Session 3
Dedicated Ocular Beamline & Universal Beamlines Adapted for Ocular Therapy

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Delivery of optimal ocular proton beams in the next decade?

First Symposium of Ocular Proton Therapy 2022

Early development of ocular PBT beams

Proton Therapy (HE): research centres

1975-01: HCL (MGH/MEEL)
Degraded 160 MeV synchrocyclotron

1986: NIRS synchrocyclotron
Vertical 70 MeV beam

1991: CPO-Curie
Degraded 200 MeV synchrocyclotron

1995: TRIUMF cyclotron
Degraded 520 MeV beam

Low-energy Proton Therapy

1984: PSI-OPTIS: Cyc.
72 MeV Injector. Dedicated

1989: Clatterbridge:
Dedicated line 60 MeV
H

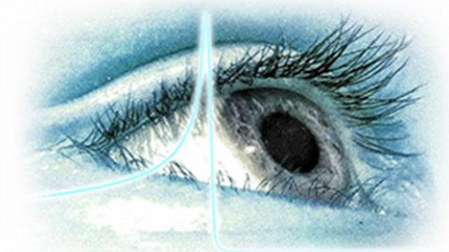
1991: CAL-Nice: Cyc.
Dedicated line 65 MeV

1994: UCSF:
Dedicated line 67.5 MeV
1998: HZB-Charite
Dedicated line 68 MeV
2001: INFN Catania

Proton (HE) Therapy Centres: purpose built

1990: LLUMC, degraded
250 MeV synchrotron
H

2002: MGH: Cyc.
degraded 230 MeV beam
H



Understanding the configurations PBT centres

Dedicated low-energy beams	Low-energy cyclotrons, eye room	CCC, Nice, UCSF, HZB
Dedicated room, shared machine	High-energy centre with eye room	PSI, Delft, IFJ
Shared treatment room, shared machine	Multi-purpose room in large centre	MGH, Curie, UFHPTI, WPE
Shared room, shared beam (adapted)	Eye treatments on gantry or fixed line	Seattle, NWPC, CNAO

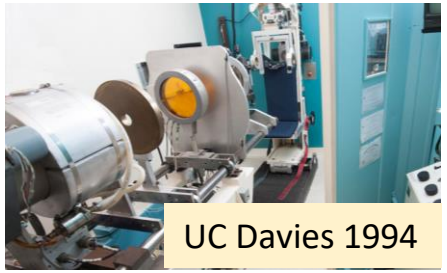
At year	Number Ocular Facilities Operating	Particle beams	Low-energy Beams (p, He)	High-energy* shared beams***	Adapted gantry beam nozzle**
1990	10	p, He	5	5	0
2000	11	p	5	6	0
2010	14	p, C	6	8	1
2021	20	p, C	5	15	3

* Degraded beams: in dedicated or shared treatment rooms

** On rotating gantry, supine/inclined couch

*** PBS or passive-scattered beams

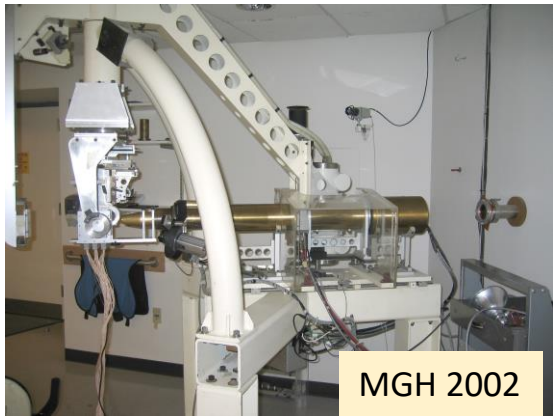
Ocular Treatment Beam Configurations in 2022


UC Davies 1994


Shanghai, 2018


Seattle 2016


UFHPTI 2012


MGH 2002


Charite HZB 1998


WPE 2021


CNAO 2016

Fun fact: >43,300 eye patients treated with PBT by 2021

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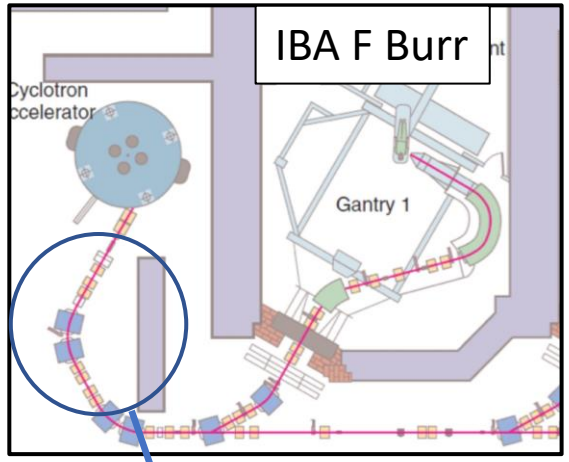
Range Straggling & Energy Degradation



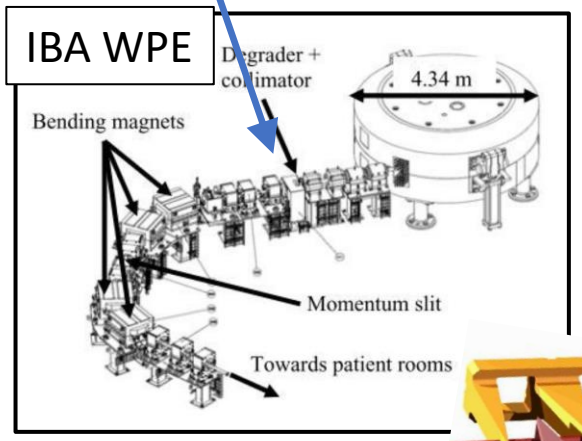
Energy Selection System (ESS) consists of :-

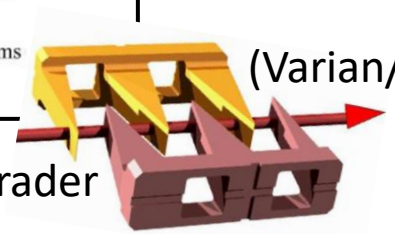
- Energy degrader (wedges, graphite, Be)
- Magnetic analyser (to select E)
- Momentum slits (to reduce ΔE)

- Energy loss, E (230 to 70 MeV)
- Energy spread ΔE ~ straggling
- Beam efficiency <1%

initial energy MeV	90-10% distal fall-off
60	1.0 mm
120	3.2 mm
160	5.2 mm
220	8.6 mm

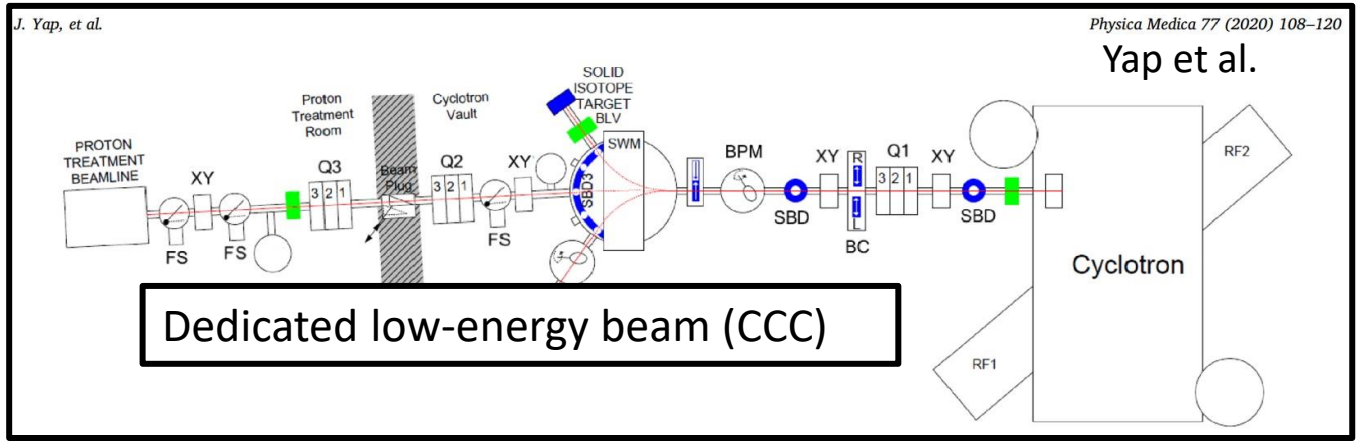
Range Straggling ∝ Initial Energy
e.g. approx. 1% of Range (water)





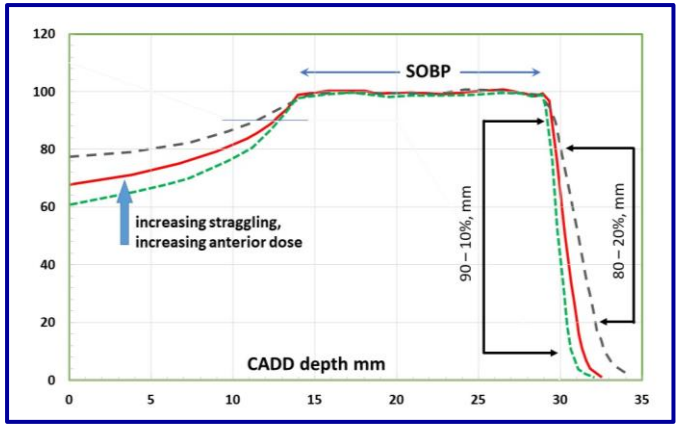
(Varian/Accel)

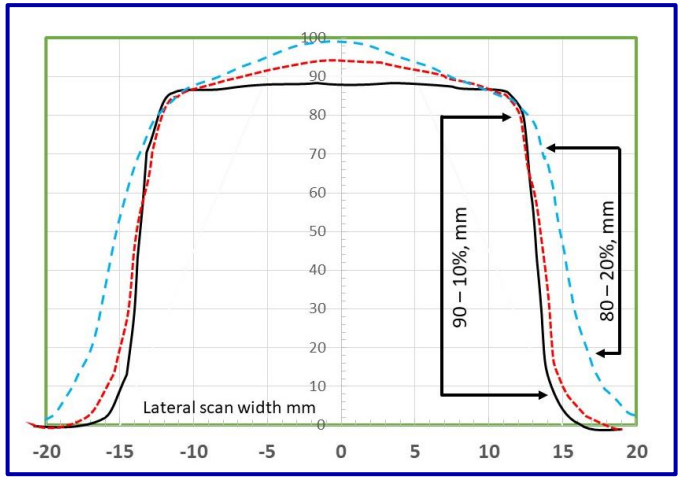
Degrader

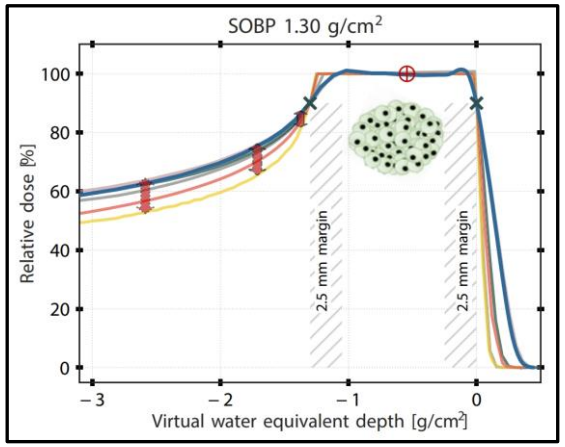


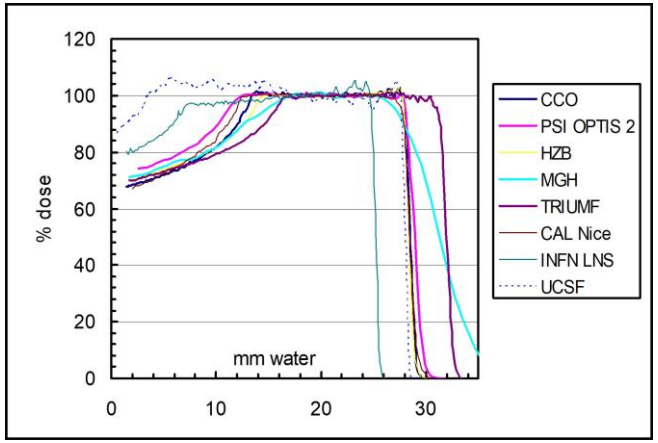
Dedicated low-energy beam (CCC)

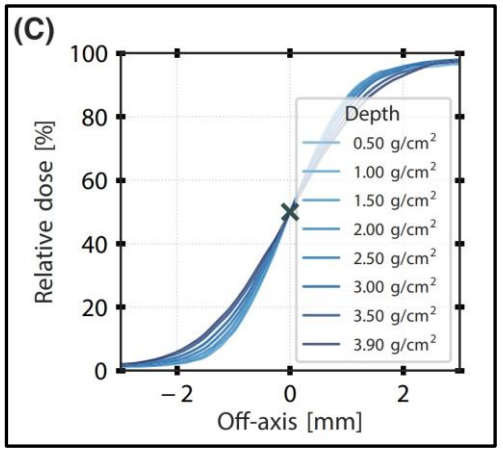
Effects of Penumbrae and Fall-off

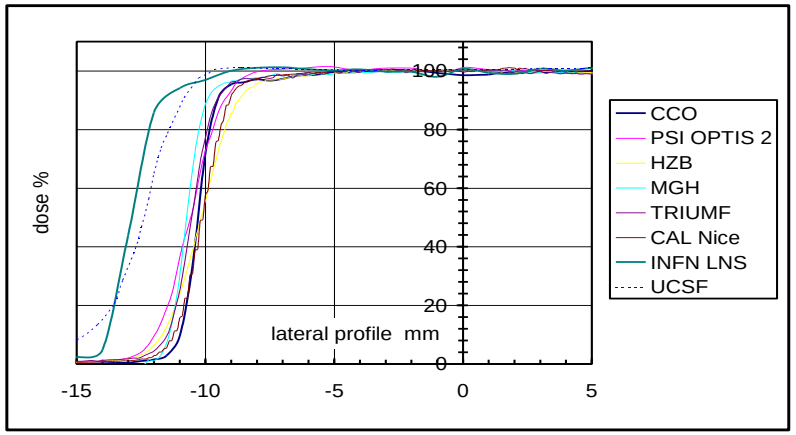








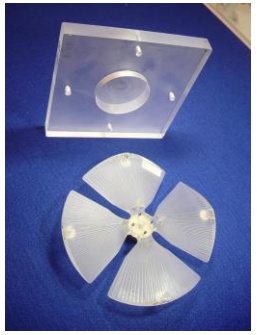




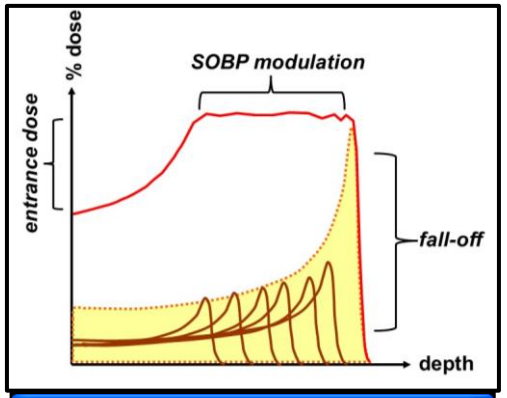
1) Kacperek A, 2012 Springer);149-177, in Ion Beam Therapy (ed. Linz U)
2) Fleury E et al. (2021). Medical Physics 48(1)
3) Gérard A. et al. (CAL, Nice) 2018, PTCOG 57, Cincinnati.

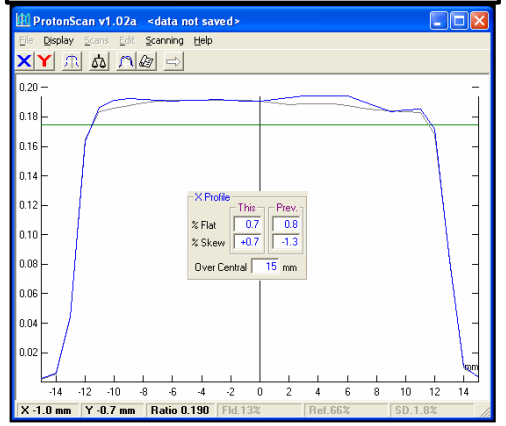
Beam characteristics of low-energy accelerators: a ‘gold’ standard for single-anterior fields

‘old time’ modulators



Parameter	Specifications	Effects
Beam penumbrae	1.1-1.5 mm (@80-20%)	OAR shielding
Beam distal ‘fall-off’	0.9-1.5 mm (@90-10%)	OAR shielding
Dose uniformity	± 2% @ 90%	Avoid cold spots, skew
Beam dose-rate/ duration	0.5 to 1.5 min.	Patient comfort/safety
Resolution in depth, modulation	0.2, 1 mm	Dose sparing
maximum/min. range and SOBP	4 – 35 mm	Deep and superficial mm
Sufficient SAD	180 to >250 cm	Parallel beam
Isocentre	7 cm	“ “

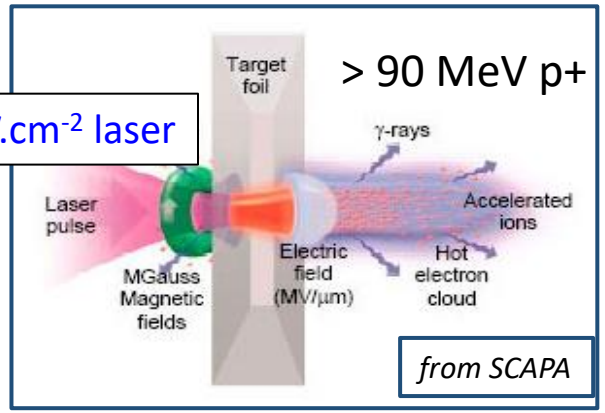




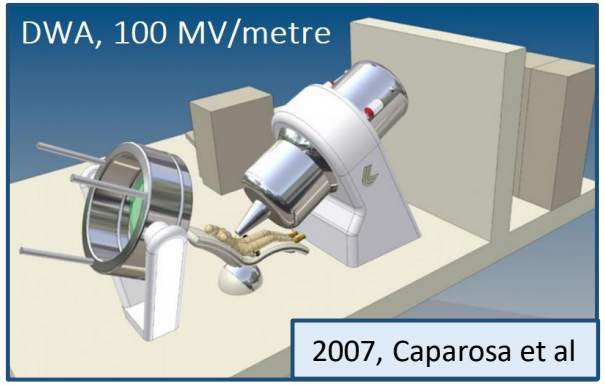
These factors are inter-dependent

Alternatives to low-energy circular accelerators

$>10^{19}$ W.cm^{-2} laser



from SCAPA

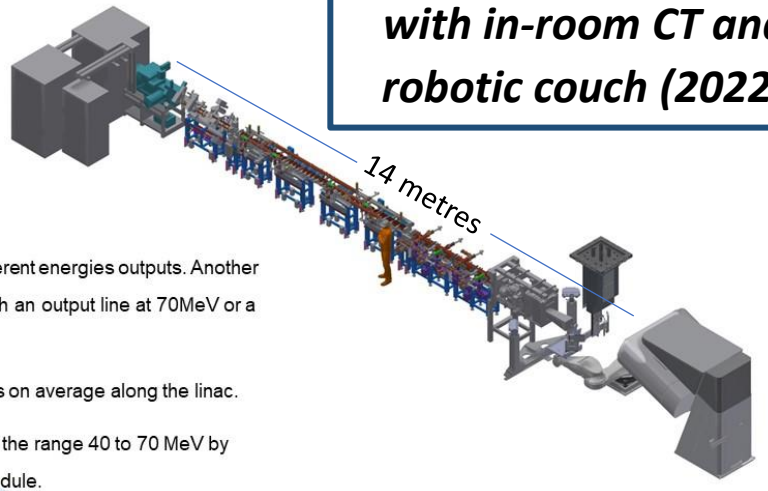


2007, Caparosa et al

Potential for Ocular Treatment

70 MeV proton linac with in-room CT and robotic couch (2022)

[AVO-LIGHT project]



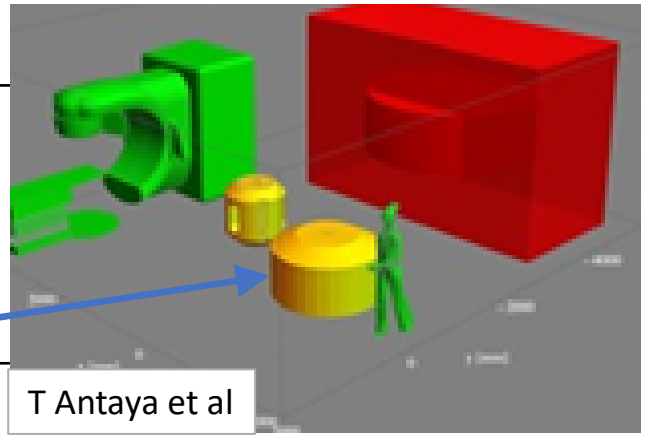
- **Modular design** which offer possibility to have different energies outputs. Another possible configuration could be a full energy 230MeV with an output line at 70MeV or a cyclinac [5].
- **Low radiation**: 1m standard concrete wall thickness on average along the linac.
- Expected **electronic energy modulation** in the range 40 to 70 MeV by controlling amplitude and phase of each accelerating module.
- Expected **volumetric rescanning with fast 5 millisecond energy changes**, maximizing the advantage of proton treatment.

With thanks: G. De Michele

But…

Recycle cyclotrons: pros and cons.

New S/C low-energy compact cyclotron: design studies, Ø 1.5 m. 5t.



T Antaya et al

Directions in eye PBT

These aspects will be covered by the Speakers in Session 3

Questions and Concerns	Details and Comments
WHY THE SHARPEST PROTON ISODOSES?	*Best at <70 MeV energies; brass collimators, best margins for OAR and planning flexibility; best conformity with passive-scattered beams; 70 MeV synchrotron beams;*
NO VENDORS FOR LOW-ENERGY ACCELERATORS	*Costs, size, compactness (S/C); novel developments unlikely in next decade; ageing heritage cyclotrons;*
PRECISION CHAIRS vs. SUPINE COUCH	*Limited experience with couch/supine treatments; advantages in anterior-lateral-oblique fields to be proven;*
ADAPTED BEAMLINES (GANTRIES/FIXED LINES)	*Degraded beams adequate if sufficiently developed;*
INCREASE IN ADAPTED/DEGRADED BEAM LINES	*Cost-effective for ocular add-on; role of pencil beams; aperture-less beams? Role for micro-MLC? Move away from modulator libraries?*
EYE PATIENT WORK FLOW	*Patient flow priorities; simulations in 'shared' room;*

Adequate beams or optimally conformal ocular beams?
Would 'adequate' penumbrae be acceptable in conventional X-radiotherapy?