ESS Accelerator Lattice Design Studies and Automatic Synoptic Deployment

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ICAP'18

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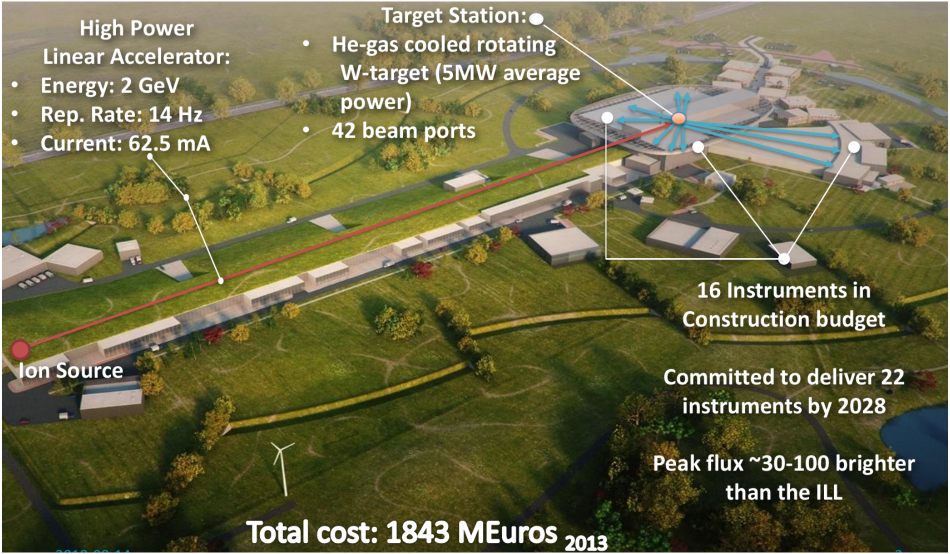
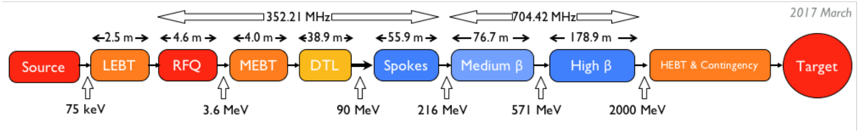


ESS Overview

ESS Overview
The ESS Linac



Parameter	Value	Unit
Average Power	5	MW
Final Energy	2	GeV
Peak Current	62.5	mA
Pulse Length	2.86	ms
Repetition Rate	14	Hz
Duty Cycle	4	%

Lattice Change Control & Deployment

The Challenge

- The beam physics design lattice is where element locations originate from in the beginning
- When a machine is built, the survey/alignment data tells you where the element is (or say, ended up)
- In between design start, and machine built, it can be unclear where things are located.

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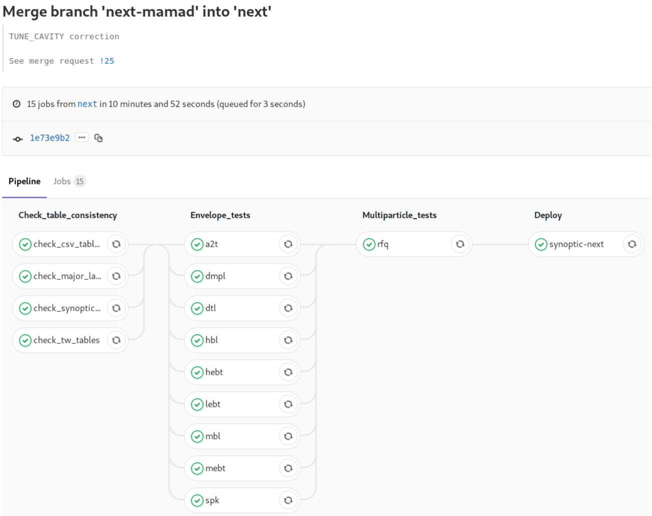
We want to..

- Provide engineers with the information we have (TraceWin files are not readable in this context)
- Try to keep things automated so that once discrepancies are found and corrected they stay corrected.
- Provide the data in a friendly format.

Lattice Change Control & Deployment



Lattice Change Control & Deployment

Merge branch 'next-mamad' into 'next'

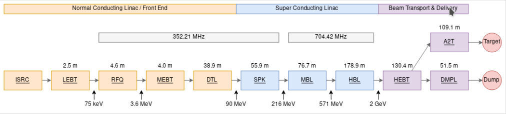
```
TUNE_CAVITY correction

See merge request !25
```

15 jobs from next in 10 minutes and 52 seconds (queued for 3 seconds)

1e73e9b2

Pipeline Jobs 15

Che



Baseline lattice (version 2017.v1)

- LEBT
- RFQ-MEBT
- DTL
- SPK
- MBL
- HBL
- HEBT
- A2T
- DumpL

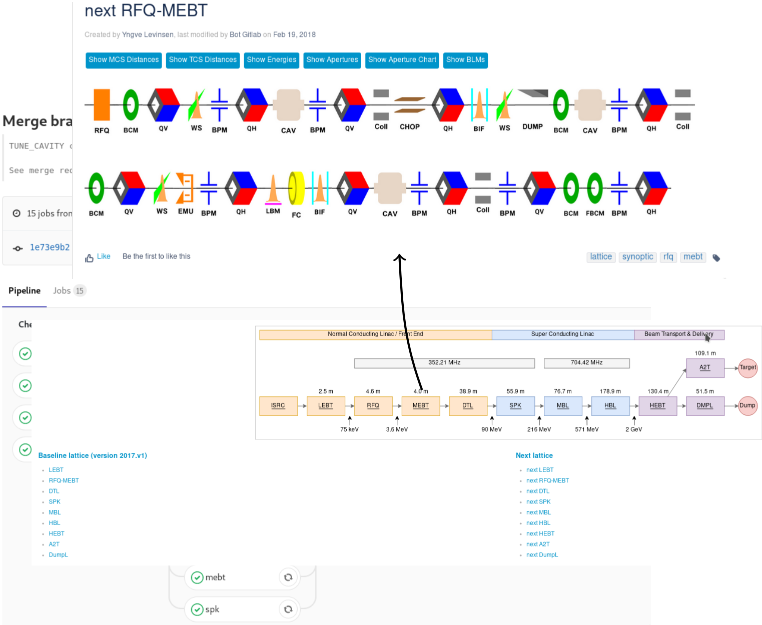
Next lattice

- next LEBT
- next RFQ-MEBT
- next DTL
- next SPK
- next MBL
- next HBL
- next HEBT
- next A2T
- next DumpL

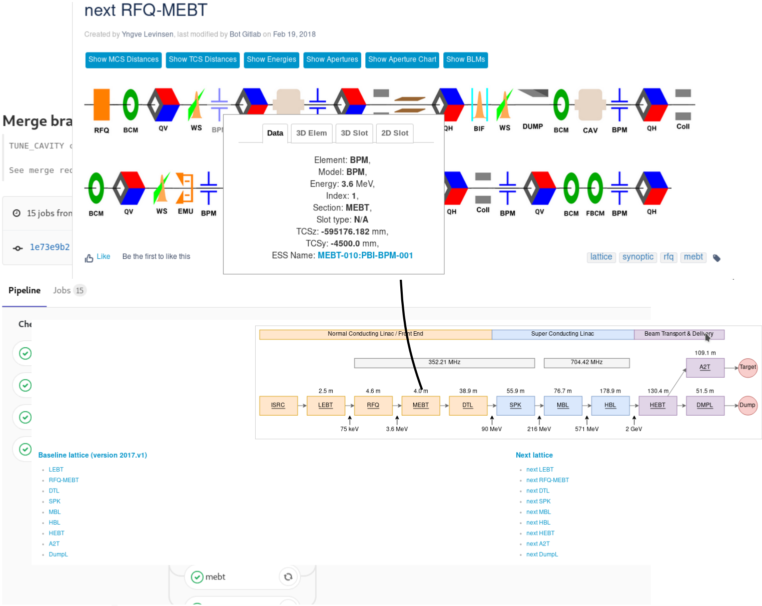
mebt

spk

Lattice Change Control & Deployment



Lattice Change Control & Deployment



Integrated Error Studies

Boundary conditions

- Excellent loss control $\rightarrow$ 1 W/m loss limit

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- Excellent loss control $\rightarrow$ 1 W/m loss limit
- Mainly losing particles from longitudinal phase space
  - strong space charge and tune depression
  - mismatch
  - non-linear fields
  - RF field changes/errors
  - errors (misalignment, machining, construction, ...)

Integrated Error Studies

Boundary conditions

- Excellent loss control $\rightarrow$ 1 W/m loss limit
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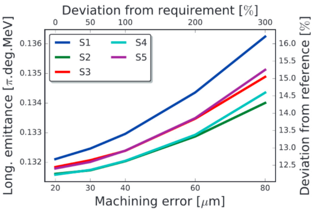
  - strong space charge and tune depression
  - mismatch
  - non-linear fields
  - RF field changes/errors
  - errors (misalignment, machining, construction, ...)
- Want to see if we can include source, LEBT and RFQ in a complete error study.

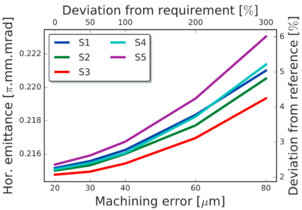
What errors do we consider?

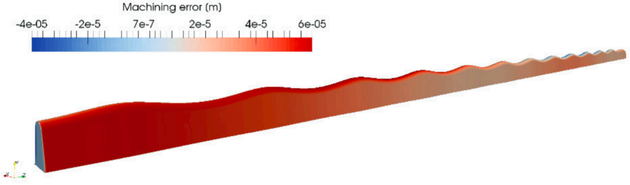
Static	
Magnets	displacement, rotation, gradient
Cavities	displacement, rotation, amplitude, phase
Instrumentation	accuracy
RFQ	field errors
Dynamic	
Cavities	amplitude, phase
Instrumentation	accuracy

Integrated Error Studies

RFQ Tolerances

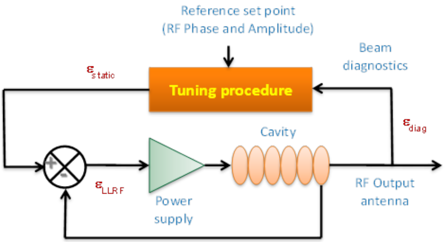






From A. Ponton, TUPAF067 IPAC'18

Integrated Error Studies



D. Uriot, TraceWin manual

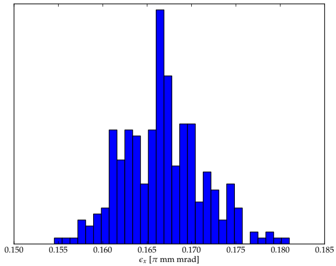
Integrated Error Studies

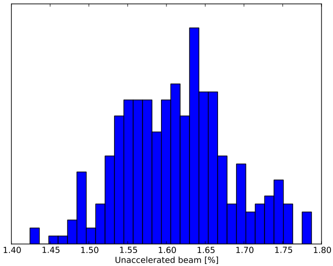
Steps

- Ion Source simulation (IBSimu)
- LEBT with static displacement of solenoids, correctors, diagnostics, correct (envelope?), track (multiparticle)
- RFQ, vane profile randomly generated based on requirements, track (multiparticle)
- MEBT-A2T, static errors, correct (envelope), dynamic errors, track (multiparticle)

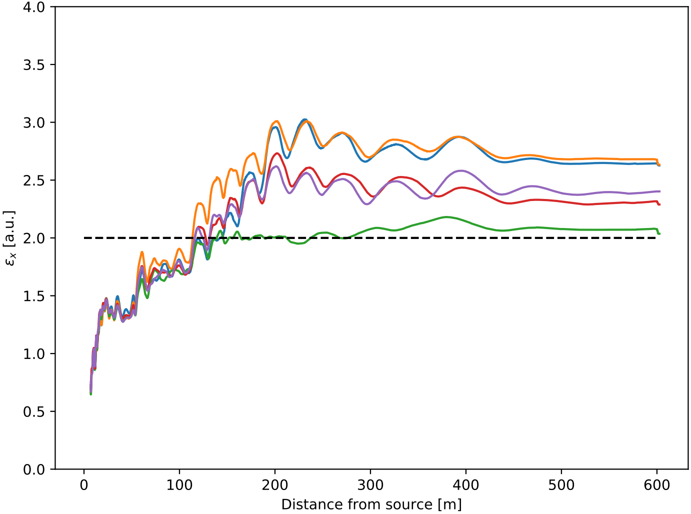
Integrated Error Studies

Beam out of RFQ

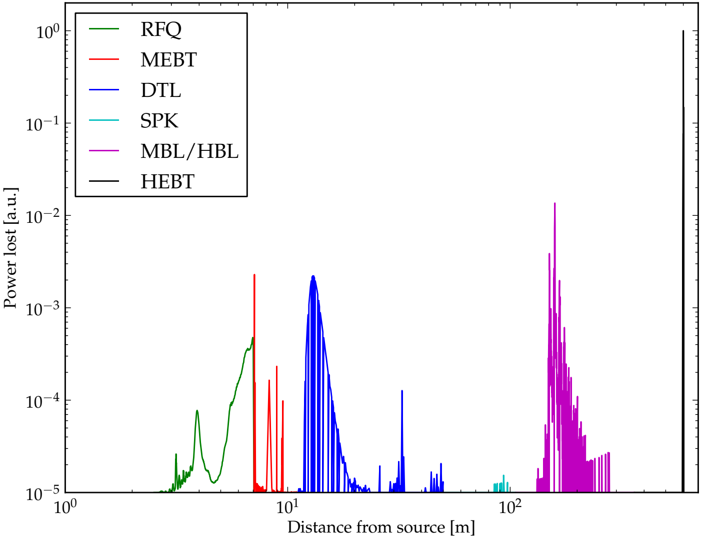




Integrated Error Studies

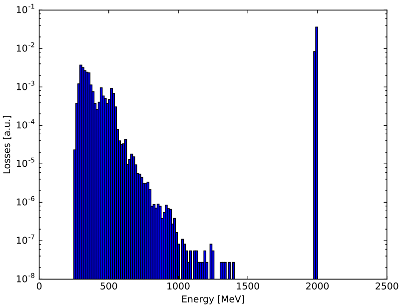


Integrated Error Studies



Integrated Error Studies

Energy distribution of losses in HEBT (HB'16)



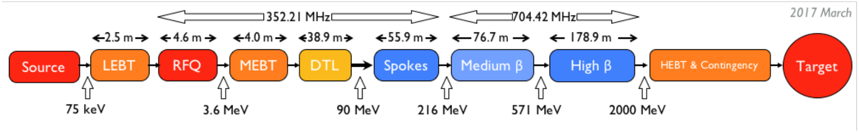
Frequency jump at 216 MeV clear source of losses

Summary

- The ESS construction is moving forward at full force
- We have developed a procedure for lattice control and automatic deployment which has proven useful to us
- Error study starting from source is looking promising but need some more polishing

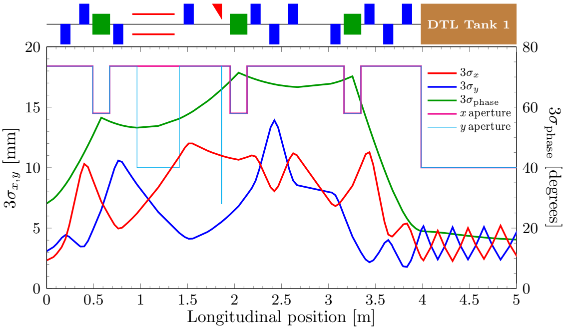
Backup

The ESS Linac



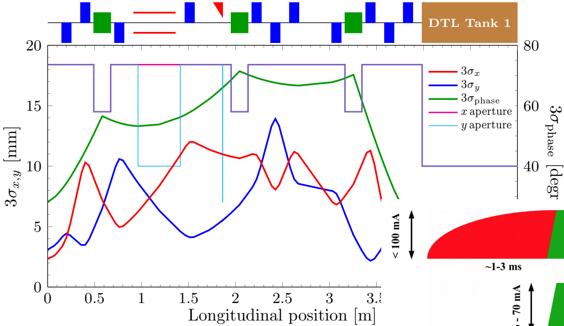
	Energy [MeV]	# modules	cav./mod.	$\beta\gamma$	Temp. [K]	Length [m]
Source	0.075	-	0	-	~ 300	-
LEBT	0.075	-	0	-	~ 300	2.5
RFQ	3.62	1	1	-	~ 300	4.6
MEBT	3.62	-	3	-	~ 300	4.0
DTL	90.0	5	-	-	~ 300	38.9
Spokes	216	13	2	-	~ 2	55.9
Med.-β	571	9	4(6C)	0.67	~ 2	76.7
High-β	2000	21	4(5C)	0.86	~ 2	178.9
HEBT	2000	-	-	-	~ 300	239.5

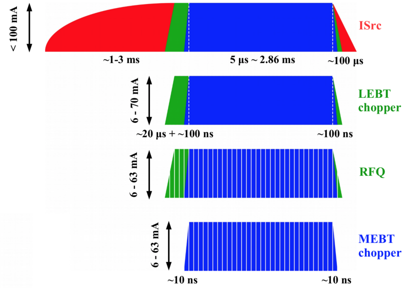
Backup



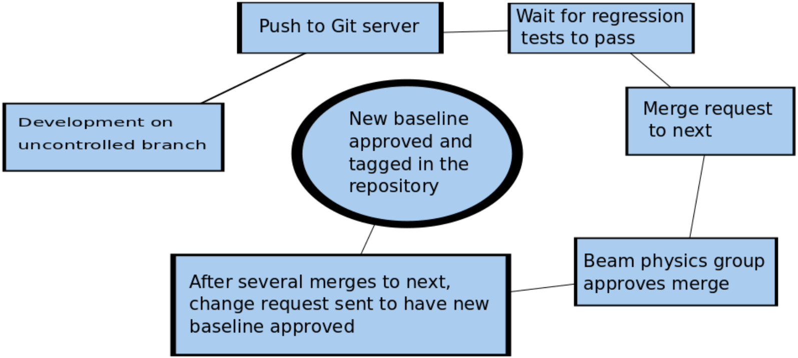
DTL Tank 1
20
15
10
5
0
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
$3\sigma_{x,y}$ [mm]
$3\sigma_{\text{phase}}$ [degrees]
Longitudinal position [m]
$3\sigma_x$
$3\sigma_y$
$3\sigma_{\text{phase}}$
x aperture
y aperture

Backup


DTL Tank 1
$3\sigma_x$
$3\sigma_y$
$3\sigma_{\text{phase}}$
x aperture
y aperture
$3\sigma_{x,y}$ [mm]
$3\sigma_{\text{phase}}$ [degr
Longitudinal position [m]


< 100 mA
~1-3 ms
5 µs ~ 2.86 ms
~100 µs
ISrc
6 - 70 mA
~20 µs + ~100 ns
~100 ns
LEBT chopper
6 - 63 mA
RFQ
6 - 63 mA
~10 ns
~10 ns
MEBT chopper

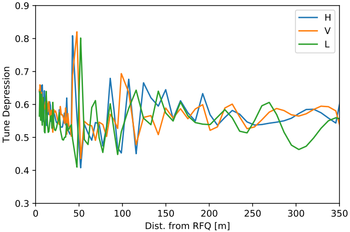
Backup

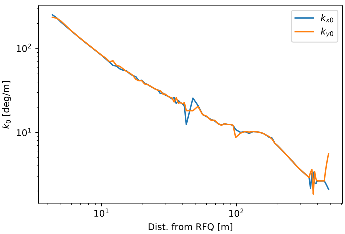

Push to Git server
Wait for regression tests to pass
Development on uncontrolled branch
New baseline approved and tagged in the repository
Merge request to next
Beam physics group approves merge
After several merges to next, change request sent to have new baseline approved

Design Main Guidelines

- The zero current phase advance per period in all the planes must be less than 90 deg
- The phase advance per meter (average phase advance) variation should be smooth and continuous
- On top of this we want the average phase advance to change monotonically
- The tune depression, k_{sc}/k_0 , must stay above 0.4 in all the planes during acceleration

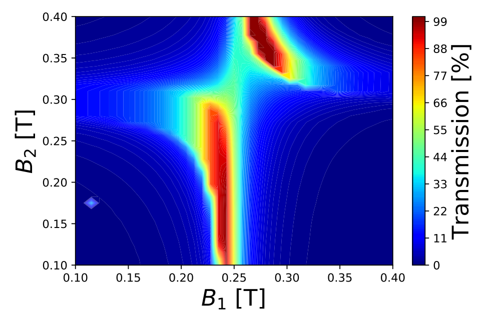
Backup
Tune Depression





Backup

LEBT Solenoid Transmission Scan



Courtesy A. Ponton

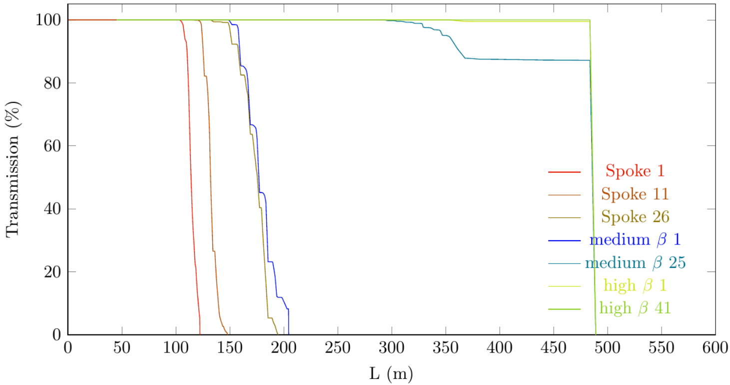
RFQ Tolerances

Parameter	Symbol	Mean value	90^{th} percentile range	Unit
Longitudinal emittance	ϵ_ℓ	0.1151	[0.1104; 0.1223]	π.deg.MeV
Transverse emittance	ϵ_t	0.2038	[0.1986; 0.2120]	π.mm.mrad
Transmission	T	0.9842	[0.9827; 0.9854]	%
Beam center offset	r	0.1266	[0.0027; 0.2548]	mm
Kinetic energy	W	3.6215	[3.6106; 3.6339]	MeV

- RFQ geometrical errors from machining, brazing, and assembly
- Affect RFQ fields by modulating quadrupolar terms and adding dipolar terms

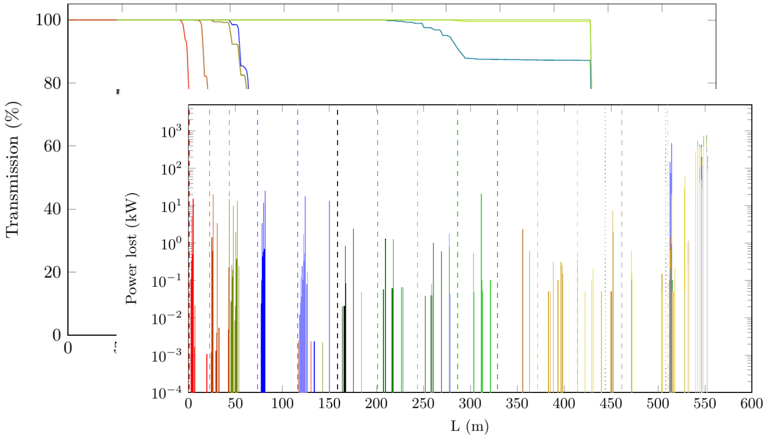
Backup

Failure Catalogue



Backup

Failure Catalogue



Failure Catalogue