Requirements for the PXIE MEBT chopper

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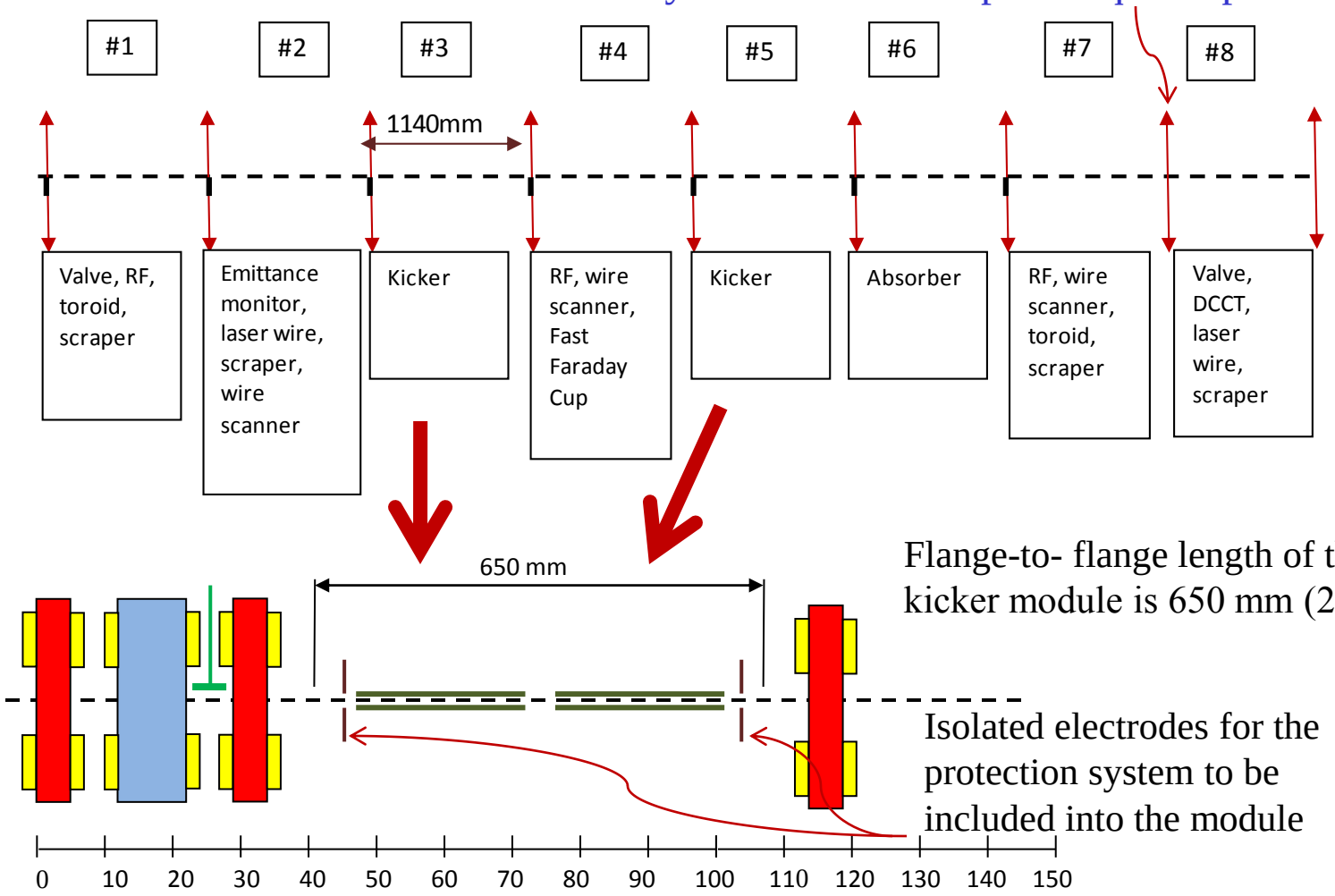
Project X meeting

Chopper for PXIE

- The chopper system for PXIE should demonstrate all features required for Project X
  - At this stage, no bunch-by-bunch current regulation
  - As a result, no kickers to correct a partially scraped beam
  - Two 50 cm kickers with ~180 deg of betatron phase advance in between
- Possible timeline
  - First beam in PXIE- May 2014
  - Production of the choppers to be installed into PXIE starts- May 2013
  - Fabrication of full-size prototype(s) starts- May 2012
  - Production design of prototype(s) starts- Jan 2012
  - Conceptual design of prototypes starts- Nov 2011
- It would be useful to set very soon the physical size for any possible design and agree about chopper specifications
- To start the discussion, corresponding drafts are presented below

Length of the chopper modules

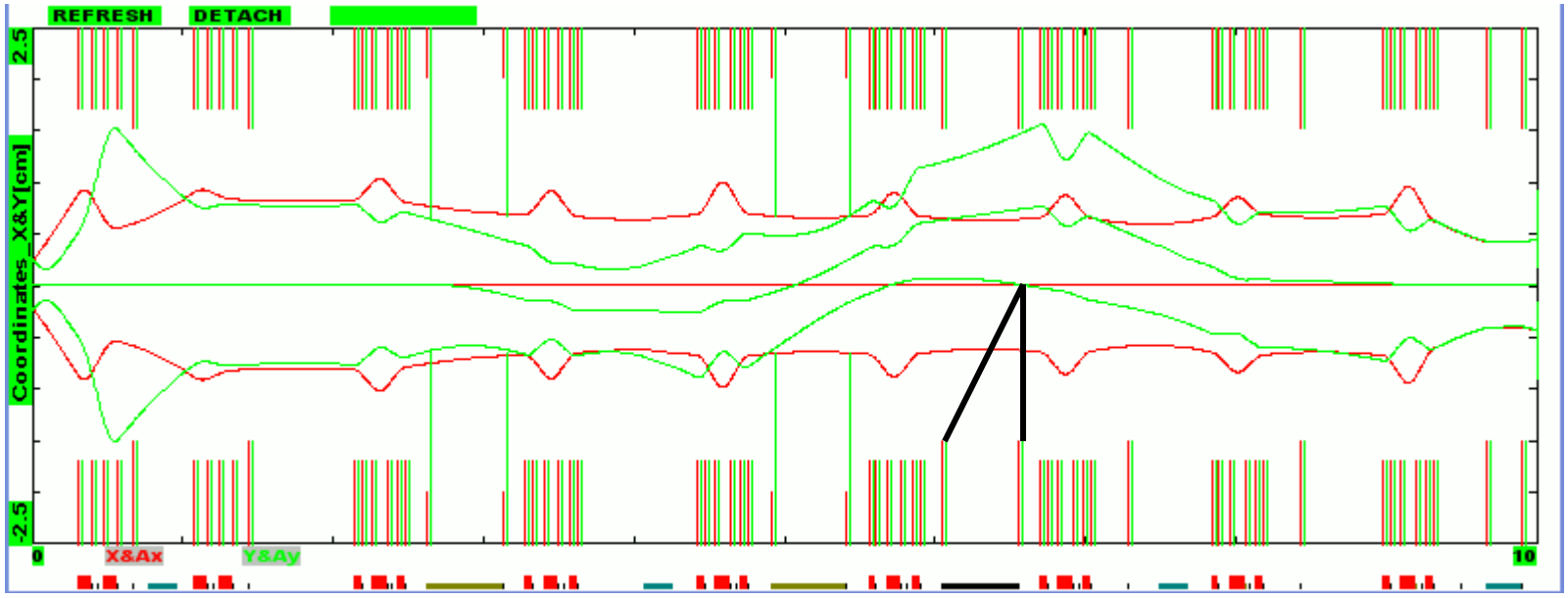
- Present arrangement of PXIE MEBT
  - Consists of sections bounded by a doublet or a triplet of quadrupoles



Flange-to- flange length of the kicker module is 650 mm (25.6”)

Isolated electrodes for the protection system to be included into the module

PXIE MEBT trajectory



- The bunches to be passed go through the MEBT being deflected up, and the bunches to be dumped are deflected down
  - Allows to use the aperture more effectively
- Two schemes of pulsing the chopper
  - In the scheme with unipolar pulses, the deflection up is made by stationary dipole correctors
  - In the scheme with bipolar pulses, both deflections are made by the chopper

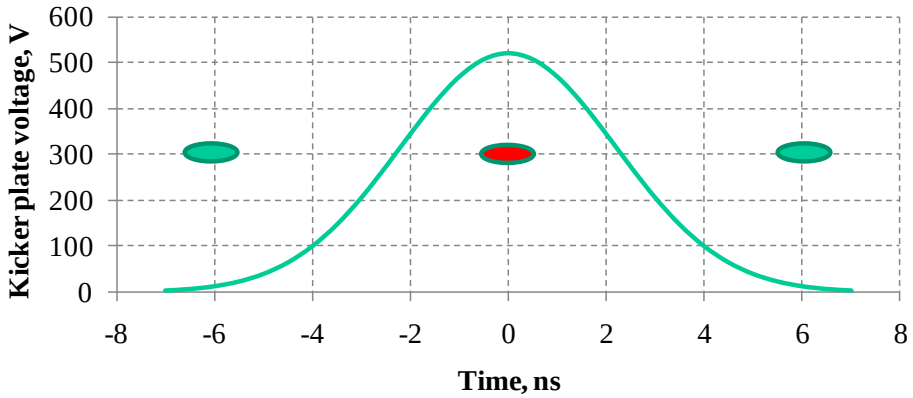
Assumptions

- Envelops of the chopped and un-chopped bunches are separated at the absorber location by 6 sigma
- The chopping voltage of opposite polarities is applied to both plates
- Normalized transverse rms emittance is 0.25 μm
  - The last version of Valery's optics allows passing the beam between kicker plates with a ~13mm gap.
    - For 6 sigma beam shift at the absorber location
    - We suggest to install protection electrodes at 13 mm separation and use 16 mm gap between kicker plates
- Longitudinal rms emittance is 0.25 μm
  - The bunch length at kickers is ~ 1.3 ns (6 sigma)
    - 6 sigma needs to be removed for chopped bunches
- Allowed perturbation of the transverse rms emittance of un-chopped bunches is 10%
  - For the unipolar scheme, requires 5% of the residual voltage for passing bunches

$$\frac{\Delta\varepsilon}{\varepsilon}\approx\left(\frac{\delta r}{\sigma}\right)^2=\left(6\frac{\delta r}{6\sigma}\right)^2=\left(6\frac{\delta U}{U}\right)^2;\ \frac{\delta U}{U}\approx\frac{1}{6}\sqrt{\frac{\Delta\varepsilon}{\varepsilon}}\approx 5\%$$

Specifications for the MEBT chopper and its driver

- Any bunch of the 162.5 MHz CW train can either pass or be removed.
- Scheme with unipolar pulses
  - For the removed bunches, the voltage applied to each chopper plate needs to be above 500 V for total 1.3 ns around the bunch center.
  - For the passing bunches, the voltage remaining at the chopped needs to be below 25 V for total 1.3 ns around the bunch center.
- Scheme with bipolar pulses
  - The voltage applied to each chopper plate needs to be above 250 V for 1.3 ns around the bunch center.
  - For the passing bunches, the pulse voltage should be flat within ±10% for 1.3 ns



Example for a unipolar pulse with required characteristics: a Gaussian-shaped pulse of 520 V amplitude and sigma = 2.2 ns.

Additional requirements

- The chopper should survive a CW beam halo loss and an accidental loss of a large portion of the beam (for a short time)
  - Need to be examined by simulating possible scenarios and designing the beam protection system
  - Example of possible requirements:
    - CW loss to each kicker plate of 20 W (0.1%)
    - Accidental loss of 10J (10 kW X 1 ms)
  - Possible presence of a beam halo means that a ceramic that can be irradiated by the halo particles is a problem

- The chopper modules should be bakeable to 150C
  - This needs to be examined in the time of designing of the vacuum system

Possible limitations

- If necessary, additional limitations can be discussed:
  - Portion of passing bunches is not more than 20%
    - During 1 μs element of periodicity, the total number of alterations (pass-> remove) or (remove->pass) is not more than (163/5) = 33
  - Beam removal for longer than 100 ns is made by LEBT kicker
    - Assumes ~50 ns rise/drop time in the LEBT kicker
  - Lower bandwidth of the chopper driver can be set to ~1 kHz
    - A DC offset is compensated with DC correctors
    - The beam is off for ~1 s to switch between timelines

- A reversed unipolar scheme, where only kicked bunches are passing, might be considered to decrease the average power
  - Factor of 4-5 decrease in the average power of the chopper/driver
  - Requires a 5% flat top
  - This scheme looks the best from the protection point of view
    - With the chopper off, the beam is at absorber