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Global overview of baseline operational parameters

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historical perspective

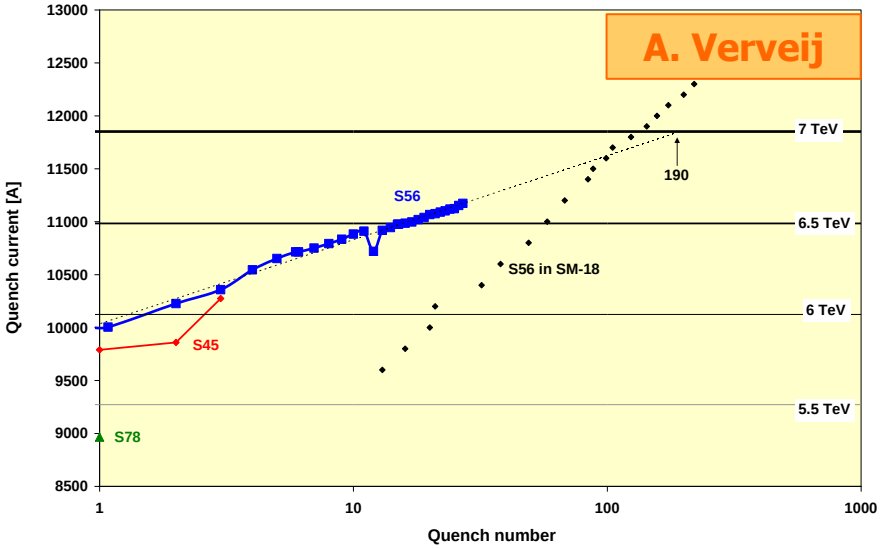
- run 1:
  - 2010: L_{peak} >10^{32} $cm^{-2}s^{-1}$ ➔ 2x10^{32} $cm^{-2}s^{-1}$
  - 2011: produce >1 fb^{-1} ➔ delivered >6 fb^{-1}
  - 2012: produce >20 fb^{-1} ➔ delivered >23 fb^{-1}
- run 2:
  - 2015:
    - restart beam operation at higher energy
    - prepare physics production for 25 ns beams
  - 2016-2017: physics production with 25 ns

outline

- baseline parameters:
  - energy
  - bunch spacing
  - optics, beta* reach
  - mitigation of instabilities
  - beam parameters
- projected peak performance

beam energy

- final answer from hardware commissioning, end of 2014
- recall that experiments need to know early on for Montecarlo simulations
  - avoid late changes
  - better be conservative in 2015
  - push more later
- max 6.5 TeV in 2015
  - expect to need ~100 training quenches
  - would be
    - 1 order of magnitude more for 7 TeV
    - ~15 for 6 TeV
  - results in ~20 min ramp



M. Solfaroli S6, J. Wenninger S1

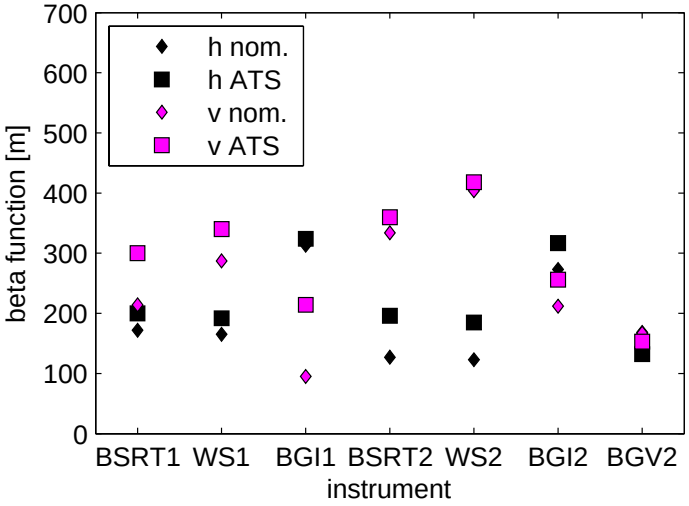
bunch spacing

- 25 ns is what the experiments are designed for
  - 50 ns: pile-up quickly becomes prohibitive
  - IP1/5 can take up to μ=50 pile-up at the start of the fill
    - note: if decide for levelling, level at μ=~30-40
- 25 ns brings along complications:
  - e-cloud and non-negligible scrubbing time
  - more long range collisions
  - larger crossing angle, higher beta*
  - higher total beam current, higher intensity per injection
  - UFOs
    - recall also scaling with energy

B. Gorini S1, G. Iadarola S2

optics

- no flat beams, no combined ramp and squeeze, no LHCb tilt
- baseline : ATS compatible optics
  - IR1/5: new collision optics
    - compatible with full ATS and flat beams
  - IR2: new collision optics and squeeze sequence
  - IR4: new optics (at WS, BSRT, BGI, ADT)
  - IR6: MKD-TCDQ exact 90 deg phase advance
  - IR8: new crossing scheme
    - increased separation
- validation ongoing
  - see next slide
- final decision at Chamonix 2014



S. Fartoukh @ LBOC and LMC

ATS validation item list

task	comment	responsible
tracking studies	dynamic aperture verification, including beam-beam weak-strong simulations and octupoles	ABP
loss maps simulations	spikes due to local collimation inefficiency might appear	collimation team
new IR8 crossing scheme verification	impact of MKI8 misfires	ABT
MKD to IR5 TCT phase advance	TCT directly exposed in case of asynchronous dump: most critical item	collimation team
MKD to TCDQ phase advance	already approved	

mitigation of instabilities

- injection:
  - Q' = 2;
  - LOF = 26 A (K_3L = 12 m^{-3}) for e-cloud?
- flat top: recommendations from collective effects (ongoing work):
  - LOF < 0, best for single beam stability
  - avoid the long-range regime in the squeeze
    - where had instabilities in 2012
    - either by large crossing angle and small emittances
    - or by collide&squeeze from beta*=3m
  - Q'=15
    - measure instability growth rate and octupole threshold vs Q' and ADT gain
  - options in cases of problems:
    - collide&squeeze
    - LOF>0
    - increase beta* and retract collimators
- problems and needs confirmed at intensity ramp-up
- to note: standing request for bunches non-colliding in IP1/5

E. Metral @ LBOC, N. Mounet S2, T. Pieloni S2

collisions and squeeze

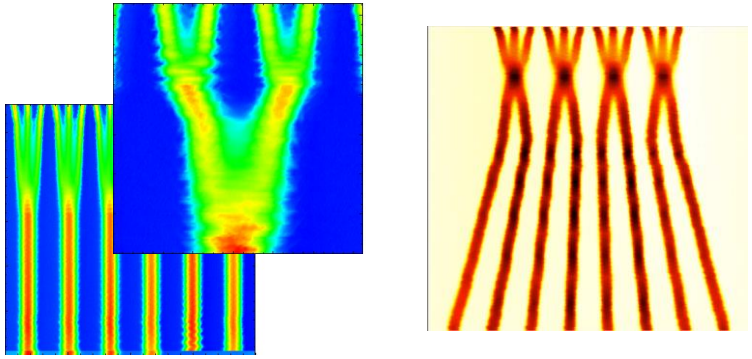
- collide & squeeze
  - positively tested in MDs in 2012
  - need for beam stability will manifest itself at intensity ramp-up
  - full operational feasibility to be demonstrated
    - mostly: orbit control and reproducibility (Δ_{bb}<**1** σ)
  - if not baseline, perform milestones tests and baseline preparation during commissioning
- beta* levelling
  - implies change of beta* during “stable beams”
  - allows control of luminosity and pile-up
  - setup overhead
    - e.g. finer beta-beating corrections
- important to gain first experience for later in run 2 or HL-LHC
  - ATLAS/CMS might need levelling if pushed scenarios work well
  - LHCb volunteers for beta* levelling, supported by other experiments
- identify turning points that can be addressed during commissioning
  - what can be learned and prepared beforehand, to be efficient later?

J. Wenninger S1, A. Gorzawski S1

beam production schemes

	25 ns standard	25 ns BCMS
(PS injections) and splittings	(4+2) x3 x2 x2	(4+4) x3 /2 x2 x2
bunches per PS batch	72	48
max number of injections into SPS	4	6 / 5
bunch population [10^{11} p/b]	1.3	1.3
ε*[μm] at LHC injection	2.4	1.3
number of bunches/ring	2748	2604 / 2508
colliding pairs IP1/5	2736	2592 / 2496

- values at SPS extraction
- recall: 8b4e BCMS
  - 1.8e11 p/b, 1.4 μm



G. Rumolo @ LBOC, H. Bartosik S2

beam parameter evolution at LHC

- emittance
  - evolution in LHC cycle not fully understood in run 1
    - some known causes for blow-up: IBS, 50 Hz noise, instabilities
    - had also additional, unknown ones
    - need the transverse emittance measurements!
  - assumptions:
    - worst case: assume 3.75 μm at start of physics
      - e.g. due to e-cloud, on selected bunches
    - best case: instabilities and blow up under control, e-cloud scrubbed
      - IBS unavoidable, simulated (M. Kuhn) for BCMS (1.3 μm, 1.3×10^{11} ppb, 1.25 ns): +20% from IBS (<0.3 μm)
      - cook up a 30% emittance increase (IBS, some V coupling, unknown sources, …)
- intensity: assume 95% transmission (2012 experience)
- bunch length: 1.25 ns in 12 MV at the flat top
  - reduce it if/when possible
  - 1.2 ns at the flat bottom in 6 MV

M. Kuhn S2, J. Esteban Mueller S2

beta* and half crossing angle

- injection:
  - 11m (10 m in IP2/8), 170 μrad, 2 mm separation (3.5 mm in IP8)
- start with a conservative scenario, push further later
  - commission to smallest beta*, push for physics when questions resolved
- collisions: start-up configuration, the safe bet
  - 2012 collimator settings in mm in IR7
  - 11 sigma beam-beam separation
  - up to 3.75 μm emittance
  - results in: 65 cm and 160 μrad
    - no need for lumi levelling nor collide&squeeze
    - assumes 2012 aperture, to be verified at start of commissioning
- collisions: ultimate configuration
  - 2012 collimator settings in sigma, plus gain from BPM TCTs
  - 10 sigma beam-beam separation
  - up to 2.5 μm emittance
  - results in: 40 cm and 155 μrad
    - requires beam stability, emittances under control, possibly levelling

J. Wenninger S1, R. Bruce S1

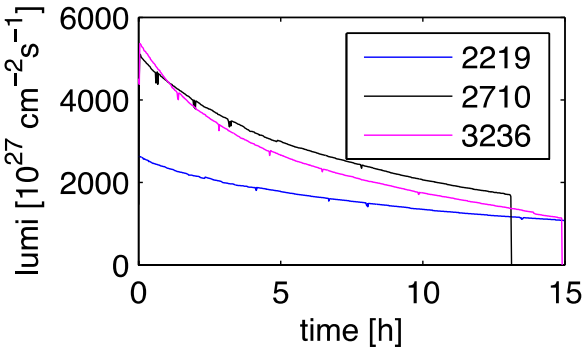
projected performance

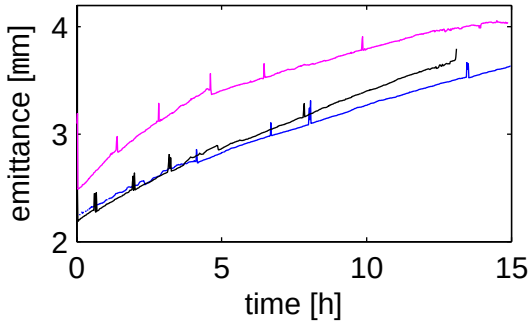
- assume BCMS, 5 injections: 25ns_2508b_2496_2108_2204_240bpi12inj
  - 6 injections: 2592 colliding pairs in IP1/5
  - for nominal scheme: 2736 colliding pairs in IP1/5
- recall the triplet cooling limit at 1.75×10^{34} $cm^{-2}s^{-1}$

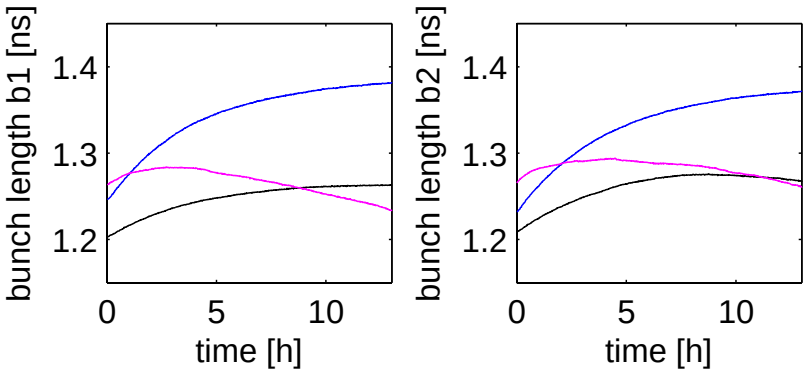
	start-up
beta* [m]	0.65
half crossing angle [μrad] (bb sep. [σ])	160 (11)
ε*[μm] at start of fill (max / best)	3.75 / 1.7
bunch population [10^{11} p/b]	1.2
(total bunches) colliding pairs in IP1/5	(2508) 2496
peak luminosity [10^{34} $cm^{-2}s^{-1}$], IP1/5	**0.7 / 1.3**
max. average pile-up (σ=85 mb)	**22 / 39**
max. stored energy [MJ]	312

run1 comparison

- example: 3 good fills
  - long, clean, high peak luminosity
    - showing curves per bunch pair
  - 2011: fill 2219
  - 2012 early: fill 2710
  - 2012 late: fill 3236
- some interesting points:
  - higher peak luminosity does not always translate to higher integrated luminosity
    - fill 2710 137 pb^{-1} vs 3236 128 pb^{-1} (6 h)
  - increased non-linearities to improve beam stability: paid in higher than linear emittance increase
  - bunch lengthening used to mitigate machine components heating: paid in higher losses
    - missing bunch lengthening or measured bunch shortening







conclusions

- 6.5 TeV, 25 ns BCMS
  - up to 1.2e11 p/b and 1.7 μm in collisions
- ATS compatible new optics, pending validation
- LOF<0, high Q`
- beta*=65/40 cm, 160/155 μrad half crossing
- can get to beyond design ($L_{peak}>10^{34}$ $cm^{-2}s^{-1}$)
  - if emittances under control

- only scrubbing and intensity ramp up will give final answers
- propose two stage approach
  - start with safe bet, no fancy options
  - push further based on acquired knowledge
  - invest early in key studies to gain flexibility and efficiency later

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