Hadron Therapy: A Physicist's View

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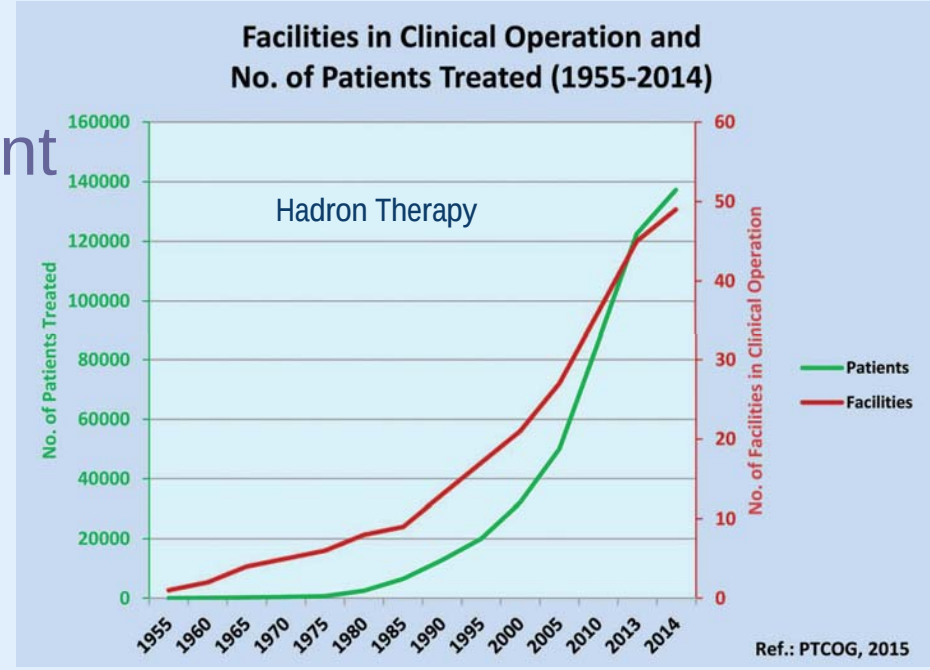
Nuclear Techniques in Human Health

Prevention, Diagnosis, Treatment

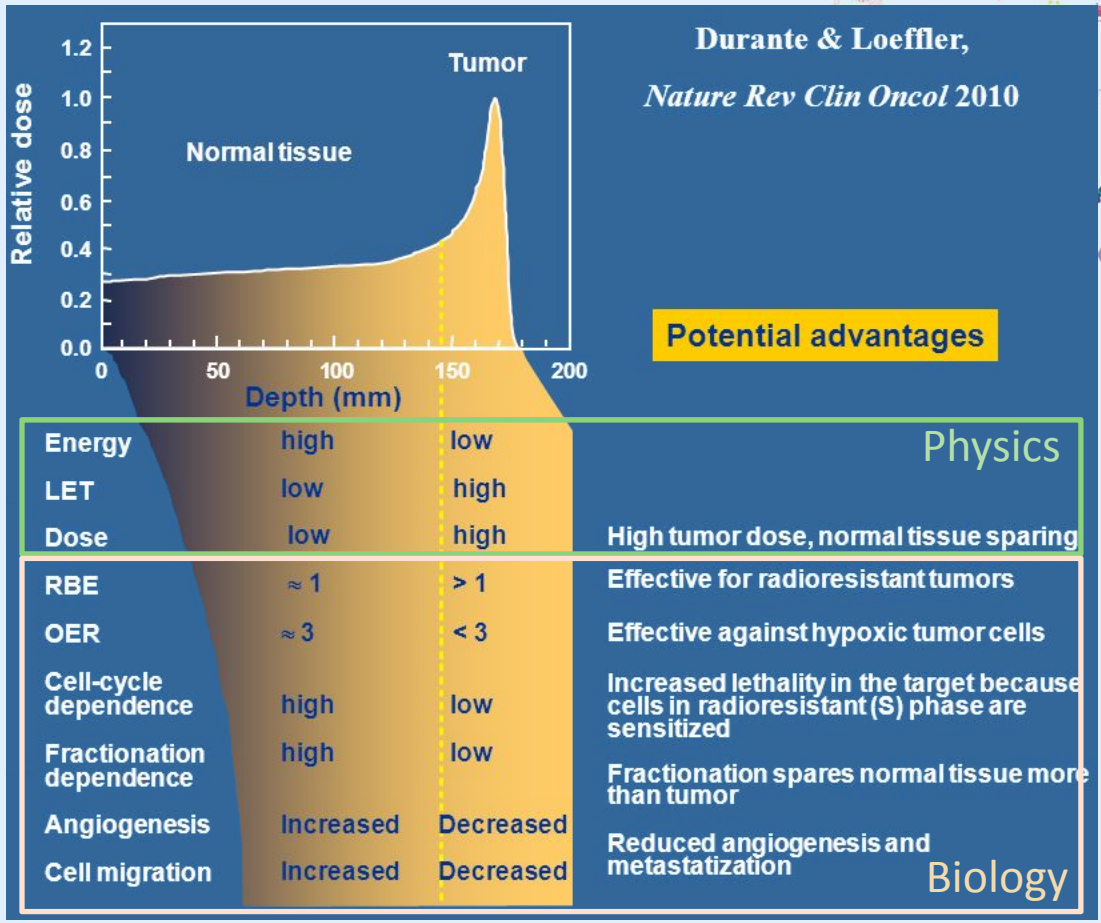
From service to value for-money

- *Hadron-therapy (proton and ions)*
  - ☺ has intrinsic physical properties to precisely target the tumors, reducing side effects
  - ☺ has remarkable biological effects on tumor cells
  - ☹ is relatively expensive
- *Continuously growing*
  - technologies development
  - improved physics and biological knowledge
  - extended cost/benefit and clinical outcomes analyses



Physics-Biology-Clinics Interplay

Clinical outcomes depend on how well we **know** and **control** the physics and the biological processes involved in the hadron therapy and how we **make them happen**



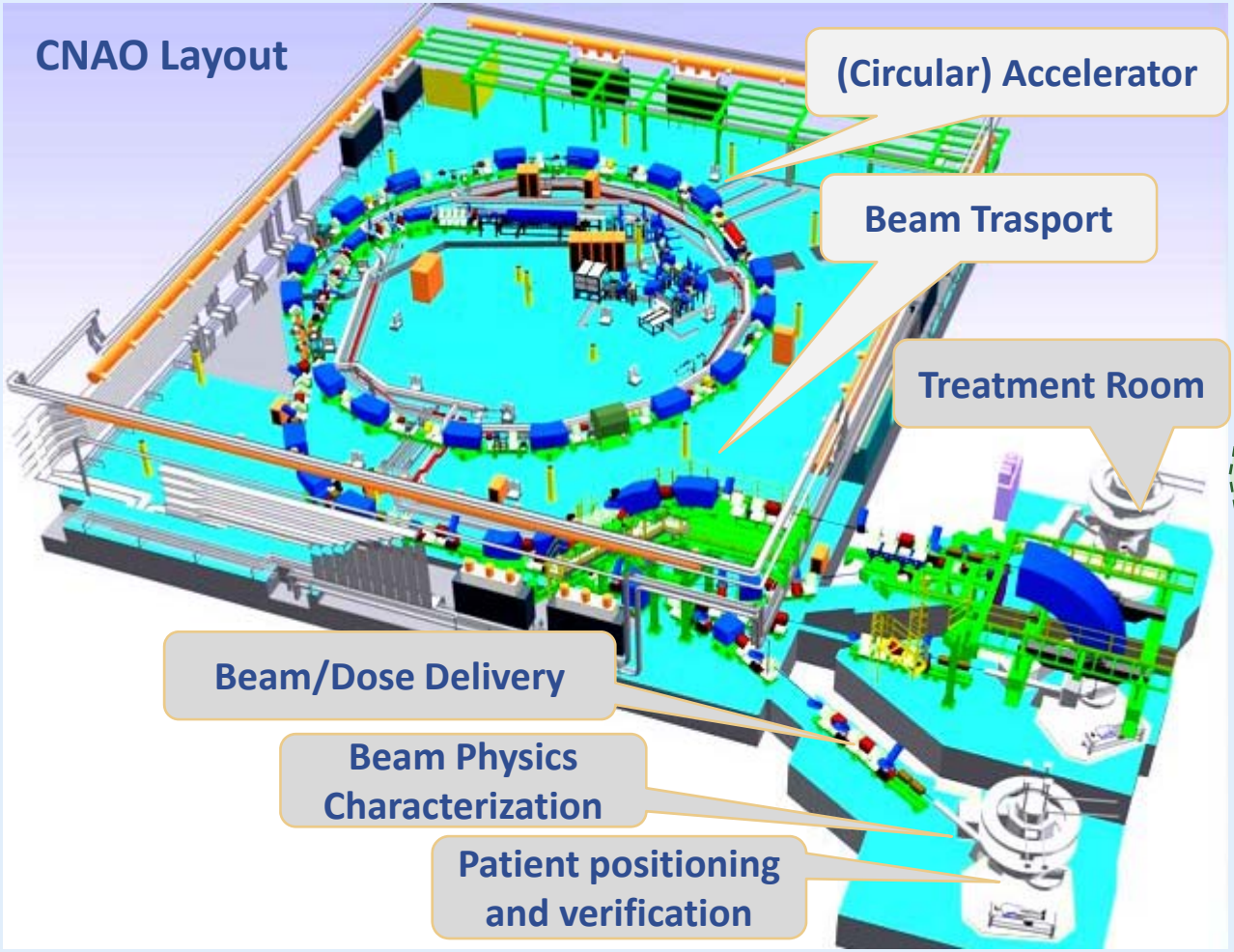
Machine
- Design and construction
- Daily quality checks

Patient Preparation
- CT (PET) imaging
- Positioning/Alignment
- Immobilization
- Treatment Planning

Treatment
- Continuous monitoring
- Stop at prescribed dose

Assessment
- On-line / Offline imaging

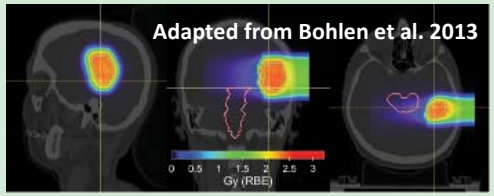
Hadron-therapy facility



Control System

Quality Assessment

Treatment planning



Patient Data Management

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Costs analysis from A. Peeters et al., Rad. & Onc. 95 (2010) 45-53

Costs (keuro)	Capital	Oper./year	Fraction	Treatment
Carbon+Proton	140000	37000	1.1	10-30
Proton	95000	25000	0.7	12-39
Photon	23000	10000	0.2	4-18

Surgery: 14-57 kUSD
Pharmacologic: 1-120 kUSD
Note: cost/treatment strongly depends on tumor and modality

Current developments directions

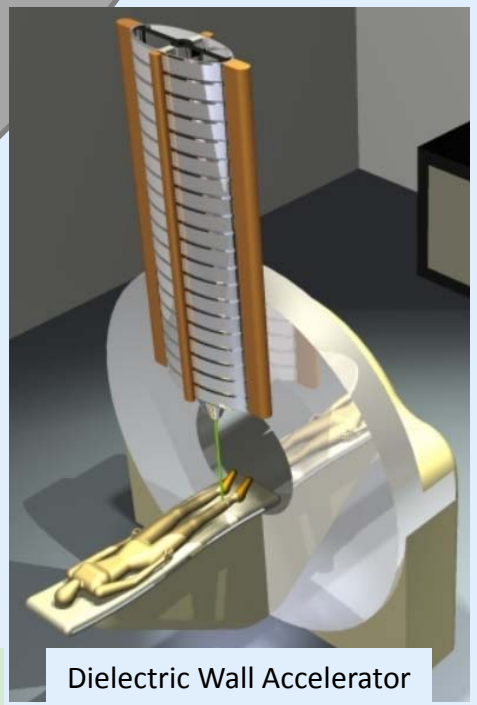
Reducing system costs

- Lower power needs
- Smaller size
- Simpler procedures
- Smaller weight

Advancing therapeutic performances

- Improved assess-ment
- Optimal dose delivery
- Accurate quality assurance
- Improved planning

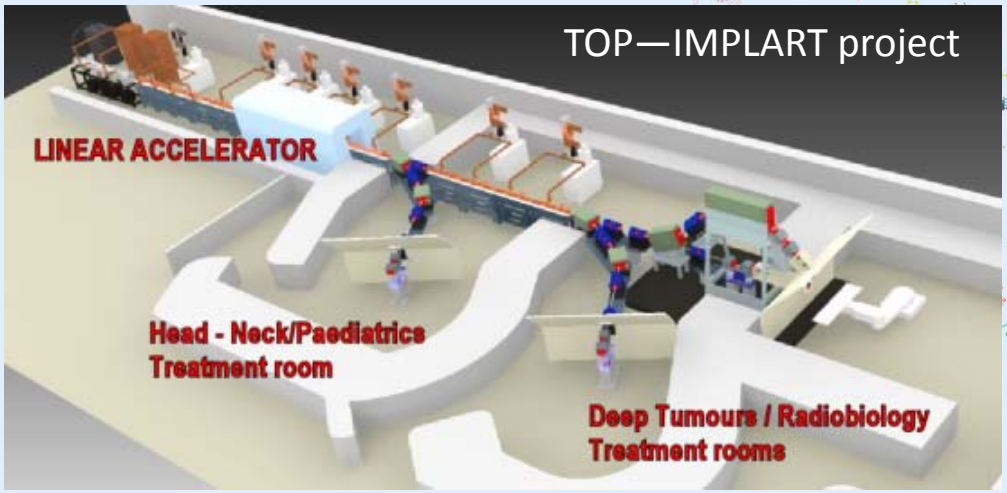
A dream device (single room facility)



Dielectric Wall Accelerator
Caporaso et al. (2009)
Artistic view

New acceleration technologies: **Linear Accelerator**, Superconducting, FFAG, Laser Acceleration, Dielectric Wall Accelerator

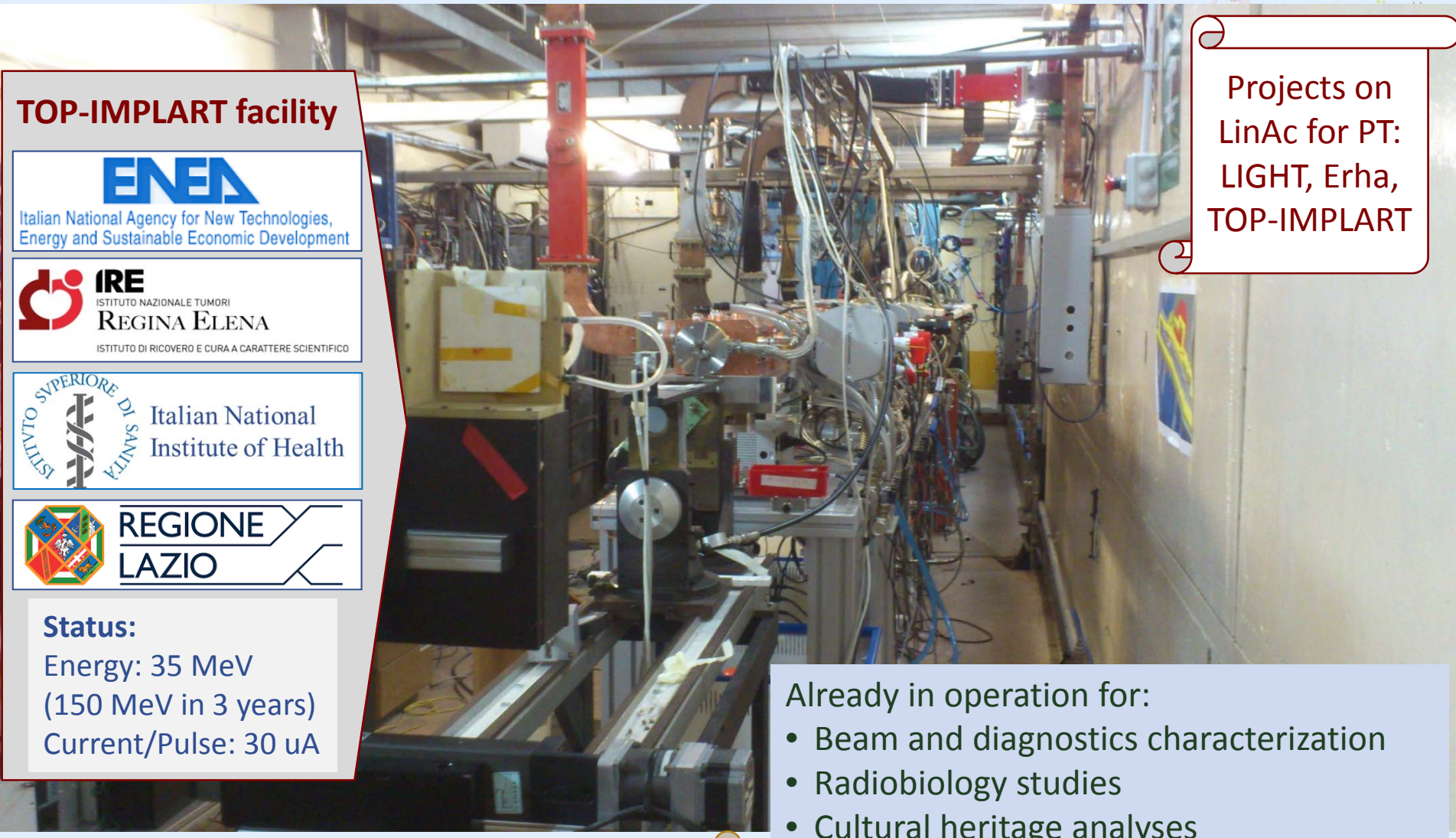
Linear Accelerator for Proton Therapy



- Compact and lightweight
- Radiation clean, reduced shielding
- Power efficient
- **Very Modular**: customizable according to needs; can be in operation during its construction
- **Performances**: all physics properties (energy, intensity, direction, …) of the particle beam can be varied quickly and actively offering improved precision and larger flexibility on dose delivery to the patient (e.g. optimal intrafraction motion control)
- Only single ion type can be accelerated
- Never used before for therapy (but physical modality similar to photon therapy)

Estimated Capital costs: 40-70 MEuro

LinAc for Proton Therapy becoming real



TOP-IMPLART facility

ENEA
Italian National Agency for New Technologies, Energy and Sustainable Economic Development

IRE
ISTITUTO NAZIONALE TUMORI
REGINA ELENA
ISTITUTO DI RICOVERO E CURA A CARATTERE SCIENTIFICO

ISTITUTO SUPERIORE DI SANITÀ
Italian National Institute of Health

REGIONE LAZIO

Status:
Energy: 35 MeV
(150 MeV in 3 years)
Current/Pulse: 30 uA

Projects on LinAc for PT: LIGHT, Erha, TOP-IMPLART

Already in operation for:
- Beam and diagnostics characterization
- Radiobiology studies
- Cultural heritage analyses
- New development (e.g LiF dosimetry)
- Radioprotection optimization studies

Current development total costs: ~6 Meuro

Robust Treatment Planning

The optimal exploitation of a very accurate equipment needs to tackle all details of the involved processes and a carefull plan

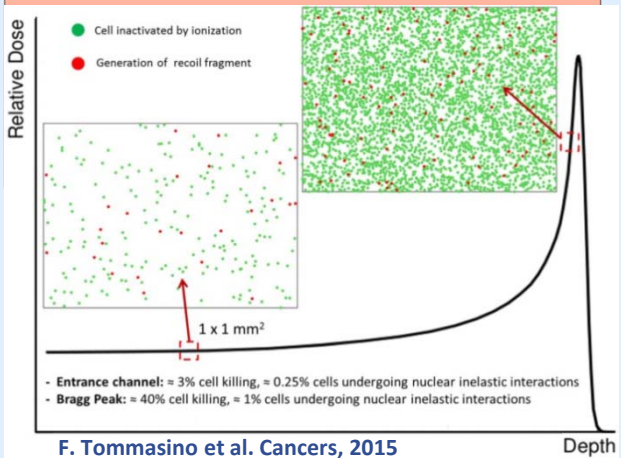
Accurate (few %) and extended low energy nuclear physics data

Radiobiology data
Anatomic and Functional Imaging of the patient

Detailed and validated accelerator description

Physics Processes

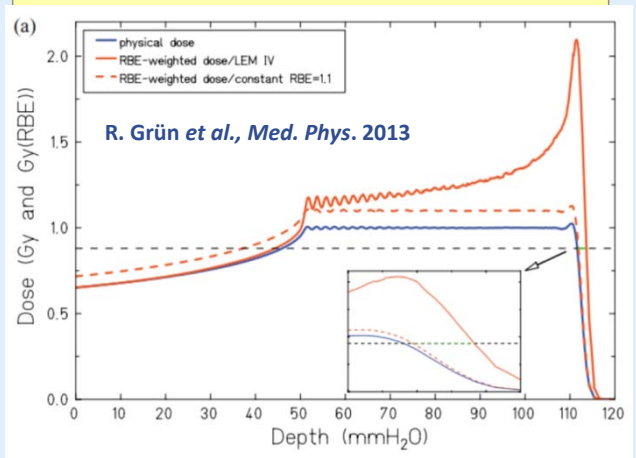
- Tracking particles in heterogeneous matter



F. Tommasino et al. Cancers, 2015

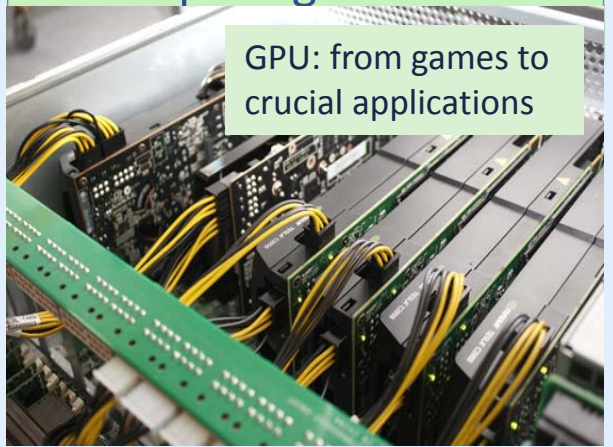
Biological Effects

- Tumor and Normal Tissue Biological / Personalized Response



Planning System

- Decision support (AI)
- MonteCarlo methods
- Computing Power



Nuclear Science and Technologies

play a major role in many key aspects of hadron radiation therapies and their improvements are substantial for the ultimate benefit of the patients

System	Planning	Treatment	Assessment
Accelerator	Quality Control	Delivery modality	Online Dose Delivered Verification
Diagnostic Devices	Imaging	Delivery control	Montecarlo validation
Redundancy and Safety	Modeling	Intra-fractional Motion control	
	MonteCarlo (computing)		

Thank You