Considerations on Running at the Z^0

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Introduction

Two main issues to be faced

- Can we adjust the components to lower beam energy?
  - Can the magnets be adjusted?
  - Do we have enough aperture?

- Which bunch charge can be used at lower energy?
  - Maximum is defined by collective effects
    - longitudinal short-range wakefields
    - transverse short-range wakefields
    - transverse multi-bunch wakefields

Tentative strategy:

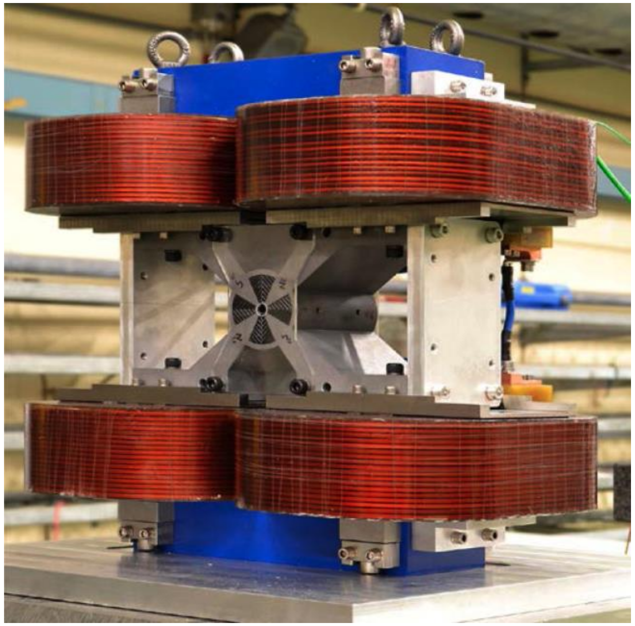
- Use full acceleration in RTML to minimise wakefield effects in RTML and at beginning of main linac

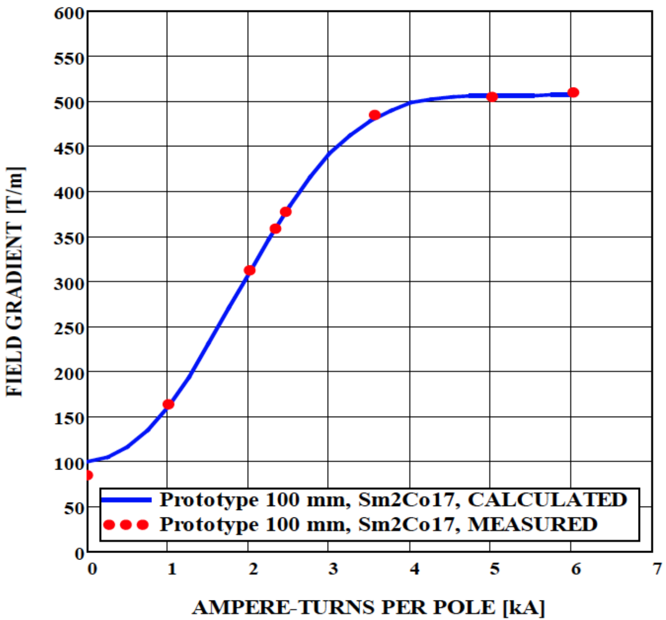
$\Rightarrow$ Main linac and BDS are the main limitations

$\Rightarrow$ Can review this but not likely to have huge improvement potential

BDS Considerations

- Can the final doublet be used at 45Gev with no important modifications?
  - A factor 4-5 is possible depending on the technology
  - ⇒ Z0 has to be explicitly foreseen the design
  - ⇒ Can likely not go further down without intervention
  - ⇒ Cannot easily run at Z0 for higher energy stages
  - ⇒ Maybe can replace doublet (or part of it) for dedicated Z0 run
  - ⇒ Need to check tolerances (field quality)





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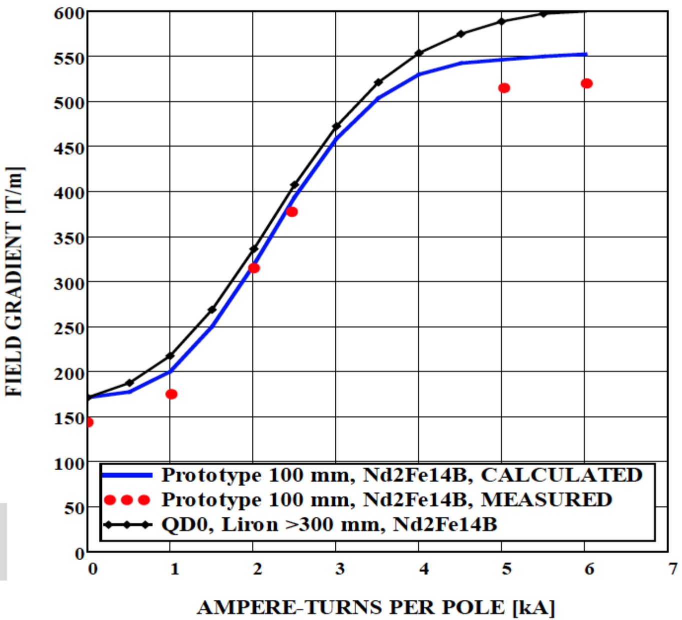

BDS Considerations II

- Final doublet defines the aperture of the collimation system
  - If we keep the doublet, absolute apertures stay the same but beam size doubles
    - ⇒ Scrape of larger fraction of the beam (more background from halo, e.g. muons)
      - ⇒ Remains to be quantified
    - ⇒ Wakefield effects increase by factor 4
      - ⇒ But can compensate by smaller bunch charge
      - ⇒ Quantitative assessment essential
  - This would become much worse for larger energy differences

- If we exchange doublet would win in aperture to increase collimation aperture
  - Could more than double it
    - Halo population significantly reduced
    - Wakefields strongly reduced
  - Have to check other magnets as well

- Can we exchange the final doublet?
  - For L* = 6m the magnets would be outside of the detector
    - ⇒ Appears possible to exchange
  - For L* < 6m the magnets reach into the detector
    - ⇒ Need to likely open detector to exchange
    - ⇒ Or find some clever solution

Luminosity

$$\mathcal{L} = H_D \frac{N^2}{4\pi\sigma_x\sigma_y} f_r n_b$$

Cannot change repetition rate f_r and did not foresee to change number of bunches per pulse n_b

The charge can change strongly
Large impact on luminosity

$$\mathcal{L} \propto H_D \frac{N^2}{4\pi\sigma_x\sigma_y} = H_D \frac{N^2}{4\pi\sqrt{\epsilon_x\epsilon_y\beta_x\beta_y}}\gamma$$

Does change somewhat with N

Does not change drastically, but could gain a little bit

Loose about factor 4 because of energy

Tentative List of Scenarios to Consider

A) Extract beam when it reaches 45GeV in linac

- Requires some modification in main linac, long transfer line
- Could be done as a stage during the construction
- Allows to use $N=N_0$

B) Accelerate beam at lower gradient in the main linac to reach 45GeV at the end

- Little hardware modification required
- Reduced charge $N=x_1 N_0$

C) Accelerate beam at full gradient in first part of linac then drift through the rest of it

- Little hardware modification required
- Could even consider to accelerate above final energy and then decelerate
- Reduced charge $N=x_2 N_0$

D) Accelerate beam at lower gradient but modify the lattice design

- Allows to make beam more stable $N=x_3 N_0$
- Important modification of main linac required
- Has impact on nominal design

Expected behaviour: $1 \geq x_3 \geq x_2 \geq x_1 \approx 0.25$

Note: Energy Spread

- We can tolerate 0.35% RMS energy spread in beam delivery system
  - Otherwise compromise luminosity
  - But will reevaluate for Z0 operation

- Main sources of energy spread
  - Correlated energy spread from linac wakefields:
    - 0.35% RMS at the end
    - Dominant factor at 190GeV
  - Initial energy spread of beam entering the linac
    - Nominal is 1.5% RMS at 9GeV
    - i.e. 0.09% at 190GeV
    - But 0.3% at 45.6GeV
    - Can maybe reduce spread if bunch charge is reduced (scenarios B, C and D)
  - Bunch-to-bunch variations from limited beamloading compensation with drive beams
    - Worse if only a part of the linac is used for acceleration (scenarios A, C, and partly D)
    - Maybe install additional klystrons?

$\Rightarrow$ Detailed integrated studies are required

$\Rightarrow$ Which spread is acceptable for physics?

Tentative Luminosities

Charge ratio	L	$L_{0.99}$	Pot. Scenarios
0.25	$1.9\times10^{32}cm^{-2}s^{-1}$ $1.7\times10^{32}cm^{-2}s^{-1}$	$1.9\times10^{32}cm^{-2}s^{-1}$ $1.7\times10^{32}cm^{-2}s^{-1}$	B
0.5	$8.4\times10^{32}cm^{-2}s^{-1}$ $7.6\times10^{32}cm^{-2}s^{-1}$	$8.2\times10^{32}cm^{-2}s^{-1}$ $7.5\times10^{32}cm^{-2}s^{-1}$	C?, D?
1.0	$3.8\times10^{33}cm^{-2}s^{-1}$ $3.5\times10^{33}cm^{-2}s^{-1}$	$3.5\times10^{33}cm^{-2}s^{-1}$ $3.2\times10^{33}cm^{-2}s^{-1}$	A

Tentative guesses for what scenarios may allow to do (lower for klystron-based design)

- Several issues to be looked at
- E.g. ignoring the issue of the uncorrelated beam energy spread
- Will have to update the estimates

Large range of luminosities

- strong dependence on the charge (slightly more than quadratic due to H_D)

Luminosity spectrum is always quite good

- in worst case 90% of luminosity above 99% of cms energy

Can you down select what you want so that we can focus on one or two scenarios?

Conclusion

- For 380GeV stage, can make it possible to operate CLIC at 91.2GeV cms
- Important effort required to do the same for higher energy stages

- Different solutions can be considered for 380GeV
  - Luminosities range from $L=1.9 \times 10^{32} cm^{-2} s^{-1}$ to $L=3.8 \times 10^{33} cm^{-2} s^{-1}$
  - Luminosity spectra are very good in all cases
  - The impact of solutions on the design differs singificantly
  - Cannot use all scenarios for calibration runs

- Need to understand luminosity requirements
  - Calibration
  - Dedicated run
  - Input from physics required

- Need to identify requirements for beam energy spread
  - Some input from physics required

- Have to do quite some work
  - Amount depending on the choice of strategy