HB 2023

ICFA

WG-B Short Summary

Beam Dynamics in Linacs

N. Evans, H.Zhao, F. Bouly

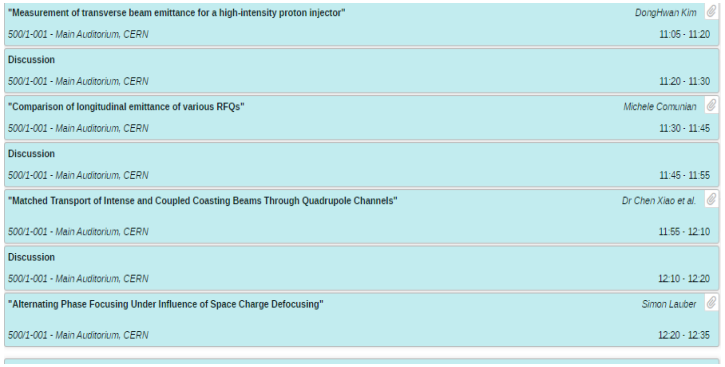
WGB global view

- 5 sessions
  - 8 invited talks
  - 13 contributed talks

Tuesday

Wenesday

Thursday



Main Remarks / identified themes

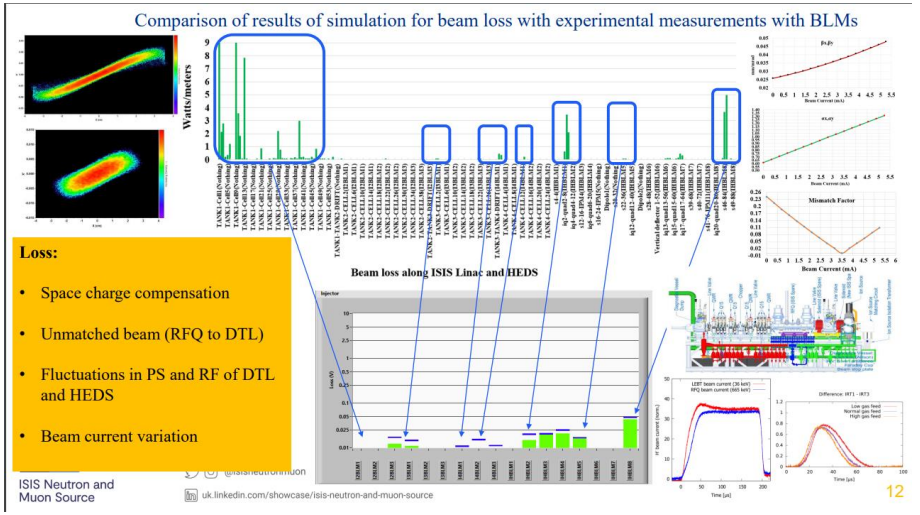
- Many talks about linacs under operation or in installation/ commissioning phase
- How do we improve Availability/Reliability /Sustainability ?
- ‘Proliferation’ of Beam dynamics codes
- The Low energy beam physics transport is not (always) well known
  - From the Source to the RFQ : what happens?
  - 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 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"*

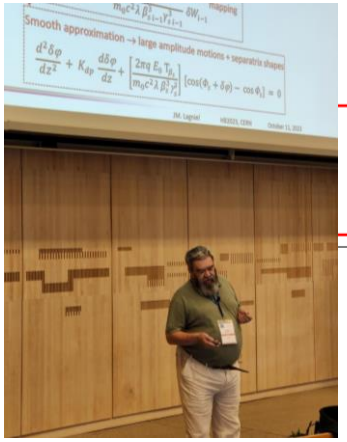


S. Ahmadiannamin

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

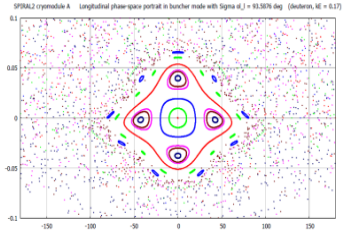
- J.-M. Lagniel, *Synchronous Phases and Transit Time Factors (σl= 90° resonance)*
- D.-O Jeon, Par*ticle resonances' domination over parametric instabilities and their mitigation*



EXCITATION BY THE CAVITY RF-FIELD

Cavity rf-field
= nonlinear longitudinal focusing force

$= [\cos(\Phi_s + \delta\varphi) - \cos\Phi_s] =$
$- [\sin\Phi_s]\,\delta\varphi$ "quadrupole" (linear focusing)
$- [\cos\Phi_s/2!]\,\delta\varphi^2$ "sextupole"
$- [\sin\Phi_s/3!]\,\delta\varphi^3$ "octupole"
$+ [\cos\Phi_s/4!]\,\delta\varphi^4$ "decapole" + ...

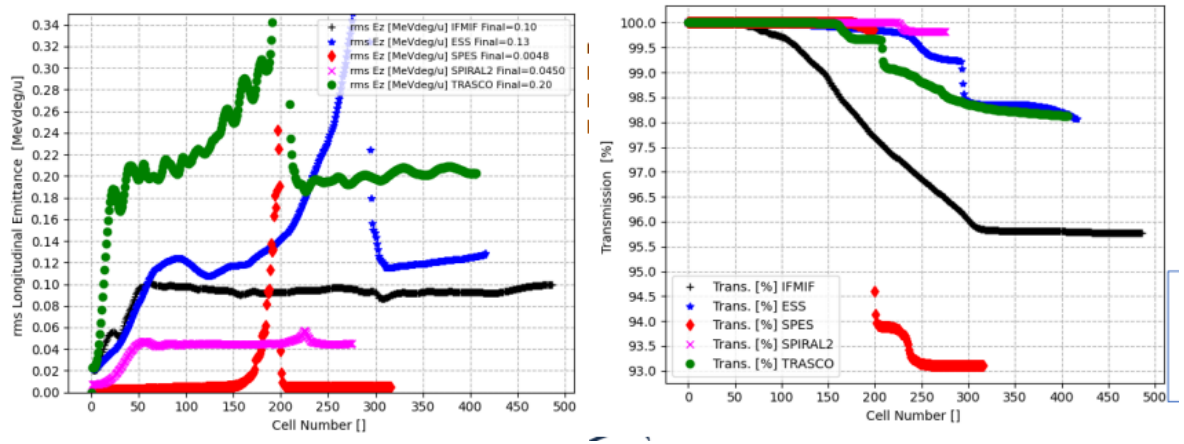


The σ_l = 90° resonance main source of excitation (as well as the other parametric resonances in the longitudinal plane !)
is the cavity rf-field, Not space-charge !
Excitation period = cavity period => consider σ_{l_l} not σ_{l_t} ... again

J.-M. Lagniel

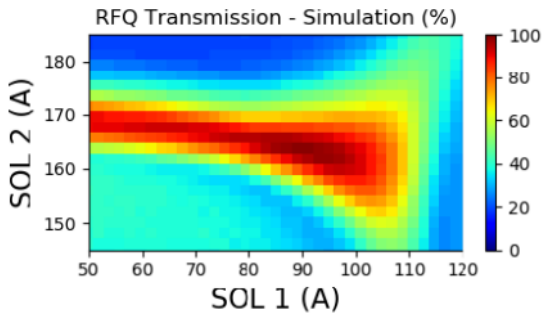
Understanding the Low energy beam physics

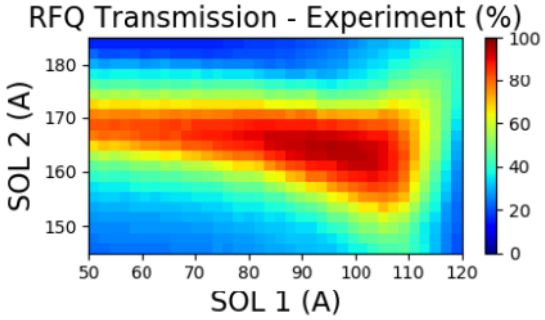
- LEBT -> RFQ-> MEBT ： the region where the beam is conditionnned
- RFQ design ：M. Communian, Comparison of longitudinal emittance of various RFQs
  - “The simulations codes can well define the beam dynamics inside any RFQs. “
  - “ The simulations codes has been compared with success with the experimental 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

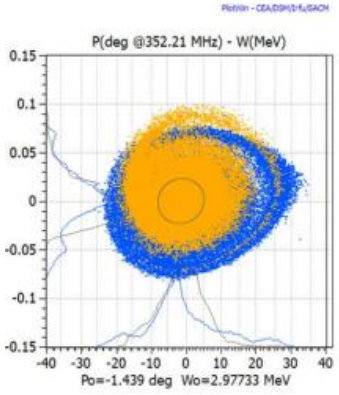
- Most critical challenge is to understand transport from the source to the RFQ.
- Well summarised from E. Sargsyan et al., *Linac4 source and low energy experience and challenges*
  - "IS04 source can reliably produce up to 50 mA of H- beam. However, the operational beam current from the source remains 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



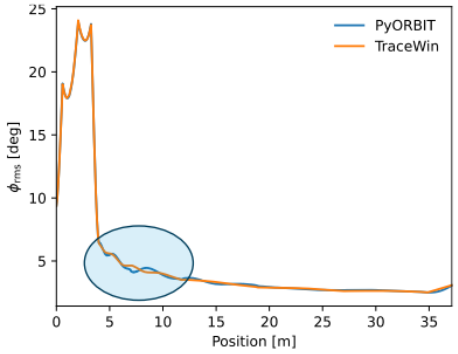


Beam dynamics codes

- 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. Yaramyschev*

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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 :

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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