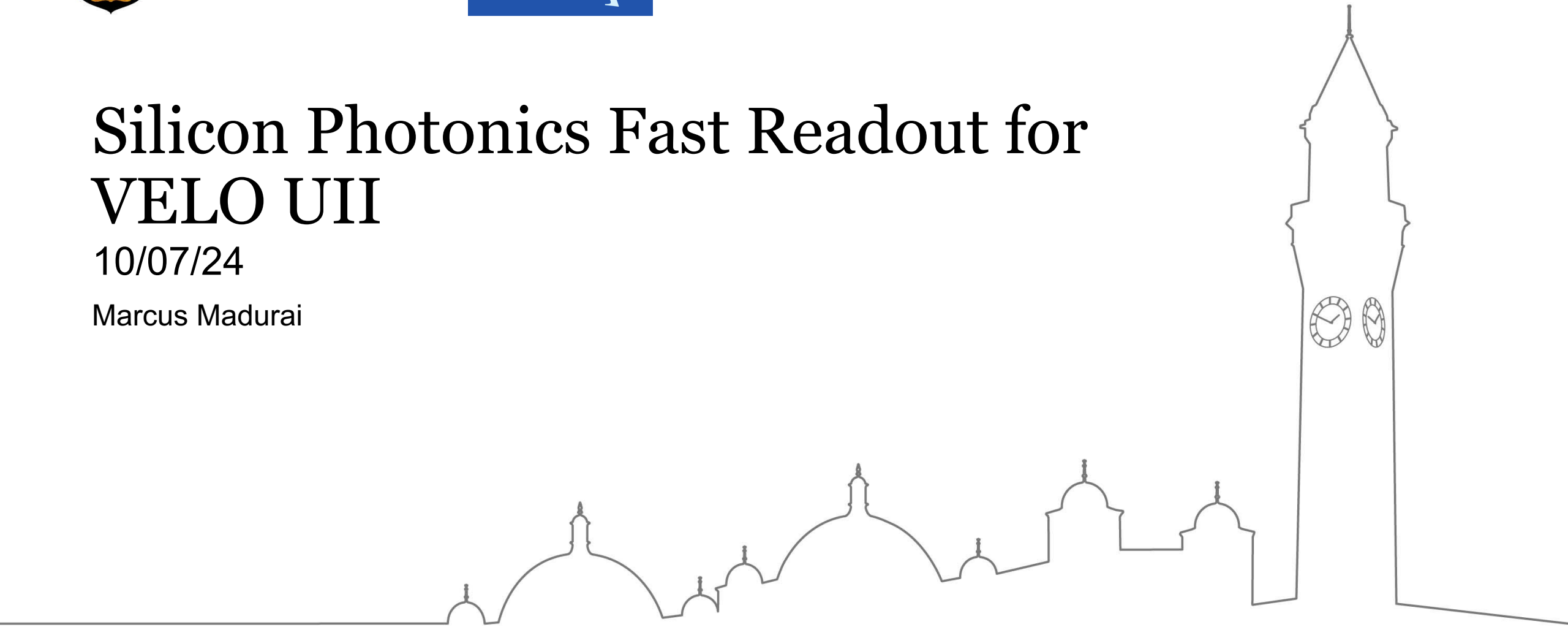
UNIVERSITY OF BIRMINGHAM

Silicon Photonics Fast Readout for VELO UII

10/07/24

Marcus Madurai

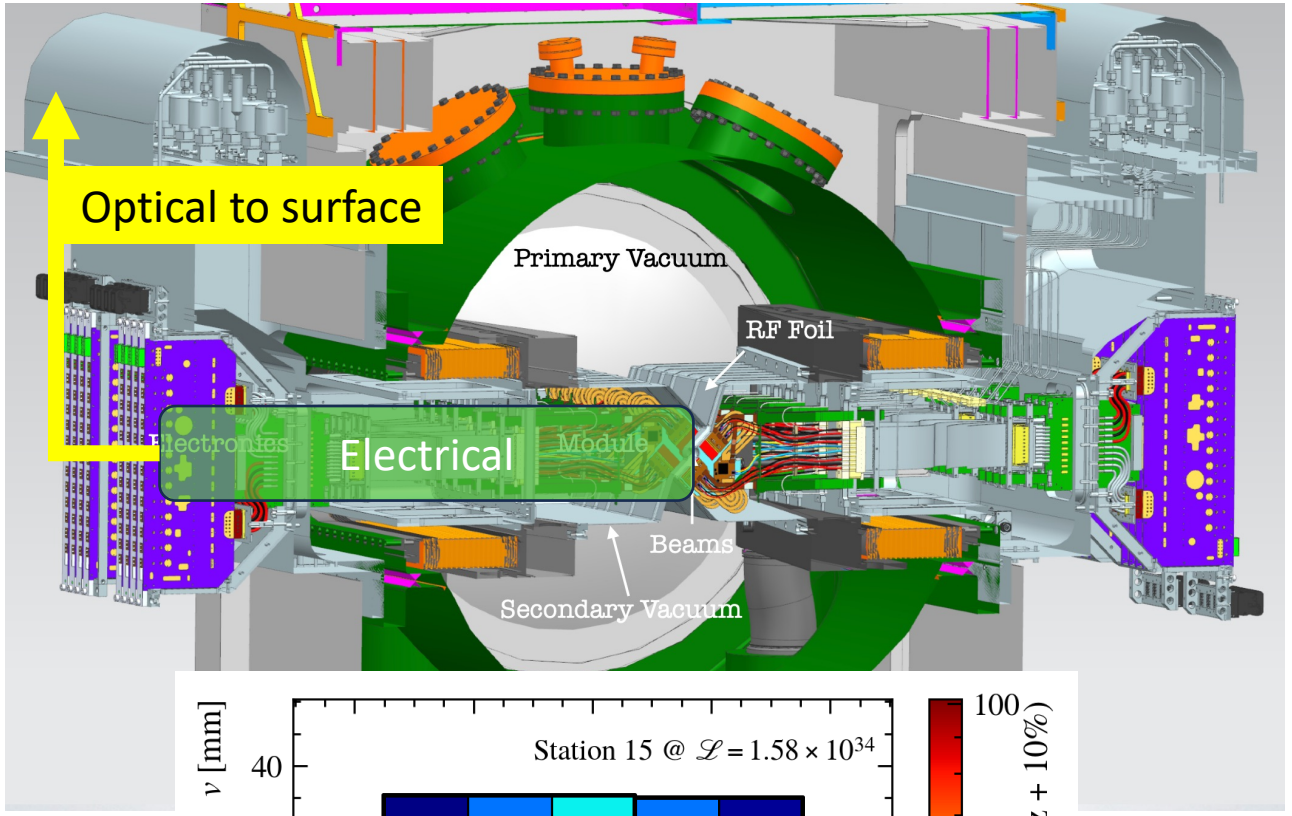


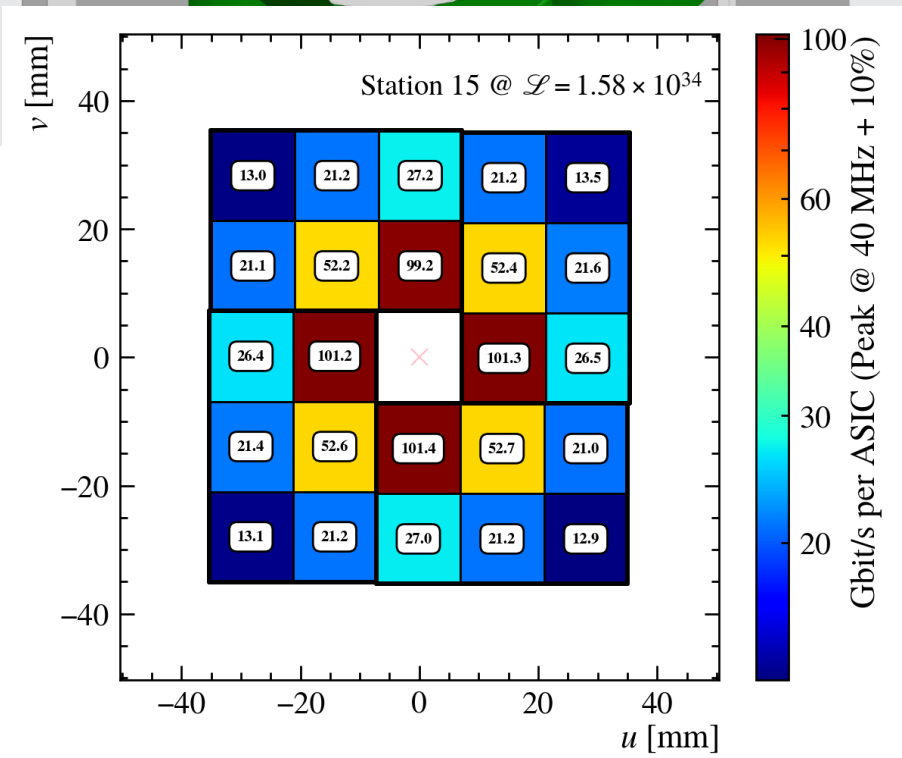
Introduction

- UI VELO peak 15 Gbps/HotASIC
- Electrical connections run 0.5 – 0.75 m from front end, through the vacuum to OPB boards. Each link 5.12 Gbps
- UII peak data rate ~100 Gbps/HotASIC with FE processing
- Two options foreseeable:

1. VTRx+ at 10.24Gbps per link → many links, material
2. Silicon Photonics can offer ~100Gbps per link
   - Minimal power consumption and size

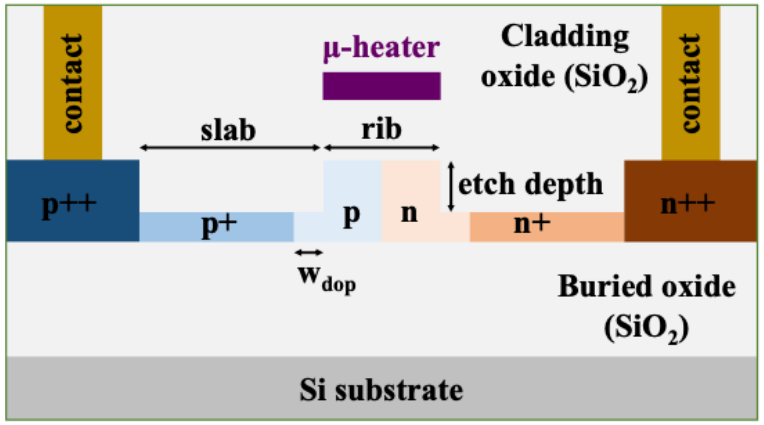
- CERN EP-ESE WP6 High Speed Links developing SiPh for last ~ 4 years

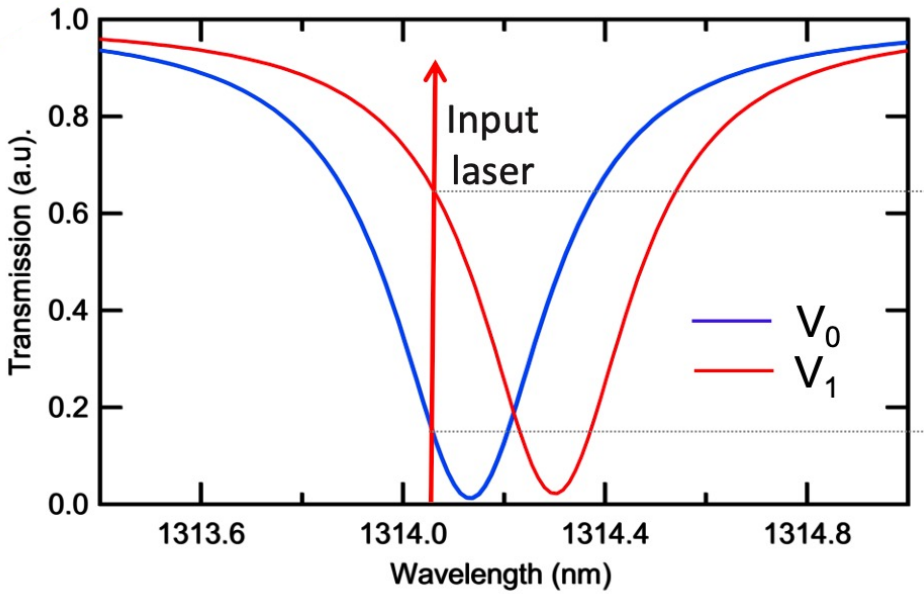


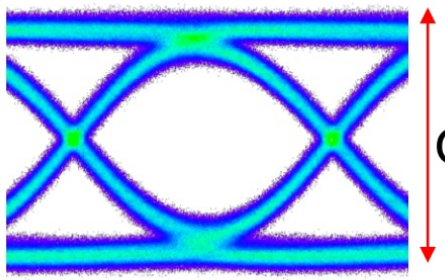


Photonic IC

- Photonic IC (PIC) contains Ring Modulators (RMs) that modulate signal onto light. Also:
  - Fibre couplers
  - Waveguides
  - Polarisation structures
- Electro-optical effect
- Thermal-optical effect







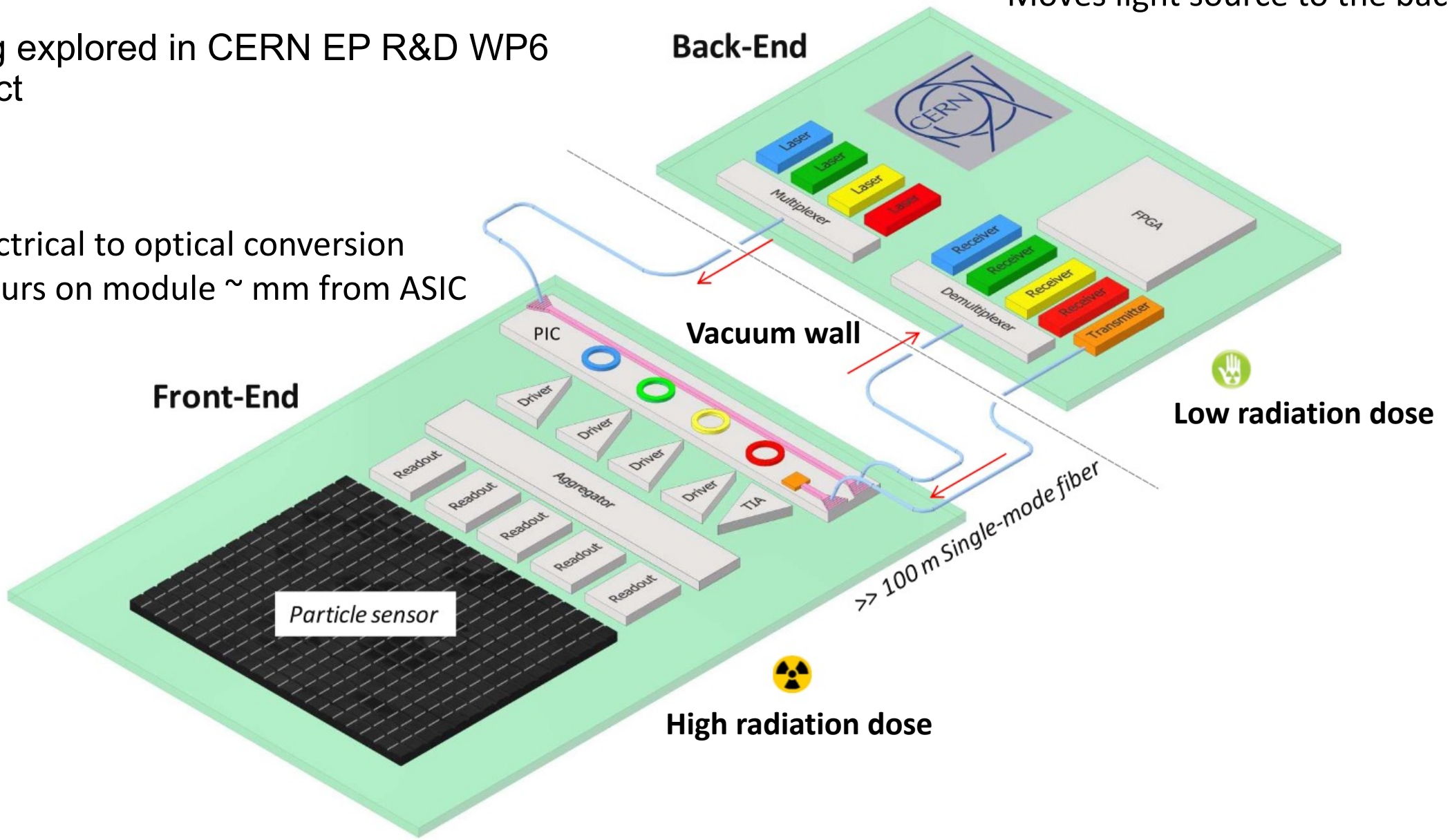
(Optical Max Amplitude)

Photonic Solution

- Being explored in CERN EP R&D WP6 project

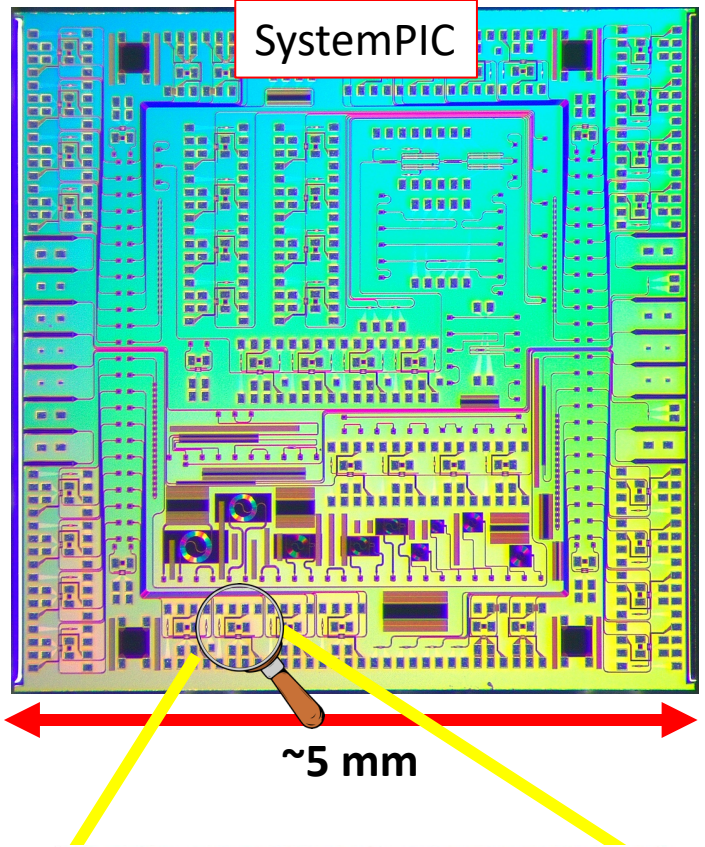
Moves light source to the back end

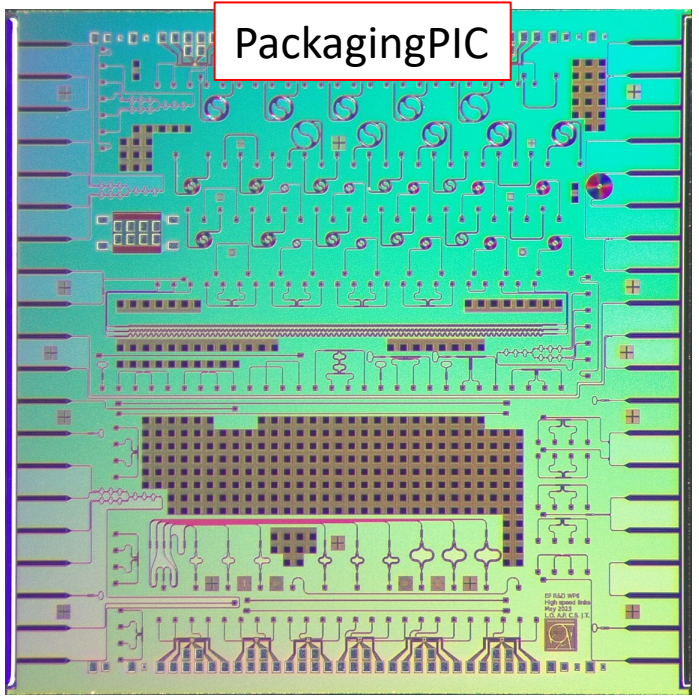
Electrical to optical conversion occurs on module ~ mm from ASIC

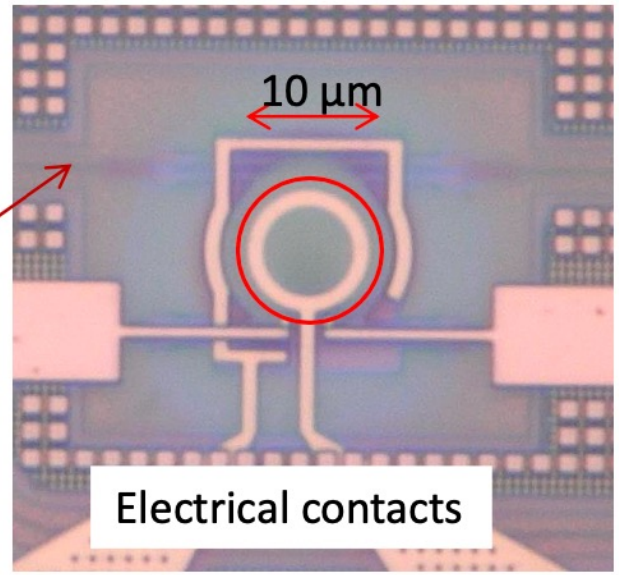


WP6 R&D @ CERN

- Two development chips
- SystemPIC (third iteration) submitted Q2 2022 received Q1 2024
  - Slight variations to RM design parameters
  - On chip polarisation test structures
  - Move to nominally use O-band to align with off the shelf components
- PackagingPIC submitted Q4 2022 received Q1 2024
  - No active modulators
  - Vary micro heater design
  - Fibre edge coupling

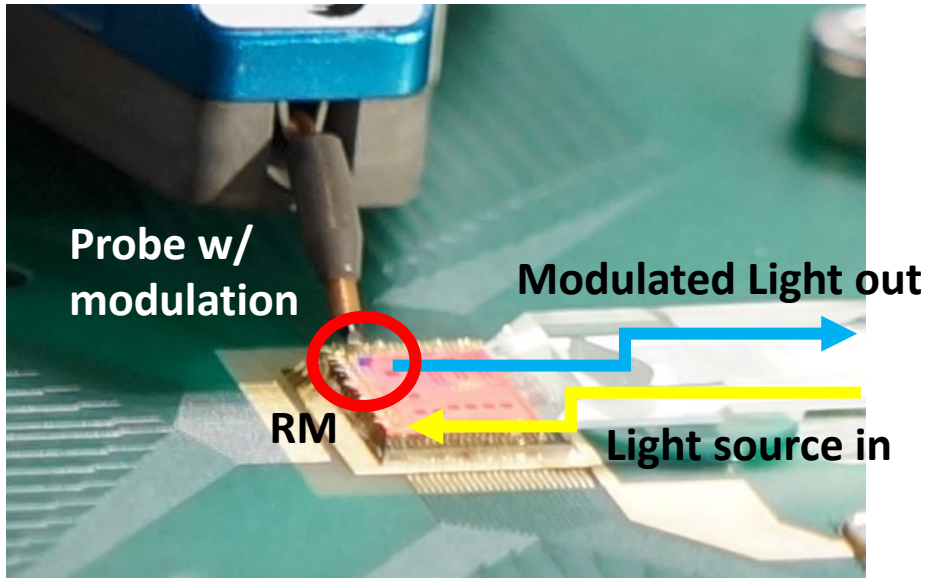


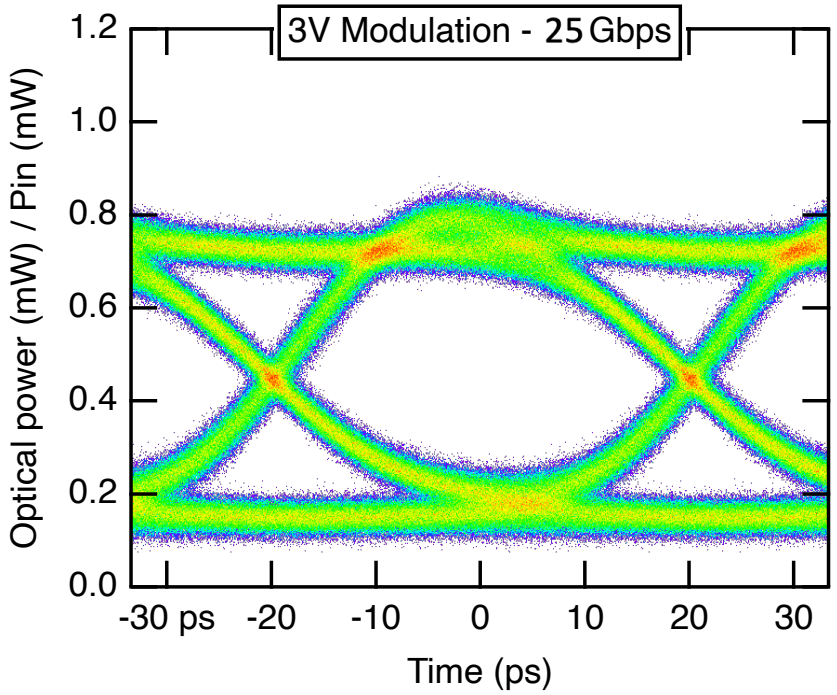


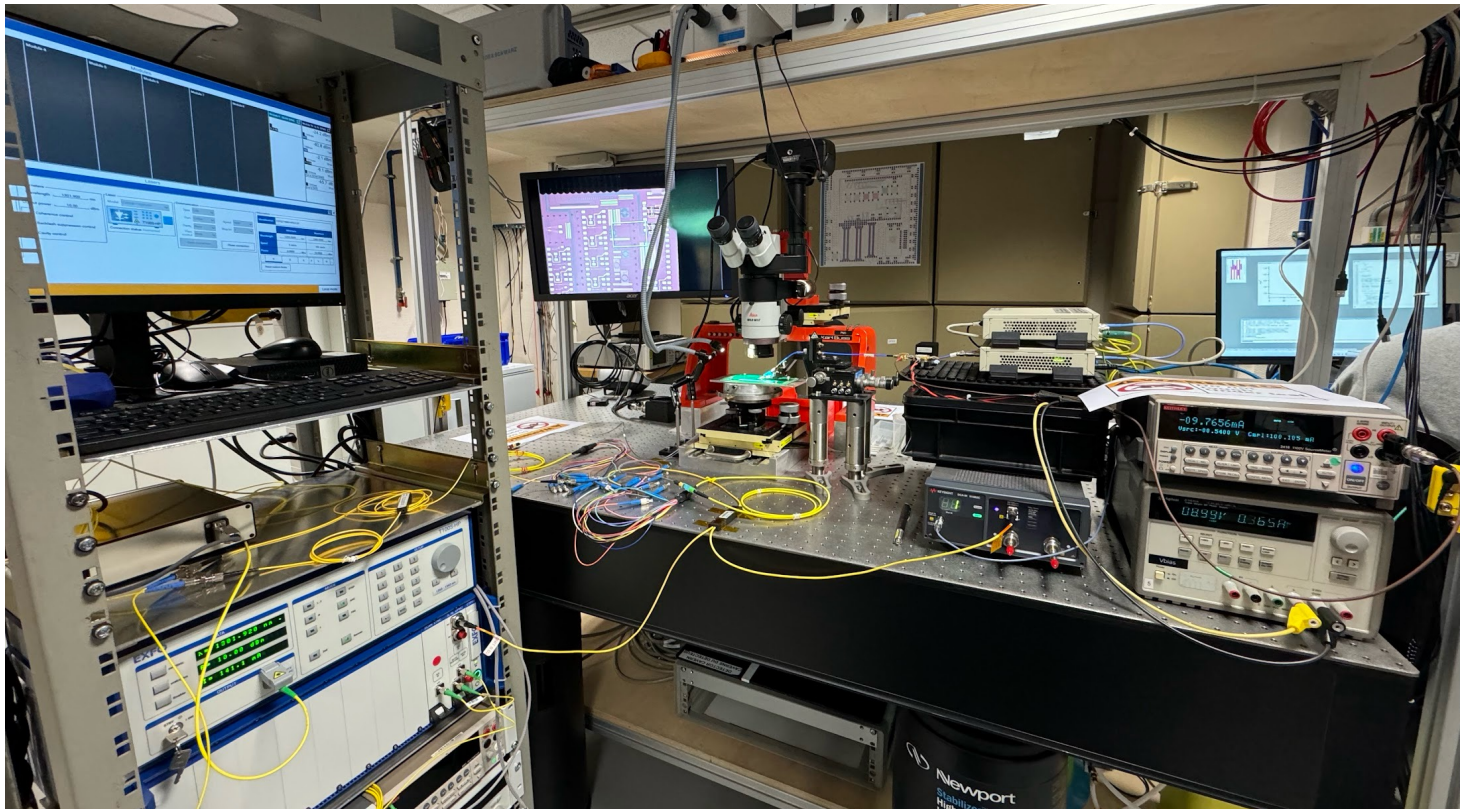


SystemPIC Characterisation

- Dynamic measurements @ CERN
- Tuneable laser to sweep wavelength and power meter to acquire spectrum
- High speed 40Ghz bandwidth probe to modulate pseudo-random 25Gbps signal
- Measure eye diagram and efficiency

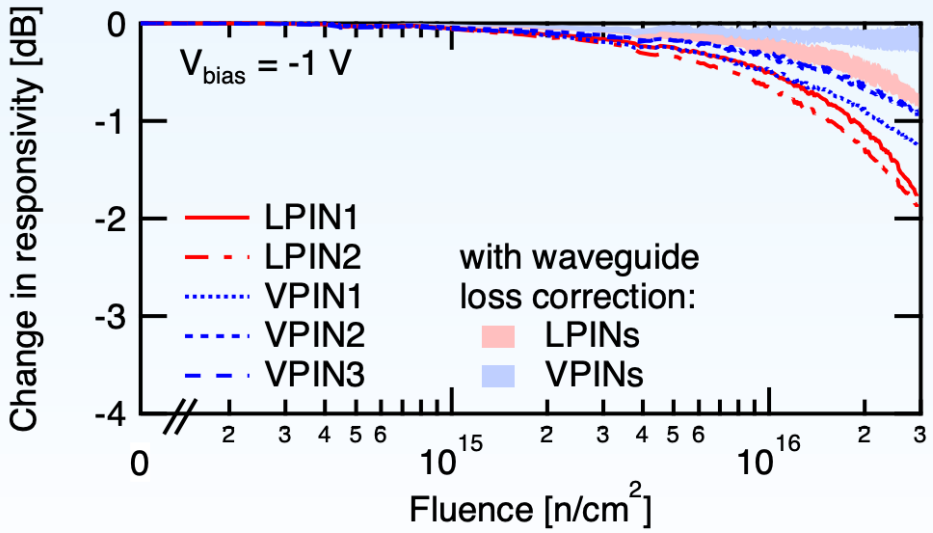


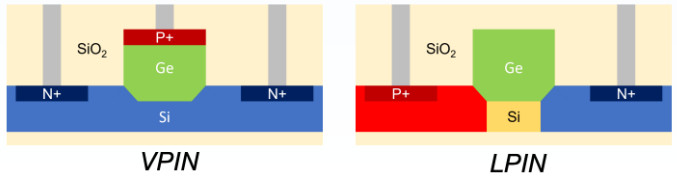




PIC Irradiation

- Radiation tolerance studies have investigated the impact of Ring Modulator design parameters and impact of temperature on device degradation
  - High-levels of doping in the RM junctions make these devices radiation tolerant
  - Raising device temperature using built-in micro-heaters further improves radiation tolerance
  - Small amounts of forward current are also effective at annealing radiation damage
- Heterogenously integrated Germanium Photodiodes will be a key component in bi-directional links
- Extensive study of irradiation of Ge-PDs show impressive radiation tolerance
  - With small reverse bias, Vertical Junction PIN photodiodes are tolerant well beyond 10^{16} /cm^2

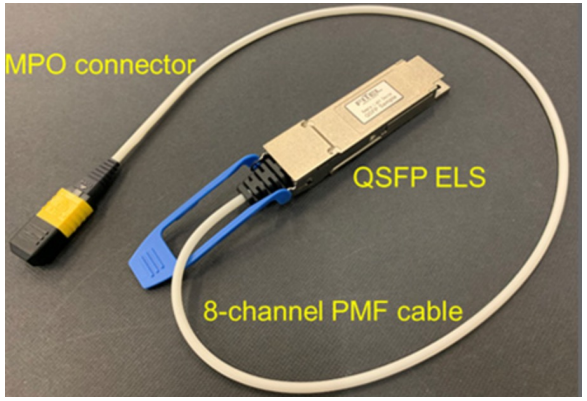


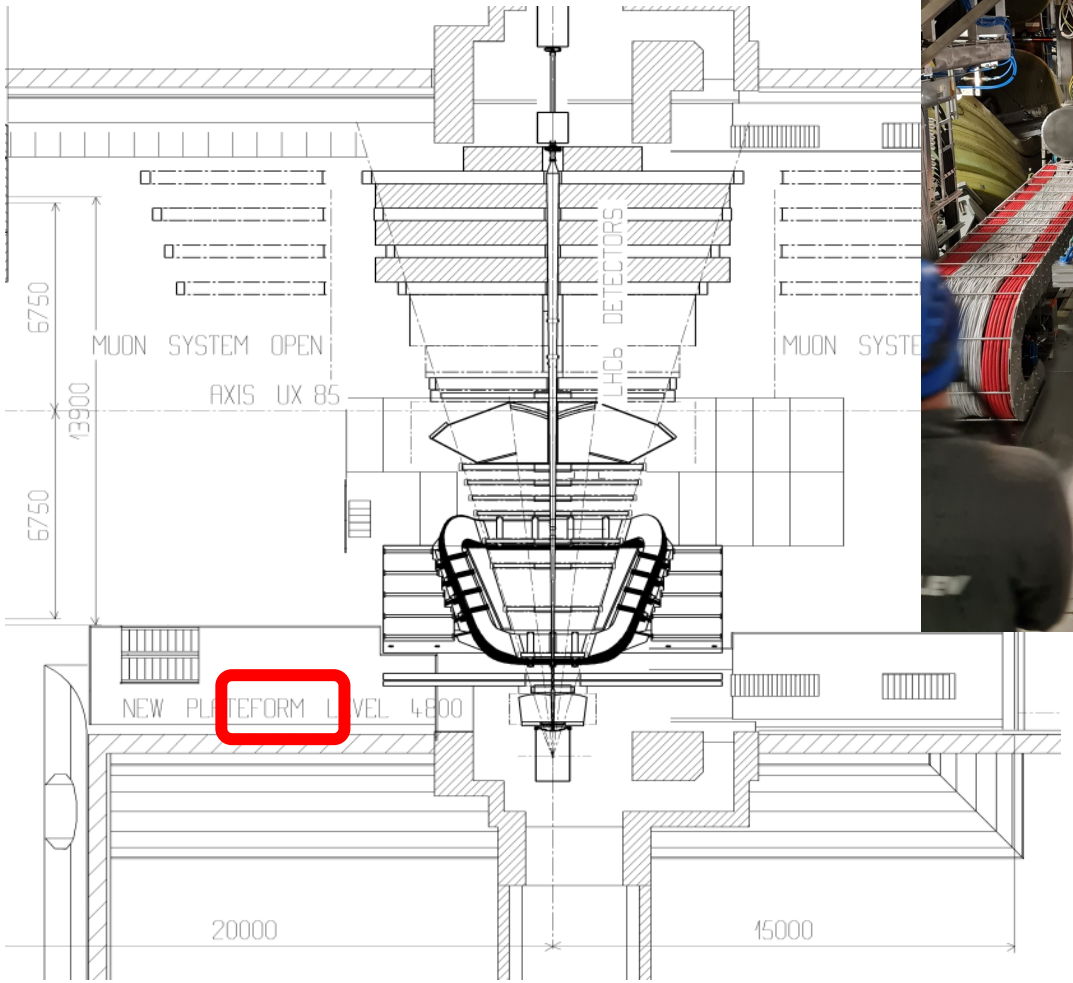


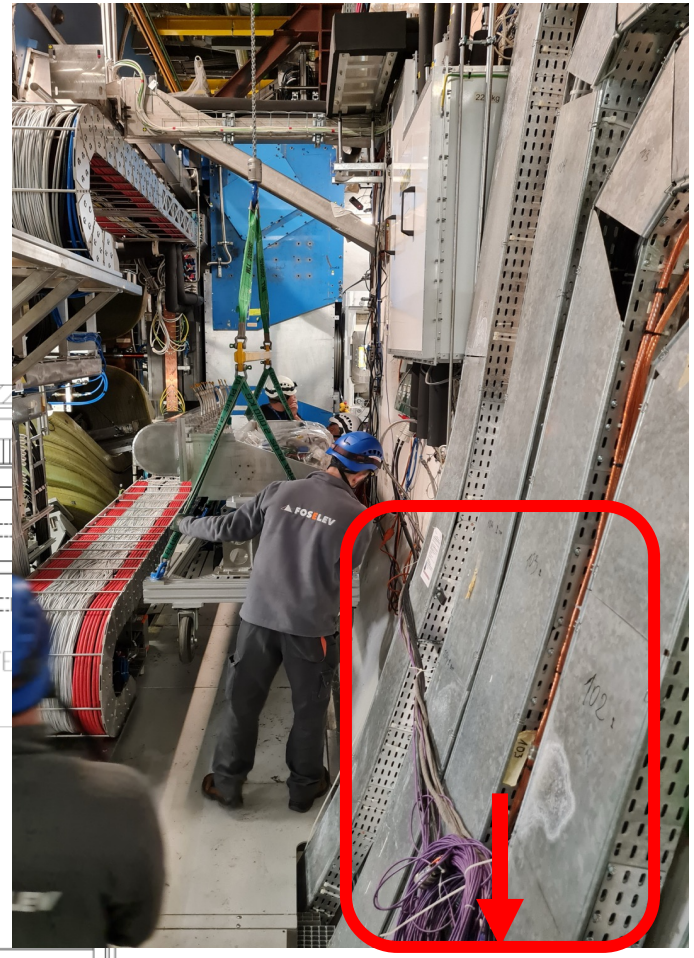
From Jan Troska EP R&D week

Light Source

- Questions surrounding light source integration to be answered
- Target new industry agreement (Multi Source Agreement QSFP External Light Source)
- Location and mounting in cavern
- Radiation tolerance
  - Dependant on light source location
- Other considerations:
  - Temperature / humidity
  - Wavelength / power stability
  - Electrical power supply
- Control system

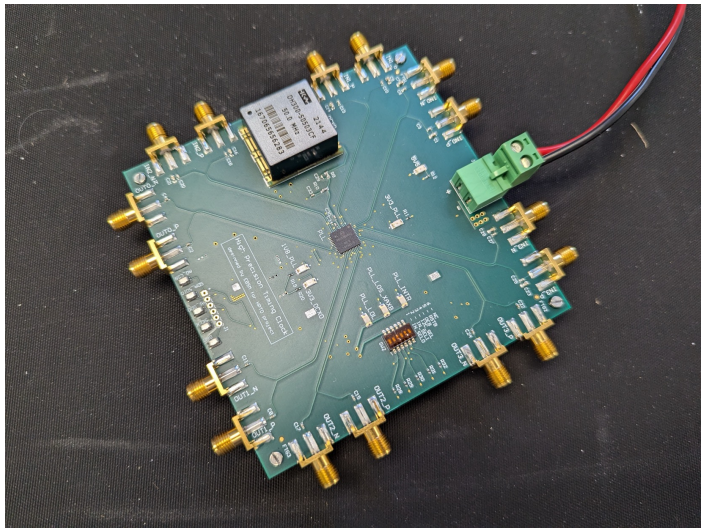


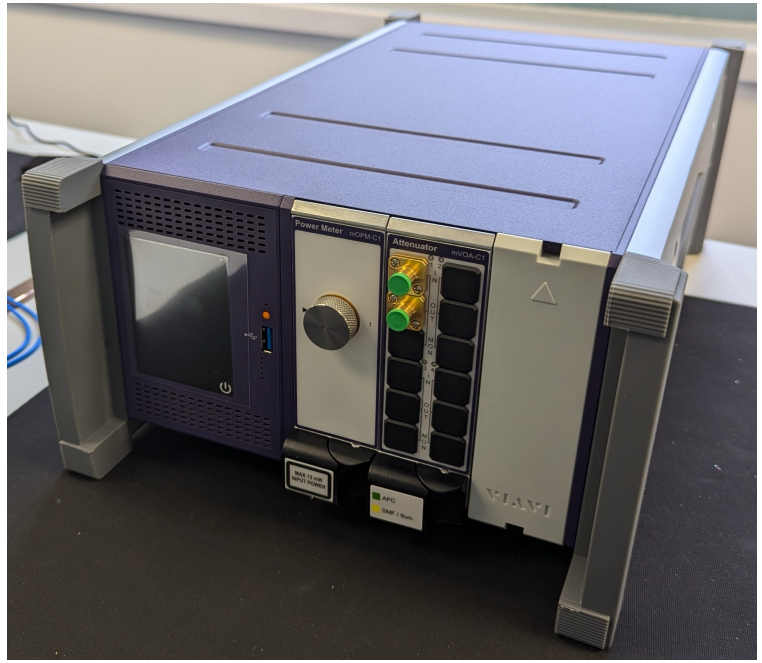


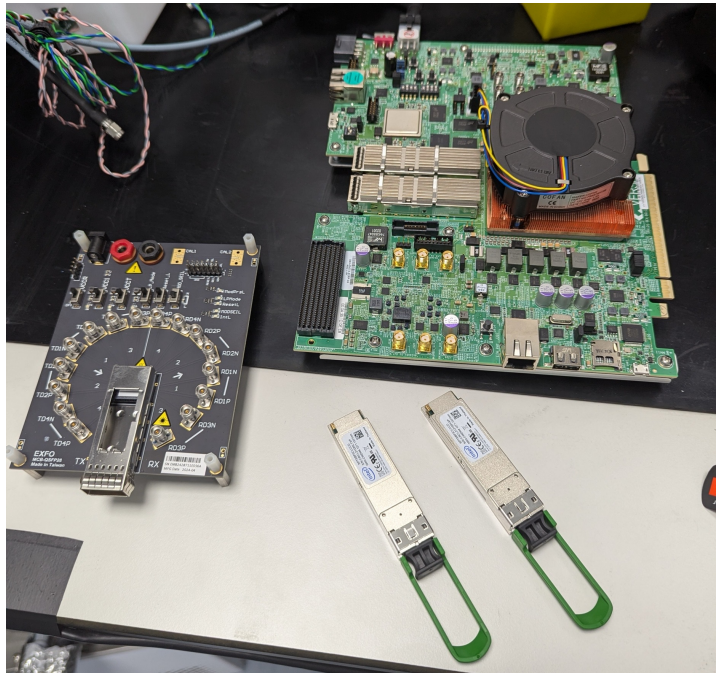


UK Activity

- Aim to build demonstrator for a SiPh link close to final integration into VELO
- Purchased various equipment:
  - High speed FPGA signal generator
  - Optical interconnects
  - Transceiver
  - Power meter
- Incorporate DART28 + PIC
- Light source acquisition and integration
- Irradiation tests as appropriate
- Environmental studies
  - Climate chamber
  - Vacuum vessel (courtesy of Oxford)







Person Power

- MM on LTA collaborating with WP6 team
- CERN doctoral student (co-supervised by Birmingham) at CERN in WP6
- FT technician + engineer posts to be advertised imminently
- Three academics
  - Karol Krizka (BILPA)
  - Daniel Johnson
  - Nigel Watson

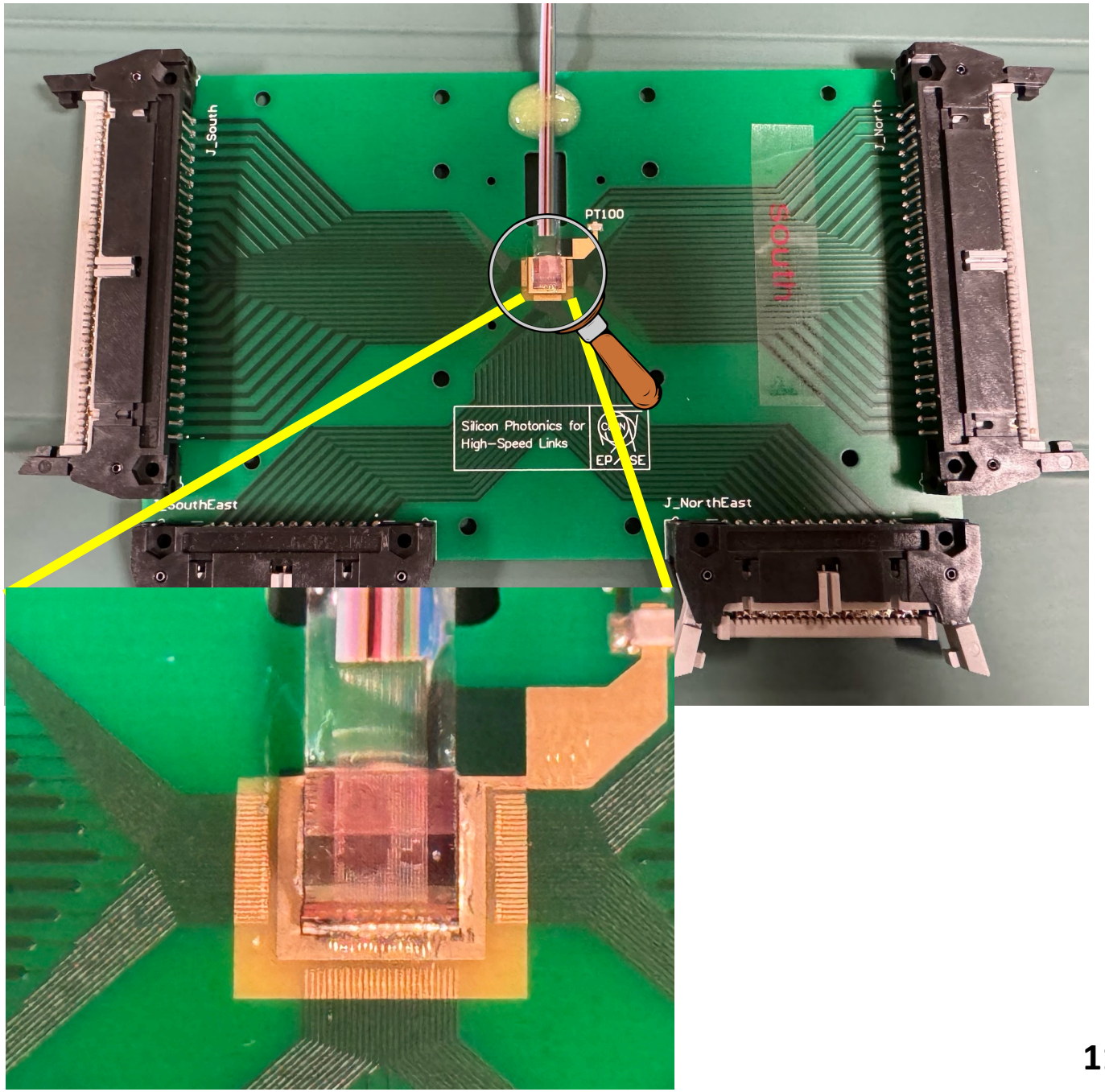
Birmingham Instrumentation Laboratory for Particle physics and Applications

BILPA

Summary

- PIC offers compact, radiation hard solution to UII VELO data rate challenges
- Mature program of SiPh development in EP-ESE WP6
- Strong partnership with EP-ESE
- Broad programme of activity in the UK
- **Next step is to define system specifications for TDR**

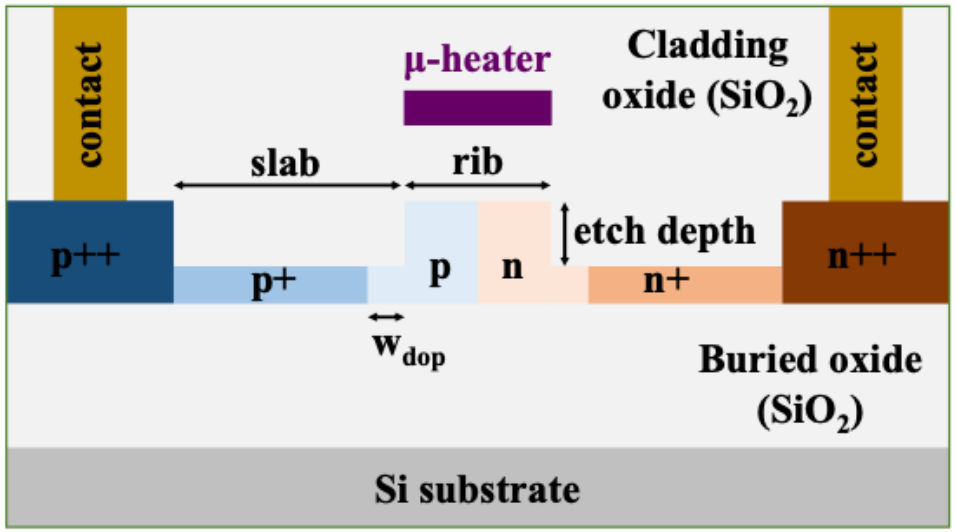
Many thanks to J. Troska, C. Scarcella, L. Olanterä, D. Alfiero, J. Buytaert, F. Martina, K. Wiley from CERN and A. Prieto, A. Torreira from USC!

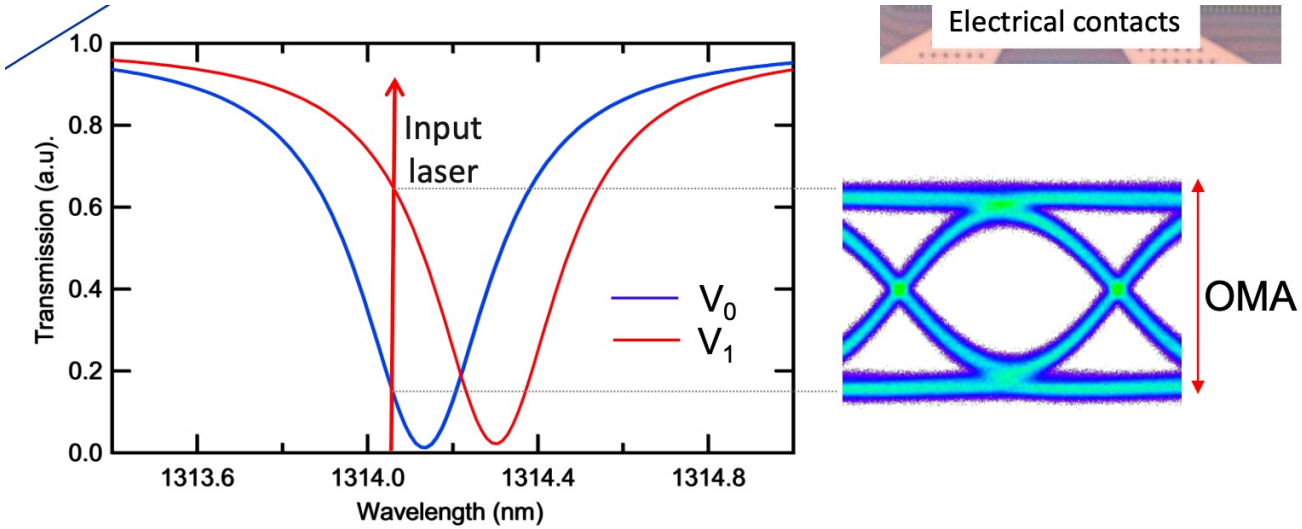


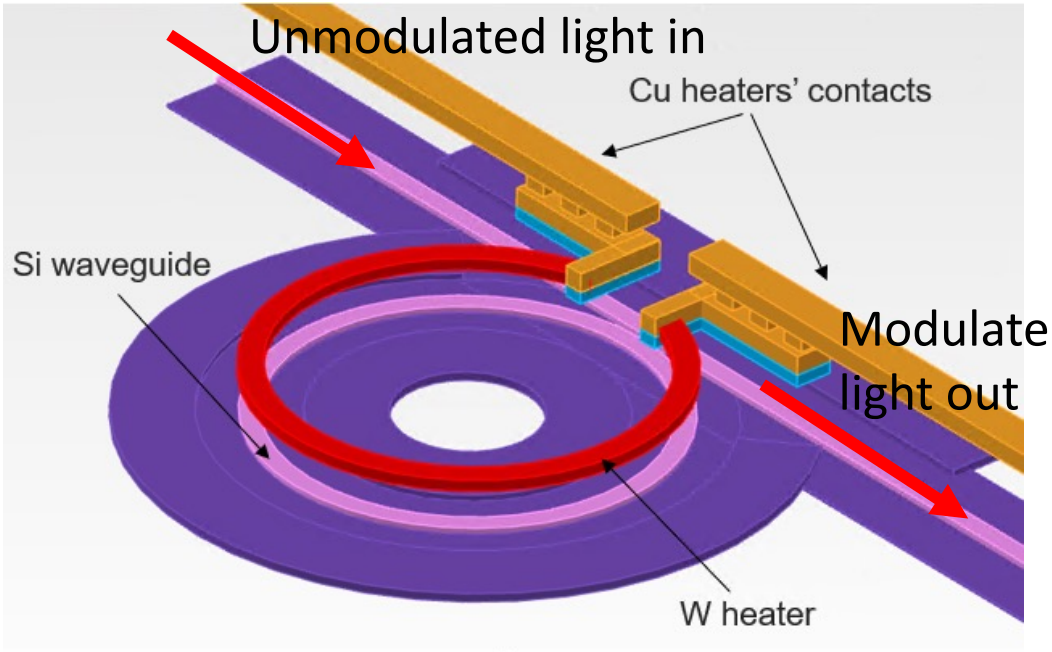
Backup

Ring Modulators

- Straight waveguide passed by circular waveguide
- Output optical power decreases at resonance
- Resonance wavelength rapidly altered by changing voltage across ring
- Modulate optical path of ring hence modulates the optical power







Ring Modulators