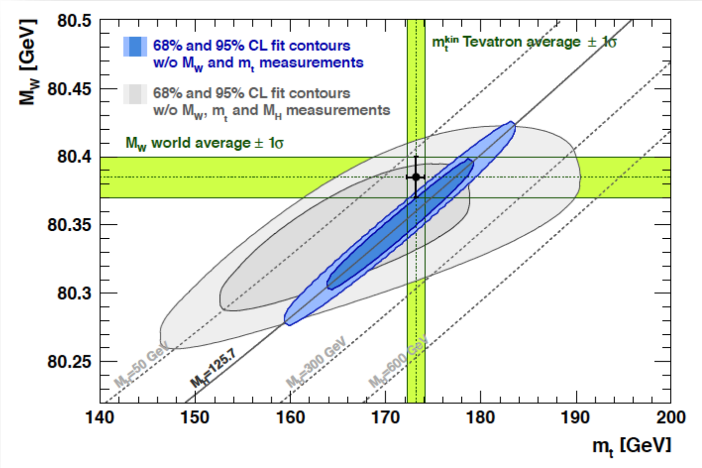
Requirements from experiments

- Recap of desiderata wrt general running conditions
  - Pileup, 25ns vs 50ns …
- Specific aspects related to optics
  - Smaller beta at injection, flat beams …
  - Special requests

BASELINE P-P RUNNING CONDITIONS

Physics after LS1: standard model and beyond

- Outstanding achievements of RUN 1 define a rich set of physics goals
  - New challenges



- Study of the "Higgs-like boson at 126 GeV"
  - Branching ratios, couplings, mass, spin/CP, …
  - Requires to cover a large range of modes:
    - H-> γγ, ZZ, WW, ττ
    - WH, ZH -> lνbb, llbb, ννbb

- Search for new physics at higher mass scale
  - Including search for new objects like Z'

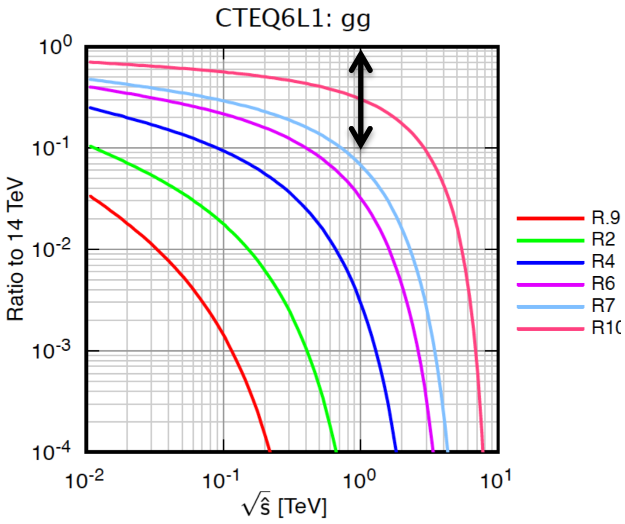
Savas Dimopoulos, CERN Colloquium, Sep 20, 2012

⇒ We need a lot of integrated luminosity useful for physics analysis

<u>Running conditions matter!</u>

Effects of change of energy

- The positive:
  - At the mass scale of 1 TeV the cross section for production of new particles is ~10 times higher at 13 TeV relative to 8 TeV



- The challenge:
  - Minimum-bias cross-section and the associated pileup increases by O(15%)
  - Expected overall multiplicity increases O(10%) at |η|<2.4, O(20%) in LHCb

⇒ At equivalent number of bunches and luminosity, events get O(25%) more busy in ATLAS/CMS and up to O(40%) in LHCb

Naturally more challenging reconstruction

Maximizing physics reach (stating the obvious….)

- Peak instantaneous luminosity isn't all
  - Should not aim for higher values at the expense of stability
- Not even delivered integrated luminosity
  - Physics selection efficiency and background rejection depend on experiment resolution as a function of the physics and the pileup
  - Same delivered luminosity could result in different usable luminosity at different running conditions
- Effective (i.e. usable for physics) luminosity is a key parameter
- Effective integrated luminosity is the ultimate goal
  - Can be different for different analyses depending on type of final state and complexity
  - Challenge is to find the proper instantaneous luminosity and trigger as the best compromise for all analyses
  - Whichever mode of operation we chose, it has to be the one which maximizes it

Effects of Pileup and bunch spacing

- **Obvious**: 50ns gives twice the in-time pileup for the same instantaneous luminosity
  - e.g. for 1e34 $cm^{-2}s^{-1}$ @14TeV: μ=27 at 25ns, μ=54 at 50ns
- **Detector** limitations (e.g. event size and bandwidth limitations in inner detectors readout)
  - Start to appear at 10^{34} $cm^{-2}s^{-1}$ and 50ns (disregarding energy-related effects)
- **Trigger** efficiency:
  - Higher pileup implies higher fake rates ⇒ difficult to keep current thresholds
- **DAQ/Trigger & Computing** resource requirements:
  - 50ns would require about twice the CPU capabilities of the high-level trigger farm, and a very significant increase of offline CPU and disk resources in comparison to 25ns, for the same amount of integrated luminosity
- **Reconstruction & Analysis** efficiency:
  - Effects become dramatic above 10^{34} $cm^{-2}s^{-1}$ at 50ns
  - At 50ns fundamental changes to reconstruction and analyses would be required
    - e.g. raising track reconstruction p_T cut
- For more details see Emilio's presentation in Evian or Richard's one in the ICFA beam-beam workshop

Recap of 25ns vs 50ns

- Running at 25ns is considered of paramount importance by all experiments to maximize ultimate physics reach
  - No leveling would be needed in IP1&5

$$\Downarrow$$

- 50ns operations should be kept to the absolute minimum required for machine setup and to establish readiness for 25ns
  - Leveling would be needed in IP1&5 but acceptable pileup still to be defined
- We do not request any optimization at 50ns, and would not like to spend any time on it
  - Except if needed to speedup 25ns commissioning
- We accept that running at 25ns could result in lower delivered luminosity in 2015 compared to a 50ns scenario
  - Longer commissioning, need for longer scrubbing period
- We feel that it is not the moment to discuss criteria that would suggest to fallback to the 50ns scheme

Bunch Length, Luminous Region, Crossing angles etc.

- The critical parameter for experiments is the luminous region rather than the bunch length
  - Longer bunches will be partially compensated by larger crossing angles
- A short luminous region gives more 'merged vertices'
  - i.e. more difficult to reconstruct the primary event vertex
  - **In general it is safe to say that the "pileup density" is the key physics parameter, even more than the absolute peak pileup value**
- A longer luminous region would benefit ATLAS and CMS tracking and vertex reconstruction at high pile up but:
  - For excessive values it will reduce track reconstruction efficiency
  - CMS: it would also worsen the mass resolution in the H->gg analysis
    - (benefits vs drawbacks under study – will also depend on the pile up conditions)
  - LHCb: despite VELO being ~1m, already some loss of "long-lived" B's….
    - Contributes to 1/3 of the systematics in lifetime measurements…not an option to make the luminous region much longer …!
    - <u>Could even be beneficial to move current luminous region upstream a bit</u>

Luminous Region, Bunch Length, Crossing angles etc.

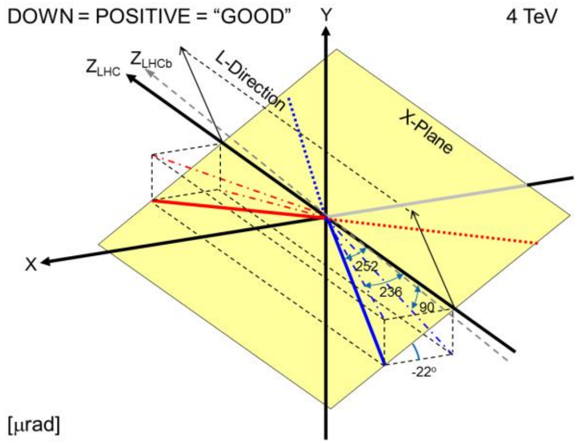
- Ultimately, we should find a good compromise between 'longish beamspot' and 'large geometric factor' (crossing angle reduction of luminosity)
  - From a physics perspective, current conditions (~45-50mm) are OK for μ~30-35,
    - A 10% increase is probably tolerable (CMS) or even desirable (ATLAS)
- Even more importantly:
  - Luminous region length should be kept as stable as possible from fill to fill over the full running period
  - Value should be known in advance for correct generation of MC samples
- Increased crossing angles (for 25ns) will have no other effect on experiment

Luminous Region, Bunch Length, Crossing angles etc.

- Luminous region transverse size
  - In general:
    - As constant as possible across all the bunch crossings,
    - As small as possible in order to maximize the luminosity (assuming we are not in a pile-up regime that would force us to level the luminosity)
  - LHCb
    - Primary vertex reconstruction benefits from small transverse luminous region
      - Cut at 300 mm
      - Luminous region about the same size (S~70 mm) with β*= 10m and 13 TeV as with 3m and 8TeV…
    - Maintain luminous region small!
      - At least in one plane e.g. if going for β* leveling

Levelling and crossing in LHCb

- It is important to keep operating with vertical external crossing angle to maintain tilted crossing scheme
  - Same boost vector amplitude in both polarities
  - Resulting angle = 340 mrad



- Will require regular polarity swaps as now for reduction of systematic error in precision measurements
  - Every ~100 pb^{-1} collected

- Leveling to at 4-6x10^{32} $cm^{-2}s^{-1}$ will be needed
  - IP8 peak luminosity with β*= 10m and tilted crossing: 9 x10^{32} $cm^{-2}s^{-1}$ ⇒ leveling lifetime would be ~8.5h to exhaustion as compared to ~14h now assuming same luminosity lifetime of ~10h
  - Operating at β*<5m would be beneficial to increase leveling lifetime to ~12h

Thoughts on β* leveling

- Several advantages from the experiments perspective:
  - Stable luminous region longitudinally (except for h-glass effect) and limited variation transversally
  - More immune to orbit variations
  - No risk of accidental head-on collisions
- One major requirement
  - Perform leveling steps in stable beams despite collimator movement
    - Otherwise ~10-15 minutes downtime at each ste
  - Possible to have tolerance on collimator settings (limited movement) vertically in IP5 and IP8 during beta-squeeze (?)

- We support it as a baseline mechanism for future leveling needs
- We would consider commissioning it in 2015 for LHCb as a test case, if it would not have a significant impact on physics time
  - How much time do you estimate to be needed?
  - What sharing between MD and Physics time?

Running conditions for ALICE in p-p periods

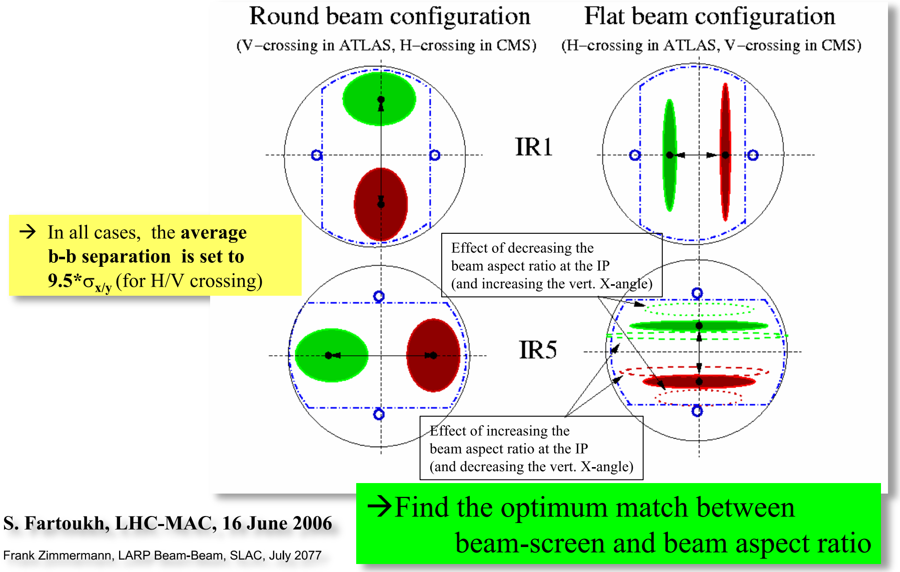
Year	System	E [TeV]	Lumi [$cm^{-2}s^{-1}$]	Rate [kHz]	Level	Weeks	Trigger
2015	p-p	13	$1\text{-}2*10^{29}$	10-20	YES	24	MB
2016	p-p	13	$0.5\text{-}1*10^{31}$	500	YES	24	RARE
2017	p-p	13	$0.5\text{-}1*10^{31}$	500	YES	24	RARE
2018	Long Shutdown 2						

- For 2015 we need 5 orders of magnitude luminosity reduction in IP2
- Beware: no filling scheme tricks available at 25ns
  - About all bunches collide in ALICE (except effect of abort gap)
- Should aim to defocus IP2 as much as possible
  - Is β^* close to 20m a possible choice?
- Still a separation of more than 5σ seems to be needed
  - What is the larger value at which we could run stably?

Experiments view on optics options

- Injecting at lower β* (5-7 m) is generally agreed to be OK
  - Special optics will be required anyway for VdM scan (see later)
  - B*=5m is still considered a valid option for LHCf run (see later)

- Very preliminary thinking about flat beam have not indicated an evident showstopper
  - Final decision will depend on accurate study based on actual value of $\beta_{x/}\beta_y$ ratio
    - Should we assume 2-3?
  - In any case a decision should be taken as early as possible to take it into account in MC production



Quick view on Heavy Ion Operations after LS1

- ALICE requests:

Year	System	E [TeV]	Lumi [$cm^{-2}s^{-1}$]	Rate [kHz]	Level	Weeks	Trigger
2015	Pb-Pb	5.1	10^{27}	8	YES	4	
2016	Pb-Pb	5.1	10^{27}	8	YES	4	
2017	p-Pb	8.2(?)	0.5-1*10^{28}	10-20	YES	2	MB
	p-Pb	8.2(?)	10^{29}	200	YES	2	RARE
2018	Long Shutdown 2						

- Beware that luminosity leveling at least in ALICE will be required

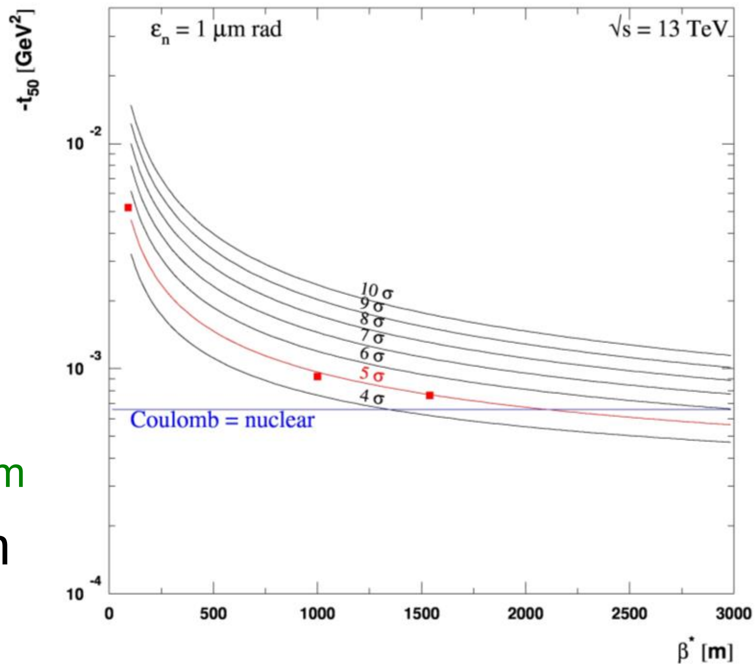
SPECIAL RUNS / SPECIAL OPTICS

Overview of special runs in 2015

- 2015 p-p period will essentially be dedicated to collect statistics at 13 TeV
  - Ideal scenario would be to collect comparable statistics w.r.t. 2012
- Few exceptions are considered
  - Run at low pileup and injection optics for LHCf
  - Run at high beta for TOTEM/ALFA
  - VdM scan(s)

High β* runs

- Reaching Coulomb-Nuclear-Interference region requires $\beta^* \geq 2500$ m
  - Needs additional return cables on quadrupole magnets
  - At the moment it is assumed that they will only be installed at the end of 2015
  - Very high β* runs are only requested after the installation
    - There is no use case for repeating β*~1km



- Both ALFA and TOTEM are interested in a run at β*=90m for diffractive physics
- TOTEM requests:
  - Strategy: small bunches (7 x 10^{10}) → low pileup (μ ~ 5%)
  - Develop enhanced setup with crossing-angle → fill with 1000 bunches
    → L ~ 1 pb^{-1} / 24h
    → Collect 400 M events of central diffraction in ~2 weeks

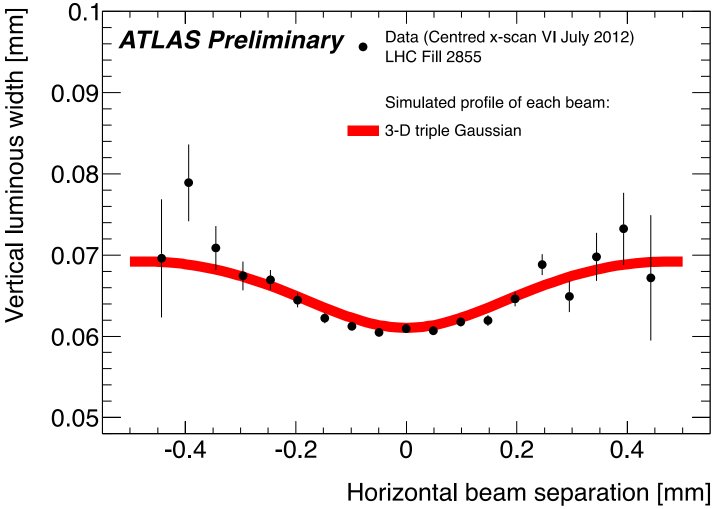
.

LHCf run

- Ideal beam conditions:
  - L~6x10^{28} cm^{-2}s^{-1}
  - 40 bunches with some non-colliding (no trains)
  - β^* = 7-11 m would be ideal, 5 m may still be acceptable
    - One option to reduce the overhead would be to qualify injection optics for stable beams
      - What about combined ramp&squeeze thoughts?
  - Ideally take data at 7 TeV and 3.5 TeV to test $\sqrt{s}$ scaling
- Constraints:
  - The run must be taken before 500 pb^{-1} of delivered luminosity in IP1
    - Afterwards will suffer from radiation damage even it is kept in sage position
  - Should agree asap on running conditions and commission them

VdM scans

- 2012 campaign showed that the non-linear x-y beam correlations are a dominant source of uncertainty in the luminosity calibration
  - Non-factorization @ IP 1, 5,8 can be studied quantitatively only by fitting the evolution of the beamspot position & luminous width during scans
    - Possible only if the vertex resolution does not dominate the luminous width
  - The problem:
    - σ_b scales like $\sqrt{(\beta^*/E_b)} \Rightarrow$ naturally smaller beamspot in 2015
    - The vertex resolution won't get any better!



- Hence VdM scans cannot be performed at injection optics
  - Dedicated optics needs to be setup for the ultimate scan
  - Ideally: $\beta^* \sim 15$ m, $\varepsilon \sim 3$ μm, $\theta_{Xing} = 0$ ($\beta_x = \beta_y$, no flat beams!)
- Scheduling needs to take into account the opposite needs of having an early calibration for cross section measurements and the need to minimize commissioning overhead at the beginning of the run
  - LPCs need your inputs on this…
  - An early scan with injection optics could be a useful option

Conclusions: standard conditions

- All experiments consider running at 25ns of paramount importance to maximize the physics reach
  - Even if it could imply less integrated luminosity in 2015
- Pileup "density" should be minimized
  - ~10% longer luminous region may be beneficial
- For what concerns specifically the beam optics:
  - Injecting at smaller β* is supported
  - Flat beams are not excluded but need more careful investigation based on actual β_x/β_y ratio
  - Running LHCb at β*<5m would be very important for leveling lifetime
  - De-focusing ALICE as much as possible should be investigated to help reaching 10^5 reduction of luminosity w.r.t. P1/5
- The experiments support β* leveling as the long-term mechanism
  - Implementing it for LHCb in 2015 could provide a useful test case: needs to be discussed in view of requested commissioning effort
- In any case it will be important to define luminous region characteristics a.s.a.p for MC production
- Runs with Pb-Pb will be scheduled in both 2105 and 2016.
  - Conditions for heavy ions runs afterwards are being discussed
    - Most likely p-Pb but energy is still unclear

Conclusions: special runs/special optics

- LHCf will need to run very early on (before 500 pb^{-1} delivered to IP1)
  - They need β* not smaller than 5m and to take data at different energies
  - Can we use injection optics?
- VdM scans will need an ad-hoc optics with round beams, large β* (~15 m), large emittance (~3 μm), and no crossing angle
  - Luminosity calibration would be needed early in the year: we need to evaluate needed commissioning time
- High Beta runs at 90m (before quadrupole cables installation) and at ~2.5km (afterwards) will be requested after LS1
  - Intermediate values (e.g. repeating 1km) are not interesting