RF Modeling Plans for the European Spallation Source

EUROPEAN SPALLATION SOURCE

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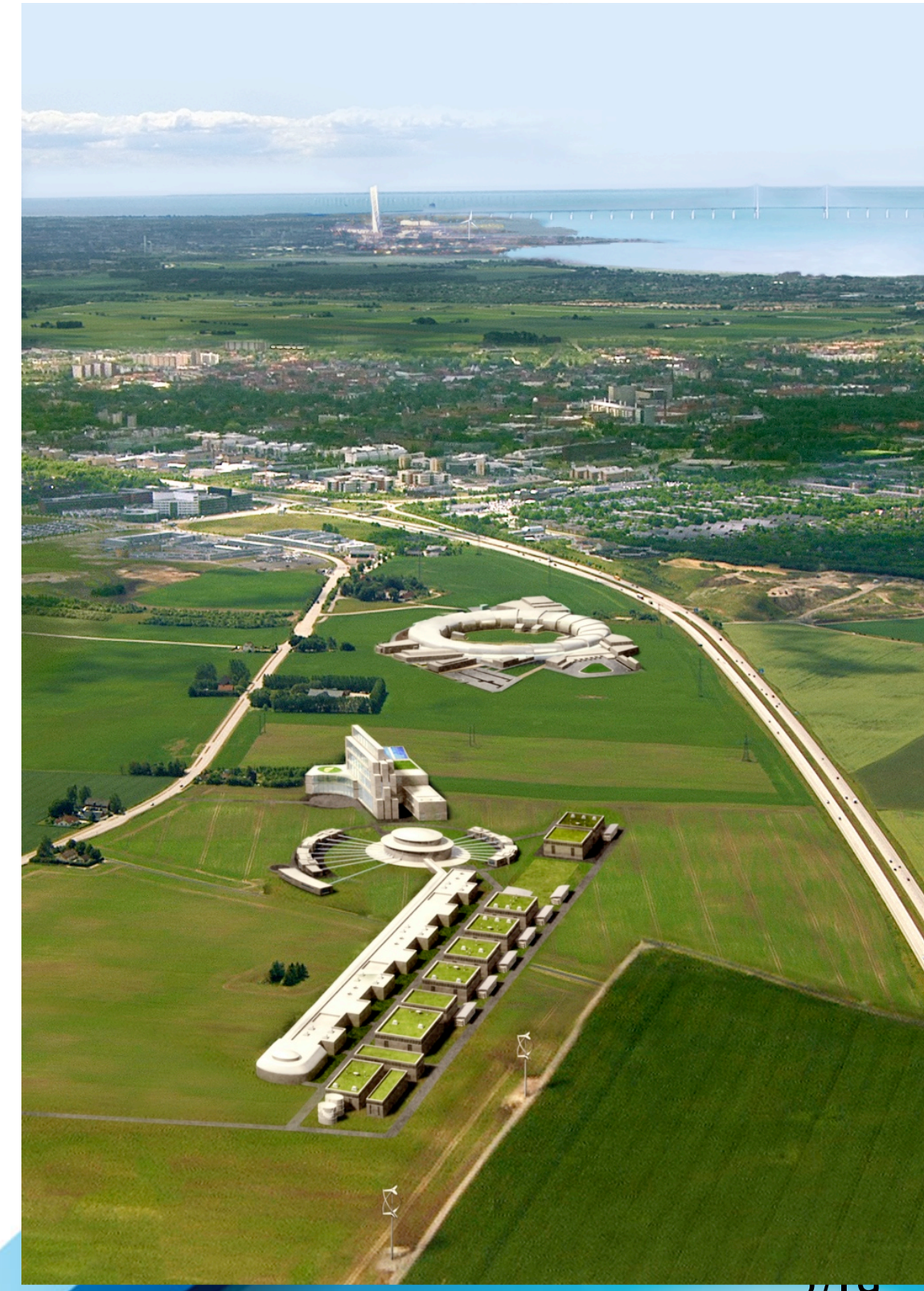
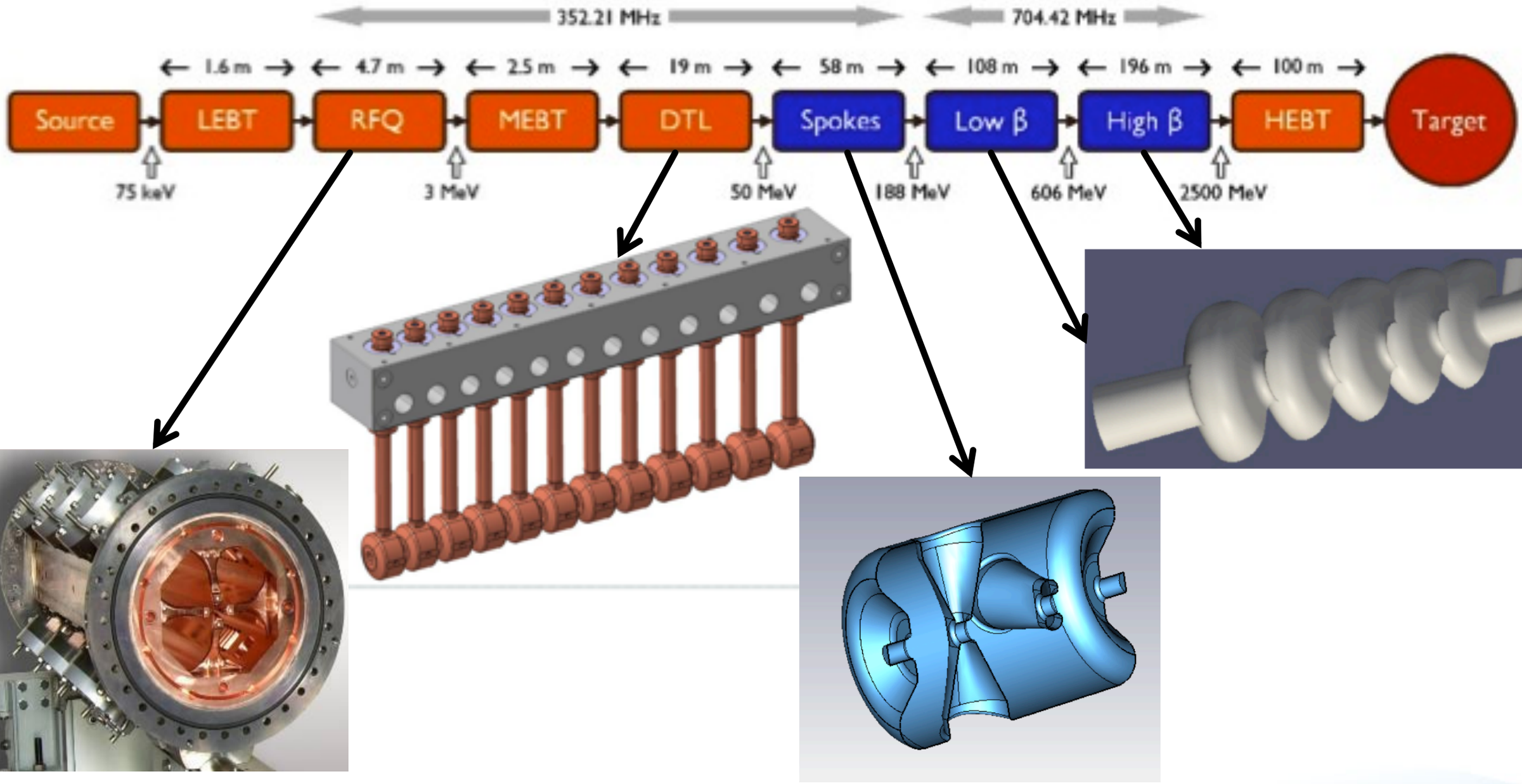
IPAC, San Sebastien, Sept. 2011

European Spallation Source

- World's most powerful pulsed neutron source
  - 5 MW, 2.5 GeV protons
  - 50 mA
  - 14 Hz, 4% duty cycle
    - → 2.86 ms pulses

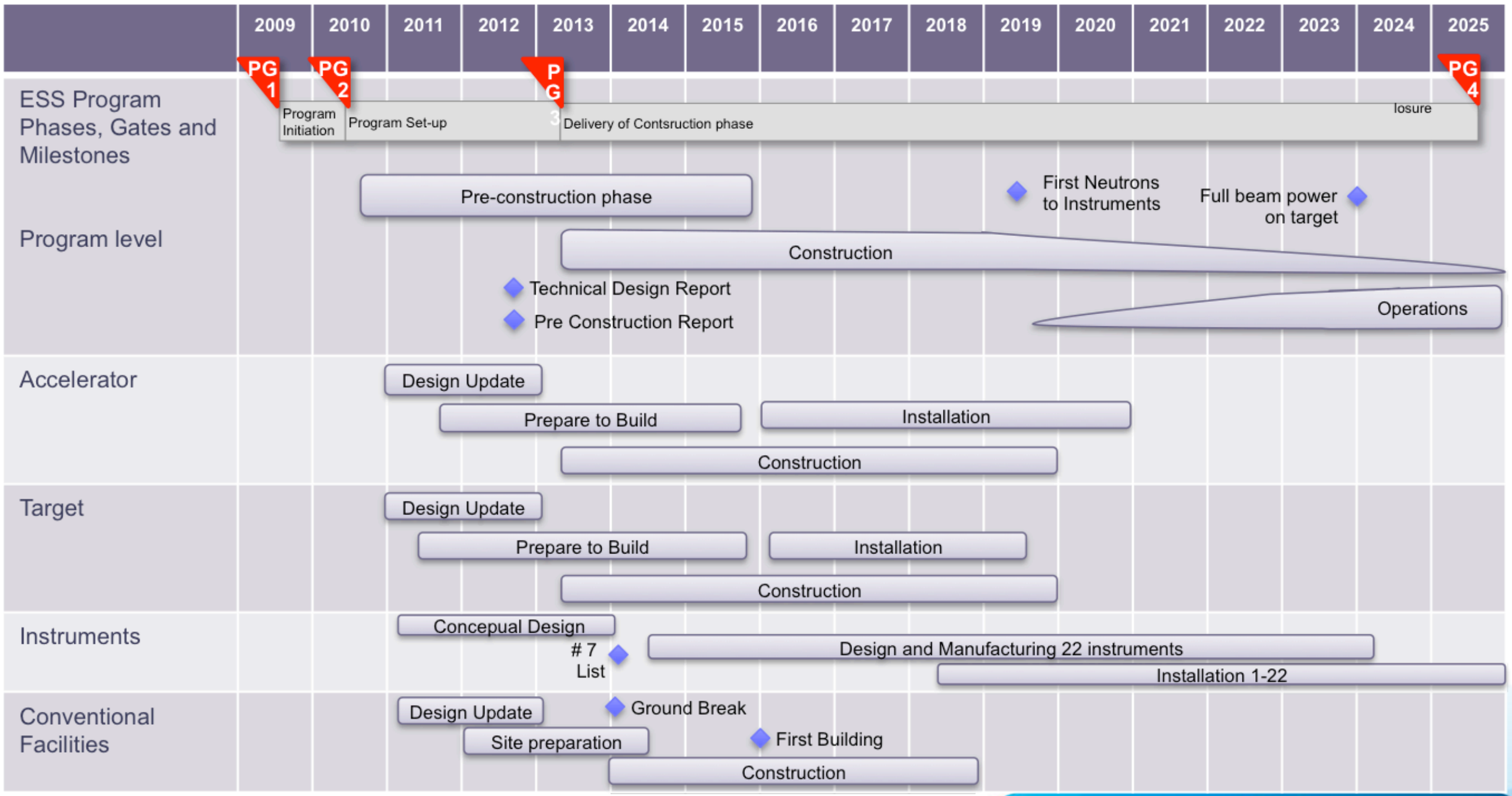


The ESS proton linac



- Single-pass linac with no accumulator ring
- Source:
  - Electron Cyclotron Resonance (ECR) source
    - 75 keV output

Schedule


2009
2010
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2025
PG 1
PG 2
PG 3
PG 4
ESS Program Phases, Gates and Milestones
Program Initiation
Program Set-up
Delivery of Contsruction phase
Closure
Program level
Pre-construction phase
First Neutrons to Instruments
Full beam power on target
Construction
Technical Design Report
Pre Construction Report
Operations
Accelerator
Design Update
Prepare to Build
Installation
Construction
Target
Design Update
Prepare to Build
Installation
Construction
Instruments
Concepual Design
7 List
Design and Manufacturing 22 instruments
Installation 1-22
Conventional Facilities
Design Update
Ground Break
Site preparation
First Building
Construction

Accelerator Design Update

Romuald Duperrier
(30 years ago)

Steve Peggs

Cristina Oyon

Josu Eguia

Work Package (work areas)

1. Management Coordination – ESS (Mats Lindroos)
2. Accelerator Science – ESS (Steve Peggs)
3. Infrastructure Services – Tekniker, Bilbao (Josu Eguia)
4. SCRF Spoke cavities – IPN, Orsay (Sebastien Bousson)
5. SCRF Elliptical cavities – CEA, Saclay (Guillaume Devanz)
6. Front End and NC linac – INFN, Catania (Santo Gammino)
7. Beam transport, NC magnets and Power Supplies – Århus University (Søren Pape-Møller)
8. RF Systems – Uppsala university (Roger Ruber)

Mats Lindroos

Guillaume Devanz

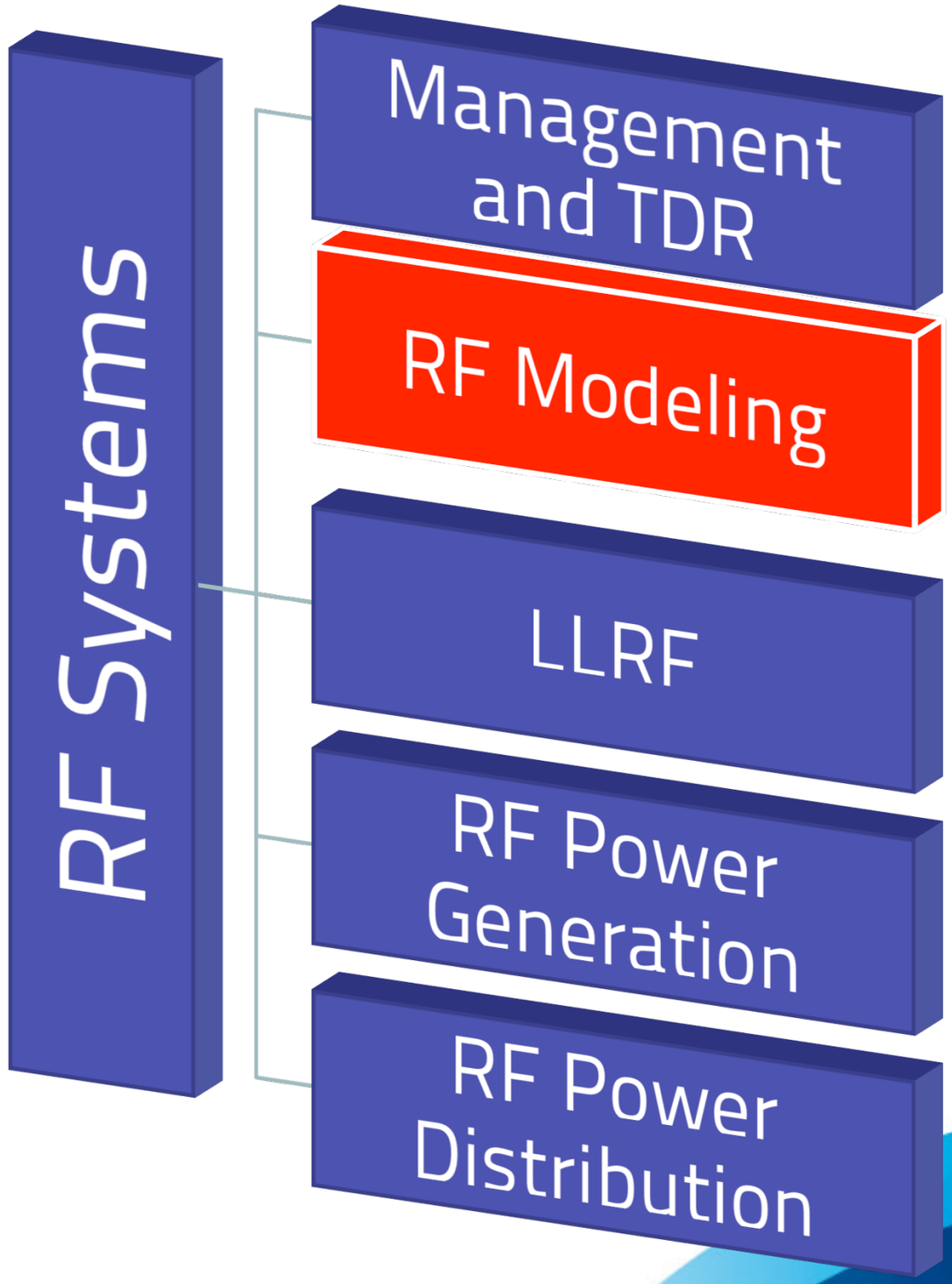
Roger Ruber

Søren Pape Møller

Santo Gammino

Sebastien Bousson

Work Package 8: RF Systems



Open Questions for RF Modeling

- Beam loss
  - Max beam loss = 1 W/m
    - Based on cryo-load, and radioactivation of beamline
  - Beam dynamics
    - Influence of HOMs
    - Halo (longitudinal & transverse)
- Field emission / Multipacting (FE/MP)
  - Q reduction
  - Cryoload
  - HOM coupler detuning
- LLRF stability
  - Pulse modulator droop & ripple
  - RF power regulation

*Superconducting Proton Linac – a similar design for a 5 GeV proton linac at CERN

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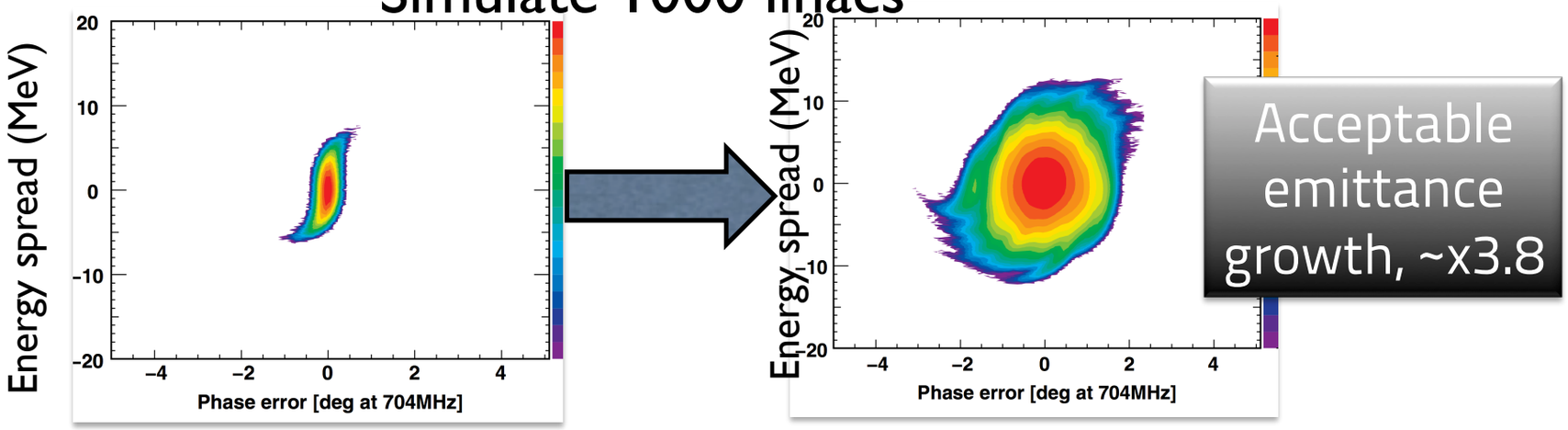
RF-Related beam dynamics

(Studies for CERN's SPL* by Marcel Schuh)

M. Schuh, F. Gerigk, J. Tuckmantel, and C. P. Welsch, Phys.Rev.ST Accel.Beams 14, 051001 (2011).

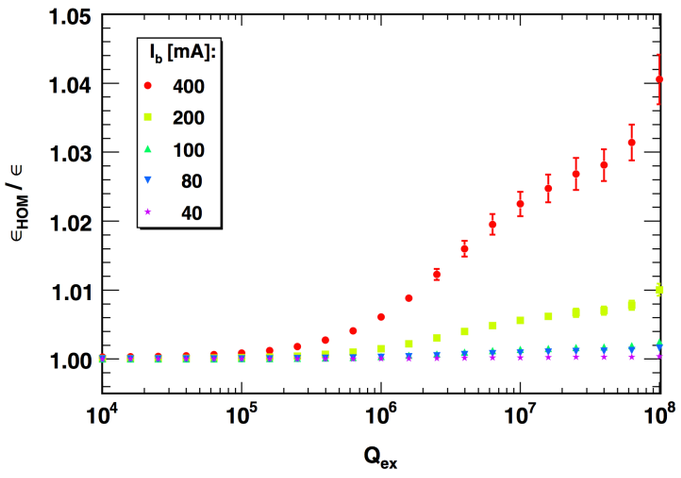
No HOMs

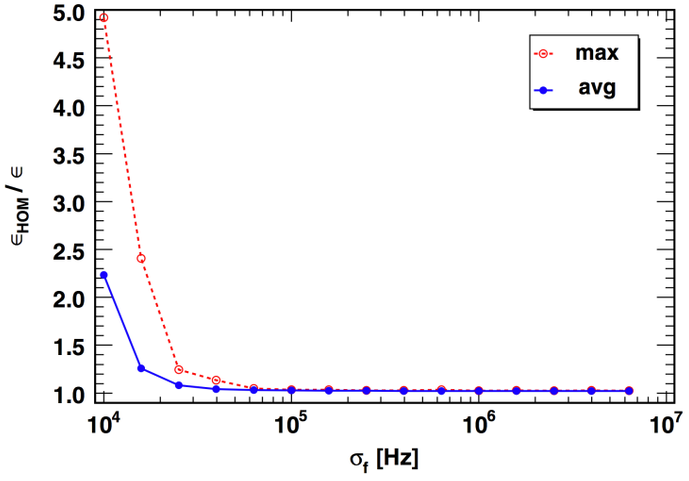
Simulate 1000 linacs



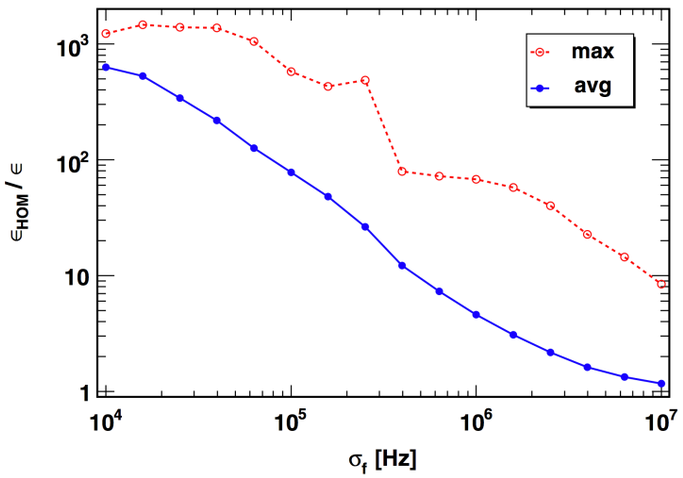
Acceptable emittance growth, ~x3.8

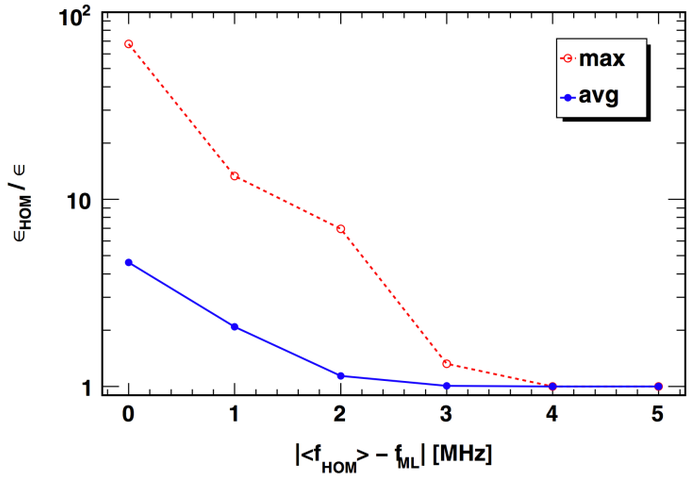
HOM far from a machine line





HOM on 2nd harmonic of beam freq.

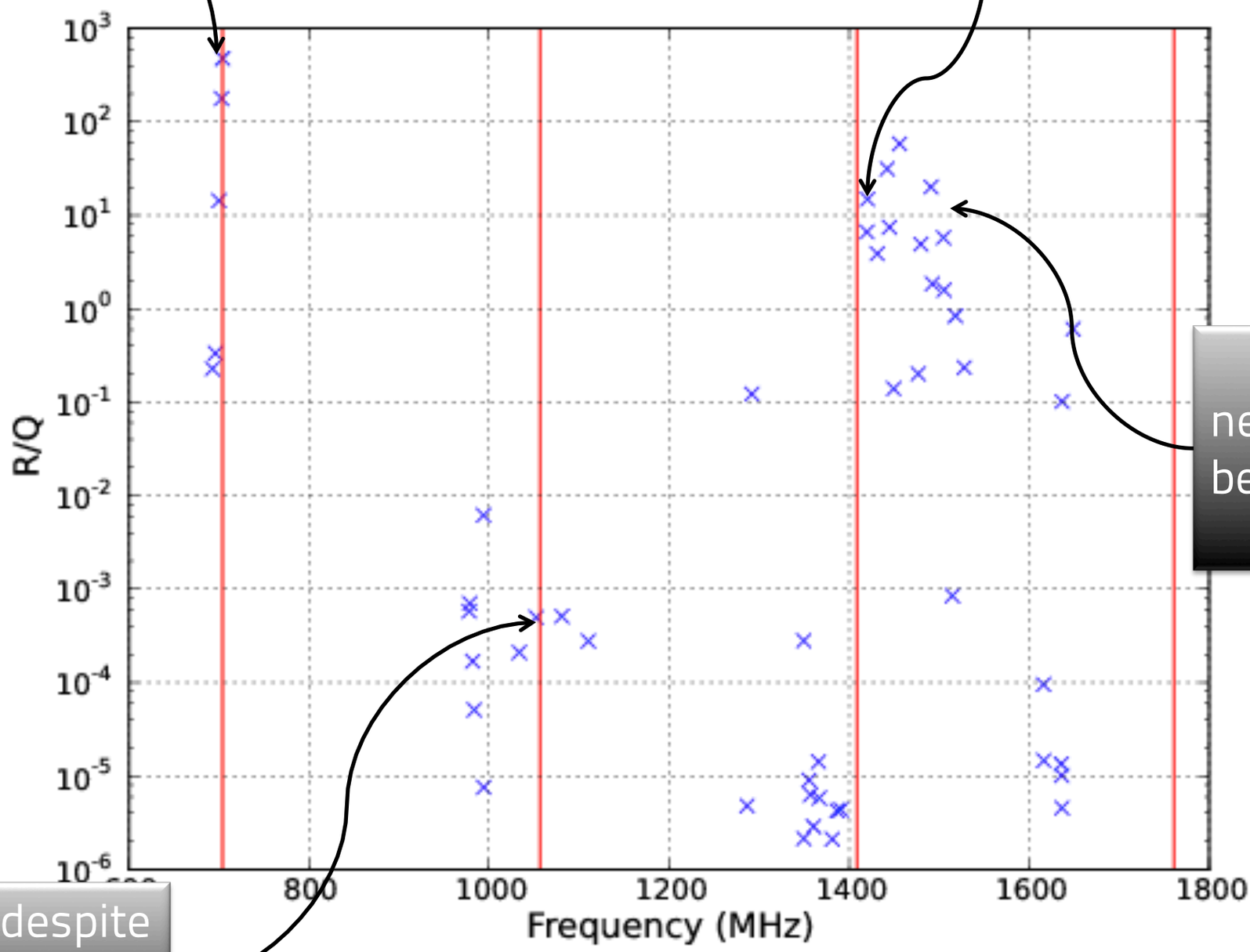




R/Q spectrum for a proposed elliptical ESS SC cavity

Accelerating mode

Of concern?



High R/Q, but negligible effect on beam since it is far from a ML

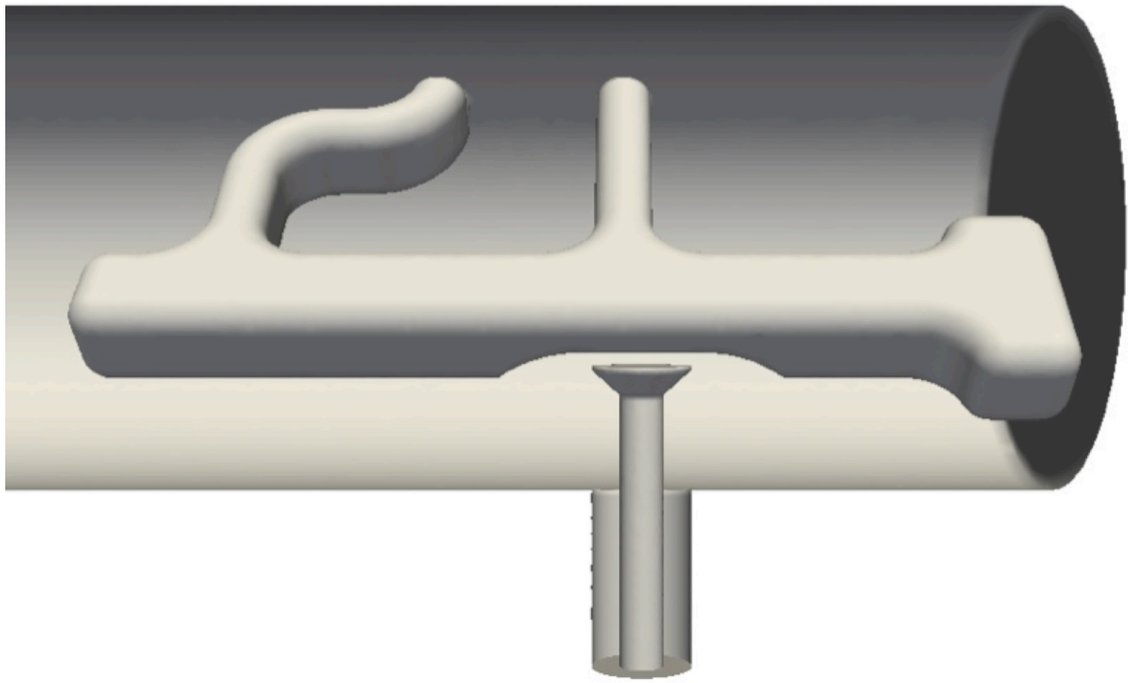
Not of concern despite closeness to ML due to low R/Q

Installation of HOM couplers?

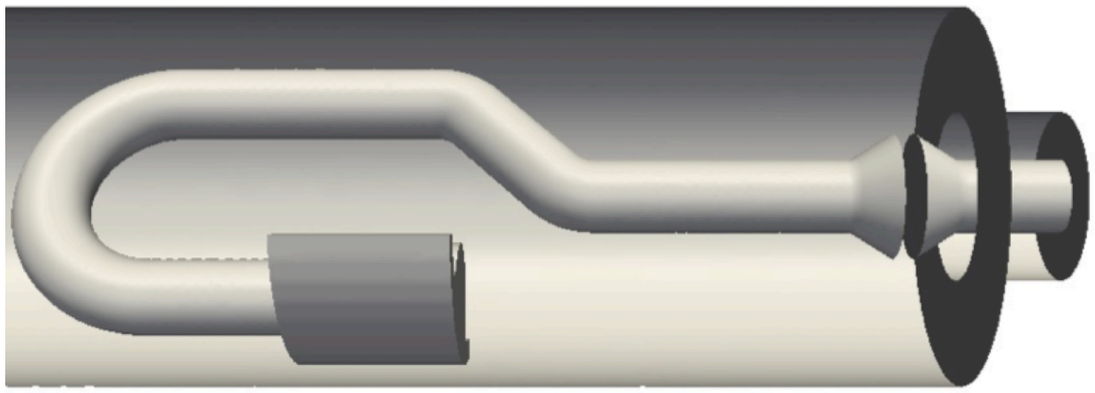
- A primary question for the RF group
- Well known risks of **not** installing
  - Beam breakup, emittance degradation, cryoload, …
- Installation also comes with risks
  - S. Kim, "SNS Superconducting linac operation experience and upgrade path", LINAC08.
  - Electron loading in the coupler
    - Field emission (FE), multipacting (MP)
  - Several SNS cavities still out of operation
- Couplers proposed for ESS should be investigated

Proposed coupler designs:
LC loops to filter accelerating mode

Re-scaled from TESLA design (R. Calaga)



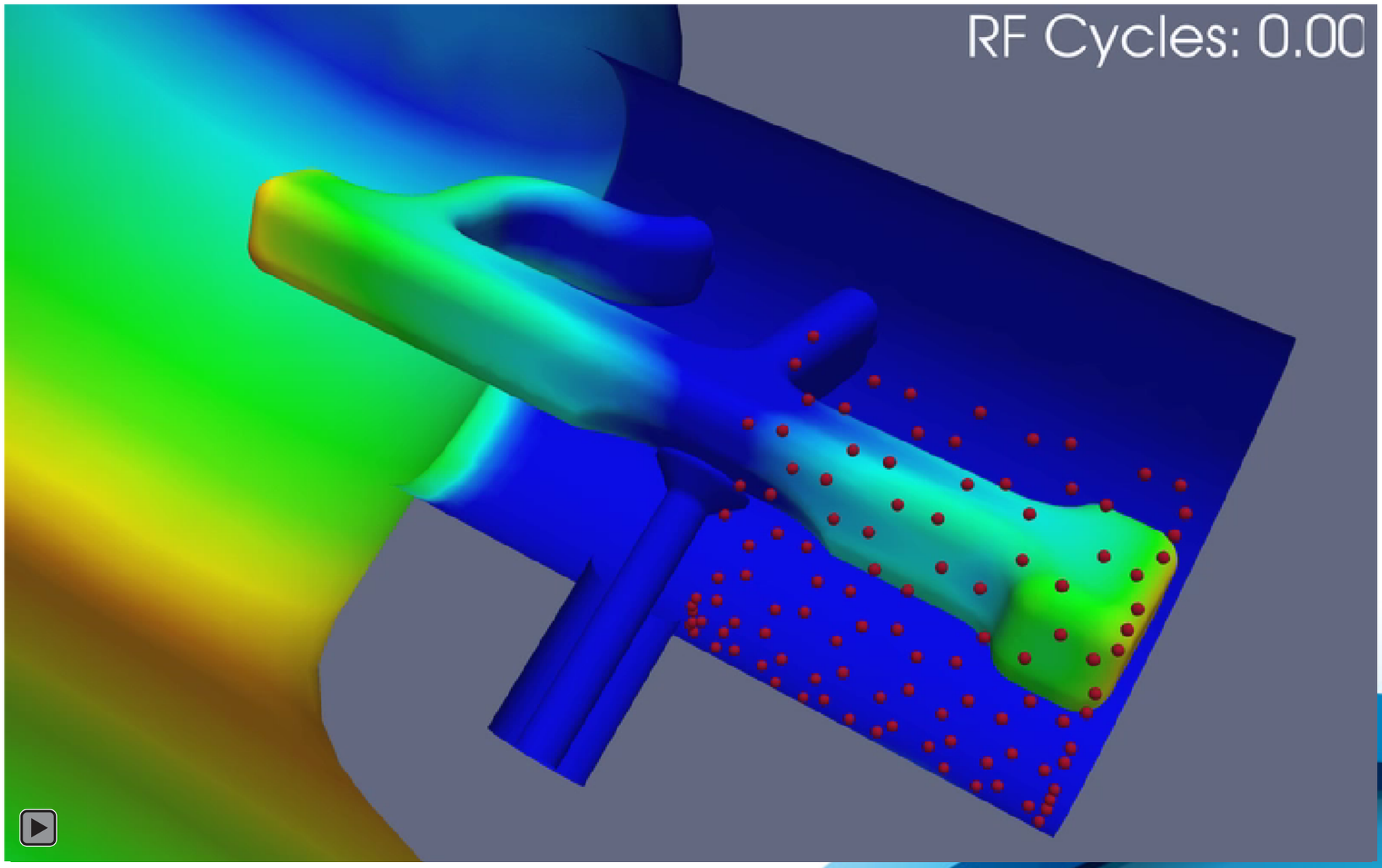
Design from Rostock University (WEPC099)



Each design has been optimised for RF properties, however investigations of FE/MP behaviour is also necessary.

Multipactor in the re-scaled TESLA design

Build cavity +coupler volume, and mesh → Find eigenmodes (using Omega3P) → Track electrons emitted from coupler surface (using Track3P → Find resonant impacts & scale by SEY



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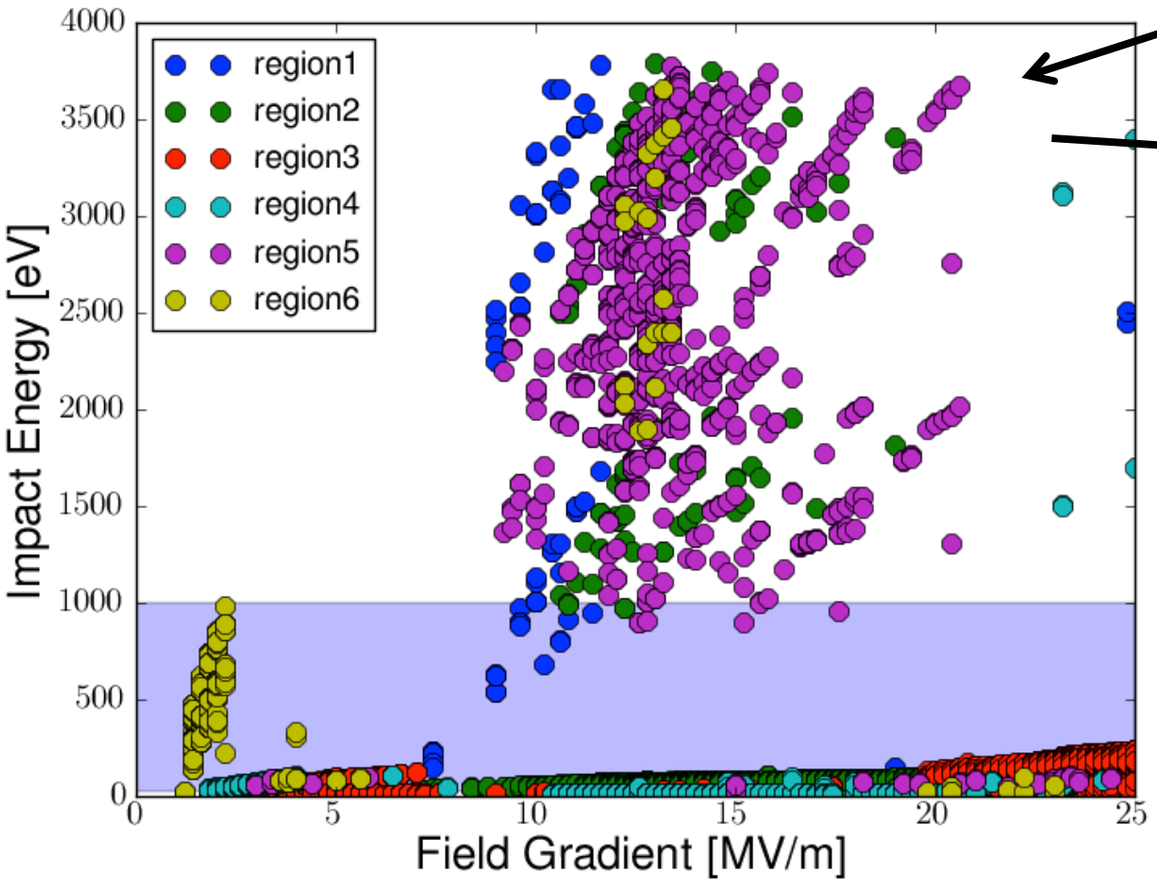
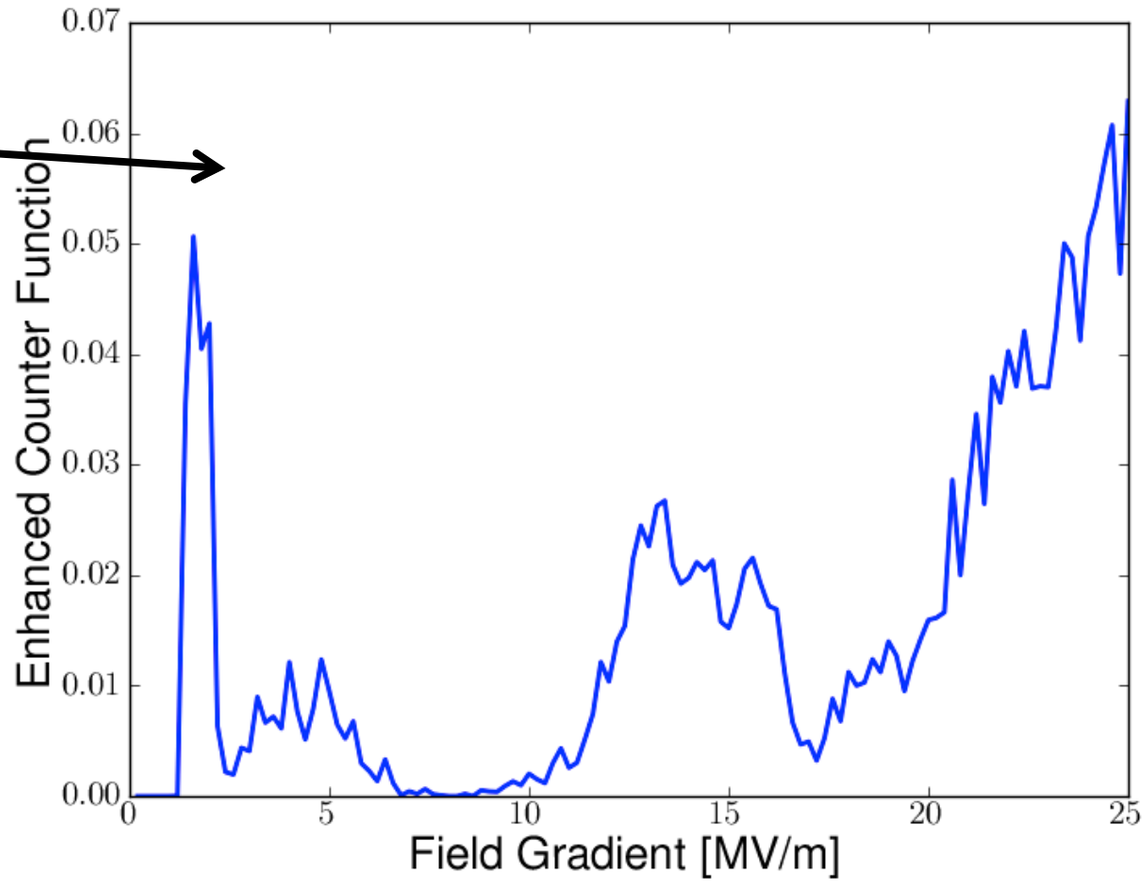
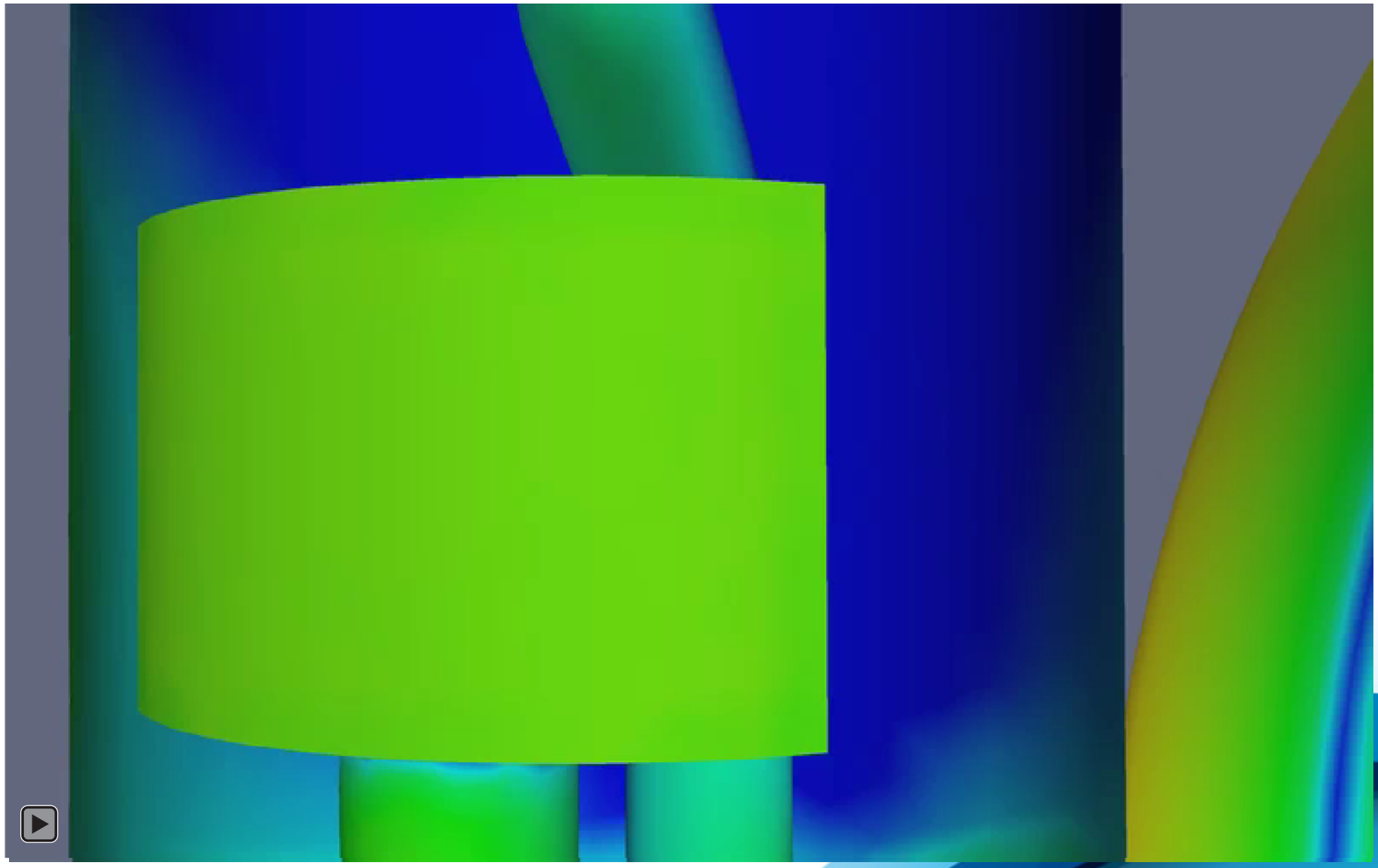




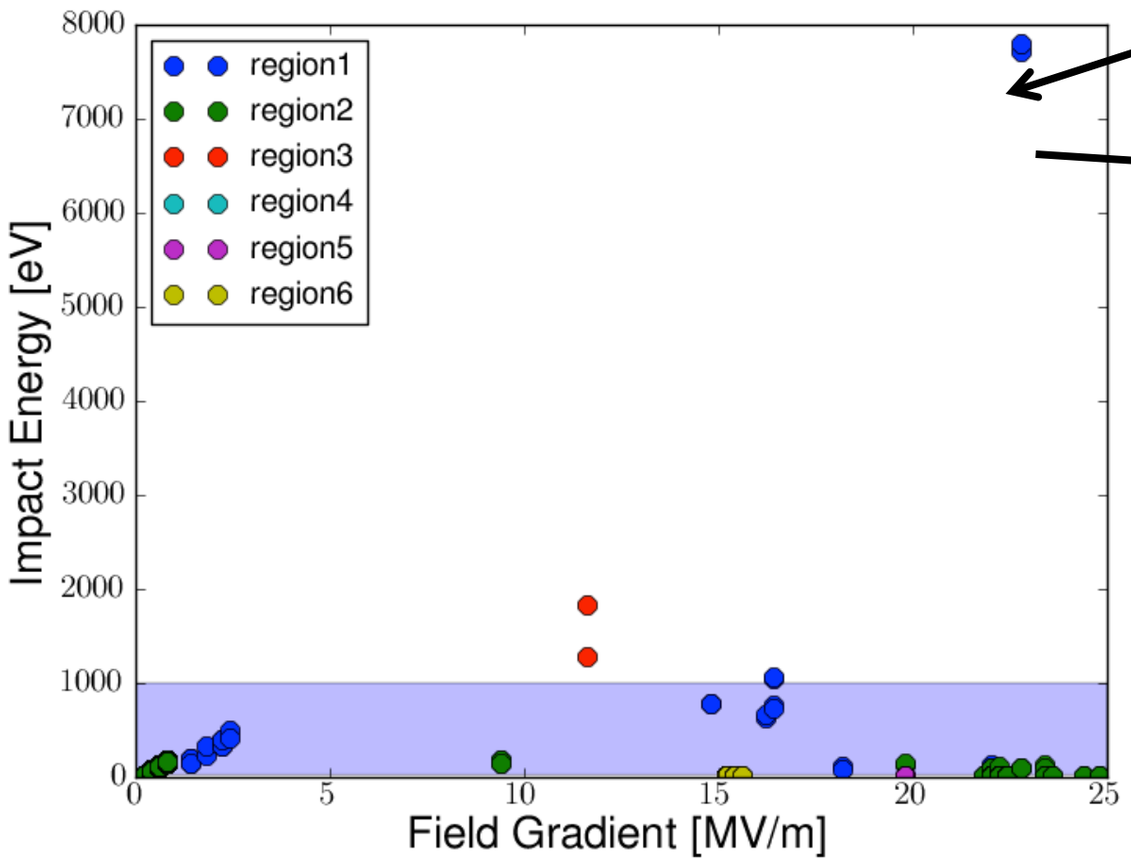
Multipactor in the Rostock design

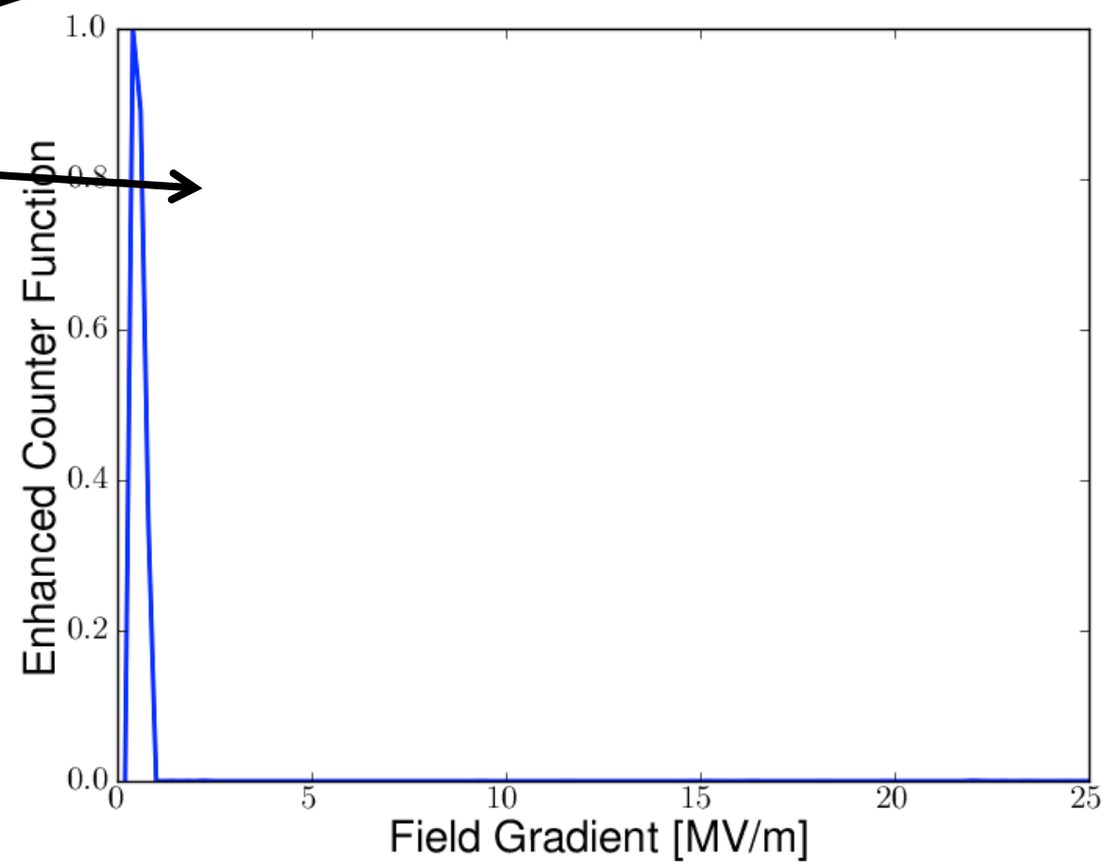
Build cavity +coupler volume, and mesh → Find eigenmodes (using Omega3P) → Track electrons emitted from coupler surface (using Track3P → Find resonant impacts & scale by SEY



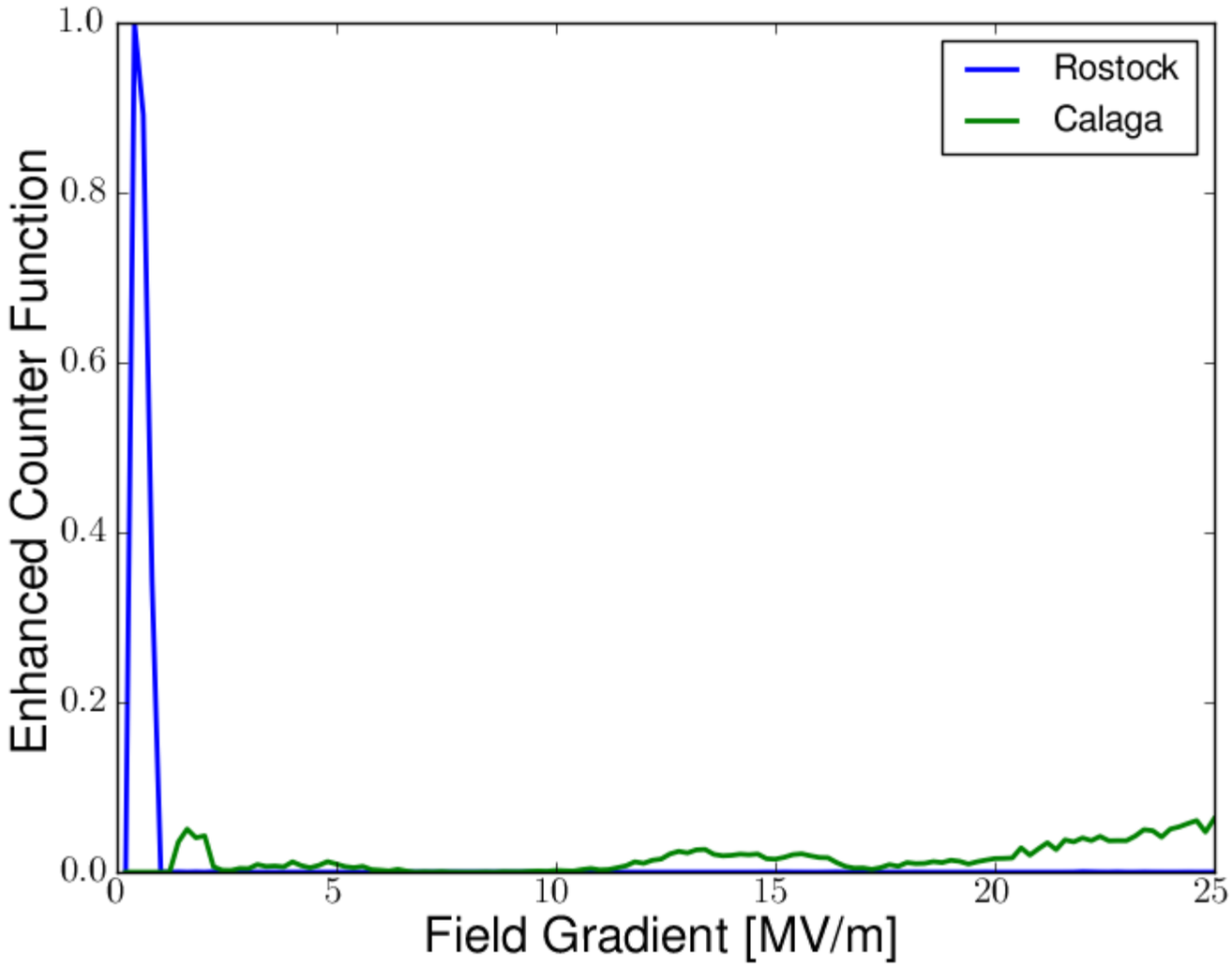
Multipactor in the Rostock design

Build cavity +coupler volume, and mesh → Find eigenmodes (using Omega3P) → Track electrons emitted from coupler surface (using Track3P → Find resonant impacts & scale by SEY





TESLA vs Rostock



Preliminary conclusions:

Large MP band in Rostock design appears risky.

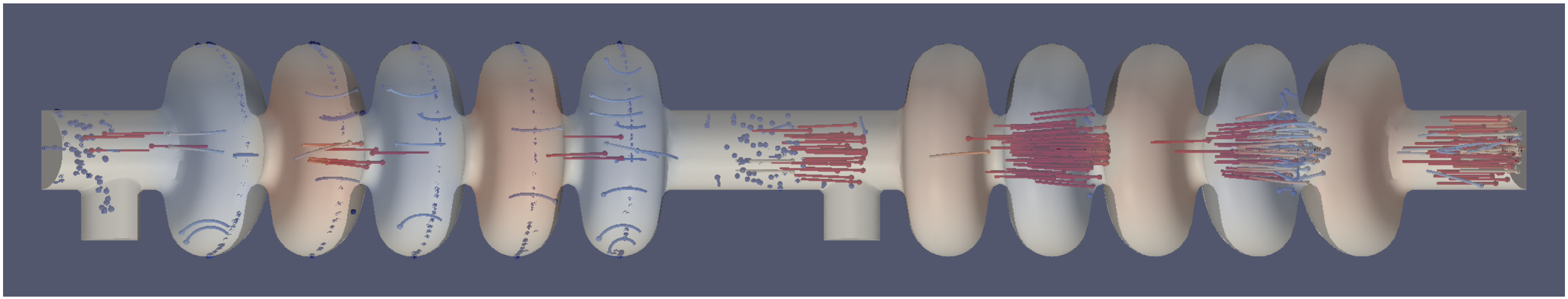
"Broadband" activity in TESLA design is undesirable

Questions:

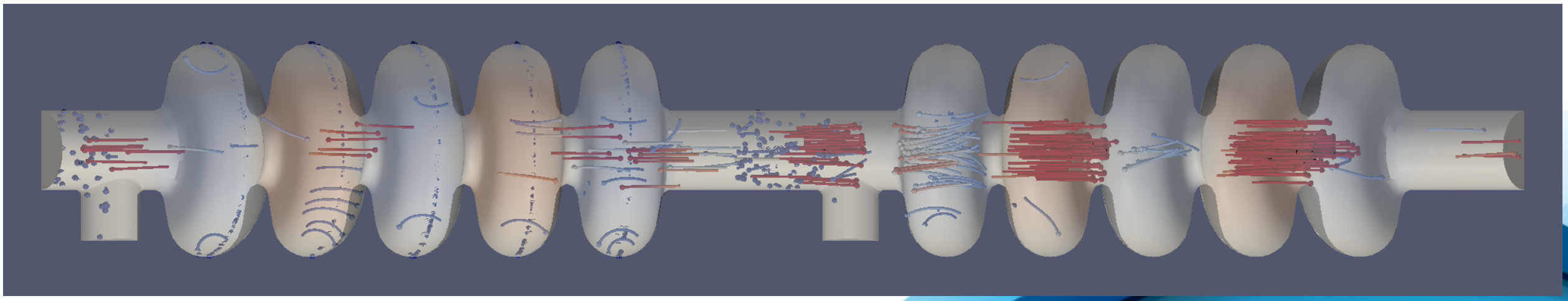
1. Ability to "process away" MP bands?
2. How much could geometrical tweaks help?
3. Trustworthiness of code? (Questionable assumptions.)

Multi-cavity Field Emission

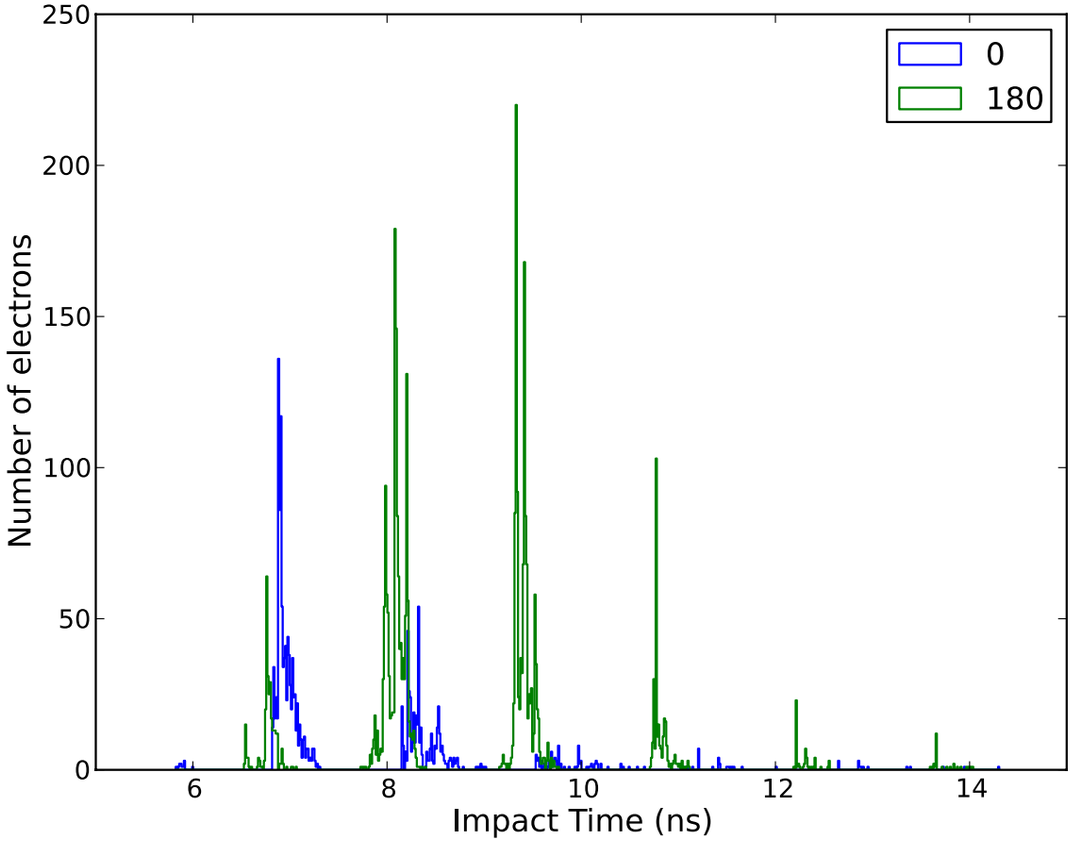
Instantaneous phase difference = 0

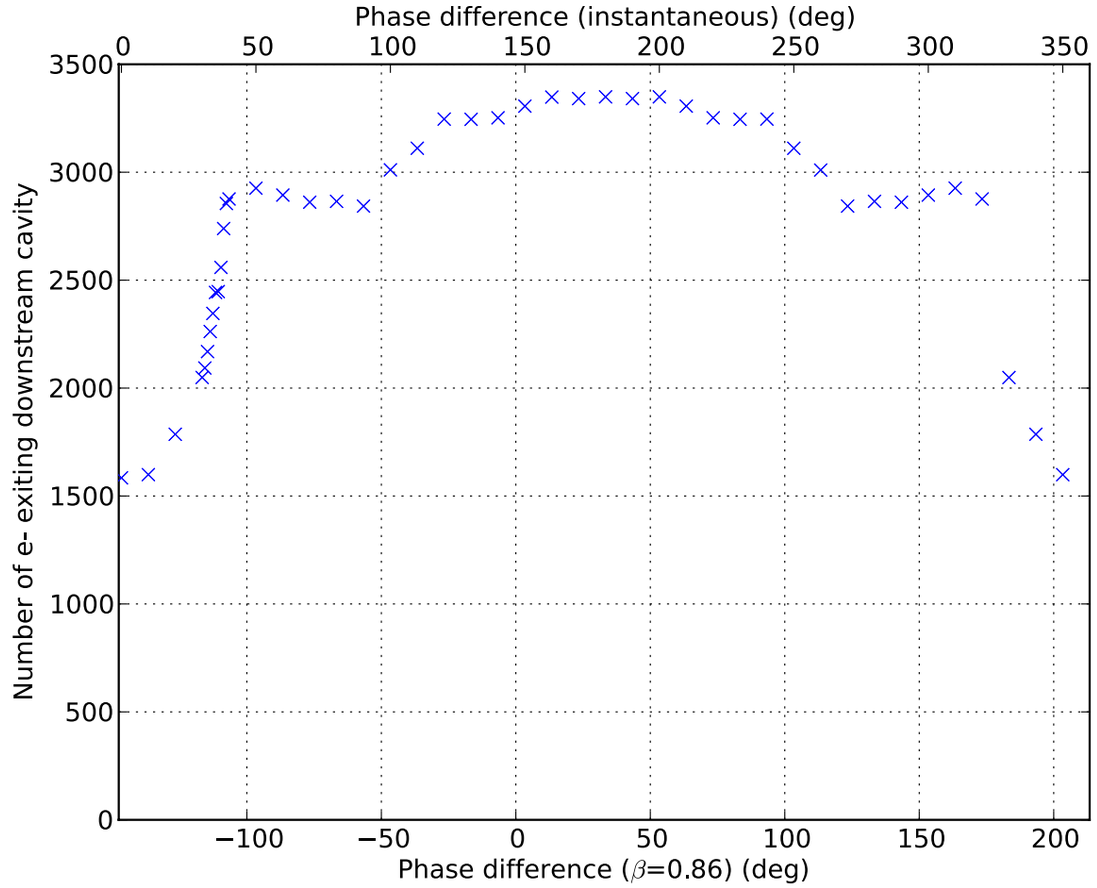


Instantaneous phase difference = 180°



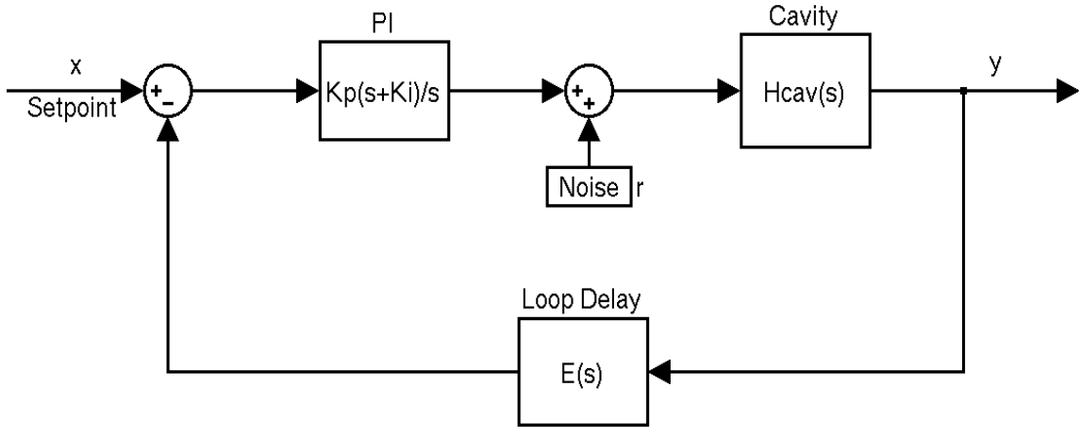
FE current is dependent on cavity phase relationship

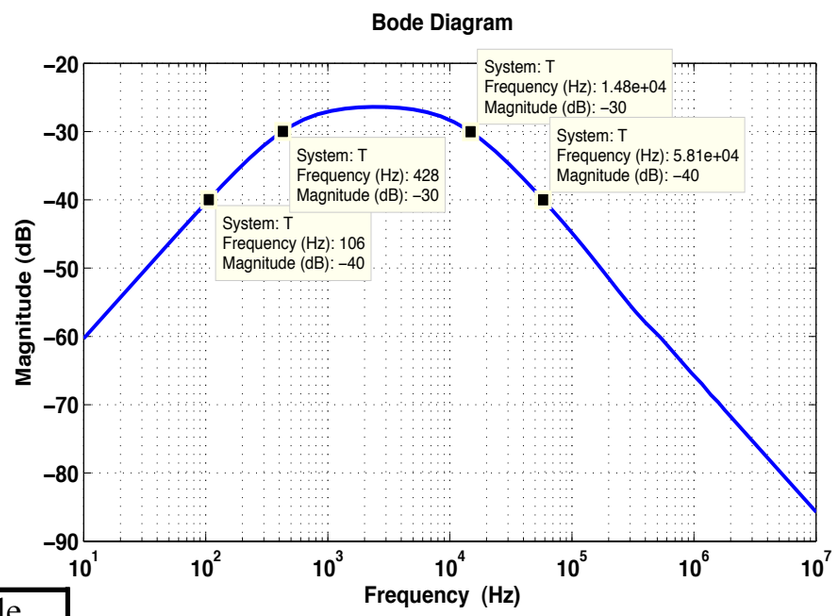




LLRF

- 1% Modulator droop/ripple induces ~10° phase & 1% amplitude klystron error
  - PI feedback necessary
    - Gain limited by loop delay & closest passband mode





Frequency Range	Gain available	Klystron output phase tolerance/degree	Modulator Ripple tolerance
f<106Hz	>100	>50	>3.3%
106Hz~428Hz	100>x>30	50>x>15	3.3%>x>1%
>428Hz	30>x>20	15>x>10	1%>x>0.6%

SC requirements

Frequency Range	Modulator Ripple tolerance
f<100Hz	<3.3%
100Hz~1kHz	<1%
>1kHz	<0.1%

If one modulator is used for entire SC & NC linac

Summary & Conclusions

- Open questions for RF modeling:
  - Beam loss
  - FE/MP
  - LLRF
- MP in HOM coupler
  - Designs may be tested in simulation
    - Provide feedback to coupler designers
    - How accurate is the code?
    - Can MP bands be processed away?
- FE within a cryomodule
  - Simulations allow an understanding of FE trajectories
  - Observed dependence on cavity parameters
- LLRF
  - Stability requirements
  - Ongoing work…

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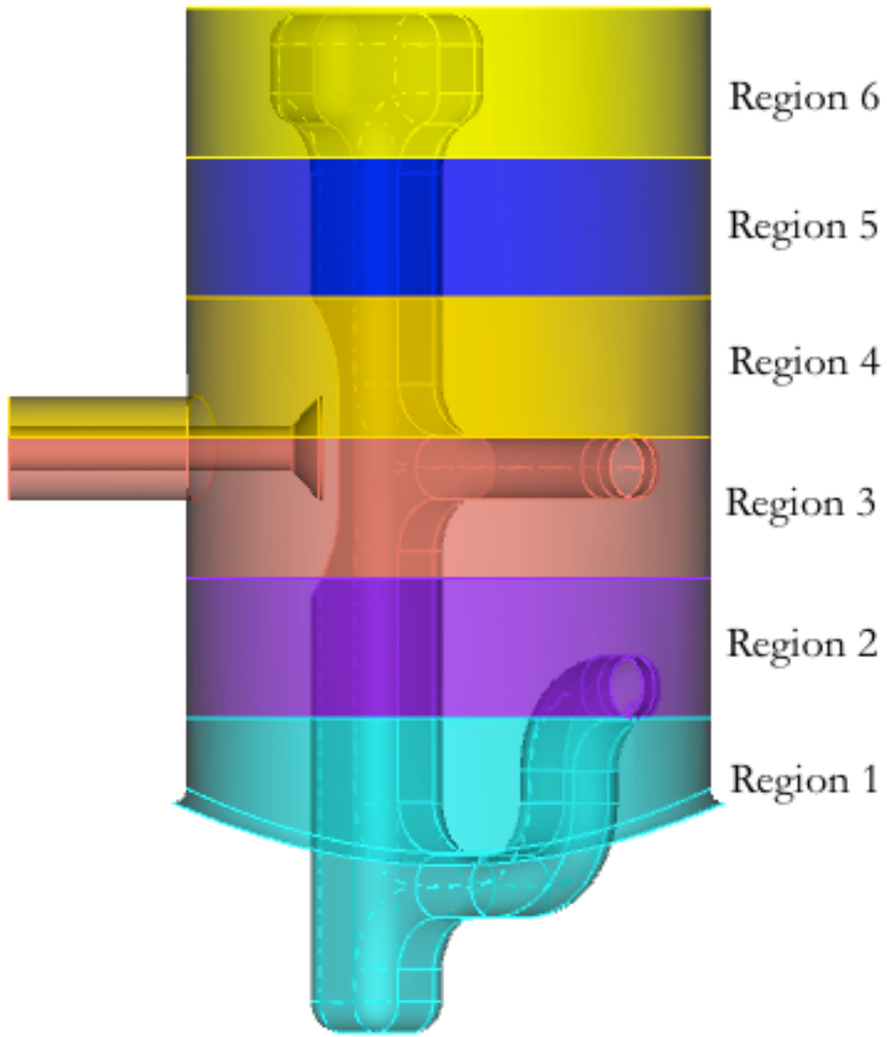
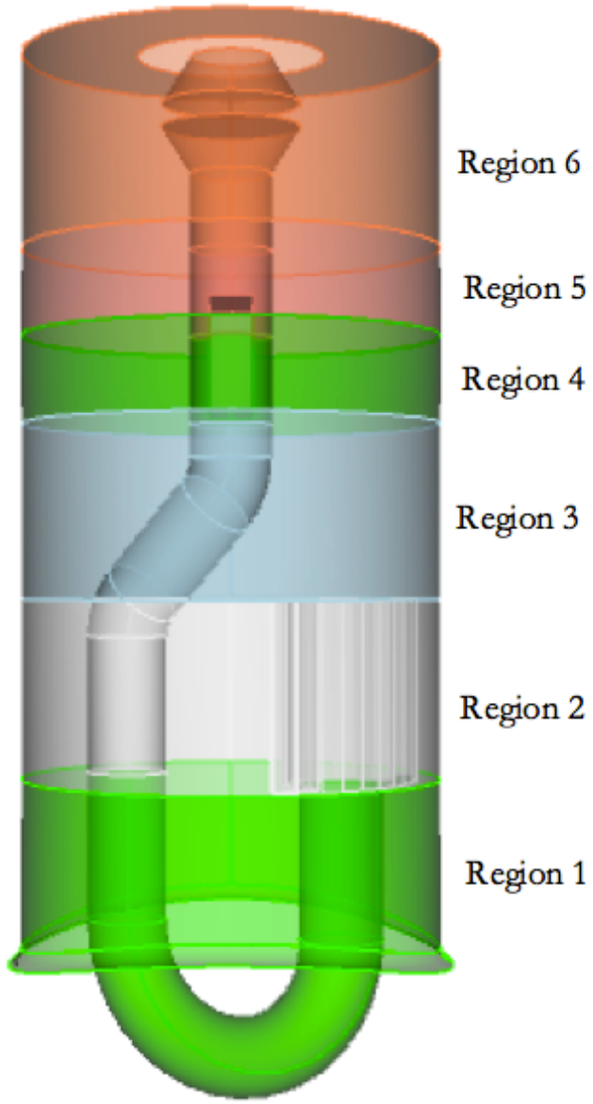
SPARE SLIDES

Coupler Regions





SEY used in postprocessing the Track3P results