Summary of session 8:

"LHC-related Projects § Studies (1)"

1. Will ALICE be running during the HL-LHC era? - *J. Wessels*
2. Will LHCb be running during the HL-LHC era? - *B. Schmidt*
3. HL-LHC operation with protons and ions - *O. Bruning*
4. Can the proton injectors meet the HL-LHC requirements after LS2? - *B. Goddard*
5. Necessary LIU studies during 2012 - *G. Rumolo*
6. SPS: scrubbing or coating? - *M. Jimenez*
7. Plans for ions in the injector complex – *D. Manglunki*

R. Garoby § S. Gilardoni (personal view) 15/02/2012

ALICE § heavy ions during HL-LHC

ALICE:

- has prepared an upgrade strategy document for the central barrel detectors and the muon arm

  ALICE @ High Rate

  endorsed by the collaboration, up for approval by the LHCC
- The upgrade strategy outlines physics case and measures to be taken in order to collect $10\ nb^{-1}$ Pb-Pb collisions
- Will extends particle identification capabilities and rate capabilities (up to 50 kHz PbPb. i.e. $L=6x10^{27} cm^{-2}s^{-1}$)

For ATLAS § CMS:

- p-p collisions will continue to be the priority for ATLAS and CMS!
- Interest in the extension of the HI program into the HL-LHC period if heavy ions can be made available without impact on the p-p HL-LHC upgrade.
- HI running to remain limited to no more than ~10% of the yearly physics time.

Will ALICE be running... ?

adapted from J.M. Jowett

2013-14		Long shutdown LS1, increase *E*
2015-16	**Pb-Pb**	Design luminosity, ~ 250 μb^{-1}/year, Luminosity levelling?
2017	**p-Pb** ***or*** **Pb-Pb**	P-Pb to enhance 2015-16 data. Energy? Pb-Pb if μb^{-1} still needed
2018	**LS 2**	? install DS collimators to protect magnets ALICE upgrade for 6 × design luminosity
2019	**Pb-Pb**	Beyond design luminosity … as far as we can. Reduce bunch spacing?
2020	**p-Pb**	
2021	**Ar-Ar**	[illegible] to be se[illegible]rom injector com[illegible]ing for SPS fi[illegible]get.
2022		LS3 [illegible]grades ?? [illegible]hastic cooling ??
>2022		Pb[illegible]uminosity p[illegible]ther [illegible]

approved program: 1 nb^{-1}

goal: 10 nb^{-1}

YES

an aside: Pb-p at high luminosity provides an unprecedented brilliant photon source…

Will LHCb be running… ?

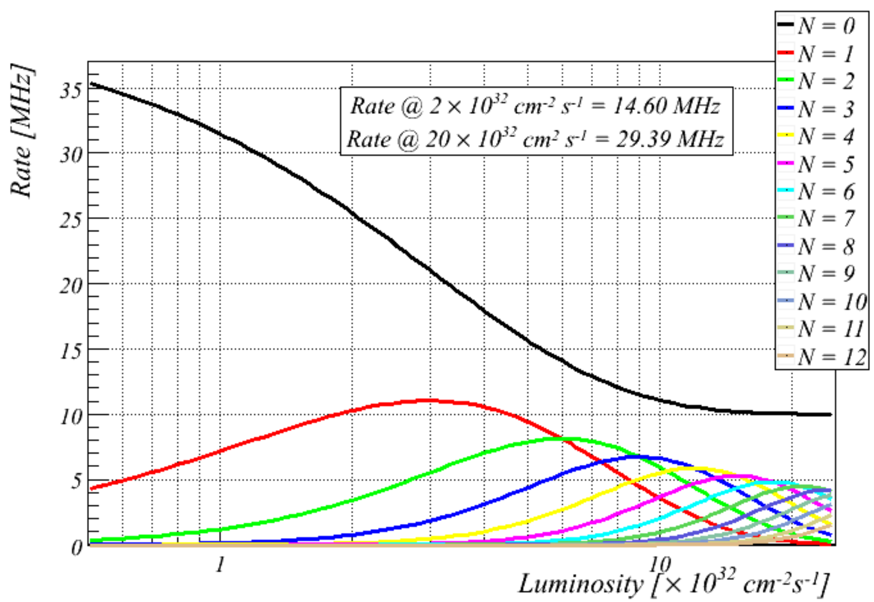
- The Physics program of LHCb is limited by the detector, not by the LHC. The detector upgrade allows LHCb to better utilise the LHC capabilities.
- The LOI for the upgrade has been submitted in March 2011 and endorsed by the LHCC in June 2011.
- LHC[illegible]as bee[illegible]nco[illegible]oce[illegible] prepa[illegible]s.
- LHCb int[illegible]s to upg[illegible]ector in LS[illegible] schedule[illegible]or 2018, [illegible] to take data [illegible] about 10 [illegible]ars after[illegible]

YES

Luminosity and Pile-Up in LHCb

- **LHCb design:** $\mathcal{L} \sim 2\text{x}10^{32}$ cm^{-2} s^{-1} at √s of 14TeV with 25 ns BX
  - interactions / bunch crossing $\mu = 0.4$
- **LHCb operation in 2011:** $\mathcal{L}$ up to 4 x 10^{32} cm^{-2} s^{-1} at √s of 7 TeV with 50 ns BX
  → $\mu = 1.6$
- **LHCb upgrade:** $\mathcal{L} > 2$ x 10^{33} cm^{-2} s^{-1} at √s of 14TeV with 25 ns BX
  → $\mu = 4$
- With 50ns BX the average pile-up would be up to 8, which leads to a too large detector occupancy

> **25 ns LHC operation is fundamental for the LHCb upgrade**



HL-LHC Performance Estimates

Nominal bunch length and minimum β*: 'HL-LHC Kickoff+'

Parameter	Nominal	minimum β* 25ns	minimum β* 50ns
N			
n_b			
beam current [A]			
x-ing angle [μrad]			
beam separation [σ			
β* [m]			
ε_n [μm]			
IBS horizontal [h]			
IBS longitudinal [h]			
Piwinski parameter			
geom. reduction			
beam-beam / IP			
Peak Luminosity			
Events / crossing			

Assume 10% … extractio … ween SPS … LHC

5.6 10^{14} and 4.6 10^{14} p/beam

…icient room for leveling
…h Crab Cavities)

…luminosity (25ns) of
…/ 0.37 10^{34} cm^{-2} s^{-1}

… 4)

…) of
… s^{-1}

…7 10^{34} cm^{-2} s^{-1} ('k' = 4.5)

…eled to 5 10^{34} cm^{-2} s^{-1})

OK for HL goals ('k' = 4)
To get 200-300 fb^{-1}/y
(Even better if emittances can be further reduced:
still a factor 1.2 to 2.5
wrt beam-beam limit)

→results in maximum fill length of

7 + 3 h and

1.7 fb^{-1} per fill

HL-LHC proton operation

- Small β^* optics solutions open the door for HL-LHC performance with leveling ➔ we need Crab cavities!

  ➔ optics design requires information on required configurations (ALICE;LHCb)!

- Bunch intensities: assuming total limit of 1 A in the LHC

  2 10^{11} ppb for 25ns and 3.5 10^{11} ppb for 50ns operation

- Bunch spacing:

  - **25ns clearly preferred** for event pileup but requires larger current wrt 50ns
  - 50ns is a very attractive backup scenario for avoiding e-cloud problems (in the SPS and the LHC!)

- Integrated luminosity:

  - **250 fb^{-1} is extremely challenging**; requires high availability and reliability

  ➔ how much time can one assume for HL-LHC physics! (MDs, TS, Pb etc.)

  150d; average fill length of 7h to 10h and average Turnaround time of ca. 5h

  ➔ ca. 70% efficiency [time required for physics fills / run time]!

Ion Operation during HL-LH

- ALICE is preparing an upgrade bid for 10nb^{-1}
  scaling 2011 and 2012 performance to 7 TeV
  ca. 500 μb^{-1} per year for a four week runn

- Doubling number of bunch
  - will double the injectio performance
  - resulting emittance ection might reduce
  performance rea
  7 TeV can partially compensate
  g a la RHIC might help

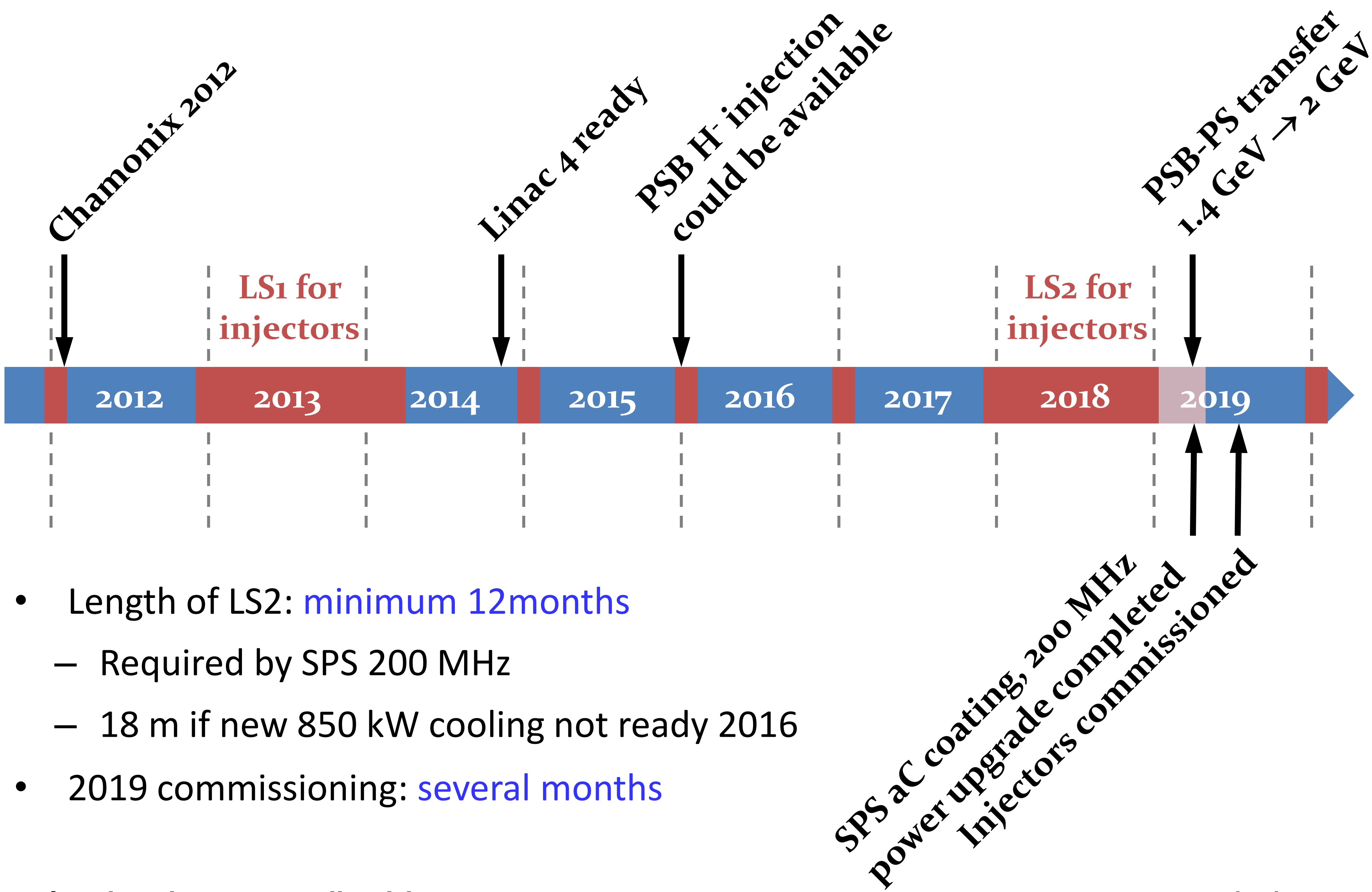
- D
  euterons is requested by ALICE, it will most likely
  ated after LS3 (development of source and injector
  be challenging before LS2).

→ running ALICE in dedicated ion mode during HL-LHC reduces time available for p-p physics by ca. 30 days

SPS beam parameters after the LIU project

- For HL-LHC era, requirements are challenging
  - 25 ns: need x2 present intensity, x2 present brightness
  - 50 ns: need x2.3 present intensity, 50% above present brightness
- Baseline LIU does not reach HL-LHC ‘point-like’ requirements.
- To even get close:
  - Need all planned upgrades to be fully effective, and to approach single bunch limits with multi-bunch operation
  - Need “stretch” loss/blowup levels in injectors, with HL-LHC ≤10% blowup, and losses of around 3%...
- Limits are different for 25 and 50 ns production
  - PSB performance sufficient with 160 MeV injection for both
  - 25 ns: PS space charge tune shift (2 GeV injection fixed by PSB).
  - 50 ns: brightness in SPS, PS longitudinal stability, PS beamloading

LIU project timeline



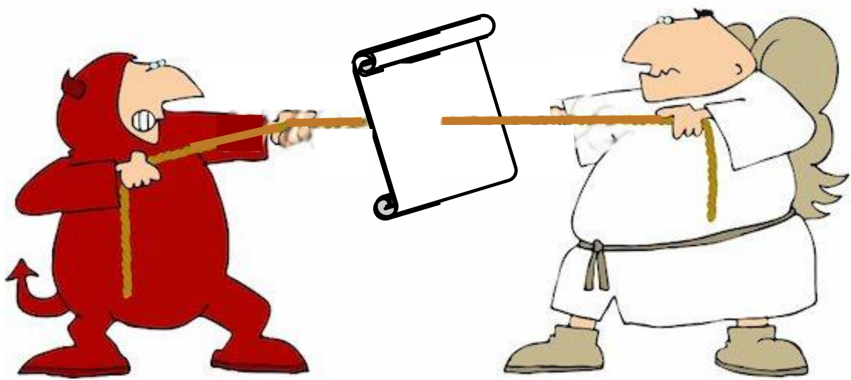
- Length of LS2: minimum 12months
  - Required by SPS 200 MHz
  - 18 m if new 850 kW cooling not ready 2016
- 2019 commissioning: several months

Can the proton injectors meet the HL-LHC requirements after LS2?

"NOT AFTER LS2, BUT MAYBE AFTER LS3

Interaction between HL-LHC and LIU teams is mandatory:

2nd joint meeting on March 30 at CERN



LIU studies during 2012

Recommendations § main subjects for each machine:

PSB → More resources desirable for the key studies

→ Resonances at 160 MeV

→ Origin of instabilities, efficiency of transverse feedback in the enlarged parameter range

PS → Important questions

→ Space charge limit at injection

→ Feedback against CBI

→ Alternative production schemes – like batch compression

SPS → Redistribution of the MD time + MD follow up meetings in the frame of SPSU-BD WG in 2012 recommended

→ More frequent – and shorter – MD blocks to allow for more continuous effort on Q20 optimization (with experts available)

→ 3 to 5-day dedicated block for scrubbing studies

SPS: scrubbing or coating ?

a-C coating: the guaranty of suppression…

- **a-C coating technology is at the same level of validation than NEG when approved for LHC!**
  - Very low SEY is compatible with ultimate bunch populations for all beampipe shapes
  - Solution of coating in-situ magnets is the only solution considered for the future
  - Industrialization process is getting validated, only MBA is pending
  - Long straight section beampipes will be coated as well (easy)
  - Reversibility is not an issue since coating can be remove using and oxygen glow discharge
  - Large scale quality is not a showstopper since already done for LHC NEG coated beampipes
  - Static vacuum behavior, slightly higher outgassing of the coating, will be worked out
- **Remaining concerns essentially logistical:**
  - Cost, Resources, Infrastructures, Duration, Radiation dose to personnel
  - Coating will be done in situ by removing the magnets from their position but doing the coating in one of the SPS caverns.

☞ **aC coating is project baseline and presently working towards assumption that this will be needed**

SPS: scrubbing or coating ?

Scrubbing: the low-cost potential alternative…

- **Ongoing simulations and Scrubbing MDs are prerequisite to decision…**
  - Solutions exists on paper to enhance the multipacting close to EC threshold and thus speed up the Dose effect on SEY
  - Only MBB dipoles (1/3 of SPS) shows a very low EC multipacting threshold
  - Benefit expected on the instability threshold resulting from the non-homogeneous distribution of electrons in dipoles required to compensate for the saturation of the SEY dose effect on StSt
  - Simulations ongoing to determine required scrubbing time/feasibility - profiting from excellent LHC data and simulations
  - A **wide band transverse feedback*** would be a very convenient add-on

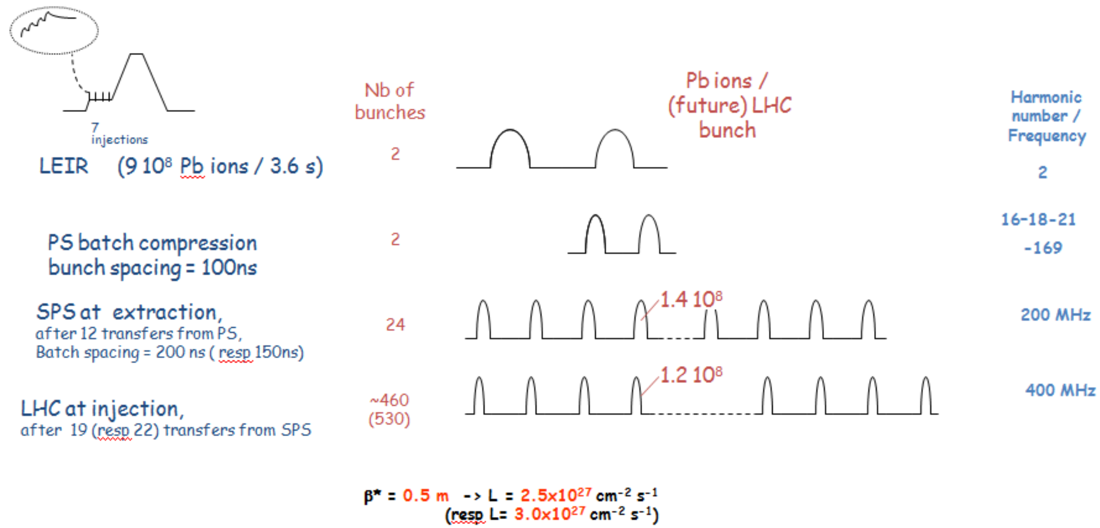
*supported by US-LARP and LIU project, joint effort of CERN, SLAC, LBNL

- **Remaining concerns:**
  - Saturation of the Dose effect on SEY of Stainless Steel beampipes is a major issue
  - Beam type required to enhance EC close to threshold
  - Unexpected limitation on beam equipments like RF, kickers due to heating

Ions in the injectors

What can we do today (i.e. 2015)?

- Same beam from Linac 3 (20mA)
  into LEIR into PS (2 bunches…)
- PS gymnastics
  - Batch compression
    h = 16 -> 18 -> 21 (100 ns)
- 12 SPS injections
  - Spaced by 200 ns
    (resp. 150 ns)
- Resulting beam
  - SPS train: 24 bunches of 1.4 x10^8 Pb^{82+}
  - Transverse emittances ~0.85mm
  - Spacing 3x100 ns + 1x200 (resp. 150) ns
  - 460 (resp. 530) bunches per LHC ring
    in 19 (resp. 22) injections from SPS
  - Luminosity increase ~25% (resp. 47%)



Ions in the injectors

Conclusions

- With the present injector complex, increasing the number of bunches seems to be the only route for a *marginally* higher luminosity, and at the expense of a longer LHC filling time
- If we are to implement the suggested improvements in order to reach the required Pb-Pb luminosity (provided the LHC can digest it), it is more than time to start the R&D on all parts of the injector chain.
- Ar and Xe will be available after LS1 (pending the precise definition/optimization of parameters) but other species, if desired, would come in addition and require more studies (e.g.: new source & pre-accelerator for deuterons, specific safety and handling measures for Uranium).

Summary § comments (1/2)

- The physics community interested in heavy ions has drawn-up plans for upgrading **ALICE** and operating it with up to **6 10^{27} $cm^{-2}s^{-1}$** during the HL-LHC era. **Other ions than Pb (if feasible) may require a long preparation in the injectors!**

- An upgrade is also planned for **LHCb** to make it capable of accepting a luminosity of **2 10^{33} $cm^{-2}s^{-1}$**. **Detailed consequences for the LHC in general and the lay-out of IP8 in particular remain to be assessed.**

- Taking into account pragmatic operational constraints, the feasible integrated luminosity in **ATLAS and CMS** with HL-LHC will be of approximately **200 fb^{-1}/year**. **The baseline solution is with 25 ns spacing between bunches, although 50 ns remains a back-up solution.**

- **The estimated beam characteristics at LHC injection after LIU still do not meet the HL-LHC „point-like" requirements.** Convergence will require **a very tight control of loss and blow-up across all machines and a close interaction between LIU and HL-LHC** for selecting the best matched sets of parameters.

Summary § comments (2/2)

- MDs in 2012 will be decisive for refining hardware specifications for the upgrade and estimating more precisely the performance reach of the injectors after LIU.

- **«In-situ» a-C coating of the SPS vacuum chambers during LS2 is the present baseline solution against e-clouds.** **Additional scrubbing MDs and simulations are mandatory for further analysis before the end of 2012.**

- In the present status of the ions injectors and once brought up to nominal energy, the LHC can potentially deliver twice the nominal luminosity in ALICE. Although modest improvements remain conceivable without major investment, **reaching ALICE upgrade goals will require more studies and R § D.** **These goals should therefore be confirmed as soon as possible for the necessary upgrades and the associated resources to be included in the LIU work programme.**