

WG-B Short Summary

Beam Dynamics in Linacs

N. Evans, H.Zhao, F. Bouly

WGB global view



- 5 sessions
 - 8 invited talks
 - 13 contributed talks

Tuesday

Wenesday

Thursday

"Multi-Beam Operation of LANSCE Accelerator Facility"	Yuri Batygin	08:55 - 09:11
Discussion		09:15 - 09:23
"30 kW Beam Commissioning of the High-Intensity Proton Accelerator IPH: Experiments, Simulations and Space Charge"	Nicolas Chauvin et al.	09:25 - 09:41
Discussion		09:45 - 09:53
"Effect of three-dimensional quadrupole magnet model on beam dynamics in the FODO line at the Spallation Neutron Source Beam Test Facility"	Trent Edward Thompson	10:10 - 10:23
Discussion		10:25 - 10:33
"The impact of high-dimensional phase space correlations on the beam dynamics in a linear accelerator"	Austin Hoover	10:35 - 10:43
Discussion		10:45 - 11:00
"High availability oriented beam dynamics for CIADS proton linac"	Shuhui Liu	11:05 - 11:22
Discussion		11:25 - 11:33
"SNS Linac Beam Dynamics: What We Understand, and What We Don't"	Andrei P. Shiphil	11:35 - 11:51
Discussion		11:55 - 12:03
"Beam physics simulation studies of 70 MeV ISIS injector linac"	Saeed Ahmad Alaminin	12:05 - 12:22
Discussion		12:20 - 12:33
"Evaluating PyORBIT as Unified Simulation Tool for Beam-Dynamics Modeling of the ESS Linac"	Juan Esteban Müller et al.	12:30 - 12:44
Discussion		12:45 - 12:59

"Synchronous Phases and Transit Time Factors"	Jean-Michel Lagneel	14:20 - 14:40
Discussion		14:40 - 14:50
"Particle resonances' domination over parametric instabilities and their mitigation"	Dong-O Jeon	14:50 - 15:10
Discussion		15:10 - 15:20
"The tracking code RF-Track and its application"	Andrea Latina et al.	15:20 - 15:35
Discussion		15:35 - 15:45
"Benchmarking of PATH and RF-Track simulation codes using the Linac4 front-end"	Giulia Bellodi et al.	15:45 - 16:00
Discussion		16:00 - 16:10
"Differential Algebra for Accelerator Optimization with Truncated Green's Function"	Chong Shik Park	16:10 - 16:25
Discussion		16:25 - 16:35
COFFEE BREAK		
"Development of non destructive beam envelope measurements using BPMs for low beta heavy ion beams in SRF cavities"	Takahiro Nishi	16:55 - 17:15
Discussion		17:15 - 17:25
"Linac4 Source and Low Energy Experience and Challenges"	Edgar Sergeyev et al.	17:25 - 17:45
Discussion		17:45 - 17:55
"Beam Loss Studies in the China Spallation Neutron Source Linac"	Ming-Yang Huang	17:55 - 18:10
Discussion		18:10 - 18:20
"Beam loss simulations for the proposed TATTOOS beamline at HIPA"	Marco Hartmann	18:20 - 18:35

"Measurement of transverse beam emittance for a high-intensity proton injector"	DongHwan Kim	11:05 - 11:20
Discussion		11:20 - 11:30
"Comparison of longitudinal emittance of various RFQs"	Michele Comunian	11:30 - 11:45
Discussion		11:45 - 11:55
"Matched Transport of Intense and Coupled Coasting Beams Through Quadrupole Channels"	Dr. Chen Xiao et al.	11:55 - 12:10
Discussion		12:10 - 12:20
"Alternating Phase Focusing Under Influence of Space Charge Defocusing"	Simon Lauber	12:20 - 12:35

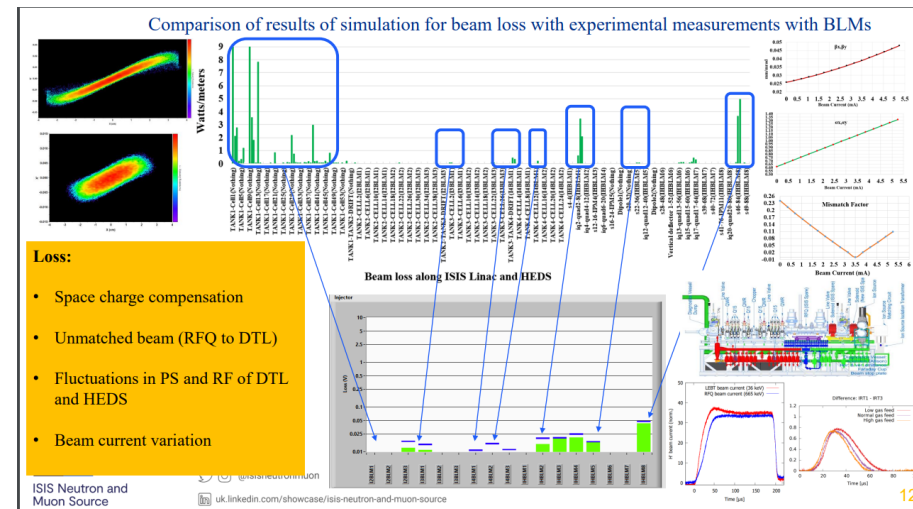
Main Remarks / identified themes

- Many talks about linacs under operation or in installation/ commissioning phase
- How do we improve Availability/Reliability /Sustainability ?
- ‘Proliferation’ of Beam dynamics codes
- The Low energy beam physics transport is not (always) well known
 - From the Source to the RFQ : what happens?
 - The RFQ : ‘essential box that reset everything’
- Challenge : the integration of beam dynamics codes into control systems of the machines

Commissioning & operation feedback

- The beam dynamics is well controlled/understood after the RFQ
- Especially true in warm (copper sections) for ‘light’ particles (p+/H-)
 - DTL, CCL operation and losses well controlled and globally understood
 - Studies and improvements plans to mitigate beam losses
 - Upgrades or compromises

- [Y. Batagin et al., Multi-Beam Operation of LANSCE Accelerator Facility](#)
- [A. Shishlo et al., SNS Linac Beam Dynamics: What We Understand, and What We Don't ?](#)
- [S. Ahmadiannamin et al., Beam physics simulation studies of 70 MeV ISIS linac](#)
- [J. Peng, M.-Y. Hunag, Beam loss studies in the CSNS linac](#)
- [S. Lauber et al., Alternating Phase Focusing Under Influence of Space Charge Defocusing"](#)

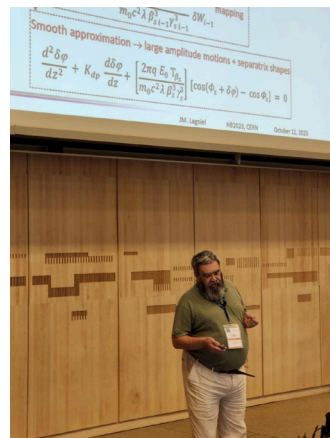


S. Ahmadiannamin

Superconducting linac tuning

- Linac with large acceptance
 - Tuning flexibility : operation modes (current, duty cycle, different A/Q beams)
 - Main cause of losses are longitudinal
- To understand and minimise the losses -> understanding the longitudinal dynamics
 - Importance of design parameter definition and computation
 - especially at high gradient

- J.-M. Lagniel, *Synchronous Phases and Transit Time Factors (σ = 90° resonance)*
- D.-O Jeon, *Particle resonances' domination over parametric instabilities and their mitigation*

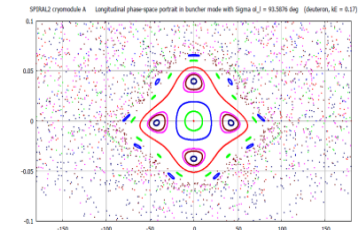


EXCITATION BY THE CAVITY RF-FIELD

Cavity rf-field
= **nonlinear longitudinal focusing force**

$$= [\cos(\phi_s + \delta \varphi) - \cos \phi_s] =$$

- [sin φ_s] δφ “quadrupole” (linear focusing)
- [cos φ_s / 2!] δφ² “sextupole”
- [sin φ_s / 3!] δφ³ “octupole”
- + [cos φ_s / 4!] δφ⁴ “decapole” + ...

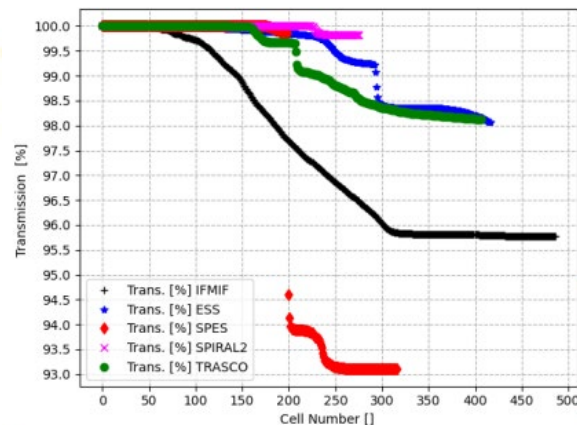
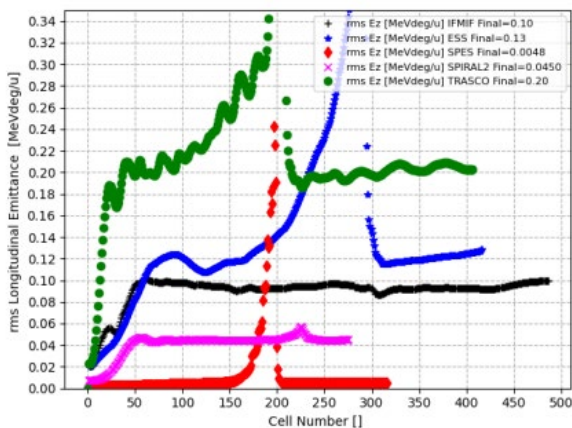


The $\sigma_l = 90^\circ$ resonance main source of excitation (as well as the other parametric resonances in the longitudinal plane!) is the cavity rf-field, Not space-charge!
Excitation period = cavity period => consider $\sigma_{l,j}$ not $\sigma_{l,t}$... again

J.-M. Lagniel

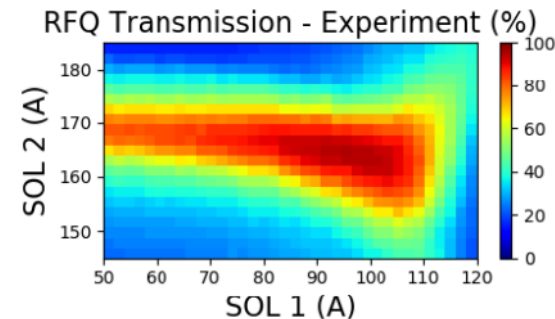
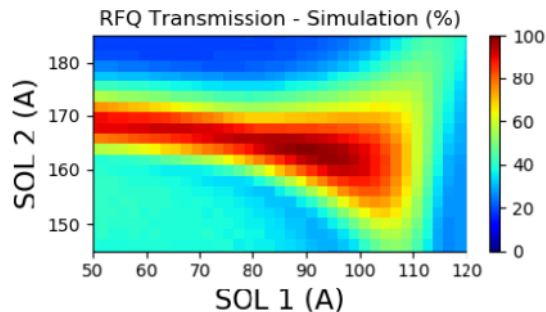
Understanding the Low energy beam physics

- LEBT -> RFQ-> MEBT : the region where the beam is conditionned
- RFQ design : [M. Communian, Comparison of longitudinal emittance of various RFQs](#)
 - “The simulations codes can well define the beam dynamics inside any RFQs. “
 - “ The simulations codes has been compared with success with the experimental results, in terms of transmission and longitudinal emittance.”
 - “No general common rules about how to do an RFQ design”
 - “The RFQ parameters must be carefully defined at the end of Gentle Buncher to get a good degree of longitudinal capture”
 - depends on the initial conditions : “At zero current higher long. Emittance for the RFQs designed for high current”
- Message for future design : Optimise the power with multi-objective algo.-> New TRASCO Design



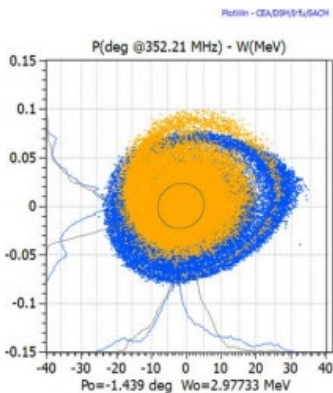
Low Energy beam Physics

- Most critical challenge is to understand transport from the source to the RFQ.
- Well summarised from [E. Sargsyan et al., *Linac4 source and low energy experience and challenges*](#)
 - “IS04 source can reliably produce up to 50 mA of H- beam. However, the operational beam current from the source remains 35 mA (27 mA out of the RFQ), as this covers the present beam intensity needs. “
- What happens in source extraction region, how to deal with SC and SCC.
- Many talks covering these topic:
 - [A. Hoover et al., *The impact of high-dimensional phase space correlations on the beam dynamics in a linear accelerator*](#)
 - [T. E. Thompson et al, *Effect of three-dimensional quadrupole magnet model on beam dynamics in the FODO line at the Spallation Neutron Source Beam Test Facility*](#)
 - [D. H, Kim et al., *Measurement of transverse beam emittance for a high-intensity proton injector*](#)
- [N.Chauvin et al., *30 kW Beam Commissioning of the High-Intensity Proton Accelerator IPHI: Experiments, Simulations and Space Charge*](#)

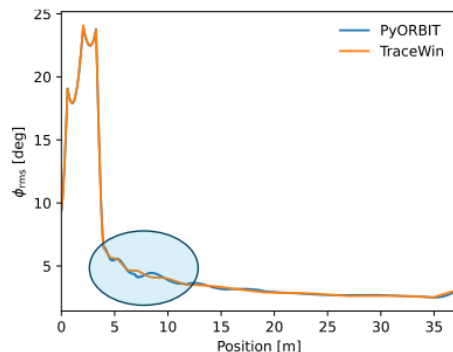


Beam dynamics codes

- We noticed a large number of codes are used/developped in the community
 - PARMILA, Track3D, Trace3D, OPENXAL OL, TRAVEL, TraceWin, IBSimu, WARP, IMPACT3D, PyORBIT, PATH, RF Track, Toutatis, PARTEQm, BDSIM, MADX, SPIRAL2 generator, ...
- Use Different solvers, approach (envelop/Tracking), space charge routine, commercial, customisation more or less possible, etc.
- Many talks covering this topic and benchmarking (w. other codes or experiements)
 - T. E. Thompson et al, *Effect of three-dimensional quadrupole magnet model on beam dynamics in the FODO line at the Spallation Neutron Source Beam Test Facility*
 - J. E. Muller et al., *Evaluating PyORBIT as Unified Simulation Tool for Beam-Dynamics Modeling of the ESS Linac*
 - A. Latina et al. *The tracking code RF-Track and its application*
 - G. Bellodi et al. , *Benchmarking of PATH and RF-Track simulation codes using the Linac4 front-end*
 - C. S. Park et al., *Differential Algebra for Accelerator Optimization with Truncated Green's Function*
 - C. Xiao et al., *Matched Transport of Intense and Coupled Coasting Beams Through Quadrupole Channels*



G. Bellodi et al., *PATH vs RF TRACK*



J. E. Muller et al.

A message : time for global review/benchmarking ?

-> Example : HIPPI project in 2004/2005

Benchmarking linac codes for the HIPPI Project

.Franchi*, R. Duperrier†, G. Franchetti*, F. Gerigk**, L. Groening*, I. Hofmann*, A. Orzhekhovskaya*, A. Sauer‡, D. Uriot† and S. Yaramyshev*

*GSI, Darmstadt, Germany

†CEA, Saclay, France

**CCLRC-RAL, UK

‡IAP, Frankfurt, Germany



Last words

- Stolen from A. Shishlo presentation :

- “• We understand very well transverse and longitudinal motion of bunch center
- Combination of empirical beam loss tuning and modelling of bunch center motion was beneficial for beam availability and low activation of SNS linac
- To improve our knowledge and operation practices further we have to use combination of envelope (fast) * PIC codes (more realistic)”

-> Integration of beam dynamics codes into control systems

- On-line monitoring /tuning

T. Nishi et al., Development of non-destructive beam envelope measurements using BPMs for low beta heavy ion beams in SRF cavities

- Model improvements (“Machine learning” or “learning the machine”) : Numerical Twin

-> Increase or ensure availability/reliability

M. Hartmann et al., Beam loss simulations for the proposed TATTOOS beamline at HIPA

- even more critical for ADS machines

S. Liu et al., High availability oriented beam dynamics for CiADS proton linac”

If you have comments remarks please send it to :

zhaohw@impcas.ac.cn

evansnj@ornl.gov

fbouly@lpsc.in2p3.fr

This will help us to to write the summary 😊

Thank you to all the speakers

Thank you to all the people who participated in the discussions

Thank you for your attention