HIGH PILE-UP TEST

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- LMC Action: Propose ways to increase luminosity for a test fill, in case the crossing angle reduction is not already sufficient
  => Requirements from the experiments
  - At least 2 trains of more than ~ 20 bunches (25 ns) + Few isolated high brightness bunches (with one non colliding)
  - Highest pile-up which can be done quickly (at least > 10%)
  - In 2017 => Trying to approach HL-LHC pile-up (140)
  - To be done soon (between MD4 and MD5)
- Potential from injectors
- LHC performance

POTENTIAL FROM INJECTORS
=> Beam parameters for some LHC beams at SPS extraction

	$\mathcal{N}$ (x 10^{11}p/b)	ε (μm)	Number of bunches/ train	Bunch spacing (ns)
High brightness LHCINDIV	2.0	1.0	Up to 4	225
LHC25 standard	1.3	2.6	Up to 72	25
LHC25 BCMS	1.3	1.6	Up to 48	25
8b+4e	1.7	2.5	Up to 56	25
LHC50 standard	1.7	1.7	Up to 36	50
LHC50 BCMS	1.7	1.1	Up to 24	50
LHC25 PBC	1.3	1.0	Up to 32	25
8b+4e (from BCMS)	1.7	1.4	Up to 32	25

G. Rumolo and H. Bartosik, *Injector beam requirements and options*, LBOC meeting, 8 April 2014

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8b+4e				25
LHC50 standard				50
LHC50 BCMS				50
LHC25 PBC	1.3	1.6	Up to 32	25
8b+4e (from BCMS)	1.7	1.4	Up to 32	25

Can be increased keeping the brightness ~ constant
=> Ex: 3 10^{11} p/b within 1.5 μm

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LHC25 BCMS	1.3	1.6	Up to 48	25
8b+4e	1.7	1.5	Up to 56	25
LHC50 standard	1.7	2.7	Up to 36	50
LHC50 BCMS	1.7	1.9	Up to 24	50
LHC25 PBC	3.2	3.5	Up to 32	25
8b+4e (from BCMS)	2.5	2.5	Up to 32	25

Further optimization should allow ~ 1.3 μm

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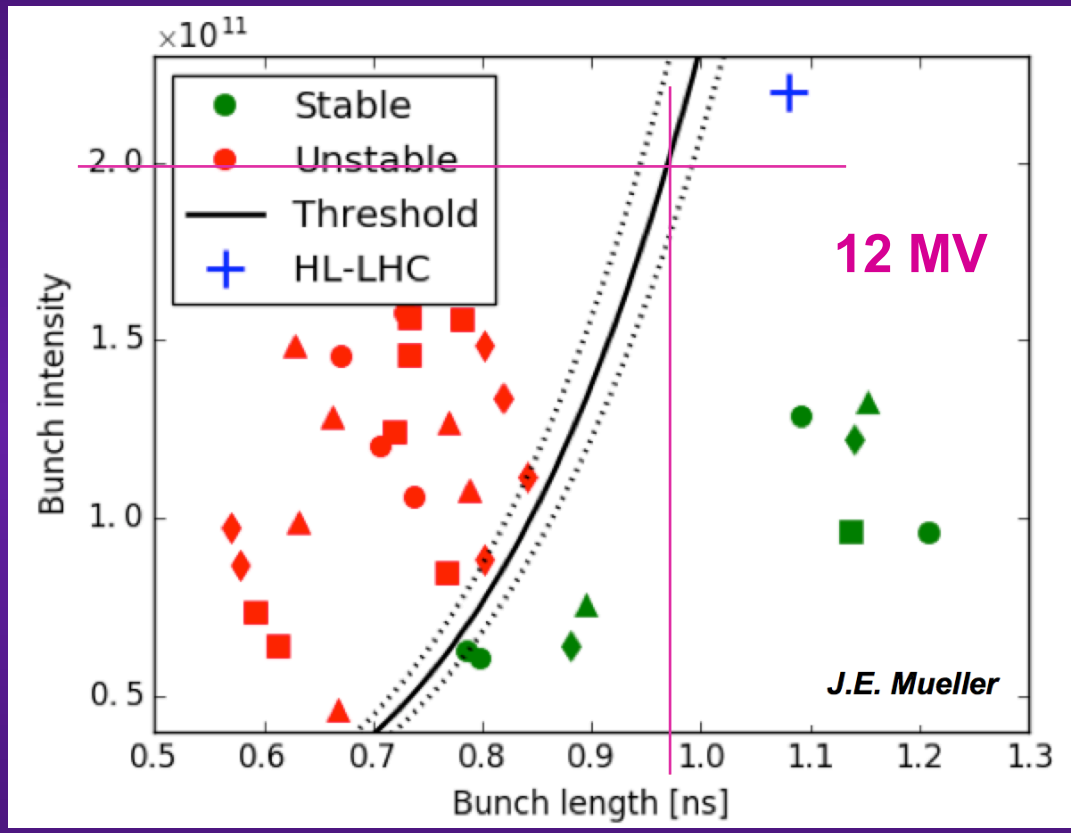
POTENTIAL FROM INJECTORS
=> Beam parameters for some LHC beams at SPS extraction

- High intensity 25 ns beams tend to be very lossy in the SPS
- Trains of 24 bunches with 25 ns spacing => Maybe slightly larger intensities (1.5e11 p/b) accelerated on (2x) slower ramp (done with doublets in 2014, needs set up)
- LHC25 BCMS could be further optimised (large longitudinal emittance in PSB, better preservation of transverse emittance) => Maybe 1.3 um (potential gain of ~ 15% in brightness)
- LHCINDIV could be injected in trains of 4x4 (set up needed in the four PSB rings)
- LHC25 PBC was produced in the PS in 2014 but never taken downstream => Needs set up
- 8b+4e starting from BCMS was never tested

LHC performance: bunch length and RF

- **Bunch length for 2 10^{11} p/b**
  - 12 MV => ~ 0.97 ns
  - 10 MV => ~ 1 ns
  - 16 MV => ~ 0.92 ns
- **Bunch length for 3 10^{11} p/b**
  - 15 MV => ~ 1 ns
  - RF set up for intensities

  from 4 10^{10} p/b to 2.1 10^{11} p/b



=> Preferable to stay with 2 10^{11} p/b. If 3 10^{11} p/b is absolutely required, RF team could shift the range to 6 10^{10} p/b - 3.15 10^{11} p/b and inject fat pilots

LHC performance: transverse emittance

- **Injection to Stable Beams: the global picture (see G. Iadarola, LBOC 27/09/16)**
  - Horizontal emittance larger than vertical by ~ 0.5 μm throughout the cycle
  - Largest increase observed in the energy ramp (~ 0.5 μm independent on the injected emittances)

"Typical" emittances before TS2 (for beam 1 and beam 2)

	Injection	Collision
Horizontal	1.7 um 1.7 um	2.5 um 2.4 um
Vertical	1.5 um 1.4 um	2.0 um 1.7um

G. Iadarola

Average ~ 2.2 μm

LHC performance: bunch intensity

- **Should be OK if**
  - ADT with high intensity settings and nominal gain
  - LOF ~ 500 A
  - Q' ~ 15
  - Coupling well corrected ($|C^-| < 0.001$-0.002)

LHC performance: instrumentation

- **Instrumentation should be OK**
  - **FBCT is not well calibrated for the high intensities (> 2 10 ^{11} p/b)**

LHC performance: summary of possible pile-up increase

	LHC25 BCMS (before Xing angle change)	LHC25 BCMS now	LHC25 BCMS pushed (~ 1.5 μm from SPS)	LHCINDIV (2 10^{11} p/b and 1 μm from SPS)	LHCINDIV (3 10^{11} p/b and 1.5 μm from SPS)
Full crossing angle [μrad]	370	280	280	280	280 / 0
Bunch intensity [10^{11} p/b]	1.1	1.1	1.3	2.0	3.0
Rms Norm. transverse emittance [μm]	2.2	2.2	2.2 / 2.5	2	2.5
4σ bunch length [ns]	1	1	1	1	1
Computed pile-up	**38**	**44** (+ 16 %)	**62 / 56** (+ 63 / 47 %)	**158** (+ 316 %)	**299 / 397** (+ 689 / 945 %)
Observed pile-up (LPCs)	ATLAS: ~ 39 CMS: ~ 42	ATLAS: ~ 43 CMS: ~ 46			