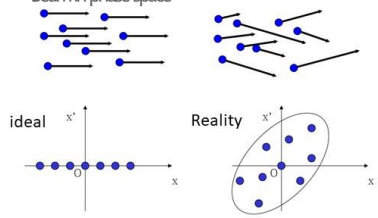
# THE IMPLEMENTATION OF THE BEAM PROFILE APPLICATION FOR KOMAC BEAM EMITTANCE

Jae-Ha Kim†, Young-Gi Song, SungYun Cho, Seunghyun Lee, Sang-Pil Yun
Korea Multi-purpose Accelerator Complex, Korea Atomic Energy Research Institute, Gyeongju, Korea

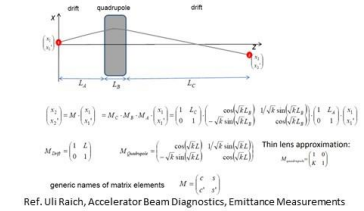
ICALEPCS 2021

## • Beam Emittance

Beam in phase space




Transport of a single partide along a transfer line

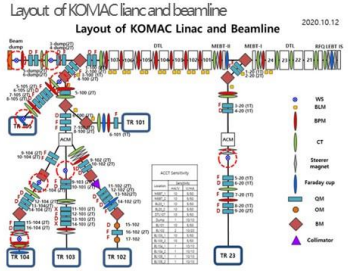



Ref. Uli Raich, Accelerator Beam Diagnostics, Emittance Measurements

- The beam is made up of so many charged particles.
- The charged particles move together with given velocity and have the same momentum as the direction of the beam in ideal case.
- But particles have a component that is perpendicular to the beam direction for various reasons.
- Beam emittance is the volume of the phase space of the particles.
- So beam emittance is a property of a beam in an accelerator.
- KOMAC installed various beam diagnosis device, that is wire scanner, to measure the beam emittance of the KOMAC

## • Wire scanner

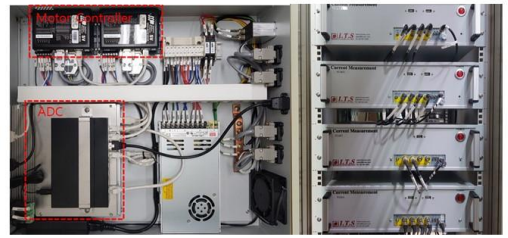
Layout of KOMAC lianc and beamline




The specification of the wire scanner

| Specification | |
|---|---|
| Wire material | W tungsten |
| Wire diameter | 0.1 mm |
| Moving speed & Range | 100 mm/s, 50 mm (± 25 mm) |
| Spatial accuracy | 0.05 mm |
| Spatial resolution | 0.1 mm |
| Mounting Flange | 6" CF |

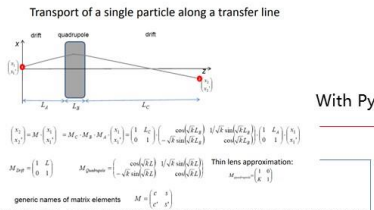
The wire scanner control unit




- KOMAC installed eight wire scanners at beamlines that ar TR23, TR103, TR104, TR105 and straight beamline to figure out the beam emittance of the KOMAC 100 MeV proton beam.
- The wire scanner is made up of motor to move the wires, DAQ system to measure the current of a beam.

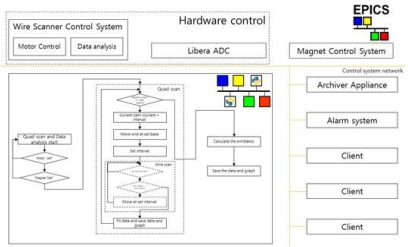
## • Calculating the Beam emittance of KOMAC

Transport of a single particle along a transfer line

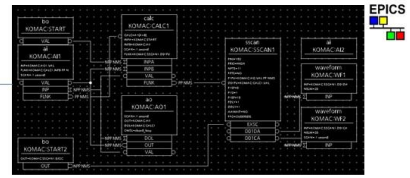



Ref. Uli Raich, Accelerator Beam Diagnostics, Emittance Measurements

With PyEPICS




With sscan, aSub record



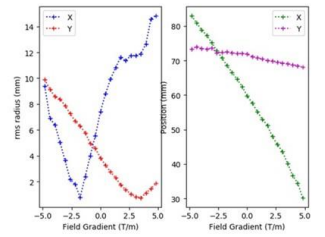

- KOMAC control system based on Experimental Physics and Industrial Contorl System (EPICS) framework has been implemented to control the 100 MeV linac.
- PyEPICS was adopted for the quad scan interface.
- Quad scan algorithm has been newly implemented with sscan, aSub record to simplify the process.

## • Quad scan interface for the beam emittance

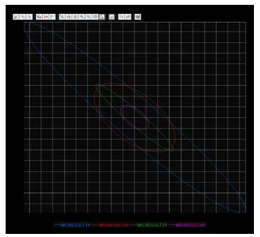
Quad scan User Interface using CSS


- The Control system Studio (CSS) has been used for the KOMAC User Interface.
- The quad scan operates in synchronization with the beam.
- The data from the wire scanner are plotted in Real-time
- After the quad scan, All the data are delivered to aSub record and are saved in text file format and in the Archive Appliance.
- aSub record calculates the rms beam size versus Field gradient.
- The beam emittance of the 100 MeV proton linac is obtained from the rms beam size versus field gradient.

The rms beam size versus Field gradient

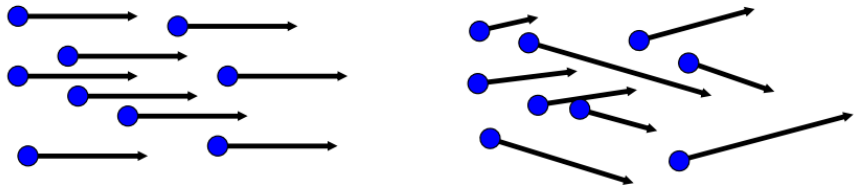


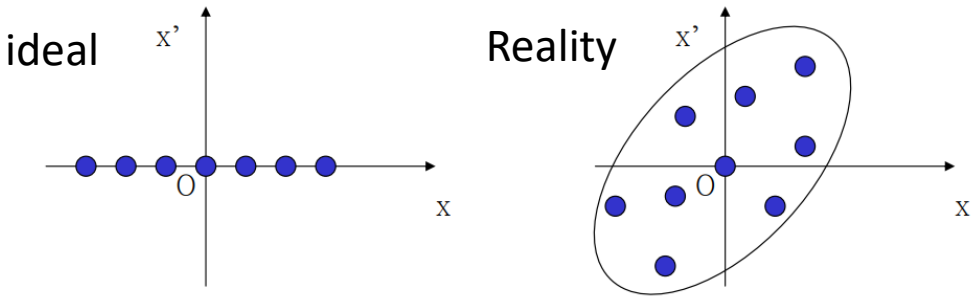

The beam emittance



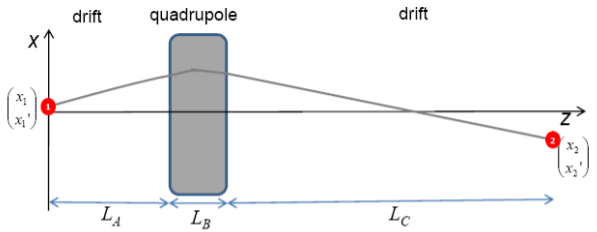
# • Beam Emittance

## Beam in phase space






## Transport of a single particle along a transfer line




$$\begin{pmatrix} x_2 \\ x_2' \end{pmatrix} = M \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix} = M_C \cdot M_B \cdot M_A \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix} = \begin{pmatrix} 1 & L_C \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} \cos(\sqrt{k}L_B) & 1/\sqrt{k}\sin(\sqrt{k}L_B) \\ -\sqrt{k}\sin(\sqrt{k}L_B) & \cos(\sqrt{k}L_B) \end{pmatrix} \cdot \begin{pmatrix} 1 & L_A \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix}$$

$$M_{Drift} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \qquad M_{Quadrupole} = \begin{pmatrix} \cos(\sqrt{k}L) & 1/\sqrt{k}\sin(\sqrt{k}L) \\ -\sqrt{k}\sin(\sqrt{k}L) & \cos(\sqrt{k}L) \end{pmatrix}$$

Thin lens approximation:

$$M_{quadrupole} = \begin{pmatrix} 1 & 0 \\ K & 1 \end{pmatrix}$$

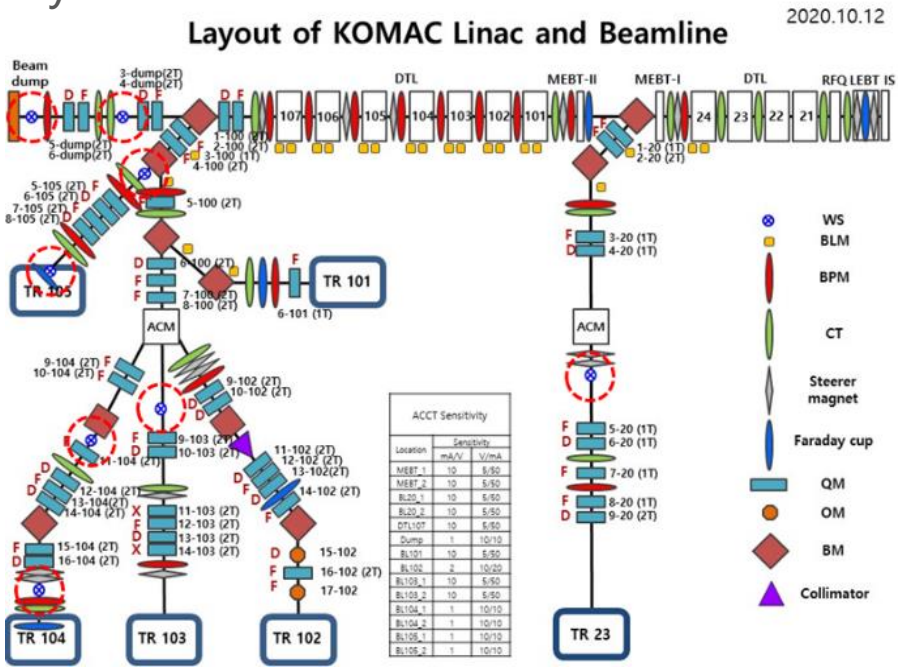
generic names of matrix elements $M = \begin{pmatrix} c & s \\ c' & s' \end{pmatrix}$

Ref. Uli Raich, Accelerator Beam Diagnostics, Emittance Measurements

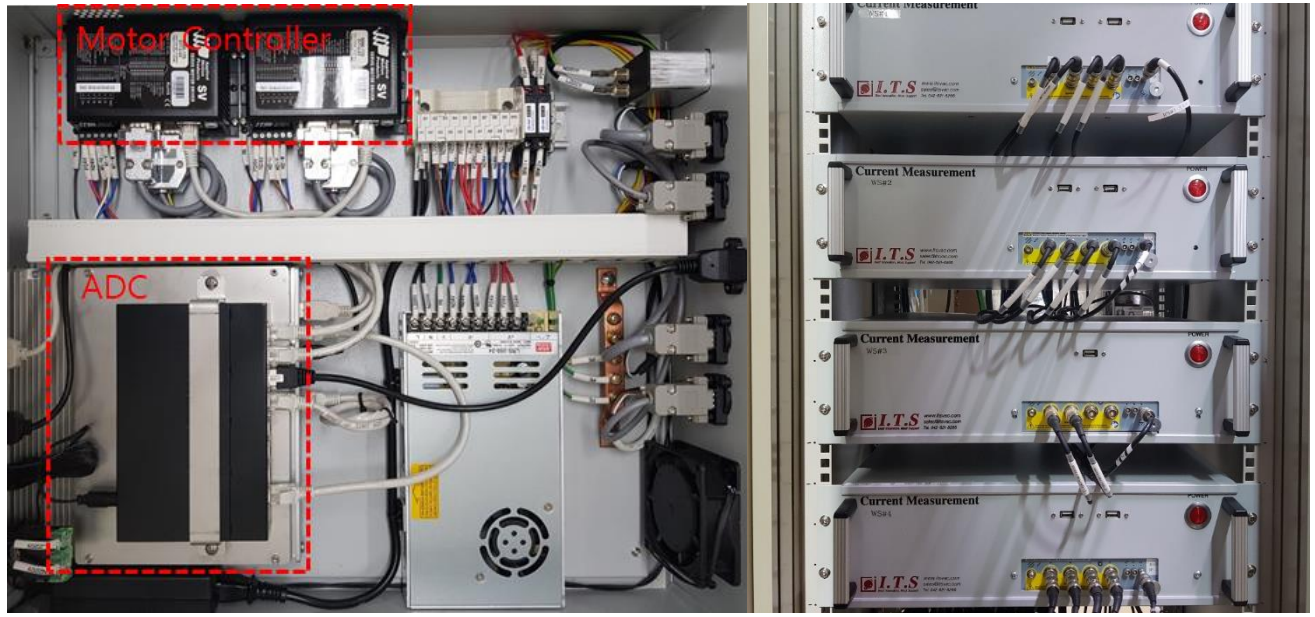
- The beam is made up of so many charged particles.
- The charged particles move together with given velocity and have the same momentum as the direction of the beam in ideal case.
- But particles have a component that is perpendicular to the beam direction for various reasons.
- Beam emittance is the volume of the phase space of the particles.
- So beam emittance is a property of a beam in an accelerator.
- KOMAC installed various beam diagnosis device, that is wire scanner, to measure the beam emittance of the KOMAC

# • Wire scanner

Layout of KOMAC lianc and beamline




The wire scanner control unit



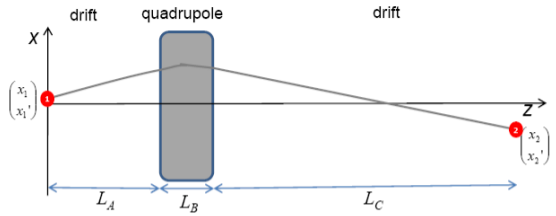

The specification of the wire scanner

| Specification | |
|---|---|
| Wire material | W tungsten |
| Wire diameter | 0.1 mm |
| Moving speed & Range | 100 mm/s, 50 mm (± 25 mm) |
| Spatial accuracy | 0.05 mm |
| Spatial resolution | 0.1 mm |
| Mounting Flange | 6″ CF |

- KOMAC installed eight wire scanners at beamlines that ar TR23, TR103, TR104, TR105 and straight beamline to figure out the beam emittance of the KOMAC 100 MeV proton beam.
- The wire scanner is made up of motor to move the wires, DAQ system to measure the current of a beam.

# • Calculating the Beam emittance of KOMAC

Transport of a single particle along a transfer line




$$\begin{pmatrix} x_2 \\ x_2' \end{pmatrix} = M \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix} = M_C \cdot M_B \cdot M_A \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix} = \begin{pmatrix} 1 & L_C \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} \cos(\sqrt{k}L_B) & 1/\sqrt{k}\sin(\sqrt{k}L_B) \\ -\sqrt{k}\sin(\sqrt{k}L_B) & \cos(\sqrt{k}L_B) \end{pmatrix} \cdot \begin{pmatrix} 1 & L_A \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_1 \\ x_1' \end{pmatrix}$$

$$M_{Drift} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \qquad M_{Quadrupole} = \begin{pmatrix} \cos(\sqrt{k}L) & 1/\sqrt{k}\sin(\sqrt{k}L) \\ -\sqrt{k}\sin(\sqrt{k}L) & \cos(\sqrt{k}L) \end{pmatrix}$$

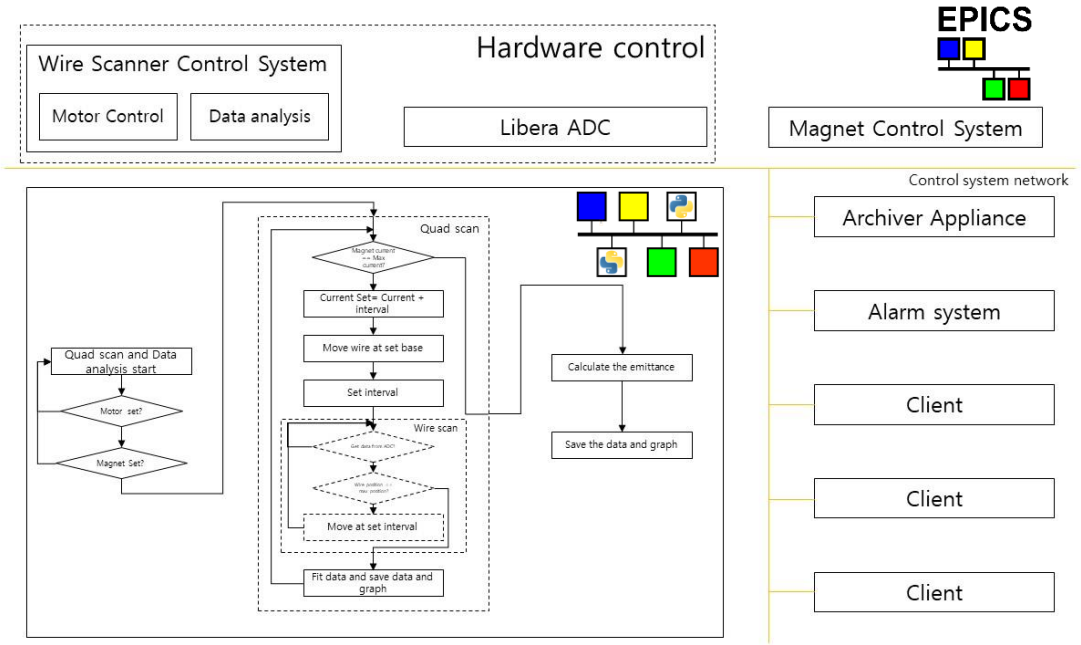
Thin lens approximation:

$$M_{quadrupole} = \begin{pmatrix} 1 & 0 \\ K & 1 \end{pmatrix}$$

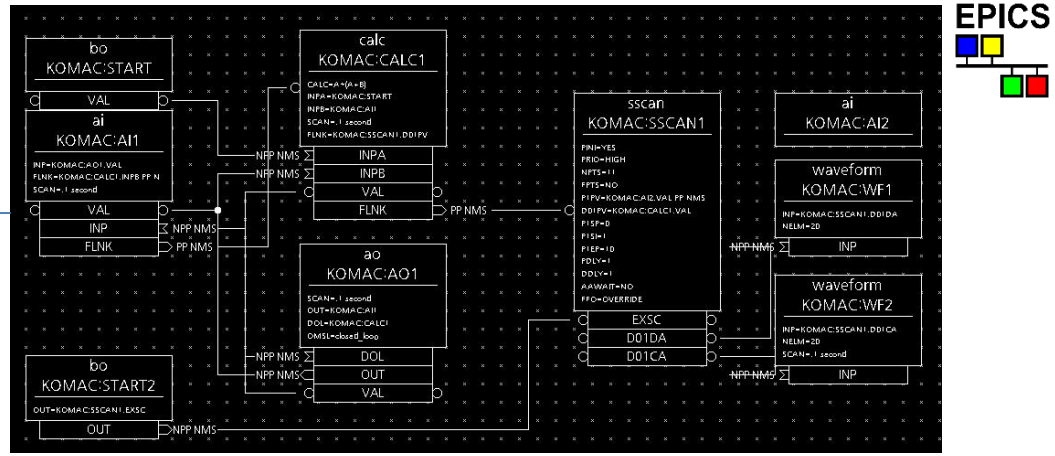
generic names of matrix elements $M = \begin{pmatrix} c & s \\ c' & s' \end{pmatrix}$

Ref. Uli Raich, Accelerator Beam Diagnostics, Emittance Measurements

With PyEPICS




With sscan, aSub record

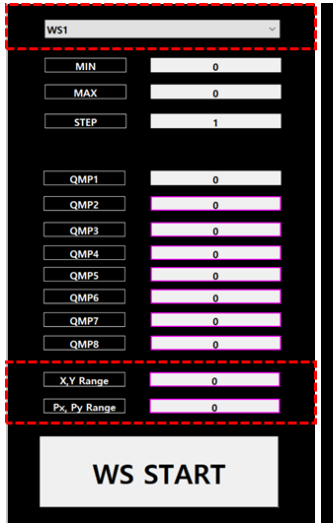


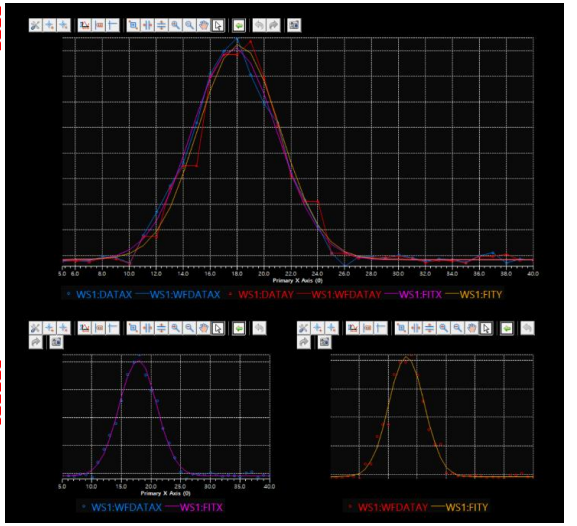

- KOMAC control system based on Experimental Physics and Industrial Contorl System (EPICS) framework has been implemented to control the 100 MeV linac.
- PyEPICS was adopted for the quad scan interface.
- Quad scan algorithm has been newly implemented with sscan, aSub record to simplify the process.

# • Quad scan interface for the beam emittance

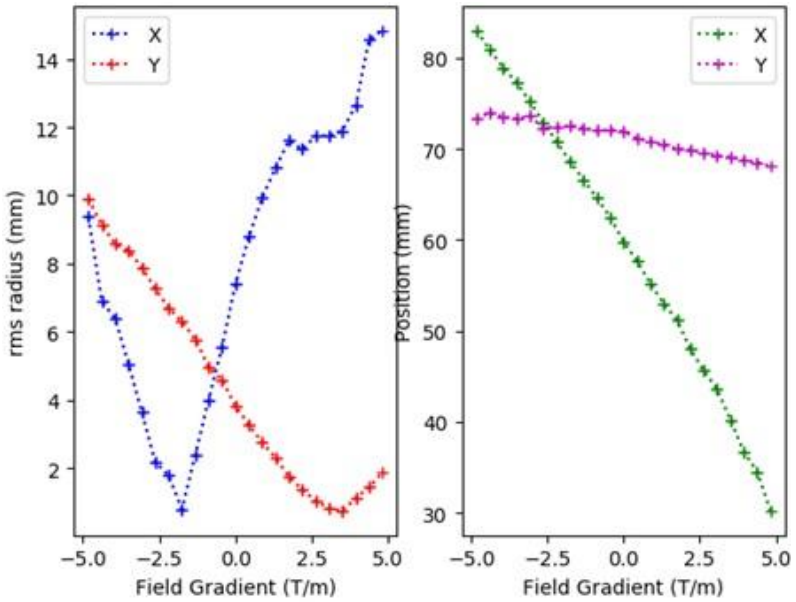
- The Control system Studio (CSS) has been used for the KOMAC User Interface.
- The quad scan operates in synchronization with the beam.
- The data from the wire scanner are plotted in Real-time
- After the quad scan, All the data are delivered to aSub record and are saved in text file format and in the Archive Appliance.
- aSub record calculates the rms beam size versus Field gradient .
- The beam emittance of the 100 MeV proton linac is obtained from the rms beam size versus field gradient.

## Quad scan User Interface using CSS


## The rms beam size versus Field gradient




## The beam emittance