

### Plans and physics outlook for non-high luminosity experiments until and after LS3 - LHCb, ALICE (pp), Forward Physics -

#### R. Jacobsson

#### Outline

- Brief physics motivations
- Upgrades, schedules and impacts
- Data taking conditions, special requests, and luminosity





### A successful recipe from Run 1

#### LHC dough

25 fb<sup>-1</sup> of high-lumi proton chunks
3 fb<sup>-1</sup> of proton powder with flavour
0.15 nb<sup>-1</sup> of lead-lead
30 nb<sup>-1</sup> of proton-lead
a pinch of high-beta proton mix



Pre-heat each ingredient before mixing to about 10<sup>16</sup> °C. Start by adding a small quantity of proton mix together with a VDM scan to avoid sticking. Add the whole quantity of high-lumi protons in chunks, crush energetically, the harder the better. Make sure to crush also small pieces together for improved flavour. Interleave with short pauses to clean off the tools to avoid too much sticking. The pauses may also be an opportunity to explore the taste and some little variation on the theme. Special high-beta proton mixture is a very healthy vitamin supplement that should not be neglected. This is the difficult part though to avoid losing the consistency by waiting to long between the high-lumi proton chunks. Top off by adding ions while stirring carefully. A variation on the them can be obtained by different combinations of purely ions or mixtures with proton and ions. It's always tempting to add a lot, be careful. Cook on the grid on slow burn for a several months and the result is irrefutable. Preferably, enjoy with a bottle of "Cuvée *Higgs*"



### In praise of diversity - complementarity

 Update of the European Strategy for Particle Physics adopted 30 May 2013 in a special session of CERN Council at Brussels

c) The discovery of the Higgs boson is the start of a major programme of work to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. The LHC is in a unique position to pursue this programme. *Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma* 

Central question: Not if, but how to accommodate this in the most efficient way!

### Opening Scenario for 2015 and Beyond



• While we had unitarity bounds for the Higgs, no such indication on the next scale....

• Precision measurements likely to have the largest discovery potential for BSM

- Higgs (EW) precision physics (mainly ATLAS/CMS)
- Flavour precision physics (mainly LHCb, and soon joined by Belle II)
- Continued direct searches for new particles (mainly ATLAS/CMS)







### In Praise of (Flavour) Precision Measurements

LHCb focus on measuring *indirect* effects of New Physics in CP violation and rare decays → Virtual contributions in box and penguin Feynmann diagrams

- Virtual effects allow probing energies higher than the E<sub>cms</sub> of the LHC
- Largely model independent, assuming flavour couplings of course!
- → Complementary to the direct searches by Atlas and CMS
- For instance  $B_d \to K^* \mu^+ \mu^-$ 
  - System described by  $q^2 = M^2(ll)$  and three angles





- Construct well predicted observables e.g.  $A_{FB}(q^2) = \frac{\Gamma(\cos \theta_{Bl} + > 0) \Gamma(\cos \theta_{Bl} + < 0)}{\Gamma(\cos \theta_{Bl} + > 0) + \Gamma(\cos \theta_{Bl} + < 0)}$ ,  $A_{FB}(q^2) = 0$
- Contribution from New Physics  $\delta C^{NP} \propto \frac{\sin \theta_i \sin \theta_j}{\Lambda_{NP}^2}$ ,  $\Lambda_{NP} \sim$  mass of new particles
- Statistical+systematic(+theory) error must be smaller than  $\delta C^{NP}$  !

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

<u>6</u>



### In Praise of (Flavour) Precision Measurements

Example:  $B_d \to K^* \mu^+ \mu^- : A_{FB}(q^2)$ 

Secret is to push down statistical errors and manage systematics!

Current measurement:

Expected future sensitivity on  $q_0^2$ :



# CERN

### In Praise of (Flavour) Precision Measurements

- Assuming the ultimate sensitivities
  - Lower bound on couplings ←→ upper bound on new physics





Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

<u>8</u>



### LHCb Upgrade Objective

#### LHC is a charm and beauty factory!

- Beauty and charm flavour sector contains a very large repertoire of decays and topologies
  - Aim at exploring all possible observables sensitive to New Physics
- In addition electroweak physics, Lepton Flavour Violation, QCD, direct search for New Particles in decays, etc
- Upgrade aim to reach experimental sensitivities which are comparable or better than theoretical uncertainties
  - Precision of many measurements not expected to be limited by systematics
  - Need 10-fold our statistics after 2017
    - ➔ Increase efficiency of hadronic channels by factor >2
    - → Increase operating instantaneous luminosity
    - $\rightarrow$  Also improve output bandwidth and lower p<sub>T</sub> to increase sensitivity for charm



### LHCb Upgrade Strategy

#### <u>Baseline</u>

- 1. Remove completely First Level Trigger → Full detector readout at 40 MHz up to CPU farm
- 2. Implement a fast high-level software trigger to select events based on their full topology
- 3. Improve sub-detectors ("consequence")
  - Geometry and granularity to allow fast full reconstruction
  - Allow increase instantaneous luminosity up to 2 x 10<sup>33</sup> cm<sup>-2</sup>s<sup>-1</sup>
  - Replacement due to radiation longevity (up to >50 fb<sup>-1</sup>)
- 4. Final output bandwidth at ~20 kHz
- Ultimate trigger flexibility to accommodate to changing physics scene!



#### Consequences:

- → 40 MHz readout requires replacing all FE and BE electronics
- → Detector and readout upgrade must be done in one Technical Shutdown to be of benefit

### Sub-detector Upgrades

Main detector replacement concern the tracking system



Removal of M1, SPD and PreShower

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

(replace HPDs + R/O, remove R1 aerogel)





### LHCb Upgrade Schedule

#### Overall generic milestones (baseline):

- in 2018/19: installation (18 months according to planning!)
- 2016-17: Quality control & acceptance tests
- 2014-16: Tendering & serial production
- 2013/2014: TDRs & prototype validation
- Q2/Q3 2013: Technical reviews & choice of technologies
- ✓ 2012/2013: Continue R&D towards technical choices
- ✓ 2012: "Framework TDR" submitted & endorsed
- ✓ June 2011: Lol submitted & encouraged to proceed to TDRs

- 18 months installation time during LS2 is mandatory
- A later start of LS2 at end-2018 would be advantageous for LHCb
- A LS1.5 is of limited use, no impact on the 18 months LS2
- Further delay of the start of LS2 beyond 2018 would be disfavoured

### LHCb Upgrade Installation Plan

#### LHCb plans installation of the upgrade in an LS2 of 18 months

• No coffee breaks!



Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

### A Possible Luminosity Projection

Assumed instantaneous luminosities levelled with lifetime >10h



• Ideally collect 8-10 fb<sup>-1</sup> before LS2

- Attractive to extend Run 2
- → Note, however that the LHCb expected system lifetime (trackers) at 10 fb<sup>-1</sup>
- $\rightarrow$  Aiming for up to >50 fb-1 by 2028 !
  - $\rightarrow$  Note the luminosity ramp-up after the upgrade.

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

### Upgrade Physics Prospects with 50 fb<sup>-1</sup>

- Expected precision based on statistics uncertainties
  - Precision not expected to be limited by systematics in many analyses

Type	Observable	Current	LHCb	Upgrade	Theory			
		precision	2018	$(50{\rm fb}^{-1})$	uncertainty			
$B_s^0$ mixing	$2\beta_s \ (B^0_s \to J/\psi \ \phi)$	0.10 [9]	0.025	0.008	$\sim 0.003$			
	$2\beta_s \ (B^0_s \to J/\psi \ f_0(980))$	0.17 [10]	0.045	$\sim 0.01$				
	$A_{ m fs}(B^0_s)$	$6.4 \times 10^{-3} \ [18]$	$0.03 \times 10^{-3}$					
Gluonic	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\phi)$	_	0.03	0.02				
penguin	$2\beta_s^{\text{eff}}(B_s^0 \to K^{*0} \bar{K}^{*0})$	_	0.13	0.02	< 0.02			
	$2\beta^{\text{eff}}(B^0 \to \phi K^0_S)$	0.17 [18]	0.30	0.05	0.02			
Right-handed	$2\beta_s^{\text{eff}}(B_s^0 \to \phi\gamma)$	_	0.09	0.02	< 0.01			
currents	$ au^{\mathrm{eff}}(B^0_s \to \phi \gamma) / \tau_{B^0_s}$	_	1%	0.2%				
Electroweak	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6 \text{GeV}^2/c^4)$	0.08[14]	0.025	0.008	0.02			
penguin	$s_0 A_{\rm FB}(B^0 \to K^{*0} \mu^+ \mu^-)$	25% [14]	6~%	6 % <b>2 %</b>				
	$A_{\rm I}(K\mu^+\mu^-; 1 < q^2 < 6 {\rm GeV^2/c^4})$	$0.25 \ [15]$	0.08	0.025	$\sim 0.02$			
	$\mathcal{B}(B^+ \to \pi^+ \mu^+ \mu^-) / \mathcal{B}(B^+ \to K^+ \mu^+ \mu^-)$	25% [16]	8%	2.5%	$\sim 10 \%$			
Higgs	${\cal B}(B^0_s  o \mu^+ \mu^-)$	$1.5 \times 10^{-9}$ [2]	$0.5  imes 10^{-9}$	$0.15 \times 10^{-9}$	$0.3 \times 10^{-9}$			
penguin	$\mathcal{B}(B^0 \to \mu^+ \mu^-) / \mathcal{B}(B^0_s \to \mu^+ \mu^-)$	_	$\sim 100 \%$	$\sim 35\%$	$\sim 5 \%$			
Unitarity	$\gamma \ (B \to D^{(*)}K^{(*)})$	$\sim 10 - 12^{\circ} [19, 20]$	$4^{\circ}$	0.9°	negligible			
$\operatorname{triangle}$	$\gamma \ (B_s^0 \to D_s K)$	_	negligible					
angles	$\beta \ (B^0 \to J/\psi \ K^0_S)$	$0.8^{\circ}$ [18]	$0.6^{\circ}$	$0.2^{\circ}$	negligible			
Charm	$A_{\Gamma}$	$2.3 \times 10^{-3} [18]$	$0.40 \times 10^{-3}$	$0.07 \times 10^{-3}$	-			
$C\!P$ violation	$\Delta A_{CP}$	$2.1 \times 10^{-3} [5]$	-					

→ But strength is the full software trigger to tune to any signature that may be popular in 2020!

• Running during HL-LHC aiming ultimately for >50 fb<sup>-1</sup>

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



• Ion programme to be covered in Session 6

→ Here only outlining upgrade schedule and needs for proton-proton data taking

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013

<u>16</u>



### ALICE Run 2

- PbPb ~1 nb<sup>-1</sup> or more at  $E_{cms}$  (nucleon-nucleon) ~ 5.1 TeV
- Run 2 goals: 5-10 times larger statistics with improved detector
  - Improve precision of current measurements and explore new observables
  - Extend Run 1 measurements to ~5.1 TeV (energy dependence)
  - → Measurements will remain statistics limited
- No special request for intermediate energy pp reference sample in Run 2
- pp data taking at 13 TeV throughout the year for physics normalization
  - For high-p<sub>T</sub> measurements/jets: the current ALICE baseline is to use pp data at 7-8-13 TeV and scale with pQCD

Ŵ	Alice (CMS,ATLAS) – Run 2								
Year	System	Luminosity							
2015	pp(13 TeV) – min bias (24 weeks)	1-10 x 10 <sup>29</sup> cm <sup>-2</sup> s <sup>-1</sup> : (10-100 kHz)							
	Pb Pb (5.1 TeV) – 4 weeks	10 <sup>27</sup> cm <sup>-2</sup> s <sup>-1</sup> : >0.5nb <sup>-1</sup>							
2016	pp(13 TeV) – rare triggers (24 weeks)	5-10 x 10 <sup>30</sup> cm <sup>-2</sup> s <sup>-1</sup> : (~500 kHz)							
	Pb Pb (5.1 TeV) – 4 weeks	10 <sup>27</sup> cm <sup>-2</sup> s <sup>-1</sup> : >0.5nb <sup>-1</sup>							
2017	pp(13 TeV) – rare triggers (24 weeks)	5-10 x 10 <sup>30</sup> cm <sup>-2</sup> s <sup>-1</sup> : (~500 kHz)							
	p Pb – min bias (2 weeks)	0.5-1 x 10 <sup>28</sup> cm <sup>-2</sup> s <sup>-1</sup>							
	p Pb – rare triggers (2 weeks)	1 x 10 <sup>29</sup> cm <sup>-2</sup> s <sup>-1</sup>							
2018	??								

- All instantaneous luminosities assumed to be levelled
- ATLAS/CMS desiderata in Run 2 ( as well as in 3, 4):
  - Reference sample at 5.1 TeV each year to follow with the annual integration of PbPb
  - → Any luminosity e.g. <10<sup>33</sup>> : Commissioning + "1 day for 30 pb<sup>-1</sup>"
  - Alice would benefit from whatever is delivered
- Energy of pPb: 8.2 TeV or 5.1 TeV (eq. PbPb at 13 TeV) to be discussed
  - If pp reference sample is needed for pPb and/or pPb needed as reference sample for PbPb may be interesting to run all samples at same E<sub>cms</sub>(nucleon-nucleon)
  - Argument for  $E_{max}$ : ultra-peripheral collisions (unique  $\gamma p$  collider)  $\rightarrow$  Measure the total  $\sigma_{\gamma p}$  at  $E_{max}$



Focus on studying the characteristics of the QGP using rare probes

- Jets: characterization of energy loss mechanism as probes of density
   pp reference data for jet scale calibration close to ion run
- <u>Heavy flavour</u>: characterization of mass dependence of energy loss, in-medium thermalization and hadronization as probes for medium transport properties
  - → pp reference data for nuclear modification factor
  - → Also factorize out effects in cold nuclear matter from pPb data
- Quarkonium: dissociation pattern and regeneration as probes of deconfinement and temperature
  - → pp reference data for nuclear modification factor
  - → Also factorize out effects in cold nuclear matter from pPb data
- Low-mass di-leptons: thermal radiation to map temperature during system evolution
  - low magnetic field to increase reach to lower pT
  - pp reference data needed to check detector performance at low field
- → All require high statistics and upgraded detectors

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



R. Jacobsson

19

 $R_{AA}(p_T) = \frac{1}{\langle N_{coll} \rangle} \frac{dN_{AA}}{dN_{nn}}$ 



### ALICE Upgrade Strategy

- High precision measurements of rare probes in PbPb collisions at low p<sub>T</sub>,
   → No trigger and high statistic
  - Upgrade the ALICE readout systems and online systems
    - Read out all Pb-Pb interactions at a maximum rate of 50kHz (i.e. L = 6x10<sup>27</sup> cm<sup>-1</sup>s<sup>-1</sup>), with a
      minimum bias trigger
      - → Allows reading out pp interactions at 200 kHz
    - Perform online data reduction based on reconstruction of clusters and tracks at 50 kHz
      - Currently 500 Hz
  - Improve vertexing and tracking at low p<sub>T</sub>
    - New Inner Tracker System
  - Upgrade of TPC from using MWPC to GEM chambers
  - → Gain a factor **100** in statistics over Run 1 + Run 2:
    - Pb-Pb recorded luminosity  $\geq 10 \text{ nb}^{-1} \Rightarrow 8 \times 10^{10} \text{ events}$



### ALICE Detector Upgrade

#### • Úpgrade plans

- New, high-resolution, low-material Inner Tracker System
  - Closer to IP (39mm  $\rightarrow$  22mm), less material and reduced pixel size
- Upgrade of TPC
  - Replacement of MWPCs with GEMs and new pipelined readout electronics
- Upgrade of readout electronics of TRD, TOF, Muon Spectrometer, ZDC
- Upgrade of the forward trigger detectors
- New 5-plane silicon telescope in front of the hadron absorber



 Lol and ITS CDR endorsed by LHCC in Sep 2012 MFT as addendum to LOI endorsed by LHCC in Sep 2013

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013





### ALICE Upgrade Installation Plan

#### • ALICE plans installation of the upgrade in an LS2 of 18 months

Title		17	2018								2019									
	11	12	01	02	03	04	05	06	07	08	09	10	11	12	01	02	03	04	05	06
Project Schedule for Installation Scenario 1		-																	-	/
Remove shielding, disconnect Miniframe, open L3 doors																				
Xmas pause		ļ																		
Bring Miniframe to surface			0																	
Remove ITS, beampipe and TPC																				
TPC upgrade, services and infrastructure modifications								_			_									
Re-install TPC and new beampipe (incl. bakeout)																				
Re-install Miniframe and reconnect TPC services																	)			
Install new ITS																				
Re-install compensator magnet, RB24 beampipe																		l		
Close L3 doors, re-install shielding																				

- TPC on the surface: 10 months
- Inner Tracker System installation and commissioning: 3 months

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



<u>22</u>

### Amount of pp Reference Data for HL-HI-LHC

#### p reference at 5.1TeV (= 13 TeV) required

- HF: charm and beuty cross sections can be scaled in E<sub>cms</sub> with pQCD, but large scaling uncertainty for charm at low p<sub>T</sub> (>50%)
- Quarkonia: no robust theoretical guidance for interpolating
- Jets: jet energy scale calibration depends strongly on E<sub>cms</sub>
- → Statistical error on pp reference should be negligible wrt PbPb



#### ● ALICE low-p<sub>T</sub>:

- $L_{int}$  (PbPb) = 10 nb<sup>-1</sup>: pp (@5.1/5.5 Tev) recorded luminosity  $\geq$  6 pb<sup>-1</sup>  $\Rightarrow$  4 x 10<sup>11</sup> events  $\Rightarrow$  2x10<sup>6</sup> s (2 month) at ~200 kHz (L levelled at 6x10<sup>30</sup>)
- → Possibly also 10<sup>9</sup> pp events at lower field for the PbPb data at lower field

#### • ATLAS/CMS (match PbPb yields at high $p_T$ ):

Equivalent luminosity needs scaling with number of partons colliding in PbPb (N<sub>coll</sub>)
 → For S>>B: Signif = 1/sqrt(S) → S<sub>PbPb</sub>~ N<sub>coll</sub> S<sub>pp</sub> (N<sub>coll</sub> ~ 1500 in central PbPb at LHC)
 → 10 nb<sup>-1</sup> PbPb: ~ 300 pb<sup>-1</sup> pp

#### → pp reference data run duration governed by Alice (end of Run 3)

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



### ALICE (ATLAS/CMS) - Run 3+4

#### Baseline schedule:

Year	System	Luminosity
2019	Pb Pb (5.1 <sup>*</sup> TeV) – 4 weeks	2.85 nb <sup>-1</sup>
2020	Pb Pb (5.1 TeV) – 4 weeks	2.85 nb <sup>-1</sup> , lower B field (0.2T)
2021	pp (5.1 TeV) – 8 weeks	ALICE: 6 pb <sup>-1</sup> (4 x 10 <sup>11</sup> events)
2022	LS3	
2023	LS3	
2024	Pb Pb (5.1 TeV) – 4 weeks	2.85 nb <sup>-1</sup>
2025	½ PbPb + ½ pPb	PbPb:1.42 nb <sup>-1</sup> , pPb:50 nb <sup>-1</sup>
2026	Pb Pb (5.1 TeV) – 4 weeks	2.85 nb <sup>-1</sup>

\*) 5.1 or 5.5 TeV equivalent to 13 or 14 TeV

- Question of long ion run before LS3, pp reference data is probably not ideal!
- ATLAS/CMS request ideally short intermediate energy pp reference data annually
   Few days of data taking
- pp (13 TeV) data taking necessary of ~1-2 months before each ion period to commission and calibrate detector (shadow data taking levelled at 2 x 10<sup>31</sup>)



### ALICE/LHCb Polarity Reversals

- LHCb: For complete control of systematics will need roughly equal statistics for both spectrometer polarities
  - ~bi-weekly swap
- ALICE: will need infrequent polarity changes for control on space charge distortions at very high luminosity
  - Once per running configuration
  - None in Run 2 pp data taking at 13 TeV
  - Run 3 and 4:
    - Keep solenoid OFF and dipole ON during rest of the year during pp operation at 13 TeV to avoid recommissioning





## Forward physics programs

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



<u>26</u>

### Forward Physics: LHCb

LHCb Forward Physics programme in the shadow of normal data taking

- Focussing on Central Exclusive Production physics with the help of additional forward shower counters to suppress inelastic background
- Run 2 conditions at  $\mu \sim 1.0$  (25ns) offers very good conditions



• Possibility of adding proton taggers in Roman pots under consideration (LHCb Upgrade)

## Forward Physics: TOTEM consolidation and upgrade

#### • From LS1 to LS3:

- Complete TOTEM's approved standalone physics programme at maximum LHC energy
  - Dedicated runs a each of the major energies (13, 14 TeV, other ?) +  $\beta^*=90m$  and  $\beta^*=2.5km$
  - Aim at performing this program in Run 2 assuming that cables for the optics are installed
- Common forward physics programme with CMS (nominal lumi): central production, hard diffraction
   → keep existing RP220 station unchanged for high-β\* operation
- → Upgrade RP spectrometer for operation at low β\* and high luminosities: Pileup resolution with timing detectors, multi-track resolution with pixel detectors

214m



- Long lever arm (~15m): optimised angular resolution
- 1 unit tilted 8° around beam axis to allow multitrack event reconstruction (beam halo pileup, background)

203m

R. Jacobsson

• Later: pixel detectors

New TCL6 collimator to protect Q6
→ Allow insertion of pots at high beam intensity

4 RP units:

Two new horizontal pots Timing detectors

Existing RP220

#### No planned running during HL-LHC foreseen



### Forward Physics: ATLAS/CMS

- ATLAS/CMS forward physics program with ALFA/TOTEM in Run 2 and Run 3 at high  $\beta^*$  and at nominal luminosity
- No high- $\beta^*$  after LS3
  - However, possible that forward physics program remains at nominal luminosity
    - Search for quartic-gauge anomalous coupling  $\rightarrow$  scattered proton
    - QCD: Diffractive events
    - ...

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



### **Requirements from Luminosity Calibration**

- Luminosity calibrations will be needed for every energy at least
  - → Assume goal will remain at 2-3%
- Required data taking conditions Run 2+3+4+...
  - Reduced bunch intensity: <8 x  $10^{10}$  to avoid effect of dynamic  $\beta^*$  and orbit distortions
  - Emittance: ~3 μm
  - β\* (ATLAS/CMS) : 15 20 m
  - $\beta^*$  (LHCb) : 30 40 m
  - β\* (ALICE) : >10 m
  - Filling scheme with well separated isolated bunches
  - Crab cavity OFF for stability
  - Crossing angle (LHCb) in XZ plane only of ~500μrad
  - (Clean RF)
- LHCb beam-gas imaging (ghost charge determination) with SMOG system will remain in LHCb upgrade and be operational beyond LS3 (HL-LHC)
- $\rightarrow$  (Likely that experiments will need low- $\mu$  running to commission new detectors)





### Summary

- So Both ALICE and LHCb is going through major upgrades in LS2 → 18 months
- An LS1.5 would not be of any significant benefit to ALICE and LHCb
- Start of LS2
  - A delay of up to a year is advantageous
- Scheduling of LS3 has little impact on ALICE and LHCb
- High luminosity programs of ALICE and LHCb is going well into HL-LHC
  - ALICE 10nb<sup>-1</sup> of ions + pPb etc (session 6)
  - LHCb >50fb<sup>-1</sup>
- Operation assumes levelled luminosities for efficiency and physics stability
  - and did I say 25ns pp operation?...
- ALICE pp requirements
  - Run 2: continuous running at 13 TeV
  - Run 3 + 4: Concentrated long period at equivalent energy >6 pb<sup>-1</sup>
    - + 1-2 months shadow data taking each year before ion run
- ATLAS and CMS preference for intermediate energy pp reference data
  - Short annual runs (few days)
- Forward Physics in special conditions is assumed to be complete by Run 3

Review of LHC and Injectors Upgrade Plans, October 29-31, 2013



### RLIUP Session 1 – talk 4

## Plans and physics outlook for non-high luminosity experiments until and after LS3

#### Abstract:

Based on the current physics scene, the future holds more than ever a joint enterprise of precision measurements and direct searches. With its very broad scientific program of heavy flavour precision measurements both in the beauty and the charm sector, as well as forward electroweak precision physics, LHCb has demonstrated to be a powerful forward general purpose detector complementary to ATLAS and CMS. After the expected lifetime of 10 /fb for the current experiment, the precision of most measurements will still be limited by statistics. Experience from Run I shows that systematic uncertainties are not expected to limit the precision down to the theoretical uncertainties. LHCb will thus undergo a major upgrade in LS2 to the ultimate flexibility of a full software trigger, together with a sub-detector configuration which should allow improving the physics yield up to an instantaneous luminosity of 2x10^33 cm-2s-1, with the goal to collect an integrated luminosity of 50-100 /fb by 2028. The flexibility of the upgrade also prepares LHCb for any changes in the physics scene beyond LS2. The ion program is an important aspect of the complete LHC physics program. For the purpose of detector commissioning and calibration, and physics normalization, the ALICE experiment requires data taking during high-luminosity proton-proton physics. This will evolve with the major upgrade of ALICE which is currently planned for LS2. In view of the LHC and the injector upgrades, this paper reviews the physics motivations, the upgrade and consolidation programs, and the operational requirements and schedule for LHCb and for the ALICE proton-proton data taking. For completeness, it also covers the impact and aspects of the LHC forward physics program which are relevant for the upgrades of the LHC and the injector complex. In particular it will try to identify any incompatibility with the requirements of the special forward physics runs.