BD-WG: Summary of R&D list

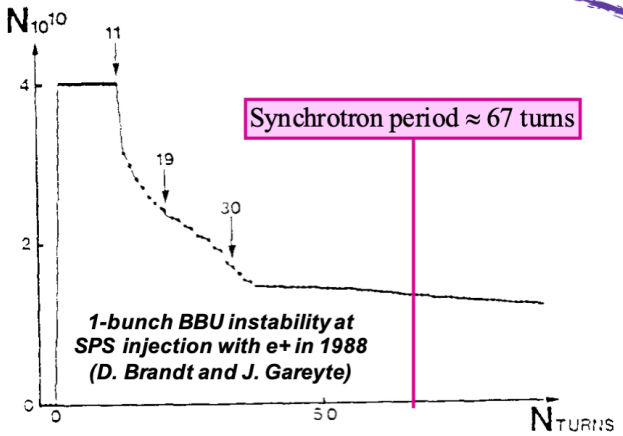
Conveners: R. Ryne, T. Raubenheimer and E. Métral

Many thanks to the participants of the BD-WG!

BD-WG: Summary of R&D list

Conveners: R. Ryne, T. Raubenheimer and E. Métral

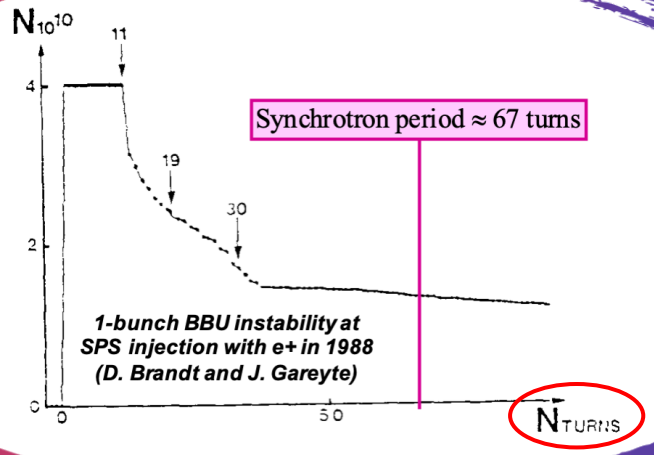
Many thanks to the participants of the BD-WG!



BD-WG: Summary of R&D list

Conveners: R. Ryne, T. Raubenheimer and E. Métral

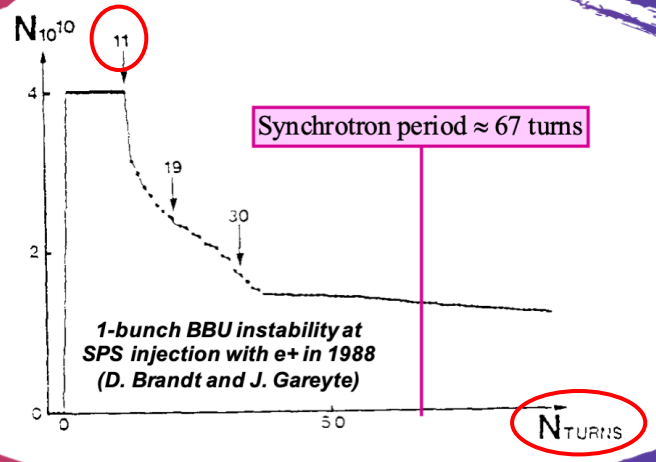
Many thanks to the participants of the BD-WG!



BD-WG: Summary of R&D list

Conveners: R. Ryne, T. Raubenheimer and E. Métral

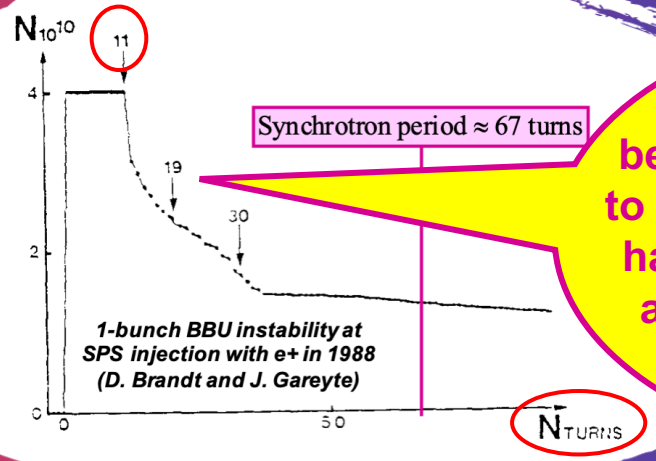
Many thanks to the participants of the BD-WG!



BD-WG: Summary of R&D list

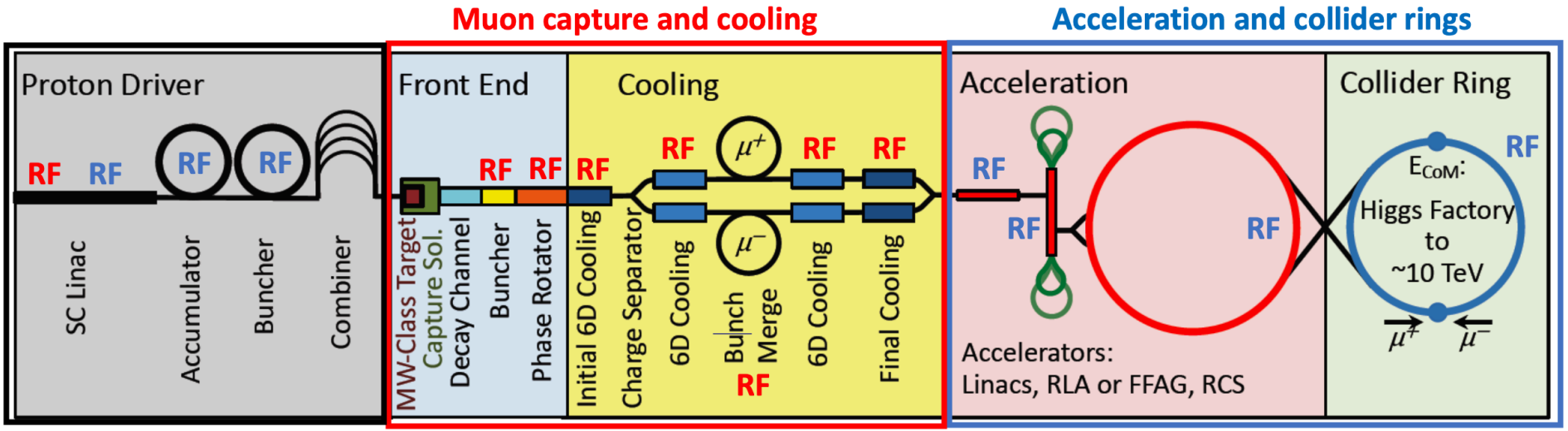
Conveners: R. Ryne, T. Raubenheimer and E. Métral

Many thanks to the participants of the BD-WG!



Even if everything needs to be done quickly with muons (due to short lifetime), many issues can happen with high bunch charges and high impedances (which is the case) => Need to be carefully studied!

Challenges at all stages!



R & D item #1:
Halo formation and beam losses in the Proton Driver

- **Why is it important? Criticality: 3** **[1 = high / 2 = medium / 3 = low]**
  - The more protons (and therefore the more muons we create), the “easier” it is afterwards
- **What are the key issues**
  - High (few MW) beam power, short (1-2 ns) bunch length, low (5 Hz) RepRate
- **What do we need before next ESPPU**
  - Detailed simulation studies to check that there are no major beam quality degradations and study in detail the halo formation and beam losses (mainly space charge effects)
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #2:
Check all cooling studies with a 2nd code

- **Why is it important? Criticality: 3**
  - Cooling it the key ingredient for a muon collider, so it has to be fully understood and optimized
- **What are the key issues**
  - Should not rely on only 1 code (ICOOL, for which the most complete simulation studies were made) => G4BL and G4MICE (e.g. ICOOL does not do hadronic interactions)
- **What do we need before next ESPPU**
  - Get all the lattices used in the past with ICOOL and redo all past cooling simulations with another code. Improve / optimize (some past constraints could be relaxed)
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #3:
Collective instabilities during ionization cooling

- **Why is it important? Criticality: 3**
  - Such mechanism could jeopardize the generation of high brightness muon beams through ionization cooling
- **What are the key issues**
  - Knowledge of collective instabilities that could arise from the interaction of the beam with electromagnetic wake fields propagating in matter (absorbers, gas-filled RF cavities, etc.) as well as with the pair of charges generated by ionization is practically non-existing
- **What do we need before next ESPPU**
  - Elaborate models that describe the electromagnetic wake fields generated by the beams passing through matter, as well as the dynamics of the charges generated by ionization including their generation, interaction with the beam and recombination
- **Which resources are required / who is willing to do it**
  - Ongoing discussions => Xavier Buffat (CERN) with some students?

R & D item #4:
New beam dynamics regime during acceleration

- **Why is it important? Criticality: 1**
  - Longitudinal and transverse emittances preservation (for luminosity) and orbit control
- **What are the key issues**
  - 2 high-charge bunches (1 of μ^+ and 1 of μ^-) with a lot of RF (strong focusing and impedance) and we need to be fast: this is a unique regime for collective dynamics, and the consequences for beam stability and operation (e.g., phase shifting to compensate potential well distortion) need to be understood
- **What do we need before next ESPPU**
  - Perform all the detailed simulations of beam dynamics with a large fractional beam loading per pass and a significant wake => Longitudinal (highest priority) but also transverse!
- **Which resources are required / who is willing to do it**
  - Ongoing discussions => Ivan Karpov (CERN) with some students

R & D item #5:
Are sextupoles needed in pulsed synchrotrons?

- **Why is it important? Criticality: 3**
  - In an ordinary synchrotron, it would be important to correct chromaticity to mitigate head-tail instabilities. Is that needed in our operating regime?
- **What are the key issues**
  - It would be preferable to avoid sextupoles to maintain a high dipole packing fraction and avoid feed-down since the beam will likely have to move in the sextupoles during the ramp
- **What do we need before next ESPPU**
  - Perform detailed simulation studies to decide on the mitigation measure: None (as we are fast enough)? Chromaticity? Transverse damper? Landau damping too slow
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #6:

Opposite sign bunches – beam crossing and wakes

- **Why is it important? Criticality: 1**
  - Both signs of muons are accelerated simultaneously in our rings. There will be 2 beam-beam collision points with wakes in the cavities, which will vary depending on where the cavities are in the ring (cavities must be distributed in several uniformly-spaced stations in the ring)
- **What are the key issues**
  - The impact of these collective effects should be understood
- **What do we need before next ESPPU**
  - Perform detailed simulation studies, studying one by one all the different aspects
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #7:

FFAs as an alternative to pulsed synchrotrons

- **Why is it important? Criticality: 2**
  - Particularly at lower energies, driving the magnets requires very rapid ramp rates. The challenges associated with this may drive us towards alternatives, in particular FFAs
- **What are the key issues**
  - E.g. vFFA relatively new concept (unique coupled optics, importance of fringe fields), no machine constructed yet, no dedicated tools to study collective effects
- **What do we need before next ESPPU**
  - E.g. vFFA is a linac from the BD point of view, so Linac tools should be able to be used but there is a need to develop dedicated tools for collective effects
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #8:

Design of the full chain (acceleration in particular)

- **Why is it important? Criticality: 1**
  - Right now most of the acceleration designs are conceptual, with few details available. We should start to put together detailed designs
  - Agreed set of baseline accelerator parameters is essential for refined studies (lattices for all stages, from past studies or to be developed/optimized => CERN repository; RF frequencies; etc.)
- **What are the key issues**
  - Particular emphasis should be placed on the longitudinal dynamics since preservation of longitudinal emittance is critical (but let's not overlook the transverse plane)
- **What do we need before next ESPPU**
  - Consistent simulation studies from the start of acceleration till the end and also the transport between the different machines
  - Would be important to decide whether we stick to the MAP setup (mostly in terms of energies and size of the RLAs and RCSs, based on other constraints) to study the feasibility, or whether we already review this before making the corresponding models and estimates
- **Which resources are required / who is willing to do it** => Ongoing discussions

R & D item #9: Longitudinal and transverse beam dynamics studies in the collider

- **Why is it important? Criticality: 2**
  - Need to operate ~ isochronous for a reasonable RF voltage
- **What are the key issues**
  - Significance of single-particle effects (resonances, working point, β-beating, …) vs. short muon lifetime?
  - No help from high synchrotron tune for beam instabilities (both longitudinal and transverse)
- **What do we need before next ESPPU**
  - Beam-beam and BBU do not appear as real showstoppers at the moment but they both need to be studied carefully to understand the performance margin and possible mitigations needed
  - Beam dynamics close to transition to be carefully looked at: lowest momentum compaction factor? Effect of nonlinear terms?...
- **Which resources are required / who is willing to do it**
  - Ongoing discussions => With HEC, Kyriacos Skoufaris (CERN), Christian Carli (CERN) et al.

R & D item #10: Impedance models

- **Why is it important? Criticality: 3**
  - Building a realistic impedance model of a machine is a necessary step to be able to evaluate the machine performance limitations, identify the main contributors in case an impedance reduction is required, and study the interaction with other mechanisms such as optics nonlinearities, transverse damper, noise, space charge, electron cloud, beam-beam (in a collider)…
- **What are the key issues**
  - Requires time and resources (and many interactions with equipment group) + Many machines
  - However: RF and Resistive-Wall dominate cooling and acceleration => Could be done quickly
- **What do we need before next ESPPU**
  - Build reasonable impedance models for all the machines => CERN repository
  - Define impedance budgets for all the machines
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

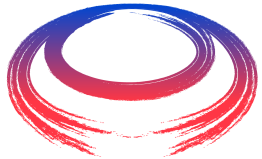
R & D item #11: Radiation mitigation by moving the beam / magnets in the collider

- **Why is it important? Criticality: 1**
  - This might be needed to reach acceptable level of radiation => Fundamental aspect of the study
- **What are the key issues**
  - All the consequences for the beam dynamics need to be carefully analysed
- **What do we need before next ESPPU**
  - Check what is needed, time scale, etc. and evaluate the impact on the collider performance
- **Which resources are required / who is willing to do it**
  - Ongoing discussions

R & D item #12:
Development of simulation tools

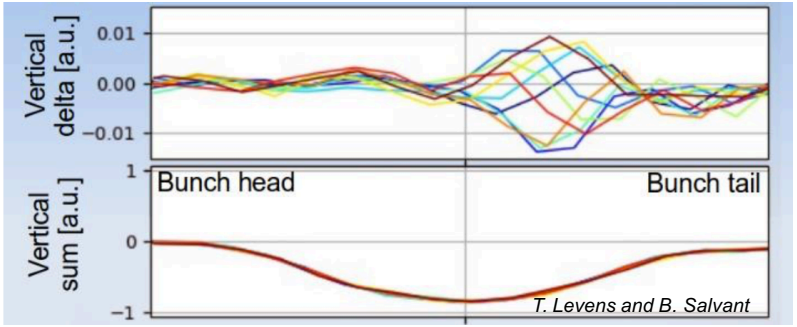
- **Why is it important? Criticality: 2**
  - Need to have a detailed understanding of many challenging mechanisms / new regimes
- **What are the key issues**
  - Collective beam-matter interaction to be studied (new wake field; impact on beam dynamics)
  - Non-standard acceleration schemes to be developed
  - Tools to study collective effects for vFFA
  - What about the study of the muon losses (we cannot collimate because muons go through everything and the issue is the decay products…)?
- **What do we need before next ESPPU**
  - Develop necessary simulation tools after review of what already exists (e.g. FCC)
- **Which resources are required / who is willing to do it**
  - Ongoing discussions => Elena Fol (CERN)

Quite some challenging and interesting work ahead of us: let's do it together!



Thank you for your attention

Another recent example in the LHC few years ago: “16L2” instability!



- **16L2:** cryogenic beam vacuum at half-cell 16 left of LHC-IP2
- **67 beam dumps in 2017** due to fast beam losses in 16L2, which led to **transverse coherent instabilities with rise-times of few 10s of turns** (i.e. 1-2 orders of magnitude faster than instabilities from e-cloud or impedance)
- **Cause**: accidental air inlet into LHC beam vacuum with beam screen at 20 K at end of Technical Stop => **Condensation and solidification of gases on beam screen surface in and around beam plug-in-module**