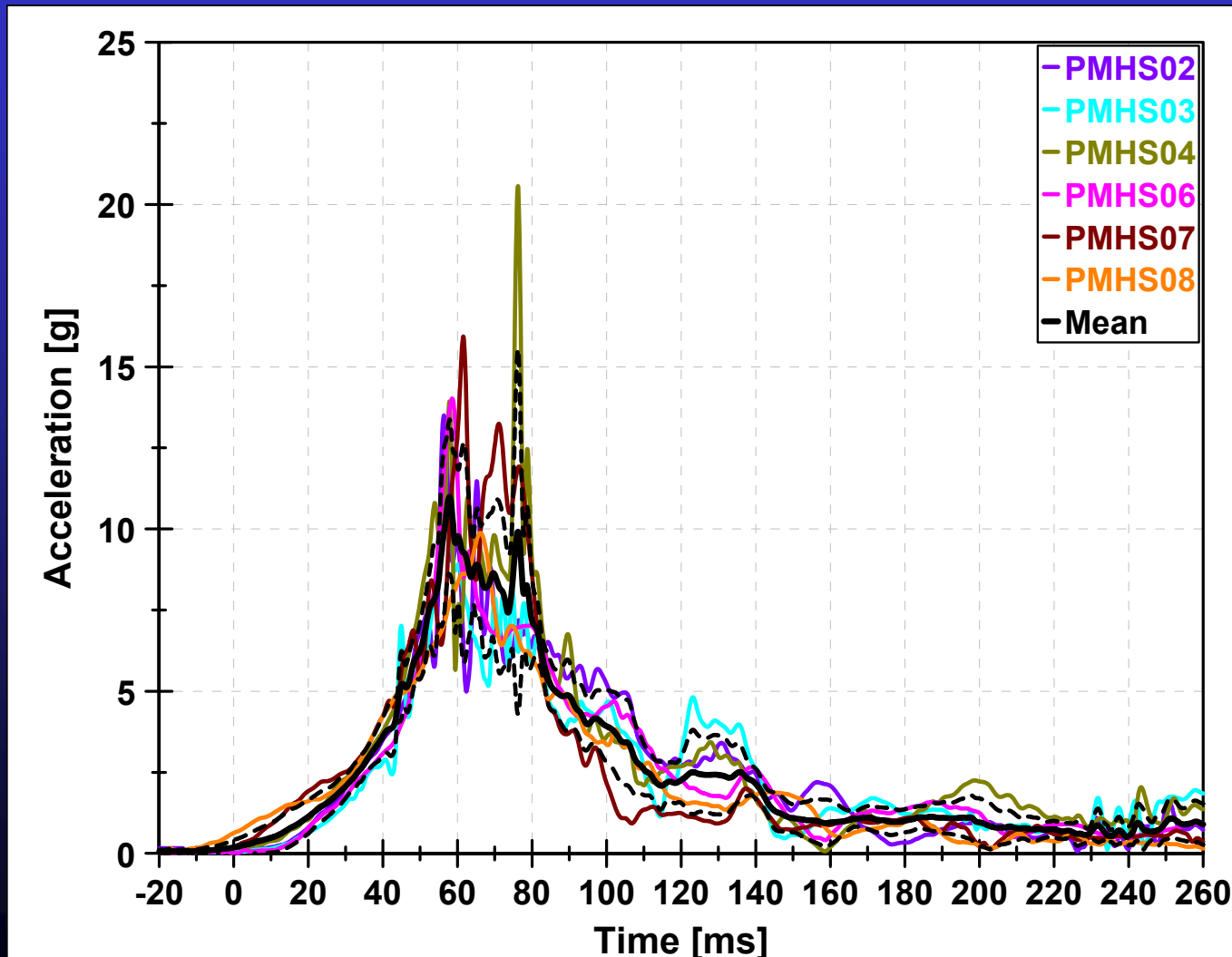


%CV (Peak)	%CV (Avg)
N/A	N/A
6.4	10.8
8.0	7.6



Internal Biofidelity

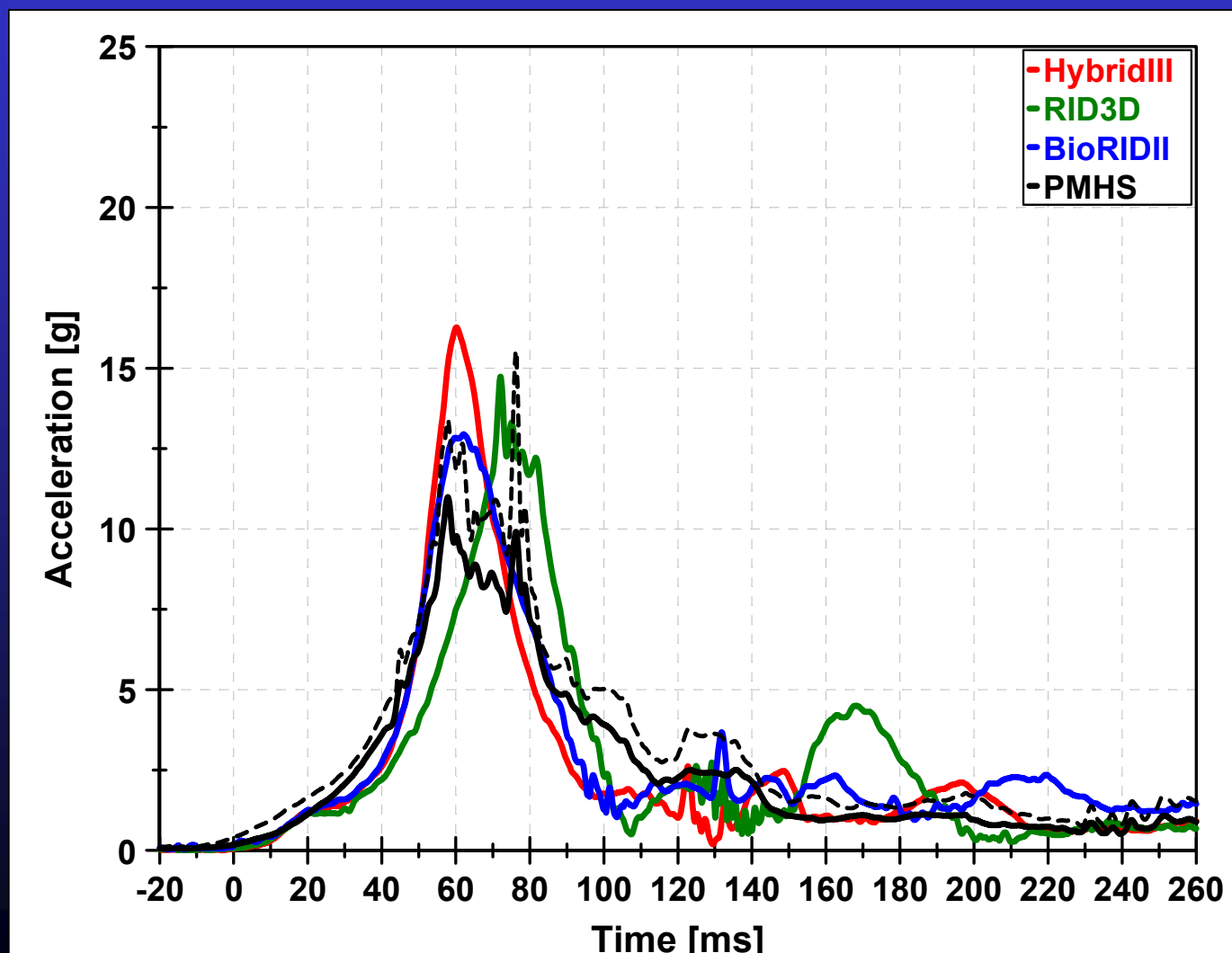
Low Speed – Pelvis Acceleration (Resultant)





Internal Biofidelity

Low Speed – Pelvis Acceleration (Resultant)



$$\sqrt{R}$$

1.61

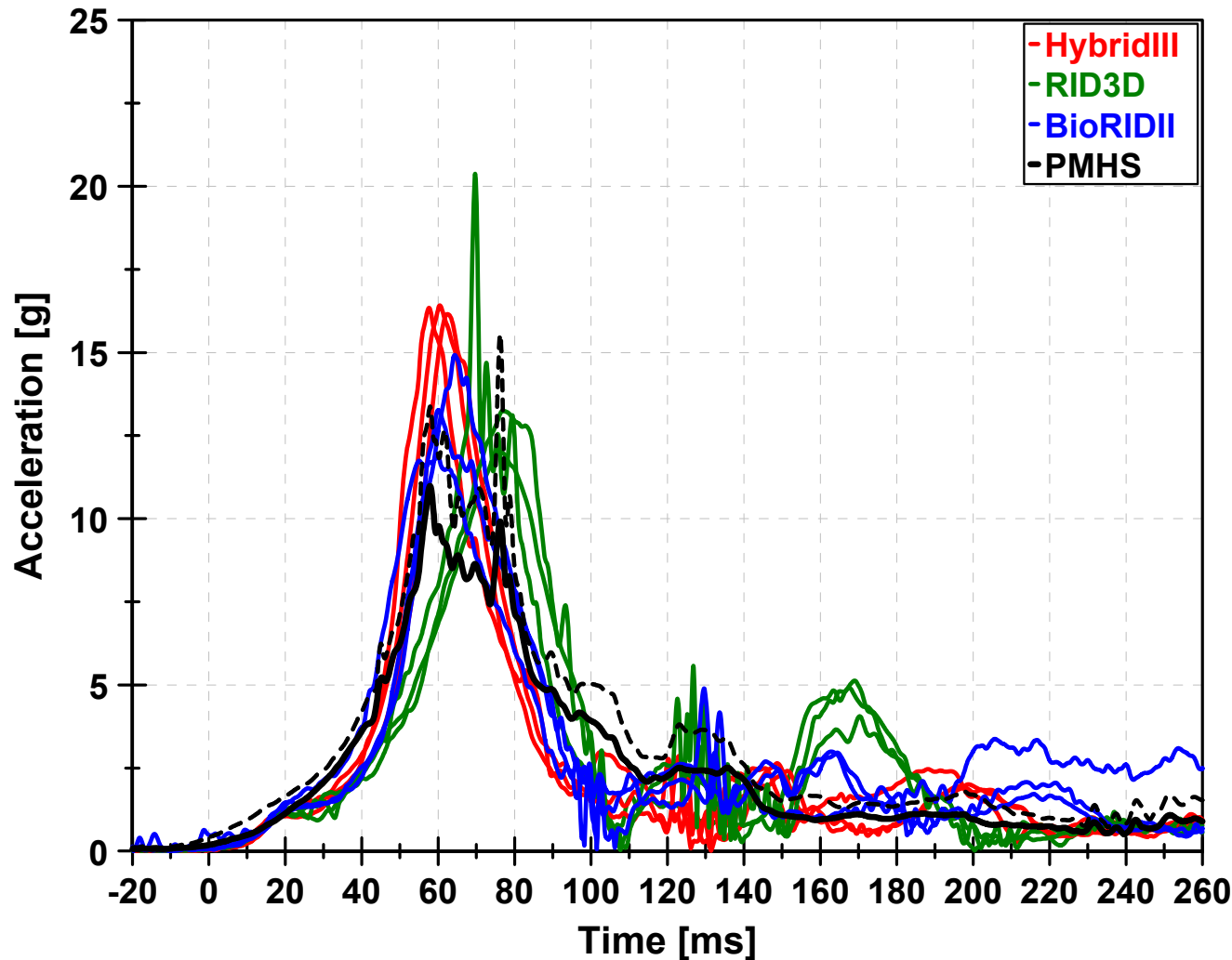
1.64

1.08



Internal Biofidelity

Low Speed – Pelvis Acceleration (Resultant)

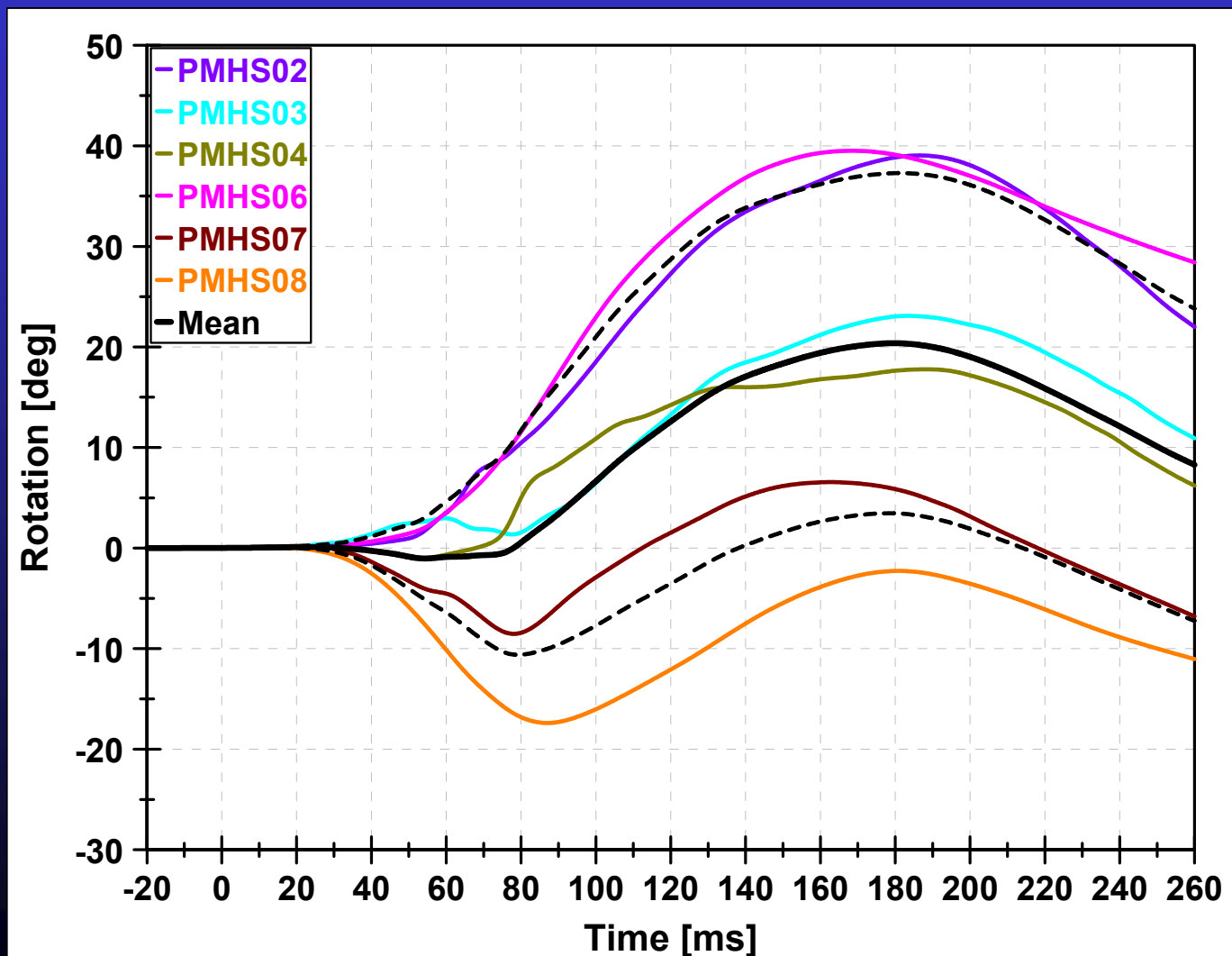


%CV (Peak)	%CV (Avg)
0.8	3.6
29.7	8.2
11.3	6.1



Internal Biofidelity

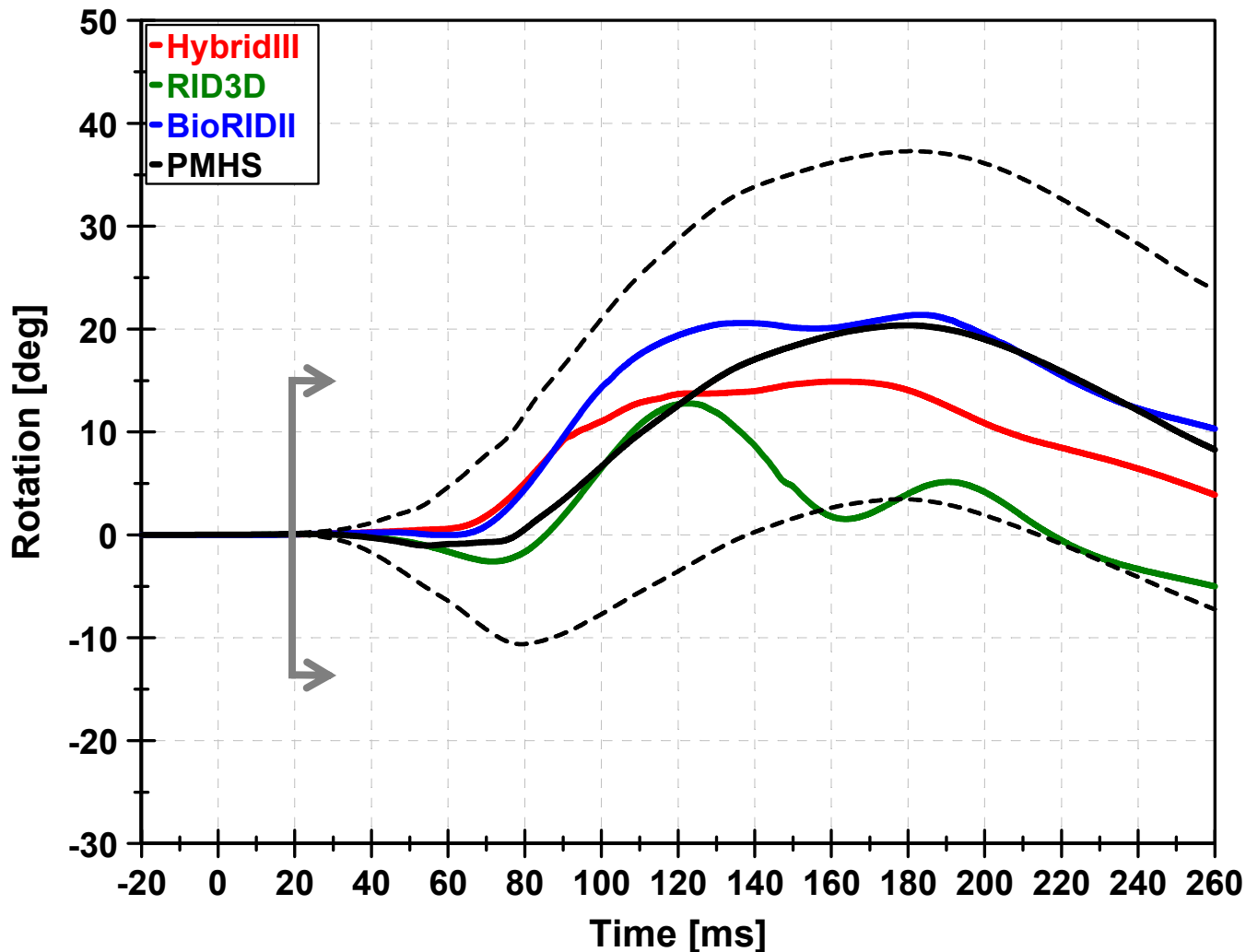
Low Speed – Pelvis Rotation





Internal Biofidelity

Low Speed – Pelvis Rotation

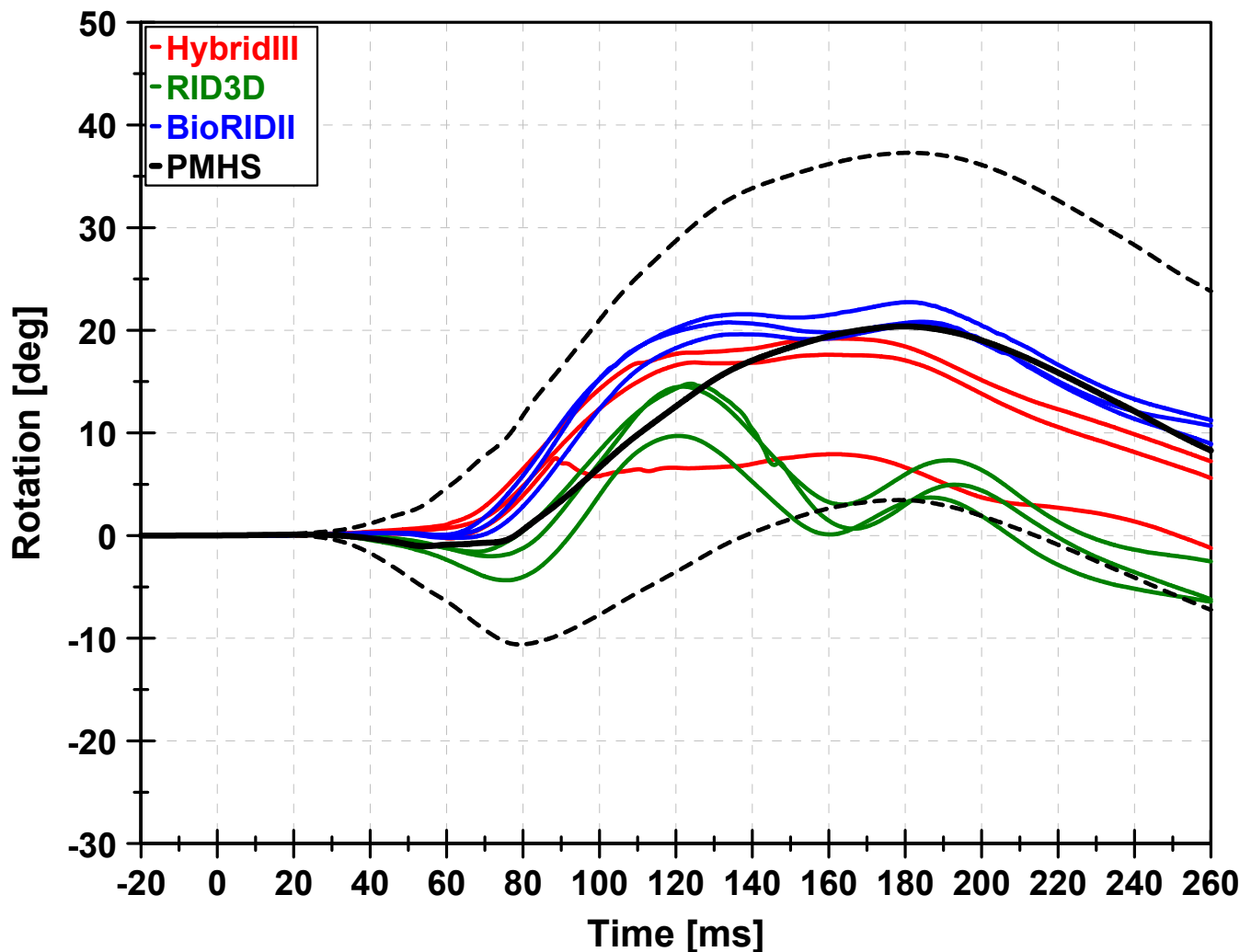


\sqrt{R}
0.34
0.78
0.24



Internal Biofidelity

Low Speed – Pelvis Rotation

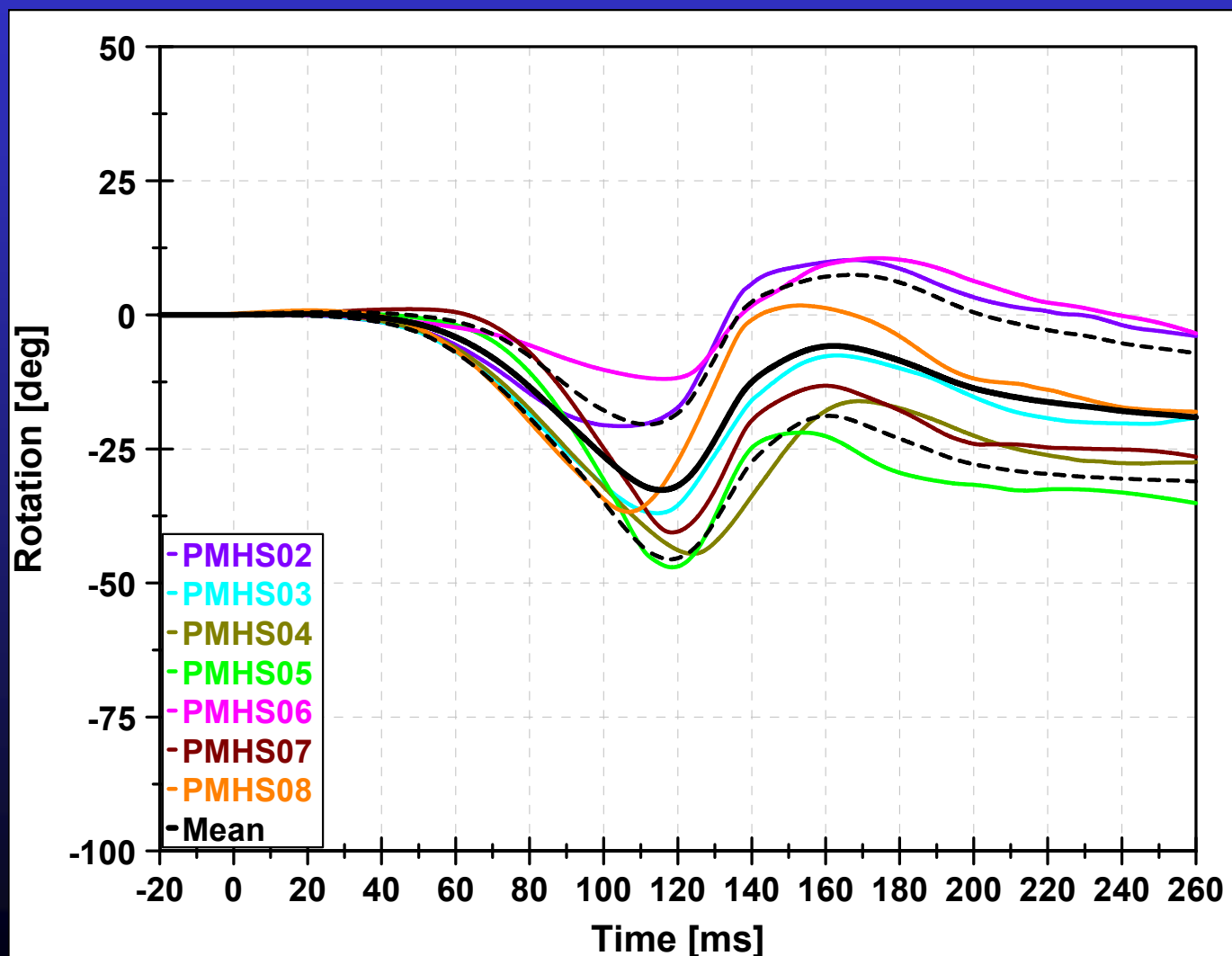


%CV (Peak)	%CV (Avg)
40.9	45.9
21.9	26.6
5.4	7.4



Internal Biofidelity

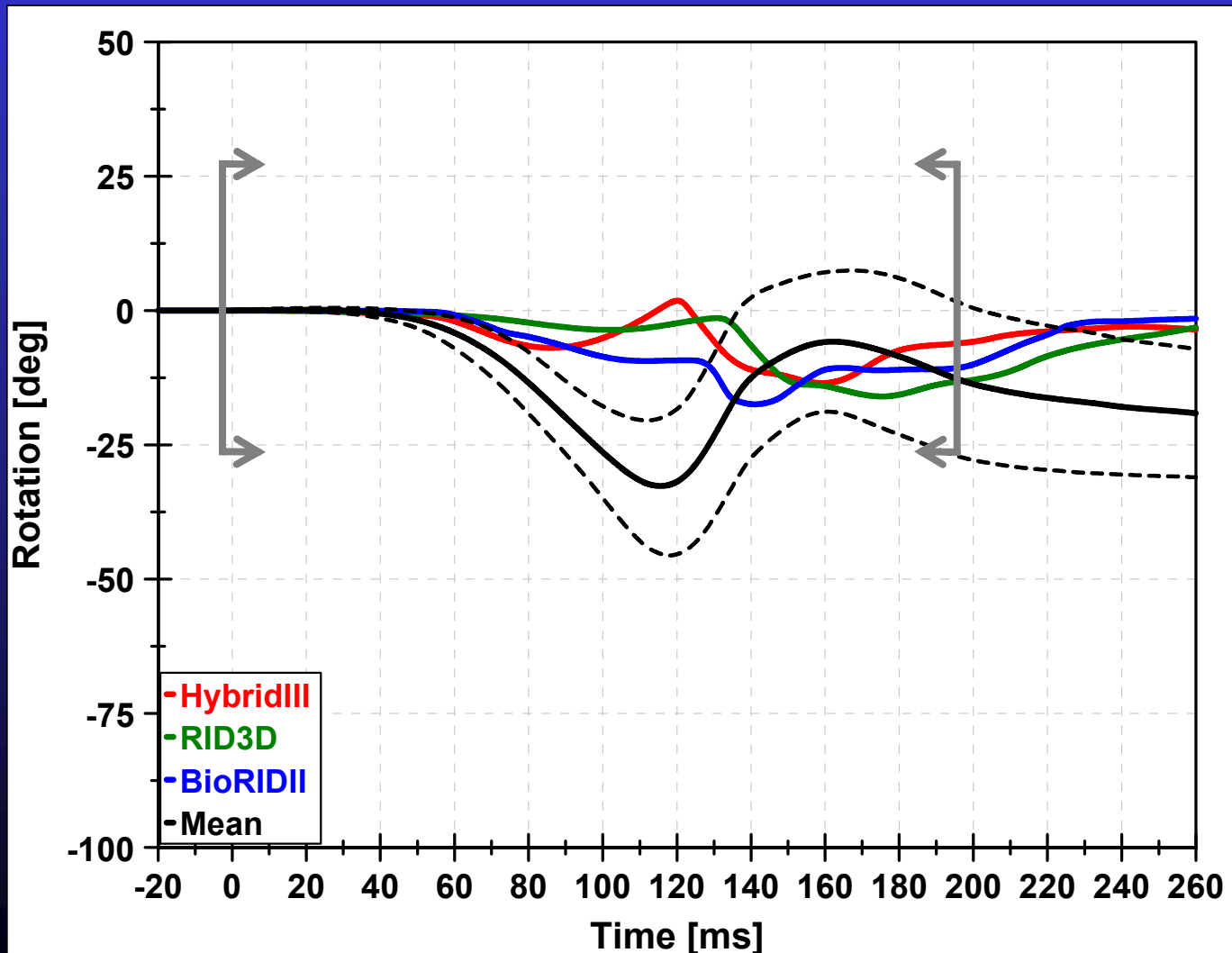
Low Speed – Head to T1 Rotation





Internal Biofidelity

Low Speed – Head to T1 Rotation



\sqrt{R}
1.25
1.30
0.96



Internal Biofidelity

Low Speed – HIC

HIC (Low Speed)

	HybridIII	RID3D	BioRIDII
PMHS 39.1 ± 8.5	176.5	175.6	136.3
	183.3	137.8	164.6
	163.3	281.7	177.8
Mean	174.4	198.4	159.6

HIC (Low Speed)

	HybridIII	RID3D	BioRIDII
\sqrt{R}	3.98	4.25	3.75
Peak C.V.	5.8	37.6	13.3



Internal Biofidelity

Low Speed Results

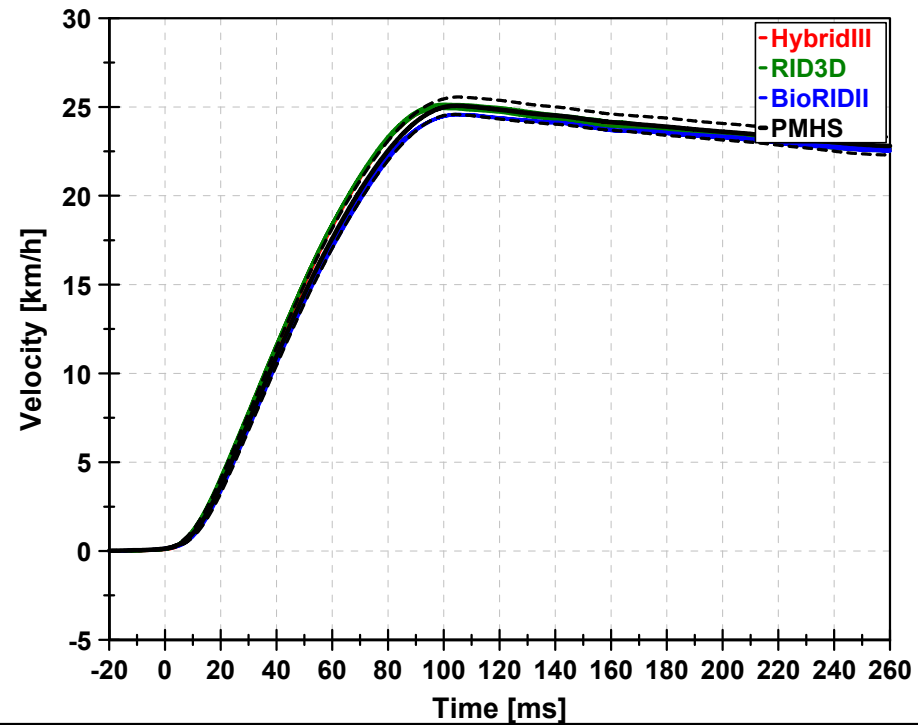
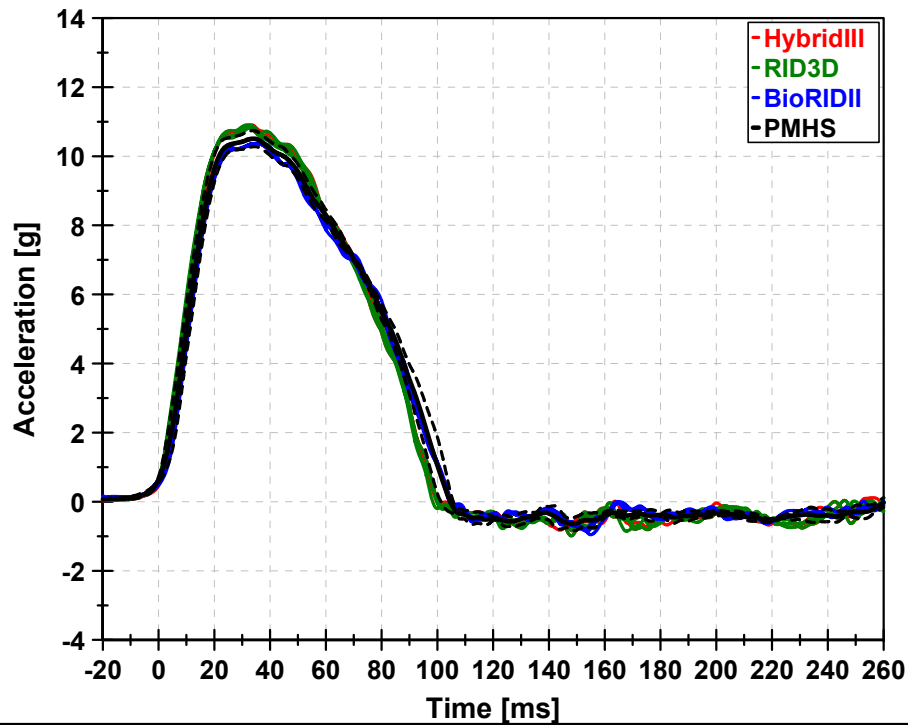
Internal Biofidelity (Low Speed)

	HybridIII	RID3D	BioRIDII
	\sqrt{R}		
Head Acc Res	5.09	3.54	4.58
Head Rotation	1.32	1.23	1.19
T1 Acc Res	2.24	2.39	3.32
T1 Rotation	1.31	0.92	0.48
T8 Acc Res	N/A	N/A	1.00
T12 Acc Res	N/A	1.04	0.67
Pelvis Acc Res	1.61	1.64	1.08
Pelvis Rotation	0.34	0.78	0.24
Head to T1	1.25	1.30	0.96
HIC	3.98	4.25	3.75
Mean	2.14	1.81	1.73



Sled Pulse

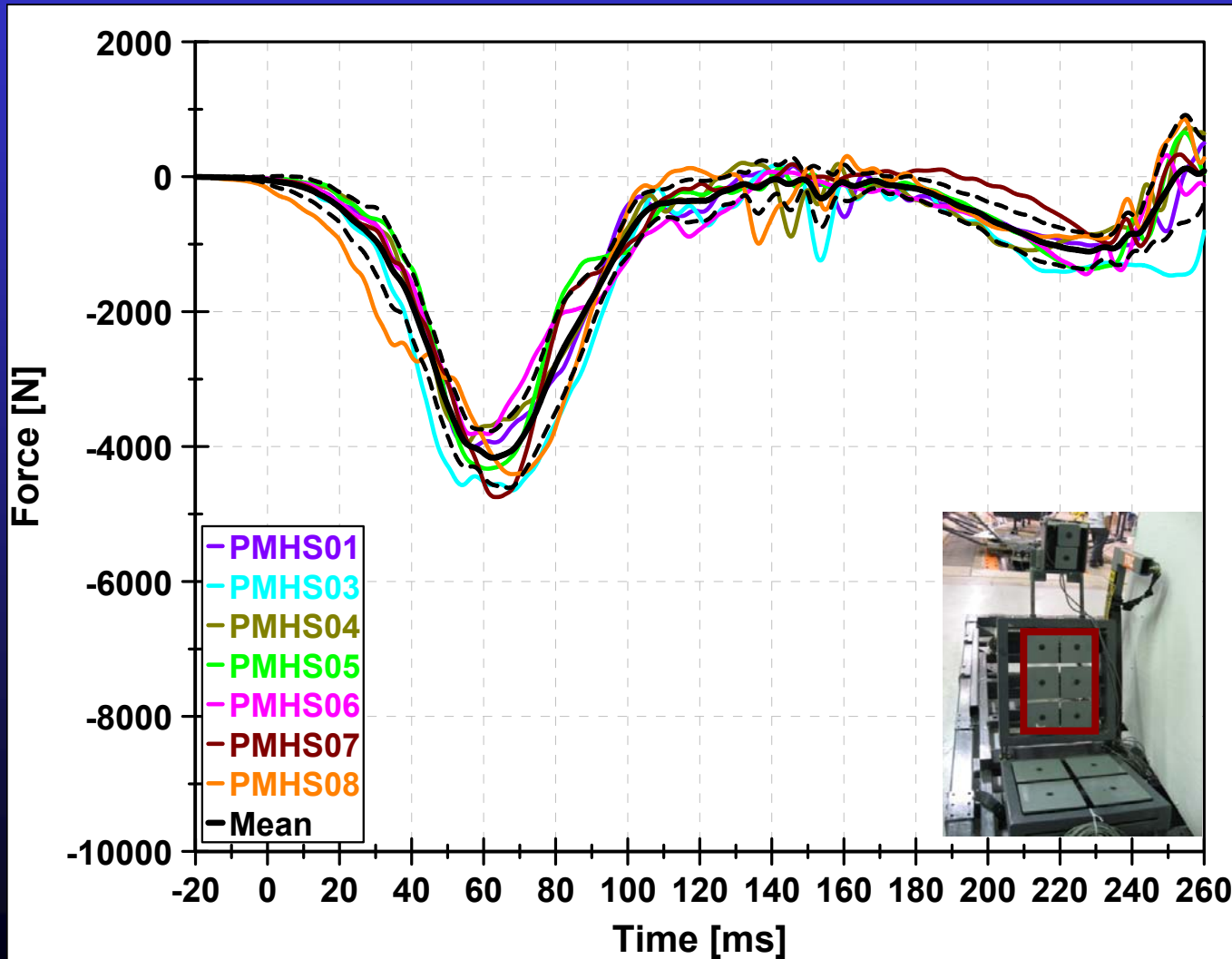
Moderate Speed (10.5 g, 24.0 kph)





External Biofidelity

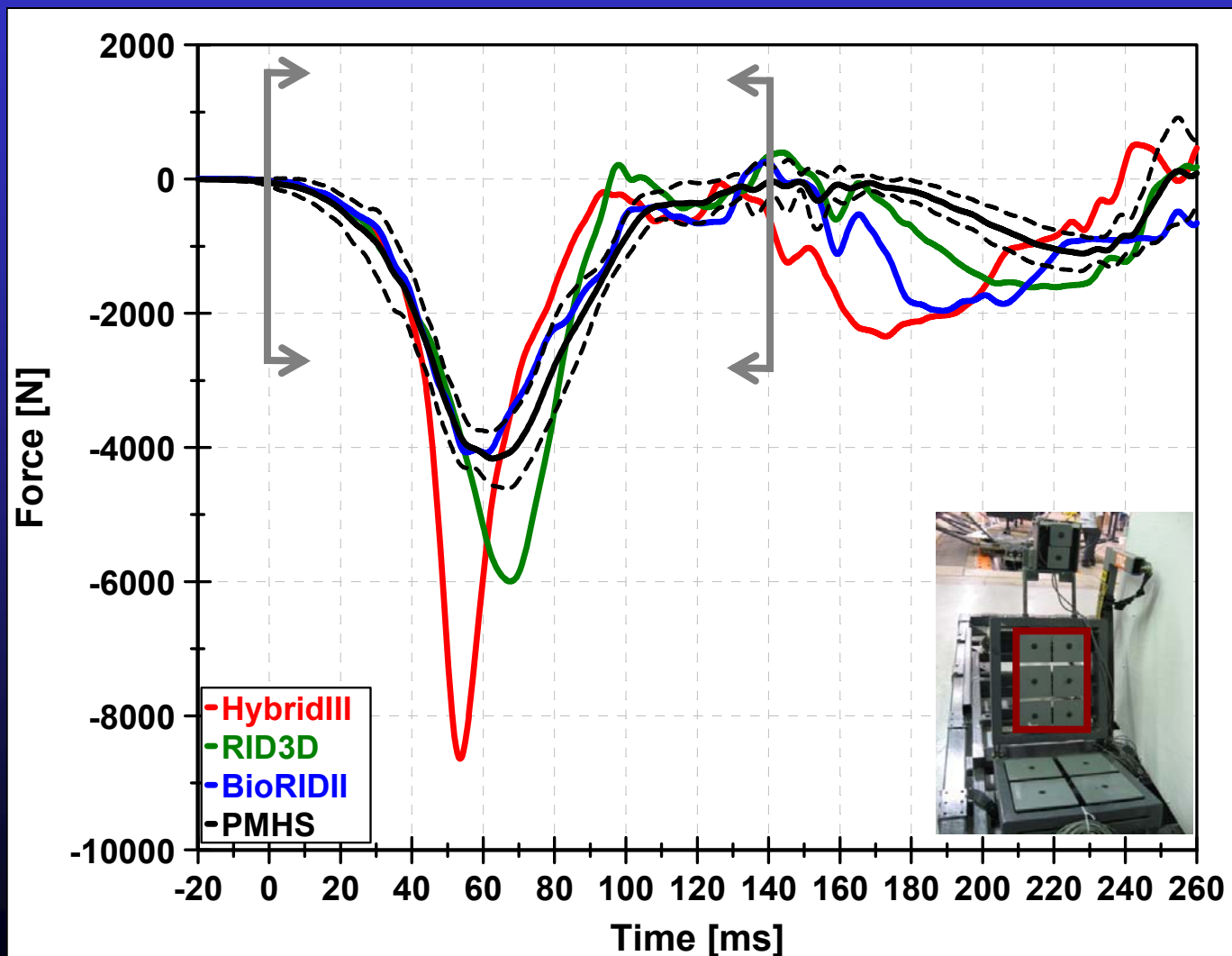
Moderate Speed – Total Seat Back Load





External Biofidelity

Moderate Speed – Total Seat Back Load



$$\sqrt{R}$$

3.35

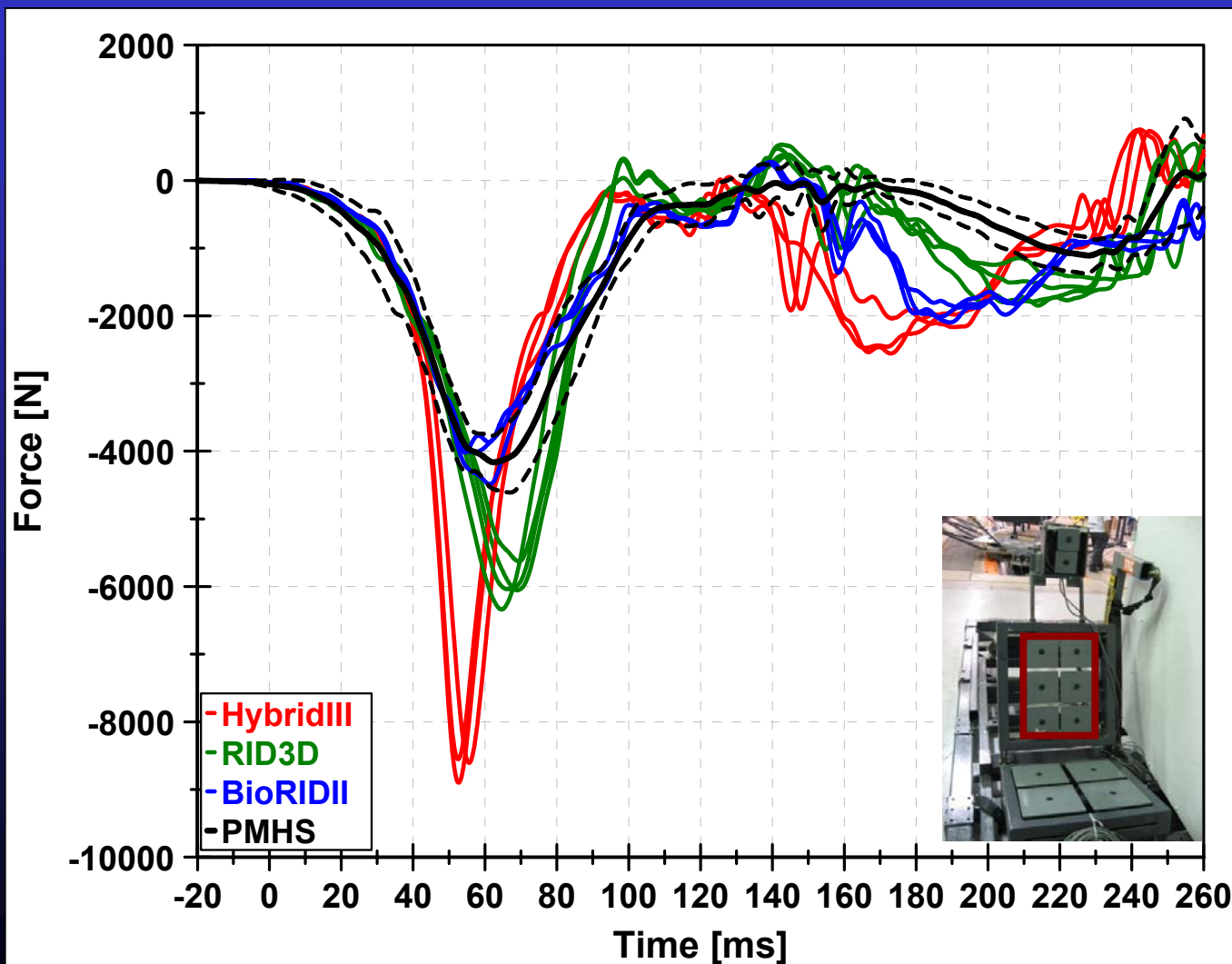
1.82

0.74



External Biofidelity

Moderate Speed – Total Seat Back Load

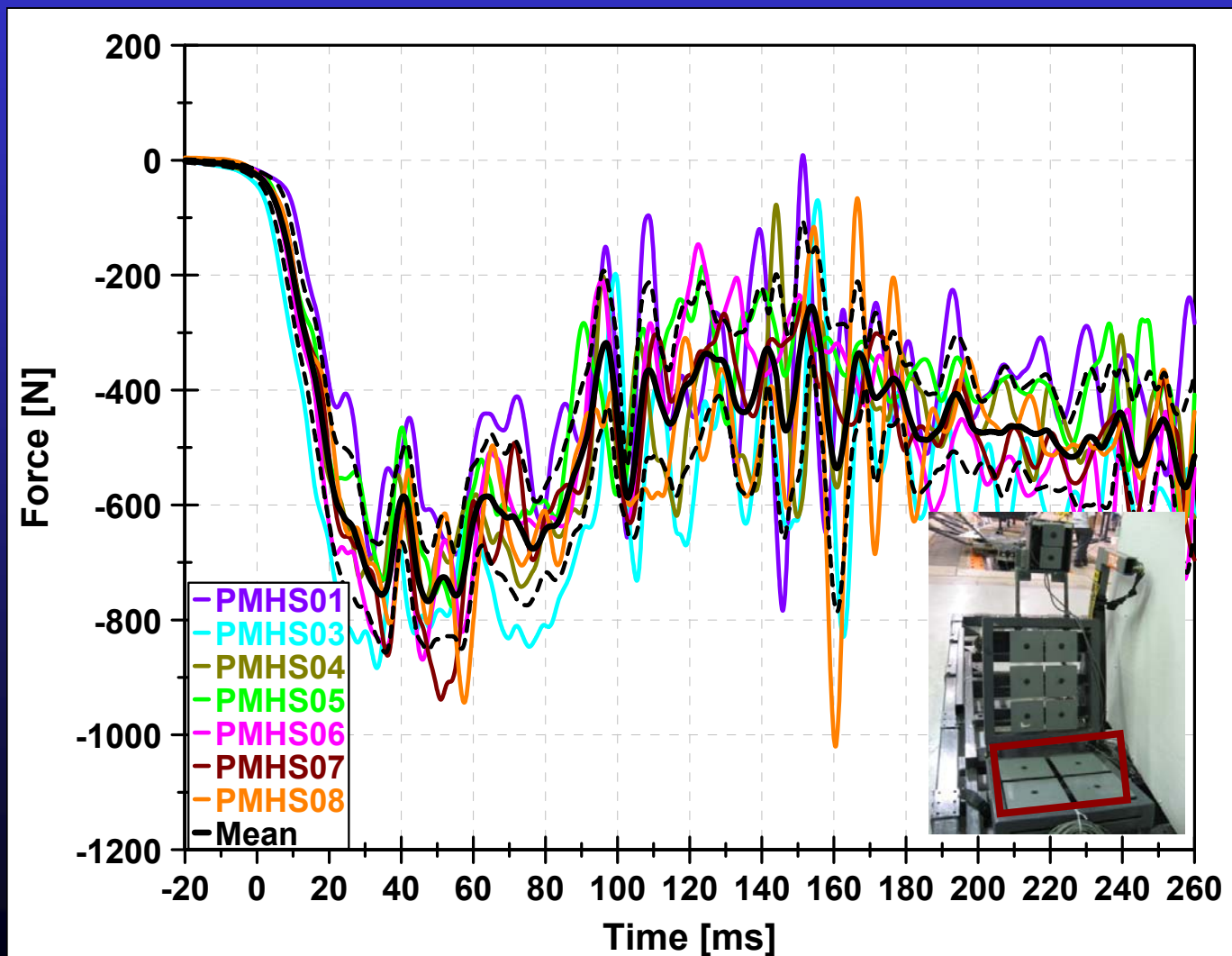


%CV (Peak)	%CV (Avg)
2.1	4.8
4.9	4.4
6.5	4.8



External Biofidelity

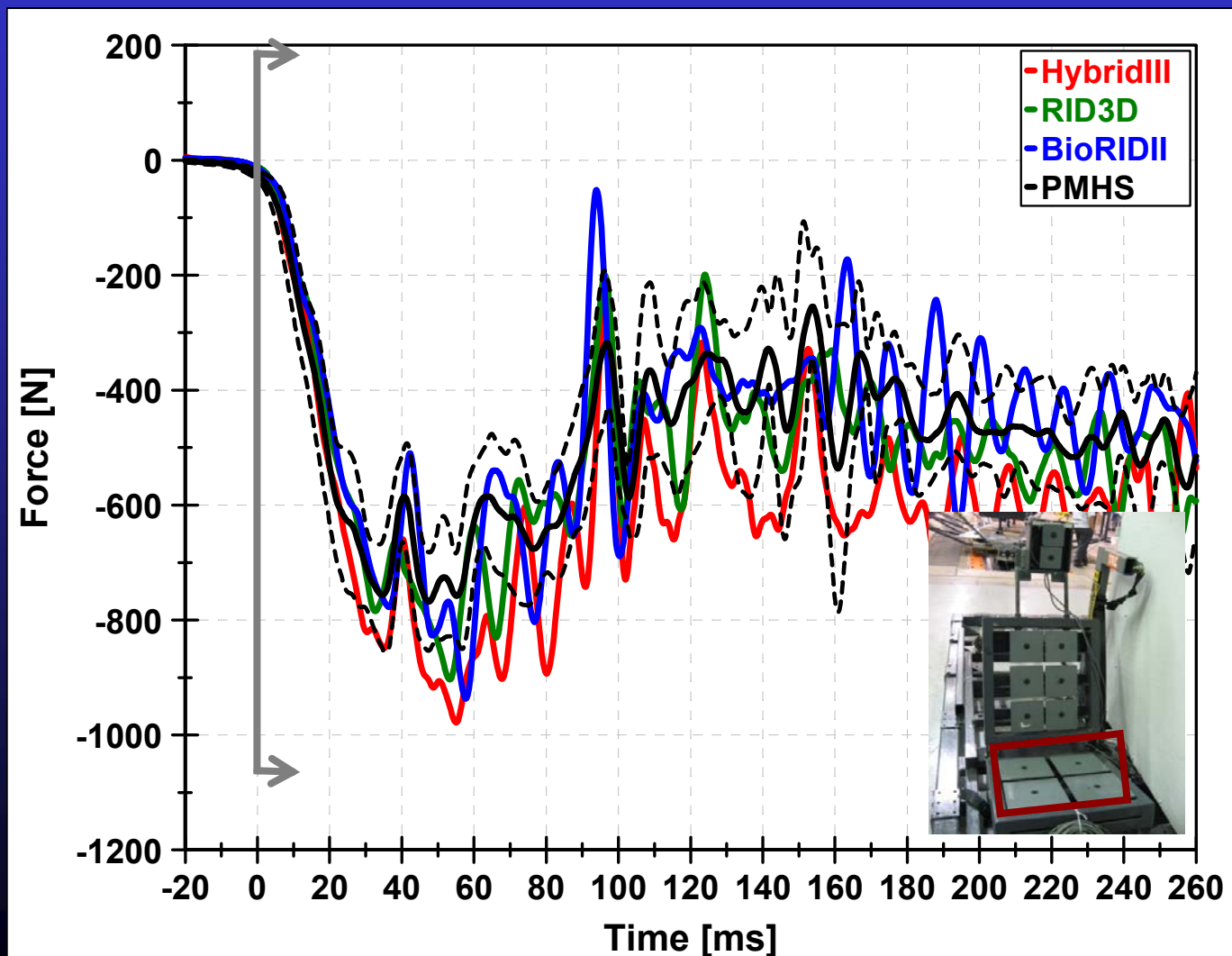
Moderate Speed – Total Seat Pan Load





External Biofidelity

Moderate Speed – Total Seat Pan Load

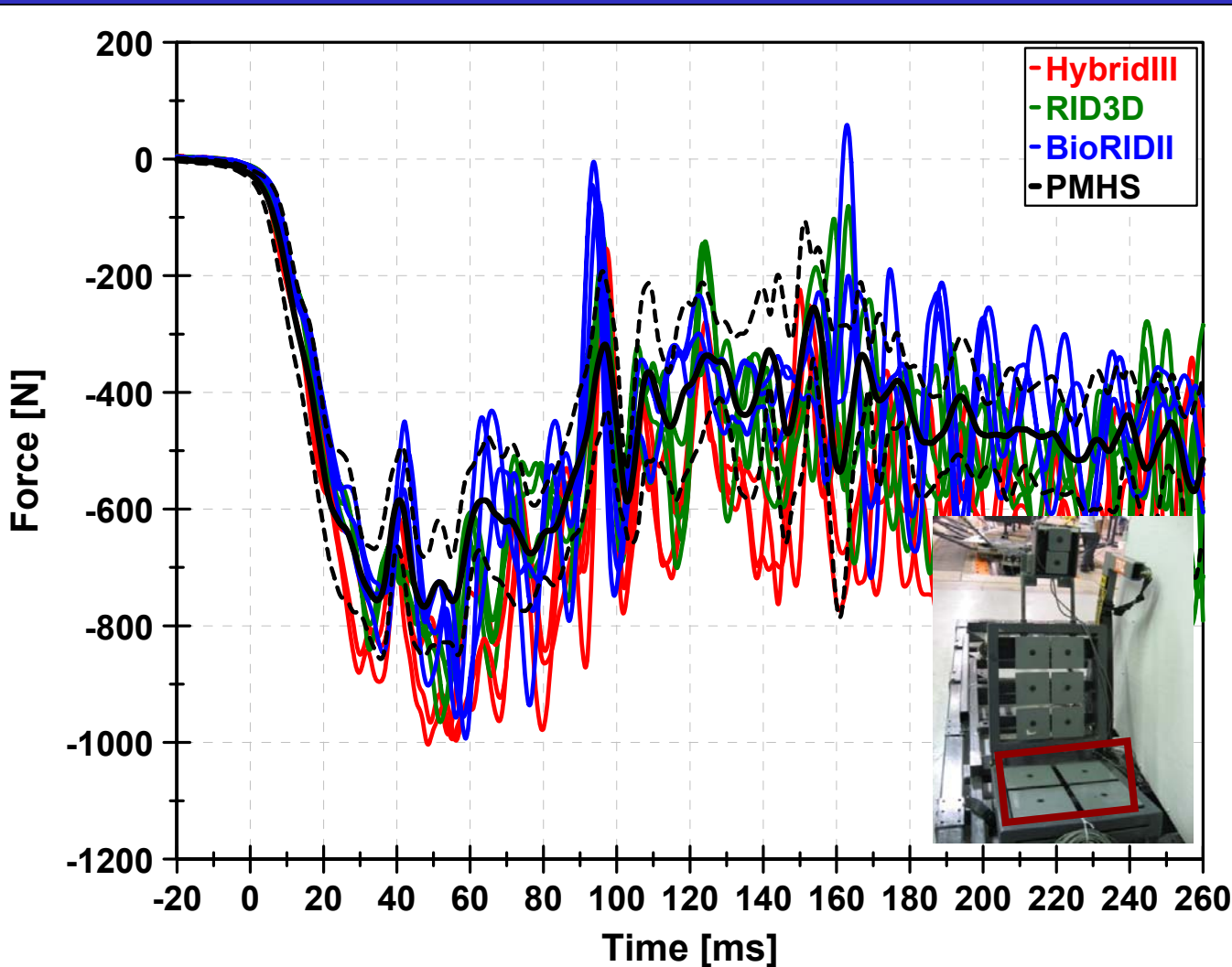


\sqrt{R}
1.43
0.71
0.91



External Biofidelity

Moderate Speed – Total Seat Pan Load



%CV (Peak)	%CV (Avg)
0.9	8.2
3.9	5.8
2.2	10.7



External Biofidelity

Moderate Speed – HR Contact Time

HRContact Time (Moderate Speed)

	HybridIII	RID3D	BioRIDII
PMHS 124.3 ± 11.5 ms	106.7	127.5	117.4
	126.5	110.3	115.8
	111.1	120.4	114.6
		121.5	
Mean	114.8	119.9	116.0

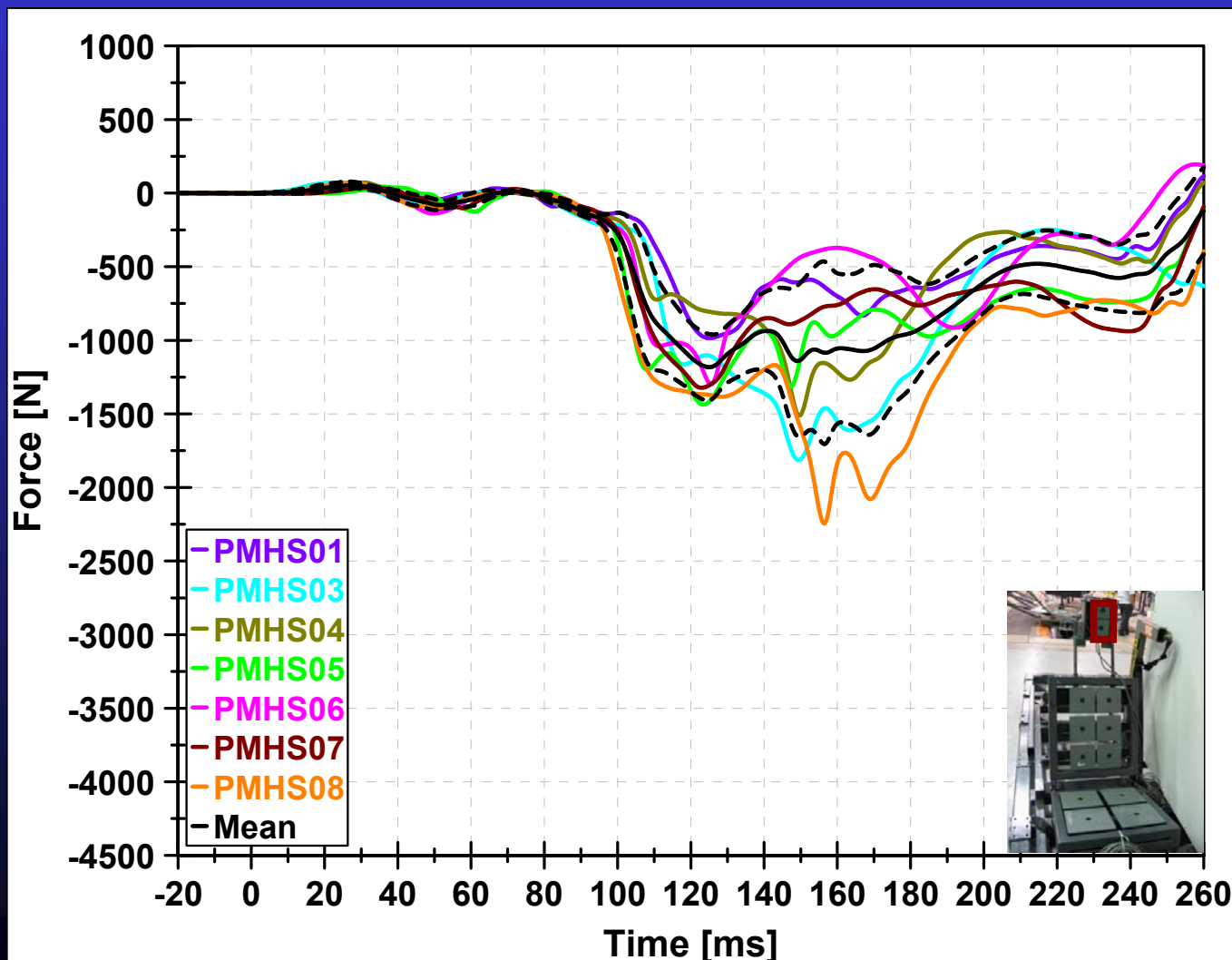
HR Contact Time (Moderate Speed)

	HybridIII	RID3D	BioRIDII
\sqrt{R}	0.69	0.14	0.53
Peak C.V.	9.0	6.0	1.2



External Biofidelity

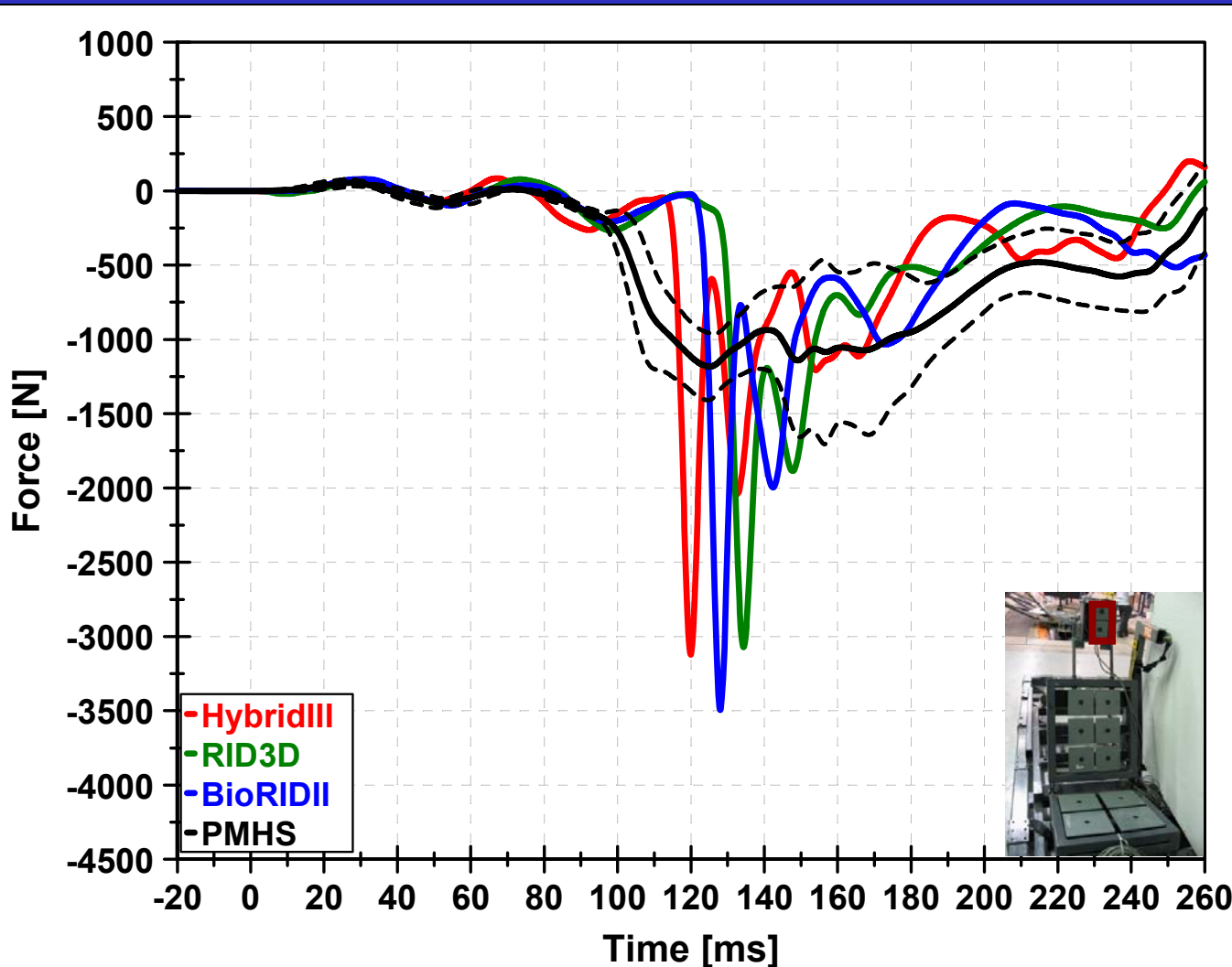
Moderate Speed – Total HR Load (Front)





External Biofidelity

Moderate Speed – Total HR Load (Front)

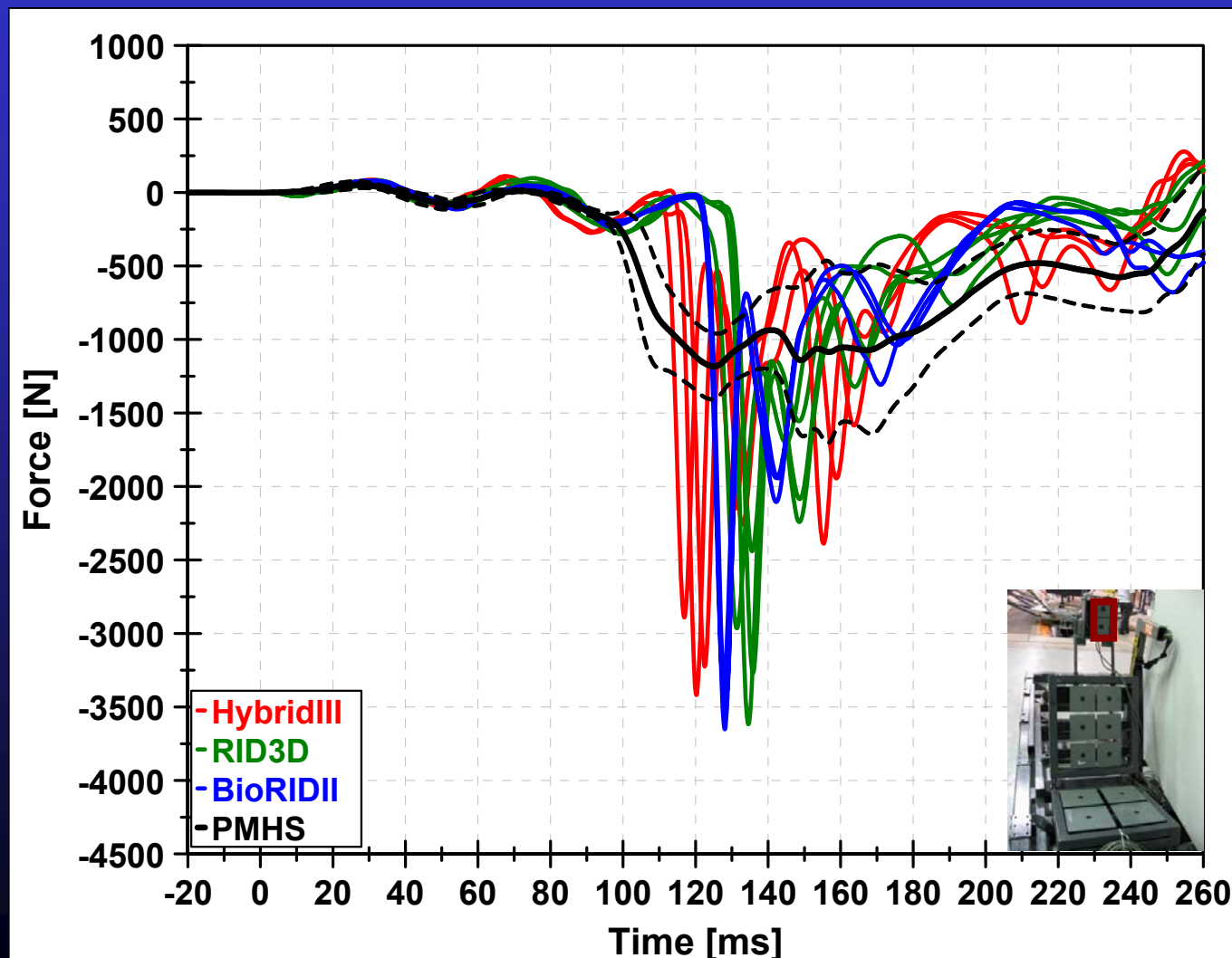


\sqrt{R}
1.47
1.72
1.66



External Biofidelity

Moderate Speed – Total HR Load (Front)

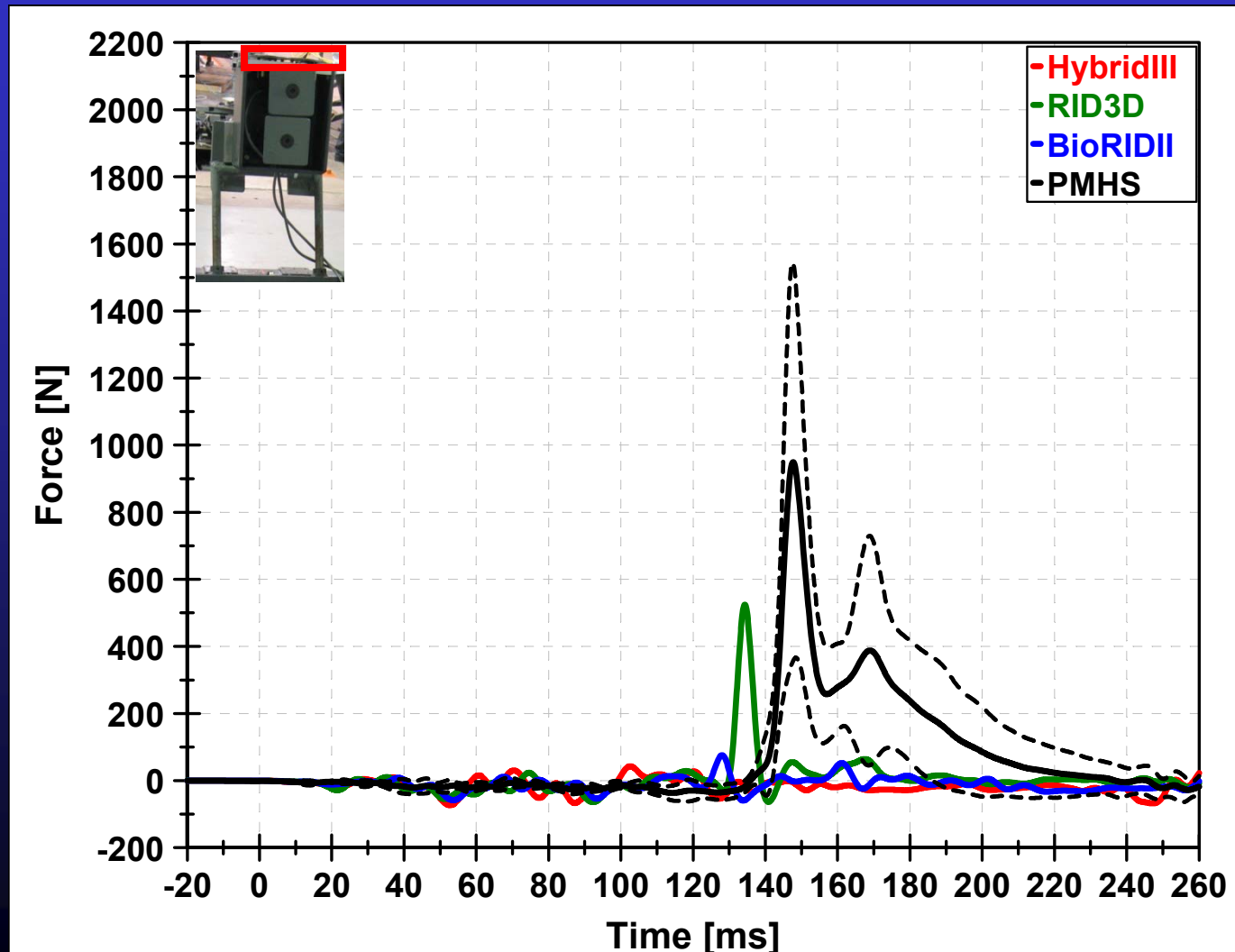


%CV (Peak)	%CV (Avg)
8.4	15.8
16.2	13.2
4.4	4.6



External Biofidelity

Moderate Speed – Total HR Load (Top)

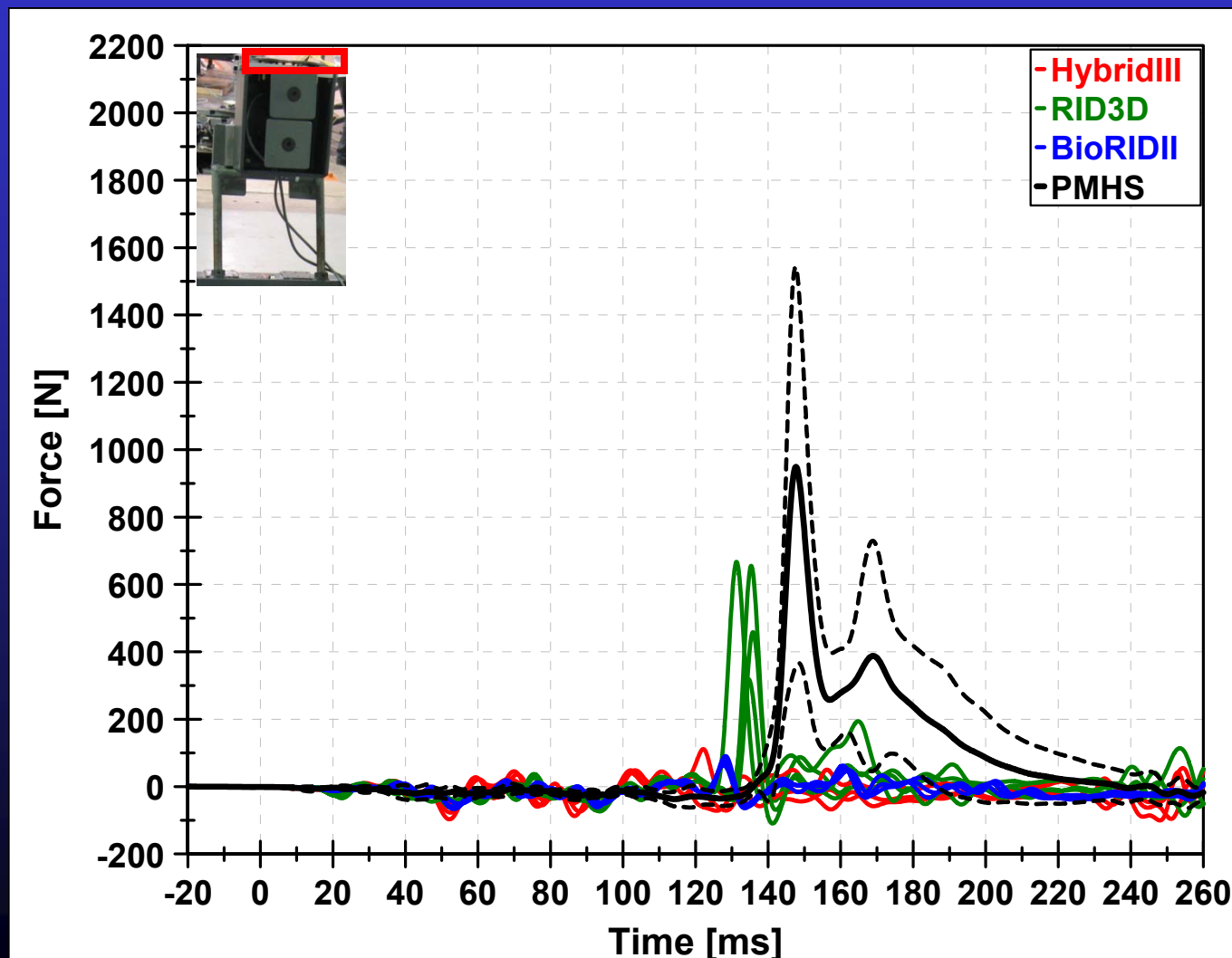


\sqrt{R}
1.44
1.09
1.41



External Biofidelity

Moderate Speed – Total HR Load (Top)



%CV (Peak)	%CV (Avg)
N/A	N/A
35.8	34.3
N/A	N/A



External Biofidelity

Moderate Speed Results

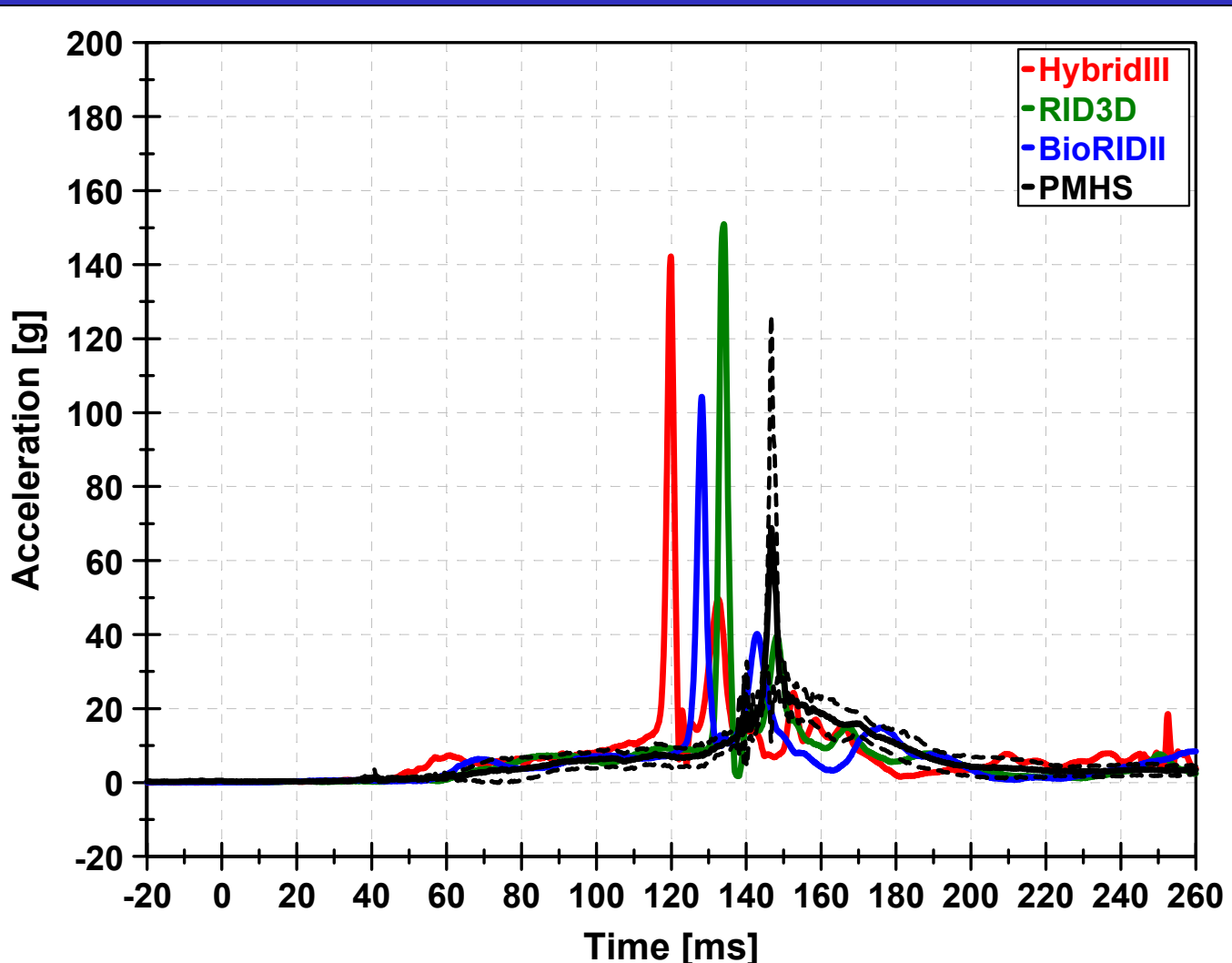
External Biofidelity (Moderate Speed)

	HybridIII	RID3D	BioRIDII
	\sqrt{R}		
Sum SB Total	3.35	1.82	0.74
Sum SP Total	1.43	0.71	0.91
HR Contact Time	0.69	0.14	0.53
Sum HR Fx	1.47	1.72	1.66
Sum HR Fz	1.44	1.09	1.41
Mean	1.68	1.10	1.05



Internal Biofidelity

Moderate Speed – Head Acceleration (Resultant)

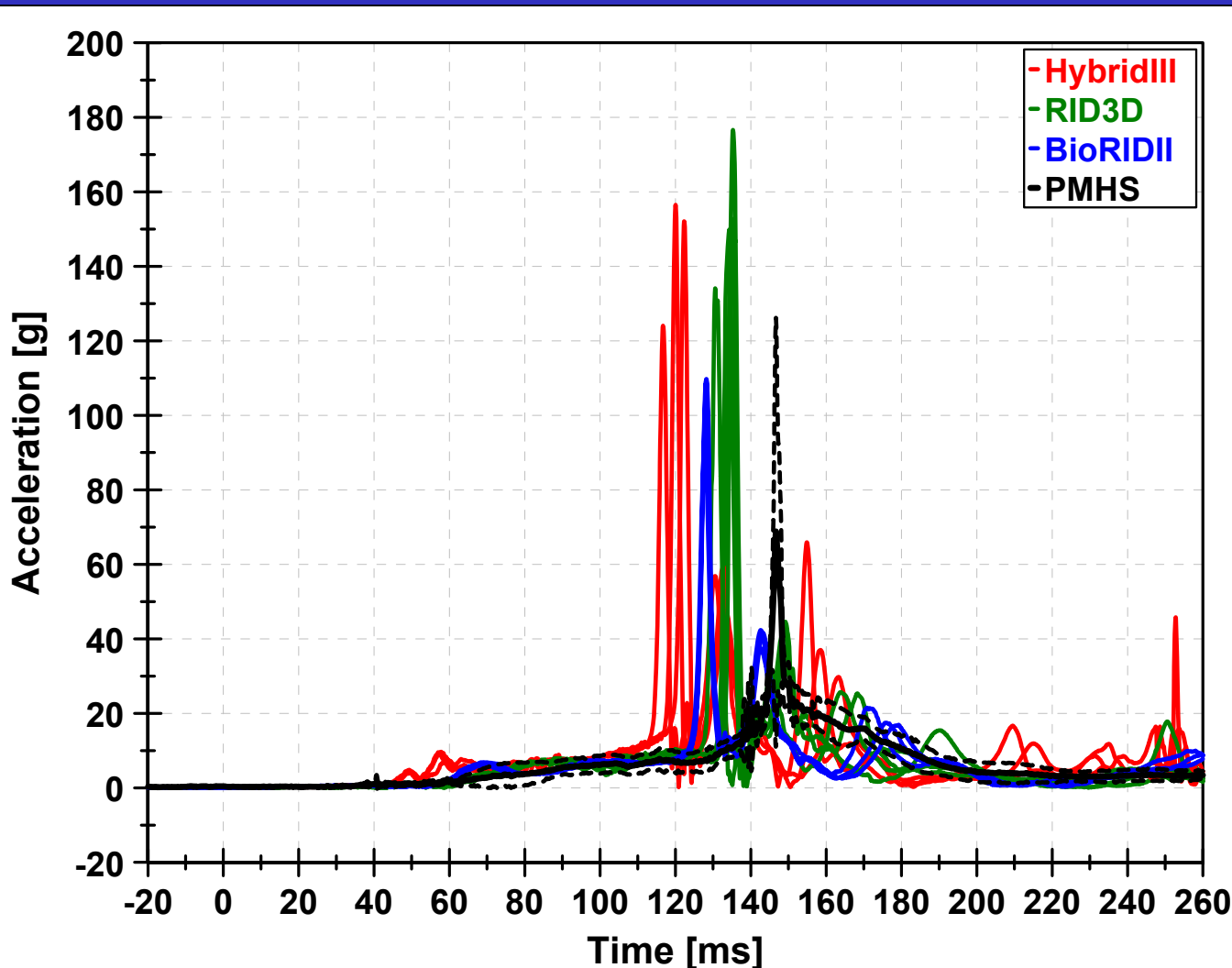


\sqrt{R}
3.06
2.90
2.33



Internal Biofidelity

Moderate Speed – Head Acceleration (Resultant)

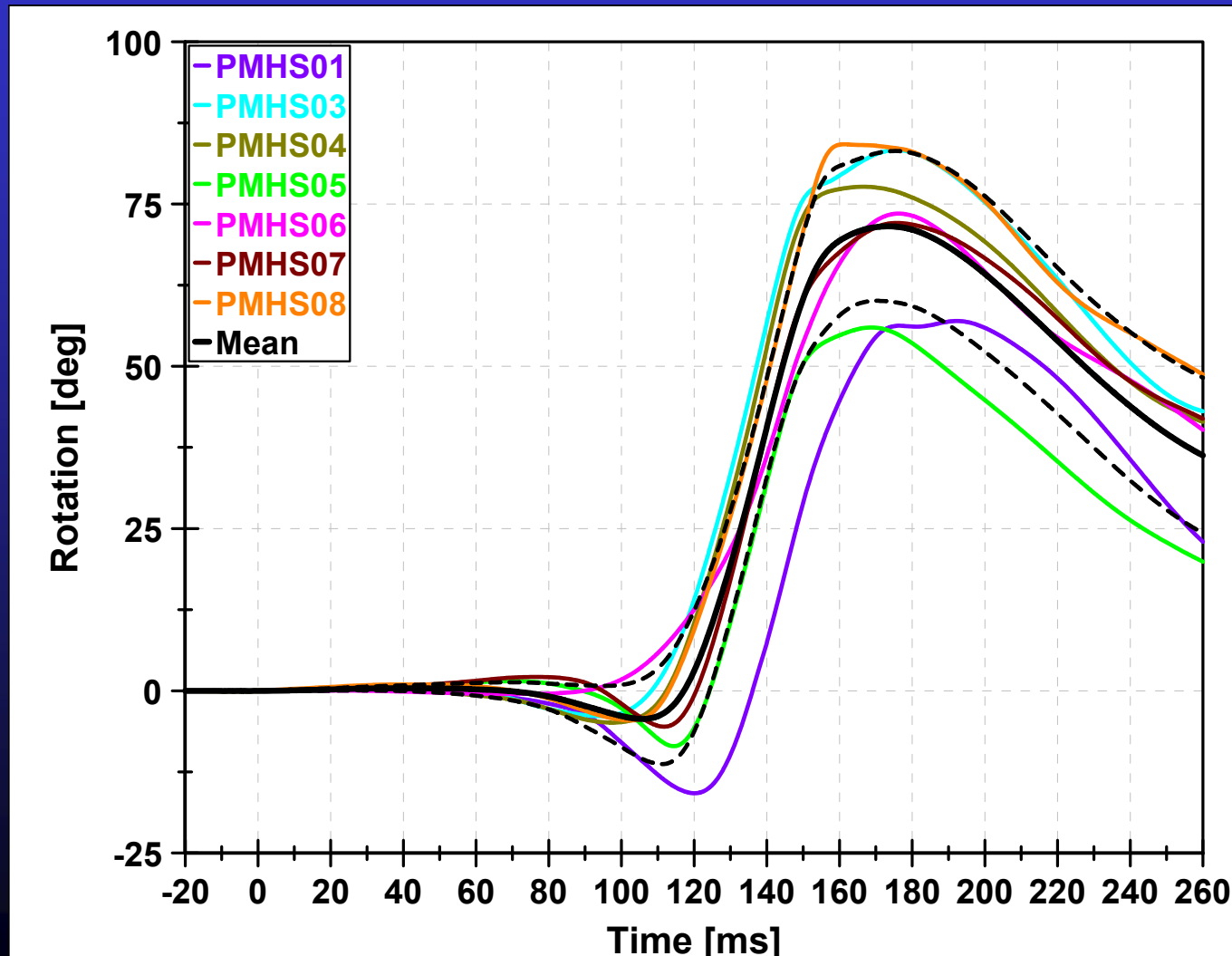


%CV (Peak)	%CV (Avg)
12.2	14.6
11.5	9.8
8.4	7.4



Internal Biofidelity

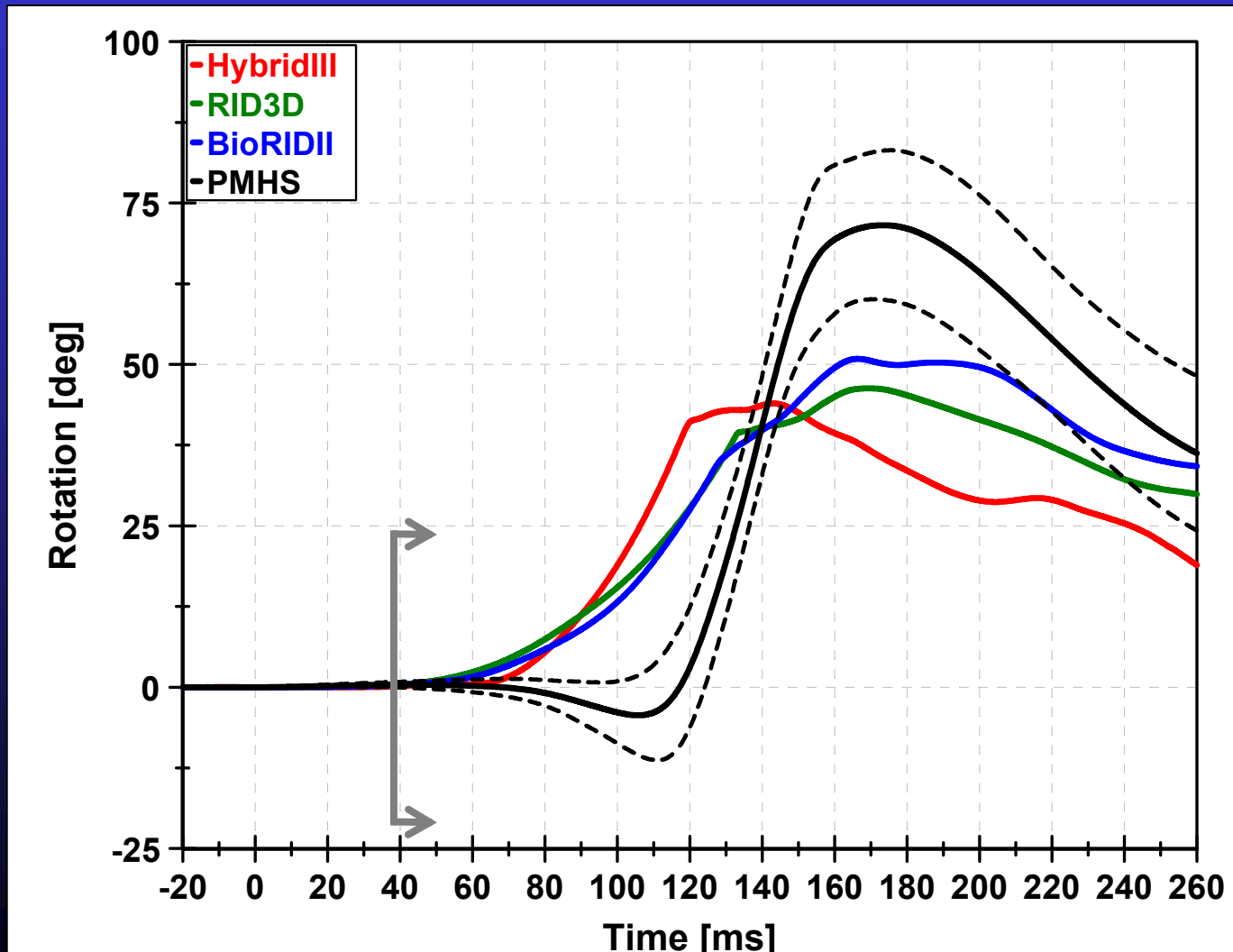
Moderate Speed – Head Rotation





Internal Biofidelity

Moderate Speed – Head Rotation

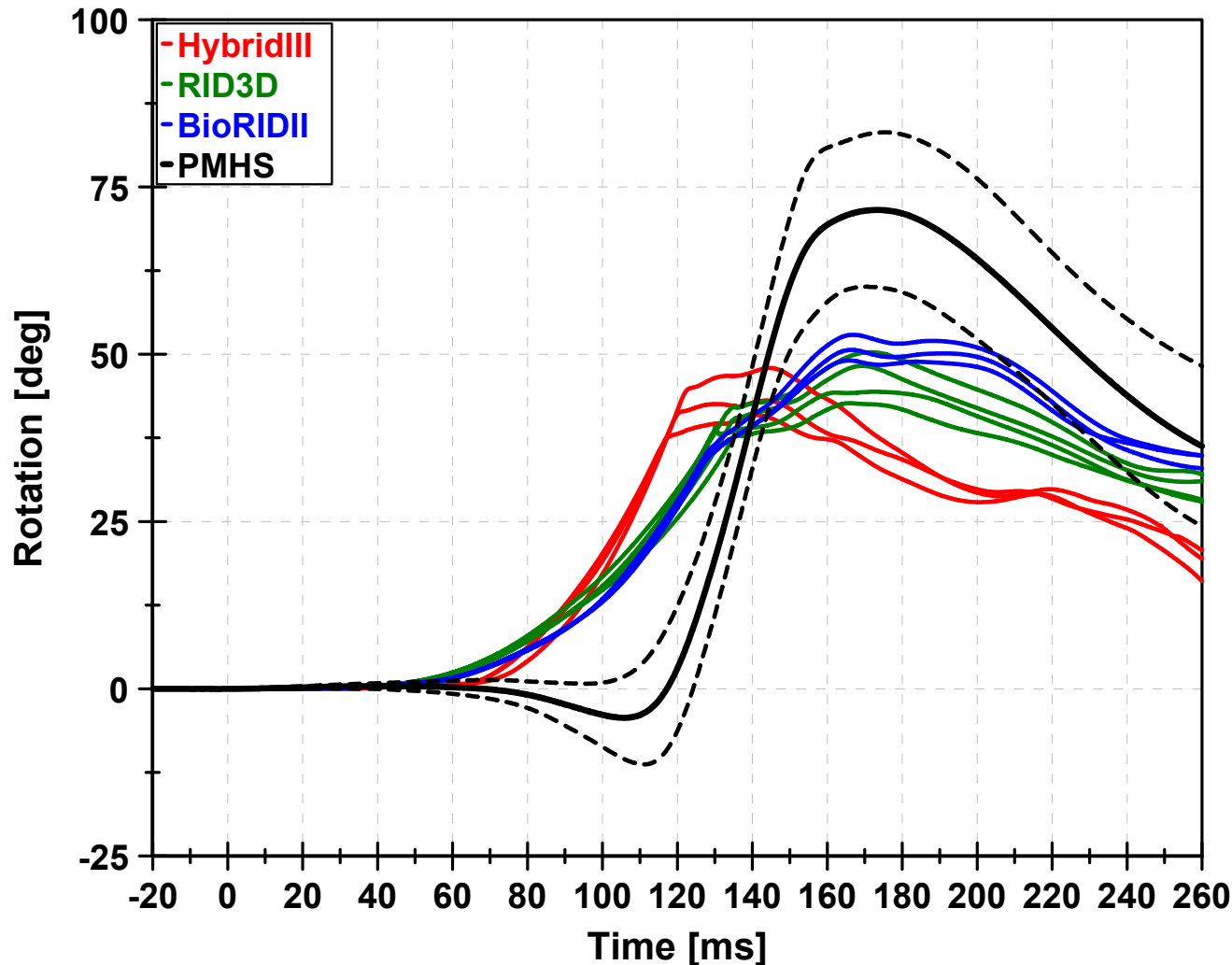


\sqrt{R}
2.67
1.91
1.55



Internal Biofidelity

Moderate Speed – Head Rotation

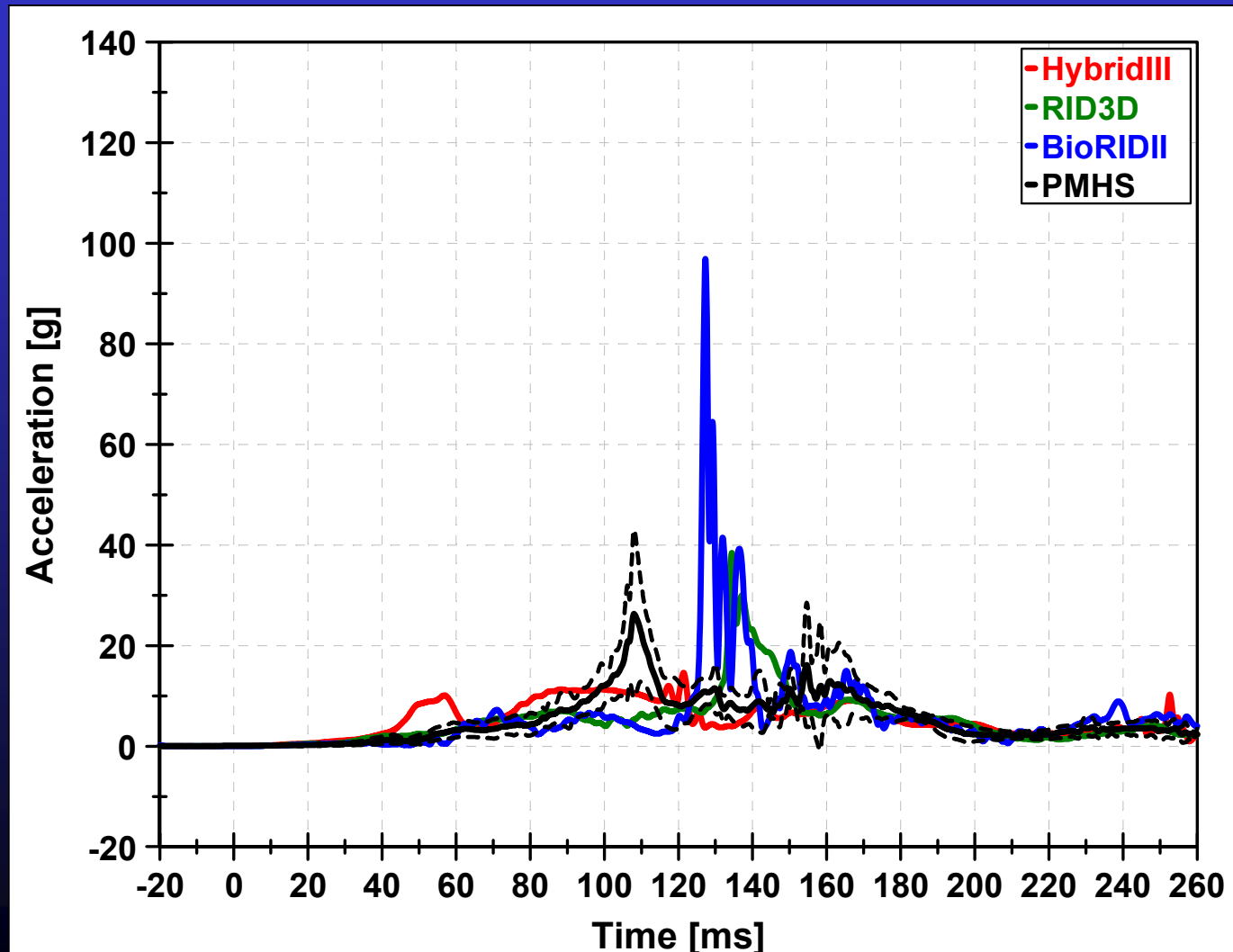


%CV (Peak)	%CV (Avg)
8.2	5.0
7.5	6.6
3.8	3.2



Internal Biofidelity

Moderate Speed – T1 Acceleration (Resultant)

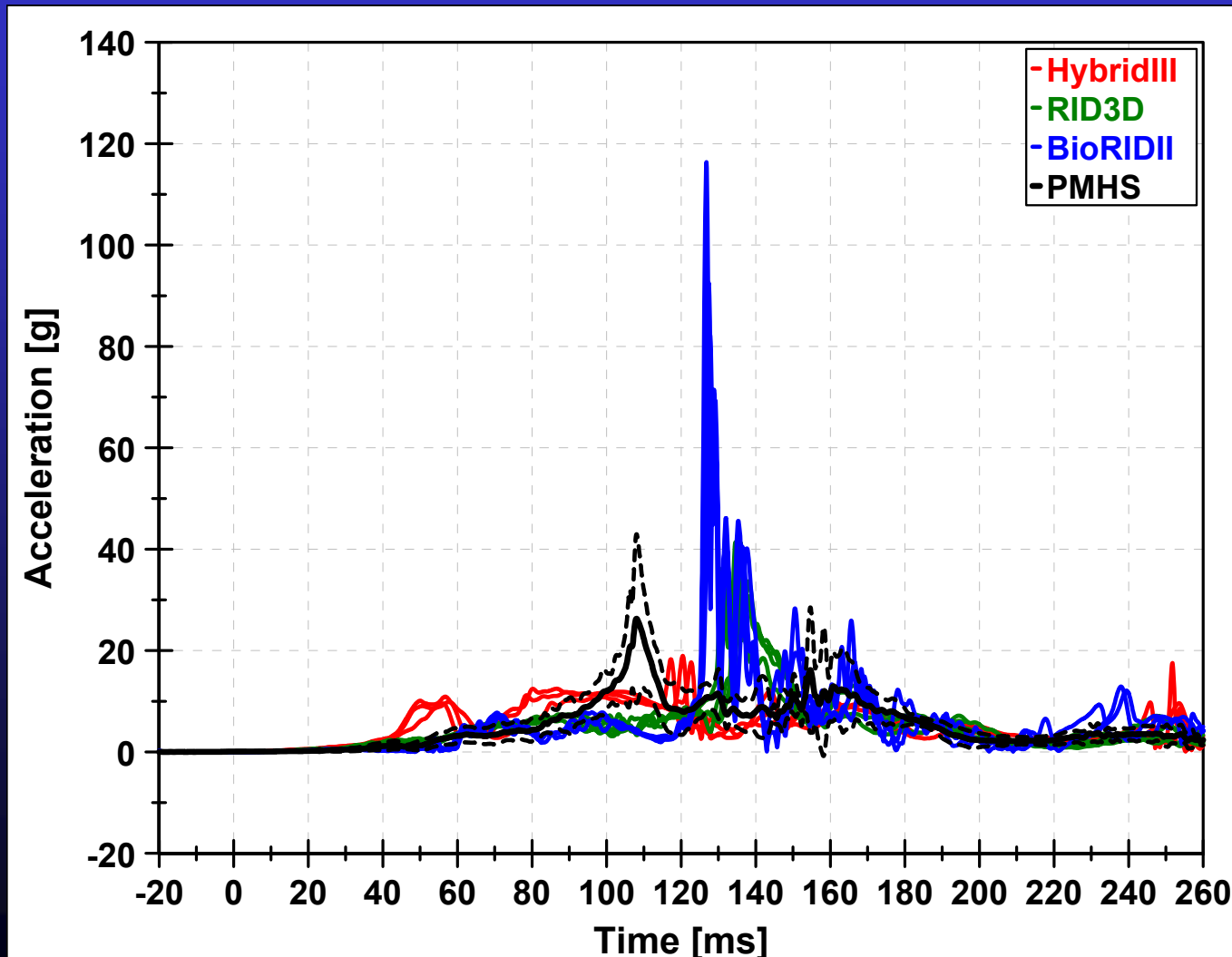


\sqrt{R}
1.03
1.60
2.71



Internal Biofidelity

Moderate Speed – T1 Acceleration (Resultant)

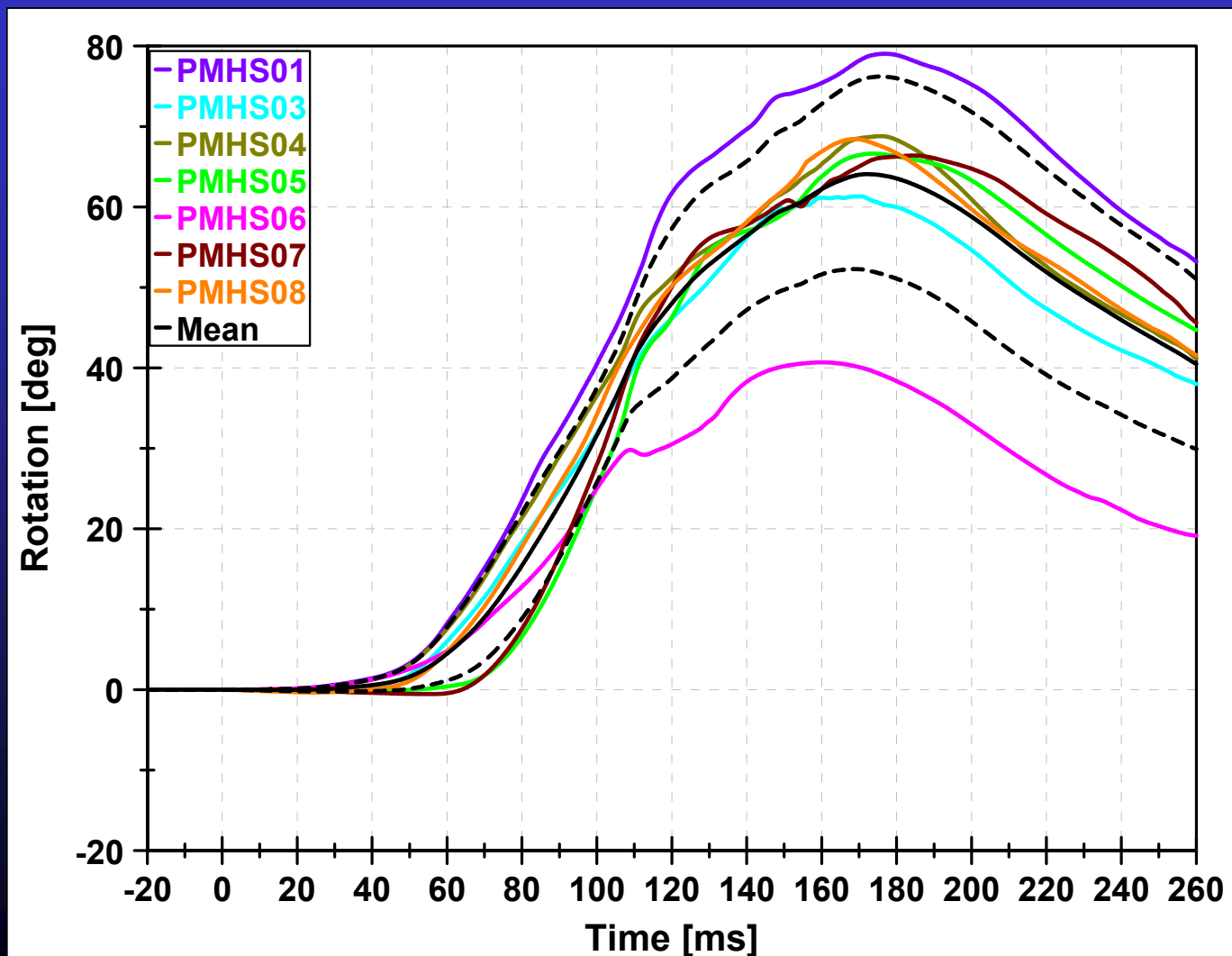


%CV (Peak)	%CV (Avg)
3.4	11.3
8.0	8.2
17.9	15.4



Internal Biofidelity

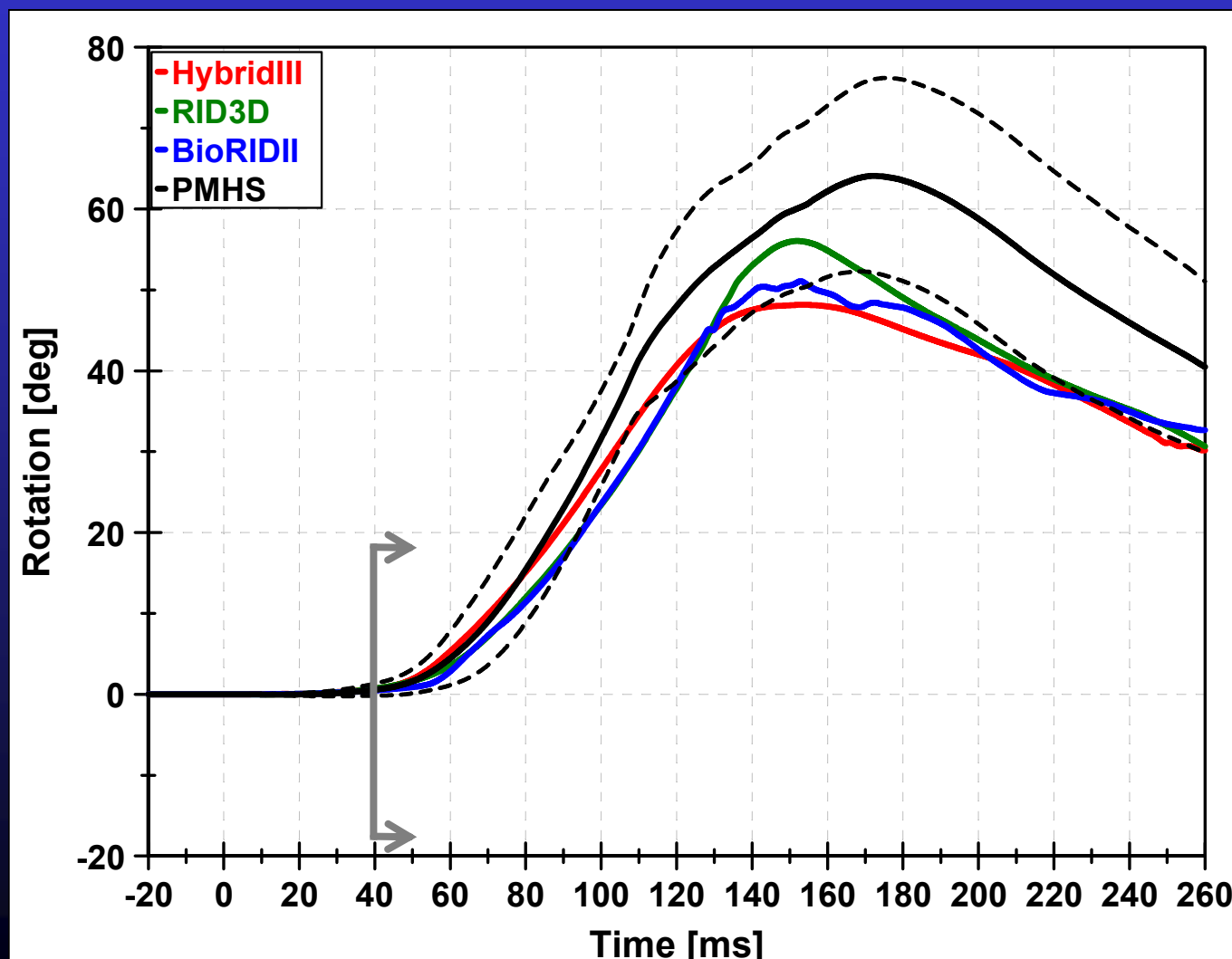
Moderate Speed – T1 Rotation





Internal Biofidelity

Moderate Speed – T1 Rotation

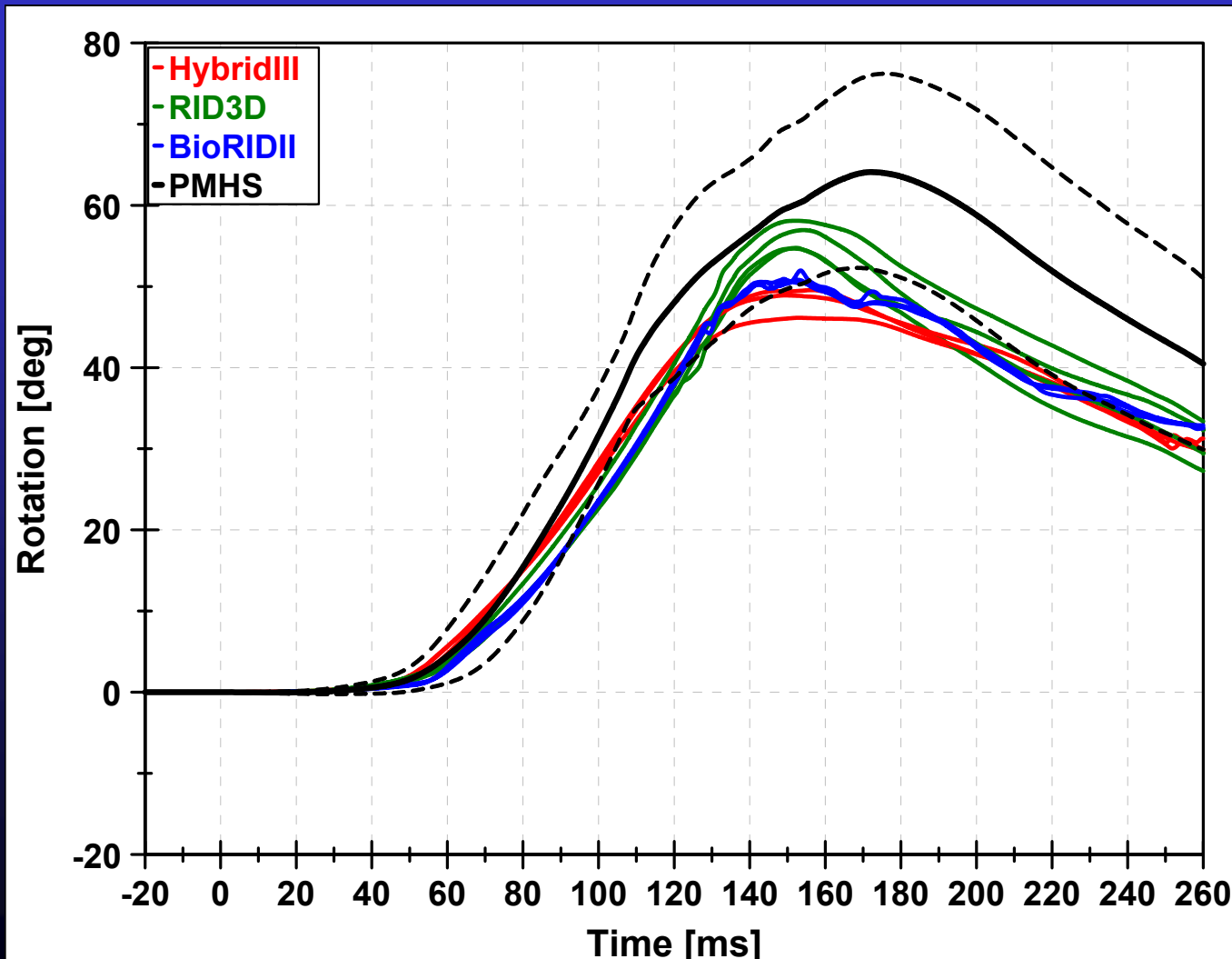


\sqrt{R}
1.18
1.03
1.15



Internal Biofidelity

Moderate Speed – T1 Rotation

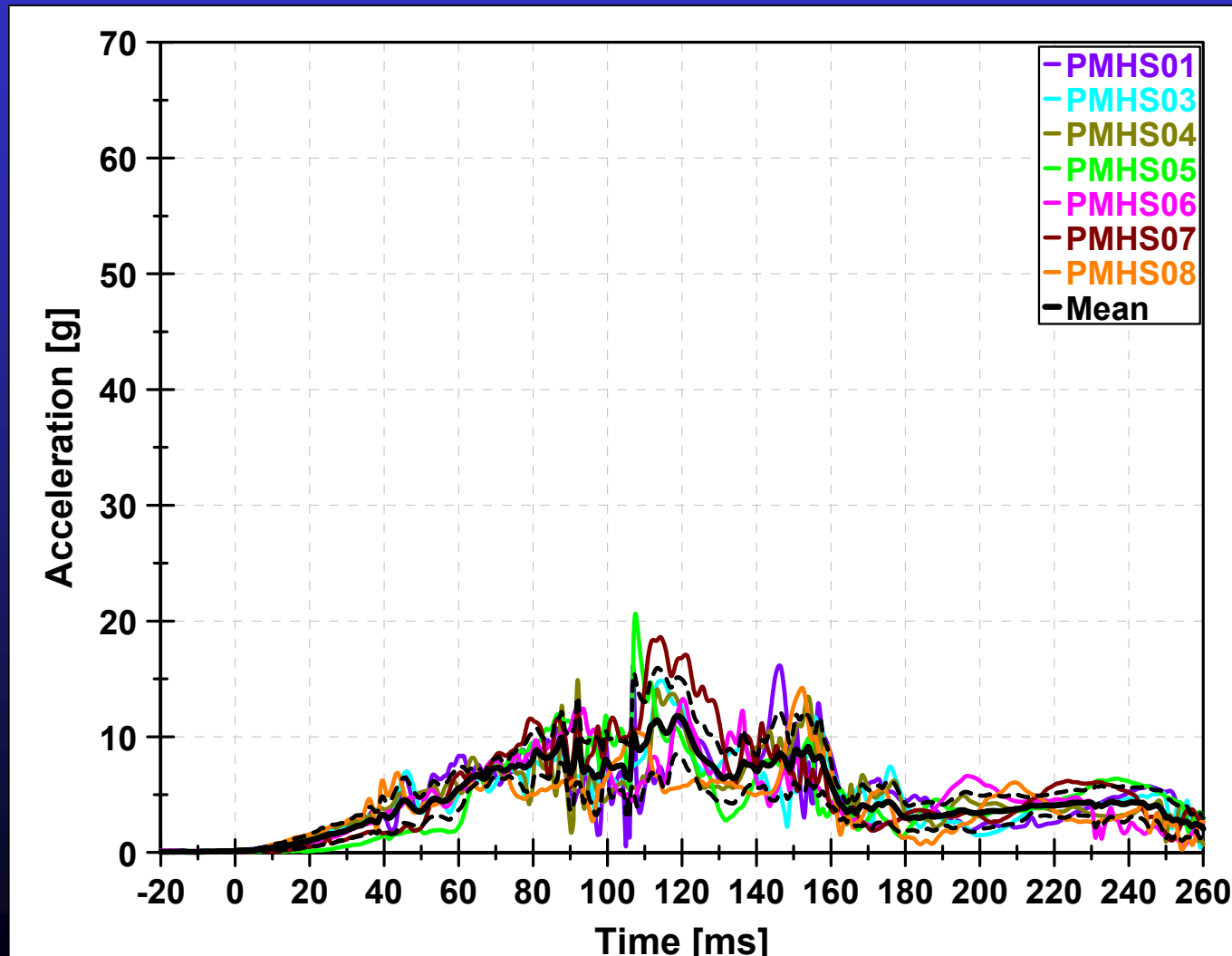


%CV (Peak)	%CV (Avg)
3.7	2.6
3.0	6.5
1.2	1.0



Internal Biofidelity

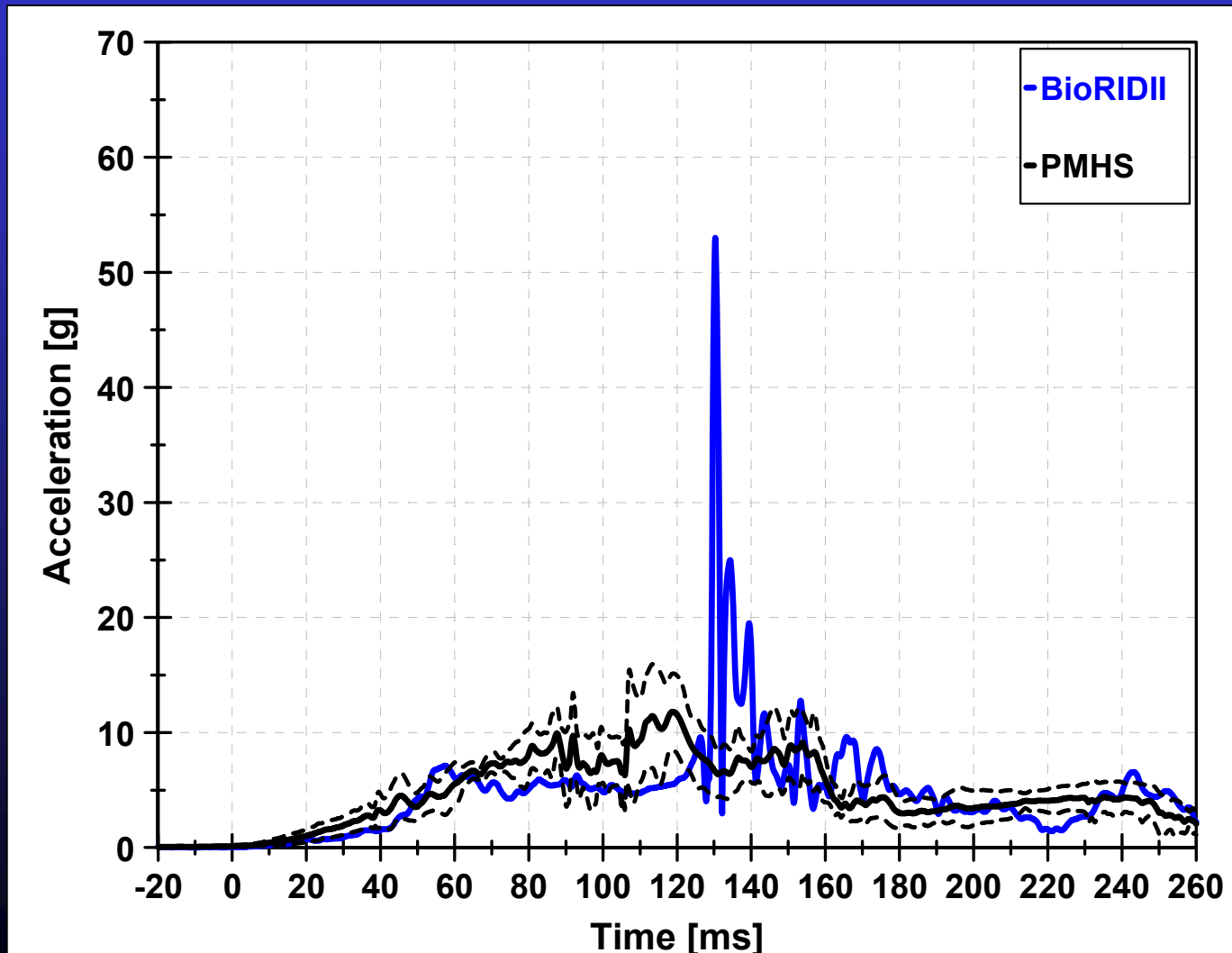
Moderate Speed – T8 Acceleration (Resultant)





Internal Biofidelity

Moderate Speed – T8 Acceleration (Resultant)

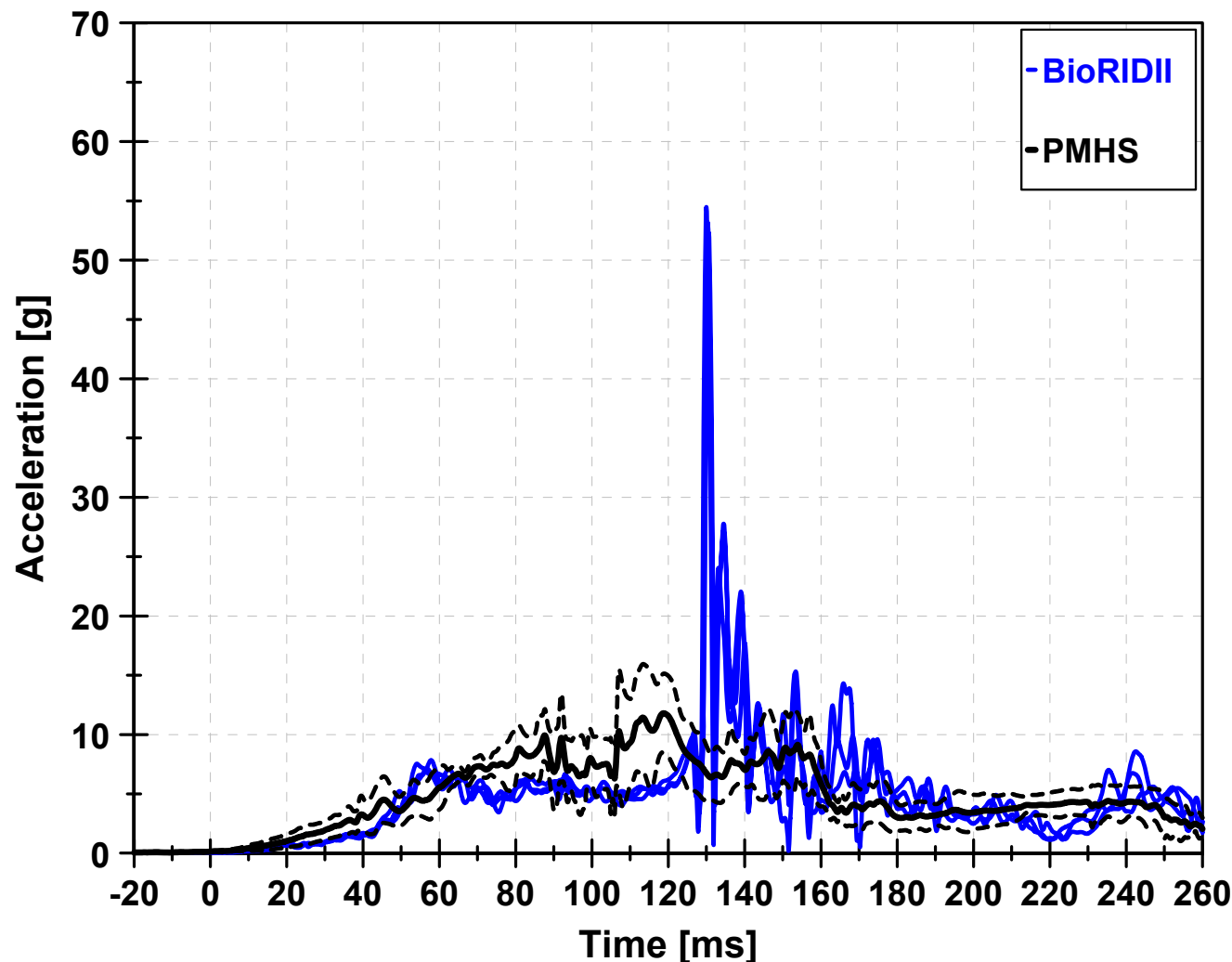


\sqrt{R}
N/A
N/A
2.47



Internal Biofidelity

Moderate Speed – T8 Acceleration (Resultant)

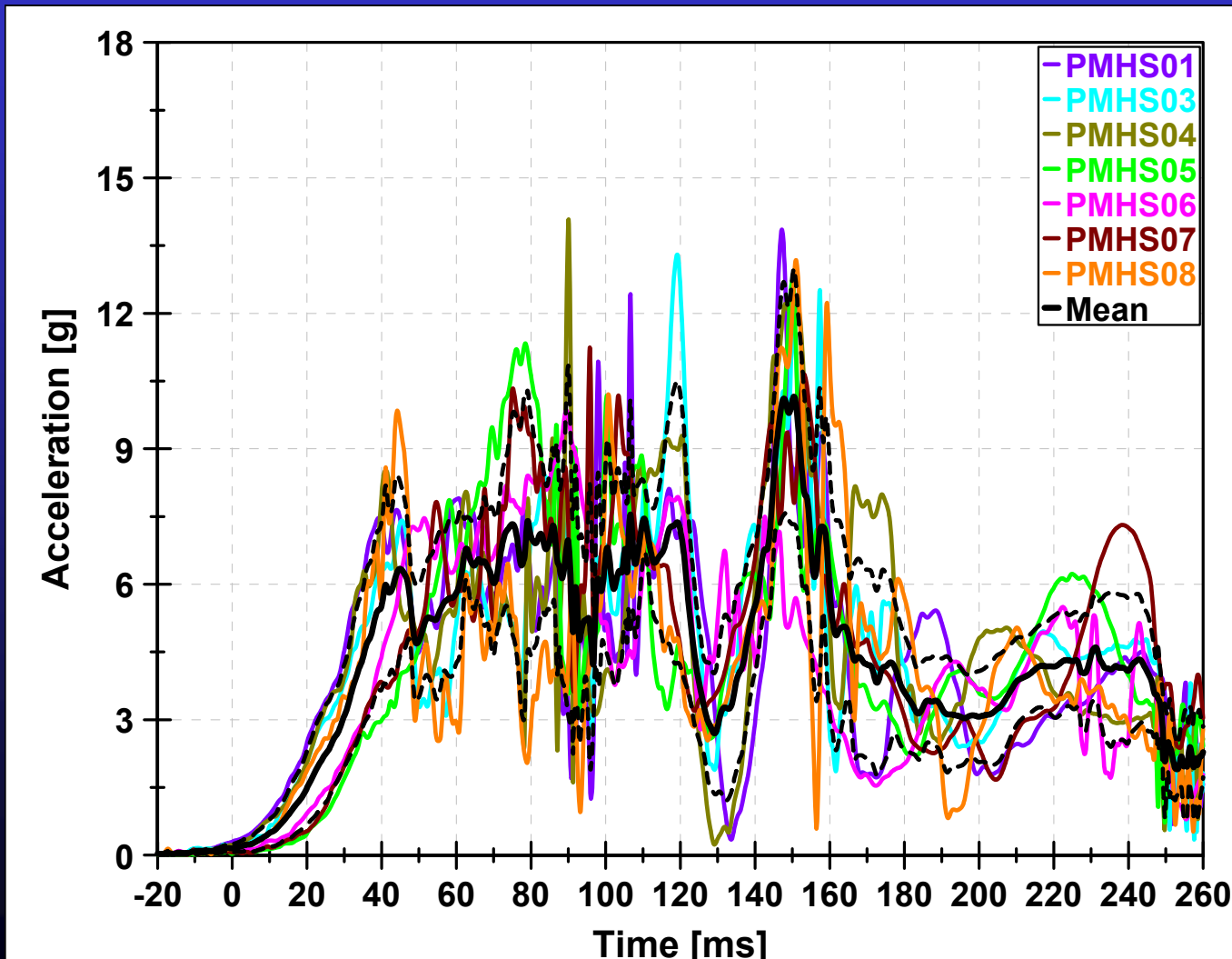


%CV (Peak)	%CV (Avg)
N/A	N/A
N/A	N/A
2.1	5.8



Internal Biofidelity

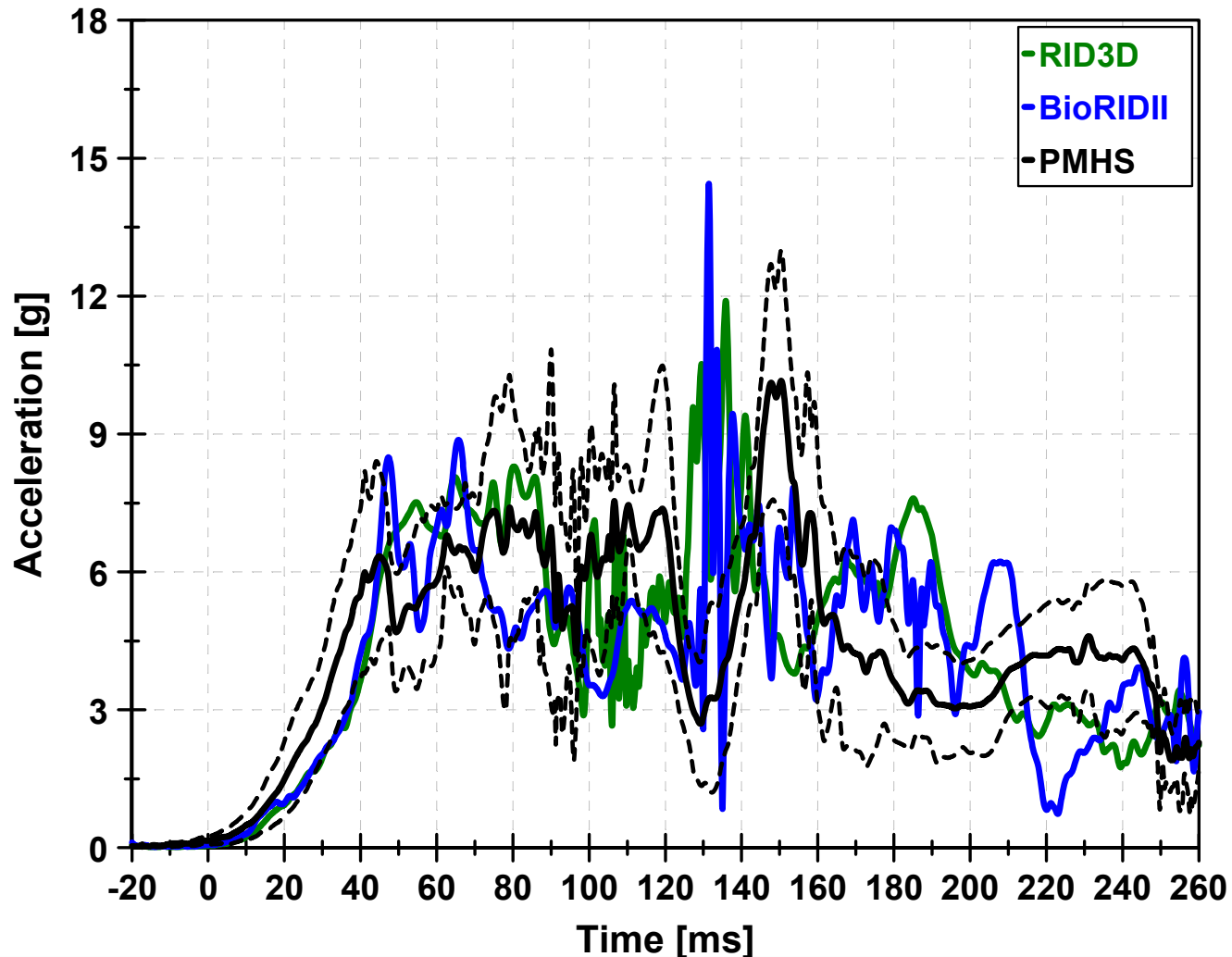
Moderate Speed – T12/L1 Acceleration (Resultant)





Internal Biofidelity

Moderate Speed – T12/L1 Acceleration (Resultant)

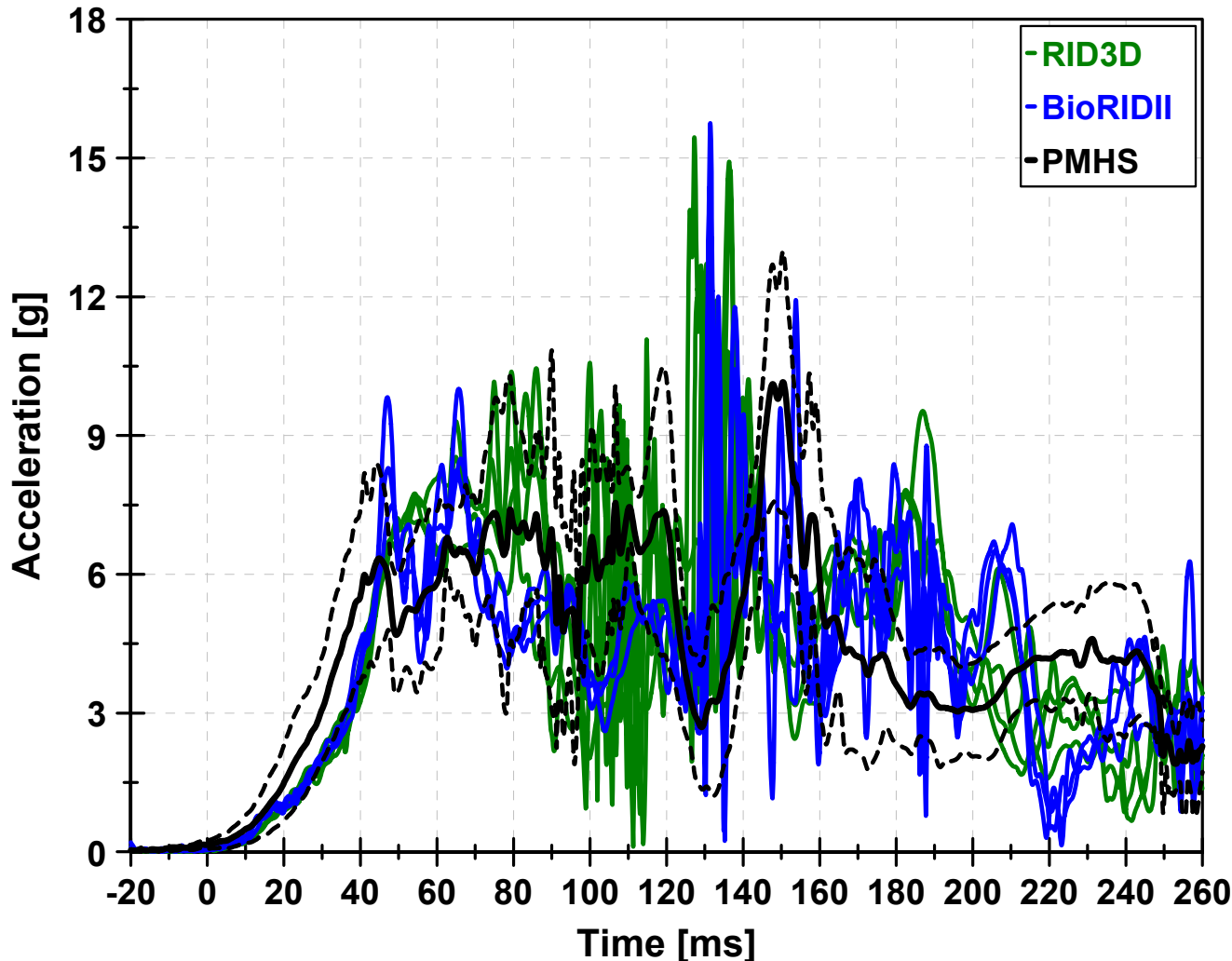


\sqrt{R}
N/A
1.34
1.26



Internal Biofidelity

Moderate Speed – T12/L1 Acceleration (Resultant)

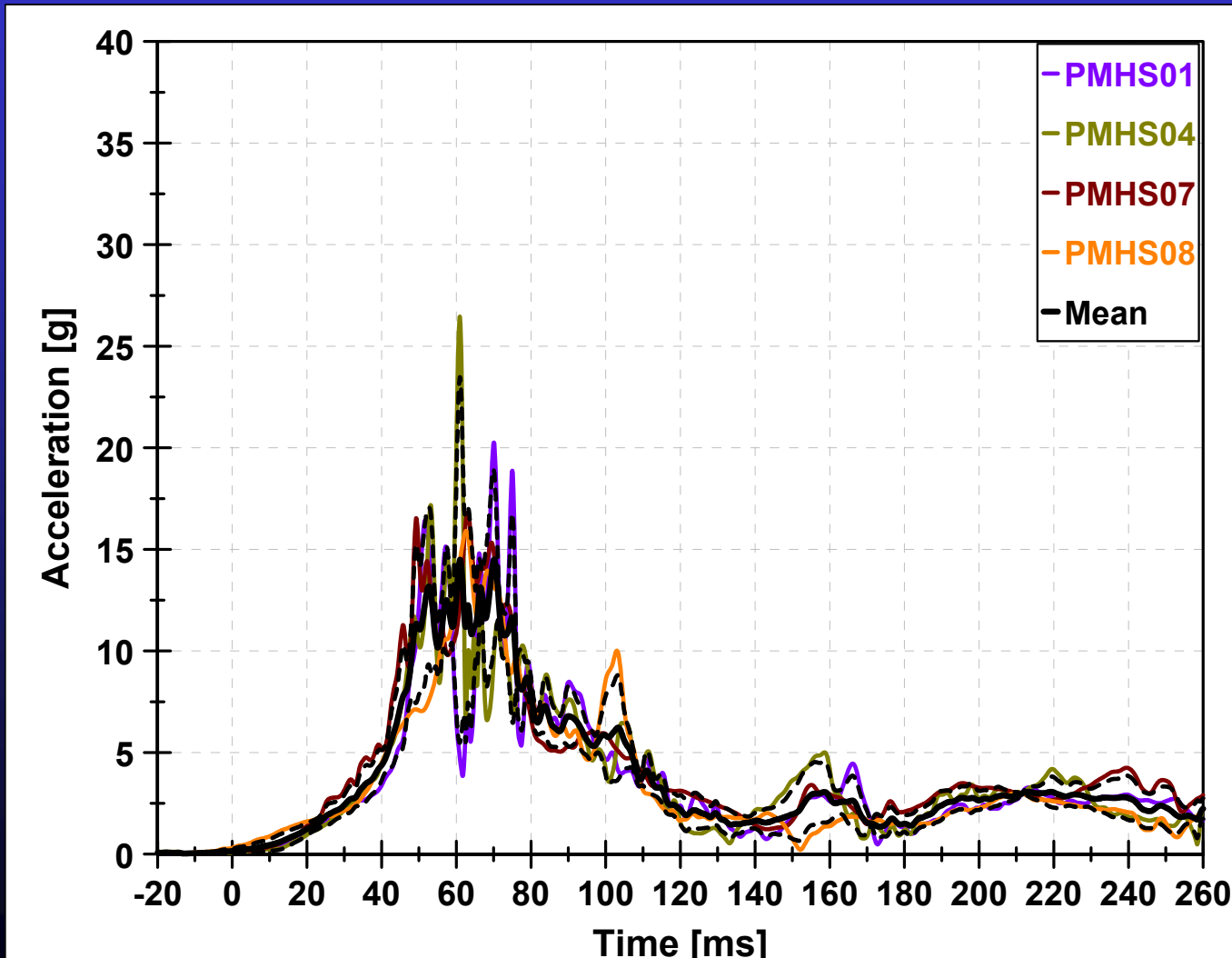


%CV (Peak)	%CV (Avg)
N/A	N/A
14.1	10.8
8.5	11.9



Internal Biofidelity

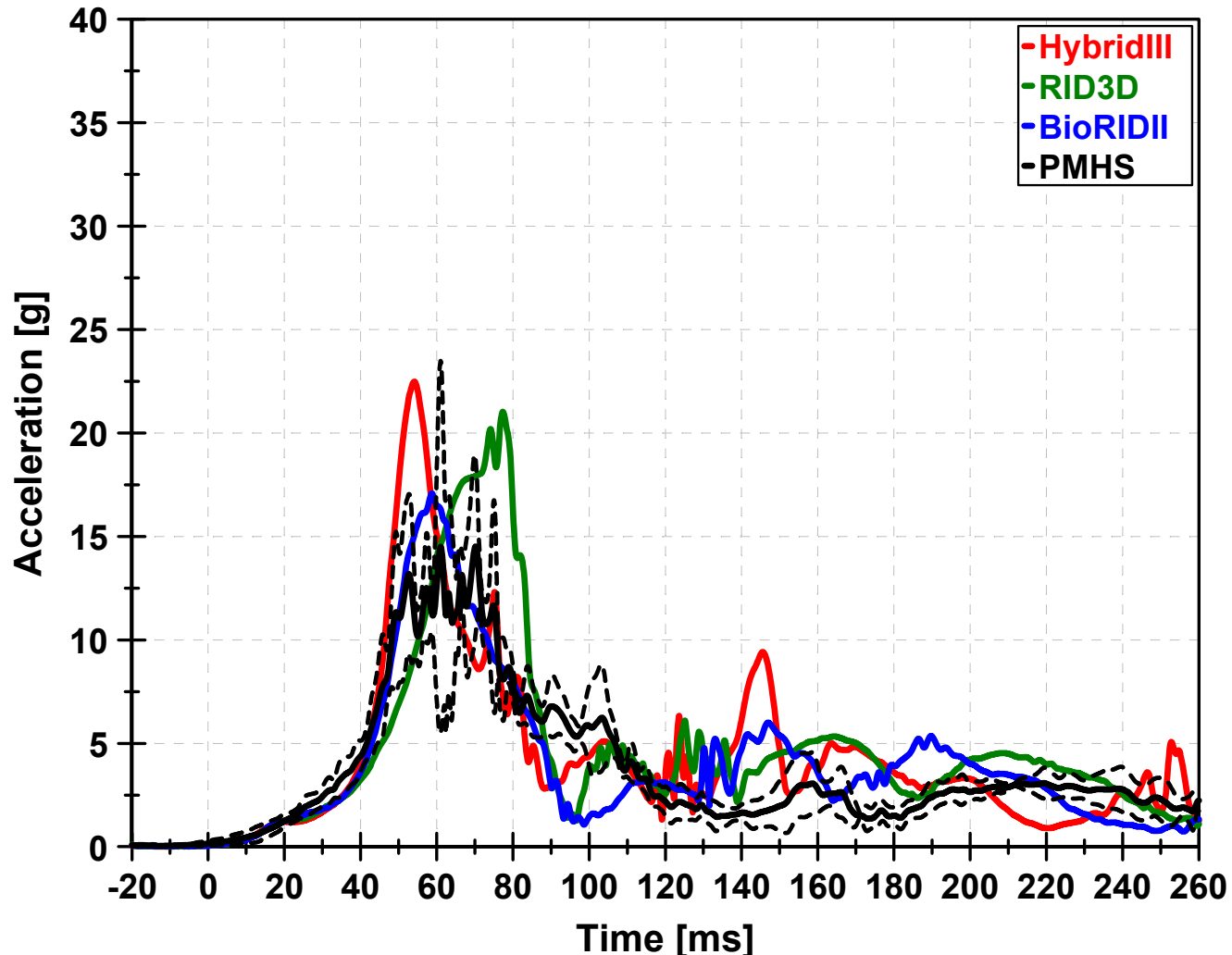
Moderate Speed – Pelvis Acceleration (Resultant)





Internal Biofidelity

Moderate Speed – Pelvis Acceleration (Resultant)



$$\sqrt{R}$$

1.77

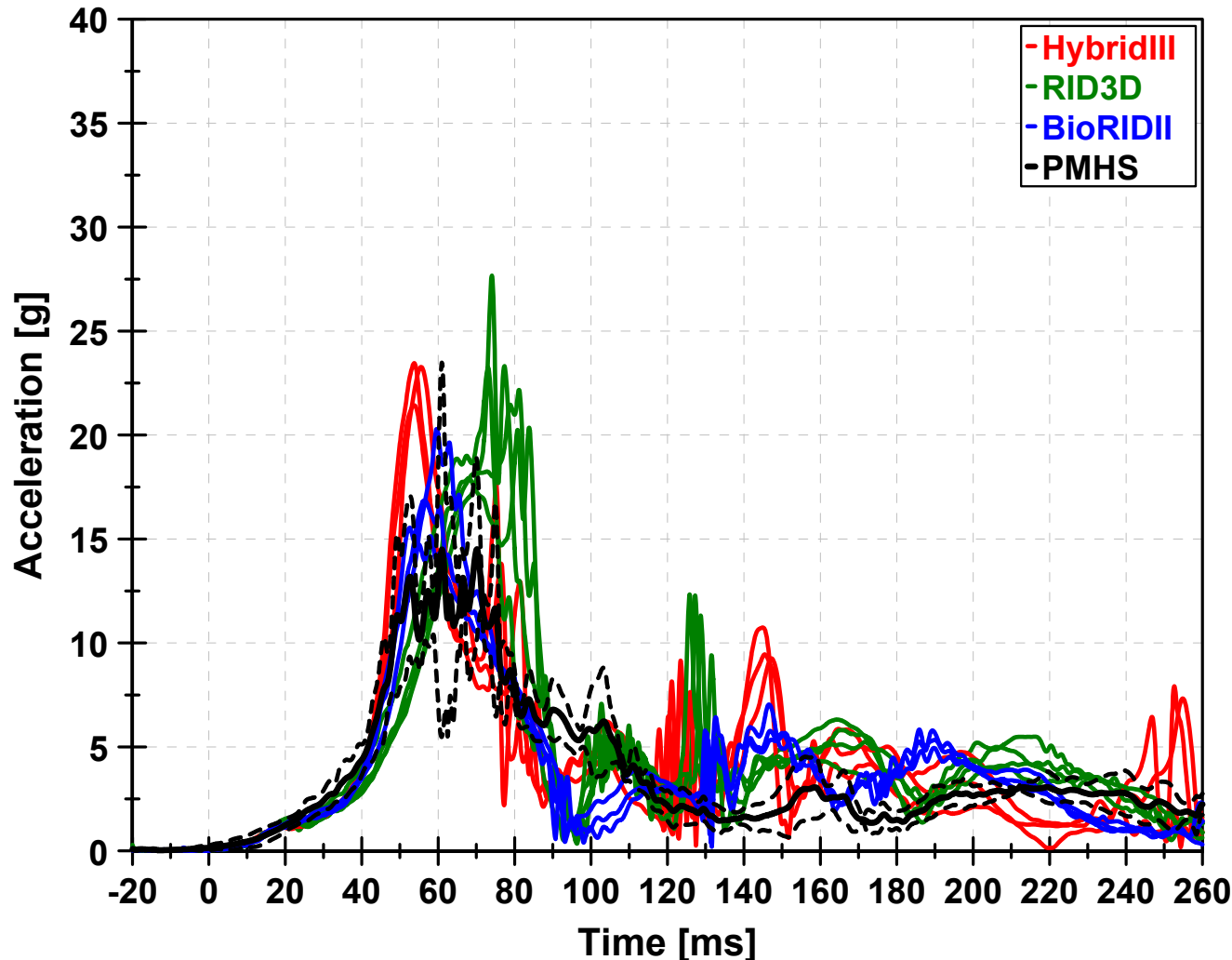
1.89

1.26



Internal Biofidelity

Moderate Speed – Pelvis Acceleration (Resultant)

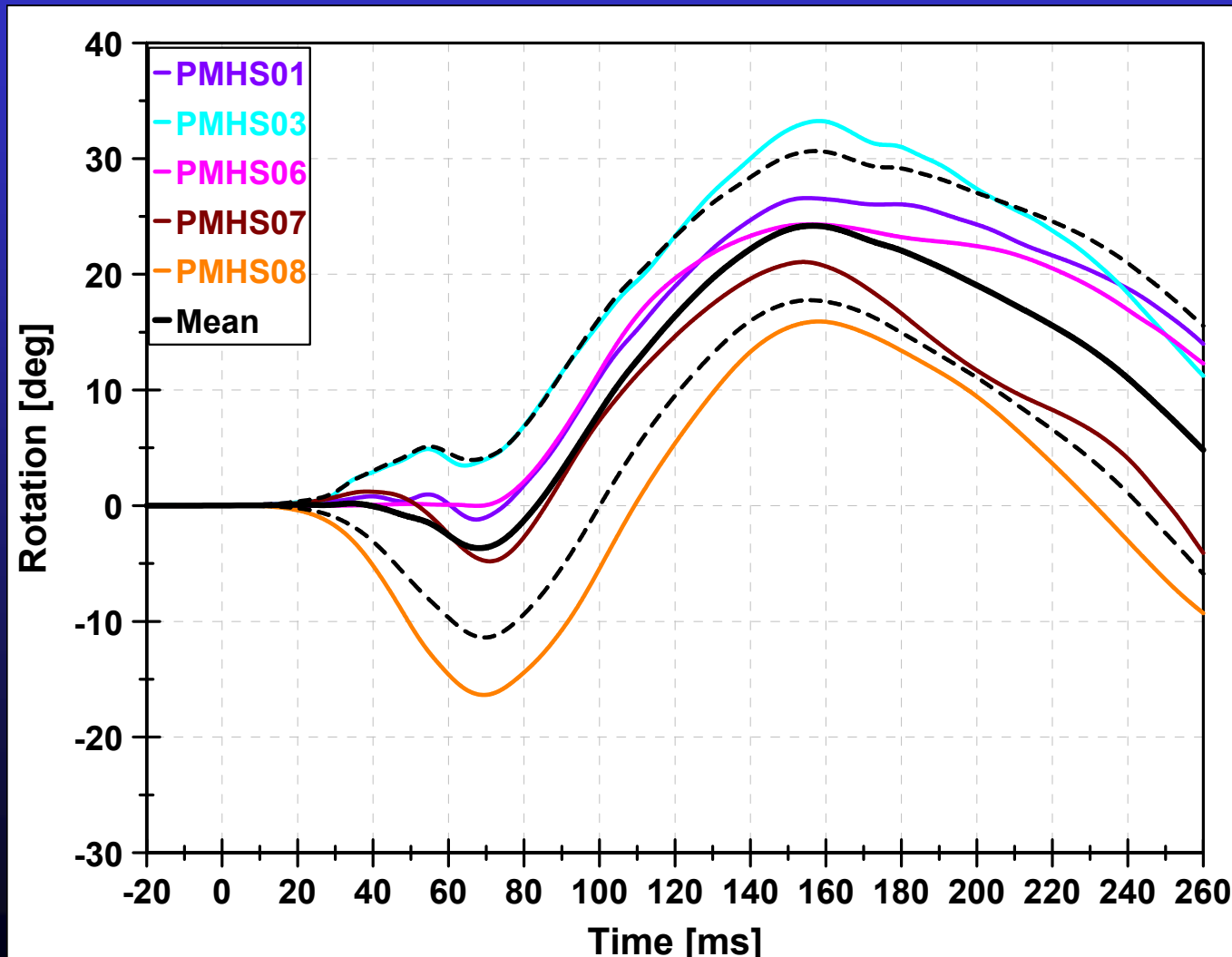


%CV (Peak)	%CV (Avg)
4.9	9.8
13.3	11.8
14.0	8.6



Internal Biofidelity

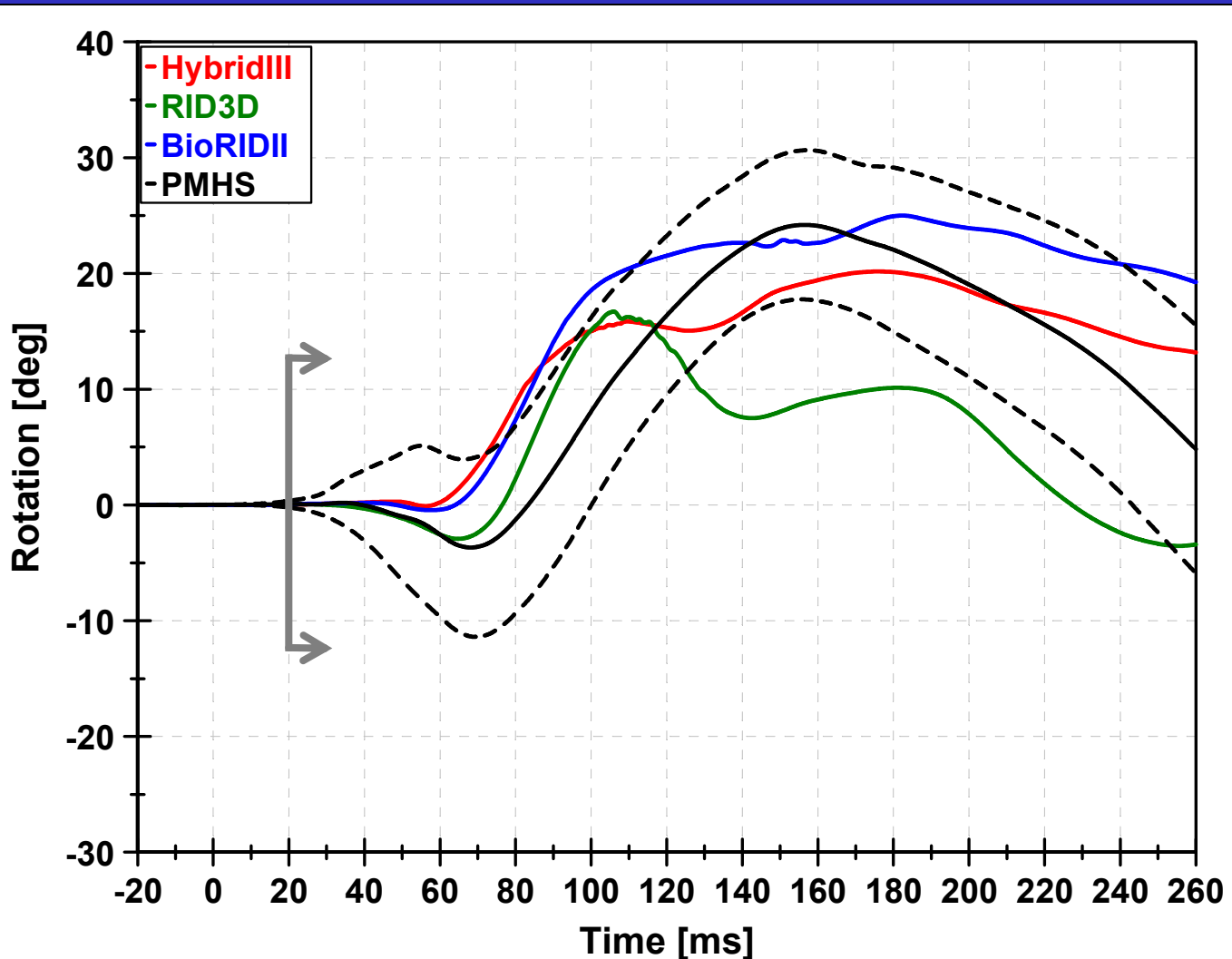
Moderate Speed – Pelvis Rotation





Internal Biofidelity

Moderate Speed – Pelvis Rotation

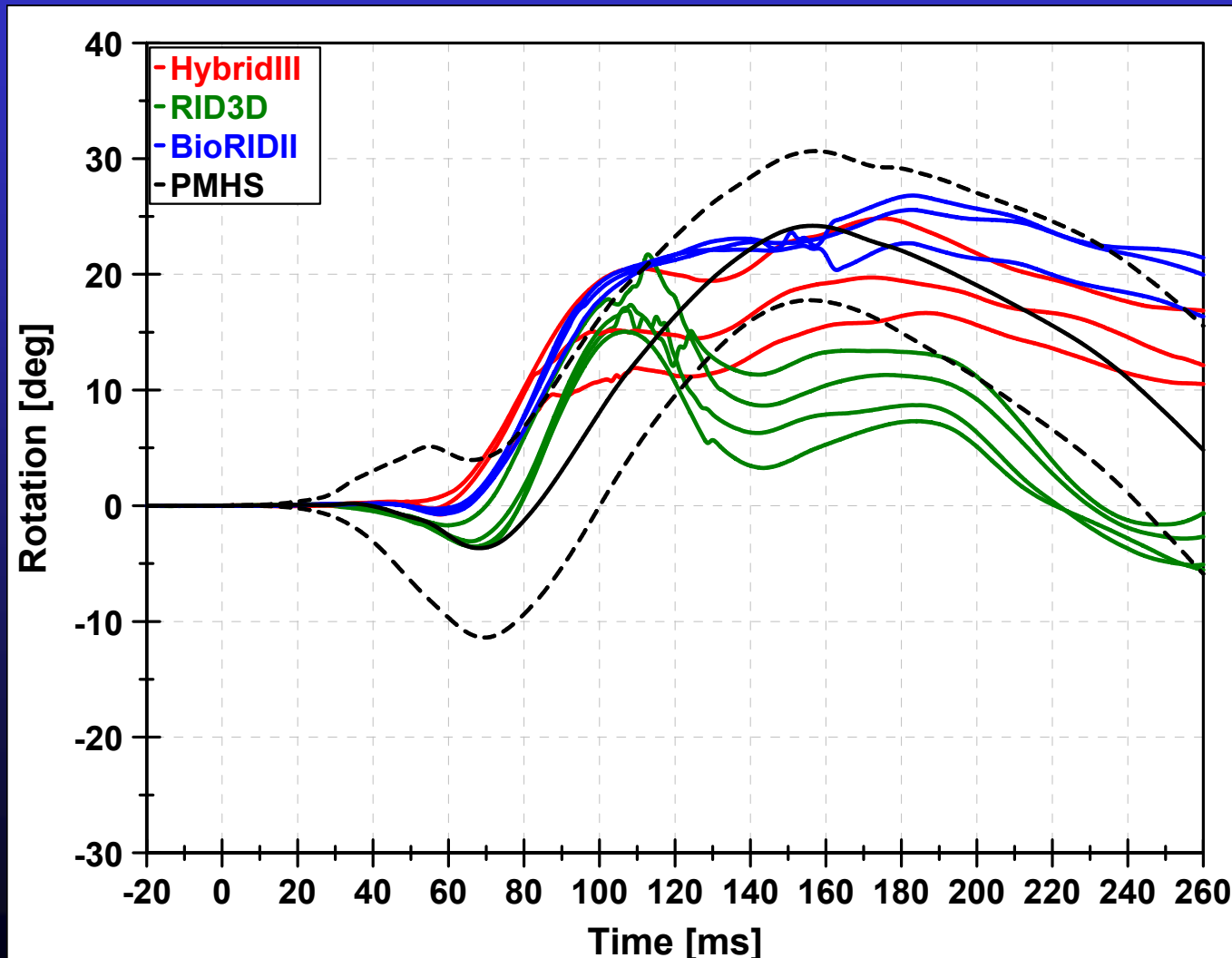


\sqrt{R}
0.62
1.33
0.85



Internal Biofidelity

Moderate Speed – Pelvis Rotation

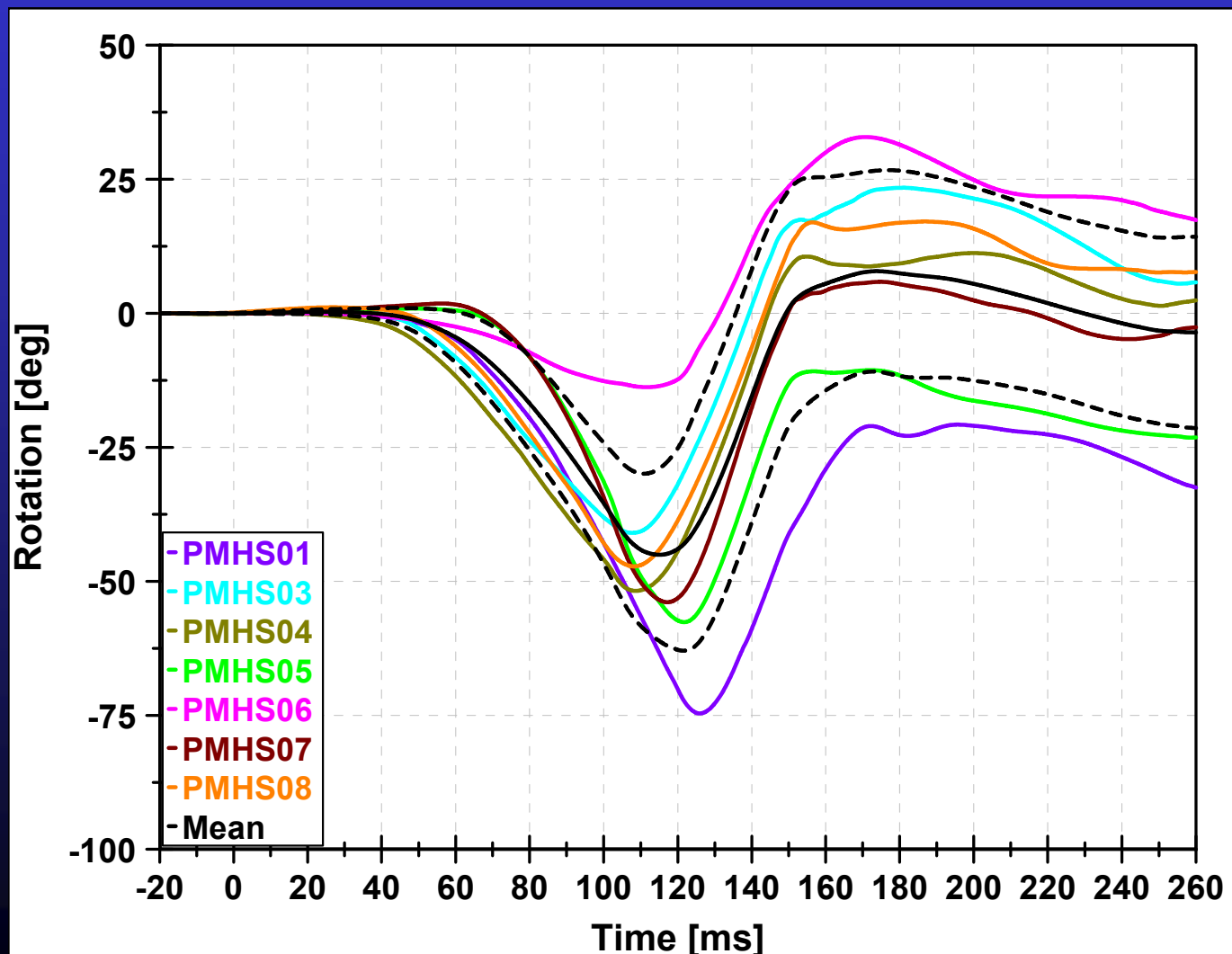


%CV (Peak)	%CV (Avg)
20.3	23.5
16.0	19.7
8.5	8.6



Internal Biofidelity

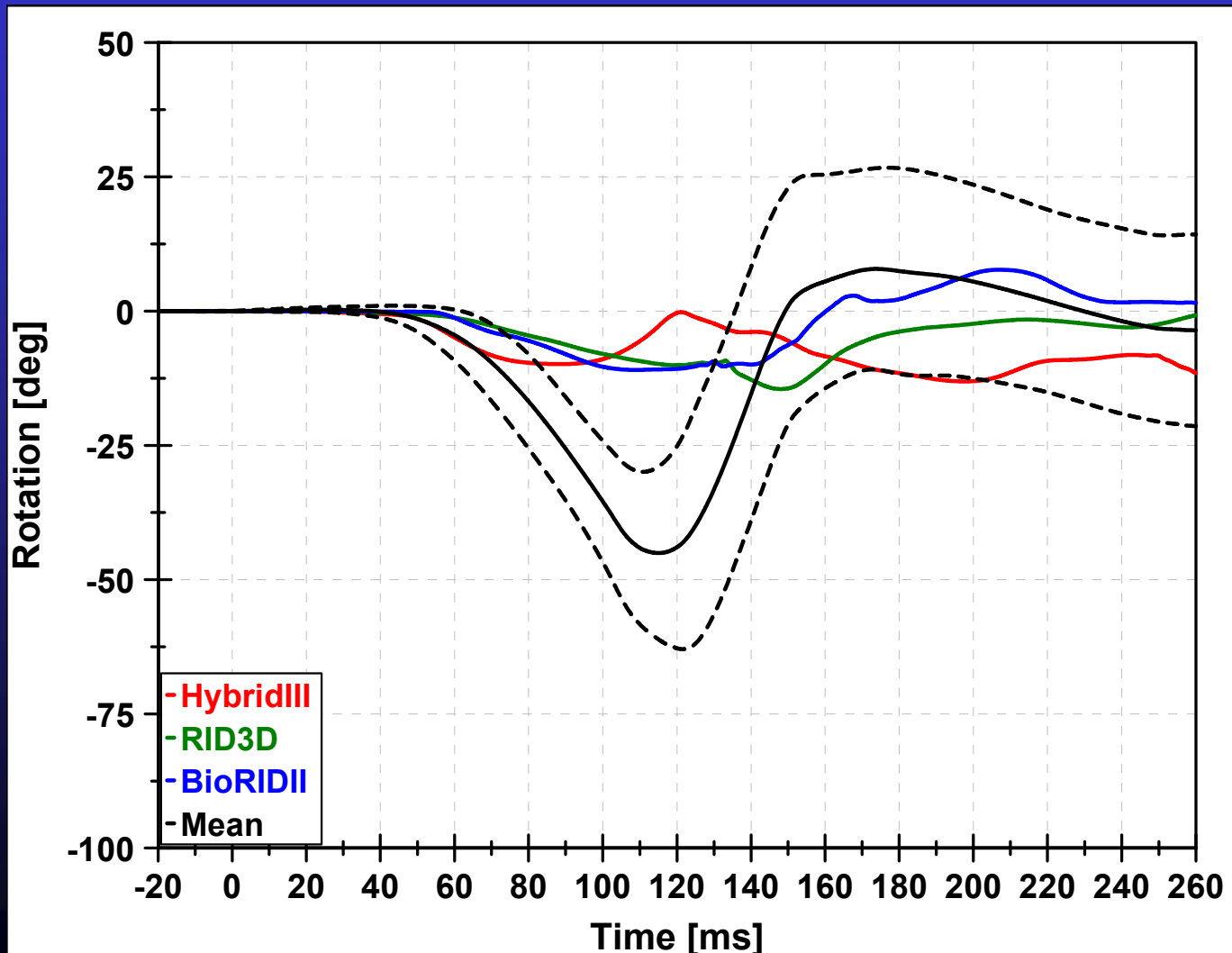
Moderate Speed – Head to T1 Rotation





Internal Biofidelity

Moderate Speed – Head to T1 Rotation



\sqrt{R}
1.29
1.12
0.99



Internal Biofidelity

Moderate Speed – HIC

HIC (Moderate Speed)

	HybridIII	RID3D	BioRIDII
PMHS 62.3 ± 18.0	239.2	470.3	193.9
	385.1	467.4	183.7
	370.8	613.3	139.3
		346.5	
Mean	331.7	475.7	172.3

HIC (Moderate Speed)

	HybridIII	RID3D	BioRIDII
\sqrt{R}	3.84	4.75	2.46
Peak C.V.	24.3	16.1	3.8



Internal Biofidelity

Moderate Speed Results

Internal Biofidelity (Moderate Speed)

	HybridIII	RID3D	BioRIDII
	\sqrt{R}		
Head Acc Res	3.06	2.90	2.33
Head Rotation	2.67	1.91	1.55
T1 Acc Res	1.03	1.60	2.71
T1 Rotation	1.18	1.03	1.15
T8 Acc Res	N/A	N/A	2.47
T12 Acc Res	N/A	1.34	1.26
Pelvis Acc Res	1.77	1.89	1.26
Pelvis Rotation	0.62	1.33	0.85
Head to T1	1.29	1.12	0.99
HIC	3.84	4.76	2.46
Mean	1.93	1.92	1.70



Final Biofidelity Results

<u>Final Biofidelity Results</u>			
	HybridIII	RID3D	BioRIDII
	\sqrt{R}		
External (Low)	1.61	1.48	0.92
Internal (Low)	2.14	1.81	1.73
Total (Low)	1.88	1.65	1.32
External (Moderate)	1.69	1.17	1.06
Internal (Moderate)	1.93	1.92	1.70
Total (Moderate)	1.81	1.55	1.38



Repeatability Results

Repeatability (Peak CV)

	HybridIII	RID3D	BioRIDII
	% C.V. (Peak)		
Low Speed	8.4	13.3	6.9
Moderate Speed	13.3	13.5	7.3

Repeatability (Avg CV)

	HybridIII	RID3D	BioRIDII
	% C.V. (Avg)		
Low Speed	11.0	10.4	6.8
Moderate Speed	12.2	9.7	7.5



Conclusions

- **Biofidelity**
 - Low Speed
 - External Biofidelity → BioRID II
 - Internal Biofidelity → BioRID II, RID3D
 - Total Biofidelity → BioRID II
 - Moderate Speed
 - External Biofidelity → BioRID II, RID3D
 - Internal Biofidelity → BioRID II
 - Total Biofidelity → BioRID II, RID3D
- **Repeatability**
 - BioRID II had best overall repeatability (all dummies acceptable)



Thank you



- **Questions?**