

CEPC machine protection and beam abort system

Yuting Wang
On behalf of the machine protection team



中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

Content



- Motivation
- Method for the simulation
- Preliminary arrangement of the global collimators
- Current simulation results
- Summary

Motivation

CEPC is e^+e^- collider designed for 4 beam operation modes

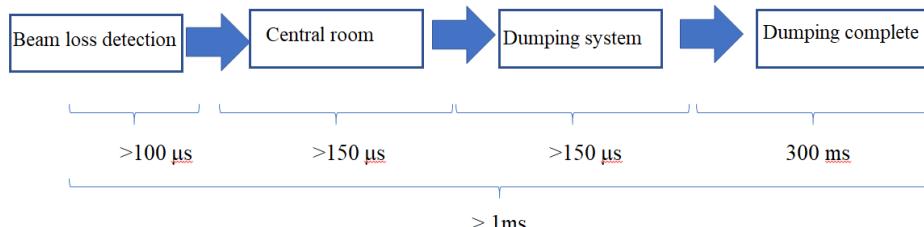
- The energy stored in the machine is very high
- Such beam is highly destructive

Priority of machine Protection

- Global equipment protection
- Reduce the background near IP

Method of machine protection

- Active protection (beam dump)
 - Response time of CEPC active machine protection system $\sim 1\text{ms}$
- Passive protection(**collimators**, shielding)
 - Fast beam loss, beam halo, synchrotron radiation (SR)...



X.H. Cui

Fig.1 Beam dump system

Table 1: Parameters for the CEPC machine protection (@ 50MW)

	Higgs	Z	W	$t\bar{t}$
Beam Energy (GeV)	120	45.5	80	180
Bunch Population/ 10^{10}	13	21.4	13.5	20
Number of Bunches	446	13104	2162	58
Total Energy (MJ)	1.1	20	3.7	0.33



[1] T. Ishibashi and S. Terui, SuperKEKB collimator design, FCC-EIC Joint & MDI Workshop 2022



Fig.2 Damage to collimator jaw due to accident beam loss in the SuperKEKB

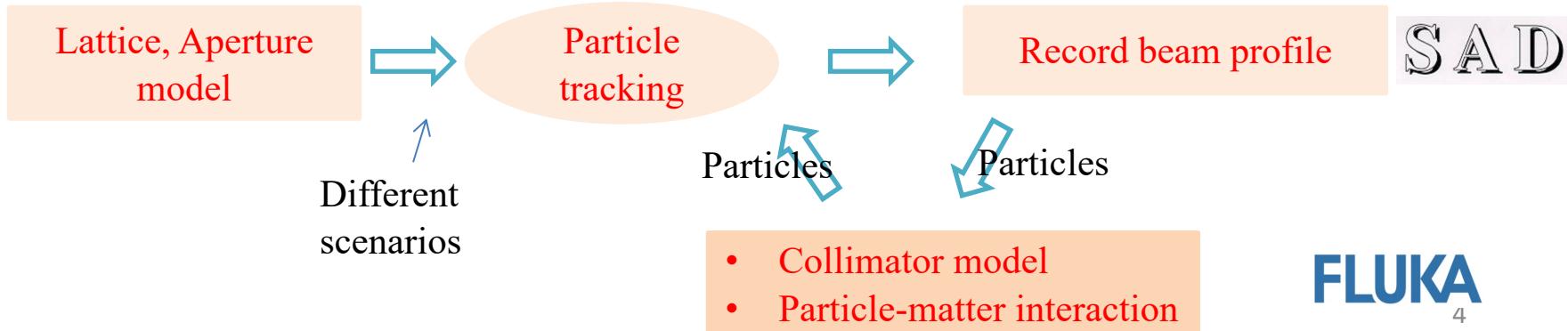
Method for Simulation

■ Requirements for simulation studies:

- Multi-turns particle tracking (6D) using the full lattice
- Synchrotron radiation, optics tapering, beam-beam effect
- Aperture model (geometry + beam-stay-clear region + momentum acceptance)
- Beam loss recording (turn, location, phase space)
- Particle-matter interaction inside the collimators
- Energy deposition and dose studies



■ Workflow



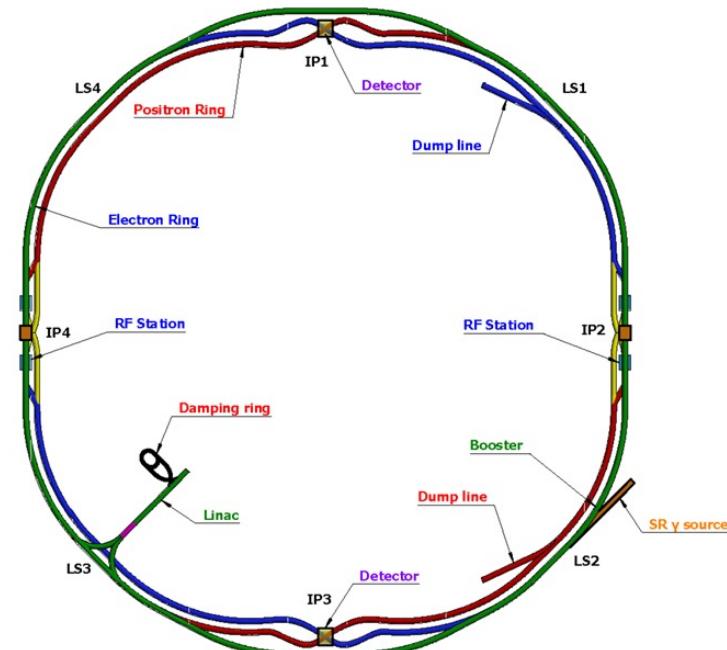
Simulation studies

- **SAD simulations**
 - Different scenarios
 - Optimum/acceptable/particular operating conditions:
 - Beam halo/tails, Top-up injection
 - Change of optics, tuning, collimator aperture setting, etc
 - Fast beam loss
 - Standard equipment failure, fast equipment, other accident beam loss, etc
 - Injection failure, SuperKEK fast beam loss (should be understand if possible)
 - Different operation modes
 - Higgs, Z, W, ttbar
- **FLUKA simulations**
 - Beam-matter interactions inside collimators
- **Optimization by coupling simulations**
 - Multi-stage collimation
 - Collimator: location, gap, length, quantity, material, deposition, taper, ect
 - Impedance budget
 - Movable collimators

- Motivation
- Method for simulation
- Preliminary arrangement of the global collimators
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Preliminary arrangement of the global collimators

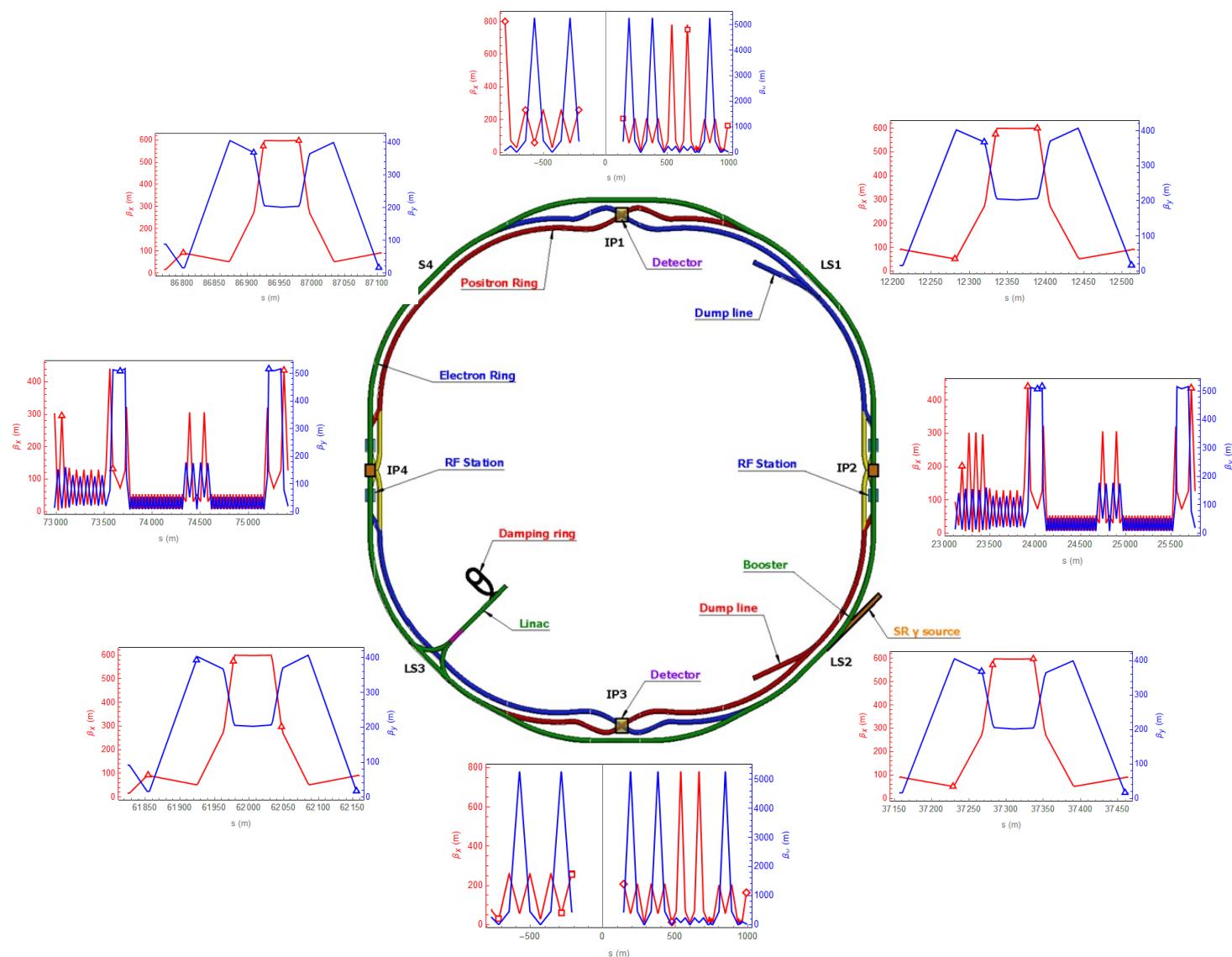
- Arrangement:
 - 30 collimators near LS1, LS2, LS3, LS4 and RF stations
 - Type: two parallel plates
 - H:V=18:12
 - Half gap: 3 mm
 - 14 collimators near IP1 and IP3
 - Type: cylindrical pipe
 - Radius: 3 mm
 - 16 collimators (reduce background) near IP1 and IP3
 - Type: two parallel plates
 - H:V=8:8
 - Half gap: 4 mm (H), 3mm (V)
 - Total: 60 collimators in current arrangement



Layout of the CEPC accelerator complex

* detail in Yiwei Wang's talk on this workshop, CEPC collider ring lattice

Higgs Mode



Preliminary arrangement of collimators for CEPC collider ring

- Motivation
- Method for simulation
- Preliminary arrangement of the global collimators
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CEPC beam loss

■ Scenarios of the fast equipment failures

- In current simulation, different starting points (LS1,LS2,LS3,LS4 and arc regions) are considered to provide a comprehensive analysis

- Critical RF failures

$\tau \approx 773 \mu s$ J.Y Zhai

- Quenches of superconducting quadrupole magnets
 - Powering failure of normal magnets
 - bending magnets
 - quadrupole magnets
 - sextupole magnets

$\tau: 10 \sim 100 ms$ Y.S Zhu

B. Chen

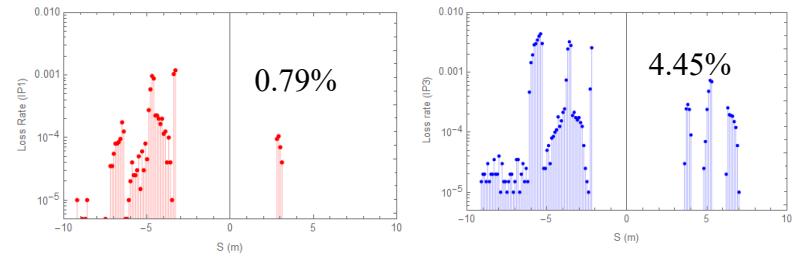
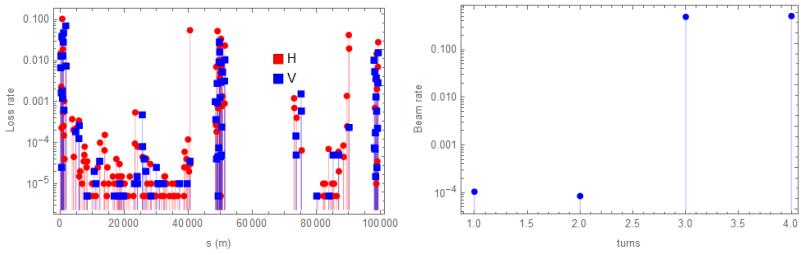
- Failure model: $Q = Q_0 e^{-t/\tau}$

- Single passage for CEPC $\sim 331 \mu s$

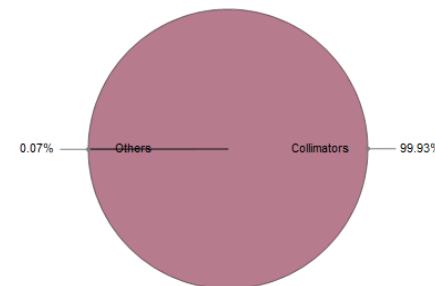
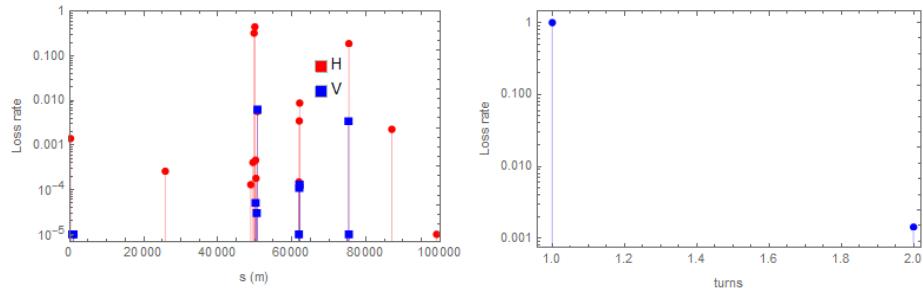
- $\tau = 10 ms$ for the magnet failures

Higgs Mode

- Failures of RF cavities without collimators (LS1)
- Fast beam loss can be observed
- Dirty IP regions (± 100 m)

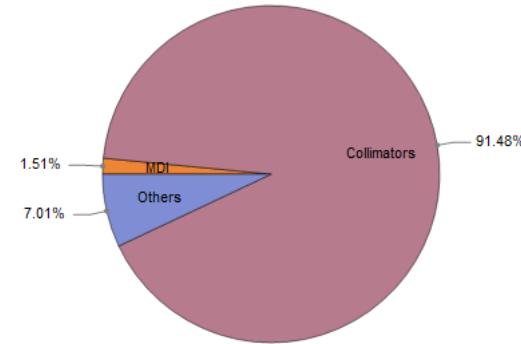
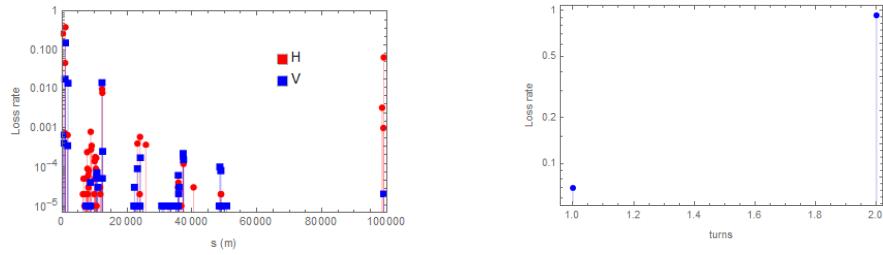


- Failures of RF cavities with collimators (LS1)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

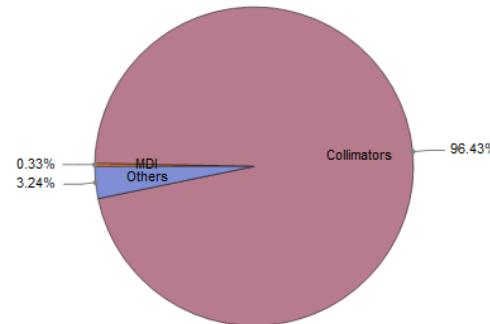
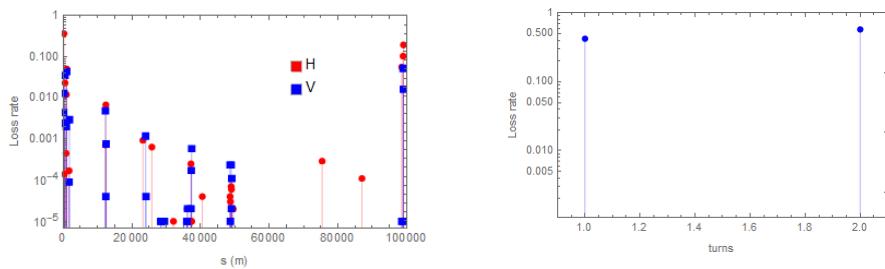


Higgs Mode

- Failures of all normal quadrupole magnets (LS4)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

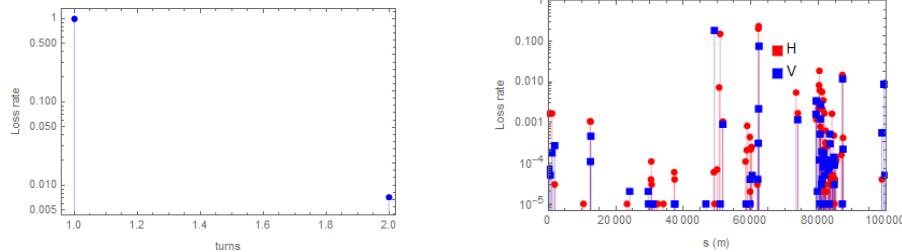


- Failures of all magnets and RF cavities (LS3)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

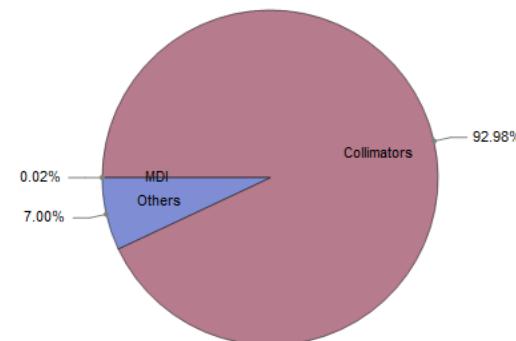
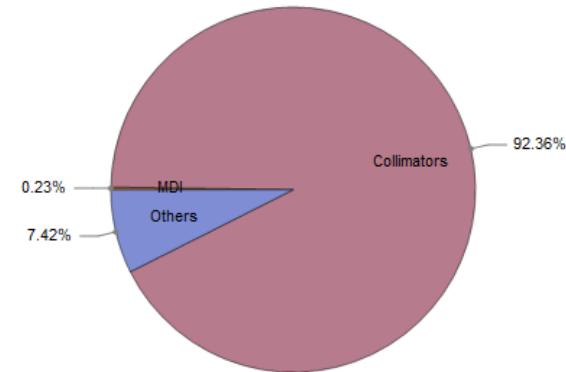
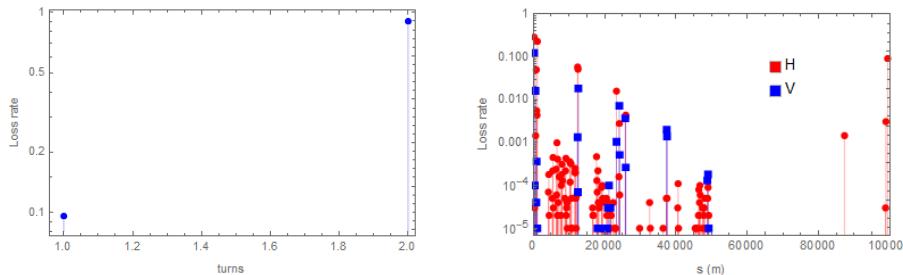


Z Mode

- Failures of all normal quadrupole magnets (LS3)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

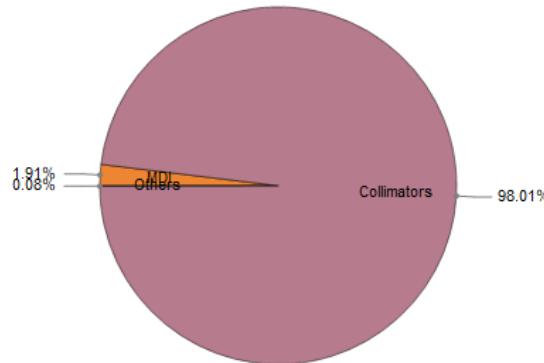
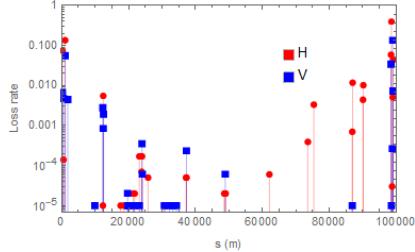
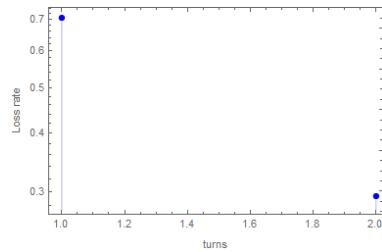


- Failures of all magnets and RF cavities (LS3)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

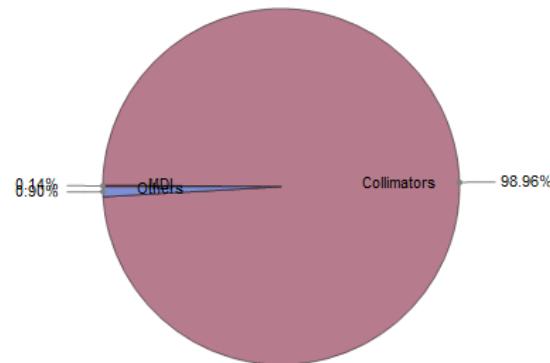
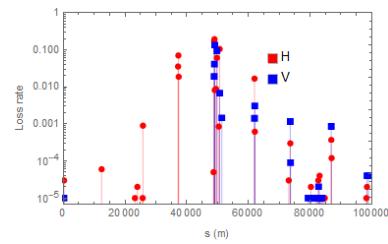
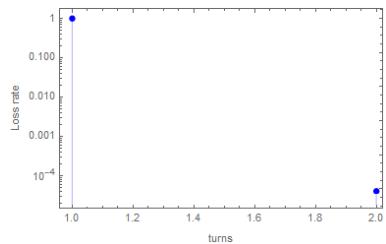


W Mode

- Failures of all normal quadrupole magnets (LS3)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

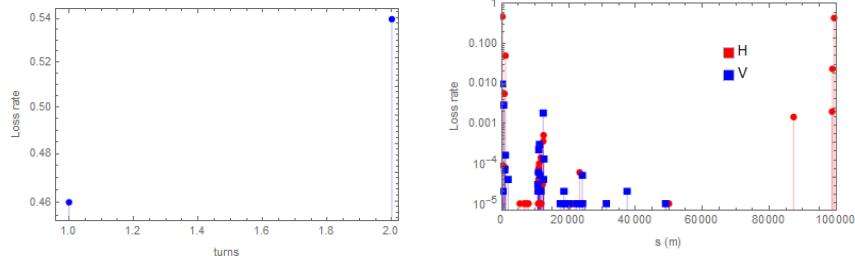


- Failures of all magnets and RF cavities (LS1)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system

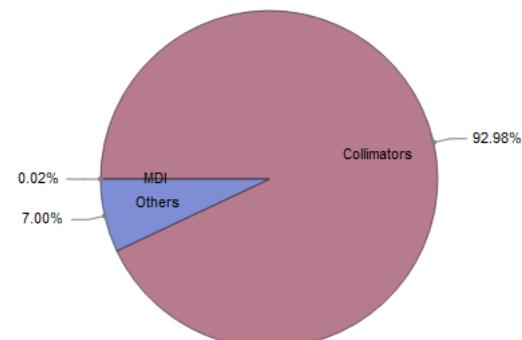
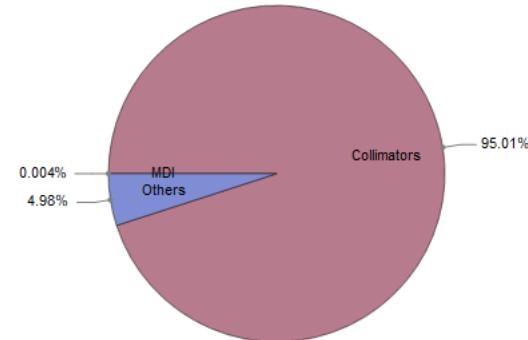
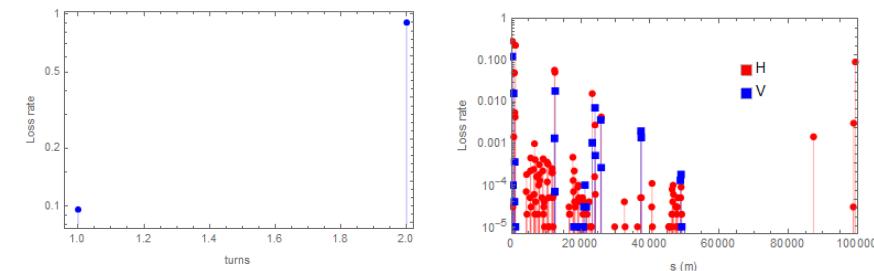


$t\bar{t}$ Mode

- Failures of all normal quadrupole magnets (LS4)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system



- Failures of all magnets and RF cavities (LS4)
- Fast beam loss can be observed
- Clean IP regions (± 100 m) with the collimation system
- Clean RF regions with the collimation system



Collimator: toy model

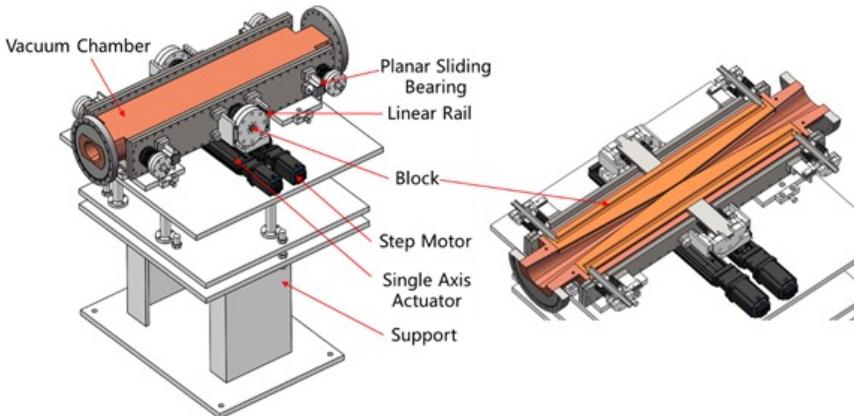
G.Y. Tang and H.J. Wang

Two geometry

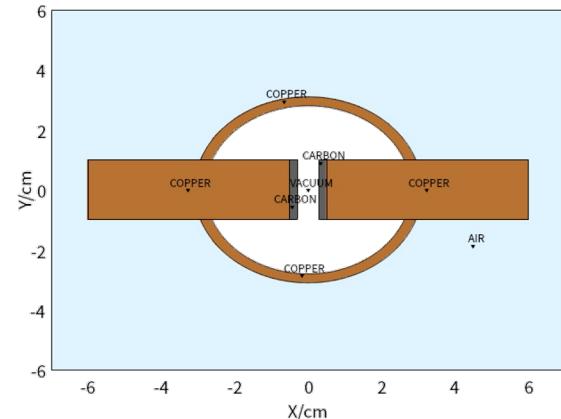
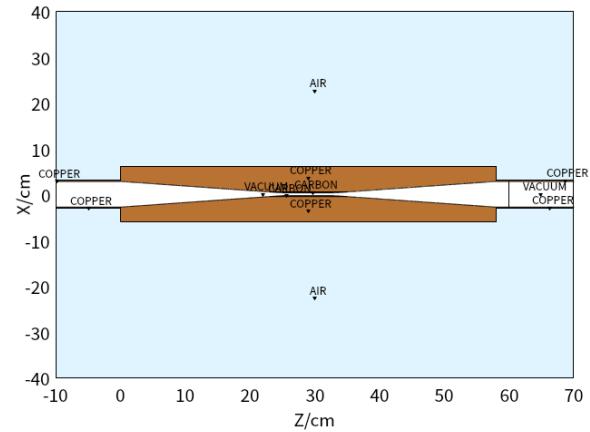
- One is HEPS-collimator type
- Two layer: metal/alloy + Carbon
- Gap: 6mm
- Thickness of carbon: 2mm

The other is metal/alloy without carbon layer

- Gap: 6 mm



Mechanical structure of the collimator



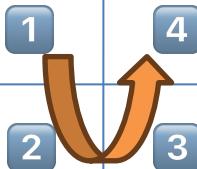
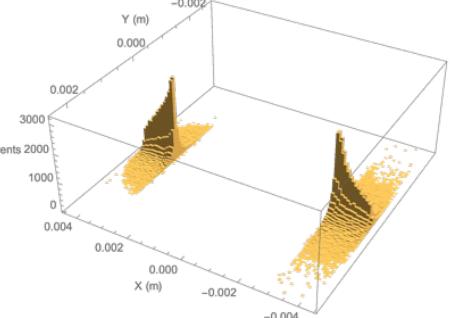
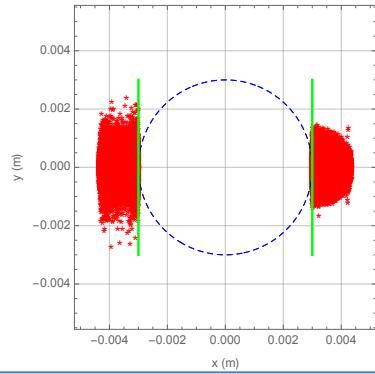
Collimator model

SAD & FLUKA coupling simulation

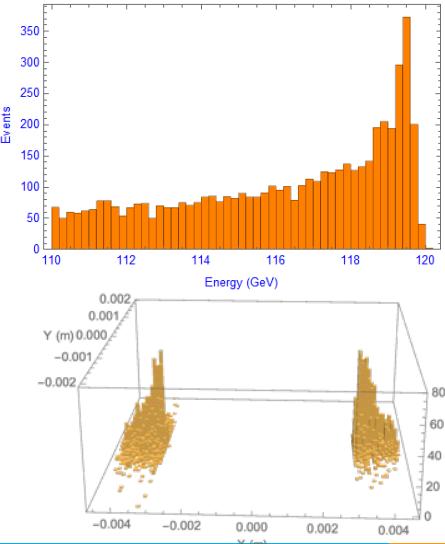
Toy collimator model: metal/alloy + Carbon

Beam loss record in collimator:

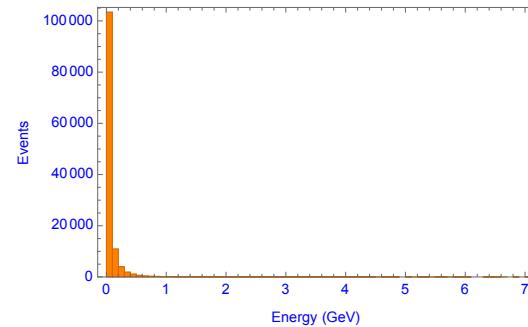
Taking bending magnets failure as an example (211648 particles)



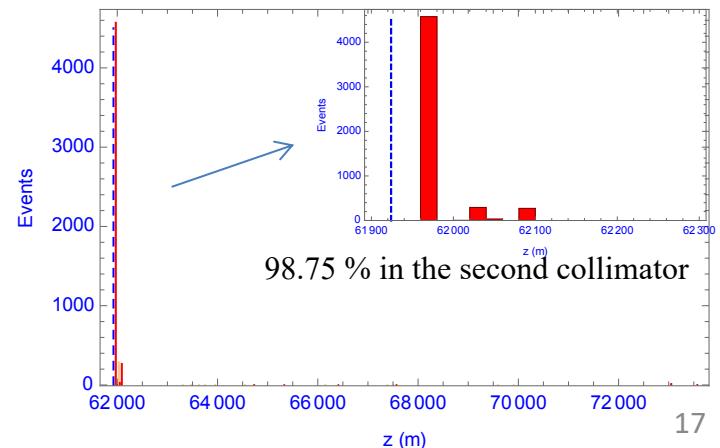
FLUKA simulation



Back to FLUKA (the second collimator)



Back to SAD simulation

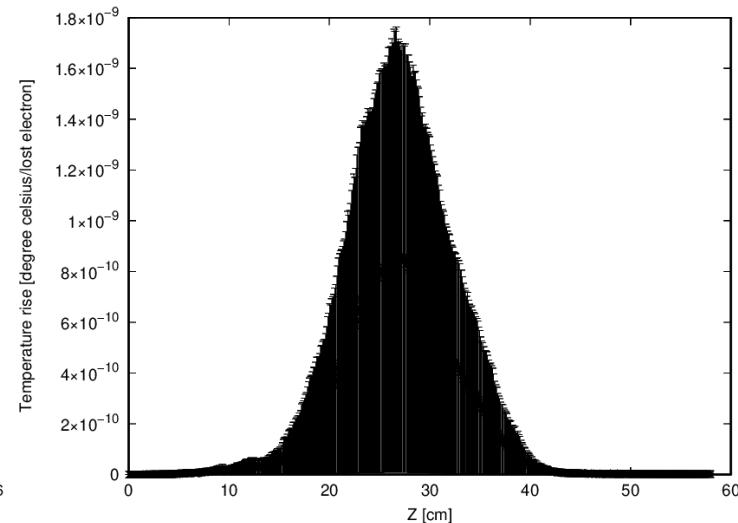
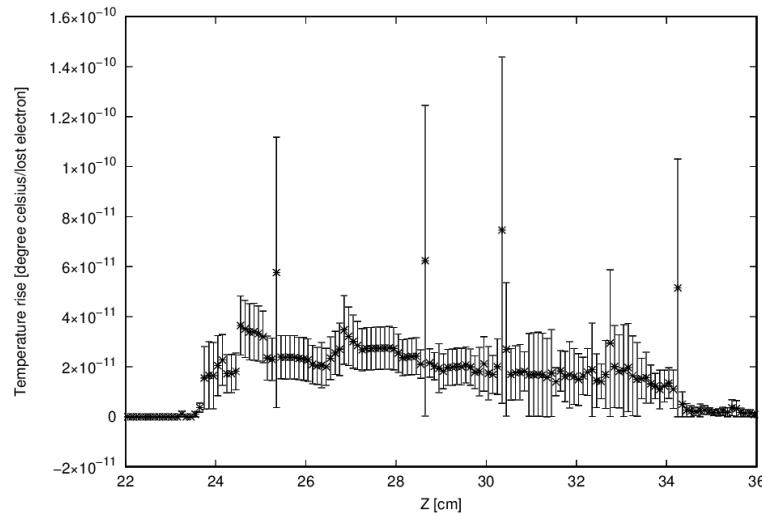


Heat deposition

Guangyi Tang

■ HEPS-Collimator type (with carbon layer)

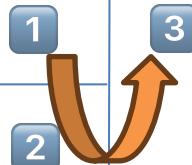
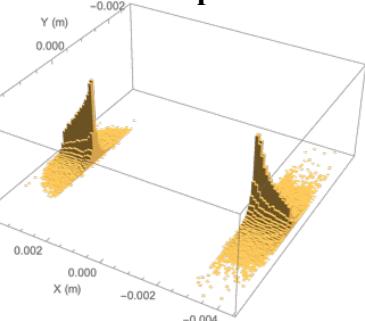
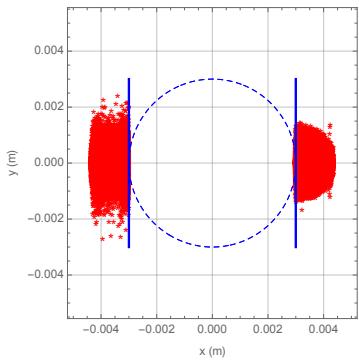
- The temperature distribution
in the first collimator: 10^{-11} °C/lost particle
- The temperature distribution
in the second collimator: 10^{-9} °C/lost particle



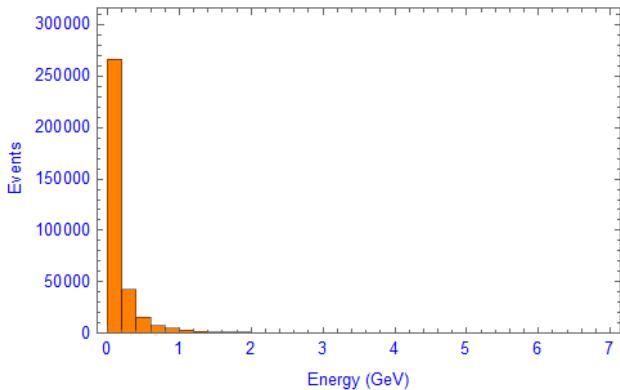
SAD & FLUKA coupling simulation

Toy collimator model: metal/alloy without carbon layer

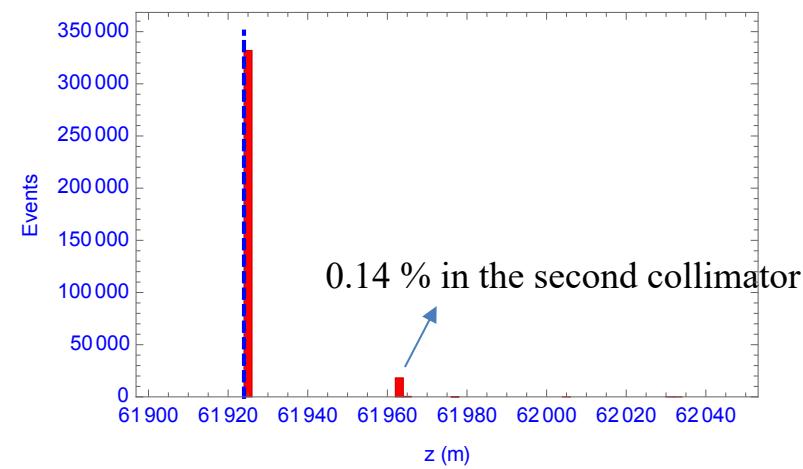
Beam loss record in collimator: Taking bending magnets failure as an example



FLUKA simulation



Back to SAD simulation

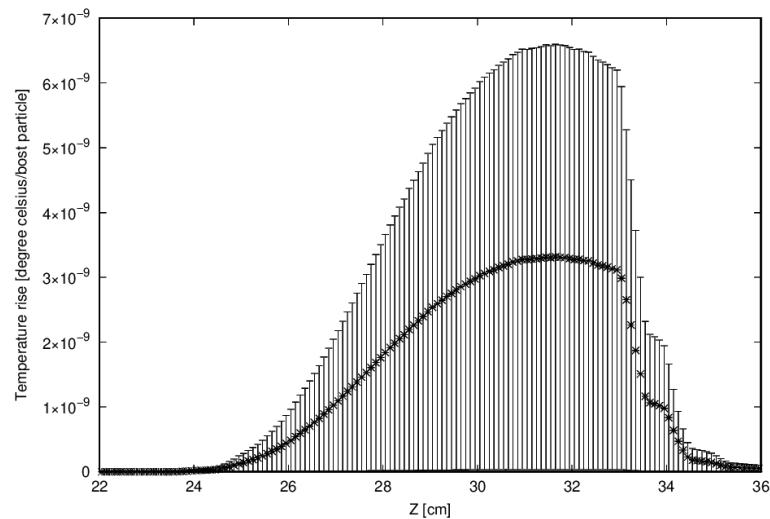


Heat deposition

Guangyi Tang

■ Metal/alloy without carbon layer.

- The temperature distribution in the first collimator:
 10^{-9} °C/lost particle

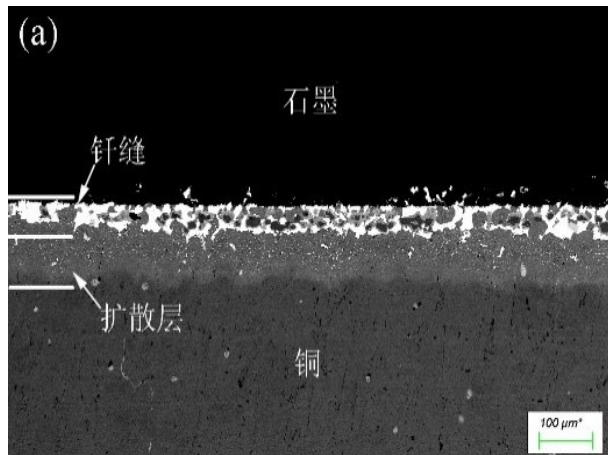


- ## ■ When the beam grazes the first collimator, the collimator would melt if there is no carbon layer. If there is a carbon layer, it protects the collimator from melting, but it generates halos, which affect the downstream a lot.

Technique studies

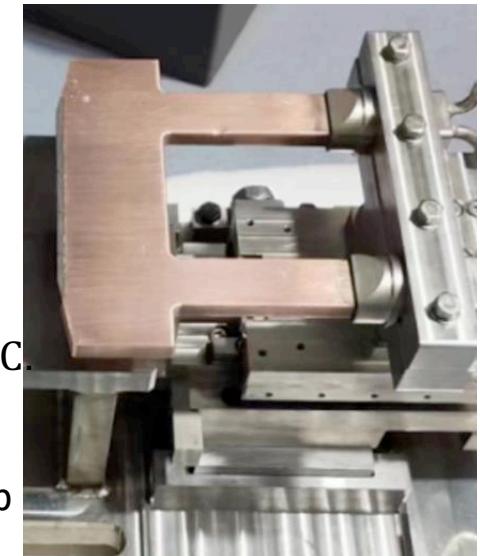
H.J. Wang

- Drawing from the experiences such as SuperKEKB or HEPS, low-Z, high-melting-point carbon-based materials need to be considered.
- We have accumulated relevant experience from the HEPS.
 - Shear strength: 38.7 Mpa between graphite and copper
 - Copper coating to improve conductivity about one level.
 - Endure more than 100 thermal shocks higher than 2000 °C.

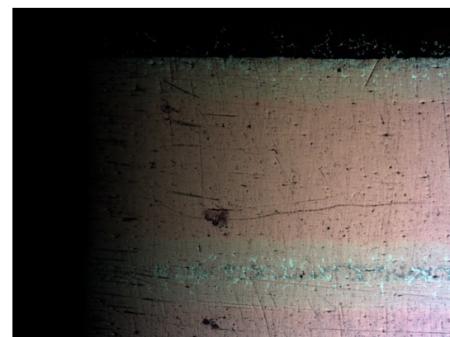


Microscopic observation of copper-graphite brazing

Jaw of HEPS collimator with copper body and graphite tip



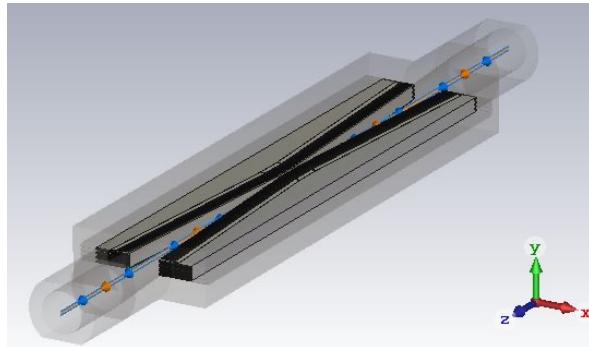
Before/after thermal shock



Impedance of the collimator

Detailed in talk of Na Wang, 23rd talk

- Impedance evaluation of the preliminary design of the collimators for the machine protection
 - 18 horizontal+12 vertical extra collimators
 - Rough estimation take the same impedance model as for the IR region (with collimator jaw gap of 4.4mm)



- Their contributions to the transverse broadband impedance is the main concern → Comparable to the total TDR transverse impedance budget \Rightarrow further optimizations are required.
 - Their contributions to the longitudinal impedance budget are trivial.

Summary

- In the preliminary arrangement, 44 collimators are installed into the CEPC collider ring to achieve passive machine protection for four operation modes.
- SAD simulation and FLUKA simulation are coupled in the preliminary collimator design.
- Toy collimator models indicate the collimator would melt if there is no carbon layer in condition of the fast beam loss. If there is a carbon layer, it protects the collimator from melting, but it generates halos, which affect the downstream a lot. One possible choice is the combination of the two collimator geometries.
- In the current arrangement, there are many challenges:
 - More simulation scenarios
 - Collimator parameters optimization: gap, length, quantity, material, ect
 - Impedance budget
 - Optimum/acceptable/particular operating conditions
 - ...

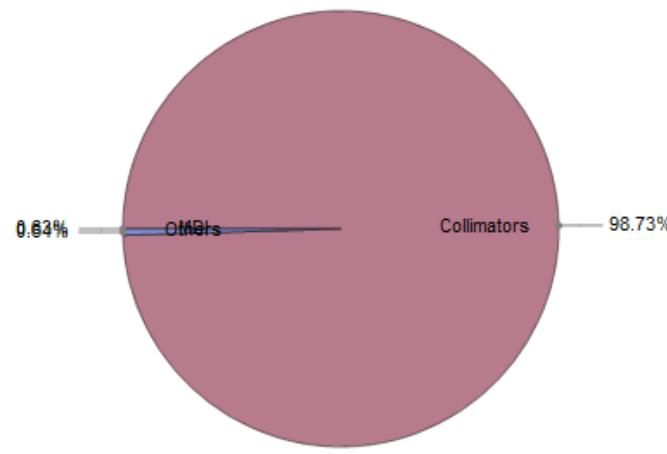
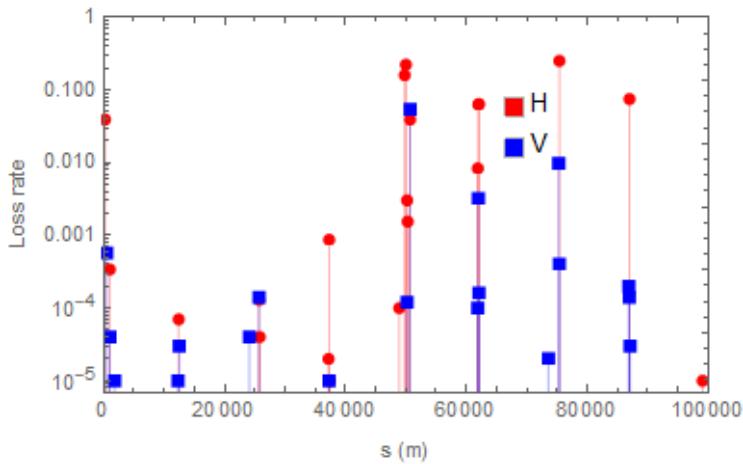
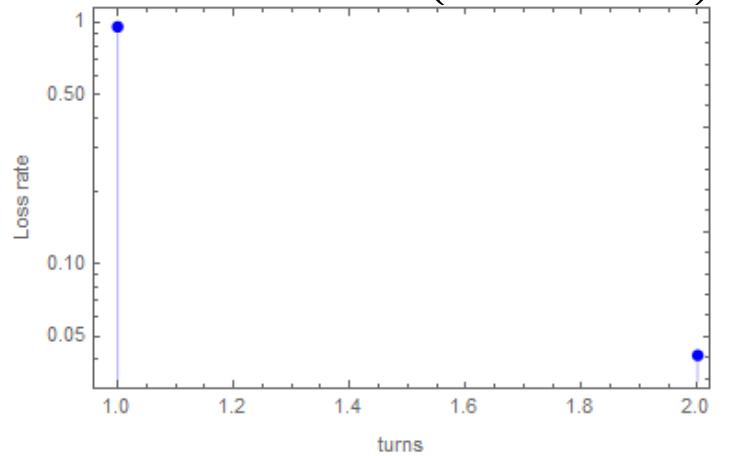
Thanks for your attention !

BACKUP

Higgs mode

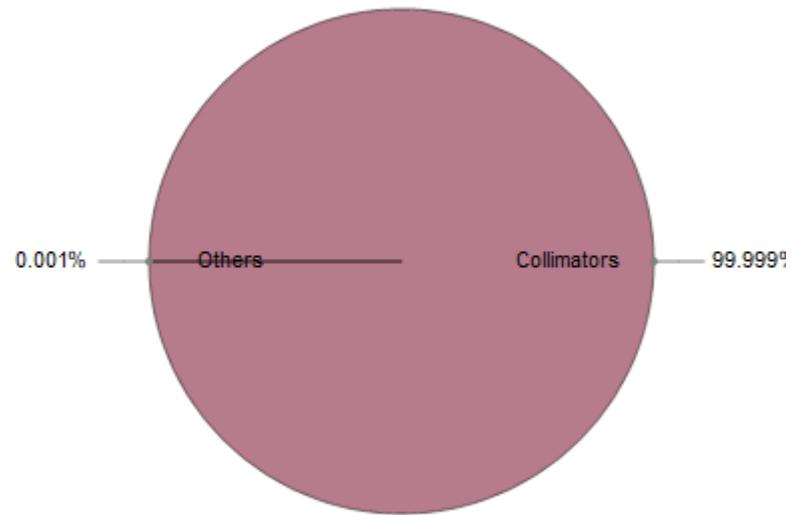
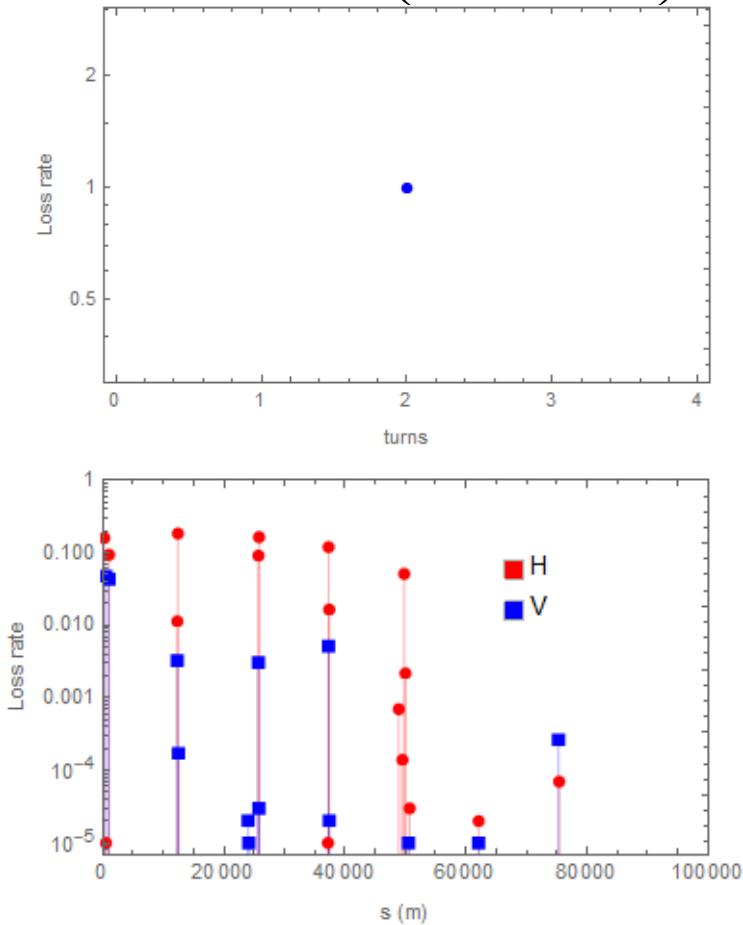
Higgs – RF failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



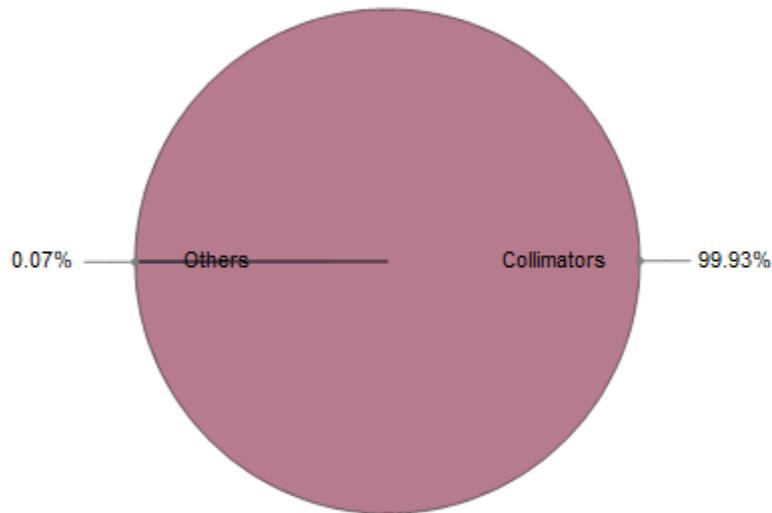
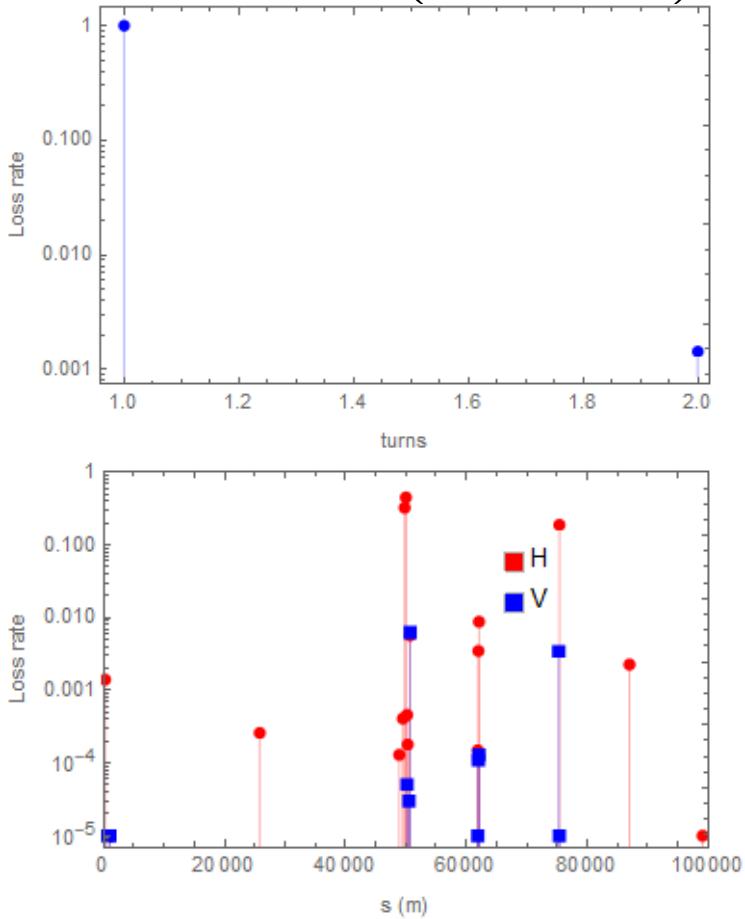
Higgs – RF failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



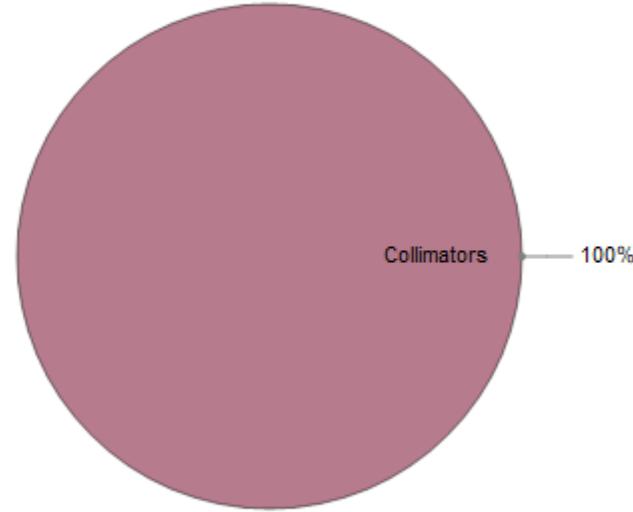
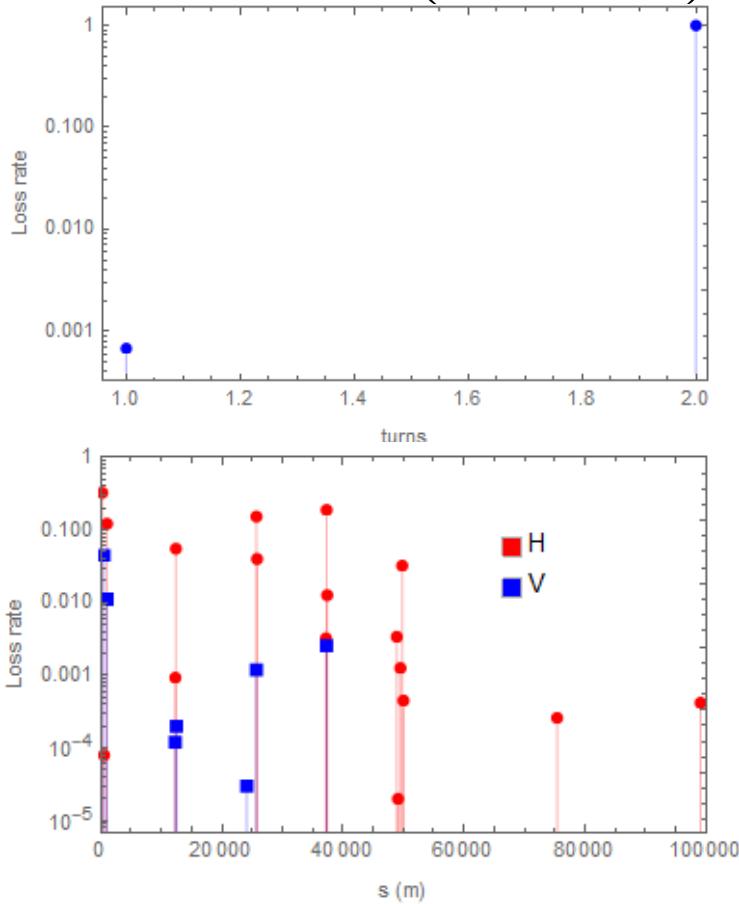
Higgs – RF failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



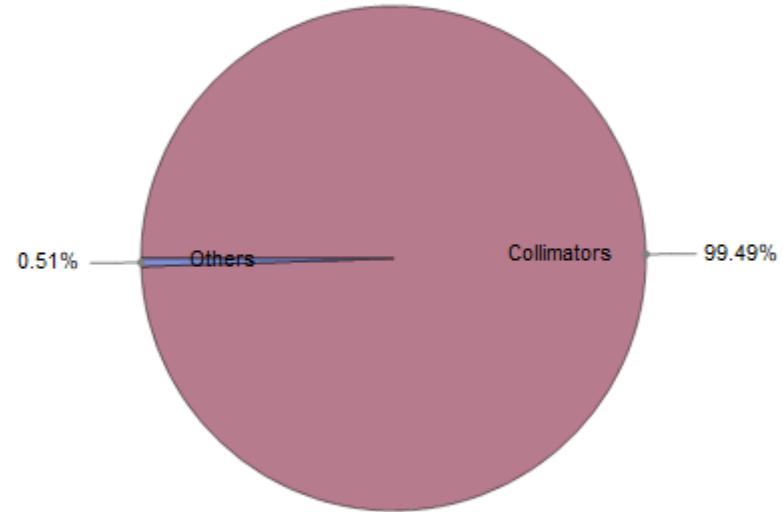
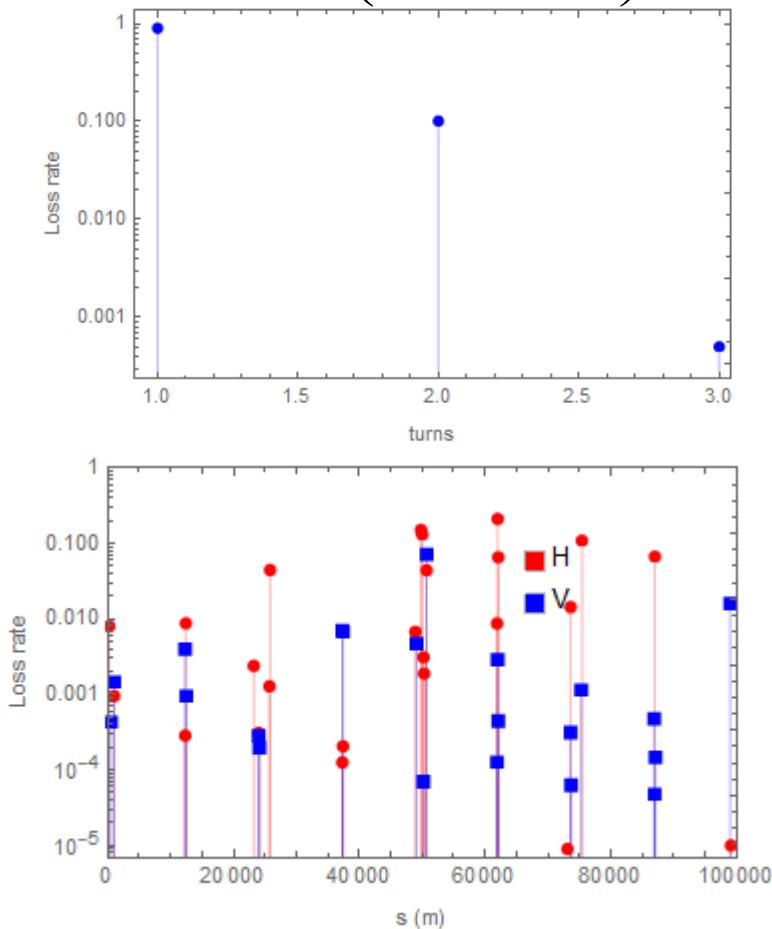
Higgs – RF failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



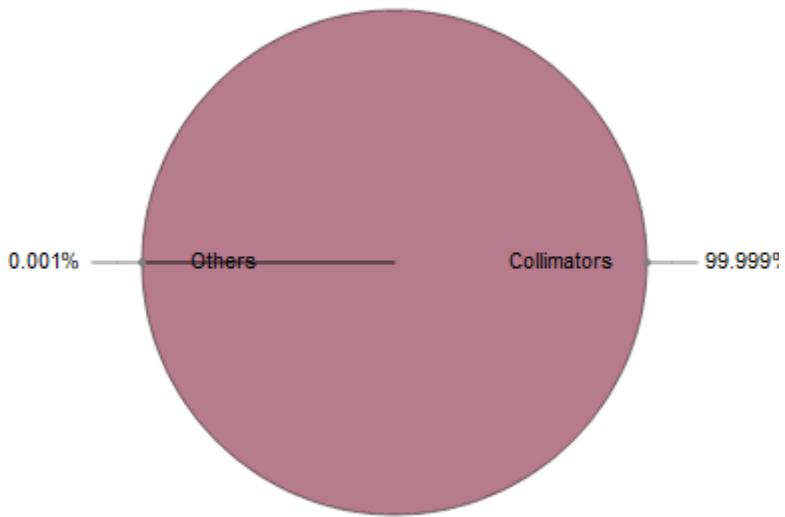
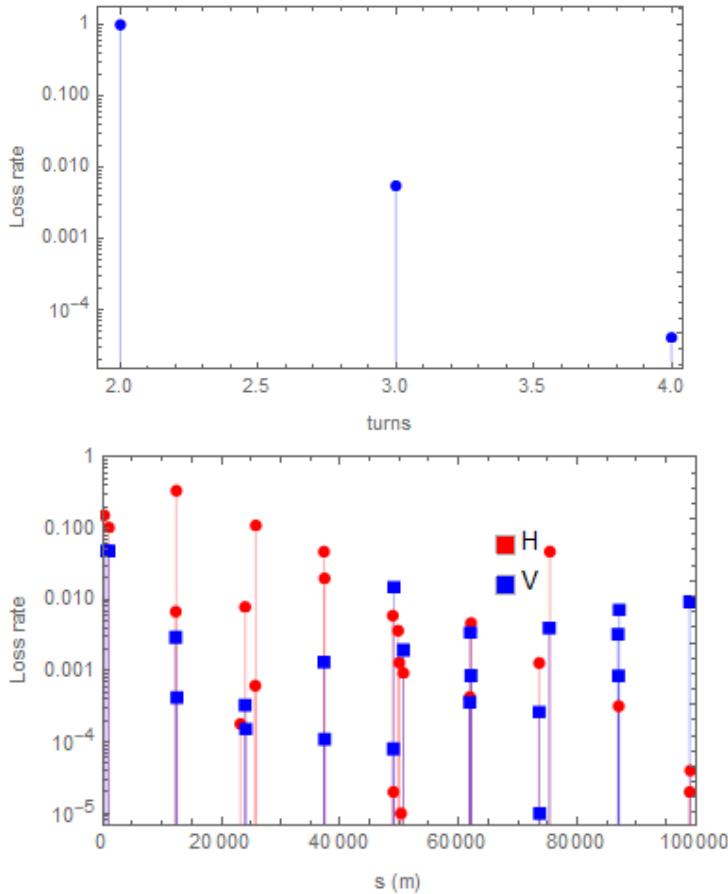
Higgs – B failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



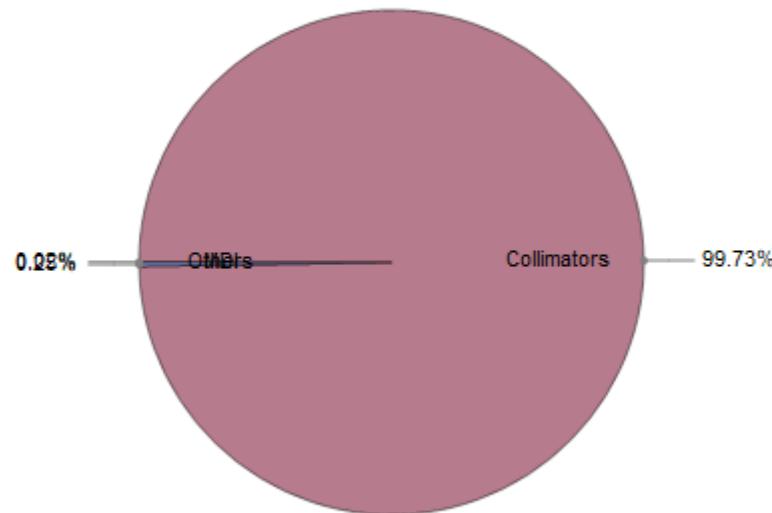
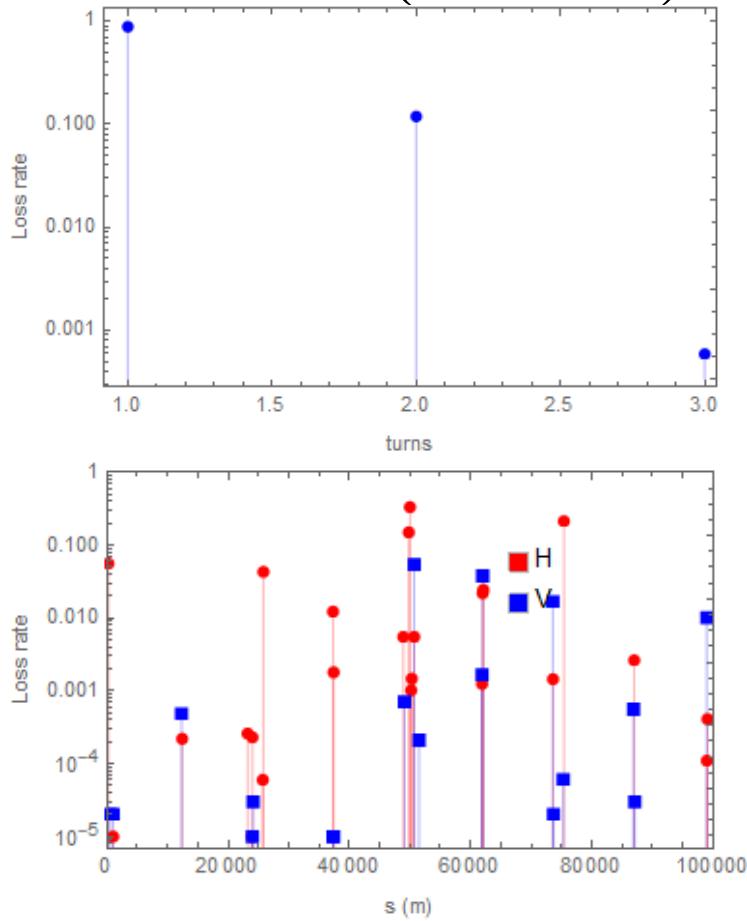
Higgs – B failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



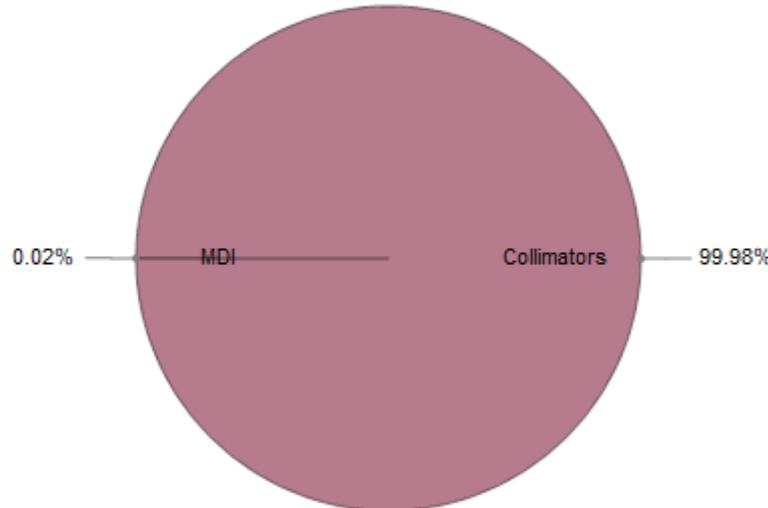
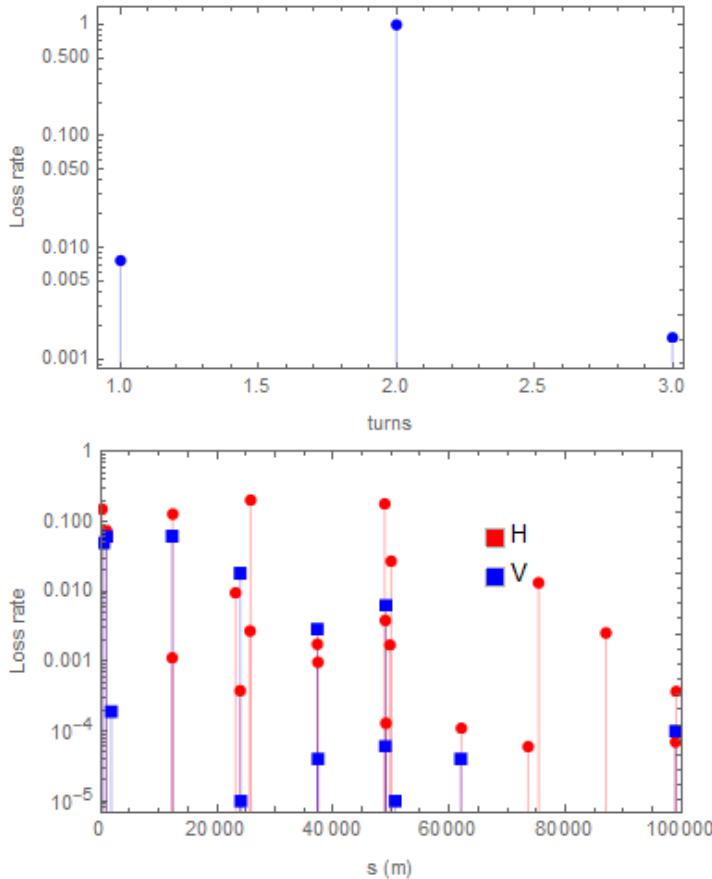
Higgs – B failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



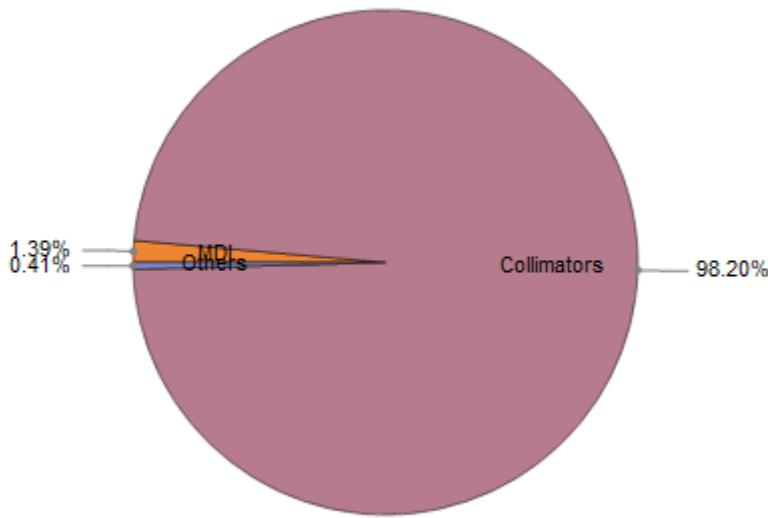
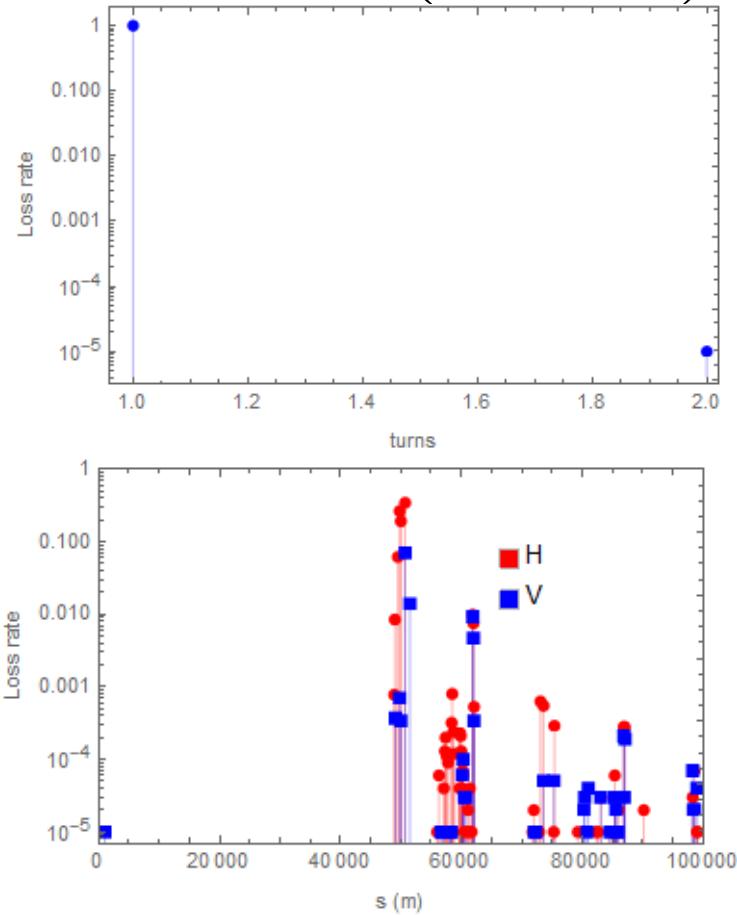
Higgs – B failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



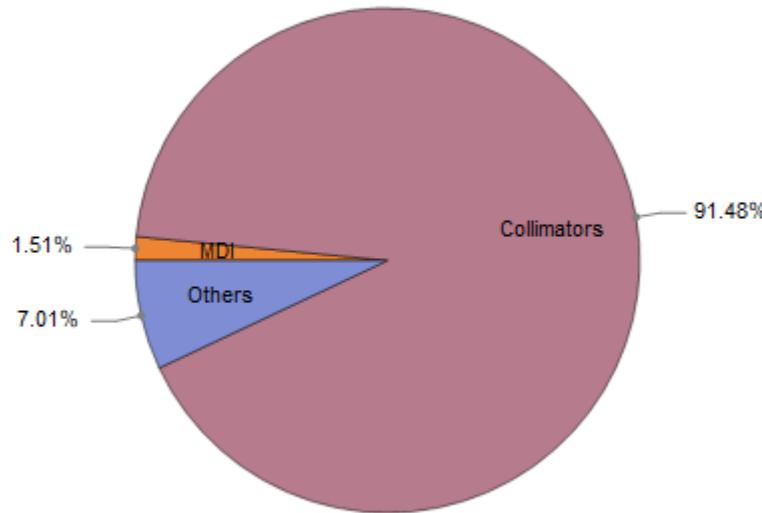
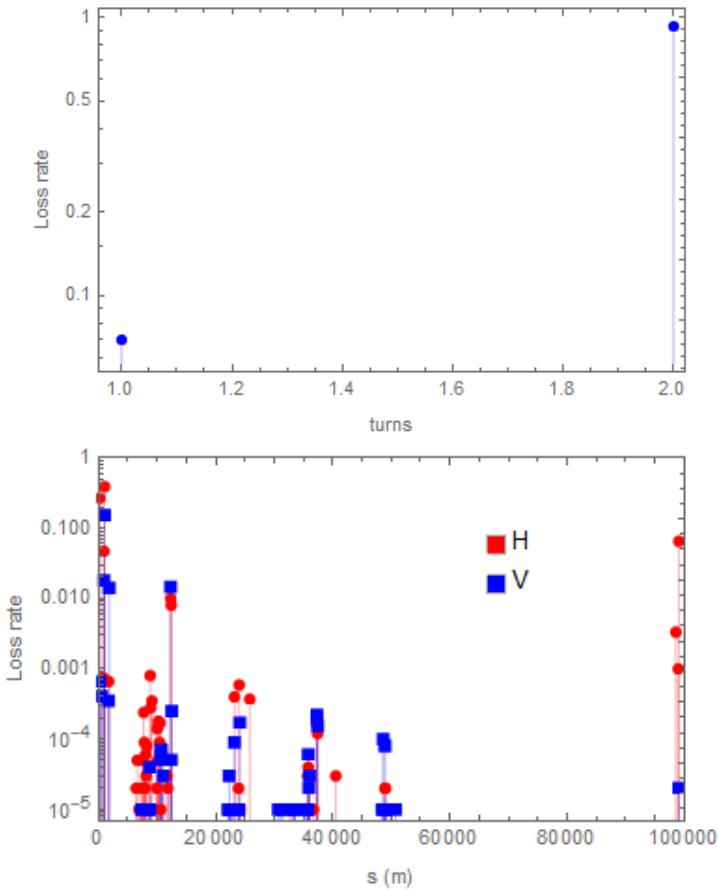
Higgs – NorQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



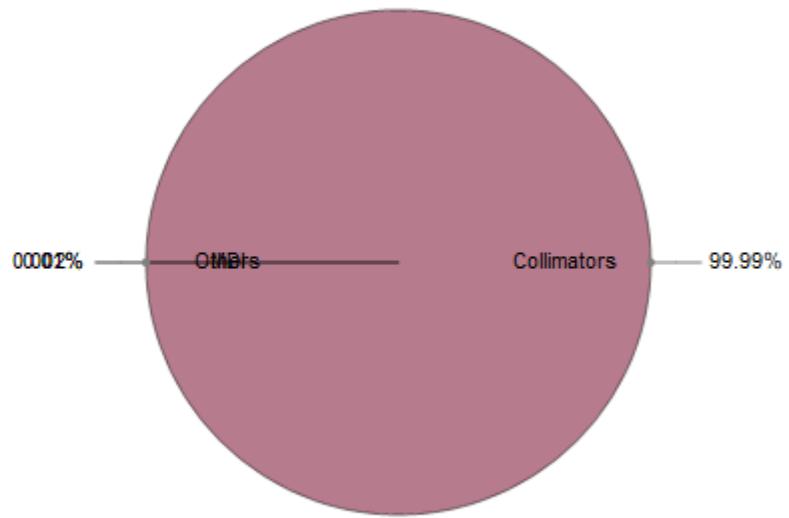
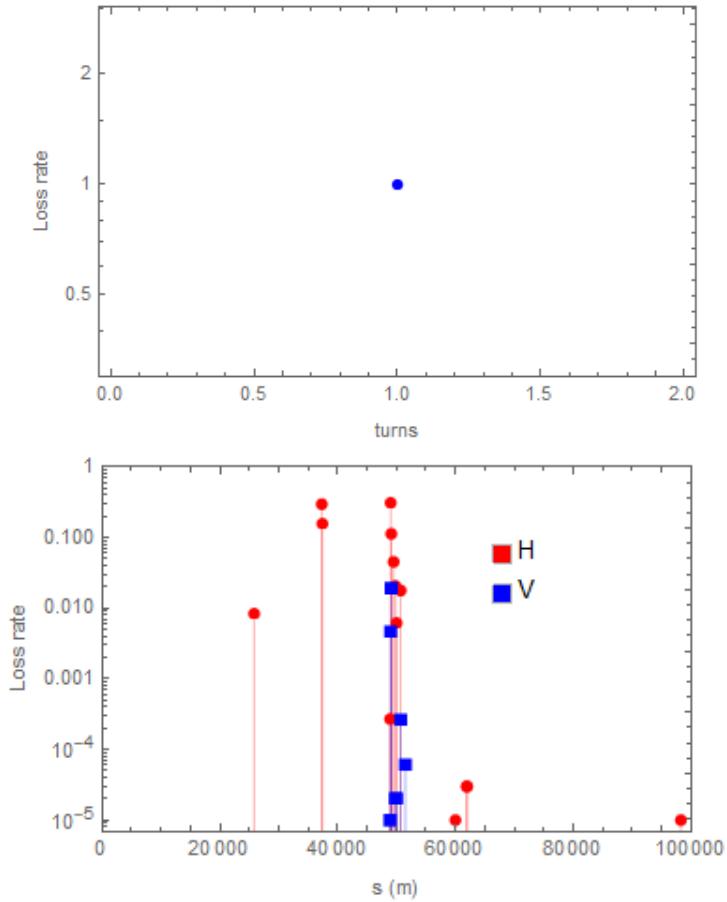
Higgs – NorQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



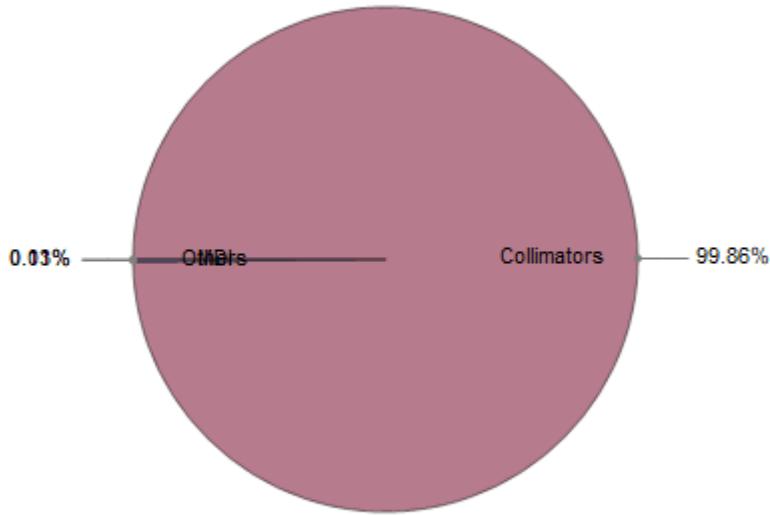
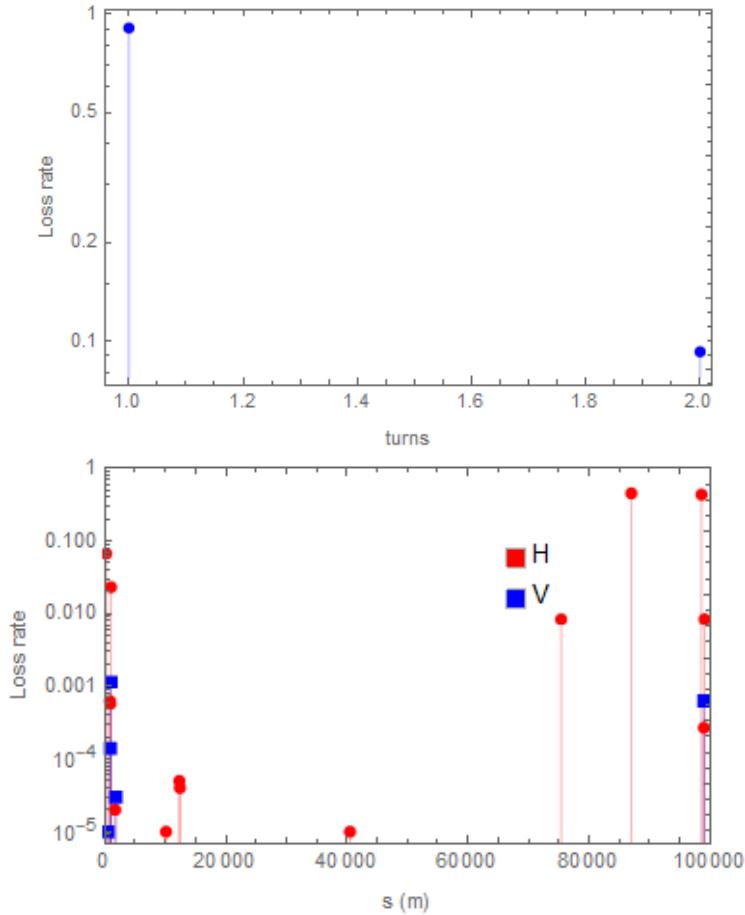
Higgs – NorQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



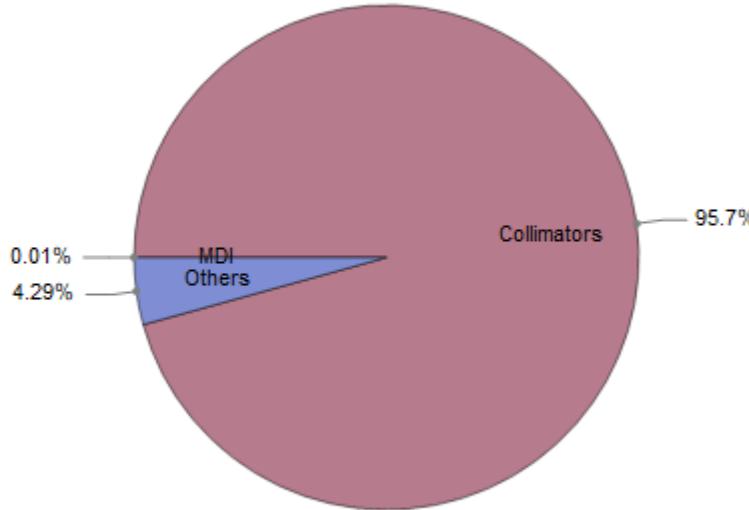
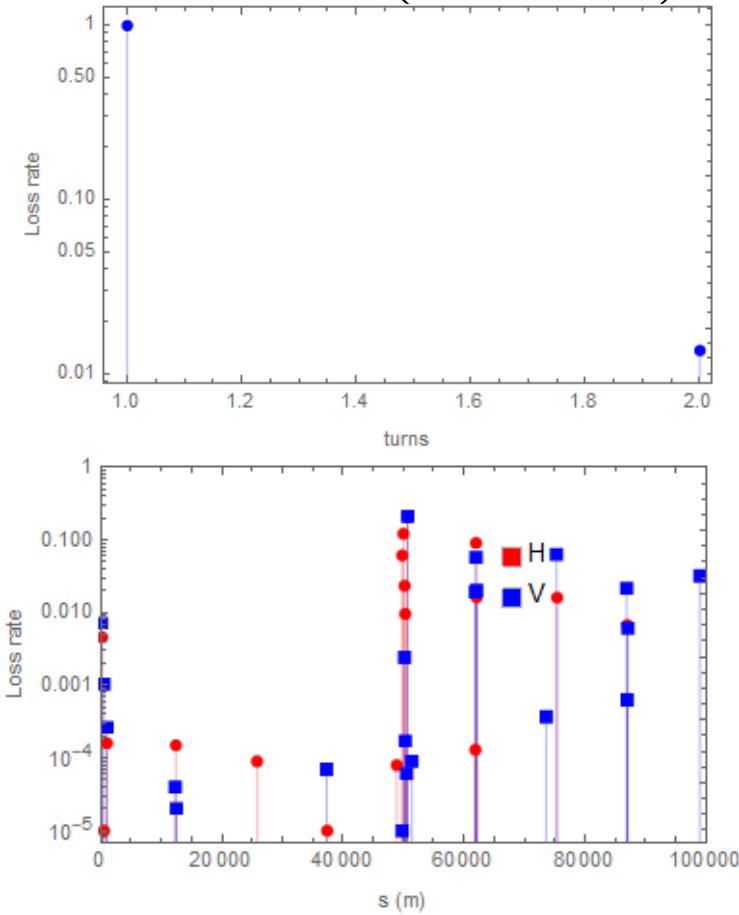
Higgs – NorQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



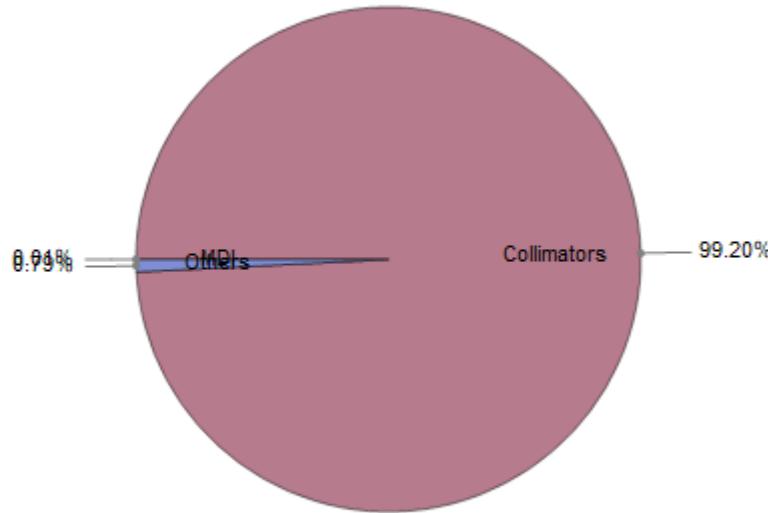
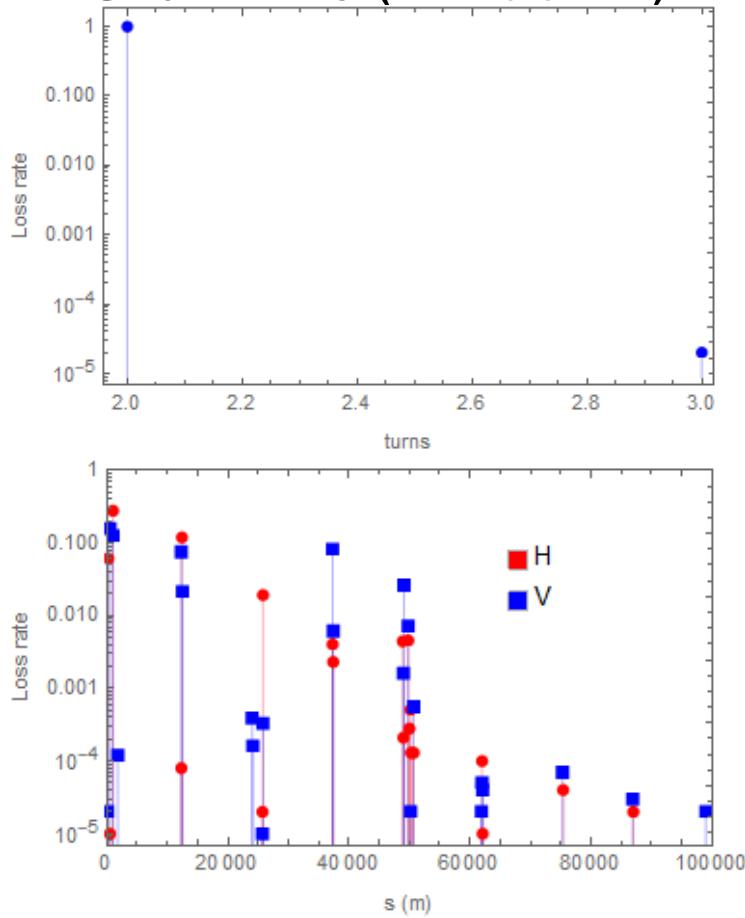
Higgs – SCQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



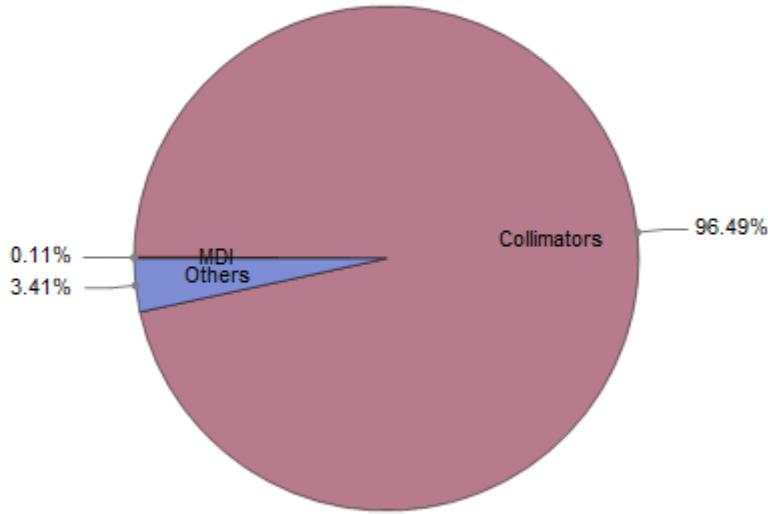
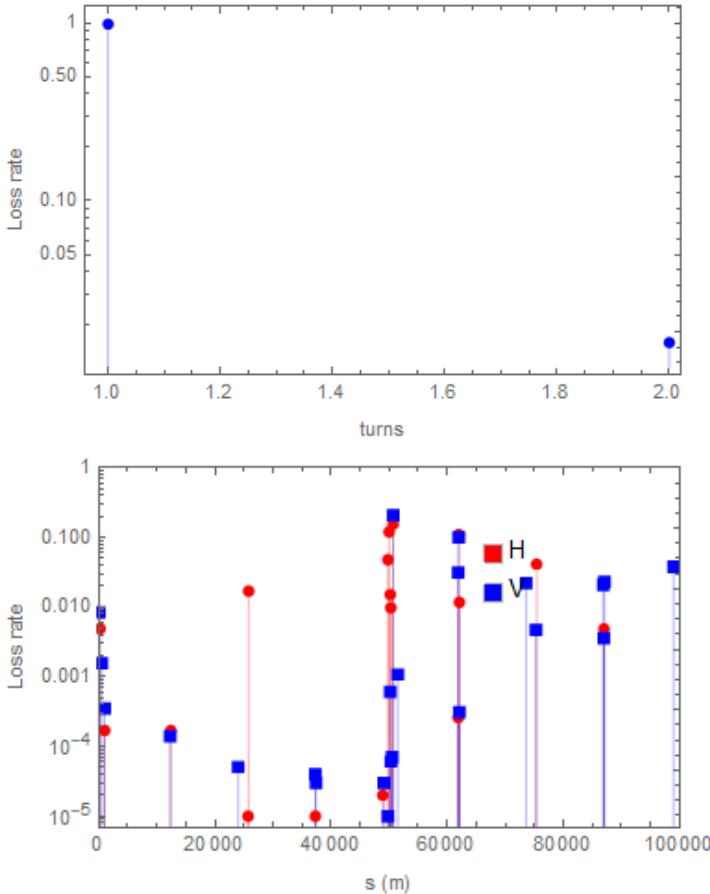
Higgs – SCQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



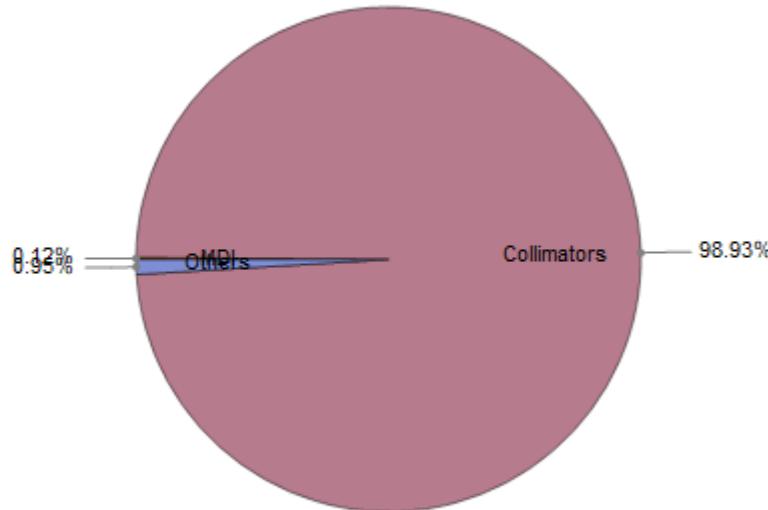
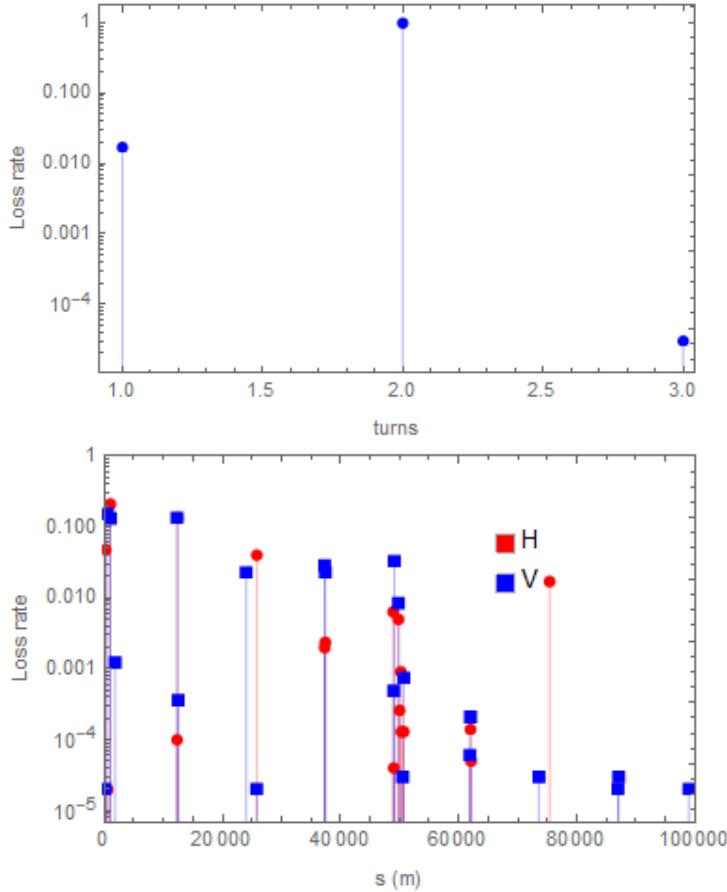
Higgs – SCQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



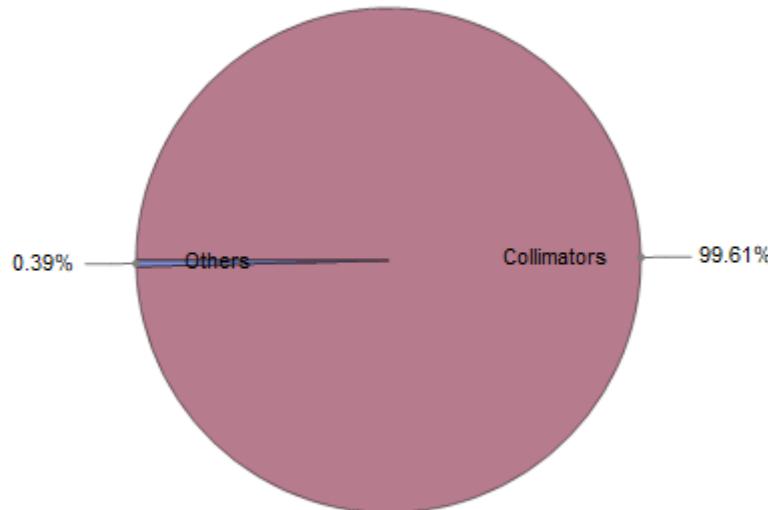
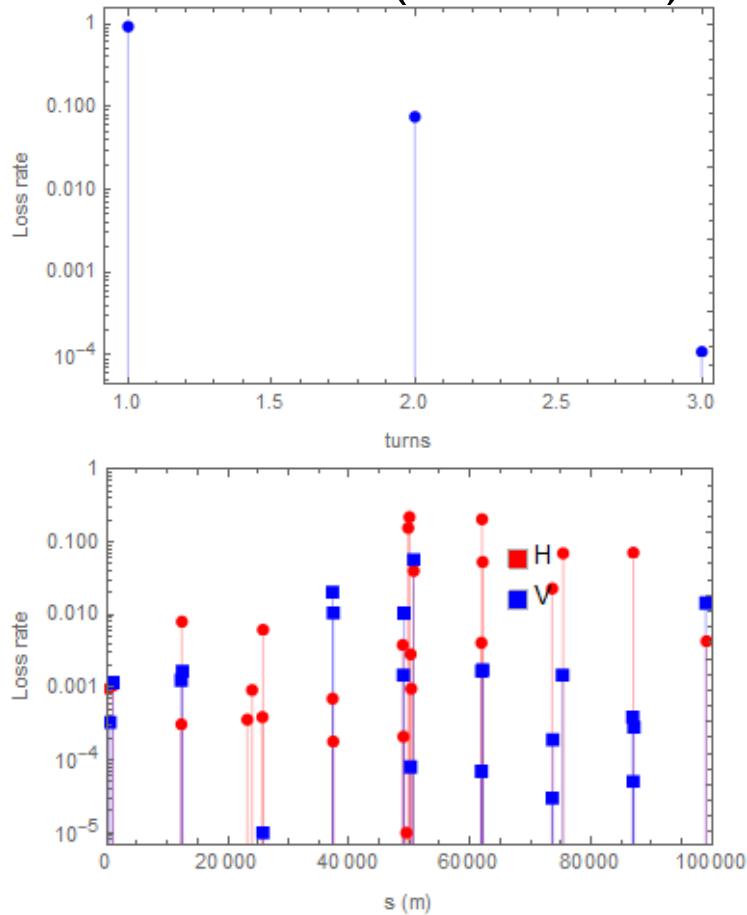
Higgs – SCQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



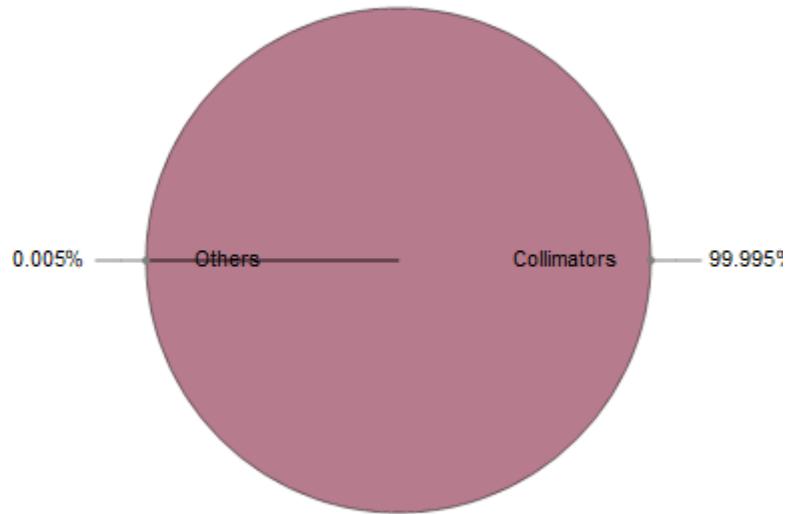
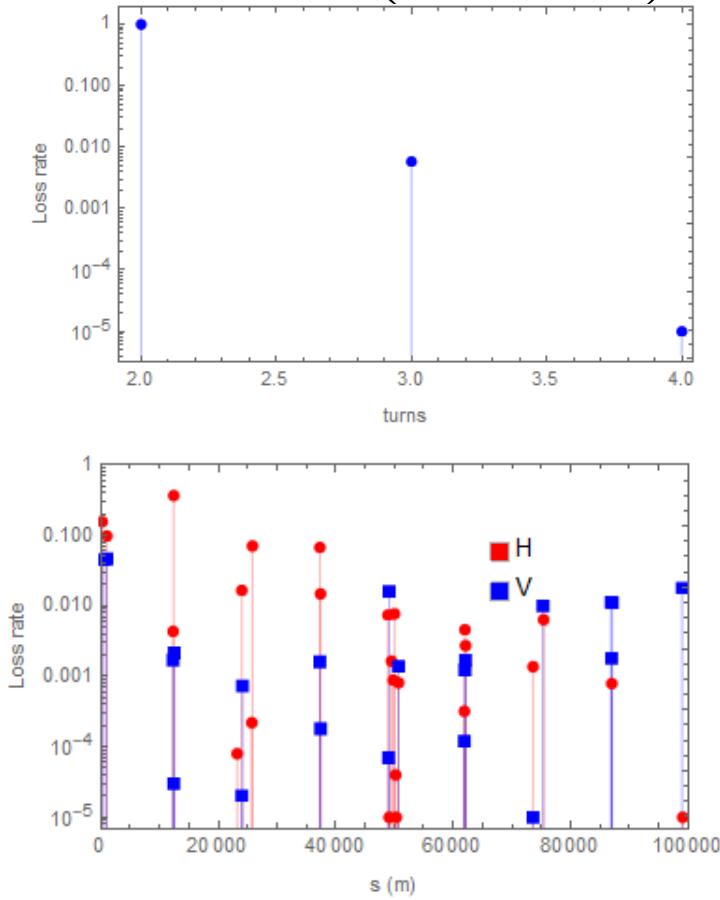
Higgs – S failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



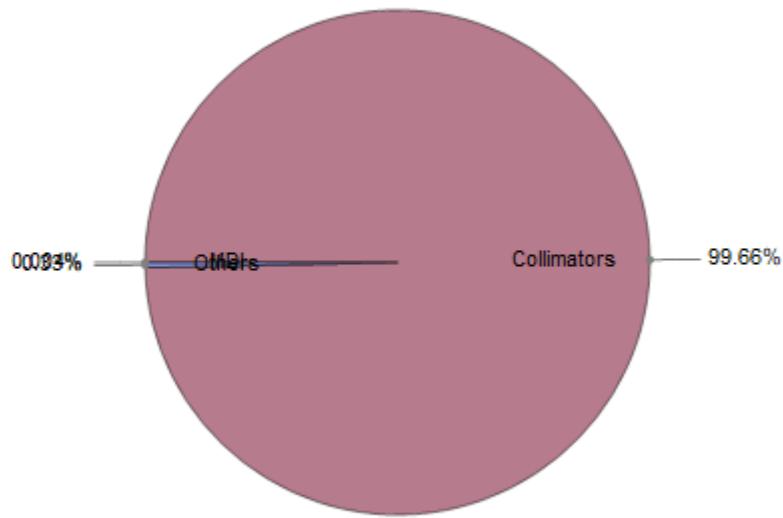
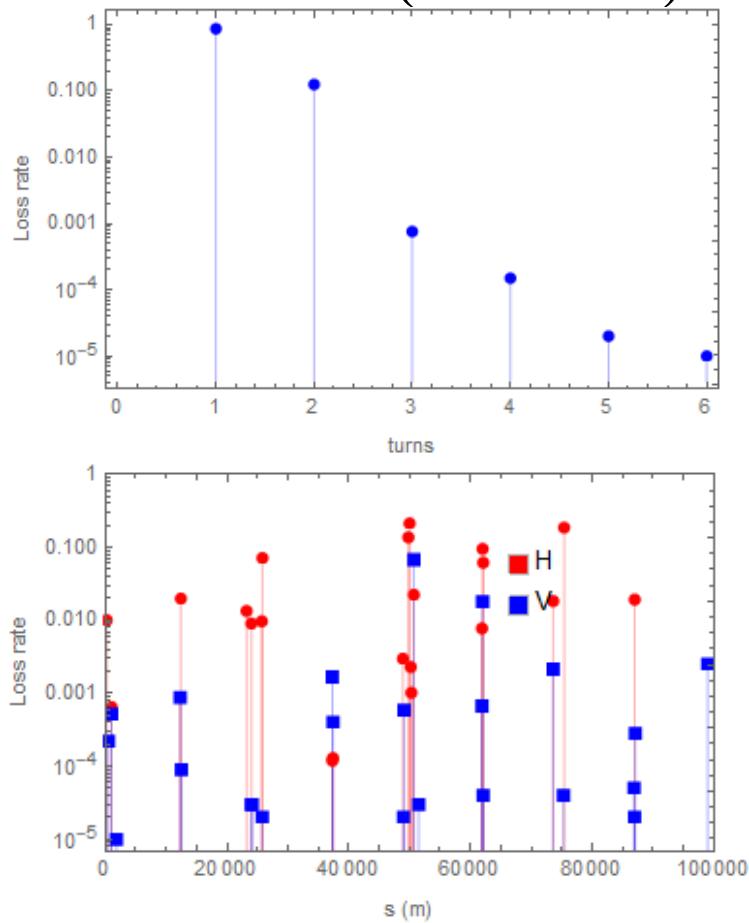
Higgs – S failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



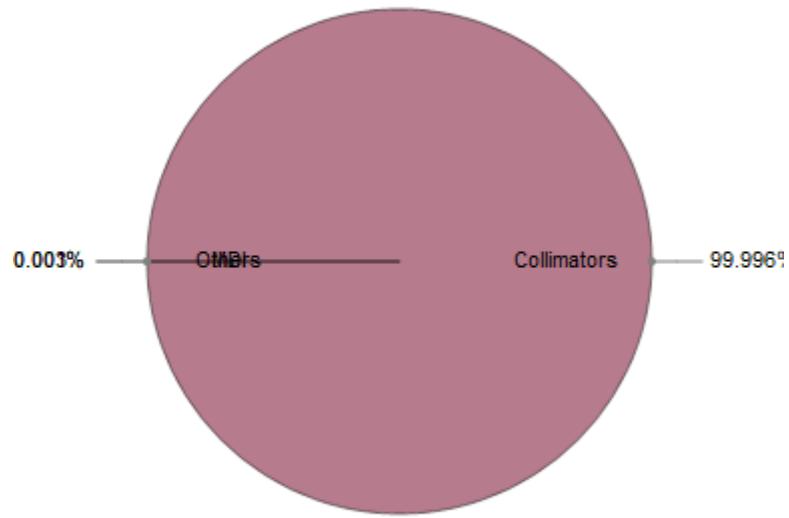
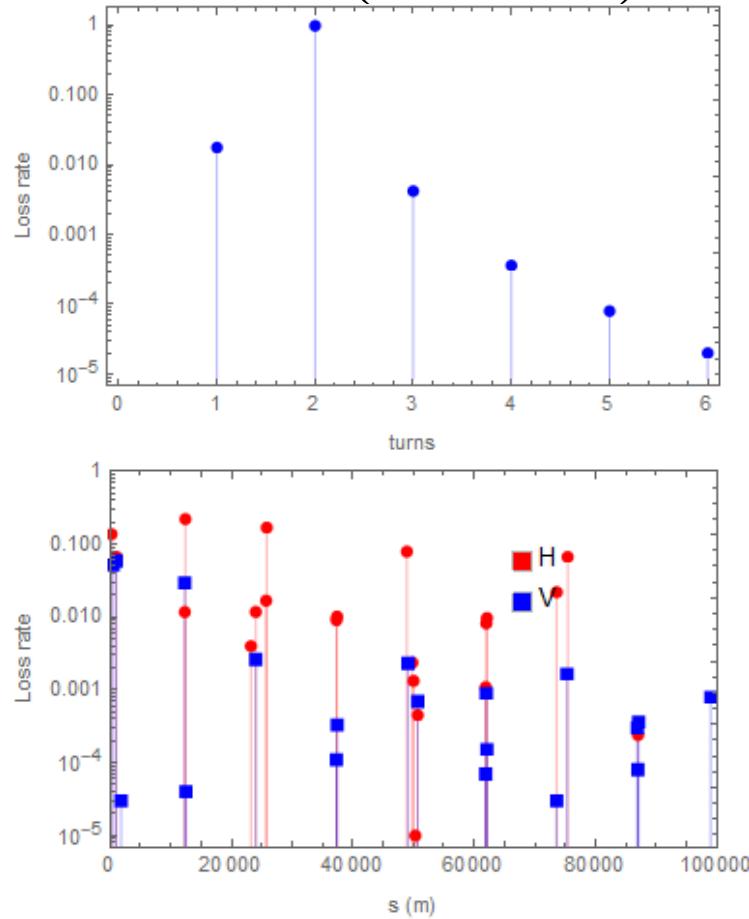
Higgs – S failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



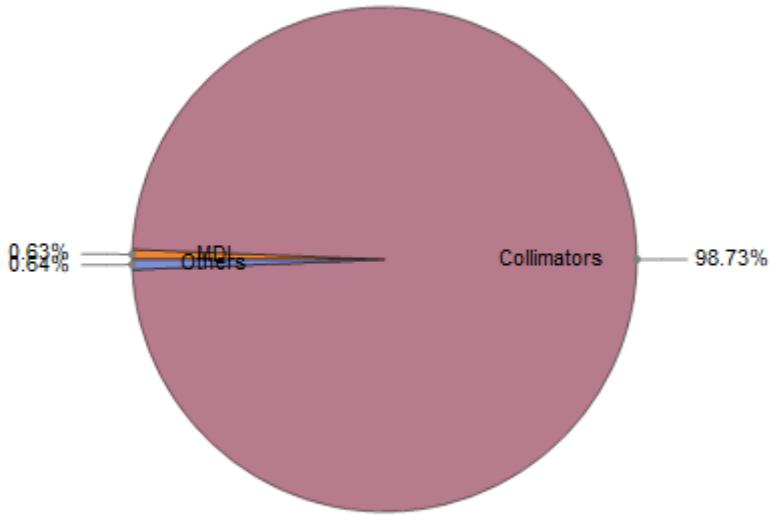
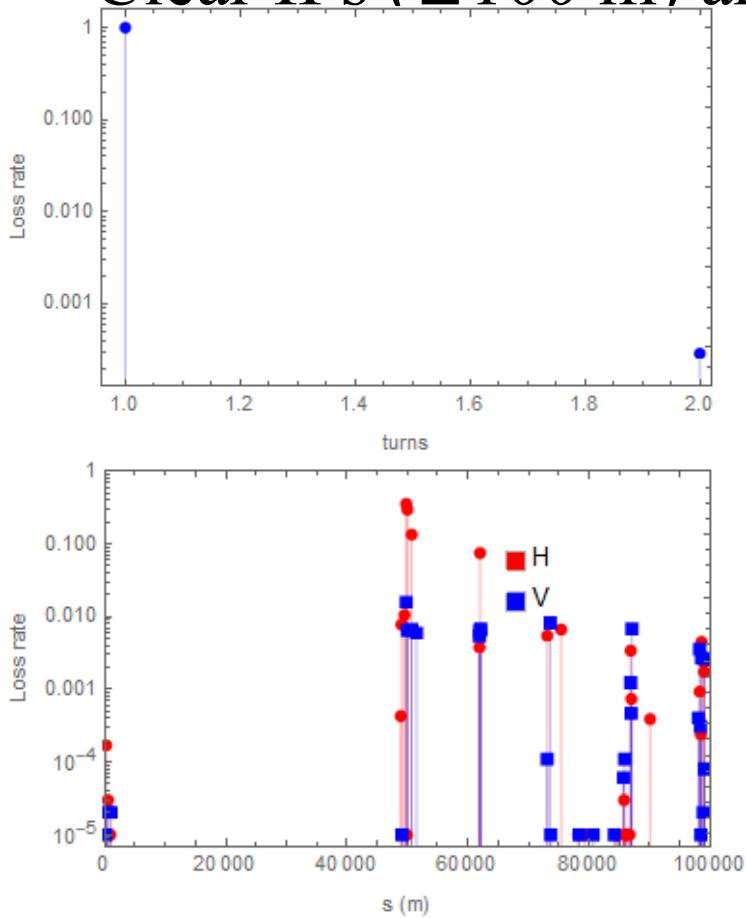
Higgs – S failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



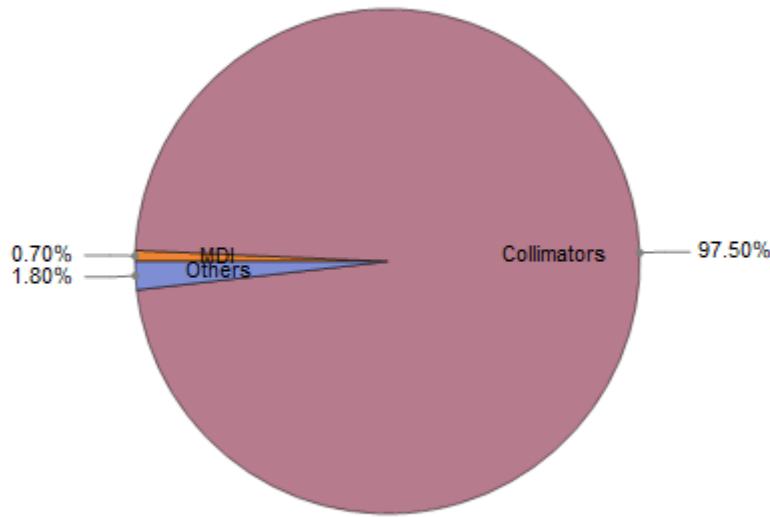
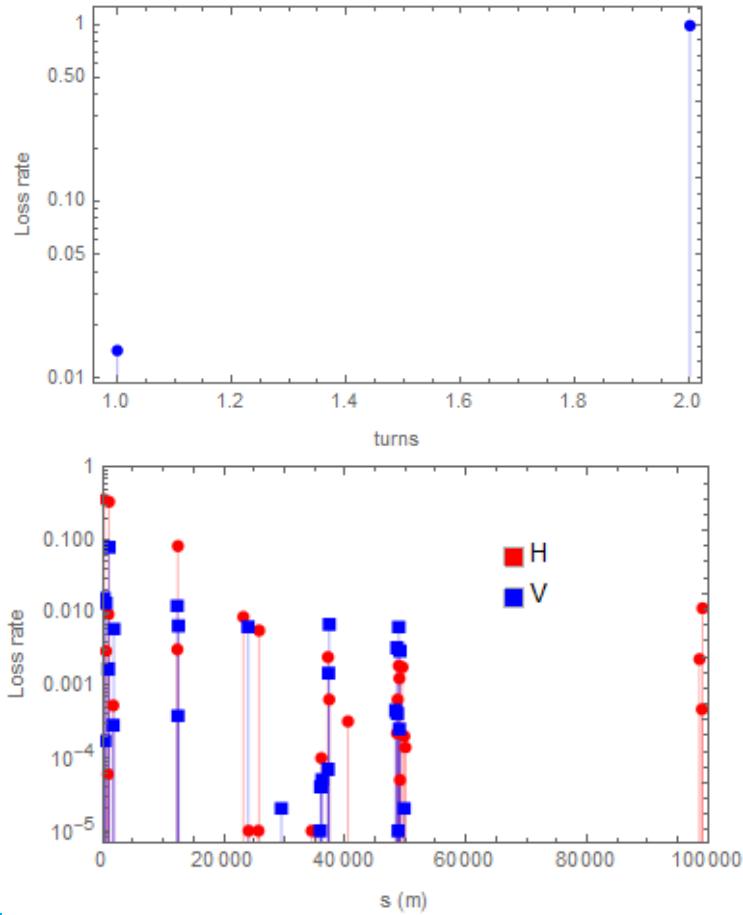
Higgs – All failures

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



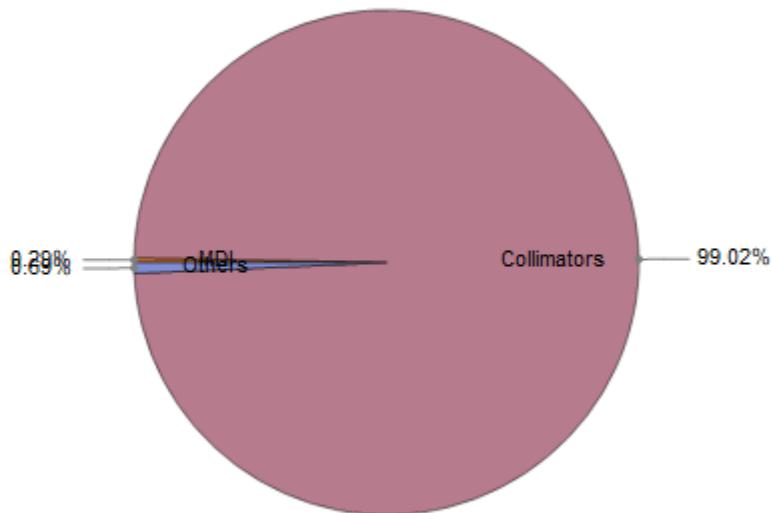
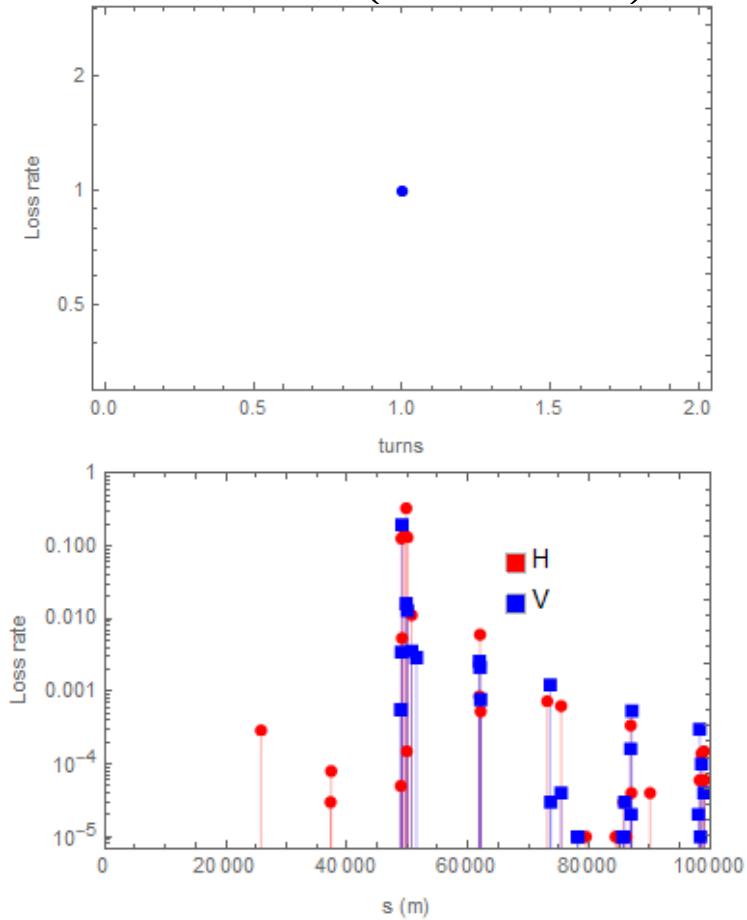
Higgs – All failures

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



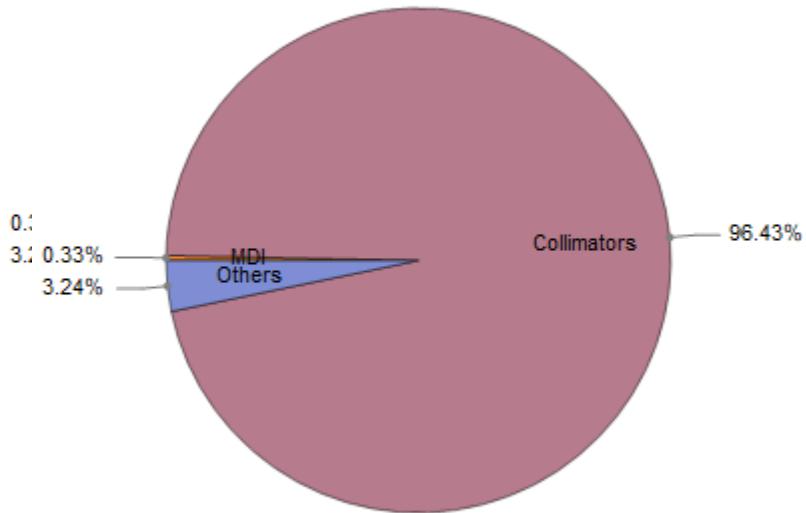
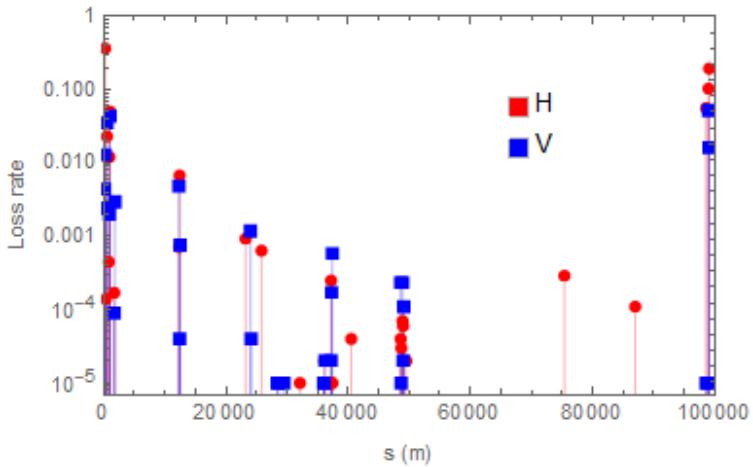
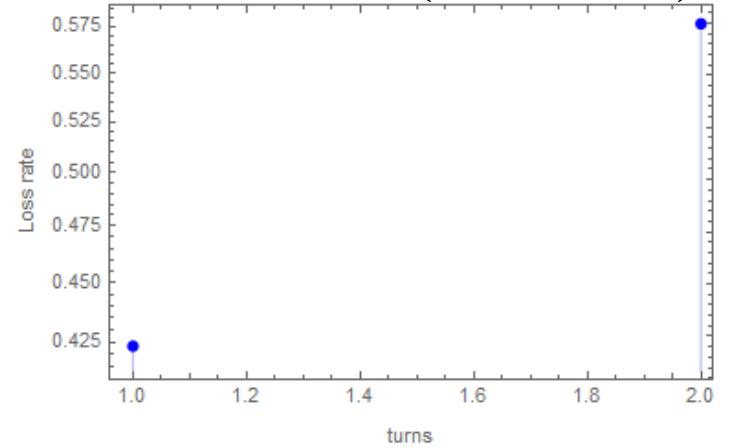
Higgs – All failures

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



Higgs – All failures

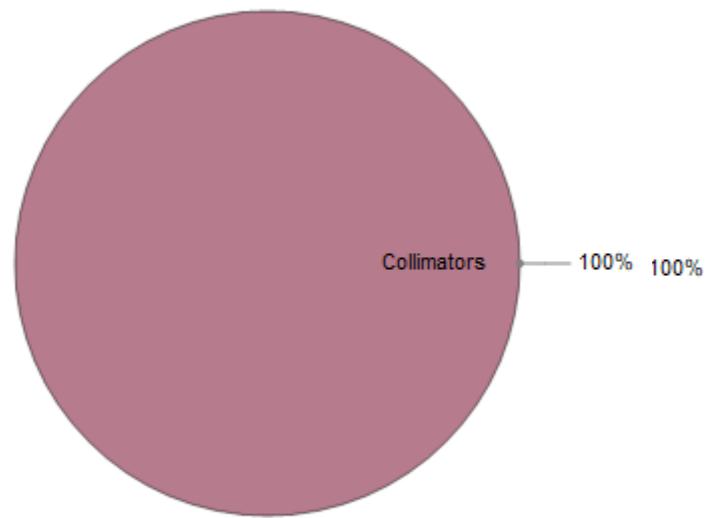
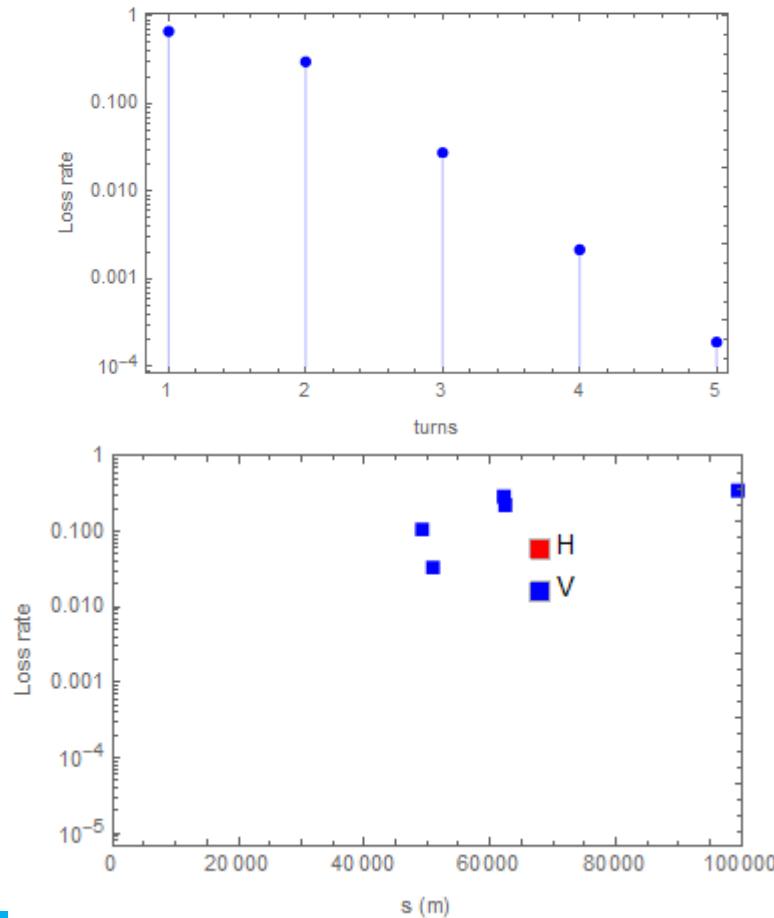
- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



Z mode

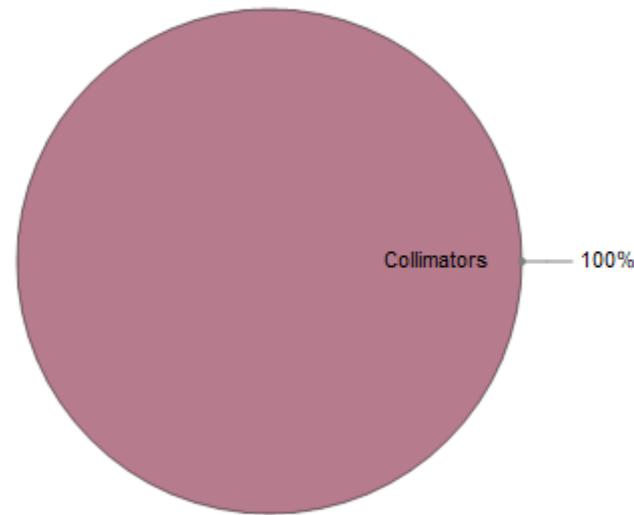
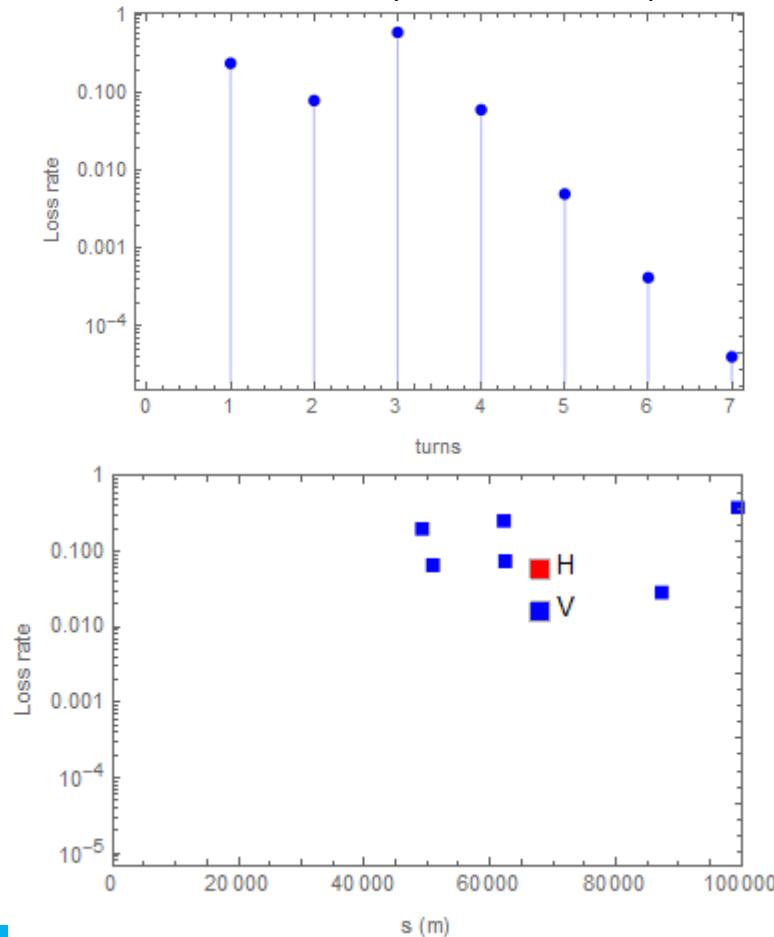
Z – RF failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



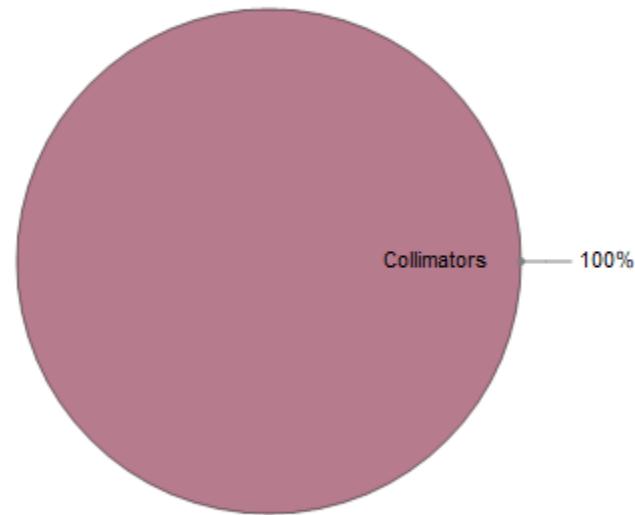
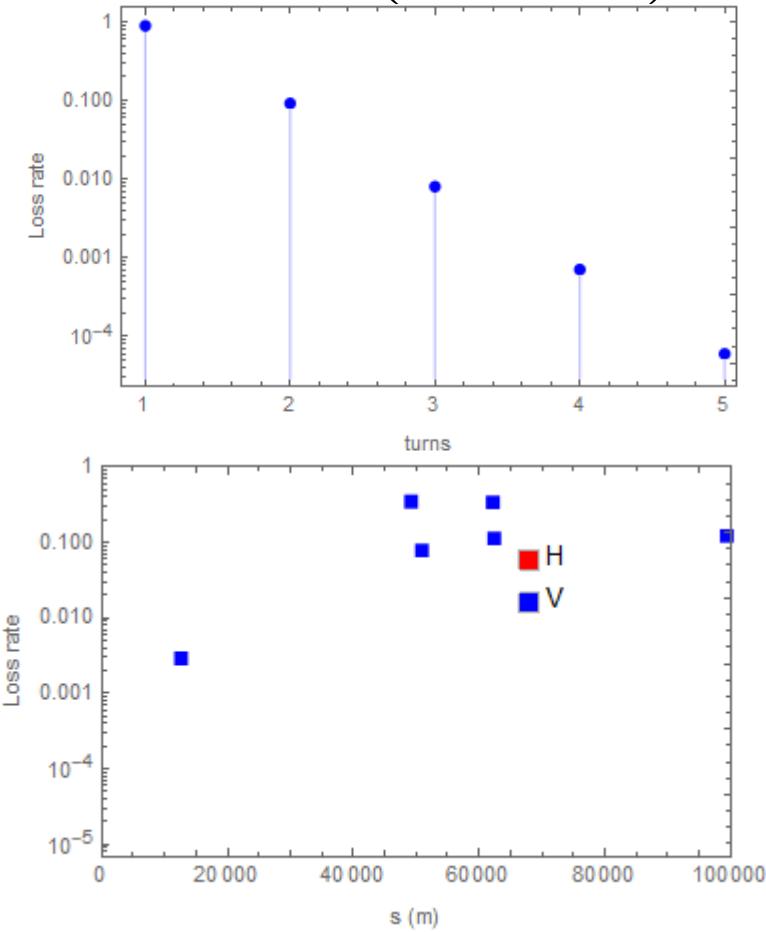
Z – RF failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



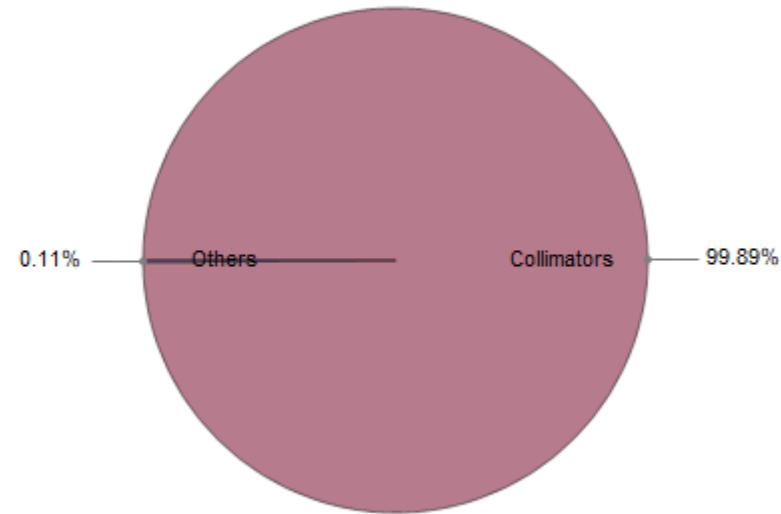
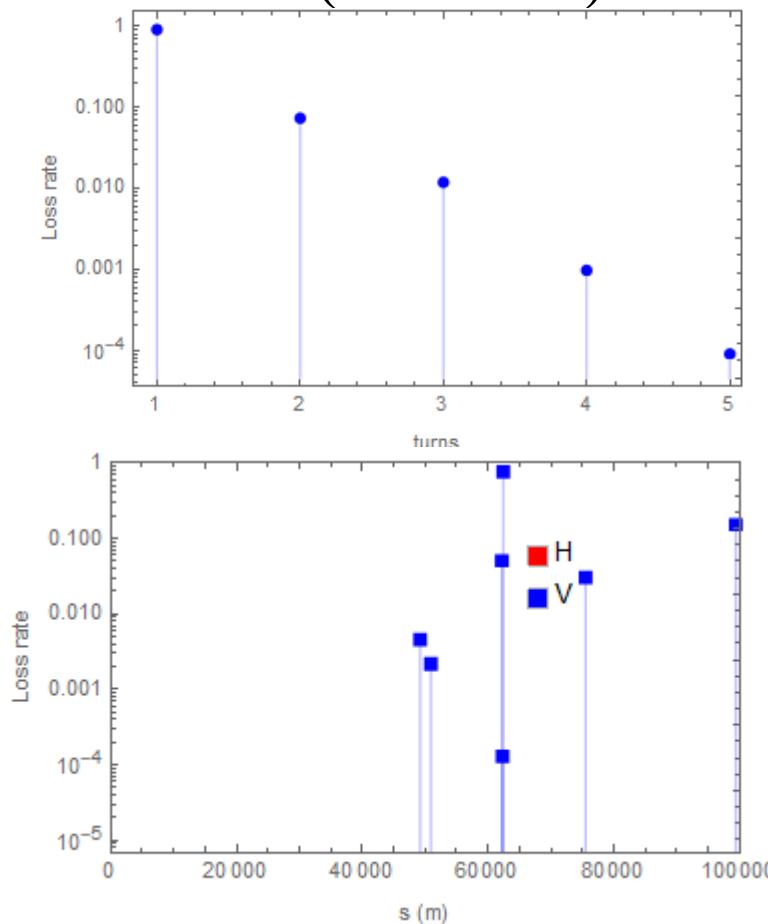
Z- RF failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



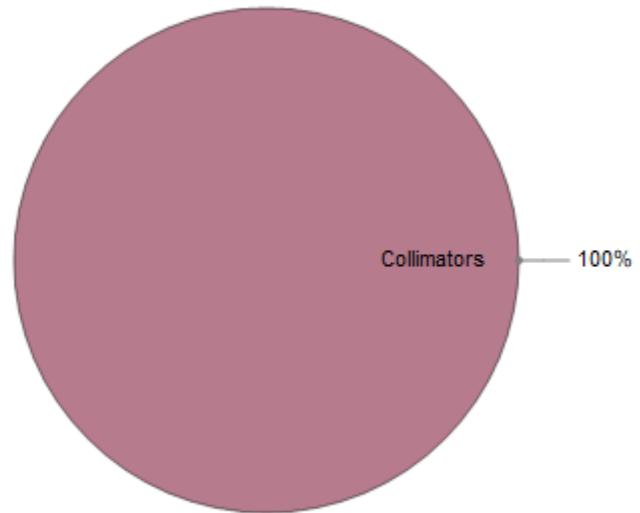
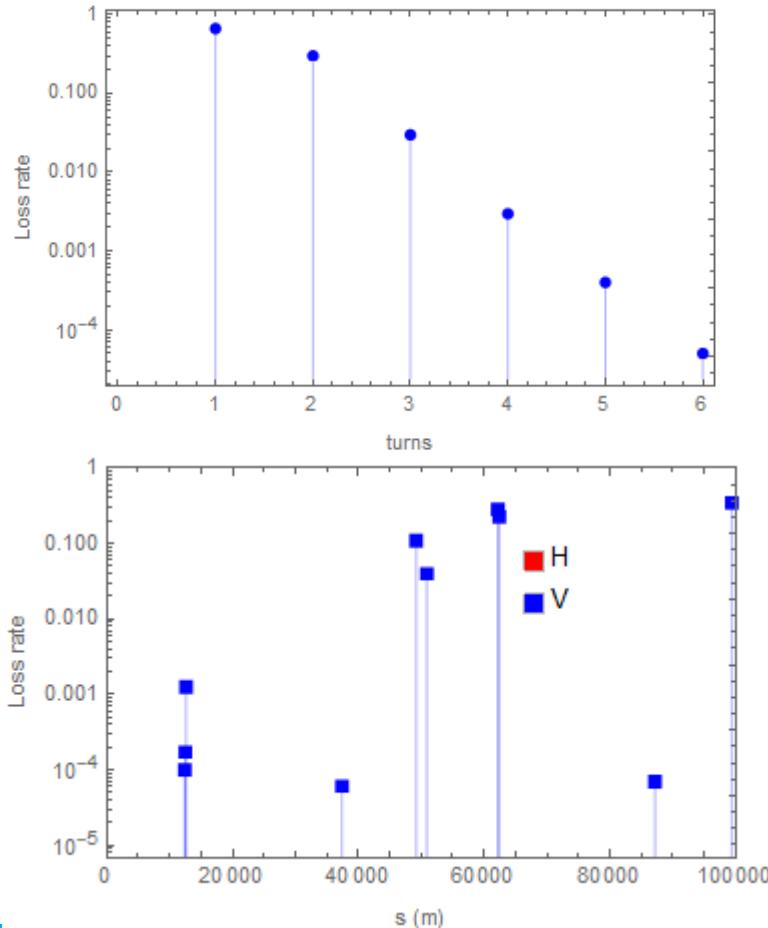
Z- RF failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



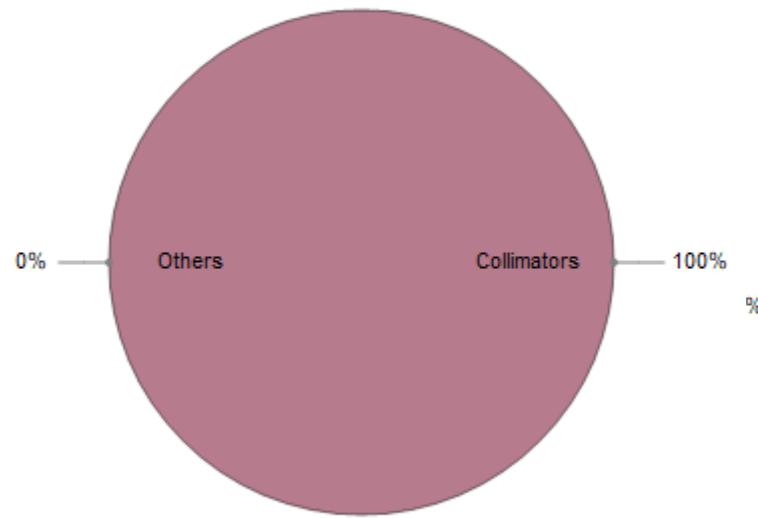
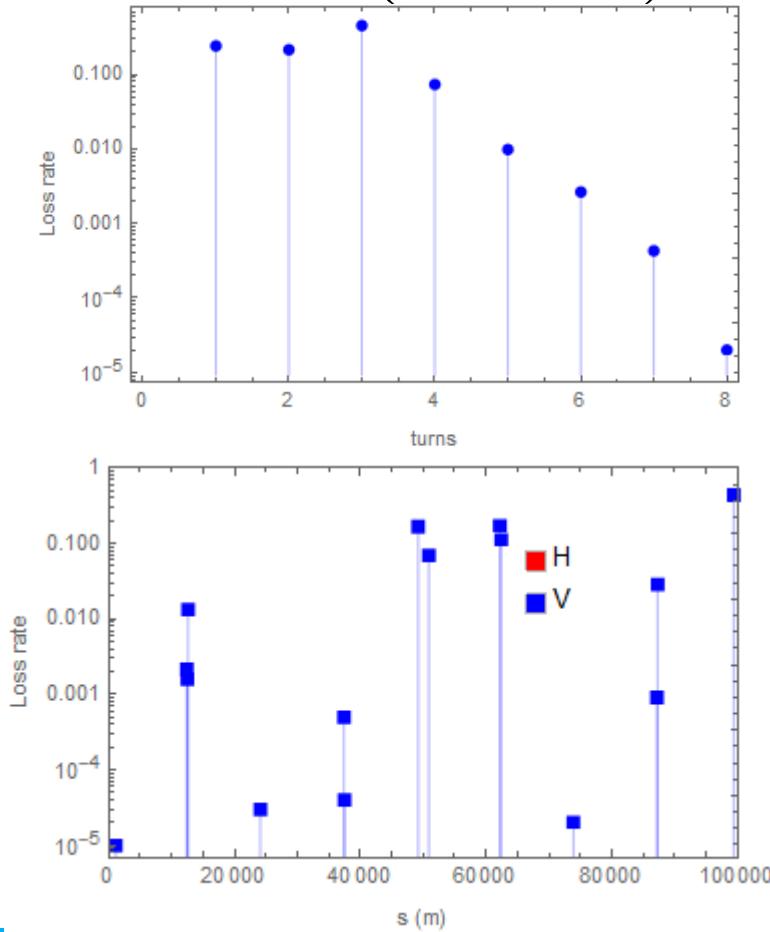
Z- B failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



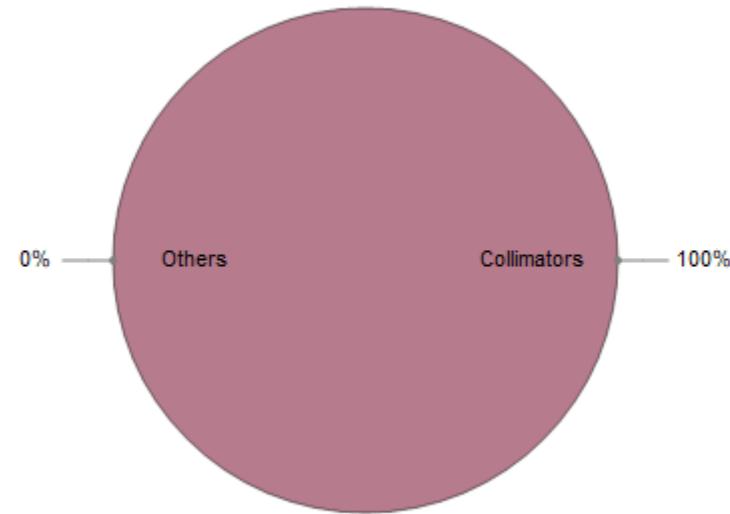
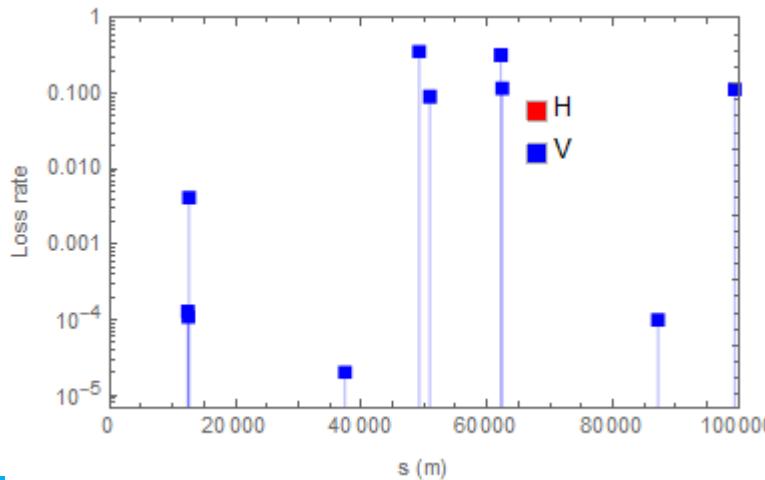
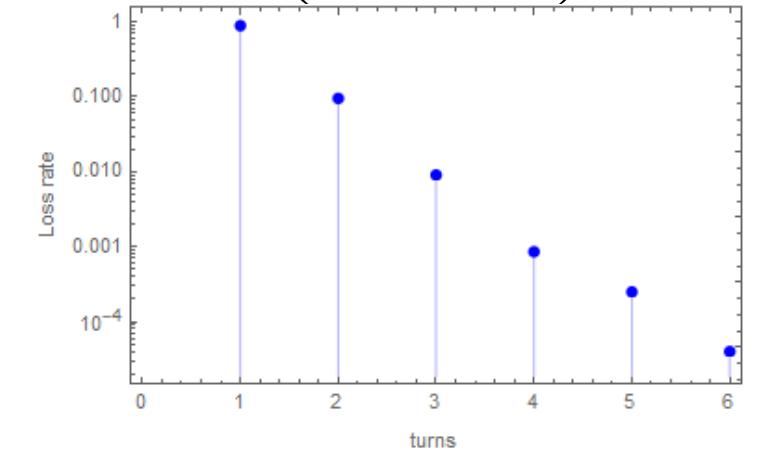
Z- B failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



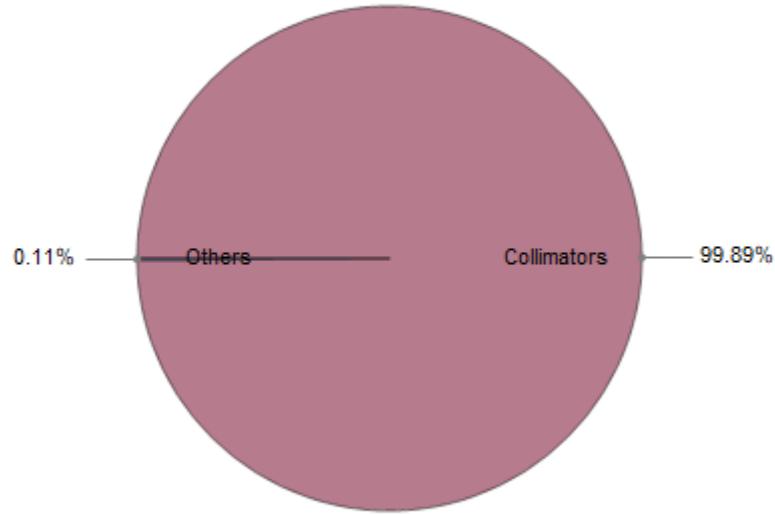
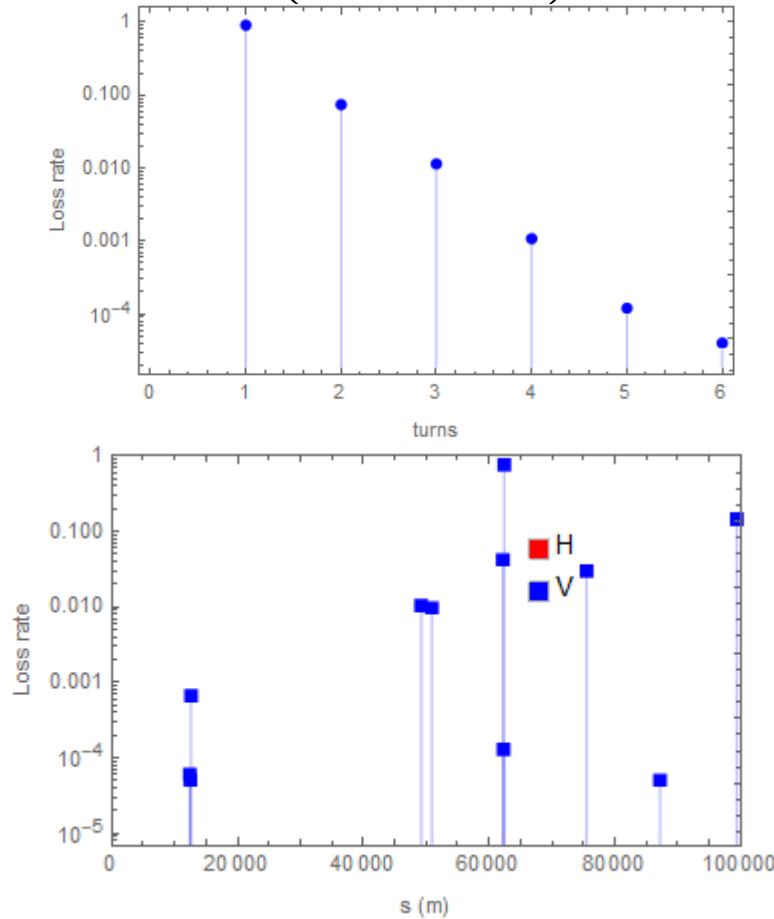
Z- B failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



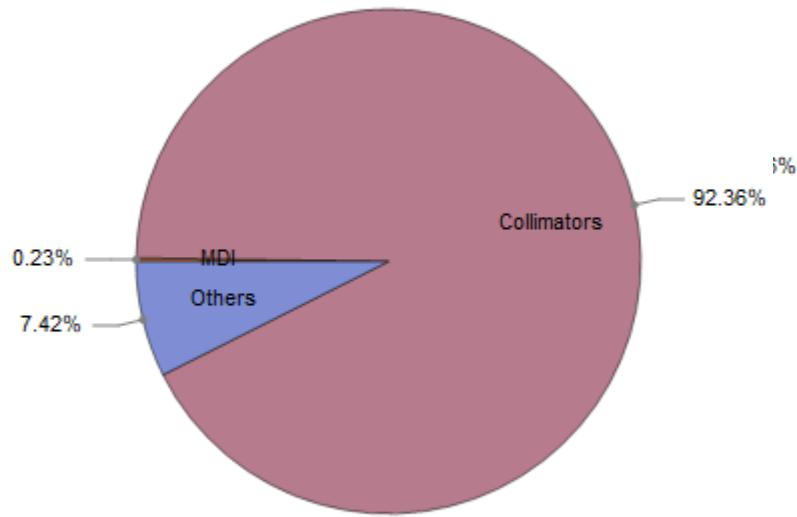
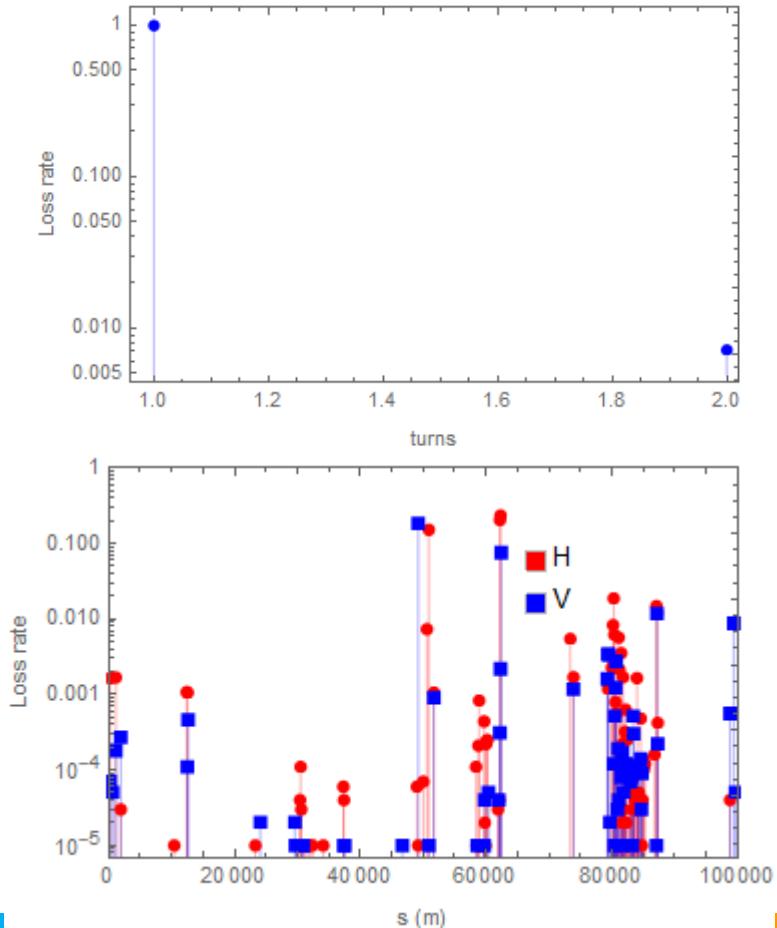
Z- B failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



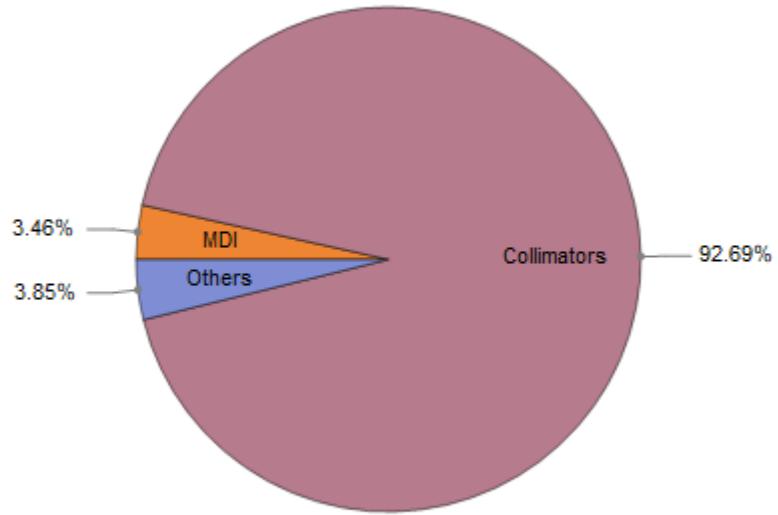
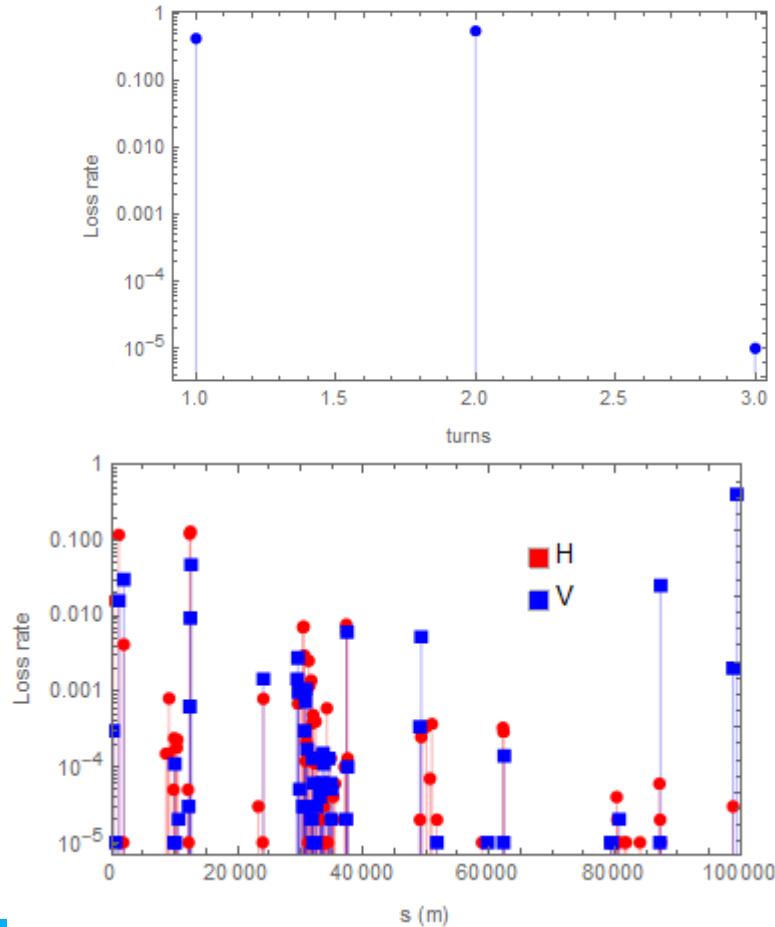
Z- NorQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



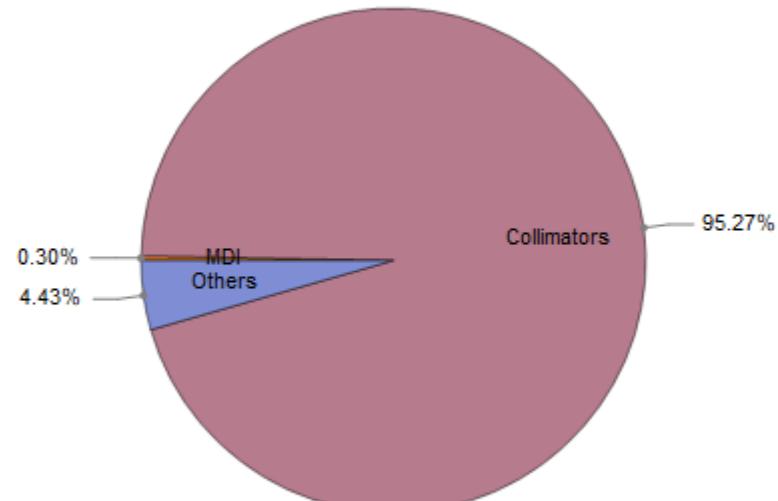
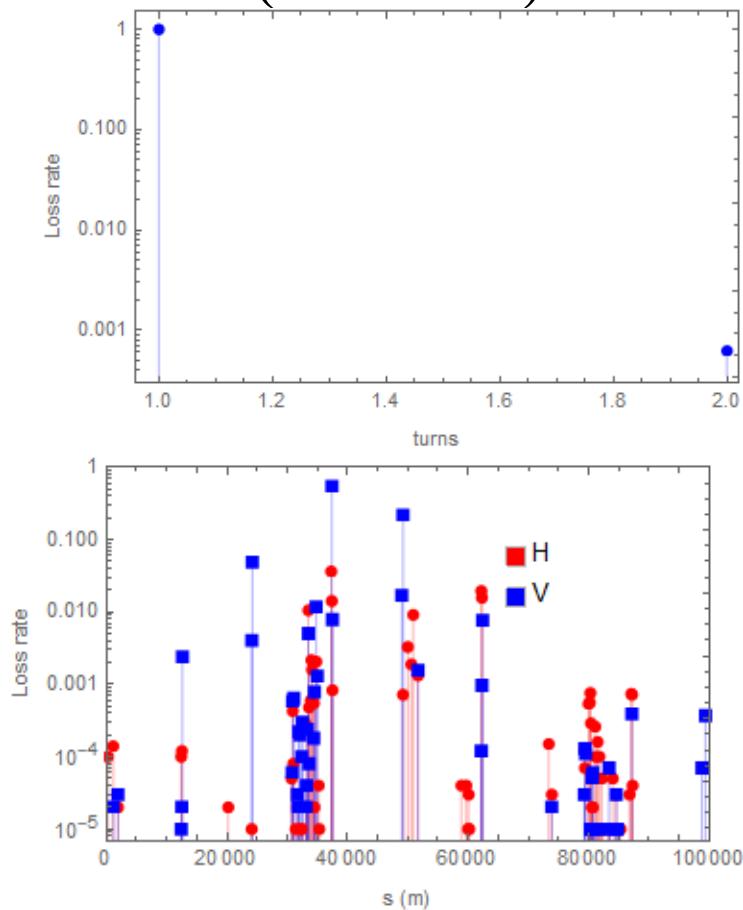
Z- NorQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



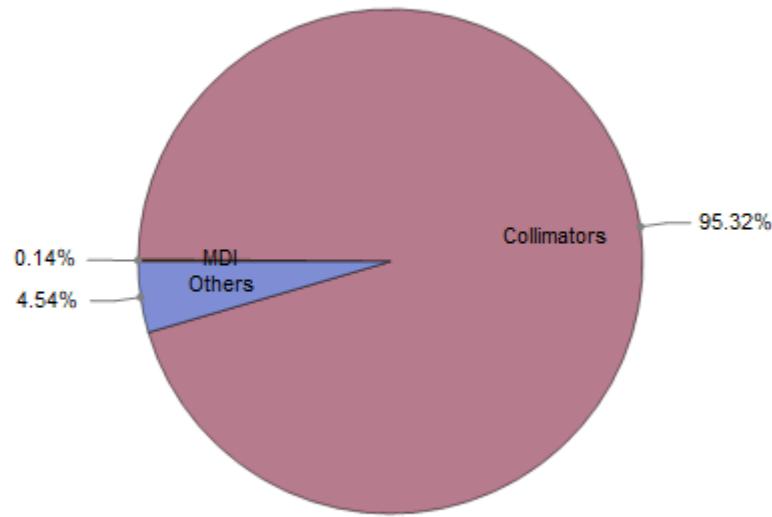
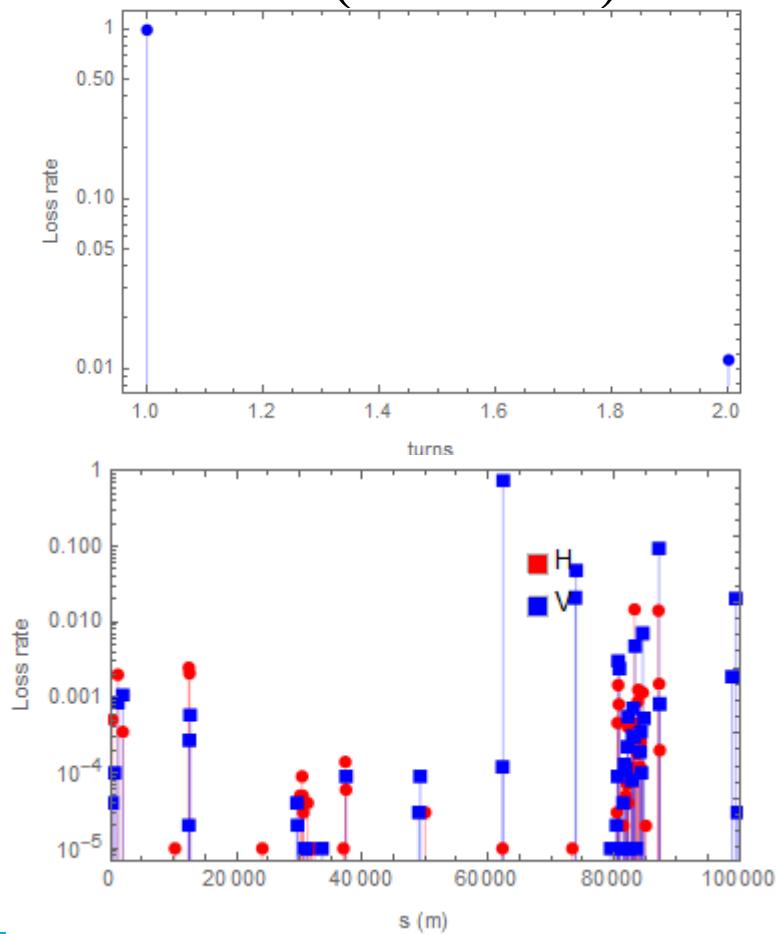
Z- NorQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



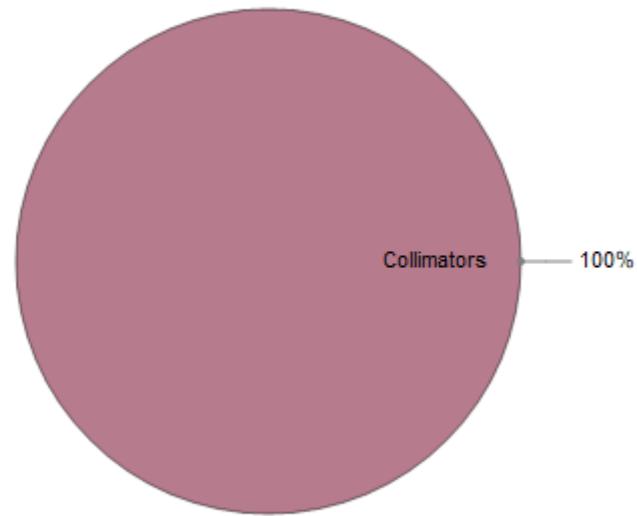
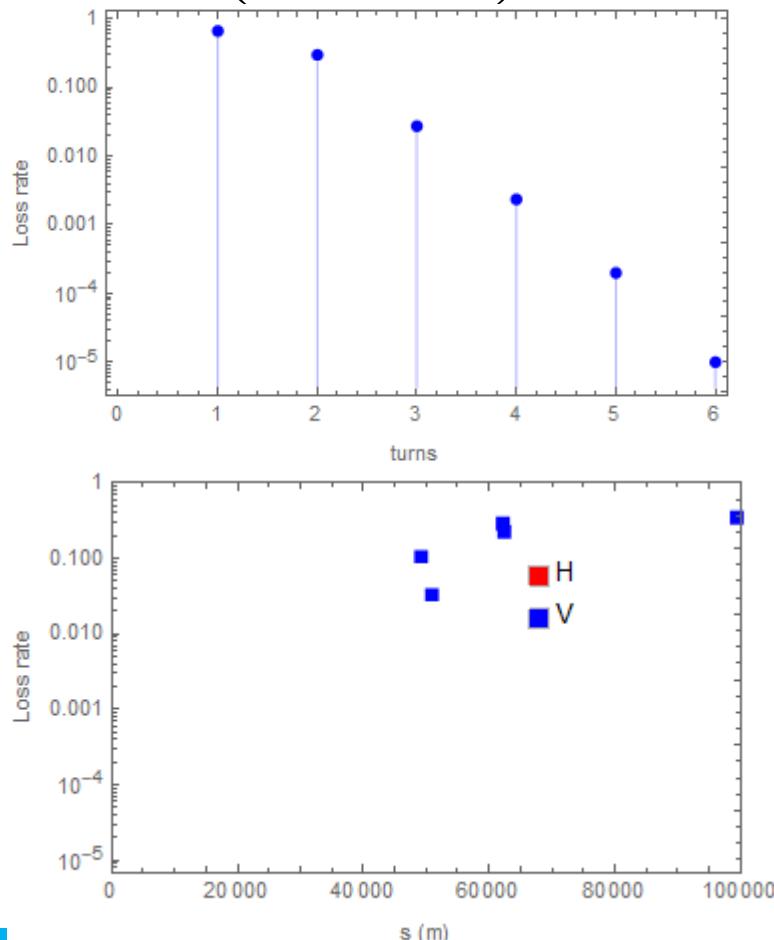
Z- NorQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



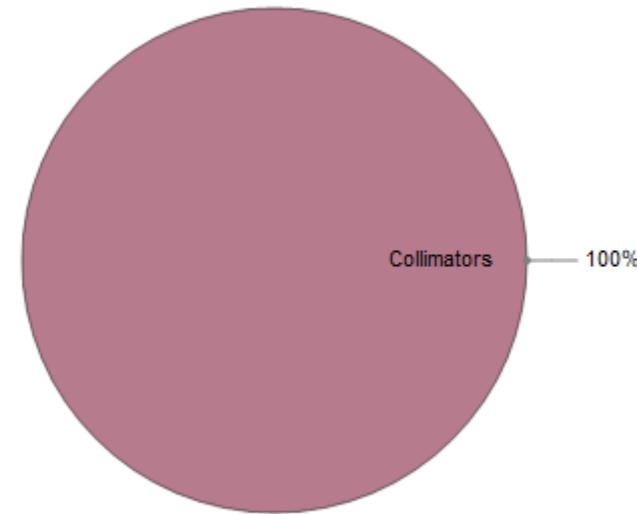
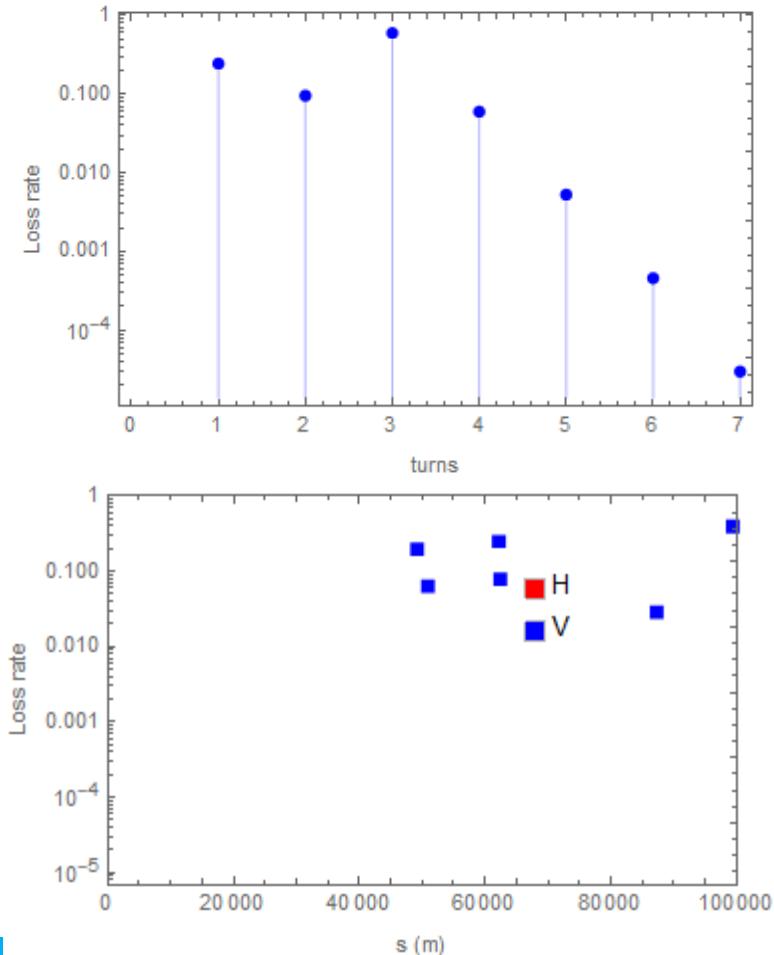
Z- SCQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



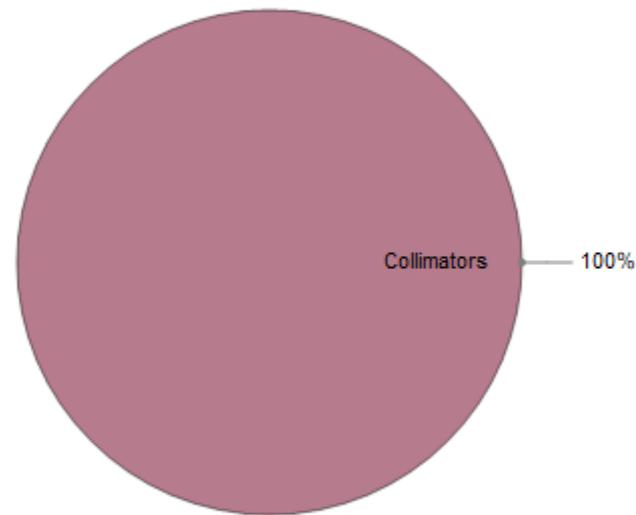
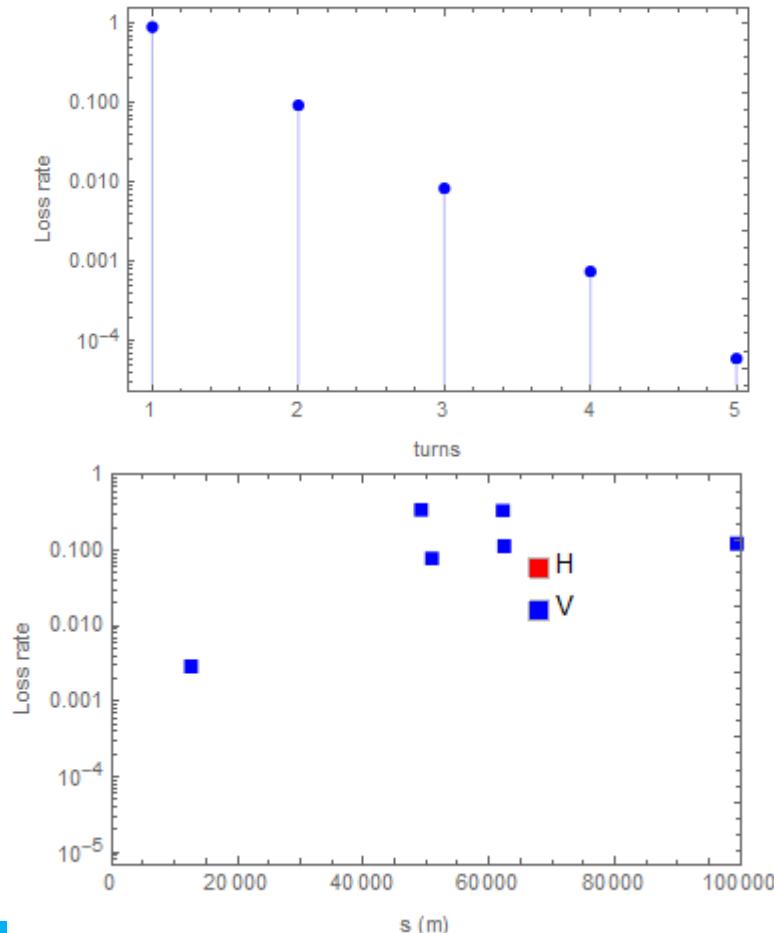
Z- SCQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



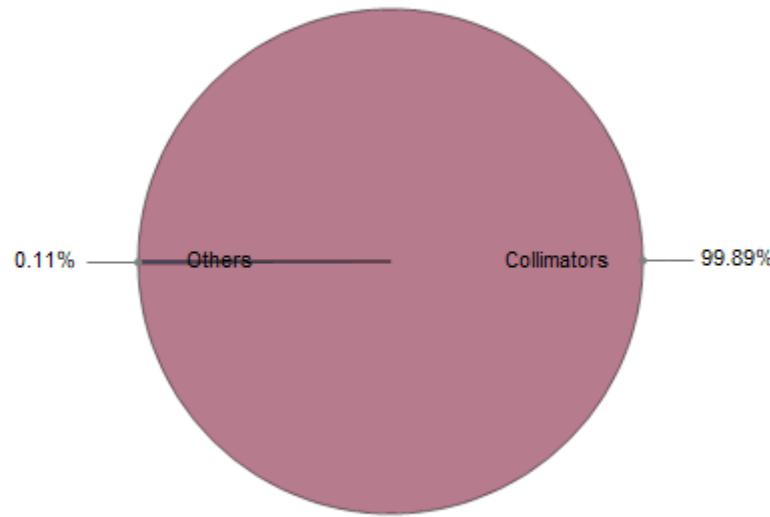
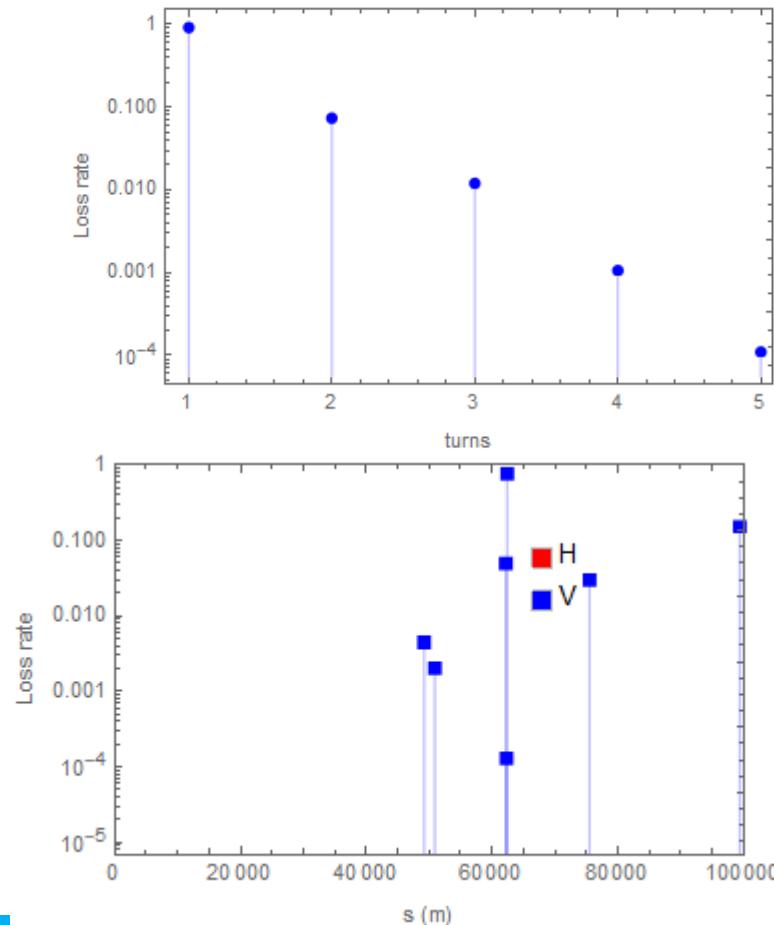
Z- SCQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



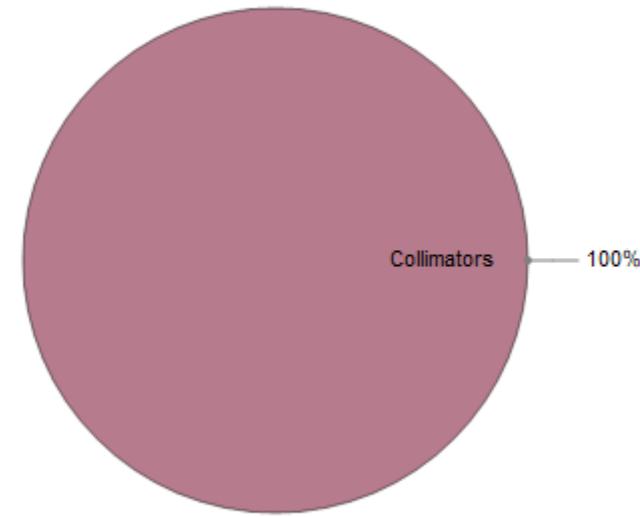
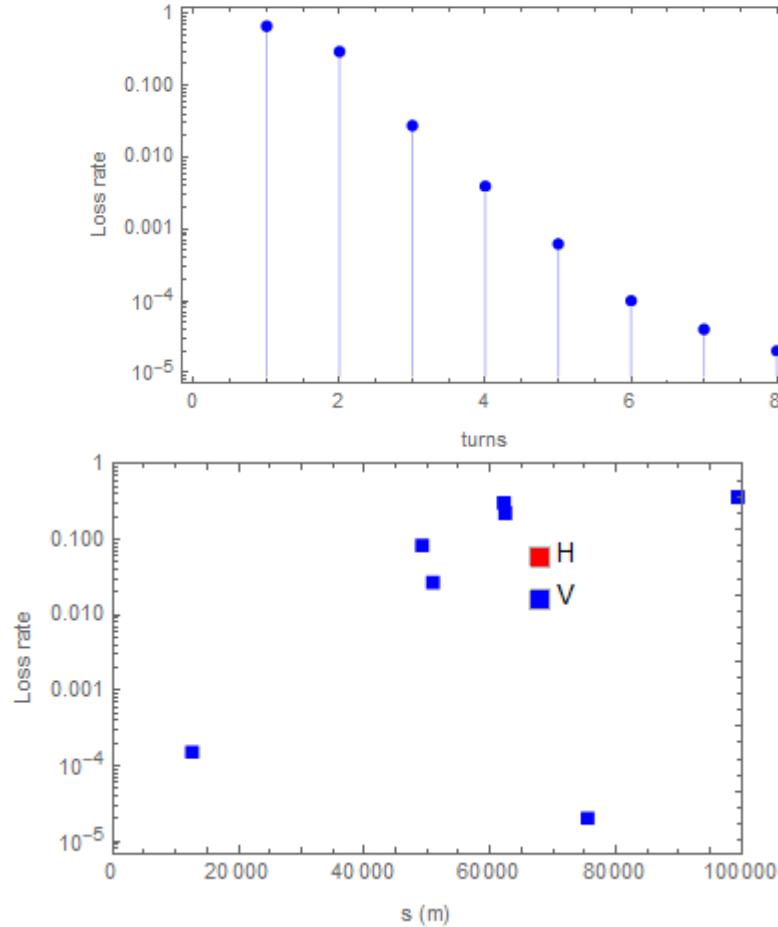
Z- SCQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



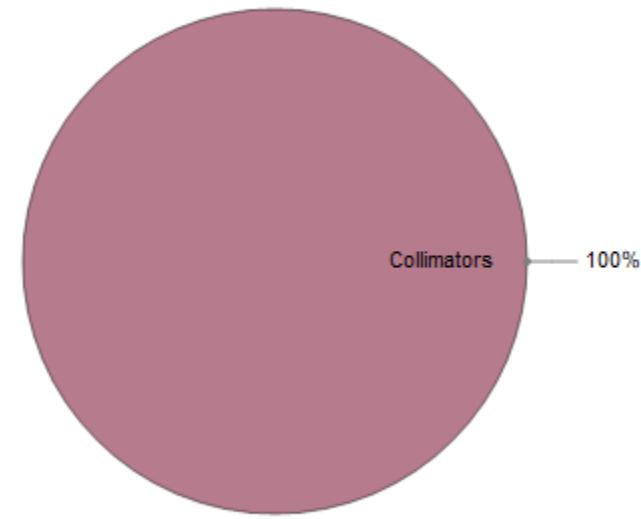
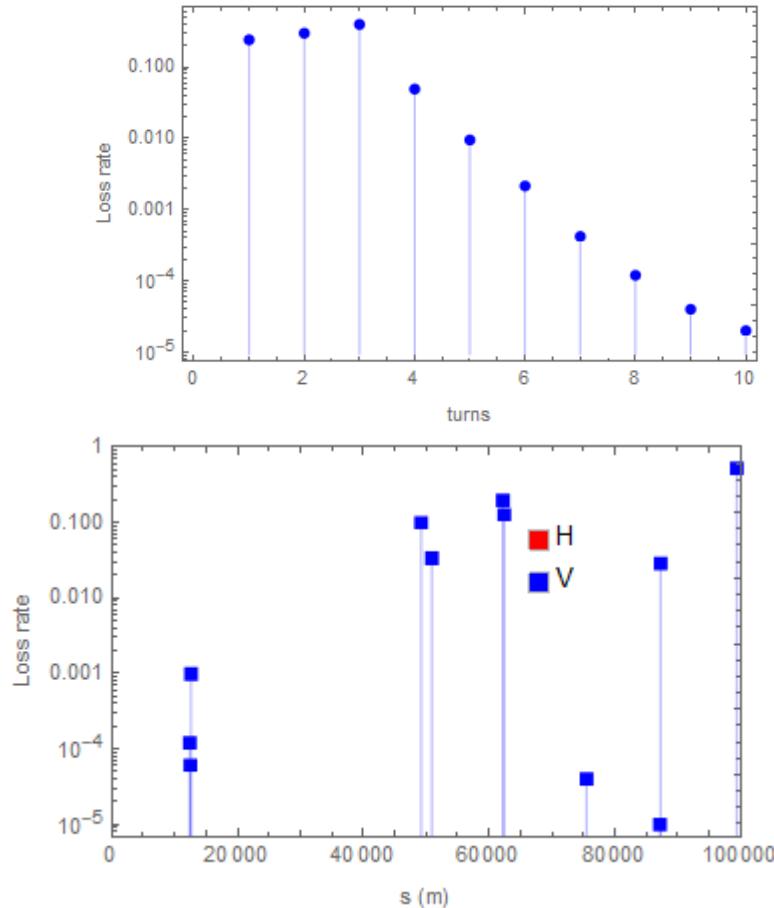
Z- S failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



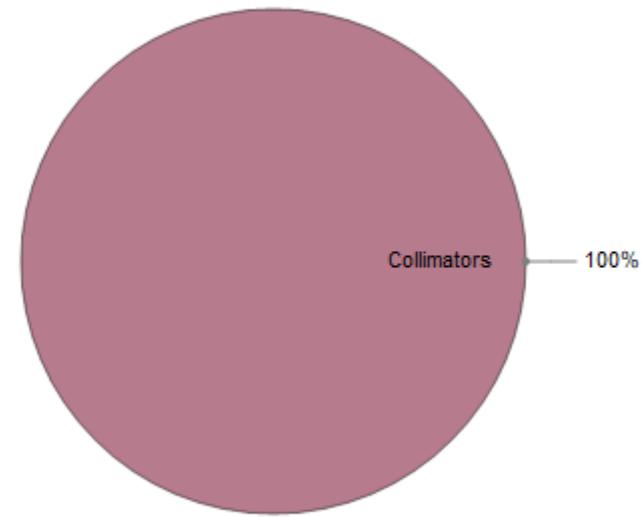
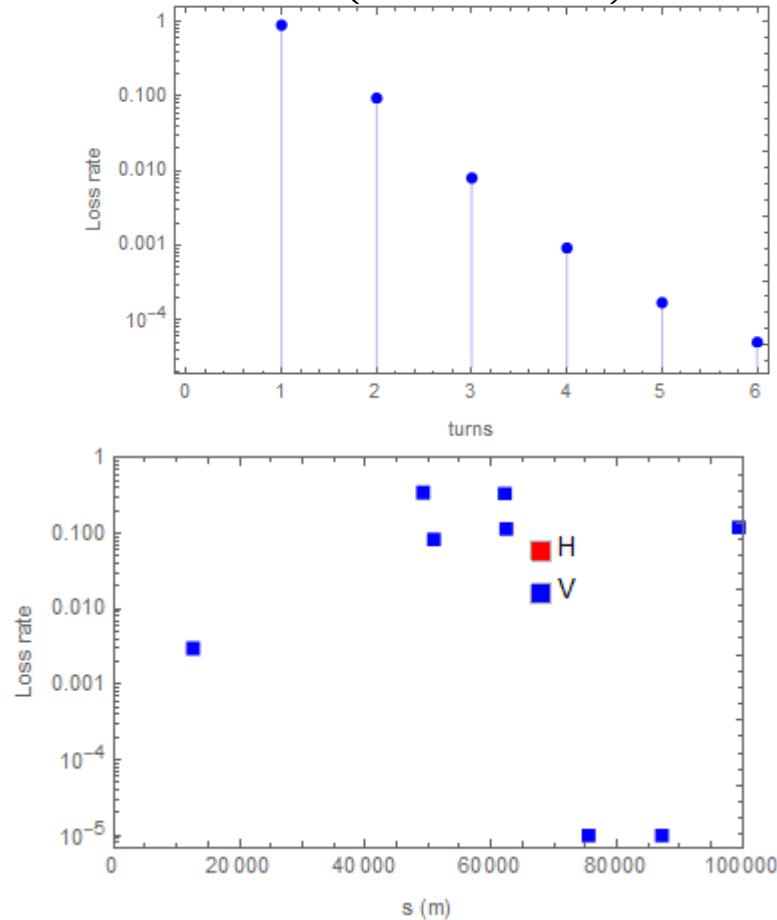
Z- S failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



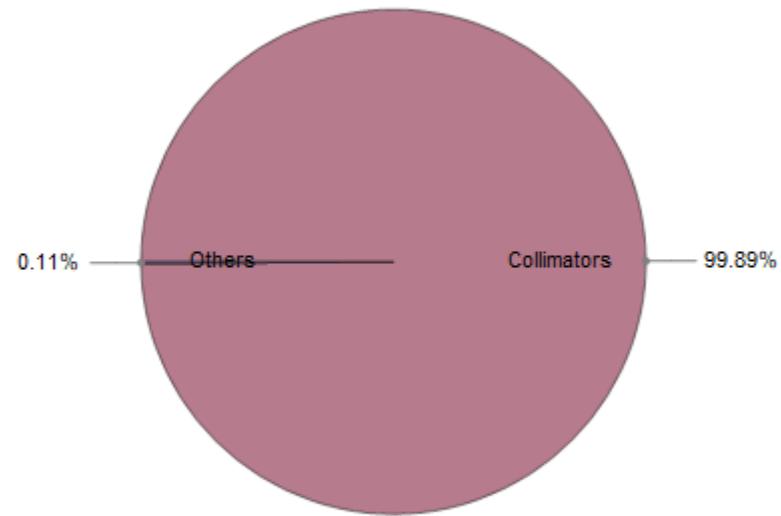
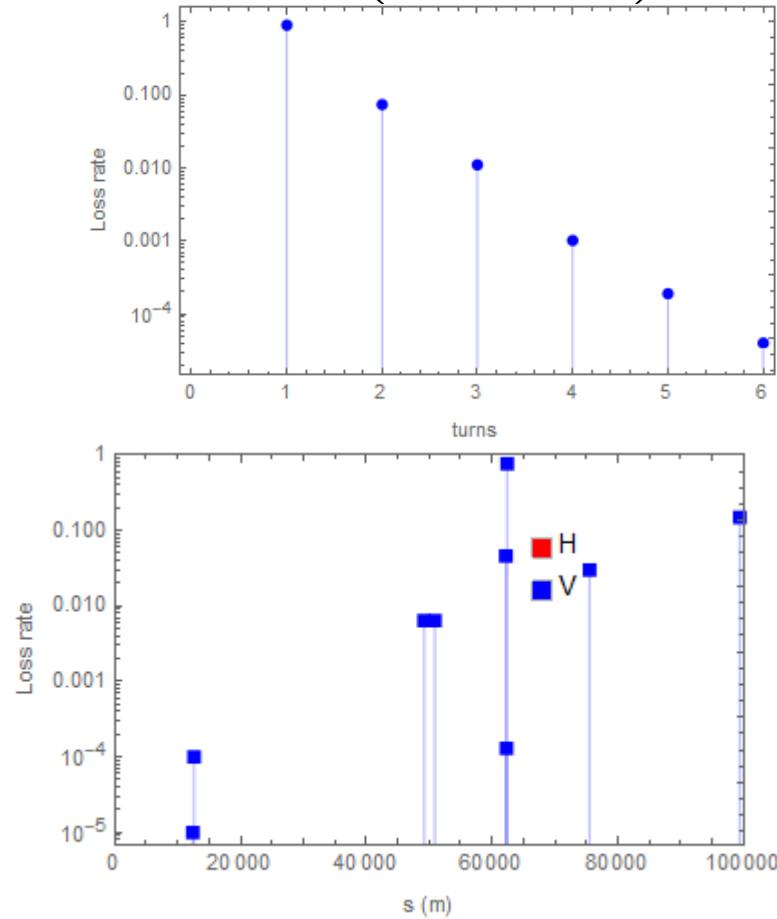
Z- S failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



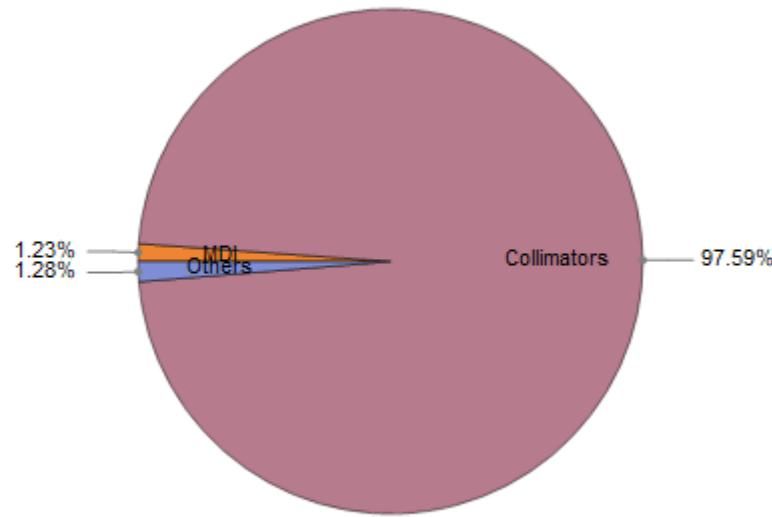
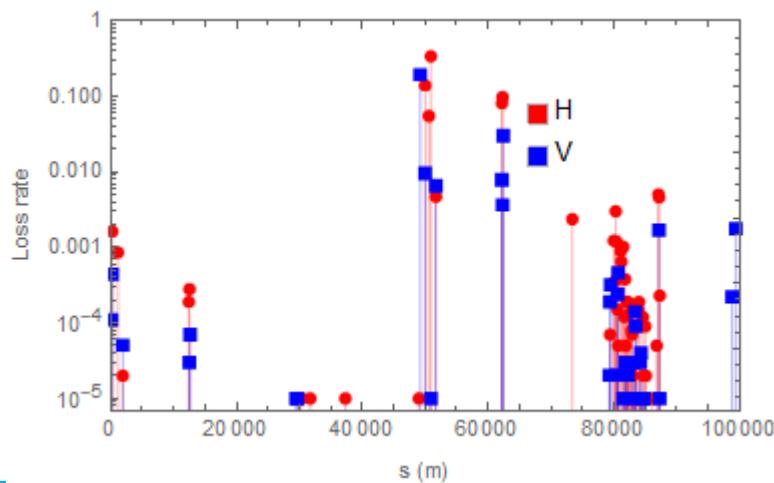
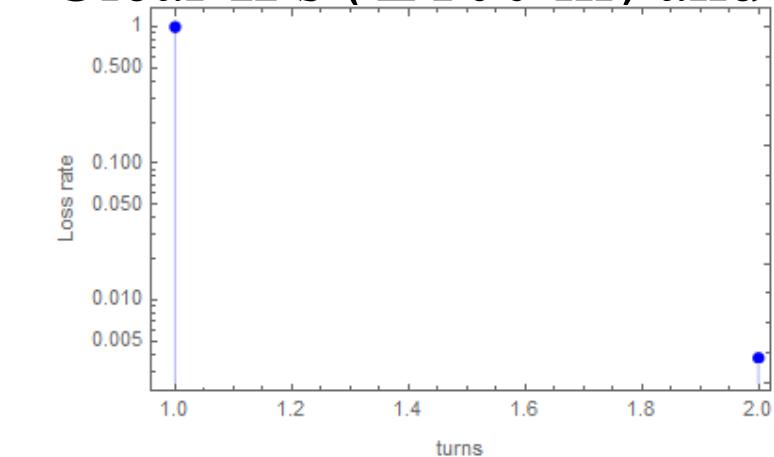
Z- S failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



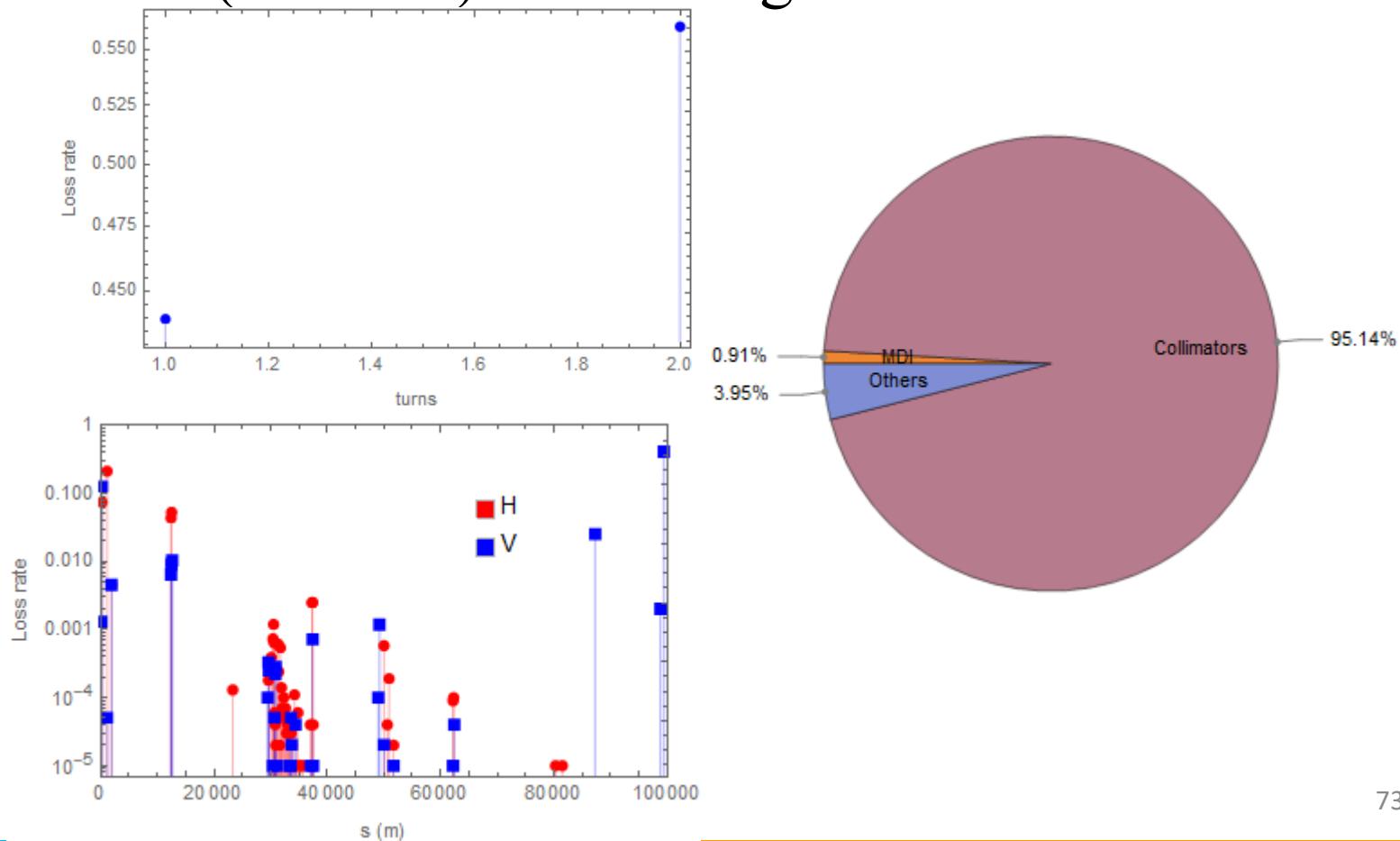
Z- All failures

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



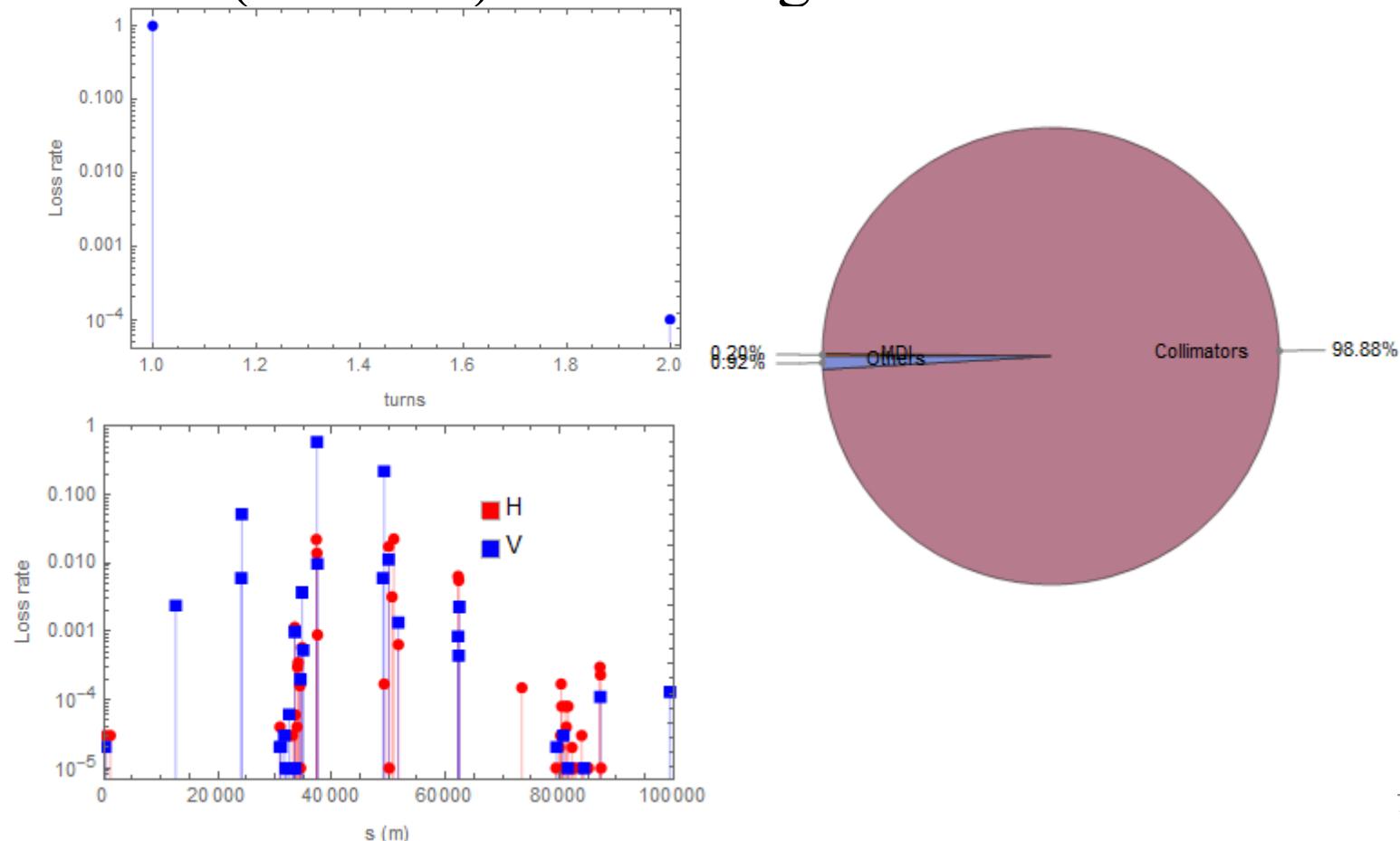
Z- All failures

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



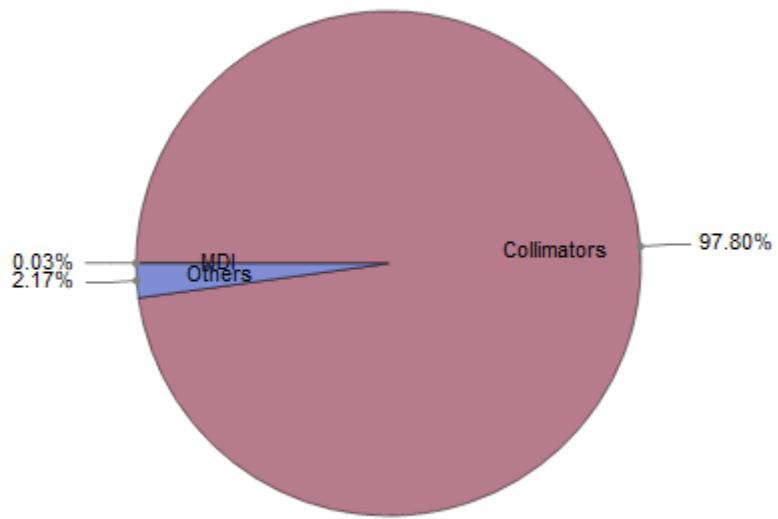
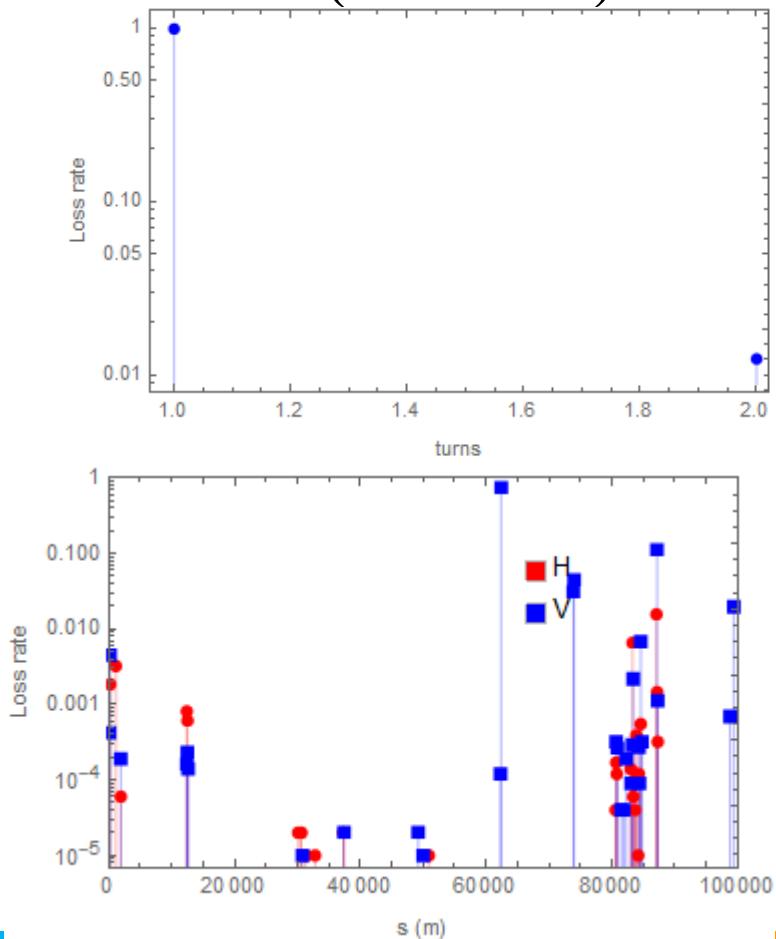
Z- All failures

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



Z- All failures

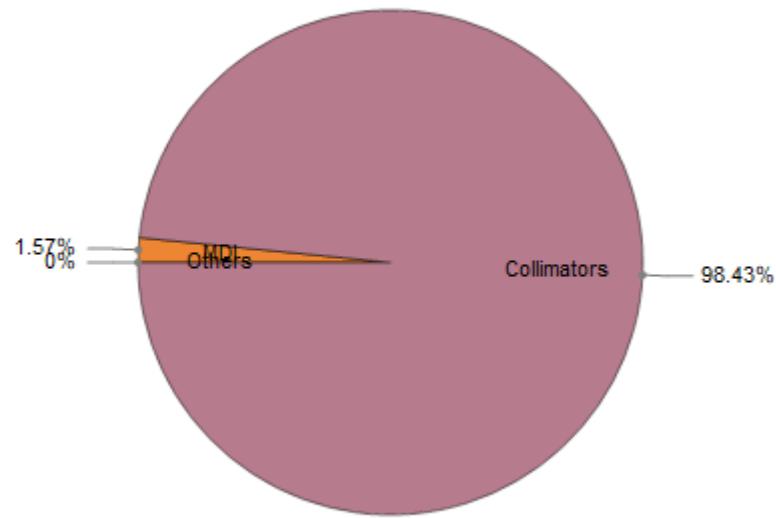
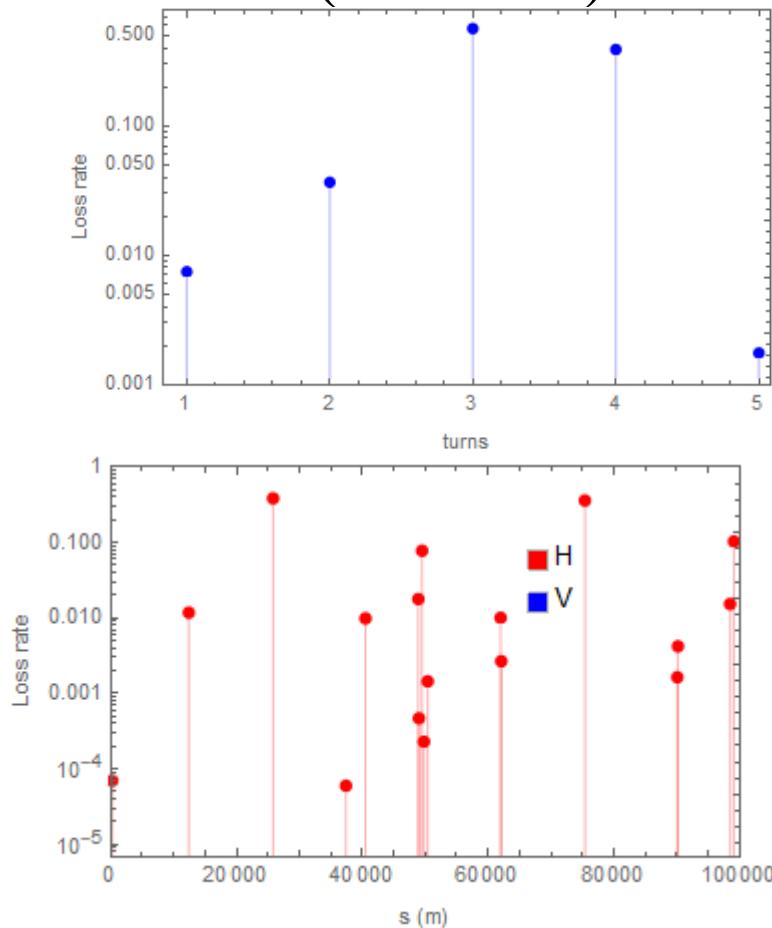
- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



W mode

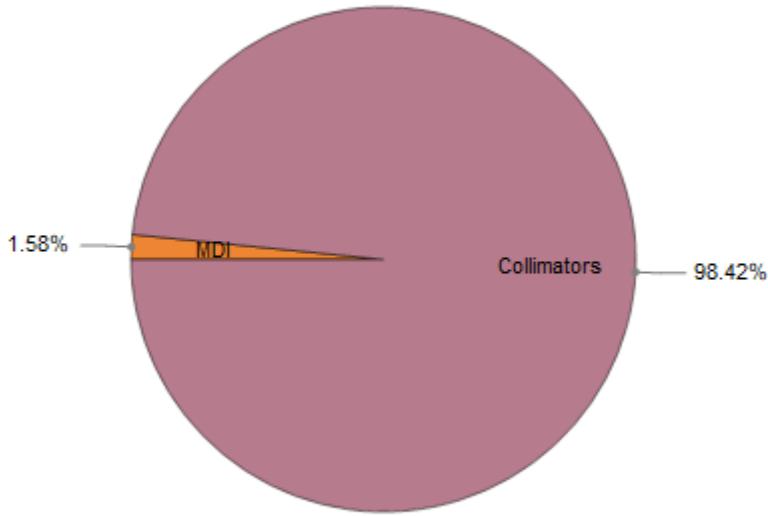
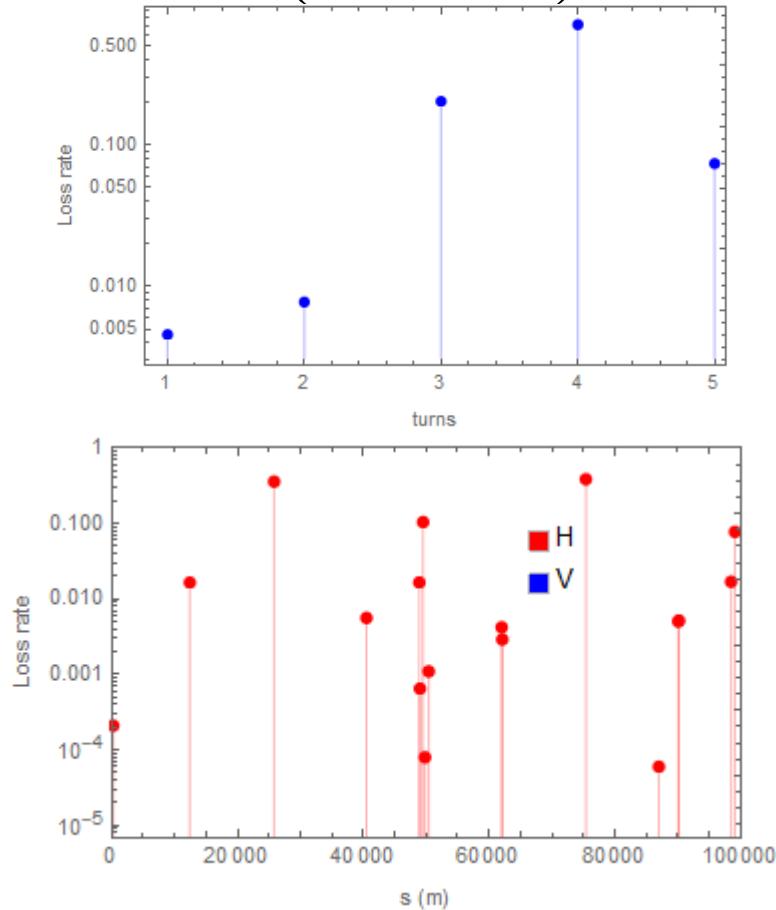
W – RF failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



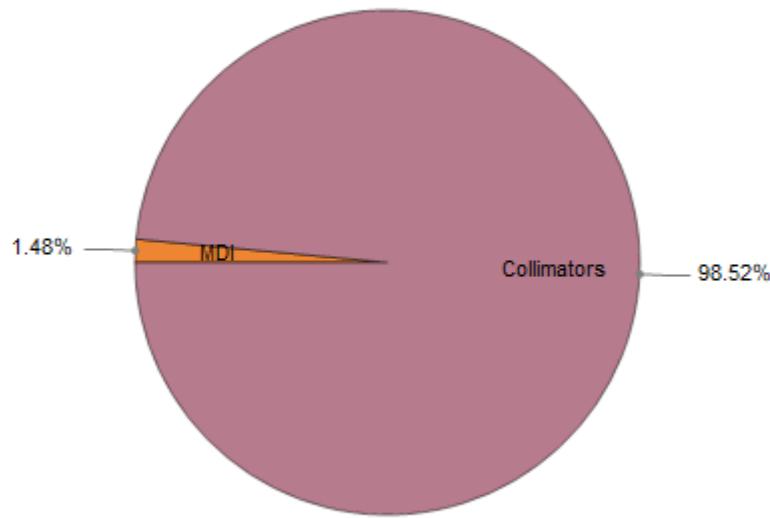
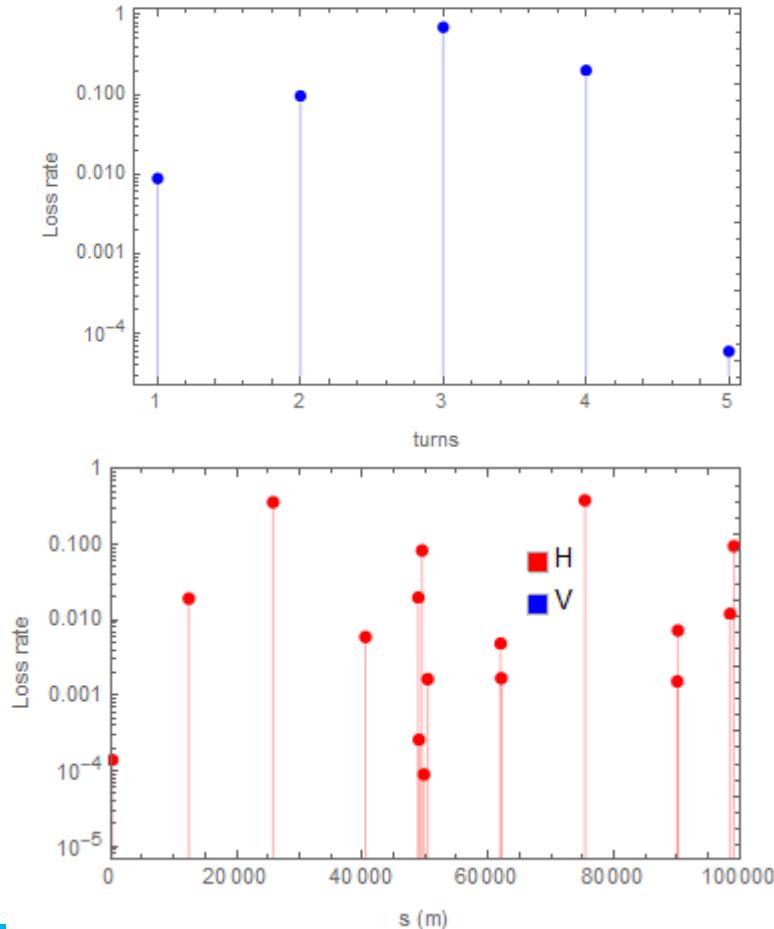
W- RF failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



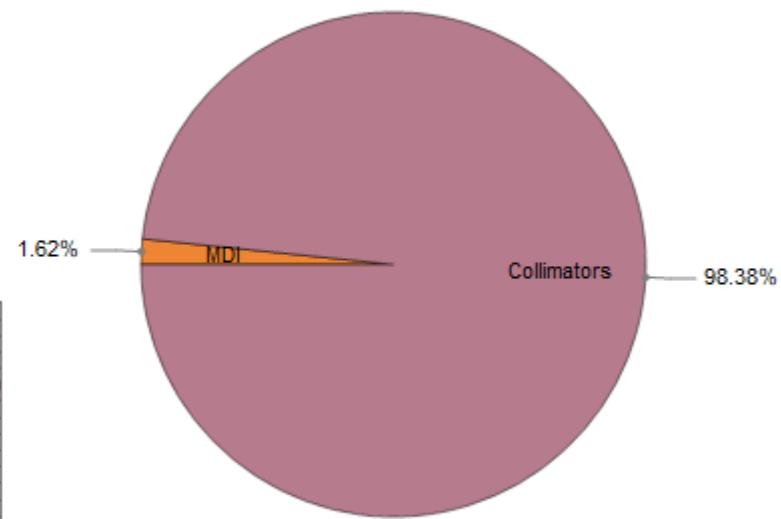
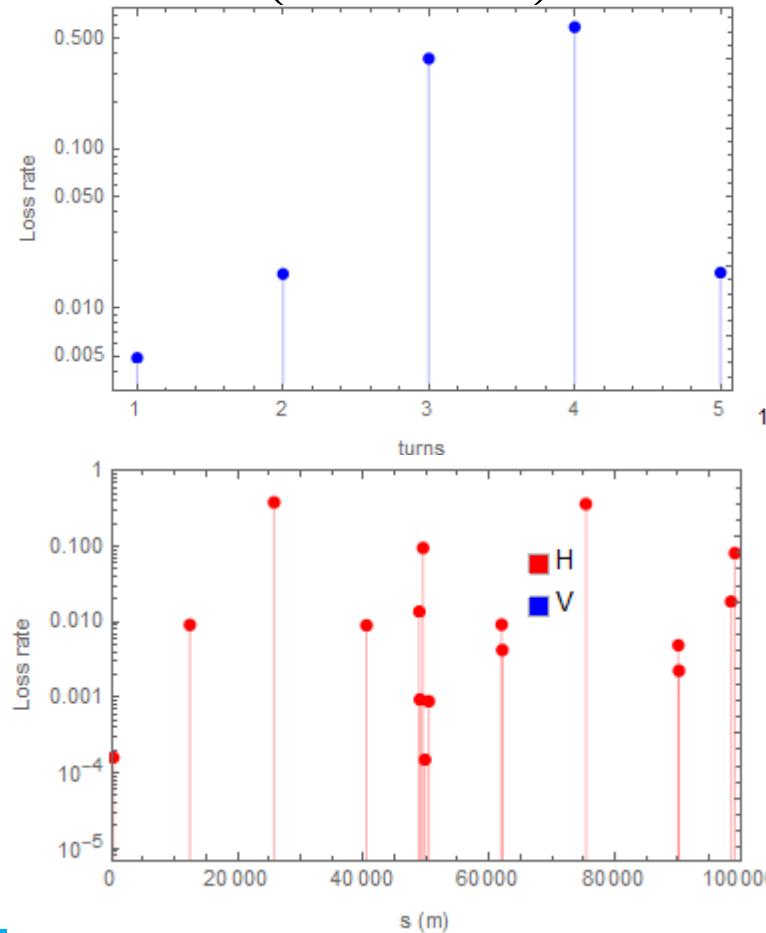
W- RF failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



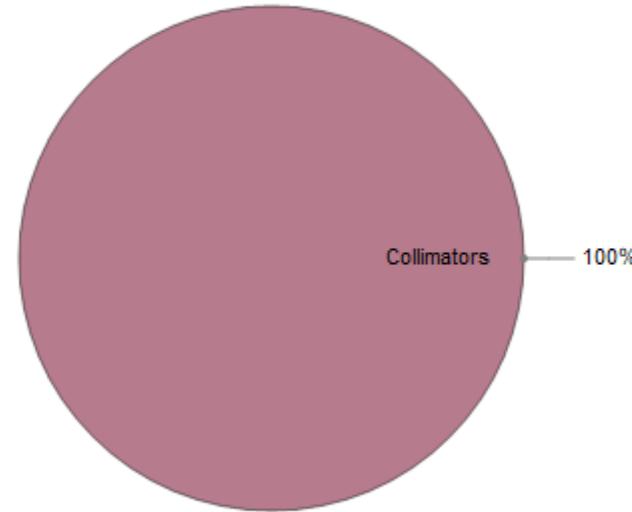
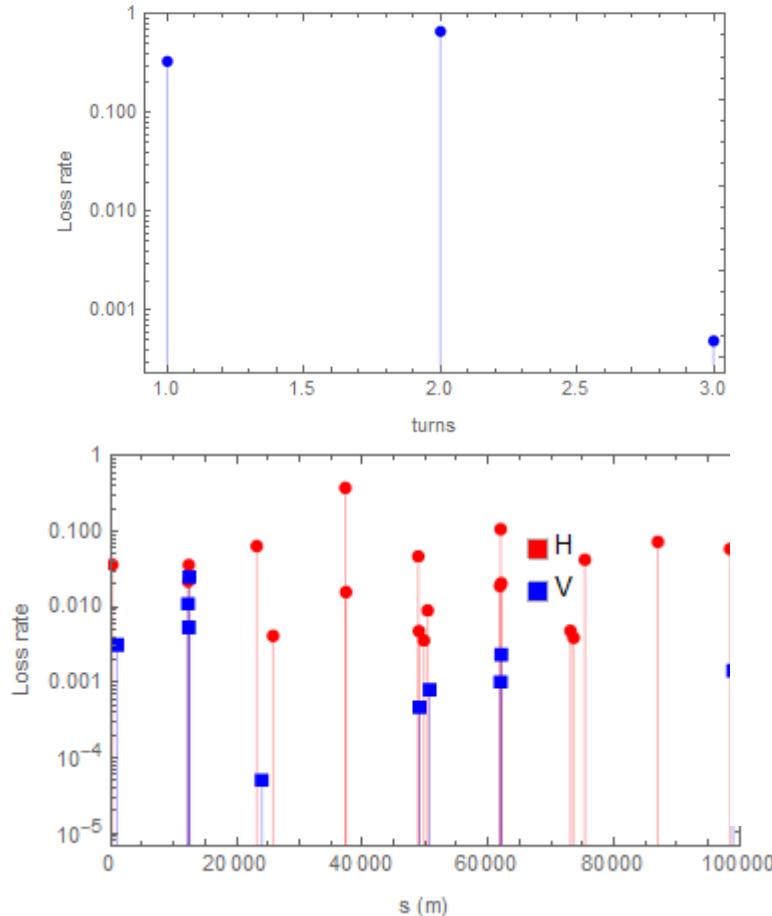
W- RF failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



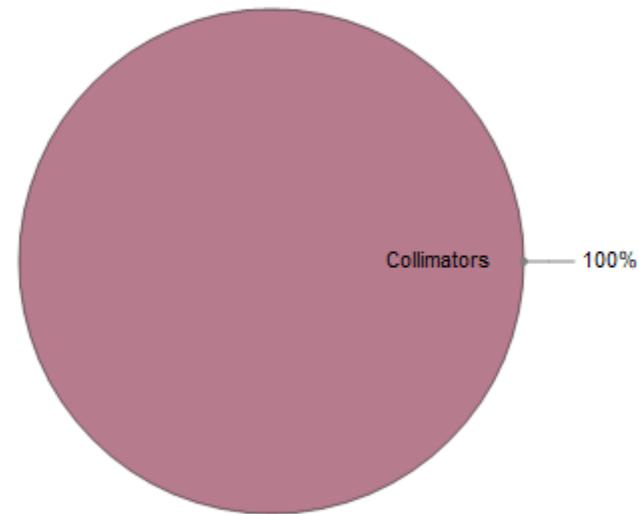
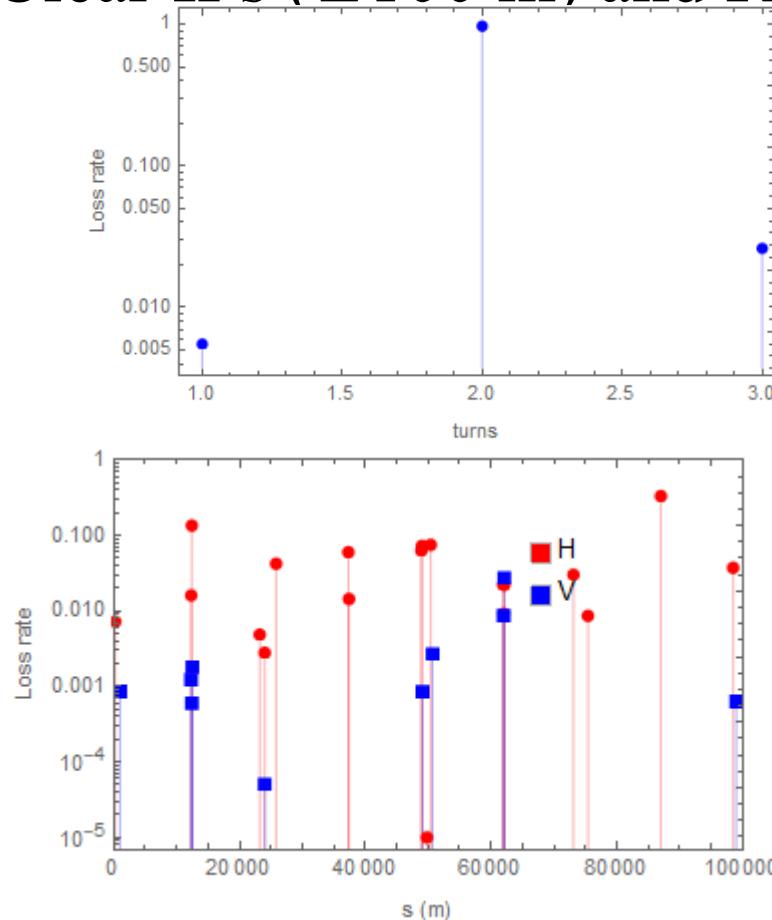
W- B failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



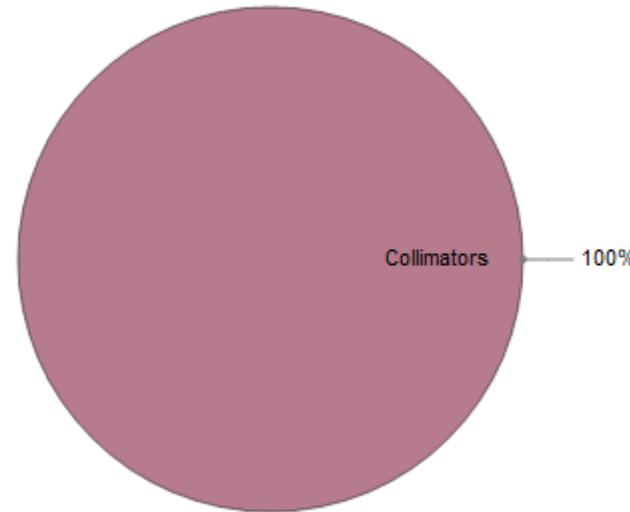
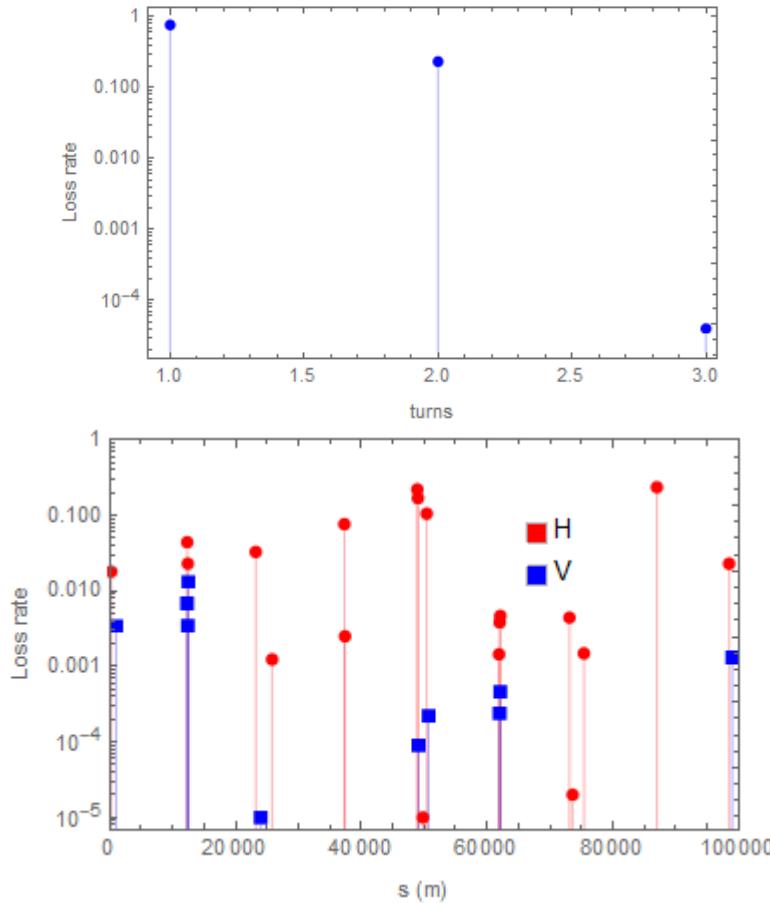
W- B failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



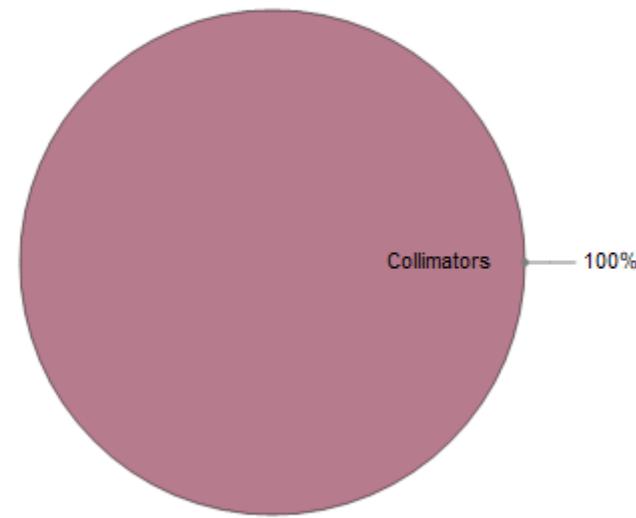
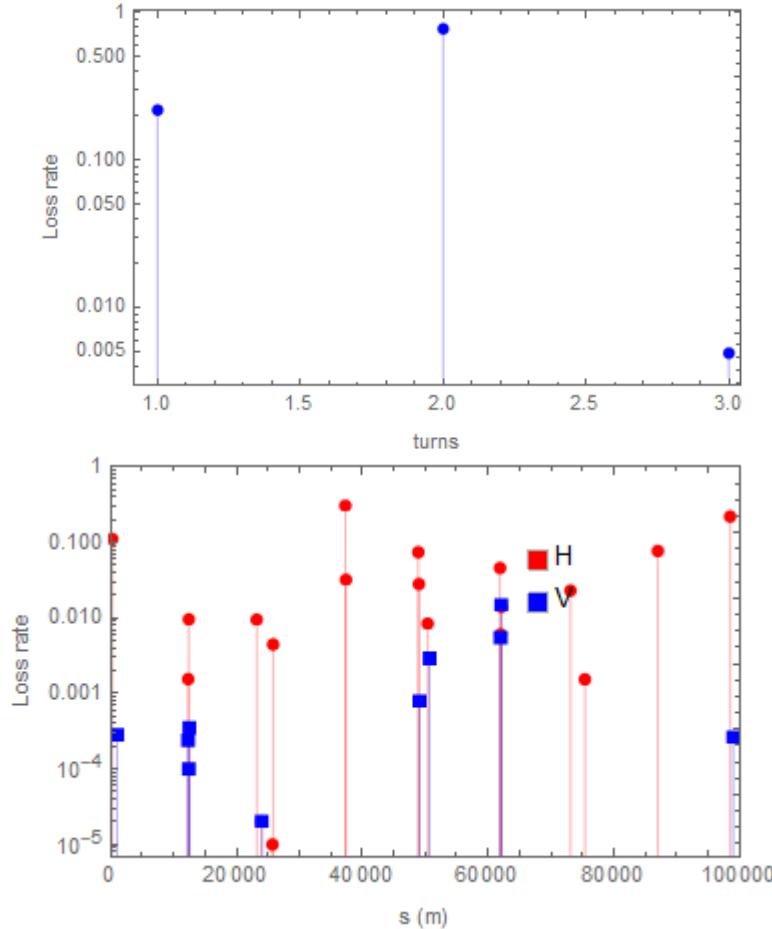
W- B failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



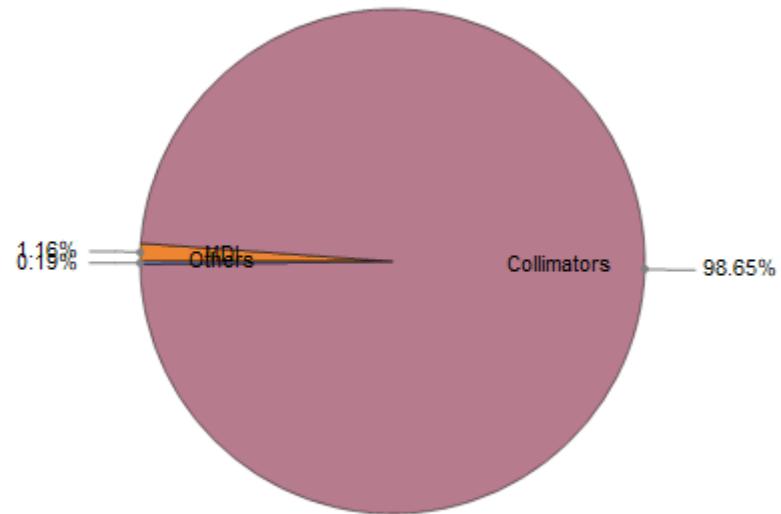
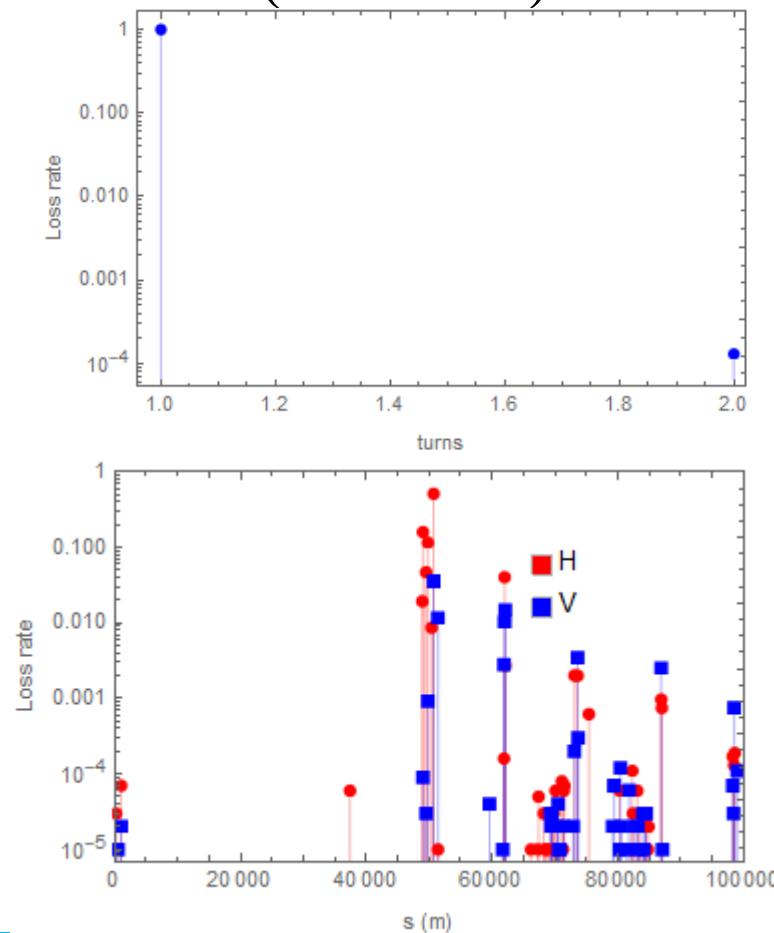
W- B failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



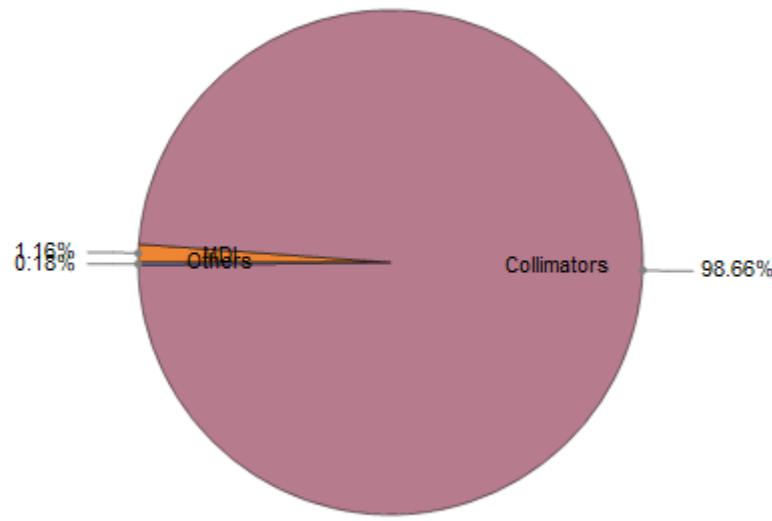
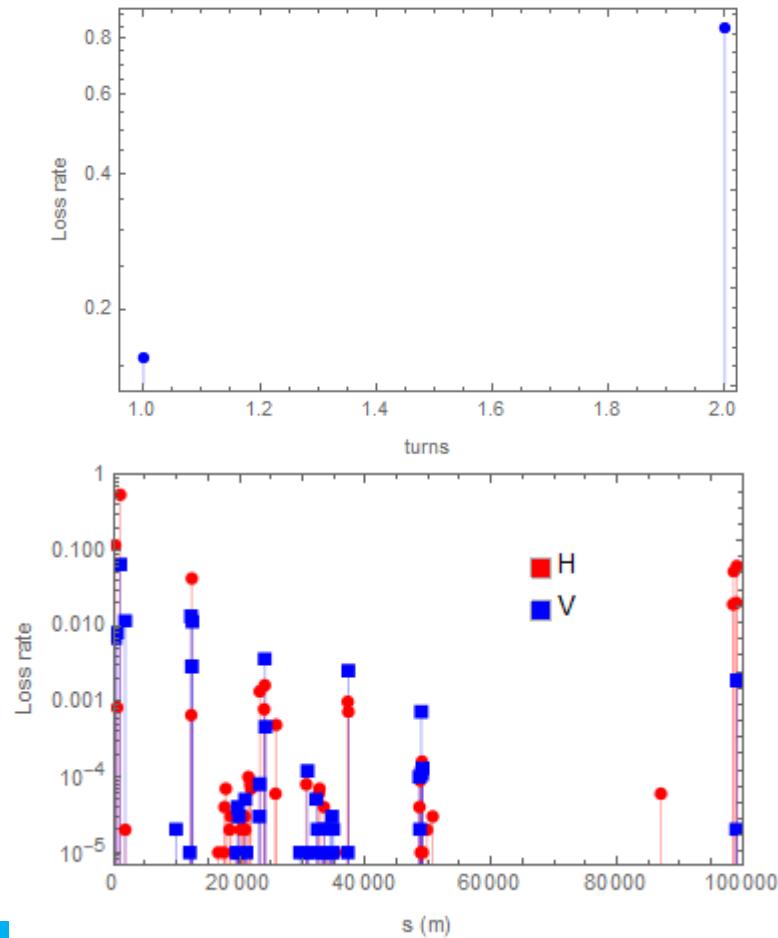
W- NorQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



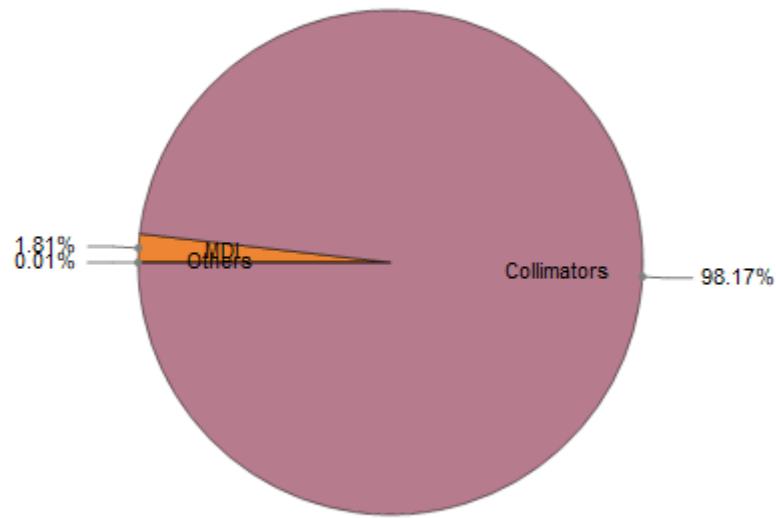
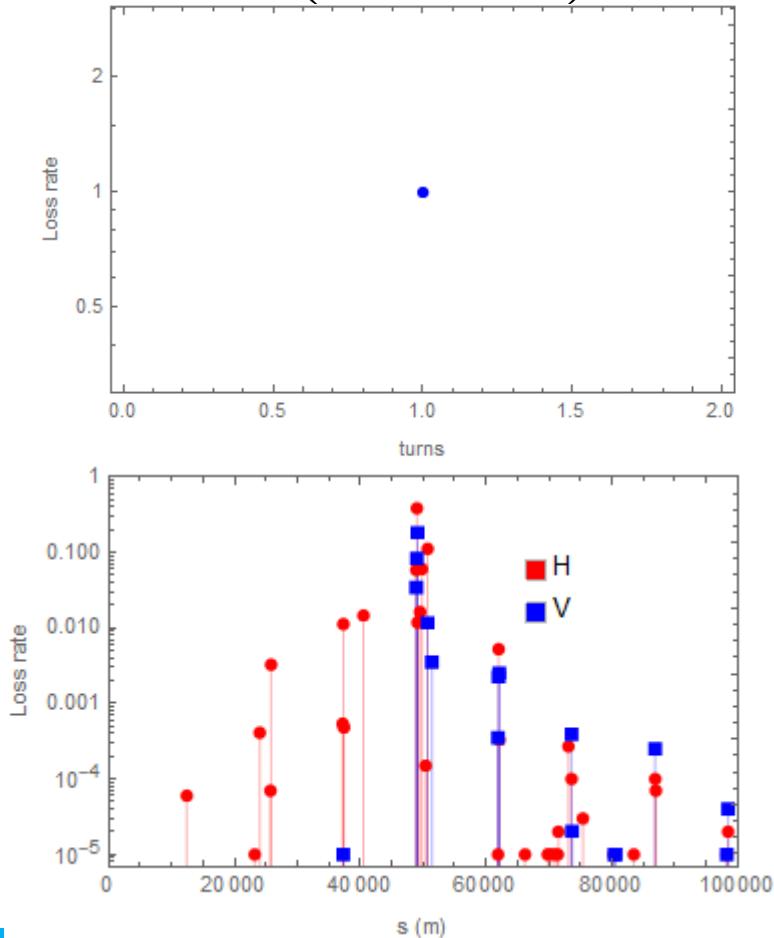
W- NorQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



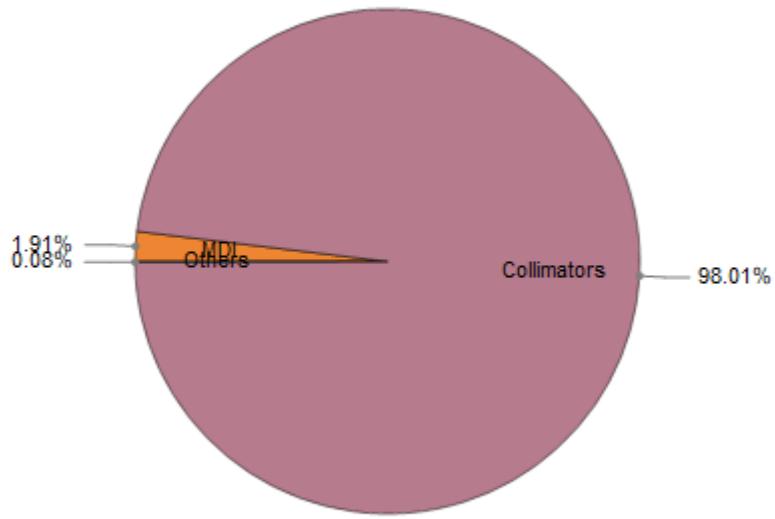
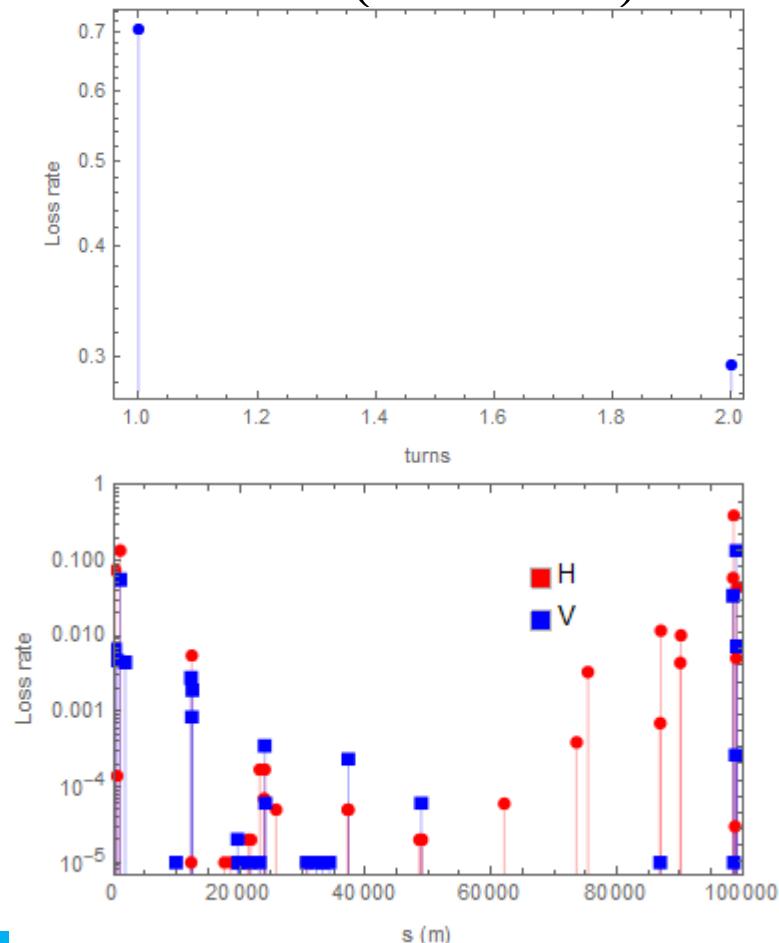
W- NorQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



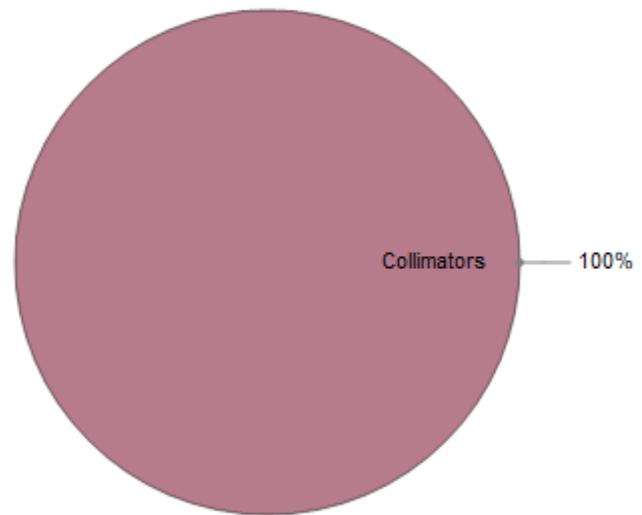
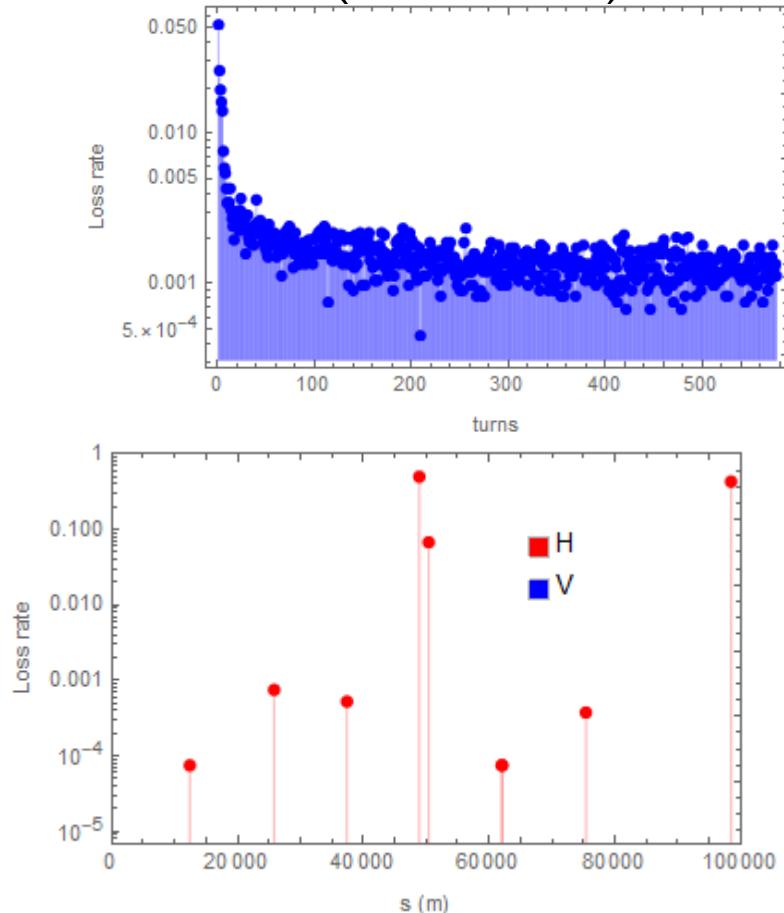
W- NorQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



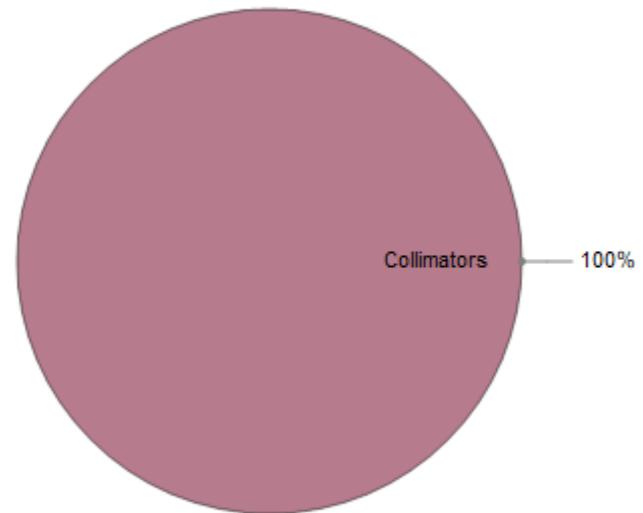
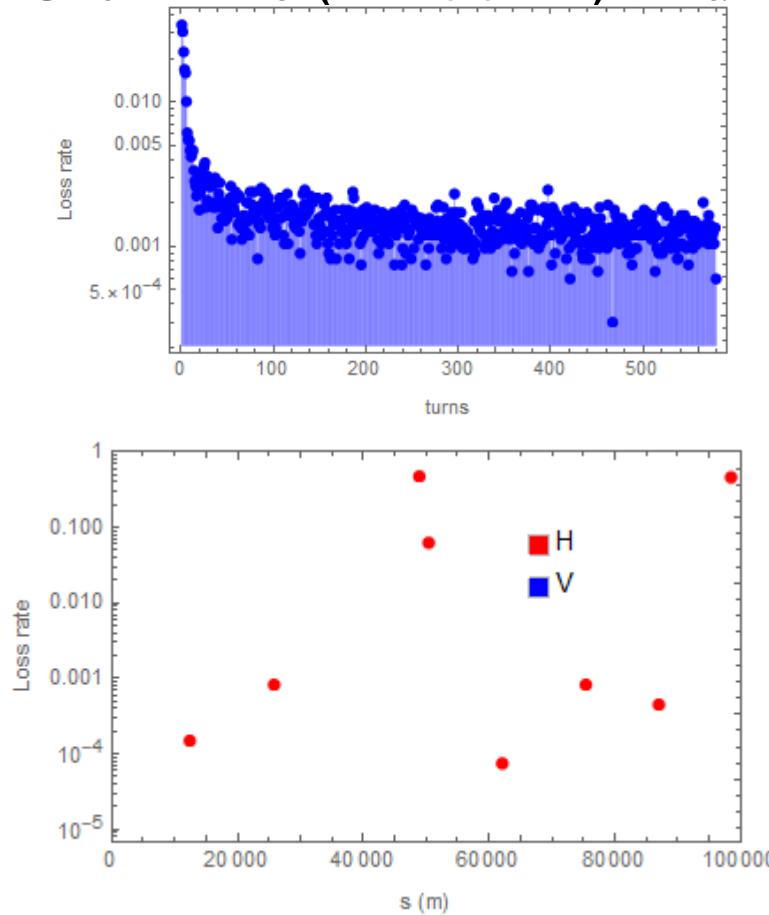
W- SCQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



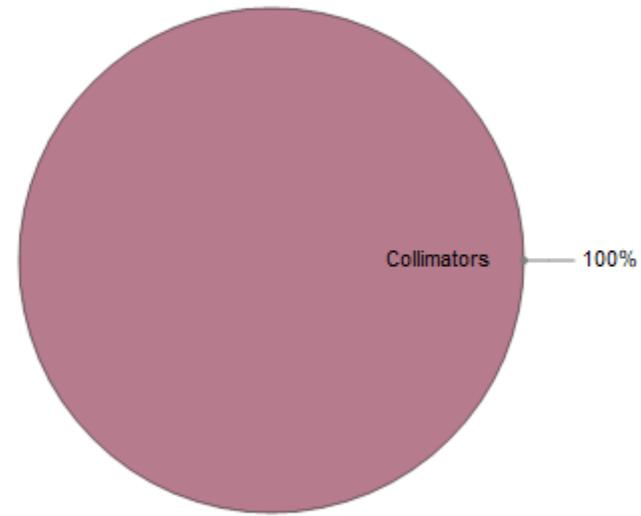
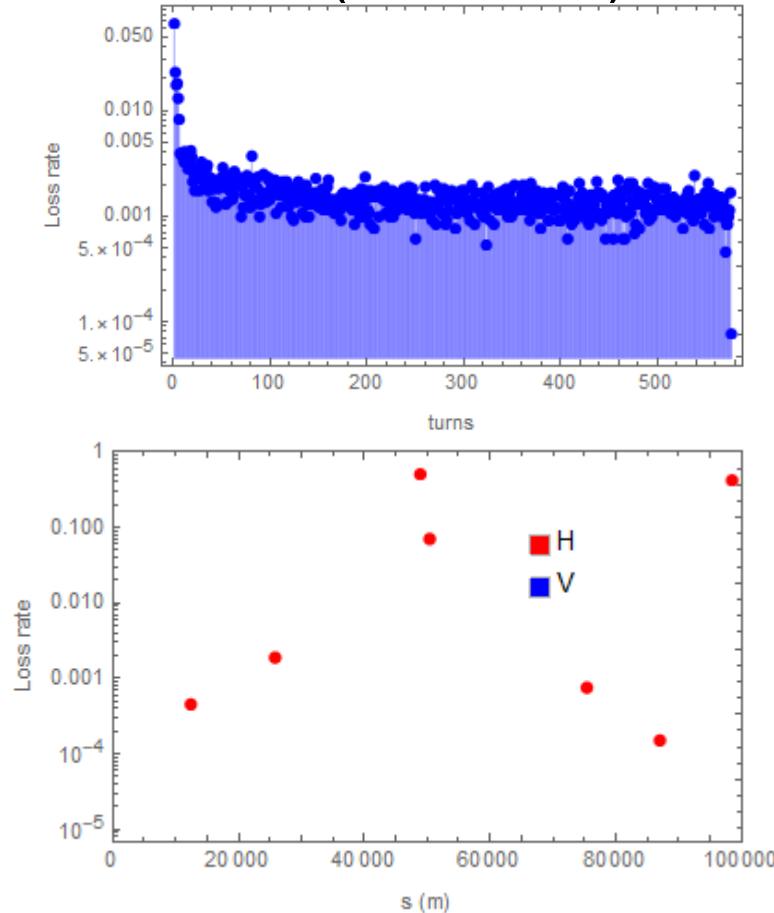
W- SCQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



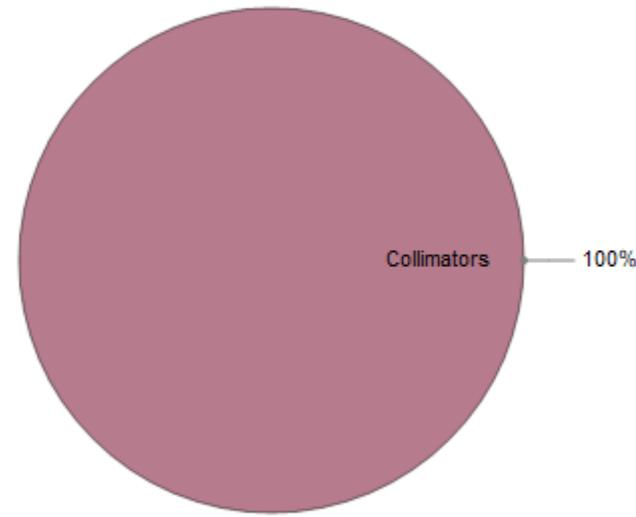
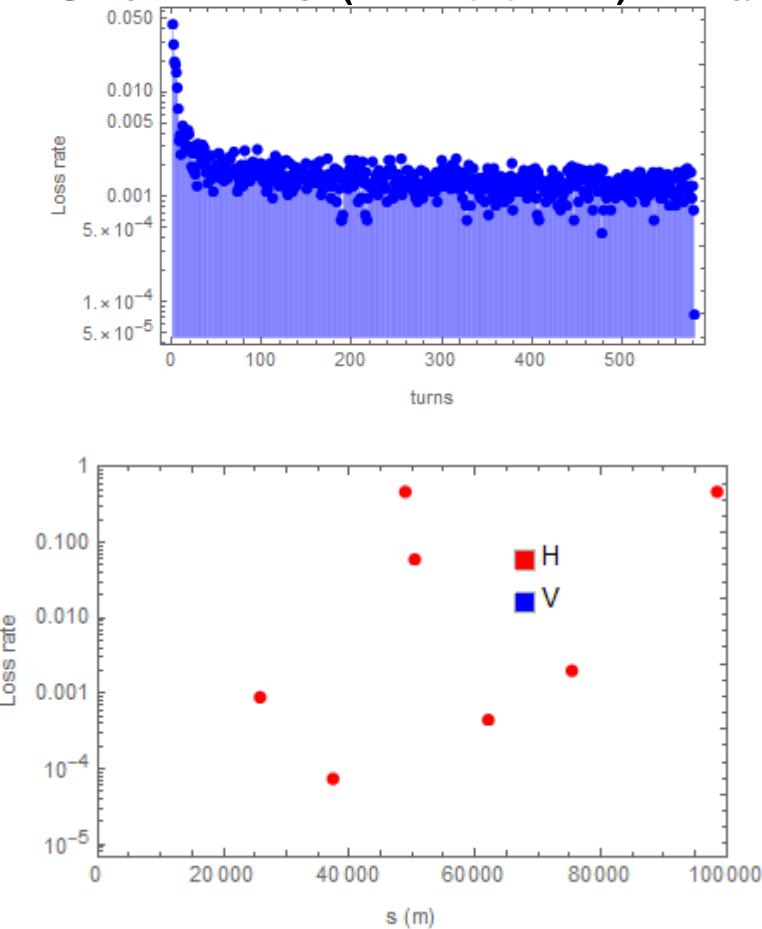
W- SCQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



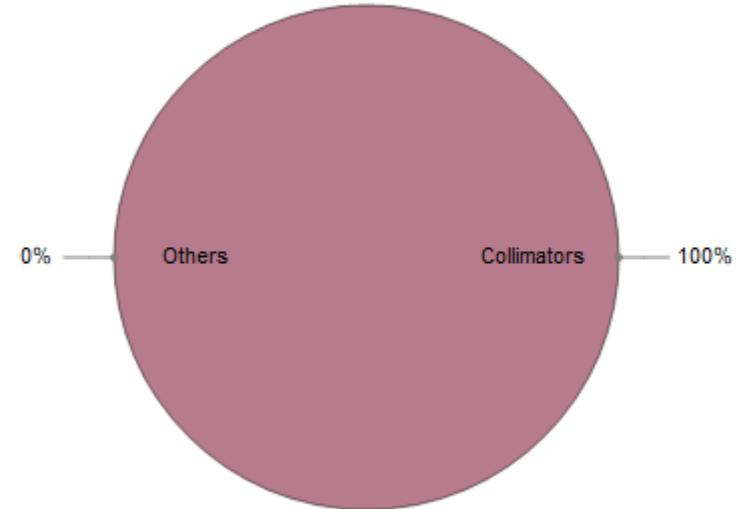
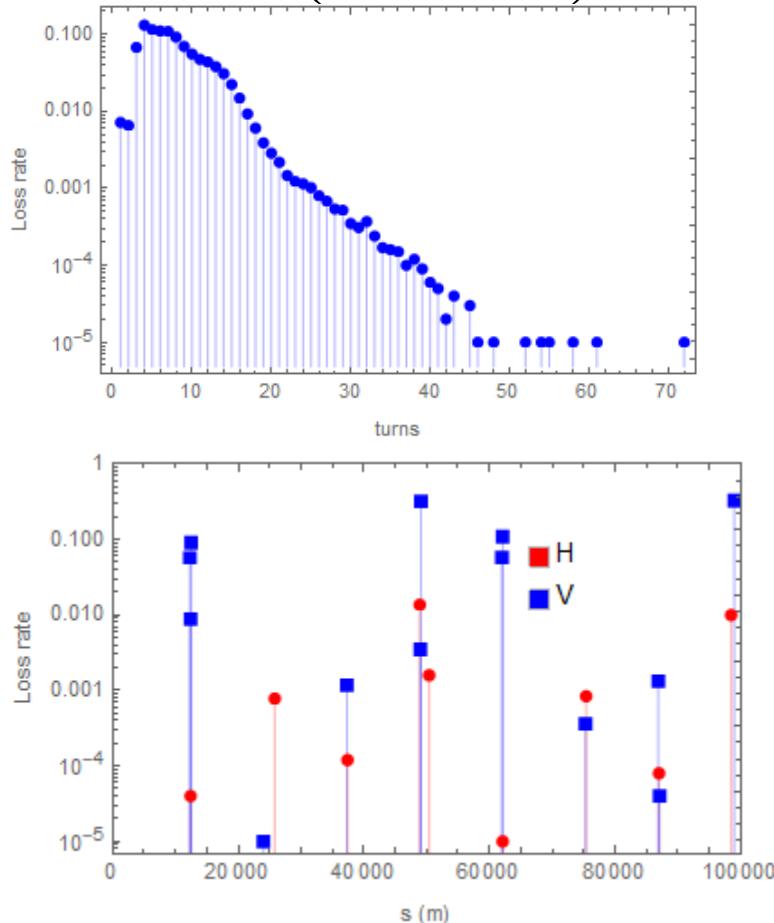
W- SCQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



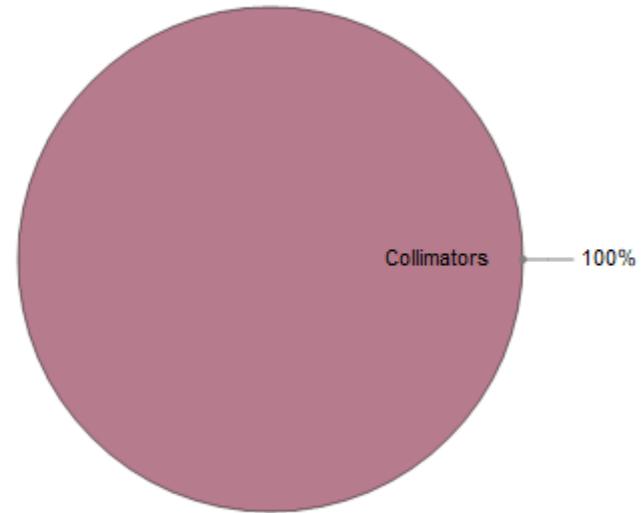
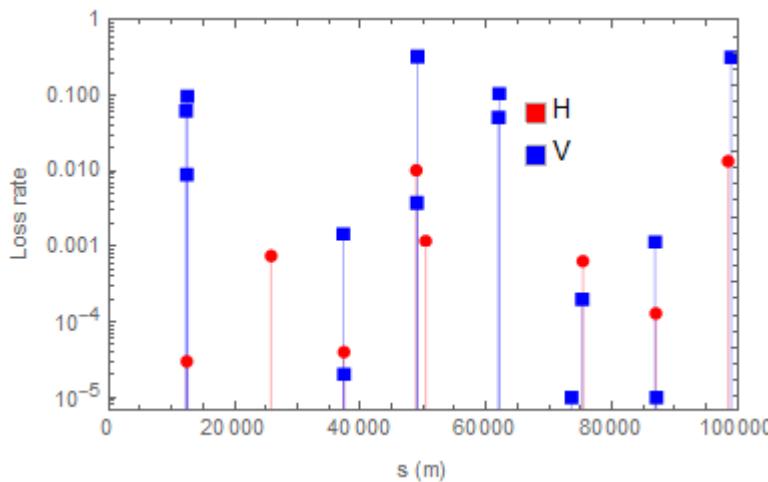
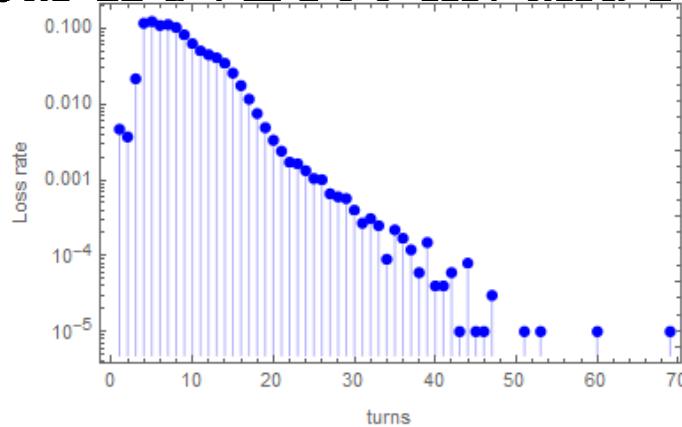
W- S failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



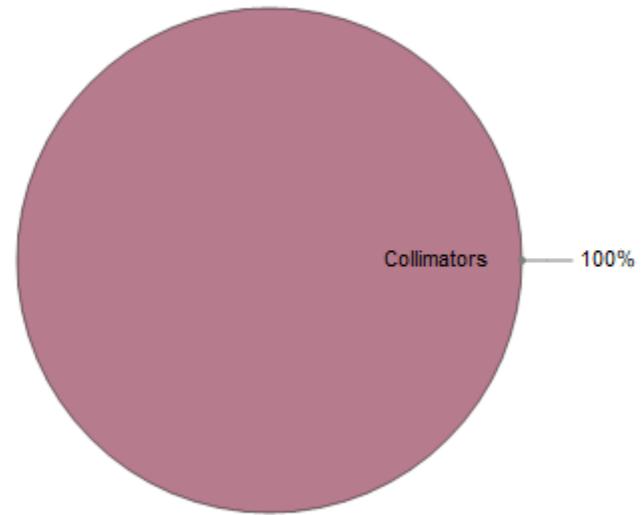
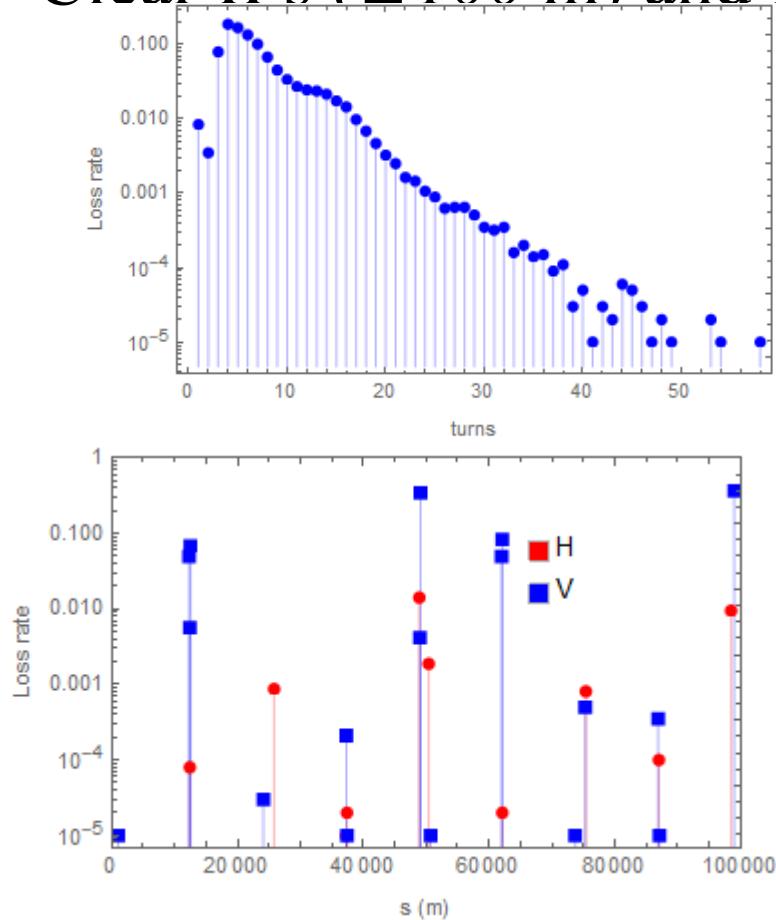
W- S failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



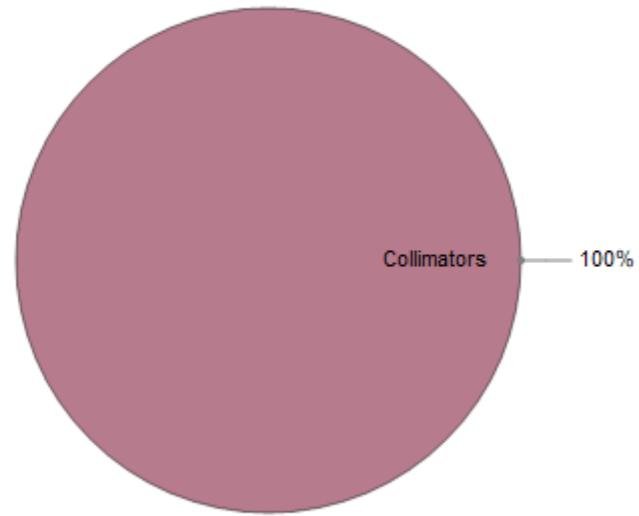
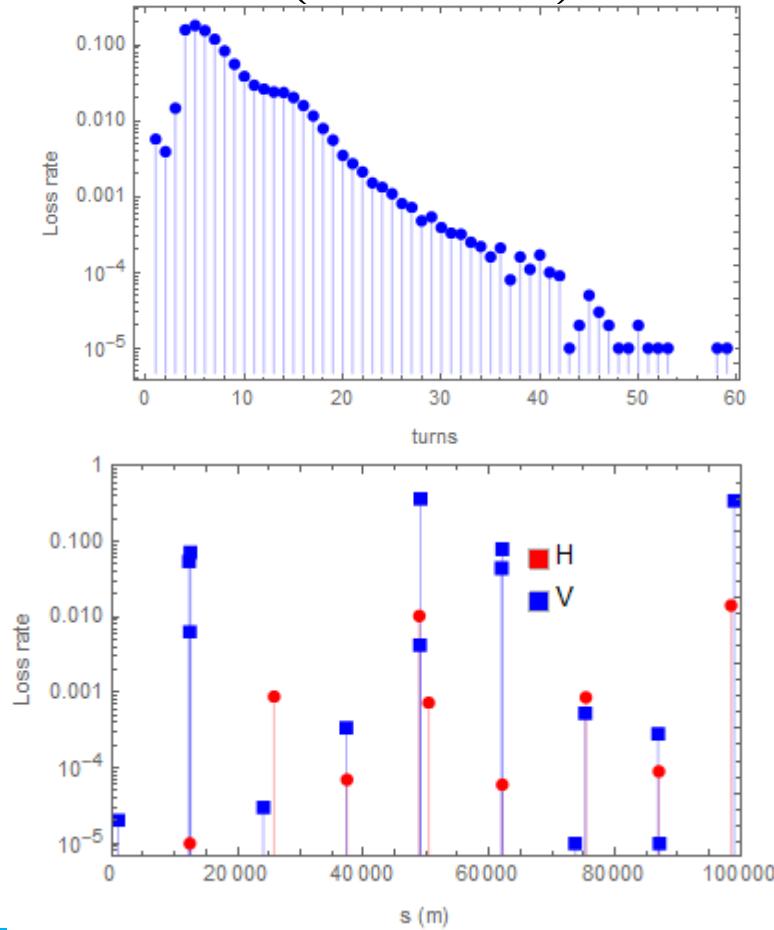
W- S failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



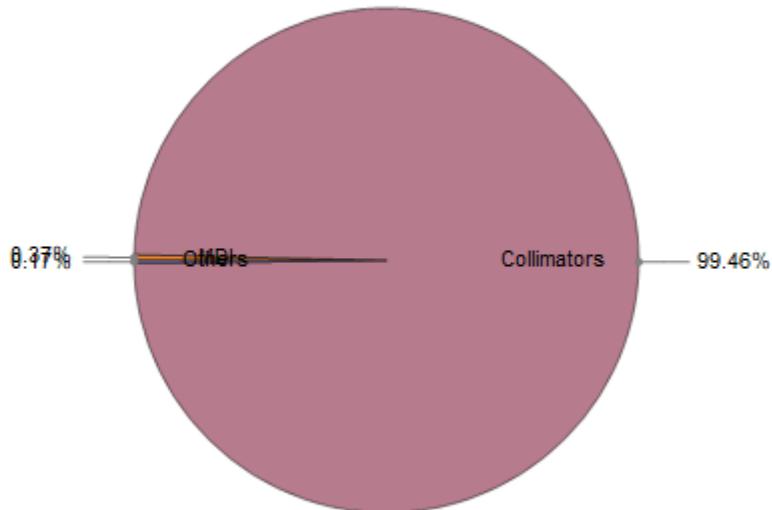
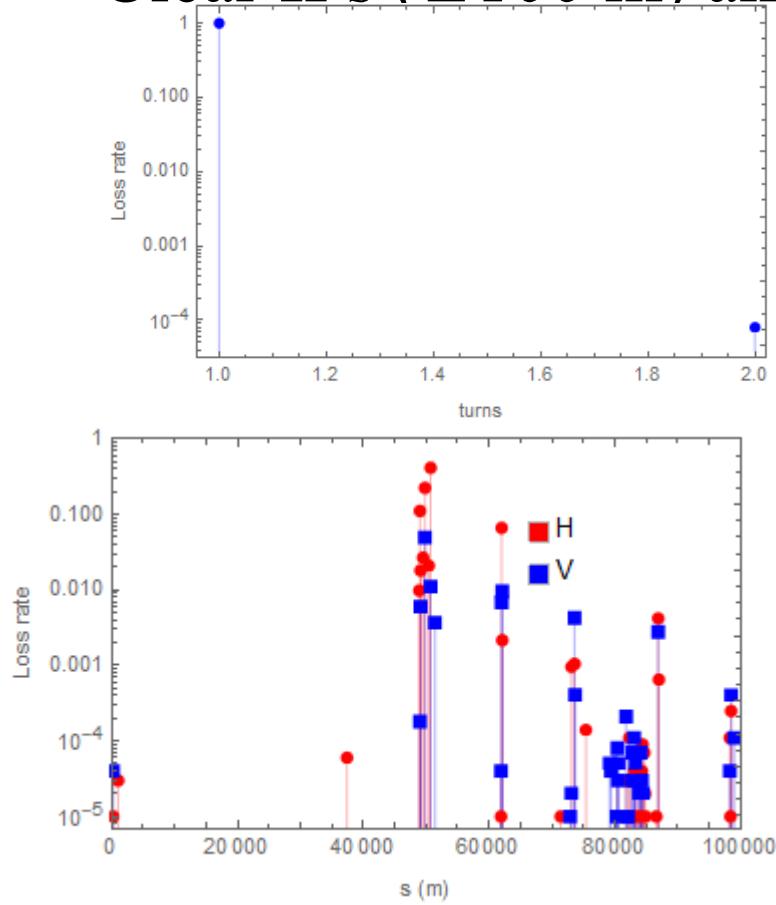
W- S failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



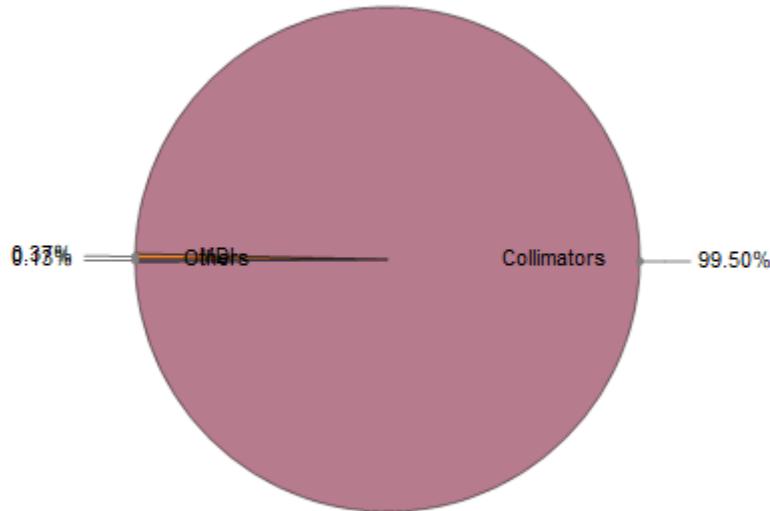
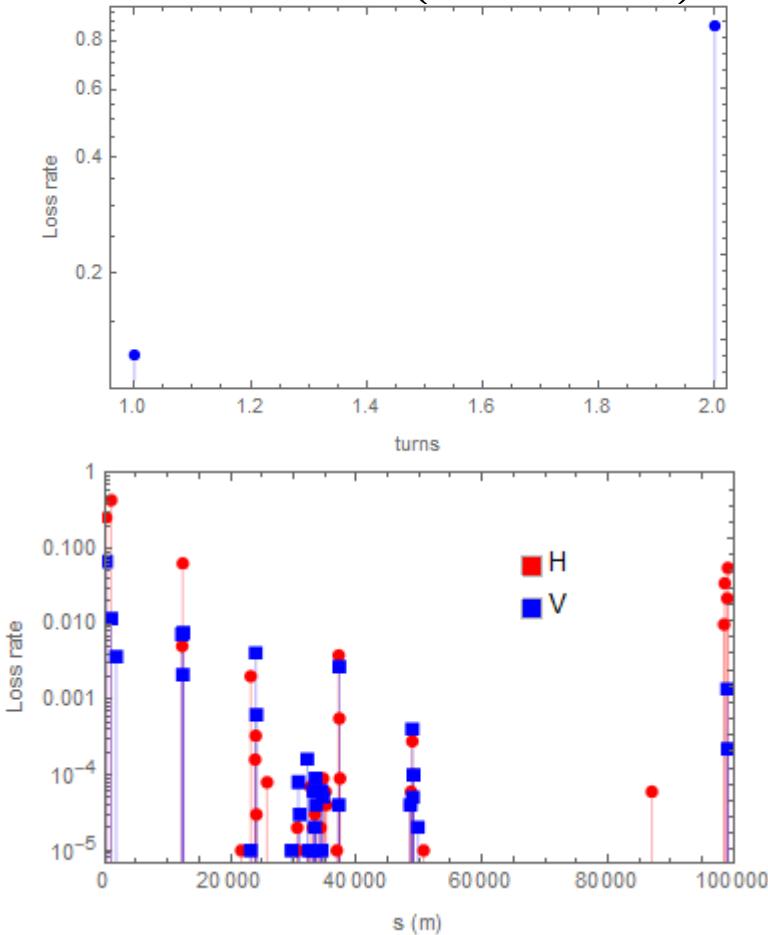
W- All failures

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



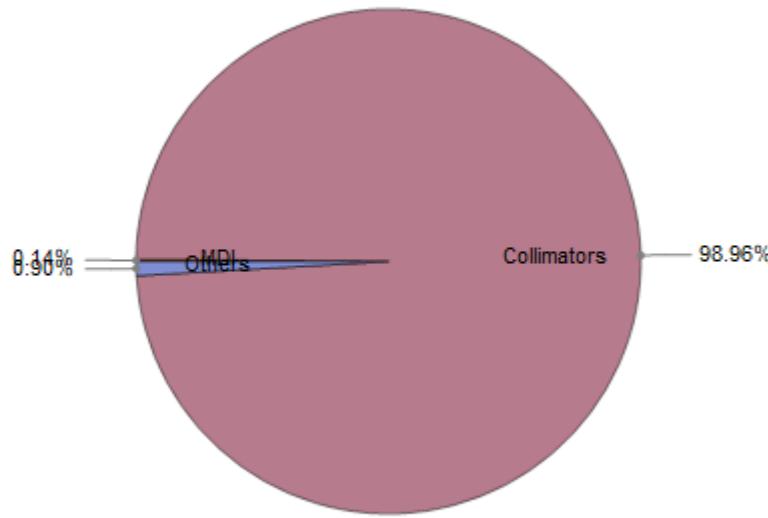
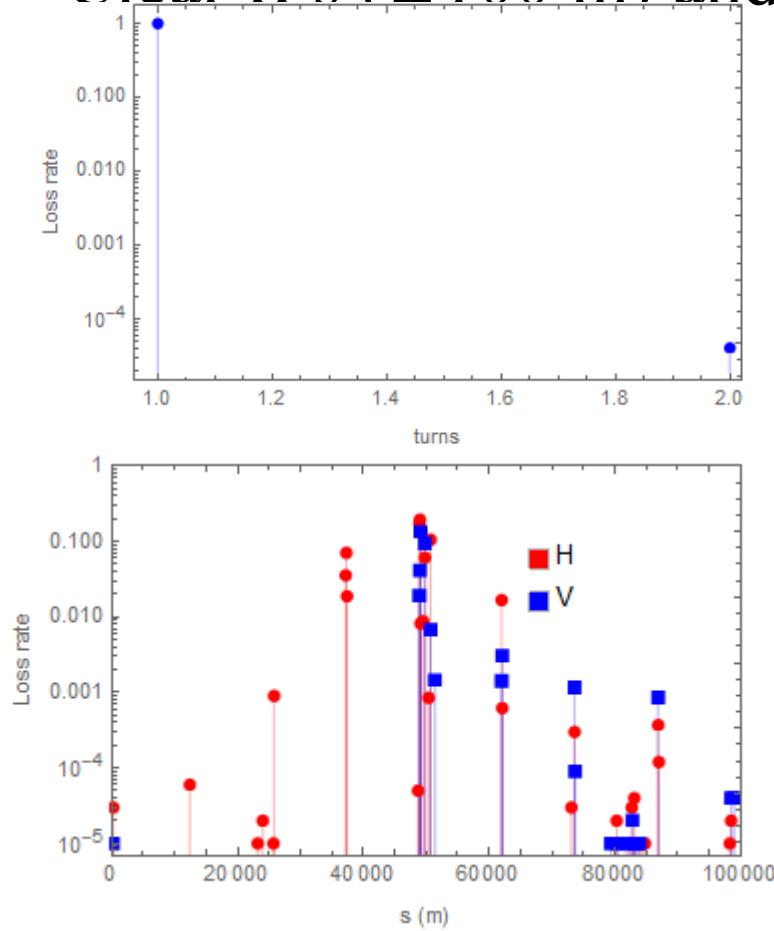
W- All failures

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



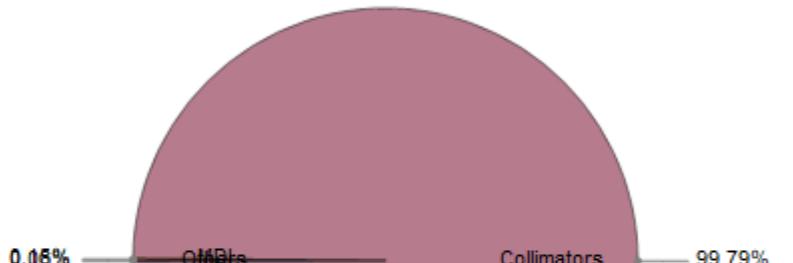
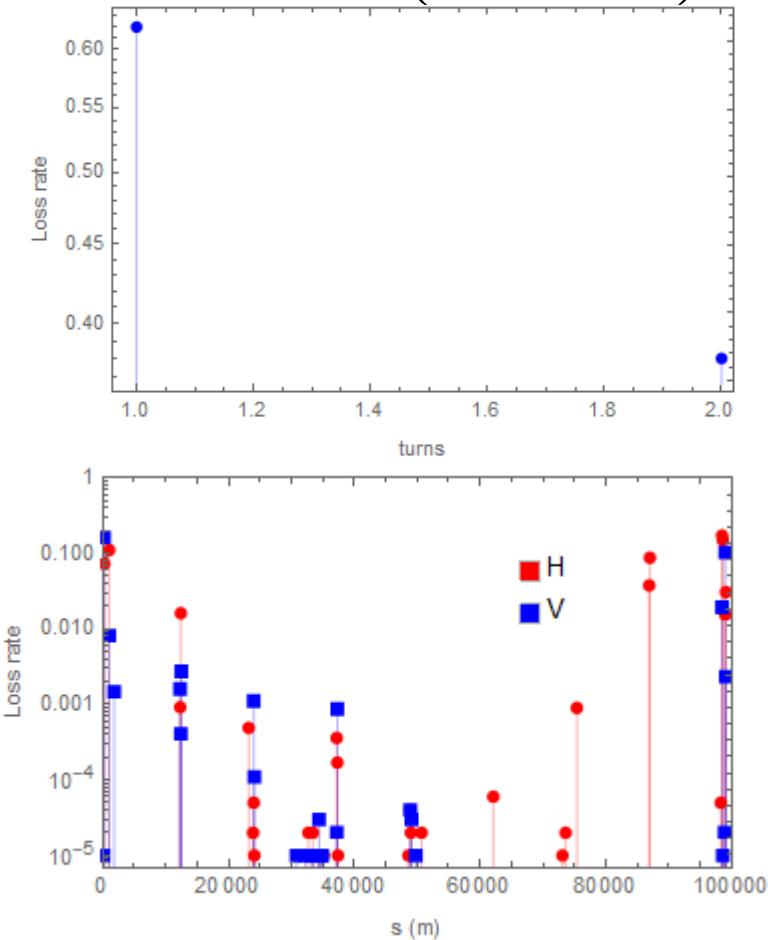
W- All failures

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



W- All failures

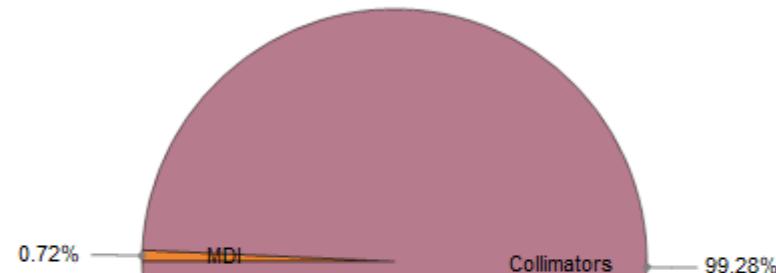
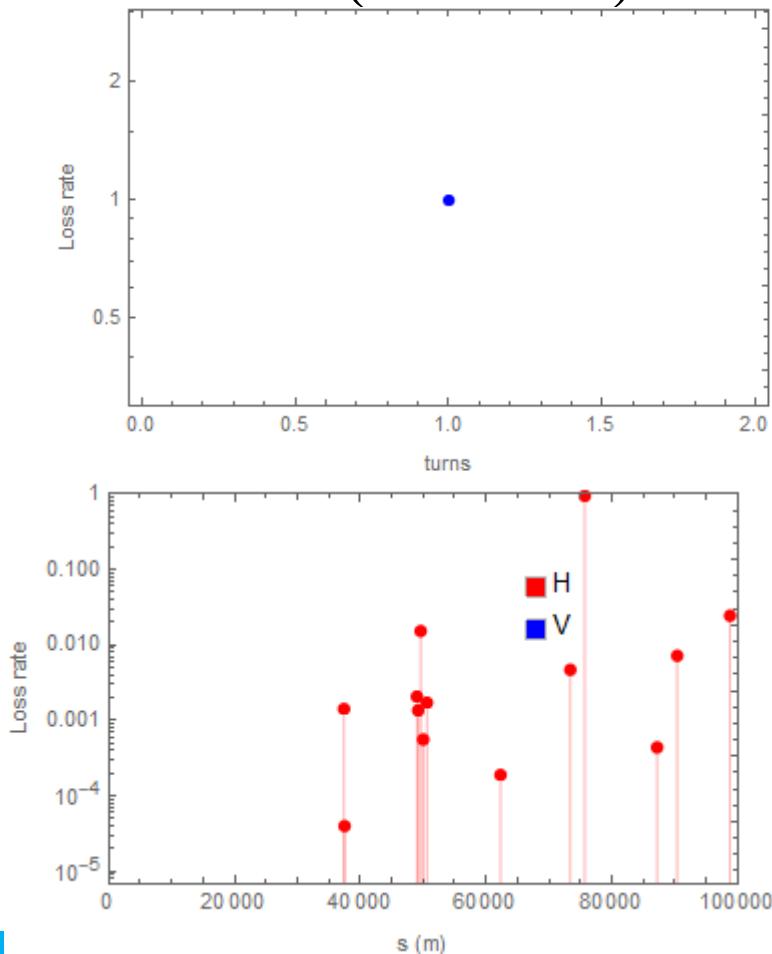
- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



ttbar mode

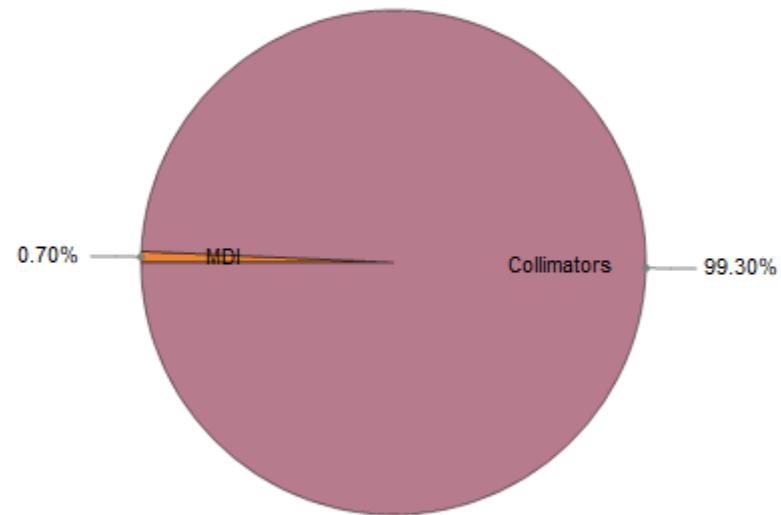
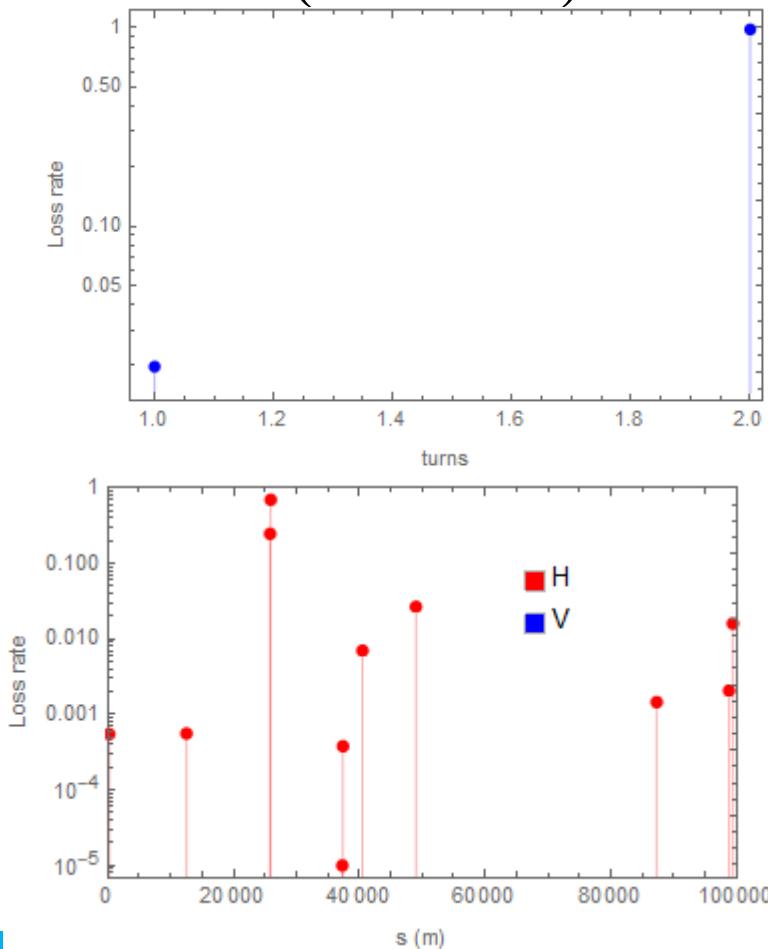
ttbar- RF failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



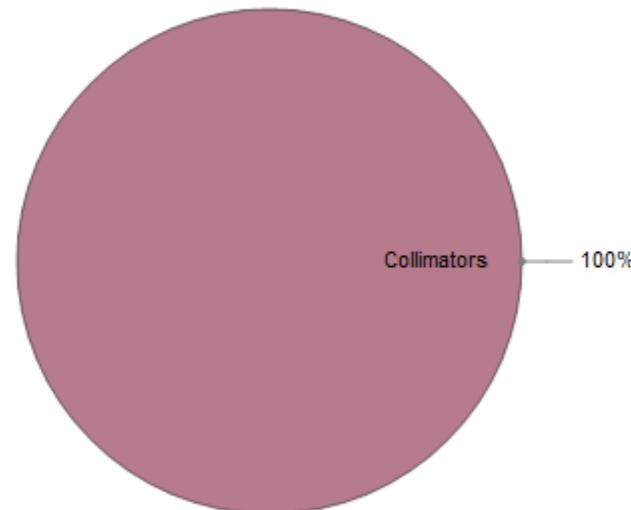
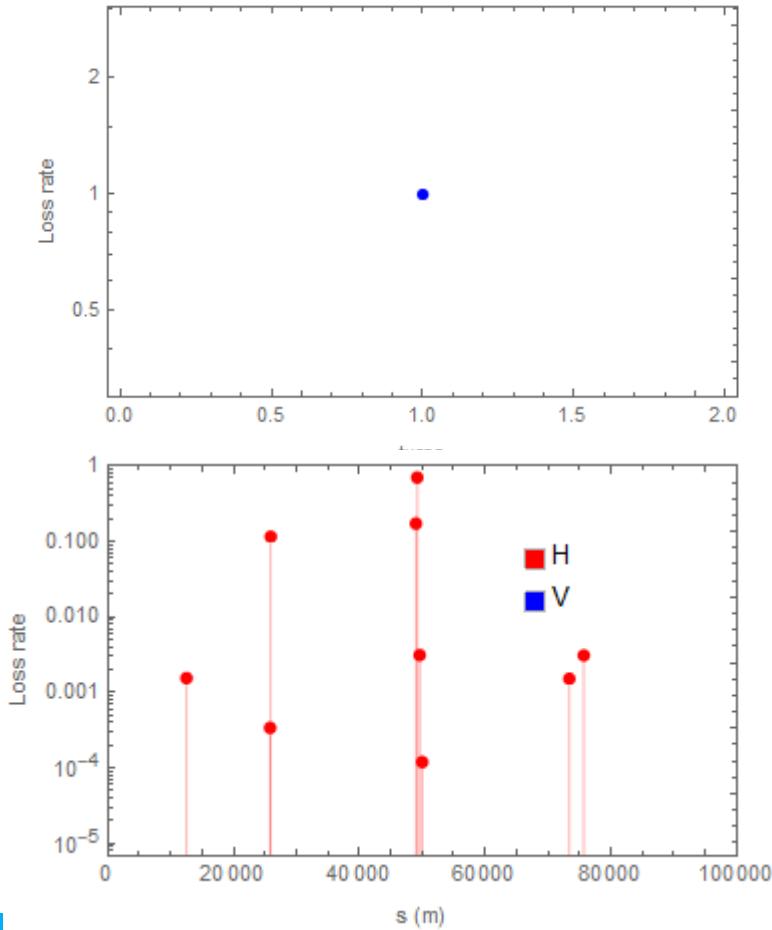
ttbar- RF failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



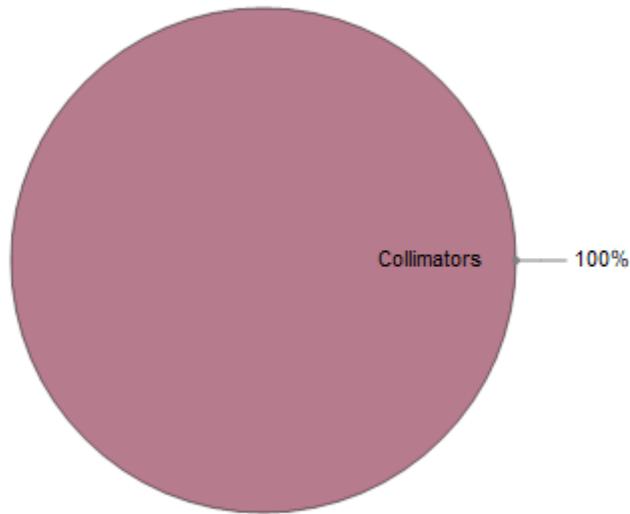
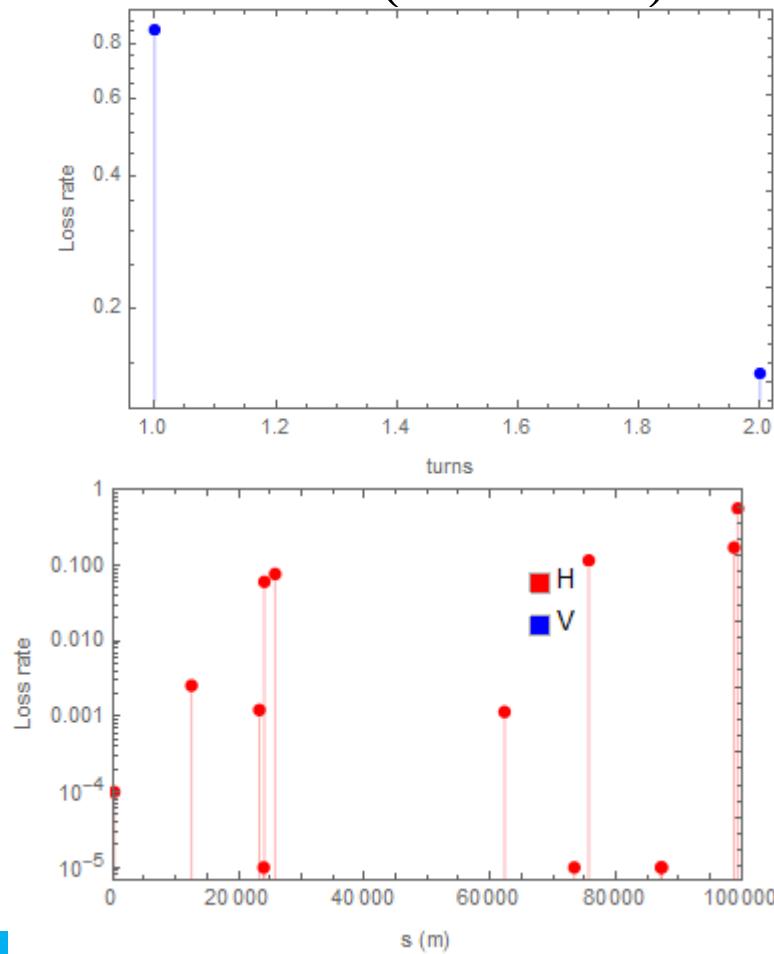
ttbar- RF failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



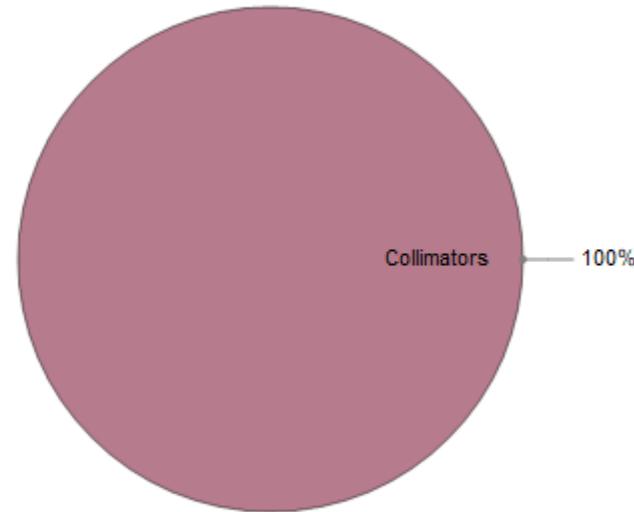
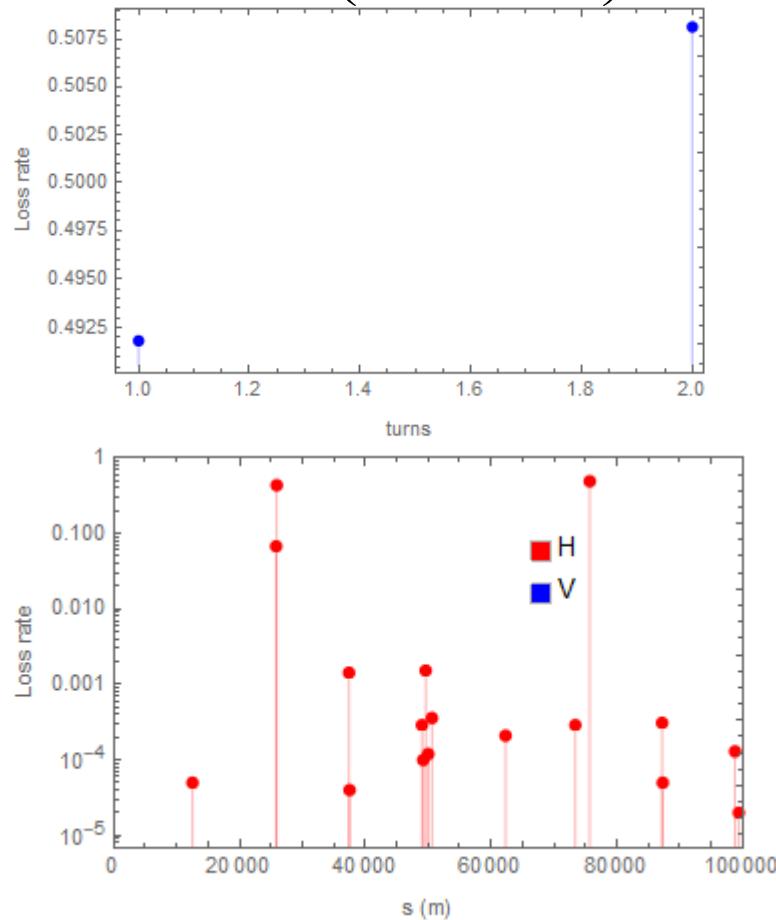
ttbar- RF failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



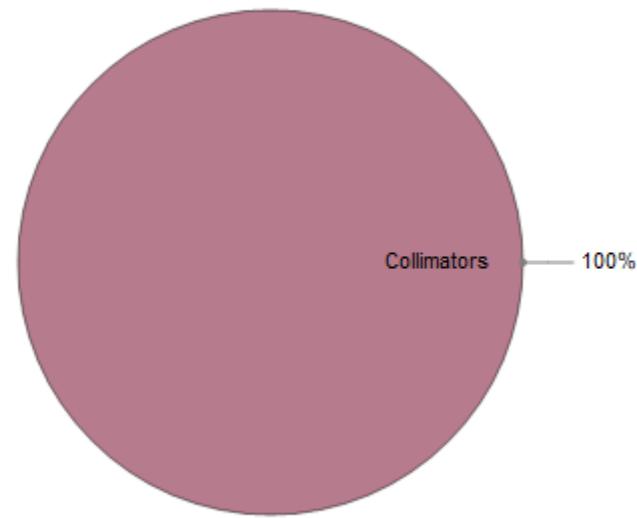
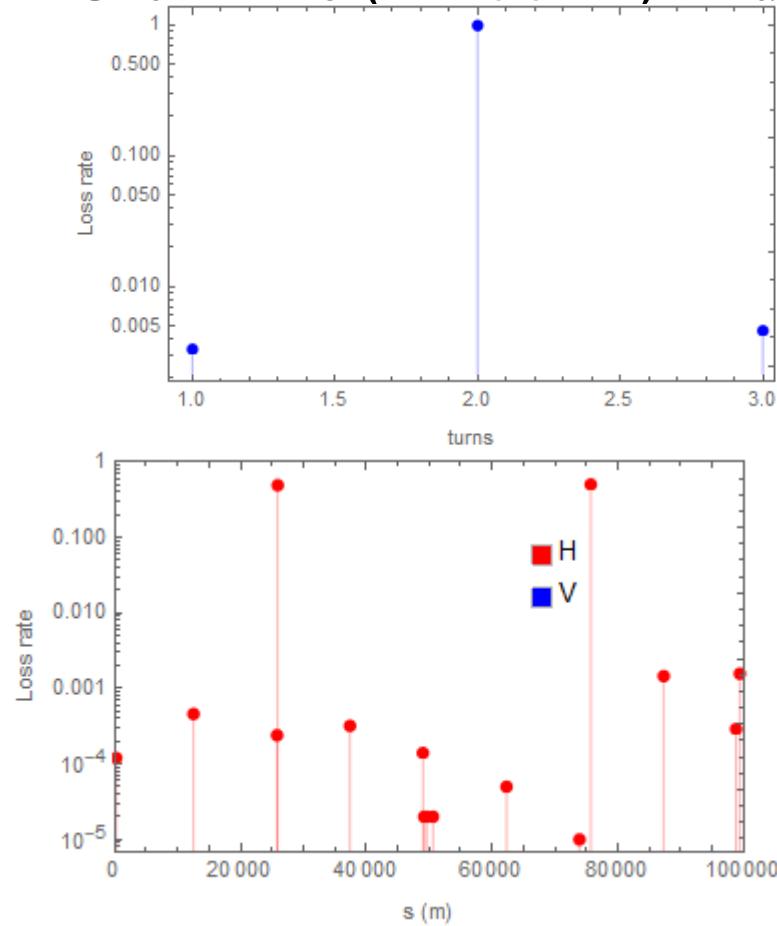
ttbar- B failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



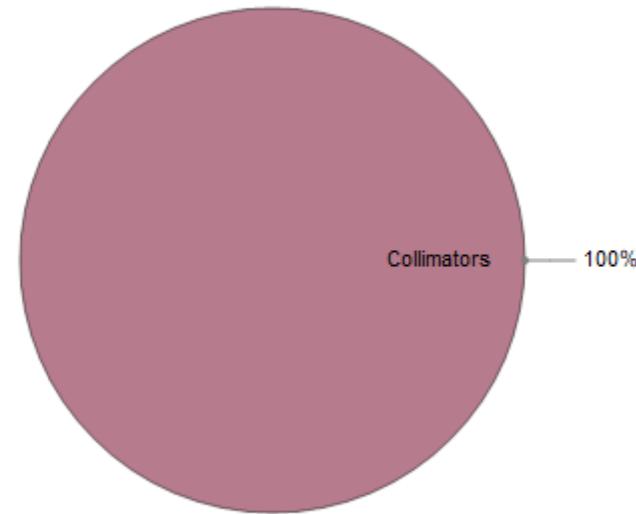
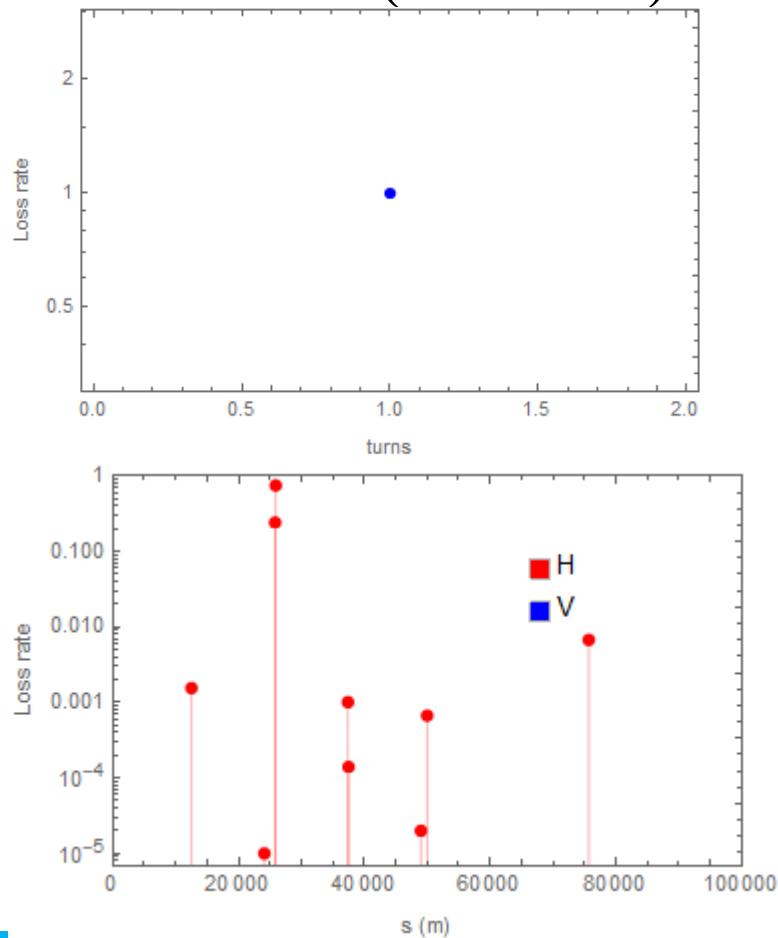
ttbar- B failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



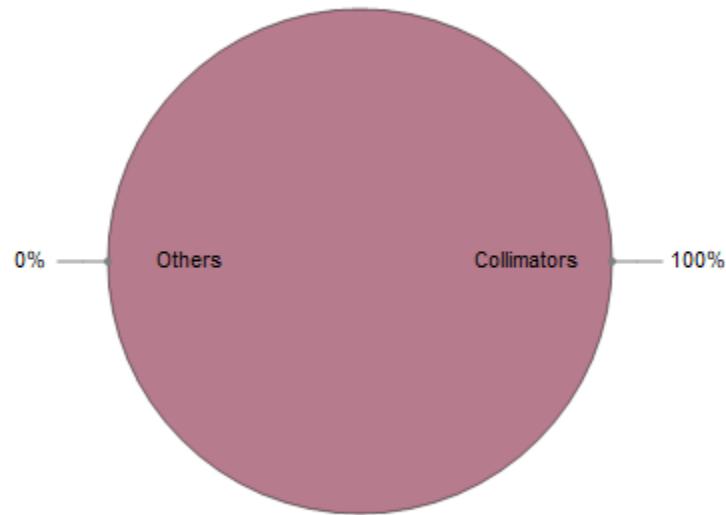
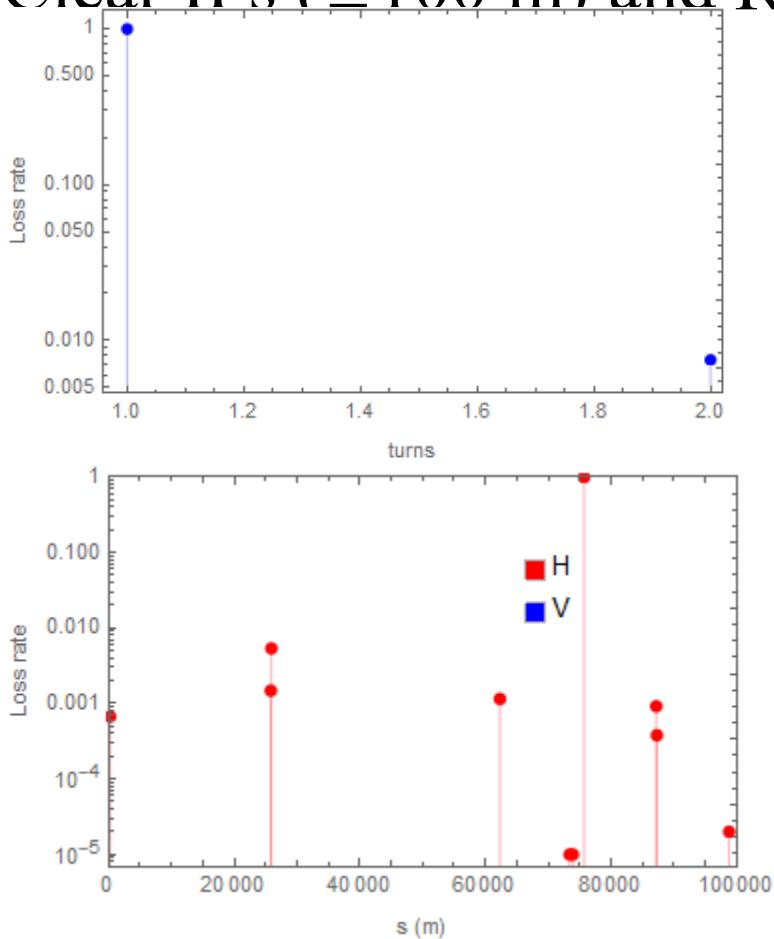
ttbar- B failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



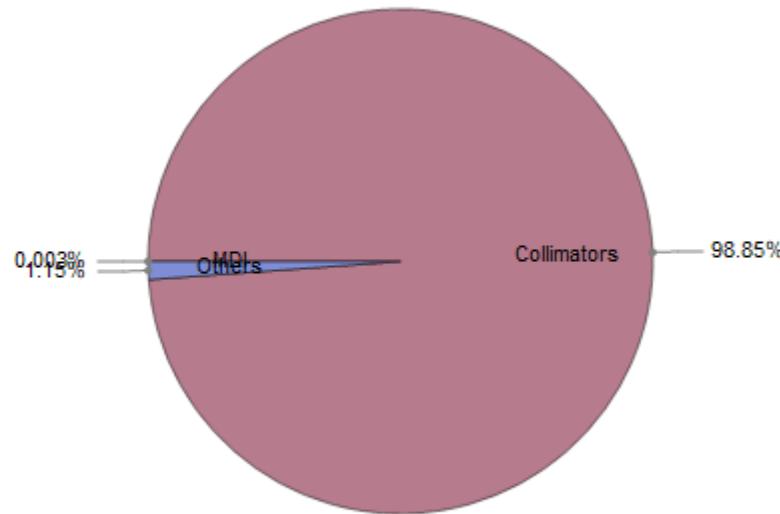
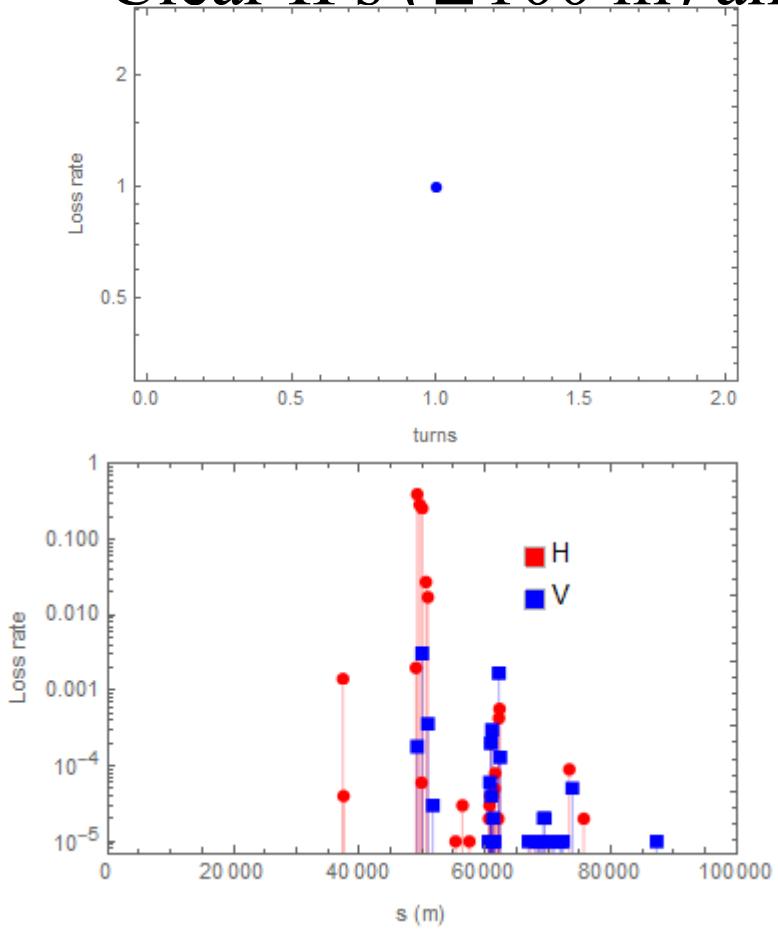
ttbar- B failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



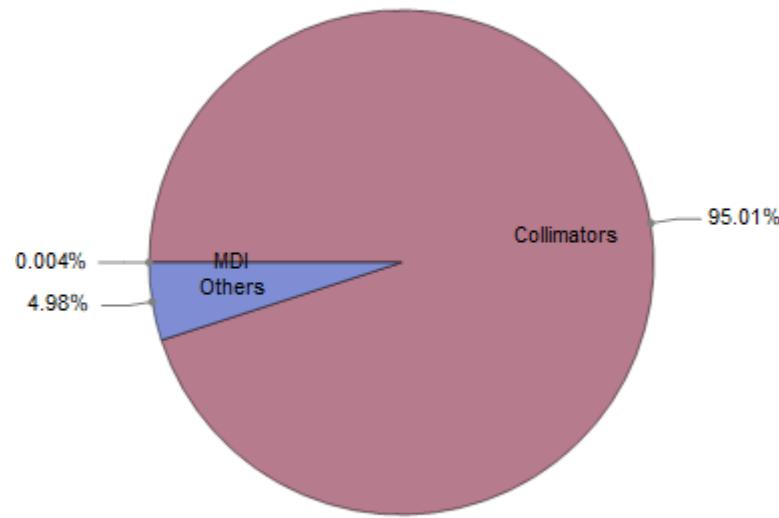
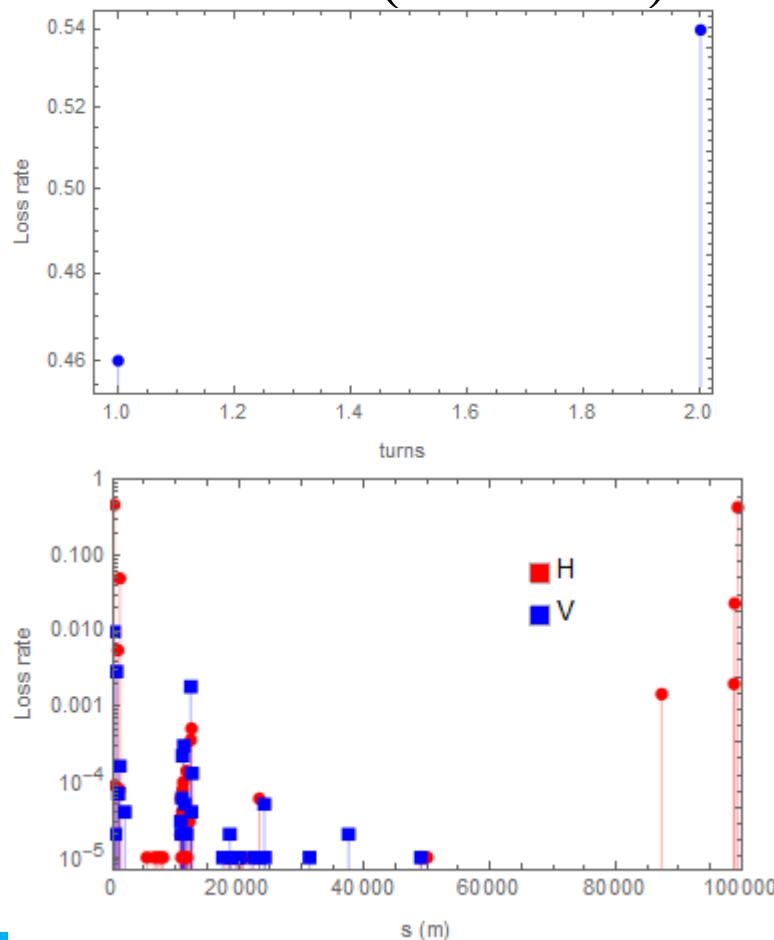
ttbar- NorQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



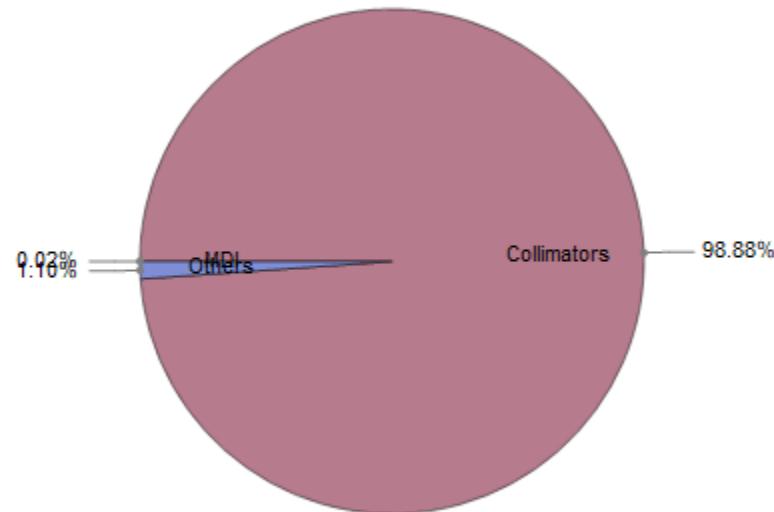
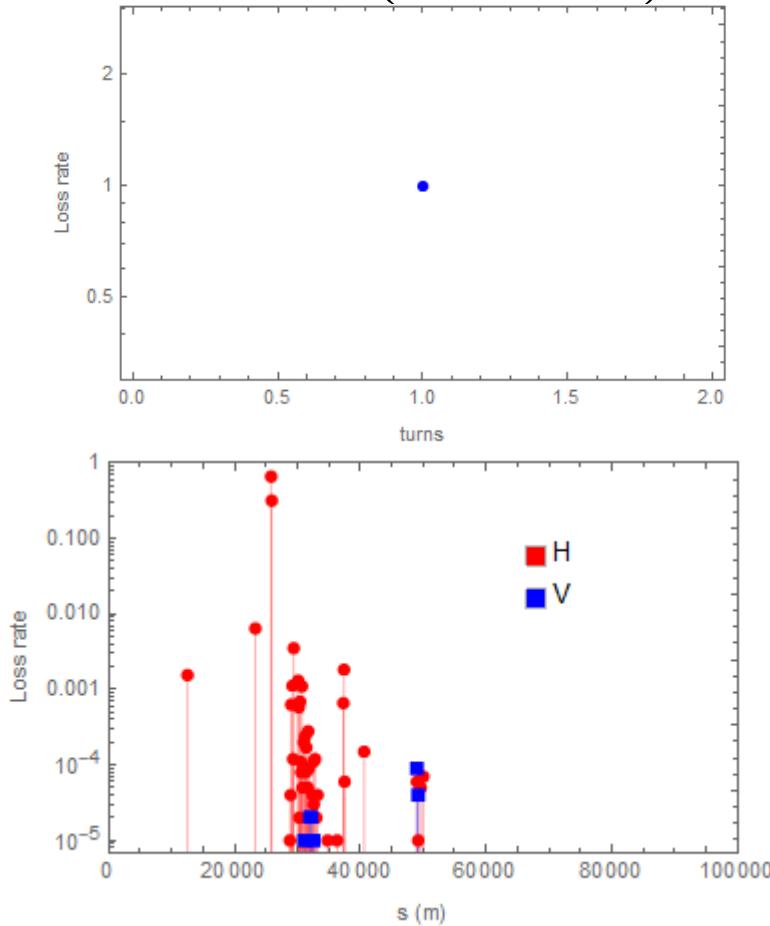
ttbar- NorQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



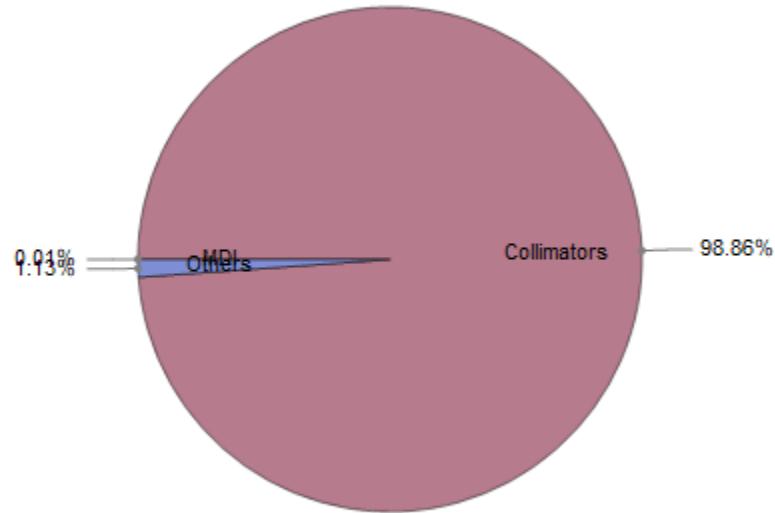
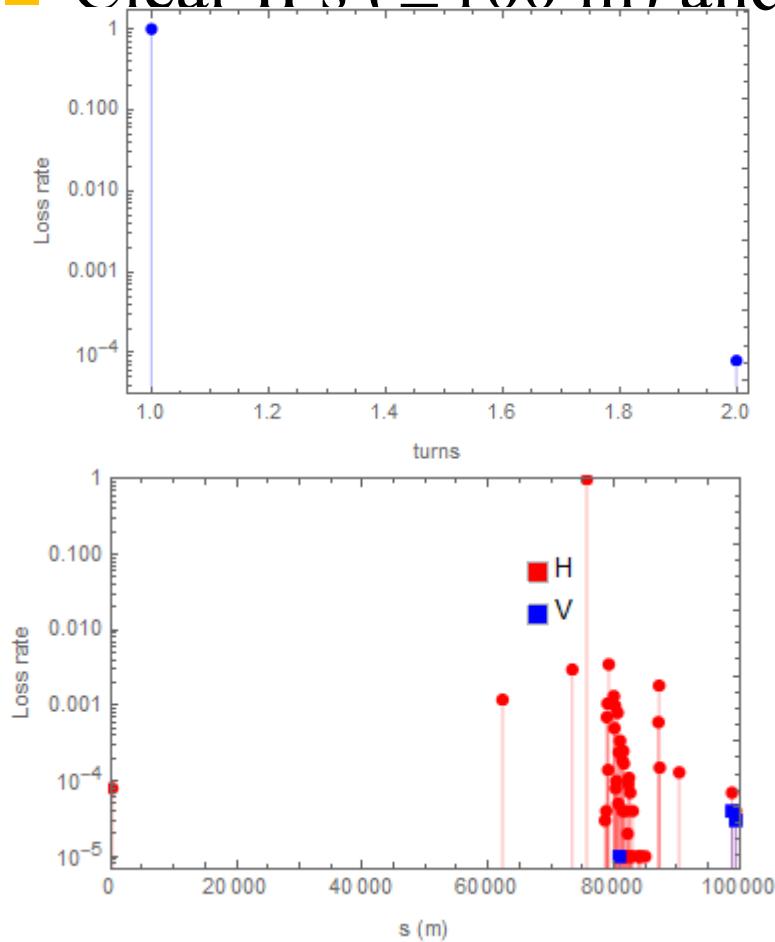
ttbar- NorQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



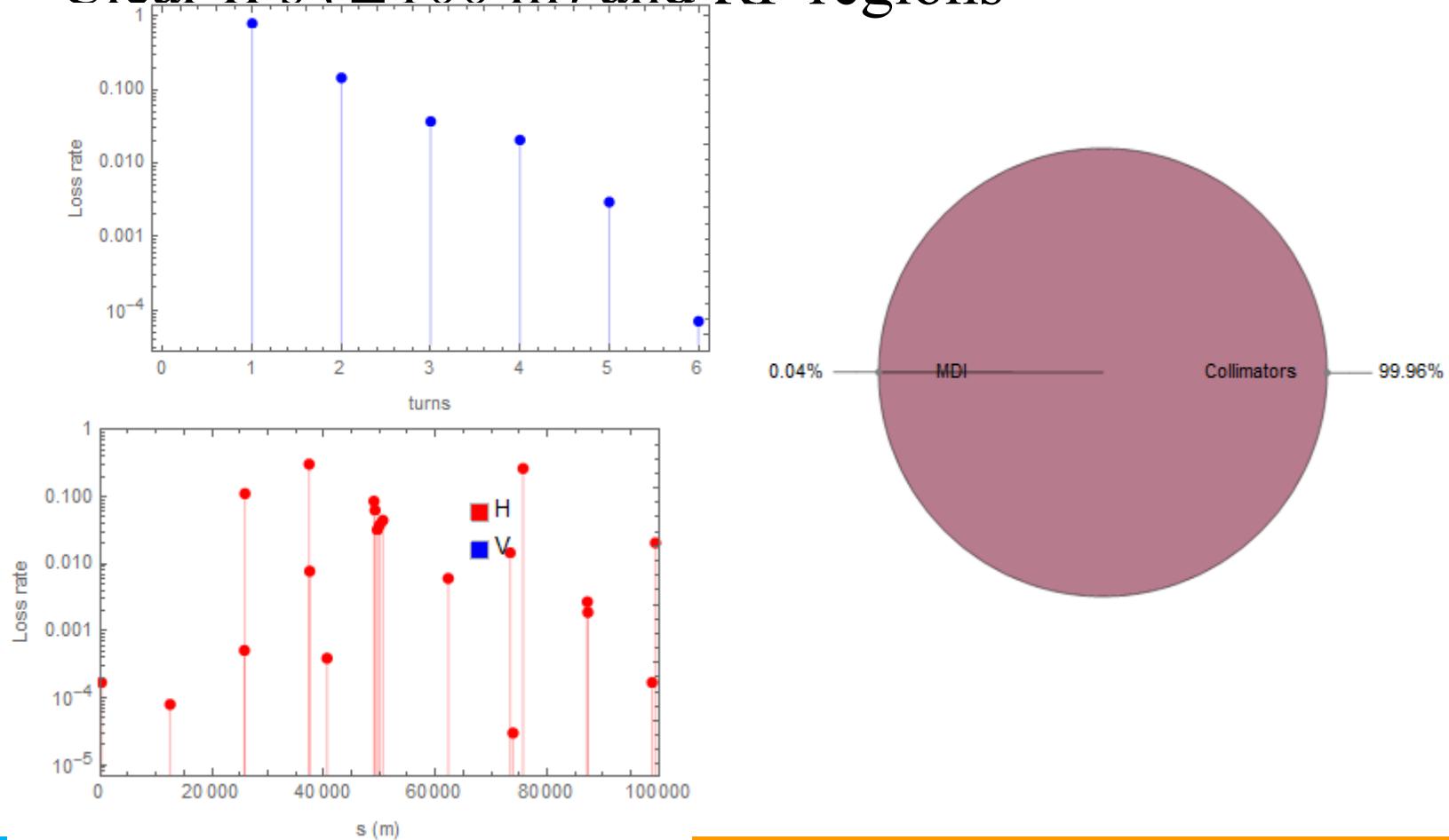
ttbar- NorQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



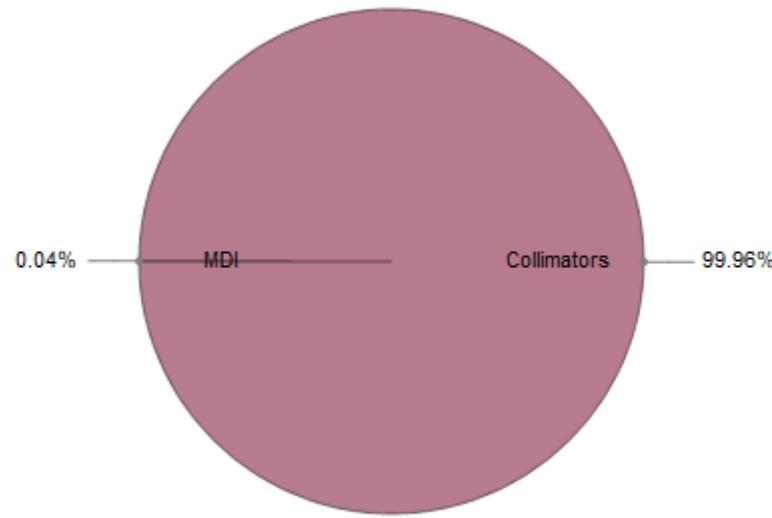
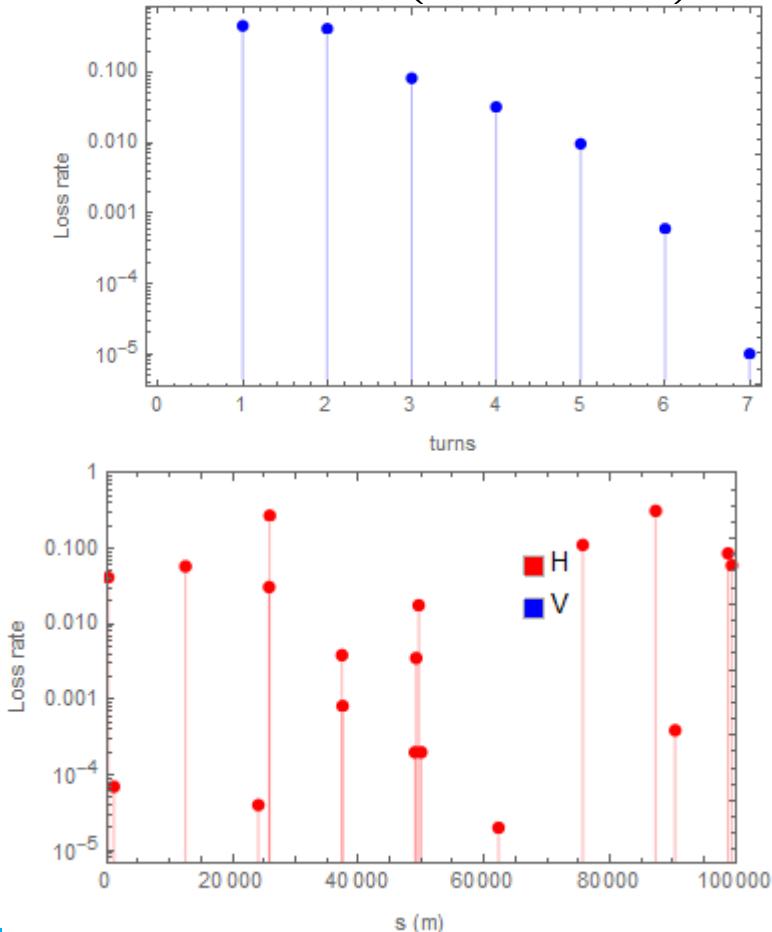
ttbar- SCQ failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



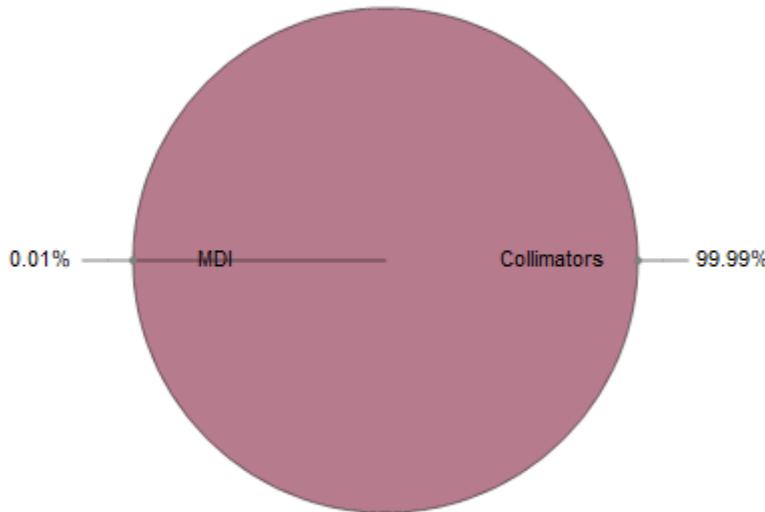
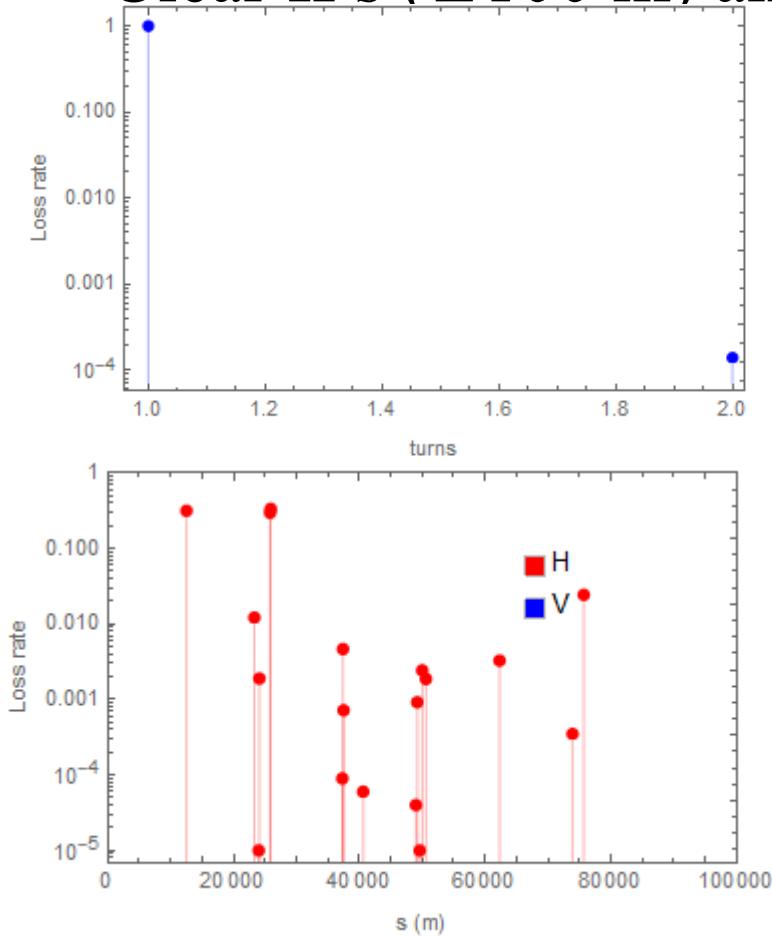
W- SCQ failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



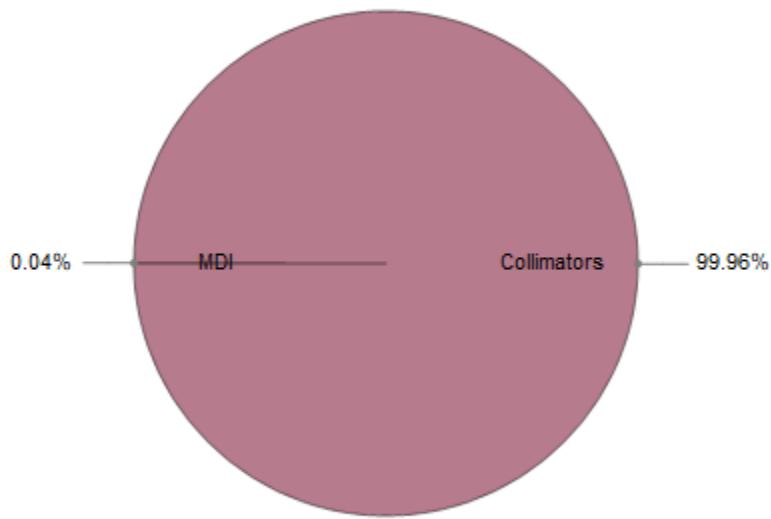
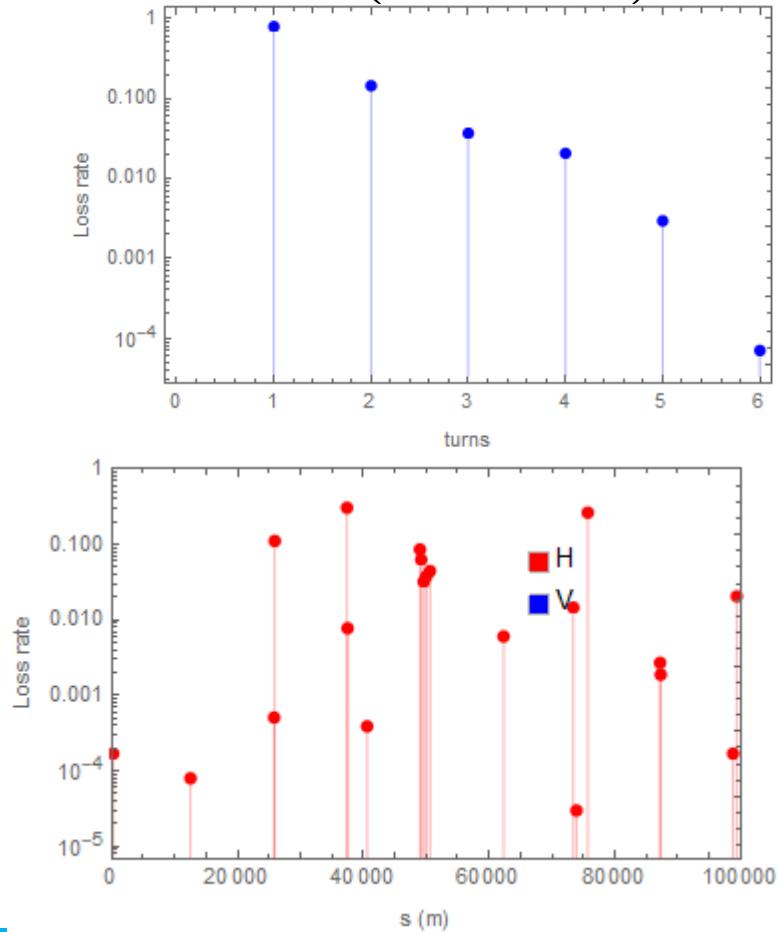
ttbar- SCQ failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



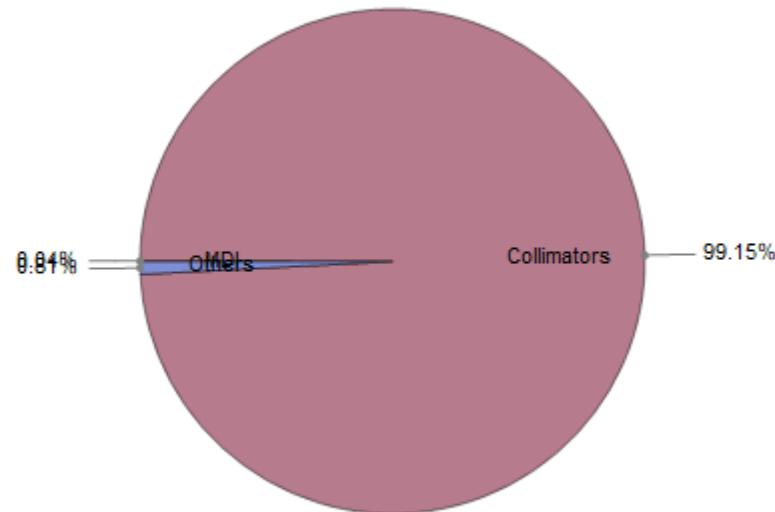
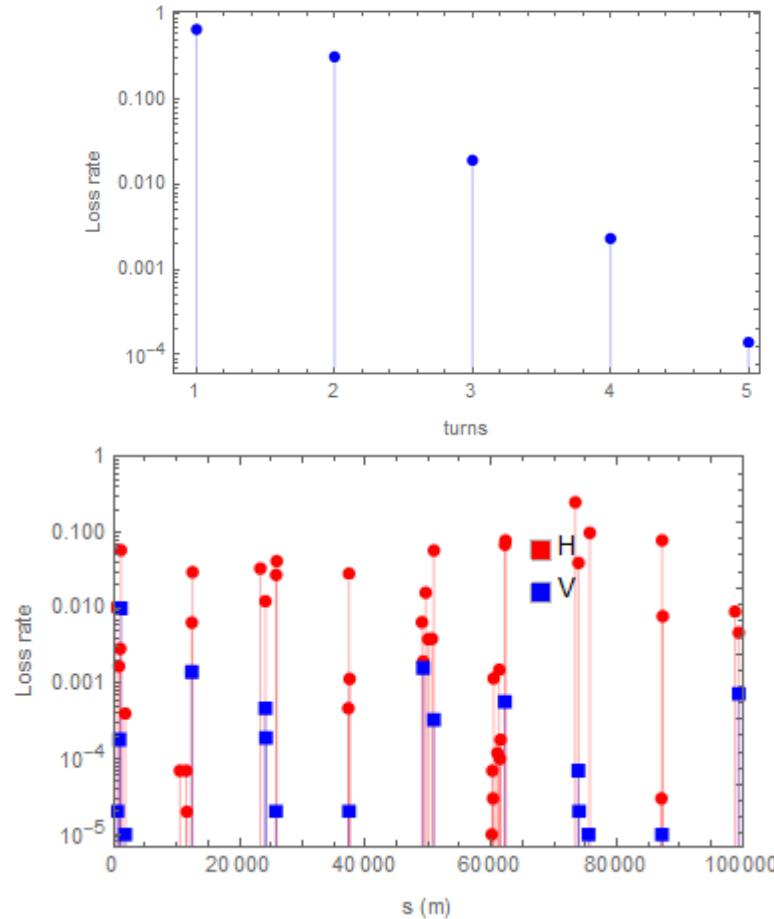
ttbar- SCQ failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



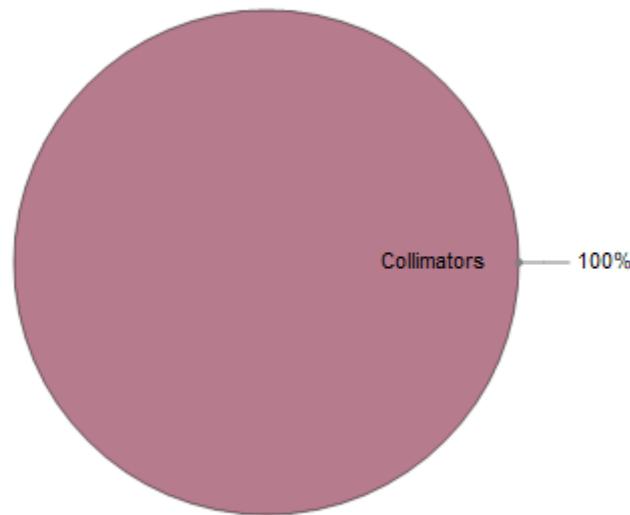
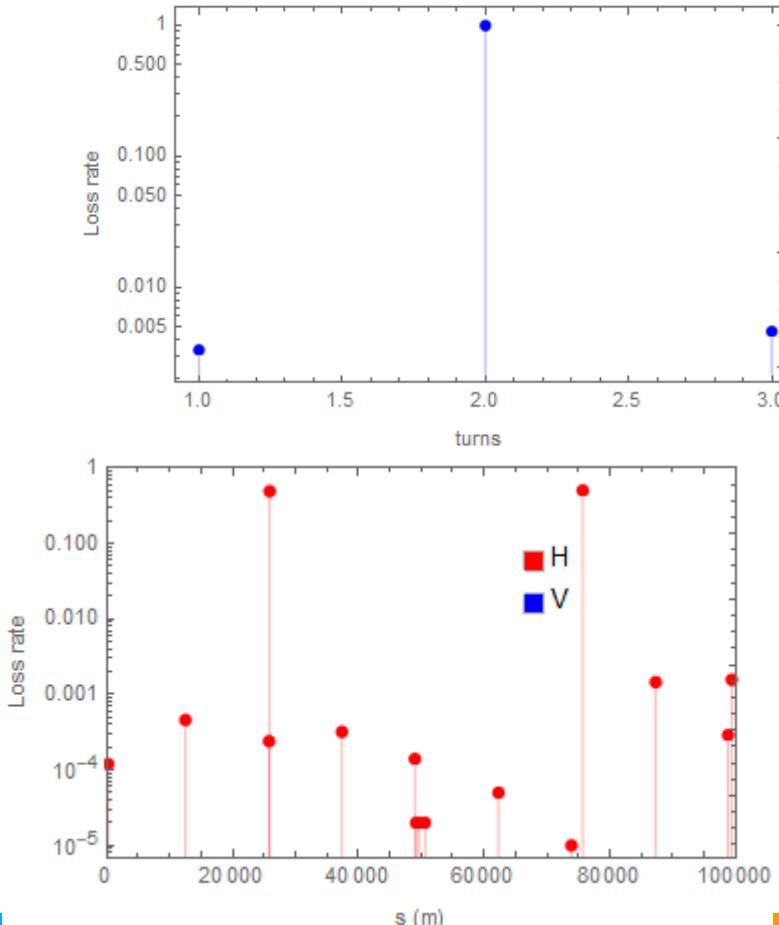
ttbar- S failure

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



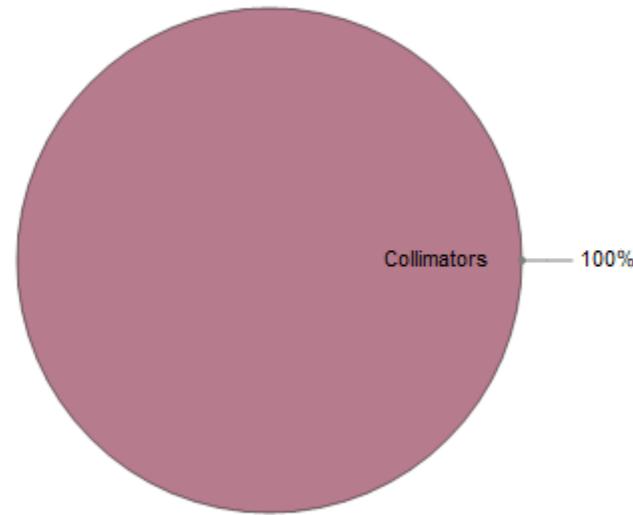
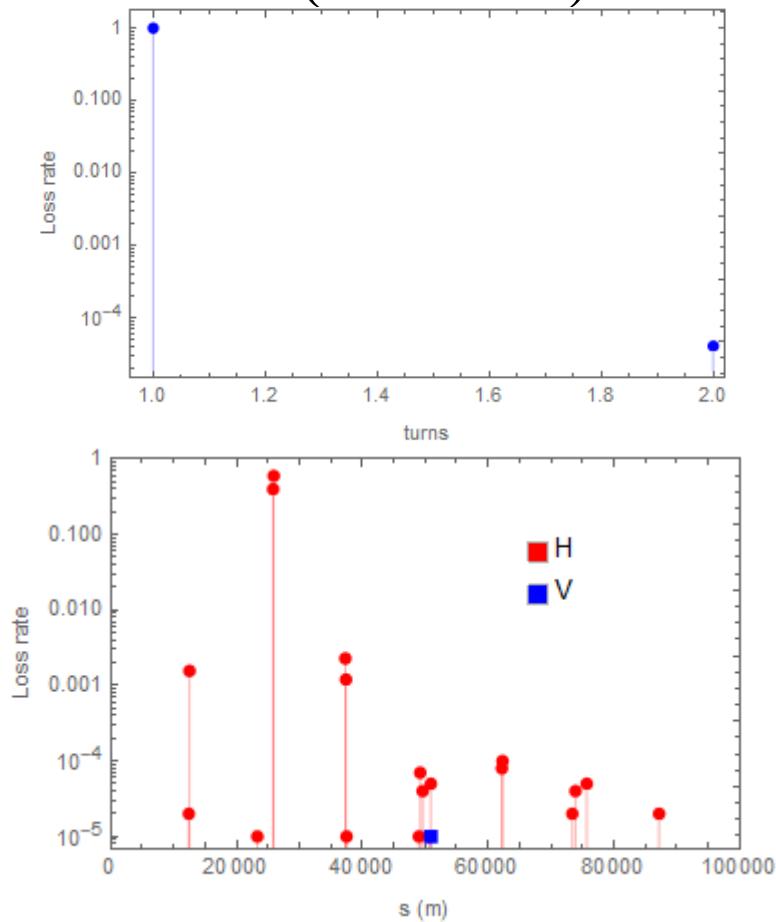
ttbar- S failure

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



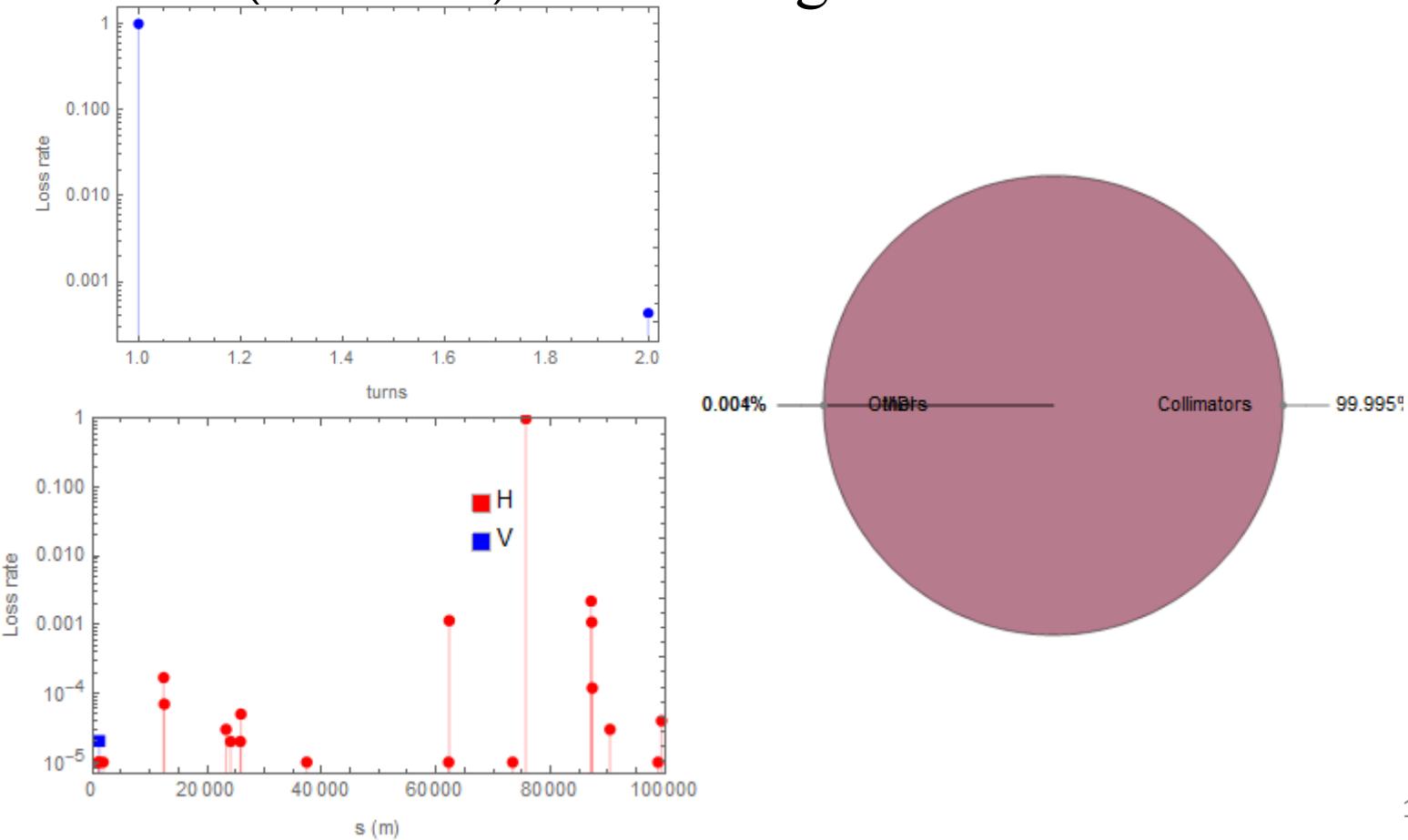
ttbar- S failure

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



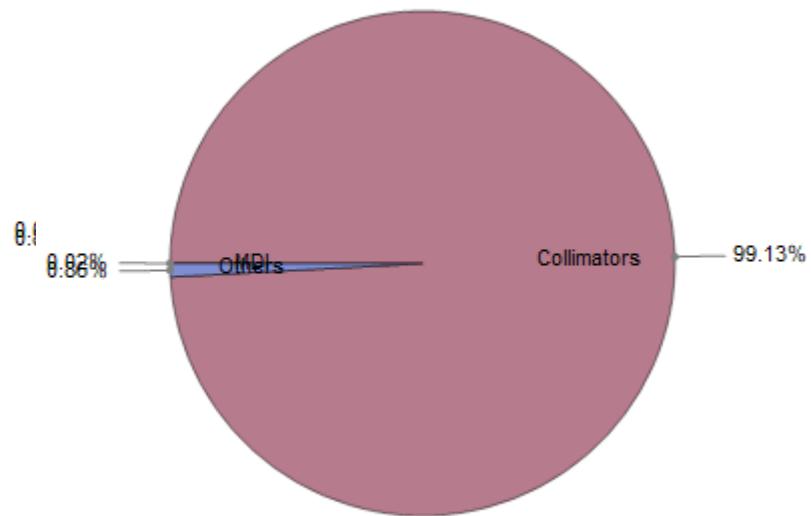
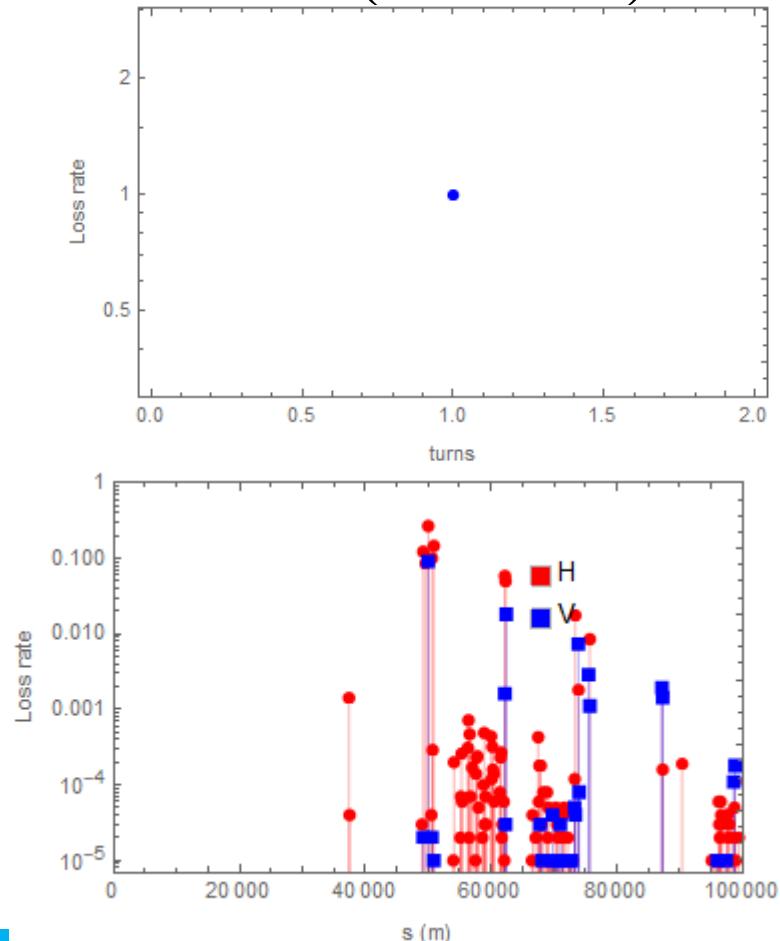
ttbar- S failure

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions



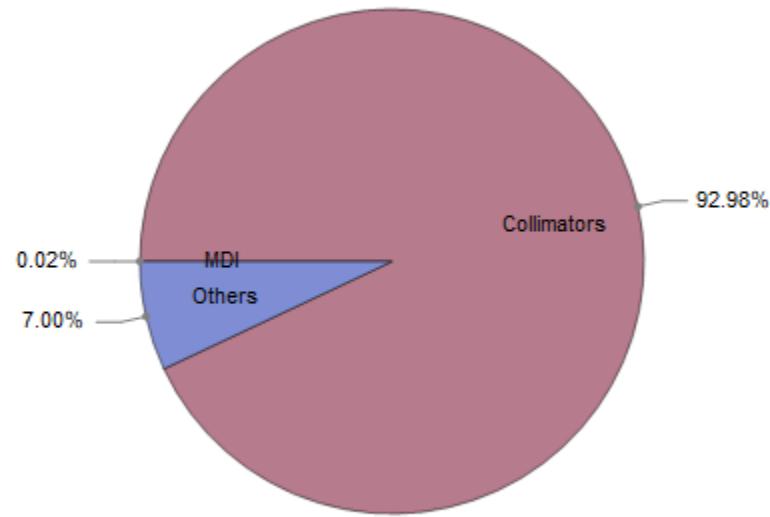
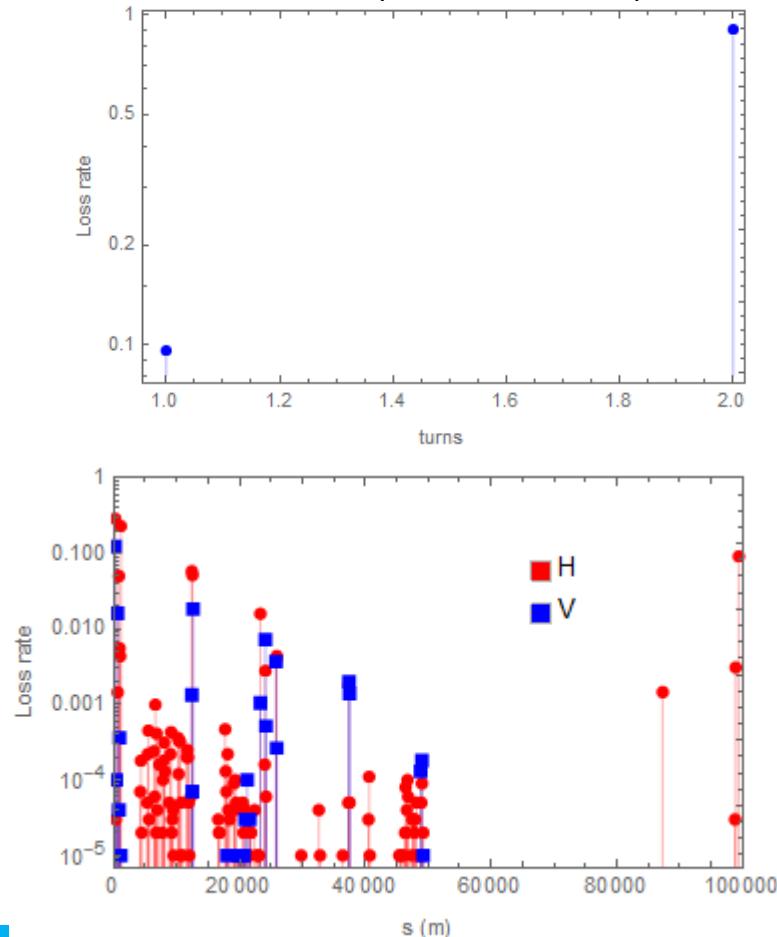
ttbar- All failures

- Simulation starts from MINJI.1
- Clear IPs (± 100 m) and RF regions



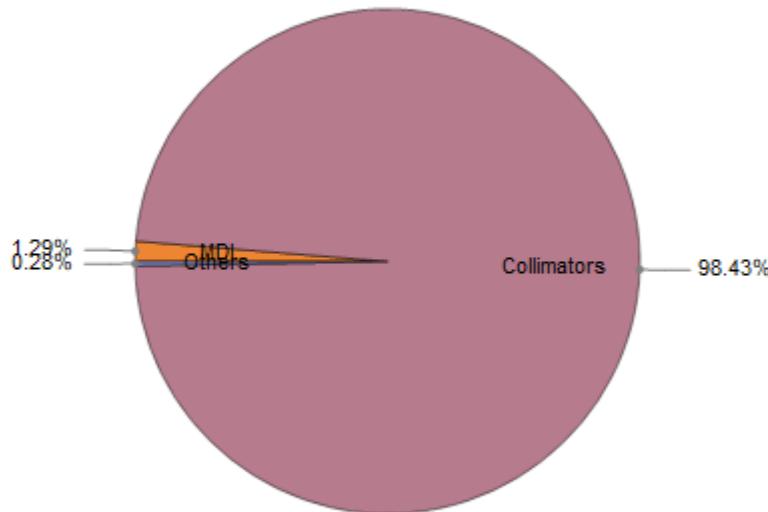
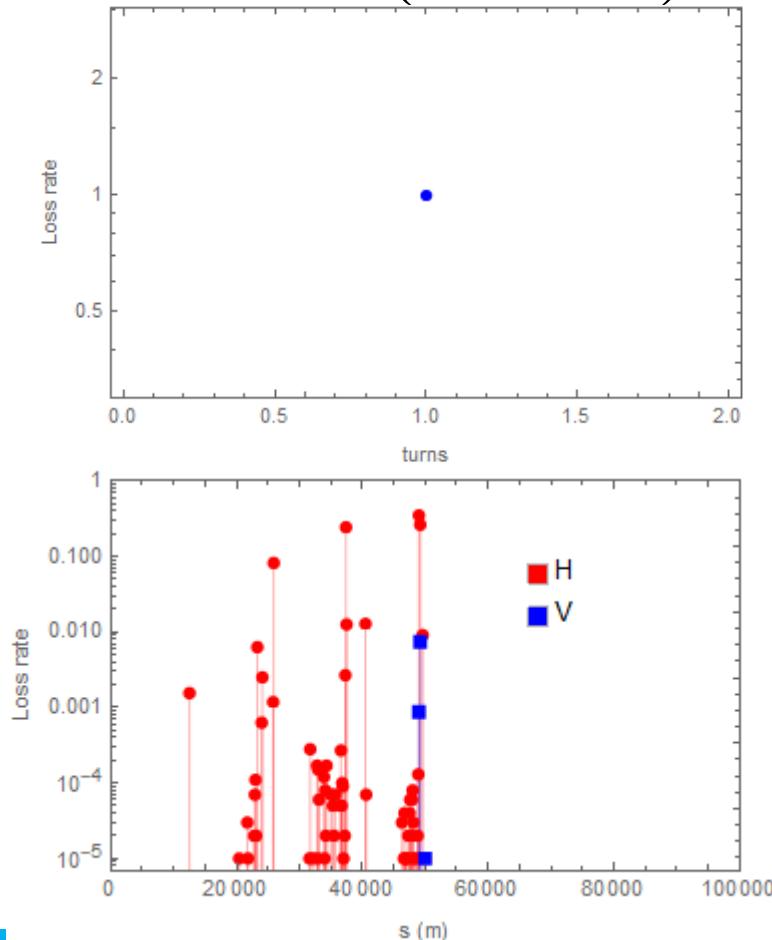
ttbar- All failures

- Simulation starts from MINJI.2
- Clear IPs (± 100 m) and RF regions



ttbar- All failures

- Simulation starts from MINJO.1
- Clear IPs (± 100 m) and RF regions



ttbar- All failures

- Simulation starts from MINJO.2
- Clear IPs (± 100 m) and RF regions

