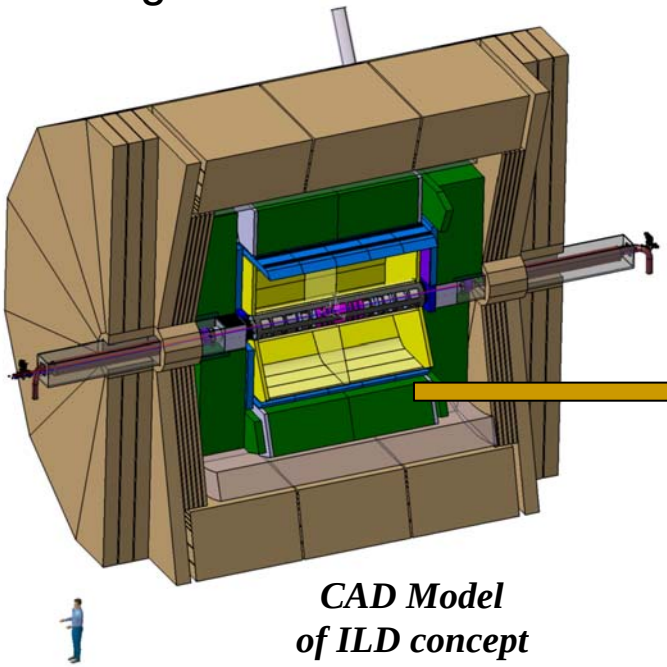
- ECAL Si/W -
Tungsten experience

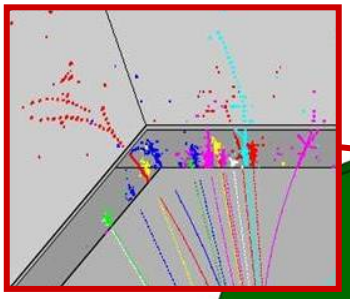
CERN

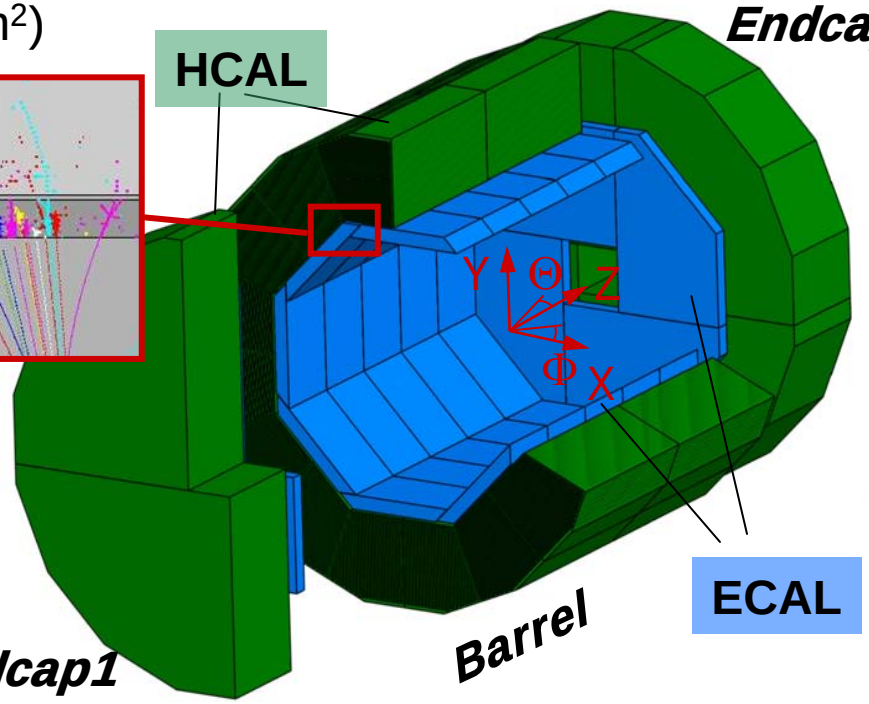
ILD - Calorimeter concept

- The calorimeter of ILD is divided in depth in an electromagnetic section (**ECAL**), and a hadronic section (**HCAL**)
- The two parts are installed inside the coil to minimize the inactive material in front of the calorimeters. To follow the symmetry imposed by the beams and the coil, the electromagnetic calorimeter is divided into a cylindrical barrel and two end-caps.
- The ECAL barrel consists of 40 identical trapezoidal modules of tungsten absorber plates (80 t) interleaved with layers of Silicon detectors with very fine segmentation of the readout (5x5 mm^2)



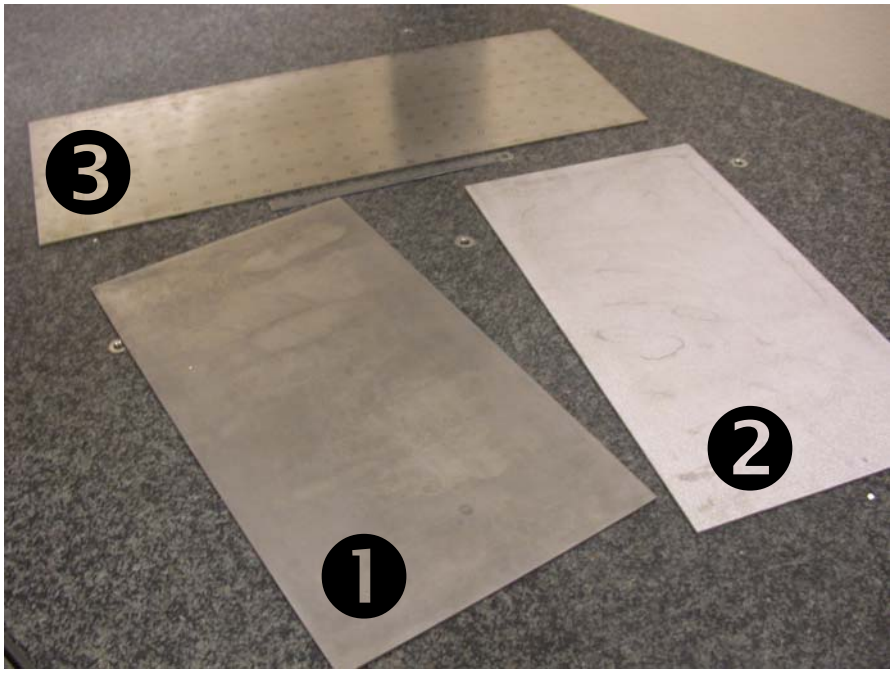
CAD Model of ILD concept





Properties of Tungsten

- A steel-gray metal
- tungsten is found in several ores: Wolframite and Scheelite.
- Production based on powder process (hot press, sintering)
- Physical Properties
  - Density: 19.3 g/cc
  - Atomic number: 74
- Mechanical Properties
  - Tensile Strength, Ultimate: 980 MPa
  - Tensile Strength, Yield : 750 MPa
  - Modulus of Elasticity: 400 GPa
  - Poissons Ratio: 0.280
  - Shear Modulus: 156 GPa
- Thermal Properties
  - CTE, linear: 4.40 µm/m-°C
  - Thermal Conductivity: 163.3 W/m-K
  - Melting Point: 3370 °C



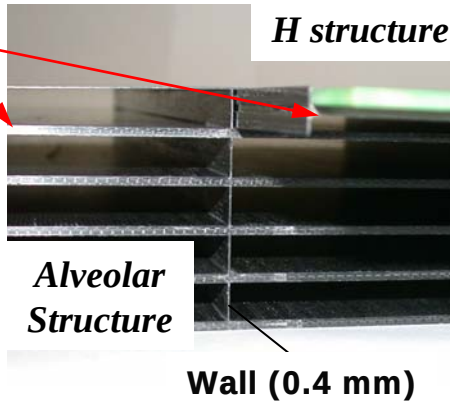
Samples of W plates

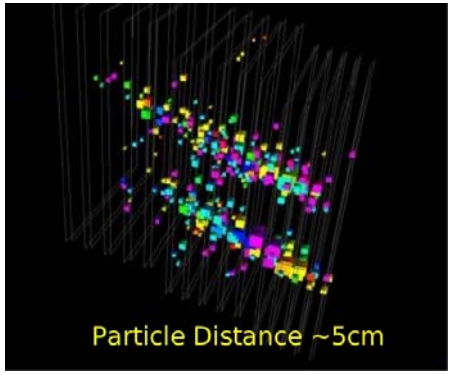
- Tungsten is often brittle and hard to machine (high hardness) in its pure state. Plates of pure tungsten can be rolled ❶, moulded (raw) ❷,or grinded ❸… The pure form is used mainly in electrical applications, but its many compounds and alloys are used in many applications

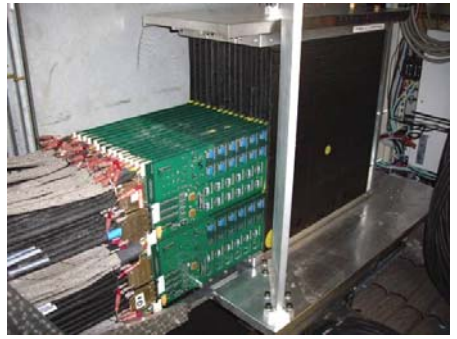
Physics Prototype (2002-2005)

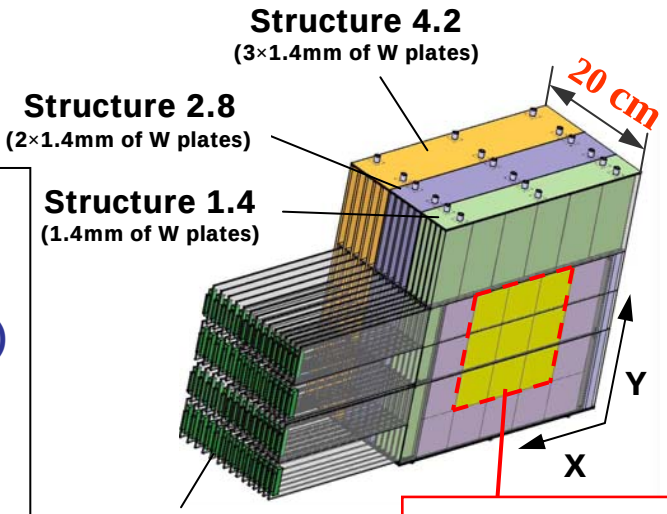
- Multilayer calorimeter as compact as possible (small Molière radius)
- Sampling of W in depth according to the need of energy resolution : 24 X_0
- Half of the tungsten plates is incorporated into a supporting alveolar composite structure (carbon) to avoid machining step and reduce dead zone

  But each layer is composed of several plates
- Half of W plates supports (H-shaped structure) 30 detection units, called detector slab, which are then slid inside each cell









- **3 structures : 24 X_0 (10×1,4mm + 10×2,8mm + 10×4,2mm)**
- **sizes : 380×380×200 mm3**
- **Thickness of slabs : 8.3 mm (W=1,4mm)**
- **VFE outside detector**
- **Number of channels : 9720 (pixel size :10×10 mm²)**
- **Weight : ~ 200 Kg**

Active zone ~10000 pixels in 0.01 m³

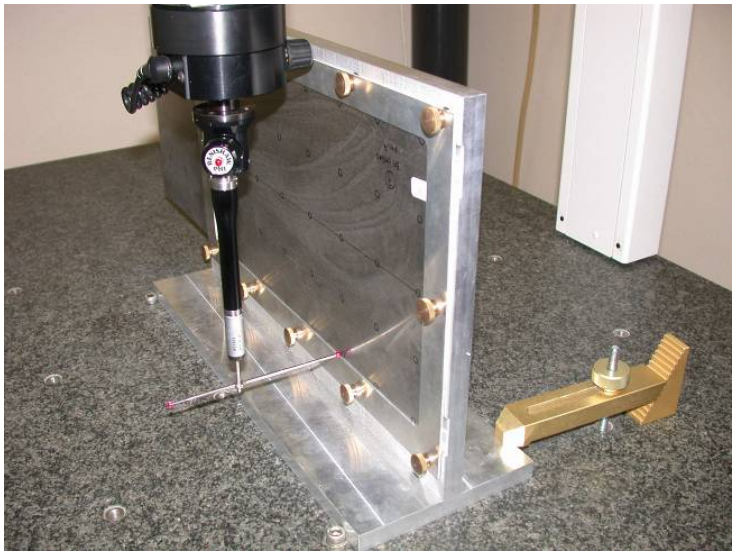
Physics Prototype (2002-2005)

- Tungsten Metrology (using 3D controller):

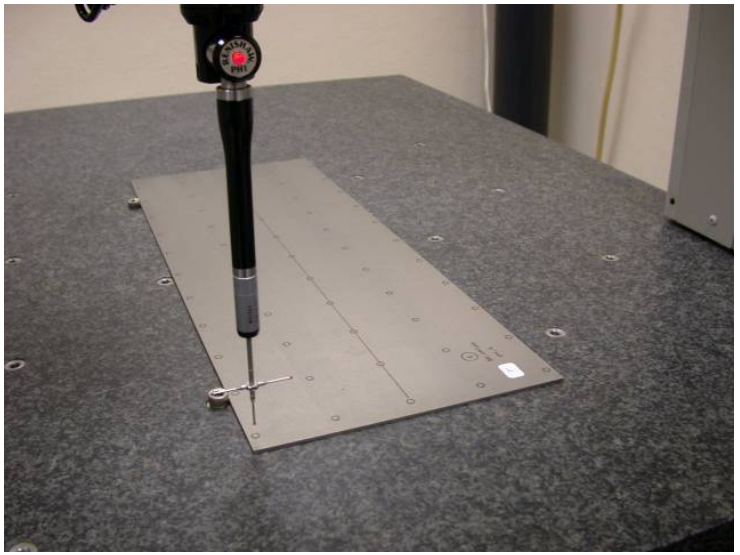
Needs : - uniformity in depth ⇒ precise thickness
- compactness ⇒ good flatness

Providers	Country	Need (Kg)	Dimensions (l,w,t)	Material	Type	Price/Kg (€)
ITEP	Russia	250	380x124x1.4	pure W	grinded	112 (2002)

- Thickness inspection :



- Global dimensions & Flatness inspection :



Physics Prototype (2002-2005)

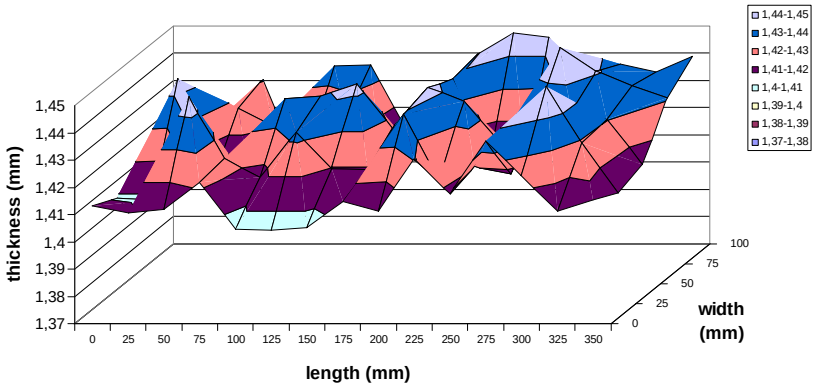
- Tungsten Metrology (examples)

  Dimension of W plates: 380 x 124 x 1.4 mm3 (grinded)

Thickness inspection :

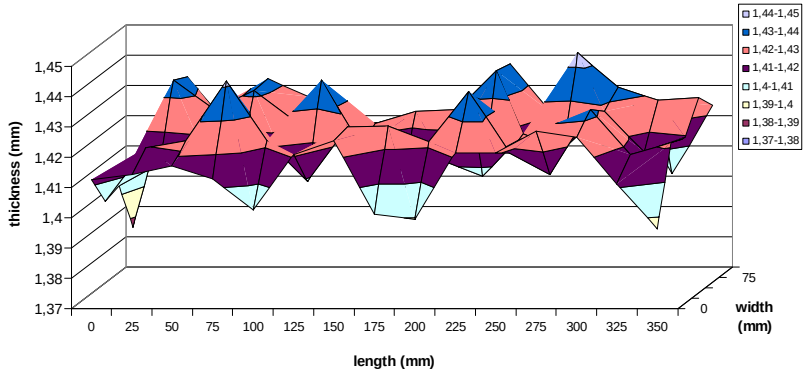
Sample #1 (thickness):

1.42 mm ± 0.02



Sample #2 (thickness):

1.42 mm ± 0.03



It confirms the good quality of the plates as measured at IHEP and ITEP

Marginal impact on the energy resolution for single particle*

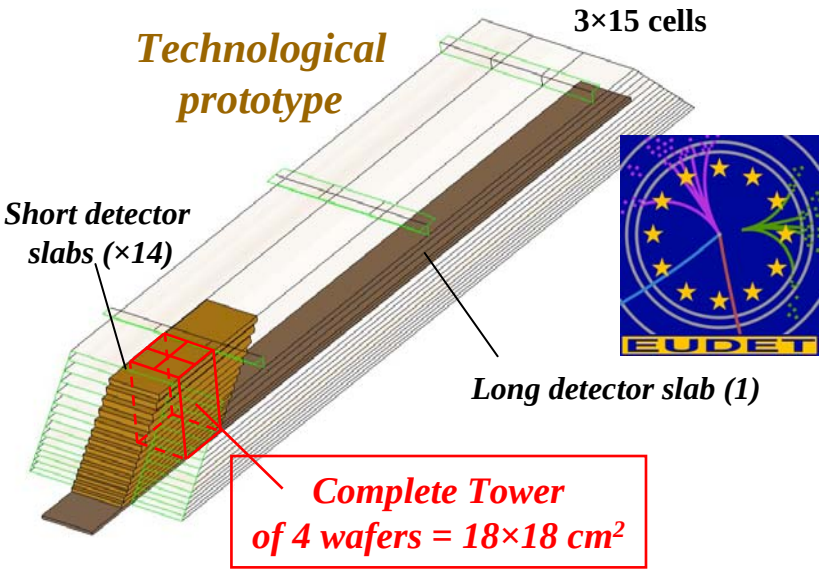
* **Following MOKKA and GEANT4**

R&D – Technological Proto (2006-2009)

EUDET module

Concept : to be the most representative of the final detector module :

- A alveolar composite/tungsten structure with
  - same radiator sampling
  - 3 columns of cells to have representative cells in the middle of the structure (with thin composite sheets)
  - Identical global dimensions (1.5m long) and shape (trapezoidal)
  - fastening system ECAL/HCAL (included in th design of composite structure)



- 15 Detector slabs with FE chips integrated
  - 1 long and complete slab with W (L=1.5m)
  - 14 short slabs to obtain a complete tower of detection (typ. L=30 cm?) and design of compact outlet.

- **1 structure : ~ 23 X_0 (20×2,1mm + 9×4,2mm)**
- **sizes : 1560×545×186 mm3**
- **Thickness of slabs : 6 mm (W=2,1mm)**
- **VFE inside detector**
- **Number of chan. : ~37890 (5.5×5.5 mm²)**
- **Weight : ~ 700 Kg**

R&D - Tungsten prospecting

- Needs : 700 Kg of W, long plates production (typ 1500x550) ?
  thickness : 2.1 or 4.2 (±0.05) MAX

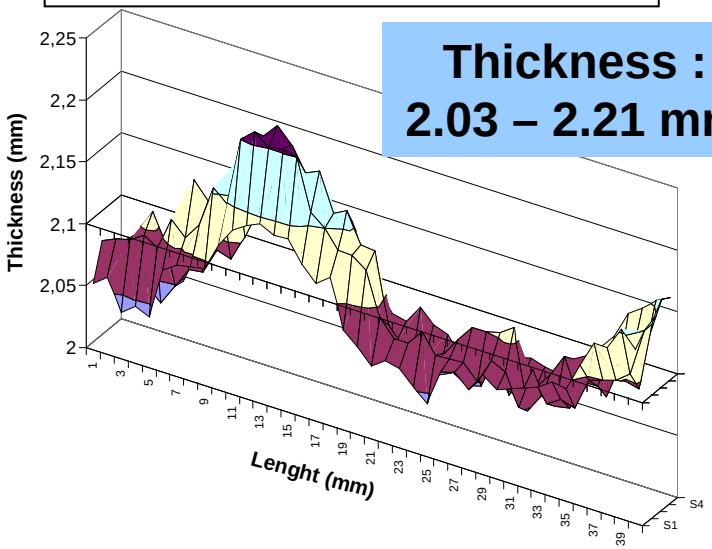
Producers	Country	Dimensions (l,w,t)	Material	Type	Price/Kg (€)
DELTA METAL	FR (CHINA)	381x212 (±0.1) x 2.1 (±0.1) 550x210 (±0.1) x 2.1 (±0.04) 550x210 (±0.1) x 4.2 (±0.04) 1500x400x?	Pure Pure Pure Pure	Rolled Grinded Grinded Rolled	130 (2006) 160 (2007) 150 (2007) ?
M&I MATERAILS	UK	250x120x6	Alloy (W-Ni-Fe)	machined	?
MARKETECH I.	USA	100x60x2.5	Alloy (W-Ni-Fe)	raw	160 (2006)
SHAANXI SINWA	CHINA	800x130x1.4 (±0.2) 800x130x2.8 (±0.3) 800x130x5 (±0.5) 400x40x?	Alloy (W-Ni-Fe) Alloy (W-Ni-Fe) Alloy (W-Ni-Fe) Alloy (W-Ni-Cu)	Rolled Rolled Rolled Rolled	?
XI'AN YI HENG	CHINA	381x212x2.1 (±0.1) 381x212x2.1 (±0.04) 1500x600x? (±0.5)	Pure Pure	Rolled Grinded	96 (2006) 320 (2006)
BAOJI BOXIN	CHINA	No reply	-	-	-
ATI	USA	381x212x2.1 (±0.05)	Alloy (W-Ni-Fe)	Rolled	300 (2006)
BFI OPTILAS	FR (CHINA)	550x210 (±0.1) x 2.1 (±0.04) 550x210 (±0.1) x 4.2 (±0.04)	Pure Pure	Grinded Grinded	150 (2007) 110 (2007)
ITEP	Russia	No solution	-	-	-

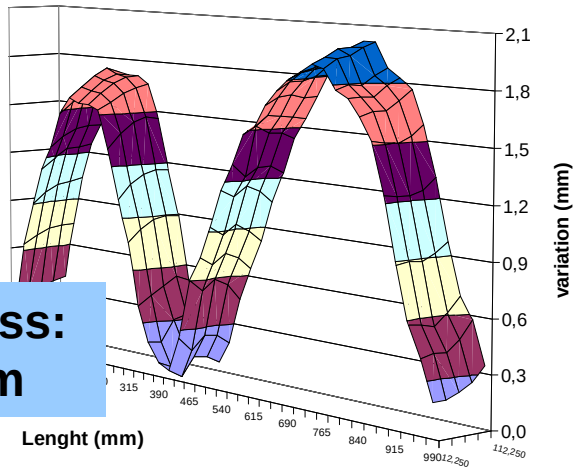
Long plates samples (SLAB)

- The LPSC (Grenoble) has ordered 2 rolled samples (from DELTA METAL) :

Sample #1: 1000x124x2.1

Thickness : 2.03 – 2.21 mm

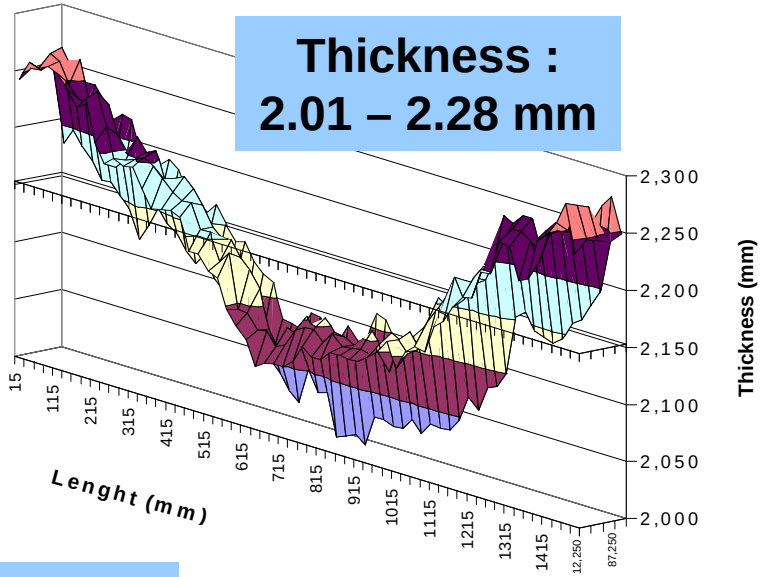




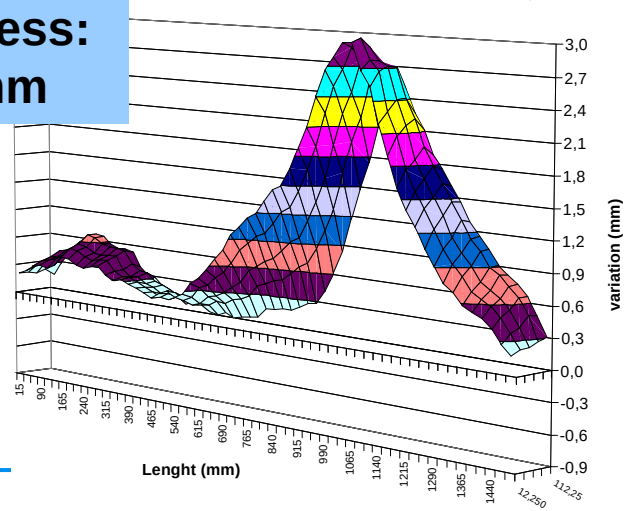
Flatness: 2 mm

Sample #1: 1500x124x2.1

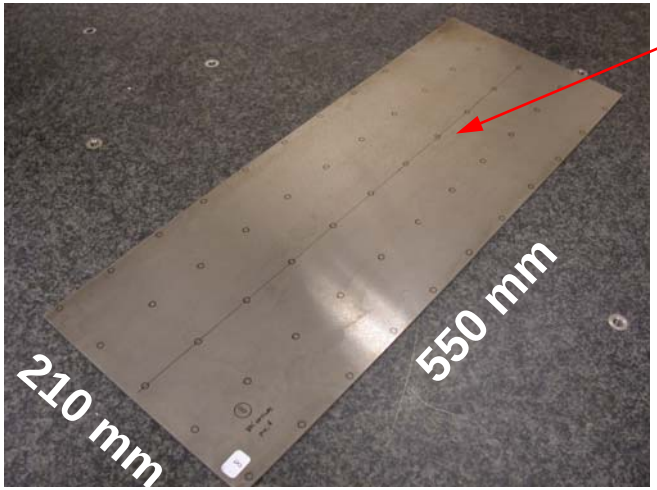
Thickness : 2.01 – 2.28 mm

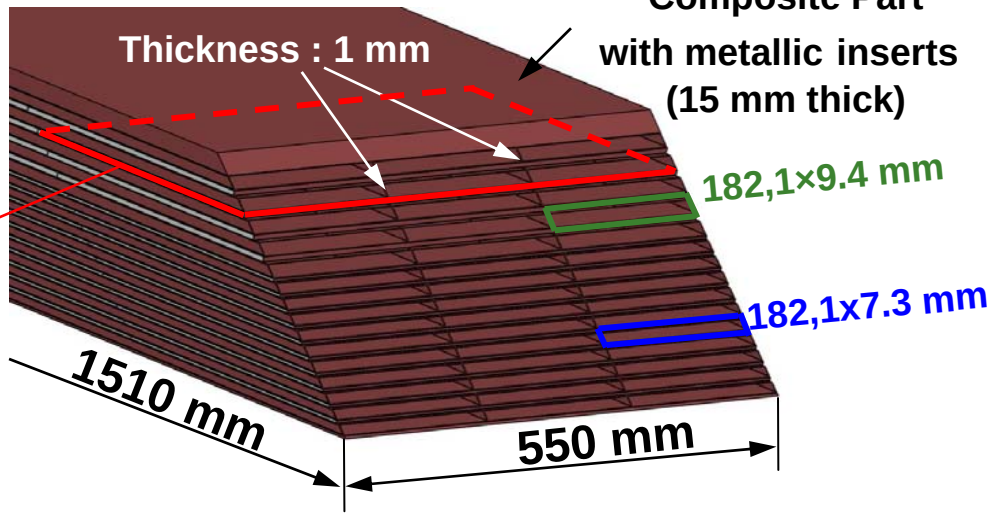


Flatness: 3 mm



W plates used for EUDET module





- All plates are grinded
- 3 different thickness
  1.05 – 2.1 – 4.2 mm
- Total cost : 97 k€ (2007)
  (134 €/Kg)

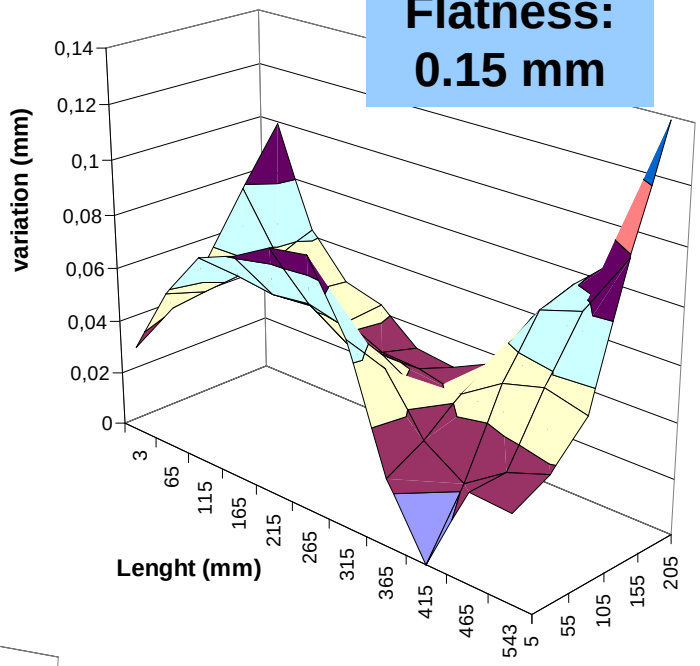
lenght (mm)	*width (mm)*	*tickness (mm)*	*unit weight (Kg)*	***REQUEST (nb)***	*WEIGHT (Kg)*		
ALVEOLAR STRUCTURE							
(+-0,1 mm)	(+-0,1 mm)	(+-0,04 mm)					
549	210	**4,2**	9,35	**22**	205,6	1040	22880
549	206,4	**4,2**	9,19	**2**	18,37	1022	2044
549	177,6	**4,2**	7,9	**2**	15,81	884	1768
549	148,8	**4,2**	6,62	**2**	13,24	738	1476
549	120	**4,2**	5,34	**2**	10,68	595	1190
(+-0,1 mm)	(+-0,1 mm)	(+-0,04 mm)					
549	210	**2,1**	4,67	**70**	327,09	694	48580
549	208,5	**2,1**	4,64	**2**	9,28	689	1378
549	188,1	**2,1**	4,19	**2**	8,37	625	1250
549	167,7	**2,1**	3,73	**2**	7,46	555	1110
549	147,3	**2,1**	3,28	**2**	6,56	488	976
549	126,9	**2,1**	2,82	**2**	5,65	419	838
549	106,5	**2,1**	2,37	**2**	4,74	352	704
549	86,1	**2,1**	1,92	**2**	3,83	285	570
549	65,7	**2,1**	1,46	**2**	2,92	218	436
549	45,3	**2,1**	1,01	**2**	2,02	150	300
549	24,9	**2,1**	0,55	**2**	1,11	82	164
SHORT SLABs							0
(+-0,1 mm)	(+-0,1 mm)	(+-0,04 mm)					0
360	180,5	**4,2**	5,27	**6**	31,6	586	3516
(+-0,1 mm)	(+-0,1 mm)	(+-0,04 mm)					0
360	180,5	**2,1**	2,63	**11**	28,97	390	4290
LONG SLABs							0
(+-0,1 mm)	(+-0,1 mm)	(+-0,02 mm)					0
272	180,5	**1,05**	0,99	**18**	17,91	179	3222
136	180,5	**1,05**	0,5	**4**	1,99	89,5	358
							0
					723,2		**97050**
						prix/kg	**134,195243**

W plates used for EUDET module

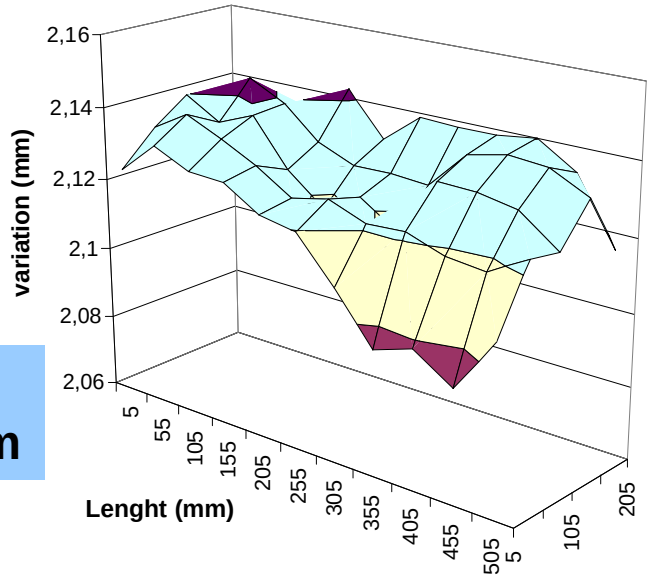
- Dimensional inspection:

  W plates: 550 x 210 x 2.1 mm3 (grinded)

Flatness: 0.15 mm



Thickness : 2.09 – 2.14 mm



⇨ Length & width (± 0.1): ***OK***

⇨ Thickness (± 0.04) : ***OK***

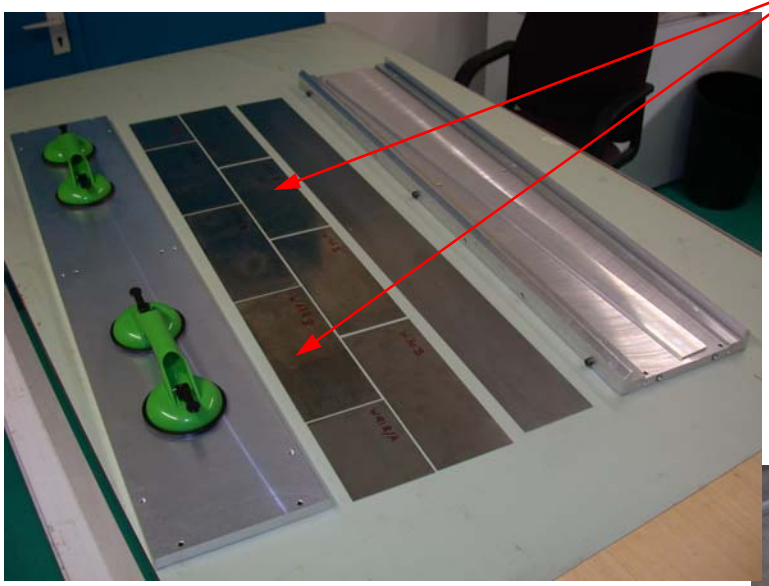
⇨ Flatness : ***< 0.3 mm***

(based on 10 samples)

W plates used for EUDET Slabs

Study of one mould for whole slab structures:

- All slabs are made by several short but precise plates, assembled in 2 layers, in order to control the thickness and the flatness



⇨ Design : ***OK***
⇨ machining : ***OK***
⇨ first H structure (1300×124): ***OK***