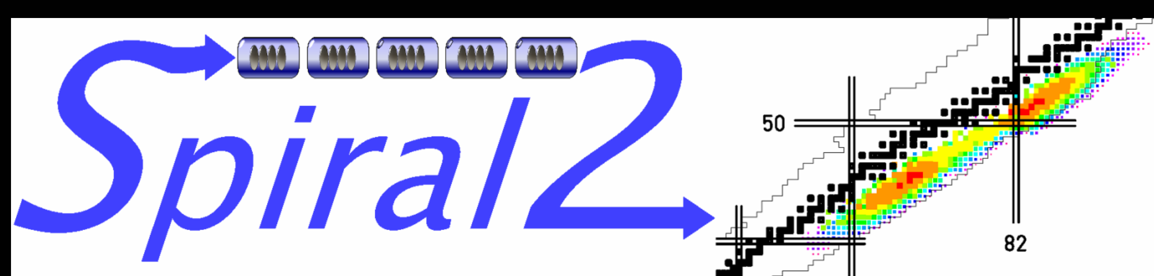
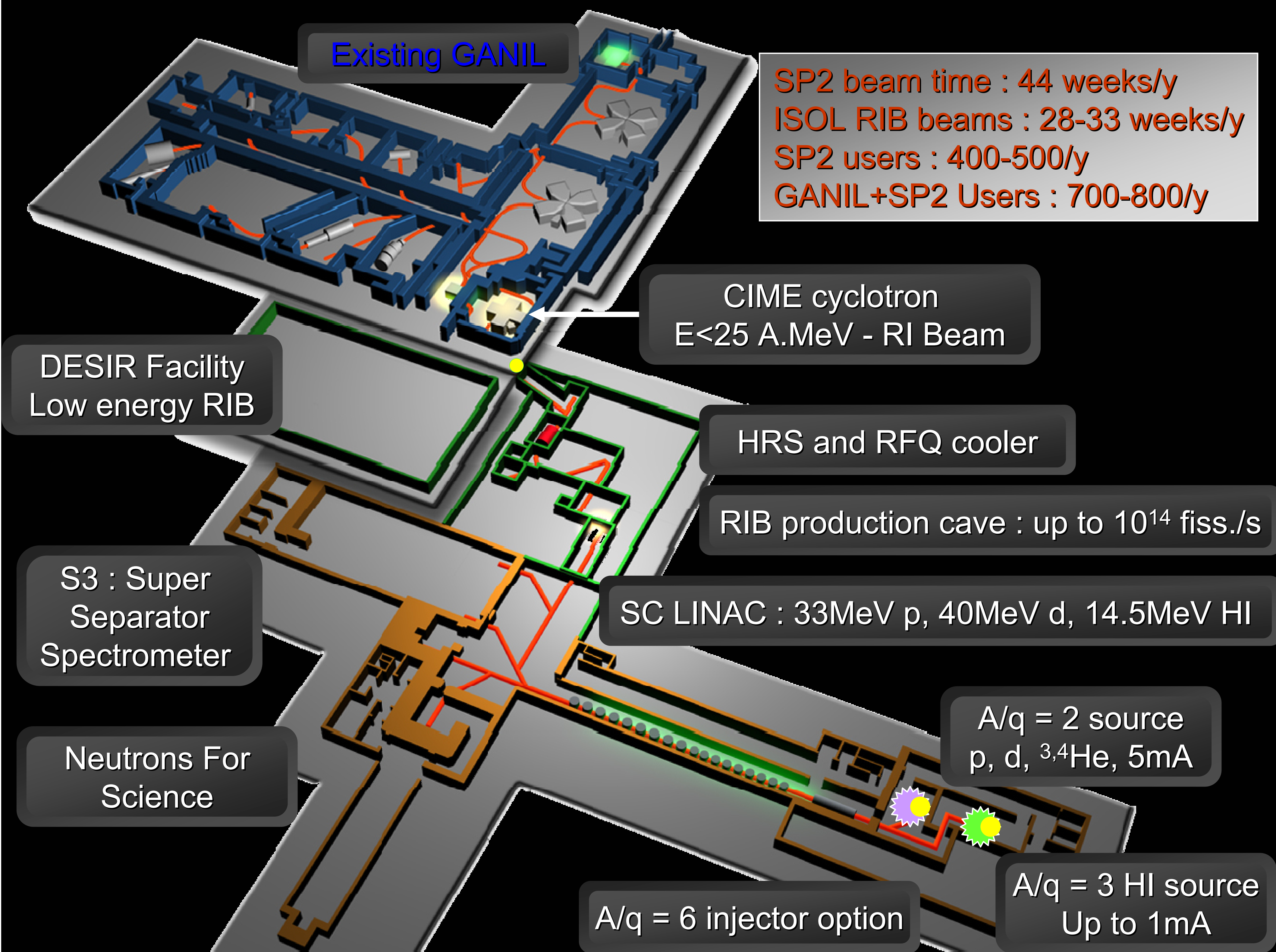
THE SPIRAL-2 SUPERCONDUCTING LINAC

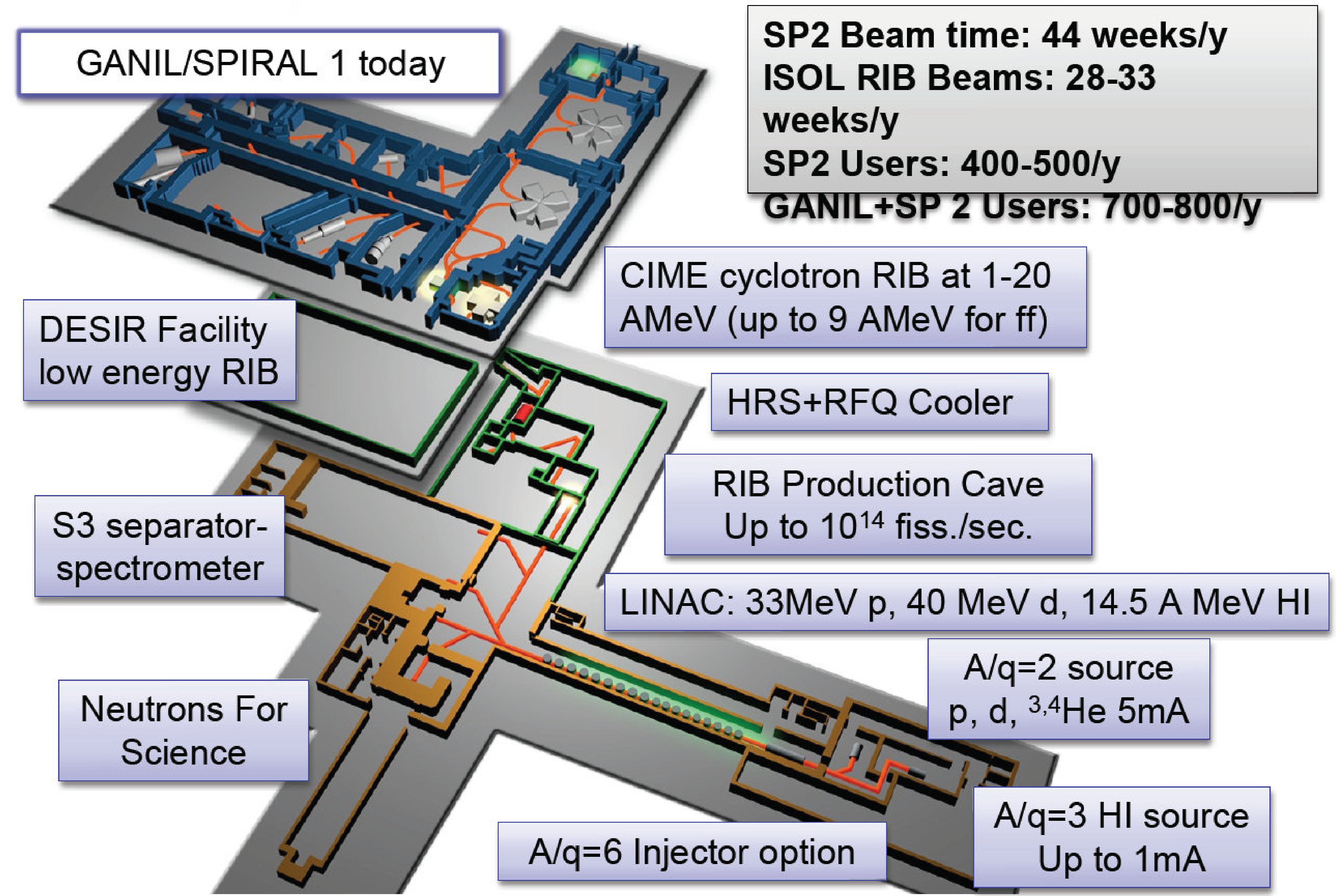
collaborations and contracts with the industries

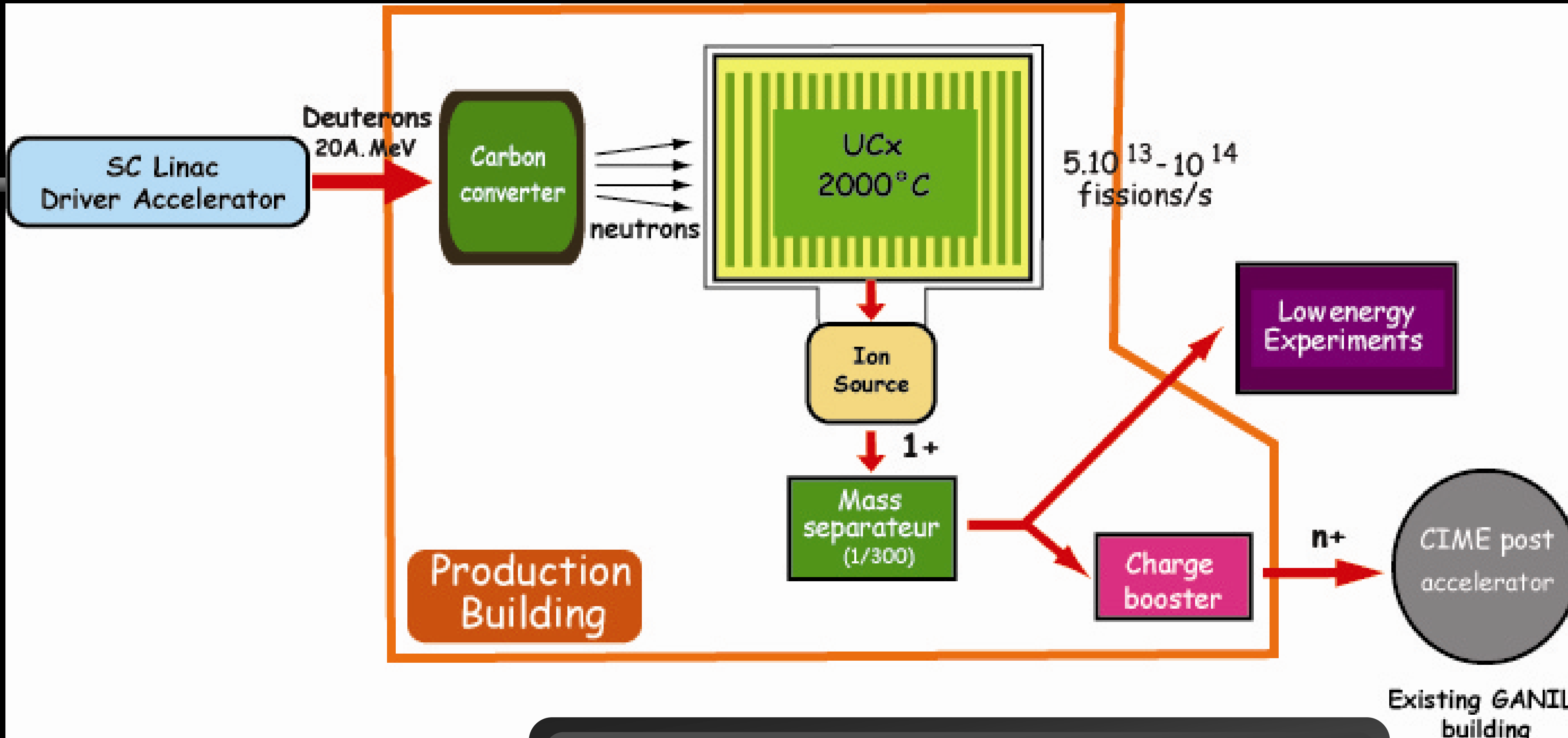
R. Ferdinand
On behalf of the SPIRAL 2 project group
PAC 2009, Vancouver

- SPIRAL 2
- Industry's involvement
- The SPIRAL 2 driver sub system descriptions

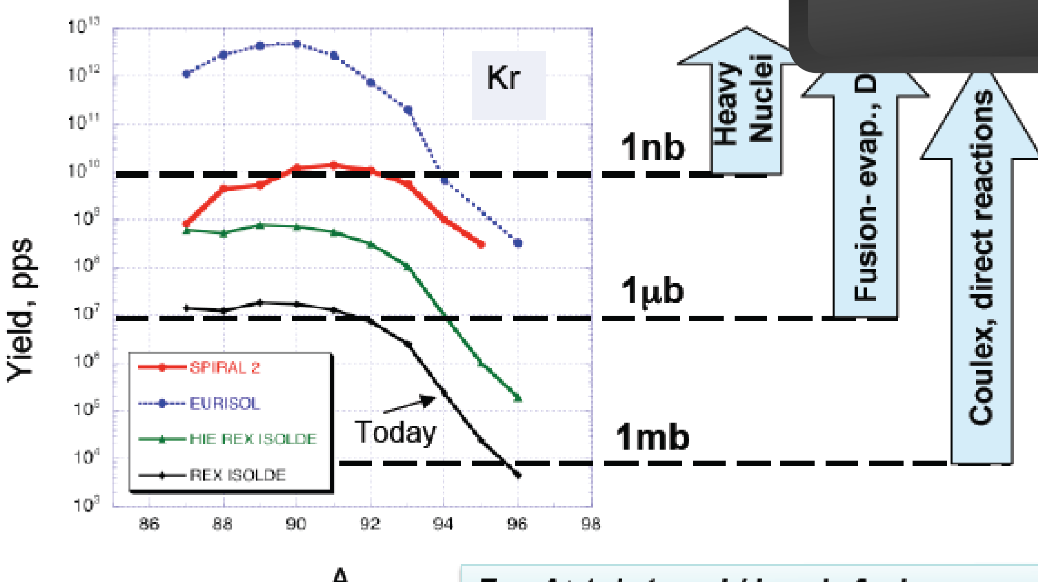



Existing GANIL
SP2 beam time : 44 weeks/y
ISOL RIB beams : 28-33 weeks/y
SP2 users : 400-500/y
GANIL+SP2 Users : 700-800/y
CIME cyclotron
E<25 A.MeV - RI Beam
DESIR Facility
Low energy RIB
HRS and RFQ cooler
RIB production cave : up to 10^{14} fiss./s
S3 : Super Separator Spectrometer
SC LINAC : 33MeV p, 40MeV d, 14.5MeV HI
A/q = 2 source
p, d, ^{3,4}He, 5mA
Neutrons For Science
A/q = 3 HI source
Up to 1mA
A/q = 6 injector option


GANIL/SPIRAL 1 today
SP2 Beam time: 44 weeks/y
ISOL RIB Beams: 28-33 weeks/y
SP2 Users: 400-500/y
GANIL+SP 2 Users: 700-800/y
CIME cyclotron RIB at 1-20 AMeV (up to 9 AMeV for ff)
DESIR Facility low energy RIB
HRS+RFQ Cooler
RIB Production Cave Up to 10^14 fiss./sec.
S3 separator-spectrometer
LINAC: 33MeV p, 40 MeV d, 14.5 A MeV HI
A/q=2 source p, d, 3,4He 5mA
Neutrons For Science
A/q=3 HI source Up to 1mA
A/q=6 Injector option



Production of Radioactive Ion Beams (ISOL method)



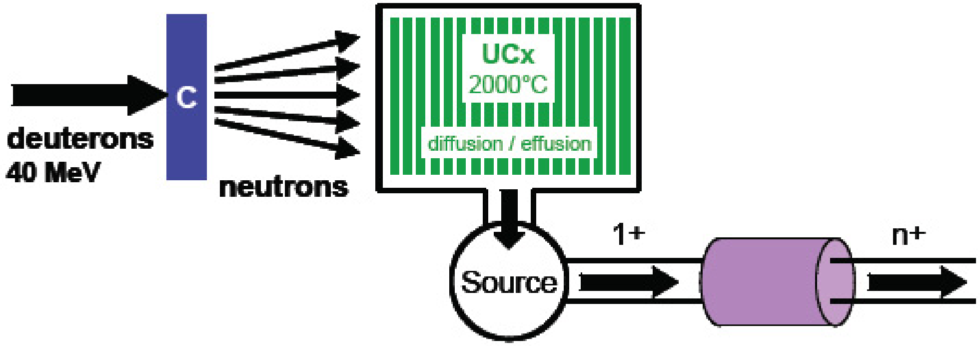
Ex.: At 1nb 1 nucl./day via fusion-evaporation

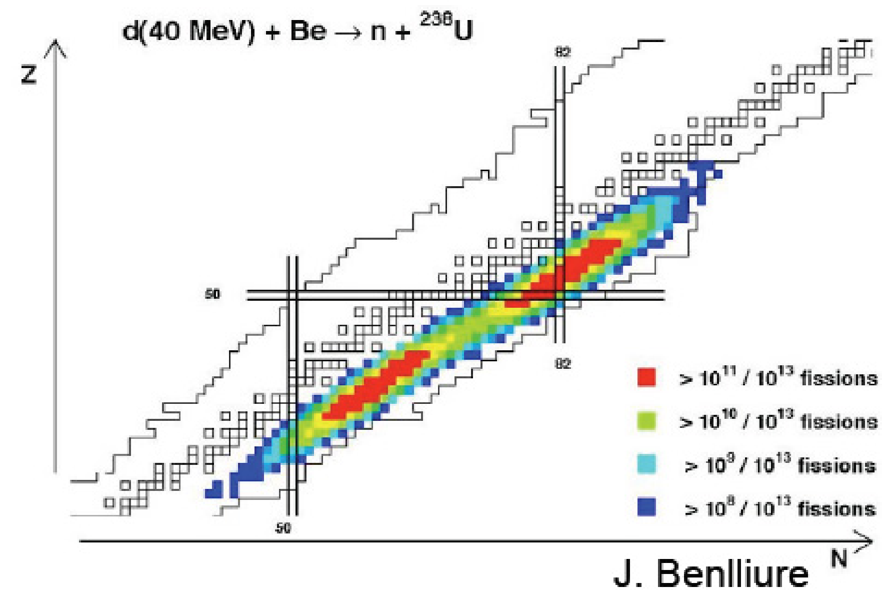
Expected yields: > 10^9 pps for ^{132}Sn

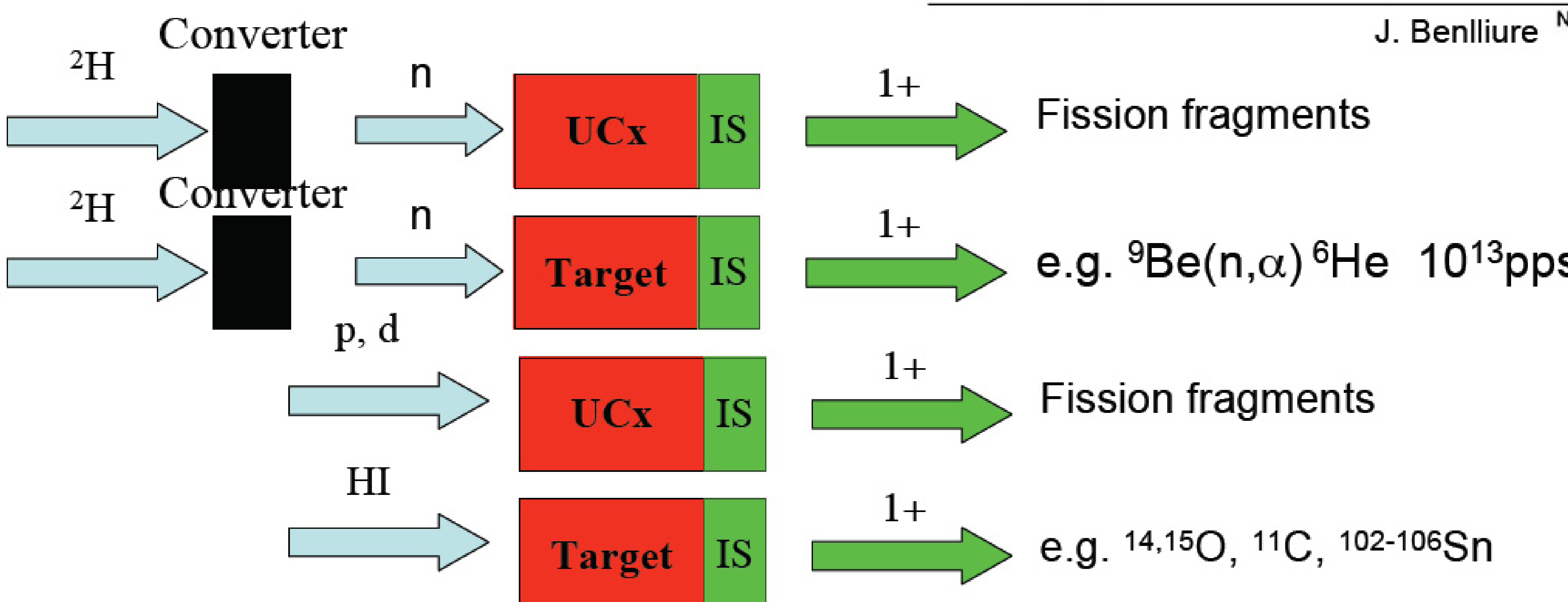
> 10^{10} pps for ^{92}Kr

- direct irradiation of the UCx target with deuteron beams for production of ^{3,4}He, ^{6,7}Li, or ^{12}C

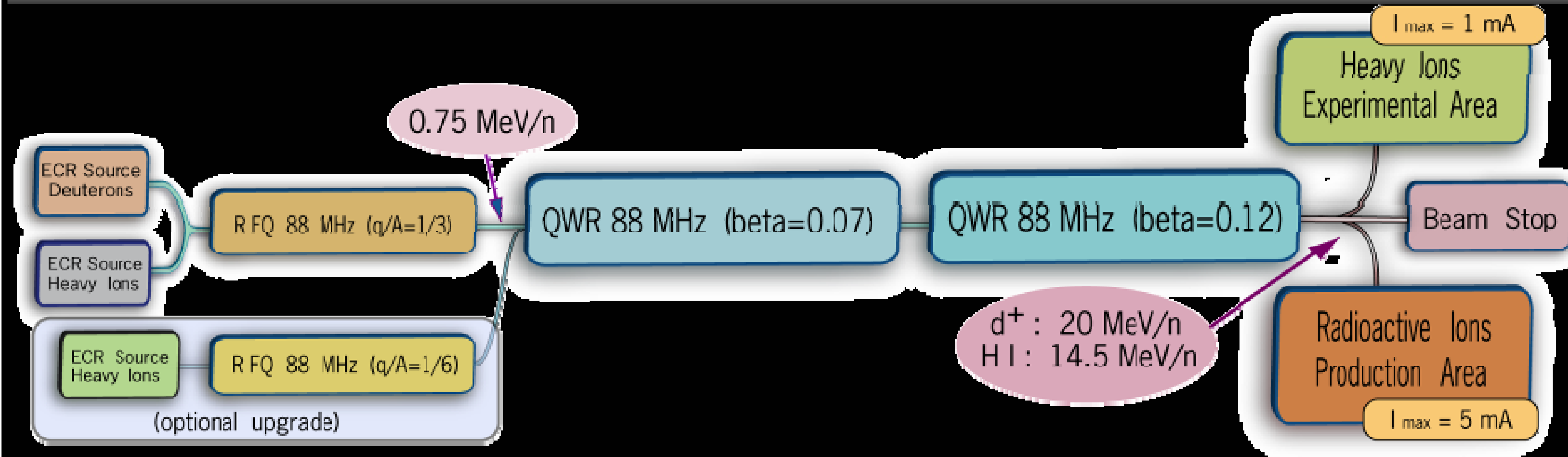
ISOL Rare Isotope Beams at SPIRAL 2







Accelerator Baseline Configuration



Particles	**p⁺**	**D⁺**	**Ions**	
Q/A	1	1/2	1/3	1/6
I (mA) max.	5	5	1	1
W_O min. (Mev/A)	2	2	2	2
W_O max. (Mev/A)	33	20	14.5	8.5
CW max. beam power (KW)	165	200	44	48

Total length: 65 m (without HE lines)

D^+ : ECR ion source
Heavy Ions : ECR Ion Source
Slow and Fast Chopper
RFQ (1/1, 1/2, 1/3) & 3 re-bunchers

12 QWR beta 0.07 (12 cryomodules)
14 (+2) QWR beta 0.12 (7+1 cryomodules)
1 kW Helium Liquifier (4.2 K)
Room Temperature Q-poles
Solid State RF amplifiers (10 & 20 KW)
6.5 MV/m max $E_{acc} = V_{acc}/(\beta_{opt}\lambda)$ with $V_{acc}=\int E_z(z)e^{i\omega z/c}dz$.

SPIRAL 2 construction

- Do we have technology transfer ?
- Innovating technologies imposes to developed a strategy between the laboratories and the industry
- Development cycle in the project
  - Construction of prototypes
  - Tests and validation
  - Pre-series with industrial partner
  - Series constructions

Activities sharing on SC linac

	Laboratories
CMA Cryostat and Cavity design	CEA Saclay
Assembly and test CMA	CEA Saclay
CMB Cryostat and Cavity design	IPN Orsay
Assembly and test CMB	IPN Orsay
A and B cavities chemistry	CEA Saclay
Clean room/HPR	CEA (proto), IPN (qualif)
Couplers	LPSC Grenoble
Alignment cavities and Cryomodules A	CEA Saclay et GANIL
Alignment cavities and Cryomodules B	GANIL
Valves box	IPN Orsay
Cryogenics	IPN Orsay
Vacuum	GANIL
coordination	GANIL

Industries involvement in accelerators

- Consider commercial companies to participate into the design phase of an accelerator project ?
  - Few companies able to design
    - Challenging projects
    - Pushing the performances
  - Commercial companies
    - Maintain very small development team
    - face a reasonable return on investment expectation
    - need a critical size, adapted organization
    - Activities aside from the mainstream, but could become a technological “showcase”

Industries involvement in accelerators

- Different if there is a chance for series production,
  - cyclotron business
    - isotope production
    - medical applications
  - series production of SC cavities for electrons and ions accelerators (XFel, ILC…)
- Long delays between the initial design ideas and the formal decision to proceed to the construction
- Difficult for the private companies to
  - appreciate the risk,
  - pay the shareholder’s dividend
  - maintain a development team.

What about SPIRAL 2

- They are industrial collaborations inside the project, but at a different level.
- It is becoming important for the project team to improve and develop these aspects
- Technology transfer requires from the accelerator staff a range of expertises
  - quality assurance,
  - legal approach,
  - finance,
  - intellectual property

Situation concerning the project

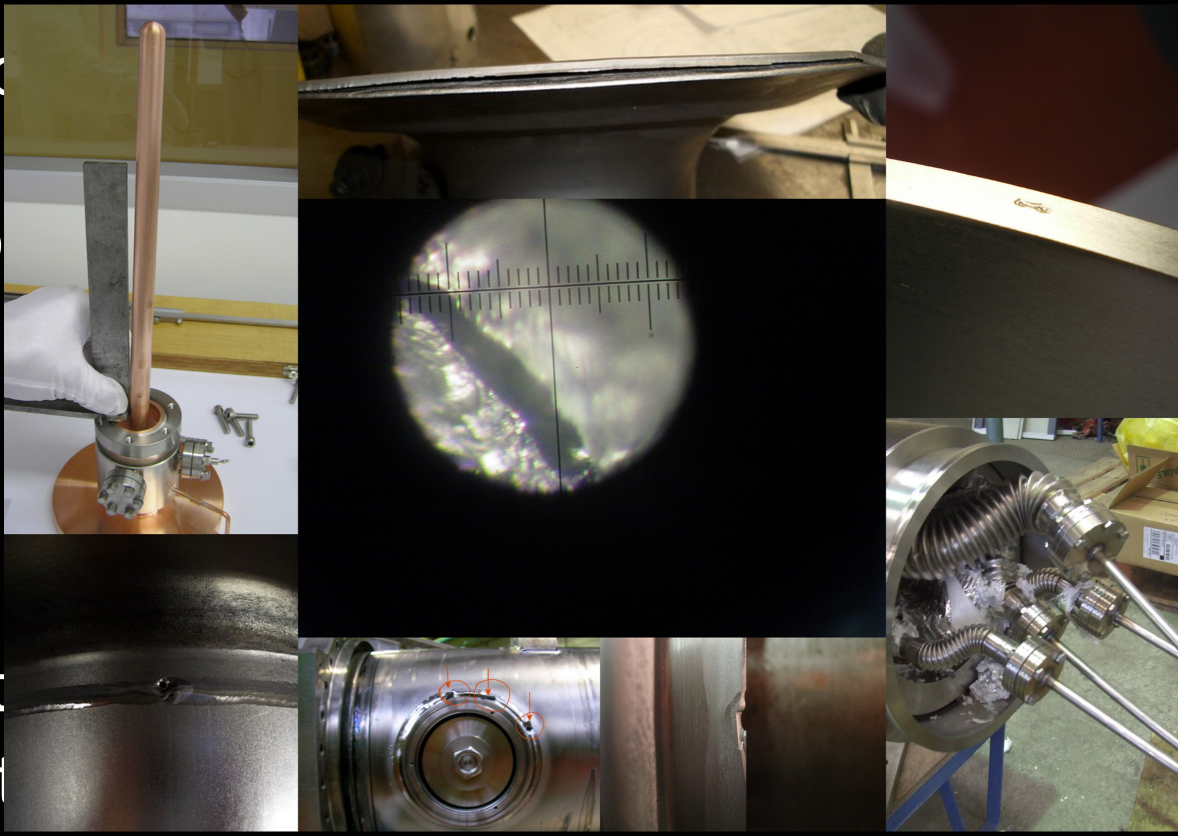
- CEA and CNRS institutions have largely improved their infrastructure equipments
  - We are de facto the R&D developers
  - Fabrications of components stopped in the laboratories and ordered to the industry
  - Sharing of know-how and the associated transfer of technology
- Supratech
  - Test stands in Orsay and Saclay
  - R&D in superconducting and cryogenic systems activities
  - An important component of the strategy for the partnership with private companies
  - Actively used for SPIRAL 2

Industrial contributions to SPIRAL-2

- contribute to the fabrication of prototypes and serial SC components
- interaction allowed to introduce a large number of improvements needed to achieve the specifications of many innovative devices
- RI GmbH (ACCEL), ZANON, SDMS, ACS, Db Elettronica, CRYODIFF, etc

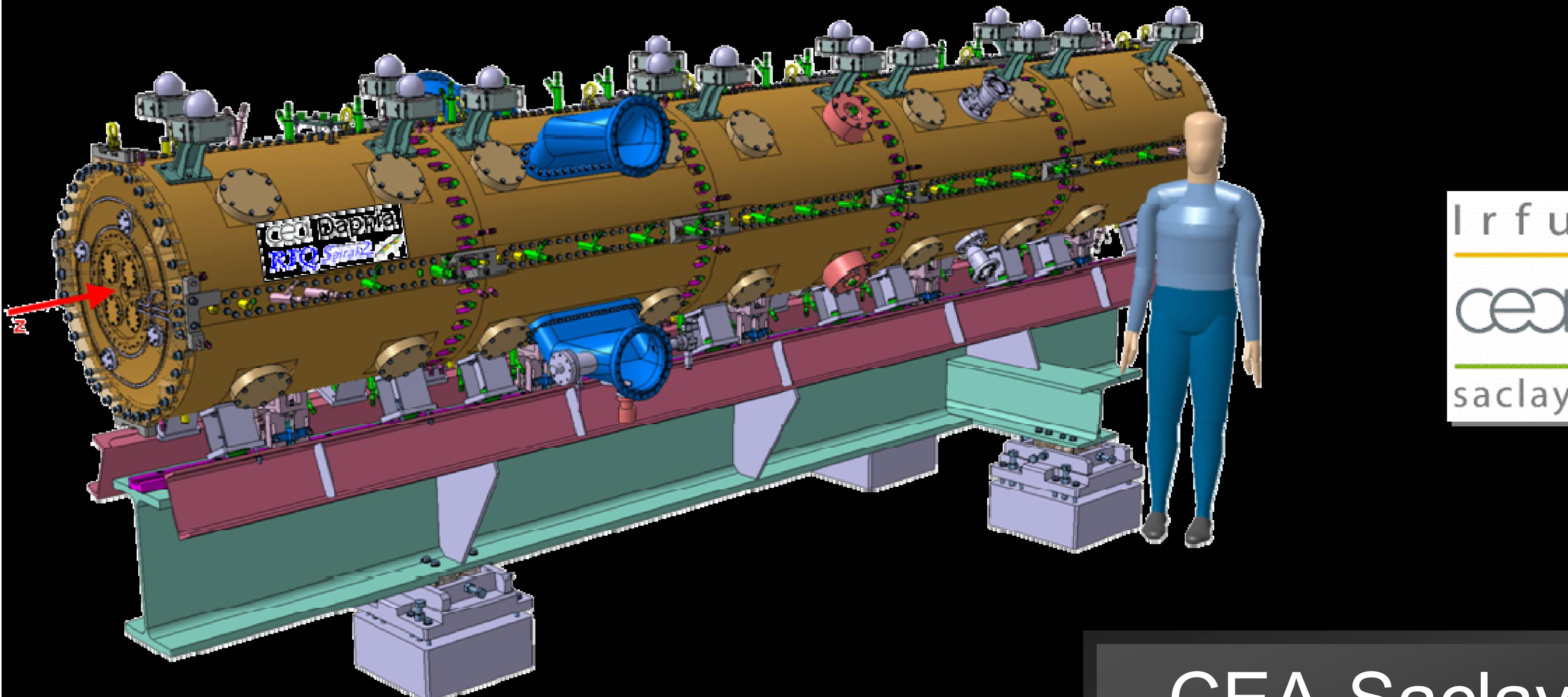
How we move from proto to series

- The goals are to respects the specifications, costs and schedule with minimisation of nonconformities
- Quality insurance
  - IS0 9001 accreditatio
    advantage
  - SP2 minimised asso
    associated costs
  - Difficulties exists : la
    tolerances
- Planning
  - schedules have to fit
  - commercial and cont



Examples on major driver sub systems

RFQ



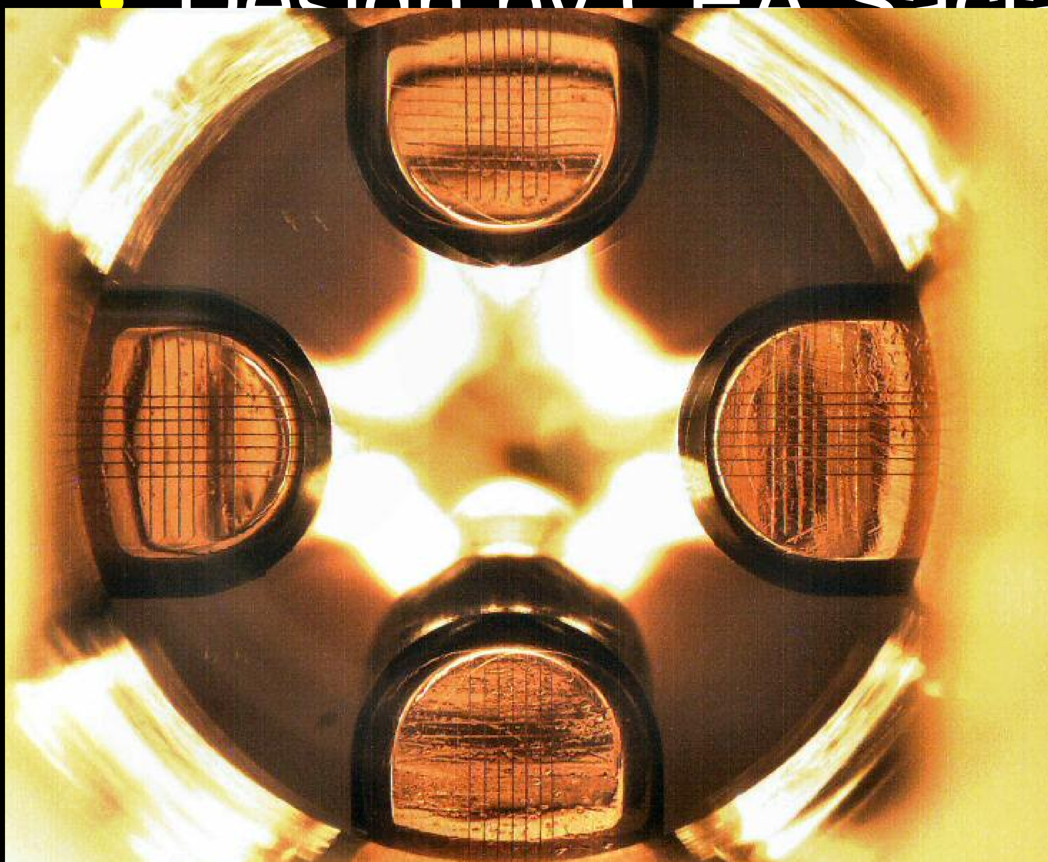
CEA-Saclay
JC Toussaint

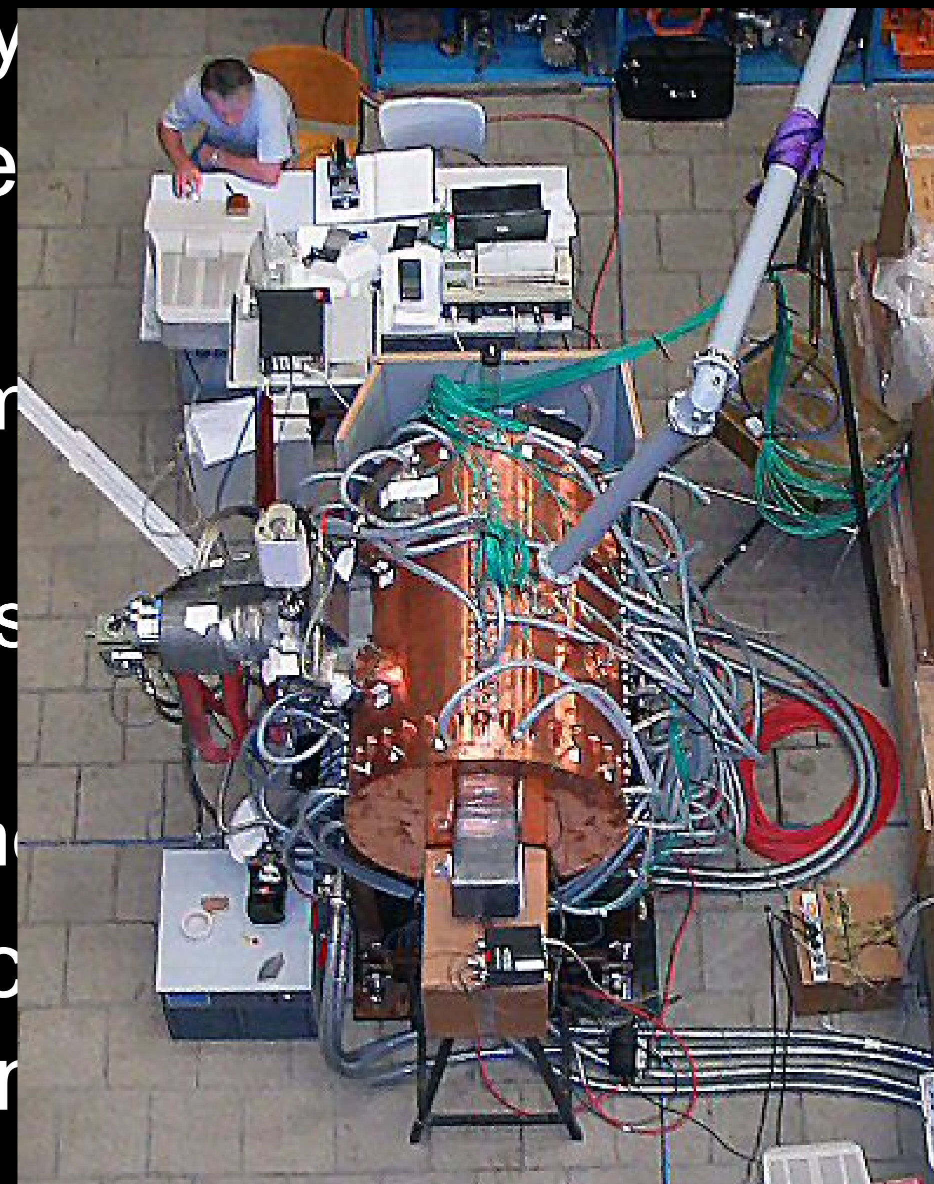
RFQ description

- Design by CEA Saclay
- 1-m prototype designed and tested at full power
  - Assembled RFQ, 25µm on the vane modulations
  - Designed for 36kW, tested up to 50kW (3 times 1 to 3 weeks)
  - Vanes displacement measured ($\sigma \approx 0.6\mu m$)
- RFQ is under construction by RI GmbH, with some other systems

RFQ description

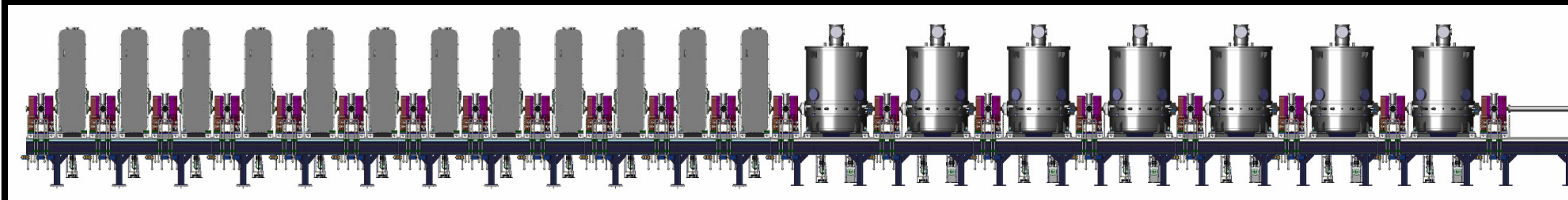
- Design by CEA Saclay



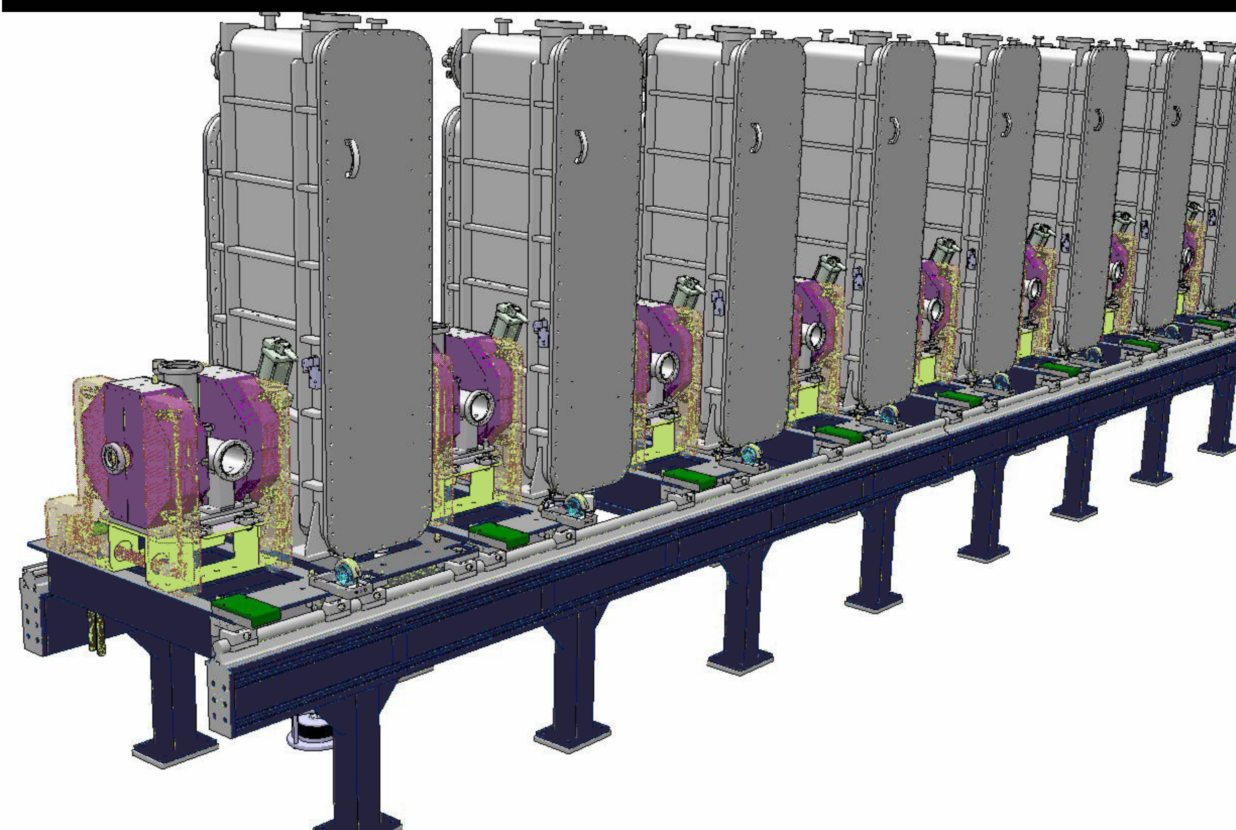


- RFQ is under construc
with some other syster

The SC accelerator sub system



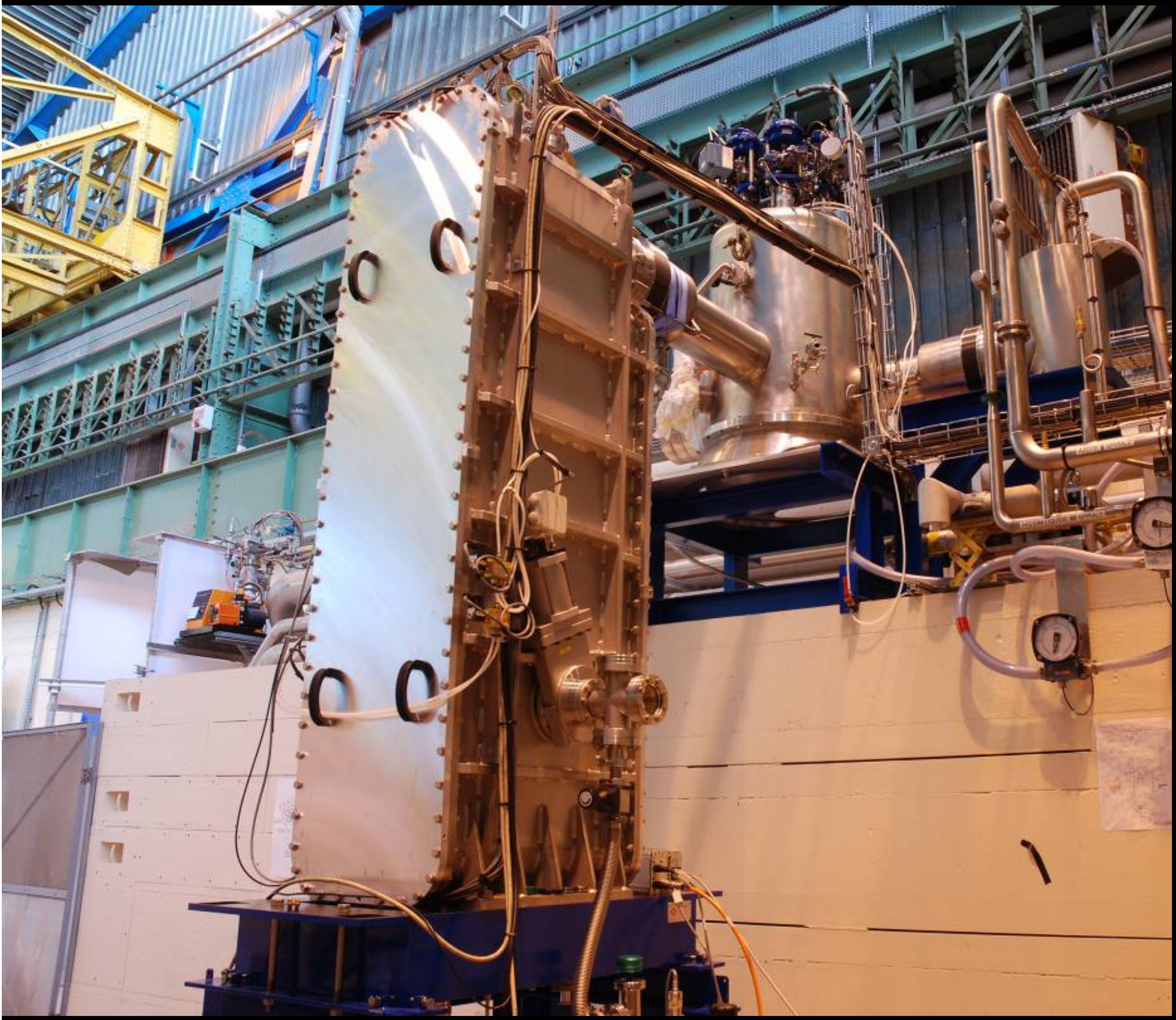
12 low beta cryomodules (0.07) and 7 high beta cryomodules (0.12)
35 m



similar development programs

- a first qualification cryomodule designed
- assembled and tested before the series production
- Qualification cryomodules must reach the specs.
- Series manufactured industrially
- Preparations and tests in the respective labs

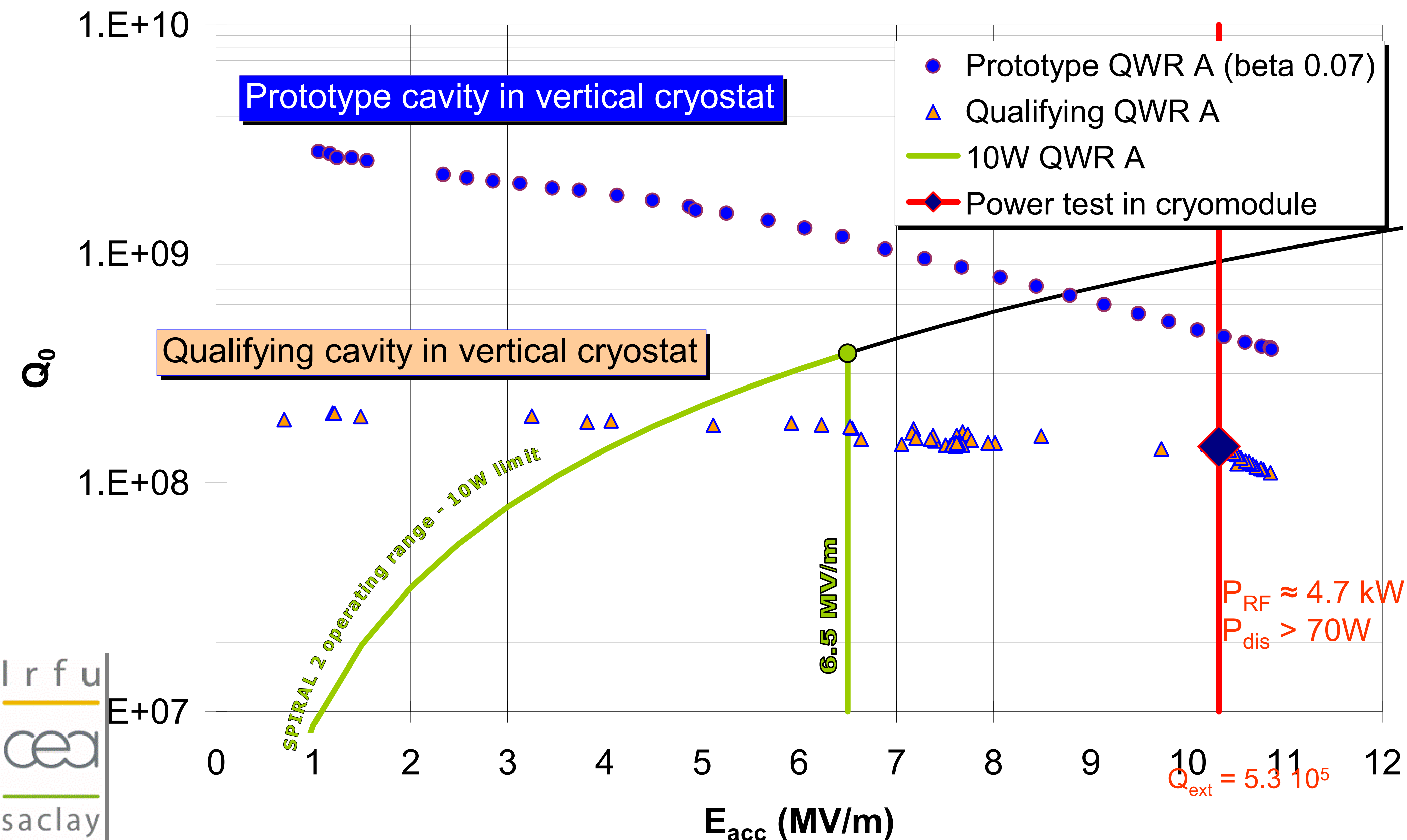
Cryomodules A - $\beta = 0.07$



CEA-Saclay
P. Bosland

Low beta cavity performances

Maximum gradient reached during the first RF power tests: 10.3MV/m



Irfu cea saclay

Status

- Cavities :
  - Order of the series placed in June 2008:
  - 1st step:
    - One cavity manufactured by ZANON
    - One cavity manufactured by SDMS
    - One received, to be tested
  - 2nd step:
    - Order of the series to ZANON or SDMS (or both) after the test in vertical cryostat of the first two cavities

- Cryostats :
  - Order should be placed in June 2009 !

RF power tests of the cryomodule

HPR rinsing and clean room assembling in the IPN Orsay SupraTech clean room

Final assembling at Saclay

the cryomodule ready for the power tests

TU5PFP041

Cryomodule B - $\beta = 0.12$

IPN-Orsay
Hervé Saugnac

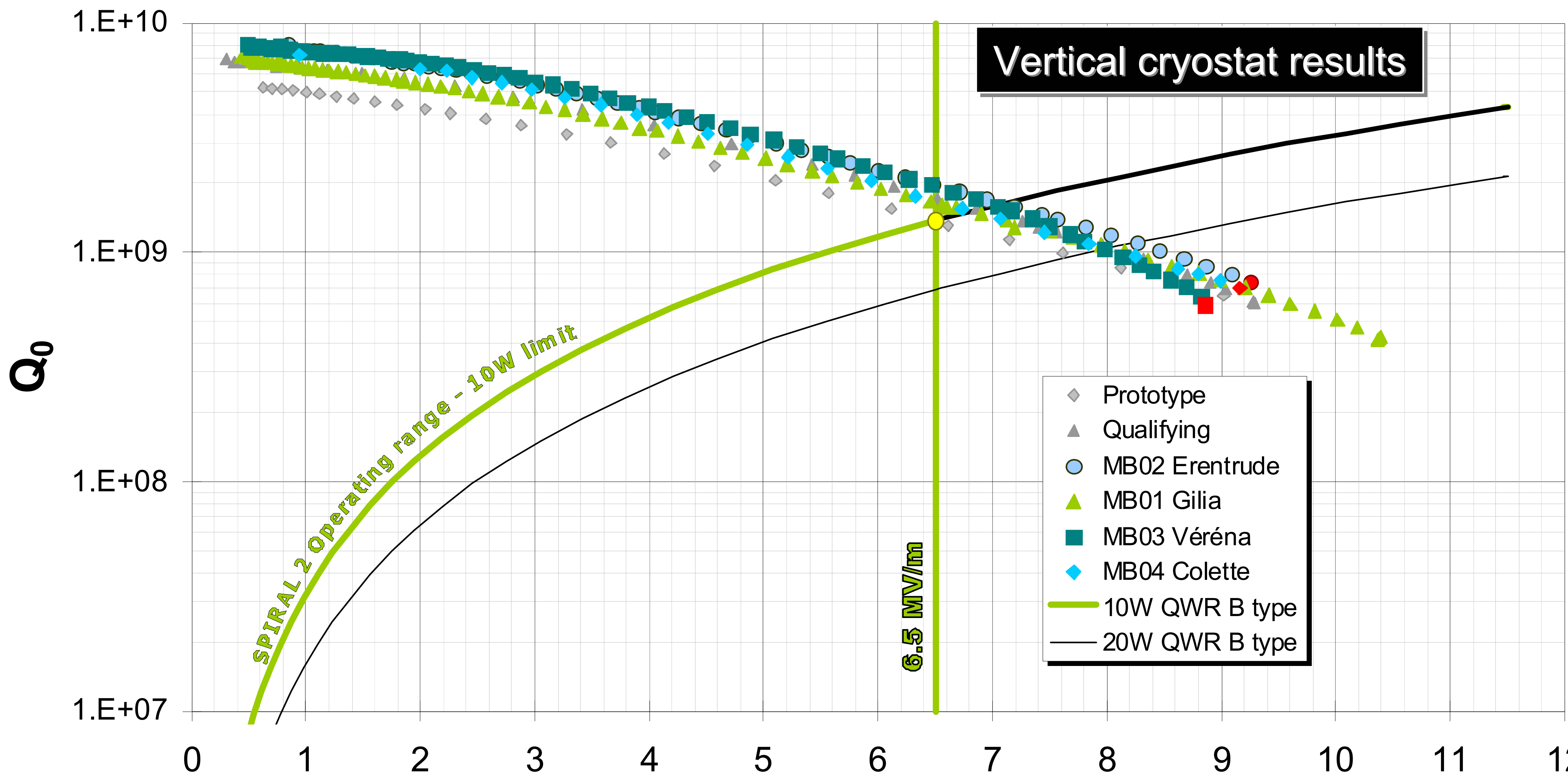
Cryomodules B - $\beta = 0.12$

- Company RI GmbH (ACCEL) selected for the 16 series cavities
  - First 6 cavities delivered
  - 4 already tested
  - Last one in January 2010

- Second call for tender for the cryostat done
  - SDMS to manufacture the 6 remaining cryostats
  - First cryostat expected End of 2009

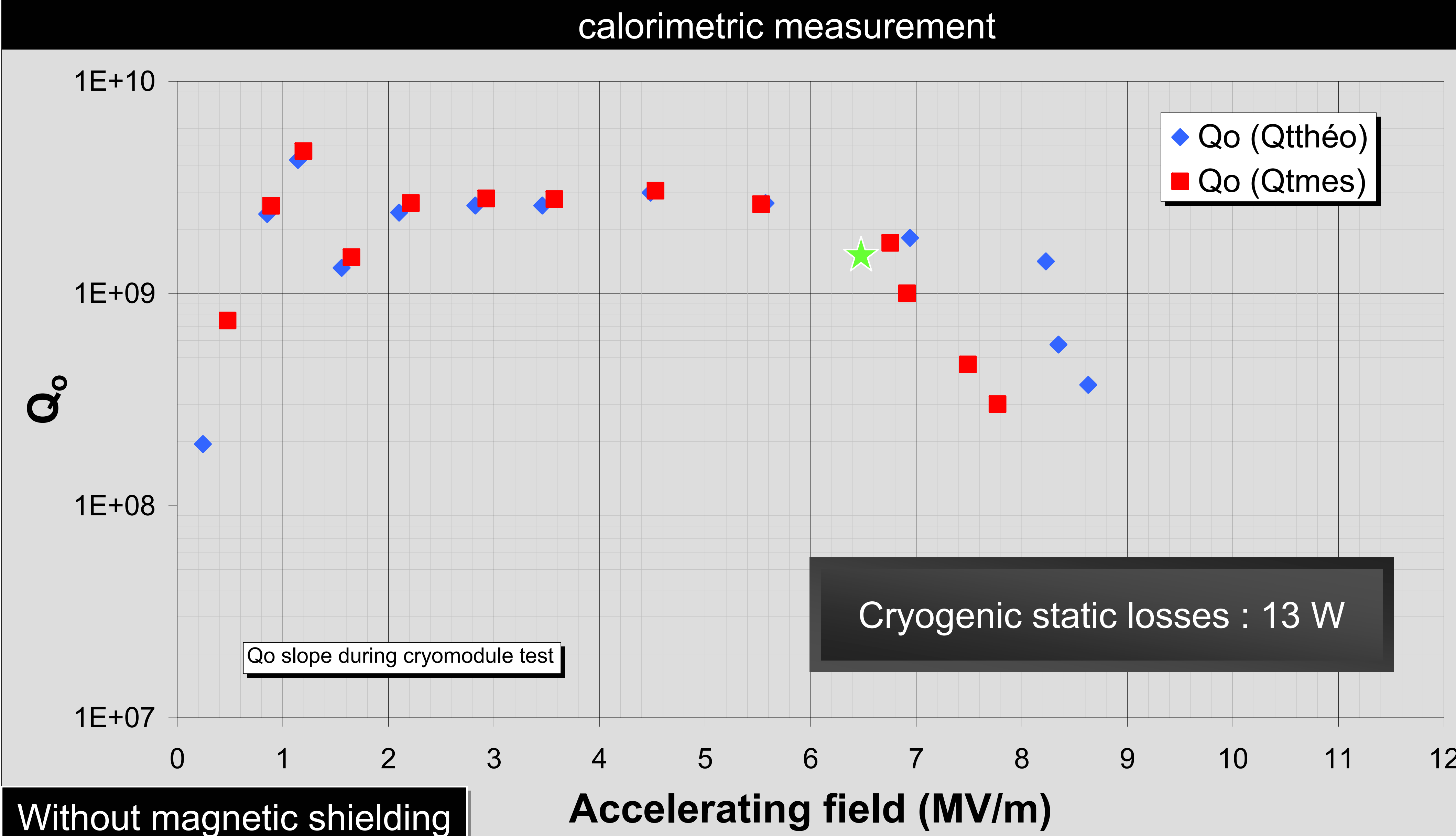
QWR B Tests

Very good sign of the company's mastery of the manufacturing procedures, and the IPN-Orsay team's cleaning and assembly procedures



QWR B (≅ = 0.12)

Power tests in the cryomodule



Without magnetic shielding

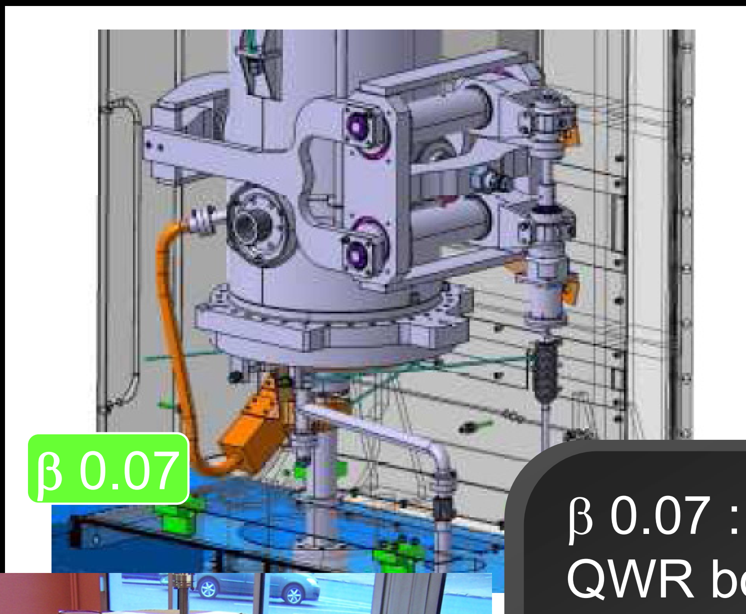

Valves box
Cryomodule
Pollution tests


Valves box
dule
lution tests

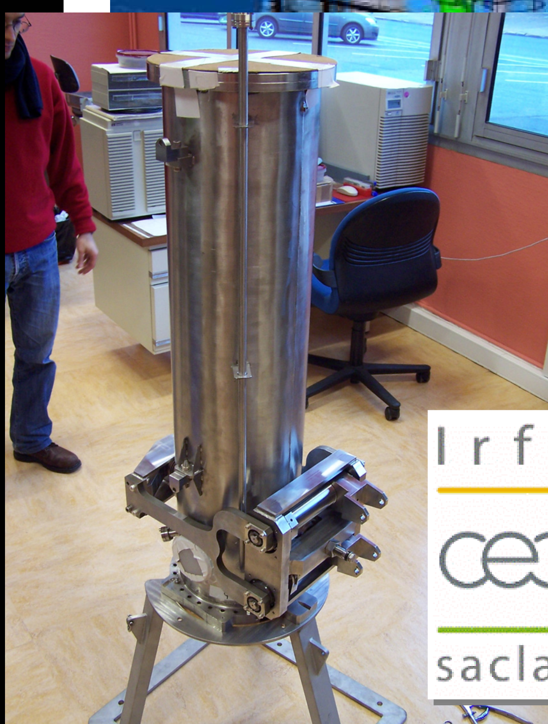
Static CMB helium consumption

- February 2008 : first measurement
  - Measurement : ≈ 13 W @4K (calculation ≈ 11 W)
  - Specs for the cryogenic system :
    - 10W @ 4K
    - 60W @ 80 K
- Some modifications were made in order to optimise this consumption.
  - Local modification where unwanted contact could arise
  - More 80K connection for a gain estimated around 2 W
- New calculated performances (measurement ongoing):
  - 4K ≈ 8.5 W
  - 80K ≈ 63 W

Cold tuning systems

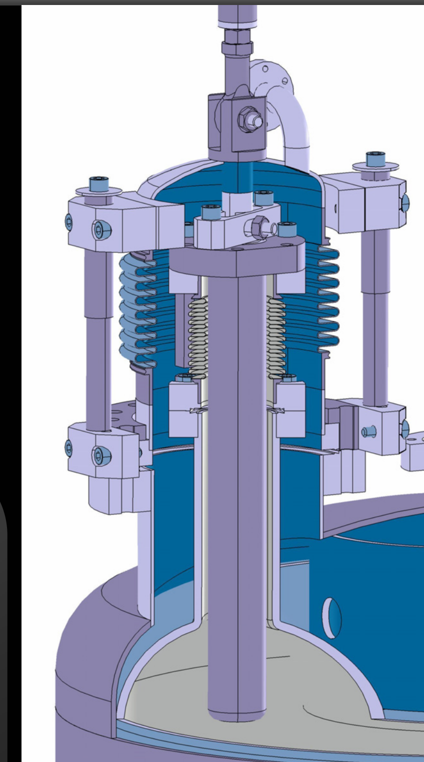


β 0.07

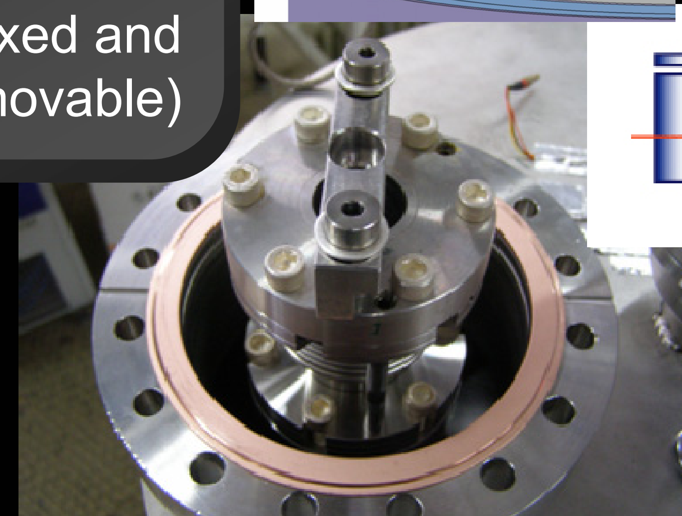


β 0.07 : mechanical tuner, QWR body deformation

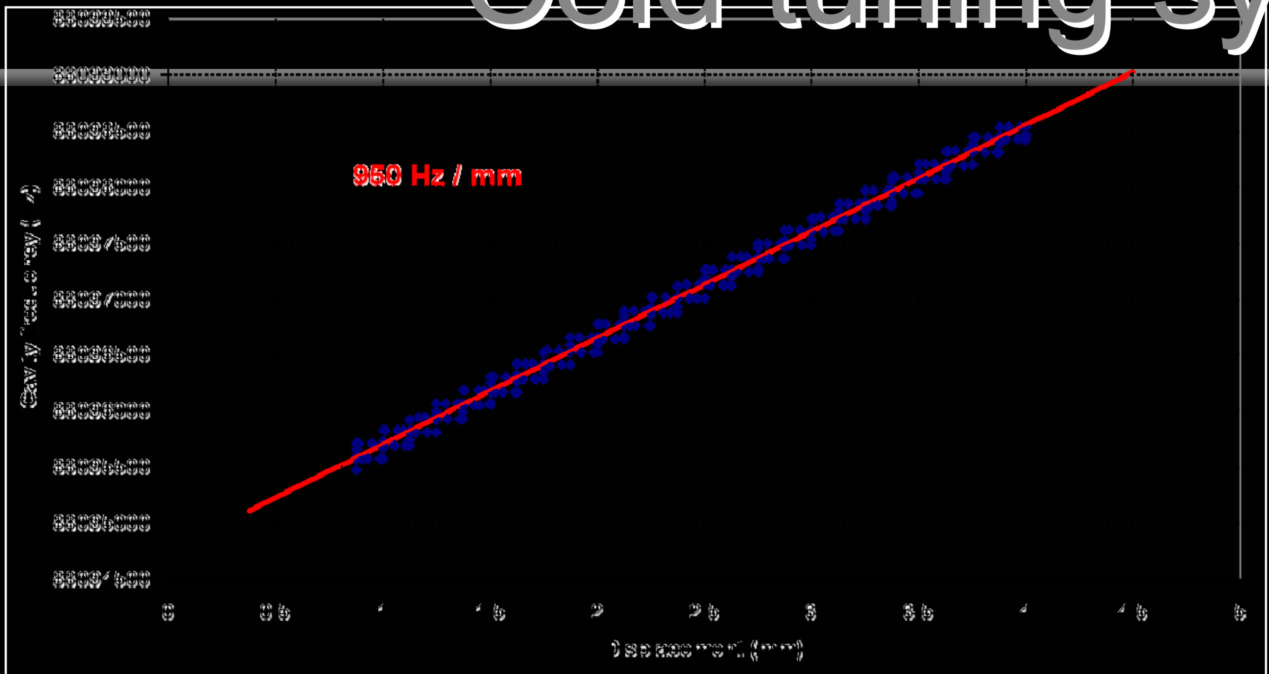
β 0.12 : plungers on QWR top volume (fixed and movable)



β 0.12

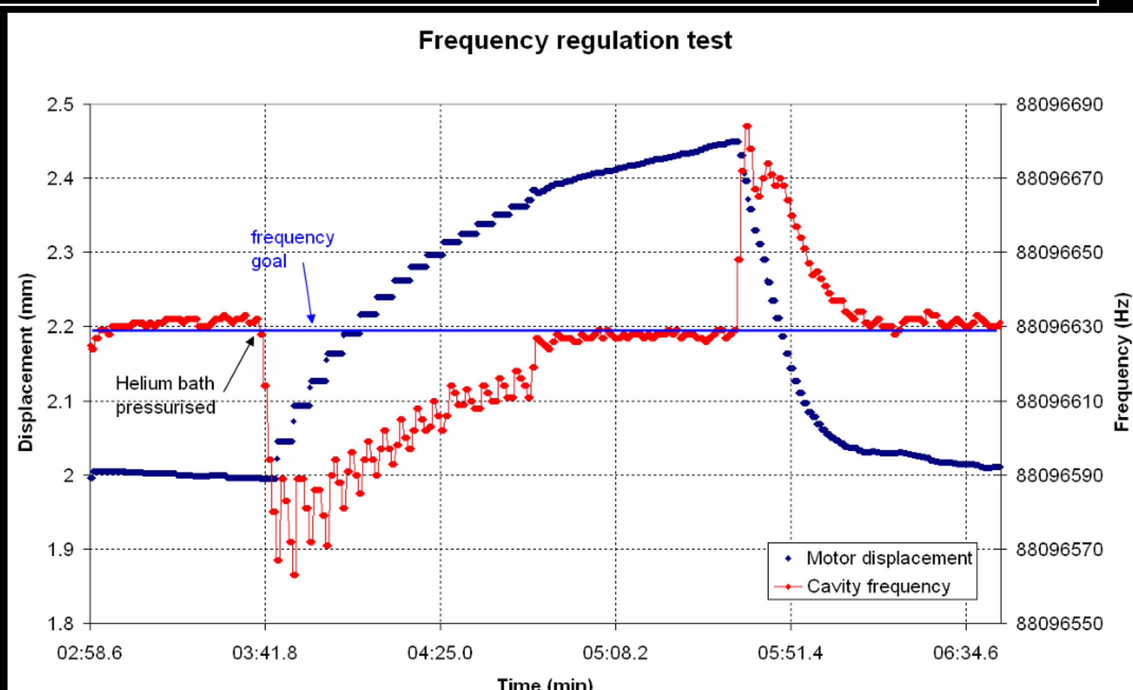


Cold tuning system



Very good linearity

Expected sensitivity



First tests of slow regulation

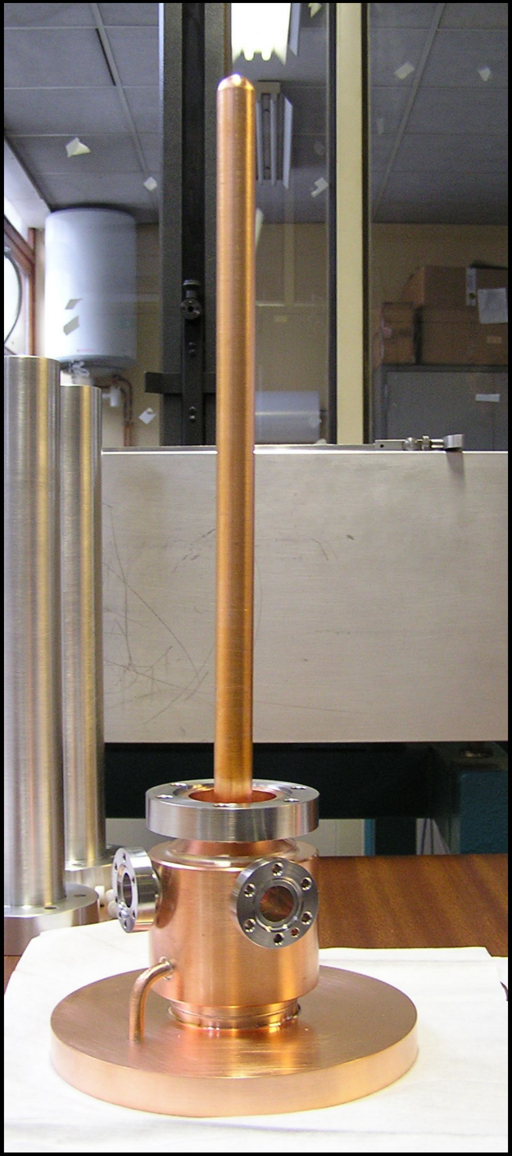
Power couplers

LPSC Grenoble
Y. Gómez-Martínez

Couplers description

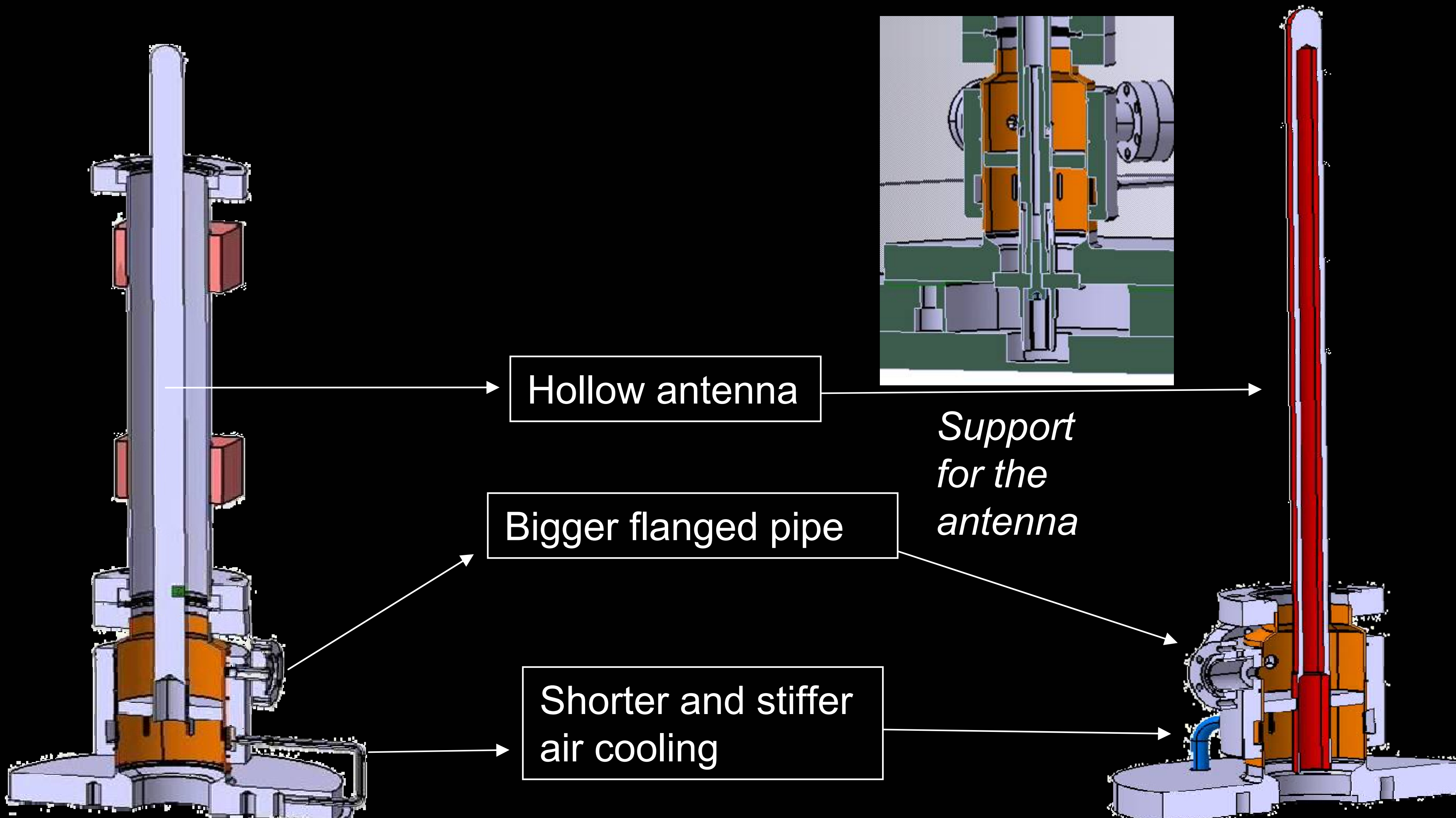
- Designed by LPSC Grenoble
- Up to 12kW CW @ 88MHz
- Fixed coaxial antenna
- Fixed coupling
- 1W on the cavity bottom
- 2 pre versions designed and tested, disk ceramic and cylindrical ceramic window
- Prototypes (disks) tested head to head 40kW
- Designed finally improved (TiN coating and hollow antenna)

Different versions



Coupleur design changes

Simulations show the improvement of the new design



Prototype coupler

New coupler

Status

- 5 prototypes tested
- Coupler conditioned up to 10 kW on the cavity (room temperature and 4K)
- SCT company won the call for tender
  - 30 couplers under fabrication
  - First 2 couplers had a too thick TiN coating

RF solid state amplifiers

GANIL

GANIL
M. Di Giacomo

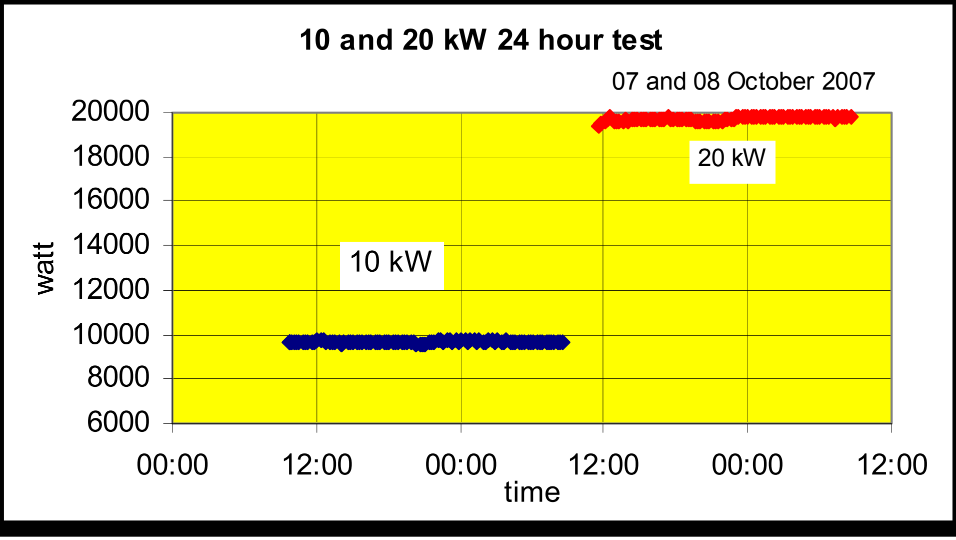
TU4RAI01

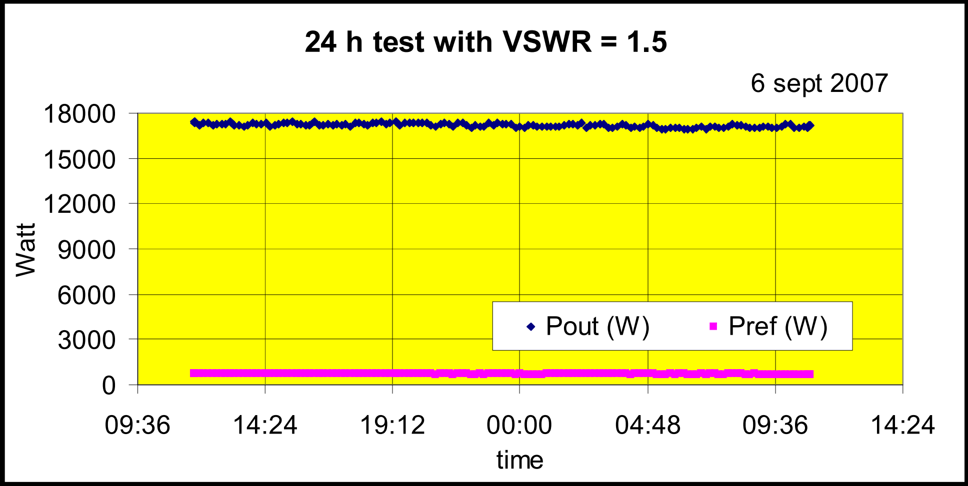
RF amplifiers

- Up to 20kW needed per cavity
- One of the example were we let the company make the design
- Prototypes architecture based on 2.8 kW racks, providing 5.5, 10 and 20 kW
- DB Elettronica provided one 10 and one 20kW prototypes
- Call for tender for the series to be soon released

Solid State Amplifiers - GANIL

10 and 20 kW amplifiers commissioned at GANIL on matched and mismatched load (VSWR >1.5 all phases)





20 KW, 88 MHZ - Test bench with variable VSWR

Used with success for the power tests on the cryomodules through the couplers

Conclusion

- The successful test of the superconducting accelerating structures has proven the concept of the SPIRAL-2 linac.
- All the tests performed on the elements demonstrate that industry is capable of delivering superconducting accelerator structures ready for testing.

Thank you