In vivo characterization of **neural and contractile properties** with resulting musculoskeletal function

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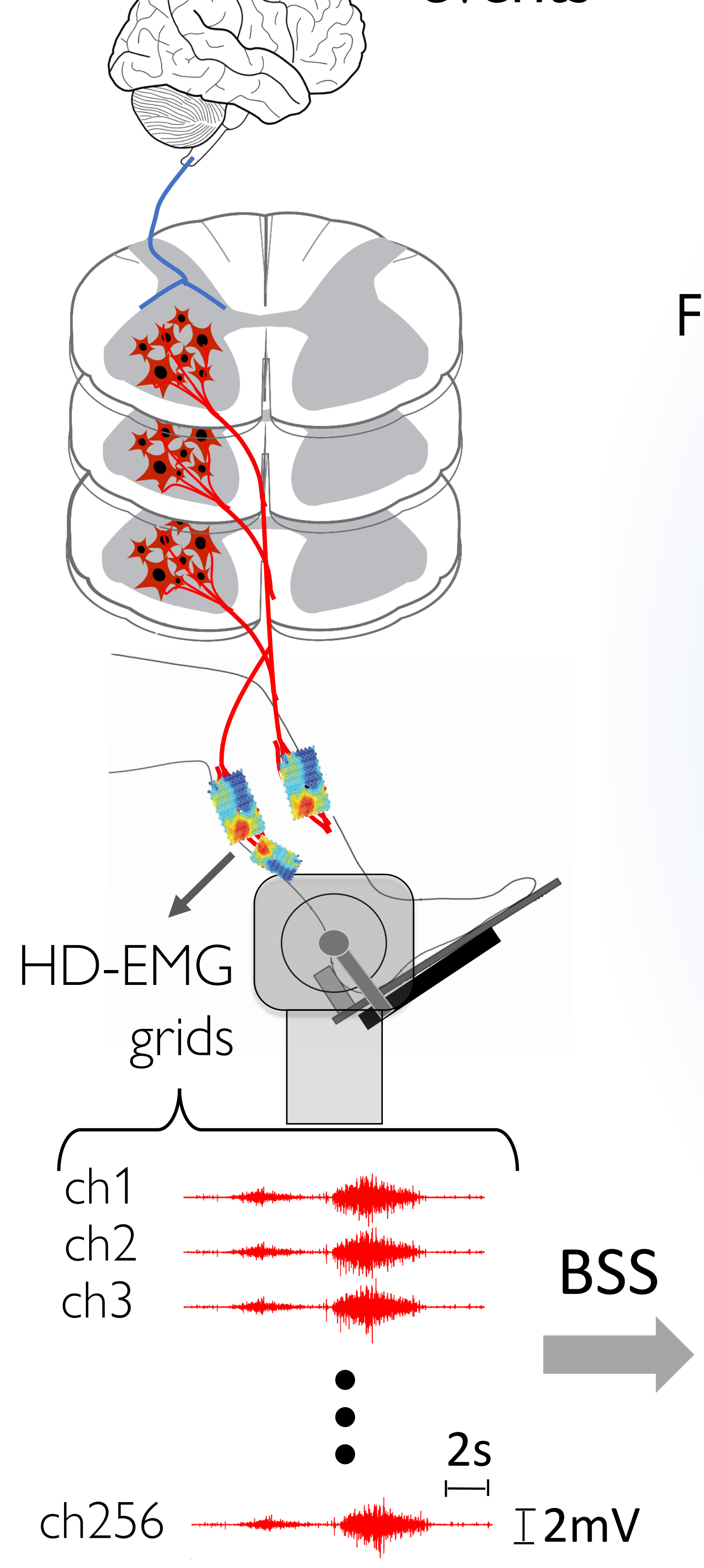
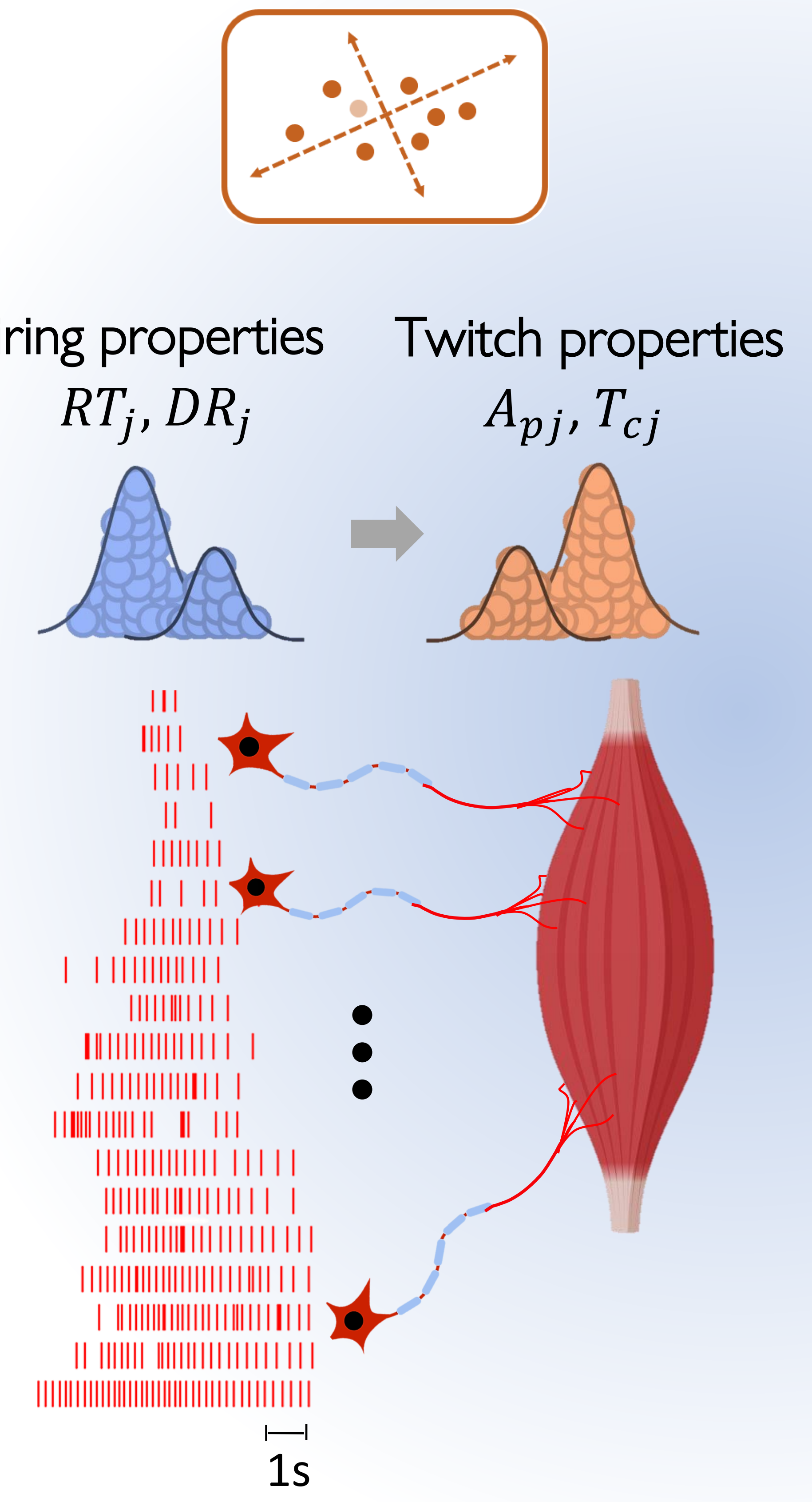
1. Decoding MU firing events

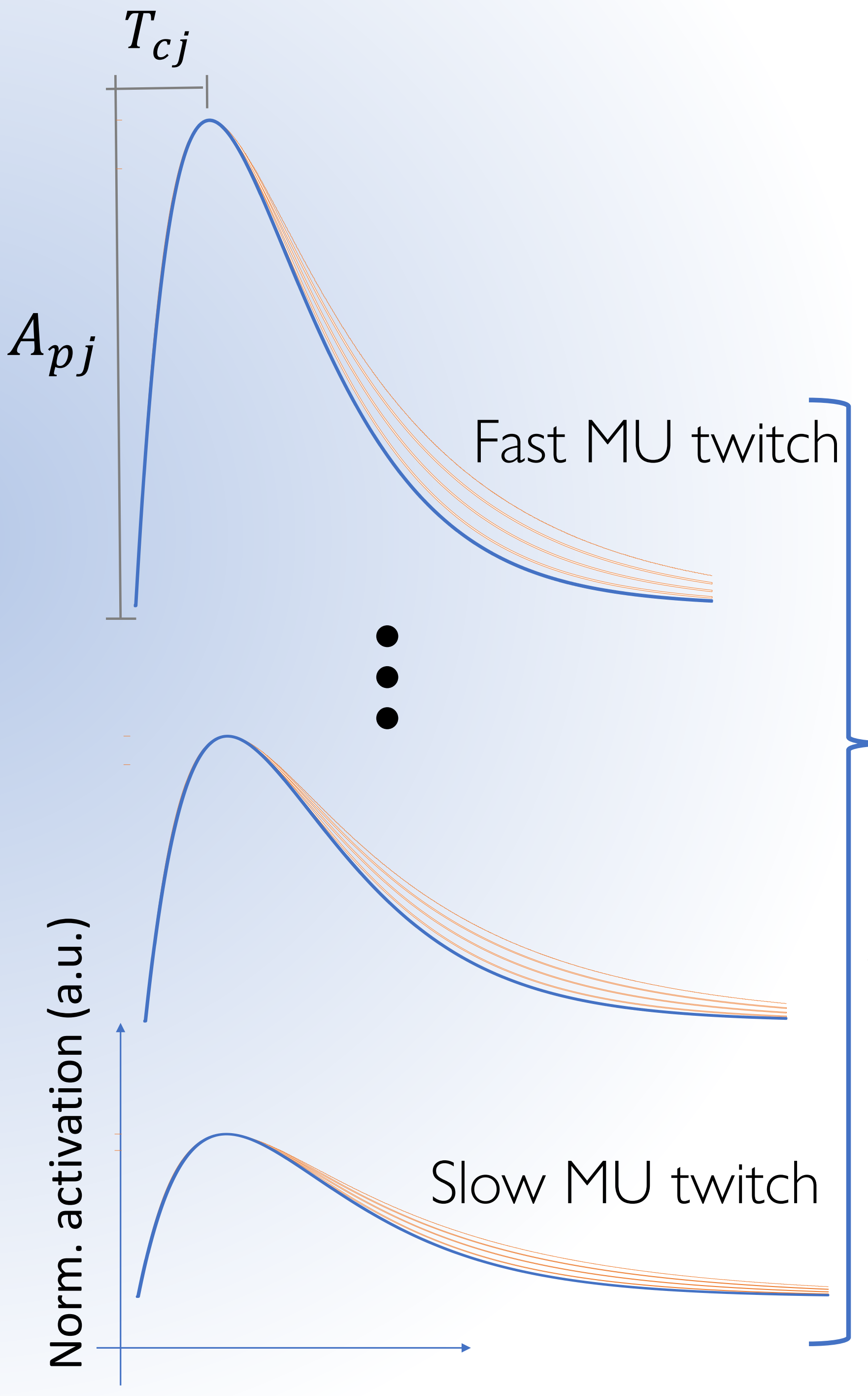


2. Neuromechanical translation

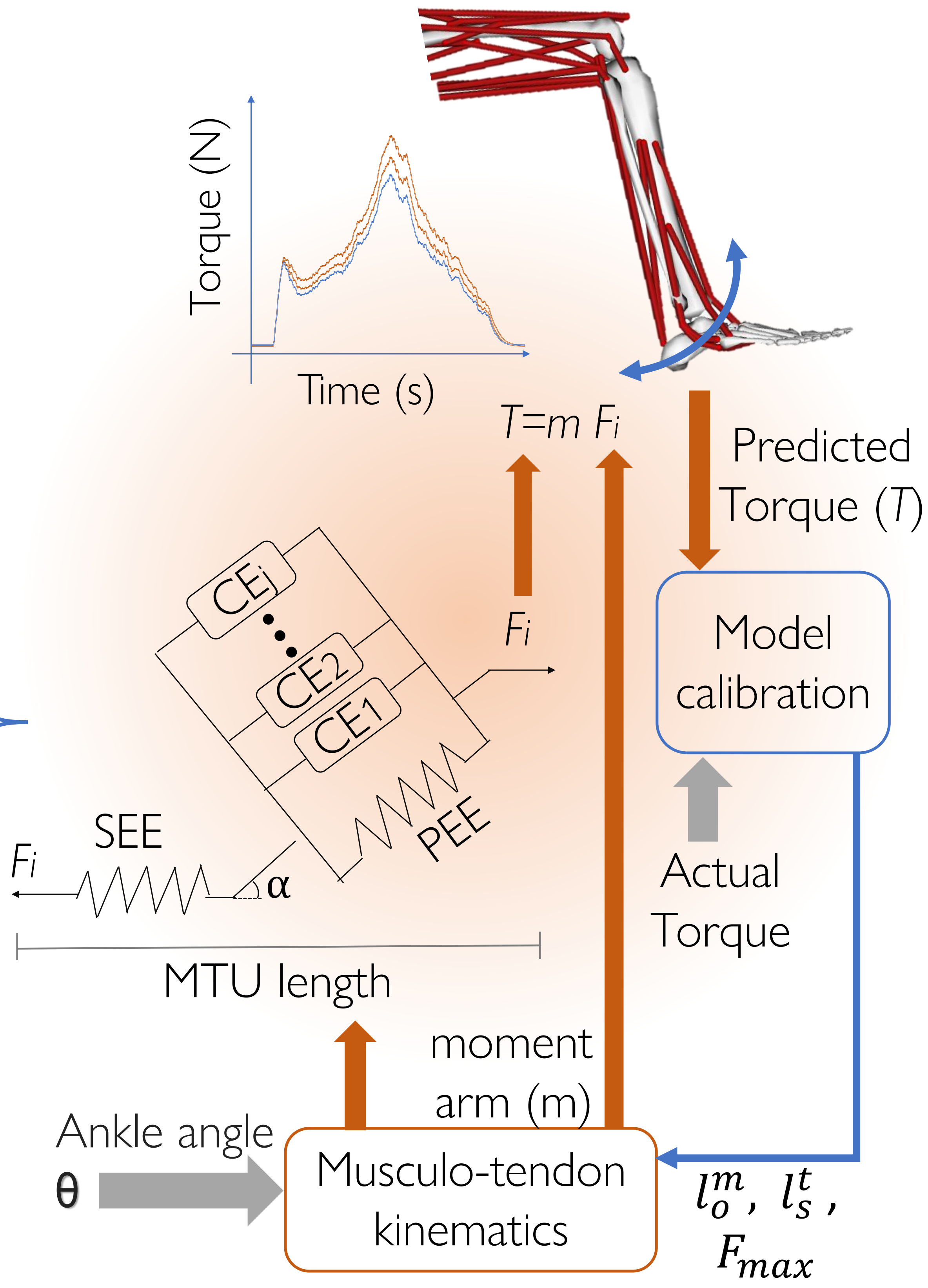


3. MU-specific activation dynamics

$$a_j(t) = A_{pj}\frac{t}{T_{cj}}\exp\left(1-\frac{t}{T_{cj}}\right)u_j(t)$$



4. Subject-specific musculoskeletal modelling



Glossary: MU - motor unit, j - suffix for MU number, RT_j - recruitment threshold, DR_j - discharge rate, A_{pj}- twitch amplitude, T_{cj} - contraction time, a_j - activation, MTU musculotendon unit, CE contractile element; SEE and PEE serial and parallel elastic elements, l_o^m- optimal fiber length, l_s^t - tendon slack length, F_{max}- max. isometric force

INTRO

- Restoring healthy movement is challenging due to our little understanding of the neuro-mechanical interplay.
- EMG-driven musculoskeletal models help understand underlying mechanisms of human movement. However, global EMGs hide the contribution of neural micro-structures to force production.
- We propose a methodology to interface with motor units (MUs) from high-density EMG, characterize their neural and contractile properties, and employ them to decode force in intact humans *in vivo*.

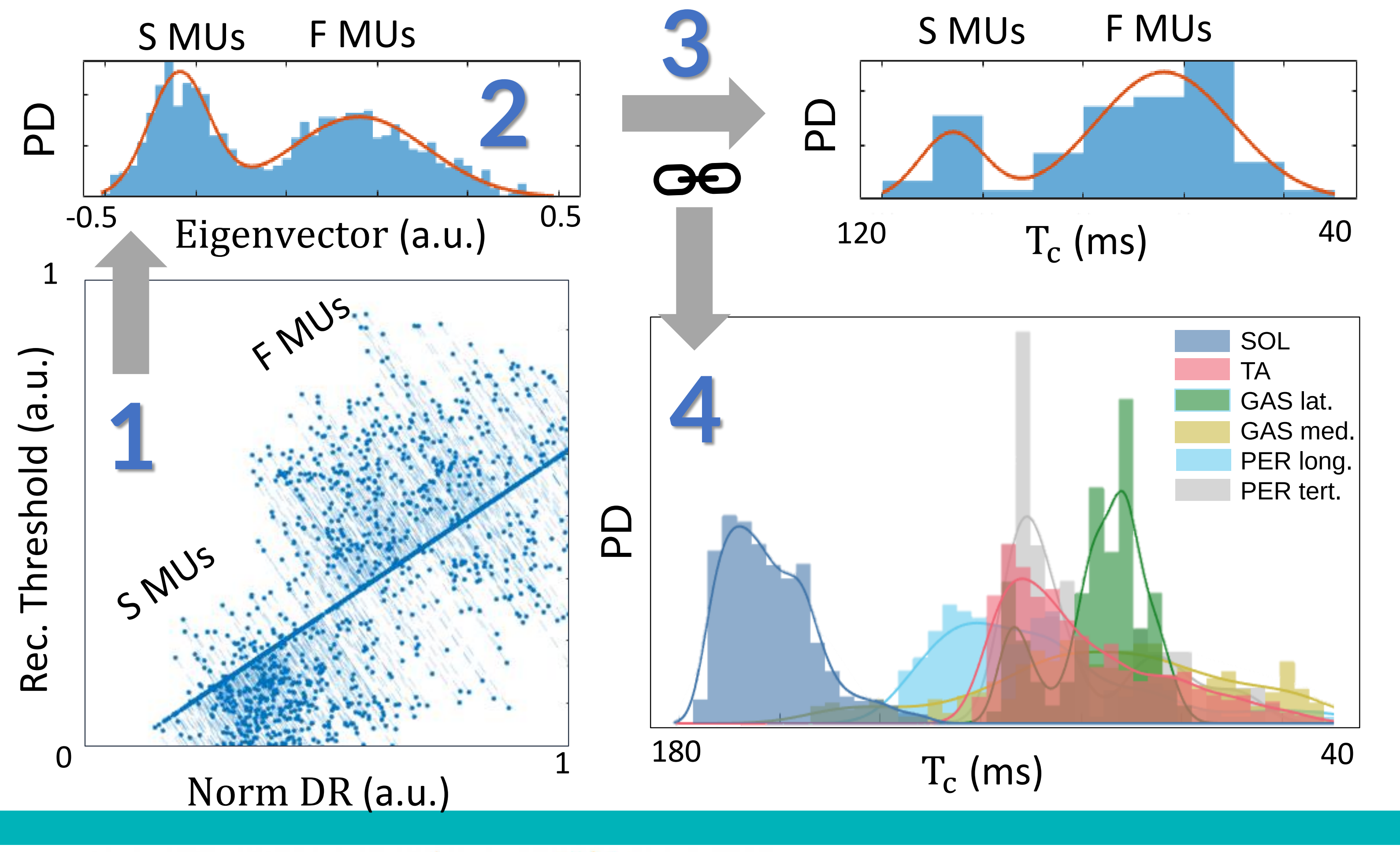
METHODS

1. Data collection: HD-EMGs from 5 lower leg muscles and torque recordings during isometric dorsi-plantar flexion contractions.
2. **Characterization of twitch properties** from MU statistical distributions.
3. **MU-specific muscle activation** using the found twitch properties.
4. **Ankle torque prediction** using musculoskeletal modelling driven by the MU-specific activation dynamics.

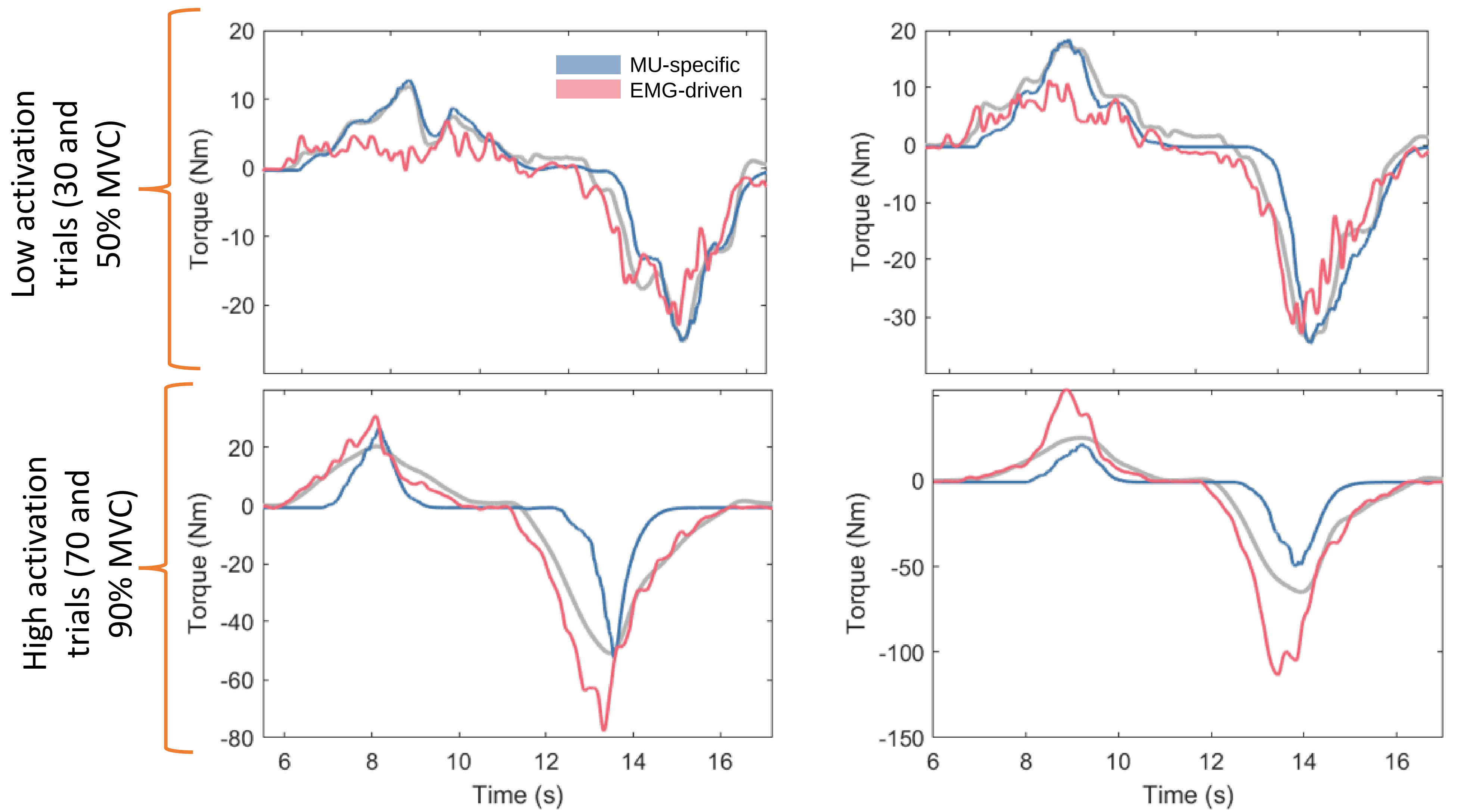
RESULTS & DISCUSSION

- We translated MU firing properties into physiologically-realistic twitch characteristics.
- Our methodology showed accurate torque predictions (norm. RMSE< 0.5) and high correlation with actual torque (R^2>0.8)
- Limitations: we are unable to decompose slow MUs at the beginning of the contraction which causes gaps by the onset of the ramp.
- Future work: quantifying changes in MU distributions due to rehabilitation training

Characterization of MU twitch properties: we employed PCA to discriminate slow (S) and fast (F) MUs according to their neural distributions **(1 & 2)** and link them (linearly) with twitch contractile properties found in humans **(3). (4) shows the results the neuromechanical mapping for all muscles**



Comparison of MU-specific vs EMG-driven: Our proposed models showed superiority in low activation trials (lower errosr and variability) but big gaps in higher activation trials



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