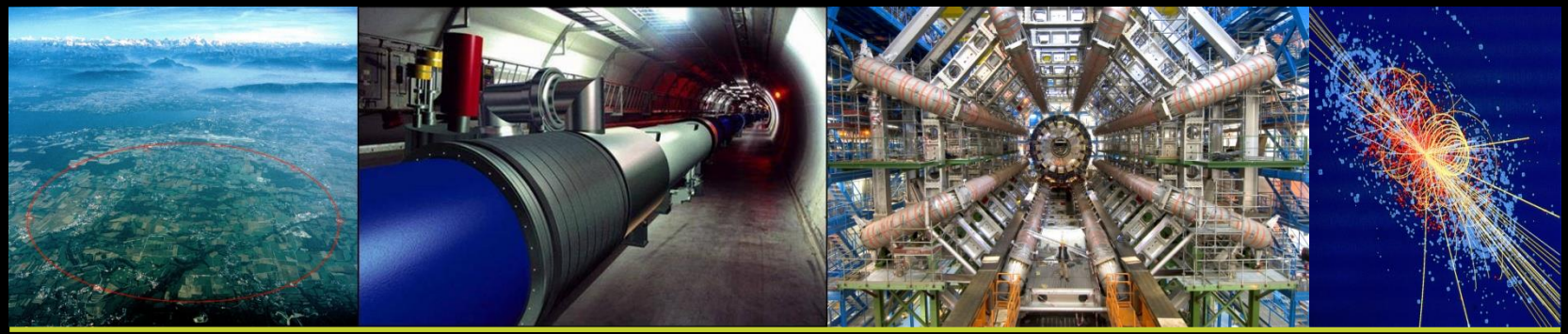


Instrumentation for Accelerators

Technologies for the HL-LHC

Hi-Lumi LHC Goes to Industry

26th June 2015

Dr. Ray Veness

CERN Beam Instrumentation Group

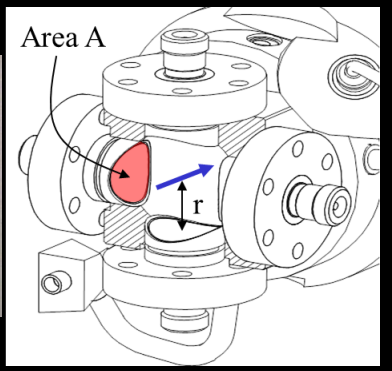
Contents

- Introduction to accelerator beam instrumentation
- Examples of technologies required for HL-LHC
- Summary and immediate needs

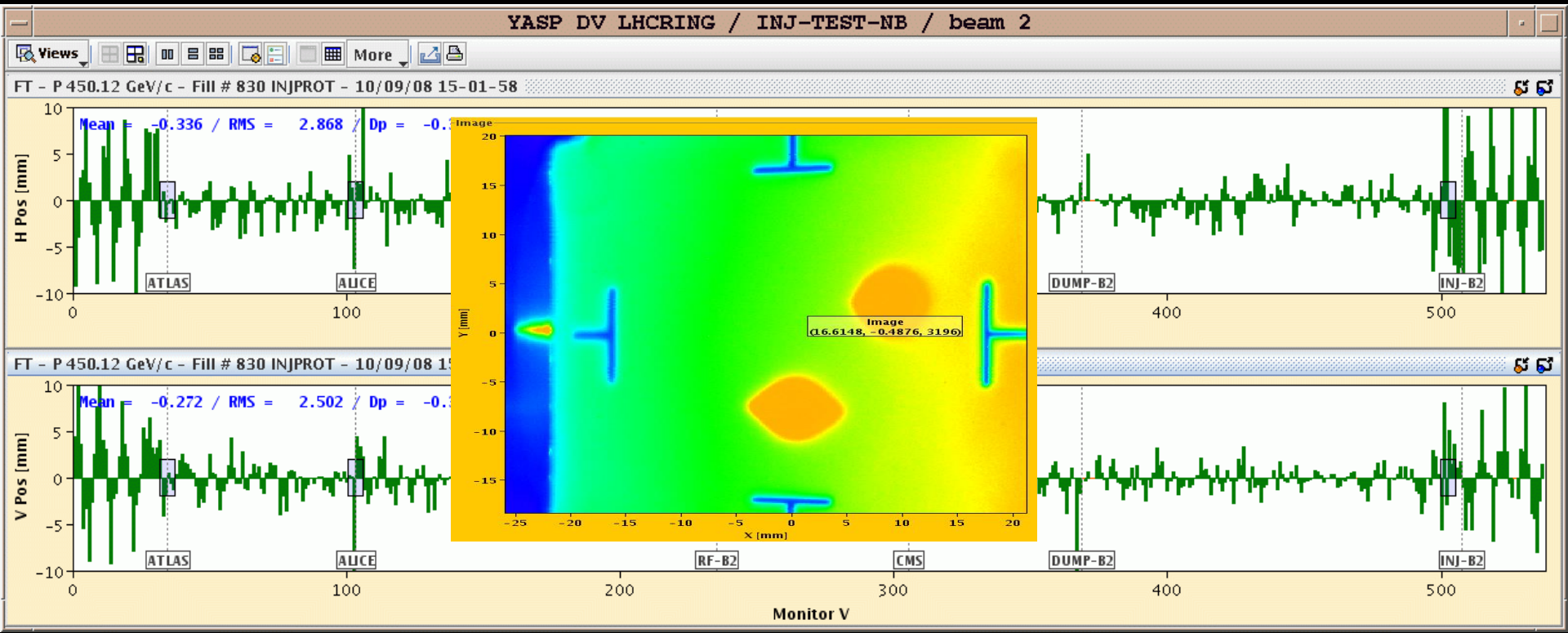
Beam instrumentation in the LHC

Controlling the Beams

- Beam Position
  - Over 500 monitors for each LHC beam
  - Measures position & allows automatic feedback on magnet strengths to stabilise at ~10 micron level



27km

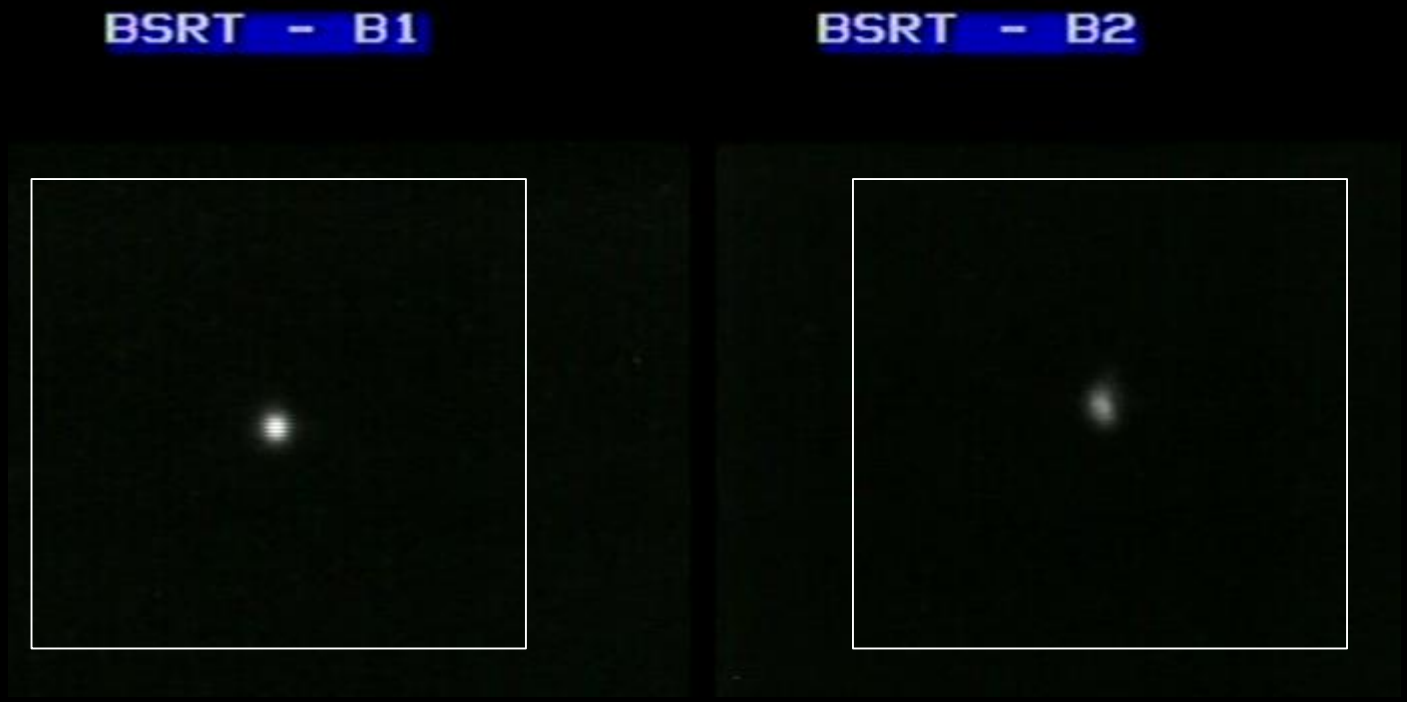


Keeping the beams safe

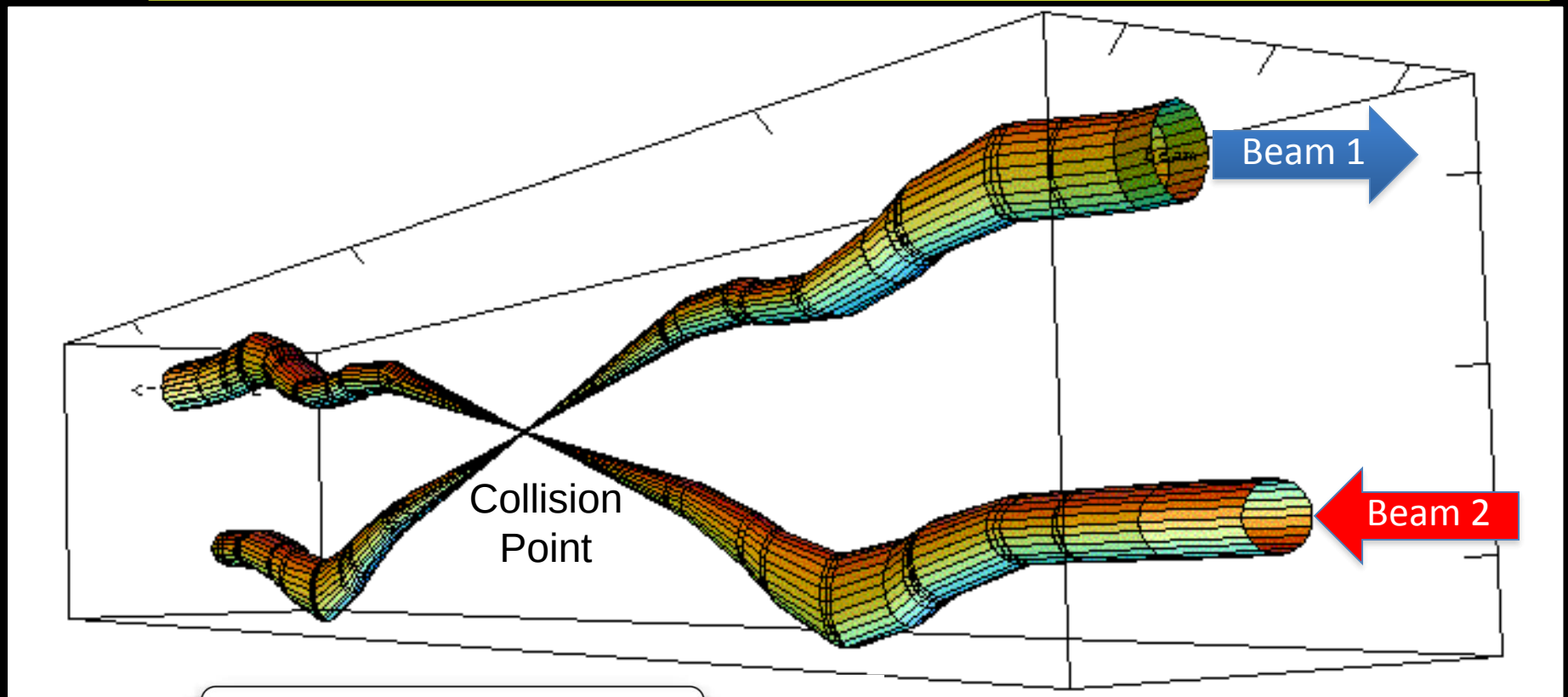
- Beam Loss
  - Almost 4000 ionisation chambers to detect any particles which escape
  - Such losses can locally heat the superconducting wires
  - Can render them normal conducting (quench) or even damage components

Optimising performance

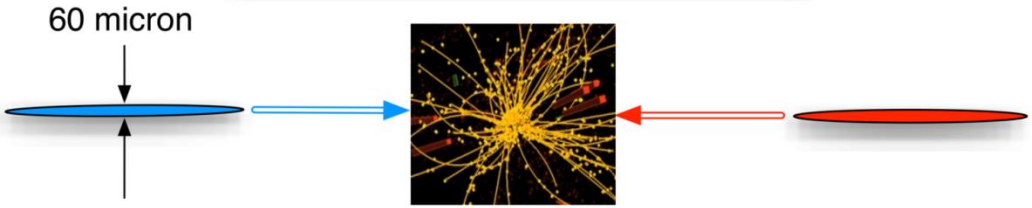
- Beam Size
  - Beam size can be measrued in many ways
  - In LHC the proton energy is high enough for them to emit visible light when they are bent by dipole magnets
  - Imaging this light can give a direct measure of the transverse beam size



Maximising collisions



140,000,000,000 protons a bunch
~30 collide at each bunch crossing



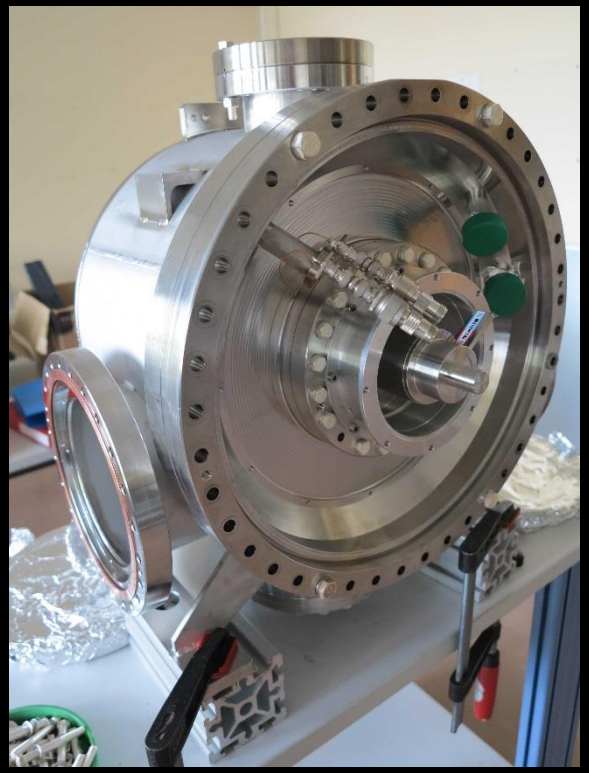
~30 collisions per crossing
11,000 crossings per second per bunch
1380 bunches
~400 million collisions per second

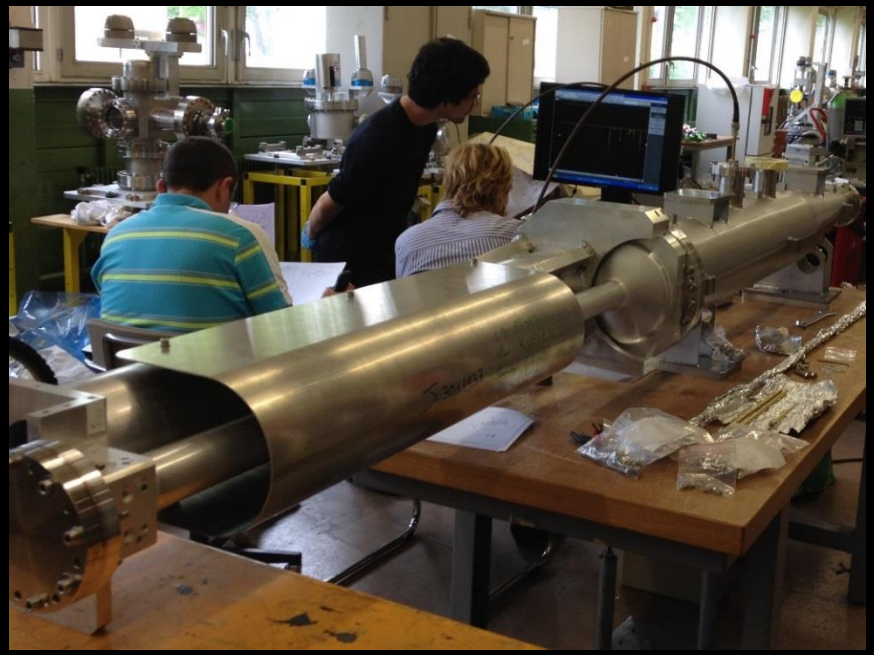
Beam Instrumentation

- Some numbers:
  - ~2500 instruments integrated into the beam vacuum system of the accelerators (including the LHC and it's injectors)
  - ~4500 instruments close to the beamlines, in the accelerator tunnels
- What is an instrument?
  - Mechanics: vacuum chamber, movement systems, beam intercepting devices
  - Detectors: Cameras, scintillators, transformers,
  - Electronics: Fast, radiation hard, analogue and digital
  - Software: acquisition, low-level controls

Mechanical Engineering

Instrument Construction

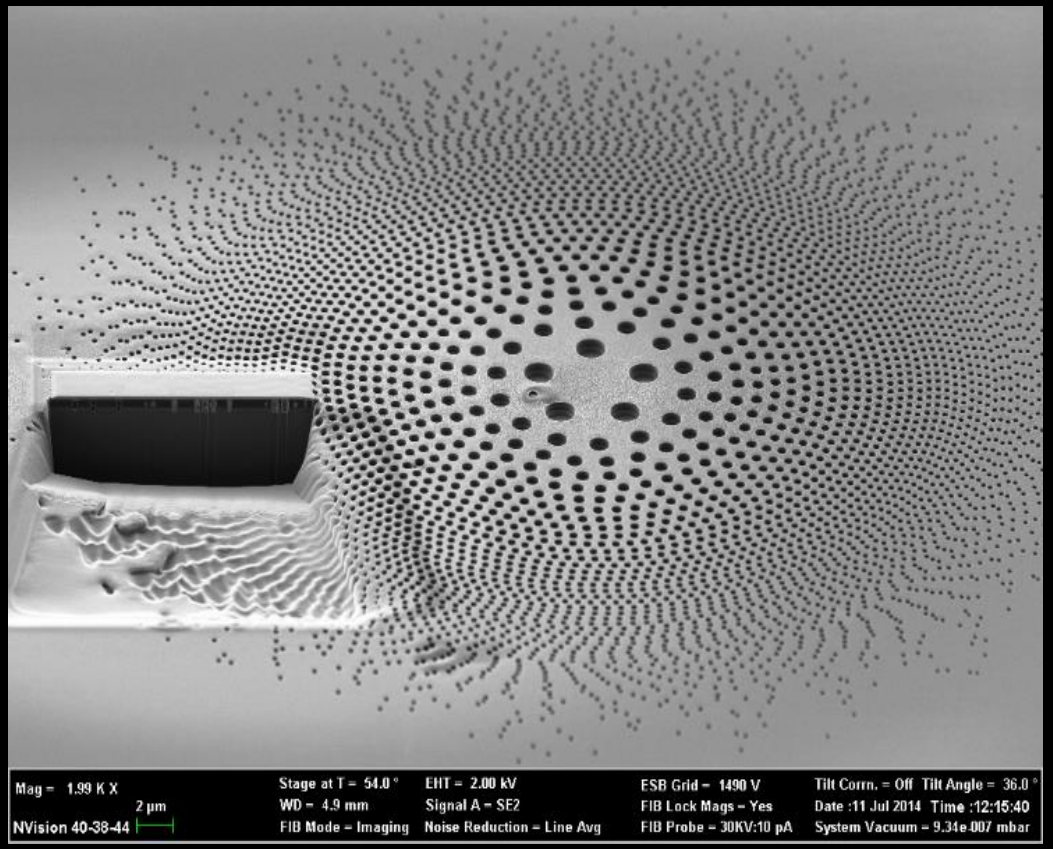




- Precision electro-mechanical instruments
  - Wire scanners for beam profile measurements
  - Beam-Gas vertexing detector for profile measurement

Mechanical Engineering

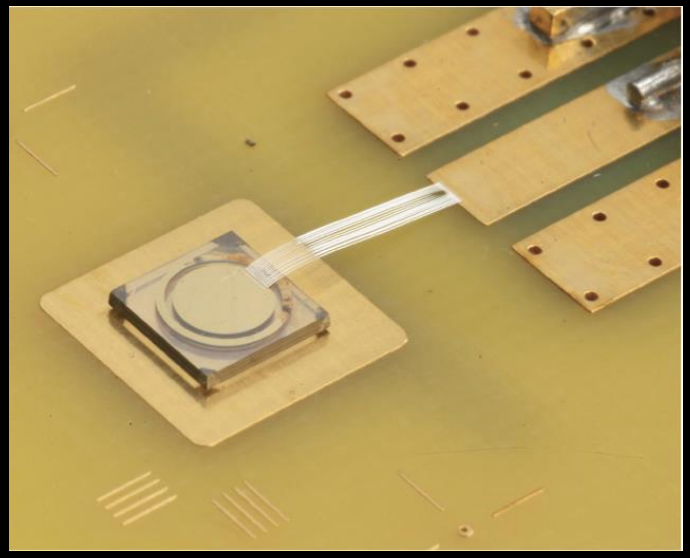
Structure Optimisation & Novel Production Techniques



- Taking advantage of new production techniques
  - Structure optimisation for production using 3D additive machining
    - Beam wire-scanner forks
  - Novel instrumentation devices requiring precision machining
    - Atomic sieve for quantum interference to achieve small diameter gas jets

Use of Semiconductors as Detectors

Diamond detectors for beam loss measurements

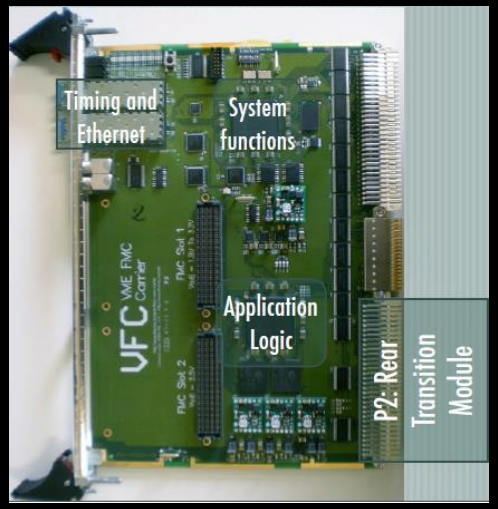


- Silicon & Diamond Detector Tests for Applications at 2 K in harsh radiation environments
  - Fast, sensitive and compact beam-loss monitoring
  - Already used at ambient temperature in LHC to distinguish bunch by bunch losses
  - Investigations now ongoing to see if they can work in cryogenic conditions under irradiation
  - Looking for industrial partners for ‘integrated instrument’ supply

Optical Signal Processing

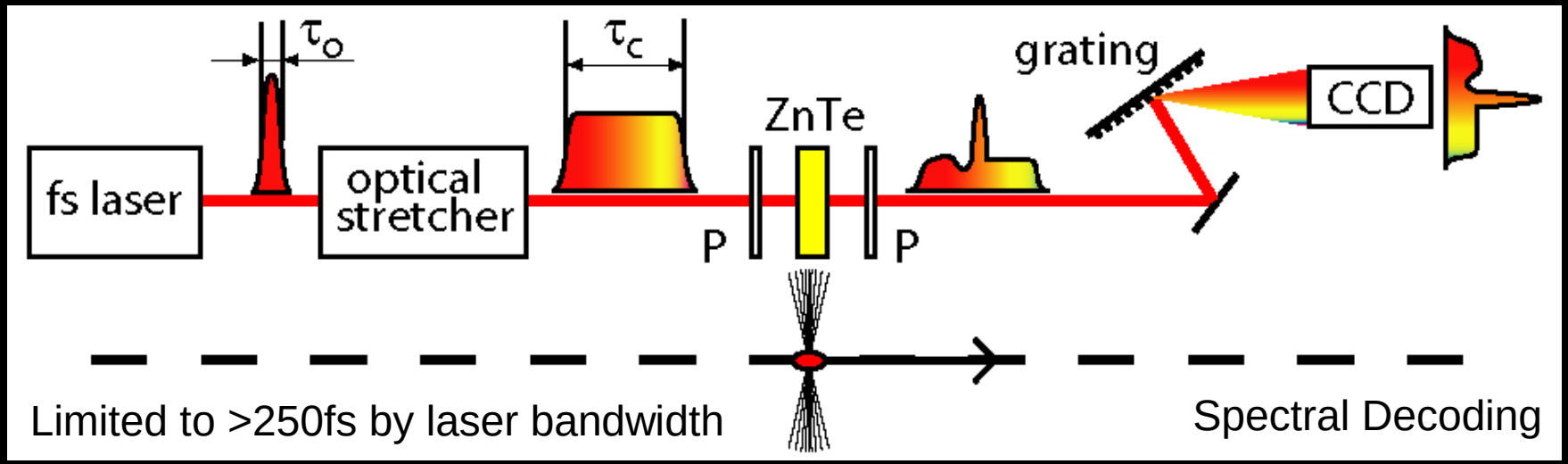
Fibre optic transmission

- Analogue and digital optical links
  - Distributed LHC beam instrumentation transmits information from radiation hard front-end electronics to surface electronics
    - 500+ stations with over 3000 links
    - Over 5000km of fibre-optic cabling
    - Radiation hard transmitters/receivers & optical fibres
- Next Generation
  - Radiation hard Gbit Links (GBT developed by PH Department)
  - Digital signal processing on custom FPGA motherboard



Longitudinal beam imaging

Electro-optical techniques

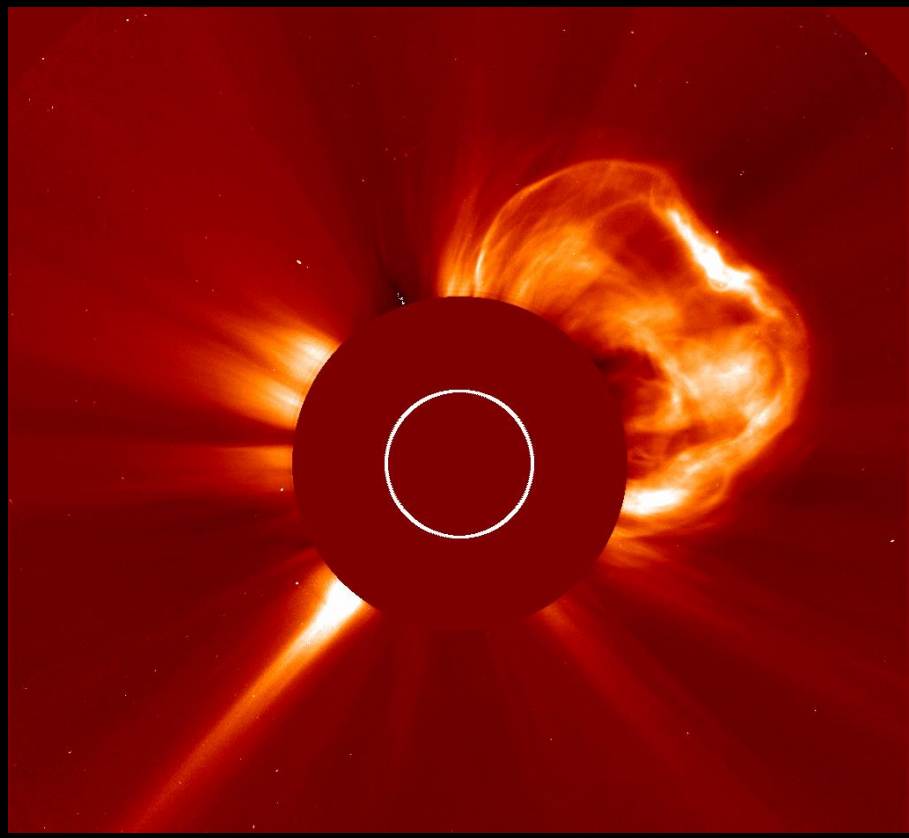


- Non destructive measurement of using lasers and electro-optical crystals
  - Femtosecond lasers, precision optics, fast cameras
- ‘Streak Cameras’ for longitudinal imaging
  - ~100 Femtosecond time resolution

Optical Signal Processing

Beam halo monitoring

- Several methods under investigation for beam halo monitoring
  - Synergies with solar and exoplanet studies
- Imaging requirements
  - High dynamic range cameras with state-of-the-art range (upto 28-bit)
  - Digital intensified cameras with nano-second time resolution and high-resolution gated image intensifier



Summary

- Beam Instrumentation at CERN
  - Design, construction & operation of instruments to observe particle beams
  - R&D to find new or improve existing techniques to fulfill new requirements
  - Work in close collaboration, both with CERN groups and experimsnts, but with science and industry in our member states and beyond
- Areas of interest for the HL-LHC
  - Applied Physics
    - Electromagnetic detector technology
    - Gas detector technology
    - Solid state detector technology
    - Electro-optical systems
  - Mechanical Engineering
    - In-vacuum, high-precision mechanics & electro-mechanics
  - Electronic & Software Engineering
    - Radiation tolerance
    - Digital signal processing
    - High frequency electronic engineering
    - Low noise, low current measurement

Main procurement identified

What and When		
Description	**Quantity**	**When**
Semi-Rigid, Radio Frequency, Coaxial Cables utilizing glass-metal or brazed ceramic sealing technology for use in cryogenic and radiation environments.	250-350	2018-2020
Radio frequency UHV feedthroughs utilising glass-metal or brazed ceramic sealing technology for use in cryogenic and radioactive environments.	250-350	2018-2020
Packaged CVD diamond detectors for the measurement of particle beams	80-100	2017-2020
Scientific CMOS cameras Scientific High Dynamic Range Cameras Scientific Streak Cameras	5 1 + 2 2	2023 2016, 2023 2019

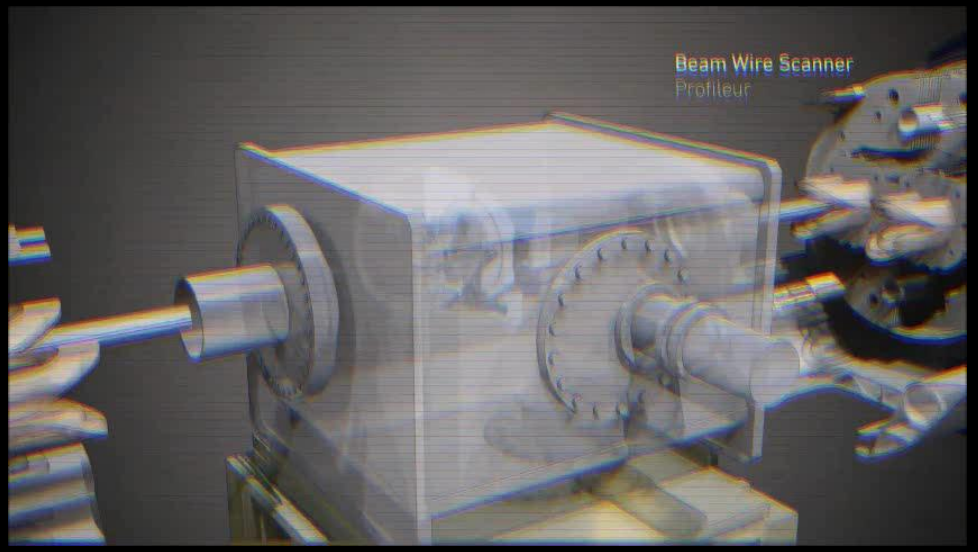
Instrumentation needs will continue to develop upto and beyond HL-LHC start-up

Thank you for your attention

Additional Material

Mechanical Engineering

Material Science



- Materials adapted for specific applications
  - Wires that survive intense beam impact in accelerator wirescanners