Mechanical Engineering Design and Simulation for SPIRAL2

- GANIL and SPIRAL2
- Mechanical Design Group @ GANIL
- Examples :
  1- CAD Integration of SPIRAL2 Installation

  2- MEBT Rebuncher (design and heat-transfer simulation)

  3- Target Station in S3 (heat-transfer transient simulation)

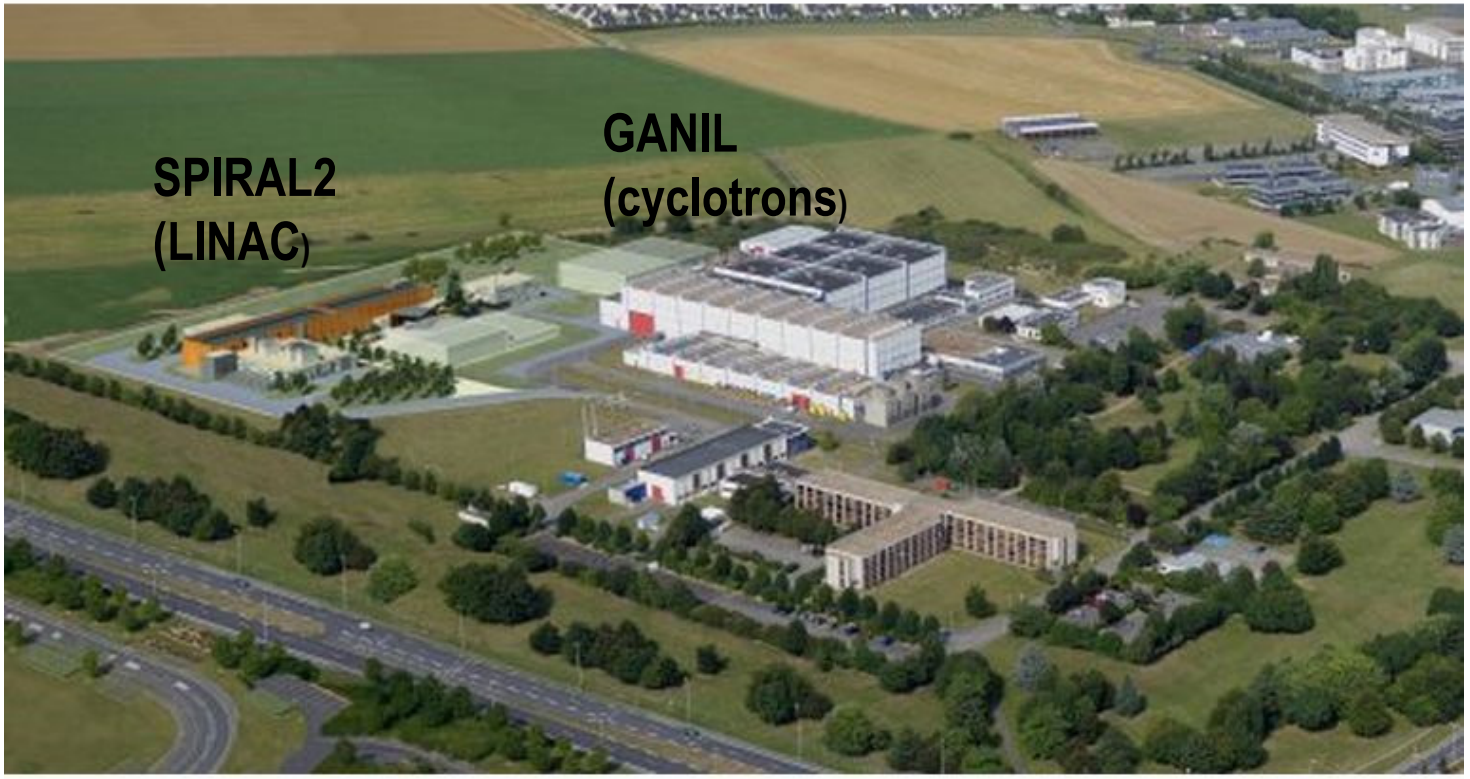
  4- Design of S.E.M. Profiler

  5- Dynamic Seismic simulation
- Conclusion

The SPIRAL2 project @ GANIL is a superconducting Ion Continuous Wave LINAC with two associated experimental areas :

- S3 (Super Separator Spectrometer)
- NFS (Neutron For Science).

Location : Caen, Normandy, FRANCE

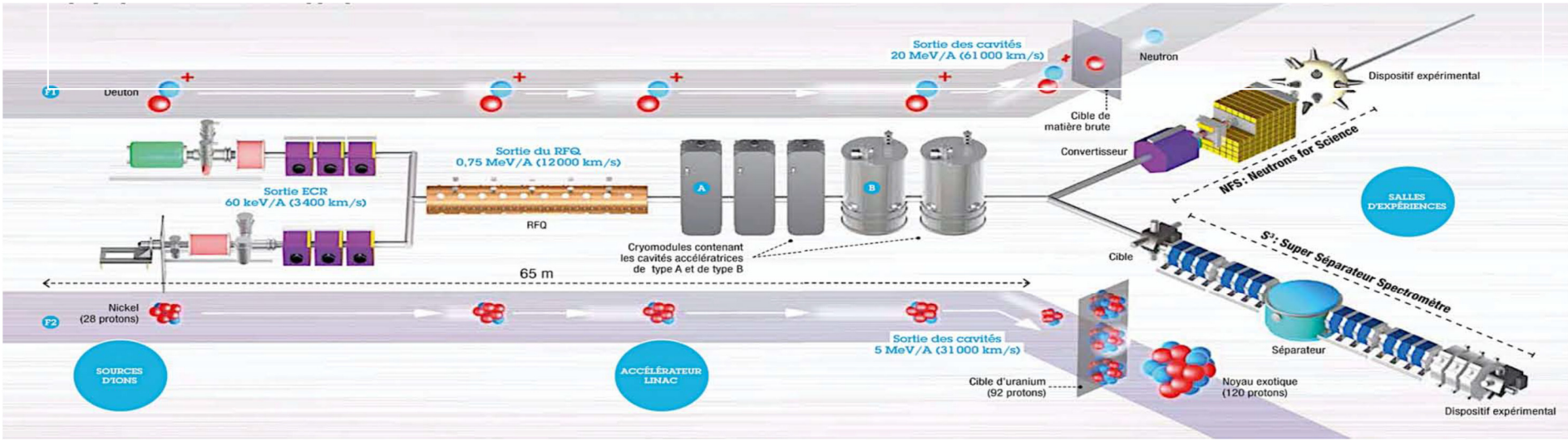


Mechanical Engineering Design and Simulation for SPIRAL2 @GANIL

SPIRAL 2 in numbers :

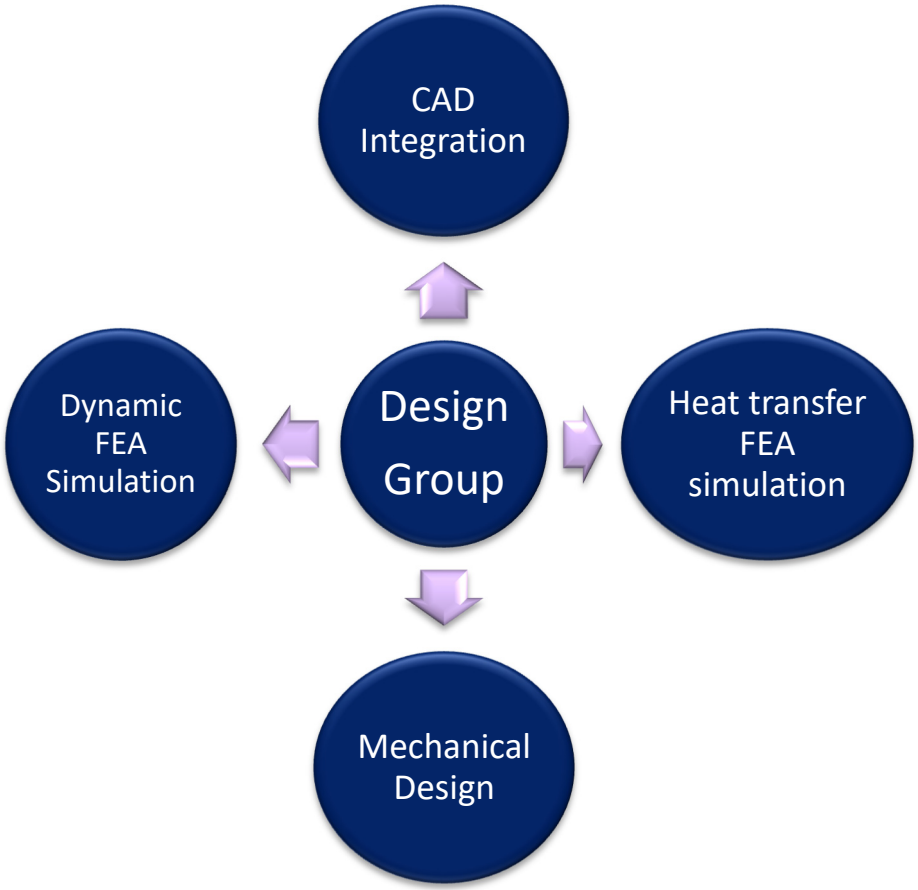
- 138,5 Millions Euros
- 20 national and international collaboration labs
- 12 years of development

Project Start 2006 → Construction begins 2011 → Building ready 2014 → First particle acceleration 2015 → First NFS Experiment 2019



Mechanical Design Group @ GANIL :

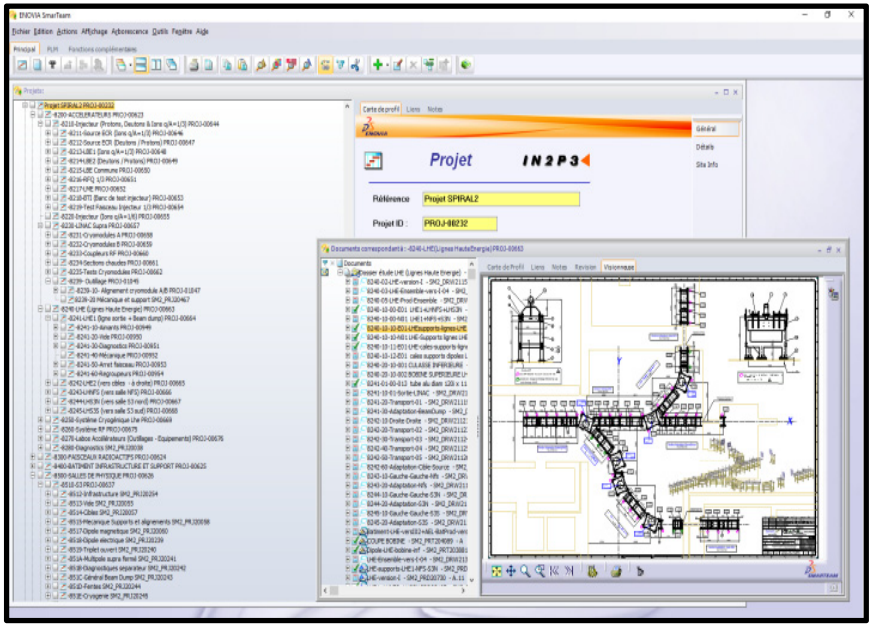
- 6 permanent engineers and designers (+ trainees and short-term contract)
- Knowledge range from : ions sources, beam lines, cryogenics, detectors, systems…
- Different types of mechanical engineering skills



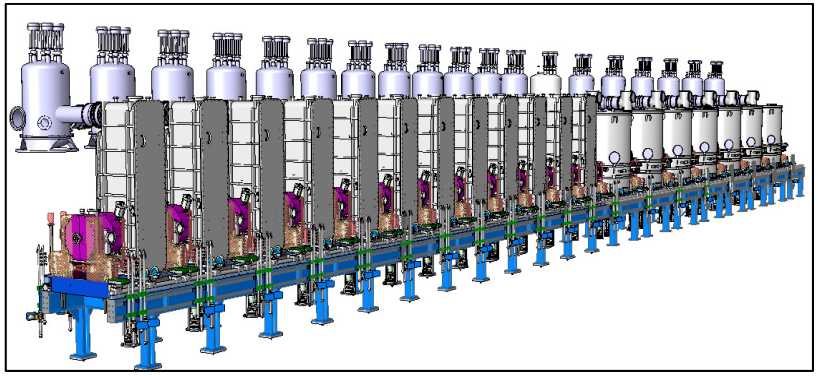
1. CAD integration of the SPIRAL2 installation

- PLM software Smarteam and CATIAv5

⇒ **allow complex collaborative design development at large scale**

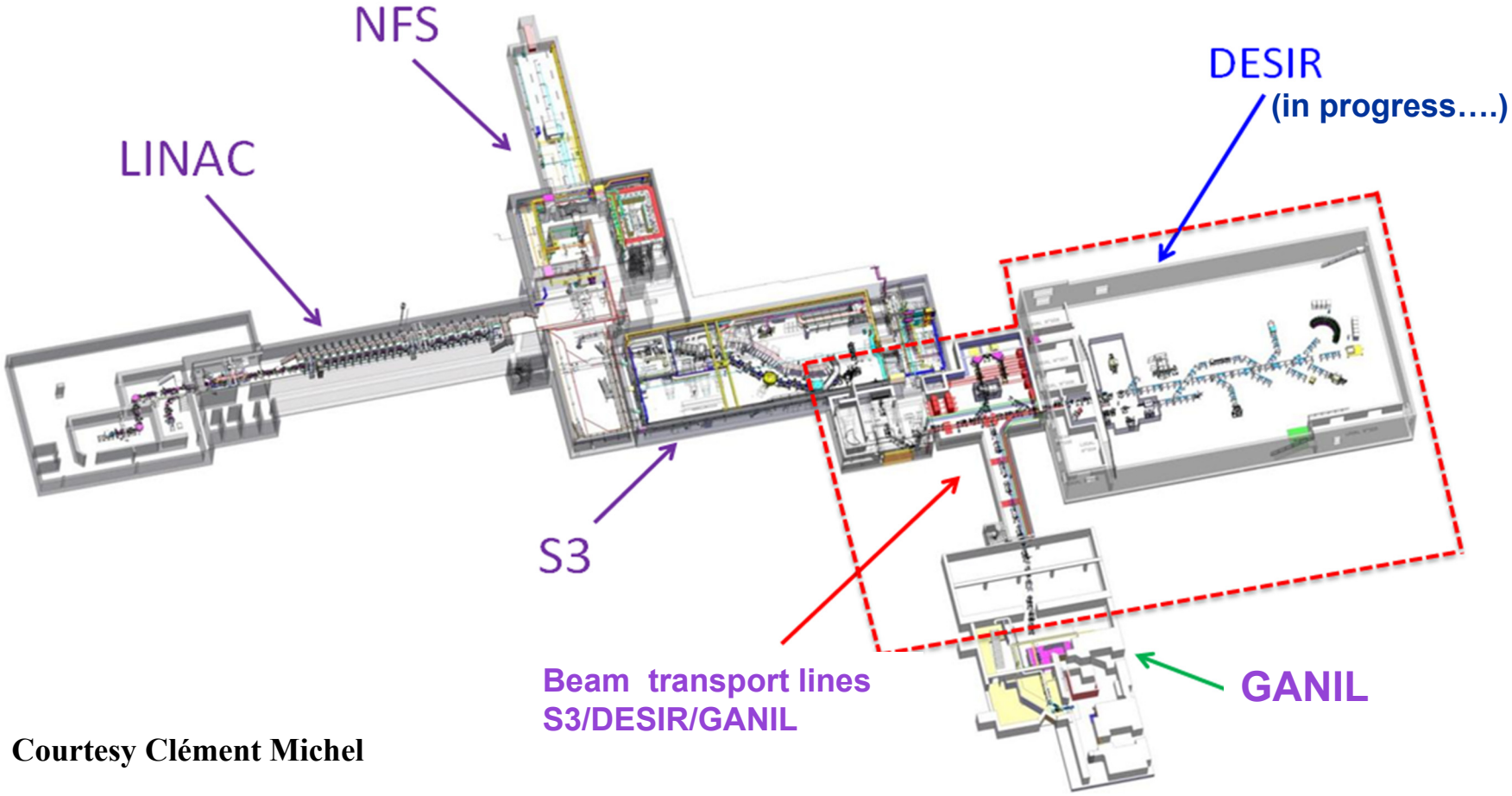


- Collaboration labs using Smarteam plateform : GANIL, IPNO, CENBG, IPHC, IPNL, LPC-C, LPSC, SUBATECH …
- Exemple : LINAC CAD integration
  - 12 Cryomodules type A (CEA /IRFU)
  - 7 Cryomodules type B (IN2P3/IPNO)



1. CAD integration of SPIRAL2 installation

- Complete CAD assembly model in CATIA v5 is 11 Giga-octets : most important CAD assembly of CNRS/IN2P3 database.
- S3 : contains 2700 differents PARTS and sub-models.



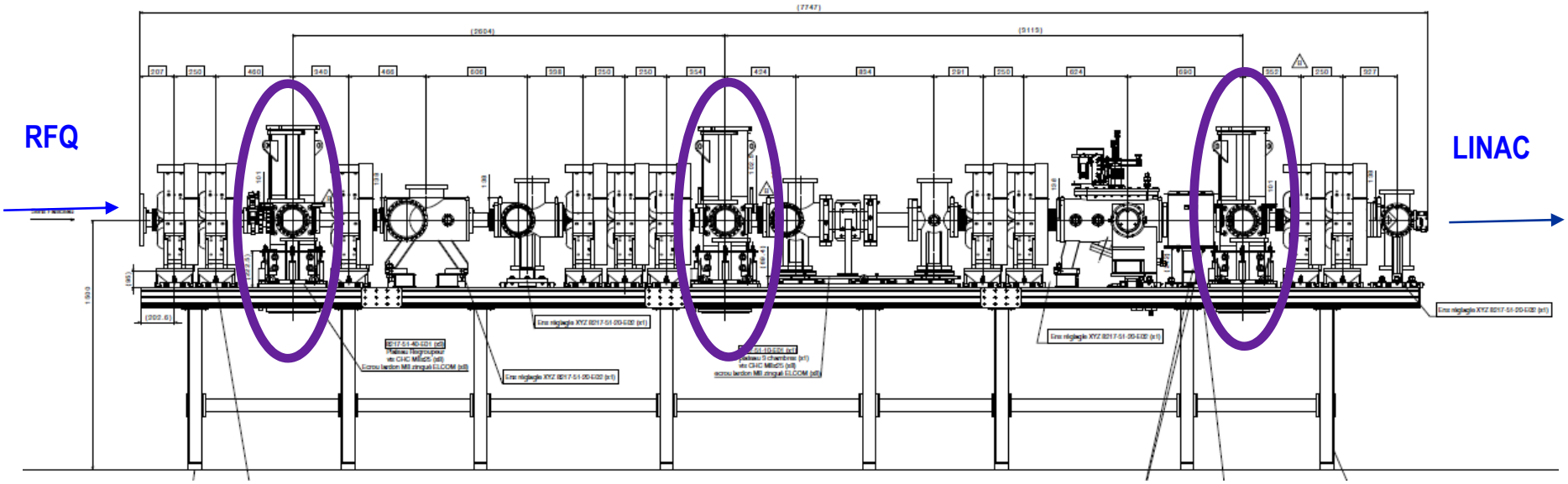
Courtesy Clément Michel

2. MEBT Rebuncher

- Radio- frequency (88 MHz) 3-gap **cavity**

⇒ **maintain beam longitudinal dimension**

⇒ **prepare beam before LINAC.**

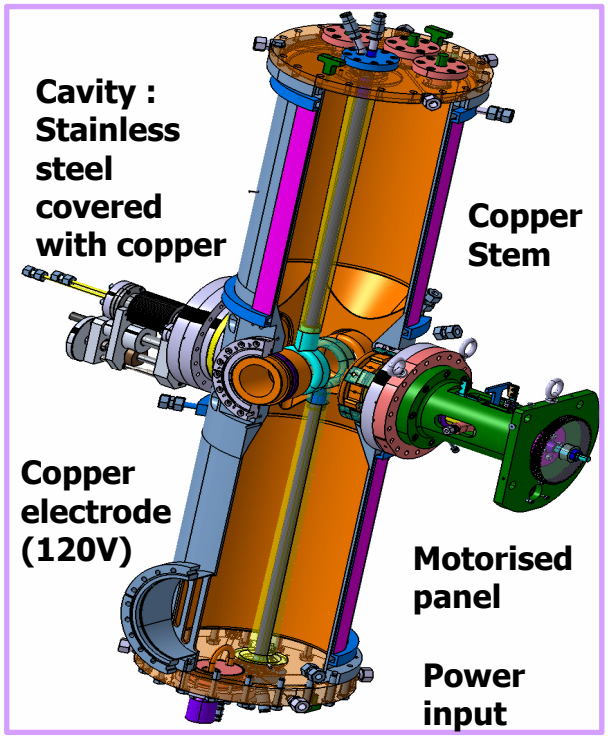


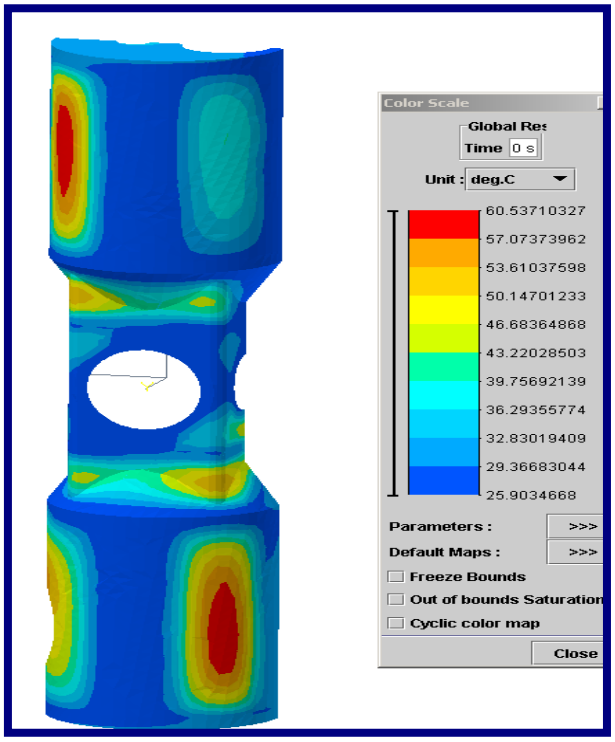
Mean Energy Beam Transport

2. MEBT Rebuncher

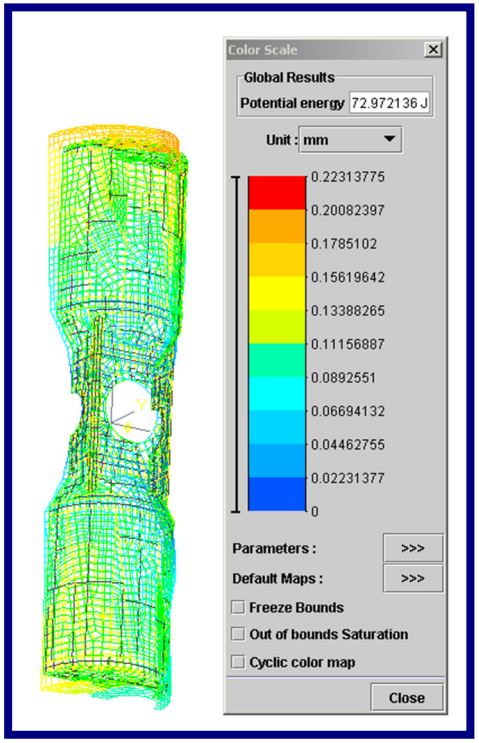
1,5 kW to be dissipated inside the cavity

Optimized cooling system : maximum ΔT=50°C between all parts





T_{max}=60°C

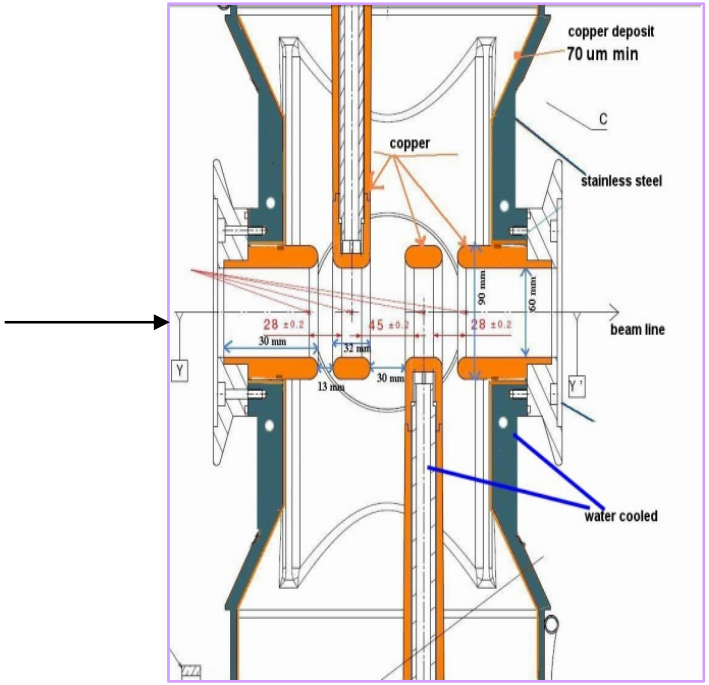


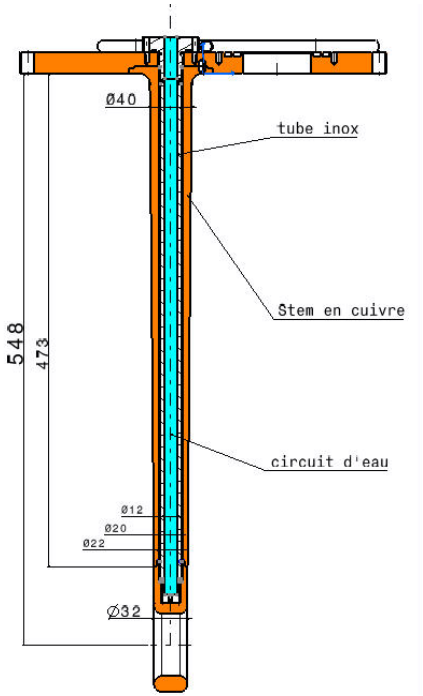
Max expansion 0,22 mm

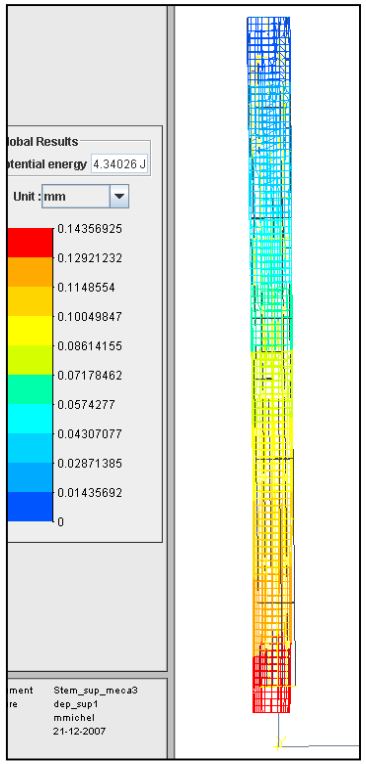
Courtesy Matthieu Michel

2. MEBT Rebuncher

Challenge : Stem differential thermal expansion shall be limited
=> to control the difference in gap and concentricity between stems .







Max expansion 0,14 mm

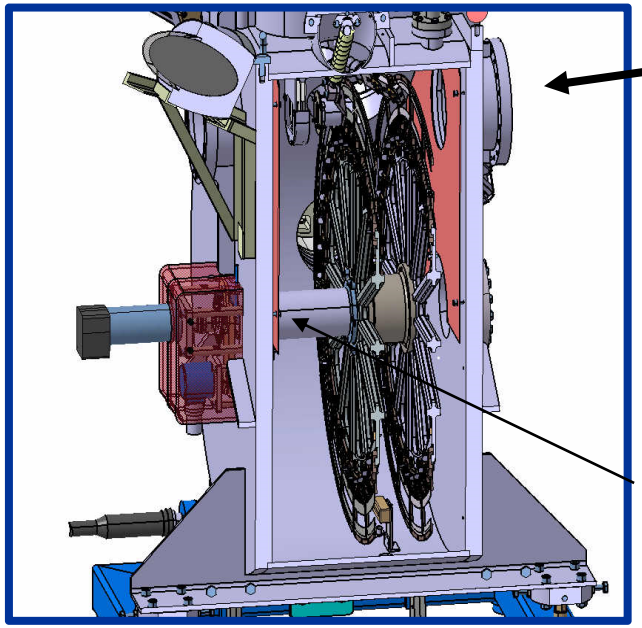
Courtesy Matthieu Michel

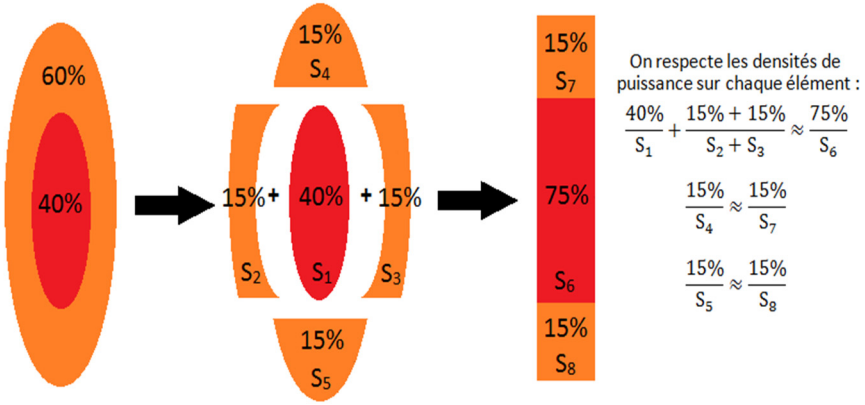
3. Target station in S3

AIM : stable behaviour of target under high beam intensity

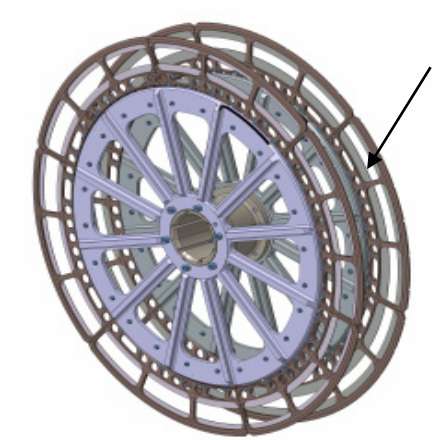
=> Rotative Target:

- Maximum rotation speed : 3000 rpm
- Beam energy : 340 MeV at 10 pµA (power 500 W to 1kW)
- Target : Ti-C-U thickness <10µm





Ion beam power distribution on the target

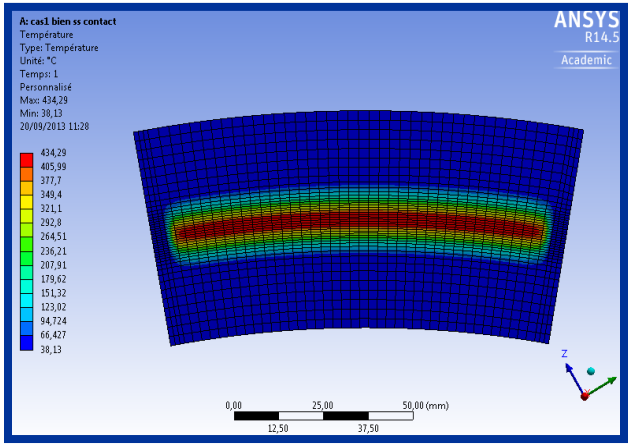


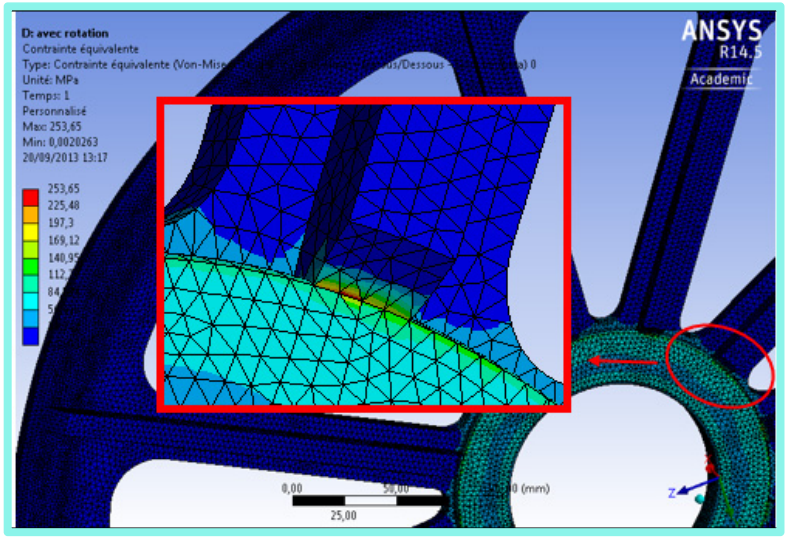
Courtesy Franck Lutton, Patrice Gangnant

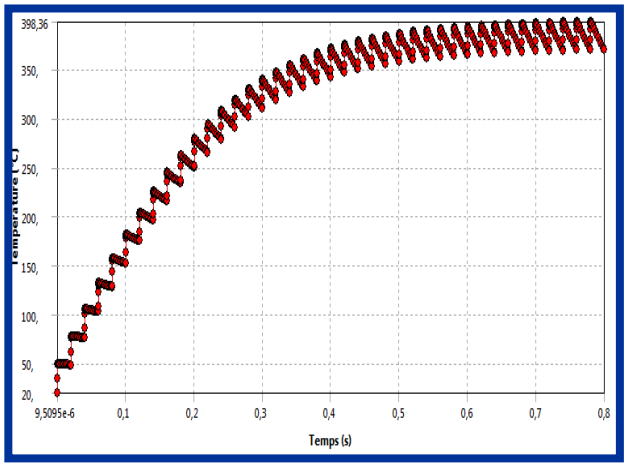
3. Target station in S3

Results of Thermal Transient analysis on the target @3000 rpm :

- Max temperature on Uranium target : 440°C *($T_{fusionU}$=1135°C)*
- Thermo-mechanical stress on wheel : 230 MPa



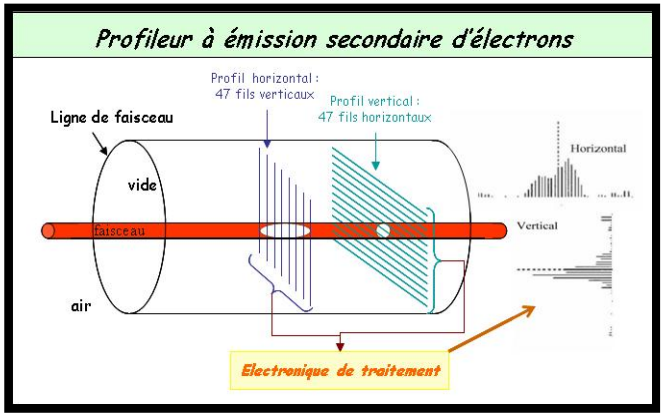




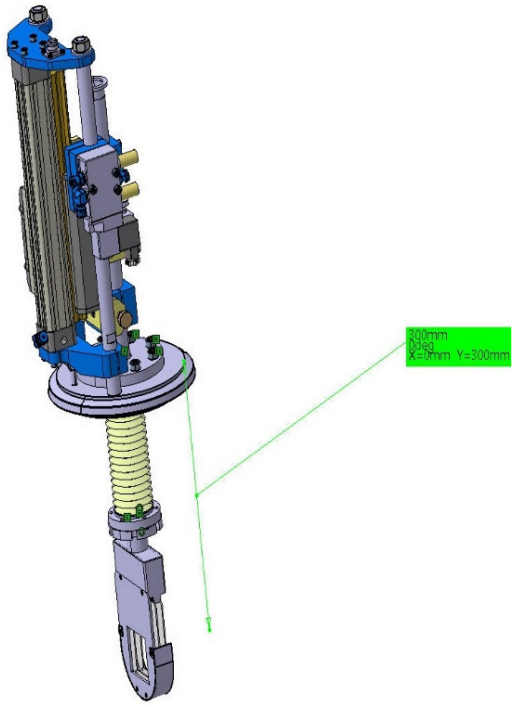
Target Temperature vs time @3000rpm

Courtesy Matthieu Michel, Franck Lutton

4. S.E.M. Profiler



- Secondary Emission Profiler : S.E.M.
- Profiler is a beam monitor : used to analyse the ion beam
- The beam **is passing through the wires and extracts electrons** => create an electrical current in the same ratio as the energy transfered to the wire.
- Profilers are composed of a grid of golden tungsten wires of Ø20 to Ø150 µm.
- The total mechanical accuracy of this diagnostic is +/- 0,1 mm
- Actuator stroke : 120 mm



Courtesy Patrice Gangnant, Roman Revenko

5. Seismic simulations

SAFETY REQUIREMENT : In case of earthquake, equipments > 500kg shall NOT be projected and affect the buidling used as containement barrier for radiation shielding.

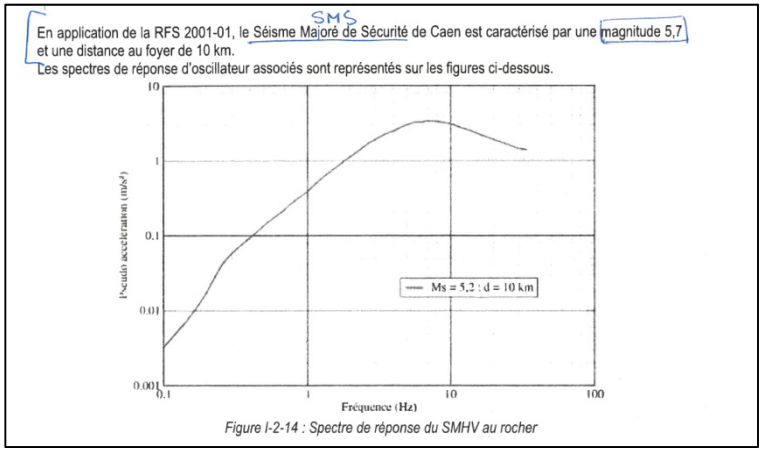
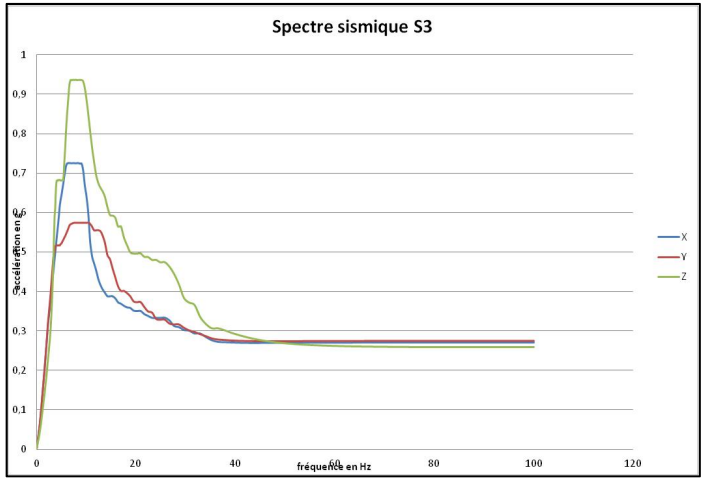


Figure I-2-14 : Spectre de réponse du SMHV au rocher

Nuclear Authority : Max Seismic risk in Normandy : magnitude 5,7

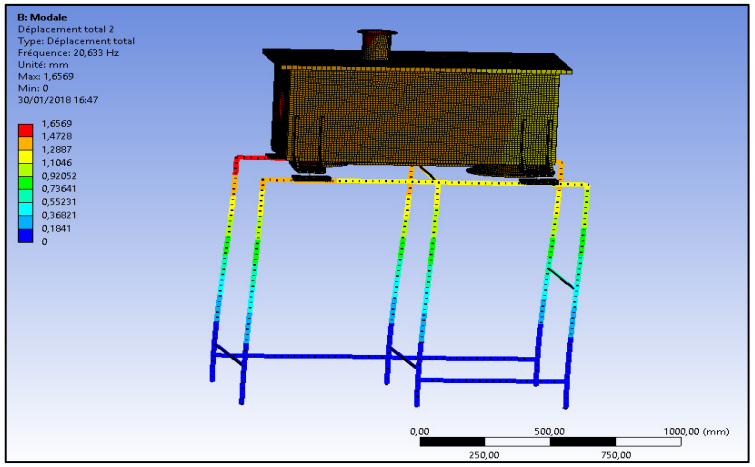


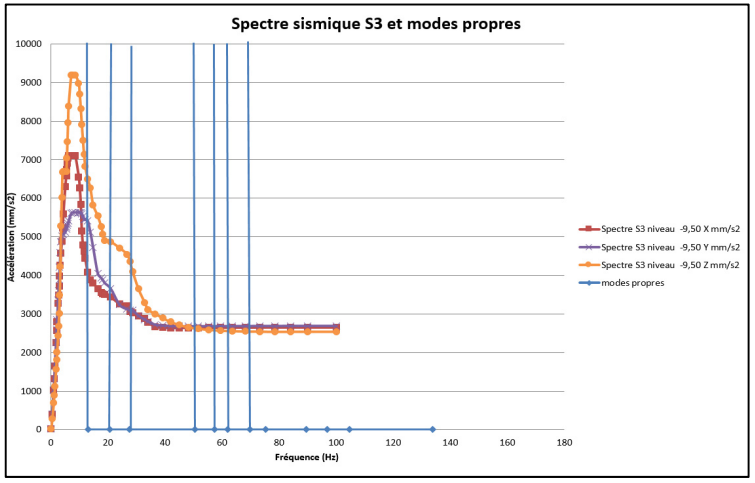
Civil Engineering : Spectral Load

Dynamic Modal-spectral Analysis

5. Seismic simulations

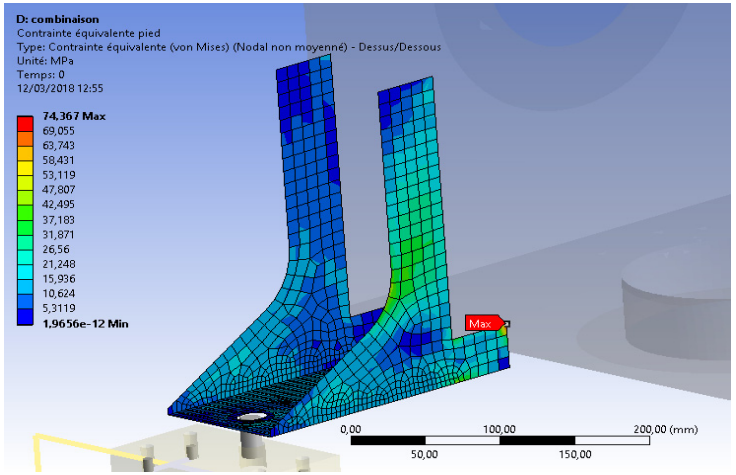
Modal Analysis : Eigen frequencies





Combined static and spectral load
Gravity +/- seismic

=> Post-treatment : Von Mises Stress on support and anchor feet

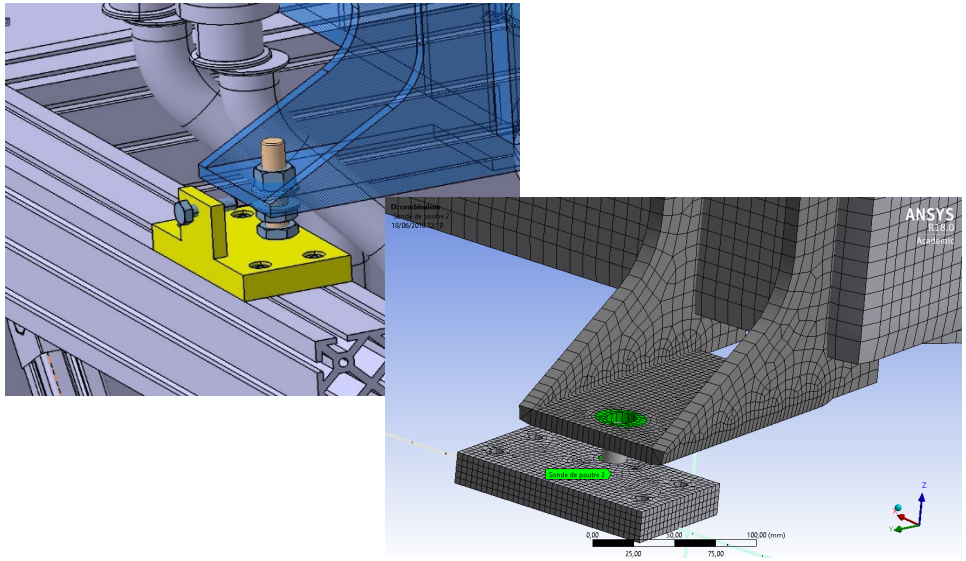


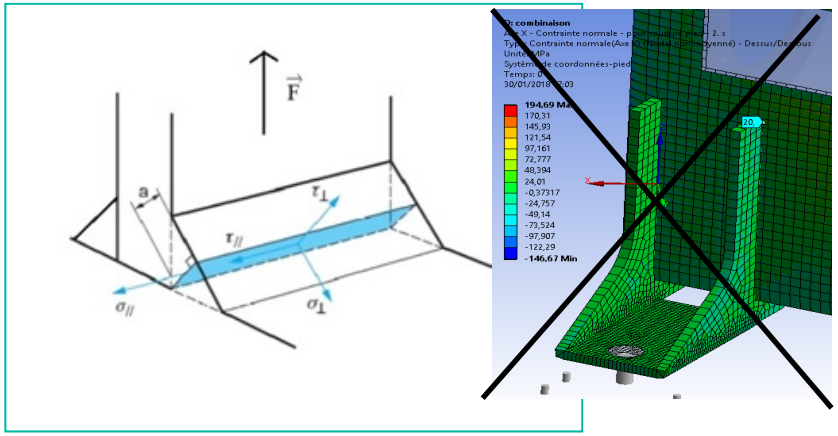
Anti-seismic anchorage to ground : HILTI type C2

	HIT-RE 500-SD + HIT-V

5. Seismic simulations

FASTERNER and WELDS : EUROCODE 3 criteria





$$\sigma_{eq} = \left[\sigma_{normal}^2 + 3\,(\tau_{normal}^2 + \tau_{paralel}^2\right]^{0.5}$$

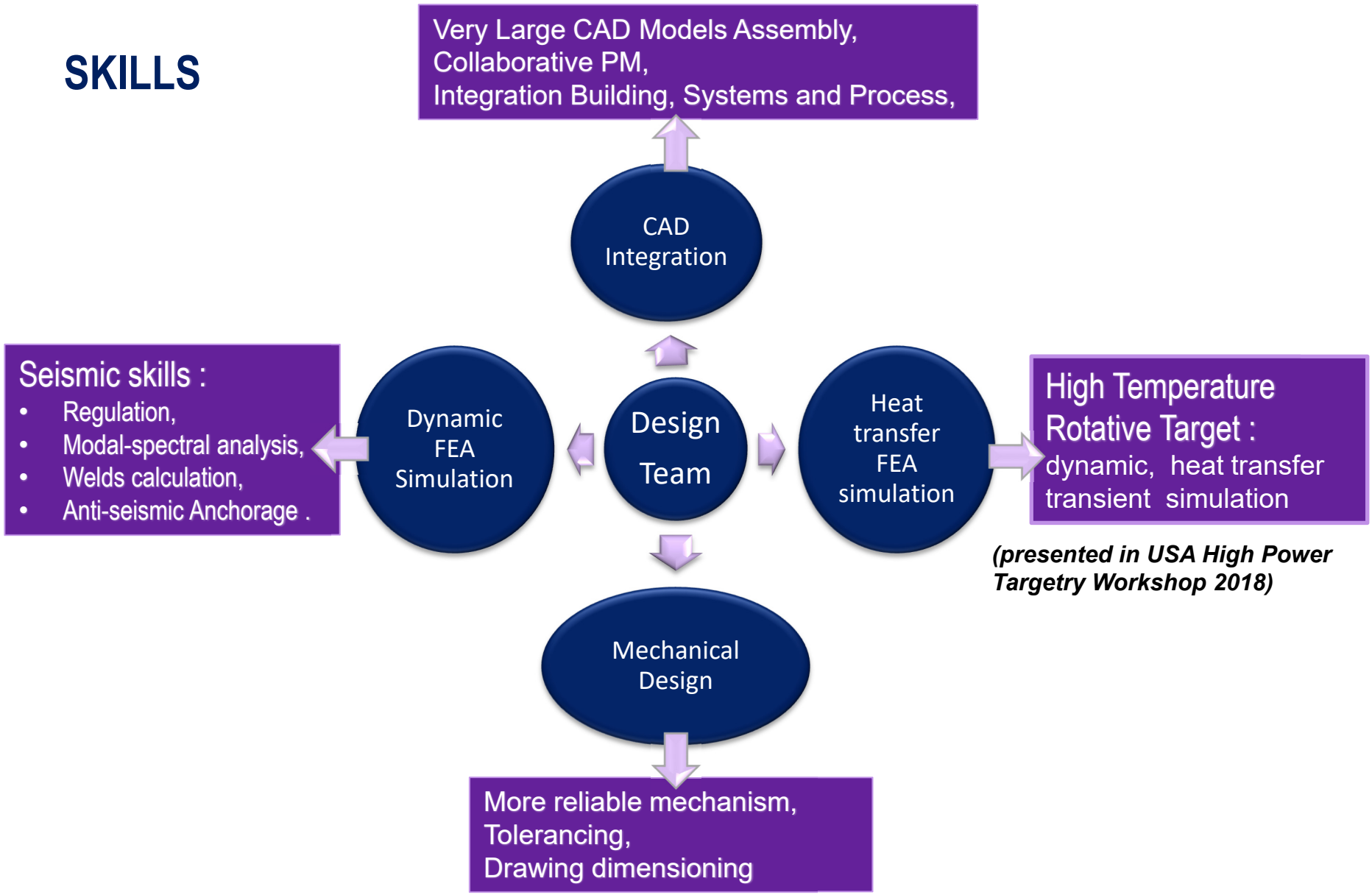
$$\frac{F_{v.Sd}}{F_{v.Rd}} + \frac{F_{t.Sd}}{1{,}4F_{t.Rd}} \leq 1$$

Combined traction and shear Criteria

$$\sigma_{eq} \leq \frac{f_u}{(\gamma_{M2})} \qquad \sigma_{normale} \leq \frac{0.9 f_u}{\gamma_{M2}}$$

=> Development of a **specific program for ANSYS to calculate normal and shear stress in the welds**

SKILLS



(presented in USA High Power Targetry Workshop 2018)

CONCLUSION

An international project of a magnitude such as SPIRAL2 has led the designers and engineers to **improve** methods of design and simulation, and has required **significant development and upgrading of skills.**

ACKNOWLEDGMENT

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And M. Walter (CC IN2P3)

Thank your for your attention