Preliminary study of proton Beam Transport in a 10 MeV Dielectric Wall Accelerator

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Dielectric wall accelerator

- Dielectric wall accelerator (DWA) originated from the linear induction accelerator (DARHT, Dragon), which is based on the pulsed power technology
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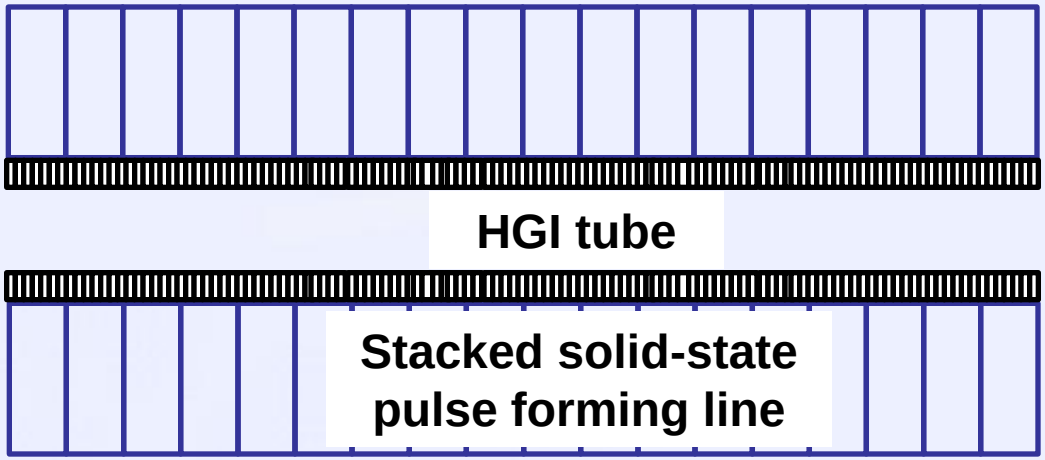
- Virtual traveling wave mode for any charged particle



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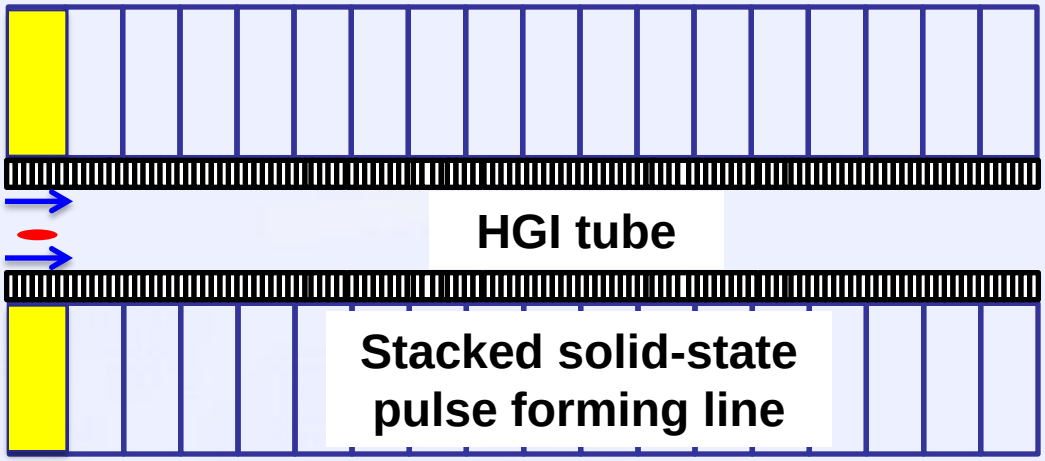

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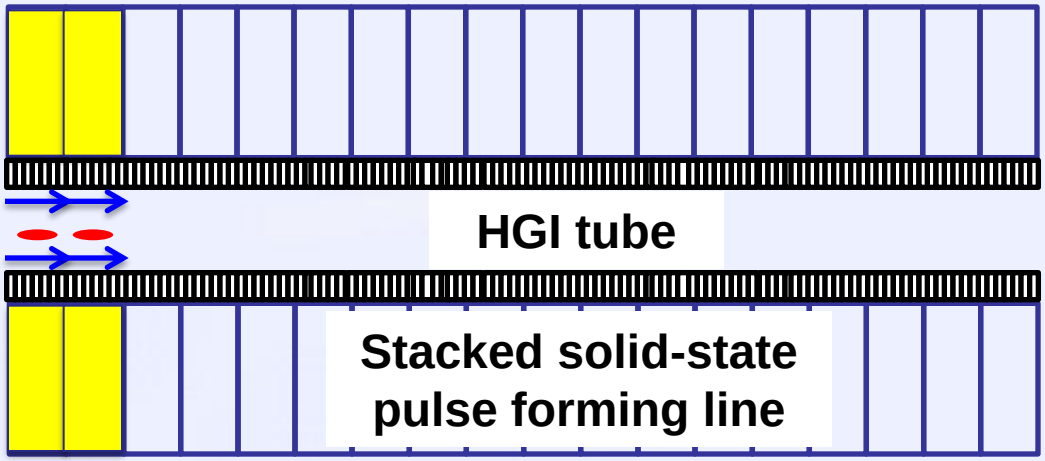

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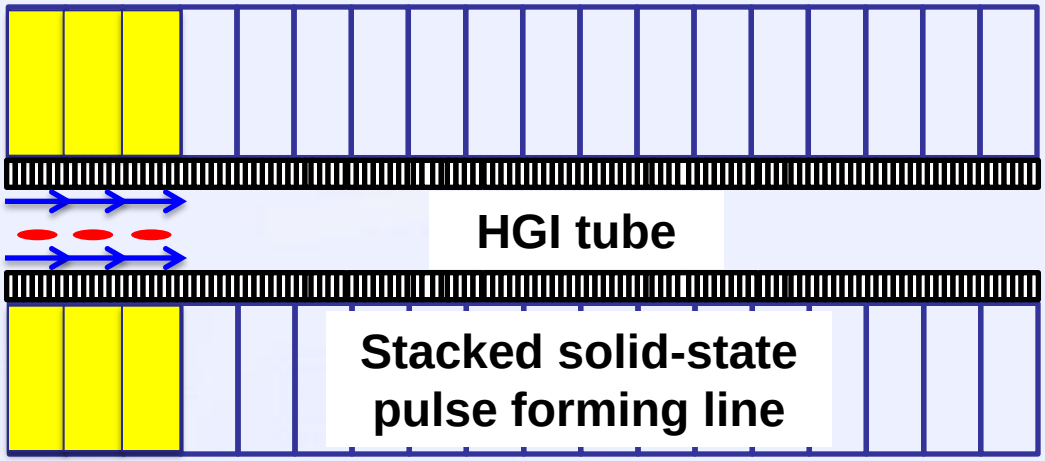

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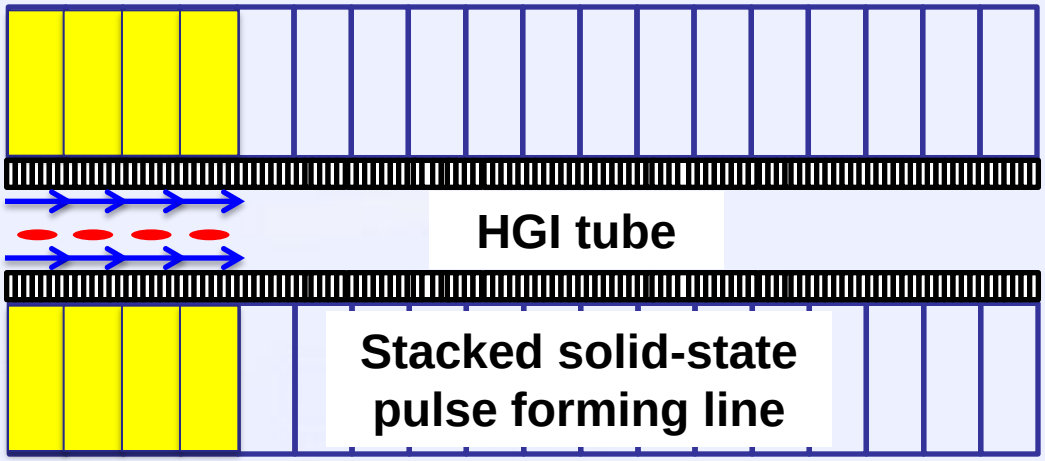

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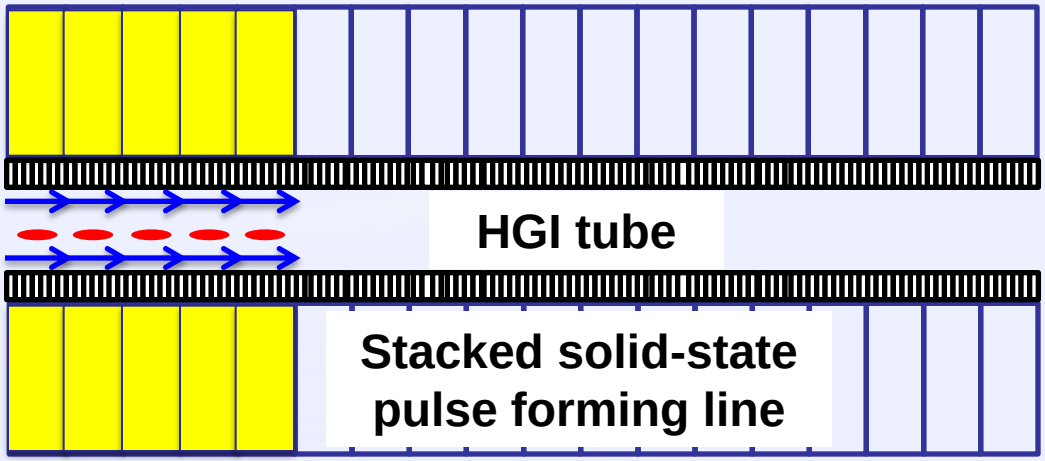

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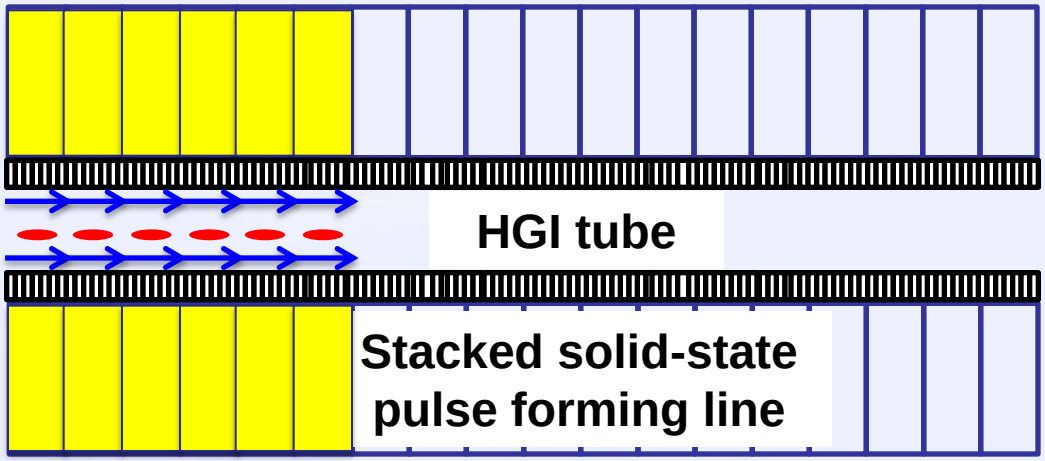

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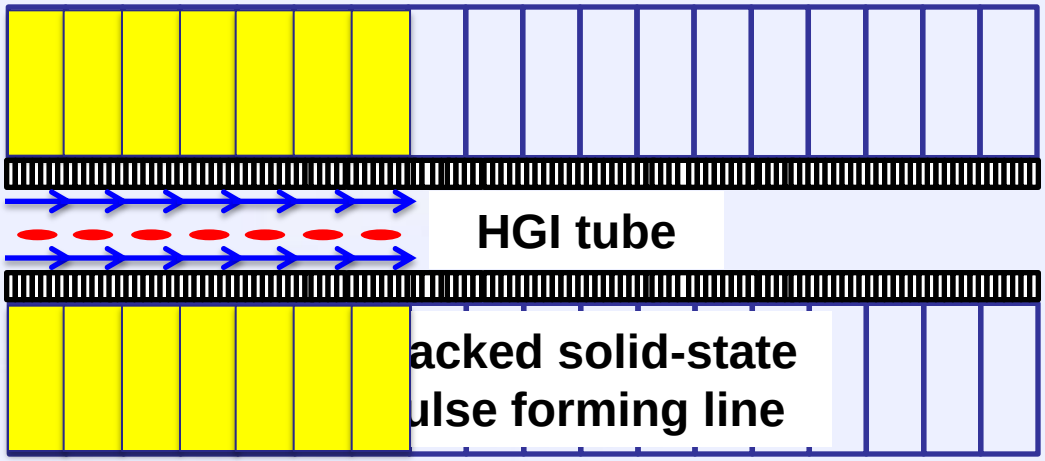

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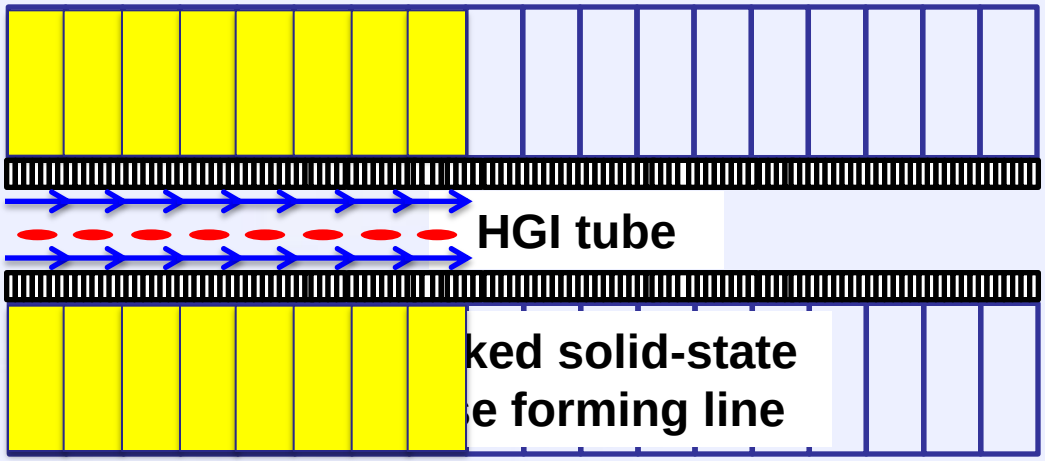

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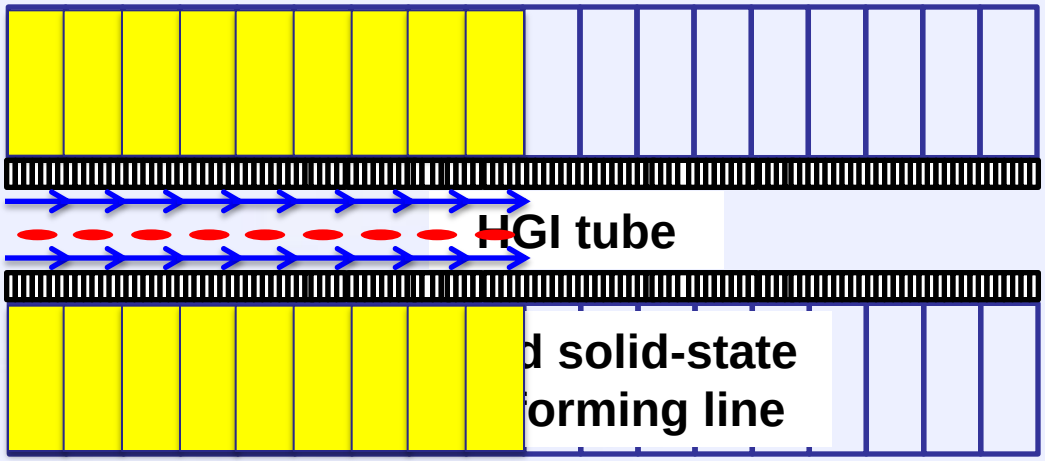

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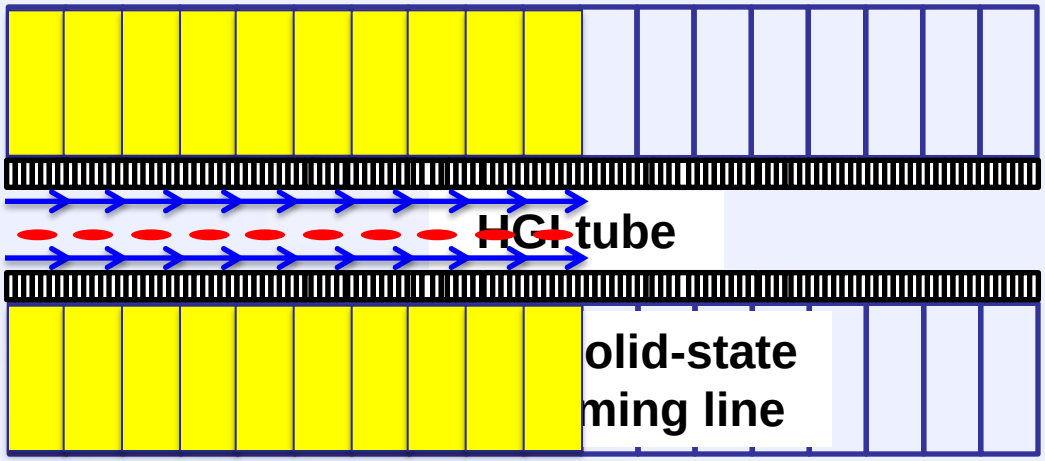

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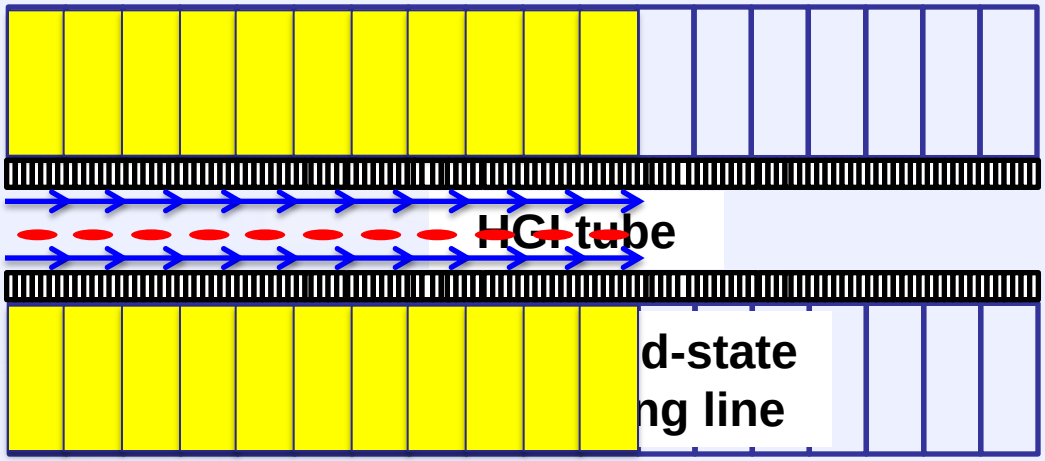

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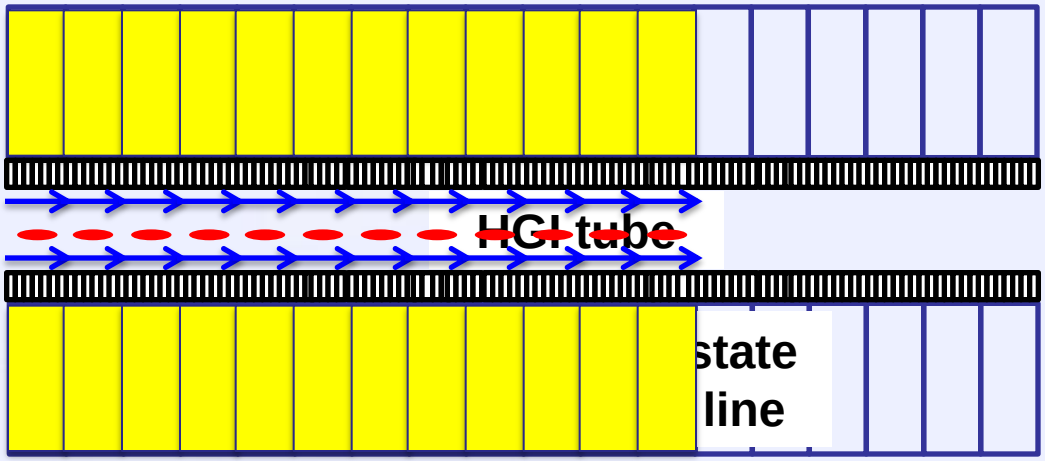

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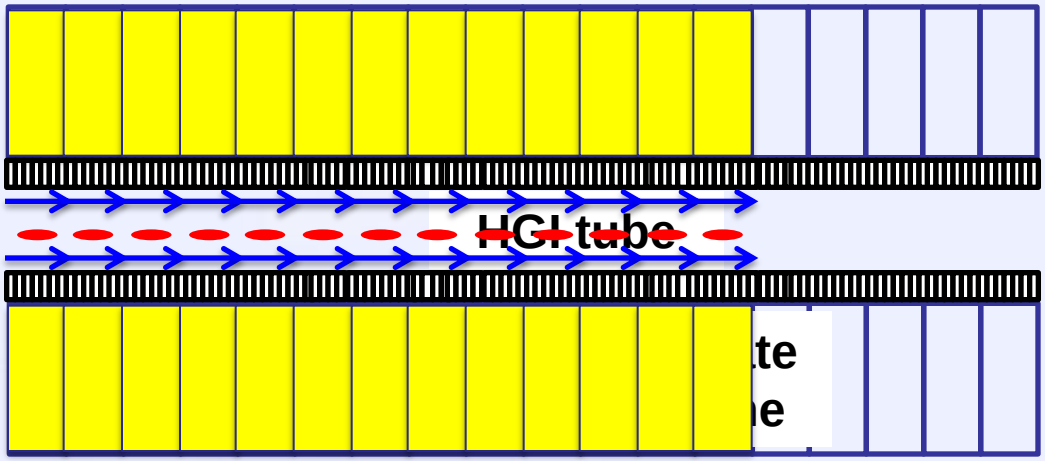

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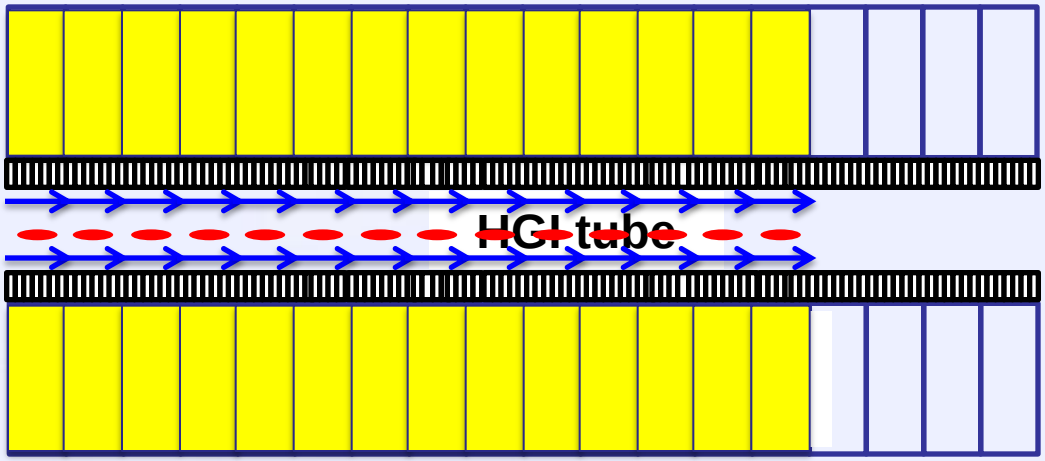

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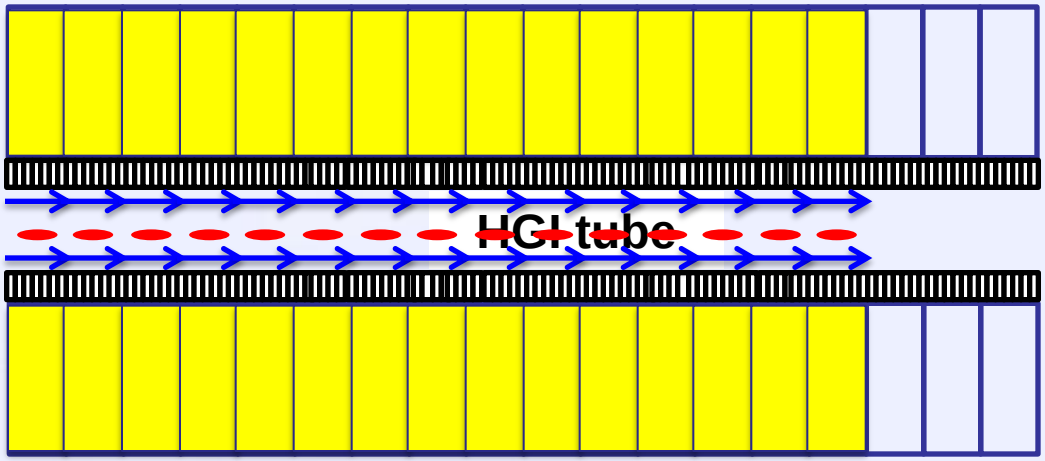

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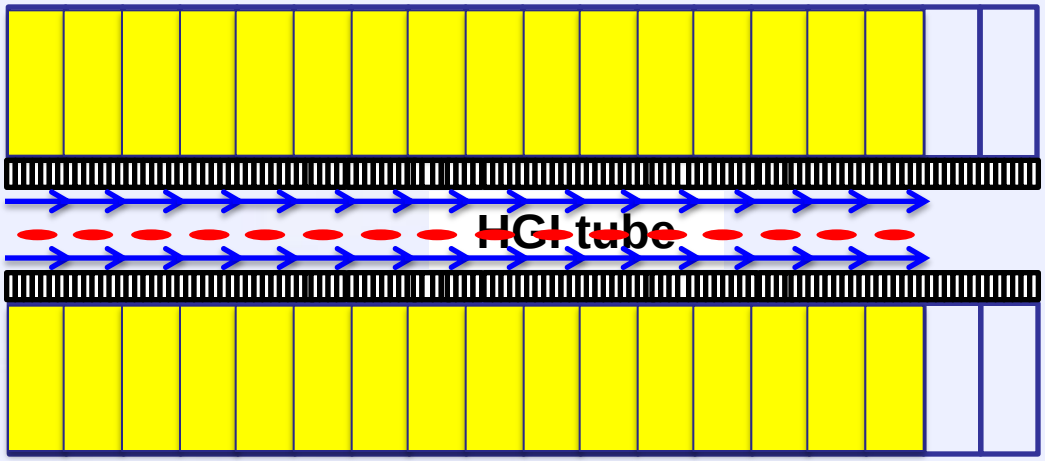

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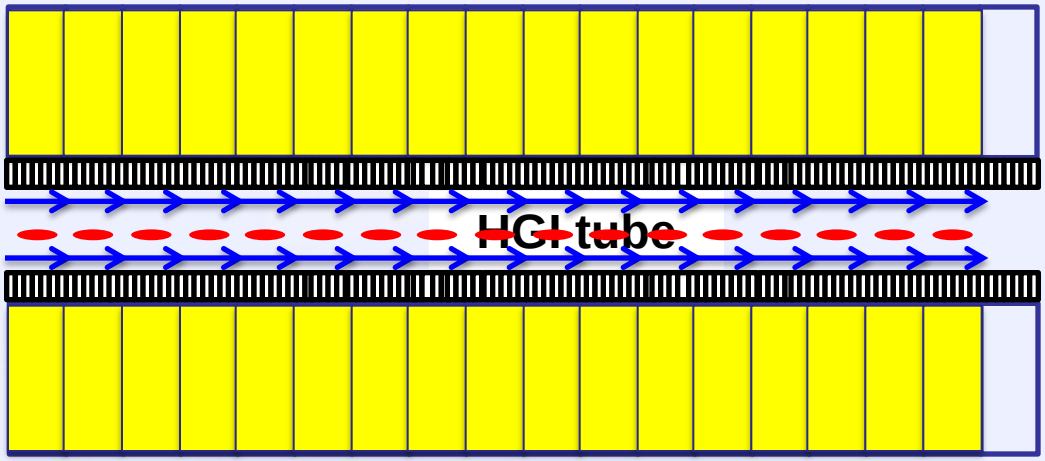

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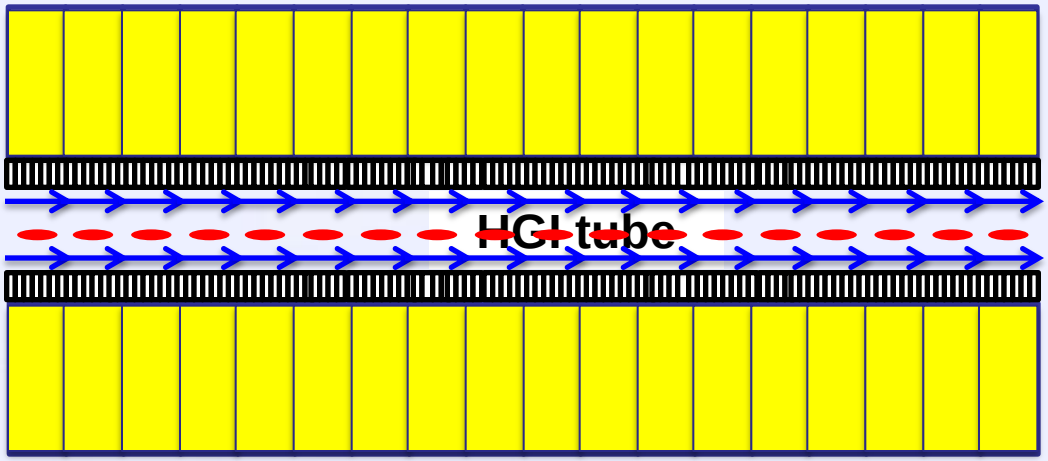
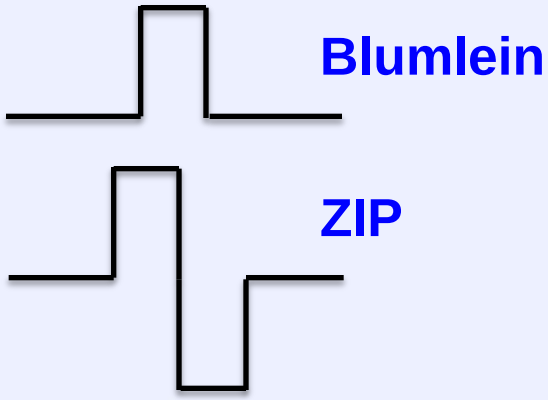
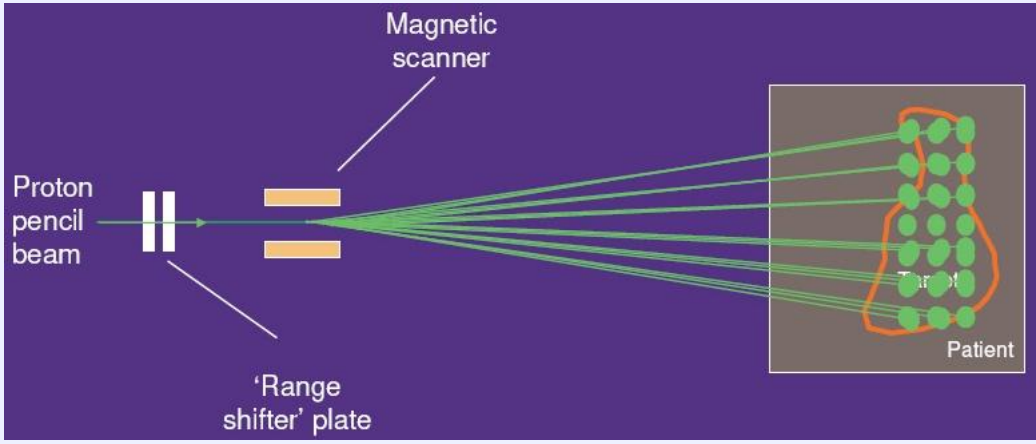
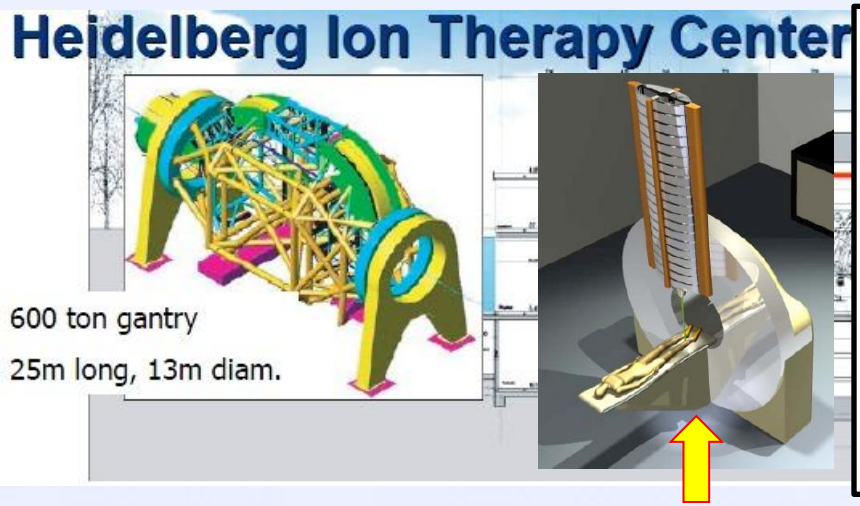




DWA for proton therapy

DWA is the next generation accelerator system for intense modulated proton therapy (IMPT) .

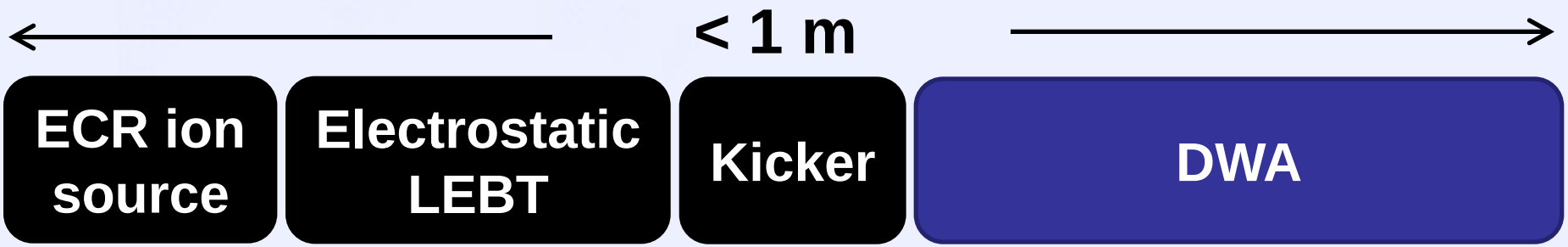




- ✓ **The spot size, dose and energy (70 ~ 250 MeV) of the bunch can be varied from shot-to-shot**
- ✓ **No gantry, the accelerator can be rotated (<3 m)**
- ✓ **No neutron production**

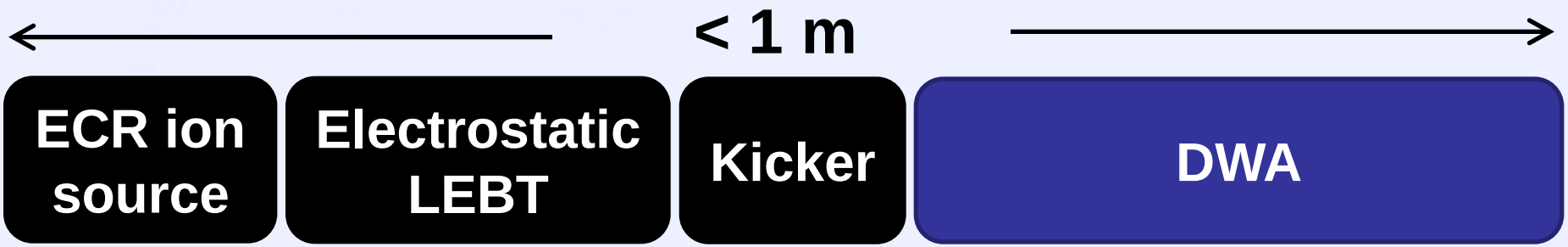
Therapy system proposed by LLNL

Schematic of a 10-MeV DWA accelerator



- A DWA system for IMPT should be not only short but also light enough (no external focusing element)
- 1 MeV (20 MV/m) → 10 MeV (25 MV/m)
- Development of the ion source and LEBT is performed by Institute of Heavy Ion Physics, Peking University

Schematic of a 10-MeV DWA accelerator



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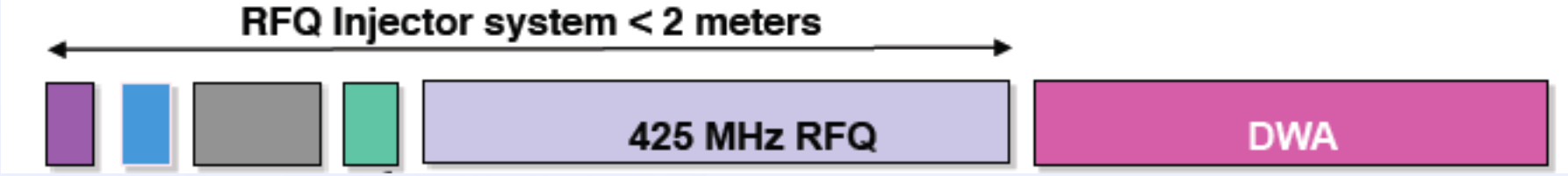
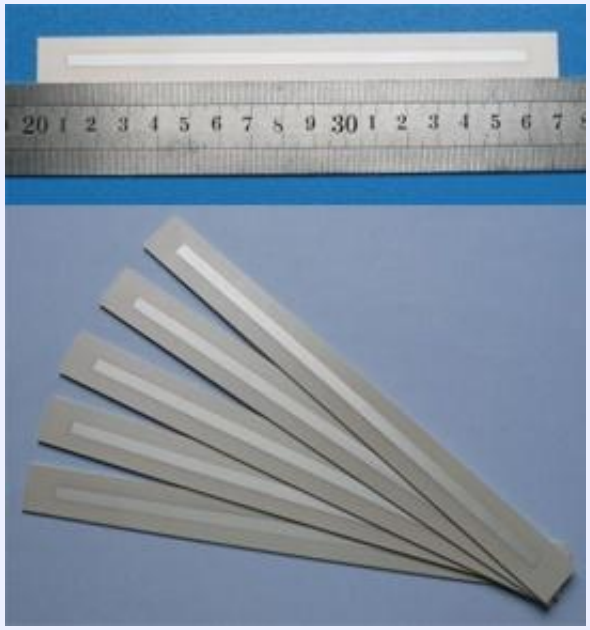
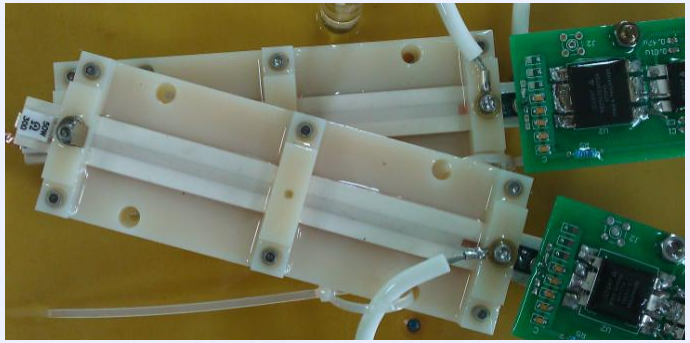


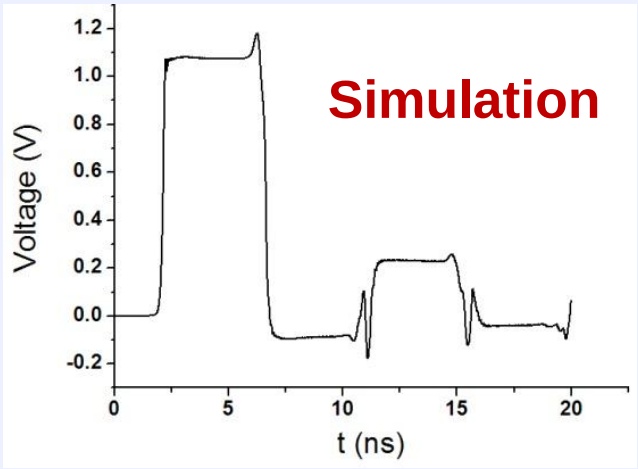
DWA in CPAC (Y.J. Chen, RPIA2011)

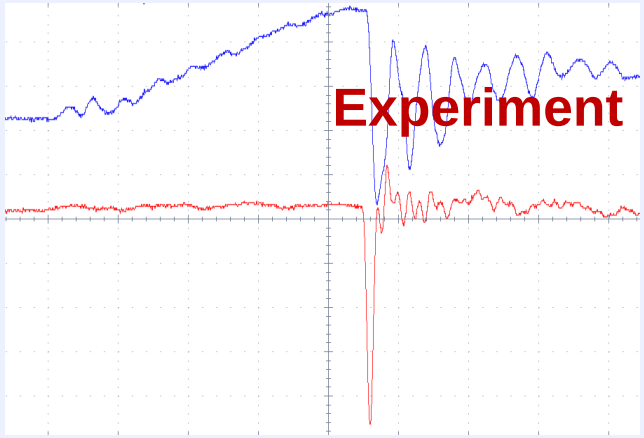
Important DWA elements developed at IFP

Solid-state parallel-plate Blumlein



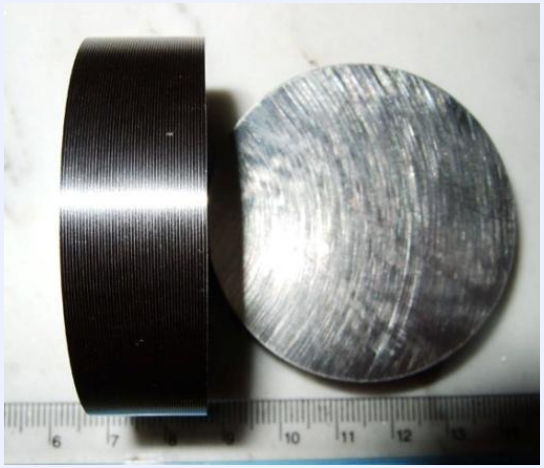




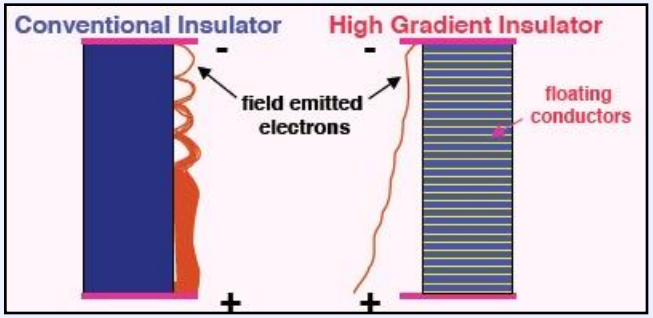


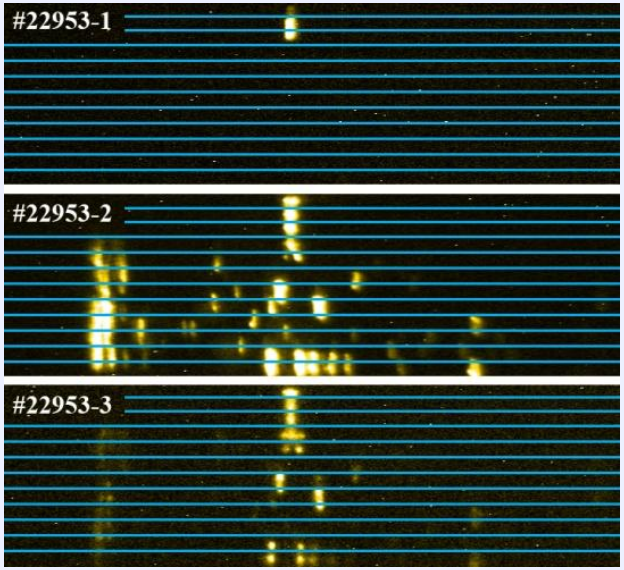
Important DWA elements developed at IFP

High gradient insulator (HGI)



High voltage breakdown mechanism of the HGI is still an open question





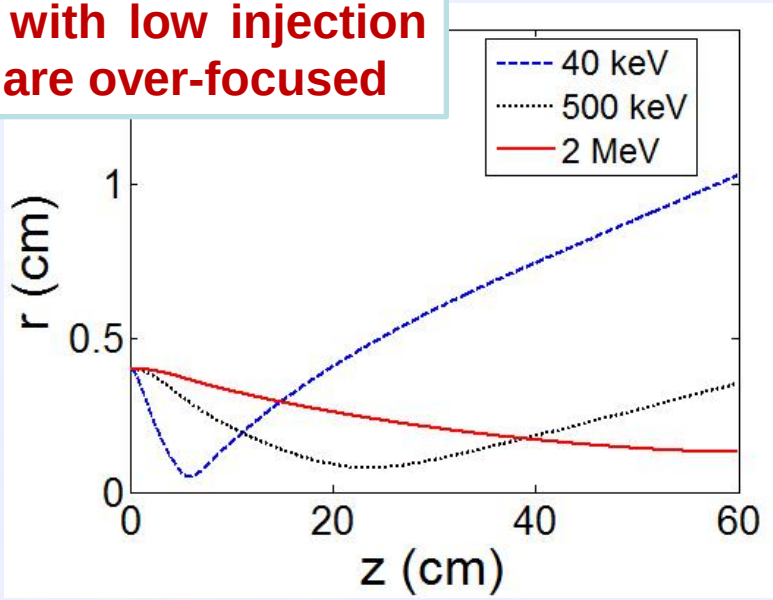
Anode (up), Cathode (down)

- Scaling law ~ $L^{-1/2}$
- Cathode triple junction initiated secondary electron avalanch
- Vacuum arcing
- Secondary electron emission from intermediate triple junction adjacent to the anode

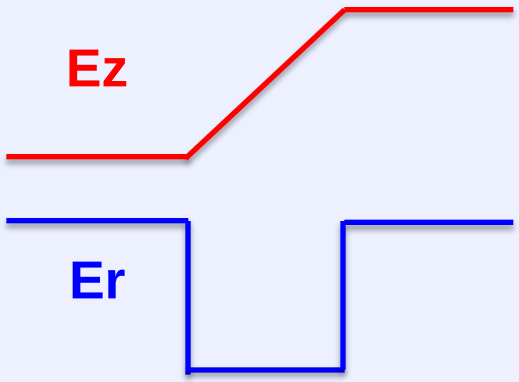
Beam Injection

- Self-focusing of the bunch: accelerating field gradient at the entrance will provide a focusing force
- The envelops for injection beam of 40 keV, 20 mA were solved
- Ez increases linearly from 0 to 25 MV/m at a distance of 5 cm

Beams with low injection energy are over-focused

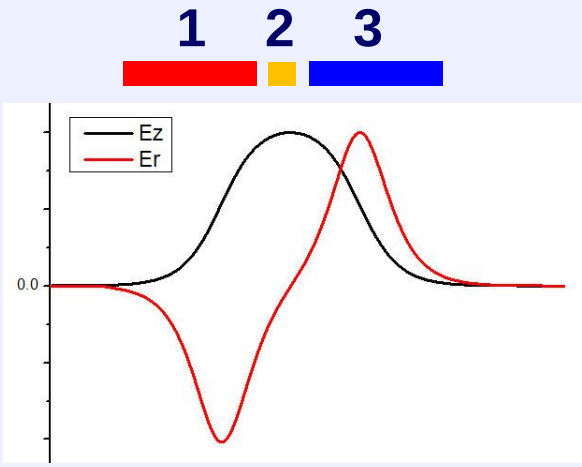


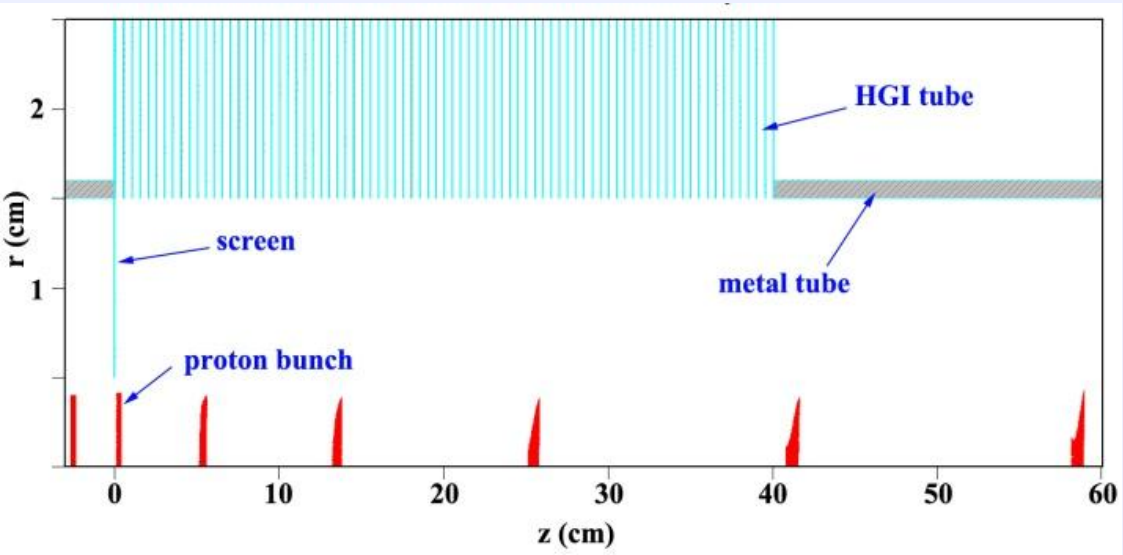
$$E_r = -\frac{r}{2}\frac{\partial E_z}{\partial z}$$



Beam Transport Simulation

- 2-D axisymmetric particle-in-cell simulation for 40 keV, 20 mA, 1ns bunch
- Increase the acceptance of the DWA since any beam loss inside the HGI tube may cause surface flashover
- Emittance growth and energy spread are all acceptable since the beam line is too short





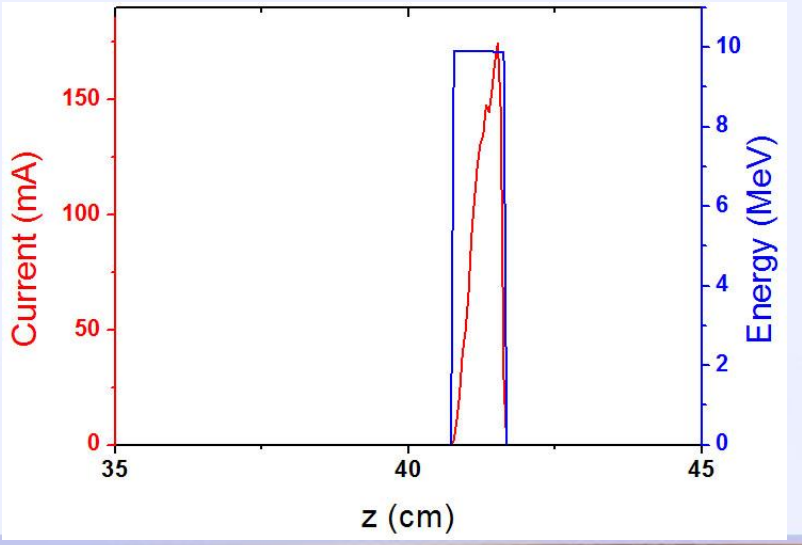
Phase 1: r – focusing
z – decompressing
Phase 2: ……
Phase 3: r – defocusing
z - compressing

Longitudinally bunching

6×10^{11} protons/min for IMPT

100 MV/m corresponds to the accelerating pulse width of 1 ns (FWHM)

	Option 1	Option 2	Option 3
Repetition rate (Hz)	10	50	50
Bunch width (ns)	0.2	0.2	0.1
Peak Current (mA)	800	160	320



- Longitudinally bunching is required
- Bunching by applying head-to-tail velocity tilt

Thank you for your attention!