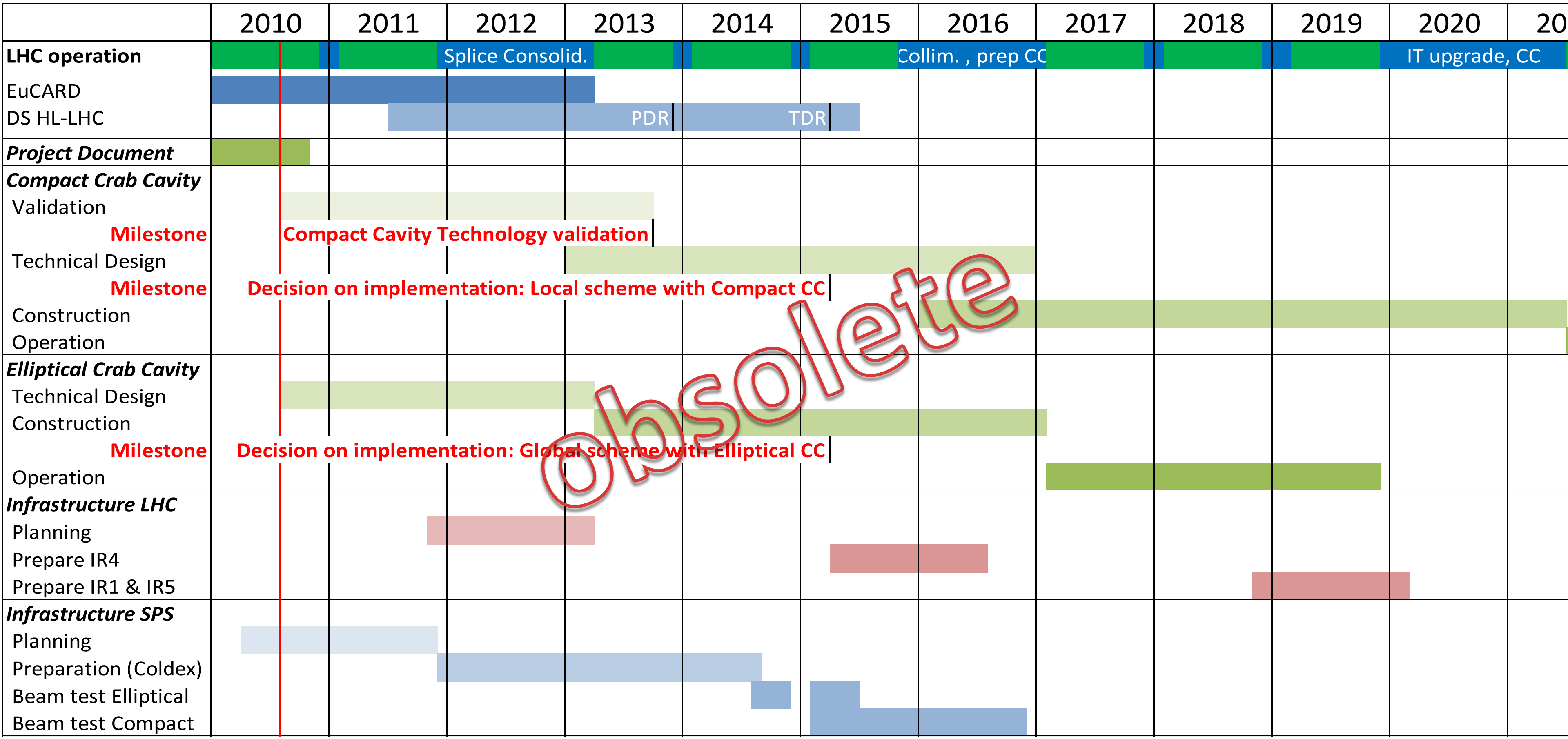
Overall Planning & HiLumi Meeting Highlights

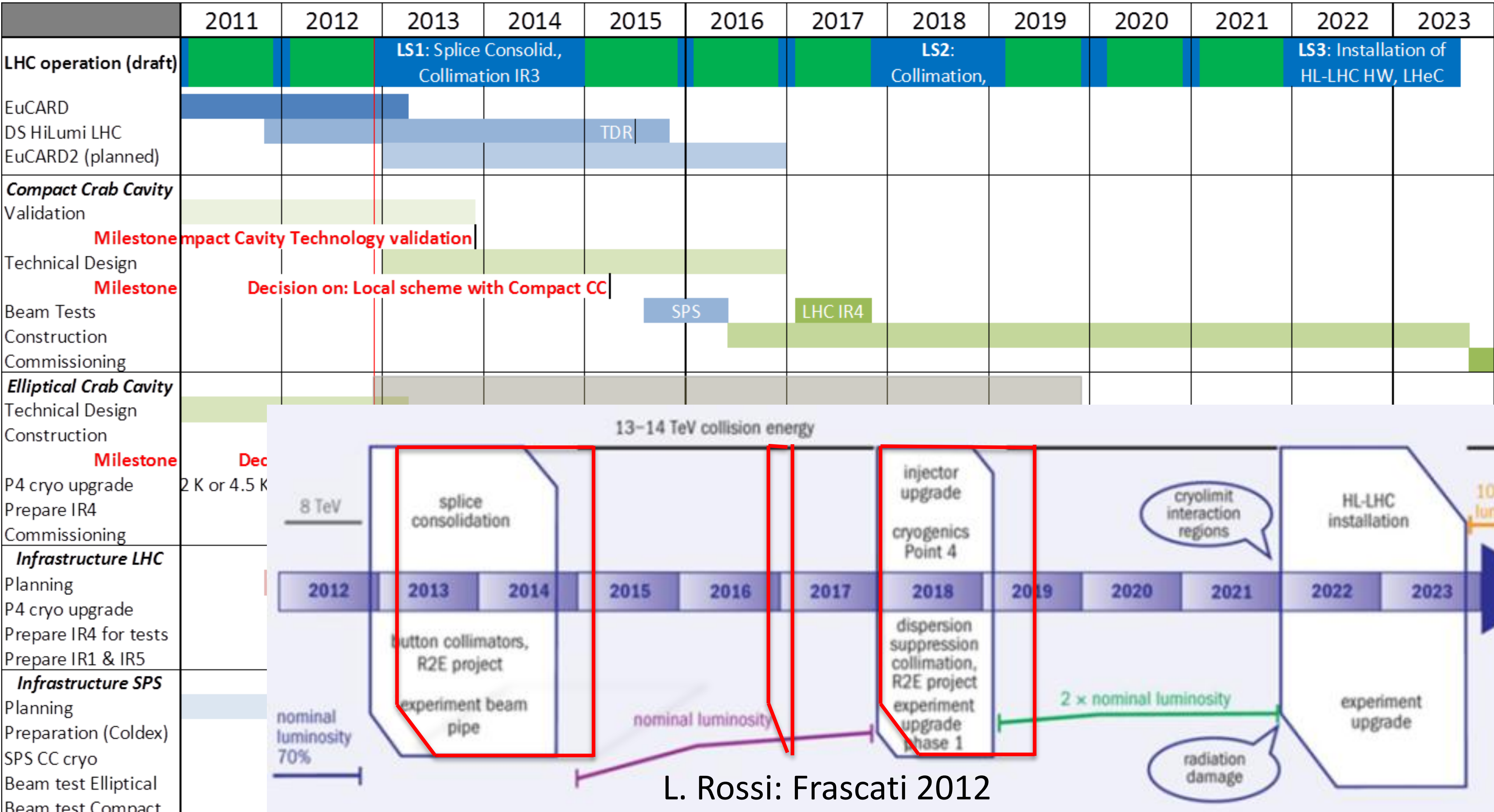
E. Jensen/CERN

The HiLumi LHC Design Study is included in the High Luminosity LHC project and is partly funded by the European Commission within the Framework Programme 7 Capacities Specific Programme, Grant Agreement 284404.

Reminder: What we planned in July 2010



Present overall planning (Dec 2012)



L. Rossi: Frascati 2012

High Luminosity LHC

Overall planning – critical decisions (in reverse order)

- Crab Cavities to be installed in LHC during LS3 (2022/23)
- Major preparations IP1/IP5 during LS2 (2018)
- CC must be tested in SPS/BA4 before LS2 (2016/17?)
  - What exactly is the scope of SPS test?
  - We have to respect certain constraints of the SPS, but not be dominated by them!
- Does a test in LHC/P4 add something? What will we not know by then that would justify the P4 test?
- Preparation SPS during LS1 (2013/14)

Imminent decisions (focus on SPS test)

- Constraints of SPS test:
  - Cryo (LHe volume, heat load, …)
  - Geometry (Y-chamber, table, avail. space, distance of 2nd beam pipe, …)
  - Power coupler ($R_i = 13.5$, $R_a = 31$ mm), connection, RF system
  - Pressure test values – compatible with safety regulations.
  - Tuner range – fast tuner?
  - We'll have those constraints frozen in January 2013

News from Frascati:

- High Luminosity LHC — Europe/Zurich timezone — LARP — **2nd Joint HiLumi LHC-LARP Annual Meeting** — 14-16 November 2012 *INFN Frascati* — Search
- https://indico.cern.ch/conferenceDisplay.py?confId=183635
- The parallel sessions on Crab Cavities can be considered “CC-12” Workshop.

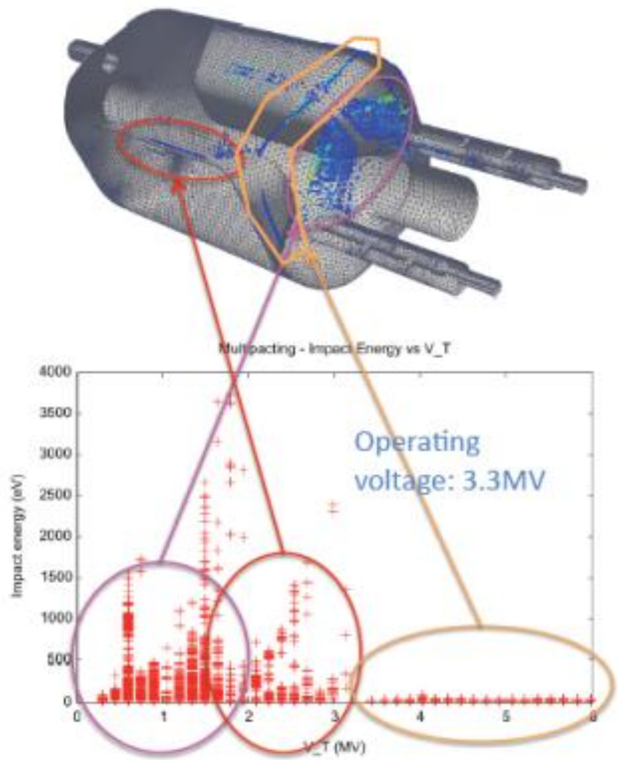
https://indico.cern.ch/conferenceDisplay.py?confId=136807

Reminder - Required kick voltage

- Design kick: 10 MV /side /IP /beam – this is reached with 3 cavities. Our reference numbers!
- Needed for full compensation: 11.8 MV … 13.4 MV; this could be reduced to 8.2 MV with new Q7+ .
- Our reference remains 10 MV – the above is possible mitigation – but is this the overall optimum (cost!)?
- Let's see the prototype cavity performance and adapt design parameters then if needed. Keep engineering margin!
- Even with reduced voltage, we should stay with 3 cavities (to reduce impact of single cavity trip)

All 3 designs:

- **<u>Common numerical tools</u>** used for comparative studies: HOMs, MP (ACE3P, Z. Li), *n*-pole (HFSS, M. Navarro-Tapia)
- HOM damping: suppression below (demanding) CM18 numbers achieved – also thanks to newly designed coaxial high-pass filters and hook-shaped couplers.
- MP simulations indicate:
  - MP at low fields is “soft” – can be conditioned;
  - MP at high fields has low impact energy.

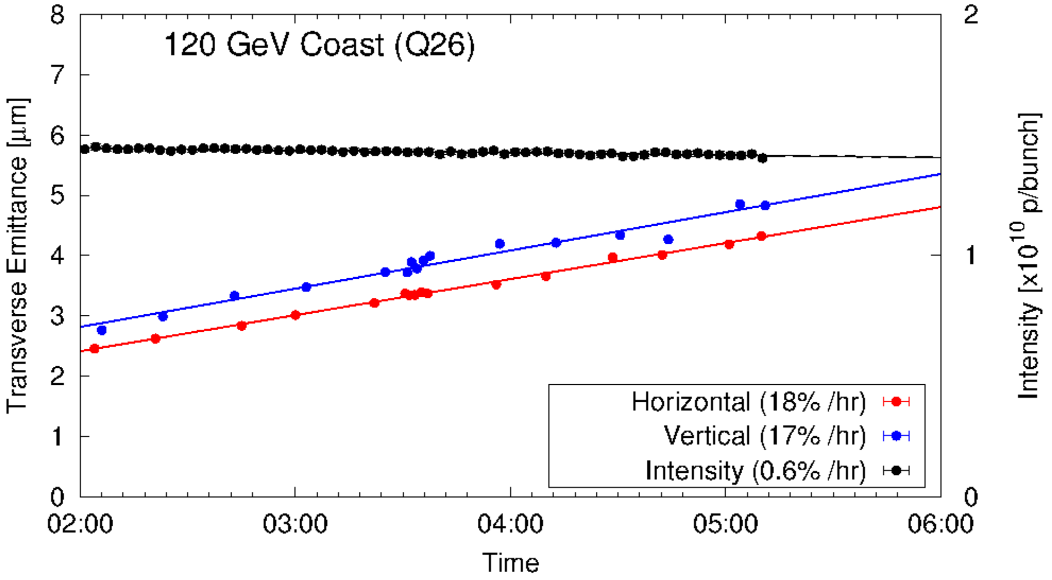


Z. Li

Getting ready for SPS tests

- SPS test is a must (LHC no best-bed!)
- Goal: Confirm that cavity can be made invisible; it would allow to try out operational scenarios.

  SPS beam may be too noisy to test additional noise injected from CCs.

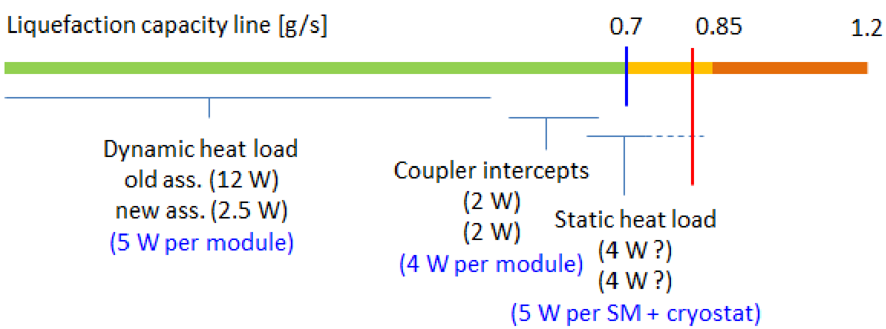


R. Calaga, A. Macpherson

- Schedule: Prepare during LS1 (RF power, cryo) – install cavities X-mas break 2015/16 – perform tests in 2016

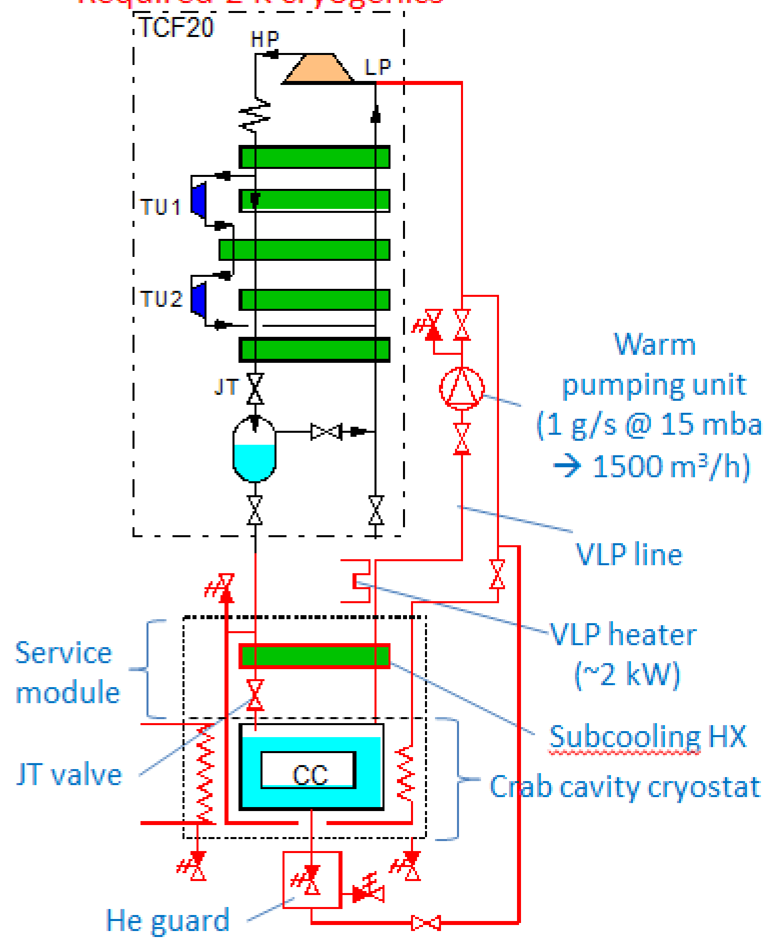
Cryo preparation for SPS tests

- Existing TCF20 should do, but liquefaction test must be done before 15-Jun-2013.
- Dynamic heat load assumed: 2.5 W/module.



- Upgrade to 2 K during LS1.

Required 2 K cryogenics



K. Brodzinski

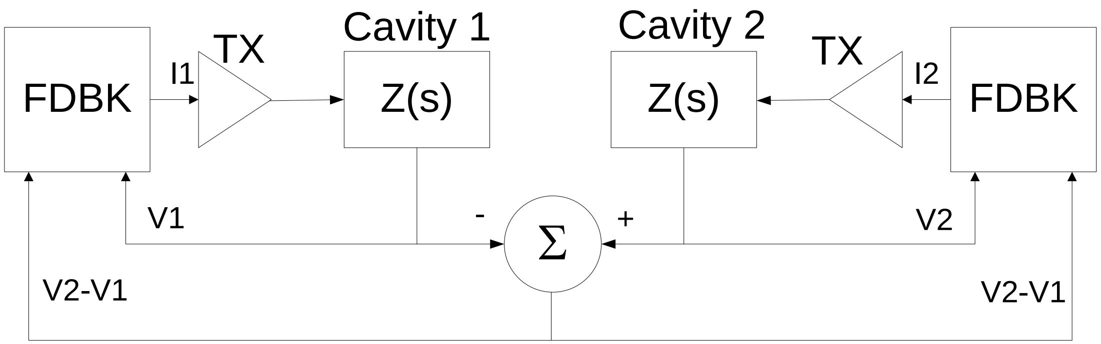
High Luminosity LHC

Dec 14th 2012

LLRF

- Active feedback (as used in many modern RF systems) is key. It can reduce Z by loop gain. Limit: $R_{min} = \frac{R}{Q}\omega_0\tau_g$. For CCs approx. 50 dB.
- Large feedback gain increases BW. Trade off against noise!
- Coupled feedback interesting and challenging – required to minimize impact of single cavity failure.

P. Baudrenghien



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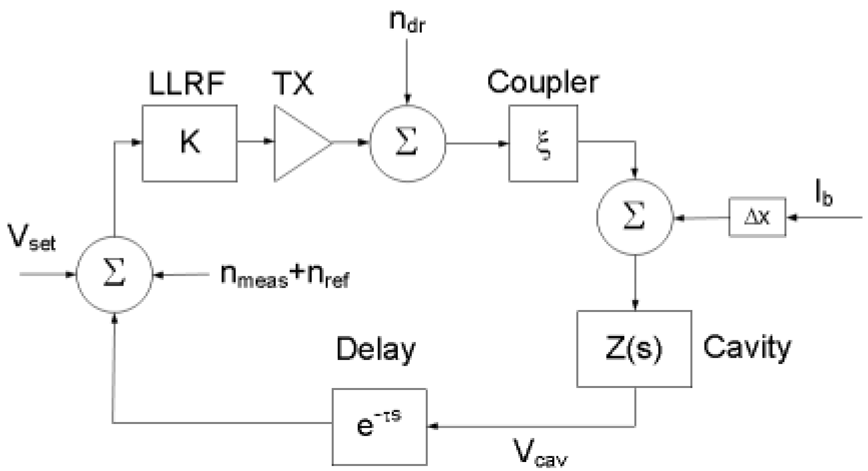
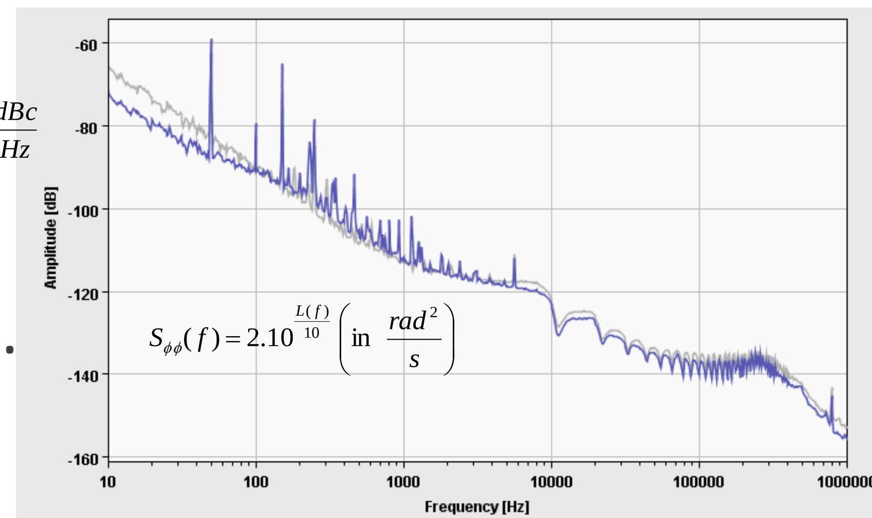
RF Noise

- Different noise sources have different spectra;
- 1^{st} betatron SB 3 kHz off – dominated by TX noise.
- Tetrode/IOT advantageous. $L(f)$ in $\frac{dBc}{Hz}$
- Scaling from ACS: expected 0.01 ° rms φ noise @ 400 MHz. This looks OK.





- Idea for noise measurement: excite on betatron SB.

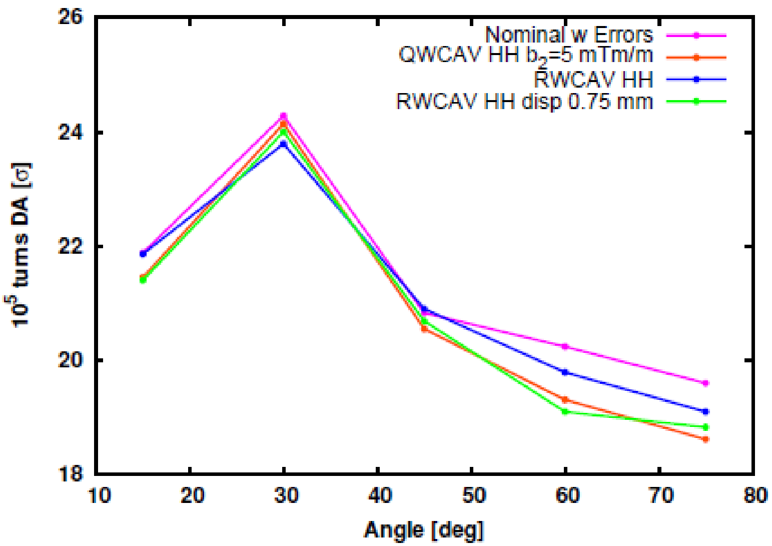
Operational scenario revisited

- Strong RF feedback on at all times!
- To keep CCs invisible during fill & ramp, detune but keep small voltage (active tuning) – dephase 3 cavities 120 ° to cancel. RF feedback provides add'l stability.
- On flat top, reduce detuning keeping V set-point small – RF feedback compensates BL. Once detuning is zero, synchronously change voltage on all CCs to desired kick.

- Much of this can be tried out, commissioned and verified in SPS tests!

n-pole errors

- For the first time, SixTrack simulations could study the effect of *n*-pole errors on beam. Results can give also tolerable misalignments:
  - QWCAV (only HV) $|d_{x,y}| < 2$ mm
  - RWCAV (HH or HV) $|d_{x,y}| < 0.75$ mm
  - 4RCAV (HH or HV) $|d_{x,y}| < 2.7$ mm
- These studies were done with older versions of the cavities.
- n-pole fields with latest versions of cavities indicate globally even smaller errors.



J. Barranco, M. Navarro-Tapia

Dec 14th 2012

Machine Protection

- One beam off – missing LRBB perturbs remaining beam 0.2 σ.

  Classification: slow | 1 s | fast | 10 ms | very fast | 0.3 ms | ultra fast

- Up to very fast (dominated by external *Q*) – there seem to be solutions. Most worrying: ultra fast (< 3 turns).
- Ultra-fast quench would lead to inacceptable displacement of 5 σ with one and 1.7 σ with 3 (decoupled) cavities.
- Can the “coupled feedback” be made reliable enough?
- Better control of transverse bunch population would help.

	Scenario 1: 3 CCs	Scenario 2: $\beta^* = 25cm$	Scenario 3: 800 MHz
CC frequency (f)	400 MHz	400 MHz	**800 MHz**
Number of independant CCs (n_{cc})	**3**	3	3
Q_{ext}	1‘250‘000	1‘250‘000	1‘250‘000
β^*	15 cm	**25 cm**	15 cm
Distance from collimators to be depleted below 1MJ.	1.7σ	1.0 σ	0.9 σ

T. Baer, B.Y. Rendón

Frascati Discussions/brain storming

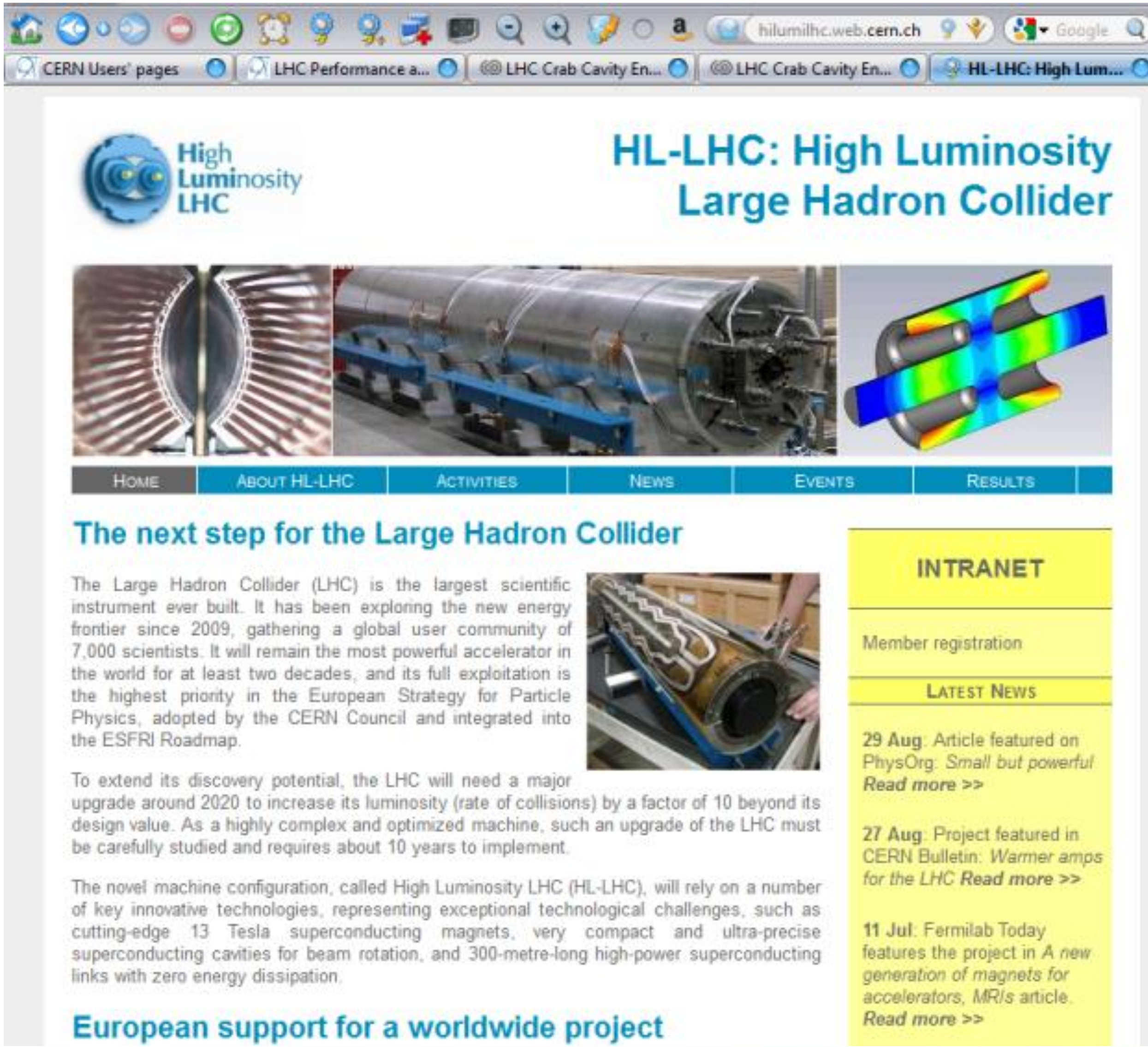
- Lots of productive/critical discussion throughout – this was really a “work”-shop. (pretty much like this one!)
- What instrumentation do we need for CCs – head-tail monitors, streak camera to measure remaining non-closure? What instrumentation do we need to make the SPS test a success?
- We need fast BLMs for MP (diamond?)
- We still need better understanding of possible (ultra) fast failure modes – cavity tests and in particular SPS tests will help this understanding.

HL-LHC – HiLumi LHC

Definition:

HL-LHC: the overall project for Luminosity upgrade

HiLumi LHC: FP7 Design Study, co-financed by EU, Grant Agreement 284404



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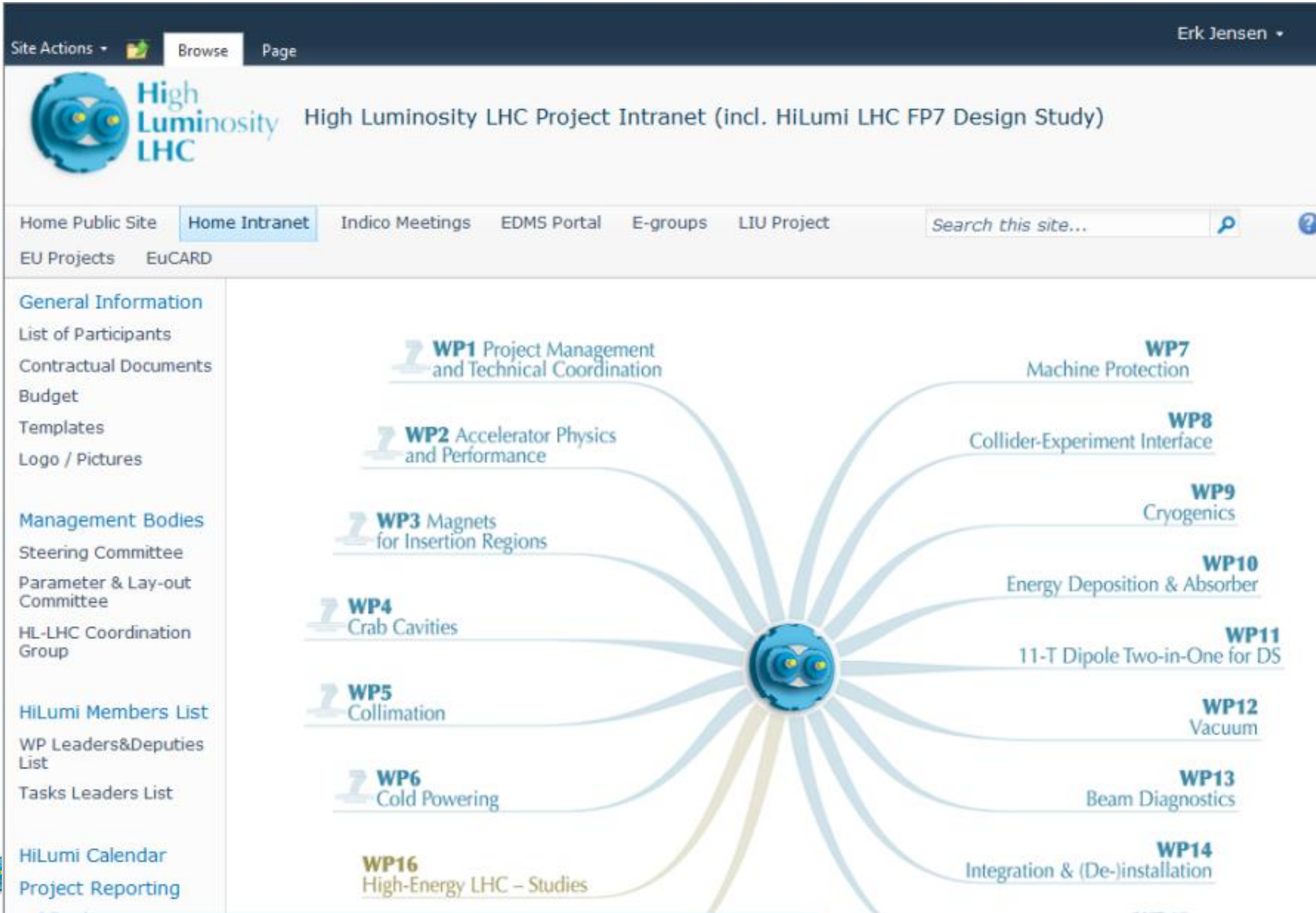
HiLumi Intranet: https://espace.cern.ch/HiLumi/default.aspx



HiLumi Description (excerpt)

HiLumi LHC started 1-Dec-2011
to run 48 months (until Nov. 2015)
Beneficiaries: CERN, CEA, CNRS, STFC, ULANC;
Associated partners: KEK, BNL, FNAL, LBNL, ODU, SLAC (US-LARP).

Tasks (see right) now revised to adapt to planning and needs (Task 4.4 to disappear).

Please register to allow use of Sharepoint site! This will allow coordination and communication!

I uploaded the "Intermediate Activity Report" there.

Task 4.1. Coordination and Communication.
- Coordination and scheduling of the WP tasks
- Monitoring the work, informing the project management and participants within the JRA
- Follow up the WP budget and use of resources

Task 4.2. Support studies
- Tunnel preparation SPS and LHC
- Local IR layout and spatial integration
- Effect of phase noise, LLRF system conceptual design
- RF power system specification
- Operational aspects (how to commission/make invisible)
- Interlocks and fast Feedback

Task 4.3. Compact Crab Cavity Design
- Complete cavity and cryomodule specifications
- Design optimisation for novel schemes
- Conceptual design of SOM, HOM and LOM couplers
- Conceptual design of helium tank and cryostat
- Multipacting simulations on cavity & couplers
- FEM simulations: mechanical & thermal aspects
- Initial down-selection of the CC options
- Completion of a full technical design on the initial down-selected options, with mechanical drawings and specification.
- Design of tooling, dies and cavity fabrication equipment

Task 4.4. Elliptical Crab Cavity Technical Design
- Coupler development and testing
- Tuner design and mock up on copper models
- Study of mechanical effects: resonances, microphonics.
- Cavity performance with couplers and horizontal cryostat
- Performance difference between 2 K & 4 K
- Cryostat and He Tank Design
- Complete the full technical design

Task 4.5. Compact Crab Cavity Validation Prototyping
- Procurement / fabrication of tooling, dies and equipment
- Construction of models (in copper initially) to refine manufacturing techniques and tooling.
- Fabrication of prototype niobium cavity
- Cleaning and electro-polishing on the bare niobium cavity. (i.e. no couplers, antennas or other accessories), including cavity surface inspection
- Development and procurement of all test equipment and instrumentation
- Low power tests and measurements on the bare cavity in a test cryostat to test for compliance with design gradient and other cavity performance specs.
- Make the final CC design down-selection

Thank you very much!

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