

Aachen, October 7th, 2026
Dr. Gereon Hellenbroich, FEV

Prepared for

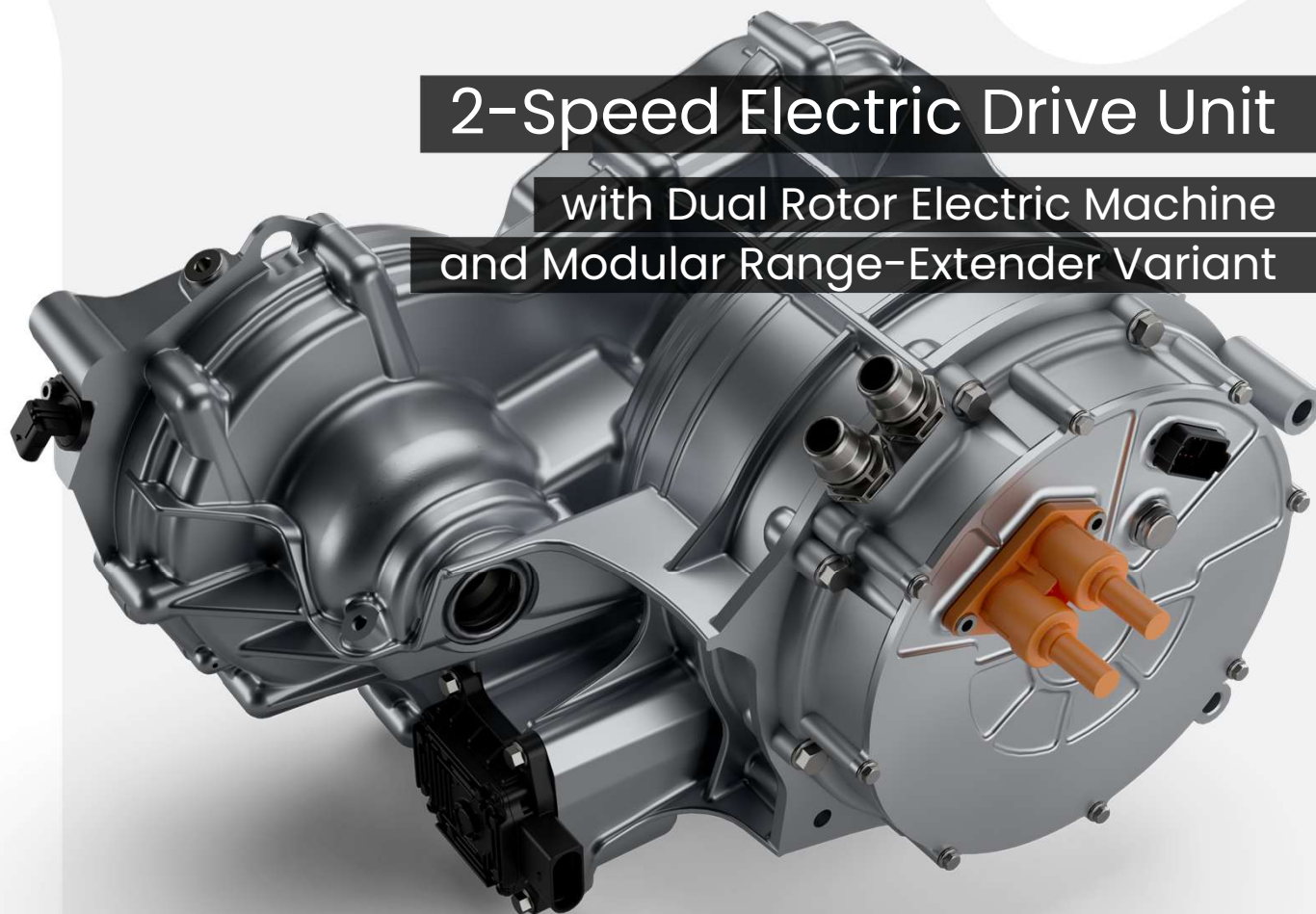
Aachen Automotive Colloquium 2026

 **AACHEN AUTOMOTIVE
COLLOQUIUM**
OCTOBER 05-07TH, 2026



Presentation

2-Speed Electric Drive Unit with Dual Rotor Electric Machine and Modular Range-Extender Variant



AGENDA

- **General specification and package**
- **DeepDrive dual-rotor, radial flux electric machine**
 - General idea and advantages
 - Torsionally stiff winding concept
- **Simulation results 1-speed vs. 2-speed**
- **Presentation of 2-speed architecture**
 - Geartrain architecture
 - Actuation concept
- **Modular range extender variant**

At just 414 mm axial length, the EDU is very compact. The weight is comparable to other single-speed EDUs, due to the low weight of EM & Inverter



DIMENSIONS AND SPECS

FEV 2-speed electric drive unit GEN2

- DeepDrive **dual rotor PMSM, 250 kW peak**
- DeepDrive **800 V SiC multi-level inverter, integrated**
- **Electro-mechanical** actuation
- Park lock function covered by shift elements, no separate park lock system needed
- System weight < 85 kg wet
- 1st speed:
 - Total gear ratio 10.160, **launch torque 4.600 Nm**
- 2nd speed:
 - Total gear ratio 6.138, **vehicle top speed: > 250 kph possible**
- Ratio spread: 1.65

368 mm



527 mm



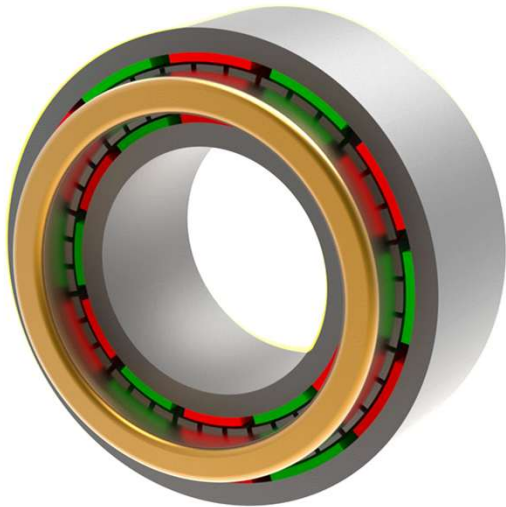
414 mm



The concept of dual-rotor, radial flux electric machines is not new, but core challenges had not been solved

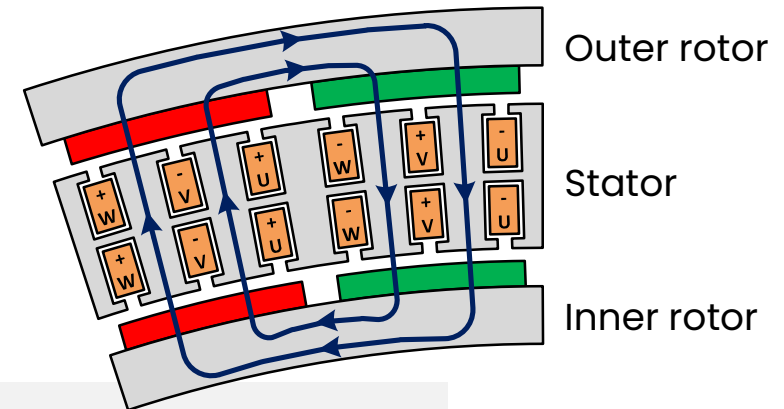
General idea of dual-rotor machines

- Replace stator back-iron (yoke) with 2nd rotor
- Double air-gap area and gain space for magnets



Advantages

- Higher torque output with given current
- No iron losses in stator yoke → excellent partial load efficiency



Key challenge of dual rotors

- Torque transfer from stator to housing
- Cooling of the winding

The “**dual-rotor problem**”, solved by DeepDrive’s winding technology

DeepDrive has solved the “dual-rotor problem” by introducing a torsionally stiff winding

Counter skewed copper bars

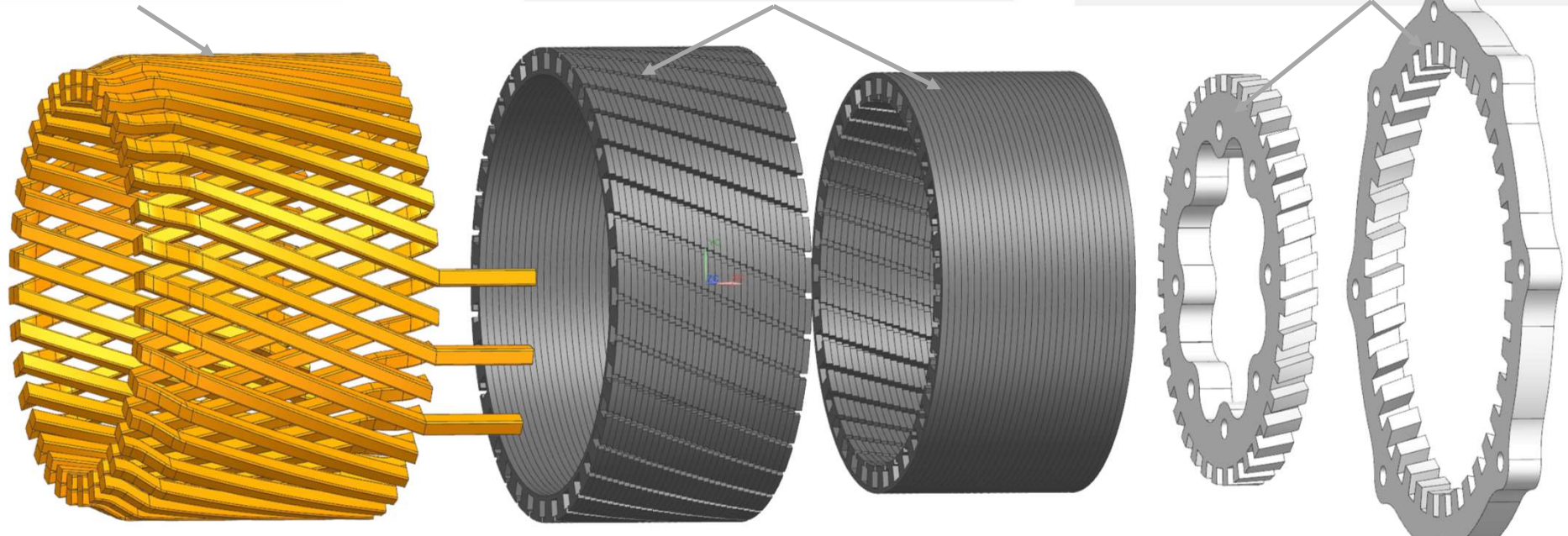
- Laser welded in both sides
- High torsional stiffness
- Distributed wave winding

Counter-skewed stacks

- Single slot per conductor
- Separated inner + outer ring
- Made from stamped segments

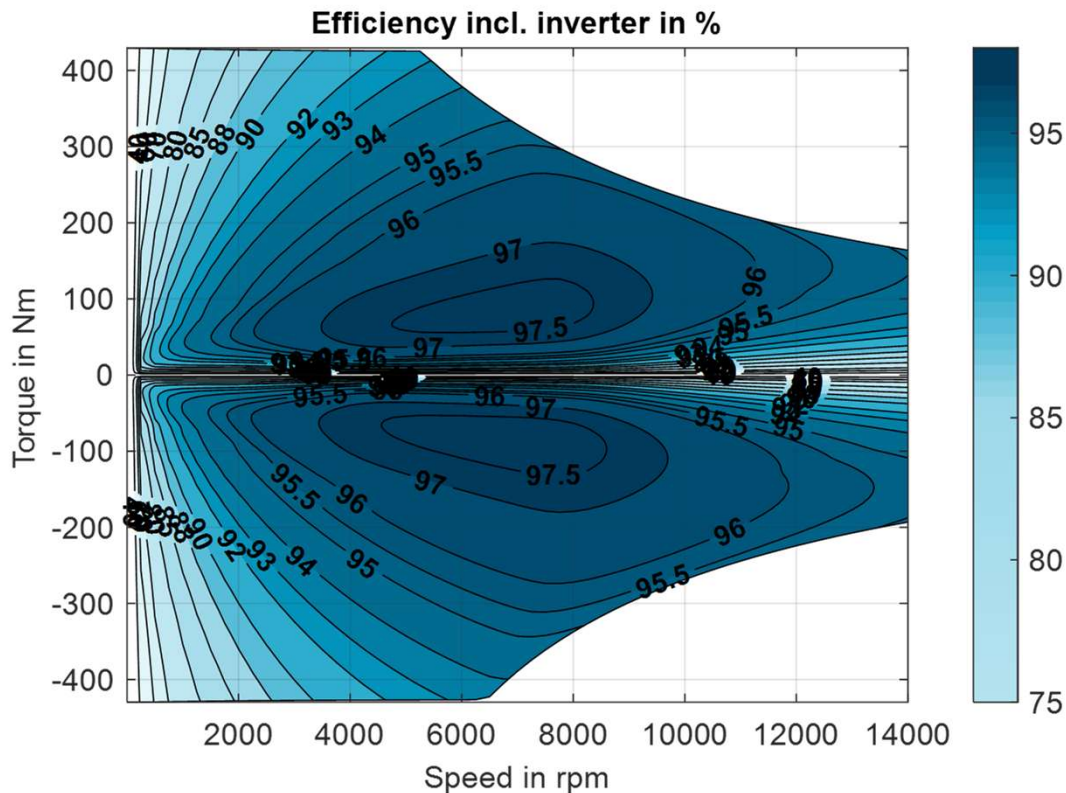
Form-fitting winding carrier

- Transfers torque to housing
- Ensures cooling of end winding
- Made from aluminum



Self-supported, torsionally stiff winding transfers torque from airgaps to axial end of machine

E-machine and inverter combined provide excellent overall efficiency. Efficiency declines beyond 8.500 rpm, leaving room for improvement by a 2nd speed



- Generally very high efficiency
 - > 97.5% peak efficiency incl. inverter
 - Focus area of efficiency in low torque/medium speed area
 - Driving cycles like WLTP or motorway driving coincide with high efficiency area
- Rather small speed range up to 14.000 rpm
- Efficiency decline beyond 8.500 rpm
 - potential for optimization of operating point by 2-speed transmission

In order to assess the benefit of the 2-speed approach, a vehicle simulation was set up



VEHICLE SPECIFICATION: C-CLASS SUV



PICTURE OF EXEMPLARY VEHICLE



COASTDOWN DATA & MASSES

	Vehicle area	2.65 m ²
	CW	0.25
	Vehicle mass	2150 (2165 kg)
	Roll. Resist. factor	0.0055

AUXILIARY POWER & TIRES

	ROLLING RADIUS	355 mm
	Auxiliary power	550 (565 W *)

* Due to actuation system power consumption

TRANSMISSION & FINAL DRIVE



Gear ratio 1 st	10.160 (also 1-speed)
Gear ratio 2 nd	6.138

Both 1-speed and 2-speed variants use the same launch ratio and achieve the same launch torque.

Top speed of 1-speed variant is limited to 185 kph due to e-machine speed limit of 14.000 rpm

POWERTRAIN SPECIFICATIONS

	E-Machine	250 kW / 450 Nm peak
	Battery	77 kWh
	Transmission	1-speed (2-speed)

Note: Values in brackets () are for the 2-speed variant

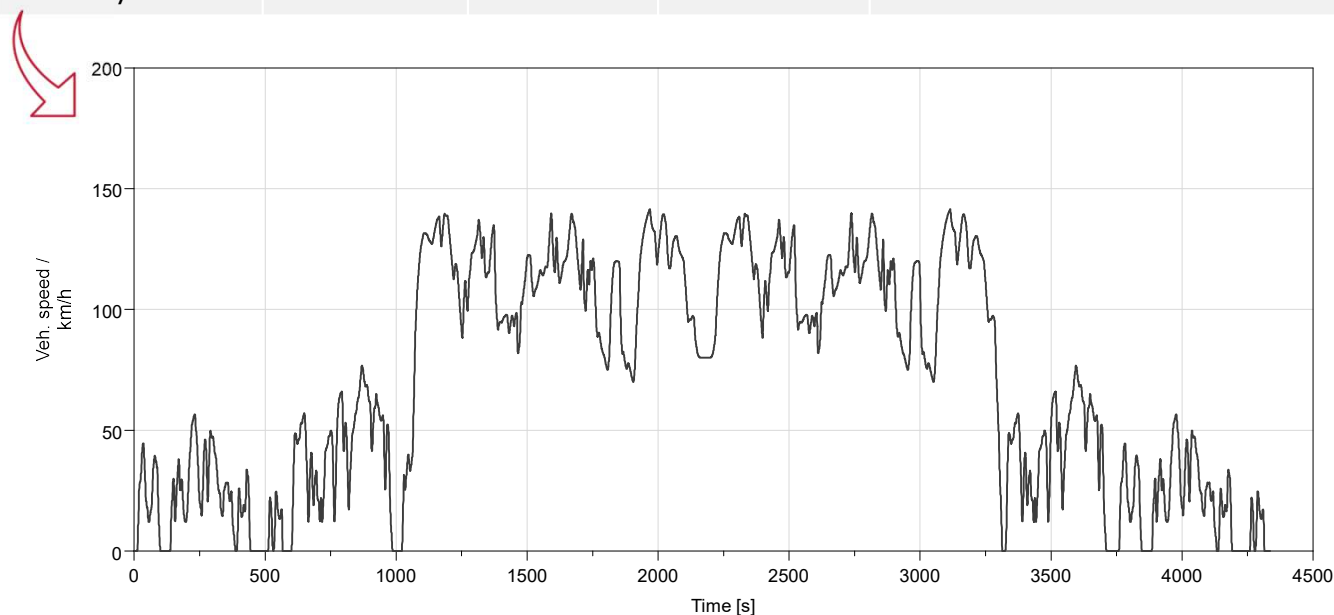
KEY FINDINGS

2-SPEED VS. 1-SPEED

- Identical efficiency observed in WLTC
- **Very good overall** energy consumption
- Disadvantage for 2-speed in low/med portion
 - at same 1st gear ratio, 2-speed will always have efficiency disadvantage
- Advantage in real world scenarios, especially at highway speeds
- **Additional optimization potential for 2-speed** due to available ratio spread
 - Optimize EM for lower speeds
 - Increase launch ratio/torque while still maintaining higher top speed capability

FEV

Cycle	1-speed	2-speeds	Unit	Consumption diff. 2-speeds vs. speed
WLTC Complete	13.7	13.7	kWh/100km	identical
WLTC LowMed	10.9	11.4	kWh/100km	+5 %
85 km FEV real-world cycle	17.1	16.6	kWh/100km	-3%

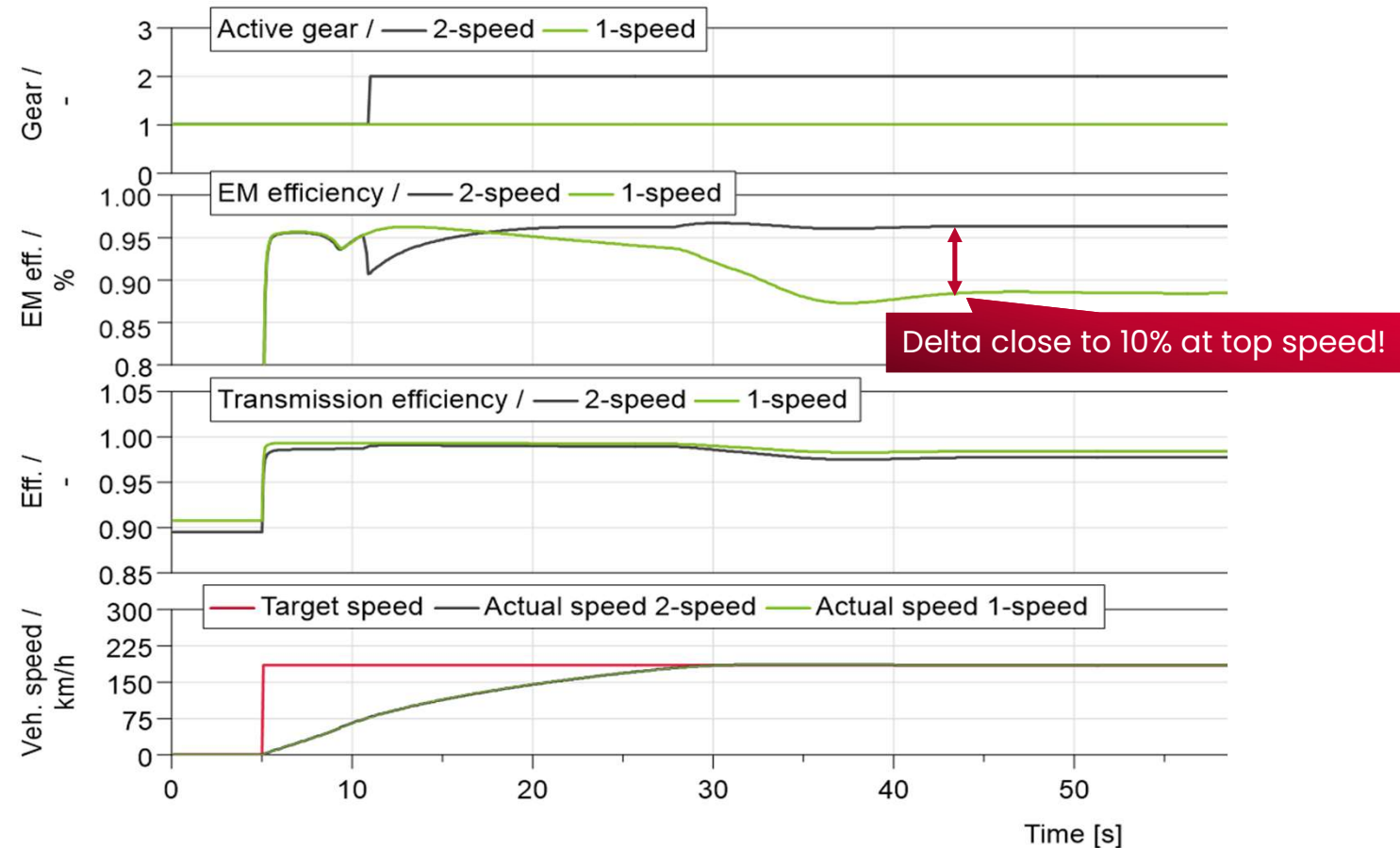


KEY FINDINGS

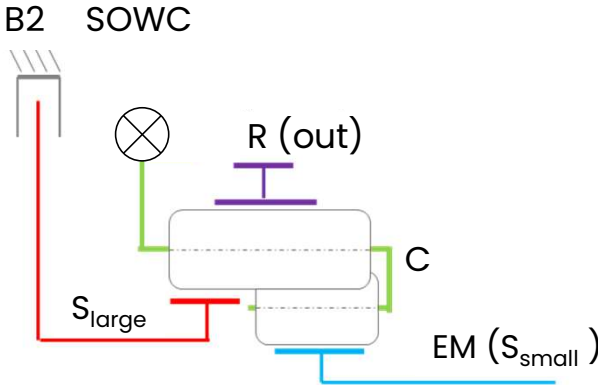
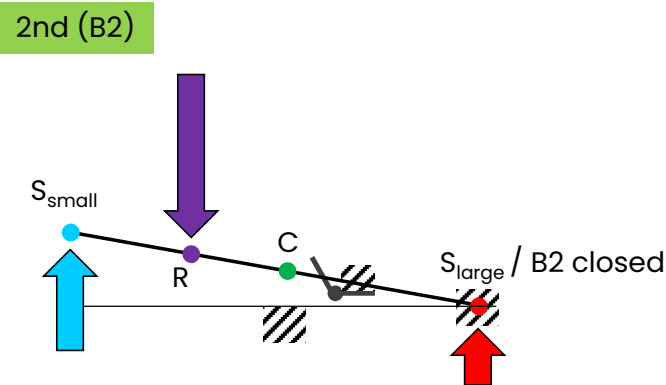
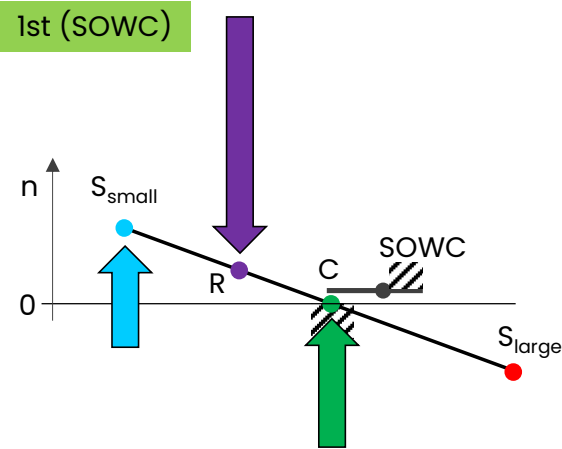
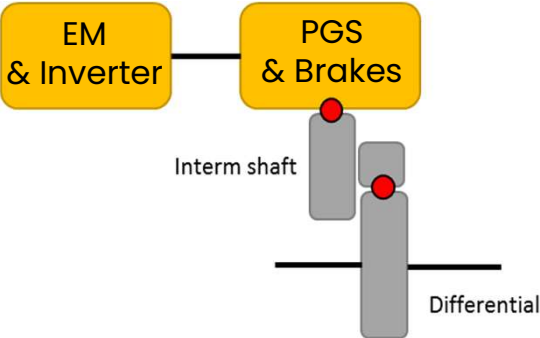
2-SPEED VS. 1-SPEED

- Full load acceleration visualizes key factors:
 - 2-speed transmission always has some (small) efficiency disadvantage compared to 1-speed due to higher complexity & losses
 - 2nd speed can **significantly** increase EM efficiency, especially at high vehicle speeds
- **Additional optimization potential for 2-speed** due to available ratio spread
 - Optimize EM for lower speeds
 - Increase launch ratio/torque while still maintaining higher top speed capability

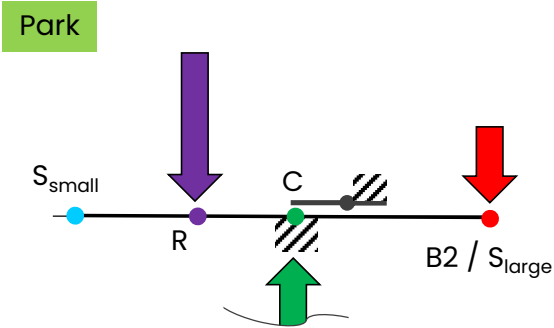
FEV



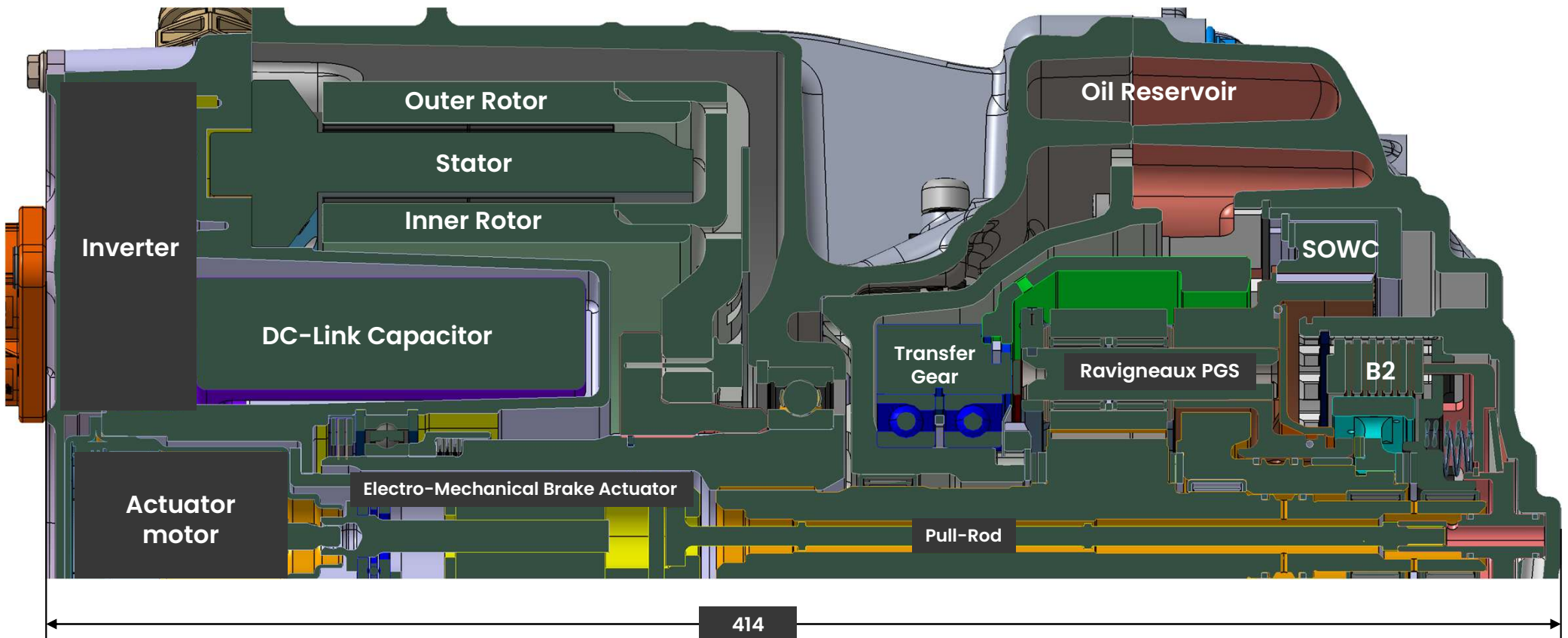
The Ravigneaux gearset provides favorable speed & torque factors. One selectable OWC and one wet disc brake enable seamless power-on shifts



Speed factors	1st	2nd
n_EM	1.000	1.000
n_SOWC	closed	0.460
n_B2	-0.851	closed
Torque factors	1st	2nd
T_EM	1.000	1.000
T_SOWC	1.425	open
T_B2	open	0.465

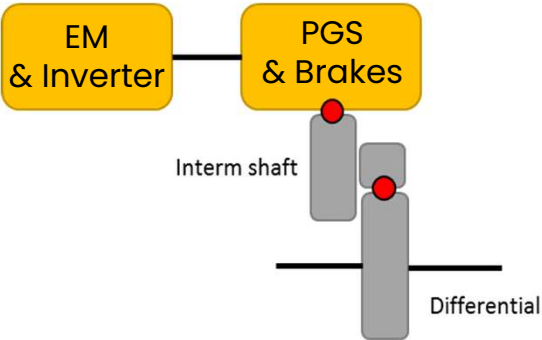


The DC-link capacitor efficiently uses the available space inside the rotor. The electro-mechanical brake actuator is arranged inside the rotor shaft.

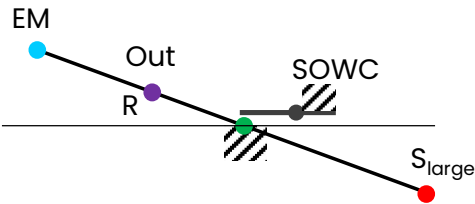


And if I need more range?
Convert it into a Parallel Range Extender!

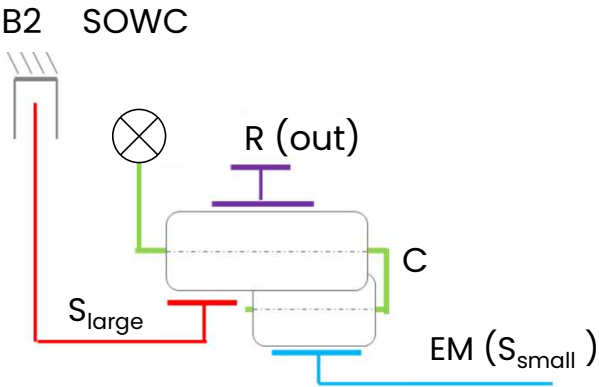
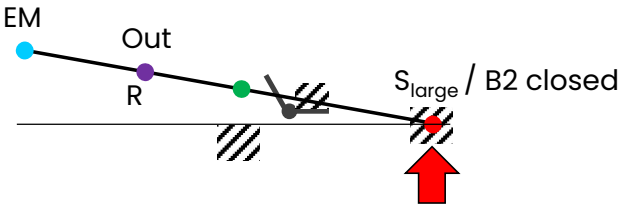
Parallel Range-Extender Option: The Ravigneaux gearset can be transformed into a dedicated hybrid transmission with minimal modifications



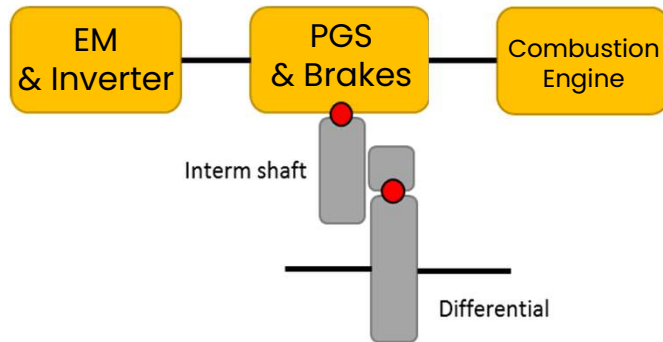
1st



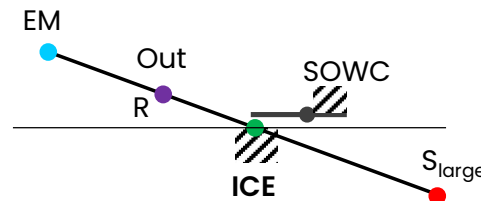
2nd



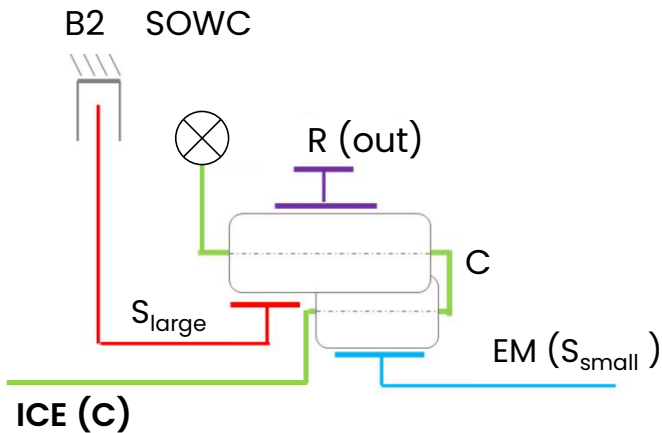
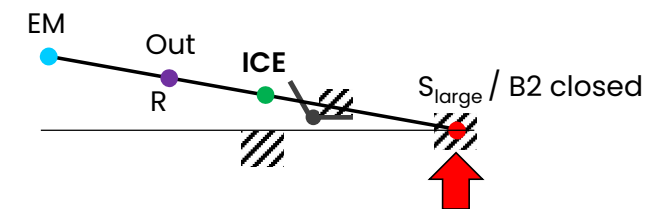
Parallel Range-Extender Option: The Ravigneaux gearset can be transformed into a dedicated hybrid transmission with minimal modifications



1st (E-Drive)



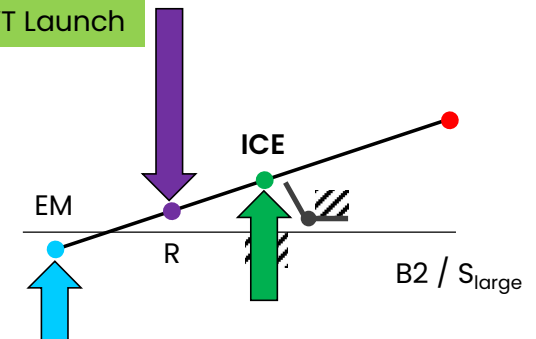
2nd (Parallel Mode)



Mode	Ratio EM	Ratio ICE
E-Drive	10.16	-
Parallel	6.138	2.823
eCVT	10.16	7.13

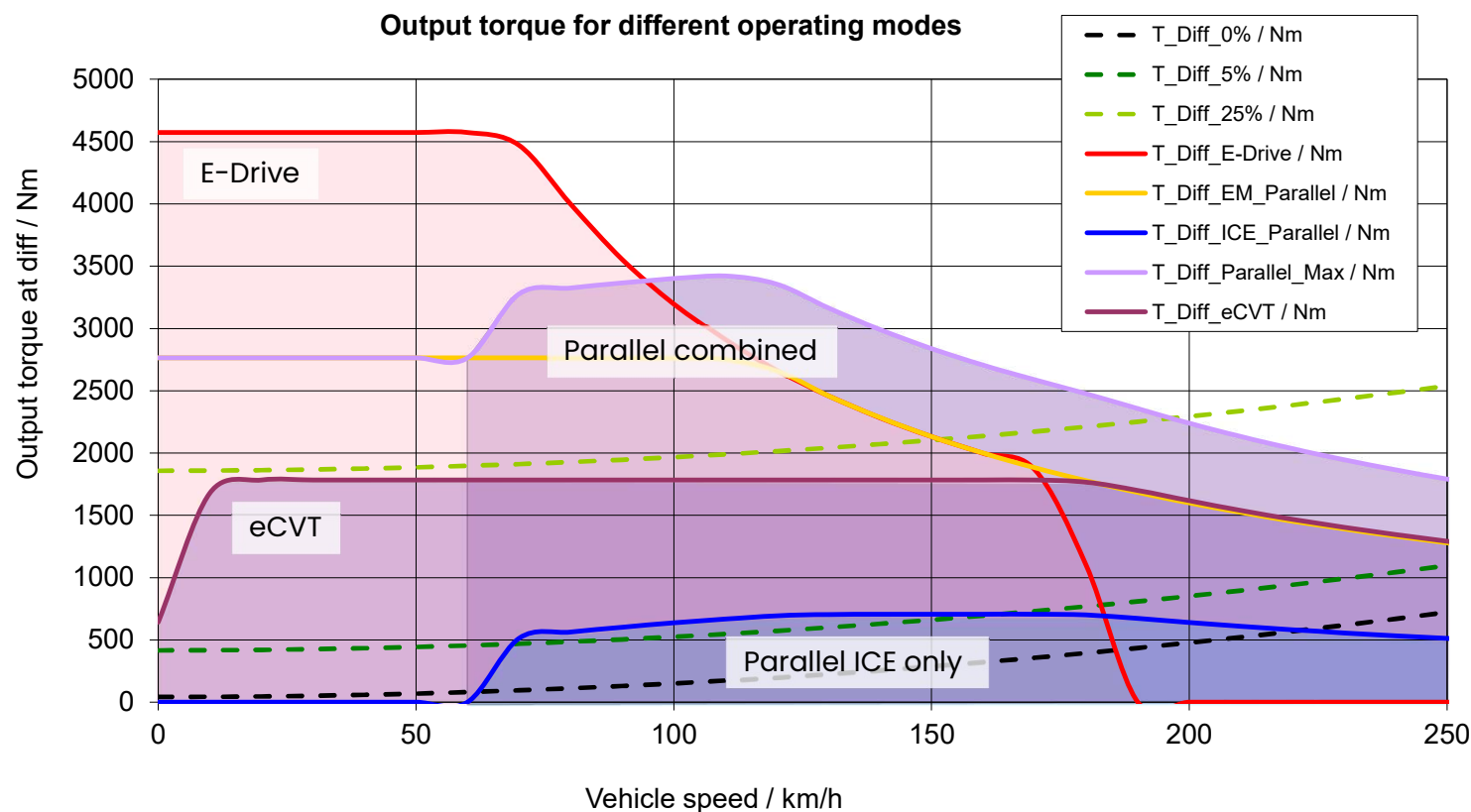
- E-drive up to 185 kph
- Parallel mode available beyond 65 kph

eCVT Launch



OPERATING MODES OF PARALLEL RANGE EXTENDER

- Flexible operation modes:
 - Pure e-drive** up to 185 kph with same performance as BEV version
 - Maximum power** will be available in parallel mode with EM and combustion engine **combined** torque
 - Combustion engine alone** can be used to propel the vehicle in parallel mode
 - eCVT** is limited in launch torque due to small combustion engine and is considered a "limp home" rather than a regular drive mode



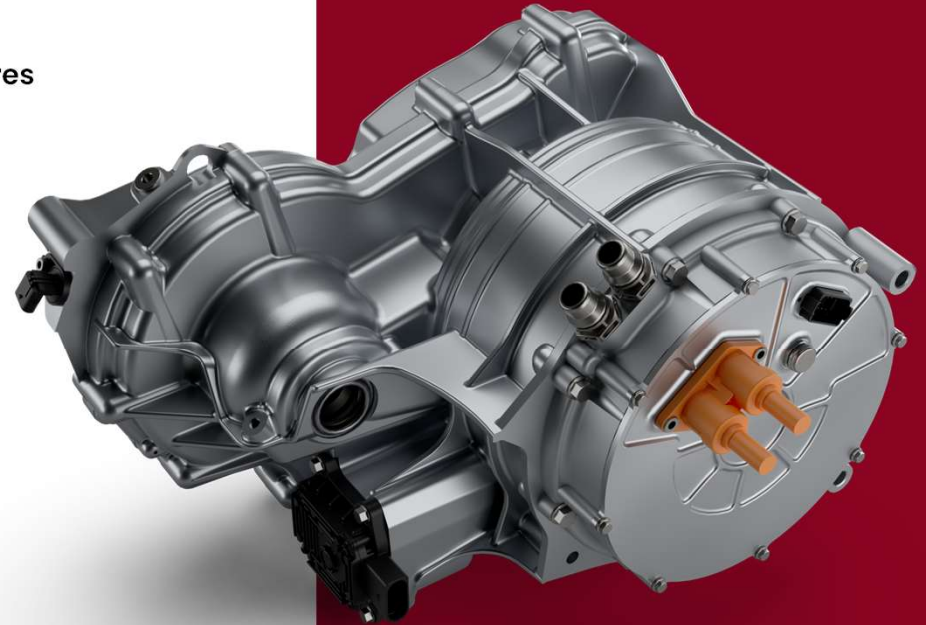
Combustion engine:
Electric machine:

1.5L 4-cyl Gasoline Turbo,
Dual rotor radial flux,

250 Nm, 100 kW
450 Nm, 250 kW peak

2-Speed Electric Drive Unit with Dual Rotor Electric Machine and Modular Range Extender Variant: Summary

- FEV has developed an innovative **2-speed electric drive unit with unique features**
 - DeepDrive dual rotor e-machine with coaxial 800 V SiC multi-level inverter
 - Ravigneaux planetary gearset with one selectable OWC and one wet disk brake
 - Electro-mechanical actuation
 - Compact and lightweight
 - 250 kW peak power, 4.600 Nm launch torque
- The Ravigneaux-based architecture has already been successfully deployed in a 1st generation prototype
- Simulations show that WLTC energy consumption is identical to a 1-speed EDU in WLTC, with **significant benefits** in real world driving scenarios, especially at high vehicle speeds
 - Additional optimization potential for 2-speed due to available ratio spread and lower required EM speed range
- With small modifications, the 2-speed EDU can be converted into a hybrid transmission, providing a **modular “Parallel Range Extender” option**
 - Potential applications include:
 - Passenger cars and SUVs with hybrid long range versions, e.g. for trailer towing scenarios
 - Light commercial vehicles with small battery BEV versions for urban delivery and hybrid versions for long-distance transport
- **Contact us** to discuss your potential application with us!



**Contact us
or
meet us at
FEV's booth
to continue the
discussion!**



2-Speed Electric Drive Unit with Dual Rotor Electric Machine and Modular Range Extender Variant



Contact

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