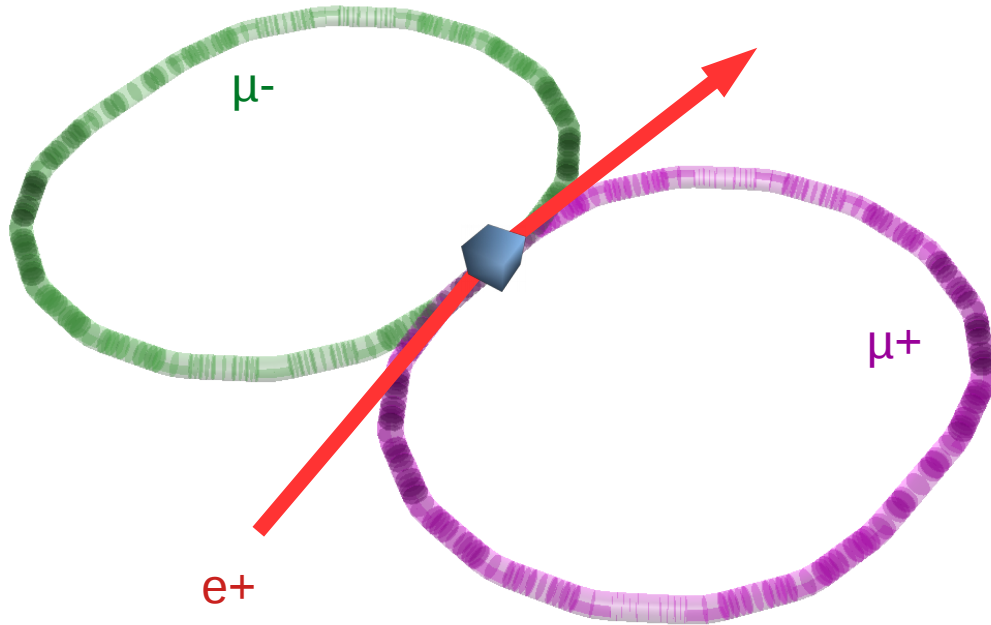


Muon Accumulator Rings

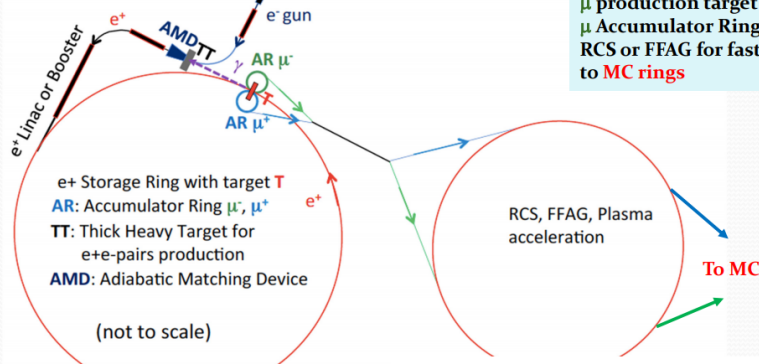


Oscar BLANCO

LEMMA

M. Antonelli. et al. Novel proposal for a low emittance muon beam using positron beam on target. NIM A 807 (2016) 101
 Muon production from positrons impinging on target

LEMMA original scheme



e^+ high intensity source
 e^+ acceleration to 45 GeV
 e^+ storage ring @ 45 GeV
 μ production target @ 22 GeV
 μ Accumulator Rings
 RCS or FFAG for fast μ acceleration
 to MC rings

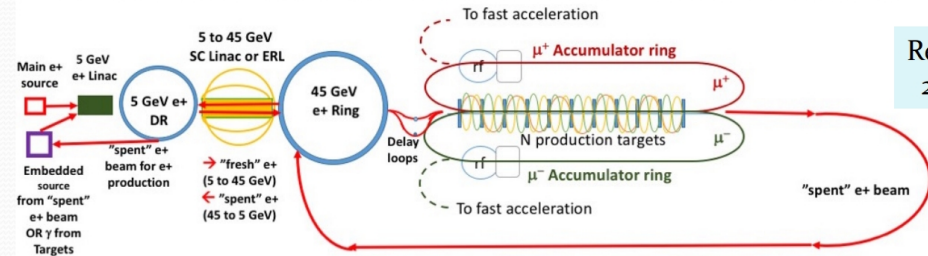
Goal: $\approx 10^{11}$ μ/s produced at target
 with target efficiency $\approx 10^{-7}$ (Be, 3mm)
Request: 10^{18} e^+/s impinging on target \rightarrow
 45 GeV e^+ storage ring with target insertion

μ^\pm produced by e^+ beam on target T @ ~ 22 GeV \rightarrow
 $\tau_{lab}(\mu) \approx 500\mu s$ ($\gamma(\mu) \approx 200$)
 Muon Accumulator Rings (MA) isochronous with
 high momentum acceptance, recombine μ^\pm bunches
 for $\sim 1 \tau_{lab} \approx 2500$ turns

Complex layout

- e^+ Source @ 300 MeV + 5 GeV Linac
- 5 GeV e^+ Damping Ring (damping ~ 10 ms)
- SC Linac or ERL from 5 to 45 GeV and from 45 to 5 GeV to cool spent e^+ beam after μ^\pm production
- 45 GeV e^+ Ring to accumulate 1000 bunches, 5×10^{11} part/bunch needed for μ^\pm production, and e^+ spent beam after μ^\pm production, for slow extraction towards decelerating Linac and the DR

- Delay loops to synchronize e^+ and μ^\pm bunches
- One (or more) Target Lines where e^+ beam collides with targets for the direct μ^\pm production
- 2 Accumulation Rings where μ^\pm are stored until the bunch has $\sim 10^9$ $\mu/bunch$
- "Embedded" e^+ source for the production of e^+ needed to restore the design e^+ beam current, either using the γ coming from the μ^\pm production targets, or the 45 GeV e^+ spent beam

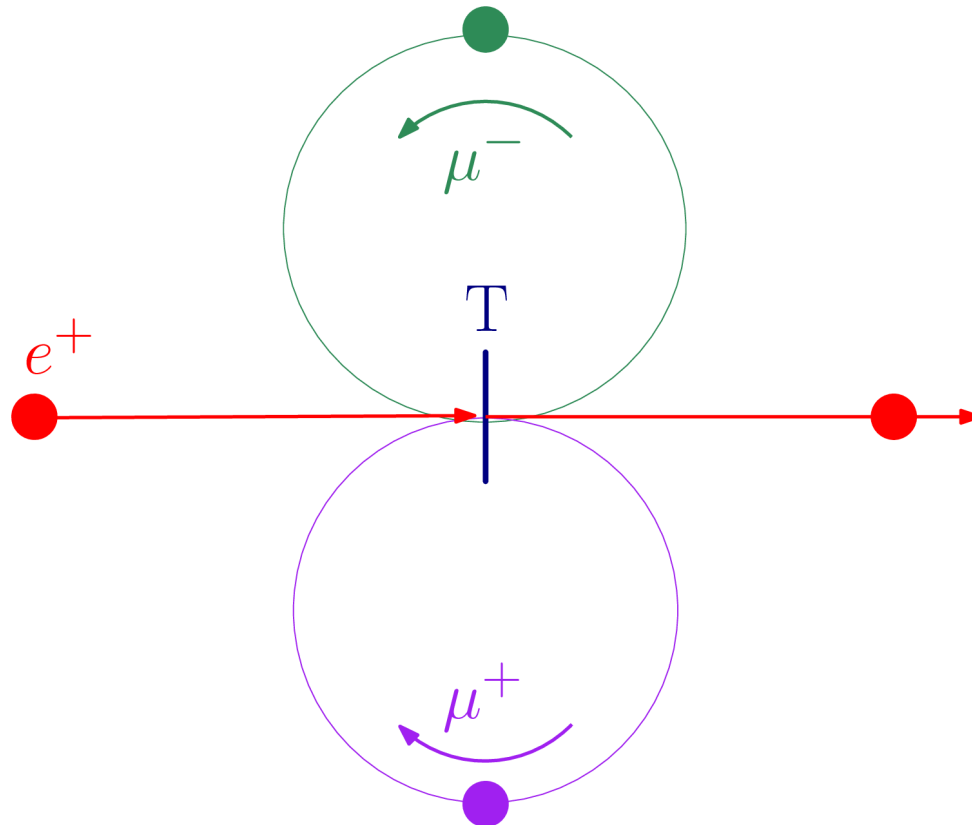


Rep rate
 20 Hz

M. Biagini, et al. IPAC19. MOZZPLS2, Positron Driven Muon Source for a Muon Collider: Recent Developments
 Several schemes are currently being studied

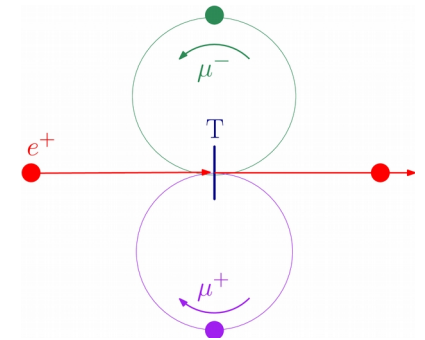
Muon Accumulator Rings

The muon accumulator rings collect and recirculate the muons produced on every positron bunch passage, increasing the muon bunch intensity



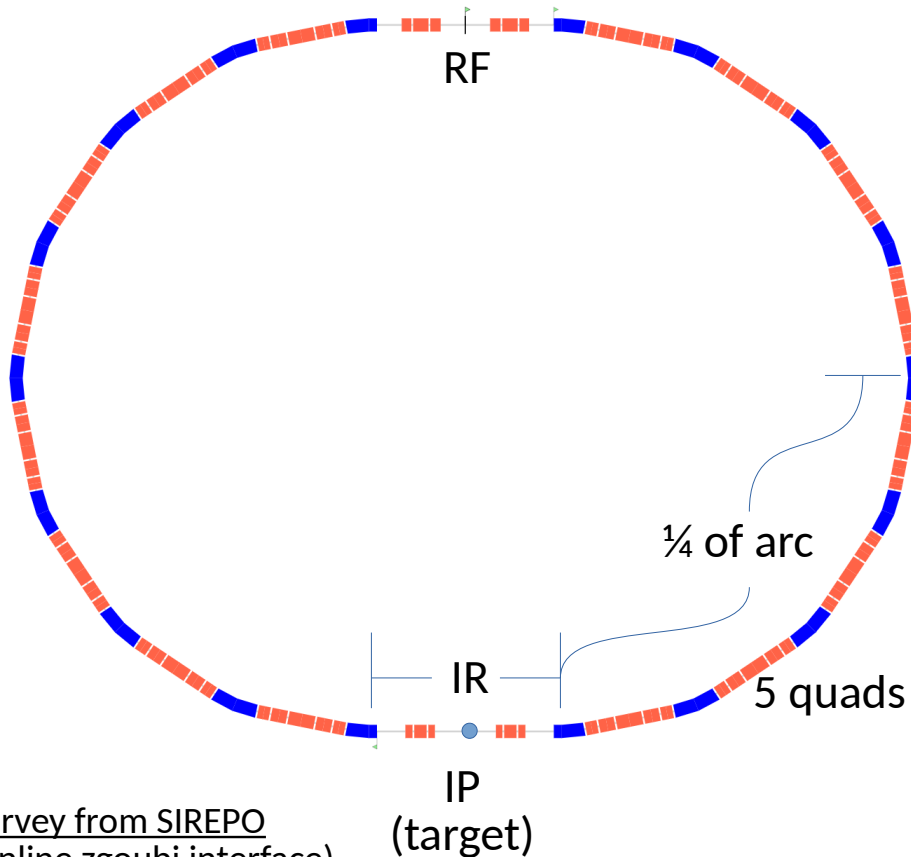
Requirements 2018 and status 2019

	Required 2018	Optics Design Status	
Small Length	60 m	150 m (x2.5)	To mitigate muon decay
Large Dynamic Ap.	$\pm 20\%$	$\pm 10\%$	Production efficiency and energy spread are proportional
Low β^*	According to target length	1.3 m	To avoid emittance growth from multiple scattering
Time of accumulation	1000 turns	-to be checked with the targets	To get $\sim 10^9$ muons in one bunch in less than 0.4 ms



Layout (One Ring)

By Pantaleo Raimondi

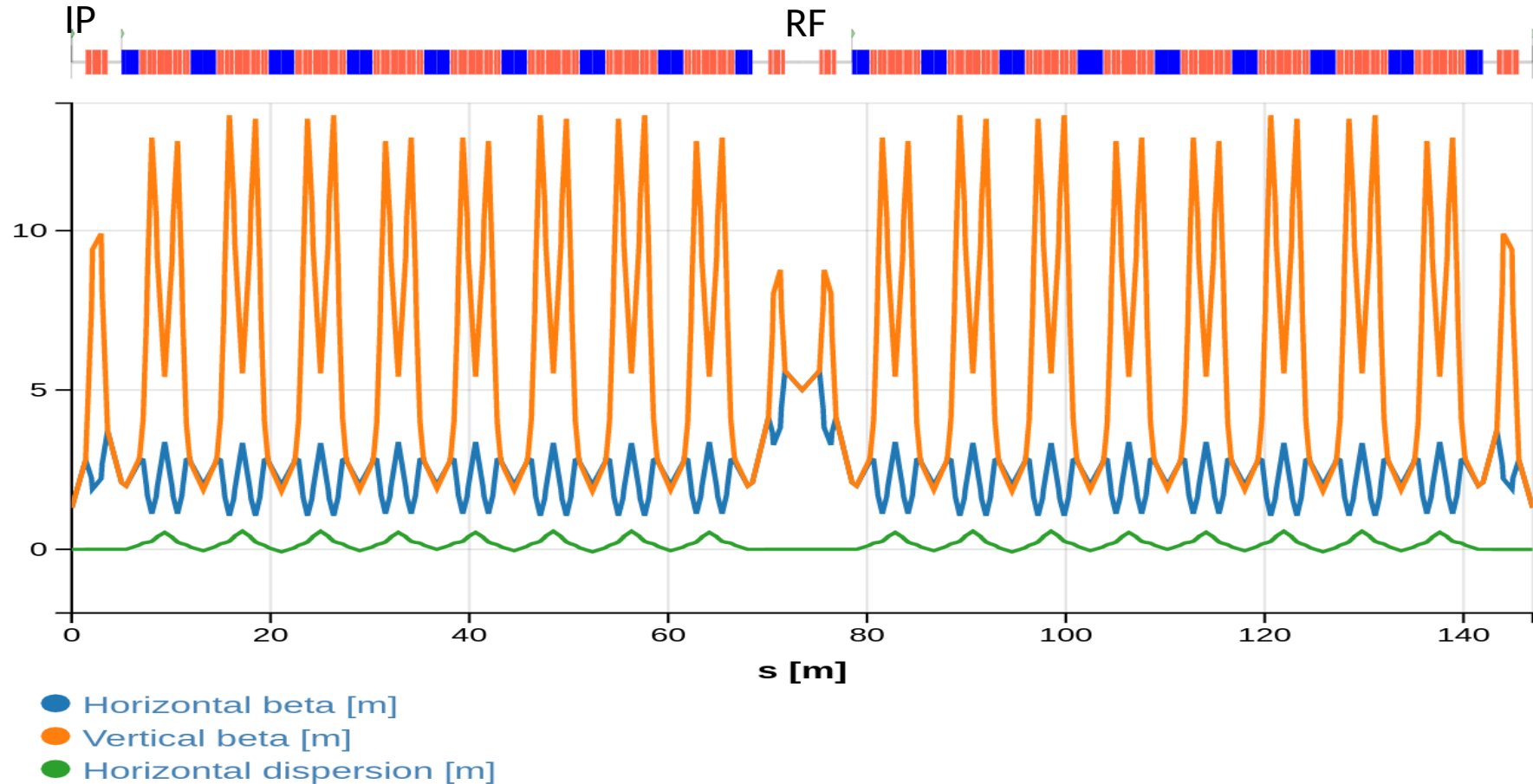


- The IR region is shared among three beams :
 μ^+ , μ^- at 22.5 GeV, and e^+ at 45 GeV
 Two triplets focus the beam around the IP (target location)
- Each $\frac{1}{4}$ of arc, is composed by 4 units of two halves of a sector bend dipole, and 5 quadrupoles. Zero-length multipoles (2nd, 3rd, and 4th order) are located inbetween quadrupoles.
- L^* is long to make space for a H_2 target of $0.3X_0$ in total
- The lattice is matched to cancel α_c
 Sextupoles cancel chrom., 2nd order disp.
 Oct, Dec, Doc opt. to cancel α_c at higher orders

Length	147 m
Energy Acceptance	± 10 %
Max. Dipole field	12 T
Quad field gradient	<151 T/m
β^*	1.3 m
Target space ($2 \times L^*$)	2×1.4 m
RF Freq	1.2 GHz
RF Voltage	100 MV

Linear Optics

First order optics agreement among MAD, MAD-X, MAD-X PTC and ZGOUBI



Chromaticity

- Natural chromaticity agrees among simulation codes

MAD (Qx',Qy')	MAD-X (DQ1,DQ2)	MADX PTC (DQ1,DQ2)	ZGOUBI (DQ1,DQ2)
-9.37	-	-9.41	-9.37
-19.69	-	-19.47	-19.69

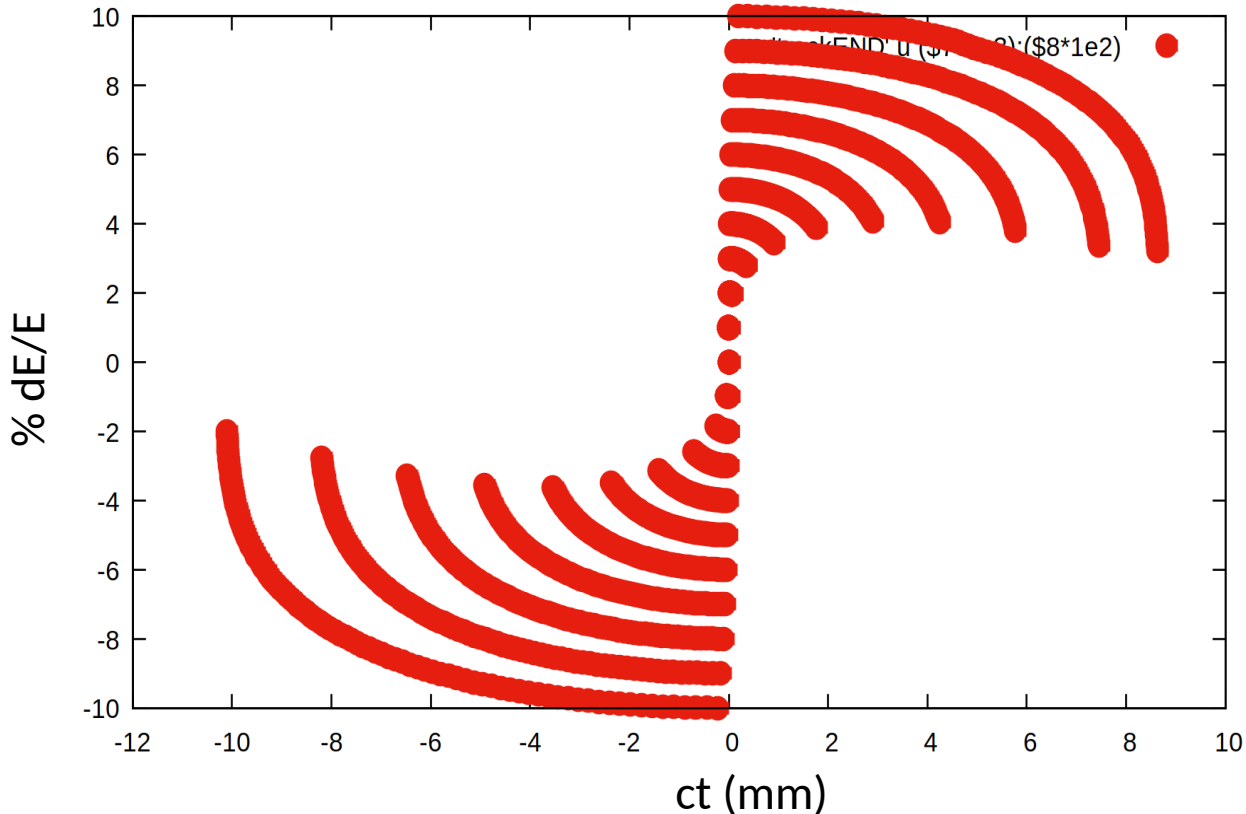
- The multipole optimization done by Pantaleo in MAD does not automatically work in PTC, therefore, a new multipole optimization has been carried out after the translation from MAD to MAD-X.

The differences in the optimization change the dynamics

MAD (Qx',Qy')	MAD-X (DQ1,DQ2)	MADX PTC (DQ1,DQ2)	ZGOUBI (DQ1,DQ2)
-0.08	-	-0.03	-0.08
0.06	-	0.00	0.05

Longitudinal Phase Space

100 turns, No Energy loss, PTC model



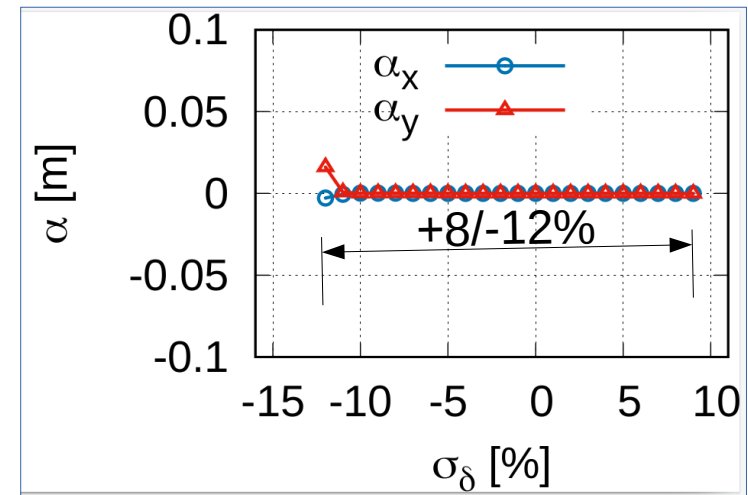
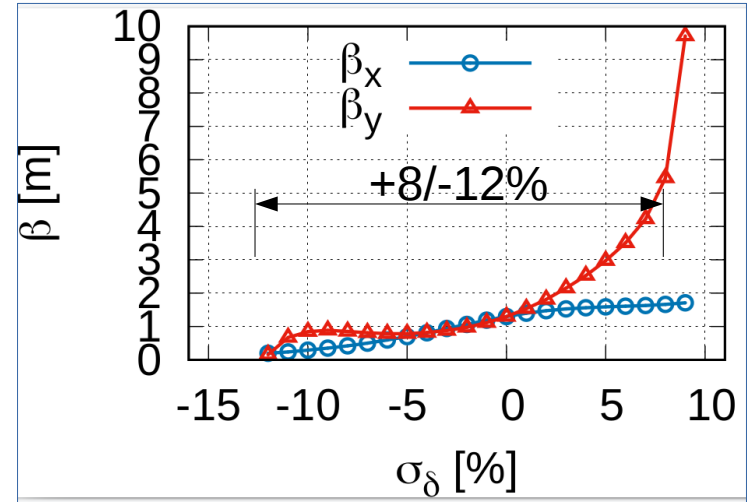
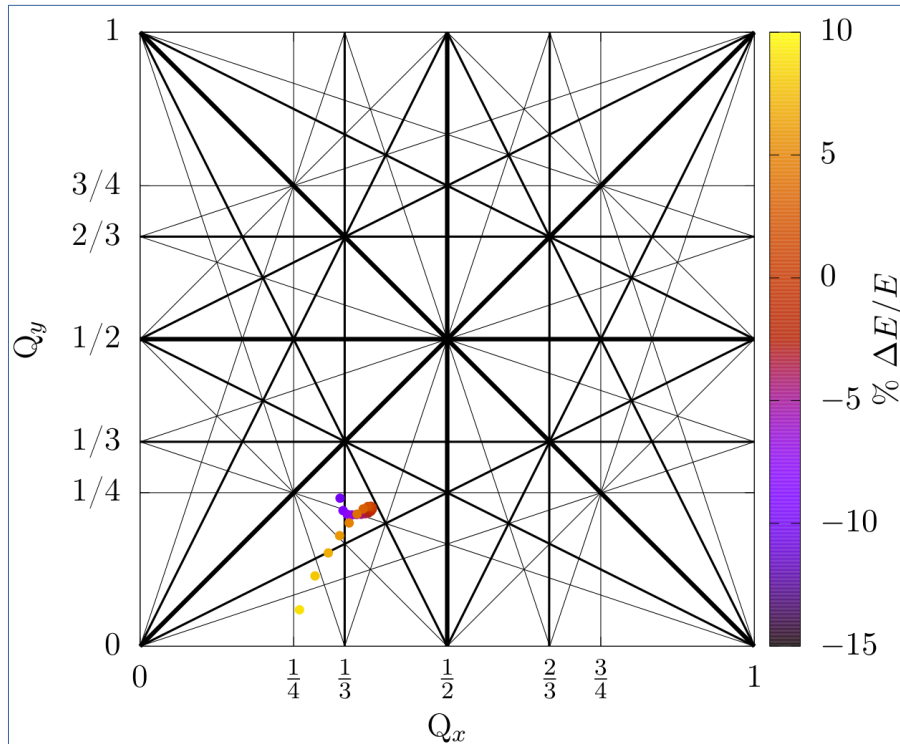
IF MUONS DO NOT RADIATE AND α_c IS ZERO, WHY DO WE NEED A CAVITY ?

We expect to have approximately 0.1~0.2% energy loss per passage through the target due to bremsstrahlung.

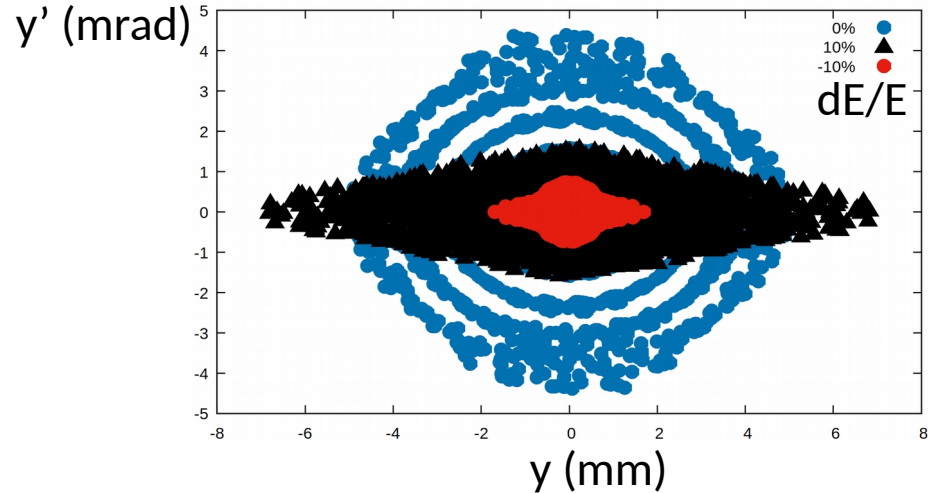
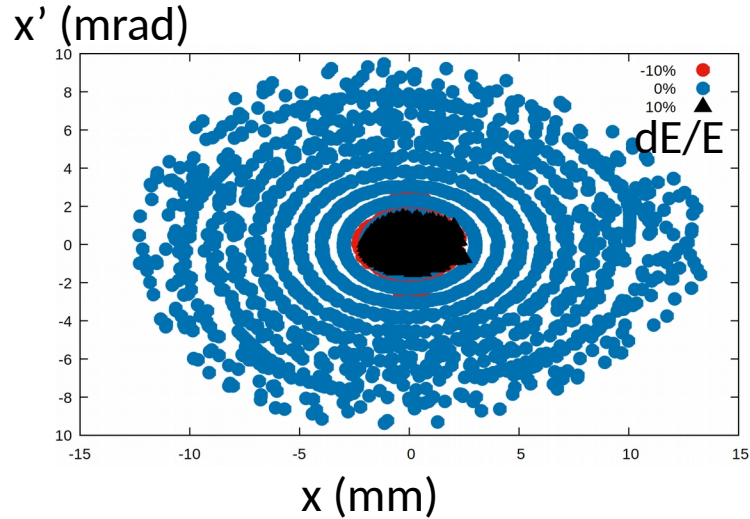
The cavity is tuned to recover the energy loss, which along all accumulation period of 1000 turns is 1~2 times the initial 22 GeV

Tune and optics functions at the IP

Using the PTC model we achieved +8/-12% energy acceptance, although, tune footprint crosses 3rd and 4th order resonances pointing to possible particle losses in a lattice with errors.



Admittance (100 turns)



- From multiturn tracking, we have estimated an admittance of 1~10 $\mu\text{m}\cdot\text{rad}$.
- This is expected to be far larger than needed as the typical muon beam emittance is much less than $1\mu\text{m}\cdot\text{rad}$

Open Questions on Optics

- Beams separation and combination scheme,
- Radiation from positron beam crossing strong magnets in the accumulator,
- Further optimization of the lattice : length reduction, increment energy, considerations on multipoles,

10% energy acceptance in the model is already a great achievement and this lattice could be used for initial studies with target.

CONCLUSIONS

The goal for LEMMA is the production of a large lifetime and small emittance muon beam from positrons impinging on a target.

LEMMA design foresees to increase the muon bunch intensity by recirculating muons on an accumulator over a fraction of the muon lifetime.

I have presented the lattice by P. Raimondi of the accumulator ring: circumference of ~150 m and $\pm 10\%$ of energy acceptance.

I used several accelerator codes (MAD, MAD-X, PTC, ZGOUBI) in order to perform the analysis and optimization of the lattice.

The plan is to continue with optimizations to reach $\pm 20\%$ energy acceptance. We are planning to study a FFA design