



Multi Analyses on Radioactive Samples

A BEAM LINE DEDICATED TO RADIOACTIVE SAMPLES AT SOLEIL

RADIATION SAFETY ISSUES



RADIATION SAFETY ISSUES AT



Contents

- Presentation of the Mars Beam Line
- Radioactives Samples
- Containment
- Specific Shieldings
- Status and forecast



TOPICS AND APPLICATIONS

Characterizing radioactive samples for environmental, health and energy applications:

- **Solution chemistry** (organic and inorganic ligands and natural organic matter)
- **Solid state physics and chemistry** (structural properties of nuclear fuel, matrix for nuclear waste storage, stability of actinide alloys, study of material for current and future nuclear facilities)
- **Interface chemistry** (RN retention in nuclear waste storage context, RN migration in the geosphere)
- **Biology** (retention & migration of RN in nuclear waste storage context, study of complexes of medical interest, biological effects due to radiations, nuclear toxicology studies)

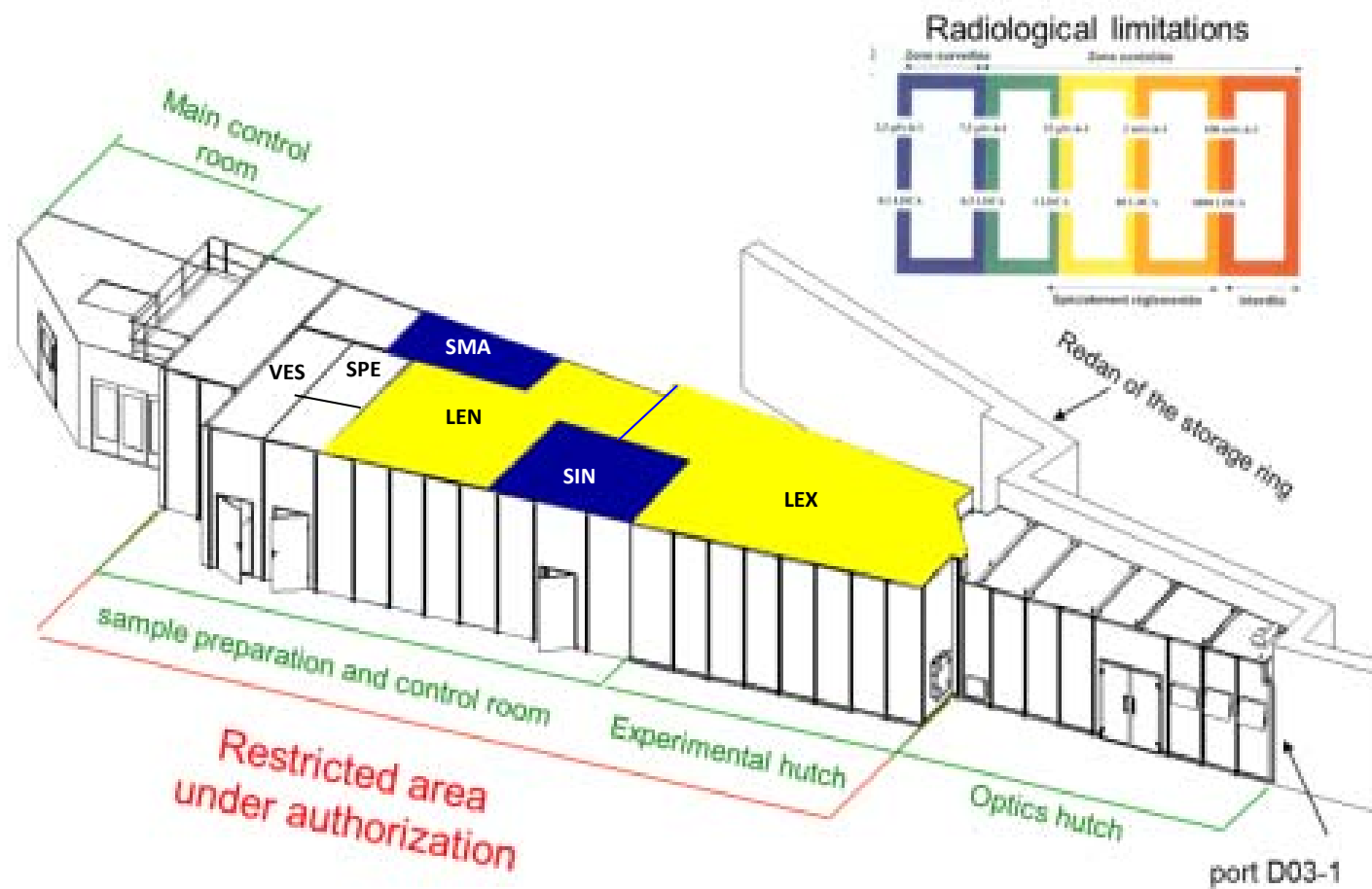
THE MARS BEAM LINE

- Set on a SR Bending Magnet, electron beam $E=2.75$ GeV, $B_z=1.71$ T (critical energy : 8.6 keV)
- Synchrotron Xray Energy range 3.5 keV – 36 keV
- Two experimental stations
 - CX2: High Resolution Diffraction spectroscopy (HRXRD)
 - CX3: Absorption spectroscopy (XAS, TXRD) and
 - Xray Fluorescence (XRF)

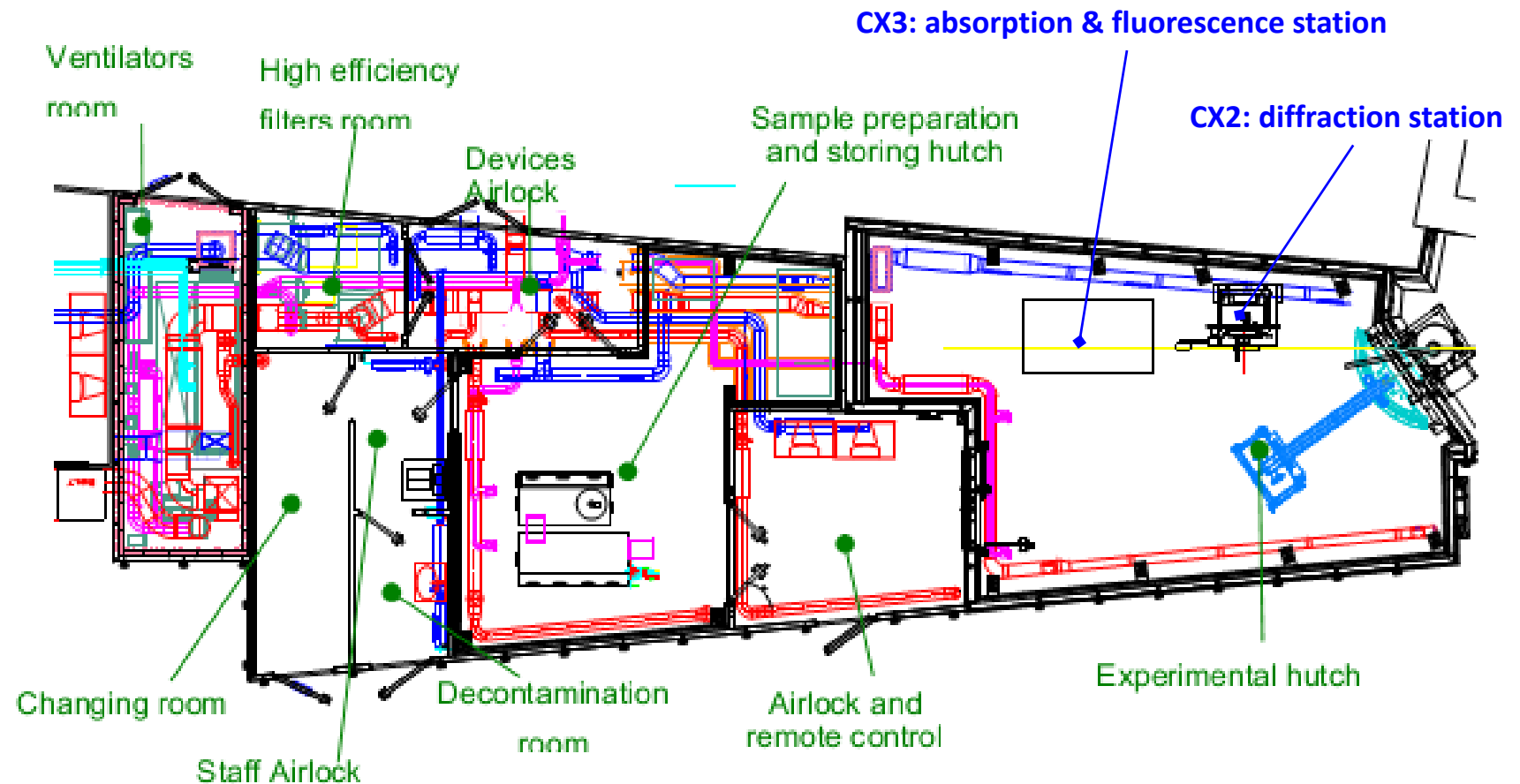
THE MARS BEAM LINE

- Versatile sample environment during experiment
→ 5 experimental families
 - F0: Normal conditions, no external constraint (P_{atm} , T);
 - F1: High temperature and pressure (<2000K, up to 100GPa);
 - F2: Low temperature (10K to 300K);
 - F3: Chemical and Redox reactions on liquid samples (300K to 450K)
 - F4: High temperature (300K to 1800K);
- Total activity able to be hosted on MARS BL:
185 GBq (max per sample: 18.5 GBq)

GENERAL LAYOUT OF THE MARS BEAMLINE



GENERAL LAYOUT OF THE MARS BEAMLINE



2 EXPERIMENTAL STATIONS



SPECIFIC EQUIPMENTS REQUIRED

- Special fireproof layer on metallic walls and ceilings
- Fireproof airtight feed-throughs for cables and pipes
- Glued metal sheets, special paint and separate gantry supporting servitudes



SPECIFIC EQUIPMENTS REQUIRED

- Absolute filters barriers on both ventilation networks and outlets ventilators connected to external chimney on the top of synchrotron building
- Dynamic containment from 2 independant ventilation networks (breathable air and process)
- Complex fire detection system connected with ventilation system and able to close fire shutters and doors



SPECIFIC EQUIPMENTS REQUIRED

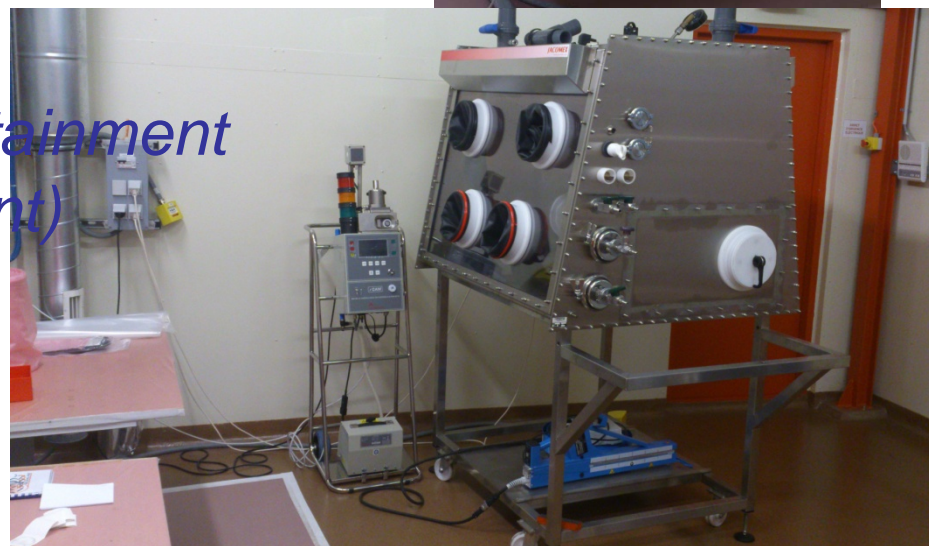
- Changing room and primary decontamination block (hands & arms)
- Specific working suite to be wear in controlled area
- Users and staff control before exiting controlled area by surface contamination monitors (α , $\beta\gamma$) for cloths, hands and feet



SPECIFIC EQUIPMENTS REQUIRED

- Sample-holder control desk (low activity samples)
- Glove box for safety controls and operation on sample holders

(eventual change of 2nd containment barrier for specific experiment)

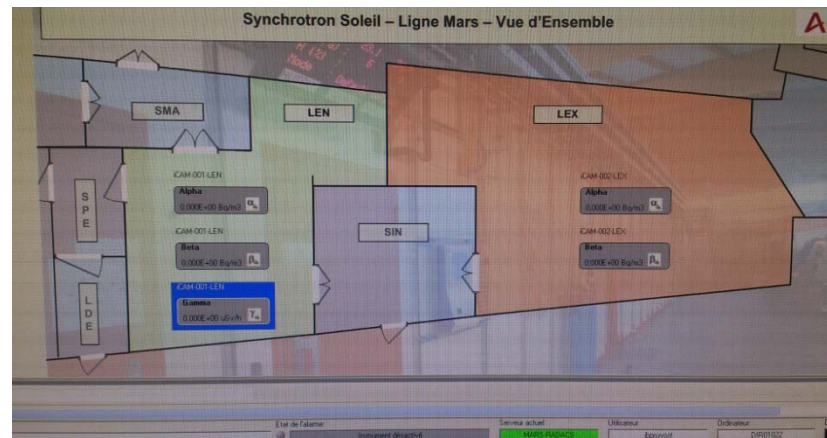


SPECIFIC EQUIPMENTS REQUIRED

- Emergency calling network system closed to each working station
- Continuous air area monitoring system for alpha and beta particles



ICAM™ probes
and RADACS™
Display
(CANBERRA)



RadSynch'13 – NSLS / BNL

8-10th May 2013

Jean-Baptiste PRUVOST

GENERAL RADIATION SAFETY GOALS AT SOLEIL

- **SOLEIL Staff and Users are Non classified workers regarding ionizing radiation hazards in the Experimental Hall**
- **Assess that in all conditions the radiation doses outside the tunnels are below the maximum dose authorized for non classified people :**
 - Annual Dose $< 1 \text{ mSv}$ \Leftrightarrow average dose rate $< 0.5 \text{ } \mu\text{Sv/h}$
- **Exposed workers limited to the one accessing tunnels during shutdown \rightarrow below B class annual dose limits (6 mSv/y)**

RADIATION SAFETY GOALS SPECIFIC TO MARS BEAM LINE

- The experiments on radioactive samples at MARS should have no effect on SOLEIL operations for both machine and BL at any time
- No direct contact between SOLEIL staff or users and the samples. All samples preparation has to be done in user's laboratory
- No contamination hazard affordable for MARS operation → particular attention on containment !
- MARS team permanent members should'nt be classified higher than B category

RADIATION SAFETY GOALS SPECIFIC TO MARS BEAM LINE

- What ever the radioactivity welcomed on MARS, doserates outside the BL rooms have to be below 0.5 $\mu\text{Sv/h}$ all around
- Containment designed and tested by users to ensure efficiency during experiment in all conditions
- Acceptance given by SOLEIL radiation safety and clearance officialy given after Regulation Authority green light
- Individual annual dose objective is to reach the same as SOLEIL exposed staff eg. $< 2 \text{ mSv/year}$

RADIOACTIVE SAMPLES

- Only Solids and liquids are allowed on MARS beam line (incl. sintered powder)
- Gaseous samples and powder are strictly forbidden on MARS
- About 400 different isotopes with activity limited up to 18.5 GBq per sample / sample holder
- Limitation also coming from corresponding dose rates and contamination levels in case of leakage of the sample containment

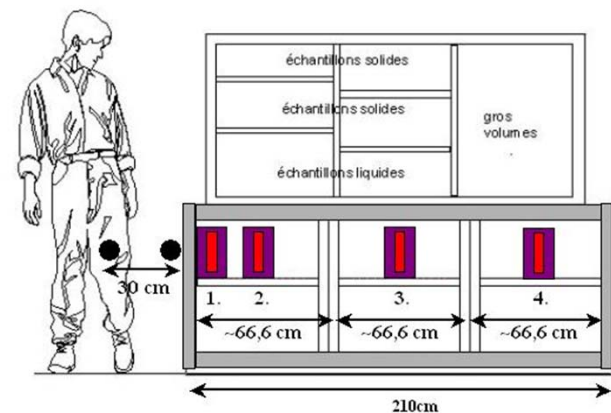
RADIOACTIVE SAMPLES

Typical examples:

- Environmental samples (solid in solution and liquid) from geological and biology studies, from rivers, mines, volcanos, etc) → few Bq to ~ 1-2 kBq U and/or Th
- Doped glass for Nuclear Waste management studies, long live and high activity ~ 100 kBq to 2 GBq
- Structure material in nuclear power plants (activated metallic alloys samples) → few kBq up to ~1GBq
- New and spent fuel samples (sections of UO_2 fuel pellets, 23mg) → up to 3 GBq

ACTIVITY THRESHOLDS PER ISOTOPES

- Doserate calculations performed with MERCURAD™ and MCNPX codes for unshielded and shielded sample holders to define maximum acceptable activity to stay below 0.5 $\mu\text{Sv/h}$ outside MARS enclosure
- Positions investigated:
 - Storage in LEN;
 - CX2 station;
 - CX3 station



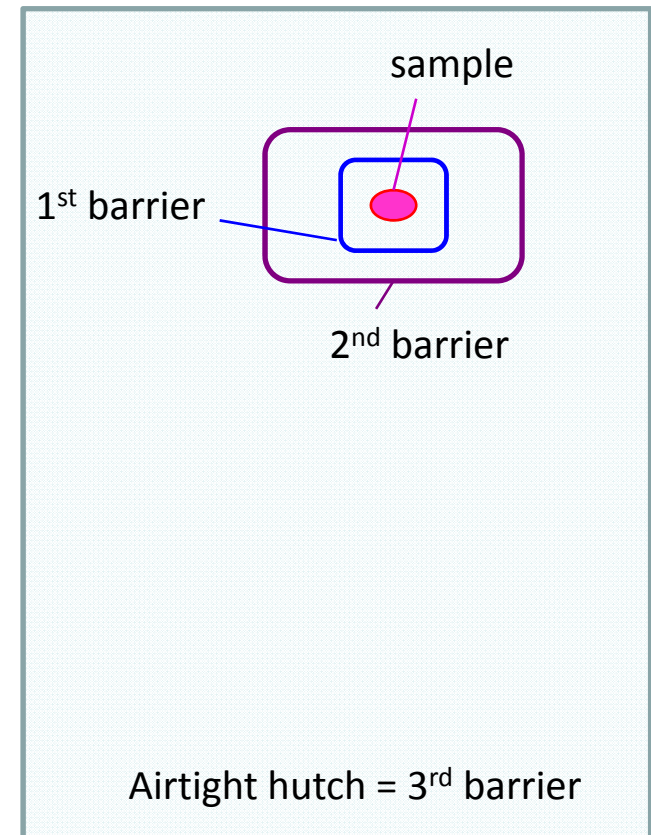
ACTIVITY THRESHOLDS PER ISOTOPES

ACTIVITE MAXIMUM AUTORISEE SUR LA LIGNE MARS PAR RADIOISOTOPE

	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)	RN	A max (Bq)
	Ac225	7,00E+08	Br82	7,28E+07	Co60m	1,44E+10	H3	3,00E+04	Kr88	2,44E+07	Pb201	5,00E+07	Pu245	1,30E+09	Sr81	7,27E+08	Tl204	1,85E+10
	Ac227	8,00E+08	Cl4	1,85E+10	Co61	7,61E+09	Hf175	1,85E+10	La140	3,26E+07	Pb203	1,85E+10	Ra223	1,85E+10	Sr83	3,86E+08	Tl207	1,85E+10
	Ac228	1,74E+08	Ga45	1,85E+10	Co62m	2,48E+07	Hf181	1,85E+10	Lu177	1,85E+10	Pb209	1,85E+10	Ra224	1,85E+10	Sr85	1,85E+10	Tl208	7,00E+06
	Ag105	1,58E+09	Ga47	1,04E+08	Cr51	1,85E+10	Hg197	1,85E+10	Mn51	1,38E+10	Pb210	1,85E+10	Ra225	1,85E+10	Sr85m	1,85E+10	Tl209	7,00E+06
	Ag110m	5,91E+07	Gd109	1,85E+10	Cs125	5,66E+08	Hg197m	1,85E+10	Mn52	2,99E+07	Pb211	5,00E+08	Ra226	1,85E+10	Sr87m	1,85E+10	Tm170	1,85E+10
	Ag111	1,85E+10	Gd113m	1,85E+10	Cs127	3,87E+09	Hg203	1,85E+10	Mn52m	3,68E+07	Pb212	1,85E+10	Ra227	1,85E+10	Sr89	1,85E+10	Tm171	1,85E+10
	Al28	1,00E+07	Gd115	1,85E+10	Cs129	1,85E+10	Ho166	2,72E+09	Mn54	2,74E+08	Pb214	1,60E+07	Ra228	1,85E+10	Sr90-Y90	1,85E+10	U230	1,85E+10
	Am237	6,79E+09	Gd115m	3,17E+09	Cs130	2,53E+09	Ho166m	1,80E+08	Mn56	4,07E+07	Pd103	1,85E+10	Rb86	9,10E+08	Sr91	1,91E+08	U231	1,85E+10
	Am238	2,13E+08	Ge134	1,85E+10	Cs132	1,31E+09	I120	3,43E+07	Mo101	5,71E+07	Pd107	1,85E+10	Rb87	1,85E+10	Sr92	3,97E+07	U232	1,85E+10
	Am239	1,85E+10	Ge136	1,85E+10	Ce134	1,85E+10	I120m	1,93E+07	Mo90	4,86E+08	Pd109	1,85E+10	Re183	1,85E+10	Ta182	8,03E+07	U233	1,85E+10
	Am240	2,77E+08							Mo93m	3,57E+07	Pm147	1,85E+10	Re186	1,85E+10	Ta183	1,85E+10	U234	1,85E+10
	Am241	1,85E+10							Mo99	9,21E+09	Pm148	1,51E+08	Re188	6,54E+09	Tb160	1,59E+08	U235	1,85E+10
	Am242	1,85E+10							Na22	7,98E+07	Pm148m	2,55E+08	Rh103m	1,85E+10	Tc96	1,08E+08	U235m	1,85E+10
	Am242m	1,85E+10	Ce141	1,85E+10	Ce138	6,75E+09	I125	1,85E+10	Na24	1,03E+07	Pm149	1,85E+10	Rh105	1,85E+10	Tc96m	4,08E+09	U236	1,85E+10
	Am243	1,85E+10	Ce143	5,94E+09	Cs137-Ba137m	3,80E+09	I126	2,98E+09	Nb88	3,62E+07	Po203	7,44E+07	Rn219	5,00E+08	Tc97m	1,85E+10	U237	1,85E+10
	Am244	6,58E+08	Ce144-Pr144	4,05E+09	Ce138	2,72E+07	I128	1,85E+10	Nb89	7,86E+07	Po205	7,05E+07	Rn220	1,85E+10	Tc99	1,85E+10	U238	1,85E+10
	Am244m	7,80E+09	Cf244	1,85E+10	Cu64	1,60E+09	I129	1,39E+07	Nb90	1,85E+10	Po207	1,84E+08	Rn222	1,85E+10	Tc99m	1,85E+10	U239	1,85E+10
	Am245	1,85E+10	Cf246	8,53E+09	Dy165	1,85E+10	I130	3,41E+08	Nb93m	1,85E+10	Po209	8,00E+08	Ru103	1,85E+10	Te116	1,85E+10	U240	1,85E+10
	Am246	1,44E+09	Cf249	1,85E+10	Dy166	1,85E+10	I131	1,79E+10	Nb94	2,36E+08	Po210	1,85E+10	Ru105	1,28E+09	Te121	1,85E+10	V48	5,69E+07
	Am246m	8,30E+07	Cf250	1,67E+07	Erl69	1,85E+10	I132m	5,51E+09	Nb95	1,66E+09	Po211	1,85E+10	Ru106-Rh106	3,76E+09	Te121m	1,85E+10	W181	1,85E+10
	Ar41	8,04E+07	Cf251	1,85E+10	Er171	1,85E+10	I133	1,17E+09	Nb96	8,78E+07	Po212	1,85E+10	Ru97	1,85E+10	Te123m	1,85E+10	W185	1,85E+10
	As73	1,85E+10	Cf252	3,39E+05	Es253	1,85E+10	I134	5,66E+07	Nb97	1,24E+09	Po213	1,85E+10	S35	1,85E+10	Te127	1,85E+10	W187	3,39E+09
	As74	6,39E+09	Cf253	1,85E+10	Es254	1,85E+10	I135	4,35E+07	Nb98	1,38E+09	Po214	1,85E+10	Sb122	4,44E+09	Te127m	1,85E+10	Xe131m	1,85E+10
	As76	5,27E+08	Cf254	1,22E+04	Eu152	9,54E+07	ln111	1,85E+10	Nb98	1,85E+10	Po215	6,00E+08	Sb124	3,75E+07	Te129	1,04E+10	Xe133	1,85E+10
	As77	1,85E+10	Cf36	1,85E+10	Eu152m	8,72E+08	ln114m	1,85E+10	Nd149	7,22E+09	Po216	1,00E+07	Sb125-Te125m	5,63E+09	Te129m	1,85E+10	Xe135	1,85E+10
	At211	1,85E+10	Cf38	2,95E+07	Eu154	1,17E+08	ln113m	1,85E+10	Ni59	1,85E+10	Pr142	9,84E+08	Sb126	3,02E+08	Te131	7,88E+08	Y91	1,85E+10
	At217	1,00E+09	Gm241	1,85E+10	Eu155	1,85E+10	ln115m	1,85E+10	Ni63	1,85E+10	Pr143	1,85E+10	Sc46	6,20E+07	Te131m	1,27E+08	Y91m	1,85E+10
	Au196	1,85E+10	Gm242	1,85E+10	Eu156	5,04E+07	lr190	8,51E+08	Ni65	1,16E+08	Pt191	1,85E+10	Sc47	1,85E+10	Te132	1,85E+10	Y92	4,68E+08
	Au198	1,85E+10	Gm243	1,85E+10	F18	1,85E+10	lr192	9,93E+09	Np237	1,85E+10	Pt193m	1,85E+10	Sc48	3,49E+07	Te133	7,71E+07	Y93	9,23E+08
	Au199	1,85E+10	Gm244	1,85E+10	Fe52	1,85E+10	lr194	3,16E+09	Np238	5,00E+07	Pt197	1,85E+10	Se75	1,85E+10	Te133m	7,42E+07	Yb169	1,85E+10
	Ba131	4,40E+09	Gm245	1,85E+10	Fe55	1,85E+10	K40	5,00E+07	Np239	1,85E+10	Pt197m	1,85E+10	Se79	1,85E+10	Te134	2,07E+09	Yb175	1,85E+10
	Ba140	1,85E+10	Gm246	8,42E+06	Fe59	8,00E+07	K42	1,91E+08	Np240	2,77E+07	Pu237	1,85E+10	Sn113	1,85E+10	Th226	1,85E+10	Zn65	1,57E+08
	Be10	1,85E+10	Gm247	1,85E+10	Fm224	1,85E+10	K43	1,31E+09	O16	2,23E+07	Pu238	1,85E+10	Sn119m	1,85E+10	Th227	1,50E+08	Zn69	1,85E+10
	Be7	1,85E+10	Gm248	2,02E+05	Fm225	1,85E+10	Kr74	7,52E+09	O17	2,23E+07	Pu239	1,85E+10	Sn121	1,85E+10	Th228	1,85E+10	Zn69m	1,85E+10
	Bi206	3,89E+07	Gm248	1,85E+10	Fm256	1,85E+10	Kr76	7,14E+09	Os191m	1,85E+10	Pu240	1,85E+10	Sn121m	1,85E+10	Th229	1,85E+10	Zr86	1,85E+10
	Bi207	1,85E+10				5,00E+08	Kr77	5,70E+09	Os193	1,85E+10	Pu241	1,85E+10	Sn119m	1,85E+10	Th230	1,85E+10	Zr88	1,85E+10
	Bi210	1,85E+10				5,00E+08	Kr79	3,23E+09	P32	1,85E+10	Pu242	4,42E+09	Sn121	1,85E+10	Th231	1,85E+10	Zr89	2,46E+08
	Bi211	1,85E+10				1,85E+10	Kr81	1,85E+10	Pa230	4,86E+08	Pu243	1,85E+10	Sn121m	1,85E+10	Th232	1,85E+10	Zr93	1,85E+10
	Bi212	1,85E+10				2,46E+07	Kr83m	1,85E+10	Pa231	1,85E+10	Pu244	1,85E+10	Sn123	8,00E+08	Th234	1,85E+10	Zr95	1,67E+09
	Bi214	1,00E+07	Co58	2,58E+08	Gd153	1,85E+10	Kr85	1,85E+10	Pa233	1,85E+10	Pu245	1,85E+10	Sn125	2,75E+08	Tl200	1,10E+08	Zr97	5,58E+08
	Bk249	1,85E+10	Co60m	1,85E+10	Gd159	1,85E+10	Kr85m	1,85E+10	Pa234	2,50E+07	Pu246	1,85E+10	Sn126	1,85E+10	Tl201	1,85E+10		
	Bk250	1,44E+06	Co60	2,51E+07	Gd17m	1,85E+10	Kr87	7,45E+07	Pa234m	5,90E+09	Pu247	1,85E+10	Sr80	1,85E+10	Tl202	1,85E+10		

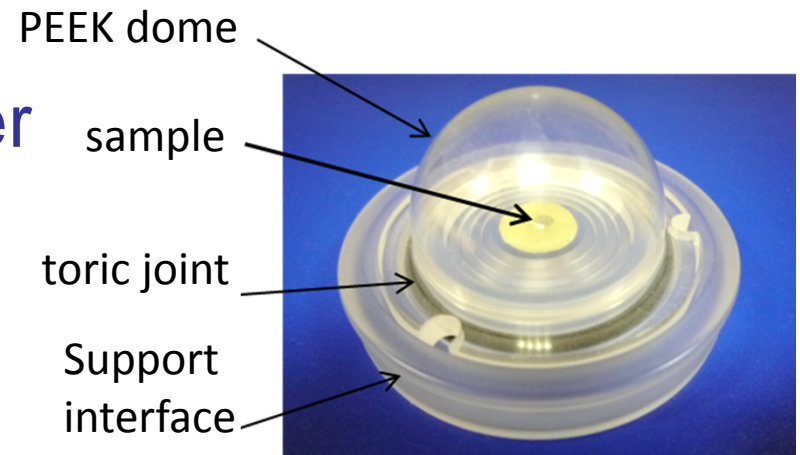
SAMPLE CONTAINMENT PRINCIPLE

- If contamination risk is present because of the sample itself and/or because of the experience, then 3 independant containment barriers are required between the sample and the environment.
- 2 1st around the sample
- 3rd beam line airtight rooms



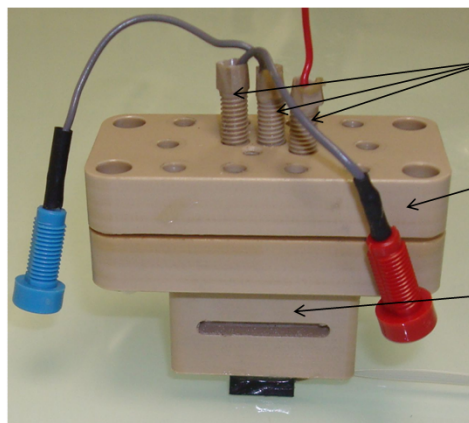
SAMPLE CONTAINMENT EXAMPLE 1

- PEEK dome sample holder (Brucker) for diffraction experiments
- Can be loaded with up to four samples
- For solid samples, mainly of low activity level and for normal conditions experiments (F0 family)



SAMPLE CONTAINMENT EXAMPLE 2

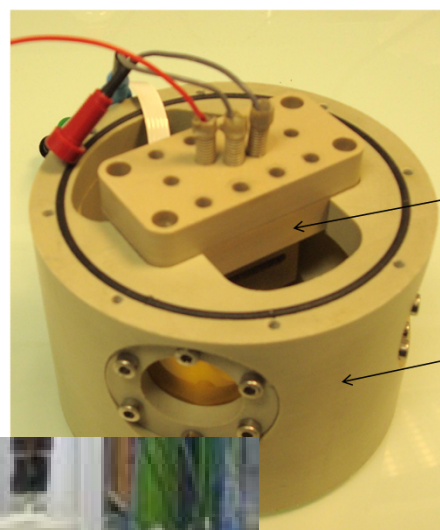
F3: liquid samples and redox reactions



Sealed electrodes

Top cover

10cm³ cell containing
the sample solution



Complete 10cm³ cell

External support with 3 kapton windows
for absorption and fluorescence
measurements

1st barrier

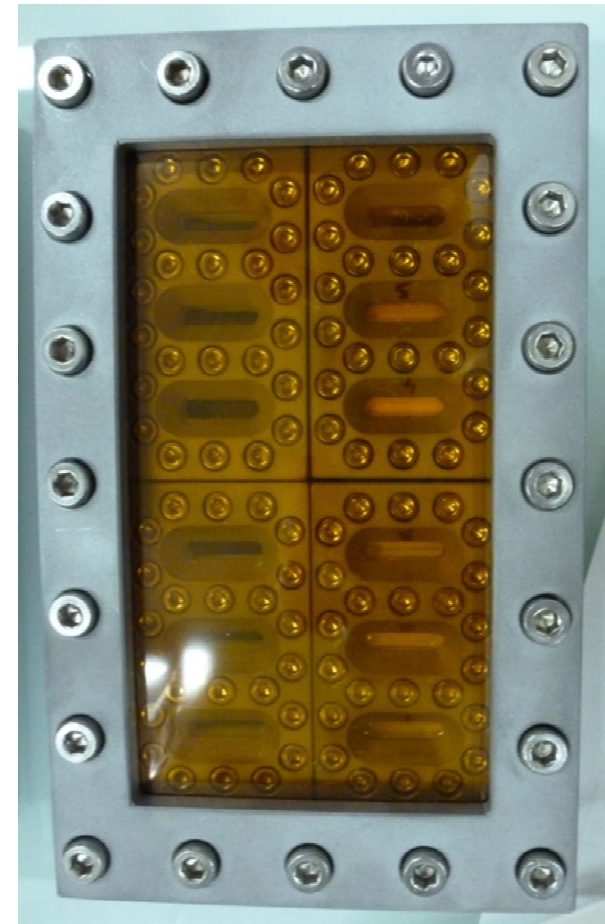
Both able to resist hi



Complete setup mounted on
CX3 station

SAMPLE CONTAINMENT EXAMPLE 3

- Multi samples holder loaded with up to 12 different samples, liquid or solid, or both
→ Typical example: natural or depleted uranium solutions (10^0 to 10^2 Bq/sample) with concentration gradient



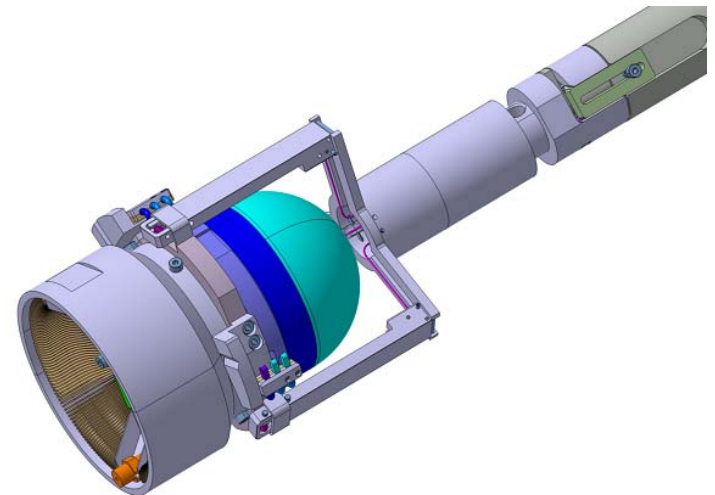
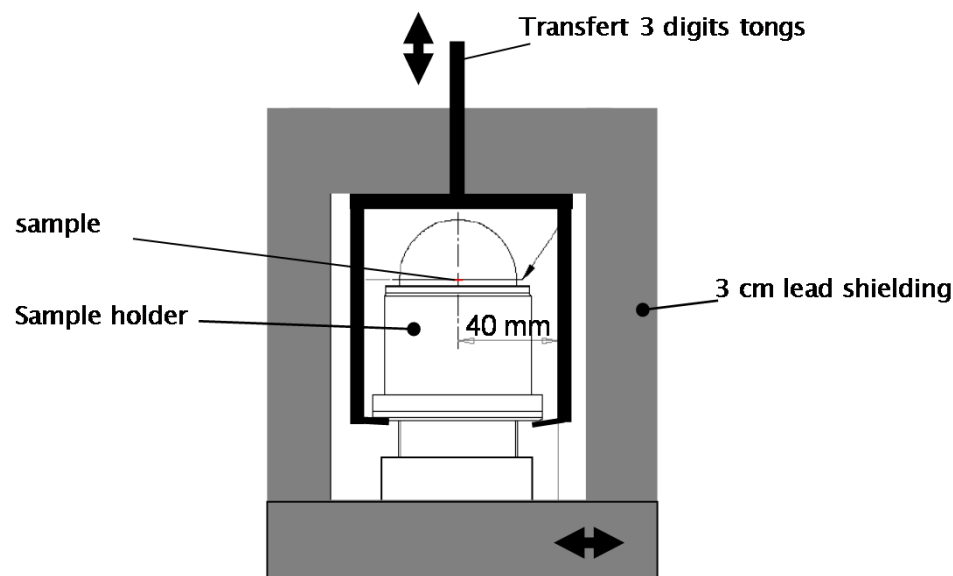
SAMPLE CONTAINMENT EXAMPLE 4

- Nuclear fuel pellet sample (PWR UO_2), new or spent (up to 90 GW.d/t after at least 1(5) years cooling)
- Typically cylindrical, 2mm diameter and 0.7mm thick
- About 23mg – 3 GBq
- The Highest dose rate source:
Up to 2 mSv/h (gamma $H^*(10)$ – 30cm)
Up to 100 mSv/h (beta $H_p(0.07)$ – 30cm)

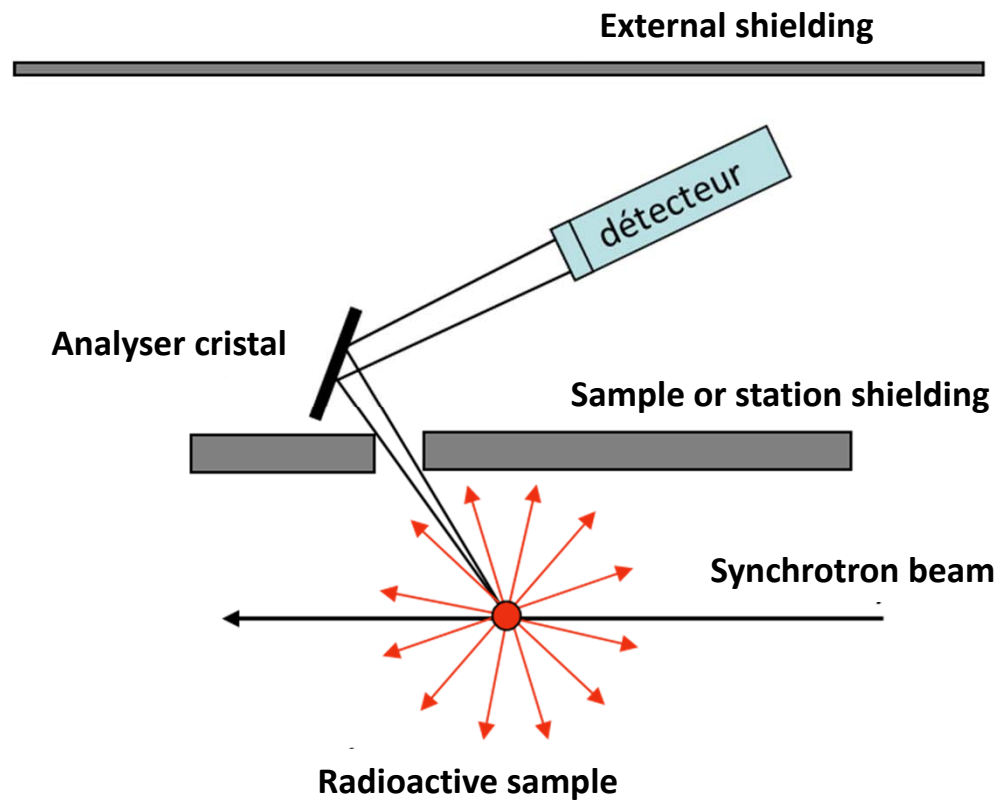


SAMPLE CONTAINMENT EXAMPLE 4

- No direct contact to the sample holder for both transfer and radiological controls
- Necessity to have a shielding around the sample holder during the whole experiment

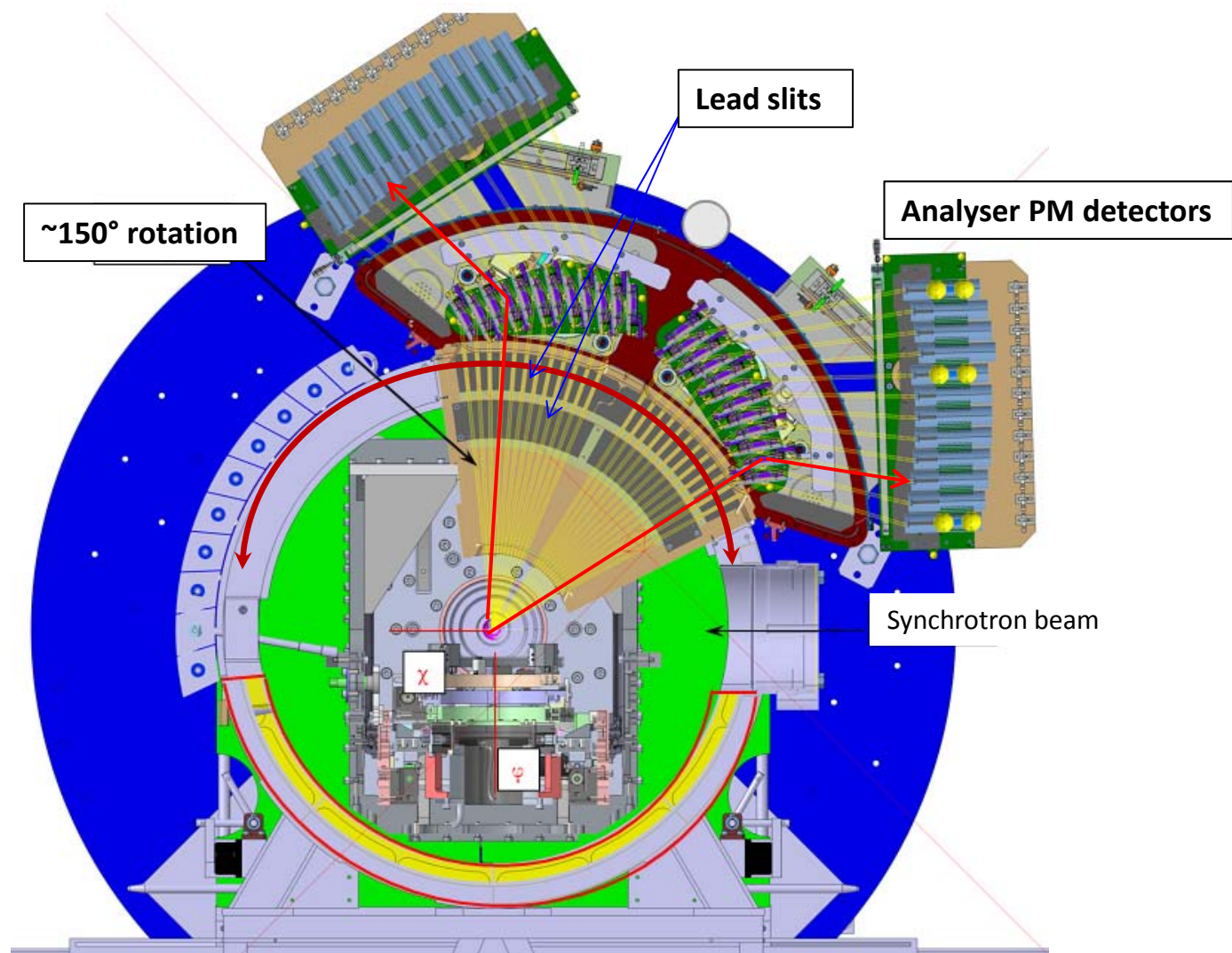


BASIC SCHEME OF MEASUREMENT

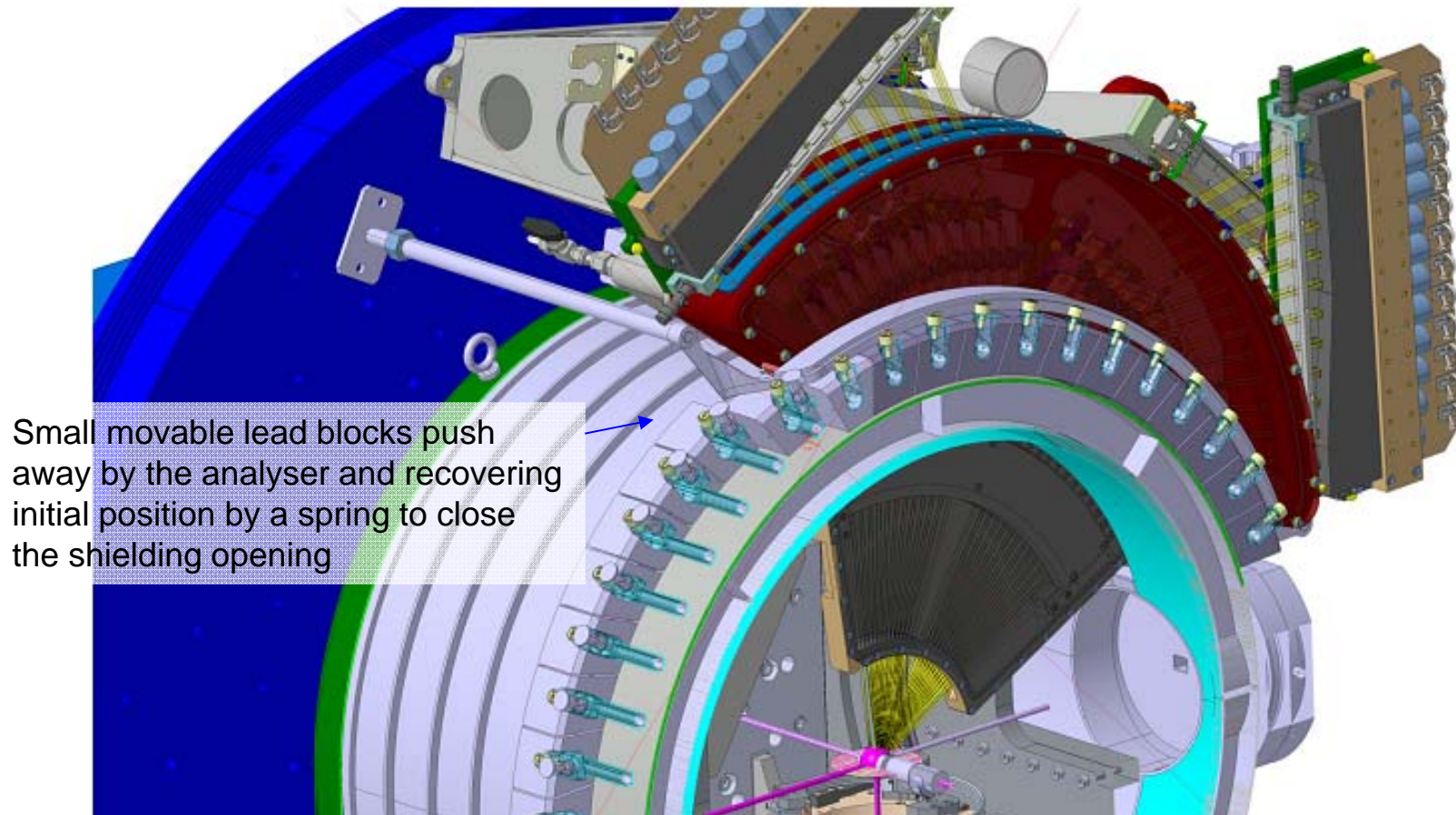


EXPERIMENTAL STATION SHIELDING

- CX2

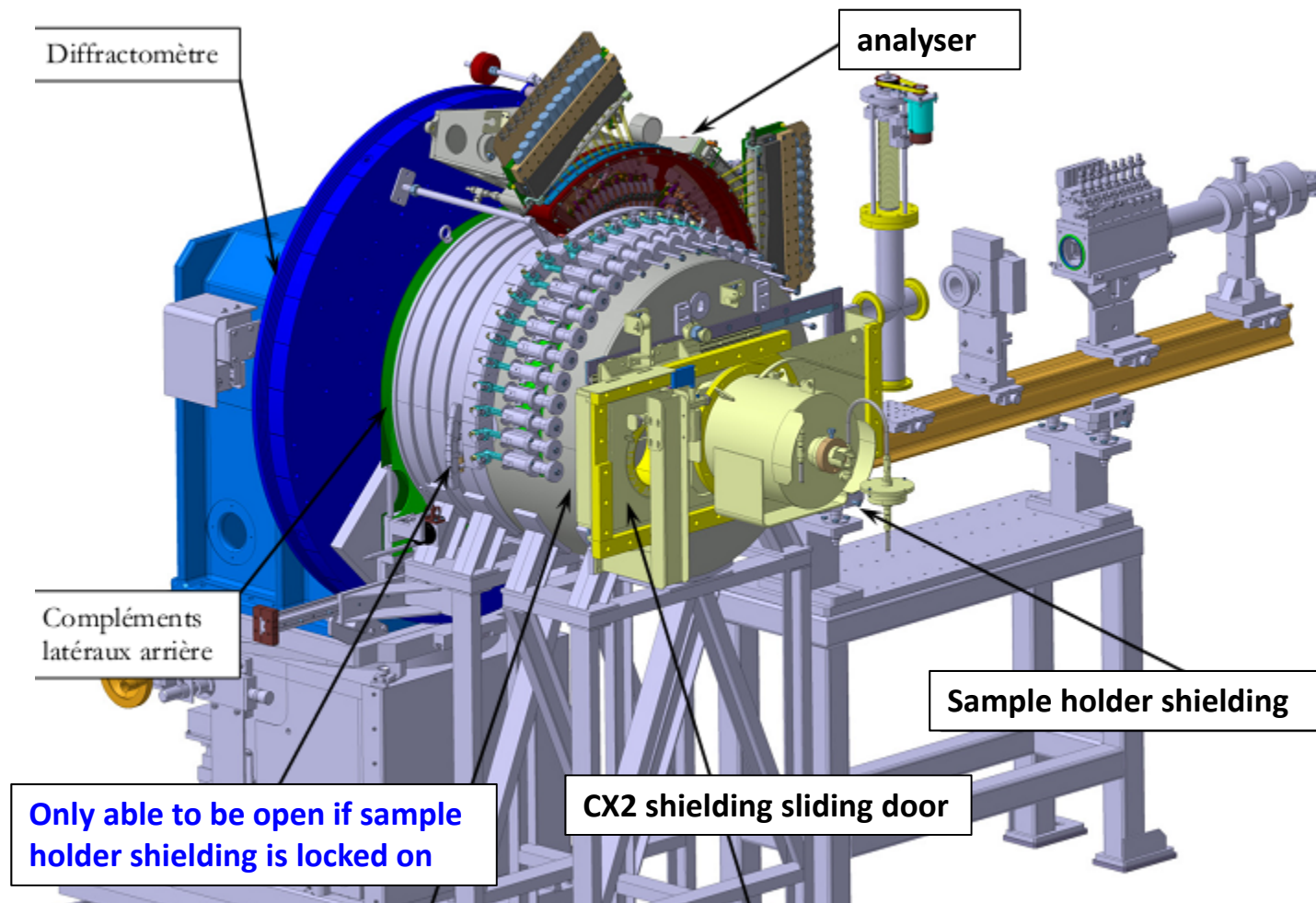


EXPERIMENTAL STATION SHIELDING

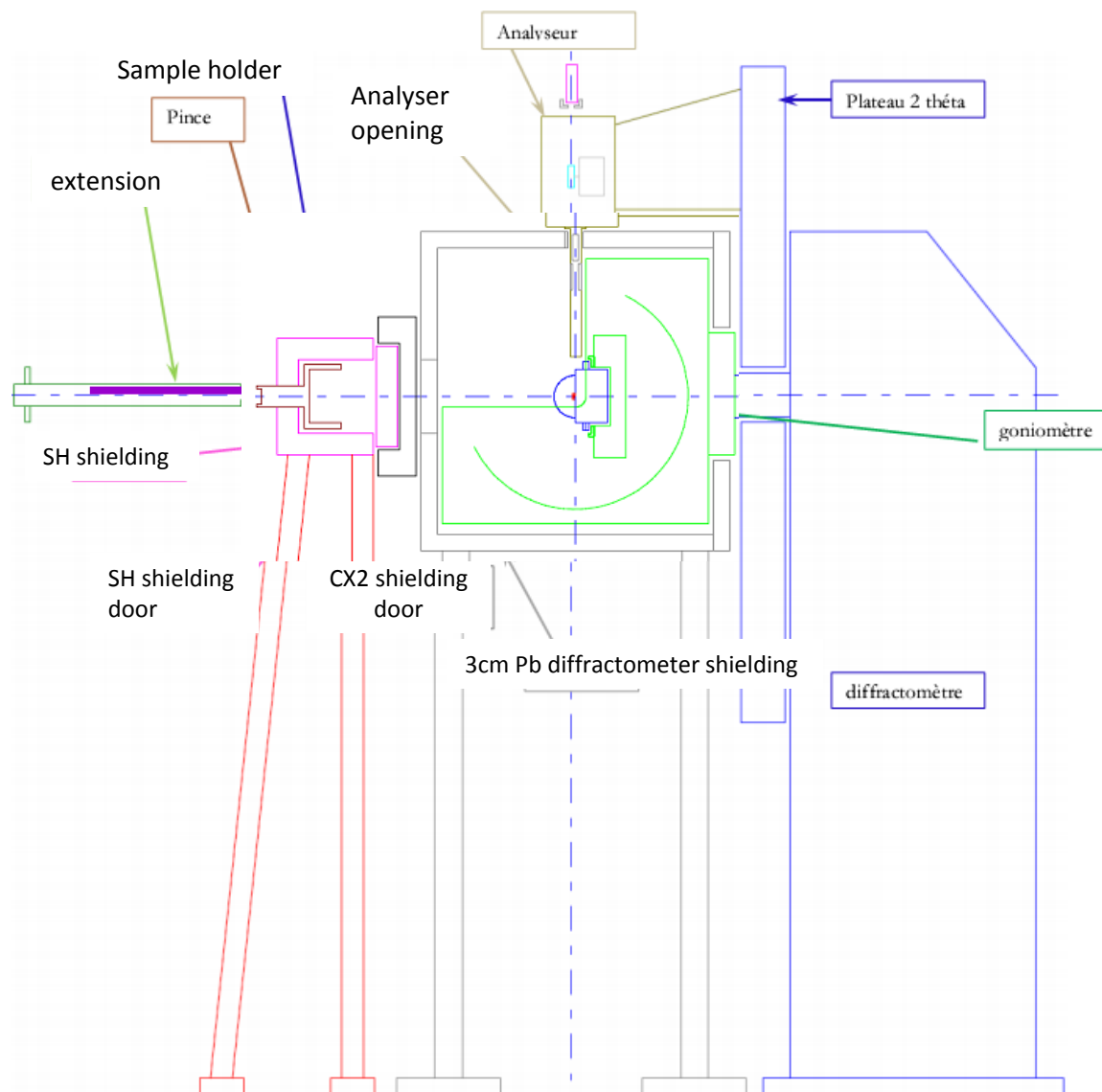


Small movable lead blocks push away by the analyser and recovering initial position by a spring to close the shielding opening

EXPERIMENTAL STATION SHIELDING

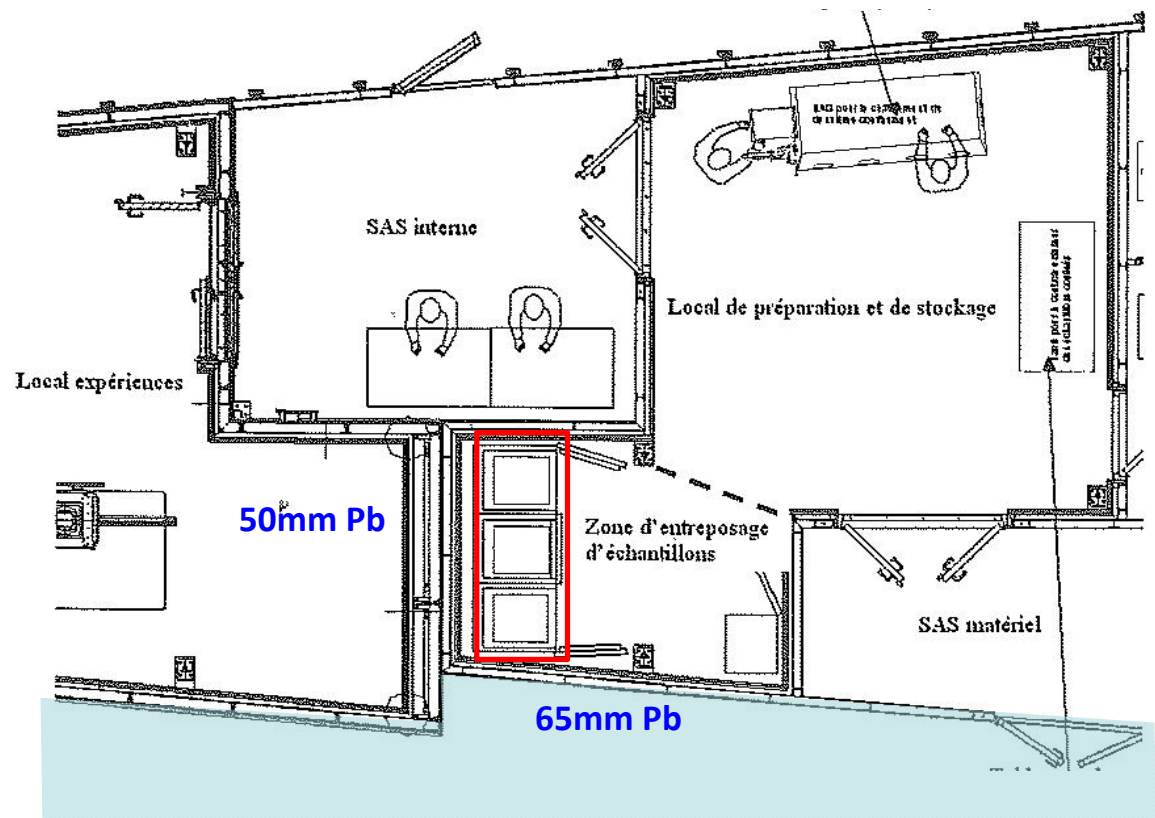


EXPERIMENTAL STATION SHIELDING



ADDITIONAL SHIELDING REQUIREMENTS

- Assuming Safe Storage of a maximum of 6 spent fuel samples at same time with their transport shielding (3cm lead)
- MERCURAD™ calculations
- Safe shielded with 5cm of lead panels and a 6.5cm on the SW



OPERATION STATUS

- MARS is already running operation with radioactive samples below exemption limit thresholds (mainly F0 but also few F1, F3 and F4) since 2010 with specific autorisation from Regulation Authority limited to few isotopes (~20)
- 27 experiments achieved up to now (12/12) with radioactive samples with satisfying scientific results (more than 12 pub.)

		Technological fields				
		F0	F1	F2	F3	F4
Radioactive classes of samples	C0 (A <1 ET)	Currently authorized	Currently authorized	2 ^{ème} level of authorization	Currently authorized	Currently authorized
	C1 (A <200 ET)	1 ^{er} level of authorization	2 ^{ème} level of authorization	2 ^{ème} level of authorization	2 ^{ème} level of authorization	2 ^{ème} level of authorization
	C2 (A <2 10 ⁴ ET)	1 ^{er} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization
	C3 (A <2 10 ⁵ ET)	3 ^{ème} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization	3 ^{ème} level of authorization

NEXT

- In september 2013, first experiment above exemption threshold is schedule if ASN autorisation is given
- Nominal operation with radioactive samples is foreseen before the end of 2015 with 28 experiments per year representing about 100 samples hosted and analysed on MARS beam line

