Optimization of the capture section

Viktor Mytrochenko on behalf of
IJCLab FCC ee team

Outline

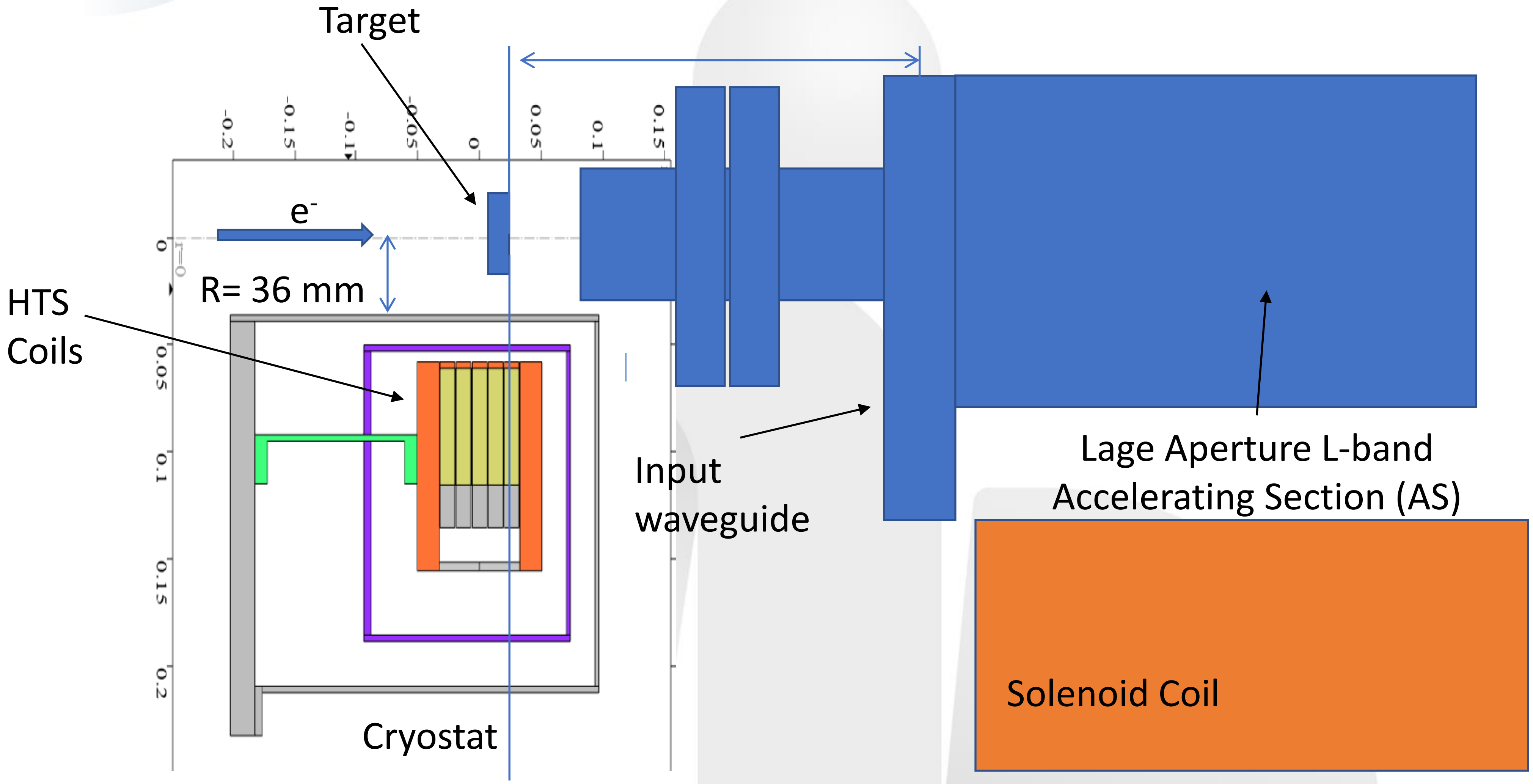
- Activity on FCC ee positron capture linac R&D using the Astra code in general
- In more detail about the hardware based initial part of the FCC ee positron linac consisting of HTS coils as a matching device and the five 3-meter-long 9/10π large aperture L-band accelerating sections
- Less hardware based initial part of the FCC ee positron linac consisting of an AMD with theoretical field and four 4.3-meter-long 9/10π large aperture L-band accelerating sections

Laboratoire de Physique des 2 Infinis

Activity on FCC ee positron capture linac R&D using the Astra code

- Benchmark ASTRA code application simulating the SuperKEKB positron capture linac;
  - 3D magnetic field maps of the flux concentrator and solenoids were accommodated
  - So far beam dynamics from the target to the exit of the first accelerating section has been simulated. Results on positron yield is in good agreement with SuperKEKB data;
- Two variants of a FCC ee capture linac with five 2 GHz 3-meter-long $9/10\pi$ sections including the Version 0 configuration are under study
  - Usage of high temperature superconducting coils as a matching device make it possible to keep constant aperture with diameter of 60 mm along the linac starting from the target. It provide high positron yield (at least 7) at the linac exit. It is unclear now how much of these positrons can be accepted into 1.5 GeV damping ring and at which stage to tailor acceptable phase space. We suggest that longitudinal acceptance would be ±3.8% at 1540 MeV of energy spread (±59 MeV) and 16.7 mm of longitudinal spread. Preliminary study of two types of chicane systems at 200 MeV shows substantial transversal emittance delusion for such parameters.
- Variant of the linac consisting of four 4.3-meter-long $9/10\pi$ sections and theoretical magnetic field of an AMD combined with constant solenoidal field along the linac was studied.
  - Results shows that it provide more compact bunches and total positron yield of about 9 (accepted yield cropped by 118 MeV and 16.7 mm window is about 8.4).

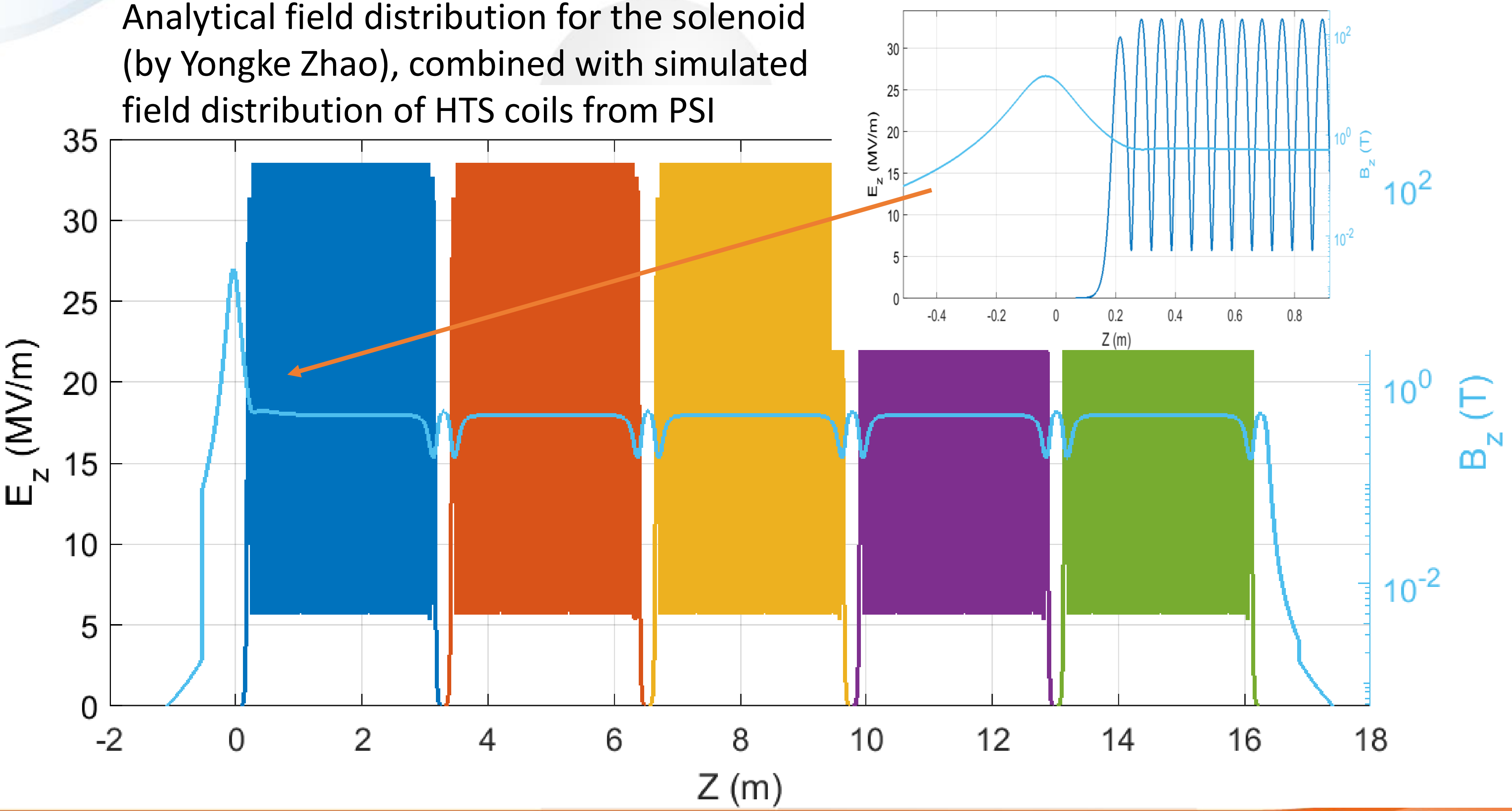
Schematic layout of the linac entrance



Magnetic and electrical on-axis fields distributions

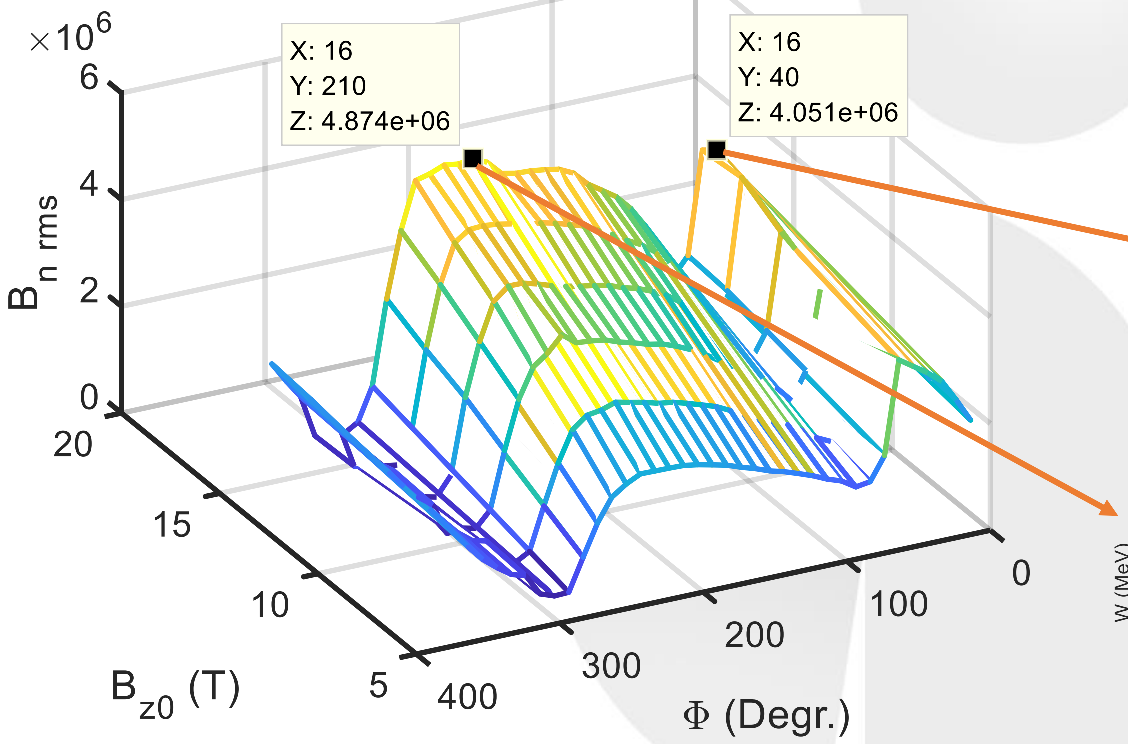
For minimum available distance between the cryostat and the section

Analytical field distribution for the solenoid (by Yongke Zhao), combined with simulated field distribution of HTS coils from PSI



Solenoid field is constant

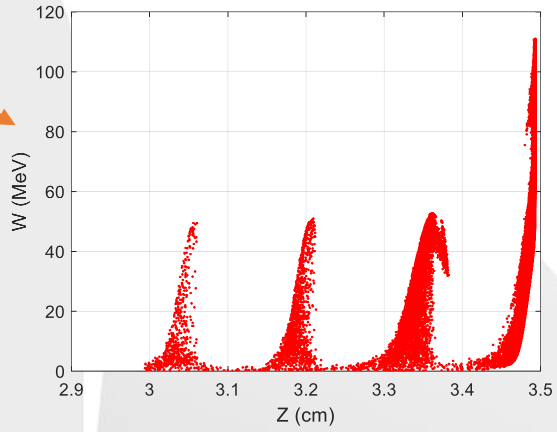
Characteristic result:
Two picks in distribution

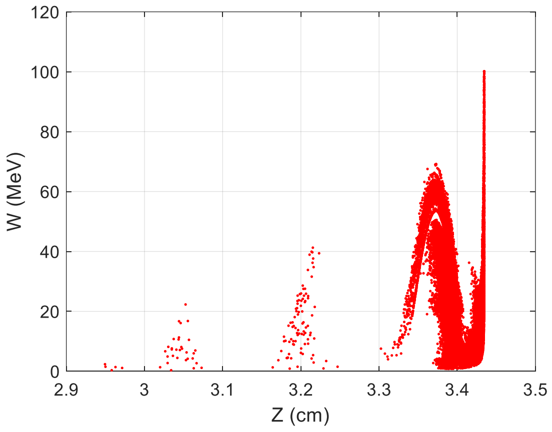


Normalized brightness

$$B_{n\,rms} = \frac{2I}{\varepsilon_{n\,x\,rms} \cdot \varepsilon_{n\,y\,rms}}$$

$$2I \propto \frac{N_p}{\Delta\Phi}$$





Phase of the sections	Phase of maximum energy gain of reference particle	Optimal phase	Φ_{opt} - Φ_{ref} (±180°)	Phases from Yongke Zhao simulation	Difference
Φ_1 (degrees)	190	40	-150	-130	20
Φ_2 (degrees)	330	180	-150	-130	20
Φ_3 (degrees)	100	320	-140	-130	10
Φ_4 (degrees)	240	130	-110	-75	35
Φ_5 (degrees)	20	270	-110	-75	35

Cropping window:

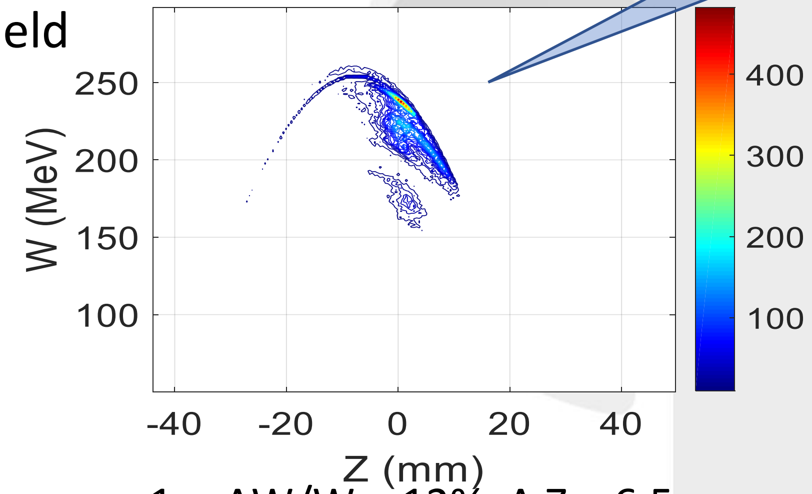
118 MeV

16.7 mm

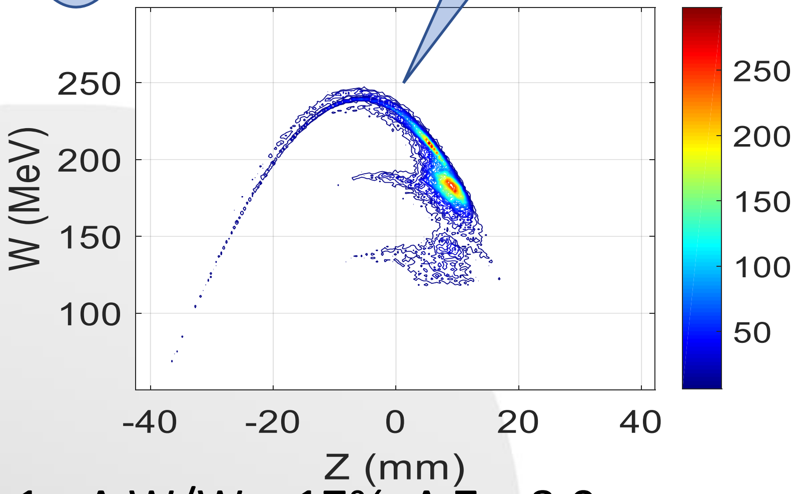
Window position adjusted to get maximum yield

Total Yield is 7.6

Accepted Yield is 6.7



1σ $\Delta W/W$ = 12%, ΔZ = 6.5 mm



1σ $\Delta W/W$ = 17%, ΔZ = 8.0 mm

Total Yield is 7.4

Accepted Yield is 6.3

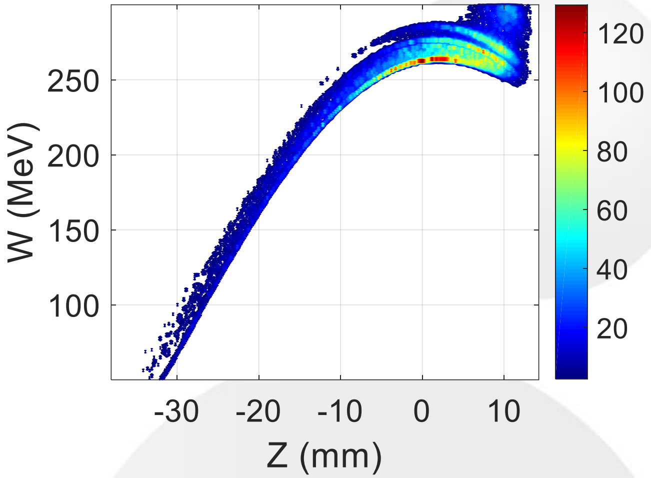
Yongke Zhao result is 5.6

Simulation of the linac Version 0

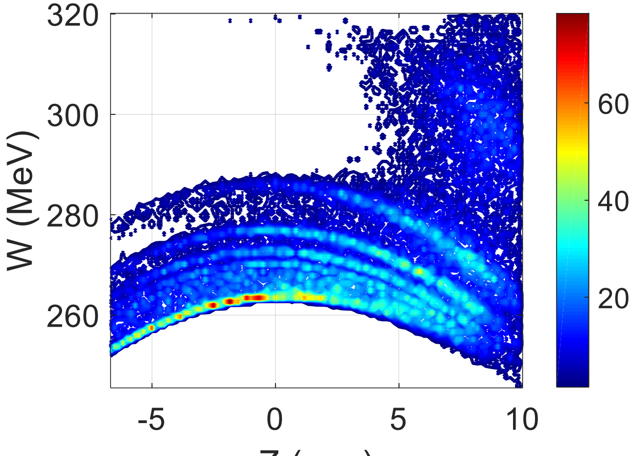
- Several scenarios for automatic linac tuning were considered
  - Maximal brightness after each section
  - Maximal yield after each section
  - Maximal brightness after the first section and then maximal energy gain

Results for the last scenario is shown here because the other ones do not provide enough energy gain

Phase of the first accelerating section is 70°

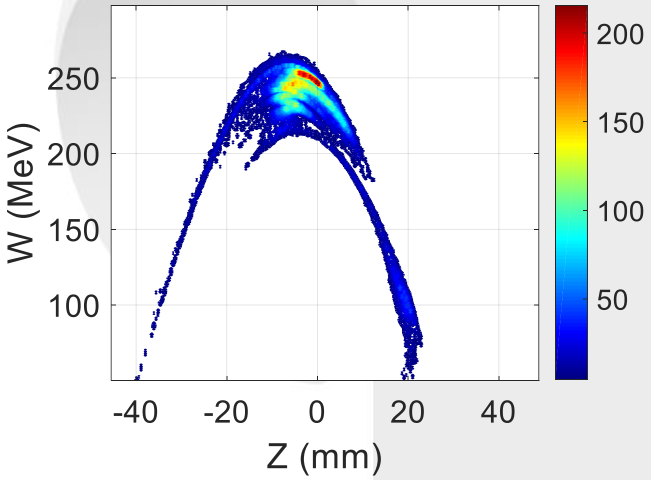


Total Yield is 6.8

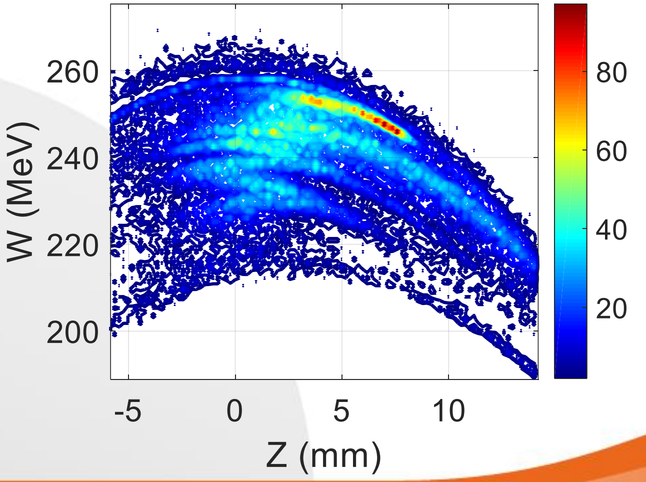


Accepted Yield is 5.5

Phase of the first accelerating section is 320 °



Total Yield is 7.6



Accepted Yield is 6.0

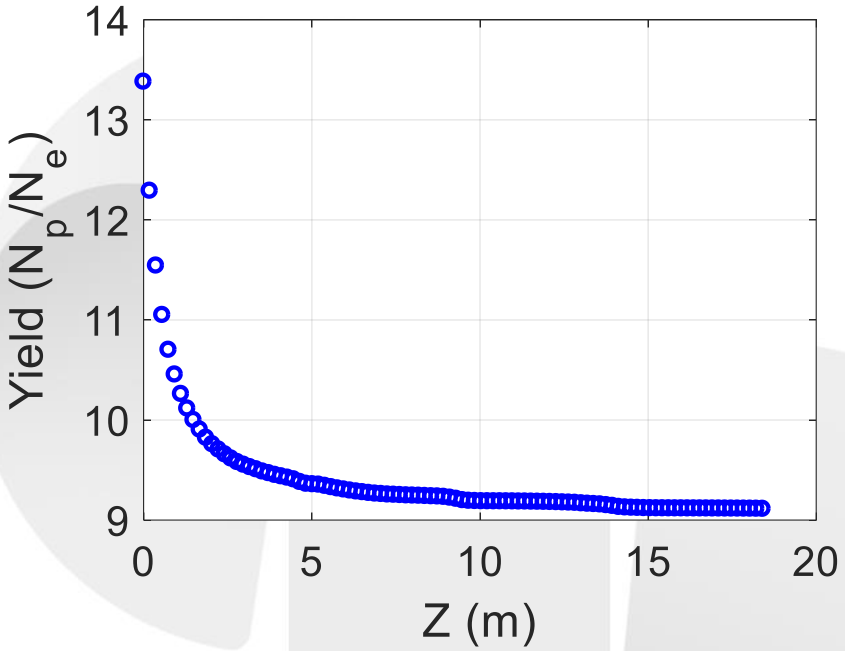
Four 4.3 m long accelerating sections. Energy gain is 15 MV/m. Distance between accelerating sections is 35 cm. Theoretical magnetic field of AMD combined with constant solenoidal field along the linac.

Results for α=60 1/m

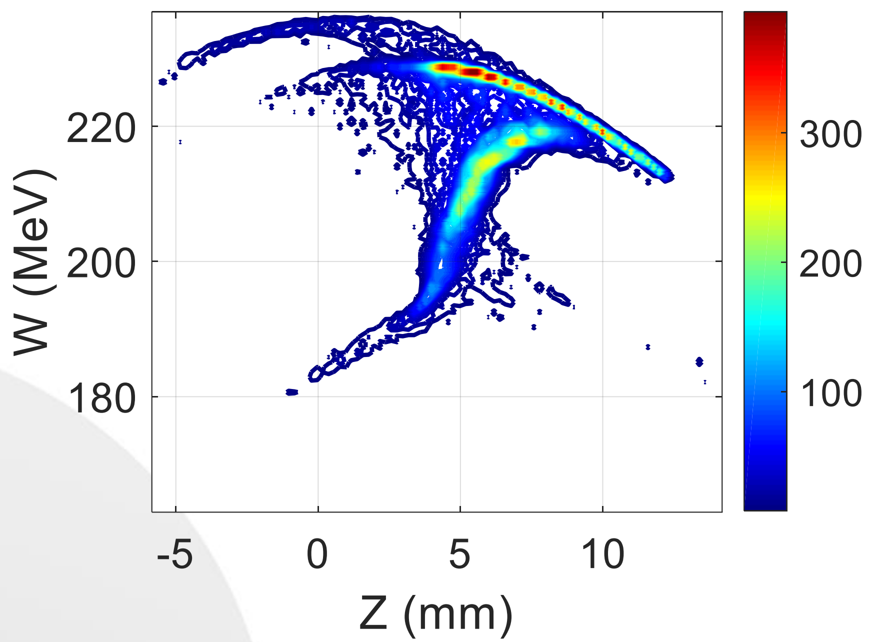
$$B_z = \frac{B_0}{1+\alpha z} + B_{sol}$$

$B_0 = 12\ T$

$B_{sol} = 0.5\ T$



Total yield is 9.2



Accepted yield is 8.4

Comparison

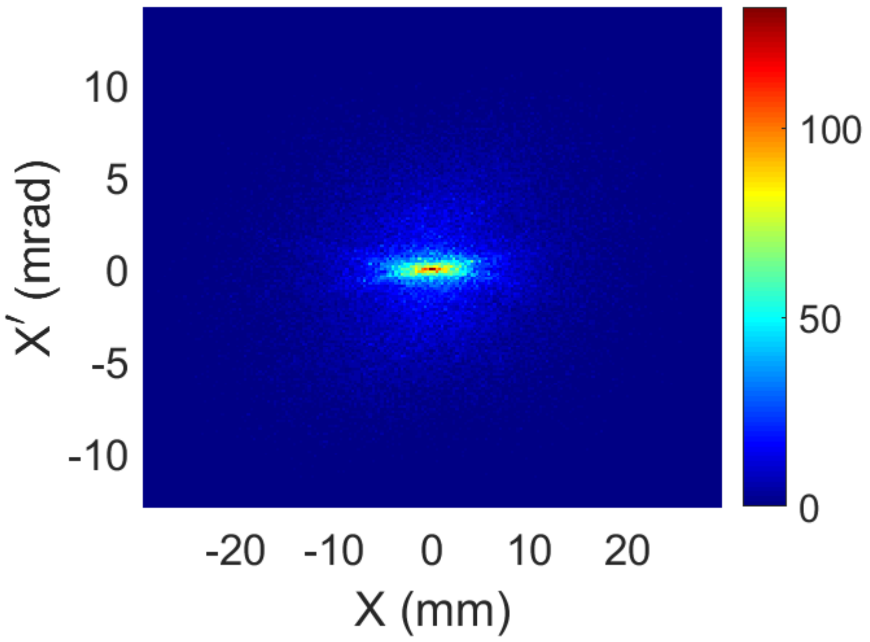
Beam parameters at the capture linac exit withing accepted window	5 3m-long-sections, minimal distance from the cryostat		5 3m-long-sections, version zero configuration		4 4.3m-long-sections
	Our phase set	Yongke phase set	Φ_1 = 70°	Φ_1 = 320°	
Accepted Yield	6.3	6.3 (5.6)	5.5	6.0	8.4
Mean Energy, MeV	217	187	274	239	217
$\varepsilon_{n\ x,y\ rms}$, mm·mrad	8980	9410	11375	11226	11494
$\sigma_{x,y}$, mm	7.9	8.6	8.0	7.8	8.1
ΔW/W rms, %	9.2	13.3	5.2	5.1	5.1
σ_z, mm	3.4	3.4	4.5	4.5	2.8

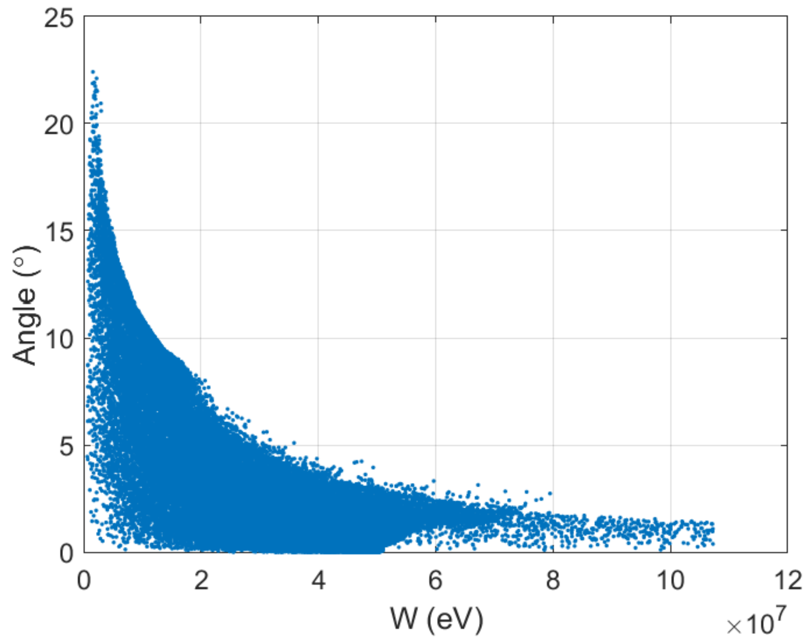
Conclusion

- Application of HTS coils as a matching device and a large aperture L-band linac make it possible to transport a huge number of positrons through a capture linac. It rises question how to manage their high phase space and at what stage to separate positrons from electrons as well as where to tailor acceptable phase space for a damping ring.
- In our opinion the 5D normalized brightness is useful parameter to optimize linac settings especially for the first section.
- There are two picks in beam normalized brightness dependence on field phase of the first accelerating section, which correspond to acceleration the head or the tail of the initial longitudinal distribution. The last one provide higher positron yield.
- There are some discrepancy between ASTRA and RF-Track results. Maybe the problem is in representation the same linac layout. The work on benchmarking is in progress.
- Results on higher yield obtained for use of 4.3-meter-long accelerating sections and theoretical magnetic field distribution of the AMD may indicate that field distribution of the HTS coils and accelerating section length need to be further optimized.

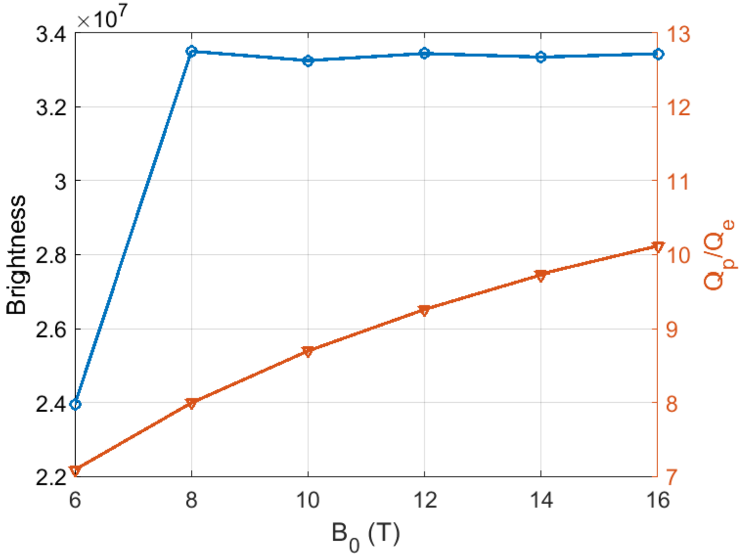
Thank you for your attention

- x rms = 8.0 mm
- emit x rms = 11391 mm*mrad
- y rms = 8.0 mm
- emit y rms = 11354 mm*mrad

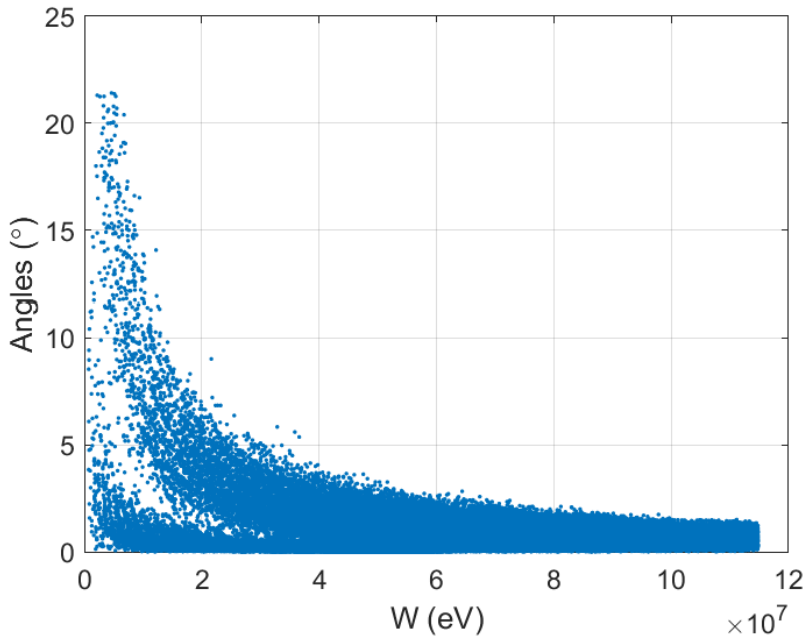




Φ=190°



Φ=190°



Φ=0°