Overview of the E-driven ILC Positron Source

LINEAR COLLIDER COLLABORATION

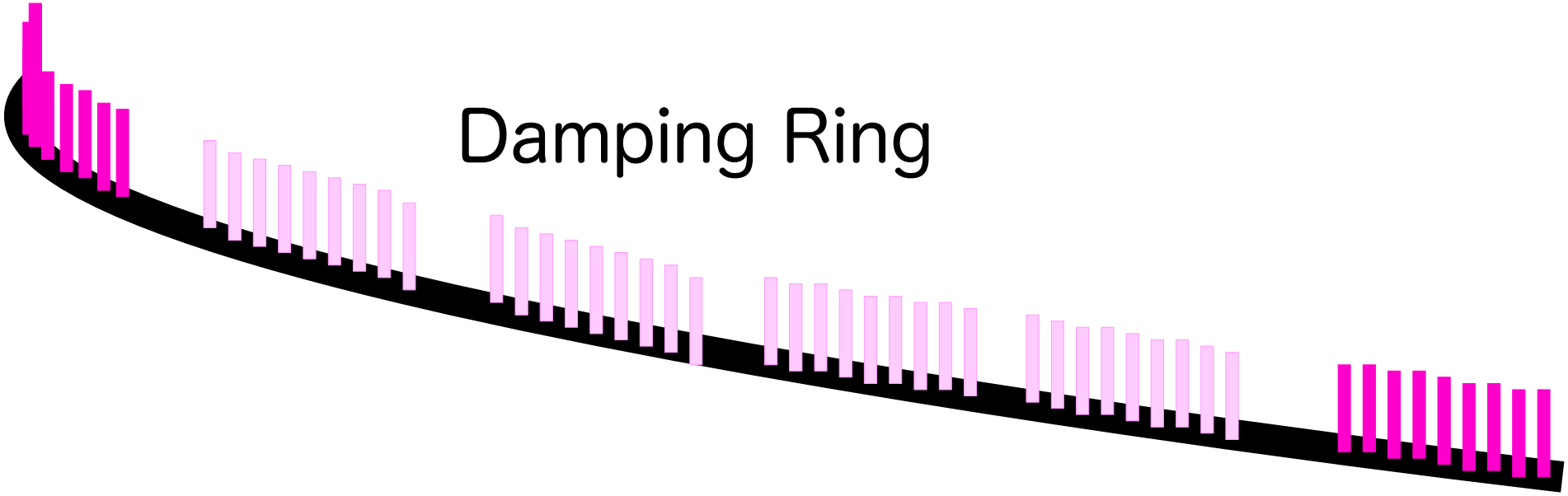
Designing the world's next great particle accelerator

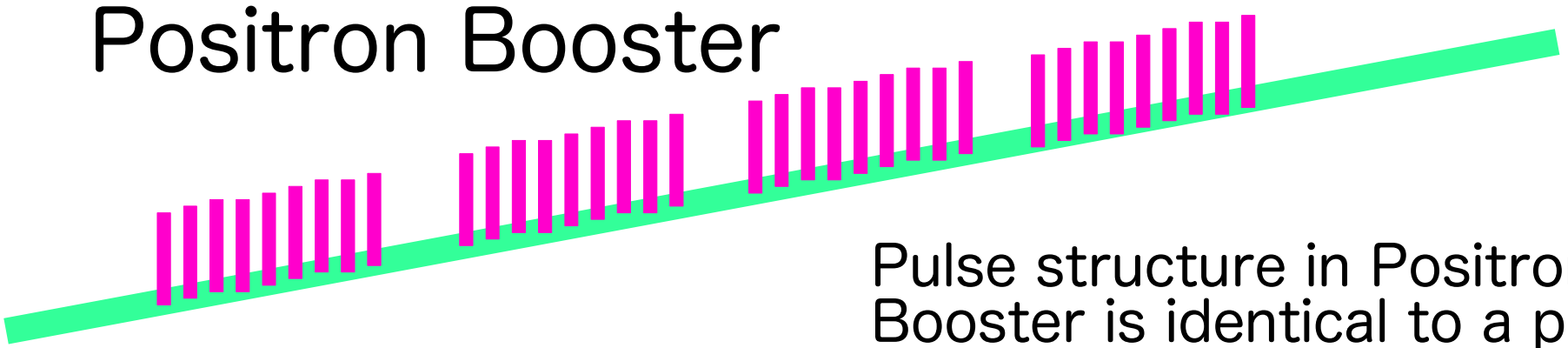
Masao KURIKI (Hiroshima University)

Basic Idea

- Number of positron per second for ILC is 50 times more than that for SLC.
- The target is easily damaged by heat load.
- Undulator: Only gamma rays (no Brems) to relax the heat load, but the beam format is fixed 2600 bunches in 1ms.
- E-driven: Expand “the positron pulse” to relax instantaneous heat rate, 2600 bunches in 63ms.
  - The positron is generated in 20 pulses which contains 130 bunches.
  - The pulse is repeated in 300Hz only for 63 ms of 200ms 5Hz operation period.

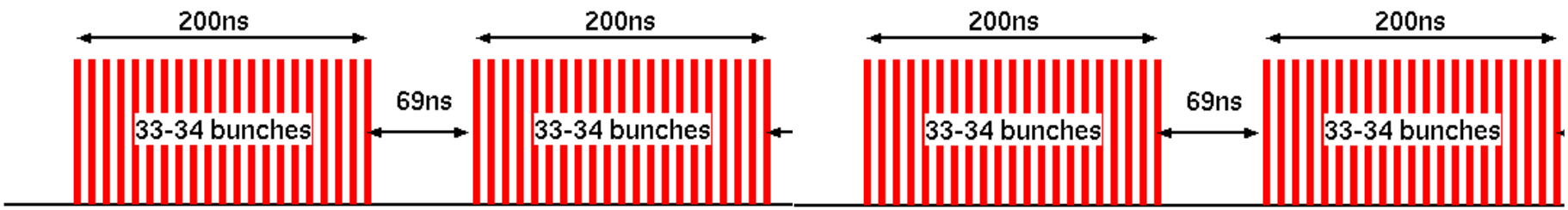
The beam handling and format

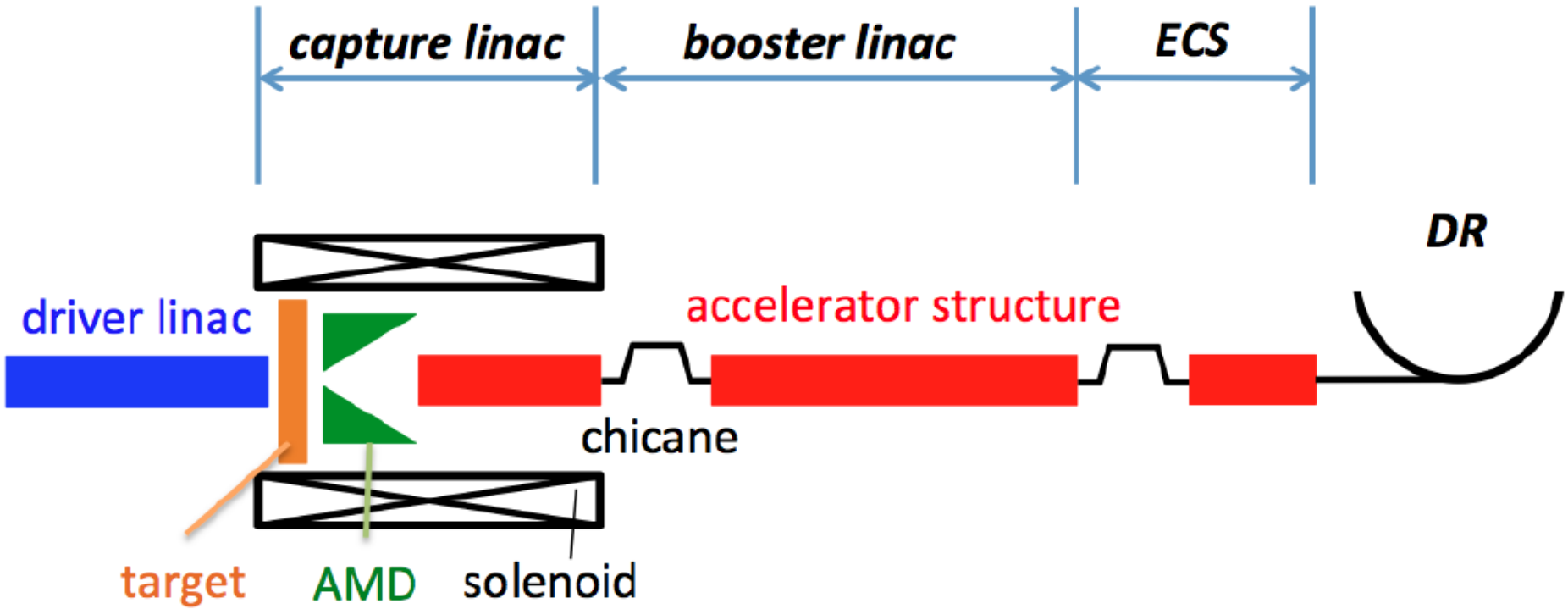




Pulse structure in Positron Booster is identical to a part of DR fill pattern.

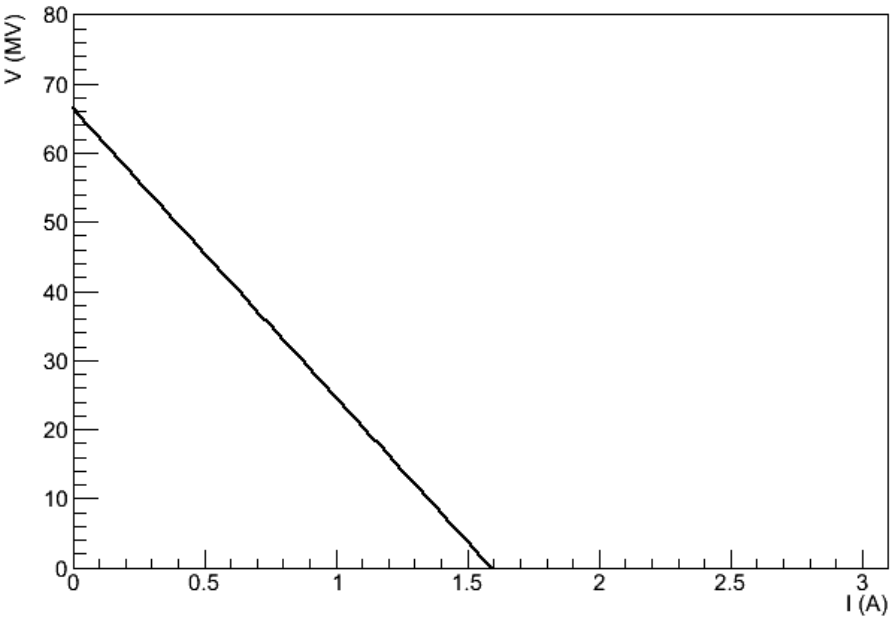
E-driven ILC Positron Source Configuration





Electron Driver

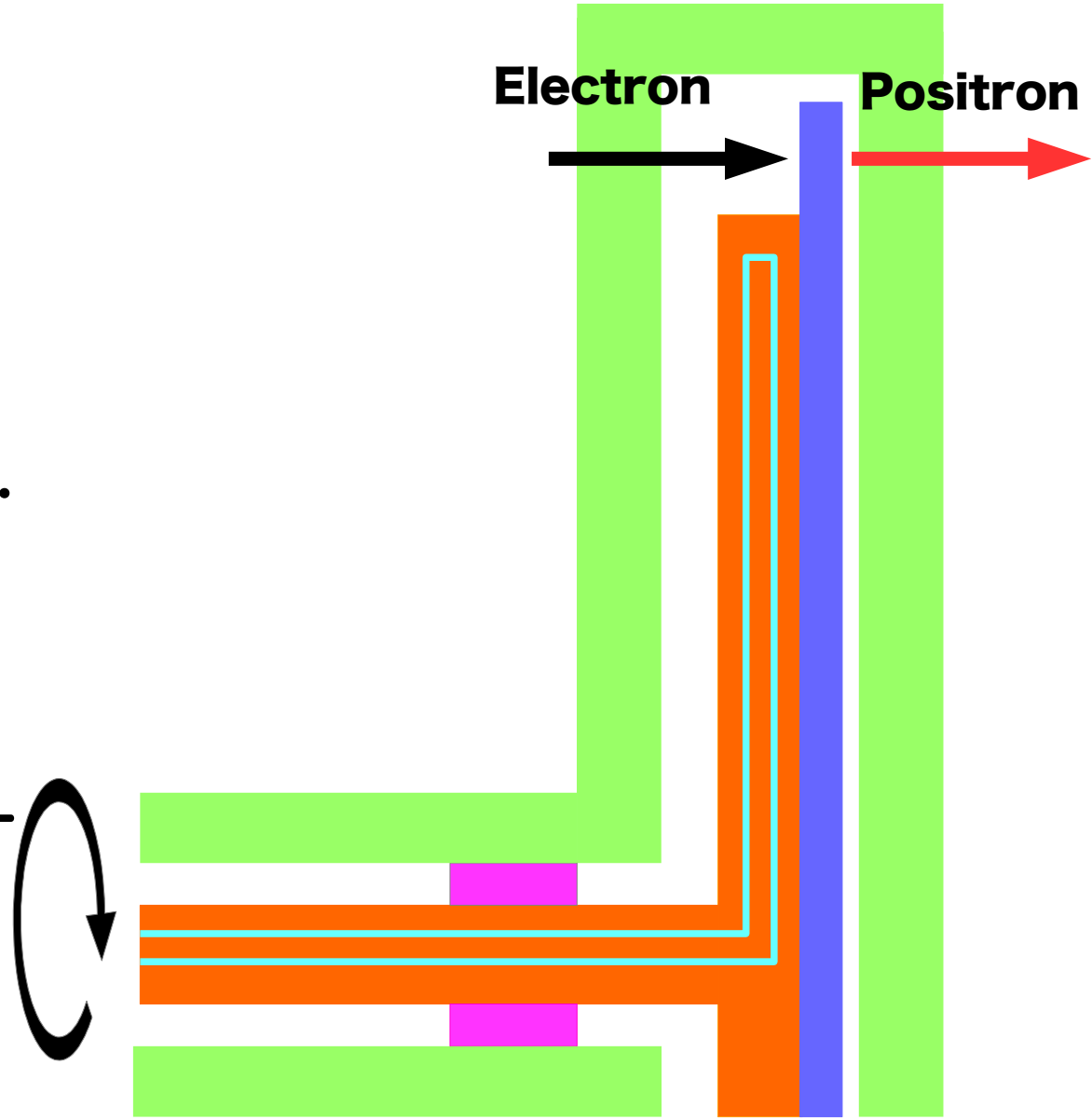
- 4.8 GeV Electron beam in the format with 3.8 nC bunch charge.
- S-band Photo-cathode RF gun for the beam generation.
- 120 of 3m S-band TW structures for the acceleration.
- 80 MW klystron-modulator drives 2 structures giving 40.1 MV/3m with 0.6A beam loading.



Lattice configuration	Number of cells	cell length	section length	Section energy
4Q + 2S	6	8.0 m	48.0 m	481 MeV
4Q + 4S	27	14.4 m	388.8 m	4330 MeV

Target

- W-Re 14mm thick.
- 5 m/s tangential speed rotation (180 rpm, 0.5m radius) in vacuum.
- Water cooling through channel.
- Vacuum seal with ferro-fluid.



Seal performance

- Leak rate 2×10^{-7} Pa.m^3/s at 1000 RPM.
- 1000 l/s pump capacity is enough to maintain UHV for accelerator.
- 1.5 MGy/year is expected for the seal. Irradiation test was performed at JAEA Takasaki lab..
- F-oil : Dissociation/degradation occurred at low dose, 0.27 MGy. No hope.
- CN-oil: 4.7 M. Gy. Viscosity increased, but NO dissociation degradation occurred. No additional leak was found with the irradiated seal at 0-600 RPM.

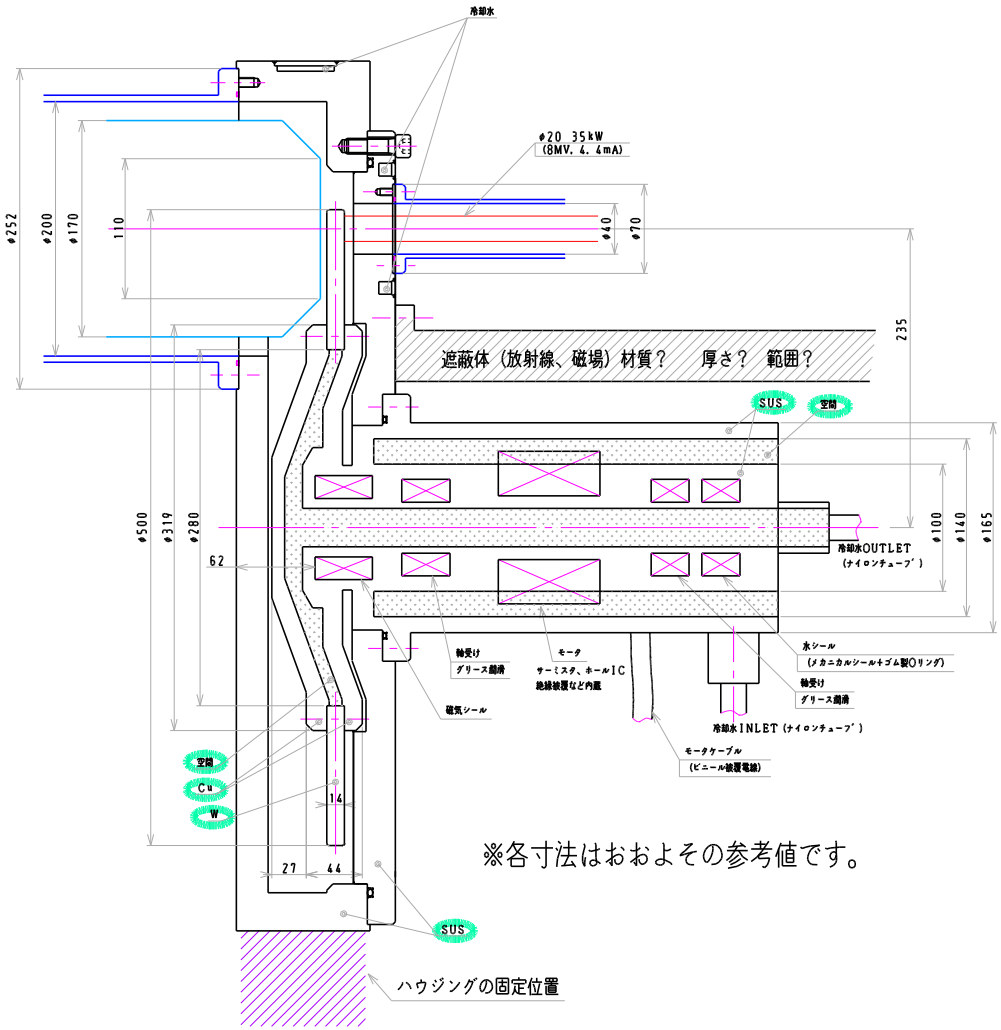
Rigaku

Rotation target design study

FY2014

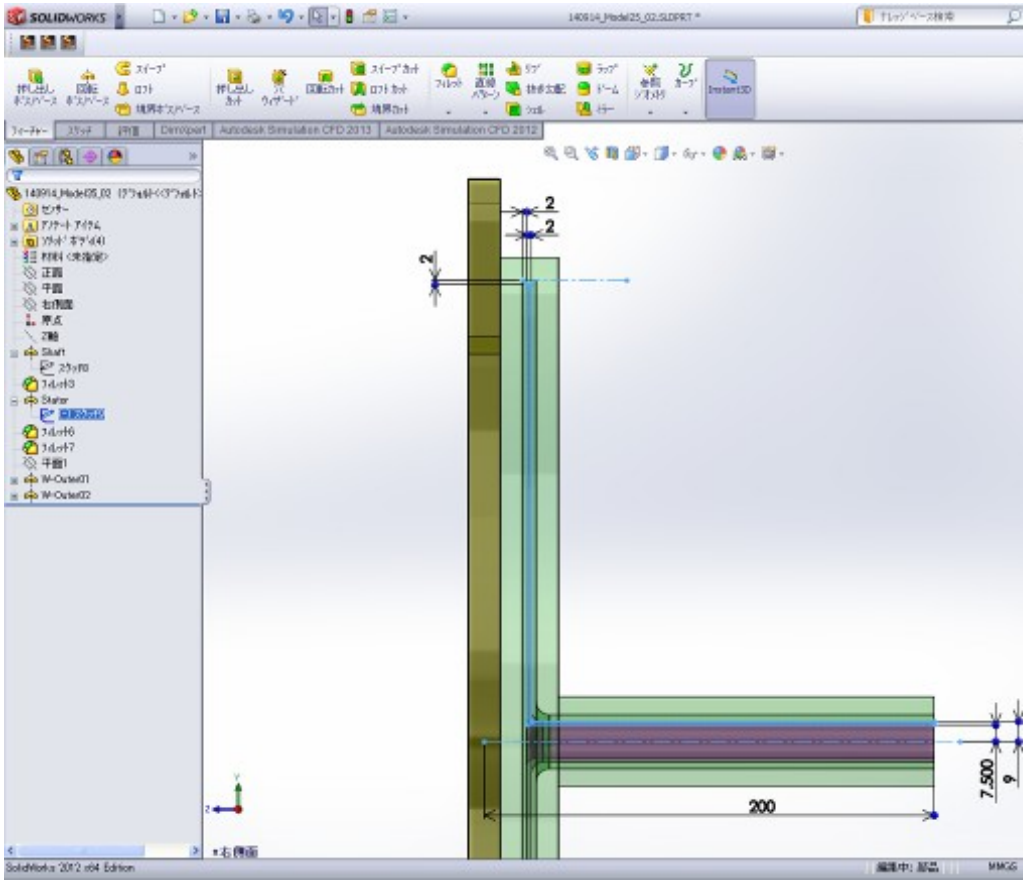
Ⅰ Direct Cooling

Ⅰ 直接冷却



Ⅱ Indirect Cooling

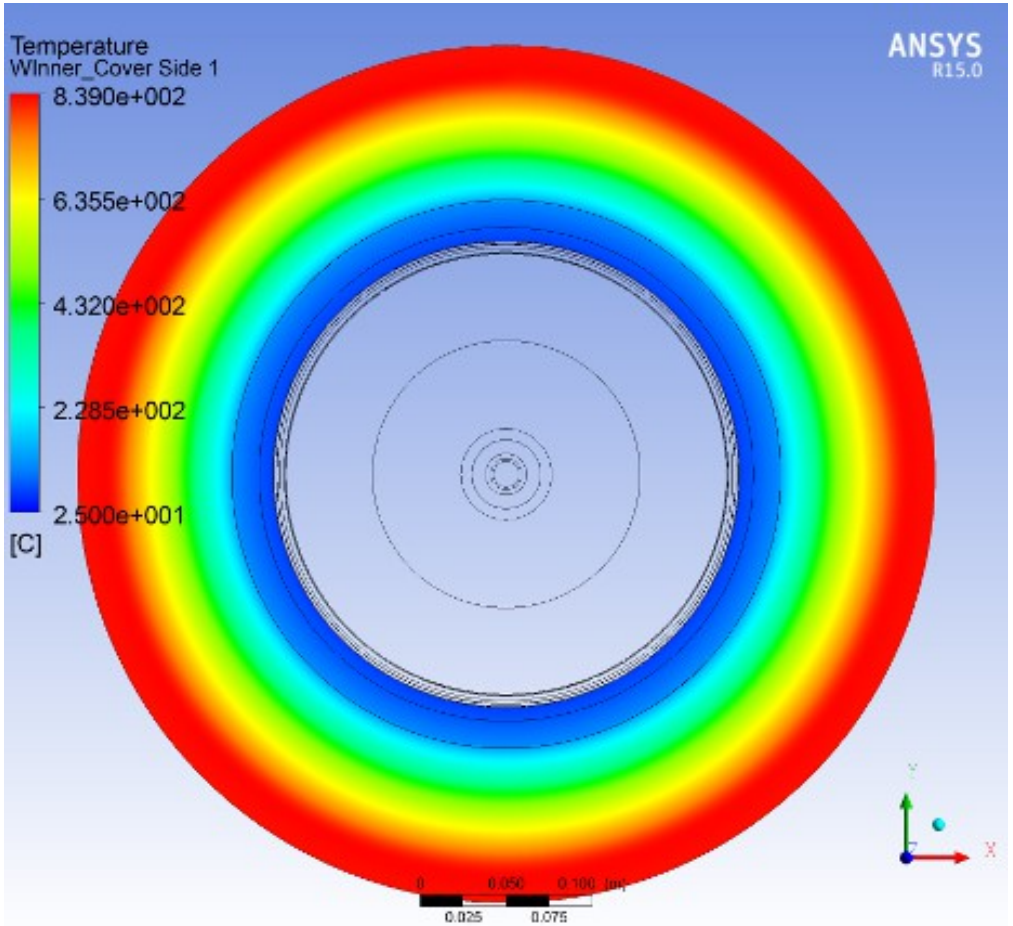
Ⅱ 間接冷却



Rigaku FY2014

Rotation target design study

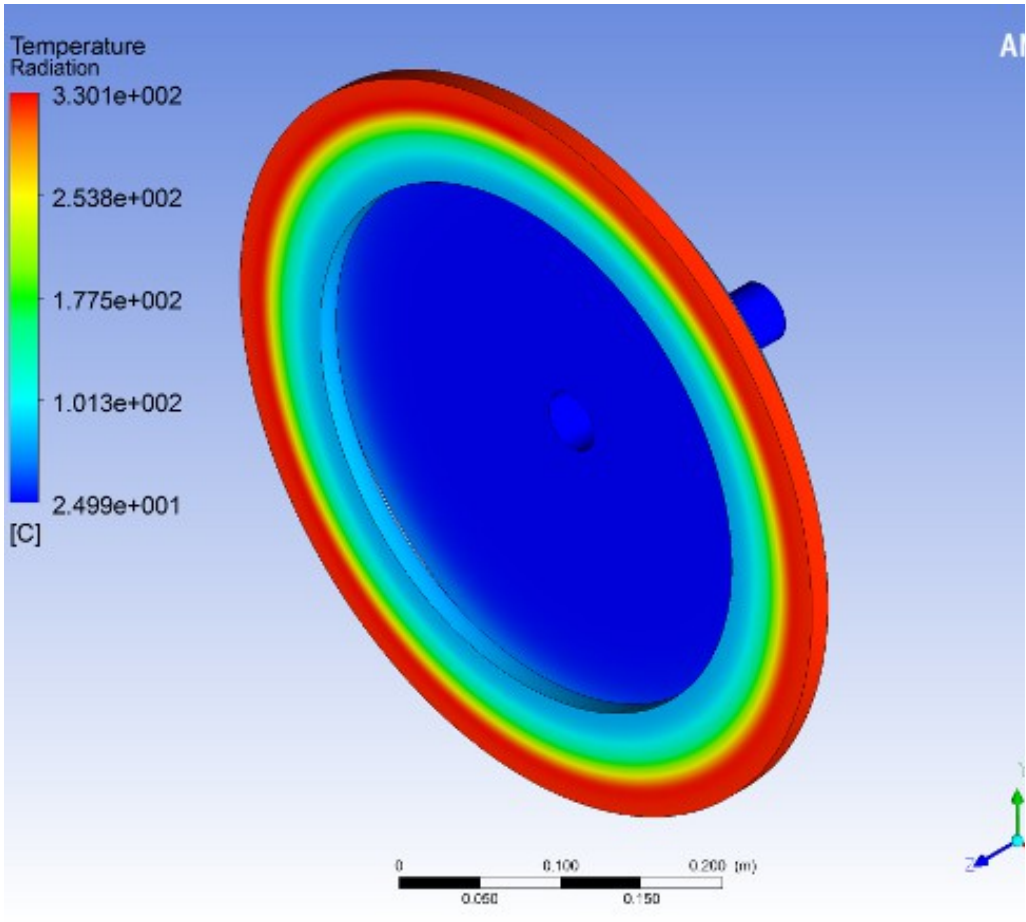
I Direct Cooling



Temperature Distribution

Max. 840℃

II Indirect Cooling



Temperature Distribution

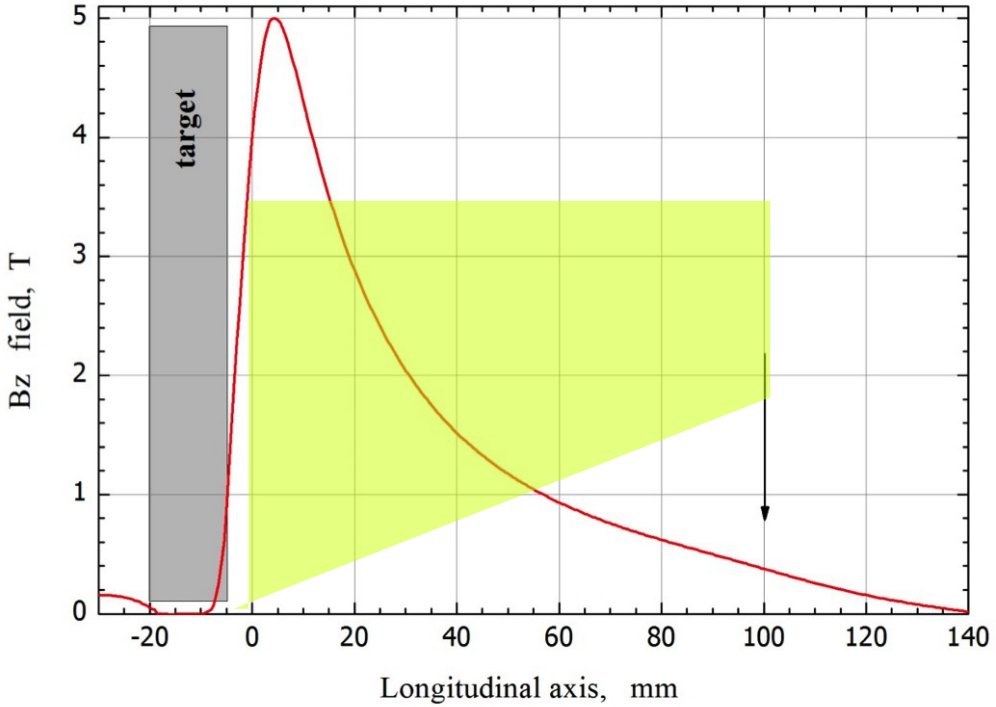
Max. 330℃

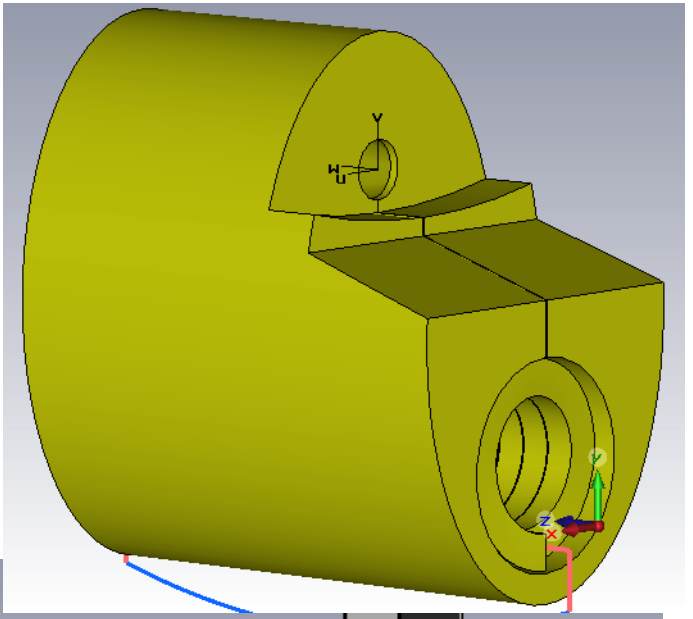
600rpm

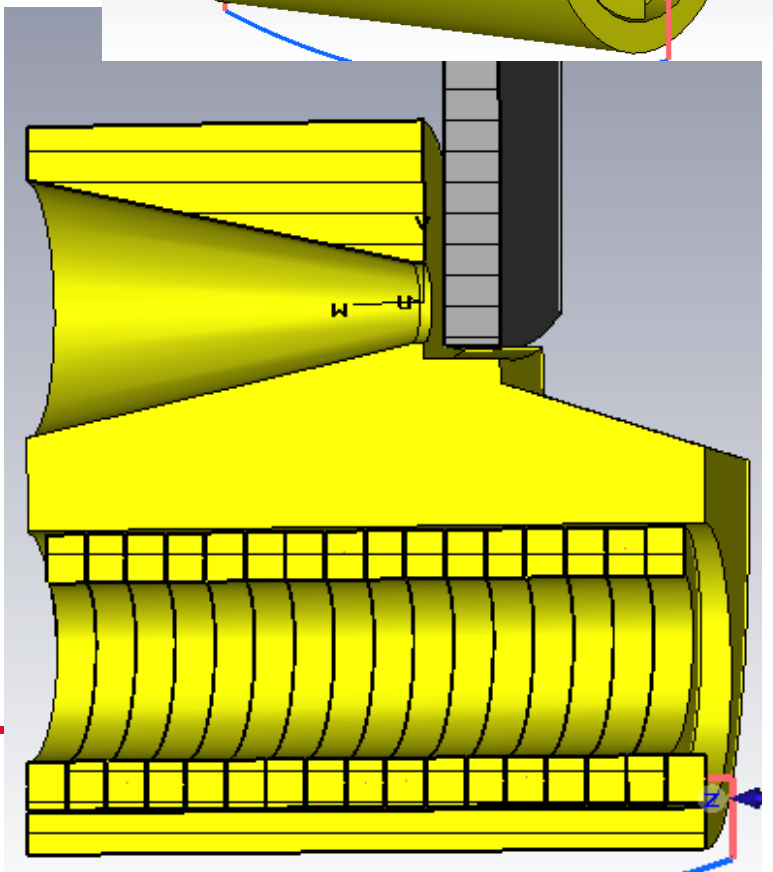
Conclusion: Indirect cooling is better.

Flux Concentrator
(P. Martyshkin)

- Flux Concentrator for AMD (Adiabatic Matching Device)
- 16 mm aperture
- 5 Tesla Peak field, 40mT trans.
- 25 kW ohmic loss.



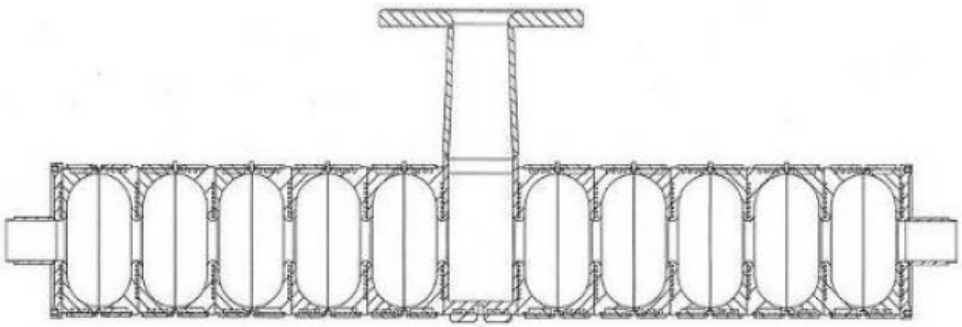


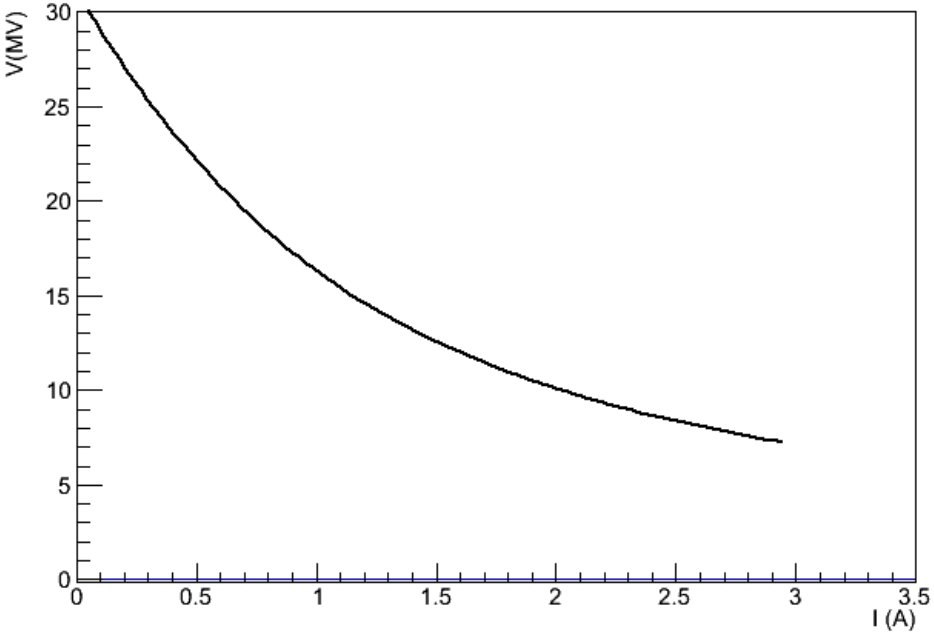


Positron Capture Linac

- L-band SW structure designed by J. Wang (SLAC) for the undulator capture section is employed.
- Two structures are driven by one 50 MM klystron.

Structure Type	Simple π Mode
Cell Number	11
Aperture 2a	60 mm
Q	29700
Shunt impedance r	34.3 MΩ/m
E_0 (8.6 MW input)	15.2 MV/m



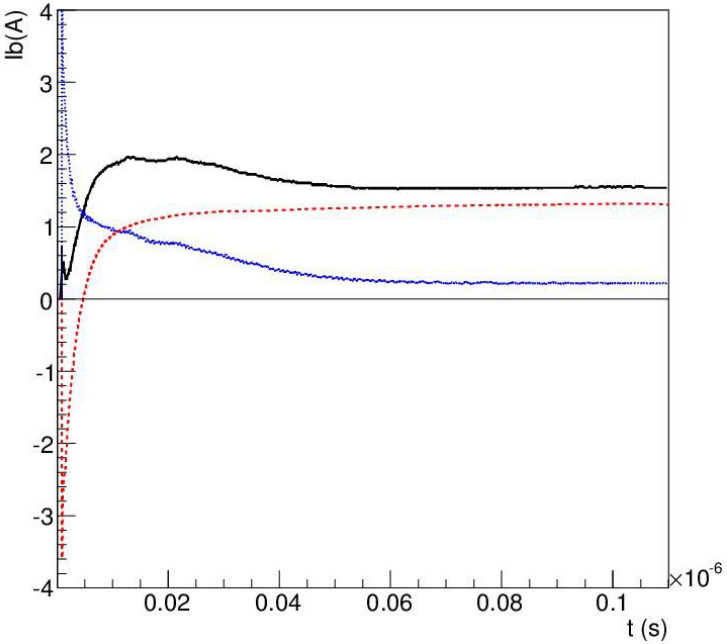


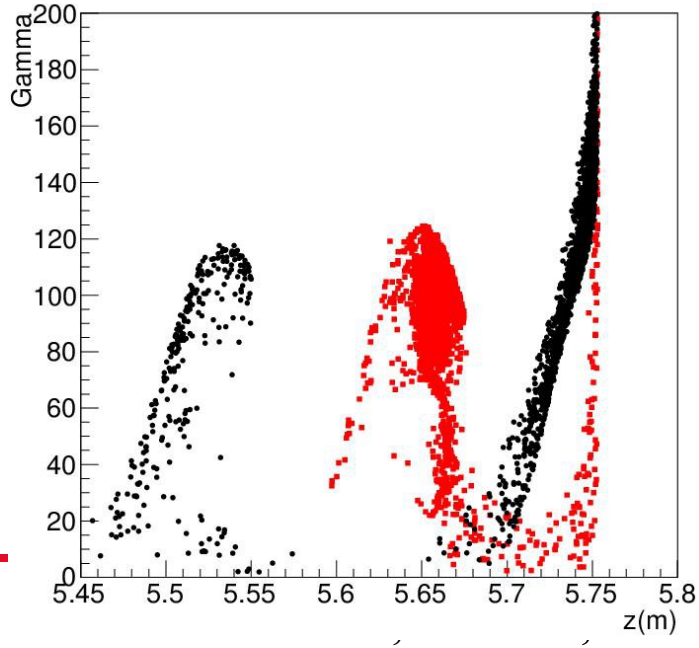
Capture Simulation

- **Beam loading current is dynamically changed,**
  - Bunching,
  - Lost particles
- **For each cells, the accelerator gradient is calculated with $I_{BL}(t)$**

$$I_{BL} = \frac{1}{t_b} \sum q_i \cos\left(\omega t_i - k z_i\right)$$

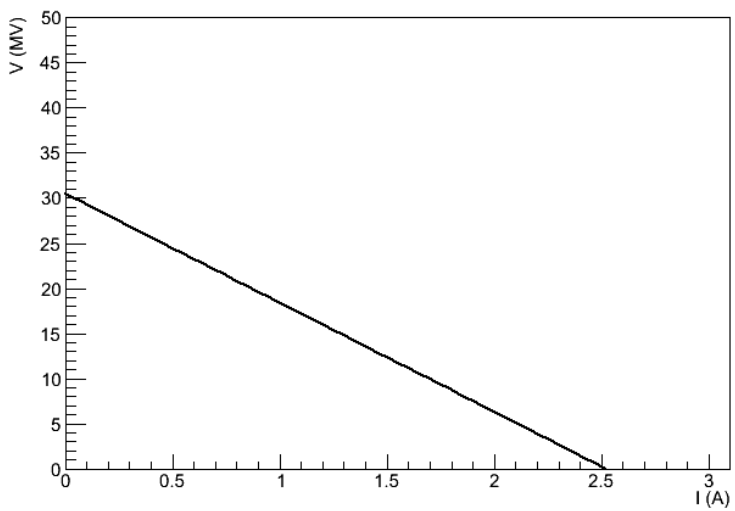
- **14 RF modules (28 L-band SW) makes the average energy of positron 250 MeV.**

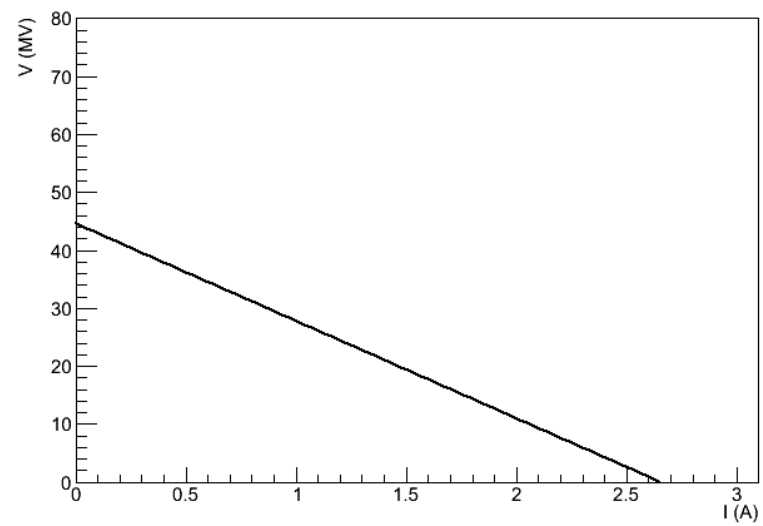




Booster

- A first half is implemented by L-band acc. And the last half is by S-band.
- 50MW L-band Klystron drives two L-band acc.
- 80MW S-band Klystron drives two S-band acc.

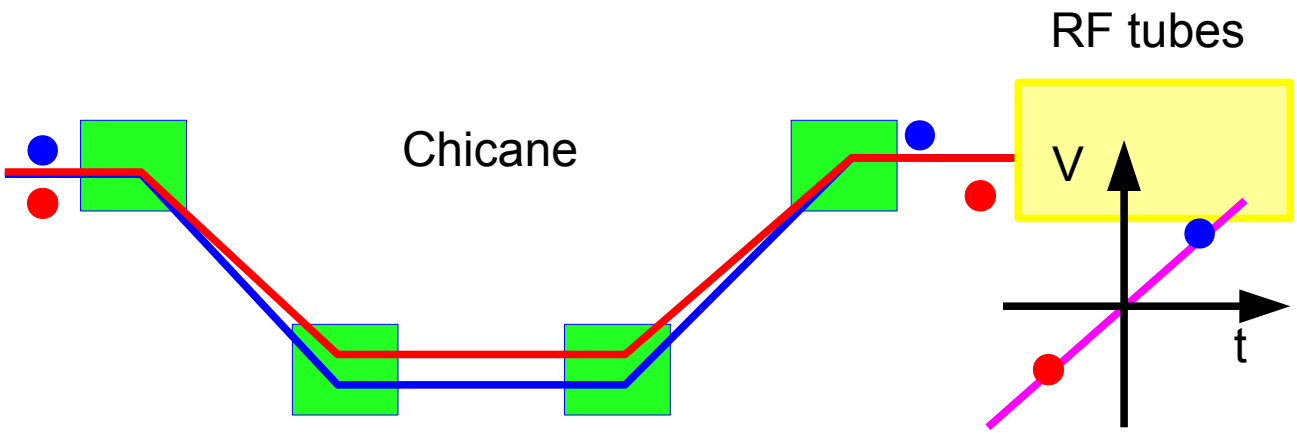


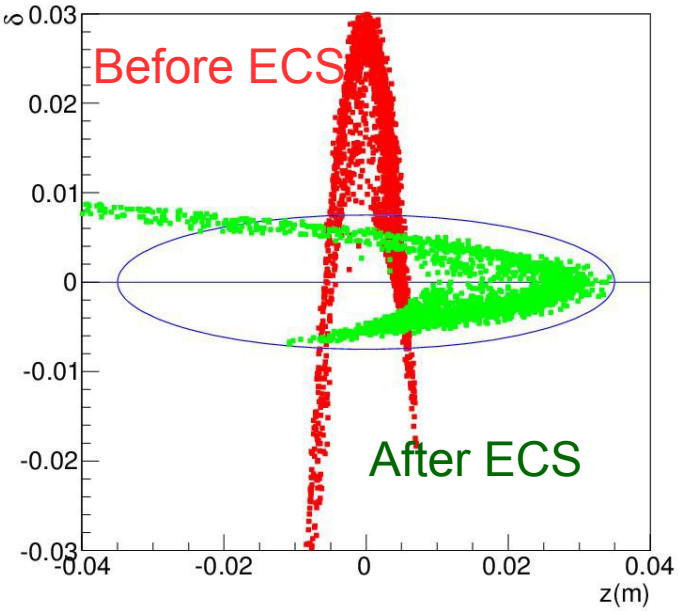


Lattice configuration	Number of lattice cells	Accelerating energy	energy at the exit	cell length	number of cells and section length (2 by 1)
4Q + 1L	12	252 MeV	502 MeV	3.8 m	12 : 45.6 m
4Q + 2L	22	924 MeV	1426 MeV	6.0 m	22 : 132.0 m
4Q + 4L	15	1260 MeV	2686 MeV	10.4 m	15 : 156.0 m
4Q + 4S	19	2394 MeV	5080 MeV	10.4 m	19 : 197.6 m

Energy Compressor

- DR longitudinal acceptance (±35mm in z, ±0.75% in δ±/±) which are too wide in z and too narrow in ∫±/±.
- Energy compressor makes a good matching to the acceptance.
- Energy Compressor consists from chicane and 5 L-band RF .
- 75.2 m.

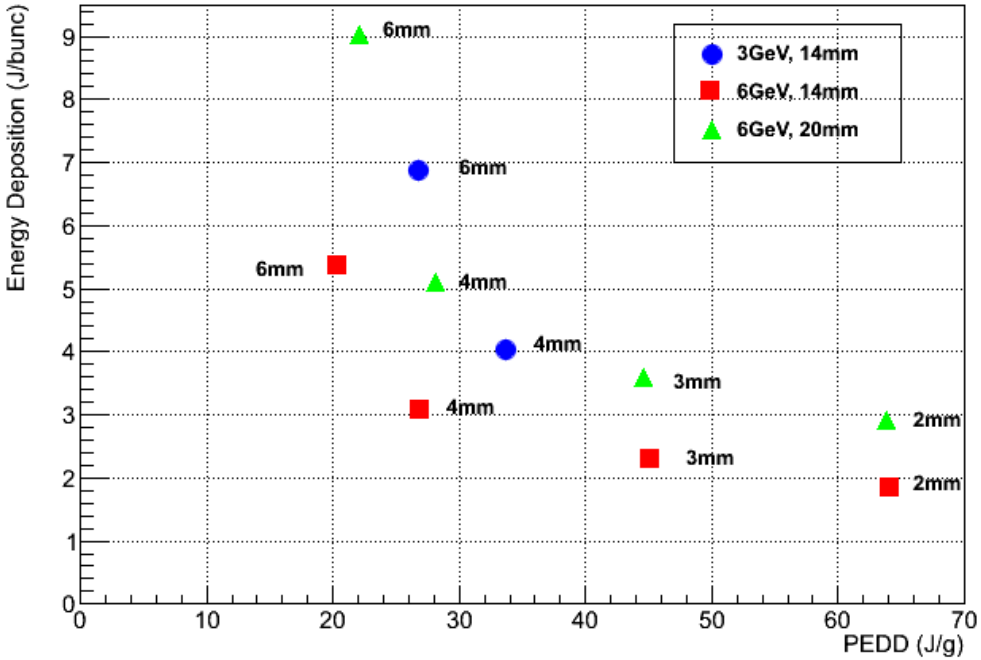




DR Acceptance

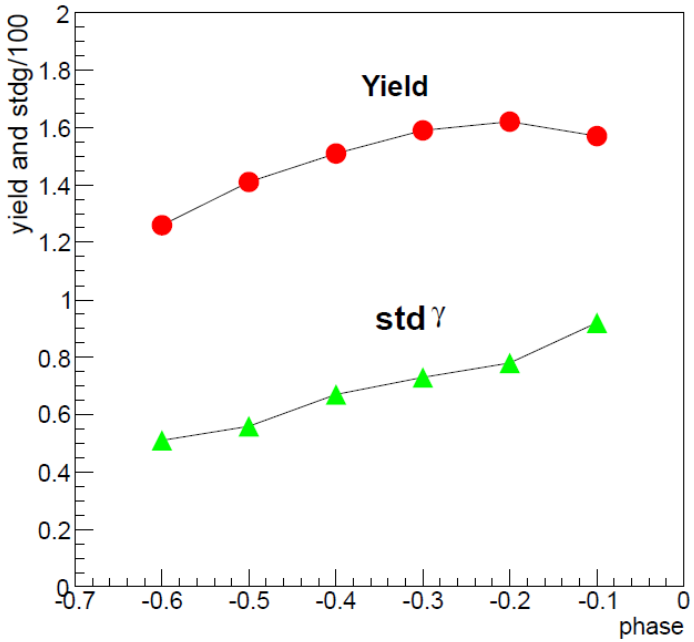
$$\left(\frac{z}{0.035}\right)^2+\left(\frac{\delta}{0.0075}\right)^2<1$$

$$\gamma A_x+\gamma A_y<0.07$$



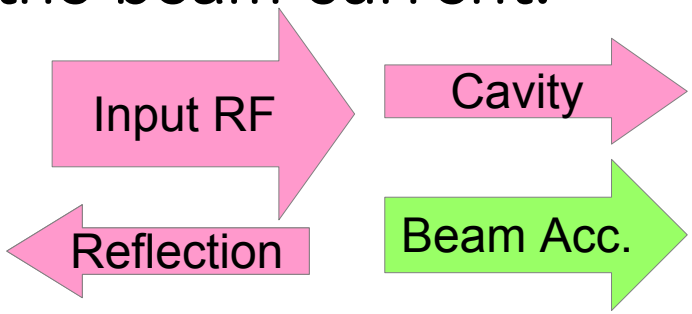
The typical yield was 1.25.

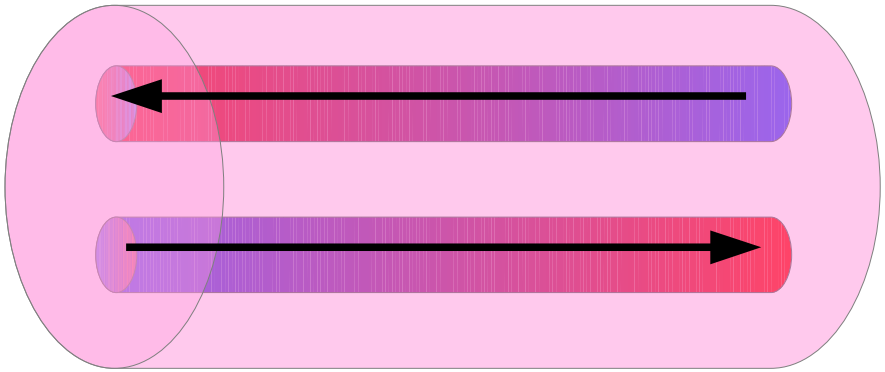
Electron intensity is normalized giving 3.0e+10 positron /bunch In DR dynamic aperture.



Cooling Water

- Cooling water capability is estimated according to the power loss in RF cavity and RF load.
- ∫T<0.1K for RF cavity and dT=11K for RF load (TDR specification).
- By employing counter flows in RF cavity, T_{out}-T_{in}=10K is acceptable for dT~0.05K (per tube)
- Because of the heavy beam load, dissipated power in RF cavity and load depend on the beam current.





- L-band SW (per tube)

Beam current (A)	$P_{acc}(kW)$	V_{acc} (l/min)	$P_{load}(kW)$	V_{load} (l/min)
0.1	3.32	4.75	5.49	7.13
0.5	1.79	2.55	3.46	4.49
1.0	1.08	1.54	2.45	3.18
1.5	0.656	0.937	1.78	2.31
2.0	0.376	0.537	1.27	1.65

- L-band TW (per tube)

Beam current (A)	$P_{acc}(kW)$	V_{acc} (l/min)	P_{load}	V_{load} (l/min)
0.00	2.16	3.08	3.15	4.09
0.50	1.66	2.38	2.42	3.14
0.80	1.40	2.00	2.04	2.65
1.00	1.23	1.76	1.80	2.34
1.50	0.867	1.24	1.27	1.65

- 2m S-band TW (per tube)

Beam current (A)	$P_{acc}(kW)$	V_{acc} (l/min)	P_{load}	V_{load} (l/min)
0.00	2.53	3.61	2.67	3.47
0.50	1.90	2.71	2.01	2.61
0.80	1.57	2.24	1.66	2.16
1.00	1.36	1.95	1.44	1.87
1.50	0.91	1.31	0.97	1.26

- 3m S-band TW (per tube)

Beam current (A)	$P_{acc}(kW)$	V_{acc} (l/min)	P_{load}	V_{load} (l/min)
0.00	3.72	5.32	1.75	2.27
0.50	2.04	2.92	0.96	1.25
0.60	1.77	2.52	0.83	1.08
1.00	0.86	1.23	0.41	0.53
1.50	0.18	0.26	0.09	0.117

Cooling Water Summary

Item	Cooling water (l/min)	Cooling water max (l/min)
L-band SW Acc.	43	133
L-band SW load	89	200
L-band TW Acc.	242	373
L-band TW load	321	495
S-band 2 m TW Acc.	170	274
S-band 2 m TW load	164	264
S-band 3 m TW Acc.	307	650
S-band 3 m TW load	132	277
Total	1470	2670

RF unit

Component	Specifications	Number (1 by 1)	Number(2 by 1)
Accelerator	1.27 m L-band SW	28	28
Accelerator	2.0 m L-band TW	71	116+4
Accelerator	2.0 m S-band TW	48	76
Accelerator	3.0 m S-band TW	120	120
Klystron	50 MW L-band	85	74
Klystron	80 MW S-band	108	98

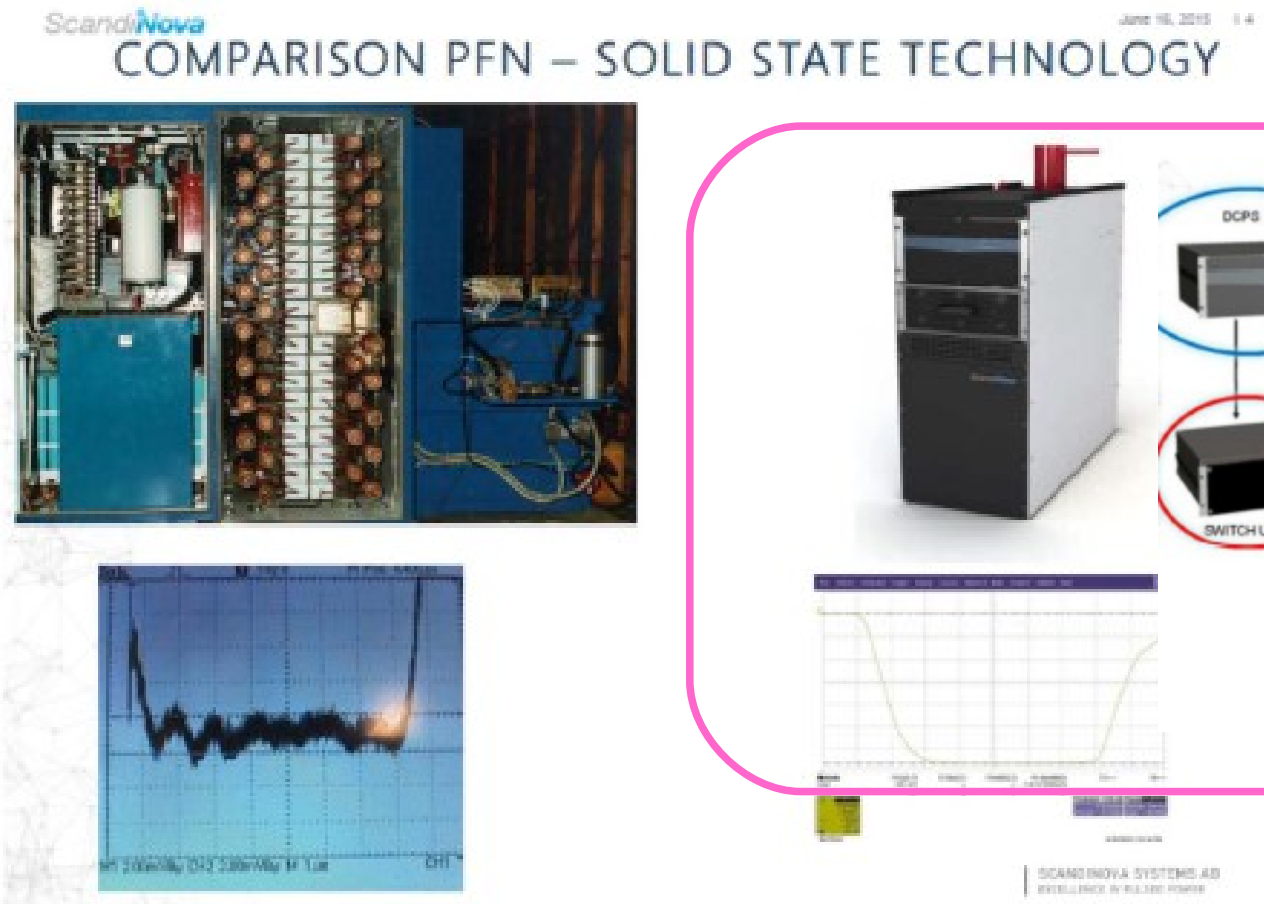
- High density of power units in the service tunnel is expected. (6.45 m/unit, average)
- Compact unit design with a good accessibility is mandatory.

Klystron (S. Fukuda)

- L band (1.3 GHz) with 50 MW-100MW and S band klystron(2.6 GHz) with 80-150MW are possible, but so far there are no commercially available klystrons.
- In order to reduce the numbers of RF source, higher output power is desirable, while requirements for minimum R&D lead to limited choice.
- For L-band, we assume a 50 MW tube, since design of this power level is not difficult.
- For S-band, we assume a 80 MW tube, since existing 2.856GHz 80 MW klystron is widely used, and frequency scaling from 2.856GHz to 2.6GHz is not so difficult. (Comments from Toshiba engineer)

Pulse Modulator (S. Fukuda)

- Solid sate modulator has a large merits
  - compact
  - maintenance ability



RF Unit

L-band Unit

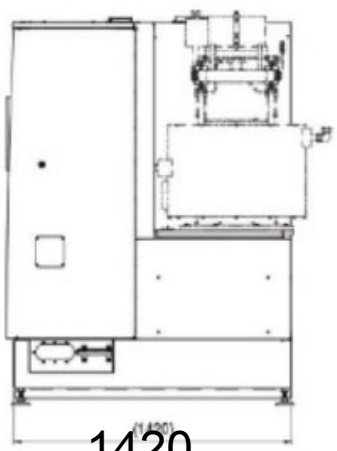
Main Parameters	Value	Unit
RF Frequency	1300	MHz
Peak Power	50	MW
Average RF Power	22.5 (0.3)¹	kW
Pulse width	0.5 - 1.5	µs
Pulse Repetition	1 - 300 (3.8)¹	Hz

¹ *Corresponding to 3,8Hz operation*

S-band Unit

Main Parameters	Value	Unit
RF Frequency	2856	MHz
Peak Power	80	MW
Average RF Power	36 (0.4)¹	kW
Pulse width	0.5 - 1.5	µs
Pulse Repetition	1 - 300 (3.8)¹	Hz

¹ *Corresponding to 3,8Hz operation*



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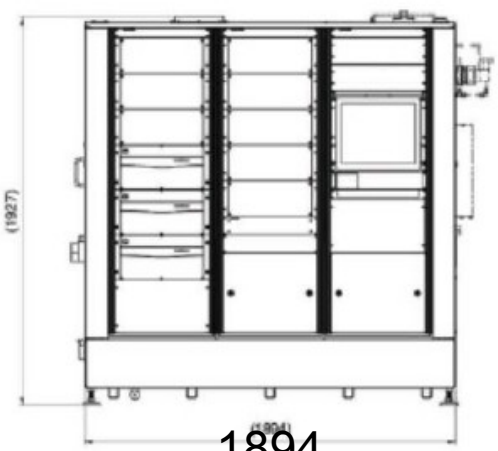

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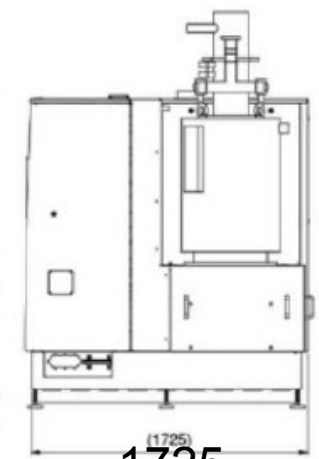

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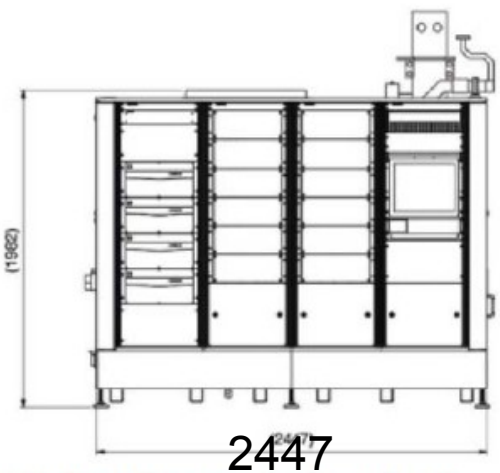

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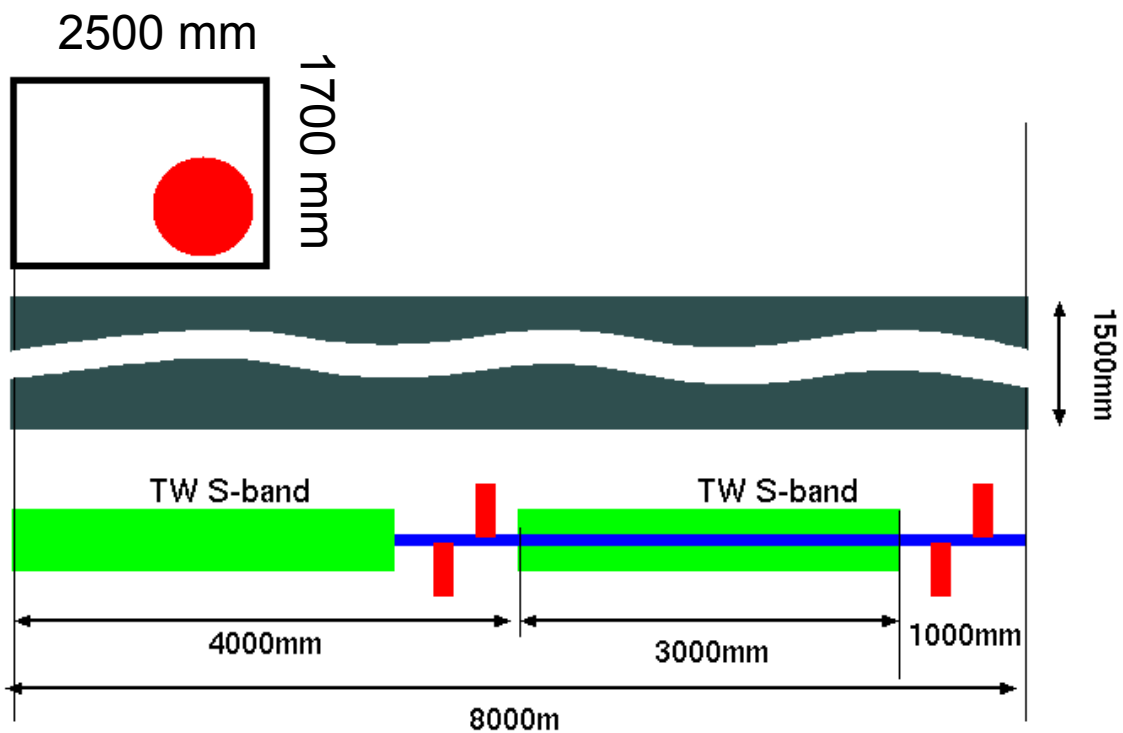
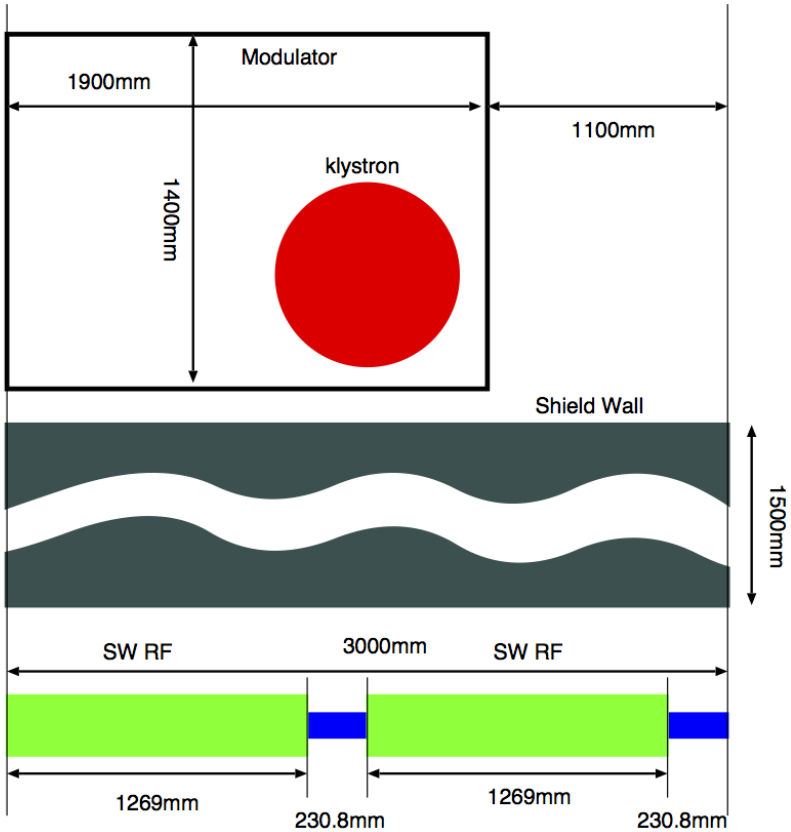
Weight approx 3900kg (including Klystron, Solenoid, oil)

RF Unit Layout

Positron Capture Linac (highest density)

S-band Electron Linac

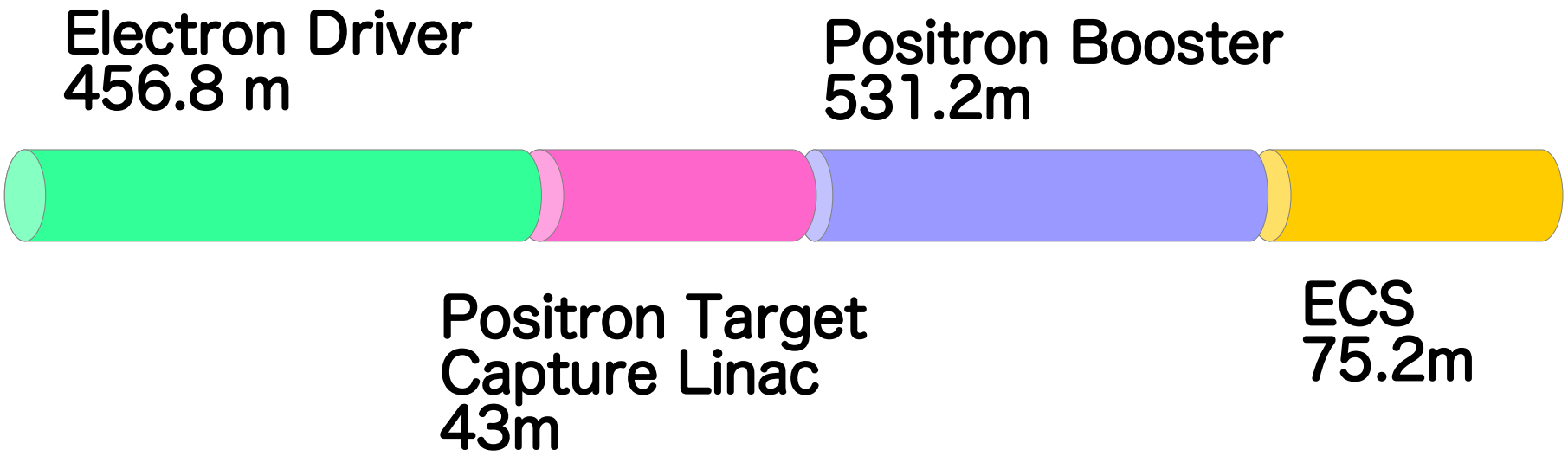




Parameter Summary

Parameter	Value	Unit
Drive Beam Energy	4.8	GeV
Target material	W-Re	
Target thicknesss	14	mm
Beam Size (rms)	4.0	mm
AMD peak field	5.0	T
R_{AMD} (smallest aperture of AMD, 2a)	16.0	mm
Average gradient (MV/m)	8.4 – 22	MV/m
Accelerator Aperture (2a)	60	mm
Solenoid	0.5	T
Booster	Hybrid (L-band + S-band)	

Overview



Total : 1110.2 m

Summary

- As a technical backup, E-driven ILC positron source has been designed.
- To relax the heat load on the target, positrons are generated in 63 ms of 200 ms.
- 14mm thick W-Re rotating target design is in progress.
- AMD (5T, 2a=16mm) is designed.
- Electron Driver, Positron Capture Linac, and Booster are designed based on off-the-shelf RF components.
- Required cooling water capability was estimated up to 2700 l/min.
- RF power module was designed. The density of the module along the service tunnel is high, but acceptable.