Design Characteristics of a Novel Linac for Challenging Environments

Summary of Session VII

Ugo Amaldi

(TERA Foundation)

Alberto Degiovanni

(Applications of Detectors and Accelerators to Medicine – A.D.A.M. – Geneva)

The program

1. Goals of Session: **Ugo Amaldi and Alberto Degiovanni** (5')
2. Experience gained from the GlobalDiagnostiX project: **Romain Sahli** (EPFL)
3. Problems posed by "difficult" environments to present linac-based systems: **John ALLEN** (Elekta**)**
4. Electron Linac Projects in Pakistan with CERN support: **Sumaira Zeeshan** (CERN)
5. IORT Linac and possible developments: **Luigi Picardi** (ENEA)
6. Experience on Electron Linacs at NCBJ (Poland): **Przemek Adrich** (National Centre for Nuclear Research, Poland)
7. Robust X-ray imaging: **David Jaffray** (Ontario Cancer Institute/Princess Margaret Institute)
8. Lower cost RT through new software tools (optimization and automation): **Johan Lof** (Raysearch Laboratories, Sweden)
9. Shielding in difficult environments: **Pawel Krawczyk** (NCJB, Poland)
10. PHASER: Application of Advanced RF Linac Technology to Medical Accelerators: **Sami Tantawi** (SLAC) and **Billy Loo** (Stanford University)
11. General design considerations on structures, power sources and accessories: **Maurizio Vretenar** (CERN)
12. Conclusions: **Ugo Amaldi**

GlobalDiagnostiX, our pathfinder

Project launched in 2012

8 institutions

20 laboratories

40 involved persons

Multidisciplinary

- Engineering
- Health
- Design
- Anthropology

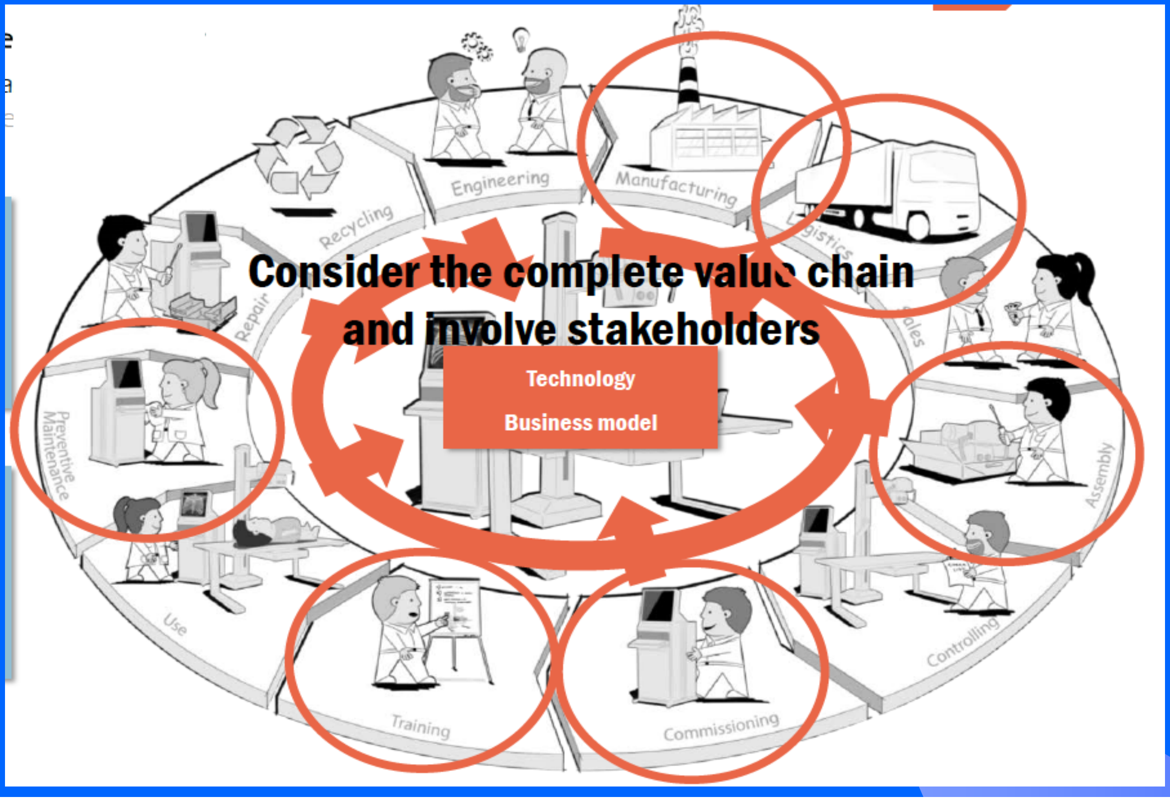
2010 CONTEXT STUDIES 2012

2012 PHASE 1: Demonstrate feasibility 2015

2016 PHASE 2: Reliability and technology transfer 2018

Romain Sahli
EPFL

GlobalDiagnostiX, our pathfinder



- Clearly identify and understand the need
- Work with locals, strong collaboration with South required

GlobalDiagnostiX, our pathfinder

A Non Governmental Organization

has breen created

to protect and licence the

Intellectual Property

This group should create a

Non Governmental Organization

to protect and licence the

Intellectual Property

of all future activities

"GlobalRT" ??

General guidelines from Session VI

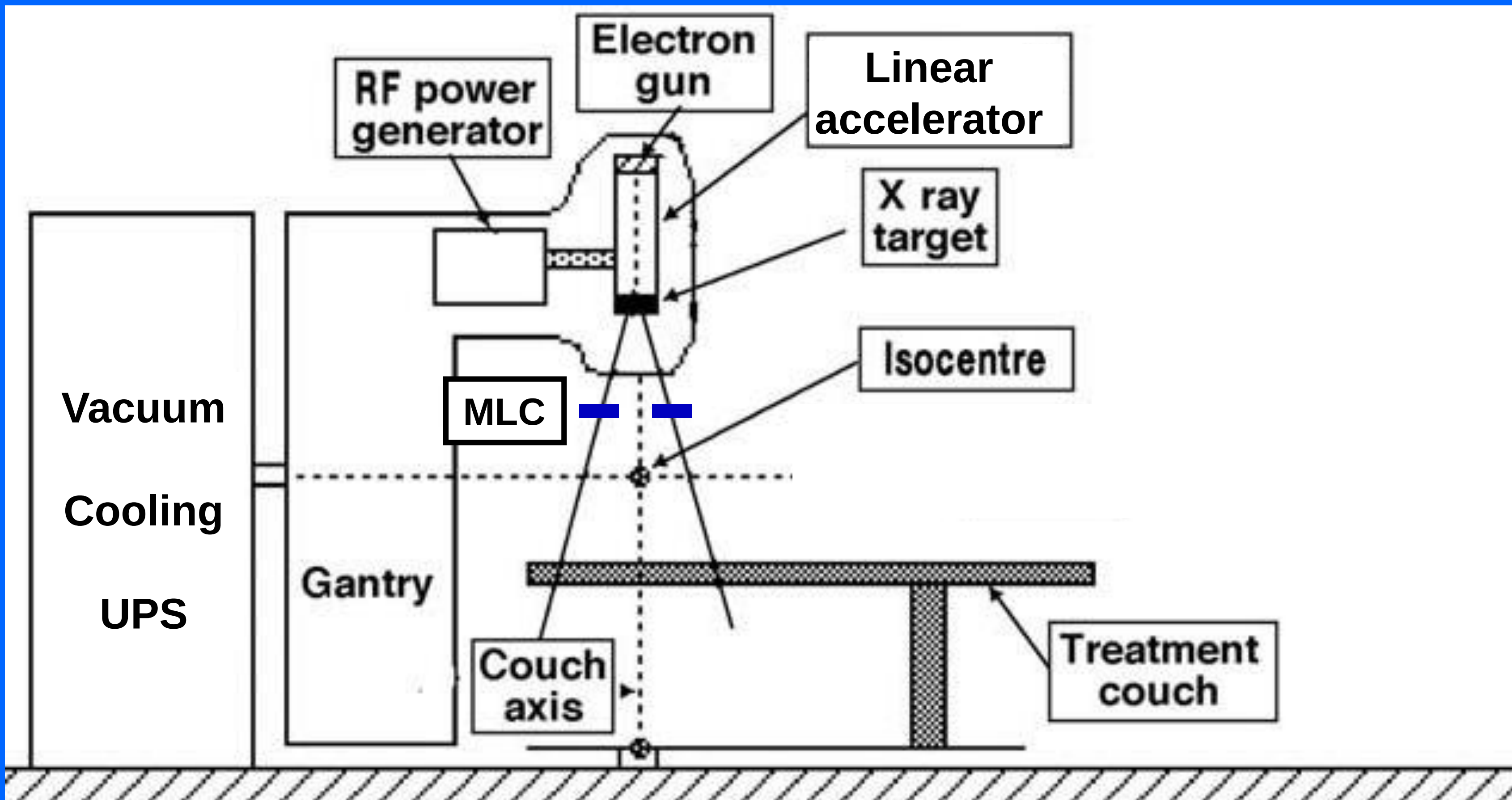
Ahmed Meghzifene
IAEA

60 Years
IAEA Atoms for Peace and Development

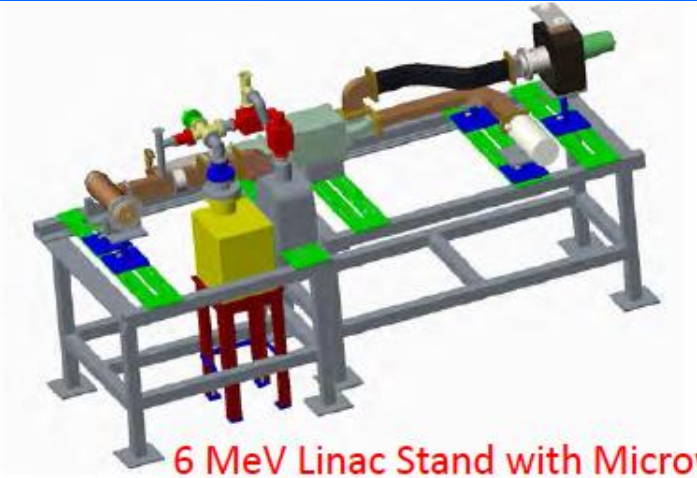
A novel accelerator designed for challenging environments should

- Fulfil existing safety and performance standards
- Be better protected against higher room temperature
- Include an interface for remote diagnosis and adjustments

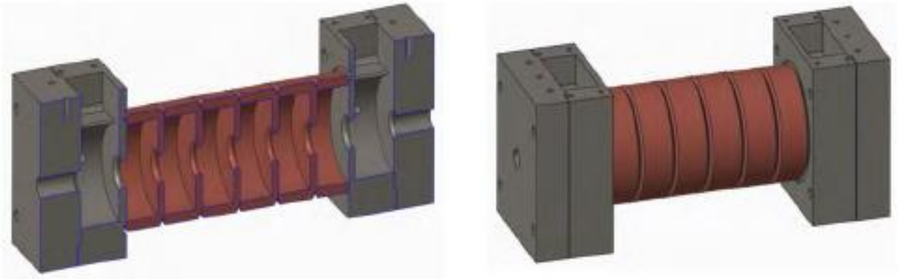
The components of a RT X-ray system



Linac and accessories

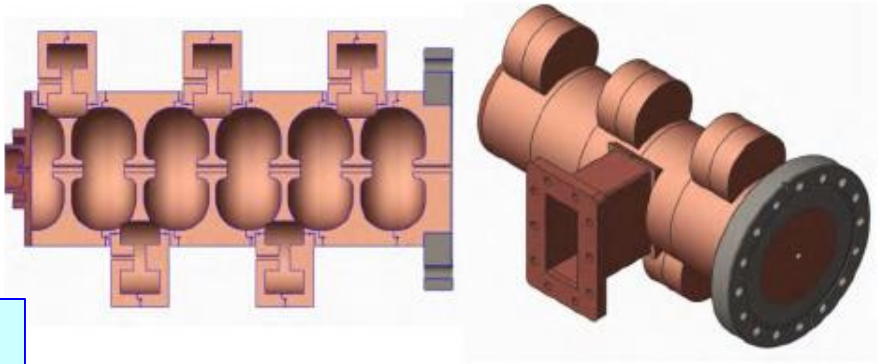


6 MeV Linac Stand with Microwave Assembly



Prototype Travelling Wave Accelerating Structure

Pakistan electron LINAC Project with CERN Support



Sumaira Zeeshan
on behalf of Pak-LINAC Team- Elekta

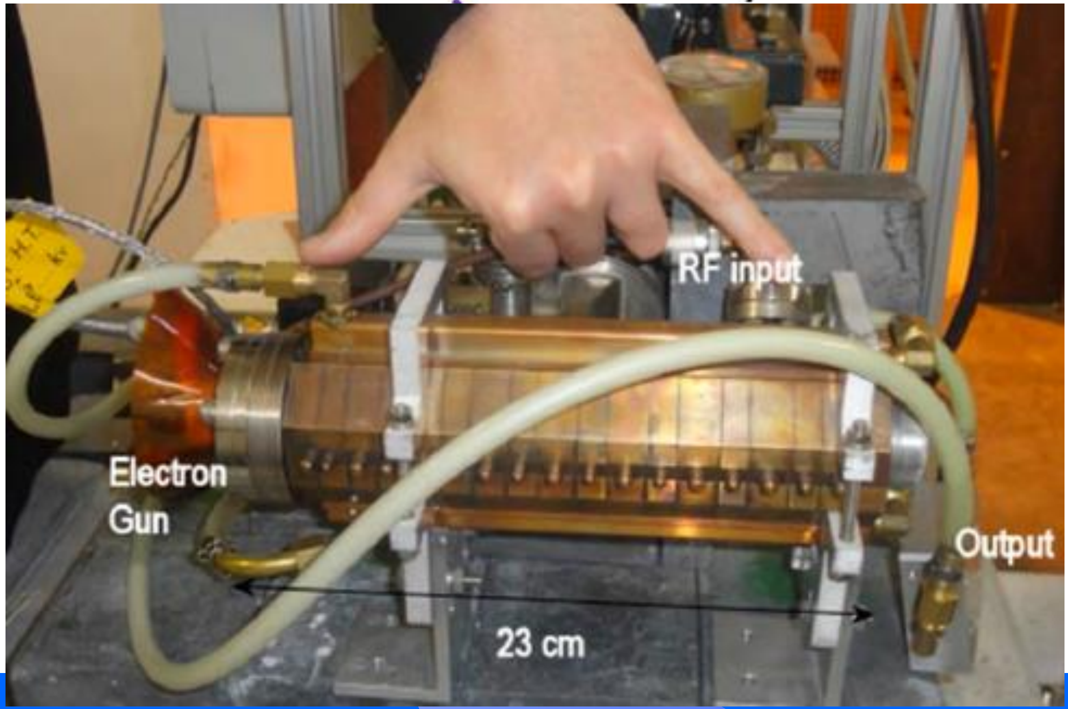
6 MeV Side-coupled Standing Wave Accelerating Structure

A 5.7 GHz short linac

Luigi Picardi

In 2010 -2012 ADAM S.A. company asked ENEA to help in the development of C-band (5712 MHz) Linacs for applications in medicine

- A 6 MeV linac for X-rays



Electron linacs for Intra Operative Radiation Therapy

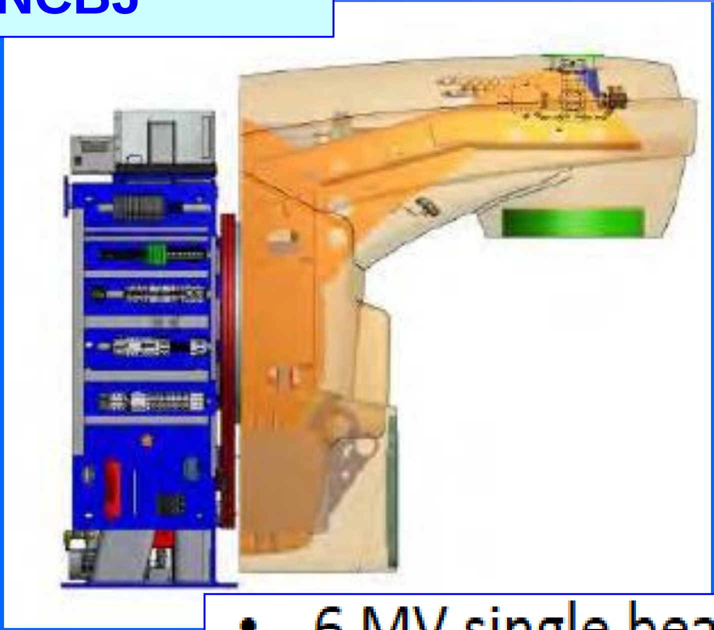
Luigi Picardi

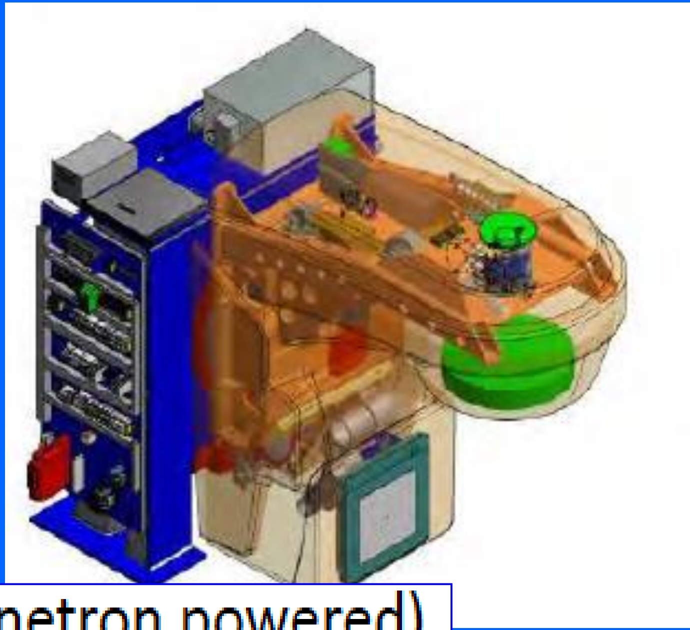
Output Energies	3 -to-12 MeV in steps
Pulse duration	4 μsec
Peak current	**1.5 mA**
Repetition frequency	1-30 Hz
Accelerating Structure	Standing wave
Magnetic lenses	**none, autofocusing**
Length	**82-92 cm (10-12 MeV)**
Weigth	**25 - 33 Kg**

Such IORT devices allow radiation therapy solutions for any Oncologic Surgical Center without requiring any specific facility, e.g. bunkers or any shielded Operating Room.

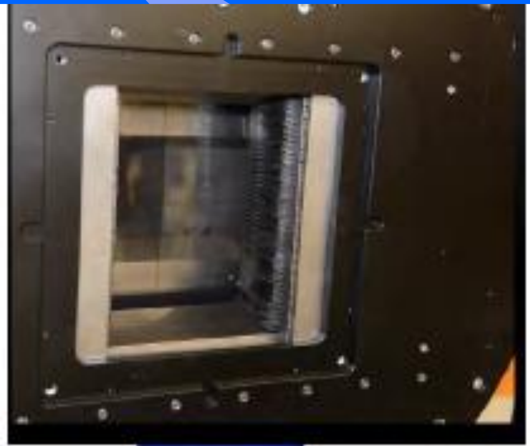
Przemyslaw Adrich
NCBJ

Coline 6 - Full-fledged therapy linac in Poland





- 6 MV single beam (magnetron powered)



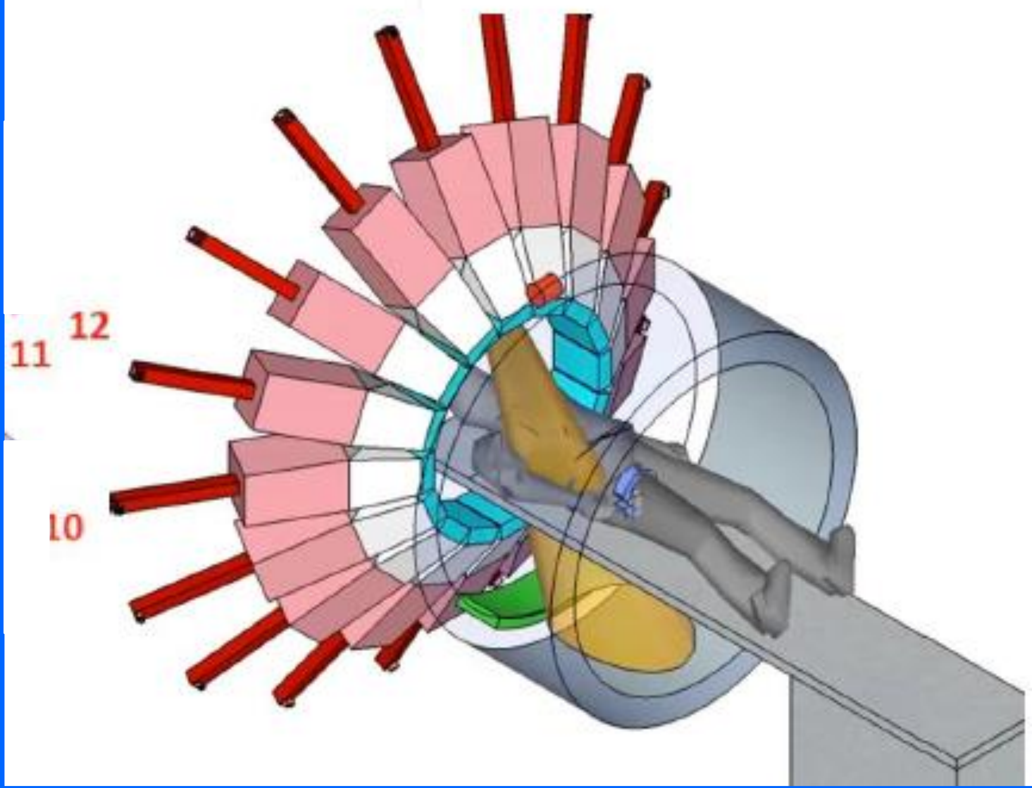
- 80 leafs MLC (proprietary)
- IMRT (sliding window, step-and-shoot)
- MV Portal Imaging (no kV imaging)

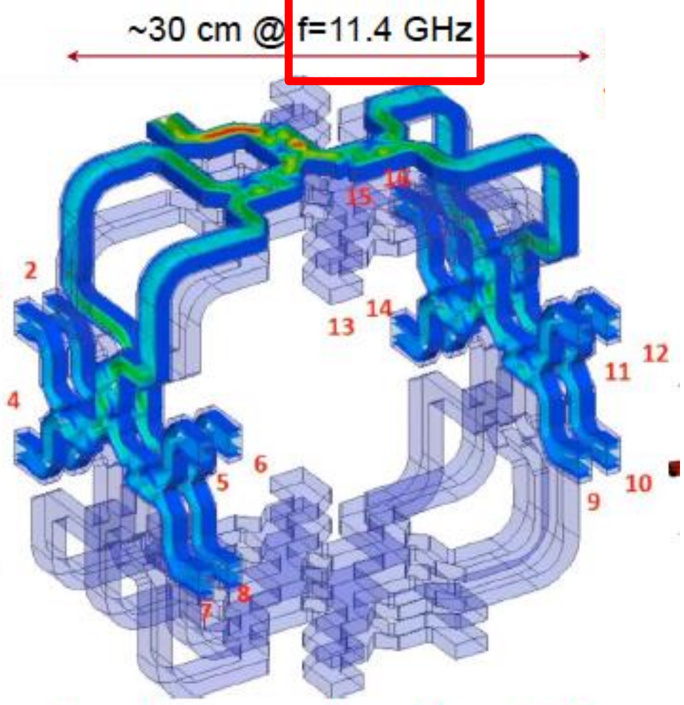
European Union
European Regional Development Fund

Billy Loo
Sami Tantawi
Stanford

PHASER for "flash" irradiation

Scanning the beam through scanning the phases of the RF sources



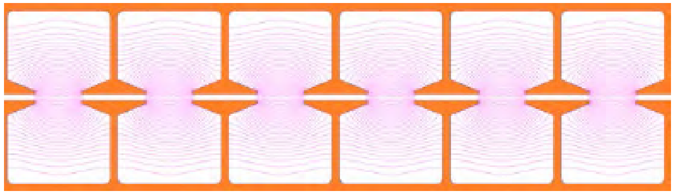


Inputs are numbered from 1-16

Accelerating structure – lower frequency

- Several linac designs at higher frequency, but what about going down in frequency, to 1 GHz?
- Larger dimensions can offer some advantages: less cells, does not need stabilization – can be made of bolted copper-plated elements, no need for brazing – could use coaxial flexible cables instead of rigid waveguide.
- Main disadvantage: some magnetrons designs exist at low frequency, but not readily available commercial units – some magnetron development is needed.

Medical Pi Mode Structure
Preliminary design by R. Wegner, CERN



6 MeV design

frequency 750 MHz

diameter ~ 300 mm

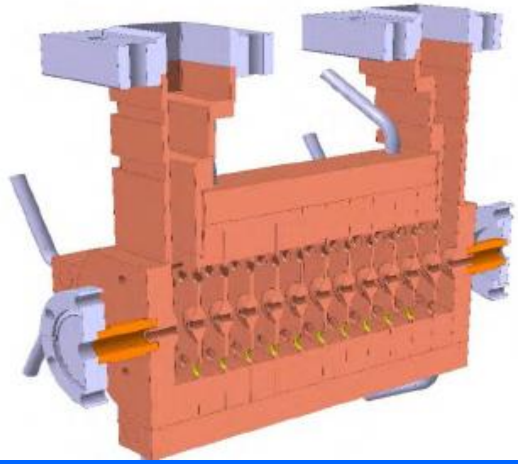
length ~ 1.4 m (7 cells)

ZTT ~ 37 MΩ/m

E0 = 4 MV/m

New type of 3 GHz linac

- Recently, CERN and TERA Foundation have developed a new high-efficiency TW at 3 GHz, the Backward TW (BTW).
- Advantages: simpler construction (diffusion bonding instead of brazing), high efficiency.



Input-output energy	25 keV – 6 MeV
Total length	0.56 m
Number of cells	14
Avg Gradient	10 MV/m
Peak Power (0 synch.ph.)	0.56 MW

Preliminary design by S. Benedetti, CERN

Power generation

Magnetron vs klystrons

RF power source


magnetron


klystron

For radiotherapy linacs:

- **Magnetrons** for low power and energy (<10 MeV).
- **Klystrons** for high power and energy (> 10 MeV).

Magnetrons (invented for radars, used in every microwave oven) are simple and inexpensive; they cannot be used for scientific accelerators because not stable in phase. Scientific applications are moving towards solid state (reliable, low voltage, but still expensive ~3 €/W).

- Magnetrons are the logical choice for a new solid and compact radiotherapy design. Companies are now producing a wide range of economic magnetrons around 3 GHz (S-band).

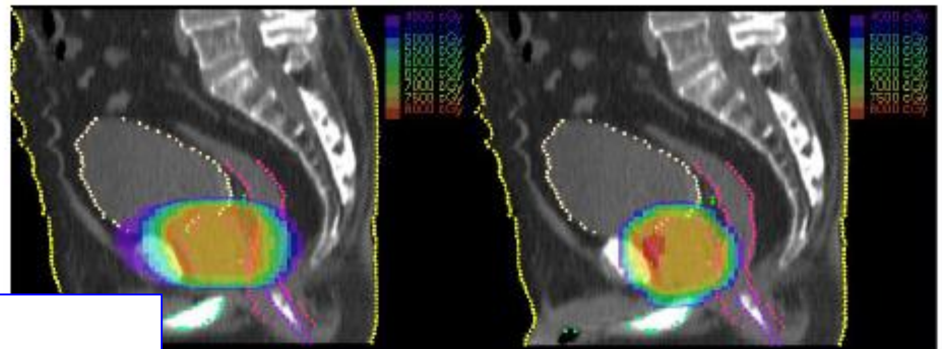
Power range between 2 and 5.5 MW

Image guided RT and MLC

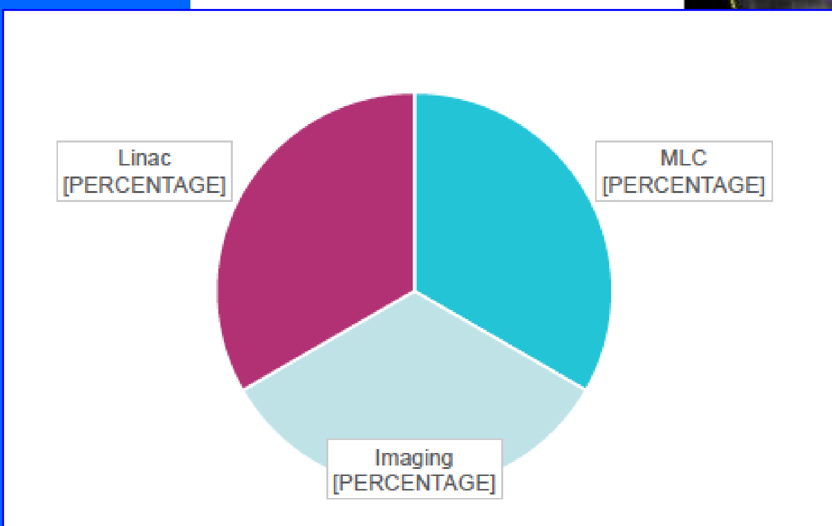
Importance of MLC

John Allen - Elekta

- What is **important**
  - High quality MLC
    - Low leakage and IMRT capable
    - IMRT reduces output factors, hence a high dose-rate becomes more important
  - Image guidance
    - To ensure that the anatomy is in the right place



Elekta

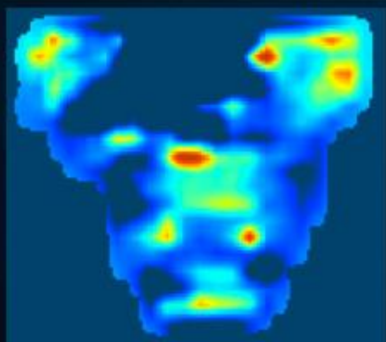


TERA

Optimization of MLC use

CONCLUSIONS

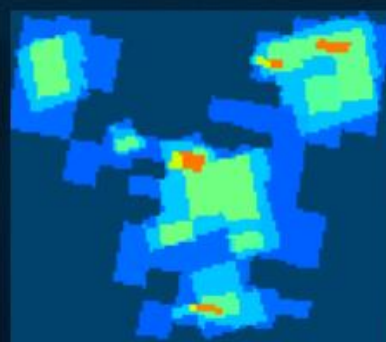
Example: Rotation of collimator can compensate for leaf width



Ideal fluence

Segment 1

Segment 2



8 segments

Software can compensate for lack of fancy and expensive features

Focus on reliability, robustness, accuracy, and cost

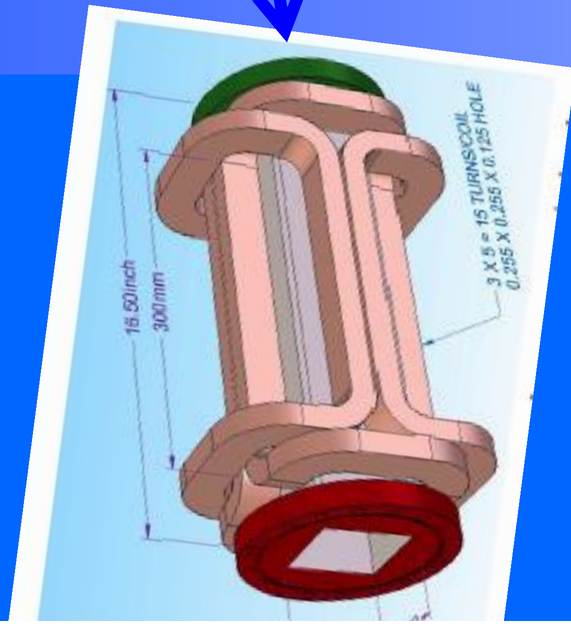
Use Plan Exploration during the design of the machine

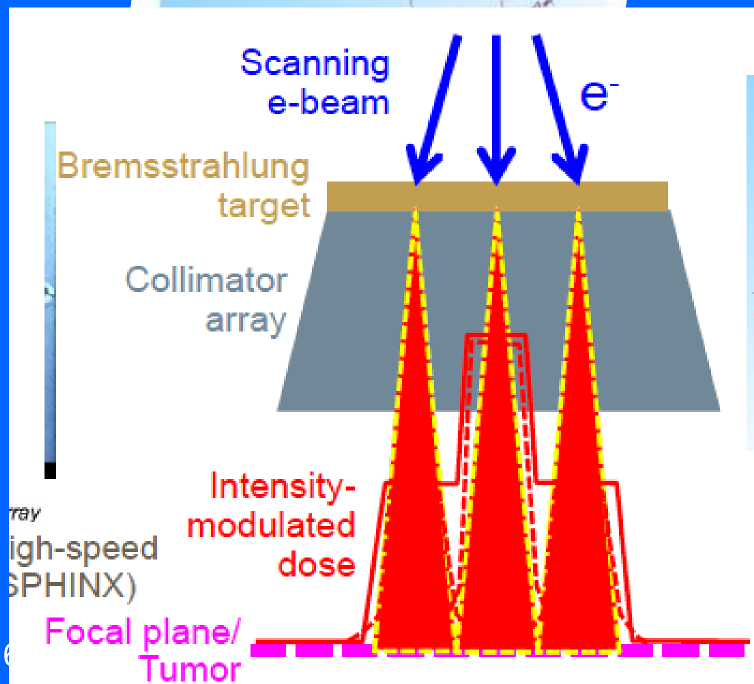
Complete planning solution should exist long before production begins

RaySearch Laboratories

Billy Loo
Sami Tantawi
Stanford

SPHINX for all-electronic intensity modulation





Shielding

Pawel Krawczyk
NCBJ

MMS system in practice - 6

Space between the wall panels

Two points of view

Conclusions: point of view from of Company

Key takeaways

The benefits of industrialization

- High quality and low cost products are best produced by industry
- Volume and standardization are key drivers of lower cost.
- Producing a “linac for everybody” will be more sustainable that any “special” device.

John Allen - Elekta

9 | Focus where it matters

Elekta

Conclusion: the point of view from a research Institution

David Jaffray

Summary

- Need to consider the treatment device in context of the system.
- The scale of the problem should push us to pursue highly innovative and disruptive solutions that cross boundaries.
- Focus on the problem: Radiotherapy for 12.5M people by 2035.
- Think beyond the scaling of current solutions.

David Pistenmaa

"DREAMLINER" LINAC FEATURES

NOVEL
MODULAR
UPGRADABLE
LOCALLY FIXABLE
ROBUST / RELIABLE
EASILY REPAIRABLE
Remote diagnostics
Turnkey installation
Less cooling needed
Optimize real time
On-board imaging
CT/MR Rx planning
Remote serviceability
Reliable in high temp
Virtual wedges/ MLCs
Reliable w/o chilled water
More efficient commissioning / nanotube-based cold cathode systems / Military-spec integrated circuits
Knowledge-based treatment planning / Remote environmental monitoring / Low demand on infrastructure / Low standby power need
Improved safety and testing technology / Non-human performance monitoring / Competency testing of operators / Integrated Educ. interfaces
Potential-failure readout
Off-grid power storage
Photons and electrons
Decreased PACS costs
3D navig vs gantries
Robust optimization
Hybridize: MR/linac
Hybridize : CT/linac
Automated Rx planning / digital detectors
Safety system for opns / Automated QA platforms
Alternate power:
Battery storage
Solar power
Fast restart
6-10 MV