

# Laser-hybrid Accelerator for Radiobiological Applications (LhARA)

## The LhARA collaboration

P. Allport<sup>1</sup>, A. Aymar<sup>2</sup>, C. J. Baker<sup>3</sup>, J. Bamber<sup>4</sup>, T. Becker<sup>5</sup>, S. Benson<sup>6</sup>, W. Bertsche<sup>7,8</sup>, R. Bingham<sup>9,10</sup>,  
 N. Bliss<sup>11</sup>, E. Boella<sup>12,8</sup>, S. Boogert<sup>13,14</sup>, M. Borghesi<sup>15</sup>, P.N. Burrows<sup>16,17</sup>, A. Carabe<sup>18,19</sup>, M. Charlton<sup>3</sup>,  
 J. Clarke<sup>11</sup>, B. Cox<sup>20</sup>, T.S. Dasalu<sup>21</sup>, M. Dosanjh<sup>22,16</sup>, N.P. Dover<sup>23,21</sup>, S. Eriksson<sup>3</sup>, O.C. Ettlinger<sup>23,21</sup>,  
 5 A. Giaccia<sup>24,25</sup>, S. Gibson<sup>13,14</sup>, R. Gray<sup>9</sup>, S. Green<sup>26</sup>, T. Greenshaw<sup>27</sup>, D. Gujral<sup>28</sup>, H.C. Hall<sup>29</sup>,  
 E.M. Hammond<sup>24</sup>, C. Hardiman<sup>30</sup>, E.J. Harris<sup>4</sup>, L. Holland<sup>31</sup>, A. Howard<sup>23</sup>, W.G. Jones<sup>23,29</sup>,  
 K.J. Kirkby<sup>32,33</sup>, A. Kirkland<sup>31,34</sup>, A. Knoll<sup>35</sup>, T. Kokalova<sup>1</sup>, T.J. Kuo<sup>21</sup>, A. Kurup<sup>21,2</sup>, J.B. Lagrange<sup>2</sup>,  
 H.T. Lau<sup>23</sup>, K.R. Long<sup>23,21,36</sup>, W.G. Luk<sup>37</sup>, A.E. MacIntosh-LaRocque<sup>23</sup>, R. Mamutov<sup>38,39</sup>, T. Masilela<sup>40,41</sup>,  
 M. Maxouti<sup>21,36</sup>, J.M. McGarrigle<sup>23,40</sup>, P. McKenna<sup>9,42</sup>, R. McLauchlan<sup>30,23</sup>, I. McNeish<sup>43</sup>, M. Merchant<sup>32</sup>,  
 10 Z. Najmudin<sup>23,21</sup>, S.R. O'Neill<sup>12</sup>, U. Oelfke<sup>4</sup>, H. Owen<sup>11</sup>, C. Palmer<sup>15</sup>, J.L. Parsons<sup>44,45</sup>, J. Pasternak<sup>21,2</sup>,  
 H. Poptani<sup>46</sup>, J. Pozimski<sup>23,21,2</sup>, Y. Prezado<sup>40,41</sup>, P. Price<sup>43</sup>, T. Price<sup>1</sup>, K.M. Prise<sup>47</sup>, P.P. Rajeev<sup>10</sup>,  
 P. Ratoff<sup>12,8</sup>, C. Rogers<sup>2</sup>, F. Romano<sup>48</sup>, G. Schettino<sup>49,50</sup>, W. Shields<sup>13</sup>, R.A. Smith<sup>23</sup>, D. Spiers<sup>9,42</sup>,  
 R. Taylor<sup>21</sup>, J. Thomason<sup>2</sup>, S. Towe<sup>51</sup>, P. Weightman<sup>27</sup>, C.P. Welsch<sup>27,8</sup>, C. Wheldon<sup>1</sup>, C. Whyte<sup>9,42</sup>,  
 R. Xiao<sup>52</sup>

<sup>1</sup> School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

<sup>2</sup> ISIS Neutron and Muon Source, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK

<sup>3</sup> Department of Physics, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, SA2 8PP

<sup>4</sup> The Institute of Cancer Research, 123 Old Brompton Road, London, SW7 3RP, UK

<sup>5</sup> Maxeler Technologies Limited, 3 Hammersmith Grove, London W6 0ND, UK

<sup>6</sup> Department of Radiology, Netherlands Cancer Institute-Antoni Van Leeuwenhoek, Amsterdam, The Netherlands

<sup>7</sup> Department of Physics and Astronomy, The University of Manchester, Oxford Rd, Manchester, M13 9PL, UK

<sup>8</sup> Cockcroft Institute, Daresbury Laboratory, Sci-Tech Daresbury, Keckwick Ln, Daresbury, Warrington UK

<sup>9</sup> Department of Physics, SUPA, University of Strathclyde, John Anderson Building, 107 Rottenrow East, Glasgow G4 0NG, UK

<sup>10</sup> Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK

<sup>11</sup> STFC Daresbury Laboratory, Daresbury, Cheshire, WA4 4AD, UK

<sup>12</sup> Department of Physics, Lancaster University, Bailrigg, Lancaster LA1 4YW, UK

<sup>13</sup> Department of Physics, Royal Holloway University of London, Egham, Surrey, TW20 0EX, UK

<sup>14</sup> John Adams Institute, Department of Physics, Royal Holloway, University of London, Egham, TW20 0EX, UK

<sup>15</sup> School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast, BT7 1NN, Northern Ireland, UK

<sup>16</sup> John Adams Institute, University of Oxford, Keble Rd, Oxford, OX1 3RH.

<sup>17</sup> Particle Physics, Denys Wilkinson Building, Keble Rd, Oxford, OX1 3RH

<sup>18</sup> Department of Medical Physics, Hampton University Proton Therapy Institute, Hampton, VA 23666

<sup>19</sup> nan

<sup>20</sup> *Dept of Medical Physics and Biomedical Engineering, University College London, WC1E 6BT*  
<sup>21</sup> *John Adams Institute for Accelerator Science, Imperial College London, London SW7 2AZ, UK*  
<sup>22</sup> *DG Unit, CERN, CH-1211 Geneva 23, Switzerland*  
<sup>23</sup> *Department of Physics, Imperial College London, Exhibition Road, London SW7 2AZ, UK*  
<sup>24</sup> *Department of Oncology, University of Oxford, Old Road Campus Research Building, Roosevelt Drive, Oxford, OX3 7DQ, UK*  
<sup>25</sup> *Department of Radiation Oncology, Stanford University, Stanford, CA 94305, USA*  
<sup>26</sup> *Department of Medical Physics, University Hospital Birmingham Foundation NHS Trust, Edgbaston, Birmingham, B15 2TH*  
<sup>27</sup> *Department of Physics, University of Liverpool, Liverpool L69 7ZE, UK*  
<sup>28</sup> *Imperial College NHS Healthcare Trust, The Bays, South Wharf Road, St Mary's Hospital, London W2 1NY, UK*  
<sup>29</sup> *Imperial College London, CRUK PPI group, Charing Cross Hospital, London W6 8RF*  
<sup>30</sup> *Dept. Radiation Physics and Radiobiology, Imperial College Healthcare NHS Trust, London, UK*  
<sup>31</sup> *Rosalind Franklin Institute, Harwell Campus, Didcot, OX11 0QX, UK*  
<sup>32</sup> *Division of Cancer Sciences, Faculty of Biology, Medicine and Health, The University of Manchester, The Christie Proton Therapy Centre, The Christie NHS Foundation Trust, Wimslow Rd, Manchester M20 4BX*  
<sup>33</sup> *Christie NHS Foundation Trust, Wilmslow Rd, Manchester, M20 4BX*  
<sup>34</sup> *Department of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, UK*  
<sup>35</sup> *Department of Aeronautics, Imperial College London, Exhibition Road, London SW7 2AZ, UK*  
<sup>36</sup> *Particle Physics Department, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK*  
<sup>37</sup> *Department of Computing, Imperial College London, Exhibition Road, London SW7 2AZ*  
<sup>38</sup> *Department of Physics, Novosibirsk State University, 2 Pirogov Street, Novosibirsk, 630090, Russian Federation*  
<sup>39</sup> *Budker Institute of Nuclear Physics, 11 Academician Lavrentyev Avenue, Novosibirsk, 630090, Russian Federation*  
<sup>40</sup> *Institut Curie-Orsay Research Center, Bat a Campus d'Orsay, 91400 Orsay, France*  
<sup>41</sup> *Institut Curie, Universit PSL, CNRS UMR3347, Inserm U1021, Signalisation Radiobiologie et Cancer, 91400 Orsay, France*  
<sup>42</sup> *University of Strathclyde and Cockcroft Institute for Accelerator Science, Daresbury*  
<sup>43</sup> *Department of Surgery and Cancer, Imperial College, Hammersmith Hospital London W12 0NN*  
<sup>44</sup> *Department of Molecular and Clinical Cancer Medicine, University of Liverpool, Liverpool, L3 9TA, UK*  
<sup>45</sup> *The Clatterbridge Cancer Centre, Bebington, CH63 4JY, UK*  
<sup>46</sup> *Institute of Systems, Molecular and Integrative Biology, University of Liverpool, Biosciences Building, Crown Street, Liverpool L69 7BE*  
<sup>47</sup> *Patrick G Johnston Centre for Cancer Research, Queens University Belfast, 97 Lisburn Road, Belfast, BT9 7AE*  
<sup>48</sup> *INFN Catania, Via Santa Sofia, 64 - 95123 Catania - Italy*  
<sup>49</sup> *Department of Physics, University of Surrey, 388 Stag Hill, Guildford, GU2 7XH, UK*  
<sup>50</sup> *National Physical Laboratory, Hampton Road, Teddington, TW11 0LW, UK*  
<sup>51</sup> *Leo Cancer Care, Broadview, Windmill Hill, Hailsham, East Sussex, BN27 4RY, UK*  
<sup>52</sup> *Corerain Technologies, 14F, Changfu Jinmao Building (CFC), Trade-free Zone, Futian District, Shenzhen, Guangdong, China*