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# Commissioning of the Non-invasive Profile Monitors for the ESS LEBT

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# Outline



1. Introduction: LEBT layout, objectives, instrumentation
2. NPM design: profiles, position, angle, size, emittance
3. NPM performance: position measured, angular resolution, emittance near focus point
4. Concluding remarks and acknowledgement

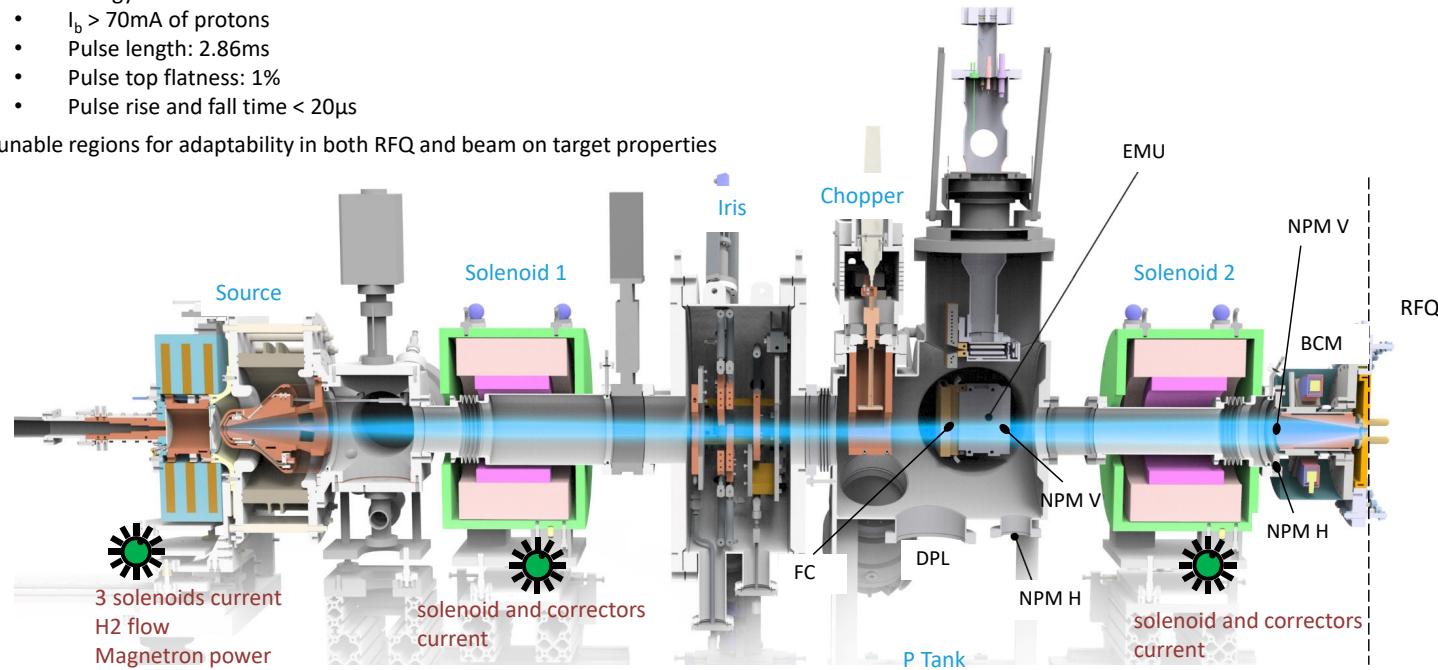
# LEBT layout

## Objectives:

Transport proton beam to RFQ with **matching** parameters:

- Emittance:  $\epsilon_N < 0.25 \pi \text{ mm.mrad}$
- $\beta = 1.7\text{m}$ ,  $\alpha = 0.17$
- Energy: 75keV
- $I_b > 70\text{mA}$  of protons
- Pulse length: 2.86ms
- Pulse top flatness: 1%
- Pulse rise and fall time  $< 20\mu\text{s}$

Find tunable regions for adaptability in both RFQ and beam on target properties



# LEBT Instrumentation

Extr. Cone



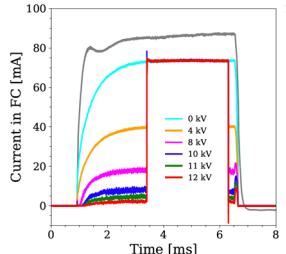
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**FC**

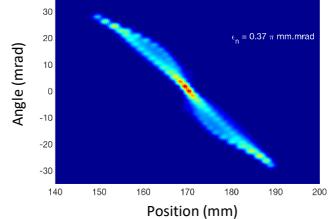
IBIC 19: MOPP044  
IPAC 19: MOPTS103



Current  
Pulse profile (time)



Emittance  
Twiss parameters



IPAC 19: MOPTS084, WEPGW076



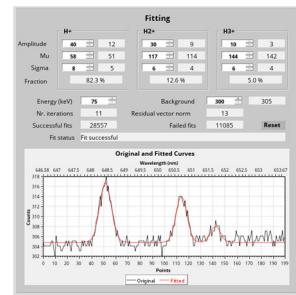
**BCM**



**NPM unit**

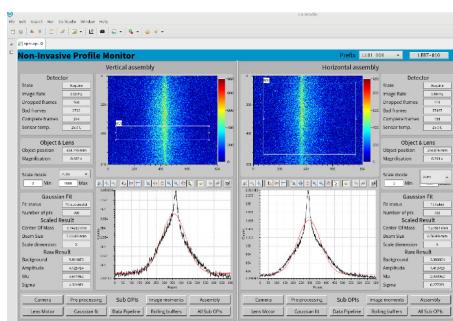
Species Fraction  
Energy

**DPL**



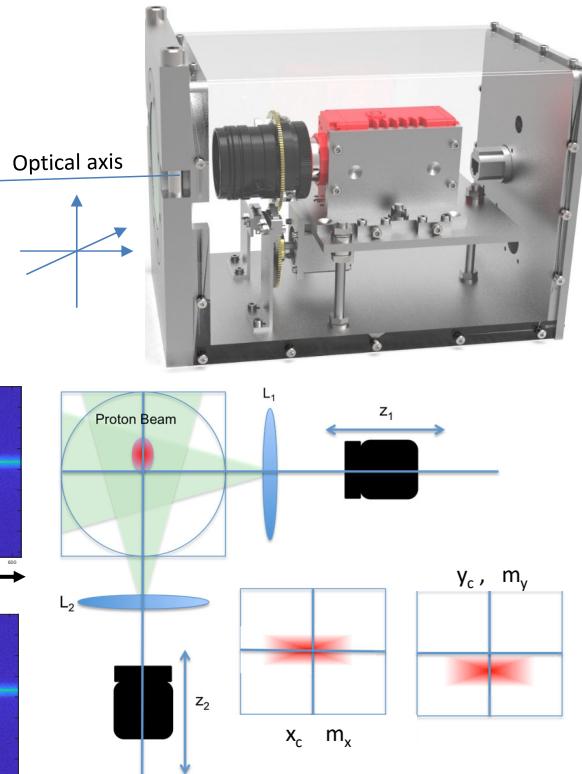
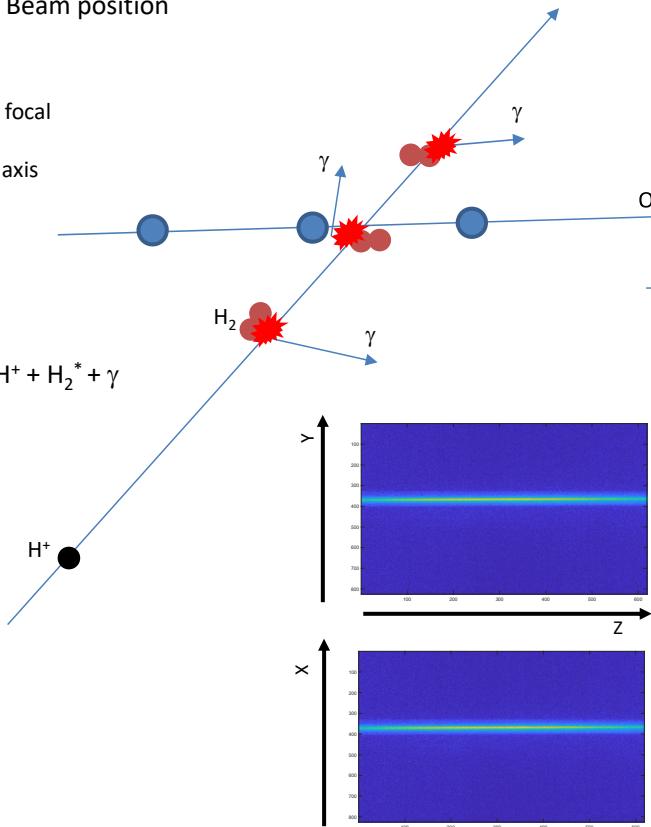
IPAC 17: MOPVA037

Profile  
Position  
Width  
Angle  
divergence



## Main function: Beam position

- ✓ Fiducialization of optical axis
- ✓ Knowledge of sensor distance to the focal plane: magnification
- ✓ Alignment of the camera with beam axis reference: 30µm accuracy



# NPM: beam position, angle, and size

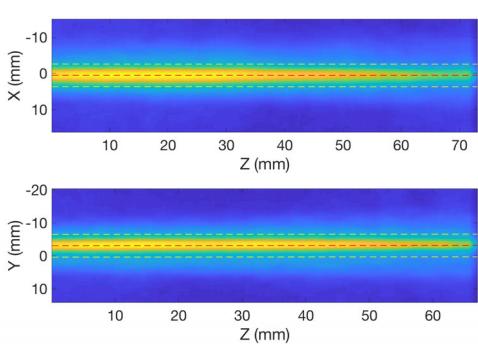


Image analysis: Gaussian fit returns:

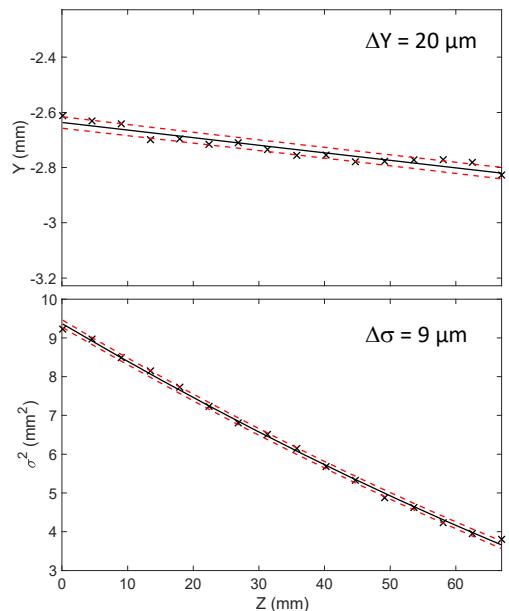
- centre
- Width
- Intensity
- Background

Centre trajectory: linear fit

- Position
- Angle

Width trajectory: quadratic

- Divergence
- Emittance



# NPM: beam position, angle, measurement precision

## Statistical measurement errors

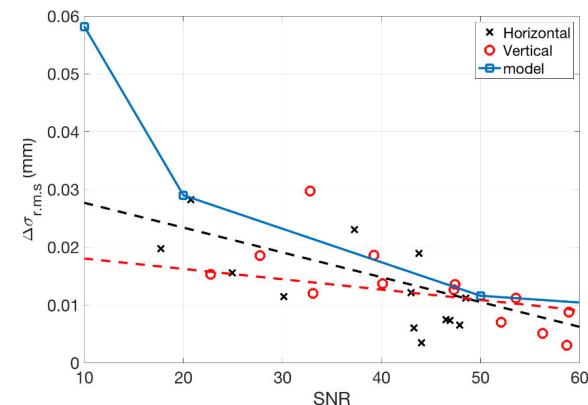
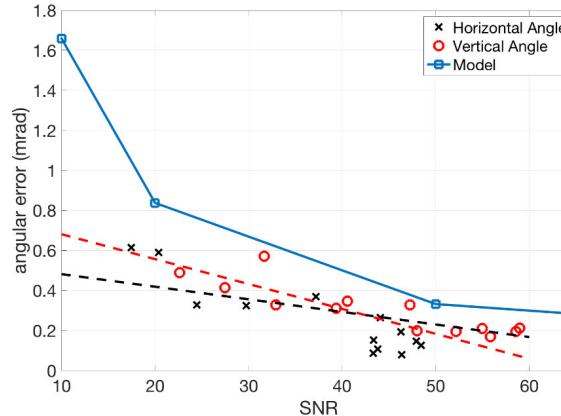
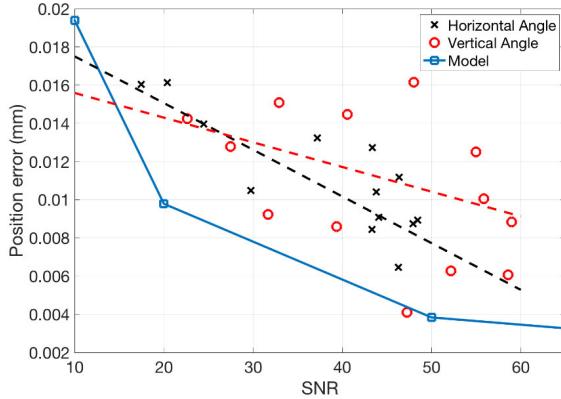
Model:

- Generate NPM image with noise
- Perform Gaussian fit along Z
- Compare results to set beam conditions

Measurements:

- Acquire set of images
- Measure beam characteristics
- Extract statistical variation

Initial requirement: 0.1mm position accuracy

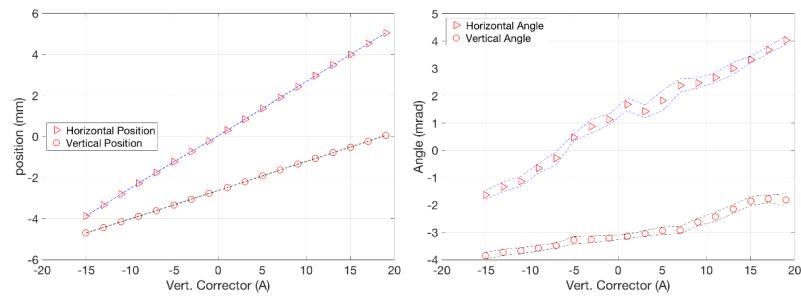
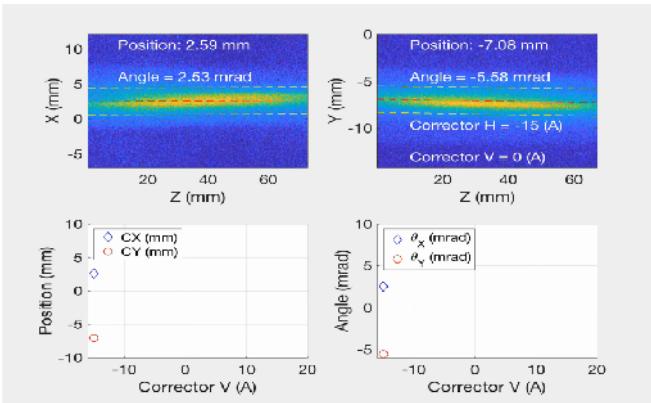


# NPM: beam position, angle, and size

## Beam based alignment \*

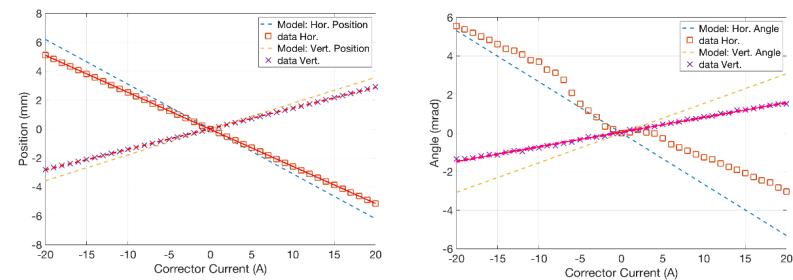
- ✓ Trajectory correction
- ✓ Polarity checks
- ✓ Model verification

### Vertical Corrector scan



➤ Find Solenoid offset and angle

➤ Comparison with model and find beam initial conditions



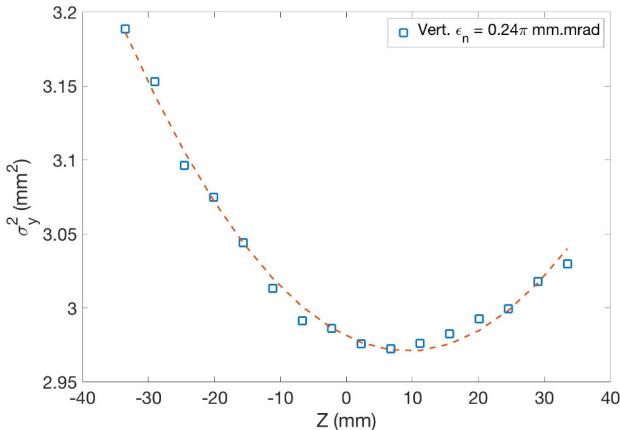
# NPM: beam size

Beam width along Z:

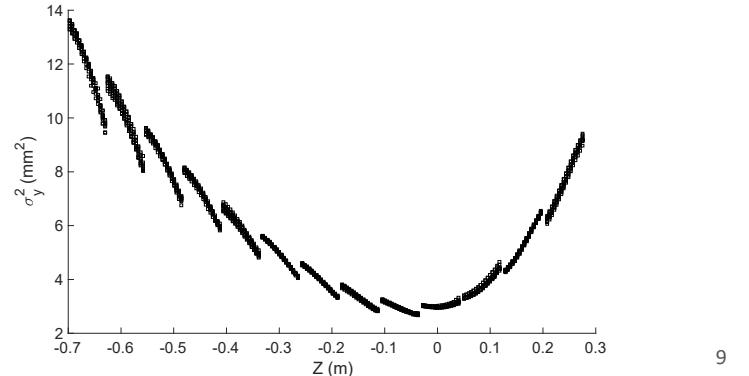
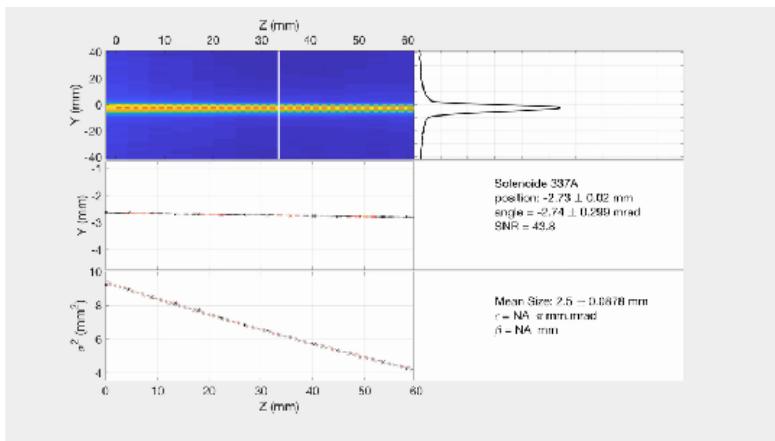
- divergence
- emittance

$e (\pi \text{ mm.mrad})$	EMU	NPM
Low current	0.25	0.24
High current	0.4	0.35 – 0.44

Emittance from quadratic fit



Solenoid scan



## Concluding Remarks

- ✓ A suite of instruments is deployed and commissioned in the ESS LEBT; A range of settings has been investigated and the beam characterised for the optimisation of the transport through the RFQ
- ✓ Non-invasive Profile Monitor has been commissioned; it matches the required performance so that beam position can be retrieved with sufficient accuracy.
  - ✓ In addition, angle and size of the beam can be measured; precision of the measurement is predicted by modelling, in a good agreement measured data.
  - ✓ the emittance can be measured in focused beam condition and for each image acquire, i.e. for every pulse delivered.

## Acknowledgment

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