SPIRAL 2 RF SYSTEMS Status report

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laboratoire commun CEA/DSM CNRS/IN2P3

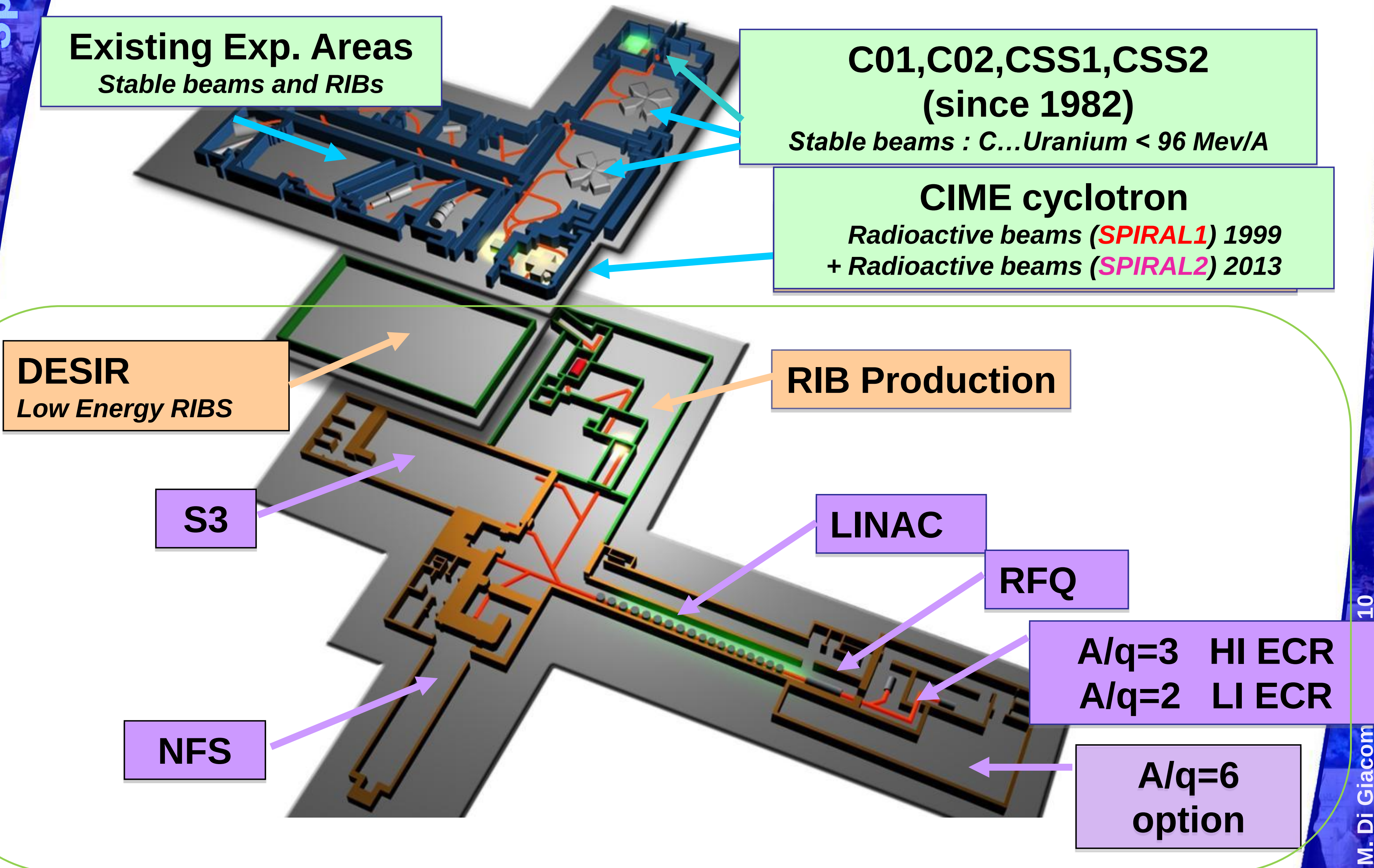
Contents

The SP2 Project

Second generation RIB facility, 190 M€ (man power included)
Very important investment with respect to the present GANIL

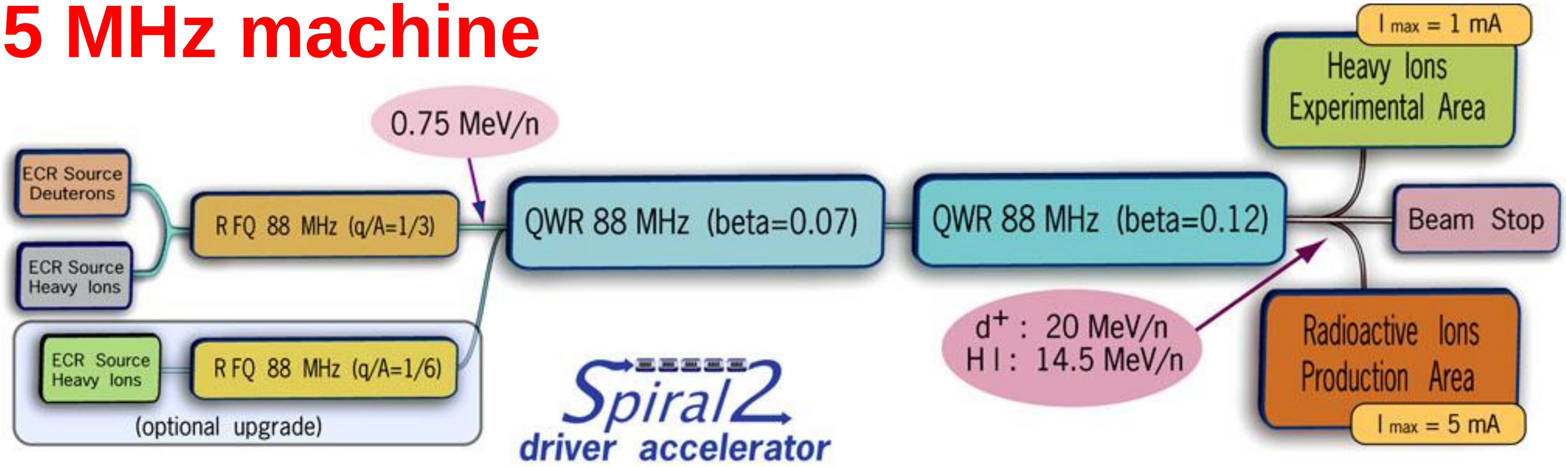
Digging begins this year,
Building available end of 2011
Linac tunnel at -9.5m, amplifiers at ground level

Facility Layout



Driver parameters

88.0525 MHz machine



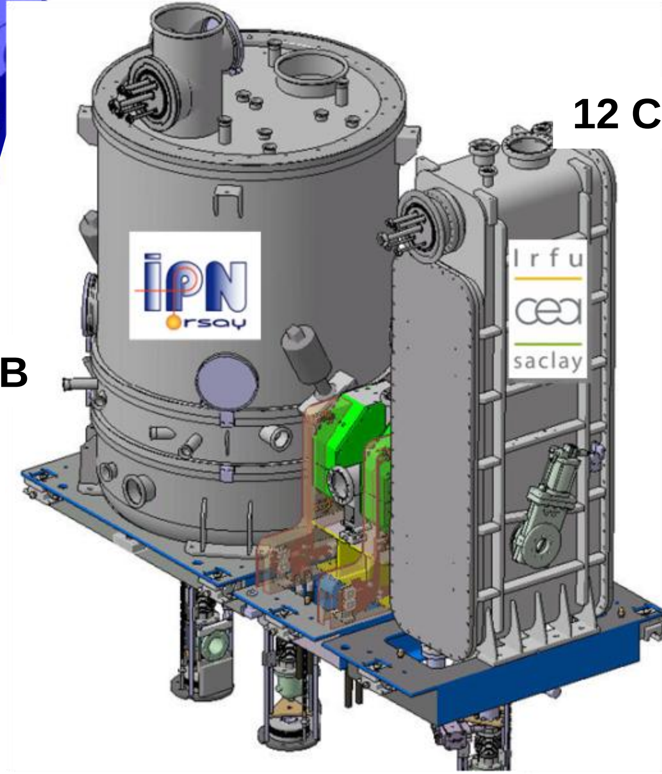
	Q/A	Intensity range (mA)	Energy range (Mev/u)	CW max beam Power (kWatt)
Protons	1	0 - 5	2 - 33	165
Deuterons	½	0 - 5	2 - 20	200
Ions	≥ 1/3	0 - 1	2 - 14.5	43.5
Ions	≥ 1/6 (1/7)	0 - 1	2 - 8.5	51

Also 3He1+ and 4He2+ for beam tests and physics…

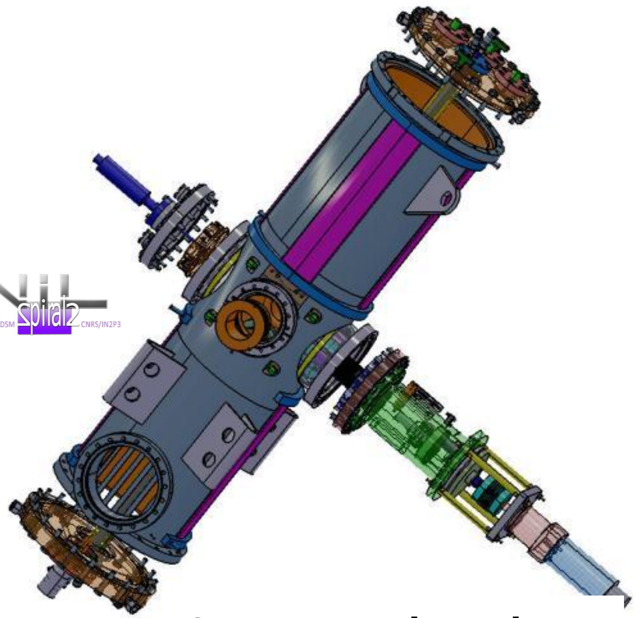
Cavities

12 CM A

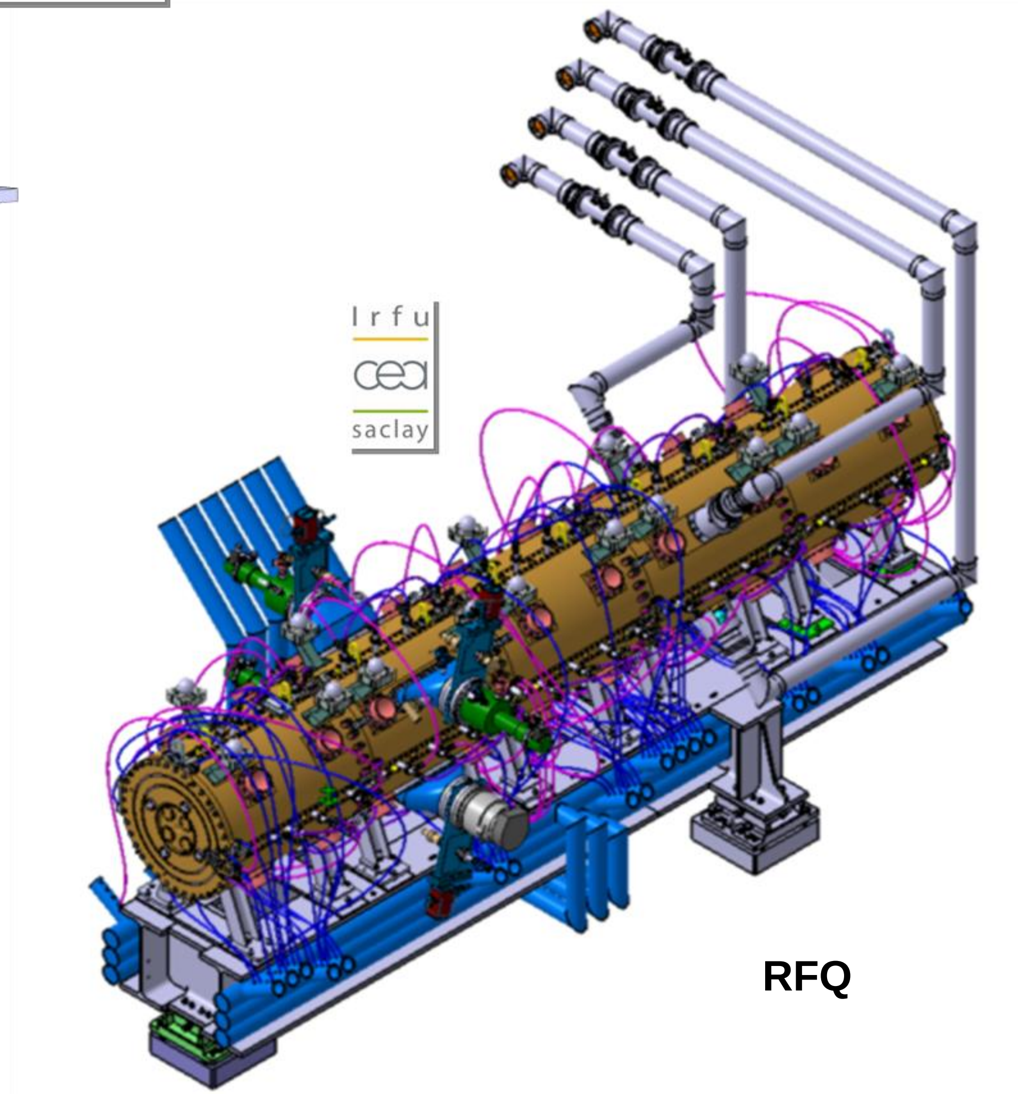
7 CMB



26 fixed, capacitive couplers



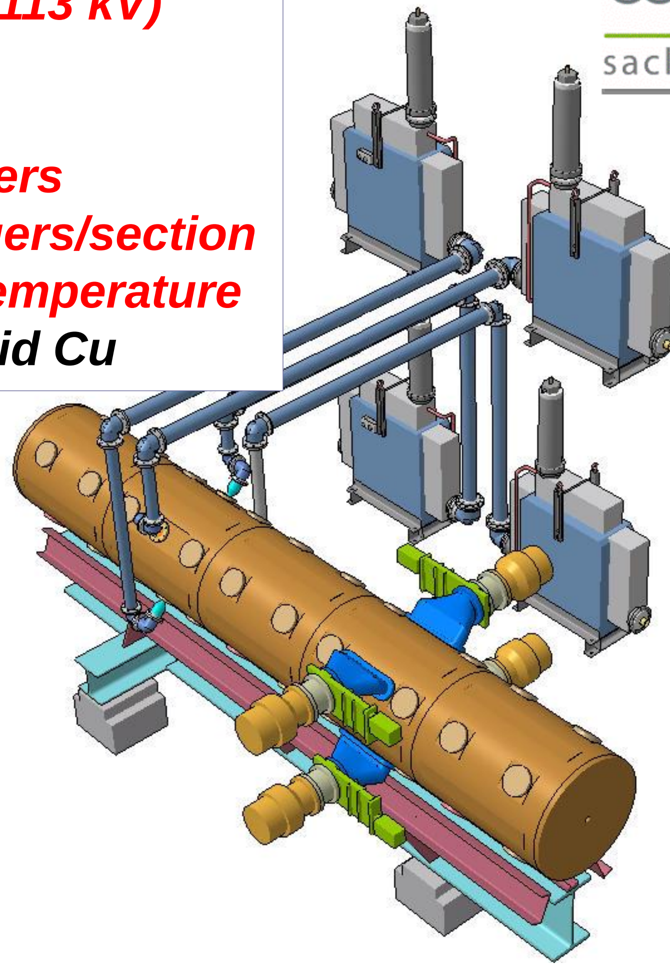
3 MEBT Rebunchers



RFQ

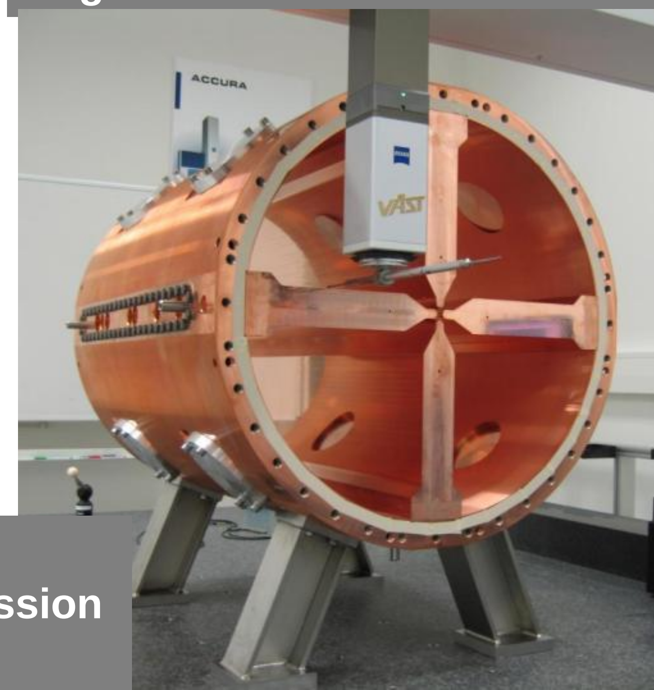
RFQ

- *4-vane RFQ (q/A: 1, 1/2, 1/3)*
- *Design: Saclay/IRFU*
- *P = 160 ÷ 200 kW (@113 kV)*
- *Qo = 14000*
- *4 input couplers*
- *Independent amplifiers*
- *Voltage low: 8 plungers/section*
- *Fine tuning: water temperature*
- *Manufactured in Solid Cu*



Irfu cea saclay

Segment S5 under construction

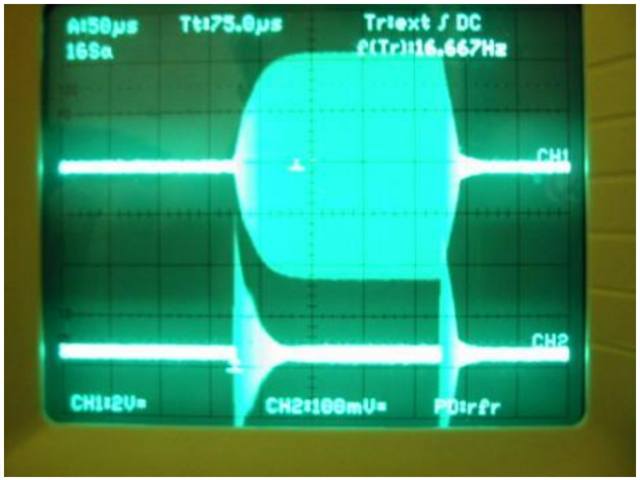


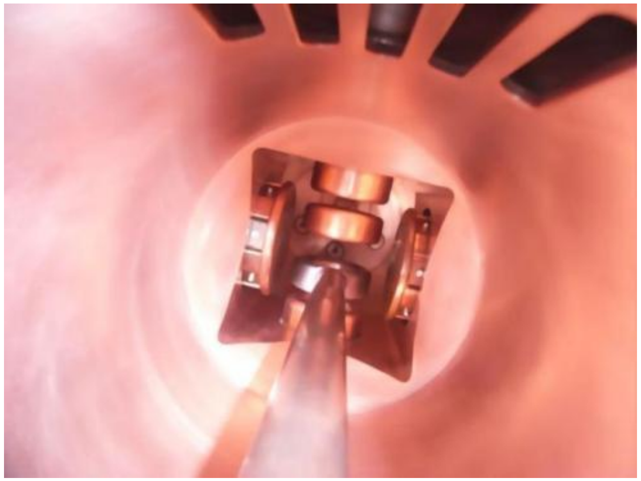
- S5: delivered soon
- Other segment planning: under discussion
- 4 inductive couplers in S4

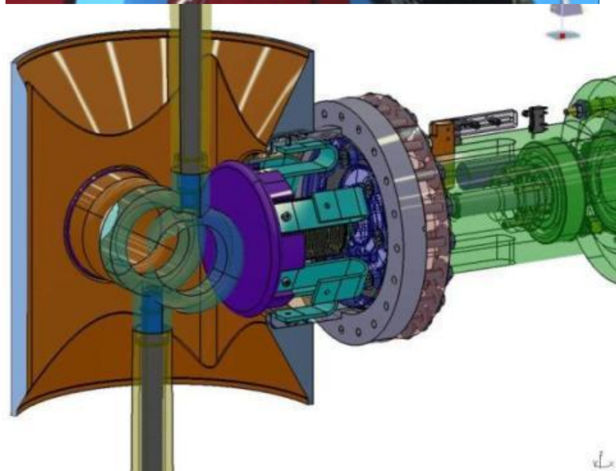
MEBT Rebuncher

- *3 gap RF structure*
- *HW tank, QW stems*
- *Design: Ganil*
- *Manufacture : SPG + Corima*
- *P = 4.5 kW @ 120 kV$_{beam}$*
- *Qo = 7500*
- *Cu plated stainless steel tank*
- *Solid Cu internal element*
- *Straight stems (vs split ring) for easier cooling*
- *Cu braids instead of sliding contacts (short stroke)*

- First cavity delivered (to used as R2)
- RF Test in progress
- R1 and R3 planned by March 2011







CMA

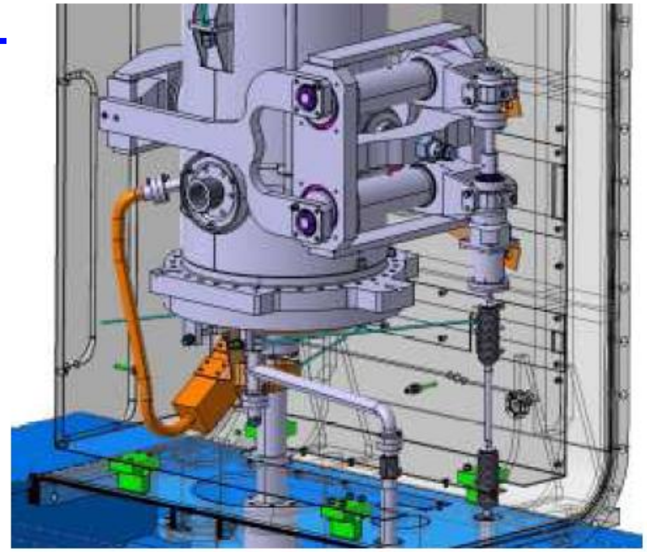
QWR , 2-gaps

6.5 MV/m Max Eacc

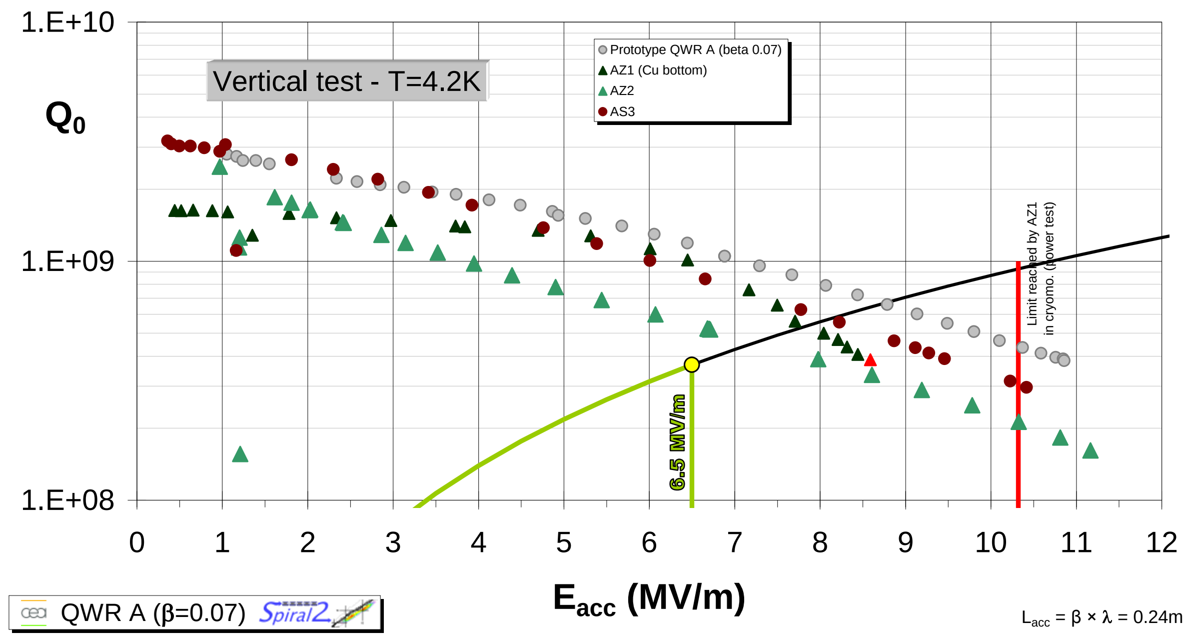
Tuner : deformation of the outer tank

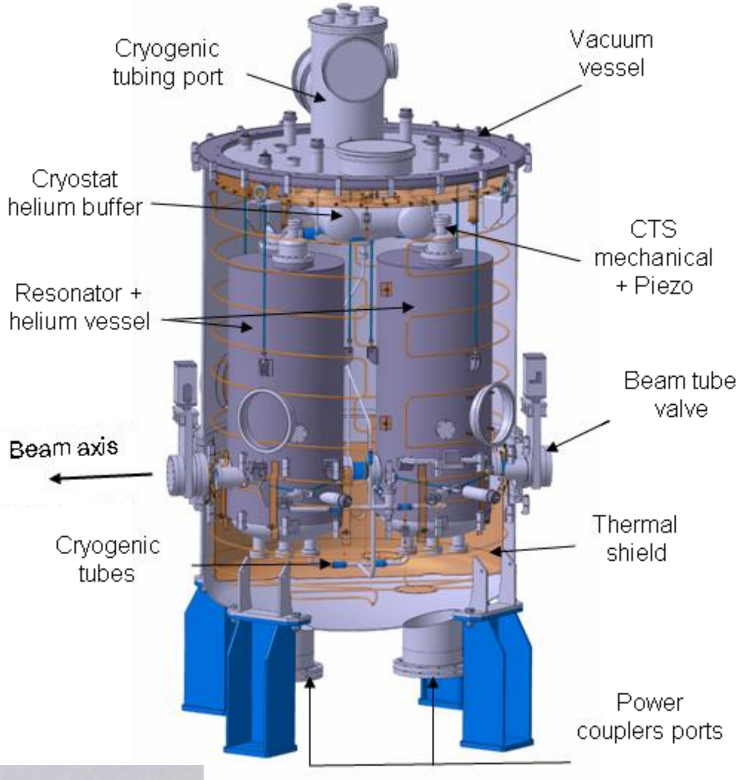
Capacitive coupler

- First CMA ready
- 1 CM/1.5 months

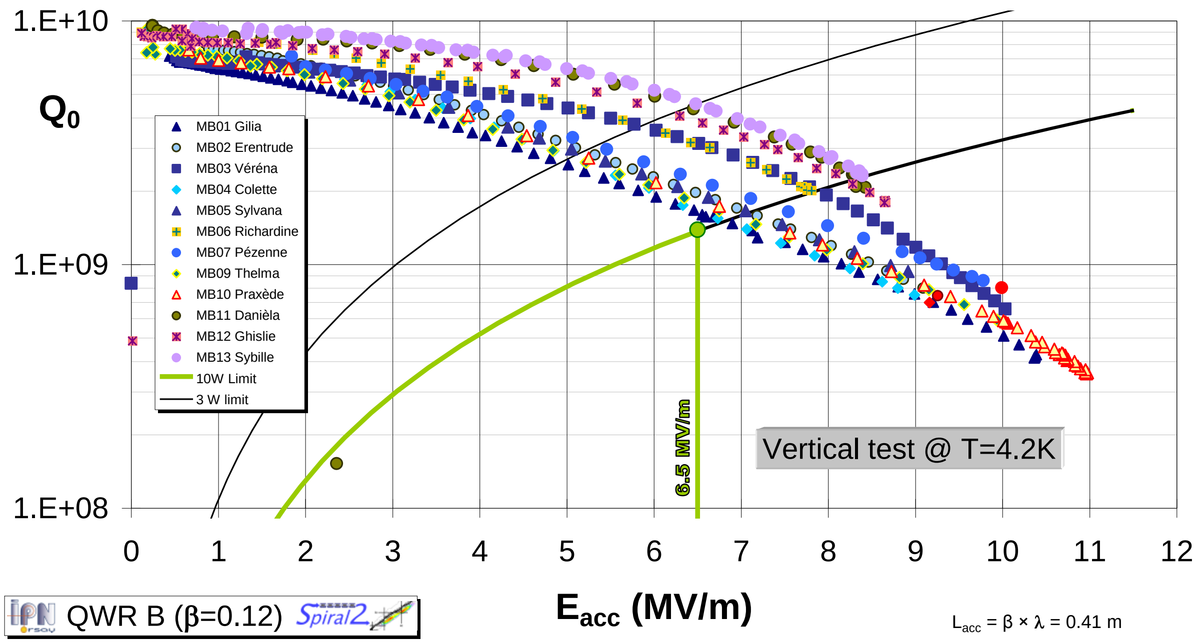


Maximum gradient reached during the first RF power tests: 10.3MV/m

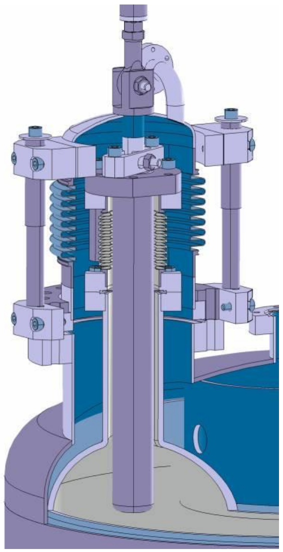




Maximum gradient reached during the first RF power tests: 8MV/m but no H shield

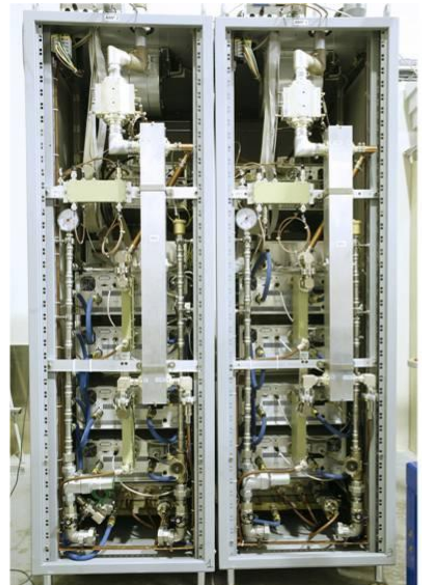


Power coupler

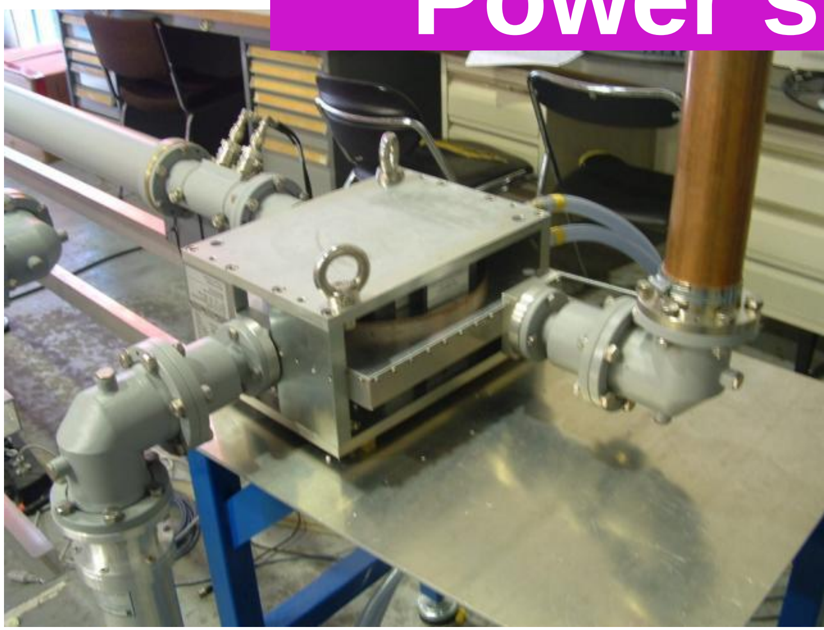


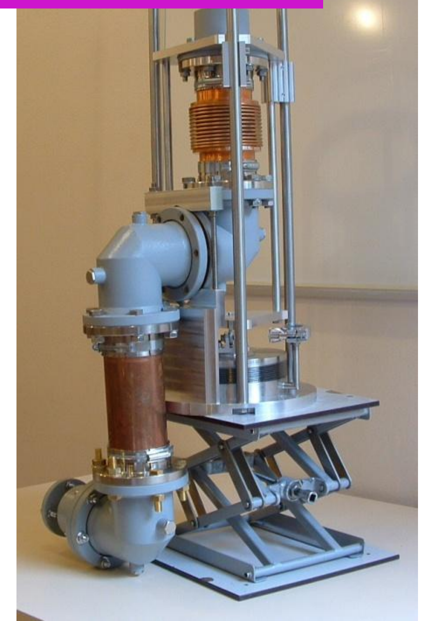
tuner

Power Systems



Power systems

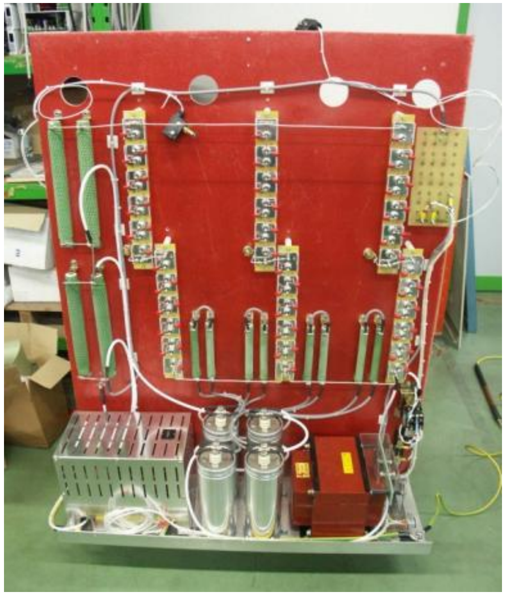




RFQ Amplifier : 4x 60 kW amps

- **60 kW each, pulsed and CW,**
- **Two stages:**
  - **3 kW solid state driver**
  - **TH535 Tetrode, 10 kV HV supply TH 18546 final stage cavity**
- **CPU: Siemens PLC**

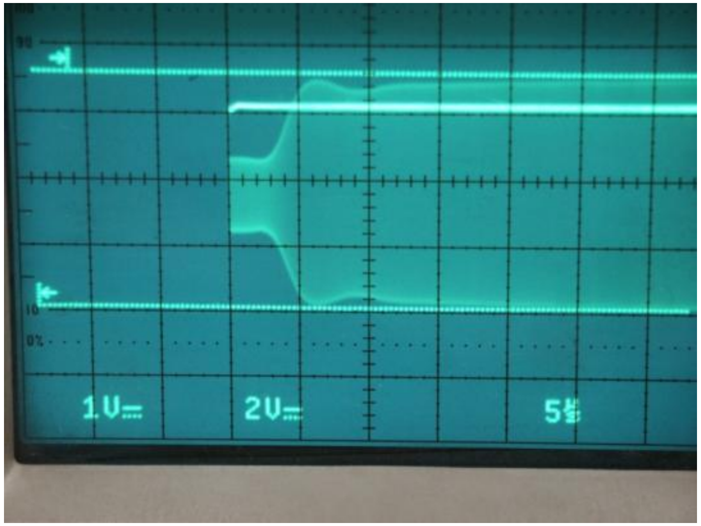
Tube cavity



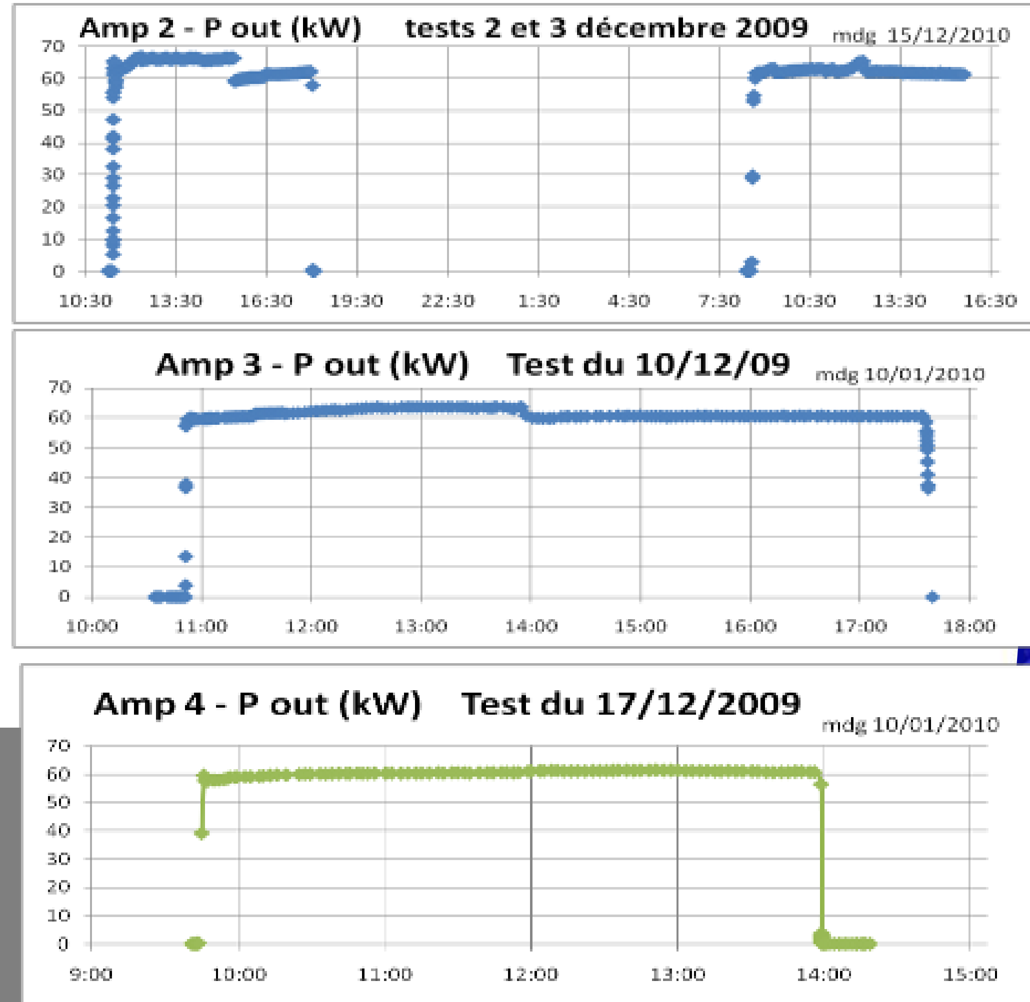
HV Power Supply

165 kVA HV transformer

RFQ Amplifiers



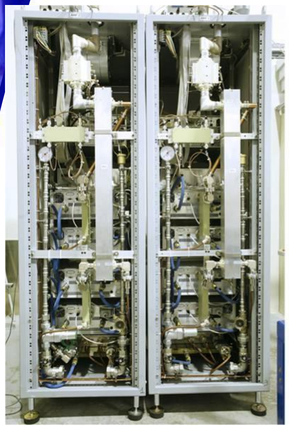
Pulse response



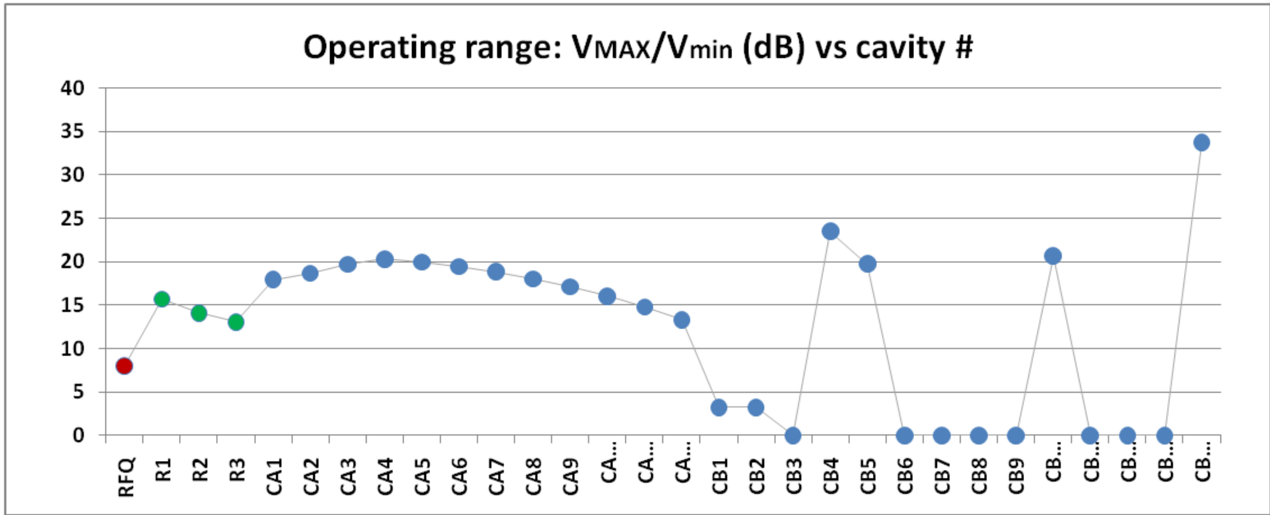
Long time tests at 60 kW

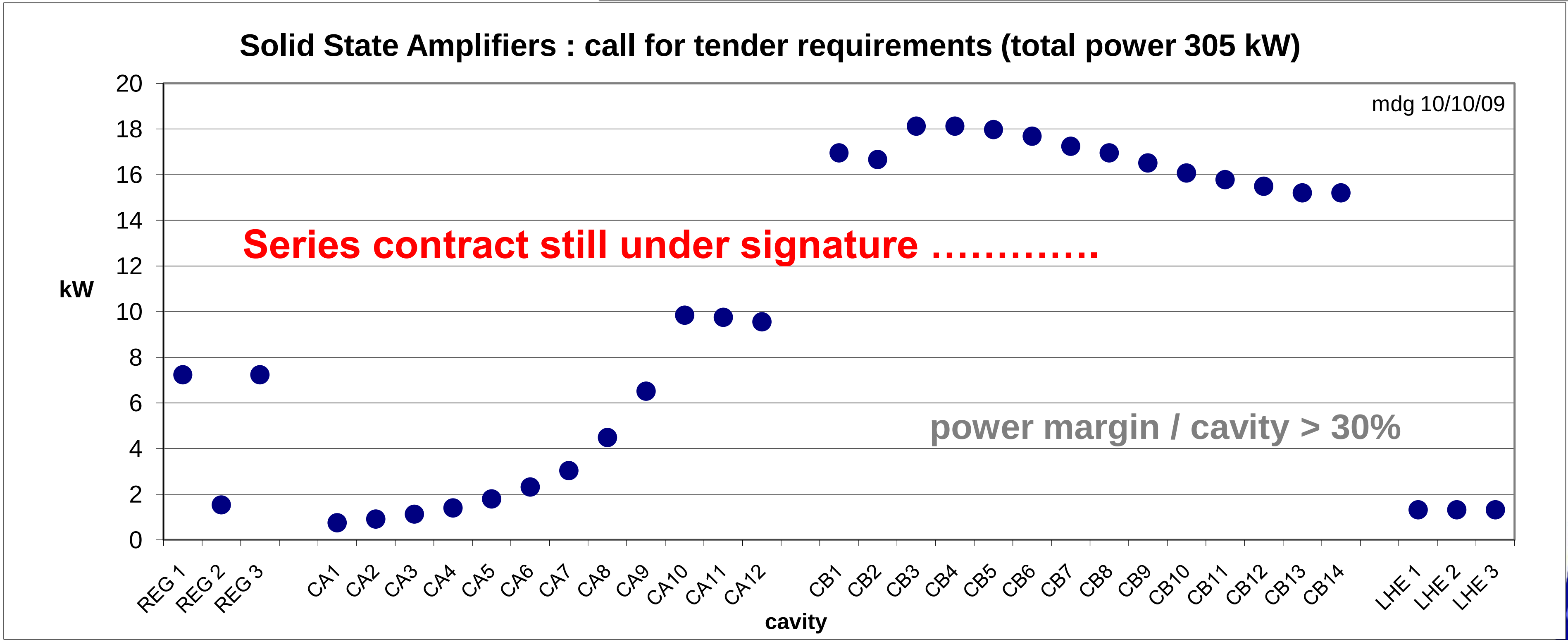
- **Long time tests of the amplifiers achieved at LNL lab. (INFN Italy)** **(end 2009)**
- **AMP1 being used for commissioning tests of other power devices.**

Solid state amplifiers

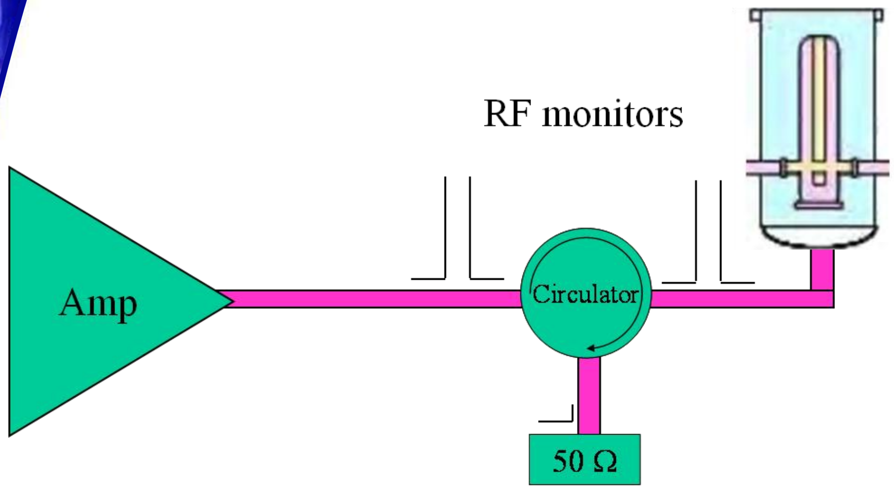


20 kW example





VSWR protection



SC cavities require high VSWR operating conditions, during:

- Coupler conditioning
- Low intensity beam operation (if fixed coupler)

External circulator to protect not only the transistors but also the combiners and the T-lines.

Adjustment of line length between circulator and cavity (minimum E field on the circulator) to reduce

- loss in the ferrite,
- residual reflected power towards the amplifier

Adjustment of line length between amplifier and circulator to optimize amplifier working impedance.

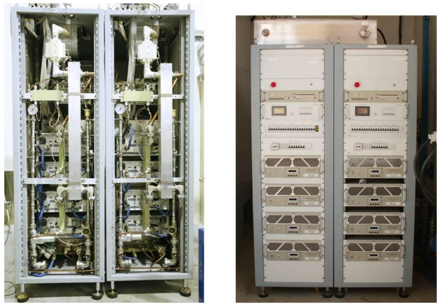
RF measurements seem not trivial after the circulator. Directional coupler position still to be chosen.

- P_{dir} probably read before the circulator.
- Cavity reflected power, P_{rev}, measured at the circulator load (thermal and/or RF).

Amplifier class

Class C initially (2005) chosen for

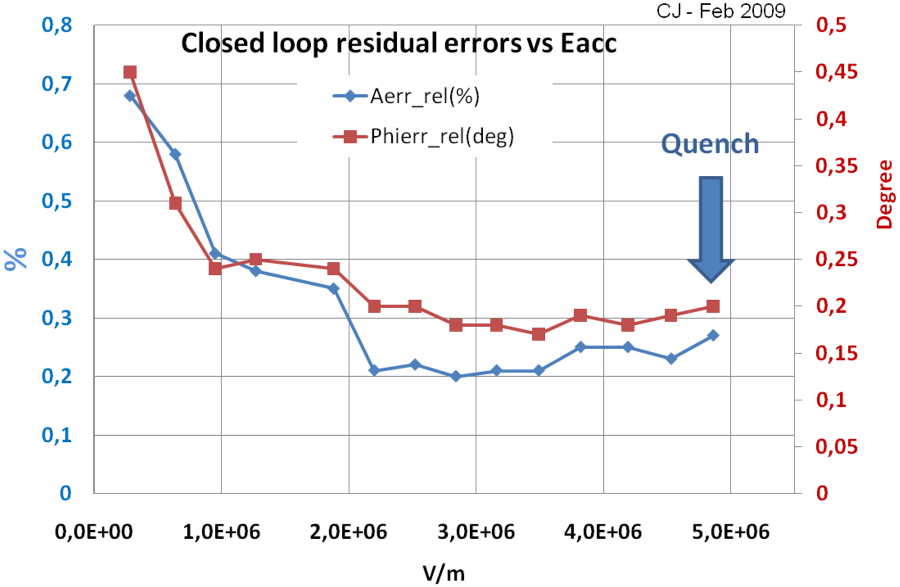
- **higher efficiency (60% AB vs 80% C)**
- **maximum reliability (FM market experience)**
- **best price**



No particular problem observed with feedback A and Φ stability well below requirements (<1% and < 0.5°) thank to the DLLRF bandwidth (>100 kHz)

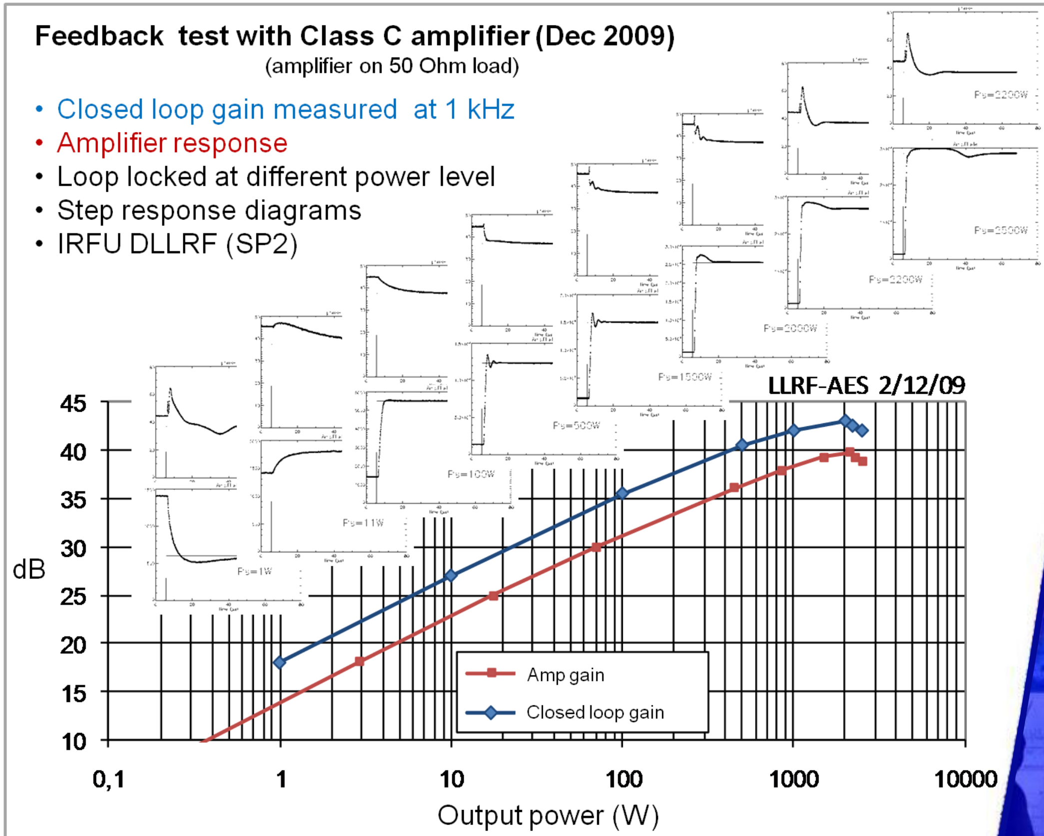
Feedback test on CMB with Class C amplifier (Feb 2009)

- Residual errors measured on cavity voltage
  Open loop perturbation: 3% A, ± 4° Φ
- Loop locked at different power levels, no PID par. Changes
- IPN Orsay DLLRF



Feedback test with Class C amplifier (Dec 2009)
(amplifier on 50 Ohm load)

- Closed loop gain measured at 1 kHz
- Amplifier response
- Loop locked at different power level
- Step response diagrams
- IRFU DLLRF (SP2)



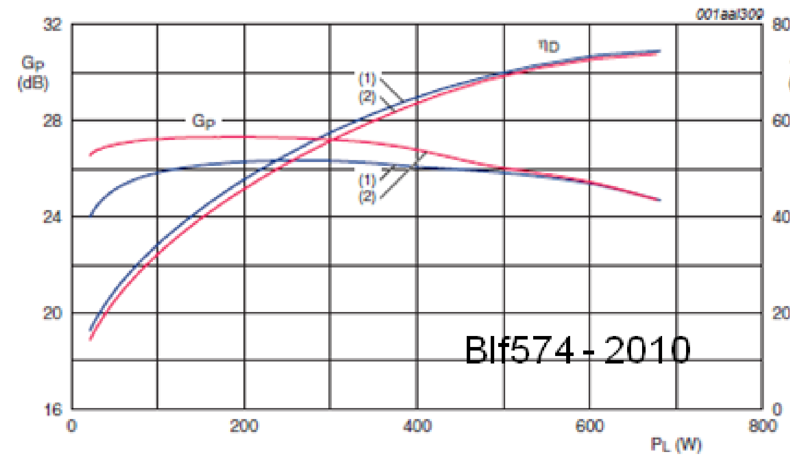
Amplifier class

But

- **New transistors have much better efficiency**
- **Class AB bias grants better matching at all power level and lower harmonics.**

- **then, final choice:**

- **class AB, with 20÷25 dB input dynamic range for 35 dB output dynamic range.**
- **10 dBm input signal for maximum output power**

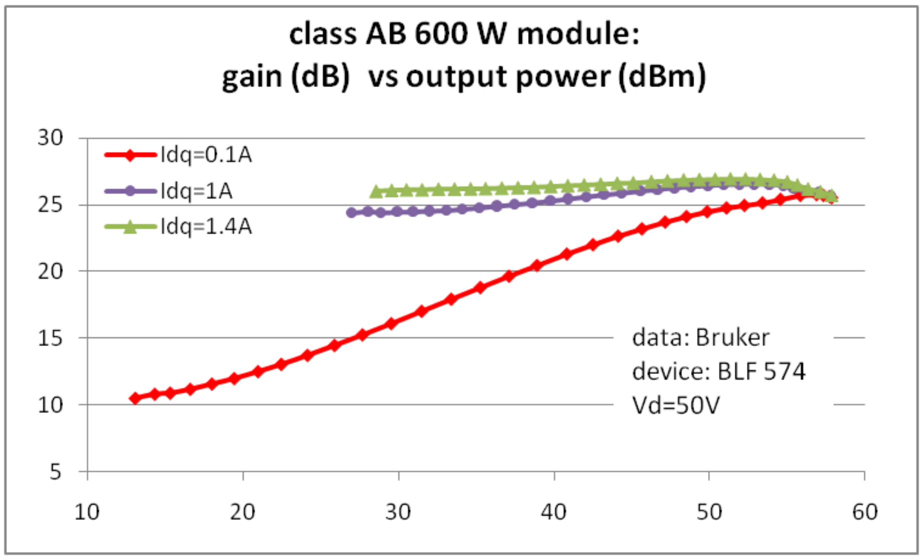


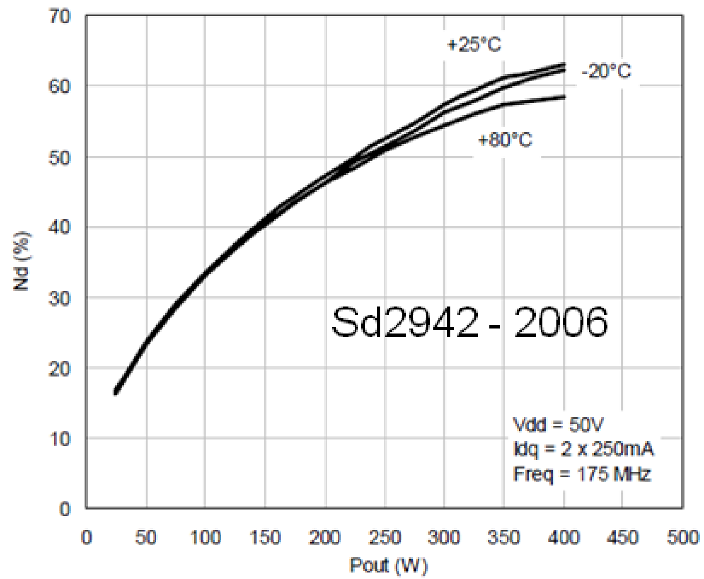
BLF574 at 98 MHz, V_{DD} = 50 V.

(1) 200 mA.

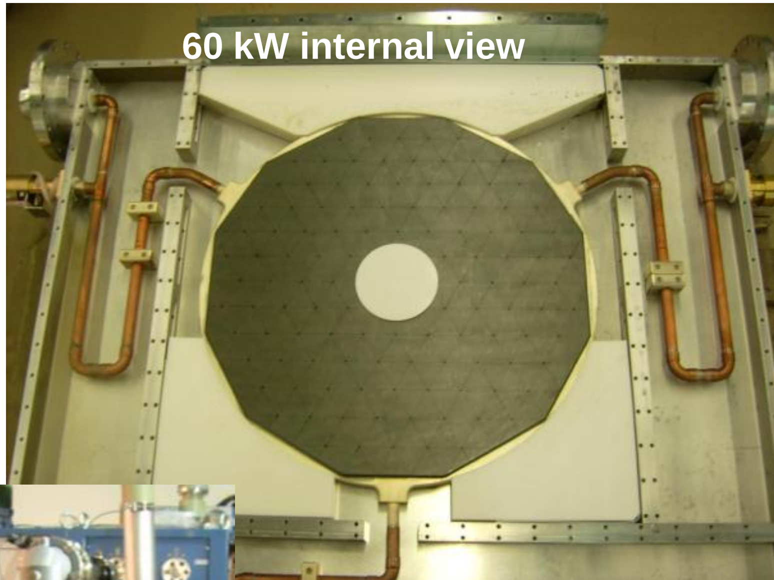
(2) 1 A.

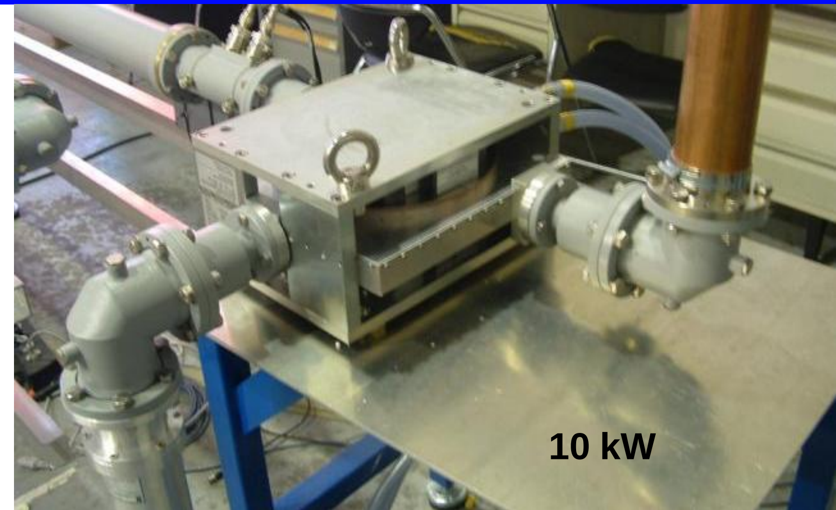
Fig 8. Output gain and efficiency comparison for Class-B and Class-AB amplifiers





Circulateurs



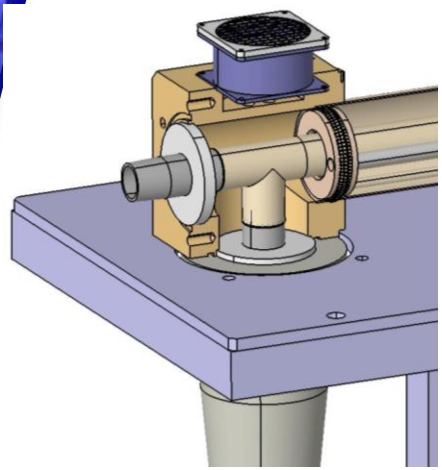


- ***AFT design and manufacture***
- ***P = 10, 20, 60 kW***
- ***10 and 20 kW are only water cooled: 5l/m***
- ***60 kW: water cooled and trim coil***

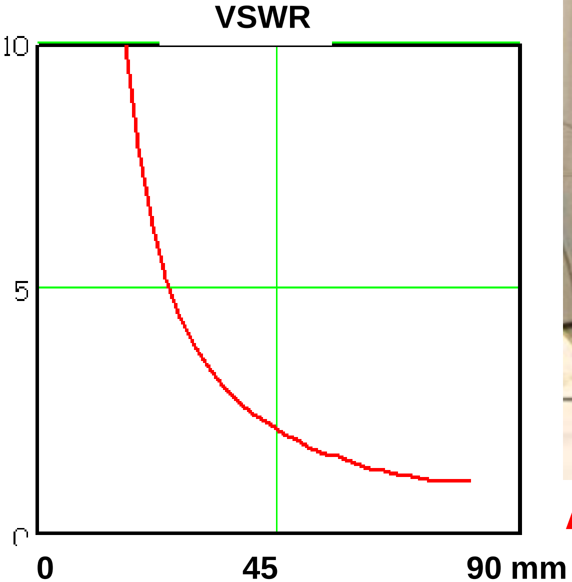
- ***All 20 and 60 kW tuned at Ganil***

- ***10 kW: all commissioned***
- ***20 kW: end of tuning and commissioning tests in Mai***
- ***60 kW: commissioning tests of the 1st one next June.***

Power Test Bench

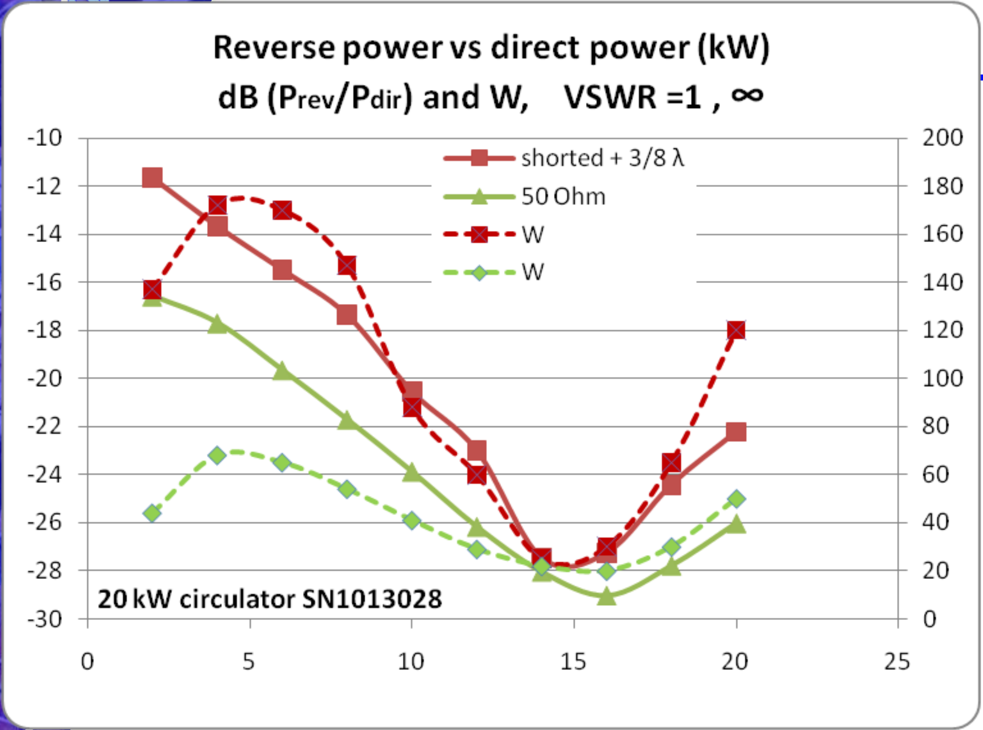


Variable VSWR device (20 kW, 88 MHz)



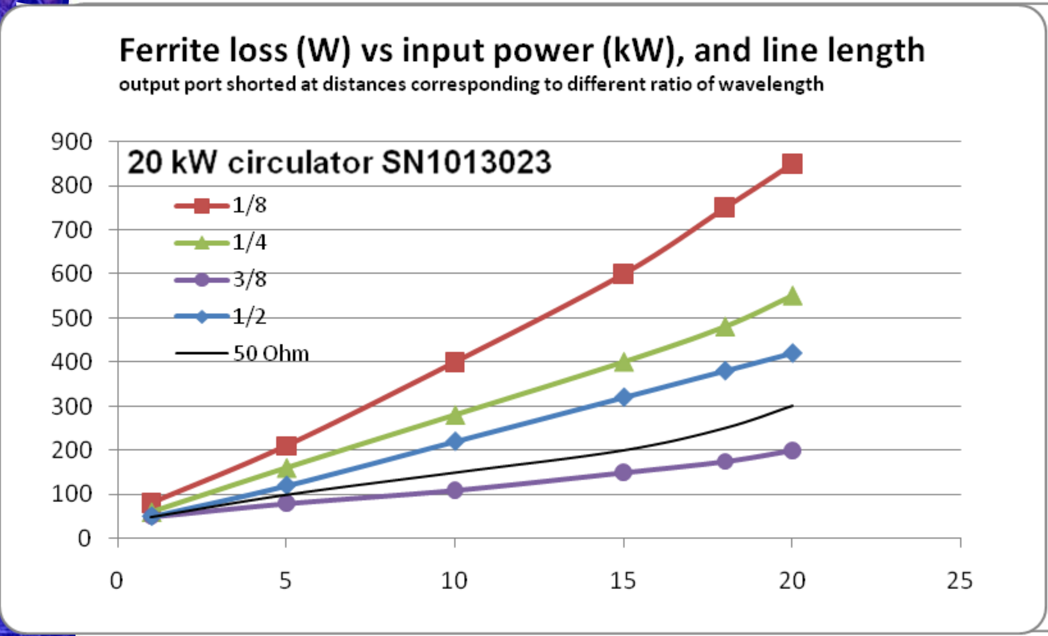
Available parameters: flowmeters, output water temperatures

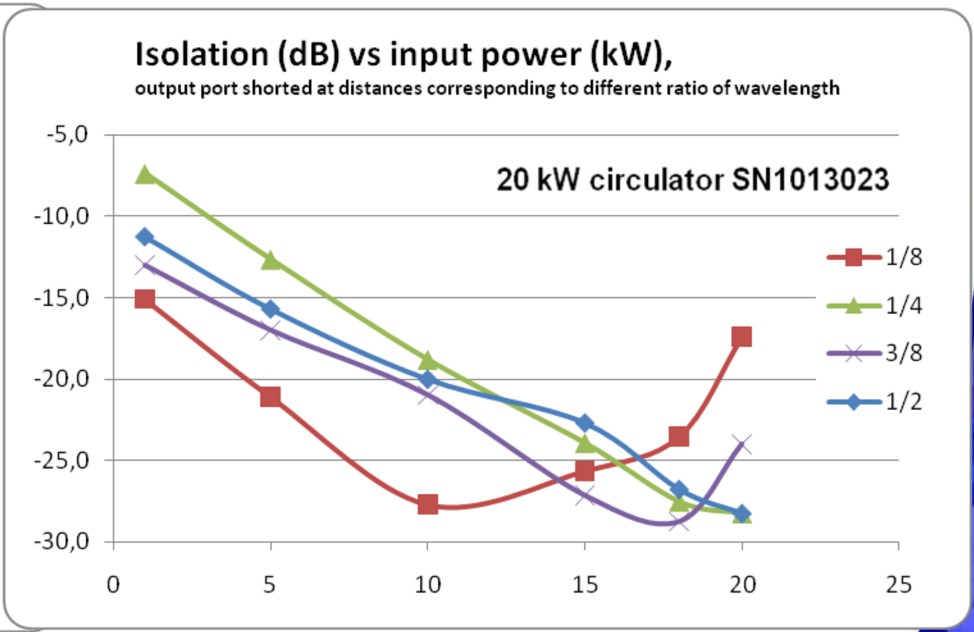
Circulateurs



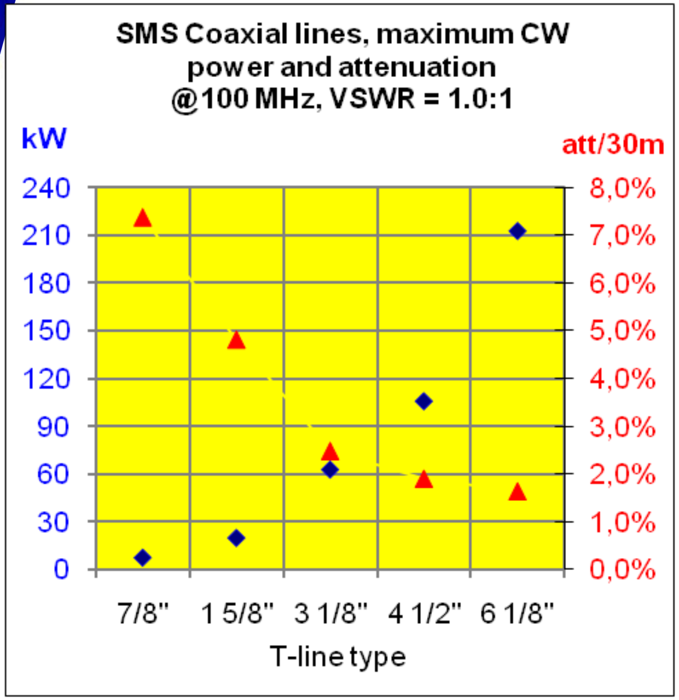
Return loss (S11) = -26 dB ÷ -23 dB (50W@10kW)
Insertion loss (S21) = -0.2 dB (500W@10 kW)
Isolation (S12) = 26 dB ÷ -23 dB (50W@10kW)
Bandwidth = > ±200 kHz

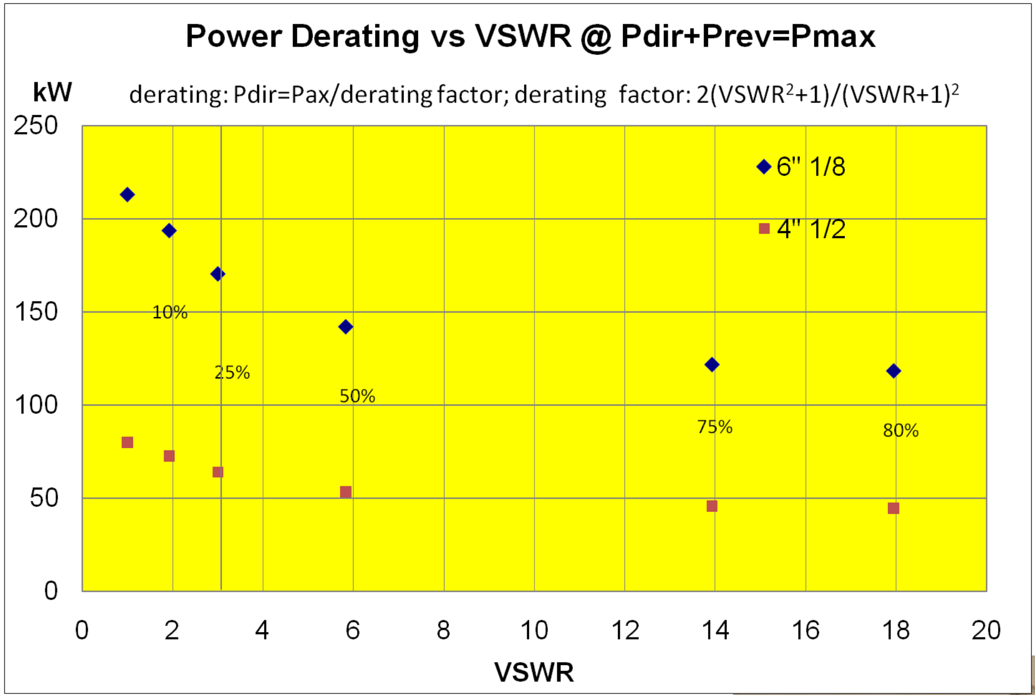
cold fo: ~86 MHz
Warm fo shifting -100 KHz/kW
Lowest E field on the ceramics reduces losses





Transmission lines





- Derating = Decrease of maximum power due to VSWR
- Factor 2 if $P_{dir}+P_{rev}=P_{max}$,
  Factor 4 if $V_{dir}+V_{rev}=V_{max}$

- EIA1$^{5/8}$" Derating test with shorted line: inner coax melted at 7 kW
- EIA 3$^{1/8}$" used on the test bench at 10 and 20 kW, all kind of mismatches (amplitude and phase) with no problems.

VSWR=∞
Inner placed at λ/4 from short circuit

Transmission lines

T-LINE STANDARDS	Amplifier to Circulator	Circulator to Cavity
RFQ	4-1/2	4-1/2
Rebuncher1 et R3	1-5/8	3-1/8
R2	1-5/8	1-5/8
CA1 to CA8	1-5/8	1-5/8
CA9 to CA12	1-5/8	3-1/8
CB1 to CM14	3-1/8	3-1/8

Conclusions

Project

The building availability is approaching quickly. A lot of work to prepare the integration of the RF systems is being done too.

RF Power System

A lot of work due to contracts already signed, and a lot still to come. Very taught but exciting period as we are learning very much.

And I'm here to learn even more …

Most of cavities and accelerator RF devices will be ready to be installed as soon as the building comes out.

First beam tests planned end of 2012

Aknowledgements

Thanks you to all this colleagues for their precious daily work and help to prepare this talk.

J.F. Leyge : MEBT Rebunchers
B. Ducoudret : Solid state amplifiers,
L. Valentin: Circulator measurements
P. Baret: RFQ Amplifiers
Ph. Galdemard: LLRF
M. Lechartier: RF System integration

M. Desmons: friendly suggestions (in any RF domain!)

R. Ferdinand : SC Linac
P. Bertrand: accelerator leader

…. and thank **you** for your attention