Pyg4ometry & BDSIM

William Shields

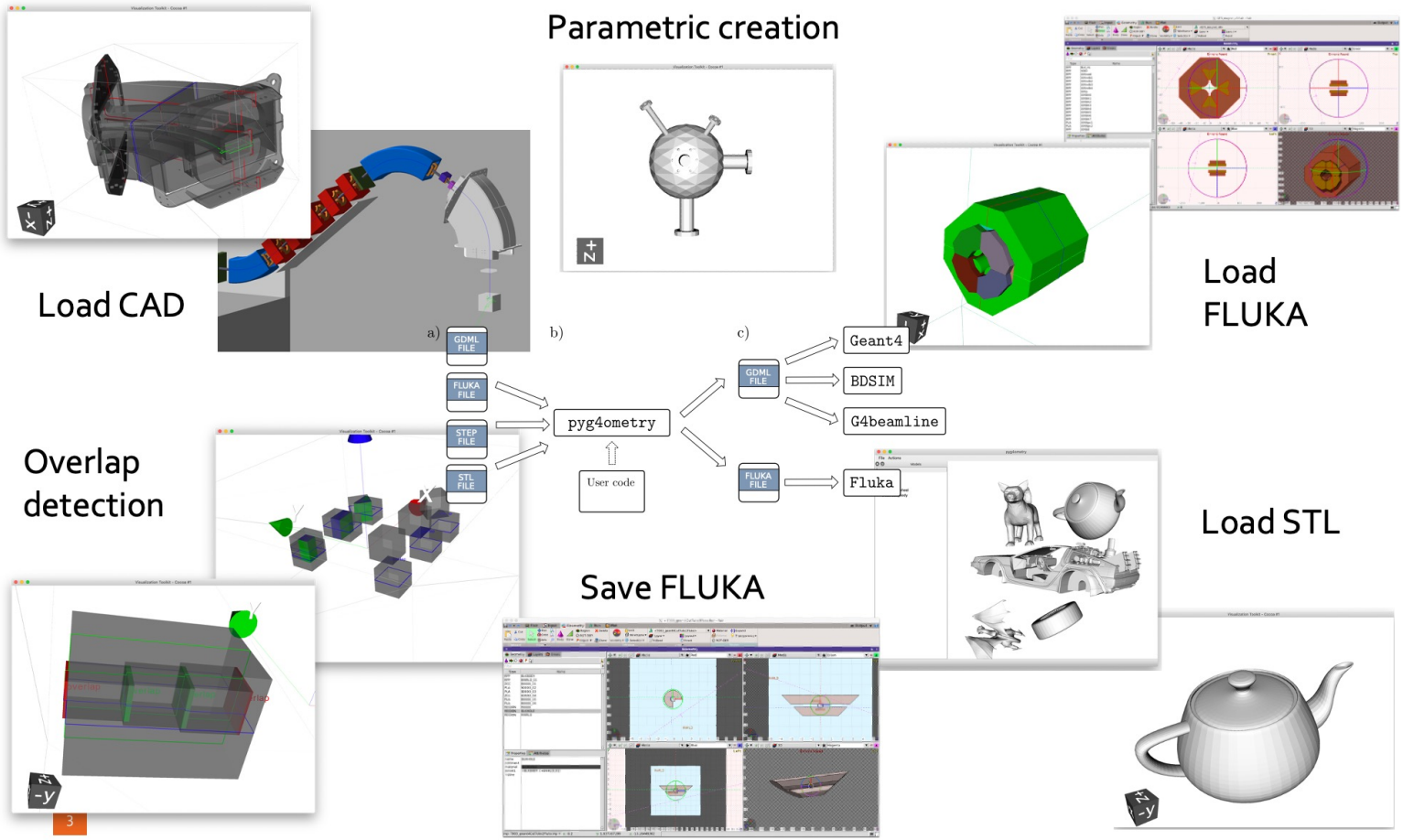
(william.shields@rhul.ac.uk)

WP6 Meeting

27th October 2022

Introduction

- Python tool for loading, manipulating, and converting geometry for Geant4 & Fluka
- Develop a rapid workflow to modify geometry in a reproducible way
- Geant4 Collaboration talk: https://indico.cern.ch/event/1156193/contributions/5063552/

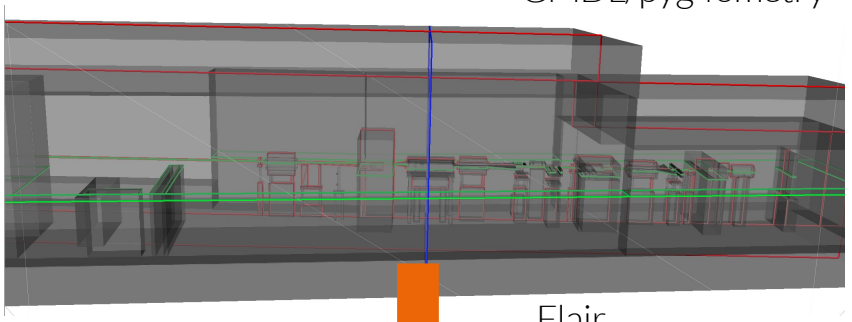


LUXE Workflow

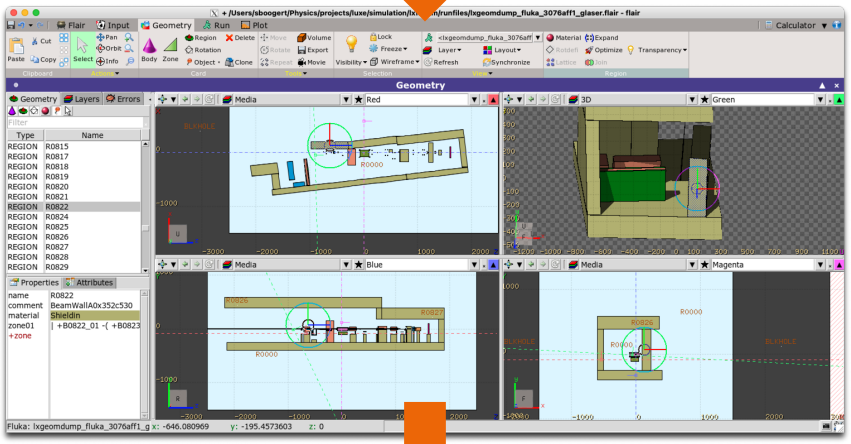
1. Run Ixsim and generate GDML geometry
2. Convert Ixsim GDML geometry to FLUKA
3. Augment with control cards (BEAM, BEAMPOS…etc)
4. Run FLUKA jobs
5. Merge output from all jobs (utilities provided by Fluka)
6. Plotting in matplotlib and/or VTK (pyvista)

- Original conversion done by 1st year PhD student in hours

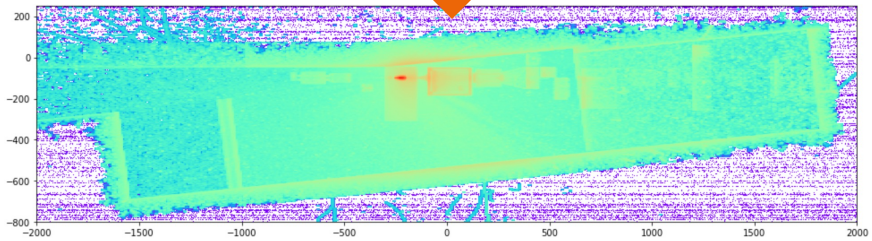
GMDL/pyg4ometry



Flair



Fluka output

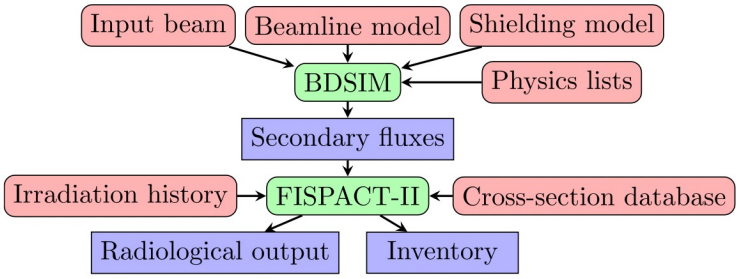


IBA Example

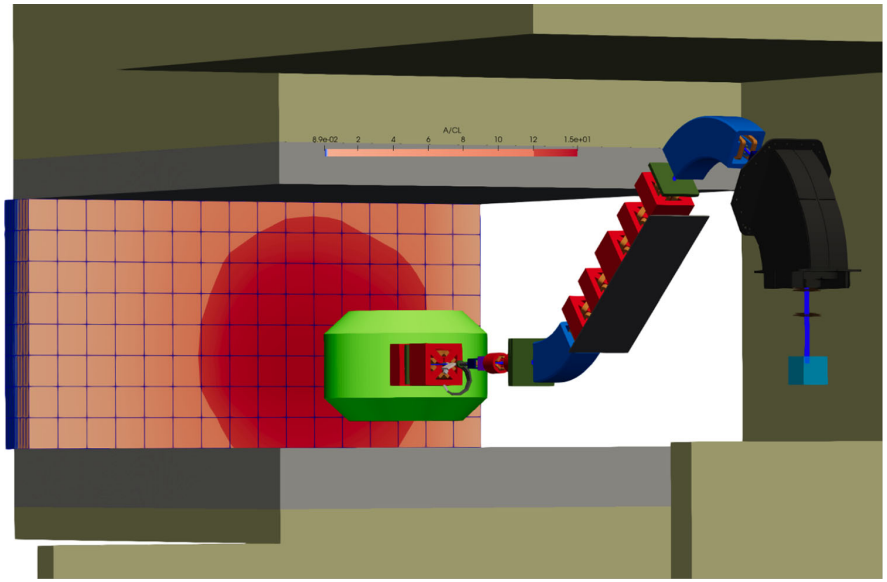
- IBA Protus One proton therapy system (ULB/IBA/RHUL)
  - https://doi.org/10.1140/epjp/s13360-022-02960-9

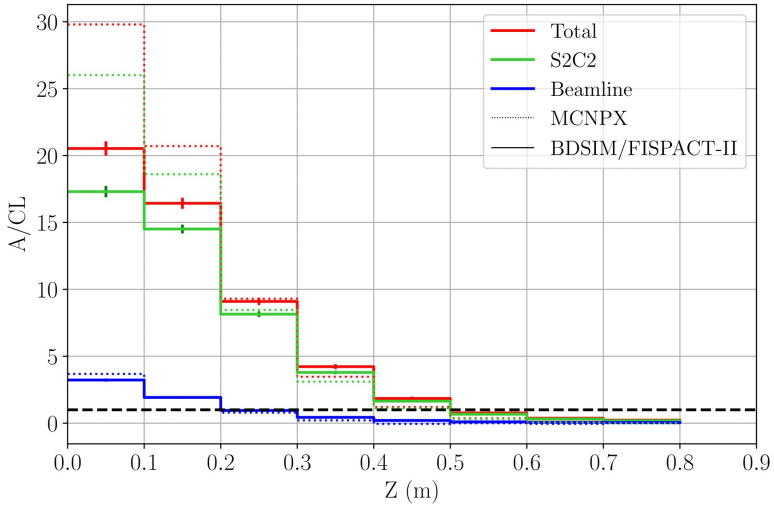
- Shielding activation studies
  - Clearance level & long-lived nuclide concentrations
  - Shielding material comparison (regular & low activation concrete)

- BDSIM FISPACT-II workflow
  - 4D scoring of secondary particle differential fluences



- Non-negligible discrepancy between BDSIM/FISPACT & MNCPX
  - Investigation ongoing (not losses)
- FLUKA / MCNP for LhARA shielding





BDSIM Survey

survey — less -S ccapv43.dat — 204×60

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### BDSIM output - created Thu Mar 12 16:32:39 2020
Type            Name                    SStart[m]   SMid[m]     SEnd[m]     ChordLength[m] ArcLength[m] X[m]        Y[m]        Z[m]        Phi[rad]    Theta[rad]
drift           o0                      0.000000    0.050000    0.100000    0.100000       0.100000     0.000000    0.000000    0.050000    0.000000    0.000000
drift           o1                      0.100000    0.175000    0.250000    0.150000       0.150000     0.000000    0.000000    0.175000    0.000000    0.000000
                gl1_fringe_in           0.250000    0.250000    0.250000    0.000000       0.000000     0.000000    0.000000    0.250000    0.000000    0.000000
solenoid        gl1_centre              0.250000    0.678500    1.107000    0.857000       0.857000     0.000000    0.000000    0.678500    0.000000    0.000000
                gl1_fringe_out          1.107000    1.107000    1.107000    0.000000       0.000000     0.000000    0.000000    1.107000    0.000000    0.000000
drift           o2                      1.107000    1.182000    1.257000    0.150000       0.150000     0.000000    0.000000    1.182000    0.000000    0.000000
drift           o2a                     1.257000    1.332000    1.407000    0.150000       0.150000     0.000000    0.000000    1.332000    0.000000    0.000000
                gl2_fringe_in           1.407000    1.407000    1.407000    0.000000       0.000000     0.000000    0.000000    1.407000    0.000000    0.000000
solenoid        gl2_centre              1.407000    1.835500    2.264000    0.857000       0.857000     0.000000    0.000000    1.835500    0.000000    0.000000
                gl2_fringe_out          2.264000    2.264000    2.264000    0.000000       0.000000     0.000000    0.000000    2.264000    0.000000    0.000000
drift           o3                      2.264000    2.339000    2.414000    0.150000       0.150000     0.000000    0.000000    2.339000    0.000000    0.000000
cavity_pillbox  s1rf1                   2.414000    2.664000    2.914000    0.500000       0.500000     0.000000    0.000000    2.664000    0.000000    0.000000
drift           o5                      2.914000    2.989000    3.064000    0.150000       0.150000     0.000000    0.000000    2.989000    0.000000    0.000000
                gl3_fringe_in           3.064000    3.064000    3.064000    0.000000       0.000000     0.000000    0.000000    3.064000    0.000000    0.000000
solenoid        gl3_centre              3.064000    3.492500    3.921000    0.857000       0.857000     0.000000    0.000000    3.492500    0.000000    0.000000
                gl3_fringe_out          3.921000    3.921000    3.921000    0.000000       0.000000     0.000000    0.000000    3.921000    0.000000    0.000000
drift           o6                      3.921000    3.996000    4.071000    0.150000       0.150000     0.000000    0.000000    3.996000    0.000000    0.000000
drift           o7                      4.071000    4.996000    5.921000    1.850000       1.850000     0.000000    0.000000    4.996000    0.000000    0.000000
octupole        oct1                    5.921000    5.971000    6.021000    0.100000       0.100000     0.000000    0.000000    5.971000    0.000000    0.000000
drift           o7a                     6.021000    6.071000    6.121000    0.100000       0.100000     0.000000    0.000000    6.071000    0.000000    0.000000
cavity_pillbox  s1rf2                   6.121000    6.371000    6.621000    0.500000       0.500000     0.000000    0.000000    6.371000    0.000000    0.000000
drift           o8                      6.621000    6.696000    6.771000    0.150000       0.150000     0.000000    0.000000    6.696000    0.000000    0.000000
                gl4_fringe_in           6.771000    6.771000    6.771000    0.000000       0.000000     0.000000    0.000000    6.771000    0.000000    0.000000
solenoid        gl4_centre              6.771000    7.199500    7.628000    0.857000       0.857000     0.000000    0.000000    7.199500    0.000000    0.000000
                gl4_fringe_out          7.628000    7.628000    7.628000    0.000000       0.000000     0.000000    0.000000    7.628000    0.000000    0.000000
drift           o9                      7.628000    7.703000    7.778000    0.150000       0.150000     0.000000    0.000000    7.703000    0.000000    0.000000
drift           o10                     7.778000    7.828000    7.878000    0.100000       0.100000     0.000000    0.000000    7.828000    0.000000    0.000000
drift           o11                     7.878000    7.953000    8.028000    0.150000       0.150000     0.000000    0.000000    7.953000    0.000000    0.000000
                gl5_fringe_in           8.028000    8.028000    8.028000    0.000000       0.000000     0.000000    0.000000    8.028000    0.000000    0.000000
solenoid        gl5_centre              8.028000    8.456500    8.885000    0.857000       0.857000     0.000000    0.000000    8.456500    0.000000    0.000000
                gl5_fringe_out          8.885000    8.885000    8.885000    0.000000       0.000000     0.000000    0.000000    8.885000    0.000000    0.000000
drift           o12                     8.885000    8.960000    9.035000    0.150000       0.150000     0.000000    0.000000    8.960000    0.000000    0.000000
octupole        oct2                    9.035000    9.085000    9.135000    0.100000       0.100000     0.000000    0.000000    9.085000    0.000000    0.000000
drift           o12ea                   9.135000    9.285000    9.435000    0.300000       0.300000     0.000000    0.000000    9.285000    0.000000    0.000000
sbend           s1esb1_even_ang         9.435000    9.461923    9.488846    0.053844       0.053846     0.000453    0.000000    9.461918    -1.570796   0.016827
sbend           s1esb1_even_ang         9.488846    9.515769    9.542692    0.053844       0.053846     0.002264    0.000000    9.515723    -1.570796   0.050481
sbend           s1esb1_even_ang         9.542692    9.569615    9.596538    0.053844       0.053846     0.005885    0.000000    9.569437    -1.570796   0.084135
sbend           s1esb1_even_ang         9.596538    9.623461    9.650384    0.053844       0.053846     0.011311    0.000000    9.622999    -1.570796   0.117788
sbend           s1esb1_even_ang         9.650384    9.677307    9.704230    0.053844       0.053846     0.018537    0.000000    9.676348    -1.570796   0.151442
sbend           s1esb1_even_ang         9.704230    9.731153    9.758077    0.053844       0.053846     0.027553    0.000000    9.729424    -1.570796   0.185096
sbend           s1esb1_even_ang         9.758077    9.785000    9.811923    0.053844       0.053846     0.038350    0.000000    9.782166    -1.570796   0.218750
sbend           s1esb1_even_ang         9.811923    9.838846    9.865769    0.053844       0.053846     0.050915    0.000000    9.834515    -1.570796   0.252404
sbend           s1esb1_even_ang         9.865769    9.892692    9.919615    0.053844       0.053846     0.065235    0.000000    9.886412    -1.570796   0.286058
sbend           s1esb1_even_ang         9.919615    9.946538    9.973461    0.053844       0.053846     0.081293    0.000000    9.937797    -1.570796   0.319712
sbend           s1esb1_even_ang         9.973461    10.000384   10.027307   0.053844       0.053846     0.099071    0.000000    9.988613    -1.570796   0.353365
sbend           s1esb1_even_ang         10.027307   10.054230   10.081153   0.053844       0.053846     0.118549    0.000000    10.038802   -1.570796   0.387019
sbend           s1esb1_even_ang         10.081153   10.108077   10.135000   0.053844       0.053846     0.139704    0.000000    10.088307   -1.570796   0.420673
drift           s1edr1                  10.135000   10.635000   11.135000   1.000000       1.000000     0.362536    0.000000    10.565789   -1.570796   0.437500
quadrupole      s1eqf1                  11.135000   11.185000   11.235000   0.100000       0.100000     0.595558    0.000000    11.063986   -1.570796   0.437500
drift           s1edr2                  11.235000   11.535000   11.835000   0.600000       0.600000     0.743845    0.000000    11.381021   -1.570796   0.437500
quadrupole      s1eqf2                  11.835000   11.885000   11.935000   0.100000       0.100000     0.892132    0.000000    11.698056   -1.570796   0.437500
drift           s1edr3                  11.935000   12.035000   12.135000   0.200000       0.200000     0.955683    0.000000    11.833928   -1.570796   0.437500
quadrupole      s1eqd1                  12.135000   12.185000   12.235000   0.100000       0.100000     1.019234    0.000000    11.969800   -1.570796   0.437500
drift           s1edr4                  12.235000   12.335000   12.435000   0.200000       0.200000     1.082786    0.000000    12.105672   -1.570796   0.437500
sbend           s1esb2_even_ang         12.435000   12.458333   12.481666   0.046663       0.046667     1.135487    0.000000    12.217172   -1.570796   0.458833
sbend           s1esb2_even_ang         12.481666   12.505000   12.528333   0.046663       0.046667     1.157037    0.000000    12.258549   -1.570796   0.501500
sbend           s1esb2_even_ang         12.528333   12.551666   12.575000   0.046663       0.046667     1.180333    0.000000    12.298969   -1.570796   0.544167
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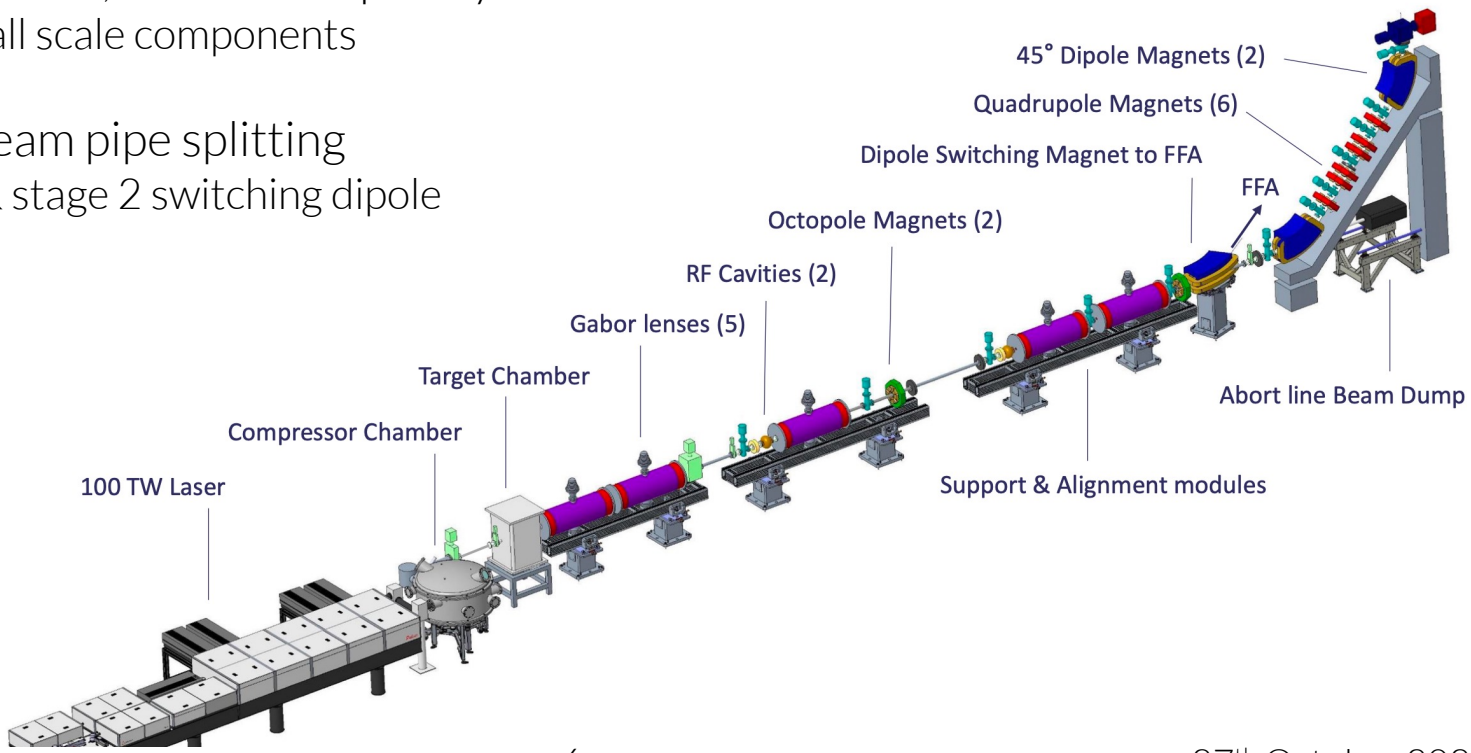
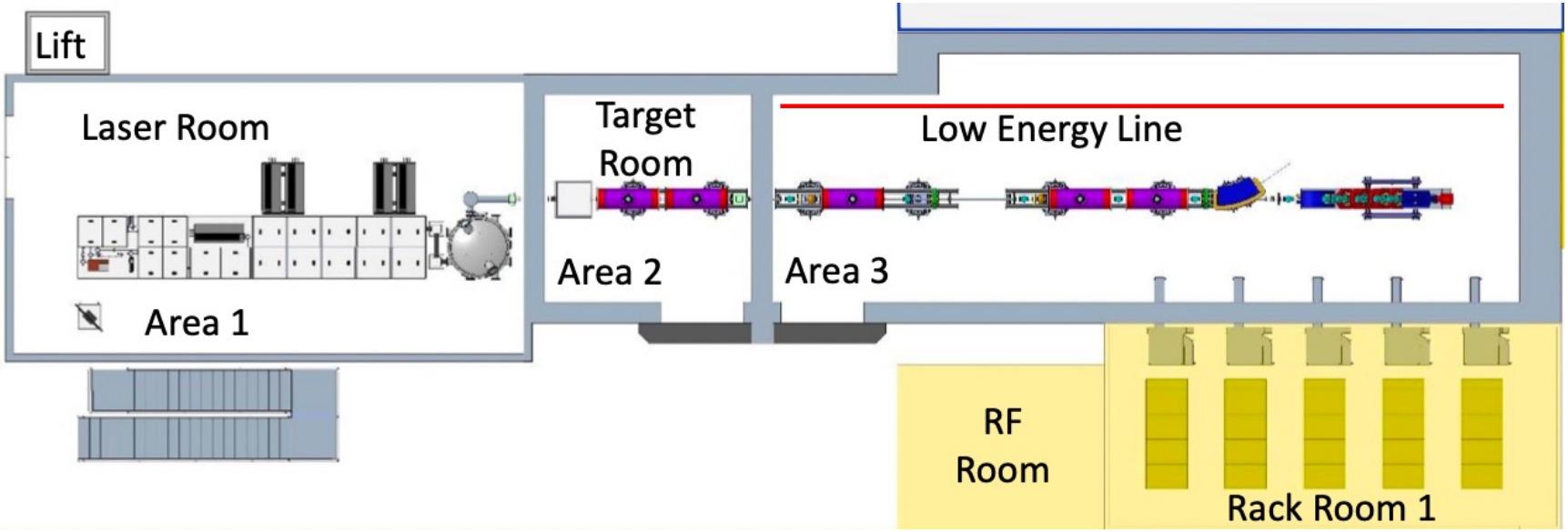
Geant4 Conversion

- Possible to convert whole stage 1 CAD into GDML
- Accurate loss & energy deposition estimation
- Degenerate EM component geometries
  - Attach fields & scale
- Inspect CAD model, reduce complexity
  - Remove small scale components
- Problematic beam pipe splitting
  - Abort line & stage 2 switching dipole



Stage 1 Shielding Conversion

- Shielding conversion possible
  - Significantly simpler
- Inspect, reduce complexity
- Include as Geant4 world volume
- Identify shielding calculation workflow
  - Sample incident flux



Summary

- Opportunity for pyg4ometry incorporation into CAD & shielding workflow

- CAD -> Geant4 / FLUKA conversion
  - Model needed for testing

- Establish feasibility

- Paper : https://doi.org/10.1016/j.cpc.2021.108228

- Manual : http://www.pp.rhul.ac.uk/bdsim/pyg4ometry/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UNIVERSITY
OF LONDON
LhARA
Laser-hybrid Accelerator for
Radiobiological Applications
JAI
John Adams Institute
for Accelerator Science
Thank you
William Shields
william.shields@rhul.ac.uk