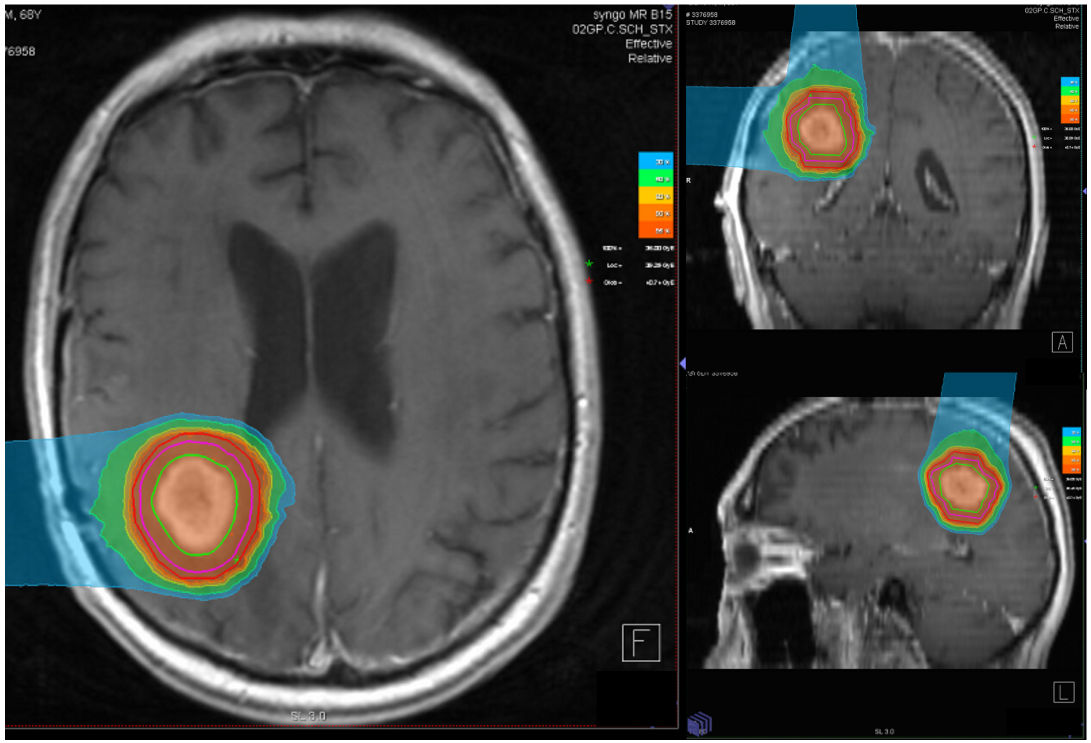
IBT with Ions Heavier than Protons: Performance and Prospects

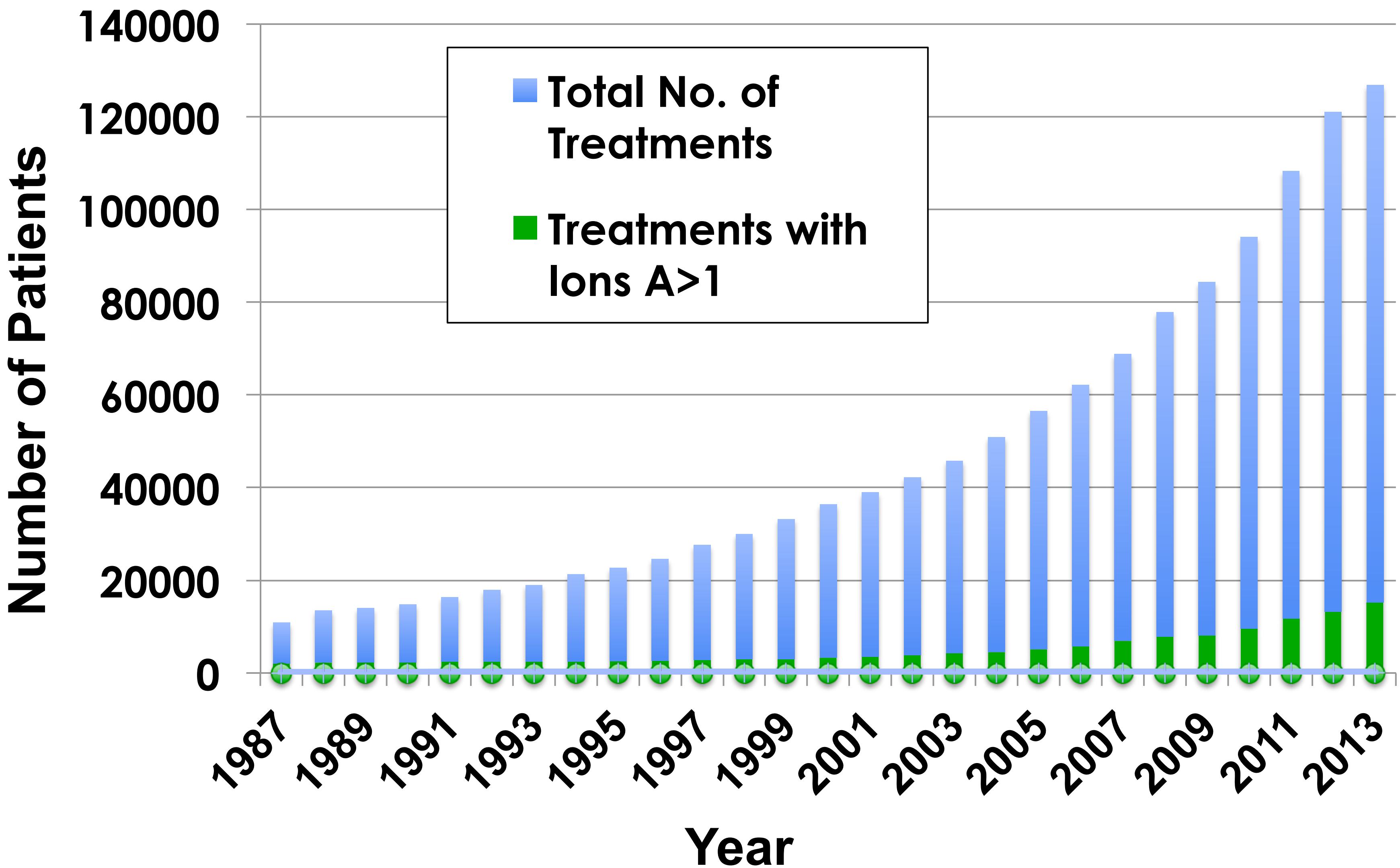


Ute Linz
Forschungszentrum Jülich

IPAC15 Richmond May 7, 2015

IBT with Ions Heavier than Protons: Performance and Prospects

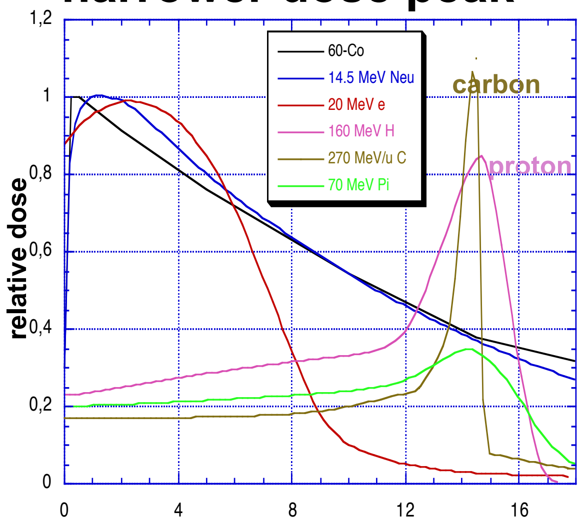
• patients treated with IBT •



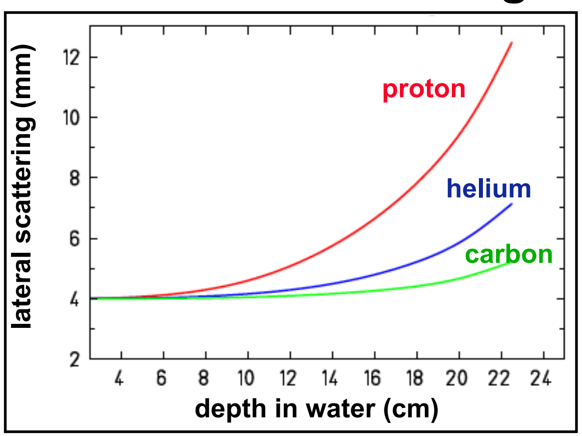
IBT with Ions Heavier than Protons: Performance and Prospects

• pros and cons of heavier ions •

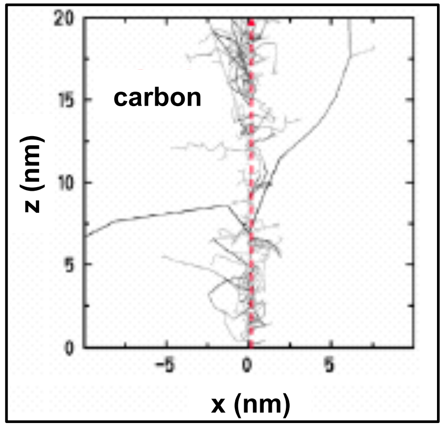
narrower dose peak

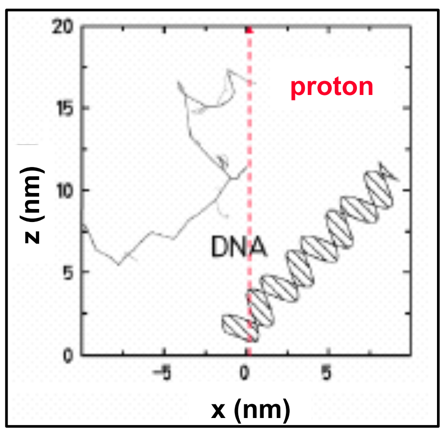


less lateral scattering

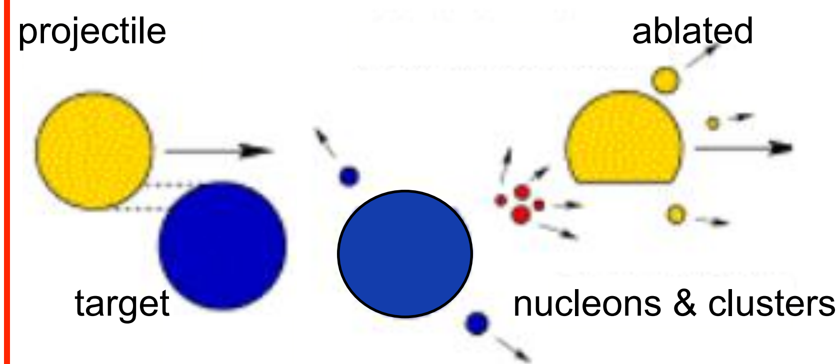


increased biol. effectiveness





nuclear fragmentation



more expensive

IBT with Ions Heavier than Protons: Performance and Prospects

• general requirements for IBT accelerators •

- High reliability
- Easy to operate
- Easy to maintain
- Easy to upgrade
- Low maintenance costs
- Low follow-up costs

IBT with Ions Heavier than Protons: Performance and Prospects

• synchrotron: slow cycling •

HIMAC, Chiba, JP	He-Xe	NIRS/Hitachi, Toshiba
HIBMC, Harima SGC, JP	H, C	Hitachi, Toshiba
HIT, Heidelberg, D	H, He, C, O	GSI
GHMC, Maebashi, JP	C	Mitsubishi
CNAO, Pavia, I	H-C	CERN
Saga HIMAT, Tosu, JP	H-C	Mitsubishi
SPHIC, Shanghai, CN	H, C	Siemens
HIRFL, Lanzhou, CN	H, C	IMP
MIT, Marburg, D	H, C	HIT/Siemens
MedAustron, WN, A	H, C	CERN
i-ROCK, Kanagawa, JP	C	Toshiba

IBT with Ions Heavier than Protons: Performance and Prospects

• synchrotron: slow cycling •

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SPHIC, Shanghai, CN	H, C	Siemens
HIRFL, Lanzhou, CN	H, C	IMP
MIT, Marburg, D	H, C	HIT/Siemens
MedAustron, WN, A	H, C	CERN
i-ROCK, Kanagawa, JP	C	Toshiba

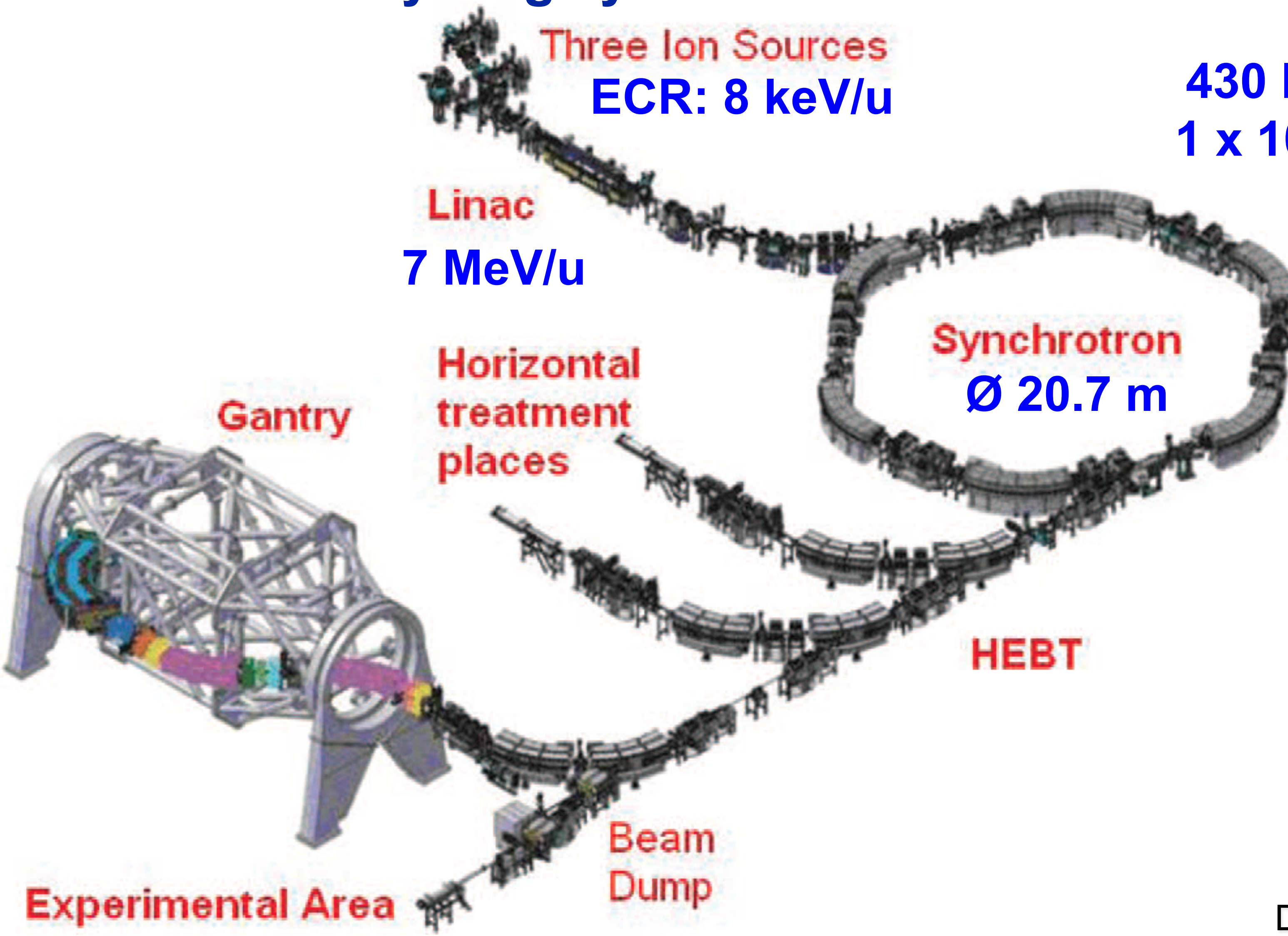
established extraction method

high beam stability in time, position, and size

IBT with Ions Heavier than Protons: Performance and Prospects

• slow-cycling synchrotron: HIT •

C^{6+}
430 MeV/u
1×10^9 pps



Data: HIT

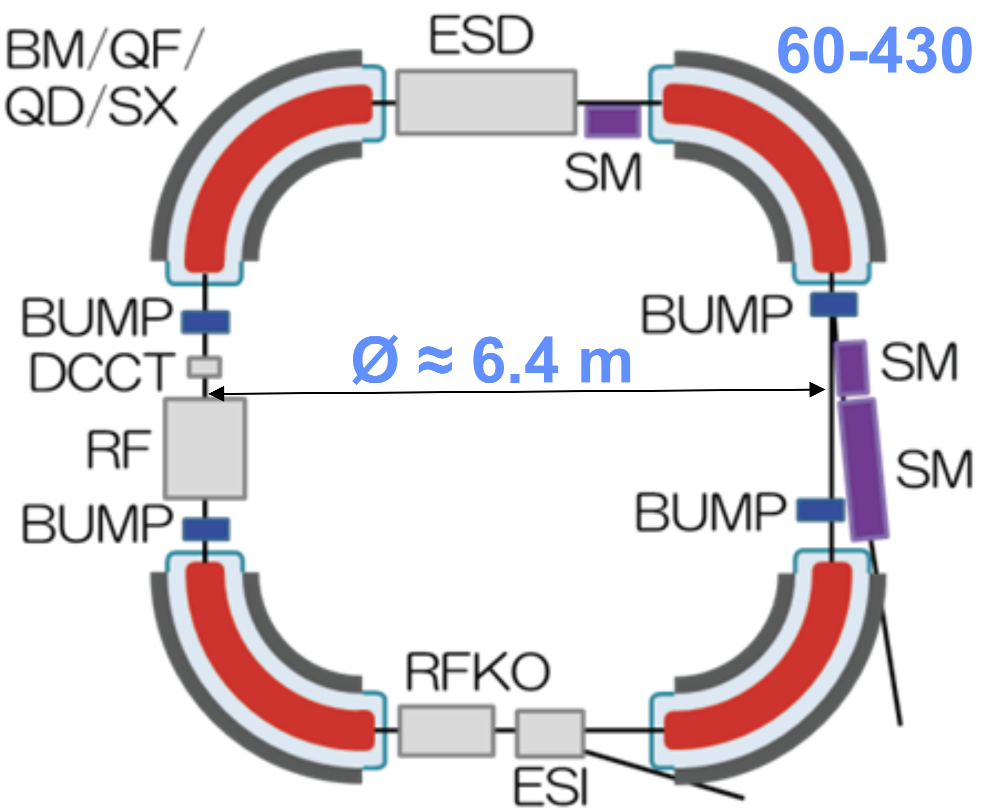
IBT with Ions Heavier than Protons: Performance and Prospects

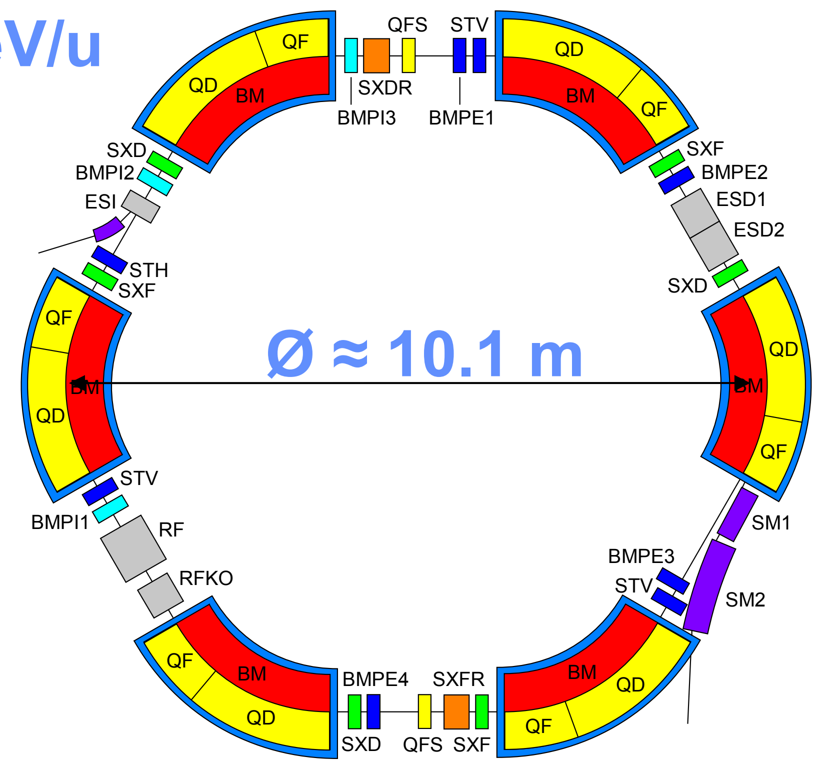
• slow-cycling synchrotron: new design study •

NIRS

C^{6+}

60-430 MeV/u





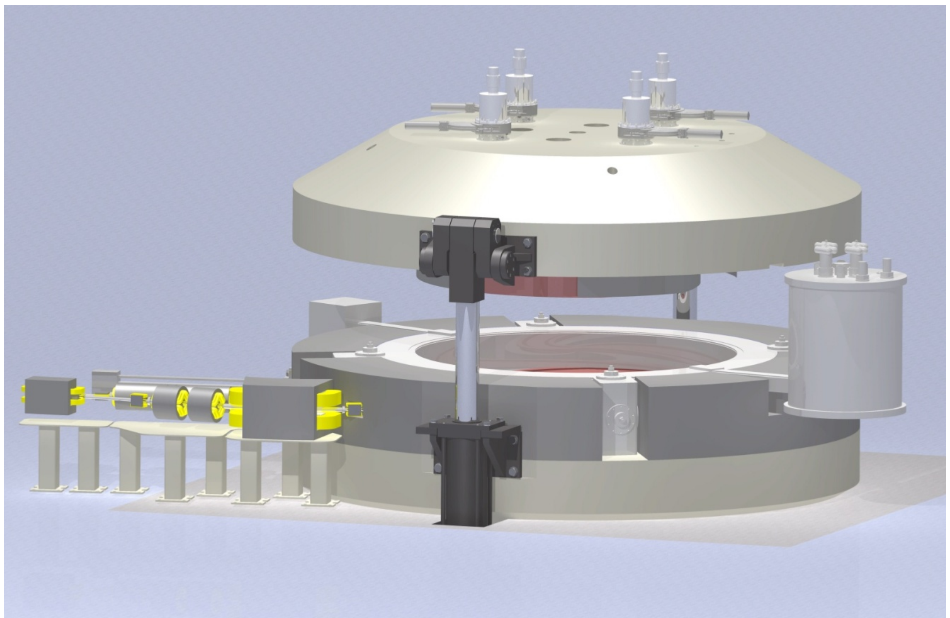
superconducting

Data: K. Noda

IBT with Ions Heavier than Protons: Performance and Prospects

• cyclotron: new design study •

IBA C400



superconducting

Ion	H, He, C
Energy (MeV/u)	400 (H:250)
Outer diameter (m)	6.6
Height (m)	3.4
Weight (t)	700
Extracted current (nA)	8
RF power (kW)	2x100
Magnetic field	4.5 T
RF Frequency	75 MHz

Data: D. Bertrand, IBA & A. Olshevskiy, JINR

IBT with Ions Heavier than Protons: Performance and Prospects

• clinical relevance of a gantry •

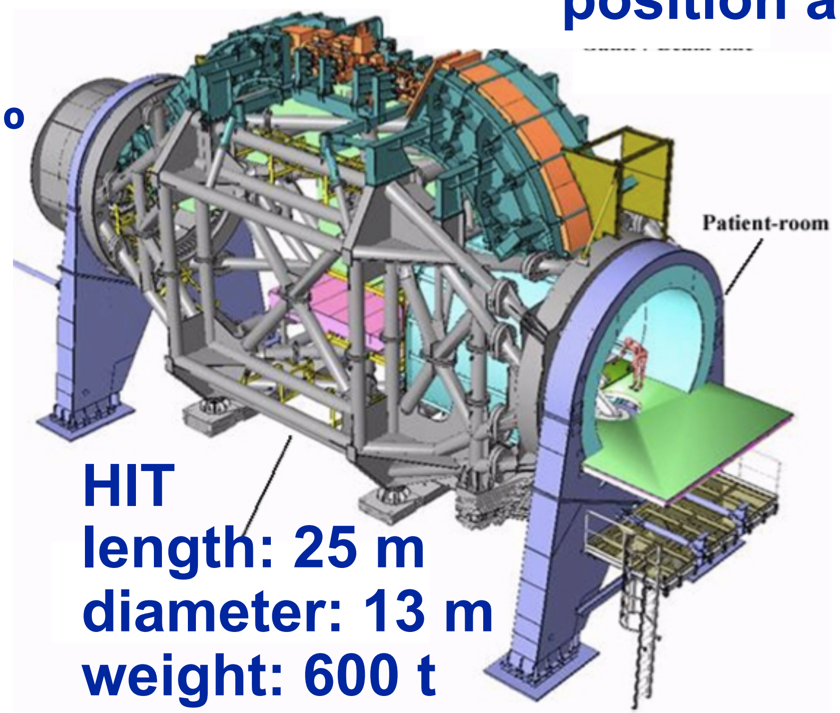
- Irradiation should occur from the optimum angle to reduce unnecessary radiation exposure
- The beam should be directed to the target not the target to the beam

IBT with Ions Heavier than Protons: Performance and Prospects

• gantry: HIT •

Rotation
range: ± 185º
accuracy: ± 0.3º
step size: 0.3º
time: 1 min/circle
braking distance: 1º

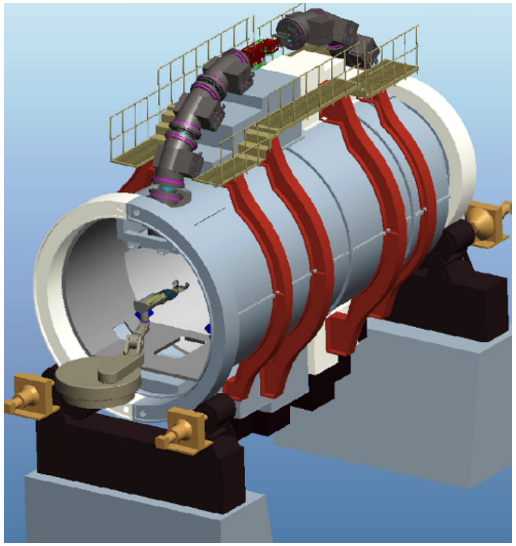
Spot
size: σ_x, σ_y <3 mm
divergence: σ_x',σ_y' <1/200 rad
position accur.:$\Delta\sigma_x$,$\Delta\sigma_y$ <1 mm



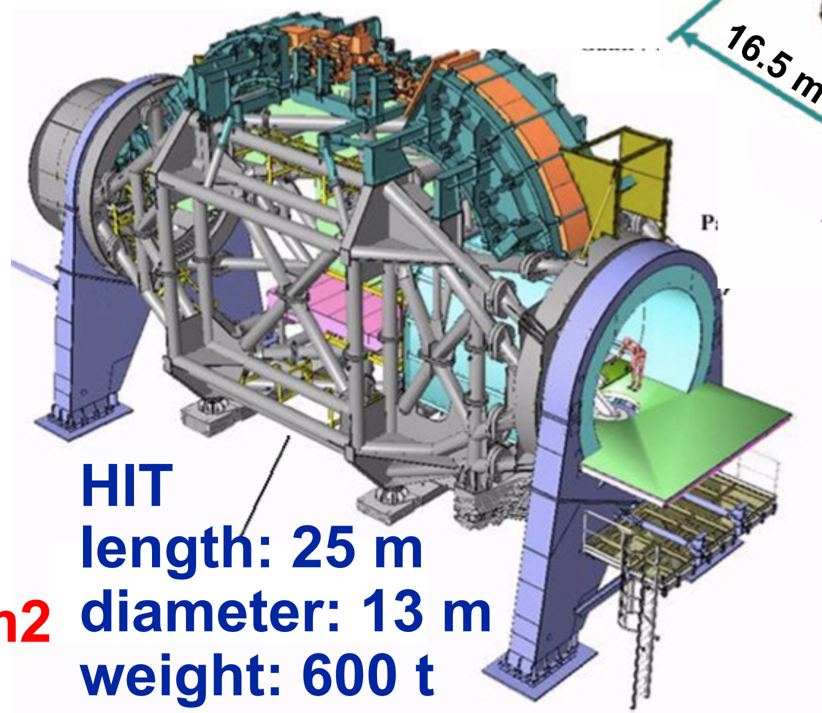
HIT
length: 25 m
diameter: 13 m
weight: 600 t
range: 30 cm
aperture: 24x22 cm2

IBT with Ions Heavier than Protons: Performance and Prospects

• new gantry concepts •



HIMAC II (2015)
length: 13 m
Ø: 11 m
weight: 300 t
range: 30 cm
aperture: 20x20 cm2



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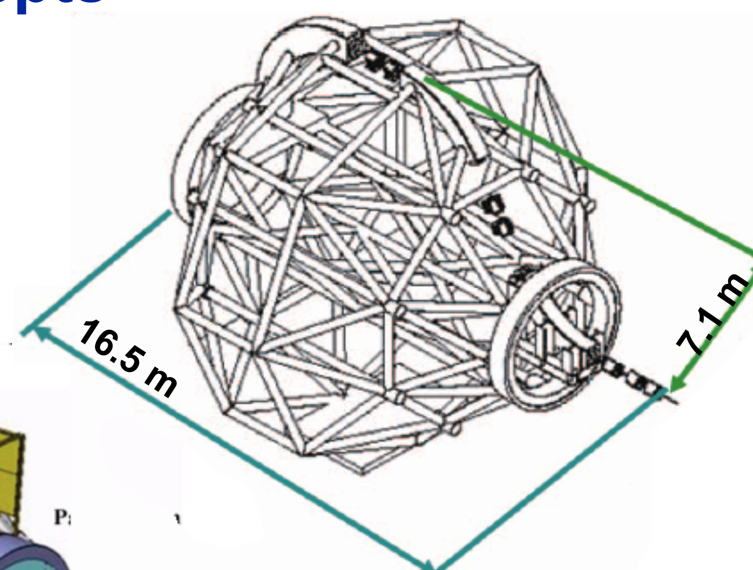
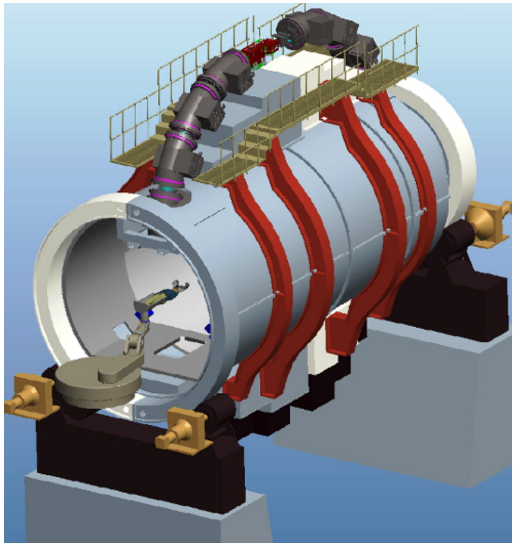


HIMAC II (2010)
length: 17 m
Ø: 14 m
weight: 300 t
range: 25 cm
aperture: 15x15 cm2

IBT with Ions Heavier than Protons: Performance and Prospects

• new gantry concepts II •



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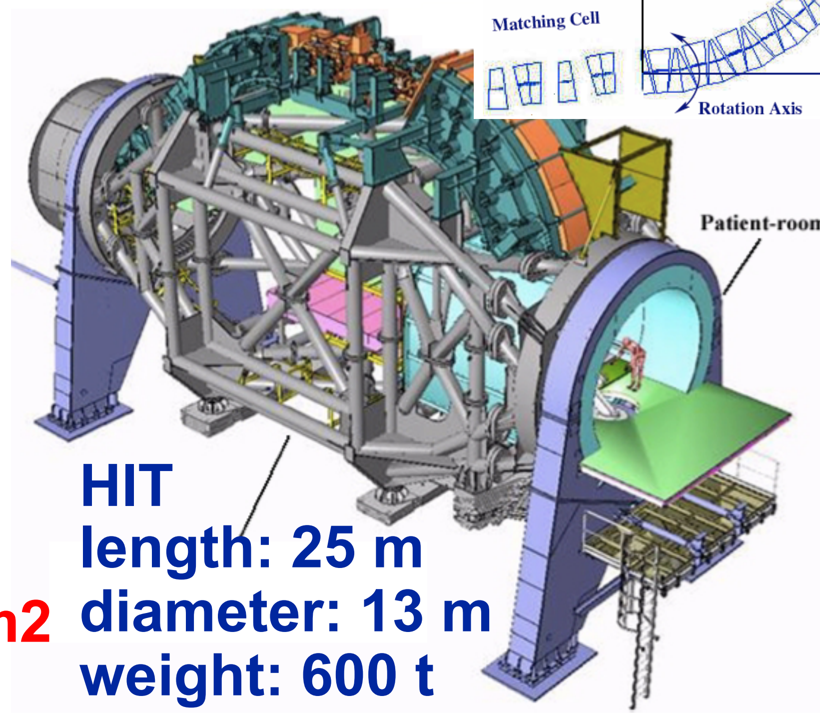

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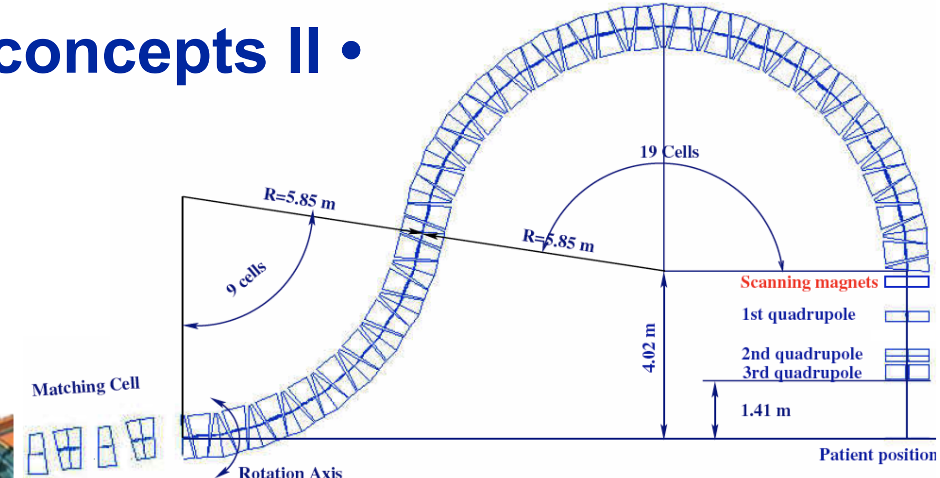


NS-FFAG
length: 30 m
Ø: 20 m
weight: ≈ 7 t
range: 25-27 cm
aperture: ? cm2

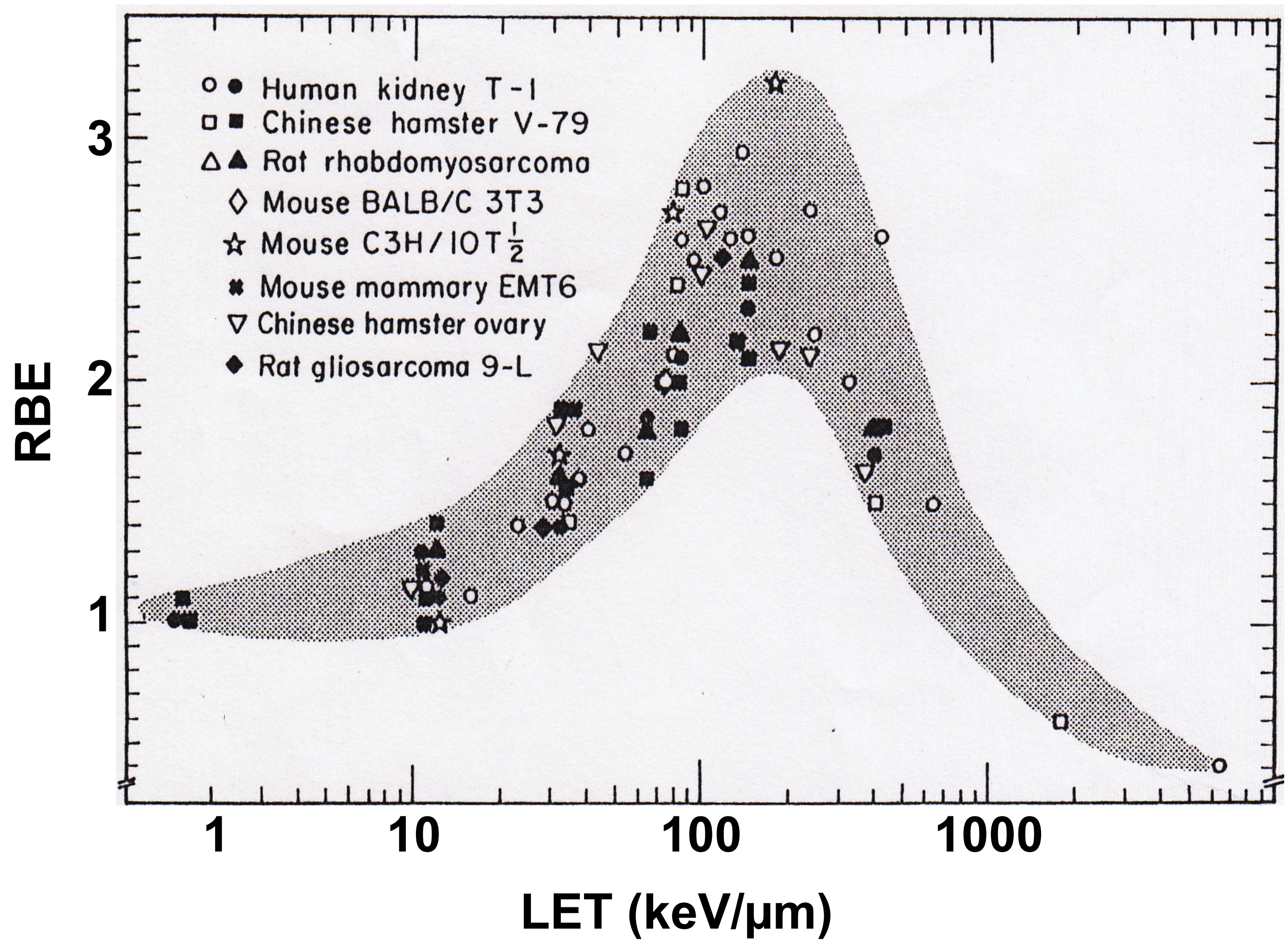
IBT with Ions Heavier than Protons: Performance and Prospects

• the optimum ion •

- high RBE in the tumor
- sparing of normal tissue
- low risk for late toxicity
- high benefit-cost ratio

IBT with Ions Heavier than Protons: Performance and Prospects

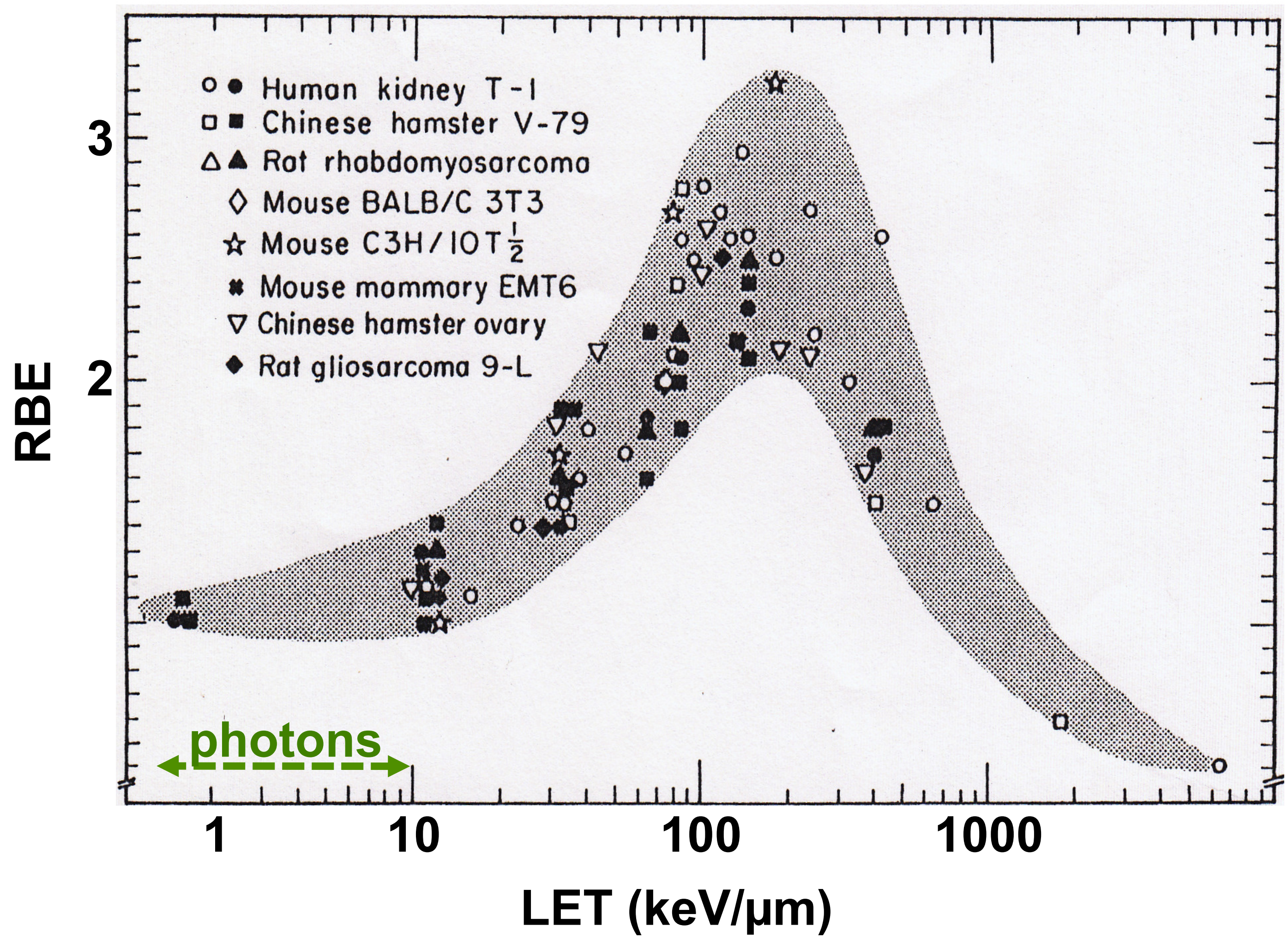
• the optimum ion: RBE vs. LET •



Data: LBL

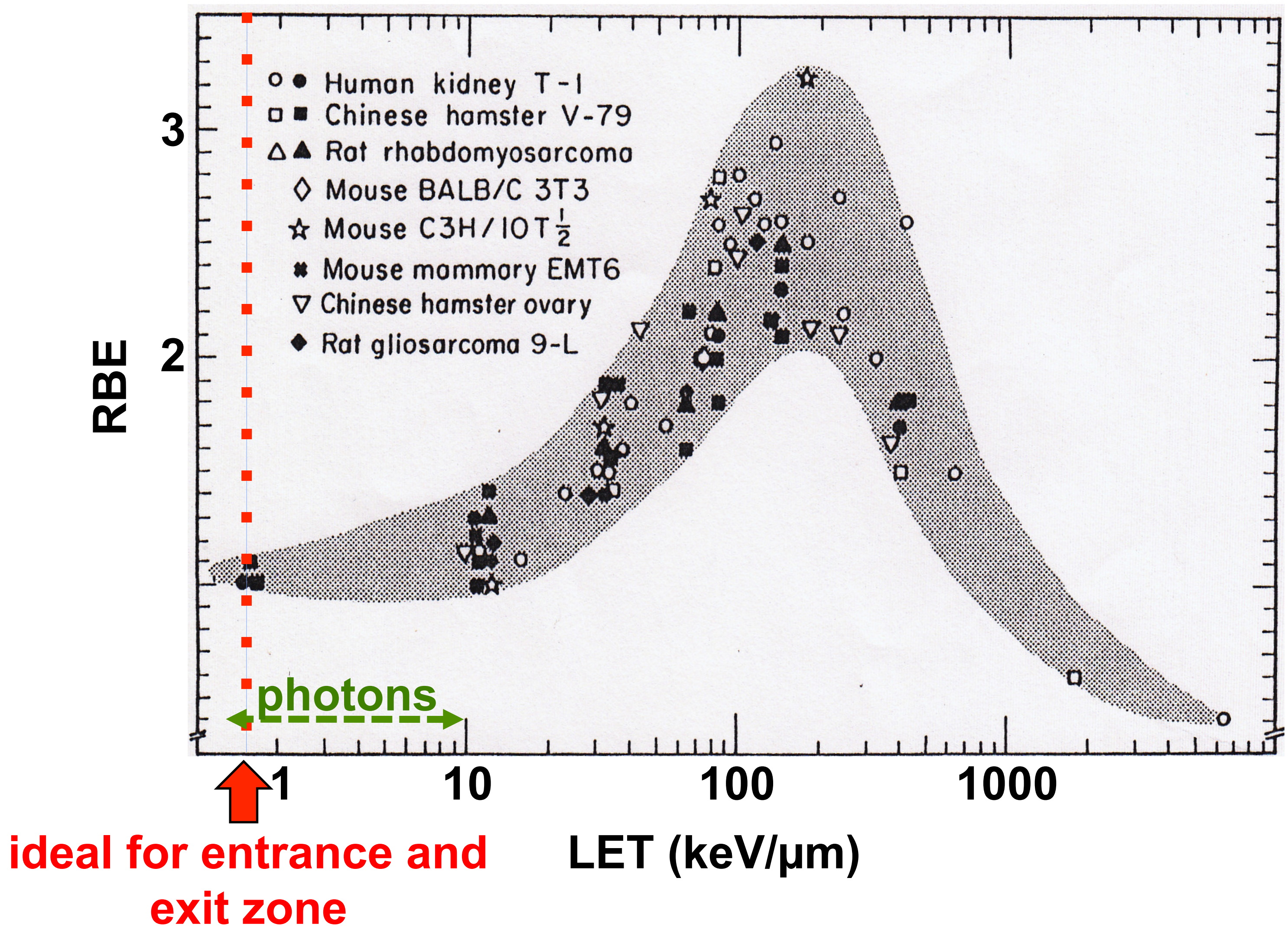
IBT with Ions Heavier than Protons: Performance and Prospects

• the optimum ion: RBE vs. LET •



IBT with Ions Heavier than Protons: Performance and Prospects

• the optimum ion: RBE vs. LET •



IBT with Ions Heavier than Protons: Performance and Prospects

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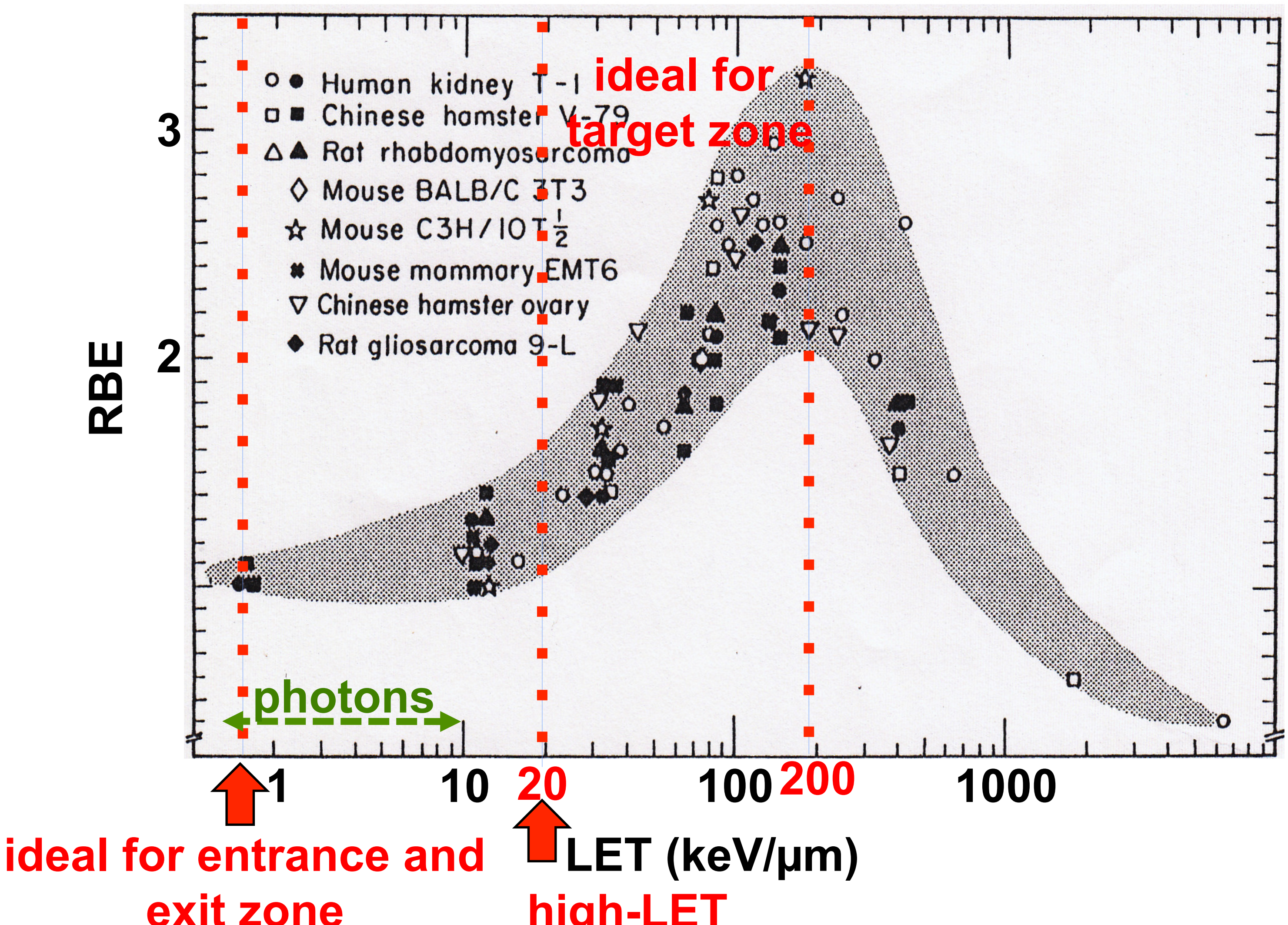
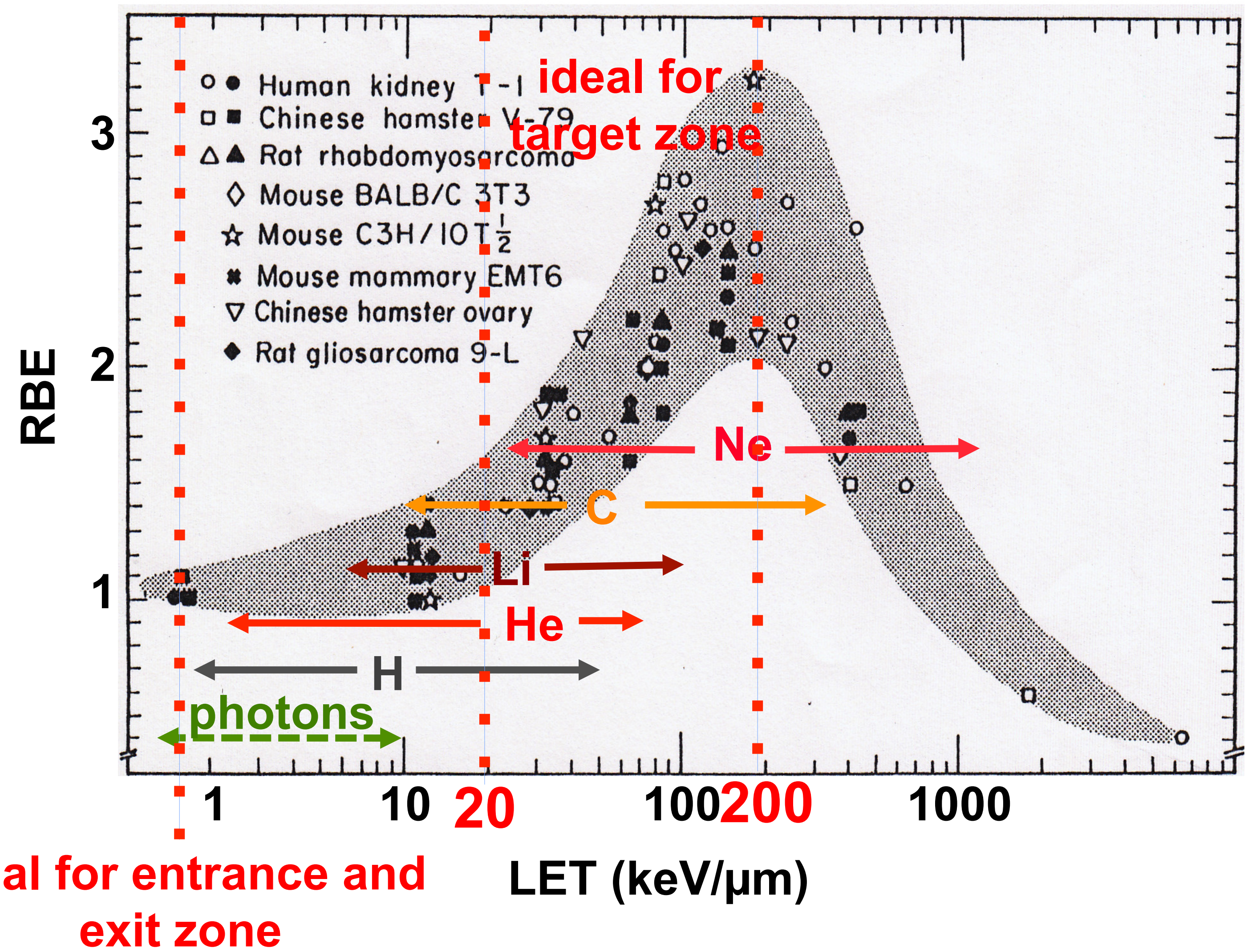


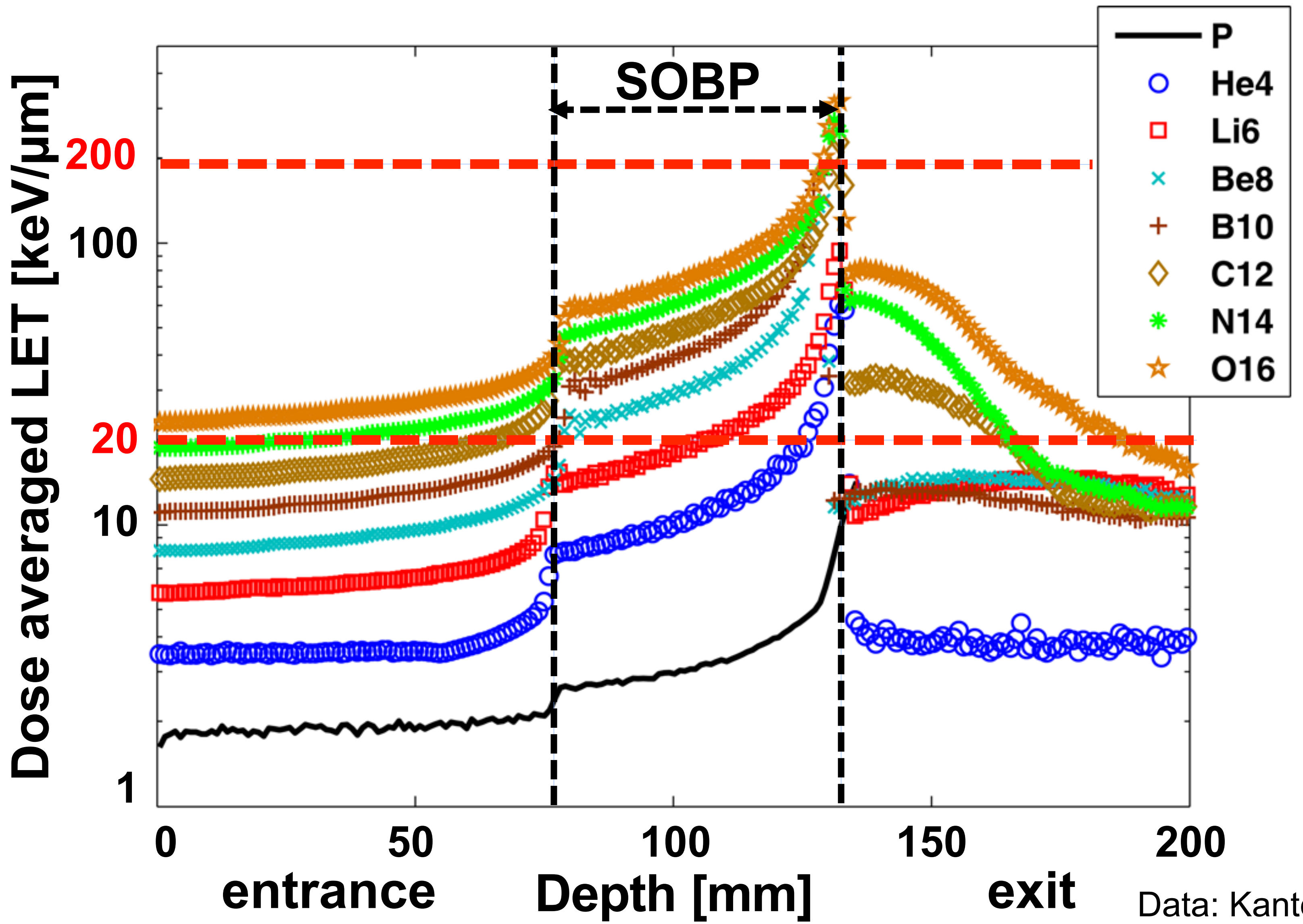
IBT with Ions Heavier than Protons: Performance and Prospects

• the optimum ion: RBE vs. LET •



IBT with Ions Heavier than Protons: Performance and Prospects

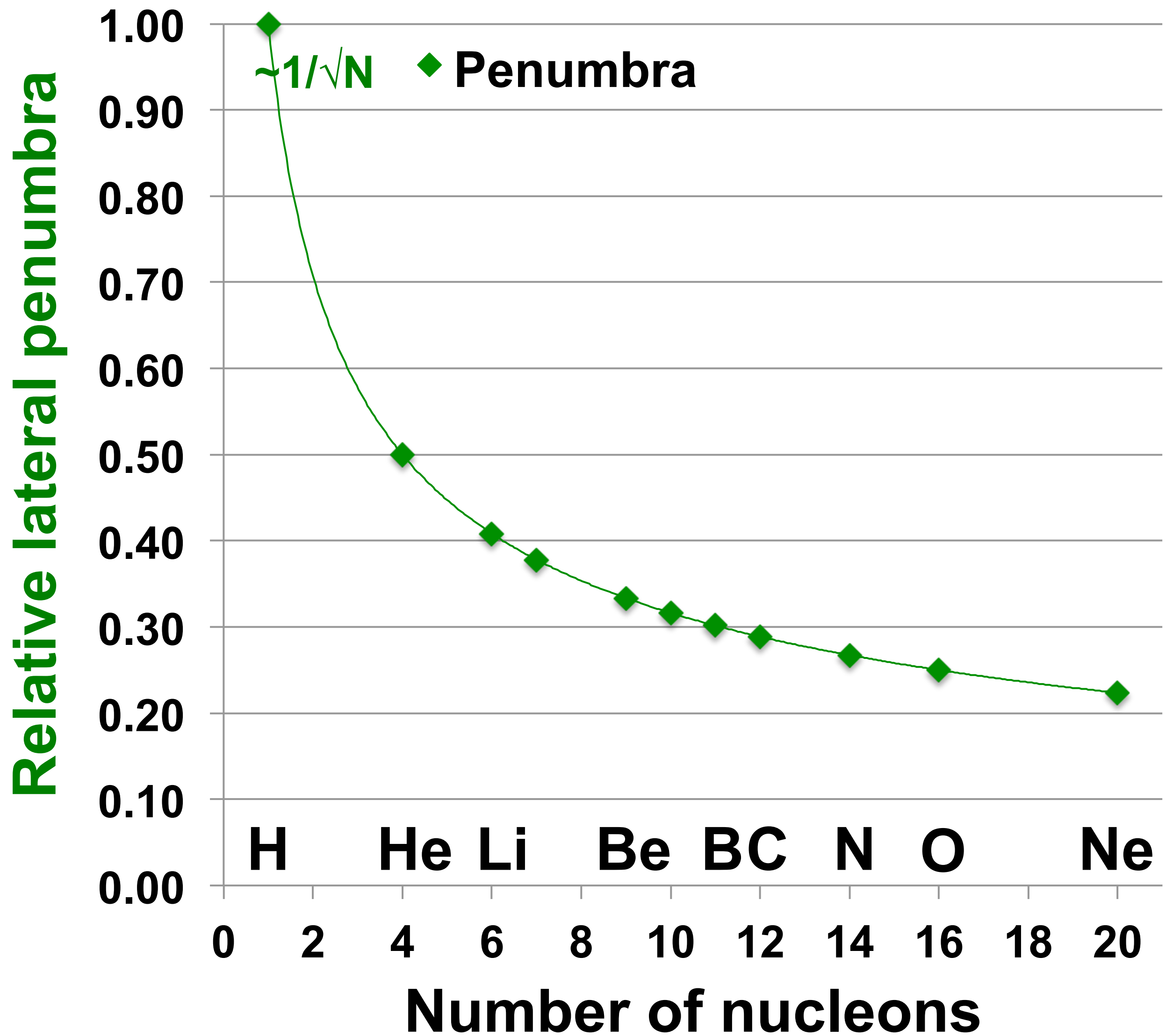
• the optimum ion: LET vs. depth dose •



Data: Kantemiris, 2011

IBT with Ions Heavier than Protons: Performance and Prospects

• the optimum ion: properties as function of nucleons •



IBT with Ions Heavier than Protons: Performance and Prospects

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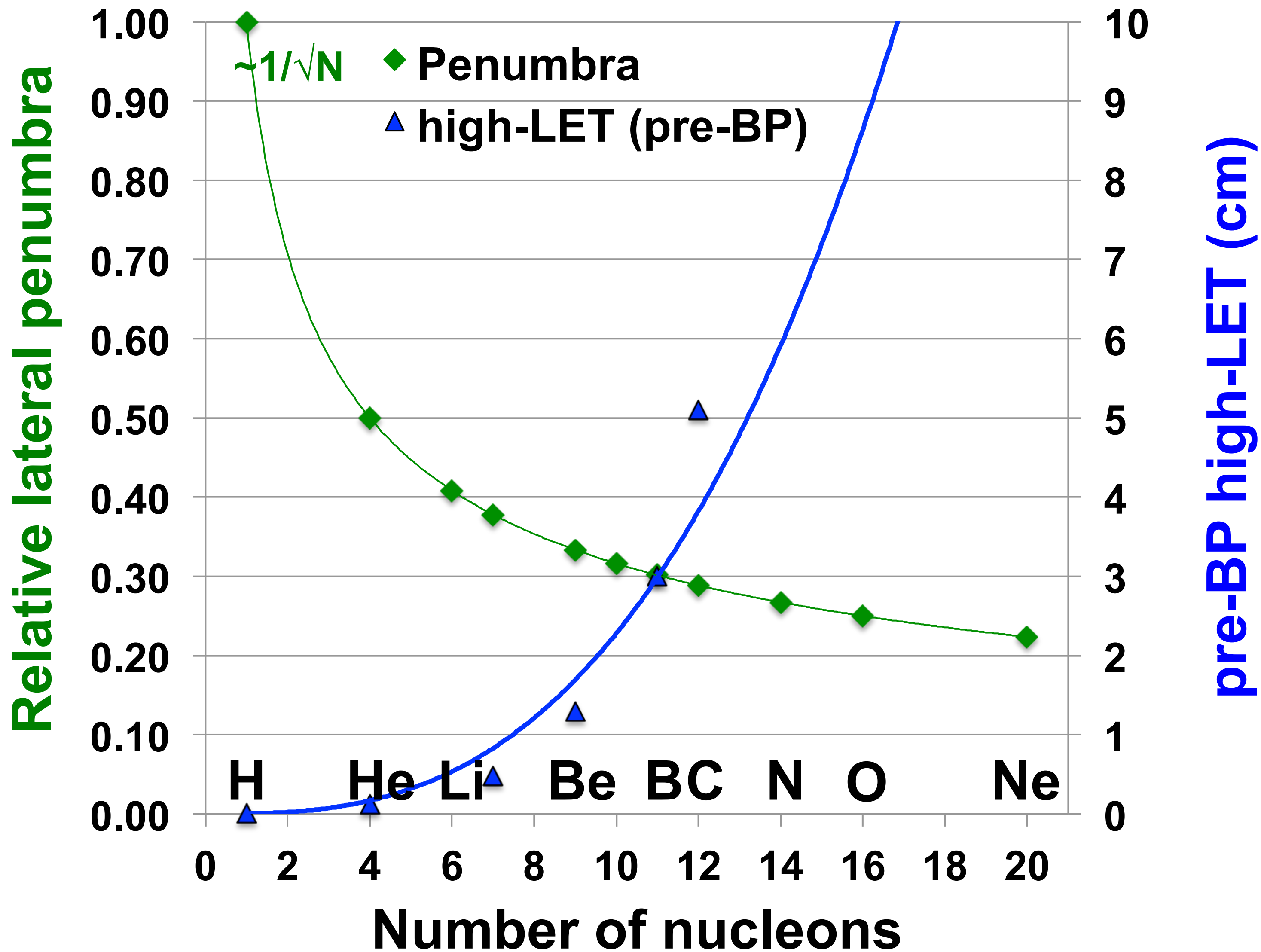

IBT with Ions Heavier than Protons: Performance and Prospects

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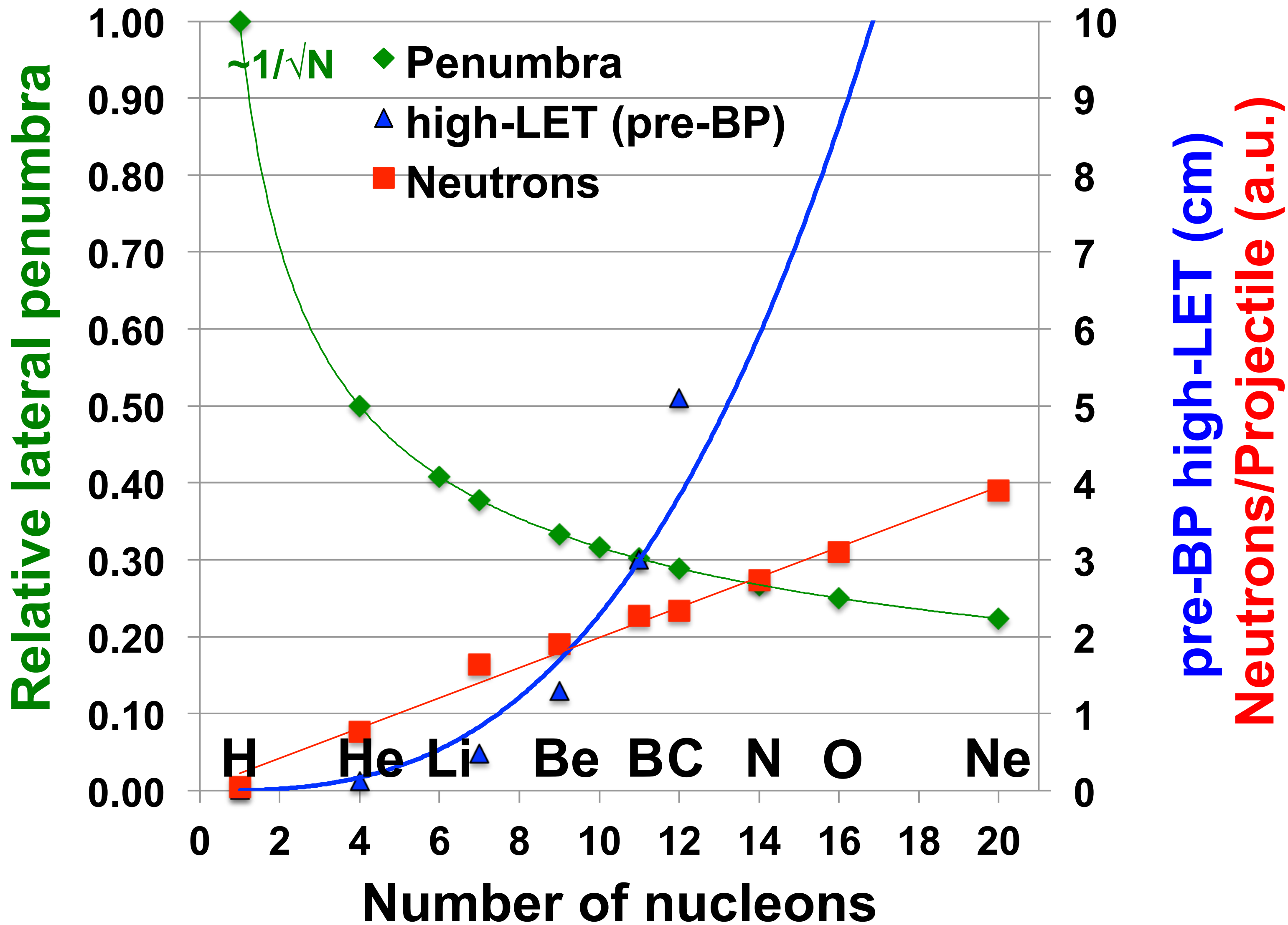
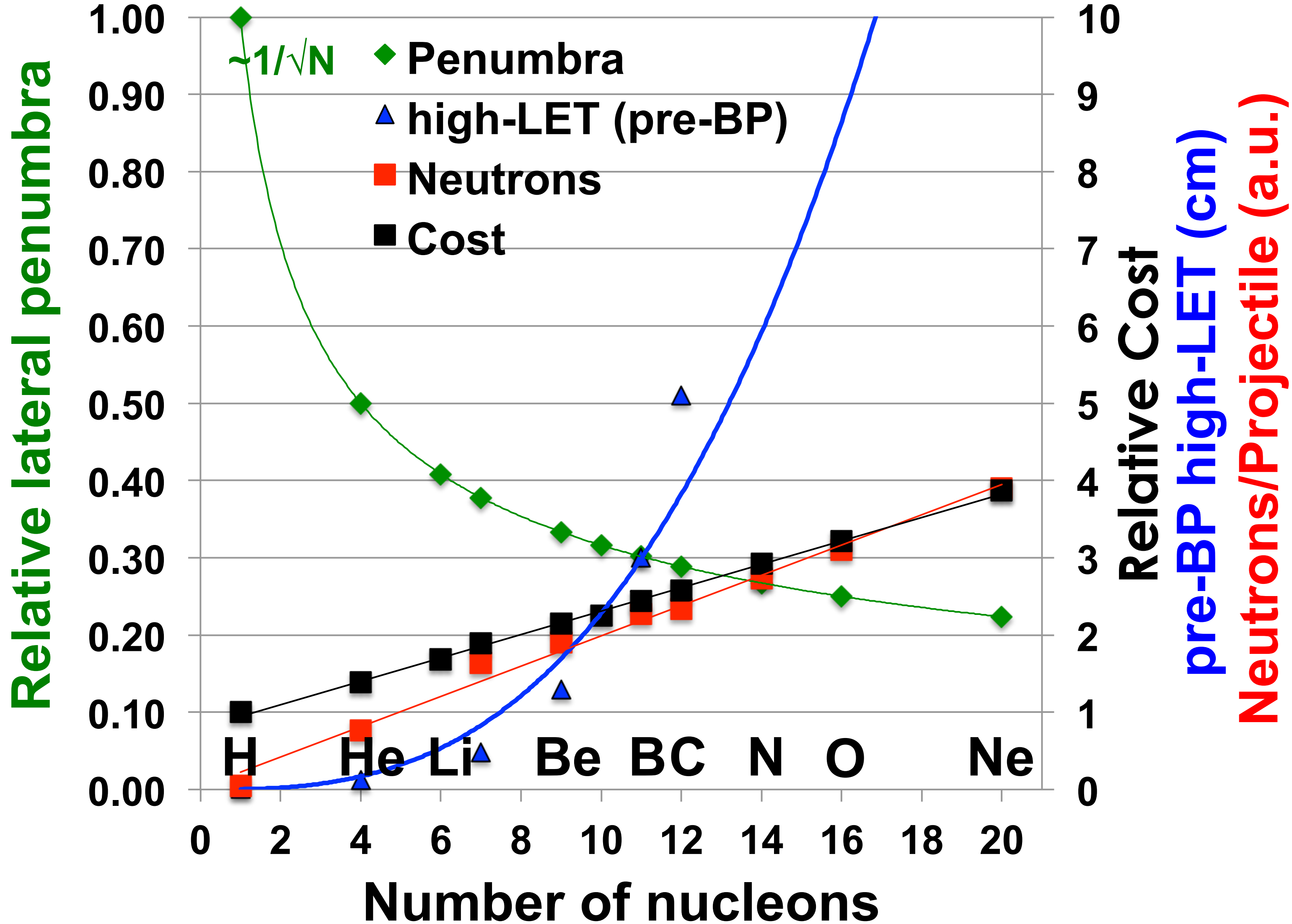


IBT with Ions Heavier than Protons: Performance and Prospects

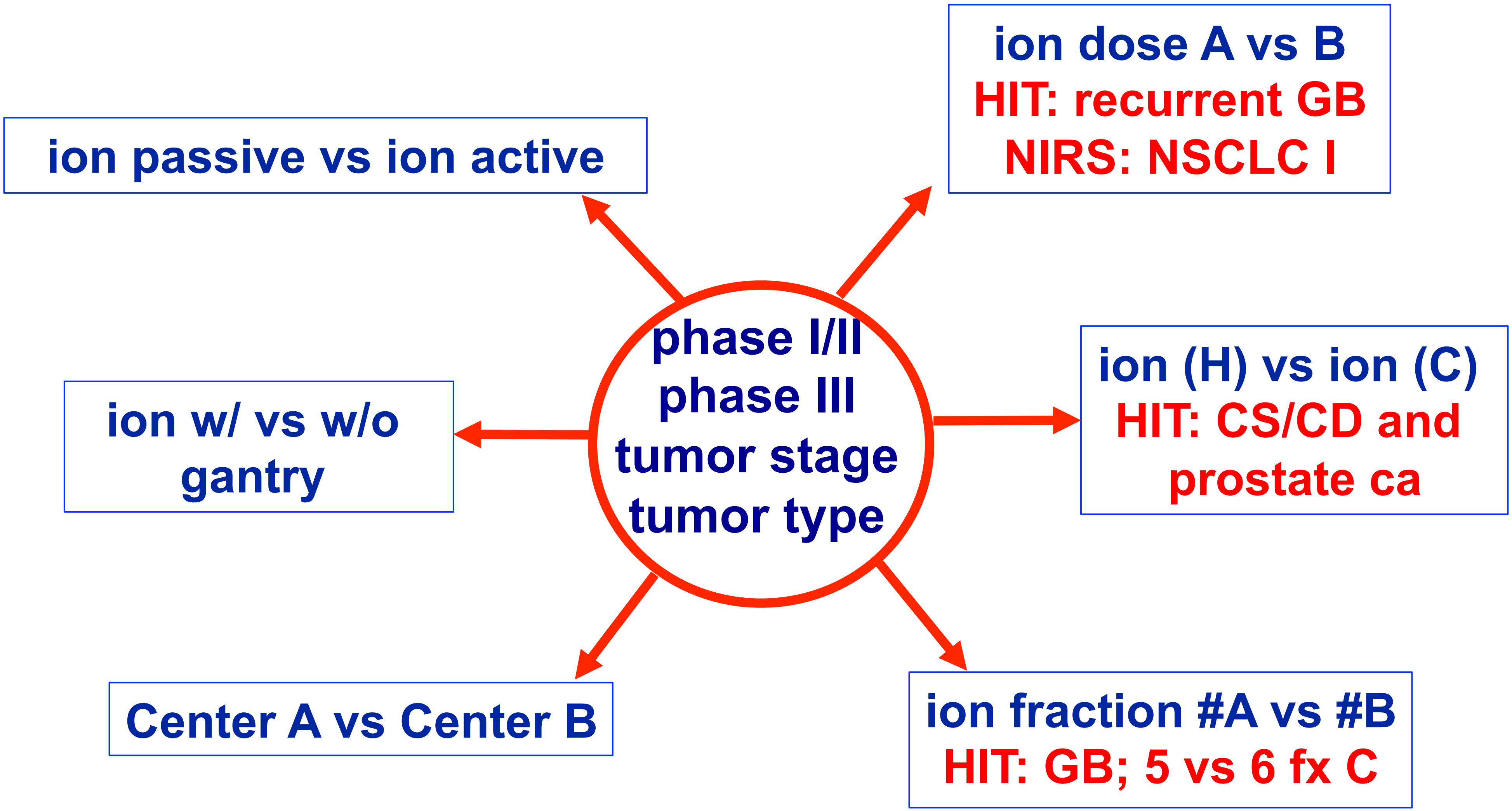
• the optimum ion: cost and properties as function of nucleons •



IBT with Ions Heavier than Protons: Performance and Prospects
• clinical issues •

IBT with Ions Heavier than Protons: Performance and Prospects

• clinical trials I •

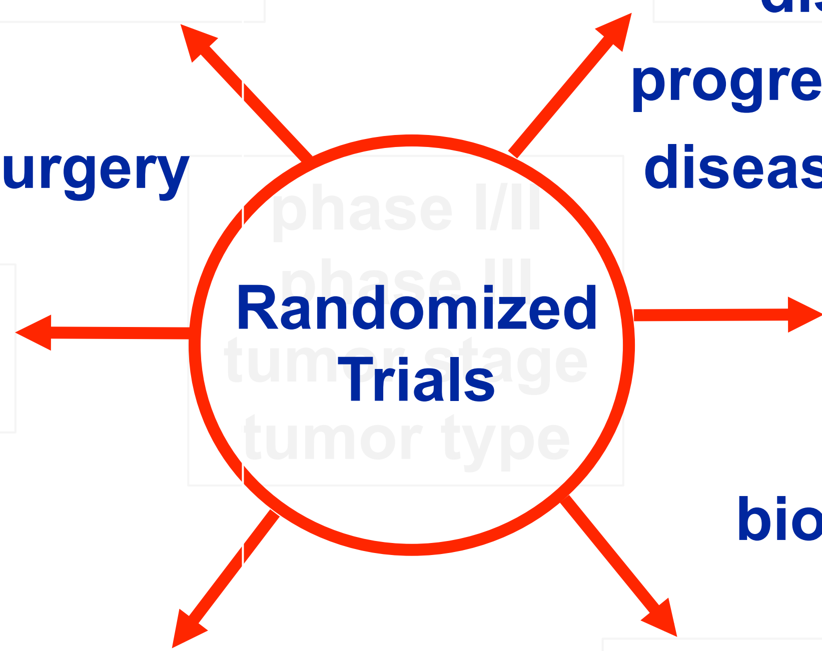


IBT with Ions Heavier than Protons: Performance and Prospects

• clinical trials II •

therapy alternatives

- Intensity-modulated RT
- Image-guided RT
- Stereotactic RT
- Stereotactic radiosurgery
- Gamma knife
- Brachytherapy
- Surgery
- Thermotherapy
- Cryotherapy
- Photodynamic therapy



endpoints

- local control
- disease-free survival
- progression-free survival
- disease-specific survival
- overall survival
- acute toxicity
- late toxicity
- biochemical endpoint
- quality of life
- second malignancy

IBT with Ions Heavier than Protons: Performance and Prospects

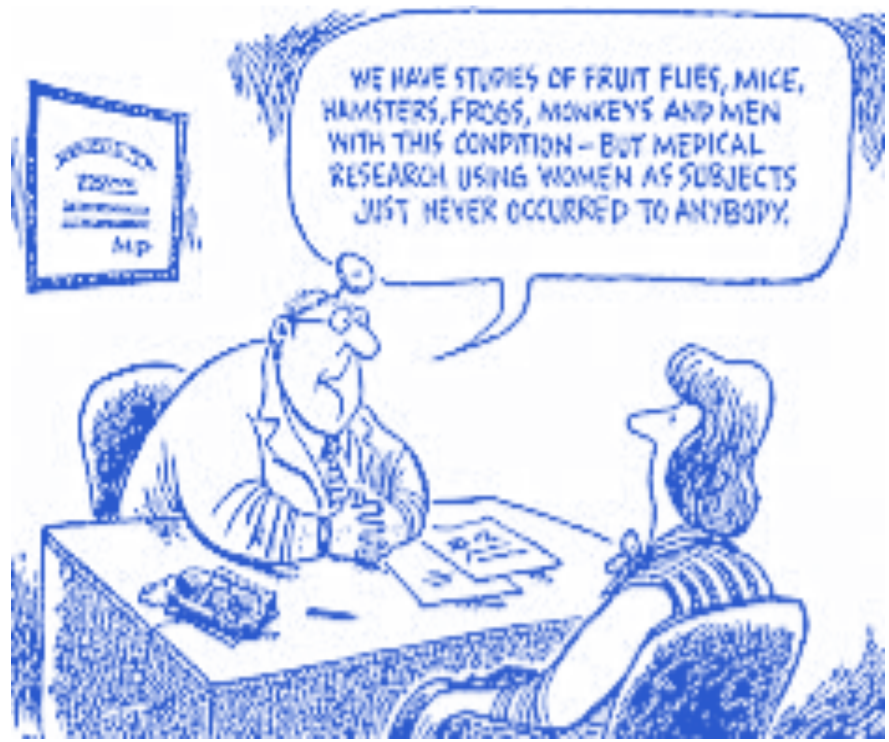
• clinical trials III •

new ion (Li, Be, B)
vs
standard ion (H, C)
or
therapy alternatives

IBT with Ions Heavier than Protons: Performance and Prospects

• clinical trials: challenges •

- duration
- financing
- continuity
- balancing of patient cohorts
- diagnostic accuracy
- diagnostic effort
- uniformity of treatment
- protocol compliance
- drop-outs
- lost to follow-up



• clinical trials: example •

Question: Does IBT reduce the number of second malignancies?

Incidence with standard RT: 0.5% in 15 years
Assumption: 60% reduction

Arm 1		Arm 2
X	modality	ion
5000	patient numbers	5000
25	expected cases	10

• clinical trials: example •

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Incidence with standard RT: 0.5% in 15 years
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Arm 1		Arm 2
X	modality	ion
5000	patient numbers	5000
25	expected cases	10

duration of study ≈ 20 years

IBT with Ions Heavier than Protons: Performance and Prospects

• tasks to improve performance and prospects •

- Reduce weight
- Reduce power consumption
- Reduce neutron activation
- Minimize system downtime
- Save resources

- Optimize patient flow
- Standardize patient reporting
- Optimize fractionation schedules
- Establish standard treatment protocols

IBT with Ions Heavier than Protons: Performance and Prospects

• tasks to improve performance and prospects •

- Reduce weight
- Reduce power consumption
- Reduce neutron activation
- Minimize system downtime
- Save resources

Reduce Cost

- Optimize patient flow
- Standardize patient reporting
- Optimize fractionation schedules
- Establish standard treatment protocols

Optimize Treatment Routine

IBT with Ions Heavier than Protons: Performance and Prospects

• Acknowledgments •

Many Thanks to

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