Using TOP-C for Proton Beam Dose Volume Simulations

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Laser-accelerated protons

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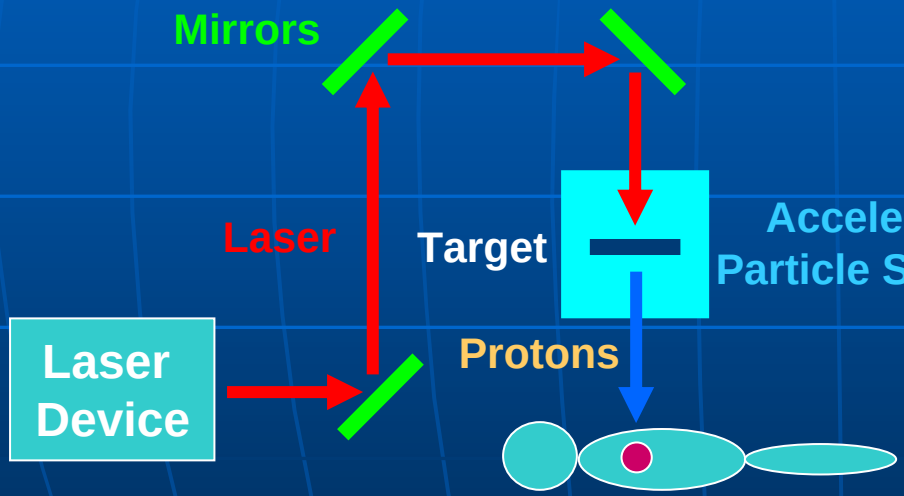
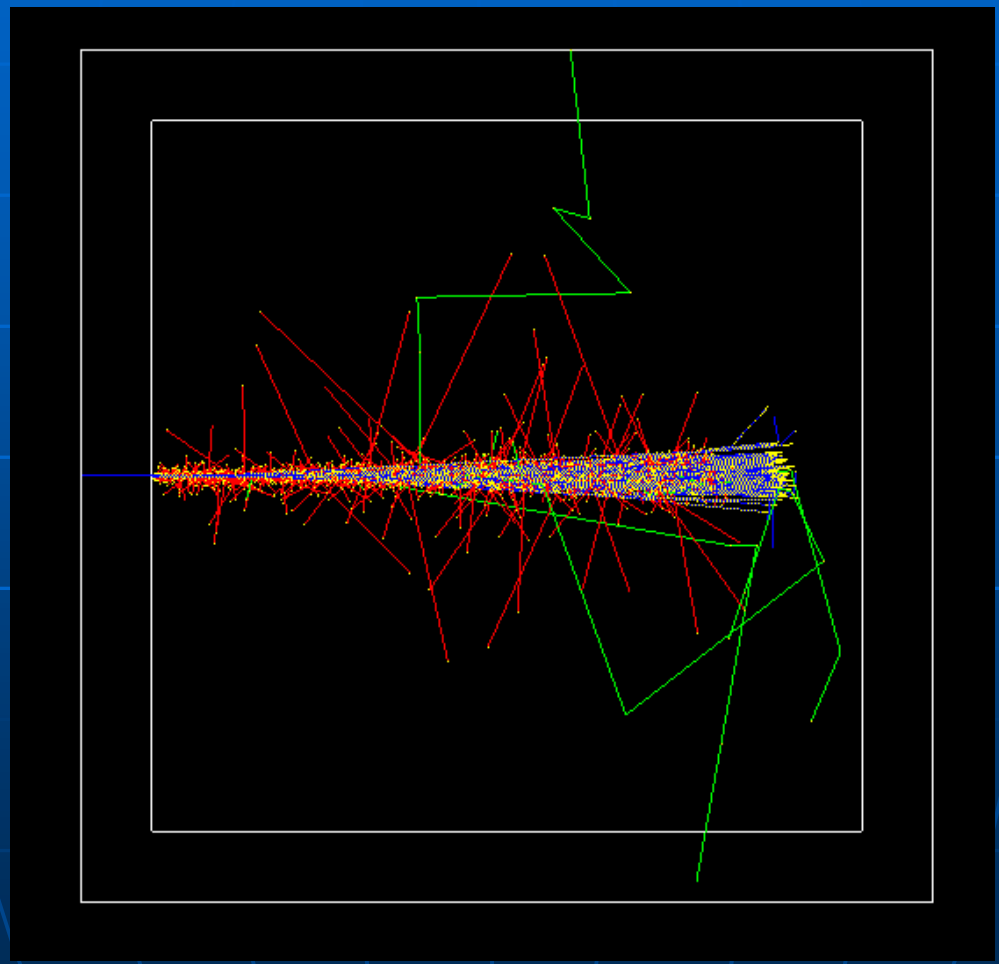


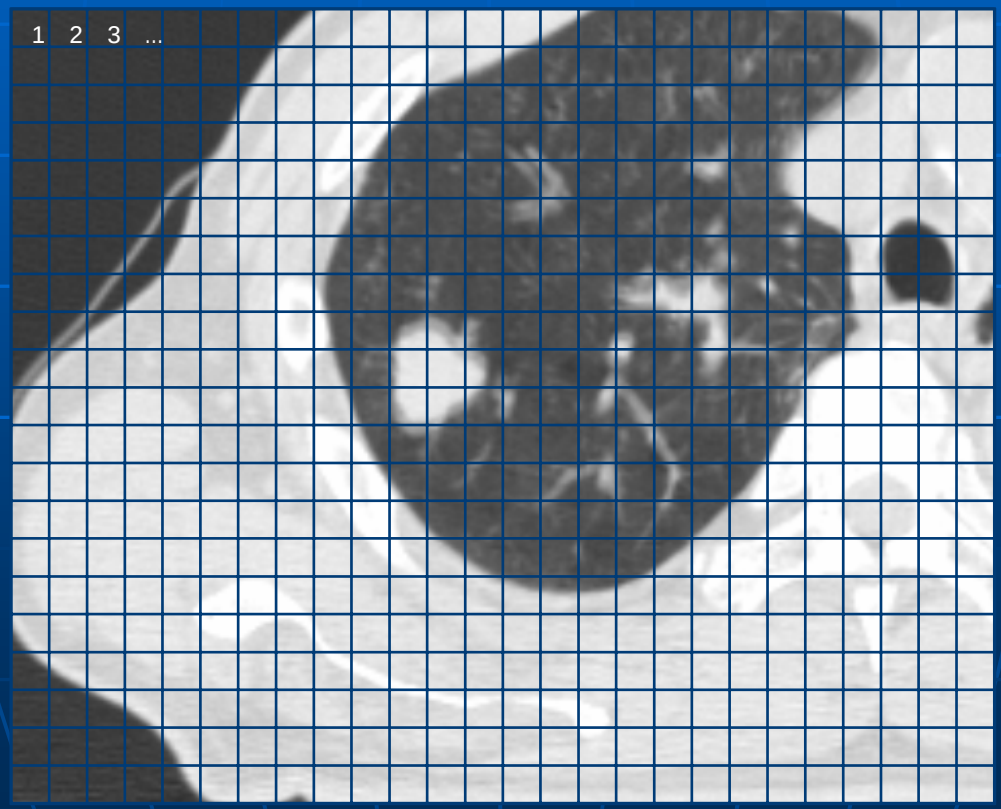
- Compact Laser Device (in the future)
- No Bending Magnets
  :Optical Beam Transport
- No Massive Radiation Shielding

GEANT4 Simulation



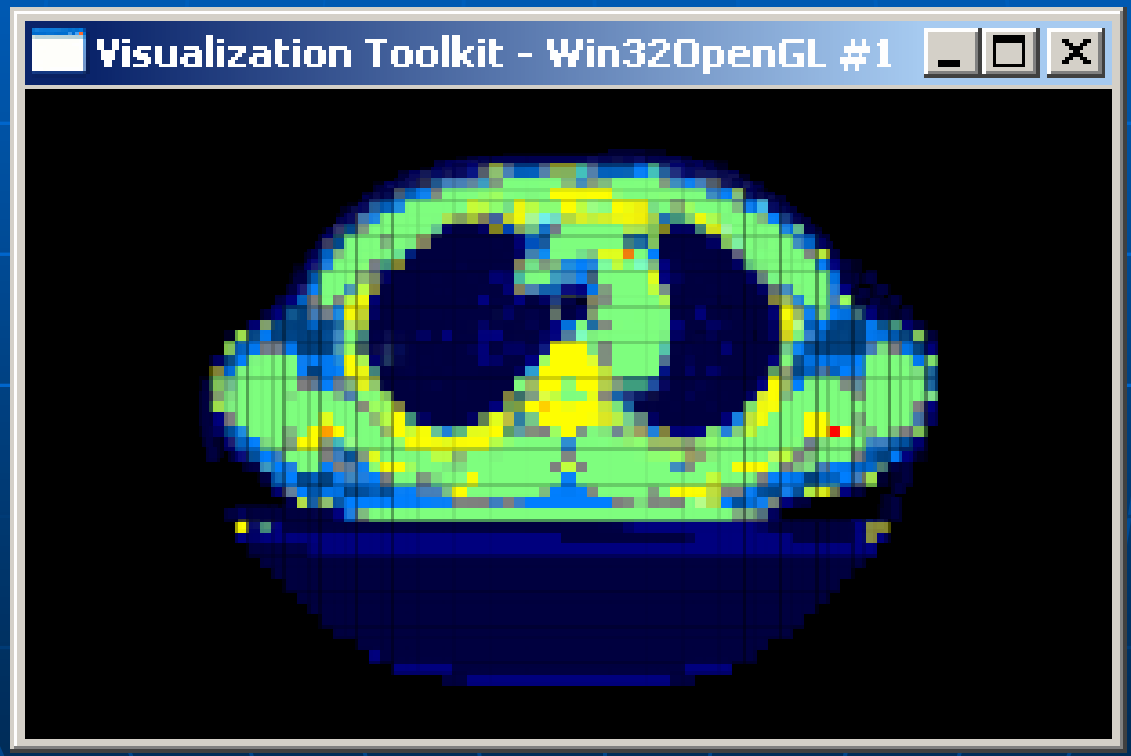
CT Volumes

- Divide the CT volume into voxels.

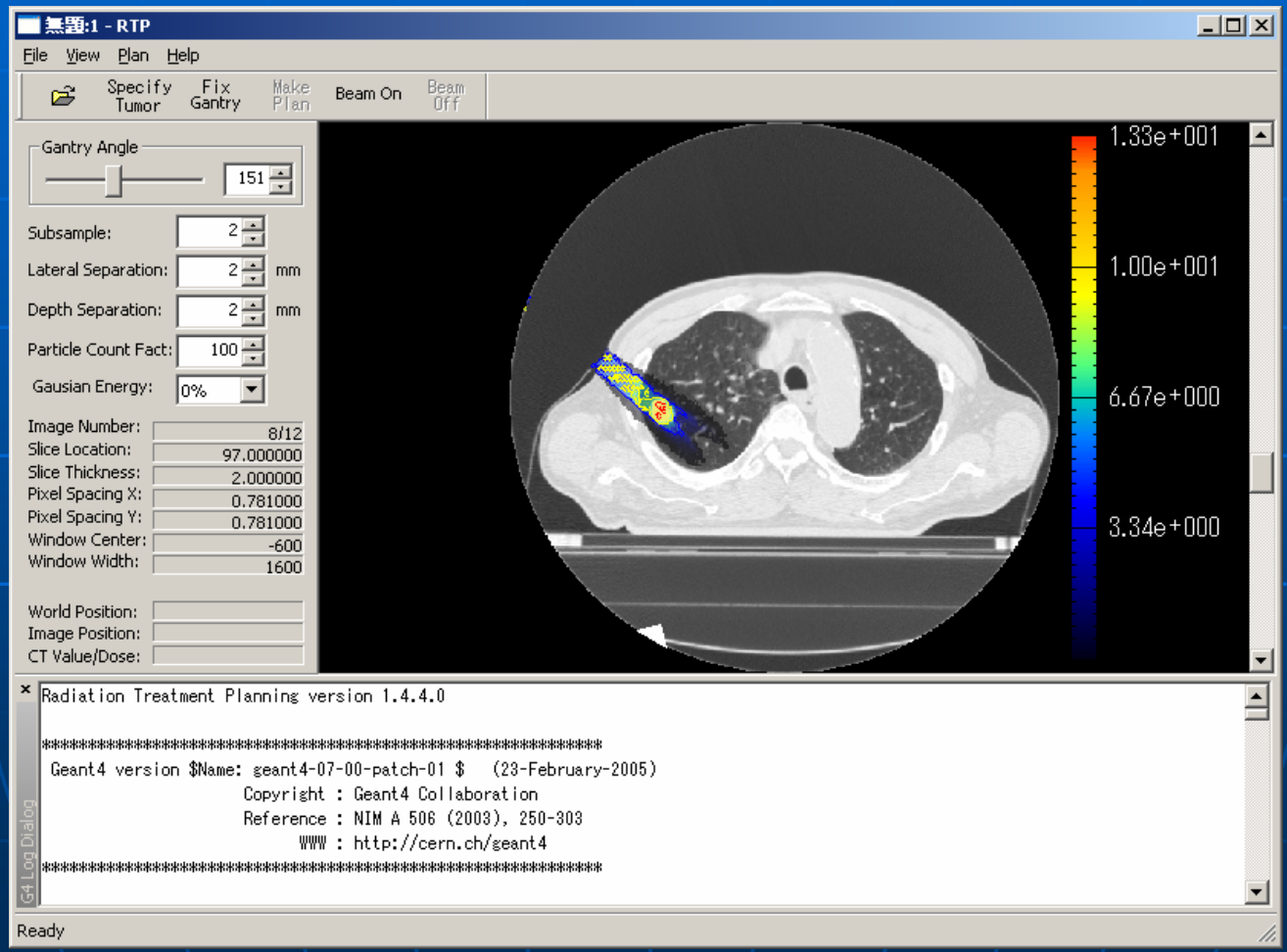


CT Volumes

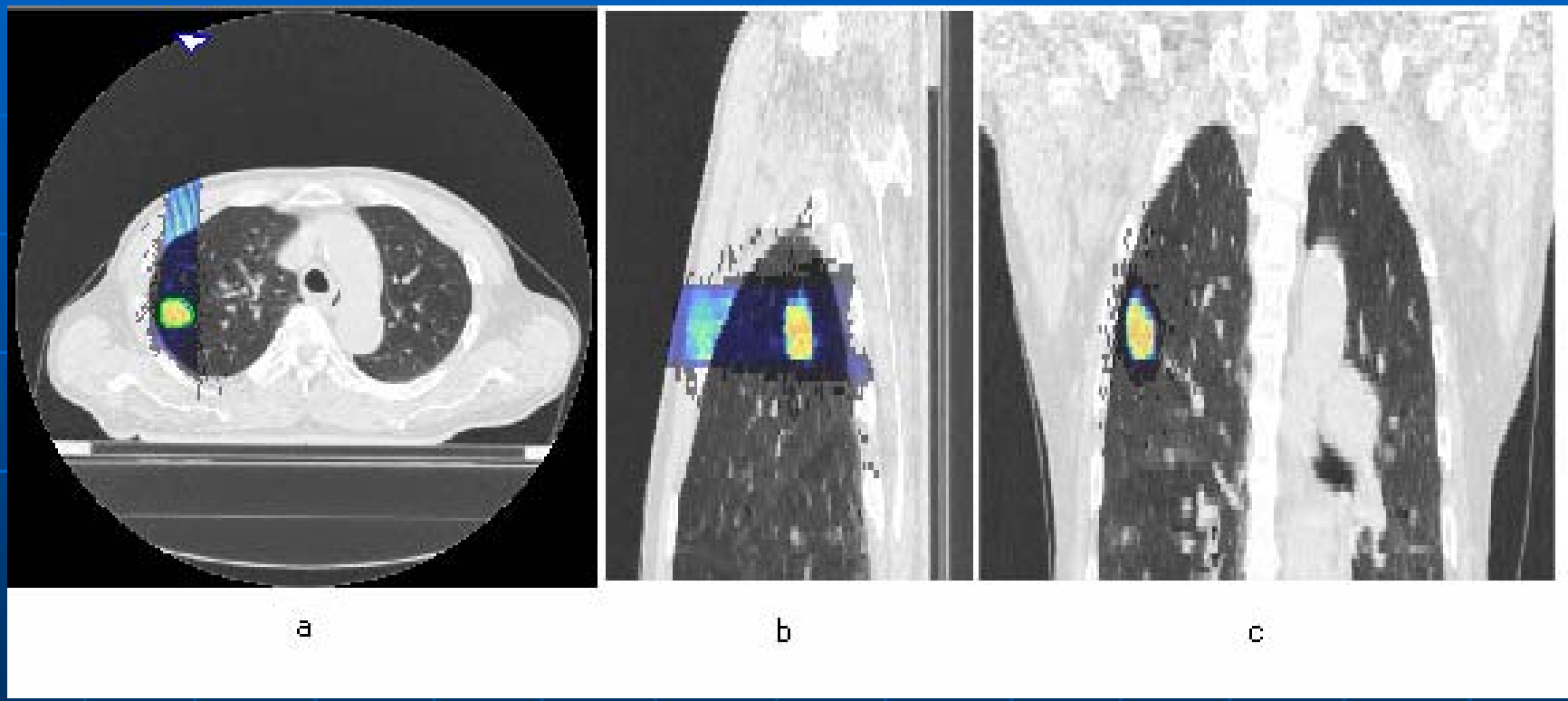
- Assign a material to each voxel.



Radiation Treatment Planning

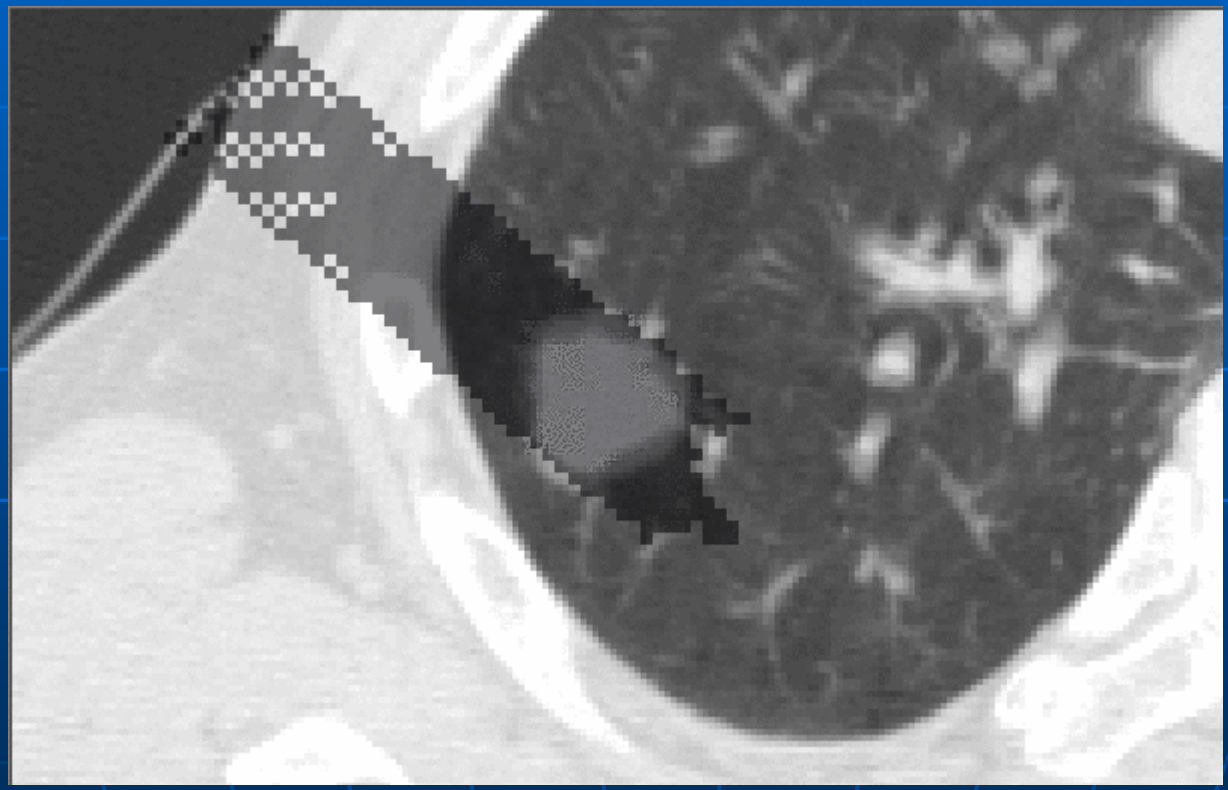


Dose Distribution Display

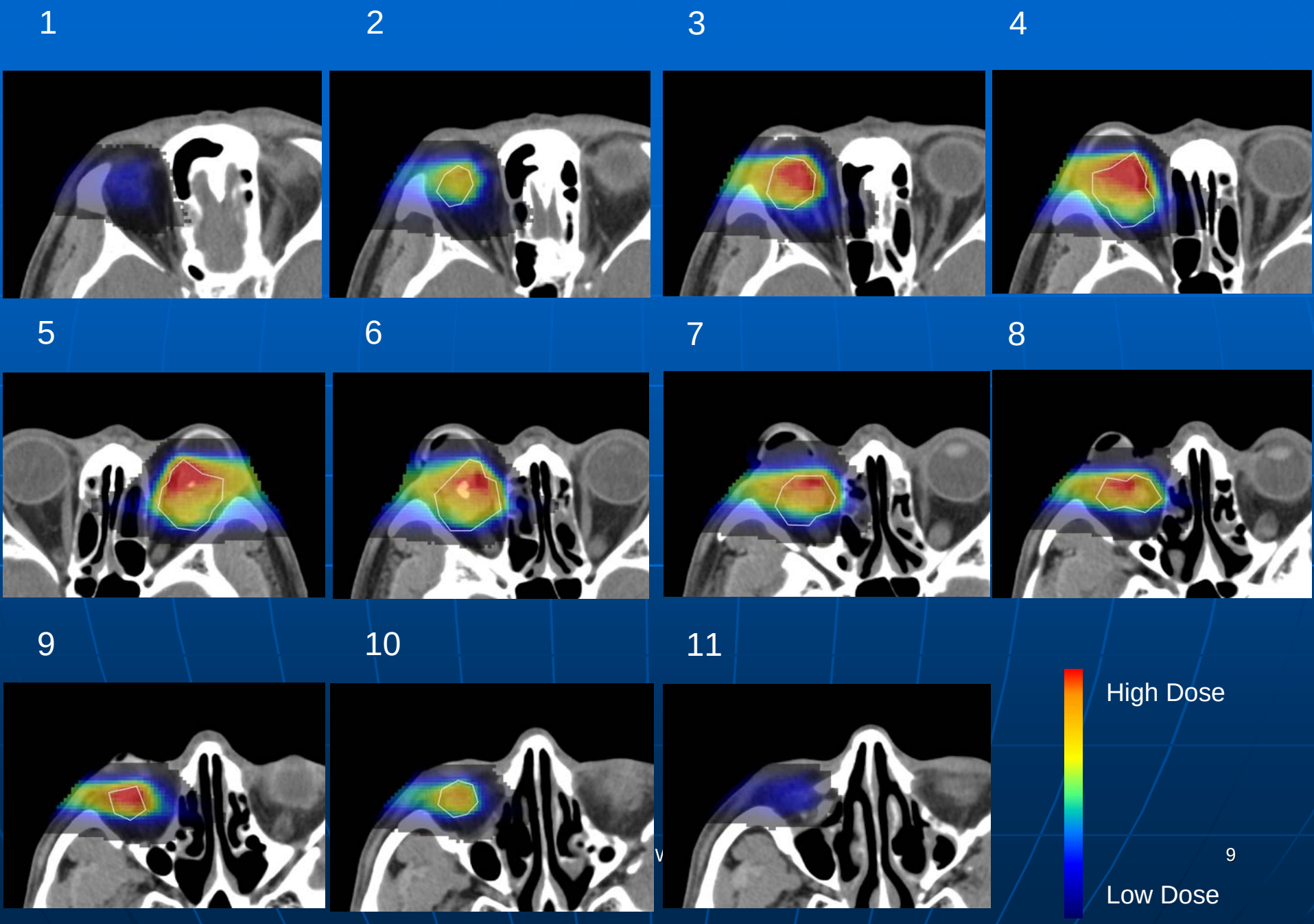


a b c

Isodose Curves



【Melanoma1: Target Volume/Color Plot 】



Linux Cluster

- 22 Slaves (clients)
  - Pentium 4 3.0 GHz
  - 2 GB Memory 40 GB HD
  - Red Hat Linux 9
- Master (server)
- Netgear Gigabit 24 switch
- Monitor–Keyboard–Mouse switch
- Air conditioner, power

Cluster: Initial Results

- Based our software on GEANT4 example ‘ParN02’ which uses TOP-C.
- Only achieved a factor of ~2.
- Due to bottleneck from each slave reporting result of *each event* to master.

Bottleneck Cause

- The bottleneck results because of the master-slave nature of TOP-C.
- The master “farms out” events to the slaves.
- The slaves simulate one event, then send a long track list back to the master.
- Each step in the track contains position (*x*,*y*,*z*) and energy deposit (~32 bytes per step).

Tracking Information

```
**********************************************************************************************************
* G4Track Information:   Particle = proton,   Track ID = 1,   Parent ID = 0
**********************************************************************************************************

Step#       X          Y          Z         KineE     dEStep    StepLeng  TrakLeng    Volume     Process
    0    -12 cm       0 fm       0 fm    160 MeV      0 eV       0 fm       0 fm       World   initStep
    1    -10 cm       0 fm       0 fm    160 MeV  1.5e-018 eV   2 cm       2 cm       World   Transportation
    2   -9.27 cm    44.9 mum  -4.45 mum   156 MeV   3.51 MeV   7.25 mm   2.73 cm    Absorber       hIoni
    3   -8.58 cm     145 mum  -18.4 mum   153 MeV   3.33 MeV   6.99 mm   3.42 cm    Absorber       hIoni
    4   -8.56 cm     146 mum  -18.2 mum   152 MeV   92.4 keV    159 mum   3.44 cm    Absorber       hIoni
    5    -8.5 cm     159 mum  -18.9 mum   152 MeV    265 keV    598 mum    3.5 cm    Absorber       hIoni
    6   -8.28 cm     197 mum  -23.4 mum   150 MeV   1.17 MeV   2.24 mm   3.72 cm    Absorber       hIoni
    7   -8.17 cm     215 mum  -25.6 mum   150 MeV    481 keV   1.01 mm   3.83 cm    Absorber       hIoni
    8   -7.92 cm     267 mum  -52.2 mum   149 MeV   1.17 MeV   2.51 mm   4.08 cm    Absorber       hIoni
    9    -7.3 cm     416 mum  -87.4 mum   145 MeV   2.99 MeV   6.21 mm    4.7 cm    Absorber       hIoni
   10   -7.04 cm     460 mum   -137 mum   144 MeV   1.36 MeV   2.59 mm   4.96 cm    Absorber       hIoni
```

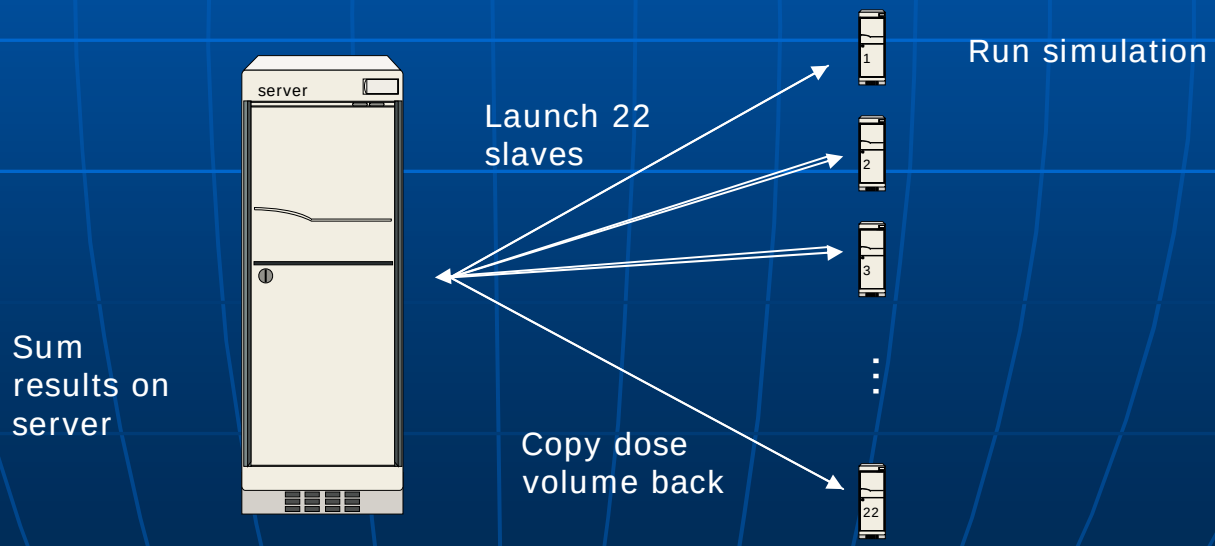
Tracking Info Overload

$$\left(\frac{10\,events}{\text{sec}}\times\frac{300\,steps}{event}\times\frac{32\,bytes}{step}\times\frac{8\,bits}{byte}\right)\times 22\,slaves=\sim 17Gbs$$

- By sending the track list of each event from each slave back to the server, we are exceeding the capacity of our network.

Workaround

- We found it better to accumulate the dose distribution on each slave, then sum up the results at the end.



Our “Parallel” Method

- Our planning software produces a long event list (initial position, direction and energy).
- Each slave has a copy of the list.
- Each slave determines which events to simulate.

Slave Event Assignment

Client	Events
slave01	1, 23, 45, 67, 89...
slave02	2, 24, 46, 68, 90...
slave03	3, 25, 47, 69, 91...
⋮	⋮
slave22	22, 44, 66, 88, 110...

```
void PrimaryGeneratorAction::GeneratePrimaries(G4Event* anEvent)
{
        if (((anEvent->GetEventID() % NumSlaves) + 1) != SlaveNum)
                return;
```

Conclusion

- By by-passing TOP-C, we were able to achieve a performance improvement of ~20 times on our cluster.
- Copying the dose volumes takes time. Can compress before copying.
- Work remains to improve our MPI interface.