WP8-HGA
High Gradient Acceleration

M. Biagini (INFN-LNF) WP8 coordinator

Tiara Kickoff Meeting, CERN, Feb. 23-24, 2011

WP8 – HGA

WP coordinator: M. Biagini (INFN). WP deputy: A. Gallo (INFN)

- Goal: energy upgrade of the Frascati SPARC test-facility linac by designing, constructing and commissioning 2 C-band (f=5712 MHz) TW high-gradient accelerating structures
- Partners: INFN, PSI, University of Rome “La Sapienza” as sub-contractor
- Duration: 3 years
- Work Breakdown:
  - WP8.1 : Study of SPARC upgrade in Energy (INFN)
  - WP8.2 : RF Low level Electronics for SPARC (PSI)
  - WP8.3 : Construction and test of 2 C-band sections (INFN)

Expected results

- Increase the potentiality of the SPARC test-facility
- Test of a hybrid linac structure (S-band injector + C-band booster)
- Development of new, compact, high gradient accelerating structures by exploiting existing facilities at INFN Frascati Labs
- Development of state-of-the-art digital RF controls for C-band applications
- Establish the C-band technology as a mature option for compact, high gradient (≥ 35 MV/m) linear accelerators for FEL facilities (SwissFEL) and injectors for high luminosity colliders (SuperB)

Budget

- Total budget: 1106 k€ , EC contribution: 349 k€
- Person/month: 54 (INFN) + 24 (PSI) =78
- Total cost: 776 (INFN) + 330 (PSI) k€
- INFN will subcontract 30 k€ to Rome University “La Sapienza” for carrying out C-band traveling wave structure bench measurements and performing beam dynamics studies for the hybrid C-band and S-band configuration
- INFN with assign a 31 months contract to an engineer starting August 2011

Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Material and travel indirect costs	Total direct costs	Total indirect costs	Total costs (direct +indirect)
PSI	24.00	189.60	37.92	0	79.20	6.25	17.09	275.05	55.01	330.06
INFN	54.00	280.80	168.48	0	176.80	8.75	111.33	466.35	279.81	746.16
Rome University				30				30		30.00
Totals:	78	470.400	206.40	30	256.00	15	128.42	771.40	334.82	1,106.22

Tasks & Subtasks

8.1	**SPARC-UP**	Study of SPARC upgrade in energy
8.1.1	**ACCP-DES**	Design of a C-band accelerating structure prototype: simulation and optimization
8.1.3	**ACCP-CAD**	Design of a C-band accelerating structure prototype: preparation of CAD mechanical drawings
8.1.4	**ACCP-DES**	Modifications of the accelerating structures design if needed after prototype test
8.2	**ACCP-CAD**	Modifications of CAD mechanical drawings if needed after prototype test
8.2	**RF-LLE**	RF Low Level Electronics
8.2.1	**LLE-DES**	Design of a digital LLRF electronics
8.2.2	**LLE-CON**	Construction and test of a prototype at SPARC
8.3	**SPARC-CON**	Construction and test of SPARC C-band section
8.3.1	**HGA-HDW**	Acquisition of necessary hardware and material
8.3.2	**ACC-PROT**	Construction and test of an accelerating structure prototype with a reduced number of cells to be tested at high power
8.3.3	**ACC-CON**	Construction, installation on SPARC of the final accelerating structures
8.3.4	**ACC-TEST**	Test of C-band upgrade at SPARC

Deliverables & Milestones

Num	Nat	Short name	Description	Month	PM
D8.1	P	**SPARC-C**	Construction of accelerating structures	**24**	**54**
D8.2	O	**SPARC-T**	Commissioning and test of the C-band Linac structure at SPARC	**35**	**24**

Num	Nat	Short name	Description	Month
M8.1	O	**HARDW-A**	Hardware acquisition	**6**
M8.2	R	**ACC-D**	Design of accelerating structures	**18**
M8.3	R	**RF-LLE-D**	Design RF-LLE	**18**
M8.4	P	**RF-LLE-P**	First RF-LLE prototype	**24**

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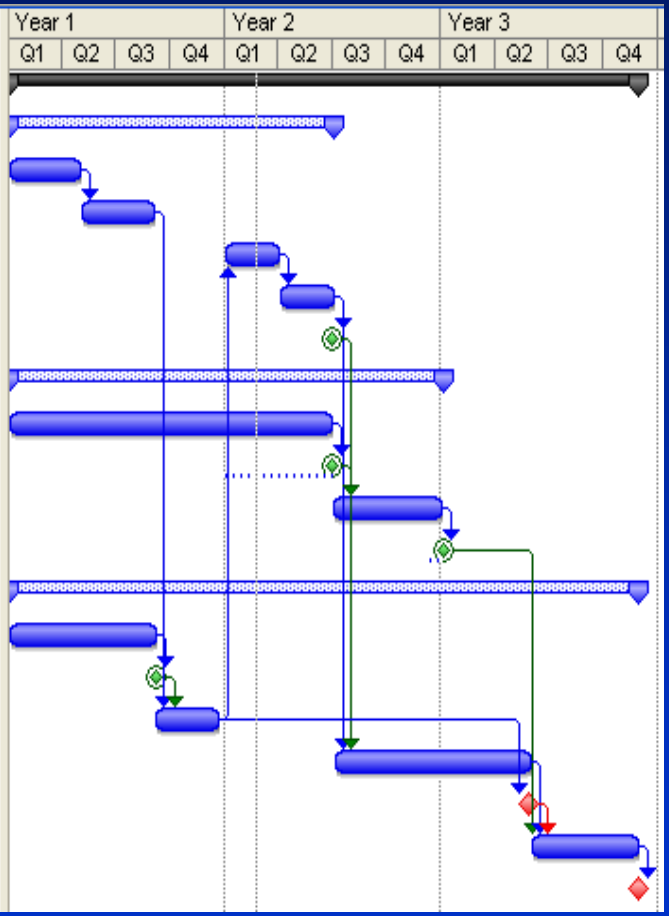
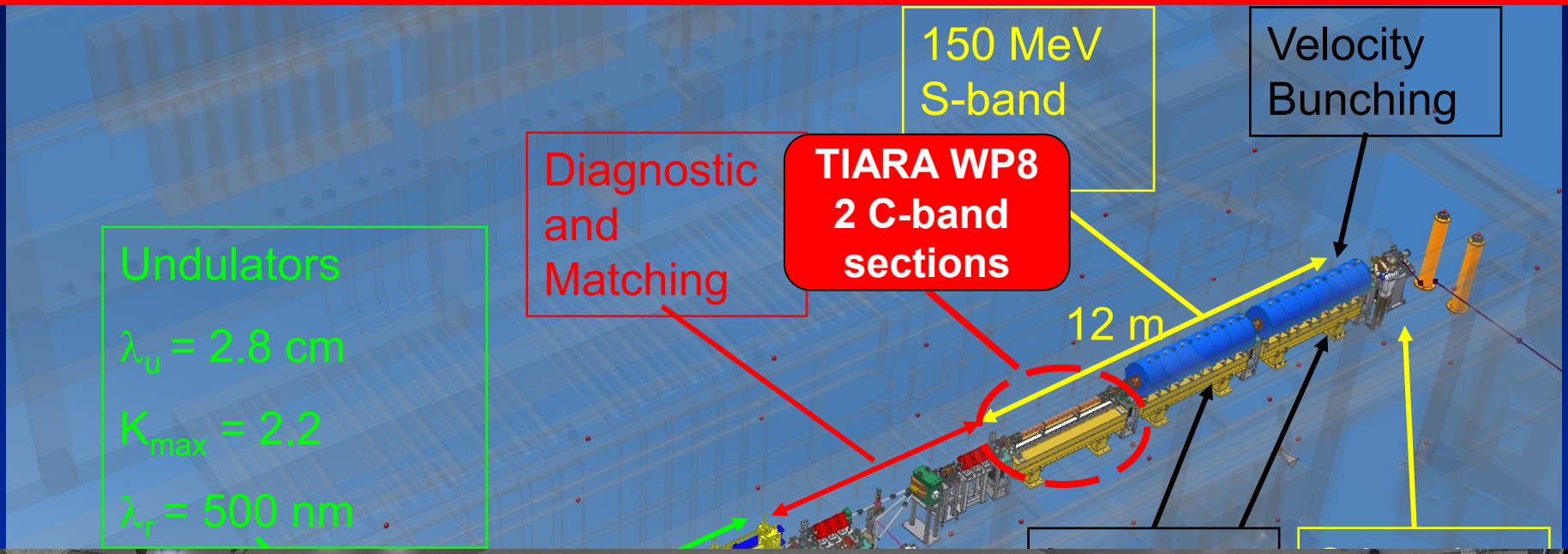
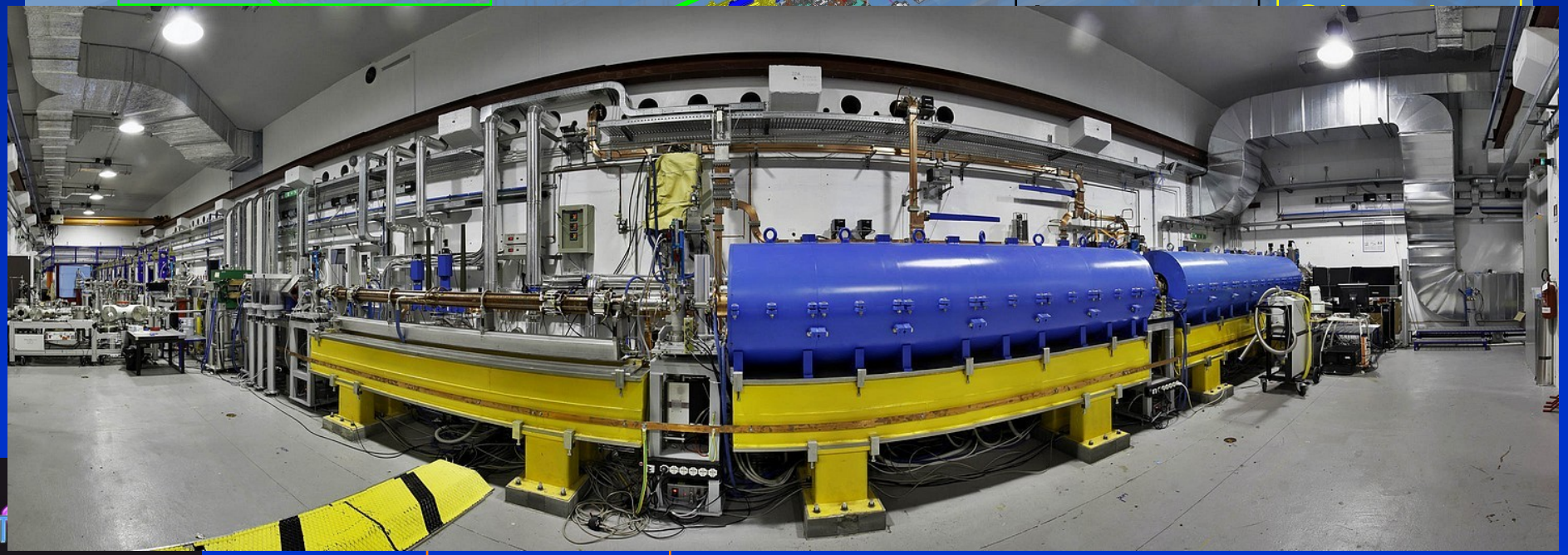
WP8 Gannt Chart

Task Name	Du
WP8: High Gradient Acceleration (HGA) R&D Infrastructure	
8.1 SPARC-UP: Study of SPARC upgrade in energy	
8.1.1 ACCP-DES: Design of a C-band accelerating structure prototype: simulation and optimization	
8.1.2 ACCP-CAD: Design of a C-band accelerating structure prototype: preparation of CAD mechanical drawings	
8.1.3 ACC-DES: Design of a C-band final accelerating structure: simulation and optimization	
8.1.4 ACC-CAD: Design of a C-band final accelerating structure: preparation of CAD mechanical drawings	
M8.1 ACC-D: Accelerating structures designed	
8.2 RF-LLE: RF Low Level Electronic	
8.2.1 LLE-DES: Design of a digital RF-LLE electronics	
M8.2 RF-LLE-D: RF-LLE-D: Low Level Electronic RF designed	
8.2.2 LLE-CON: Construction and test of a prototype at SPARC	
M8.3 RF-LLE-P: RF-LLE-P: First RF-LLE prototype	
8.3 SPARC_CON: Construction and test of SPARC C-band section	
8.3.1 HGA-HDW: Hardware and material acquisition	
M8.4 HARDW-A: Hardware and material acquisition	
8.3.2 ACC-PROT: Construction and test of an accelerating structure prototype	
8.3.3 ACC-CON: Construction of two final accelerating structures	
D8.1 SPARC-C: Construction of accelerating structures finished	
8.3.4 ACC-TEST: Test of SPARC C-band upgrade	
D8.2 SPARC-T: Report on commissioning of accelerating structures	

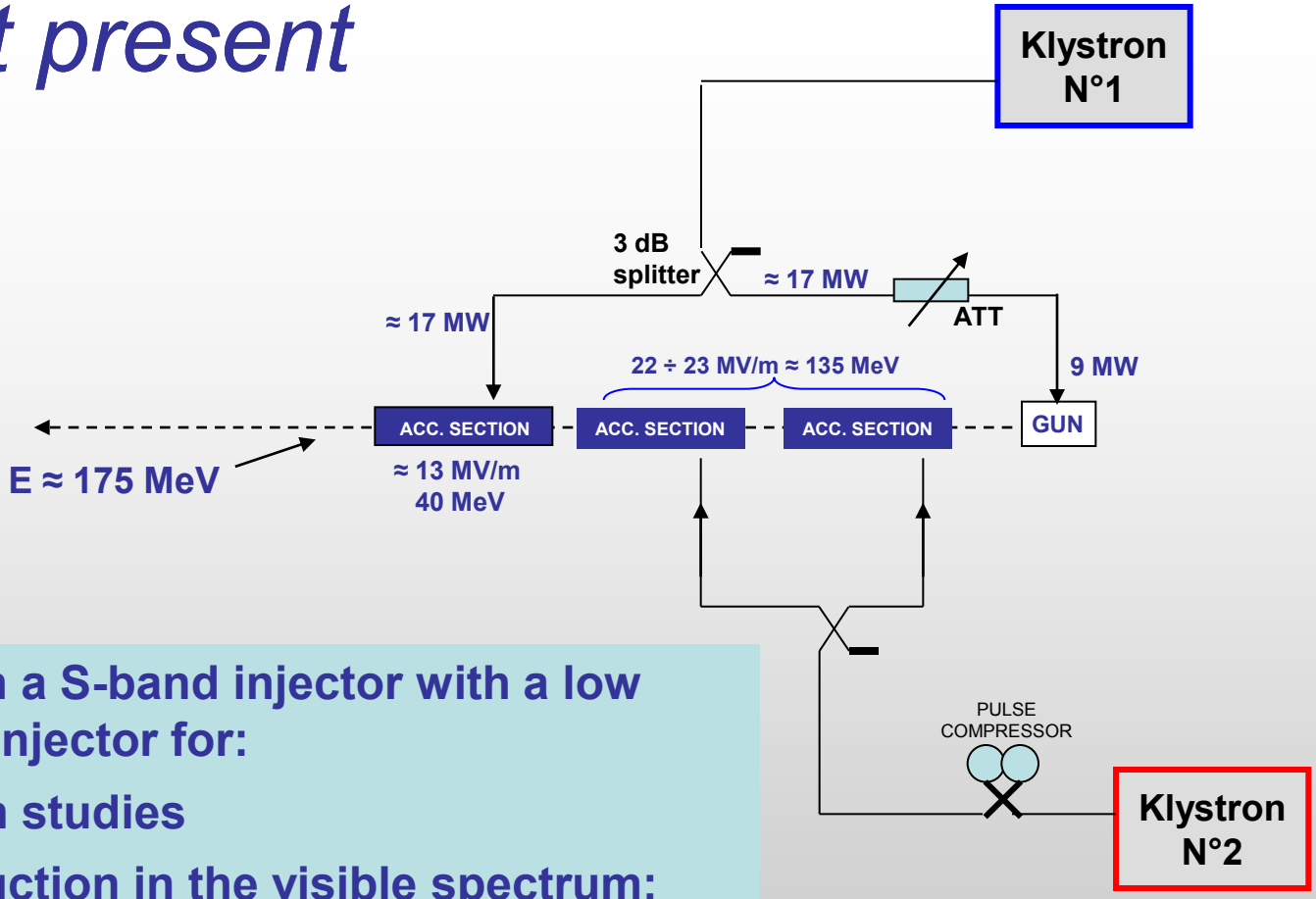


SPARC Test Facility @ LNF





SPARC at present

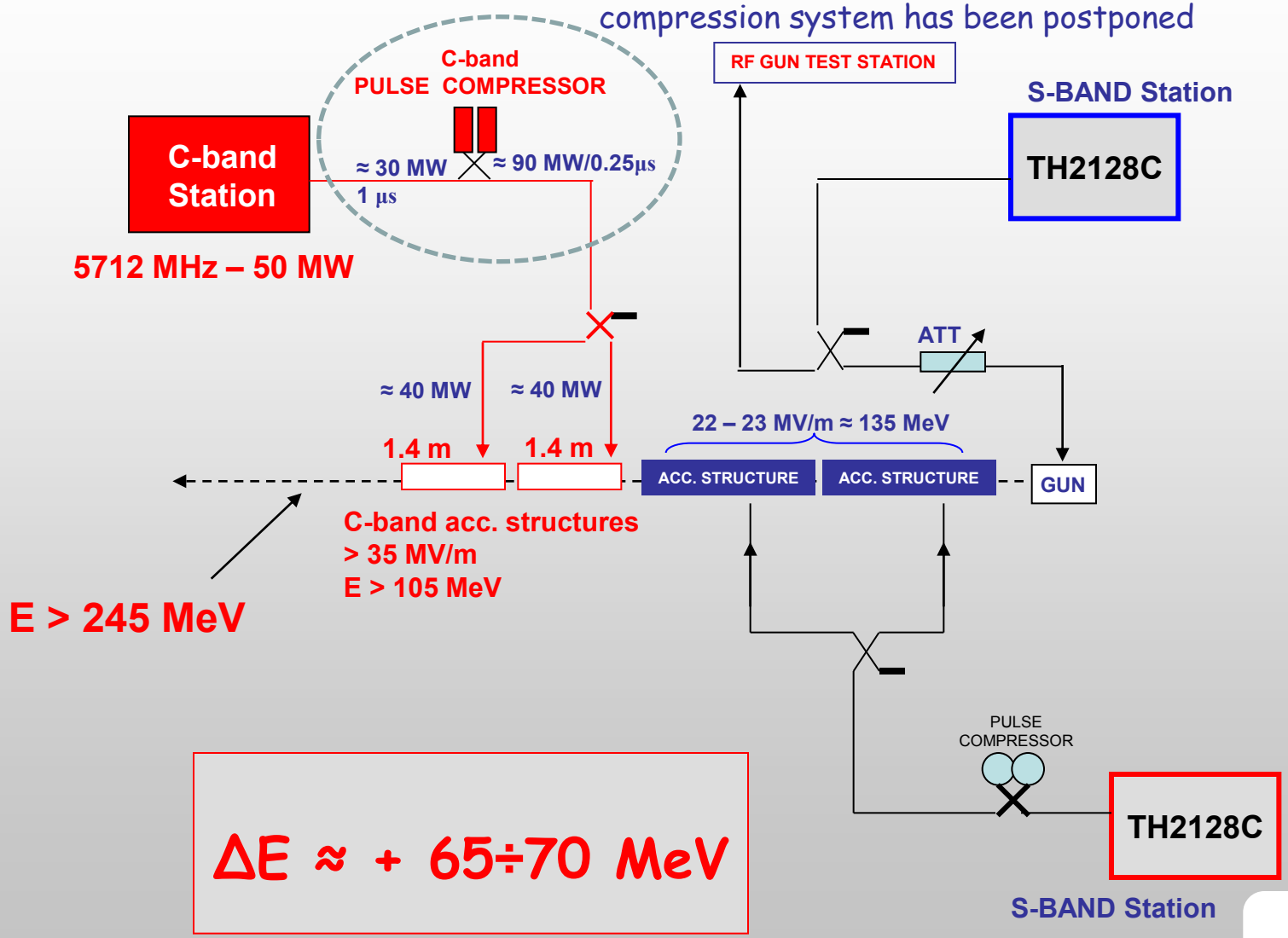


Test facility based on a S-band injector with a low emittance RF photo-injector for:

- High brillance beam studies
- FEL radiation production in the visible spectrum;
- FEL Seeding experiments;
- FEL cascade tests;
- Plasma acceleration experiments;
- THz radiation production;
- …

SPARC energy upgrade with a C-band system

Because of budget reduction, development of pulse compression system has been postponed

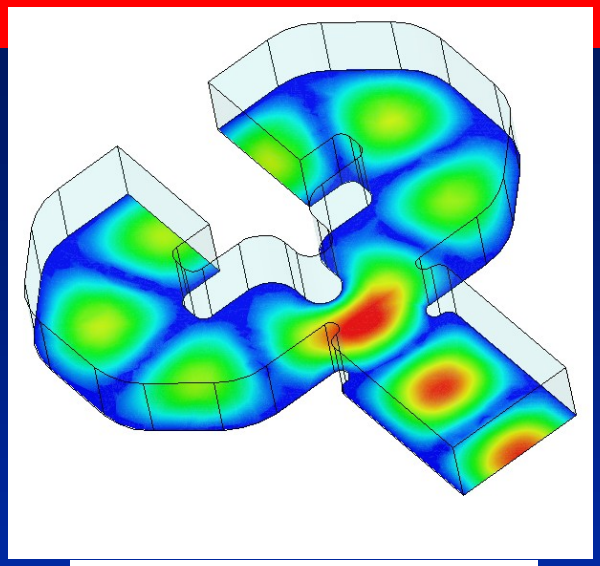


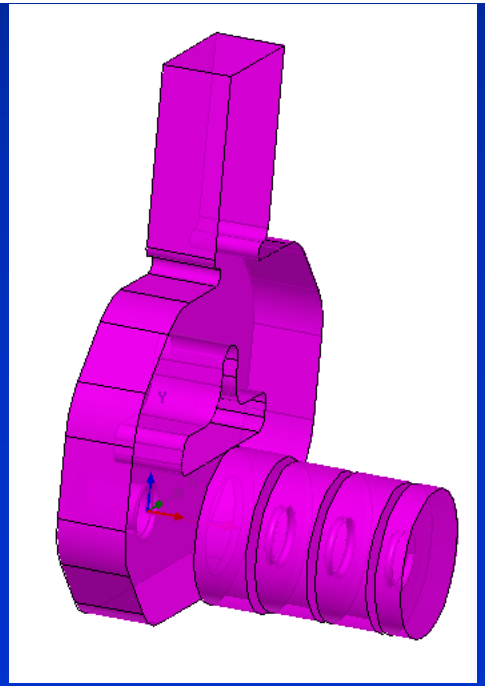
ΔE ≈ + 65÷70 MeV

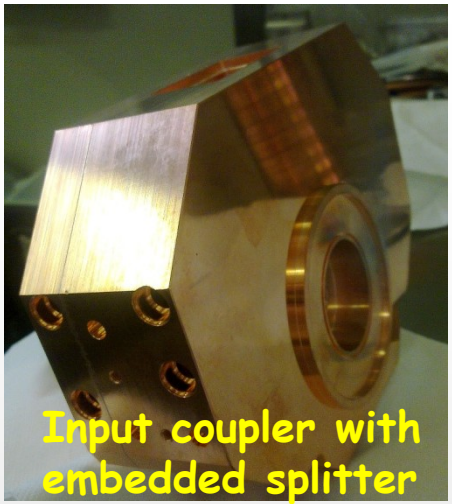
R. Boni
INFN Istituto Nazionale di Fisica Nucleare

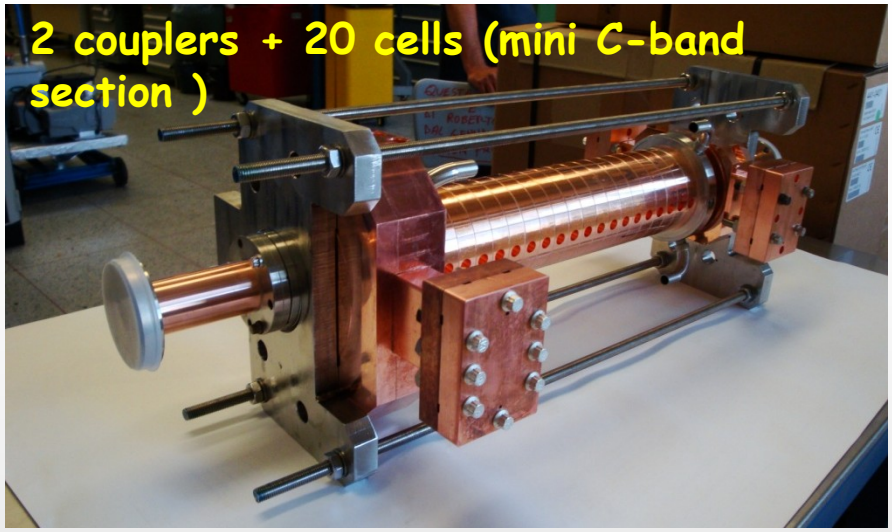
HGA studies in 2010

- During 2010 activity on design, construction and test on input/output couplers for C-band TW, constant impedance accelerating structures has started at LNF
- A special two-arms coupler including an embedded RF splitter has been designed and built. A mini-section including 2 couplers separated by 20 cells has been built and tested at the KEK C-band facility. This work is preliminary to the TIARA WP8 target

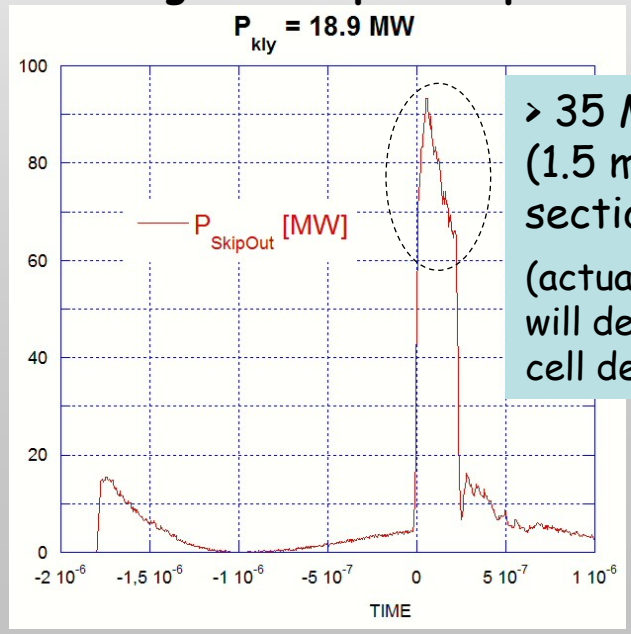








Measured RF power flow through the input coupler

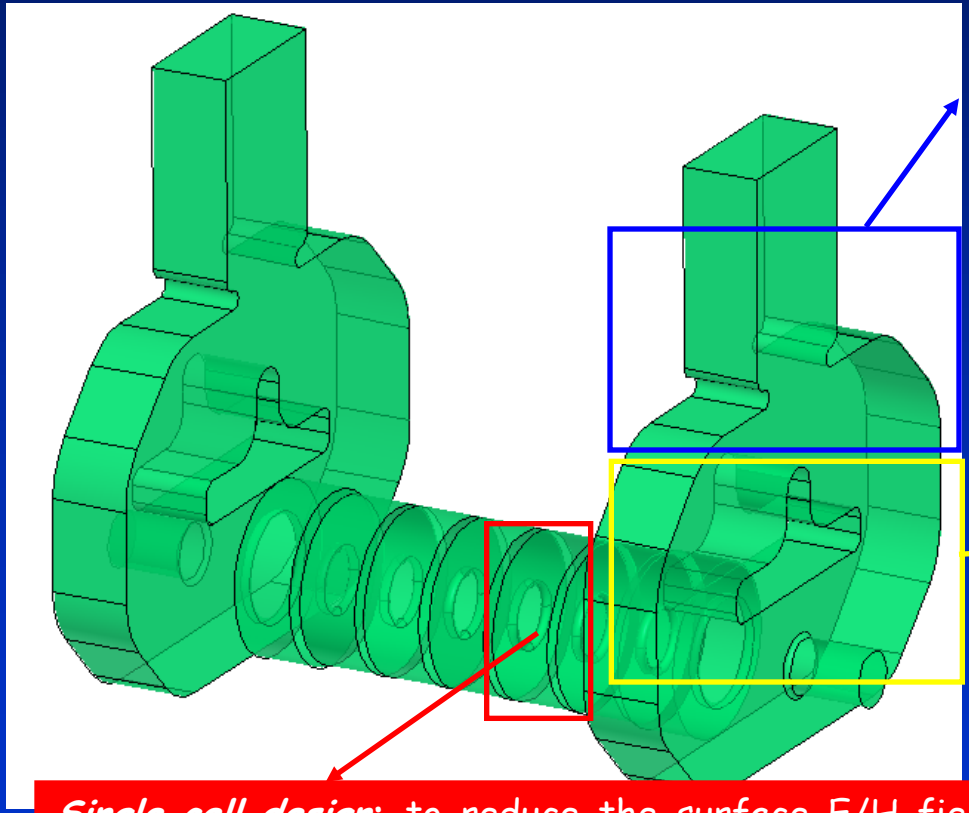


> 35 MV/m on a full (1.5 m) length section

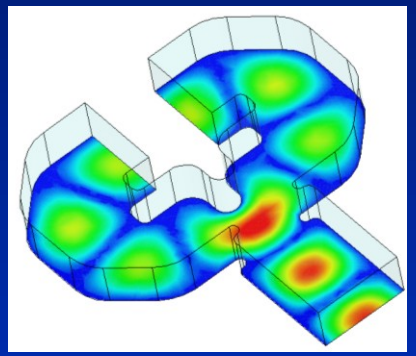
(actual gradient value will depend on final cell design)

8.1: SPARC-UP Study of SPARC upgrade in energy

- Task goal: electro-magnetic design and production of CAD drawings of C-band accelerating section prototype and final units (due M18)
- For this aim the e.m. design activity has been divided in three different parts



Splitter: for a symmetric feeding of the structure. Already designed, built and tested



Coupler design: based on the "new generation" of couplers proposed and adopted at SLAC for high gradient X Band structures (waveguide couplers). Already designed, built and tested

Single cell design: to reduce the surface E/H fields reducing the break-down probability as much as possible and allowing reaching safely 35 MV/m. Field attenuation and group velocity have to be also optimized to fully exploit the Pulse Compression System potentiality. **This part needs more study and optimization**.

8.1: SPARC-UP Study of SPARC upgrade in energy

- During 2011 a C-band accelerating structure prototype will be electro-magnetically and mechanically designed
- Optimization of the geometry of the cells, and consequent re-adjustment of the input/output couplers are the main tasks of the e.m. design
- The exact number of cells of the prototype has been chosen to be the full-length structure (≈ 80 cells, 1.4 m)
- Prototype construction and power test (see 8.3.2) will give hints for e.m. and CAD design of the final accelerating structures
- This work will be carried out under the responsibility and expertise of the INFN Frascati group, with the collaboration of University of Rome “La Sapienza” in particular for what concerns the cold bench characterization and tuning of the prototype and final accelerating sections and beam dynamics studies for the hybrid C-band and S-band configuration

8.2: RF Low Level Electronics for SPARC

PAUL SCHERRER INSTITUT
PSI
T. Schilcher

- Task: design a flexible and high performance low level RF system for 5712 MHz (C-band) **(due M24)**
- Milestones:
  - mid 2012: design of C-band LLRF system ready
  - end of 2012: test of C-band LLRF electronics prototype @ INFN
- LLRF design goals:
  - fast intra pulse phase modulation capabilities to drive RF pulse compressor
  - ultra low jitter drive signal to pre-amplifier/klystron (goal: <5 fs added jitter by LLRF system [100 Hz -10 MHz])
  - high resolution amplitude/phase measurements (goal: phase resolution < 0.02º RMS, amplitude resolution < 0.02% RMS within RF pulse)
  - pulse-to-pulse feedback for drift compensation (up to 100 Hz rep. rate)
  - dedicated high speed interfaces to diagnostic devices for beam based feedbacks

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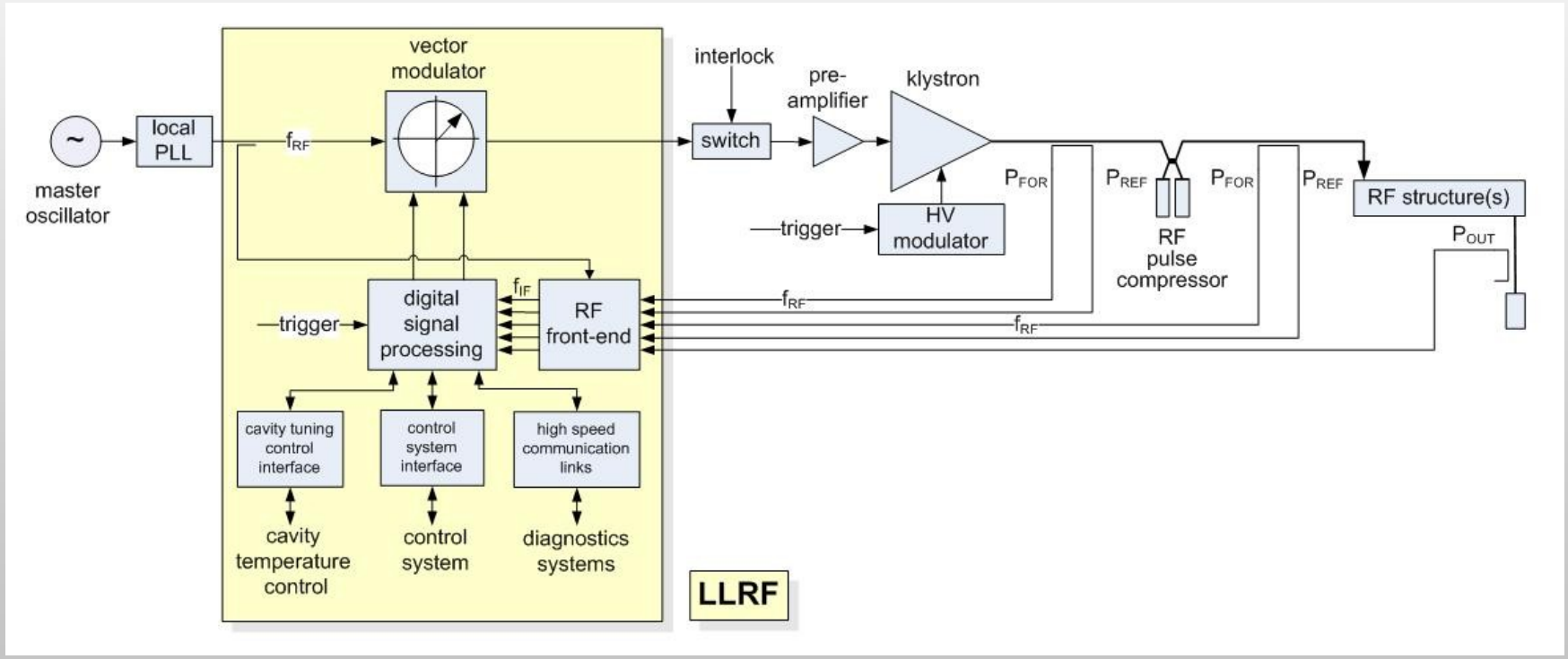
LLRF System Layout

digital LLRF system:

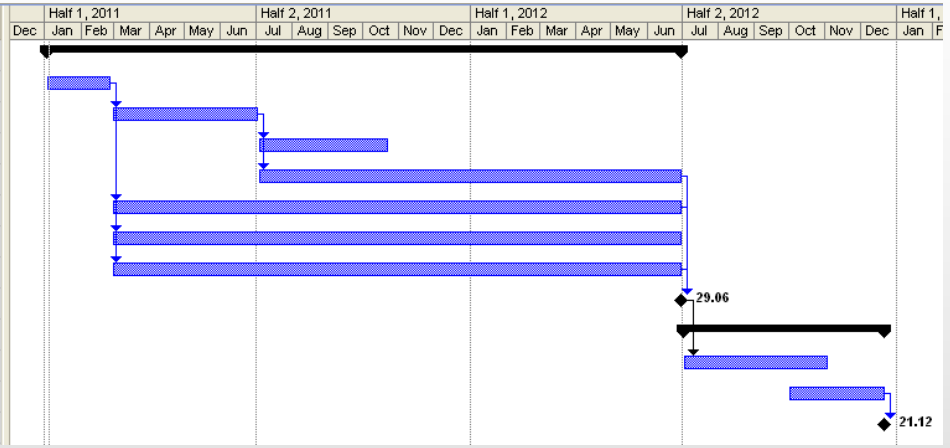
- FPGA/PPC platform
- ADC/DAC boards (16 bit, 125/250 MS/s)
- RF signal down conversion to IF frequency ($f_{IF}=f_{C\text{-band}}/128$ = 44.625 MHz)
- up-conversion to 5712 MHz with vector modulator
- control system interface: VMEbus/Ethernet



LLRF development steps

time schedule:

Task Name	Duration	Start	Finish
LLRF System Design	**390 days**	**Mon 03.01.11**	**Fri 29.06.12**
define system requirements	8 wks	Mon 03.01.11	Fri 25.02.11
digital platform evaluation	18 wks	Mon 28.02.11	Fri 01.07.11
DSP hw procurement	16 wks	Mon 04.07.11	Fri 21.10.11
SW/FW development	52 wks	Mon 04.07.11	Fri 29.06.12
RF front-end development	70 wks	Mon 28.02.11	Fri 29.06.12
vector modulator development	70 wks	Mon 28.02.11	Fri 29.06.12
LO generation unit	70 wks	Mon 28.02.11	Fri 29.06.12
design finished	0 days	Fri 29.06.12	Fri 29.06.12
Construction & Test	**125 days**	**Mon 02.07.12**	**Fri 21.12.12**
hw construction	18 wks	Mon 02.07.12	Fri 02.11.12
system integration & test	12 wks	Mon 01.10.12	Fri 21.12.12
LLRF prototype tested	0 days	Fri 21.12.12	Fri 21.12.12



workflow:

- definition of requirements (PSI & INFN)
- prototype development @PSI
  (involved manpower: 1 RF engineer, 2 FW/SW engineers, 2 electrical engineers, 1 technician)
- test of prototype @ PSI together with people from INFN
- integration of LLRF system into SPARC by INFN people with support from PSI and commissioning @ SPARC

8.3: SPARC-CON Cavities construction

- Procedures for acquisition of the bulk copper are well advanced. Milestone 8.4 will be probably reached ≈3 months earlier
- Prototype construction will start as soon as e.m. design and CAD drawings will be completed. Due to the positive results on the mini C-band section, we consider the RF couplers design basically done. Therefore, prototype construction will start ≈ 3 months earlier with respect to the plan (due M24)
- After the installation the commissioning of the sections will take place (due M35)

Conclusions

- WP8 activities started already both at INFN and PSI
- Thanks to the work done in 2010 on RF couplers, including positive high power tests performed at KEK, the design of the C-band section prototype will be completed by mid 2011, and construction will start soon after
- The design of the RF-LLE has also started at PSI. First step will be a joined (INFN and PSI) detailed definition of the functionality and specifications of the interface with the SPARC control system
- The construction of cavities will probably happen few months sooner than planned, this will give more time for the commissioning of the structures that will in any case end with the end of the program