Quality Assurance Programme for the Environmental Testing of CMS Tracker Optical Links

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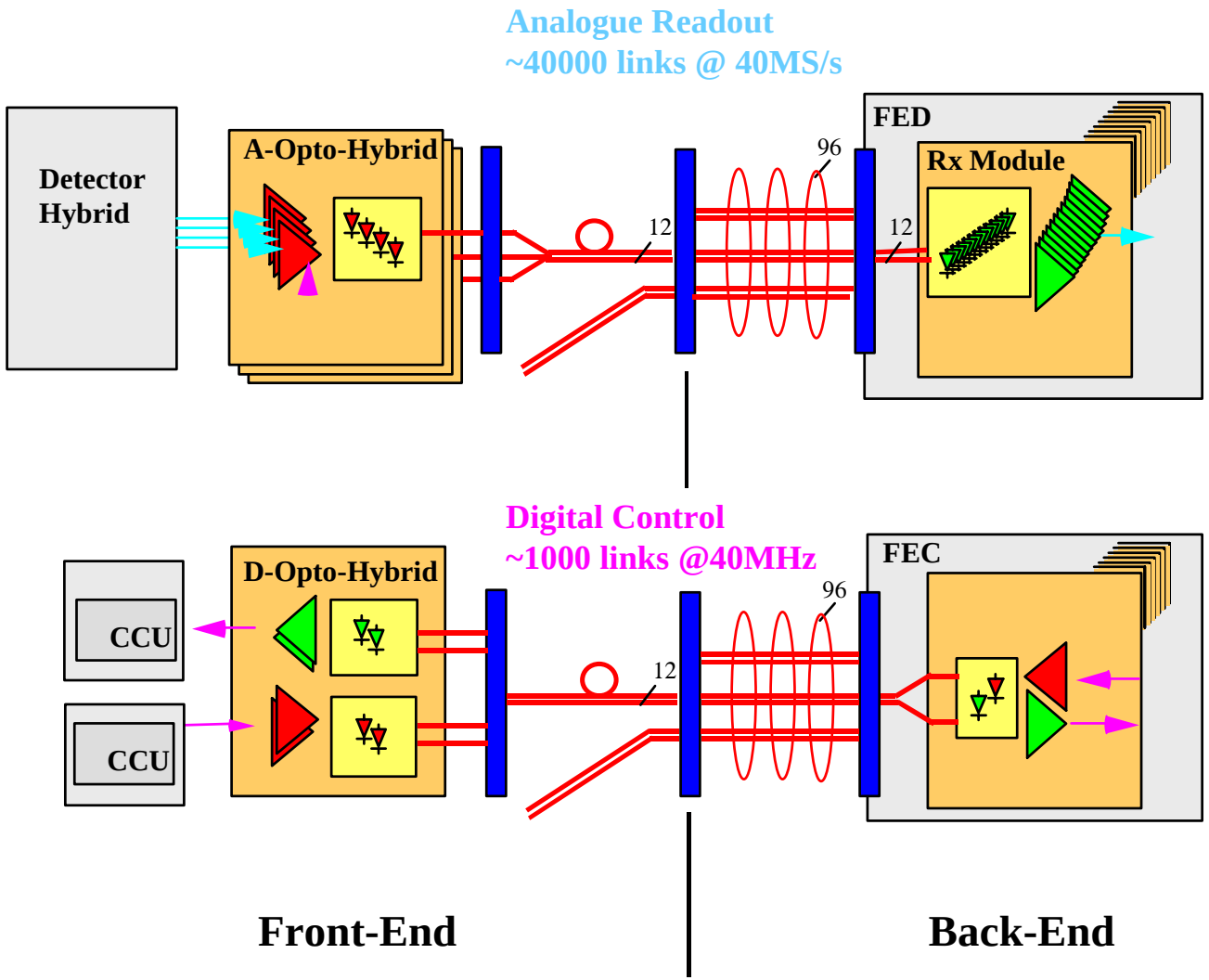
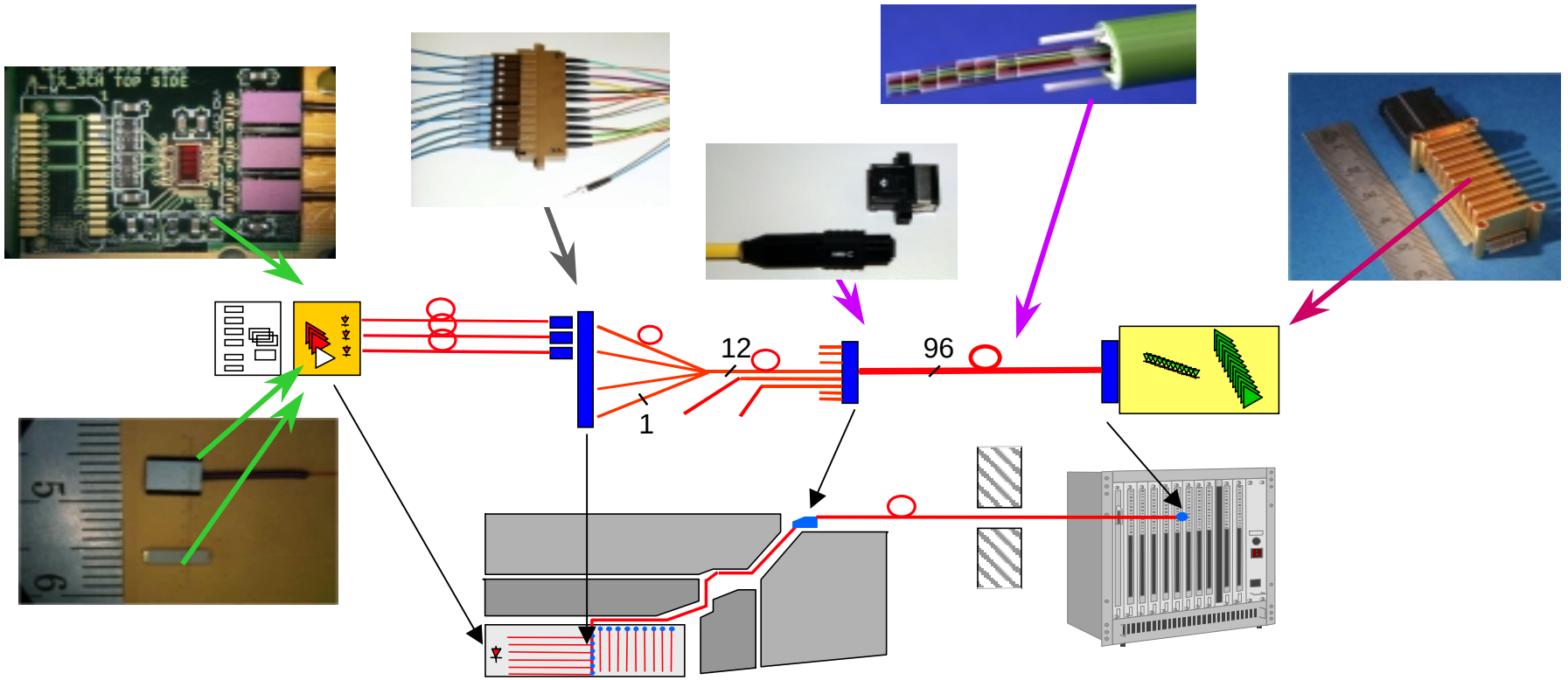
Outline

- Introduction
  - CMS Tracker Optical link systems and components
  - Tracker environment
  - COTS issues
- Quality Assurance
  - QA manual
  - Evolution of QA procedures
- Environmental QA Programme
  - Sample validation
  - Advance validation testing
  - (Pre-production qualification)

CMS Tracker o-link systems



Component overview



- Examples of (close-to-final) analogue readout link components shown.
  - All COTS or COTS-based.
- digital control links use similar devices

Tracker environment

- T ~ -10°C
- B = 4T
- High radiation field
- 10 years minimum operational lifetime
  - components typically specified for T > -20°C
  - non-magnetic components chosen
  - link performance not affected by 4T field
- **Main issue is radiation damage**

high collision rate
high energy
large number of tracks

$\Rightarrow$ radiation damage

COTS issues

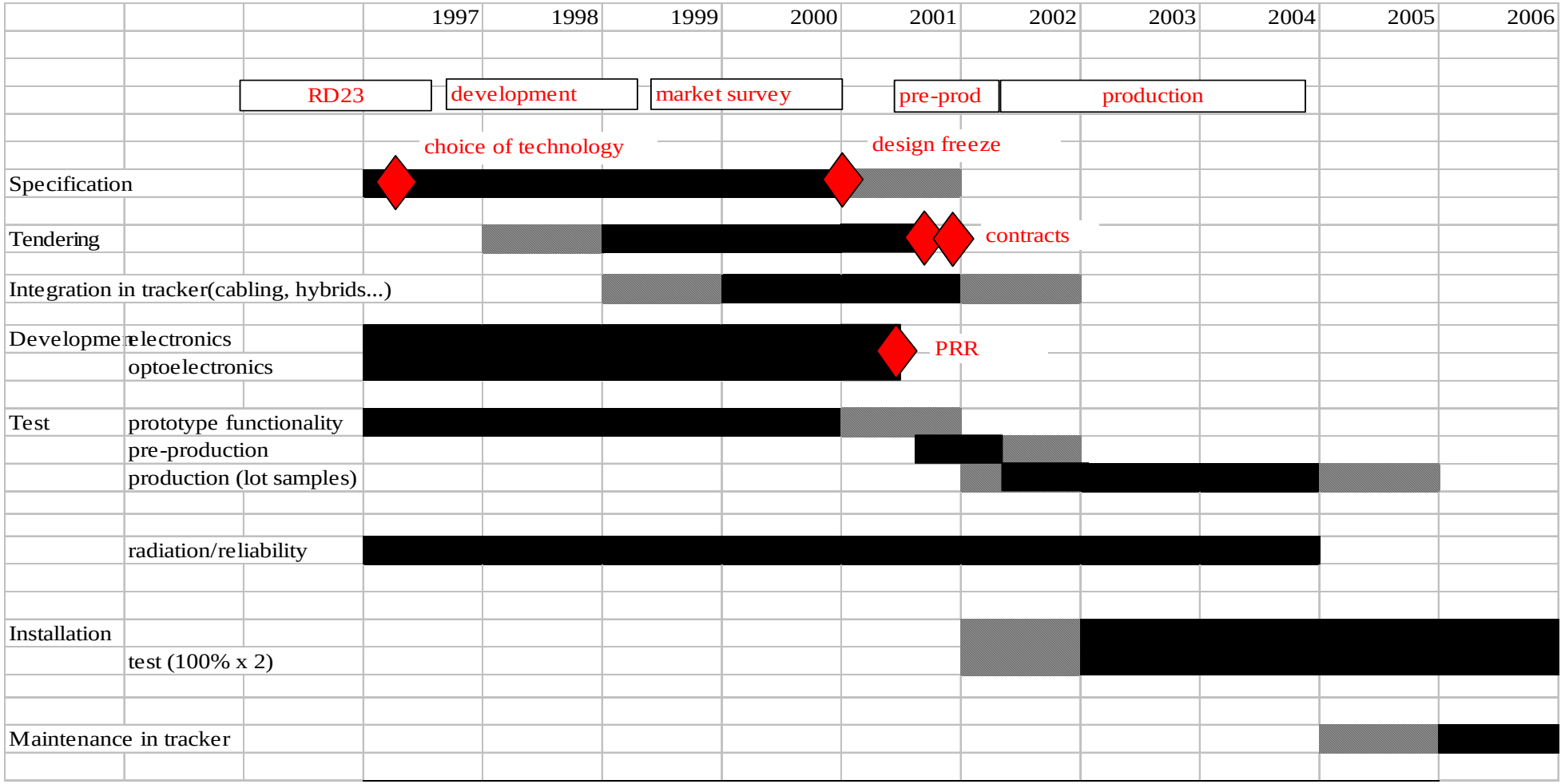
- Extensive use COTS in CMS optical links
  - benefit from latest industrial developments
    - cheaper, "reliable" manufacturer-qualified devices
- COTS not made for CMS environment
  - no guarantees of long-life inside CMS
  - In earlier development phase
    - validation testing of COTS mandatory to enable selection for CMS
  - In production phase
    - environmental QA testing mandatory before components integrated into CMS
      - ideally test at simplest level, e.g. laser die before batches produced
        - concept of Advance validation test (AVT)

QA overview

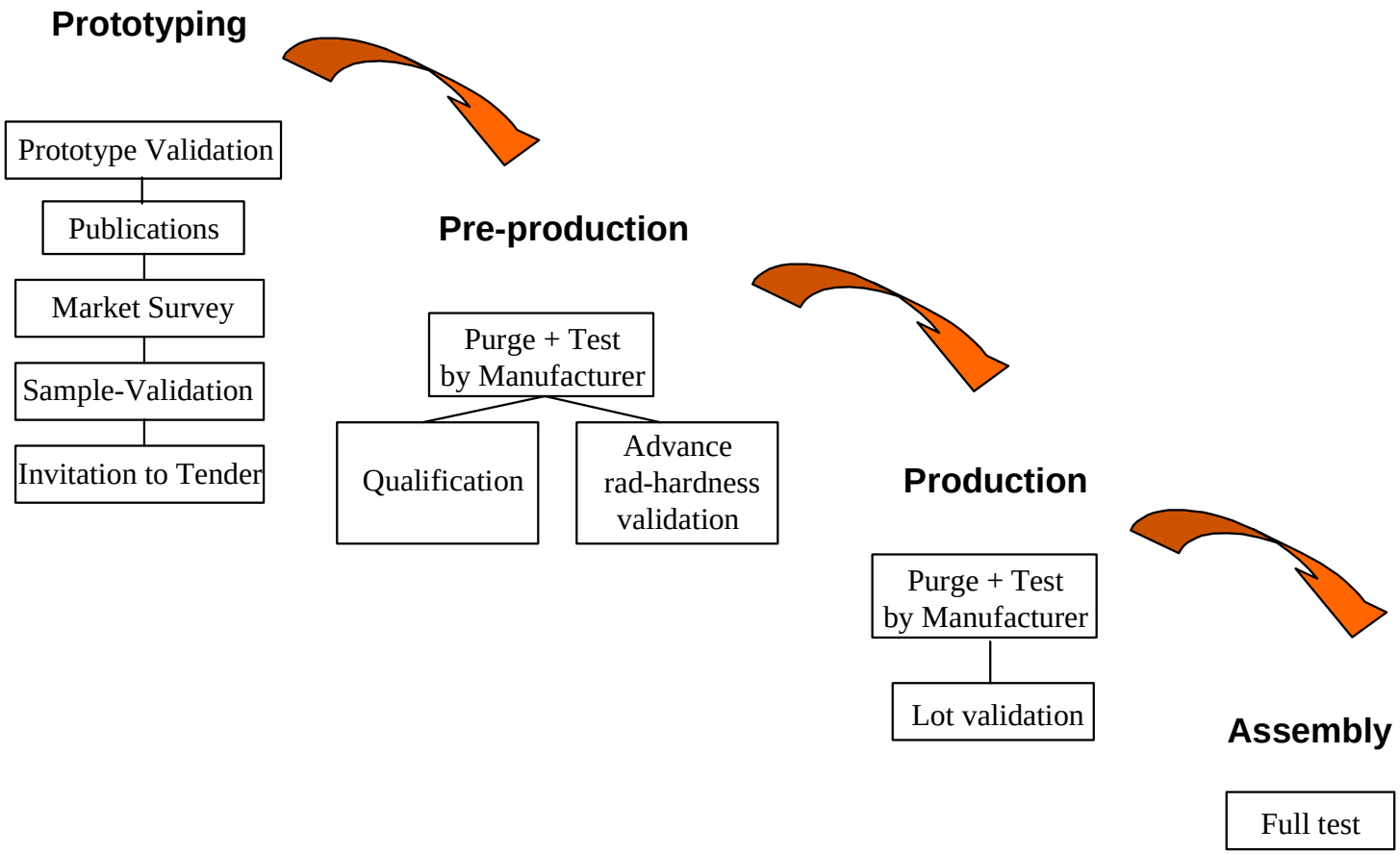
- System and component definition
  - Specs and responsibilities
  - Assembly flow and quantities
  - Project schedule
- QA Procedures
  - Sample validation, qualification and lot validation
- QA programme
  - Functionality testing
  - **Environmental testing**
- Traceability
- Maintenance
- Safety
- Documentation

  - *QA manual available http://cern.ch/cms-tk-opto/QA/*

Project Roadmap



Evolution of QA procedures



Sample validation

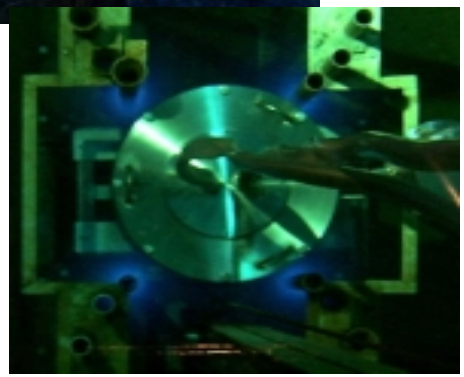
- Started with early prototype testing
  - functionality and radiation resistance

- Formal QA started in framework of Market Surveys
    - MS 2690 Lasers
    - MS 2691 connectors
    - MS2811 fibre/cable
    - MS2810 Rx modules (no CERN-specific env. Tests of Rx)
  - Allowed qualification of manufacturers

Accelerated test philosophy

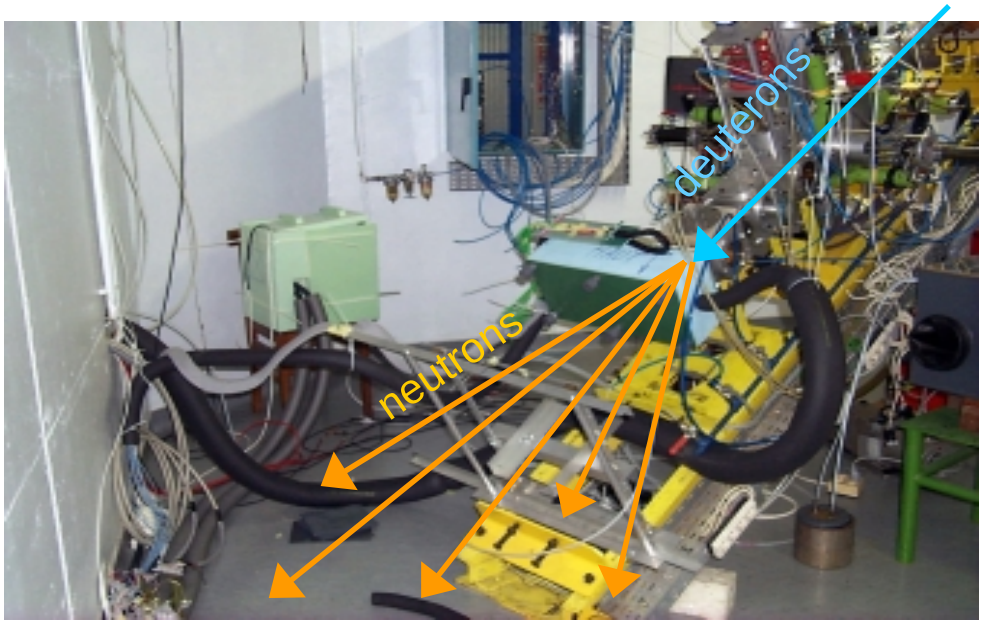
- Forced to make accelerated tests due to limited time available
  - try to test **'worst-case'** of total exposure equivalent to 10yrs in Tracker
    - higher dose rates or fluxes
    - also can include other factors
      - e.g. increased temperature, bias
        - enhance annealing
        - accelerate wearout
  - With accumulated understanding of effects can use only few radiation sources
    - gamma - ionisation damage
    - neutron - displacement damage
    - proton, neutron - single event effects
- Make the accelerated tests then extrapolate to CMS Tracker conditions

Irradiation at SCK-CEN and UCL



SCK-CEN Co-60 γ dose rate 2kGy/hr underwater source

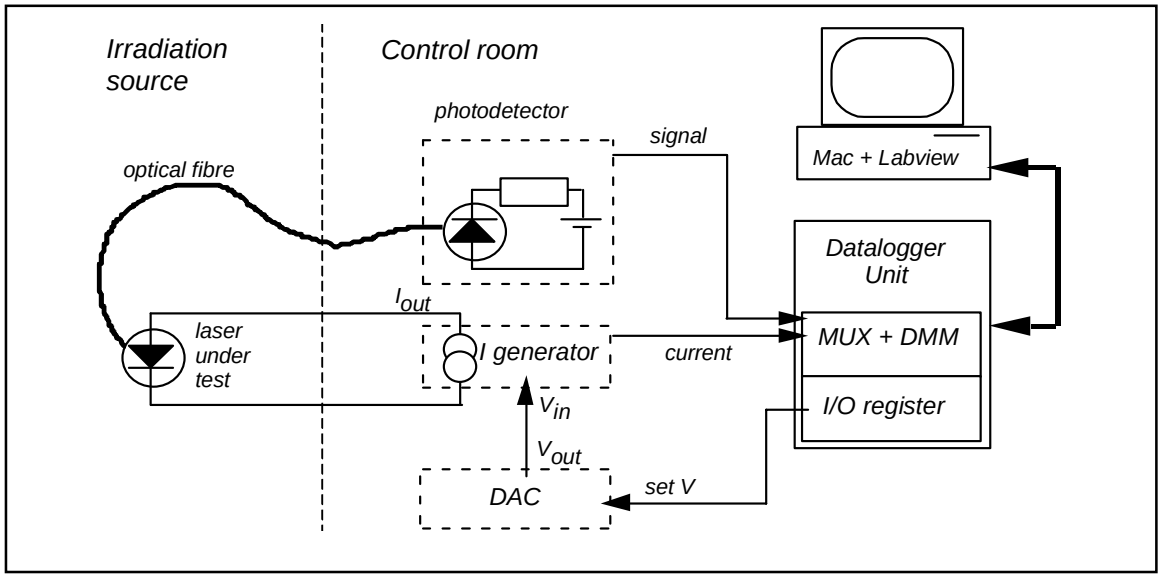
UCL ~20MeV neutrons
flux ~ 5×10^{10} n/cm^2/s



Samples stacked inside cold box (-10°C)

Irradiation test system

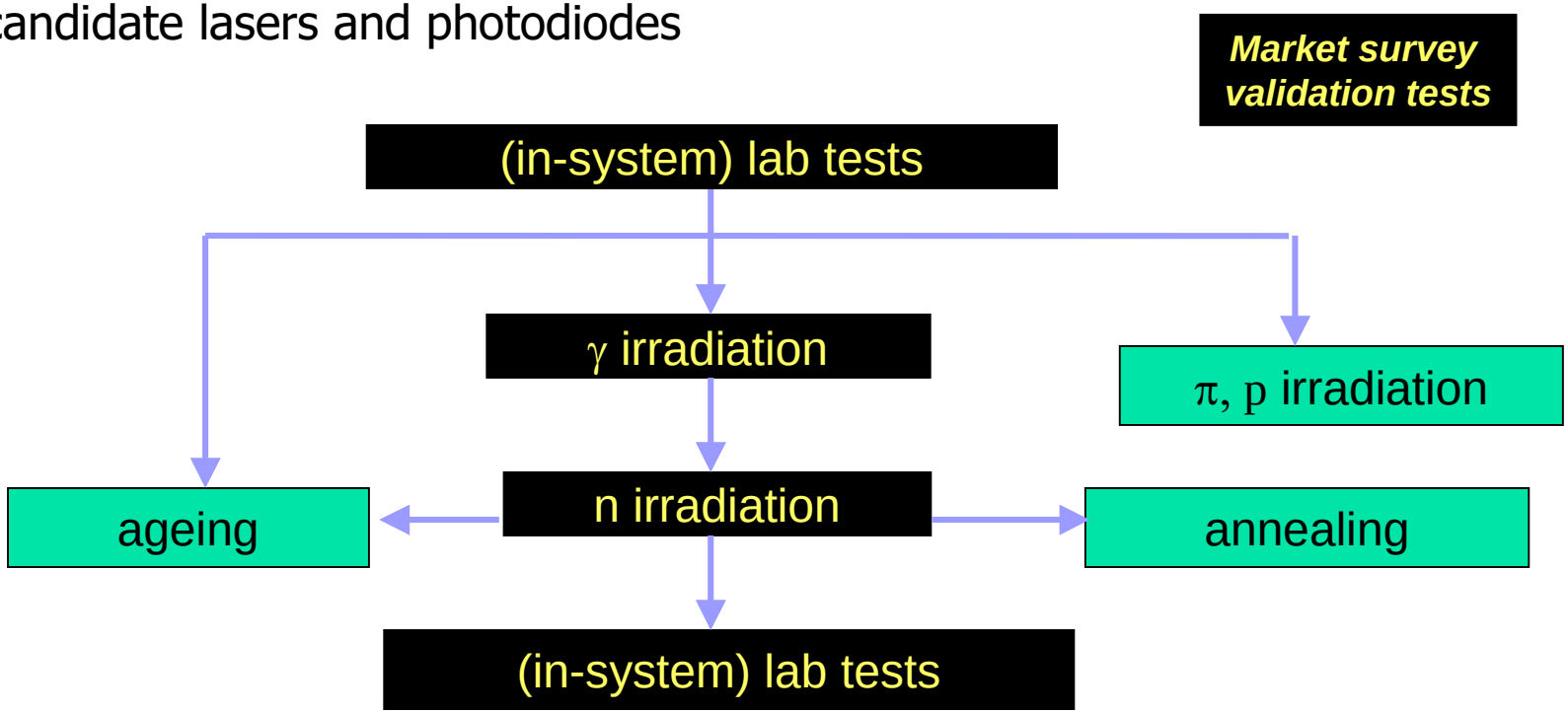
- in-situ measurement setup (lasers)



- in-situ data necessary for accurate extrapolation of data to expected CMS Tracker conditions

Sample validation procedure

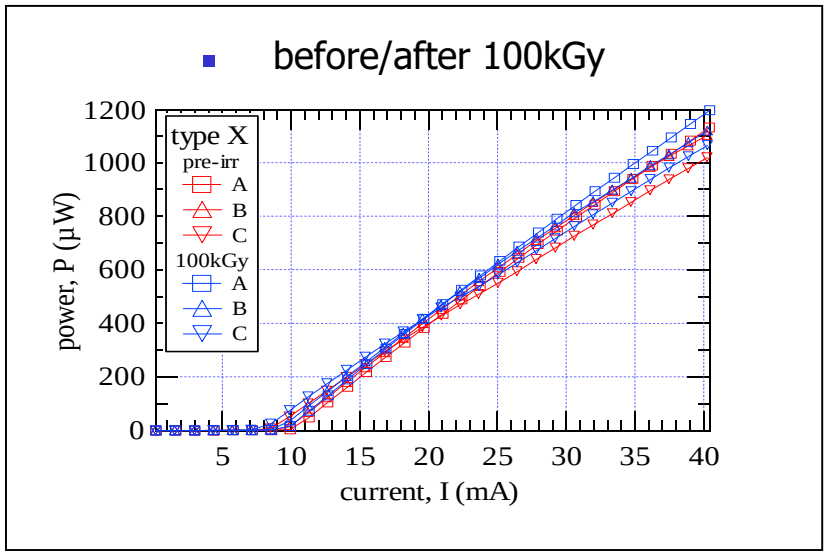
- E.g. candidate lasers and photodiodes

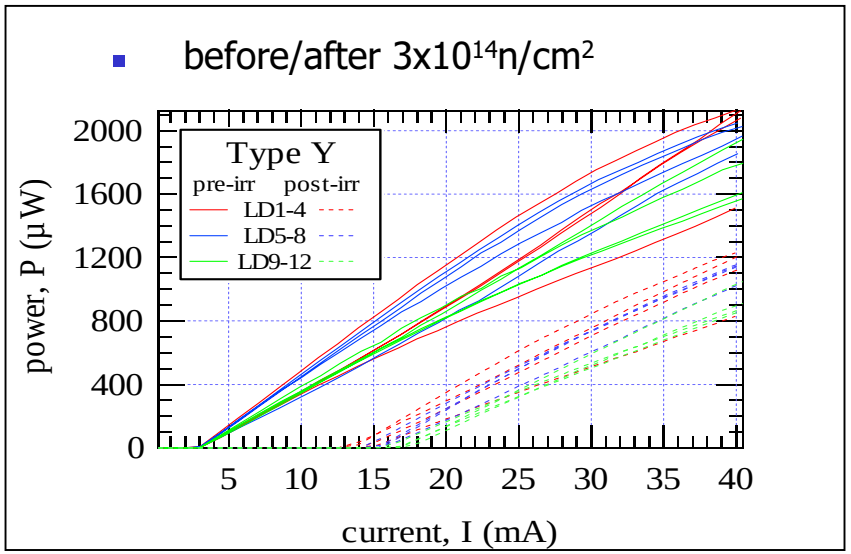


- Extensive set of accelerated tests on many components have provided knowledge of
  - suitability of candidate components
  - damage factors of different radiation sources
  - annealing rates and acceleration factors

Radiation damage

- E.g. lasers (also systematic tests of all the other link components - see PRR slides)





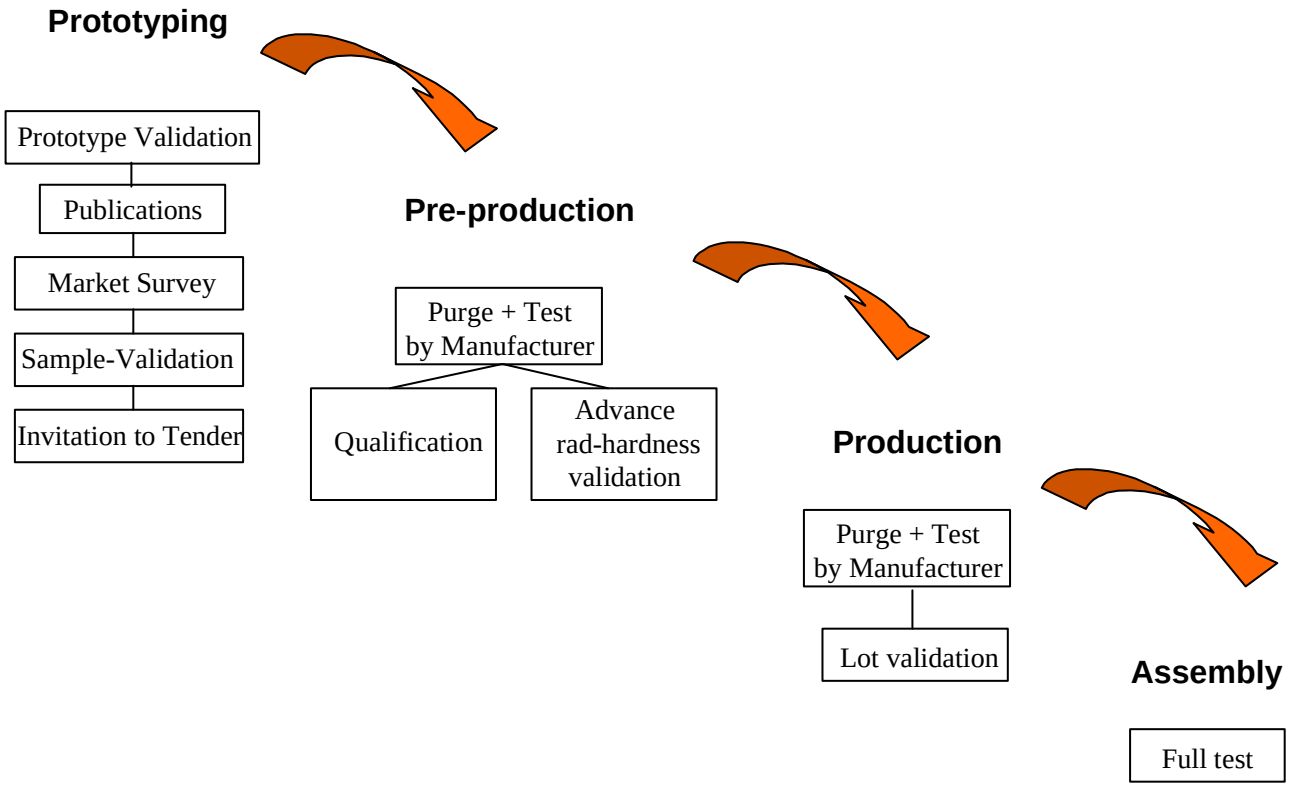
- Typical effects (visible on L-I characteristics of all laser types tested)
  - no ionization damage at level of laser die
  - displacement damage - increase in threshold current and decrease of efficiency
    - consequence of decreased carrier lifetime (c.f. other semiconductor devices)

Outcome of sample validation

- Feedback of effects into system specifications
  - Mitigation of unavoidable effects
    - e.g. laser threshold increase
  - Increased confidence of ultimate system reliability
- Selection of suitable components
  - Choice of technologies
  - Market Surveys
    - Qualified suppliers sent Invitation to Tender
- Development of procedures for QA in pre-production
  - Advance validation tests
  - Pre-production qualification

QA procedures

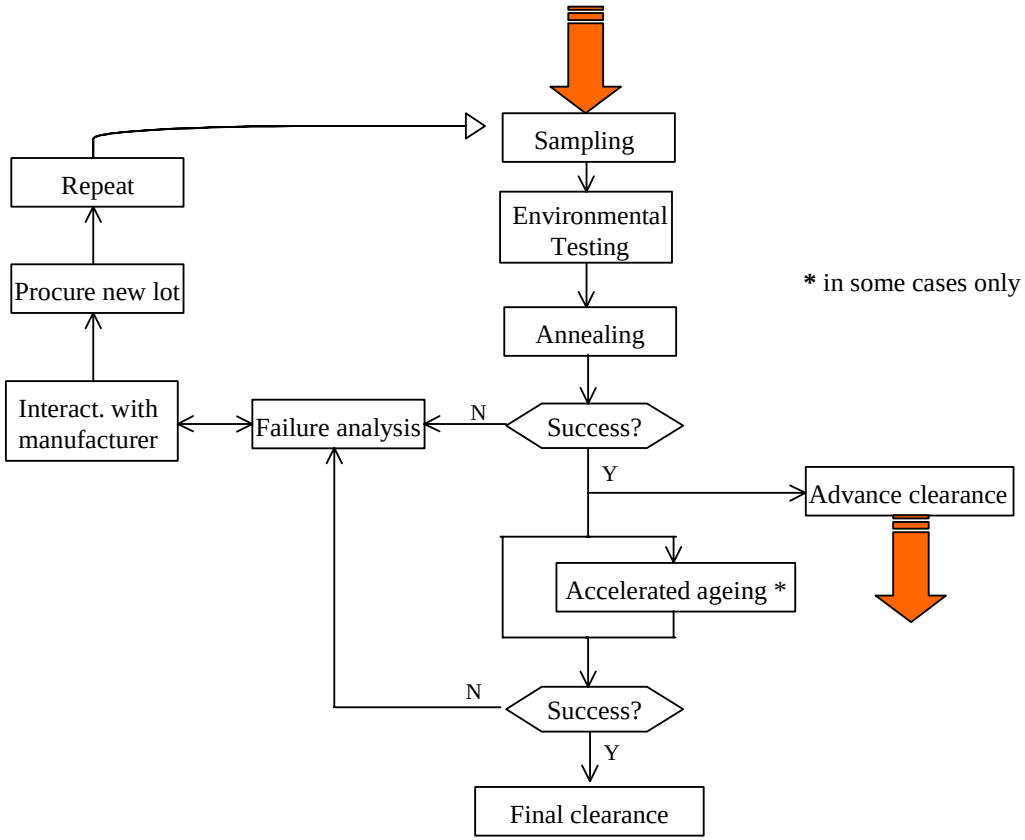
- Evolution of QA procedures



Advance rad-hardness validation

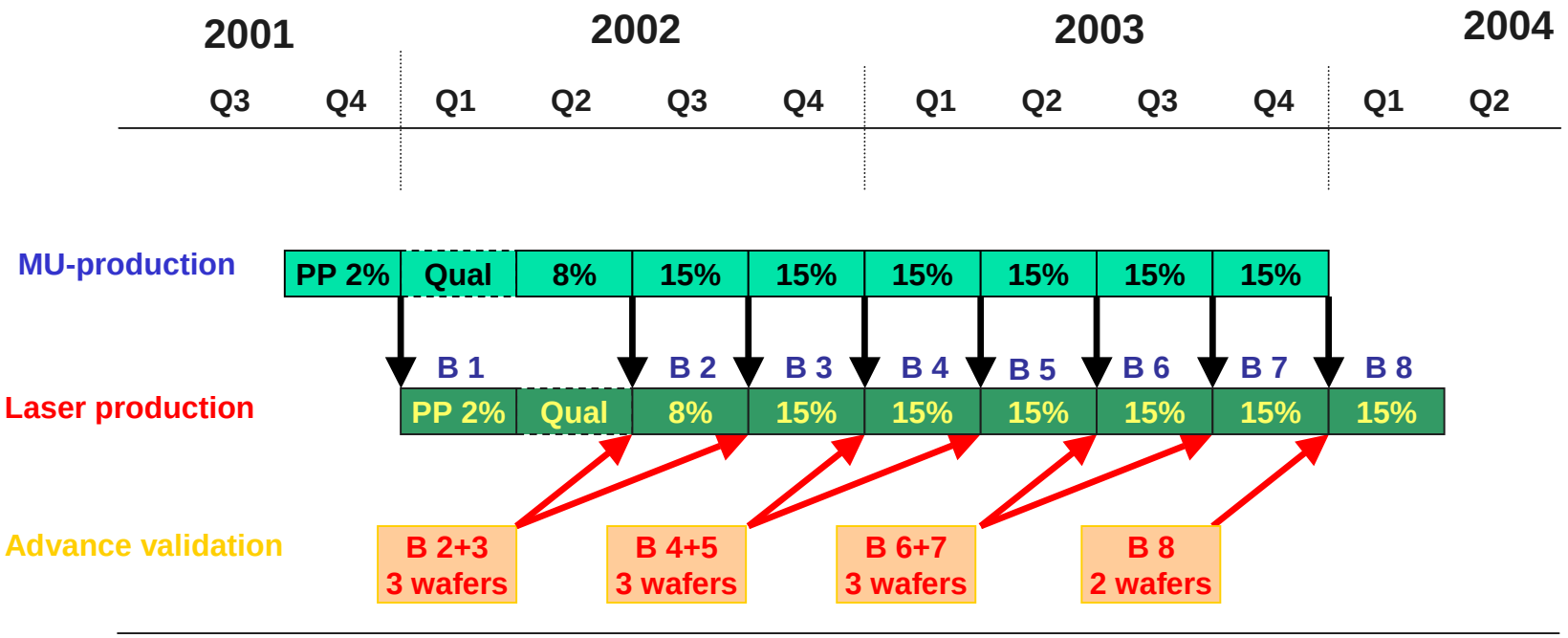
- All components manufacturer-qualified as market ready
  - However COTS not guaranteed radiation-resistant
- Must avoid rejection of final production batches of assembled devices due to non-compliance with environment
  - difficult to remedy, plus resources and schedule too tight
- Propose to do **advance validation test (AVT)** of radiation resistance
  - laser die
  - photodiode die
  - naked fibre
- Validated laser and photodiode wafers and fibre spools stored and subsequently used in production

AVT procedure



Laser AVT planning

- Preliminary scheduling of laser AVTs



Laser AVT details

- Overall, many aspects to consider specific to AVT, in discussion with suppliers
  - precise scheduling and number of AVT's
  - lead-time for AVT sample delivery
  - AVT turn-around time
    - determines number of wafers to test
    - determines levels of stock on-hold
      - during AVT
      - after AVT before final assembly
    - impacts cash-flow
    - also, a lot of other logistics to fix….
  - definition of acceptance criteria and action in case of non-compliance

Production/Test QA Overview

	Q4 00	Q1 01	Q2 01	Q3 01	Q4 01	Q1 02	Q2 02	Q3 02	Q4 02	Q1 03	Q2 03	Q3 03	Q4 03	Q1 04	Q2 04
Buffered Fibre	IT		AVT	C1	Prod (1m)										
					1										
MU-MU jumpers		IT		C2	P-prod	Qualif	Prod								
					0.02		0.08	0.15	0.15	0.15	0.15	0.15	0.15		
Laser Transmitter		IT		C3		P-prod	Qualif	Prod							
						AVT			AVT		AVT		AVT		
						0.02		0.08	0.15	0.15	0.15	0.15	0.15	0.15	
Ruggedized Ribbon	IT			C1	AVT	Prod (3m)									
						1									
12MU-12MU Ribbon Harness		IT		C2			P-prod	Qualif	Prod						
							0.02		0.18	0.2	0.2	0.2	0.2		
Terminated Ribbon				IT	C5			P-prod	Qualif	Prod					
								0.02	0	0.18	0.2	0.2	0.2	0.2	
Dense Multi-Ribbon Cable	IT			C1	AVT	Prod (3m)									
						1									
Terminated Multi-Ribbon Cable				IT	C5		P-prod	Qualif	Prod						
							0.02		0.08	0.15	0.15	0.15	0.15	0.15	0.15
ARx12 ASIC			Des		Prod	Test									
					1										
Rx Module			IT		C4		Prod								
(most aggressive scenario)							1								
Legend:	IT	Invitation to Tender						Prod		Production					
	C	Contract						P-prod		Pre-Production					
	AVT	Advance Validation Test						Qualif		Qualification					

Expected outcome of AVT

- If successful, validated sub-components can pass onto full production
  - Plan to build up validated stock
    - in case of (later) problems
    - to make best use of our resources

- If samples found to be non-compliance
  - then lot not purchased by CERN
    - COTS product can be redirected into usual marketplace
  - request new samples from a different lot/wafer and re-test

- Should avoid rejection of final production batches of assembled devices due to non-compliance

Conclusions

- Project development phase complete, moving into (pre-)production
  - 4/5 Tenders closed
  - Contract discussions underway
- Many QA issues in optical link project
  - QA manual written (+will evolve)
    - PRR passed
- Environmental QA
  - Sample testing
    - valuable experience gained in development phase
      - also basis for QA in production
- Special AVT procedures
  - complicated but essential for much of environmental QA in production