Heavy Ion planning

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Original requests from experiments for 2016 HI period

- ALICE: p-Pb at 5 TeV (1000M MinBias events at 10e28, and some running at high lumi for rare triggers 10e29)
- ATLAS: Ar-Ar, Pb-Pb, p-Pb at 8 TeV
- CMS: p-Pb at 8 TeV, Pb-Pb

(ATLAS/CMS strongly opposed to p-Pb running at 5 TeV)

- LHCb: p-Pb (either energy) (~20/nb)
- LHCf: interest in joining an 8 TeV p-Pb run

- Input from LHC:
  - Strong constraint to shut off proton injection before HI period in 2018 (to not delay important LIU work in LS2), such that any p-Pb in Run-2 would have to happen in 2016
  - Running with Ar not possible in 2016

Arguments for different energies for p-Pb

- ALICE would like p-Pb at 5 TeV as this is the same nucleon-nucleon collision energy as the Pb-Pb data taken in 2015.
  - They would like to use the p-Pb data (and 5 TeV p-p data taken in 2015 and in the future) as a reference for the Pb-Pb data
- ATLAS/CMS would like p-Pb at 8 TeV for the following main reasons:
  - Higher luminosity (~20% increase due to the higher energy) and significantly larger cross sections for relevant processes (EW bosons, jets, quarkonia, heavy flavor)
  - Higher multiplicity fluctuations to study collectivity in small systems at high-multiplicity
  - Study the collision energy dependence of ridge/flow

- In 2013 there was a p-Pb run at 5 TeV where ~30/nb of data were delivered to each experiment. The expected 2016 dataset would be ~1.5x this and so would not improve results by a large factor for ATLAS/CMS. However in 2013 ALICE took most of the data in rare trigger mode, and so running at 5 TeV in 2016 would increase their MinBias dataset by ~x10 which would be vey important for them.

Options presented at Chamonix

Heavy Ion running

- Significantly different requests from experiments on the Heavy Ion configuration
- Still under discussion, plan to converge on strategy before the March LHCC
- The current options available:

	2016	2018
A	p-Pb @ 5 TeV	Pb-Pb @ 5 TeV
B	p-Pb @ 8 TeV	Pb-Pb @ 5 TeV
C	Pb-Pb @ 5 TeV	Pb-Pb @ 5 TeV

remarks:

A- favoured by ALICE, LHCb – dis-favoured by ATLAS/CMS

B- favoured by ATLAS/CMS, LHCb , (LHCf would take data in such a run) – dis-favoured by ALICE

C- favoured by ATLAS/CMS – but ALICE/LHCb favour having p-Pb in Run-2

Strong constraint from LHC to turn protons off before the Heavy Ion period in 2018

Experiments would like a 5 TeV p-p reference run but there are differing requests on if this would be included in the Heavy Ion period or not. One option could be to take this during 2017, when no Heavy Ion run is foreseen (e.g. during ramp-up or at the end of year).

Proposal to run at both 5 & 8 TeV in 2016

- Following on from this there was a proposal from John Jowett to run at both 5 TeV and 8 TeV during the 2016 Heavy Ion period
- Since ALICE want a low luminosity (10e28) the 5 TeV part could be done with less setup time, and very long fills (if no collisions in other experiments) so a substantial part of the ALICE request could be delivered in a short time
- The 8 TeV part of the run would then be optimized for high luminosity running in ATLAS/CMS (but also colliding in ALICE/LHCb) with short fills (2hrs) due to large luminosity burn-off
  - The setup time for this should be minimized by re-using the 13 TeV pp optics (Beta*, crossing angle etc..)
- After discussing with the experiments the beam direction reversal (which is time consuming and requires machine setup and validation time) would only be done for the 8 TeV part

- With such a scheme it is hoped that we could provide ~70% of the originally expected data in each configuration (although firm luminosity numbers will take time to arrive at) - **but clearly this is a compromise** and the experiments would receive less than in their original requests
- This scheme is not compatible with taking p-p reference data in the scheduled Heavy Ion 4 week period, so if this goes ahead it needs to be understood reference data would be taken elsewhere
- It is clear that there is an increased risk for such a scheme as any multi-day loss in machine availability would significantly effect the physics – however it should be noted that in previous HI runs the machine availability has been very high

Some points to consider

- In addition after various discussions we believe the following :
  - 1 long fill (~1/2 a day) in the 8 TeV period should be dedicated to LHCf to take data (if approved to do so by the LHCC) which would require running at lower luminosity (but with same optics) for this fill
  - Upto 1 week of 5 TeV p-p reference data could be taken in 2017 (when no Heavy Ion run is foreseen)
    - ALICE requested 2 weeks in the remaining Run-2 period, ATLAS strongly oppose taking p-p reference data outside of the scheduled Heavy Ion time.
    - We believe that 1 week at the end of 2017 running could be used as a cool-down period for shutdown work that needs to access activated areas.
  - No 8 TeV p-p reference run should be taken (a lot of 2012 8 TeV data exists and 2011/2010 7 TeV data with lower trigger thresholds could also be used in some cases)

Open questions

- After discussions with the experiments this is seen as a viable option, although there are a number of important points that need to be resolved, but many require additional information not yet available
  - The order of the 5 TeV and 8 TeV parts (should be decided by the machine if either order is most efficient)
  - The sharing in time between the 2 energy periods (and how to adapt this to any lost time)
  - The luminosity sharing between LHCb and the other experiments (LHCb nor originally foreseen to take HI data)
  - How many VdM scans would be needed (this takes time)

A very preliminary indicative timeline could look something like
(order of things could be changed, time for some operations change)

week1	set up 5	set up 5	set up 5	5 TeV	5 TeV	5 TeV	5 TeV
week2	5 TeV	5 TeV	set up 8	set up 8	set up 8	set up 8	set up 8
week3	LHCf run	8 TeV	8TeV	8 TeV	8 TeV	8 TeV	reversal / 8 TeV
week4	reversal / 8 TeV	8 TeV	8 TeV	8 TeV	8 TeV	8 TeV	MD

operation	days
5 TeV setup	3
8 TeV setup (both directions)	5
direction reversal	1
MD	1
LHCf	1
5 TeV data taking	6
8 TeV data taking	11 days (5.5 for each direction)
Total	28 days (= 4 weeks)

Preliminary luminosity estimates

- Many thanks to Reyes, Michaela & John we received some preliminary luminosity estimates from a model based on the 2013 running
  - Model takes into account IBS, radiation damping, burn off and an additional exponential intensity decay of the Pb beam with an empirical lifetime based on 2013 observations, emittance and bunch length evolution during fill
- Very preliminary conclusions:
  - 5 TeV part: fills should be very long (23 hr) (5hr turnaround) => 900M events in 6 days – assuming no faults
  - 8 TeV part: fills ~5hrs long (~6/nb per fill @ IP1/5) (5hr turnaround)

  => >~70/nb (11 days taking into account intensity ramp-up, reversal etc..)
  - Of course additional downtime and VdM scans etc.. would lead to less luminosity/statistics
  - LHCb is not included in these estimates and experts will look into this, but there could be some small reduction in 8 TeV number due to this

Two operating energies under consideration

- Like p-Pb in 2013 *and* Pb-Pb in 2015

$$E = 4\ Z\ \text{TeV} \Rightarrow \sqrt{s_{NN}} = 5.02\ \text{TeV}$$

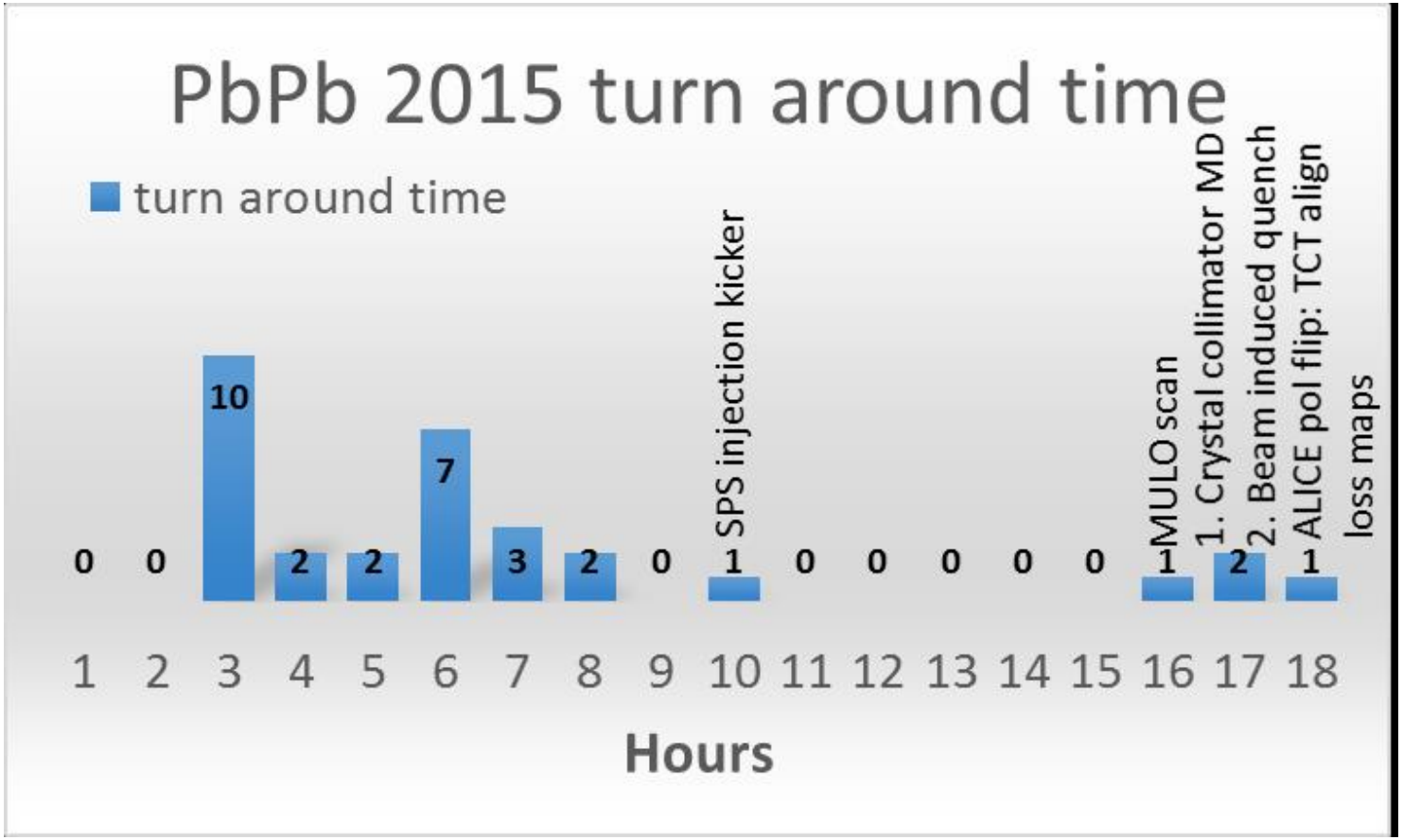
  - Filling schemes >400 bunches (Reyes, Chamonix)
  - Re-run of 2013 with some more bunches, ALICE levelling for longer
  - Off-momentum squeeze ⇒ similar optics β*=0.8 m (probable ALICE aperture limit sooner because of IP displacement), possibly lower elsewhere
- Highest energy available $E = 6.5\ Z\ \text{TeV} \Rightarrow \sqrt{s_{NN}} = 8.16\ \text{TeV}$
  - Similar filling scheme and intensity,
  - Smaller unequal beam sizes in collision ⇒ higher luminosity and higher losses ?
  - Squeeze will be (0.38×) less off-momentum ⇒ smaller β*=0.5 m (??) possible, allows fills to be shortened, but reduces ALICE levelling time

Either case requires full set-up, new squeeze, loss maps, etc

Reyes, Michaela

Turn around calculation

After analysis of the 2015 ion run, the average turn around time we consider for 2016 is 5 hours.



Reyes, Michaela

The model involves:

In what concerns beam parameters we have assumed the 2015 performance reach as presented in Chamonix 2016:

1. ALICE levelled at 4Z TeV, beta* = 3 m and at constant luminosity of 1e28 cm-2s-1; IP1&5 separated (we ignored LHCb).
2. IP1&5 head-on (again IP8 ignored) at 6.5Z TeV and beta* = 0.4 m;

- Number of colliding bunches = 400
- Pb bunch intensity (highest average achieved in 2015) = 1.8e10 p
- p bunch intensity (conservative, MD to achieve 4-5e10) = 1.8e10
- Normalized emittance (Pb,p) = 1.5 umrad
- IP1&5 ½ angle = 185 urad for beta* = 0.4 m, => Geometric reduction factor ~0.6