Extrapolations to 6-10 TeV, what is needed

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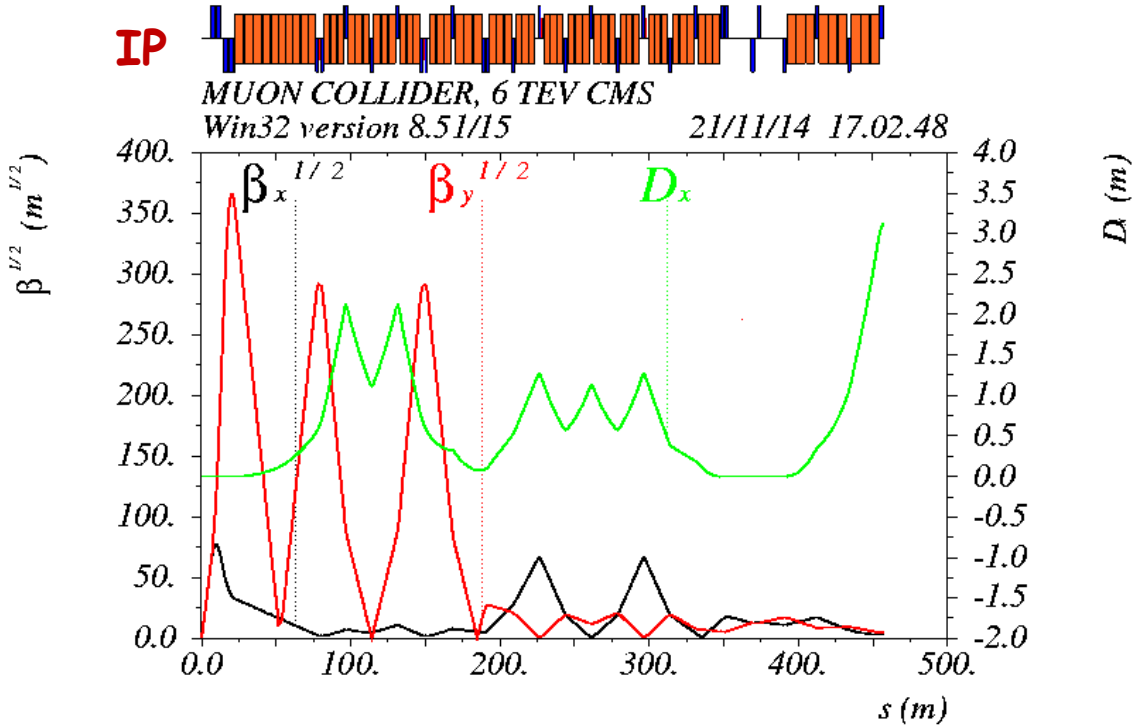
Interaction Region Linear Optics for 6 TeV Design

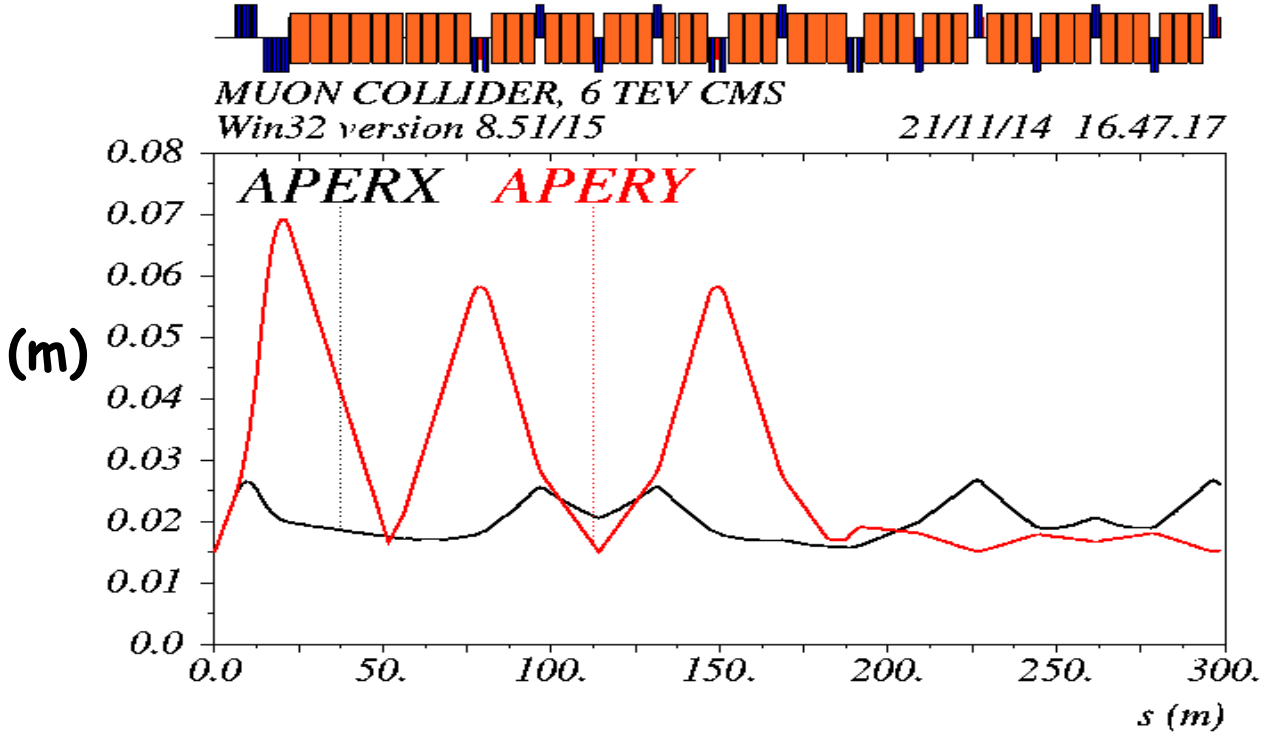


Field@poletip:
<15 T in quads
<20 T in bends

$\beta^*_{x,y}$ =1 cm

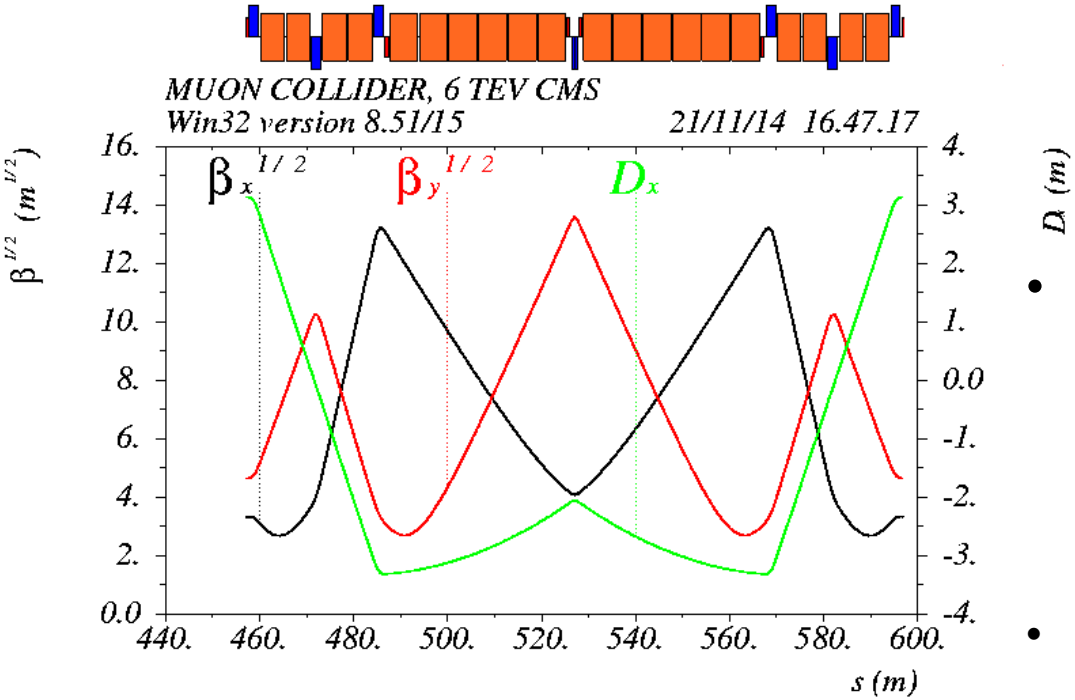
L* =6 m

Aperture of IR magnets



The half aperture calculation in IR is based on the definition:
$5\sigma_{x,y}$+ 15 mm

Arc Cell Linear Optics for 6 TeV Design



- $\mu_x/\mu_y = 0.875/0.875 \times 2\pi$, 8 cells per quarter ring for 3rd and 4th order resonance cancellation
- Nearly isochronous

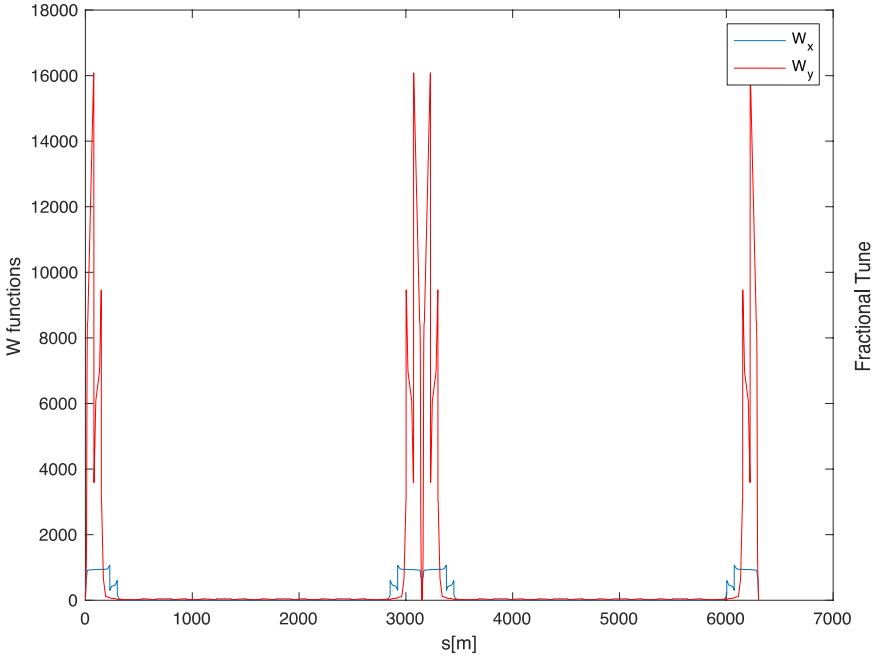
Modification of the 3 TeV design (by Y. Alexahin et al)
Field increased with energy: < 15T in quads, < 20T in bends

Main Parameters

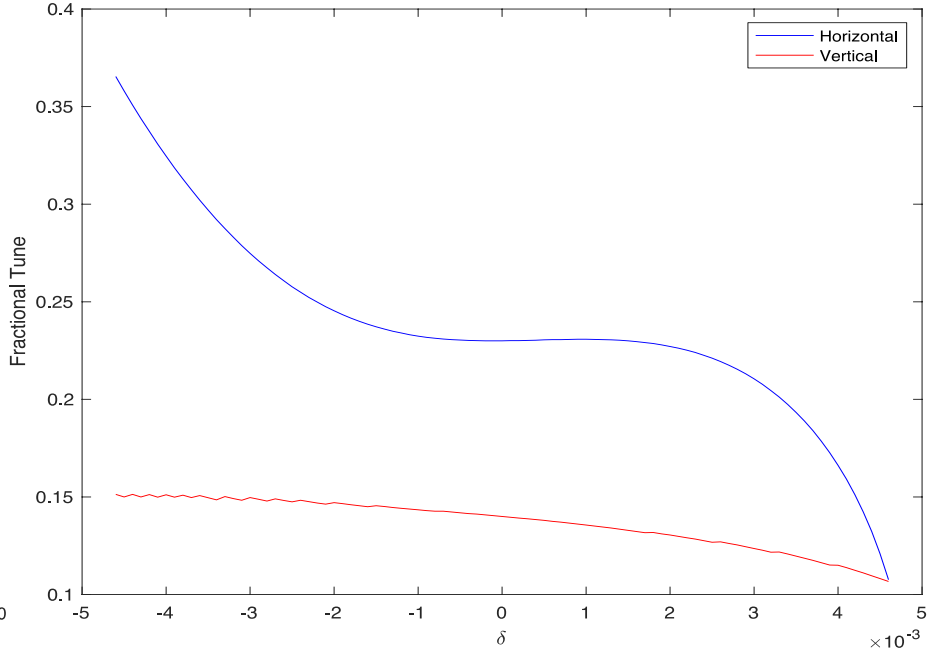
Parameter	Unit	1.5 TeV design	3 TeV design	6 TeV design
Beam energy	TeV	0.75	1.5	3.0
Number of IPs		2	2	2
Circumference	m	2730	2767	6302
β^*	cm	1	1	1
Tune x/y		18.56/16.58	20.13/22.22 (temporary)	38.23/40.14 (temporary)
Momentum compaction		-1.30E-5	-2.88E-4	-1.22E-3
Normalized emittance	(π)mm·mrad	25	25	25
Momentum spread	%	0.1	0.1	0.1
Bunch length	cm	1	1	1
Muons/bunch	10^{12}	2	2	2
Repetition rate	Hz	15	15	15
Average luminosity	10^{34} cm^{-2}s^{-1}	1.1	4.5	7.1

Chromatic Optics

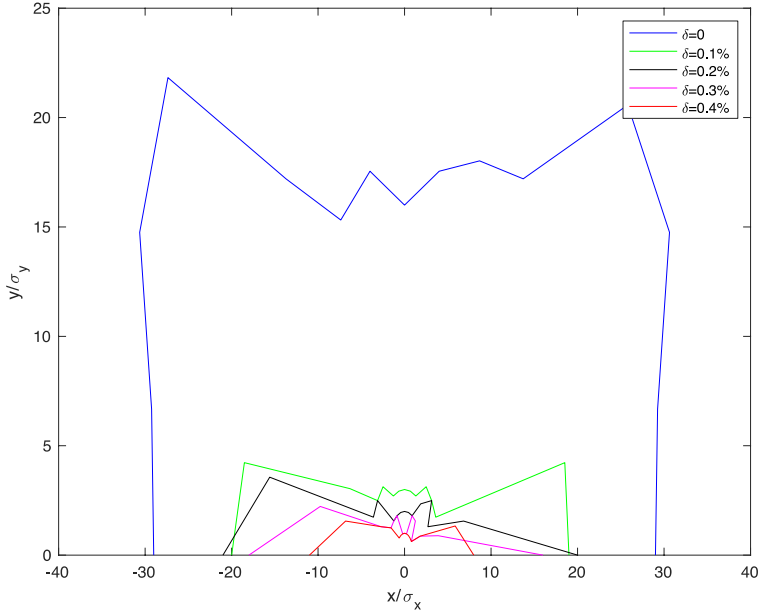
Chromatic Beta Beating



Nonlinear Chromaticity

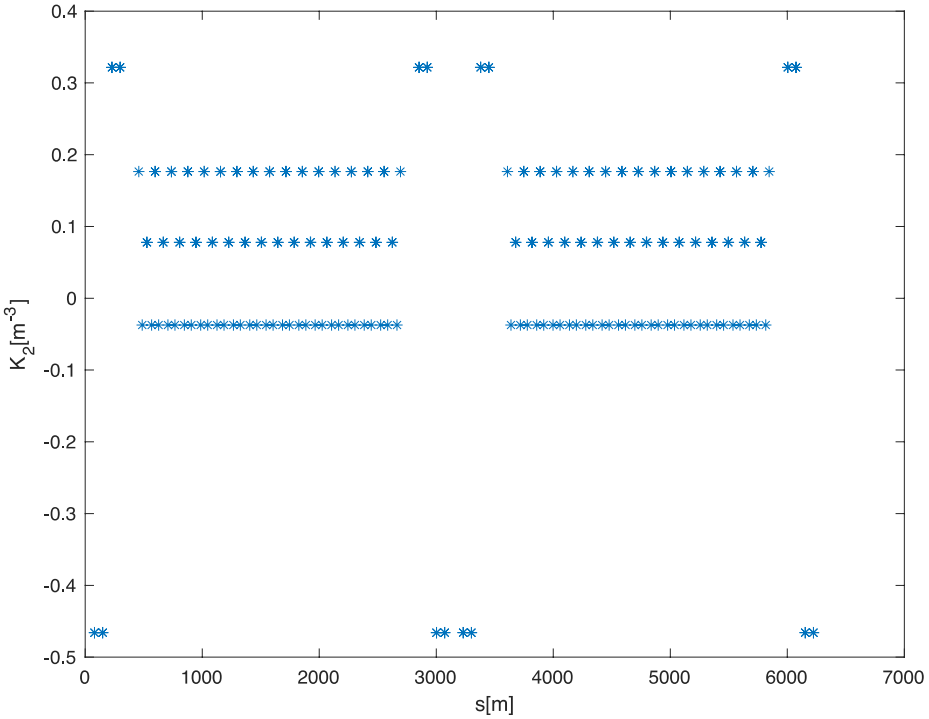


Dynamic and Momentum Apertures

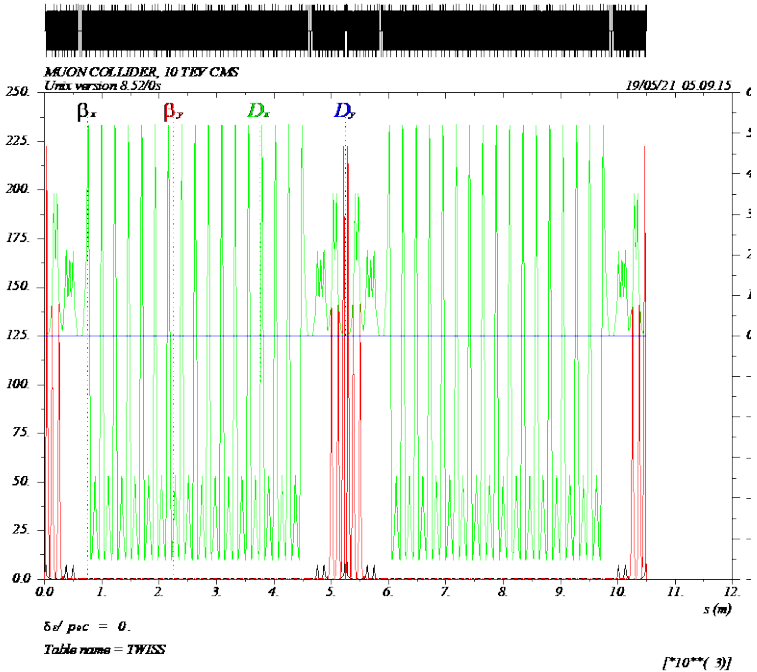


Tracking with synchrotron oscillation

Sextupole Schemes



Linear Optics of 10 TeV (CM) Muon Collider

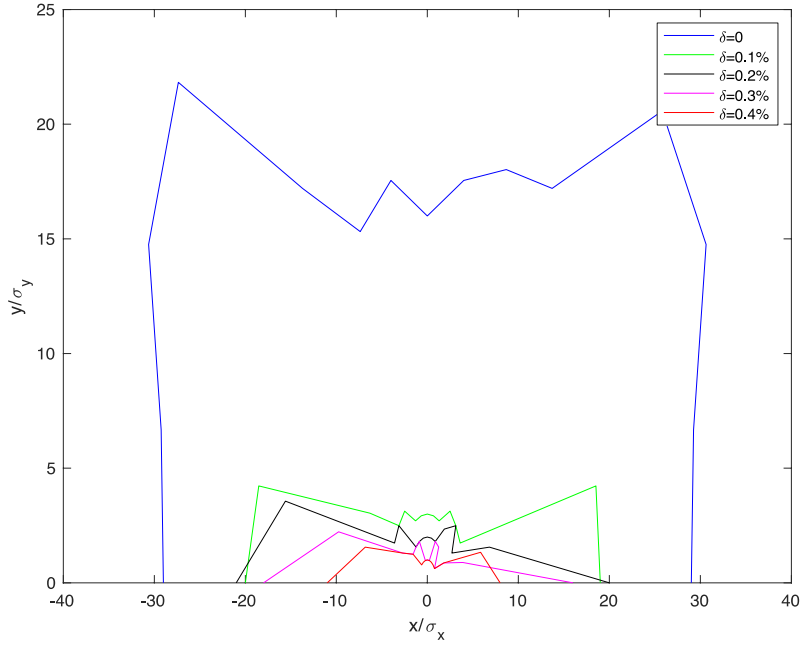


- Scaled from 6 TeV design with factor: F=10/6
  - All: Length->Length*F
  - Bending angle kept same
  - K_1->K_1/F^2
  - K_2->K_2/F^3
- Keep phase advances same
- No change of beam size

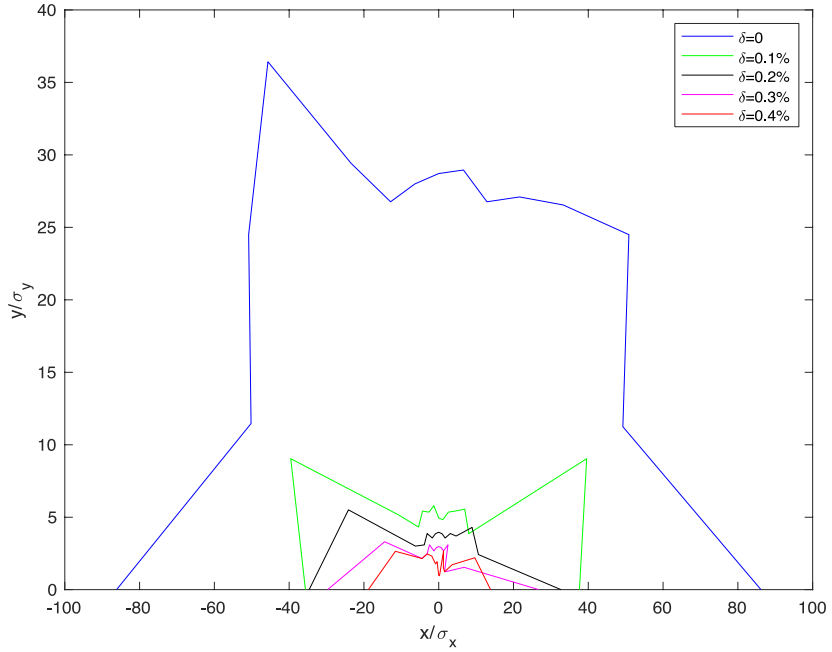
$\beta^*_{x,y}$ =1.7 cm, L* =10 m, Circumference=10.5 km

Comparison of Dynamic Apertures

6 TeV



10 TeV



Dynamic aperture is large in a big ring

Luminosity

- Bunch luminosity:

$$L_b = f_{rev} \frac{N_b^2}{4\pi\sigma_x\sigma_y} R_g$$

where R_g is a geometrical reduction from the hourglass effect and crossing angle. It is also a good indicator for dynamical effects at high bunch charge.

- Total luminosity:

$$L = n_b L_b$$

Beam-Beam Limit

- For round beams , the beam-beam parameter is given by

$$\xi = \frac{r_\mu N_b \beta^*}{4\pi\gamma\sigma^2}$$

And the luminosity can be rewritten as

$$L = \frac{c\mathrm{I}\gamma\xi}{r_e r_\mu \mathrm{I}_A \beta^*} R_g$$

where I_A=17045 A. We should expect the luminosity increases linearly with respect to the energy. A smaller β^* and larger ξ is also helpful. Taking an example of the 6 TeV (CM) design at E_0=3 TeV, we have I=0.016 A, ξ=0.0868, R_g=0.8, β^*=0.01 m and the luminosity is 14×10^{34} $cm^{-2}s^{-1}$.

Summary

- Preliminary designs of 6.3 km 6TeV and 10.5 km 10TeV CM energy muon collider rings are presented
- The IR chromatic correction scheme uses –I non-interleaved pairs of sextupoles
- The arc chromatic correction scheme provides local cancelation of sextupole resonance driving terms in each quarter ring
- The dynamic aperture is very large and the momentum dynamic aperture of bare lattice is up to 0.4%

What Next?

- Study tolerance of the lattices
- Low the beta* at the IP
- Shorten the L* for the detectors
- Realistic IR magnets
- Study the energy deposition in IR
- Study radiation from the rings
- Optimization of luminosity and mitigation of risks

Acknowledgements and References

- We would like to thank our former colleague: Min-Huey Wang who has done the most work on the 6 TeV design
- Special recognition of the work of Yuri Alexahin (FNL) who was the leader in the lattice design of the muon colliders

- References:

  - Y. I. Alexahin, E. Gianfelice-Wendt, V.V. Kashikhin, N.V. Mokhov, A.V. Zlobin, and V.Y. Alexakhin, “Muon collider interaction region design”, PRSTAB 14, 061001 (2011)
  - M.-H. Wang, Y. Nosochkov, Y. Cai, and M. Palmer, “Design of a 6 TeV muon collider”, 2016 JINST 11 P09003
  - J. P. Delahaye, at al. “Input to the European Particle Physics Strategy Update: Muon Colliders”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Thank you
for attention