New Irradiation facility at CERN: CHARM

CERN R2E project

Electronics Coordination Board 11th October 2013

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for the CERN R2E Project
www.cern.ch/r2e

!!! Many Thanks To All Project Members
and for the fruitful collaboration with the PH department !!!

Outline

- **Introduction**
  - Why do we do radiation tests ?
  - **Radiation field**
  - Particle spectra and energy dependence
- **New facility**
- **Conclusion**

CHARM

Cern **H**igh Energy **A**cceleRator **M**ixed Field/Facility

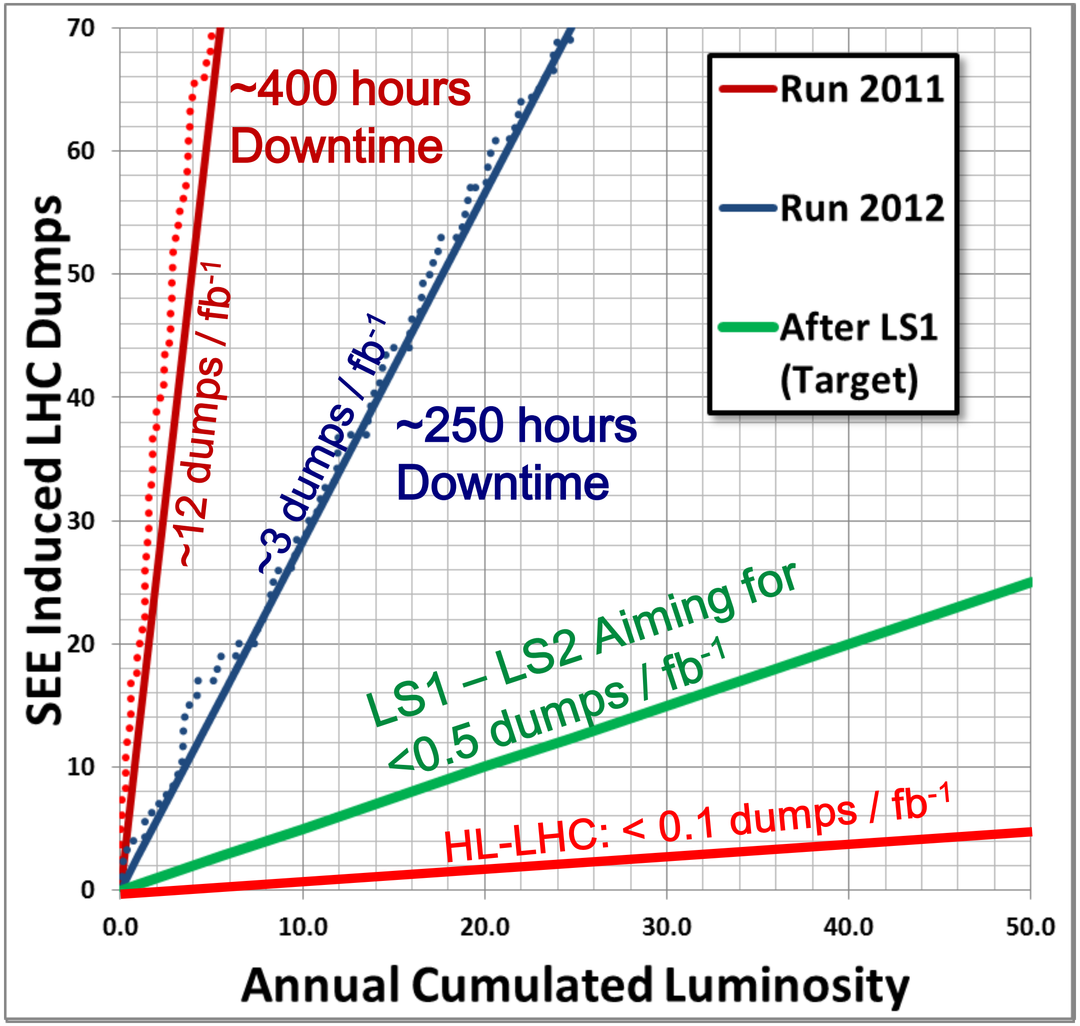
- We'd also Other Good Options,

  … But

- CHER (French = expensive)
  (Cern High Energy Radiation Facility

LHC R2E: Past/Present/Future

R2E SEE Failure Analysis



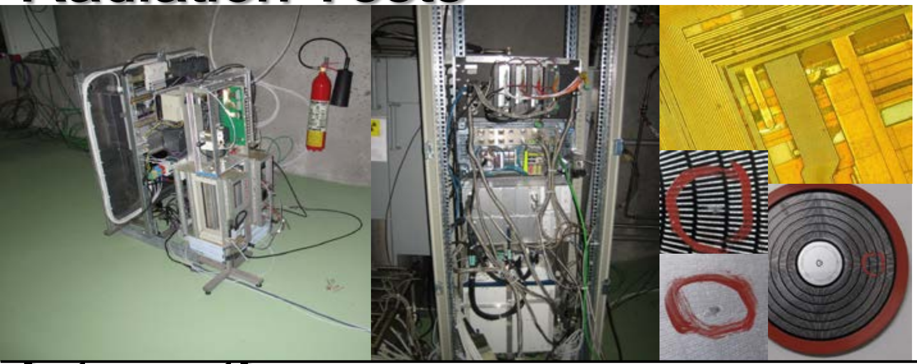
- **2008-2011**
  - Analyze and mitigate all safety relevant cases and limit global impact
- **2011-2012**
  - Focus on long downtimes and shielding
- **LS1 (2013/2014)**
  - Final relocation and shielding
- **LS1-LS2 (2015-2018)**
  - Tunnel equipment and power converters

List of groups/projects for the future

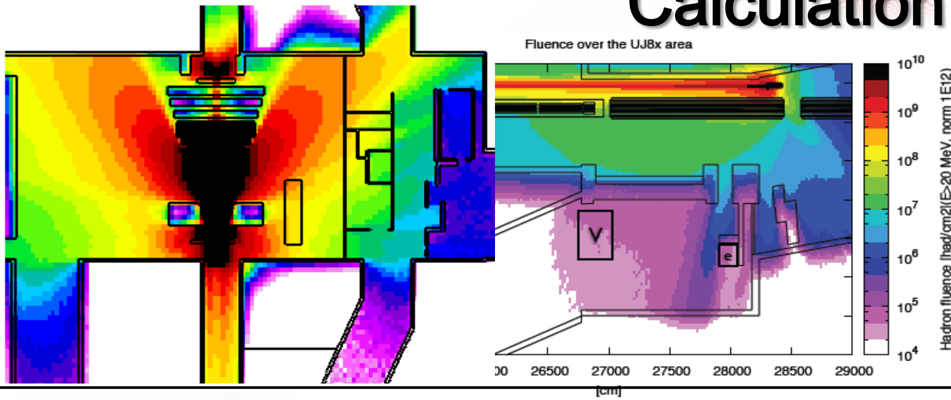
- TE/EPC (e.g Power converters) -> *Development up to 2018*
- EN/EL (e.g UPS) -> *Development up to 2016*
- QPS
- LHC experiments
- Cryogenics
- Beam Position Monitor
- EN/STI (e.g. component tests, RadMON V6)
- Beam Loss Monitors
- EN/ICE
- From Outside (Universities, laboratories, industrials: *e. g. radiation tests with particle spectra representative of atmospheric/ground environments*)
- And others ….

R2E Mitigation Project Building Blocks

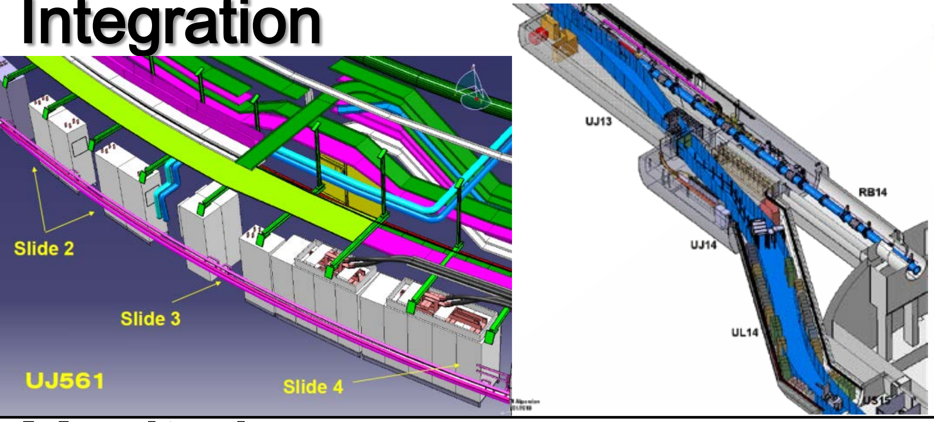
Radiation Tests



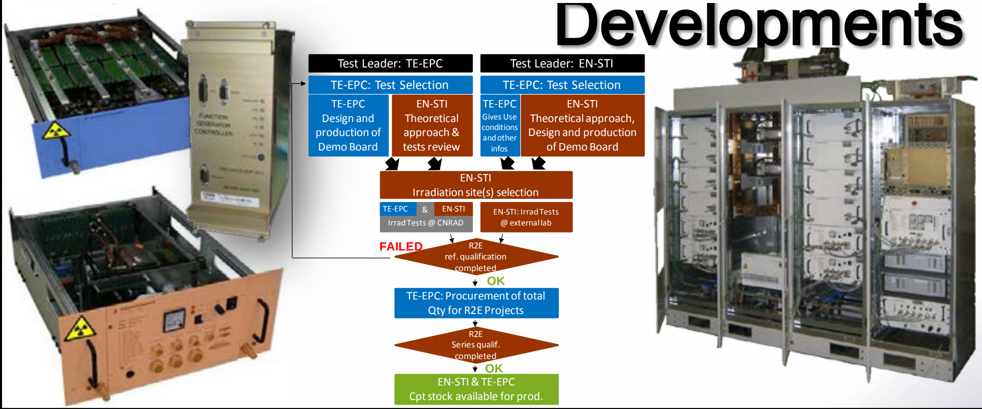
Calculation



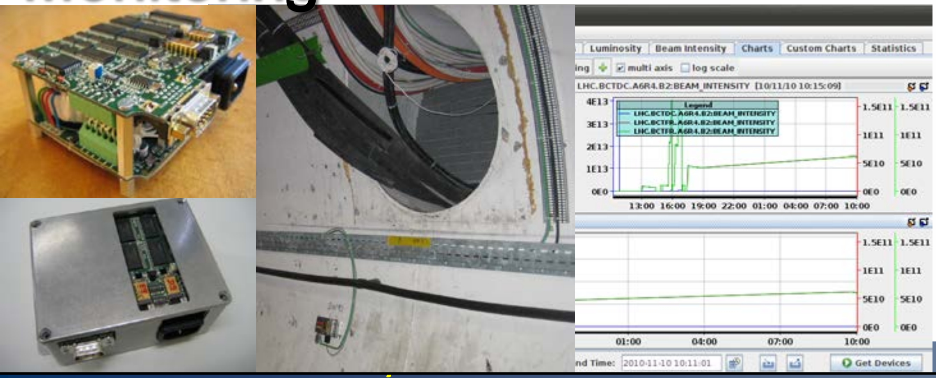
Integration



Developments



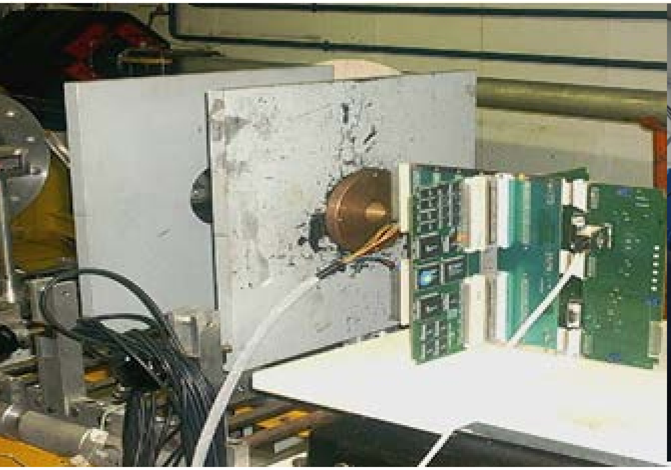
Monitoring

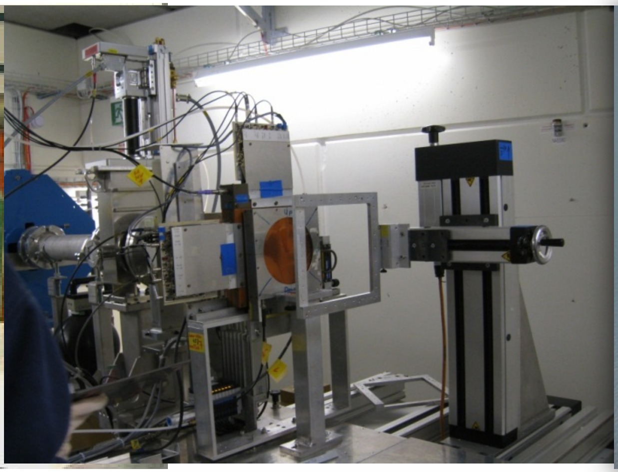


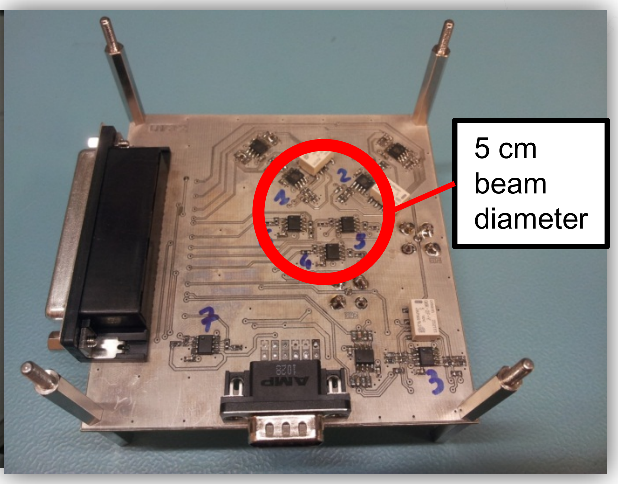
Implementation

Size Matters?

TEST COMPONENTS/CARDS:







OR EVEN TEST THIS:

HERE

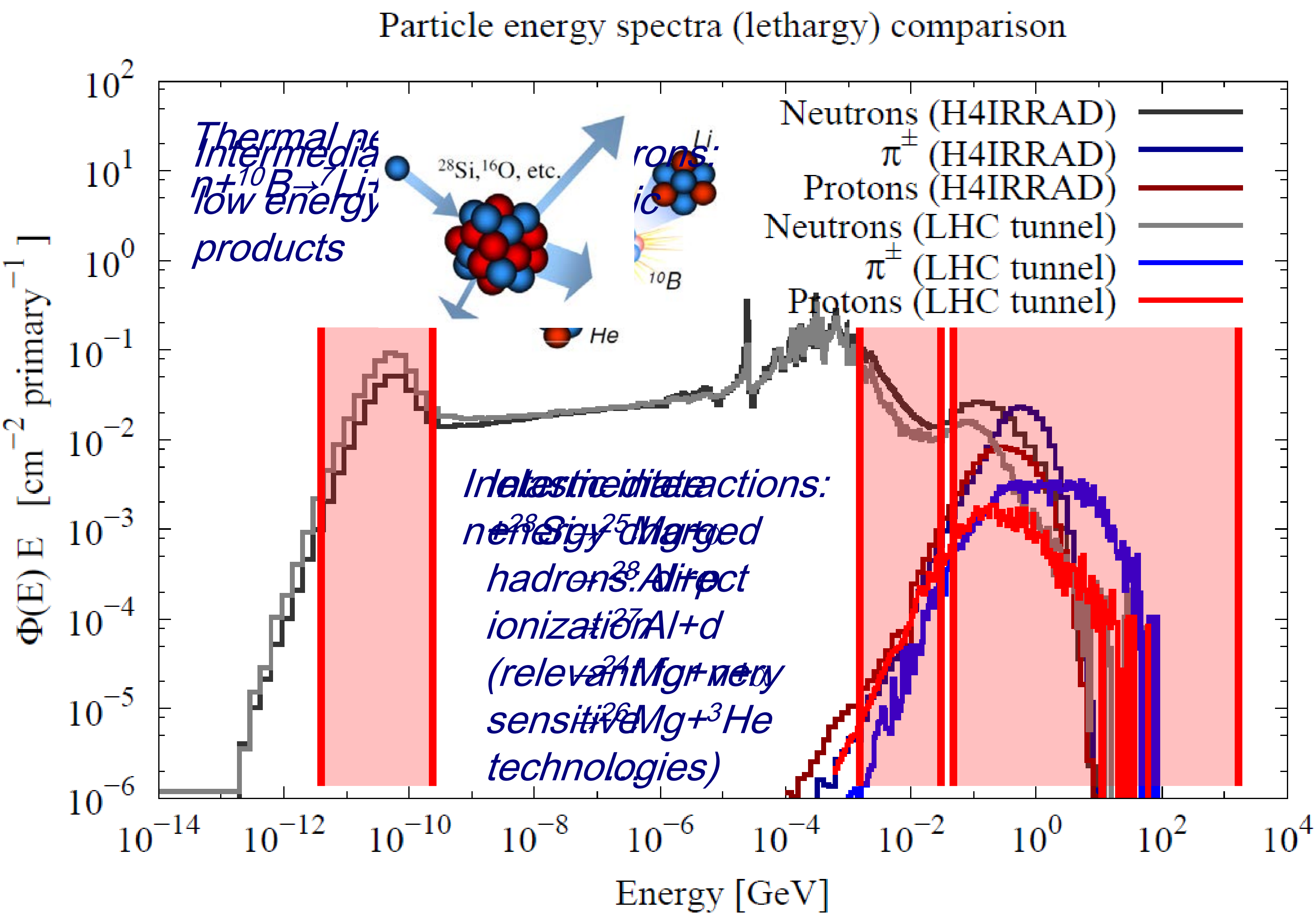
(W)HOW ???

The High-E Accelerator Environment

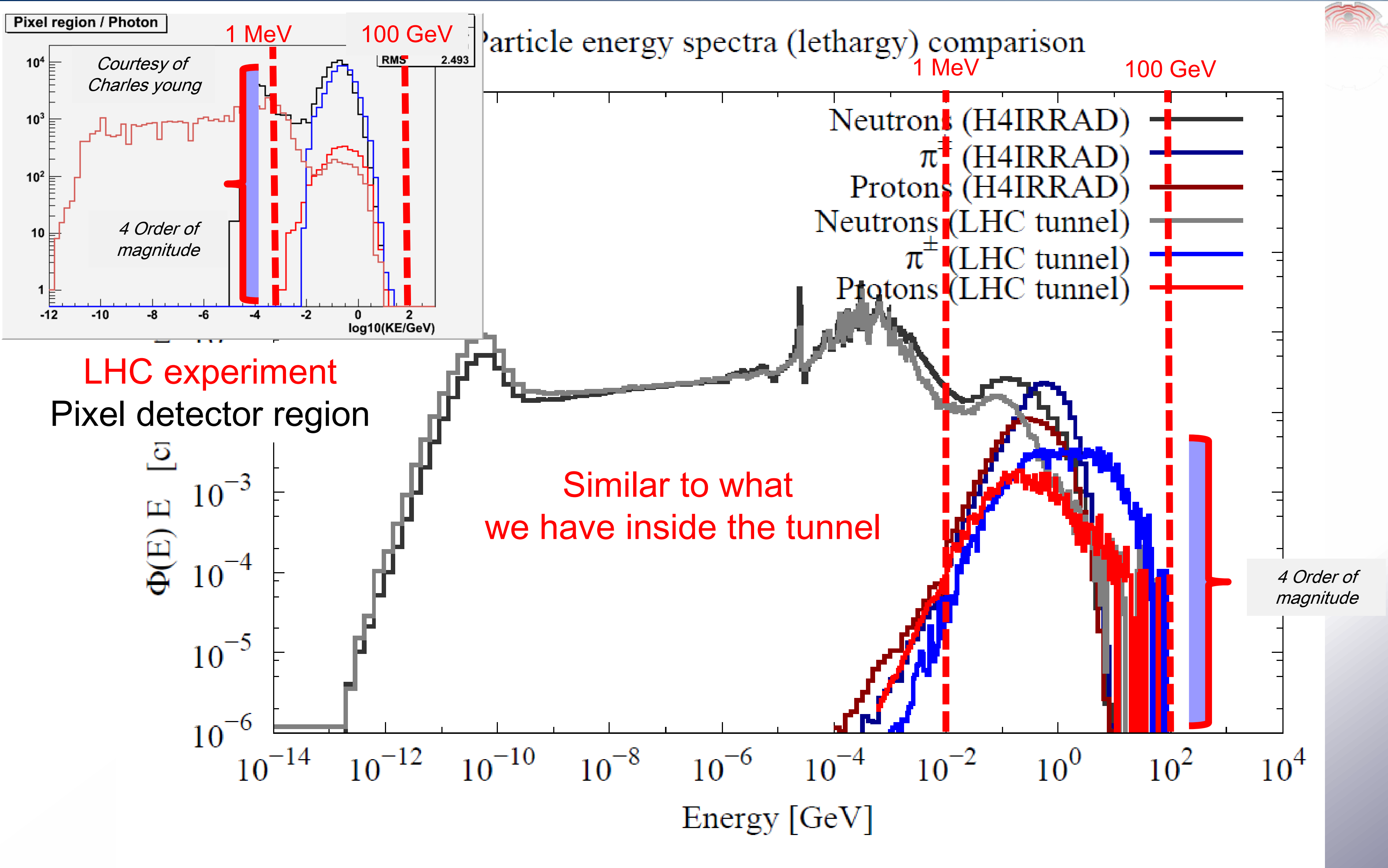
- Radiation fields originated by **very high energy particles** interacting with different elements (collimators, gas, targets, etc.)
- **Wide range of intensities**!

Ground level	Avionic	ISS Orbit	LHC machine	LHC Detectors	
1-2.10^5	**≈ 2.10^7**	**≈ 1.10^9**	**10^6 - 10^{11}**	**> 10^{11}**	*HEH/cm²/yr*

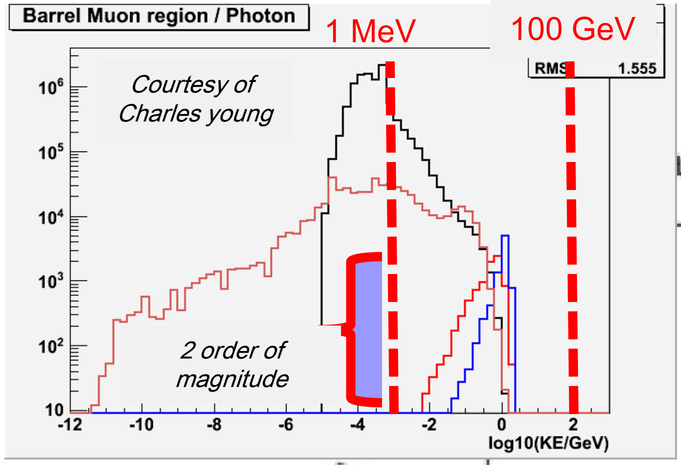
Particle Energy Spectra – The Source



Particle Energy Spectra – The Source

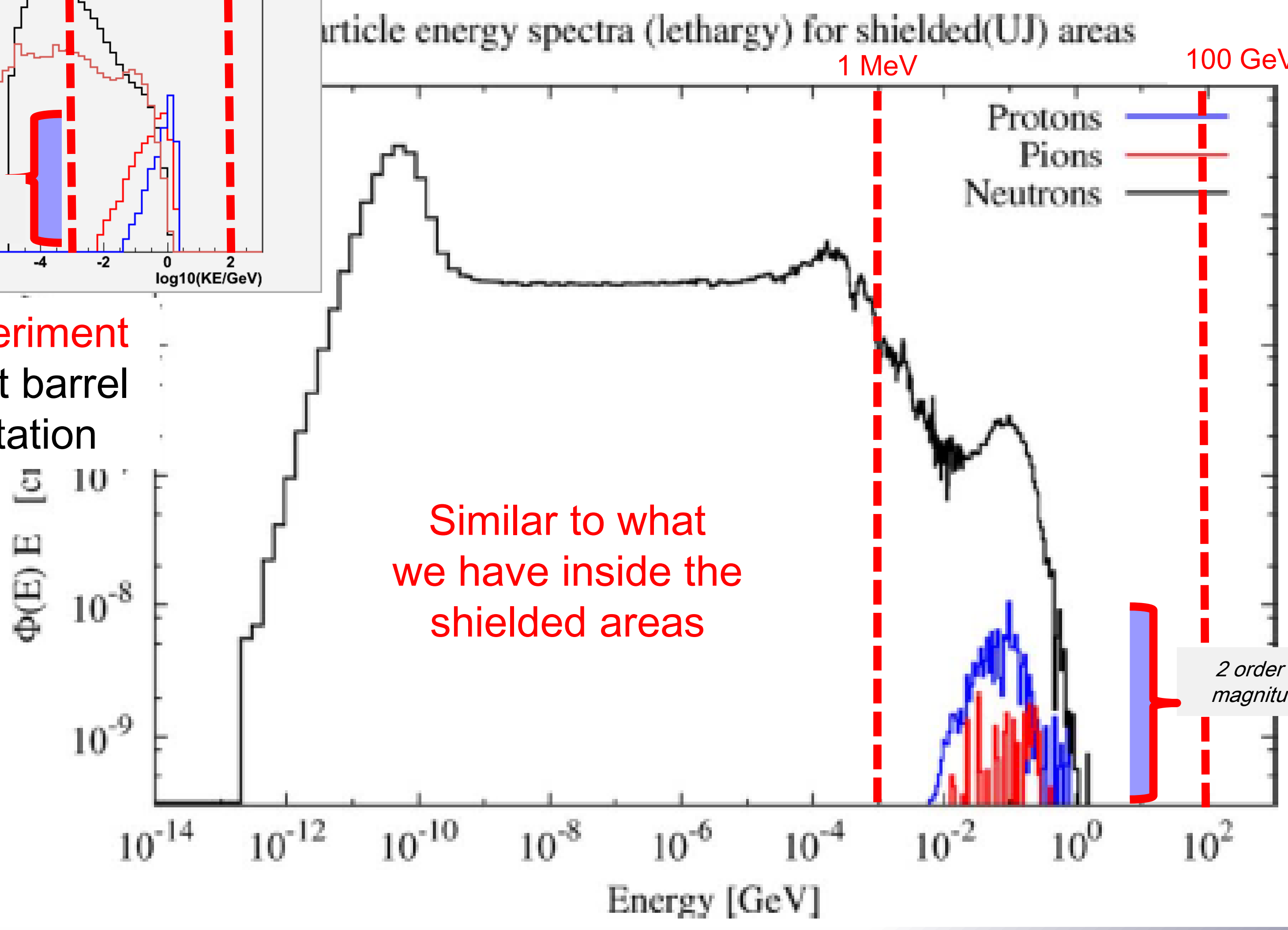


Particle Energy Spectra – The Source



LHC experiment

Outermost barrel muon station

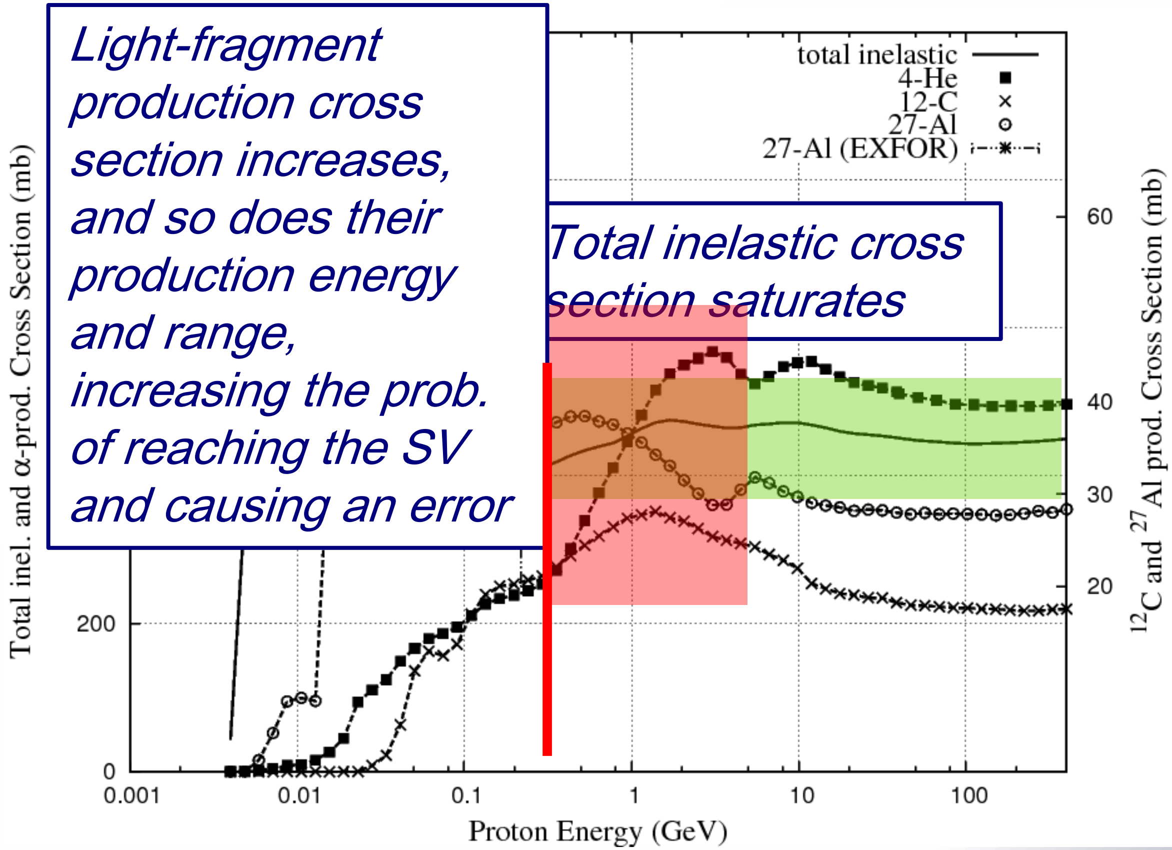


Similar to what we have inside the shielded areas

Energy Dependence

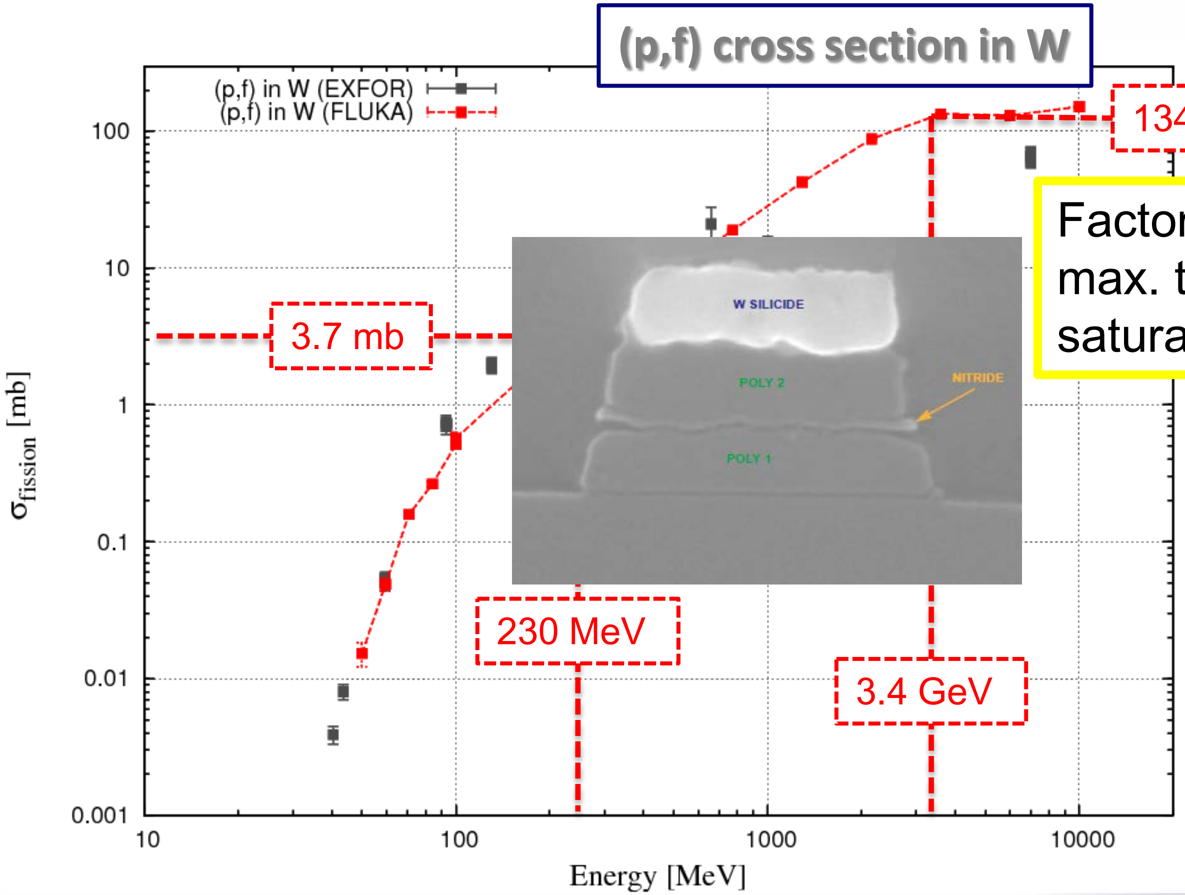
Above ~100 MeV, the total hadron-Silicon inelastic cross section is saturated, however:

- more light, long-ranged fragments are produced
- and they are produced with larger energies (and therefore ranges)



Fission: Energy Dependence

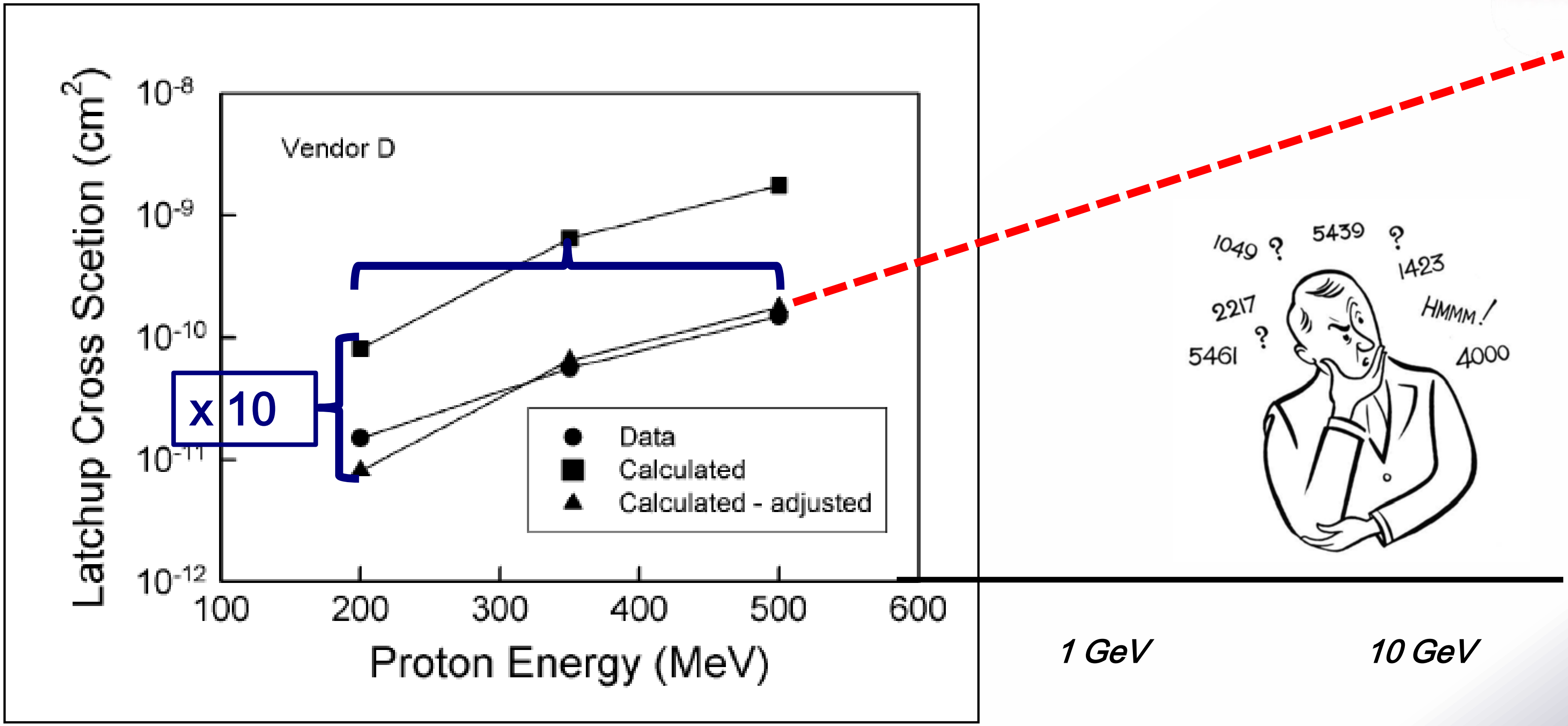
- **High-Z materials** (namely **tungsten**) are often used in the interconnection layers of the memories, **near the sensitive volumes**
- Energetic hadrons can induce **fission** in these materials, producing very **high-LET fragments** that can **dominate the SEE cross section**



Factor ~35 between max. test energy and saturation

ATTENTION

SEL: Energy Dependence

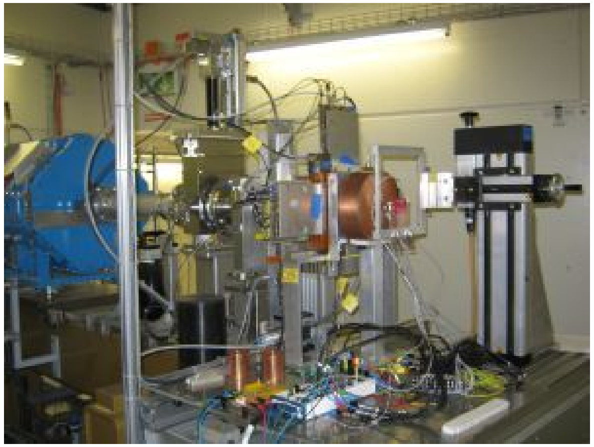


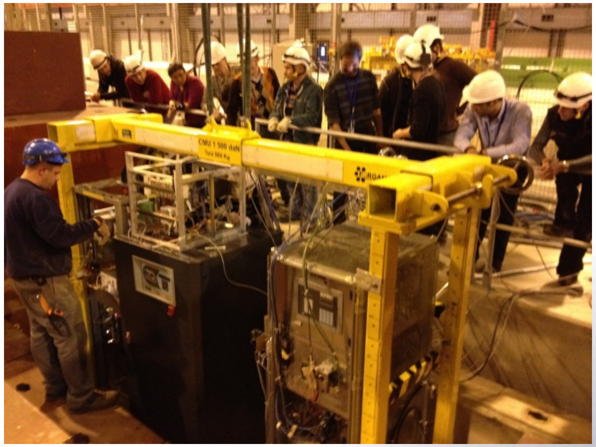
Schwank 2005 (IEEE TNS)

R. Garcia-Alia (CERN Thesis 2012-2014)

How do we deal with SEEs within the R2E project ?

- Commercial components to be used in systems operating in radiation environments need to be **tested**.
- Standard **SEE test** are carried out at **PSI** (30-230 MeV protons) or at CERN **in-house text facilities** (mixed-radiation field).
- Testing is **expensive** and **time-consuming**, however the **criticality** of many of the potential failures is high (especially in terms of **beam-time loss**).
- The **risk** is foreseen to increase in the upcoming years due to increasing sensitivity and LHC intensity/luminosity.



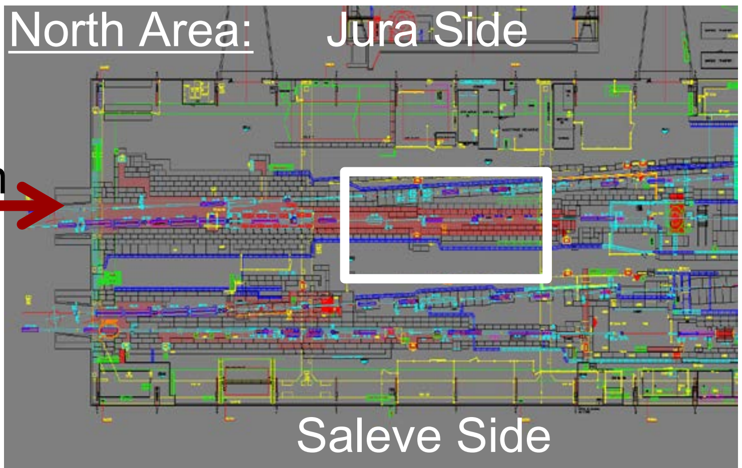


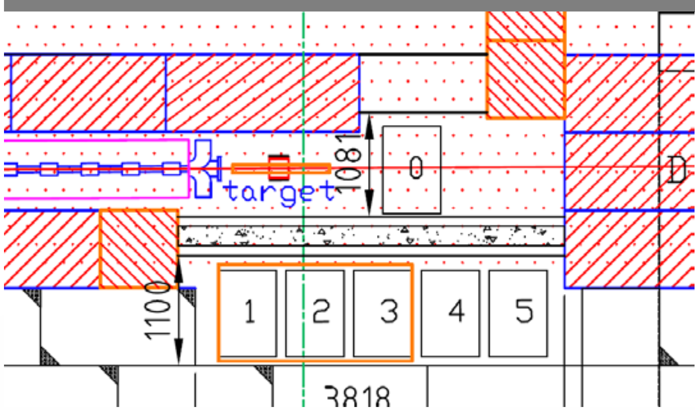
New Facility Required

Extensive and **complex radiation test campaigns** exceed CERN's current test possibilities (~~CNRAD~~, H4irrad, PSI) – Important to think ahead!

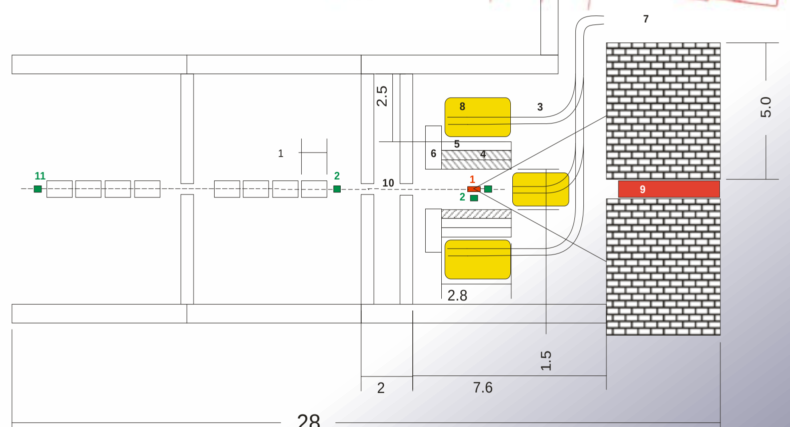
- **H4IRRAD (2011)**

SPS Beam



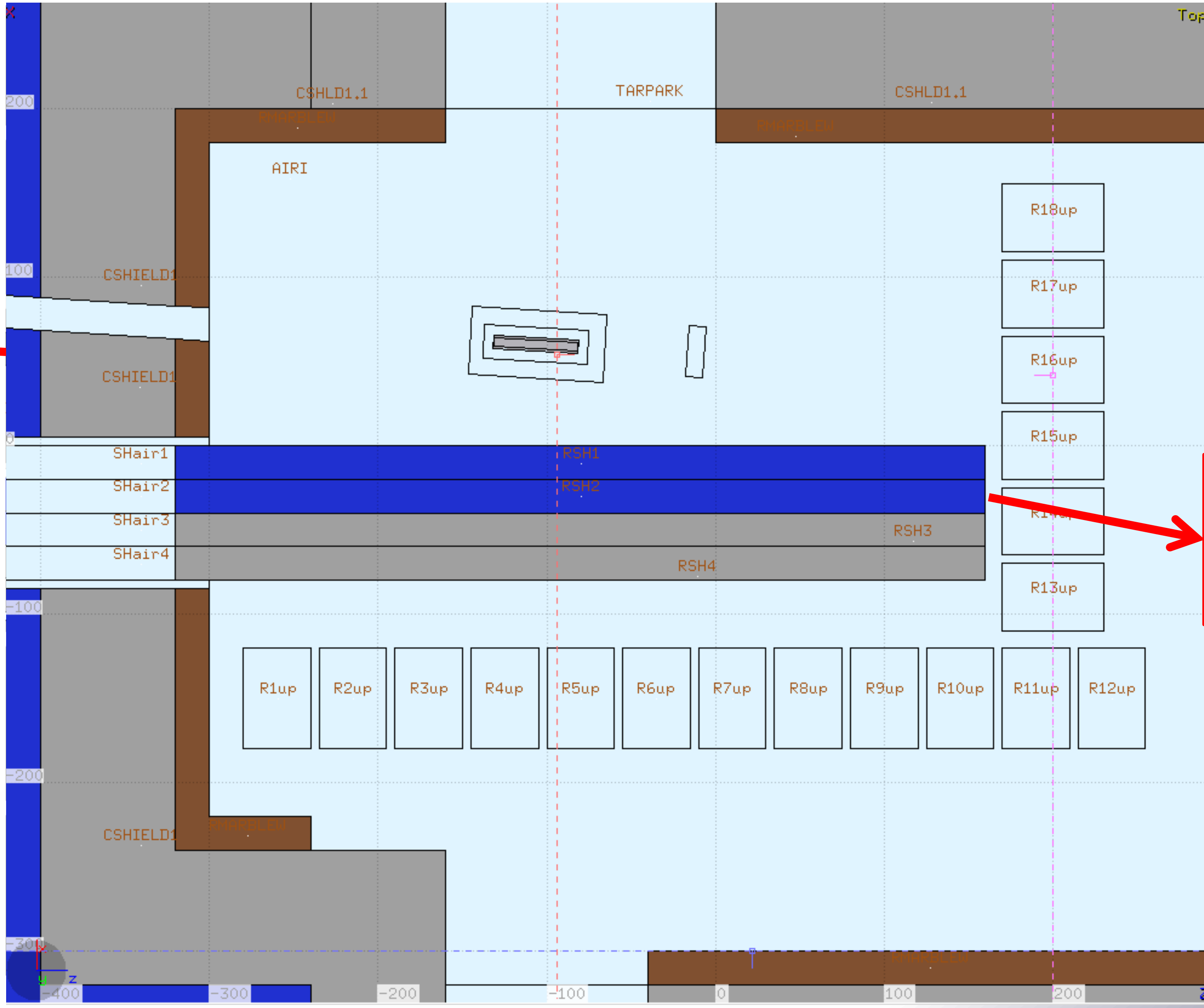


- **PS-EastArea (2014)**



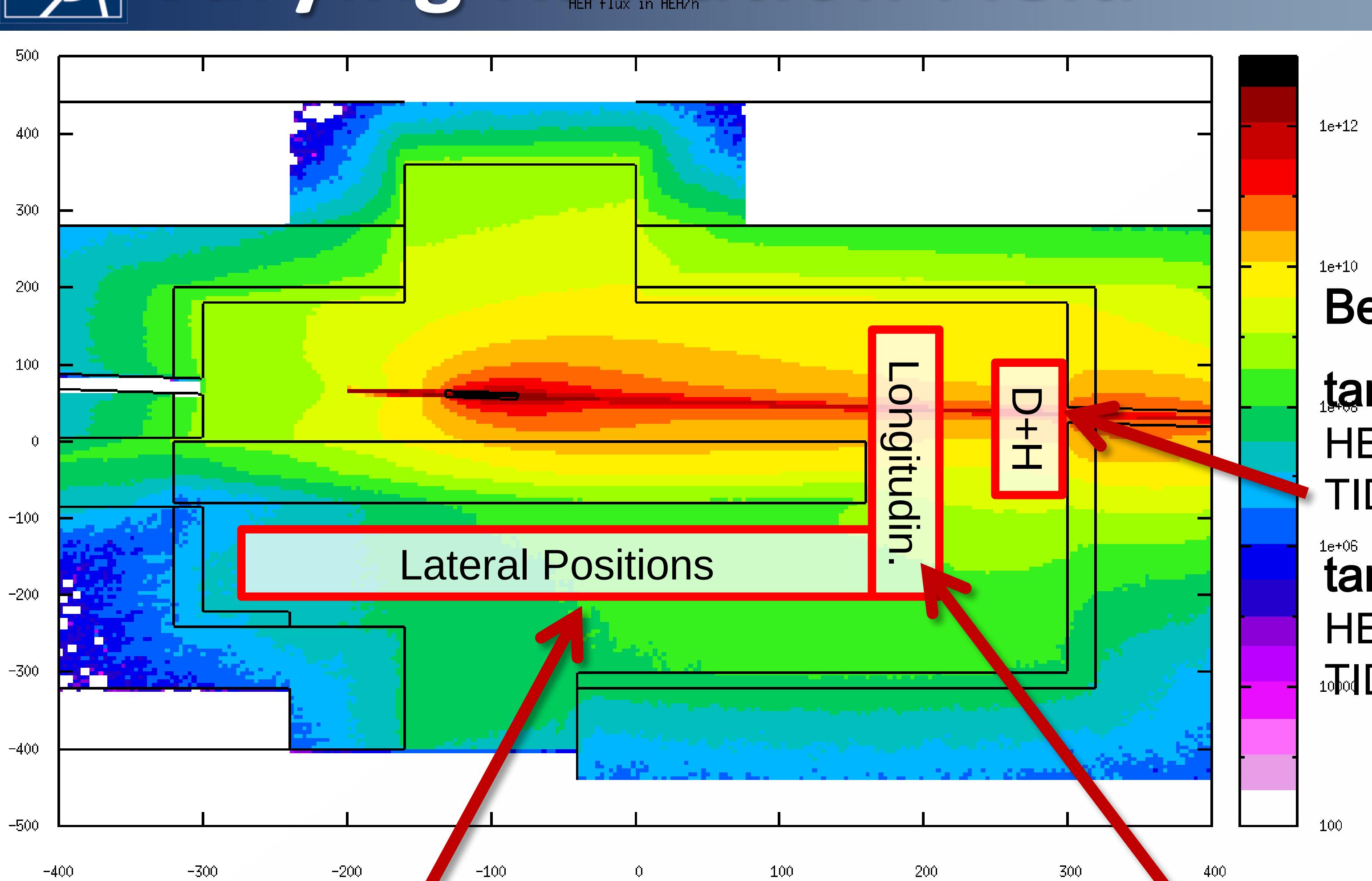
Approach: Test Positions

24 GeV/c protons



4x40 cm movable shielding

Varying Radiation Field



Beam Position

target in:

HEH: $>10^{11}\mathrm{cm}^{-2}\mathrm{h}^{-1}$

TID: $>100\ \mathrm{Gyh}^{-1}$

target out:

HEH: $>10^{13}\mathrm{cm}^{-2}\mathrm{h}^{-1}$

TID: $>10\ \mathrm{kGyh}^{-1}$

HEH: $10^{8}\mathrm{cm}^{-2}\mathrm{h}^{-1} – 10^{11}\mathrm{cm}^{-2}\mathrm{h}^{-1}$

TID: $0.1\mathrm{Gyh}^{-1} – 100\mathrm{Gyh}^{-1}$

(gradients to be considered)

Full racks, crates, set of cards, components

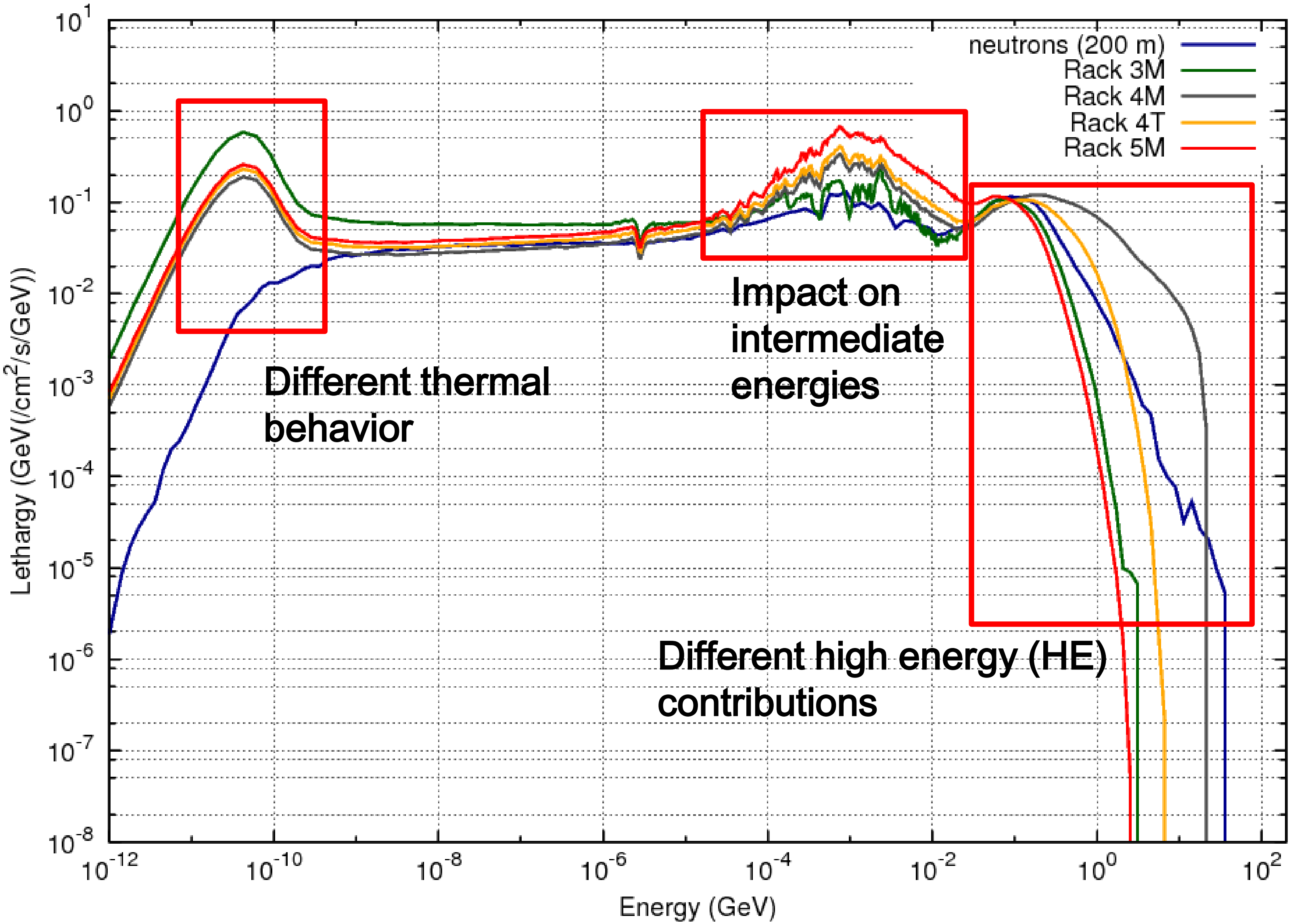
HEH: $10^{7}\mathrm{cm}^{-2}\mathrm{h}^{-1} – 10^{10}\mathrm{cm}^{-2}\mathrm{h}^{-1}$, TID: $10\mathrm{mGyh}^{-1} – 10\mathrm{Gyh}^{-1}$

Comparison with previous test areas

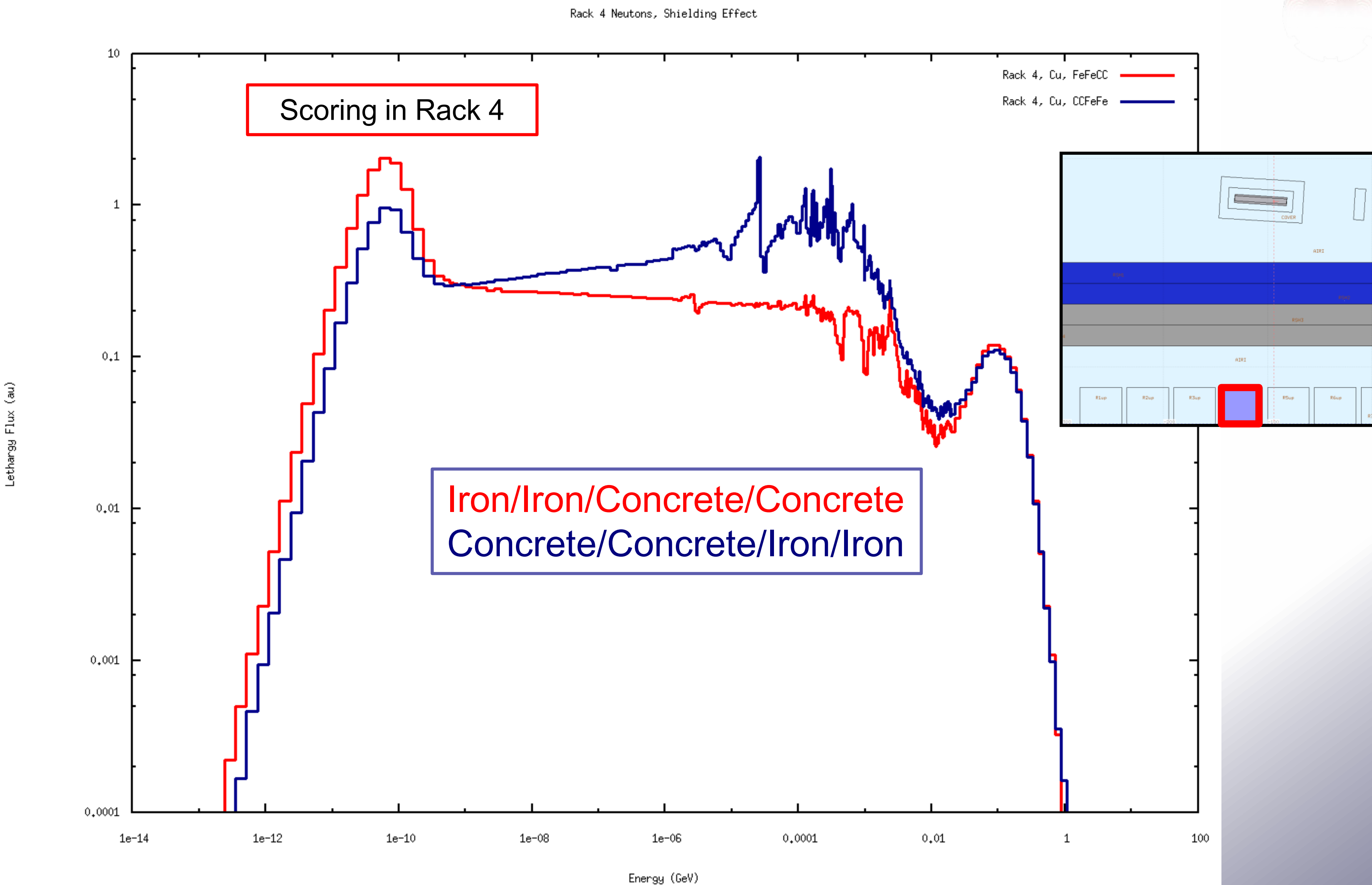
- Intensity reachable for 1 year (220 days) of beam operation in comparison to previous experimental test areas

	CNRAD	H4IRRAD	CHARM	
			Max	Min
HEH (cm^{-2})	≈ 6×10^{12}	≈ 3×10^{12}	_Target Out:_ $>5.3\times10^{16}$ _Target IN:_ $>5.3\times10^{14}$	$>5.3\times10^{10}$
Dose (Gy)	≈ 880	≈ 315	_Target Out:_ $>53\times10^{6}$ _Target IN:_ $>530\times10^{3}$	>53

Test positions: -> Spectra

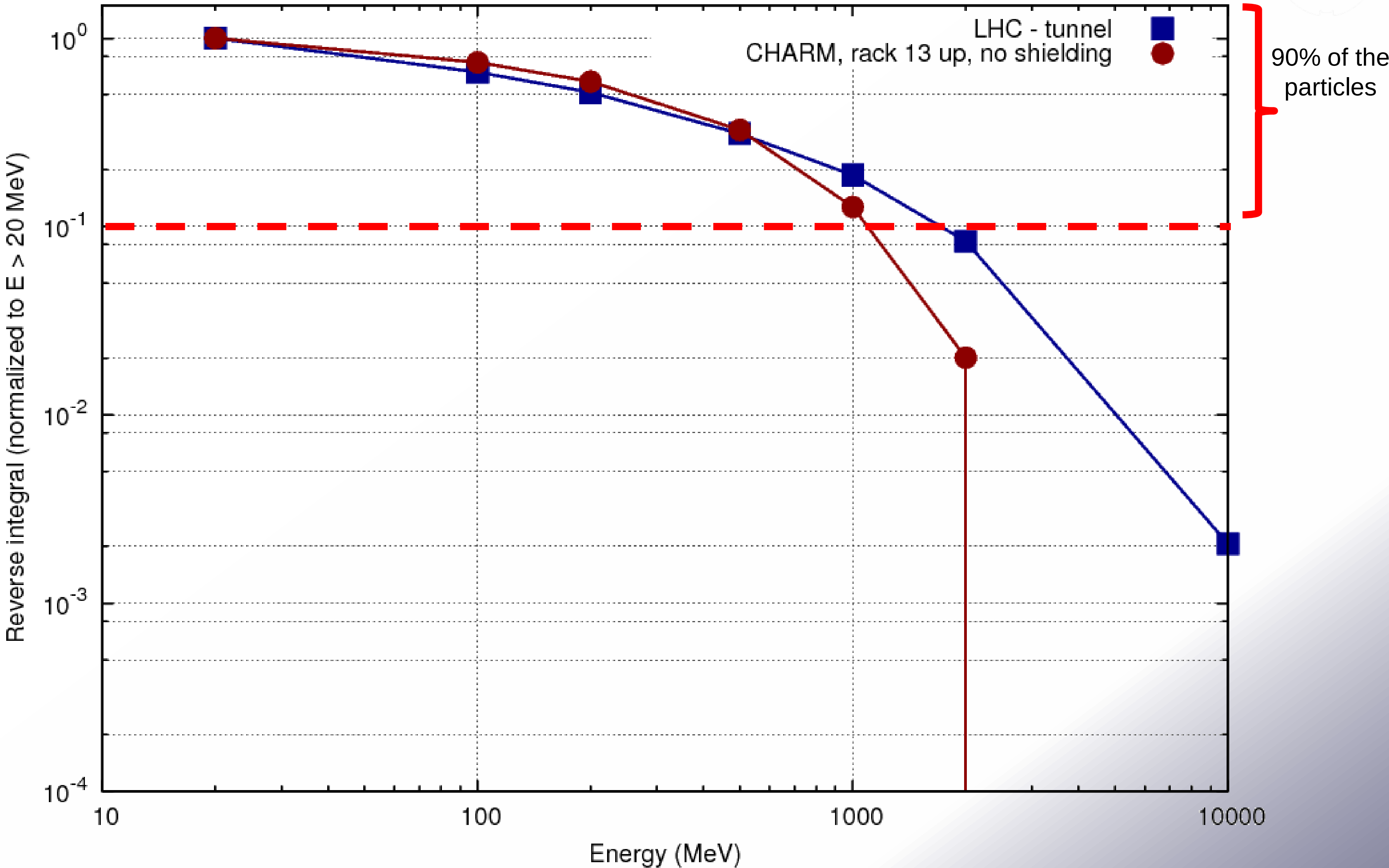


Shielding Configuration: -> Spectra



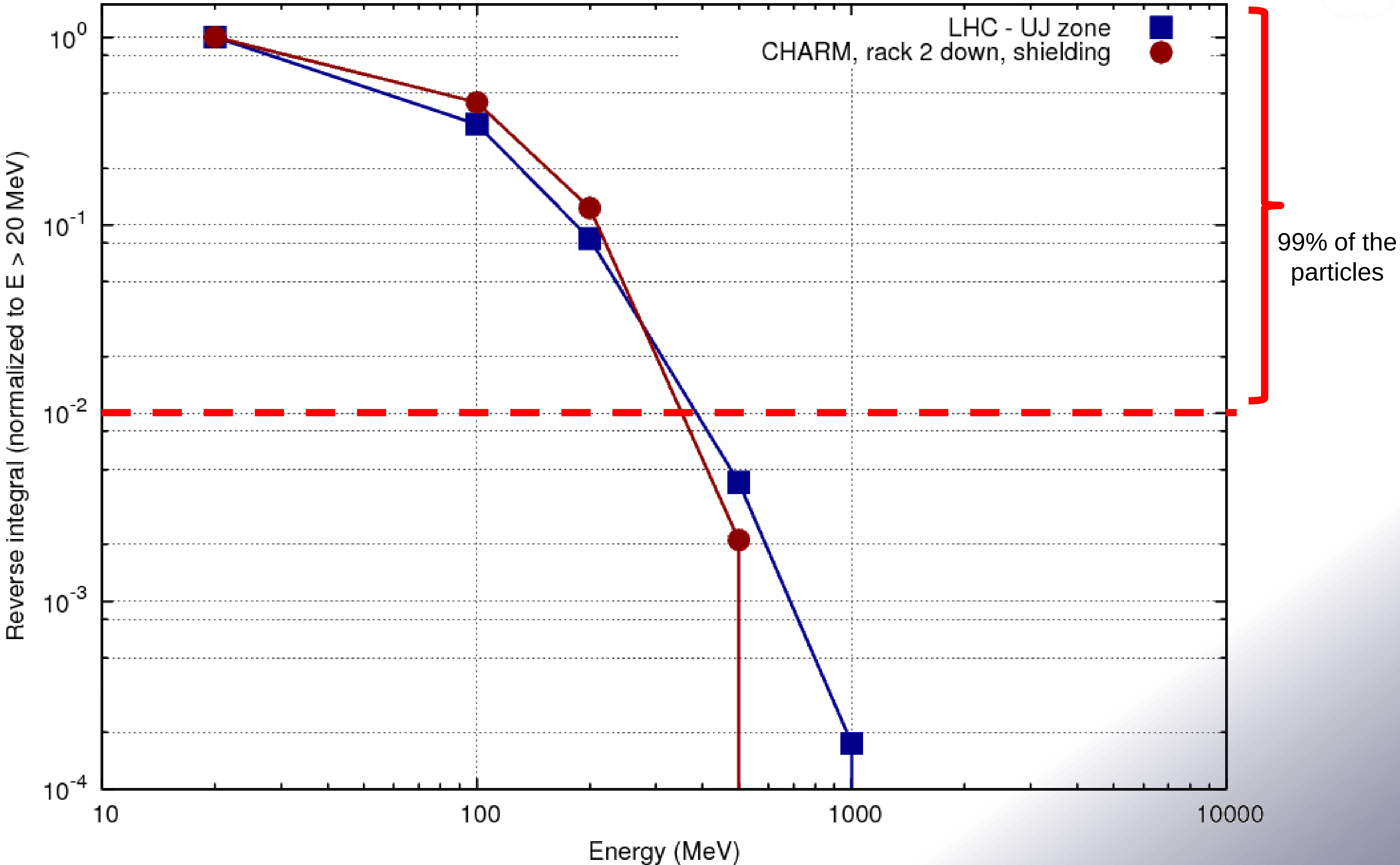
Representative Test Locations

Accelerator Tunnels



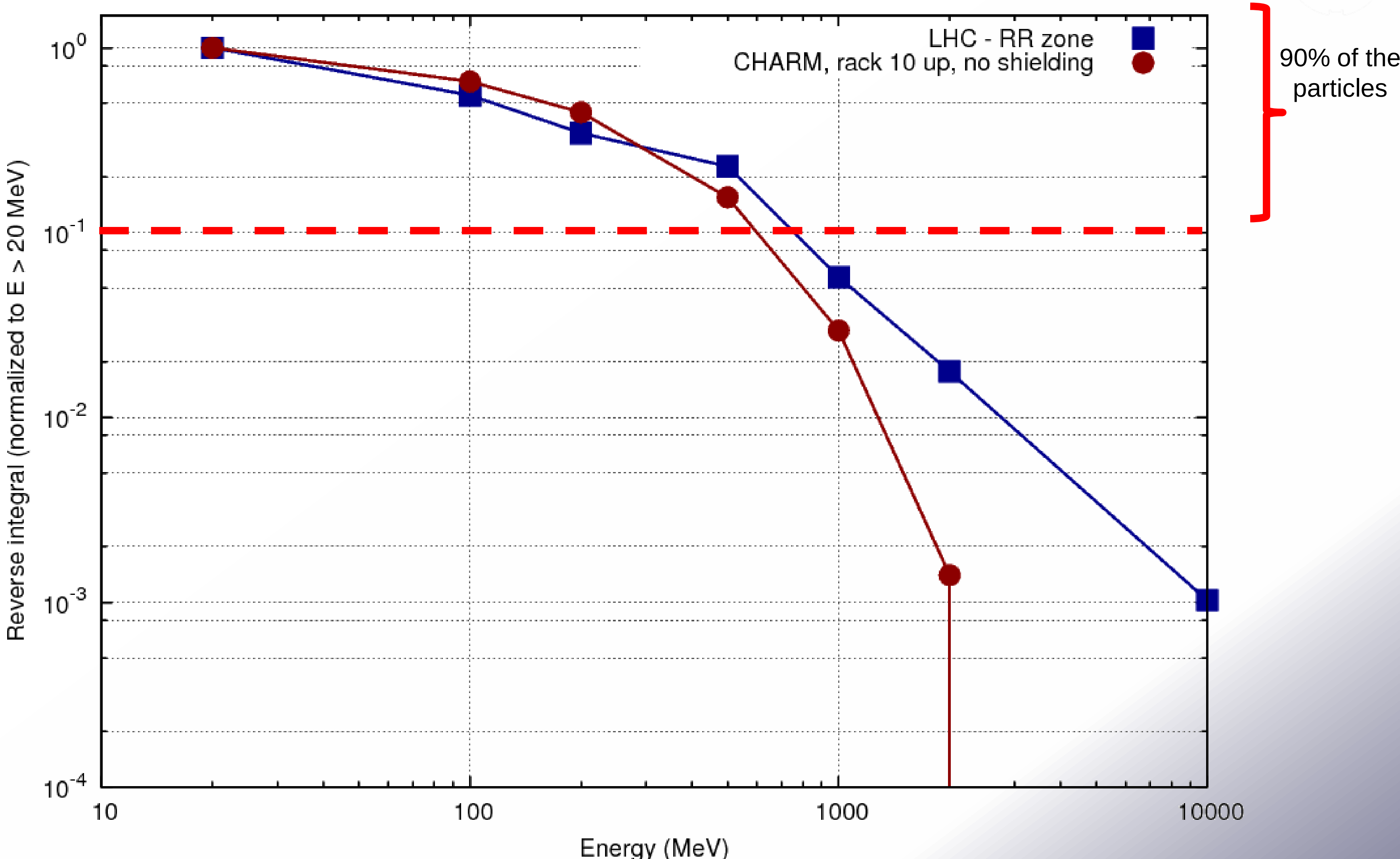
Representative Test Locations

Accelerator Shielded Areas 1

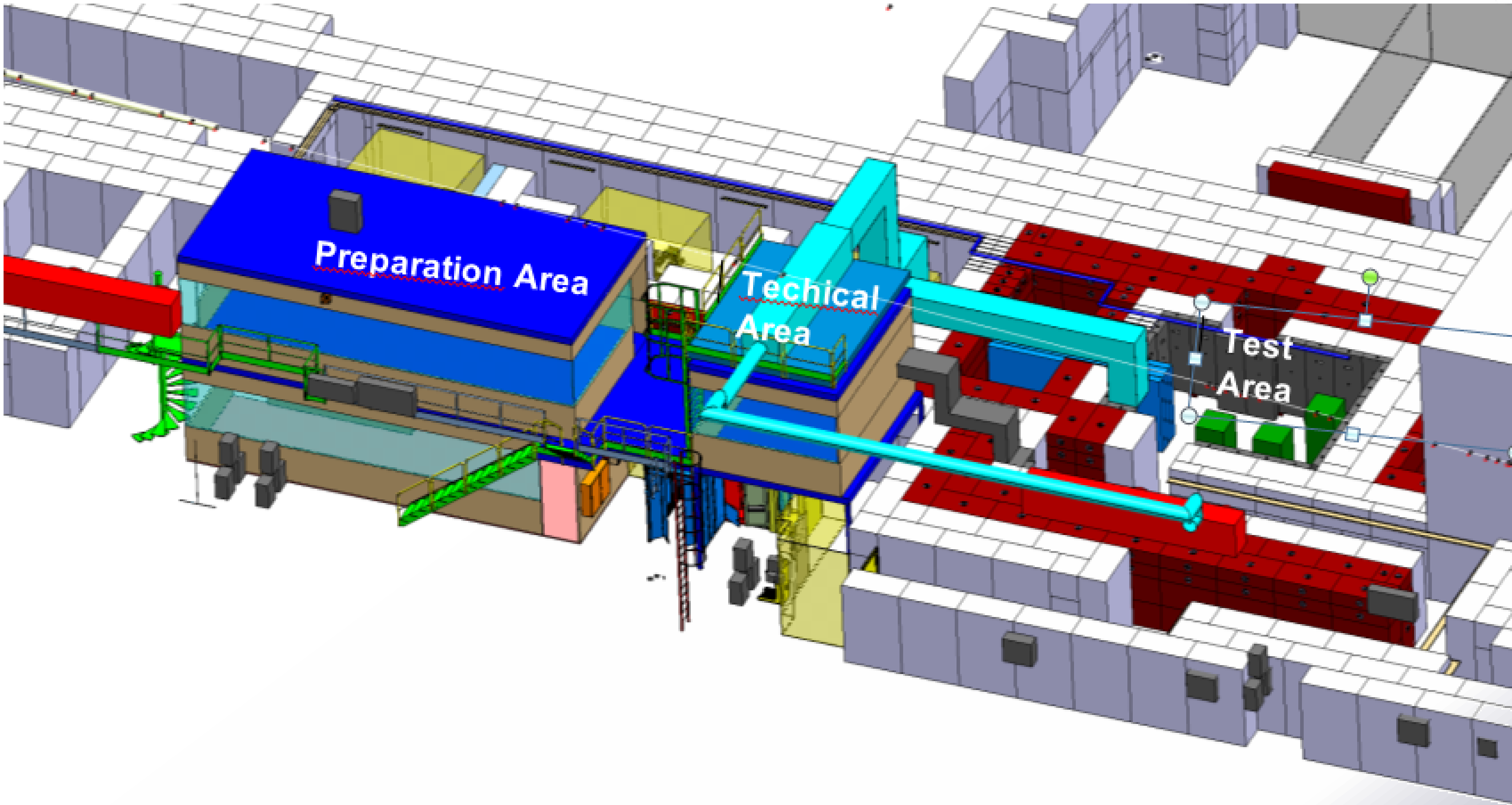


Representative Test Locations

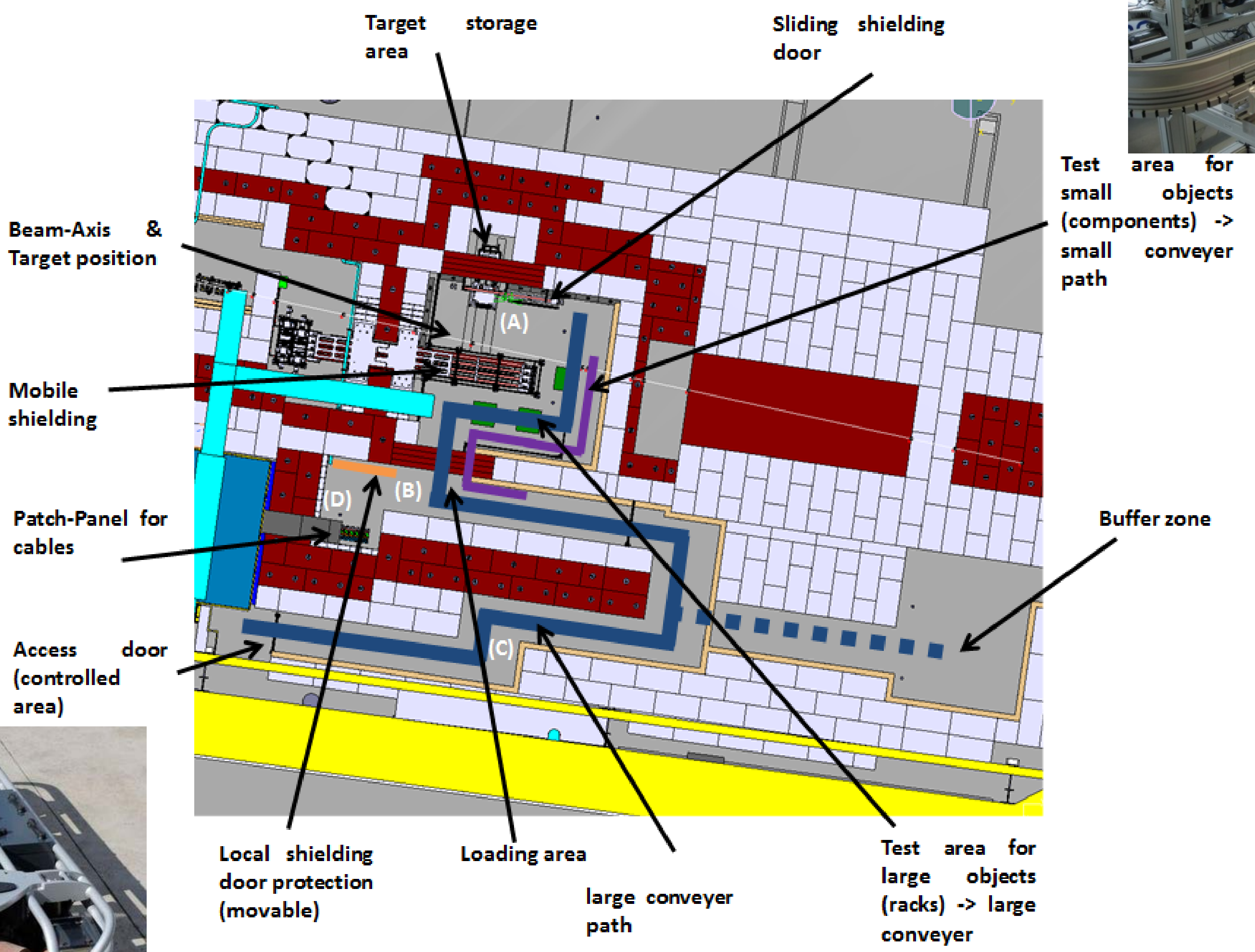
Accelerator Shielded Areas 2



Facility Overview



Main Elements

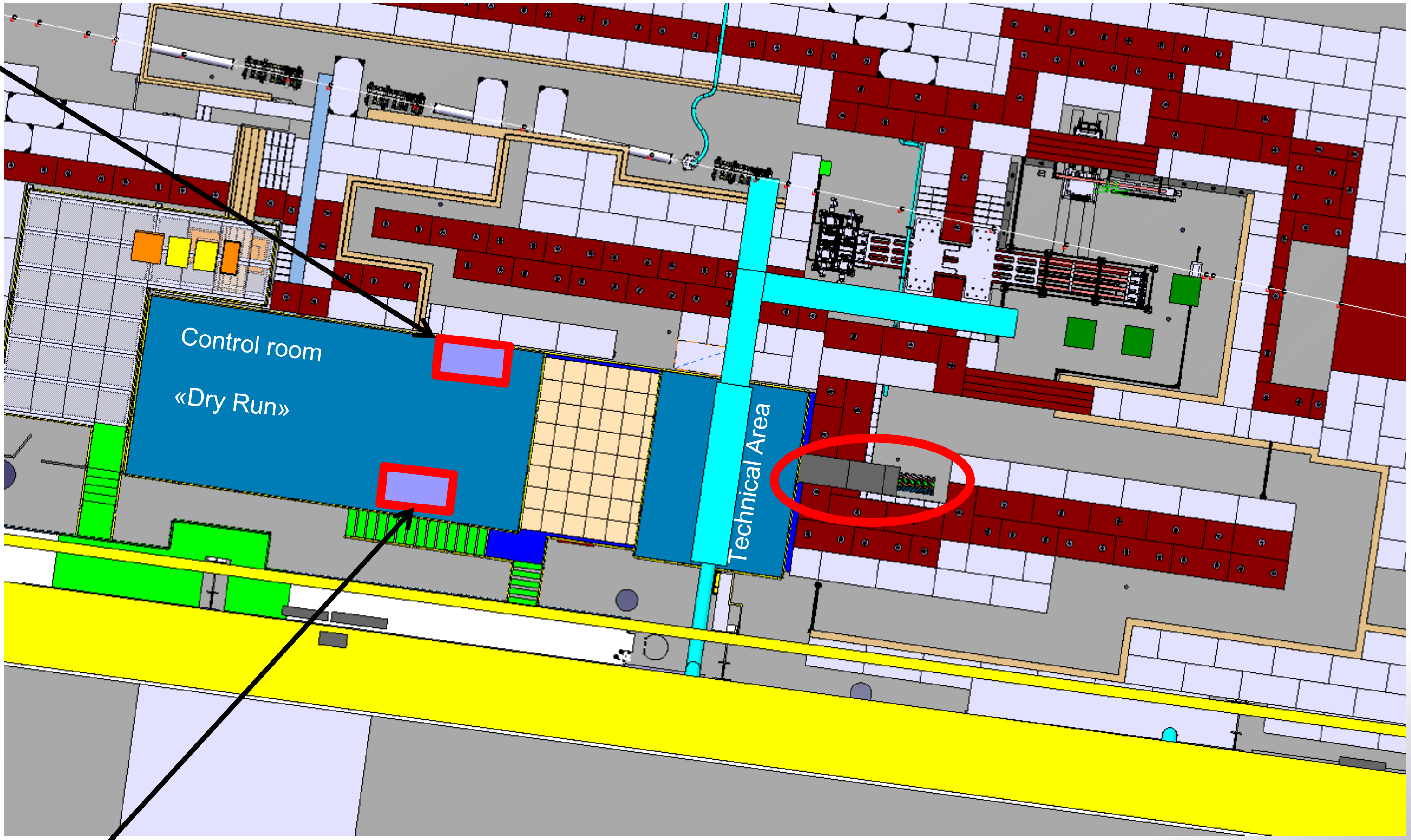


Patch Panel – Cable list

Cable Type	Code S.C.E.M	Connectors	Code S.C.E.M	Number of cables
NER48	No S.C.E.M	Burndy (female)	09.31.05.184.8 (connector) 09.21.05.430.0 (contact F)	6
Profibus	04.21.60.020.4	3 types	09.10.10.A	4
Single mode optical Fibres - Connector E2000				12
Single mode optical Fibres - FC/PC connectors				12
Multimode optical fibers -FC/PC connectors				24
Ethernet connections	04.21.70.105.9	RJ45	09.65.10.106.8 (connector) 09.65.10.121.0 (Cover) RS 453-2450 (panel socket)	12
CB50	04.61.11.225.6	BNC	09.46.11.700.4	50
WorldFIP	04.21.60.120.1	Connectors + boitier de raccordement	09.10.60.020.7 (Connector) 09.10.60.010.7 (FIP box)	3
Muti cond. Twisted/pair and shielded/pair	04.21.44.180.6	Prise rect. + contact femelle + Straight Metal Housing	09.21.07.075.9 (connector) 09.21.07.409.9 (contact F) 09.21.07.285.8 (socket 24B)	6
230V	04.08.61.733.6	Fiche Cable + Prise Cable + Prise Mur	09.00.03.020.2 + 09.00.03.220.6 + 09.00.03.370.3	10
CABLE CU EXTRA FLEX 5X1,5MM2	04.08.61.735.4	Prise rect. HAN Q7/0 + contact femelle + Straight Metal Housing	09.21.07.027.9 + 09.21.07.457.9 + 09.21.07.220.8	8
Triphasé	04.08.61.739.0	Prise 32A Mur RG	09.00.10.334.4	4
MCA24	04.21.48.324.9	SUB – D 25 male	09.21.20.710.8 (25 pin male connector) 09.21.23.144.1 (plastic hood)	2
MCA8	04.21.48.308.9	SUB – D 9 male	09.21.20.702.8 (9 pin male connector) 09.21.23.140.5 (plastic hood)	4
NG04	04.21.52.180.6	BURNDY ROUND MULTI-PIN CONNECTORS	09.31.05.200.5	2
Samtec EQCD (ucoax)	No S.C.E.M	Integrated with cable	No S.C.E.M	3
Samtec paire differentielle (ucoax)	No S.C.E.M	Integrated with cable	No S.C.E.M	3
CBH50 (High Voltage)	04.31.51.555.2	Fiche Cable sertie Teflon - Femelle SHV 5kV	09.41.25.108.3	12
Unipolar cable	04.08.61.994.7	Cosses	04.76.21.114.0	4
Cable for cooling (water)	38.20.10	Voir avec CV pour diamètre en fonction de la longueur (éviter trop de perte de charge)	Besoin aux bornes du convertisseur de 3l/min et 3 bars (à H4 cable 16*27)	2
ND26	04.21.52.020.1	Capot+ Connecteur SubD female+ Connecteur SubD Male	09.21.23.015.8 + 09.21.20.709.1 + 09.21.20.710.8	10
CKB50 (triax cables) internal conductor	04.61.11.254.1	Specific connectors that will be bought by BE/BI team + connectors for the insulated patch panel		10
Serial Link (RS485)	04.21.48.308.9	Connecteurs femelle	09.21.21.010.2 (Connector) 09.21.21.310.3 (Contact F)	4
USB	No S.C.E.M	Integrated with cable	No S.C.E.M	5
Total				**212**

Facility Overview

Patch Panel «IN»



Patch Panel «OUT»

Facility Design Targets

- Contrary to other facilities:
  - Setup needs to be radtol
  - Large distance: ≈ 30 m of cables. Designer needs to integrate in their design the possibility to measure short signal (e.g. short transient "few ns")
- **But …**
- Numerous **representative radiation fields**
  - Mixed-Particle-Energy
  - Direct beam exposure
- **Large range of fluxes and dose ranges** (covering accelerator, but also other applications)

Facility Design Targets

- Possibility for **large volumes**/high number of components or full systems
- **Easy usage**
  - Dedicated preparation area
  - Cables pre-installed + patch panel
  - Conveyer systems
- Detailed, on-line and **high-accuracy monitoring** (CERN RadMon system)

Conclusions

- **High-energies are of concern!** (especially for destructive failures)
- Testing **complex systems or many components** can be important/useful
- **Representative environments** are an efficient approach also for LHC experiments
- A **new test facility** will soon be available at **CERN (mid-2014)**