Possible configurations for RFQ beam characterization

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Introduction

- Scope
  - Temporary configurations of the beam line immediately following the RFQ and used for characterization of the RFQ beam
  - The total duration is 3 – 6 months
    - Plan: a shutdown around Jan 2016 to install a full-length MEBT with vision to install HWR cryomodule in 2017
- Assumptions
  - The prototype bunching cavity can be used in the MEBT
  - At least two doublets arrive from India by the time of RFQ arrival
  - RFQ installation and RF conditioning takes not more than 2-3 months
  - Everything else (LEBT, RF amplifiers, water system etc.) works close to expectations
    - In part, the LEBT beam is characterized up to 10 mA
- Disclaimer
  - For initial discussion
    - Need to find consensus on what to measure and in what sequence
    - Simulations needs to be done in parallel with mechanical design

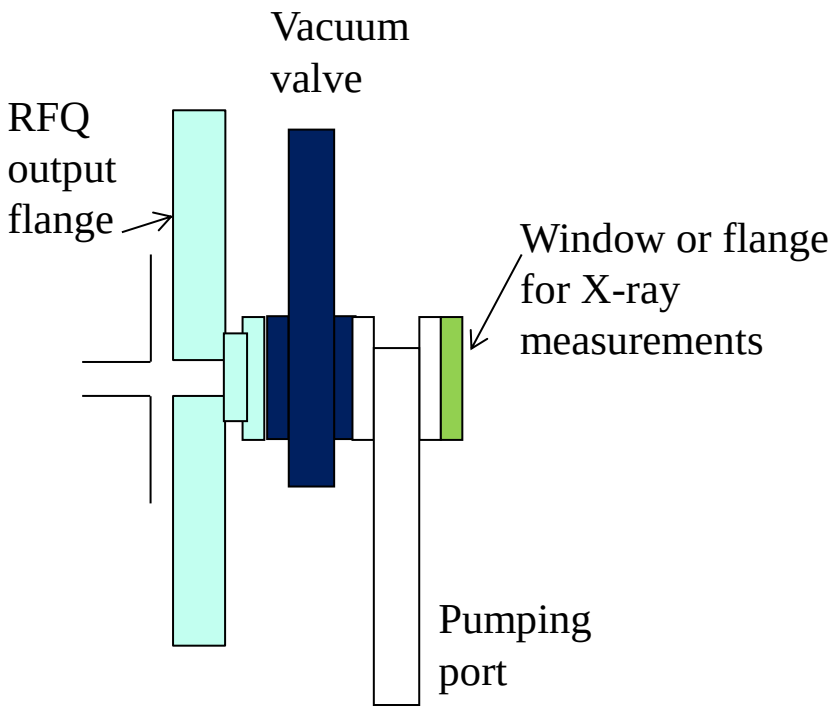
Characteristics to measure and tools

Parameter	FRS value	Measur. precision	Diagnostics main	Secondary
Energy	2.1 MeV	0.3%	Time-of-flight monitor (Movable BPM)	BPMs in doublets
Current	1 – 10 mA	3% abs. 1% rel.	Toroids	LEBT FC, Dump
Transverse emittance	< 0.25 μm (0.15 μm)	5%	Double slit	LEBT scanner
Long. emittance	1 eV·μs	5%	Fast Faraday Cup +buncher scans	BPM second harmonics
Transmission efficiency	95%	1%	Toroids	
Twiss parameters	Small α		Double slit; FFC+buncher	LEBT scanner

RFQ FRS: http://projectx-docdb.fnal.gov/cgi-bin/ShowDocument?docid=894

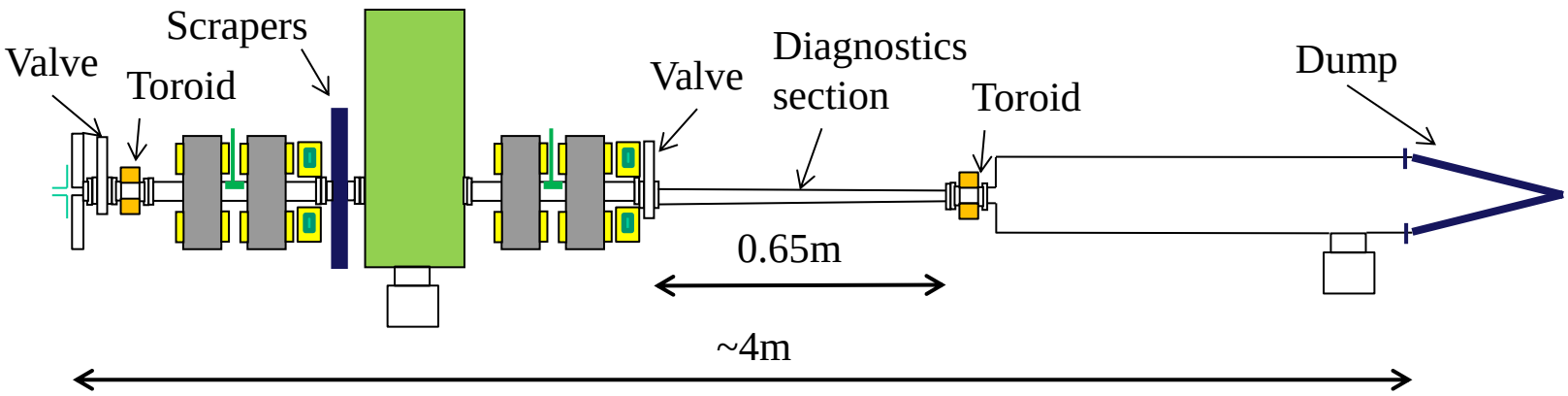
Configuration #0

- Configuration during RFQ RF conditioning
  - To measure X-rays longitudinally
    - May want a capability to replace the X-ray window/flange
  - Put the vacuum valve as the first element after RFQ, if possible
    - Or toroid, then valve



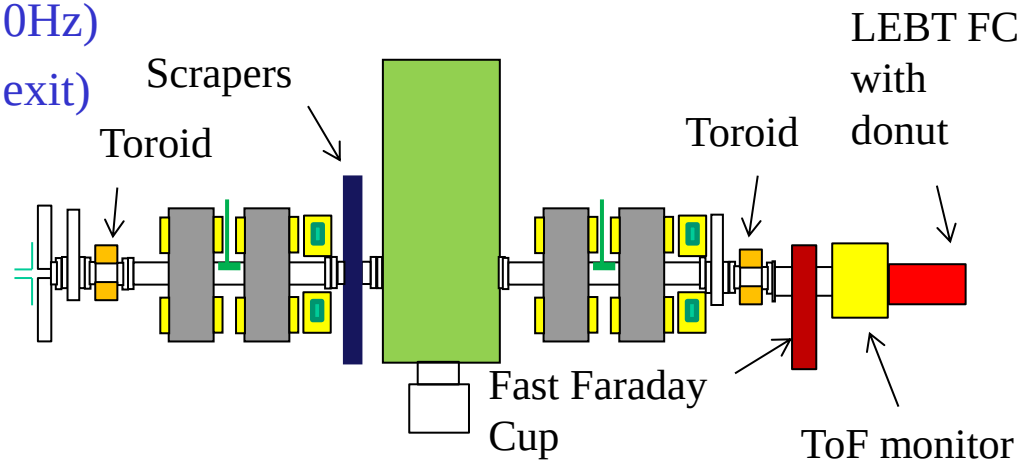
Configuration #1elements

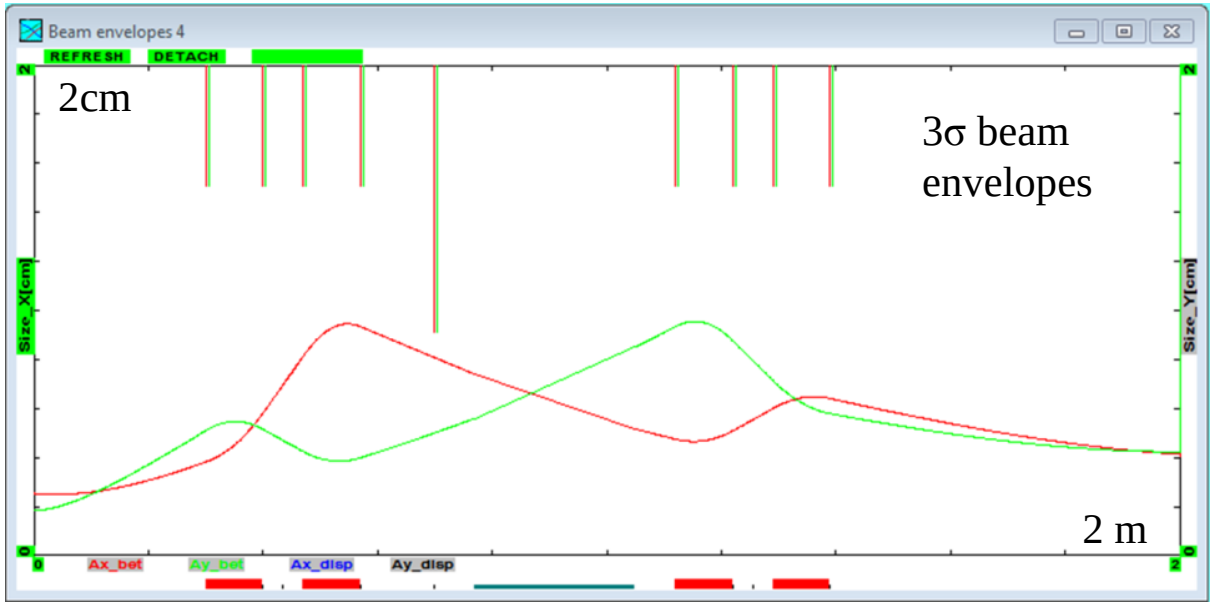
- Fully assembled MEBT section #0 + space for diagnostics section + drift space to increase the beam size + dump
  - + diagnostics: slits/scrapers; FFC, toroid, ToF, LEBT scanner
- Reasoning
  - Because the beam at the RFQ diverges fast both transversely and longitudinally, the beam measurements are difficult without quads or even with one doublet as well as without a bunching cavity
  - This arrangement should allow all principal measurements by shuffling the elements after the second doublet



Configuration #1_1

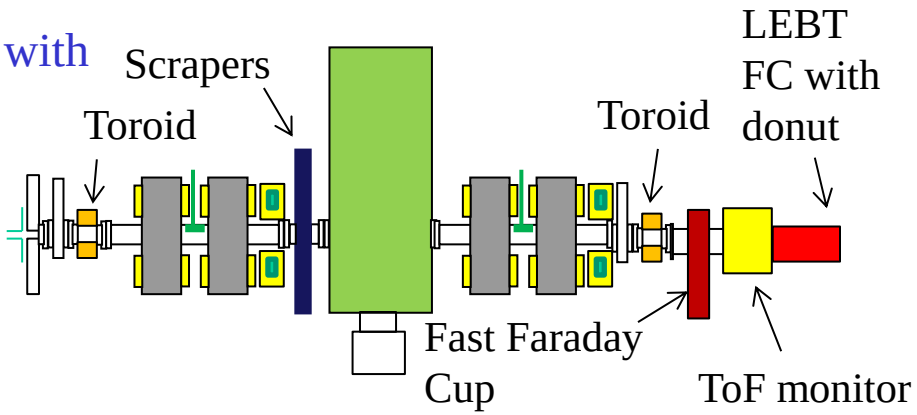
- Features:
  - Pulsed mode only (<1 ms @ 10Hz)
  - Total length ~2 m (from RFQ exit)
  - Typically small beam size after quads ≤2 mm rms
  - Bunch length for ToF σ_z <10°





Configuration #1_1(cont.)

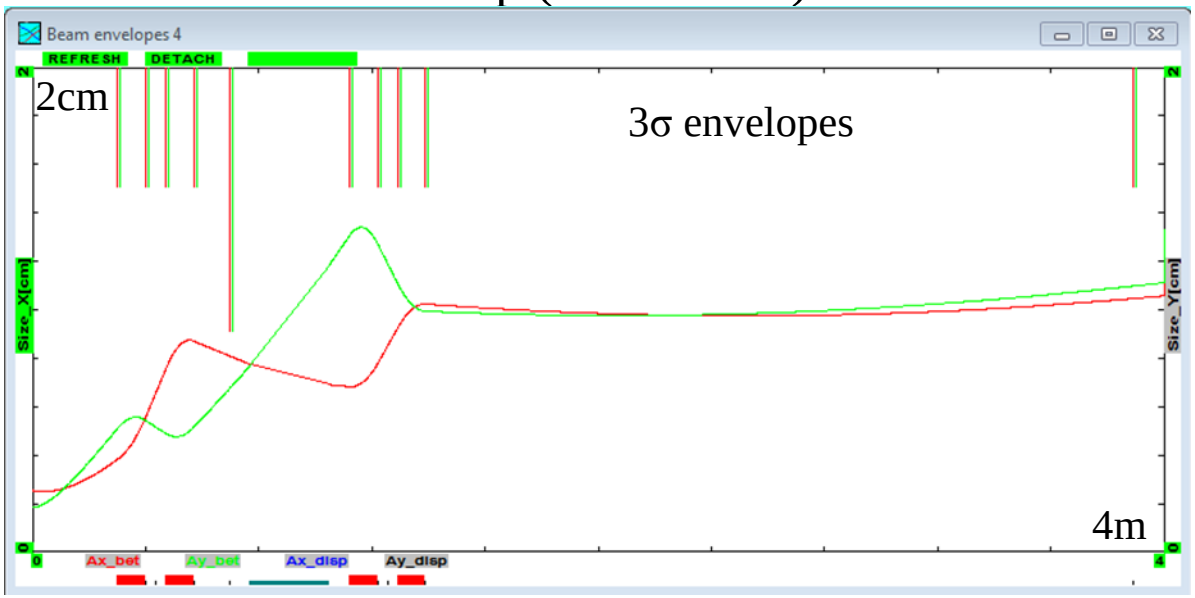
- Mode: pulsed only (<1 ms @ 10Hz)
- Goals
  - Measure the current loss in RFQ (transmission)
    - Toroids upstream and downstream of the RFQ
  - Commissioning
    - quads and dipole correctors, scrapers, BPMs, buncher, ToF monitor, MPS
  - Estimate the current of not-accelerated particles
    - Toroids upstream and downstream of the doublets + "LEBT" Faraday cup
  - Energy measurement with time-of-flight ("ToF BPM")
  - Bunching cavity characterization
  - Beam size measurements with the donut
  - Bunch length measurements with
    - Fast Faraday Cup
    - BPM second harmonics
  - Most of LEBT tuning
  - Machine protection system

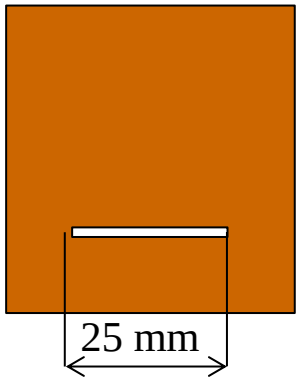


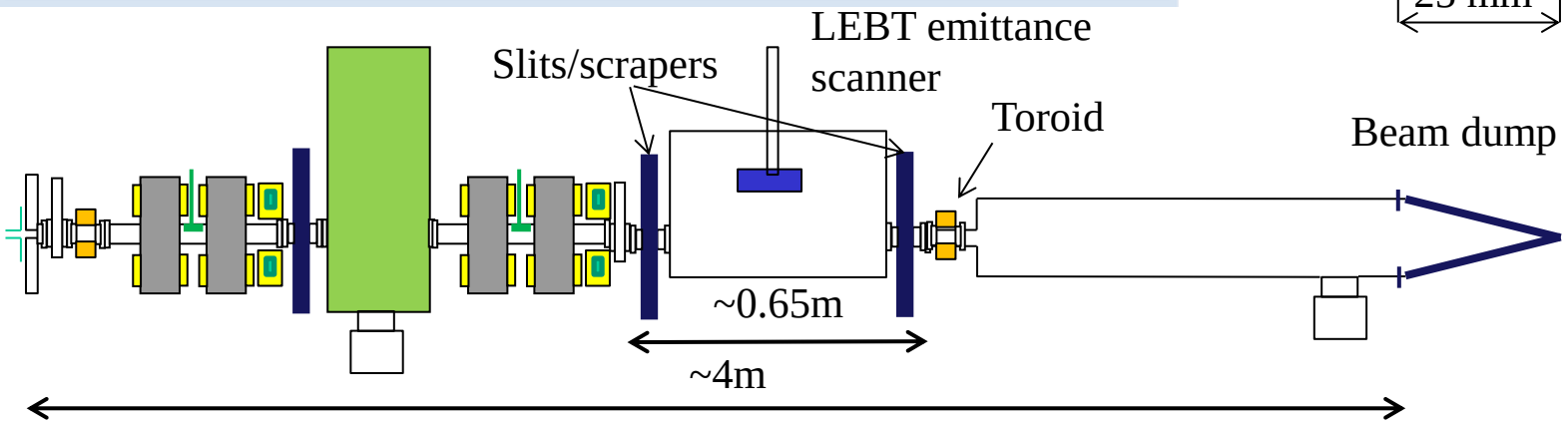
Configuration #1_2

- Insert the LEBT emittance scanner and slits/scrapers
- Add the beam dump (SNS/HINS)

$\varepsilon_{rms,n} = 0.15\,\mu m,\ \sigma_x \approx 4\,mm \Rightarrow \sigma_{x'} \approx 0.6\,mrad$

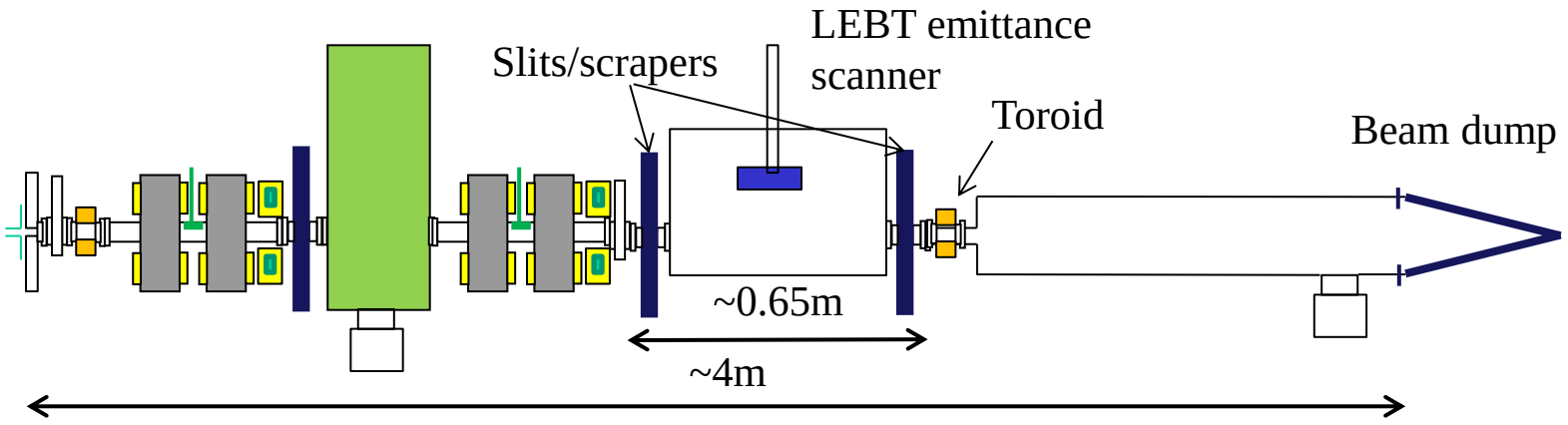






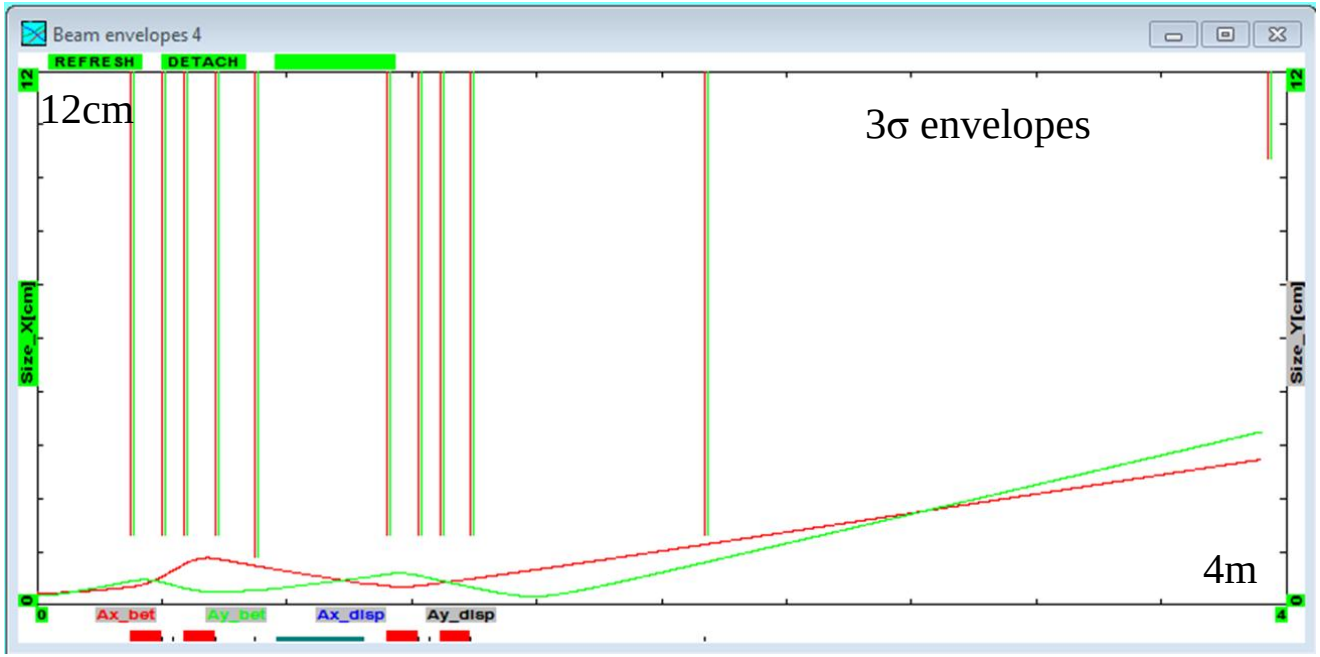
Configuration #1_2 – emittance measurements

- Compare double-slits measurements with the LEBT emittance scanner
  - With a large beam so $\varepsilon_{rms,n} = 0.15\,\mu m,\ \sigma_x \approx 4\,mm \Rightarrow \sigma_{x'} \approx 0.6\,mrad$
- LEBT scanner at MEBT:
  - ±180 mrad at 30 keV => ±2.5 mrad max at 2.1 MeV; i.e. ~ $\pm 4\sigma_{x'}$
- Current reading: beam dump

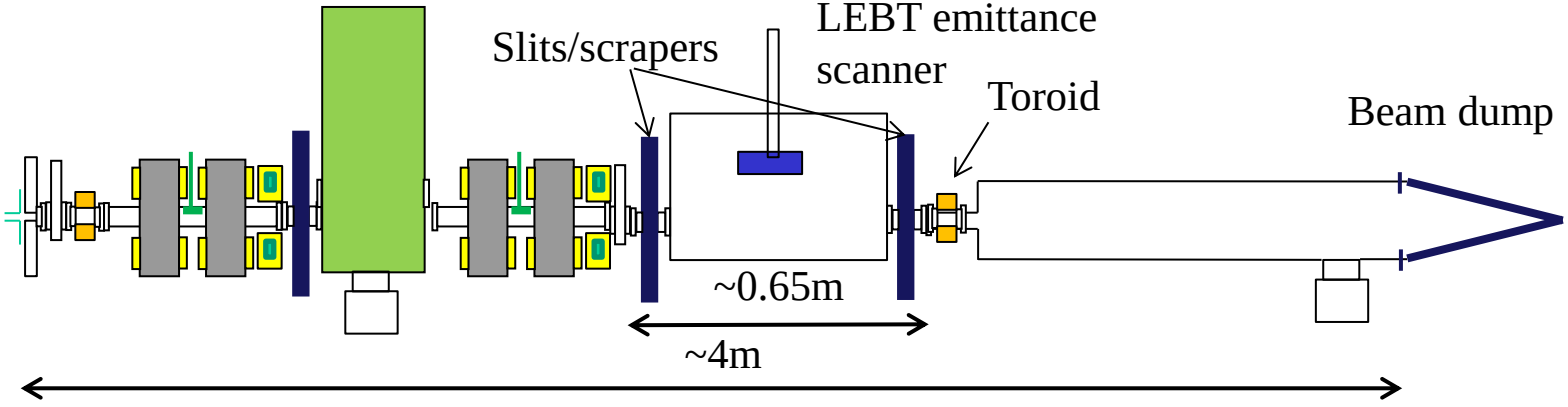


Configuration #1_2 – high power

- Pass a high duty factor beam to the beam dump (<I> ~ 2mA)

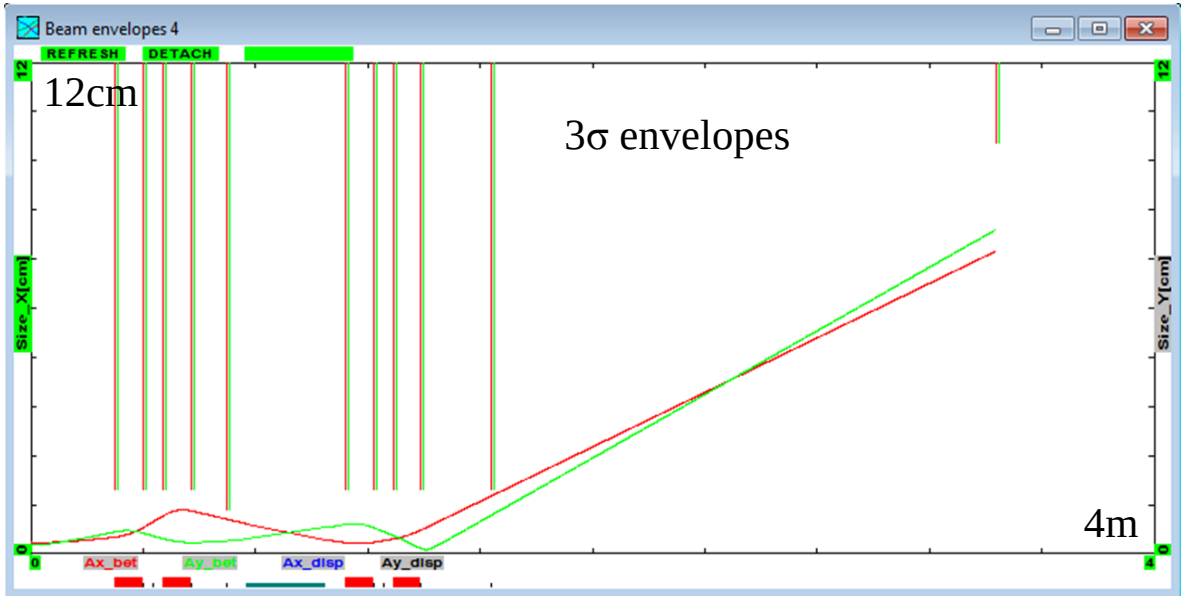


Compare toroid and beam dump readings

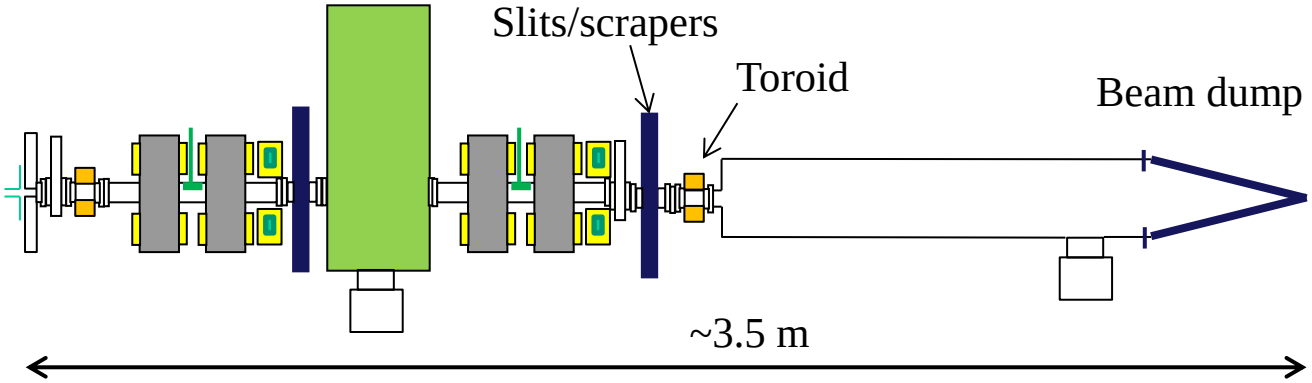


Configuration #1_3

- Move the beam dump close to the quads to defocus the beam
  - Goal: <I>= 7 mA (CW or long pulses)



- Create beam with σ_x= 25 mm
- Measure the beam size with slits
- Compare toroid and beam dump readings



Summary

- Estimations with OptiM show that the RFQ beam can be characterized with 3 configurations in the following sequence
  - 1-1: commissioning of focusing elements, transmission, LEBT tuning, energy, longitudinal measurements, MPS
    - Pulse mode only
  - 1-2: transverse measurements, high duty factor beam
    - Pulse to a low-current CW
  - 1-3: CW beam above nominal 5 mA
- All preparations seem to be doable within the present budget in time for RFQ commissioning