STATUS REPORT:

BEAM DYNAMICS DESIGN STUDIES FOR THE HIE-ISOLDE ENERGY UPGRADE

MATTHEW FRASER – BE-RF-BR (CERN)

mfraser@cern.ch

TALK OVERVIEW

✓ Overview of the Design Study for 10 MHz Post-accelerated Beams:

a. background of project: motivation and concept
b. feasibility studies for pre-bunching and chopping
c. RF and beam dynamics simulations of existing structures
d. beam dynamics simulations of new structures: expected performance
e. outlook and further work

✓ Development of an automatic tuning routine for HIE-ISOLDE linac cavities.

✓ HEBT and stray magnetic fields in the experimental hall.

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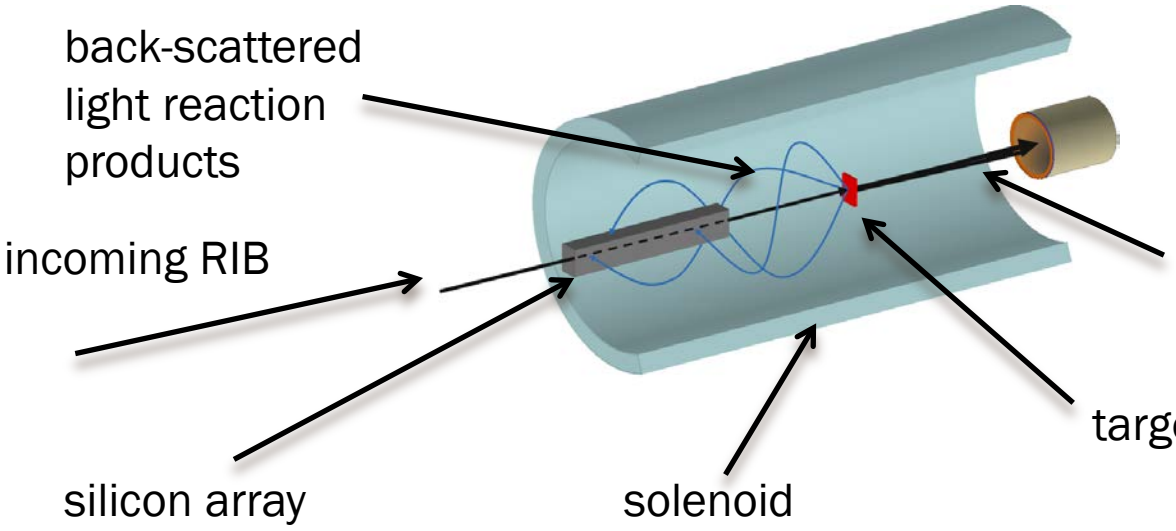

B=2T

Particle	T_{cyc} (ns)
p	34.2
$^{3}He^{2+}$	51.4
d, α	68.5
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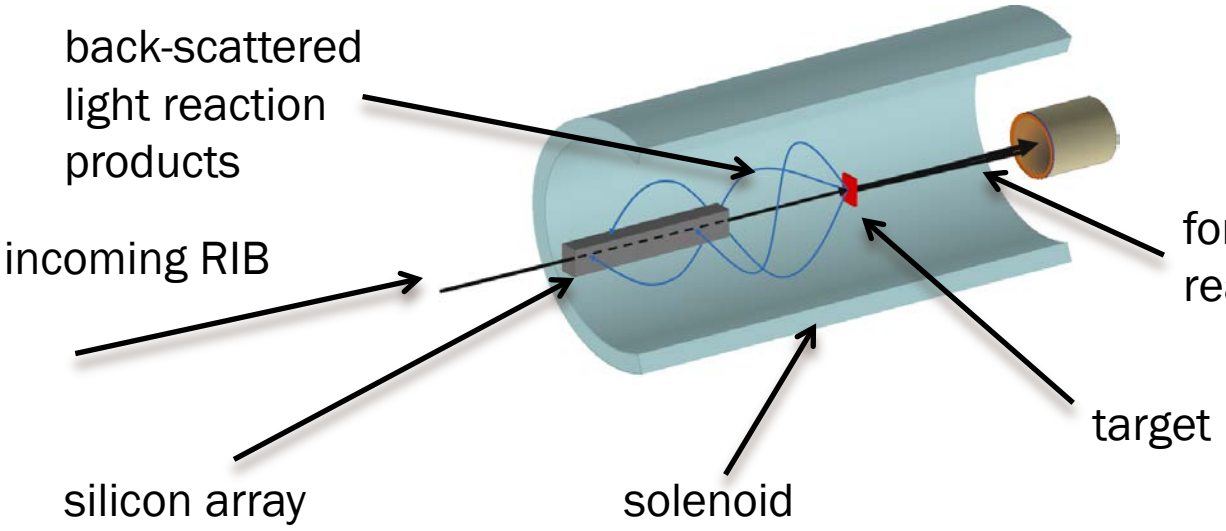
- ✓ Opportunity for other experiments to use beam time structure to reduce backgrounds.



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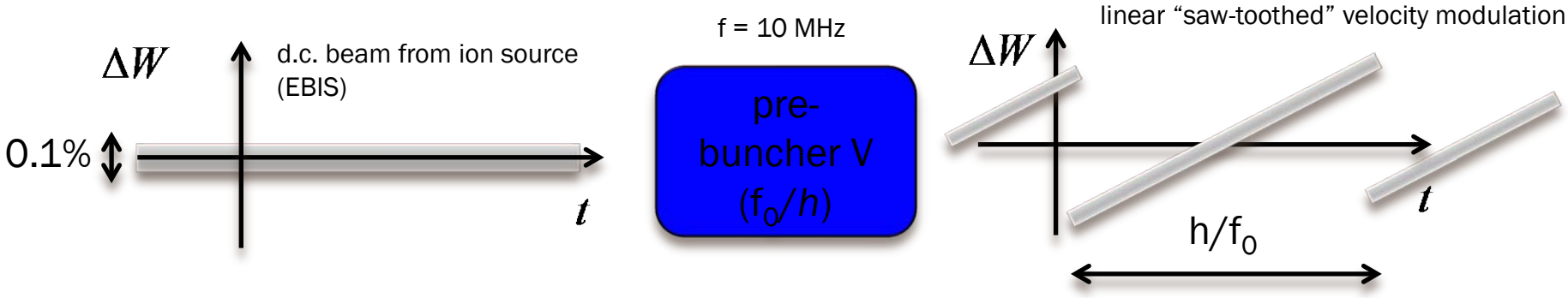

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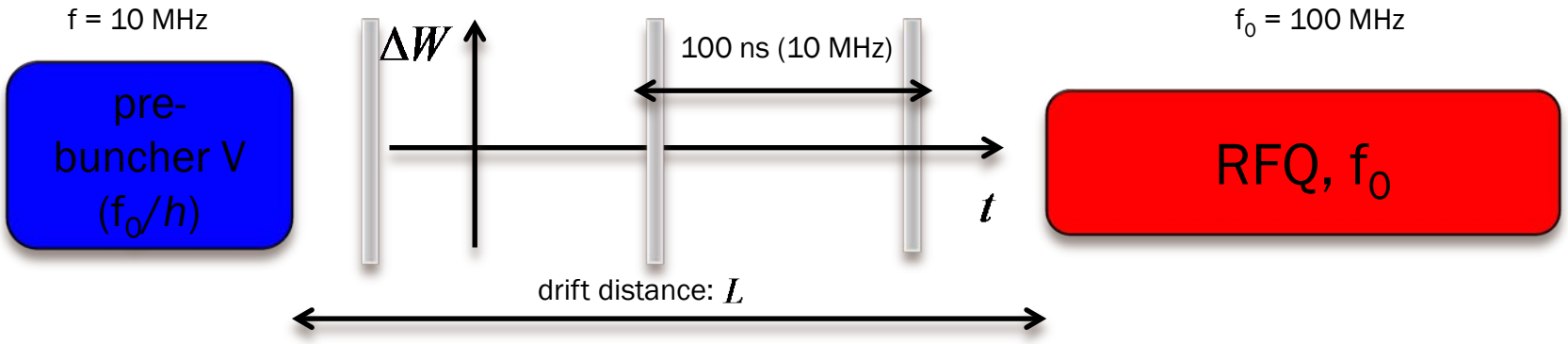

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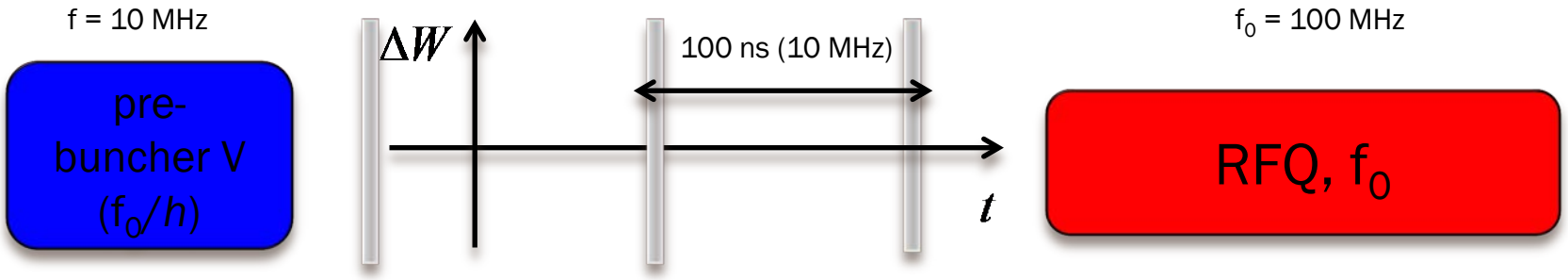
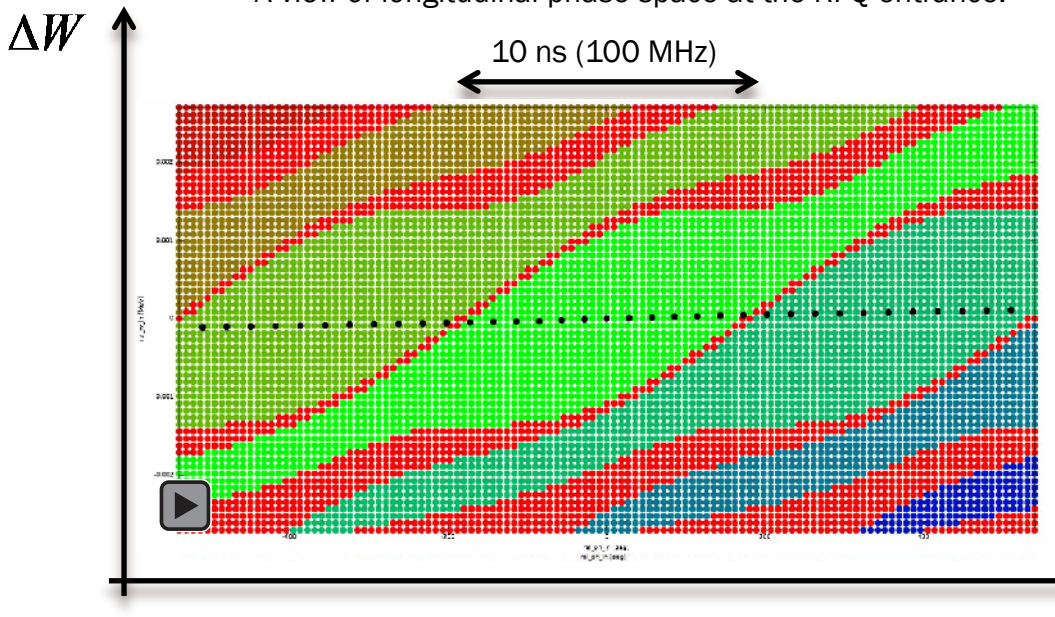


A view of longitudinal phase space at the RFQ entrance:



Variation of voltage on pre-buncher from 0.1 to 2.0 kV

Mixing 3 harmonics:
10.128, 20.256, 30.384 MHz

Drift distance fixed, L = 1.4 m

V_L_const.avi

V_L_const.wmv

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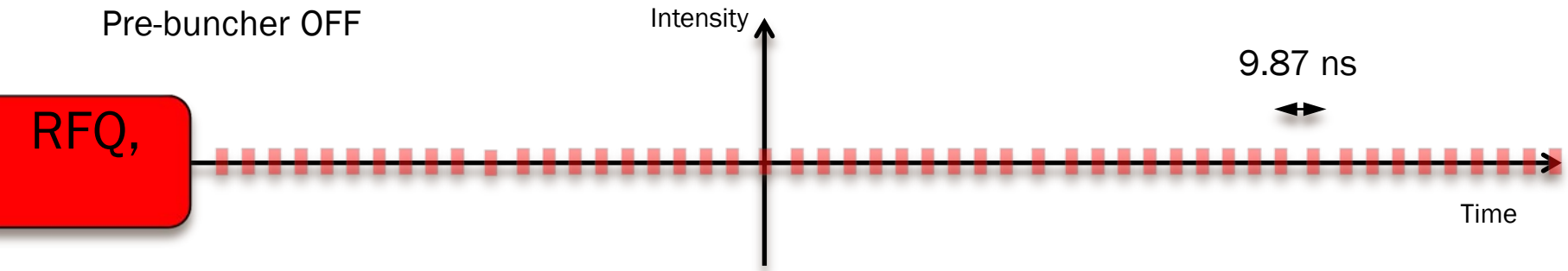

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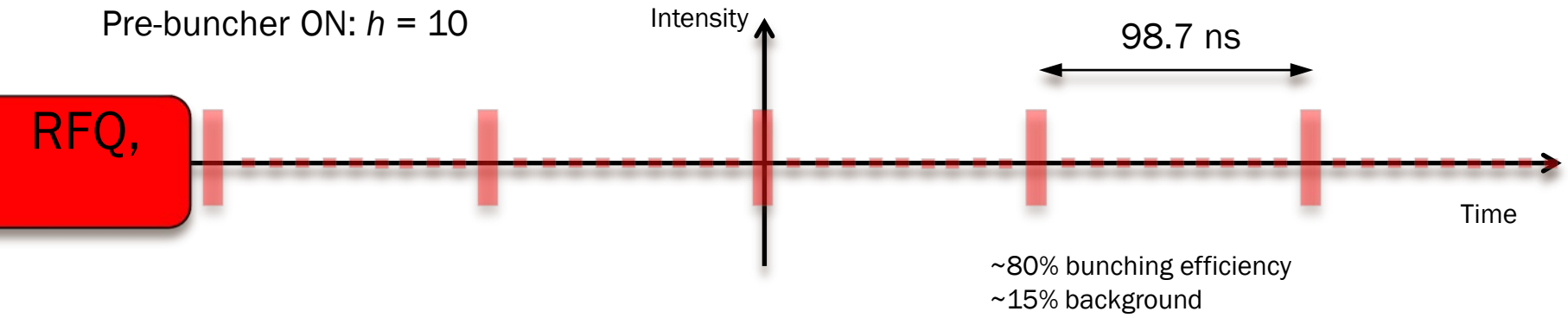

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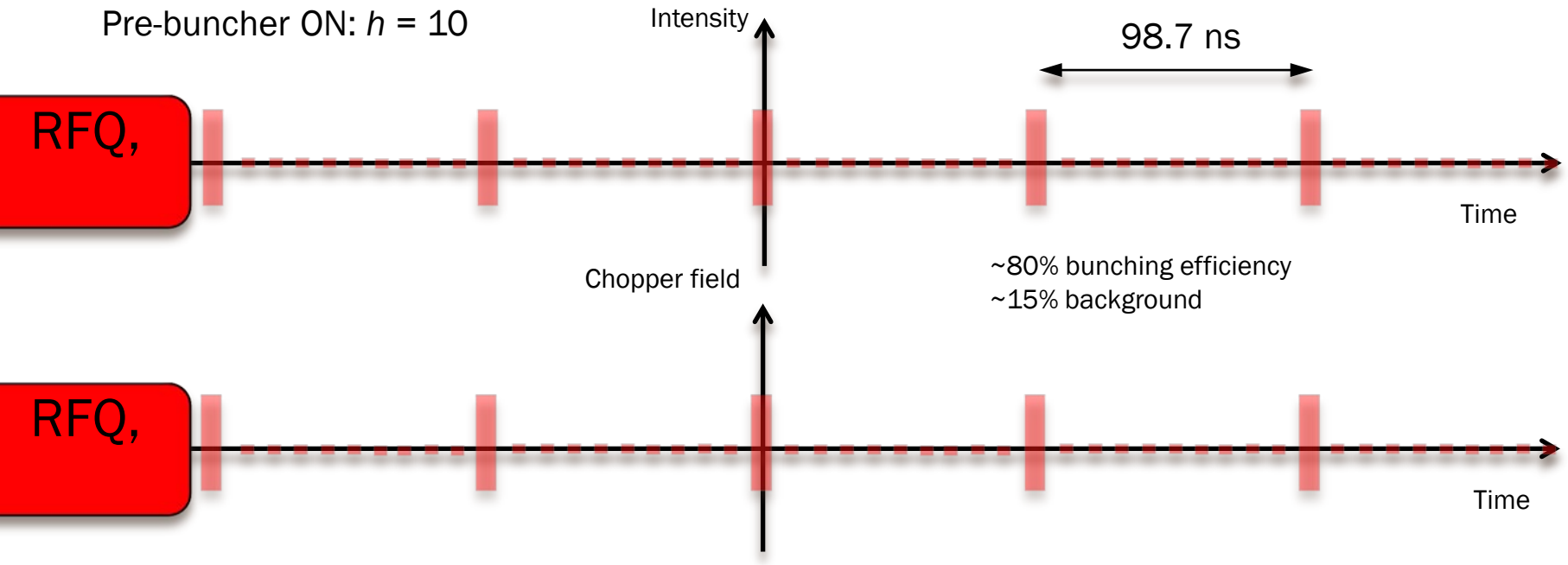

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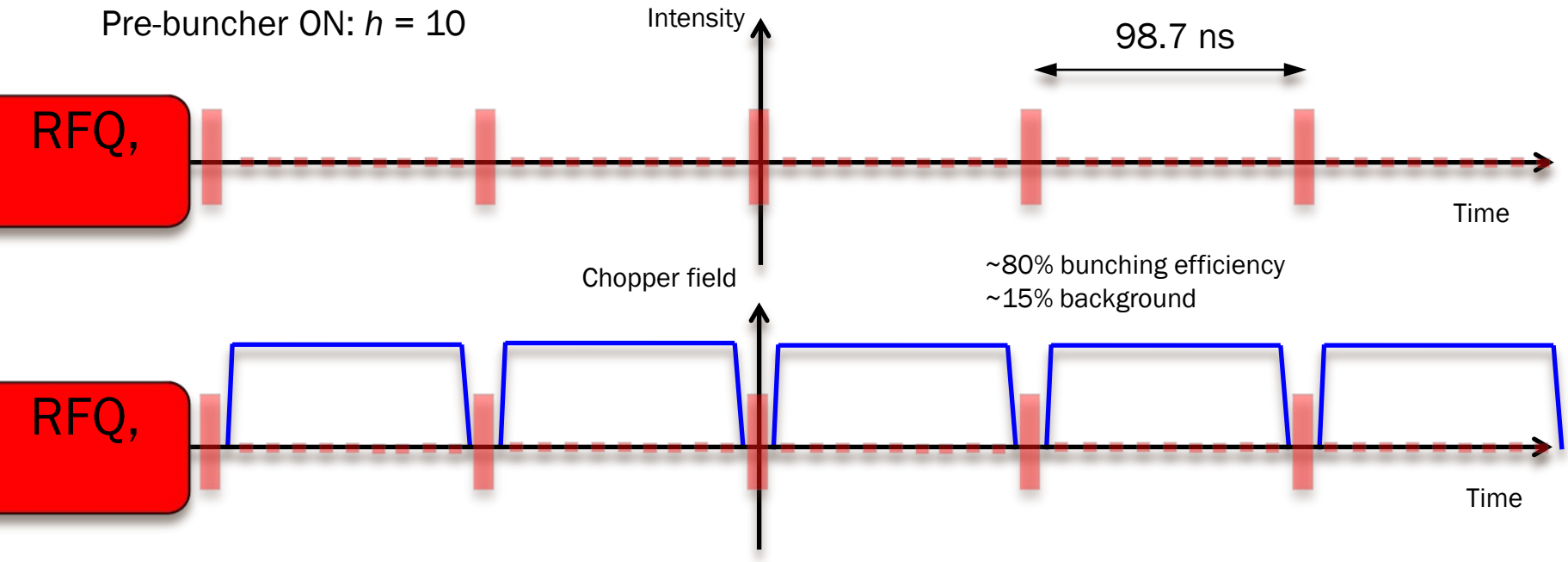

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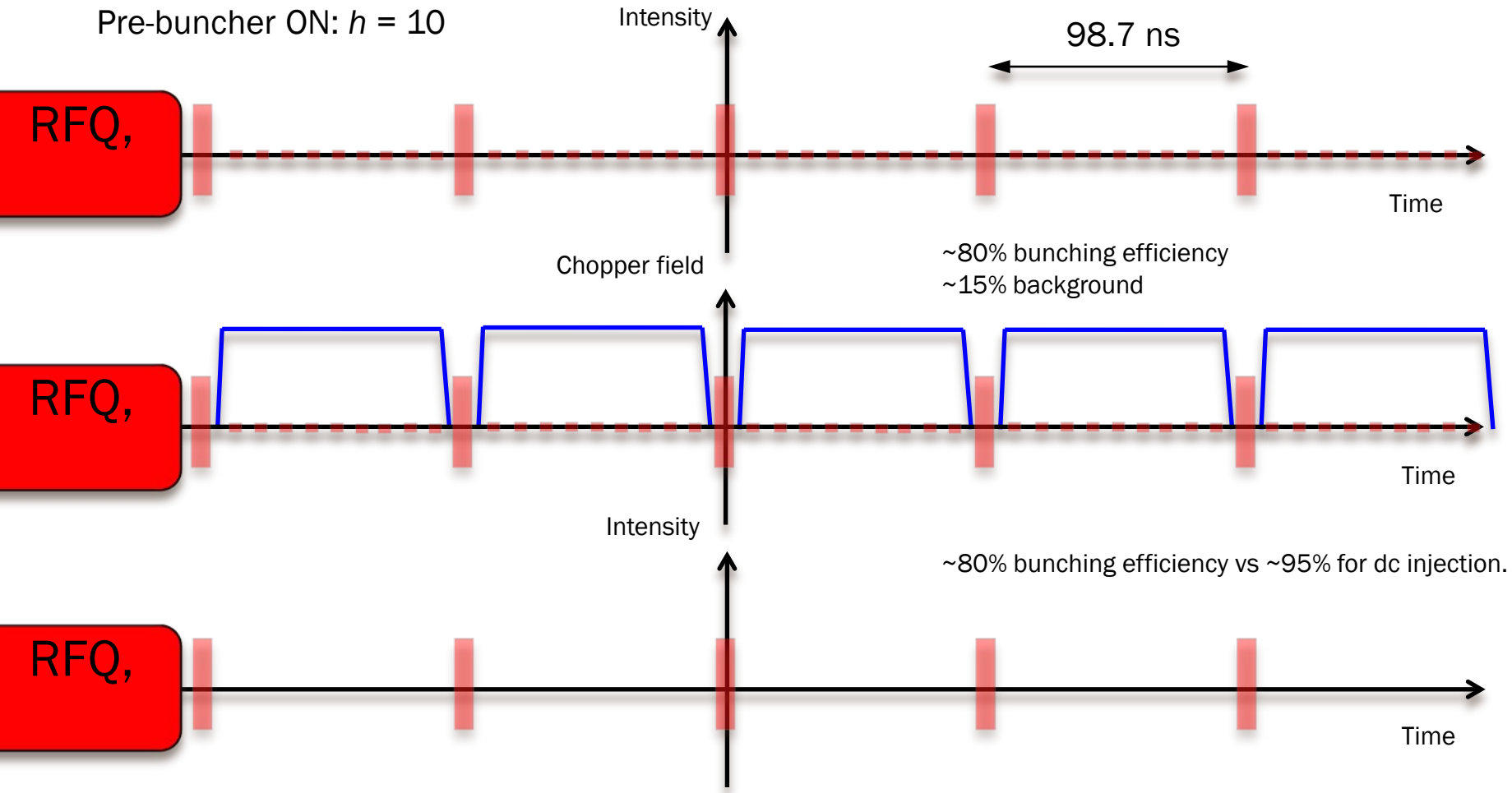

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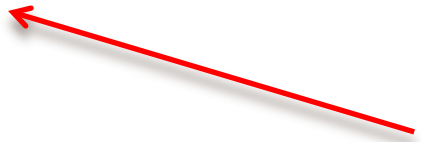

This RFQ was retrofitted with external buncher, by request of experiments, like in our case.

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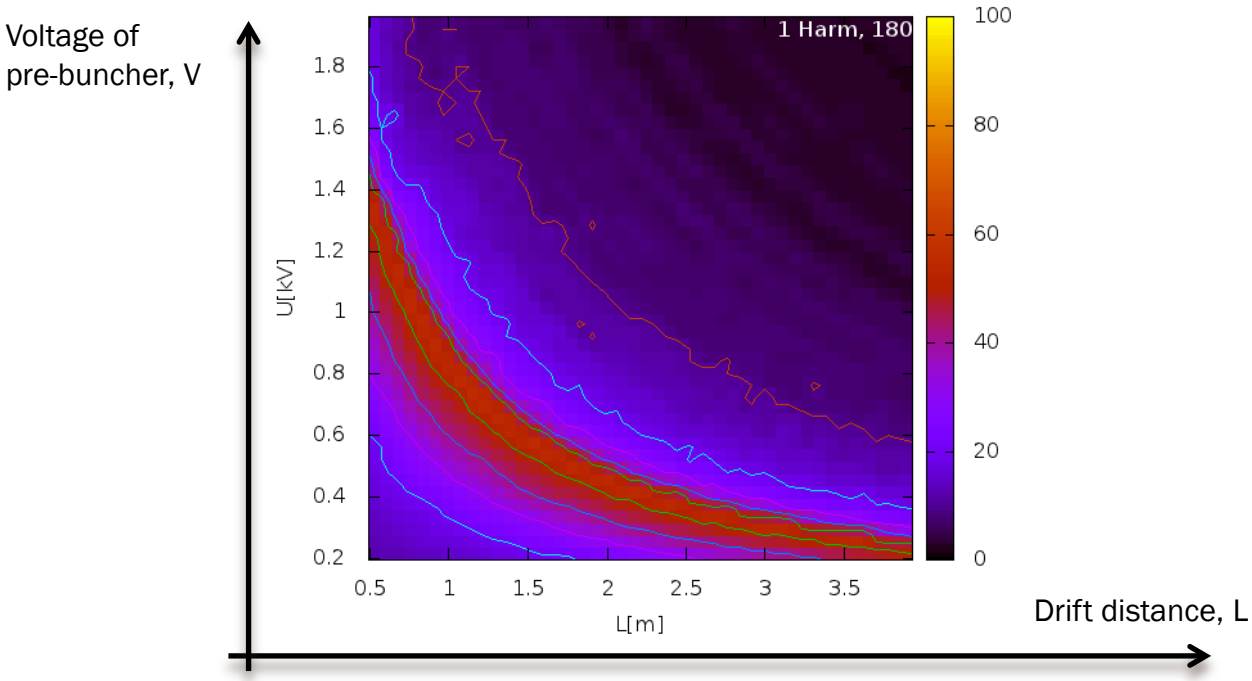
FEASIBILITY STUDY OF PRE-BUNCHING

✓ Feasibility of pre-bunching proven with simplified pre-buncher and LEBT model.

Beam Dynamics Feasibility Study for an RFQ Sub-harmonic Pre-buncher at REX-ISOLDE
I.B. Magdau and M.A. Fraser
CERN-HIE-ISOLDE-PROJECT-Note-0015

Single harmonic:
10.128 MHz

Transmission in Main 10 MHz bunch



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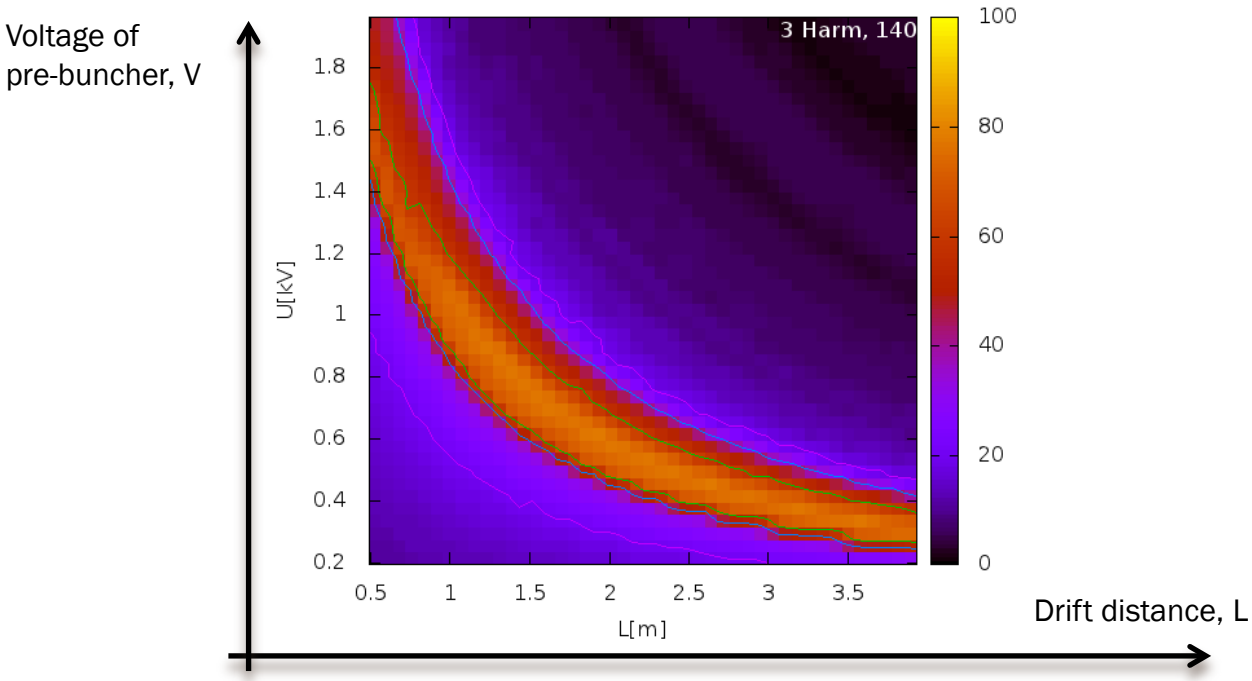

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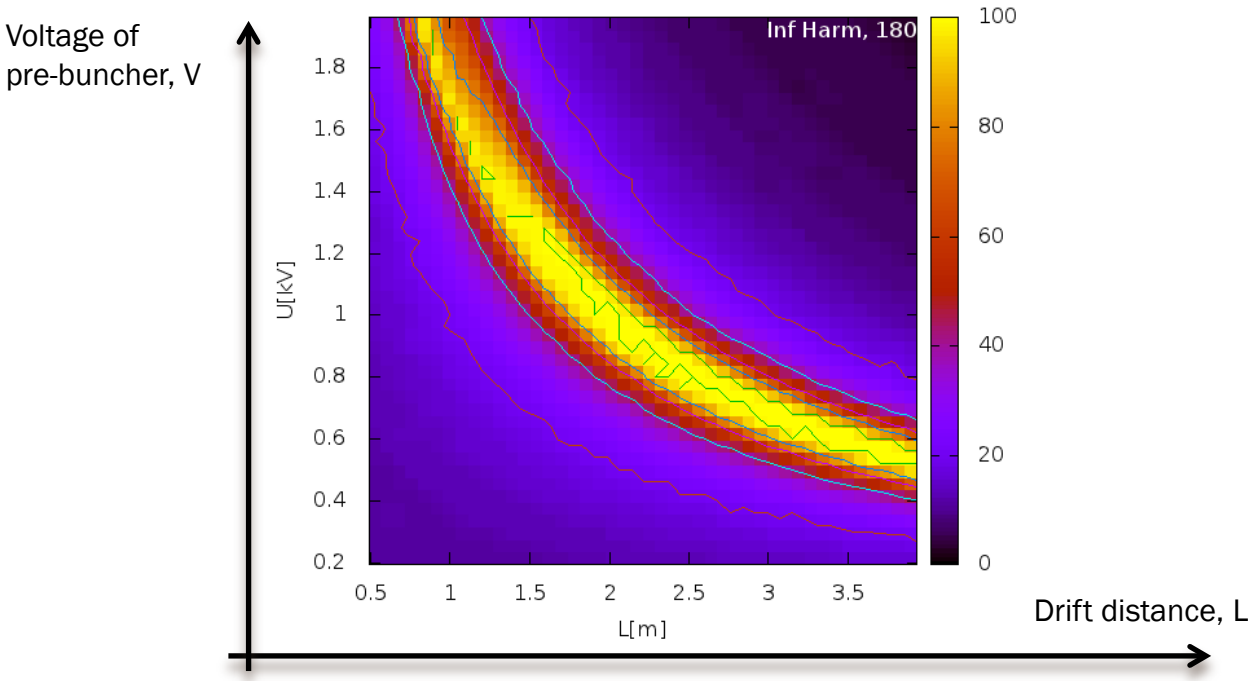
Infinite harmonics
("saw-tooth" linear bunching)

Transmission in Main 10 MHz bunch



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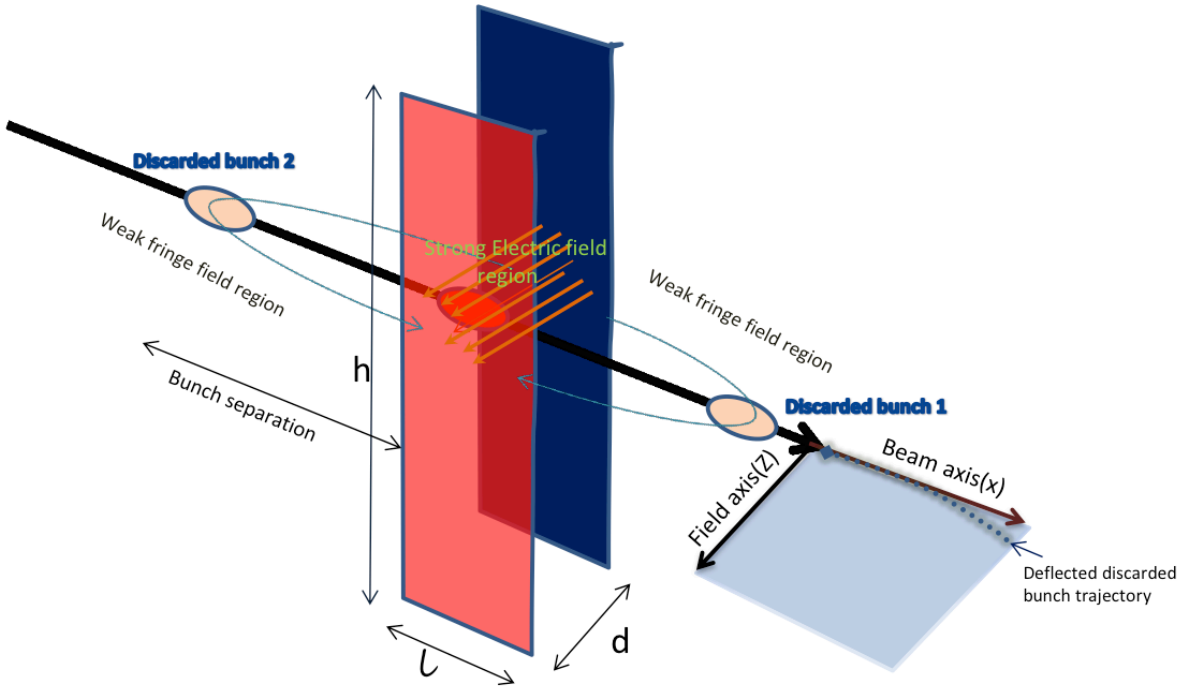
Investigating the Feasibility of a Travelling-wave Chopper for the Clean Separation of 10 MHz Bunches at HIE-ISOLDE

A. Mukhopadhyay, M.A. Fraser, R. Calaga, F. Caspers and M. Paoluzzi

To be published: CERN-HIE-ISOLDE-PROJECT-Note-0026



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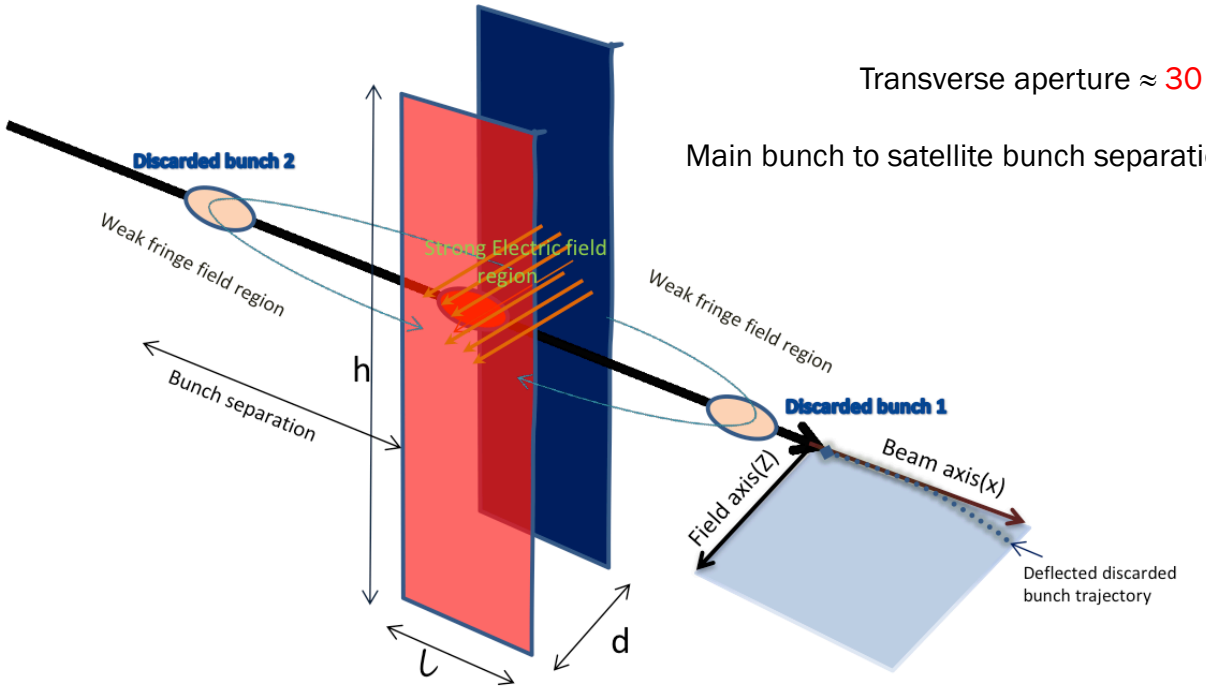

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Possibility for collaboration with Linac4 chopper technical design team.

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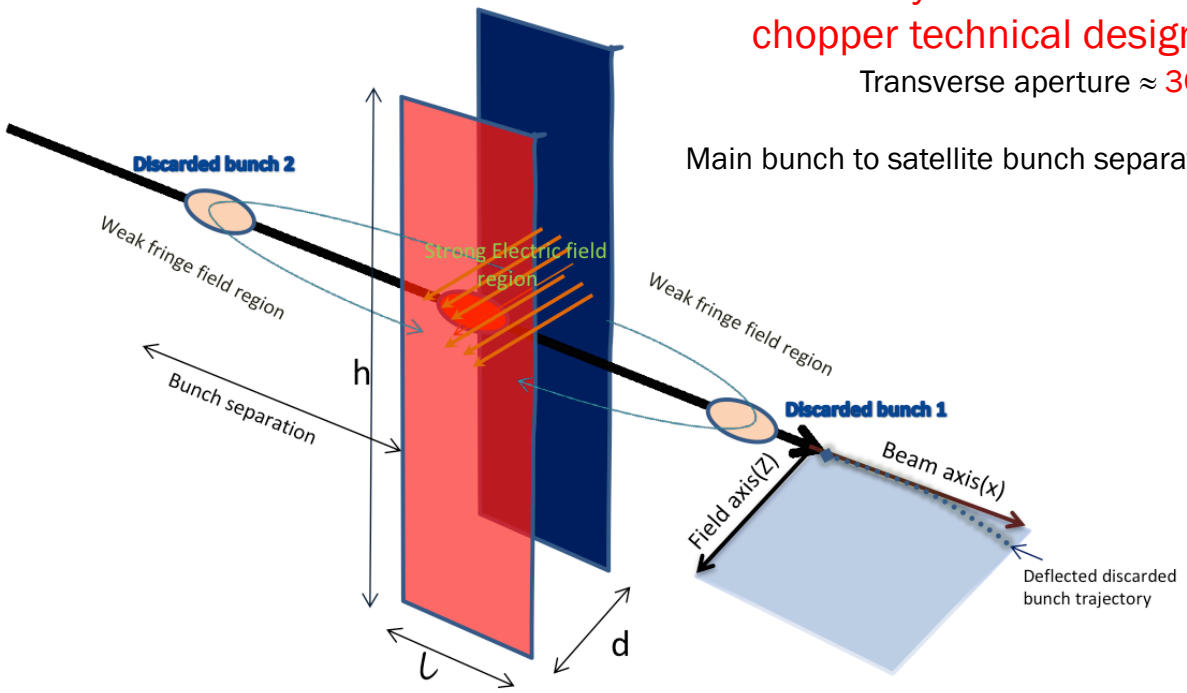

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RFQ EM SIMULATIONS

✓ Simulated RFQ electrodes in EM field solver code to compute a field map.

REX-ISOLDE RFQ Beam Dynamics Studies using CST EM Studio®
M.A. Fraser and R. Calaga
To be published: CERN-HIE-ISOLDE-PROJECT-Note-0025

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N10 X0.0 Z15.508
N11 G2 X-2.488 Z15.341 II0.000 KI-18.708
N12 G2 X-6.894 Z14.583 II7.999 KI-59.622
N13 G3 X-11.300 Z13.824 II-12.406 KI58.863
N14 G3 X-13.788 Z13.658 II-2.488 KI18.542 ...
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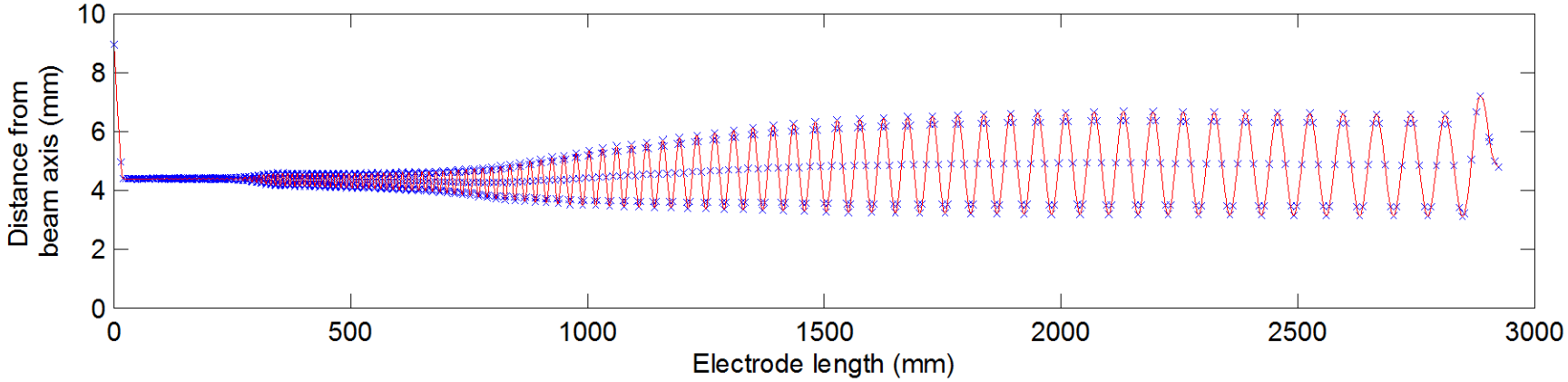

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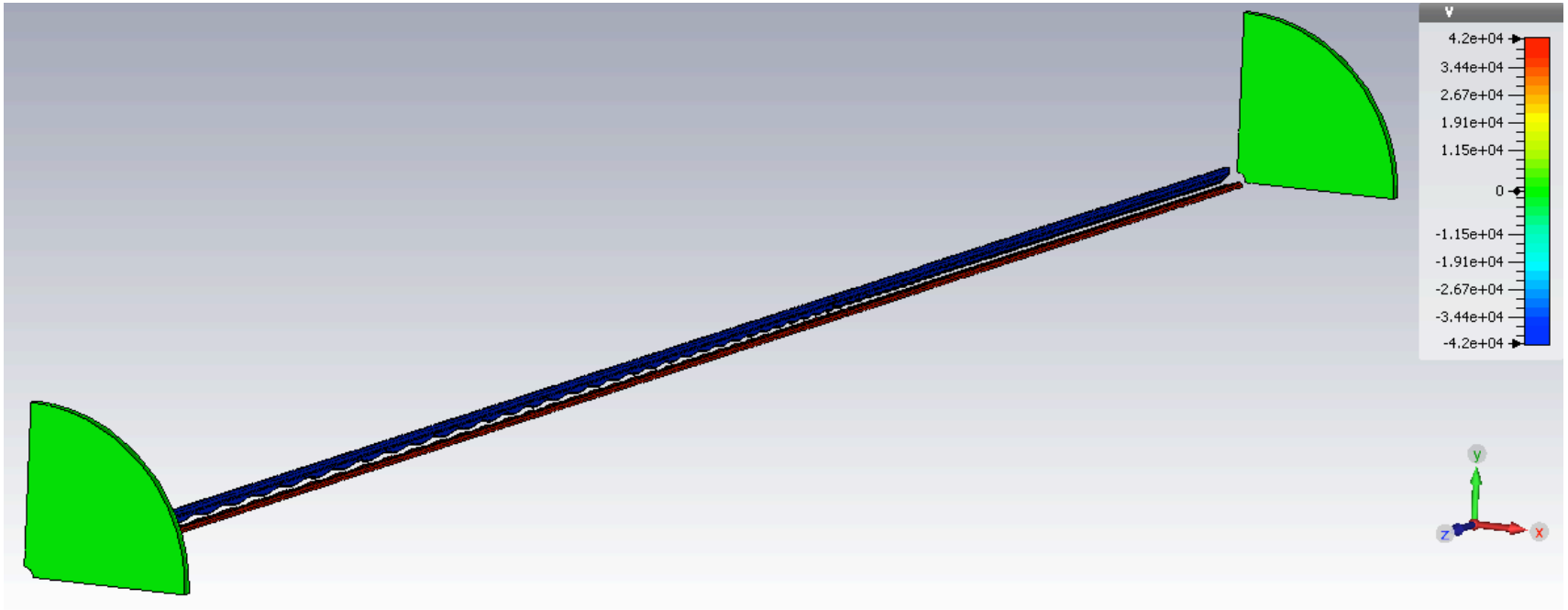

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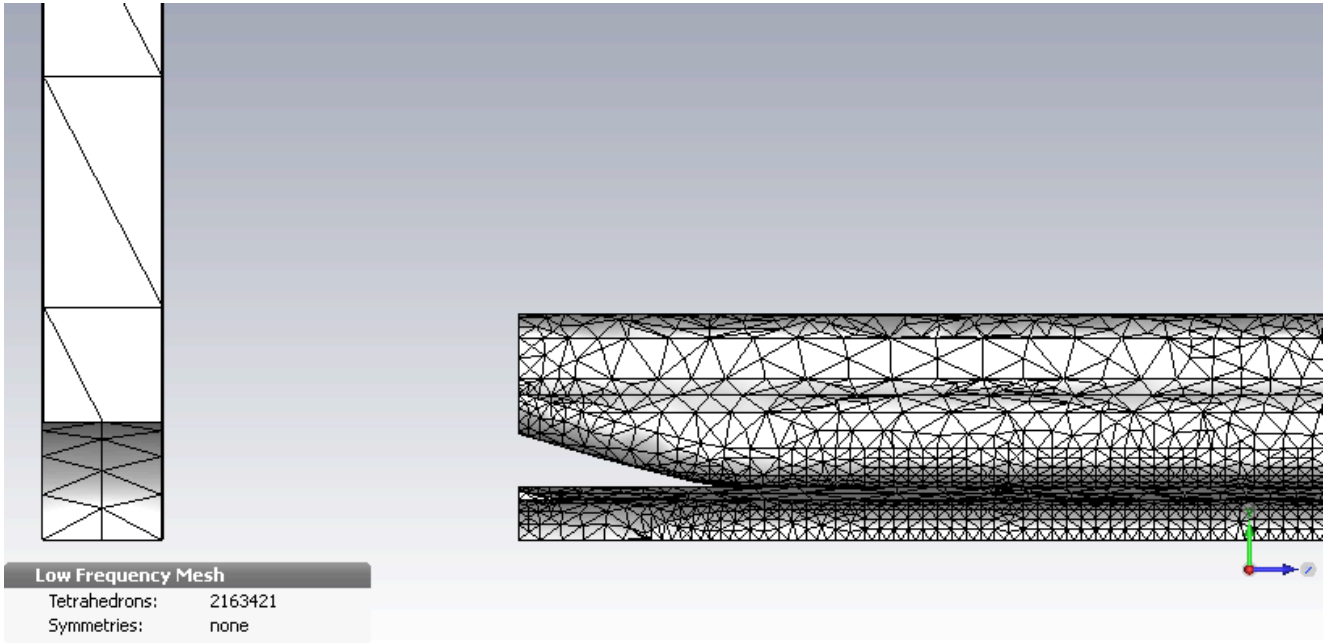

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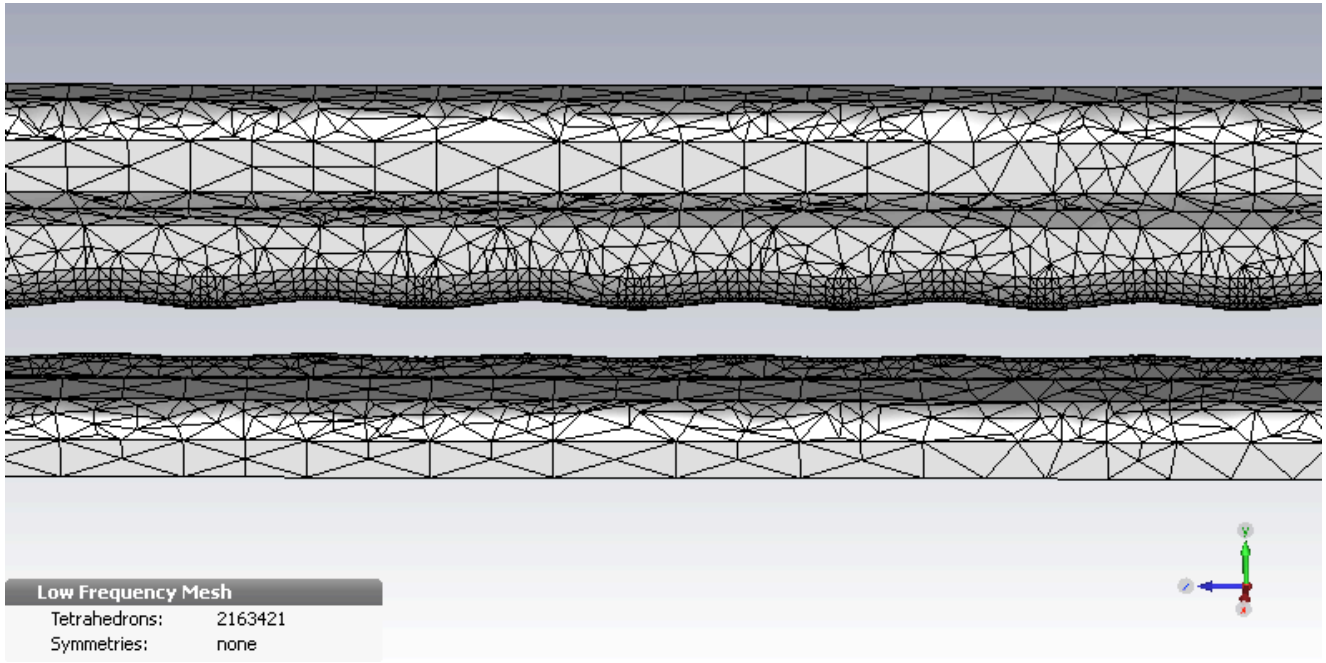

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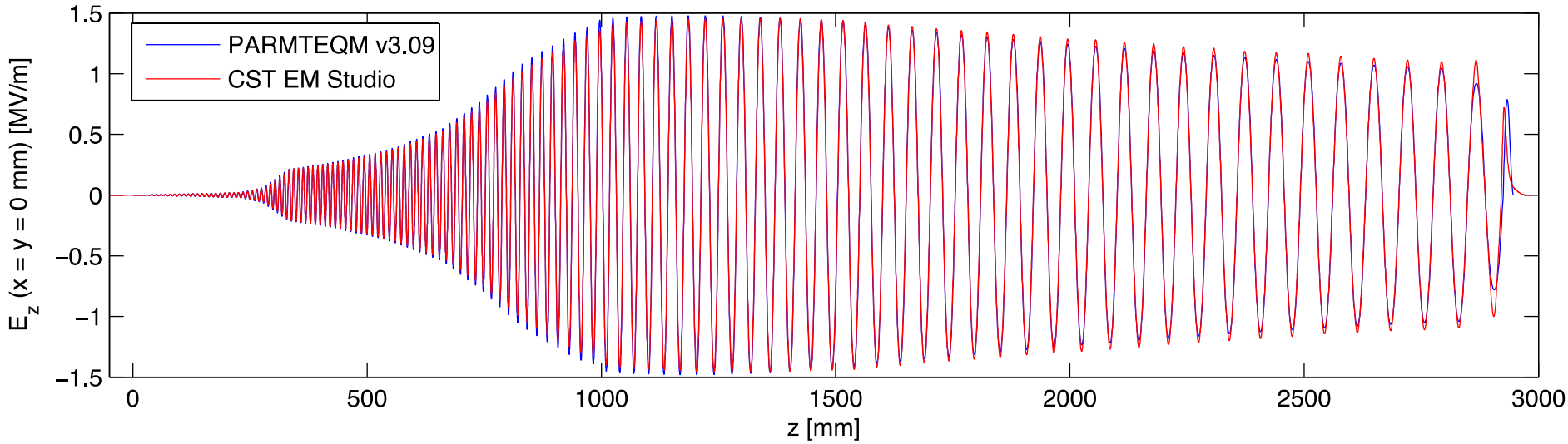
✓ Finished with a 3D field map, compared to first model used in feasibility study:



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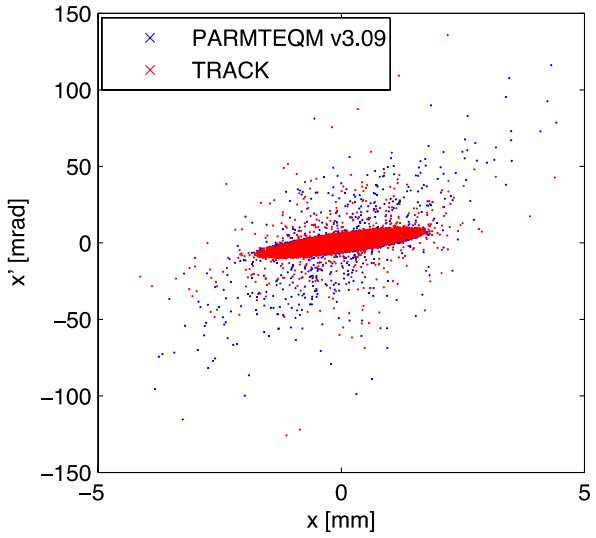
✓ And particle tracking showing we understand the beam dynamics in the RFQ:

Transverse phase space
x – x'



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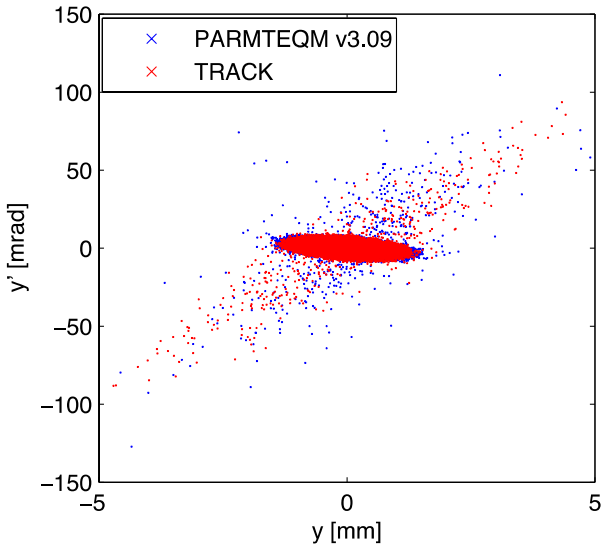
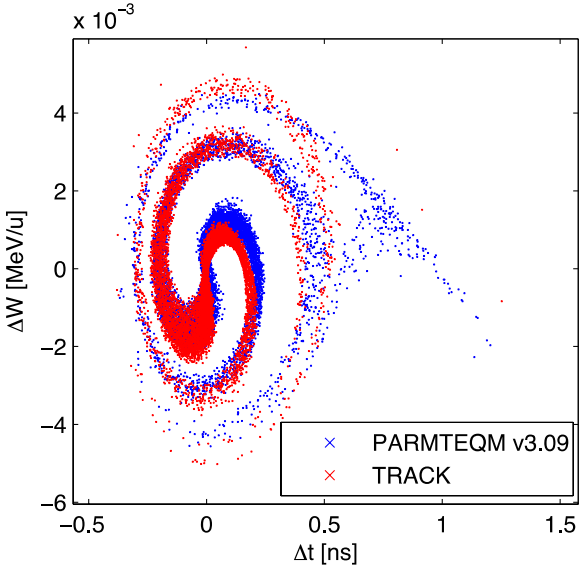
y – y'



Longitudinal phase space
Δt – ΔW



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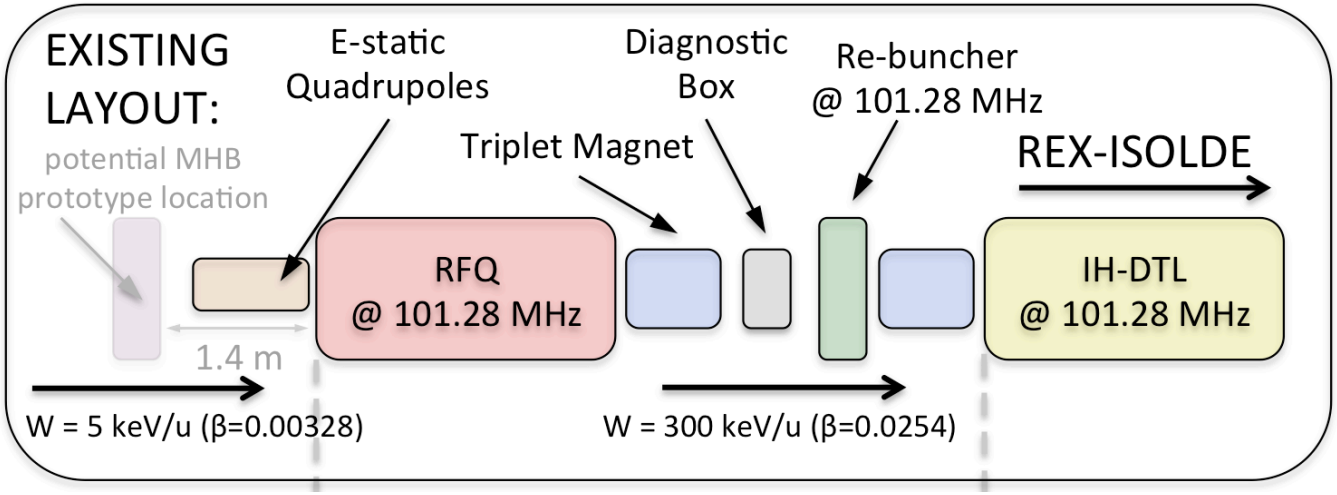
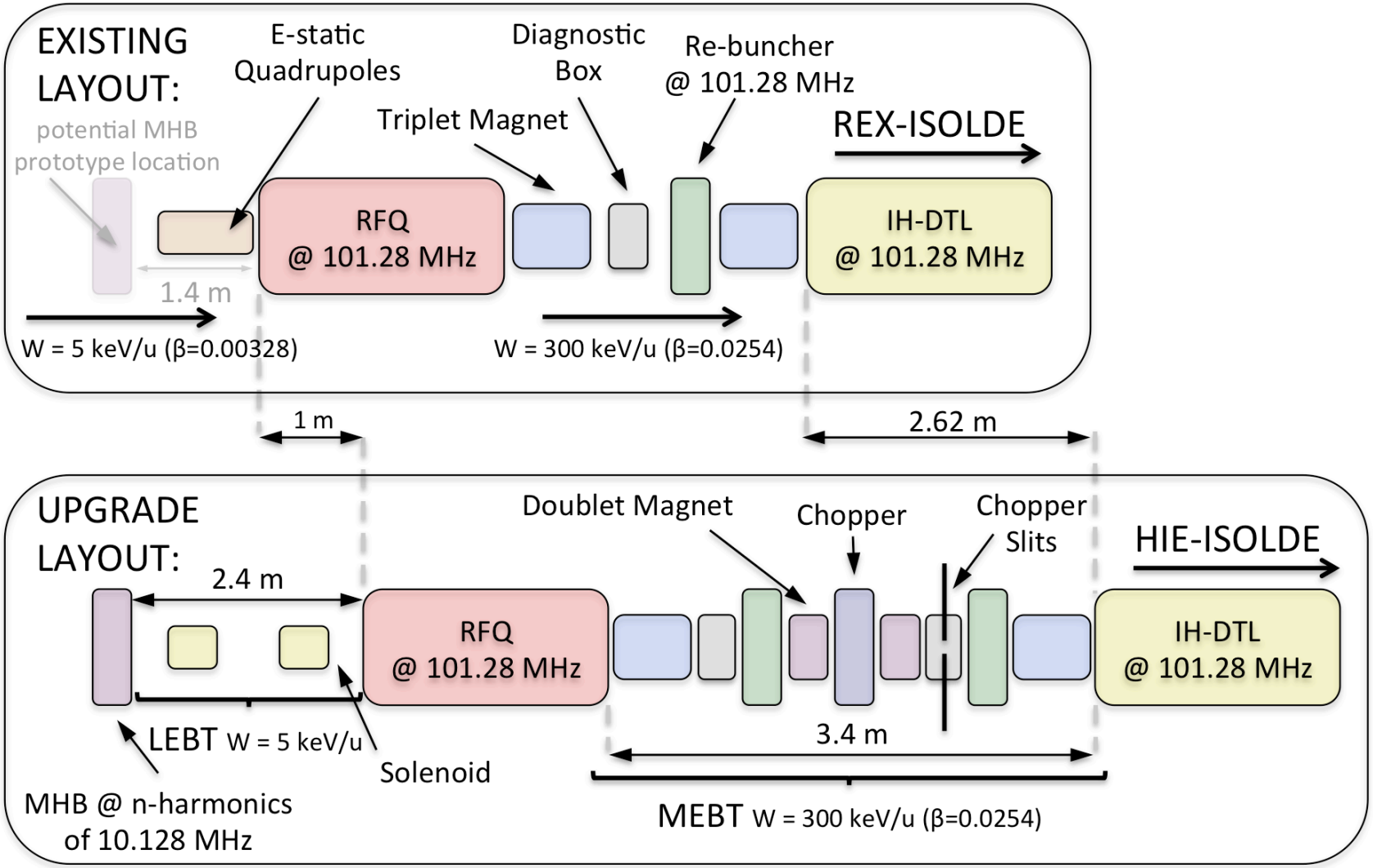


BASELINE LAYOUT: STAGE 3 (2017+)



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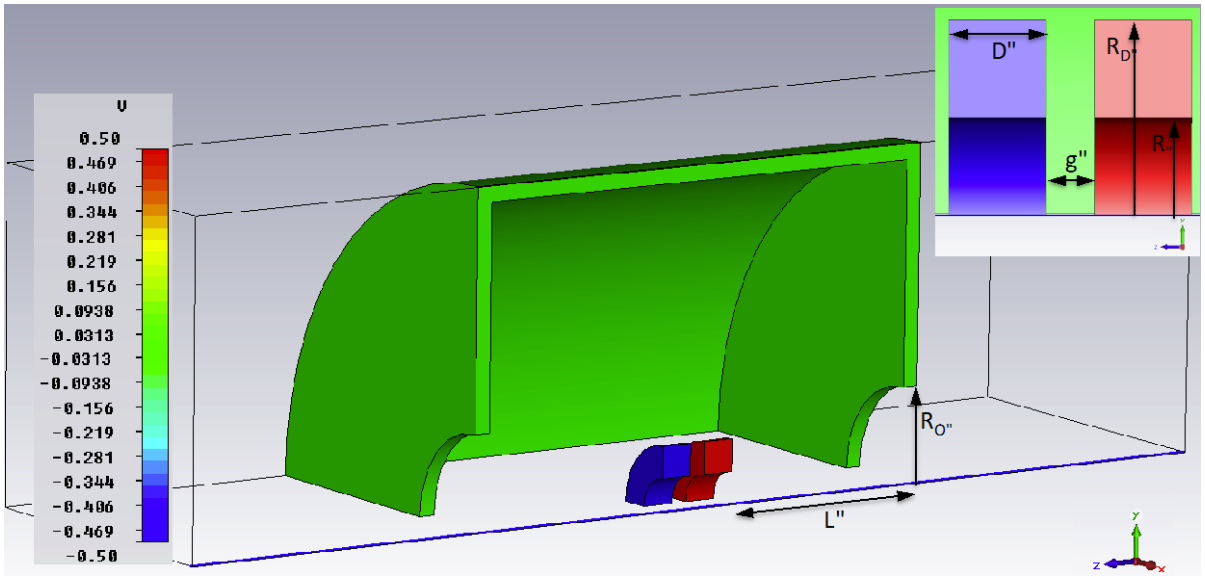
- ✓ Studied a single gap, gridless buncher mixing 4 harmonics of 10.128 MHz: based on experience of ANL and TRIUMF.

  Design Study for 10 MHz Beam Frequency of Post-accelerated RIBs at HIE-ISOLDE
  M.A. Fraser, R. Calaga and IB. Magdau
  Published in the proceedings of IPAC'13

- ✓ Field map computed using CST EM Studio®:



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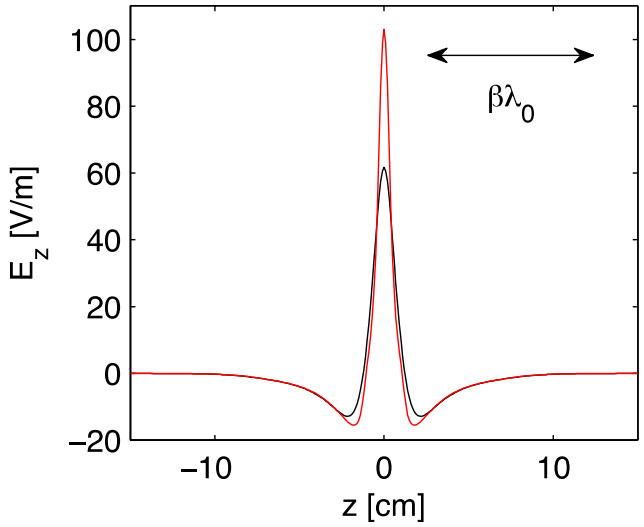

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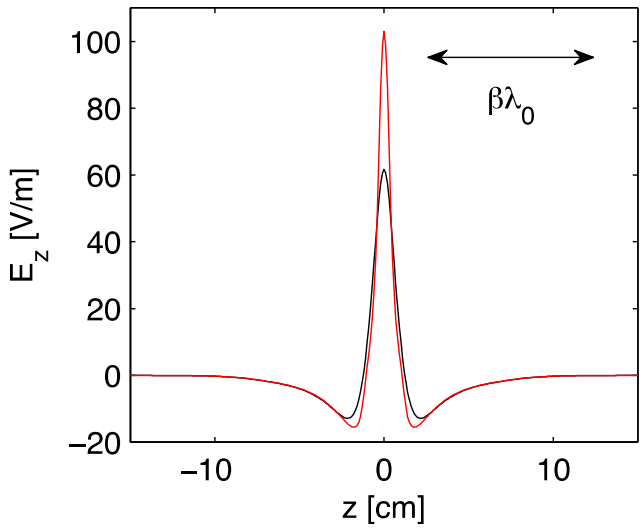
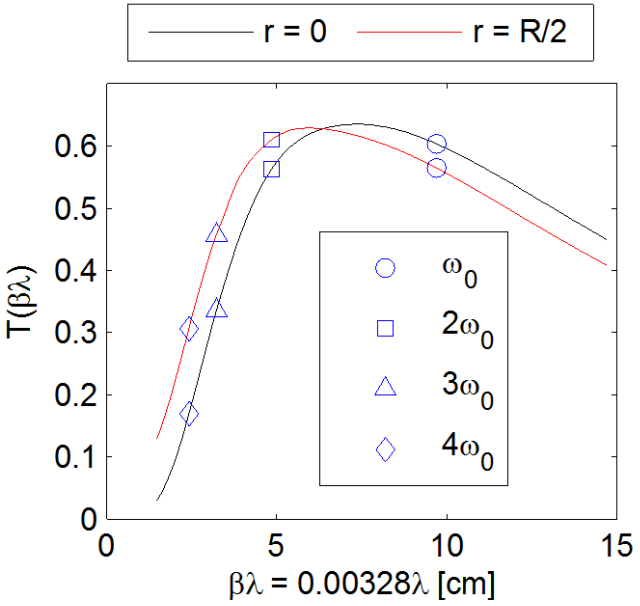


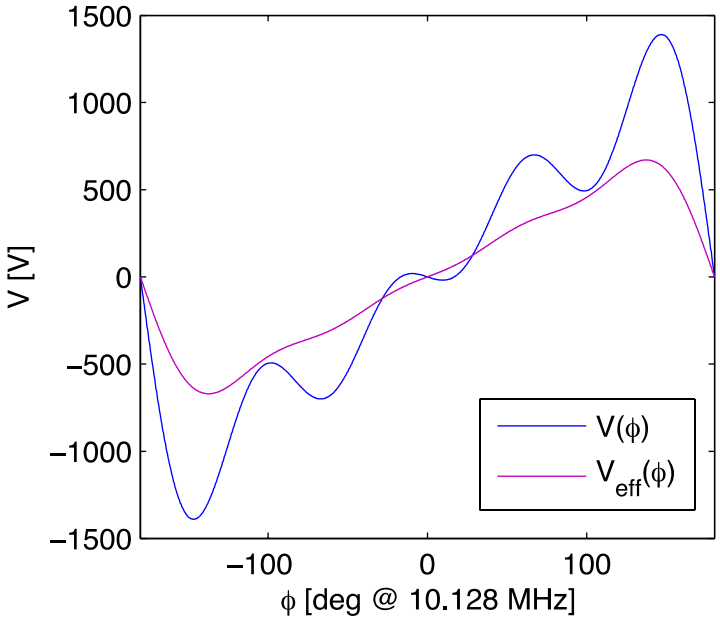


PRE-BUNCHER GEOMETRY

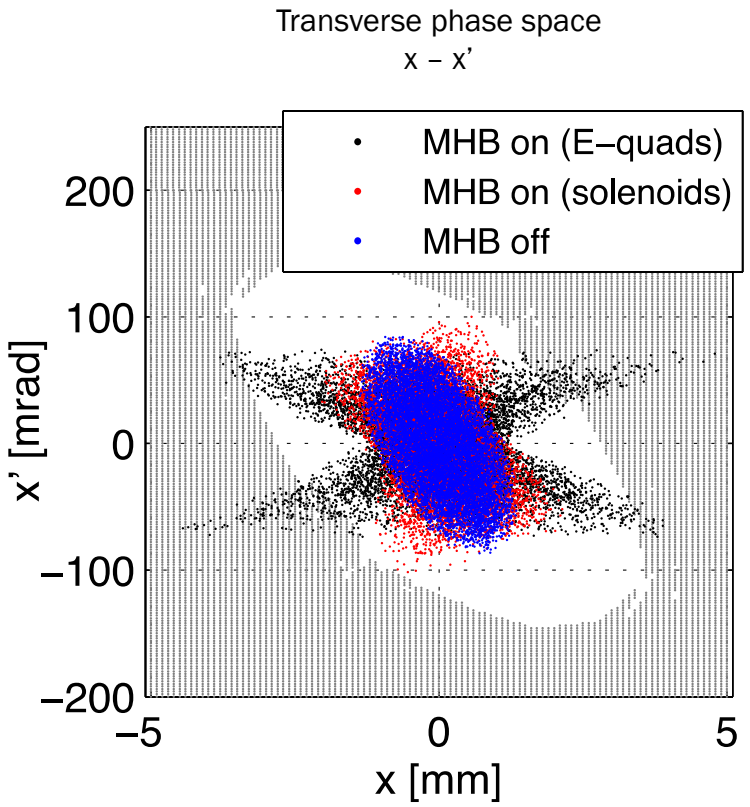
- ✓ Studied a single gap, gridless buncher mixing 4 harmonics of 10.128 MHz: based on experience of ANL and TRIUMF.

  Design Study for 10 MHz Beam Frequency of Post-accelerated RIBs at HIE-ISOLDE
  M.A. Fraser, R. Calaga and IB. Magdau
  Published in the proceedings of IPAC'13

- ✓ Tune each frequency component to achieve a linear energy gain transfer to beam:



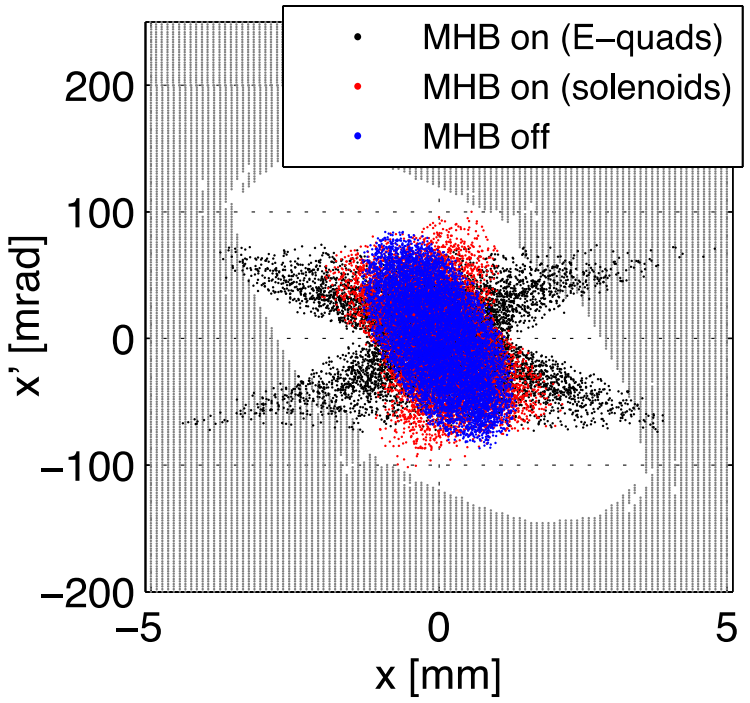
BASELINE PERFORMANCE: BEAM PHASE SPACE ENTERING RFQ



✓ Chromatic aberrations are strong with electrostatic quadrupoles.

BASELINE PERFORMANCE: BEAM PHASE SPACE ENTERING RFQ

Transverse phase space
x – x'



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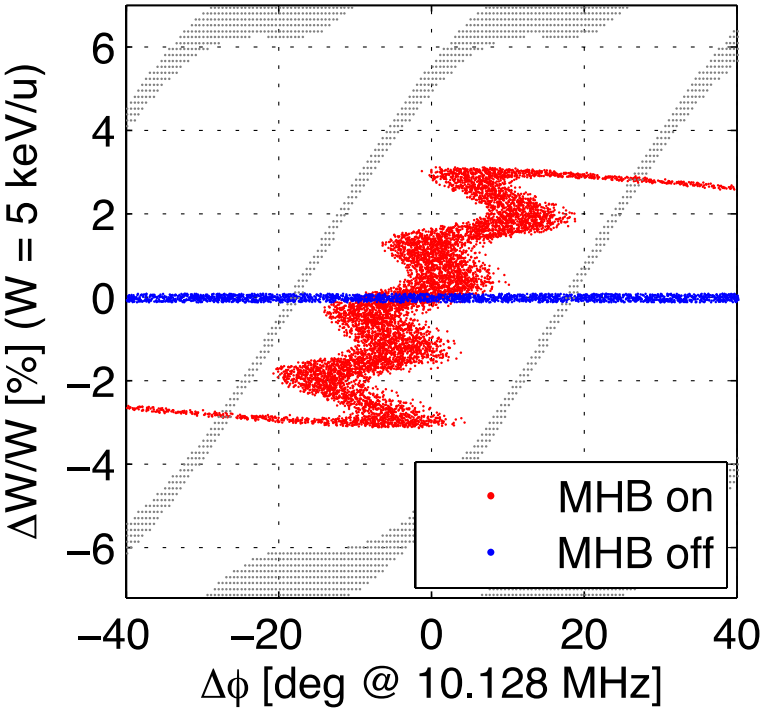
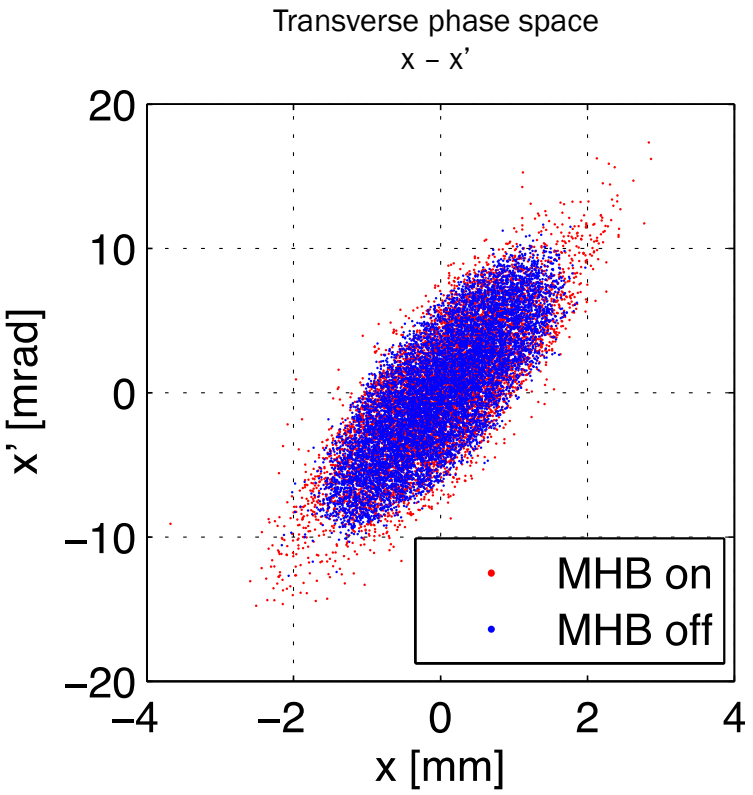
Longitudinal phase space
Δϕ – ΔW



✓ Energy spread from EBIS.
✓ Isochronous effects cause phase lagging (path length differences)

BASELINE PERFORMANCE: BEAM PHASE SPACE EXITING RFQ



✓ Small transverse emittance growth with solenoids.

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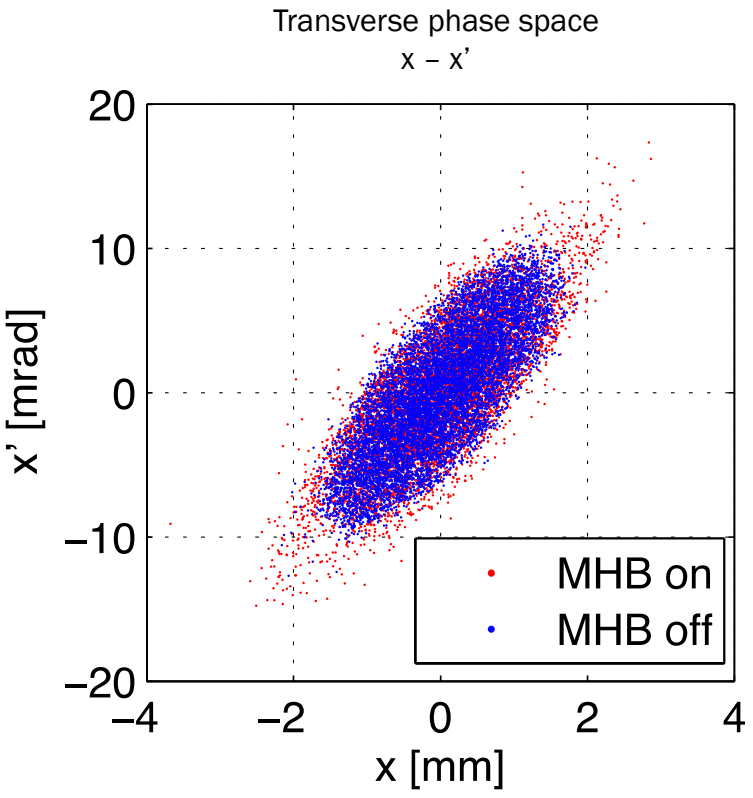

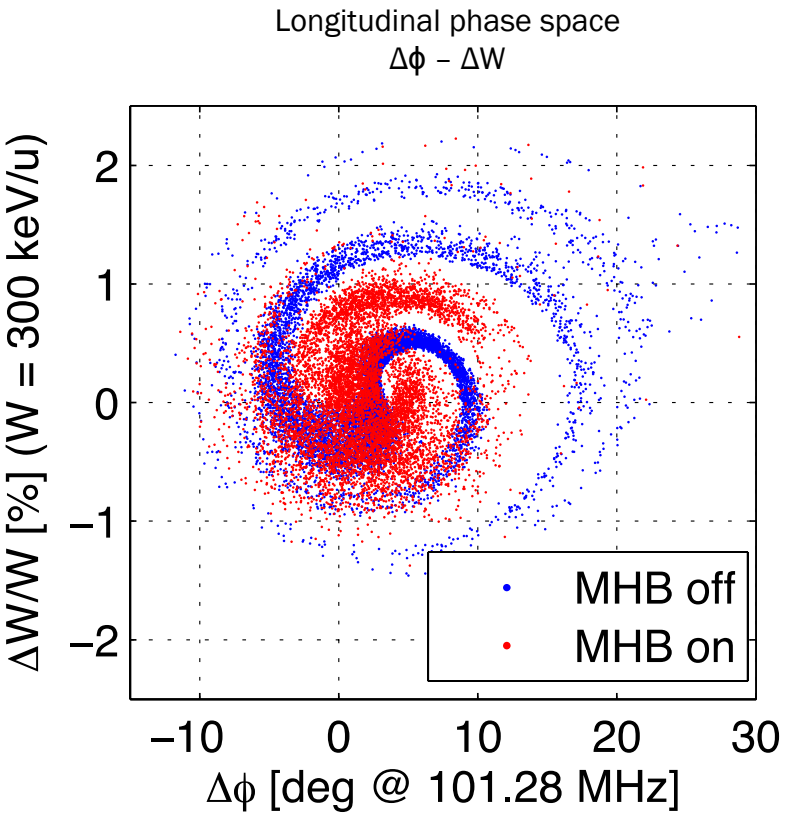

✓ Small transverse emittance growth with solenoids.

✓ Longitudinal emittance is reduced with multi-harmonic buncher (MHB).

BEAM DYNAMICS RESULTS
BASELINE SCENARIO

Table 1: Nominal performance of 10 MHz bunching system at output of the RFQ ($W = 0.3$ MeV/u, $\beta = 0.0254$)

MHB	**T [%]**	$\epsilon_{t,x,y}^{\text{n,rms}}$ **[mm mrad]**	$\epsilon_{l}^{\text{n,rms}}$ **[ns keV/u]**
On	82	0.060, 0.063	0.16
Off	94	0.051, 0.051	0.24

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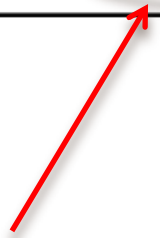

Quite a conservative estimate of the emittance:
others have quoted these numbers as total emittance.

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  e. outlook and further work
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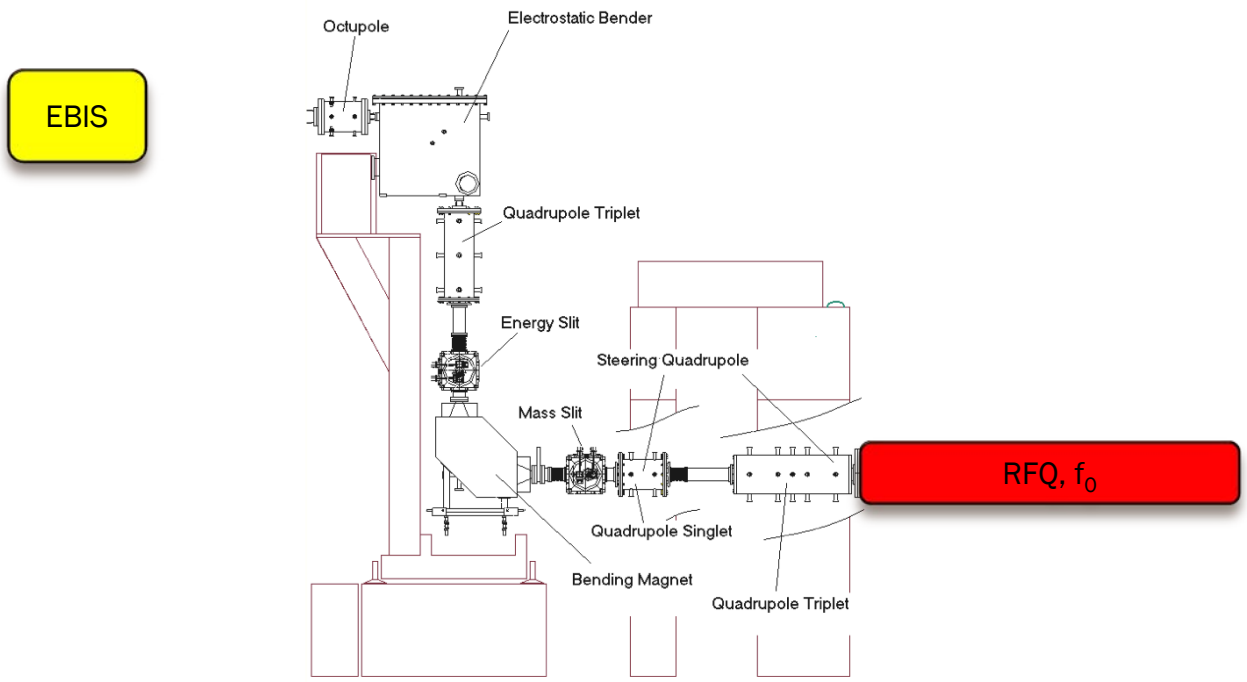
- ✓ Summary
- ✓ Additional Slides

FURTHER WORK...

- ✓ Simulated the A/q-separator with COSY-∞ and TRACK: now have a useful tool for more complicated design studies:

Beam Dynamics Simulations of the REX-ISOLDE A/q-separator
M.A. Fraser, D. Voulot and F. Wenander
To be published: CERN-HIE-ISOLDE-PROJECT-Note-0027



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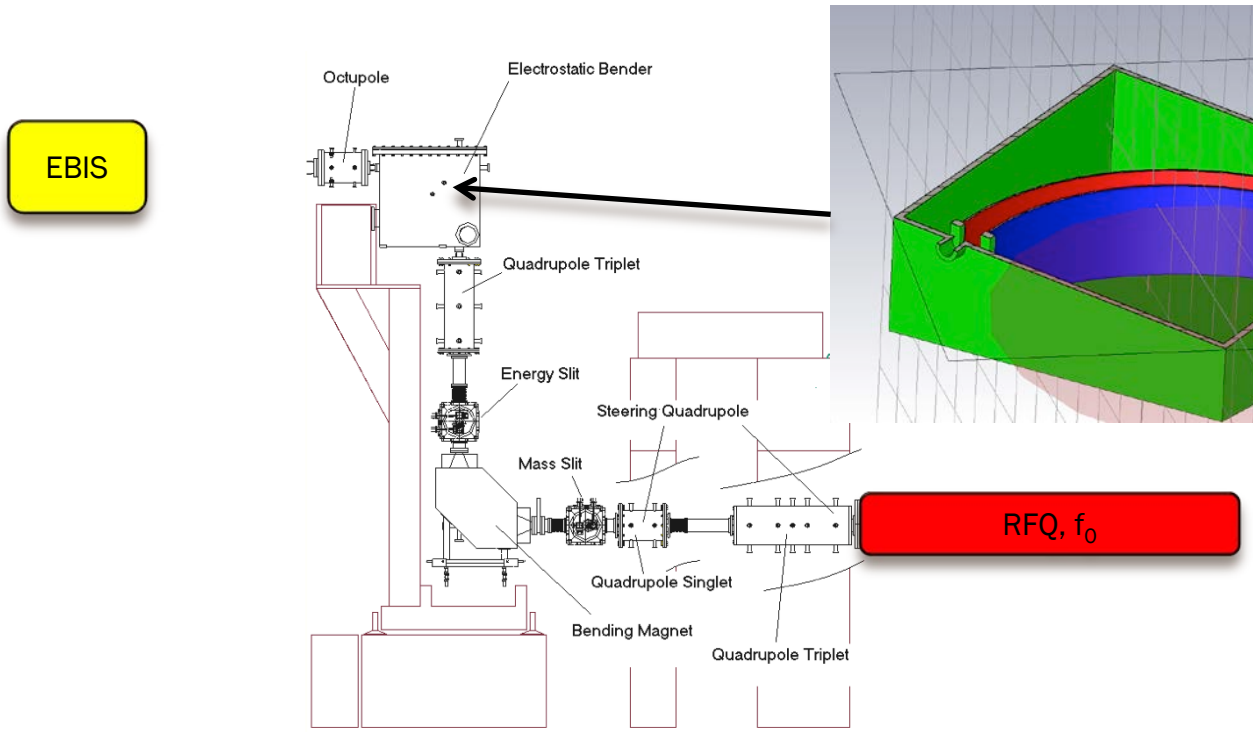

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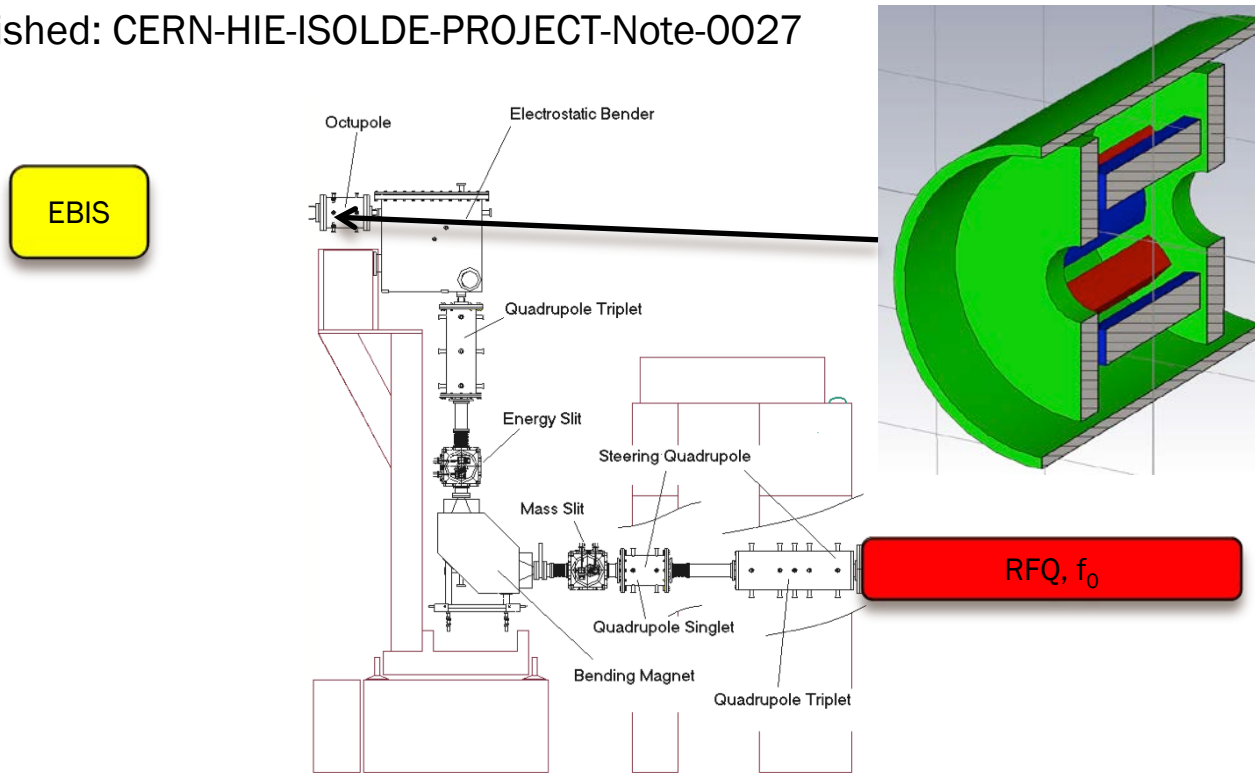

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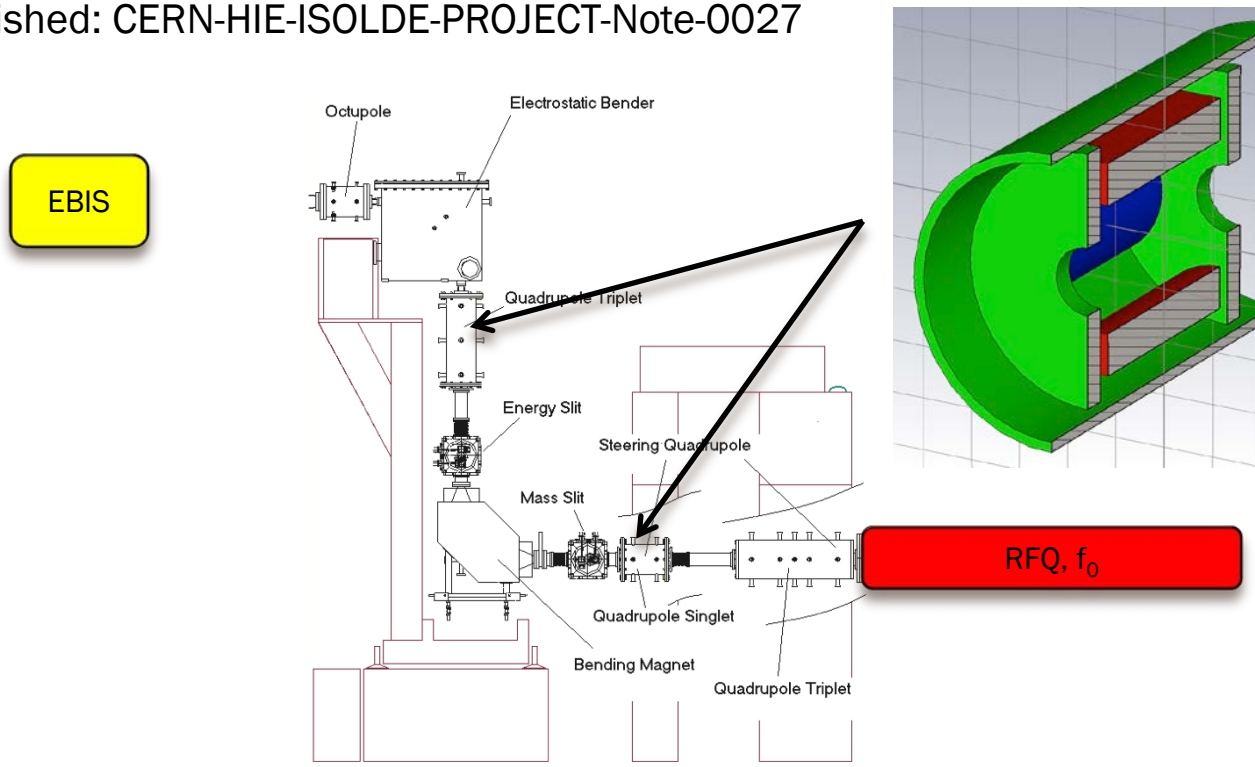

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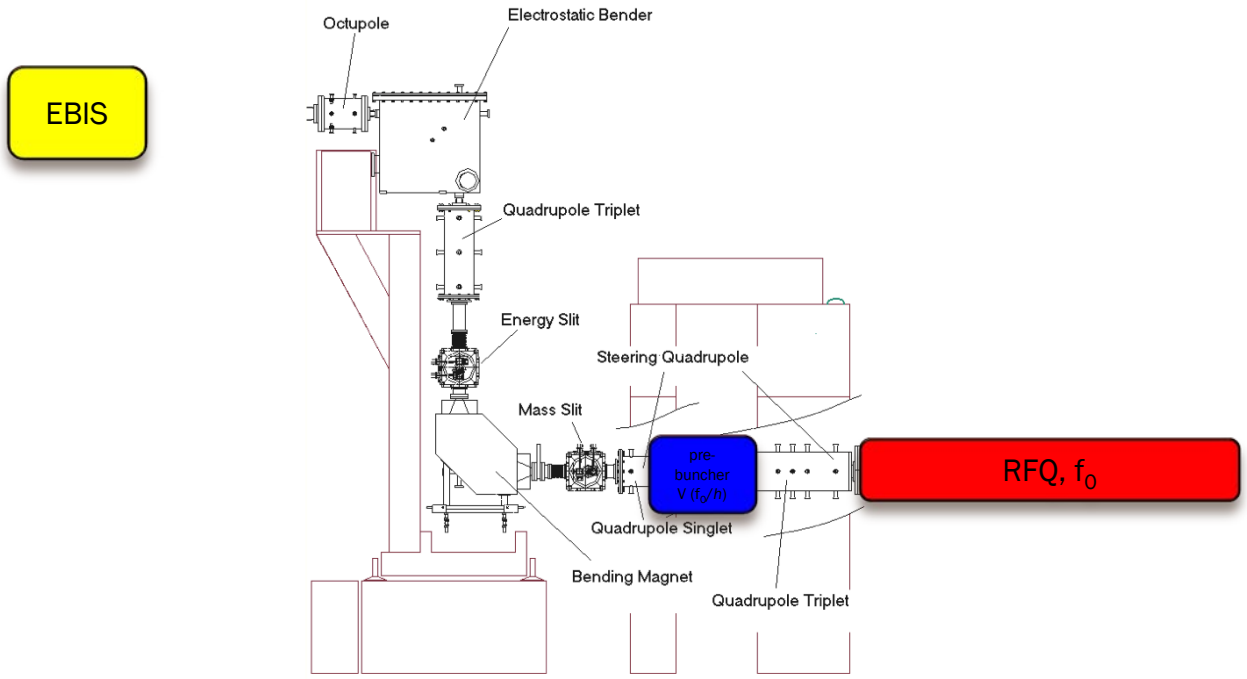

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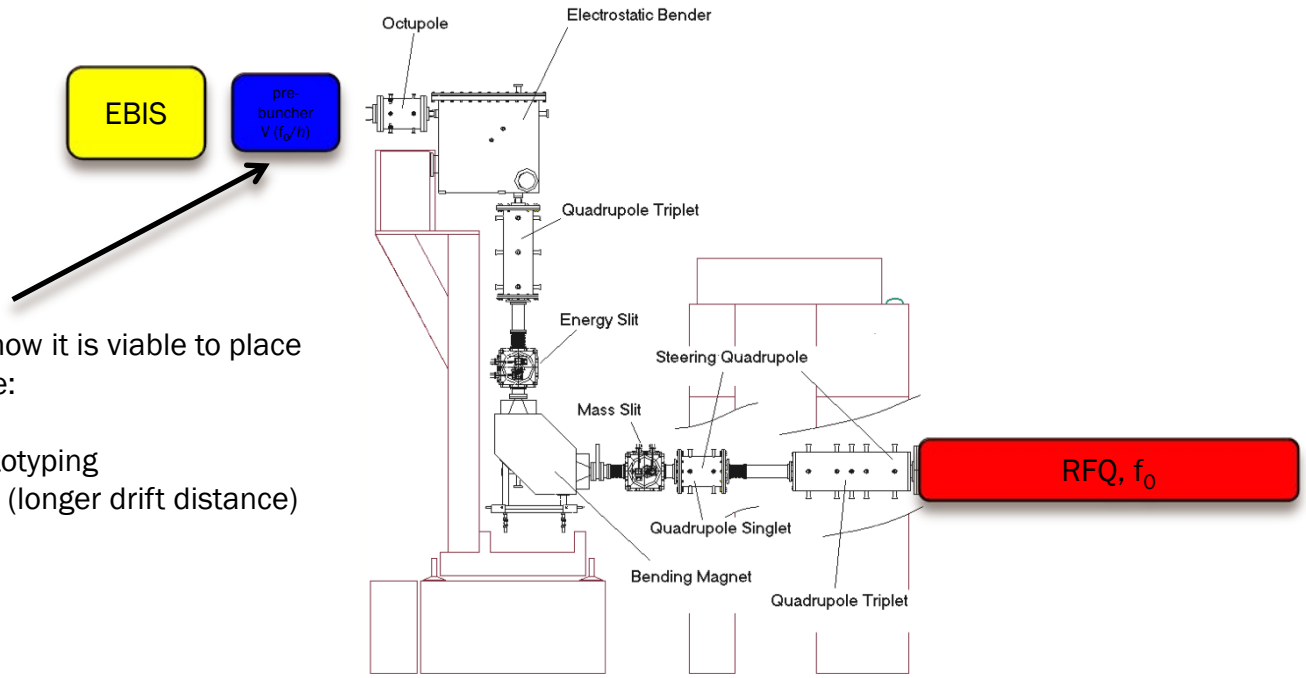

Latest studies show it is viable to place pre-buncher here:

a. place for prototyping
b. lower voltage (longer drift distance)

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  b. investigate a resonant chopper (similar to TRIUMF)
  c. error studies

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- ✓ More discussion with users as to requirements: better understanding of the effects of unbunched background, can < 1% specification be revised?

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- ✓ Developed a software routine to calculate and send the rf phase and voltage to each cavity of the HIE-ISOLDE linac.

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S. Haastrup and M.A. Fraser
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- ✓ Tests with two cavities at REX carried out:

  Preliminary Beam Tests at REX for an Automatic Cavity Phasing Routine at HIE-ISOLDE
  M.A. Fraser, D. Voulot, J. Broere, D. Lanaia and D. Valuch
  CERN-ACC-NOTE-2013-0028/CERN-HIE-ISOLDE-PROJECT-Note-0021

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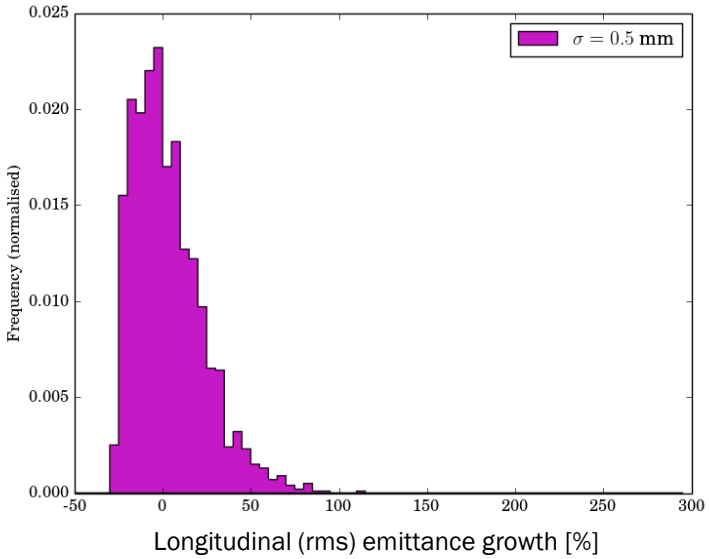

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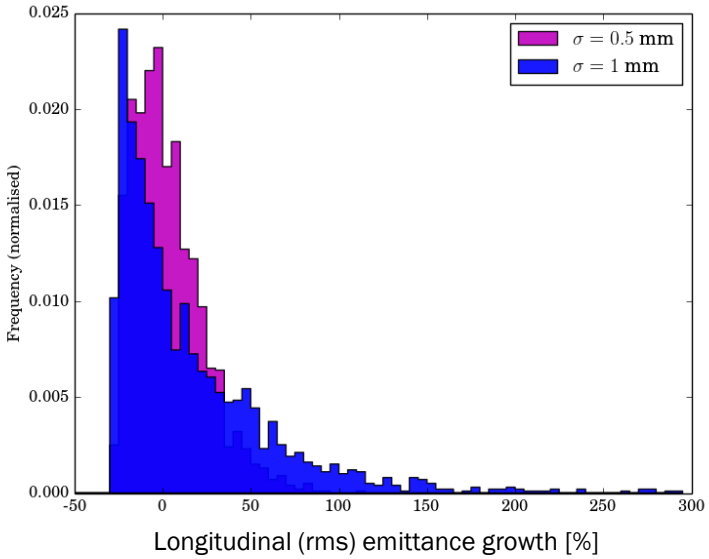

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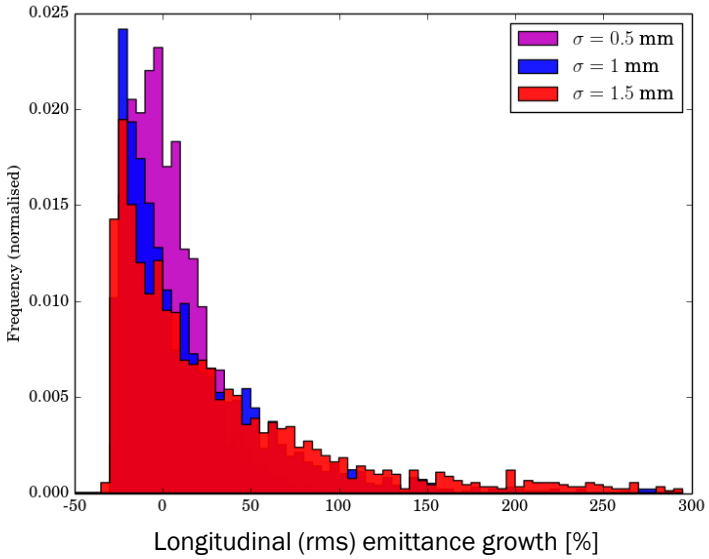

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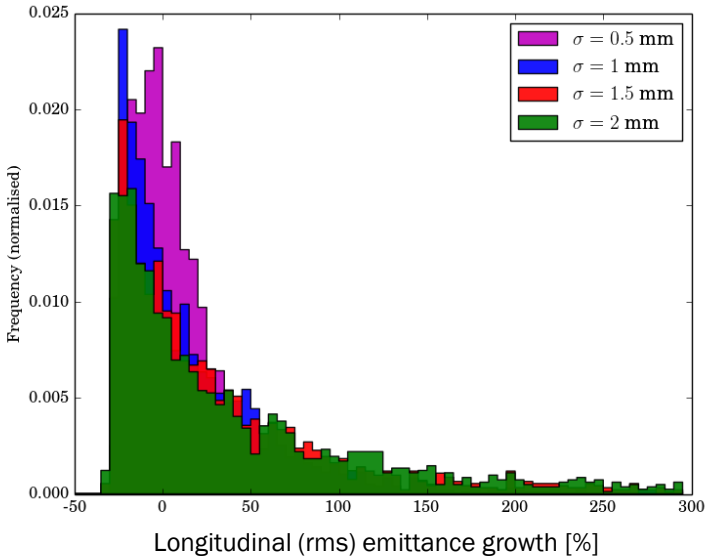

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Error	Tolerance* (σ)
RF phase [deg]	1
RF voltage [%]	1.5
Cavity position [mm]	1.5

*normal error distribution truncated at ±3σ

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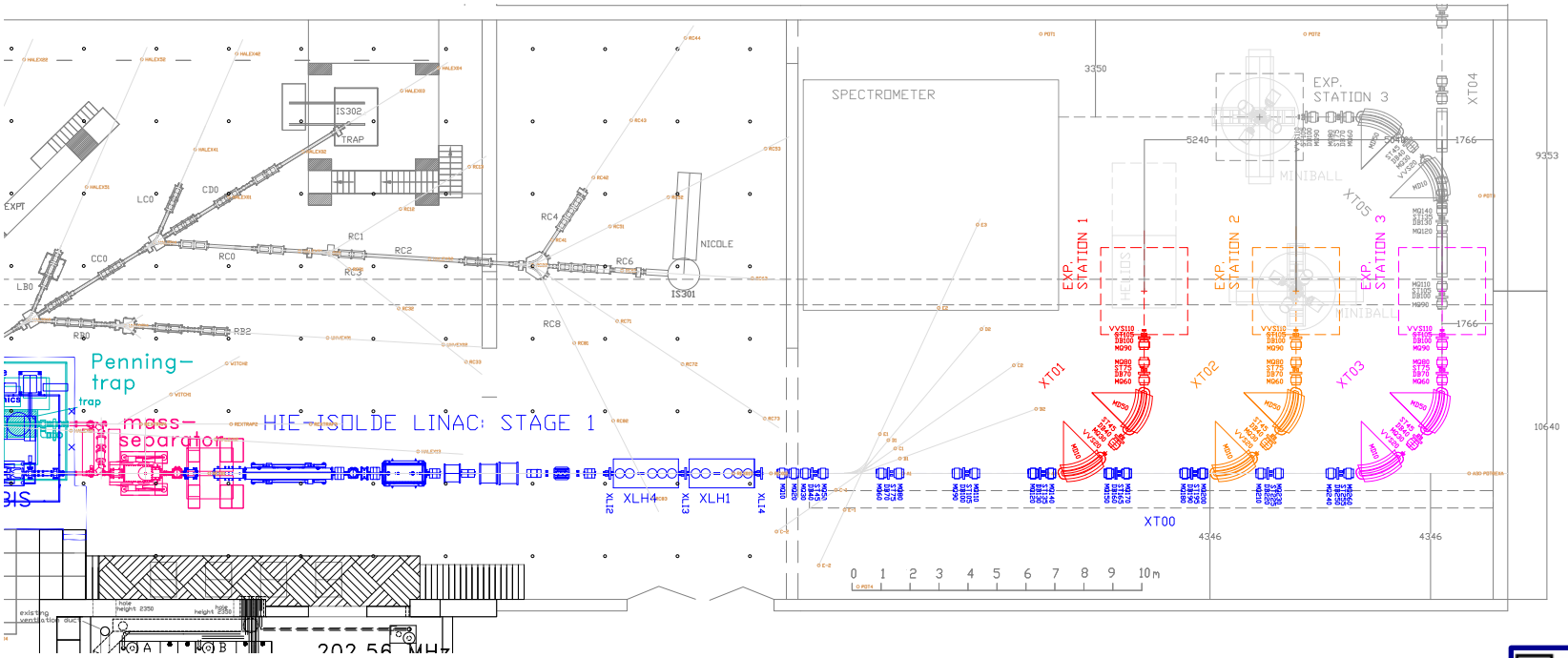
HEBT STUDIES AND STRAY B-FIELD LIMITS

✓ HEBT design frozen for first stages and report to be published:

HIE-ISOLDE HEBT beam optics studies with MADX

A. Parfenova, J. Bauche, M.A. Fraser, B. Goddard, M. Martino and D. Voulot

To be published: CERN-HIE-ISOLDE-PROJECT-Note-0028



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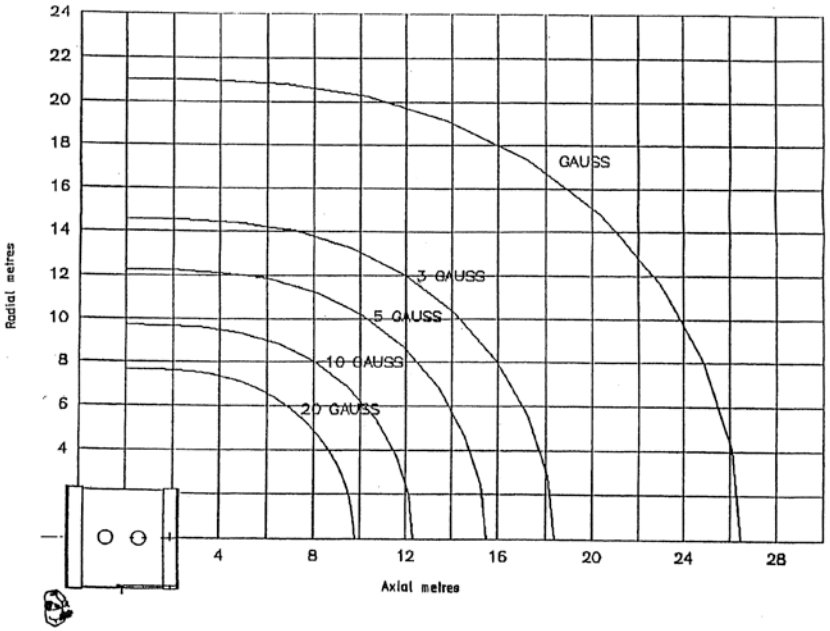
- ✓ Concerns of stray magnetic fields being brought into the experimental hall motivated a study of effects of stray field on beam delivery:



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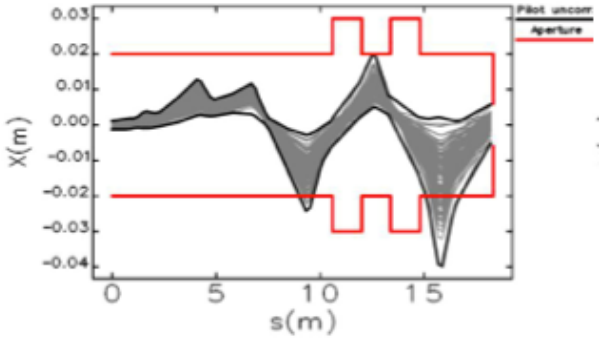
- ✓ We can correct for over 20 Gauss along beam line with the pilot beam.
- ✓ BUT we lose control over steering/correction when scaling for radioactive beam (if experiment field doesn't scale).
- ✓ For low energy beams (0.3 MeV/u): we consider a worst case scenario, stray field uniform and perpendicular to the trajectory, scaling from A/q = 4.5 to 2: e.g. 5 Gauss:

Pilot uncorrected



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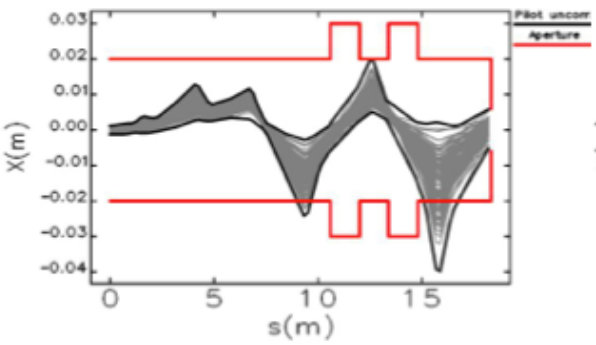

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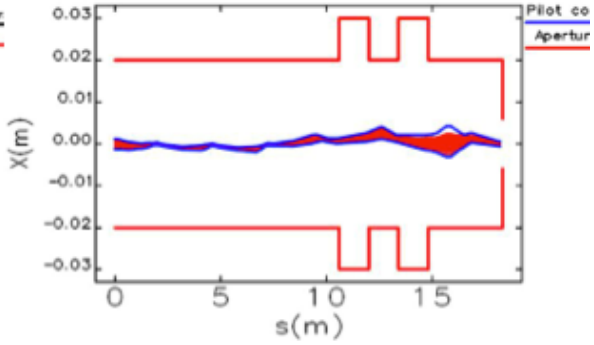

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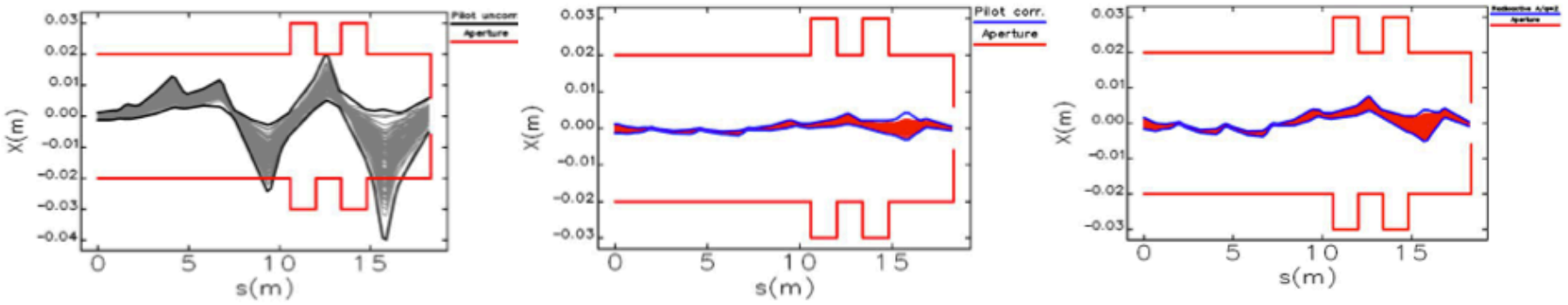
Pilot uncorrected | **Pilot corrected** | **Radioactive beam A/q=2**



- ✓ Admittedly, a conservative limit is given at 5 Gauss (10 times Earth's field).
- ✓ Report to be published…

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SUMMARY

✓ Status of Conceptual Design for 10 MHz bunch frequency for post-accelerated beams was presented and is nearing completion.

✓ Technical choices need to be made for the 10 MHz system.

✓ Constraints have been given by existing A/q-separator for EBIS upgrade.

✓ Tools for the operation of the superconducting linac are being developed: for more information see Davide Lanaia's presentation at HIE-ISOLDE Technical Workshop.

✓ HEBT design is frozen and is in advanced stages of procurement.

✓ The effects of stray fields on the beam in the HEBT has been investigated and limits specified.

ACKNOWLEDGEMENTS

- BE/ABP: FREDERIK WENANDER, JEAN-CHRISTOPHE GAYDE, GUILLAUME KAUTZMANN
- BE/OP: DAVIDE LANAIA, DIDIER VOULOT
- EN/HDO: YACINE KADI
- BE/RF: JOHANNES BROERE, RAMA CALAGA, FRITZ CASPERS, MAURO PAOLUZZI, DANIEL VALUCH
- TE/MSC: JEREMIE BAUCHE, YANN LECLERCQ
- TE/VSC: GIOVANNA VANDONI
- TE/ABT: BRENNAN GODDARD, ANGELINA PARFENOVA
- SUMMER STUDENTS: STEN HAASTRUP, IOAN-BOGDAN MAGDAU AND ABHISEK MUKHOPADHYAY

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- MY CERN PHD SUPERVISOR: MATTEO PASINI

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