RF parameters for Muon Collider: RF frequency and gradient considerations

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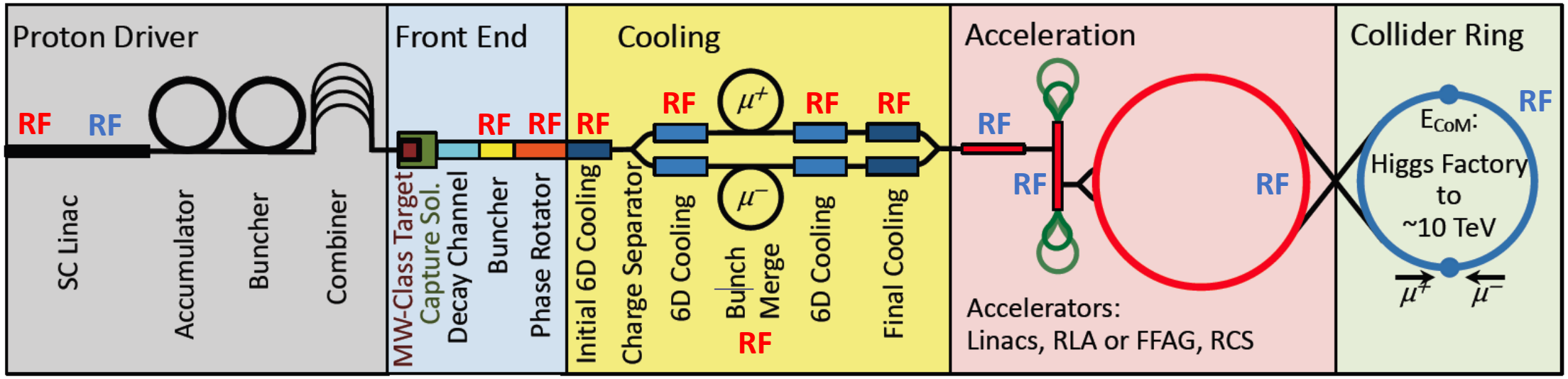
RF pulse length and frequency landscape



Linac: ~1-5 ms

- SNS: **402.5, 805** MHz
- ESS, SPL, CERN-L4: **352, 704** MHz
- PIP-II: **325, 650** MHz

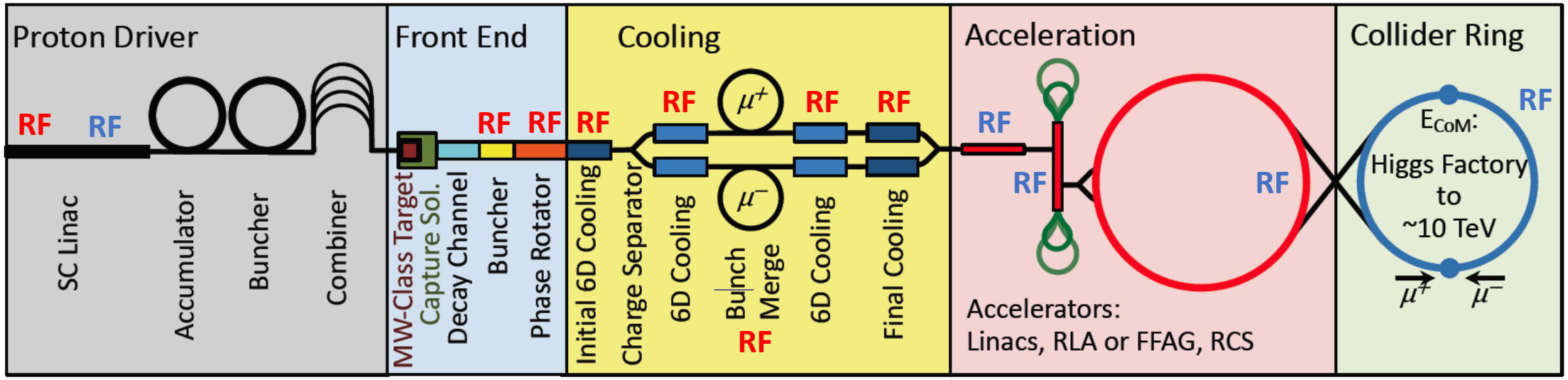
Muon cooling RF: ~0.1-0.5 ms

- Many frequencies in Buncher, Rotator, Merge, Final Cooling
- Cooling cells have two harmonic frequencies:
  - MAP: **325, 650** MHz
  - Alternative: **352, 704** MHz

Accelerator SRF: ~1-10 ms

- LA, RLA:
  - MAP: **325, 650** MHz
  - CERN-L4, SPL, ESS: **352, 704** MHz
- RCSs:
  - MAP: **1300** MHz (very high)
  - LEP: 352 MHz; LHC: 400 MHz
  - FCC: 400, 800, 600(?) MHz
  - CEPC: 650 MHz

Beam time structure and RF frequency



Two RF harmonics are used for low and high energy part of the linac

Single p-bunch

Many frequencies are used for bunch manipulations, Majority of cavities at two RF harmonics in 6D cooling

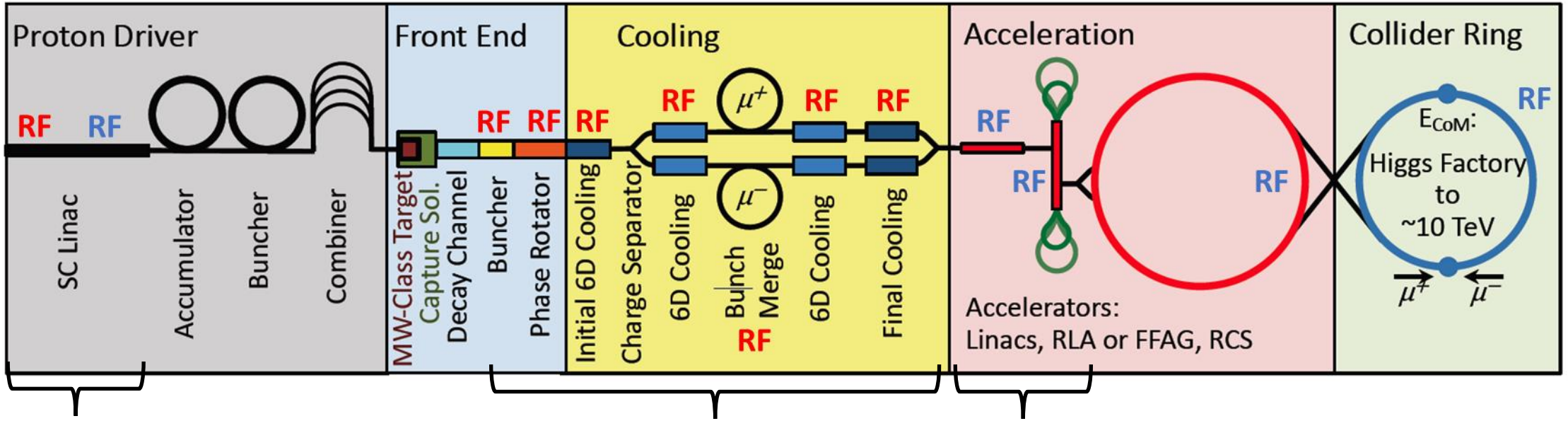
Two single μ+ & μ- bunches

Several RF frequencies are used for low and high energy part of the accelerator complex. Not necessarily harmonics.

Single bunch operation does NOT require the RF frequency in proton driver linac, muon cooling and accelerator complexes be related

Common frequency for pulsed linacs

Proton driven Muon Collider Concept (MAP collaboration)



- There might be **some reasons** to keep the close frequencies the same in the pulsed linac type complexes:
  - Proton driver linac; Muon cooling complex Linac and RLA for muon accelerators
- For example, in MAP: 325, 650 MHz are used in all 3 of them.
- CERN L4, LEP, ESS: 352, 704 MHz could be used instead
- Possible reasons for common frequency for the 3 complexes (to be discussed):
  - **LLRF, controls, waveguide components, RF power sources, SRF cavities** …

Commercial RF power sources

- Commercially available RF power sources are at the frequencies of currently running proton linacs:
  - SNS:
    - Thales: TH2168: **805**MHz, 5MW, 1.5ms;
    - Thales: TH2177: **402.5**MHz, 2.5MW, 1.33ms
  - ESS, L4:
    - CPI: VKP-8352A/B:**352**MHz, 2.8MW, 100kW
    - CPI: VKP-8292A: **704**MHz, 1.5MW, 74kW
    - CANON: E37504 **704**MHz, 1.5MW, 74kW, 3.5ms, 14 Hz
- 650MHz: No high (>1MW) RF power sources (?, TBC)
- 325 MHz: CANON E3740A: 3MW, 95kW, 0.6ms, 50Hz
- … more info is needed

Collider, demonstrator and RF test stand

- Already for muon cooling Demonstrator a new RF power source must be designed and build. Can be at any specified frequency
- On the other hand, RF test stand and possibly first cooling cell prototype cavities must be built and tested on shorter time scale
- Little room for getting a new RF power sources at a specified frequencies for the RF test stand
- Probably must rely on available commercial RF power sources at 704 MHz
- This may limit the choice of the RF frequency for the collider muon cooling complex to 352, 704 MHz.

Summary

- Although it is not a MUST, It make sense to keep the close RF frequency in the proton drive, muon cooling and muon linacs the same
- On a short timescale, availability of the RF power sources at 704 MHz drive the frequency choice for the RF test stand and possible the first muon cooling cell cavity prototypes
- Proton driver design is based on the SPL, ESS and is used 352 and 704 MHz. No major redesign work seems to be necessary in the linac. It make sense to keep these frequencies
- On the other hand, muon cooling complex and muon linacs will be redesigned in any case, so it can be done at the different frequency compared to MAP design

RF parameters in the document

Table 12.1: Some RF Parameters proposed to be used by the beam dynamics studies.

Proton Driver				
Linac				
RF frequencies	[MHz]	352	704	
Muon cooling complex				
6D-cooling channels				
RF frequencies	[MHz]	352	704	
Maximum Accelerating field in cavity (conservative)	[MV/m]	22	30	
Maximum Accelerating field in cavity (optimistic)	[MV/m]	35	50	
Acceleration complex				
Linacs				
RF frequencies	[MHz]	352	704	1056
Maximum Accelerating field in cavity (conservative)	[MV/m]	20	25	30
Maximum Accelerating field in cavity (optimistic)	[MV/m]	30	40	50
RCSs				
RF frequency	[MHz]	1300		
Maximum Accelerating field in cavity (conservative)	[MV/m]	30		
Maximum Accelerating field in cavity (optimistic)	[MV/m]	50		

- RF frequencies are discussed above
- Accelerating gradients. Two levels are proposed:
  - Conservative, to be used in the baseline, as it is the case now
  - Optimistic, to be used for exploratory studies to evaluate the impact of going to higher gradient
- These levels are consistent with the state-of-the-art in NRF and SRF technology R&D.