A Yet Another New MEBT Lattice and Remaining Uncertainties

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Recent MEBT lattices and outline

- Recent MEBT lattices
  - **2014.v1** (2014 baseline)
    - Chopper surrounded by a quad.
    - Misunderstanding in the chopper volt definition (4 kV for plate-to-beam-axis).
  - **2015.v0a** (presented at the Chopper Workshop in Jan)
    - Chopper and quad separated.
    - Proper chopper volt interpretation (plate-to-plate 5 kV).
  - **2015.v0b** (minor changes of 2014.v0a)
    - Reference for the Bilbao's integration.
  - **2015.v0c** (the current ESS version)
    - Implemented the Bilbao's integration work.
    - A few remaining uncertainties.
  - **2015.v1?** (next step)
    - Implement buncher and quad field maps.
    - ...
- In this presentation...
  - Check basic beam properties of the new 2015.v0c lattice.
  - Remaining uncertainties and their potential impacts on the lattice.
    - Integration of EMU and diagnostics box.
    - Chopper parameters.

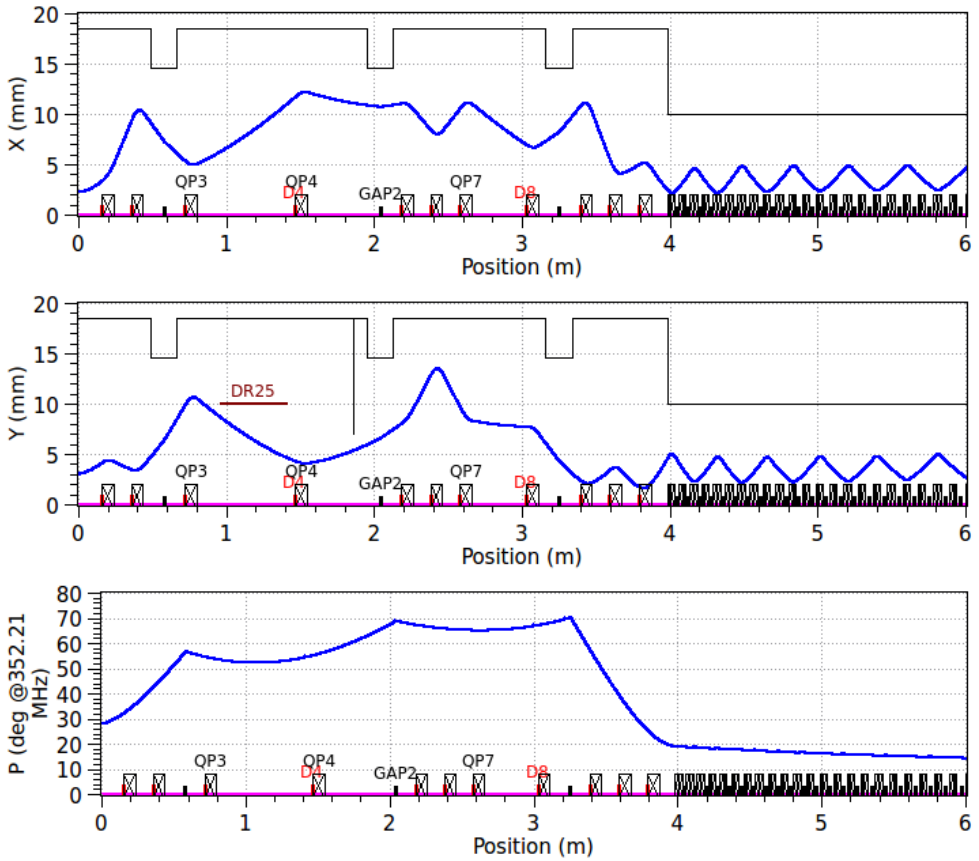
Lengths of elements and spaces in 2015.v0c

	2015.v0b	Bilbao's excel v3	2015.v0c
Quad	100 (10+80+10)	100 (6+88+6)	100 (6+4+80+4+6)
Buncher	190	180	180
Chopper	550 (50+450+50)	550 (50+450+50)	550 (50+450+50)
Dump	200 (150+0+50)	200	200 (150+0+50)
Initial drift	150	133 (30+103) ??	150 (72+35+43)
Final drift	100	113 (103+30) ??	100 (43+35+22)
Quad-quad drift	100	100 (102.6 for WS)	100
Quad-buncher drift	30	41	41
Chopper-Q4 drift	30	0	0
Q4-dump drift	120	102.6	150
Diag box drift	350	350	350 (400, 450)

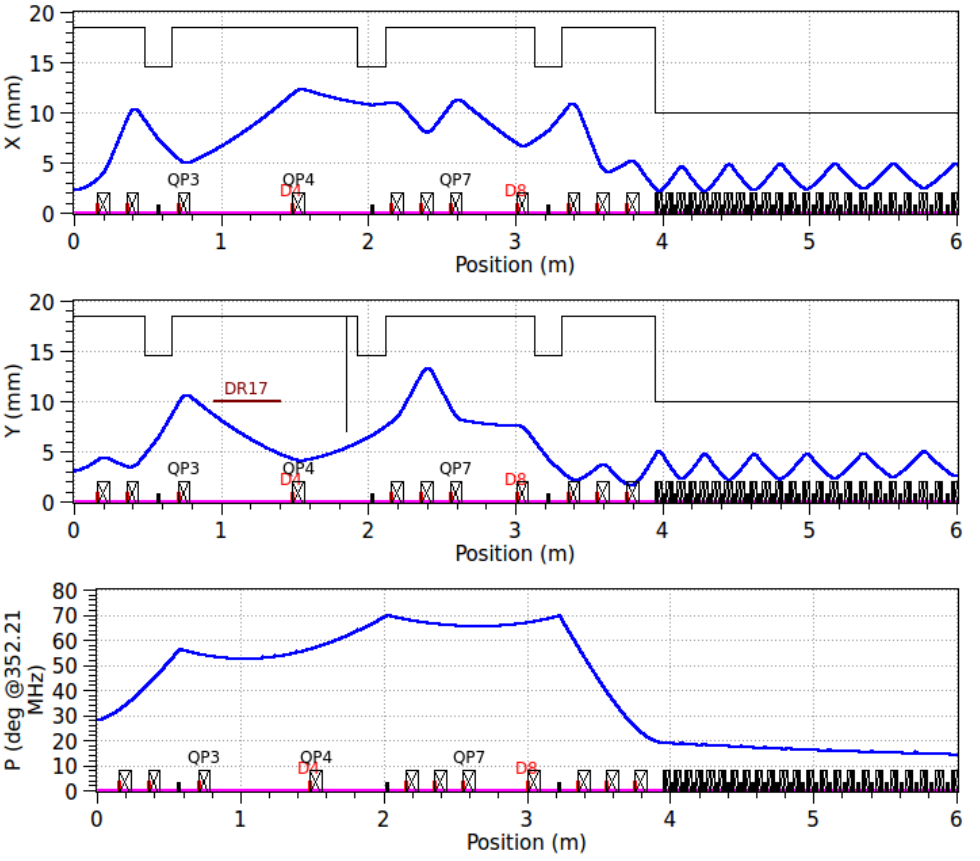
- Practically, the only change from 2015.v0b to 2015.v0c is in the quad-buncher space so the difference should be very small.
- From beam dynamics point of view, the initial drift certainly has some margin (a few cm ??) but the final drift is tighter. More about the interfaces from Aurélien?

2015.v0b vs 2015.v0c: envelopes

2015.v0c



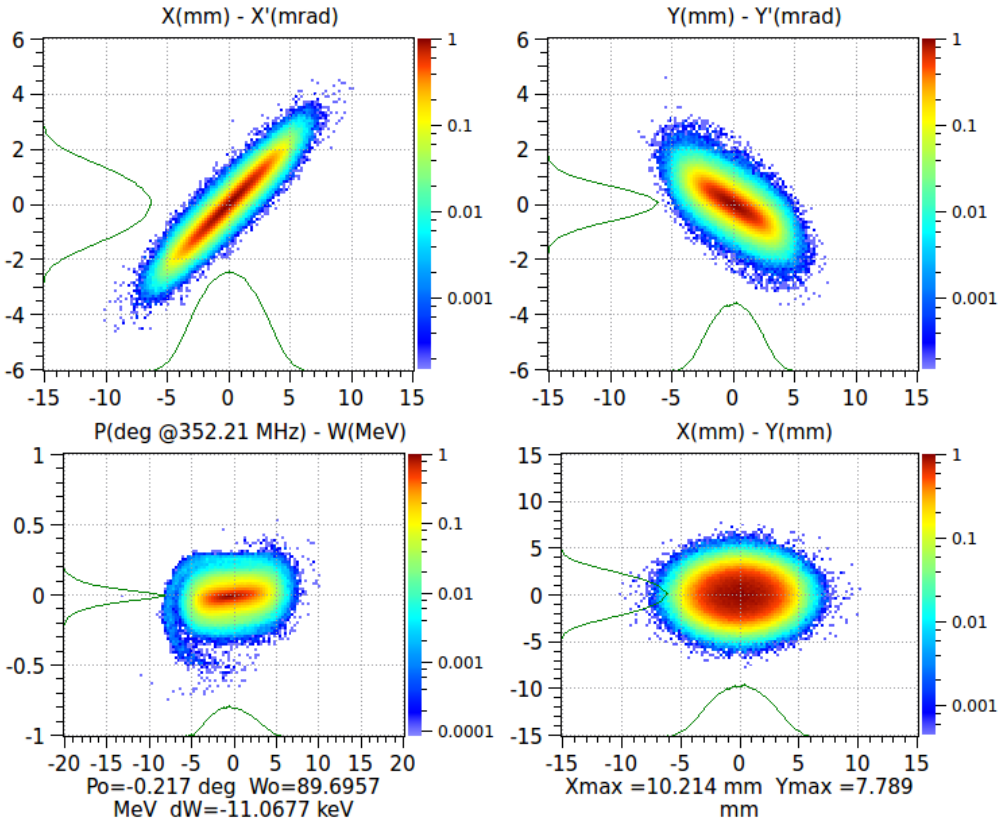
2015.v0b



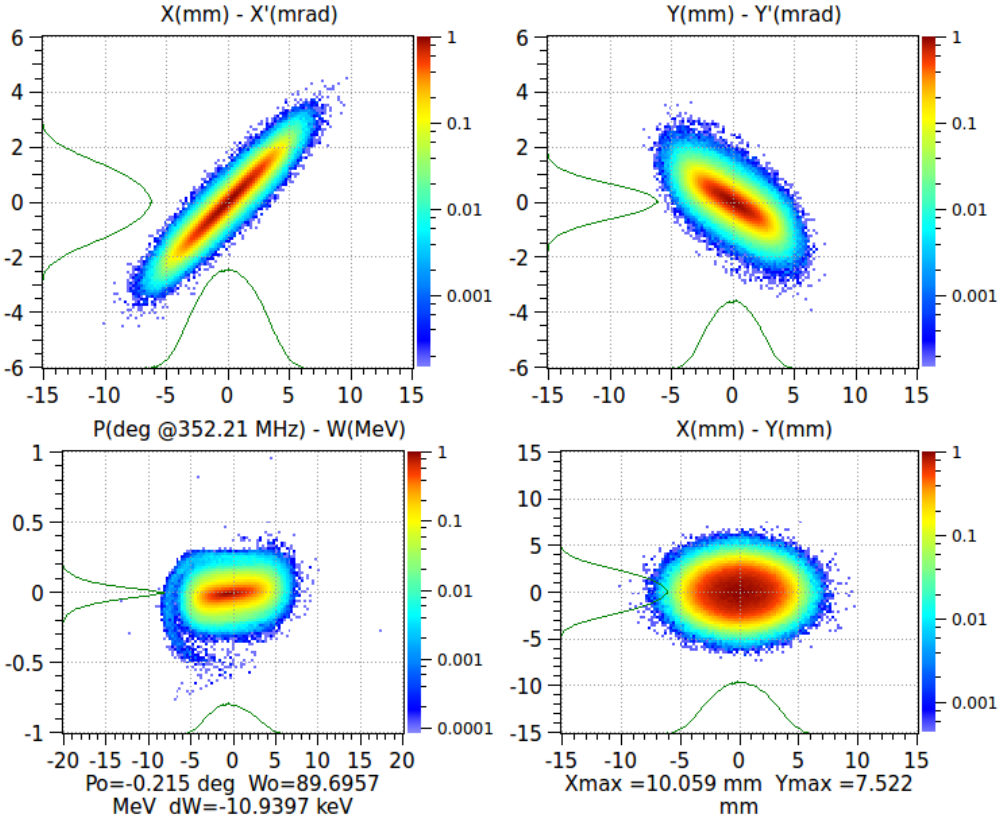
3σ envelopes. The two cases are almost identical and we can expect that so as beam quality.

2015.v0b vs 2015.v0c: DTL output distributions

2015.v0c



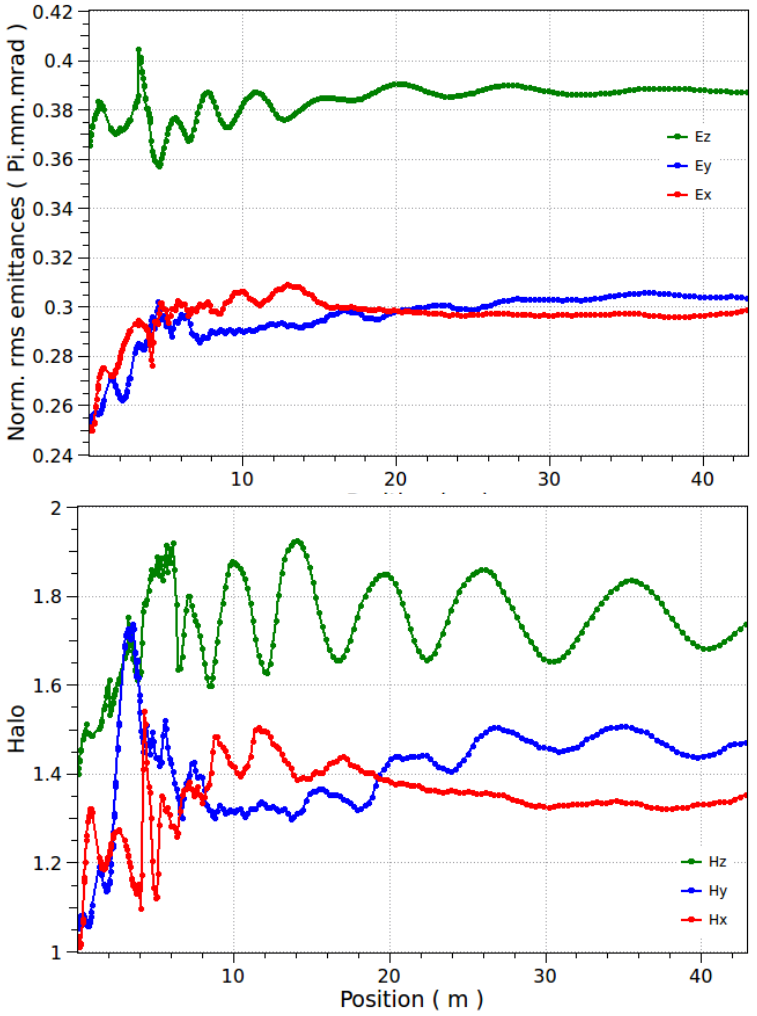
2015.v0b



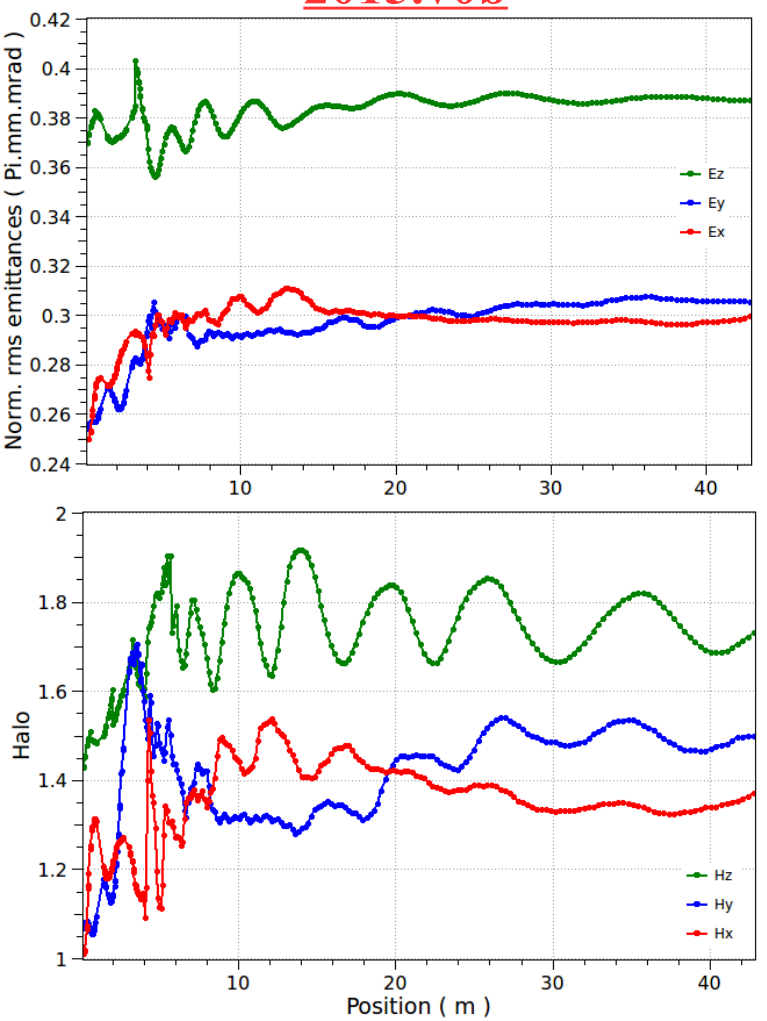
~1M macro-particles at the DTL exit. Again, the situation is like "Where's Wally".

2015.v0b vs 2015.v0c: emittances and halo

2015.v0c



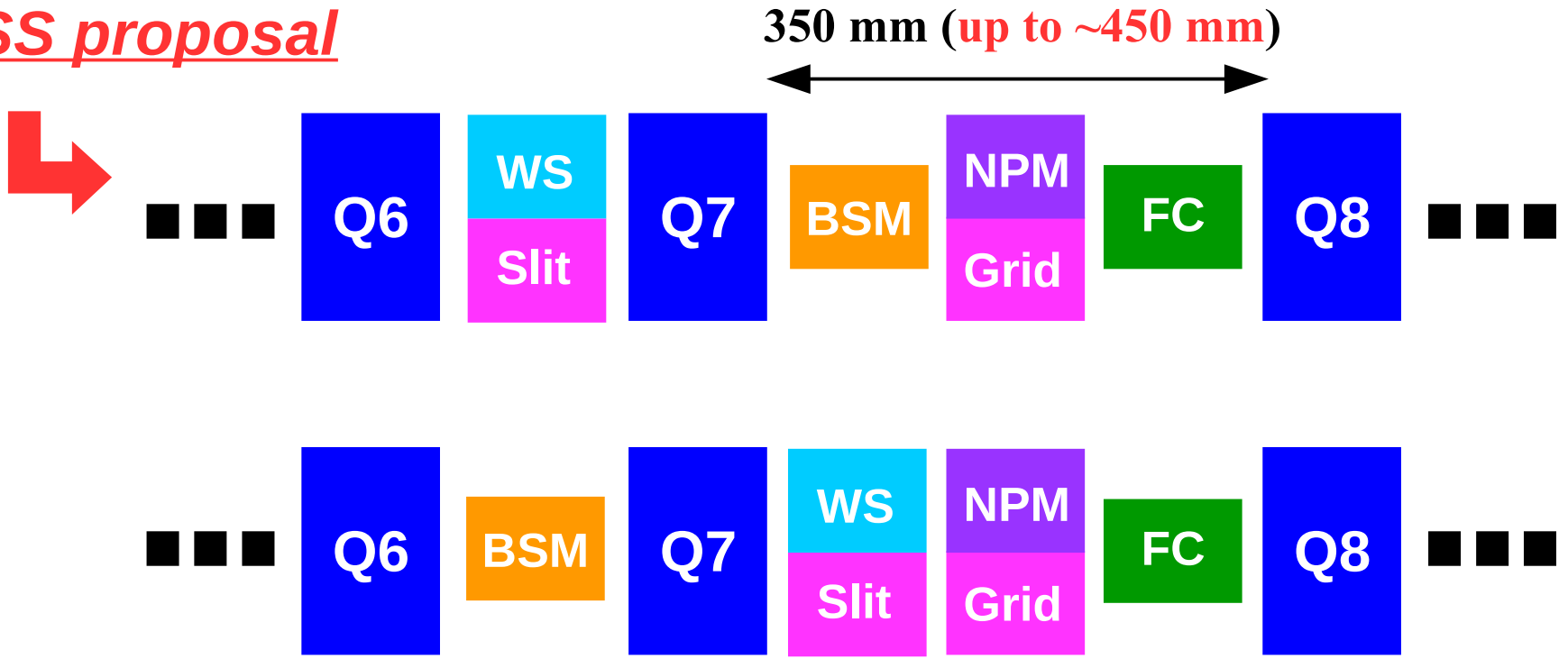
2015.v0b



- Emittances and halos are also very very close for the two cases.
- Matching is done with the envelope so can be still improved in simulations.
- **The new 2015.v0c is practically the same as 2015.v0b in terms of beam quality so the Bilbao's integration v3 is surely fine (after extending the distance to the dump) from the point of view of beam dynamics.**

Remaining uncertainty (1): EMU and diag box layout

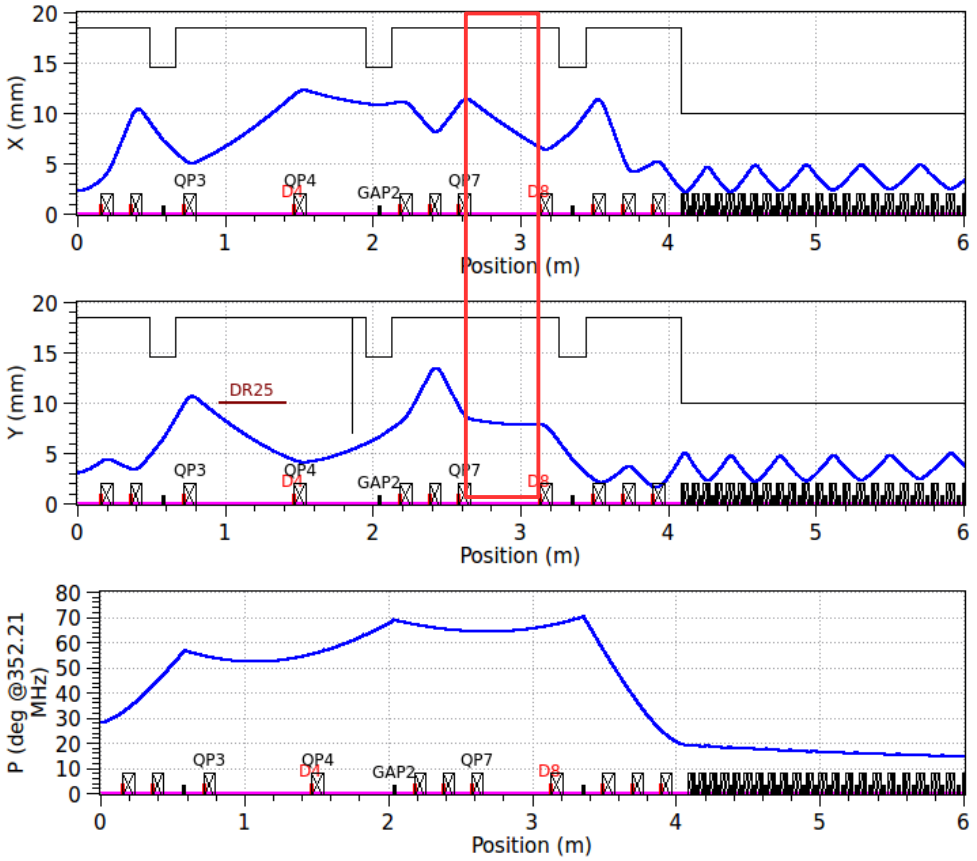
ESS proposal



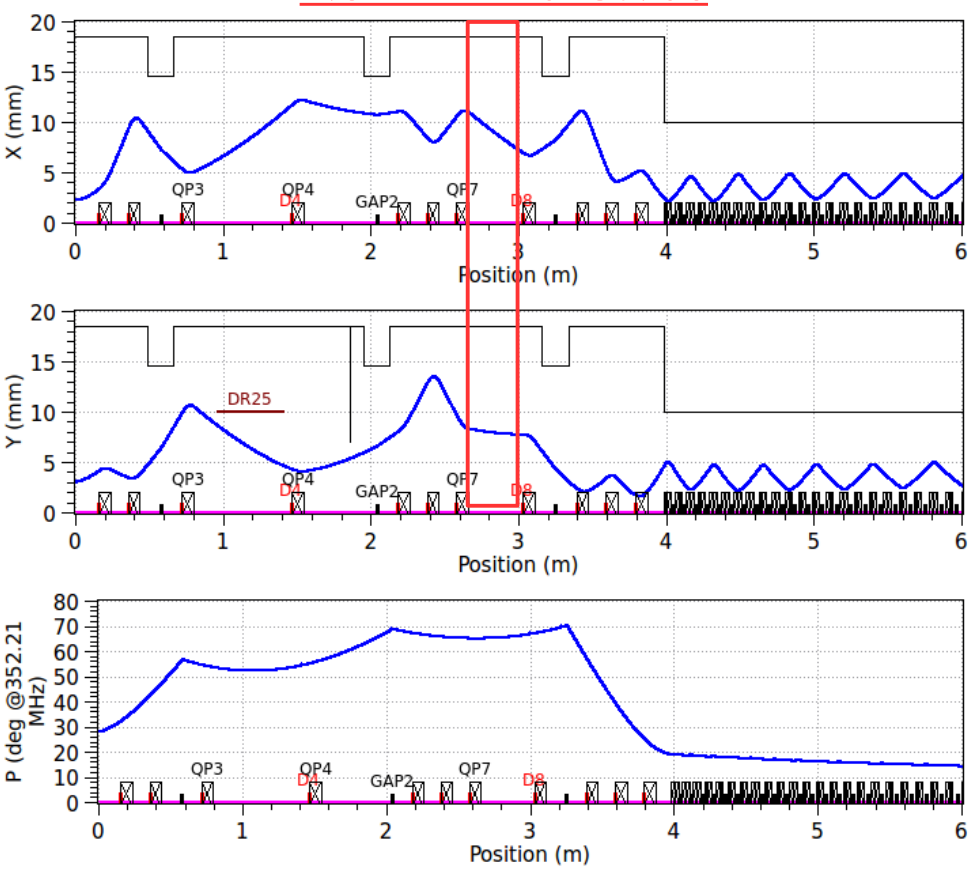
- Constraints:
  - FC should be the last in the diag box. (For tuning/commissioning)
  - Slit-grid distance should be at least 350-400 mm.
  - BSM estimated ~150 mm.

450 mm for the diag box space: envelopes

450 mm case



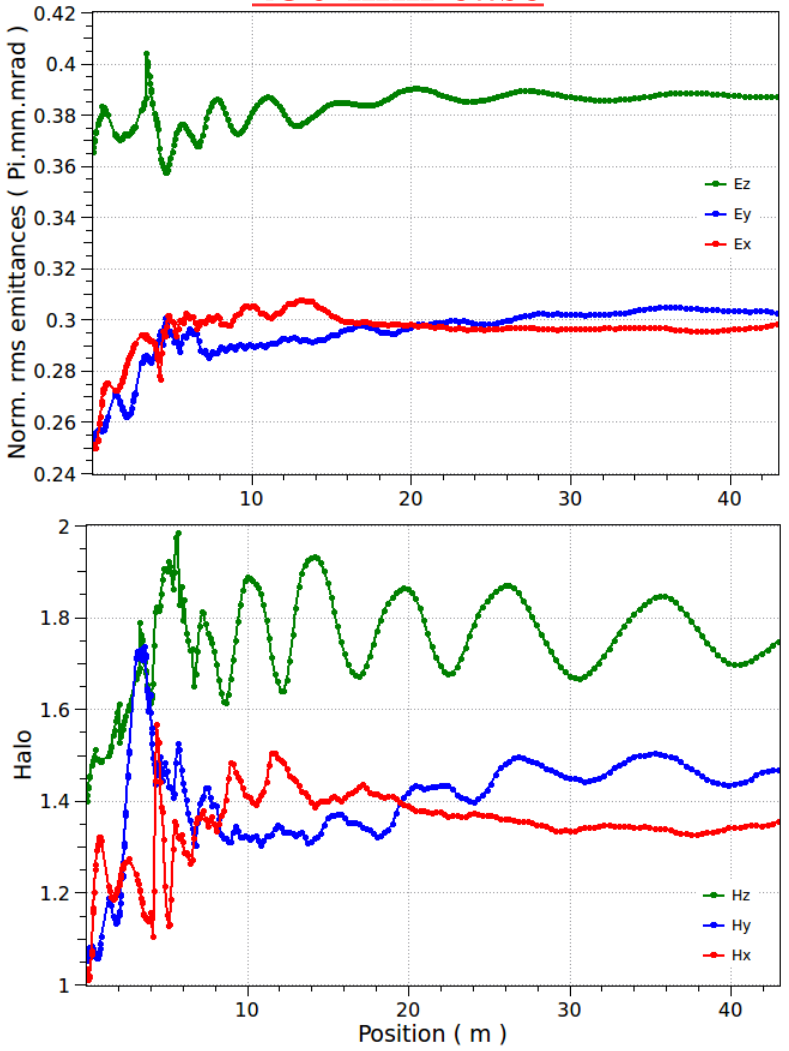
Nominal 2015.v0c



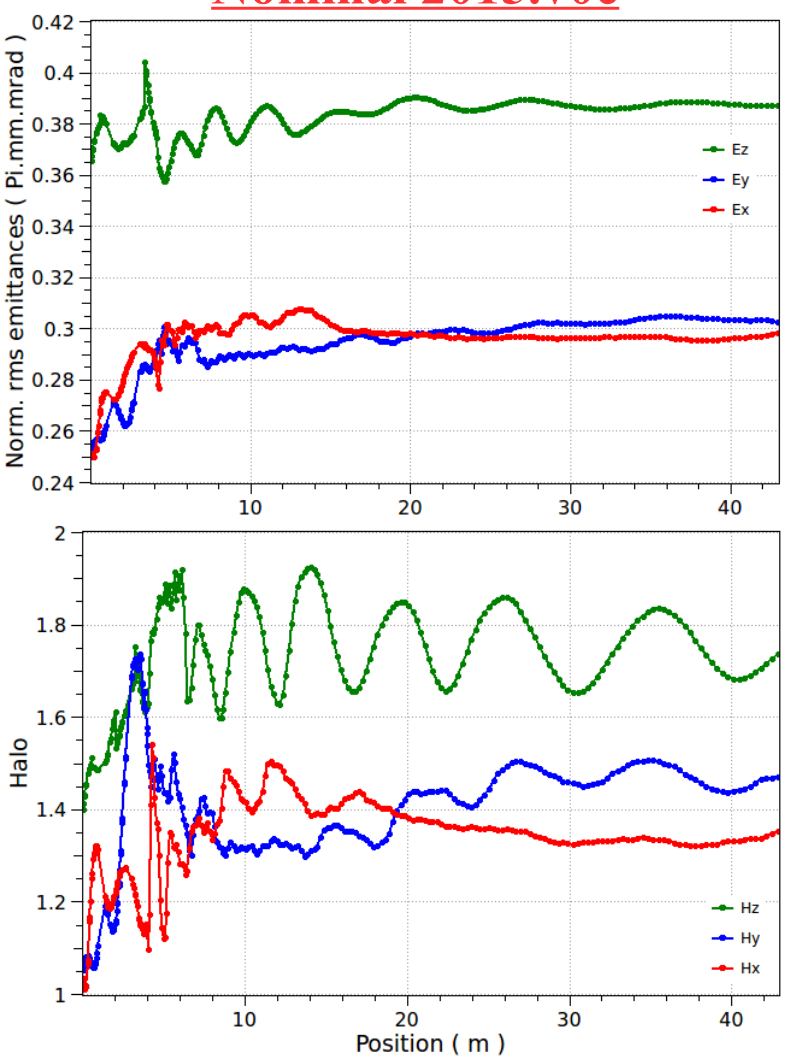
- In case 350 mm isn't enough to house BSM, Slit/NPM, and FC, I extended this part to 450 mm and see impact on the beam.
- I could maintain very similar patterns for all 3 planes. (But, the manual fine-tuning took a bit more effort.)

450 mm for the diag box space: emittance and halo

450 mm case



Nominal 2015.v0c



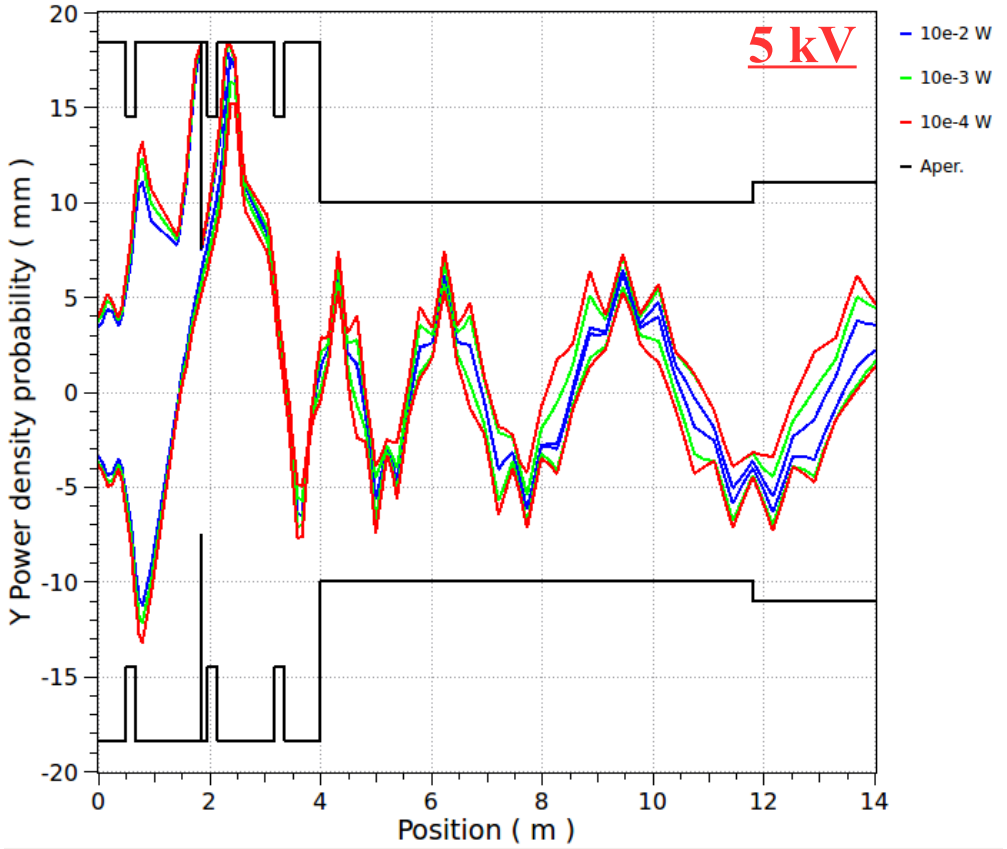
- Emittances and halos are surprisingly similar.
- **How much should we reserver now?**

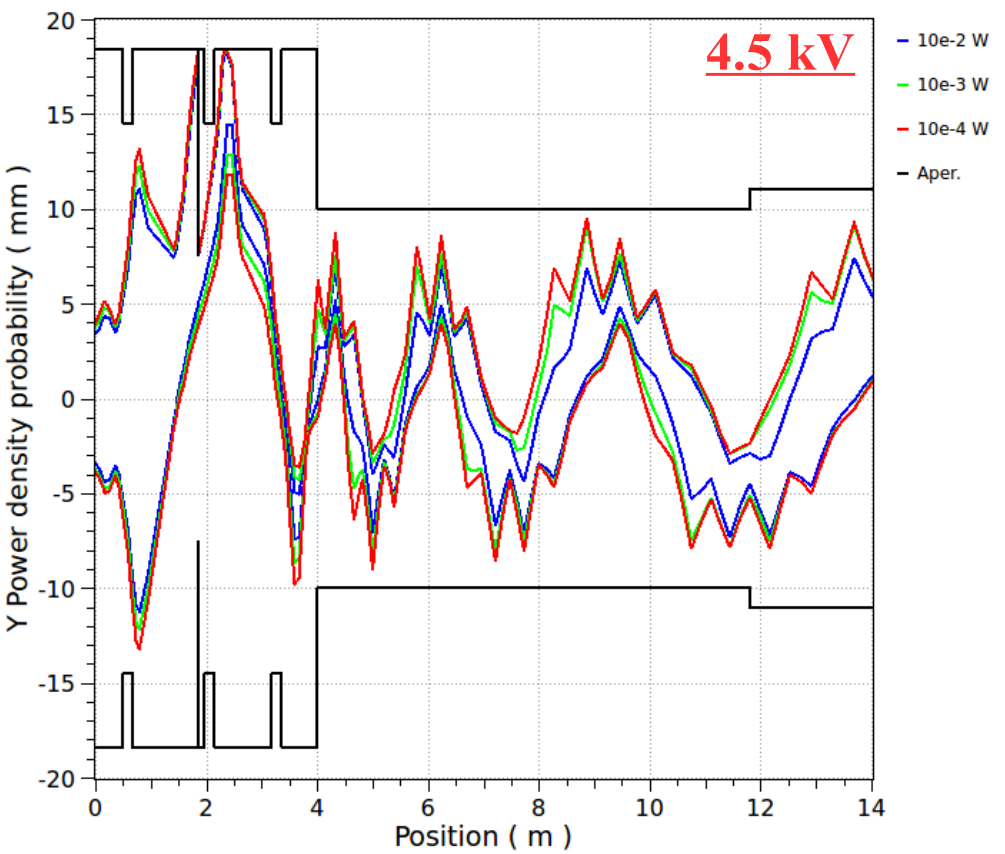
Remaining uncertainty (2): chopper parameters

Voltage [kV]	**5**	**4.5**	**4**
Plate length [mm]	**450**	**450**	**450**
Dump opening [mm]	**7**	**7**	**6**
Deflection [mrad]	**15.56**	**14.00**	**12.4**
Displacement at dump [mm]	**13.1**	**11.8**	**10.5**
Efficiency [%]	**99.95**	**99.58**	**99.60**
Efficiency with 0.5 mm offset	**99.87**	**99.16**	**99.20**
Loss in dump [W]	**~1**		**~5**

- Efficiency requirement is 99%. (A part of the reason is to protect the following scraper. Could it be revised?)
- Empirical Eq for σ at the dump: $(\Delta y - 7 - 0.5) / 3.09$. It is also empirically known that 13-14 mm displacement at the dump and ~1.8 mm σ at the dump makes the beam happy.
- Efficiency better than 99% achieved for 4.5 kV with no change → margin is ~10%.
- **4 kV case required a smaller dump opening and optics change → worse beam quality.**
- **For the 4 kV case, extending the chopper-dump distance didn't help the beam quality → a soft limit to the lattice.**

Power density of the leaking particles

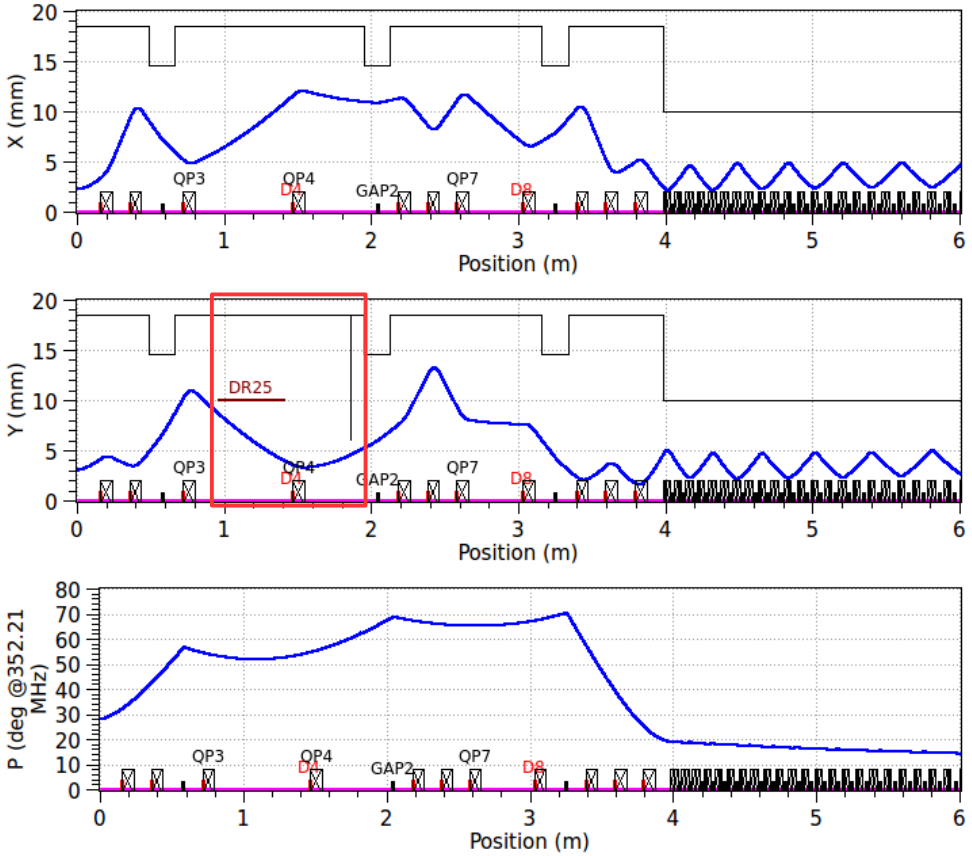




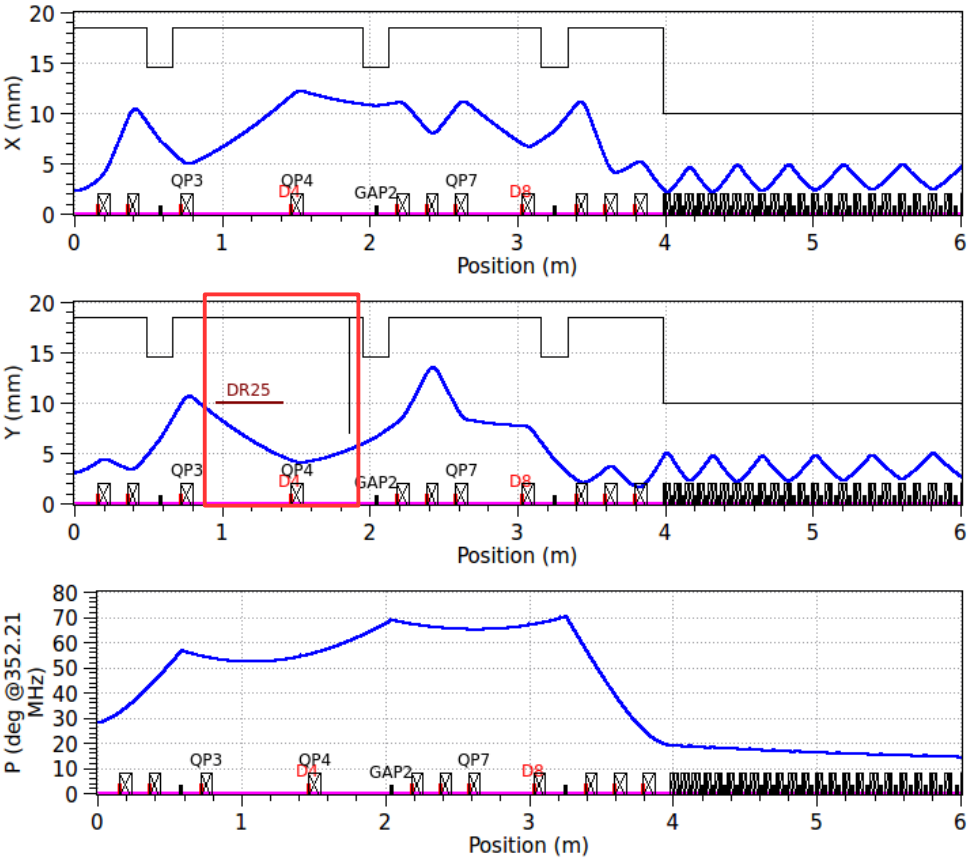
- Power densities of the particles leaking from the chopper dump.
- No scraper, ~0.5 mm trajectory offset at the dump, and assuming 0.04% duty cycle (**20-30 [us] / 2.86 [ms] * 4%**).
- Clearly no issue for the 5 kV case. For the 4.5 kV case, the clearance of the 1E-3 W curve is only ~1 mm at some locations. Given the RMS trajectory in Tank1 is the order of 0.5-1 mm, it is a bit worrisome without the scrapers.
- As listed in the table, ~0.8% is the intensity for the 4.5 kV case. These results also support the ~99% efficiency requirement.

4 kV chopper: envelopes

4 kV



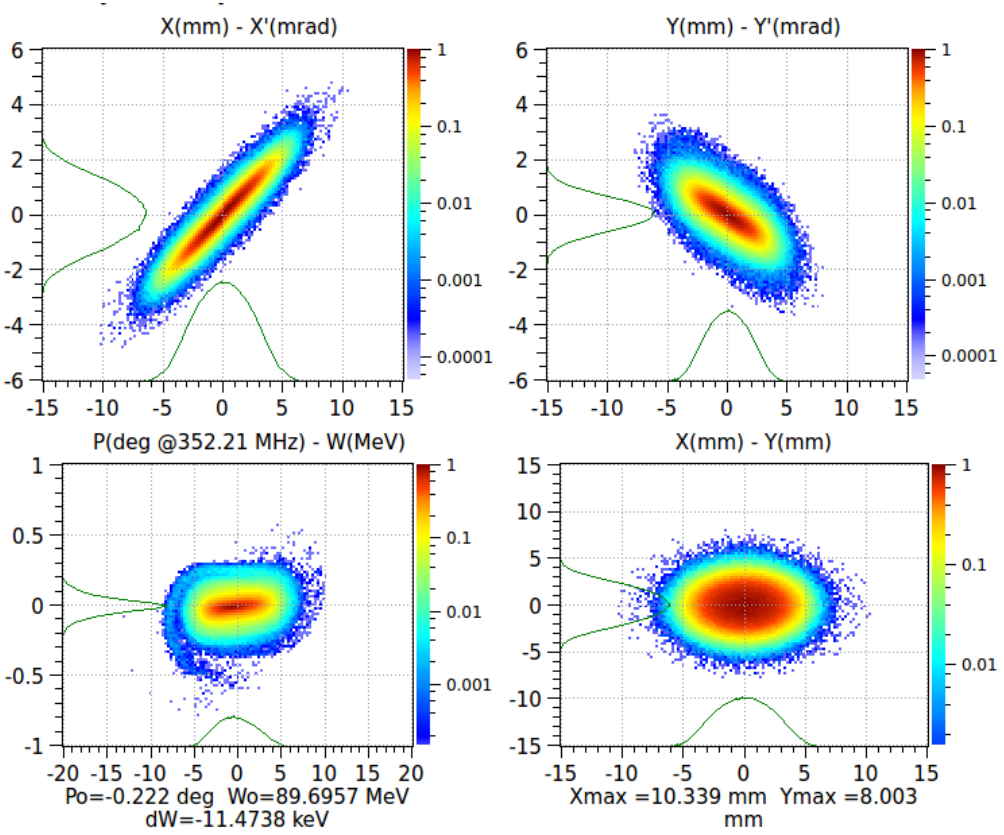
Nominal 2015.v0c



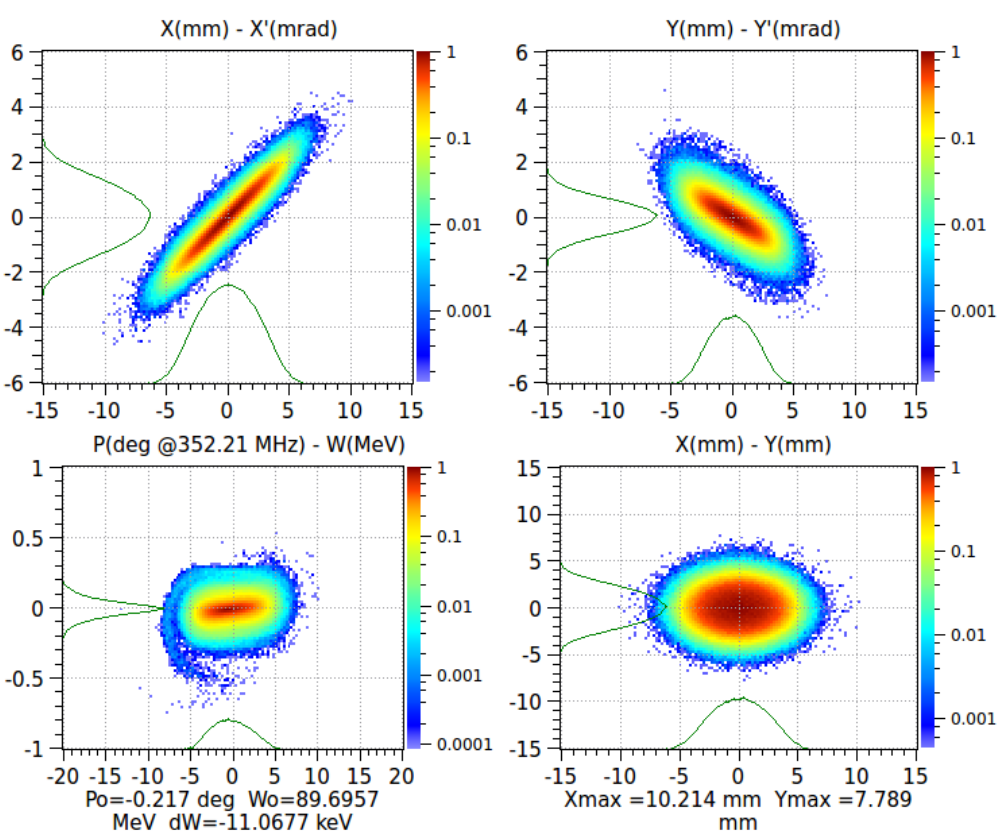
The 4 kV case required a smaller dump opening (6 mm) and minor changes in the optics (not the lattice). The overall patterns of the envelopes are still quite similar but I couldn't avoid to squeeze the beam more at Q4. It may not look so significant but the beam quality is still spoiled due to the high space charge in our machine.

4 kV chopper: DTL output distributions

4 kV

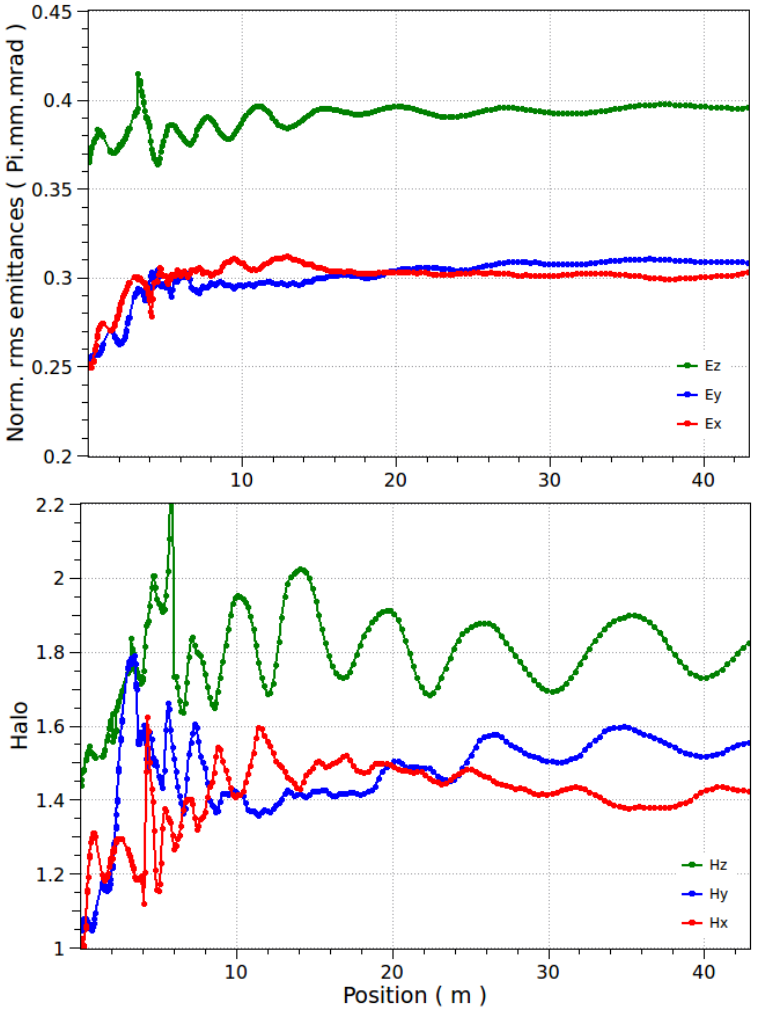


Nominal 2015.v0c

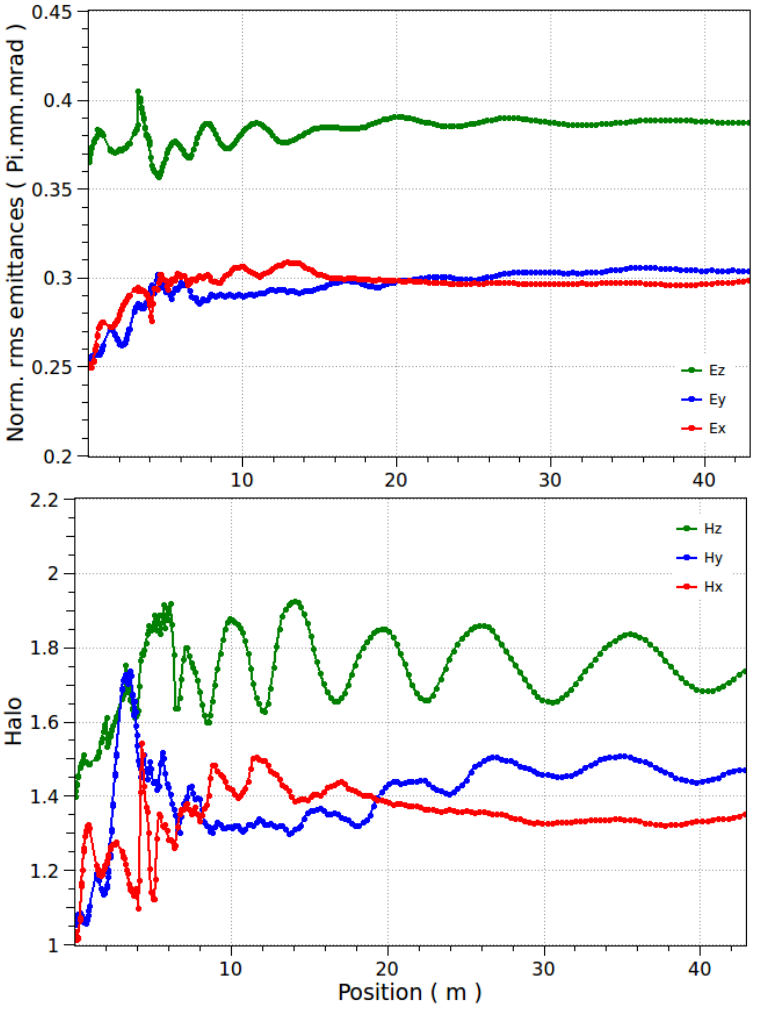


4 kV chopper: emittance and halo

4 kV

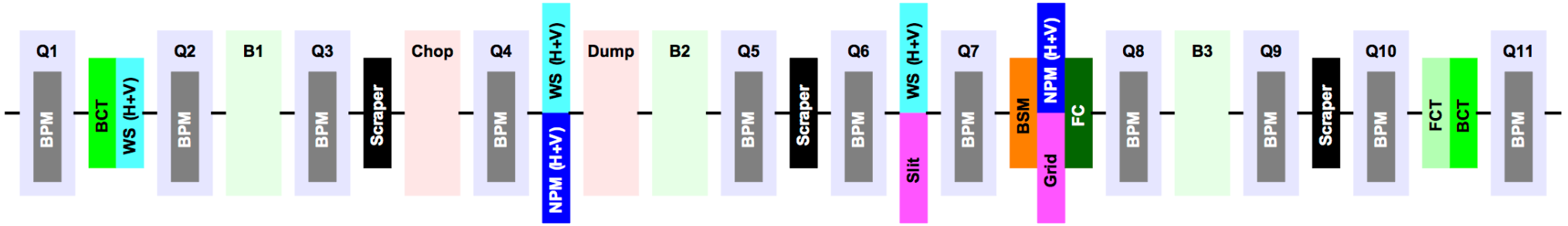


Nominal 2015.v0c



- Not significant, but 4 kV case shows some visible difference.
- **I'd suggest to keep the chopper-dump distance and 5 kV requirement. This way we have some margin. This presented 4 kV lattice could be a fall-back solution but we need a movable dump.**

Additional things to discuss about diagnostics ?



- Fast current transformer better before FC?
- Number of BPMs. (6 was enough for 2014 lattice for trajectory correction. To be checked.)
- WS/NPM and WS/Slit possible? Hard? Is it better to have WS and scraper at the same location?
- …
- Tom may have further comments?
- Beam physics group has started studying tuning/commissioning in detail so the most may be homework to us.

Conclusions

- The MEBT lattice 2015.v0c was produced based on the previous version 2015.v0b and the Bilbao's work on the integration. The difference from the previous version is small so the new lattice provide good beam quality as its predecessors.
- One remaining uncertainty is the integration of the BSM, EMU, and diagnostics boxes. It was checked that the space between Q7 and Q8 could be extended from 350 mm to up to 450 mm with practically no impact on the beam (as long as it doesn't go over the margin of the total linac length, off course).
- Performance of the chopper in case the achieved voltage is lower than the nominal 5 kV was studied. It was identified that the lattice has a soft limit on the length between Q4 and the dump. Because extending this length doesn't help the lower voltage, we don't reserve any margin for this length.
- More detailed studies on each diagnostics device are desired and on-going with the beam physics group.