

# Laser-hybrid Accelerator for Radiobiological Applications (LhARA)

## The LhARA collaboration

H. Ahmed<sup>1</sup>, P. Allport<sup>2</sup>, R. Amos<sup>3</sup>, C. J. Baker<sup>4</sup>, J. Bamber<sup>5</sup>, T. Becker<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>7,8</sup>, M. Borghesi<sup>13</sup>, C. Burne<sup>2</sup>, P.N. Burrows<sup>14,15</sup>, M. Charlton<sup>4</sup>,  
J. Clarke<sup>16</sup>, B. Cox<sup>3</sup>, T.S. Dascalu<sup>12,8</sup>, M. Dosanjh<sup>14,15</sup>, N.P. Dover<sup>17,18</sup>, S. Eriksson<sup>4</sup>, O.C. Ettlinger<sup>17,18</sup>, A.  
5 Fernandez-Rodriguez<sup>19,20</sup>, A. Giaccia<sup>21,22</sup>, S. Gibson<sup>23,24</sup>, R. Gray<sup>9,8</sup>, S. Green<sup>25</sup>, T. Greenshaw<sup>26</sup>,  
D. Gujral<sup>27</sup>, H.C. Hall<sup>28</sup>, E.M. Hammond<sup>21</sup>, C. Hardiman<sup>29</sup>, E.J. Harris<sup>5</sup>, P.R. Hobson<sup>30</sup>, L. Holland<sup>31</sup>,  
A. Howard<sup>17</sup>, R.P. Hugtenburg<sup>32</sup>, A. Isaac<sup>4</sup>, S. Jamison<sup>12</sup>, W.G. Jones<sup>17,28</sup>, K.J. Kirkby<sup>33,34</sup>, A. Kirkland<sup>31,35</sup>,  
A. Knoll<sup>36</sup>, N. Kumar<sup>37,8</sup>, T.J. Kuo<sup>17,18</sup>, A. Kurup<sup>17,18</sup>, J.B. Lagrange<sup>38</sup>, H.T. Lau<sup>17</sup>, K.R. Long<sup>17,18</sup>,  
W.G. Luk<sup>39</sup>, A.E. MacIntosh-LaRocque<sup>17,18</sup>, T. Masilela<sup>19</sup>, M. Maxouti<sup>17,18</sup>, J.M. McGarrigle<sup>17,19</sup>,  
10 A. McIlvenny<sup>40</sup>, P. McKenna<sup>9,8</sup>, R. McLauchlan<sup>29,41</sup>, I. McNeish<sup>42</sup>, M. Merchant<sup>33</sup>, Z. Najmudin<sup>17,18</sup>,  
O. Nicholas<sup>4</sup>, S.R. O'Neill<sup>12,8</sup>, L. Obst-Huebl<sup>40</sup>, U. Oelfke<sup>5</sup>, H. Owen<sup>16</sup>, C. Palmer<sup>13</sup>, J.L. Parsons<sup>43</sup>,  
J. Pasternak<sup>17,18</sup>, M. Patel<sup>37,8</sup>, R. Pattathil<sup>1</sup>, M. Pereira<sup>23,24</sup>, H. Poptani<sup>44</sup>, F. Pouzoulet<sup>19</sup>, J. Pozimski<sup>17,18</sup>,  
J. Prado Pico<sup>45</sup>, Y. Prezado<sup>19,20,46</sup>, P. Price<sup>42</sup>, T. Price<sup>2</sup>, K.M. Prise<sup>47</sup>, P. Ratoff<sup>12,8</sup>, R. Razak<sup>17,18</sup>,  
C.T. Rogers<sup>38</sup>, F. Romano<sup>48</sup>, P. Ruksasakchai<sup>4</sup>, G. Schettino<sup>49,50</sup>, W. Shields<sup>23,24</sup>, B. Smart<sup>51</sup>, R.A. Smith<sup>17</sup>,  
15 A. Snijders<sup>40</sup>, D. Spiers<sup>9,8</sup>, R. Taylor<sup>17,18</sup>, J.W.G. Thomason<sup>38</sup>, S. Towe<sup>52</sup>, M. Turner<sup>45</sup>, P. Underwood<sup>52</sup>,  
A. Vikhoreva<sup>11</sup>, P. Weightman<sup>26</sup>, C.P. Welsch<sup>37,8</sup>, C. Wheldon<sup>2</sup>, C. Whyte<sup>9,8</sup>, R. Wilson<sup>9</sup>, R. Xiao<sup>53</sup>

1 Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK

2 School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK

3 Dept of Medical Physics and Biomedical Engineering, University College London, WC1E 6BT

4 Department of Physics, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, SA2 8PP

5 The Institute of Cancer Research, 123 Old Brompton Road, London, SW7 3RP, UK

6 Maxeler Technologies Limited, 3 Hammersmith Grove, London W6 0ND, UK

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

8 Cockcroft Institute for Accelerator Science, Keckwick Ln, Daresbury, Warrington WA4 4AD

9 Department of Physics, SUPA, University of Strathclyde, Glasgow G4 0NG, UK

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

11 Technology Department, STFC Daresbury Laboratory, Daresbury, Cheshire, WA4 4AD, UK

12 Department of Physics, Lancaster University, Bailrigg, Lancaster LA1 4YW, UK

13 School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast, BT7 1NN, Northern Ireland, UK

- 14 Particle Physics, Denys Wilkinson Building, Keble Rd, Oxford, OX1 3RH
- 15 The John Adams Institute for Accelerator Science,, University of Oxford, Keble Rd, Oxford, OX1 3RH.
- 16 Accelerator Science and Technology Centre, STFC Daresbury Laboratory, Daresbury, Cheshire, WA4 4AD, UK
- 17 Department of Physics, Imperial College London, Exhibition Road, London SW7 2AZ, UK
- 18 The John Adams Institute for Accelerator Science, Department of Physics, Imperial College London, Exhibition Road, London SW7 2AZ, UK
- 19 Institut Curie-Orsay Research Center, Bat a Campus d'Orsay, 91400 Orsay, France
- 20 Institut Curie, Universit PSL, CNRS UMR3347, Inserm U1021, Signalisation Radiobiologie et Cancer, 91400 Orsay, France
- 21 Department of Oncology, University of Oxford, Old Road Campus Research Building, Roosevelt Drive, Oxford, OX3 7DQ, UK
- 22 Department of Radiation Oncology, Stanford University, Stanford, CA 94305, USA
- 23 Department of Physics, Royal Holloway University of London, Egham, Surrey, TW20 0EX, UK
- 24 The John Adams Institute for Accelerator Science, Royal Holloway University of London
- 25 Department of Medical Physics, University Hospital Birmingham Foundation NHS Trust, Edgbaston, Birmingham, B15 2TH
- 26 Department of Physics, University of Liverpool, Liverpool L69 7ZE, UK
- 27 Imperial College NHS Healthcare Trust, Department of Clinical Oncology, Charing Cross Hospital, London W6 8RF, UK
- 28 CRUK PPI group, Charing Cross Hospital, London W6 8RF
- 29 Dept. Radiation Physics and Radiobiology, Imperial College Healthcare NHS Trust, London, UK
- 30 School of Physical and Chemical Sciences, Queen Mary University of London, Mile End, London E1 4NS, UK
- 31 Rosalind Franklin Institute, Harwell Campus, Didcot, OX11 0QX, UK
- 32 Department of Biomedical Sciences, Faculty of Science and Engineering, Swansea University, Singleton Park, Swansea, SA2 8PP
- 33 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
- 34 Christie NHS Foundation Trust, Wilmslow Rd, Manchester, M20 4BX
- 35 Department of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, UK
- 36 Department of Aeronautics, Imperial College London, Exhibition Road, London SW7 2AZ, UK
- 37 Department of Physics, University of Liverpool, Liverpool L69 7ZE, UK
- 38 ISIS Neutron and Muon Source, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK
- 39 Department of Computing, Imperial College London, Exhibition Road, London SW7 2AZ
- 40 Berkeley, USA
- 41 Department of Physics, Imperial College London, Exhibition Road, London SW7 2AZ, UK
- 42 Department of Surgery and Cancer, Imperial College, Hammersmith Hospital London W12 0NN
- 43 Department of Cancer and Genomic Sciences, College of Medicine and Health, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK
- 44 Institute of Systems, Molecular and Integrative Biology, University of Liverpool, Biosciences Building, Crown Street, Liverpool L69 7BE
- 45 DG Unit, CERN, CH-1211 Geneva 23, Switzerland
- 46 University of Santiago de Compostela, Center for Research in Molecular Medicine and Chronic diseases, 15782, Santiago de Compostela, Spain
- 47 Patrick G Johnston Centre for Cancer Research, Queens University Belfast, 97 Lisburn Road, Belfast, BT9 7AE
- 48 INFN Catania, Via Santa Sofia,64 - 95123 Catania - Italy
- 49 Department of Physics, University of Surrey, 388 Stag Hill, Guilford, GU2 7XH, UK
- 50 National Physical Laboratory, Hampton Road, Teddington, TW11 0LW, UK
- 51 Particle Physics Department, STFC Rutherford Appleton Laboratory, Harwell Oxford, Didcot OX11 0QX, UK
- 52 Leo Cancer Care, Broadview, Windmill Hill, Hailsham, East Sussex, BN27 4RY, UK
- 53 Corerain Technologies, 14F, Changfu Jinmao Building (CFC), Trade-free Zone, Futian District, Shenzhen, Guangdong, China