PAUL SCHERRER INSTITUT

PSI

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Generic FPGA based platform for distributed IO in a Proton Therapy Patient Safety Interlock System

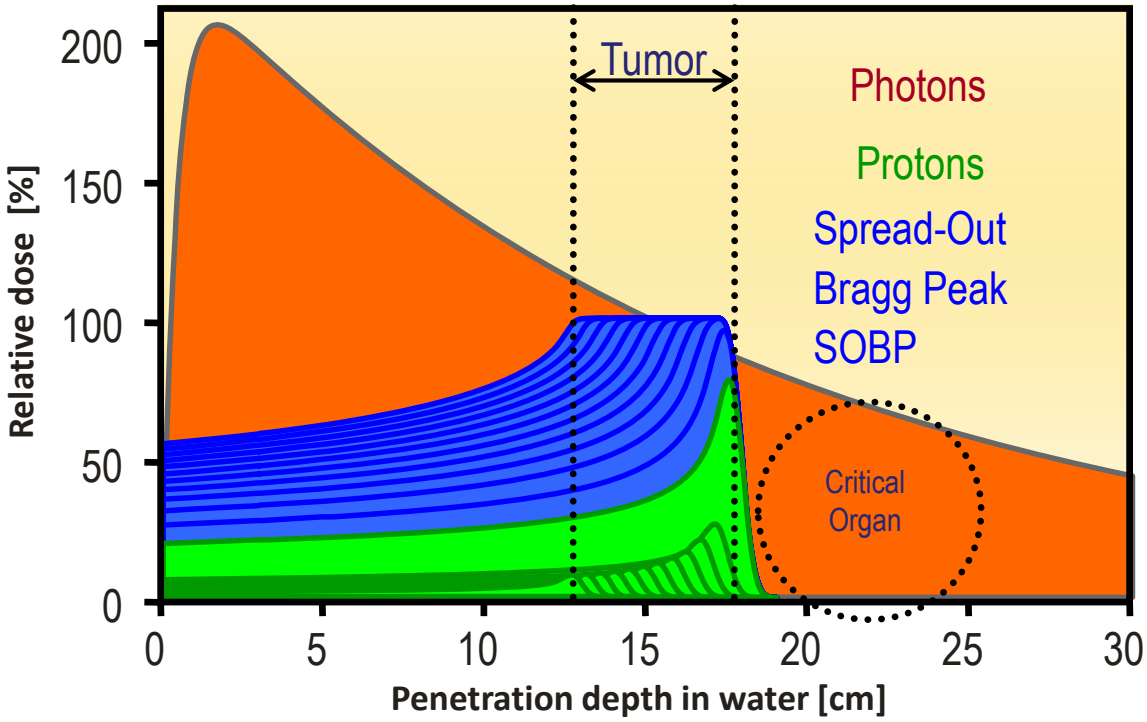
June 08, 2016

Agenda

- Proton therapy at PSI
- Gantry 3 – Patient Safety System
- SCB – The new signal interface concept
- Outlook

Proton therapy at PSI

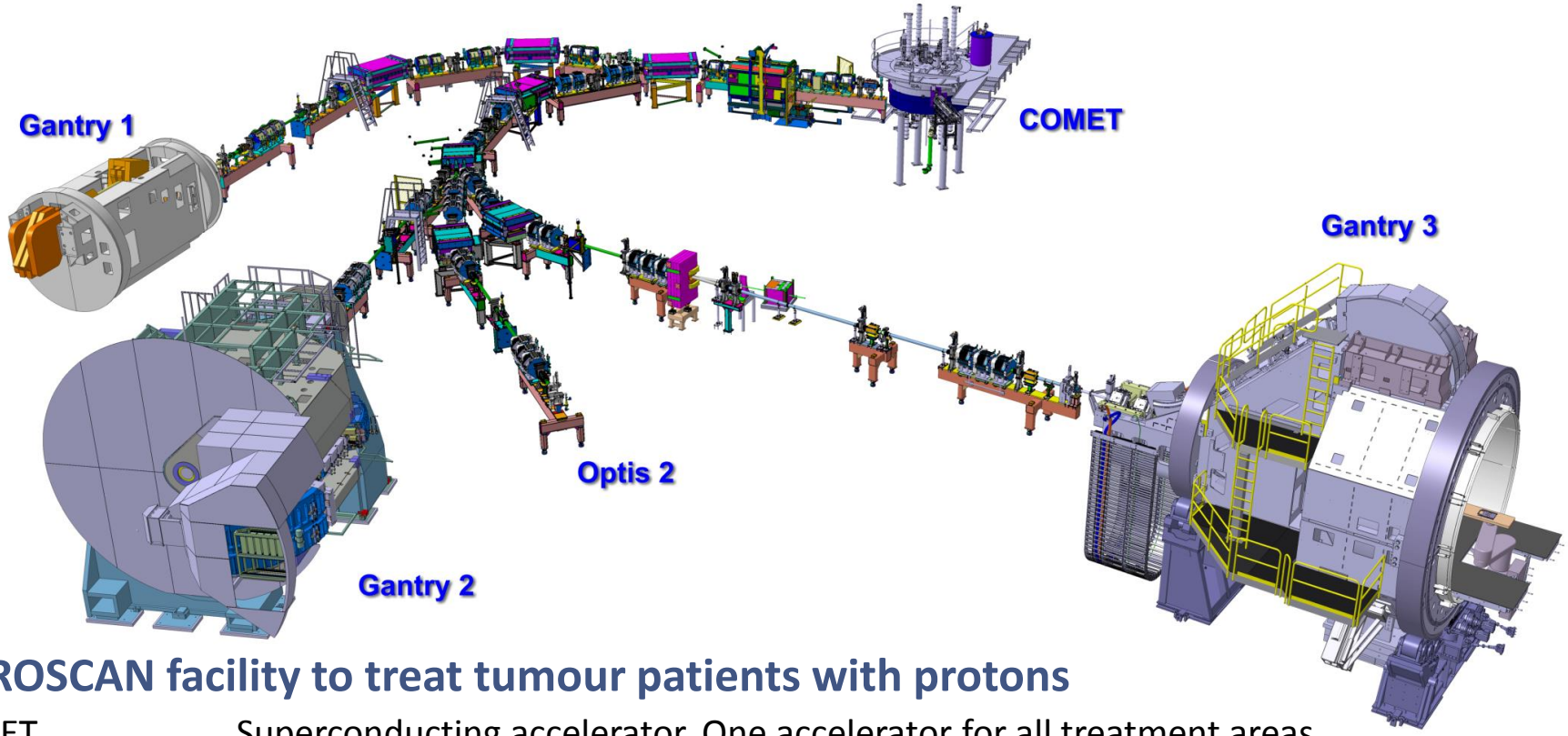
The power of protons in radio therapy



Proton therapy vs. conventional radio therapy (photons)

- Better dose conformation to target / tumor
- Less dose to healthy tissue

Proton therapy at PSI

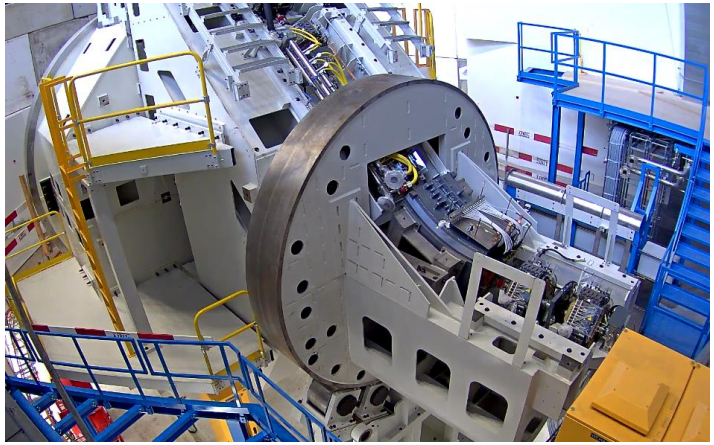


PSI PROSCAN facility to treat tumour patients with protons

- COMET — Superconducting accelerator. One accelerator for all treatment areas
- Gantry1 — PSI development. In operation since 1996. Worldwide 1st gantry with spot scanning technology.
- Gantry2 — PSI development. Performance optimized Gantry design for continuous scanning technologies.
- OPTIS2 — PSI development. Horizontal fixed beamline based on scattering technology
- Gantry3 — Commercial gantry from VARIAN Medical Systems. Based on raster scanning technology

Proton therapy at PSI

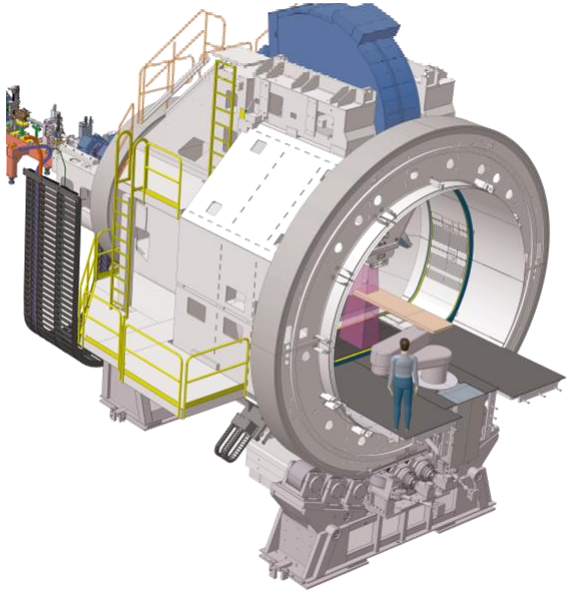
Gantry3 – The new treatment machine at PSI



- **Manufacturer** VARIAN MEDICAL SYSTEMS
- **Gantry technology**
  weight 270 t
  diameter 10.5m
  rotation 360°
  energy switching time 200ms
  beam position precision 1mm
  raster scanning technology
- **Purpose**
  Expansion of treatment capacity at PSI

  Research collaboration with industry
- **Challenges**
  Installation and commissioning in parallel to clinical operation

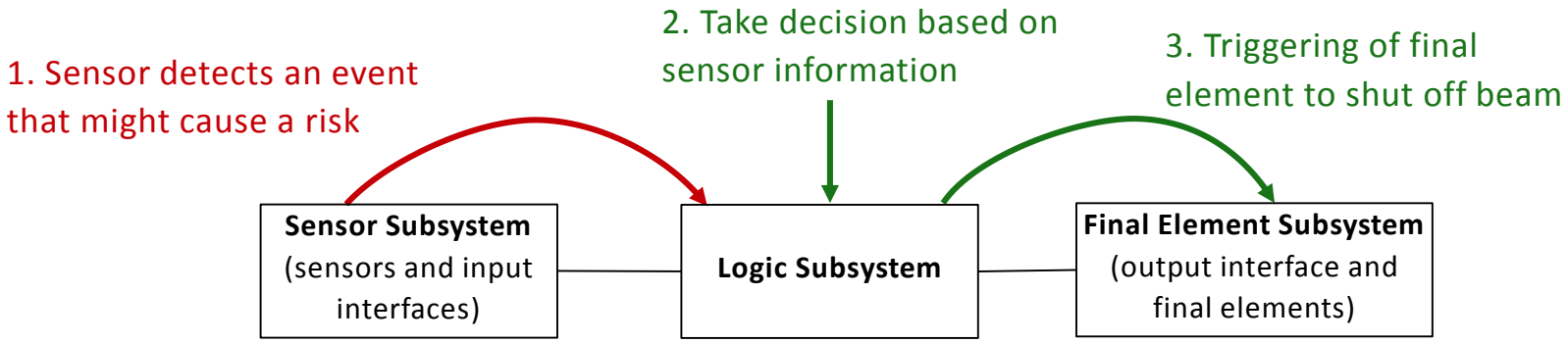
  Connecting a commercial gantry to the PSI PROSCAN facility



Gantry3 Patient Safety System

Main functionality of a Patient Safety System (PaSS)

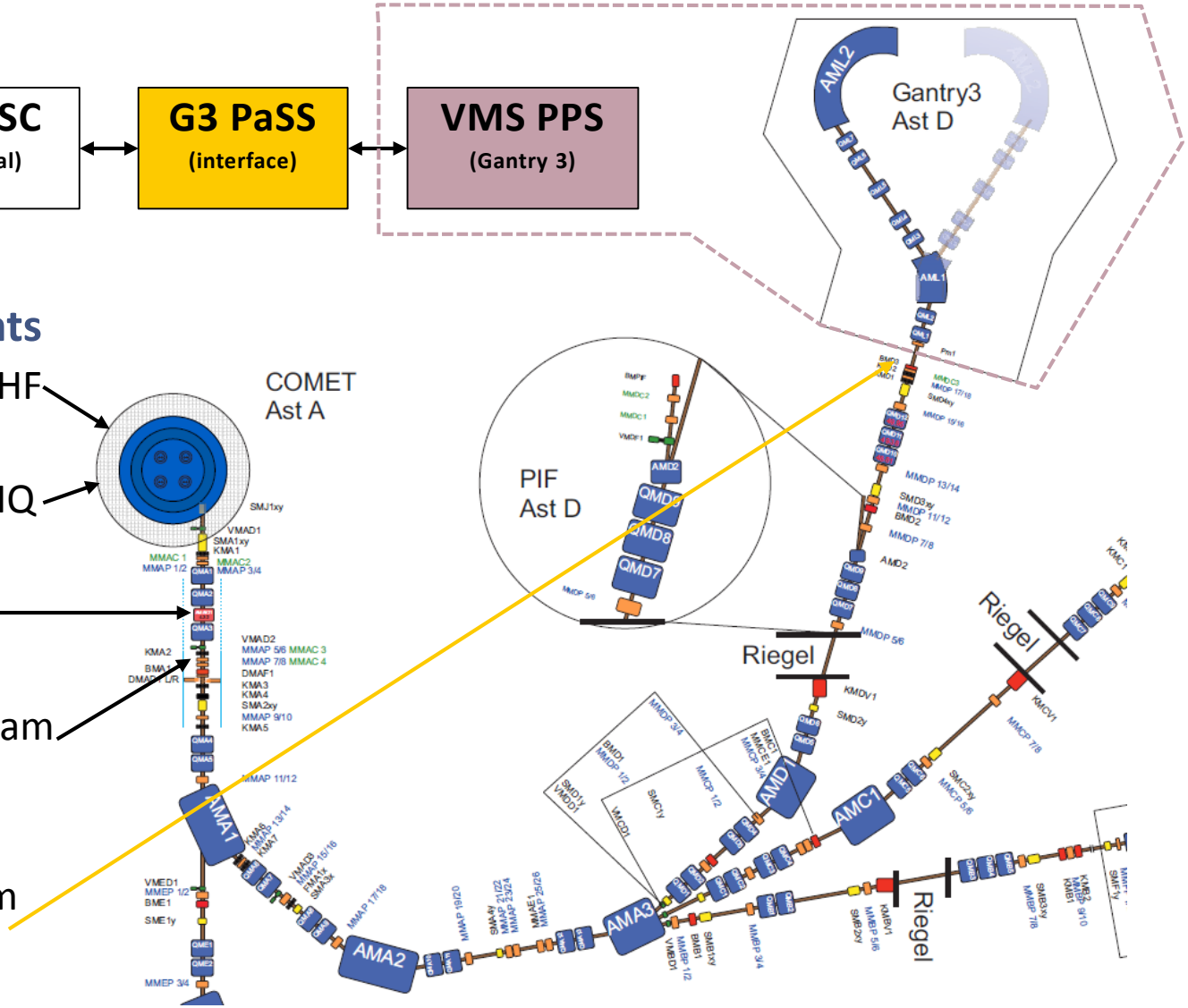
- Protect the patient from radiation hazards
  - E.g. Wrong dose at wrong location or overdoses
- To reach the goal it is necessary to bring the machine into a safe state



Gantry 3 – Patient Safety System

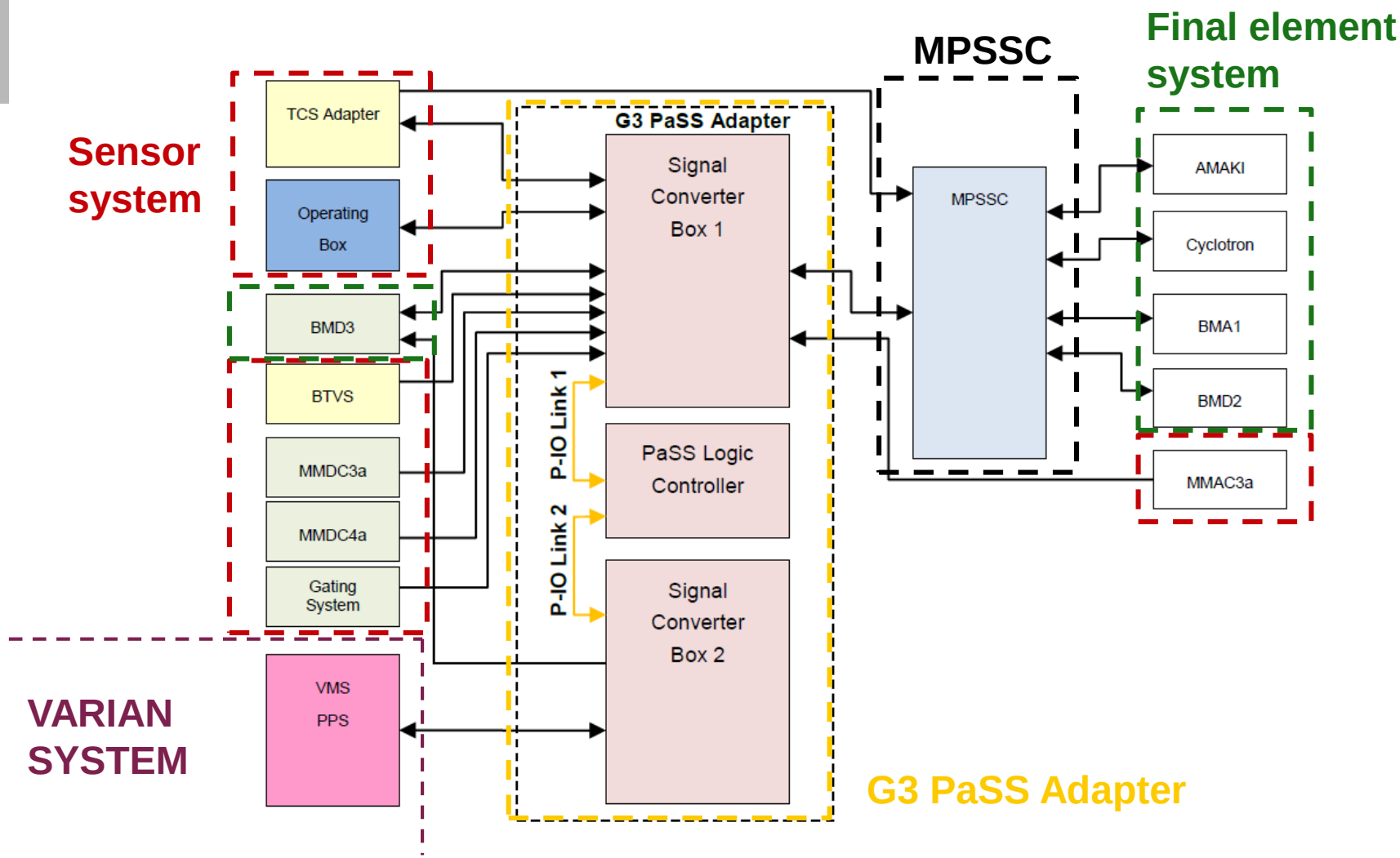
Final elements

- Cyclotron HF
- Cyclotron IQ
- AMAKI
- Central beam stopper
- Local beam stopper



Gantry 3 Patient Safety System

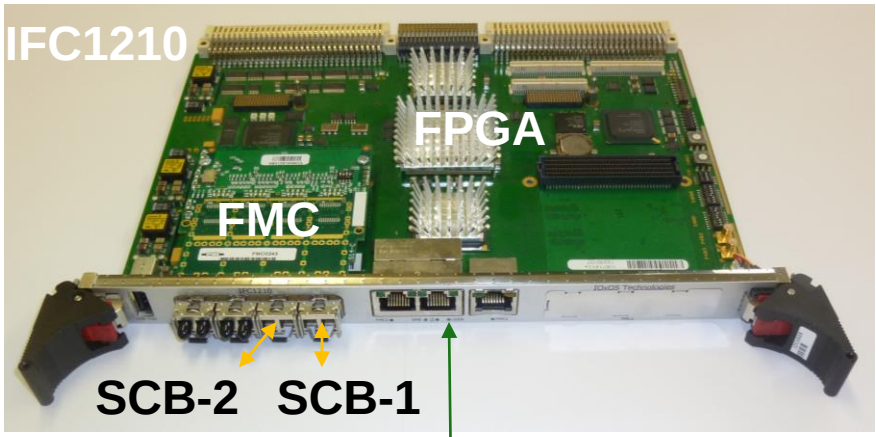
G3 PaSS System Overview



Gantry 3 – PaSS Hardware Technology

G3 PaSS Logic Controller

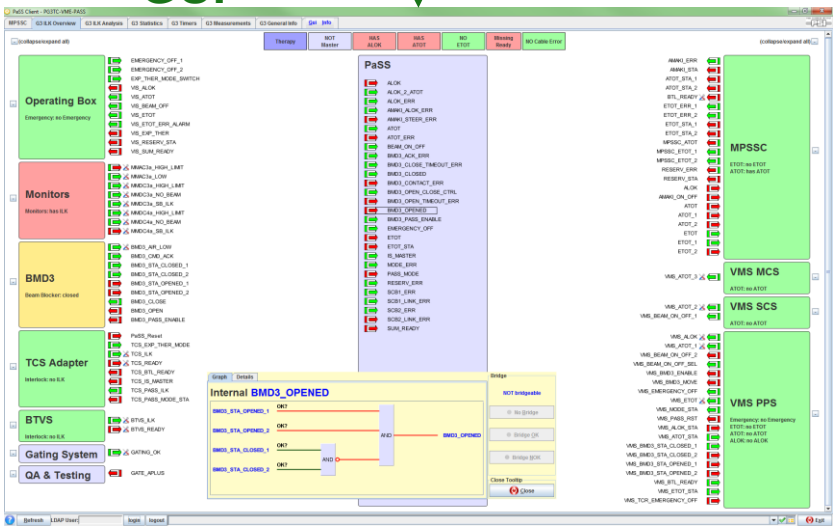
- IFC1210 VME based IOC controller:
  - COTS from IOxOS Technologies
  - Central Virtex 6 FPGA
  - Dual core PowerPC
  - 2x FMC standard slots
  - 2x Ethernet



- COTS FMC module
  - Supporting up to 4 SFP transceiver slots
  - Used for high speed communication of distributed IO system

EPICS

GUI



- PaSS logic is completely implemented in FPGA and works standalone.

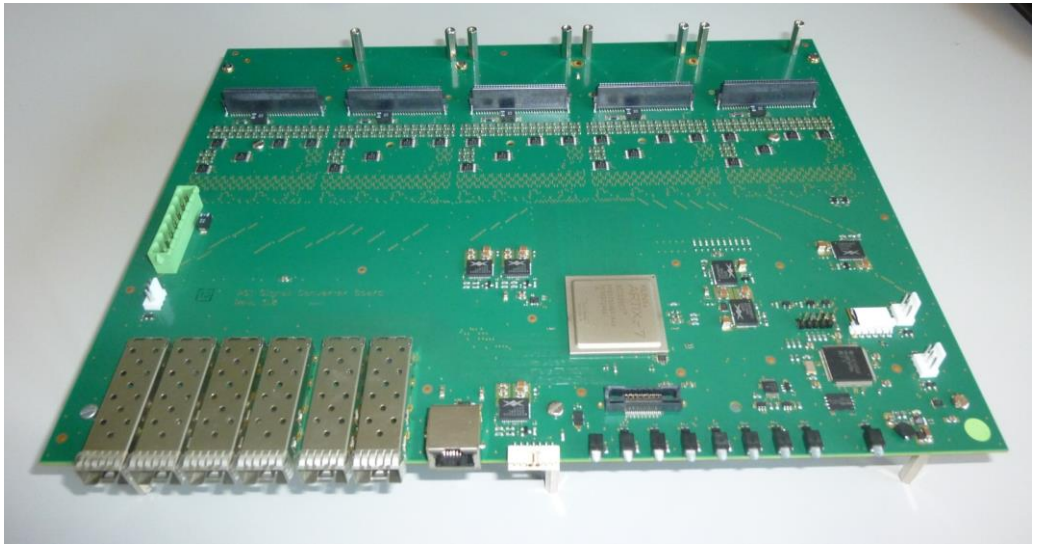
- New GUI is based on EPICS communication. It has improved features for debugging and measurements

SCB – The new signal interface concept

SCB – Signal Converter Board – HW Feature

- Developed in collaboration with Super Computing Systems
- Based on XILINX – ARTIX 7 FPGA
  - 215 K Logic Cells / 1.46 kB RAM / **500 IO**
- 6x SFP Gbit optical links
- 10x PlugIn ports with up to 34 IO signals on each port
  - PlugIn HW board defines interface standard on each port
- 4x Temperature monitor

SCS super computing systems



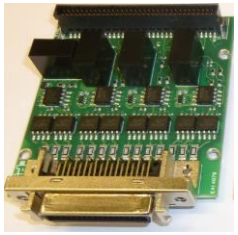
SCB – The new signal interface concept

SCB – Signal Converter Board – HW Features

- FAN control and supervision
- PCB design
  - 16 Layer PCB
  - 4 mil structures
  - ~1650 components
- Designed to fit into standard 19” crate
- Flexible interface concept with PlugIns
  - Application specific interface can be realized with less development effort
  - Supported interface standards
    - +24V DIO
    - Optical IO
    - PSI 3-wire inteface
    - Analog out
    - TTL IO

SCB – Box build design – Front view

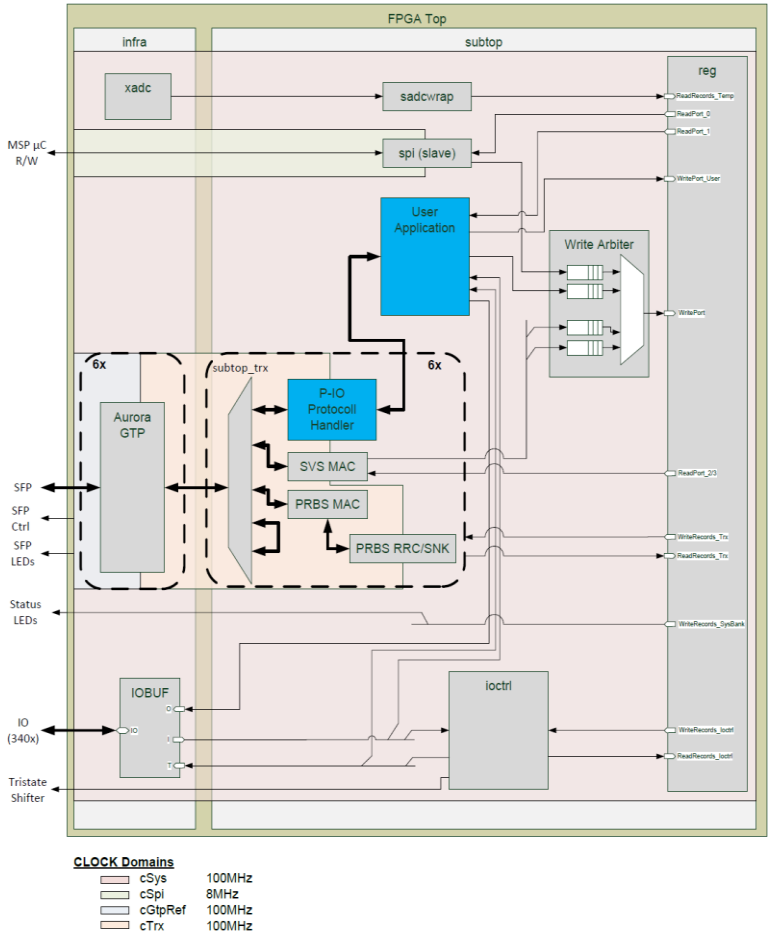
SCB – Box build design – Back view



SCB – The new signal interface concept

SCB – Firmware Framework

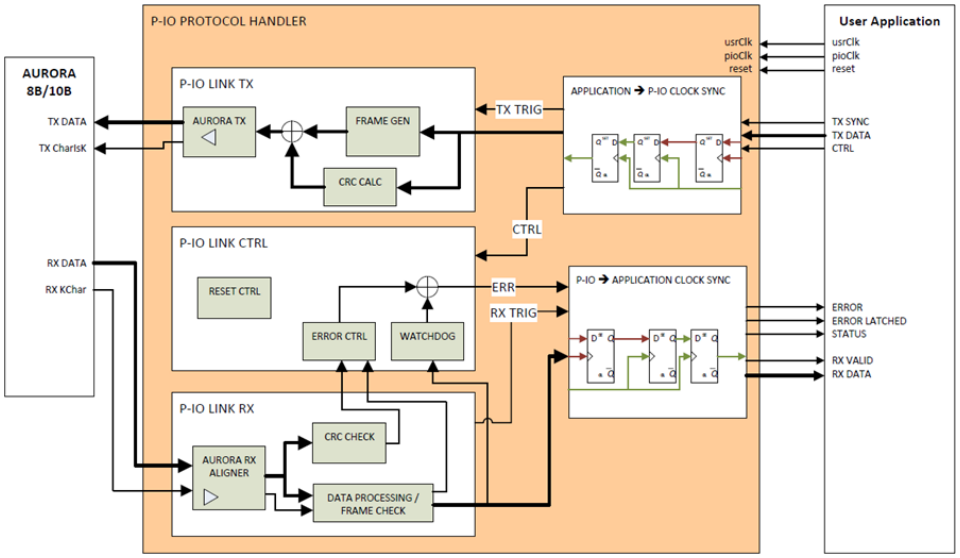
- FPGA framework supports all interface features of the SCB HW platform
  - GTP AURORA Link layer 2 or 2.5 Gbit/s communication
  - Multiplexer for easy configuration of GTP communication protocol
  - Central register block with up to 256 registers. Accessible via µC and SVS communication link.
  - IO control block for configuration of all 340 PlugIn IOs (application dependent)
- 100MHz central clock frequency of FPGA logic
- FPGA configuration is handled via system µC
- Simple integration of USER and application specific features

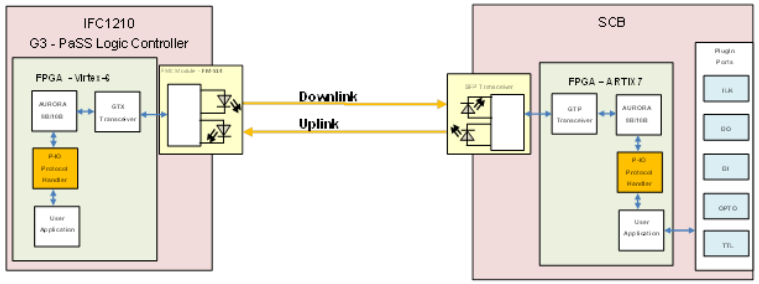


SCB – The new signal interface concept

P-IO Communication Link

- P-IO Link ➔ PaSS IO Link
- VHDL component, which **can be simply integrated into any FPGA** with an XILINX AURORA link
- Simple interface towards AURORA core and user application of FPGA
- Based on streaming mechanism
- Number of data transmitted over P-IO link can be simply defined before compilation by one constant





SCB – The new signal interface concept

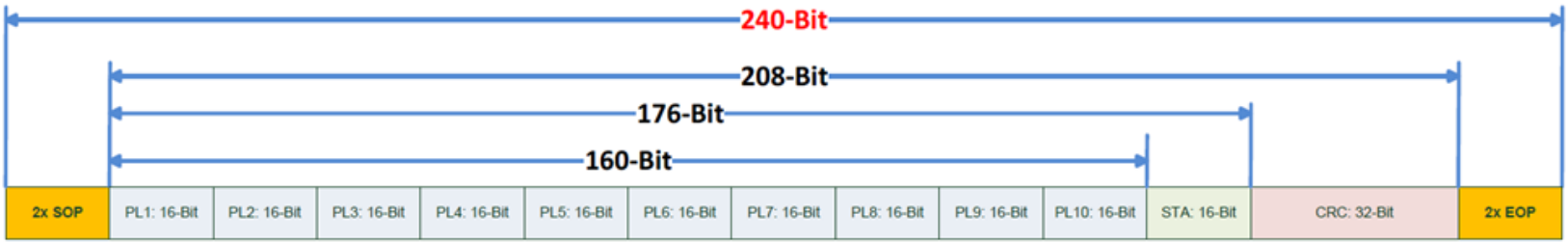
P-IO Communication Link

- P-IO Frame for G3 PaSS application
  - SOP/EOP characters to detect frame boundaries
  - 10 x16-Bit data (16 – Bit for each PlugIn)
  - 16-Bit device status word
  - 32-Bit FRAME CRC checksum
  - Frame length: 240 bit (300 bit 8B/10B encoded) ➔ 150-ns @ 2GBit/s

- Many link supervision functions to guarantee a safe data communication between IFC1210 and SCB
  - FRAME integrity check (detection of wrong order of SOP / EOP)
  - CRC check based on the CRC-32 polynomial according IEEE 802.3 (Ethernet)

$$CRCpoly = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

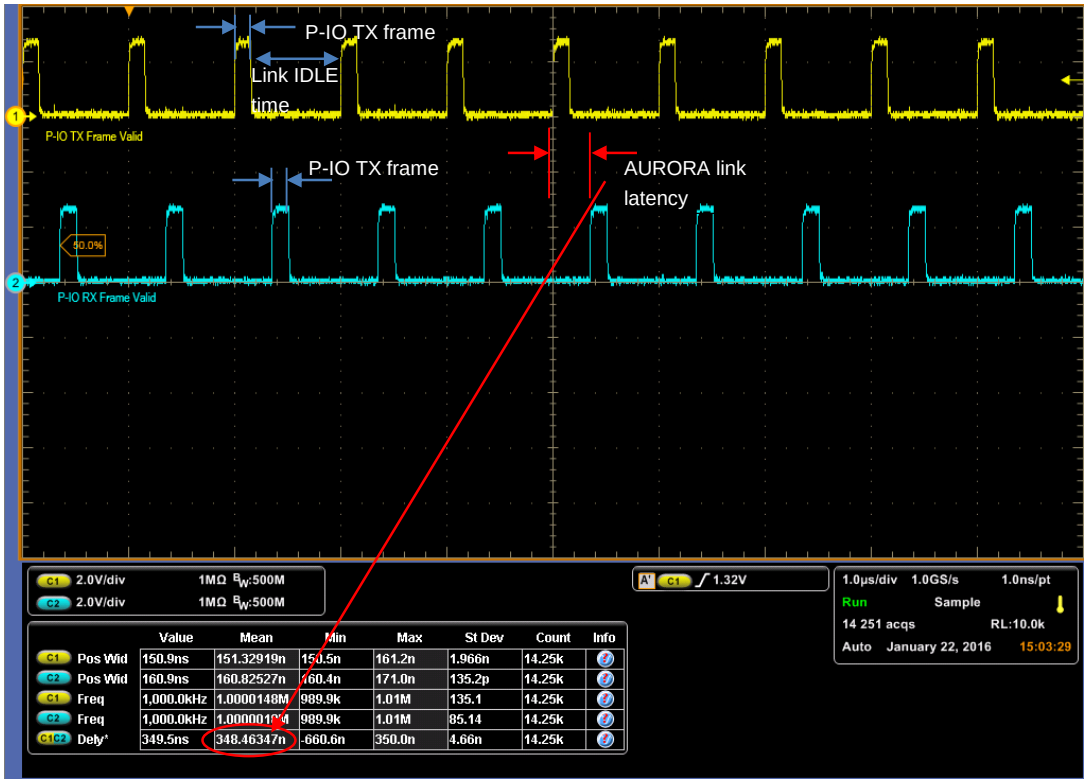
  - Watchdog supervision function to supervise the channel partner alive status



SCB – The new signal interface concept

P-IO – Performance Characteristic

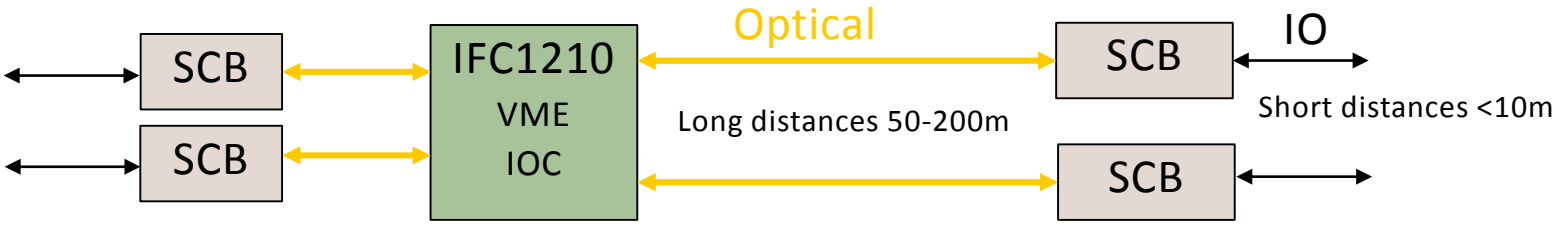
- Frame repetition rate is set to 1MHz
- Frame length 150ns ➔ Link load 15%
- AURORA link latency TX/RX ~350ns
- Link system latency is less than 4µs



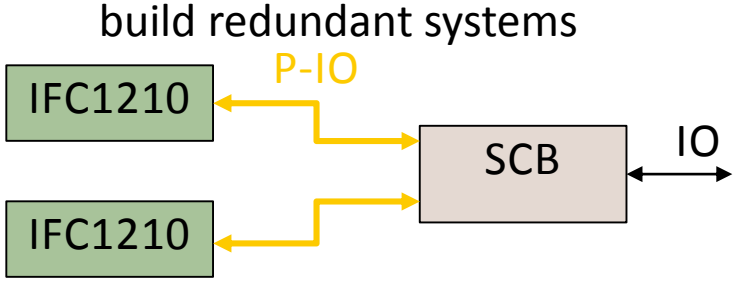
SCB – The new signal interface concept

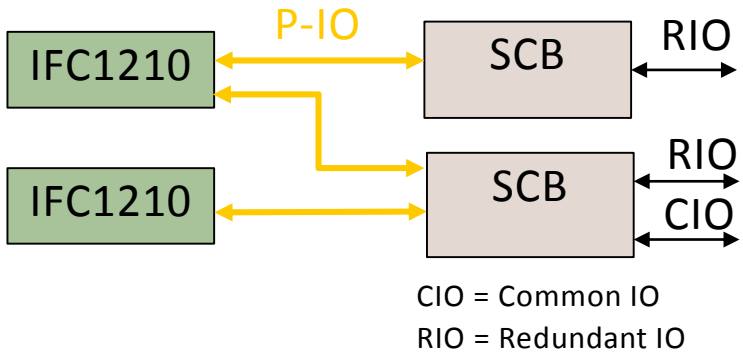
SCB – Summary

- Based on state of the art technology
- Very flexible platform for distributed / high density IO
- P-IO link is safe and easy to integrate into FPGA applications
- Up to 8 SCBs can be connected to one IFC1210 VME IOC
- Allows installations optimized for cost and EMC in wide spread facilities like PROSCAN



- With the combination IFC1210 / SCB and P-IO link it is simple to build redundant systems





Outlook

Where is the project today?

- Technical commissioning of Gantry3 started in November 2015
- G3 PaSS is in operation since November 2015
- No changes on the logic since February 2016
- Final integration tests have to be done
- 1st patient is planned for early 2017

Future projects

- Platform can be used for a technology upgrade of existing PSI PaSS systems
- Optical P-IO link communication can be used for performance optimization of the beam position verification system in Gantry2
- Flexible SCB – IO concept allows design of standalone controller independent of the VME platform.

Thank you for your attention