LIU-SPS sub-project

B.Goddard
On behalf of LIU-SPS project team

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- Present limitations and motivation for upgrade
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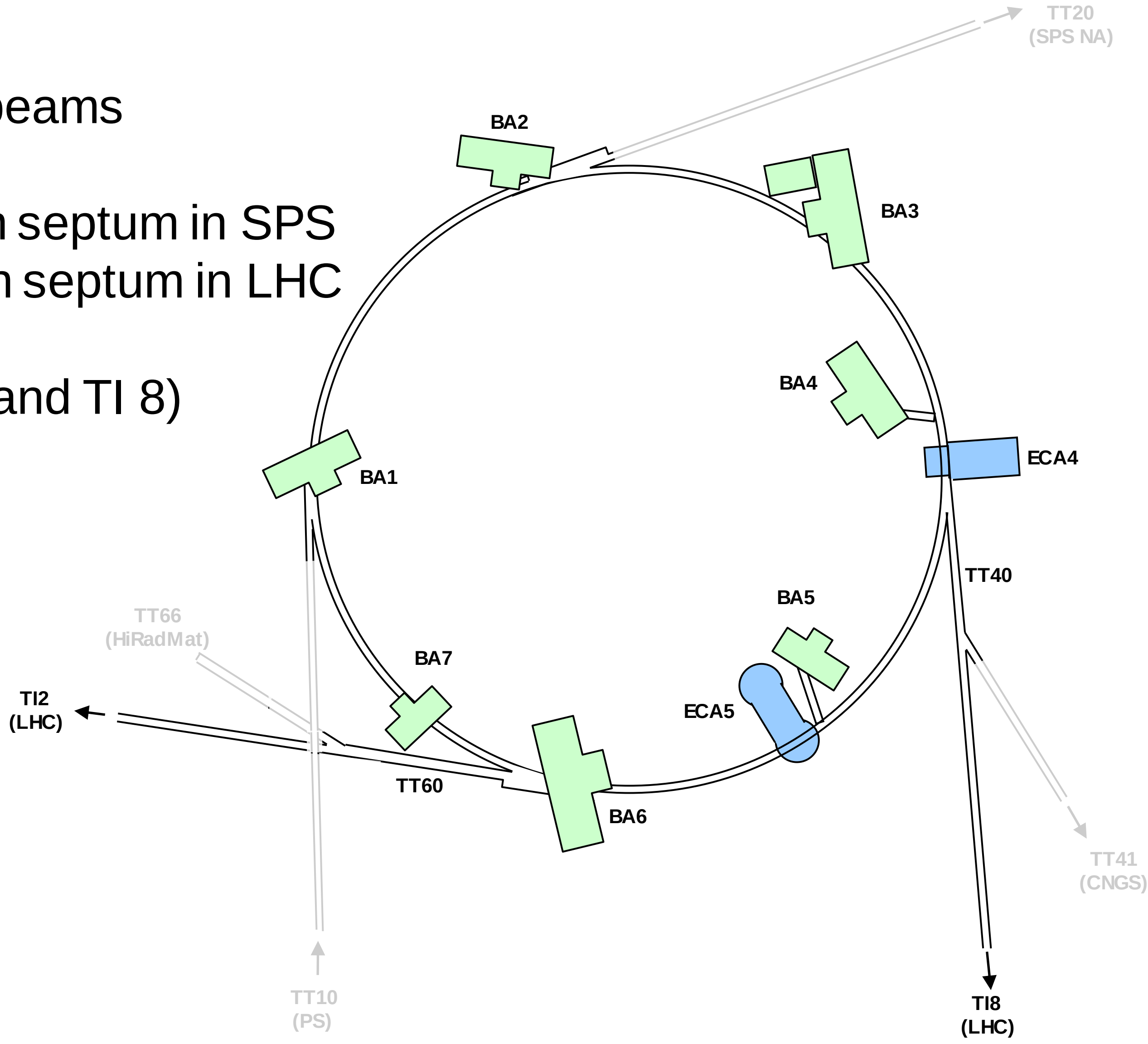
- Project organisation and planning
- Remaining unresolved questions

LIU-SPS scope

SPS for LHC beams

From: injection septum in SPS
To: injection septum in LHC

(includes TI 2 and TI 8)



Requirements from HL-LHC

Target: 250-300 fb^{-1} per year

Parameter	nominal	minimum β* 25ns	minimum β* 50ns
N	1.15E+11	**2.0E+11**	**3.3E+11**
n_b	2808	2808	1404
beam current [A]	0.58	**1.02**	**0.84**
x-ing angle [μrad]	300	475	520
beam separation [σ]	10	10	10
β* [m]	0.55	**0.15**	**0.15**
ε_n [μm]	3.75	2.5	3.0
ε_L [eVs]	2.51	2.5	2.5
energy spread	1.00E-04	1.00E-04	1.00E-04
bunch length [m]	7.50E-02	7.50E-02	7.50E-02
IBS horizontal [h]	80 -> 106	**25**	**17**
IBS longitudinal [h]	61 -> 60	**21**	**16**
Piwinski parameter	0.68	**2.5**	**2.5**
geom. reduction	0.83	**0.37**	**0.37**
beam-beam / IP	3.10E-03	**3.9E-03**	**5.0E-03**
Peak Luminosity	$1\ 10^{34}$	**$7.4\ 10^{34}$**	**$8.4\ 10^{34}$**
Events / crossing	19	**141**	**257**

at LHC collision!

Reminder: 2011 = 5.6 fb^{-1} with 3.5 $x10^{33}$ $cm^{-2}s^{-1}$

Main challenges and limits

- Beam quality to LHC
  - Preservation of transverse emittance from PS into LHC
  - Limitations, instabilities
- Beam loading and high power for RF system
- Electron cloud induced effects
  - Mitigation measures to apply
- Beam loss control and robustness of machine protection devices
- Beam instrumentation
- "Operational" limitations: beam heating, ZS sparking, vacuum, dump, ...

Beam quality to LHC

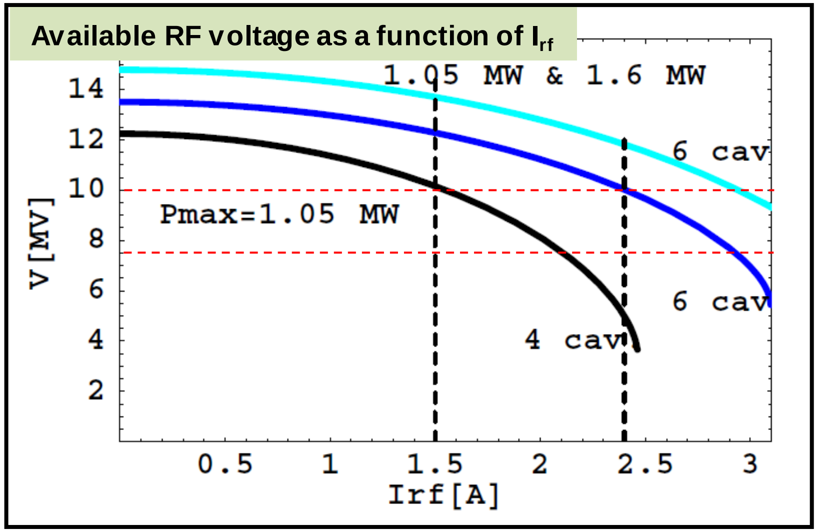
- LHC is requesting smallest emittance, and higher intensities.
  - 2.2e11 p+/b in 2.5 μm for 25 ns, 288b
  - 3.6e11 p+/b in 3.0 μm for 50 ns, 144b
- Need large improvement, c.f. (already excellent!) 2011 performance

	Present 25 ns	Required 25 ns	present 50 ns	Required 50 ns
Ib [p+]	1.10E+11	2.20E+11	1.60E+11	3.60E+11
Emitt [m.rad]	3.00E-06	2.50E-06	2.00E-06	3.00E-06
Nb	288	288	144	144
Spacing [ns]	25	25	50	50
Bunch brightness [p+/m.rad]	3.67E+16	8.80E+16	8.00E+16	1.20E+17
Beam brightness [p+/m.rad]	1.06E+19	2.53E+19	1.15E+19	1.73E+19
Itot [p+]	3.17E+13	6.34E+13	2.30E+13	5.18E+13
Irf [A]	1.41	2.82	1.02	2.30
Brightness factor needed	**1.00**	**2.40**	**1.00**	**1.50**
Intensity factor needed	**1.00**	**2.00**	**1.00**	**2.25**

- Ecloud, instabilities and beam losses becoming critical
  - ecloud mitigation
  - Potential gains from lower γ_T (Q20)?
  - High bandwidth damper (TMCI, ECI, general)
  - Impedance campaign to continue

RF 200 MHz

- Presently 18 sections arranged in 4 cavities (2x4, 2x5), each cavity with 700 kW
  - Beam loading: limited to 1.5 A total RF current with 25 ns, or 1.2e11 p+/b
- Using 2 spares, rearrange 20 sections into 6 cavities (4x3, 2x4), with 1000 and 1400 kW per cavity (in pulsed mode)
  - Can then provide 10 MV at extraction for intensity up to 2.3e11 p+/b
- Without this upgrade, will be limited to about 1.6e11 p+/b at 25 ns (even with pulsed power of 1 MW)
- Rearrangement also reduces beam coupling impedance from 4.5 to 3.7 MΩ

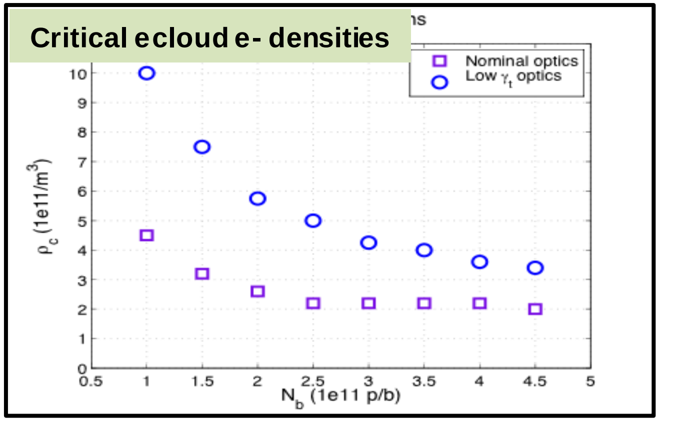


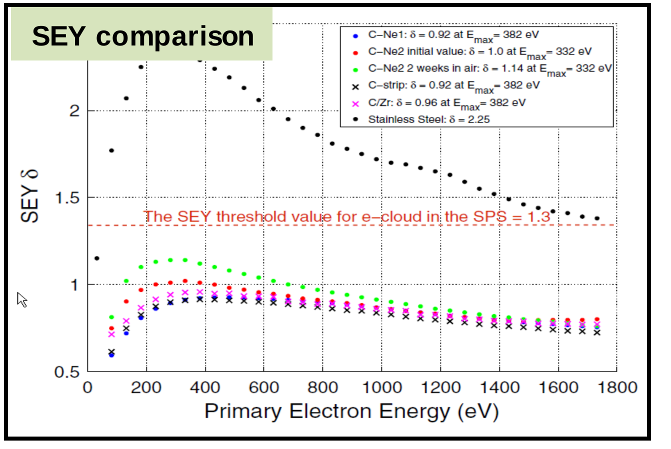
total number n_{cav}	n_{cav} with n_{sect} 3	4	5	Z MΩ	V [MV] for 1 MW 1.54 A	2.3 A	3.0 A
4	0	2	2	4.5	9.9	6.5	0
5	2	3	0	3.6	10.6	8.8	3.6
6	4	2	0	3.7	12.7	10.3	5.9
					25 ns: 1.2e11	1.8e11	2.3e11

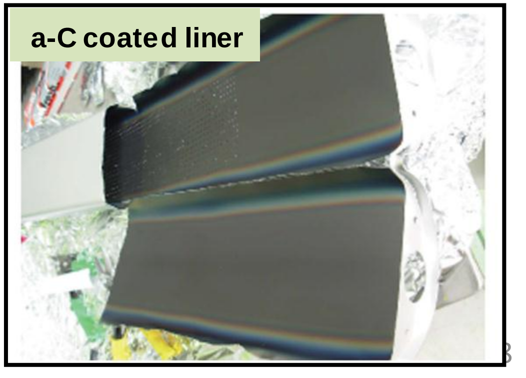
E.Montesinos et al.

Ecloud mitigation

- electron cloud strongly affects SPS beams
  - Beam loss, vacuum, instabilities, incoherent emittance growth
- Huge efforts in past decade to understand and investigate mitigations
- Objective for end of 2012 is to decide on needed mitigation strategy
- Possible feasible mitigations are:
  - Amorphous carbon coating of all SPS dipoles and quadrupole chambers (need >90% of machine length treated). Reduces SEE yield below 1.0, and suppresses multipacting.
  - Rely on scrubbing, as in LHC (possibly with enhanced techniques). Will be helped by improved vacuum sectorisation.
  - High bandwidth damper to fight ecloud instability





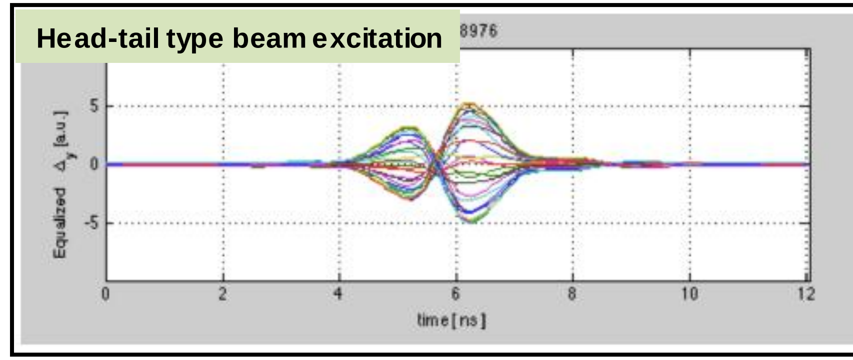


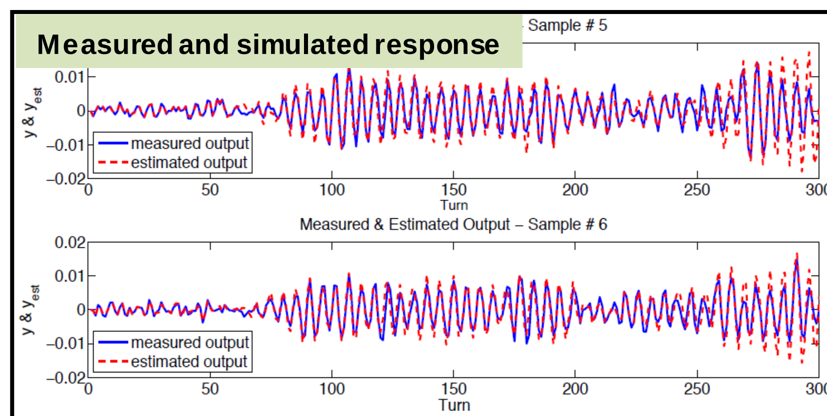
J.M.Jimenez, M.Taborelli et al.

SPS Upgrade LIU Project

High bandwidth feedback

- Intra-bunch GHz feedback system could help stabilise beam against ECI and TMCI
  - Under development with LARP
  - Start with vertical plane
  - Could allow low chromaticity/higher intensities
- High bandwidth pickup installed in SPS
  - 20-40 GS/sec sampling
  - PU used to drive beam with different excitation functions (3.2/4 GS/sec) and measure response
- Simulation and modelling effort
  - Understanding MD data and specifying required performance (power, bandwidth) via reduced models and numerical simulations
- Phased development
  - Demonstrator (closed loop) for 2012
  - Prototype ready for 2015
  - Final system implemented in LS2

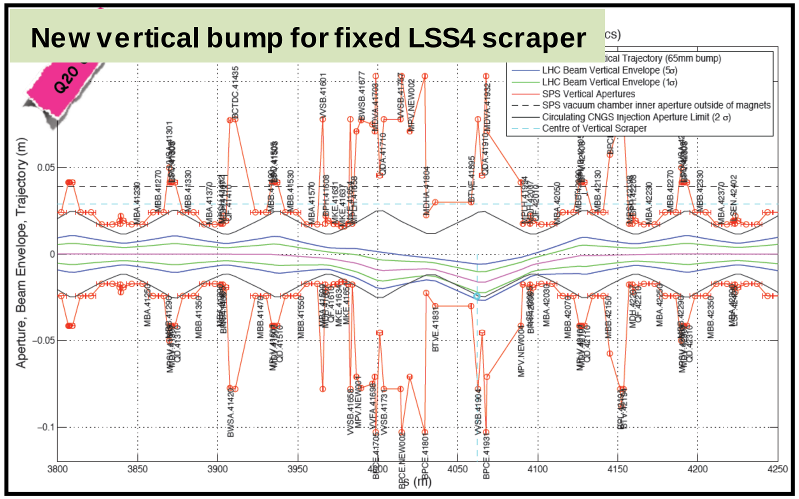




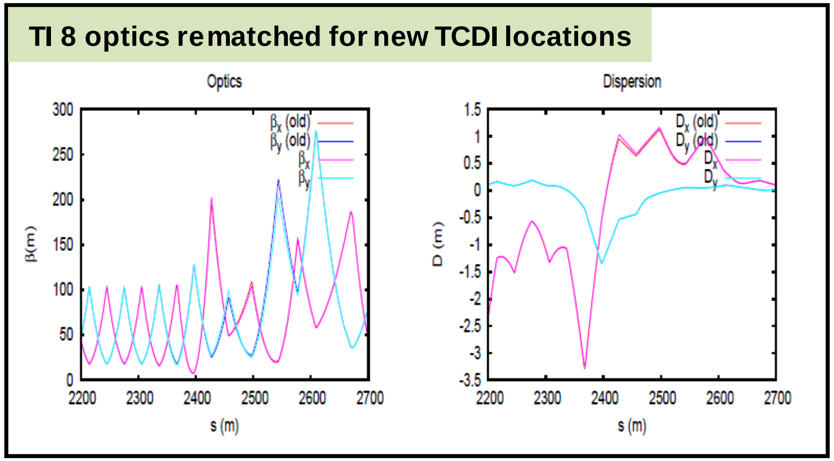
Beam loss and machine protection

SPS Upgrade LIU Project

- Scraper redesign with magnetic bump
  - Under study for LSS4 re-using extraction bumpers, with fixed scraper blocks
- Upgrade of TCDI collimators
  - New locations further upstream to reduce cross talk with LHC, possible new design for robustness and protection
- Upgrade of extraction protection devices
  - To cope with higher beam intensity and smaller emittances
- Beam loss, activation and component doses
  - Beam loss inventories, FLUKA simulations and dose estimates
- Machine protection and beam instrumentation improvements
  - Interlocking elements, especially BLMs



New vertical bump for fixed LSS4 scraper



TI 8 optics rematched for new TCDI locations

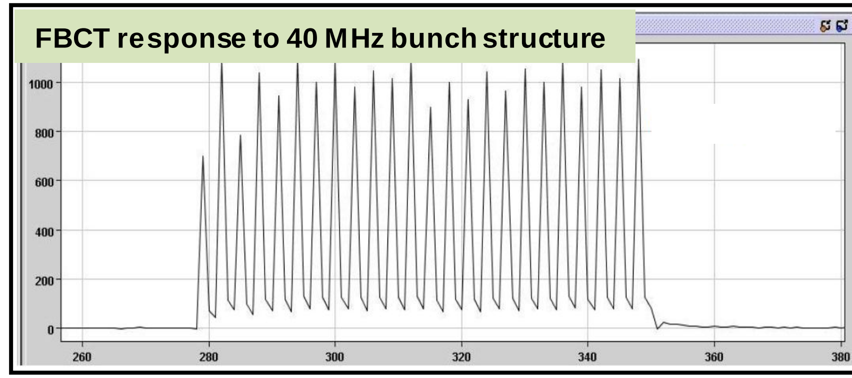
M.Meddahi et al.

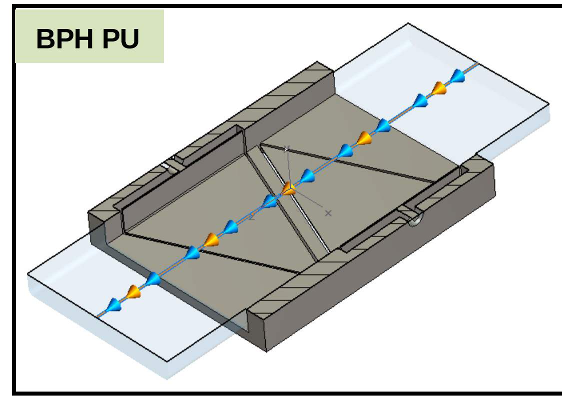
Beam instrumentation

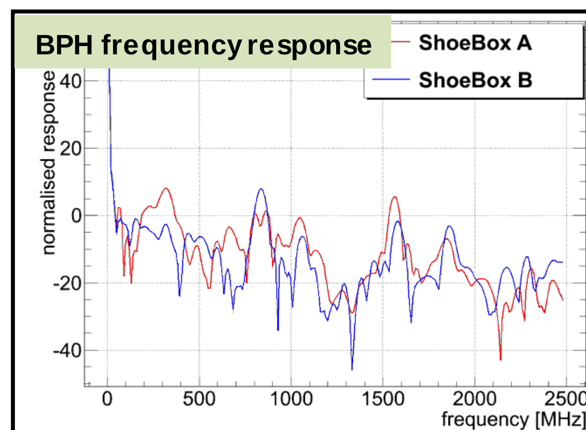
- New MOPOS system (already in CONS)
  - Bunch-by-bunch, turn-by turn
- New BLM system
  - Upgrade electronics, acquisition to 'LHC-like'
  - Addition of fast (ns response) diamond BLMs
- Improved wirescanners
  - Key elements for beam optimisation and quality monitoring
  - New prototype to install in SPS
- Upgraded residual gas BGI monitor
  - Continuous monitoring of beam size and possibly transverse beam quality

– Improved FBCT and DCBCT
  - FBCT SW and HW improvements to remove limitations and give turn-by-turn data

– Tune, head-tail, matching monitor, ...



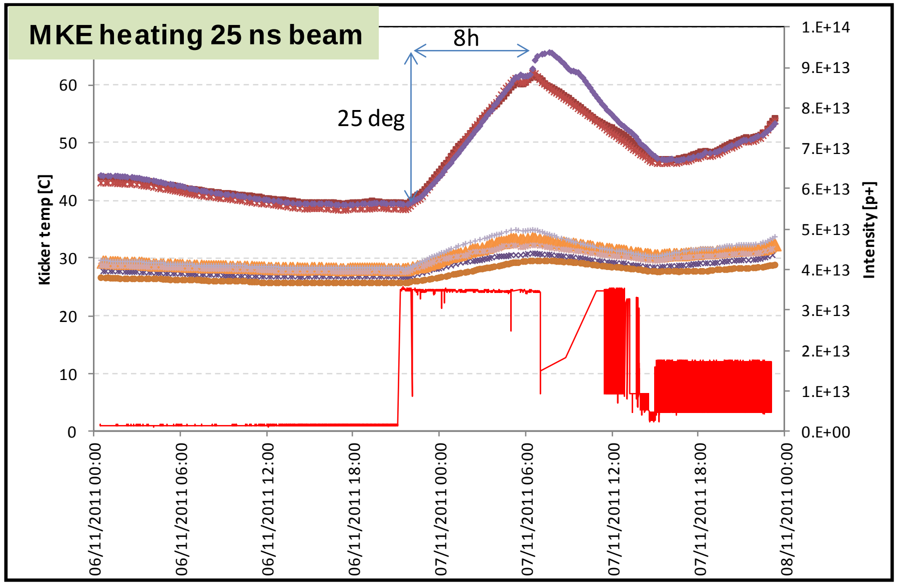


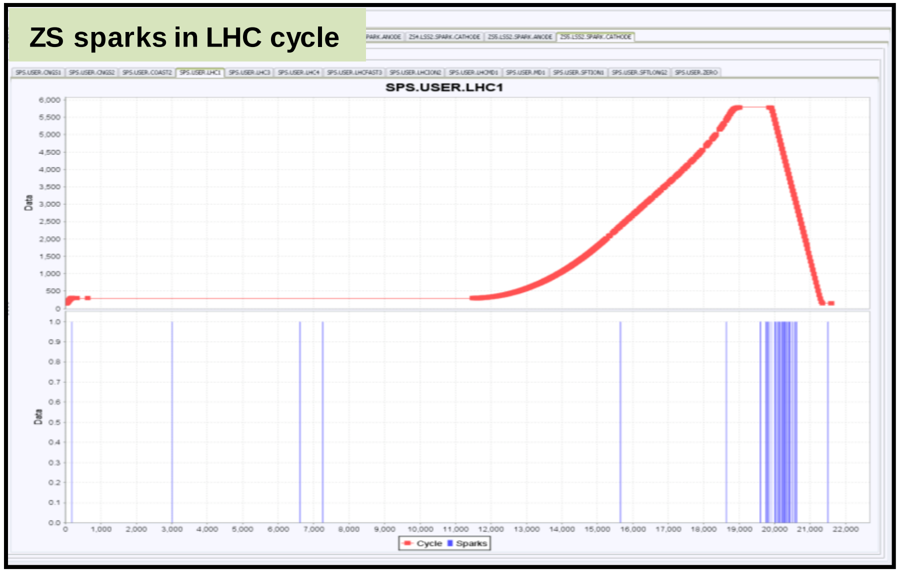


L.Jensen et al.

Operational limitations

- Heating of MKE extraction kickers
  - Serigraphy reduces effect by factor of 3: final kicker to be equipped in LS1
  - Possible new redesign possible with open C core kicker, with beam bumped in just before extraction
- Sparking of ZS septa
  - Modulation of main and ion trap voltage effective; SPS supercycle containing FT beam for North Area affected
- Beam dump outgassing
  - Limitation more for special modes like scrubbing
  - Extra pumping and sectorisation being studied
  - New dump design or relocation also possible
- Vacuum sectorisation
  - General improvement planned (scrubbing, kicker conditioning, dump outgassing)





Other systems and teams

- Many other systems and teams are heavily involved in LIU-SPS upgrade
  - Vacuum (200 MHz, kickers, dump, BI, damper, sectorisation, ...)
  - Controls (for BI, other FECs, data, SW, ..)
  - Existing transverse damper system (new PUs, increased power?)
  - OP (operational beams, applications, MD, ...)
  - ABP (optics, apertures, Q20, collective effects, collimation, ...)
  - Magnets (aC coating, Q20 implementation, scraper studies, ...)
  - FLUKA (many energy deposition studies)
  - Power convertors (new/upgraded convertors, stability improvements, ...)
  - Cabling (everywhere)
  - Cooling and ventilation (200 MHz)
  - Design office (everywhere)
  - Workshop
  - Shutdown coordination
  - Safety
  - Consolidation
  - Transport
  - Survey
  - Radioprotection
  - …

SPS Upgrade
LIU Project

Beam dynamics

- Instabilities
- Intensity limitation studies
- Impedance
- Longitudinal issues
- Feedbacks
- Simulations

Specifications

- RF system upgrade
- Wide bandwidth FB
- e-cloud limits
- Impedance upgrade
- Instrumentation

E.Shaposhnikova

e-cloud mitigation

- Mitigation necessity
- Surface treatments
- Aging studies
- Vacuum issues
- Simulations

Specifications

- Coating technology
- Magnet chambers
- Instrumentation

J.M.Jimenez

Beam loss, protection, TLs

- Beam loss scenarios
- Collimation studies
- Scraper studies
- Beam dump design
- Extraction protection
- TL and LHC injection protection

Specifications

- Collimation system
- Scraper upgrade
- Beam dump
- Instrumentation
- Extraction diluters
- TL protection devices

M.Meddahi

Operational issues
Beam deployment
Radioprotection
General services
Powering
Layouts and DBs
Optics files
Integration
Planning
EVM, APT, MTP
Shutdown coordination
Surface space
Safety, risk

B.Goddard (deputy E.Shaposhnikova)

LIU-SPS coordination meeting

Hardware and other implementation workpackages

- 200 MHz RF
- Magnet chamber e-cloud mitigation
- Collimation system
- Wide band feedback
- Beam instrumentation (SPS and TLs)
- RF low level control upgrade
- ZS test area
- Extraction diluters
- Transfer line collimators
- Scraper upgrade
- Beam dump relocation/redesign
- Further impedance reduction
- New extraction kickers
- ZS upgrade
- Update layout and optics DB
- Update of drawings

SPS Upgrade LIU Project

Planning

Activity status (snapshot)

- Being implemented
  - RF 200 MHz upgrade
  - (some) beam instrumentation upgrades
  - Vacuum sectorisation
  - Kicker impedance reduction (MKE/MKDV)
- Still being developed/prototyped
  - (some) beam instrumentation upgrades
  - aC coating of dipoles and other elements
  - High bandwidth transverse feedback system
- Still in conceptual study phase
  - Upgraded transfer line collimators
  - Upgraded extraction protection devices
  - Upgrade of existing damper system
  - New scraper concept
  - New/relocated beam dump
  - New extraction kicker concept

Unresolved questions

- Ecloud mitigation – aC coating or scrubbing (+HBW damper)?
  - Final answer MUST come at end 2012
  - Plan 5 days "scrubbing run" early 2012 to investigate how far scrubbing can take us – will need high quality beams from PSB and PS
  - Potential issue with aC of unexplained high vacuum pressure
- Is Q20 a real operational alternative for after LS1?
  - Need to still solve some issues
  - Strong push for MD (again) for 2012
- Is any further impedance reduction possible (or necessary?)
  - New MKE a possibility, but very heavy activity
- Is an external beam dump feasible?
  - Study needs to be completed in 2012

Summary

- SPS performance is already excellent for LHC beams
  - 50 ns: almost reaching LHC ultimate intensity, and already at 50% (!) above ultimate brightness
  - 25 ns: reached LHC nominal intensity, and already at 10-15% above nominal brightness
- For HL-LHC era, requirements are challenging
  - 50 ns: need x2.3 present intensity, 50% above present brightness
  - 25 ns: need x2 present intensity, x2 present brightness
- Work is well advanced for some systems, with others still 'conceptual'
- Main upgrade items will only be ready after LHC LS2, around 2019

- Finally, thanks to all those who have worked directly and indirectly on the SPS over the years to put us in this strong position!