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Error Study and Orbit Correction Simulation for 200 MeV Energy Upgrade at KOMAC

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- **Introduction**
- Beam dynamics and error study of 200 MeV LINAC
- Orbit correction simulation with error
- Summary

Korea Multi-purpose Accelerator Complex

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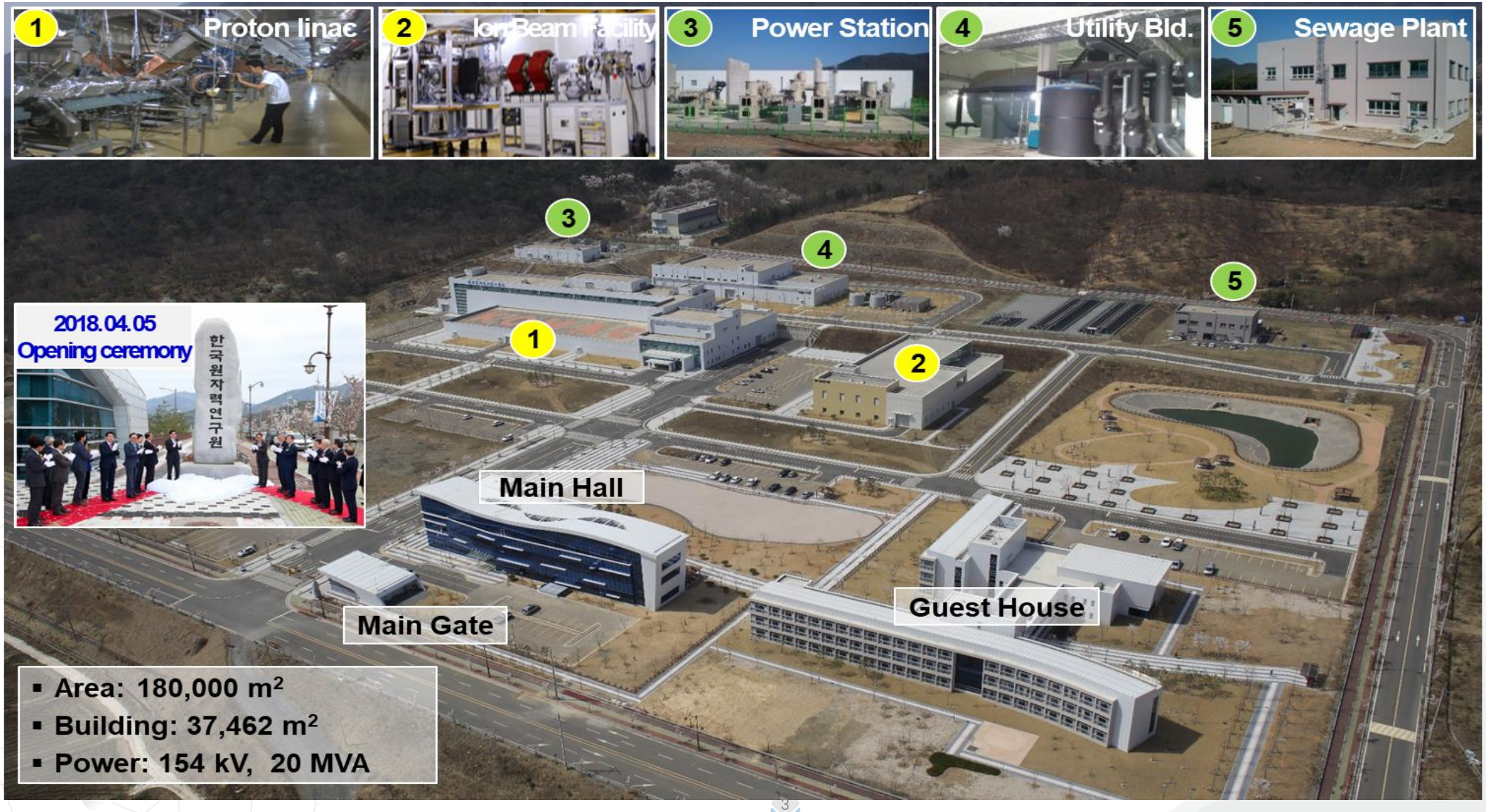

100 MeV LINAC at KOMAC

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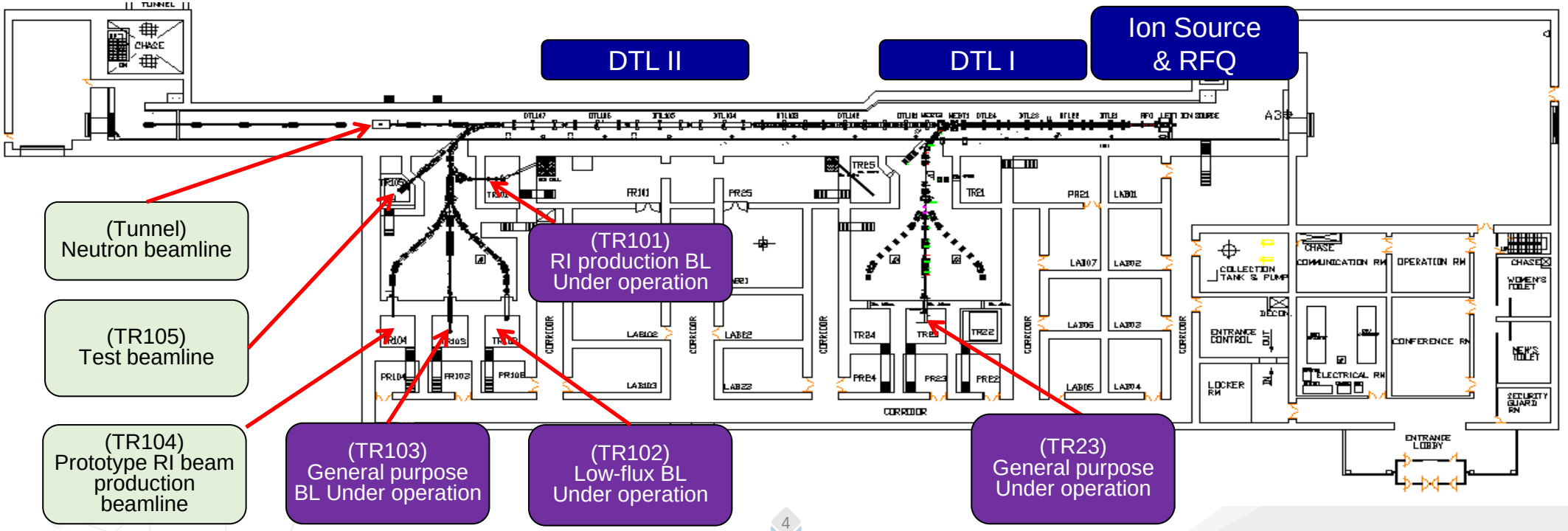
Features of KOMAC 100MeV linac

- 50-keV Injector (Ion source + LEBT)
- 3-MeV RFQ (4-vane type)
- 20 & 100-MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 6 Beamlines for 20 MeV & 100 MeV

Output Energy (MeV)	20	100
Max. Peak Beam Current (mA)	1 ~ 20	1 ~ 20
Max. Beam Duty (%)	24	8
Avg. Beam Current (mA)	0.1 ~ 4.8	0.1 ~ 1.6
Pulse Length (ms)	0.1 ~ 2	0.1 ~ 1.33
Max. Repetition Rate (Hz)	120	60
Max. Avg. Beam Power (kW)	96	160



Roadmap of KOMAC

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	2020 ~ 2024	2025~2029	2030~2040
100 MeV	User demand analysis	Beamline development (5 ea. → 10 ea.)	User service for research and industrial purpose
200 MeV	Preliminary feasibility study (2021~)	Development	User service for research and industrial purpose
1000 MeV Grade		User demand analysis (~2029)	Preliminary feasibility study (2030~)

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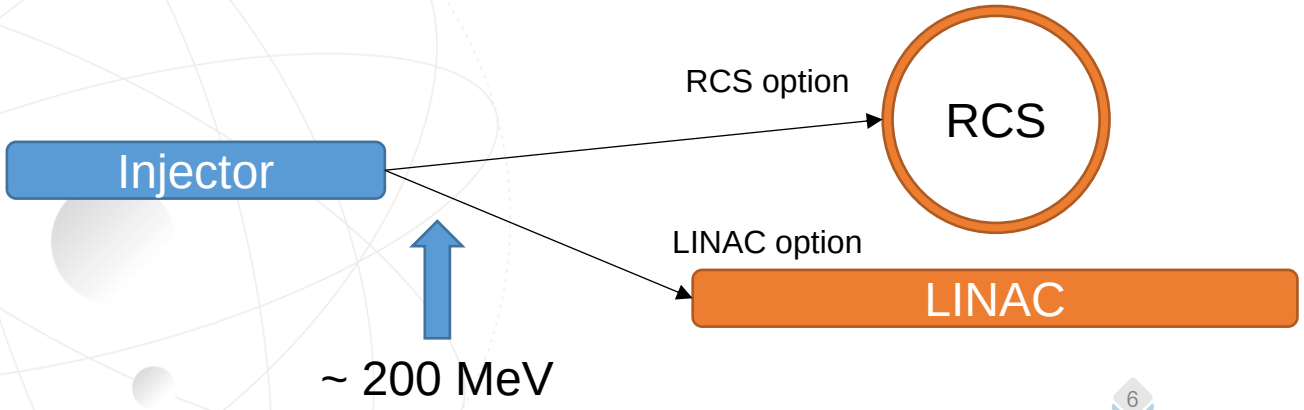
Why 200 MeV ?

- Increasing demand
  - Terrestrial radiation test of semiconductor
  - Space radiation test of space parts
- Common to Short / long pulse neutron source
  - RCS injector: > 200 kW @ 1 GeV
  - Linac injector: accelerating structure transition



- 100 MeV -> 200 MeV
  - Single accelerator structure
  - Possible within existing site (without further site preparation)
- Required modifications for RCS option
  - H- source
  - MEBT (chopper)
  - Increasing beam current up to 40 mA

200 MeV LINAC Type Option 1: SC HWR

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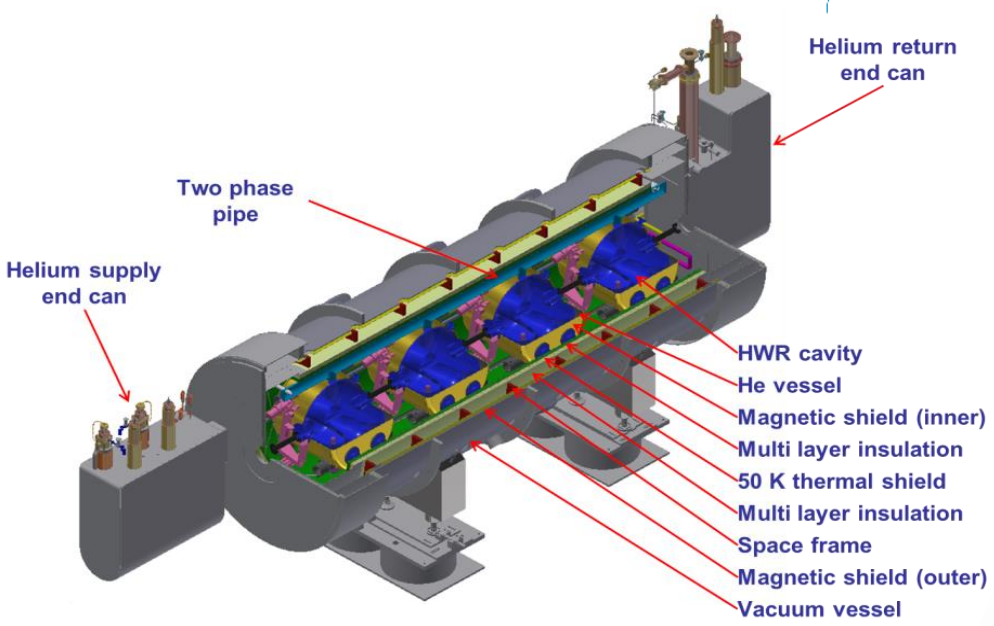
- **Type: Superconducting HWR**
- **Use proven technology**
- **Cylindrical cryomodule**
- **9 CMs, 36 HWRs from 100 to 200 MeV**

Parameter	Unit	KOMAC HWR(0603)	FRIB (2013)
Frequency	MHz	**350**	322
Optimum beta	-	**0.56**	0.53
Stored energy	J	**23.1**	29.48
V_{acc} (@β_{opt})	MV	**3.61**	3.7
V_0	MV	**4.14**	-
E_{acc} (@β_{opt})	MV/m	**7.53**	7.5
E0	MV/m	**8.63**	-
Ep	MV/m	**29.08**	26.5
Bp	mT	**61.66**	63.2
Ep/Eacc	-	**3.86**	3.53
Bp/Eacc	mT/(MV/m)	**8.19**	8.43
R/Q (@β_{opt})	ohm	**256.6**	229.5
G	ohm	**116.1**	107.4
Q_0 (@Rs=20 nΩ)	-	**5.81E+9**	-
Cavity loss (@R_S=20 nΩ)	W	**8.75**	7.9
Aperture	mm	**40**	40
L_{eff} ($\beta_{opt}\lambda$)	m	**0.480**	0.493
Cavity inner diameter	m	**0.45**	0.46



- **CM length: 3,600 mm (5,430 mm including end cans)**
- **CM diameter: 1,200 mm**
- **Heat load per CM**

	2 K	50K
Static	11.0 W	144 W
Dynamic	8.1 W	-
U-tube and line*	10 W	24 W
Total	29.1 W	168 W

130 W (4.5 K equivalent) / cryomodule**

*** Ref. SNS cryomodule parameter**
**** Including 25% margin**

200 MeV LINAC Type Option 2: NC SDTL

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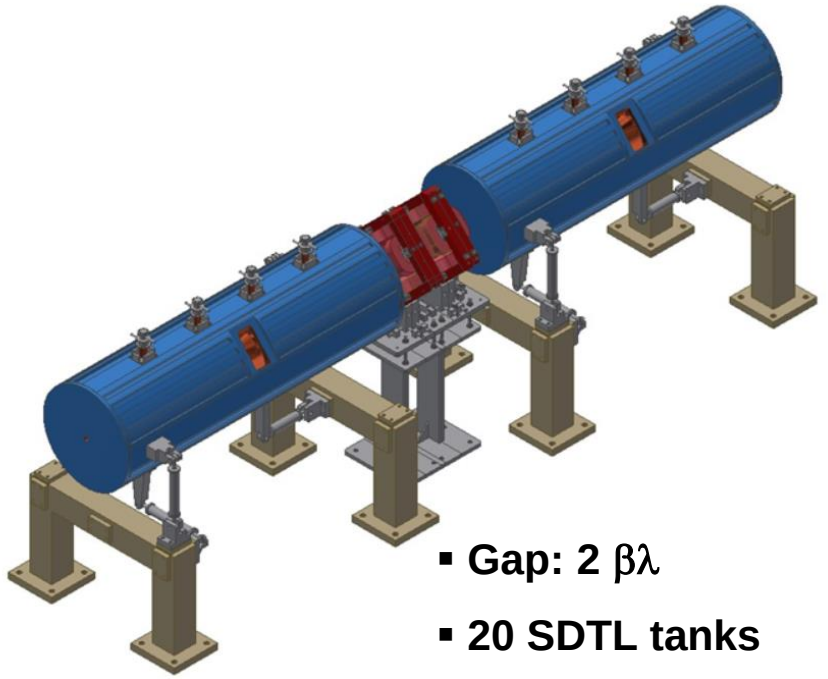
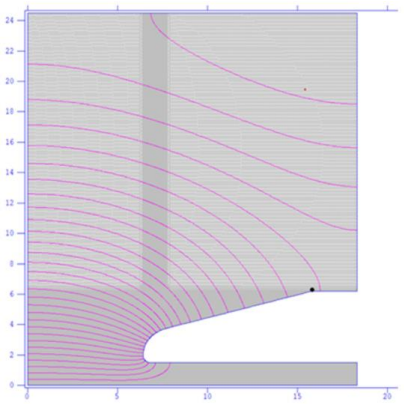
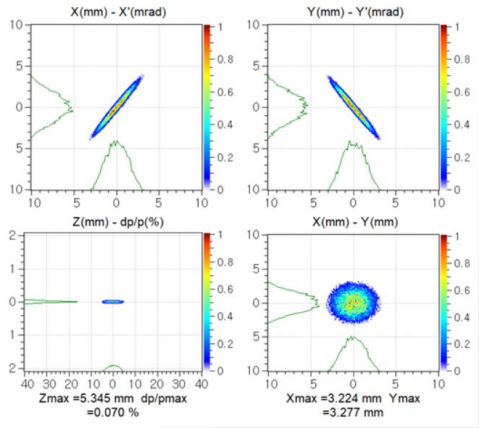
- Type: Separate Drift Tube Linac
- Use proven technology
- Doublet focusing external to cavity
- Cell optimization for ZTT
- Kilpatrick < 1.5
- RF power per tank < 1.2 MW @ 40 mA

Parameter	Unit	KOMAC SDTL
Frequency	MHz	350
Number of tanks	-	20
Input energy	MeV	102.6
Otutput energy	MeV	200
Tank length	m	1.9 ~ 2.4
Number of DT	-	4
Number of cell	-	5
Tank inner diameter	mm	491.6



- **Gap: 2 βλ**
- **20 SDTL tanks**
- **Total length: 60 m**





200 MeV Layout (NC SDTL-type)

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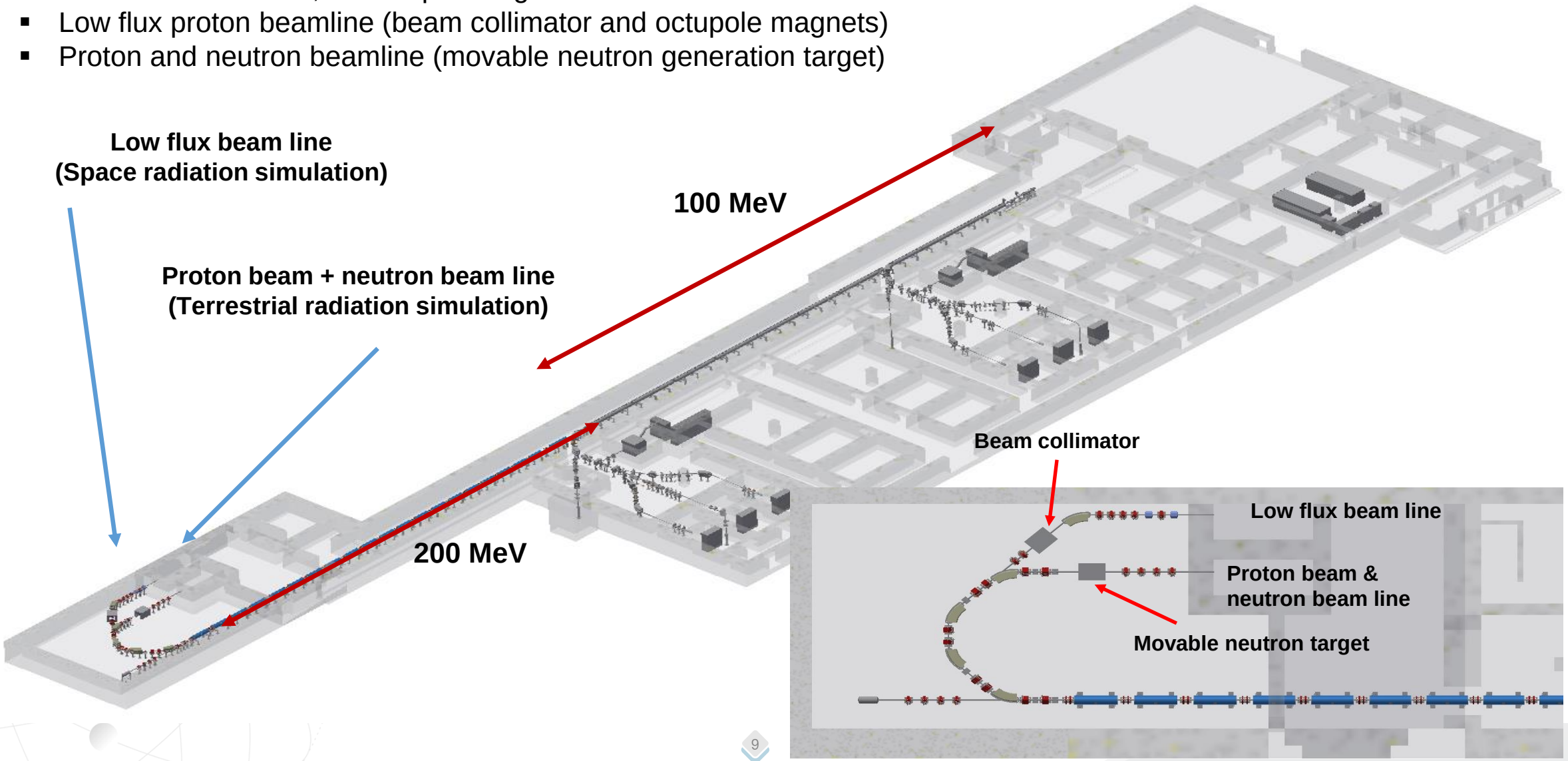
Based on user demand, we are planning to install two beamlines

- Low flux proton beamline (beam collimator and octupole magnets)
- Proton and neutron beamline (movable neutron generation target)



- Introduction
- **Beam dynamics and error study of 200 MeV LINAC**
- Orbit correction simulation with error
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200 MeV Energy Upgrade Beam Dynamics

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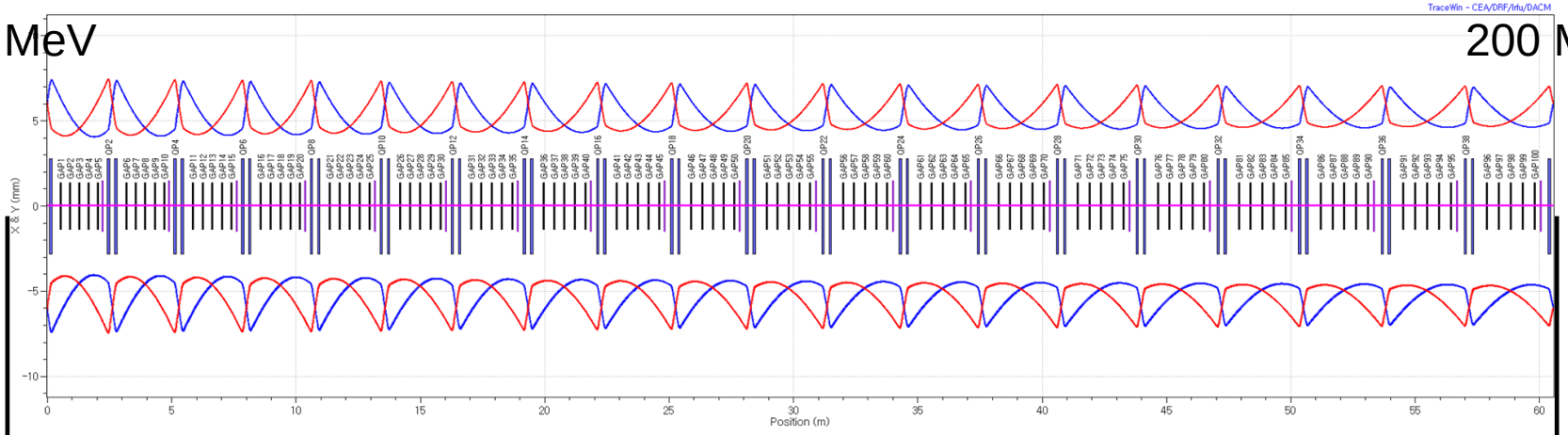
100 MeV

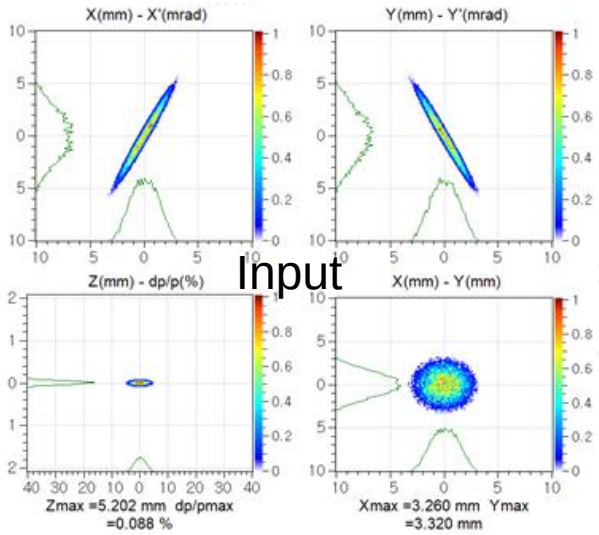


200 MeV

Initial current : 20mA

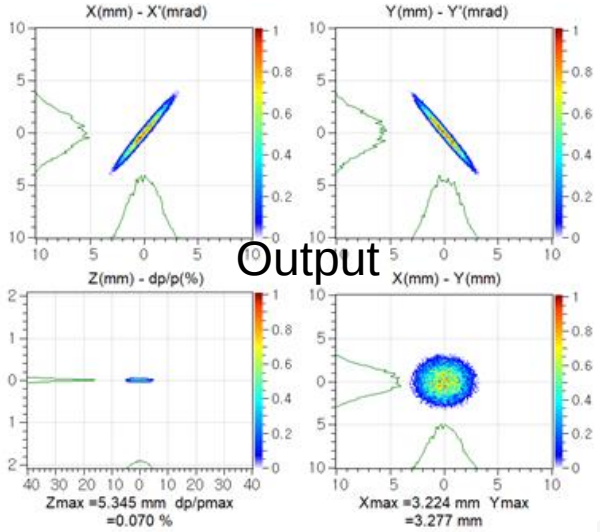
Initial energy: 100 MeV

Output energy: 200 MeV



Input

	Emit (Norm, rms)	α	$\beta\ (m)$
x	0.224	-5.416	3.072
y	0.226	5.447	3.122
z	0.295	-0.023	5.961



Output

	Emit (Norm, rms)	α	$\beta\ (m)$
x	0.225	-5.474	4.395
y	0.227	5.421	4.387
z	0.302	0.035	10.48

200 MeV Energy Upgrade Error Study

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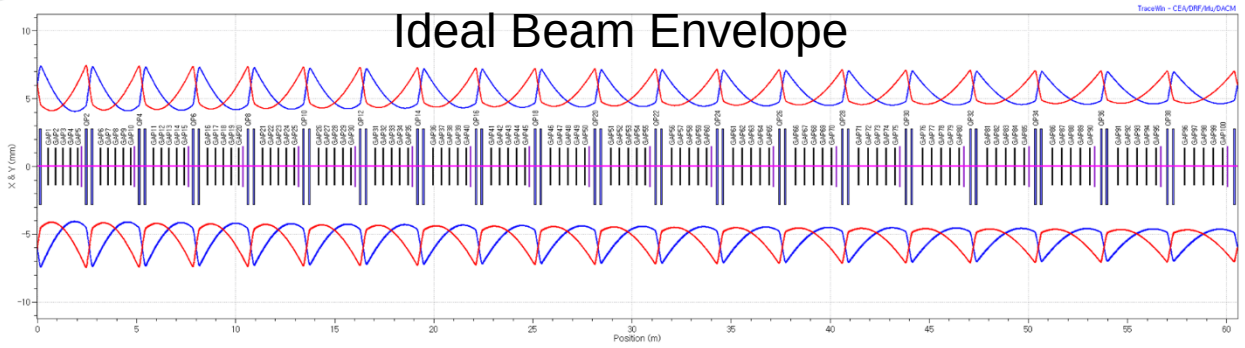
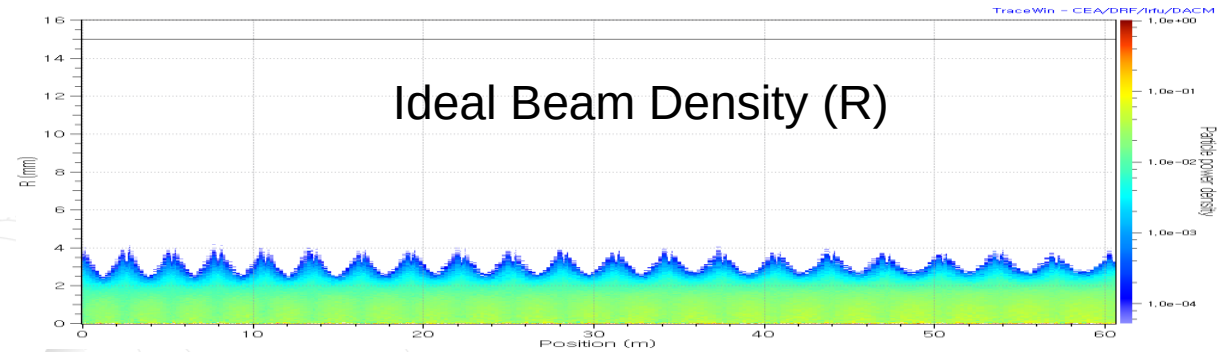
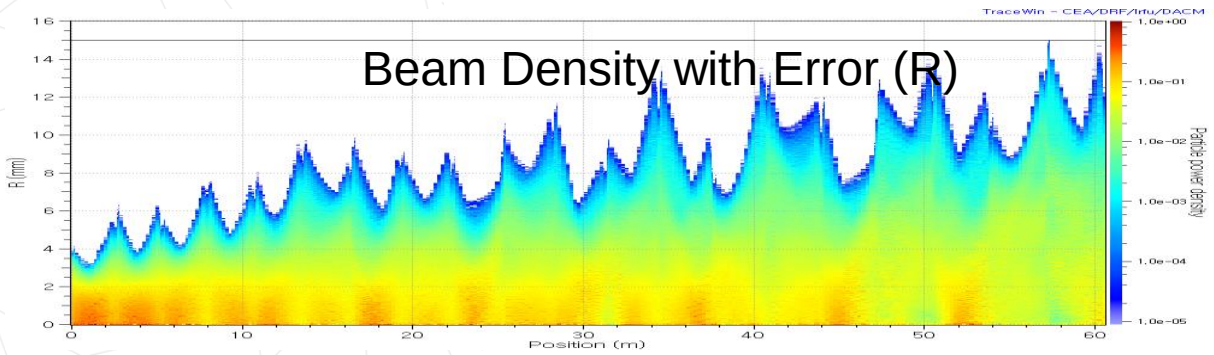
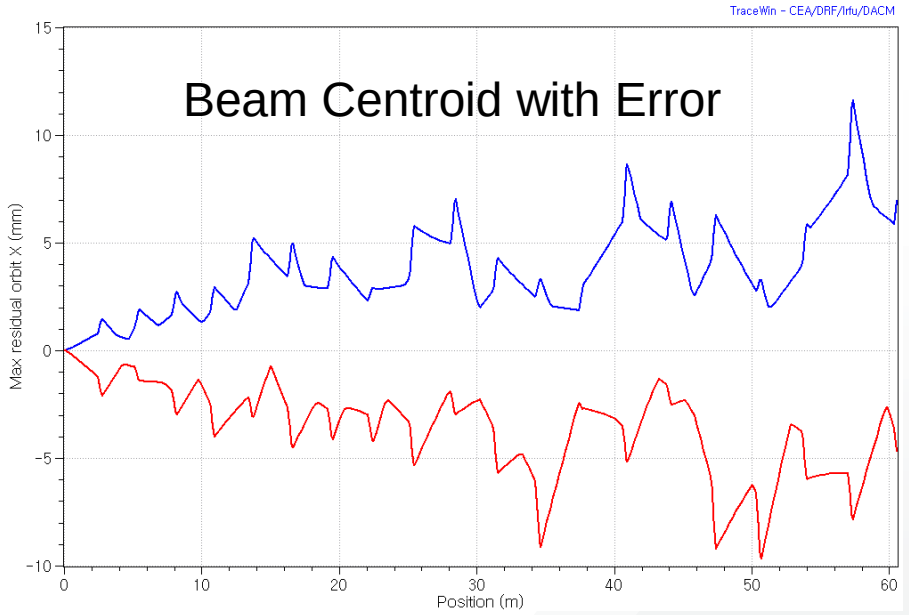






Why Error Study?



External error change the beam dynamics

We need to set Criteria

Error Study Setup

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Beamline Error (Quad, Cavity)

Error Type	Value
Quad magnet displacement (dx, dy)	$\pm 300\ um$
Quad magnet rotation (ϕ_x, ϕ_y, ϕ_z)	$\pm 0.5°$
Quad magnet gradient	$\pm 3\%$
Cavity displacement (dx, dy)	$\pm 300\ um$
Cavity rotation (ϕ_x, ϕ_y)	$\pm 0.5°$
Cavity Acc. Voltage	$\pm 3\%$
Cavity Phase (ϕ_{sync})	$\pm 3°$

# of Error lattice: 200 (10 lattice * 20 step)

Error statistical set up: 10 lattice per 1 step

Input Beam Error

Error Type	Value
Input beam center (x)	$\pm 2.5\ mm$
Input beam angle (y)	$\pm 5\ mrad$
Input beam center (x)	$\pm 2.5\ mm$
Input beam angle (y)	$\pm 5\ mrad$
Input beam matching (x)	$150\ \%$
Input beam matching (y)	$150\ \%$
Input beam matching (x)	$150\ \%$

Error distribution type: Uniform distribution

Input Beam Current : 20 mA

Error Study with Quad Magnet Error

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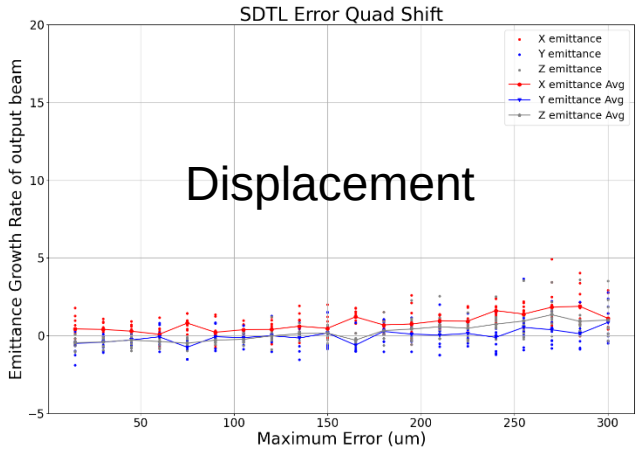
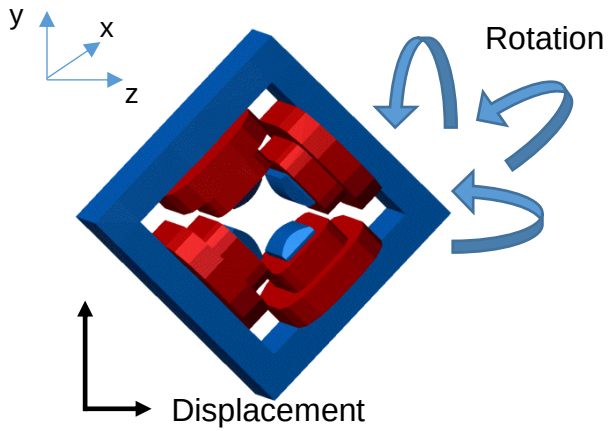
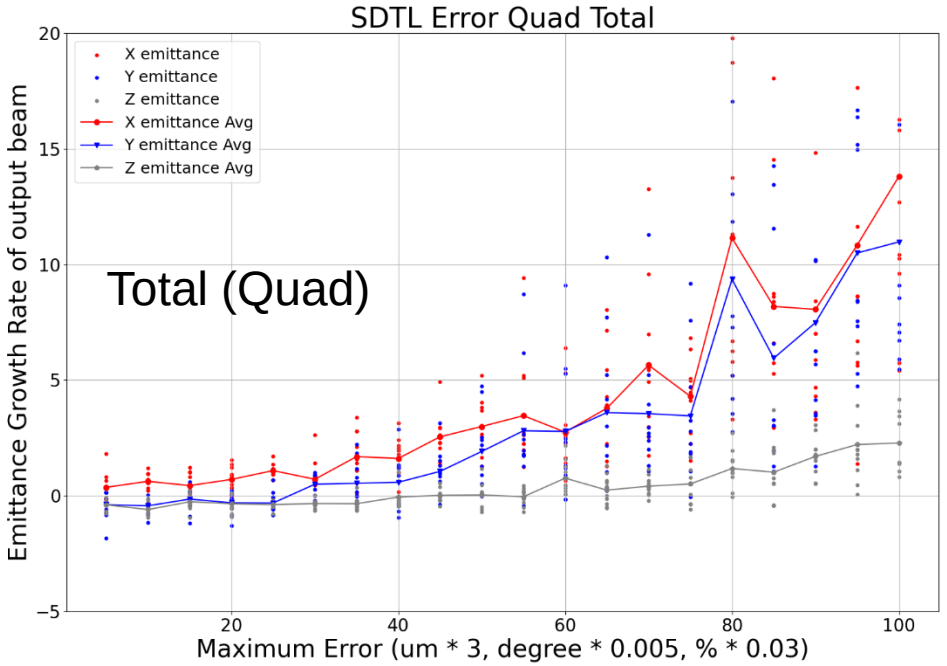
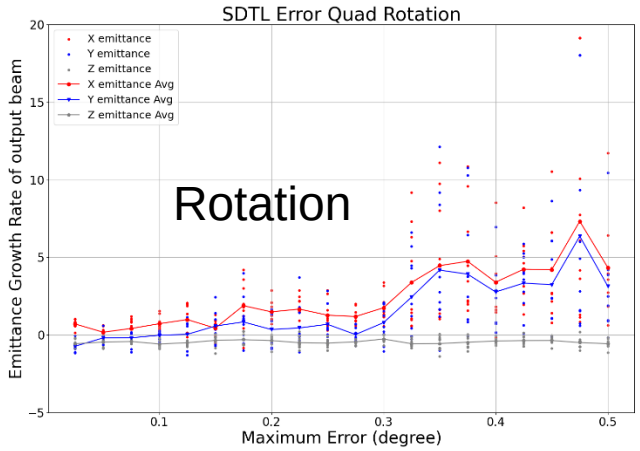
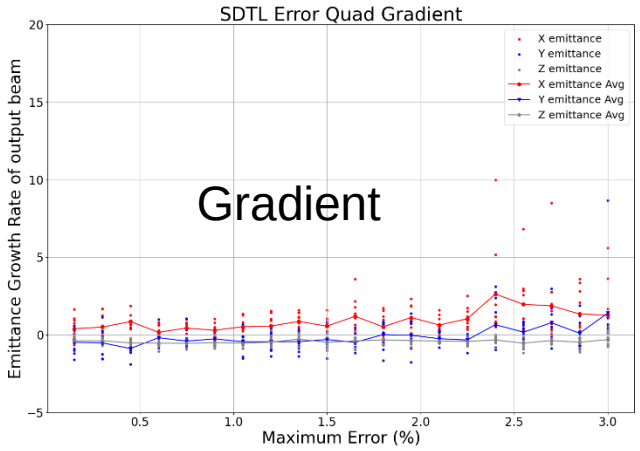
Beamline Error (Quad)











Max emittance growth : ~ 10 %

Error Study with Cavity Error

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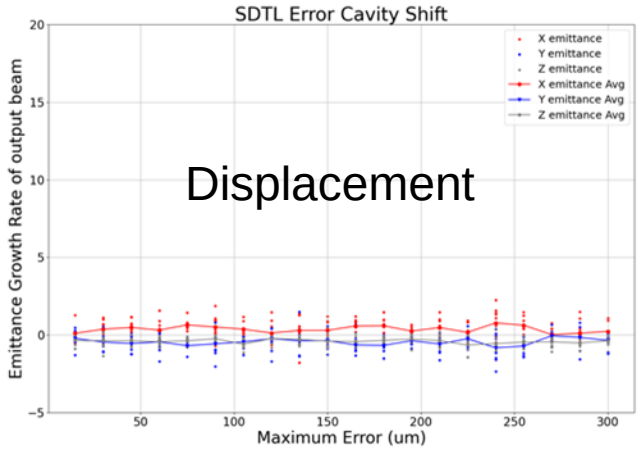
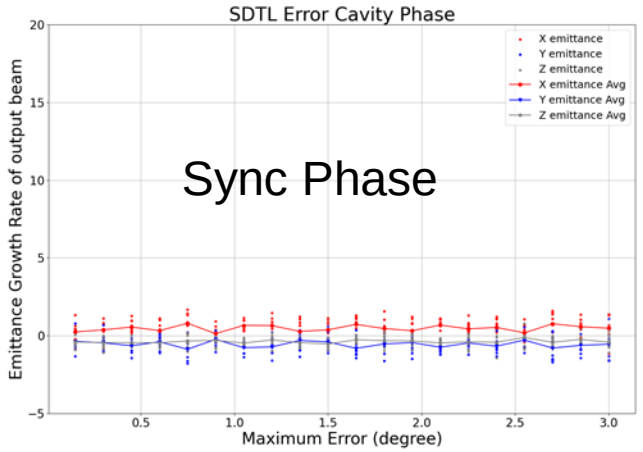
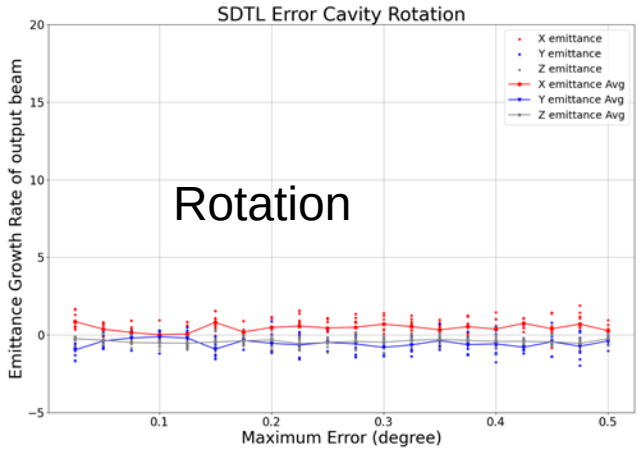
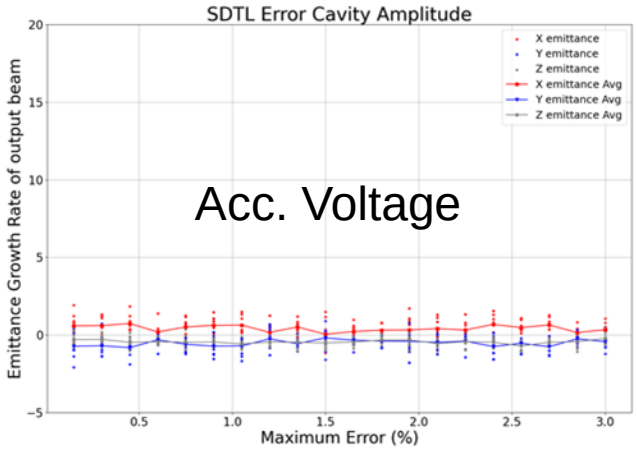
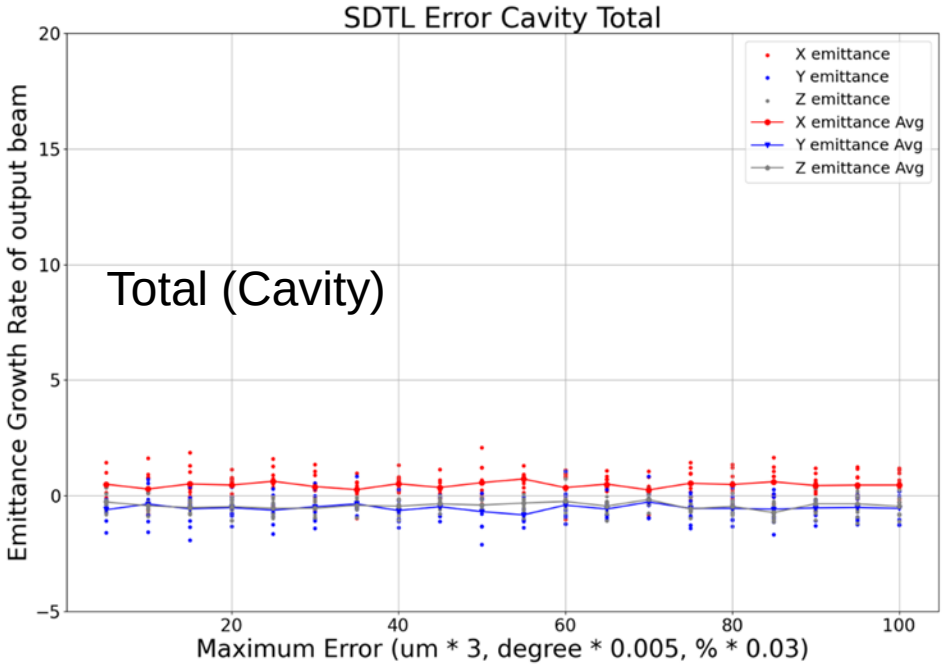
Beamline Error (Cavity)





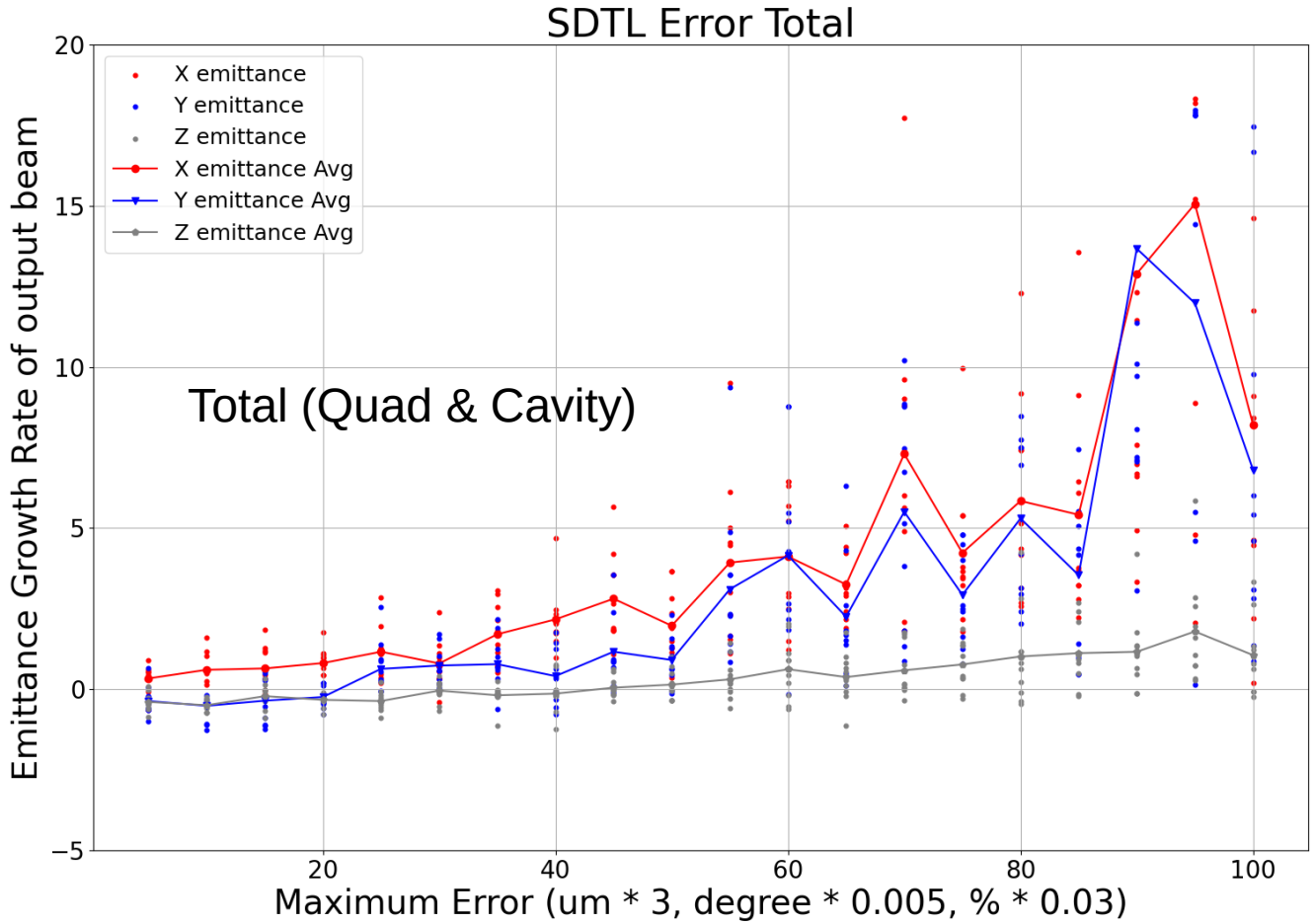






Almost non-effective

Error Study with All types of Error



Error from quad magnet is **dominant**

but not Significant

In terms of emittance growth

Input Beam Centroid Shift

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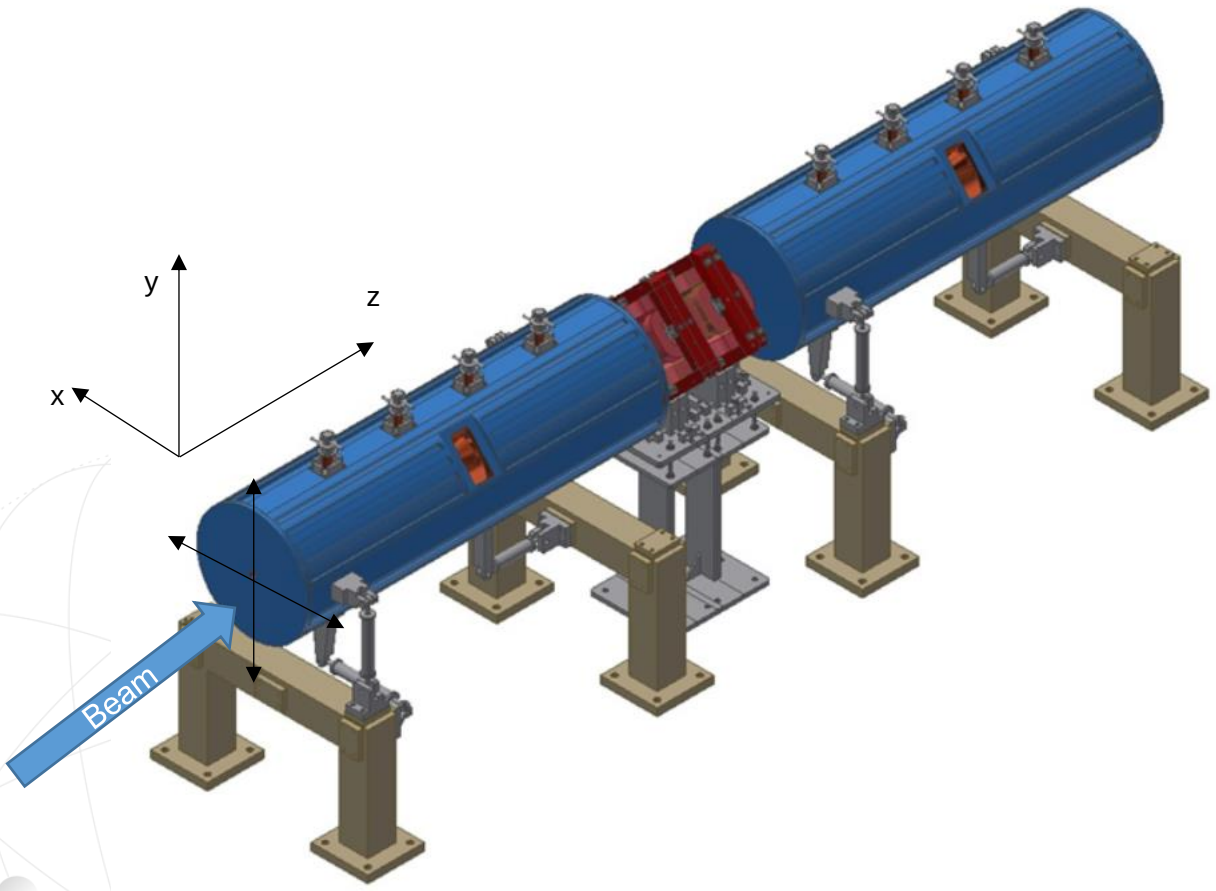
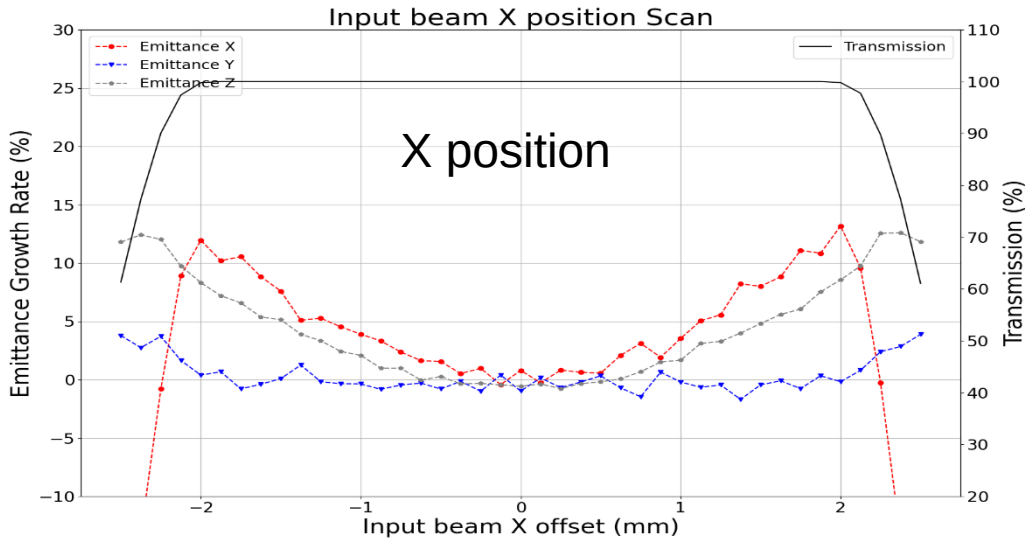
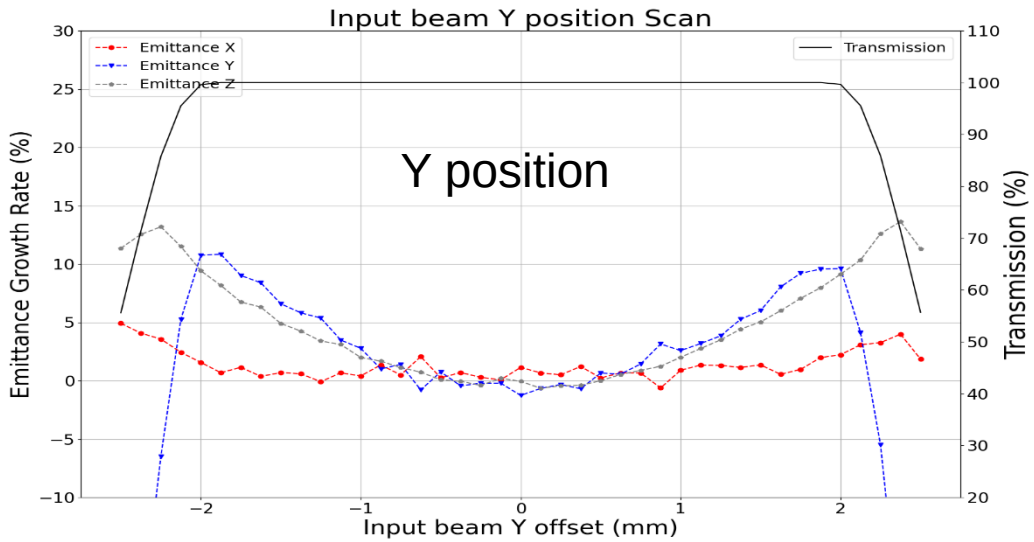
Input Beam Error (Centroid Shift)





Very significant



Input Beam Angle Shift

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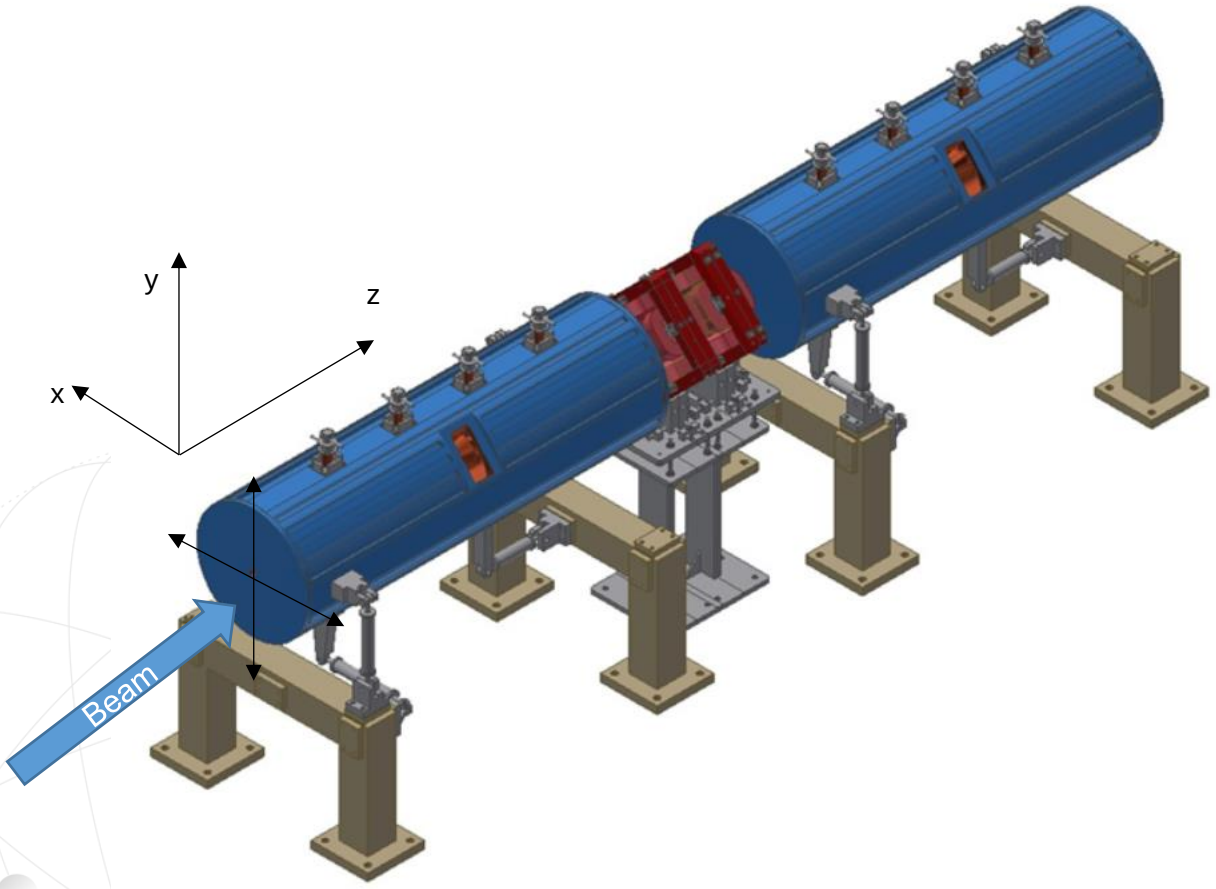
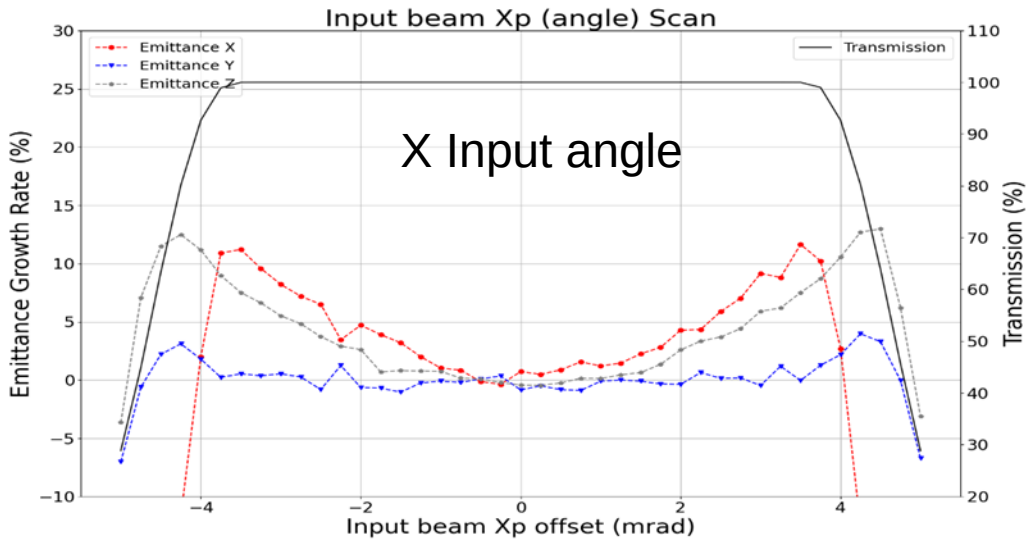
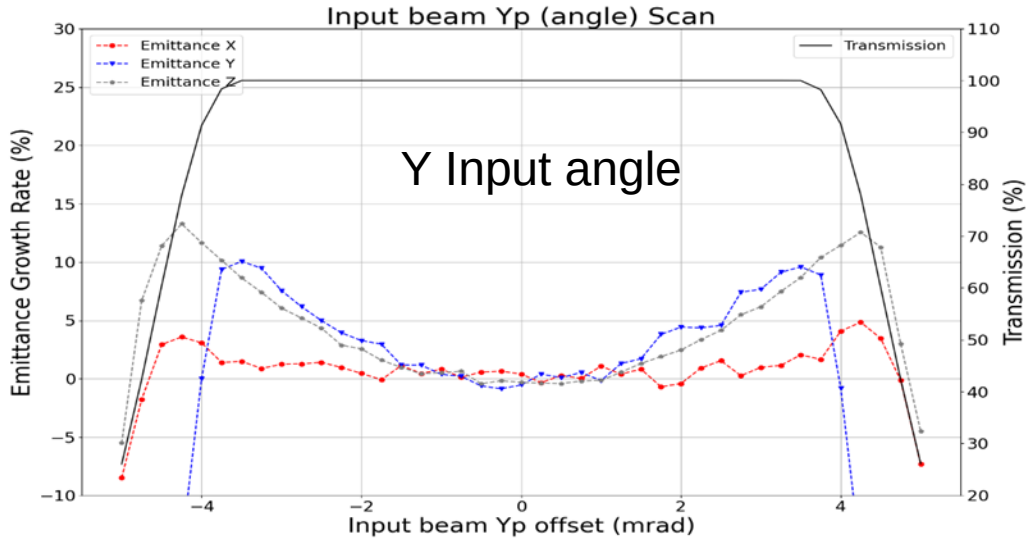
Input Beam Error(Input beam angle)





Very significant



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Orbit Correction Simulation Setup

Steer type 1 (Both x, y)

Steer type 2 (x, y separate)

Installation type 1

Installation type 2

Installation type 3

Total Case : 6

Steerer type * Installation type

Input error : Beamline error

Orbit Correction Simulation Centroid Result 1

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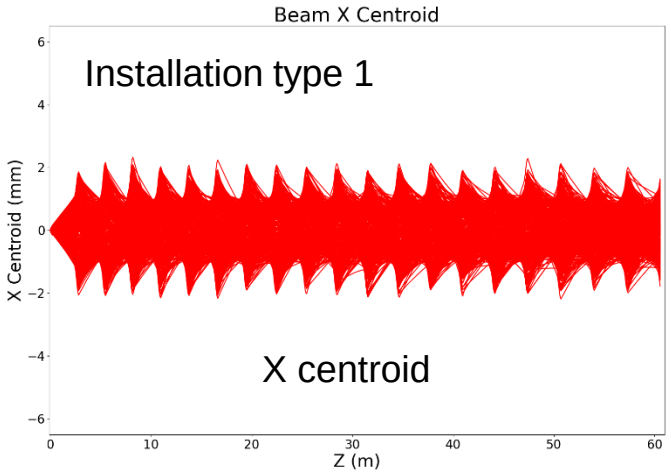
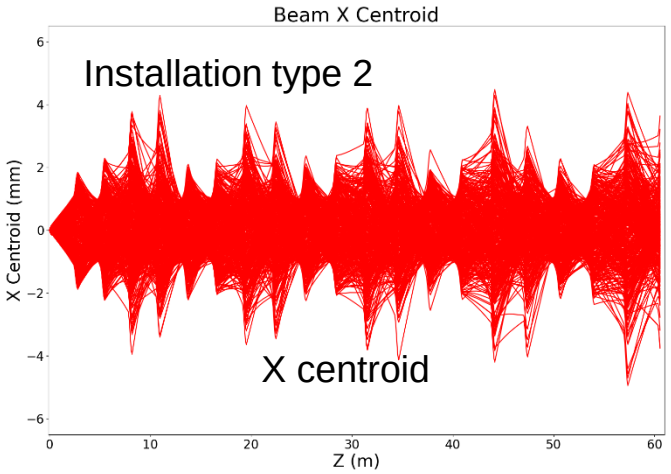
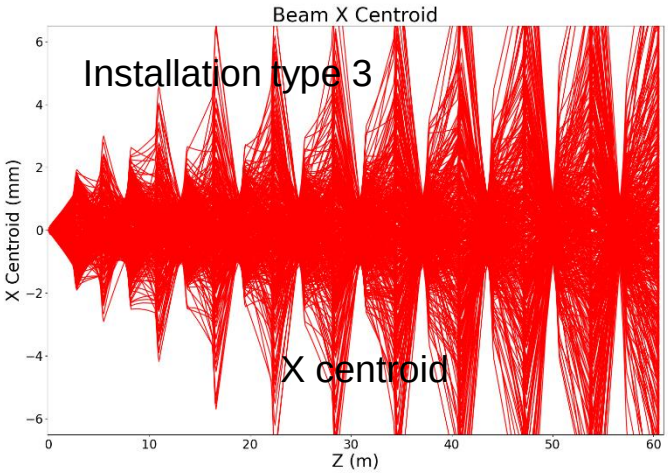
Steer type 1



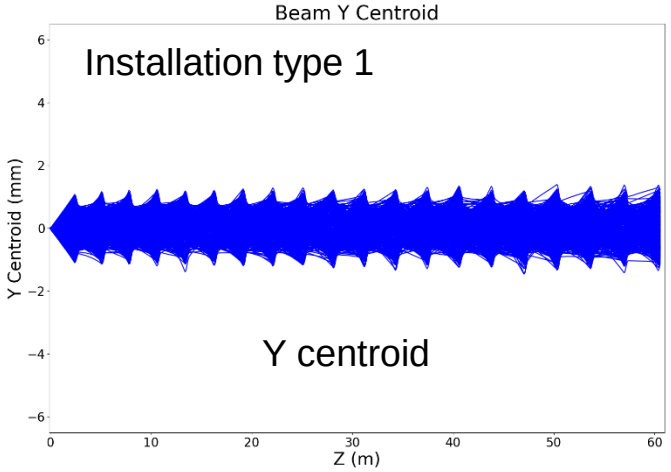
Possible

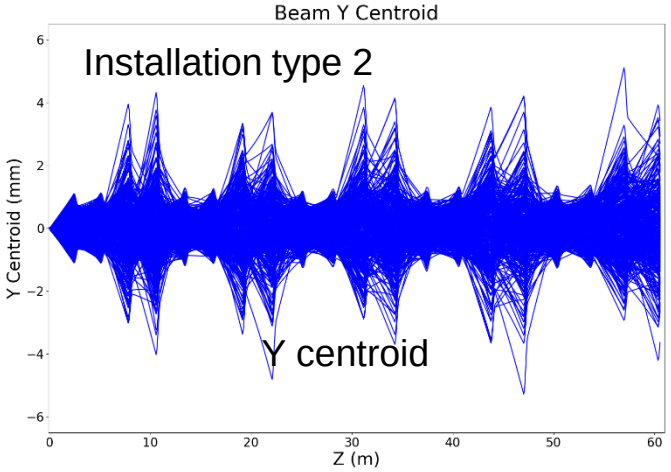


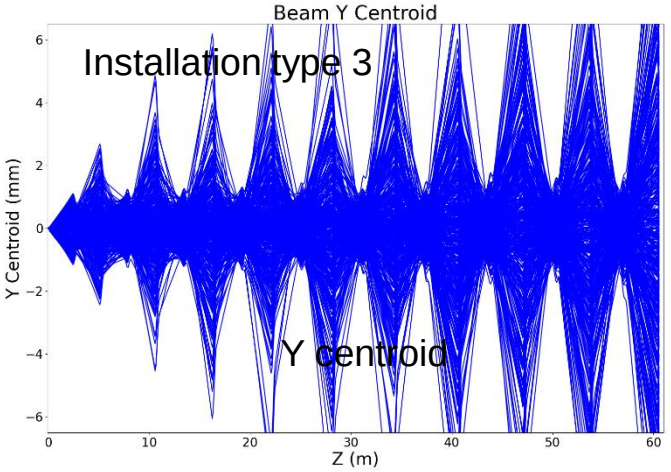
Possible



Impossible







Orbit Correction Simulation Centroid Result 2

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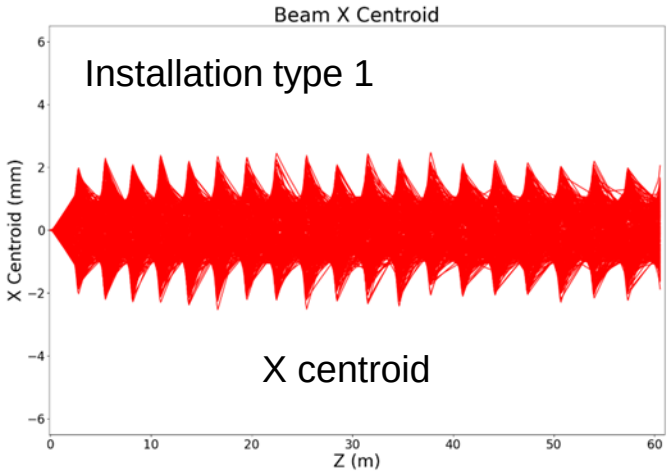
Steer type 2



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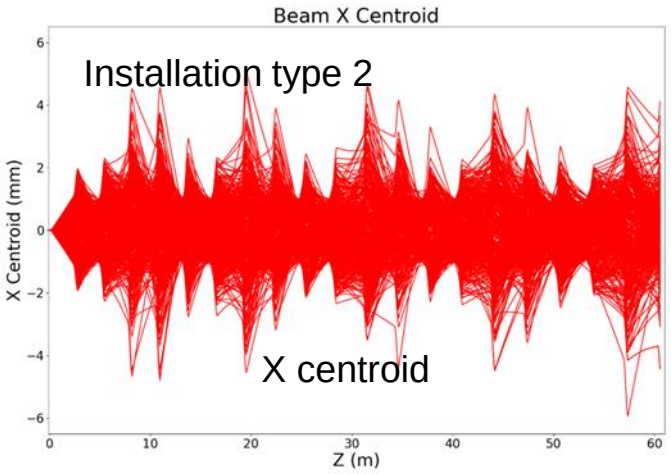

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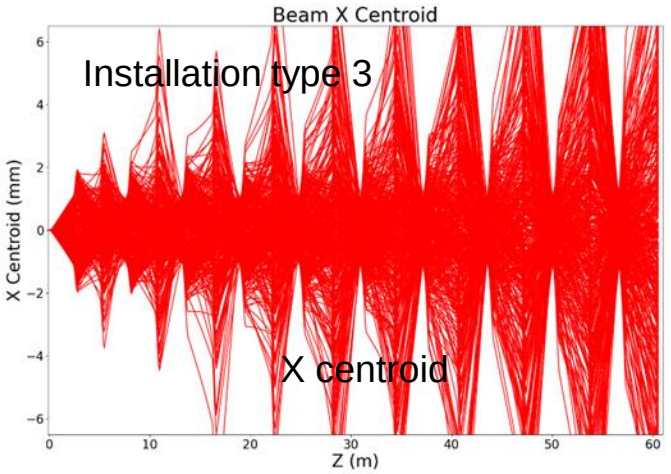
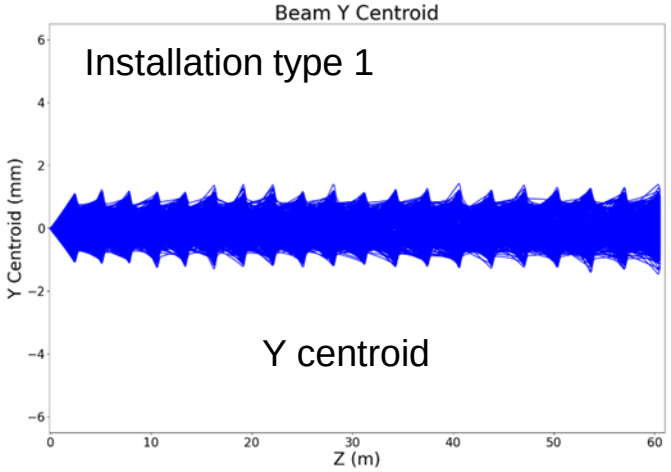
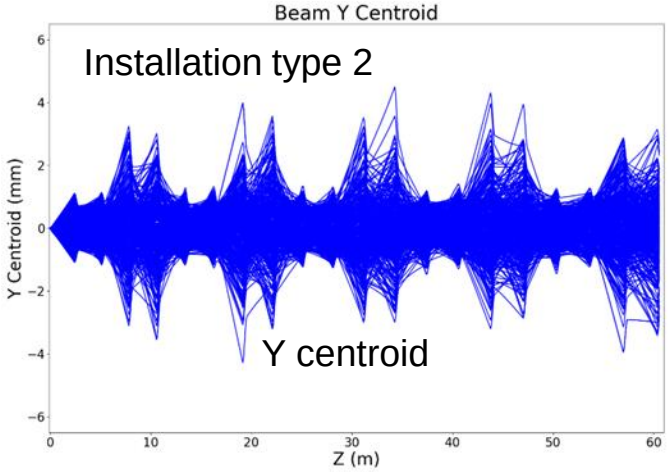
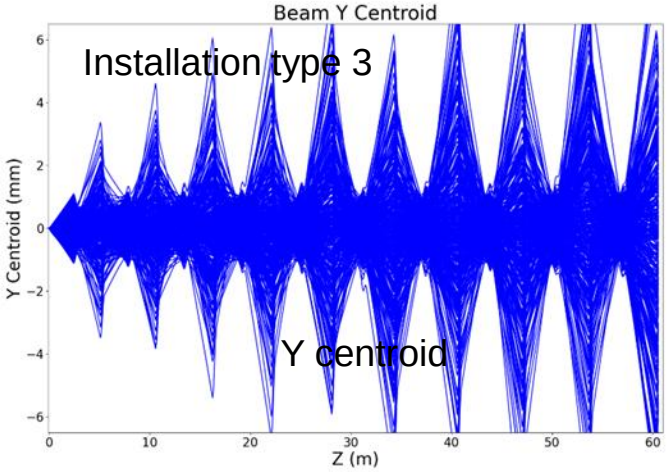


Impossible







Orbit Correction Simulation Field Strength

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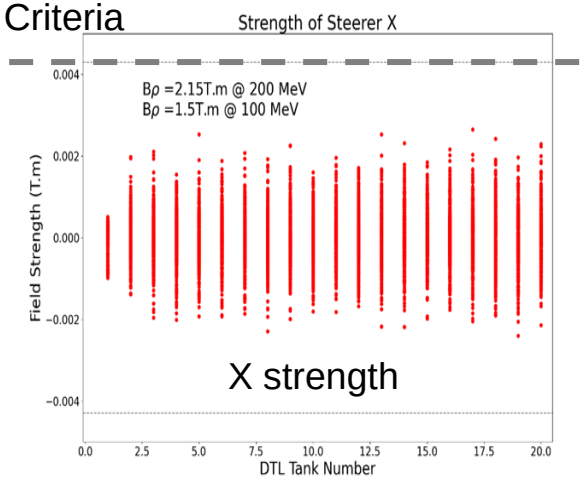
Steer type 1

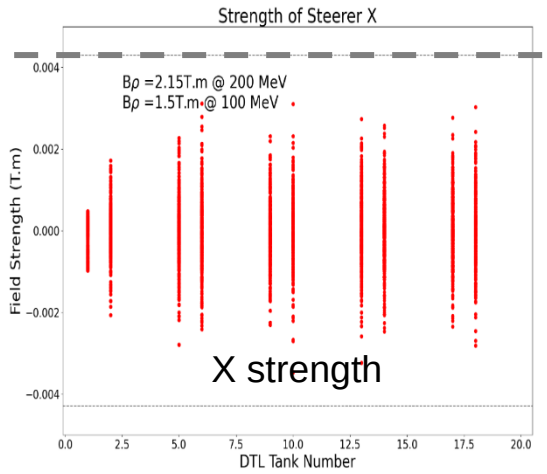
Reasonable

Steer type 2

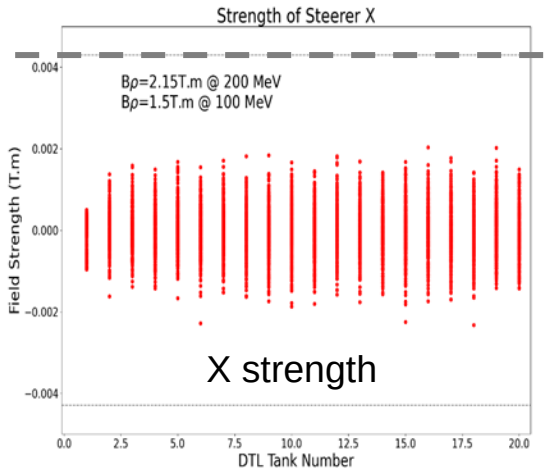
Criteria



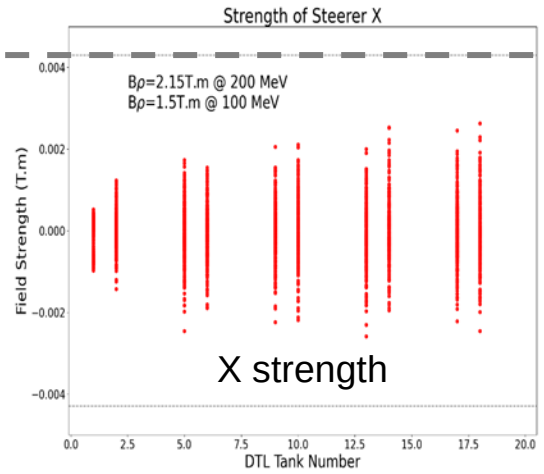
Installation type 1



Installation type 2

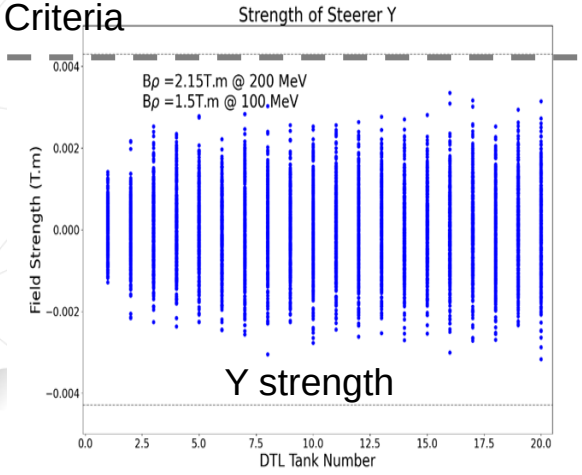


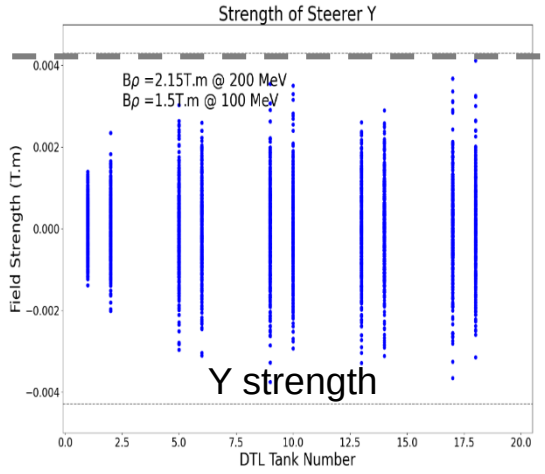
Installation type 1

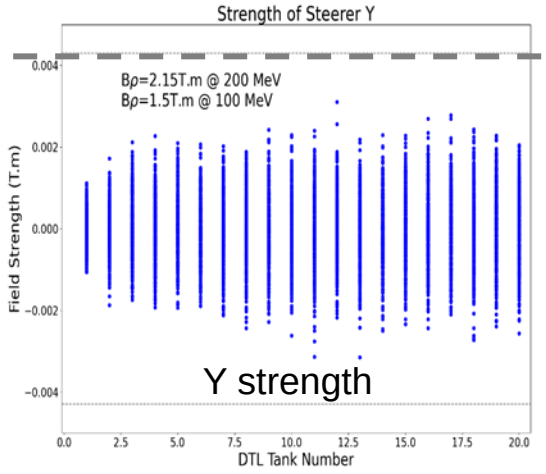


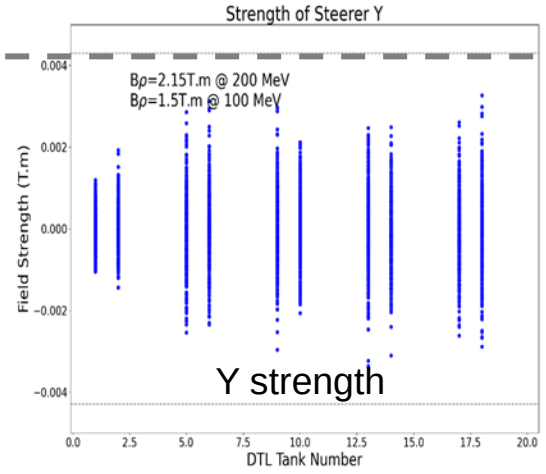
Installation type 2

Criteria









- Introduction
- Beam dynamics and error study of 200 MeV LINAC
- Orbit correction simulation with error
- **Summary**

Criteria of Maximum Error & Steering Magnet

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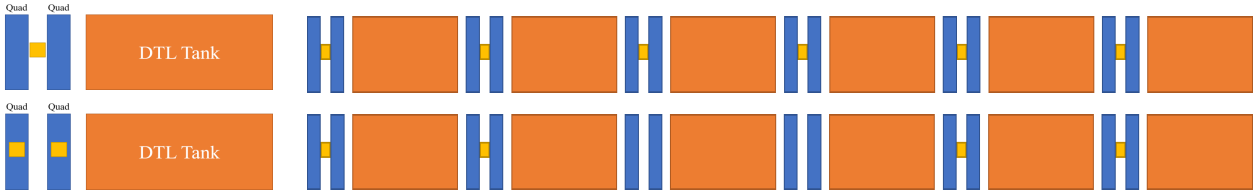
Criteria of Maximum Error

Error Type	Value
Quad magnet displacement (dx, dy)	$\pm 150\ um$
Quad magnet rotation (ϕ_x, ϕ_y, ϕ_z)	$\pm 0.25°$
Quad magnet gradient	$\pm 1.5\%$
Cavity displacement (dx, dy)	$\pm 150\ um$
Cavity rotation (ϕ_x, ϕ_y)	$\pm 0.25°$
Cavity Acc. Voltage	$\pm 1.5\%$
Cavity Phase (ϕ_{sync})	$\pm 1.5°$
Input beam Position (x, y)	$\pm 1\ mm$
Input beam angle (x, y)	$\pm 2\ mrad$

Suppress Emittance growth below 5%

Criteria of Steering Magnet



[Steer type 1 & 2 + Installation type 1 & 2] are **Possible**

Required maximum field for steering magnet

$$\boldsymbol{4.3 * 10^{-3}\ T.m}$$

$(2\ mrad\ @\ 200\ MeV)$

Summary

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- KOMAC start to prepare the energy upgrade up to 200 MeV
- The lattice type is SDTL and the total length is around 70 m
- The designed SDTL lattice is robust for external error (Quad & Cavity)
- Even if there is error, the corrector magnet can adjust it within 2 mrad range

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Thank you

10/24/2024

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Input Beam Mismatch

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Input beam error (Input beam mismatch)