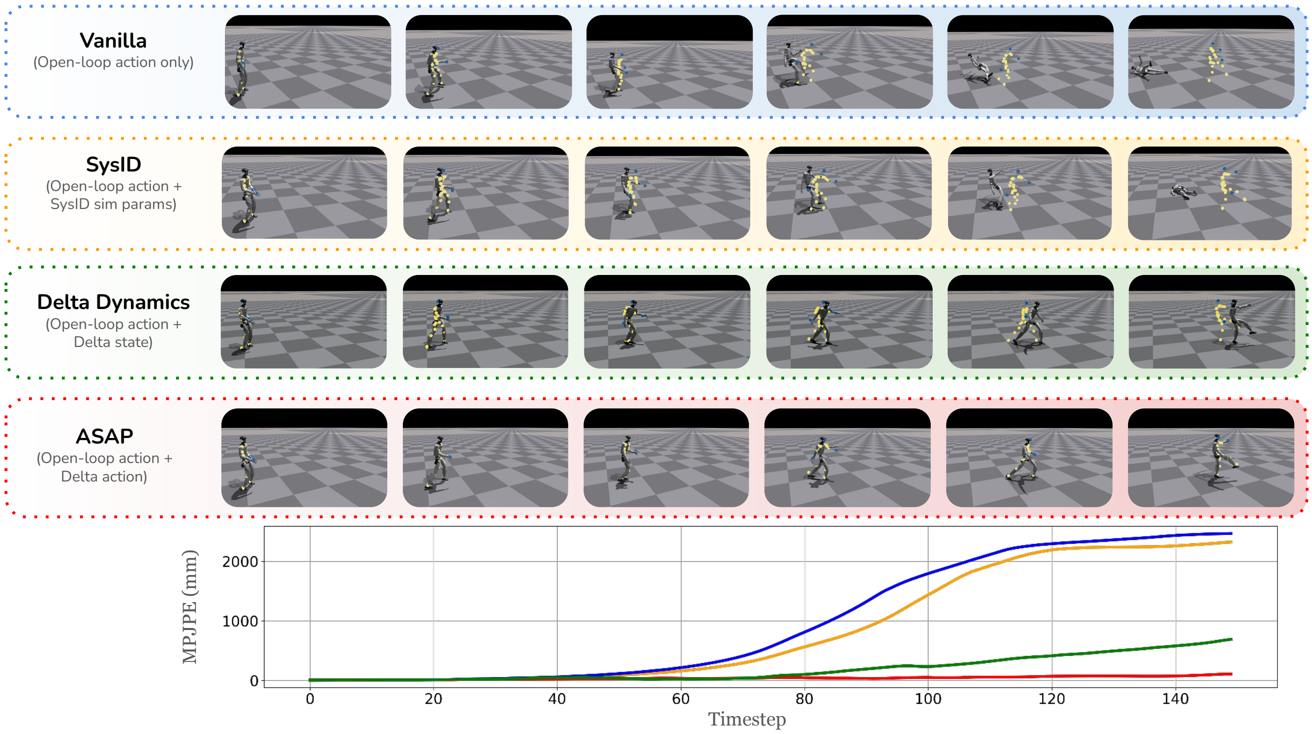

Fig. 5. Replaying IsaacSim State-Action trajecories in IsaacGym. The upper four panels visualize the Unitree G1 humanoid executing a soccer-shooting motion under four distinct open-loop actions. Corresponding metric curves (bottom) quantify tracking performance. Importantly, our delta action model (ASAP) is trained across multiple motions and is not overfitted to this specific example.

capture a broad range of motor capabilities and demonstrate the sim-to-real capability for agile whole-body control.

Baselines. We have the following baselines:

`Oracle`: This baseline is trained and evaluated entirely within IsaacGym. It assumes perfect alignment between the training and testing environments, serving as an upper bound for performance in simulation.

`Vanilla` (Figure 4 a): The RL policy is trained in IsaacGym and evaluated in IsaacSim, Genesis, or the real world.

`SysID` (Figure 4 b): We identify the following representative parameters in our simulated model that best align the ones in the real world: base center of mass (CoM) shift (c_x, c_y, c_z), base link mass offset ratio k_m and low-level PD gain ratios (k_p^i, k_d^i) where $i = 1, 2, ..., 23$. Specifically, we search the best parameters among certain discrete ranges by replaying the recorded trajectories in real with different simulation parameters summarized in Table VII. We then finetune the pretrained policy in IsaacGym with the best SysID parameters.

`DeltaDynamics` (Figure 4 c): We train a residual dynamics model $f_\theta^\Delta(s_t, a_t)$ to capture the discrepancy between simulated and real-world physics. The detailed implementation is introduced in Section VIII-C

Metrics. We report success rate, deeming imitation unsuccessful when, at any point during imitation, the average difference in body distance is on average further than 0.5m. We evaluate policy's ability to imitate the reference motion by comparing the tracking error of the global body position $E_{\text{g-mpjpe}}$ (mm), the root-relative mean per-joint (MPJPE) E_{mpjpe} (mm), acceleration error E_{acc} (mm/frame^2), and root velocity E_{vel} (mm/frame). The mean values of the metrics are computed across all motion sequences used.

TABLE III
OPEN-LOOP PERFORMANCE COMPARISON ACROSS SIMULATORS AND MOTION LENGTHS.

Simulator & Length		IsaacSim				Genesis			
Length	Method	$E_{\text{g-mpjpe}}$	E_{mpjpe}	E_{acc}	E_{vel}	$E_{\text{g-mpjpe}}$	E_{mpjpe}	E_{acc}	E_{vel}
0.25s	OpenLoop	**19.5**	15.1	**6.44**	**5.80**	19.8	15.3	6.53	5.88
	SysID	**19.4**	15.0	**6.43**	**5.74**	19.3	15.0	6.42	5.73
	DeltaDynamics	24.4	**13.6**	9.43	7.85	20.0	**12.4**	8.42	6.89
	ASAP	**19.9**	15.6	**6.48**	**5.86**	**19.0**	14.9	**6.19**	**5.59**
0.5s	OpenLoop	33.3	23.2	6.80	6.84	33.1	23.0	6.78	6.82
	SysID	32.1	22.2	6.57	6.56	32.2	22.3	6.57	6.57
	DeltaDynamics	36.5	**16.4**	8.89	7.98	27.8	**14.0**	7.63	6.74
	ASAP	**26.8**	19.2	**5.09**	**5.36**	**25.9**	18.4	**4.93**	**5.19**
1.0s	OpenLoop	80.8	43.5	10.6	11.1	82.5	44.5	10.8	11.4
	SysID	77.6	41.5	10.2	10.7	76.5	41.6	10.0	10.5
	DeltaDynamics	68.1	**21.5**	9.61	9.14	50.2	**17.2**	8.19	7.62
	ASAP	**37.9**	22.9	**4.38**	**5.26**	**36.9**	22.6	**4.23**	**5.10**

A. Comparison of Dynamics Matching Capability

To address **Q1** (*Can ASAP outperform other baseline methods to compensate for the dynamics mismatch?*), we establish sim-to-sim transfer benchmarks to assess the effectiveness of different methods in bridging the dynamics gap. IsaacGym serves as the *training environment*, while IsaacSim and Genesis function as *testing environments*. The primary objective is to evaluate the generalization capability of each approach when exposed to new dynamics conditions. *Open-loop* evaluation measures how accurately a method can reproduce testing-