BEAM DYNAMICS SIMULATIONS ON THE ESS-BILBAO RFQ

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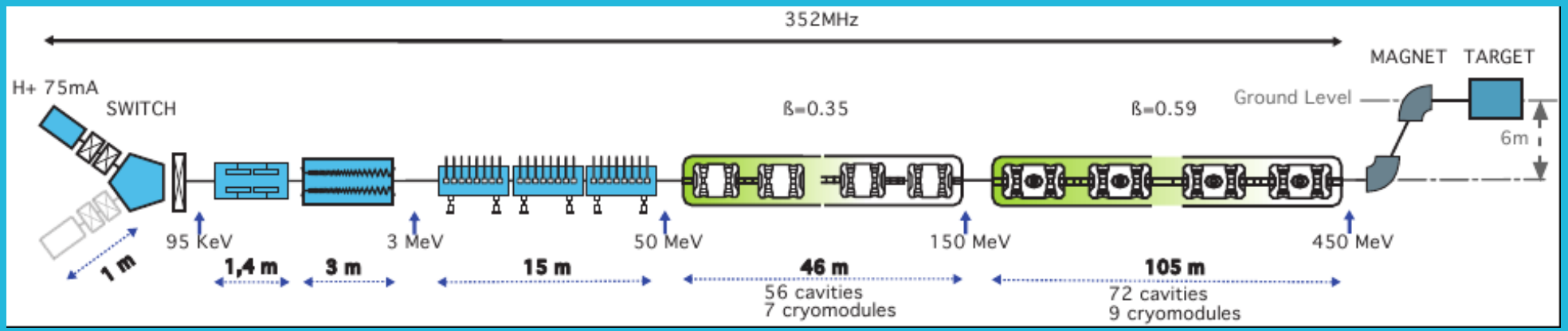
OUTLINE

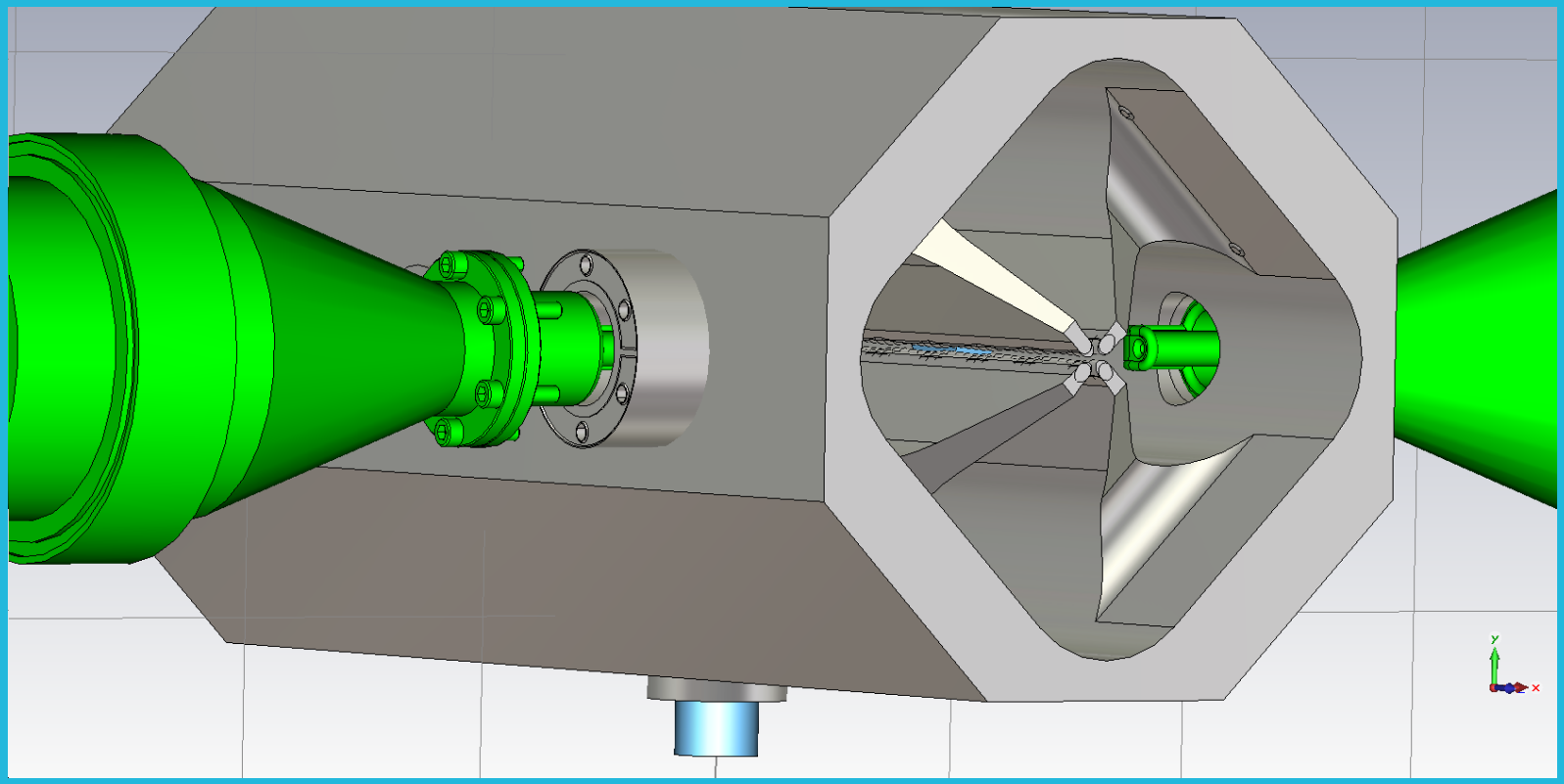
- ESS-Bilbao Overview
- Characteristics of the RFQ
- RFQ Vane Modulation Design: RFQSIM
- Multiparticle Tracking Simulations
  - RFQSIM
  - GPT
- Conclusions and Future Work

ESS BILBAO OVERVIEW

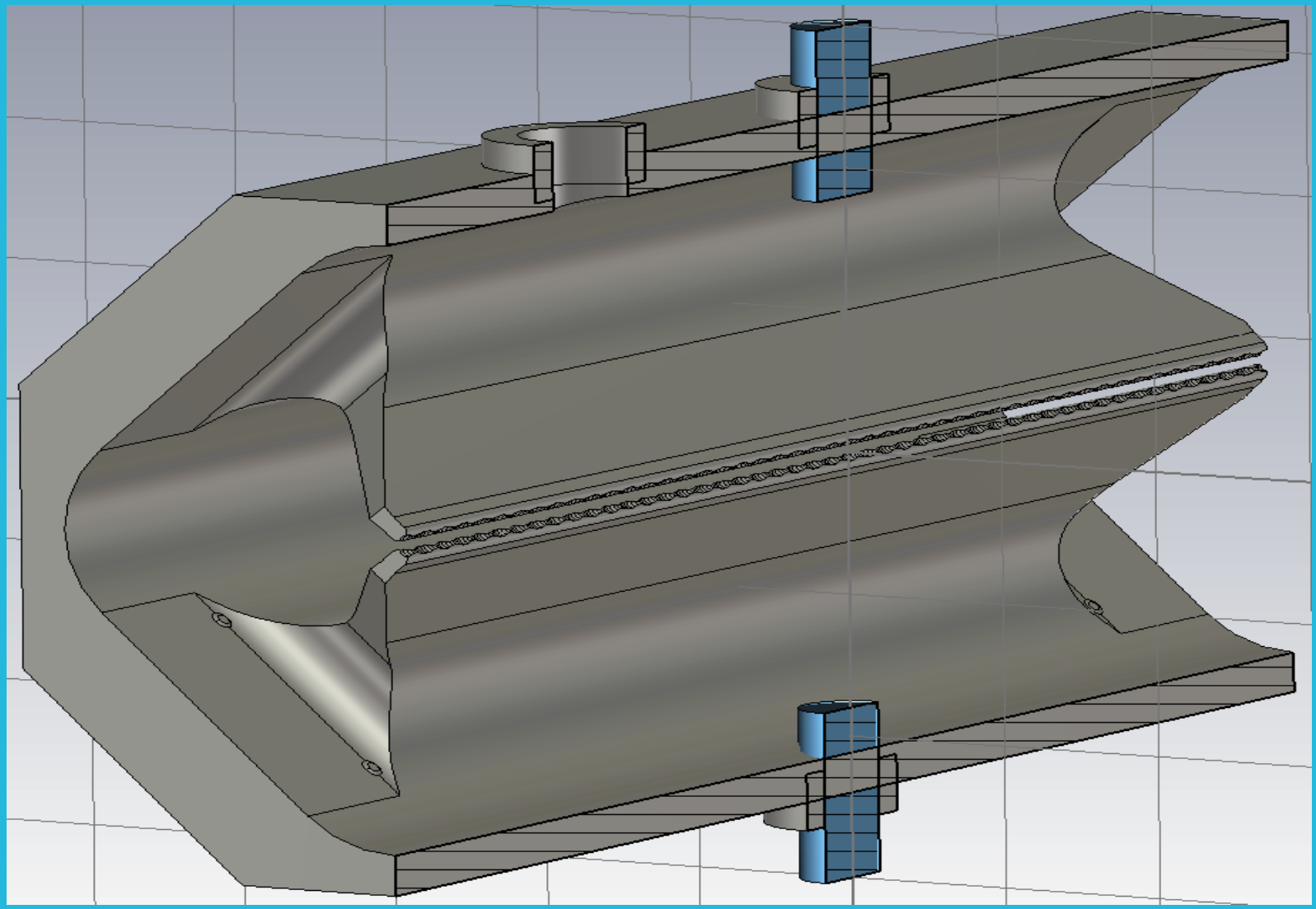
- In-development **LINAC** in Bilbao (Spain).
- Will accelerate **H^+** and **H^-** beams up to **50 MeV** in the first stage, and plans to reach ~500 MeV in a later second stage.
- Pulsed beam ~ 1.5 ms long, up to 75 mA of peak current.
- Source (75 keV) → LEBT → **RFQ (3 MeV)** → MEBT → DTL (50 MeV)



- **4-vane** RFQ, accelerates from 75 keV to 3 MeV.
- RF frequency of **352.2 MHz**.

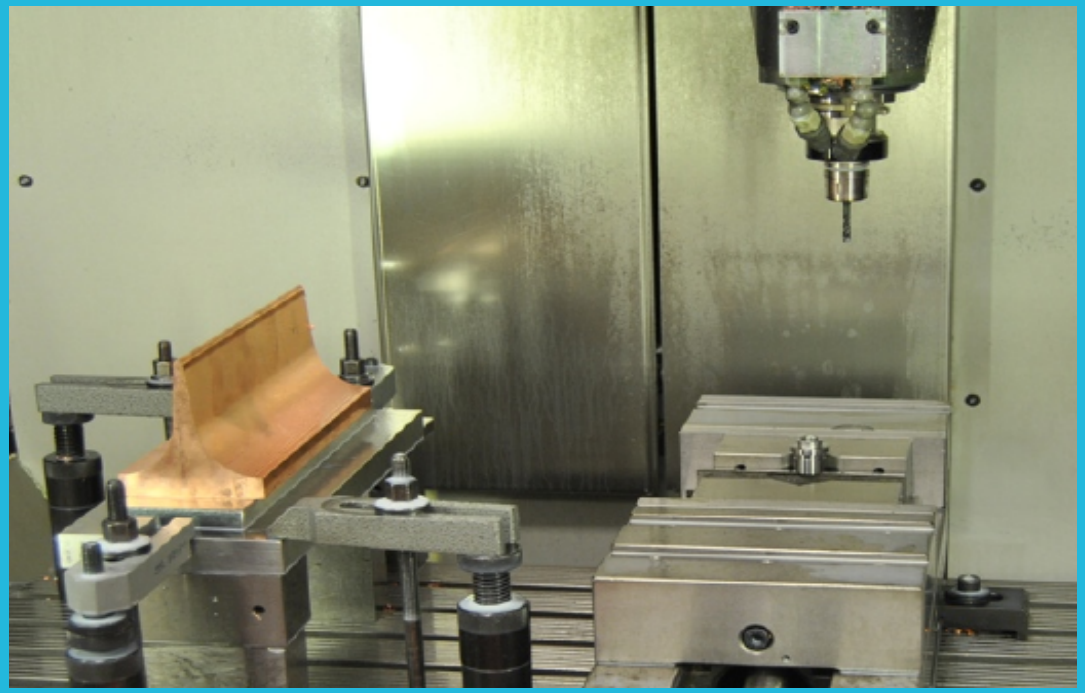


Cavity design: **couplers** and **tuners** positions



Low Level RF control system, **cold model** to be built in Aluminum.

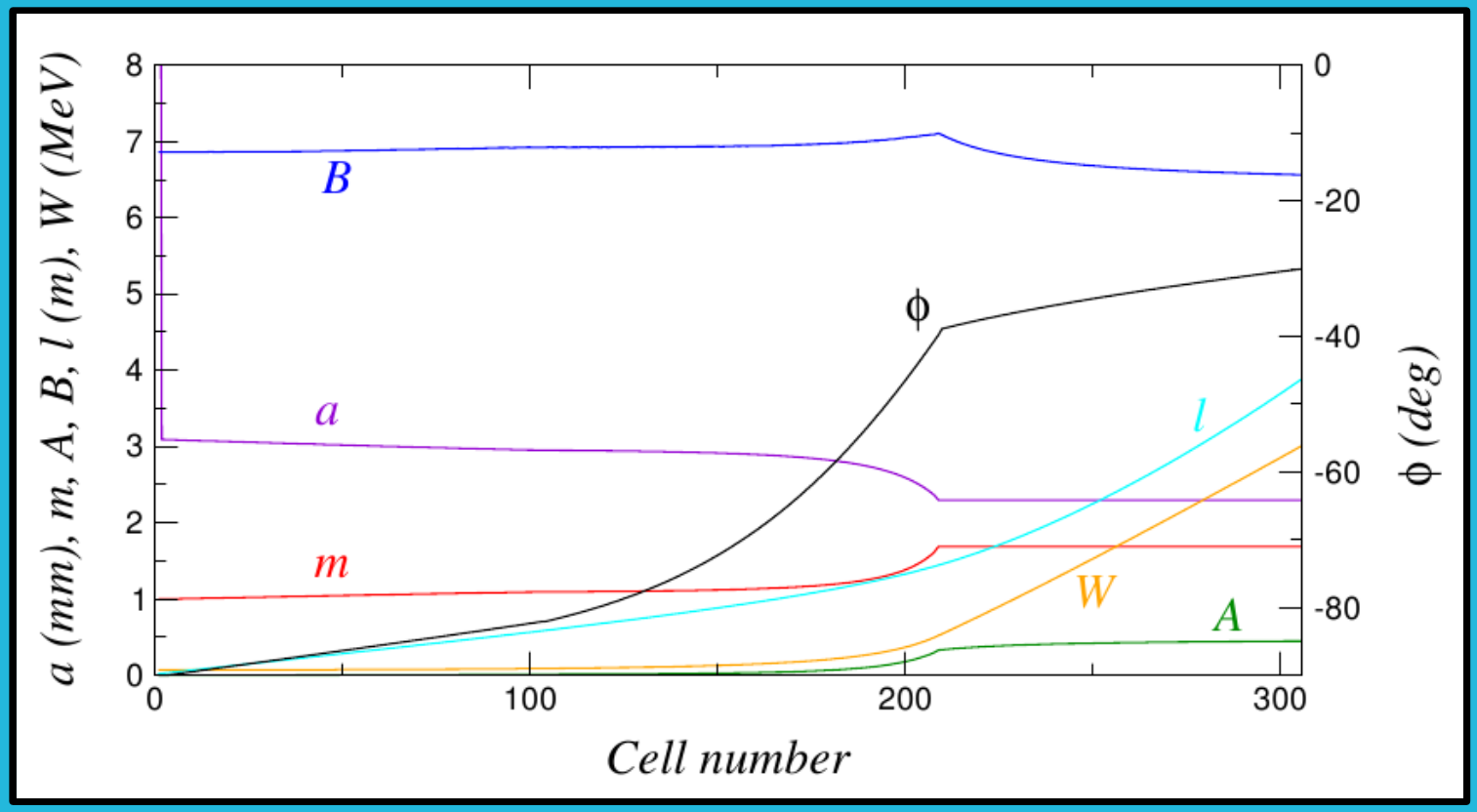
- Thermo-mechanical simulations to design cooling system.
- Vacuum system.
- Mechanical design: four models will be fabricated in oxygen-free copper, in order to test different part-joining methods.



- Vane modulation design: RFQSIM.

- Vane modulation designed with **RFQSIM** (written by Alan Letchford, ISIS).
- Generates cell parameters based on the K-T method. Performs particle tracking simulations using **8-term multipole** expansion.
- Many variables need to be scanned in order to find the best designs.
- Designs evaluated in terms of length, Bravery Factor, particle tracking results (emittance growth, transmission).

ϕ_{sh}	ϕ_{gb}	ϕ_f	a (mm)	m	W_{gb} (MeV)	BF	Length (m)	Cells	ΔE (%)	Transm. (%)
-85	-40	-30	2.3	1.67	0.50	1.80	4.11	339	3.5	97.7
-82	-39	-32	2.3	1.69	0.50	1.79	3.9	307	3.2	96.7
-82	-39	-30	2.3	1.69	0.50	1.79	3.89	306	3.5	96.7
-82	-39	-28	2.3	1.69	0.50	1.79	3.84	305	2.8	96.4
-80	-38	-30	2.2	1.75	0.50	1.83	3.55	270	5.2	94.4
-80	-40	-30	2.4	1.62	0.45	1.76	3.88	284	6.2	96.1
-82	-41	-30	2.4	1.60	0.45	1.77	4.08	309	4.7	96.2
-84	-38	-30	2.2	1.76	0.55	1.82	3.94	334	2.2	96.9
-83	-38	-30	2.3	1.72	0.55	1.77	4.08	346	4.0	97.0
-82	-38	-30	2.3	1.72	0.55	1.77	4.05	342	3.0	95.8



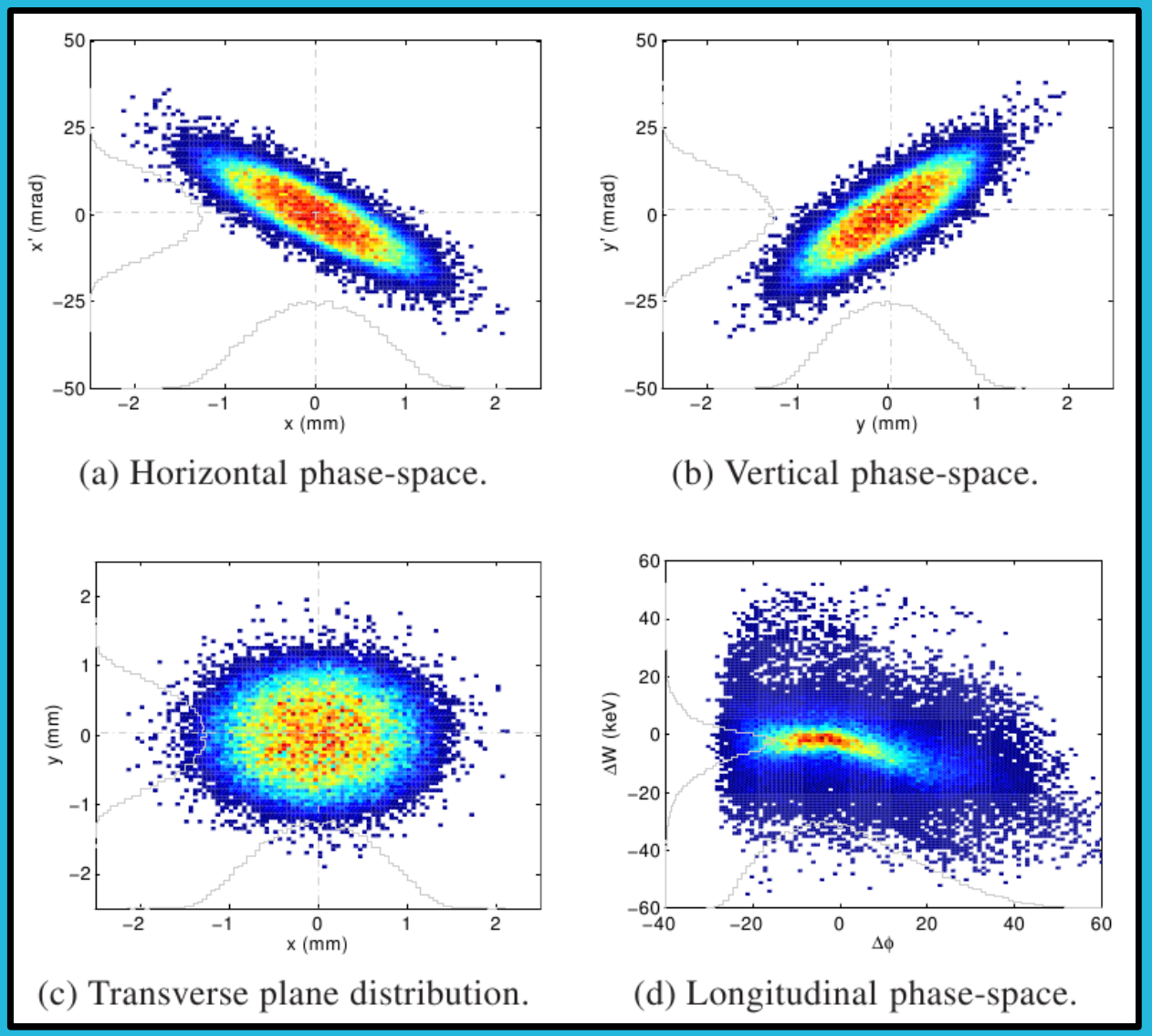
- Total length = 3.89 m, 306 cells.
- Average displacement (R_0) of 3.09 mm, final synchronous phase (ϕ_s) of -30°.
- Bravery Factor ~ 1.79.

INPUT

- Protons, 5000 macroparticles.
- K = 75 keV, I = 75 mA.
- Ɛ = 0.20 π mm mrad.
- Input beam C-S parameters calculated with Trace2D.
- Distribution: 4D waterbag transv., 2D waterbag longitudinally.

OUTPUT

- K = 3.01 MeV, I = 72.2 mA.
- Ɛ < 0.21 π mm mrad.
- ΔK/K = 0.37%, with 92% of the particles less than 20 keV apart from the mean energy.

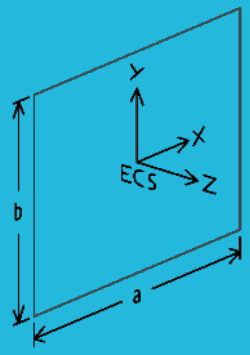


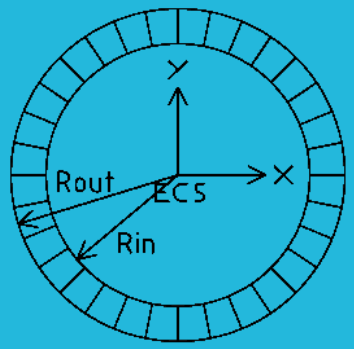
(a) Horizontal phase-space. (b) Vertical phase-space.

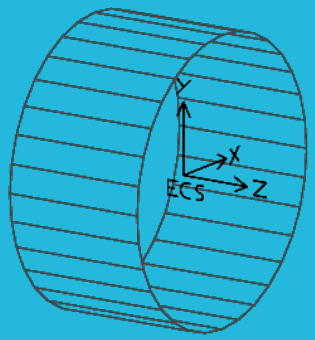
(c) Transverse plane distribution. (d) Longitudinal phase-space.

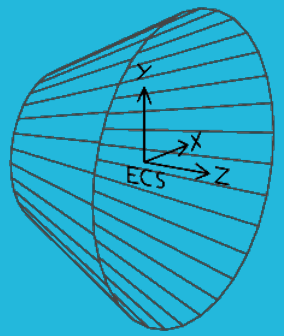
- General Particle Tracer (Pulsar Physics, NL).
- RFQSIM space-charge algorithm implemented into GPT.
- Same input distribution as the one used in RFQSIM simulations.
- GPT has no specific code for RFQs:
    - Field map calculated externally using 8-term multipole expansion, then used as an input in GPT.
    - Boundaries not defined
- First results: very good transmissions, but poor emittances.

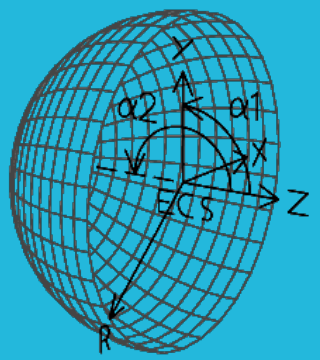
GPT: particle killing

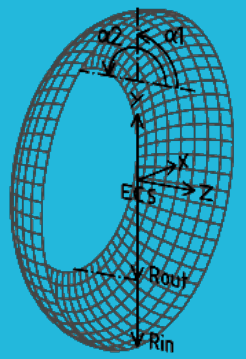


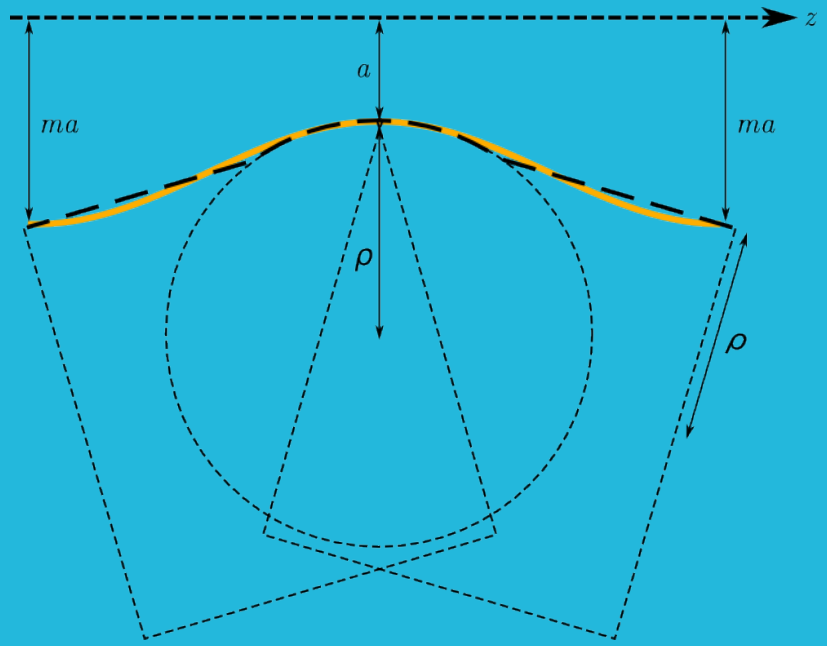


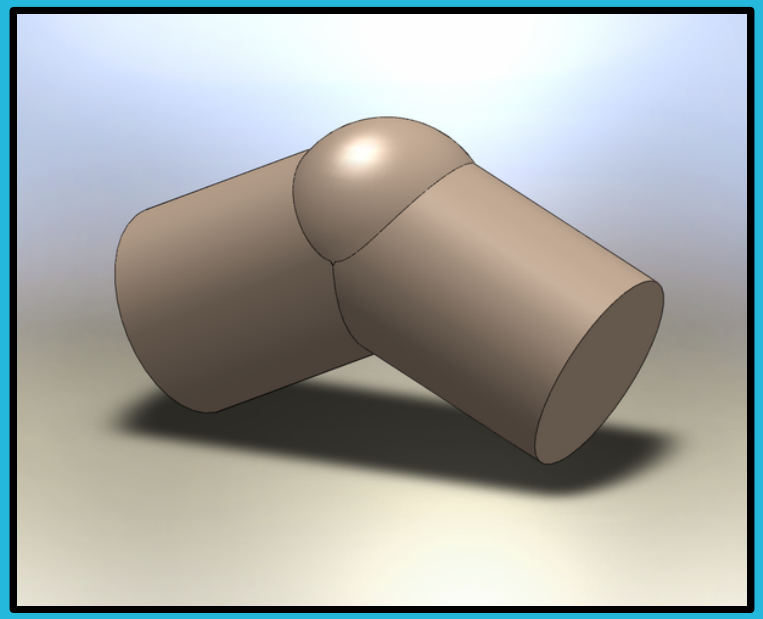




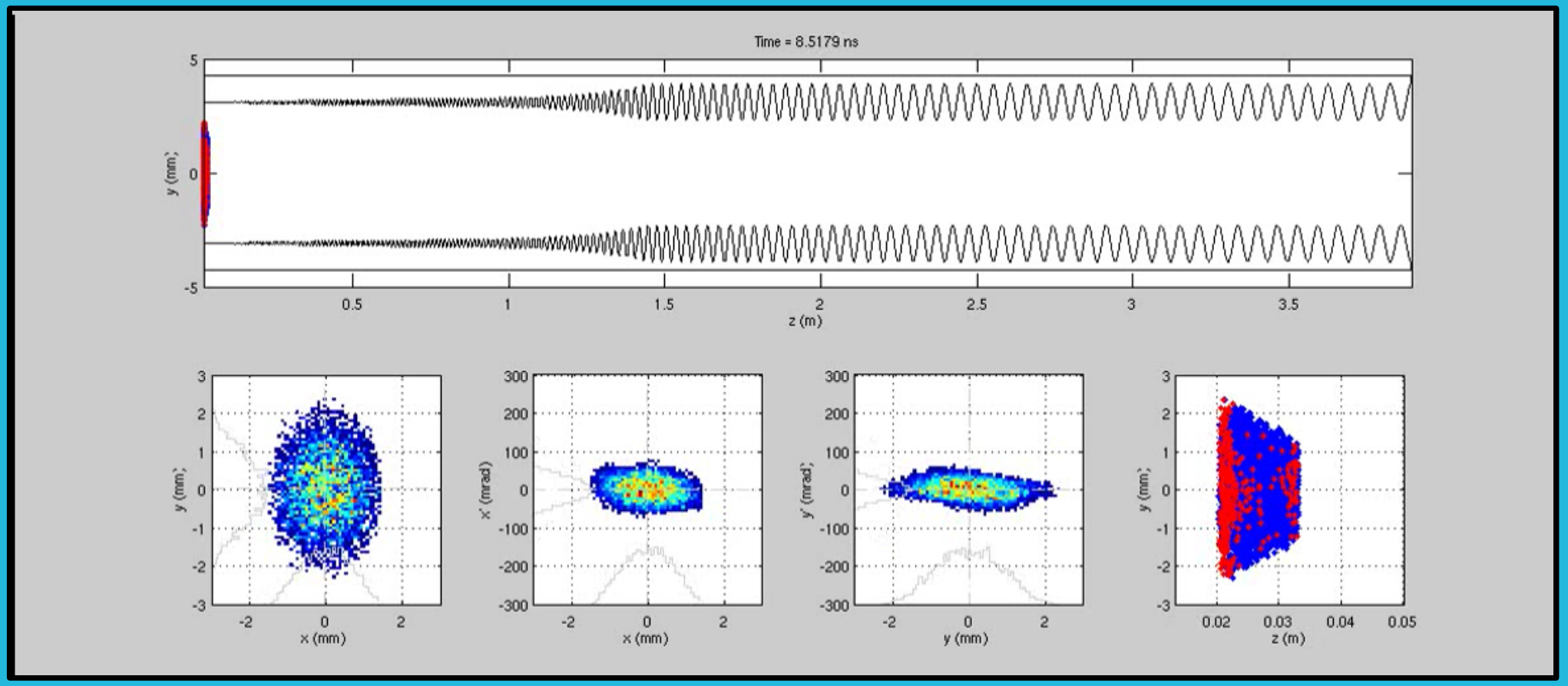




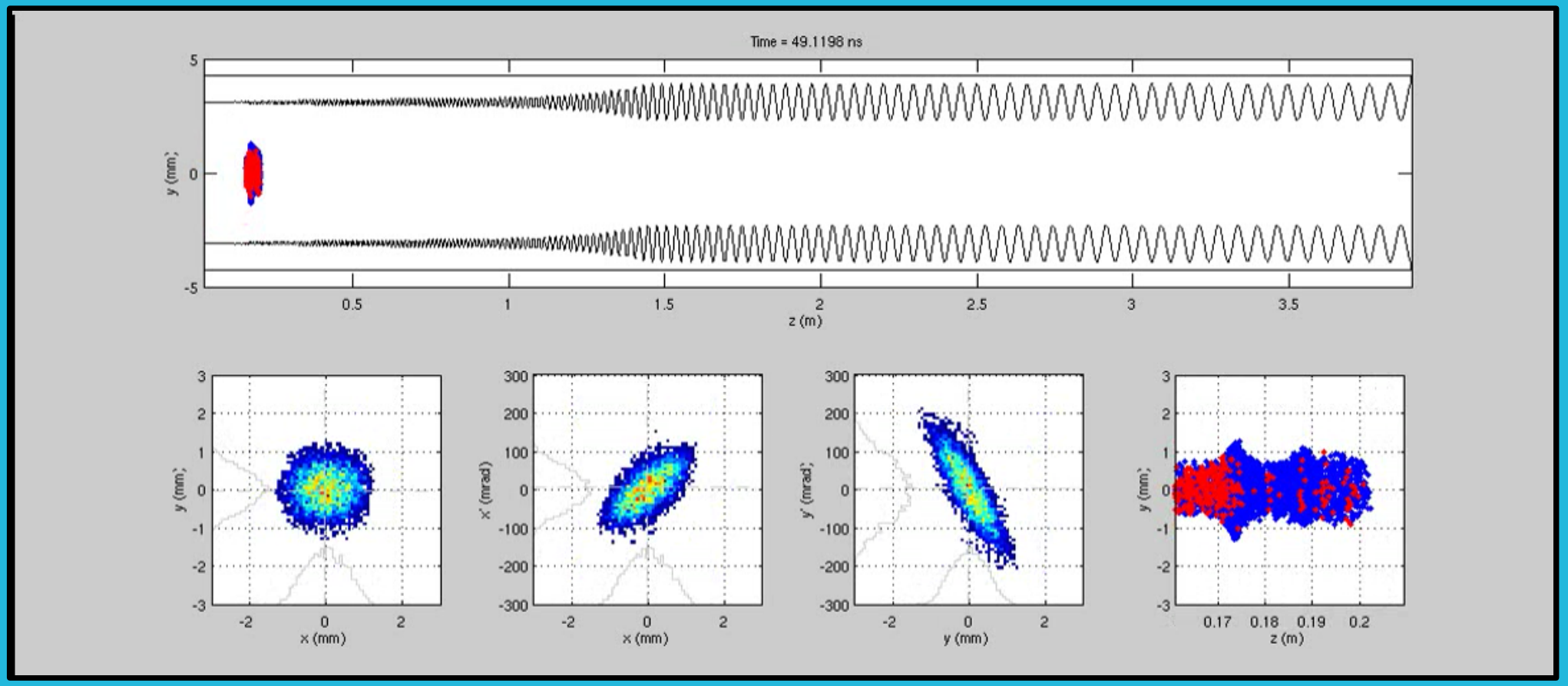




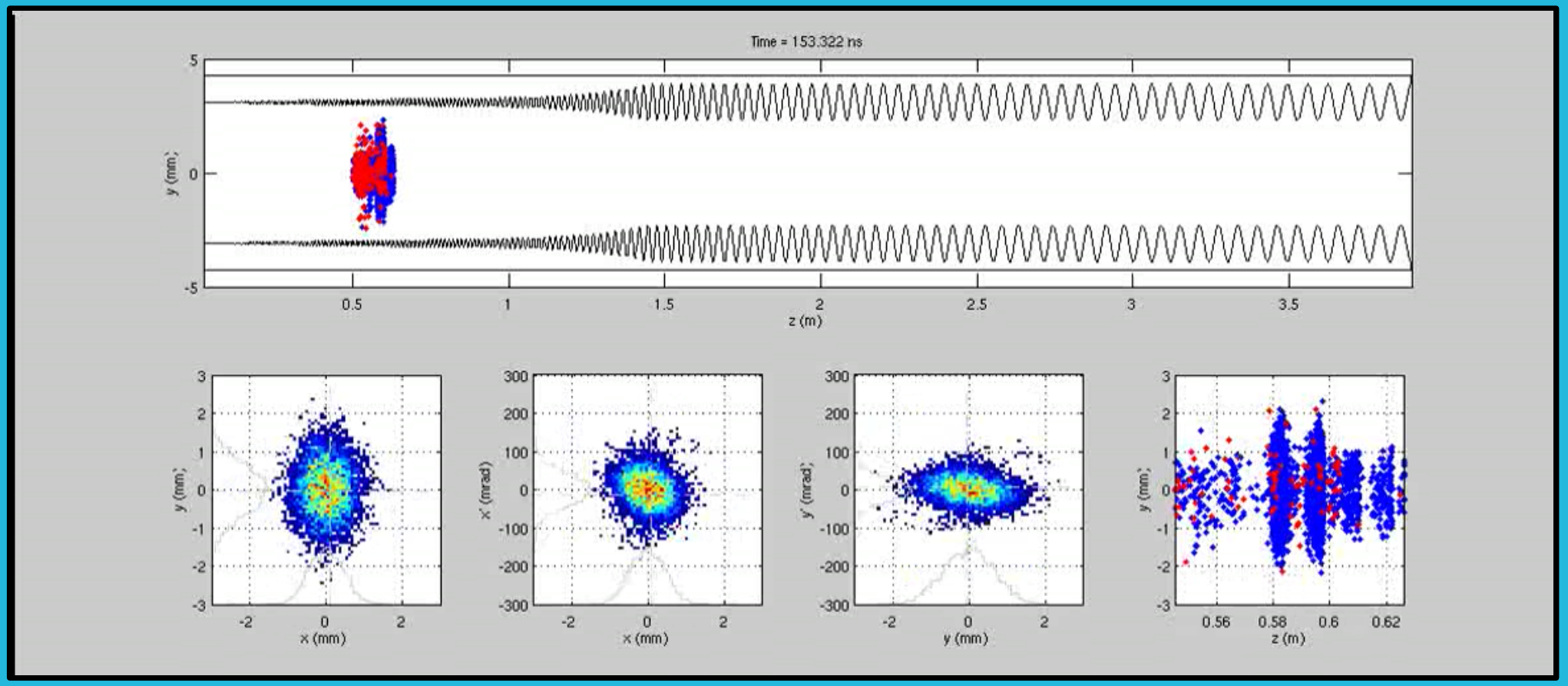
GPT: video (start)



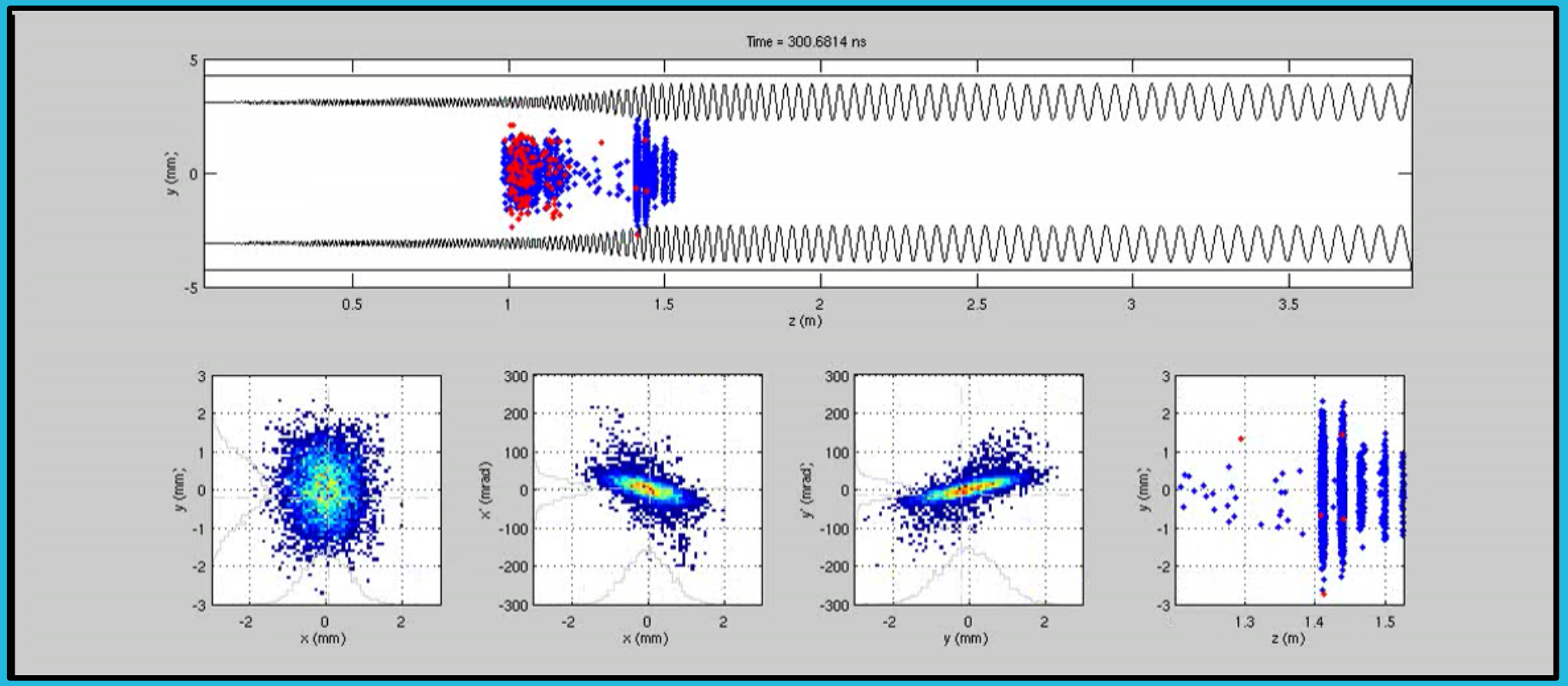
GPT: video (50 ns)



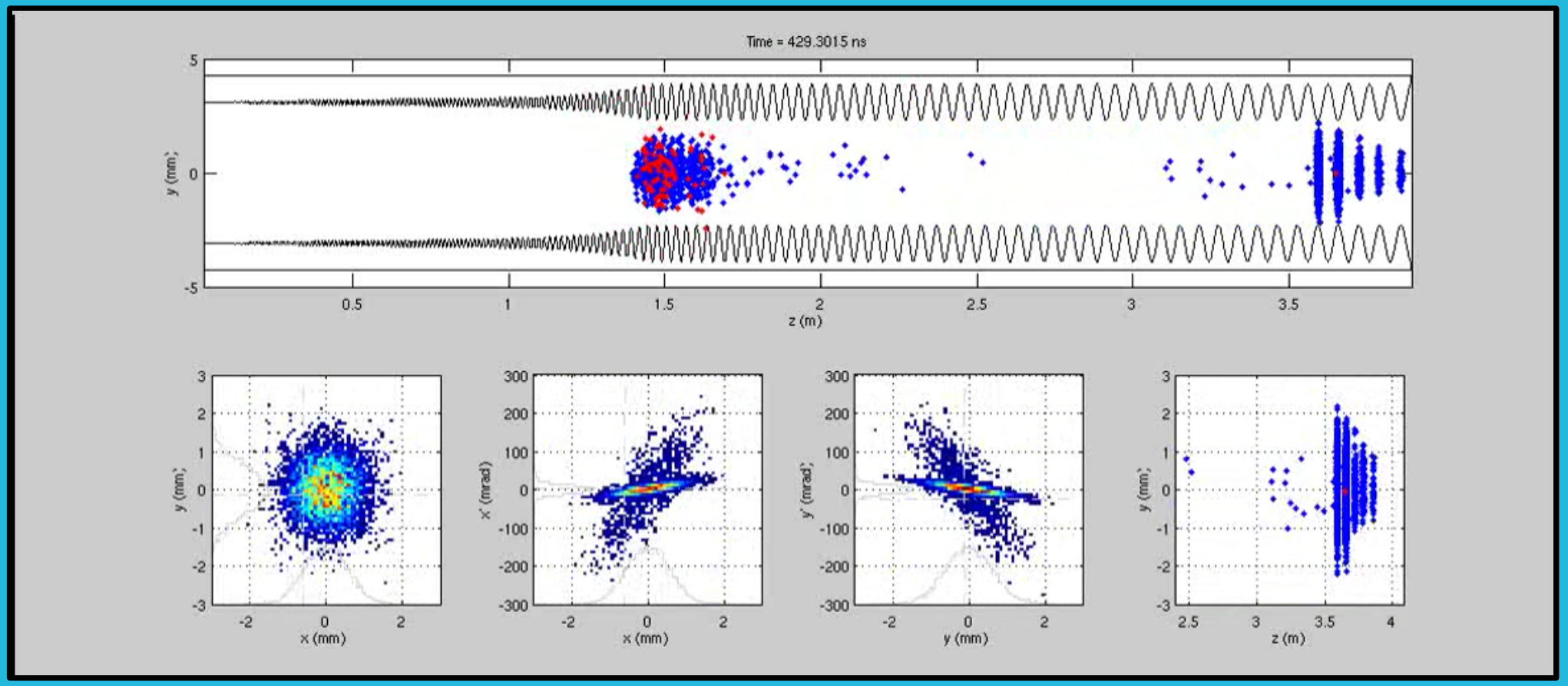
GPT: video (150 ns)



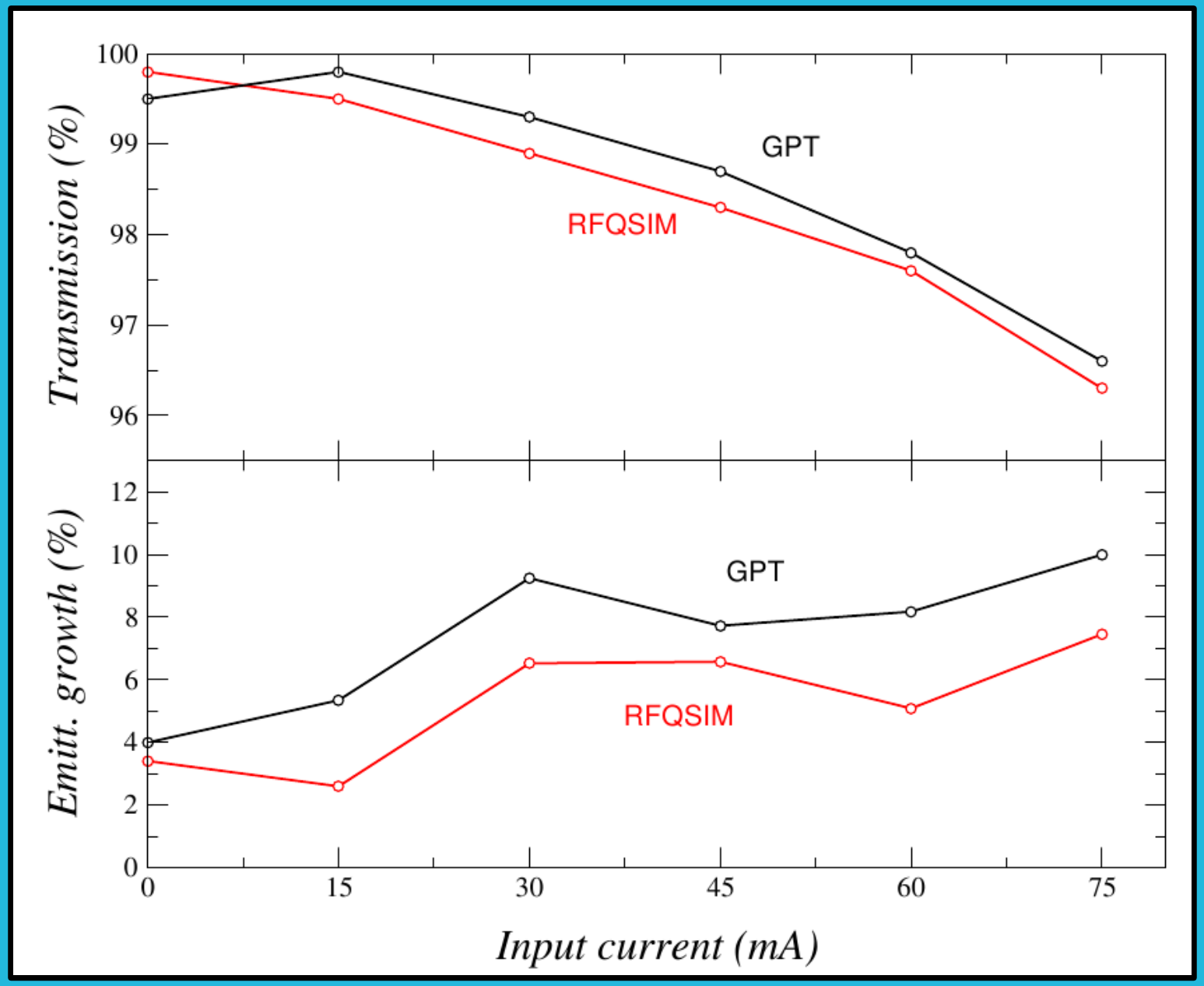
GPT: video (300 ns)



GPT: video (430 ns)



Comparison: RFQSIM vs. GPT



CONCLUSIONS AND FUTURE WORK

- We have presented a vane modulation design for the ESS-Bilbao RFQ.
- Multiparticle tracking simulations performed using two different computer codes show promising results.
- Future work:
    - Perform simulations with TRACK (Brahim Mustapha).
    - Create 3D model, obtain a field map from Finite Element Analysis.
    - Estimate acceptance.
    - Vane geometry error analysis.