Design Status of the MESA Injector

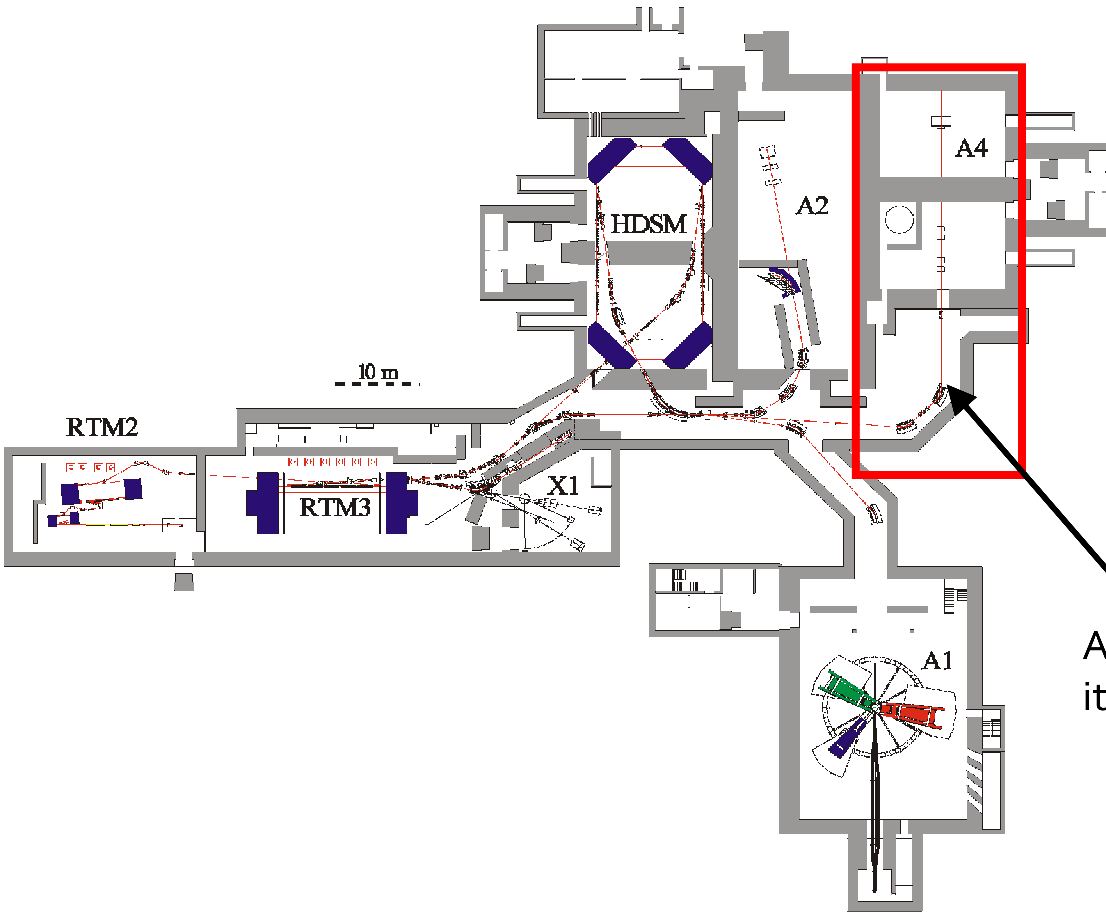
Robert Heine

on behalf of MESA-CARE

Outline

- Motivation: MESA
- MAMI-ILAC
- Injectors for MESA
- Summary

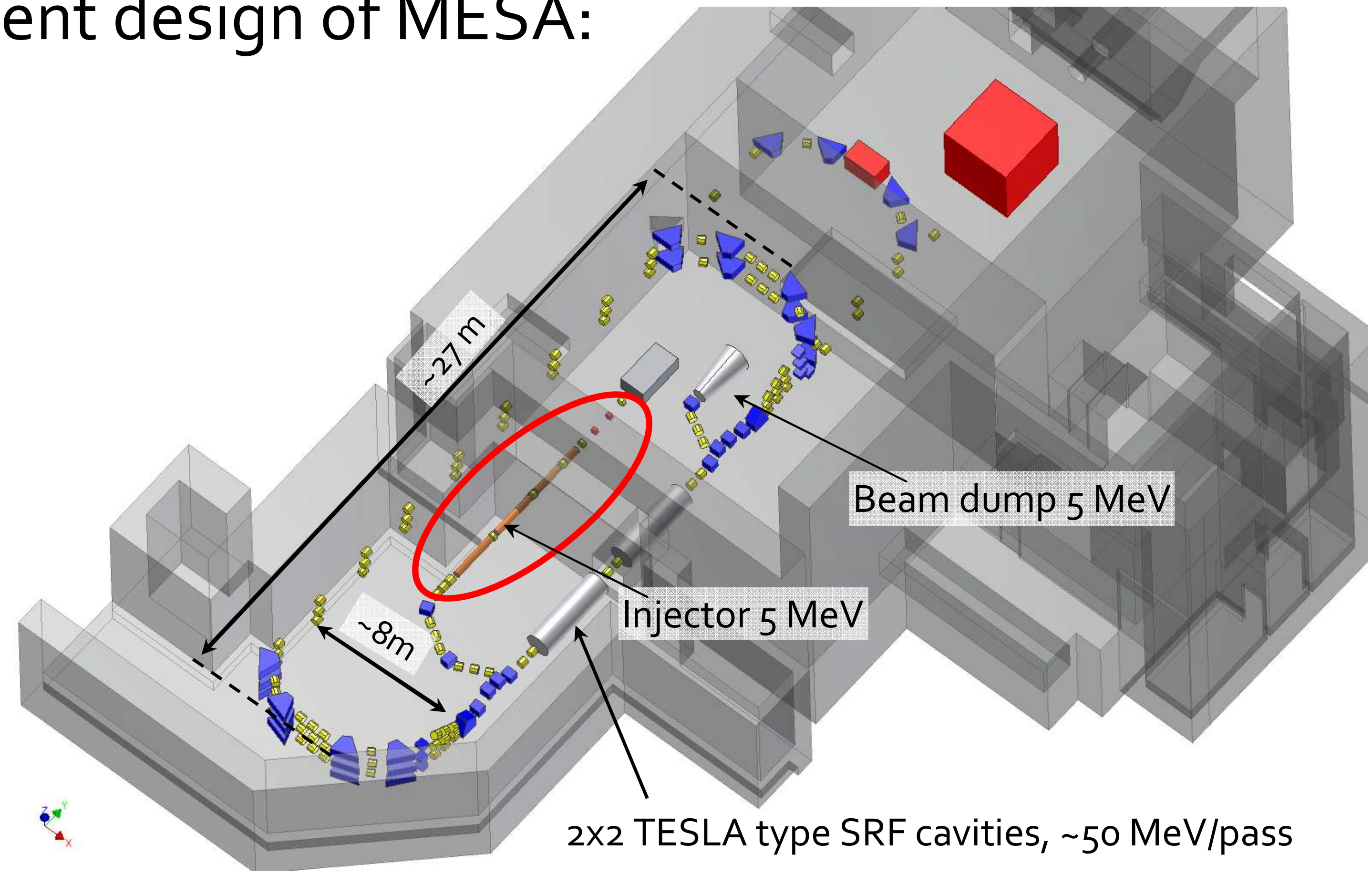
Floor Plan of MAMI and Experimental Halls



Area for MESA and its experiments

Motivation: MESA

Current design of MESA:



Lattice design by R. Eichorn

Working Hypothesis

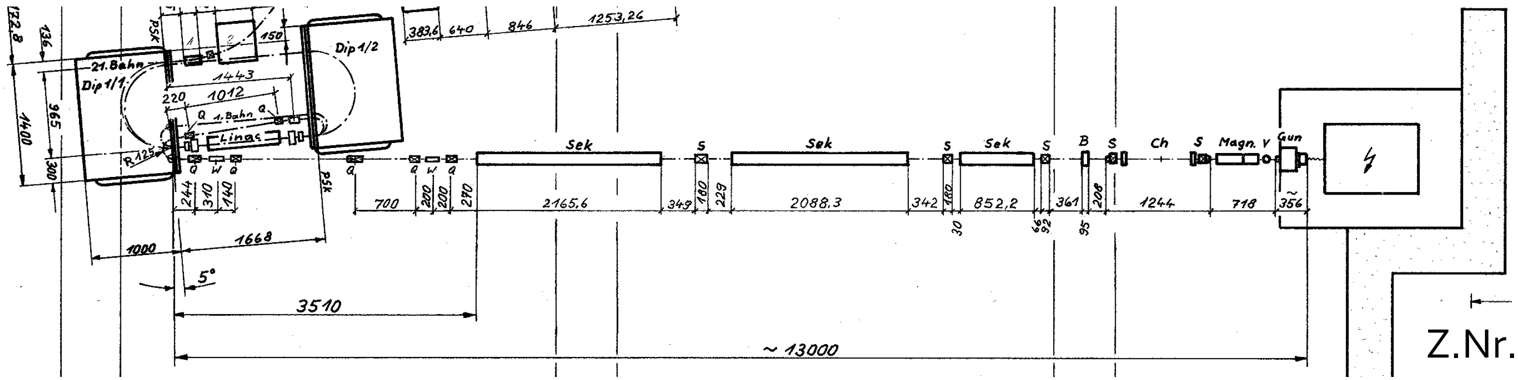
- Take MAMI-ILAC as a blue print for MESA injector
- scale it to 1.3 GHz
- aim at comparable ΔE and $\Delta \psi$
- at $E_{\text{end}} = 5$ MeV, $I_{\max} = 10$ mA

MAMI Injector Linac

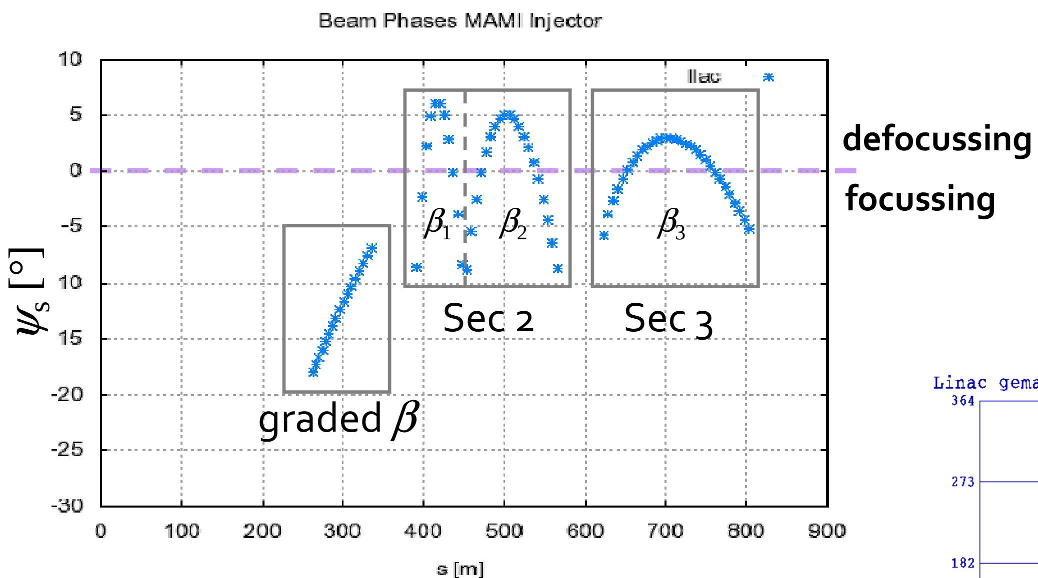
- 100 keV DC source (ΔE=2.5eV, I_b=100μA, ε = 1 π mm mrad)
- Chopper system
- Fundamental buncher
- (2nd harmonic buncher to capture more beam from photo gun)
- Section 1: β = 0.548–0.876, 17 AC (100–550 keV)
- Section 2: β_1= 0.9176, 11 AC; β_2= 0.966, 20 AC
- Section 3: β_3= 0.987, 31 AC
- E_{end}=3.5 MeV, ΔE=4 keV ($\Delta E/E$ = 0.06 %), $\Delta\psi$ = 3°

(MAMI Annual Report 1988/89, p.4)

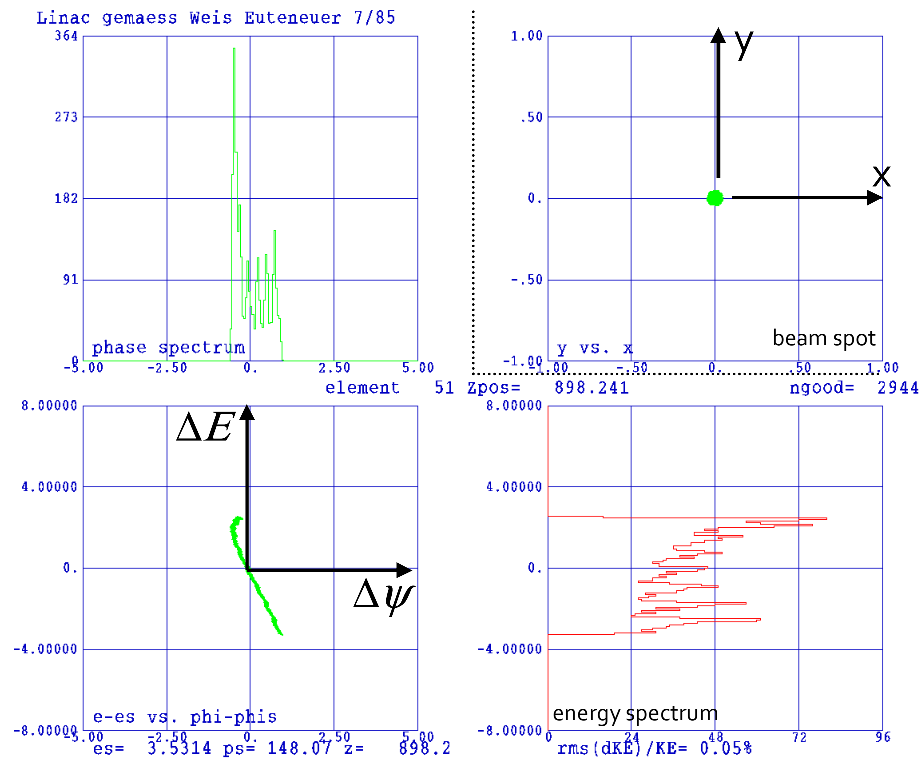
MAMI Linac 2.45 GHz



Z.Nr. 605f



Beam phases taken from T. Weis MAMI 12/84



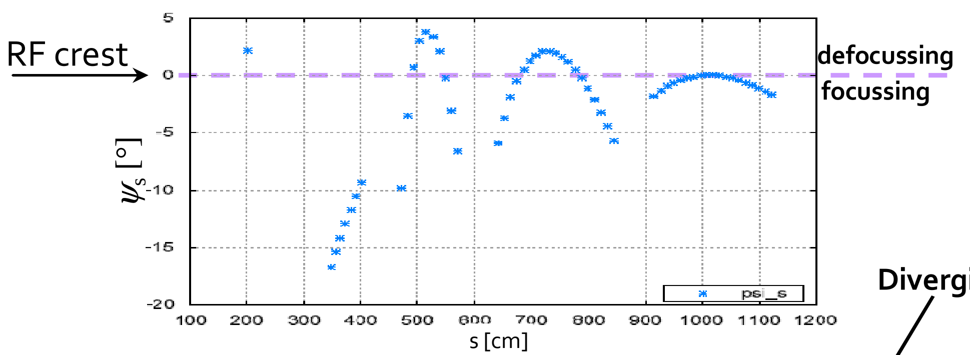
Simulated rms emittance growth during acceleration:
$\Delta\varepsilon_{x,n}$=4,7%

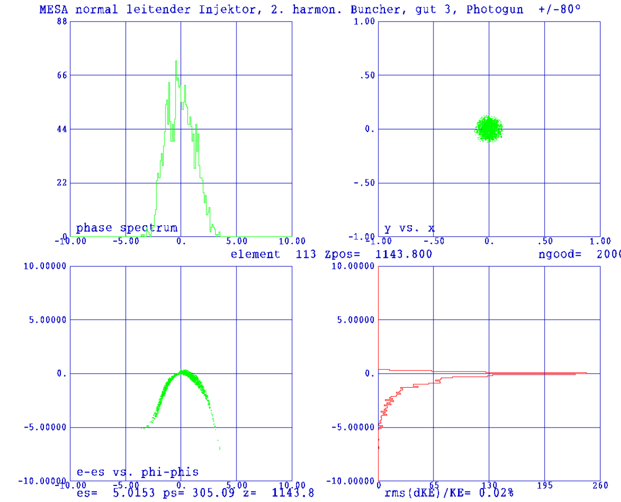
$$\varepsilon_{x,rms} = \frac{1}{N}\sqrt{\sum_{i=1}^{N} x_i^2 \sum_{i=1}^{N} x_i'^2 - \left(\sum_{i=1}^{N} x_i^2 x_i'^2\right)^2} = \frac{\varepsilon_{x,n,rms}}{1000\beta\gamma}$$

Injectors for MESA

Normal Conducting Injector V1

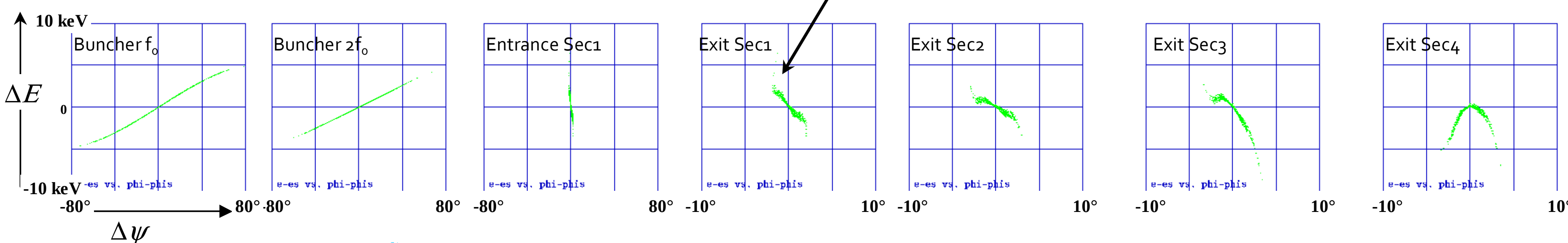
- Section 1: $\beta = 0.548 - 0.896$ (graded β)
- Section 2: $\beta = 0.946 = (\beta_{out} - \beta_{in})/2$
- Section 3: $\beta = 0.983$
- Section 4: $\beta = 0.993$

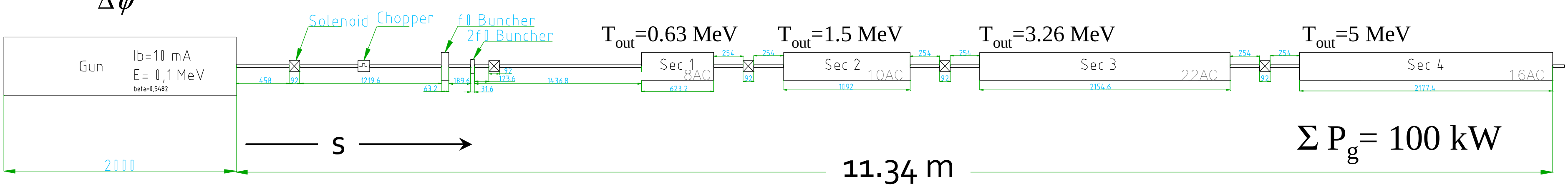




Diverging beam

T=5.02 MeV $\Delta\psi_{100\%} < \pm 3.6°$ $\Delta T/T_{rms}$=0.02%





Normal Conducting Injector V1

- Section 1: $\beta = 0.548 - 0.896$ (graded β)
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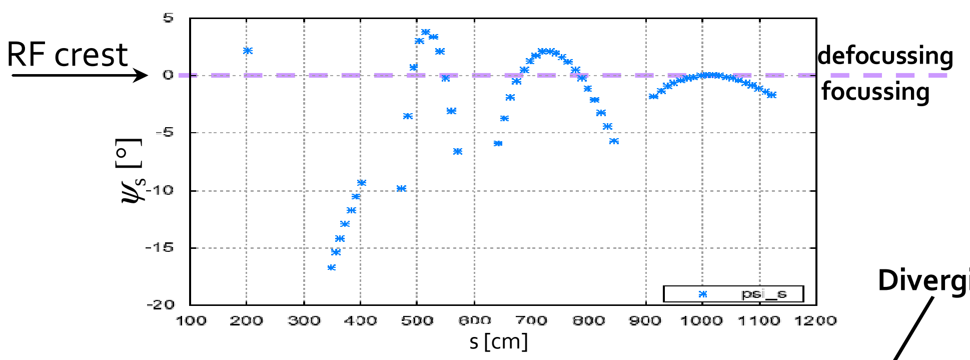
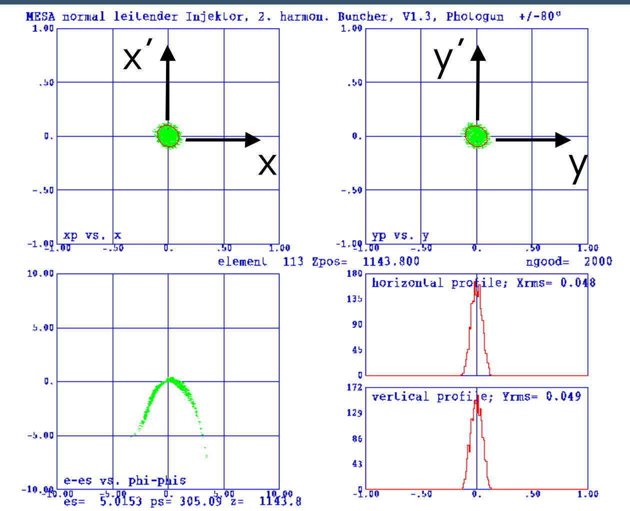
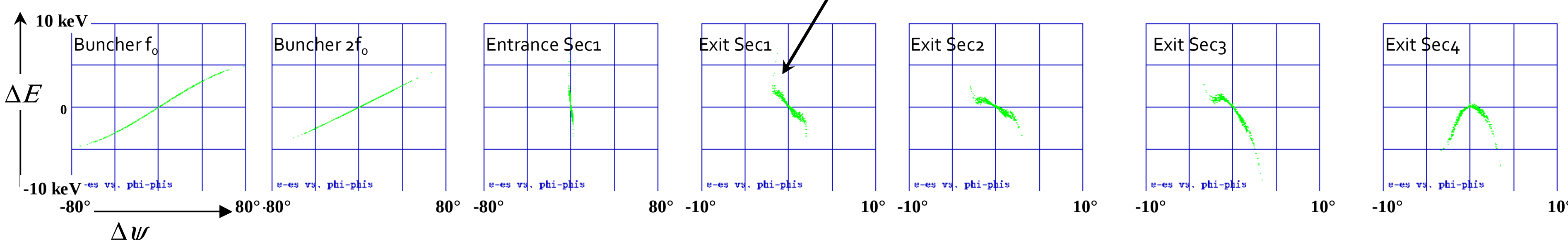


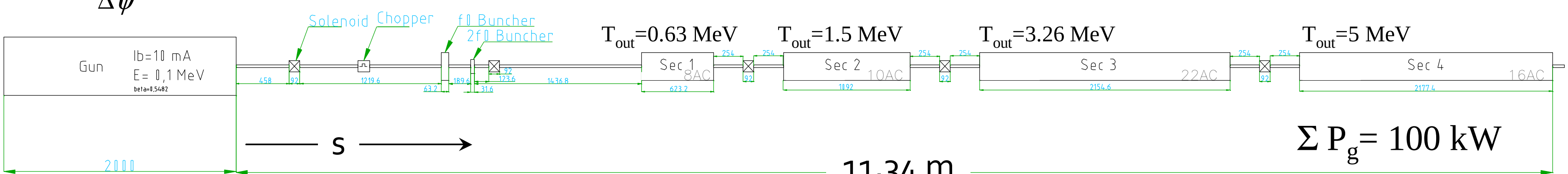


$(\Delta\varepsilon_{x,n}=4{,}1\%)$

Diverging beam

T=5.02 MeV ✓ $\Delta\psi_{100\%} < \pm3.6°$ ✗ $\Delta T/T_{rms}$=0.02% ✓

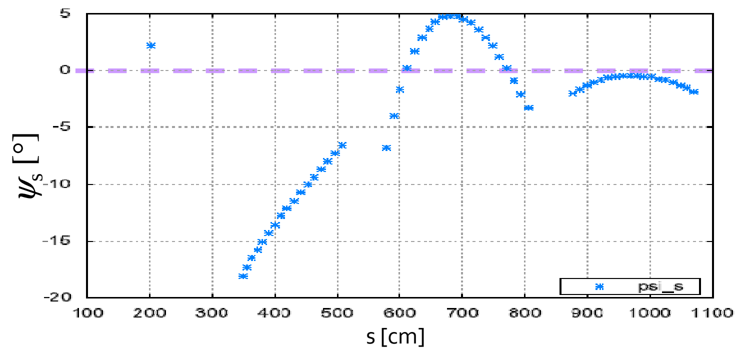


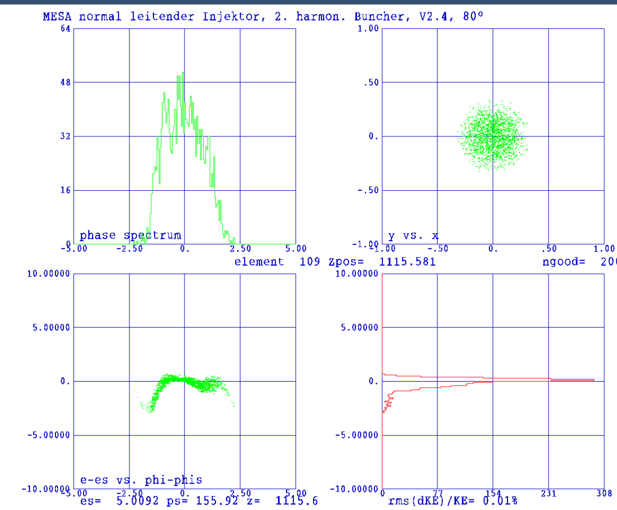


ΣP_g= 100 kW

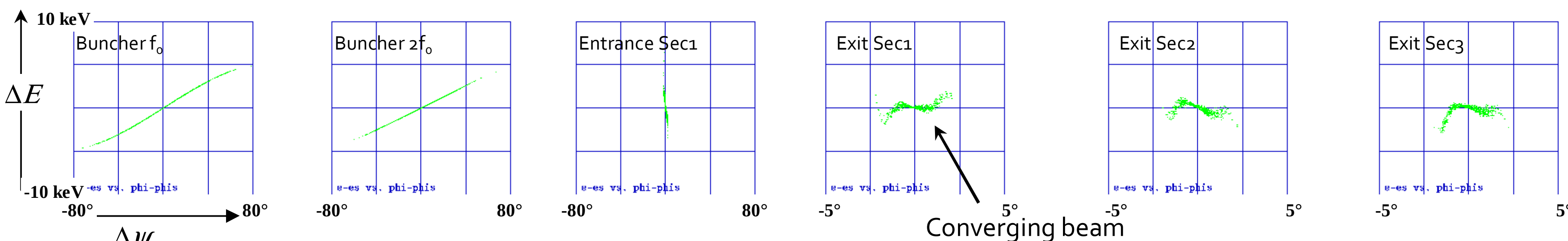
Normal Conducting Injector V2

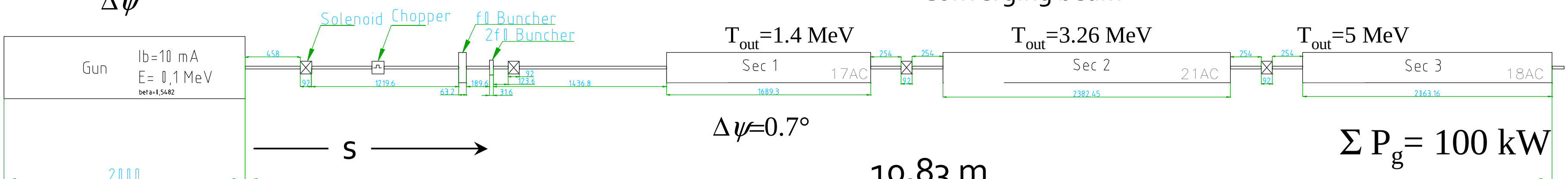
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.982$
- Section 3: $\beta = 0.995$





T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓





Normal Conducting Injector V2

- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.982$
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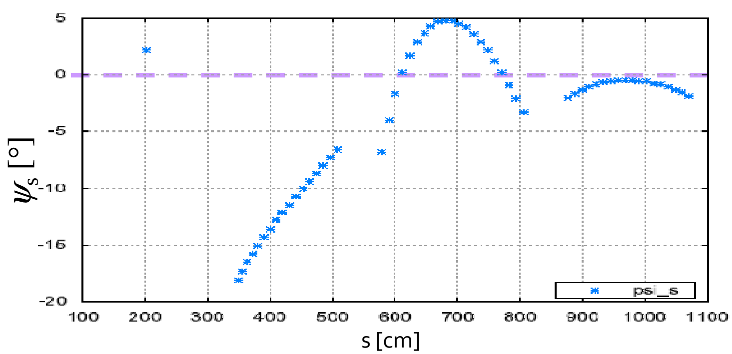
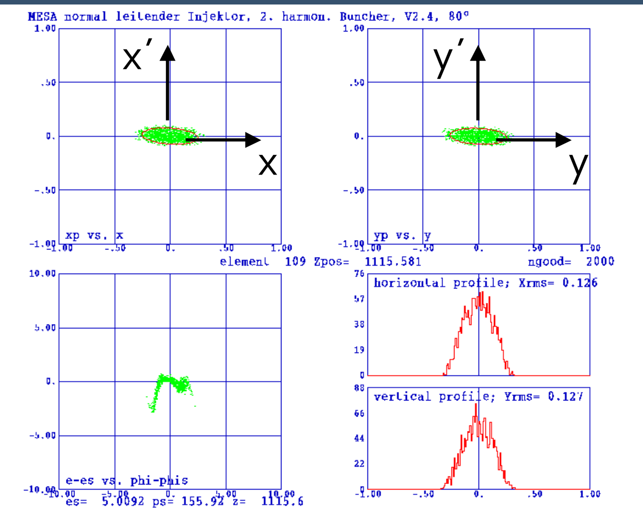
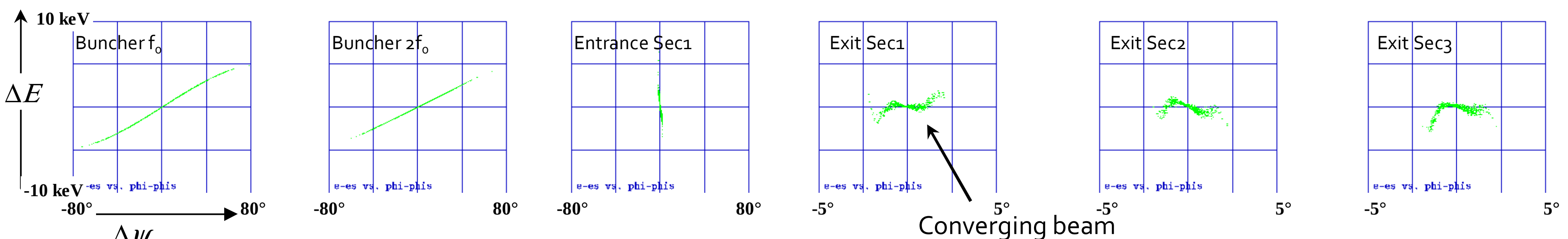
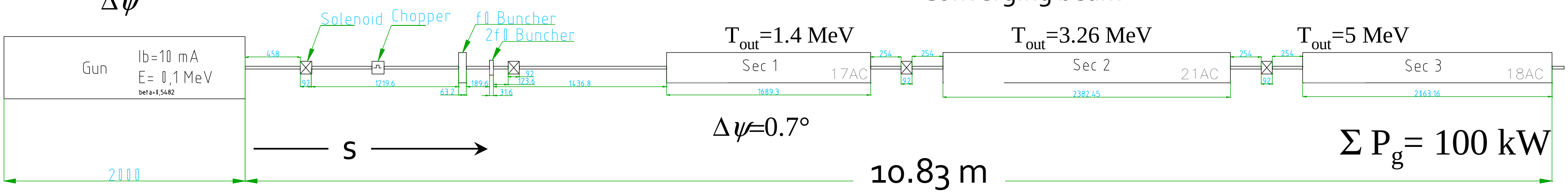




$(\Delta\varepsilon_{x,n}=3,3\%)$

T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓





Normal Conducting Injector V2

- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.982$
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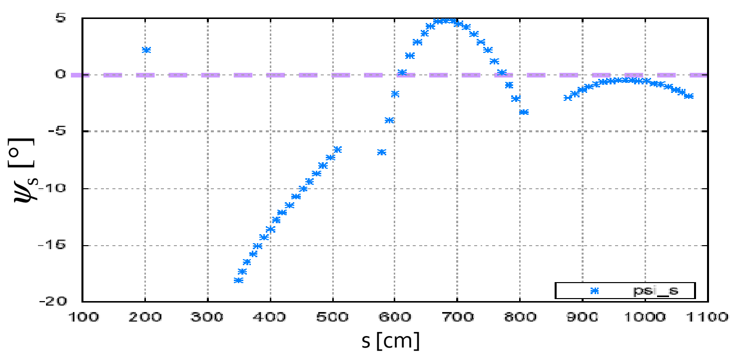
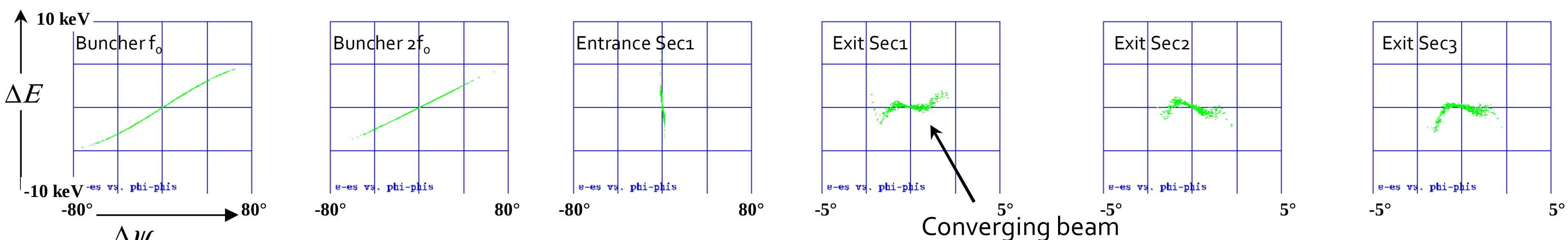
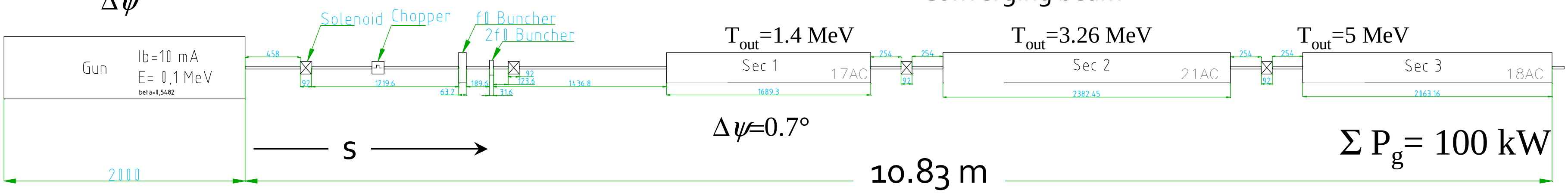


- Acceptable solution
- $\Delta\psi$ can by minimised by running Sec 2&3 at a different phase, but on cost of $\Delta T/T$

- Injector is rather long
- RF demands are high

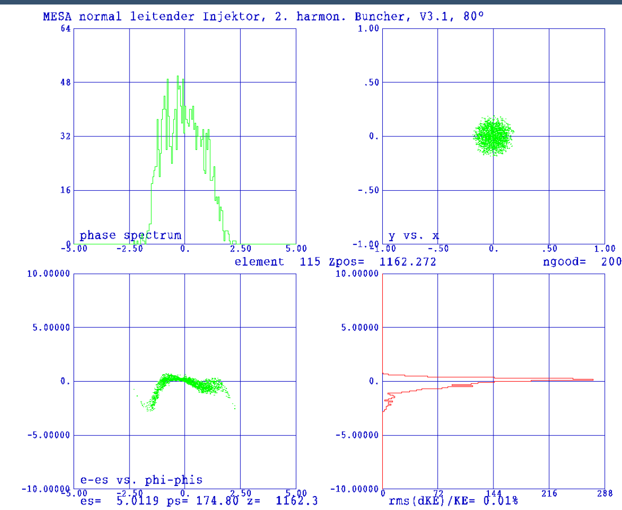
T=5.01 MeV $\Delta\psi_{100\%} < \pm 2.3°$ $\Delta T/T_{rms}$=0.01%

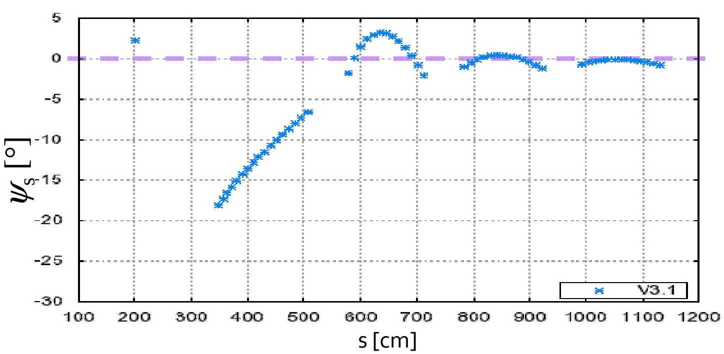




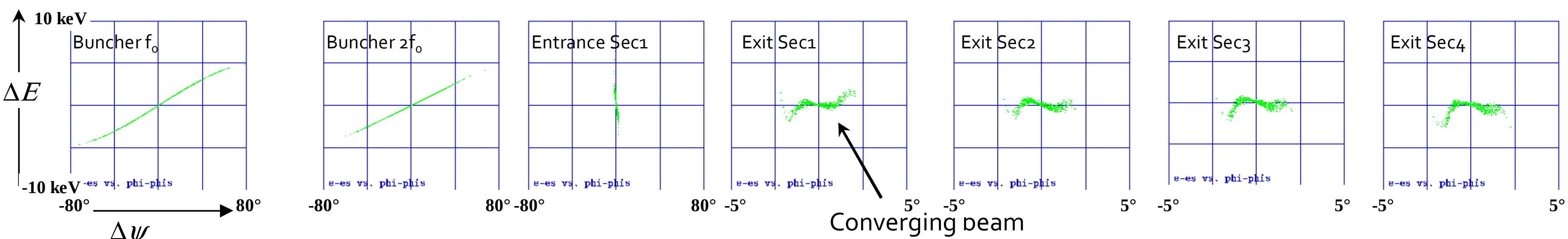
Normal Conducting Injector V3

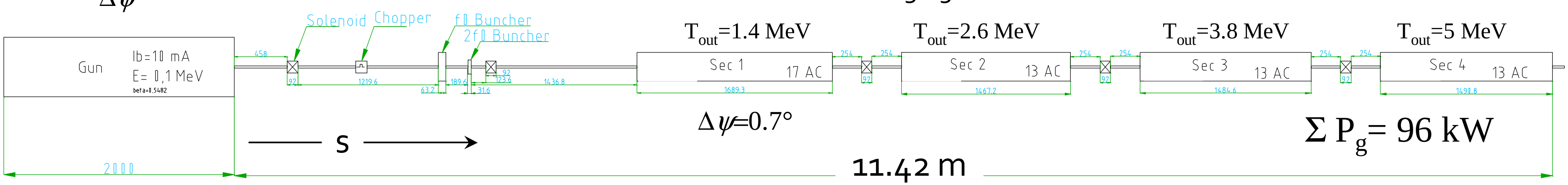
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 0.99$
- Section 4: $\beta = 0.995$





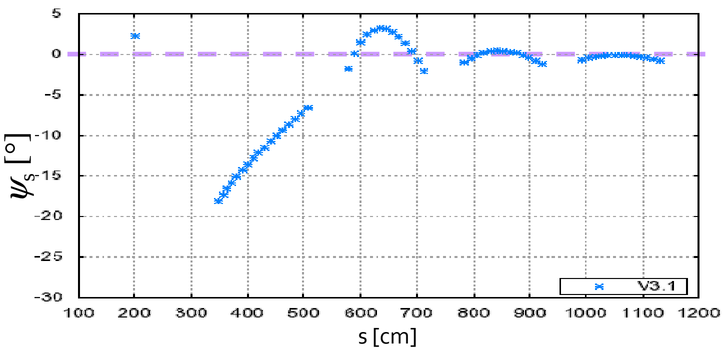
T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓

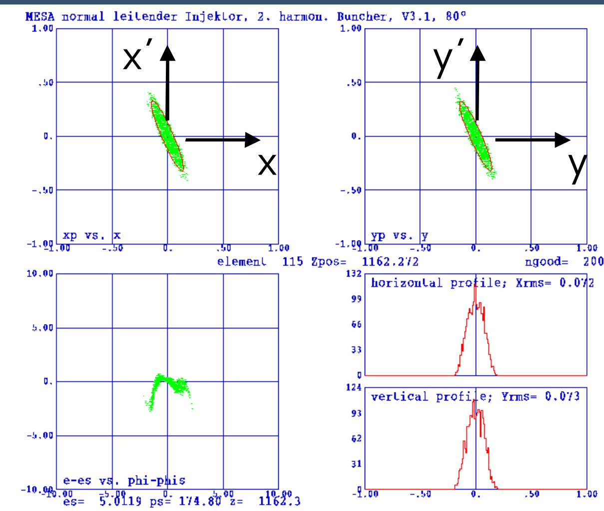




Normal Conducting Injector V3

- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 0.99$
- Section 4: $\beta = 0.995$

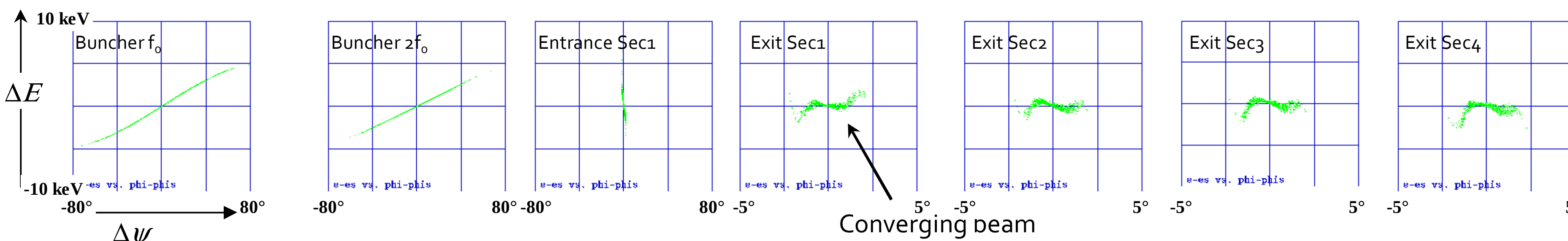


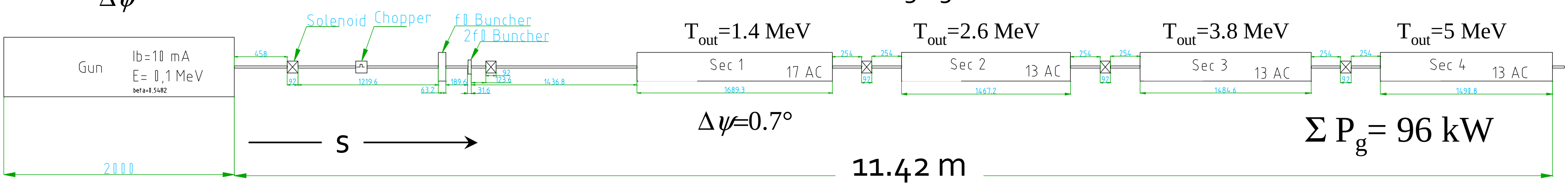


$(\Delta\varepsilon_{x,n} = 3,3\%)$

✓ (✓) ✓

$T = 5.01$ MeV $\Delta\psi_{100\%} < \pm 2.3°$ $\Delta T / T_{rms} = 0.01\%$



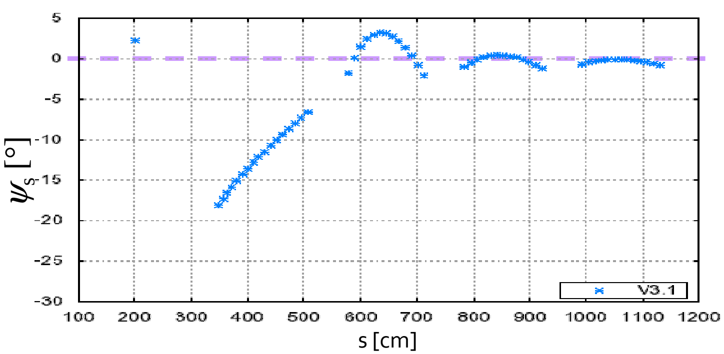


$\Sigma P_g = 96$ kW

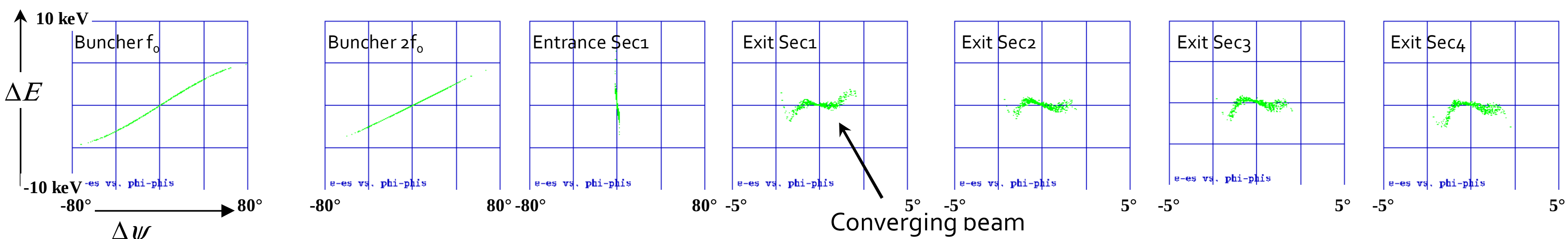
Normal Conducting Injector V3

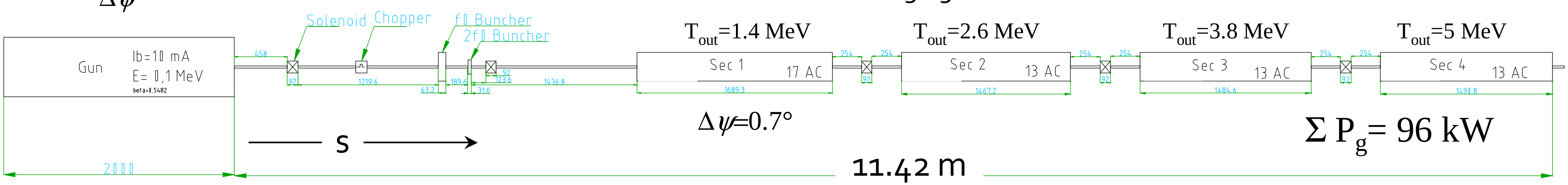
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 0.99$
- Section 4: $\beta = 0.995$

- Solution comparable to V2
- Less RF demands (<30kW/section)
- Injector is longer



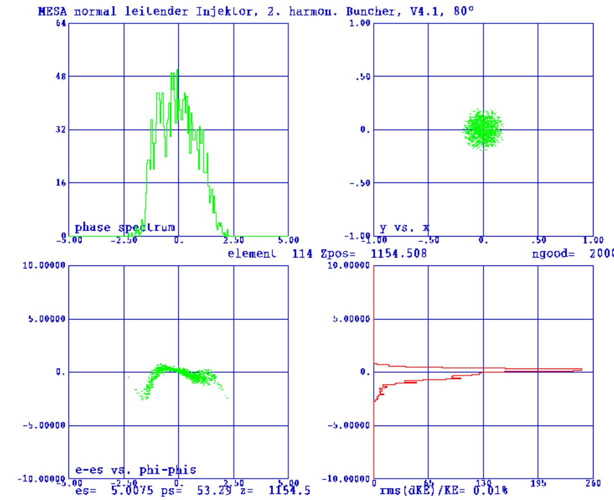
T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓

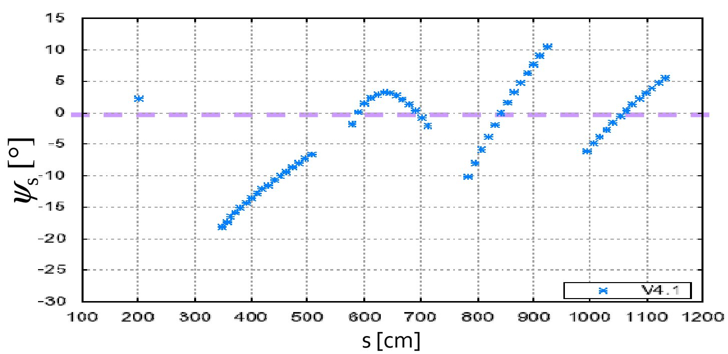




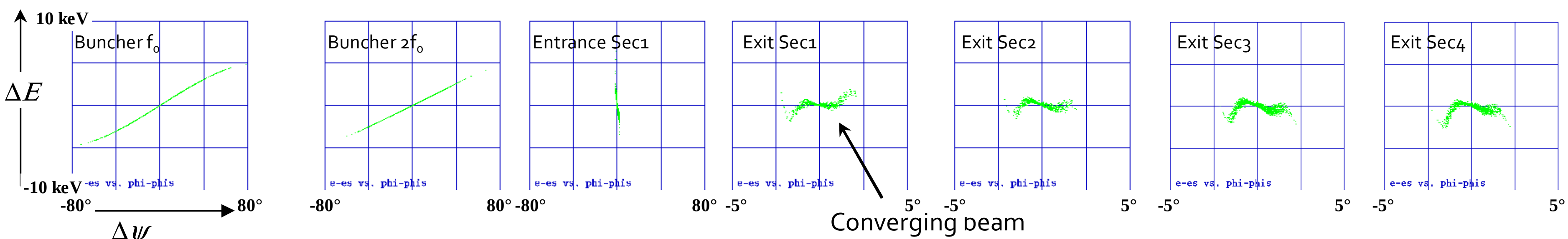
Normal Conducting Injector V4

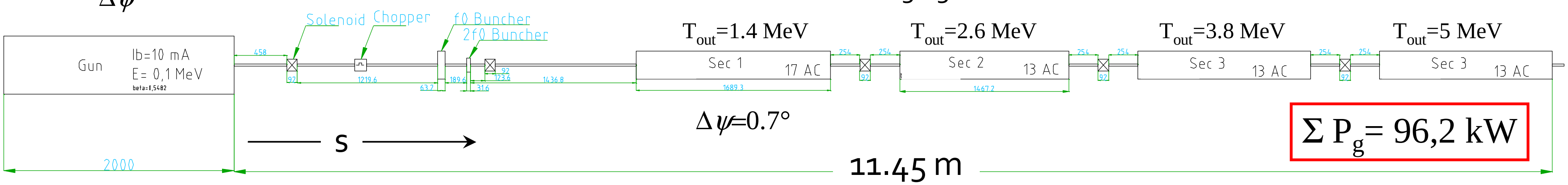
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 1$
- Section 4: $\beta = 1$





T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓

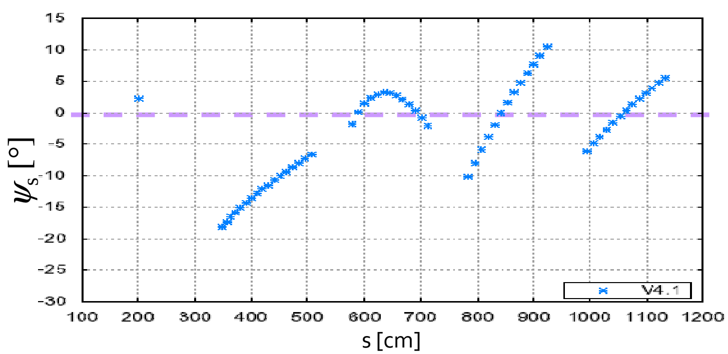


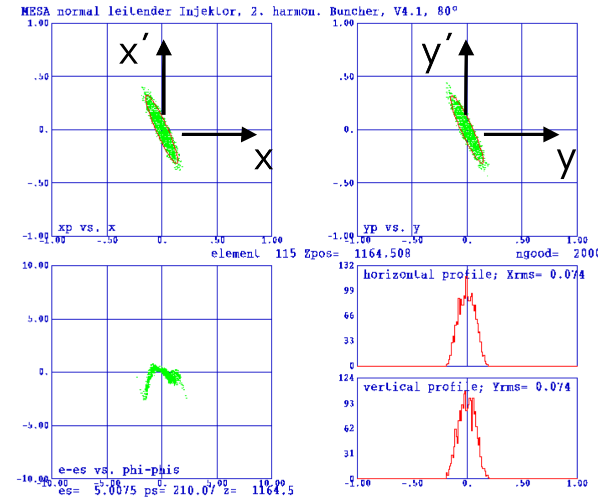


ΣP_g= 96,2 kW

Normal Conducting Injector V4

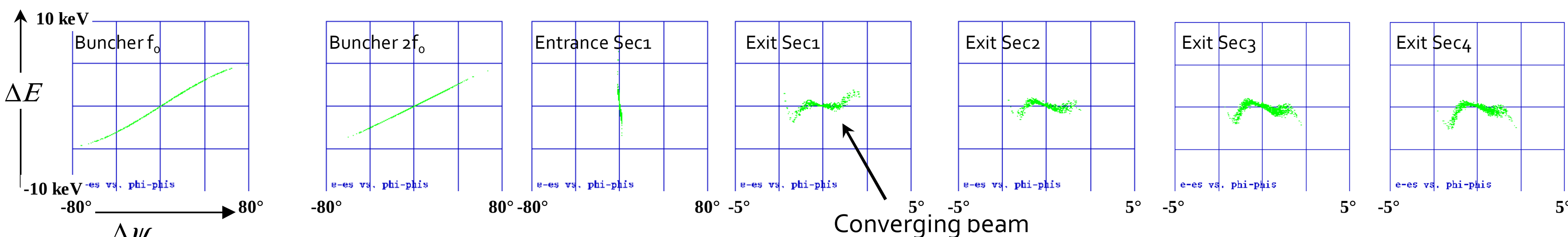
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 1$
- Section 4: $\beta = 1$

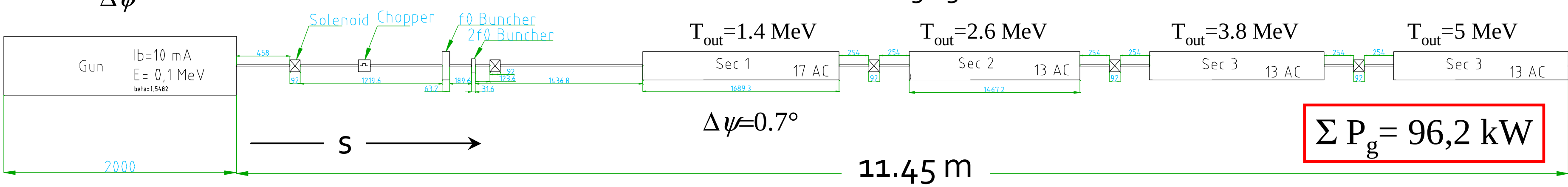




$(\Delta\varepsilon_{x,n} = 3{,}3\%)$

$T = 5.01$ MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms} = 0.01\%$ ✓

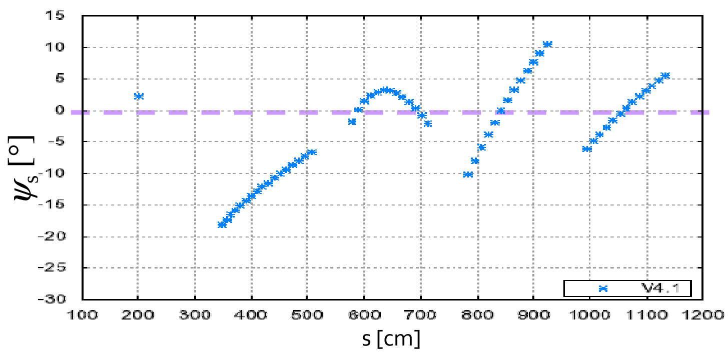




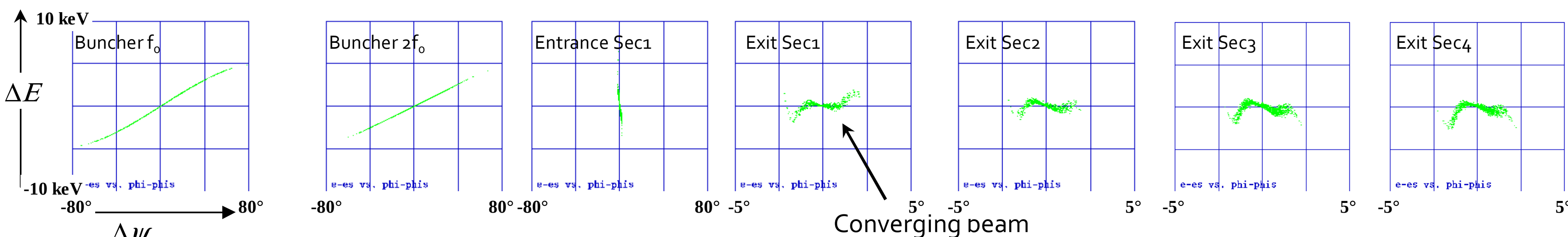
Normal Conducting Injector V4

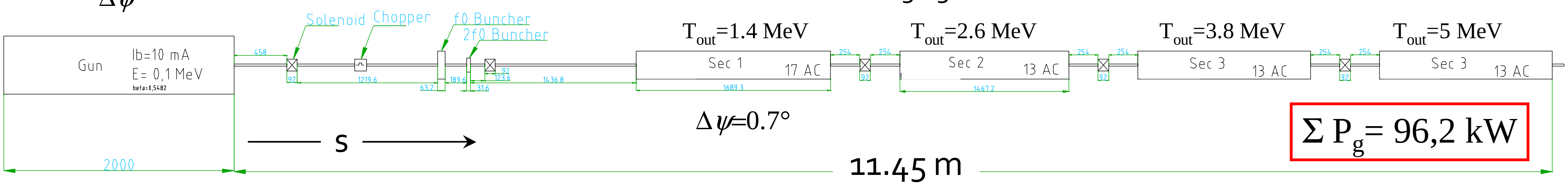
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 0.979$
- Section 3: $\beta = 1$
- Section 4: $\beta = 1$

- Solution nearly identical to V3
- Less RF demands (<30kW/section)
- Section 3 & 4 are identical
- Injector is longer



T=5.01 MeV ✓ $\Delta\psi_{100\%} < \pm 2.3°$ (✓) $\Delta T/T_{rms}$=0.01% ✓





TESLA SRF Structure

Source: HZB Homepage

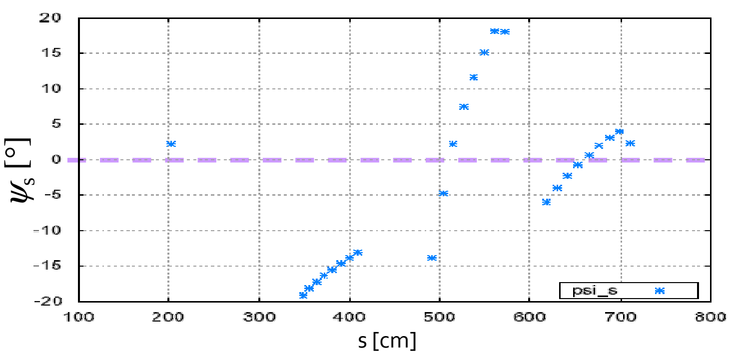
π-mode, $E_{CW} < 20\ \mathrm{MV/m},\ \beta = 1$

R/Q=518 Ω
$Q_0 > 5\cdot10^9$
TT≈0.73

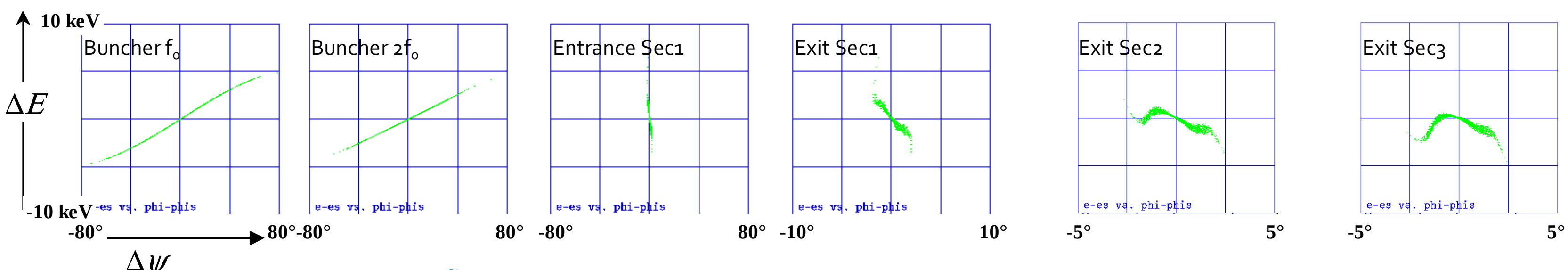
Hybrid Injector V1

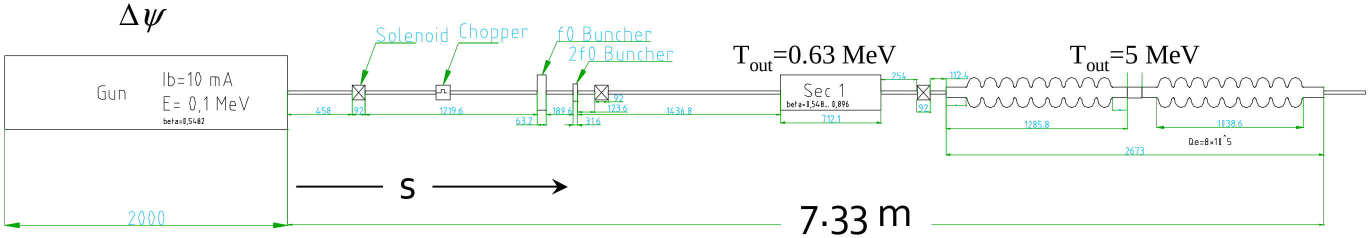
- Section 1: $\beta = 0.548 - 0.896$ (graded β)
- Section 2: $\beta = 1$
- Section 3: $\beta = 1$

Hybrid injector stands for the combination of a normal conducting graded β section with superconducting TESLA sections



T=5.02 MeV ✓ $\Delta\psi_{rms} < \pm 2.6°$ o $\Delta T/T_{rms}$=0.01% ✓



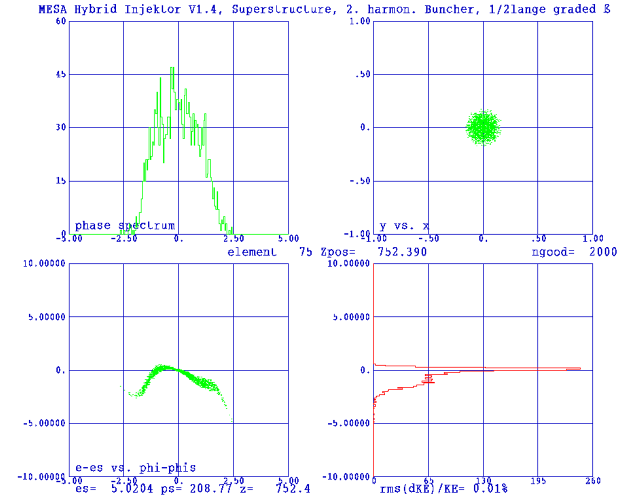


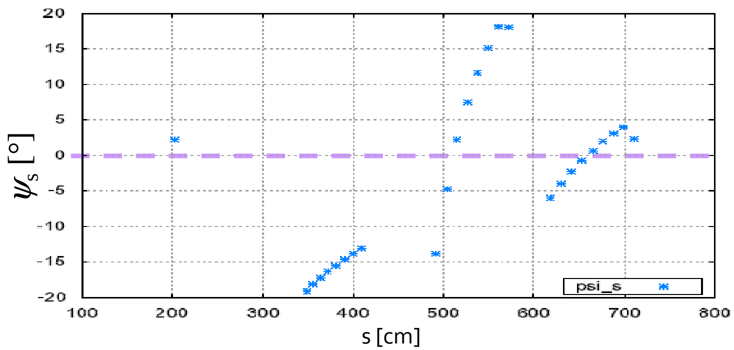
E= 2.85 MV/m P_c=3,4 W

ΣP_g= 71 kW

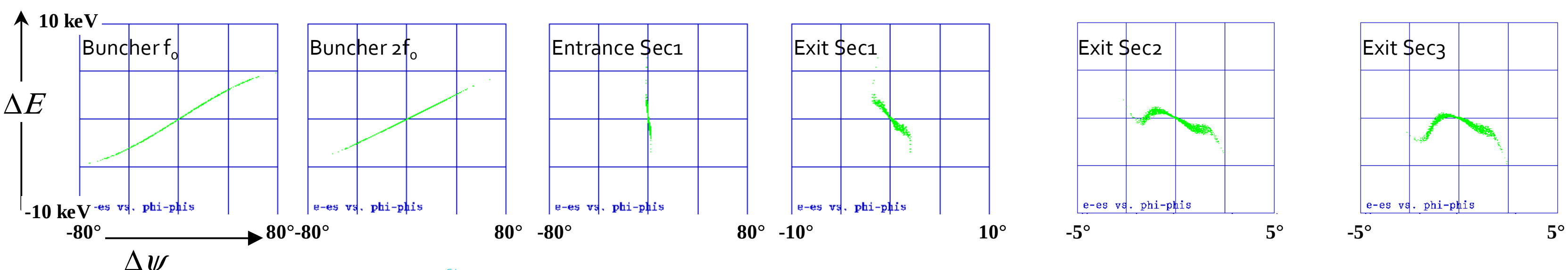
Hybrid Injector V1

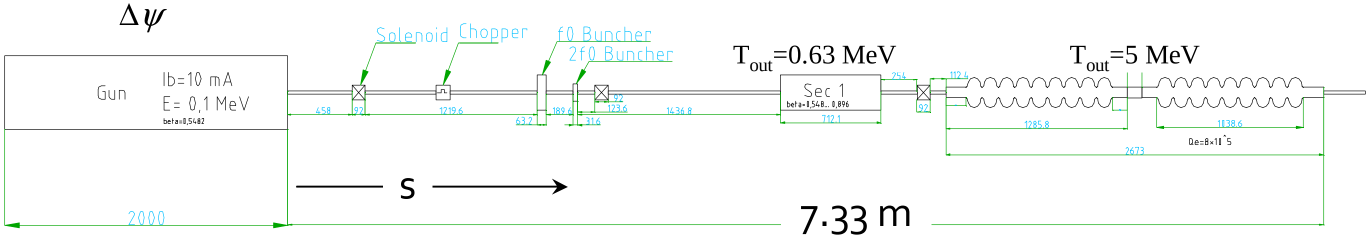
- Section 1: $\beta = 0.548 - 0.896$ (graded β)
- Section 2: $\beta = 1$
- Section 3: $\beta = 1$





T=5.02 MeV ✓ $\Delta\psi_{rms} < \pm 2.6°$ o $\Delta T/T_{rms}$=0.01% ✓





E= 2.85 MV/m P_c=3,4 W

ΣP_g= 71 kW

- Section 1: $\beta = 0.548 - 0.896$ (graded β)
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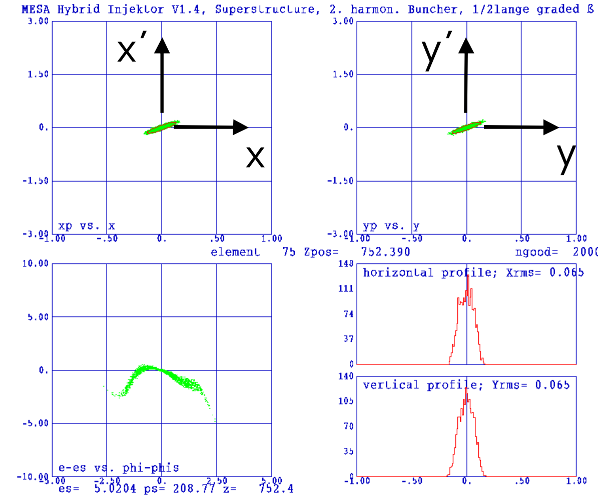
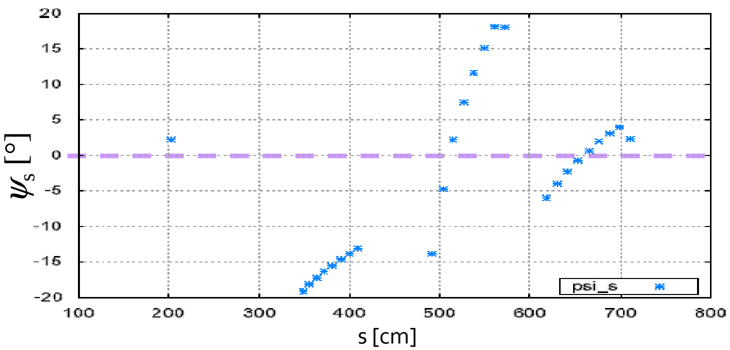
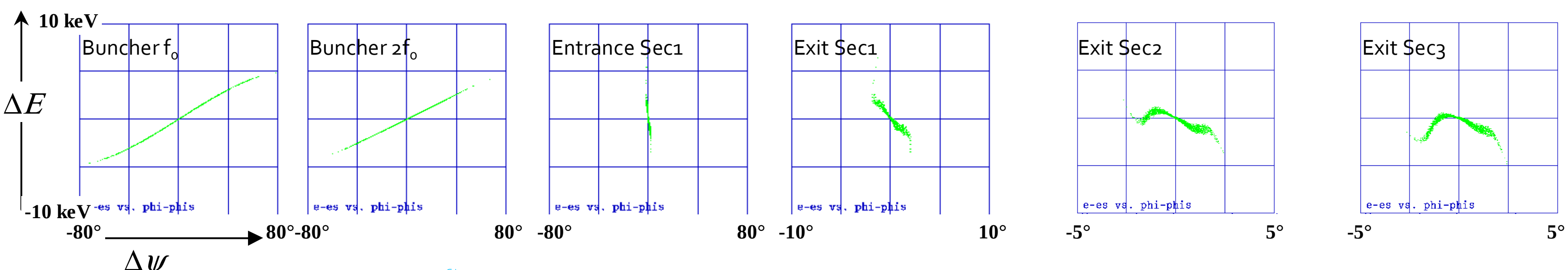
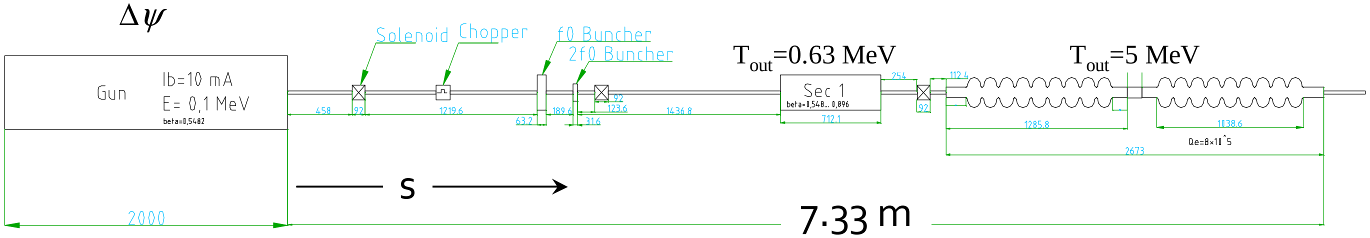


$(\Delta\varepsilon_{x,n}=1.6\%)$



T=5.02 MeV ✓ $\Delta\psi_{rms} < \pm 2.6°$ o $\Delta T/T_{rms}$=0.01% ✓



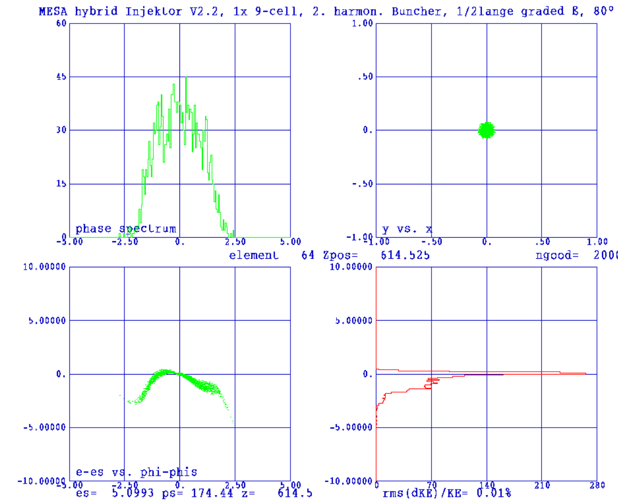


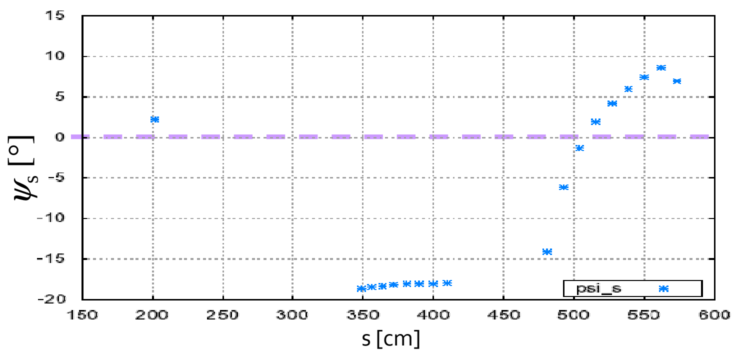
E= 2.85 MV/m P_c=3,4 W

ΣP_g= 71 kW

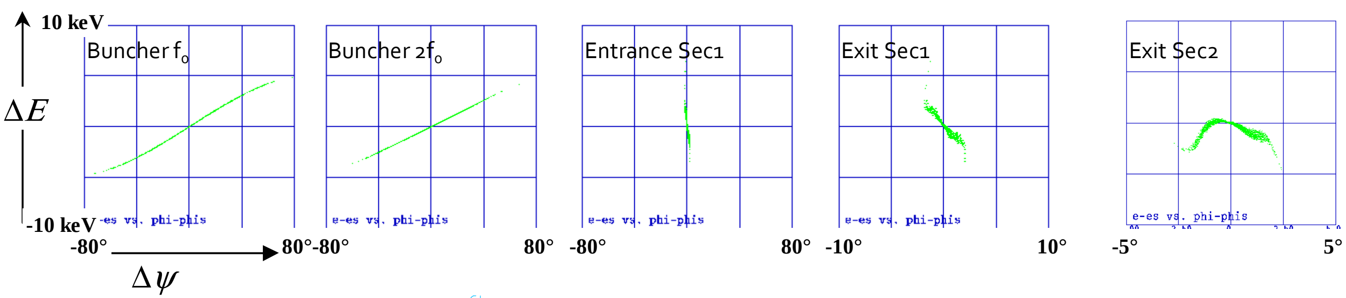
Hybrid Injector V2

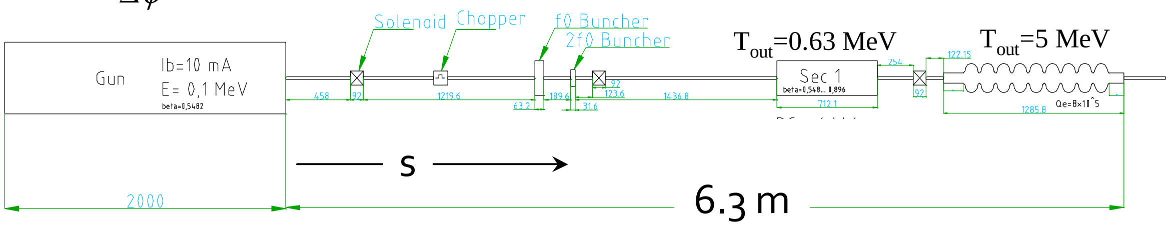
- Section 1: $\beta = 0.548 - 0.896$ (graded β)
- Section 2: $\beta = 1$





T=5.1 MeV ✓ $\Delta\psi_{100\%} < \pm 2.6°$ o $\Delta T/T_{rms}$=0.01% ✓



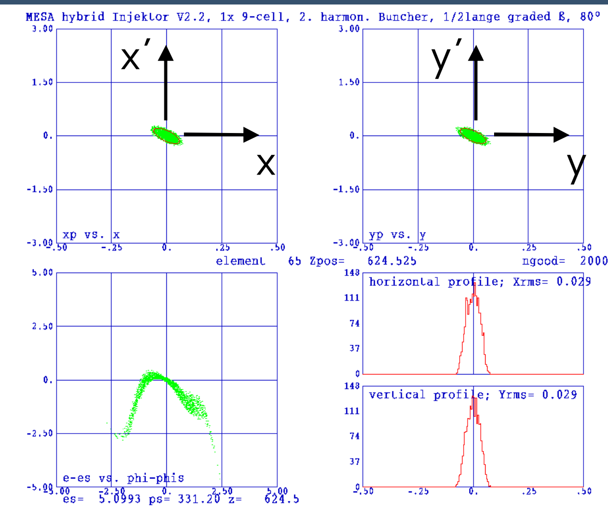


E= 5.75 MV/m P_c=6,9 W

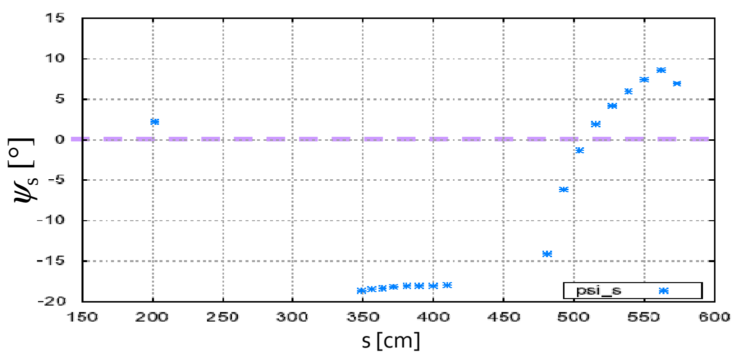
ΣP_g= 71.8 kW

Hybrid Injector V2

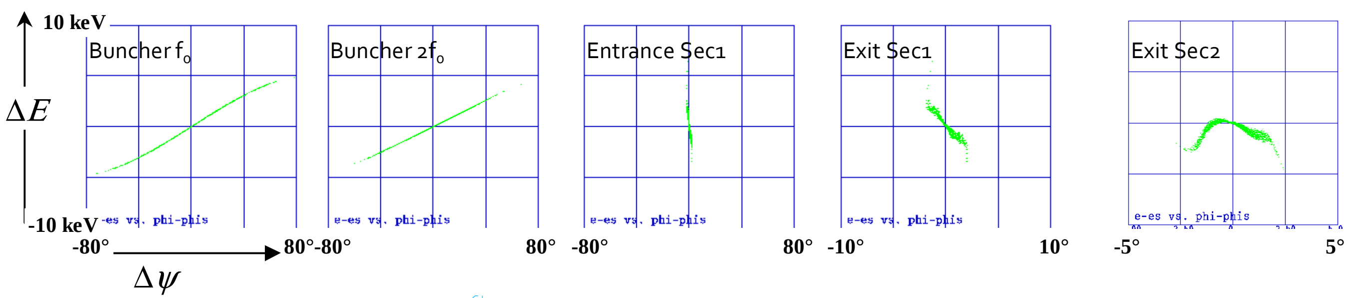
- Section 1: $\beta = 0.548 - 0.896$ (graded β)
- Section 2: $\beta = 1$

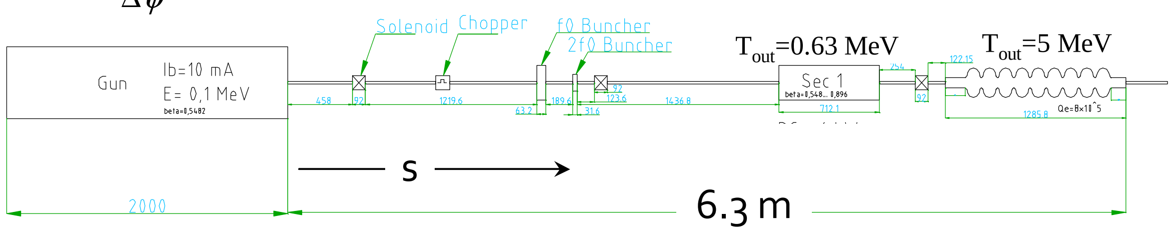


$(\Delta\varepsilon_{x,n}=1.6\%)$



T=5.1 MeV ✓ $\Delta\psi_{100\%} < \pm 2.6°$ o $\Delta T/T_{rms}$=0.01% ✓



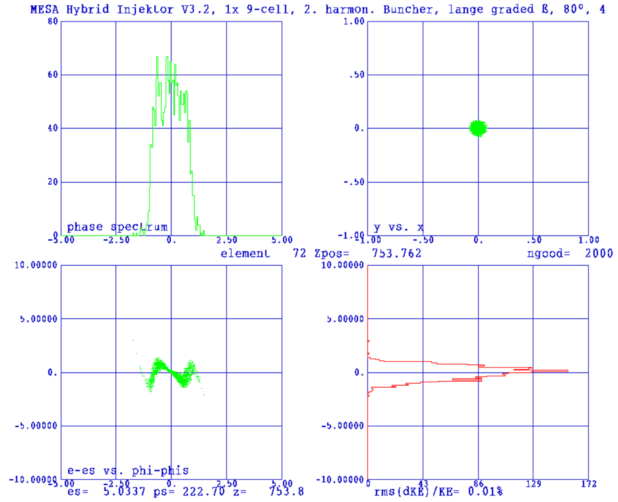


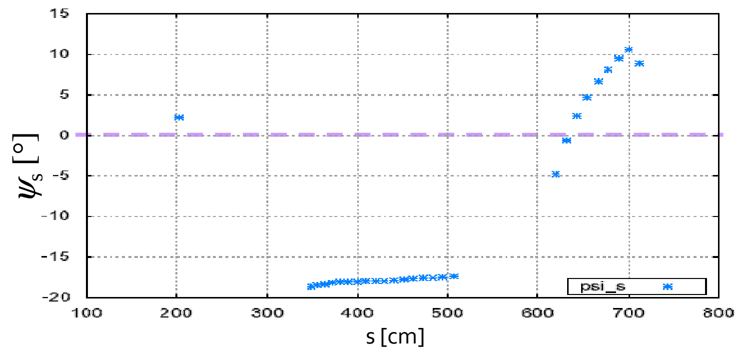
E= 5.75 MV/m P_c=6,9 W

ΣP_g= 71.8 kW

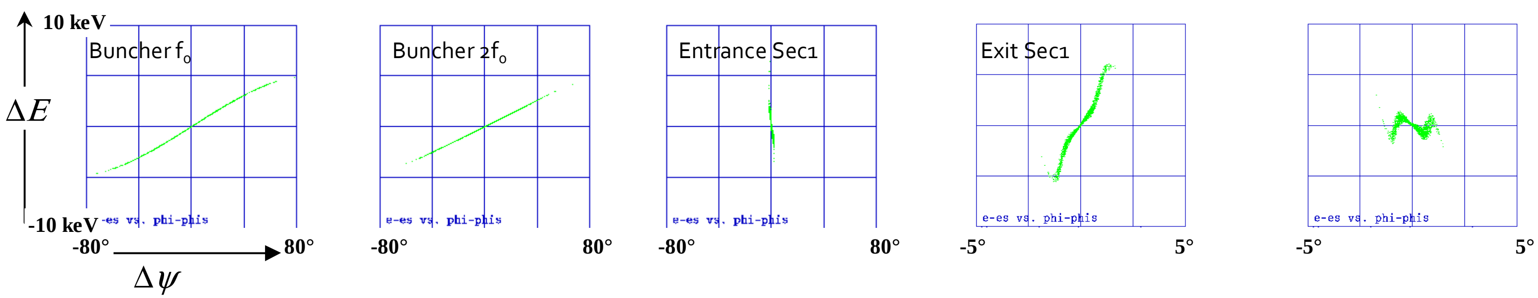
Hybrid Injector V3

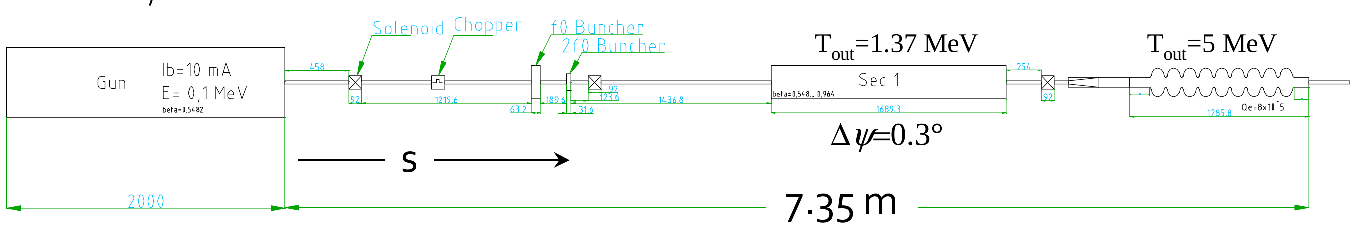
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 1$





T=5.03 MeV $\Delta\psi_{100\%} < \pm 1.7°$ $\Delta T/T_{rms}$=0.01%

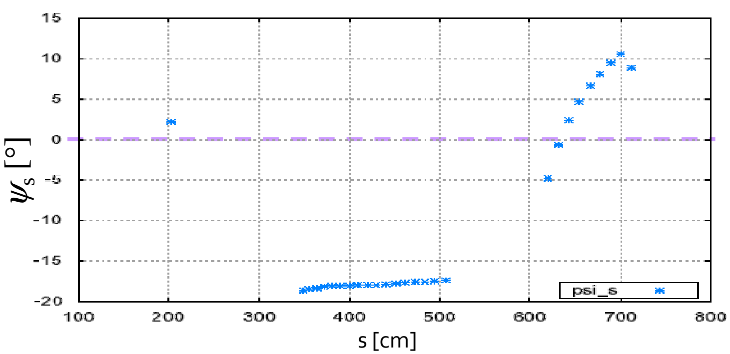


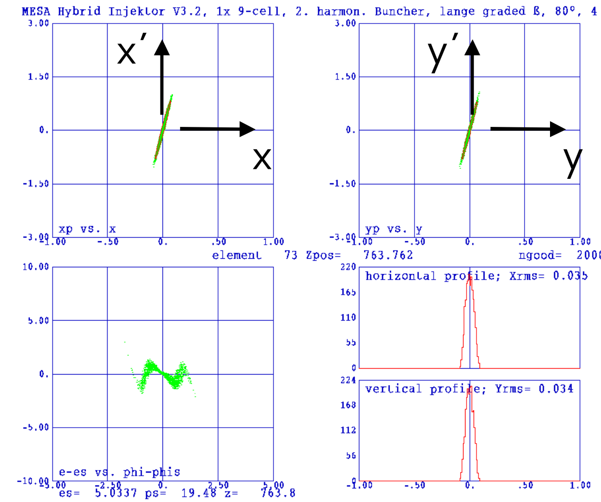


E= 4.65 MV/m P_c=4,5 W

$\boxed{\Sigma P_g = 74.2 \text{ kW}}$

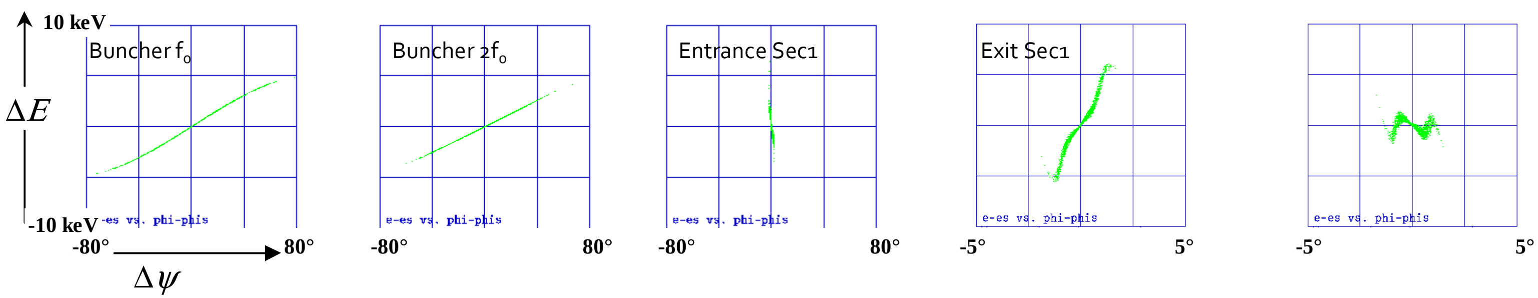
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 1$

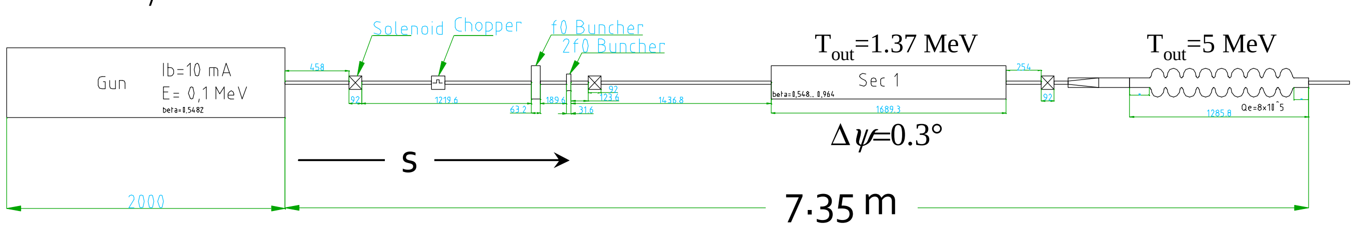




($\Delta\varepsilon_{x,n}$=2,5%)

T=5.03 MeV $\Delta\psi_{100\%} < \pm 1.7°$ $\Delta T/T_{rms}$=0.01%





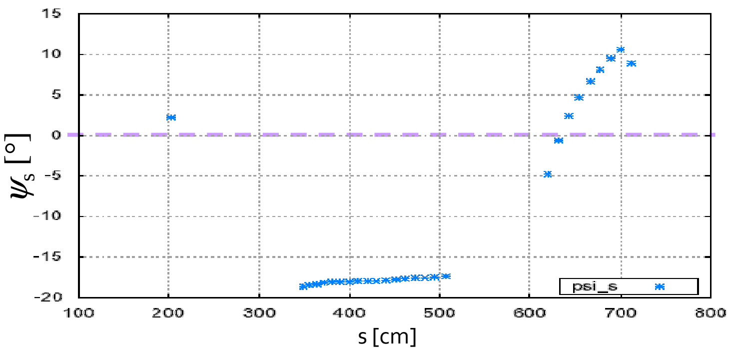
E= 4.65 MV/m P_c=4,5 W

ΣP_g= 74.2 kW

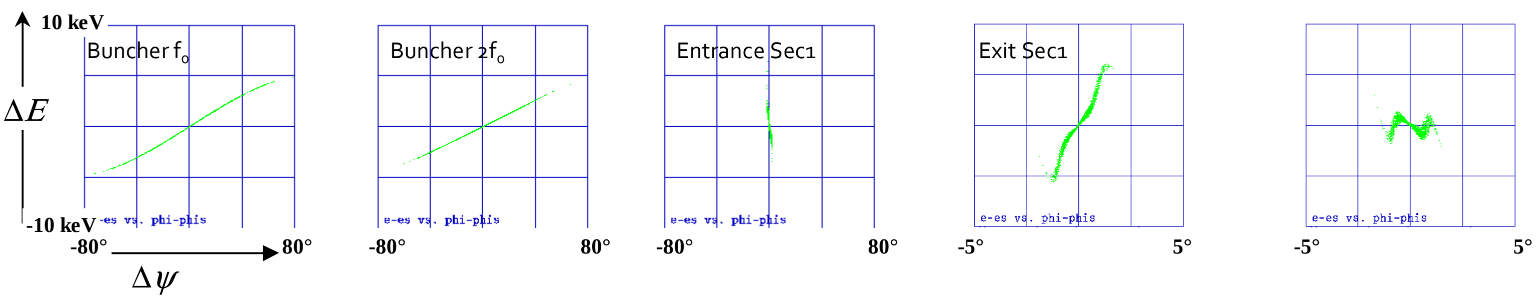
Hybrid Injector V3

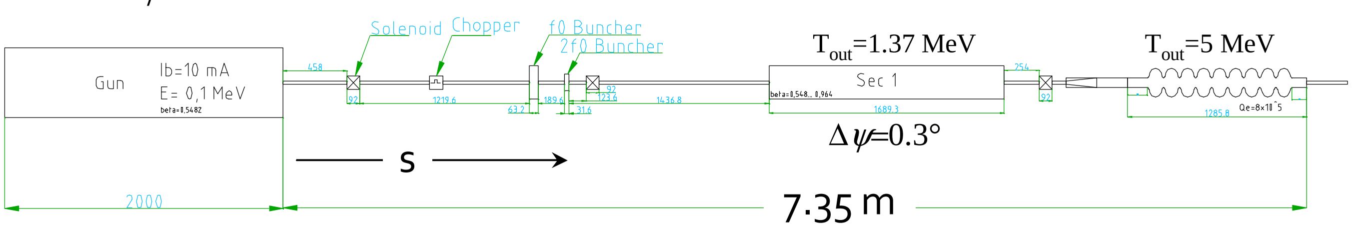
- Section 1: $\beta = 0.548 - 0.964$ (graded β)
- Section 2: $\beta = 1$

+ Solution meets all demands!
+ Injector is compact
- SRF needs more investment cost
- Larger LHe system necessary



T=5.03 MeV ✓ $\Delta\psi_{100\%} < \pm 1.7°$ ✓ $\Delta T/T_{rms}$=0.01% ✓





E= 4.65 MV/m P_c=4,5 W

$\boxed{\Sigma P_g = 74.2 \text{ kW}}$

Summary

- Several configurations of the MESA injector have been presented
- Two concepts were followed: a completely normal conducting and a hybrid superconducting concept
- Both concepts are competitive
- The hybrid concept gives a smaller long. phase space, is more compact and technologically more interesting
- The normal conducting concept has a slightly larger long. phase space, is more space consuming but based on established technology

Thank you for your kind attention!