# nonlinear single track model

The vehicle dynamics model and the tire model can be found in the *sim_vehicle_dynamics* repository under *models /vehicledynamics*.

## Vehicle kinematics

The dynamic model of the vehicle is based on a single track model as depicted on the right.

The model includes the following effects:

- Position of the centre of gravity and wheelbase
- Steering wheel angle at the front axle
- Mass and Yaw inertia
- Nonlinear tire forces based on a simple Pacjeka model (see below for details)
- Transient behavior for tire slips (modeled via simple first order low passes)
- Aerodynamic drag and lift
- Wheel rotational dynamics for longitudinal slip
- Position dynamics based on standard kinematic equations

The model does not include the following effects:

- Load transfer in longitudinal and lateral direction
- Vertical dynamics
- Pitch / Roll
- Suspension setup and steering geometry

Another important point is the modelling of vehicle standstill. Using the standard tire slip definition, this leads to a division by zero. To circumvent this, a second vehicle kinematics model based purely on vehicle geometry and assuming zero slip is used. These two models are blended around a low speed of approx. 5-10kph to achieve stable numeric results.
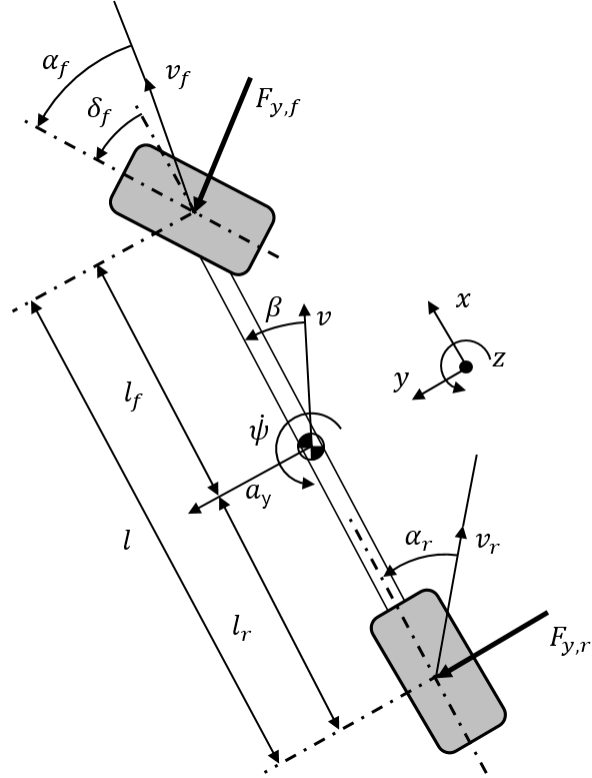
## Tire model

For longitudinal and lateral tire forces, a five coefficient Pacjeka model is used:

$$F_s(\alpha) = F_z \cdot \mu(\alpha) = F_z \cdot D \sin\left(C \arctan\left(B\alpha - E\left(B\alpha - \arctan\left(B\alpha\right)\right)\right)\right)$$

An exemplary resulting lateral model is depicted on the right. The tire slips are calculated for all four wheels upon the exact kinematic equations. Afterwards the resulting forces are summed for each axle and used within the single track model. This enables to have four independently driven motors without modelling load transfer.

The model includes the following effects:

- Linear and nonlinear tire operating range
- Linear load dependency

The model does not include the following effects:
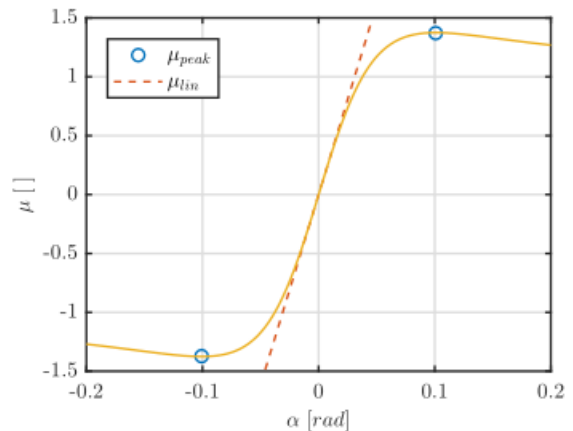
- Combined tire operation (so the sim is overly optimistic in this aspect)
- Load degressivity (important for more precise over- and understeer analysis)
- Camber and tire degradation