Constrains on Laser system implementation in the SPS tunnel

Gamma Factory Meeting
Faculty of Physics, Astronomy and Applied Computer Science
Jagiellonian University
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Requirements for laser installation

General requirements:

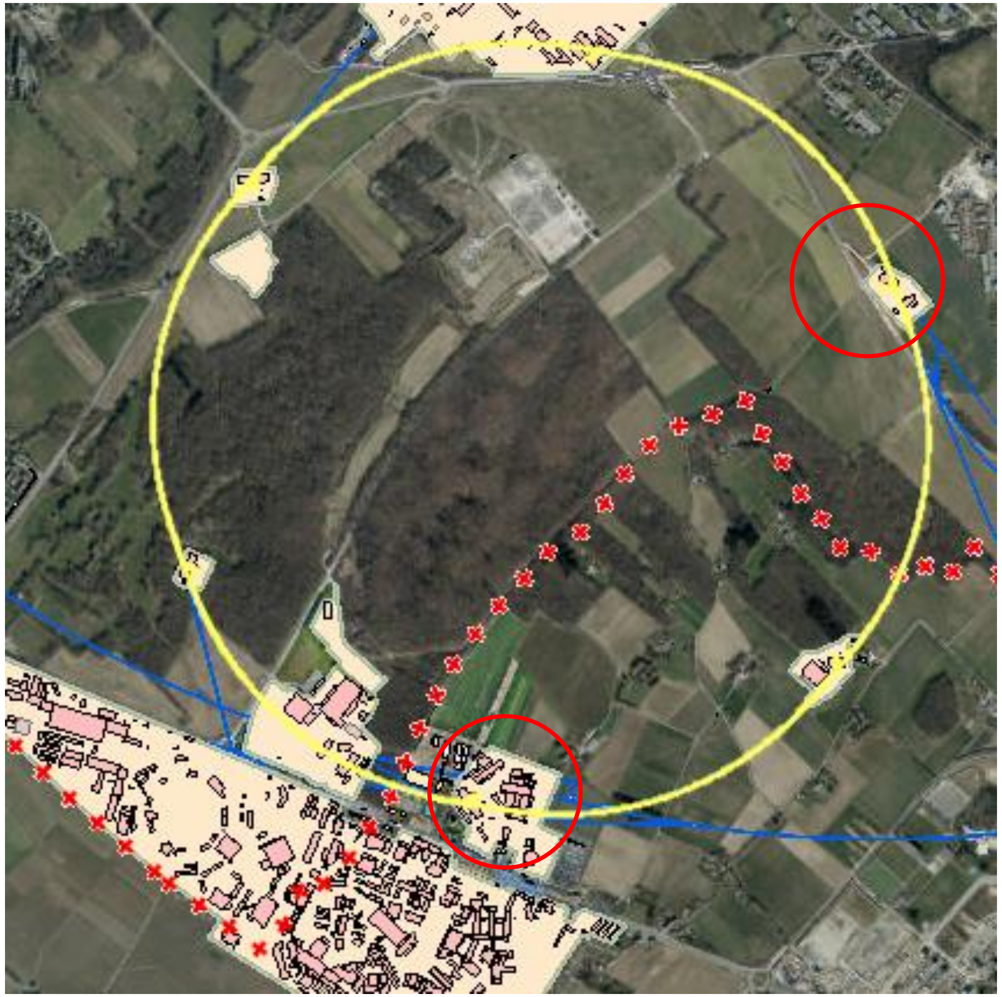
- Space for laser, optics, diagnostics, other electronic devices
- Electrical power
- Laser cooling => autonomous water circuit preferable
- Temperature stability => typically better than +/- 1° C
- Air purity => typically ISO 7 or better
- Class 4 laser safety => Designated Laser Area with access controls + enclosed beams outside DLA (Class 1)

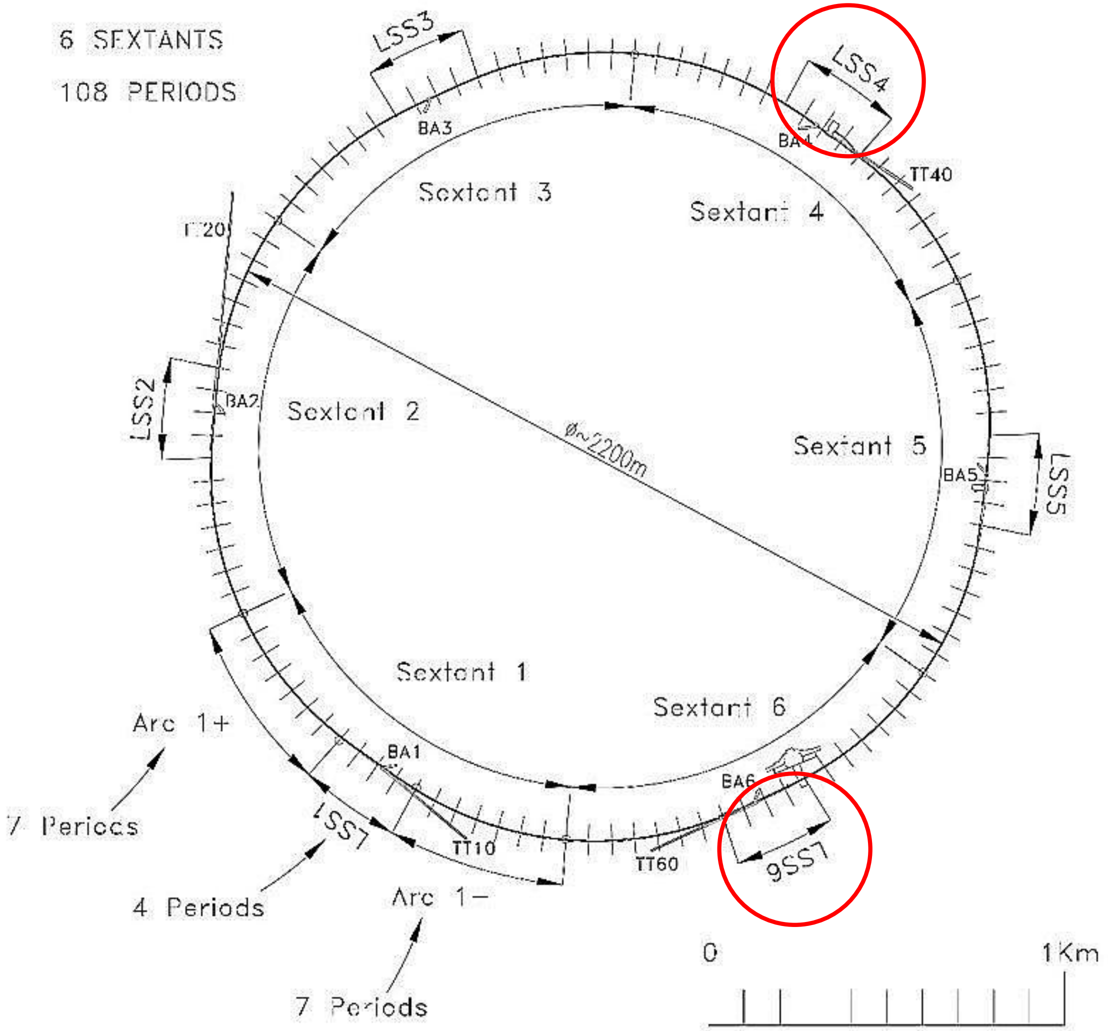
Specific requirements:

- Synchronization to the machine timing
- Integration into the CERN control system

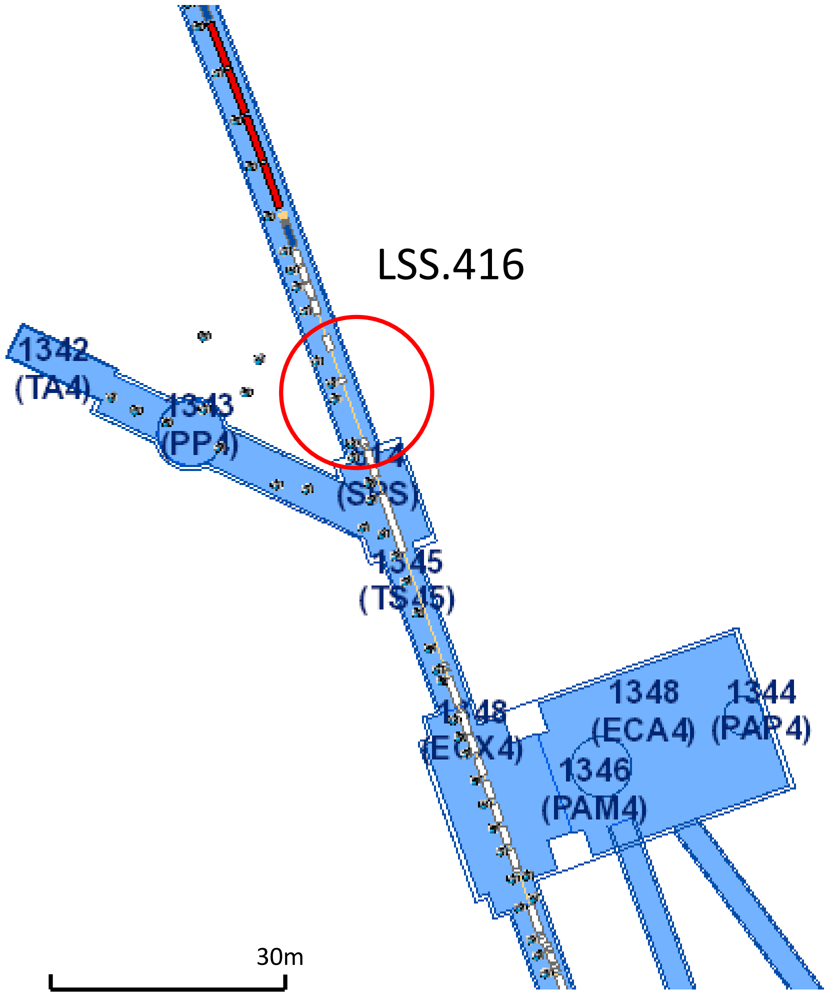
Interaction regions in SPS rings

Starights ections LSS4 and LSS6 were considered



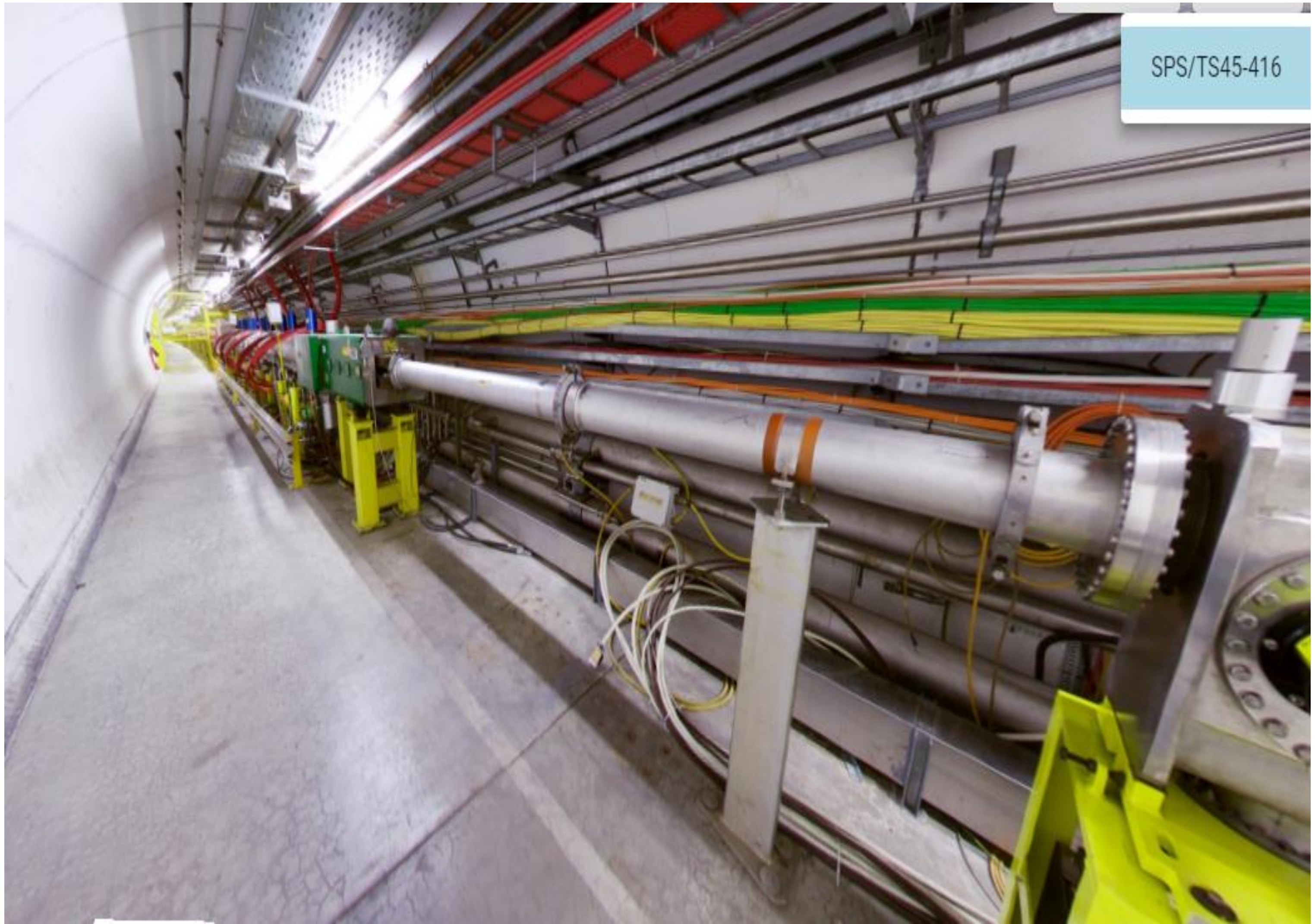


Straight section LSS4



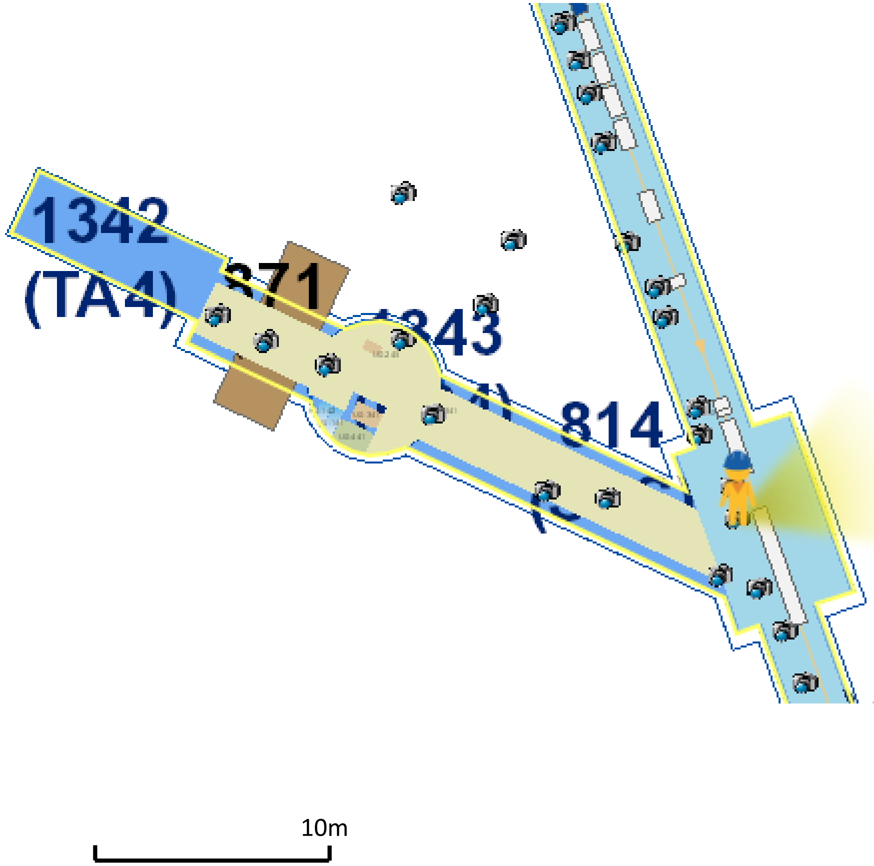
Passage should be left free for transport.

Practically no space for laser installation next to the beam line.

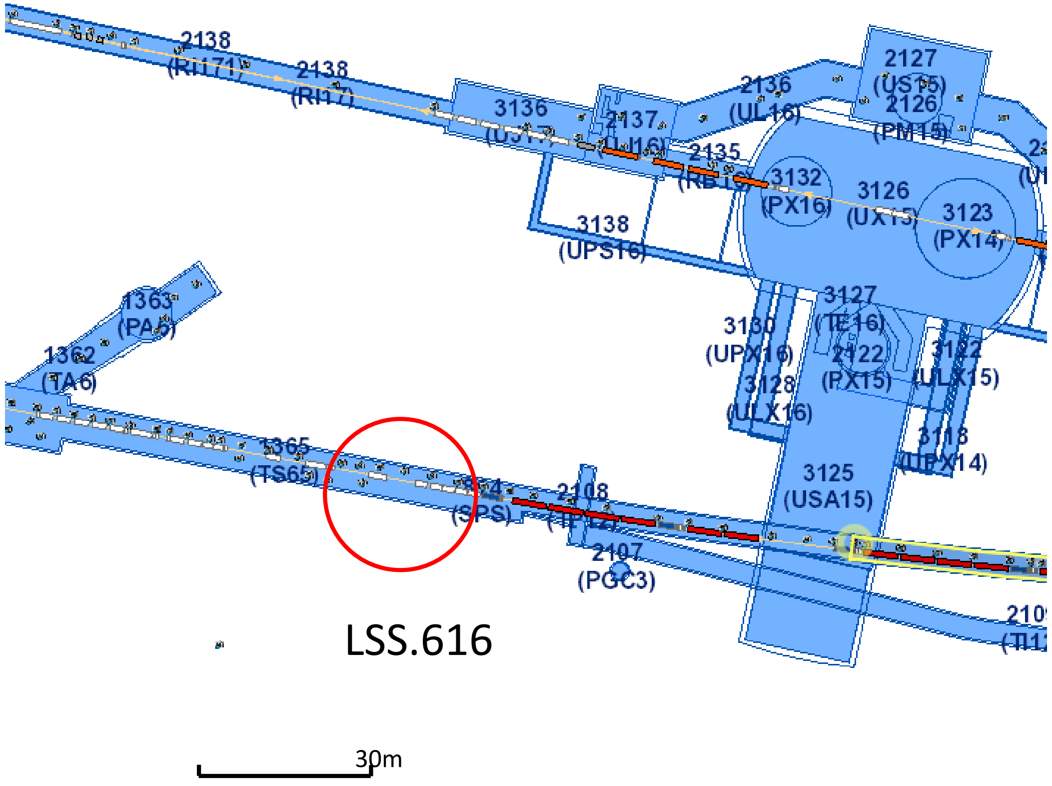


Straight section LSS4

Could it be possible to place the laser in neighbouring areas?

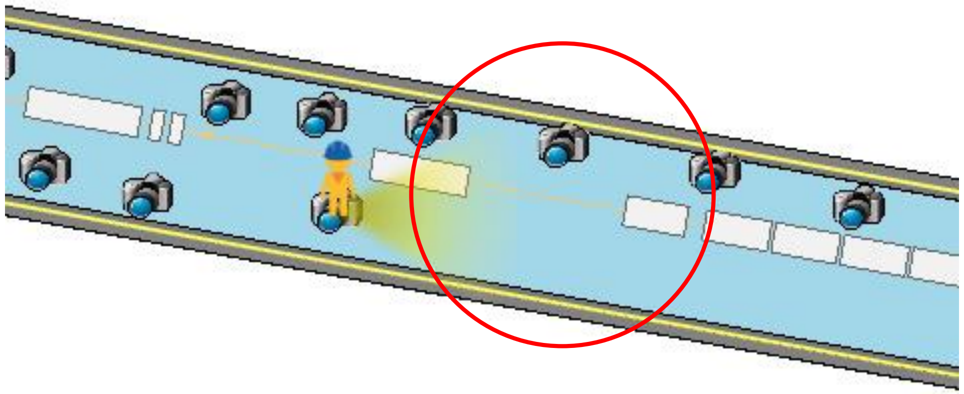


Straight section LSS6



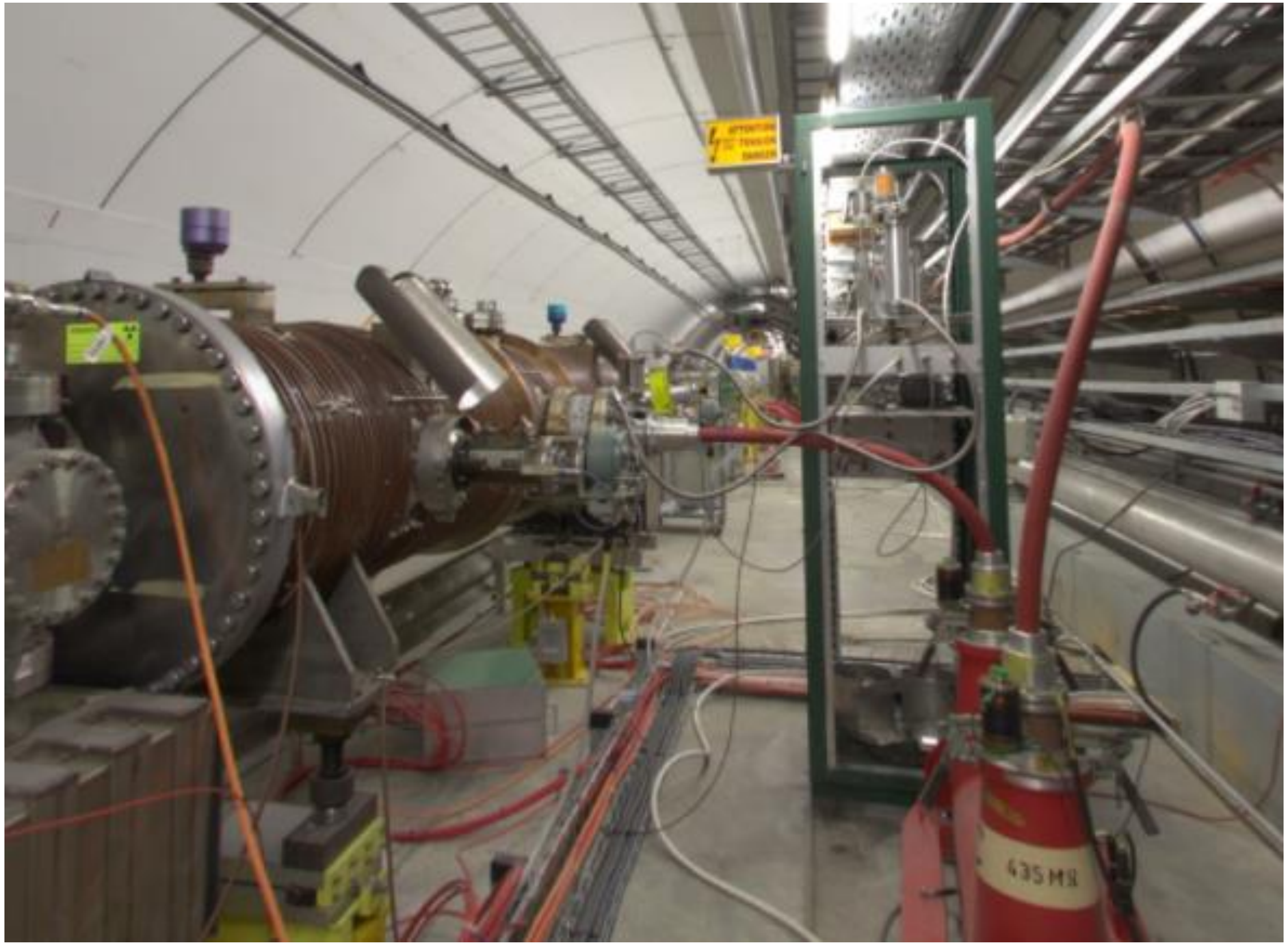
Tunnel is larger

Straight section LSS6



LSS.616

Space behind the beam line looks free



SPS Radiation Survey Results

Measurements taken after 30 hours of cool-down:

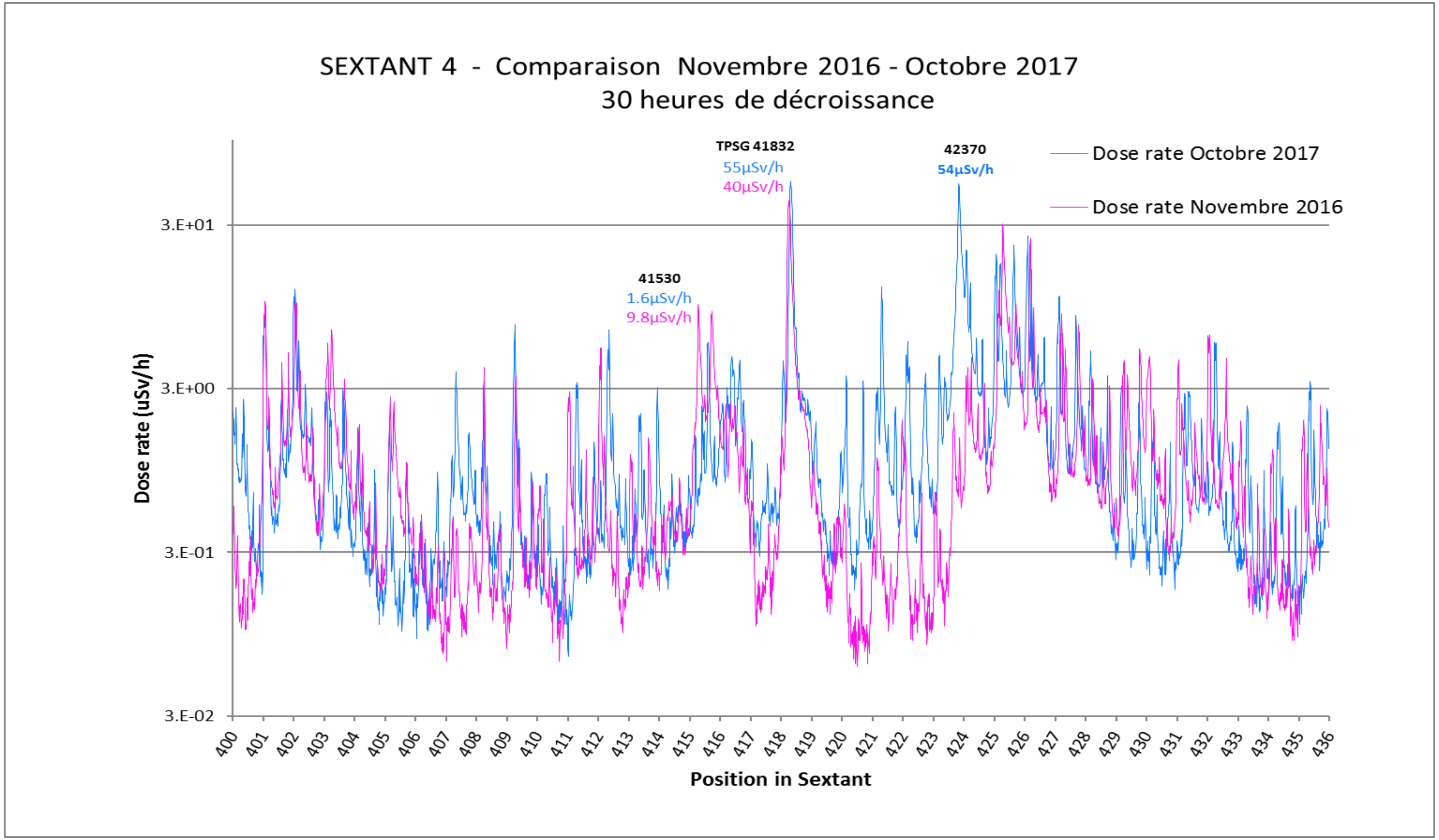
- 2017 Physics run (protons) from 8th May2017 to 23th Oct 2017
- 2016 Physics run (protons) from 11th Mar 2016 to 14th Nov 2016

Measurements taken after 2 months of cool-down - Jan 2018

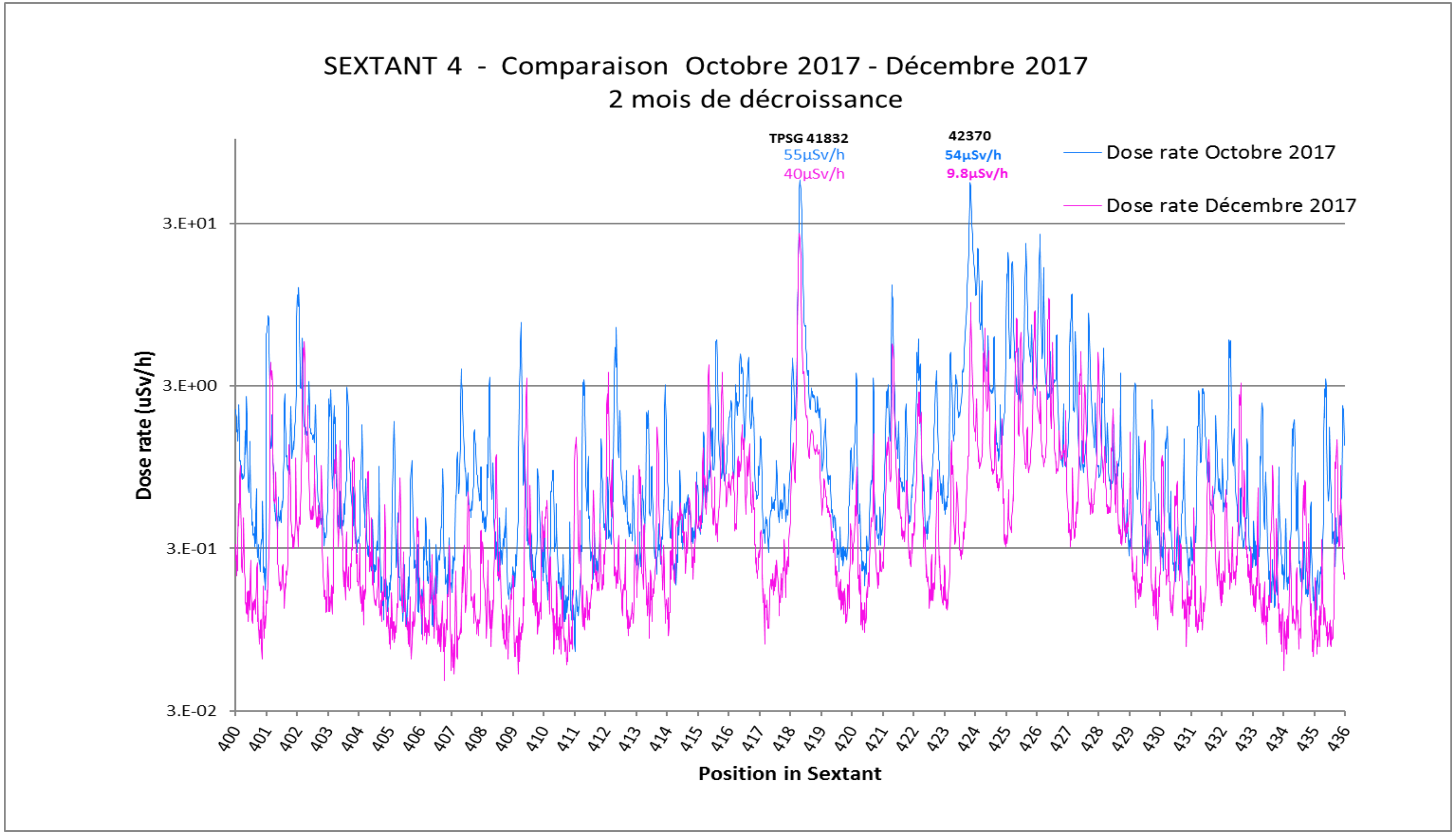
- PCMx probe SAPHYMO
  (plastic scintillator – 200cm^3)
- Distance ≈ 1m from beam line
- All along the 7km of the SPS Ring (≈ 18000 measurements).
- Labview registration application
- Survey usually performed after 30 hours of cool-down

Measuring probe
Plastic scintillator Vol: 200cm^3

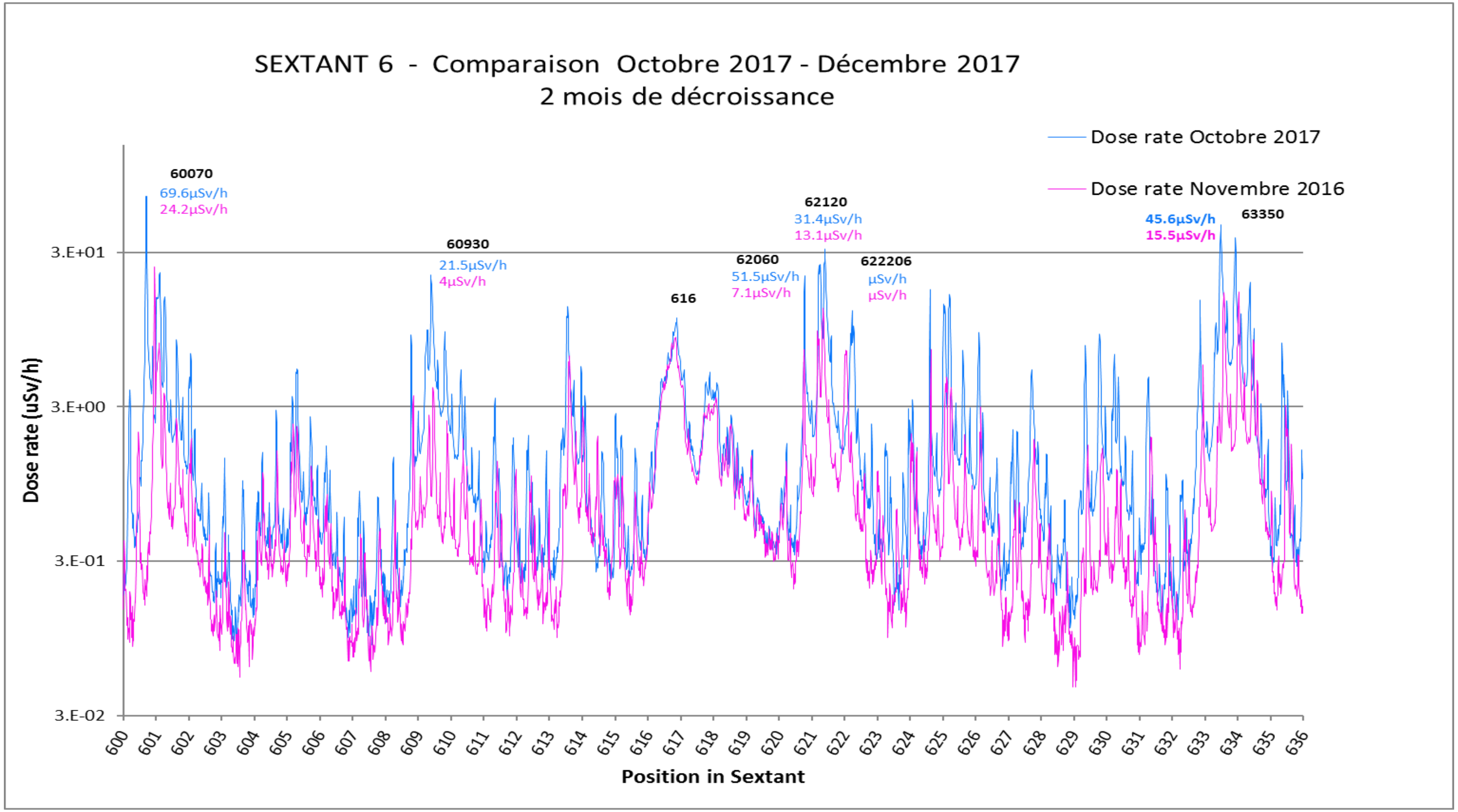
SPS Radiation Survey Results



SPS Radiation Survey Results



SPS Radiation Survey Results



HSE
Occupational Health & Safety
and Environmental Protection Unit

(HSE-RP)

SPS Radiation Survey Results

For access after 30 h cool-down:

None of the two areas is particularly problematic. However, both areas have some small areas with higher dose rates.

Latest Radiation Survey made on 18.12.2018

Eléments/Positions	Mesures AD6 au contact [µSv/h]	Mesures AD6 à 40 cm [µSv/h]
VVSB.41601 - start	4	2
VVSB.41601 - end	3	3
MDH.41607 - start	3	2
MDH.41607 - end	6	1.6
BPH.41608 - start	6	1.6
BPH.41608 - end	4.7	1.2
QF.41610 - start	4.7	1.2
QF.41610 - end	4.2	0.9
MKE.41631 - start	2.5	1.7
MKE.41631 - end	2	1.2
MKE.41634 - start	1.8	1.3
MKE.41634 - end	2.1	0.9
MKE.41637 - start	2.4	1
MKE.41637 - end	2.4	1.5
MKE.41651 - start	2.7	1.5
MKE.41651 - end	3	0.9
VVSB.41658 - start	2.8	2.9
VVSB.41658 - end	8	2.9
MPLH.41658 - start	30	3
BWSB.41677 - start	7.5	3.8
BWSB.41677 - end	8.3	1.5
VVFA.41698 - start	2.4	1.2
VVFA.41698 - end	2.9	1.1

Eléments/Positions	Mesures AD6 au contact [µSv/h]	Mesures AD6 à 40 cm [µSv/h]
VVSB.61601 - start	2	0.3
VVSB.61601 - end	2	0.3
MDH.61607 - start	0.2	0.2
MDH.61607 - end	10	0.8
BPH.61608 - start	10	0.8
BPH.61608 - end	10	0.8
QF.61610 - start	2	0.3
QF.61610 - end	1	0.3
MKE.61631 - start	2	0.2
MKE.61631 - end	2	0.2
VBBA.61633 - start	3	0.2
VBBA.61633 - end	3	0.2
MKE.61634 - start	8	0.6
MKE.61634 - end	4	0.3
VBBA.61636 - start	3	0.3
VBBA.61636 - end	3	0.3
MKE.61637 - start	4	0.3
MKE.61637 - end	5	0.3
VBBA.61655 - start	4	0.2
VBBA.61655 - end	4	0.2
MPLH.61655 - start	5	0.3
MPLH.61655 - end	22	2
ZS.61676	16	1.9
VBBA.61678 - end	40	5

LSS6 looks slightly better regarding the radiation emitted by beam line equipment

Radiation on Electronics measurements

Performed by EN/SMM-RME (EDMS document 2080251)

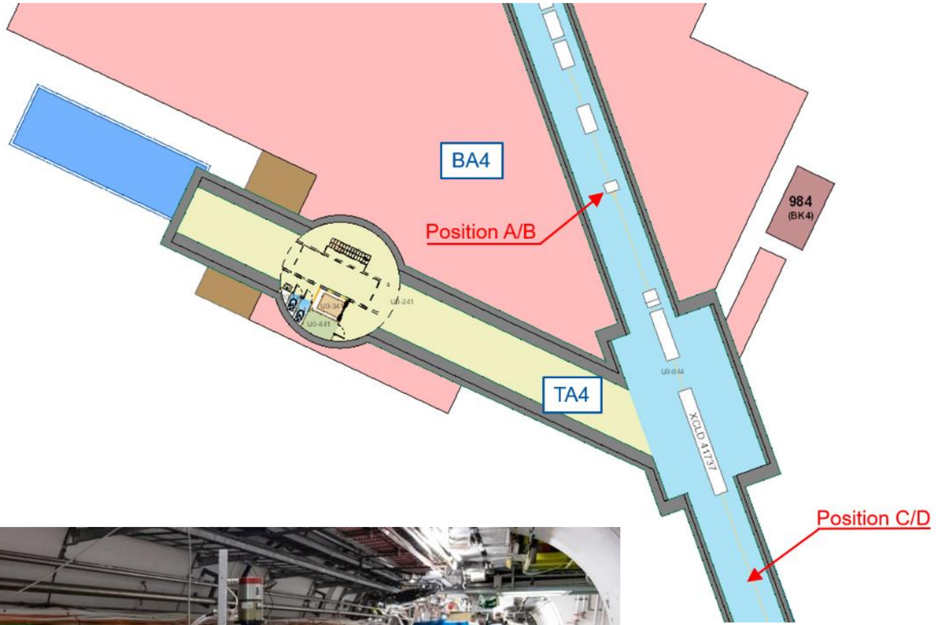
- Measurements performed at the IR locations in LSS4 and LSS6
- Period of measurements: 18/09/2018 – 17/01/2019
  - ➢Covers operation with protons and ions
  - ➢Beam operation stopped on 10.12 => in total ~ **1700 h of beam time**
- Measured values
  - Φ_{HEH} - High Energy Hadron fluence
  - Φ_{ThN} - Thermal Neutron fluence
  - TID - Total Ionizing Dose (using passive silicon dosimeters)
- Method to measure HEH using BatMon system:

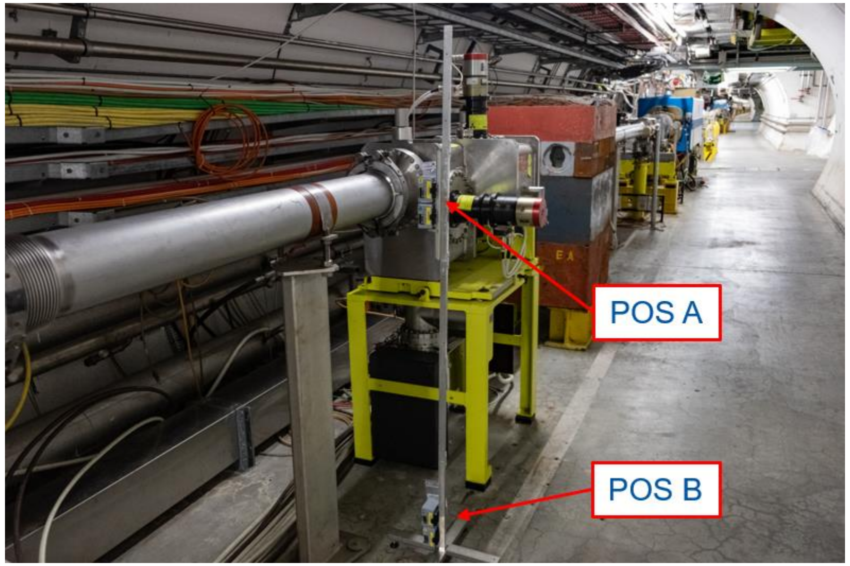
The Single Event Upsets (SEUs) induced by radiation in SRAM memories biased at two different voltages are measured and converted in fluences by solving the system:

$$\begin{cases} SEU_{5V} = \sigma_{5V}^{ThN} \times \Phi_{ThN} + \sigma_{5V}^{HEH} \times \Phi_{HEH} \\ SEU_{3V} = \sigma_{3V}^{ThN} \times \Phi_{ThN} + \sigma_{3V}^{HEH} \times \Phi_{HEH} \end{cases}$$

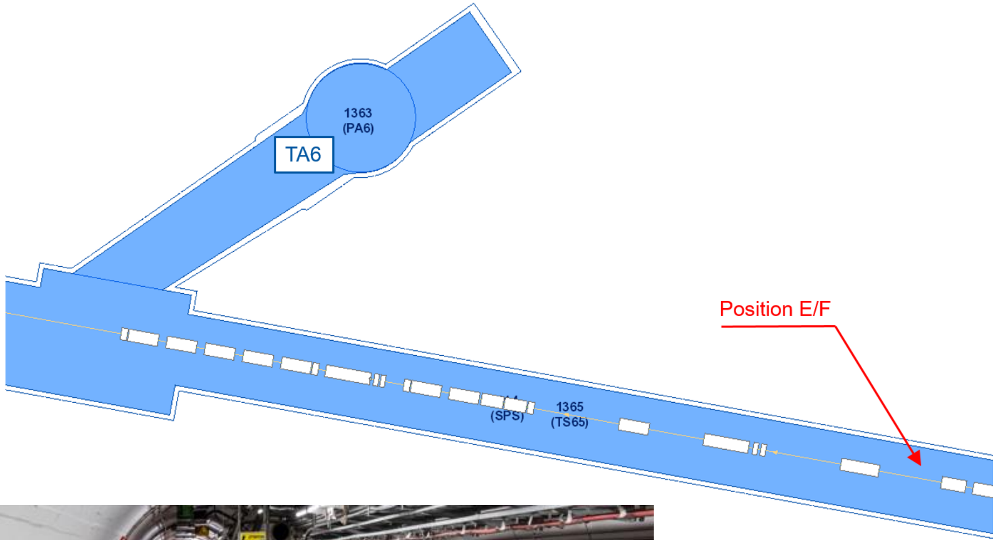
Radiation on Electronics measurements

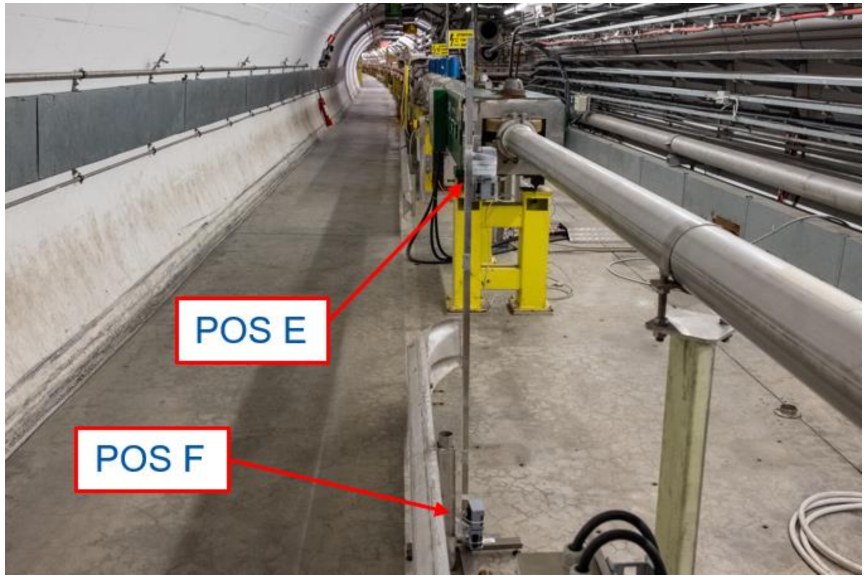
Position of detectors in LSS4





Position of detectors in LSS6





Radiation on Electronics measurements

Number of SEU detected by each BatMon pair

Long Straight Section	Position	Height	SEU 3V	SEU 5V
LSS4	A	Beam	20963	10498
	B	Floor	10351	1177
LSS6	E	Beam	N/A	17577
	F	Floor	20181	N/A

Summary of the fluences and the R factor measured

$$R = \frac{\Phi_{ThN}}{\Phi_{HEH}}$$

Long Straight Section	Position	Height	R-factor	Φ_{HEH} [pp/cm^2]	Φ_{ThN} [pp/cm^2]
LSS4	A	Beam	0.1	8.88×10^9	8.30×10^8
	B	Floor	1.9	8.80×10^8	1.64×10^9
LSS6	E	Beam	0.1*	1.50×10^{10}	1.40×10^9
	F	Floor	1.9*	2.04×10^9	3.81×10^9

Radiation on Electronics measurements

Summary of the measured TID for each position

Long Straight Section	Position	Height	TID [Gy]
LSS4	A	Beam	10.5
	B	Floor	4.8
LSS4	C	Beam	5.4
	D	Floor	3.9
LSS6	E	Beam	9.8
	F	Floor	4.0

Further data analysis and implications for electronics will be performed by EN/STI-BMI

Comparison with AWAKE conditions

No visible influence of proton beam on the devices

Fluka simulation by HSE-RP

Simulation Parameters:

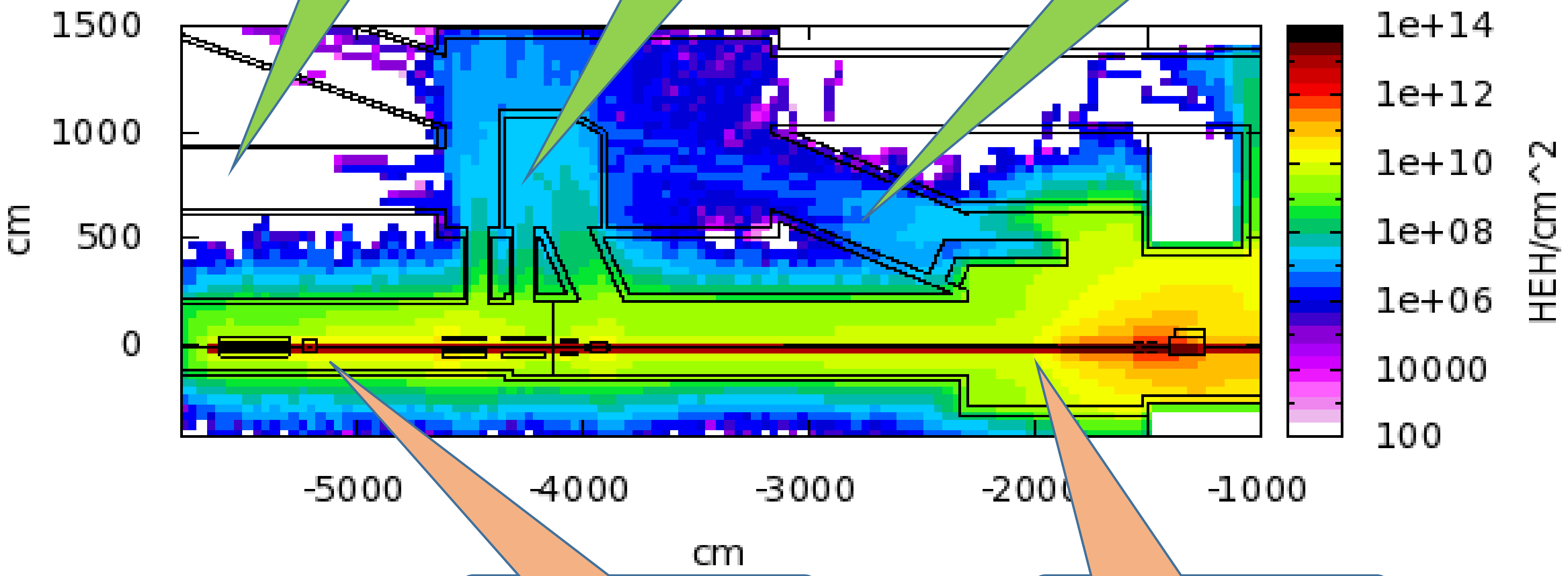
- $3x10^{11}$ p+/bunch
- 1 shot every 30 s
- 400 GeV

- Experimental runs:
  - 4 weeks per run
  - 2 runs per year
- Annual intensity: $4.8x10^{16}$

Laser room

UV beam diagnostics

Streak camera



Digital cameras

Digital cameras

SEUs regularly detected during proton beam time

Synchronization to the machine timing

Phase stability conditions of the laser-ion interaction

- The integer harmonic of laser mode locking should be equal to an integer harmonic of the SPS RF frequency

$$f_{ML} \times M = f_{RF,SPS} \times D$$

$\Rightarrow$*laser mode locking frequency should be specified accordingly*

- Stabilized optical link between laser and SPS beam control equipment

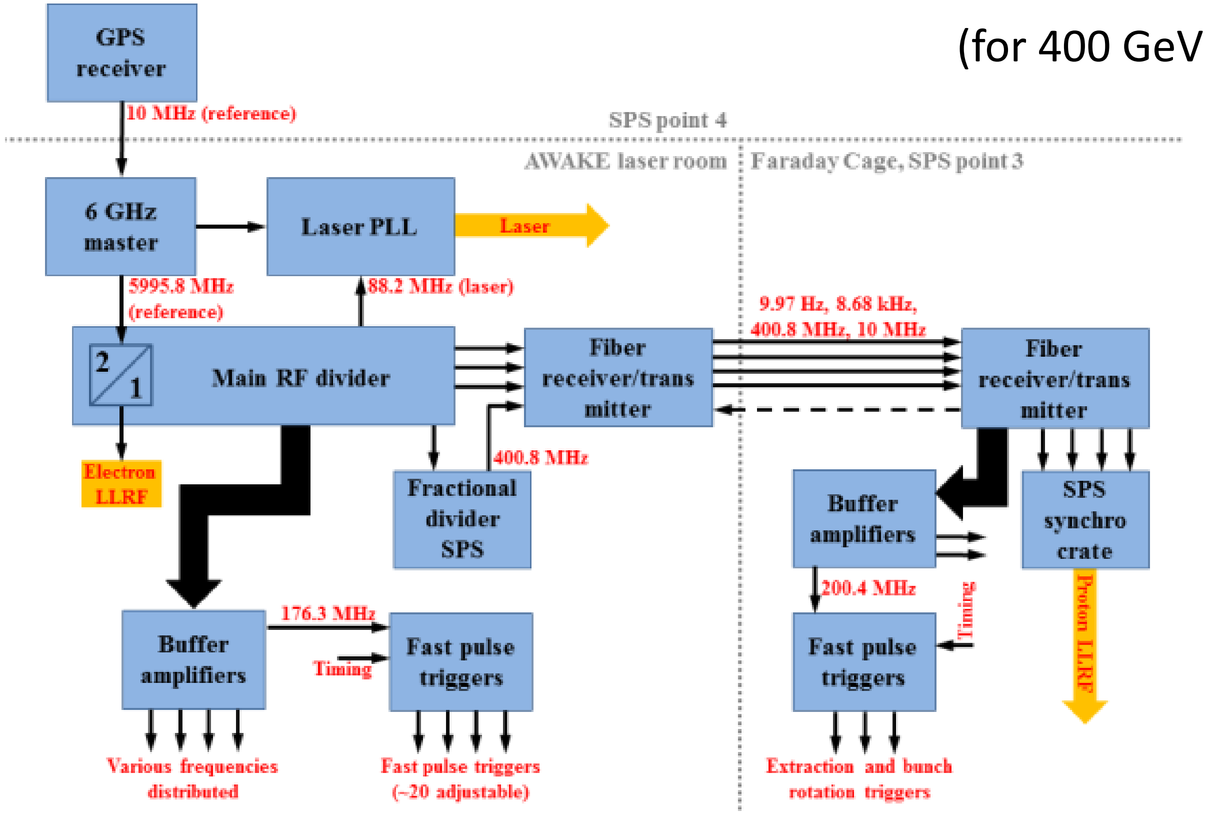
Synchronization to the machine timing

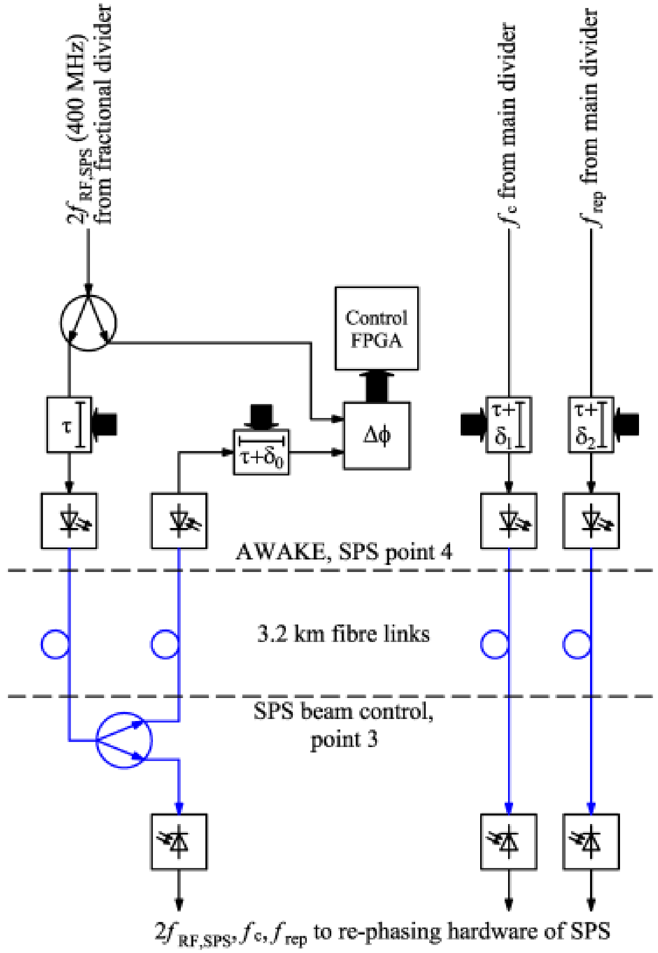
AWAKE example

$$f_{ML} \times 25 = f_{RF,SPS} \times 11$$

$$f_{RF,SPS} = 200.394322(500)\ MHz$$
$$f_{ML} = 88.1735\ MHz$$

(for 400 GeV protons)





H. Damerau et al., "RF Synchronization and Distribution for AWAKE at CERN" - in Proceeding of IPAC2106 [THPMY039]

Laser beam control and diagnostics

At CERN the accelerator control system is based on the Real-time FESA (Front-End Software Architecture) framework. => FESA classes are required for laser beam elements

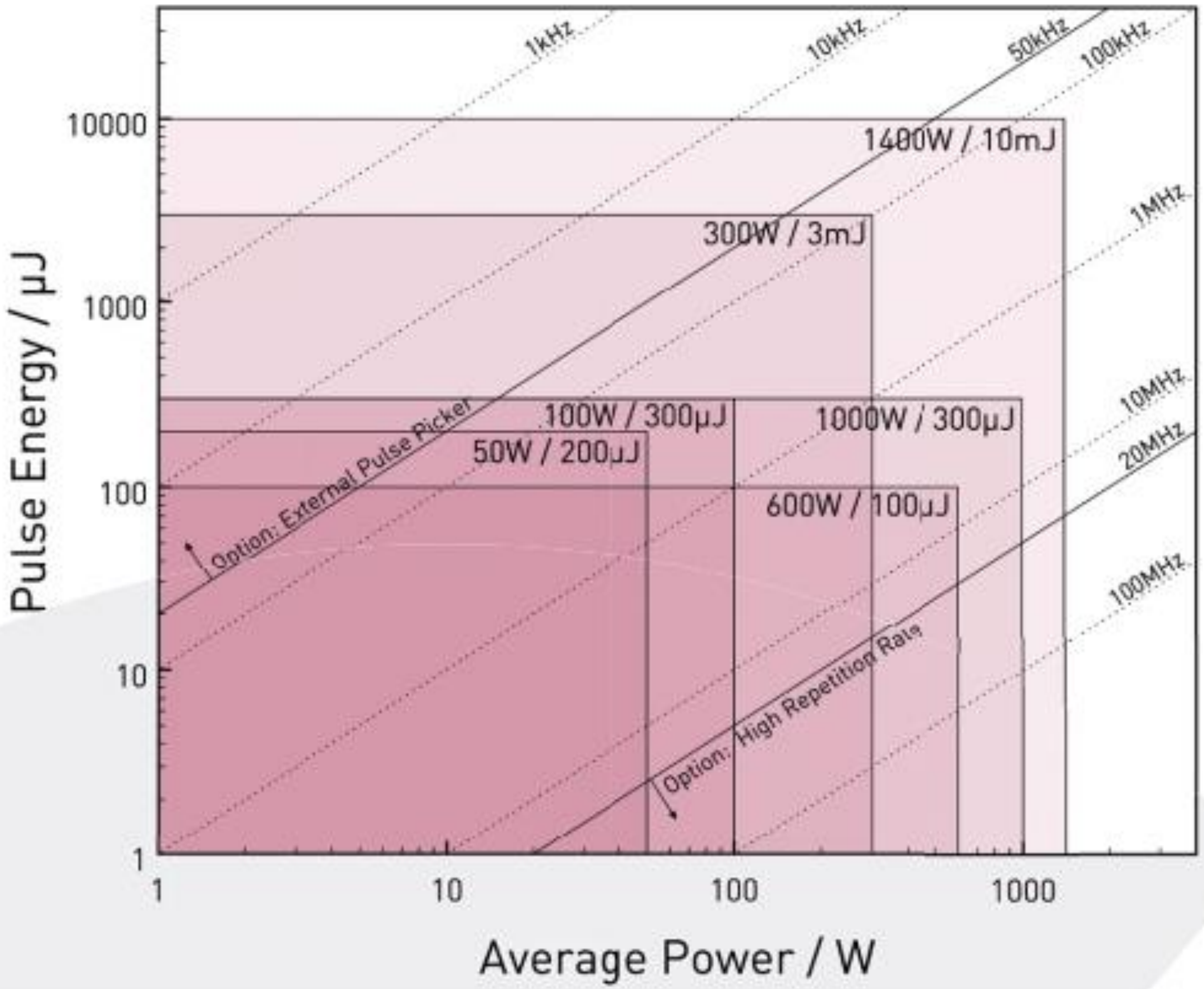
- Motorization of laser mirrors, translators and other movable elements
- Laser shutters and dumps
- Laser power/energy meters
- Acquisition of laser beam images

Summary

- Location for laser installation should fulfil certain requirements
  - Space
  - Air quality
  - Temperature stability
  - Safety (enclosure)
- IR location at LSS6 offers some space near the beam line, where a laser installation could be placed,
- The residual radiation conditions in both locations are acceptable for human work during the no-beam periods
- Risks of laser electronics damage by HEH and thermal neutrons shall by analysed by experts. A qualified advice on possible shielding is expected
- Laser synchronization is a separate task to work out.
- Control of laser beam elements and diagnostics should be designed in accordance with CERN standards.

CUSTOMIZED kW- AND mJ-CLASS FEMTOSECOND LASER SYSTEMS

ActiveFiberSystemsGmbH(AFS)islocatedinJena, knownasthe“cityofphotonics”inGermany.Asa spin-offfromtheFraunhoferIOFJenaandtheInsti-tuteofAppliedPhysicsattheuniversityofJenaAFS representstheexpertiseofinnovativesolid-state-laser development.



Overview of available laser parameters