SARAF Phase-I front-end proton deuteron beam characterization

October 24th, 2007

Dan Berkovits on behalf of SARAF team

Content

1. ECR+LEBT emittance measurements
2. H_2^+ as a mimicking beam of deuterons
3. RFQ first proton beam test

LEBT – emittance measurement

SOREQ

magnetic mass analyzer

FC

C. Piel EPAC 2006

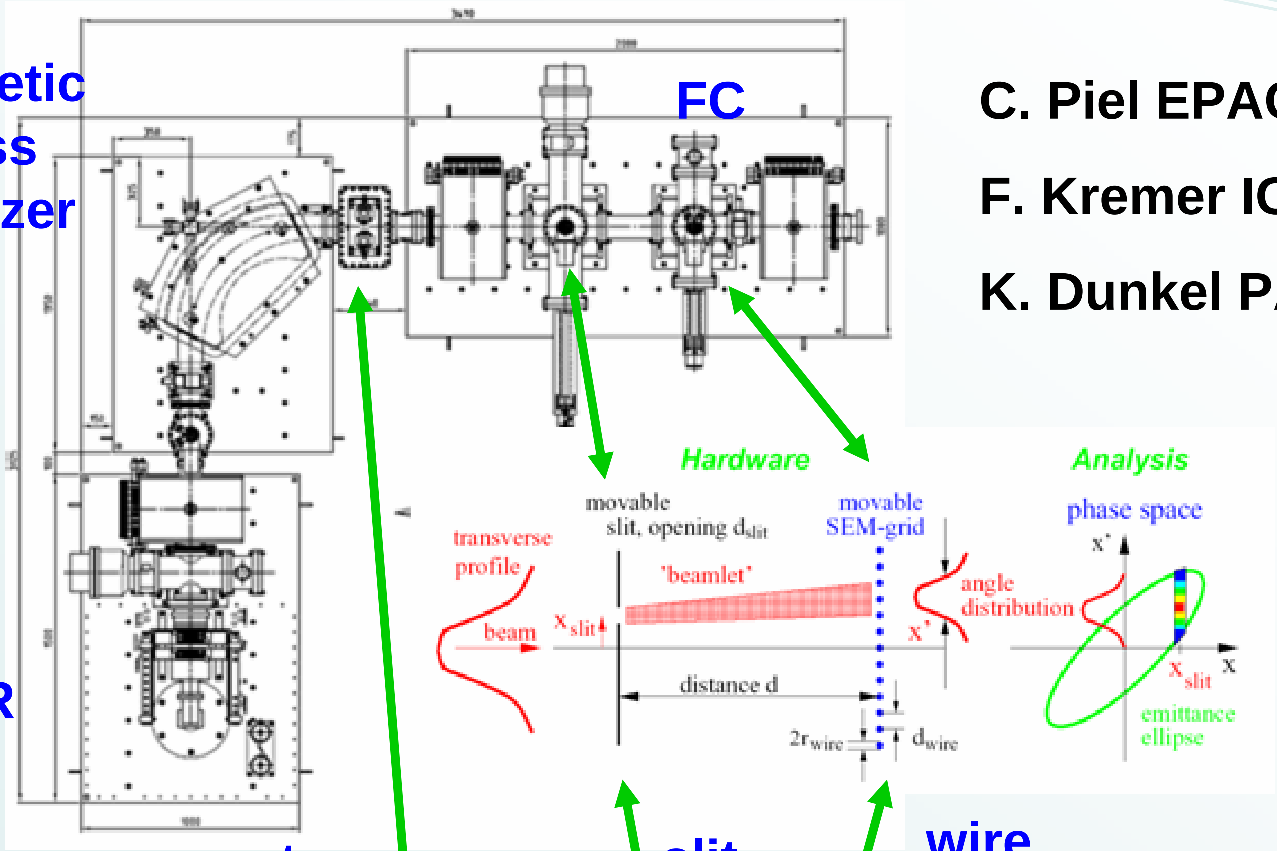
F. Kremer ICIS 2007

K. Dunkel PAC 2007

Dunkel PAC 2007

Kremer ICIS 2007

ECR

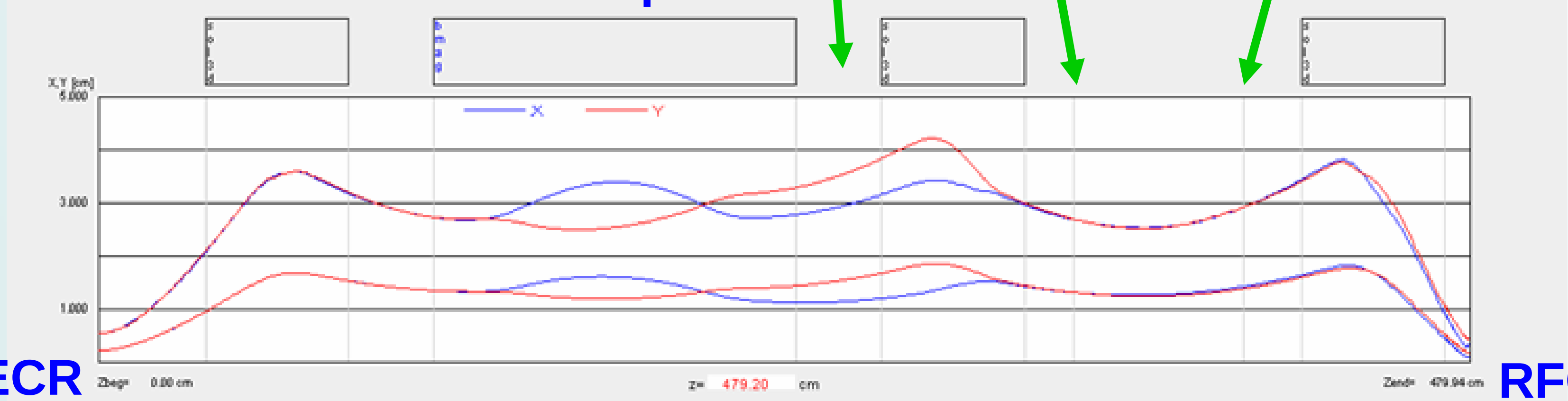


P. Forck JUAS 2003

aperture

slit

wire



5 mA proton beam optics

ECR

RFQ entrance

EIS: Reached current stability values during FAT

±% peak to peak integrated over 10 sec within one hour

Particles Beam current	Protons	H_2^+	Deuterons	Specification
5.0 mA	2.5	2.5	2.5	**2.5**
2.0 mA	2.5	5.0	2.5	**2.5**
0.04 mA	7.5	3.0	5.0	**5.0**

EIS: Reached emittance values during FAT

$\varepsilon_{rms\_norm.\_100\%}$ [π mm mrad]

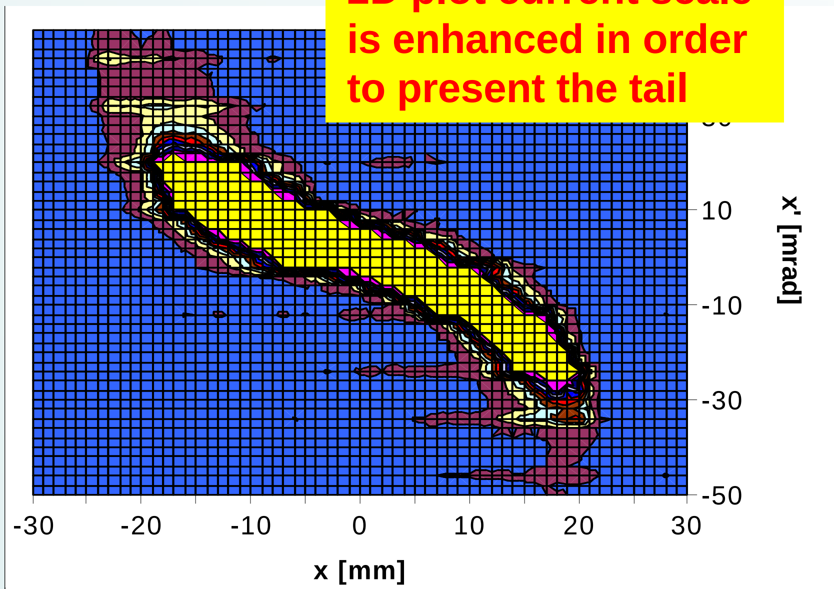
Particles Beam current	Protons X / Y	H_2^+ X / Y	Deuterons X / Y
5.0 mA	0.2 / 0.17	0.34 / 0.36	0.13 / 0.12
2.0 mA	0.13 / 0.13	0.30 / 0.34	0.14 / 0.13
0.04 mA	0.18 / 0.19		0.05 / 0.05

Specified value = 0.2 / 0.2 [π mm mrad]

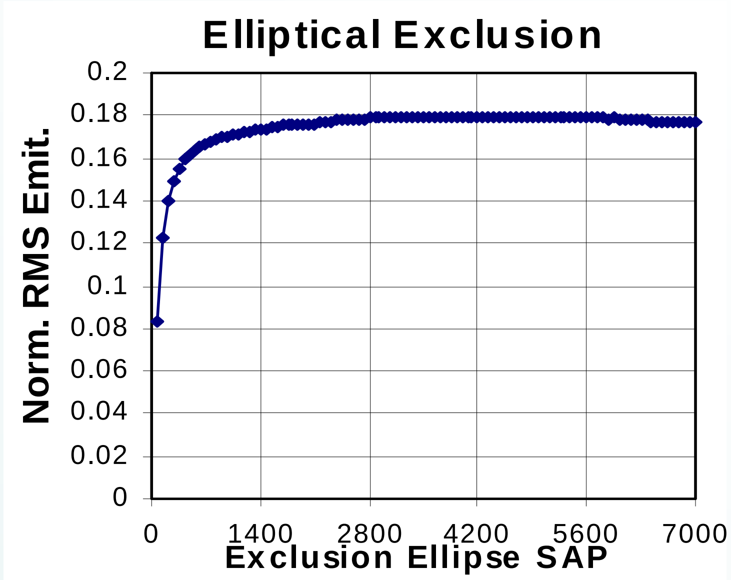
protons emittance preliminary results

SOREQ

2D plot current scale is enhanced in order to present the tail

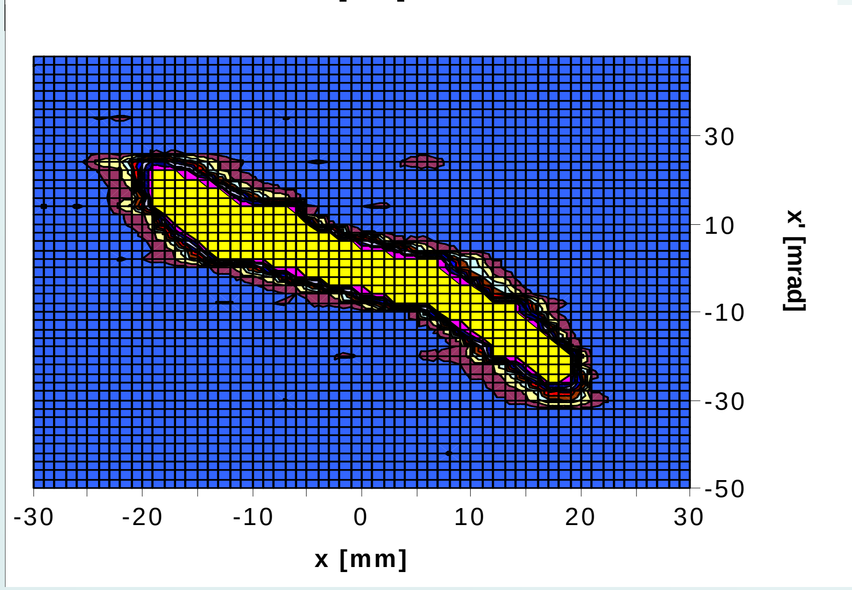


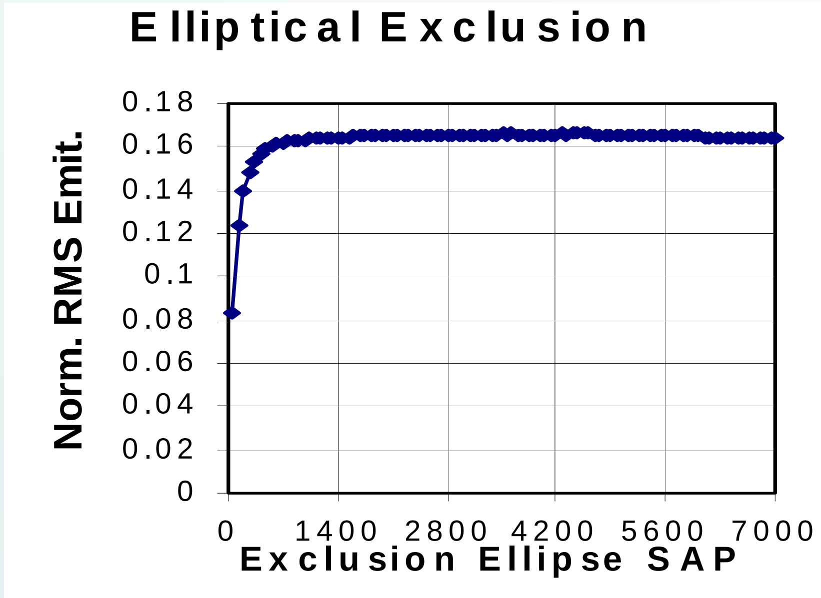
π mm mrad



protons

Open aperture 4.7 mA



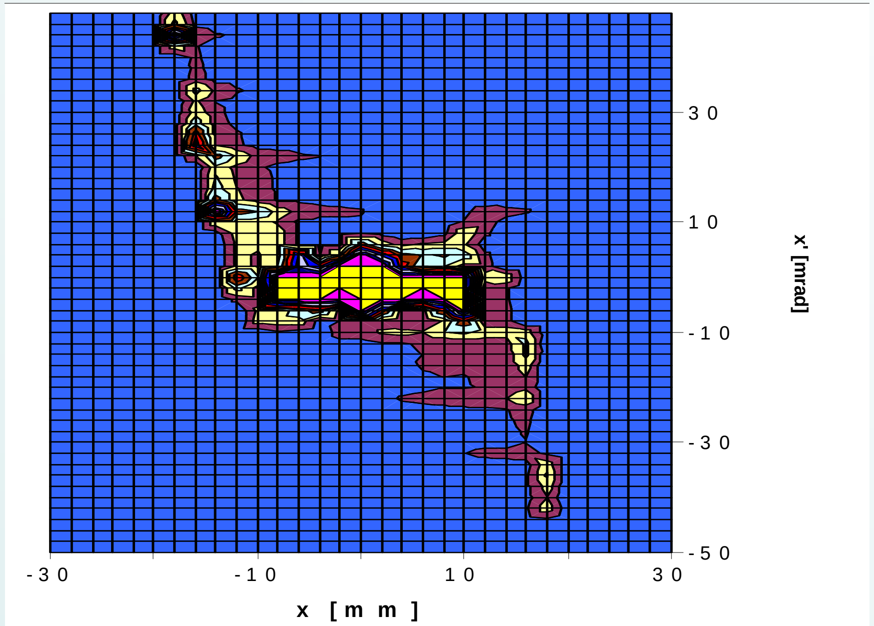


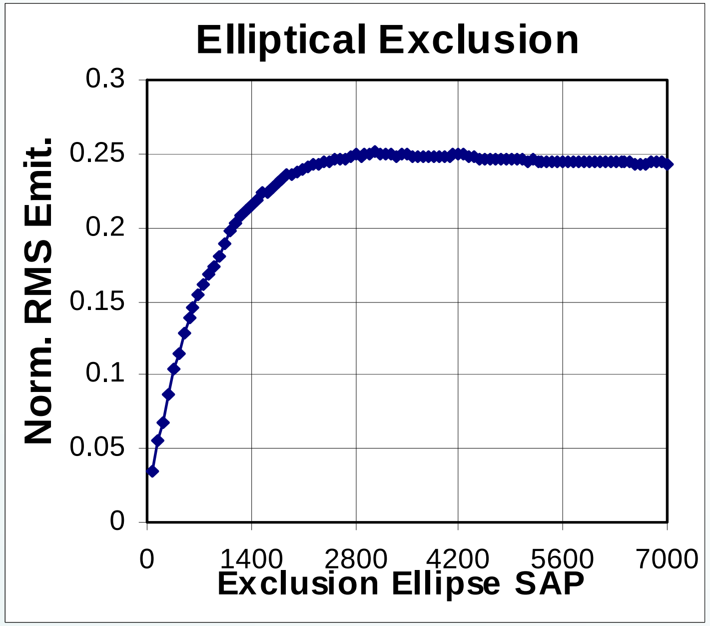
Aperture cut to 4.5 mA

emittance analysis with the SCUBEEx code by M. P. Stockli and R.F. Welton, Rev. Sci. Instr. 75 (2004) 1646

deuterons emittance preliminary results

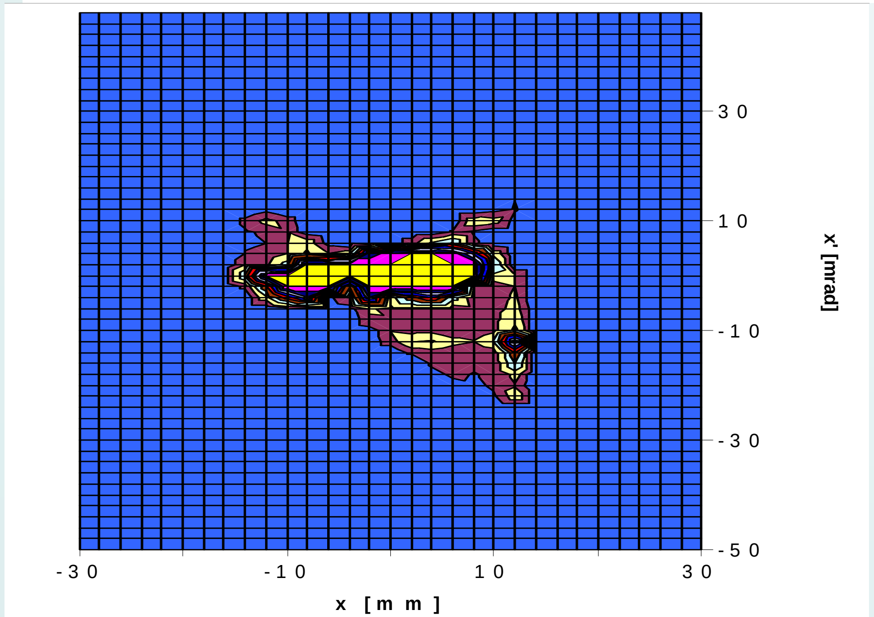
π mm mrad

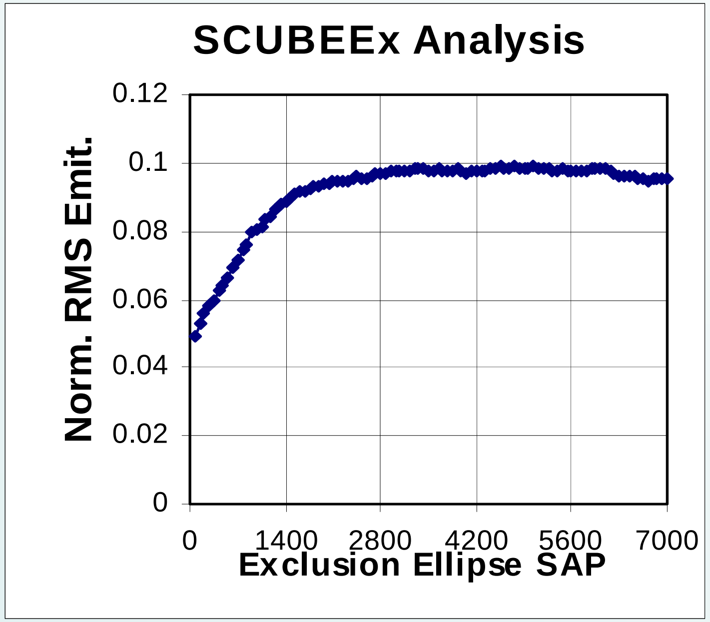




deuterons

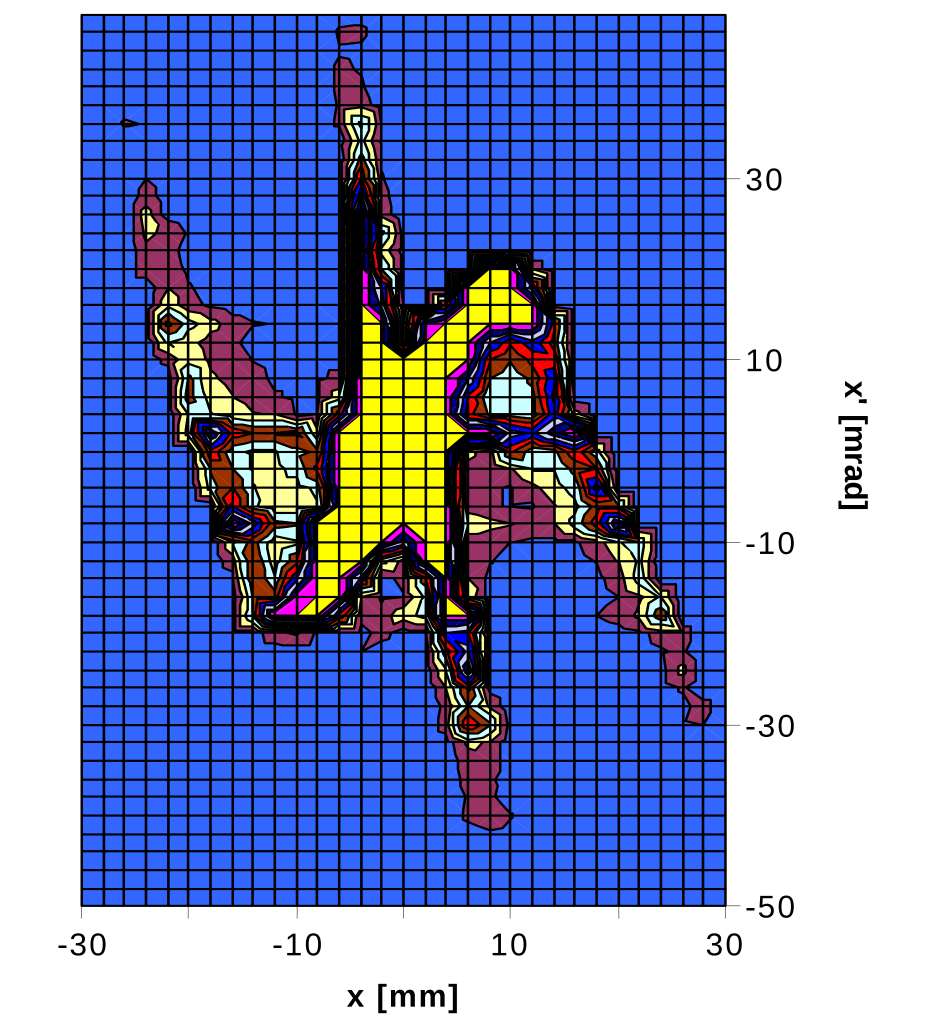
6.1 mA open aperture





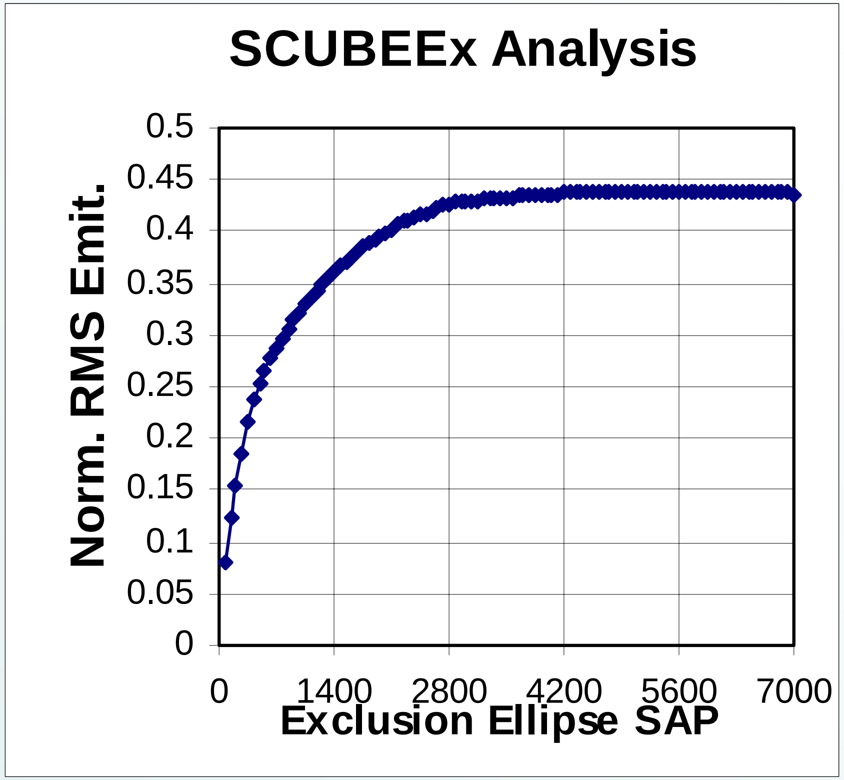
aperture cut to 5.0 mA

H_2^+ emittance preliminary results



H_2^+
5.0 mA
open aperture

π mm mrad



Gases purity used in the tests:
H_2 – 99.999%
D_2 – 99.7% isotopic abundance

H_2^+ as a mimicking beam of deuterons

- In order to:

1. Reduce radioactivity during commissioning and every day tune
2. Have higher low-energy proton current for experiments

- However, there are some differences:

1. ECR ionization efficiency
2. Molecule breakup in the residual gas
3. ….

Charge and energy transfer

SOREQ

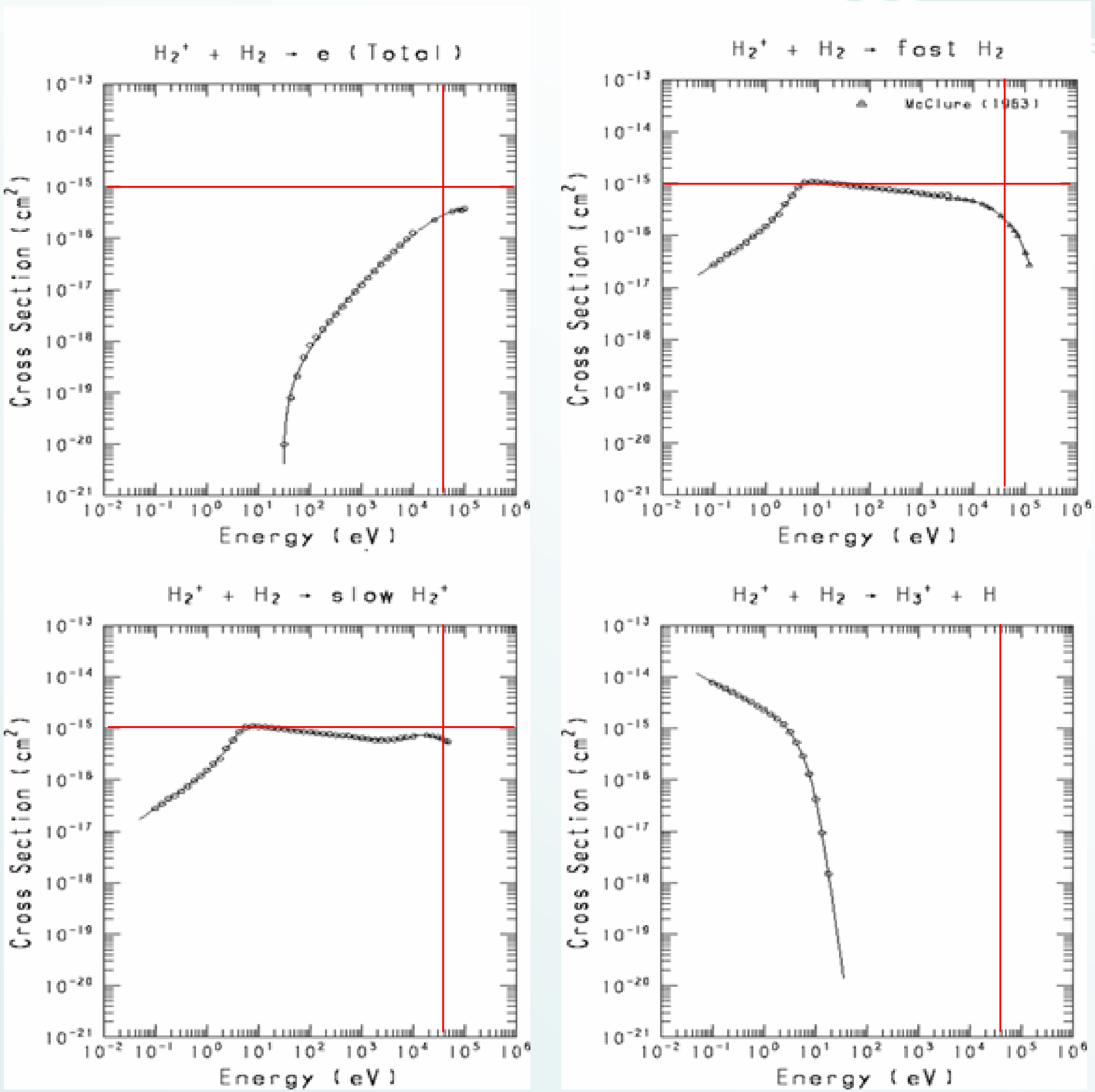
$H_2^+ + H_2^0$

beam + gas

>90% of the residual gas is hydrogen from the ion source

Collisions with residual gas induces emittance growth due to charge exchange, energy transfer and molecule breakup

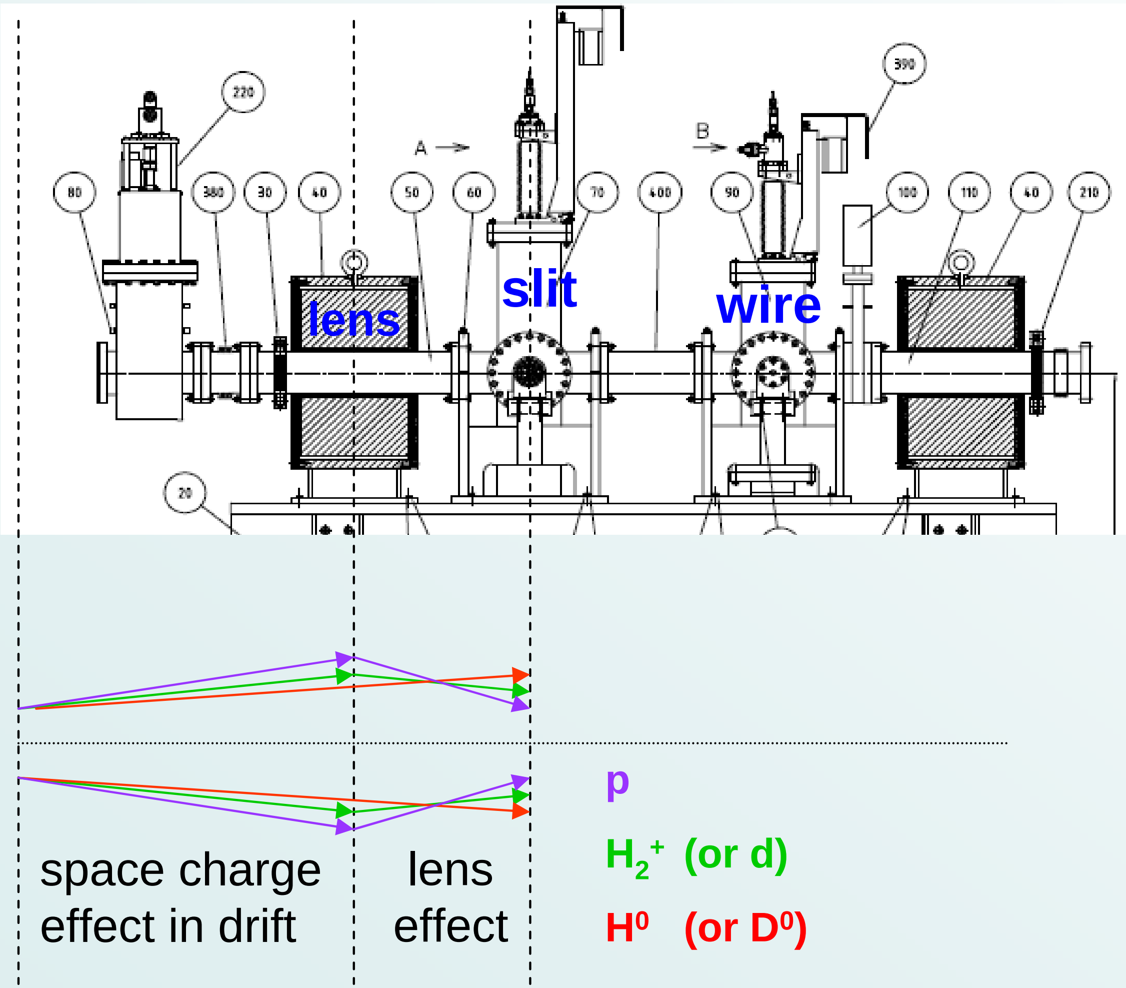
T.Tabata and T.Shirai, Atomic Data and Nuclear Data Tables 76 (2000)1.

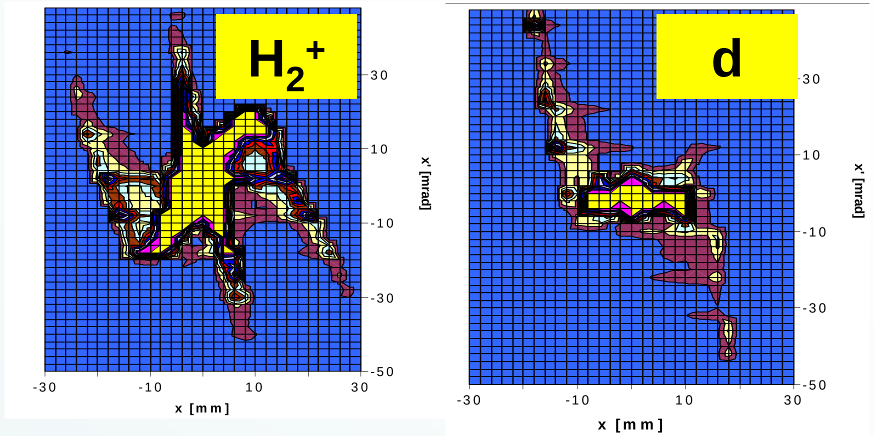


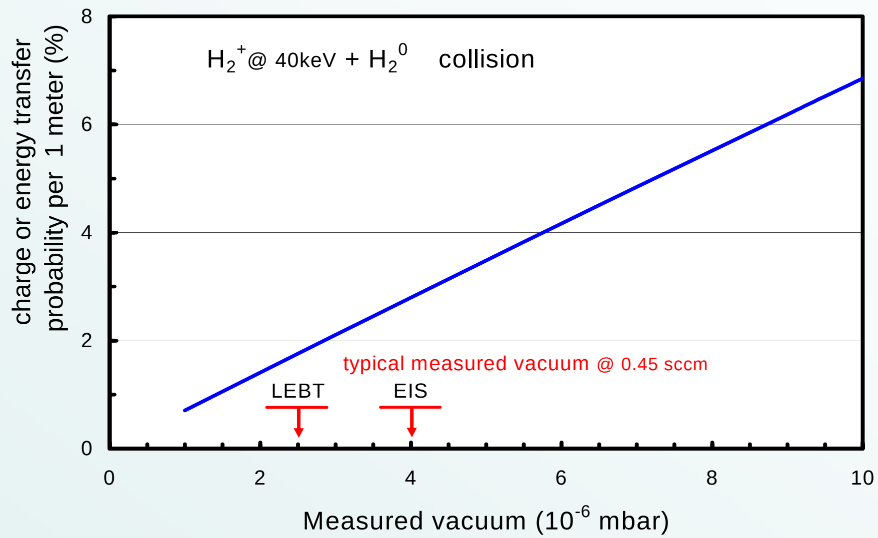
Residual gas collision emittance growth

SOREQ

ACCEL



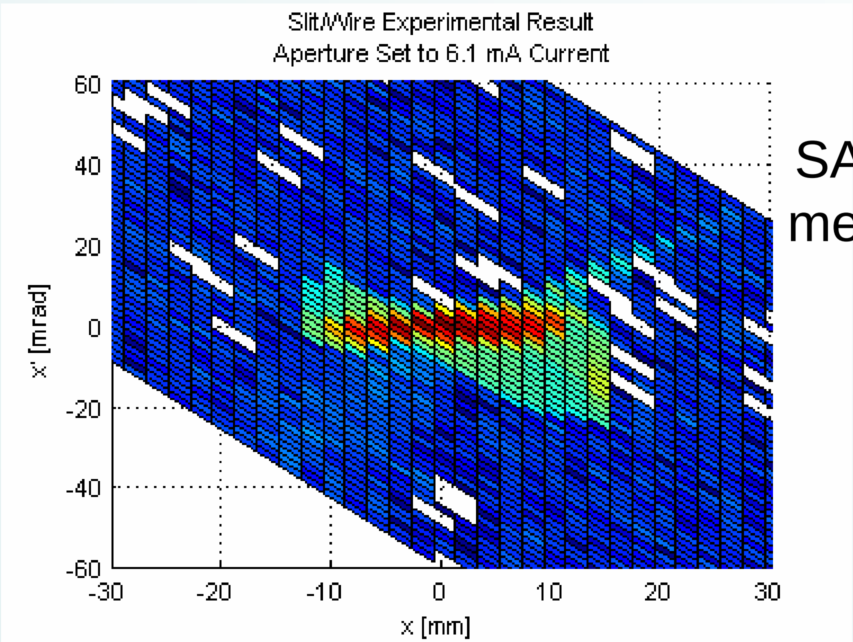




- If ions beam and neutral atoms beam are not concentric it points that lens is steering

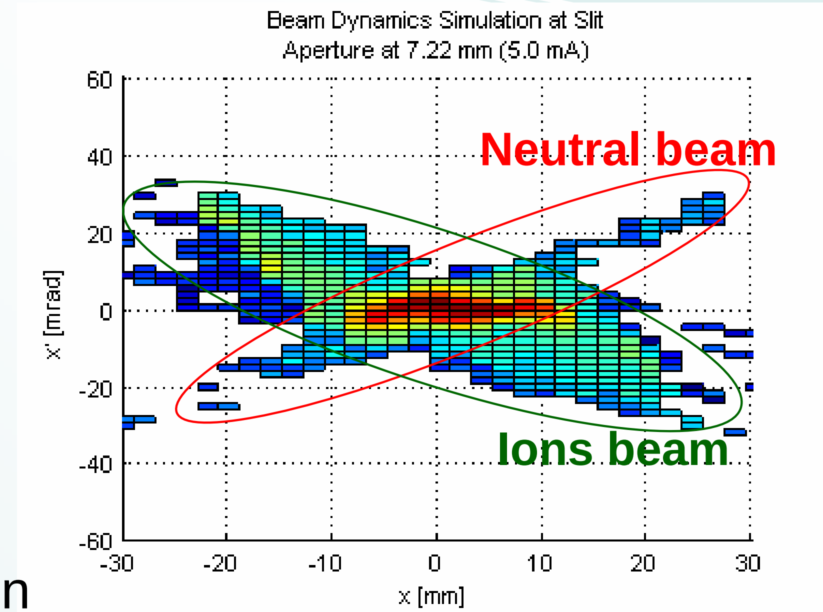
Ion neutralization in the LEBT

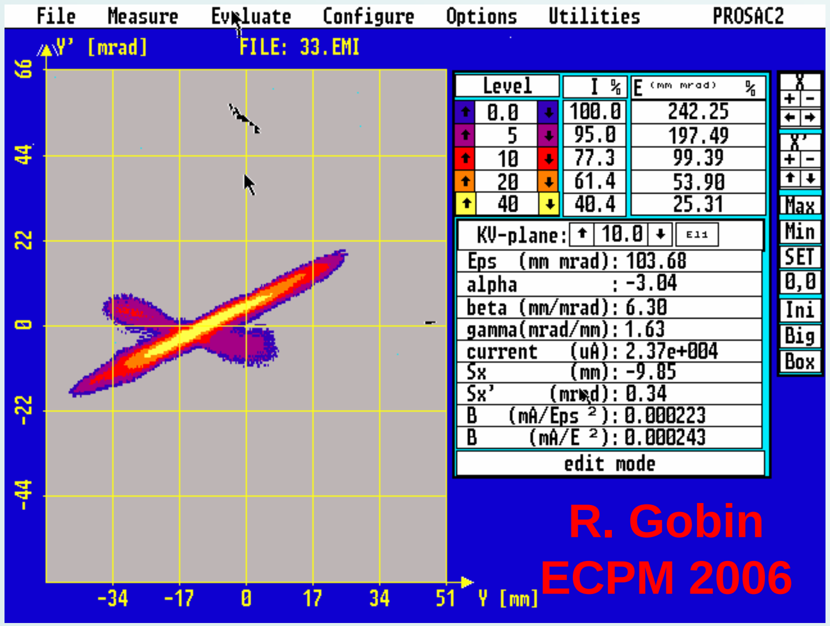
deuterons



SARAF measur.

SARAF optimal tune simulation

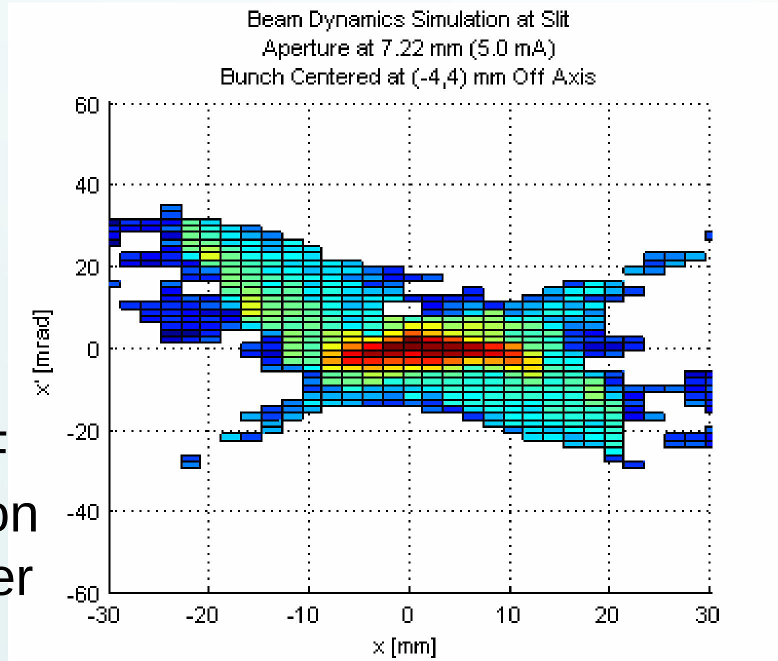




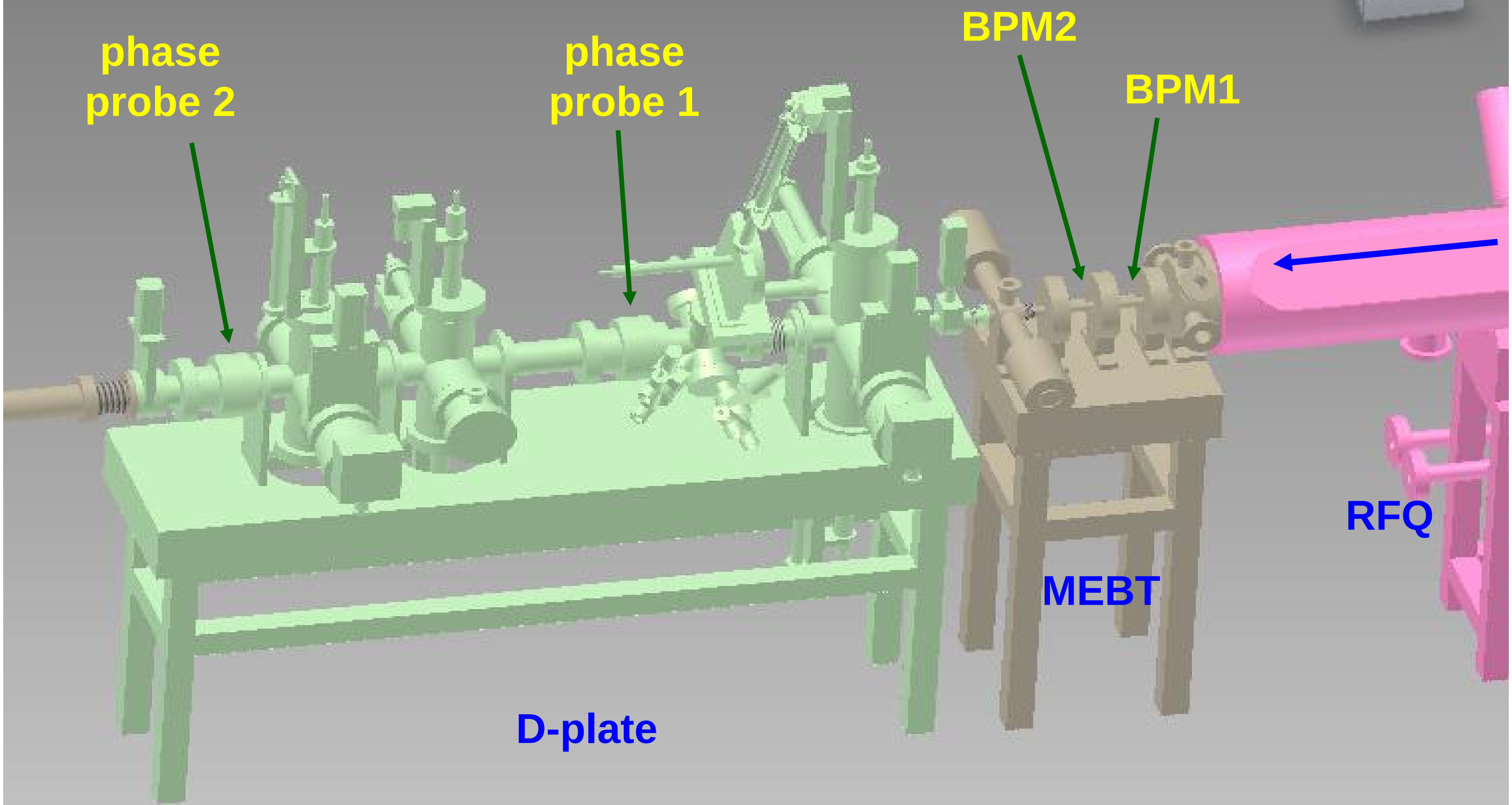
R. Gobin ECPM 2006

SILHI measur.

SARAF simulation with steer



RFQ test setup (schematic)

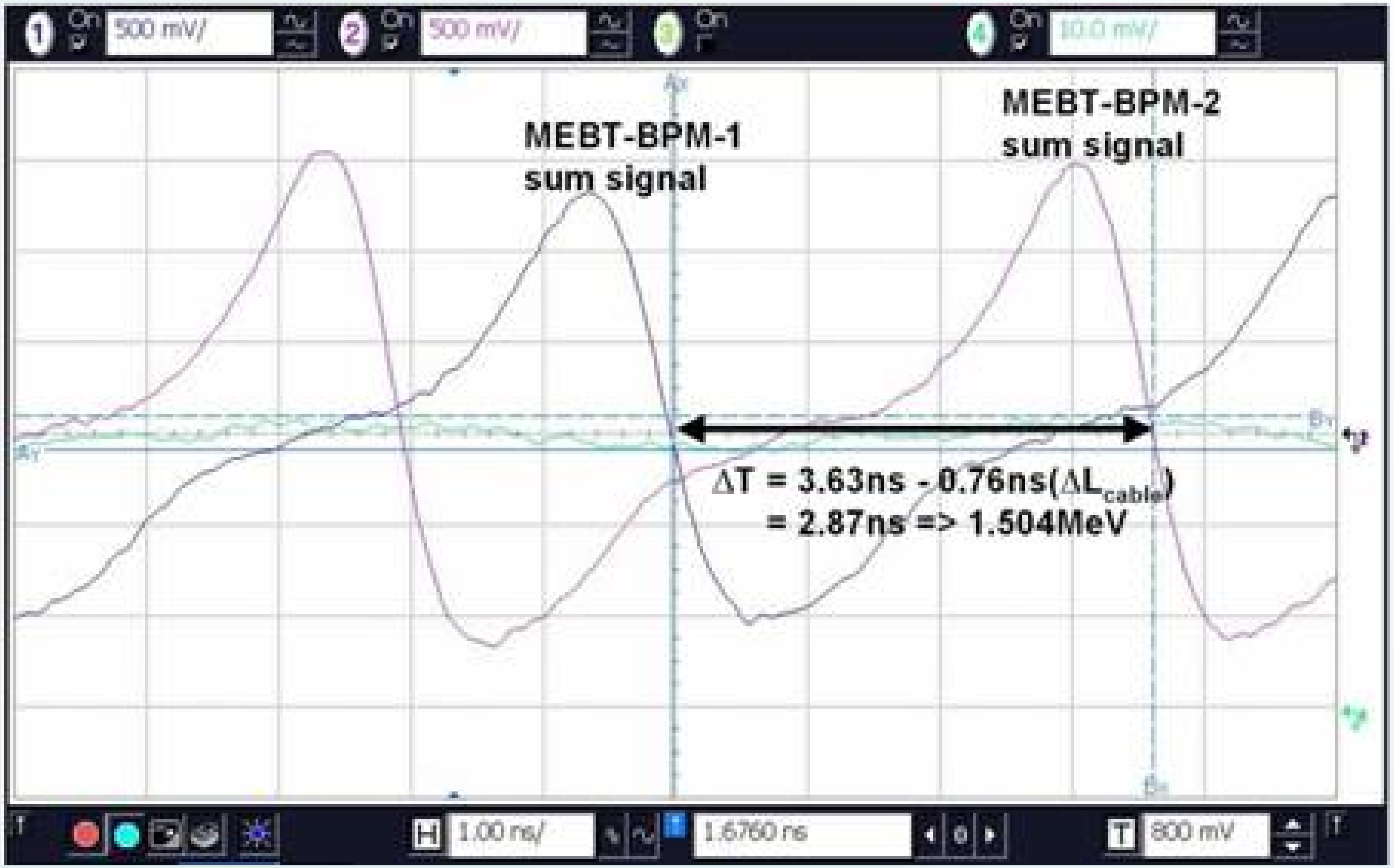


protons RFQ commissioning - TOF

Beam Energy Measurement using TOF between 2 BPMs sum signals, 145 mm apart,

E = 1.504 ± 0.012 MeV

C. Piel PAC 2007

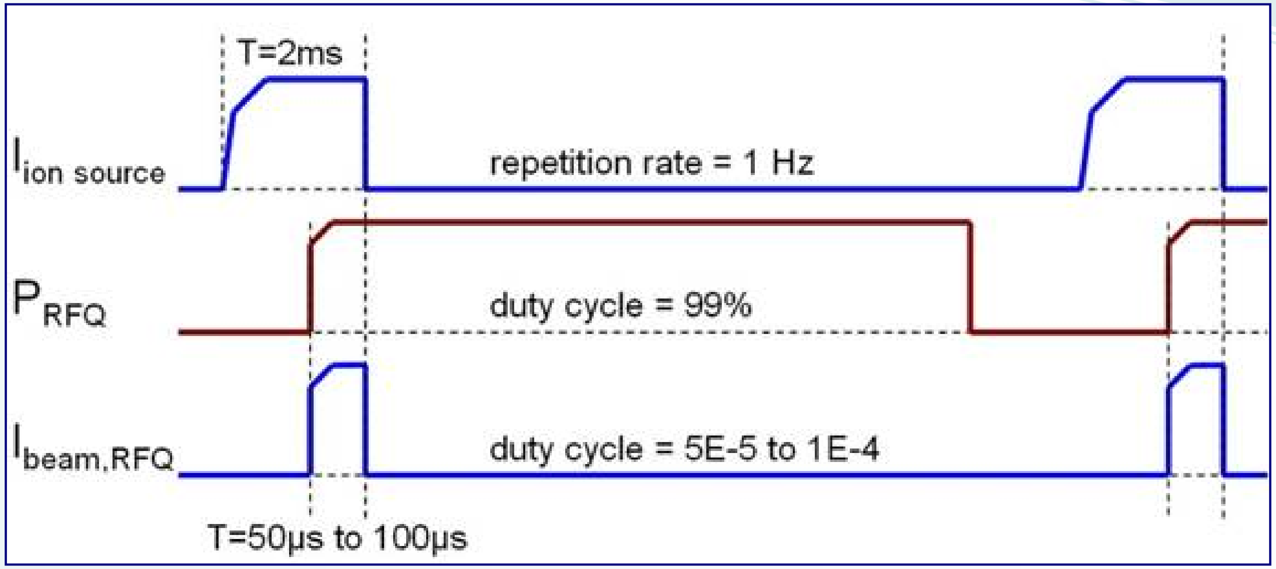


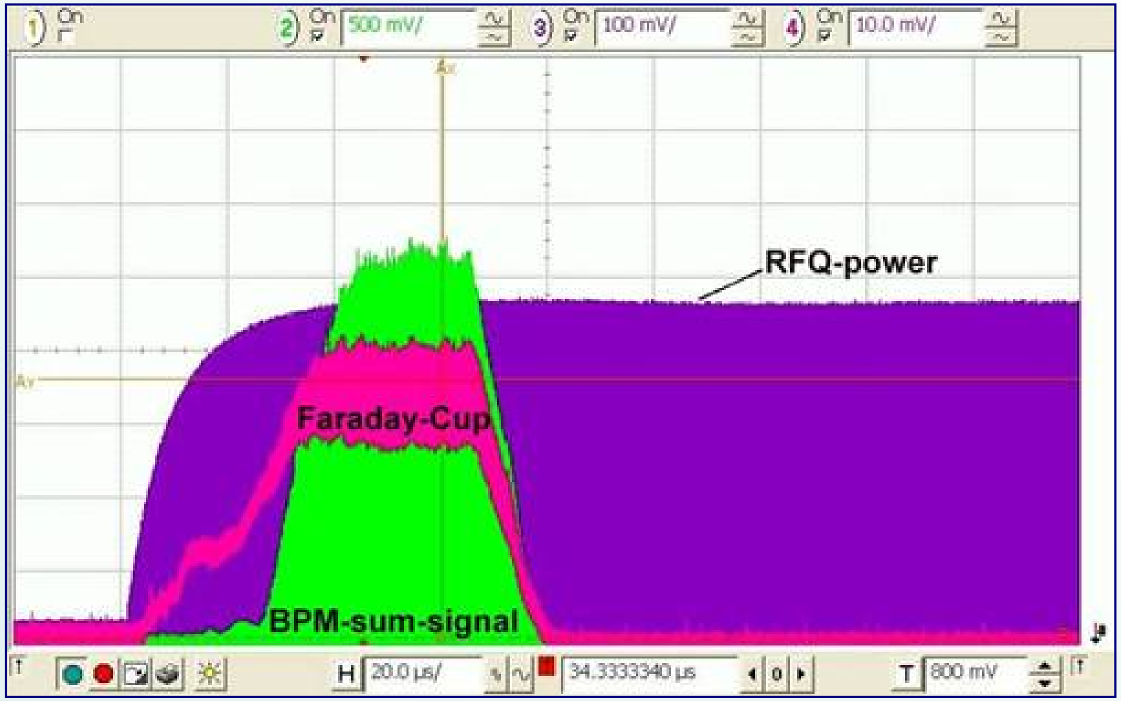
Button pickup for 2 mA pulse and 15 mm bore radius gives a signal high above noise.

Bunch width measured at β=0.056 is larger than the predicted value due to the induced charge broadening.

protons RFQ commissioning – pulse mode

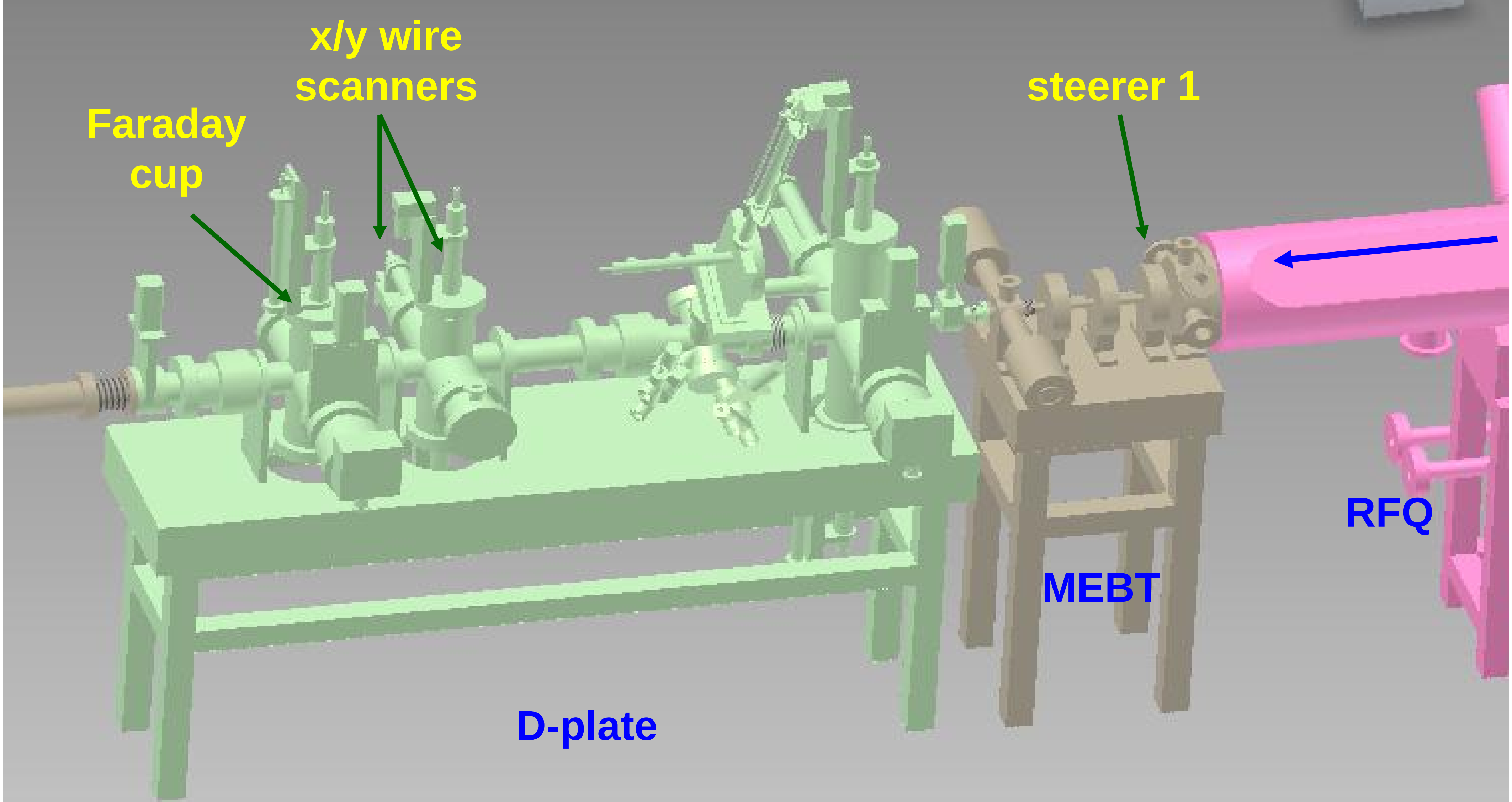
- 1.5 MeV x 2 mA p ⎝ 3 kW
- Maximum beam on diagnostics – 200 W. High power requires pulsed beam
- Pulsing established by combining slow rise time and low DF Ion Source pulses with shifted high DF (99%) RFQ pulsing, in order to test the beam with RFQ rods at CW power





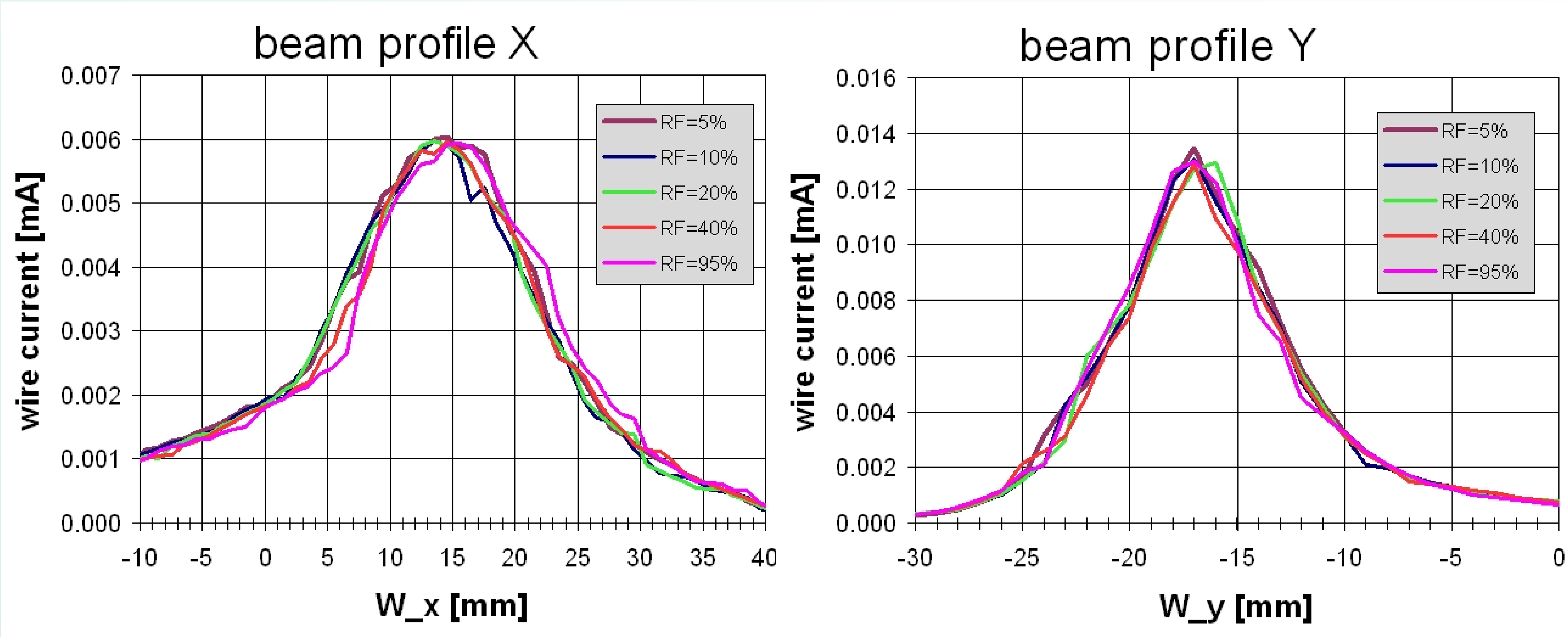
C. Piel PAC 2007

RFQ test setup (schematic)



protons RFQ commissioning - wire

X and Y transverse beam profiles as measured by wire scanners in D-Plate. There is no effect of the RFQ power duty cycle on beam position or shape



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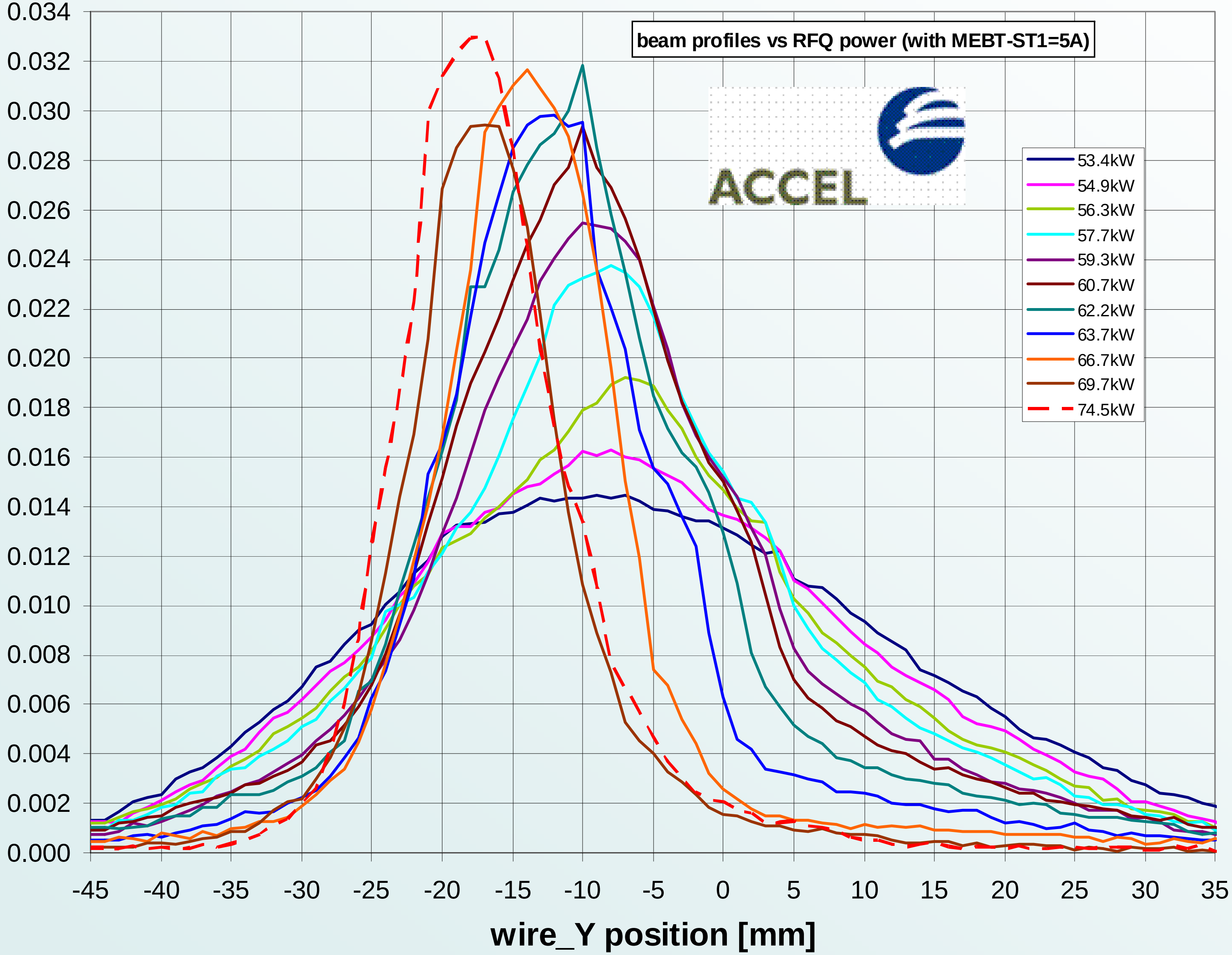
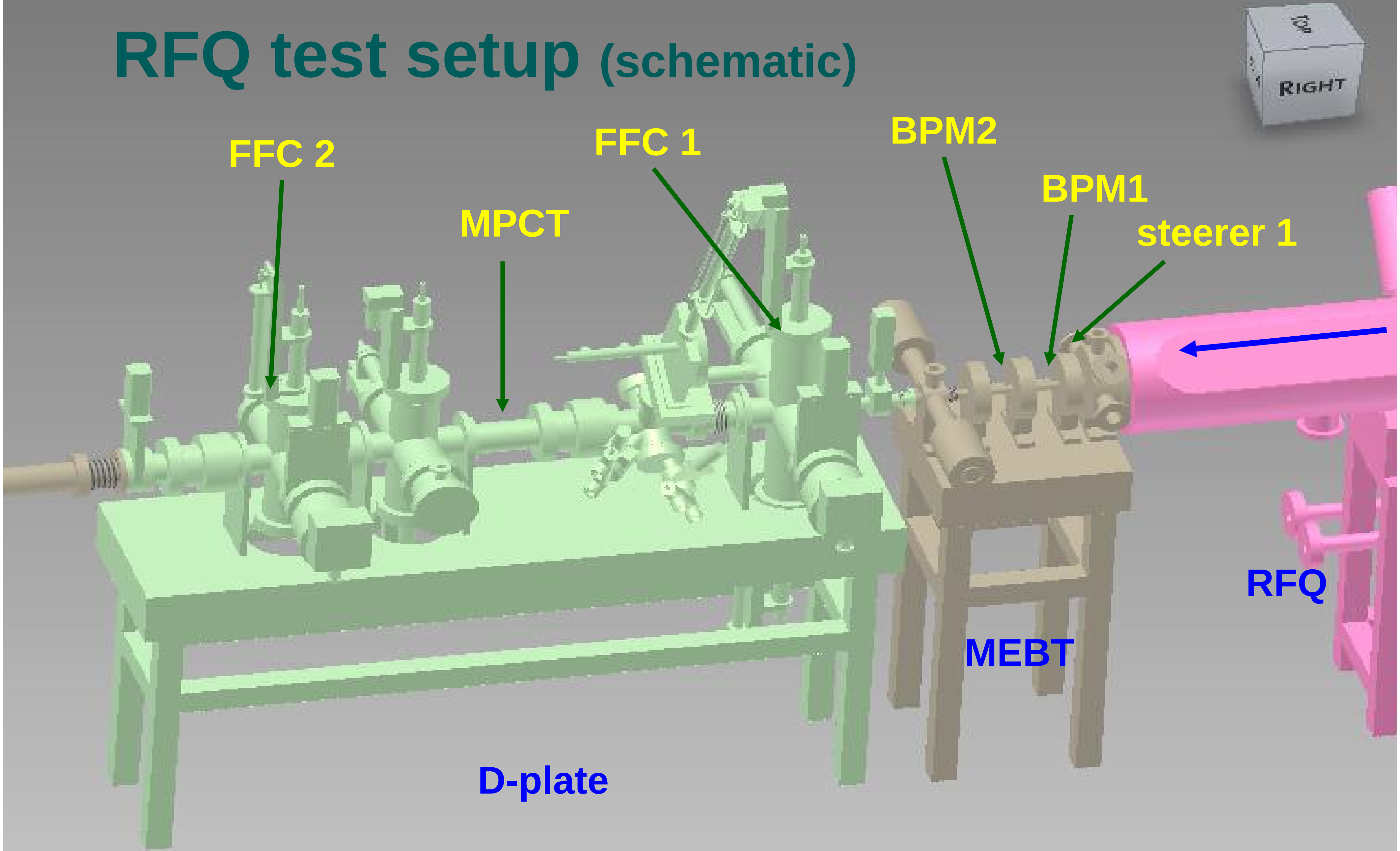
RFQ Steering vs RFQ PS forwared power



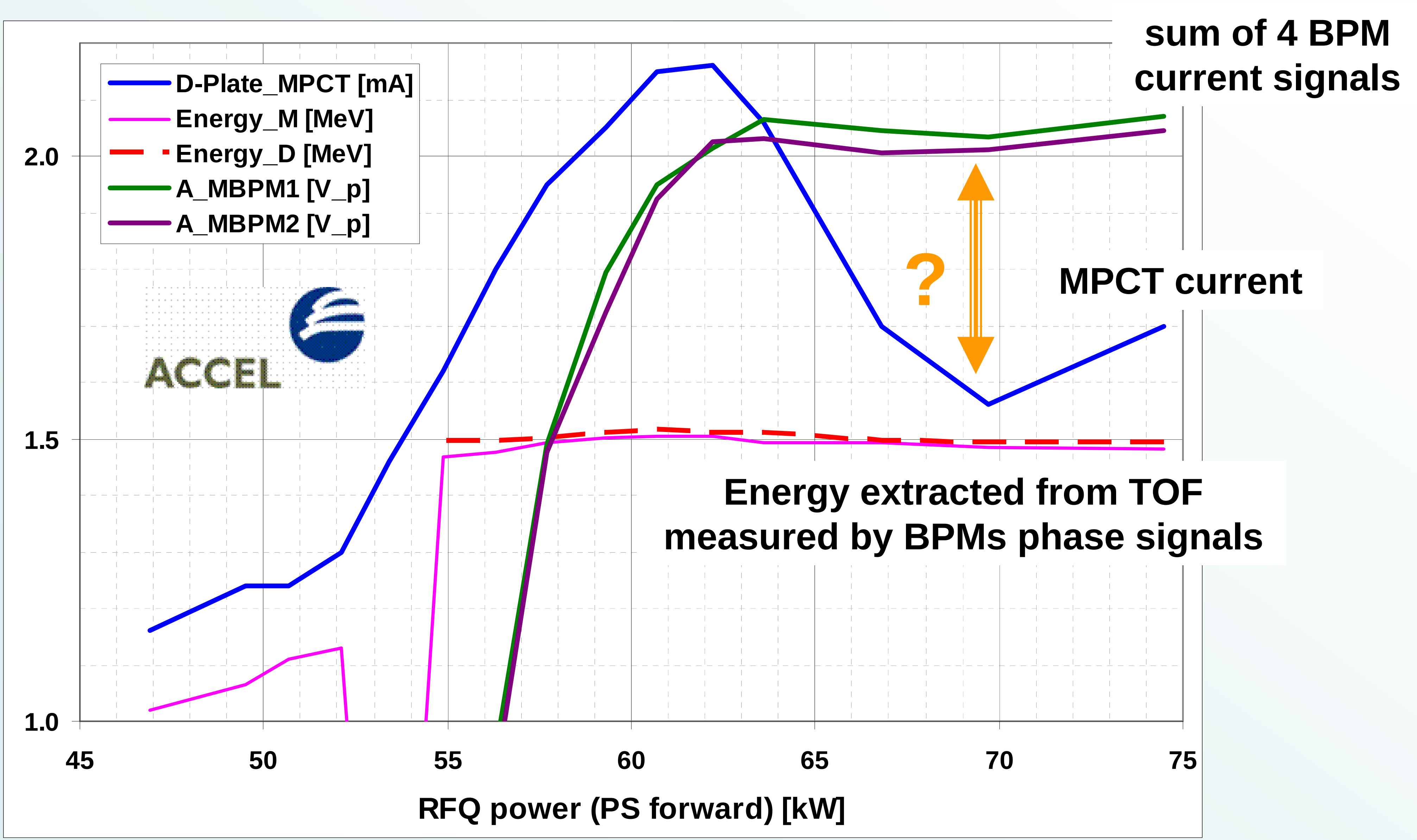
The x phase space is not steered as much as the y phase space.

The reason for the steering is not yet clear. It might be due to mismatch by the LEBT or misalignment.

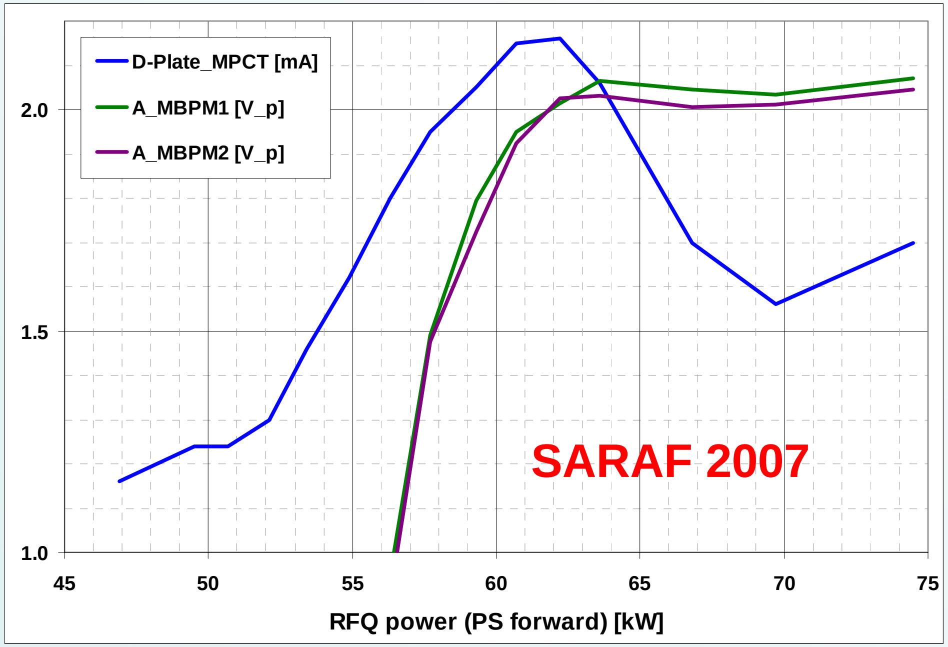
RFQ test setup (schematic)

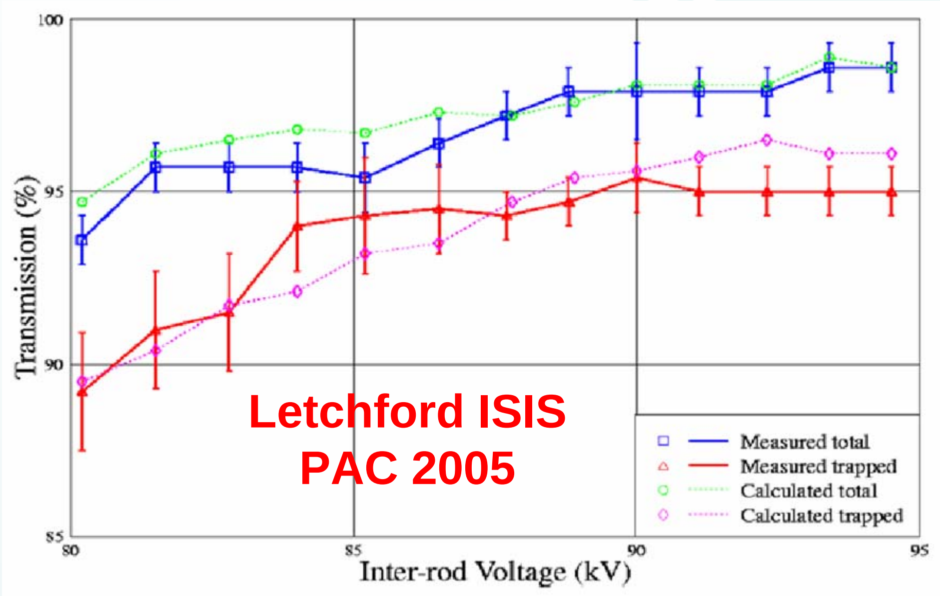


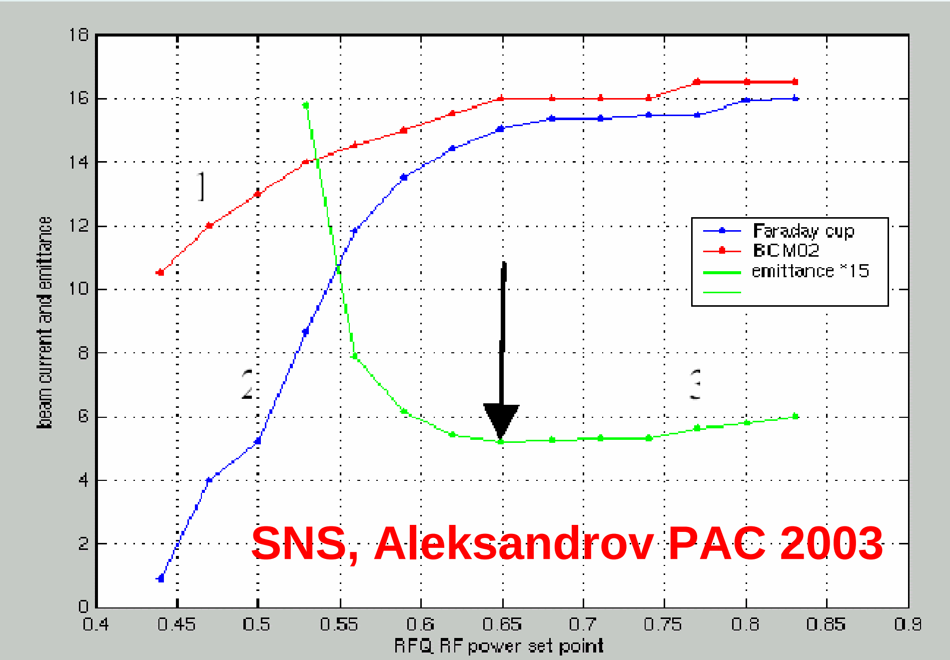
proton 3 mA injection current and energy downstream the RFQ

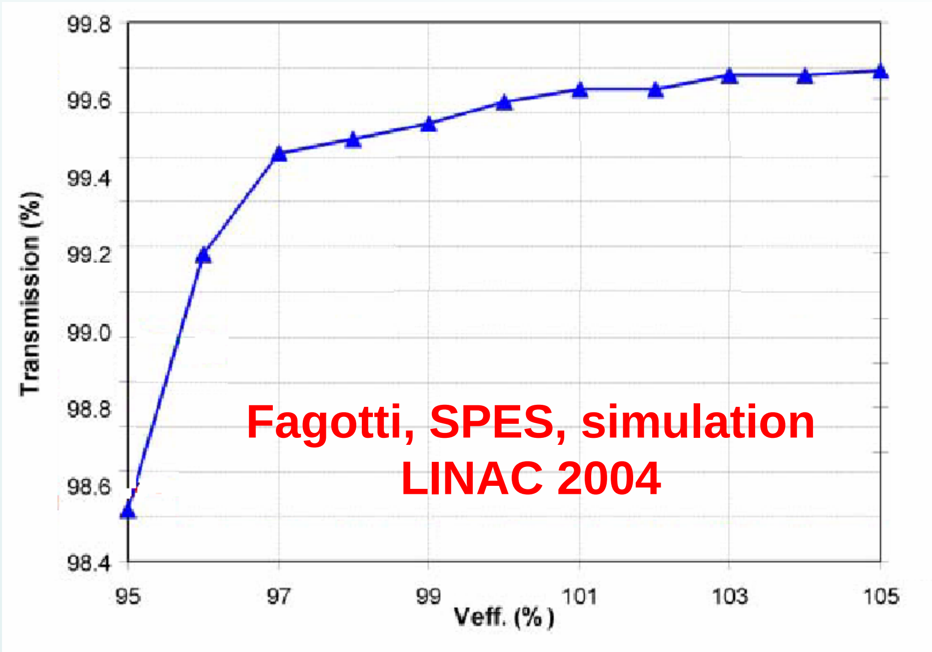


Transmission literature comparison



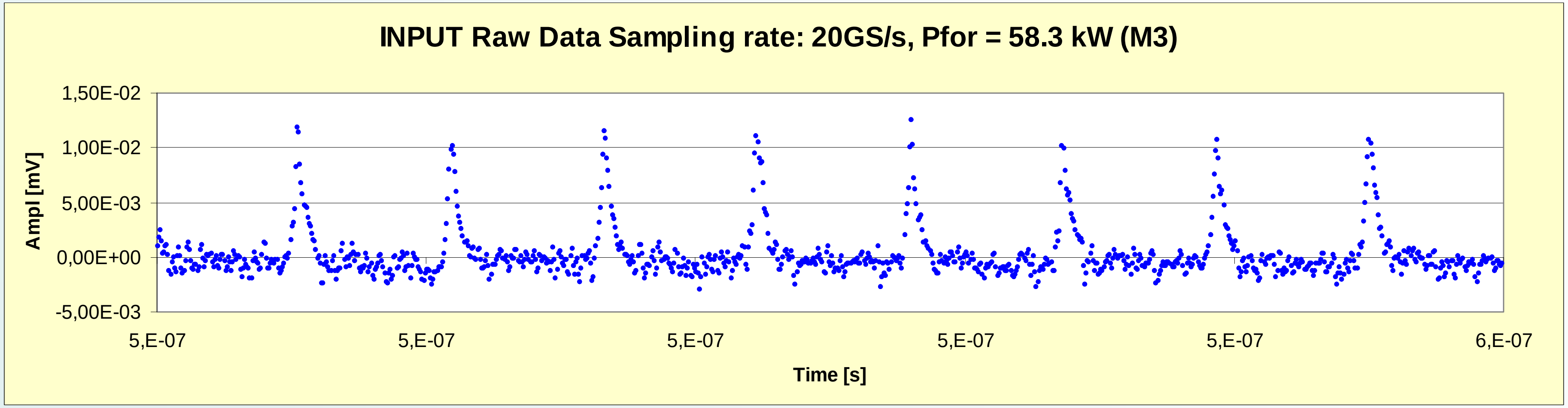




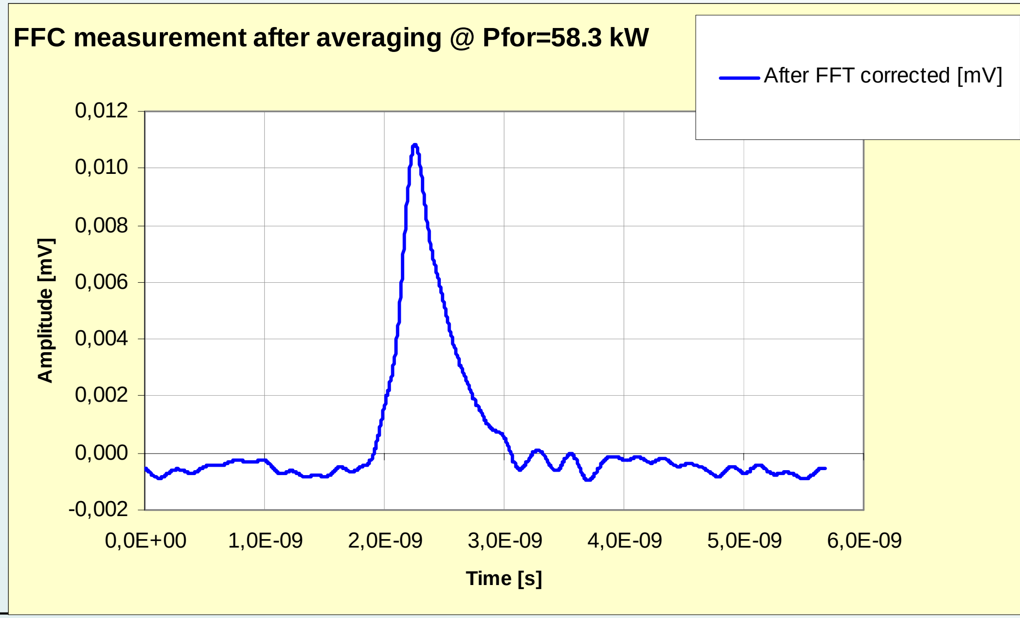


Protons Commissioning of RFQ - FFC

Fast Faraday Cup (FFC) raw data of measured longitudinal beam profiles. The overall bandwidth is 6 GHz which allows measurement of bunch length σ > 26 psec



Measured longitudinal beam profile after averaging of up to 100 bunches of one macro-pulse and a Fourier correction.



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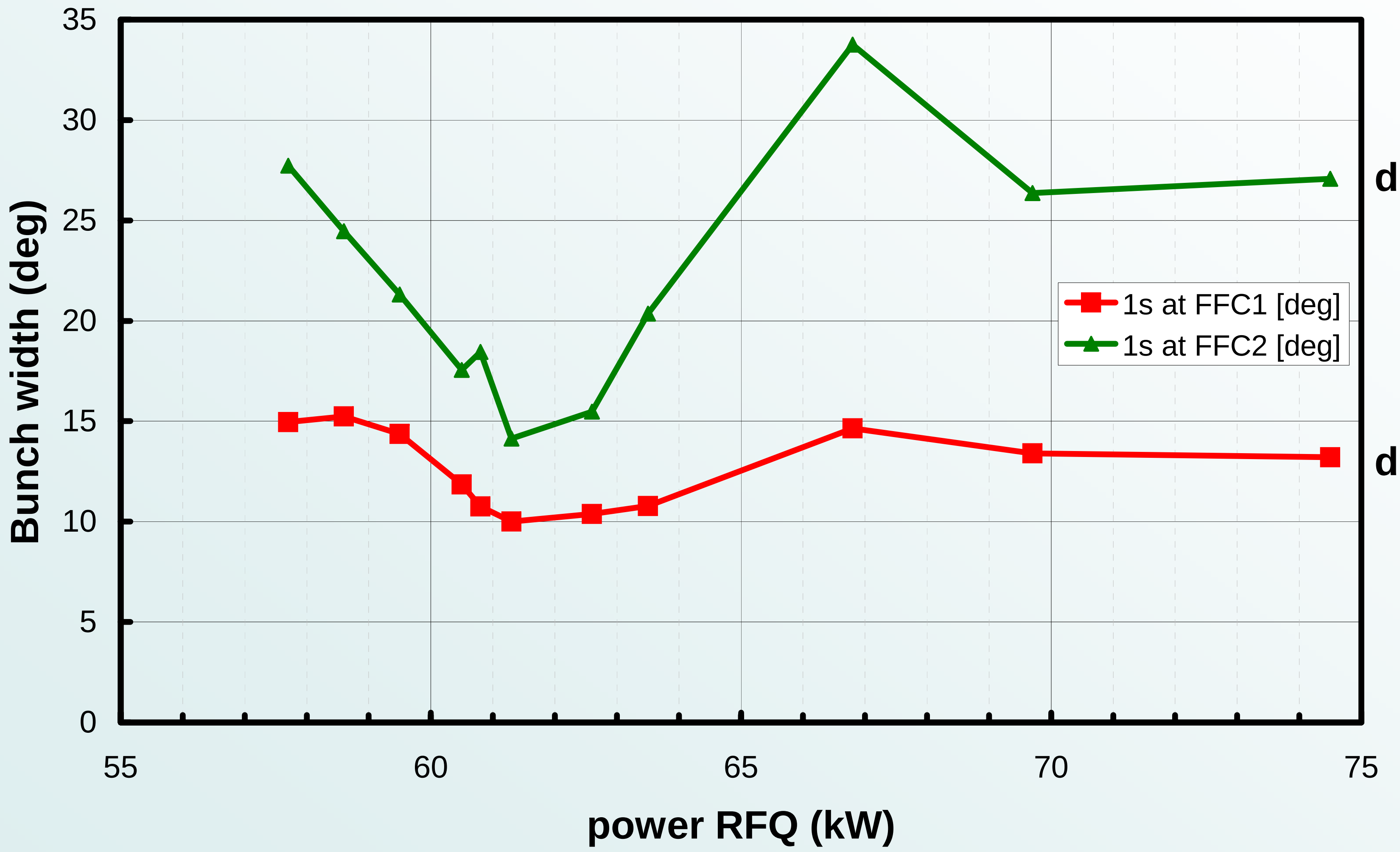
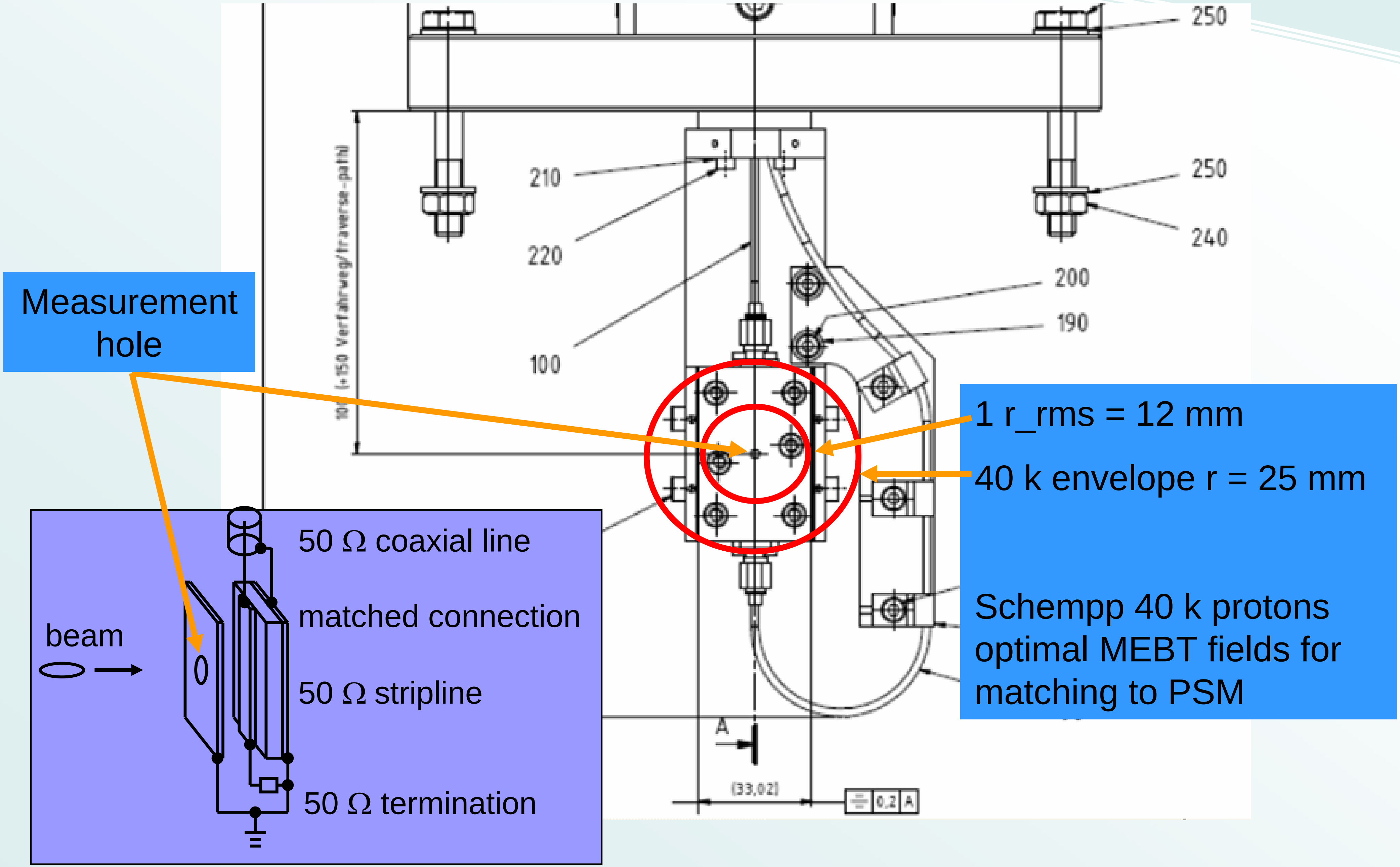
proton bunch width measured at FFCs



265 cm downstream the RFQ

106 cm downstream the RFQ

FFC


Measurement hole
1 r_rms = 12 mm
40 k envelope r = 25 mm
Schempp 40 k protons optimal MEBT fields for matching to PSM
50 Ω coaxial line
matched connection
beam
50 Ω stripline
50 Ω termination
250
210
220
100
250
240
200
190
A
(33,02)
0,2
A

Measurement of Longitudinal Emittance

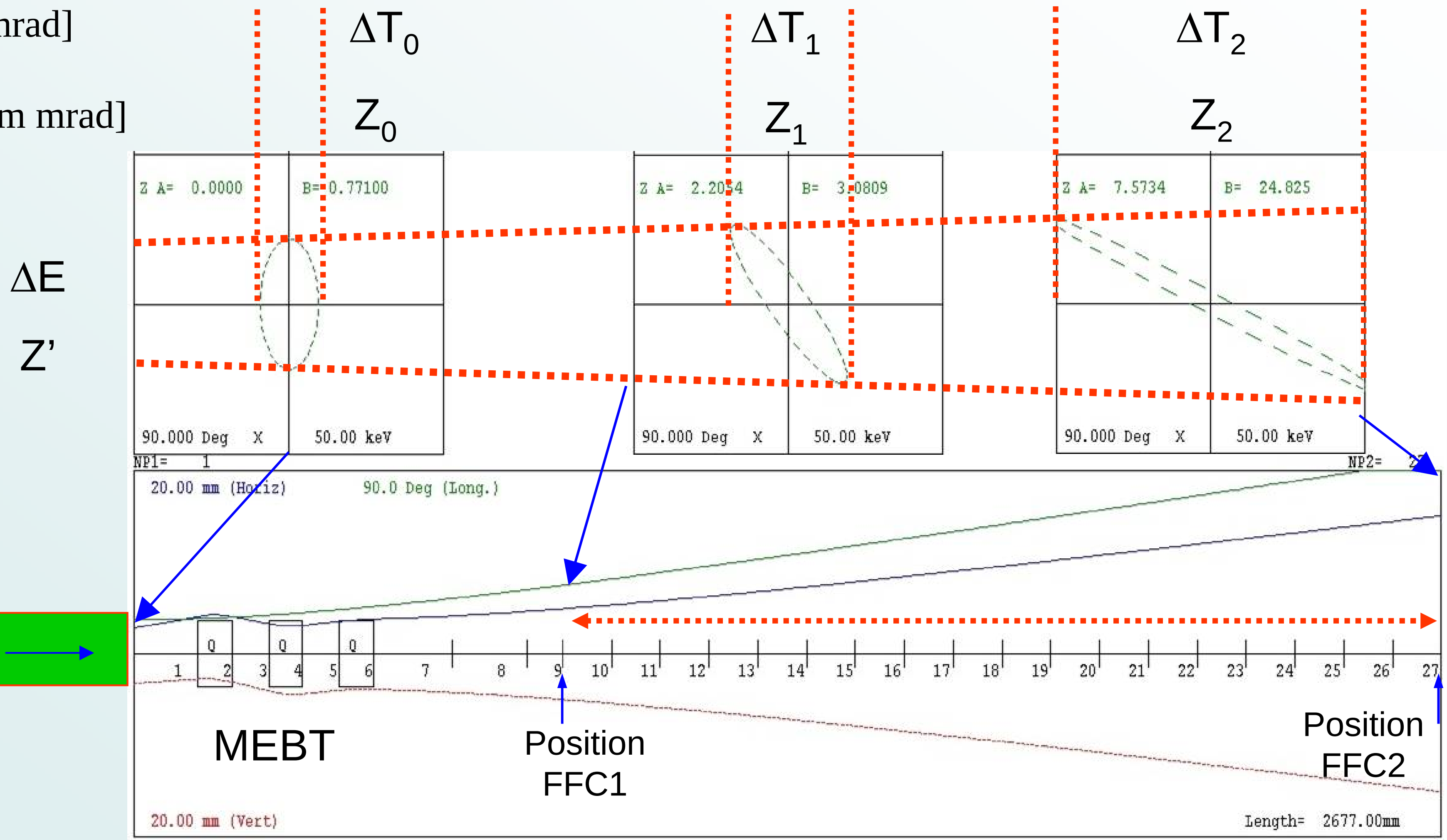
Formalism excluding space charge

$z = \phi\ \beta\lambda / 2\pi$ [mm]

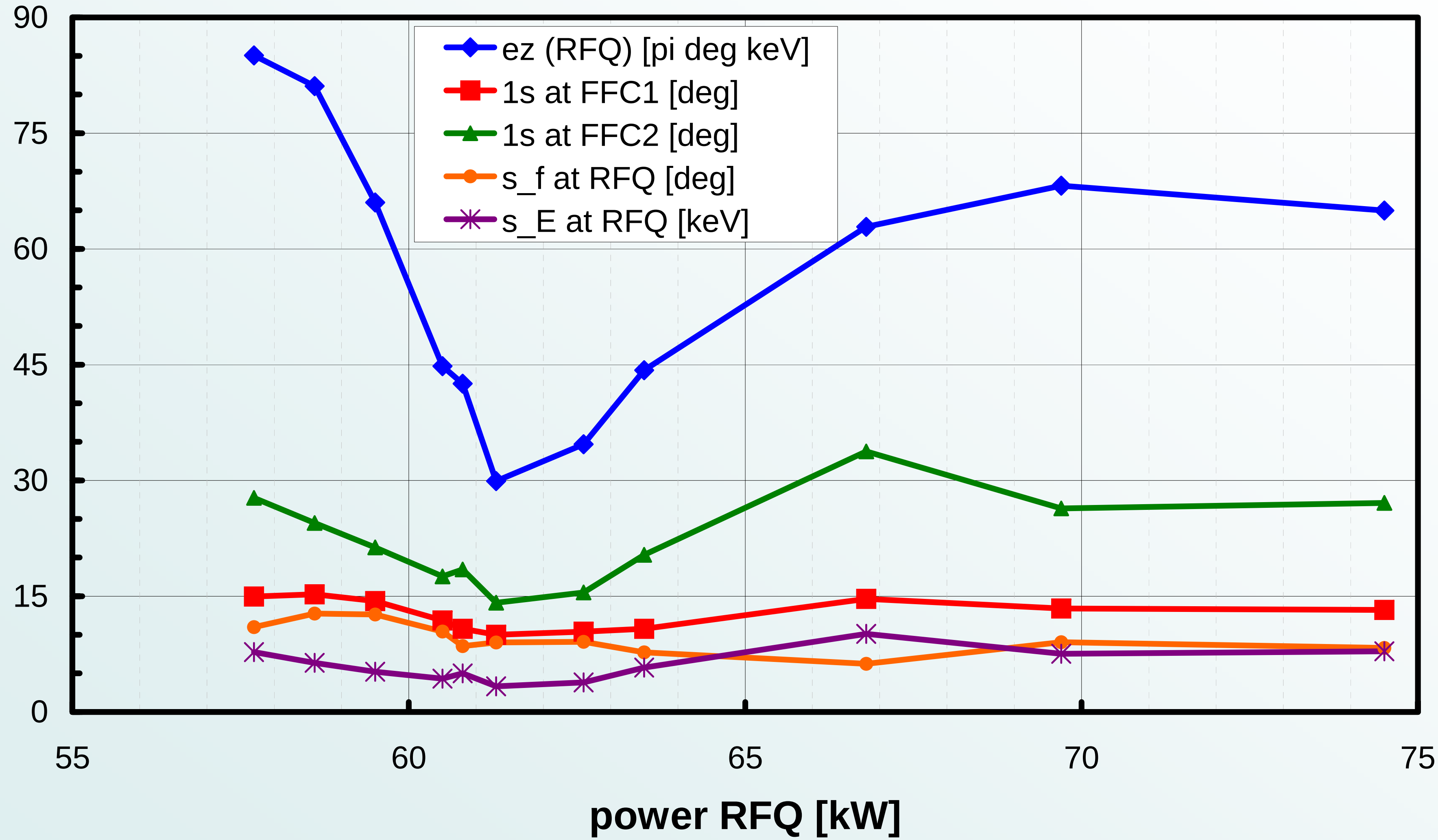
$z' = (z_2 - z_1)/L$ [mrad]

$\varepsilon = z_0 * z'$ [π mm mrad]

Development of phase space ellipses after different drift lengths



Approximated longitudinal emittance extracted from bunch width measurements



Specified longitudinal rms emittance = 120 π deg keV, realistic value 74 π deg keV

END