

Design of Collimator Control System for PWFA

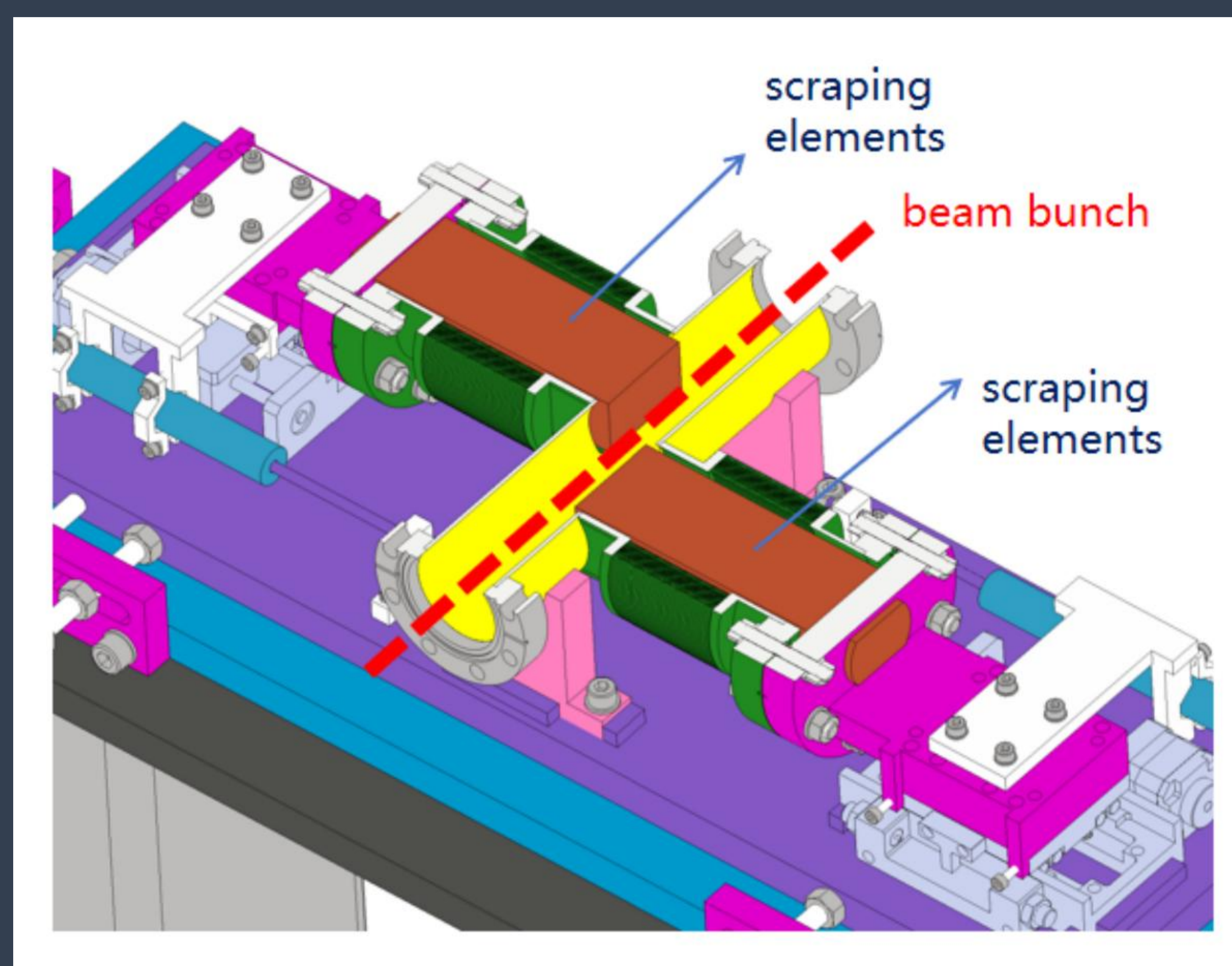
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ABSTRACT

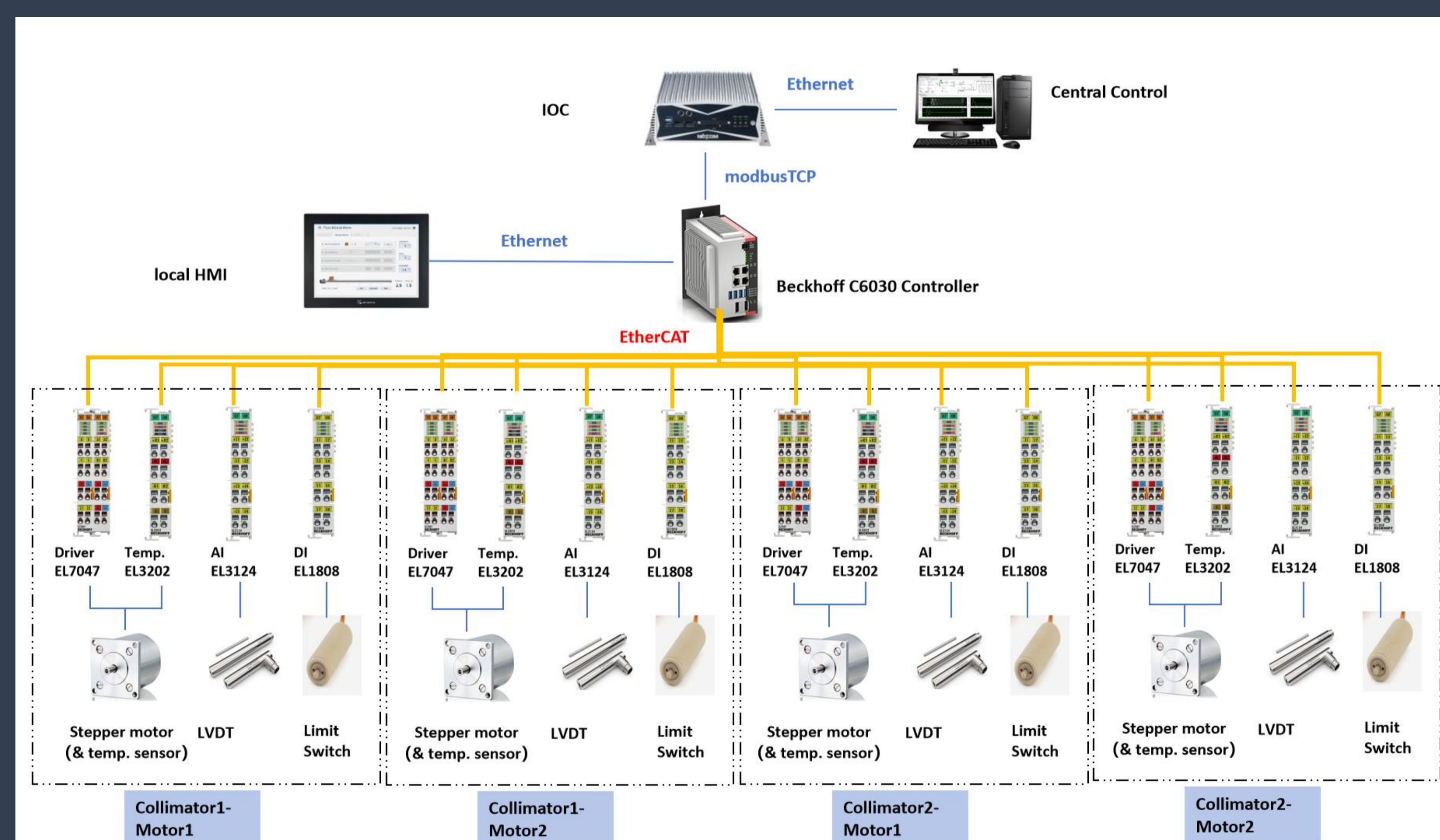
The primary function of the collimator in the PWFA project is to reduce the lateral dimensions of the beam bunch and select a very small and precise beam bunch through the high-precision movement of its scraping elements. The control system employs EtherCAT bus technology to enable precise motion control of the collimator's scraping components. Given the intense radiation environment, Linear Variable Differential Transformers (LVDTs) are utilized for position feedback, replacing conventional optical encoders. Furthermore, the system incorporates multiple levels of safety protection, ensuring operational safety. Using Safety-over-EtherCAT, a safety integrity level of SIL-3 can be achieved. To facilitate remote operation, the system adopts the Experimental Physics and Industrial Control System (EPICS) framework and communicates with EPICS Input/Output Controllers (IOCs) using the MODBUS TCP protocol.

SYSTEM DESIGN

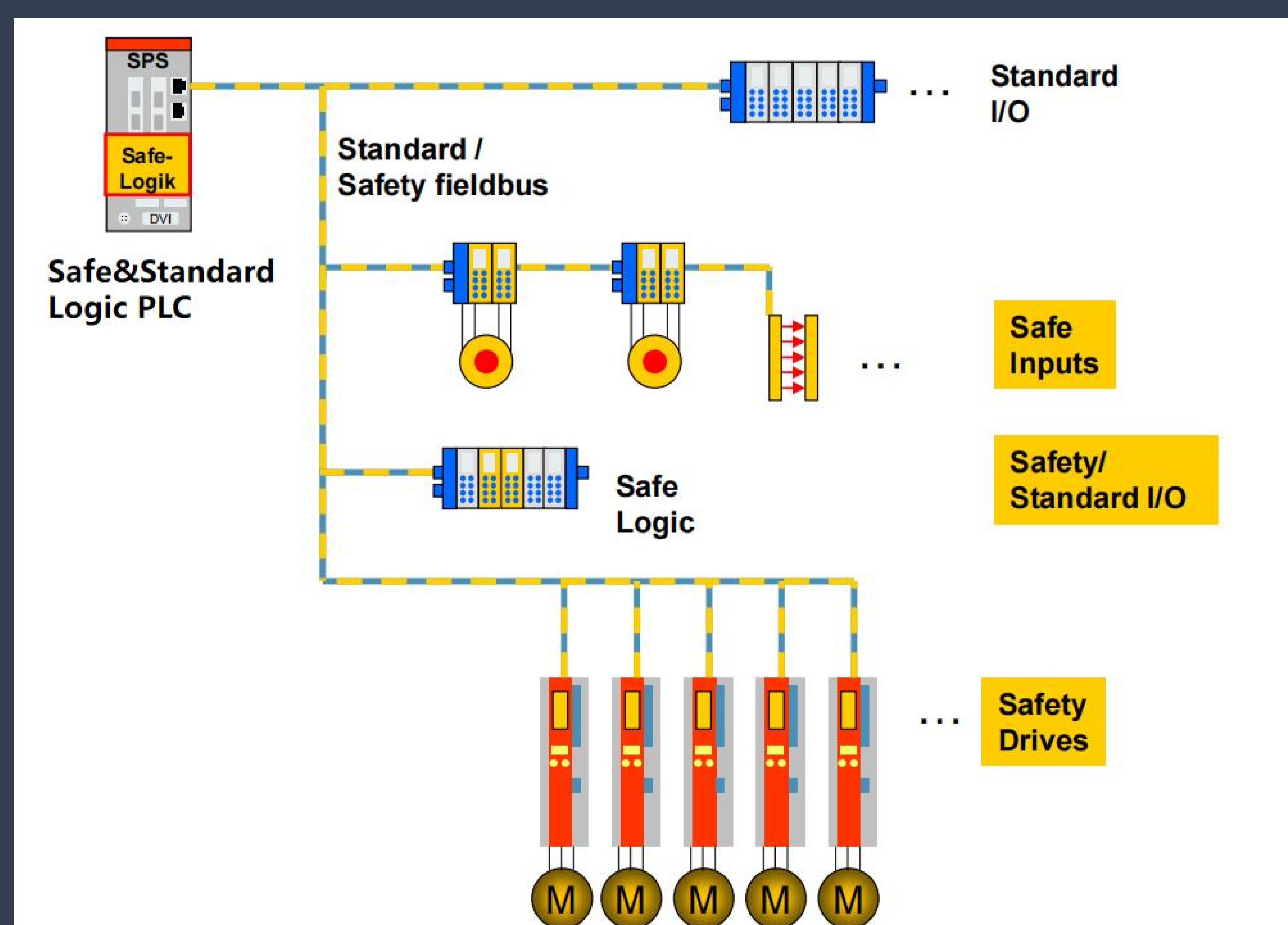
- **EtherCAT Control Architecture:** distributed system design based on EtherCAT industrial Ethernet bus technology, leveraging its capabilities for high-speed data transmission and high-precision synchronization to ensure precise control of the collimator. The system consists of a master station and multiple slave stations, where the master station is responsible for issuing control commands and collecting feedback information; the slave stations include drive units for stepping motors and I/O modules for sensor signal acquisition.
- **Absolute Position Calibration:** In a high-radiation environment, an LVDT sensor is used to achieve high-precision positioning instead of a linear encoder.
- **Safety System Design:** Multiple layers of safety protection, including software limits, mechanical limit switches, and emergency stop switches. Functions such as emergency stop for motors, motor temperature monitoring, and PLC software protection are all integrated into the safety system. Using Safety over EtherCAT, a safety integrity level of SIL-3 can be achieved.
- **Remote Control:** Realization of remote control via MODBUS TCP protocol communication between Beckhoff PLC and EPICS IOC. The EPICS OPI interface is developed using Phoebe CSS.



Scraping elements of collimator



EtherCAT Control Architecture



Safe-Over-EtherCAT Safety Architecture