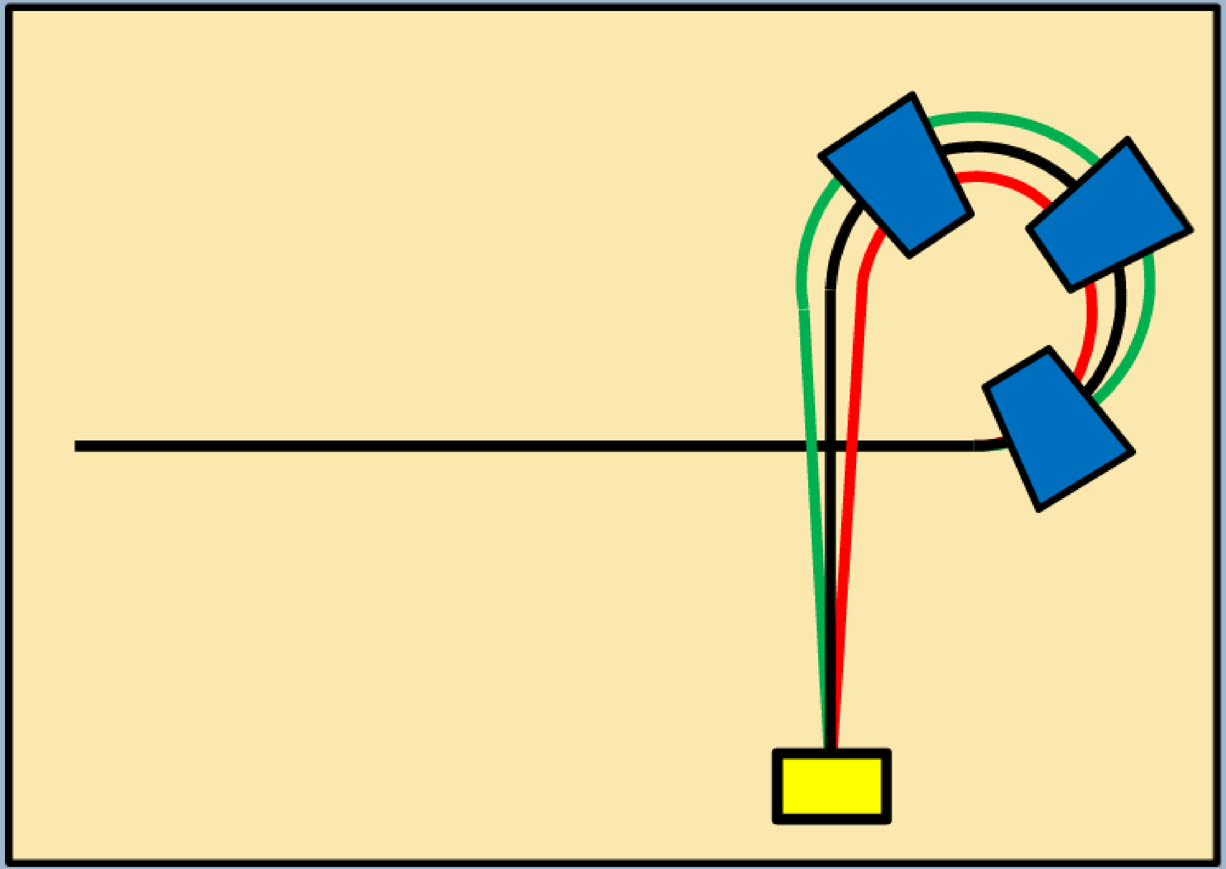
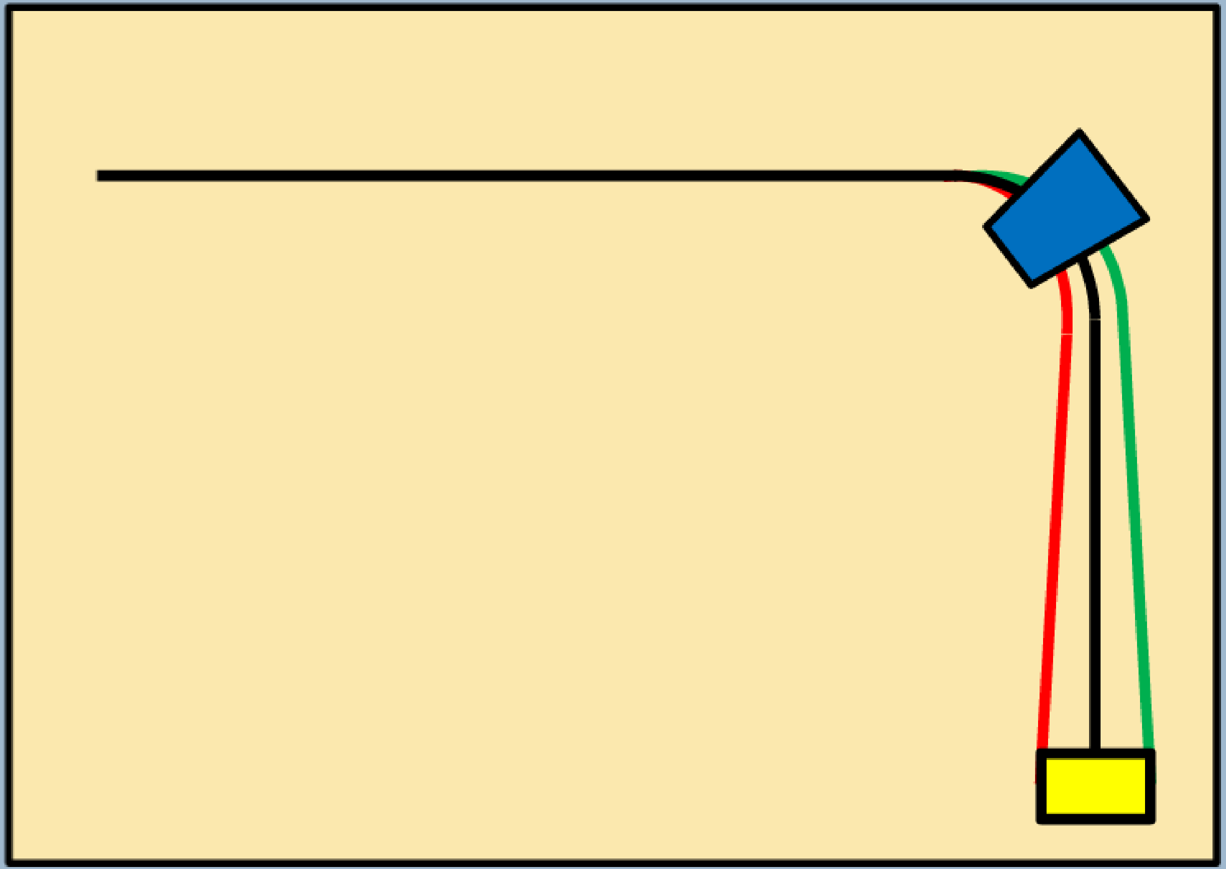
Discuss the following two beam transport designs in the context of medical linac. Which one is better?

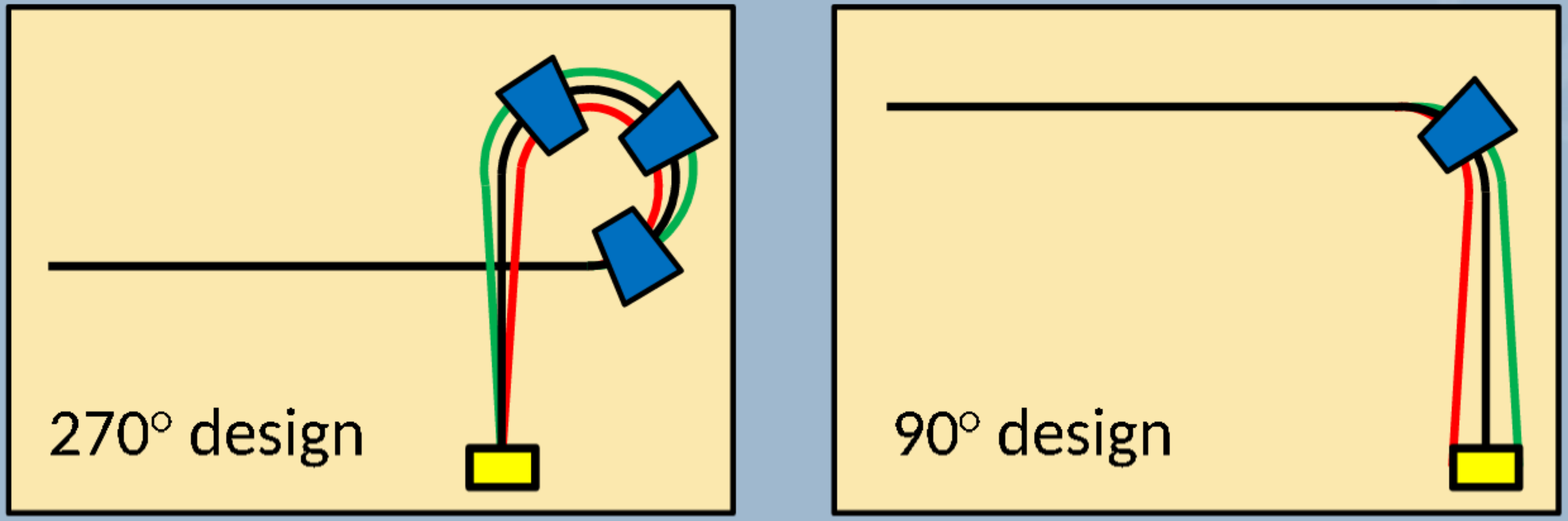




Follow Up

- Which line (red, black, green) corresponds to electron with higher energy?
- Is bending magnet necessary in linac? Can you design a linac without it?
- Your flatness and symmetry are off. Do you have the engineer adjust the bending magnet?

What are these? Which one is better?

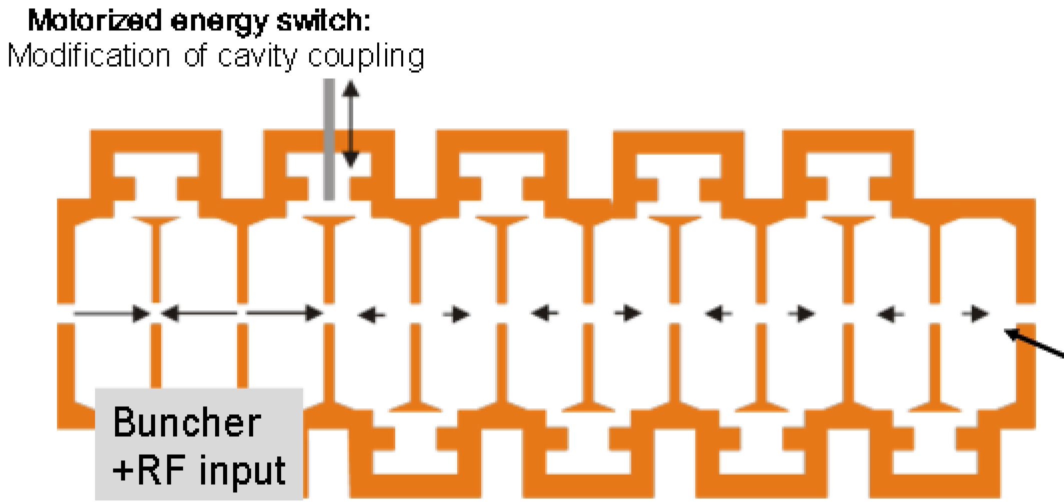


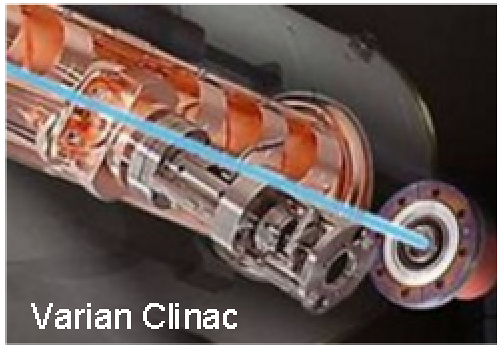
- These are different designs for bending magnet used to bend perpendicularly the trajectory of electrons coming out from accelerating waveguide so that they go toward the target.
- The 270° design is better because it focuses the beam if there is any energy spread in the beam spectrum (which is always there)
- From low to high energy: Red, Black, Green (higher energy → straighter trajectory)

Your flatness and symmetry are off. Do you get the engineer to adjust the bending magnets?

- No, the bending magnets perform the bulk of 90^o or 270^o bending of the beam. You cannot adjust them.
- The fine tuning of the beam is done by 4 pairs of steering coils: 2 for position (radial & transverse) and 2 for beam angle (radial & transverse)
- Position controls where the beam hits the target, angle controls the beam direction when it hits the target
- You adjust flatness and symmetry by adjusting these steering coils.

Change of number of active cells





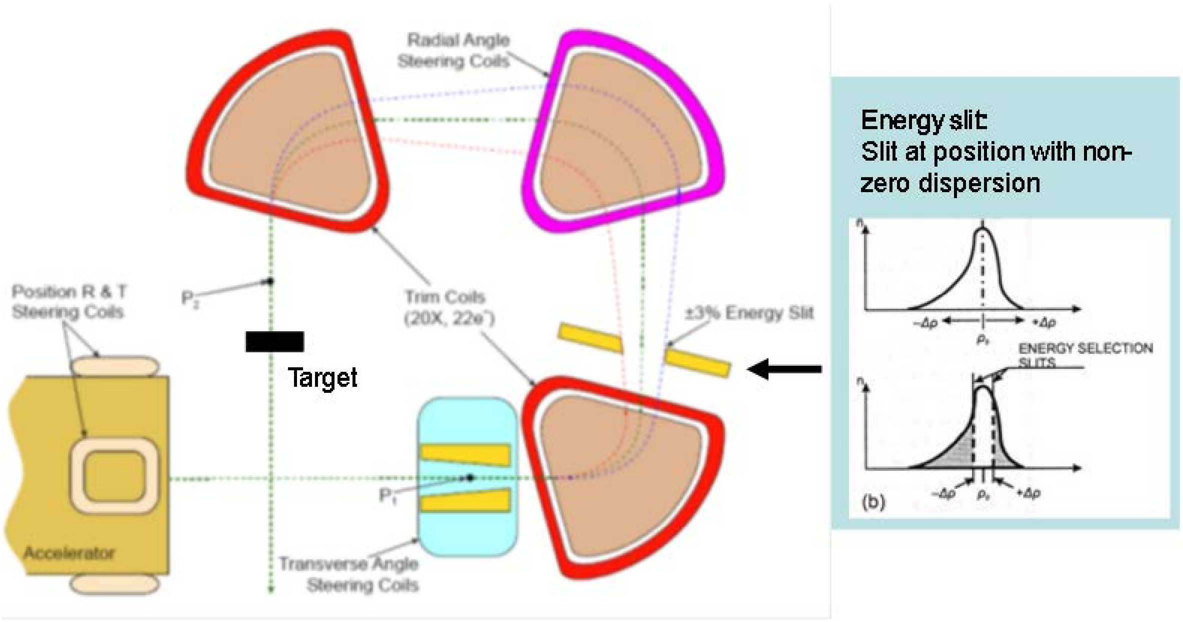
Same electric field in buncher for all beam energies

⇒ Design of optimum capture efficiency and energy spread for **wide range** of beam energies

⇒ Efficient transfer of electrons from gun to target for all energies

⇒ **High dose rate** for all energies

Varian



Elekta

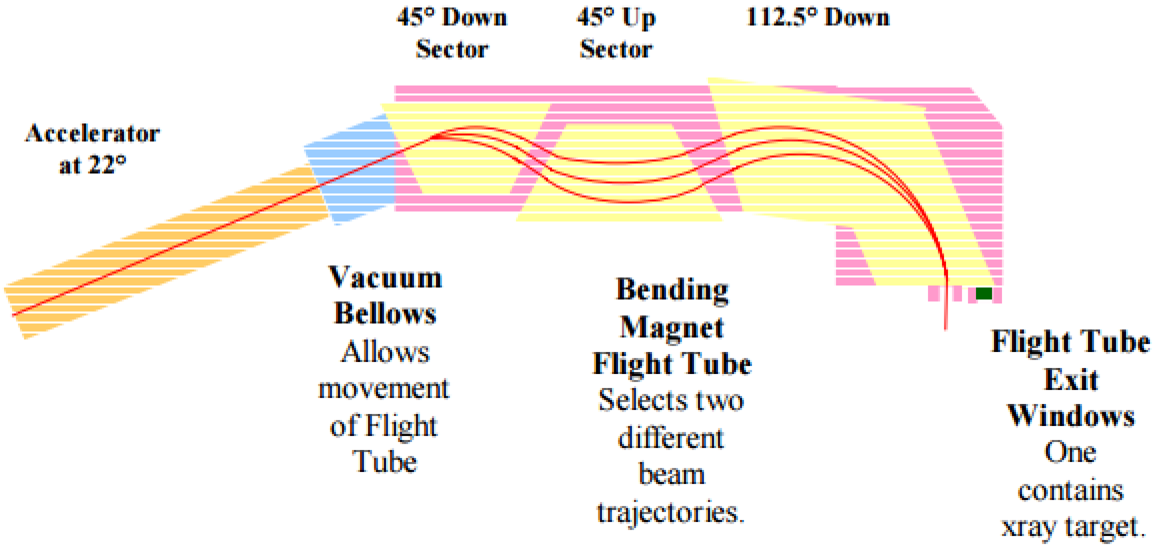
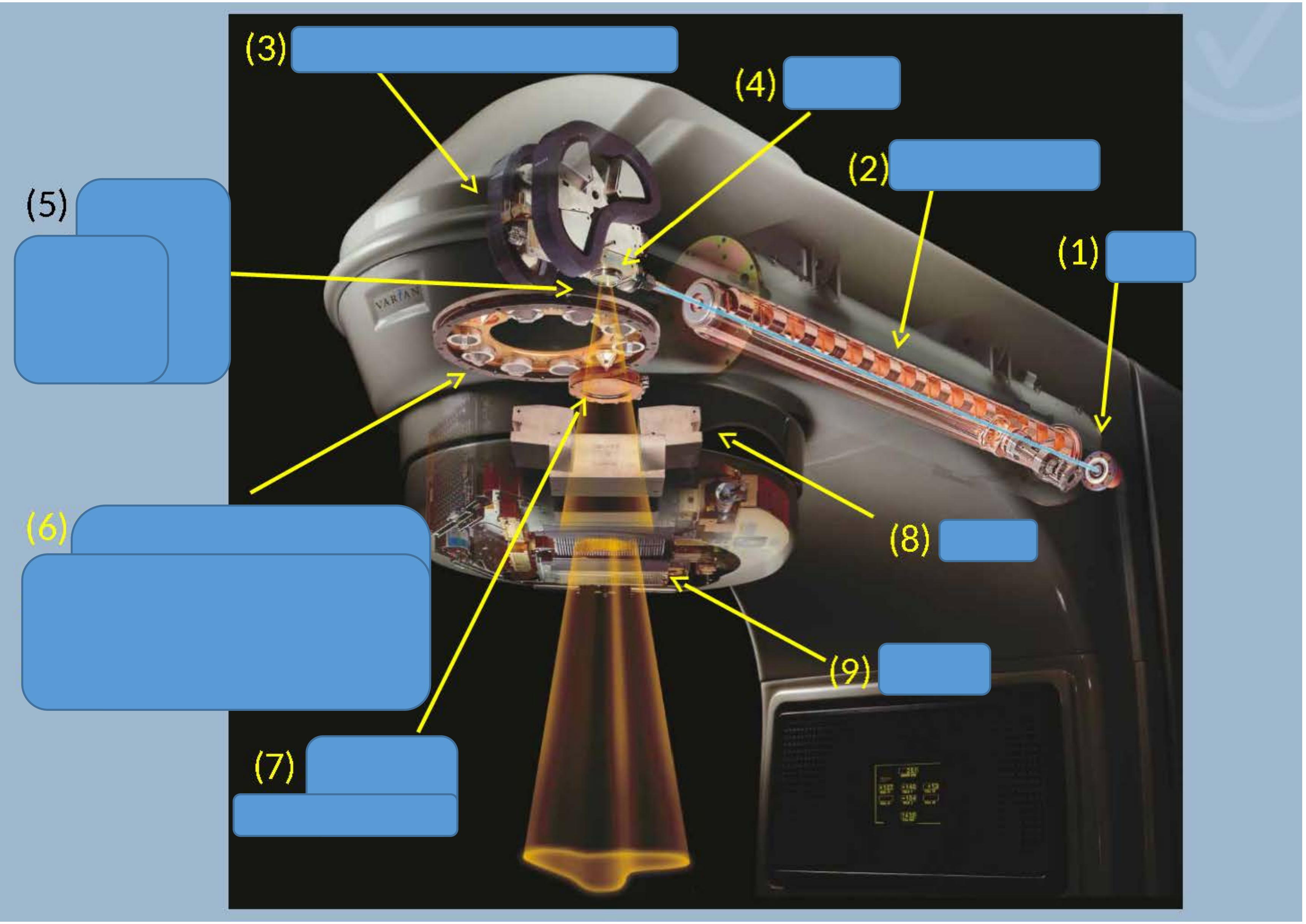
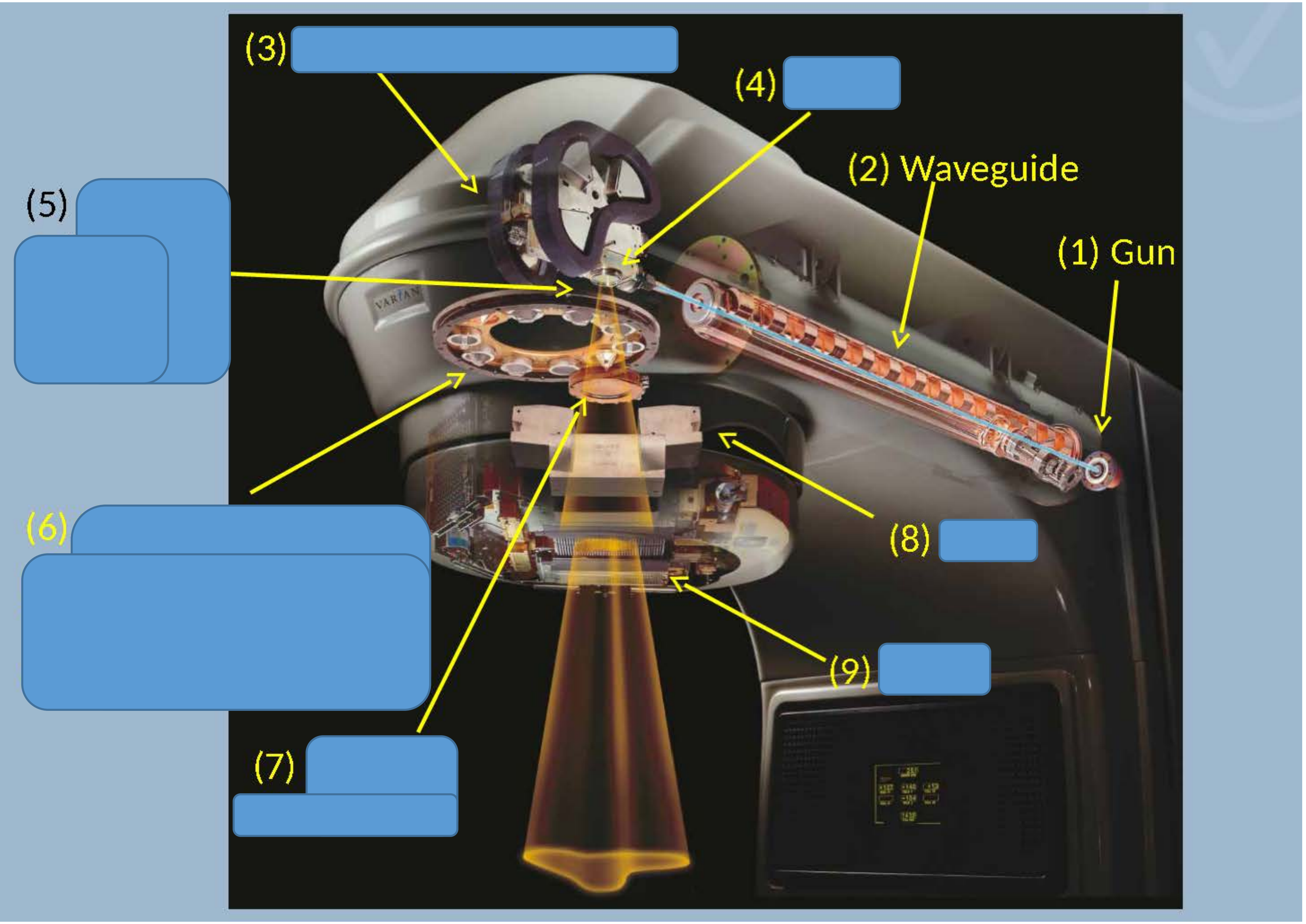


Figure 5: Simplified layout of 202.5° bending magnet system, flight tube, bellows, and dual ports (conceptual).



1. Electron gun
    - Generates electrons through **thermionic emission**.
    - Injects pulses of electrons to electron accelerator.

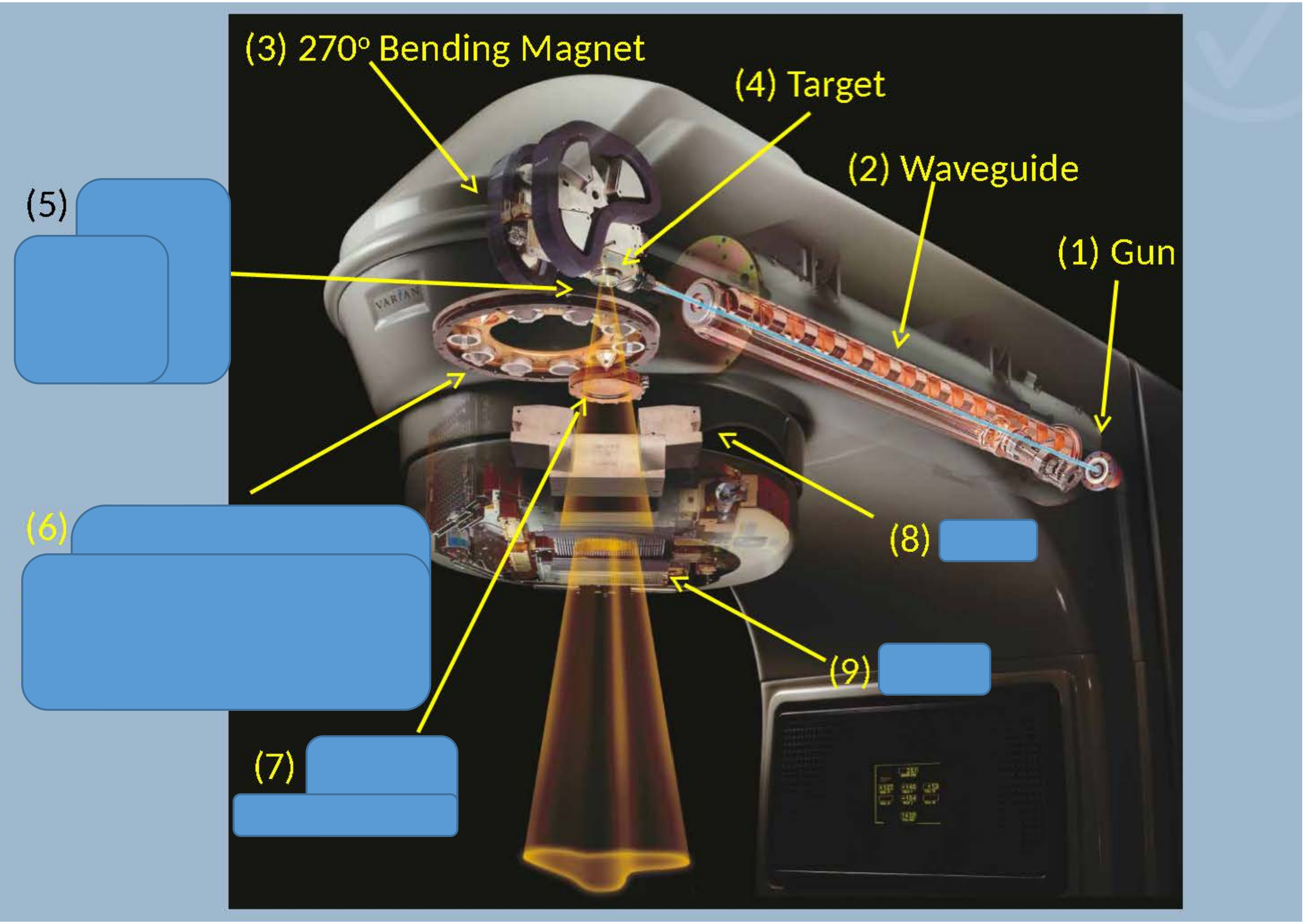
2. Accelerating waveguide
    - Either traveling or standing wave; standing is shorter
    - **3000 MHz** (**S band**)
    - CyberKnife, Tomotherapy = operates at **9000 MHz (X band)**
    - Powered by either magnetron (<=6MV) or klystron (>6MV).



3. Bending magnet
   - 270o design (**achromatic**)
   - Focus the beam;
     Angle
     Position
     Energy

4. Target
   - Converts electrons to bremsstrahlung photons
   - Conversion efficiency is on the order of **1% (1-20%??)**
   - Made of high-Z materials (good for bremsstrahlung process)
   - Usually some **tungsten alloy***

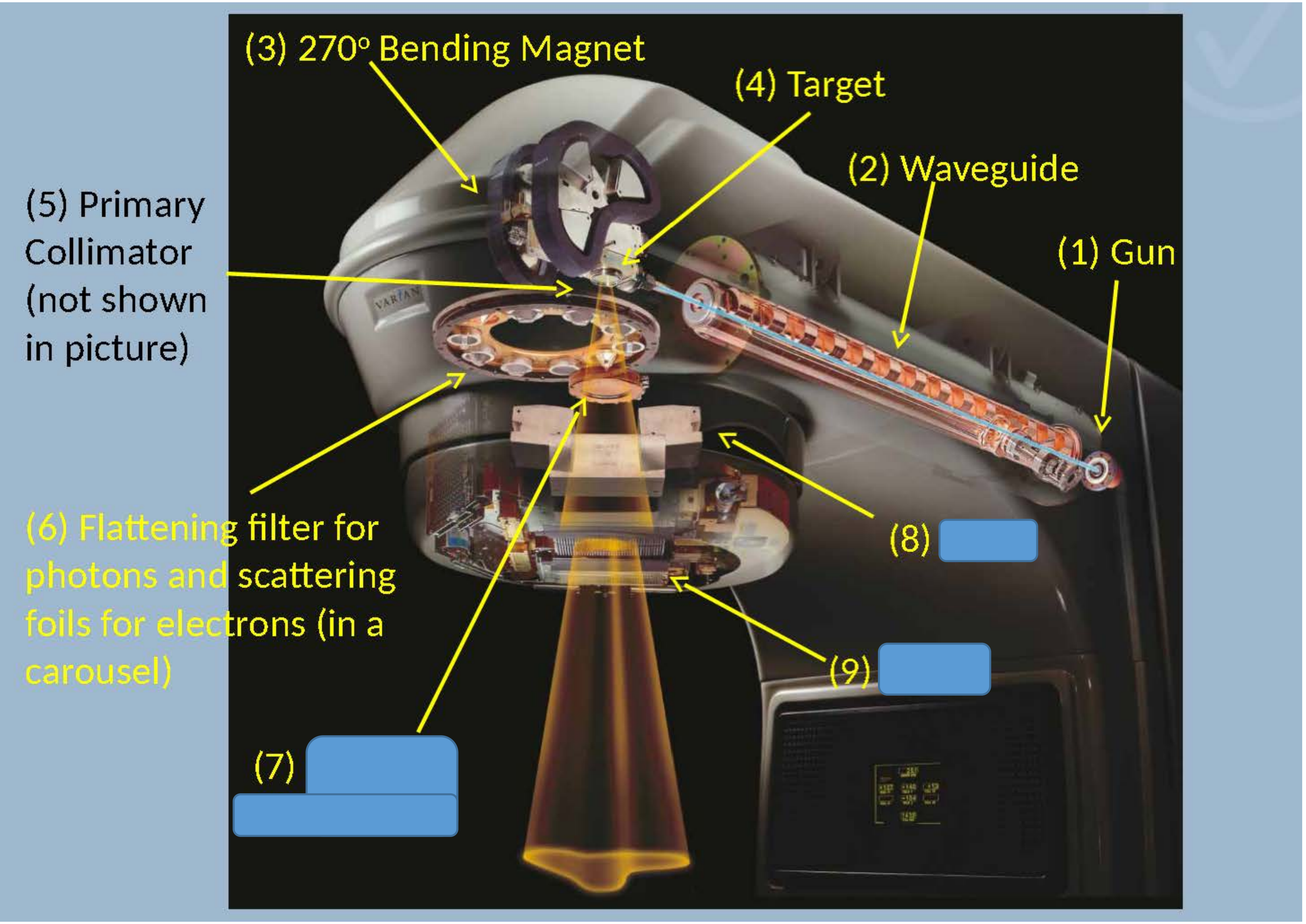
*lower E uses higher Z target while higher E uses lower Z target



5. Primary collimator
   - Collimates the beam coming out of target to a **circular beam**
   - Minimizes side leakage to **0.1%**

6A. Flattening filter (for photons)
   - **Cone shaped** to reduce beam fluence at center
   - Should not use high-Z material because it changes spectrum
   - Usually made of medium-Z material, usually **aluminum**
   - Creates flat beam at specific depth, usually **10 cm**

6B. Scattering foils (for electrons)
   - **Each electron energy** has its own foil
   - Could be 1 or 2 layers (one for scattering, one for flattening)



7. Monitor chambers
   - There are two layers (for MU1 and MU2)
   - Each one has 5 leads (center, ±X, ±Y) for output and symmetry*.

*positioned AFTER the flattening filter.

8. Jaws
   - The higher the jaw position, the larger its penumbra
   - Leakage max should be less than **2%** by IEC. Usually **<0.5%**.

9.MLC
   - Leakage should be less than 5%.
   - Usually <1% (intraleaf) and 1-2% (interleaf)

- It is known efficiency of x-ray production in thick targets is proportional to the atomic umber (Z) of the material. Therefore high Z targets produce beams with highest efficiency. However experiments conducted showed that in the forward direction within +/-15%, the x-ray yield is independent of the target atomic number. The x-ray yield is even slightly higher for low Z targets in comparison to high Z target such as lead. On the central axis at electron kinetic energies greater than 15 MeV, the effective energy from a low Z target is higher than a high Z target. Low Z target produces more penetrating beam in forward direction than high Z target. Effective energy of photon beam is highest in the forward direction. Greater than 15 degrees from the central axis does not add value to the beam but only counts as leakage