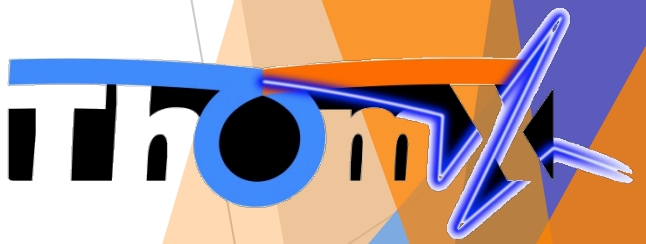
The ThomX synchronisation scheme



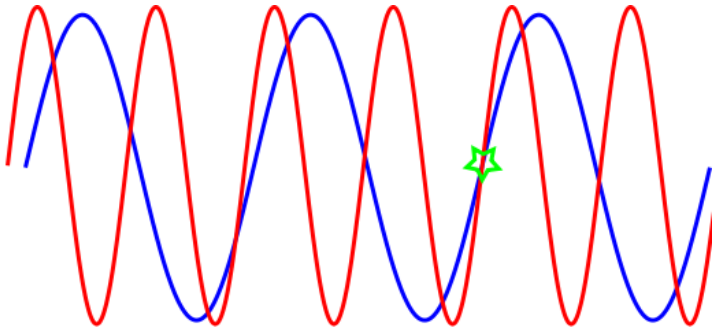
Nicolas DELERUE

LAL

Programme Investissements d'avenir de l'Etat ANR-10-EQPX-51. Financé également par la Région Ile-de-France. *Program « Investing in the future » ANR-10-EQOX-51. Work also supported by grants from Région Ile-de-France.*

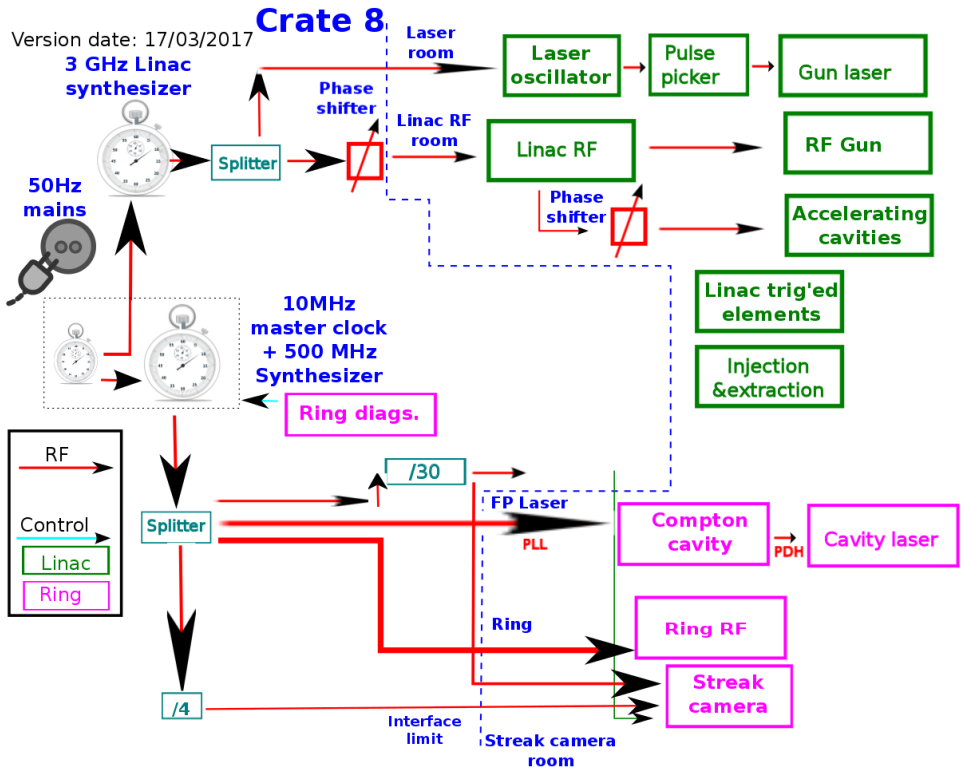
ThomX frequencies

- The ThomX gun and linac will be based on the the LEP Injector Linac (LIL) technology and use a fixed frequency of 2998.55MHz.
  - To get the maximum accelerating gradient in the gun its frequency will be fixed by the cooling water.
- The ThomX ring will operate at the 30th harmonic of 500MHz (16.7MHz).
  - The frequency of the ring will change due to environmental variations.
  - Acceptable ring frequency variations are up to 1% (we expect much less)
- As a consequence, if we set the ring frequency at a sub-harmonic of the linac frequency at a given time, this will no longer be true a few days/weeks later.
- We choose different frequencies and heterodyne operations.



Two RF frequencies

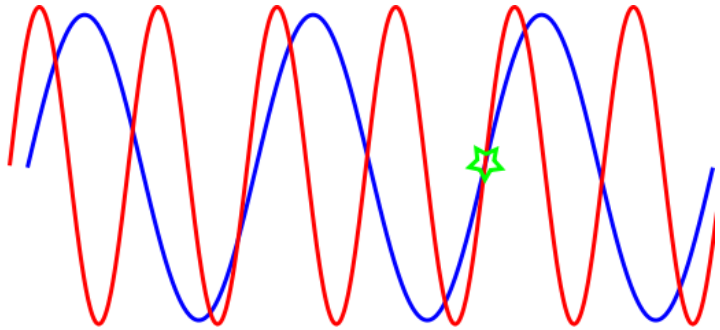
- With this scheme the linac and the ring have their own clock and live their own lives…



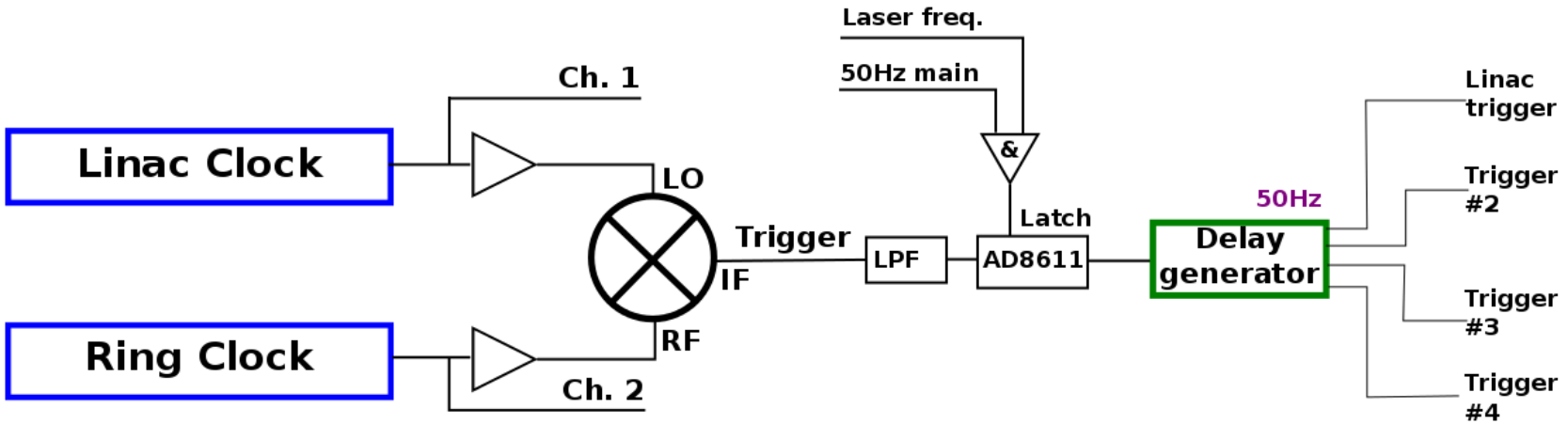
- However with independant clocks it will be difficult to pass electrons fro one to each other.

Finding the correct time to trigger injection

- Even two truly independant clocks are sometimes in phase…



- We will use a mixer to detect these coincidences

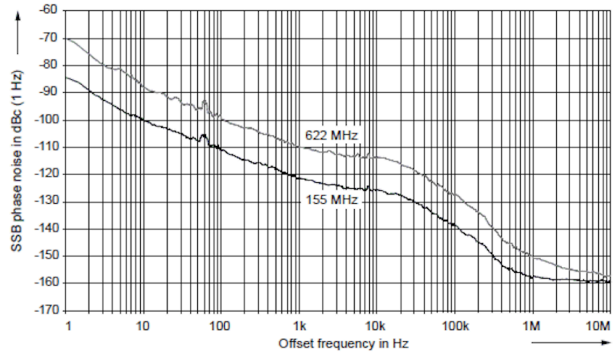


Heterodyne triggering tests

- We have done several tests (also for another project) on heterodyne triggering.
- The noise is obviously better if we operate at lower frequencies.
- A jitter below 1ps is expected.
- For it to work the ring must NOT be at an harmonic of 2998.55MHz.
- Instead it must be at least 5kHz away from such harmonic…
- To avoid another problems with the mains all triggering will be done with the 50Hz electrical grid potential will be 0V.
- With a frequency difference of 5kHz this leads to a trigger within 0.2ms of the mains crossing 0V.

Clocks Hardware

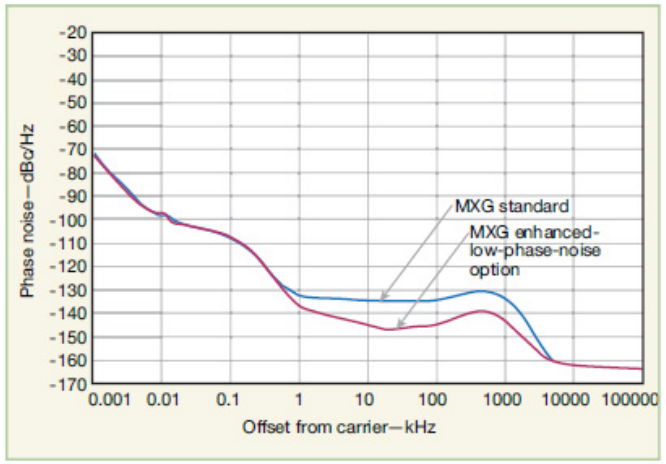
- Linac Clock: Rohde & S SMA-100A, up to 6GHz, Low phase noise



Clock synthesizer (R&S®SMA-B29 option): SSB phase noise measured with R&S®SMA-B22 option.

- Ring Clock: Keysight N5181B MXG X-Series, up to 3GHz, Low phase noise, AM FM Phase noise modulation.

4. The MXG signal generators employ a triple-loop synthesis approach and unique frequency plan to achieve outstanding spectral purity to 6 GHz.



Firing everybody at the same time

- Once we know that the linac and the ring are in phase, we can fire everything at the right time…
- For that we will use a delay generator.
- Product selected: 3 x Greenfield GFT1020.
- Triggering will be 50 Hz or « On demand » (from ~25Hz to single shot).

Datasheet du GFT1020

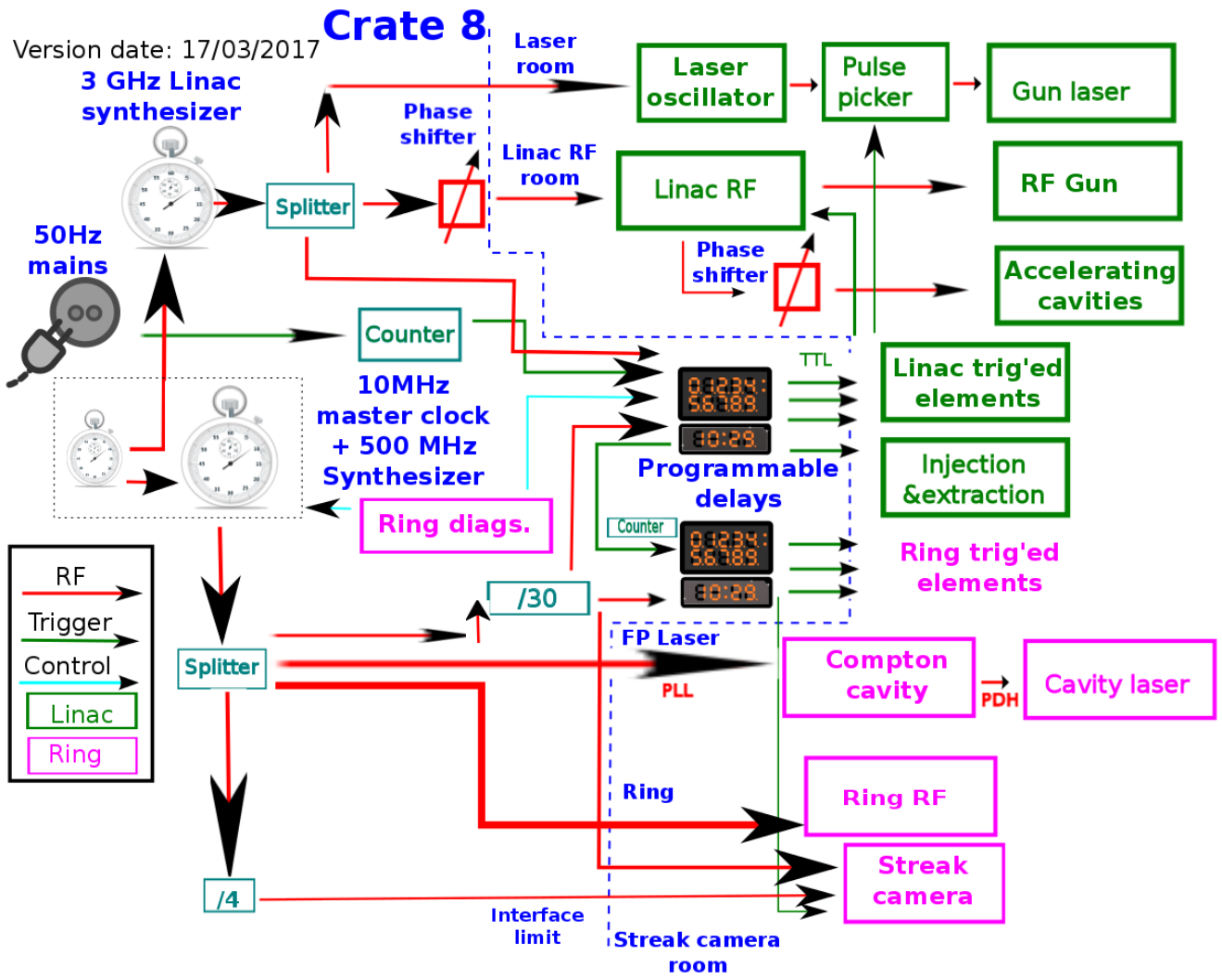
GREENFIELD TECHNOLOGY

GFT1020
20 Channel Digital Delay Generator

Features

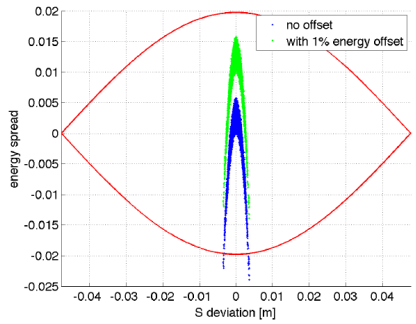
- 20 independent delay Channels
  - 100 ps resolution
  - 25 ps rms jitter
  - 10 second range
- Output pulse up to 6 V/50 Ω
- Independent trigger for every channel
- Fours Triggers
  Three are repetitive from three internal generators
  One is single-shot from External input, Push button or Software
- External Clocking up to 100 MHz

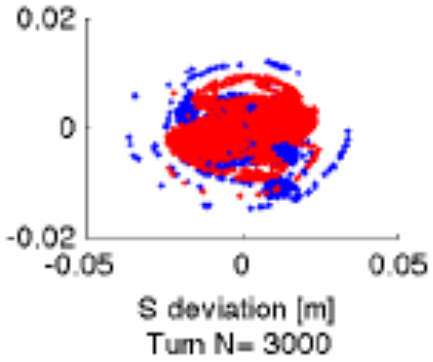
Complete synchronisation scheme



Fibre or not fibre?

- Some very interesting paper report on very low jitters achieved with fibre-based timing distribution systems.
- Such systems can be purchased commercially.
- Jitters below 100fs seem achievable…
- However
  - The ThomX bunch length is several ps in the linac.
  - The buckets in the ring will be about 250ps and such duration will be reached after a few thousand turns.
- A jitter of 1ps will not have a significant effect on the machine's performance.
- Analog to fiber conversion also introduces a jitter
  => not suitable for time critical elements (pulsed elements).
- We decided not take the fibers' option!

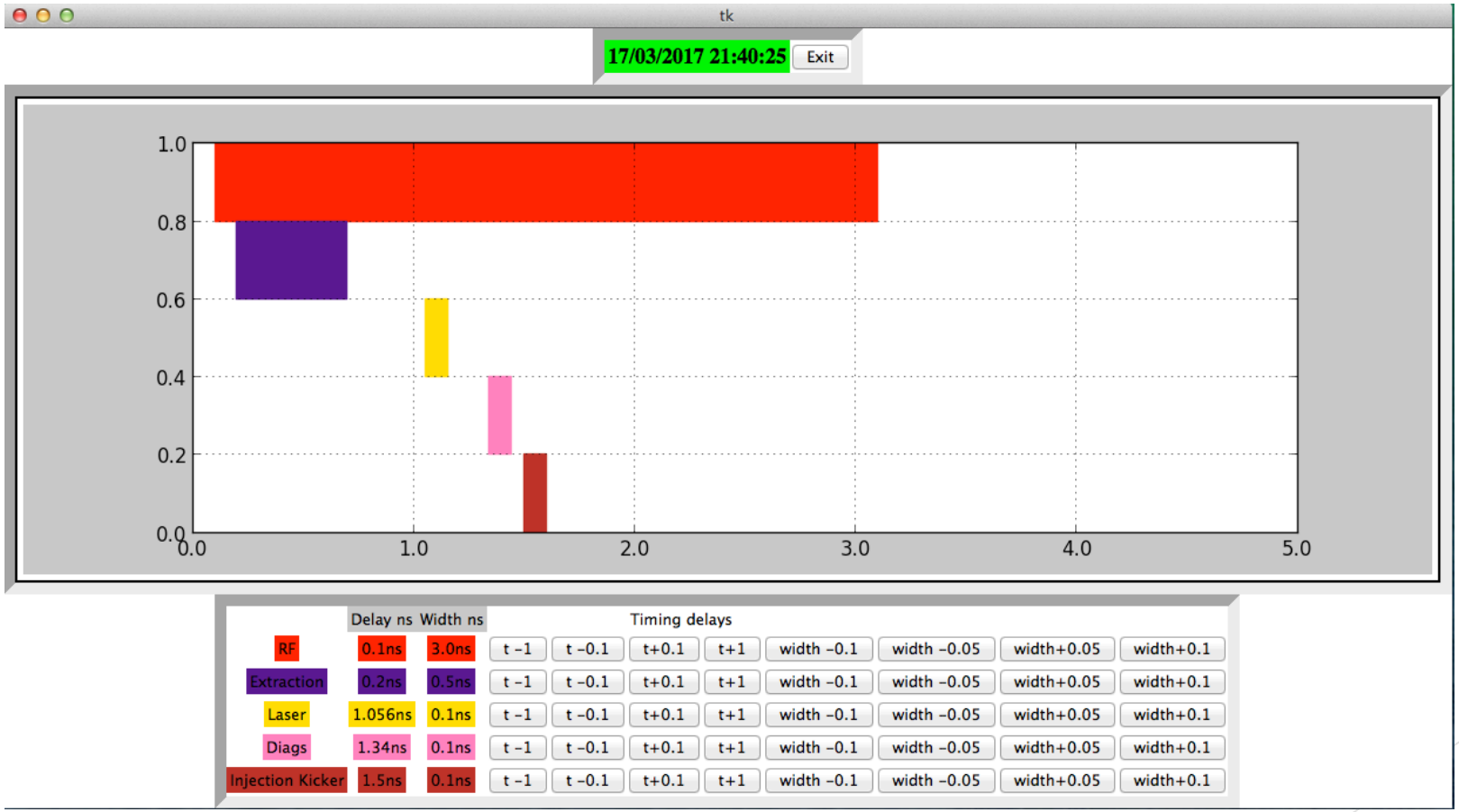




I. Drebot's thesis

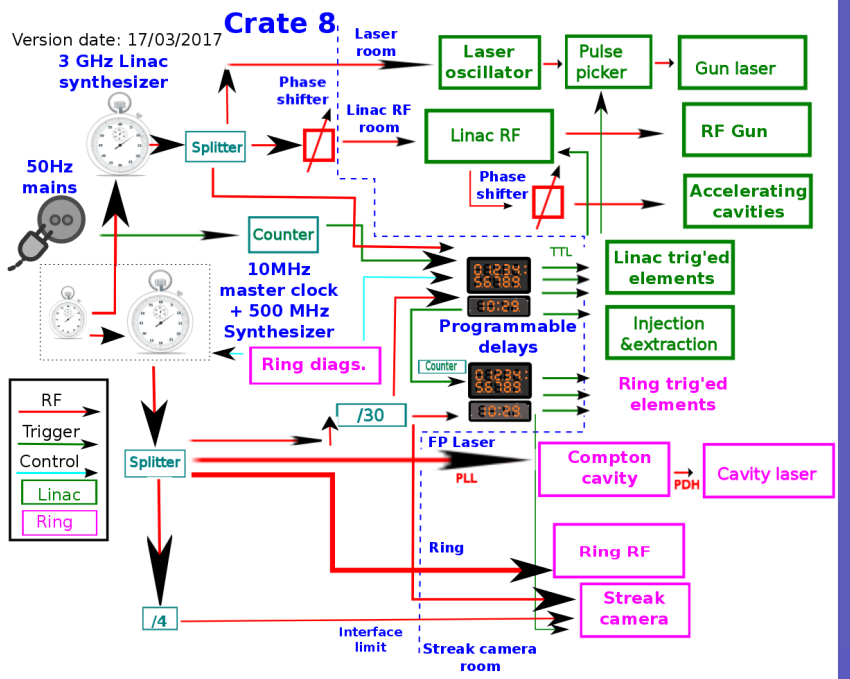
Control panel

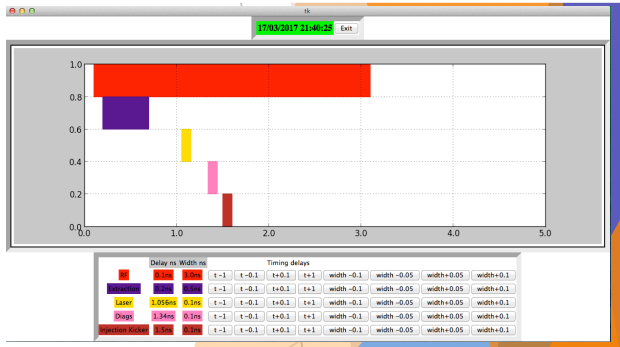
- Already written (Python/Tkinter) interfaced with Tango variables.



Summary

- The ThomX synchronisation scheme is based on heterodyne triggering.
- Requirements on the jitter are of the order of 1ps.
- RF synthesizers are already delivered and tested.
- Delay generators ordered (delivery expected in April/May)
- All components specified. Some minor RF components (phase shifter) still to be ordered.
- Control graphical interface ready.





Datasheet du GFT1020

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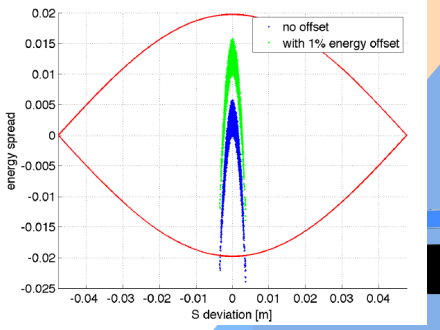
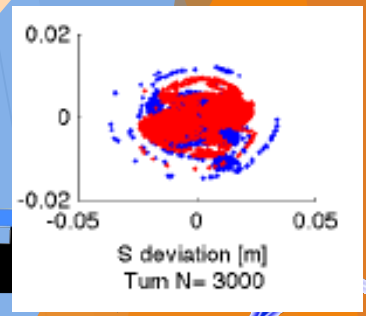
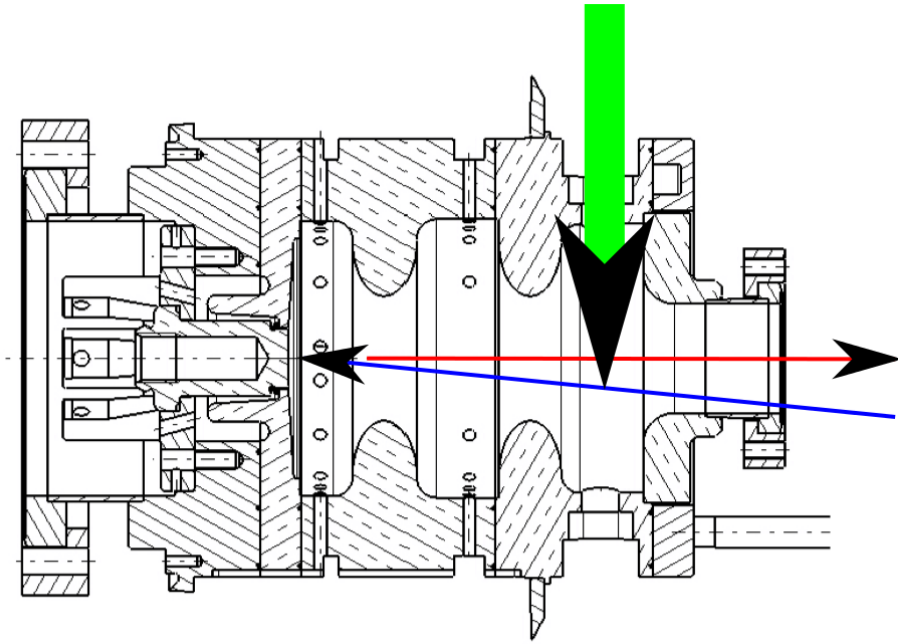


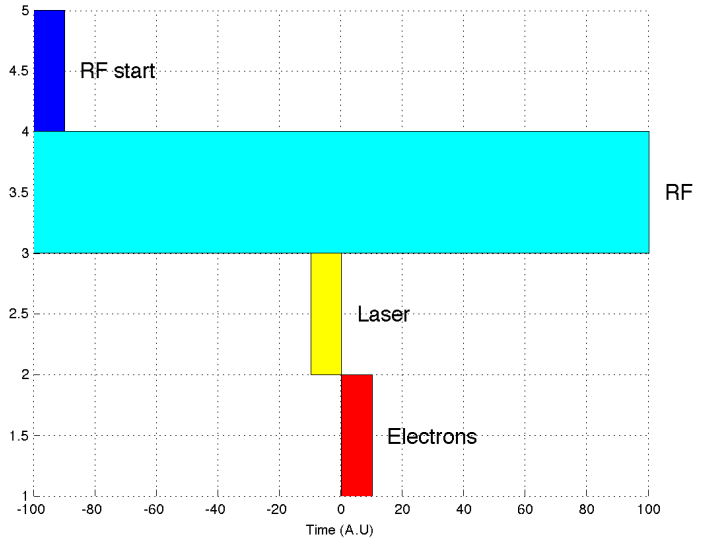


Thank you for your attention

ThomX, from injection to extraction….

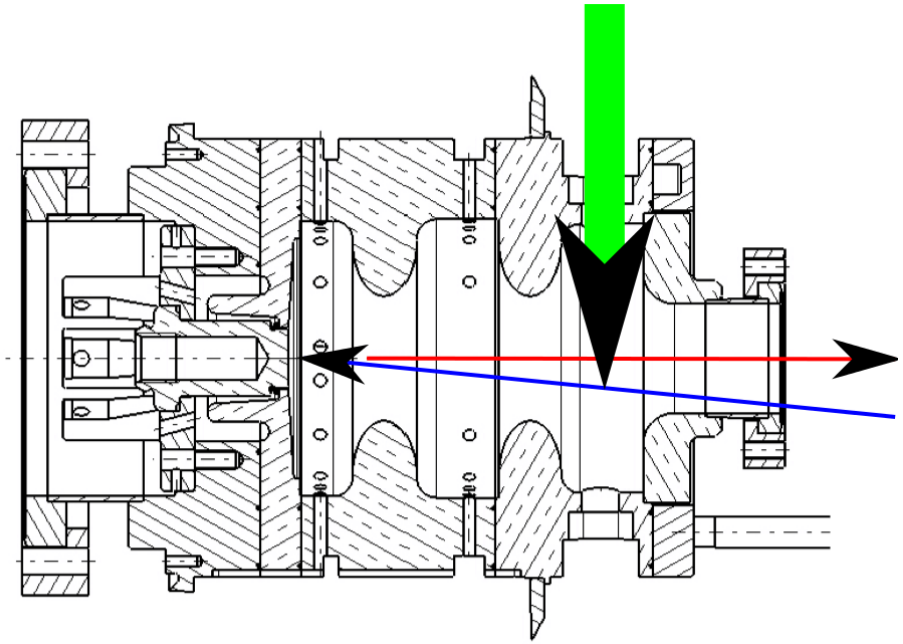
- We will look at what happens in ThomX from injection to extraction.
- (1) Electrons production
  - This happens when the laser hits the photocathode
  - However the electrons will be accelerated only if the RF is present and has already filled the gun.

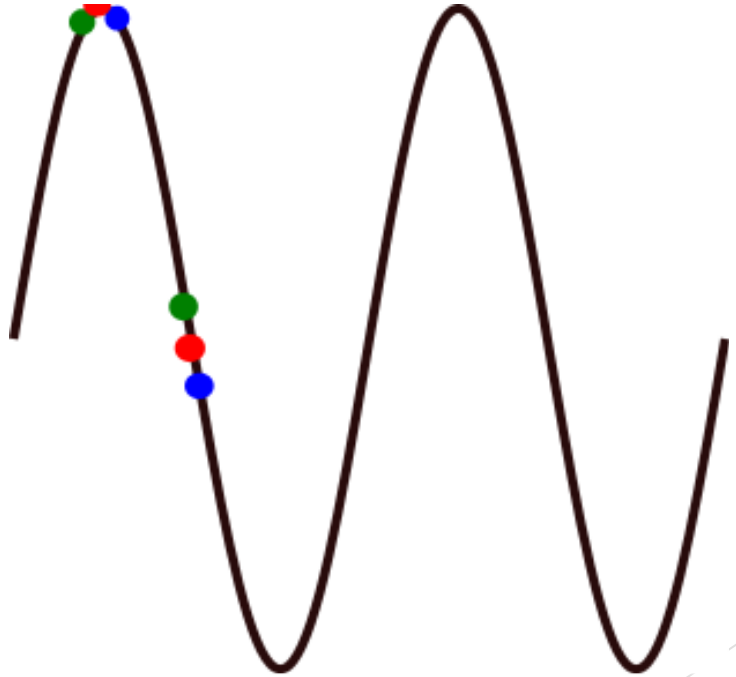




ThomX, from injection to extraction….

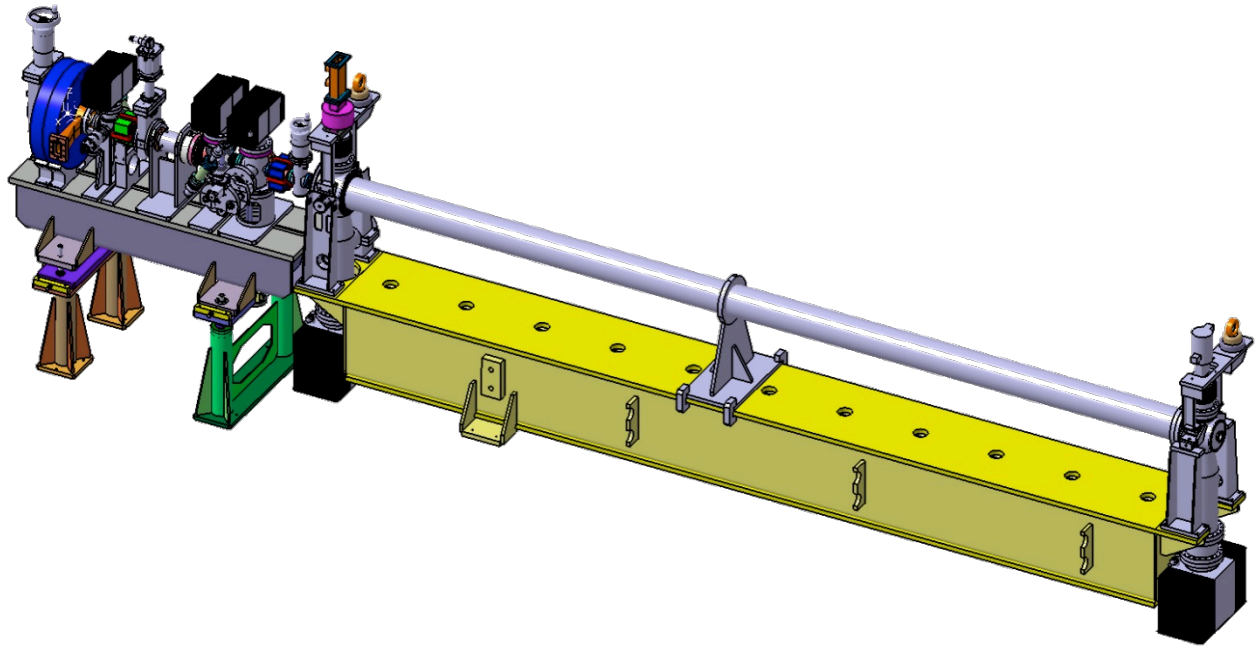
- (2) Electrons acceleration
  - To be accelerated the electrons must be at the correct phase in the RF.
  - Any variation in the RF phase, either in the gun or in the linac will result in energy fluctuations.

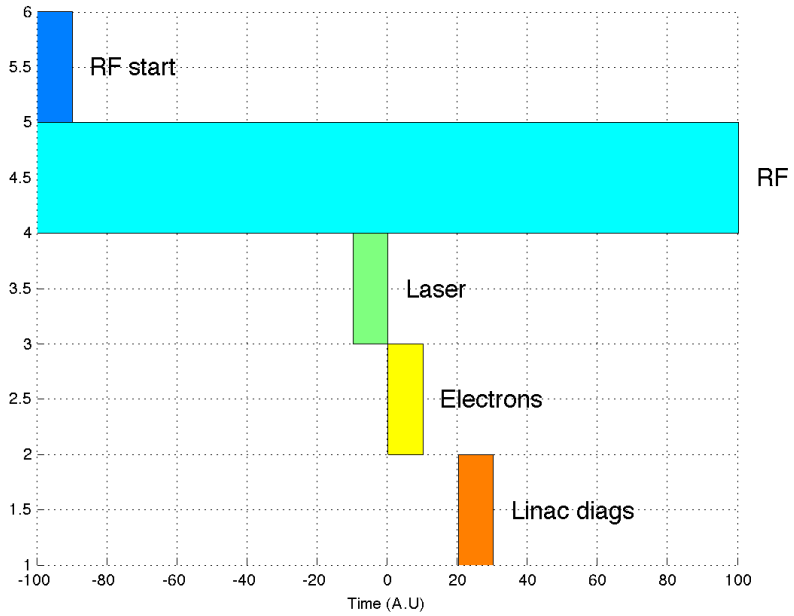




ThomX, from injection to extraction….

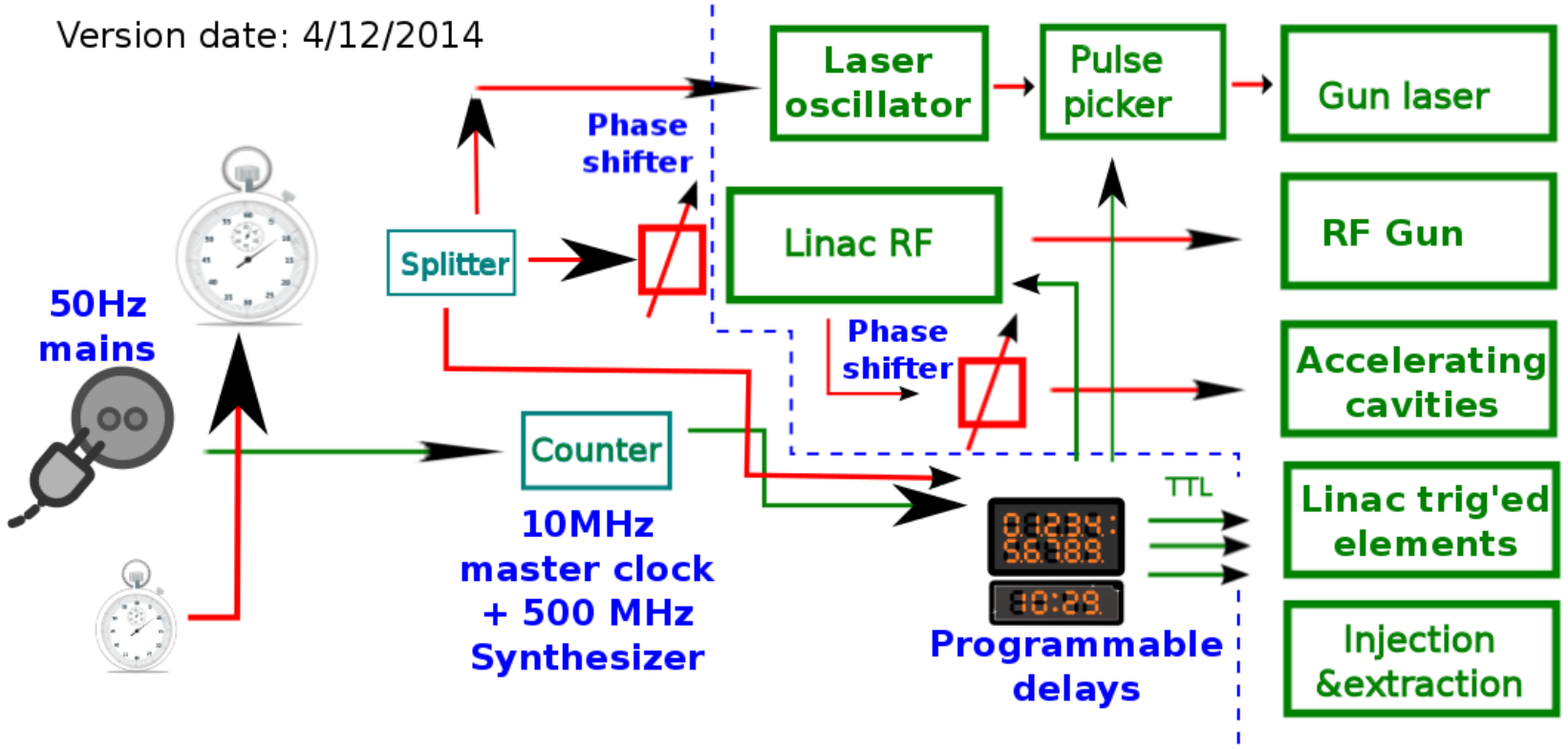
- (3) Linac diagnostics
  - All the linac diagnostics must be ready to take date when the electrons arrive.
- This also require the mains' phase to be the same from shot to shot.





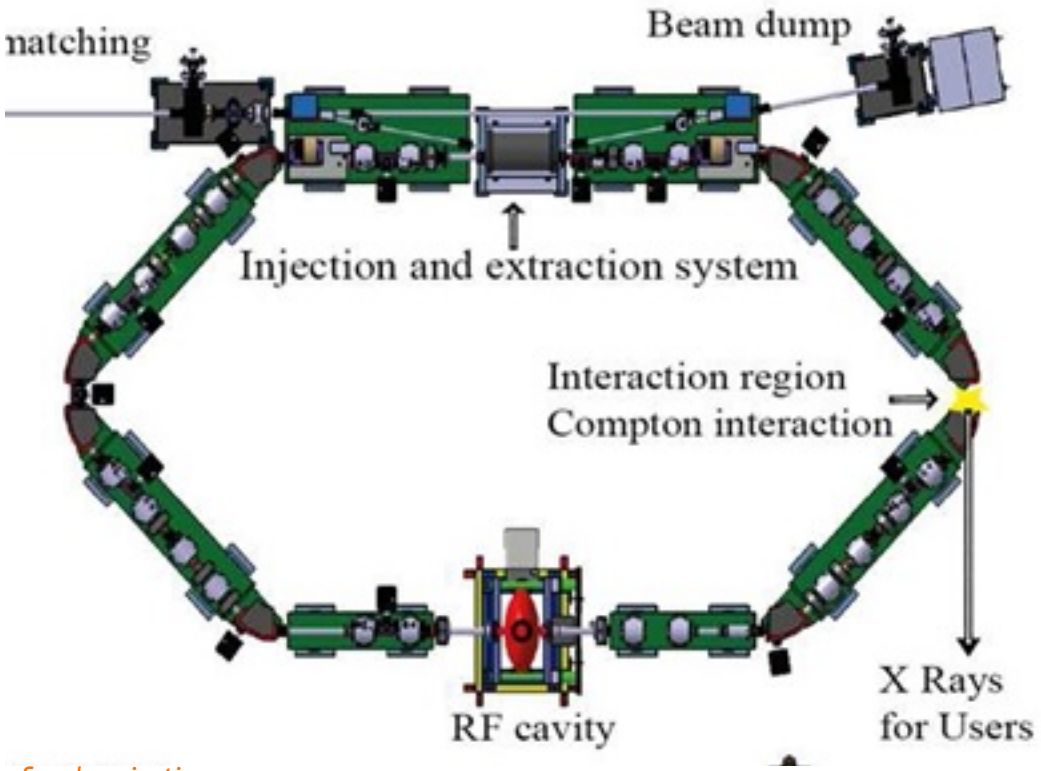
ThomX, from injection to extraction….

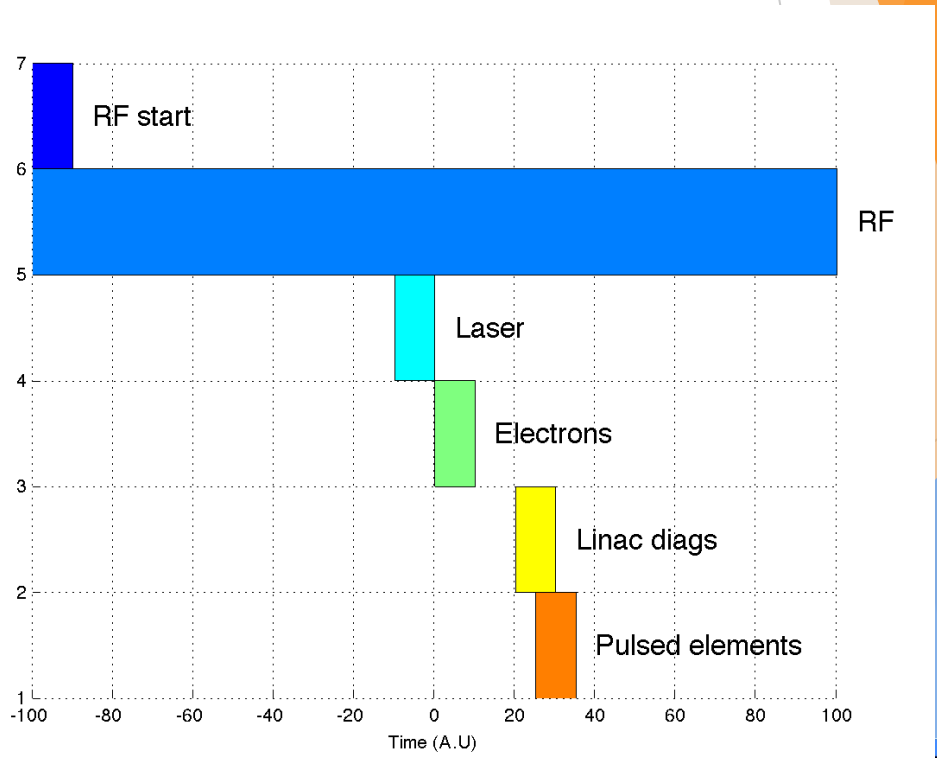
- Timing distribution for the linac



ThomX, from injection to extraction….

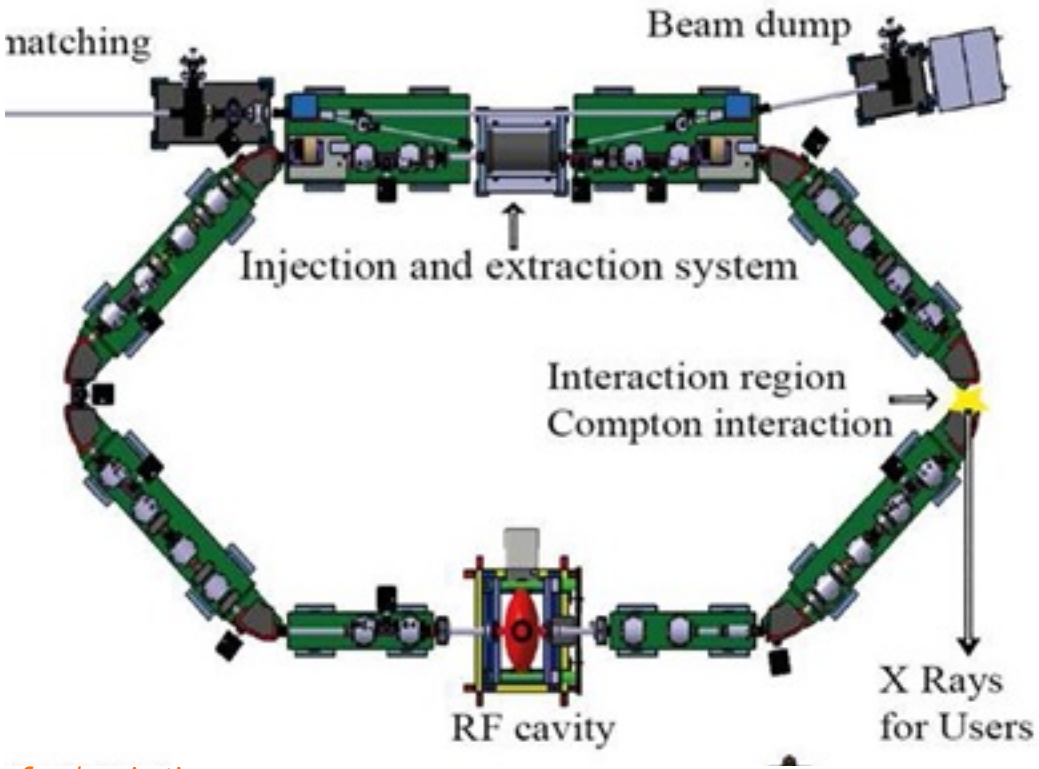
- (4) Ring injection
  - Once the electrons reach the end of the linac they enter the ring.
  - The pulsed elements (septum, kickers,…) must fire at the good time.

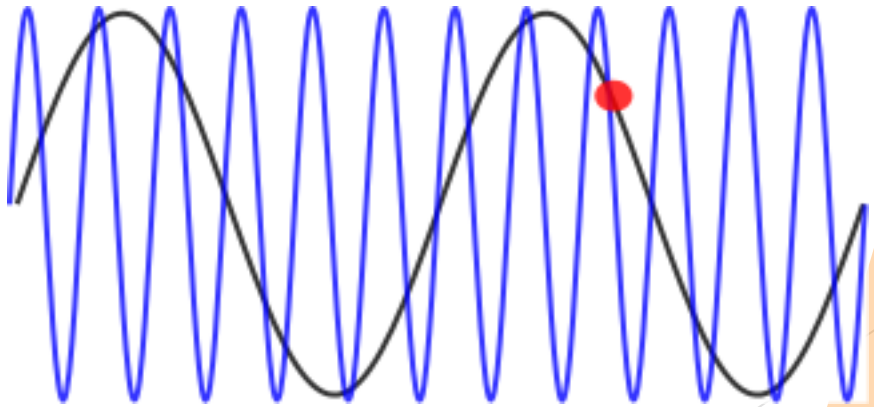




ThomX, from injection to extraction….

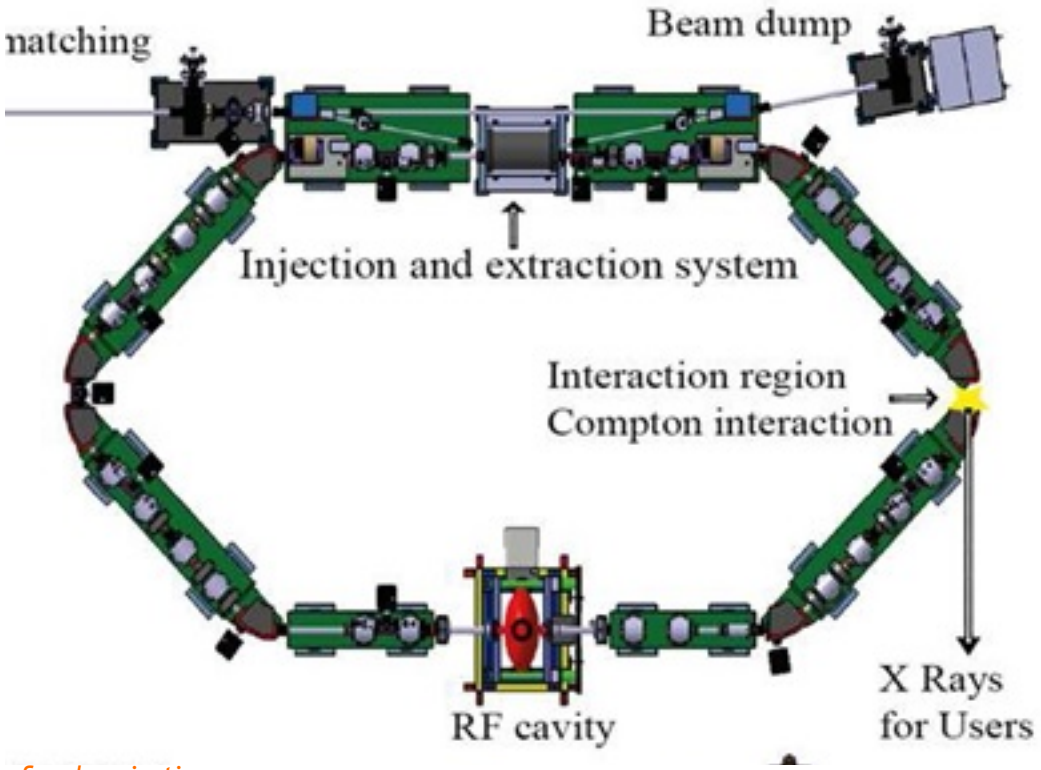
- (4) Ring injection
  - The phase at which the electrons are injected is very important, otherwise they won't be captured correctly in the ring!

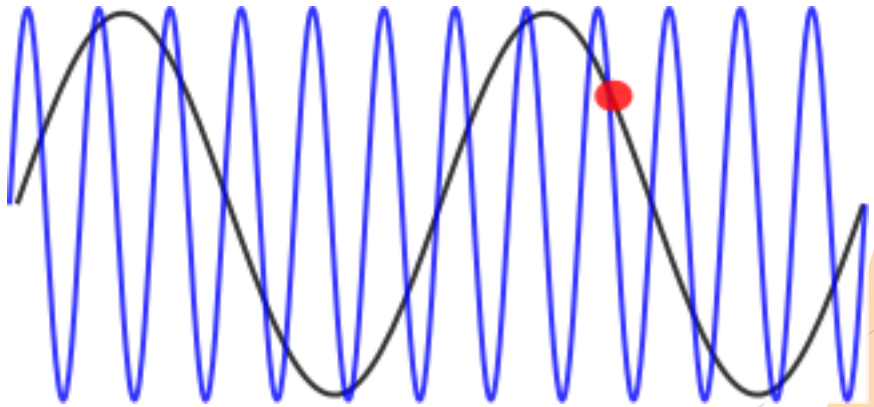




ThomX, from injection to extraction….

- (4) Ring elements
  BUT the ring frequency can change!!!
  - The ring must have its own clock!
  - The injection must occur only at a fixed phase of the ring wrt to the linac…
  - This clock is also distributed to all ring diags, the FP cavity and the X-line.





ThomX, from injection to extraction….

- (4) Ring extraction
  - After 20 ms the pulsed elements must fire again to extract the electrons
  - In fact the pulsed element do the extraction and injection on the same HV pulse.
  - So the extraction is triggered by the following injection.