Development of a Pulsed Injection Stripline for Diamond-II

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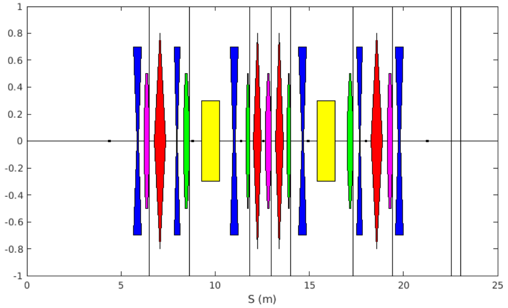
Contents

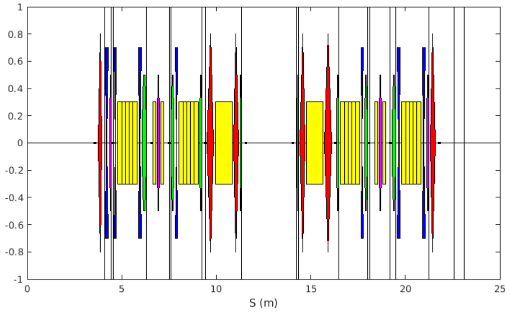
- Overview of Diamond and Diamond-II
- Injection Scheme for Diamond-II
- Stripline Design
- EM Simulations
- Particle Tracking
- Pulser Development
- Prototype
- Conclusions

Diamond and Diamond-II

- Diamond:
- 3 GeV, DBA, 3.1 nm emittance



- Diamond-II:
- 3.5 GeV, hybrid-6BA, 120 pm emittance



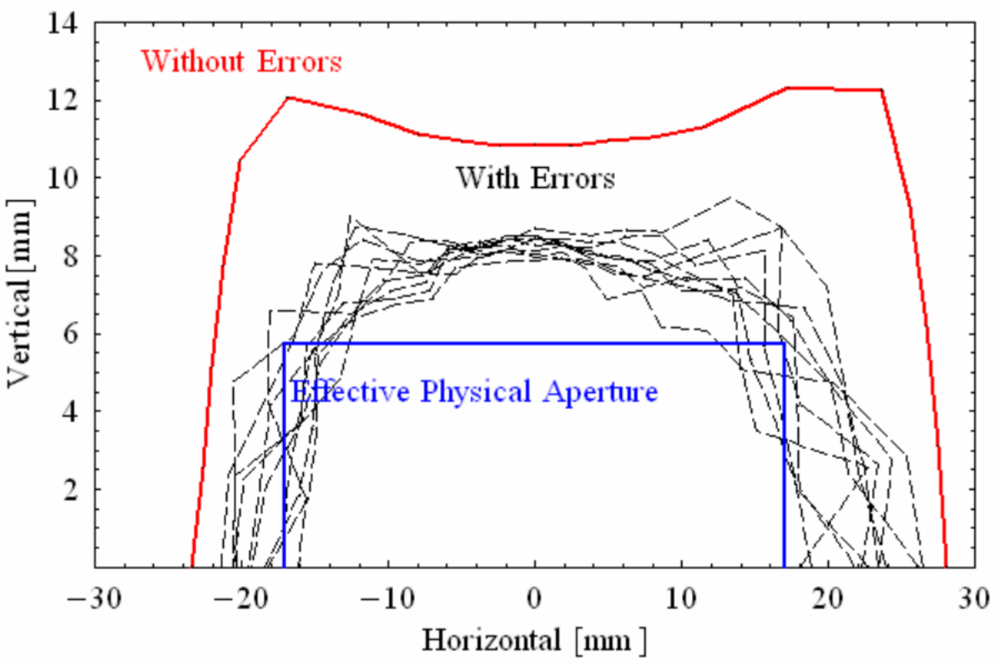
Parameter	Units	Diamond (no IDs)	Diamond (with IDs)	Diamond-II (no IDs)	Diamond-II (with IDs)
Energy	GeV	3.0	3.0	3.5	3.5
Beam current	mA	300	300	300	300
Beam lifetime	h	~ 10	~ 10	7.0	7.5
Circumference	m	561.571	561.571	560.561	560.561
Harmonic number		936	936	934	934
RF frequency	MHz	499.654	499.654	499.511	499.511
Total bending angle	deg.	360	360	388.8	388.8
Emittance (horizontal, natural)	pm rad	2729	3100	163	120
Emittance (vertical)	pm rad	8	8	8	8
Energy spread (rms)	%	0.096	0.107	0.095	0.109
Energy loss per turn	MeV	1.01	1.52	0.72	1.68
Momentum compaction factor	10^{-4}	1.57	1.56	1.042	1.041
Damping partition number J_x	-	1.00	1.01	1.87	1.37
Optimum RF voltage	MV	2.2	2.5	1.4	2.5
Natural bunch length (rms)	ps	11.4	11.0	12.5	11.7
Average bunch length (rms)	ps	17	17	49	48

Diamond and Diamond-II

- Significantly reduced dynamic aperture compared to Diamond

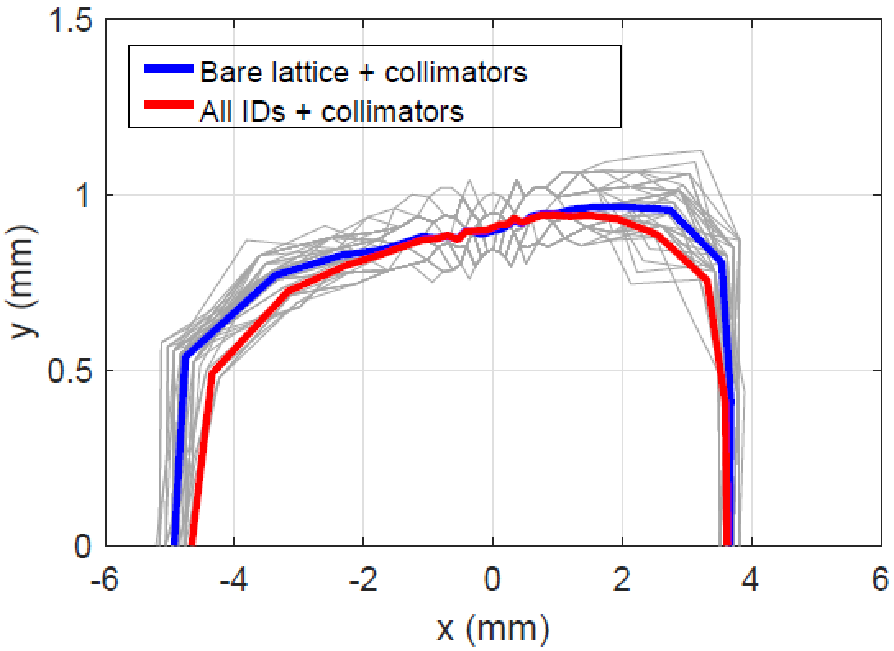
Diamond

S. Smith, J. Jones, H. Owen, EPAC'02



Diamond-II

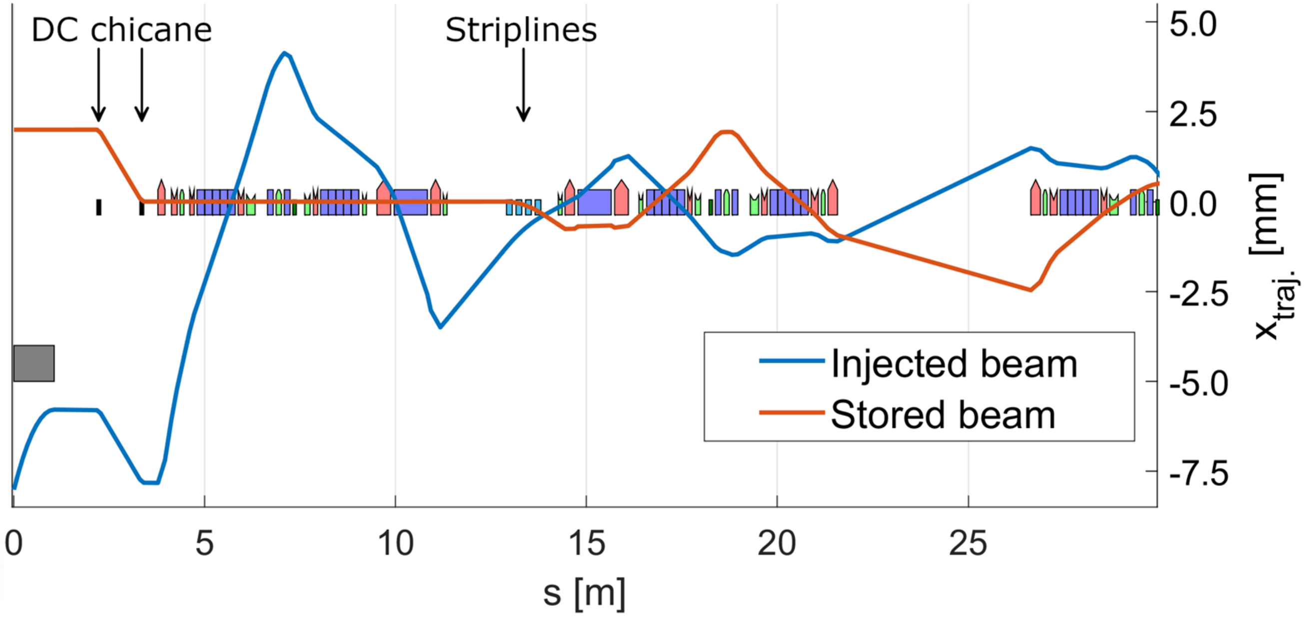
H.C. Chao, Diamond-II TDR, 2022



Contents

Diamond-II Injection

- Aperture sharing injection scheme
- Kick single bunch - 2 ns bunch separation
- Off axis injection into small dynamic aperture



175 urad kick
15-20 kV
>0.8 GHz bandwidth

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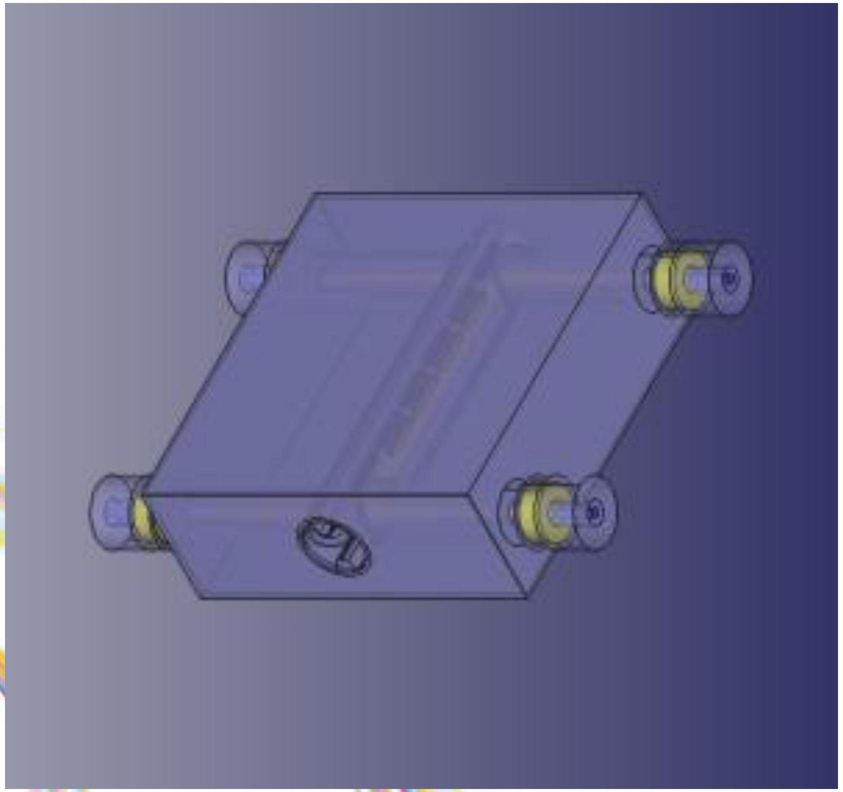
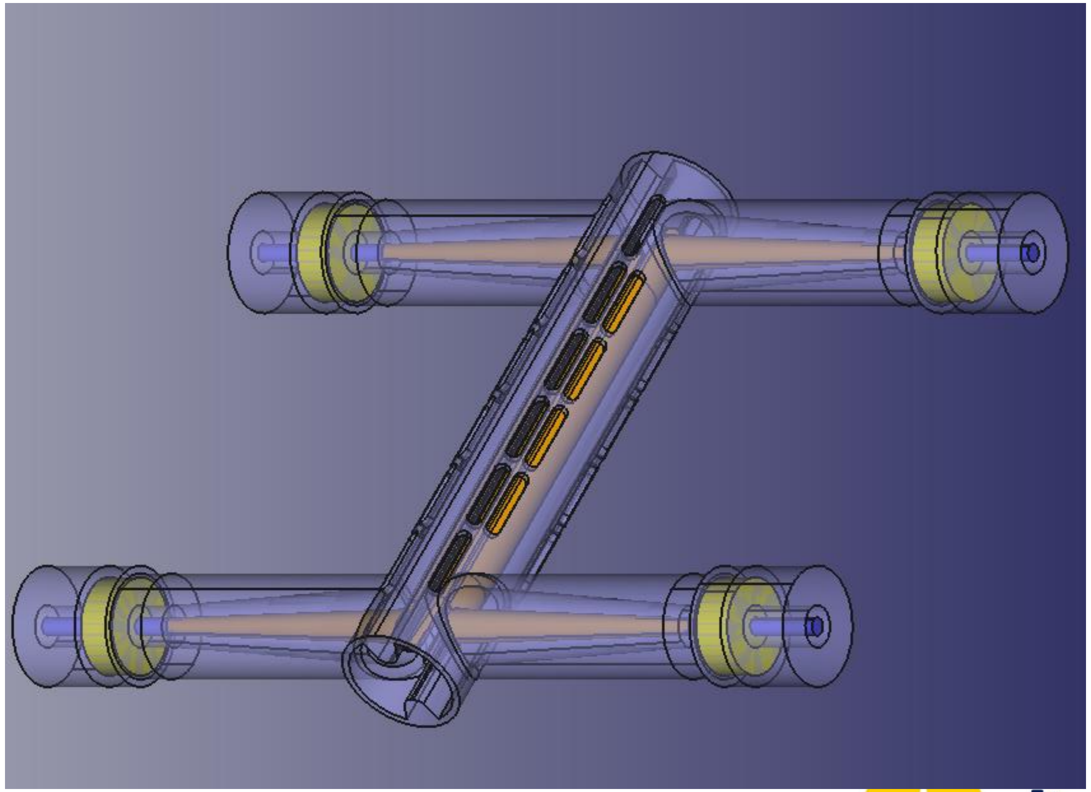
Stripline Design

- Evolved from MBF stripline design, influenced by SLS 2.0
- Large vacuum chamber
- Internal beam pipe with pumping grills
- 150 mm stripline length, 180 mm whole module



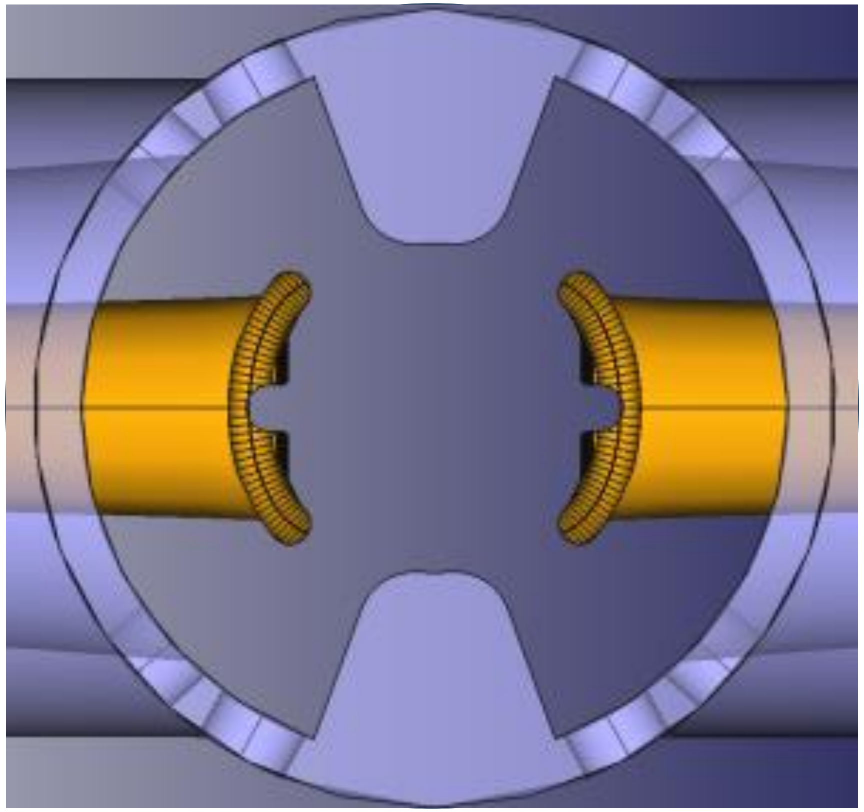


Stripline Design

- Circular arc radius 7 mm
- Flat central section 6.2 mm from beam axis and vertical inserts
  - improves field uniformity
- Cut-out for synchrotron radiation

- Ends optimised to minimise field roll-off and reflections

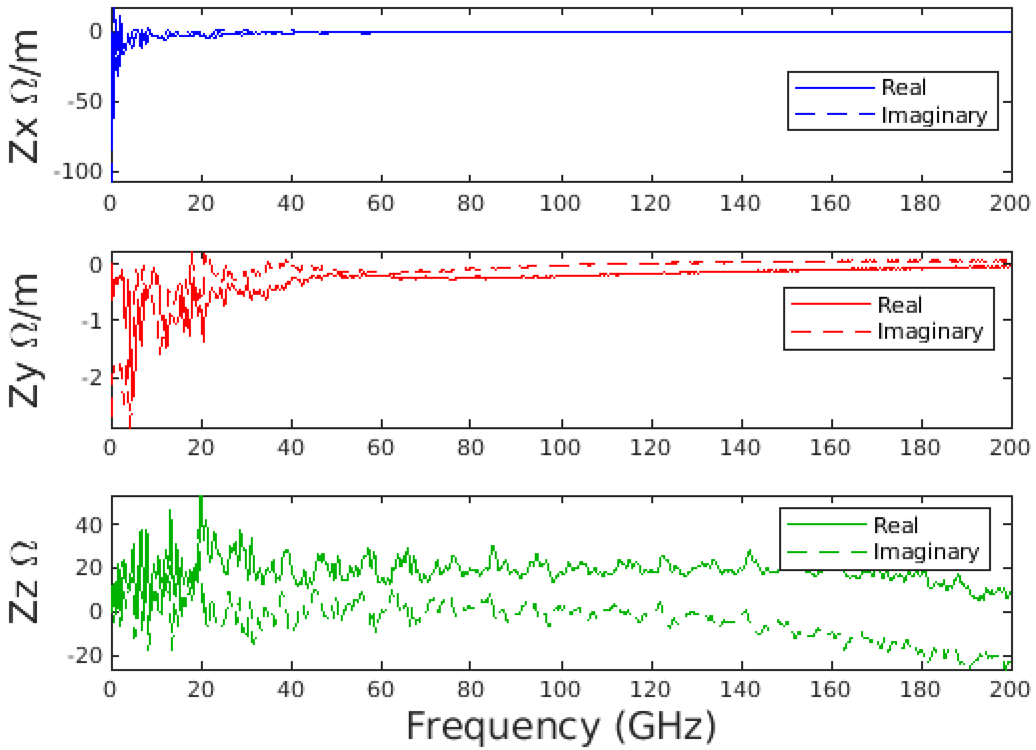
- Rounded edges and maximised spacing to avoid arcing



Contents

Wakefields and Impedance

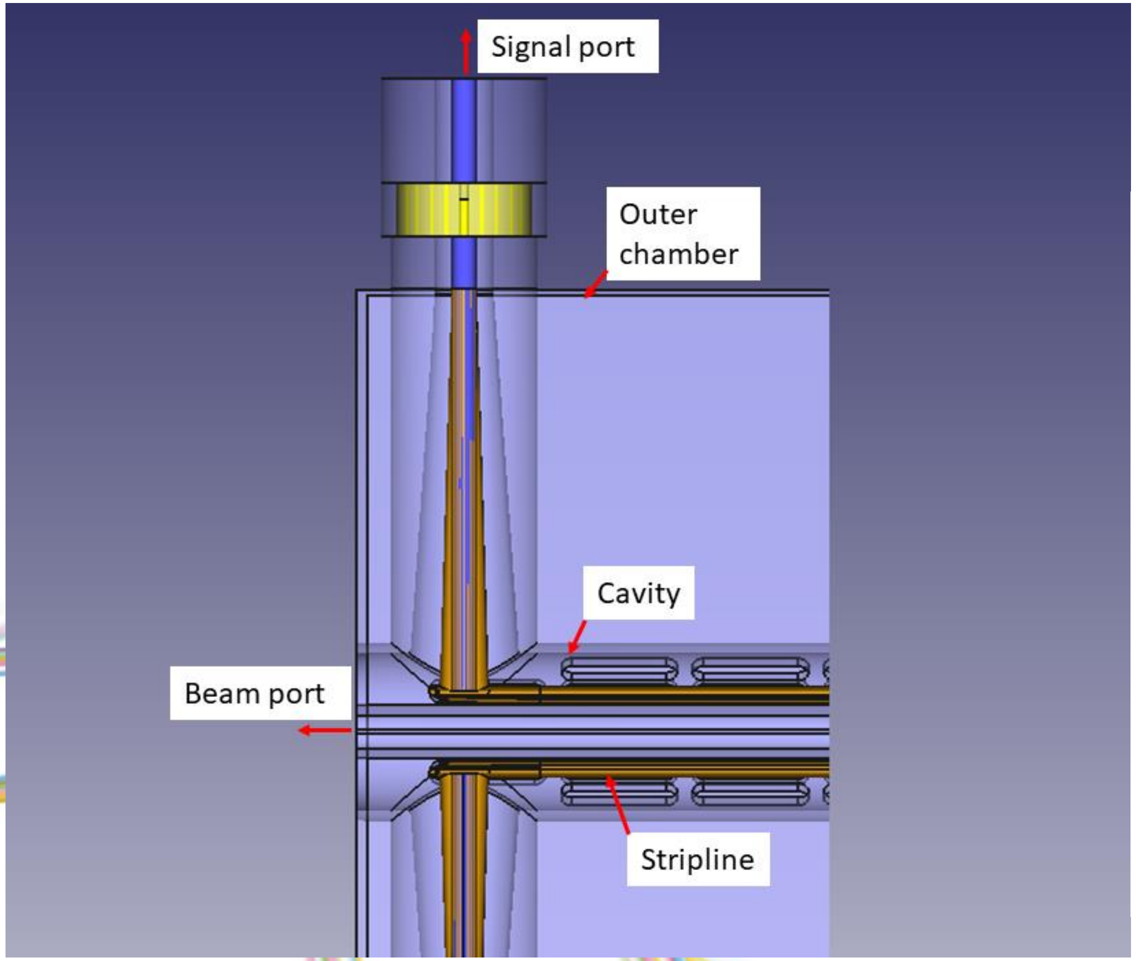
- CST Studio + GdfidL, 0.5 mm bunch, 300 mm wake length

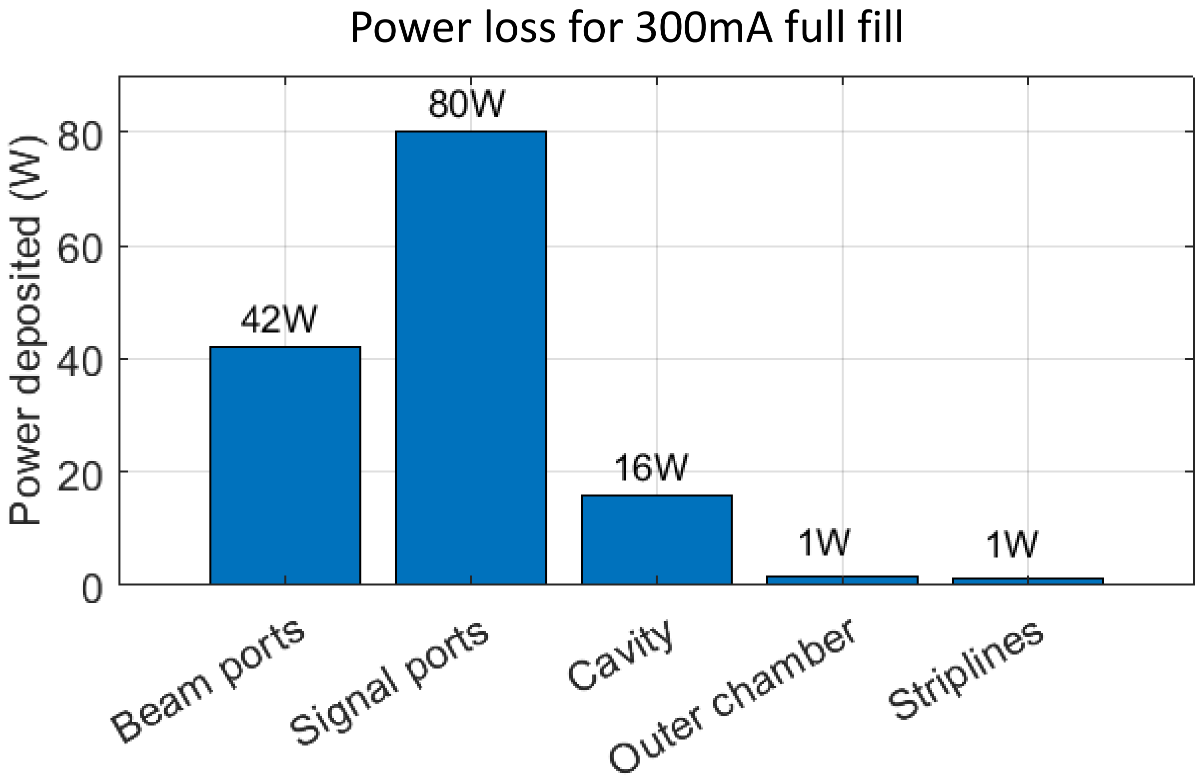


Loss/kick factors

kx (V/pC/mm)	0.1350
ky (V/pC/mm)	0.0496
kz (V/pC)	3.3689

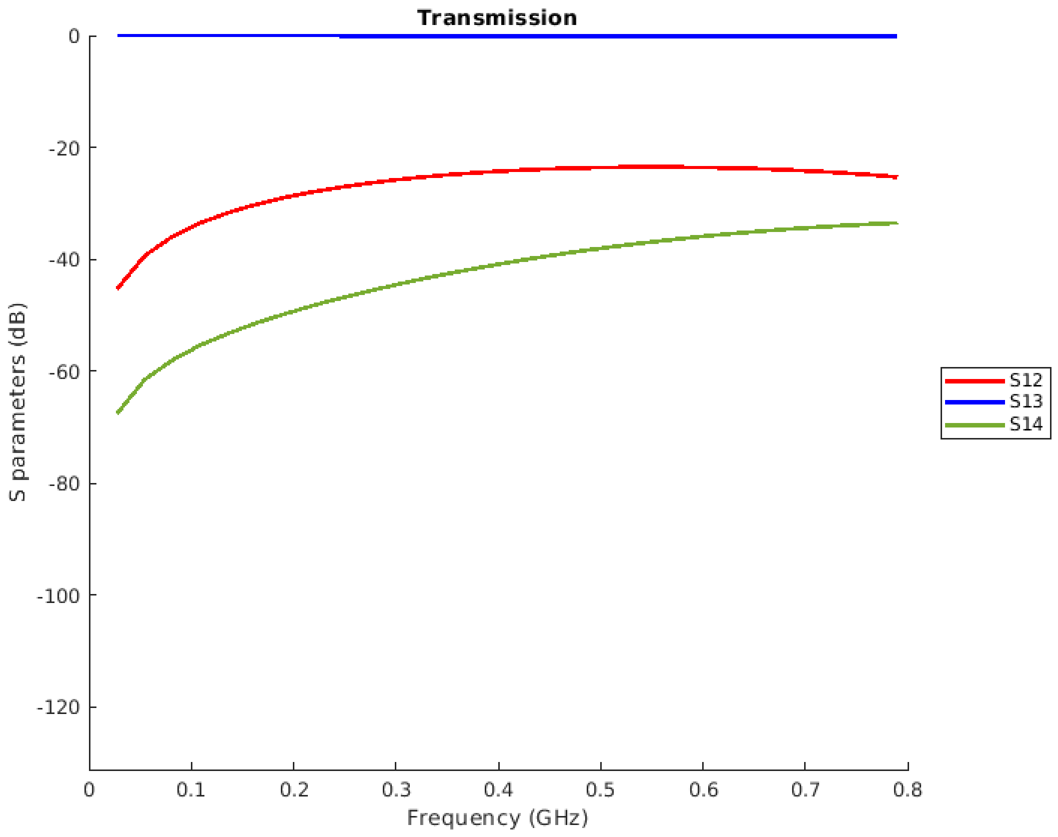
Power Loss From Beam

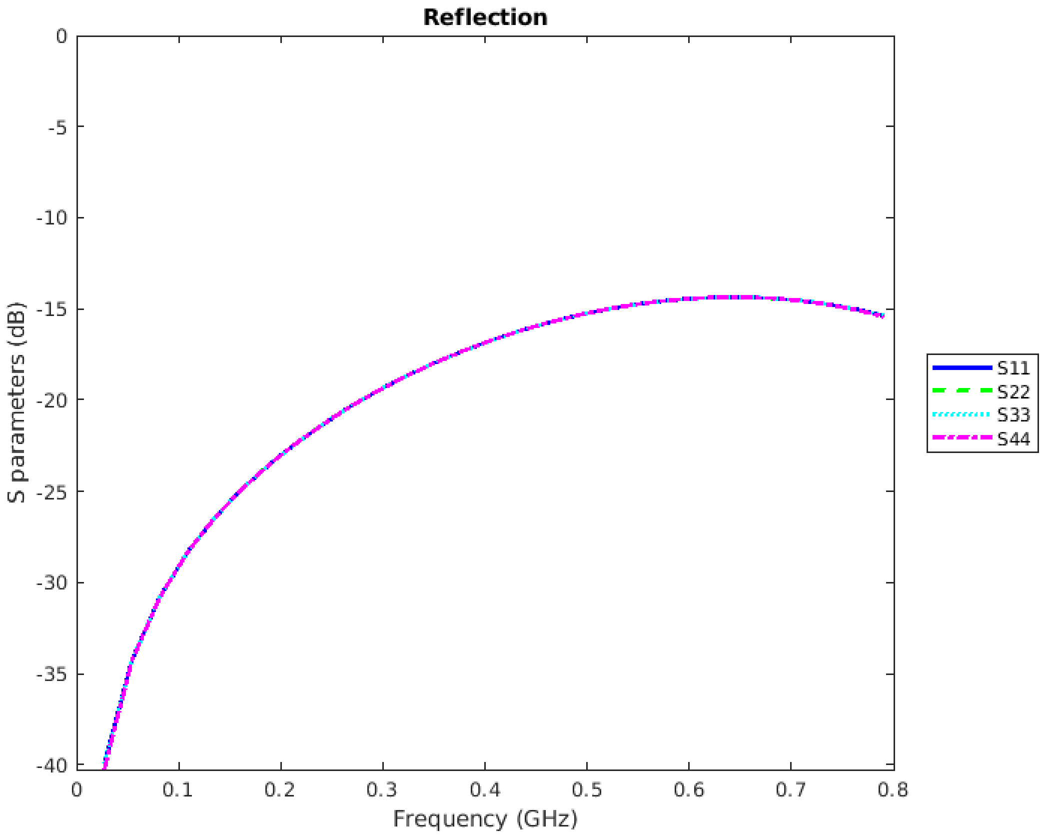




S-parameters

- Peak reflection -14 dB

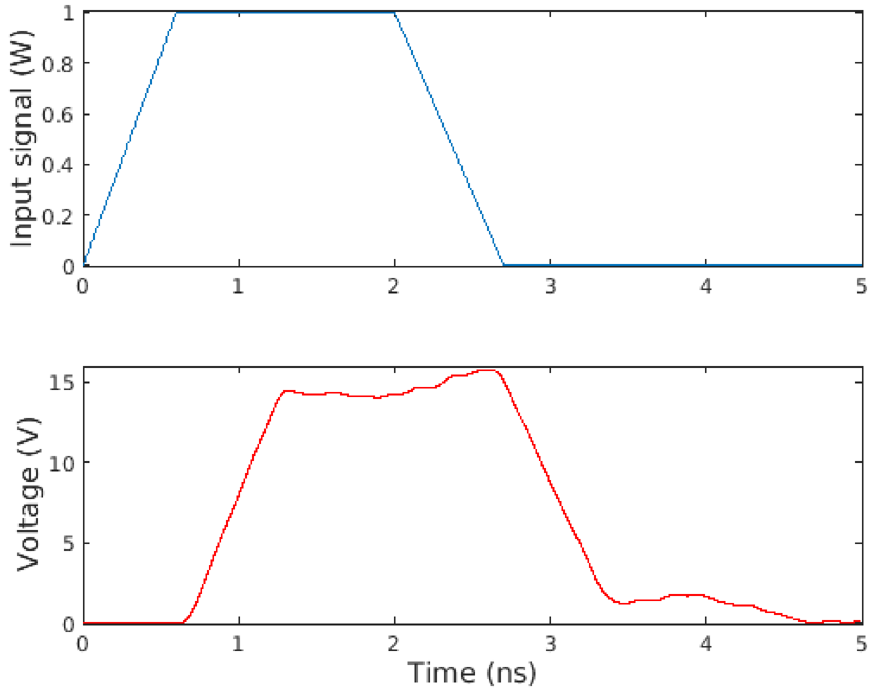




EM Simulations

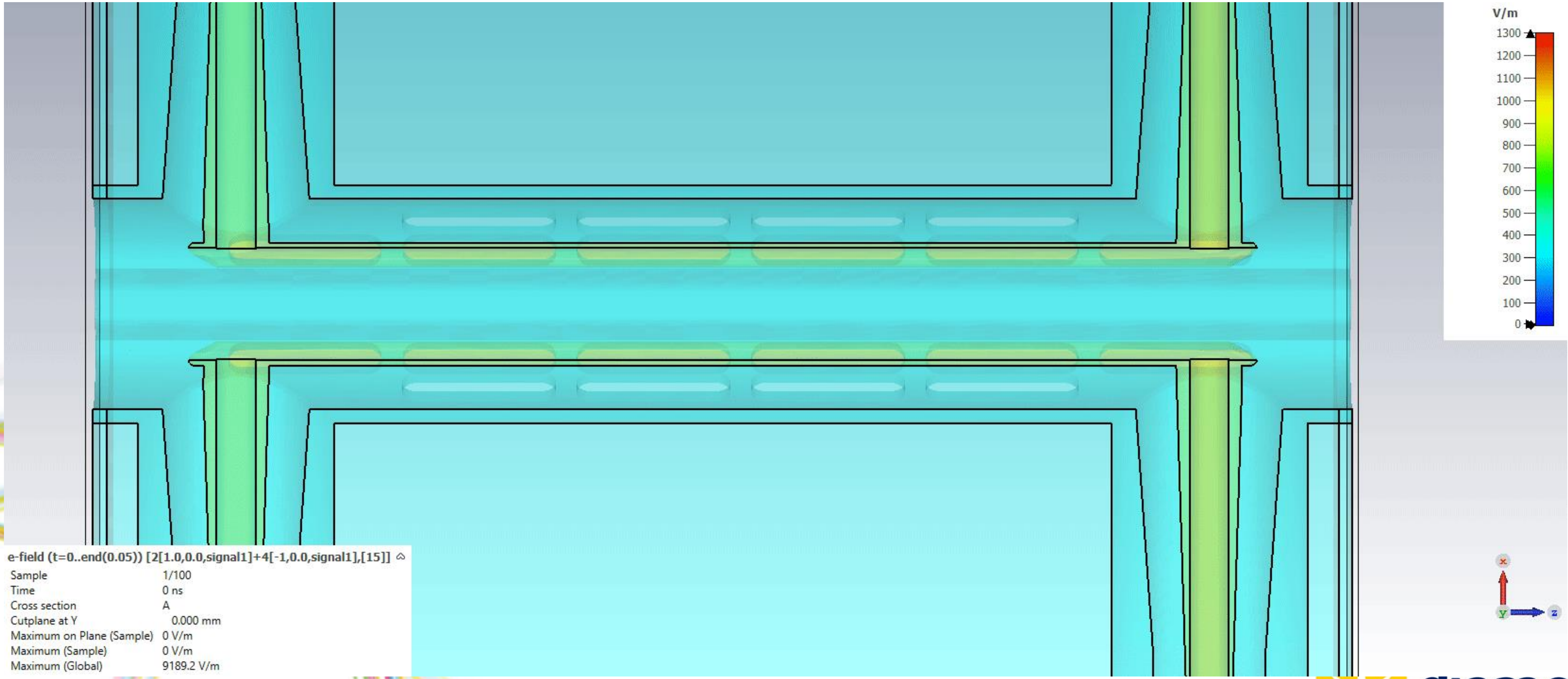
- Representative pulse
- 0.6 ns rise time, 1.4 ns flat top, 0.7 ns fall time

- Voltage between plates varies due to reflections
  - Ringing after pulse could hit following bunches



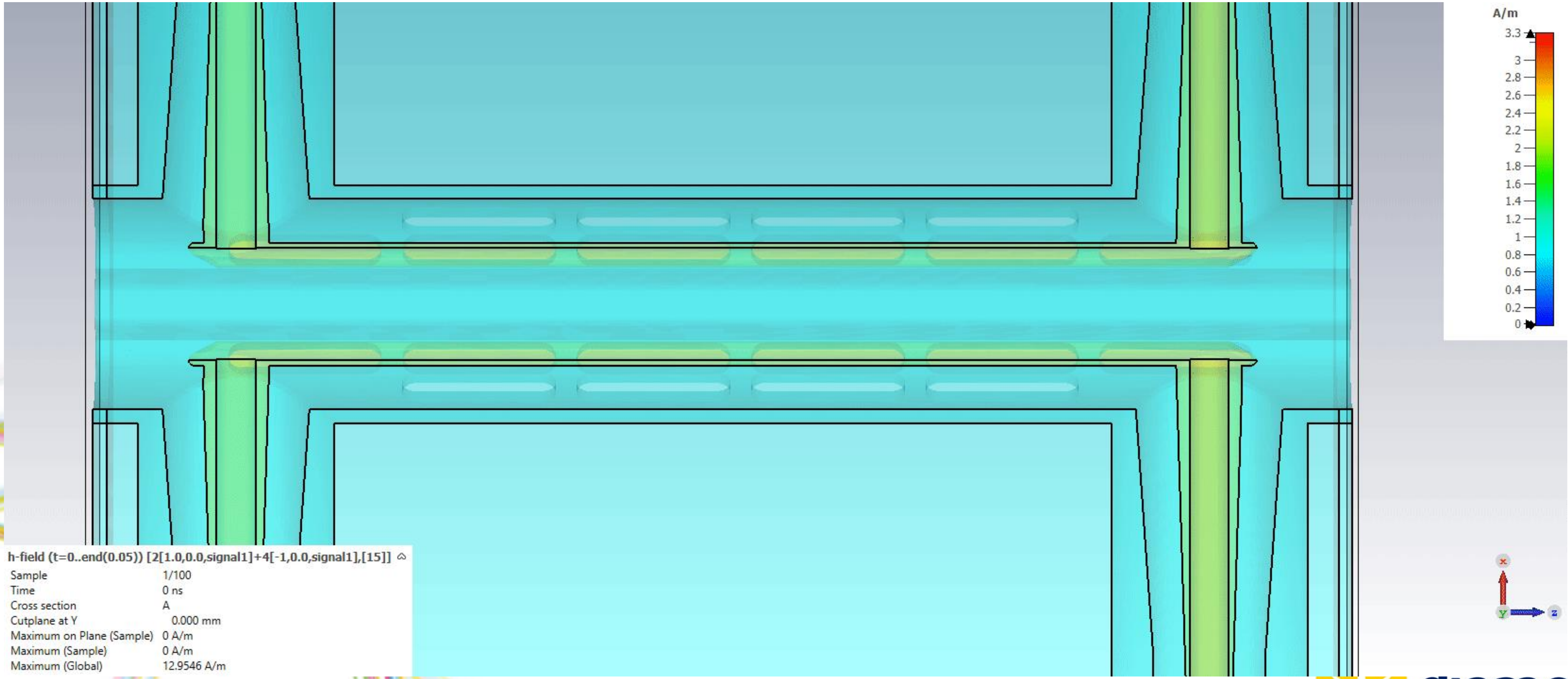
EM Simulations

- Full 3D E-field simulations



EM Simulations

- And B-field



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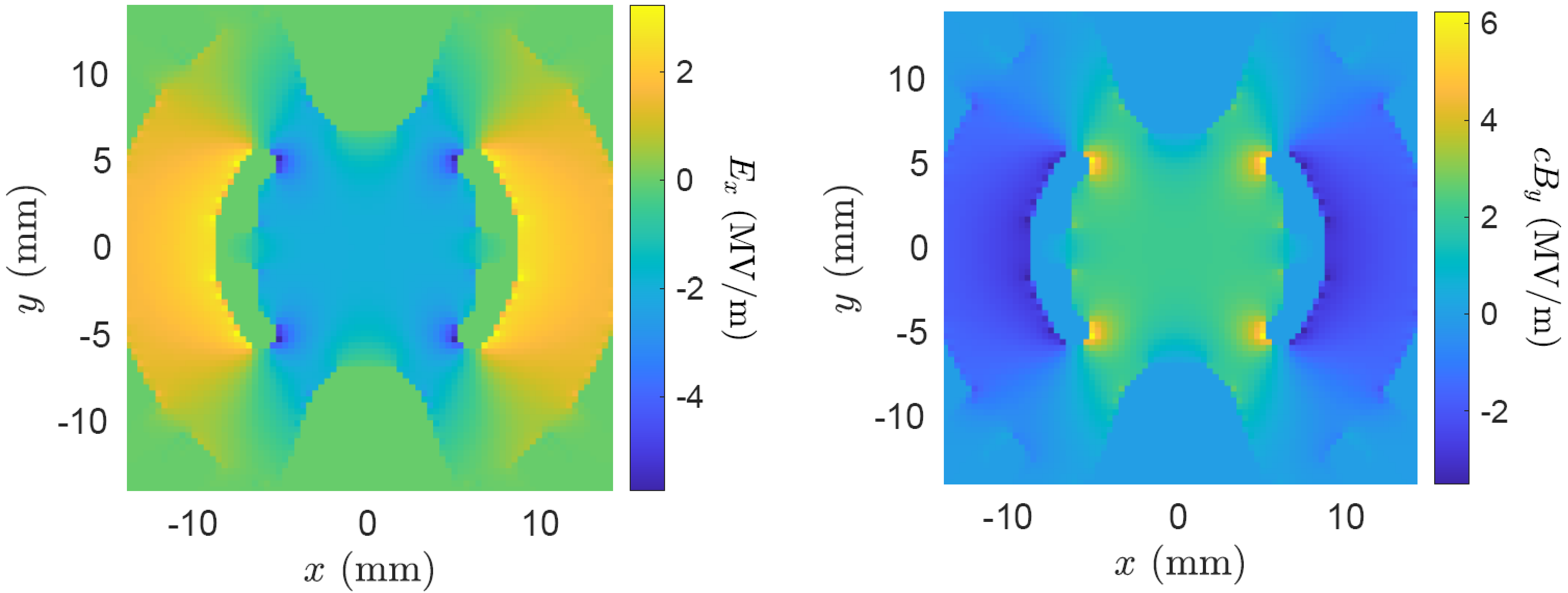
Particle Tracking

- Field maps at slice through centre

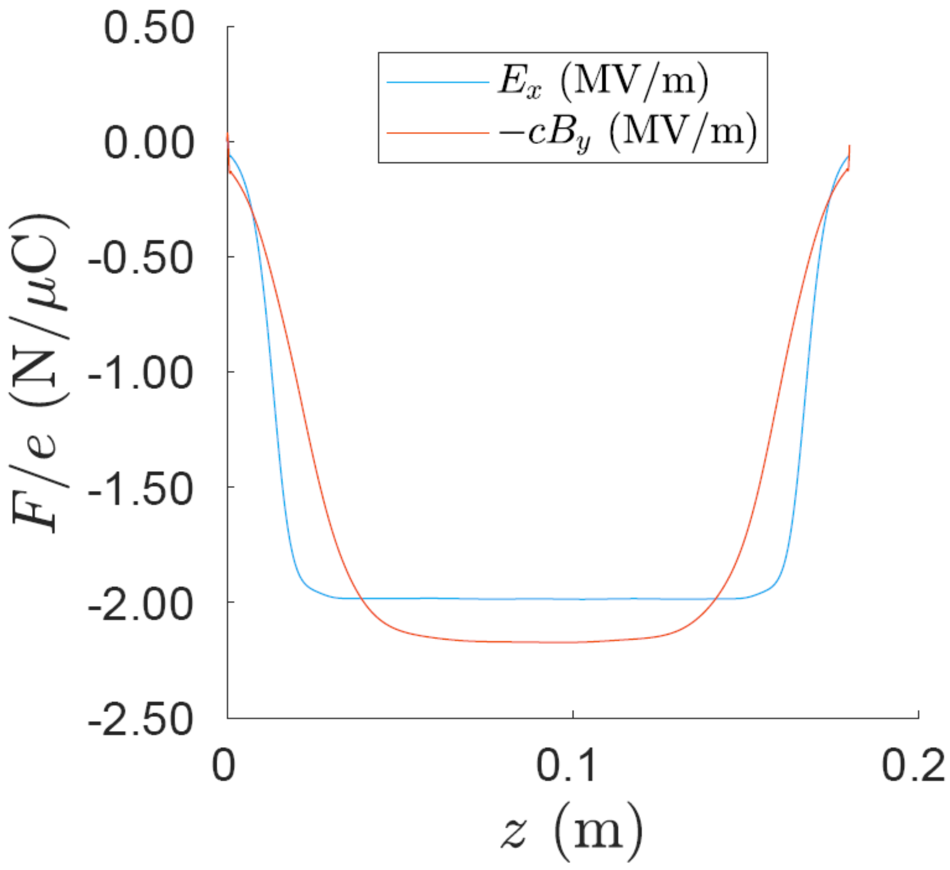


- Translate to kickmaps for tracking in Elegant and AT

diamond

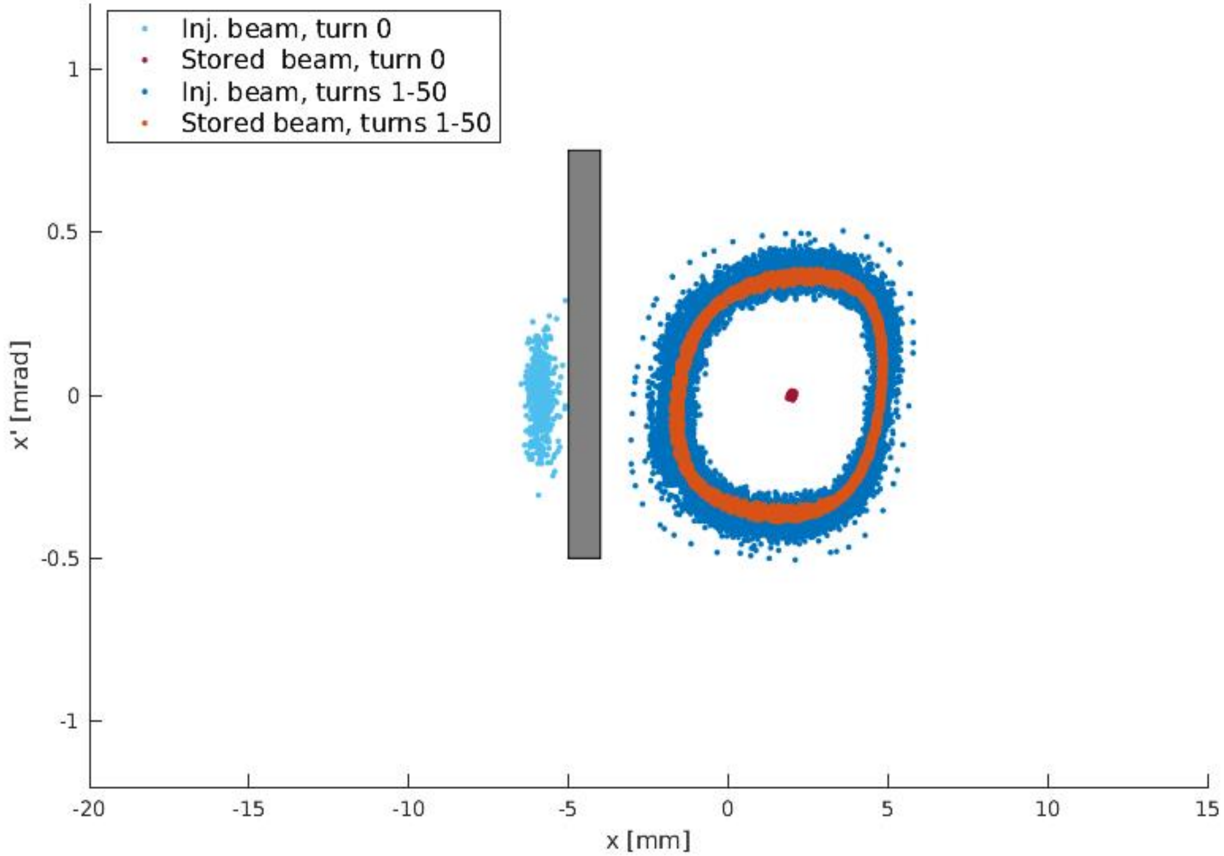
Particle Tracking

- Force from fields seen by beam



Particle Tracking

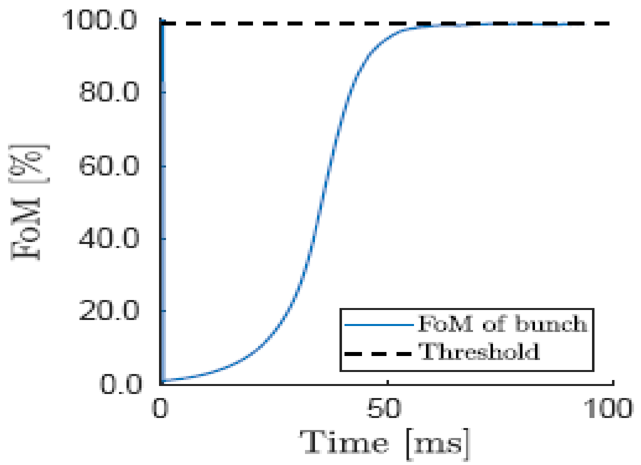
- Phase space for injected and stored beams
- Ideal stripline
- Simulated kickmap



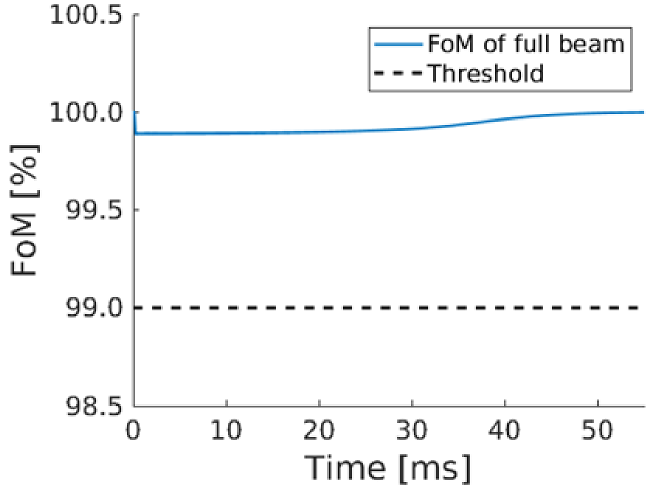
Stored Beam Distortion

- Figure of Merit: the light flux integrated over 100 µs through a transverse full-width half-maximum slit located 45 meter downstream of the source point > 99%

Kicked bunch

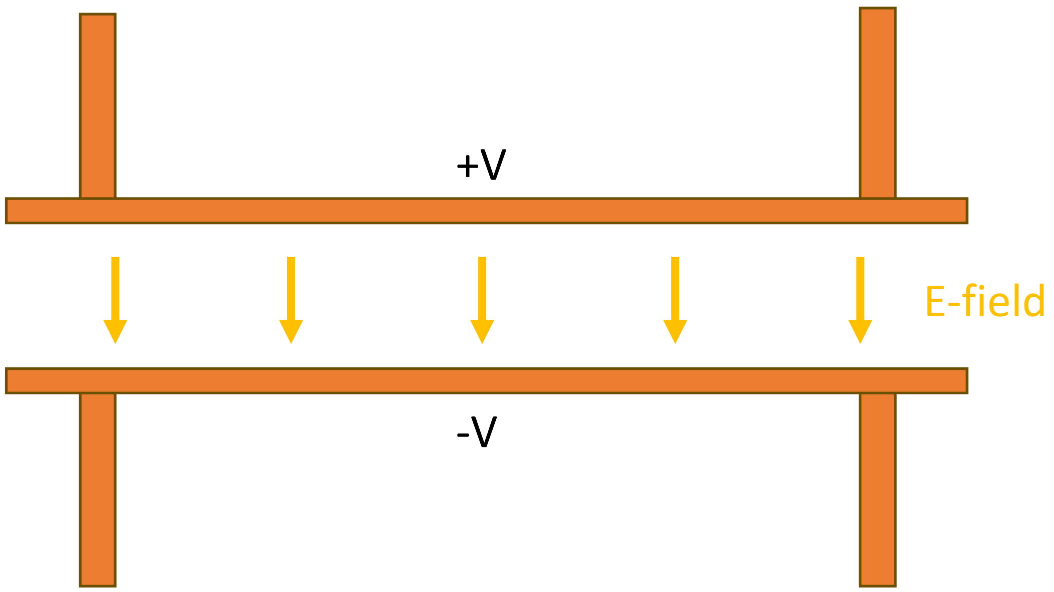


Full beam



Stored Beam Distortion

- Kick to following bunch, depends on residual fields
- Direction of travel important for B-field - first reflection kicks in opposite direction from E-field



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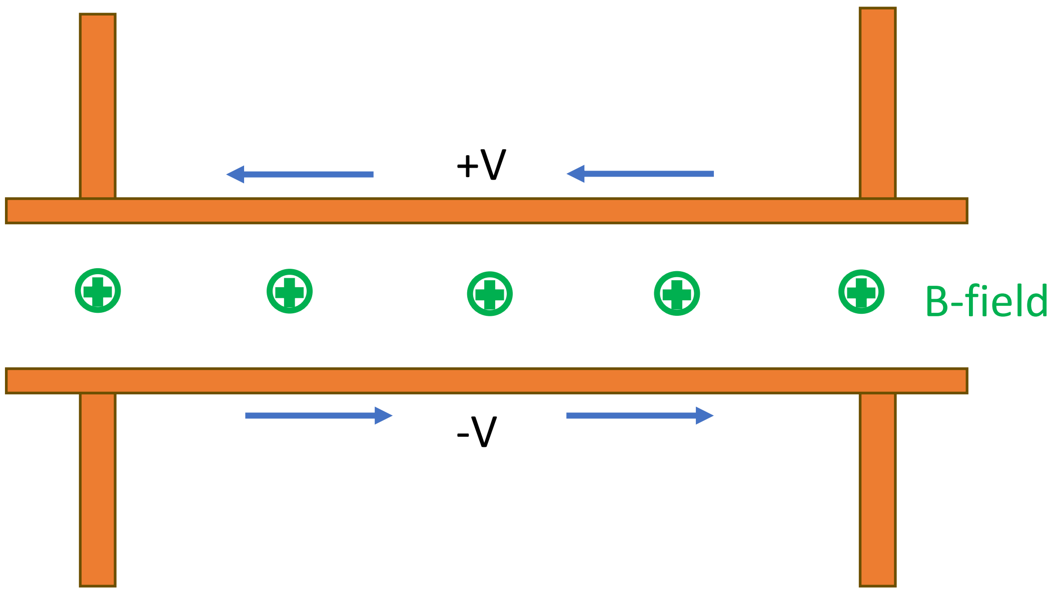

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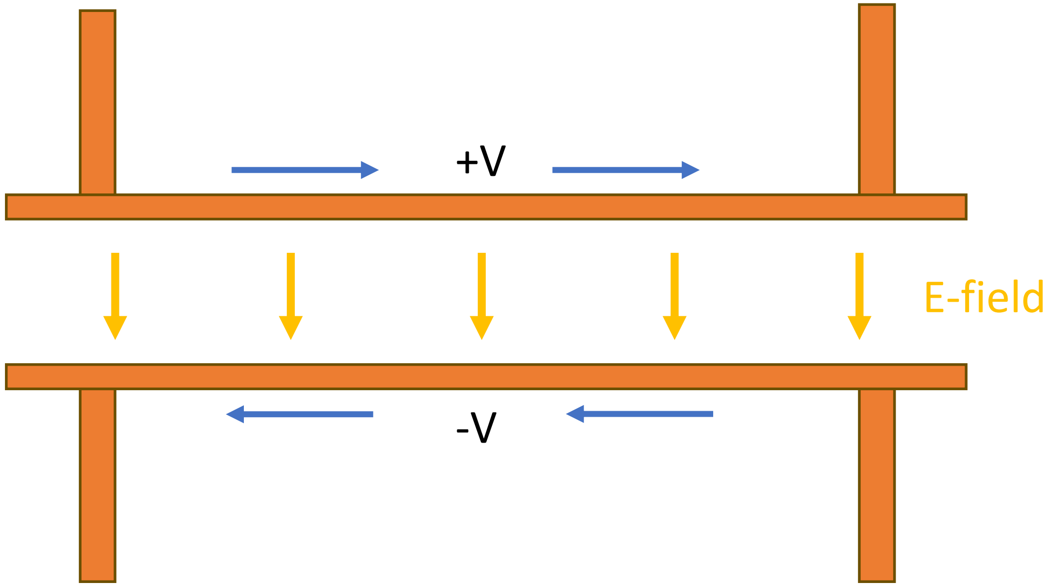

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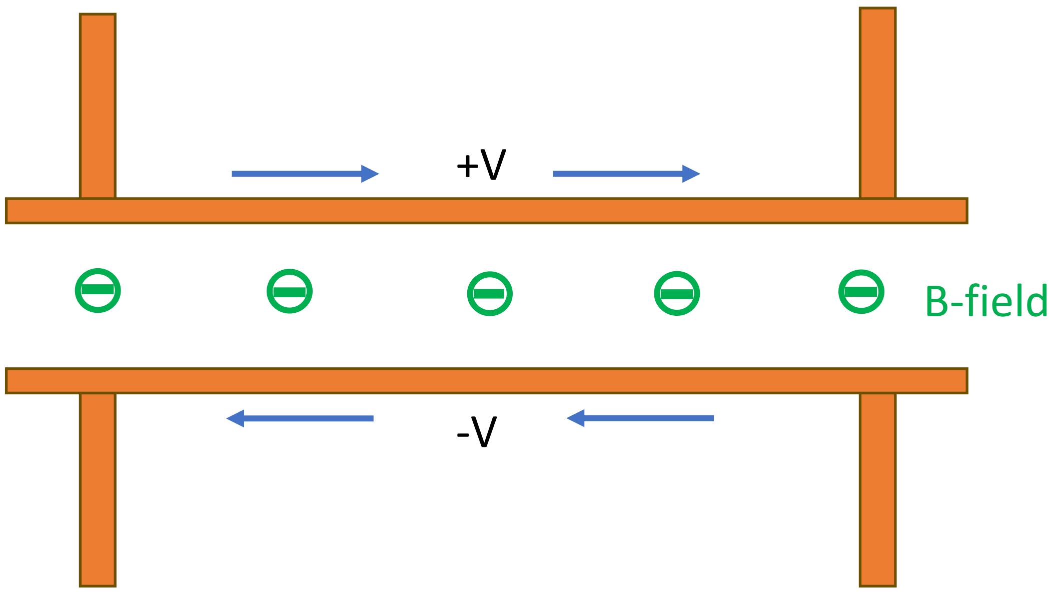
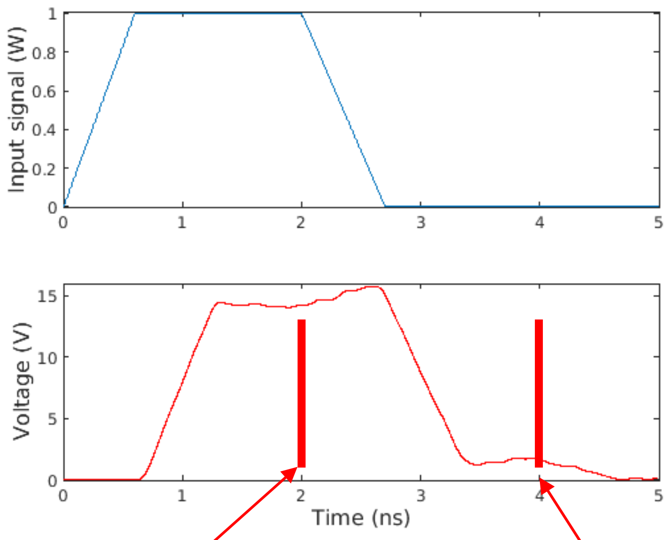


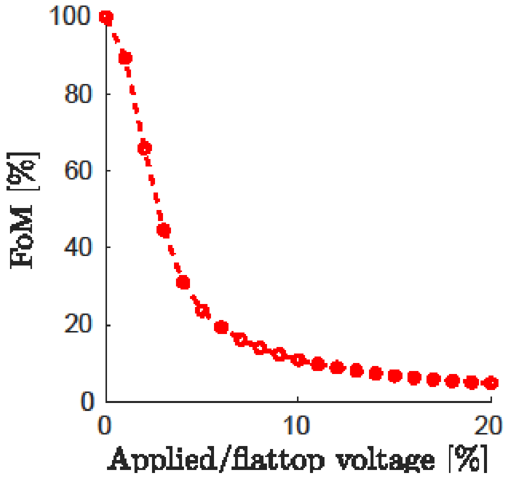
Stored Beam Distortion

- Voltage at following bunch

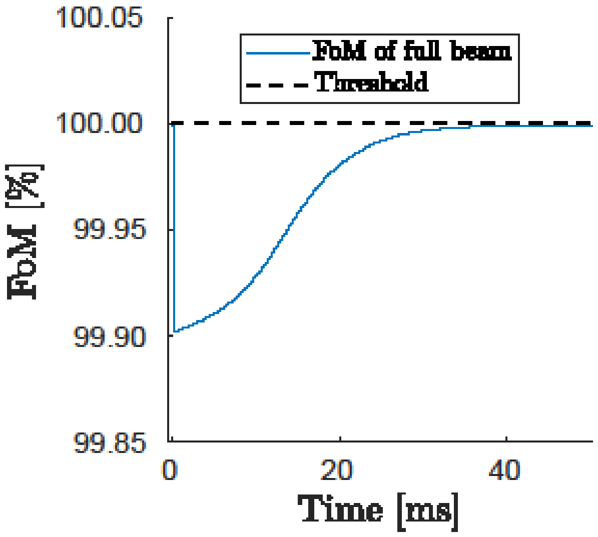


Target bunch
Following bunch

Reduction in brightness in following bunch



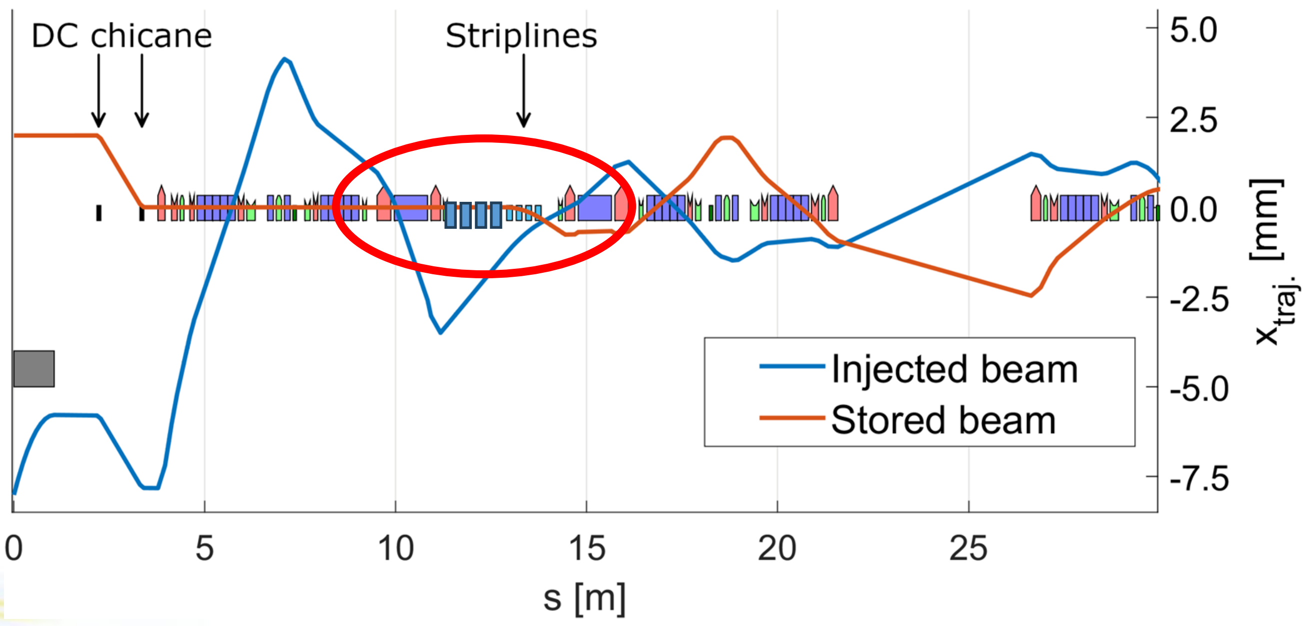
Effect on beam with 10% kick



Reduction in brightness to following bunch and full beam depends on details of reflections

How Many Kickers?

- More kickers - reduced kick/voltage required, but can't have optimal placement
- Cost reduction from relaxed requirements offset by more components



4 striplines:
173.82 urad kick
Injection efficiency = 100%

6 striplines:
124.47 urad kick
Injection efficiency = 98%

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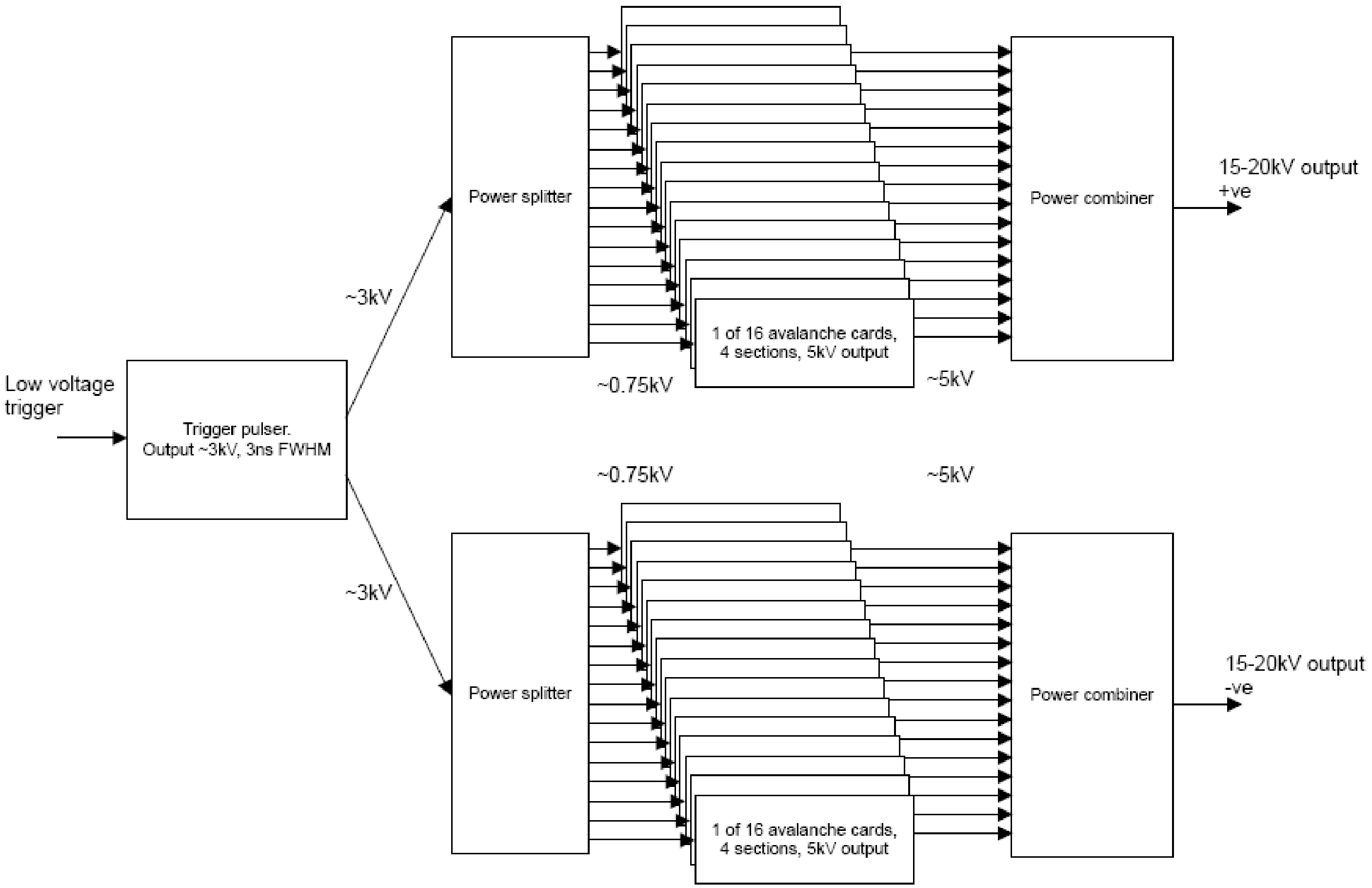
Pulser Development

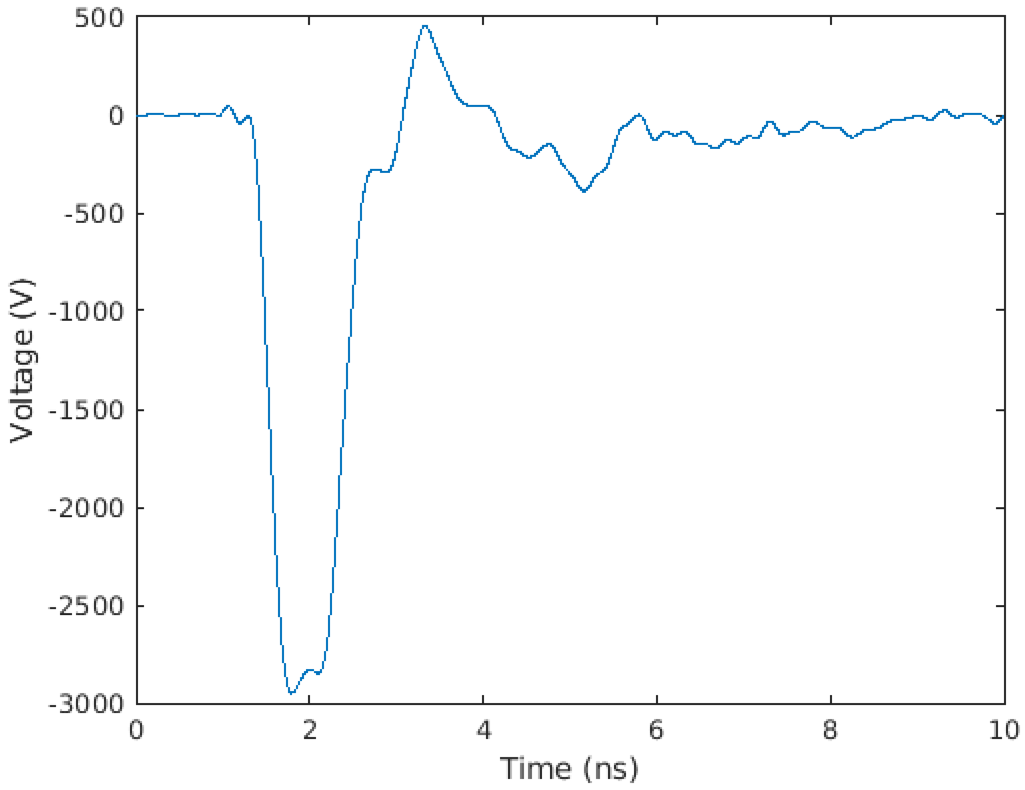
- Pulser design proposal by Kentech

- Array of voltage avalanche cards
- 4 small avalanche stacks which are summed
- Not reliant on a single HV switching device
- Easy swap of individual cards
- Individual sections can be enabled/disabled
- Low jitter (few ps RMS)



Pulser Development

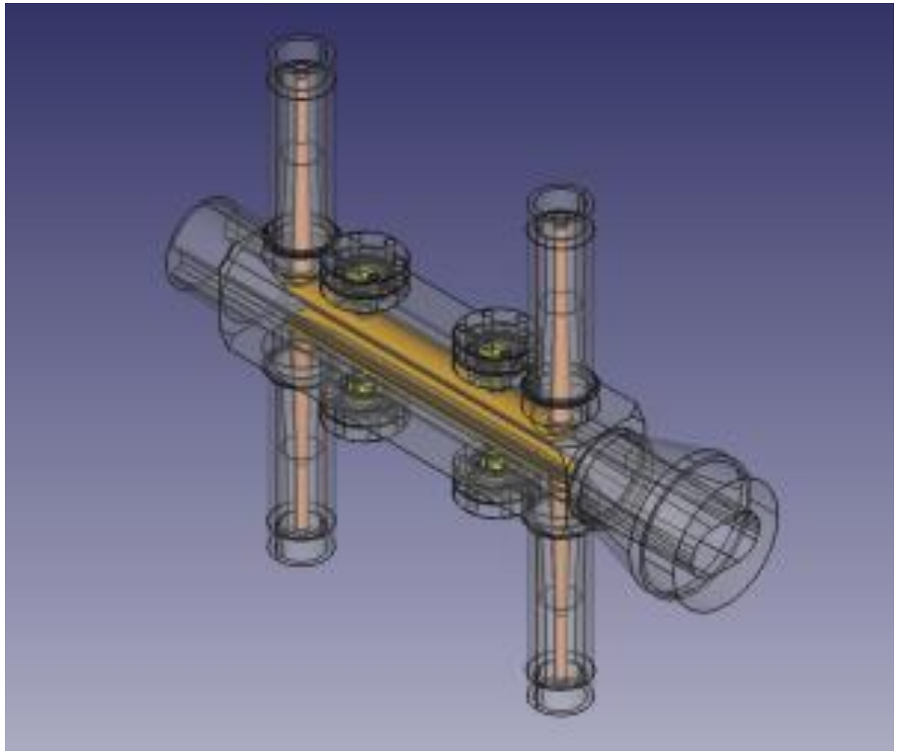
- Proof of concept demonstrates ~1 ns pulse at 3 kV
- Post-pulse ringing can be reduced with passive pulse-forming
- Early demonstrator - development ongoing



Contents

Prototype Stripline

- Similar design - larger aperture and rotated by 90° to avoid blocking injection in Diamond



Prototype Testing Plan

- Order December 2023
- Lab tests
  - S-parameter measurements - validate simulations
  - Vacuum tests
  - Pulser characterisation

- Installation in booster-to-storage-ring transfer line (June 2024)
  - Kick magnitude and field quality - validate simulations
  - Power reflection and beam-induced effects

- Installation in storage ring (August 2024)
  - Beam-induced heating with stored beam
  - Impedance and beam dynamics

Contents

Conclusions

- Aperture sharing injection scheme for Diamond-II using stripline kickers
- Stripline mechanical design in progress but well advanced
- Realistic simulations and particle tracking give confidence in early idealised calculations
- Feedthrough samples on order for testing, should meet requirements
- Pulser requirements are realistic, prototype under development
- Prototype stripline for testing at Diamond under development, aim to start testing early next year

Thanks

- Anusorn and Alun
- The Diamond engineering team
- Kentech