New Irradiation facility at CERN: CHARM

CERN R2E project

LHCb Upgrade Electronics meeting 13th February 2014

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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 High Energy AcceleRator Mixed Field/Facility

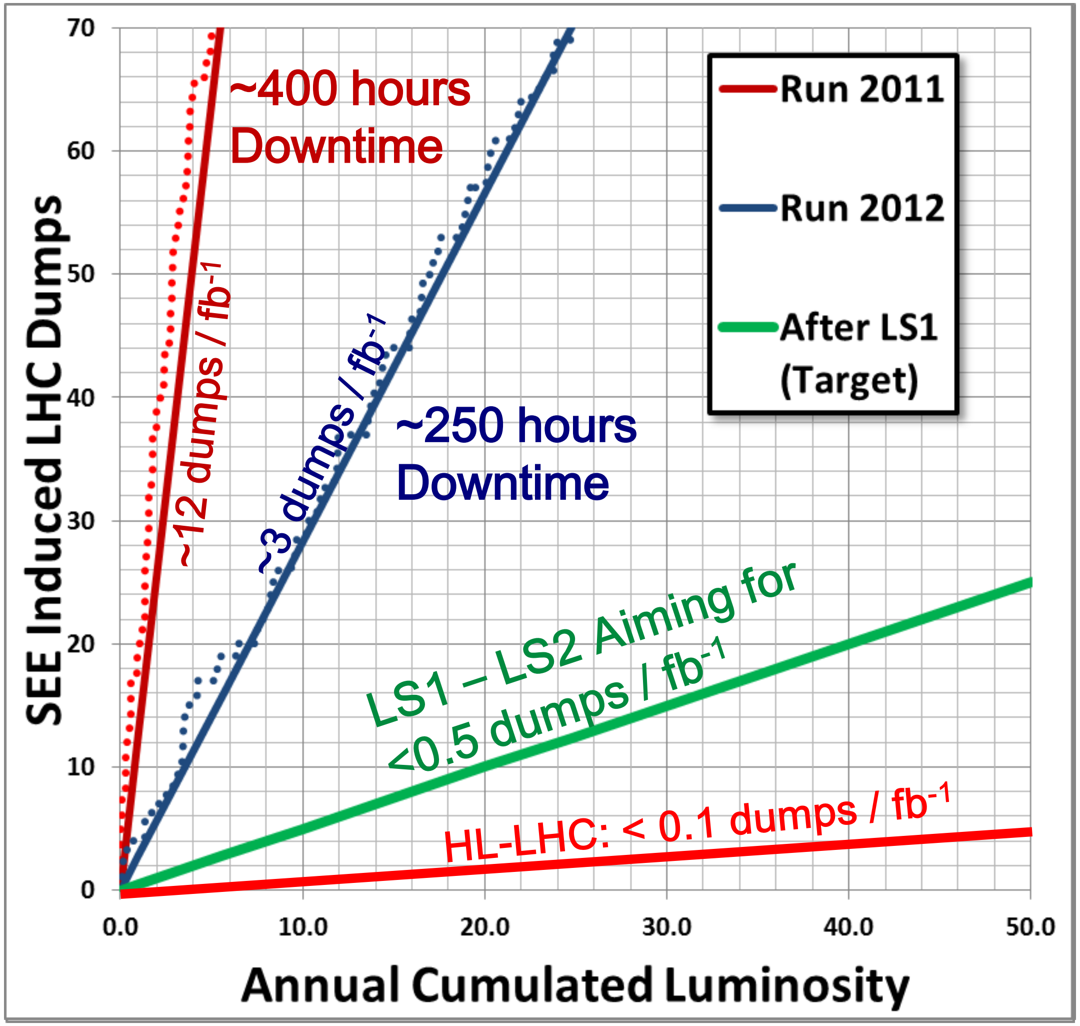
- We'd also Other Good Options,

  … But

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

LHC R2E: Past/Present/Future

R2E SEE Failure Analysis



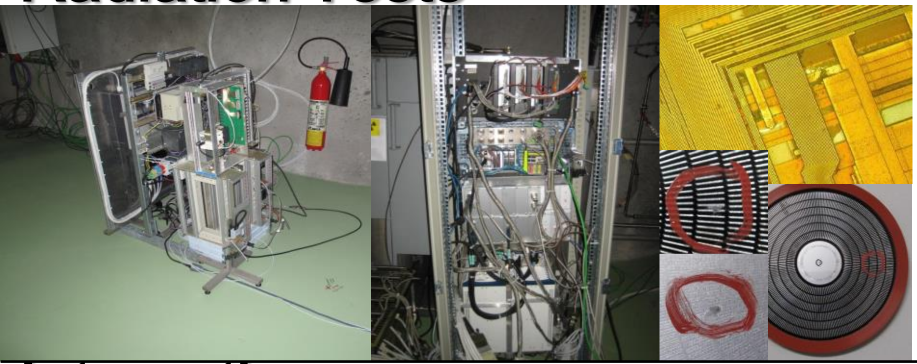
- **2008-2011**
  - Analyze and mitigate all safety relevant cases and limit global impact
- **2011-2012**
  - Focus on long downtimes and shielding
- **LS1 (2013/2014)**
  - Final relocation and shielding
- **LS1-LS2 (2015-2018)**
  - Tunnel equipment and power converters

List of groups/projects for the future

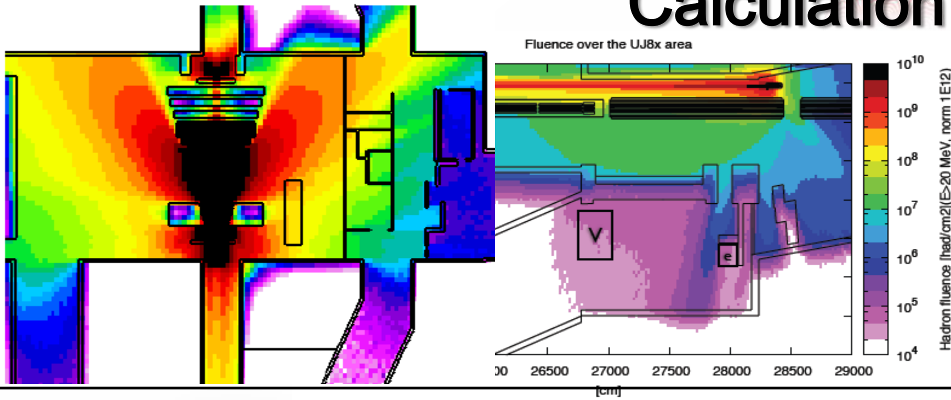
- TE/EPC (e.g Power converters) *-> Development up to 2018*
- EN/EL (e.g UPS) *-> Development up to 2016*
- QPS
- LHC experiments
- Cryogenics
- Beam Position Monitor
- EN/STI (e.g. component tests, RadMON V6)
- Beam Loss Monitors
- EN/ICE
- From Outside (Universities, laboratories, industrials: *e.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

R2E Mitigation Project Building Blocks

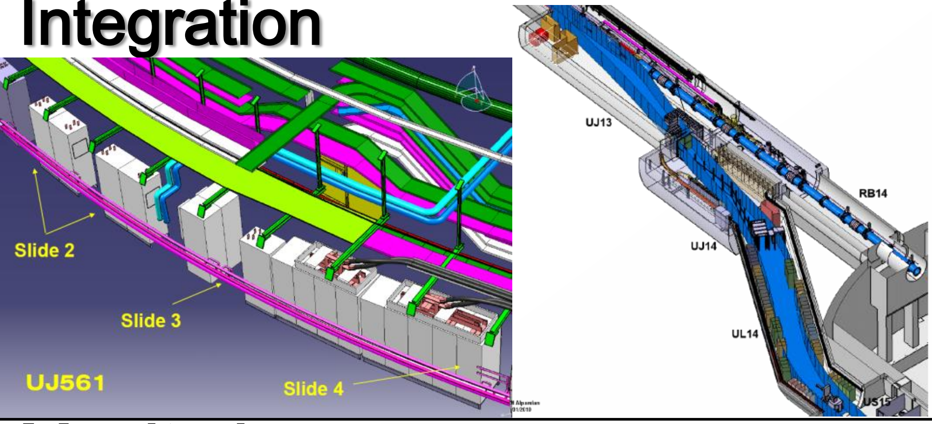
Radiation Tests



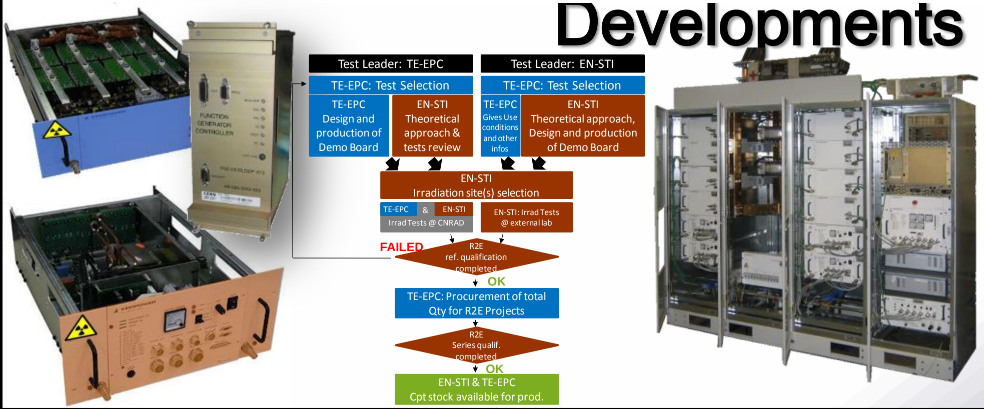
Calculation



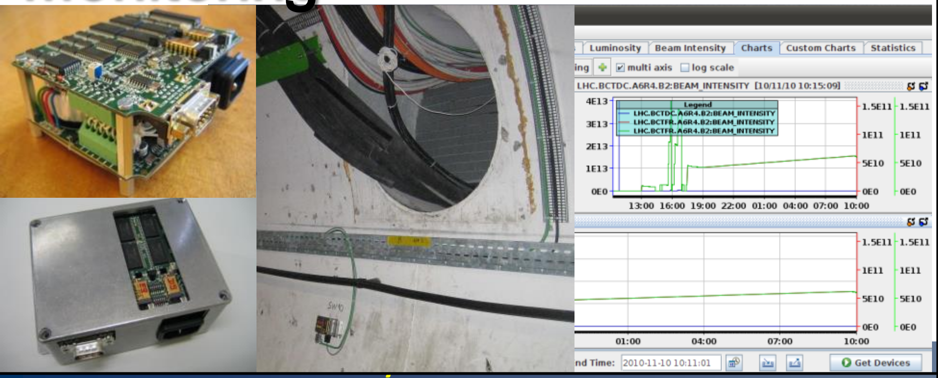
Integration



Developments



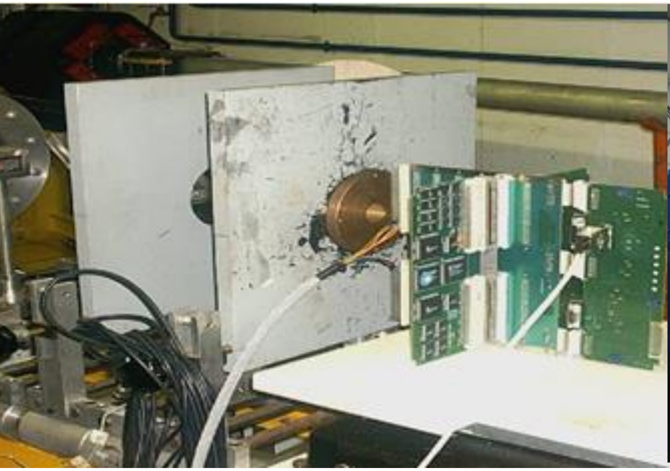
Monitoring

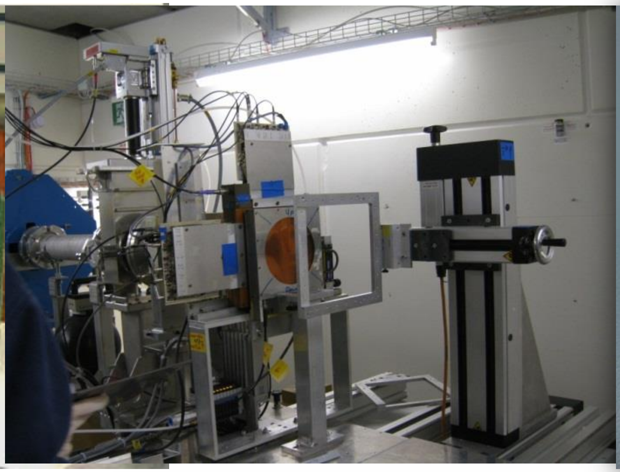


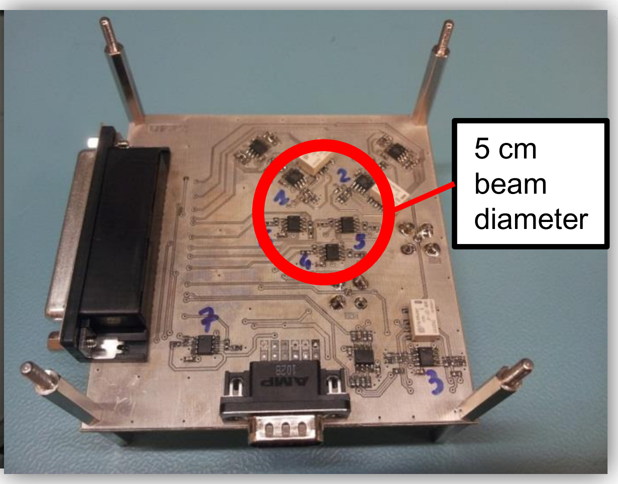
Implementation

Size Matters?

TEST COMPONENTS/CARDS:







OR EVEN TEST THIS:

HERE

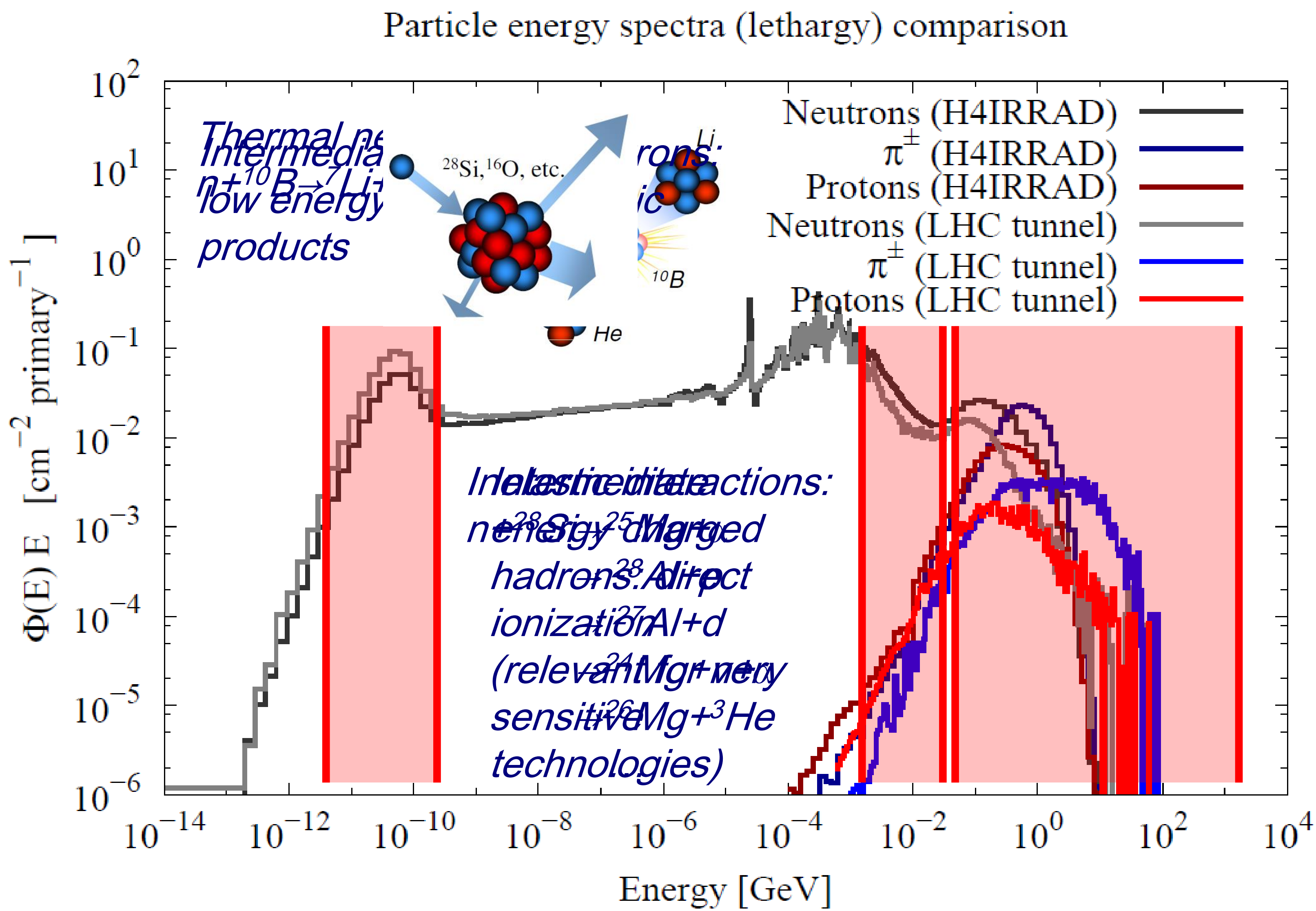
(W)HOW ???

The High-E Accelerator Environment

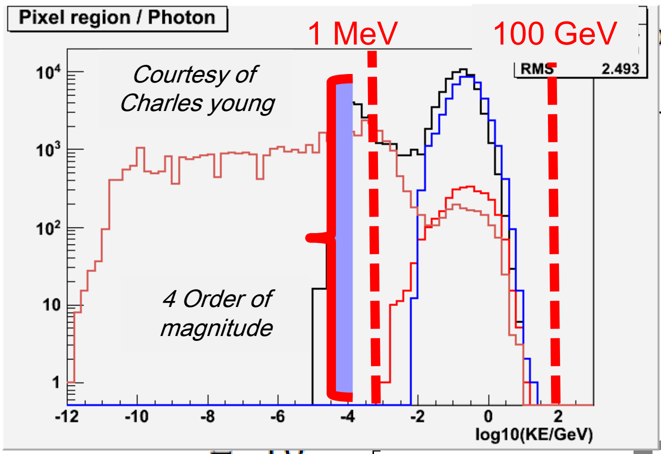
- Radiation fields originated by **very high energy particles** interacting with different elements (collimators, gas, targets, etc.)
- **Wide range of intensities**!

Ground level	Avionic	ISS Orbit	LHC machine	LHC Detectors	
$1\text{-}2.10^5$	$\approx 2.10^7$	$\approx 1.10^9$	$10^6 - 10^{11}$	$> 10^{11}$	$HEH/cm^2/yr$

Particle Energy Spectra – The Source

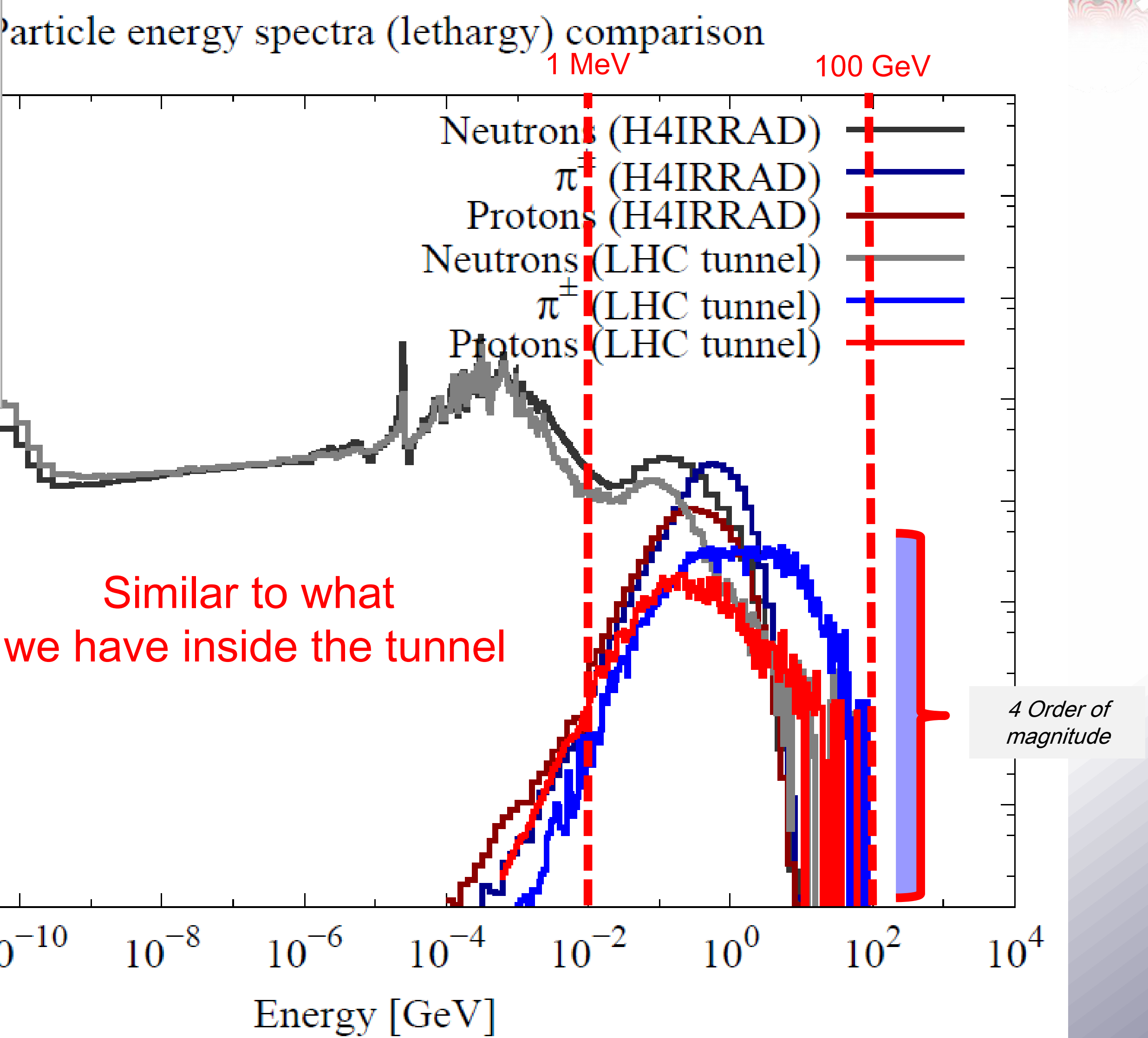


Particle Energy Spectra – The Source



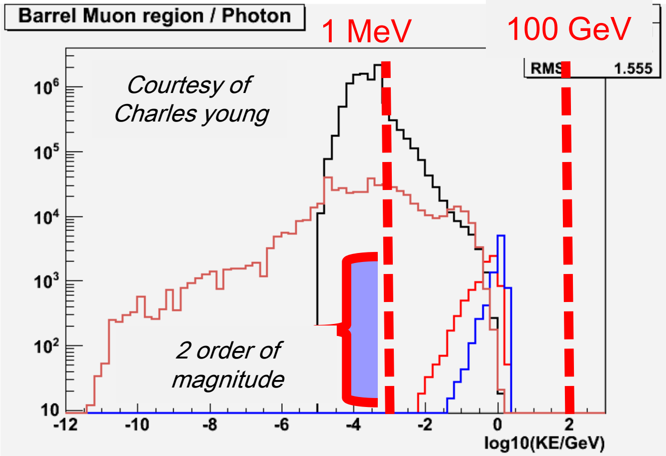
LHC experiment

Pixel detector region

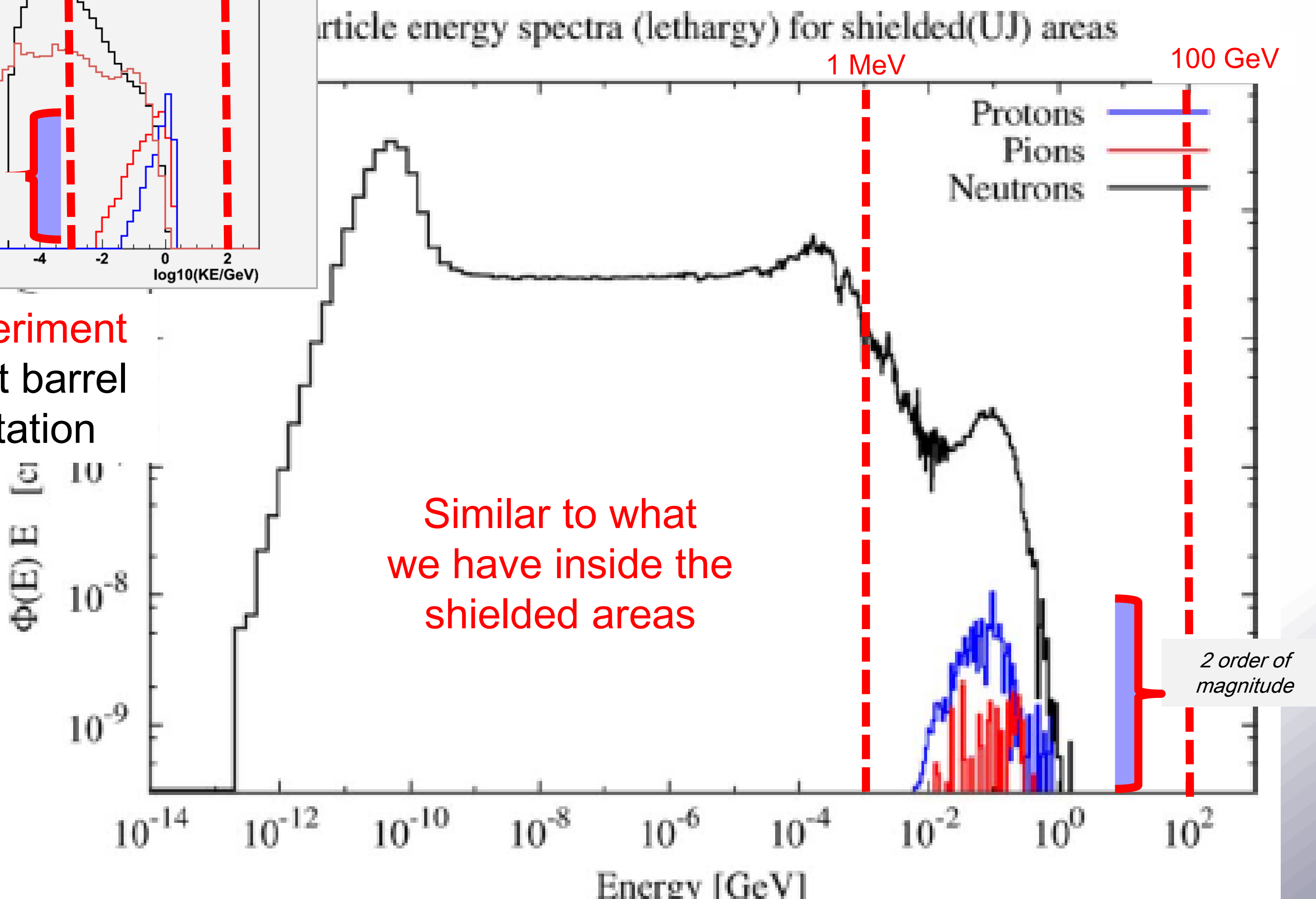


Similar to what we have inside the tunnel

Particle Energy Spectra – The Source



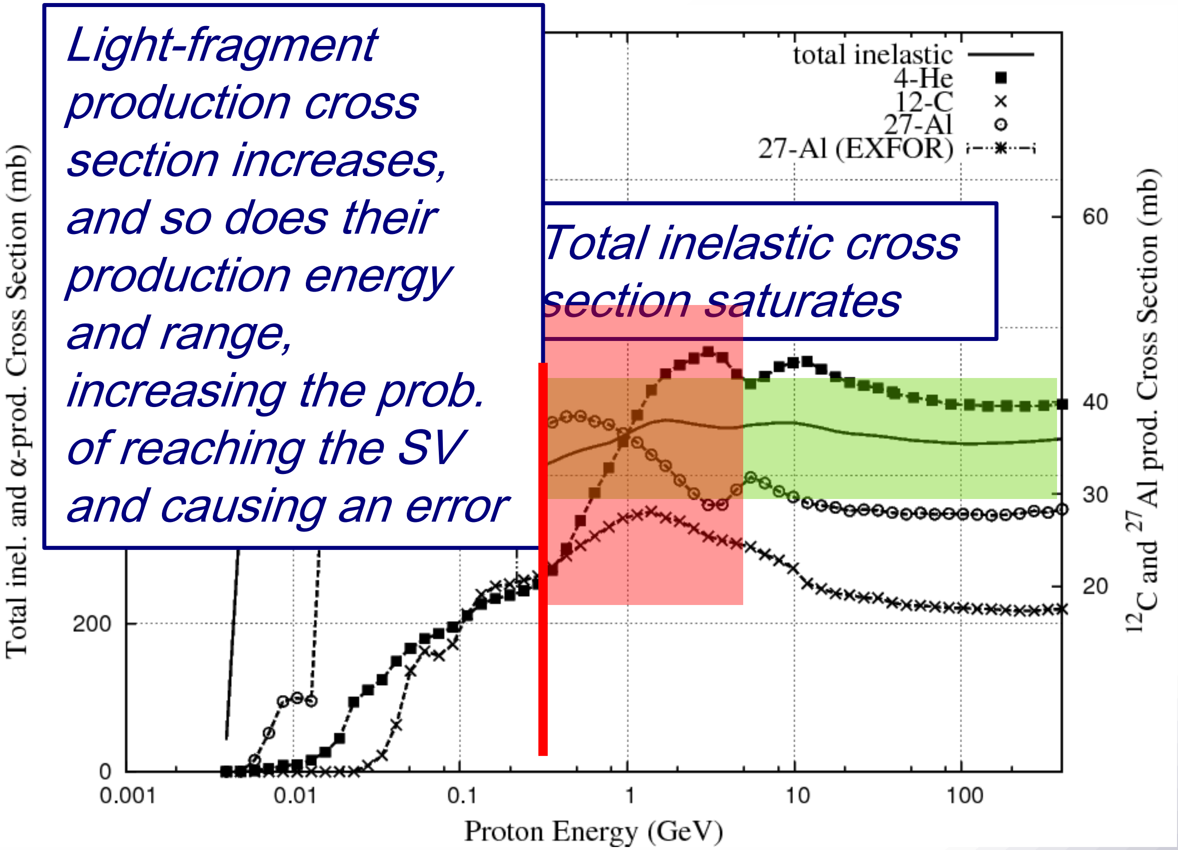
LHC experiment
Outermost barrel muon station



Energy Dependence

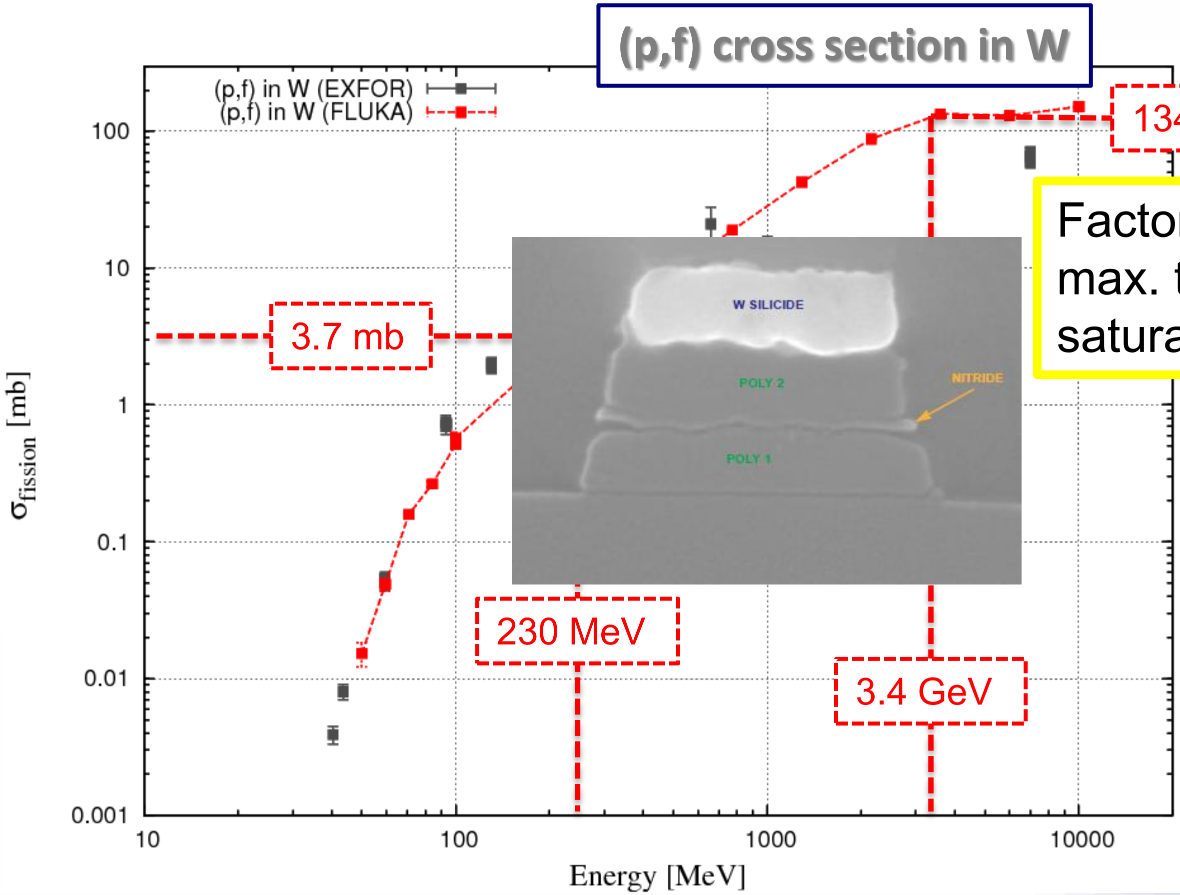
Above ~100 MeV, the total hadron-Silicon inelastic cross section is saturated, however:

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



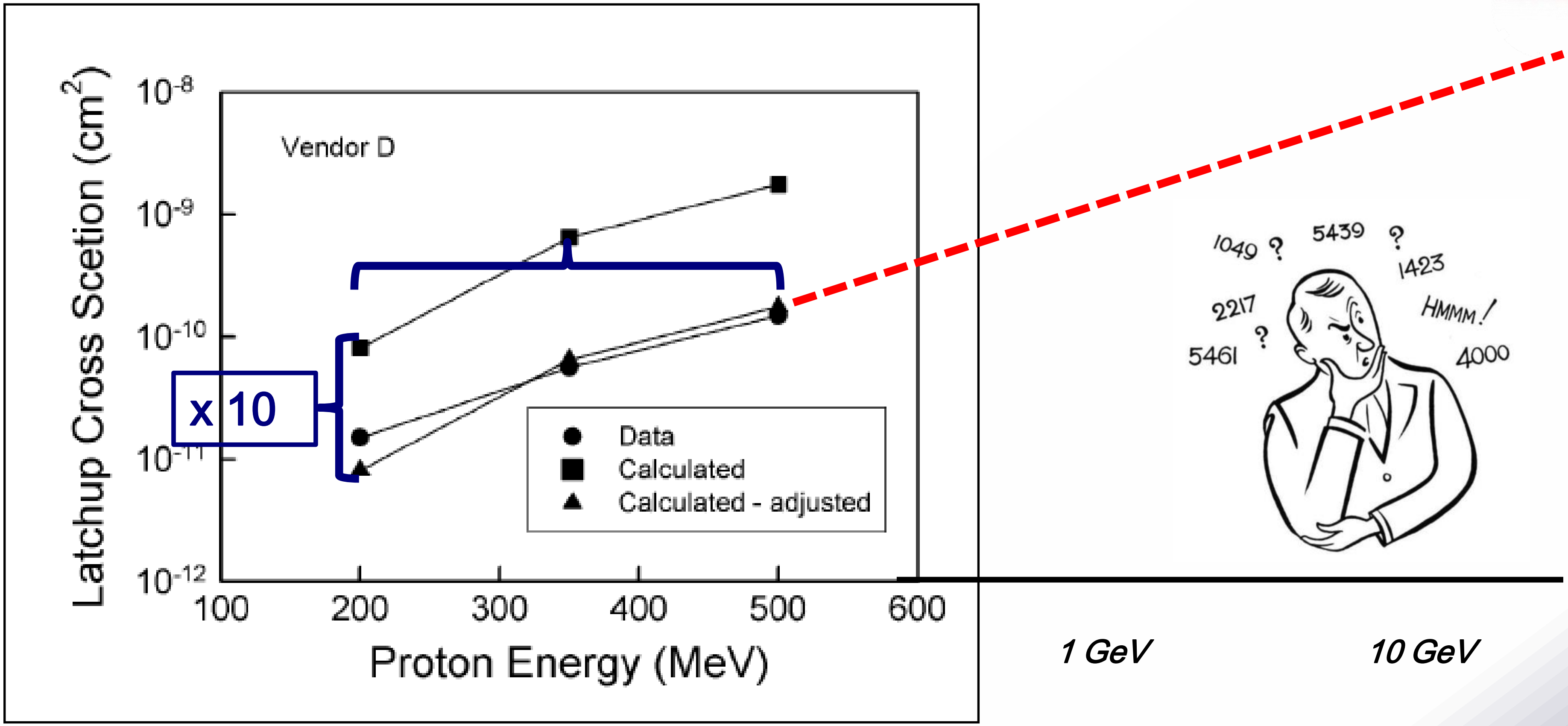
Fission: Energy Dependence

- **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

SEL: Energy Dependence

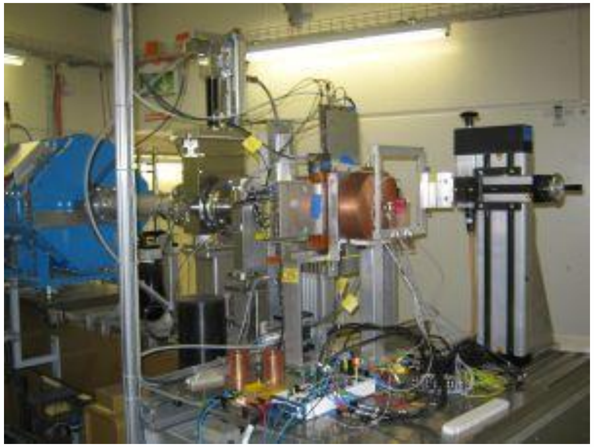


Schwank 2005 (IEEE TNS)

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 test 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.

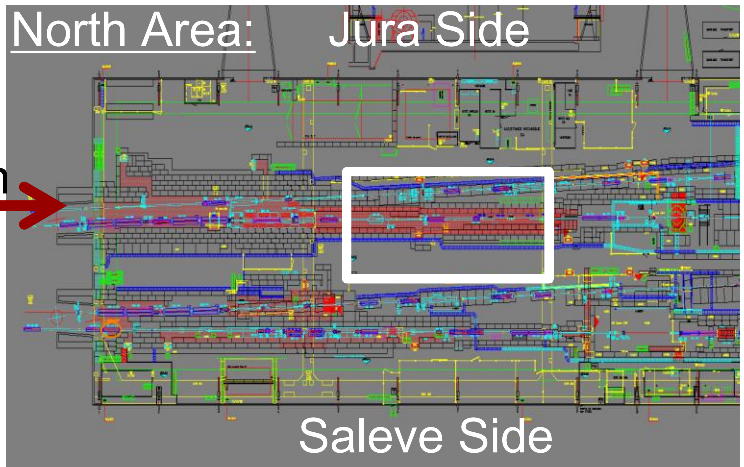


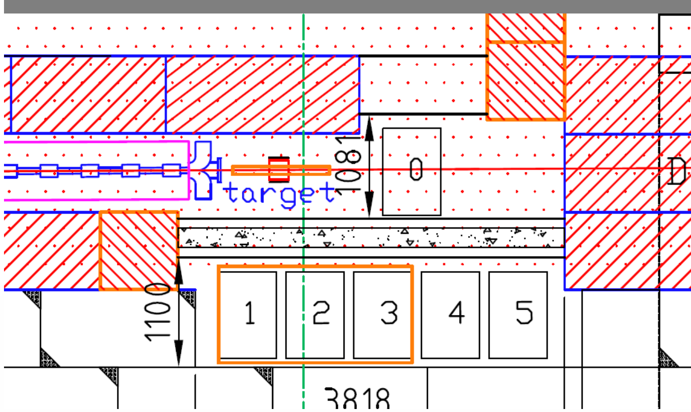
New Facility Required

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

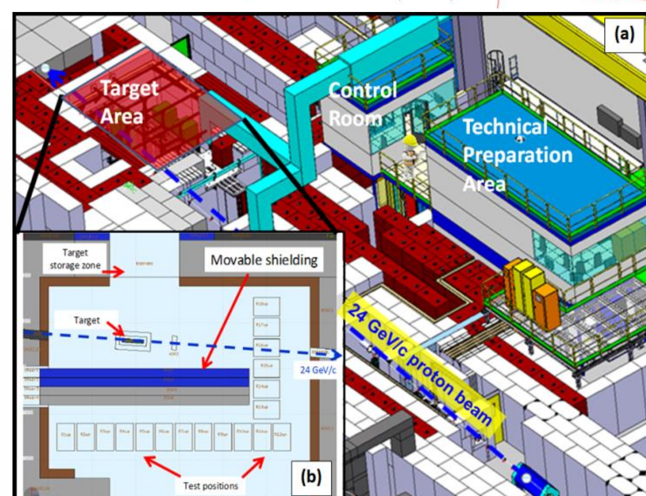
H4IRRAD (2011)

SPS Beam



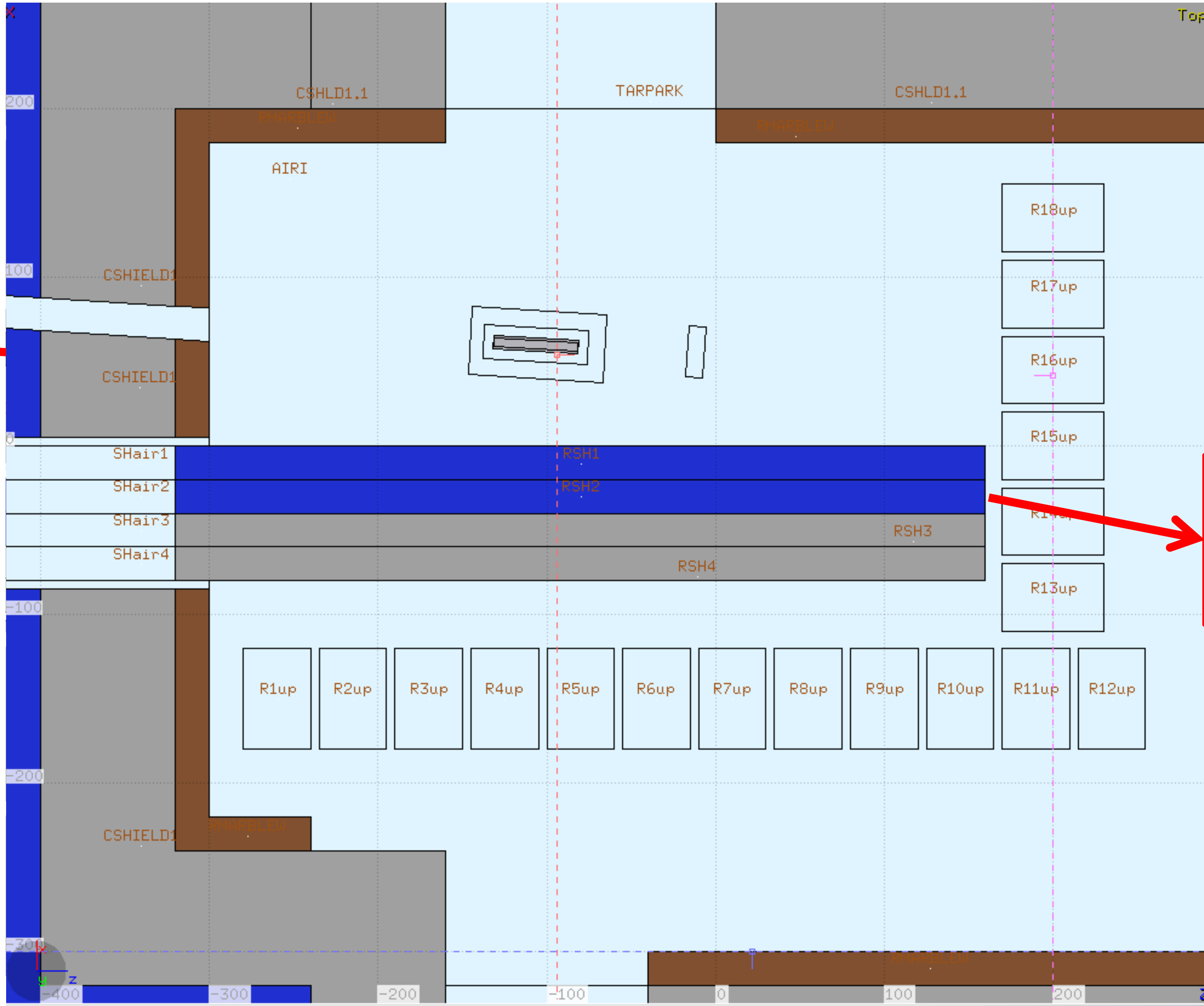


CHARM (2014)



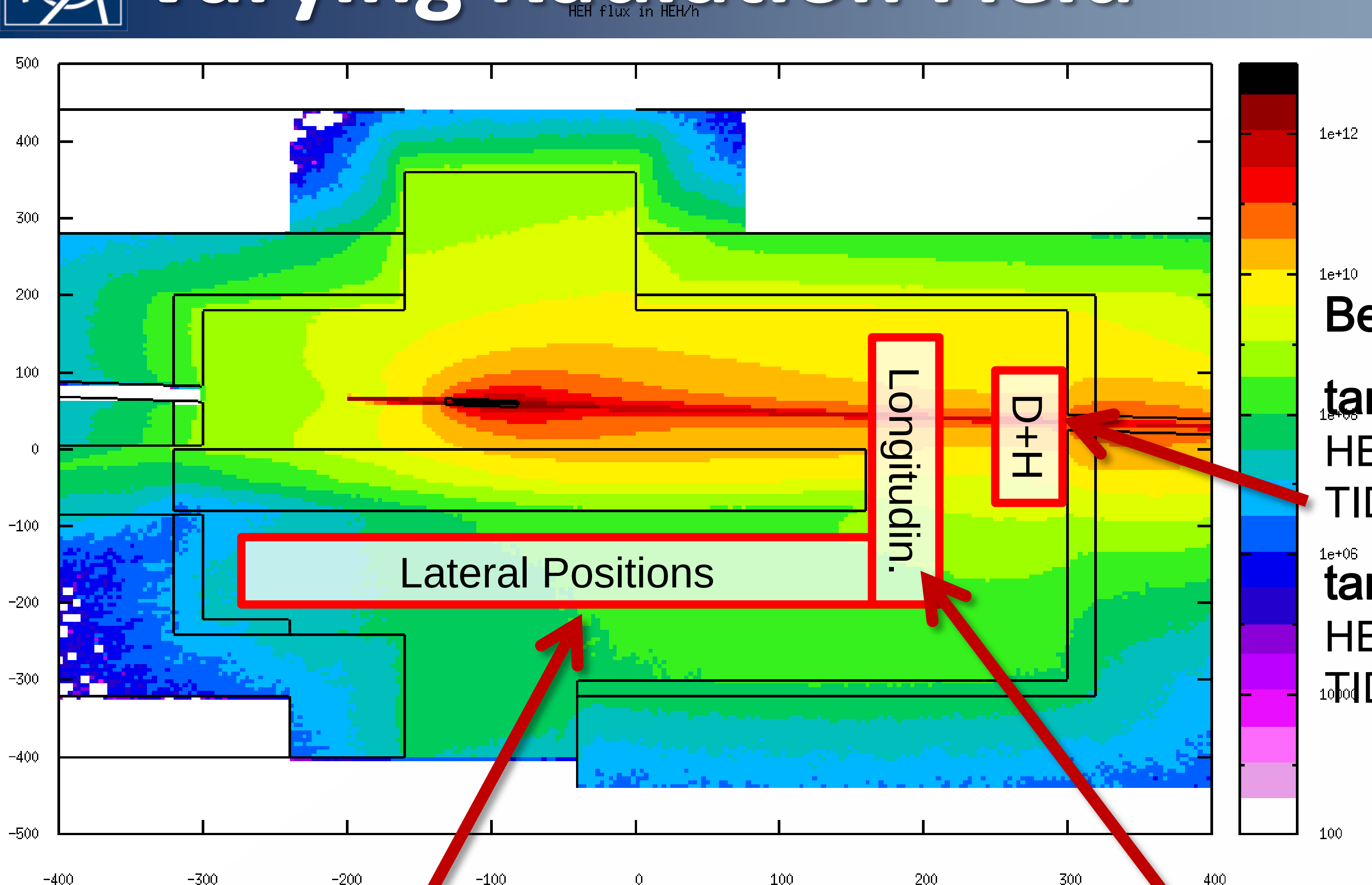
Approach: Test Positions

24 GeV/c protons



4x40 cm movable shielding

Varying Radiation Field



Beam Position

target in:
HEH: $>10^{11} cm^{-2}h^{-1}$
TID: >100 Gyh^{-1}

target out:
HEH: $>10^{13} cm^{-2}h^{-1}$
TID: >10 $kGyh^{-1}$

HEH: $10^{8} cm^{-2}h^{-1} – 10^{11} cm^{-2}h^{-1}$
TID: $0.1 Gyh^{-1} – 100 Gyh^{-1}$
(gradients to be considered)

Full racks, crates, set of cards, components

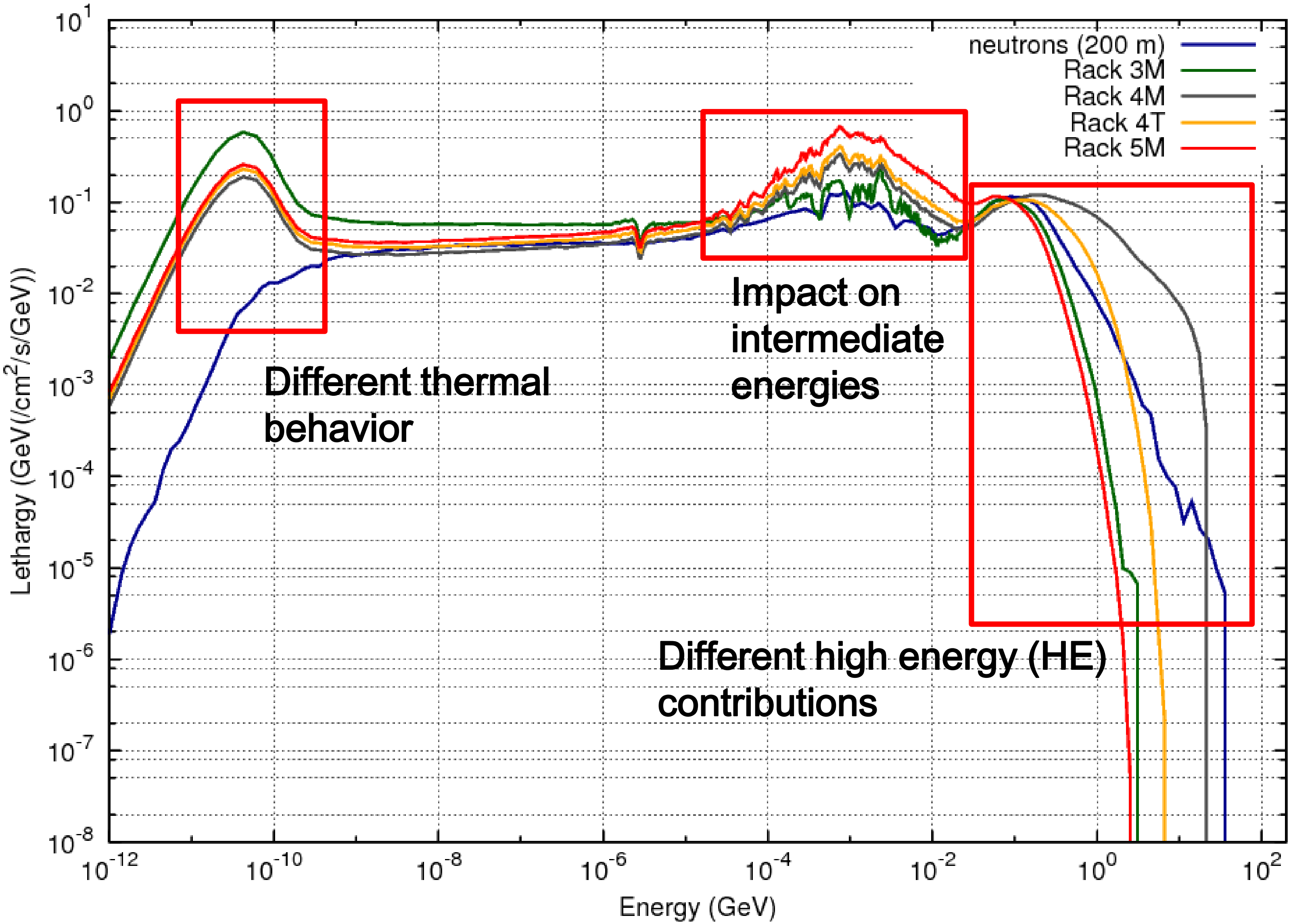
HEH: $10^{7} cm^{-2}h^{-1} – 10^{10} cm^{-2}h^{-1}$, TID: $10 mGyh^{-1} – 10 Gyh^{-1}$

Comparison with previous test areas

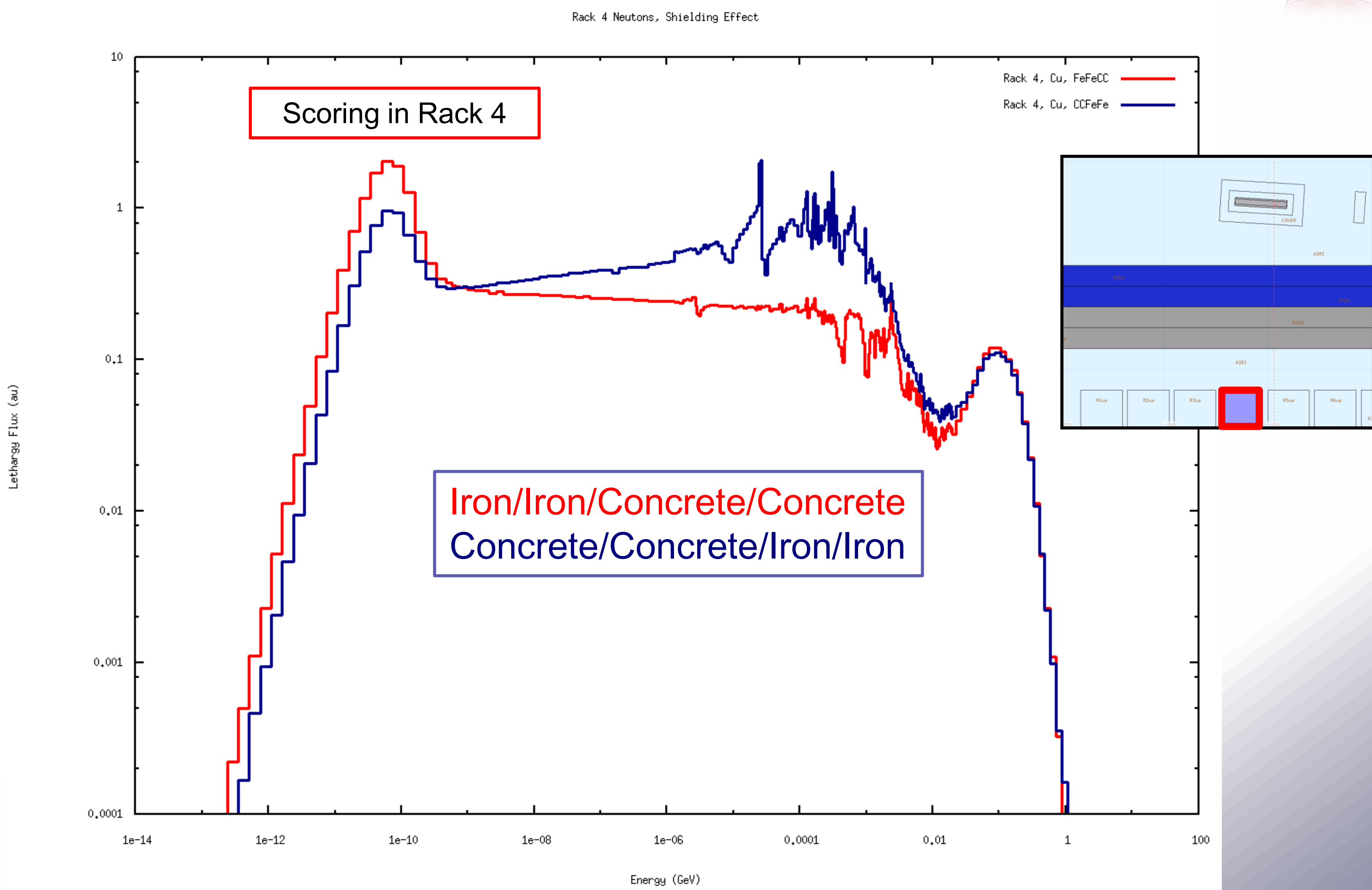
- Intensity reachable for 1 year (220 days) of beam operation in comparison to previous experimental test areas

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

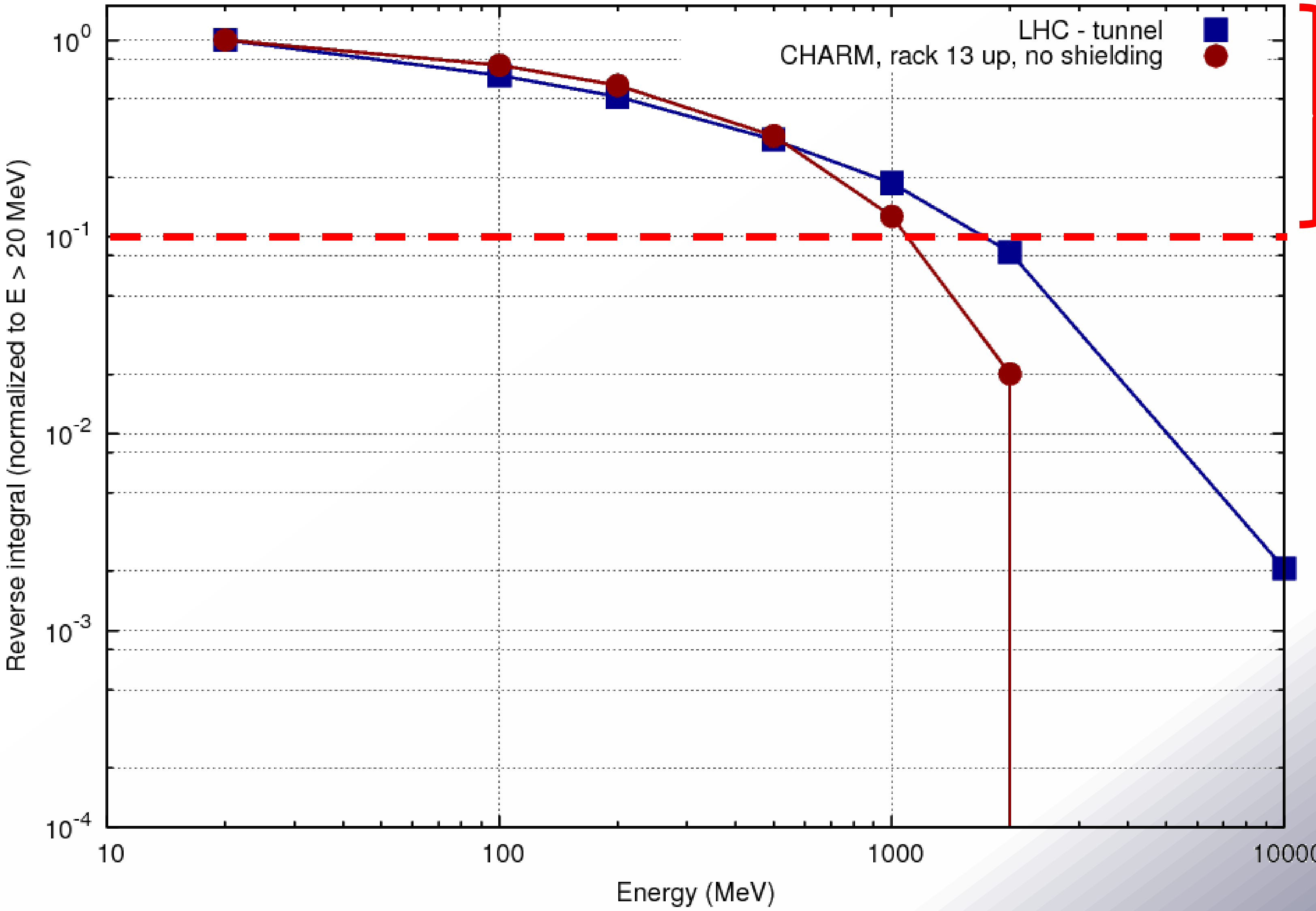
Test positions: -> Spectra



Shielding Configuration: -> Spectra



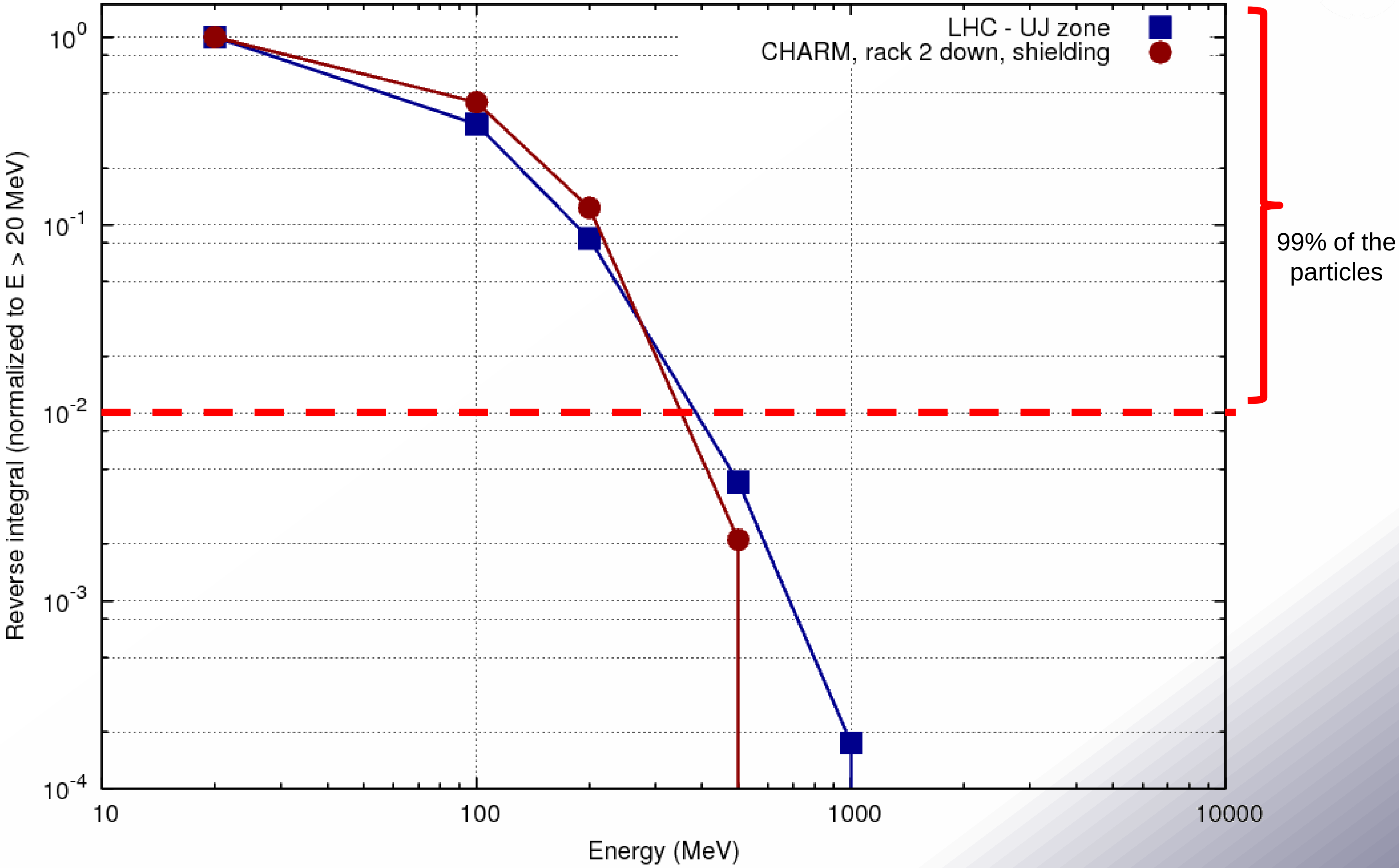
Accelerator Tunnels



90% of the particles

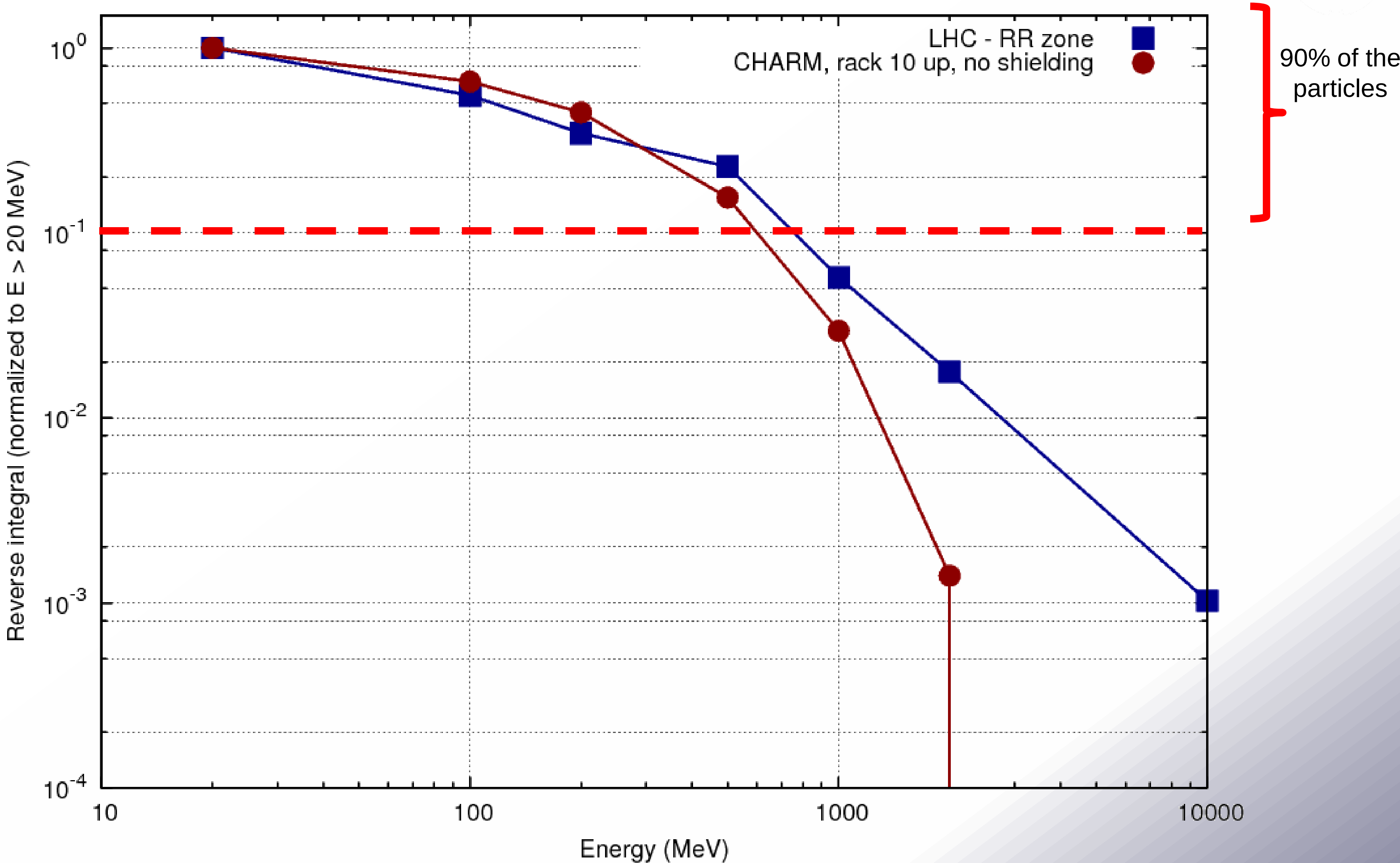
Representative Test Locations

Accelerator Shielded Areas 1

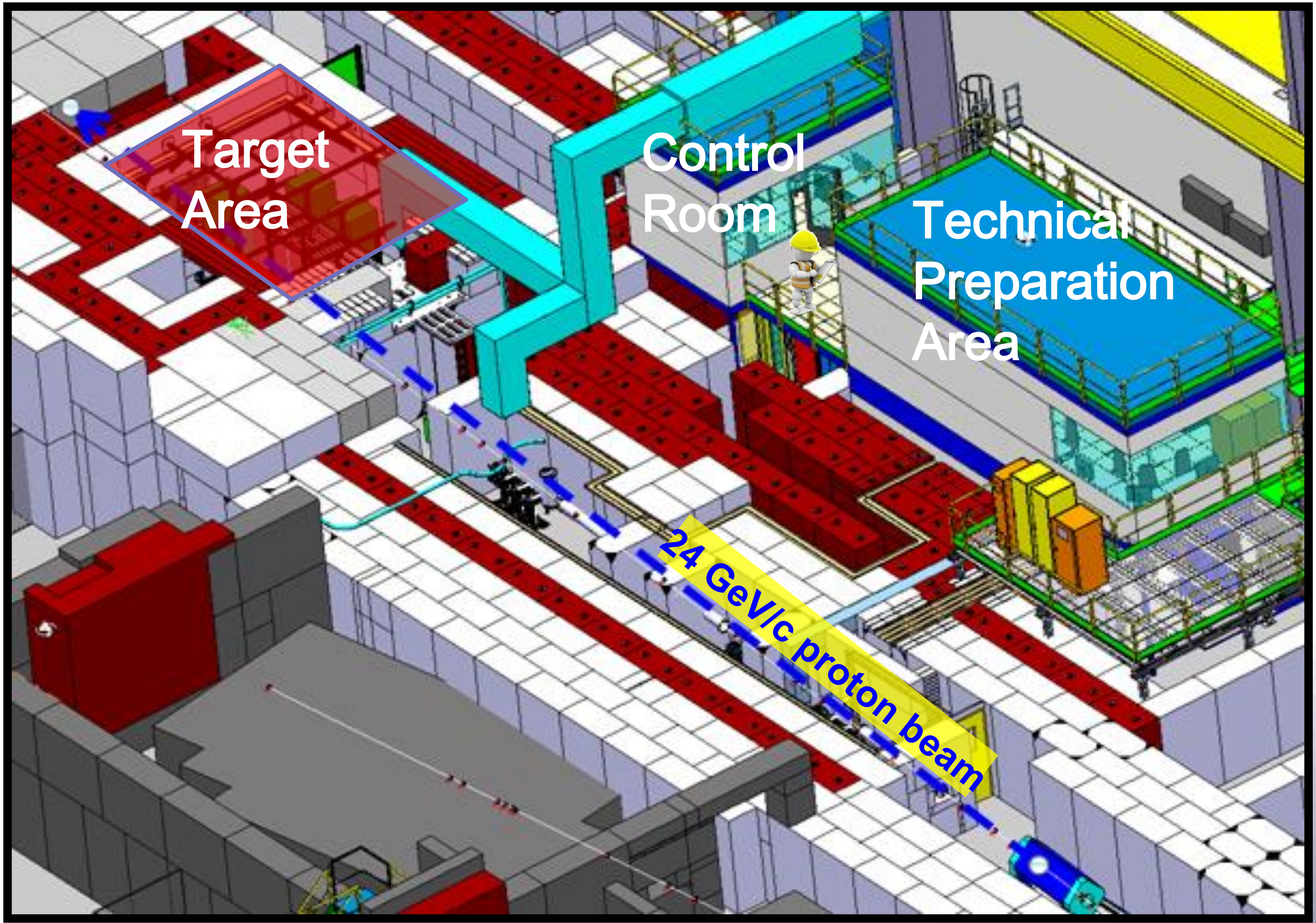


Representative Test Locations

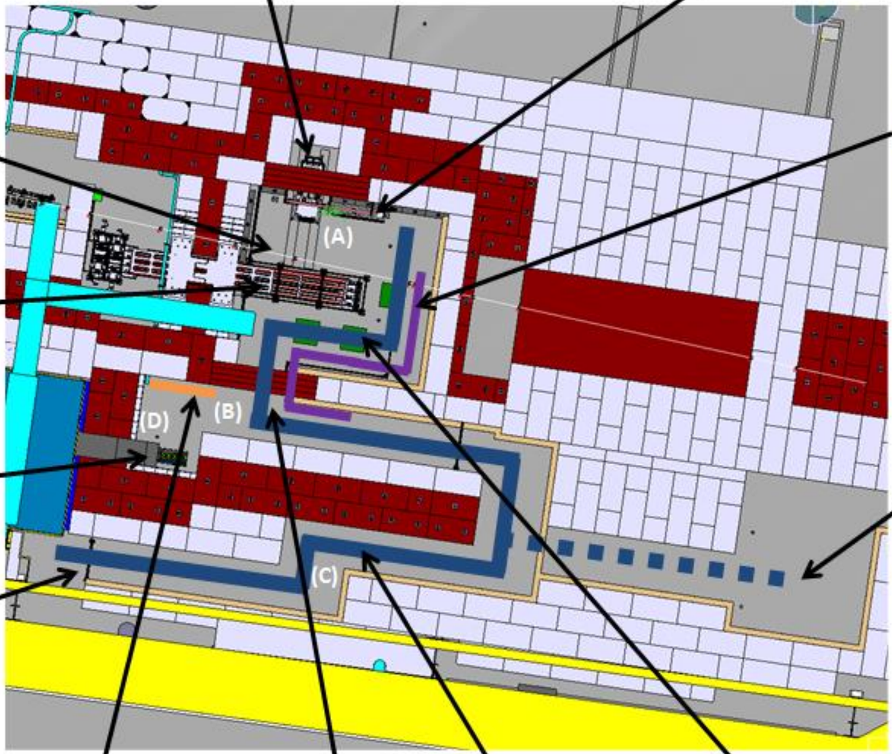
Accelerator Shielded Areas 2



Facility Overview



Main Elements



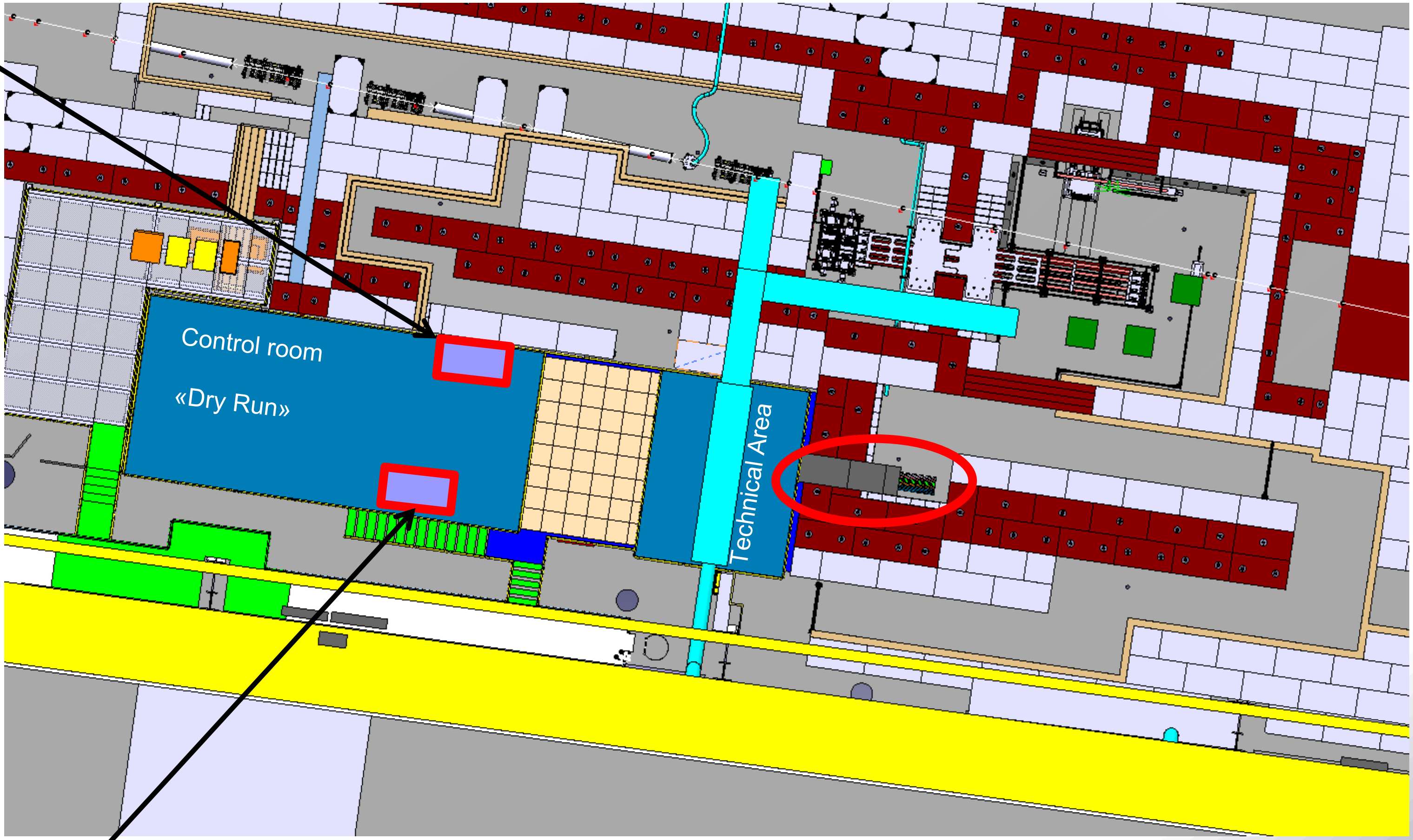
Patch Panel – Cable list

Cable Type	Code S.C.E.M	Connectors	Code S.C.E.M	Number of cables
NE48 (Between both patch panel - For Montrac)	04.21.52.150.2	Burndy (female)	09.31.05.184.8 (connector) 09.21.05.430.0 (contact F)	6
NER48 (Between patch panel and Hypertack)	No S.C.E.M	Burndy (male) - Only at 1 side - Other side "Hypertack"	09.31.05.280.9 (connector) 09.21.05.420.2 (contact M)	6
NE48 (Between both patch panel)	04.21.52.150.2	Burndy (female)	09.31.05.184.8 (connector) 09.21.05.430.0 (contact F)	10
NER48 (Between patch panel and equipment to be tested)	No S.C.E.M	Burndy (male)	09.31.05.280.9 (connector) 09.21.05.420.2 (contact M)	10
Profibus	04.21.60.020.4	Specific connectors (Profibus M12 from Siemens)		4
Single mode optical Fibres - Connector E2000				24
Multimode optical fibers -ST connectors		To be checked by Simao (EN/EL/CF) + Additional spares (Simao knows)		24
Ethernet connections (Check with Maryse Da Costa)	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 09.46.11.460.1 (Traversée chassis F/F)	50
WorldFIP	04.21.60.120.1	Connectors + boitier de raccordement	09.10.60.020.7 (Connector) 09.10.60.010.7 (FIP box)	4
Muti cond. Twisted/pair and shielded/pair (Check with specific connectors provided by Nikolaos)	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)	10
230V (CABLE CU EXTRA FLEX 3x 1,5MM2) (Power is providing by the electrical network - connectors only on the patch panel of the radiation test area) Protect them independently	04.08.61.733.6	Fiche Cable + Prise Cable + Prise Mur	09.00.03.370.3	[illegible]
3-Phase (CABLE CU EXTRA FLEX 5X1,5MM2) For TE/EPC (Louis de Mallac) (Power not provided by the electrical network - connectors on both patch panel) No protection - Need direct connection	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	[illegible]
3-Phase (CABLE CU EXTRA FLEX 5X6MM2) - 400 V For TE/EPC (Power is providing by the electrical network - connectors only on the patch panel of the radiation test area) 3*Without differential protection. 1*With differential protection All With circuit breaker	04.08.61.570.7	Prise 32A Mur 3*32A (female)	09.00.10.334.4	4
3-Phase (CABLE CU EXTRA FLEX 5X16MM2) - 400 V For other EN/EL (Power is providing by the electrical network - connectors only on the patch panel of the radiation test area) Without differential protection	04.08.61.590.3	Prise 63A Mur (provided by EN/EL) 3*63A (female) + 1*63A Male	09.00.10.063.8 - Plug with contact pilote	4
Connection to ground	To be defined by EN/EL	To be defined by EN/EL	To be defined by EN/EL	4
MCA24	04.21.48.324.9	SUB – D 25 male	09.21.20.709.1 (25 pin female connector)	4
MCA8	04.21.48.308.9	SUB – D 9 male	09.21.20.701.9 (9 pin female connector)	6
NG04	04.21.52.180.6	BURNDY ROUND MULTI-PIN CONNECTORS	09.31.05.104.4 (4 pin female connector for chassis mounting) + 09.21.05.450.6 (CONTACTS FOR MULTI-PIN CONNECTORS BURNDY)	4
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 + 09.41.25.170.7	14
Unipolar cable	04.08.61.994.7	Rapid connection	Marcin has the reference	4
ND26	04.21.52.020.1	Connecteur SubD female+ contacts	09.21.21.090.6 + 09.21.21.310.3	10
CKC50 (triax cables) internal conductor	Will be on the CERN store in January 04.21.52	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
VH4				2
CB50 (for remote reset)	04.61.11.225.6	BNC	09.46.11.700.4 09.46.11.460.1 (Traversée chassis F/F)	10
Total				255

In total 255 cables available

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)**