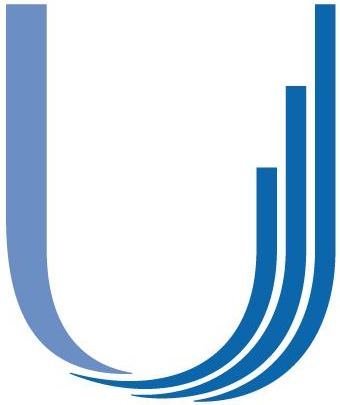


LHC Injectors Upgrade

LHC Injectors Upgrade

LIU Beam Studies Day – setting the scene

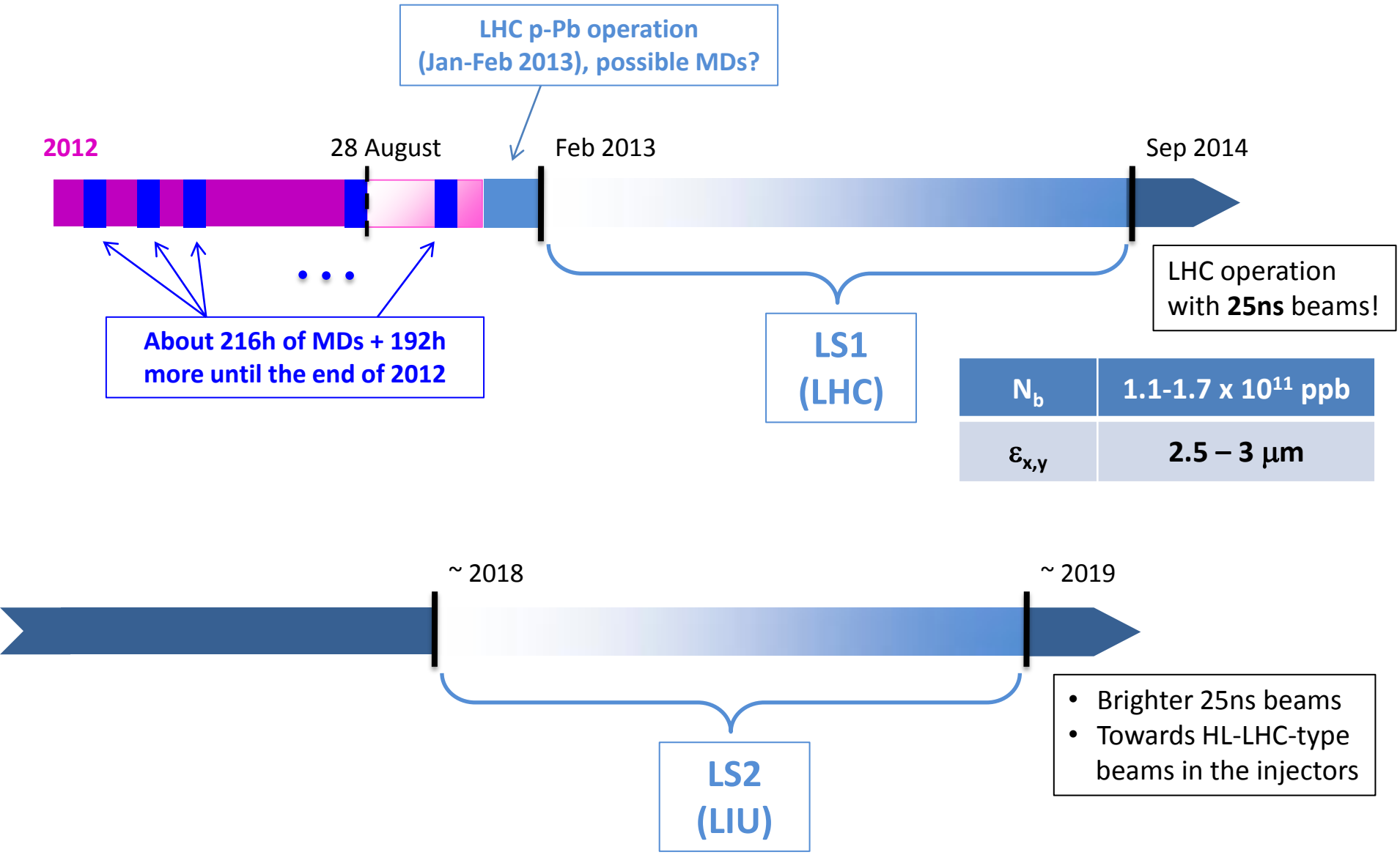
Giovanni Rumolo

in *LIU Beam Studies Day, CERN, 28 August 2012*

- **Milestones for future LHC beams**
- **Injector MD schedule: where we are now, how much is left**
- **Requests for LIU MDs this year and current status**
  - → **PSB**
  - → **PS**
  - → **SPS**
- **Concluding remarks**

Rough timeline 2012 – .. (as of now)

LHC Injectors Upgrade



N_b	1.1-1.7 x 10^{11} ppb
$\varepsilon_{x,y}$	2.5 – 3 μm

Rough timeline 2012 – .. (as of now)

LHC Injectors Upgrade

LHC p-Pb operation

2012

O. Brüning, HL-LHC/LIU Day, 30 March 2012

Parameter	nominal	minimum β* 25ns	minimum β* 50ns
N	1.15E+11	2.2E+11	3.5E+11
n_b	2808	2808	1404
beam current [A]	0.58	1.12	0.89
x-ing angle [μrad]	300	480	550
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	1.20E-04	1.20E-04	1.20E-04
bunch length [m]	7.50E-02	7.50E-02	7.50E-02
IBS horizontal [h]	80 -> 106	20.0	20.7
IBS longitudinal [h]	61 -> 60	15.8	13.2
Piwinski parameter	0.68	2.54	2.66
geom. reduction	0.83	0.37	0.35
beam-beam / IP	3.10E-03	3.9E-03	5.0E-03
Peak Luminosity	1 10^{34}	9.0 10^{34}	9.0 10^{34}
Events / crossing	19	171	340

at LHC collision

4

peration
25ns beams!

ns beams
-LHC-type
beams in the injectors

LS2
(LIU)

Translated for the injectors …

B. Goddard, HL-LHC/LIU Day, 30 March 2012

25 ns	PSB inj	PSB extr/PS inj	PS extr/SPS in		
Energy GeV	0.16	2			000
Nb	1	1			308
Ib [e11 p+]	35.2	33.5			2.2
Ib in LHC [e11 p+]	2.9	2.8	2.7	2.4	2.2
Exyn [mm.mrad]	1.9	2.0	2.1	2.3	2.5

- Space charge in the PSB ($\Delta Q>0.36$) ?
- Space charge in the PS ($\Delta Q>0.28$) ?

50 ns	PSB inj	PSB extr/PS inj	PS extr/SPS inj	SPS extr/LHC inj	LHC top
Energy GeV	0.16	2	26	450	7000
Nb	1	1	36	144	1404
Ib [e11 p+]			4.2	3.9	3.5
Ib in LHC [e11 p+]			4.2	3.9	3.5
Exyn [mm.mrad]			2.5	2.7	3.0

- Longitudinal instabilities in the PS?
- Space charge in the SPS ($\Delta Q>0.15$) ?

	PSB	PS	SPS	LHC
loss %	5	5	10	10
blowup %	5	5	10	10

Translated for the injectors …

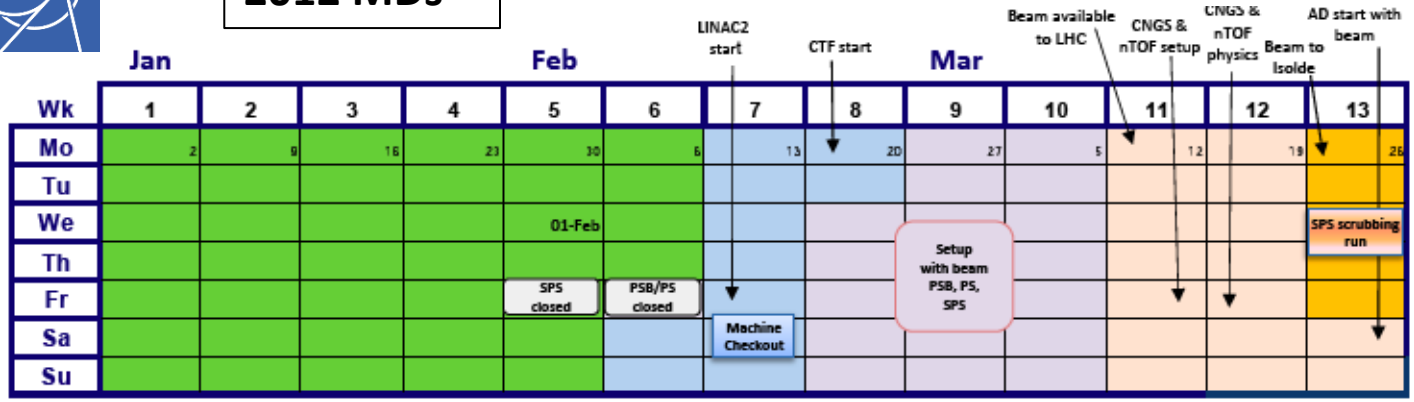
B. Goddard, HL-LHC/LIU Day, 30 March 2012

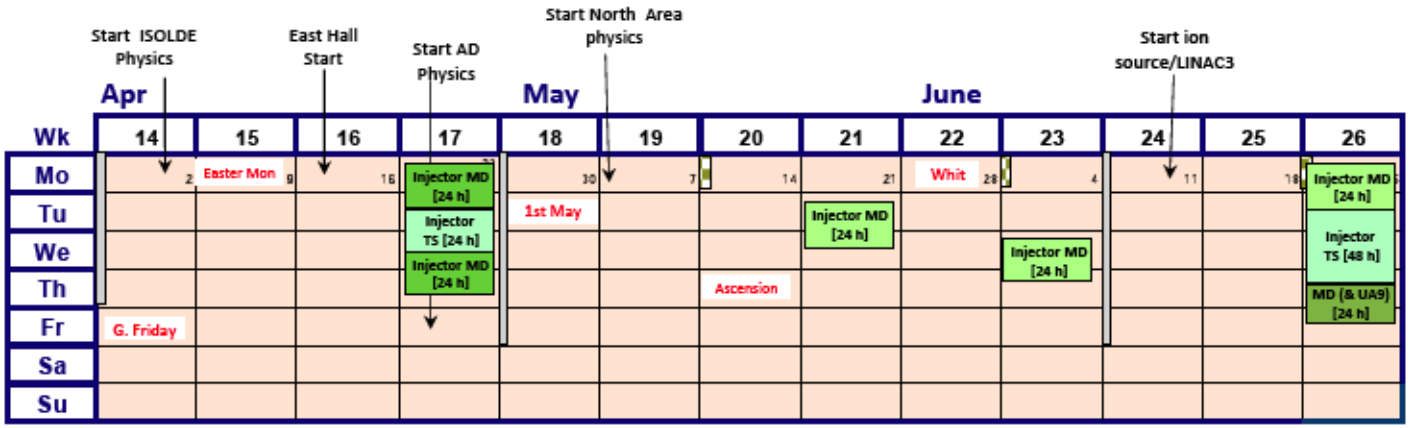
25 ns	PSB inj	PSB extr/PS inj	PS extr/SPS inj	SPS extr/LHC inj	LHC top
Energy GeV	0.16	2	26	450	7000
Nb					2808
Ib [e11 p+]					2.2
Ib in LHC [e					2.2
Exyn [mm.					2.5
50 ns					
Energy Ge					7000
Nb					1404
Ib [e11 p+]					3.5
Ib in LHC [e					3.5
Exyn [mm.					3.0

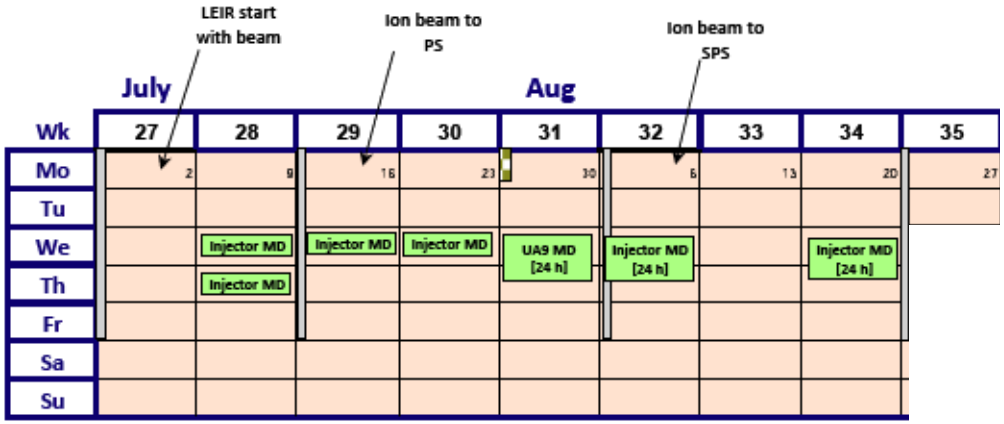
- Space charge in the PSB, PS, SPS (acceptable ΔQ)
  - → Do we fully understand the effects and do we have simulation tools (benchmarked with our machines) for predictions ?
- Longitudinal instabilities in the PS
- Longitudinal instability and TMCI in the SPS
  - → Is Q20 optics enough to raise these thresholds above the requested values?
- Electron cloud effects with larger intensity (PS & SPS)
  - → Can we rely on scrubbing or do we need coating ?
  - → High bandwidth transverse feedback system ?

	PSB	PS	SPS	LHC
loss %	5	5	10	10
blowup %	5	5	10	10

2012 MDs





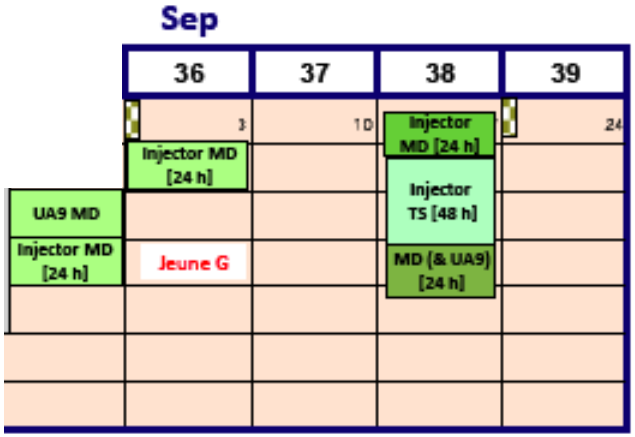


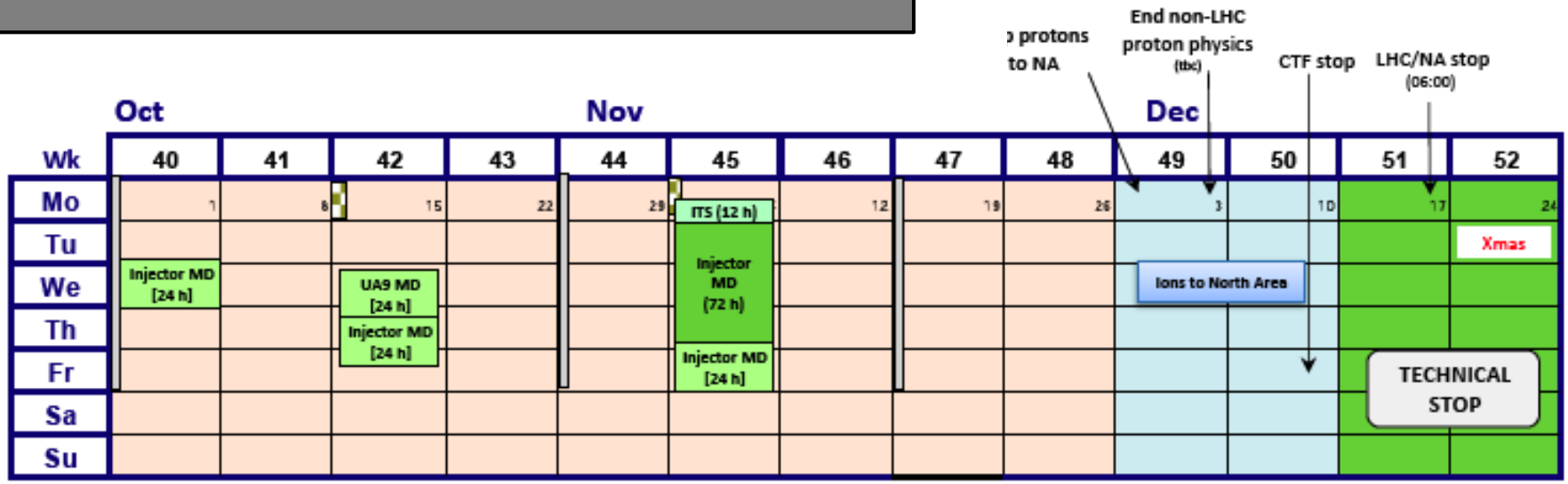
- More than half-way through the 2012 run
  - ☑ 5-days scrubbing run
  - ☑ 3 blocks of fully dedicated MDs
  - ☑ 8 blocks of floating MDs (sometimes split into 12h blocks)

2012 MDs

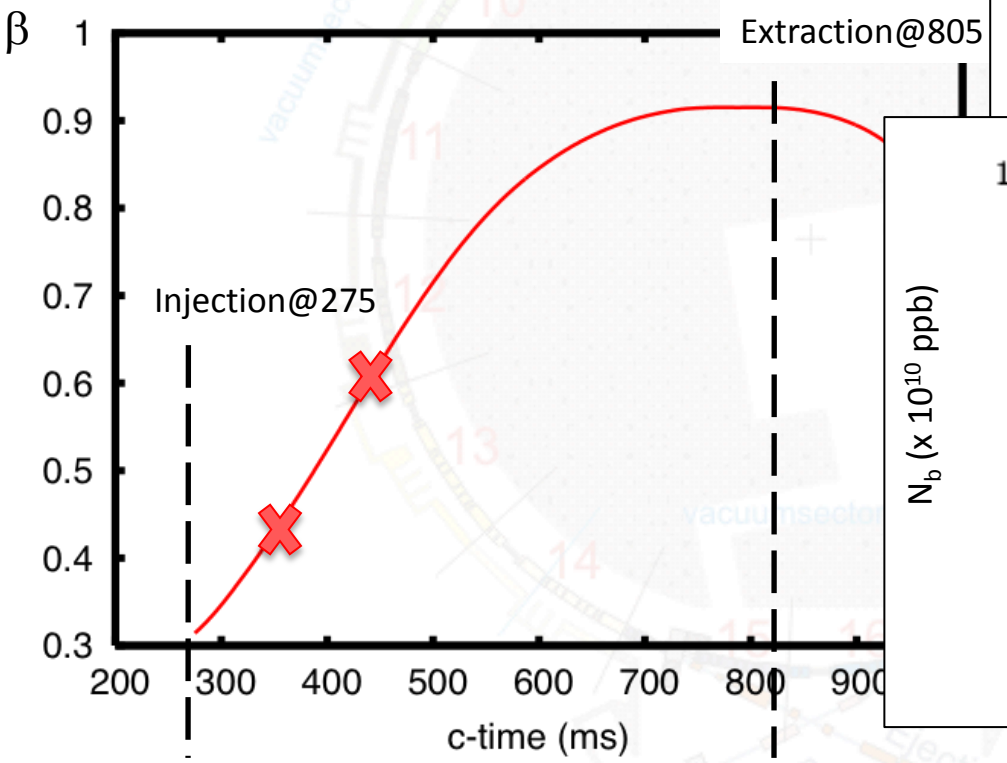
LHC Injectors Upgrade

- How much time is left
  - ☑ 3 blocks of floating MDs
  - ☑ 96h (4 blocks) of floating MDs to be rearranged (LHC TS will not take place)
  - ☑ Restore the weekly 12h MDs on Wednesdays to optimize use of time for users
  - ☑ Can we still use some MD time in 2013 during the p-Pb LHC run?
  - ☑ Parallel MDs will continue in all injectors



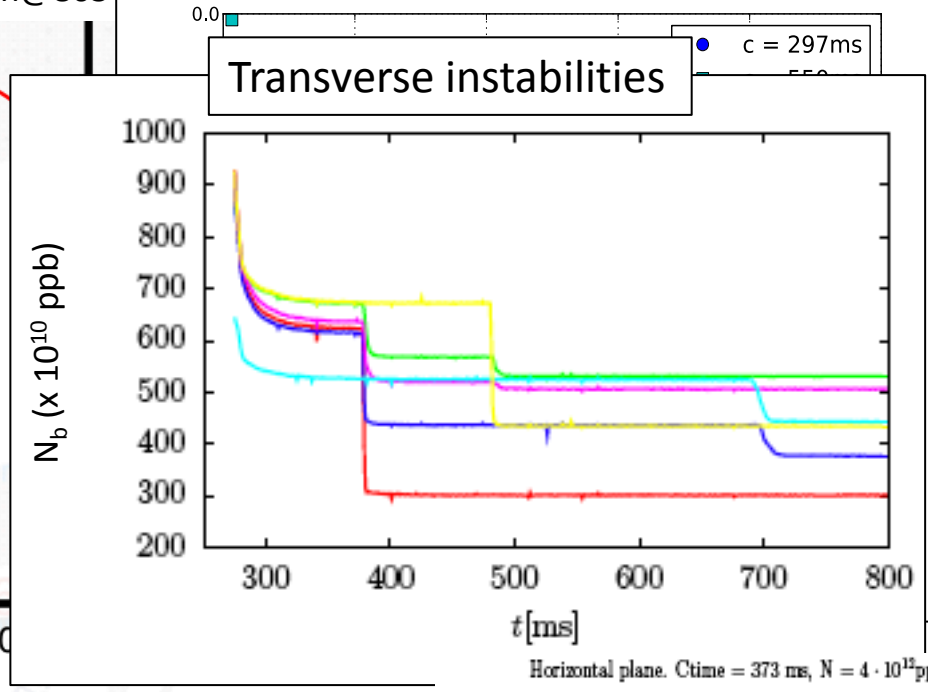


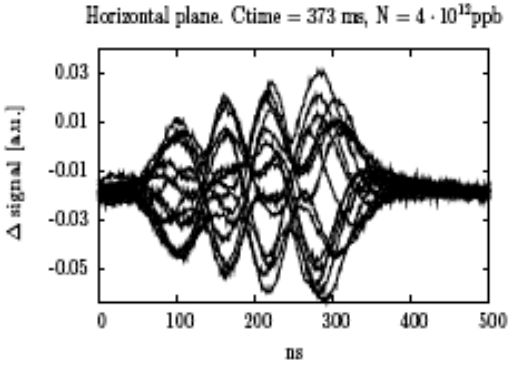
PSB intensity limitations



Space charge

Transverse instabilities





- Space charge (losses, emittance blow up)
- Instabilities along the cycle (efficiency of the transverse feedback system)
- LHC beams presently not limited by these effects

PSB in 2012

From MSWG meeting, 17 February 2012

- **LIU-PSB activities in 2012 (RF, hardware)**

① Continue deployment of the digital RF control

① Test the newly installed Finemet prototype cavity hardware

- **LIU/Beam dynamics/performance MDs**

⊙ Parametric dependence of the transverse instabilities and identification of the impedance source, importance of the damper

⊙ Determine resonance diagram with tune scans at 160 MeV to optimize placement of working point at injection with Linac4

⊙ Optics model based on turn-by-turn data from the available BPMs

⊙ Study the efficiency of the resonance compensation schemes

⊙ Space charge induced emittance blow up

⊙ Capture and acceleration in h=2

⊙ Equalization of transverse emittances across rings

⊙ Bunch lengthening at top energy for PSB-PS transfer (in view of 2GeV)

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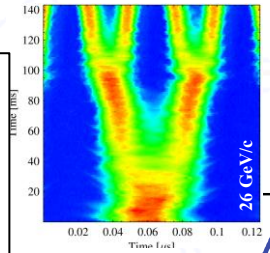
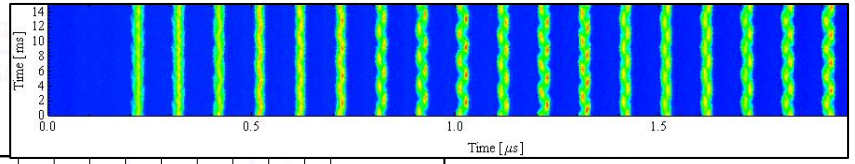
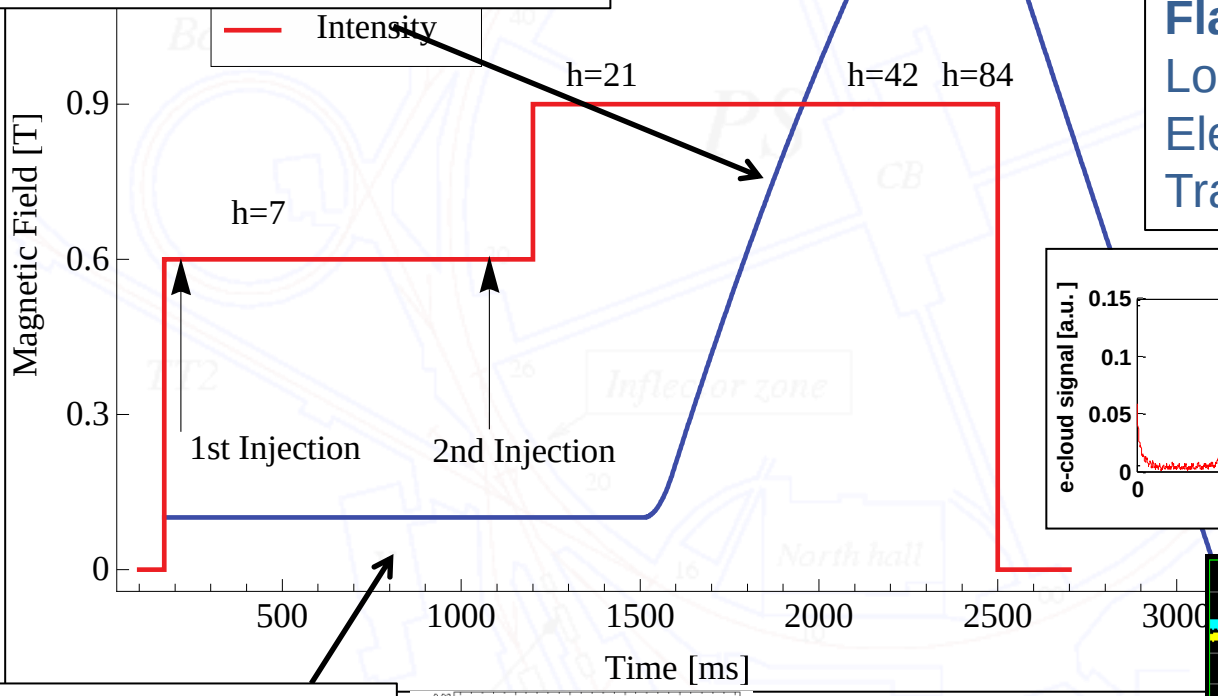
  - Parametric dependence of the transverse instabilities and identification of the impedance source, importance of the damper
  - Determine resonance diagram with tune scans at 160 MeV to optimize placement of working point at injection with Linac4
  - Optics model based on turn-by-turn data from the available BPMs
  - Study the efficiency of the resonance compensation schemes
  - Space charge induced emittance blow up (**effect of working point**)
  - Capture and acceleration in h=2
  - Equalization and **optimization** of transverse emittances across rings
  - Bunch lengthening at top energy for PSB-PS transfer (in view of 2GeV)

PS intensity limitations

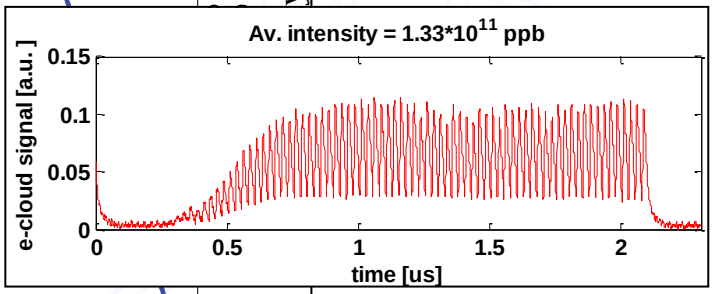
Acceleration/Bunch splittings
Longitudinal CBI
Transient beam loading
Transition crossing

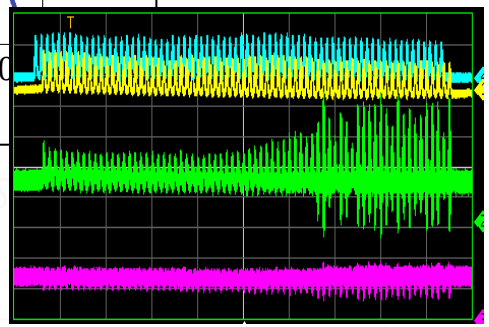




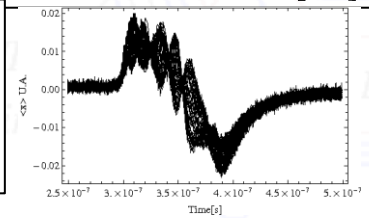


Flat top:
Longitudinal CBI
Electron cloud
Transverse instabilities





Injection flat bottom:
Space charge
Headtail instability



PS MDs in 2012

From MSWG meeting, 17 February 2012

- **LIU PS machine studies requested in 2012**

- Space charge studies: is 0.26 the limit for the PS?
- Additional feedback against longitudinal CBI (should extend the intensity reach for 50 and 25ns beams!)
- Batch compression h=9 →10 → 20 →21, acceleration, transfer to SPS
- Batch compression + bunch merging scheme
- One-turn feedback against transient beam-loading
- Electron cloud measurements in presence of B field and with double step bunch rotation
- PS-SPS transfer studies (SPS capture loss maps as a function of PS bunch rotation timings)
- Commissioning of transverse feedback system
- Head-tail instabilities on the flat bottom
- Transverse instabilities of short intense bunches at flat top
- Impedance identification for modeling
- Miscellaneous injection studies and optics model at different energies
  - ✓ Tuning of working point from injection in 5 CM
  - ✓ Tests of low energy elements
  - ✓ Acceleration-deceleration for double batch transfer

PS MDs in 2012

From MSWG meeting, 17 February 2012

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- ✓ Space charge studies: is 0.26 the limit for the PS? **Integer crossing**
- ✓ Additional feedback against longitudinal CBI (should extend the intensity reach for 50 and 25ns beams!)
- ✓ Batch compression h=9 →10 → 20 →21, acceleration, transfer to SPS/**LHC**
- ✓ Batch compression + bunch merging scheme
- ✓ One-turn feedback against transient beam-loading
- ✓ Electron cloud measurements in presence of B field and with double step bunch rotation
- ✓ PS-SPS transfer studies (SPS capture loss maps as a function of PS bunch rotation timings)
- ✓ Commissioning of transverse feedback system **@injection**
- ✓ Head-tail instabilities on the flat bottom
- ✓ Transverse instabilities of short intense bunches at flat top
- ✓ Impedance identification for modeling (**transverse & longitudinal**)
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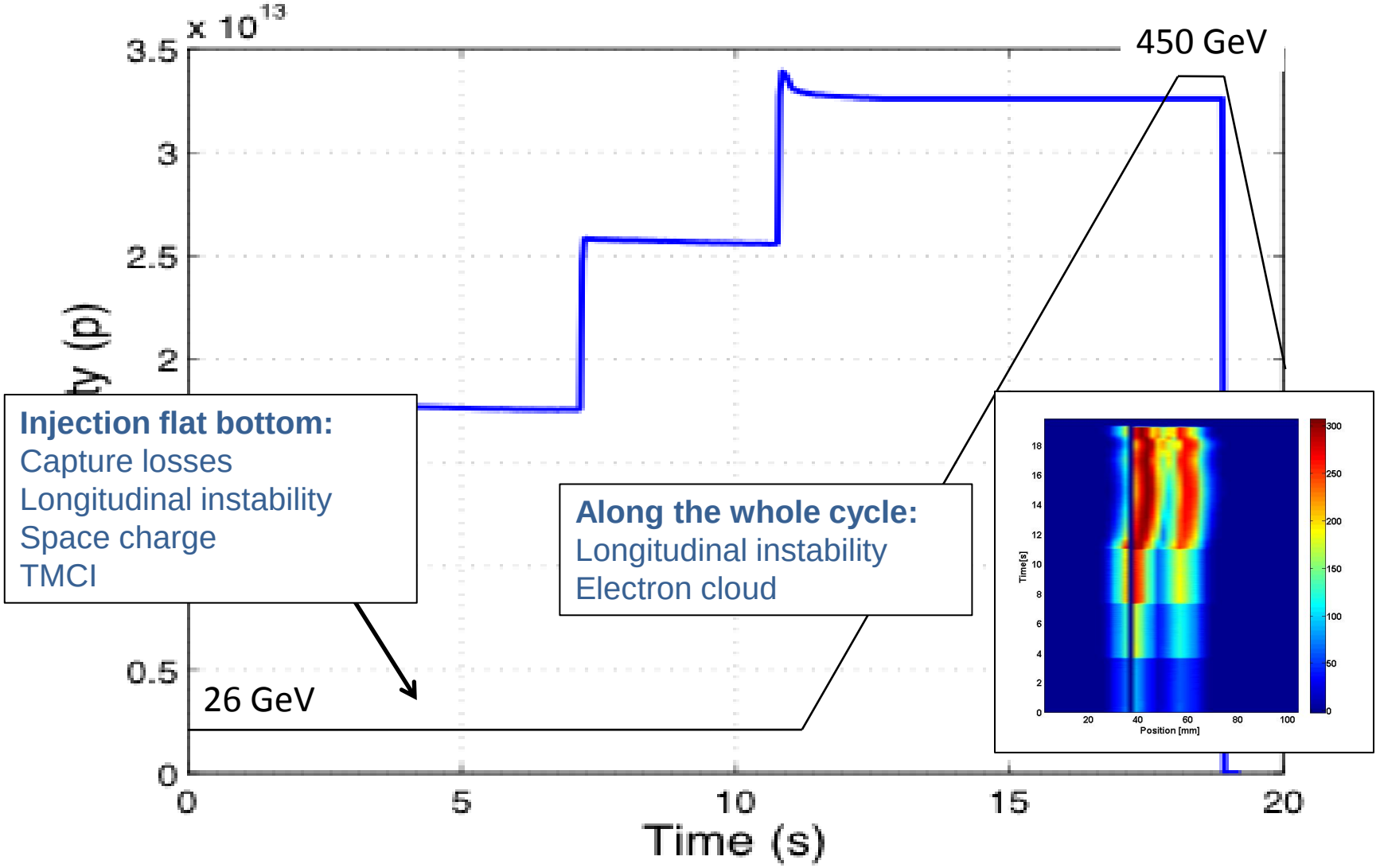
  - ✓ Tests of low energy elements
  - ✓ Acceleration-deceleration for double batch transfer

SPS intensity limitations



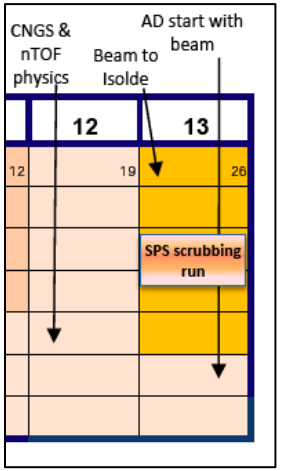
SPS MDs in 2012

From MSWG meeting, 17 February 2012

- **2012 electron cloud studies**

  Scrubbing in W13 and e-cloud MD sessions

  → Qualification of 25ns beams
  → Interpretation of the pressure data
  → Testing efficiency of scrubbing with uncaptured beam
  → Monitor and qualify beam induced scrubbing under different beam/chamber conditions (beam observables, direct electron cloud observables)
  → Validate simulation models on scrubbing times (like for LHC)
  → New setups for validation of a-C coating



- **Other LIU SPS machine studies in 2012**

⊙ Q20 optimization
  - ✓ Longitudinal stability and quality at extraction
  - ✓ Injection tests into LHC
  - ✓ Transverse emittance preservation and single bunch limits
  - ✓ Nonlinear optics model
  - ✓ Instabilities (TMCI, ECI)
  - ✓ Extension of Q20 to fixed target physics cycles

⊙ ZS studies

⊙ Tests with increased peak RF power

⊙ High bandwidth feedback studies (close feedback loop and prove damping of head-tail modes)

⊙ Impedance identification

SPS MDs in 2012

From MSWG meeting, 17 February 2012

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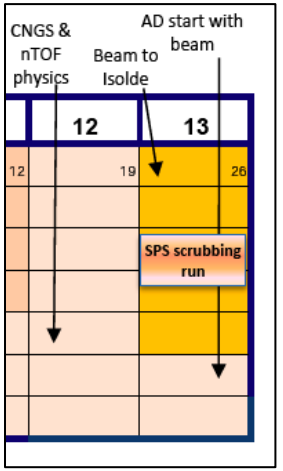


- **Other LIU SPS machine studies in 2012**

  - ✓ Q20 optimization (**single and multi-bunch!**)
    - ✓ Longitudinal stability and quality at extraction (also for **Q26 high intensity**)
    - ✓ Injection tests into LHC
    - ✓ Transverse emittance preservation and single bunch limits
    - ✓ Nonlinear optics model
    - ✓ Instabilities (TMCI, ECI)
    - ✓ Extension of Q20 to fixed target physics cycles
  - ✓ ZS studies
  - Tests with increased peak RF power
  - ✓ High bandwidth feedback studies (close feedback loop and prove damping of head-tail modes)
  - Impedance identification

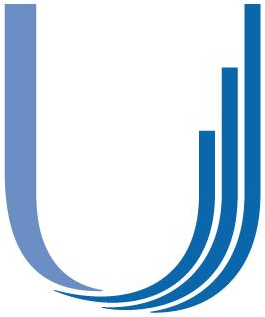
In conclusion

Most of the requested LIU MDs in PSB/PS/SPS have progressed significantly in 2012 and status will be reviewed in the next talks

- **PSB**
  - → LHC beams performance and optimization (B. Mikulec)
  - → RF and transverse feedback aspects (A. Findlay)
  - → Space charge effects (A. Molodozhentsev)
- **PS**
  - → Space charge limit at injection (R. Wasef)
  - → Transverse studies (S. Gilardoni)
  - → Longitudinal studies, alternative schemes (H. Damerau)
- **SPS**
  - → Q20 single and multi-bunch operation (H. Bartosik)
  - → Electron cloud studies: coating vs. scrubbing (G. Iadarola)
  - → Longitudinal beam stability & quality (T. Argyropoulos)
  - → High bandwidth transverse feedback system (W. Höfle)

Some key questions (that will be addressed today)

- Are we on the right path to provide LHC with the required beams at the different stages (post-LS1, post-LS2)?
- Which studies will still require more information and significant MD time before LS1?
- Is any study presently limited by instrumentation or diagnostics? Any improvement possible before LS1?
- Is any study strongly relying on the installation and test of new hardware before LS1?
- How can we optimize the use of the remaining available MD time? Do we need to request for more?
- Which are the main motivations why we could benefit from the extension of the MD run into 2013?
- …



LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!