http://cern.ch/SLHC-PP

1st Annual Meeting of EuCARD

STFC-RAL, Didcot-UK, (13th) 14th - 16th April 2010

Status of LHC upgrade plans and the SLHC-PP

Roland Garoby

15 April, 2010

This project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under the Grant Agreement nº212114

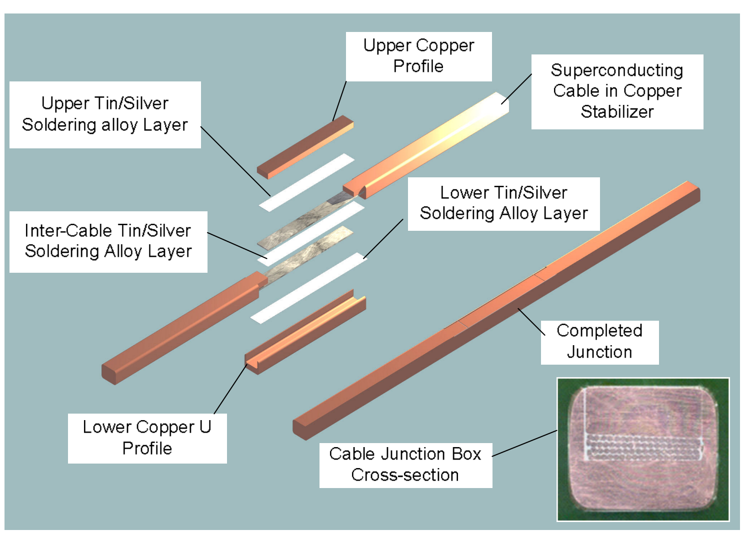
Outline

1. LHC status
2. Projected LHC progress
3. LHC upgrade after 2020
4. SLHC-PP
    - Description
    - Status
    - Plans
5. Summary

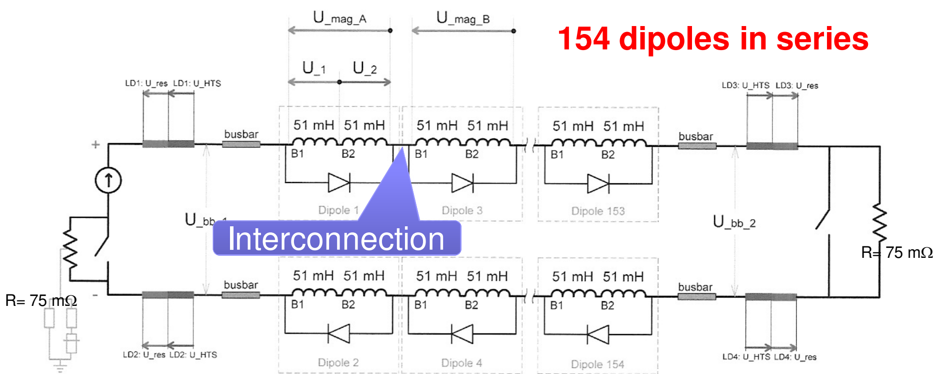
1. LHC status

Turning-on the LHC is not trivial…

The culprit (Sept. 2008)…

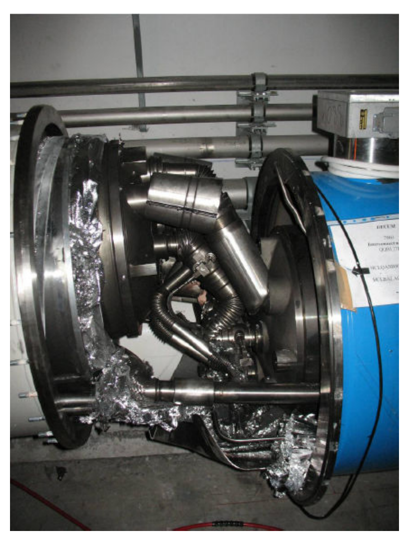


Dipoles current supply scheme

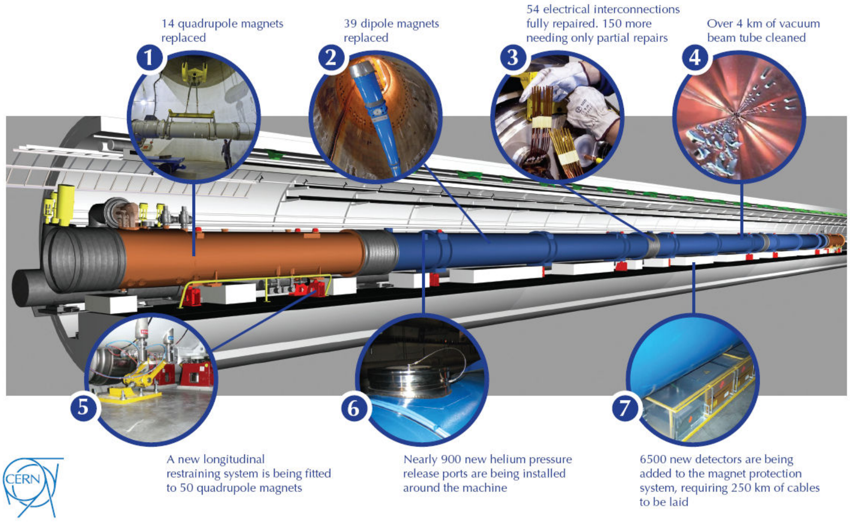


L= 15 Henrys ➔ Time constant ~ 100 s

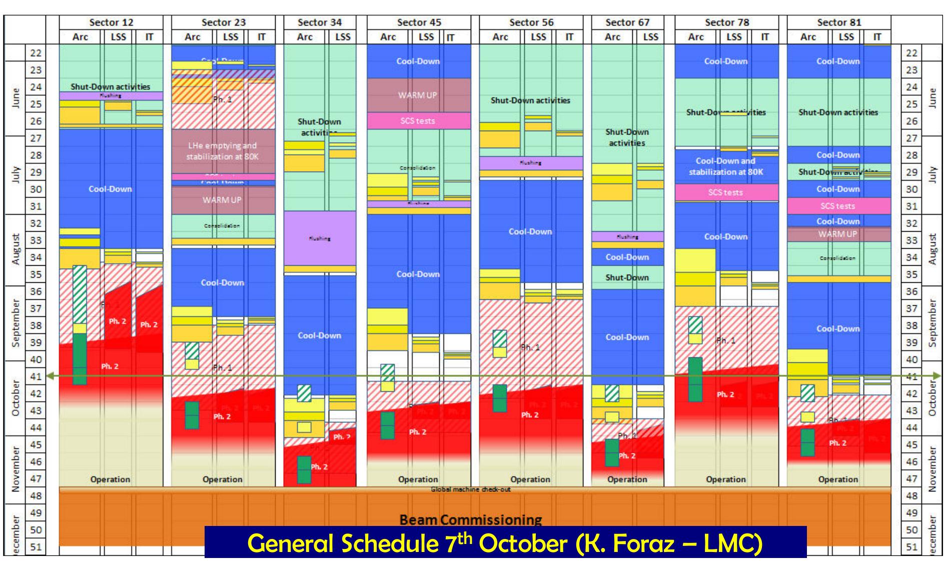
The result in sector 3-4



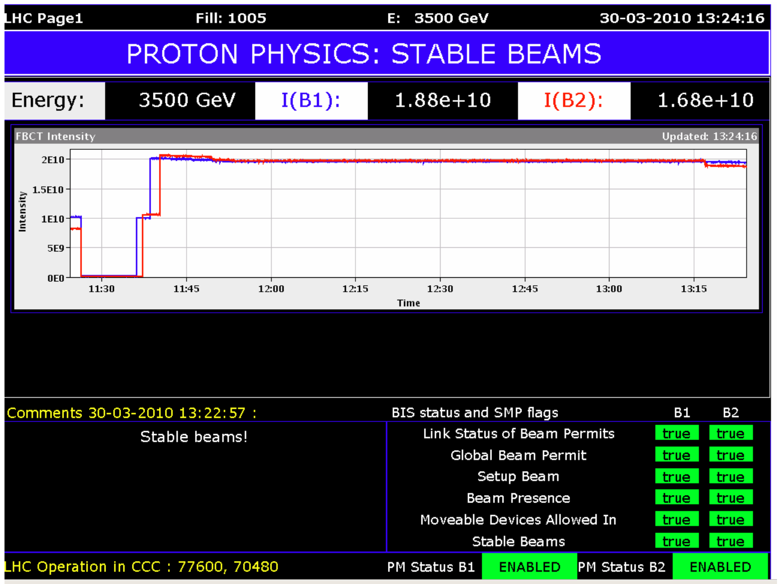
Repair and consolidation work



Repair planning in 2009



First collisions at 7 TeV c.m. (30th March, 2010)



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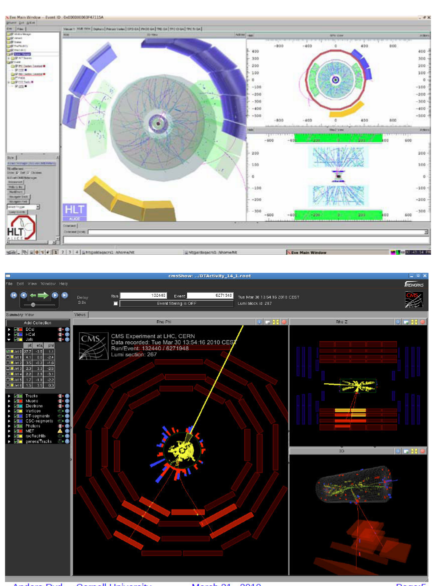
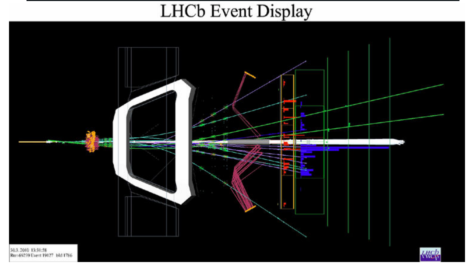


LHCb Event Display



2. Projected LHC progress

Based on talks at the Chamonix 2010

"LHC Performance workshop"

http://indico.cern.ch/conferenceDisplay.py?confId=67839

Near future: 2010

from M. Lamont

Step	E [TeV]	Fill scheme	N	β* [m] IP1 / 2 / 5 / 8	Run time (indicative)
1	0.45	2x2	5×10^{10}	11 / 10 / 11 / 10	
2	3.5	2x2	$2 - 5\times10^{10}$	11 / 10 / 11 / 10	Weeks
3	3.5	2x2*	$2 - 5\times10^{10}$	2 / 10 / 2 / 2	
4	3.5	43x43	5×10^{10}	2 / 10 / 2 / 2	Weeks/Months
5	3.5	156x156	5×10^{10}	2 / 10 / 2 / 2	
6	3.5	156x156	9×10^{10}	2 / 10 / 2 / 2	
7	3.5	50 ns - 144**	7×10^{10}	2.5 / 3 / 2.5 / 3	Months
8	3.5	50 ns - 288	7×10^{10}	2.5 / 3 / 2.5 / 3	
9	3.5	50 ns - 720	7×10^{10}	2.5 / 3 / 2.5 / 3	Months

* Turn on crossing angle at IP1.

**Turn on crossing angle at all IPs.

One month: 720 bunches of 7 10^{10} at $\beta^* = 2.5$ m gives a peak luminosity of 1.2 10^{32} $cm^{-2}s^{-1}$ and an integrated of about 105 pb^{-1} per month
[15% nominal – 28 MJ]

Near future: 2011

from M. Lamont

3.5 TeV: run flat out at up to ~100 pb^{-1} per month

	No. bunches	ppb	Total Intensity	β*	Peak Lumi	Integrated Lumi [pb^{-1}]
50 ns	432	7 e10	3 e13	2	1.3 e32	~85
Pushing intensity limit	720	7 e10	5.1 e13	2	2.2 e32	~140
Pushing bunch current limit	432	11 e10	4.8 e13	2	3.3 e32	~209

Either way should be able to deliver around 1 fb^{-1}

Medium term: until 2015

from M. Lamont

- Two years at 3.5 TeV
- 2010: should peak at 10^{32} and yield up to 0.5 fb^{-1}
- 2011: ~1 fb^{-1} at 3.5 TeV
- 2012: splice consolidation (and cryo collimator prep.)
- 2013: 6.5 TeV - 25% nominal intensity
- 2014: 7 TeV – 50% nominal intensity

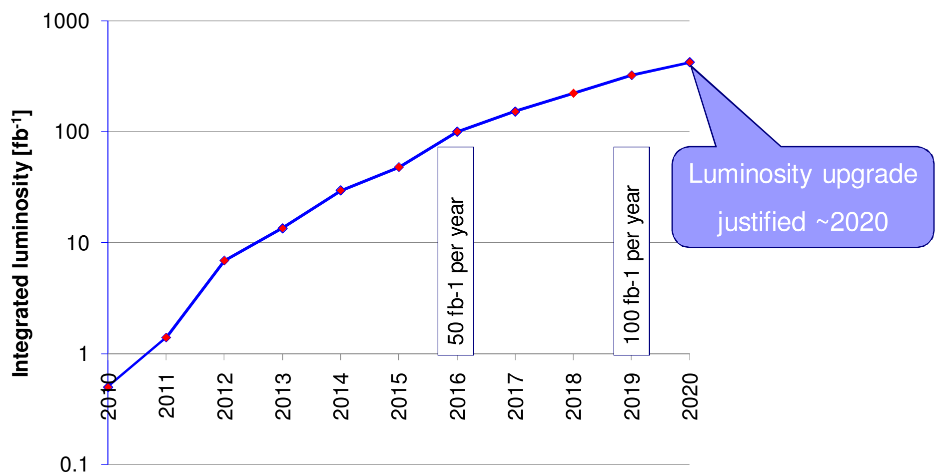
} Aggressive

Year	Months	Energy	β*	I_b	N_b	Peak luminosity	Lumi / month	Int lumi / Year	Int. lumi cumul.
2010	8	3.5	2.5	7 10^{10}	720	1.2 10^{32}	-	0.2	0.2
2011	8	3.5	2.5	7 10^{10}	720	1.2 10^{32}	0.1	0.8	1.0
2012									
2013	6	6.5	1	1.1 10^{11}	720	1.4 10^{33}	1.1	7	8
2014	7	7	1	1.1 10^{11}	1404	3.0 10^{33}	2.3	16	24

Projection until 2020

from M. Lamont

Pushing to nominal in 2016 and taking a couple of years to get to ultimate
[potential to push phase 1 upgrade not included]

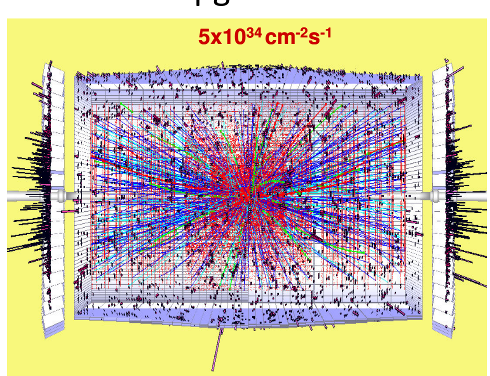


3. LHC upgrade after 2020

Based on talks at the Chamonix 2010 “LHC Performance workshop” http://indico.cern.ch/conferenceDisplay.py?confId=67839

+ report from Task Force on the LHC upgrade

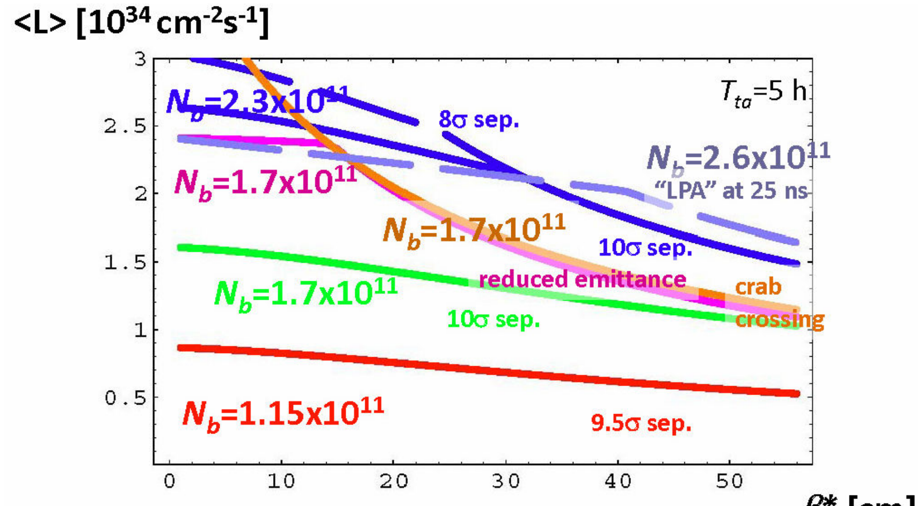
(L. Rossi – 10/03/2010)



Generated tracks per crossing, $p_t > 1$ GeV/c cut, i.e. all soft tracks removed!

Luminosity vs β*

from F. Zimmermann



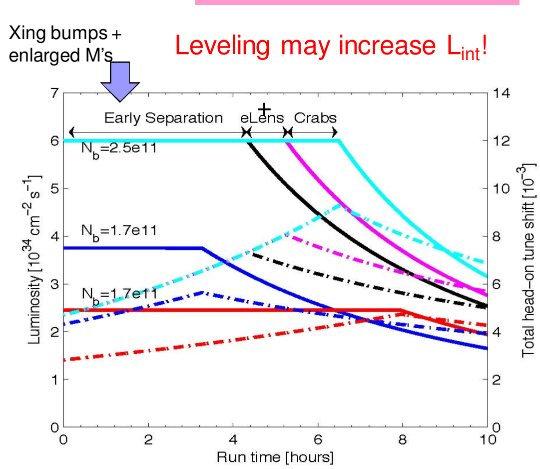
1. Beam intensity (N_b) is more important than β^*
2. Reducing β^* only helps when combined with Crab cavities or smaller emittances

Luminosity leveling with θ_c

from J.P. Koutchouk

$$\Delta Q_{bb} \propto L \quad \text{versus } \theta_c$$

Leveling may increase L_{int}!



studied in G. Sterbini's PhD

Crab Xing: minor optical side effects, challenge shifted to active HW and insertion design.

Early Separation Scheme: no optical side effects; not as efficient as crab Xing; passive and robust.

Xing bumps: probably not an option (constraints on max and min beam separation).

In all cases, initial reduction of the length of the luminous region

Means to increase luminosity

from F. Zimmermann

- Upgrade scenarios with 25 & 50 ns spacing
- Maximum N_b ~2.3x10^{11} at 25 ns, ~5.0x10^{11} at 50 ns
- Minimize Turn around time: T_{ta} - 10→2 h: 2x higher <*L*>
- β^* : factor 2 reduction → 10-20% higher <*L*>
- **N_b: factor 2 increase → 5 times higher <*L*>!**
- Crab crossing or lower emittance: 20-100% higher <*L*>
- Luminosity optimization assumes two IPs; needs/policy for ALICE & LHCb?
- θ_c leveling can increase run time by factor 1.5-3, & reduce pile up, at ~ constant <L>
- Annual luminosities may reach 150-300 fb^{-1}

⇒ Emphasis on N_b (!!), T_{ta} (!) and Crab crossing

Critical R & D items

from L. Rossi

✓ High Field Quaduproles

⇒ **reduced β^* and/or more radiation hardness**

✓ 120 mm I.D. Nb-Ti models to proof design: in case Nb_3Sn or Nb_3Al will not perform sufficiently (part of risk mitigation / contingency plan)

⇒ **reduced β^***

✓ Crab Cavities

⇒ **get higher luminosity from reduced β^***

✓ SC cables for installing Power Converter on the surface and other means of rad-hazard mitigation

⇒ **increased radiation hardness**

Accompanying measures

- ✓ Implement full performance collimation in LHC

  ⇒ increased beam current in the LHC to nominal and possibly beyond

- ✓ Build, commission and operate Linac4 (~beginning 2015)

  ⇒ increased beam brightness at PS injection

- ✓ Consolidate & upgrade the other injectors (increase PSB energy, upgrade PS and SPS)

  ⇒ increased beam brightness/intensity at LHC injection at minimum cost

- ✓ Pursue SPL R & D focusing on high beam power

  ⇒ potential for application to other physics programmes as well

4. SLHC-PP

http://cern.ch/SLHC-PP

The Preparatory Phase of the Large Hadron Collider upgrade (SLHC-PP) is a project co-funded by the European Community in its 7th Framework Programme [Grant Agreement n° 212114], CERN and 18 European research institutes and universities.

18 partners

Official starting date: 1st April 2008

Foreseen end date: 31st March 2011

Total cost: 15.571 MEuros / EU contribution: 5.2 Meuros

The main aim of the Preparatory Phase project of the Large Hadron Collider upgrade (SLHC-PP) is to prepare the SLHC project for a decision on the approval of its implementation by 2011...

Budget situation (February 2010)

#	Participant	Max Total EC contribution	Prefinancing Received (2008)	Payment 1 (2009)	Total received to date	% received funds	Ceiling	To be paid to reach the ceiling
1	CERN	3,062,484.0	1,633,324.80	1,122,910.80	2,756,235.60	90%	2,756,235.60	-
2	AGH-UST	104,000.0	55,466.67	30,152.86	85,619.53	82%	93,600.00	7,980.47
3	CEA-Saclay	465,460.0	248,245.33	170,668.67	418,914.00	90%	418,914.00	-
4	CIEMAT	152,645.0	81,410.67	37,983.98	119,394.65	78%	137,380.50	17,985.85
5	CNRS-IN2P3	105,600.0	56,320.00	993.72	57,313.72	54%	95,040.00	37,726.28
6	CTU	44,940.0	23,968.00	16,478.00	40,446.00	90%	40,446.00	-
7	DESY	99,691.0	53,168.53	1,408.45	54,576.98	55%	89,721.90	35,144.92
8	ETH Zürich	89,131.0	47,536.53	32,681.37	80,217.90	90%	80,217.90	-
9	FOM-NIKHEF	64,200.0	34,240.00	23,540.00	57,780.00	90%	57,780.00	-
10	GSI	72,225.0	38,520.00	11,593.03	50,113.03	69%	65,002.50	14,889.47
11	Imperial	89,131.0	47,536.53	30,770.97	78,307.50	88%	80,217.90	1,910.40
12	INFN	40,000.0	21,333.33	14,666.67	36,000.00	90%	36,000.00	-
13	PSI	108,225.0	57,720.00	30,747.45	88,467.45	82%	97,402.50	8,935.05
14	STFC	489,850.0	261,253.33	76,351.76	337,605.09	69%	440,865.00	103,259.91
15	UBONN	120,000.0	64,000.00	44,000.00	108,000.00	90%	108,000.00	-
16	UNIGE	35,310.0	18,832.00	12,947.00	31,779.00	90%	31,779.00	-
17	USFD	32,100.0	17,120.00	11,770.00	28,890.00	90%	28,890.00	-
18	RWTH Aachen	25,000.0	13,333.33	9,166.67	22,500.00	90%	22,500.00	-
		5,199,992.0	2,773,329.05	1,678,831.40	4,452,160.45	86%	4,679,992.80	227,832.35

86% EC funds already received and distributed

Ceiling: EC retains 10% till end of the project

Description

The activities are divided into 8 work packages, including one to co-ordinate the activities of the remaining 7.

Work package nb.	Type of activity	Description
W P 1	Management	SLHC-PP Project Management
W P 2	Coordination	Coordination for the SLHC accelerator implementation
W P 3	Coordination	Coordination for the S-ATLAS experiment implementation
W P 4	Coordination	Coordination for the CMS2 experiment implementation
W P 5	Support	Radiation protection and safety issues for accelerator and experiments
W P 6	RTD	Development of Nb-Ti quadrupole magnet prototype
W P 7	RTD	Development of critical components for the injectors
W P 8	RTD	Tracking detector power distribution

Status WP1 & 2

WP1: Project Management Leader: R. Garoby (CERN)

- **Coordination and financial follow-up of whole project**
- **Monitoring and reporting: organization of Annual meetings, edition of annual reports…**
- **Dissemination: Annual Public Meetings (next one on June 23 @ CERN), contribution to other events (e.g. ECRI, Barcelona, March 2010)…**

WP2: Coordination for SLHC implementation Leader: T. Otto (CERN)

- **sLHC Web site** [http://project-slhc.web.cern.ch/project-slhc/index.html]
- **Filing of information: new series for sLHC reports & project notes on the CERN Document Server, structured storage for all documentation (e.g. SPL) in EDMS, structured filing of all meetings (e.g. SPL) in Indico**
- **Development/implementation of upgraded EVM tool**
- **Preparation of Quality Assurance plan**

Status WP3

Leader: S. Stapnes (CERN)

Coordination for S-ATLAS experiment implementation

- **Establish management structure and review office for R & D**
- **Schedule R & D phase**
- **TDR and MoU for new "IBL" (approved project - phase 1)**
- **LoI for phase 2**

Organisation

- PO --> Open meetings, Joint with USG
  - All players present, much more efficient technical discussions
  - Open to all: very important to give all players a say
  - Allows input on things we are not aware of
- USG Enlarged
  - IBL rep plus separate Pixel rep
  - Germany now represented
  - French representation under discussion
- IBL: approved project
  - Project Leader (PL)
  - Technical Coordinator (TC)
  - Management Board
  - Sub-groups
  - Functioning well

5 Feb 2010 Nigel Hessey, Nikhef SLHC-PP Meeting, Madrid 8

Organisation (cont.)

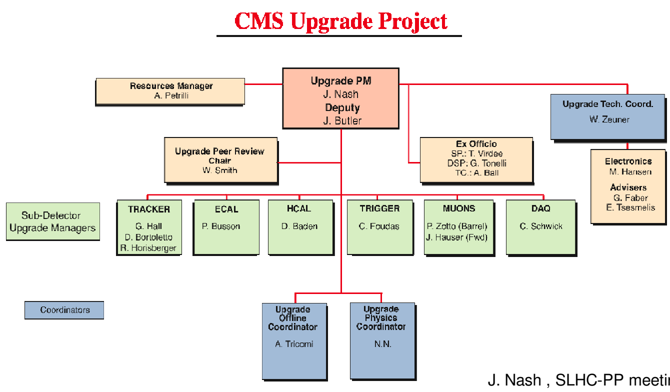
- Inner Tracker
  - Extra pixel person brought in to cover sLHC Pixels
  - Strips: Strengthened with one new person
  - Strips structure in place, but still some key positions not really covered
  - Pixels more focussed on IBL
  - Working on an Inner Tracker Management Board

Status WP4

Leader: J. Nash (Imperial College)

Coordination for CMS2 experiment implementation

- Establish project structures for construction and installation
- MoU and cost book
- Organize Technical Coordination
- Pilot design and schedule of upgrade project



J. Nash , SLHC-PP meeting
Madrid (Feb. 2010)

Status WP5

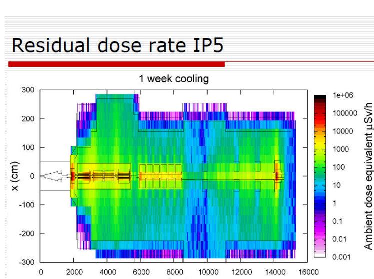
Leader: T. Otto (CERN)

Radiation protection and safety issues (accelerators and experiments)

- Identification of crucial radioprotection issues
- Identification of critical areas for maintenance
- Assessment of radiological impact on personnel and environment
- Investigation of operative procedures of intervention
- Estimation of radioactive waste in terms of nature, amount and cost of elimination

$\Rightarrow$ Validation of simulation tools

$\Rightarrow$ Estimation of radiation levels in accelerators and experiments



Ambient dose rate map around old triplet

After one week, dose rate in excess of 100 µSv/h at 1.5 m distance

Severe constraint for manual labour in the triplet region

Similar environment expected for upgrade Phase I -> Phase II

M. Fürstner, S. Roesler, CERN

Status WP6 – 1/8

Leader: S. Russenschuck (CERN)

Development of Nb-Ti quadrupole magnet prototype

- **Design, development, manufacture and test of a large bore (~130 mm diameter) NbTi quadrupole for the interaction regions of the LHC upgrade and corrector magnets**

⇒ **Challenges (Heat load, powering and protection, axial forces, collaring)**

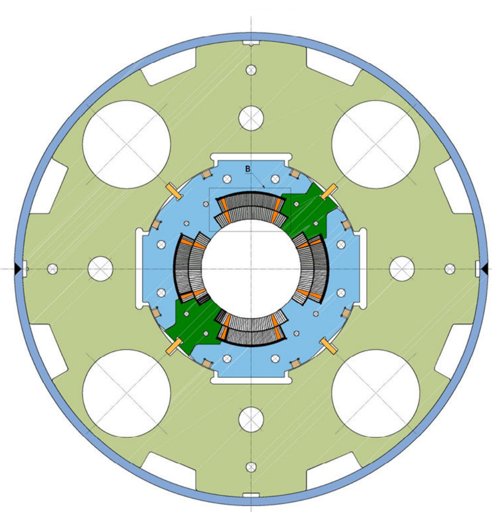
⇒ **New features (Porous cable and ground-plane insulation, tuning shims)**

⇒ **Integrated design process (quench simulation, end-spacer design)**

Status WP6 – 2/8

from S. Russenschuck

Low-β Quadrupole MQXC



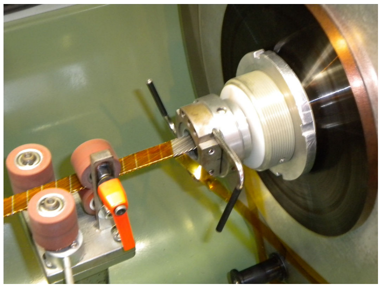
Coil aperture	120 mm
Gradient	127 T/m
Operating temp	1.9 K
Current	13.8 kA
WP on load-line	85%
Inductance	5.2 mH/m
Yoke ID	260 mm
Yoke OD	550 mm
Magnetic length	9160 mm (Q1,Q3) 7760 mm (Q2)

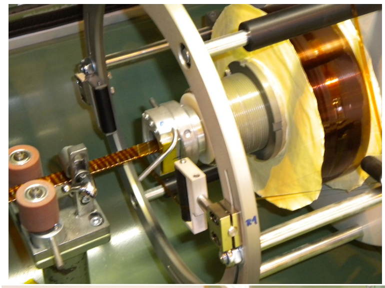
- LHC cables 01 and 02
- Porous cable polyimide insulation
- Yoke OD identical to MB
- Self-supporting collars
- Single piece yoke
- Welded-shell cold mass

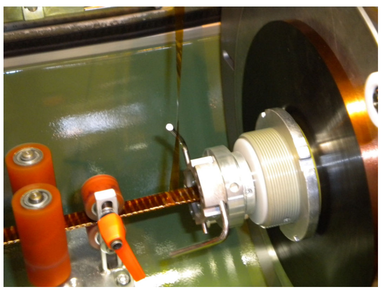
Status WP6 – 3/8

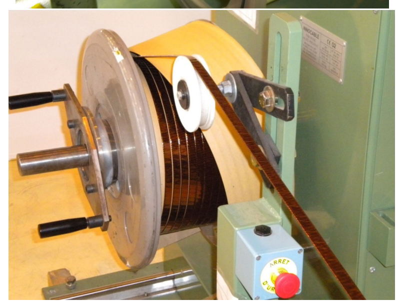
from S. Russenschuck

Cable wrapping machine fully Commissioned





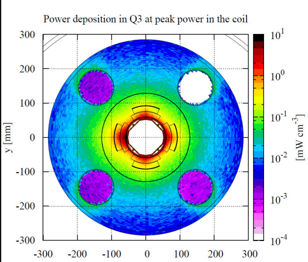


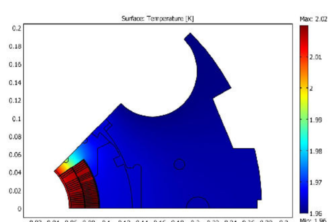


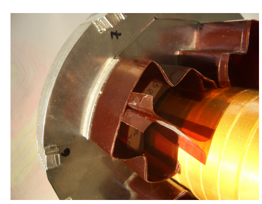
Status WP6 – 4/8

from S. Russenschuck

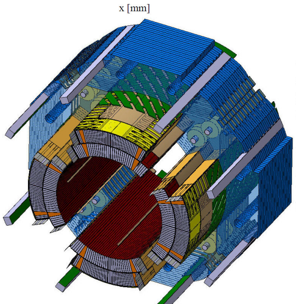
Extraction of the Steady-State Heat-Load (Porous Ground-Plane Insulation)

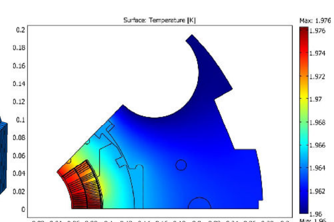


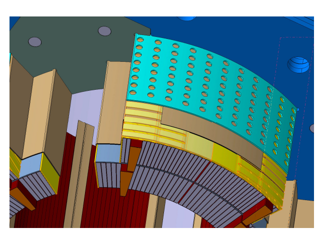




Conventional ground insulation







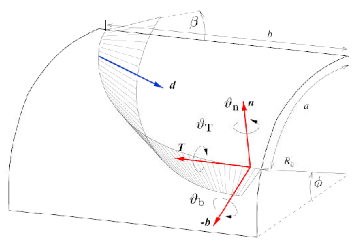
Open KCS ground insulation

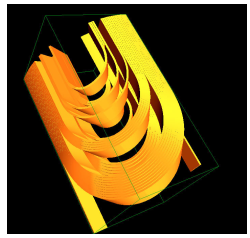
Status WP6 – 5/8

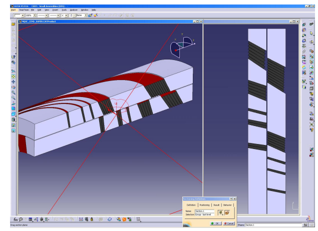
from S. Russenschuck

End spacer design and manufacture

Differential Geometry Model

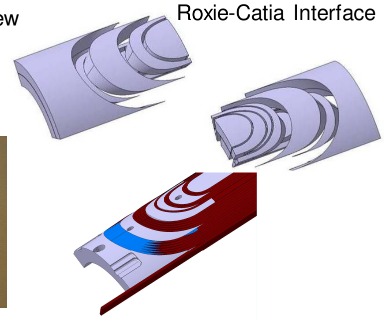






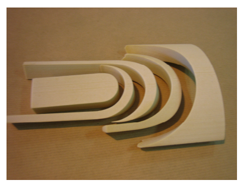
Virtual Reality Preview

Roxie-Catia Interface



CNC-Machining

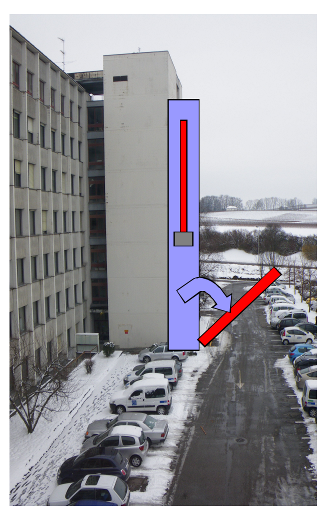
Rapid Prototyping



Status WP6 – 6/8

from S. Russenschuck

Vertical collaring – hardly possible for a 10 m long magnet!

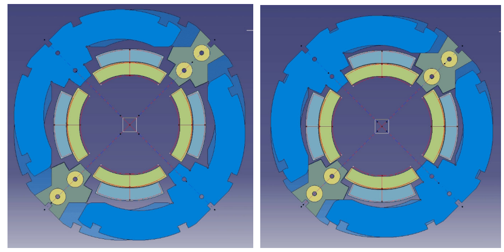


Status WP6 – 7/8

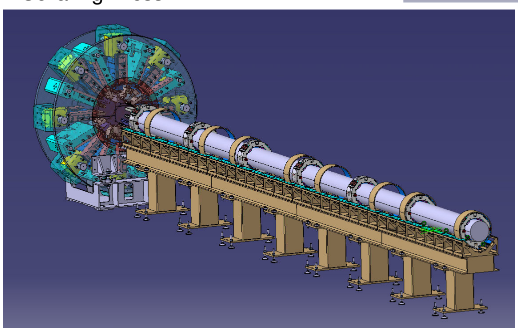
from S. Russenschuck

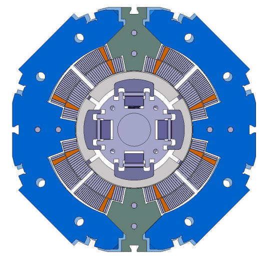
Horizontal collaring

Self-locking collars



Collaring Press



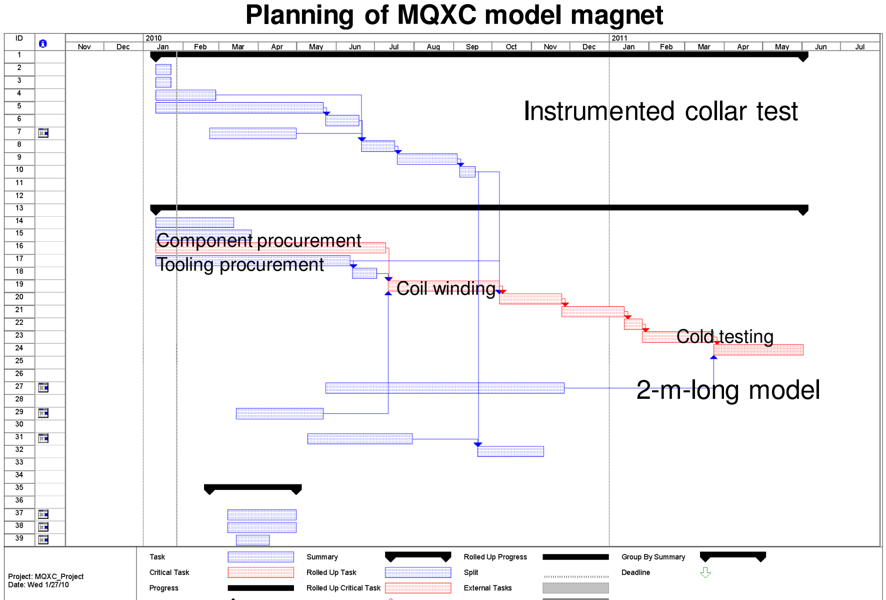


Assembly mandrel

Status WP6 – 8/8

from S. Russenschuck

Planning of MQXC model magnet



Status WP7 – 1/6

Leader: R. Scrivens (CERN)

Development of critical components for the injectors

- **To develop a test bed of the plasma generator of a high duty factor H^- RF ion source**
- **To elaborate architecture, to specify components and to demonstrate performance of an RF system stabilizing properly the accelerating field in pulsed superconducting cavities**

Status WP7 – 2/6

from R. Scrivens (CERN)

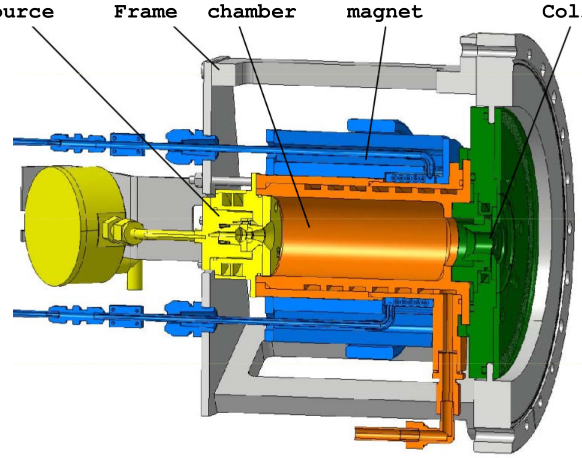
Plasma generator for H^- ion source

During the project second year:

Thermal issues that required solutions were detailed.

The plasma generator was completely redesigned in order to include cooling, and mitigate the effects of adding this.

It is now partially in production.



Status WP7 – 3/6

from R. Scrivens (CERN)

Test area in preparation, demin water, gas, electricity updated.
Vacuum system now installed.

Status WP7 – 4/6

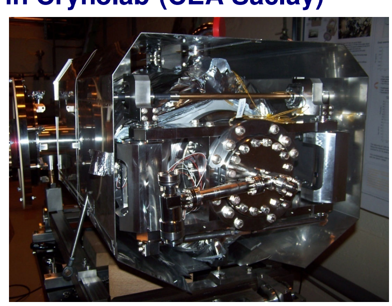
from G. Devanz (CEA)

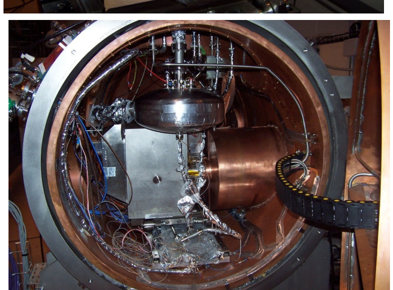
Tuner and coupler characterization in Cryholab (CEA-Saclay)

Designed & built within HIPPI (CARE – EU FP6)

The full system :

- **Beta 0.47 5-cell 704 MHz cavity**
- **1MW power coupler**
- **Magnetic shield**
- **Piezo tuner**

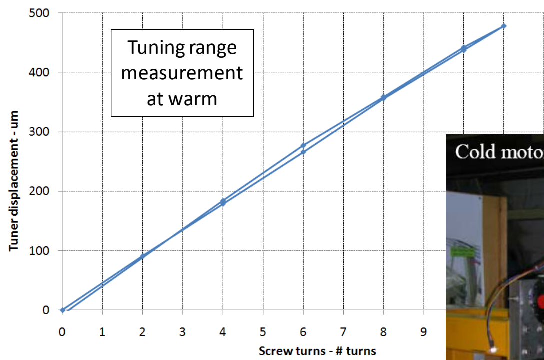


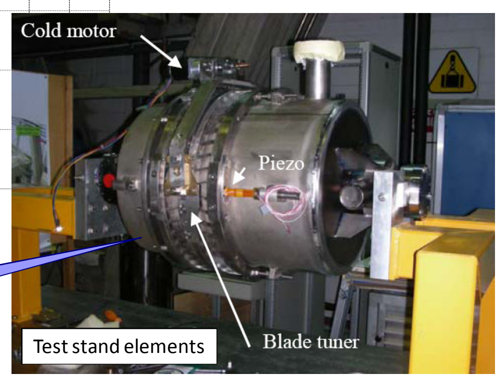


Status WP7 – 5/6

from P. Pierini (INFN)

Special test stand at LASA (Milano) for evaluation of INFN tuner performance



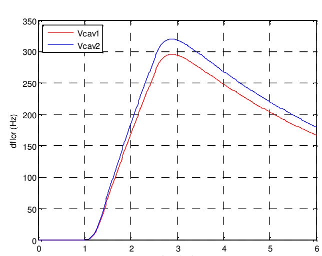


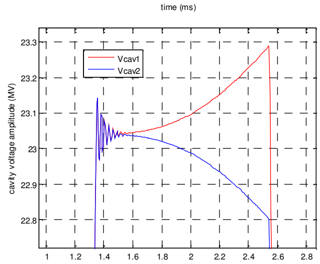
Designed & built within HIPPI (CARE – EU FP6)

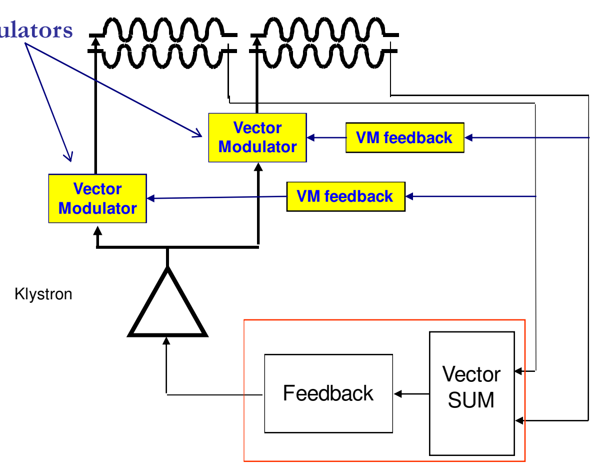
Status WP7 – 6/6

from O. Piquet (CEA)

Possible layout for the initial high energy part of LP-SPL







Analyzed and reported by O. Piquet (CEA-Saclay) during LLRF09 workshop

Status WP8 – 1/6

Leader: W. Dabrowski (AGH-UST)

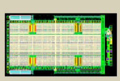
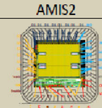
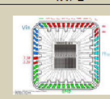
Tracking detector power distribution

- To explore various DC-DC conversion options as well as serial powering schemes
- To select the most suitable schemes for integration into dedicated ASICs
- To test the scheme in full-scale S-ATLAS and CMS2 detector module prototypes.

Status WP8 – 2/6

from G. Blanchot (CERN)

DC-DC conversion ASIC prototypes

Prototype	AMIS1	AMIS2	IHP1
ASIC			
Techno	AMIS 0.35	AMIS 0.35	IHP 0.25
Package	QFN48	QFN48 QFN32	QFN48 QFN32
PCB			
Vin	3.3V to 15V	3.3V-12V	2.5V to 12V
Vout	Programmable	Presets at 1.2/1.8/2.5/3/5V	Programmable
Iout	2A	3A	3A
Fsw	1 MHz	1 MHz	2.0 MHz
Efficiency	< 80%	82%	87%
Gate Delay	Fixed	Programmable	Adaptative
Comment	First Prototype. Required an external sawtooth generator and regulators.	Second Prototype. Programmable gate delay improves efficiency. Sawtooth generator integrated, still requires external regulator.	Third Prototype. Adaptative gate delay further improves efficiency.

3 ASIC Prototypes were produced:

AMIS Technology:

- First sample with core DC/DC functions.
- Second sample, now fully functionnal.

IHP technology:

- Fully functional DCDC.

Regulators for control circuitry are still external: they will be integrated in the next IHP sample (in production)

SLHC-PP Meeting February 2010 G. Blanchot, CERN - PH/ESE

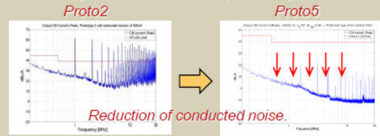
Status WP8 – 3/6

from G. Blanchot (CERN)

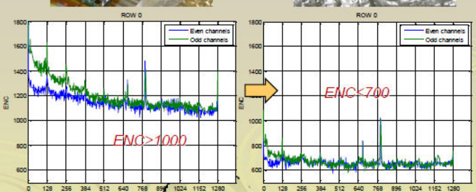
System tests

Tracker modules have been powered successfully with DCDC prototypes.

- Emission of noise of DCDC :
  - Noise measured in lab.
  - Conducted noise strongly reduced now.
  - DCDC emits E and H fields, that have been reduced but are still present.



- Susceptibility of hybrids
  - Susceptibility measured at Liverpool hybrids setup.
  - Hybrids were found to be sensitive to E and H fields, not sensitive to conducted noise.
  - Shielding of DCDC will be required.
    - Thin foils are sufficient to limit the coupling.
  - Susceptibility bandwidth characterized.



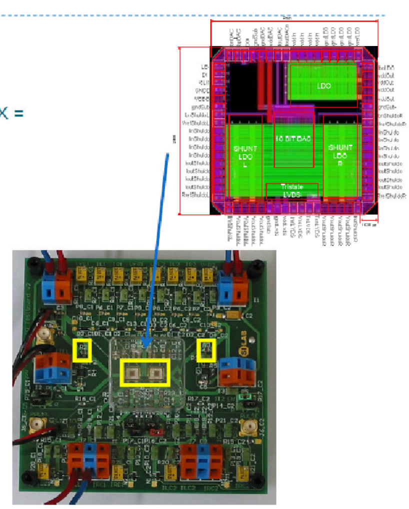
SLHC-PP Meeting February 2010 G. Blanchot, CERN - PH/ESE 8

Status WP8 – 4/6

from L. Gonella

Serial powering scheme: prototypes and test system

- 2 prototypes submitted and tested
  - September 2008, March 2009
  - V_{out} = 1.2-1.5V, $V_{dropout}$MIN = 200mV, I_{shunt}MAX = 0.5A, R_{in} = 4Ω, R_{out} = 30mΩ
- test setup
  - two SHULDO regulators connected in parallel on the PCB
  - biasing & reference voltage is provided externally
  - input & load current is provided by programmable Keithley sourcemeter
  - input & output voltages are measured automatically using a Labview based system
  - shunt current is measured by 10mΩ series resistors and instrumentation opamp

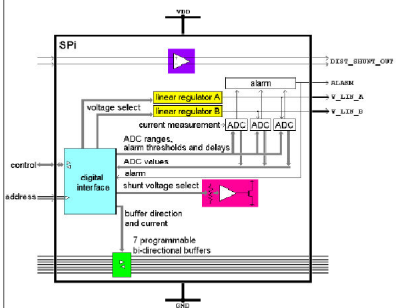


8 L. Gonella - ATLAS Upgrade Week - Nov. 2009

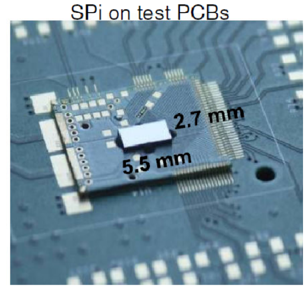
Status WP8 – 5/6

Serial Power Interface

Serial Power interface. Generic chip in 0.25 µm CMOS. Designed by M. Trimpl (FNAL), M. Newcomer, N.Dressnandt (Penn), specified by RAL.



SPi on test PCBs



- 68 I/O bumps
- 76 power bumps
- Minimum pitch 275 µm

- Two shunt regulator schemes
- Data communication/ AC coupling
- Power management
- Monitoring/alarms

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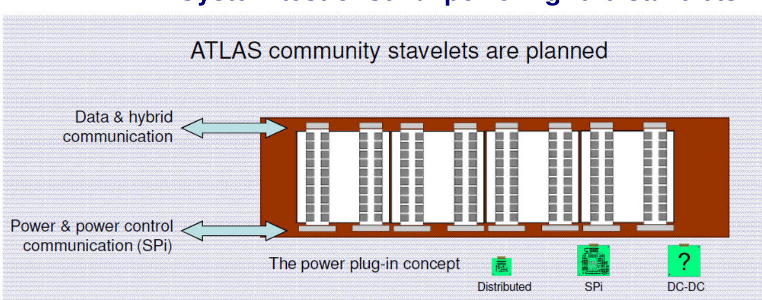
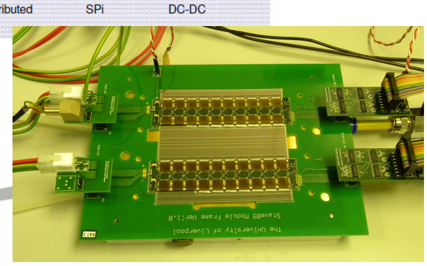
11

Status WP8 – 6/6

System test of serial powering: the stavelets





- It allows comparison of different power configurations
- Different bus cable designs
- Different grounding and shielding concepts
- Stavelets early 2010, realistic stave 09 late 2010 ?
- Stavelets allow testing of different powering options

16

5. Summary

- LHC upgrade plans are being reconsidered, taking into account the “real” speed of progress of LHC performance
- As a result, the lifetime of the LHC will probably extend until ~2030
- R & D on crucial items is essential to allow for a full exploitation of the LHC potential for physics
- Although based on assumptions made in 2007-2008, the SLHC-PP remains a highly valuable contribution to the preparation of the LHC upgrade, participating to a good communication between accelerators and experiments.
- The SLHC-PP will terminate at the foreseen date in April 2011, fulfilling completely almost all of its objectives.
- The next step has to take due account of the new context, and especially of the early experience running the LHC.

Thank you for your attention!