# Stripline kickers for top-up injection into PETRA IV

## Design evolution, prototype results & future plans

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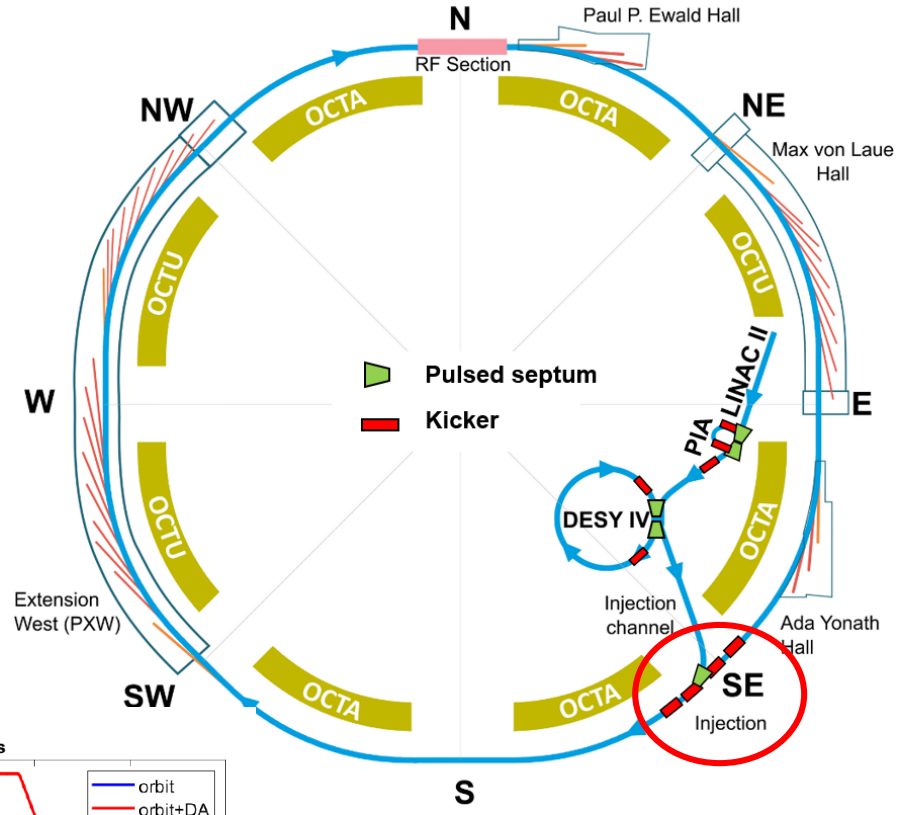
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

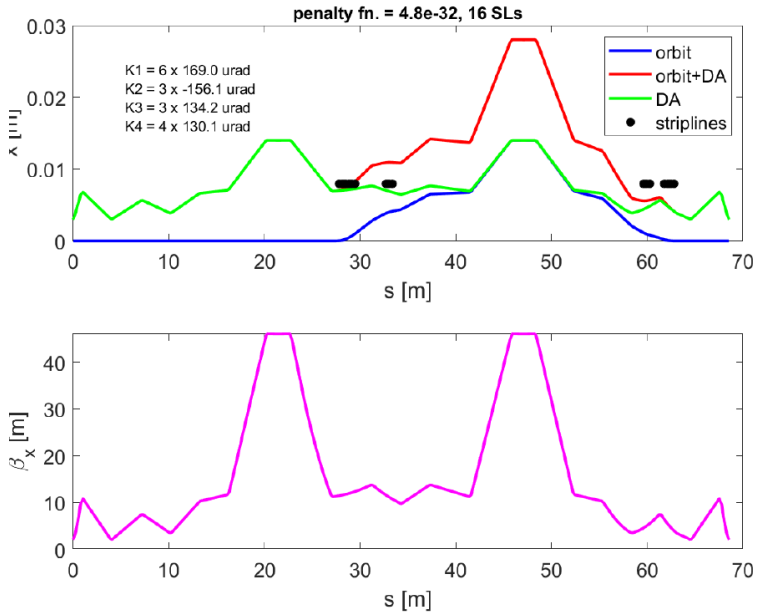
DESY.

# Overview of PIV kickers & septa

## Positions & requirements of injection elements

- Mainly slow kickers up to PETRA ring
- Original design: swap-out injection of 20 bunch trains @4ns separation
  → 80ns flat top, 2 kickers, 4x 1m modules each
- Lattice change in winter 2021
  → 2ns bunch separation, top-up injection
- Kickers for 4 bump injection of single bunches
  → ~11+4 modules, 0.35m

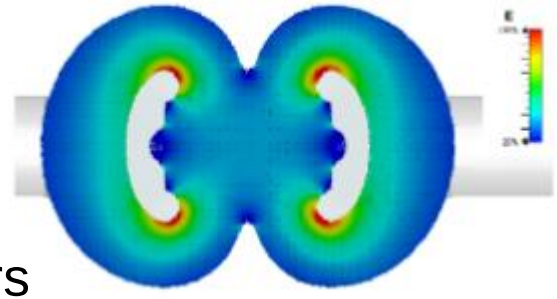


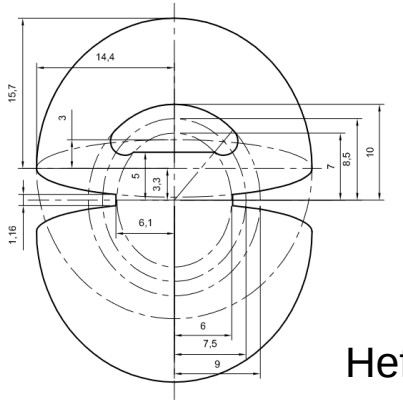
# Literature study

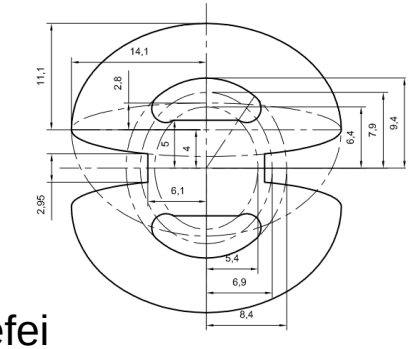
## Available concepts

- Various institutes building swap-out kickers (ANL, LBNL, HEPS, CERN, …)
- Base concept similar: reduce odd/even mode impedance deviation from 50Ω
- Various implementation concepts
- Main difference to PIV: limited no. of modules



SLS2.0

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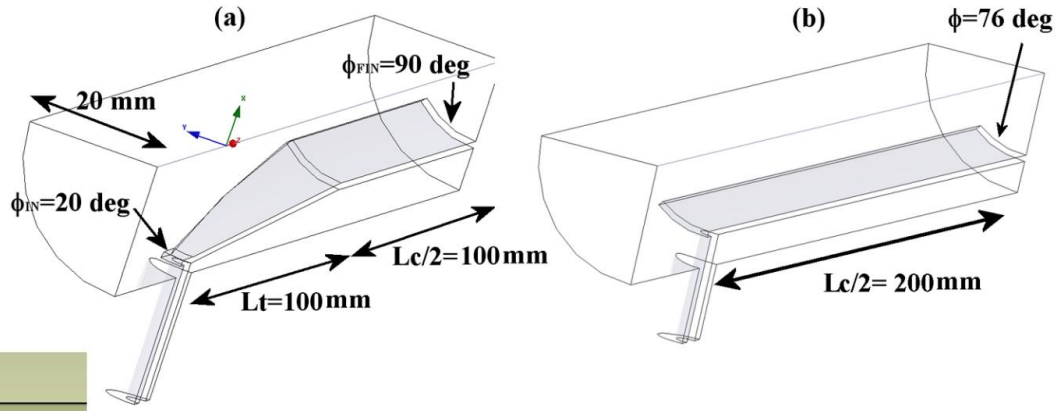


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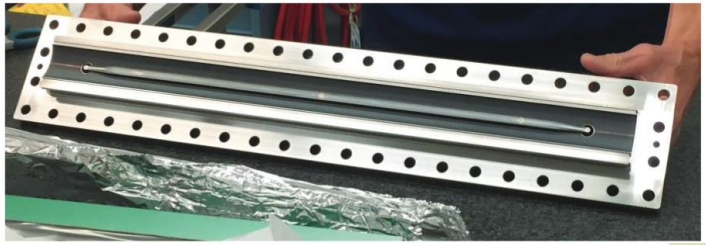
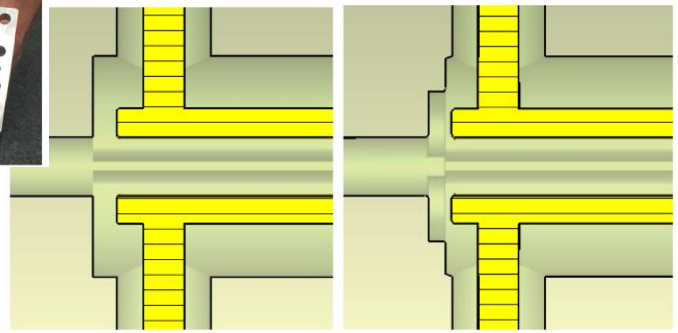
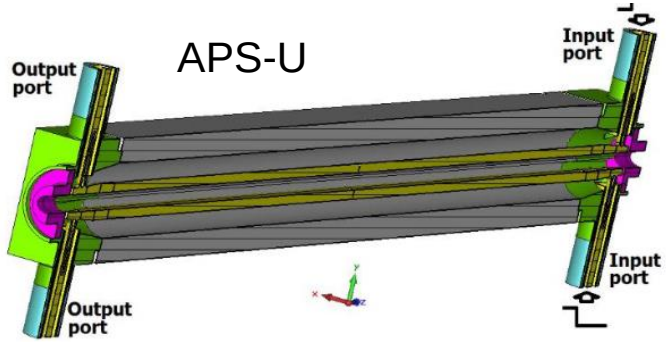


ALS-U



HEPS

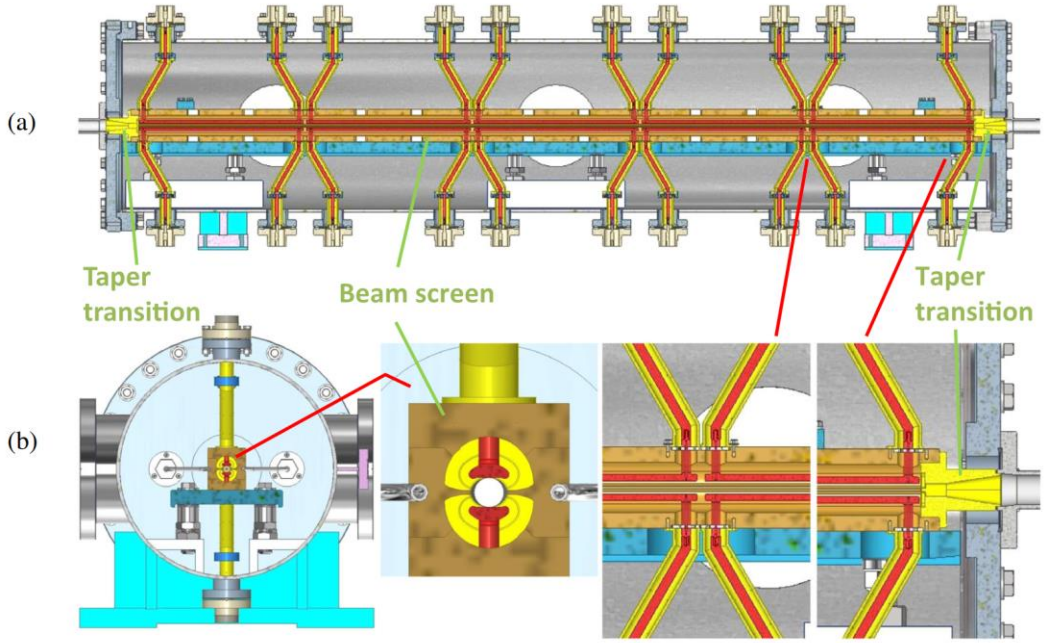



APS-U

# Literature study

## Assembly concepts

- Two options for overall setup:
  - Single kickers
  - One chamber with all modules
- Save space on beam impedance matching sections
- Reduce transverse beam coupling impedance
- Challenging device (>5m length)
- PETRA IV: various kicker positions w/ different no. of modules…
- Close proximity of two modules seems to reduce beam impedance (HEPS study)




HEPS

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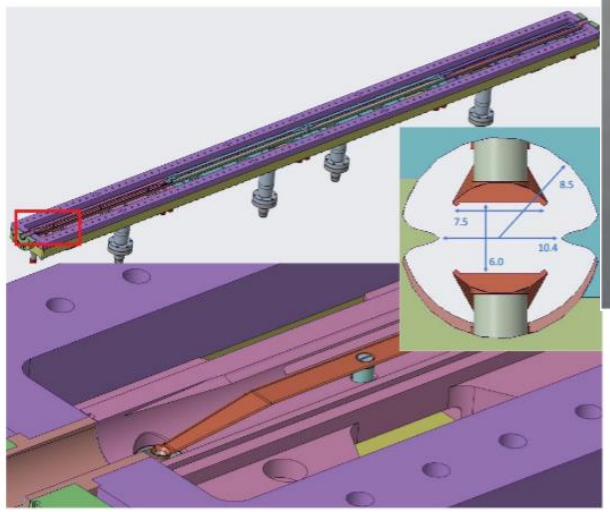
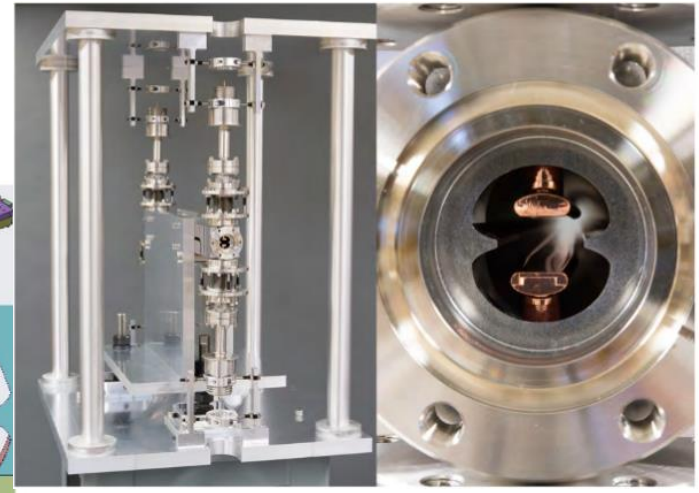


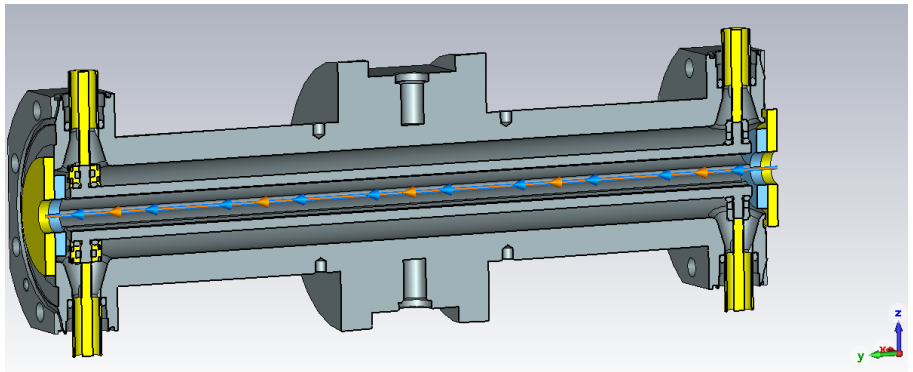


APS-U

# What we chose to do

## Design concept PETRA IV

- Use commercial HN-feedthroughs
- Straight input connections
- Stand-alone module that’s easy to assemble in groups
- Assembly as simple as possible
- Use commercial FID pulsers
  → seek for alternatives in parallel to secure long-term availability
- Use the same layout for feedback kickers (larger aperture, ~shorter, ~16 modules hor. & vert.)
- Integration of feedthroughs into flanges (→ closest proximity of modules)
- Main concern: heating by beam-induced power
  → W / Mo blades originally
  → Now Cu blades due to minor heating & stability of feedthroughs



# Max. voltage definition

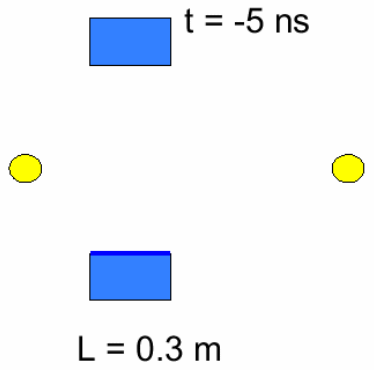
## Testing Ceramtec feedthroughs

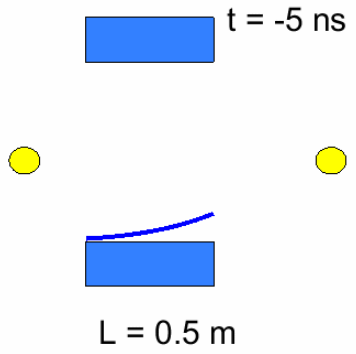
- Kick strength given by blade distance & voltage
  - Blade distance → beam dynamics
  - Voltage → breakdown (~at feedthrough)
- Feedthroughs specified for 7kV
- DC breakdown tests → 15kV
- Pulse test → need pulser w/ U >15 kV
- Test pulser has required dynamic range 8-15 kV
  (min = <50% max challenging)
- Note: 1 breakdown → feedthrough breakdown voltage reduced to ~50-70%
- (Also did RF-heating test w/ <2GHz, 400W → no heating)

# Pulse & length requirements

## Drive electronics overview

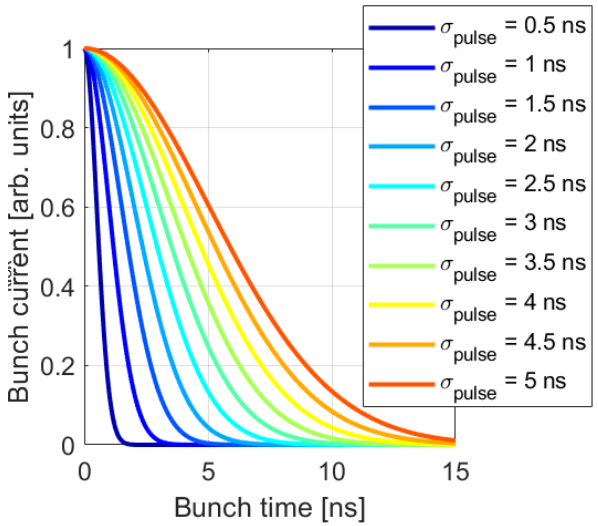
- Counter-propagating pulses
  → pulse & stripline length critical
- Project specification: disturbance of only 1 bunch…
- → Many modules, very few pulser technology choices:
  - SOS diodes (available but ~slow)
  - Semiconductor self-breakdown (rectifying diodes/avalanche diodes: low energy/~slow)
  - Semiconductor impact-ionisation (drift step recovery diodes/thyristors: proprietary/slow fall?)
  - Spark gap sharpeners (jittery)

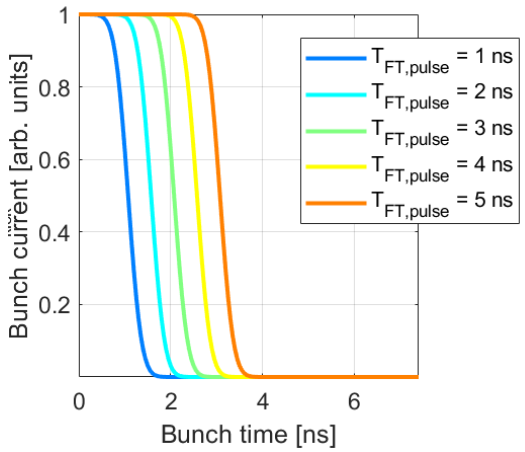


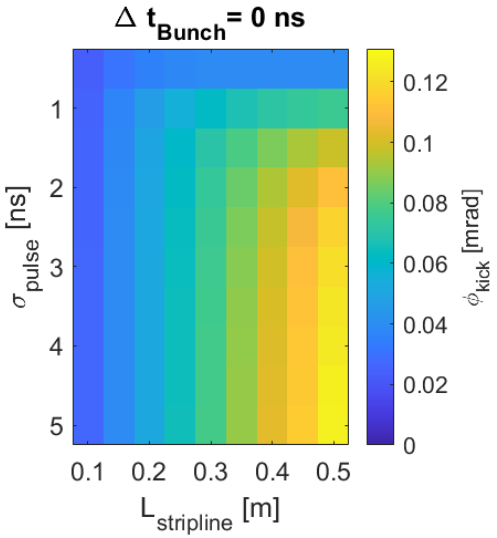
# PETRA IV injection kicker parameters

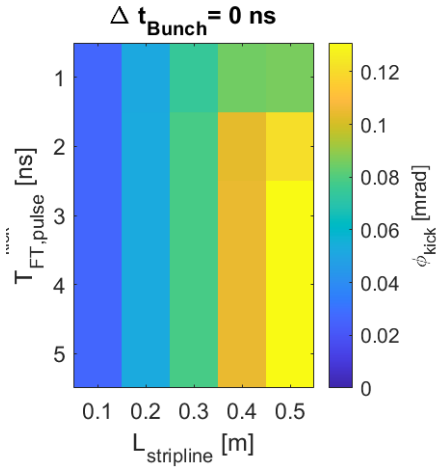
## Define stripline length & pulse length



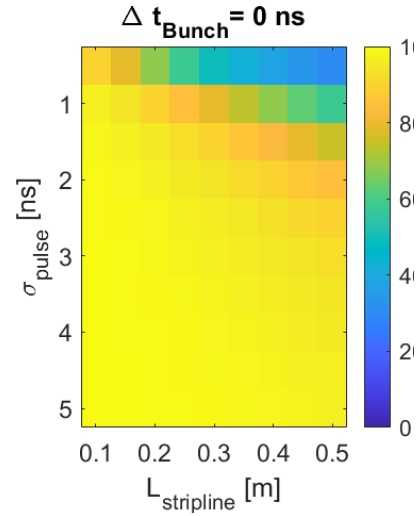



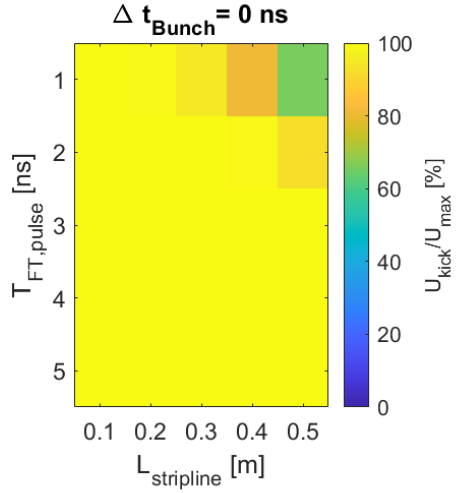

*Absolute kick strengths (@6GeV)*



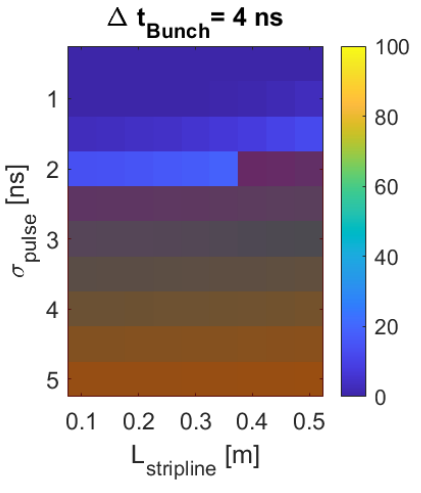



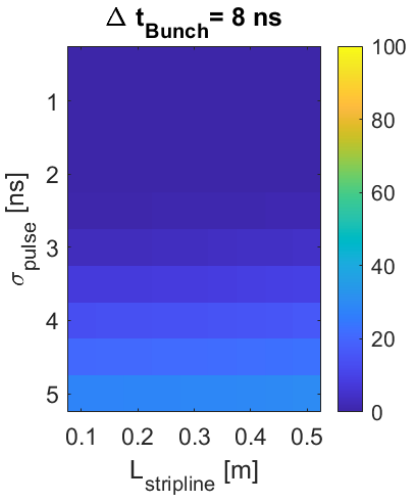

*Kicker spatial "efficiency"*

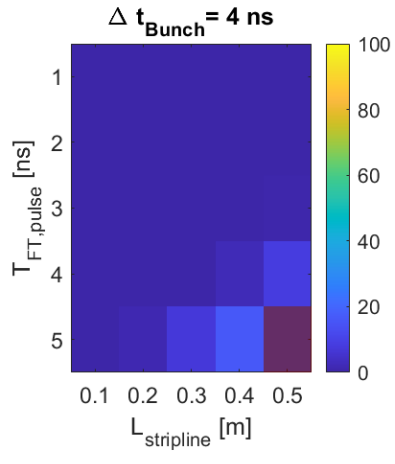


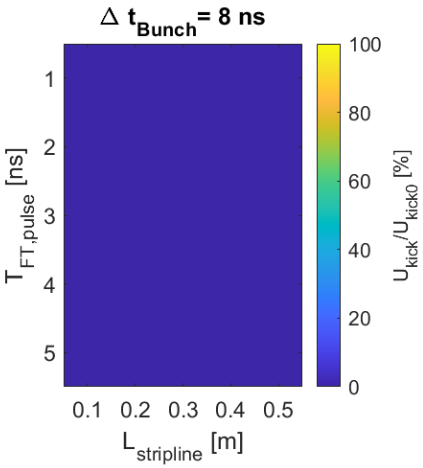




*Kick strengths on neighbouring bunches*



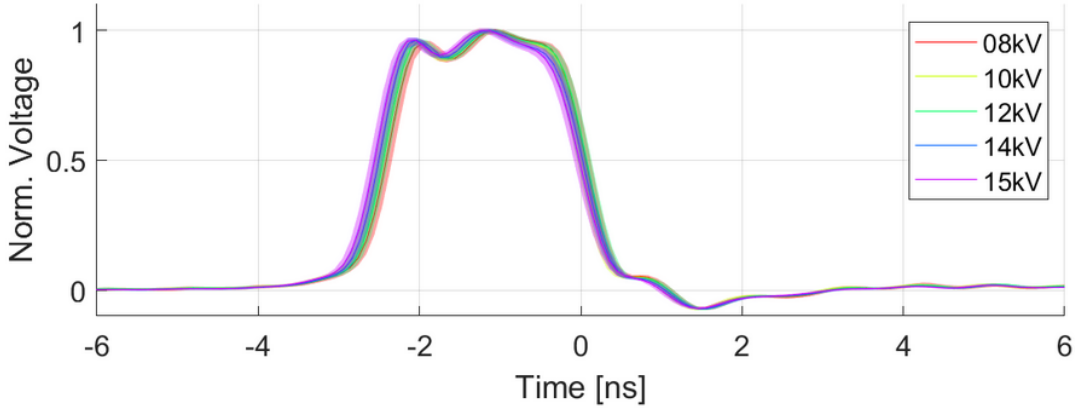



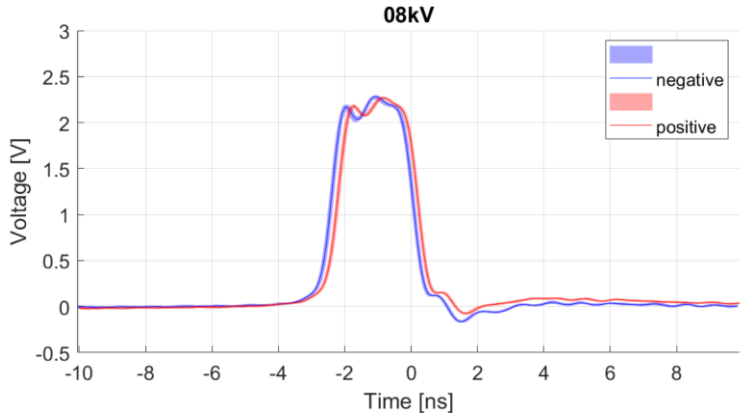



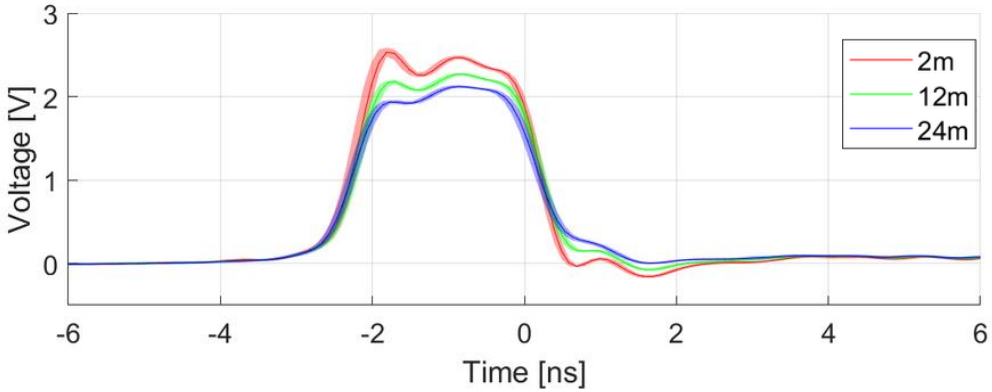
# Pulser technology

## Drive electronics overview

- Collaboration w/ ETH Zurich on SiC MOSFET pulser in Inductive Adder/Marx topology
  → expecting ~7ns rise, ~10ns fall times
  → too slow as standalone driver
- Another company offered 3ns rise time pulser
  → too slow
- Ordered FID pulser w/ 0.5ns rise time, ~3ns pulse duration
  → arrived & fulfills specs



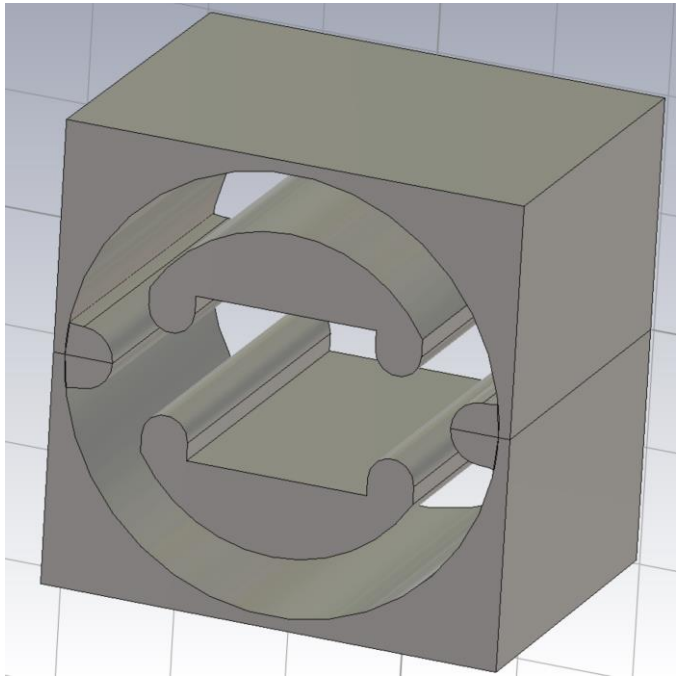



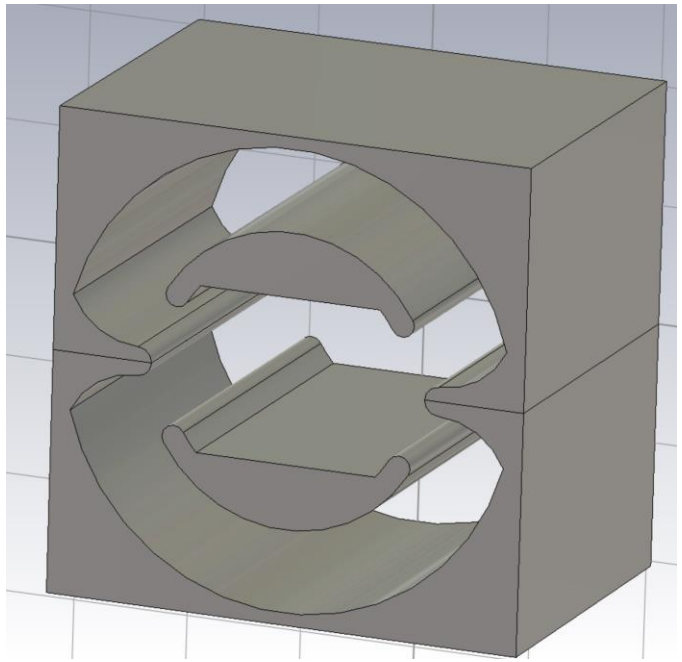



# Cross-section simulations

## Brief reminder

- Design goals
  - Electrical impedance 50Ω
  - Impedance of beam-induced fields ~50Ω
  - Field flatness <1%
  - → weighted goal function
- Different options for geometries
  - “CERN”-design
  - “APS”-design
  - Side “fenders”
  - → did rough optimisation of two layouts to find best geometry
- Gap 14mm (dia.), GFR 4.5mm (rad.)

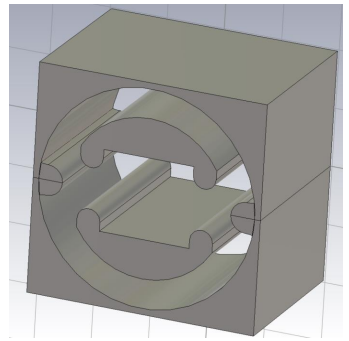


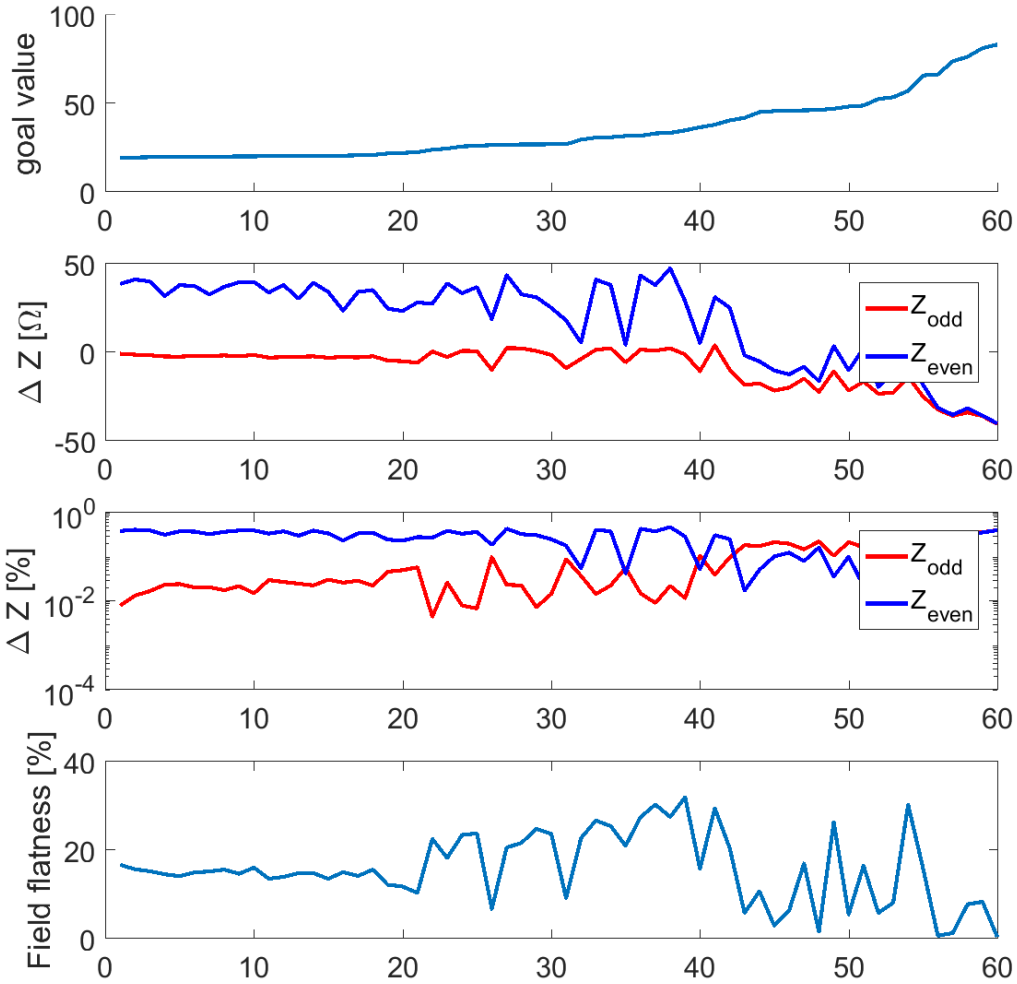


# Cross-section simulations

## Rough scan results

- Bayesian optimisation of several geometric variables
- All simulations done in CST
- “CERN-like” design
  - ~50Ω odd mode impedance
  - 80-90Ω even mode impedance
  - ~14% field flatness



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**STRIPLINE KICKERS FOR INJECTION INTO PETRA IV**

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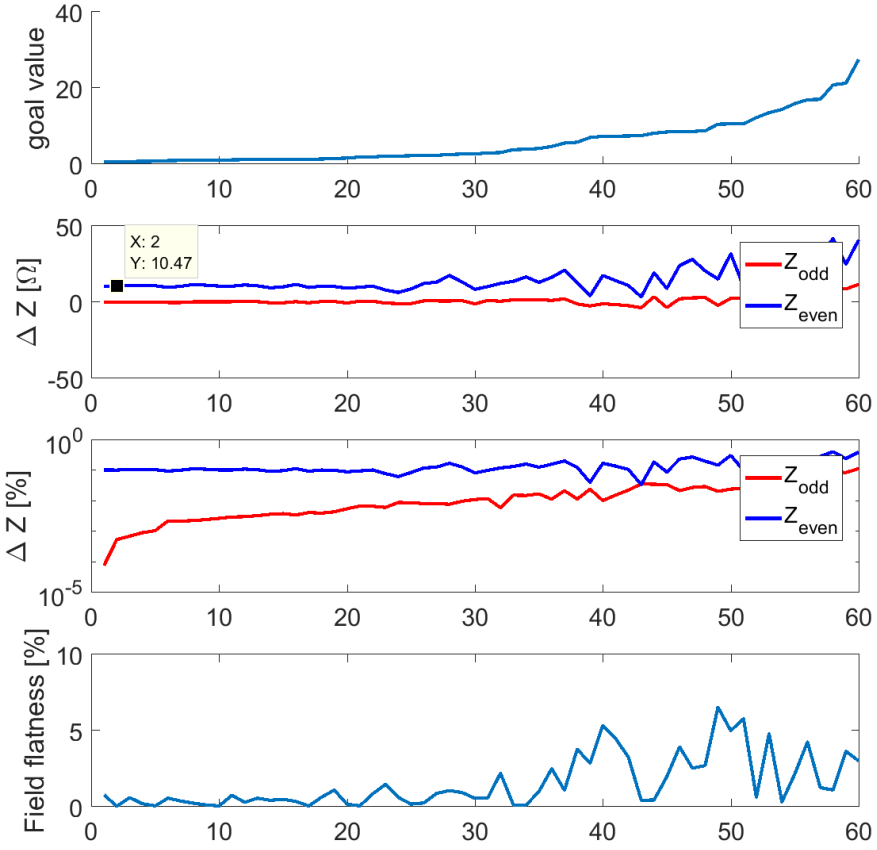
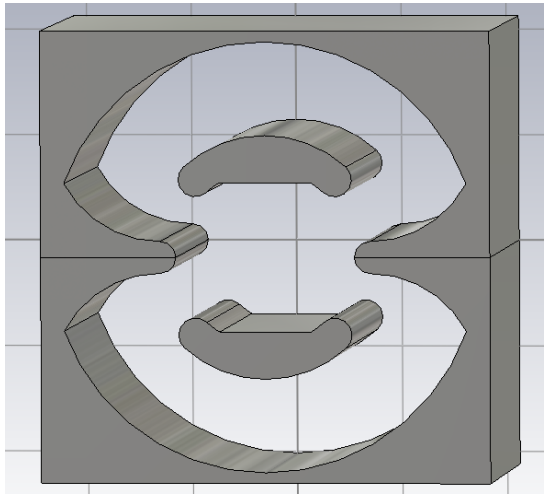
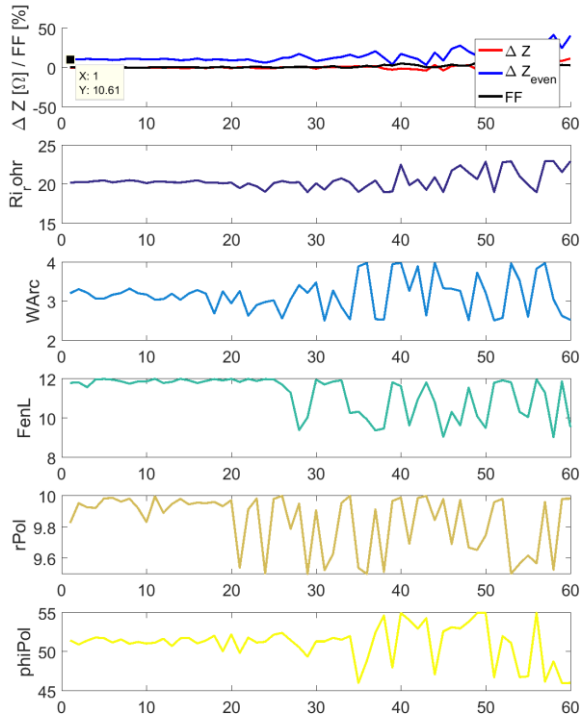
# Cross-section simulations

## Details of HEPS-like design scan

- Choose arc width as free parameter
- → “APS-like” design
- Parameter trade-off much better
- Final design:
  - Z_odd = 49.95Ω
  - Z_even = 57.7 Ω
  - FF = 0.2% (GFR w/ 9mm diam.)



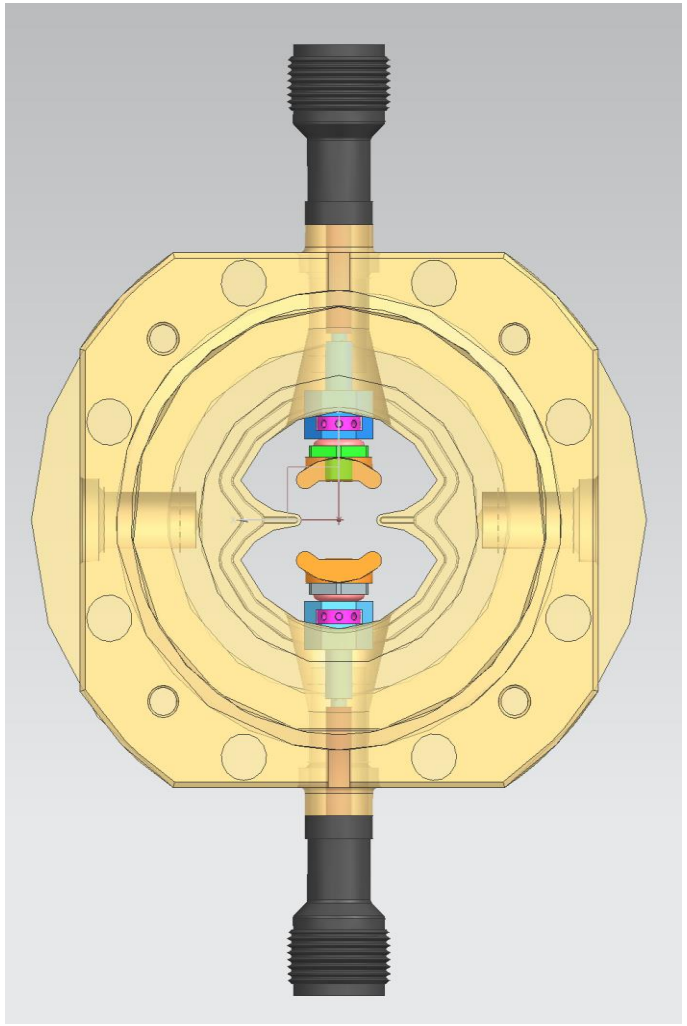



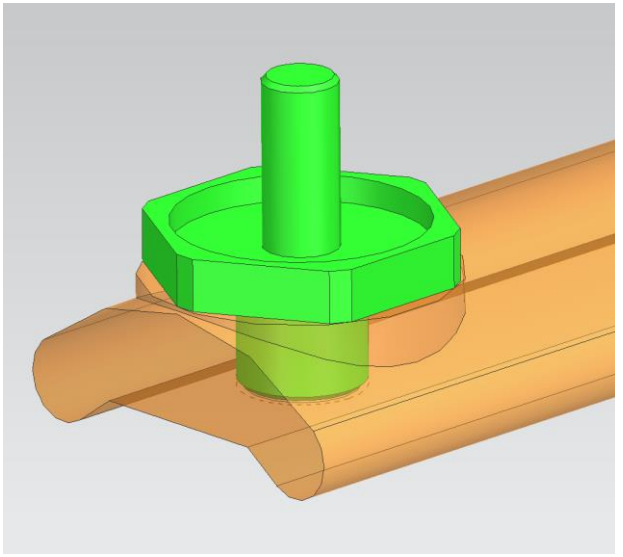


# Mechanical design

## Detailed design choices

- Have sliding contacts at one stripline end
- No transverse position adjustment
- Height adjustment by double-threaded nut
- Contacts w/ RF springs
- ~Simple connection design so far

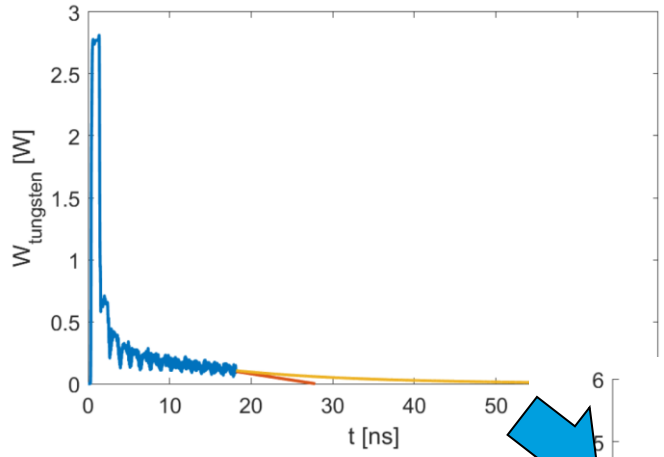


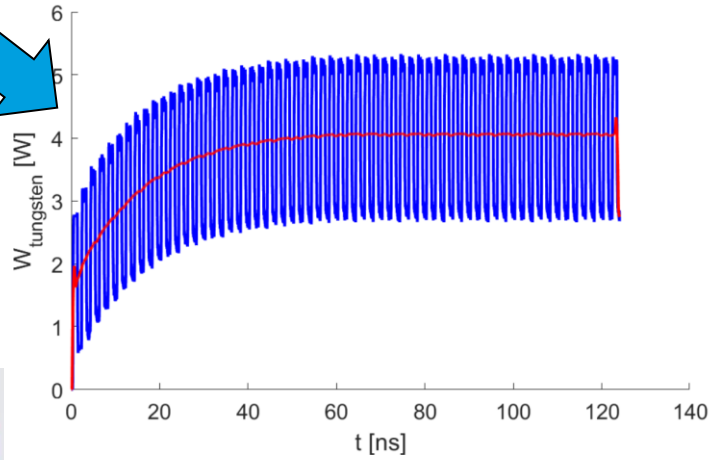


# Heat load simulations

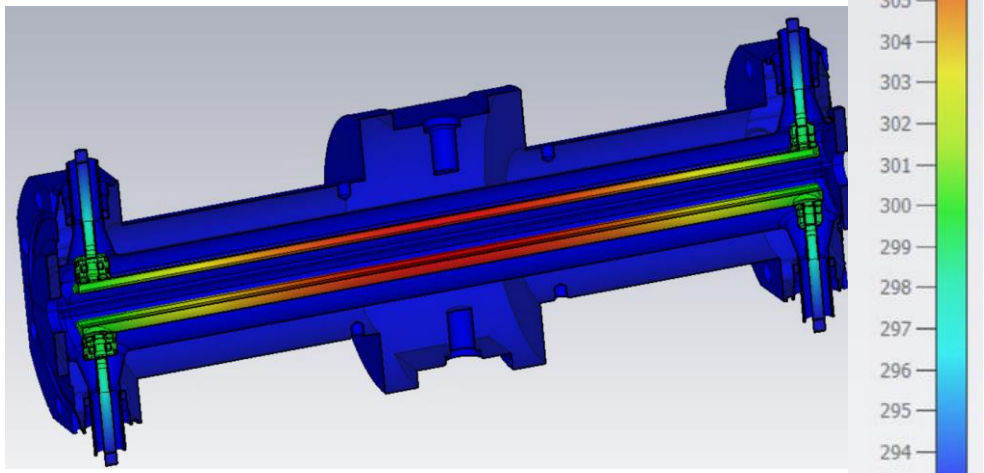
## CST wakefield solver + thermal solver

- Simulated heat load on stripline by beam
- MAX IV beam parameters
- Found quite small heat load
- Originally took tungsten as blade material (~less expansion, more rigid)
  → changed to Cu → even lower heat load



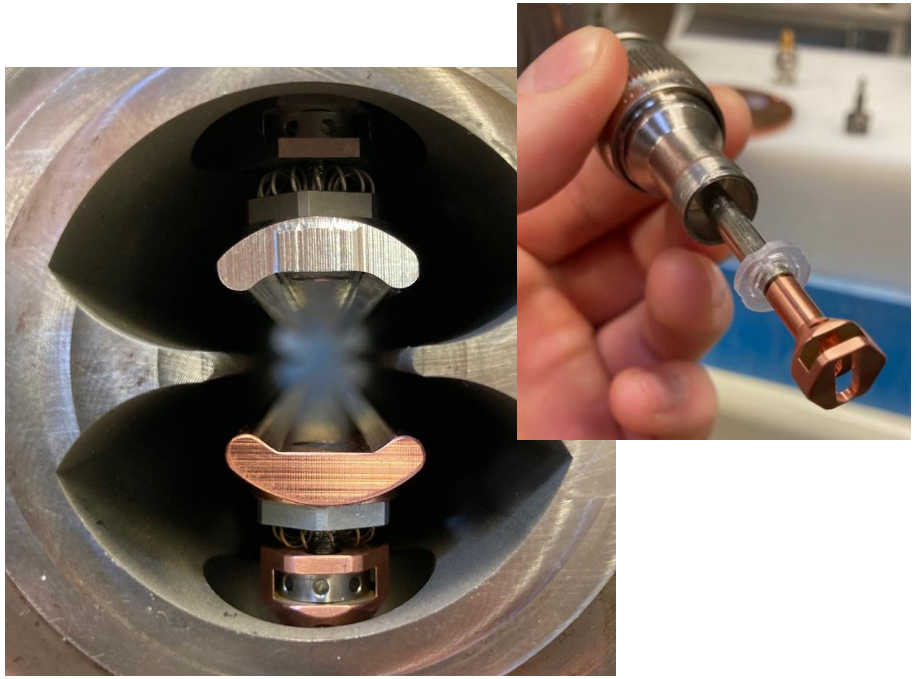

- Expect max. few 10W of power to pulser/attenuators



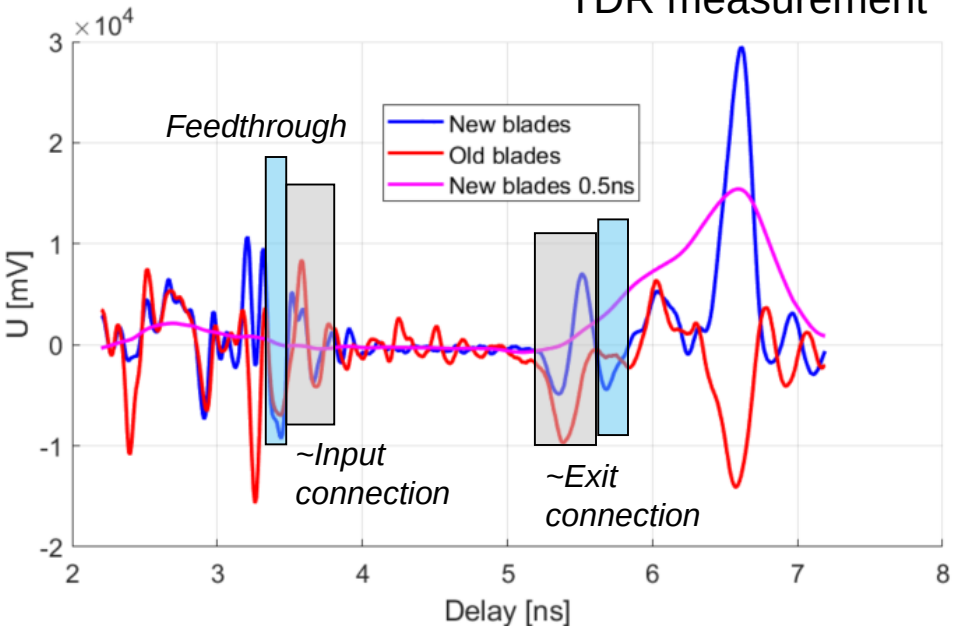
# Current status

## Prototyping, etc.

- Prototype built & tested
- Iteration of blades & connecting parts
  → looks ~good, now preparing beam tests
- Load resistor test setup being built
- Developing in-vacuum blade temperature meas.
- Further optimisation of connectors for 2nd prototype
- Main open questions:
  - Kick behaviour → beam measurements @ARES
  - Beam heat deposition → beam measurements @MAX IV (2023)



TDR measurement

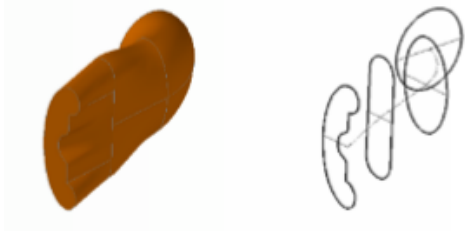


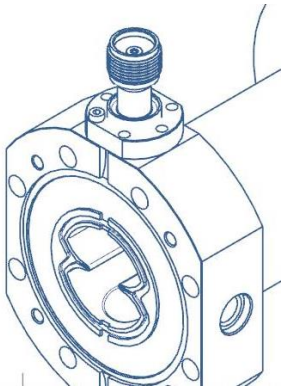
# Summary & outlook

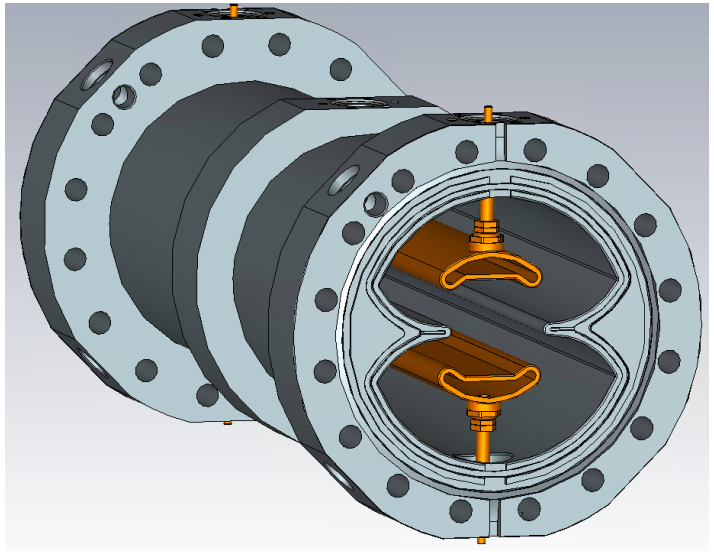
## Concluding prototype phase

- 1st “single bunch“ top-up injection scheme
- kicker prototype performs ok so far
  - TDR measurements look fine
  - Beam measurements (beam heat deposition) ~July
  - Beam measurements (deflection details) ~autumn
- Vacuum layout (NEG? Pumping ports? …)
- 2nd prototype for final demonstration 2024
  - Feedthroughs on flanges
  - ~Optimised blade connections
  - 350mm effective length
  - In-vacuum temperature monitoring
- FB kicker prototype being designed on same principle

*More complex/sophisticated input connection design, e.g. @SLS2.0*







# *Thank you for your attention!*

**Contact**

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