RECOVERING THE POSITRON BEAM AFTER MUON PRODUCTION IN THE LEMMA MUON SOURCE

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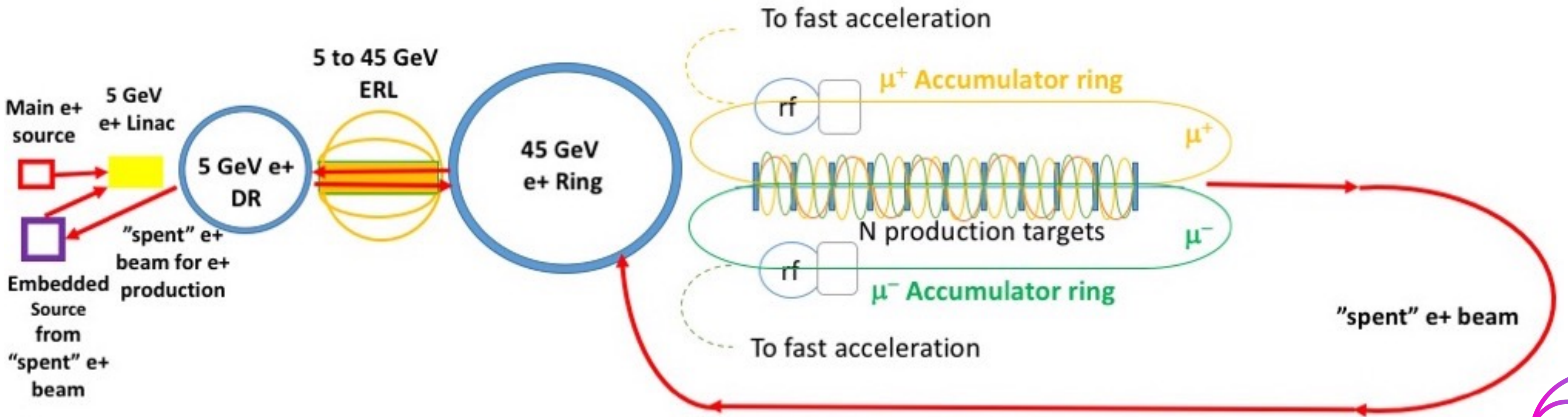
In the LEMMA muon source proposal a **positron beam at 45 GeV** is used to produce **muons at threshold** by interaction with some targets. In order to release the required intensity on the main positron source, orders of magnitude higher than the state of the art, the possibility to recover the primary positron beam after the interaction with the targets, was studied. The beam particle distribution, with a strongly degraded energy spread after the interaction, was injected back into the main low emittance, large energy acceptance 45 GeV ring. Studies of injection efficiency were performed. The possibility of compressing the beam in a linac before injection was also studied. As a result, even without compression, about 80% of the disrupted positron beam can be injected back into the ring.



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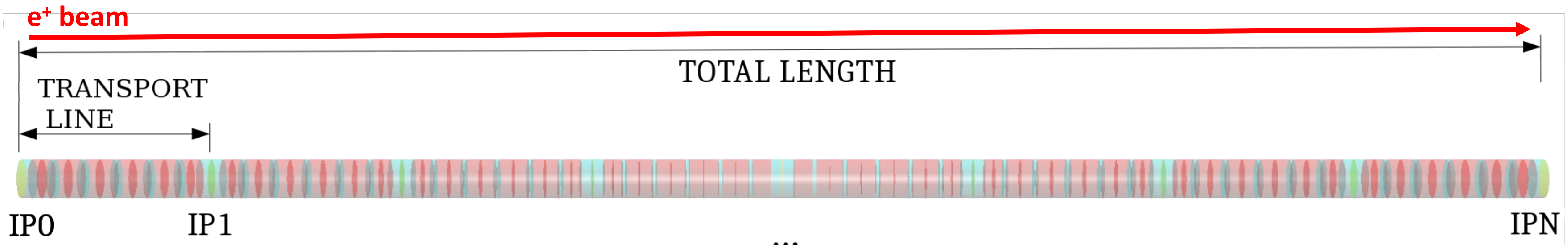
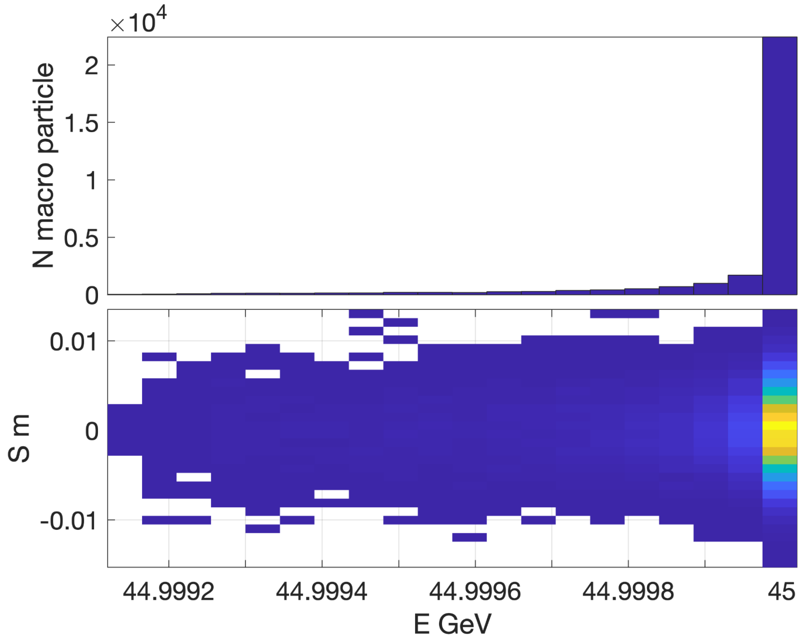
Creating Muons From Positrons



Muon and positron beam transport through a common line with targets in multiple IPs.

- Targets are separated by a transport line with magnets common to 3 beams (e^+, μ^+, μ^-)
- Line must focus (low β) the beams at each IP to achieve the production of new μ with minimal growth of the final μ beam emittance
- Length should be as small as possible in order to minimize μ decay issues
- Chromaticity cannot be corrected with standard method, because this would split the 3 beams → other method used to mitigate the chromatic effect



Positron beam distribution after the interaction with the 10 targets

45GeV Positron Ring

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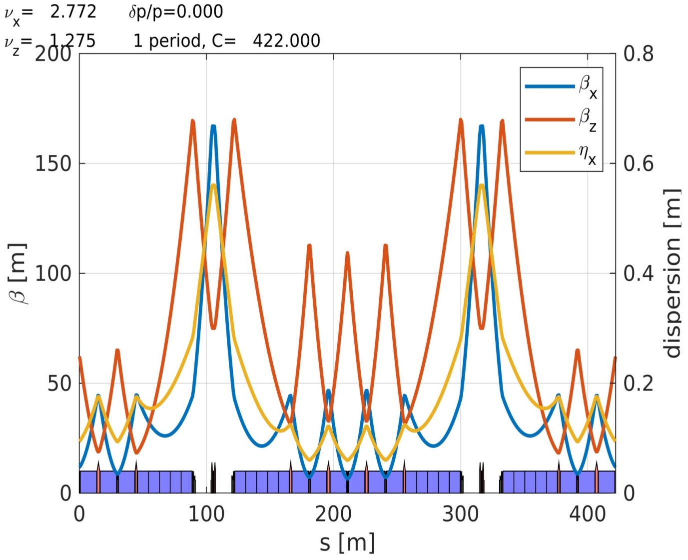
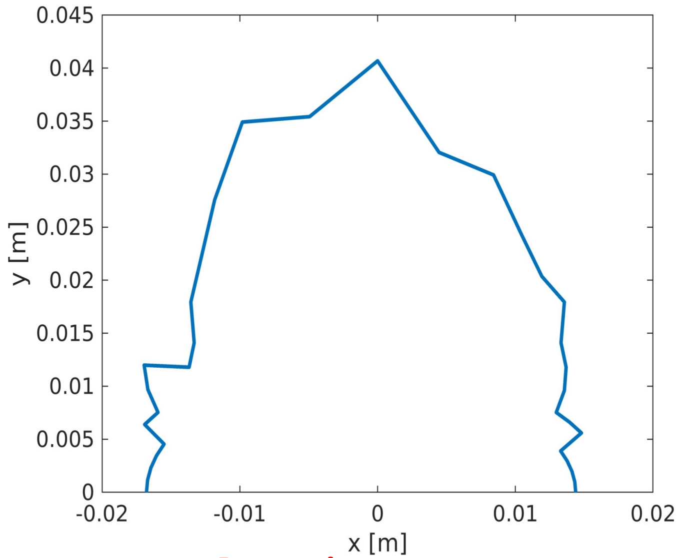
Positron Ring parameters

Parameter	Units	
Circumference	Km	27
Beam current	A	0.89
N. part/bunch		$5x10^{11}$
N. bunches		1000
Hor. emittance	nm	0.7
Nat. bunch length	mm	1.9
Energy spread		$7x10^{-4}$
bunch length (0A)	mm	2.0
Damping time (x,y)	ms	68
Damping time (s)	ms	34
RF frequency	MH	500
RF Voltage	MV	477
Energy acceptance	%	±8

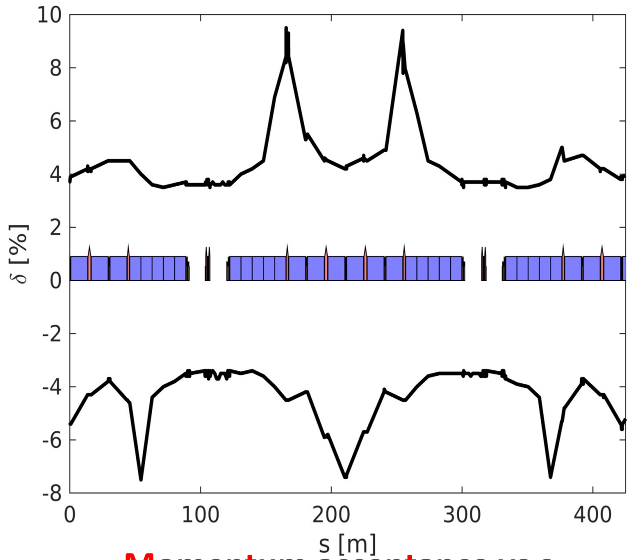
- The PR at 45 GeV has small beam emittance, mostly round beams, and large energy acceptance in order to accommodate the "*spent*" beam coming back after the **muon** production
- A large circumference can accommodate the requested **1000** bunches with **$5x10^{11}$ e^+/bunch** with less important synchrotron losses → **27 km** circumference (LHC-like)
- Achieved energy acceptance so far ranges from **±8%** to **±4%**
- The lattice is inspired by the ESRF upgrade hybrid multi-bend achromat lattice



Optical functions



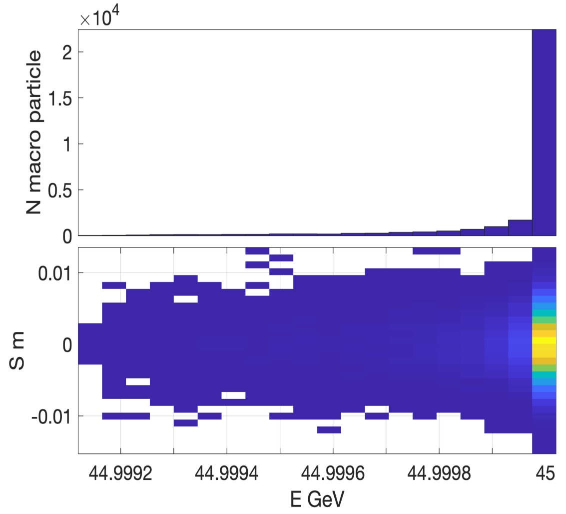
Dynamic aperture



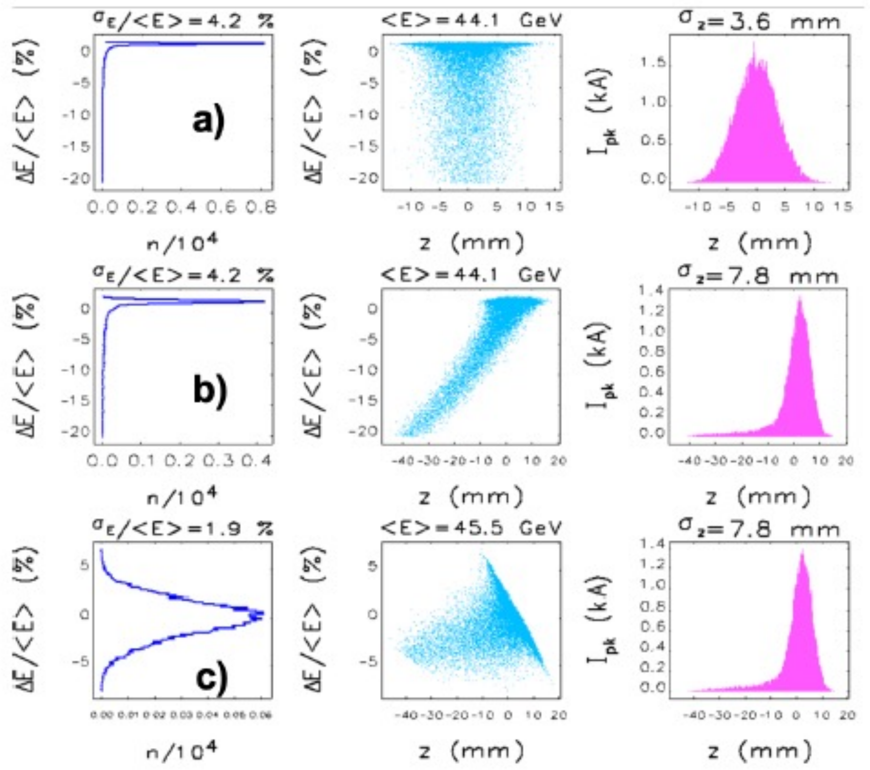
Momentum acceptance vs s

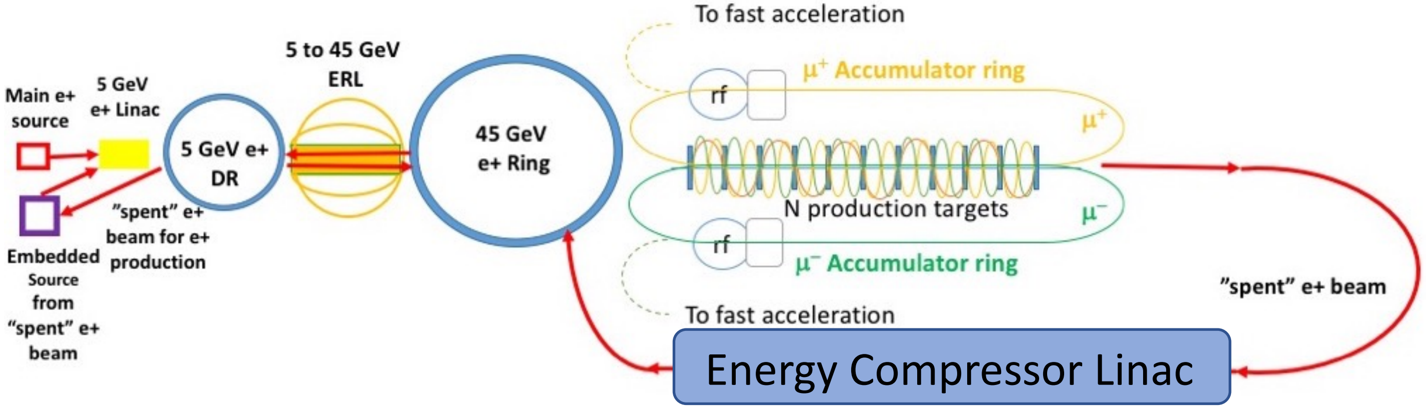
Compressor LINAC

e^+ beam energy distribution after interaction with targets: 90% of beam survives



- A Linac can compress the energy spread of *spent* e^+ beam after interaction, before re-injection in the PR
- One chicane + L-band (XFEL-like) linac, compression from ~ 20% → 2% total
- Final bunch length σ < 1 cm





Longitudinal phase space distribution of the positron beam in the compressor linac: a) entrance of the matching section upstream the magnetic chicane, b) exit of the chicane, c) exit of the linac

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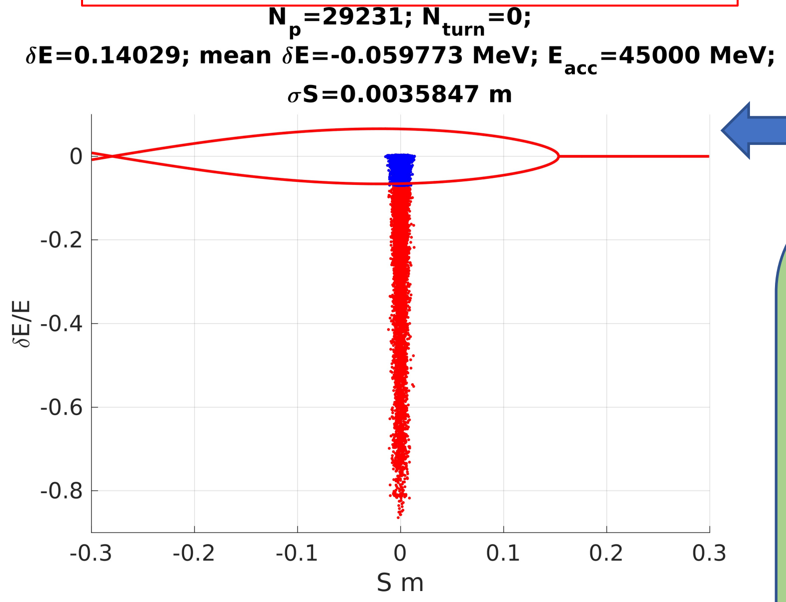
INJECTION INTO POSITRON RING

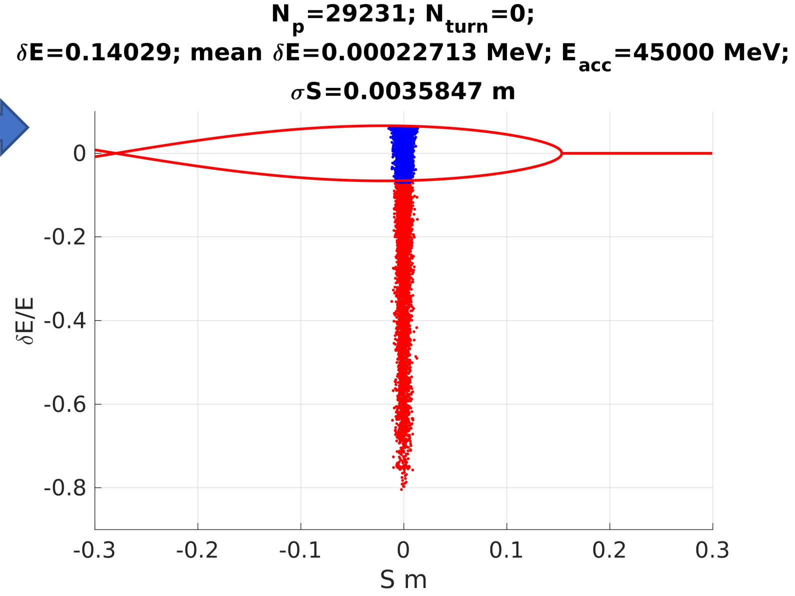
Example of (linear) tracking injection

Without energy offset

With energy offset 6%

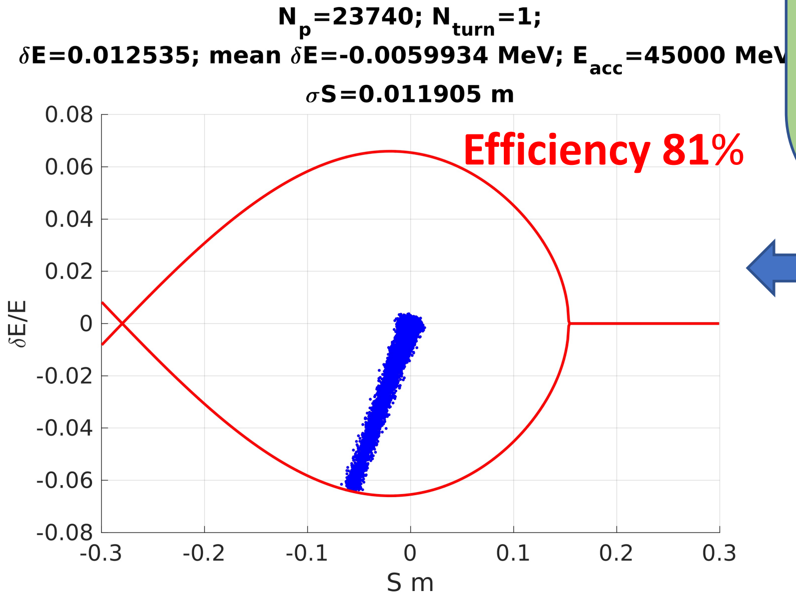


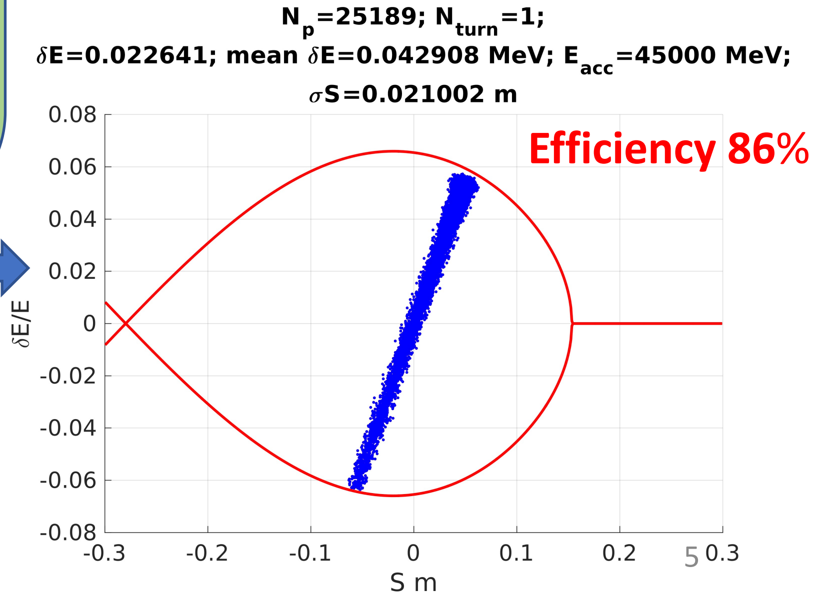
Beam at injection



About **~20%** of particle are lost when injecting the beam directly after the target (with an energy spread of ~15%) into the ring with energy acceptance ~8%. Injecting the beam with an energy offset results in more particles to be captured inside the bucket, increasing the injection efficiency

Beam after 1 turn

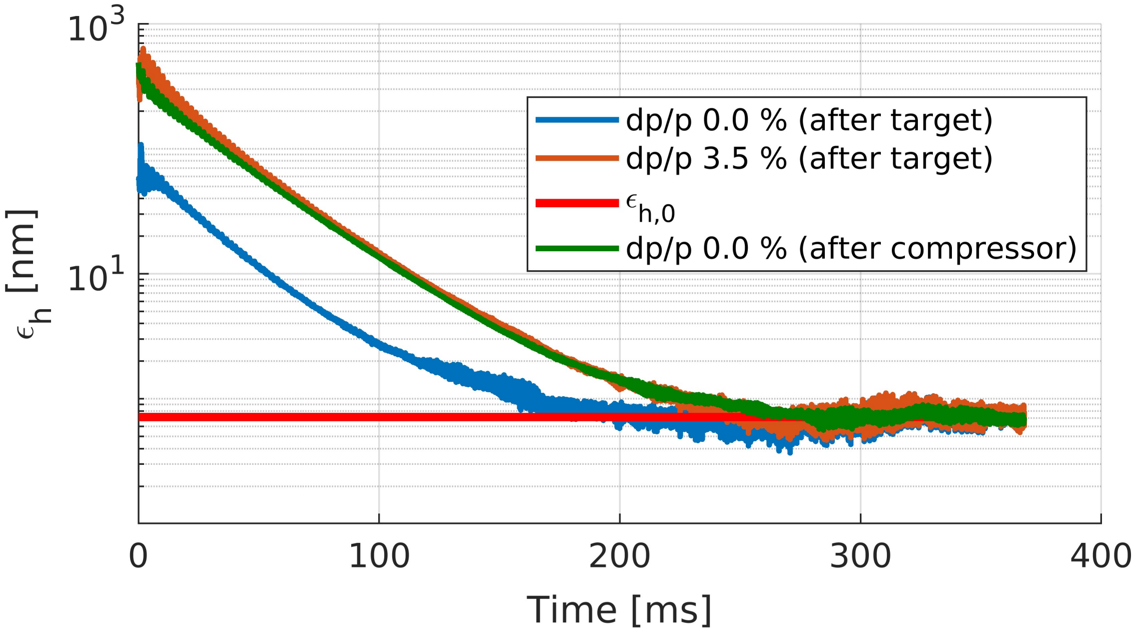




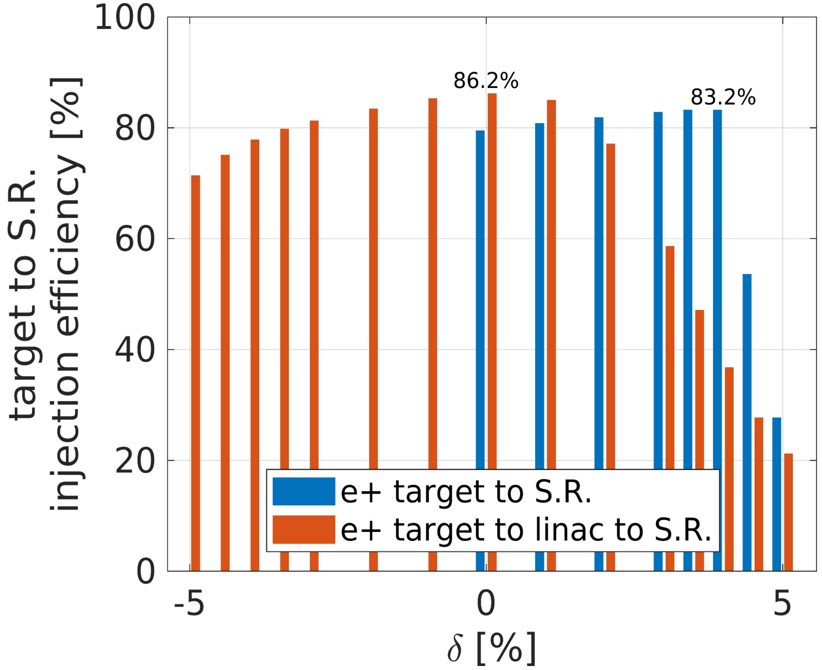
Injection with energy offset requires 6D tracking simulation until beam converge to the equilibrium

INJECTION INTO THE POSITRON RING

Particles are tracked into the PR for **4096** turns. The 6D tracking of about **$3\text{x}10^4$ particles** is performed using **Accelerator Toolbox**



Horizontal beam emittances after injection in the PR for two different injected beam energy offsets of the beam distribution after targets(blue, orange), and after compression (green). In red the equilibrium beam emittance



Injection efficiency vs beam energy offset for beam after targets (blue) and after compression (red)

CONCLUSIONS

This work aimed at studying if the disrupted LEMMA e^+ beam, after the interaction with muon production targets, could be injected back into the ring, to release the stress on the main e^+ source. From first studies an **injection efficiency of 86.2%** has been achieved for the beam compressed by the linac and **83.2%** for the beam coming directly from the targets. Optimization of the e^+ ring acceptance and design of a zero dispersion injection section could improve these efficiencies. Further improvements could be achieved with the optimization of the final distribution of the compressor linac beam