FCC-hh DUMP CONCEPTS

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FCC week Rome, 11th - 15th April 2016

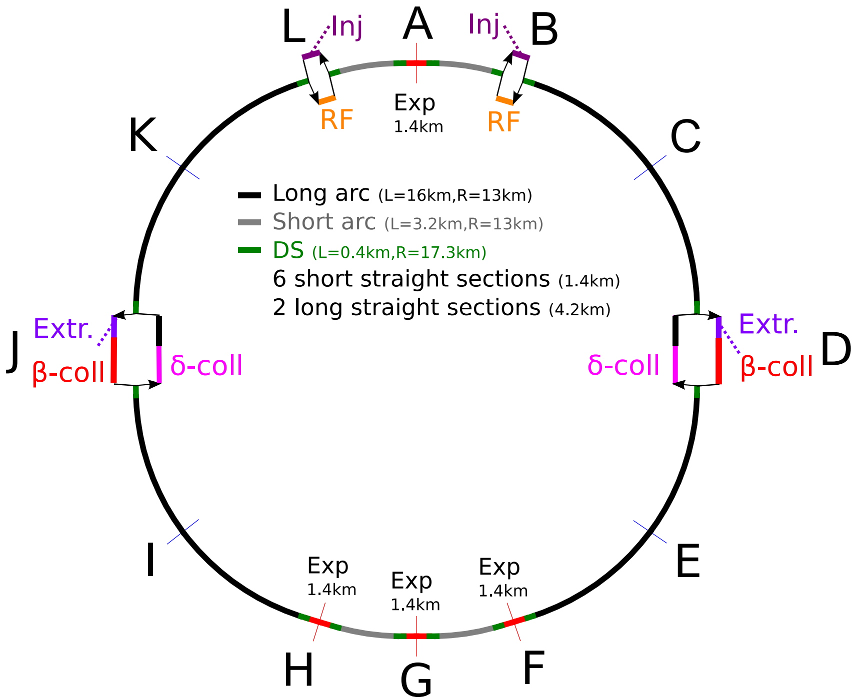
Outline

- Extraction in the overall machine layout
  - Baseline option
  - Alternative
- What did we have last year
- Extraction layout
- Optics
- Hardware specifications
- Dilution system studies

Extraction system in overall machine layout

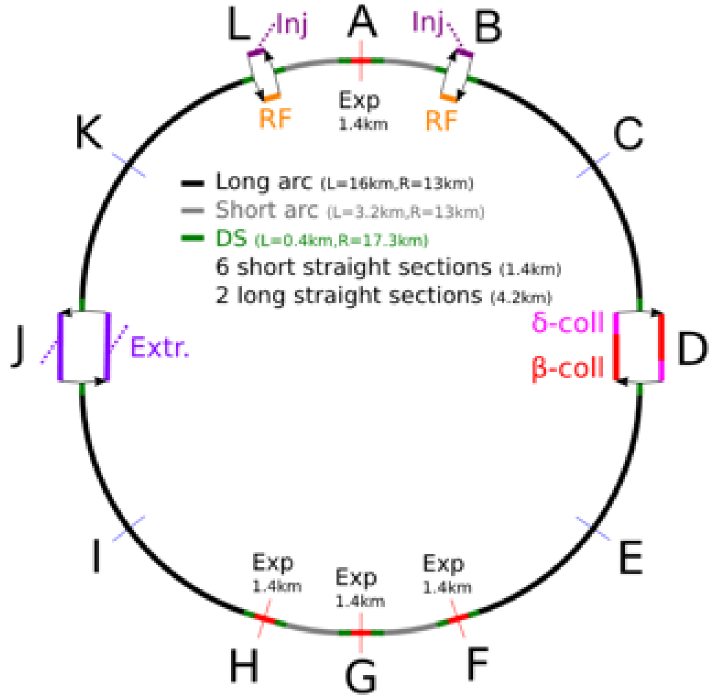
Baseline

- Extraction system followed by betatron collimation on one beam
- Momentum collimation on the other beam – loss shower on sensitive kicker electronics!

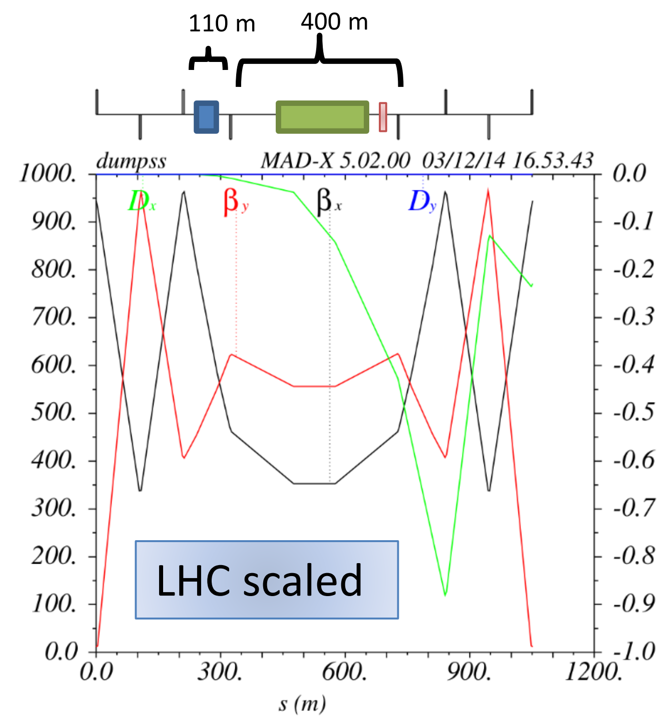


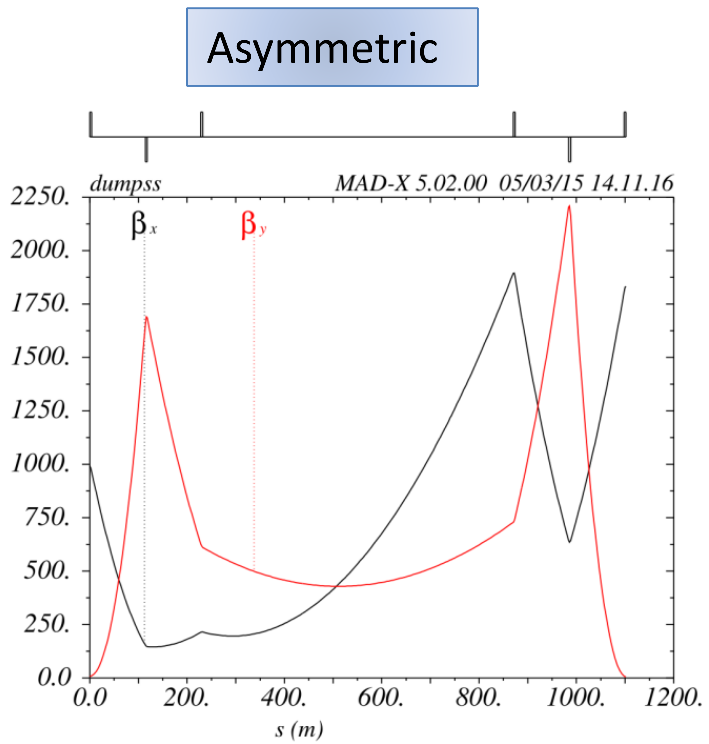
Alternative ESS layout

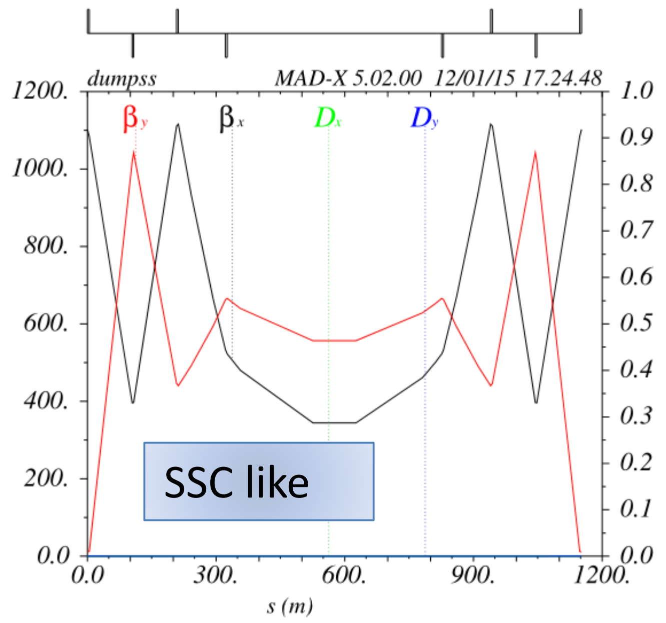
- Both extraction systems in one ESS
- Betatron and momentum collimation in opposite ESS



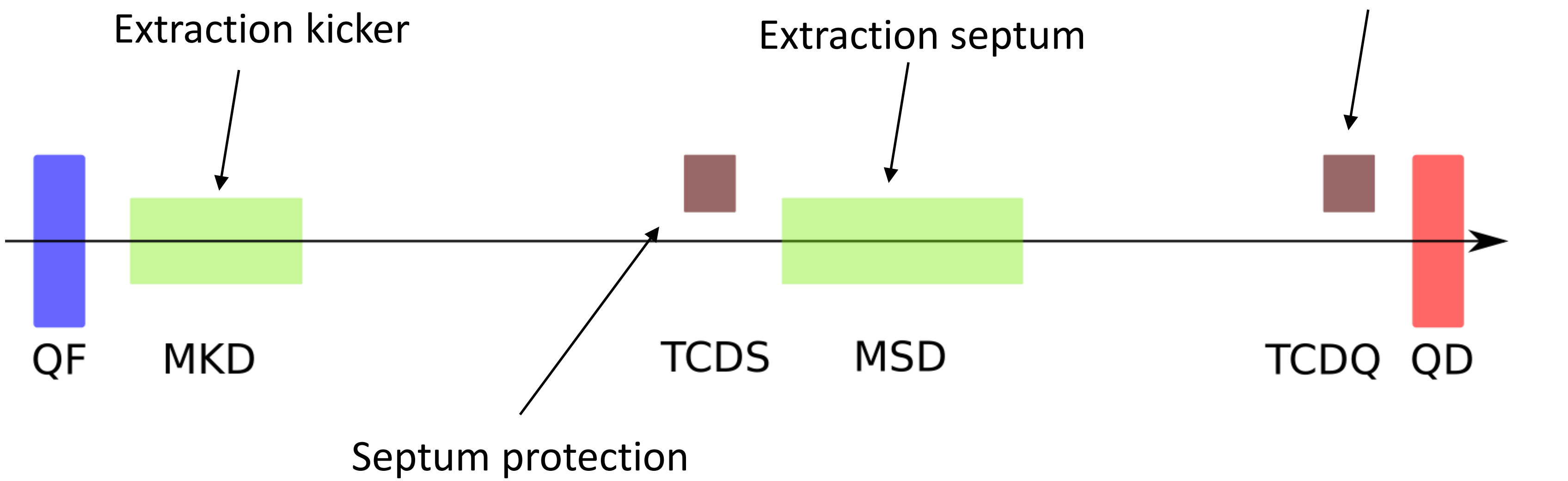
Options we had in Washington





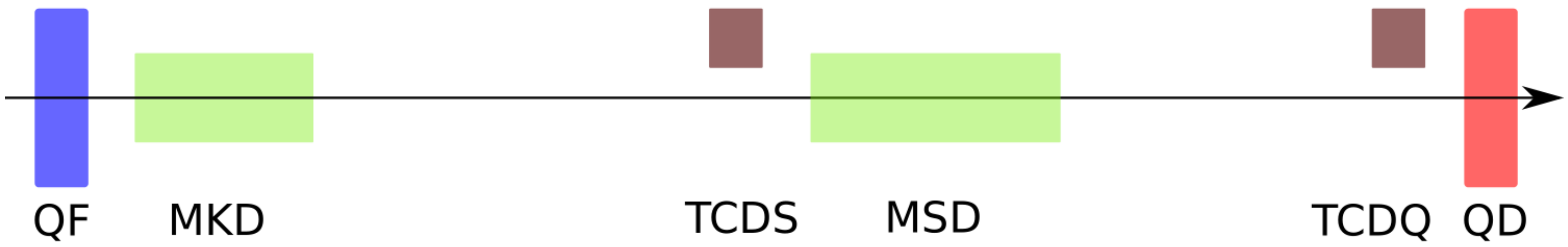


Dump system layout



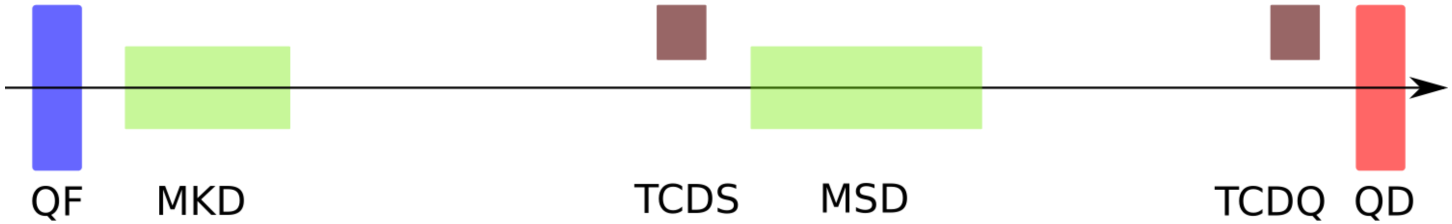
- Design is driven by protection against failure cases – asynchronous beam dump due to kicker pre-fire
- Impact of a single bunch at 50 TeV in present absorber materials for LHC can cause localized material damage (see talk by A. Lechner in this session)
- Need to separate bunches by O(mm) on absorbers for a beam size of a few 100 um
- Septum protection is most critical since closer to the kicker

Dump system layout



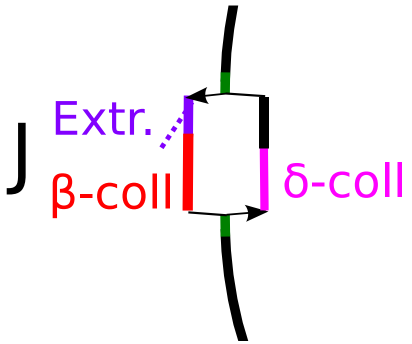
- Push the septum as far downstream as possible to get more distance to the kicker for septum protection
  - High-field Lambertson of 2 T, still huge power consumption if normal conducting (see talk by M. Atanasov)
  - Rather go for a staged approach with a ~10 m long normal conducting septum and downstream a superconducting one (possible solution with a superconducting shield, see talk by D. Barna)
- Instead of increasing the rise time of the extraction kicker REDUCE it – went from LHC scaled 10 us to **1 us to sweep the beam faster in case of a failure**

Hardware requirements

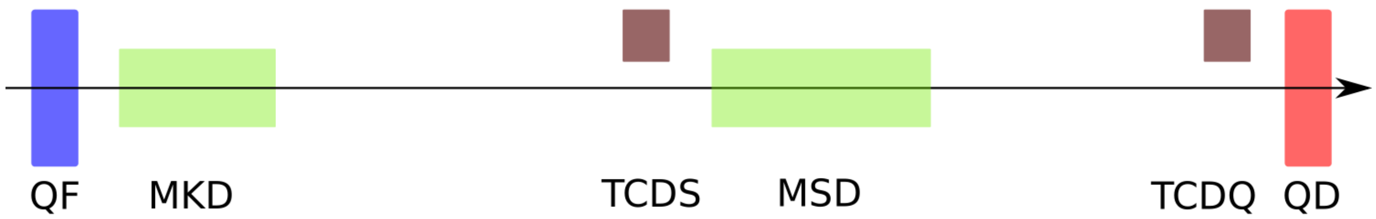


Kicker

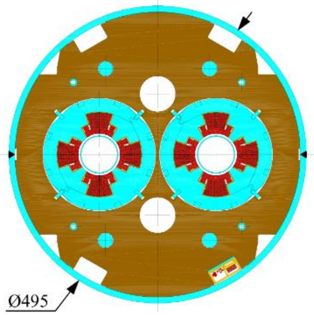
- 0.13 mrad
- 1 us field rise time
- Present LHC kicker generator complexity does not allow to scale up the system (availability)
- With moderate required deflection aim at a highly segmented system of low complexity – helps for reaching a very short rise time and a small beam perturbation in case of single module failure (see talk by Thomas Kramer)
- Envisage a compact power generator right below the magnet in the tunnel – also controls electronics in tunnel → high sensitivity to radiation → single beam shielding of momentum collimation needs careful study (see talk by P. van Trappen, poster by J. Rodziewicz)



Hardware requirements

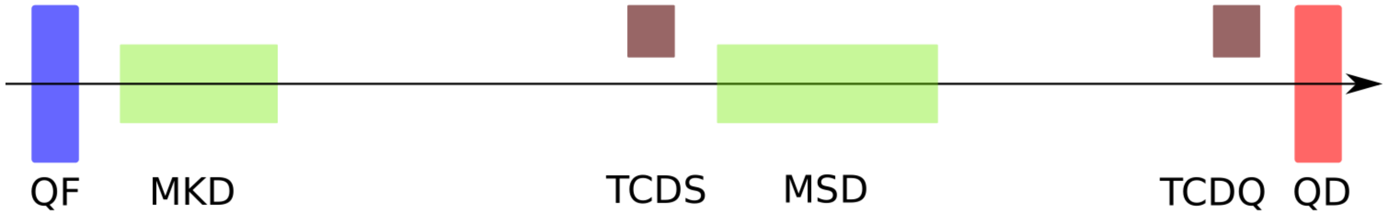


- Septa
  - 500 T.m integrated field → this assumes full clearance of the QD cryostat (500 mm diameter)
  - Also investigate a triple chamber quadrupole to pass the extracted beam through the cryostat with significantly reduced kick angle for the septum
  - Blade thickness to be defined, assume +/- 10 sig +/- 3 mm and a blade thickness of 15 – 20 mm
  - Need aperture strategy for circulating beam

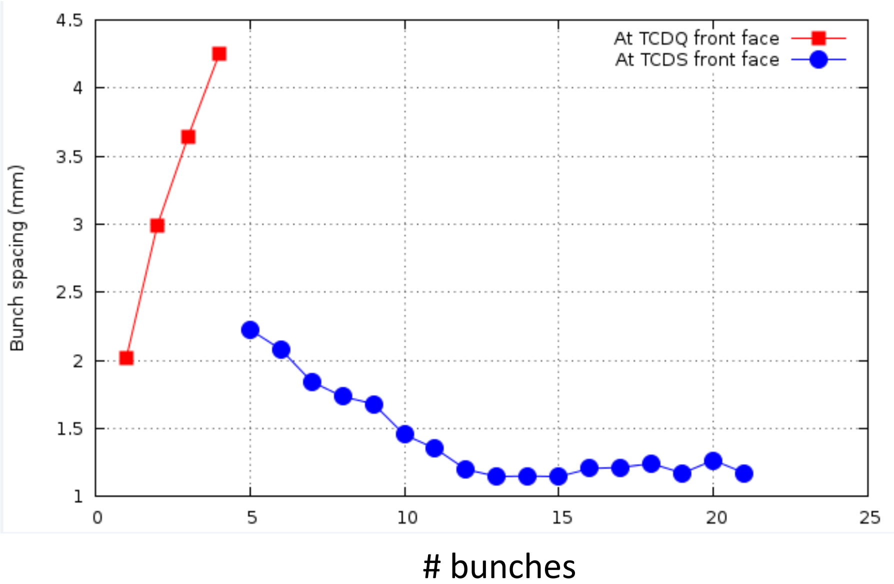


- Extraction insertion quadrupoles
  - Might use enlarged aperture or triplet quads to digest the increased beam size

Extraction protection

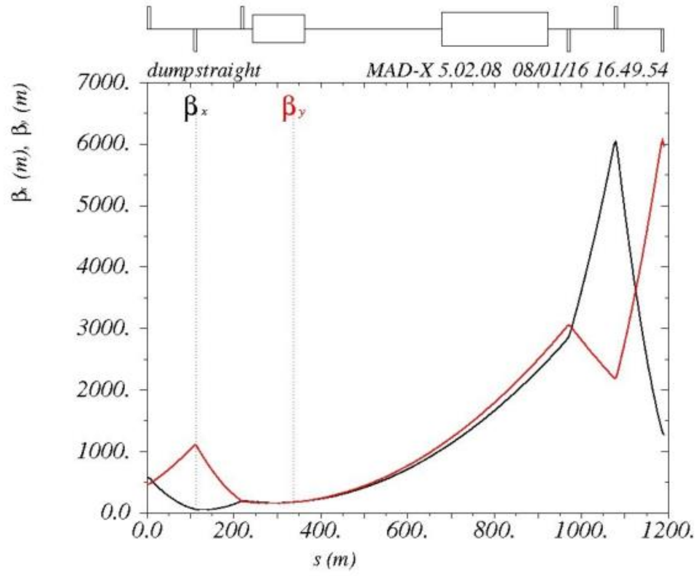


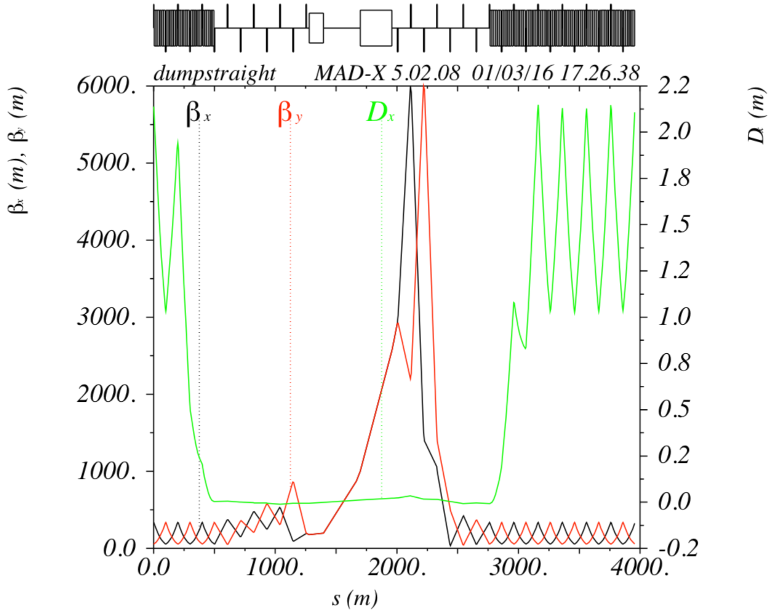
- Septum protection absorber of about 10 m right upstream the blade – details on material choice by Anton Lechner
- Quadrupole and downstream machine protection absorber of about 10 m upstream QD
  - Assumed 9.5 sigma setting according to an older collimation scheme; will be iterated with collimation team after FCC week
- For kicker waveform used a squeezed LHC case and derived bunch distribution along the absorbers
- Consider extraction bump to reduce kicker strength
- No elements in half-cell downstream, masks for further downstream quadrupoles



Extraction insertion optics

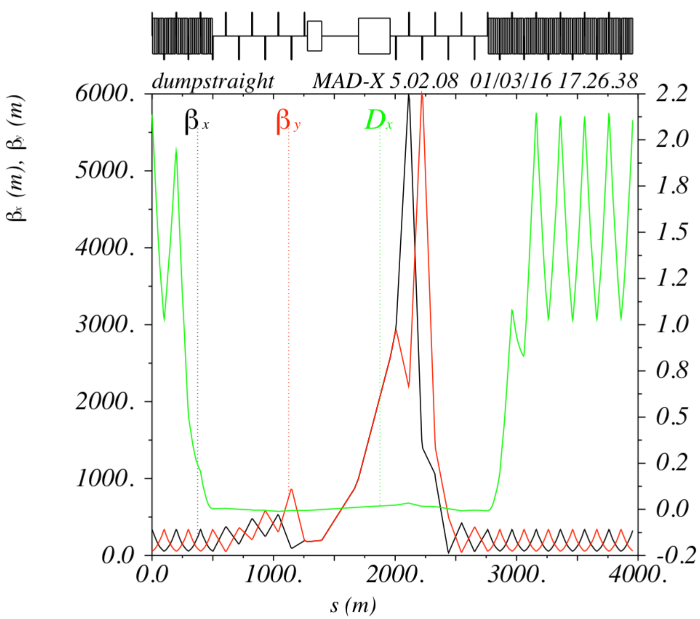
- **High beta functions** at the septum and quadrupole protection **absorbers** (min of 800 m)
- **Low beta function** in bending plane at the **extraction kicker** opens the possibility not to retrigger the full system in case one of the 300 units is pre-firing and thus **significantly reduce the probability of an asynchronous beam dump** (see B. Goddard's talk)
- Consider further increasing beta function at absorbers – envisage **ramping optics** between injection energy (big beam size, less critical for absorbers) and flattop (smaller beams, most critical for absorbers)

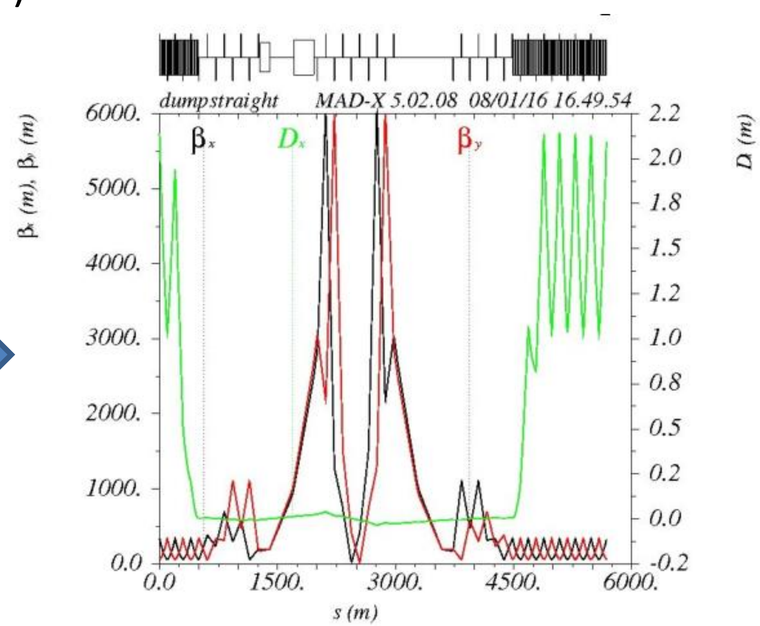




Extraction insertion optics - alternative

- **High beta functions** at the septum and quadrupole protection **absorbers** (min of 800 m)
- **Low beta function** in bending plane at the **extraction kicker** opens the possibility not to retrigger the full system in case one of the 300 units is pre-firing and thus **significantly reduce the probability of an asynchronous beam dump** (see B. Goddard's talk)
- Consider further increasing beta function at absorbers – envisage **ramping optics** between injection energy (big beam size, less critical for absorbers) and flattop (smaller beams, most critical for absorbers)

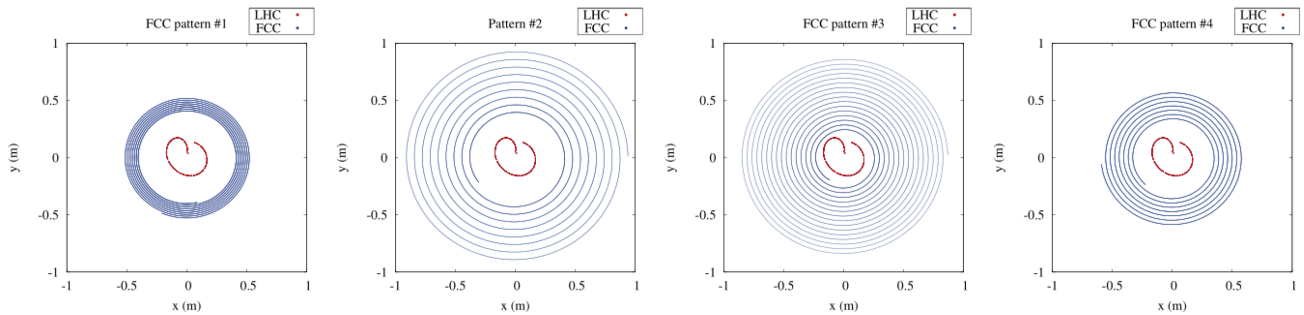




Energy deposition studies on the dump absorber

	MKB frequency modulation	Frequency	B·dl[a]	Distance between neighbouring bunches	Distance between neighbouring branches
#1[b]	No	32.8 kHz	34 Tm	2.00–2.64 mm	1.6 cm
#2	No	32.8 kHz	56 Tm	1.87–4.70 mm	6.5 cm
#3[c]	No	50.9 kHz	53 Tm	1.83–6.95 mm	4.0 cm
#4[c]	Yes	20–43 kHz	39 Tm	1.90 mm	3.7 cm

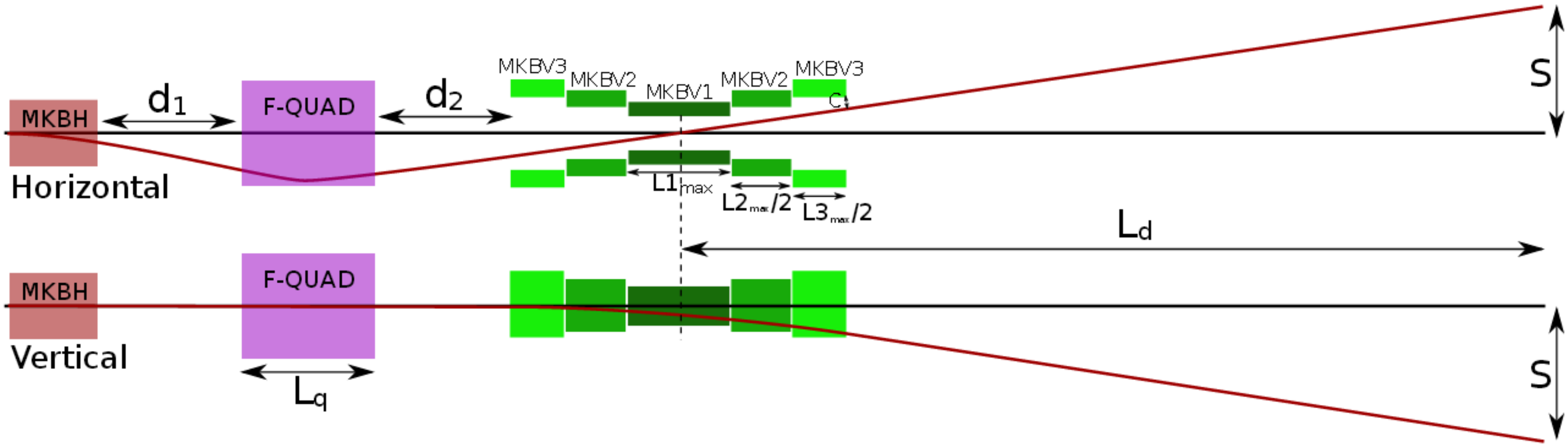
[a] For a dump line length of 2.5 km. [b] See F. Burkart, FCC Dump Meeting, 02/07/2015, [c] See F. Burkart, FCC Dump Meeting 02/12/2015.



- Assumed dump line length of 2.5 km
- Beam size increase without further defocussing
- Need to separate bunches by ~1.8 mm and spiral branches by ~4 cm (Anton Lechner talk)
- Have to keep attention on the dump absorber dimensions

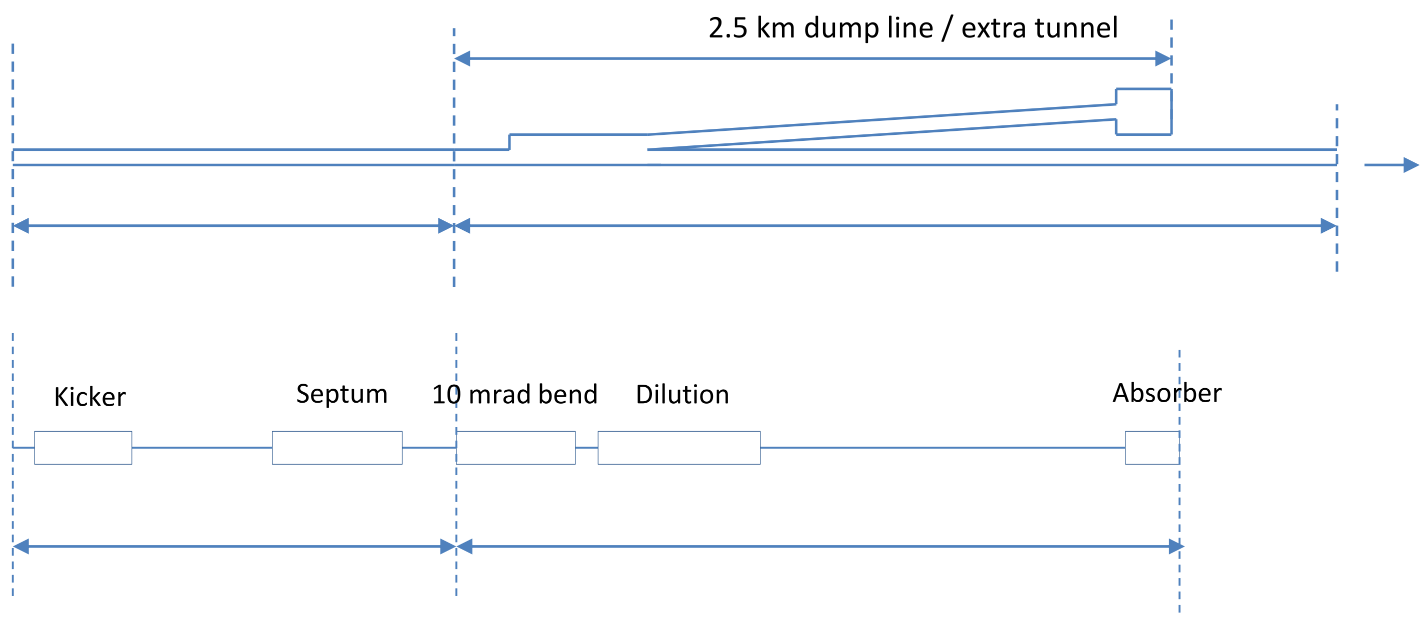
Dilution system

- Initial studies showed that the dilution kicker system is highly demanding in terms of integrated field, frequency program and aperture
  - Dilution pattern optimisation – Poster by D. Barna
  - Kicker system electrical parameters – Talk by Thomas Kramer
- Try to ease HW requirements by implementation of an over-focussing quadrupole



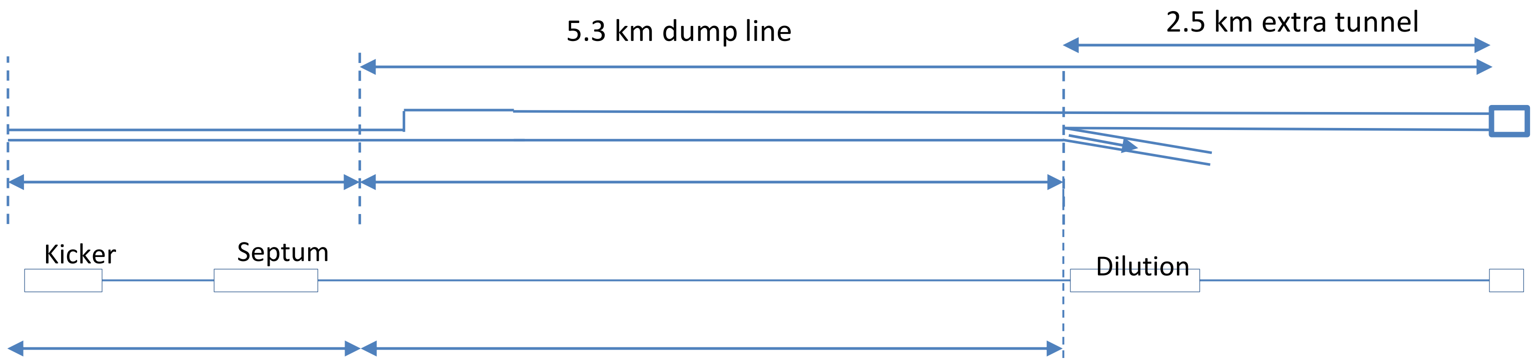
Layout of dump line: bend into separate tunnel

- Need about one arc cell bending
- Dilution system and dump absorber in parallel to ESS
- 2.5 km extra tunnel



Feed dump line through collimation area

- Bigger tunnel required or separation in between
  - Beam separation due to septum 8.5 m after 2.8 km
  - 2.5 km added tunnel for dilution and dump absorber as soon as arc starts



Conclusions

- Baseline layout with extraction and collimation in one ESS
  - Impact of radiation on electronics needs careful follow up
  - Alternative layout with extraction and collimation fully separated avoids this issue
- Extraction concept driven by the main failure case of an asynchronous beam dump
  - Maximised lever arm (layout), beam spot size (optics) and sweep speed (kicker rise time) to avoid damage of extraction protection absorbers
  - Design frozen at beginning of 2016 to investigate feasibility of hardware (presented in 3 dedicated talks)
- Dilution on dump absorber
  - 2.5 km dump line length
  - Several dilution patterns were simulated → defined minimum bunch and spiral spacing
  - Optimisation algorithm for dilution kickers
  - Consider over-focussing quadrupole to support dilution kicker system
- To be studied:
  - Extraction bump
  - Ramped optics between injection and extraction energy to further increase betas
  - Updates in collimator settings, optics matching to collimation