Review of Beam Vacuum Windows at CERN

Michael MONTEIL
TE-VSC

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Plan

Introduction

I – Inventory

1 - Motivations
2 - Results
3 - Layout, Examples
4 - Design verification
5 - Inventory of spare windows available and missing
6 - Naming convention

II – Another design example: *HiRadMat window*

Conclusion

Introduction

What are CERN windows' ?…

A window is a transparent opening in a wall or door that allows the passage of light […] Windows are held in place by frames, which prevent them from collapsing in.

Credits: Wikipedia

Introduction

What are CERN beam vacuum windows' ?…

A window is a "transparent opening" in a vacuum beam line (~~wall or door~~) that allows the passage of particles (~~light~~). […] Windows are held in place by flanges (~~frames~~), which prevent them from collapsing in.

Credits: "Wikipedia"

In other words…

Interface AP/VAC, located at the beginning or the end of a beam vacuum line and traversed by the beam.

Introduction

What are their role ?…

1) The window have to resist collapse to $\Delta P >= 1$ bar for years
   - How?
     - High mechanical properties
       - Low creep
     - Sufficient thickness
2) The window have to be leak-tight
3) The window have to resist and also to be transparent to the beam passage
   - How?
     - Reducing energy deposition (The window is not a dump block !)
       - Light materials (C, Be, Al…) (Low-Z materials)
       - Low thickness
     - High temperature resistance

I-1 – Motivations

Main motivation…

- Windows have been used at CERN since the the PS period
  - Drawings and mechanical designs lost with structure changes at CERN unreferenced or unobtainable.

Answer some important questions such as…

- How many windows ?
- Where are those windows ?
- What is the design ?
  - How accurate is this design… Safety factor ?
  - How dangerous is the window ? (Be…)
- What about spares ?
  - How many existing windows already have spare ? …Or Not ?
  - Impossibility to prepare some spares without initial drawings

Beginning of 2010, no listing of the windows under VSC's responsibility…

- what I had:
  - Jan Hansen gave to me a folder with all the PS windows
  - Giovanna Vandoni provided me a document with some SPS window locations

I-2 - Results

After few weeks of archeology in CERN Archives…

- Listing (Excel file) of the windows with:
  - How many VSC's windows ?

    …35 Windows (16 different designs)
  - Their location
  - The design
    - Diameter

      …60 mm -> 600 mm
    - Thickness

      …25 µm -> 25 mm
    - Material

      …Ti Grade 2&5, 316L, 304L, Be, C-C, Al99%
    - Drawing numbers

I-2 - Results

As things stand at the present…

- 2 Excel tables… (2 tabs in on file)
  - Inventory of VSC's vacuum windows sorted by window's type
  - Inventory of VSC's vacuum windows spares

…with:

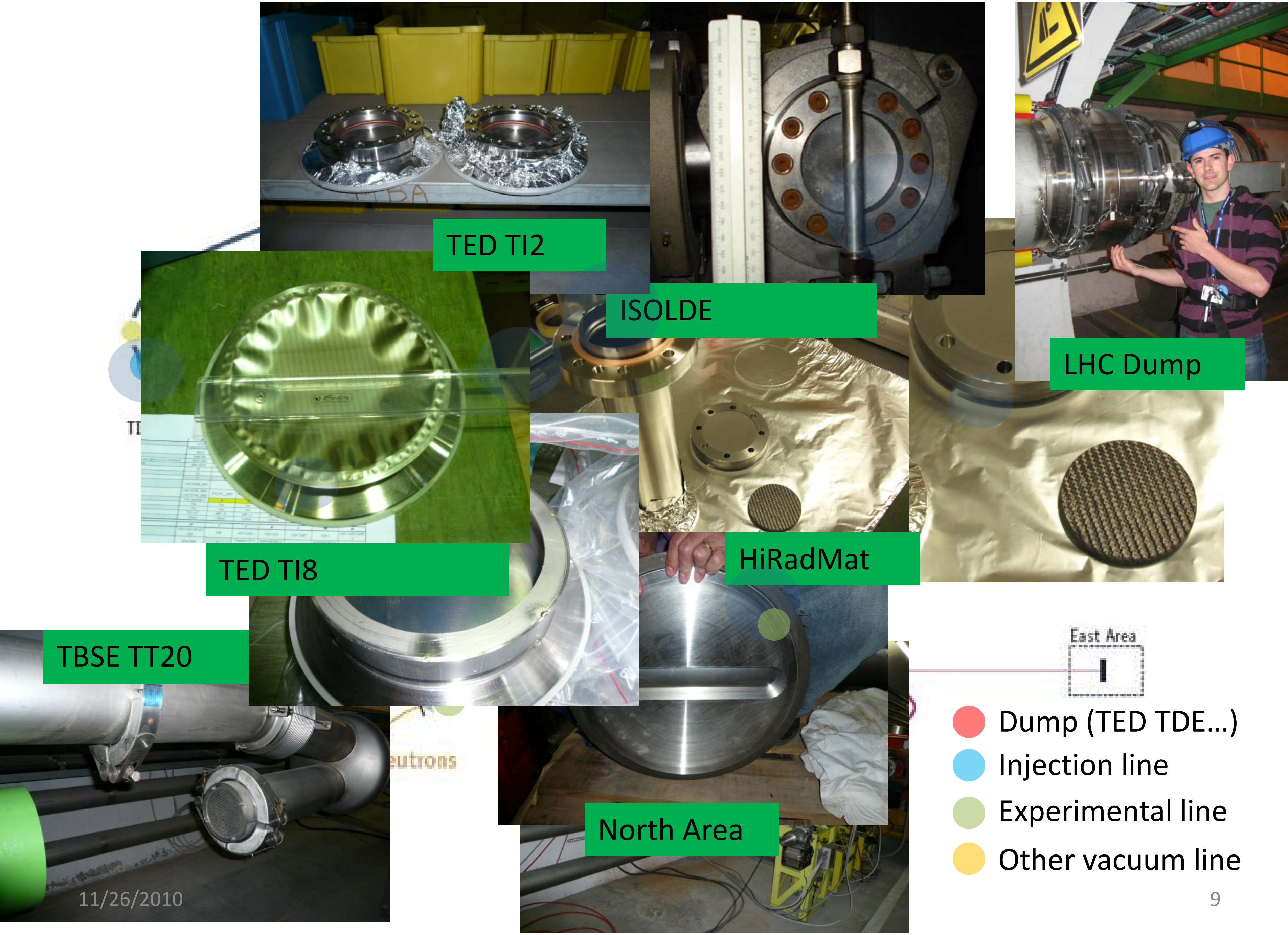
- Geometry
  - Diameter
  - Thickness
  - Material
- Drawings
  - Layouts
  - Locations
  - Assembly
  - Parts

- 2 Folders with
  - Drawings hardcopies
  - Layouts hardcopies

Window's type	***A***	***B***	***C***	***D***	***E***	***F***	***G***	***Q***
Window's location	VDWB TDE entrance window 1 VDWB TDE entrance window 2	Window FTN - Section 747	Window AD #1 - MTV-6048 Window AD #2 - QDE-6060	Window AD #3 - SLV-6066	Window AD #4 - QDC53 Window AD #5 - QFC54	Window PSB #1 - BTM-SVHG3	Window Isolde #1 - BTY-TRA213 Window Isolde #2 - BTY-TRA325	PS East Area Window
Layout drawings	LHCTDE__0020 LHCTDECL0035	PS_LMTTX0307 PS_LMTTX0309 PS_IVC__0026 PS_IVC__0027	PS_LMTTX0275 PS C-4500-72- PS_LMTTX0293	PS_LMTTX0275 PS_LMTTX0299	AD_LM___0042 AD_MQDNA0026	PSBIHENS0031 PSBIHENS0074 PSBIHENS0104	ISLIHENS0100 ISLIHENS0009 ISLBGSEM0001	
	LHCTDE__0023		PS_LMTTX0275 PS C-4500-72- PS_LMTTX0296 PS C-4484-72-		AD_LM___0042			
Window's name (Line | Location on the line | Drawing name)	TD62 | - | LHCVWLZA TD68 | - | LHCVWLZA	FTN | Section 747 | PS_VWDAA	9000 | MTV6048 | PS_VWJSA 9000 | QDE6060 | PS_VWJSA	9000 | SLV6066 | PS_VWISA	9000 | QDC53 | PS_VWETA 7000 | QFC54 | PS_VWETA	BTM | SVHG3 | PS_VWBSA	BTY | TRA213 | PS_VWFSA BTY | TRA325 | PS_VWFSA	| | SPSVWMSB
Material – Material 1	SIGRABOND C-C 1501 G	Al (99%)	Steel 316L	Steel 316L	Titanium Grade 5	Inox	Steel 316L	AISI 316 L
Material – Material 2	Steel 316L	-	-	-	-	-	-	-
Geometry – Diameter Material 1 - Diameter under pressure	648.5 - 600	145.2 - 130	300 - 251	250 - 166	140 - 123	220 - 200	110 - 96	89 - 82 - 80
Geometry – Diameter Material 2 - Diameter of tightness (mm)	669 - 632.5	-	-	-	-	-	-	0
Geometry – Thickness Material 1 (mm)	15	0.2	0.05	0.05	0.05	0.0508	0.025	0.025
Geometry – Thickness Material 2 (mm)	0.2	-	-	-	-	-	-	-
Drawing of the actual design – With naming convention – Assembly	LHCVWLZA0001	PS_VWDAA0001	PS_VWJSA0001	PS_VWISA0001	PS_VWETA0001	PS_VWBSA0001	PS_VWFSA0001	PS_VWMSA0001
Drawing of the actual design – With old drawing number – Assembly	LHCVDWB_0001	-	PS C-3841-43-3	PS C-3849-43-3	PS C-5201-43-4 & PS C-4940-43-4	PSB IHENS 0363 3	ISLIVC__0015	unknown original drawings
Drawing of the actual design – With old drawing number – Window	LHCVDWB_0005 - LHCVDWB_0006	PS_IVC__0047	PS C-3843-43-3	PS C-3851-43-3	PS C-4938-43-4	SI 3 79 1118 1	ISLIVC__0015	unknown original drawings
Drawing of the spare design – With naming convention – Assembly	LHCVWLZA0001	PS_VWDAA0001	PS_VWJSB0001	PS_VWISB0001	PS_VWETA0001	PS_VWBSA0001	PS_VWFSB0001	PS_VWMSB0001
Number of spare available	Yes ; quantity : 1	1	Under manufacturing: 2 for this	Under manufacturing: 2 for this	1	2	Under manufacturing: 2 for this design	Under manufacturing: 2 for this
Type of spare window		XI	CI	CII	X	XII	CIII	CIV
Plans good to produce spare windows ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Diameter flange (mm)	Non Standard OD722.5	Non standard OD150	Conical OD332	Conical OD266	ISO-CF DN160	ISO-CF DN200	Conical OD195	Conical OD106

Window's type	***H***	***I***	***J***	***L***	***M***	***N***	***O***	***P***	***R***
Window's location	TED TT21 TED TT60 TBSM LSS1 T2-1 T6 TBSE TT21	TBSE TI8 TED TI8	TED TI2 TED TT41 TBSE TT41	TT41 CNGS	Mobile Window BA80 #1 Mobile Window BA80 #2 Mobile Window BA80 #3	T2-2	T2-3 T4	TT66	Mobile Window BA80 #4 Mobile Window BA80 #5 Mobile Window BA80 #6 Mobile Window BA80 #7
Layout drawings	SPSLTT200001 SPSLTT200002 SPSLTT200017 SPS8097001135 SPSLTT600002 SPSLTT600006 SPS8034060061 SPSLNINS0003 SPSLTT200001 SPSLTT200001 SPSLTT200001 SPSLTT200003 SPSLTT200020 SPS8097003102	SPSLTT400001 LHCLSI__0014 LHCLSI__0018	LHCLSI__0013 LHCLSI__0002 SPSLTT400001 SPSLTT400013 SPSVCPEB0129 SPSLTT400001 SPSLTT400014 SPSJTT410003			SPSLTT200001	SPSLTT200001 SPSLTT200001		
Window's name (Line | Location on the line | Drawing name)	TT21 | 210358 | SPSVWHSA TT60 | 610321 | SPSVWHSA LSS1 | 11672 | SPSVWHSA TT23 | - | SPSVWHSA TT25 | - | SPSVWHSA TT21 | 210614 | SPSVWHSA	TI8 | 80243 | SPSVWHTC TI8 | 87765 | SPSVWHTC	TI2 | 29133 | SPSVWHYA TT40 | 400354 | SPSVWHYA TT41 | 410113 | SPSVWHTA	TT41 | - | SPSVWGXA	TT20 | - | SPSVWHTA TT20 | - | SPSVWHTA TT20 | - | SPSVWHTA	TT23 | - | SPSVWKAA	TT23 | - | SPSVWKAB TT24 | - | SPSVWKAB	TT66 | 660830 | SPSVWAXA	TT20 | - | SPSVWHTB TT20 | - | SPSVWHTB TT20 | - | SPSVWHTB
Material – Material 1	Steel 304L	Titanium Grade 5	SIGRABOND C-C 1001 G	SIGRABOND C-C 1001 G	Titanium Grade 2	Al	Al	SIGRABOND C-C 1001 G	Titanium Grade 5
Material – Material 2	-	-	Titanium Grade 5	Be	-	-	-	Beryllium PF-60	
Geometry – Diameter Material 1 - Diameter under pressure	146-130	100 - 84	95.5 - 85	68.5	?- 150	Design MT 350x60 with pumping pipe	Design MT 350x60	70	161 - 150
Geometry – Diameter Material 2 - Diameter of tightness (mm)	-	-	152 - 100	60	-			?? - 70	-
Geometry – Thickness Material 1 (mm)	0.1	0.1	2	2.5	0.1			5.6	0.1
Geometry – Thickness Material 2 (mm)	-	-	0.2	0.254	-			0.254	-
Drawing of the actual design – With naming convention – Assembly	SPSVWHSA0001	SPSVWHTC0001	SPSVWHYA0001	SPSVWGXA0001	SPSVWHTA0001	SPSVWKAA0001	SPSVWKAB0001	SPSVWAXA0001	SPSVWHTB0001
Drawing of the actual design – With old drawing number – Assembly	SPS8034060061 + SPS8034060063	LHCTED__0170 + LHCTED__0171	SPSVCPEB0077	SPSVWG__0001	246593 + 246592	EA-8088-2951-2 +8089-2083-1	EA-8088-2951-2 +8089-2083-1	-	246593 + 246592
Drawing of the actual design – With old drawing number – Window	SPS8034060063	-	SPSVCPEB0075	-	-	V. De Jesus	V. De Jesus	-	
Drawing of the spare design – With naming convention – Assembly	SPSVWHSA0001	SPSVWHTC0001	SPSVWHYA0001	SPSVWGXA0001	SPSVWHTB0001	SPSVWKAA0001	SPSVWKAB0001	SPSVWAXA0001	SPSVWHTB0001
Number of spare available	7	2 + 3 + 3	2 + 3 + 3	1	Under manufacturing: 1 for the design SPSVWHTA and SPSVWHTB	1	4	Under manufacturing: 1 for this design	Under manufacturing: 1 for the design SPSVWHTA and SPSVWHTB
Type of spare (See table of spares)	I	II + IV + CVII	II + IV + CVII	III	CV	IX	VIII	CVI	CV
Plans good to produce spare windows ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Diameter flange	Conical OD206	Conical OD206	Conical OD206	Conical OD95	Conical OD206	Non standard OD390	Non standard OD390	ISO-CF DN63	

All the data will be uploaded on EMDS (and CDD) (Plans, Layouts, Excel file…)


TED TI2
ISOLDE
LHC Dump
TED TI8
HiRadMat
TBSE TT20
North Area
East Area
Dump (TED TDE…)
Injection line
Experimental line
Other vacuum line

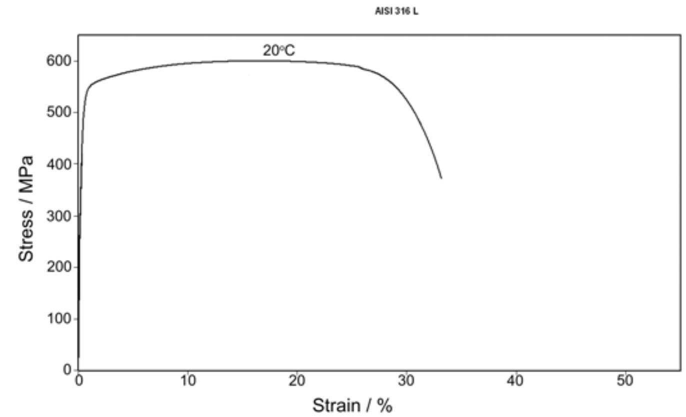
I-4 - Design verification

What was our motivation ?

- Studies was done a couple of decades ago…
  →Need to check those designs again

How ?

- No analytical calculations because of the non linear properties of materials
  → Calculations in ANSYS



I-4 - Design verification

Just a quick insight into the model

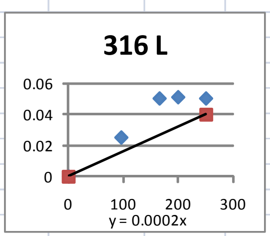
- ANSYS v12
- 1D-model

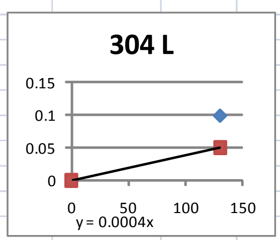
- Load 2 bars and reduce window's thickness until the window breaks.

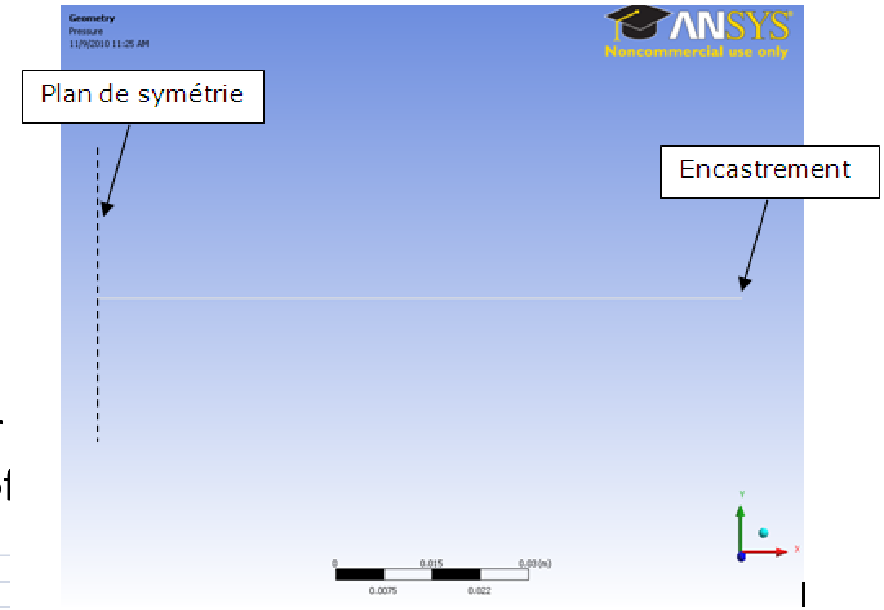
- Good news ! All the windows can endure 1 bar
- Better news, they should withstand to a load of

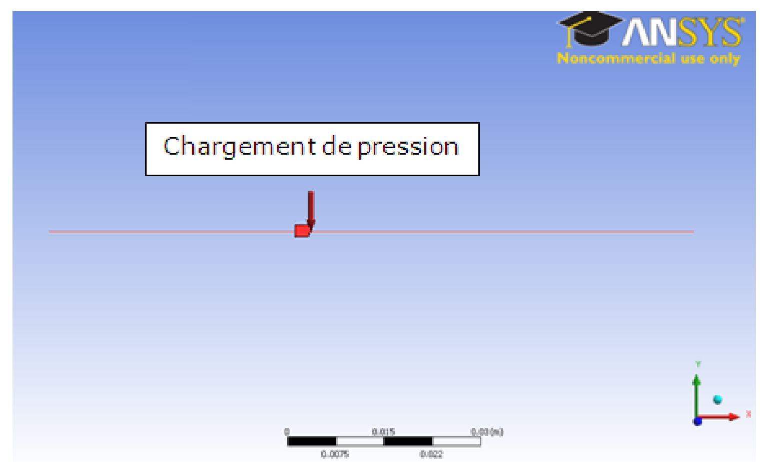
316L	
Diam (mm)	Ep (mm)
0	0
96	0.025
166	0.05
200	0.0508
251	0.05

304L	
Diam (mm)	Ep (mm)
0	0
130	0.1



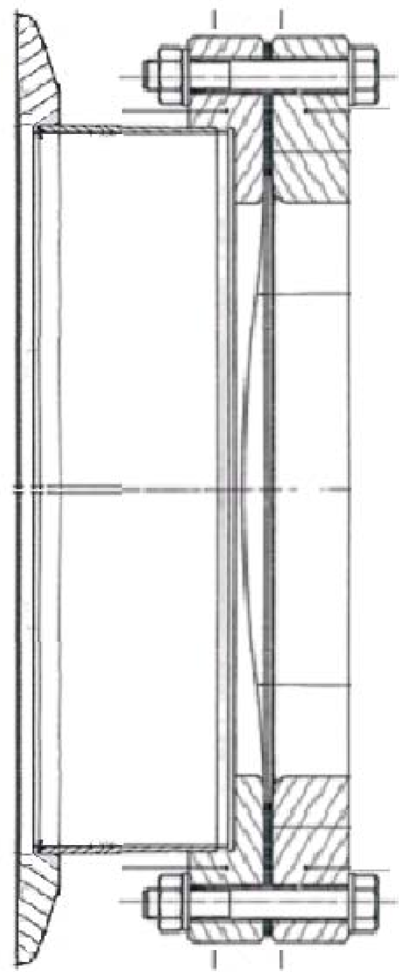


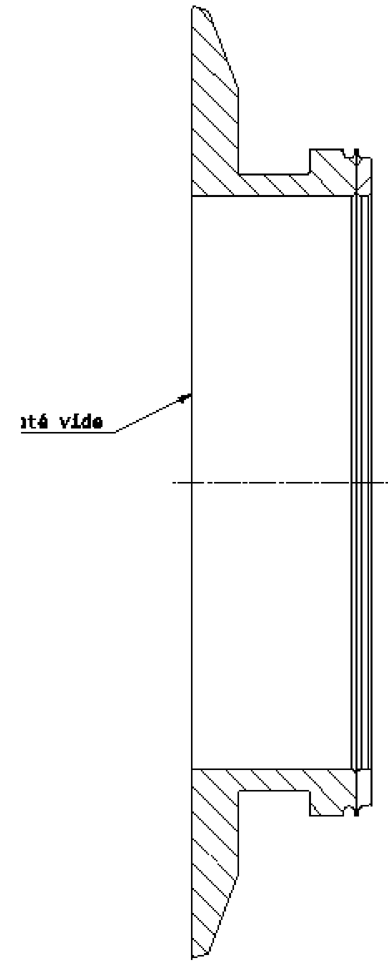




I-5 - Inventory of spare windows

- Status at the beginning of 2010
  - Spares Available
    - for 9 designs
  - Spares Missing
    - for 7 designs
- Manufacturing of the missing spares
  - For some windows, new design welded (without screws)
    - Simpler design
    - Better leak-tightness





I-5 - Inventory of spare windows

PS spares

Type of spare	Assembly	Number of spares	Material	Old drawing name	Old	New drawing name	Design Identified	Spare for type:
CI	Under manufacturing	2	AISI 316L	PS C-3841-43-3		PS_VWJSB0001	Yes	C
CII	Under manufacturing	2	AISI 316L	PS C-3849-43-3		PS_VWISB0001	Yes	D
CIII	Under manufacturing	2	AISI 316L	ISLIVC__0015		PS_VWFSB0001	Yes	G
CIV	Under manufacturing	2	AISI 316L	Unknown original drawings		PS_VWMSB0001	Yes	Q

SPS spares

Type of spare	Assembly	Number of spares	Material	Old drawing name		New drawing name	Design Identified	Spare for type:
CV	Under manufacturing	1	Ti Grade 5	(VAT drawings: 246593 + 246592)		SPSVWHTB0001	Yes	M & R
CVI	Under manufacturing	1	Be + C-C	-		SPSVWAXA0001	Yes	P
CVII	Under manufacturing	3	Ti Grade 2 (Original : Ti Grade 5)	LHCTED__0170		SPSVWHTC0001	Yes	I & J

PS spares

Type of spare	Assembly	Number of spares	Material	Old drawing name		New drawing name	Design Identified	Spare for type:
X	Ready to use	1 (+1 Ti +2St-St W/O flange)	Ti	PS C-5201-43-4 & PS C-4940-43-4		PS_VWETA0001	Yes	E
XI	Ready to use	1	Al	PS_IVC__0047		PS_VWDAA0001	Yes	B
XII	Ready to use	2	Inox	PSB IHENS 0363 3		PS_VWBSA0001	Yes	F
XIII	Ready to use	1	-	-		-	No	-
XIV	Ready to use	1	-	-		-	No	-
XV	Ready to use	1	-	-		-	No	-
XVI	Ready to use	1	-	-		-	No	-
XVII	Ready to use	1	-	-		-	No	-
XVIII	Ready to use	2	-	-		-	No	-
XIX	Ready to use	2 (+1 Window W/O flange)	-	-		-	No	-
XX	-	-	-	-		-	No	-
XXI	Ready to use	5	-	-		-	No	-

SPS spares

Type of spare	Assembly	Number of spares	Material	Old drawing name		New drawing name	Spare Identified	Spare for type:
I	Ready for use	7	Steel	SPS8034060061 + SPS8034060063		SPSVWHSA0001	Yes	H
II	Ready for use	2	Ti + C-C	SPSVCPEB0077		SPSVWHYA0001	Yes	I & J
III	Ready for use	1	Be + C-C	SPSVWG__0001		SPSVWGXA0001	Yes	L
IV	Ready for use	3	Ti	-		-	No	I & J
V	Knife + foil	7	Steel	-		-	No	-
VI	-	2	-	-		-	No	-
VII	-	2	-	-		-	No	-
VIII	V. De Jesus	4	Al	EA-8088-2951-2 +8089-2083-1		SPSVWKAB0001	Yes	O
IX	V. De Jesus	1	Al	EA-8088-2951-2 +8089-2083-1		SPSVWKAA0001	Yes	N

Tree Page - Mozilla Firefox

https://cs-ccr-oas1.cern.ch/pls/htmldb_accdb/f?p=142:4:1199192226155339::::P4_LETTER,P4_DETAILS,P4_CODE:V,YES,VWAXA

Entities and Signals
NAMING DATABASE

Home | Signal Simple Extraction | Signal Experts Interface | LHC Equipment Codes | SPS Equipment Codes | PS Equipment Codes | Print | Help

SPS Systems | SPS Equipment Codes

SPS Equipment Codes - System: V

Collapse Tree | Expand Tree

- V Vacuum
  - VB Vacuum Bellows
  - VC Vacuum Chambers
  - VD Vacuum Chambers / Pumping modules
  - VE Vacuum Chambers
  - VG Vacuum Gauges
  - VKNV vacuum chamber, not bakeable, V type (?)
  - VMSM vacuum multi service module
  - VP Vacuum Pumps
  - VV Vacuum Valves
  - VW Vacuum Windows
    - VWA Vacuum Windows with flange diameter: ISO-CF DN63
      - VWAXA Vacuum Window, flange diameter: ISO-CF DN63, material: CFC + Beryllium, type A
    - VWB Vacuum Windows with flange diameter: ISO-CF DN200
    - VWD Vacuum Windows with flange diameter: Non standard OD150
    - VWE Vacuum Windows with flange diameter: ISO-CF DN160
    - VWF Vacuum Windows with flange diameter: Conical OD195
    - VWG Vacuum Windows with flange diameter: Conical OD95
    - VWH Vacuum Windows with flange diameter: Conical OD206
    - VWI Vacuum Windows with flange diameter: Conical OD266
    - VWJ Vacuum Windows with flange diameter: Conical OD332
    - VWK Vacuum Windows with flange diameter: Non standard OD390
    - VWL Vacuum Windows with flange diameter: Non Standard OD722.5
    - VWM Vacuum Windows with flange diameter: Conical OD106
  - VZBA (?)

Details for Entity Codes: VWAXA

Description	Vacuum Window, flange diameter: ISO-CF DN63, material: CFC + Beryllium, type A
Equipment Code	YES - Equipment code used for equipment design
Responsible	Jose Miguel JIMINEZ
Owner Group	TE/VSC
Designer	Michael MONTEIL

Done

4:37 PM Thursday

I-6 - Naming convention

Vacuum	Window	Flange Diameter	Material	Type	Comment	Code Window	Description
V					Vacuum		
	W				Window		
		A			ISO-CF DN63		
			X		CFC + Beryllium		
				A	Type A	VWAXA	Vacuum ; Window ; Flange Diameter: ISO-CF DN63 ; Material: CFC + Beryllium ; Type A
		B			ISO-CF DN200		
			S		Steel		
				A	Type A	VWBSA	Vacuum ; Window ; Flange Diameter: ISO-CF DN200 ; Material: Steel ; Type A
		D			Non standard OD150		
			A		Aluminium		
				A	Type A	VWDAA	Vacuum ; Window ; Flange Diameter: Non standard OD150 ; Material: Aluminium ; Type A
		E			ISO-CF DN160		
			T		Titanium		
				A	Type A	VWETA	Vacuum ; Window ; Flange Diameter: ISO-CF DN160 ; Material: Titanium ; Type A
		F			Conical OD195		
			S		Steel		
				A	Type A	VWFSA	Vacuum ; Window ; Flange Diameter: Conical OD195 ; Material: Steel ; Type A
				B	Type B	VWFSB	Vacuum ; Window ; Flange Diameter: Conical OD195 ; Material: Steel ; Type B
		G			Conical OD95		
			X		CFC + Beryllium		
				A	Type A	VWGXA	Vacuum ; Window ; Flange Diameter: Conical OD95 ; Material: CFC + Beryllium ; Type A
		H			Conical OD206		
			S		Steel		
				A	Type A	VWHSA	Vacuum ; Window ; Flange Diameter: Conical OD206 ; Material: Steel ; Type A
			T		Titanium		
				A	Type A	VWHTA	Vacuum ; Window ; Flange Diameter: Conical OD206 ; Material: Titanium ; Type A
				B	Type B	VWHTB	Vacuum ; Window ; Flange Diameter: Conical OD206 ; Material: Titanium ; Type B
				C	Type C	VWHTC	Vacuum ; Window ; Flange Diameter: Conical OD206 ; Material: Titanium ; Type C
			Y		CFC + Titanium		
				A	Type A	VWHYA	Vacuum ; Window ; Flange Diameter: Conical OD206 ; Material: CFC + Titanium ; Type A
		I			Conical OD266		
			S		Steel		
				A	Type A	VWISA	Vacuum ; Window ; Flange Diameter: Conical OD266 ; Material: Steel ; Type A
				B	Type B	VWISB	Vacuum ; Window ; Flange Diameter: Conical OD266 ; Material: Steel ; Type B
		J			Conical OD332		
			S		Steel		
				A	Type A	VWJSA	Vacuum ; Window ; Flange Diameter: Conical OD332 ; Material: Steel ; Type A
				B	Type B	VWJSB	Vacuum ; Window ; Flange Diameter: Conical OD332 ; Material: Steel ; Type B
		K			Non standard OD390		
			A		Aluminium		
				A	Type A	VWKAA	Vacuum ; Window ; Flange Diameter: Non standard OD390 ; Material: Aluminium ; Type A
				B	Type B	VWKAB	Vacuum ; Window ; Flange Diameter: Non standard OD390 ; Material: Aluminium ; Type B
		L			Non Standard OD722.5		
			Z		CFC + Steel		
				A	Type A	VWLZA	Vacuum ; Window ; Flange Diameter: Non Standard OD722.5 ; Material: CFC + Steel ; Type
		M			Conical OD106		
			S		Steel		
				A	Type A	VWMSA	Vacuum ; Window ; Flange Diameter: Conical OD106 ; Material: Steel ; Type A
				B	Type B	VWMSB	Vacuum ; Window ; Flange Diameter: Conical OD106 ; Material: Steel ; Type B

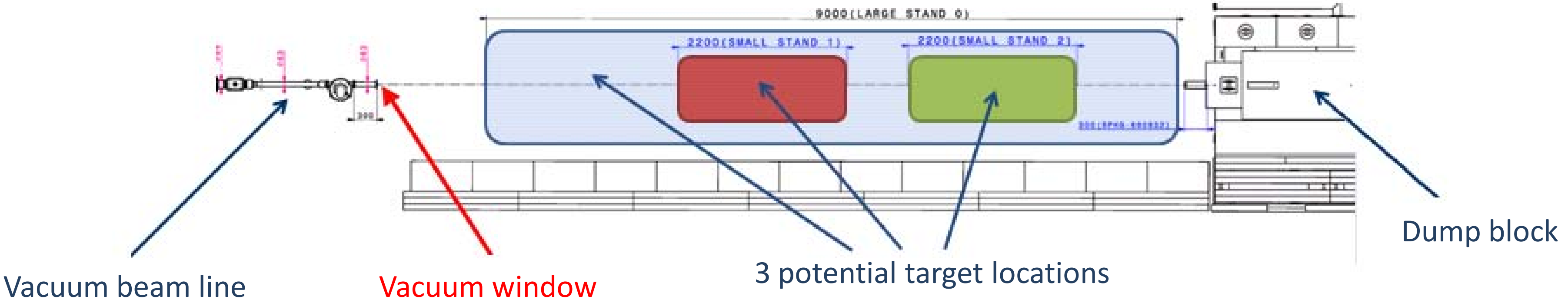
Vacuum	*Window*	*Flange Diameter*	*Material*	*Comment*
V				Vacuum
	W			Window
		A		ISO-CF DN63
		B		ISO-CF DN200
		C		CF DN100
		D		Non standard OD150
		E		ISO-CF DN160
		F		Conical OD195
		G		Conical OD95
		H		Conical OD206
		I		Conical OD266
		J		Conical OD332
		K		Non standard OD390
		L		Non Standard OD722.5
		M		Conical OD106
			A	Aluminium
			B	Beryllium
			S	Steel
			T	Titanium
			X	CFC + Beryllium
			Y	CFC + Titanium
			Z	CFC + Steel

II - Introduction

- The HiRadMat (High-Radiation to Materials) facility
  - will allow testing of accelerator components, in particular those of the LHC, under high-intensity pulsed beams.

- To reach this intensity range, the beam will be focused on a focal point where the target to be tested is located.

- A 60 mm aperture vacuum window will separate the vacuum of the beam-line which is kept under high vacuum (10^{-8} mbar), from the test area which is at atmospheric pressure.



II - Functional specifications

- This window has to:
  - maintain the required differential pressure between the beam line vacuum and the experimental area which is kept under atmospheric pressure.
  - cope with the repeated dynamic thermal load of the beam of $4{,}9.10^{13}$ protons per pulse at 1/18 Hz and 440 GeV. The beam properties at the window location are shown in the Table 1.

Parameter	Symbol	Protons	Ions
Beam energy	E	440 [GeV]	497 [GeV]
Max. bunch intensity	N_b	$1{,}7.\,10^{11}$ [protons]	$7.\,10^{7}$ [ions]
Maximal number of bunches per pulse	n_{max}	288	52
Max. pulse intensity	$N_p = n_{max} * N_b$	$4{,}9.\,10^{13}$ [protons]	$3{,}64.\,10^{9}$ [ions]
Bunch spacing	Δt_b	25 [ns]	100 [ns]
Beam size	σ_{beam}	0,5 [mm]	0,5 [mm]
RMS bunch length	σ_z	11,24 [cm]	11,24 [cm]
Pulse length	t_p	7.2 [μs]	5.2 [μs]
Number of pulses per cycle		1	1
Cycle length		18 [s]	13,2 [s]

II - Energy deposition and associated temperature

- In passing through matter, particles ionize and excite the atoms they encounter. A part of the beam energy E, is transferred to the matter.
- FLUKA calculations were done for protons, as the energy deposited by ions is a factor of two smaller than for protons.
- The thickness of the window was chosen to be significantly smaller than the nuclear interaction length and radiation length in the material so that only ionization and excitation losses occur.
  - Low-Z materials are preferable as the stopping power scales with Z. The candidate low-Z materials are: C-C 1501 G, Beryllium PF-60, Titanium and Al.

Material	Energy [GeV/cm³/proton]	T_{max} [°C]	Error [%]
C-C	0,40	**623**	0,5
Beryllium	0,58	**497**	5,0
Titanium Grade 5	0,62	*1411*	0,8
Aluchrom	1,03	*1591*	1,2

Table 1: Energy deposition per unit of volume and maximum temperature in the 4 candidate low-Z materials

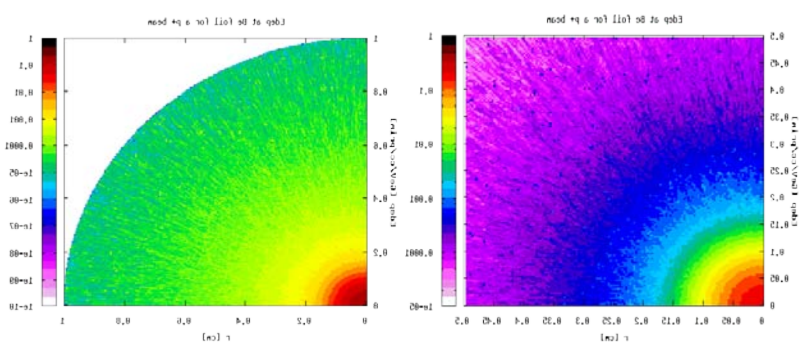


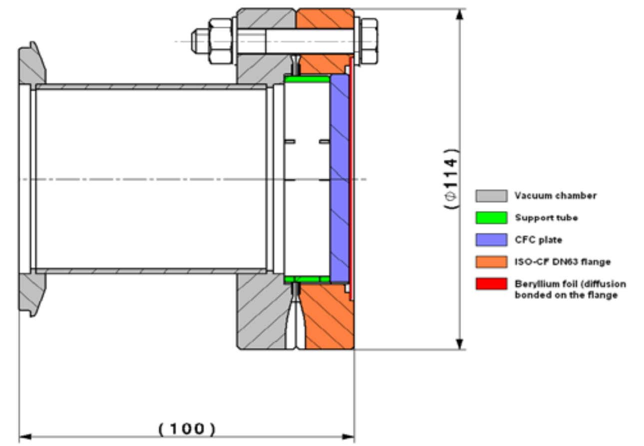
Figure 1: Energy deposited in the matter

Credits: Juan Blanco

- FLUKA calculates the energy deposition on the window, given the beam profile and the energy (Figure 1).
- This energy analytically integrated using the heat capacity, to get the punctual and conservative temperature increase.
  - Energies and maximum temperatures results are shown in Table 1
    - It predict that only beryllium and Carbon Fiber reinforced Carbon (C-C) do not exceed an acceptable temperature.

II - Conceptual design

- With respect to temperature considerations, C-C and beryllium are the only suitable materials.
- For the selection of a vacuum window, other constraints apply.
  - There is no UHV leak tight form of carbon existing in industry
  - Beryllium is a fragile and toxic material with high restrictions on use at CERN
- The proposed solution consists of using
  - a 0,5 cm-thick C-C plate to support the 10^3 mbar differential pressure load due to its high mechanical properties.
  - a 0,25 mm-thick, leak-tight, beryllium foil is laid on this C-C plate, thereby maintaining vacuum to 10^{-8} mbar.



- The beryllium foil will be installed on the high pressure side of the window, since the outgassing rate of the C-C is low (1,3.10^{-8} mbar.l.s^{-1}.cm^{-2} without bake-out and 1,3.10^{-11} mbar.l.s^{-1}.cm^{-2} with a 24h-long bake-out at 300°C).
- To prevent any oxidation of the beryllium foil at high temperature, a Ti + Nb coating has been made on the atmospheric side of the foil.

II - Mechanical design

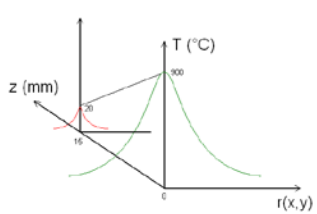
ANSYS Workbench v12.0.1

- The geometry is presented in Figure 1.
- APDL command lines to define
  - Element types
  - Material properties (MKIN)
  - Temperature load
  - Post-processing results.

- Both MKIN data and CTE data are a function of the temperature given in Equation 1.

$$T(r) = T_{amb} + (T_{max} - T_{amb})e^{-\frac{1}{2\sigma_{beam}^2}r^2}$$

Equation 1: Analytical estimation of the temperature distribution in the matter around the centre of the HiRadMat beam impact



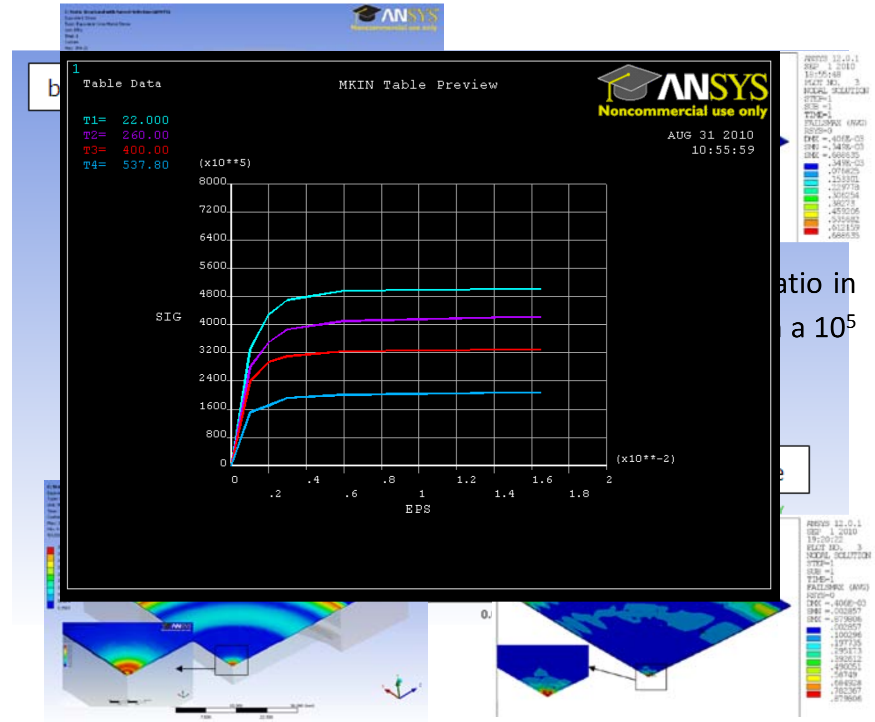


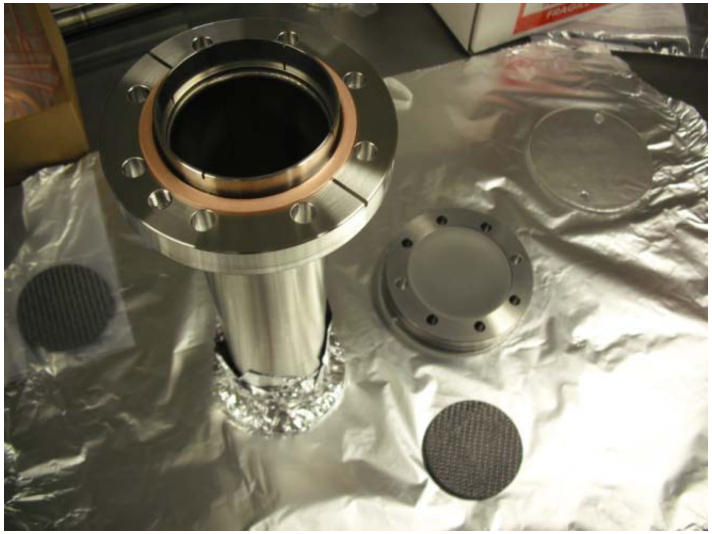
Figure 1: Geometry of the FEM calculation

Figure 7: Stress in the beryllium foil with a 10^5 Pa load + proton pulse

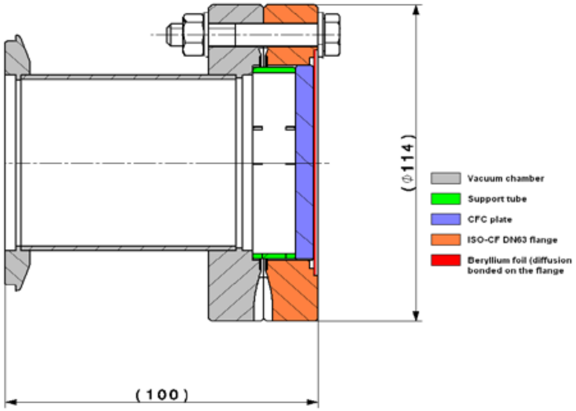
Figure 8: $_s(T)/U_s(T)$ in the beryllium foil with a 10^5 Pa load + proton pulse

II – Once the window designed

- Manufacturing, DONE
- Cleaning, DONE
- Assembling, maybe today



- Leak detection, in the next days
- To be installed during the next technical stop.



Conclusion

- Now, we are able to:
  - Locate a window
  - Know in a few minutes its design and its drawing
  - Design new windows
  - Replace a window in case of unexpected failure (spares available)

- HiRadMat window should be ready for the next technical stop

Every good thing comes to an end…

Thanks to all my VSC colleagues for those 2 wonderful years !

All the best for 2011

Thank you for your attention…

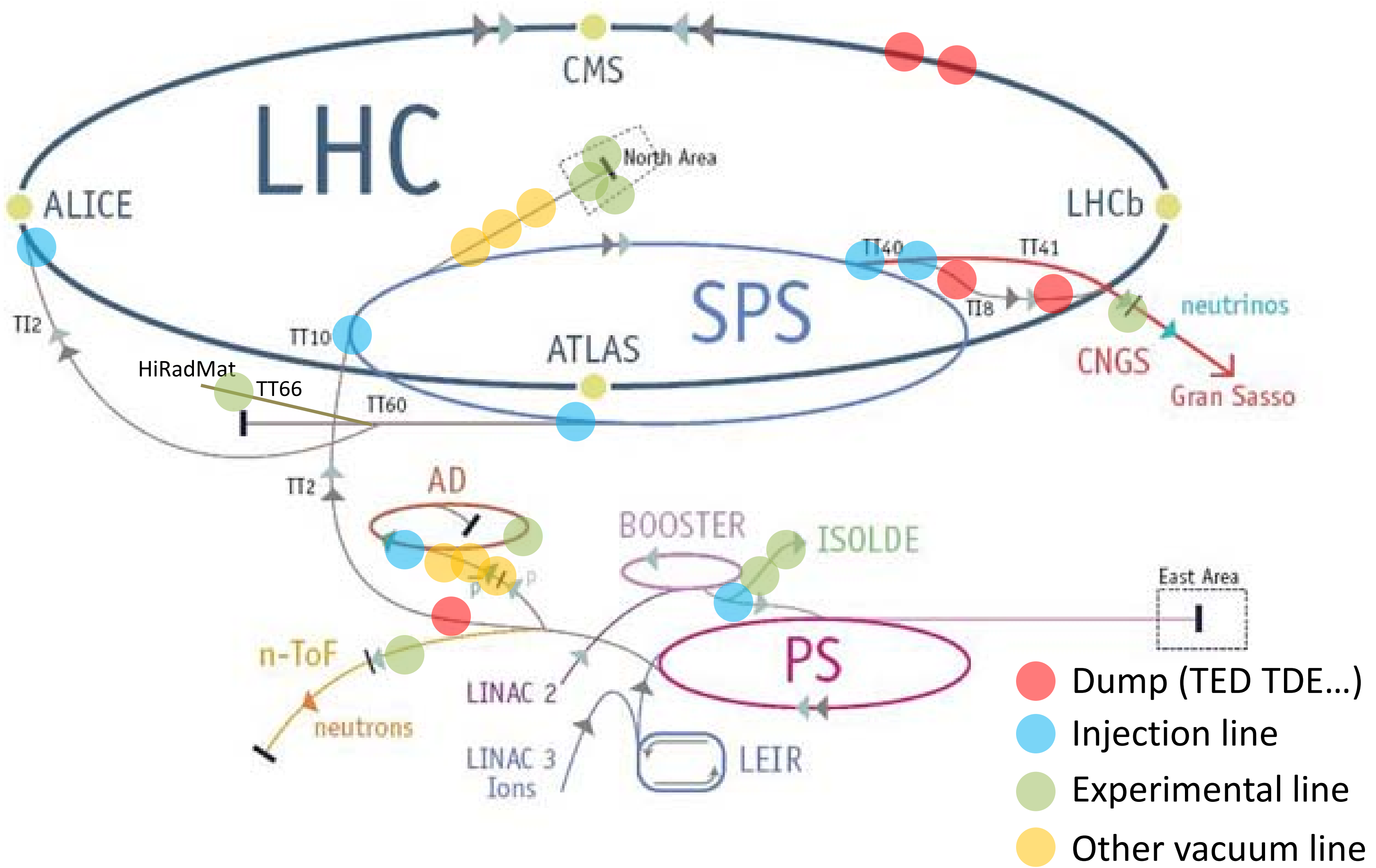
…Any questions ?

Thanks to: Hendrik, Jan, Jarmo, Kurt, Miguel, Paolo, Ray and Wim for their contribution in this project

Michael MONTEIL
TE/VSC
michael.monteil@cern.ch

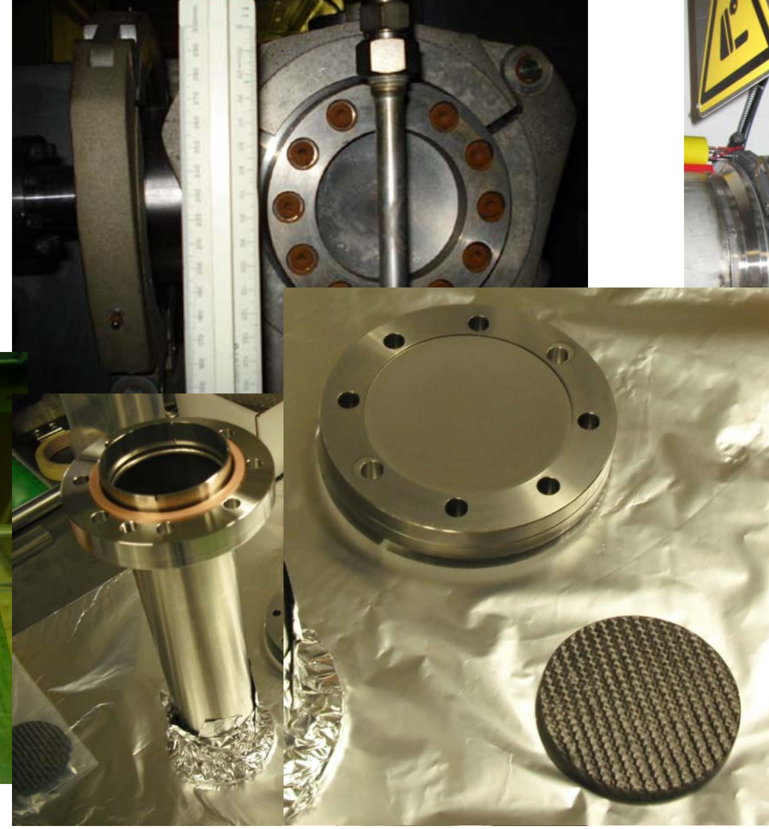
Backup slides

II-2-B Layout


CMS
LHC
North Area
ALICE
LHCb
TT40
TT41
SPS
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
HiRadMat
TT66
TT60
Gran Sasso
TT2
AD
BOOSTER
ISOLDE
East Area
n-ToF
PS
LINAC 2
neutrons
LINAC 3
Ions
LEIR
Dump (TED TDE…)
Injection line
Experimental line
Other vacuum line

TED TI2

TED TI8



HiRadMat

C Dump

TBSE TT20

TED TT20

North Area