EucARD Annual Meeting

11-13 May 2011, CNRS Paris

WP10 - SRF

“SC RF technology for higher intensity proton accelerators & higher energy electron linacs”

O. Napoly (CEA)

WP10-SRF Task 'Patchwork'

WP 10 Organisation, version 07.04.10					
Task	**Subtask**	**task / subtask leader**	**leading laboratory**	**participating laboratories**	**Task description**
10,1		**O. Napoly, O. Brunner**	**CEA**	CEA, CERN	**SRF Coordination and Communication**
10,2		**S. Chel**	**CEA**	CEA, CERN, CNRS,	**SPL Cavities**
	10.2.1	G. Orly	IPN-Orsay	CNRS	Design and fabrication of β = 0.65, 704 MHz elliptical cavity.
	10.2.2	S. Chel	CEA	CEA	Design and fabrication of β = 1, 704 MHz elliptical cavity.
	10.2.3	V. Parma	CERN	CERN, CEA, CNRS	Study of interfaces between the cavity and the cryomodule.
10,3		**P. McIntosh**	**STFC**	STFC/Daresbury,UNIMAN,ULANC,CERN	**Crab cavities**
	10.3.1	F Zimmerman	CERN	CERN, ULANC	Design, build and test a single LHC crab cavity.
	10.3.2	R.M. Jones	UNIMAN	UNIMAN	Design, build and test a single CLIC crab cavity.
	10.3.3	A Dexter	ULANC	ULANC	Design, build and test a LLRF and synchronization systems.
10,4		**S. Calatroni**	**CERN**	CI, CEA, CERN, CNRS/IPNO, DESY, INFN-LNL, IPJ Swier	**Thin Films**
	10.4.1	S. Calatroni	CERN	INFN-LNL, CERN	Improve the Nb sputtering technology for low beta cavities.
	10.4.2	J. Sekutowicz	DESY	DESY, IPJ Swierk	Perform arc sputtering of photo cathodes (Pb).
	10.4.3	R. Seviour	CI	CI, CEA, CERN, CNRS/IPNO, INFN-LNL	Research on new technologies for thin film depositing of superconductors for SC cavity applicati
10,5		**R.M. Jones**	**UNIMAN**	DESY, UNIMAN, UROS	**HOM Distribution**
	10.5.1	N. Baboi	DESY	DESY	Development of HOM based beam position monitors (HOMBPM).
	10.5.2	R.M.Jones	UNIMAN	UNIMAN	Development of HOM Cavity Diagnostics and ERLP (HOMCD).
	10.5.3	U. von Reinen	UROS	UROS	Measurement of HOM Distributions and Geometrical Dependences (HOMDG).
10,6		**M. Grecki**	**DESY**	DESY, TUL, IPJ, WUT, IFJ-PAN	**LLRF at FLASH**
	10.6.1	T. Jezynski	DESY	DESY, TUL, WUT	Development of ATCA carrier boards with FPGA and DSP
	10.6.2	D. Makowski	TUL	TUL, DESY, WUT	Development of AMC and RTM modules required IO functionality
	10.6.3	M. Grecki	DESY	DESY, TUL, IFJ-PAN	ATCA implementation of cavity resonance control
	10.6.4	J. Szewinski	IPJ	IPJ, DESY	Development of beam based longitudinal feedbacks for the ATCA based LLRF system
10,7		**J. Teichert**	**FZD**	FZD, HZB	**SCRF gun at ELBE**
	10.7.1	T. Kamps	HZB	HZB, FZD	Slice diagnostics system
	10.7.2	R. Xiang	FZD	FZD	Improvement of preparation chamber for GaAs photo-cathodes
	10.7.3	J. Teichert	FZD	FZD, HZB	SCRF gun experimental tests
10,8		**W. Kaabi**	**LAL-Orsay**	LAL	**Coupler Development at LAL**
	10.8.1	W. Kaabi	LAL-Orsay	LAL	Cleaning studies on samples
	10.8.2	M.Lacroix	LAL-Orsay	LAL	Automation of coupler washing

WP10-SRF Fifteen Institutes

Krakow

Swierk

Pushing Accelerator Performance Barriers

R&D is needed to advance the Superconducting RF Technology for Accelerator applications

- High Gradient barrier (ILC, SPL, ESS, etc…) → Task 10.2, 10.4
- High Q0 barrier (efficiency, duty cycle) → Task 10.4
- High RF Power barrier (HPPAs) → Task 10.2, 10.8
- High Stability and Reliability barriers (ILC, XFEL, ADS) → Task 10.5, 10.6
- Low Beta barrier (e.g. Spiral2 β=0.07) → Task 10.4
- Industrialization and cost barrier (ILC) → Task 10.8
- New Applications barrier:
  - Crab cavities (LHC, ILC) → Task 10.3
  - SC-RF Gun (electrons) → Task 10.4, 10.7
  - Energy Recovery Linac (ALICE, BERLinPro) → Task 10.5, 10.7

WP10-SRF 2nd Annual Review

4-5 May 2011, IN2P3 – Inst. Phys. Nucl. Orsay

Hui-Min Gassot

42 Participants, including the 2 Coordinators + 7 Task Leaders

14/15 Partner Institutes represented

WP10-SRF 2nd Annual Review
4-5 May 2011, Cockcroft Institute, Daresbury

https://indico.cern.ch/conferenceDisplay.py?confId=118190

33 talks, including 3 from PhD students

Ben Hall,	Lancaster University	T10.3
Pei Zhang,	Manchester University, working at DESY	T10.5
Thomas Fligsen,	Rostock University	T10.5

04/2010-03/2011 WP10 Campaign in a Nutshell

Last year campaign has been dominated by the Beam Developments

- **First beam in a fully SC RF gun** (Thin films + SRF Gun)
- **Beam excited HOMs measured at FLASH 3.9 GHZ module** (HOM)

  (cf. 2nd highlight talk by Roger Jones)
- **Beam energy stability improved at FLASH** (LLRF)
- **Beam Slice Emittance measurements at ELBE SCRF gun** (SRF Gun)

  (cf. 1st highlight talk by Jeniffa Rudolph)

The Design and Technology Developments show less rapid progress.

Beam Developments

T10.4 : Pb/Nb SRF Gun

Aim of the study (M36) : produce and test a fully SC RF Gun using SC Pb photocathode deposited on SC Nb 1-½ Cavity

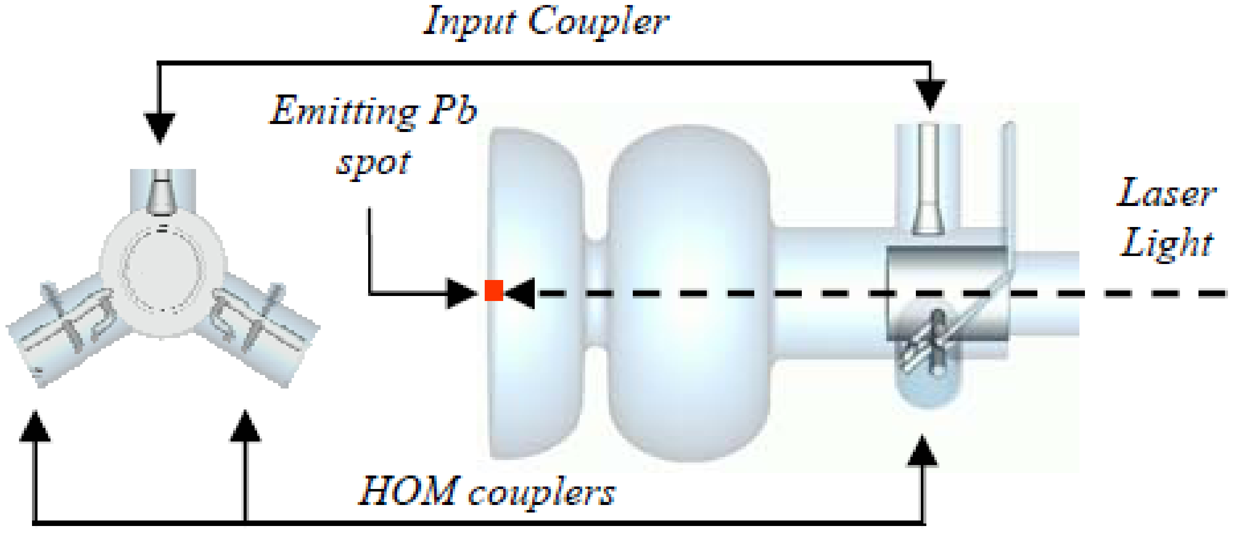
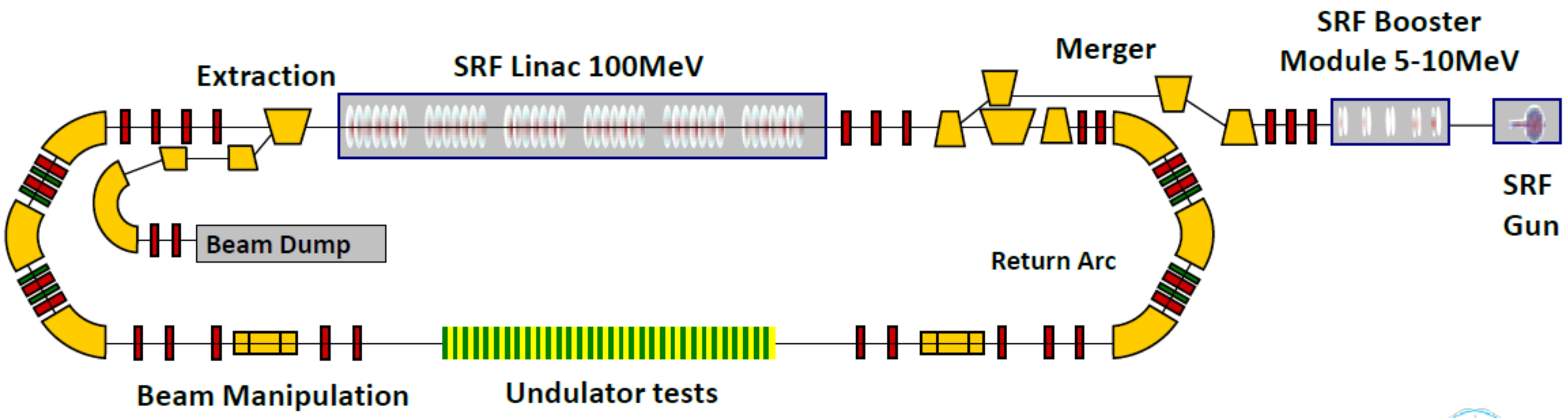


Figure 1: 1.6-cell SRF-injector cavity with 2 HOM couplers and an input coupler.

T10.7 : SRF Gun

At HZB we are working on BERLinPro, a physics and technology study for an Energy Recovery Linac



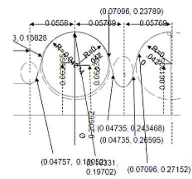
Max. beam energy	100 MeV
Max. average current	100 mA
Nominal bunch charge	77 pC
Max. rep. rate	1.3GHz
Normalized emittance	< 1mm mrad
Cryo load @ 1.8K	240 W

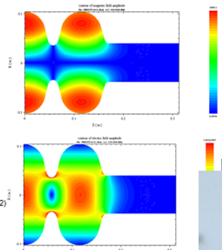
The SRF Gun needs to fulfill these challenging target parameters

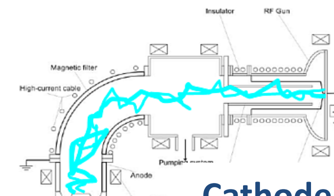
HZB Helmholtz Zentrum Berlin

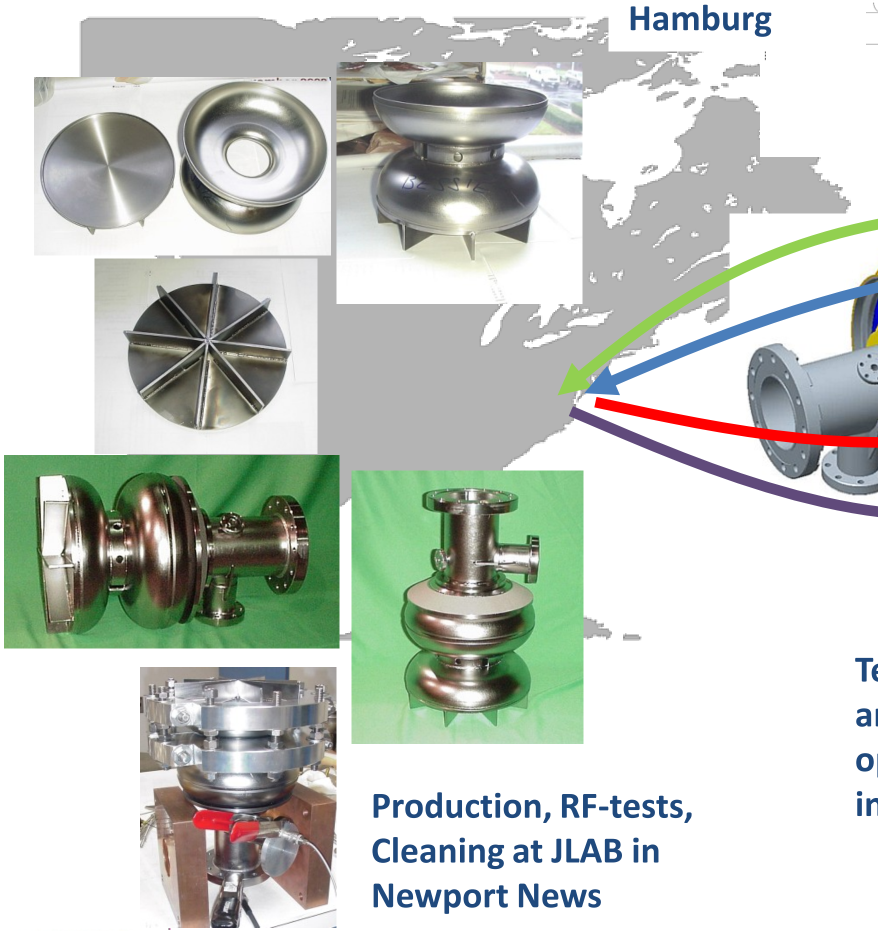
The cavity collected some 20.000 air miles… keeping its Q vs E_{pk} performance…

EM Design at DESY in Hamburg





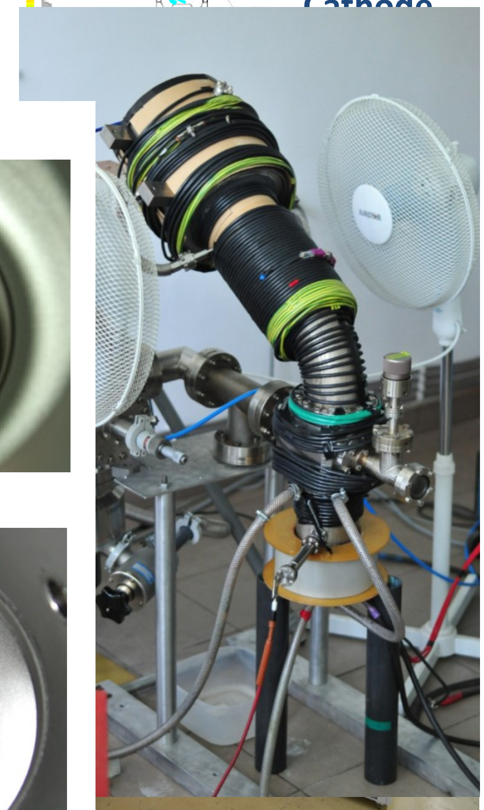




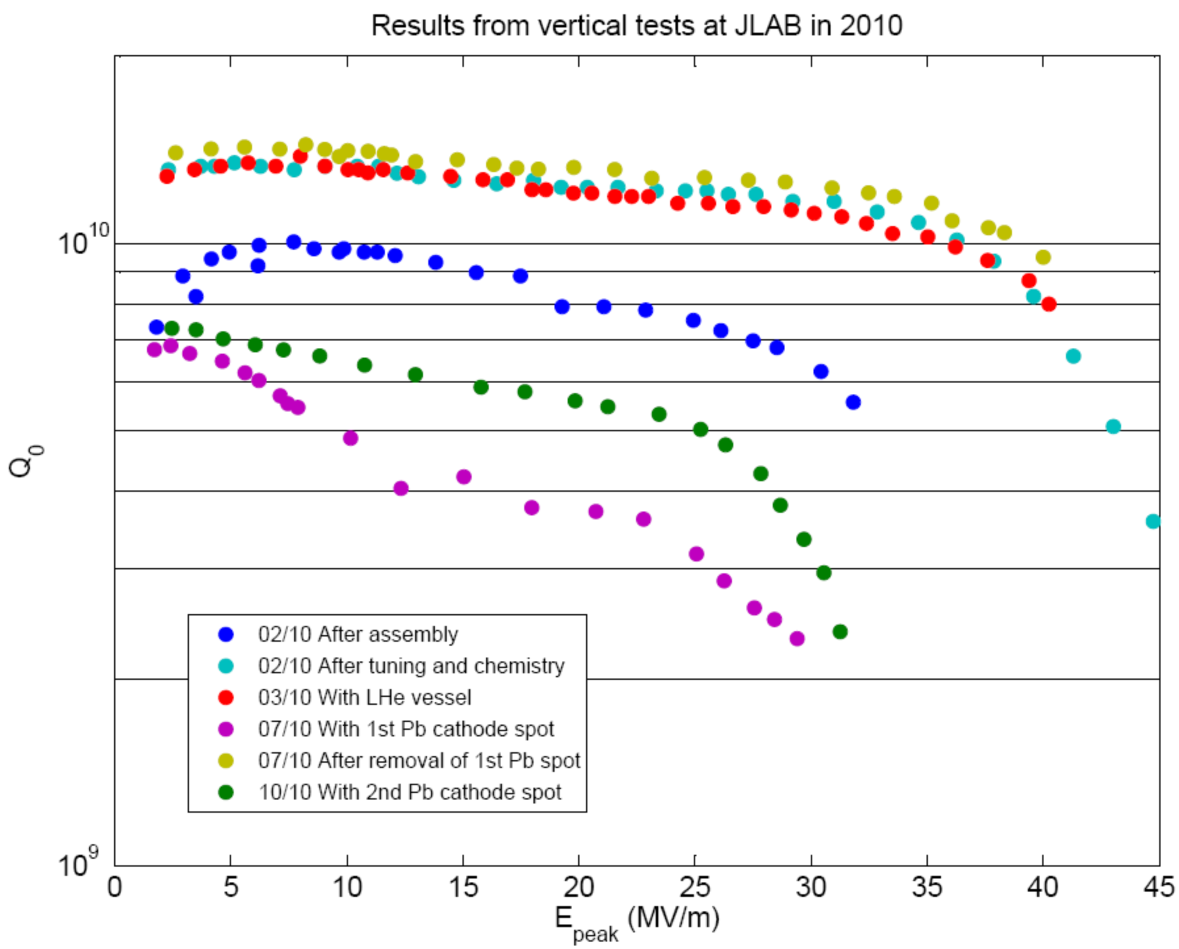
Production, RF-tests, Cleaning at JLAB in Newport News

before

after

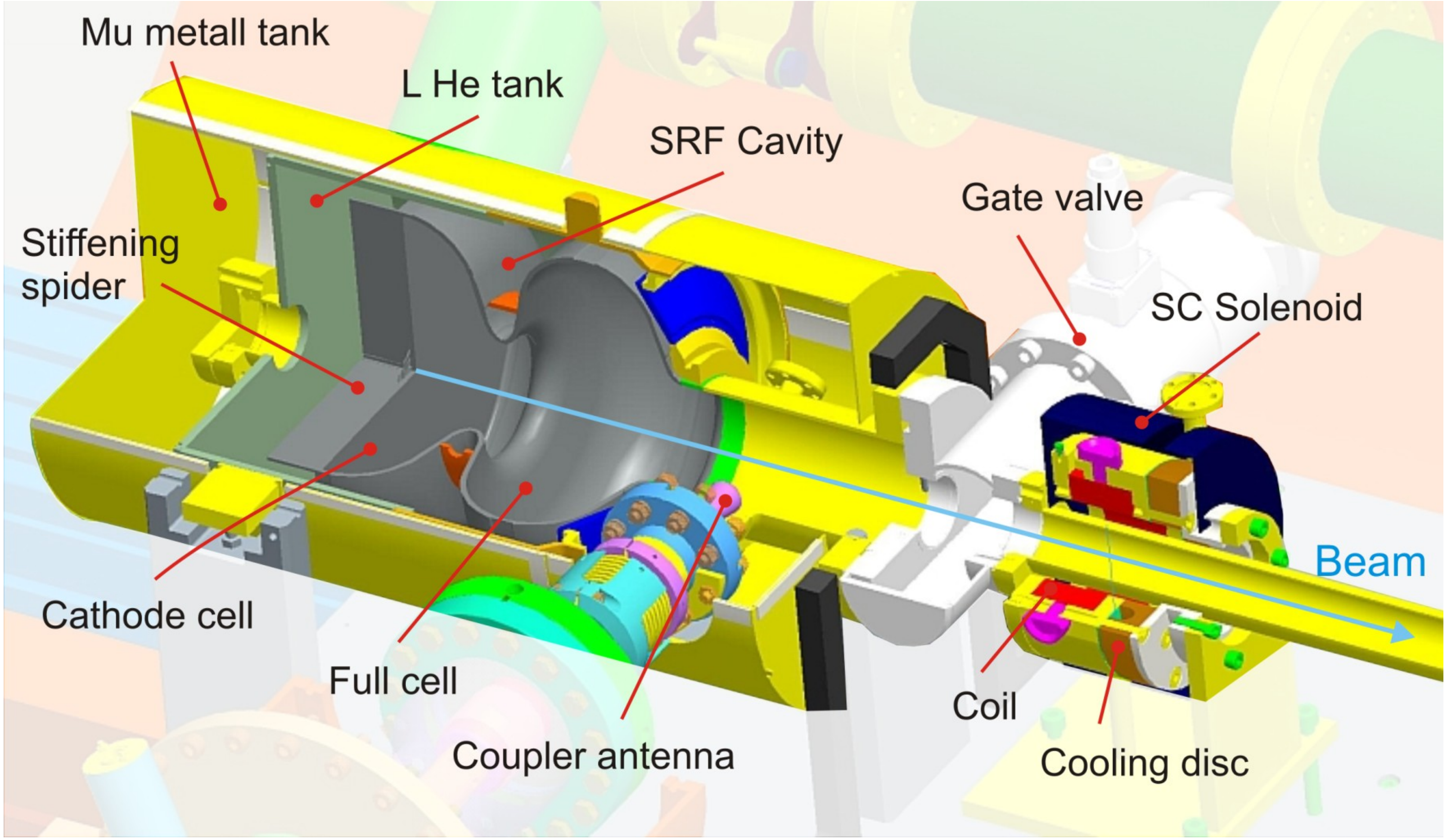


Results from vertical tests at JLAB, from assembly of cavity to delivery for Berlin

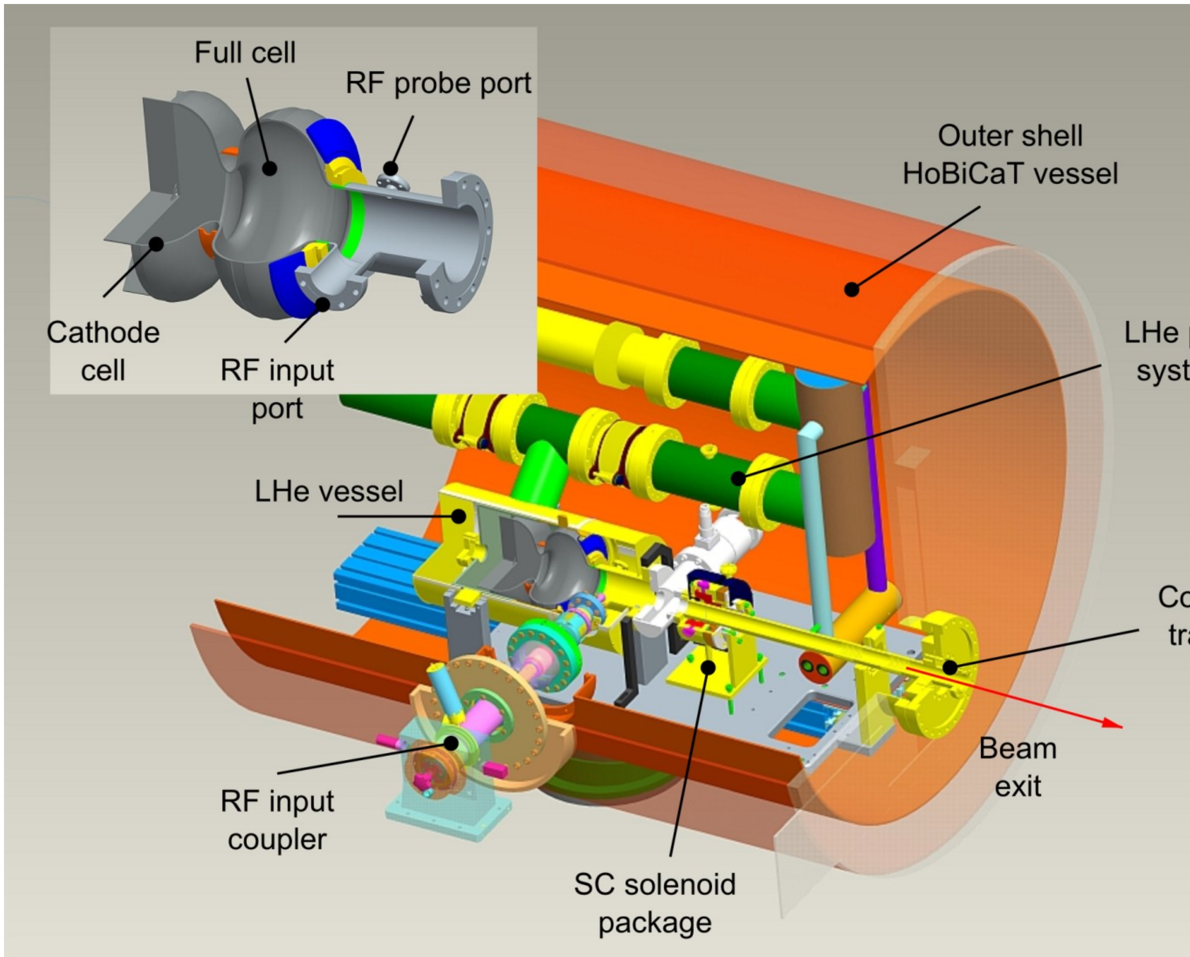


02/10 Initial test after assembly, tuning, BCP etching and rinsing of the cavity. The field flatness was only 66%.
02/10 Further tuning improved field flatness to 94%, the following BCP treatment improved the RF performance.
03/10 After installation of the helium vessel, limitation by moderate field emission.
07/10 With first cathode coating
07/10 Test after accidential loss of lead cathode and removal of remnants by grinding and BCP.
10/10 With second cathode coating

Complete cold mass: cavity, coupler, gate valve, solenoid and beam pipe



Completed cold mass now inside cryomodule of HoBiCaT.



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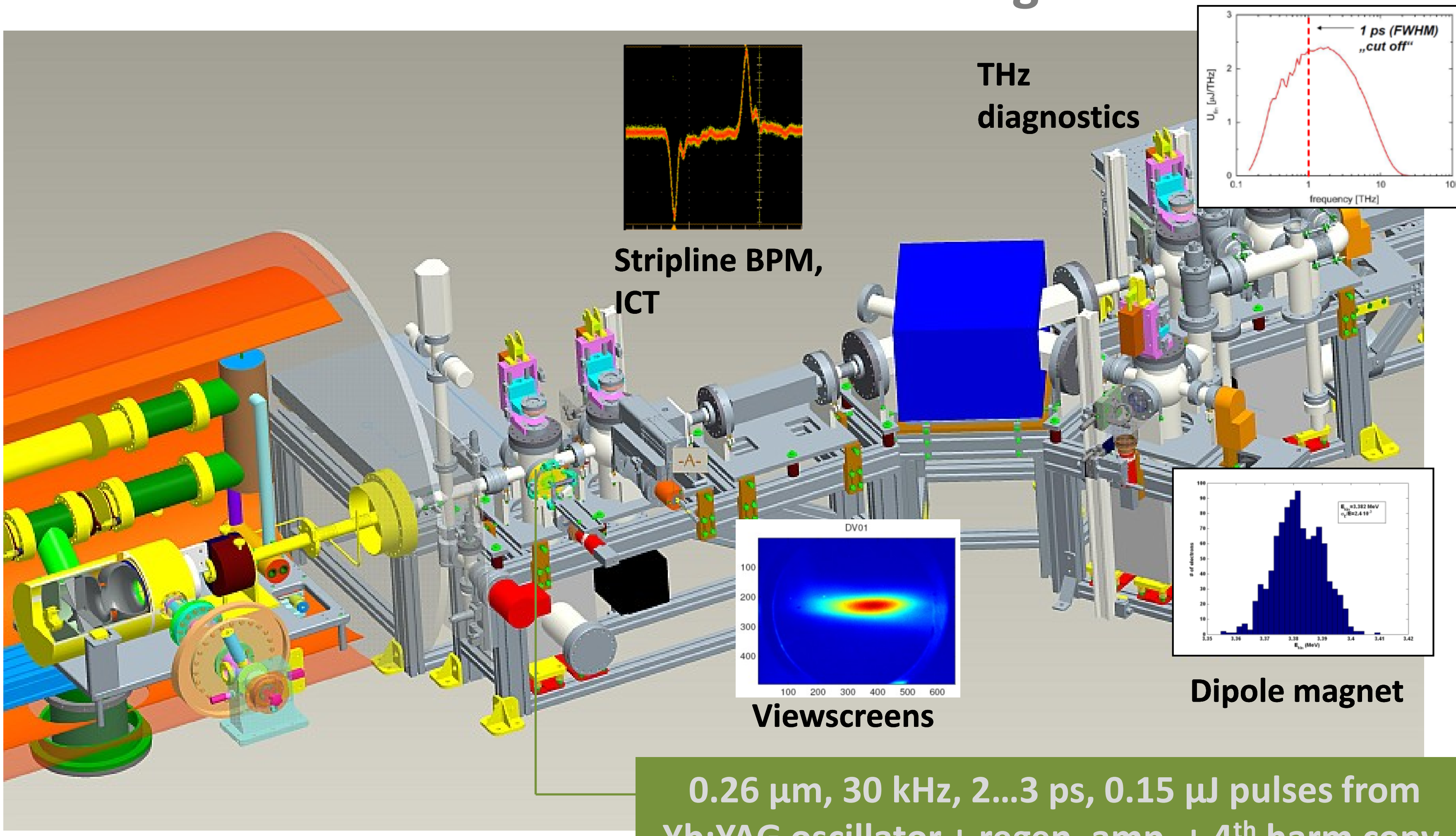
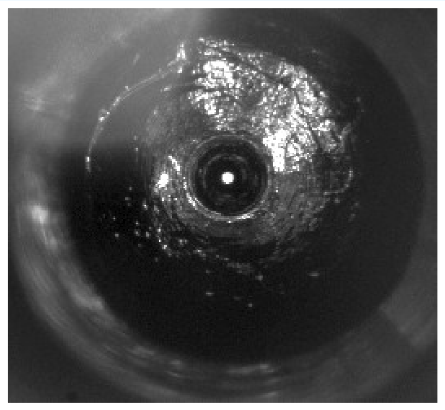
Two more systems required for beam test: drive laser and electron beam diagnostics

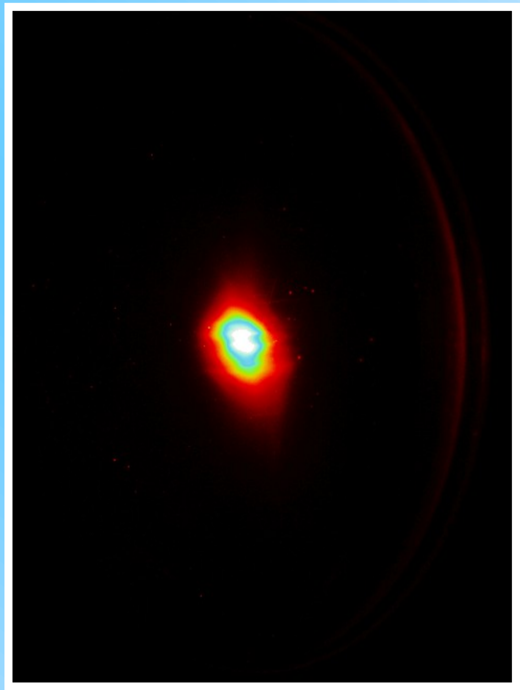


0.26 µm, 30 kHz, 2…3 ps, 0.15 µJ pulses from Yb:YAG oscillator + regen. amp. + 4^{th} harm conv.

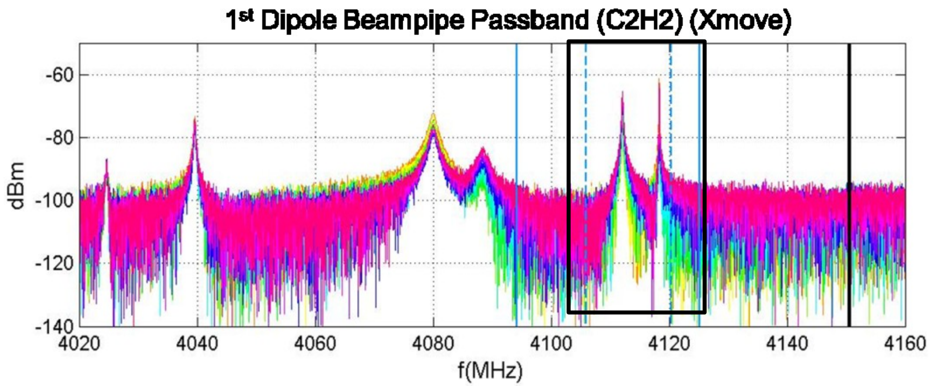
T10.4 + T10.7 : Pb/Nb SC-RF Gun Operation

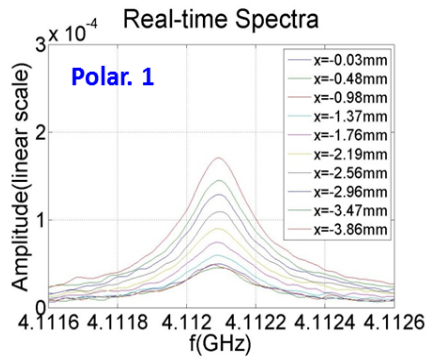
First beam of photoelectrons from Pb cathode generated and accelerated at 21st April 2011, < 2 years after project approval

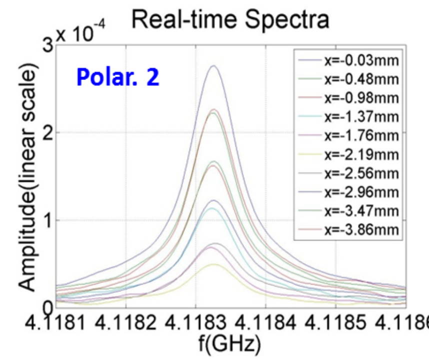




Task 10.5: 1st Dipole Beampipe Modes

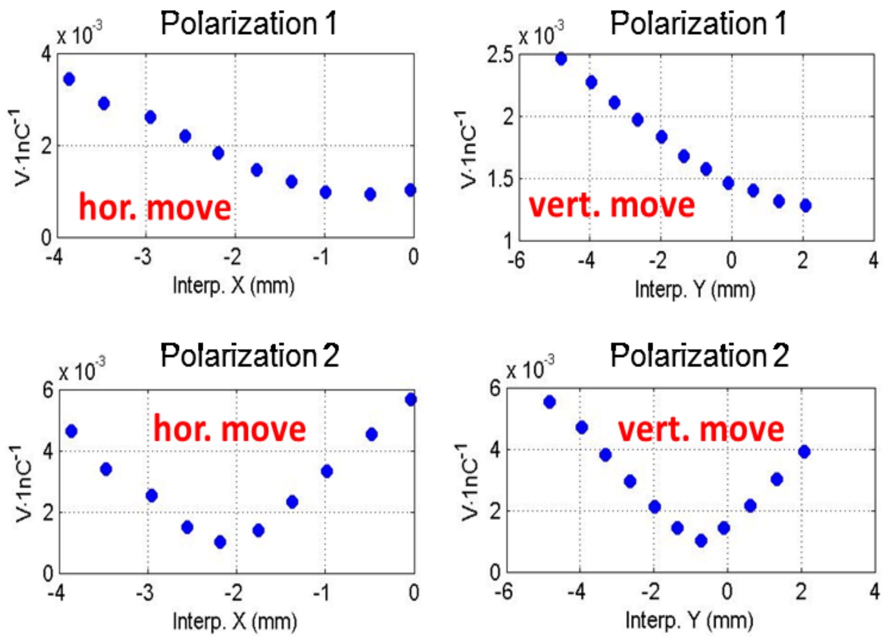


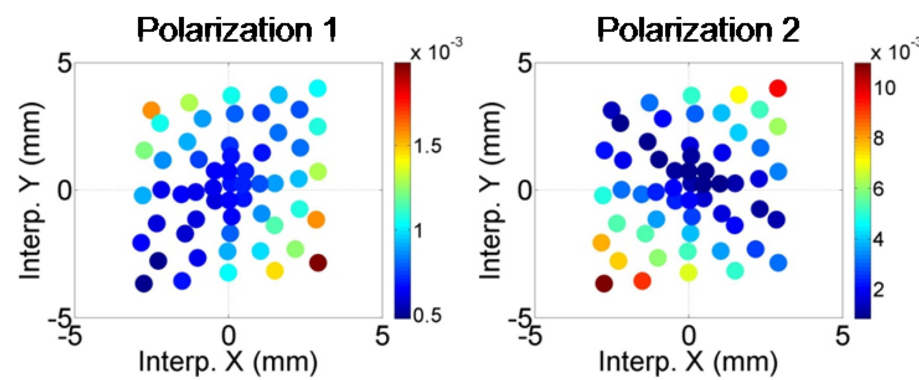


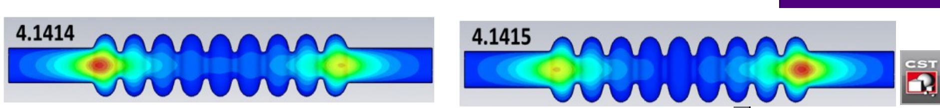


- Lorentzian fit to get mode amplitude

$$y = y_0 + A \cdot \frac{w^2}{(x - x_0)^2 + w^2}$$

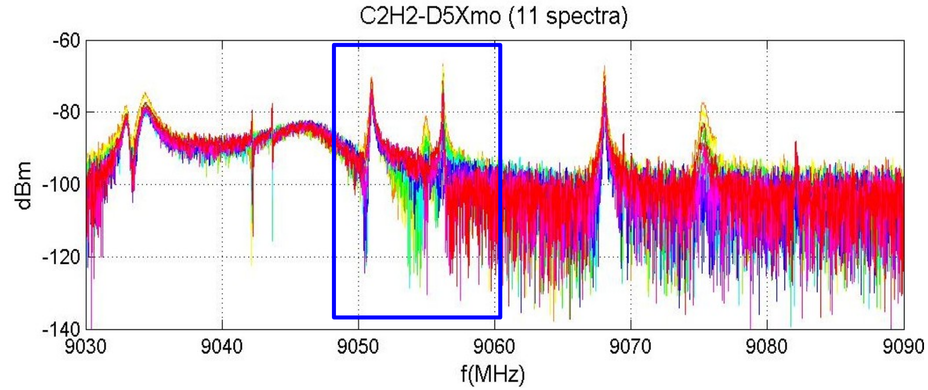


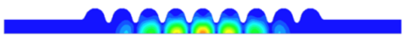
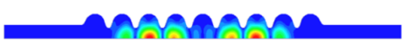
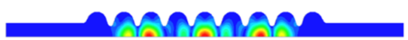
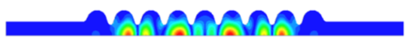
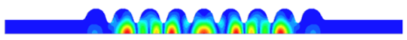
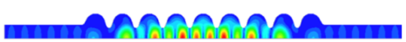




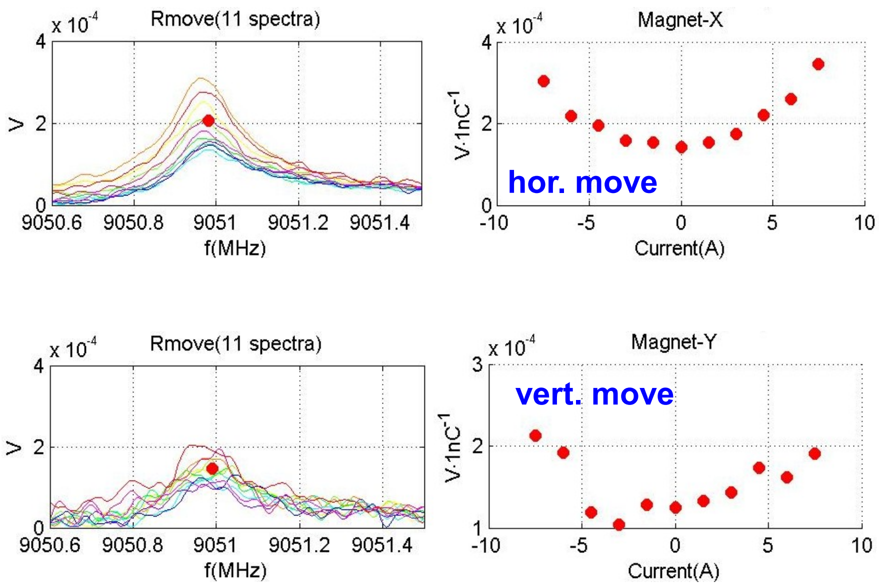
Task 10.5: 5th Dipole Cavity Band

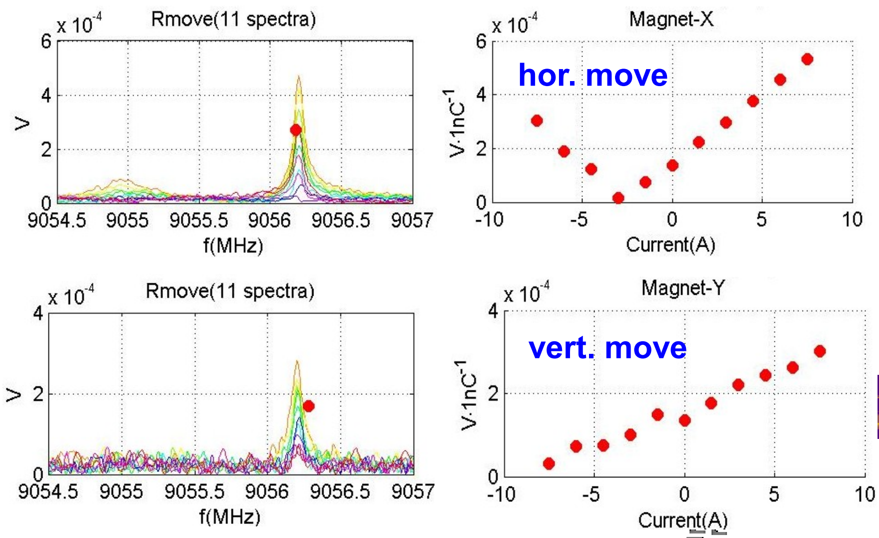
The Cockcroft Institute
of Accelerator Science and Technology



5th Dipole Band†	*f* (GHz)	R/Q
	9.0560	0.00
	9.0568	0.05
	9.0585	0.07
	9.0620	2.17
	9.0703	4.04
	9.0933	0.55

localized!





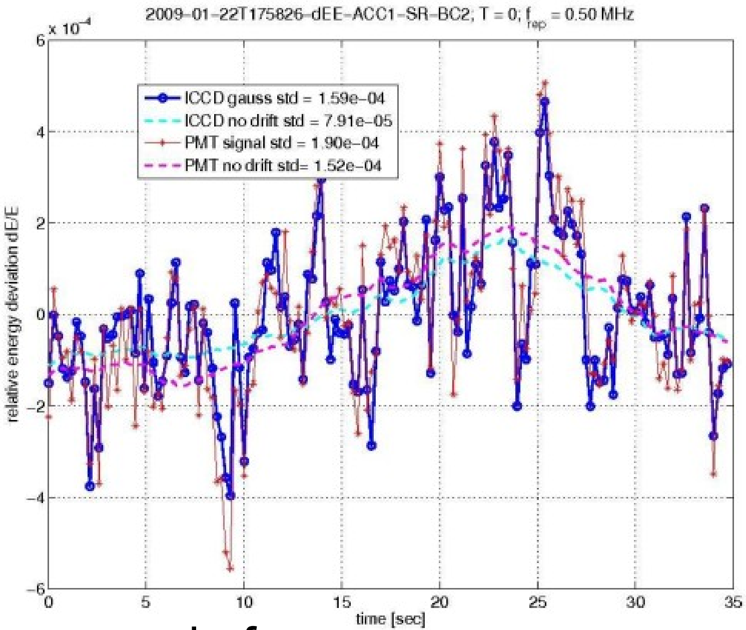
† I.R.R. Shinton, et al., "Mode Distribution …", CI Internal Note

WP10.6 (LLRF at FLASH)

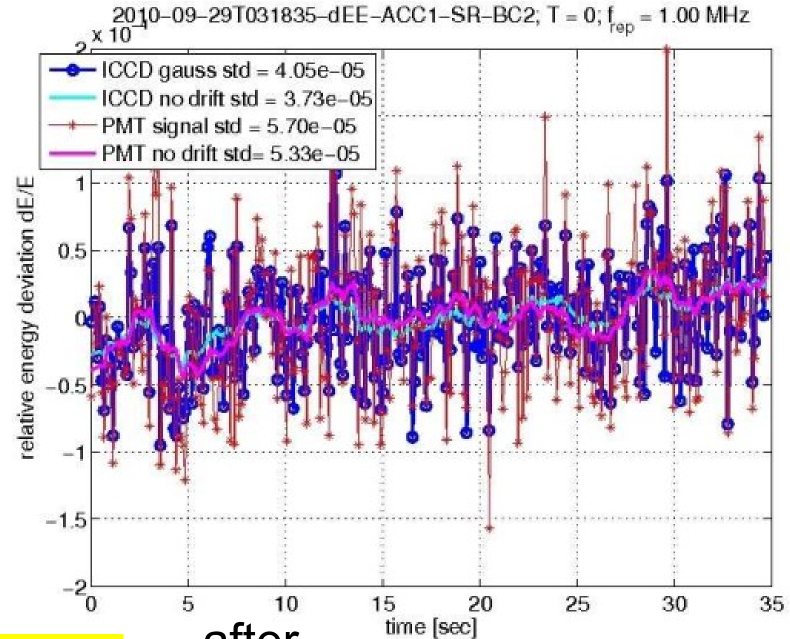
from ATCA (Advanced Telecommunications Computing Architecture) to µTCA

- µTCA decided as the hardware platform (formerly ATCA)
  - most of the ATCA development transfered to the new platform
  - small (3-4 months) delay in milestones not affecting the final deliverables
  - installation of the system at FLASH will be done during the next shutdown period (September 2011 – March 2012)
- even with temporarily installed (03.2010) LLRF system (SimconDSP) the beam performance was significantly improved (see next slide).

Energy stability after FLASH upgrade



before



after

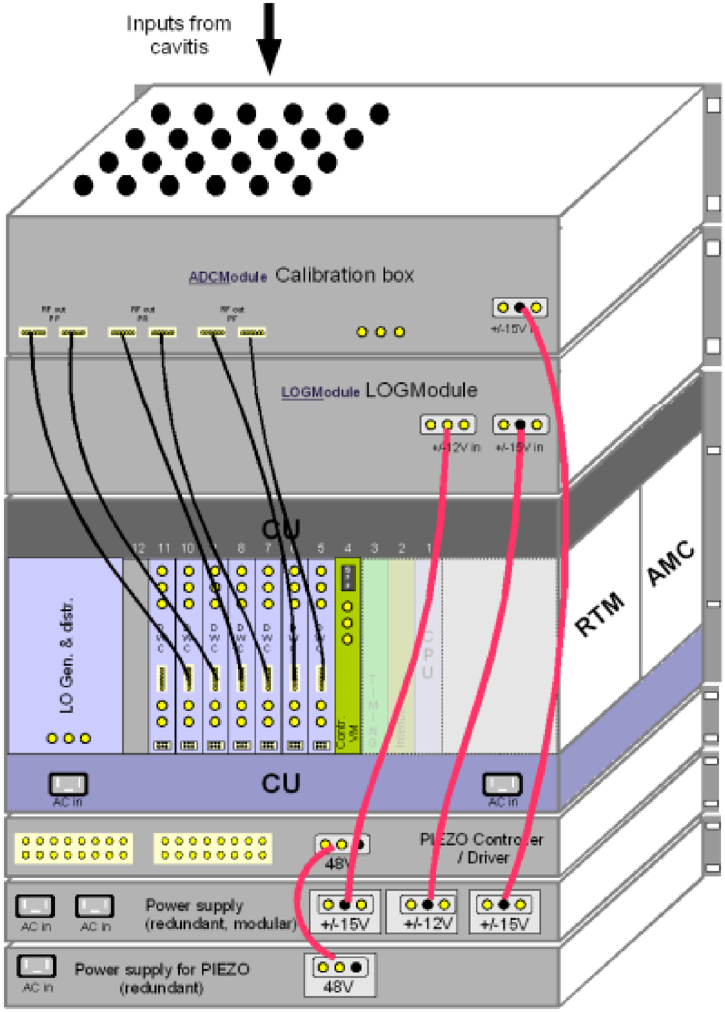
Christopher Gerth, et al.

- FLASH elogbook 22.1.09 18.08h
- ACC1 off-crest
- Typical values of dE/E = 1.5e-4

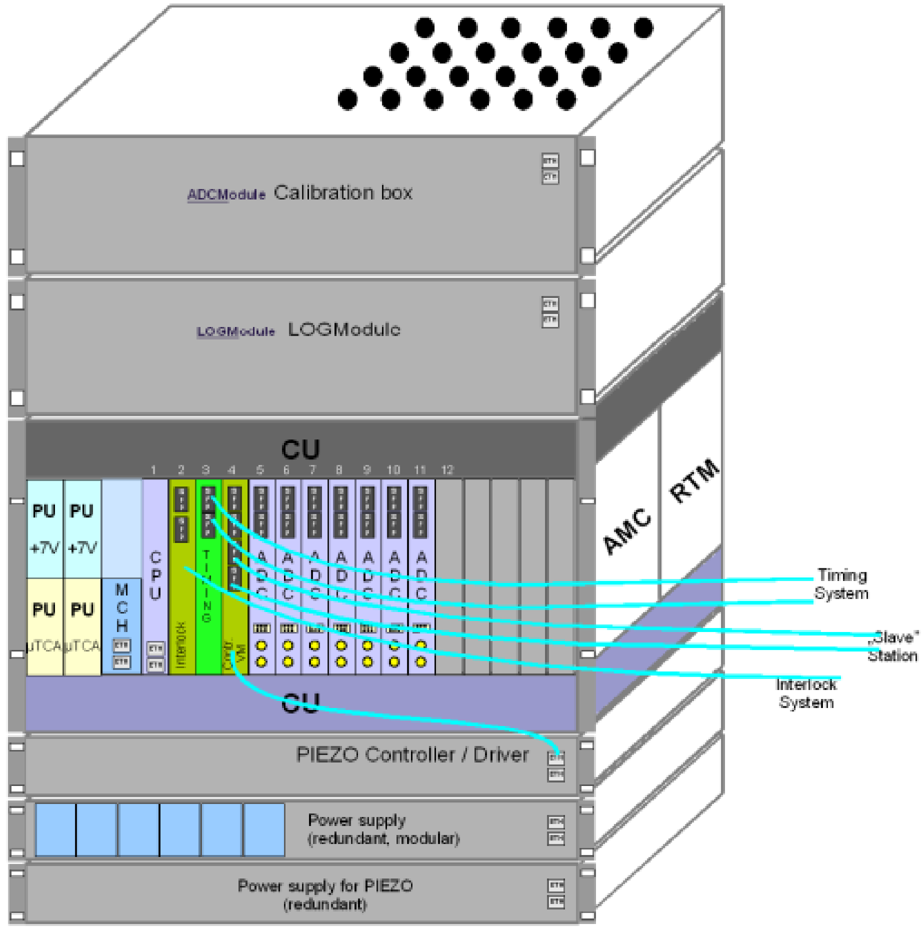
- FLASH elogbook 29.9.10 03.21h
- ACC1, ACC39 on-crest
- Best results: dE/E = 0.5e-4

This is not only effect of LLRF upgrade but several other system upgraded as well.
But after upgrade the LLRF operation has improved a LOT – *official* opinion of FLASH operators and experts.

uTCA LLRF System



back-side view



front-side view

Status of system components

- μTCA carrier board – under debugging
- fast ADC boards – manufactured and tested
- downconverter board – manufactured and tested
- piezo control board – under debugging
- vector modulator – PCB routing
- ATCA board with ultra-fast ADCs for testing of the direct sampling – under debugging and tests

From Projected Emittance to Slice Emittance

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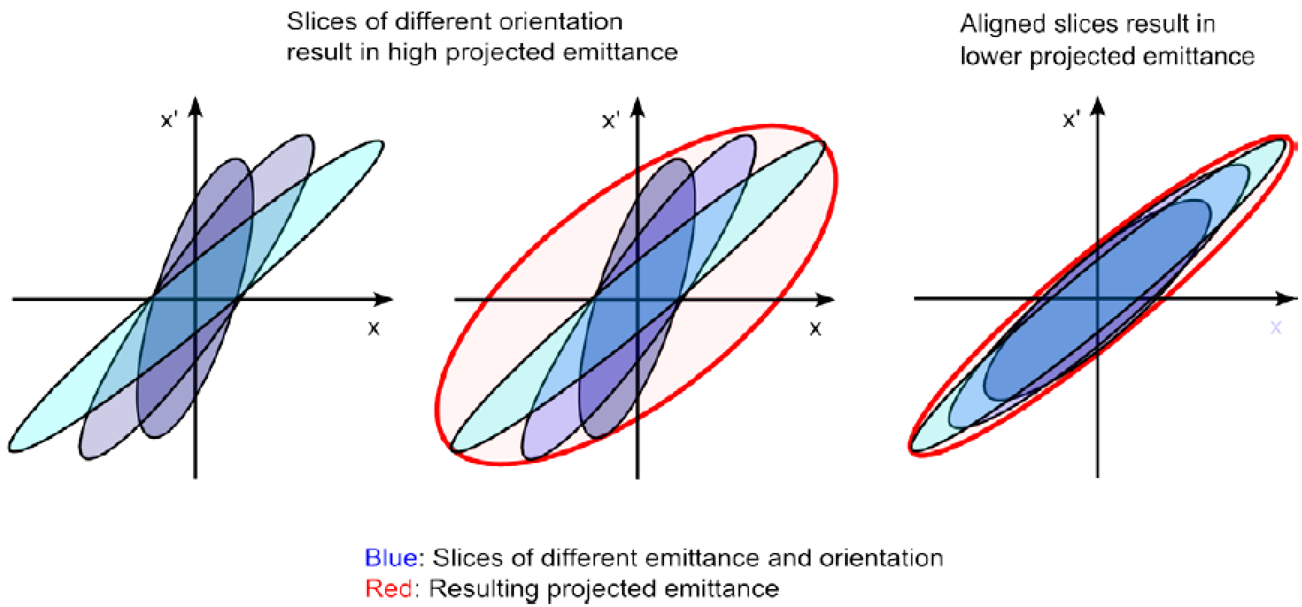
- Normally: image beam on screen, measure projection of whole bunch
  - → ‘Projected emittance’
- ‘Slice Emittance’: emittance as function of longitudinal position in bunch
  - Slices experience different focusing effects
  - Relevant for: emittance compensation schemes, FEL operation



T10.7 : Slice Emittance Measurement

Browne-Buechner Spectrometer

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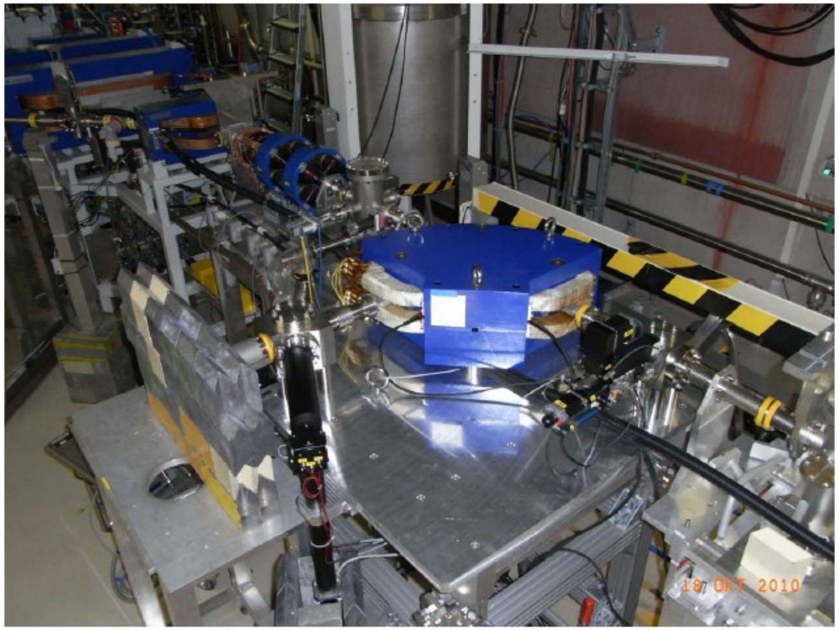
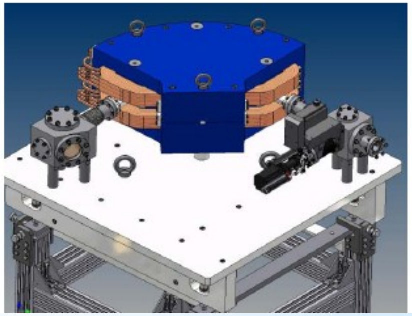
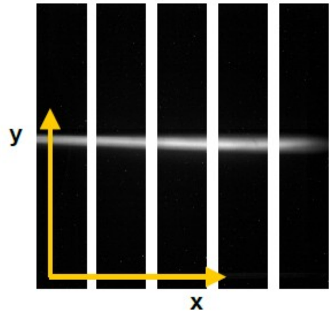
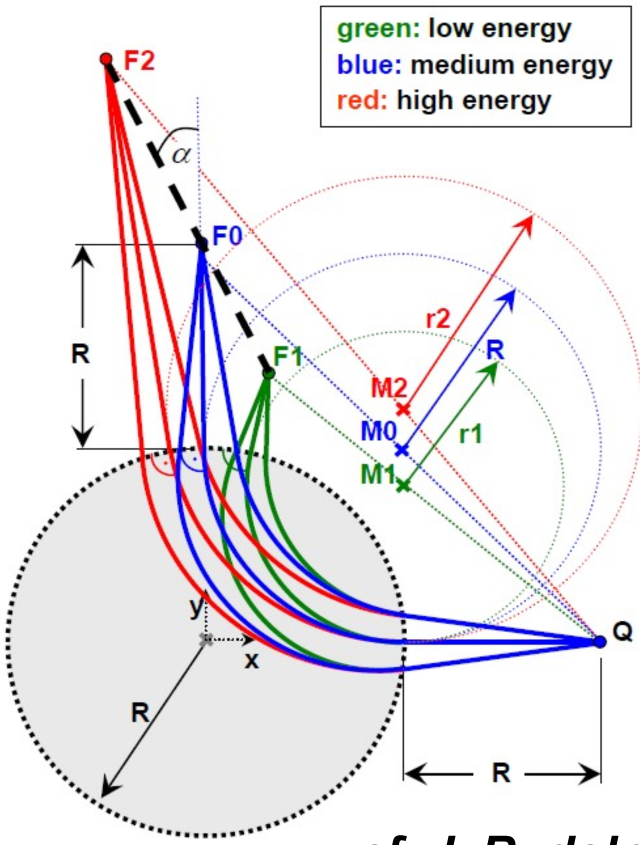








cf. J. Rudolph's talk

Design and Technology Developments

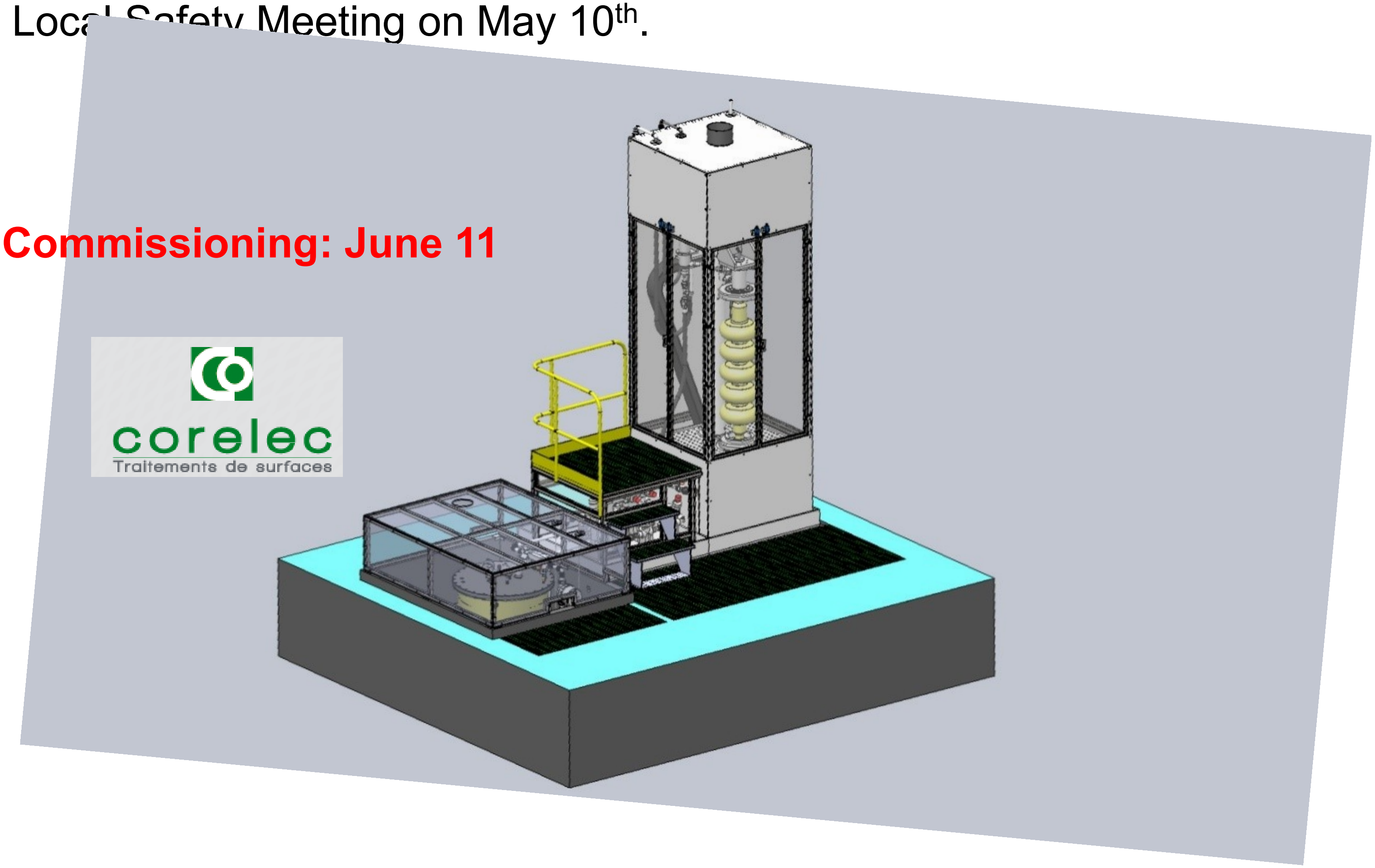
T10.2 Proton Cavities
Vertical Electropolishing for SC cavities

Irfu
cea
saclay

CORELEC Industries chosen for the set-up fabrication

- Contract signed on november 2010
- Single-tank set-up has been chosen
- Local Safety Meeting on May 10^{th}.

Commissioning: June 11



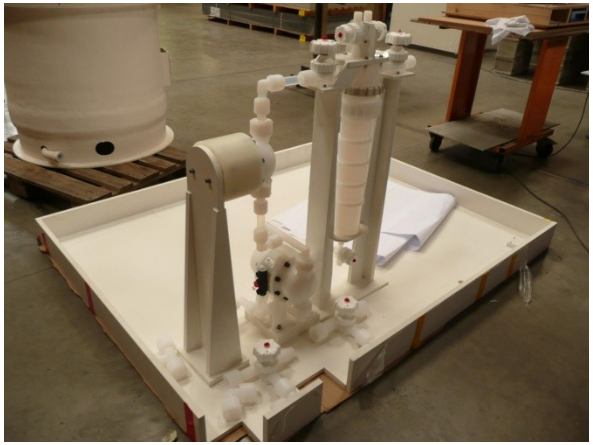
T10.2 Proton Cavities
CONSTRUCTION PROGRESS @ CORELEC

Main cabinet

Electric cabinet

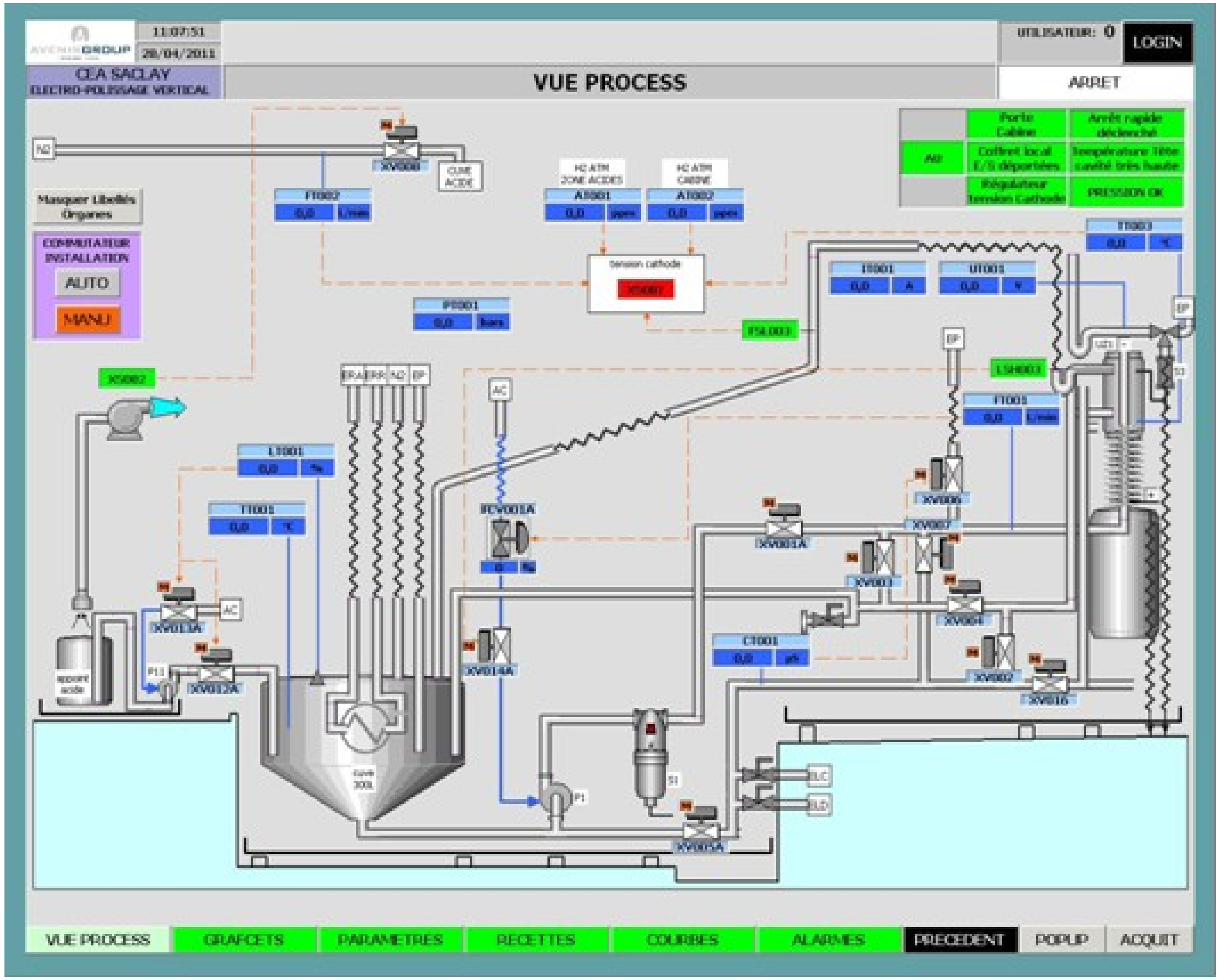
T10.2 Proton Cavities
CONSTRUCTION PROGRESS @ CORELEC


acid tank with teflon inner coating


pump + filter

fluid distribution valves (PFA)

T10.2 Proton Cavities
PROGRAMMING OF THE AUTOMAT



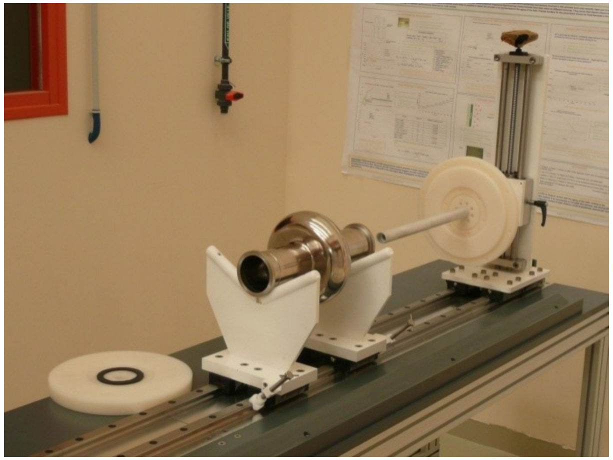
- Automated process piloted through a touch screen
- Manual mode or programmed sequences

T10.2 Proton Cavities
PREPARATION OF THE AREA AT CEA

Irfu
cea
saclay

Civil engineering and floor covered with acid-resistant painting

Set-up for cavity preparation



T10.3 CLIC Crab Cavities RF control: Kick and tolerance for 3 TeV CM

To minimise required cavity kick R12 needs to be large (25 metres suggested)
Vertical kicks from unwanted cavity modes are bad one needs R34 to be small.
For 20 mrad crossing and using as 12 GHz structure

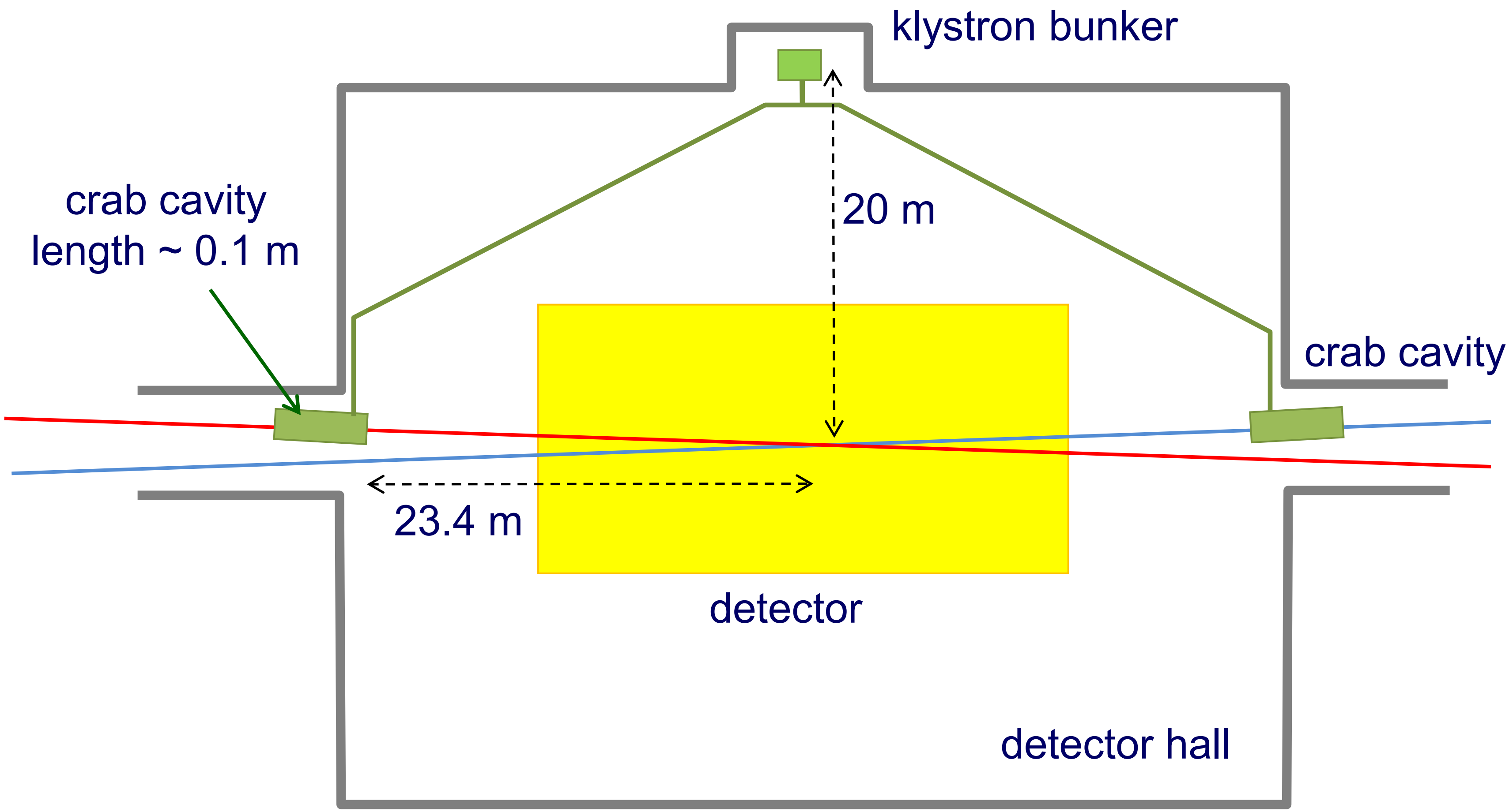
$$V_{crab} = \frac{\theta_c E_o c}{2 R_{12} \omega} = \frac{2 \times 10^{-2} \times 1.5 \times 10^{12} \times 3 \times 10^{8}}{2 \times 25 \times 2\pi \times 12 \times 10^{12}} = 2.4 \text{ MV}$$

Error in kick tilts effective collision from head on.

Luminosity Reduction Factor $S \approx \frac{1}{\sqrt{1 + \left\{ \frac{\sigma_z \theta_c}{4\sigma_x} \frac{\left(\left|\delta V_1\right| + \left|\delta V_2\right|\right)}{V_{crab}} \right\}^2}}$ gives

amplitude error on each cavity	**1.0%**	**1.5%**	**2.0%**	**2.5%**	**3.0%**
luminosity reduction	**0.9953**	**0.9914**	**0.9814**	**0.9714**	**0.9596**

T10.3 CLIC Crab Cavities RF control: Waveguide routing?



T10.3 CLIC Crab Cavities RF control: CLIC Solution

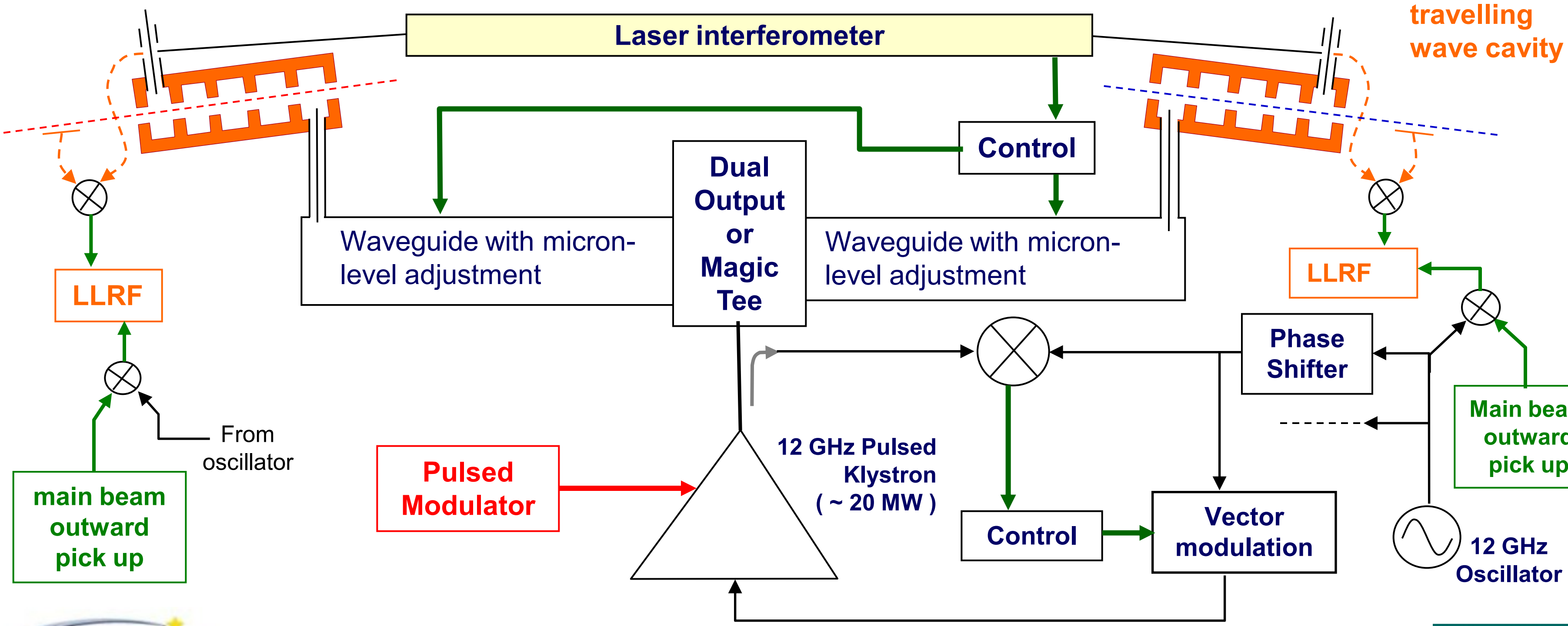
Wakefields	Large irises Small number of cells Strong damping
Phase and amplitude control	Passive during 156 ns bunch train
Beamloading compensation	High energy flow through cavity * *small number of cells* * *high group velocity* * *low efficiency*
Phase synchronisation (4.4 fs)	Same klystron drives both cavities Temperature stabilized waveguide
Phase reference	Optical interferometer
Phase measurement calibration	DBM and Down conversion to ~ 1 GHz, Digital phase detection Staggered sample and hold
Phase stability	Thick irises Strong cavity cooling

T10.3 CLIC Crab Cavities RF control: Crab Cavity RF

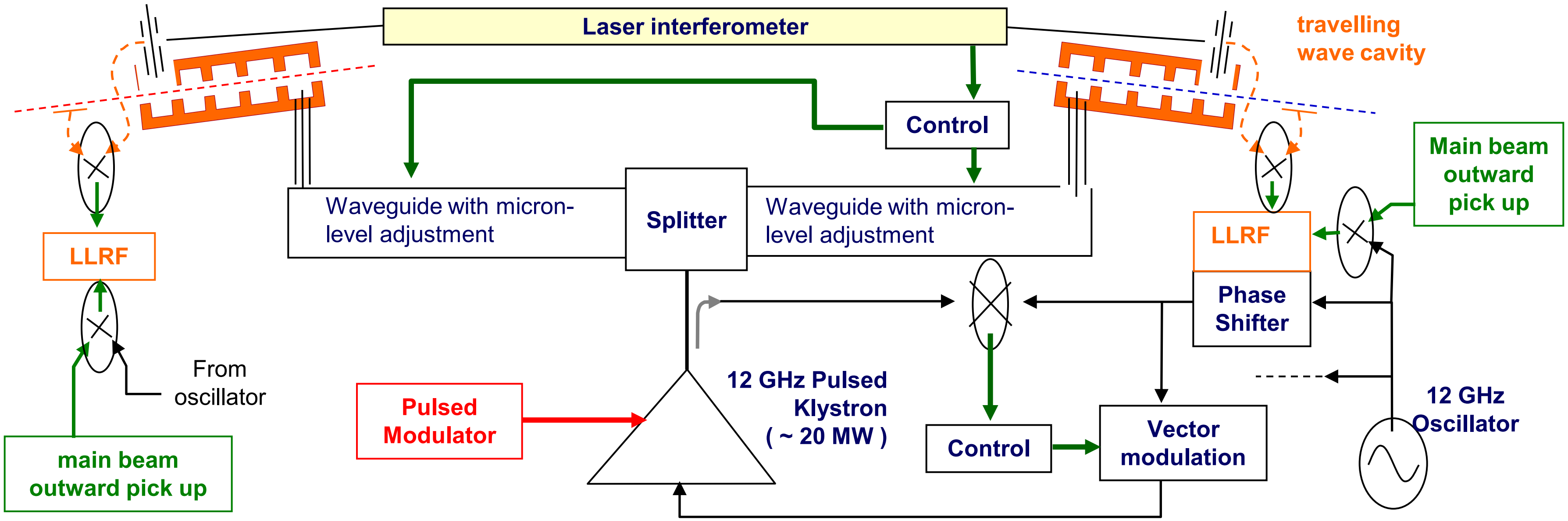
- **Beamloading constrains us to high power pulsed operation**
- **Intra bunch phase control looks impossible for a 140 ns bunch**

SOLUTION

- **One Klystron (~ 20 MW pulsed) with output phase and amplitude control**
- **Intra bunch delay line adjustment for phase control (i.e. between bunch trains)**
- **Very stable cavities**



T10.3 CLIC Crab Cavities RF control: RF Layout and Procedure



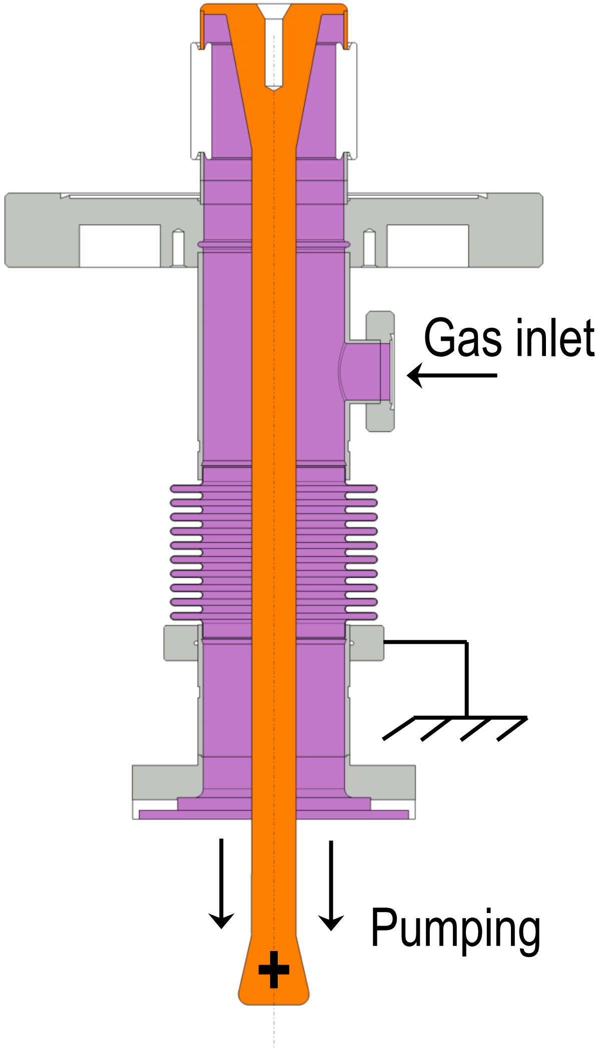
Once the main beam arrives at the crab cavity there is insufficient time to correct beam to cavity errors. These errors are recorded and used as a correction for the next pulse.

0. Send pre-pulse to cavities and use interferometer to measure difference in RF path length (option1)
1. Perform waveguide length adjustment at micron scale (option 2 use measurements from last pulse)
2. Measure phase difference between oscillator and outward going main beam
3. Adjust phase shifter in anticipation of round trip time and add offset for main beam departure time
4. Klystron output is controlled for constant amplitude and phase
5. Record phase difference between returning main beam and cavity
6. Alter correction table for next pulse

T10.8 : LAL Coupler Plasma Discharge Cleaning

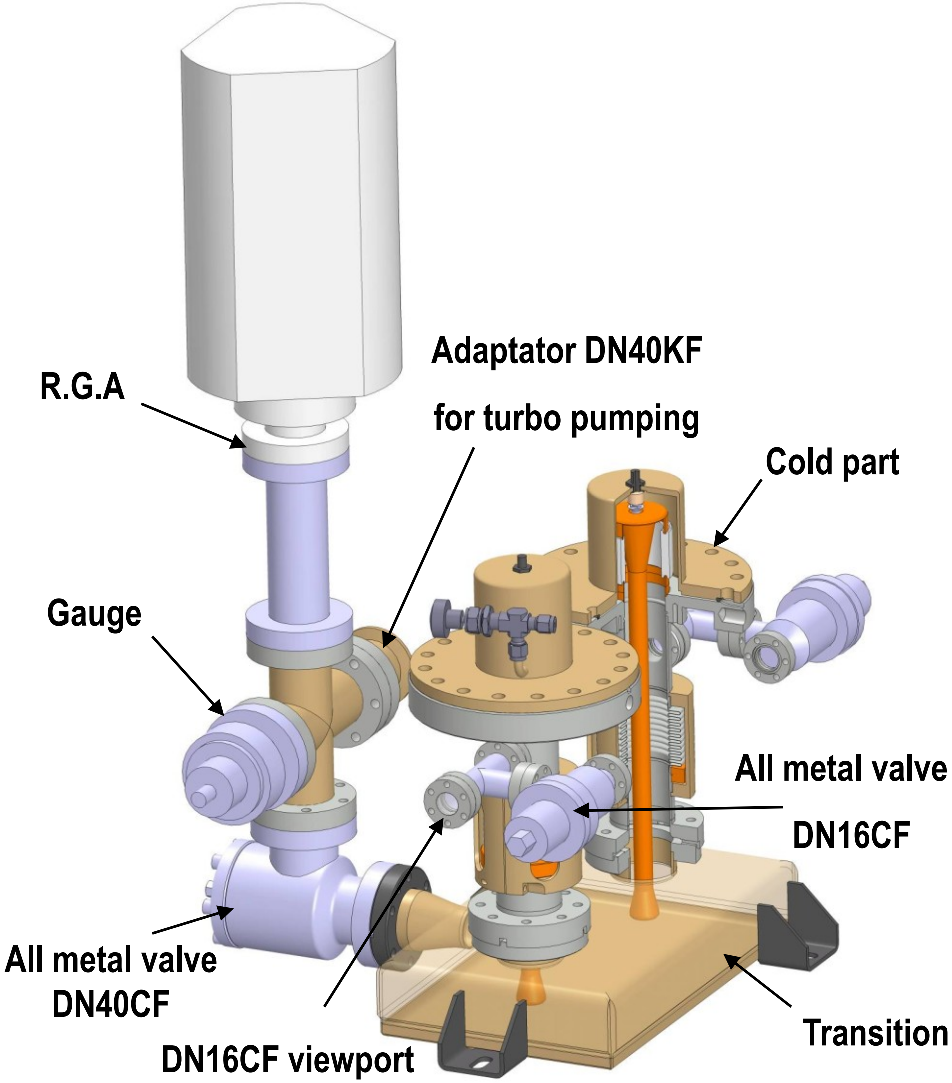
Plasma discharge cleaning of power coupler

- Gas discharge introduction into internal coupler part
- Controlled pumping to reach 10^{-1} mbar pressure and create a laminar pumping flux
- Direct current bias application with a positive antenna voltage and a grounded coupler corps
- Plasma creation at all power coupler internal parts



T10.8 : LAL Coupler Plasma Discharge Cleaning

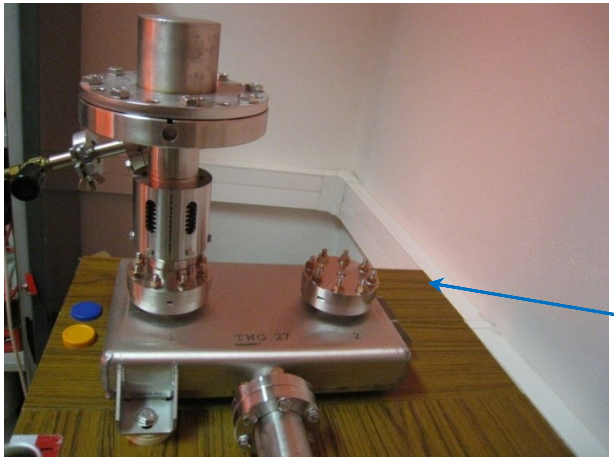
Experimental assembly

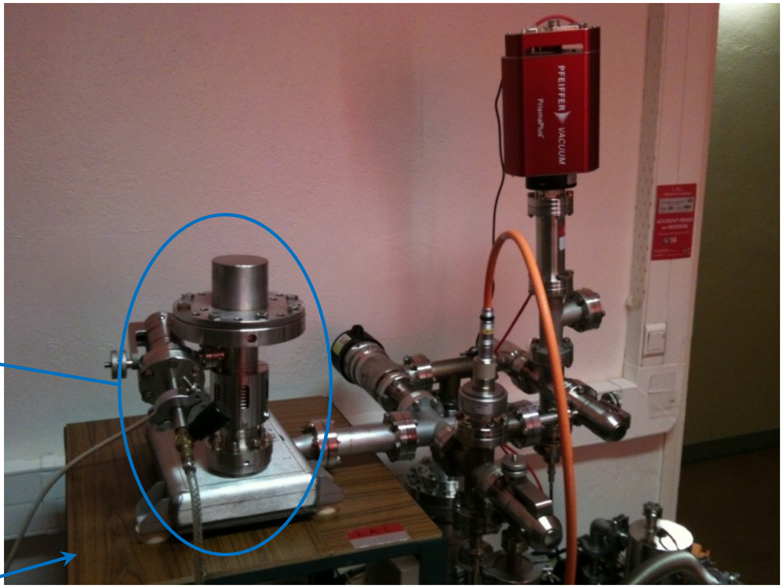


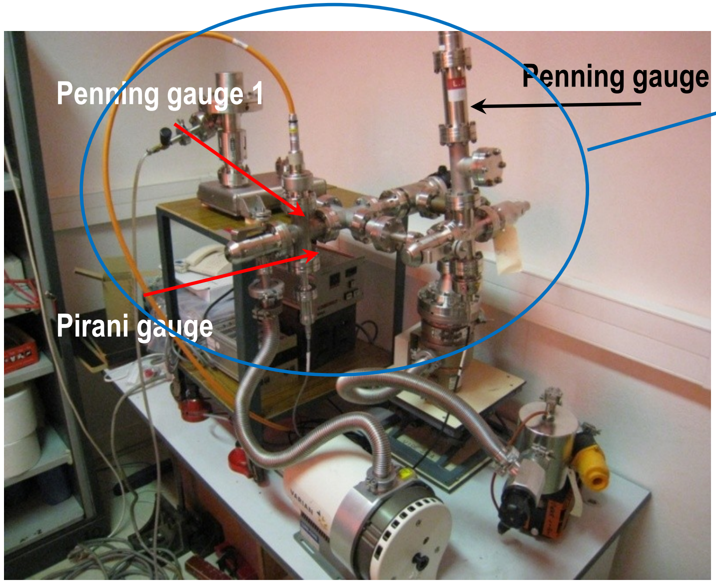
- Treatment of two cold coupler parts and the transition wave guide box (TWG) in the same time
- Gas inlet in the top of cold coupler parts and pumping at the exit of the TWG to get a laminar flux
- The RGA for pumped gas analysis
- Copper samples could be placed at the internal of the coupler for SEY measurements after treatment.

T10.8 : LAL Coupler Plasma Discharge Cleaning

Experimental assembly







System vacuum characterization before plasma discharge cleaning

WP10 Deliverables: 15 units

Ref.	N°	Deliverable Name	Deliverable Type	Task	Delivered by Contractor (s)	Planned (in months)
10.4.1	1	QE data for Pb/Nb deposited photo cathode samples	Report	Thin Films	DESY, IPJ	12 ✓
10.7.1	2	Results of slice measurements	Report	SCRF Gun	FZD, HZB	24 ✓
10.8.1	3	Test and operation of the coupler preparation procedure	Report	Coupler Development	CNRS-LAL	24 +10
10.4.4	4	New thin film techniques for SC cavities and photocathodes	Demonstrator	Thin Films	ULANC	30
10.2.1	5	Results of SC proton cavity tests (β = 1 and β = 0.65)	Report	SPL cavities	CEA, CNRS-IPNO	33
10.7.2	6	Results for GaAs photocathodes	Report	SCRF Gun	FZD, HZB	33
10.3.1	7	LHC crab cavity final report	Report	Crab cavities	CERN	36
10.3.2	8	CLIC crab cavity final report	Report	Crab cavities	UNIMAN	36
10.3.3	9	LHC and CLIC LLRF final reports	Report	Crab cavities	ULANC	36
10.4.2	10	RF measurements on thin film deposited QWR prototype	Report	Thin Films	CERN	36
10.4.3	11	Cold test results for the test cavities w/out the deposited lead photo cathode	Report	Thin Films	DESY	36 ✓
10.5.2	12	Report on HOM experimental methods and code	Report	HOM distribution	UNIMAN	40
10.6.1	13	Report on system test and performance	Report	LLRF at FLASH	DESY	42
10.1.1	14	SRF web-site linked to the technical and administrative databases	Web-Site	Coordination	CEA, CERN	48
10.5.1	15	HOM electronics and code to probe beam centring on 3.9 GHz cavities	Report	HOM distribution	DESY	48

Conclusions

- All Tasks have continued their efforts.
- Some tasks are delayed, but within 48 months
- Some task are *nearly* closed (e.g.T10.3.3, T10.4.2, T10.7.1)
- Many challenging
  - RF designs,
  - Technology Developments,
  - Realizations,
  - Beam experiments (FLASH, ELBE)

  ahead of us.

Thank You for Your Attention