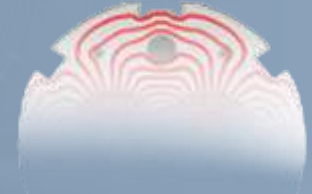




R2E and Availability



CERN Radiation 2 Electronics (R2E) – Chamonix 2014

September 23rd 2014

M. Brugger on behalf of the CERN R2E Project
www.cern.ch/r2e

!!! Many Thanks To All People Involved !!!

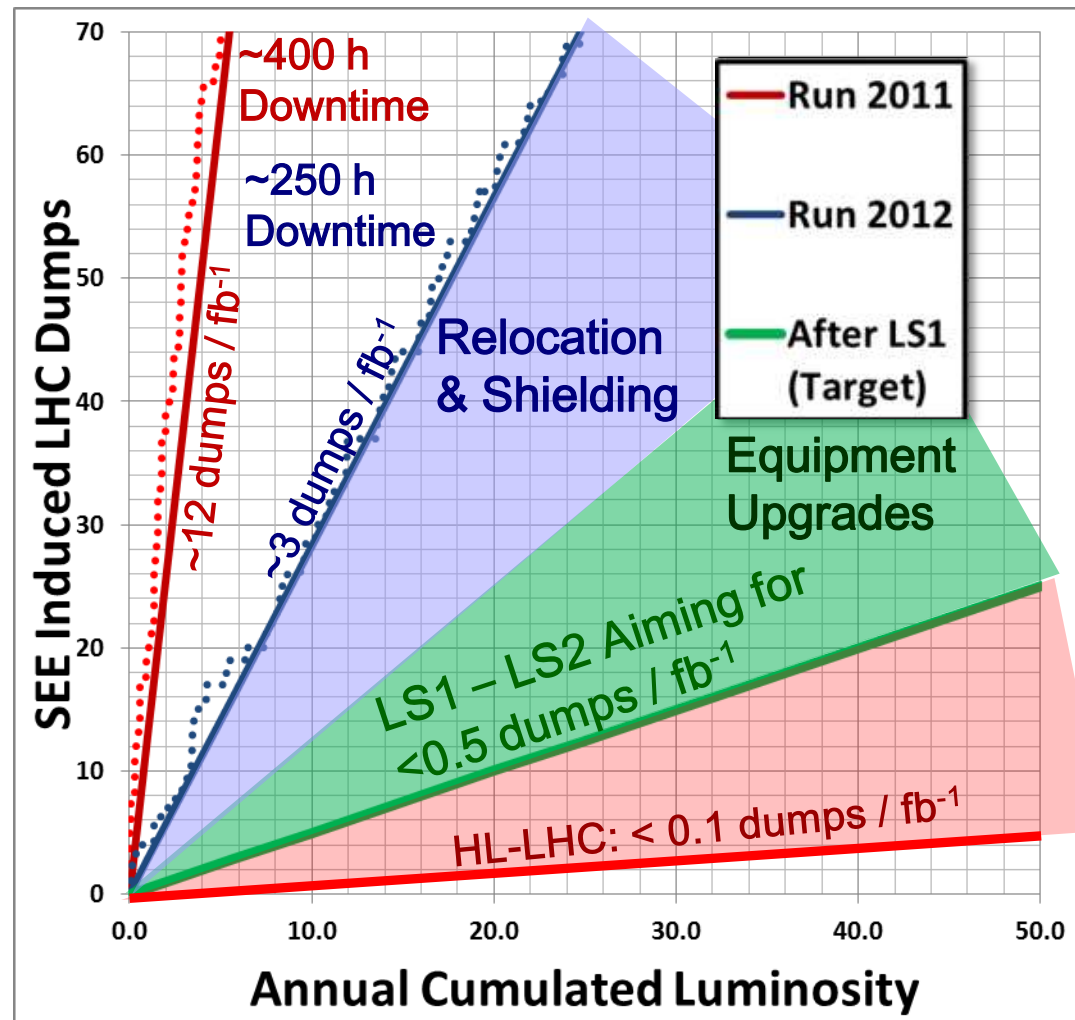


Chamonix in September



R2E After LS1?

R2E SEE Failure Analysis



2008-2011

- Analyze and mitigate all safety relevant cases and limit global impact

2011-2012

- Focus on long downtimes and shielding

LS1 (2013/2014)

- Final relocation and shielding

LS1-LS2 (2015-2018)

- Tunnel equipment and power converters

-> LS3-HL-LHC

- Tunnel Equipment (Injectors + LHC) + RRs



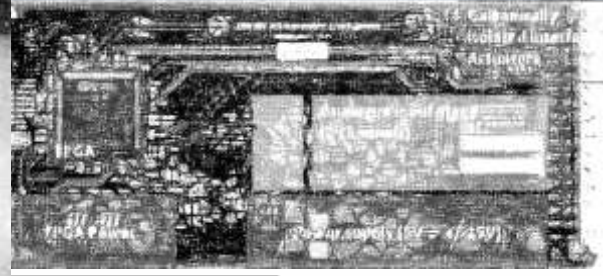
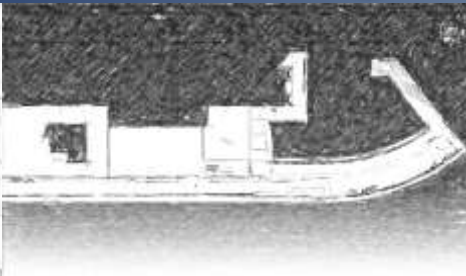
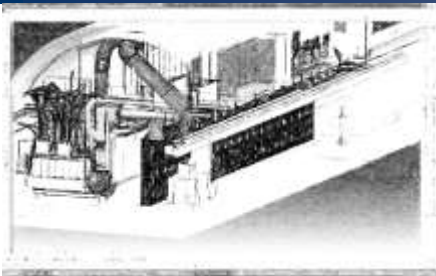
CERN A&T Projects & Groups

Team	Activity	Devices components			System	Type
		Analogue	Digital Mixed	Power		
TE/MPE	QPS	x	x		Custom	COTS
TE/EPC	Power Converter	x	x	x	Custom	COTS
TE/CRG	Cryogenics	x	x		Custom	COTS/Rad hard
BE/ABT	Interlock and Kicker	x	x	x	Semi-Custom	COTS
EN/STI	Radiation Monitor	x	x		Custom	COTS
BE/BI	Beam instrumentation	x	x		Custom	COTS/Rad hard
BE/RF	RF Cavities	x		x	Custom	COTS
BE/CO	Control equipment	x	x		Custom	COTS
EN/MEF	Survey	x	x		Custom	COTS
TE/VSC	Vacuum equipment	x	x		Semi-Custom	COTS
IT	IT tools		x		Semi-Custom	COTS
EN/EL	Light, LED	x			Semi-Custom	COTS
GS/ASE	Safety, Alarms	x	x		Semi-Custom	COTS
EN/STI	Radiation test activities	x	x	x	-	-



What's needed after LS1

- @ Quick look on **LS1**:
 - @ Mitigation -> (almost) Prevention
- @ >LS1 Priority: **Tunnel & RR equipment**
- @ **R2E qualification procedure**
- @ **Life-Time issues**
(Radiation Damage in general)
- @ 2015+ operation requirements
- @ **R2E/Availability Workshop**
- @ **Needs**



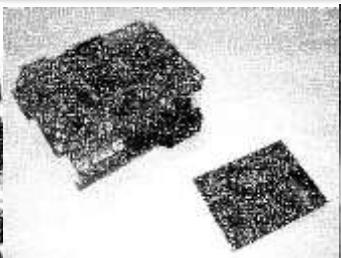
Relocation & Shielding

Equipment Upgrades

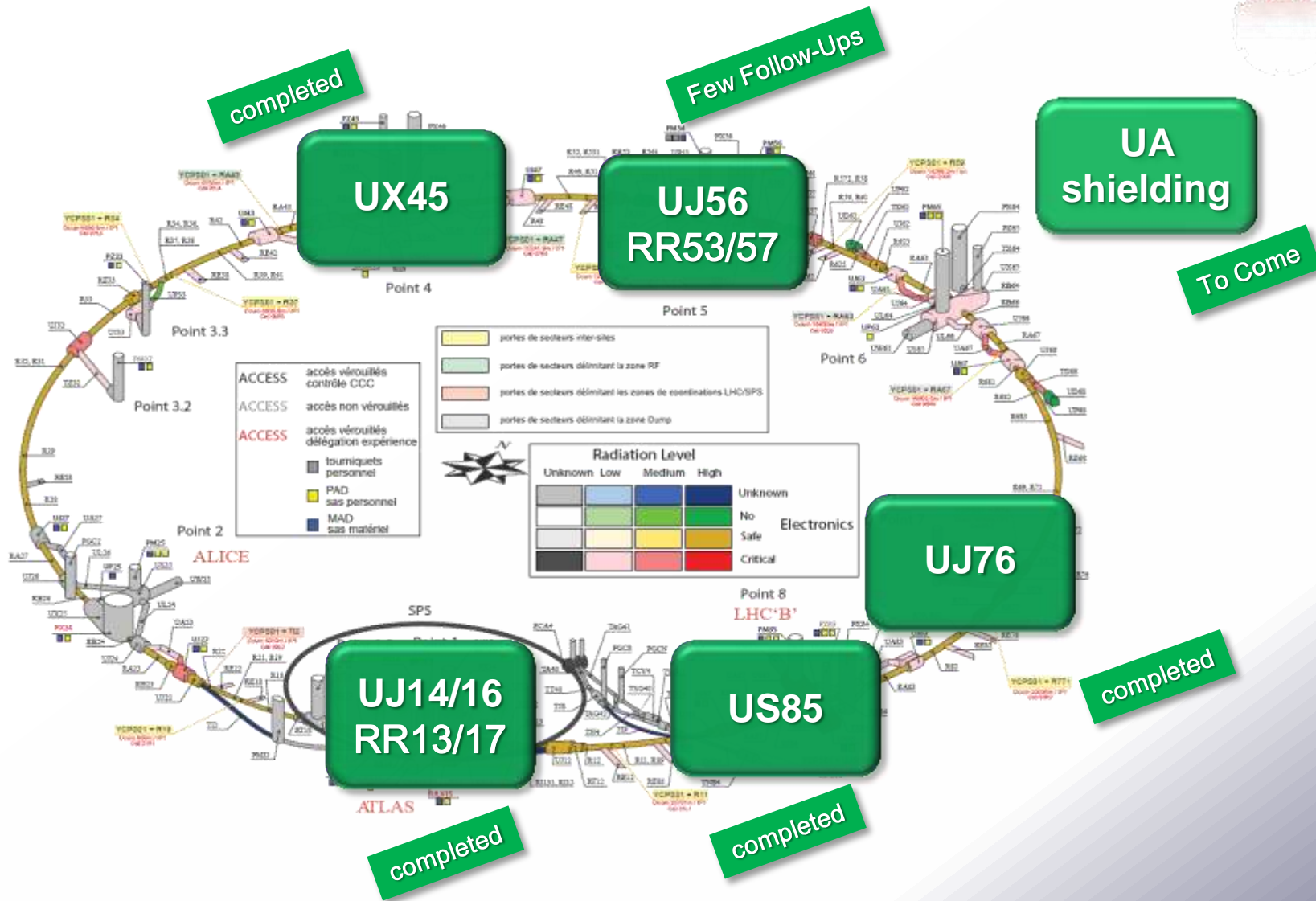


Testing & Facilities

Monitoring



Relocation/Shielding Overview



© A.L. Perrot

Relocation & Shielding

- @ **Integration** study/checks/follow-ups
- @ **>100 Racks** to be relocated
- @ **Cabling** (>130km, >2500cables)
- @ **Cooling & Ventilation**
- @ **Civil Engineering**
- @ **Shielding**
- @ **Safe Rooms**
- @ **P4 Relocation**
- @ **Planning & Schedule**
- @ **Coordination**
- @ **No Accident!**
- @ **MANY THANKS TO ALL TEAMS/PEOPLE INVOLVED!**





■ 2012:

~70 beam dumps due to **Single Events** on different equipment
 ~1/2 in UJs – the rest in the RRs and Tunnel

➤ LS1 Focus:

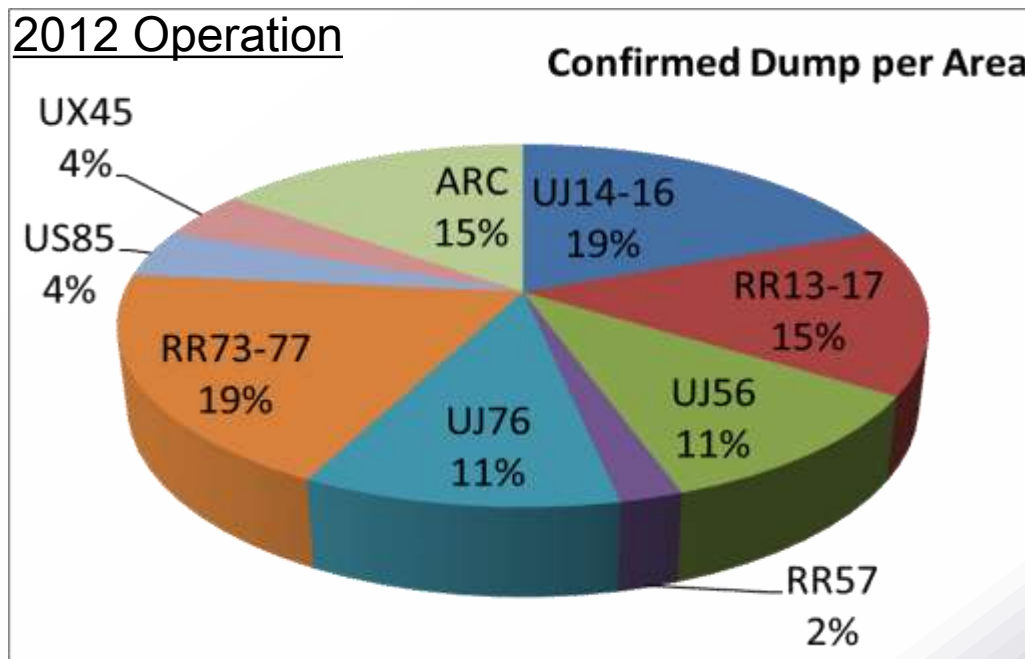
- **'Solve' UJs**
- 'Limit' impact on RRs
- Failures in tunnel

➤ >LS1:

- +radiation levels
- **tunnel equipment will become the focus!**

➤ Ultimate/HL-LHC:

- Determine final exposure (radiation levels + #systems)
- Preventive maintenance to avoid equipment failures
- Injectors to be kept in mind



Relocation & Shielding

- Ⓢ **relocations** in P1/5/7/8 (~100 racks, >>1000 cables, etc.)
- Ⓢ **shielding** of RRs (P1/5), US/UW (P8)
- Ⓢ **additional relocation at P4** (cryogenics mainly)
- Ⓢ smaller shielding activities followed (ducts, mazes)

Equipment Upgrades

- Ⓢ **QPS**
 - Ⓢ new boards (IPQ/IPD/IT, 600A boards, QDS)
 - Ⓢ firmware (DQQBS, DQQDC) + >LS1 preparations
- Ⓢ **Power-Converters** (Mitigation + R&D):
 - Ⓢ power part bug-fix (auxiliary power supply)
 - Ⓢ control (FGClite prototype and first series)
- Ⓢ **Cryogenics** (Beam-Screen Heaters, etc.) + **Others**

Monitoring

- Ⓢ **RadMon New Generation**
 - Ⓢ final development + pre-series and production
 - Ⓢ installation (LHC + Injector)
- Ⓢ Post-LS1 **radiation level follow-up** (LHC + Injectors)

Testing & Facilities

- Ⓢ **New Facilities:**
 - Ⓢ PS-EastArea new test facility (CHARM)
 - Ⓢ Co-60 Facility @ CERN (in collaboration with RP)
- Ⓢ **PSI** test campaigns (16 during 2013)
- Ⓢ **External** companies: Fraunhofer + others (e.g, CEA)

Past:

Errors done , Identified & Mostly Corrected

FROM MITIGATION



Present:

Direct impact is (mostly) mitigated

"Today's R2E situation is good & promising"

TO PREVENTION

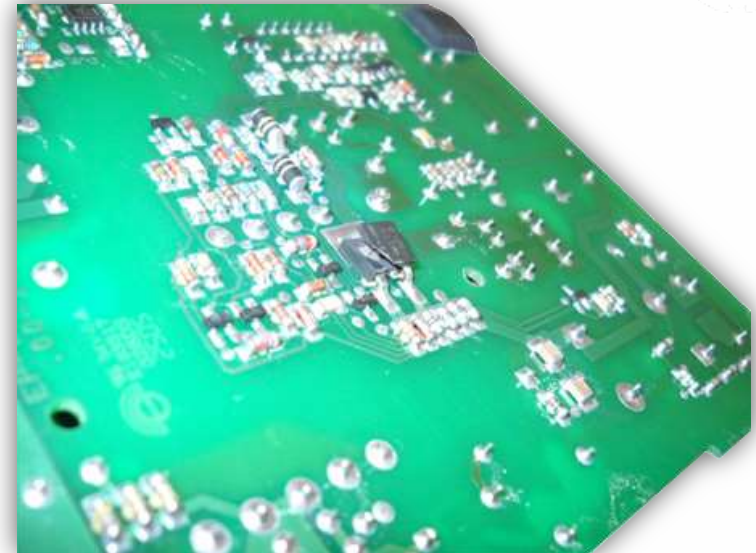


Future:

Conditions become more severe,
reliability more and more important:
an ambitious target, to quantify & achieve

"We've to think ahead and ensure R2E stability"

SEE: Power-Converter (LHC_RR)



⇒ Premature Beam Dump
& LHC Downtime

© Y. Thurel et al



FGClite Development

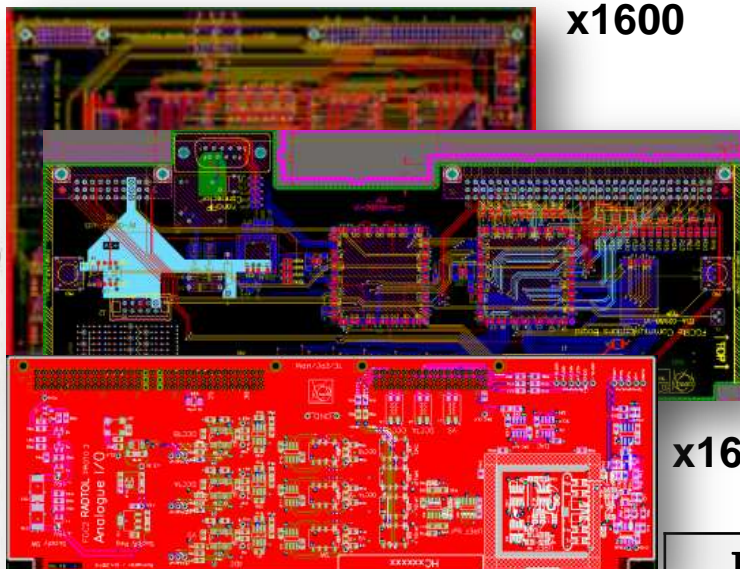
© S. Uznanski



New Radiation-Tolerant design optimized for high availability !!!



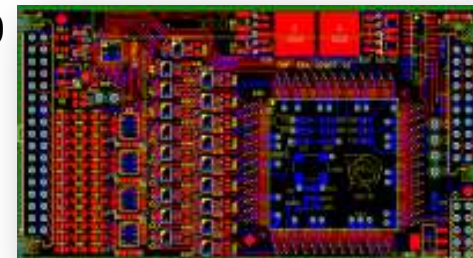
6U cassette



x1600

x1600

x3900



x1600

	Semiconductor			
	Board 1	Board 2	Board 3	Board 4
Diodes	8	13	59	6
LED		6		3
Quartz	1	2	2	1
Opto			4	
Transistor	7	20	27	
IC	22	5	26	30
Total	38	46	118	40

0.5M semiconductors/2.3M components

New testing infrastructure to qualify components under radiation

Real-time SEE & TID tests, & multiple components

Hard Failure

An error induced by faulty device operation. DATA is lost AND data/function is lost and can no longer operate at that location.

Soft Failure

An event corrupting only the DATA stored in a device. The device itself is not damaged and functionality is restored when new data is written.

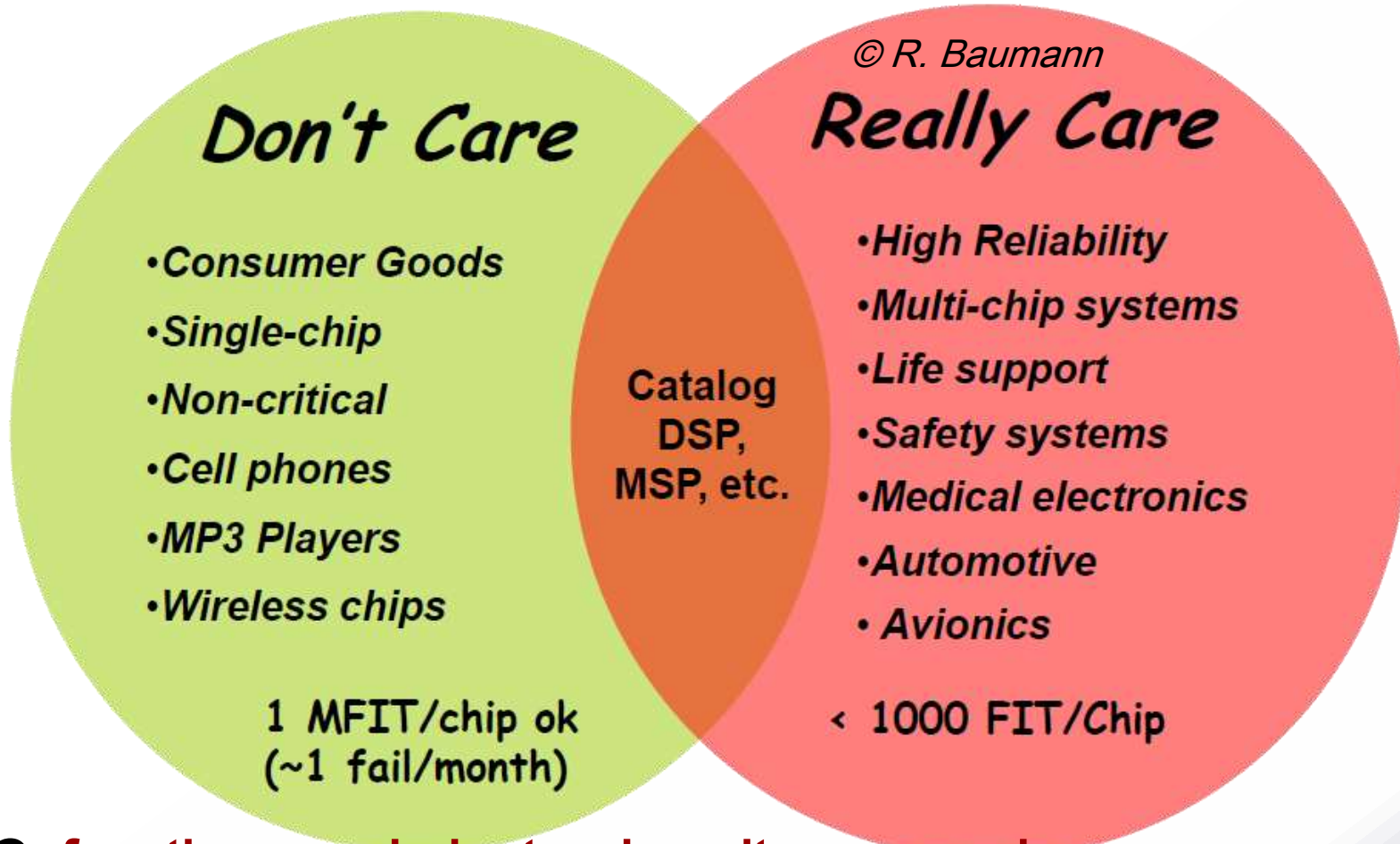
$$1 \text{ FIT} = \frac{1 \text{ failure}}{10^9 \text{ dev} - \text{hrs.}}$$

1 FIT is 1 failure in 114,155 years!

or 100,000 FIT is ~ 1 failure/year



© R. Baumann



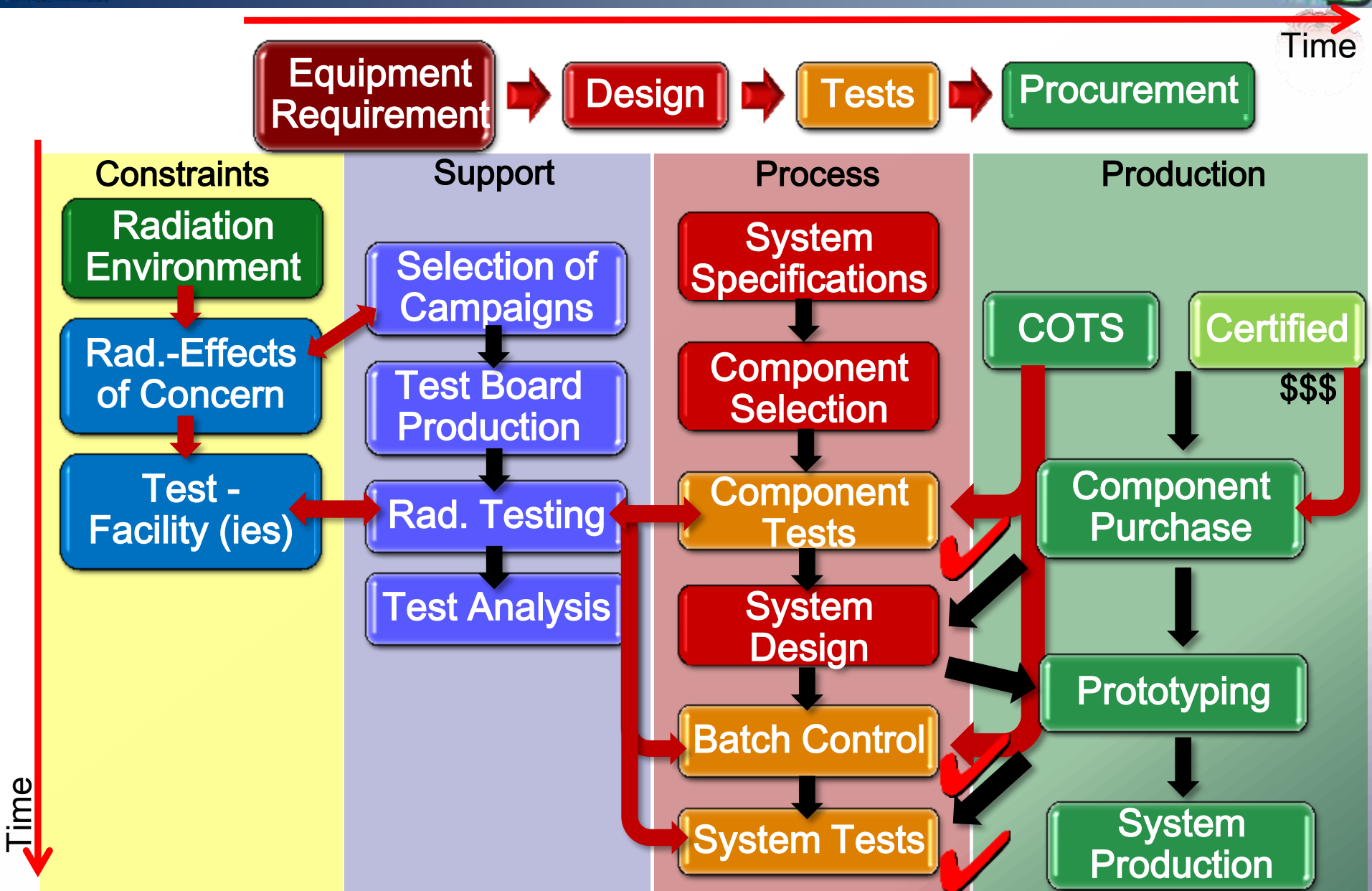
LHC: few thousand electronic units exposed

Aim: less than one radiation induced failure per operational week

Reliability in FIT: -> aiming for few FITs/SYSTEM!

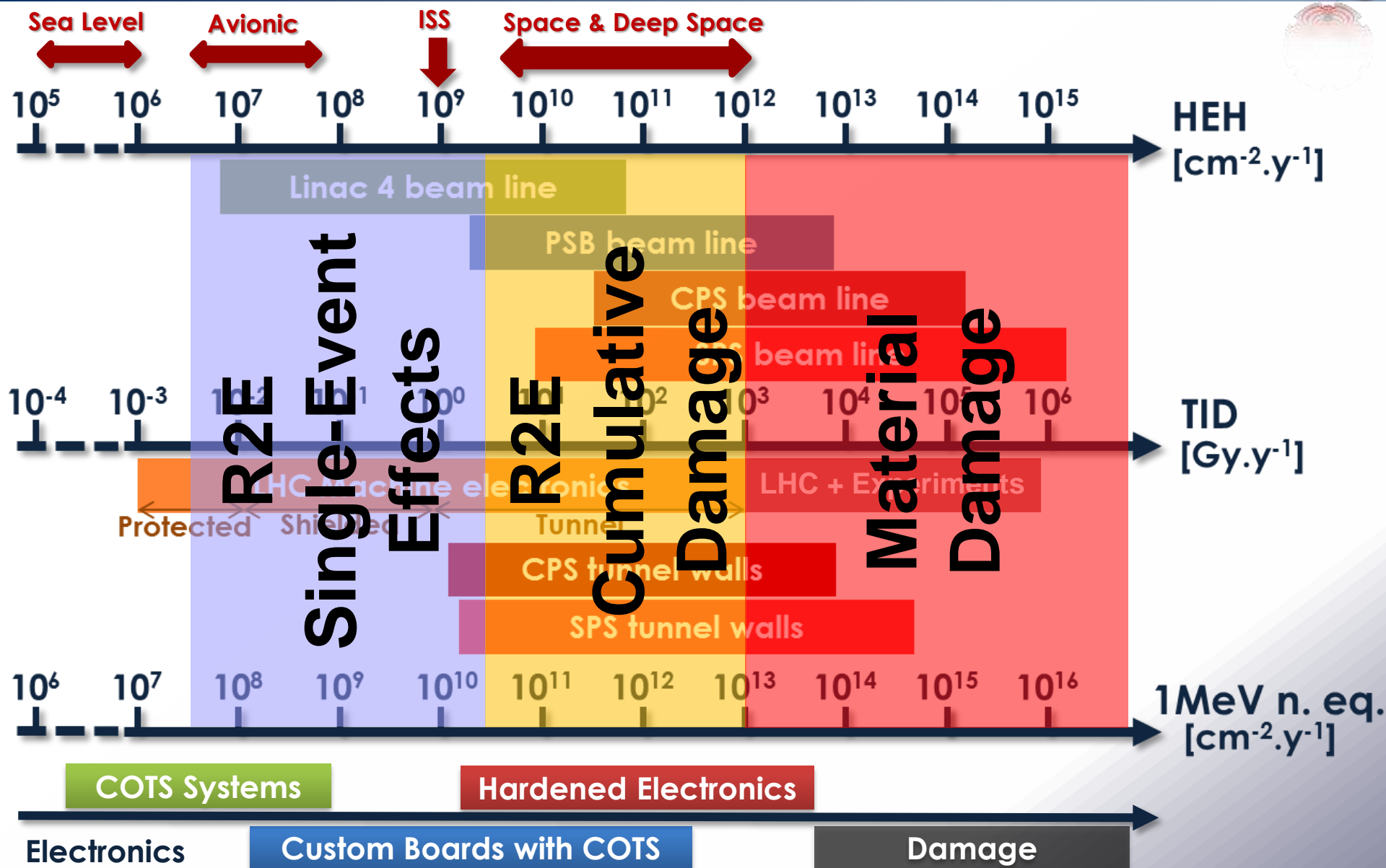
Per Chip? (better don't do it)

A (Rough) Map to Rad-Tol





CERN Radiation Levels



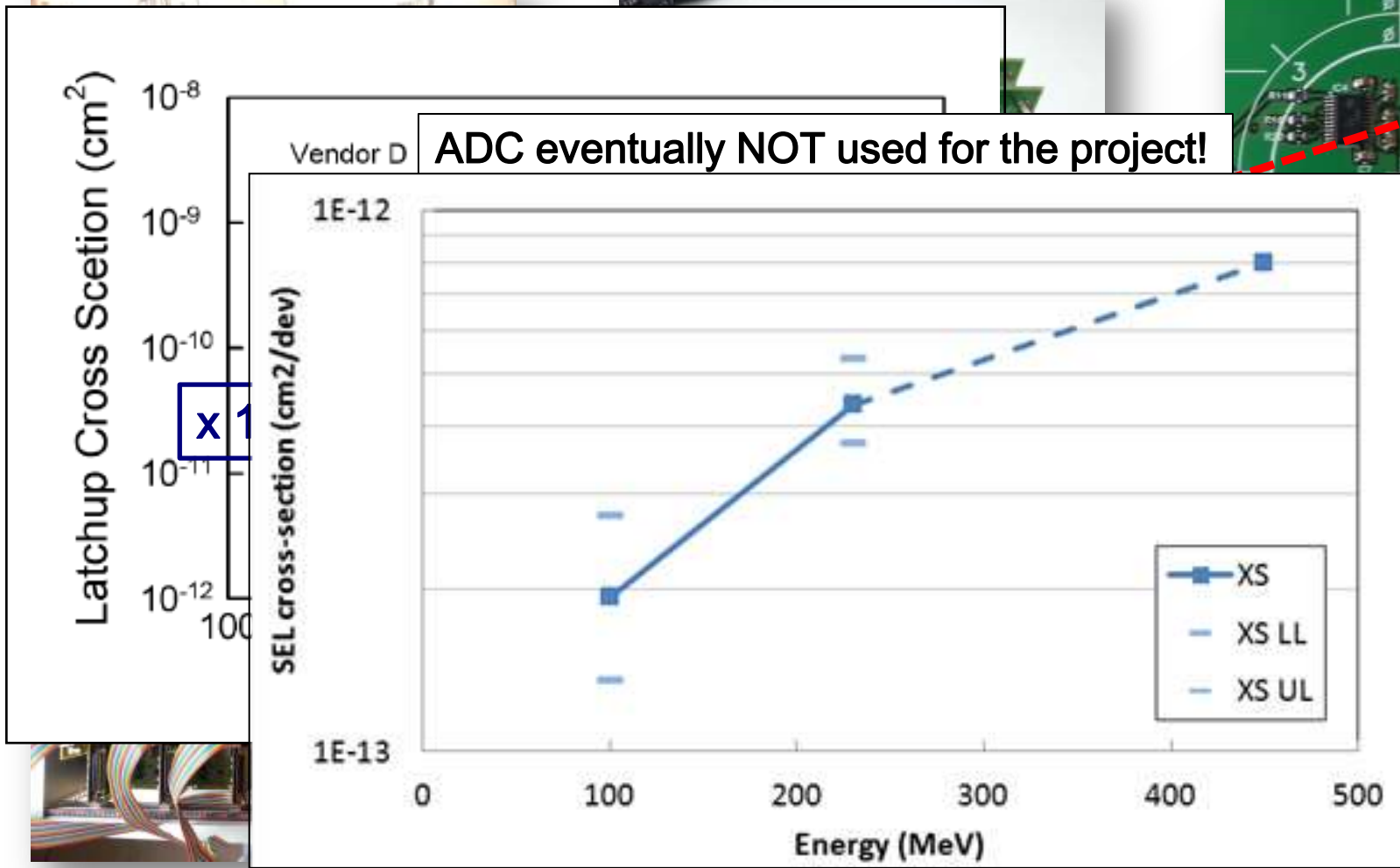


- ⊙ CERN A&Ts electronic designs are based predominantly on COTS
- ⊙ 2011-2014: almost 100 components tested/characterized
- ⊙ Special agreements & Blanket Contracts
 - ⊙ “Prime-Time” at PSI
 - ⊙ “Main customer” of Fraunhofer
- ⊙ Radiation test team of EN/STI working together with all equipment groups
- ⊙ Coordinated through the RadWG



⊙ Available Data

- ⊙ See [summary table](#) of RadWG test campaigns
- ⊙ See [Twiki](#) for all Fraunhofer related tests



Tester Control Electronics

Tester Control Software

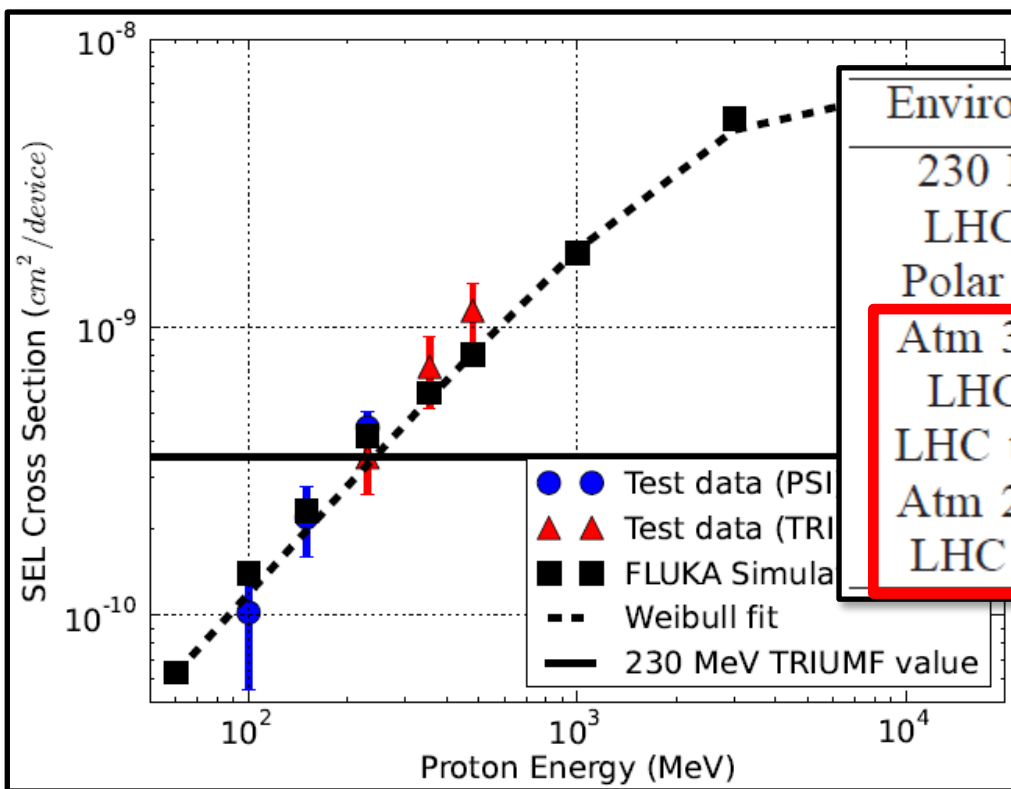
Effect Analysis

© S. Uznanski et al

SEL: Energy Dependence

- ⊙ Important possible dependency for high-energies
- ⊙ Strong impact on various radiation environments

Compared to 100MeV



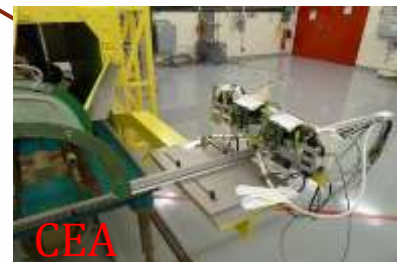
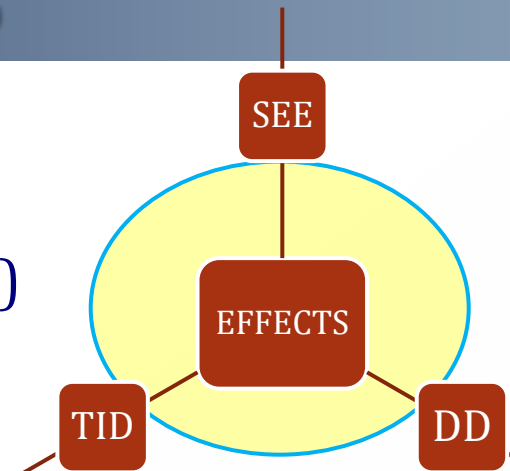
Environment	Case I	Case II	Case III
230 MeV	1.8	2.8	3.4 (1.0)
LHC HS	0.7	0.8	0.9
Polar Orbit	0.9	1.6	2.5
Atm 375 m	1.0	2.1	3.3 (1.0)
LHC LS	1.3	5.2 (1.9)	9.7 (2.8)
LHC tunnel	1.5	9.6 (3.4)	20 (5.8)
Atm 20 km	1.2	10 (3.6)	23 (6.7)
LHC Exp.	1.6	18 (6.3)	40 (12)

↑ No W ↑ W from rev. Eng. ↑ Full layer of W

-> see thesis of R. Garcia Alia

Standard facilities

- PSI. Proton beam (>15 tests per year, [see 2013 list](#))
- CEA, Fraunhofer. Displacement damage (few tests per year)
- Fraunhofer. Co-60. Total Ionizing dose (blanket contract:>10/y)

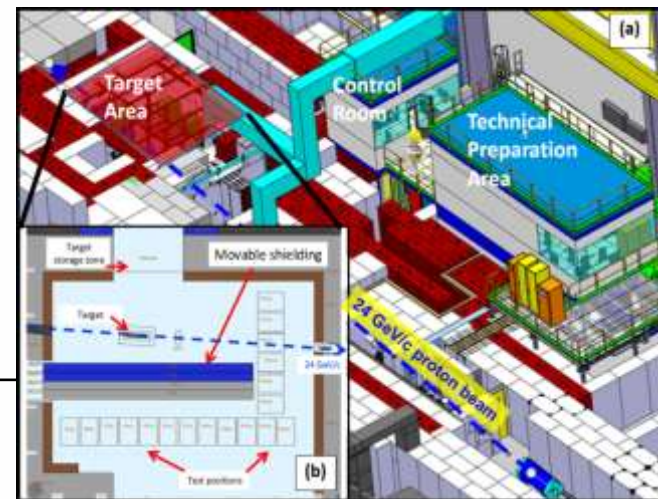


In-house

- (CNRAD, H4IRRAD)
- CHARM (soon operational)**
 - A unique test facility for CERN and external institutes/groups/customers
- Co-60 (under construction)**

Coordination and Operation

- >20 equipment groups affected





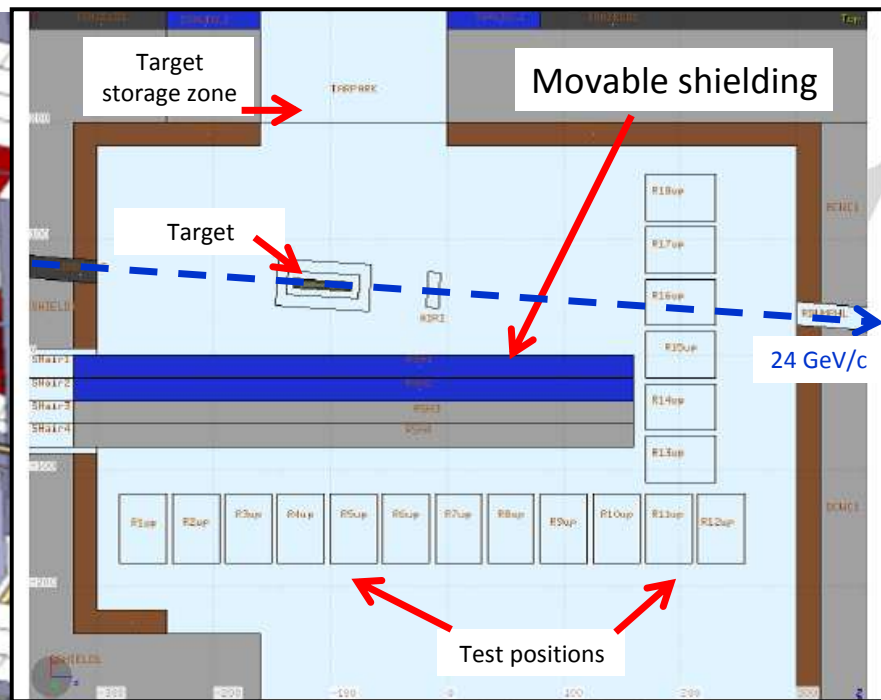
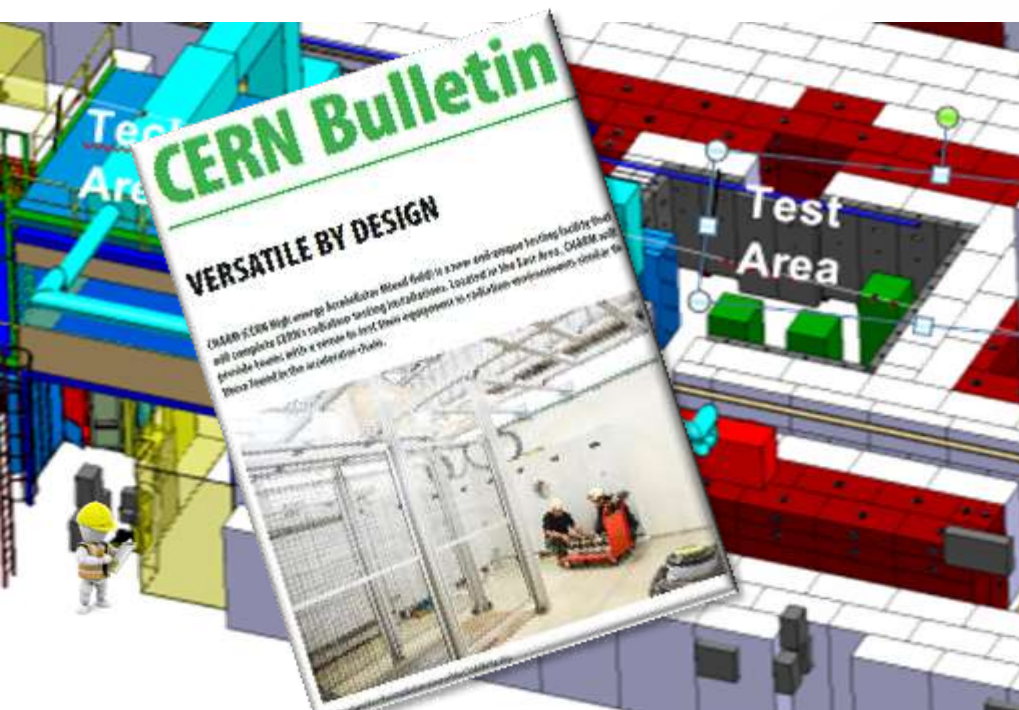
New CERN Mixed-Facility



CHARM

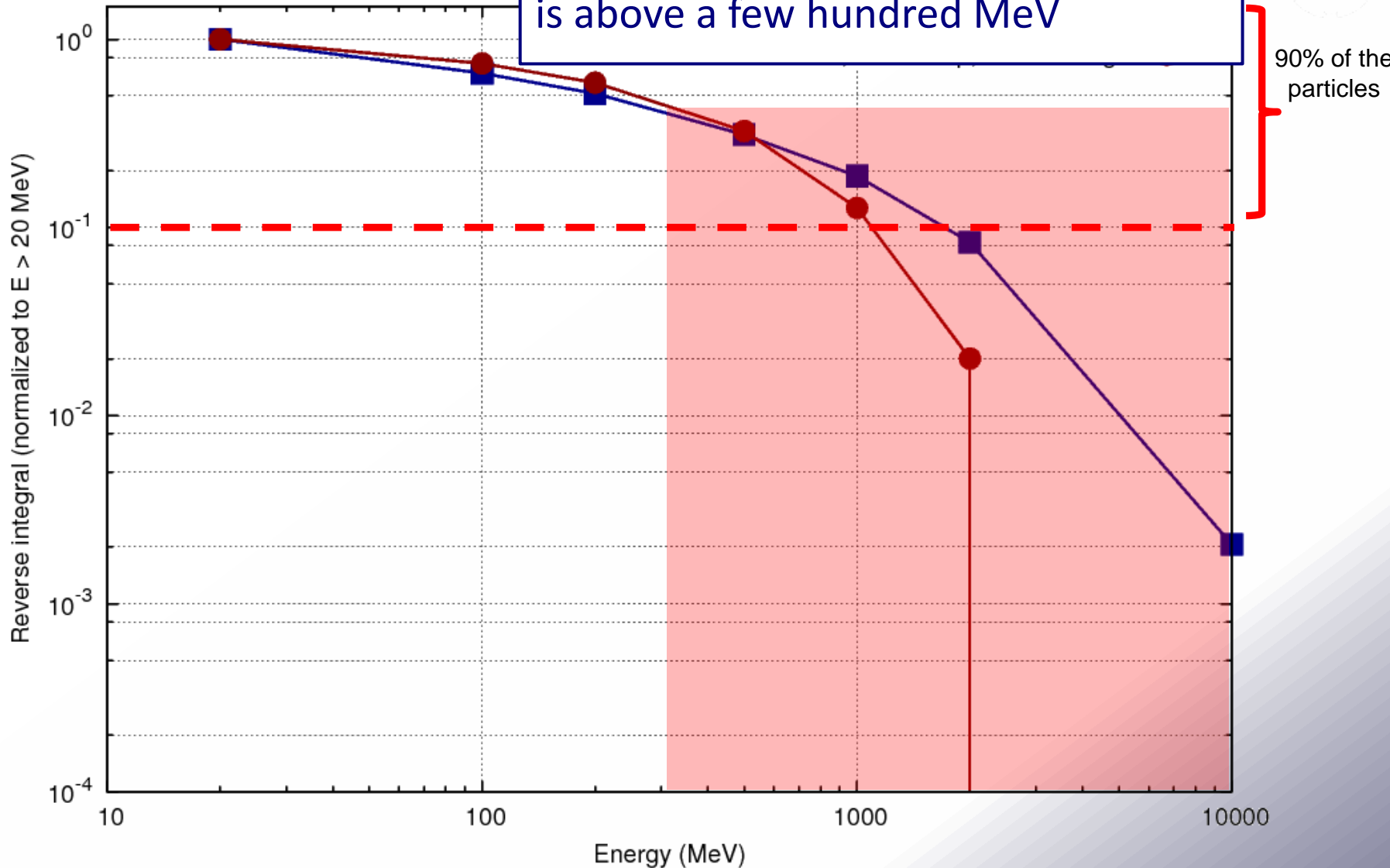
Cern High Energy

Accelerator Mixed Field/Facility



Accelerator Tunnels

~50% of the high-energy hadron flux is above a few hundred MeV

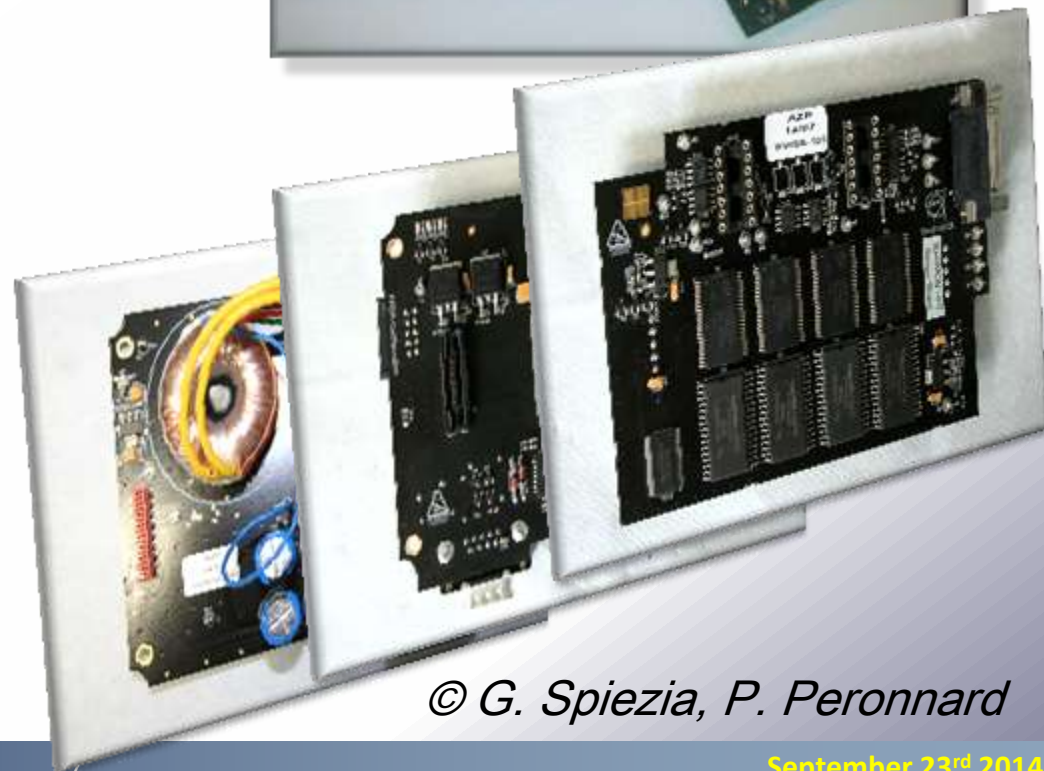




CHARM – In short



- Ⓢ **New RadMon Version (v6)** developed and validated
- Ⓢ **Major improvements in Dosimetry** (Range, Accuracy)
- Ⓢ **Modular design** for future upgrades
- Ⓢ **Deported unit** now at a distance of up to 100m!
- Ⓢ **LHC >500 units!**
- Ⓢ **+ Injector chain** (PSB, PS, SPS)



© G. Spiezia, P. Peronnard



Predictions & Fault-Tracking



Weekly R2E Shift

eLogBook + 8:30h

Equipment Groups

DBs

@ **New fault tracking tool (AFT)**

Rad WG web site-Detail

@ Will still require **iterations with equipment groups and coordination through the RadWG**, but expected to be

@ **Faster**

@ **More reliable and efficient**

@ **Getting feedback/data also on faults not dumping the beam**

Mps Expert Comment	Mps Dump Cause	Mps First detection	Seu Dump	Seu Appeared Other Than Dump	Radwg Entry
Suspected SEU on QPS. Dump clean.	QPS	PIC	Possible	YES	RadWG link1 RadWG link2

The Challenge for >2014

Ⓢ Maintain the knowledge and support
(built-up over past 5 years!)

Ⓢ **Radiation levels** follow-up

Ⓢ **Component** selection and **System Layout**

Ⓢ **Test** campaigns and test setups

Ⓢ **Facilities**

Ⓢ **Rad-tol design**

Ⓢ Coordination

Ⓢ Verification

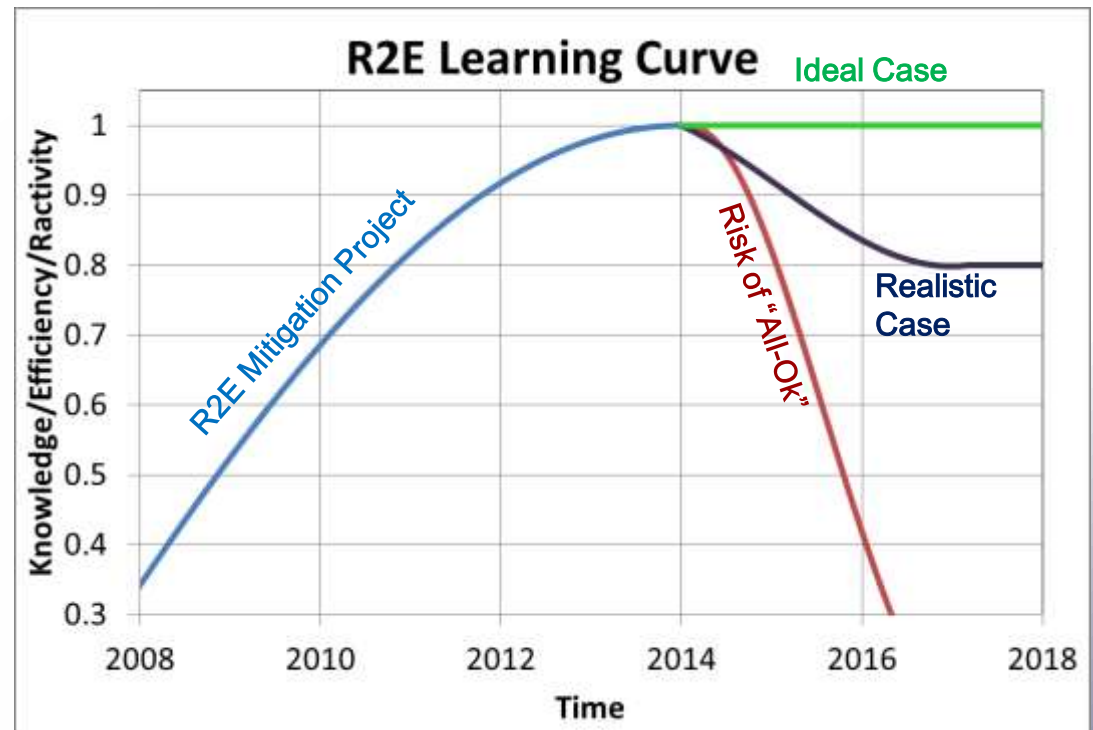
Ⓢ **Rad-Testing**

Ⓢ Coordination

Ⓢ Optimization

Ⓢ Documentation

Ⓢ Etc.



Thanks



R2E Project Mandate

Limit R2E related failures impacting operation

Support: CERN accelerator complex

- ⊙ Provide **Radiation Maps** (calculations & monitoring)
- ⊙ Provide **Monitoring** and calibration during tests
- ⊙ Assure correct **Developments** and respective **Support**
 - ⊙ R2E knowledge, test campaigns, facilities, coordination
- ⊙ Analyse **Equipment Failures**
- ⊙ Implement **Mitigation** measures

⊙ **“Quality-Assurance”**

Profit from synergies

⊙ Radiation test campaigns

⊙ New radiation tolerant developments





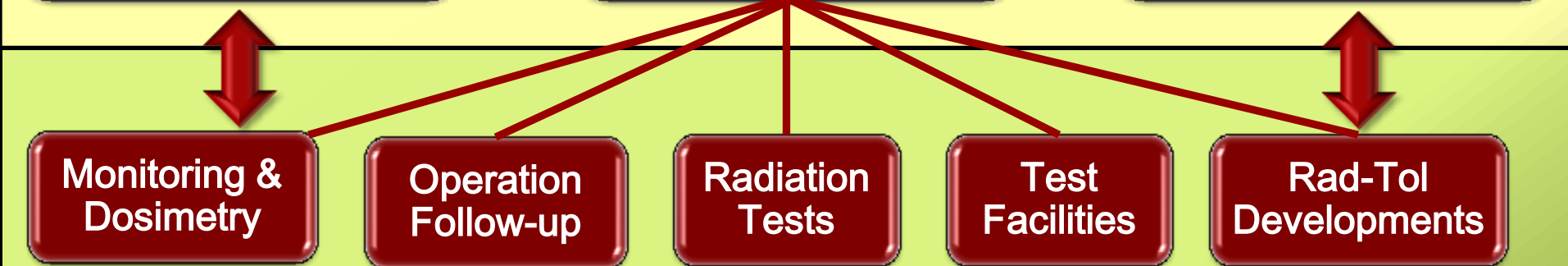
R2E Organization Break-Down



LHC and Injector Committees
(IEFC, LMC)



R2E Project



Implement, Support, Coordinate, Develop, Operate, Maintain



What's NEXT LS1-LS2-LS3-HL



LHC Tunnel & RR
Equipment

Radiation
Monitoring

Injector Chain
Radiation Maps

CERN Test
Facilities

R2E Knowledge

External Test
Facilities &
Contracts

Radiation Tests
and Support

R2E Guidelines
and "Policy"

Injector Chain
"Equipment"

- ⊙ Numerous **systems** affected
(powering, control, cooling, monitoring, etc.)
- ⊙ Several critical for **beam operation**
- ⊙ Some to be located in “**high-radiation**” areas

A few (simple) numbers

- ⊙ ~20 different **exposed system**
- ⊙ From a few to a **few thousand units** each
- ⊙ number of parts per (per system)
range **from a few to a few hundred**

$$N_{failures} = \int \phi(x)\sigma(x)dx \times N_{devices} \sim \Phi(x > X)\sigma \times N_{devices}$$

- ⊙ **Reliability = low number of failures/short down-times!**