Beam-beam strong-strong actions. Status on 29/08/2019 => Answers with XavierB + comments in red during the meeting

1) **From 27/11/2015:** Following the discussions at the meeting on 27/11//2015 and in Beam-Beam meeting with presentation from Y. Alexahin define the constraints (if any) on beam stability on the IP1-5 phase advance difference between beam 1 and beam 2. **No optimization is needed (see presentation at WP2 meeting on 1/4/2016 - https://indico.cern.ch/event/463031/). Publish a note summarizing the findings and results (appear in the note with LaurentB et al., see below).** Is there any "coupling" effect between the damper action on each beam via the beam-beam? Is the coupling of the action of the damper on B1(2) to B2(1) via beam-beam taken into account in Nested Head-Tail or in DELPHI? **This needs to be studied. Should this be done using the realistic damper model introduced by J. Komppula?**

   => The study of the phase advance was not pursued further than the presentation at WP2 on 1/4/2016, given the low potential for improvement or degradation linked to the phase advance between IPs. The feedback and coherent beam-beam interactions are taken into account consistently in COMBI and BimBim. A detrimental impact of the two dampers acting on each beam was never observed. DELPHI does not include the effect of beam-beam interactions. It is planned to study the more realistic damper models in order to evaluate the feasibility of a reduction of the bandwidth to minimise the noise on the beam (next year). Part of PHD of SondreF but might be difficult before the end of the PHC (priority is on the noise).

2) Following the presentation of X. Buffat at the Annual meeting (https://indico.cern.ch/event/549979/contributions/2263213/attachments/1371406/2080727/2016-11-15_BBOP-expanded.pdf) do we understand why the strong-strong simulations with damper are providing optimistic results?

   => It is now understood as an effect of chromaticity mostly (difference between Alexahin's strong-strong model and Lebedev's weak-strong mode). These aspects are detailed in a paper by XavierB which will be circulated in the coming weeks (to be published in PRAB).

3) TRAIN upgrade:
   a) Global luminosity optimisation is still missing. **Not urgent.**

   => TRAIN is intrinsically not meant for this, the orbit optimisation requires an external loop alternating MAD-X and TRAIN executions. Currently the estimates are done by applying the correction ad-hoc, which is considered a good approximation in the LHC regime, i.e. for which the strong-strong correction with respect to weak-strong is small (it wouldn't be the case for LEP for example). No further work on this aspect is planned at this point.

4) Need to verify that the proposed operational scenario (**CERN-ACC-NOTE-2018-0002**) with negative octupoles is robust both for the nominal and ultimate scenarios from the point of view

of DA including beam-beam effects and taking into account of PACMAN effects. Verify with respect to the two polarities of ALICE and LHCb and with realistic separations **(low impact)**

=> This has been studied in detail: The PACMAN effects were reported in two notes (CERN-ACC-NOTE-2018-0036 with LaurentB et al. and CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.). The other aspects related to the robustness of the scheme in terms of beam stability are described in a note that is close to finalisation (on "Strategy for octupoles"). Few aspects remain to be understood in terms of DA, in particular the effect of linear coupling and the potential of the optimisation of the PHYSICS beam process (see WP2 talk on 17/09/19).

a) verification at injection (Requirements on crossing angle and separation at all points at injection. Define the minimum crossing angle and separation at injection from beam-beam effects (transients at injection, etc.). (see also action following WP2 meeting on 19/3/2019 - https://indico.cern.ch/event/803396/): Gianluigi proposed checking how large the contribution to beam kick at injection can be. Presentation at the WP2 meeting on 16/4/2019 (https://indico.cern.ch/event/804350/): for the beam-beam separations considered in the operational scenario the expected blow-up due to beam-beam kicks at injection is negligible. **Done.**

=> Done indeed. Is there anything more to do here? No

b) verify the stability through ramp and squeeze and squeeze (also including the case with reduced crossing angle at the beginning of the fill). **Done. Being documented in a note**

=> CERN-ACC-NOTE-2018-0036.

c) collision process and stable beams (also including the case with reduced crossing angle at the beginning of the fill):

i) Evaluate stability and orbit offsets due to PACMAN effects. **Done. Note to be finalized (with Ariadna)**

(1) at crab cavities.
(2) at collimators
(3) at electron lens

=> For the moment it was decided with the collimation team to use a criterion based on most pessimistic phase advances between the IPs and the given aperture bottlenecks. The corresponding reduction of the protected aperture is acceptable in the ultimate scenario but not for flat options. The latter requires further investigations. This is detailed in a note CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.

ii) Evaluate the dynamic effects (tune, orbit, chromaticity) when going in collision for with levelling by separation in IP2 and particularly IP8 **– Done. Note to be finalized**

=> This is detailed in a note CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.

iii) Evaluate impact of PACMAN effects on luminosity. **Done. Note to be finalized.**

=> This is detailed in a note CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.

iv) ACTION (Xavier, Ariadna): Check if the filling scheme and/or phased advance can be optimized for the number of collisions in IP2,8 to lower the effects on PACMAN bunches.

=> Light optimisations are possible, but do not seem relevant (as there are always bunches more critical than these ones). This is detailed in a note CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.

v) ACTION (Xavier, Ariadna): Study the impact of orbit errors on linear coupling of PACMAN bunches and define the tolerances

=> This was studied in detail and the difference between initial expectations and measurements was understood. A tolerance is given in the same note in terms of roll angle error of the crossing angle plane.

vi) Most of it done (see presentation at WP2 meeting on 12/6/2018 (https://indico.cern.ch/event/733521/). Need to document in a note and distribute to relevant WPs: Action: Xavier. Note to be finalized

=> See CERN-ACC-NOTE-2019-0037 with AriadnaRM et. al.

5) Effect of noise to be included (vibrations, ripple of the power converters of the main magnets and triplets/matching section, noise of feedback and crab cavities, effect of feedback, effect of beam beam). A simplified model with no attenuation from the beam screen and a constant inductance as assumed by S. Kostoglou in her studies. **Not very clear action?**

=> Once the attenuation is properly taken into account, the effect of field ripple is no longer compatible with observation, as opposed to what XavierB said in the WP2 talk on 20/03/2018. The other possible mechanism is the one proposed by RiccardoDM et al. (http://accelconf.web.cern.ch/AccelConf/p07/PAPERS/TUPAS033.PDF).

=> The goal of Gianluigi is to collect all the info linked to noise (which is both important for emittance growth and beam stability) and put them in a table => Will be done by GuidoS.

6) Update after meeting on 18/4/2017 (https://indico.cern.ch/event/632391/attachments/1456956/2248683/Minutes_92WP2_20170418.docx) PACMAN effects:

=> The first action on the 8b4e is done in the note on PACMAN effects mentioned

above. The second on the effect of the variation of the footprint during offset levelling in IPs 2 and 8 should be more on HSI side. Concerning the reduced crossing angle, it seems out of question now given the recent findings about beam stability and DA (see WP2 talk on 17/09/19).

7) From WP2 Meeting on 08/05/2018 (https://indico.cern.ch/event/726041/): PACMAN bunches having different orbits might feature different separations during the collision process and cross minimum of stability at different timings. **Action: Xavier to verify. Not urgent but should be done.**

=> Correct but what can be done here? We need to check quantitatively what is then the time window during which the minimum of beam stability is reached (to be compared to instability rise-time of the instabilities).

8) Estimate the expected beam-beam kick and orbit distortion in case of a dump of a single beam. This is important to determine potential machine protection issues. **The effects should be particularly estimated at collimators and at other aperture bottlenecks (e.g. triplets).**

=> Issue was not addressed by us yet, XavierB only provided few recommendations to TE-MPE on how to evaluate these effects using MAD-X and they conducted a detail study (e.g. http://accelconf.web.cern.ch/AccelConf/ipac2018/papers/mopmf042.pdf). Should we do something more? No IF they are indeed following this up.

9) Can we exclude operation with a crossing angle at 45 degrees? Do we have simulations for that case? It could allow changing regularly the orientation to minimize radiation. Advantages/disadvantages for machine protection? From e-mail of E. Metral on 3/12/2018: Long-range interactions would introduce a strong linear coupling (|C-|~1E-2) that would need to be globally corrected. This correction will jeopardise the stability of non-colliding bunches. An uncorrectable PACMAN linear coupling around 4E-3 is also expected. Solutions might exist to maintain the beam stability, such as an increase of the tune separation, or a passive compensation between the IPs 1 and 5 imposing the phase advance between the two IPs, they would require detailed studies to see whether some optimization of the phase advance between IPs should and can be optimized. **This should be studied and the impact on stability for HL-LHC and for LHC addressed in particular at the end of the squeeze and in the collision process.**

=> The studies were up to now focused on the present baseline showing already difficulties in terms of coupling generated by skew long-range interactions, mostly due to the small tune separation imposed by DA. By relying on passive compensation of linear coupling due to long-range on a skew crossing plane the sensitivity to orbit misalignment will be increased and bunch-to-bunch intensity variations will generate an additional contribution to linear coupling. Consequently, this option does not seem favoured and currently we do not plan more studies on it. But if the expected gain is high enough we can have a look, as we need to prepare new optics with different

phase advances between IPs, study it and design an experimental program. No request for the moment

10) Define tolerances on bunch-to-bunch population and emittance (also H/V differences) from beam-beam considerations.

=> No expected issue from strong-strong beam-beam point of view, as long as the bunch brightness does not exceed the design (and as long as we do not rely on passive compensation for linear coupling).

11) Studies to be performed for back-up/alternative scenarios:
    a) Action: Xavier to evaluate the impact on luminosity of long range effects for 8b+4e.

        => Done and described in the note mentioned above.

    b) Evaluate the dynamic effects (tune, orbit, chromaticity) when going in collision for:
        i) Flat optics **(by end 2019)** **=> Is it really needed by this date (as we believe we have many other higher priorities before)? => This does not seem doable by end of 2019 but if this becomes a higher priority, this can be done instead of other things. No request for the moment**

⇨ **No other request by Gianluigi => Priority is to make sure that we consolidate what we have. The next questions will concern the possible ramp-up during Run 4 and then we will move to the flat optics.**