STATUS OF FCC-hh EXTRACTION

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FCC-hh general design meeting, 3rd March 2016

Outline

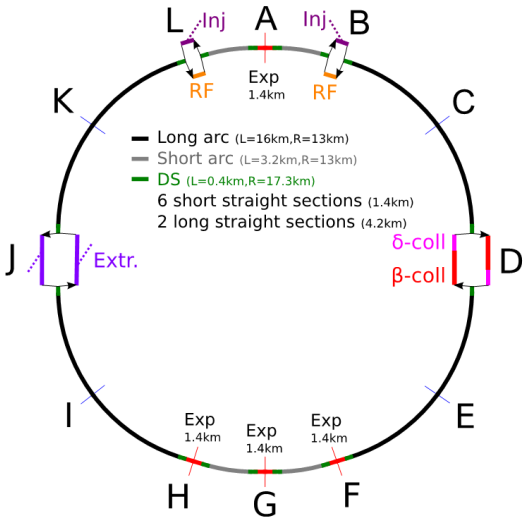
- Overall ESS layout
- Extraction – collimation in separate ESS
- Extraction followed by collimation
- Energy deposition studies
- Dilution system studies

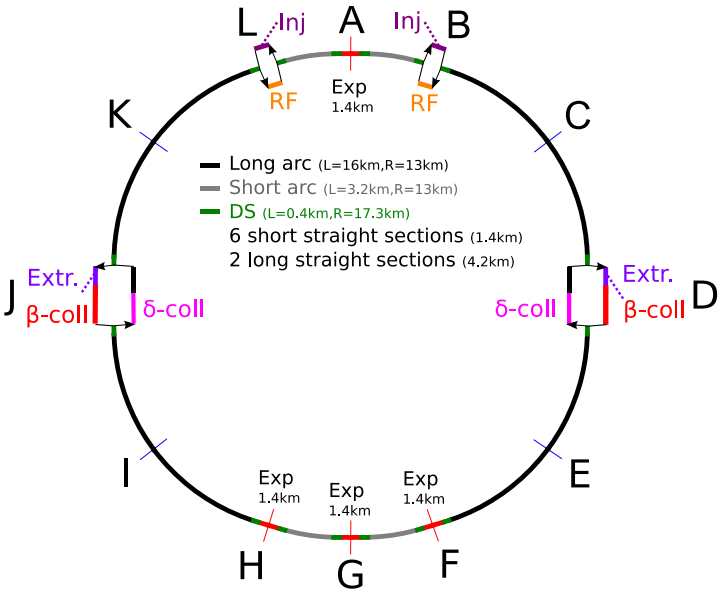
General layout

- After lattice review in Orsay, Nov-2015 worked on ‘alternative baseline’ with extraction and collimation separated into the two ESS

Alternative Baseline Option

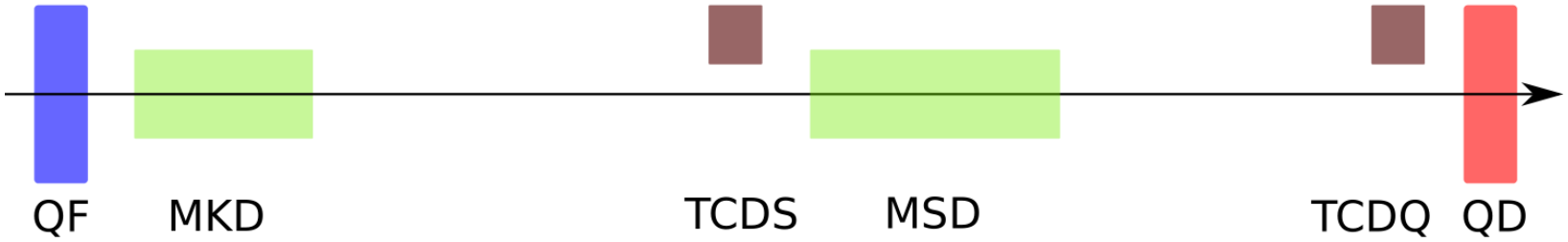
- Betatron and energy collimation are lumped together
  - Potentially improved collimation efficiency
  - Betatron collimation system followed by energy collimation in each beam
  - How much separation is required?
- Both beams are extracted in the same insertion
  - Have to figure out best configuration





Both extractions in one ESS - layout

L. Stoel, FCC dump meeting, 20th Jan. 2016

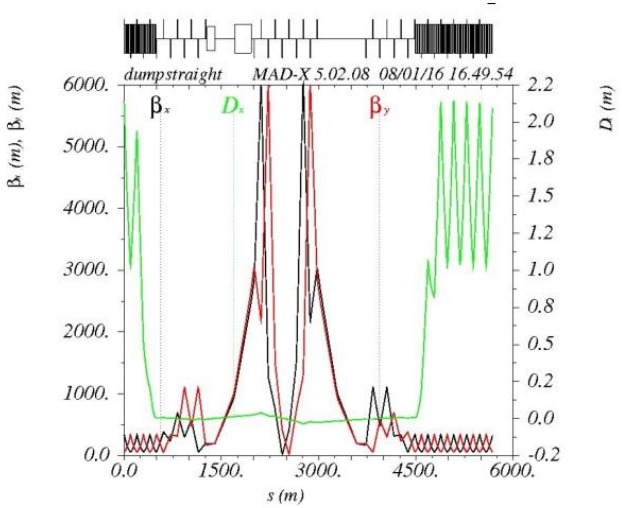


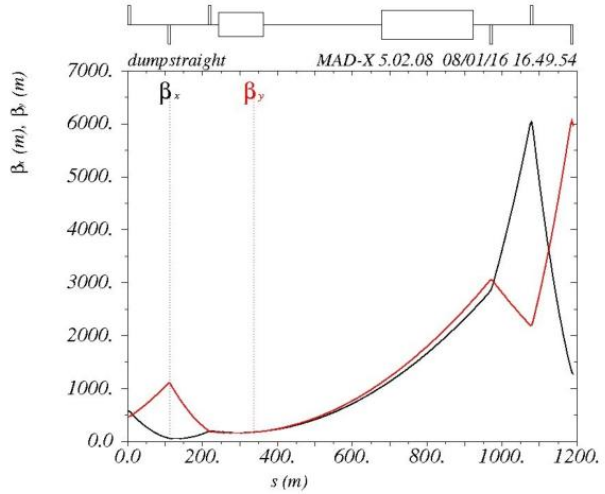
Old	
Quad	6.8 m
Drift	20 m
Kicker	120 m
Drift	270 m
Septum	200 m
Drift	135 m
Quad	6.8 m

New		
Quad	6.8 m	
Drift	20 m	
Kicker	120 m	0.13 mrad
Drift	315 m	
Septum	245 m	2 T
Drift	45 m	
Quad	6.8 m	500 mm clearance

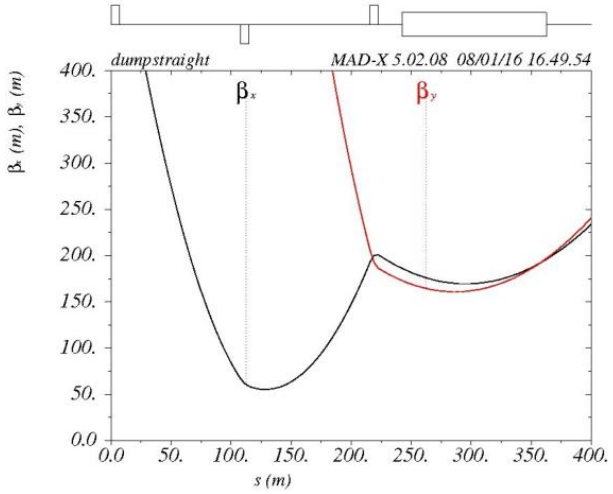
We wanted to shift the TCDS (and thus the septum) as far downstream as possible, to gain more bunch separation through a bigger lever arm.

Both extractions in one ESS - optics



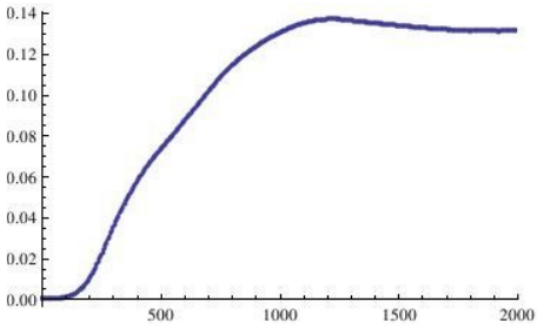


- Insertion length: 18.5 cells = 4 km.
- Collimators downstream of the TCDQ may still be an issue. This could lead to substantial optics changes.
- We now assumed we need almost 500 mm separation at the quadrupole after the septum.



Extraction protection elements - assumptions

- The start of the TCDS (TCDQ) is 30 meters before the start of the septum (quadrupole).
- The TCDS is located directly in front of the septum blade and has equal thickness.
- The TCDQ is aligned to 9.5 sigma. (The most recent collimation scheme I could find is TCP at 7.6, TCS at 8.8 and TCT at 12.6 sigma.)
- The kicker rise will be similar to a scaled version of the LHC MKD waveform.



Extraction protection elements – input for FLUKA

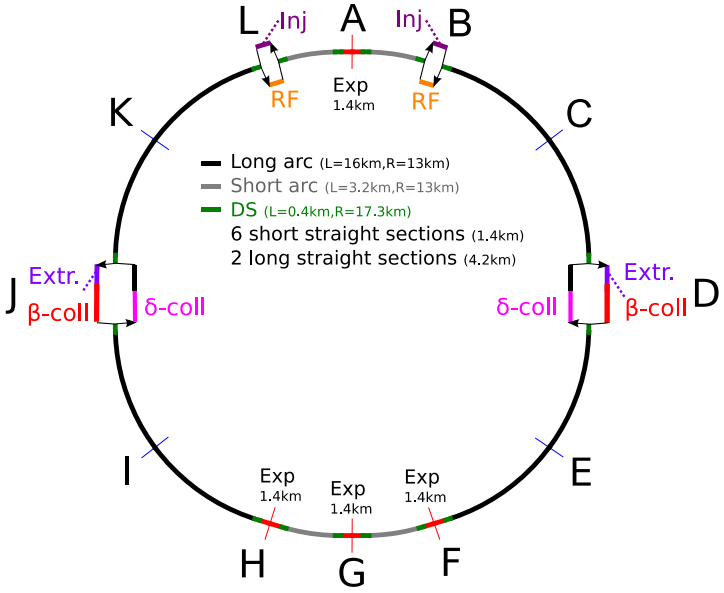
Probabilities of impact tbd., particle energy 50 TeV, grazing and full impact with turn-by turn losses.

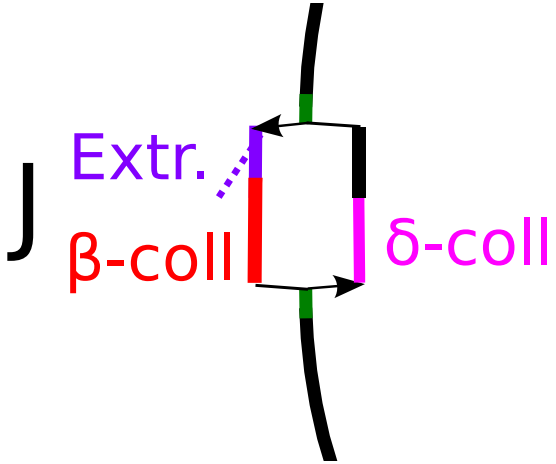
	Number of bunches	Beam size	Bunch separation
TCDQ	~5	0.34 mm	2+ mm
TCDS	~18	0.20 mm	1.1 - 1.9 mm, most 1.2 - 1.3 mm
Absorbers further downstream	tbd	tbd	–

Assuming an initial septum blade thickness (and TCDS thickness) of 26 mm.

Extraction system with downstream collimation

- Can find a solution if one of the collimation systems is downstream of and on the same beam as extraction
- Problem with present baseline: Momentum collimation showers impacting on extraction kicker electronics





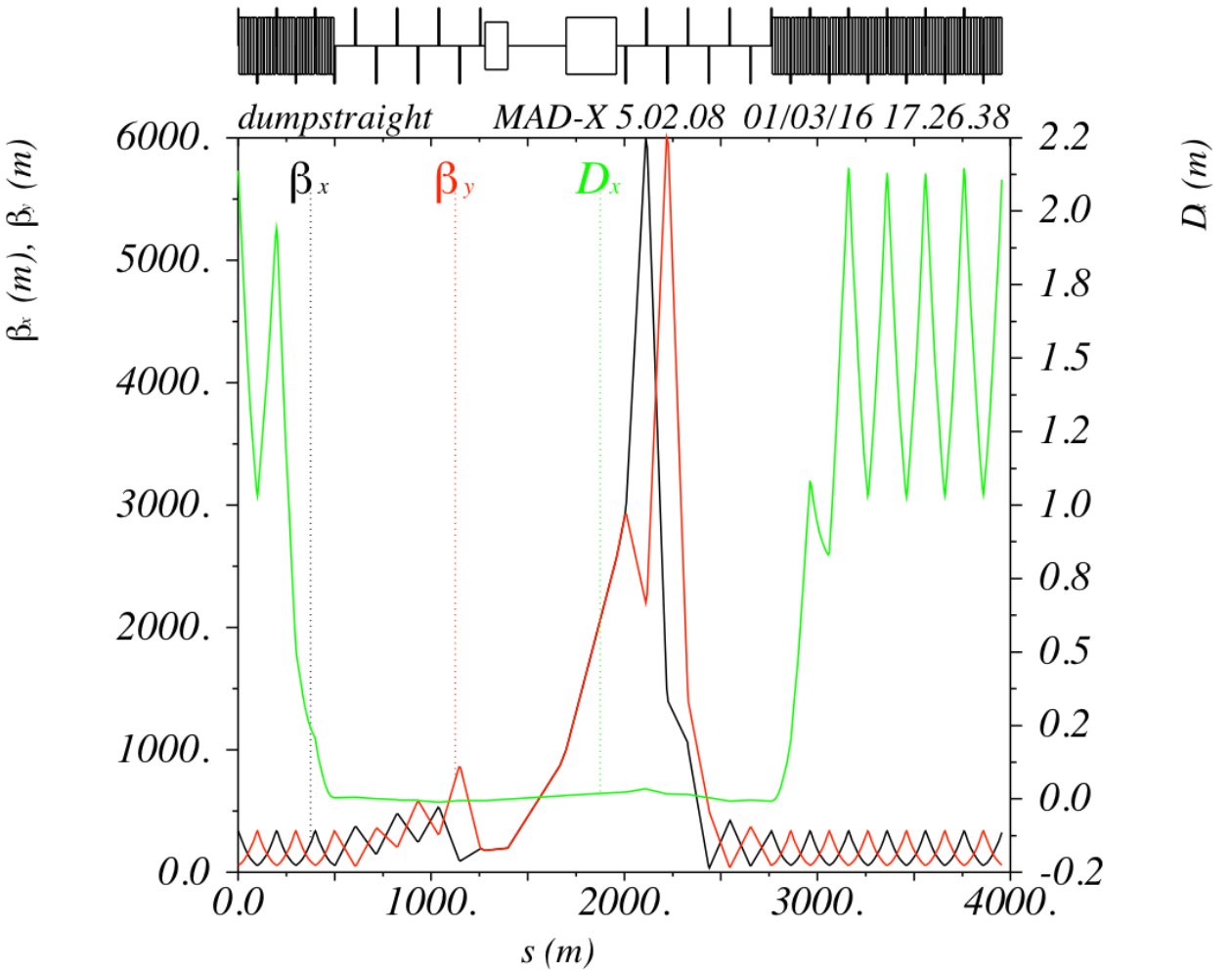
Extraction followed by collimation system - optics

F. Burkart, FCC dump meeting, 2nd March 2016

About 2 km including optics matching and extraction protection

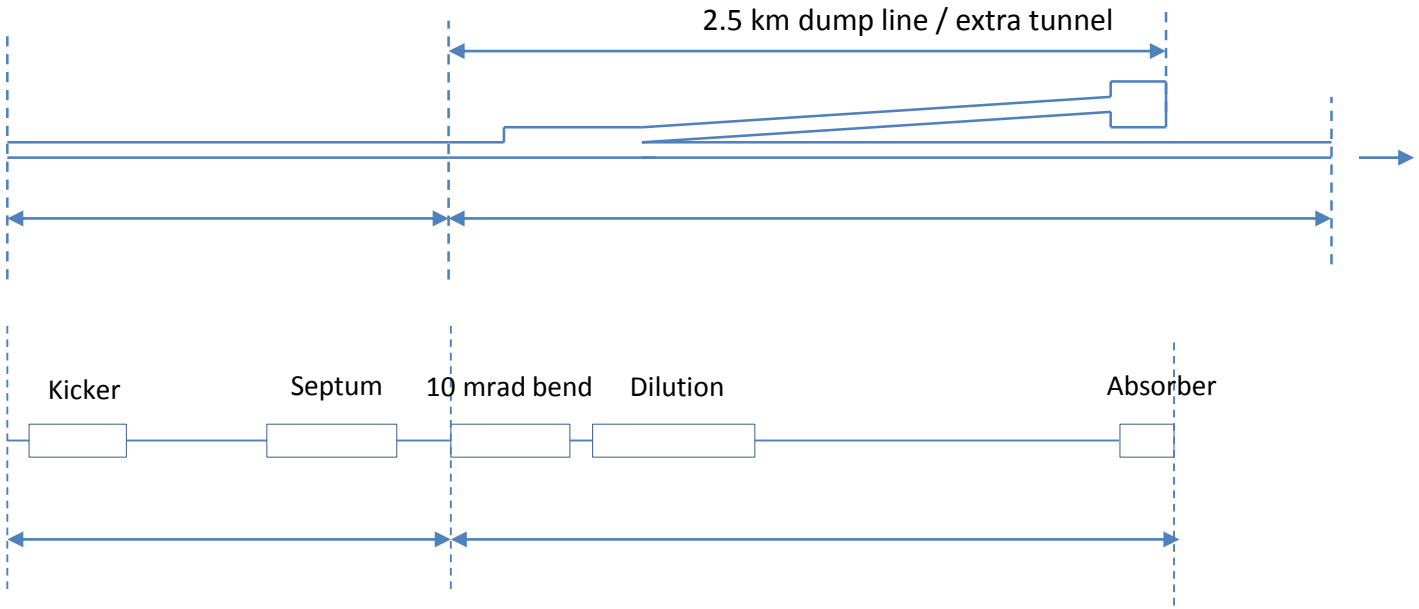
Still issue with showers on dilution system – two options:

- Bend into separate tunnel
- Pass collimation and add dilutions system after arc separation



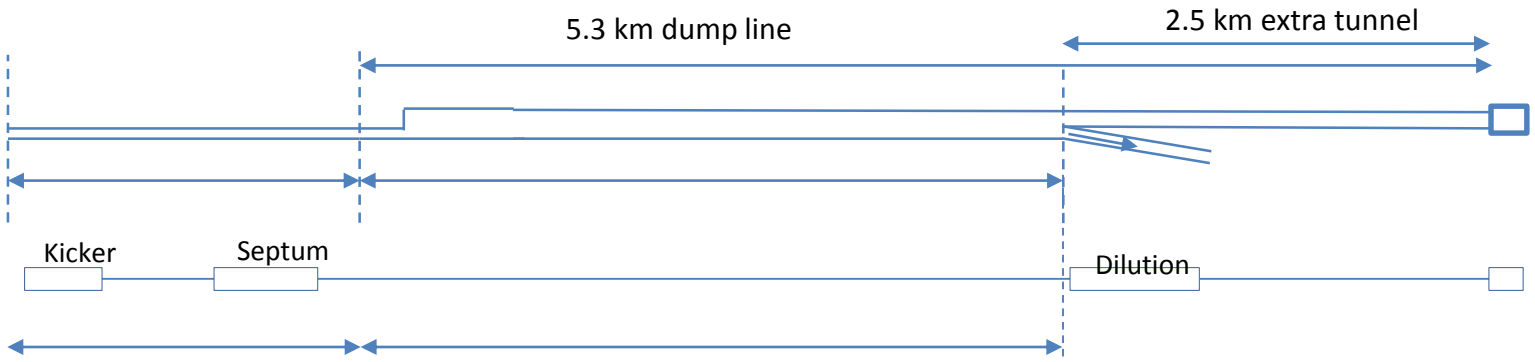
Bend into separate tunnel

- 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



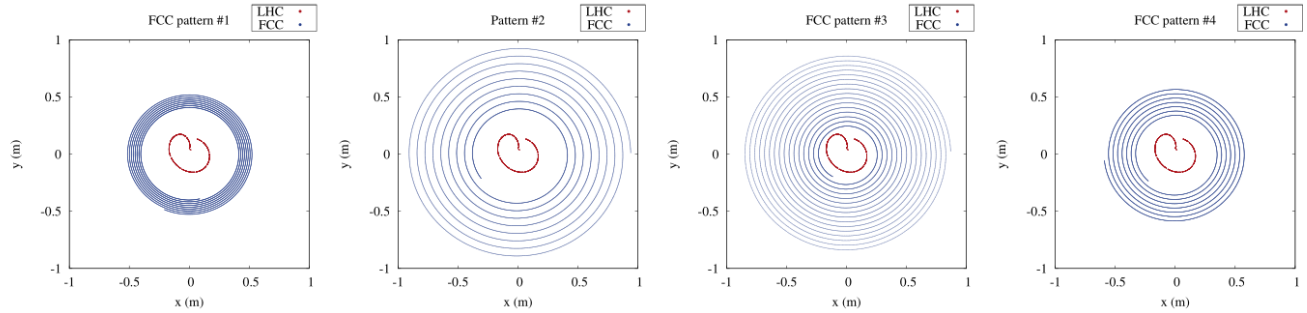
Energy deposition studies on the dump absorber

A. Lechner, FCC dump meeting, 20th Jan. 2016

Overview of multi-spiral dilution patterns (from F. Burkart)

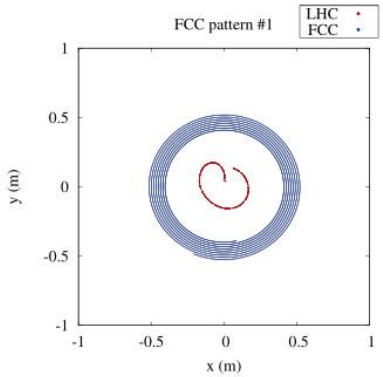
	MKB frequency modulation	Frequency	B·dl[a]	Distance between neighbouring bunches	Distance between neighbouring branches
#1[b]	No	32.8 kHz	34 Tm	2.00–2.64 mm	1.6 cm
#2	No	32.8 kHz	56 Tm	1.87–4.70 mm	6.5 cm
#3[c]	No	50.9 kHz	53 Tm	1.83–6.95 mm	4.0 cm
#4[c]	Yes	20–43 kHz	39 Tm	1.90 mm	3.7 cm

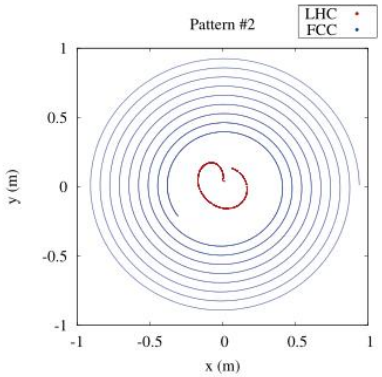
[a] For a dump line length of 2.5 km. [b] See F. Burkart, FCC Dump Meeting, 02/07/2015, [c] See F. Burkart, FCC Dump Meeting 02/12/2015.

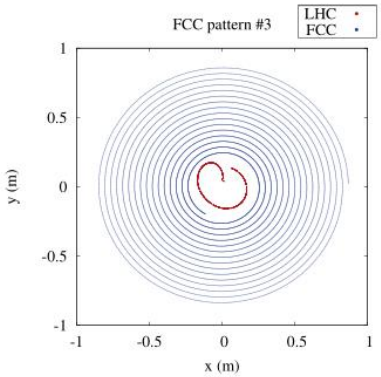


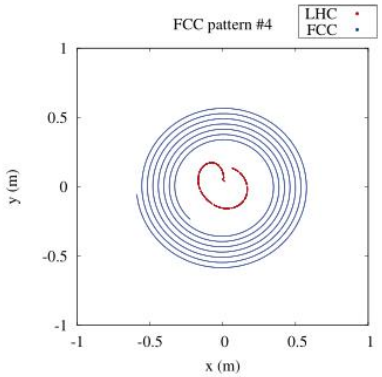
- Some remarks:
  - Pattern do not yet account for realistic filling schemes including gaps
    → this will still increase the total swep path length by several 10%
  - Only studied regular sweeps as shown above, but did not yet assess the consequences of failure scenarios for the different pattern/kicker parameters

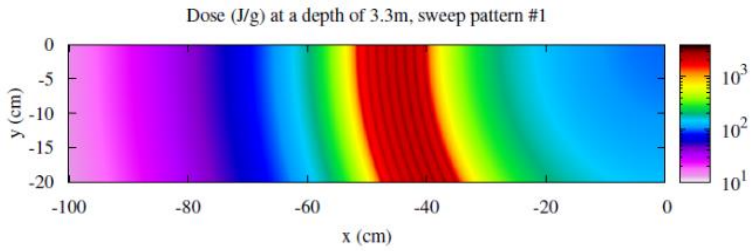
Overlap of neighbouring branches

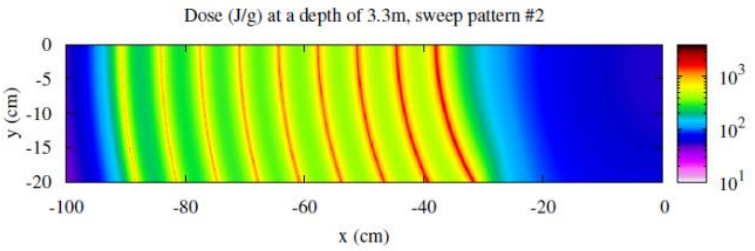


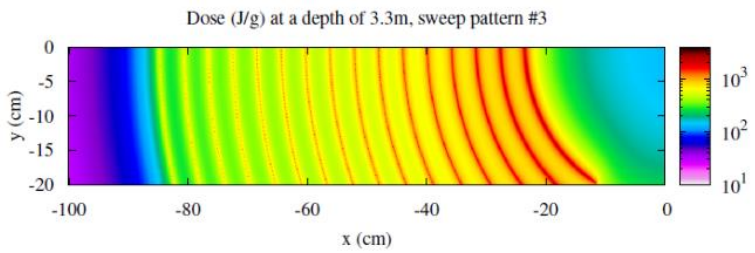


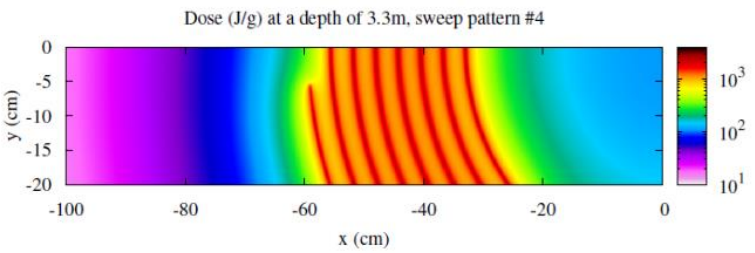












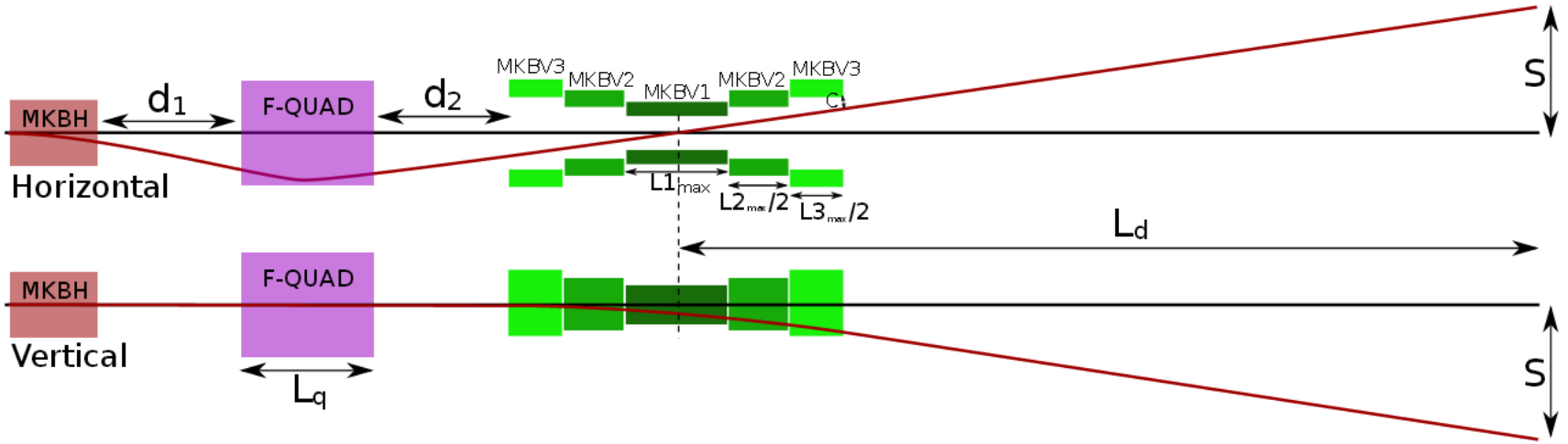
Conclusions and next steps

- Multi-spiral sweep pattern:
  - Assuming a minimum bunch separation of 1.8 mm, neighbouring branches should be separated radially by ∼4 cm or more to avoid too much overlap of shower tails from different branches†
  - Pattern #2, #3 and #4 give rise to peak temperatures not too far from our goal (comparable to what we expect for regular dumps of HL-LHC beams)
    → this leaves margin for sweep failures
  - Large dump cross section could be an issue for manufacturing (1.5-2.5 m diameter)
- Next steps (short to mid-term):
  - Should account for a realistic filling scheme → will increase of sweep path length
  - Effect of additional quad in dump line
  - Should study and classify different dilution failures (likelihood of occurrence, energy densities, temperatures, consequences for dump core)
- Next steps (mid to longer-term):
  - Thermo-mechanical simulations → energy densities/temperatures are only a first indicator if the load is acceptable and do not give the full picture of the material response

† By increasing the bunch separation, one could probably reduce branch separation at the cost of a longer sweep path length (matter of optimization).

Dilution system

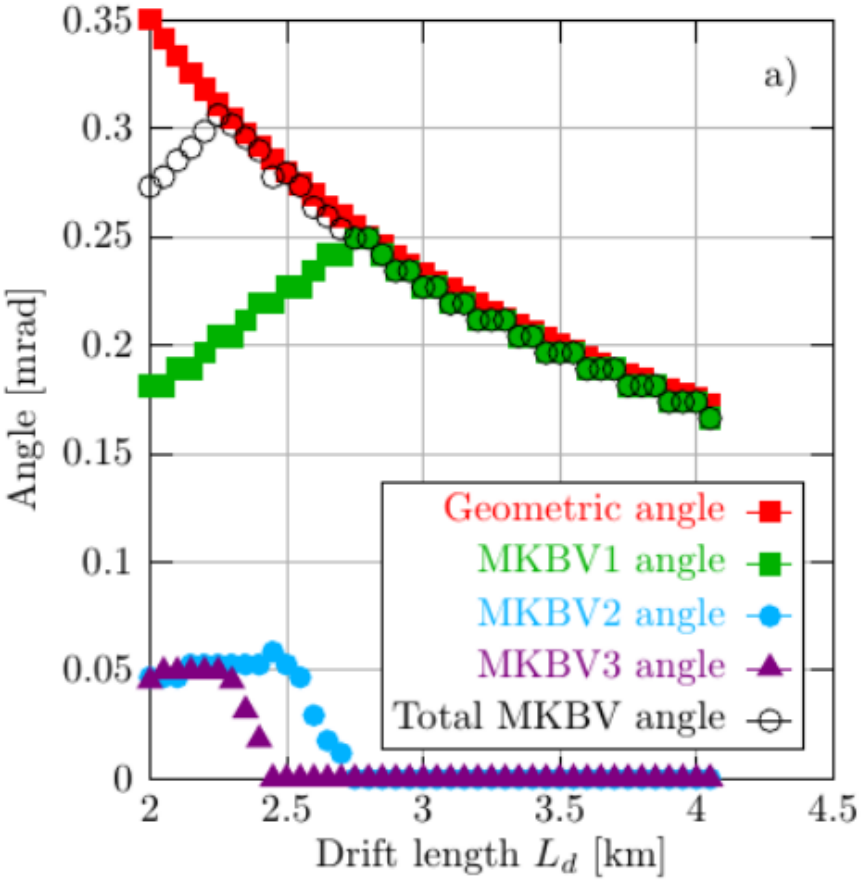
D. Barna, FCC dump meeting, 2nd March 2016



- Initial studies showed that the dilution kicker system is highly demanding (B.dl, rise time, frequency, aperture)
- Studied overfocussing quadrupole

Dilution system

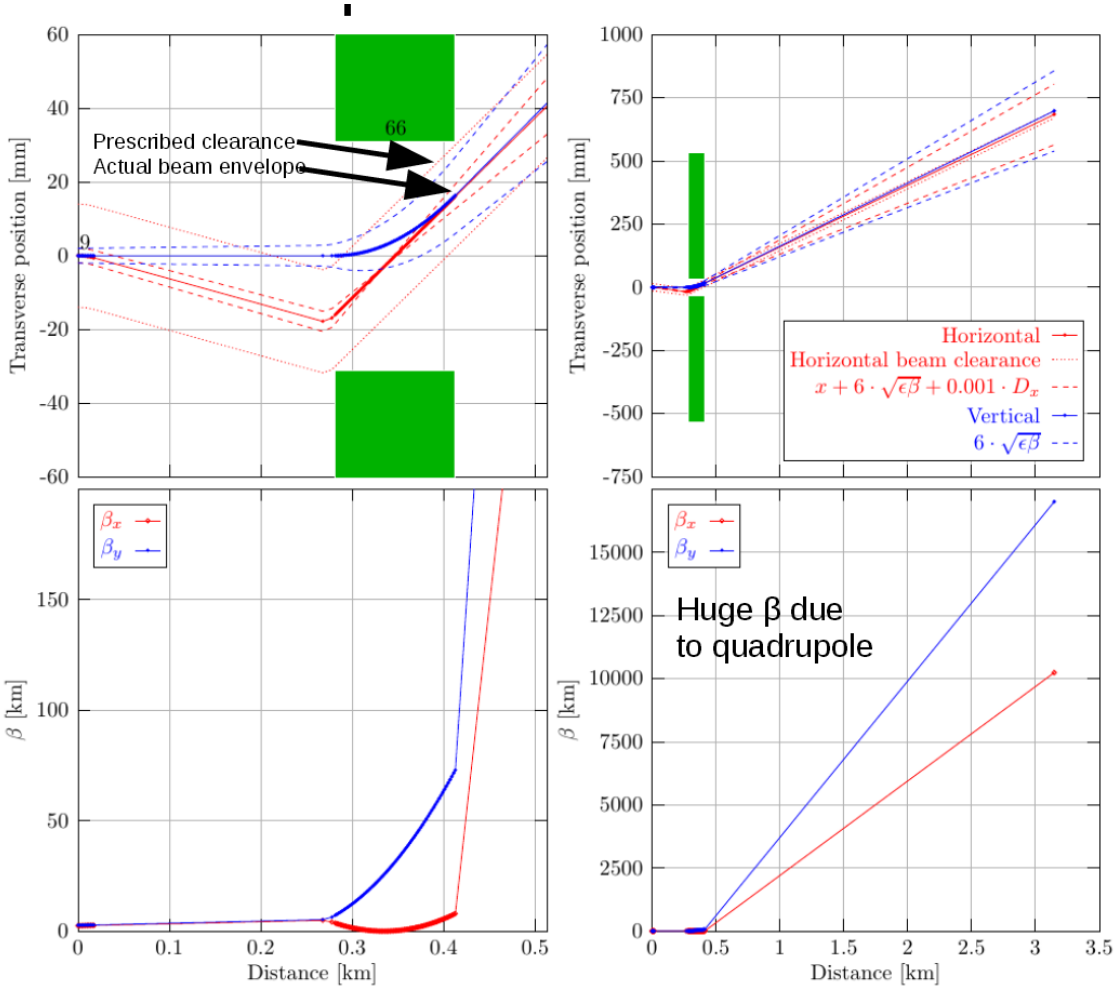
- With three different kicker types 2.5 km dump line



Dilution system

Beta functions at dump block become huge

→ to be iterated with FLUKA simulations – overlap vs peak



Conclusions

- Present baseline layout does not work for extraction system → request change of this baseline
  - Two extractions in one straight OK – preferred solution
  - Collimation system on same beam downstream extraction OK
- Single extraction system including optics matching and extraction protection of about 2 km
- From this concept prepared table of beam parameters for extraction protection – under study by Anton Lechner
- Initial dilution patterns were simulated by Anton → defined minimum bunch and spiral spacing
- Rigorous analysis of dilution concept
  - 2.5 km dump line length
  - Consider overfocussing quadrupole to support kickers – need to study failure scenarios
  - Huge beta functions at dump to be studied by FLUKA – initial parameters might be iterated