Preliminary Results on Transverse Phase Space Tomography at KOMAC

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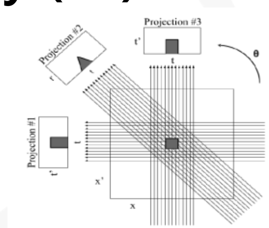
Introduction

» Motivation

- **Beam loss is a critical issue to be avoid in the high power proton accelerators due to machine protection from radiation.**
- **Nonlinear processes add higher order moments and cause halo and tail structures to the beam → Resulting in beam losses.**
- **We have a upgrade plan for our 100 MeV linac. For the stable operation of a high intensity accelerator and machine protection from radiation in the high power proton linac, we developed Computational Tomography (CT) method to characterize beams.**

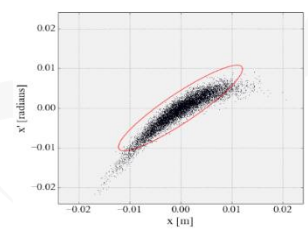


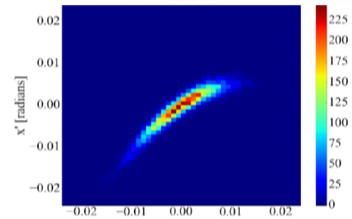
Radon Transform

f(x,y) → *P(t)*

Inverse Radon Transform

(back projection, reconstruction)





$$P(t) == \iint_{R^2} f(x,y)\delta(x\cos\theta + y\sin\theta - t)\,dx\,dy$$

Ref: Transverse Phase Space Tomography in Beamlines by Adam Watts (2018)

Experimental setup

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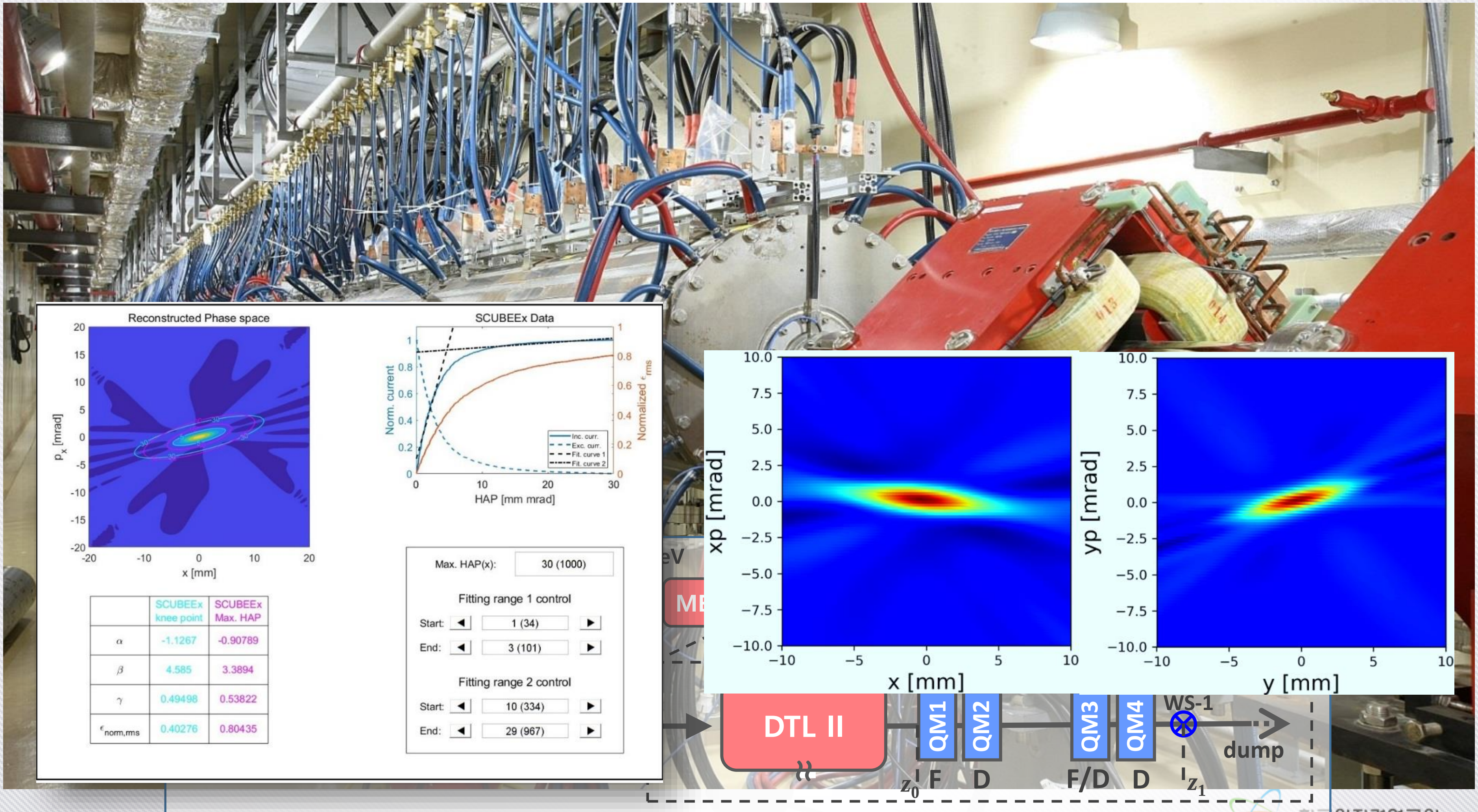
100 MeV Linac & DUMP beamline for CT measurement



	SCUBEEx knee point	SCUBEEx Max. HAP
α	-1.1267	-0.90789
β	4.585	3.3894
γ	0.49498	0.53822
$\epsilon_{norm,rms}$	0.40276	0.80435

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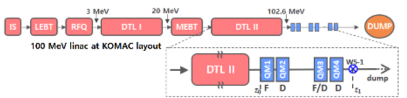
Introduction & Motivation

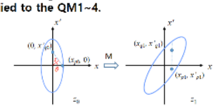
- Beam loss is a critical issue to be avoid in the high power proton accelerators due to machine protection from radiation.
- Nonlinear processes add higher order moments and cause halo and tail structures to the beam. It eventually causes beam losses
- We have a 100 MeV proton linac which is planned to be upgraded for higher energy. For the stable operation and machine protection from radiation in the high power proton linac, we developed Computational Tomography (CT) method to characterize beams.
- CT method : a set of one-dimensional beam profile data (x or y) obtained under various strengths of a quadrupole magnet → two-dimensional phase space distribution (x-x′ or y-y′). A filtered back projection algorithm is introduced to reconstruct the beam distribution in the phase space.

CT Experimental Setup and Method



CT experimental setup layout in the dump beamline

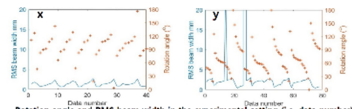
- Dump beamline is used for the reconstruction of the beam phase space distribution using the CT method.
- Rotation : first four quadrupole magnet (QM1~4)
- Detector : a wire scanner (WS-1) in the beamline
- Magnet setting: QM1 = 60 A, QM2 = 50 A, QM3 = -110~110 A and QM4 = 0~80 A
- The wire scanner (WS-1) measures the beam profile in x and y for every setting of QM1~4 during the measurement. The beam profiles are modified by the elongation factors and the rotation angles set by the currents applied to the QM1~4.



$$\begin{pmatrix} x_{p1} & x_{q1} \\ x'_{p1} & x'_{q1} \end{pmatrix} = \boldsymbol{M} \begin{pmatrix} x_{p0} & 0 \\ 0 & x'_{q0} \end{pmatrix} = \begin{pmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{pmatrix} \begin{pmatrix} x_{p0} & 0 \\ 0 & x'_{q0} \end{pmatrix} = \begin{pmatrix} M_{11}x_{p0} & M_{12}x'_{q0} \\ M_{21}x_{p0} & M_{22}x'_{q0} \end{pmatrix}$$

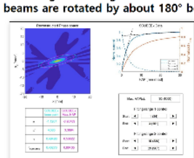
$$tan\theta = \frac{x_{p0}}{x'_{q0}} = \frac{M_{12}}{M_{11}}$$

$$a = \frac{x_{p1}}{s} = \frac{M_{11}x_{p0}}{s} = \frac{M_{11}}{cos\theta}$$



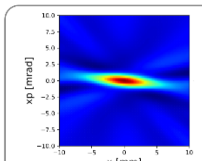
Rotation angle and RMS beam width in the experimental setting (i.e. data number)

- Before the CT measurement, we performed the quad scan measurement to get the beam parameter at z0.
- To obtain the required quadrupole magnet settings (QM1~4) for the CT measurement, we estimate the RMS beam width and rotation angle for x and y direction using the beam parameters at z0.
- With the estimated magnet settings of QM1~4 we set in the CT experiment, the beams are rotated by about 180° both in x and y.

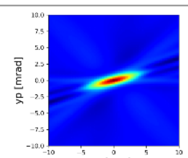


- We have developed a MATLAB based post-processing program which evaluates a phase space reconstruction and a beam emittance using the Self-Consistent UnBiased Exclusion analysis (SCUBEEx) which reduces the effect of artifacts and negative current.

Result & Conclusion



norm. rms ϵ_x = 0.57 pi mm mrad
α_x = 0.17
β_x = 3.19 pi mm/mrad



norm. rms ϵ_y = 0.80 pi mm mrad
α_y = -0.91
β_y = 3.39 pi mm/mrad

- The diagnostic method for the reconstruction of the beam phase space distribution in the (x-x′) and (y-y′) coordinates is developed using the CT technique at KOMAC.
- The beam profiles in x and y are measured in the dump beamline of the 100 MeV proton linac at KOMAC.
- The beam distribution in the phase space is reconstructed by the filtered back projection algorithm and the set of the beam profiles measured at various rotation angles set by the quadrupole magnets (QM1~4).
- The horizontal and vertical emittances of 100 MeV proton beam are evaluated from reconstructed beam distribution in phase space using the SCUBEEx method.

Acknowledgement & Reference

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