A new generation of arc detectors for the LHC and Linac4 high power RF system

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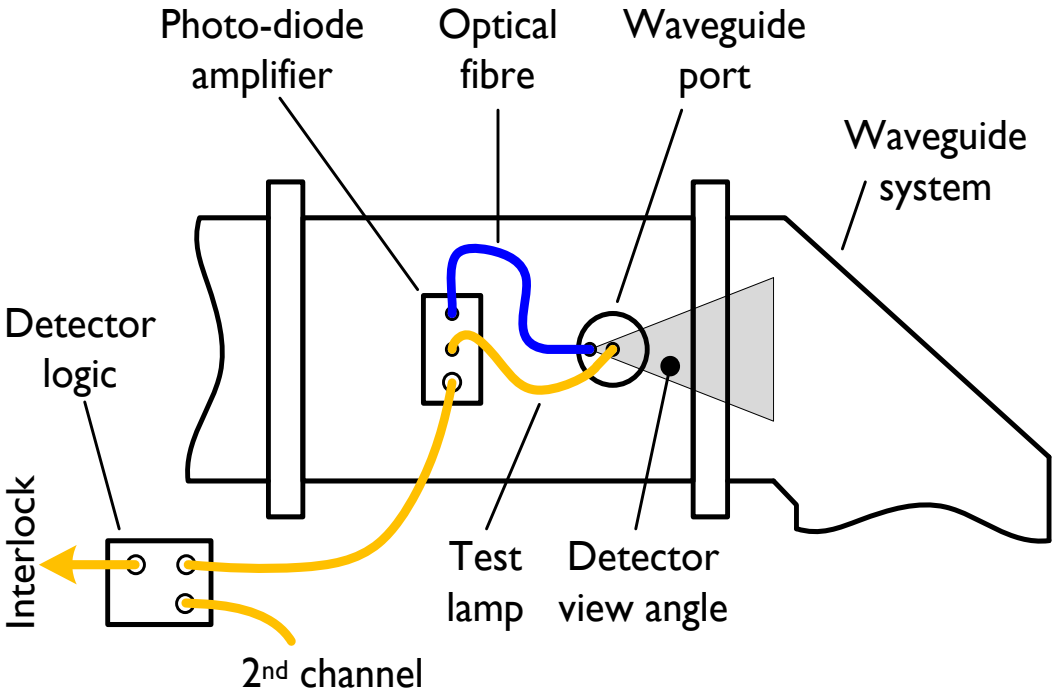
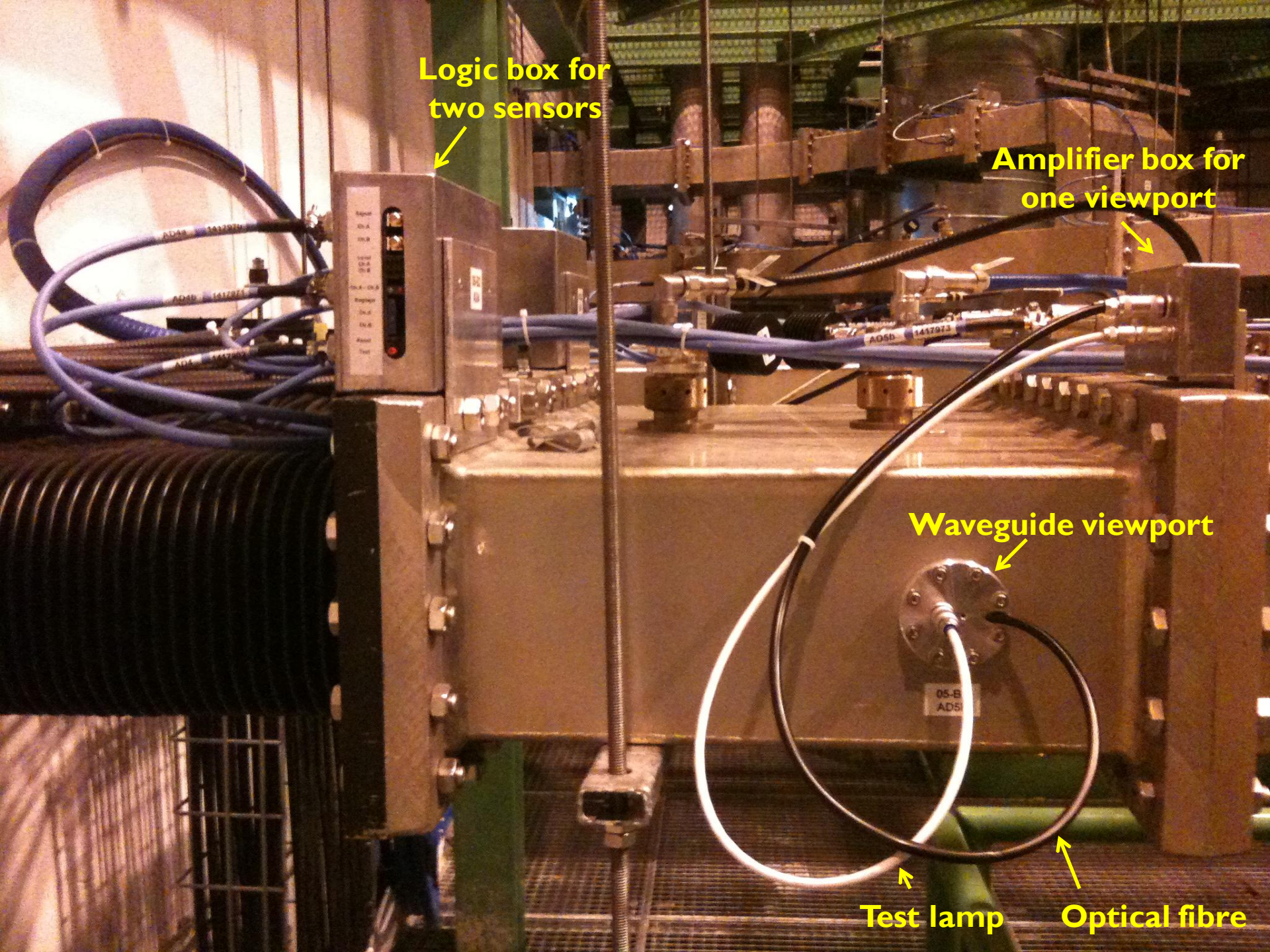
LHC RF system

- The LHC has 16 RF stations, each powered by 300kW / 400MHz CW klystron
- The waveguide system is protected by a system of optical arc-detectors
- Since Summer 2011 every trip of RF station is connected to the Beam Dump – false trips are very expensive in terms of physics time

Arc detectors currently in use

- Design of the current arc detectors inherited from LEP times:
  - Optical fibre + external photodiode amplifier
  - Detection condition "2 lux for 2 μs"




Logic box for two sensors
Amplifier box for one viewport
Waveguide viewport
Test lamp
Optical fibre

Arc detectors currently in use

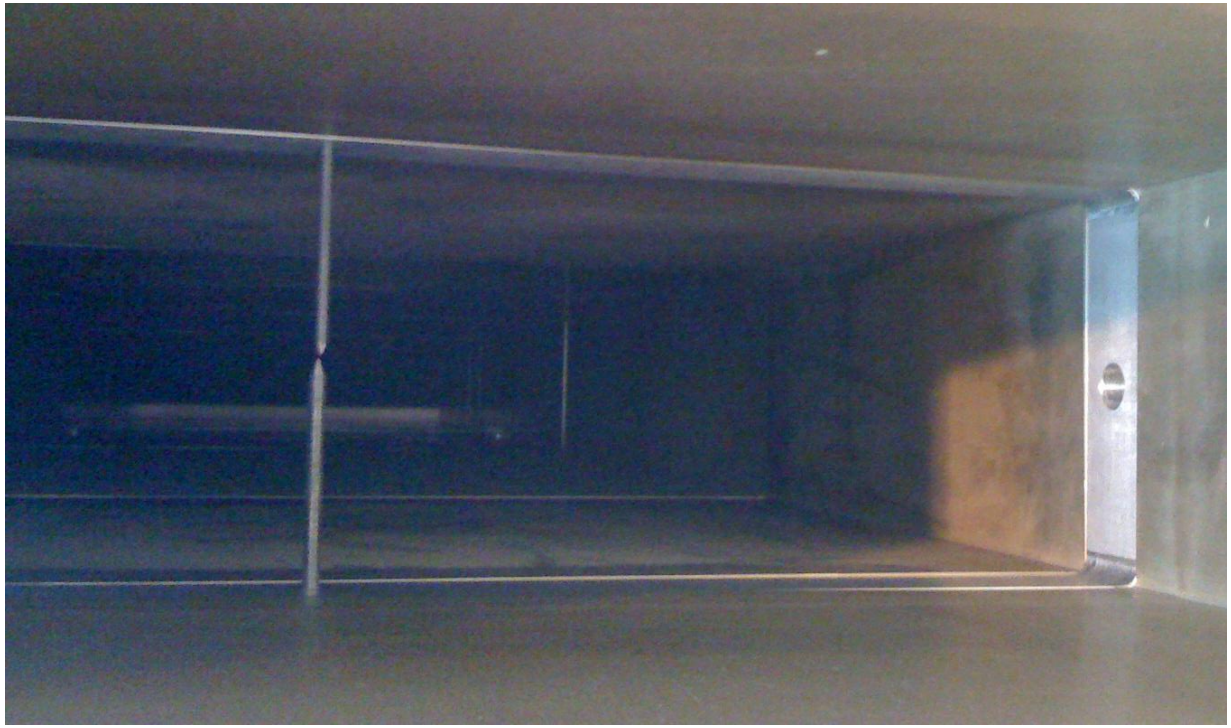
- Two sensors could be connected in OR or AND configuration
- AND configuration for places where false trips are expected
  - Problem with redundancy if one sensor fails
- Optical fibres recuperated from LEP
  - Some suffer from x-ray induced opacity
- False trips due to high energy secondary showers for tunnel sensors

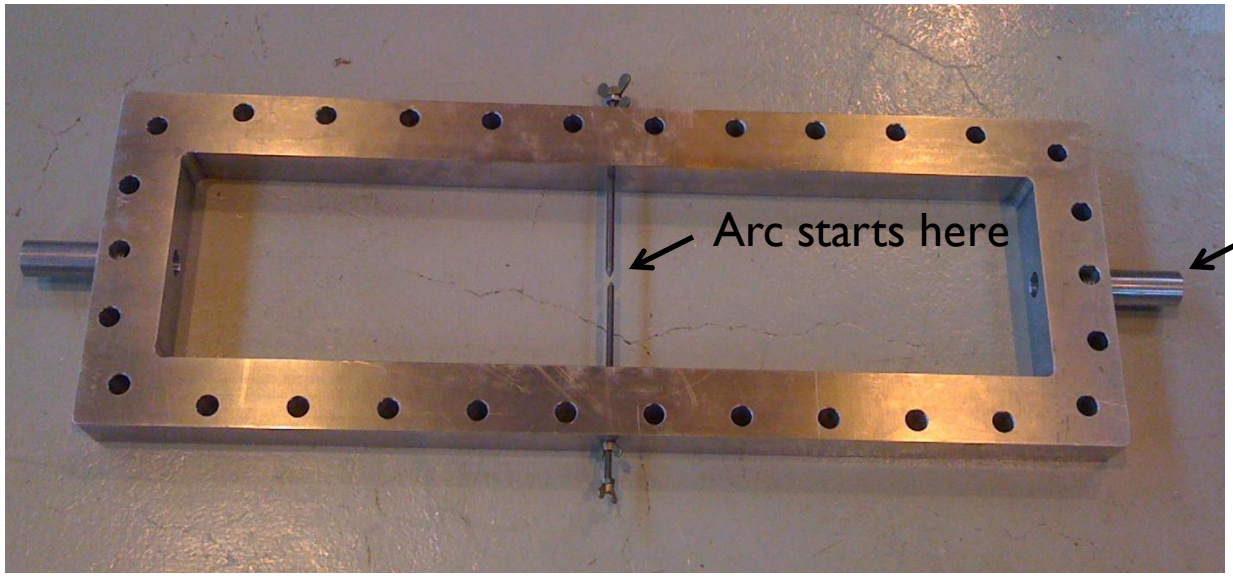
Performance in 2011

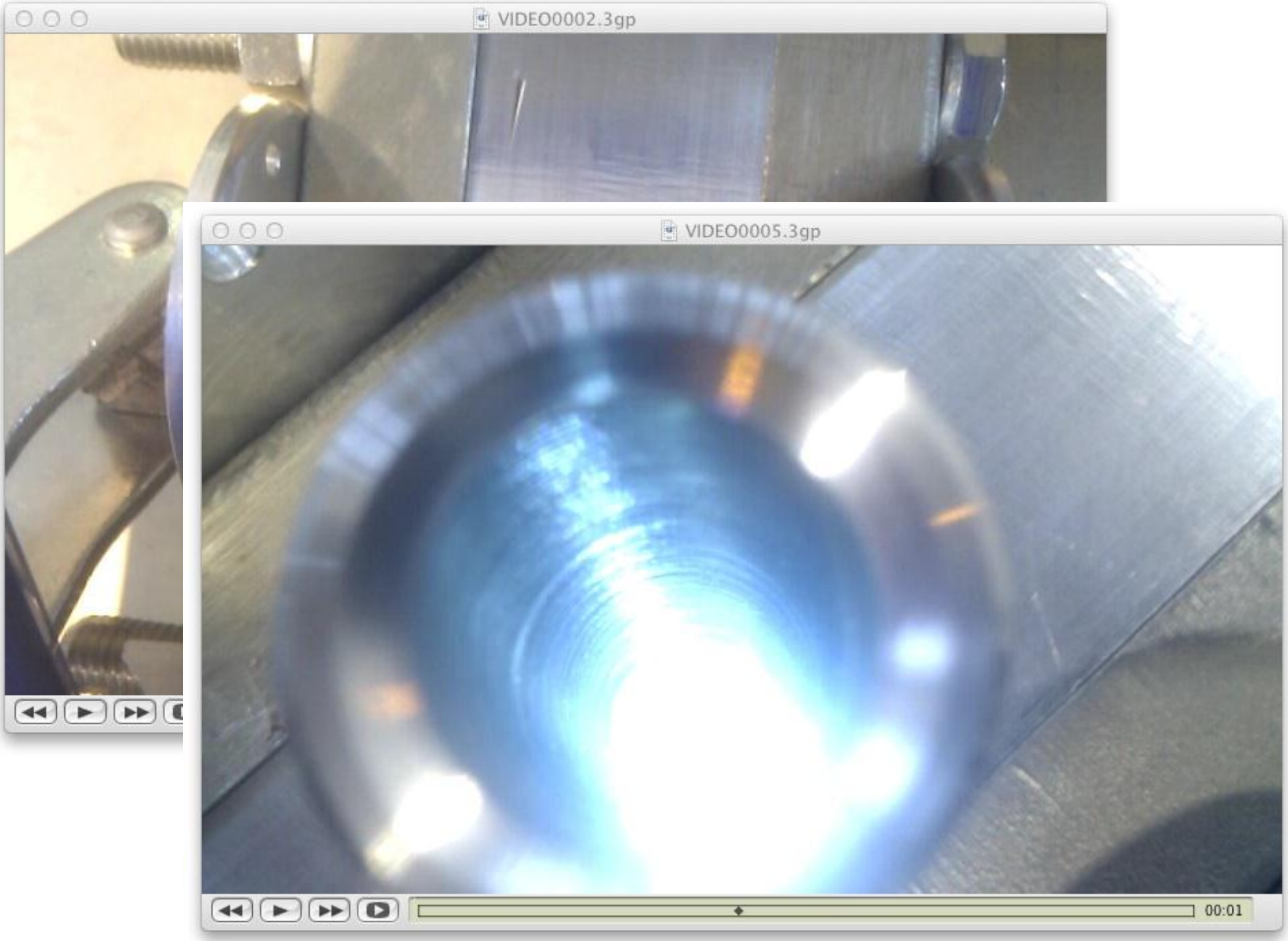
- Summer 2011 – significant increase of intensity in LHC
  - Every other fill was dumped by false Arc Detector trip (cavity window detectors, not foreseen to work in radioactive environment)
- After 4 lost fills… urge need for a crash program:
  - Precise determination of the failure mode
  - Modification of filters (foreseen in the design)
  - Relocation of some electronics
- Call for a new, more robust design

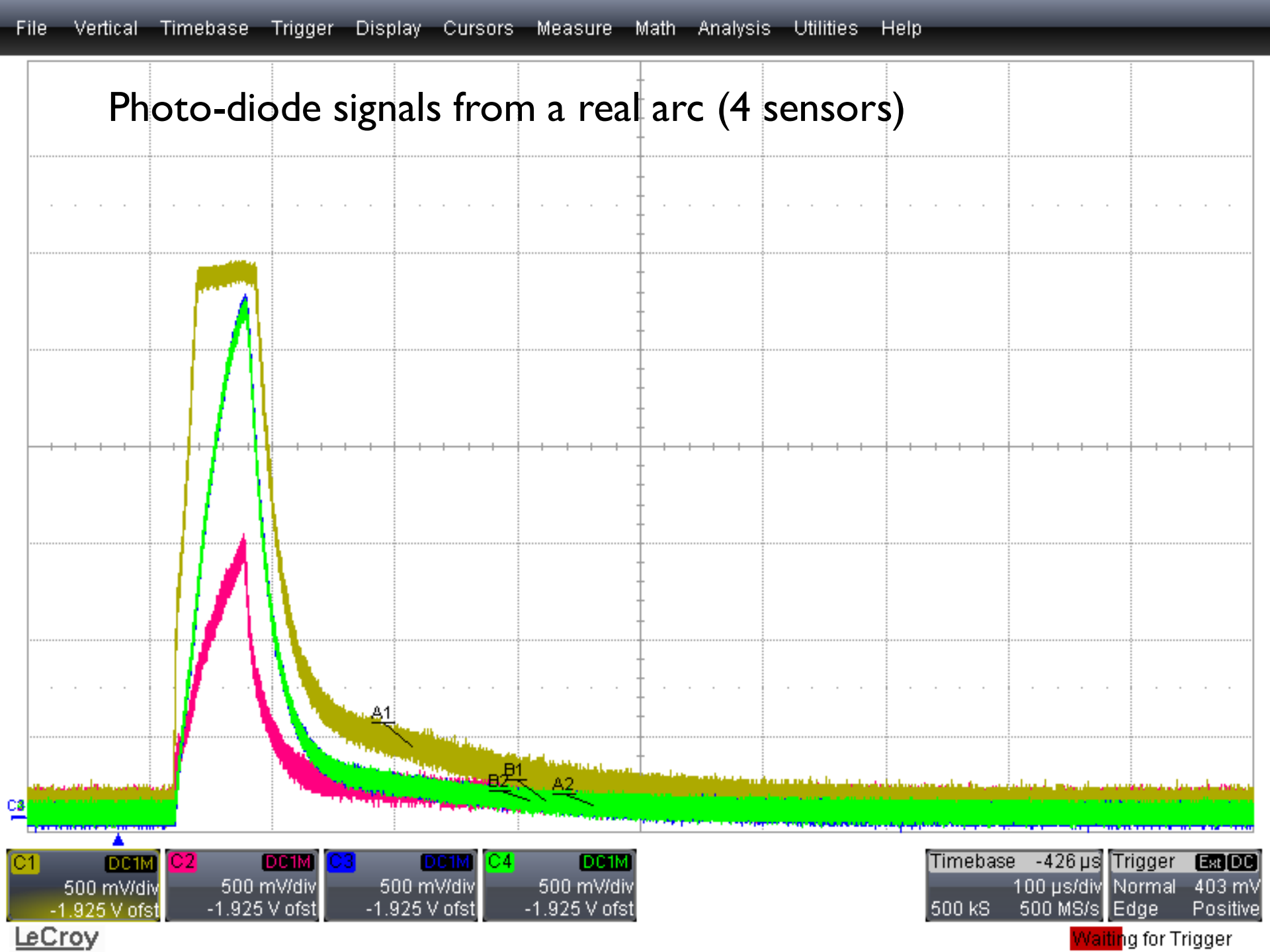
Upgrade program

- Step 1 – redefinition of the design parameters
  - Do we need 2 lux for 2 μs constraints?
- We'll find out only by measuring a real arc

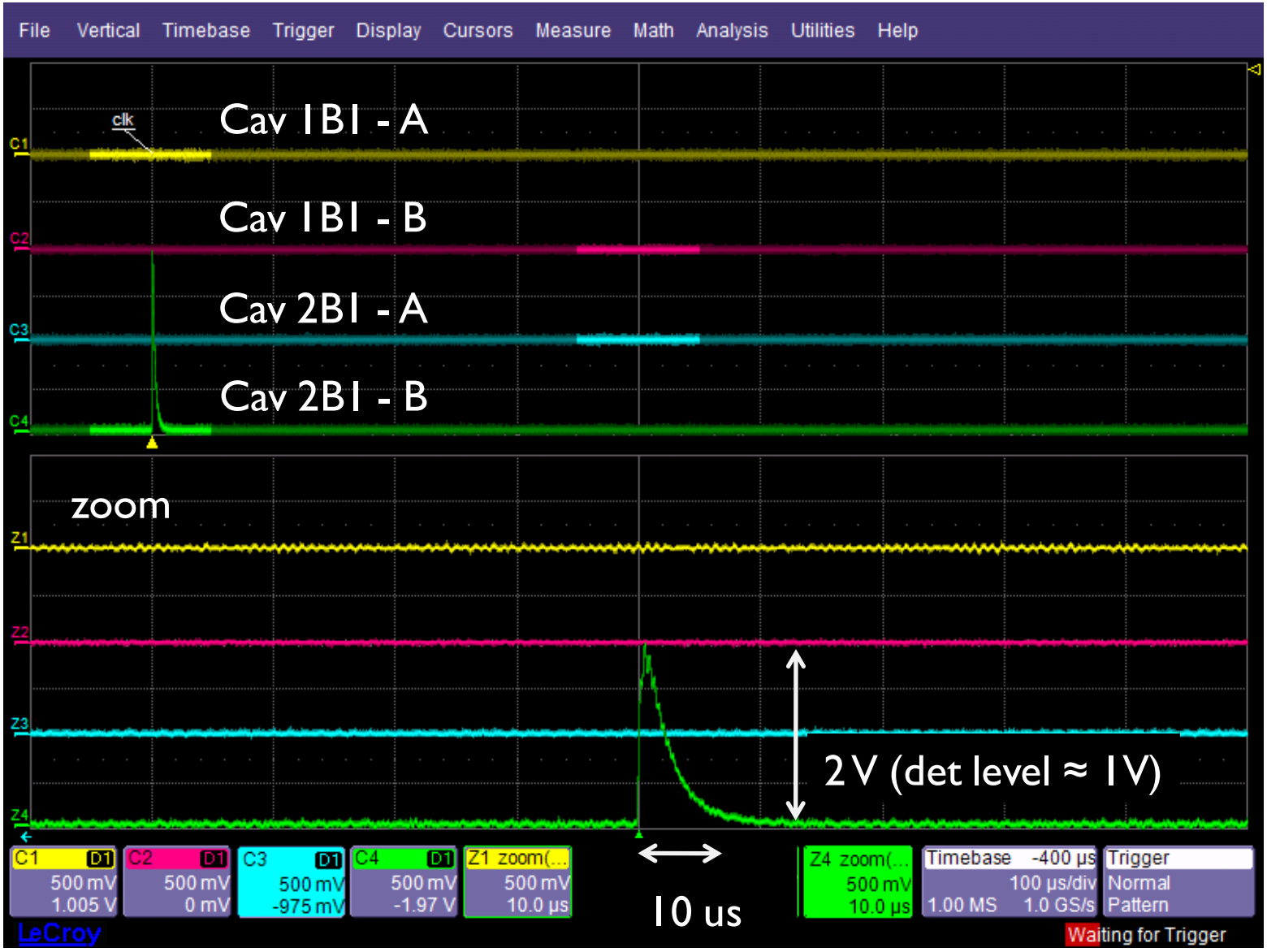



Arc starts here
Observation port


VIDEO0002.3gp
VIDEO0005.3gp
00:01


File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
Photo-diode signals from a real arc (4 sensors)
A1
B1
B2
A2
C3
C1 DC1M 500 mV/div -1.925 V ofst
C2 DC1M 500 mV/div -1.925 V ofst
C3 DC1M 500 mV/div -1.925 V ofst
C4 DC1M 500 mV/div -1.925 V ofst
Timebase -426 µs 100 µs/div 500 kS 500 MS/s
Trigger Ext DC Normal 403 mV Edge Positive
LeCroy
Waiting for Trigger

Sensitivity to radiation – how does the perturbation look like?



Measurements - summary

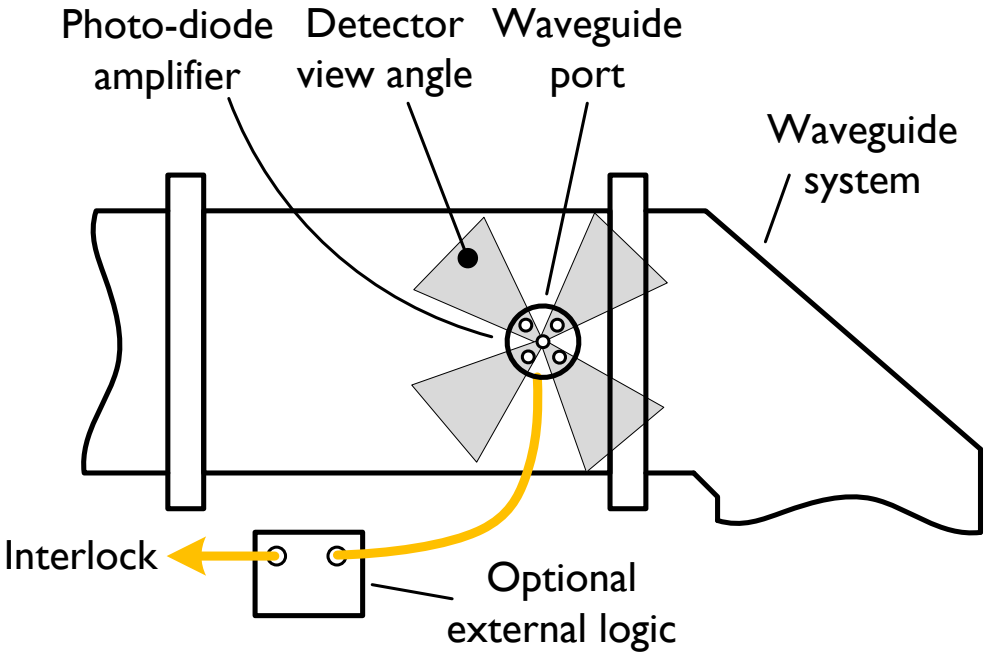
- Sensitivity is kept high, same value as in the current system
  - Light from a strong arc saturates the photodiode amplifier making the detection more reliable
- Radiation induced signals are unavoidable
  - Very reproducible short spikes, triggering only one sensor at the time
  - Intelligent algorithm could deal with them

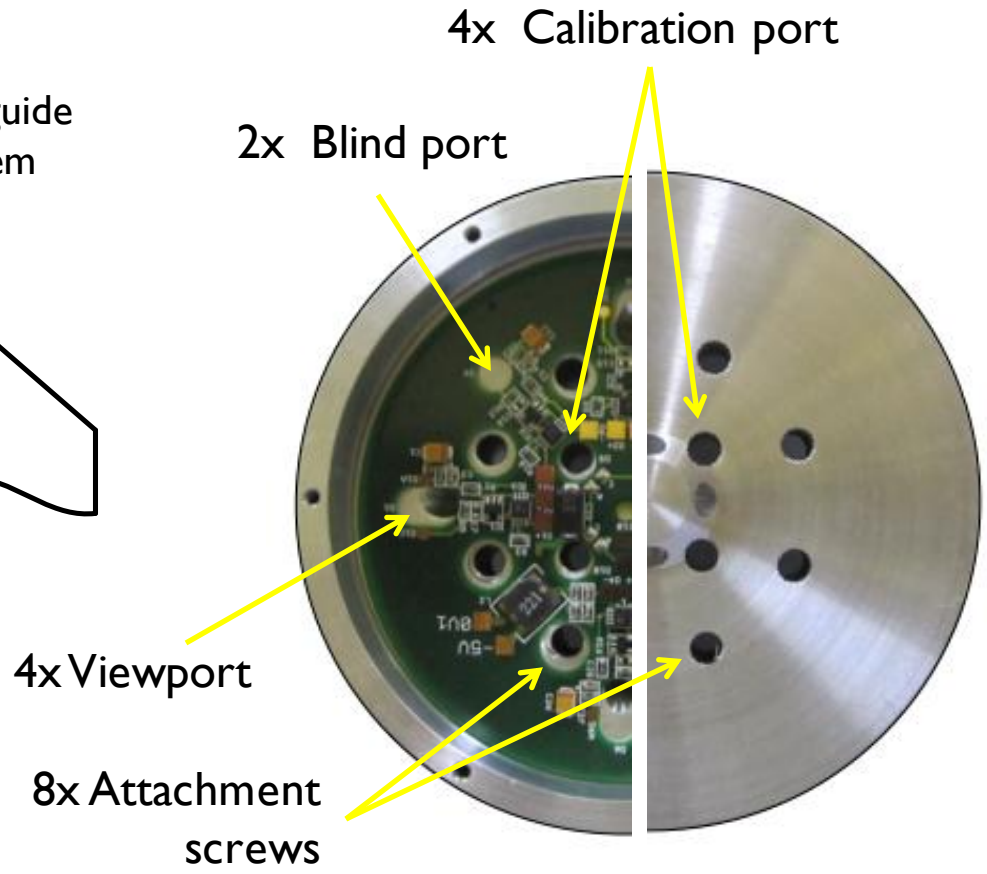
Upgrade program

- Step 2 – redefinition of the reliability, redundancy and construction complexity
- Four redundant sensors in one viewport looking in all directions (spaced by 90 degrees)
- More advanced interlock logic
- Elimination of the optical fibres for simplicity and cost reasons

New design

- New design – the "showerhead"





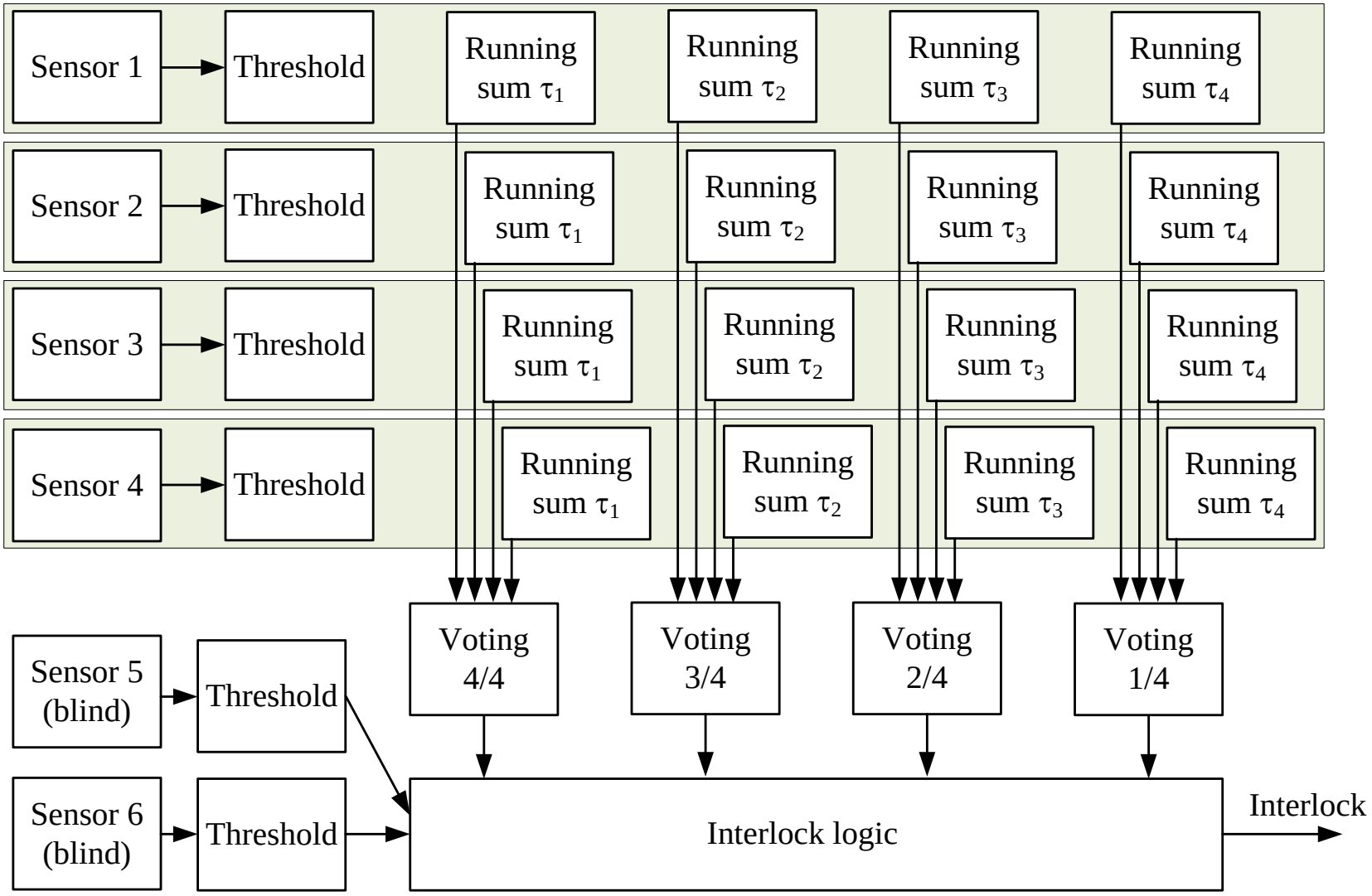
New design

- New detection algorithm introduces a voting logic on a running sum for each of the four detectors

- The interlock is issued if:
  - light is detected on 4 out of 4 channels for time τ_4 OR
  - light is detected on 3 out of 4 channels for time τ_3 OR
  - light is detected on 2 out of 4 channels for time τ_2 OR
  - light is detected on 1 out of 4 channels for time τ_1,
  - Where $\tau_1 > \tau_2 > \tau_3 > \tau_4$ (e.g. 100-50-25-15μs)

- Interlock could be masked if the blind channel triggers

New design


Sensor 1
Threshold
Running sum τ_1
Running sum τ_2
Running sum τ_3
Running sum τ_4
Sensor 2
Threshold
Running sum τ_1
Running sum τ_2
Running sum τ_3
Running sum τ_4
Sensor 3
Threshold
Running sum τ_1
Running sum τ_2
Running sum τ_3
Running sum τ_4
Sensor 4
Threshold
Running sum τ_1
Running sum τ_2
Running sum τ_3
Running sum τ_4
Voting 4/4
Voting 3/4
Voting 2/4
Voting 1/4
Sensor 5 (blind)
Threshold
Sensor 6 (blind)
Threshold
Interlock logic
Interlock

Summary

- No false arc detector trips in LHC since the modification
- New arc detector design is more robust, reliable and offers sufficient redundancy to use detectors in AND mode
- New fibres-less design – simpler, more reliable, cheaper
- First 20 units were produced and will be evaluated in LHC soon
- Gradual replacement of the current arc detectors in LHC is foreseen (120 units), Linac4 will use already the new model

References

D. Valuch, N. Schwerg, O. Brunner: PERFORMANCE OF THE ARC DETECTORS OF LHC HIGH POWER RF SYSTEM

Proceedings of IPAC2011, San Sebastián, Spain, pp. 1704-1706

http://accelconf.web.cern.ch/AccelConf/IPAC2011/papers/tups072.pdf