ELI-NP Summer School Bucharest 21-25 September 2015

Opportunities for International Collaboration in Laser Driven Ion Therapy (Turkey and Rumania)

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Towards Laser Driven Hadron Cancer Radiotherapy: A Review of Progress

Applied Sciences, 4, 402-443,2014

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C-M Ma et al
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The Turkish Team consists of :

1) **3 Physicists,**

2) **3 Inorganic and Biochemists,**

3) **2 Pathologists**

4) **5 Surgeons of different specialities**

5) **2 Tissue biologists**

6) **2 Oncologists**

Before this kind of research is permitted, this must be passed by Ethics committee which was passed on the 26th November 2013

I lead an Internatıonal Consortıum tryıng to sıte a centre for laser drıven proton/heavy ıon therapy somewhere ın the world

Last year I was ınvıted to lead a Russıan sıte ın Nızhny Novgorod but fınally we were not funded

I have a contract to help sıte thıs ın Turkey

Cancer Statistics

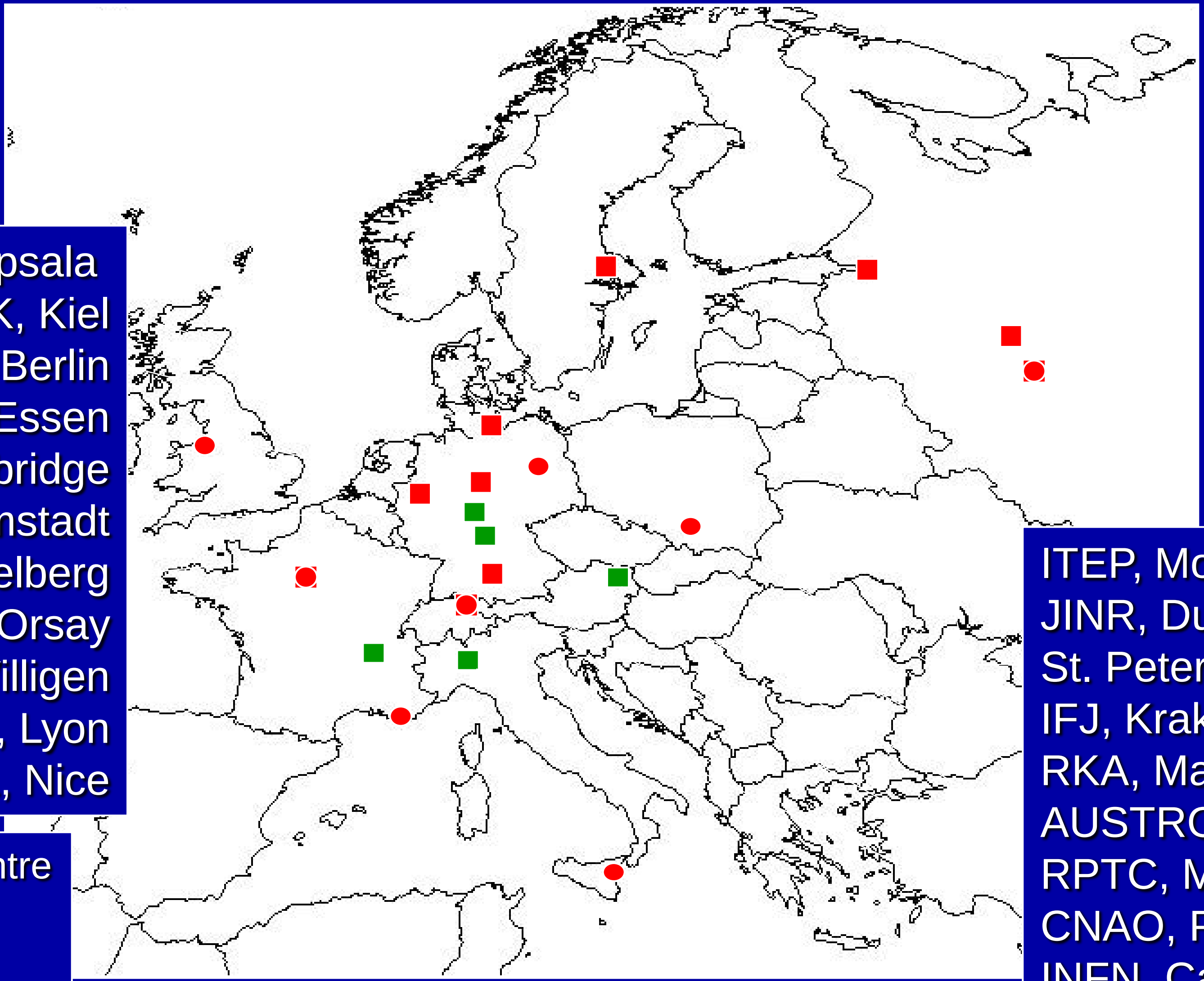
- 4% of people in developed countries are diagnosed with cancer each year
- 50% of these receive radiotherapy (X-rays) and surgery or both
- 100,000 patients have been treated with hadron therapy (protons and carbon ions)

Two Important Quotes

- **Ugo Amaldi *NIM A620, 563, 2010***
- **If 200 MeV proton accelerators would be as cheap and small as the 10 MeV electron linacs used in conventional radiotherapy, at least 90% of the patients would be treated with proton beams.**
- **Charlie Ma *Med.Phys.33, 571-573, (2006)***
- **Within the Next Decade Conventional Cyclotrons for Proton Therapy will become obsolete and replaced by far less expensive Machines using Compact laser systems for the Acceleration of the protons.**

There are 39 Conventional Accelerator Proton-Heavy Therapy Centres around the World

Proton and ion therapy in Europe



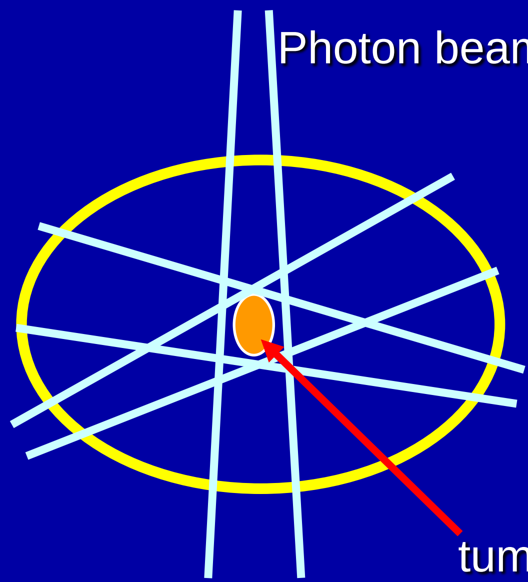
TSL, Uppsala
NRoCK, Kiel
HZB, Berlin
WPE, Essen
CCO, Clatterbridge
GSI, Darmstadt
HIT, Heidelberg
CPO, Orsay
PSI, Villigen
Etoile, Lyon
CAL, Nice

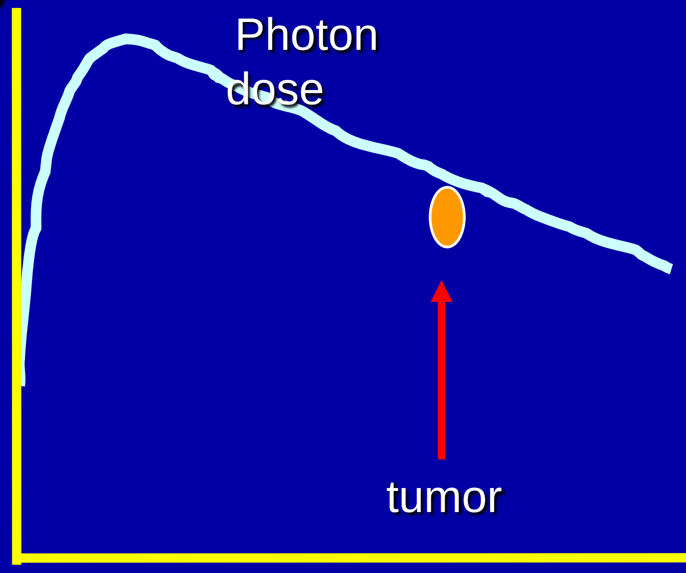
- Proton Centre
- Ocular
- Carbon

ITEP, Moscow
JINR, Dubna
St. Petersburg
IFJ, Krakow
RKA, Marburg
AUSTRON
RPTC, Munich
CNAO, Pavia
INFN, Catania

Radiation Therapy

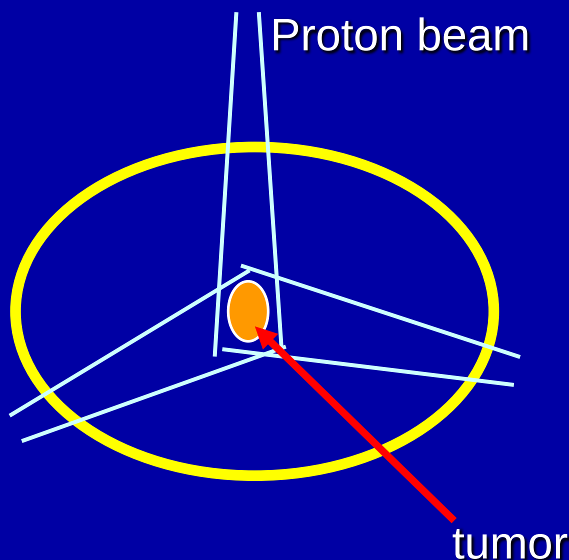
- Photon beams are commonly used for radiation therapy

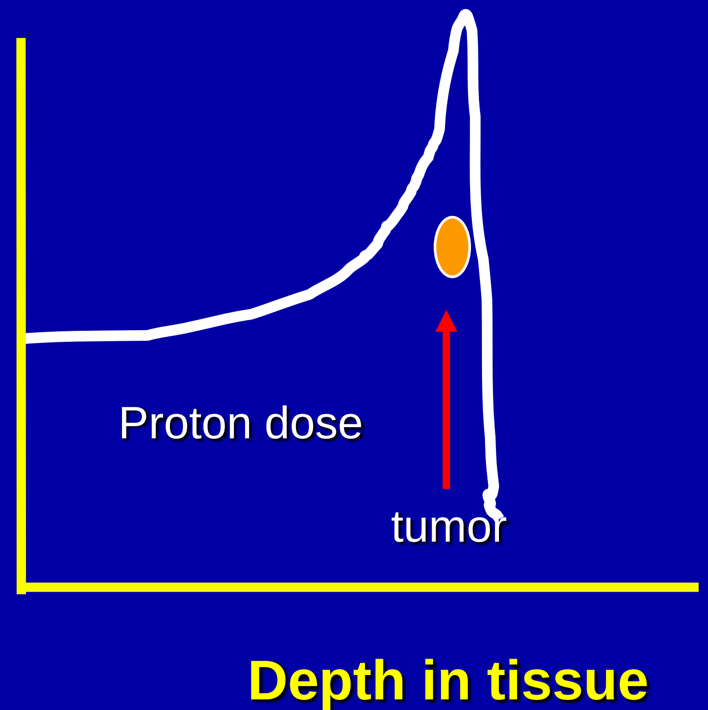




Why Proton Therapy?

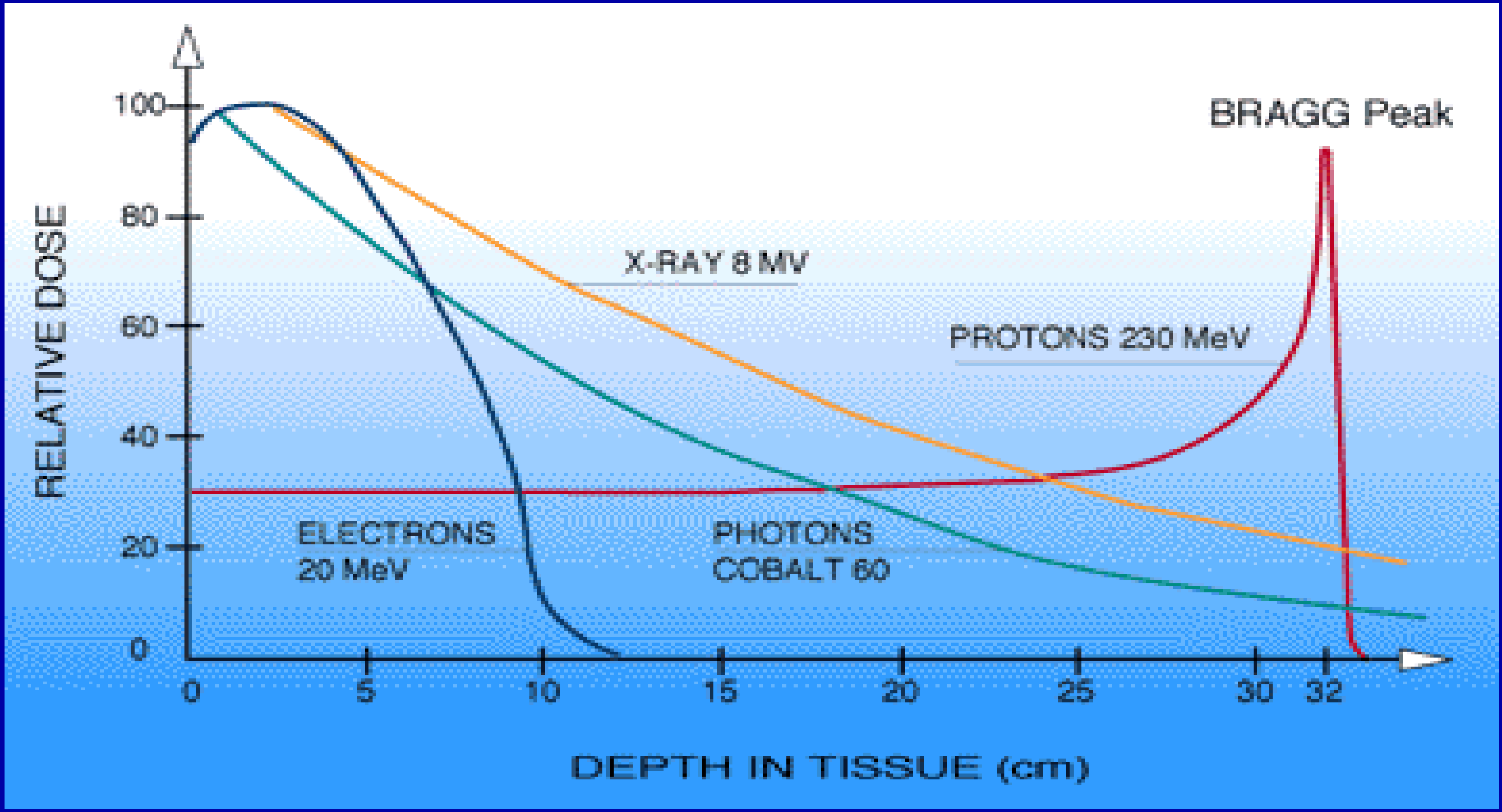
- Protons have better dosimetry properties than photons





Ion Therapy is a tissue sparing therapy

Bragg peak



At present 99% of radiotherapy is done with photons

What proton energy do we need for deep sited tumours e.g. in stomach?

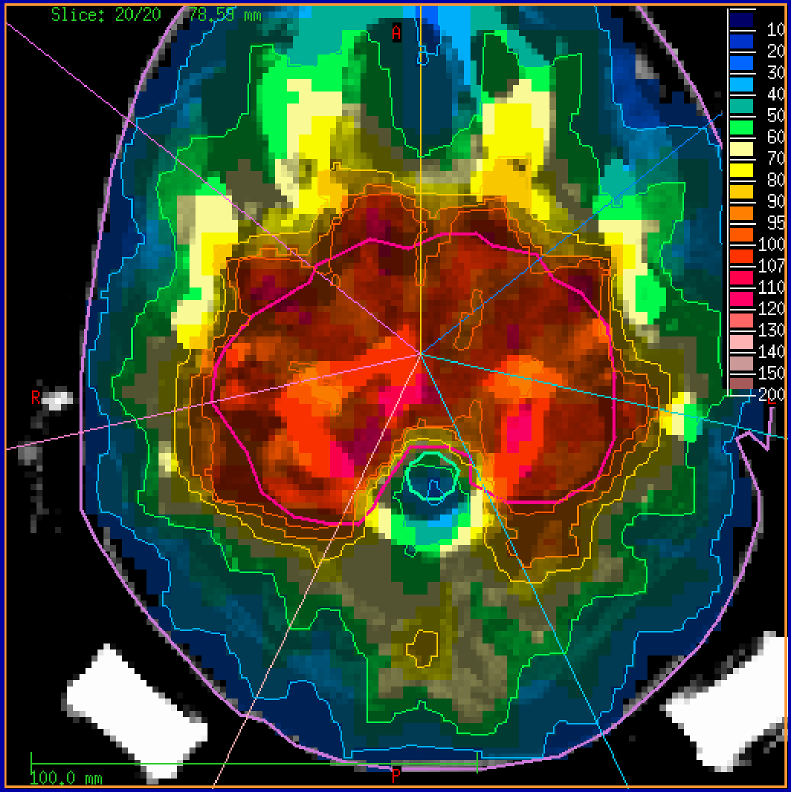
250 MeV

For Ocular tumours

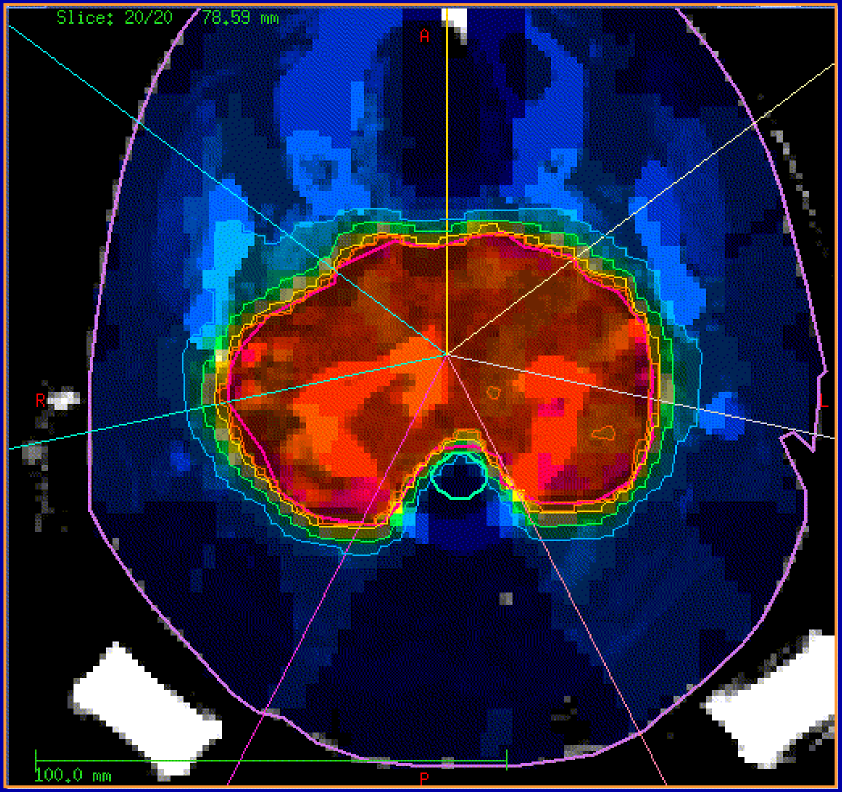
70 MeV

Dose distribution

With X ray radiotherapy

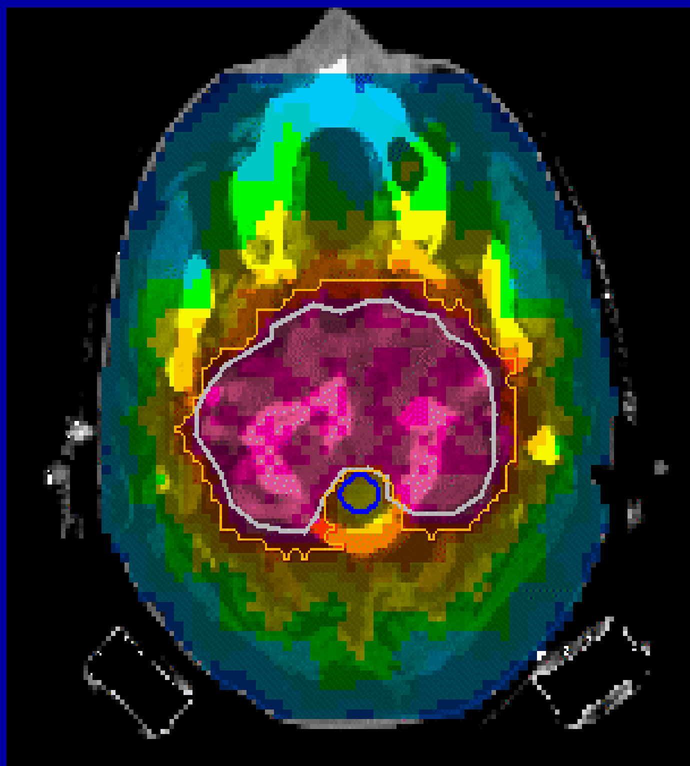


By protontherapy

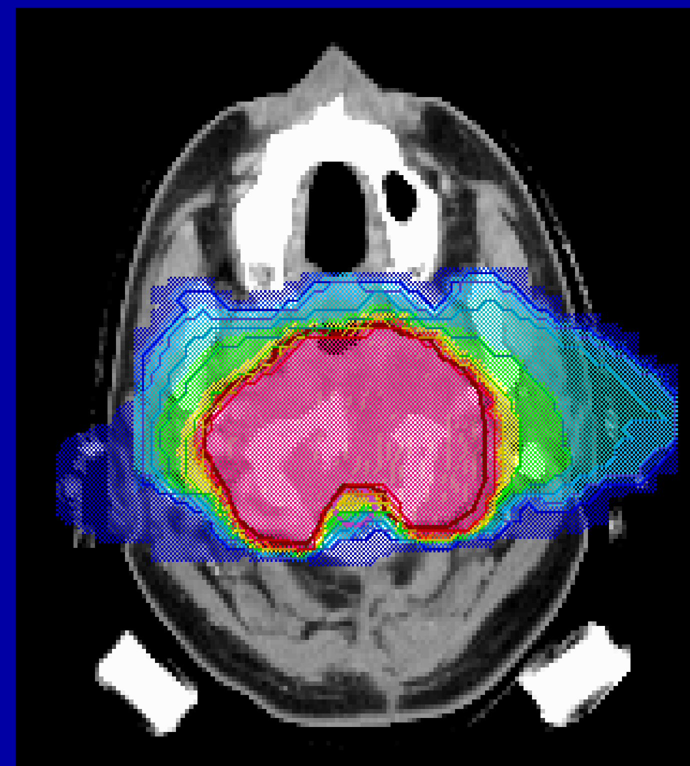


Tissue Sparing

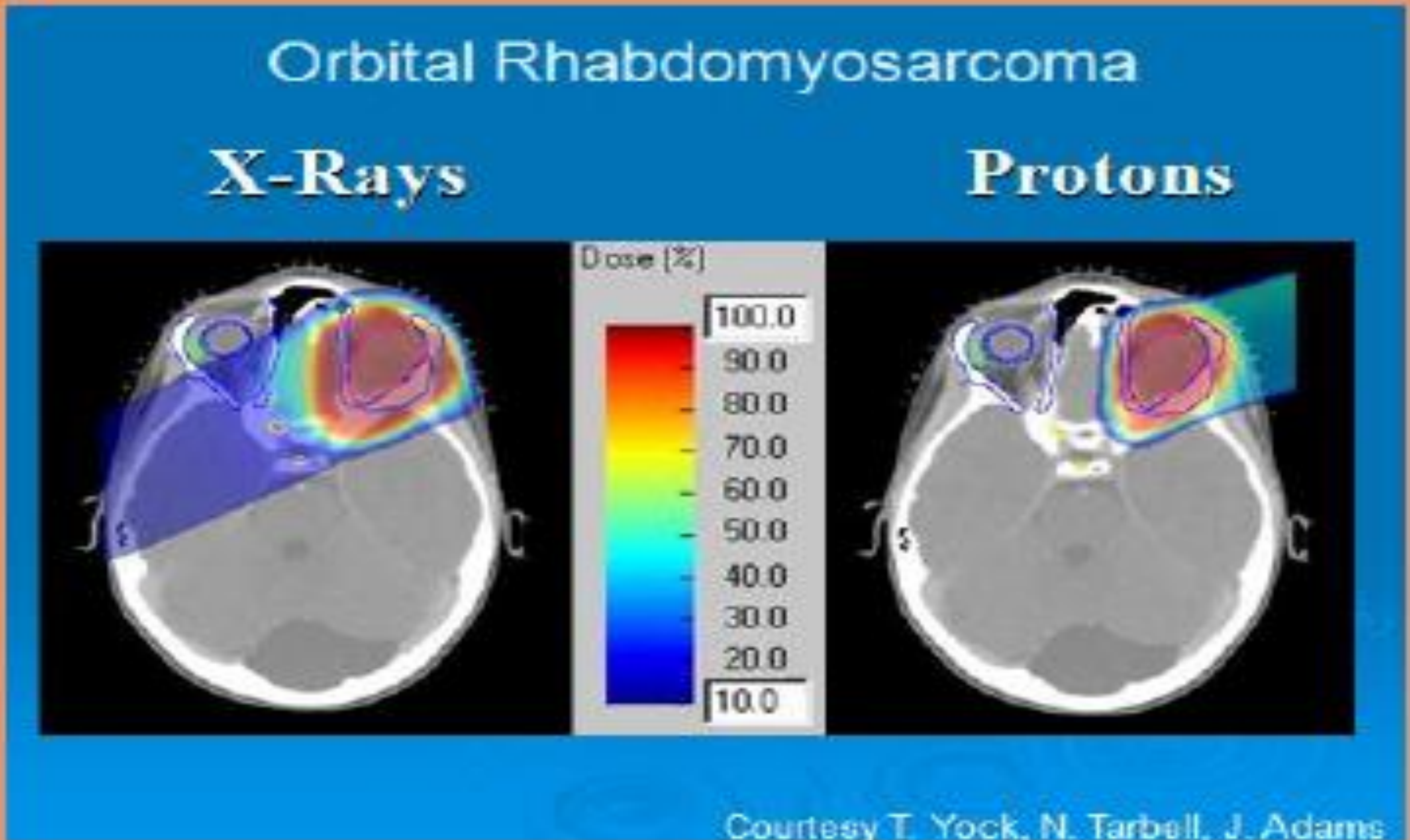
Dose Difference Between X-rays and Carbon Ions



Ultrahard X-rays



Carbon ions



Example of proton therapy for a rare orbital tumour in a child. The x-ray comparison shows that the beam deposits radiation in a much wider area with consequent risks of future toxicity such as bilateral blindness.

The Story of Ashya King

Ashya King (5 years old) lives in Southampton UK and was being treated for a brain tumour in the UK.

He was removed from the hospital by his parents a year ago and fled to Prague for proton therapy

Ashya King Family. Ashya is one of seven siblings aged 5


PROTON
THERAPY
CENTER

Proton Cyclotron in Prague for proton therapy

Milestones

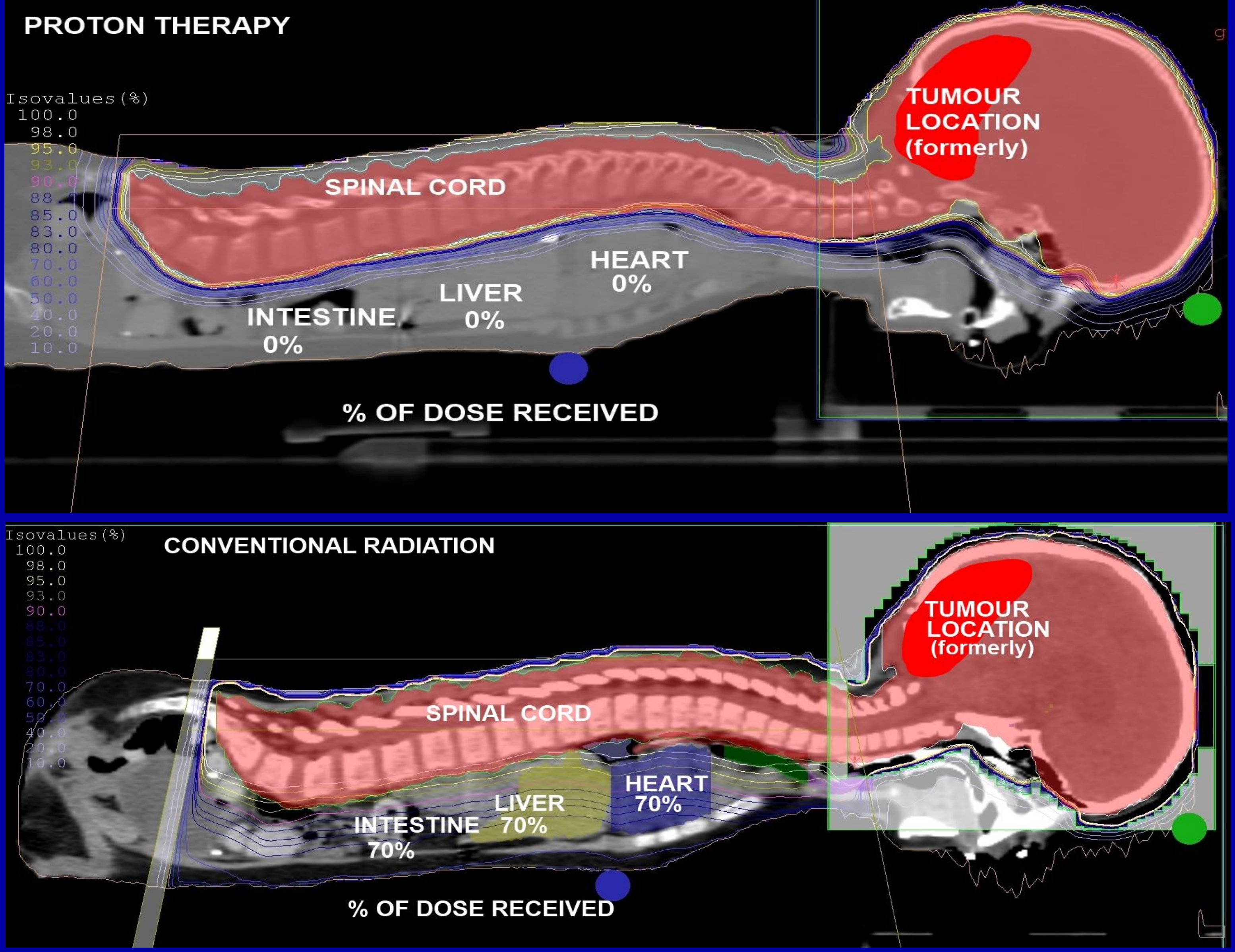
1999 – Vision to build a Proton Center in Prague, The Czech Republic.
2004 – Initiation of preparation and planning for the project
2006 – Initiation of design work
2007, April – Municipal decision (05/04/2007)
2008, June – Building permit (09/06/ 2008)
2009, May – Building started (01/05/ 2009)
2010, June – Fabric completed (24/07/2010)
2011, April – Installation of the cyclotron
2012, December – 1st treatment room became operational and treatment of first patients commenced
2013, January – 2nd treatment room became operational
2013 – Gradual operation of the 3rd, 4th and 5th treatment rooms and continuous

The proton treatment in the Czech republic was partially funded by the UK charity Kids "n" Cancer for £100,000

Diagnostics at the proton therapy Centre in Prague

Proton therapy Centre Prague. The patient is fixed and proton beam is rotated around the patient to irradiate all sides of a tumour

Ashya King: Inside the Prague Proton Therapy Centre where British five-year-old was treated



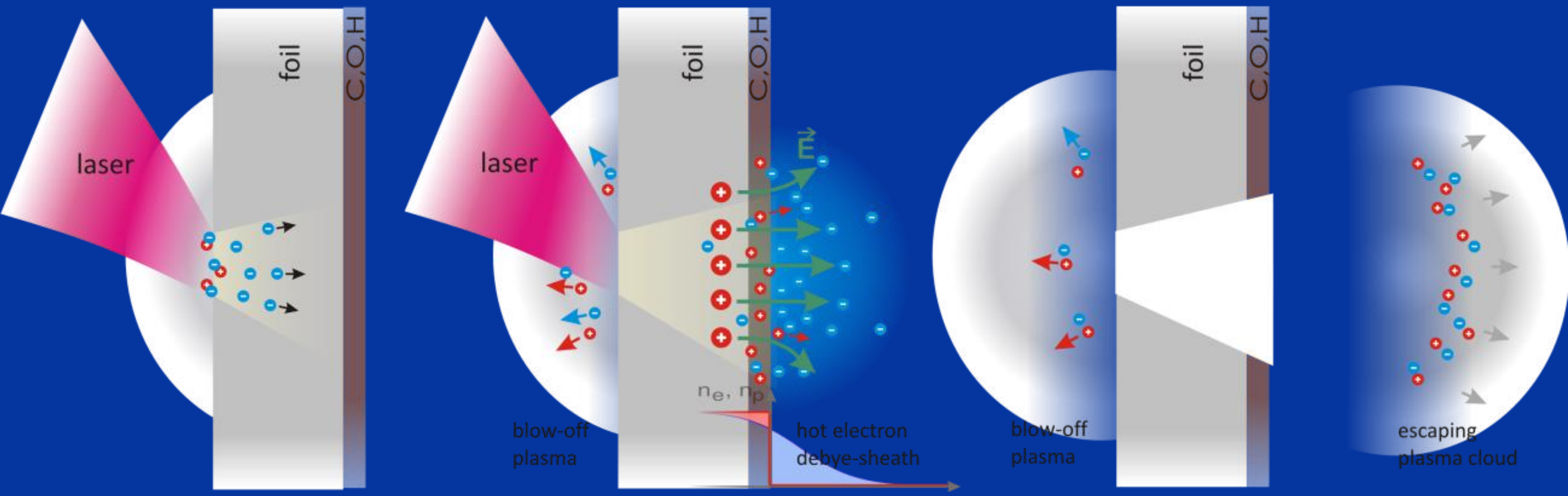
Difference between conventional X-ray therapy and proton therapy showing tissue and organ sparing

Ashya leaving hospital after proton treatment lasting six weeks

Laser Driven Proton Beams Beams

Where are we?

Laser particle acceleration mechanisms
Protons: Target Normal Sheath Acceleration (TNSA)



The laser light:

- focused to (10 µm)^2
- creates a plasma at the front surface of the foil (Ti: 2 µm)

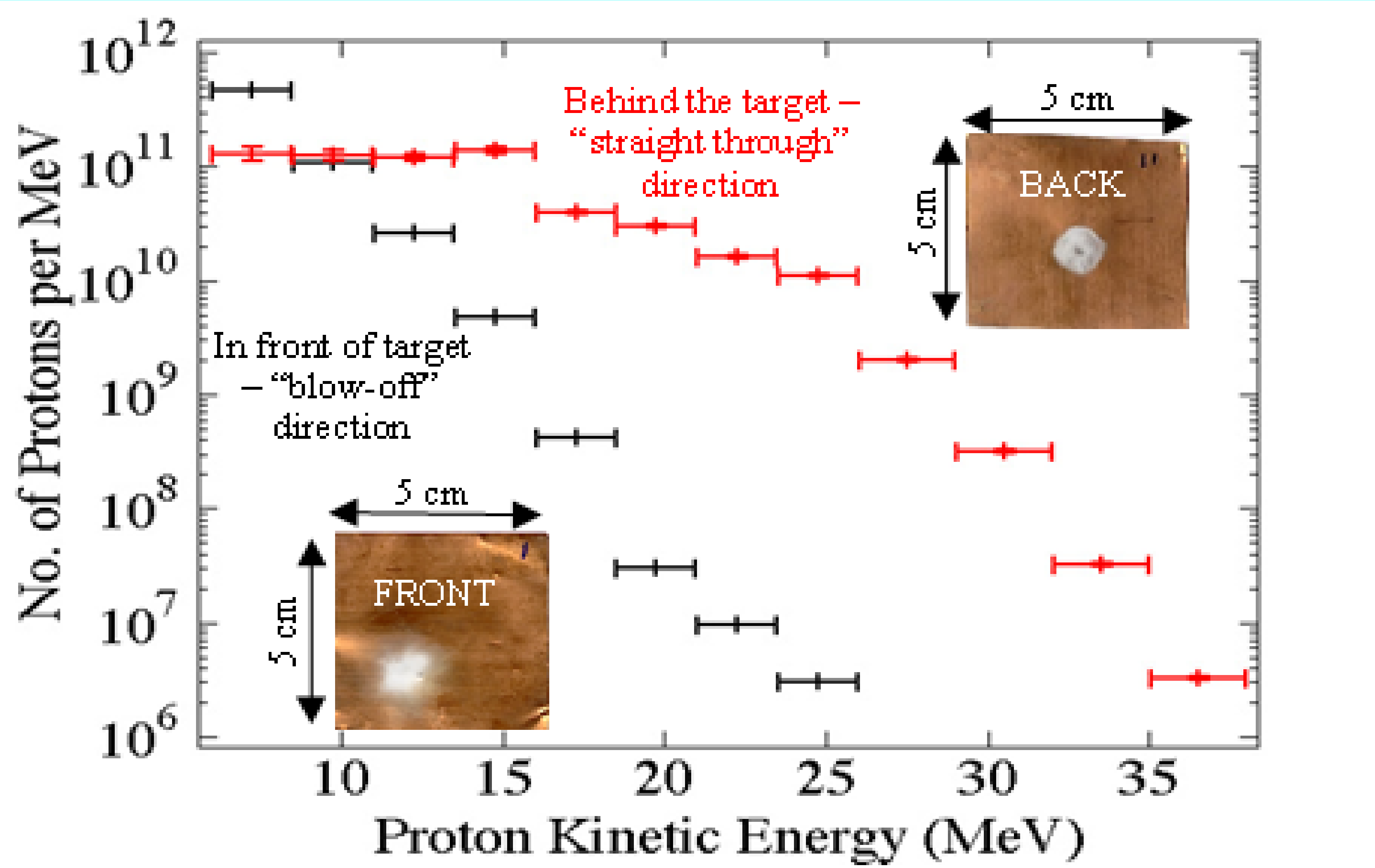
The electrons:

- propagate through the foil
- exit the foil
- build up a quasi-static electric field

The electric field:

- ionizes the rear surface of the foil
- accelerates the protons

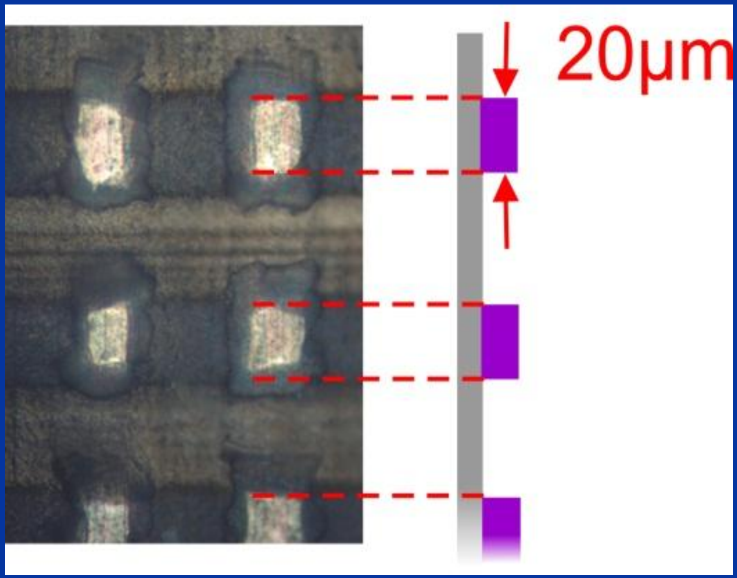
Proton Spectra from 100TW

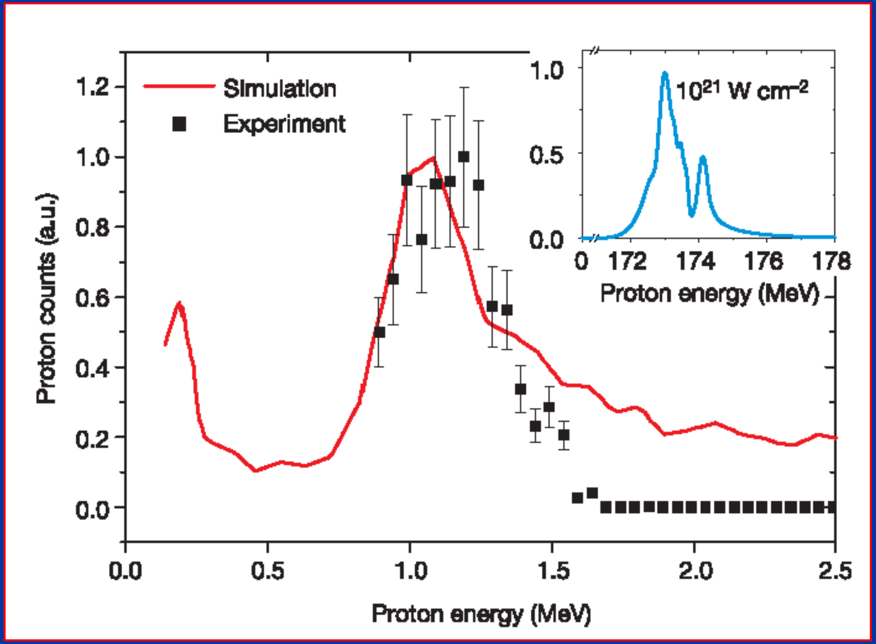


TNSA proton acceleration from micron foils leads to a continuous spectrum with upper energy levels of about 70 MeV and this has not changed for more than ten years.

Research on laser particle acceleration
Radiator target development

- Increase of proton energy at given laser power
- From exponential to (quasi) monochromatic energy spectra
- Low divergence beams





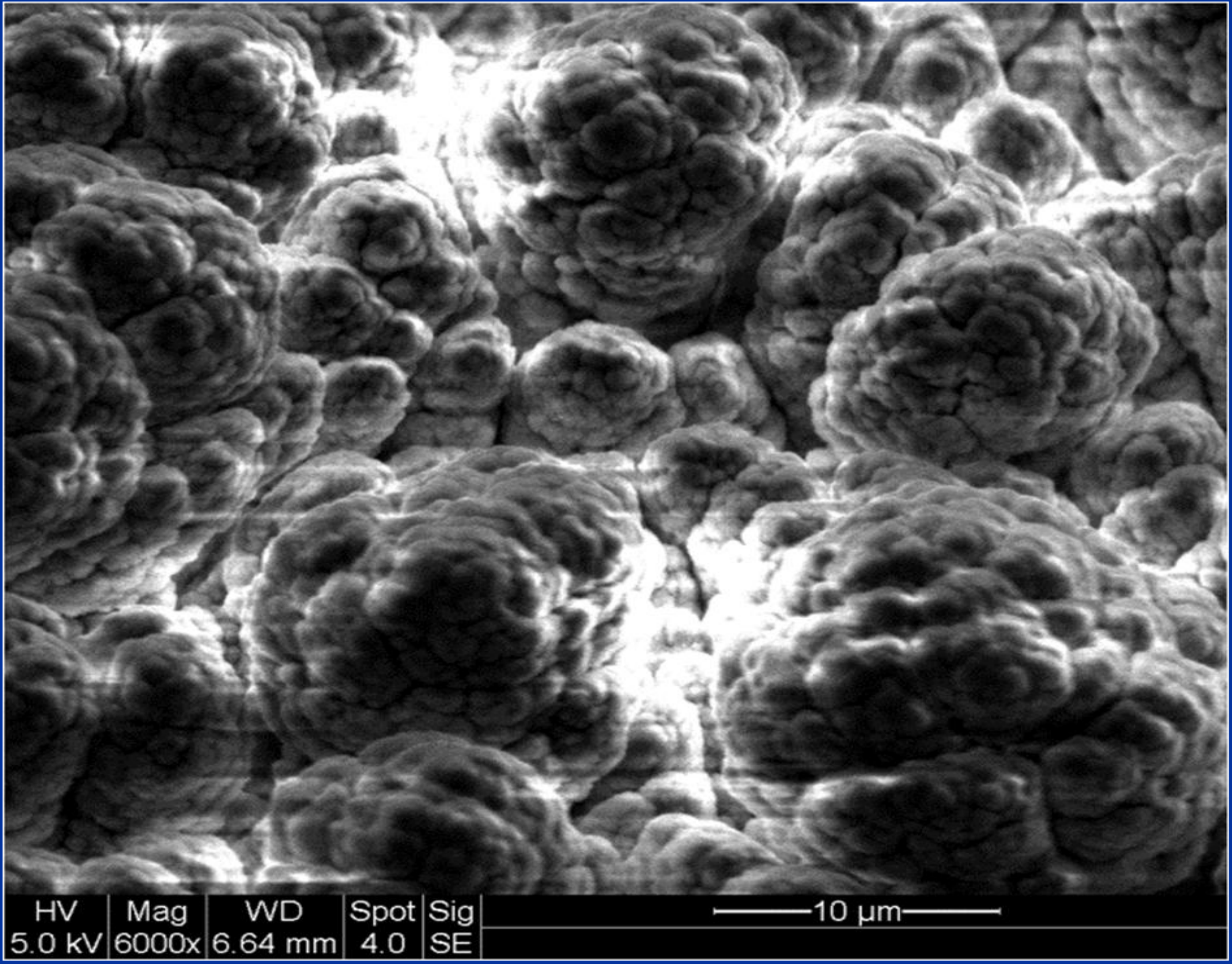
H. Schwoerer et al.: Nature 439 (2006) 445

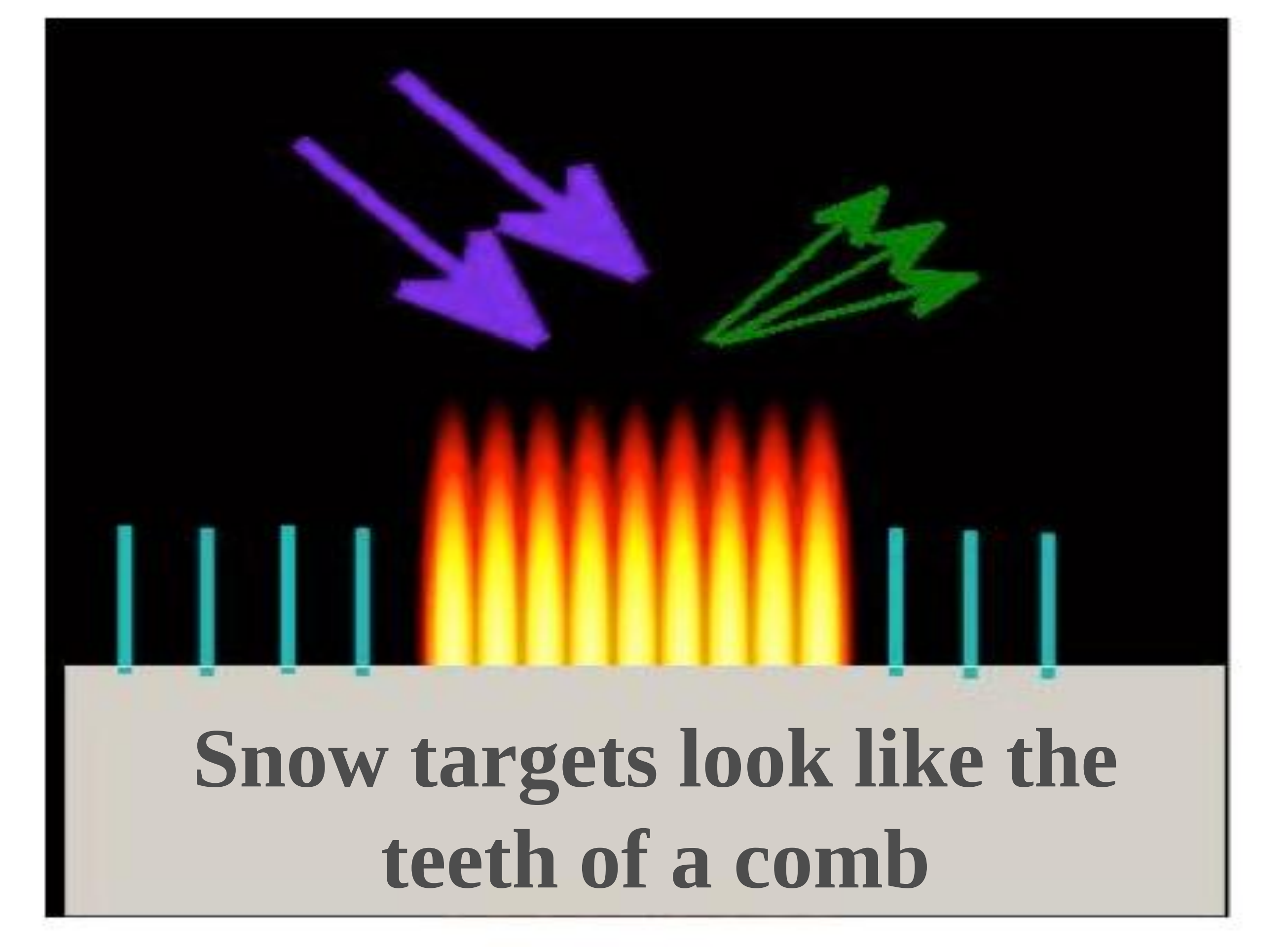
Snow Targets

Zigler et al

PRL 110, 215004 2013

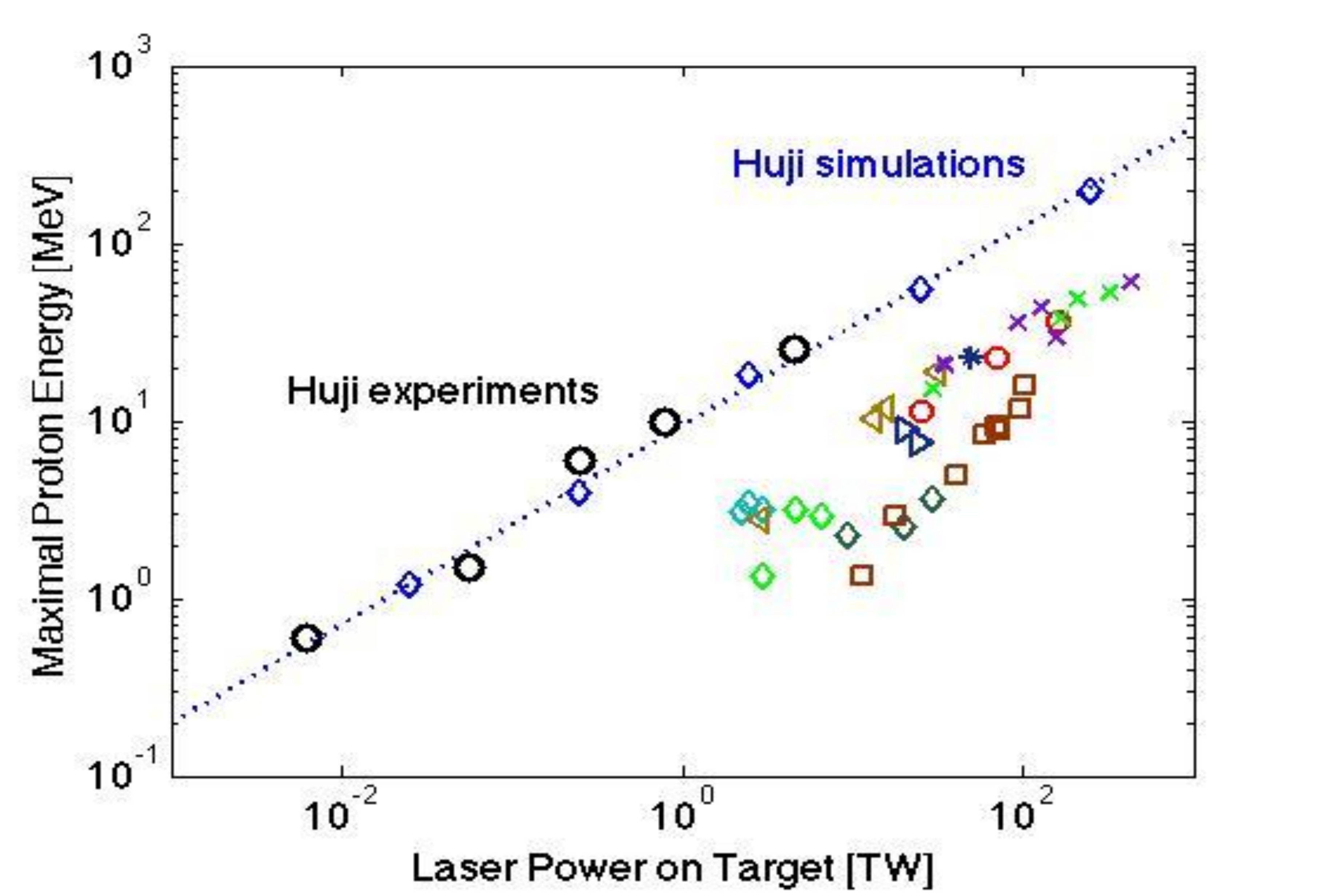
Snow Targets on Sapphire Substrates

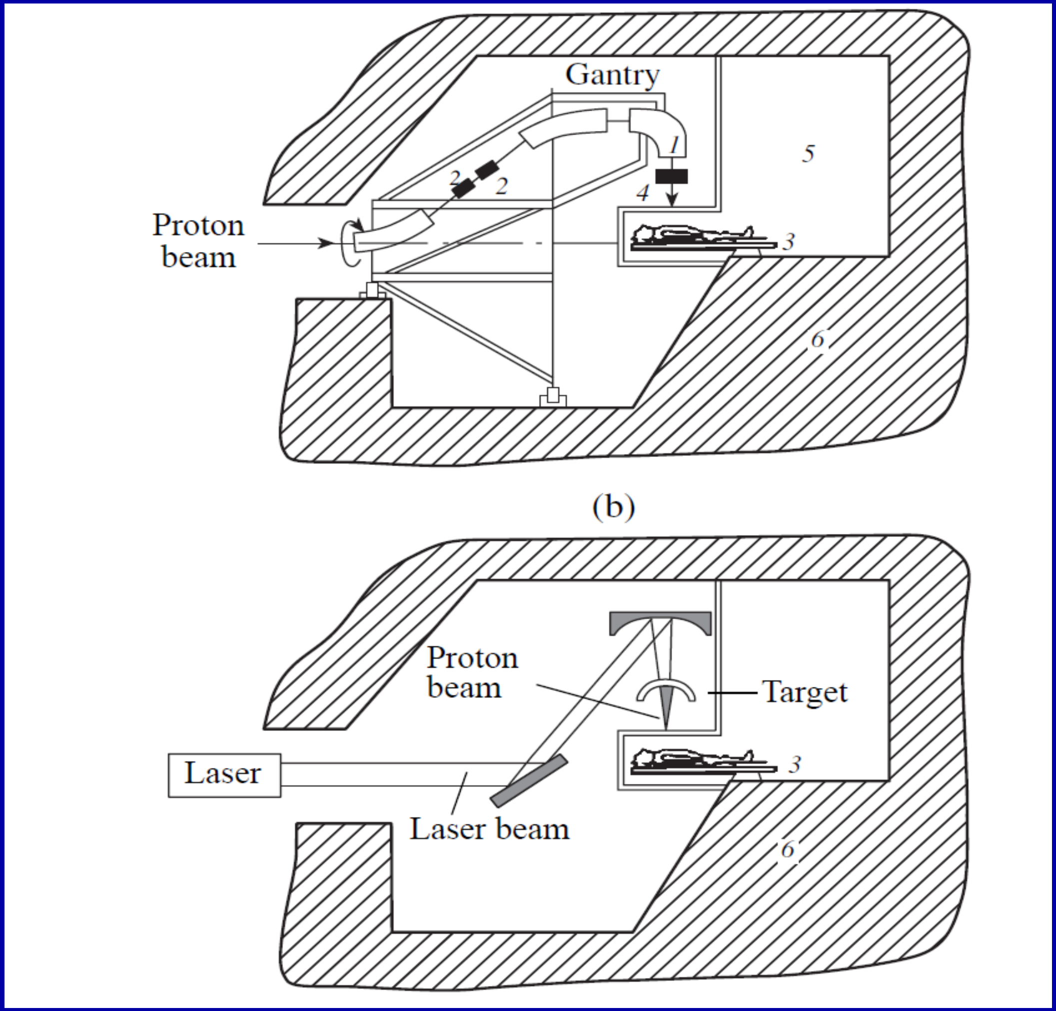




Snow targets look like pillars and when the laser strikes the pillars/teeth the proton acceleration is not typically TNSA in nature

Proton Energy as a function of Laser Power





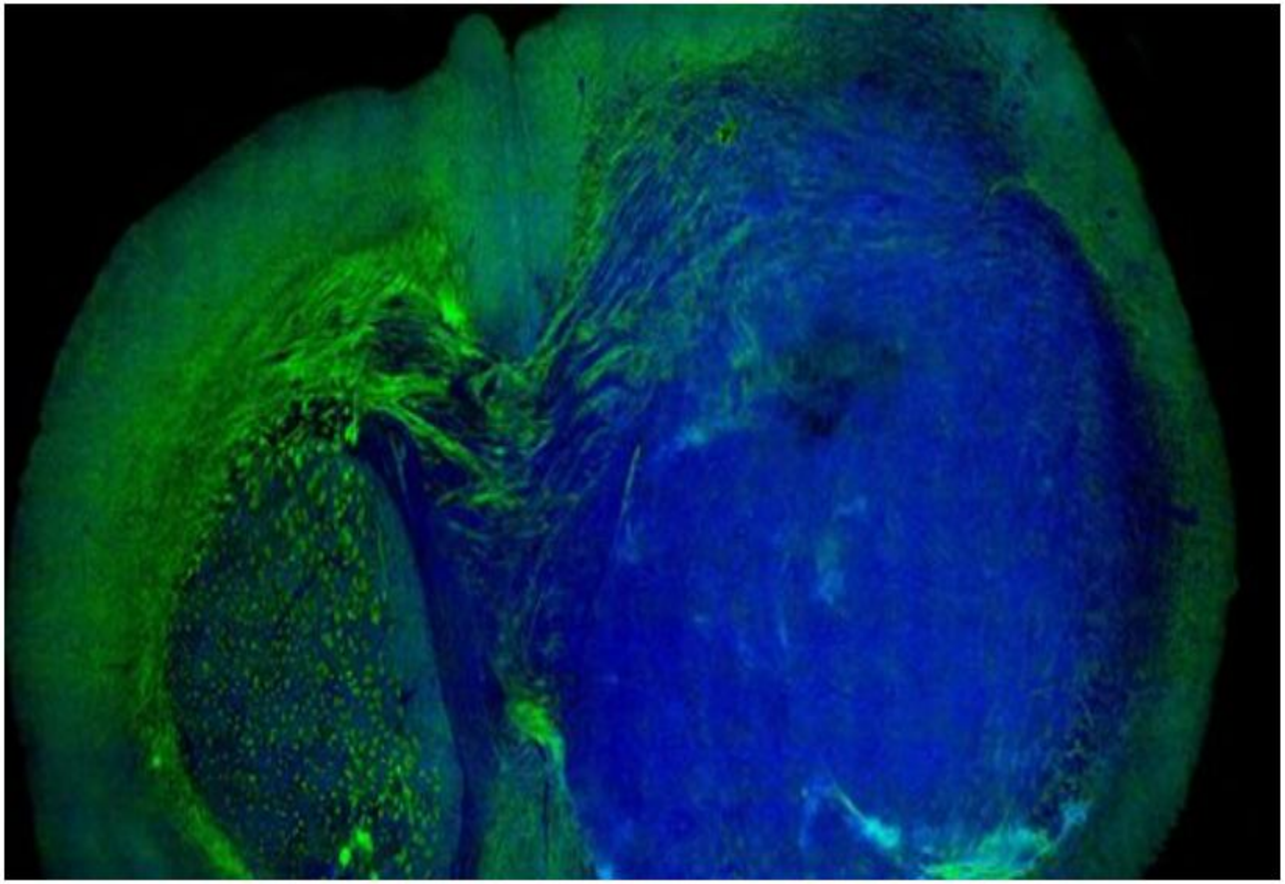
Gantries for conventional accelerator 100 tons and an optical gantry which is very compact, light using mirrors

Opportunities for International Collaboration in Laser Ion Therapy

You need clinicians, physicists, pathologists, tissue scientists all working in concert

The first potential research project in Turkey by the Turkish/Strathclyde Collaboration is using a laser to differentiate between healthy and cancerous tissue.

This will be carried out using laser desorption mass spectrometry and principal component analysis



The edges of the tumour in blue are clear against the green healthy tissue

The edges of the tumour in blue against the green healthy tissue

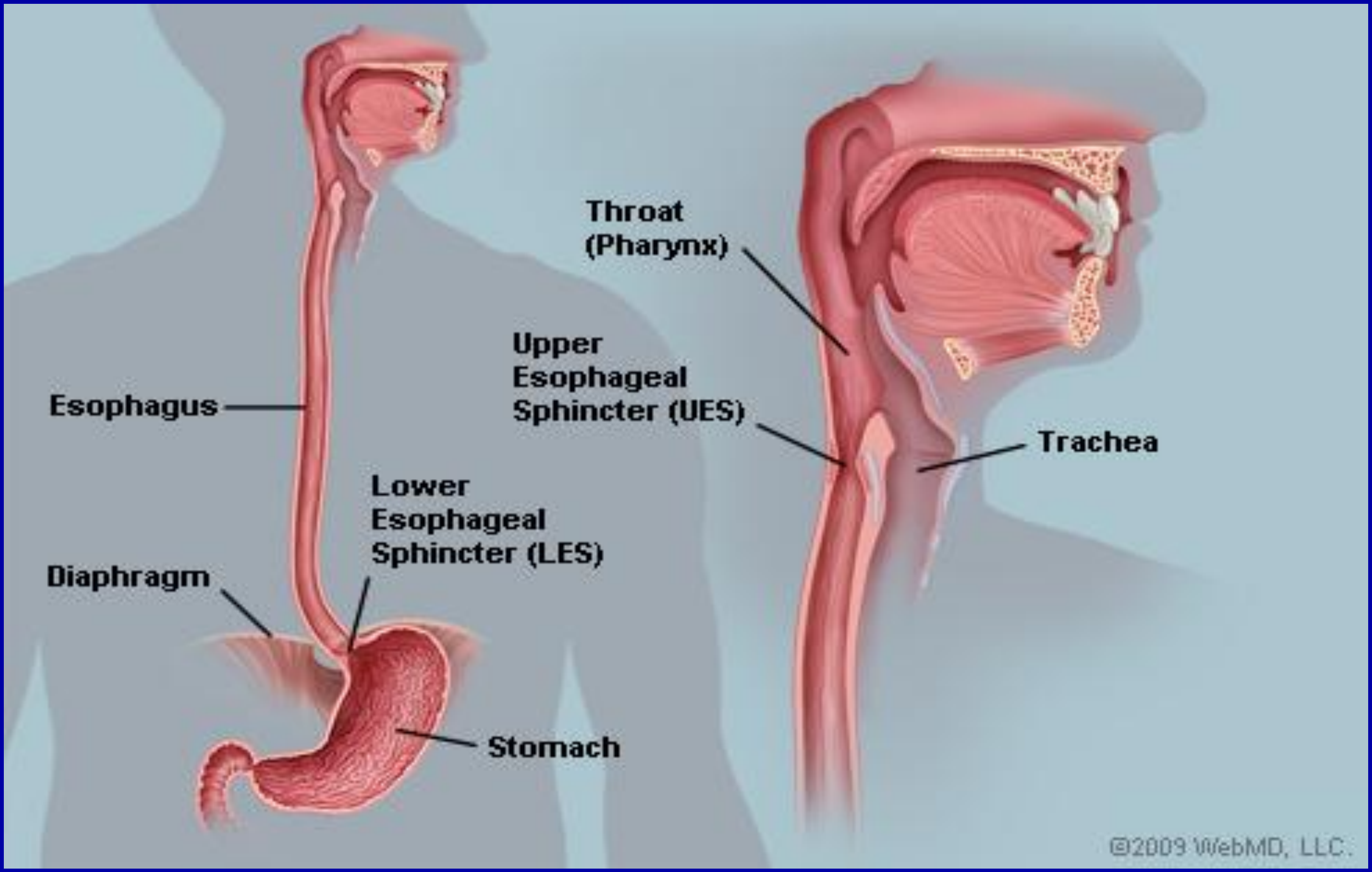


Diagram of the stomach and esophagus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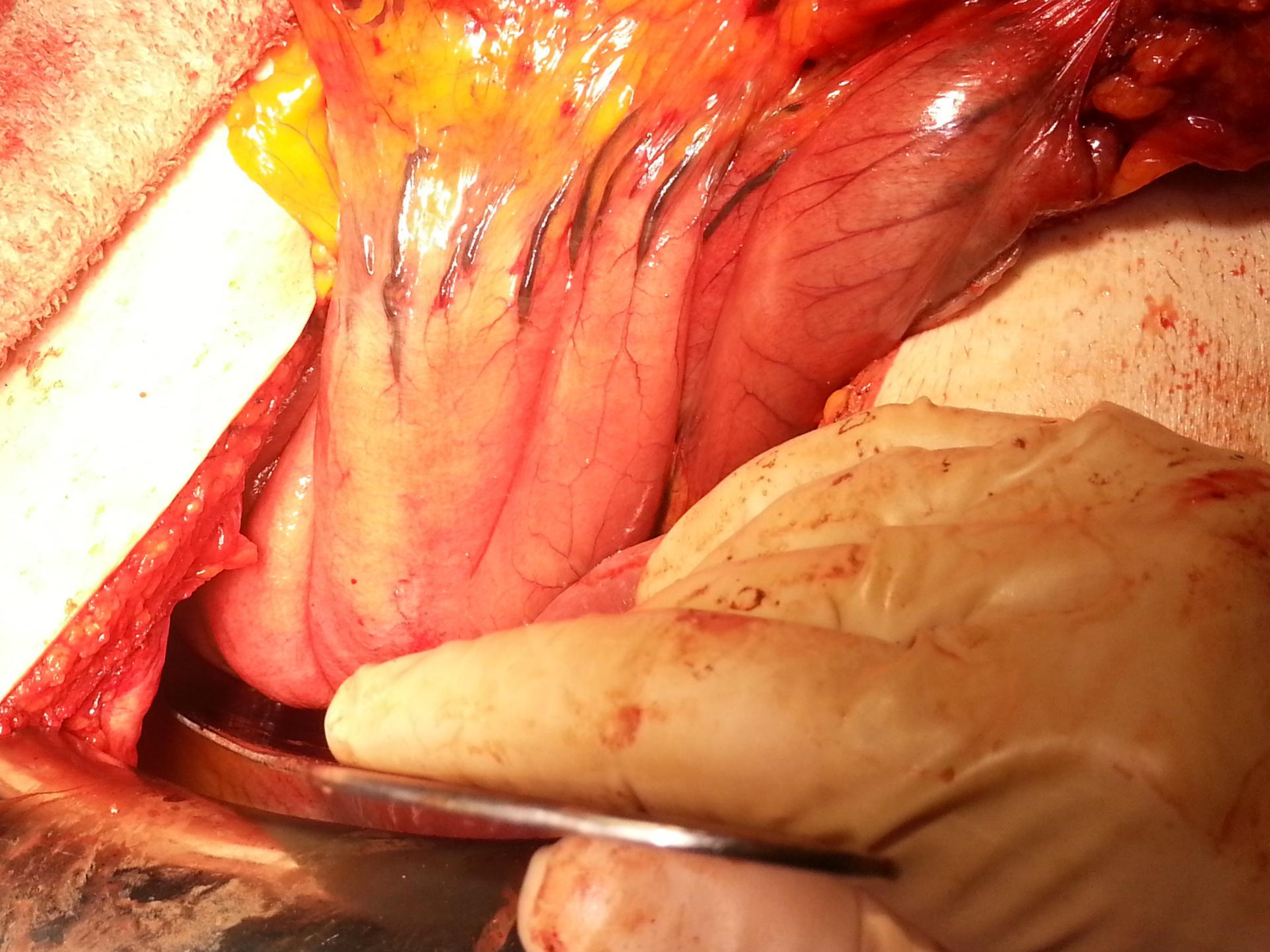
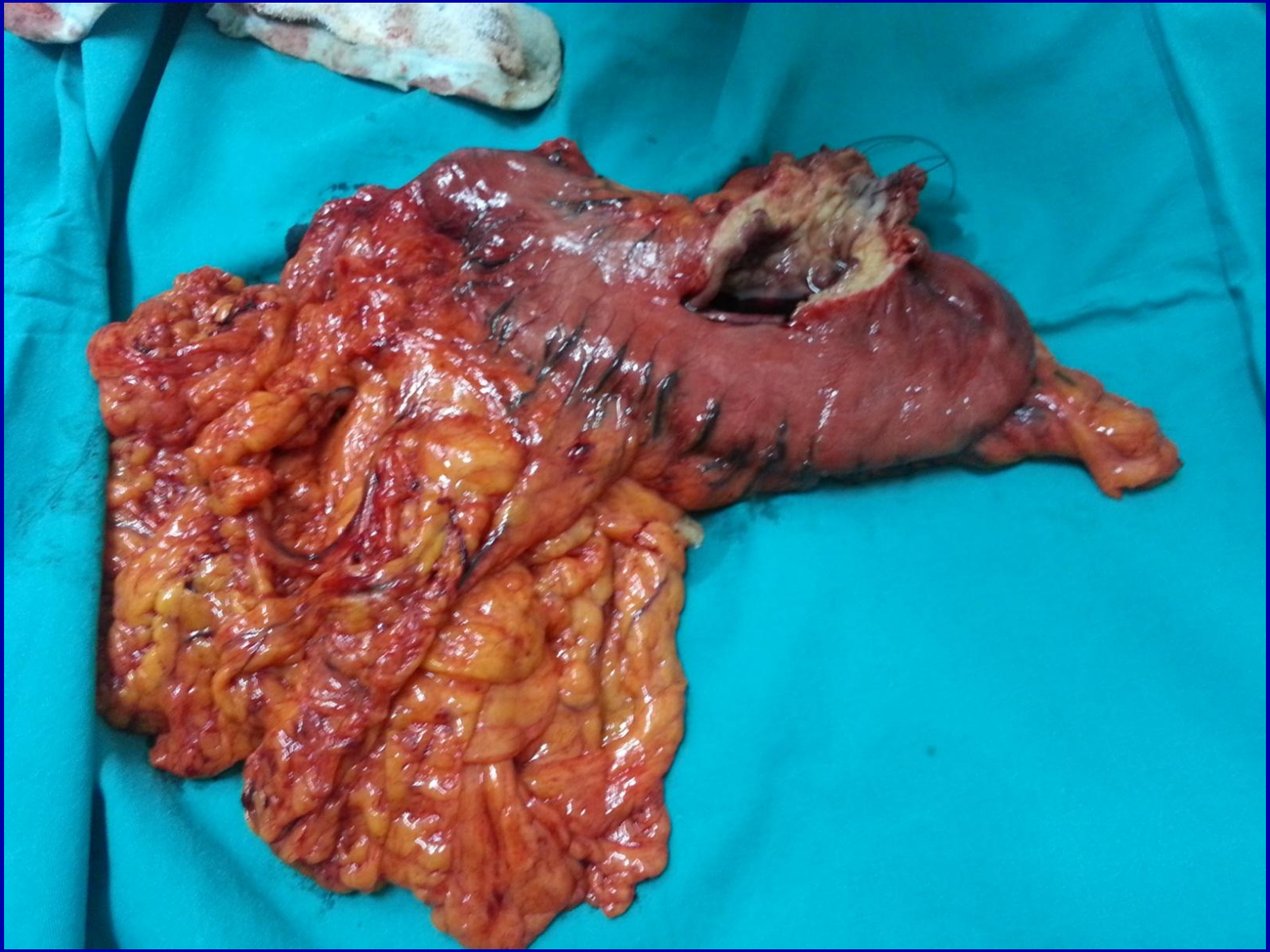
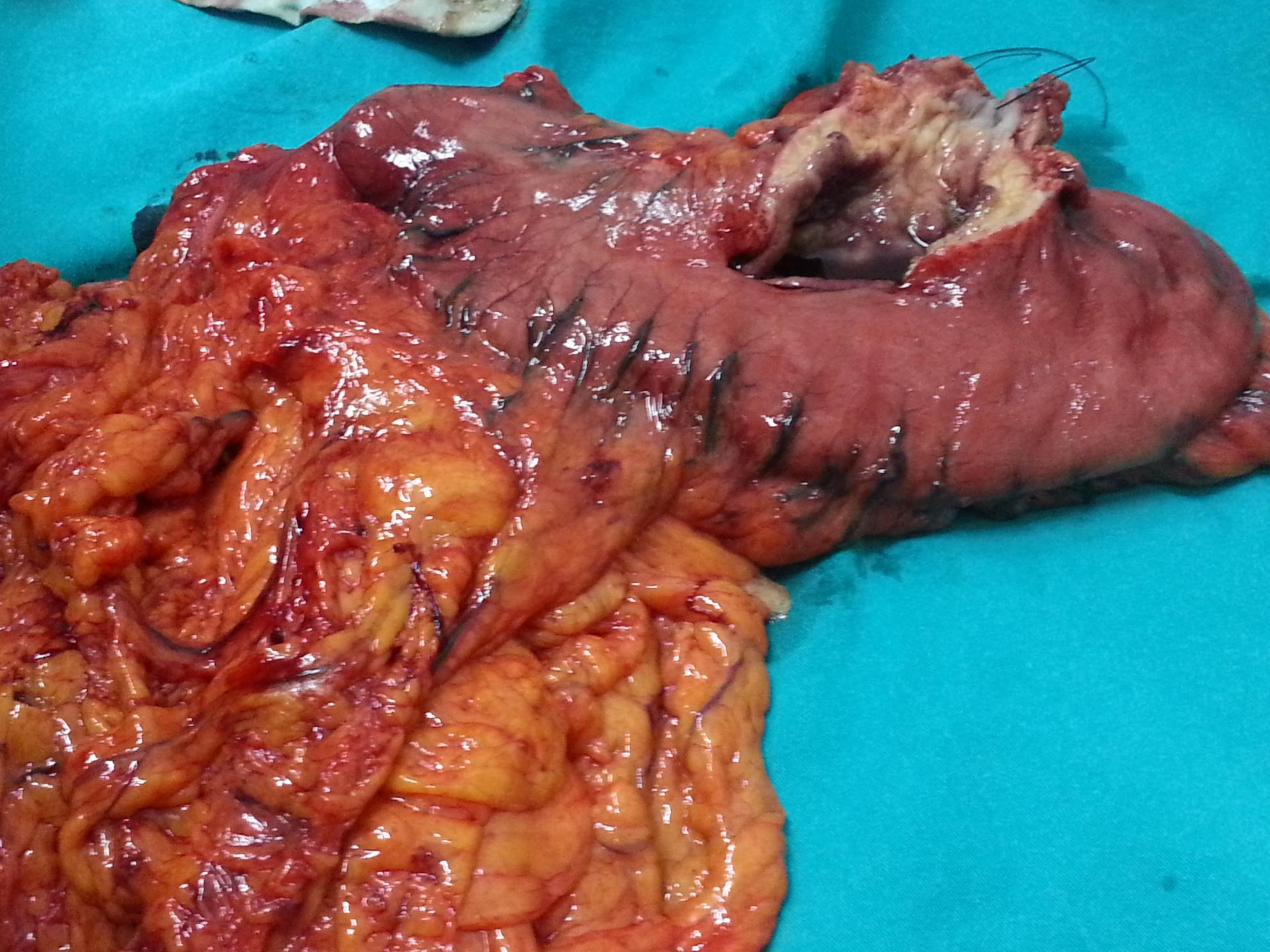


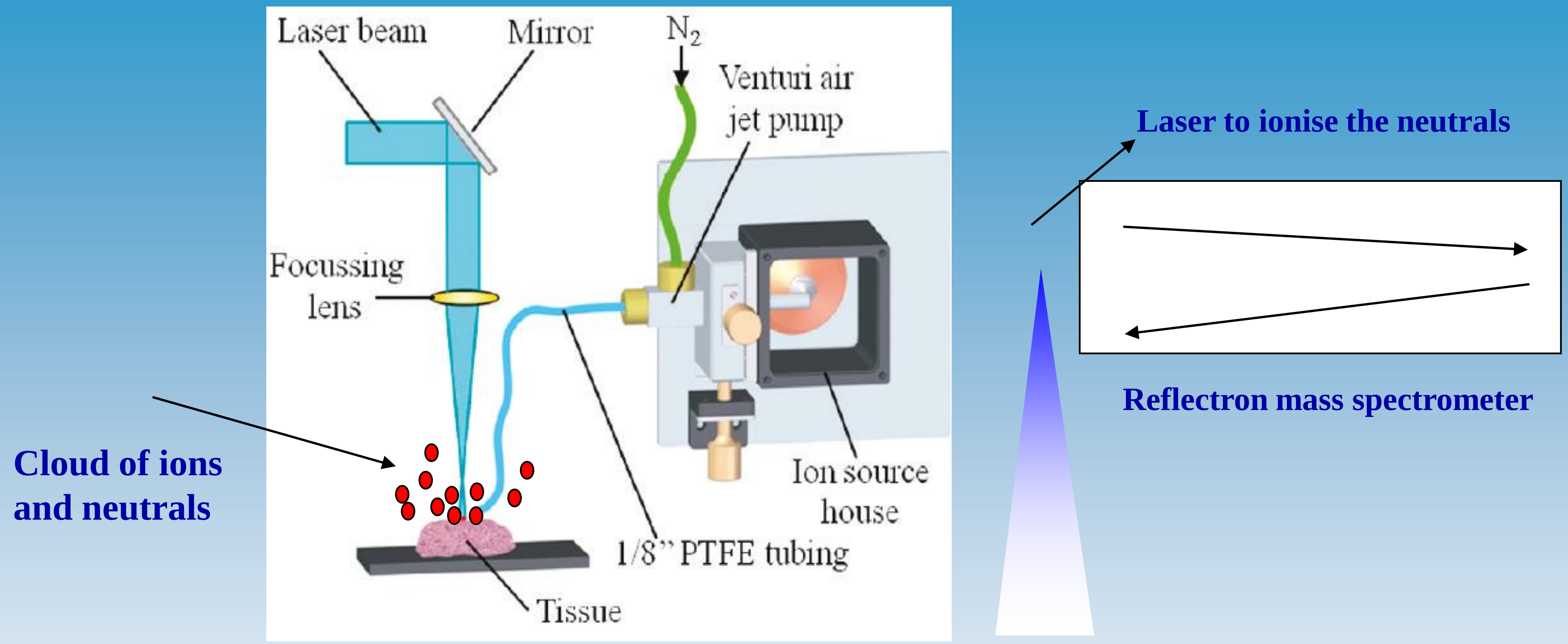


Tumour Removed from Stomach and Esophagus operation ın Selcuk Hospıtal, Konya



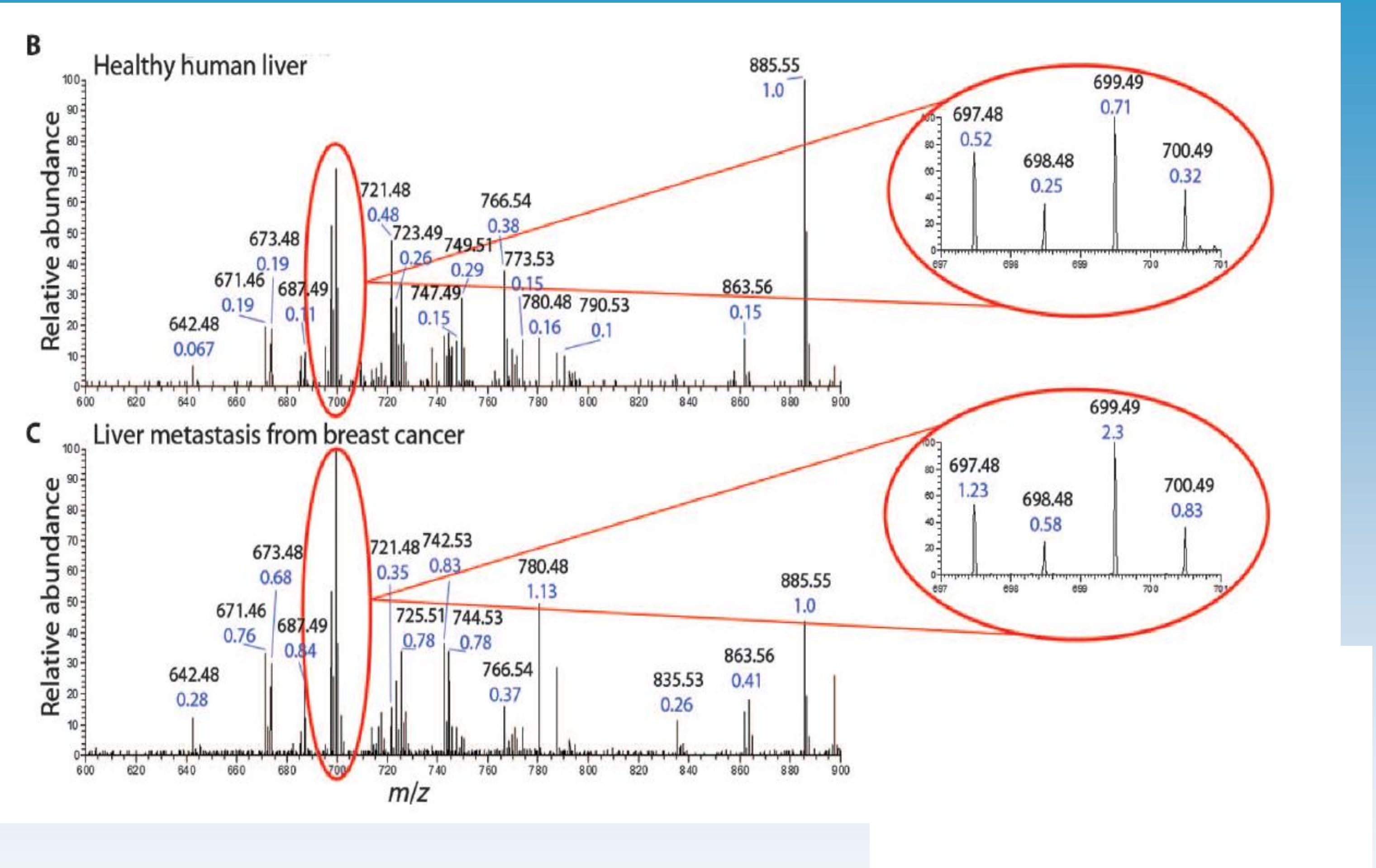
The surgeon removed about a 1mm section of the esophagus and sent to pathologists. It takes about 30 mins to check whether the tissue is cancerous or healthy.

The Surgeon wants an intraoperative real time technique to reduce time under anaesthetic or to reduce number of resections.

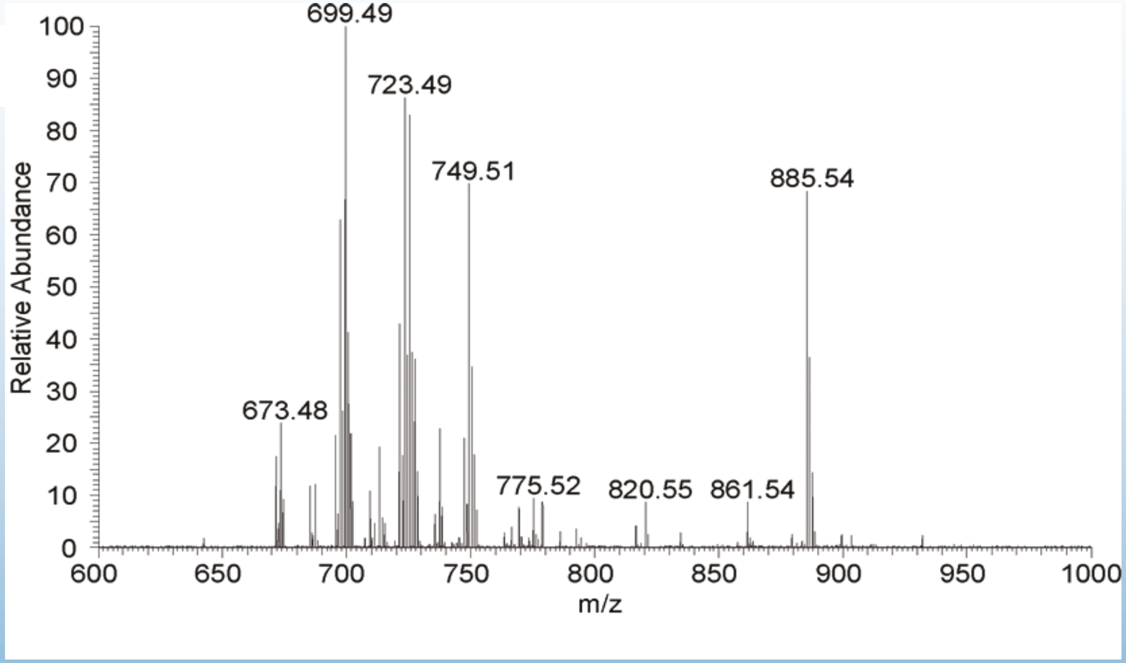


Laser Desorption of Molecules which are then vacuumed up and analysed by Mass Spectrometer and the Principal Components measured

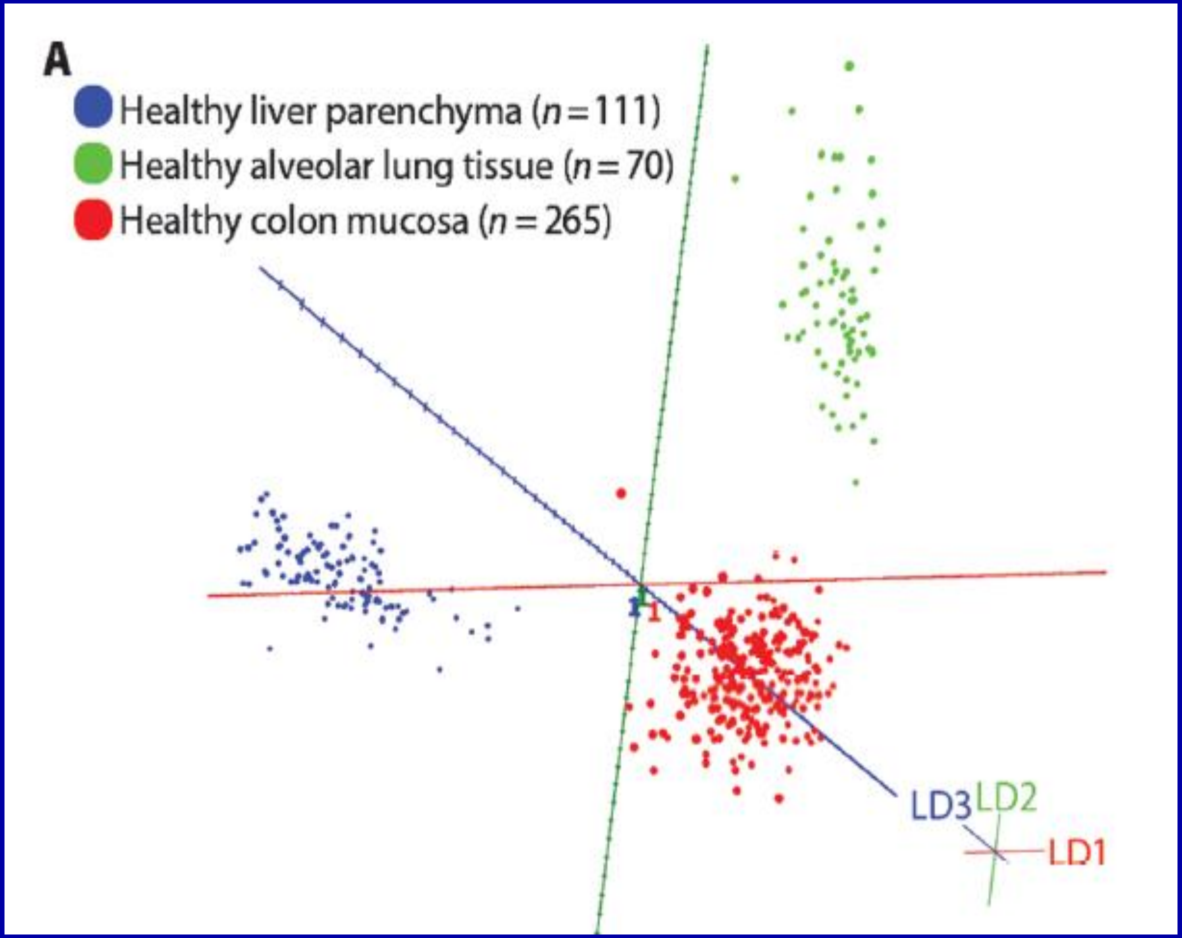
Zoltan Takats et al Anal Chem 2011,83,1632 IC



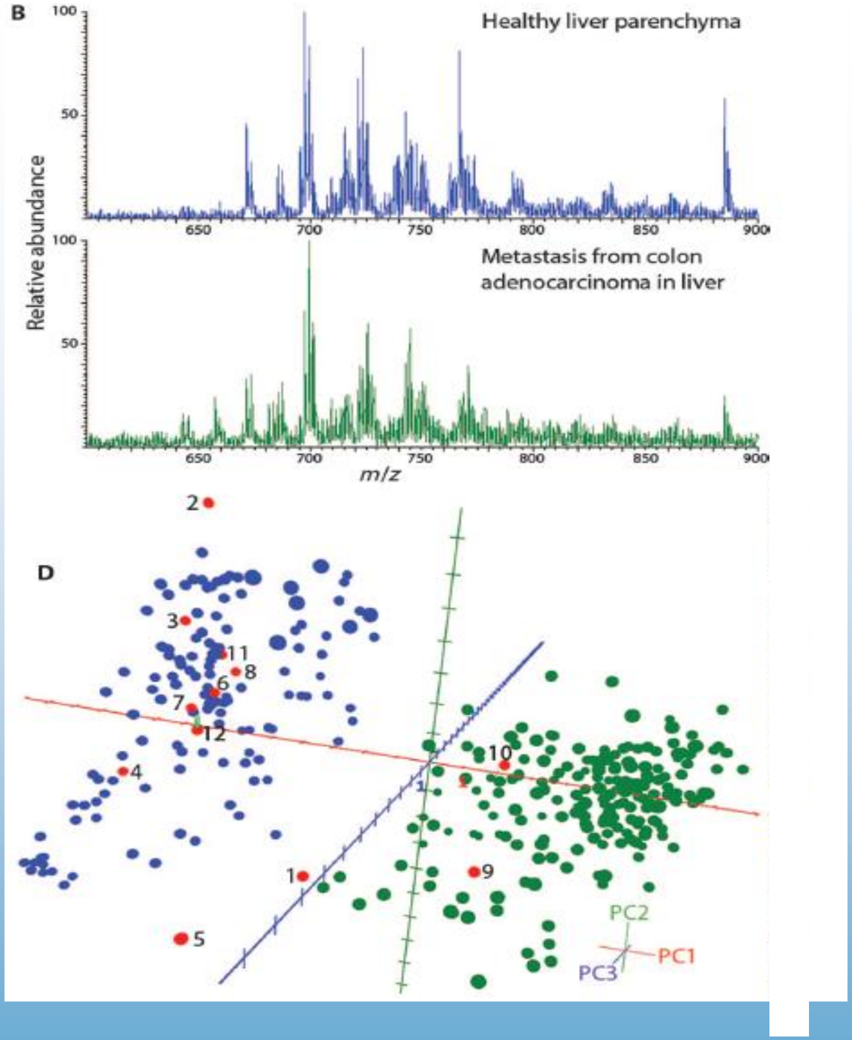
Laser Desorption Mass Spectra of Healthy and Cancerous Tissue



A liver spectrum taken at 355 nm showing prominent peaks at m/z =700, 723, 749 and 885. These are the Principal Components. The PC ratios are calculated



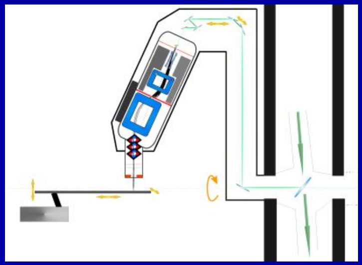
Principal Component Differences between Healthy Tissues



Principal Component Differences between Healthy and Cancerous Tissue

Thank you for listening

Content of Talk






1. Conventional accelerators for proton therapy
2. Recent Laser particle acceleration mechanisms and results
3. Intraoperative Laser Desorption of healthy and cancerous