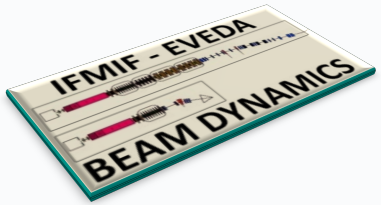
Catalogue of Losses for the Linear IFMIF Prototype Accelerator

HB2014, East Lansing, MI.

N. Chauvin[1]*, P.A.P. Nghiem[1], M. Comunian[2], C. Oliver Amoros[3], D. Uriot[1]

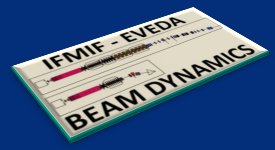
*Nicolas.Chauvin@cea.fr

[1] Commissariat à l'Énergie Atomique et aux Énergies Alternatives, DSM/Irfu; F-91191 Gif-sur-Yvette, France.
[2] INFN/LNL, Legnaro, Padova, Italy.
[3] CIEMAT, Madrid, Spain



November 13, 2014

Outline



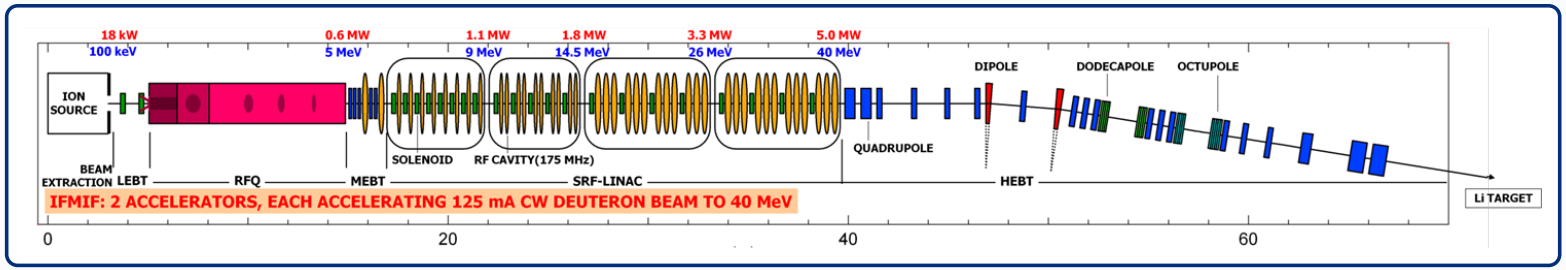
1. **Linear IFMIF Prototype Accelerator**

2. **Catalogue of Losses: Issues and Strategy**
   - LIPAc Beam Losses Issues
   - Procedure for Catalogue of Losses

3. **Simulation Results**
   - A. Ideal machine
   - C. Beam commissioning, tuning, exploration
   - E. Sudden failure

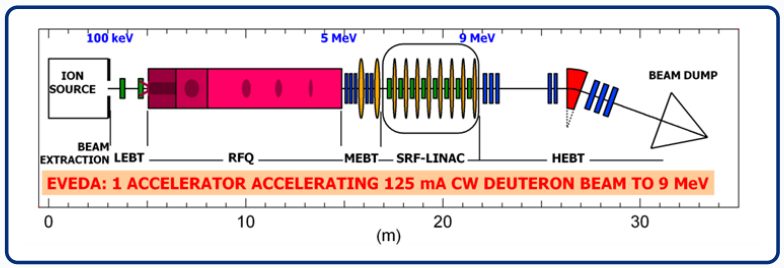
Outline

IFMIF & LIPAc



IFMIF Accelerator: 125 mA/40 MeV D^+ beam – 5 MW

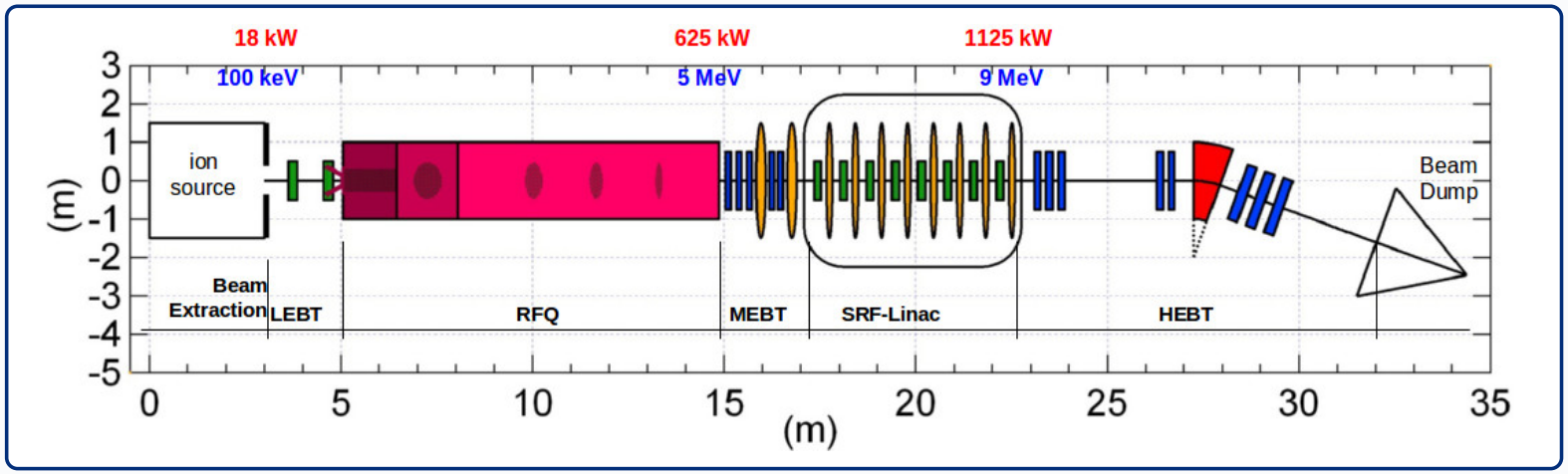
Goal of IFMIF: Produce a flux of 10^{18} $n.m^{-2}s^{-1}$ with a broad peak at 14 MeV.



Linear IFMIF Prototype Accelerator (LIPAc): 1.125 MW

Goals of LIPAc: demonstrate feasibility and validate design & technology

Introduction
LIPAc layout and main parameters

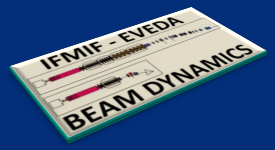


LIPAc Main Parameters

- Continuous D^+ beam
- Intensity: 125 mA
- LIPAc final energy: 9 MeV
- Hands-on maintenance
- ECR source & 2 solenoids LEBT
- 9.78 m 4-vanes RFQ @ 175 MHz
- MEBT and SFR linac (HWR)
- HEBT, Diagnostics Plate and Beam Dump

Outline

LIPAc Beam Losses Issues



High Beam Power

- The **whole** accelerator is concerned by **high power beam**: from 15 kW in the LEBT to 1.125 MW in the HEBT.
- Even a **tiny part** of the beam, when lost, represents a **significant power deposition**.

Beam Losses

- **Permanent loss** can **activate** material: hands-on? Also cooling cryogenic systems potential problems.
- **Accidental loss** leads to sudden **heat deposition** and can damage equipment.

High beam power almost all along the accelerator: meticulous and exhaustive prediction of losses is needed

LIPAc Beam Losses Issues

High Beam Power

- The **whole** accelerator is concerned by **high power beam**: from 15 kW in the LEBT to 1.125 MW in the HEBT.
- Even a **tiny part** of the beam, when lost, represents a **significant power deposition**.

Beam Losses

- **Permanent loss** can **activate** material: hands-on? Also cooling cryogenic systems potential problems.
- **Accidental loss** leads to sudden **heat deposition** and can damage equipment.

High beam power almost all along the accelerator: meticulous and exhaustive prediction of losses is needed

LIPAc Beam Losses Issues

High Beam Power

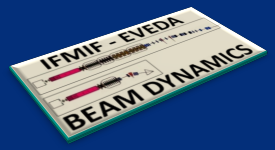
- The **whole** accelerator is concerned by **high power beam**: from 15 kW in the LEBT to 1.125 MW in the HEBT.
- Even a **tiny part** of the beam, when lost, represents a **significant power deposition**.

Beam Losses

- **Permanent loss** can **activate** material: hands-on? Also cooling cryogenic systems potential problems.
- **Accidental loss** leads to sudden **heat deposition** and can damage equipment.

High beam power almost all along the accelerator: meticulous and exhaustive prediction of losses is needed

Procedure for Catalogue of Losses



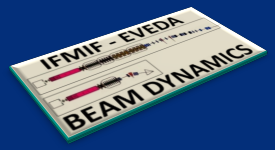
Double Issue

1. **Define thoroughly the loss situations in the accelerator lifetime**
2. **Define the protocols to simulate and estimate them**

Five loss situations can be determined

A. Ideal machine
B. Machine “day one”
C. Beam commissioning, tuning, exploration
D. Routine operation
E. Sudden failure

Procedure for Catalogue of Losses



Double Issue

1. **Define thoroughly the loss situations in the accelerator lifetime**
2. **Define the protocols to simulate and estimate them**

Five loss situations can be determined

A. Ideal machine

B. Machine “day one”

C. Beam commissioning, tuning, exploration

D. Routine operation

E. Sudden failure

Procedure for Catalogue of Losses

A. Ideal machine

Situation: Nominal machine parameters and tunings, without any error. We cannot hope to have less losses than that: reference case.

Simulation: Start-to-end simulation without any error for the nominal accelerator tuning.

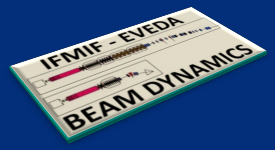
B. Machine "day one"

Situation: The accelerator components have been fabricated and aligned as specified. The tunable parameters (accelerating and focusing fields and gradients) are set at their optimised values given by beam dynamics simulation.

Simulation: Start-to-end error study without any correction.

- Alignment errors are randomly distributed within tolerances.
- Tunable parameter errors are randomly distributed within a $\pm 10\%$ range of their nominal values.

Procedure for Catalogue of Losses



C. Beam commissioning, tuning, exploration

Situation: Beam commissioning phase or whenever beam tuning is necessary.

Simulation: Start-to-end error study with orbit correction.

- Alignment errors are randomly distributed within tolerances.
- Tunable parameter errors are randomly distributed within a $\pm 10\%$ range of their nominal values.

D. Routine operation

Situation: The accelerator has been assembled within the specified tolerances, is correctly tuned and the beam trajectory is corrected.

Simulation: Start-to-end error study with orbit correction.

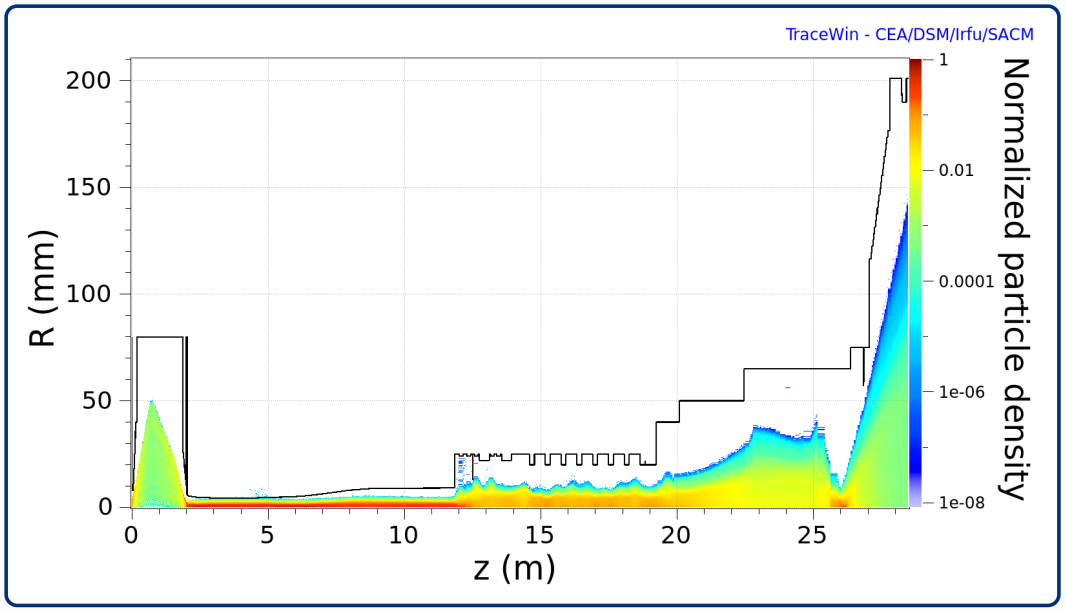
E. Sudden failure

Situation: Failure or sudden trips of one or several tunable elements (power supply, RF power, electronics...).

Simulation: Individual component or all the components at once are set from 110% to 0% of their nominal values.

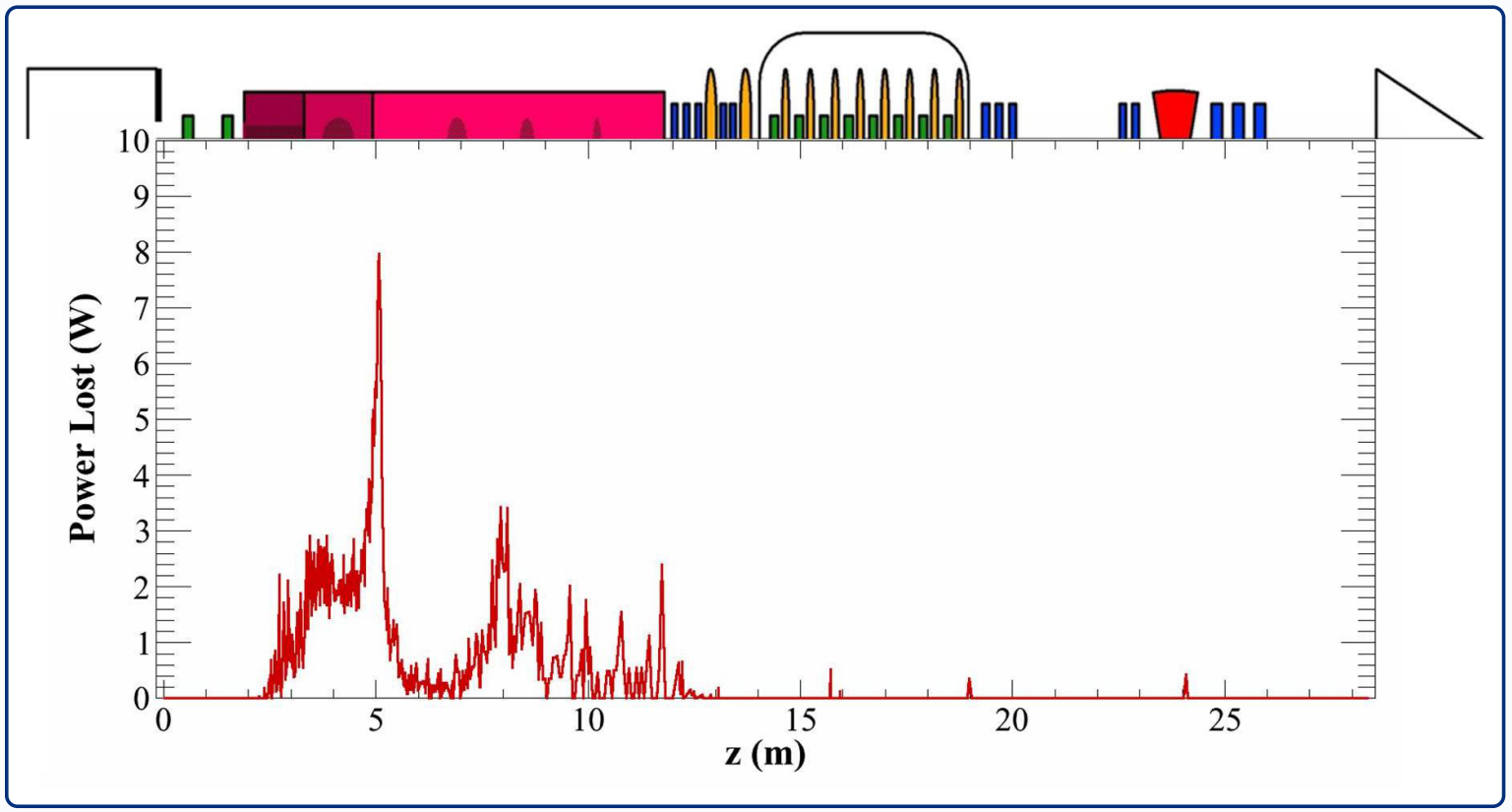
Simulation conditions

- Code used: TraceWin
- ECR source extraction system simulated with AXCEL-INP
- Simulations were performed with 10^6 particles
- Element fields maps were used as much as possible
- Simulations were performed at full beam intensity
- Error studies were done with 500 cases
- Dedicated data analysis software have been developed



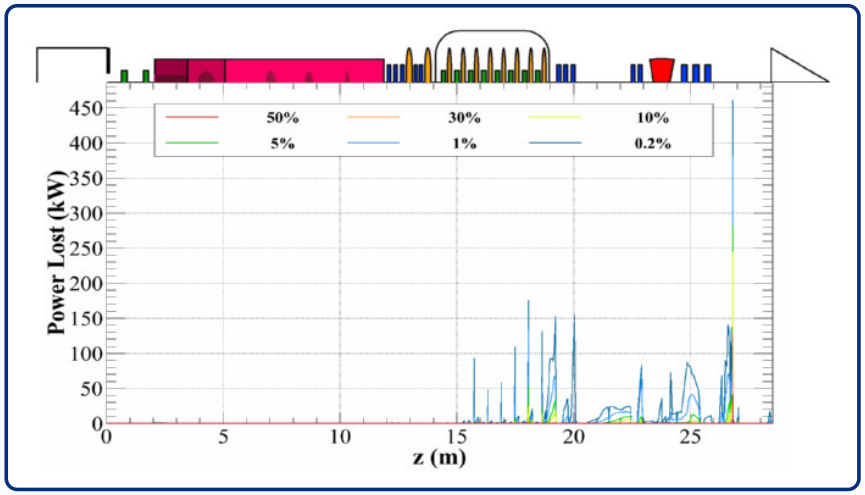
Outline

A. Ideal Machine

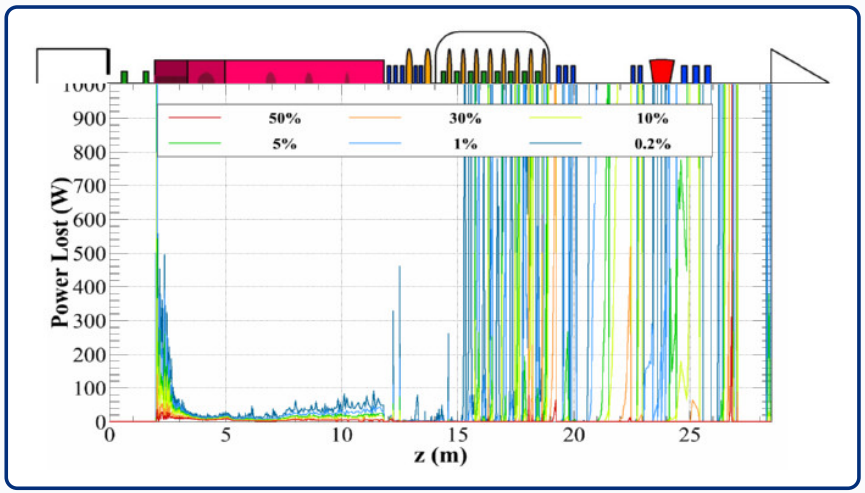


Nominal Case – Losses mainly in the RFQ (1 kW), MEBT scrappers (10 W) and in the HEBT bending magnet (1 W).

C. Beam Commissioning, Tuning, Exploration



Beam power lost probabilities



Beam power lost probabilities (zoom)

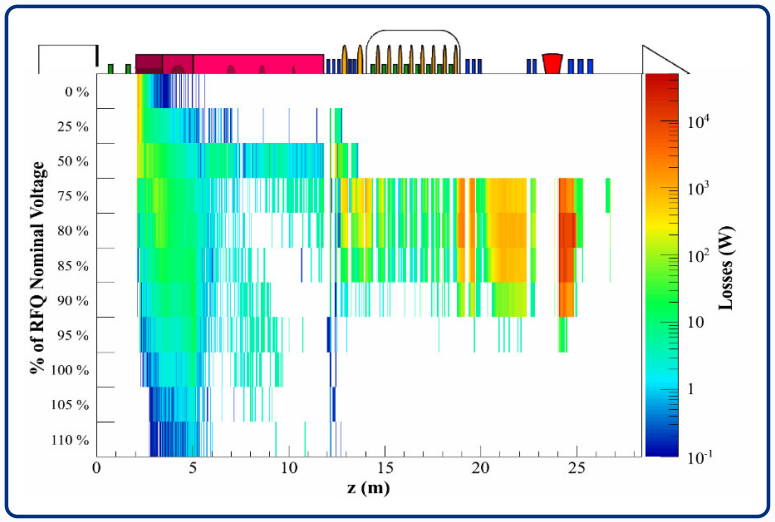
Power lost in 5% of the cases:

- 70 kW locally
- more than 100 kW in the SRF linac.

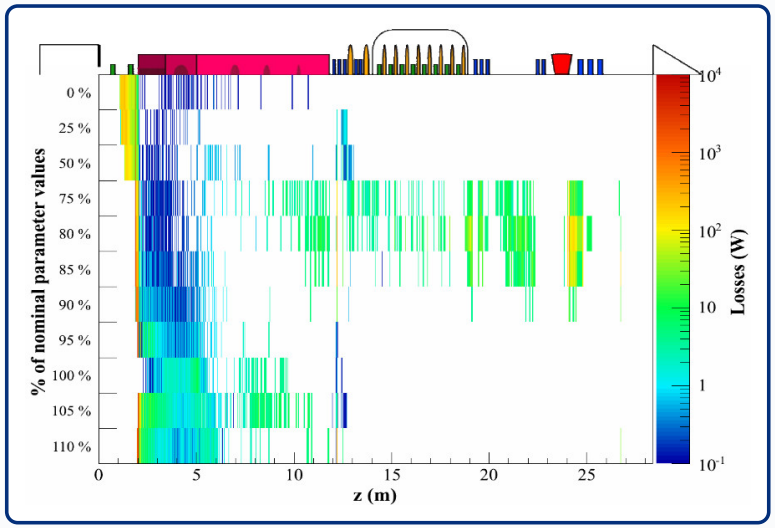
$\Rightarrow$ Beam tuning at 10^{-5} duty cycle

$\Rightarrow$ Maximum variation of tunable parameters: 5% of the nominal values

E. Sudden Failure



Beam power lost in case of RFQ failure



Power lost in case of LEBT and RFQ failure

- ∼10 W losses in the SRF linac for 90% of the RFQ voltage
- Less losses in SRF linac and HEBT in case of failure of the three elements

⇒ MPS has to shut the beam when the RFQ voltage is less than 95% of its the nominal values

Conclusion

Conclusion

- Beam losses have been evaluated during different stages of the LIPAc lifetime
- Method mainly based on error studies simulations
- The procedure can be applied to any accelerator
- Impact on several accelerator subsystems
- Starting point to discuss the MPS

Much more on the subject:

P.A.P. Nghiem, N. Chauvin, M. Comunian, C. Oliver AND D. Uriot
A catalogue of losses for a high power, high intensity accelerator
Laser and Particle Beams (2014), 32, 461–469.

Thank you for your attention