LINAC4 as BKP for LINAC2

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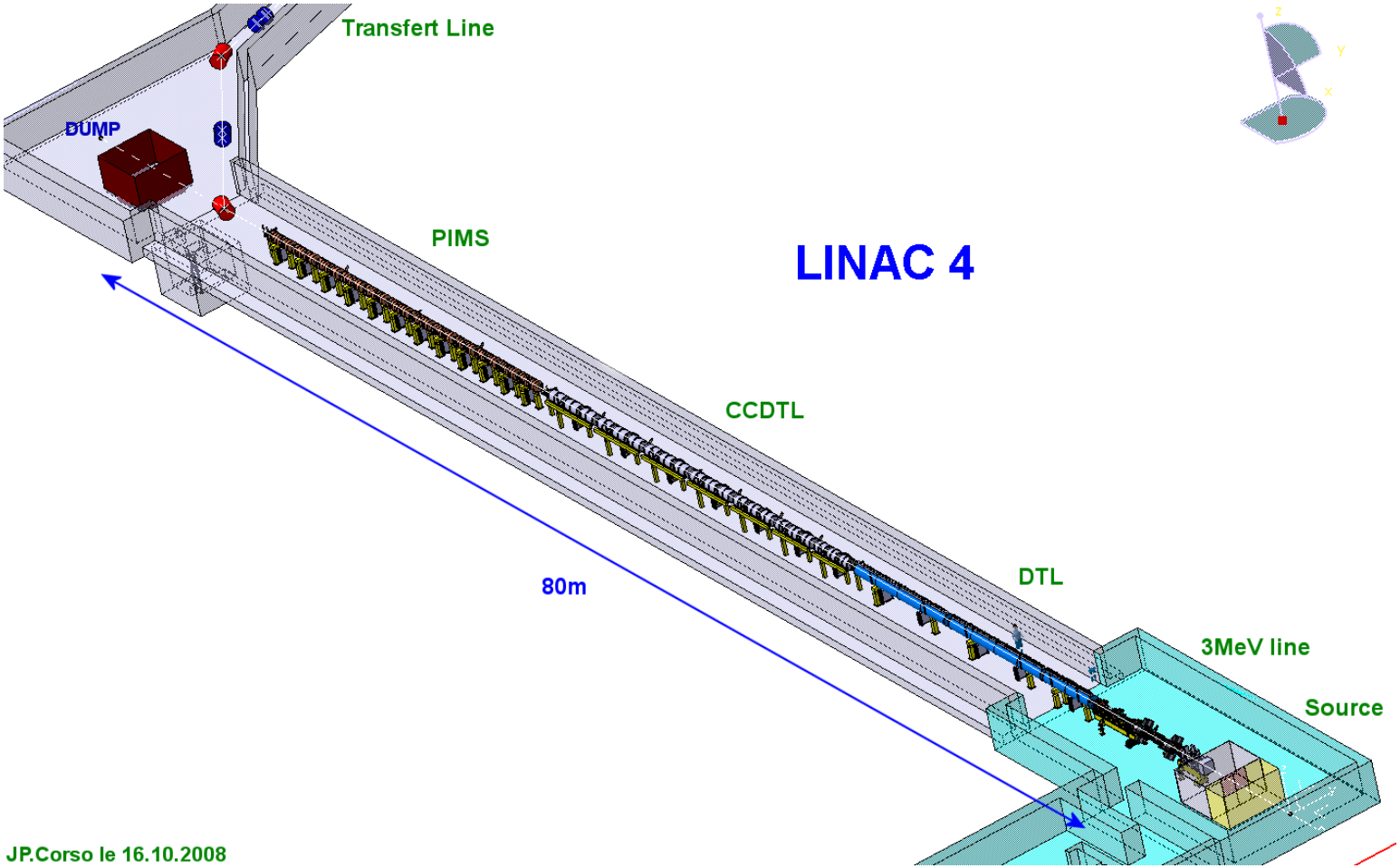
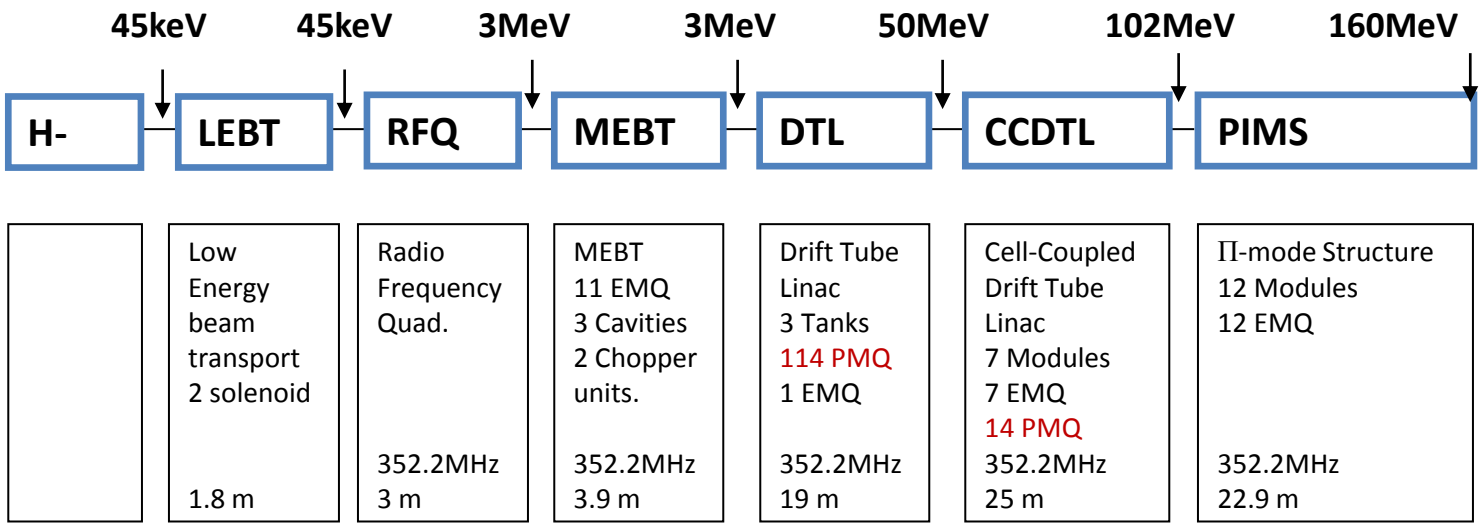
for the LINAC4 beam dynamics team

1. How to accelerate and transport protons
2. 50 MeV and 160 protons
3. Limitation to intensity and emittance
4. Comparison with LINAC2
5. Conclusions

Layout of LINAC4



Layout of LINAC4



- Up to 3 MeV "charge insensitive"
- In the MEBT line we have to respect the chopping dynamics
- We need to match to a permanent focusing channel in the DTL and CCDTL

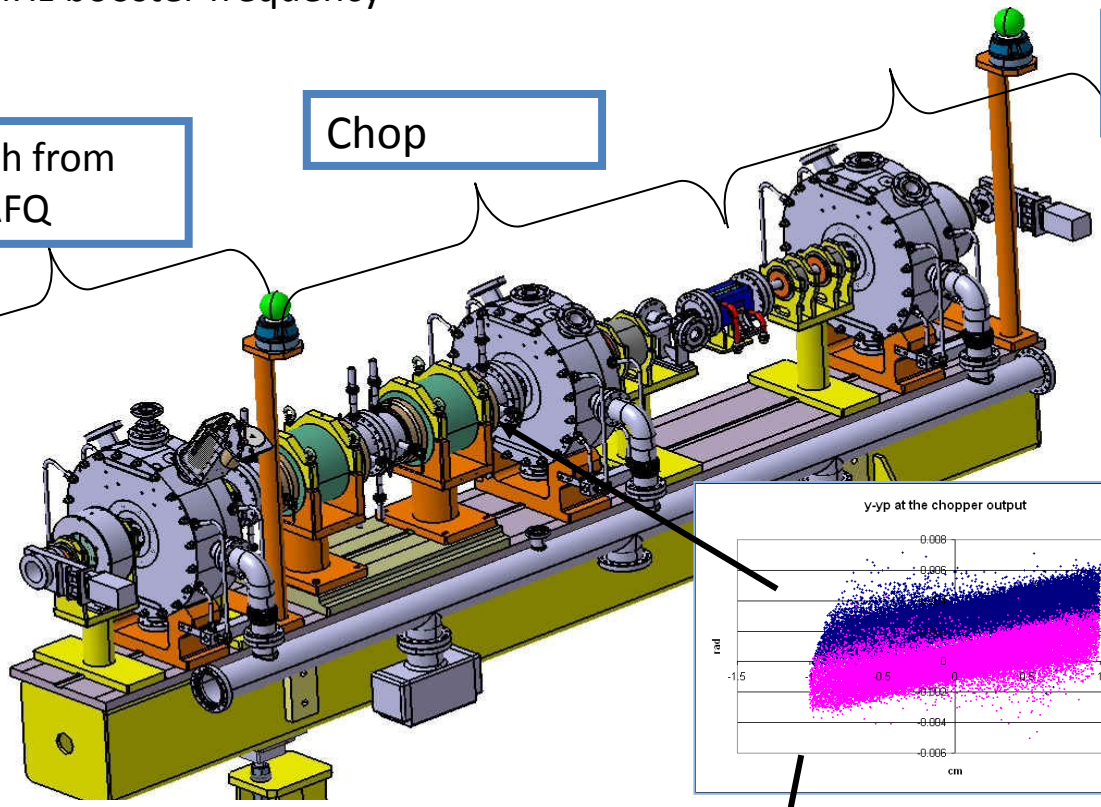
Chopper line dynamics-

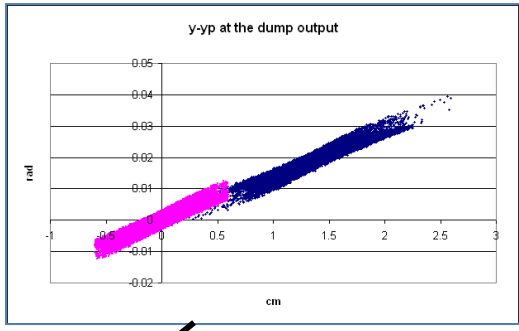
removing micro-bunches (150/352) to adapt the 352MHz linac bunches to the 1 MHz booster frequency

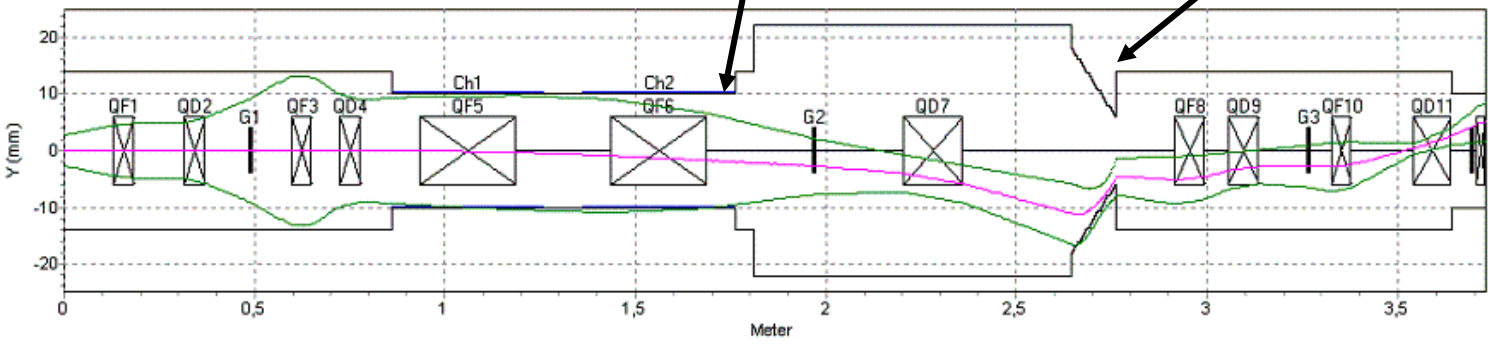
Match from the RFQ

Chop

Match to the DTL

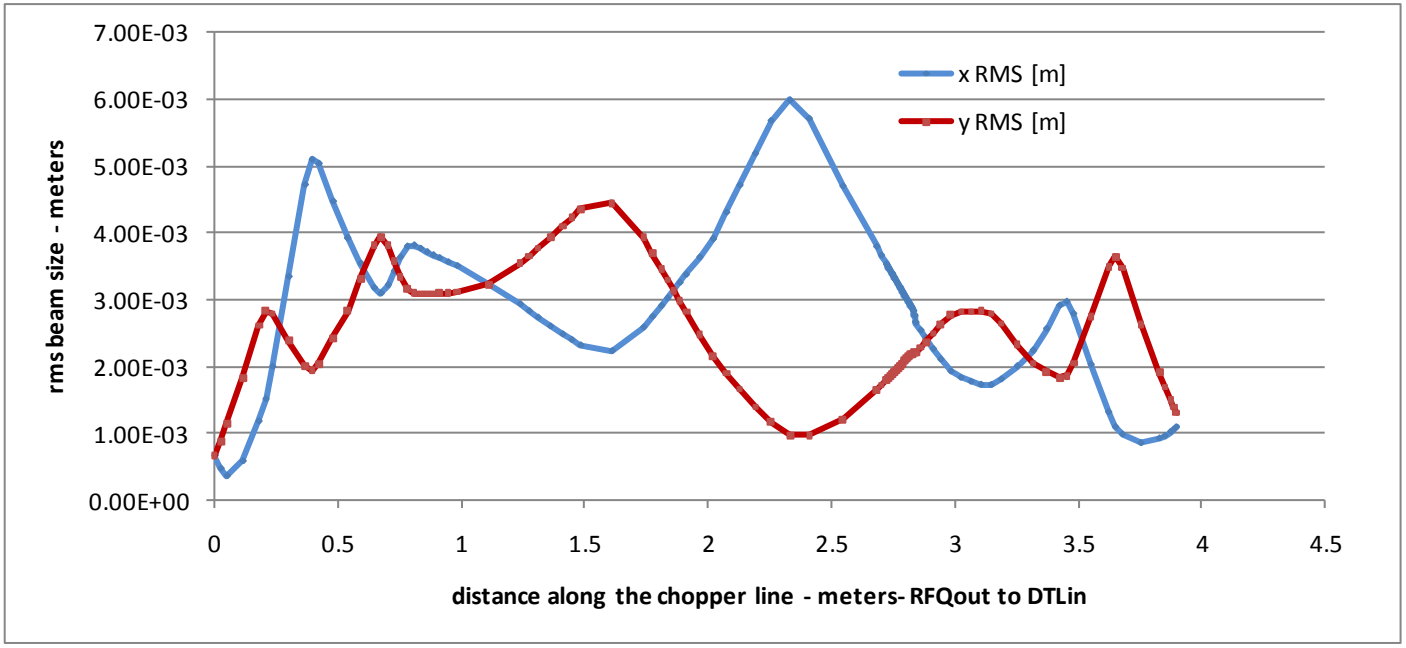






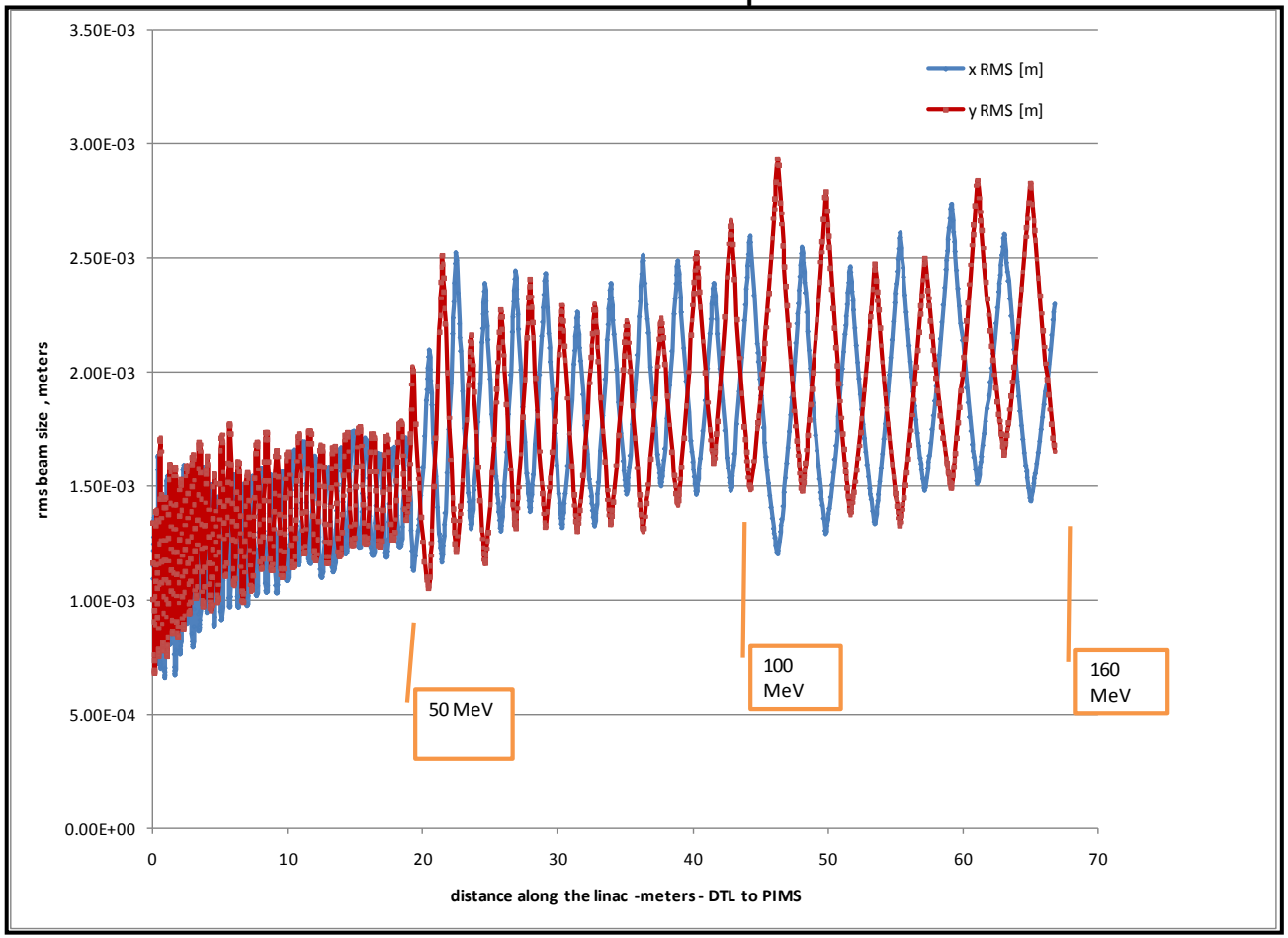
Accelerating protons

- Rematch the chopper line :
  - » Exactly same dynamics as for the H- until the dump
  - » Rematch to the DTL with the last 4 quadrupoles



160 MeV protons

- Once re-matched at the DTL input we are OK until the end of the PIMS



E = 0.35 pi rms norm

DW=120 keV (1 rms)

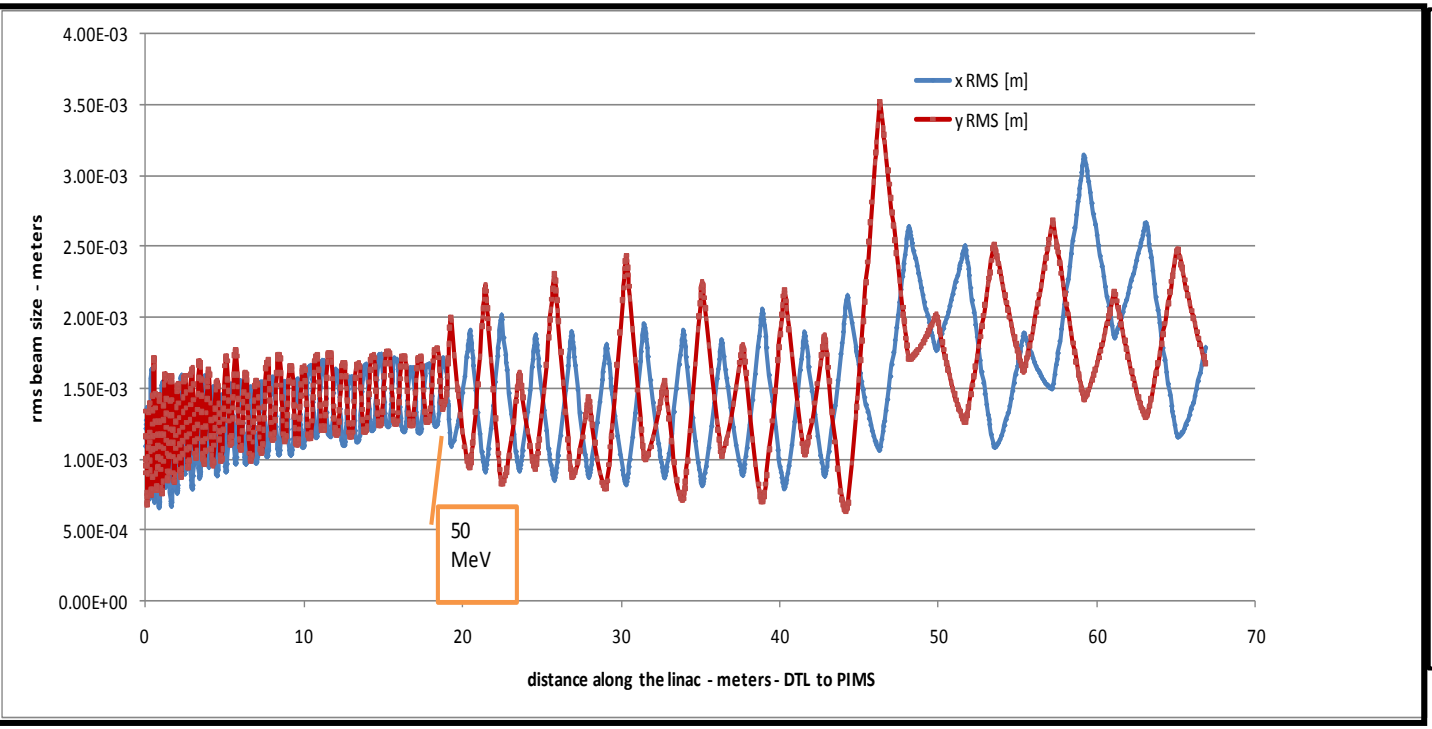
40 mA

160 MeV

400 µsec

50 MeV protons

- Switch off or do not install CCDTL and PIMS
- Install all the quadrupoles-retune PIMS quads



E = 0.28 pi rms norm

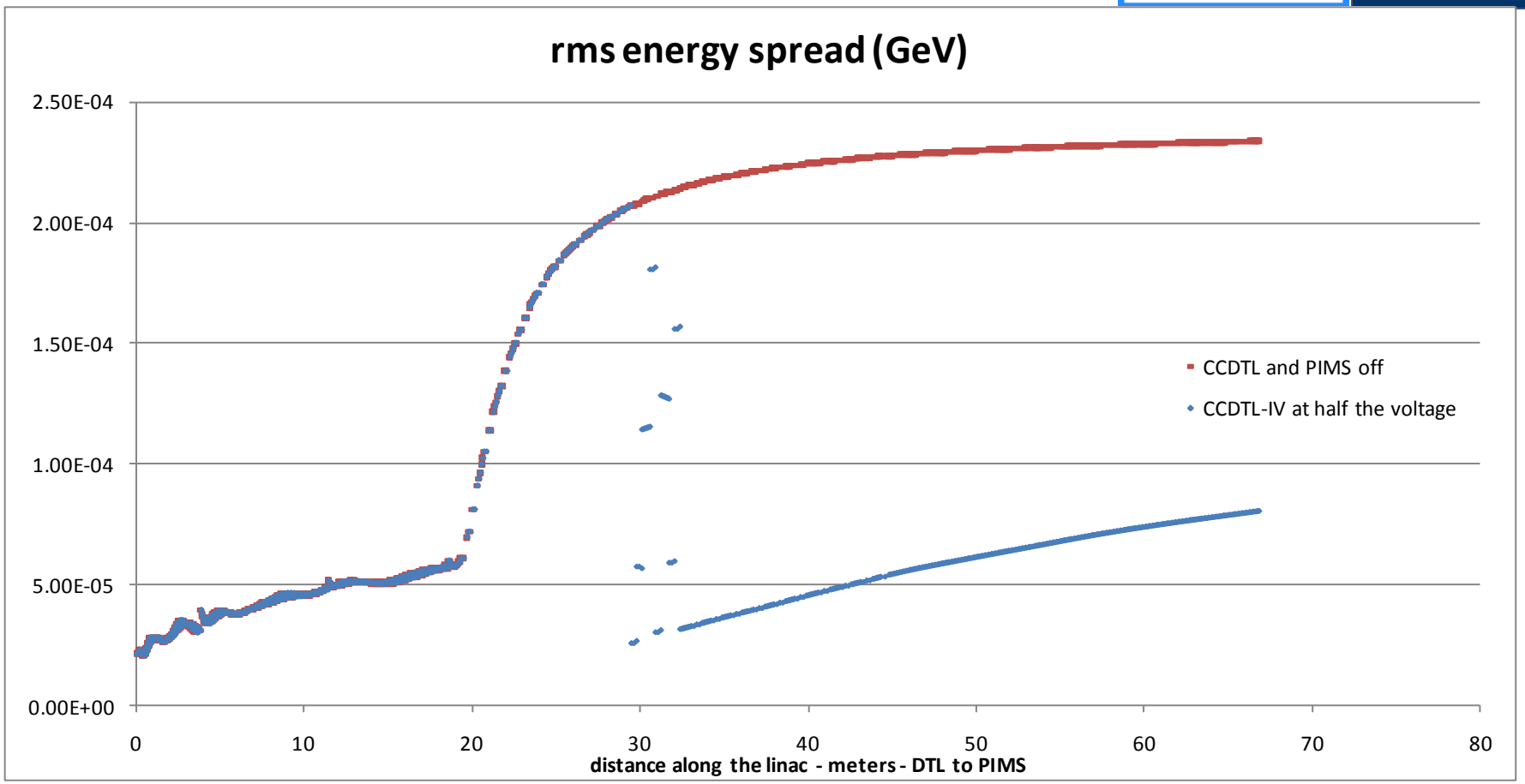
DW=250 keV (1rms)
(can be improved)

40 mA

50MeV

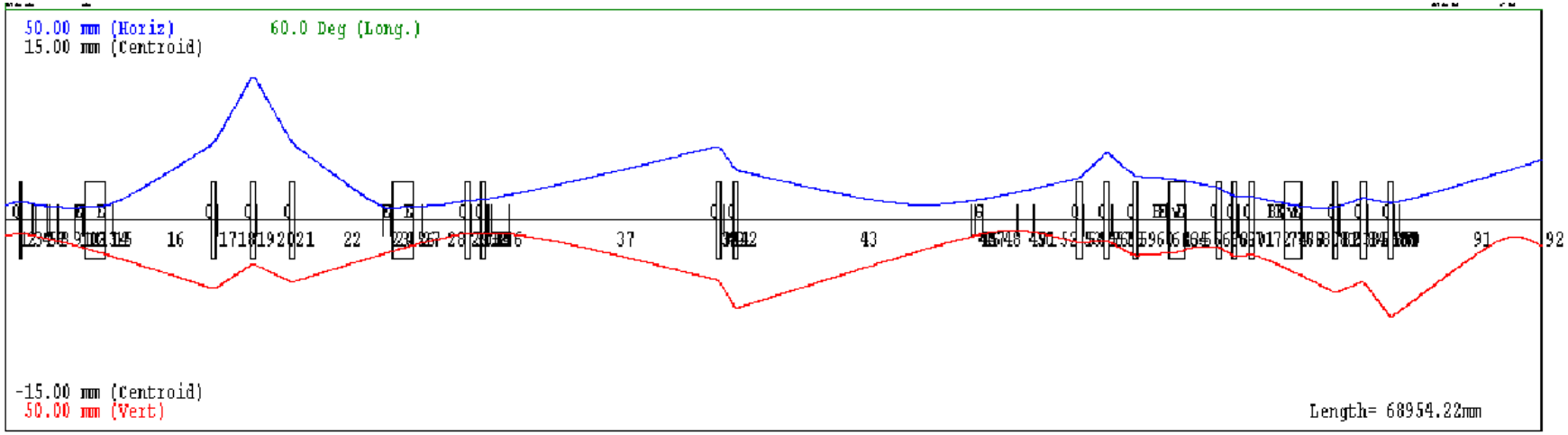
400 µsec

Energy spread



Transfer lines-50MeV

- Re-matched up to BHZ20.
  - all quadrupoles values are lower than for the 160MeV case.
  - De-buncher switched off
- Envelopes ok.

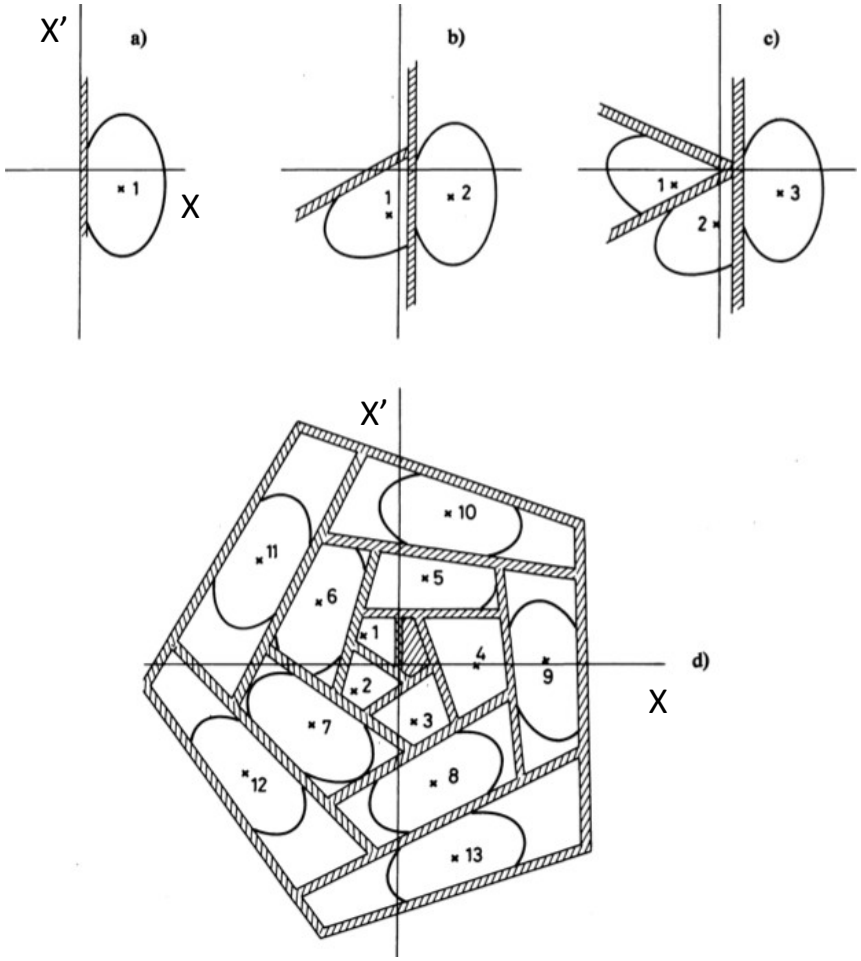


Horizontal (blue) and vertical (red) envelopes in the transfer line – PIMSout to BHZ20

At the PSB distributor

	energy	current	Pulse length (4rings)	Emittance (rms mm mrad)	Energy spread (rms –keV)
LINAC4	50MeV	40 mA	400μs	0.3	250 100 (CCDTL mod4)
LINAC4	160 MeV	40 mA	400μs	0.3	120
LINAC2	50 MeV	160mA	100μs	1	160 (measured 3/2011)
		Current in linac4 is limited by the klystron (beam loading)	Present distributor is limited to 15 turns (100μs)	We could profit from smaller emittance with the new distributor	

Recap on conventional Multiturn Injection – C. Carli



Sketch of conventional multiturn injection (betatron tacking in hor. phase space from P. Van der Stok, CERN/PS/BR 81-28

- Septum (magnetic for PSB) separates space in
  - Region for incoming beam
  - Region for circulating beam
- Different injected turns in distinct regions of phase space
- Limited phase space density in receiving synchrotron
  - High beam current required
  - Small emittances required

- Note on H^- charge exchange Injection
  - No septum … different turns injected in same phase space regions
  - Longer pulse and lower beam current with Linac4

Injection of protons from Linac4 into the PSB – C. Carli

- 50 MeV protons from Linac 4
  - Beam current about a factor four lower (40 mA instead of 160 mA)
  - Horizontal (norm. rms) emittance about a factor three lower (~0.3 μm instead of ~1.0 μm)
  - Pessimistic scaling for intensity reduction (for LHC and high intensities)
    - Keep the same injection bump, number of turns …
    - Intensity larger than ¼ the one available with Linac2 (better injection efficiency)
  - Optimistic scaling
    - Reduction only by ratio of brightness from Linac: factor 3/4
    - Slower injection bump (KSWs) and more injected turns
  - Simulations of injection required for more precise picture
  - May-be useful depending on LHC request (e.g. 75 ns LHC beam with double batch PS filling)

- 160 MeV protons from Linac4
  - Technical issues: strengths of Linac2 equipments in the injection line (distributor, vertical septum, vertical bend, injection septum & bumpers …)
  - Not of interest:
    - Less intensity with shorter revolution period (1.0 μs instead of 1.6 μs @50MeV)
    - Higher energy not of interest to mitigate space charge effects (lower intensity)

Summary

LINAC2	50 MeV	160mA	100μs 1Hz	15 turns	Present situation
LINAC4 + present PSB injection	50MeV	40 mA (chopped)	400μs 1Hz	15 turns (limit of present distributor)	Can make some of the LHC beams, needs simulation.
LINAC4 + new distributor	50MeV	40 mA (chopped)	400μs 1Hz	25 turns	*Can we profit from smaller emitt?*
LINAC4 + DIS+ SMV + SMH?	160MeV	40 mA	400μs 1Hz	25 turns	PSB can handle 160MeV proton w/o major refurbishing. Will not profit from higher injection energy because of the low current.

Conclusions

- Linac4 can accelerate protons both to 50 and 160MeV
- Linac4 (low current - long pulse) is not optimal for delivering protons to the PSB
- Linac4 could deliver enough 50 MeV protons to make some LHC beams, but PBS simulations are needed to confirm.
- Linac4 can deliver a 160MeV proton beam with the same qualities as the nominal H- beam. Injection into the PSB is not straightforward.