

DEVELOPMENT OF THE GEANT4 VALIDATION WEB INTERFACE FOR END USERS

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 - A. PDS Team
 - 1. Krzysztof Genser
 - 2. Tomasz Golan
 - 3. Robert Hatcher
 - 4. Adam Para
 - 5. Gabriel Perdue
 - 6. Hans-Joachim Wenzel
 - 7. Julia Yarba
- VIII. References

INTRODUCTION: GEANT4 BACKGROUND

- Models the interaction of particles with matter
- Wide breadth of scope
 - Education
 - Medicine
 - Space and Radiation
 - High Energy Physics
- Ever evolving

EVOLUTION AND IMPROVEMENT

- All aspects in scope of critical importance
- Constantly Improving
 - One major release per year
 - Several minor releases per year (average about 3)
- **Validation Library**
 - Keep track of improvements between releases
 - Data base which houses experimental and simulation data
 - Graphs stored as image blobs – becoming cumbersome
 - **Currently working to present data dynamically at the user's request**

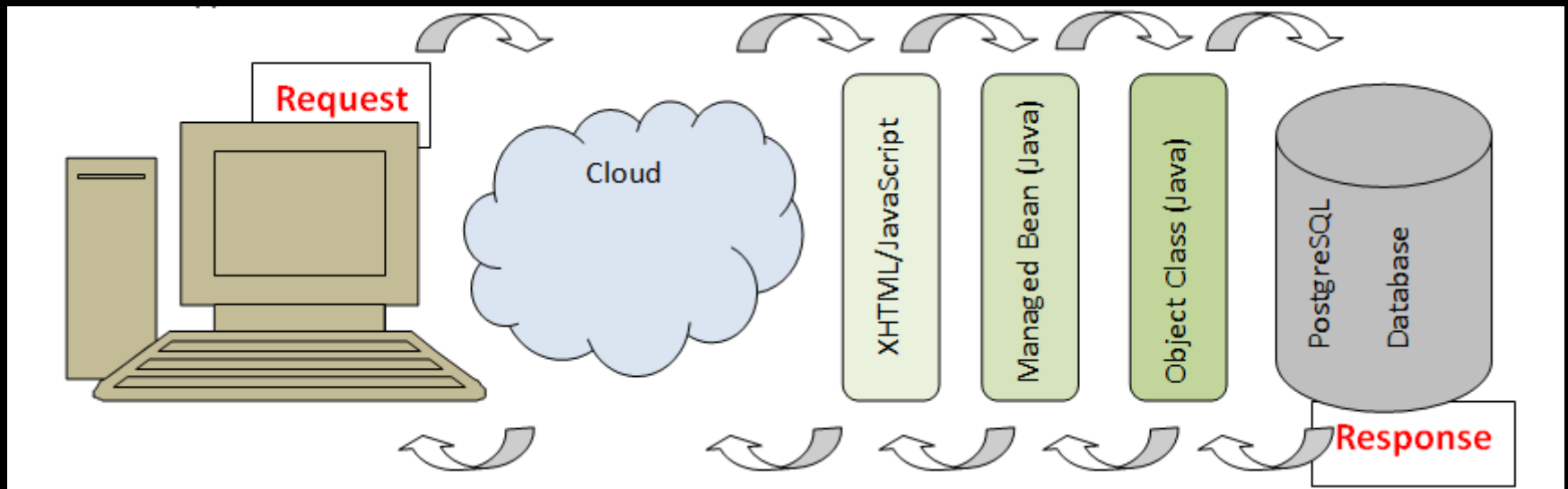
SOFTWARE TOOLS

- NetBeans 8.0 Integrated Development Environment (IDE)
 - Provides framework within which to edit, compile, and debug code
- PrimeFaces 4.0
 - Library providing rich, easily configurable user interface components
- JavaServer Faces (JSF) 2.0
 - Framework for constructing user interfaces with components
- PostgreSQL Database
 - Database within which the raw data and static images are stored

SOFTWARE TOOLS

- Java
 - Object oriented programming language with pre-defined classes and class objects
- JFreeChart
 - Chart viewing program which runs directly from Java
- JavaScript
 - Client side data parsing language compatible with web browsers
- HighCharts
 - JavaScript based chart viewing program
- XHTML
 - Webpage formatting language

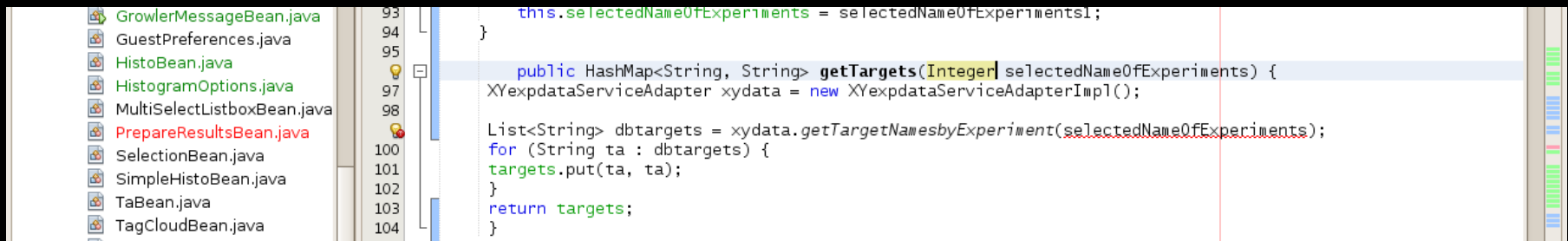
METHODS AT A GLANCE



PROGRAMMING METHODS

IDE

- All Programming, regardless of language, protocol, or tool kit was completed within the NetBeans 8.0 IDE.
 - Provides immediate feedback for coding discrepancies
 - Displays compiler read out to easily locate the position of compiler errors
 - Displays system read out statements for debugging
 - Capability to display project on built in browser or external browser.



PROGRAMMING METHODS

WEB PAGE

- XHTML main framework within which all other web page programming structured
- JavaScript used to parse data, complete actions, and fill HighCharts
- Heavy reliance on PrimeFaces 4.0 for easily configurable UI components
- JSF component library utilized where necessary



The screenshot shows an IDE with a project explorer on the left and a code editor on the right. The project explorer lists the following files and folders:

- Libraries
- G4WebApp
 - Web Pages
 - WEB-INF
 - javadoc
 - plugins
 - syntaxhighlighter
 - templates
 - DBStatistics.xhtml
 - DataOverlay.xhtml
 - DataOverlay19.xhtml
 - DataOverlayFranz.xhtml
 - DataOverlayFranzwServlet.xhtml
 - DataOverlayNA61.xhtml
 - DisplayTest.xhtml
 - DisplayTestResults.jsp
 - FranzAgain.xhtml
 - FranzwPopup.xhtml (selected)
 - G4.gif

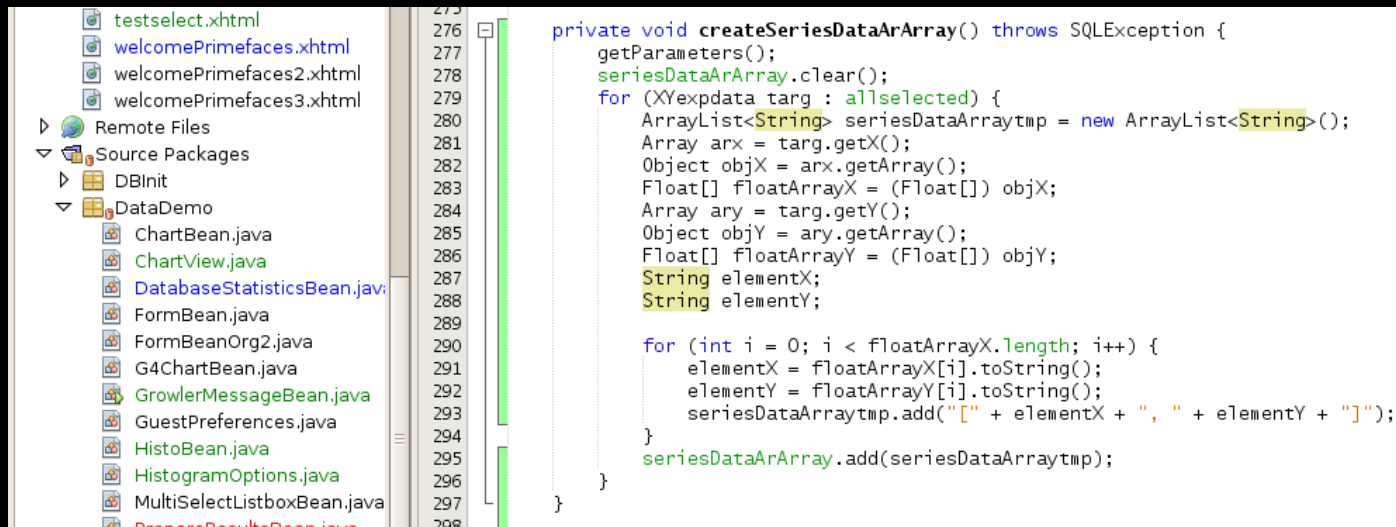
The code editor displays the content of `FranzwPopup.xhtml`:

```
23 <script>
24     process = function()
25     {
26         window.open('about:blank', 'popup', 'width=320,height=400,resizeable=yes, scrollbars=yes');
27         document.login.setAttribute('target', 'popup');
28         document.login.setAttribute('onsubmit', '');
29         document.login.submit();
30     };
31 </script>
32 <f:facet name="first">
33     <meta content='text/html; charset=UTF-8' http-equiv="Content-Type"/>
34     <title>PrimeFaces</title>
35 </f:facet>
36 </h:head>
37
38 <h:body id="showdataForm">
39
40
41     <p:layout fullPage="true">
42
43         <p:layoutUnit position="north" size="120" resizable="true" closable="true" collapsible="true" >
44             
```

PROGRAMMING METHODS

MANAGED BEANS

- Managed Beans act as an intermediary to send request parameters to the Object Class and parse returned data into a usable format
- The data is then displayed presented on a JFreeCharts plot backed by a Java servlet and also passed back to the XHTML page



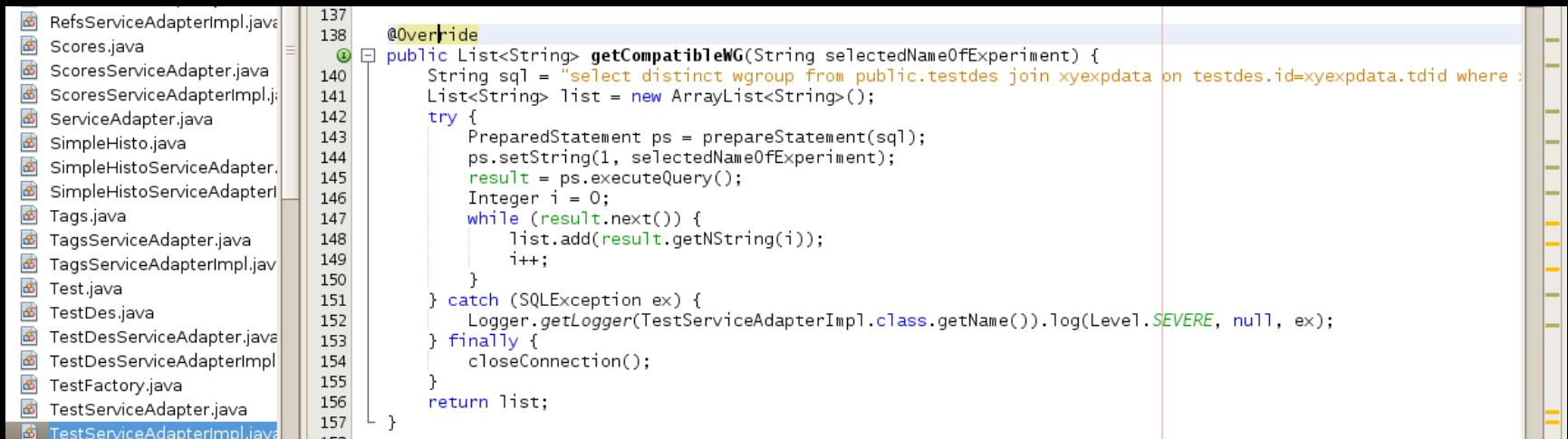
The screenshot shows an IDE with a project structure on the left and Java code on the right. The project structure includes a 'DataDemo' package with several Java files, including 'ChartBean.java', 'ChartView.java', 'DatabaseStatisticsBean.java', 'FormBean.java', 'FormBeanOrg2.java', 'G4ChartBean.java', 'GrowlerMessageBean.java', 'GuestPreferences.java', 'HistoBean.java', 'HistogramOptions.java', 'MultiSelectListboxBean.java', and 'PrepareResultsBean.java'. The code on the right is a Java method named 'createSeriesDataArArray()' which takes an 'SQLException' as a parameter. It uses 'getParameter()' to get data, clears a 'seriesDataArArray', and then iterates over 'allselected' data to populate an 'ArrayList<String>' with formatted data points. The code is as follows:

```
275 private void createSeriesDataArArray() throws SQLException {
276     getParameters();
277     seriesDataArArray.clear();
278     for (XYexpdata targ : allselected) {
279         ArrayList<String> seriesDataAraytmp = new ArrayList<String>();
280         Array arx = targ.getX();
281         Object objX = arx.getArray();
282         Float[] floatArrayX = (Float[]) objX;
283         Array ary = targ.getY();
284         Object objY = ary.getArray();
285         Float[] floatArrayY = (Float[]) objY;
286         String elementX;
287         String elementY;
288         for (int i = 0; i < floatArrayX.length; i++) {
289             elementX = floatArrayX[i].toString();
290             elementY = floatArrayY[i].toString();
291             seriesDataAraytmp.add "[" + elementX + ", " + elementY + "];");
292         }
293         seriesDataArArray.add(seriesDataAraytmp);
294     }
295 }
```

PROGRAMMING METHODS

OBJECT CLASS

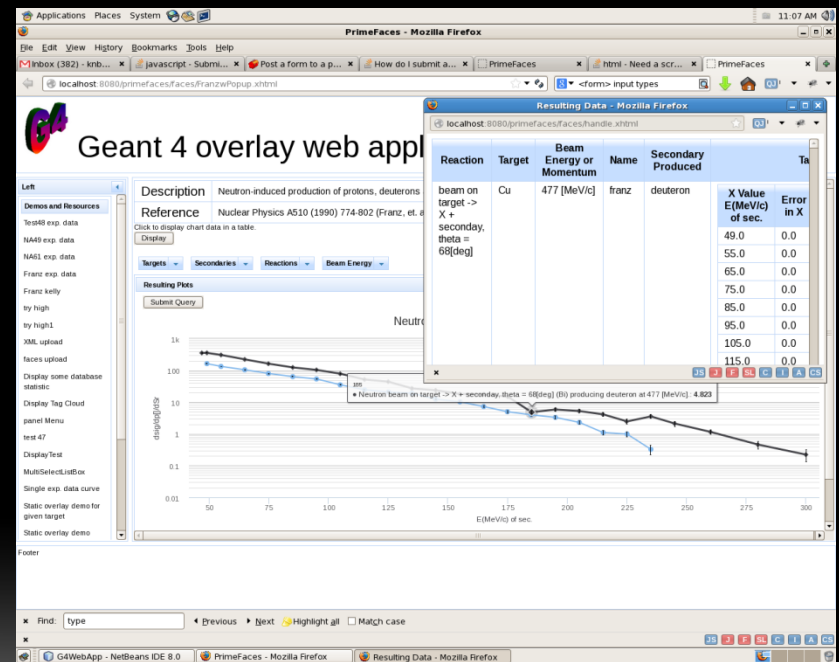
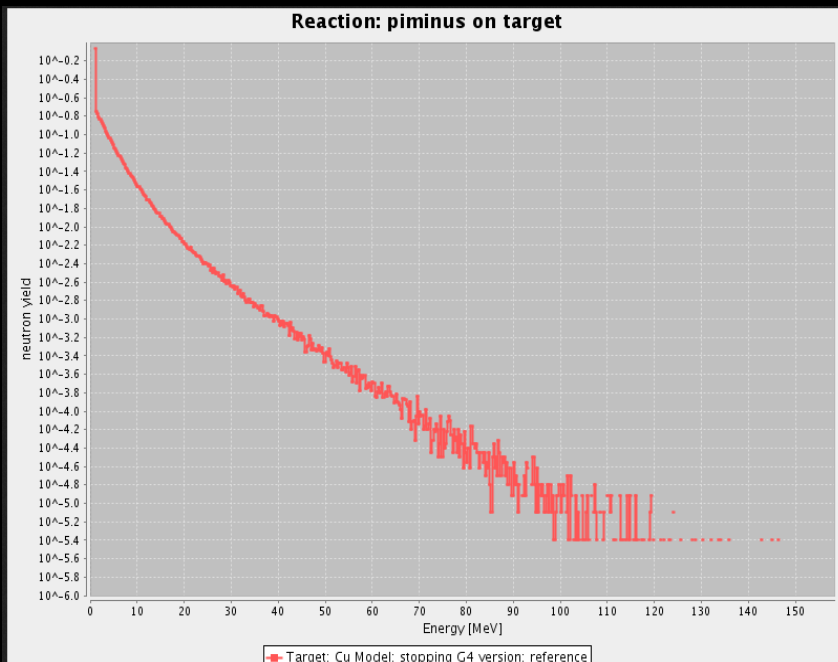
- Object classes define non-Java items in such a way that Java can manipulate them.
- They receive parameter values from the managed bean; typically a string or integer.
- These values are placed into a prepared SQL statement which the object class passes to the database.
- They then iterate over the database responses and define them for further parsing before passing them back to the managed bean.



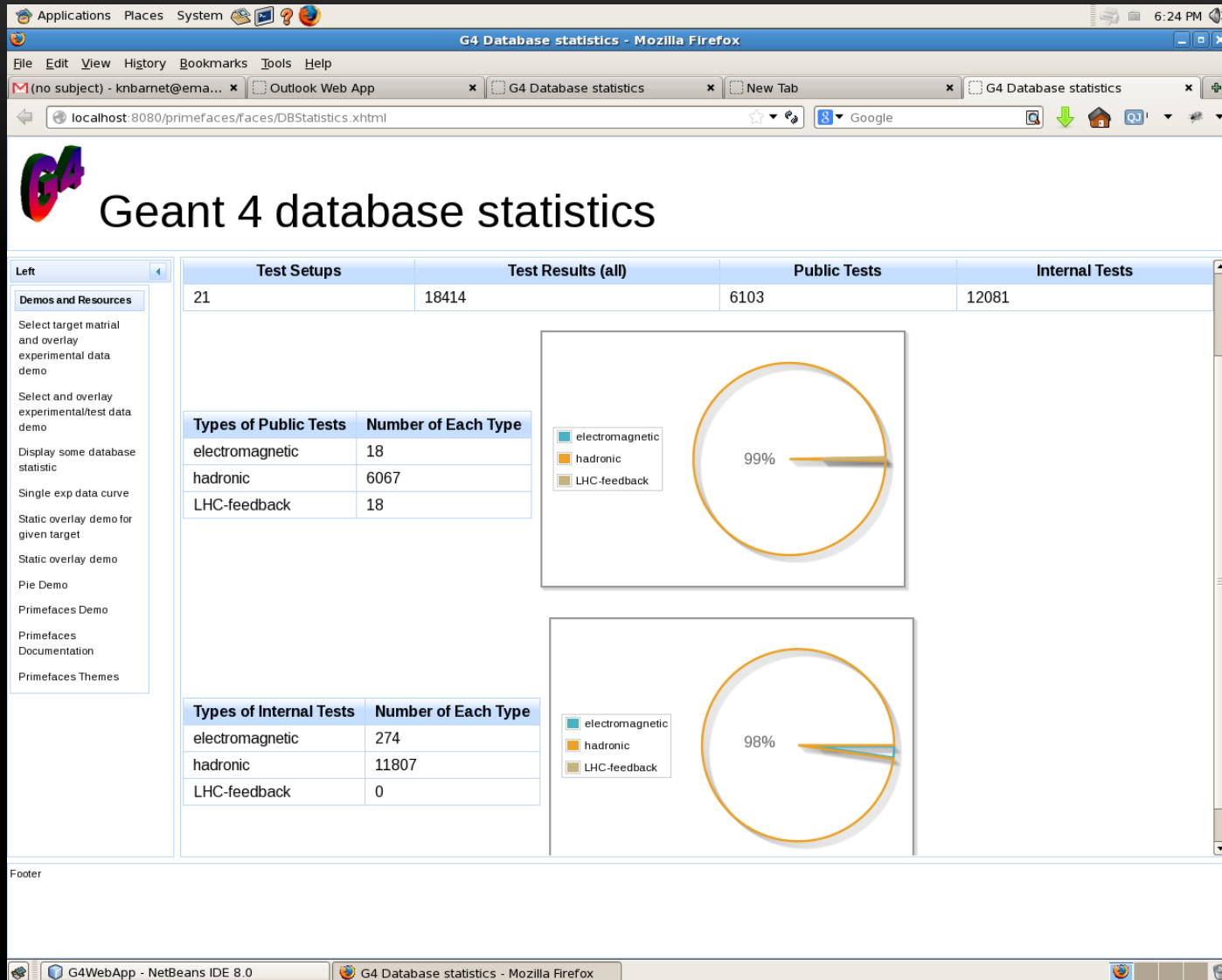
```
137
138
139 @Override
140 public List<String> getCompatibleWG(String selectedNameOfExperiment) {
141     String sql = "select distinct wgroup from public.testdes join xyexpdata on testdes.id=xyexpdata.tdid where ";
142     List<String> list = new ArrayList<String>();
143     try {
144         PreparedStatement ps = prepareStatement(sql);
145         ps.setString(1, selectedNameOfExperiment);
146         result = ps.executeQuery();
147         Integer i = 0;
148         while (result.next()) {
149             list.add(result.getString(i));
150             i++;
151         }
152     } catch (SQLException ex) {
153         Logger.getLogger(TestServiceAdapterImpl.class.getName()).log(Level.SEVERE, null, ex);
154     } finally {
155         closeConnection();
156     }
157     return list;
158 }
```

RESULTS

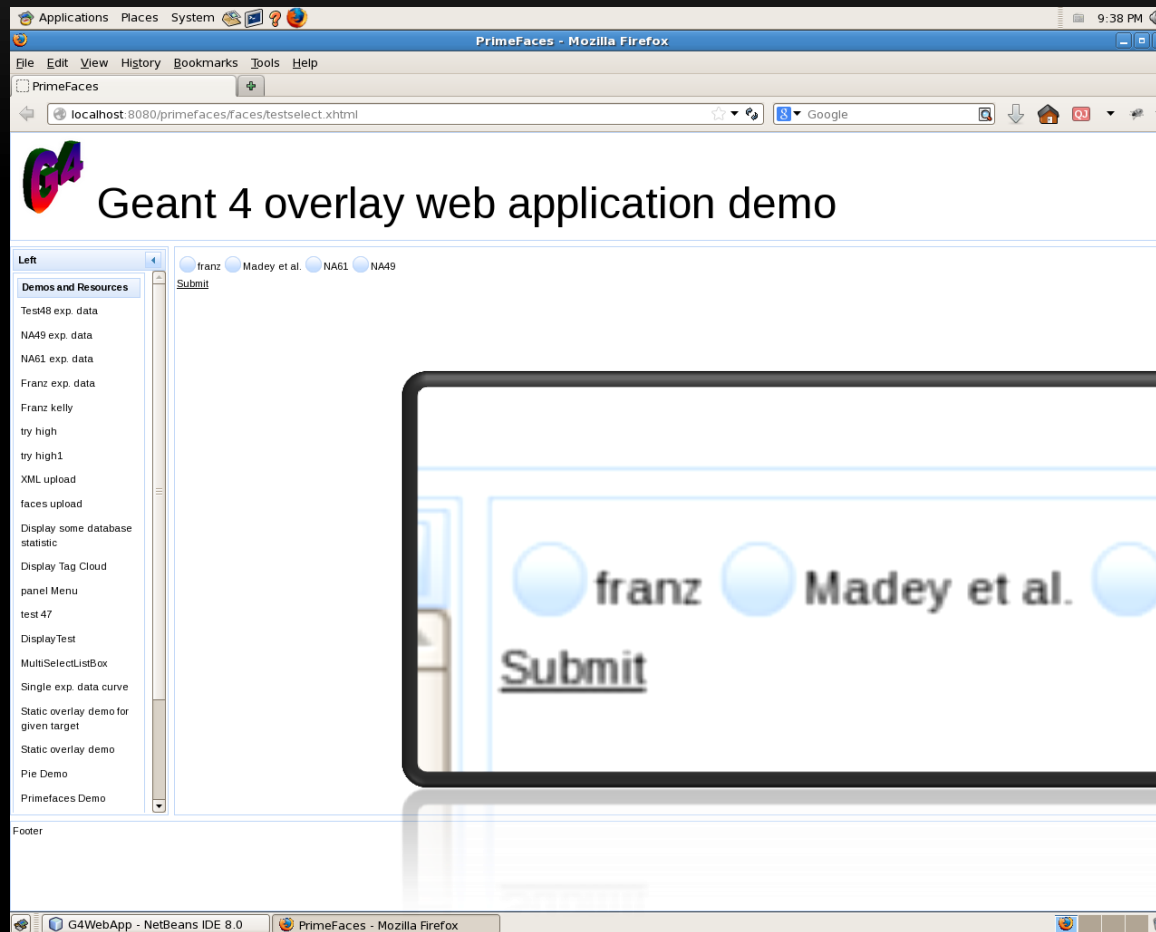
- Each individual, complete method functions as intended; however, they are not yet assembled into one coherent web application.



RESULTS: DATABASE STATISTICS



RESULTS: TOP SELECTION



RESULTS: REFINE BY TARGET

The screenshot shows a web browser window titled "PrimeFaces - Mozilla Firefox" displaying the "Geant 4 overlay web application demo". The application has a sidebar on the left with a "Demos and Resources" menu. The main content area shows a "Description" of neutron-induced production and a "Reference" to Nuclear Physics A510 (1990) 774-802. A "Targets" dropdown menu is open, showing a list of elements: Cu, Pb, C, Al, Ta, N, and O. A larger, semi-transparent inset window is overlaid on the right side of the browser, showing a similar "Targets" dropdown menu with the same list of elements. The browser's address bar shows the URL "localhost:8080/primefaces/faces/FranzwPopUp.xhtml".

RESULTS: REFINE BY SECONDARY

The screenshot shows a web browser window titled "PrimeFaces - Mozilla Firefox" displaying the "Geant 4 overlay web application demo". The application has a sidebar menu on the left with items like "Demos and Resources", "Test48 exp. data", "NA49 exp. data", "NA61 exp. data", "Franz exp. data", "Franz kelly", "try high", "try high1", "XML upload", "faces upload", "Display some database statistic", "Display Tag Cloud", "panel Menu", "test 47", "Display Test", "MultiSelectListbox", "Single exp. data curve", "Static overlay demo for given target", "Static overlay demo", "Pie Demo", and "Primefaces Demo". The main content area has a "Description" section with the text "Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth." and a "Reference" section with "Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)". Below these is a "Display" button and a "Click to display chart data in a table." link. A "Targets" dropdown menu is open, showing a search bar and a list with "neutron" selected. The "Secondary" dropdown menu is also visible, showing a search bar and a list with "neutron" selected. The "Reactions" and "Beam Energy" dropdown menus are also present. The application is running on a localhost address: localhost:8080/primefaces/faces/FranzwPopUp.xhtml. The footer shows "G4WebApp - NetBeans IDE 8.0" and "PrimeFaces - Mozilla Firefox".

RESULTS: REFINE BY REACTION

The screenshot shows a web browser window titled "PrimeFaces - Mozilla Firefox" displaying the "Geant 4 overlay web application demo". The application has a left sidebar with a "Demos and Resources" menu. The main content area shows a "Description" of neutron-induced production and a "Reference" to Nuclear Physics A510 (1990) 774-802. Below this, there are tabs for "Targets", "Secondaries", "Reactions", and "Beam Energy". A "Resulting Plots" section contains a "Submit Query" button and a search input field with the text "piminus on target". A modal dialog box is open over the search input, showing the same text "piminus on target". The browser's address bar shows the URL "localhost:8080/primefaces/faces/FranzwPopUp.xhtml". The system tray at the bottom shows "G4WebApp - NetBeans IDE 8.0" and "PrimeFaces - Mozilla Firefox".

Applications Places System 9:38 PM

PrimeFaces - Mozilla Firefox

File Edit View History Bookmarks Tools Help

PrimeFaces

localhost:8080/primefaces/faces/FranzwPopUp.xhtml

Google

Geant 4 overlay web application demo

Left

Demos and Resources

- Test48 exp. data
- NA49 exp. data
- NA61 exp. data
- Franz exp. data
- Franz kelly
- try high
- try high1
- XML upload
- faces upload
- Display some database statistic
- Display Tag Cloud
- panel Menu
- test 47
- Display Test
- MultiSelectListBox
- Single exp. data curve
- Static overlay demo for given target
- Static overlay demo
- Pie Demo
- Primefaces Demo

Description Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.

Reference Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.

Display

Targets Secondaries Reactions Beam Energy

Resulting Plots

Submit Query

piminus on target

Neutron Induced Particle Production

ondaries Reactions Beam Energy

piminus on target

Neutron Indu

Footer

G4WebApp - NetBeans IDE 8.0 PrimeFaces - Mozilla Firefox

RESULTS: REFINE BY BEAM ENERGY

The screenshot displays the 'PrimeFaces - Mozilla Firefox' browser window showing the 'Geant 4 overlay web application demo'. The application interface includes a left sidebar with a 'Demos and Resources' list, a main content area with a 'Description' and 'Reference' section, and a 'Beam Energy' dropdown menu. The dropdown menu is open, showing two options: '1.4 [GeV/c]' and '1.4 [GeV/c]'. A larger inset shows the same dropdown menu with the same options.

Geant 4 overlay web application demo

Description Neutron-induced production of protons, deuterons and tritons in Copper and Bismuth.

Reference Nuclear Physics A510 (1990) 774-802 (Franz, et. al.)

Click to display chart data in a table.

Display

Targets **Secondaries** **Reactions** **Beam Energy**

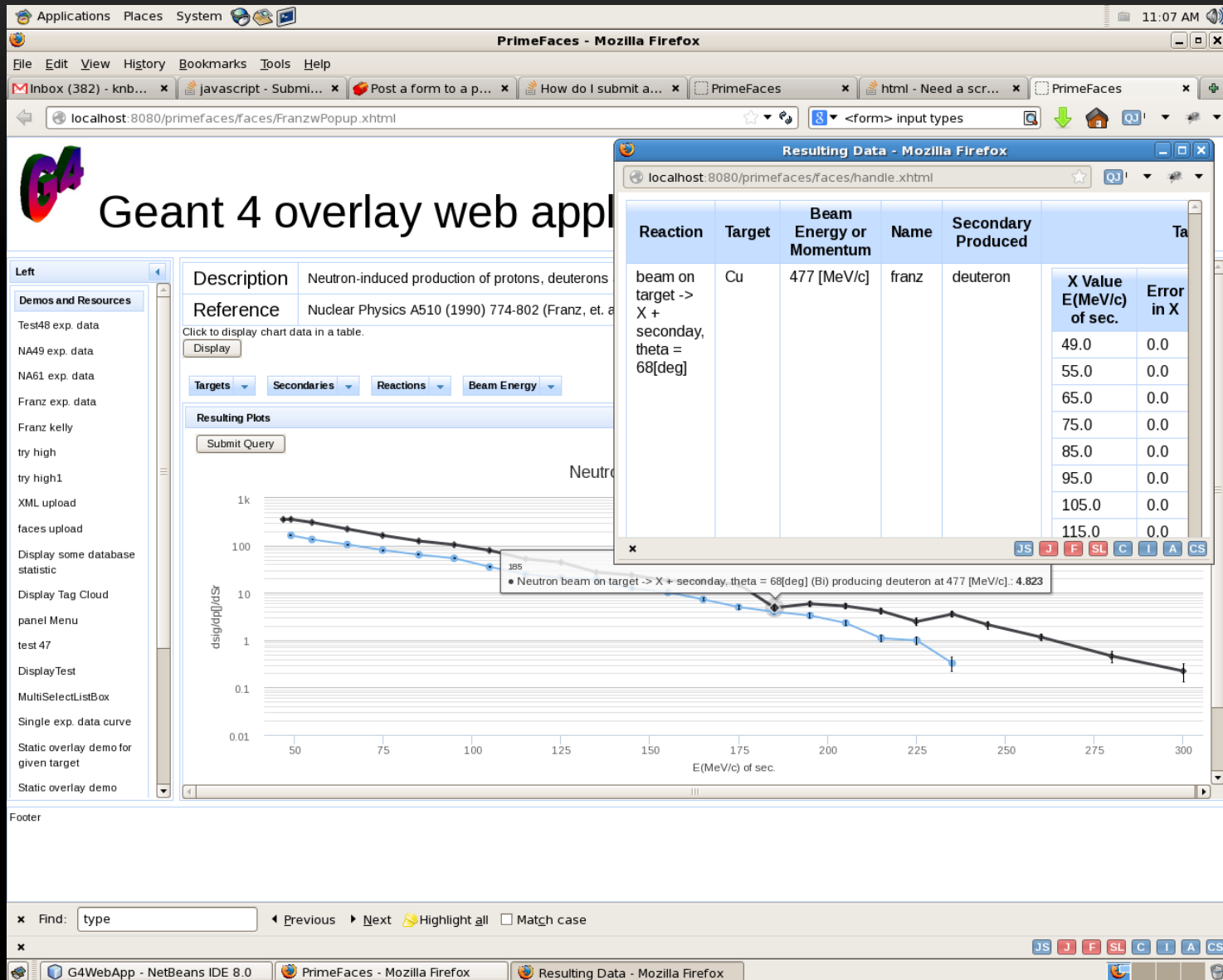
Resulting Plots

Submit Query

1.4 [GeV/c]

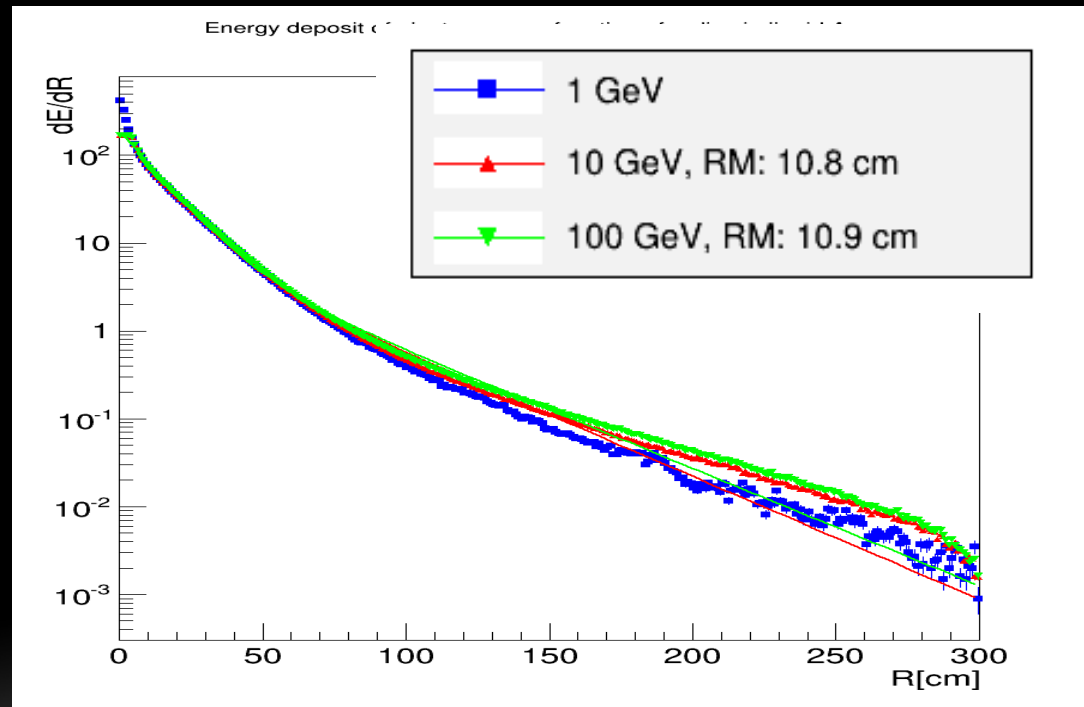
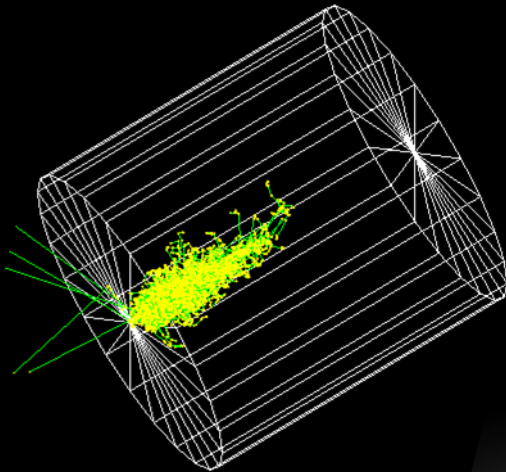
1.4 [GeV/c]

RESULTS: DYNAMICALLY CREATED PLOT



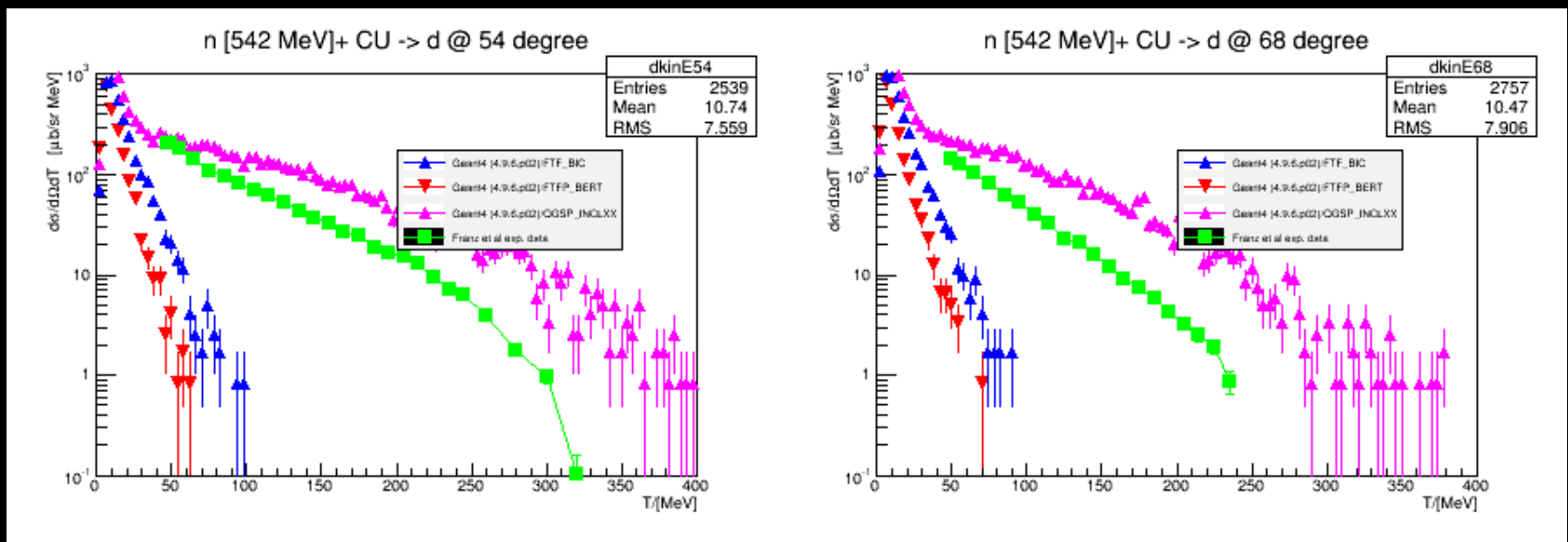
DISCUSSION: GEANT4 VALIDATION

- Precise liquid argon modeling crucial due to use in future experiments
 - LArIAT
 - MicroBoone
 - LBNE



DISCUSSION: GEANT4 VALIDATION

- Geant4 is the current standard for modelling physical interaction, and popularity is growing.
- As the user base increases, so must ease of use as well as number of tests.



CONCLUSION

- Discussed
 - What Geant4 is and its implications
 - Current application being created
 - Materials and Methods
 - Results and Discussion
- Continuous validation is key to improvement
- Expanding the validation library is the only means by which to do that
- A more diverse, robust validation library from which to draw upon will attract a wider audience

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- PDS Team:
 - Krzysztof Genser
 - Tomasz Golan
 - Robert Hatcher
 - Adam Para
 - Gabriel Perdue
 - Hans-Joachim Wenzel
 - Julia Yarba

REFERENCES

- [1] K. Kleinknecht, "Measurement of ionization," in Detectors for Particle Radiation, 2nd ed. Cambridge: CU Press, 1998, ch. 2, sec. 4, pp. 59.
- [2] H. Schultz-Coulon, "Calorimetry I: Electromagnetic Calorimeters," Univ. Heidelberg, Heidelberg, DE, Rep. 2014.
- [3] Atlas (2007). Liquid argon properties [Online]. Available: http://lartpc-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=206;filename=Liquid_argon_properties.pdf;version=1

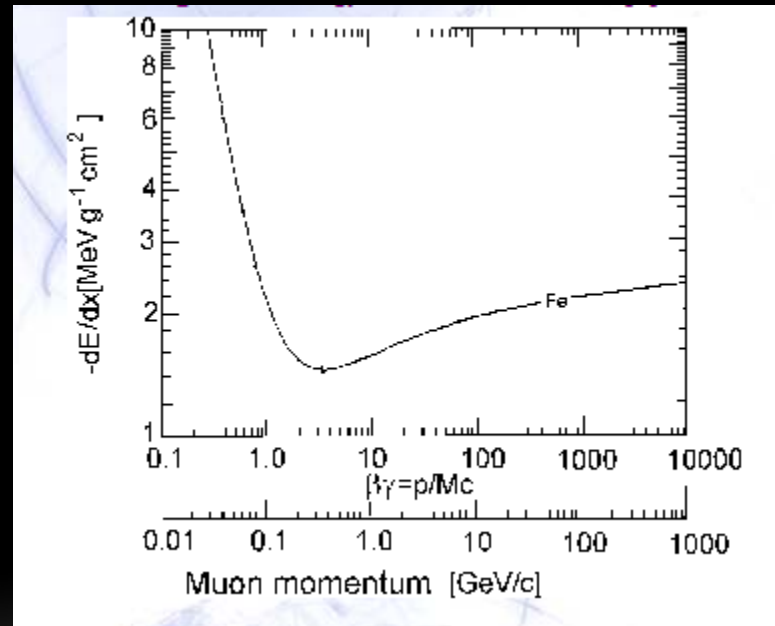
APPENDIX: SUPPLEMENTAL MATERIAL

EXAMPLE IN MEDICINE: PROTON THERAPY

- Bethe-Bloch equation describes the stopping power as a function of the change in energy of the beam per change in distance and

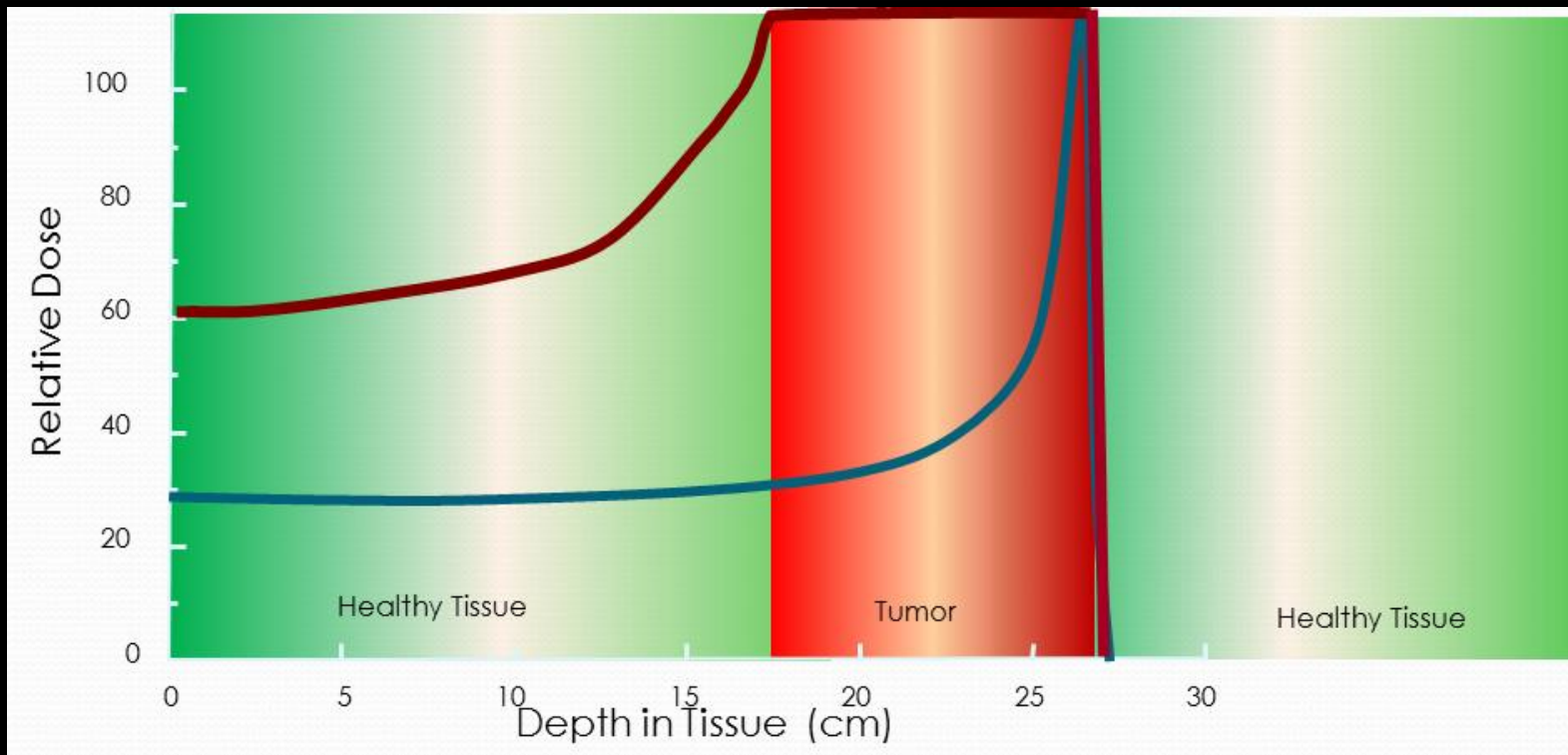
- $$-\frac{dE}{dx} = K Z^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2} \right]$$

- $$K \equiv 4\pi N_A r_e^2 m_e c^2 / A$$



EXAMPLE IN MEDICINE: PROTON THERAPY

- A Bragg Peak is the point at which an element loses momentum and deposits most of its energy.
- By varying the beam intensity over time, the Bragg Peak can be spread out.

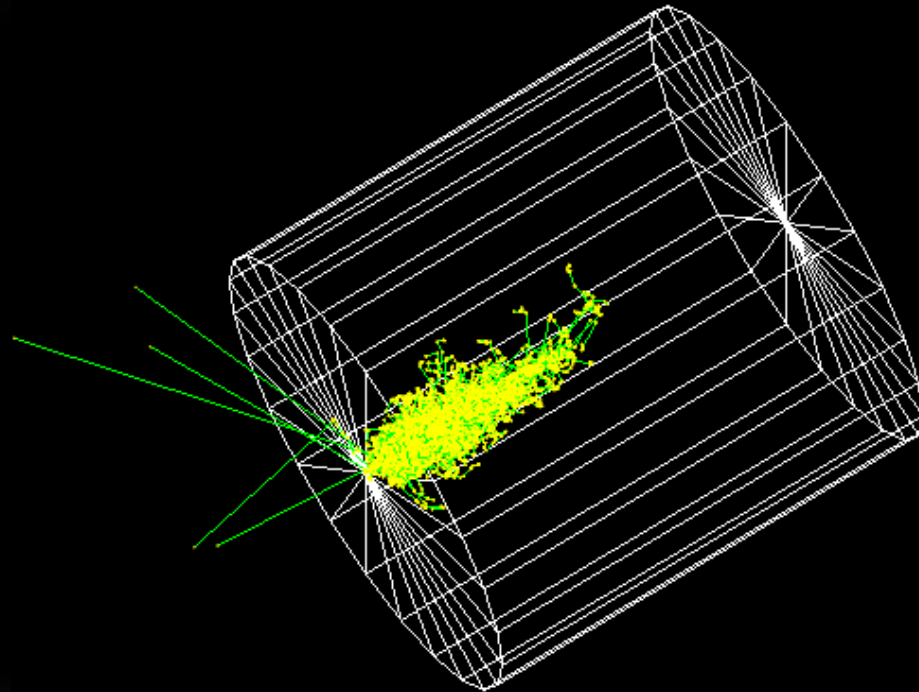


LIQUID ARGON

Property	Value
ρ (density)	1.4 g/cm^3
R_M (Moliere Radius)	9 – 11 cm
X_0 (Radiation Length)	14 cm
Z (Atomic Number)	18
A (Atomic Weight)	39.94
IA (Nuclear Interaction Length)	83.6 cm

GEANT4 SIMULATION OF EM SHOWER IN LIQUID ARGON

- 10 GeV Beam
- Liquid Argon Target
 - Radius: 3 m
 - Length: 6 m

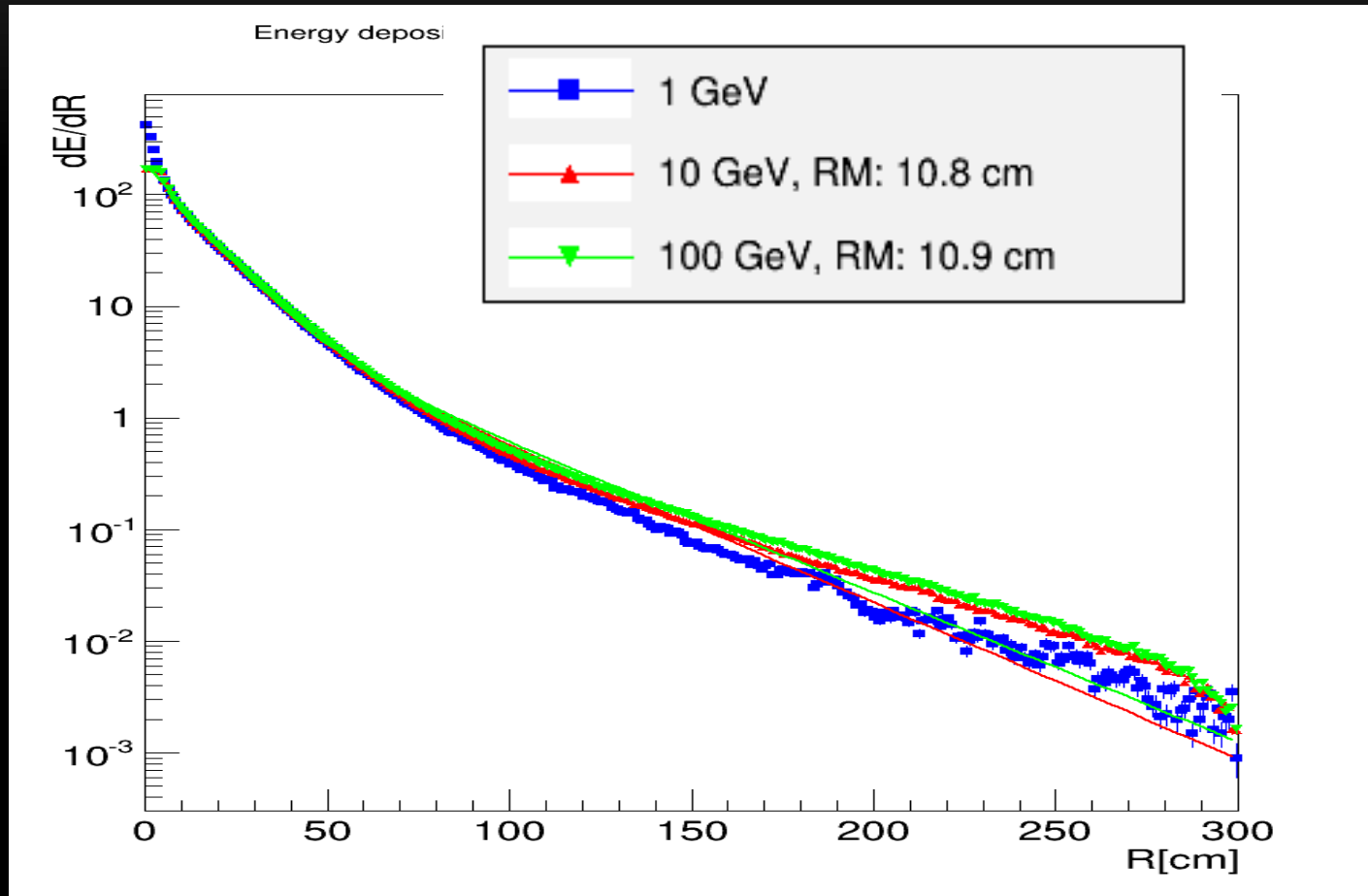


TRANSVERSE ELECTROMAGNETIC SHOWER PROFILE

- Radius within which 90% of the interactions occur
 - Literature: 9-11 cm [1]
 - Geant4: 11.31 cm
- $F(z) = \alpha e^{-\frac{R}{R_M}} + \beta e^{-\frac{R}{\lambda_{min}}}$ [2]
 - $\alpha \equiv$ short depth parameter
 - Dominates within the Moliere Radius
 - $\beta \equiv$ long depth parameter
 - Dominates beyond the Moliere Radius
 - It is important to note the parameters of the double exponential formula are highly correlated, so one must carefully interpret the 11.32 cm.

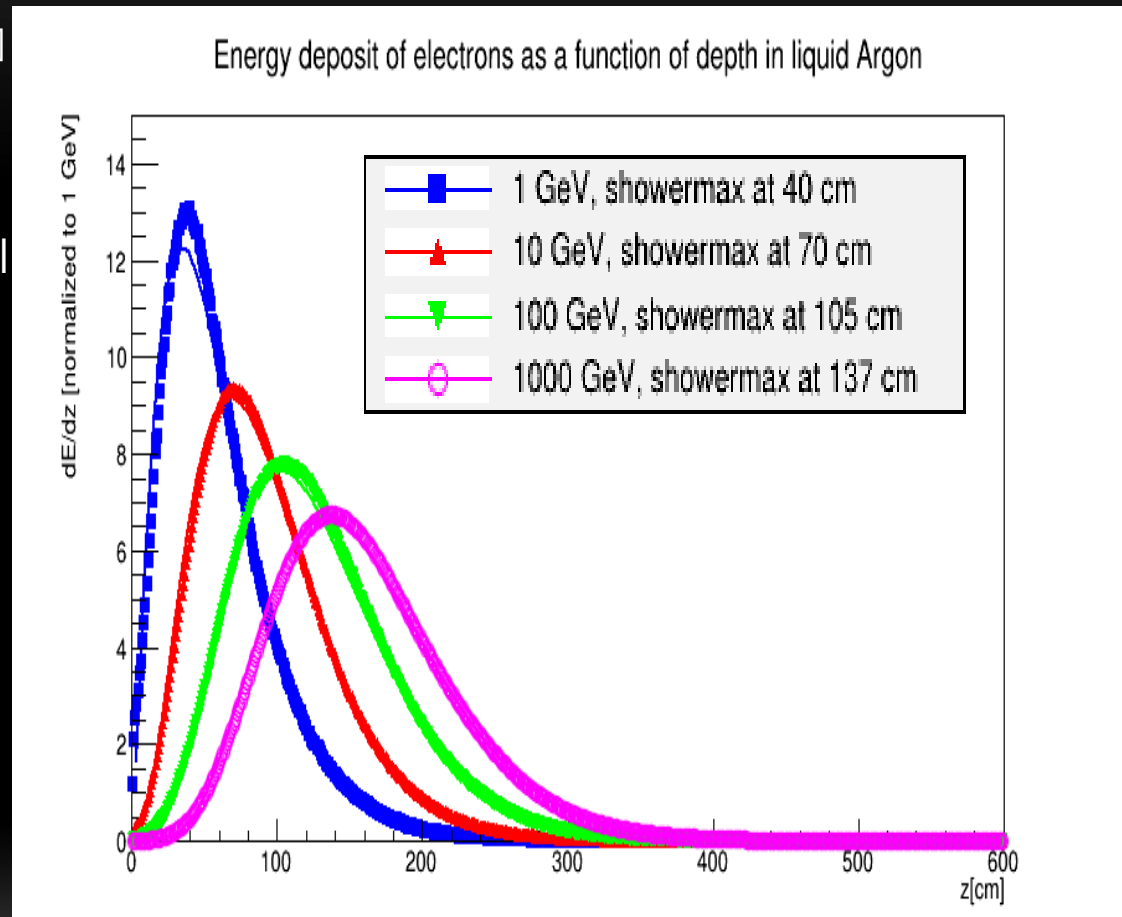
TRANSVERSE ELECTROMAGNETIC SHOWER PROFILER RADIUS (M_R)

- Primarily energy independent except at tails ends




LONGITUDINAL PROFILE

- $\frac{dE}{dt} = E_0 \left(\frac{z}{X_0}\right)^\alpha e^{-\beta\left(\frac{z}{X_0}\right)}$ [2]
- Radiation length (X_0)
 - Characterizes the material
 - When used as a unit of measure, produces the same curve regardless of the target material
- Fit for X_0
 - 12 (10 GeV)
 - 13.7 (100 GeV)
 - 14.6 (1000 GeV)



SHOWER MAX (T_{MAX})

- Depth at which the maximum energy is deposited.
- $t_{max} = \ln \frac{E_0}{E_c} - 1$ [2]  (Rule of thumb)
- By nature, “rule of thumb” is imprecise

Peak Energy (GeV)	1	10	100	1000
Manual Calculation (cm)	33	65	97.4	129.6
G4 (cm)	40	70	105	137

SHOWER MAX (T_{MAX})

Ln (E_0/E_c) vs. Shower Max [cm] for Simulation and Rule of Thumb Calculation

