# Study of S-band High Gradient Accelerating Structure for the Acceleration of Protons from 30MeV to 230MeV

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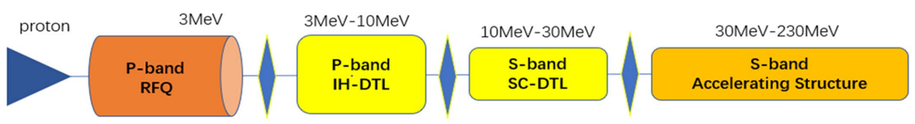
## ABSTRACT

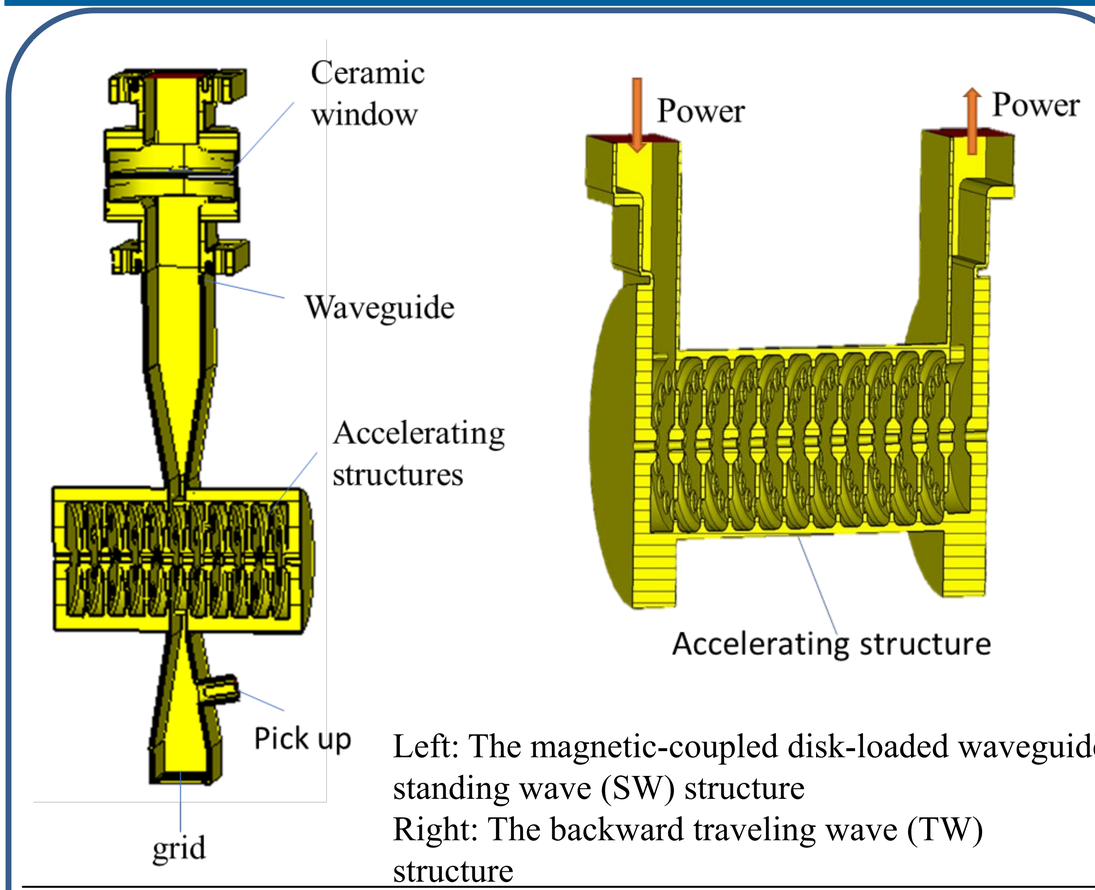
S-band high-gradient accelerating structures were proposed to accelerate protons from 30MeV to 230MeV for a compact therapy Linac in IMP. A backward traveling wave structure and a high-gradient standing wave structure were developed, and the differences between the two types of structures were analyzed. In this paper, A new-shaped accelerating structure with reduced coupling holes and thermal stress was developed, along with a novel cooling channel design, which allows the cooling water flow in the middle of the disk, thus making it possible for higher duty cycle and longer RF pulse operation. It provides a wider application scenario for the high-gradient accelerating structure. The research on high gradient accelerating structure is consistent with the trend of linear accelerator technology (compact, flexible and economical). The design and optimization of the linac and the status of the prototype cavity will be discussed in this paper.

## Layout of compact therapy Linac




- From 30MeV-230MeV, the S-band accelerating structure contains 24 tanks.
- The effective length of accelerating structures with energies of 30-230 MeV is less than 6 m.

## Comparison of SW and TW

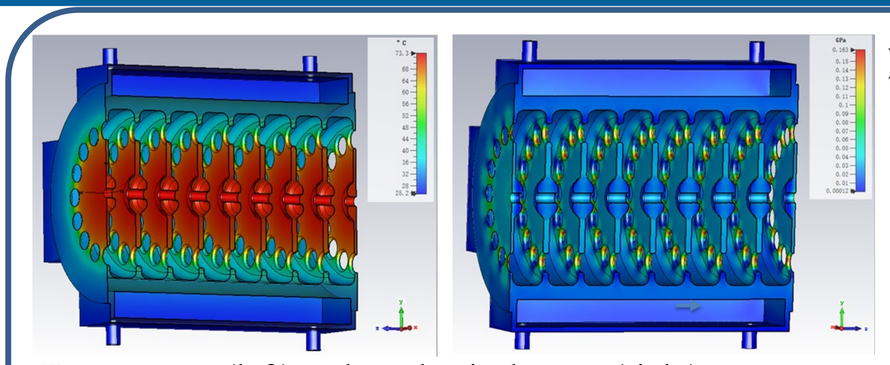



Left: The magnetic-coupled disk-loaded waveguide standing wave (SW) structure
Right: The backward traveling wave (TW) structure

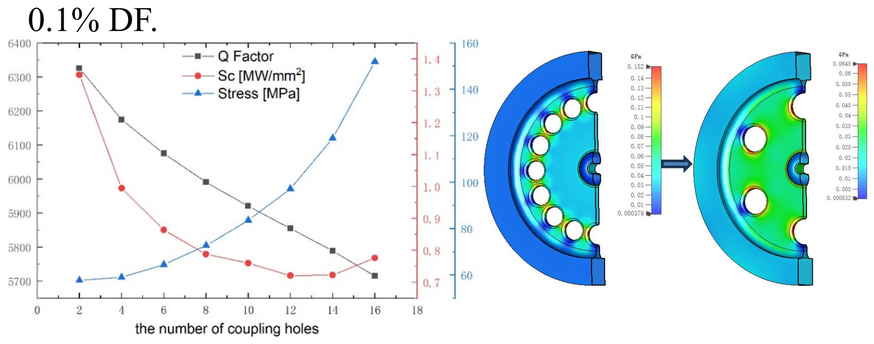
| Parameter (Unit) | SW | TW |
|---|---|---|
| Frequency (GHz) | 3 | 3 |
| Phase advance per cell | $\pi$ | $5\pi/6$ |
| phase velocity $v_p$ (c) | 0.26 | 0.26 |
| Accelerating gradient $E_{acc}$ (MV/m) | 30 | 30 |
| Number of accelerating cells | 11 | 12 |
| Structure active length (mm) | 143 | 182 |
| Shunt impedance ($M\Omega/m$) | 39 | 41 |
| Quality factor Q | 6051 | 7000 |
| Peak electric field (MV/m) | 116 | 113 |
| Peak $S_c$ (MW/$mm^2$) | 0.731 | 0.718 |
| Group velocity $v_g$(first/last) (% of c) | | 0.218/0.37 |
| Filling time (ns) | 637 | 223 |
| Input power (MW) | 4.4 | 11.3 |

- The TW structure has a shorter filling time.
- The TW structure has no mode instability problem and is easier to tune.
- The SW cavity requires a lower input power to reach the target $E_{acc}$, which is more friendly to klystron. It also has higher energy utilization efficiency:$\eta = \frac{W_{beam}}{W_{in}}$
- The SW structure has power reflection, so it is necessary to install a circulator.

## Number of coupling holes



Temperature (left) and mechanical stress (right) distribution in the structure for a 30MV/m gradient and 0.1% DF.

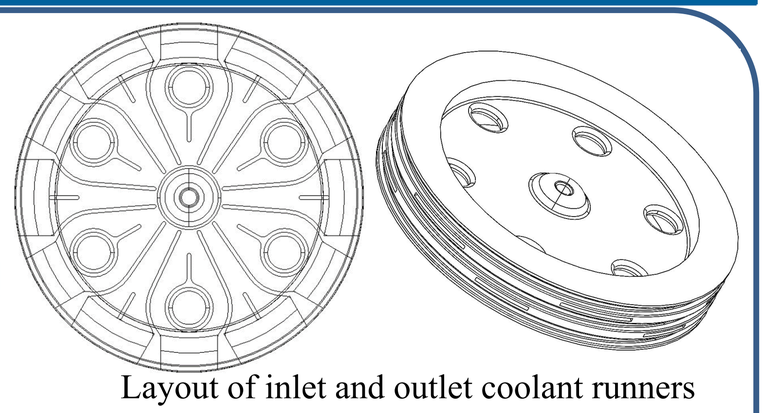



Left: Q factor, Sc, and stress vary with the number of holes.
Right: the stress distribution in the structure with 16 and 6 coupling holes respectively.

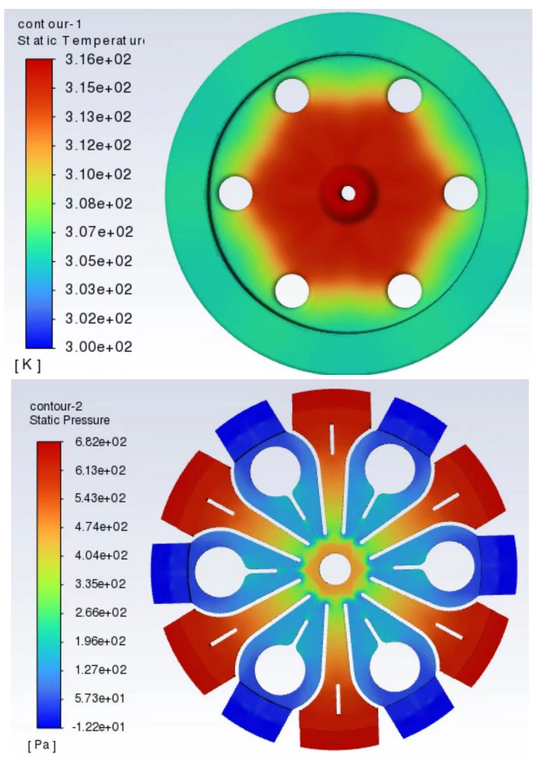
- For the structures with 16 coupling holes, the peak temperature rise is higher than 50 ℃ and the peak stress is 163 MPa, well above the yield stress of the annealed copper.
- Cells with different numbers of coupling holes maintain the cell-to-cell coupling constant by adjusting the holes' diameter.
- After systematic analysis, six coupling holes are optimal.

## Novel cooling channel

- A novel cooling channel was developed for higher duty cycle and longer RF pulse operation.



Layout of inlet and outlet coolant runners




Temperature (top) and pressure (bottom) distribution in the structure.

- The iris thickness is 3mm. Six-inlet channels and six-outlet channels are designed on the iris.
- Using parallel channels to keep coolant flow resistance as low as possible.
- When the water flow rate is 1.5 L/min, the novel cooling channel can make the temperature rise of the cavity 54% lower than the traditional external cooling, and the peak pressure generated by the water is only 0.7 kPa.