DEVELOPMENT OF THE GEANT4 VALIDATION WEB INTERFACE FOR END USERS

K. Nicole Barnett 2014

Fermilab

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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
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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**

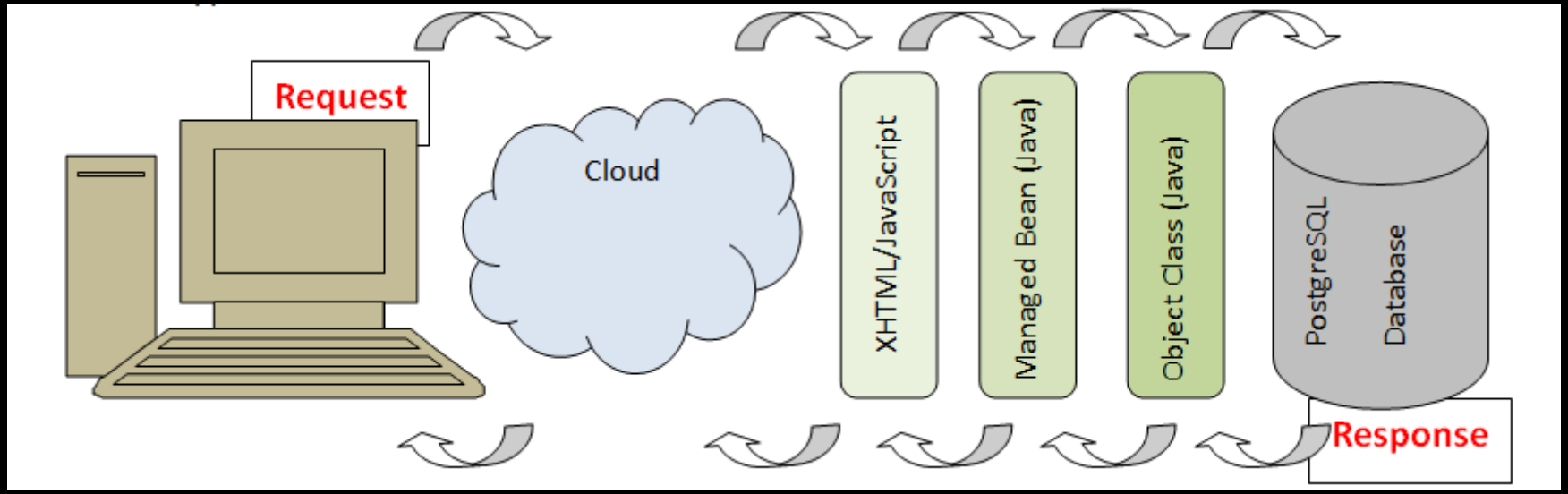
SOFTWARE TOOLS

- 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

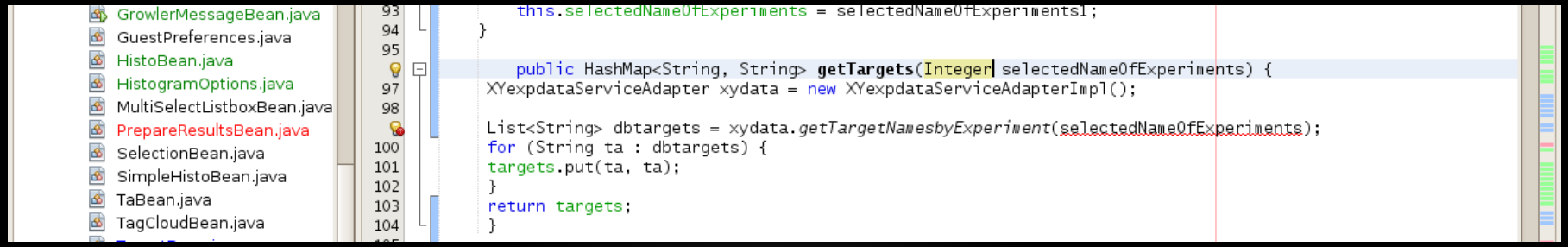
- Java
  - Object oriented programming language with pre-defined classes and class objects
- JFreeChart
  - Chart viewing program which runs directly from Java
- JavaScript
  - Client side data parsing language compatible with web browsers
- HighCharts
  - JavaScript based chart viewing program
- XHTML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



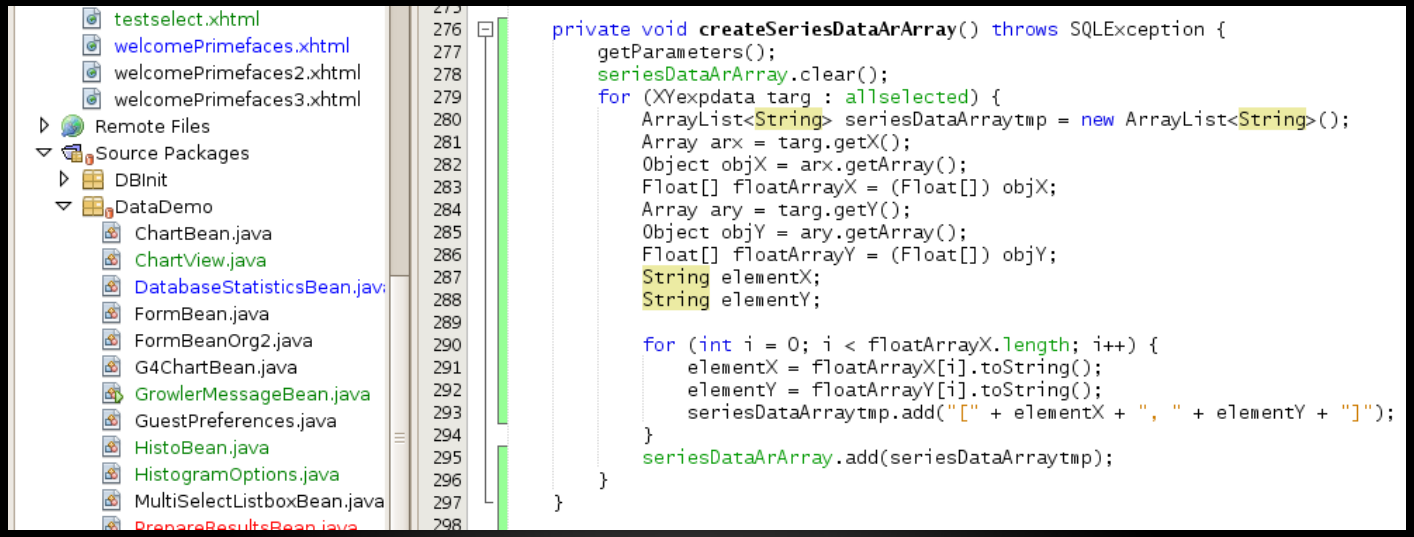
PROGRAMMING METHODS

WEB PAGE

- XHTML main framework within which all other web page programing 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

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

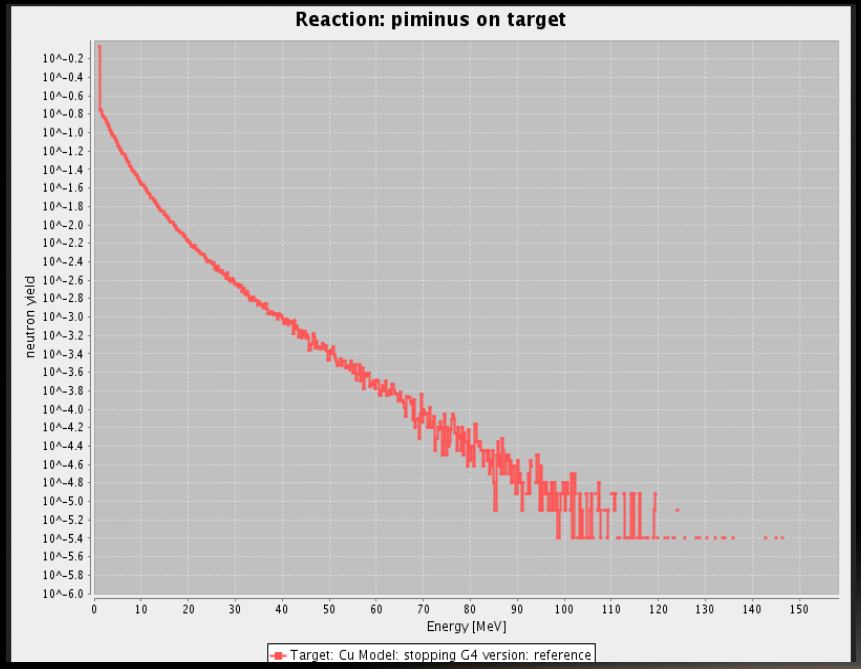


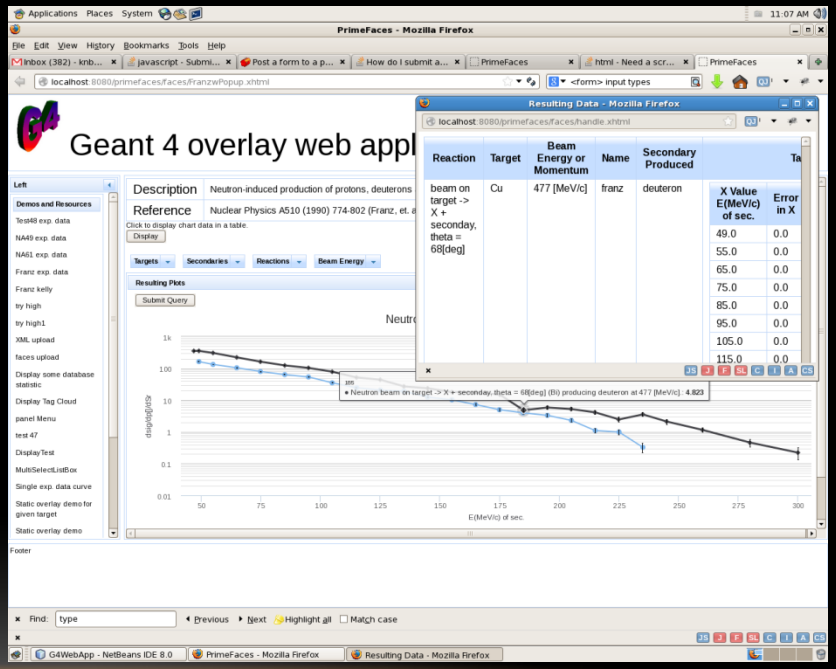
PROGRAMMING METHODS
OBJECT CLASS

- 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.

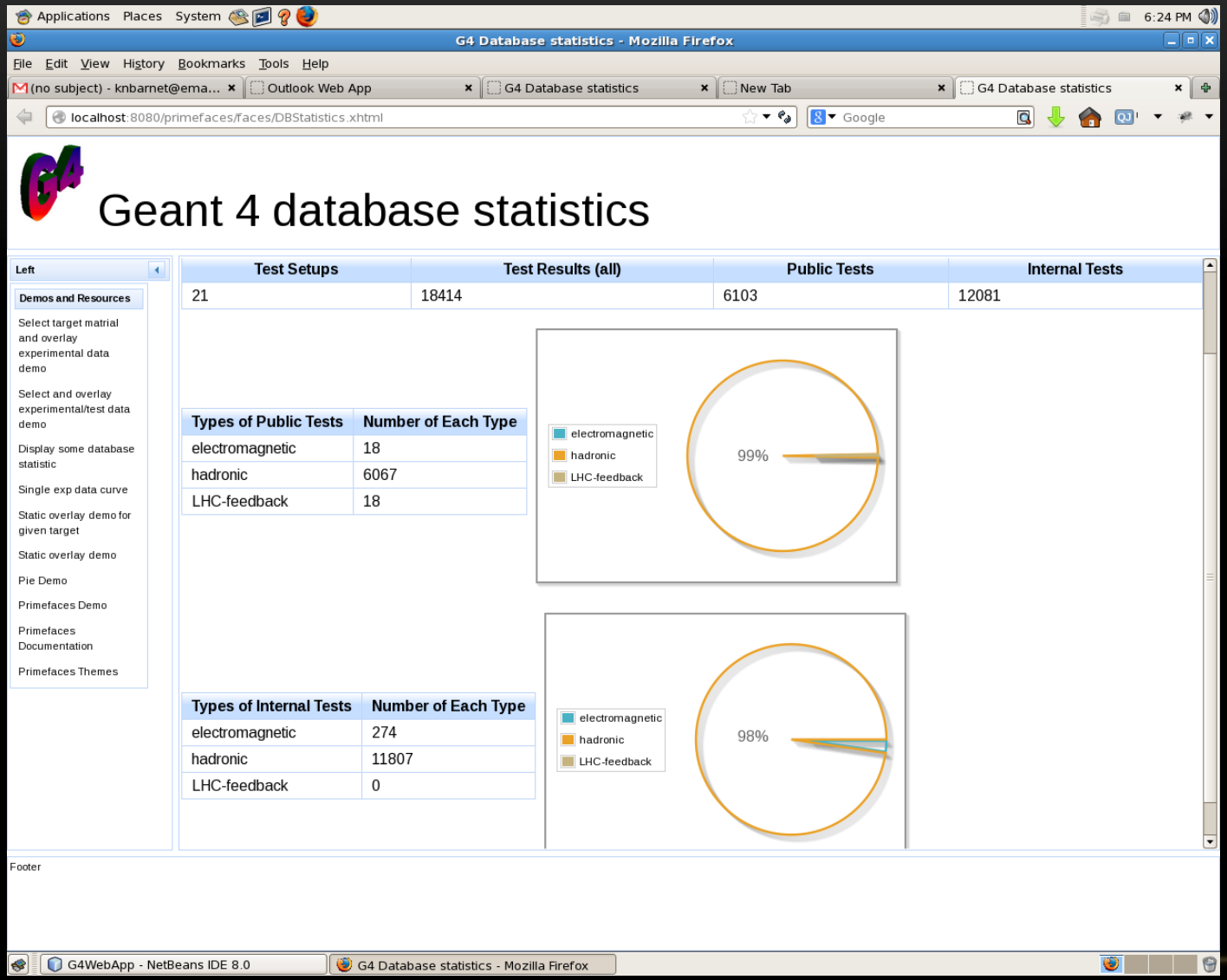
RESULTS

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

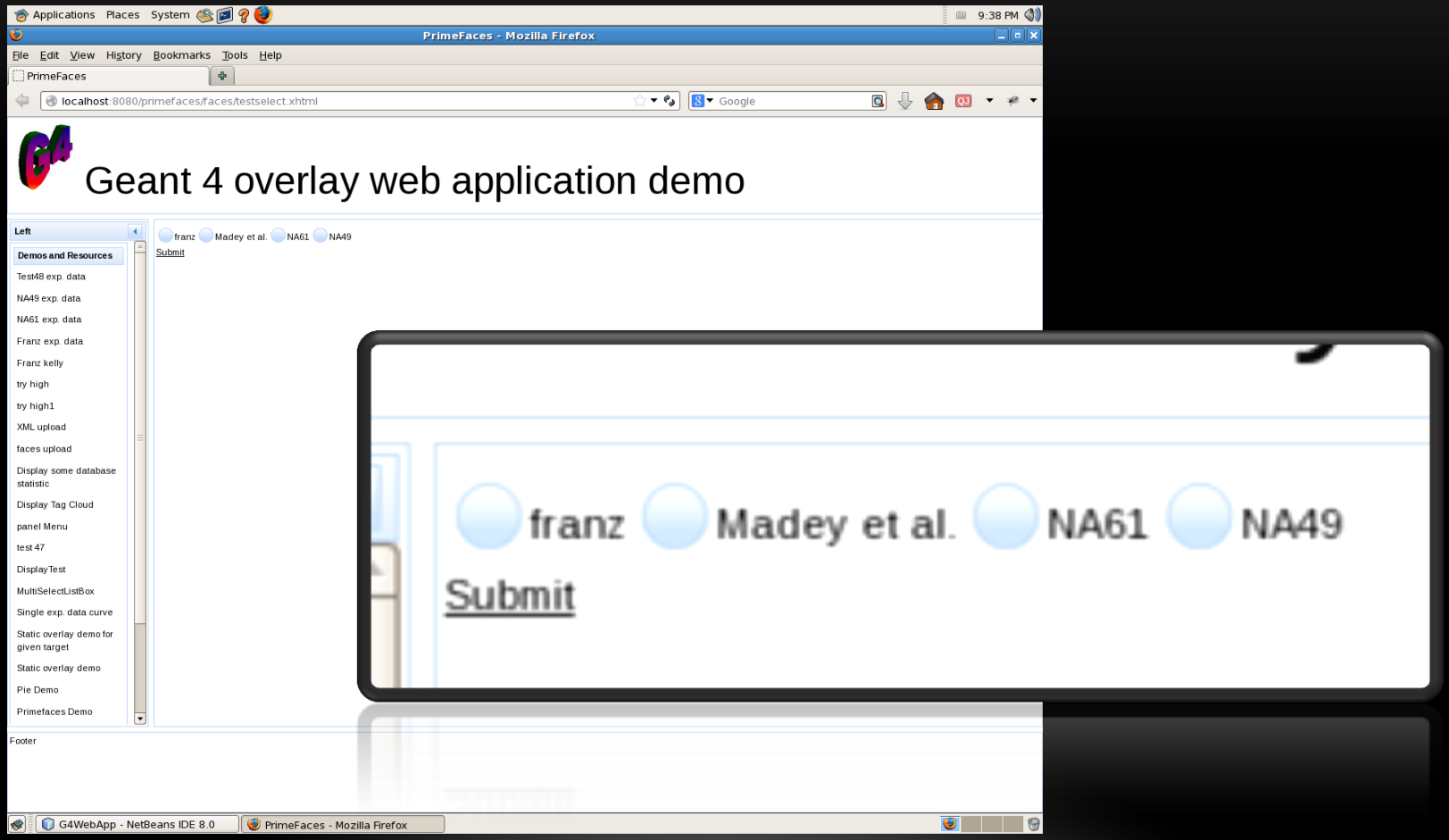




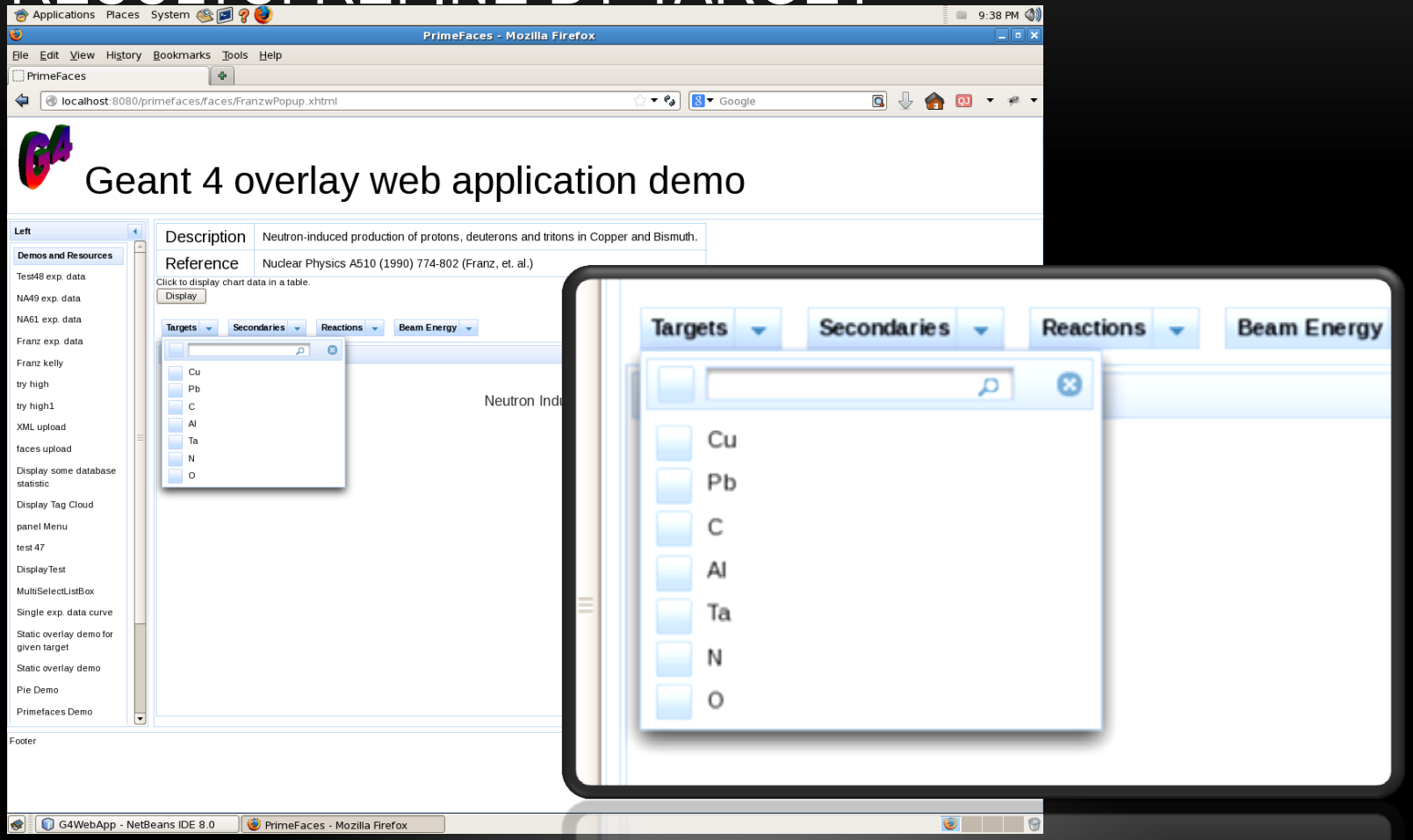
RESULTS: DATABASE STATISTICS



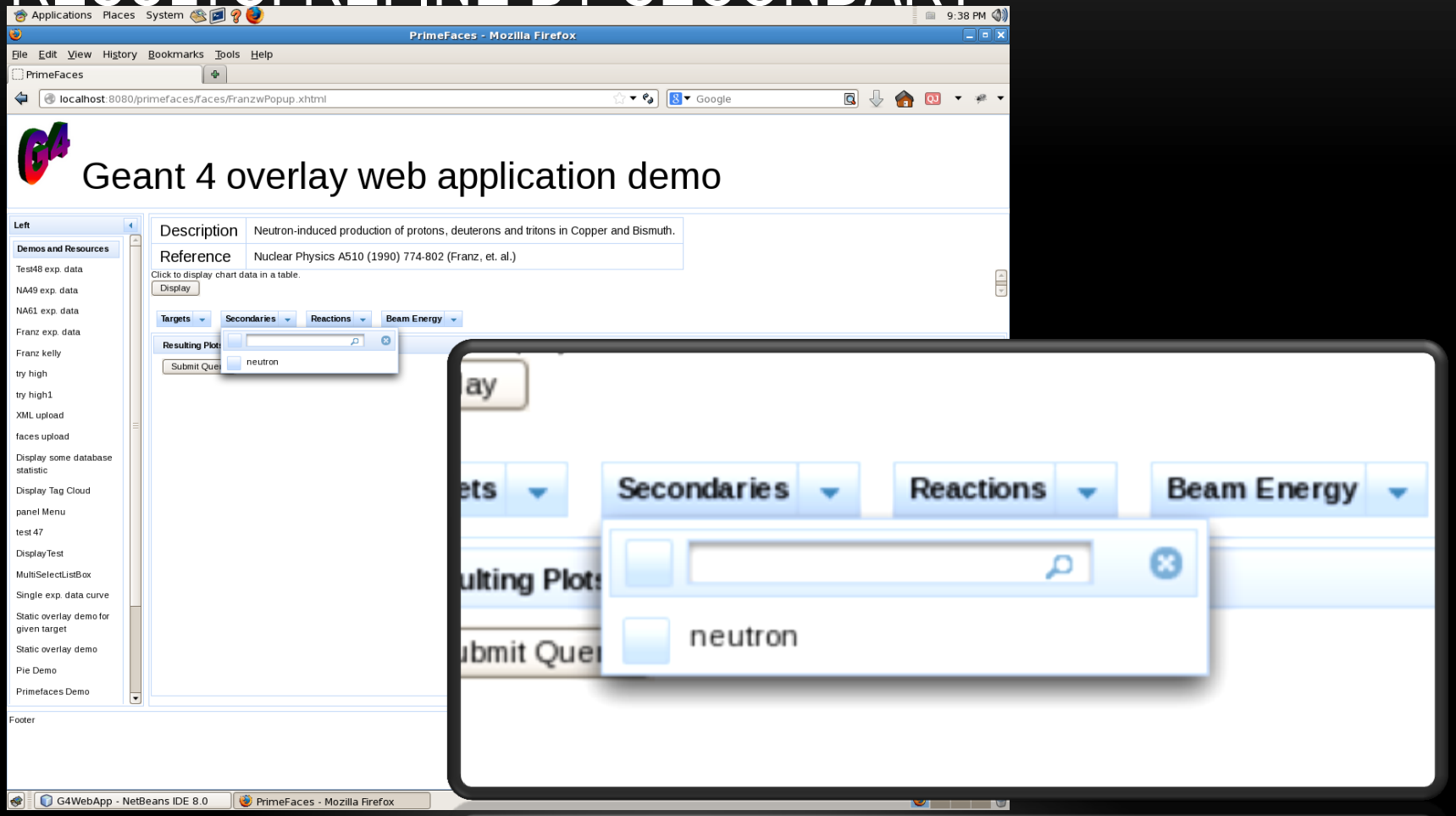
RESULTS: TOP SELECTION



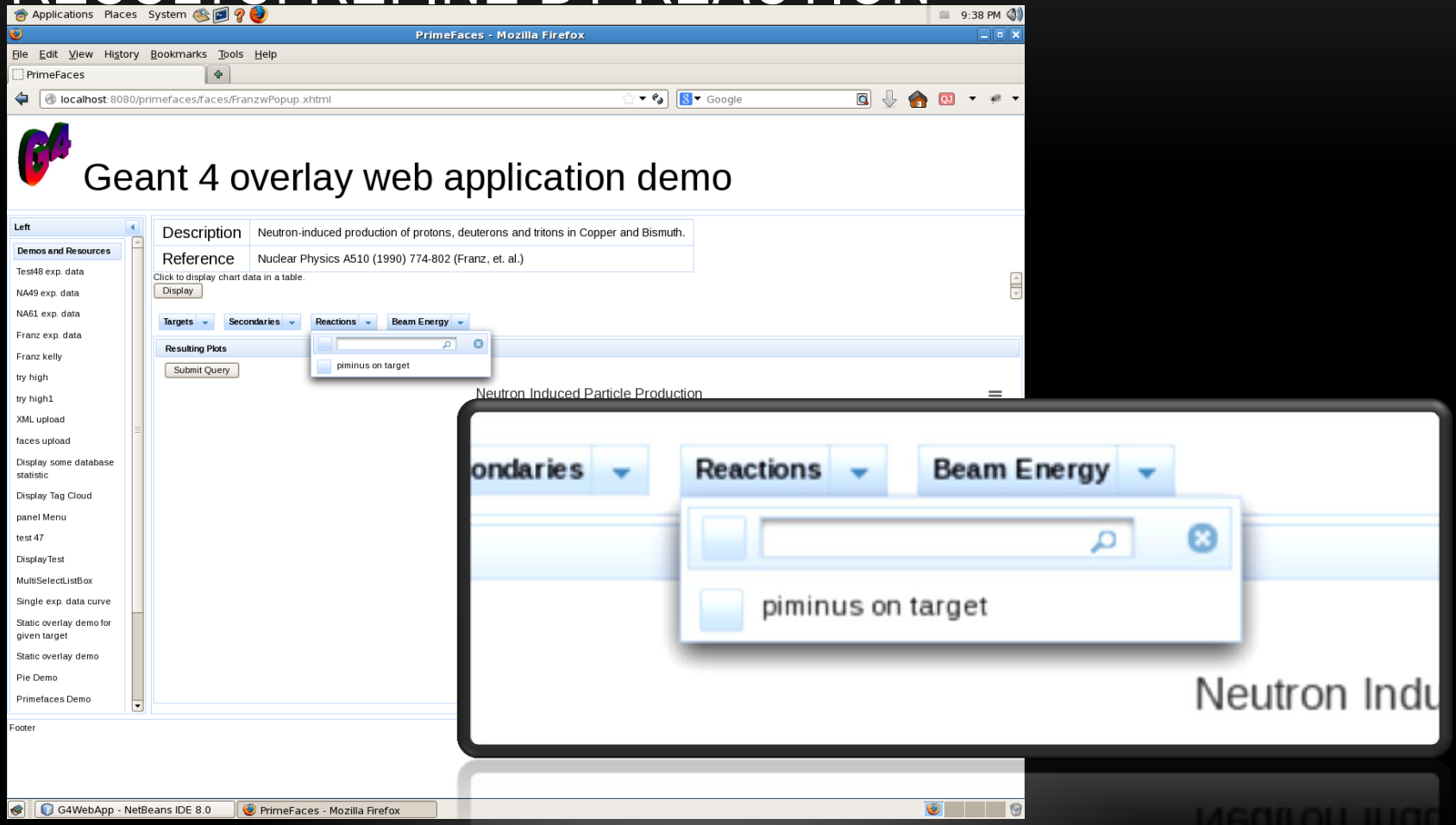
RESULTS: REFINE BY TARGET



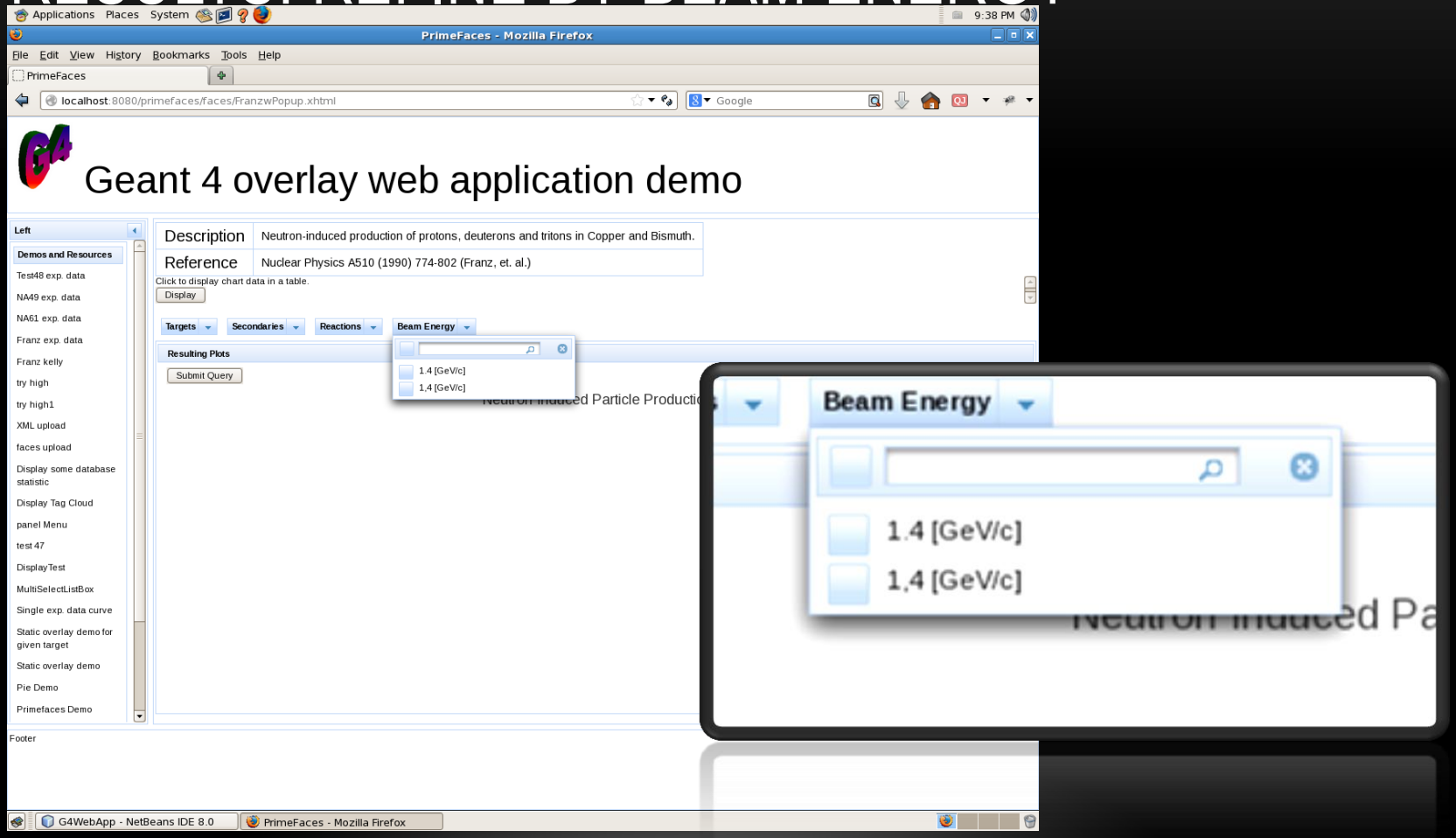
RESULTS: REFINE BY SECONDARY



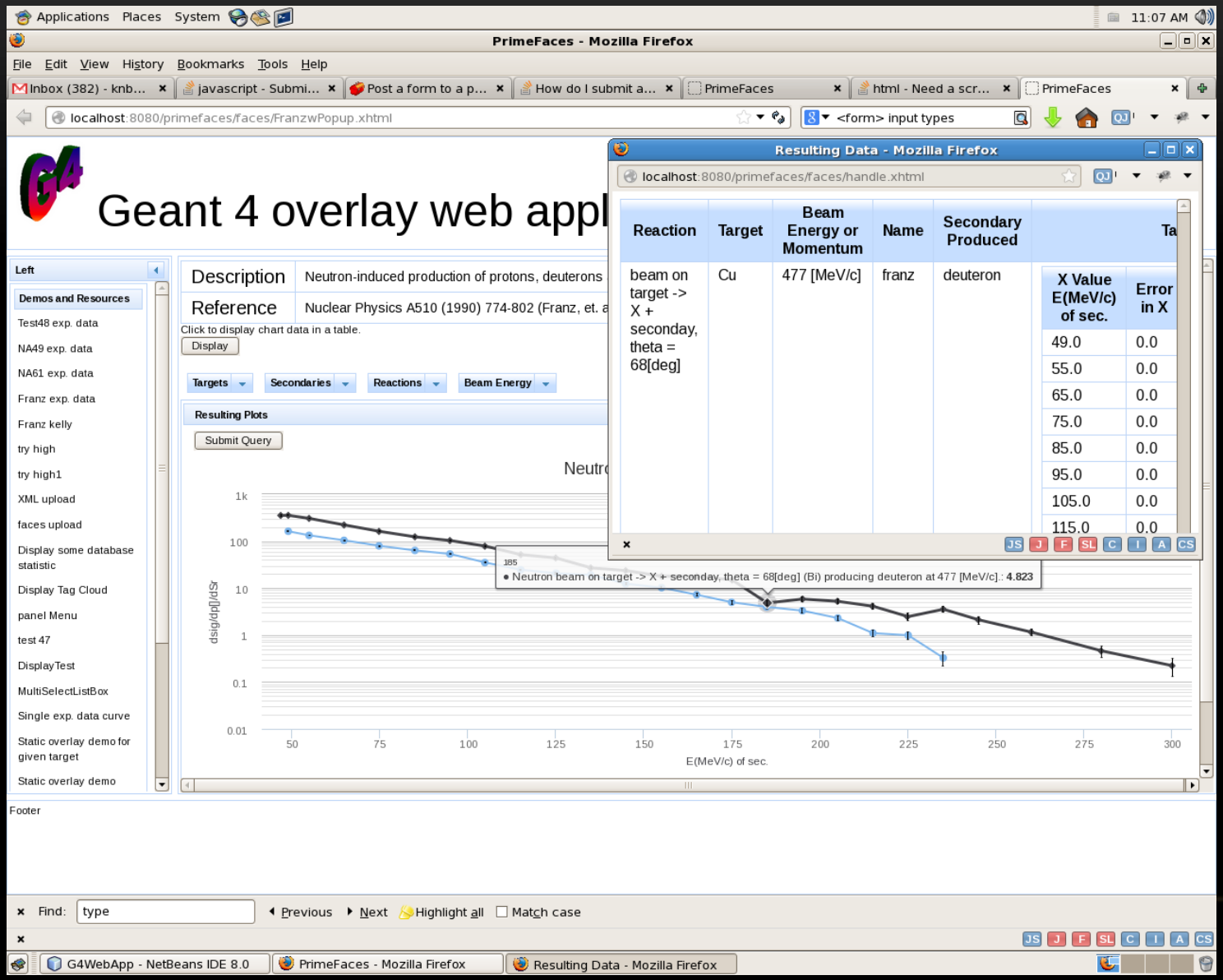
RESULTS: REFINE BY REACTION



RESULTS: REFINE BY BEAM ENERGY

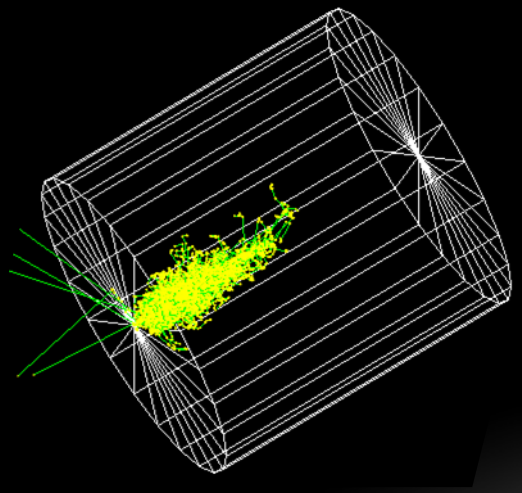


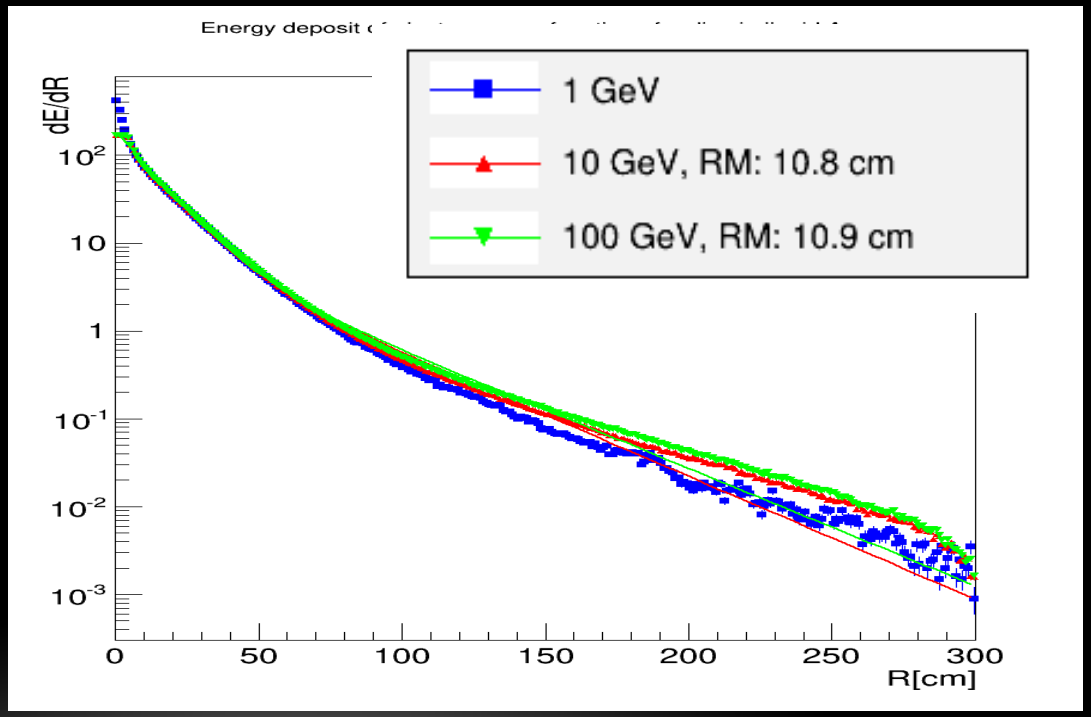
RESULTS: DYNAMICALLY CREATED PLOT



DISCUSSION: GEANT4 VALIDATION

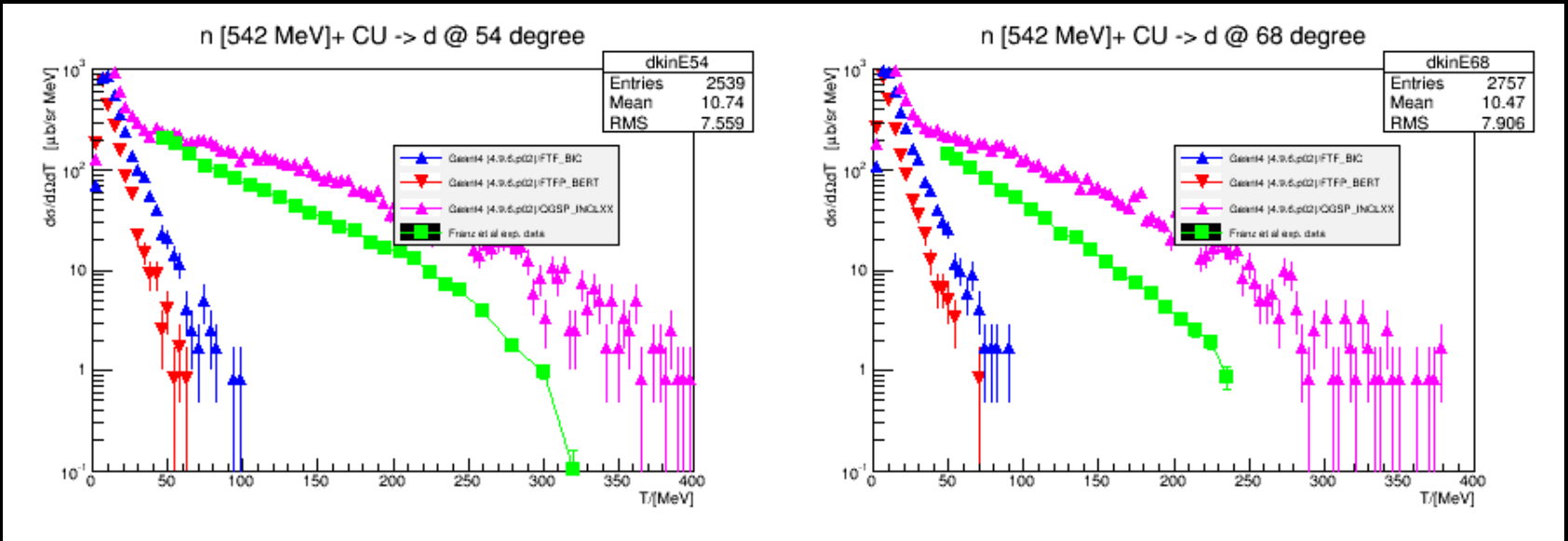
- Precise liquid argon modeling crucial due to use in future experiments
  - LArIAT
  - MicroBoone
  - LBNE





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 it's 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.

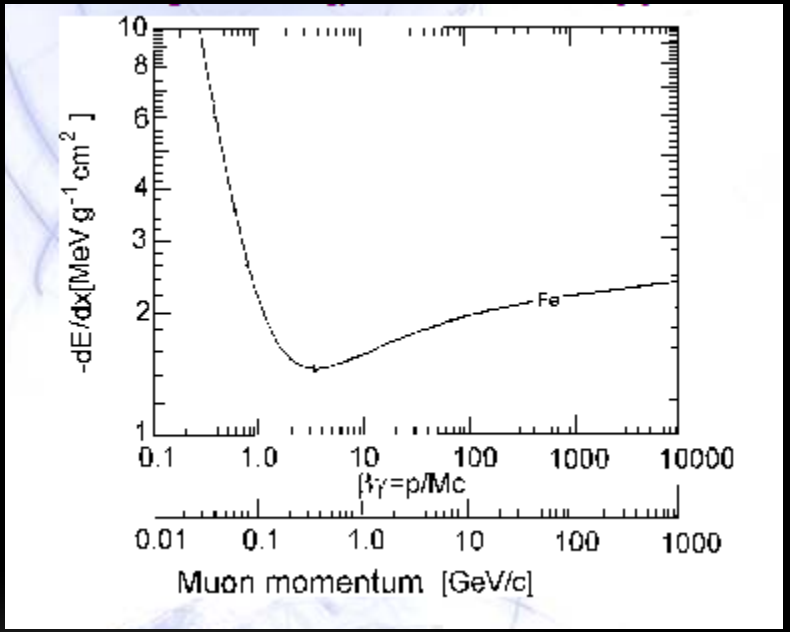
[2] H. Schultz-Coulon, “Calorimetry I: Electromagnetic Calorimeters,” Univ. Heidelberg, Heidelberg, DE, Rep. 2014.

[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

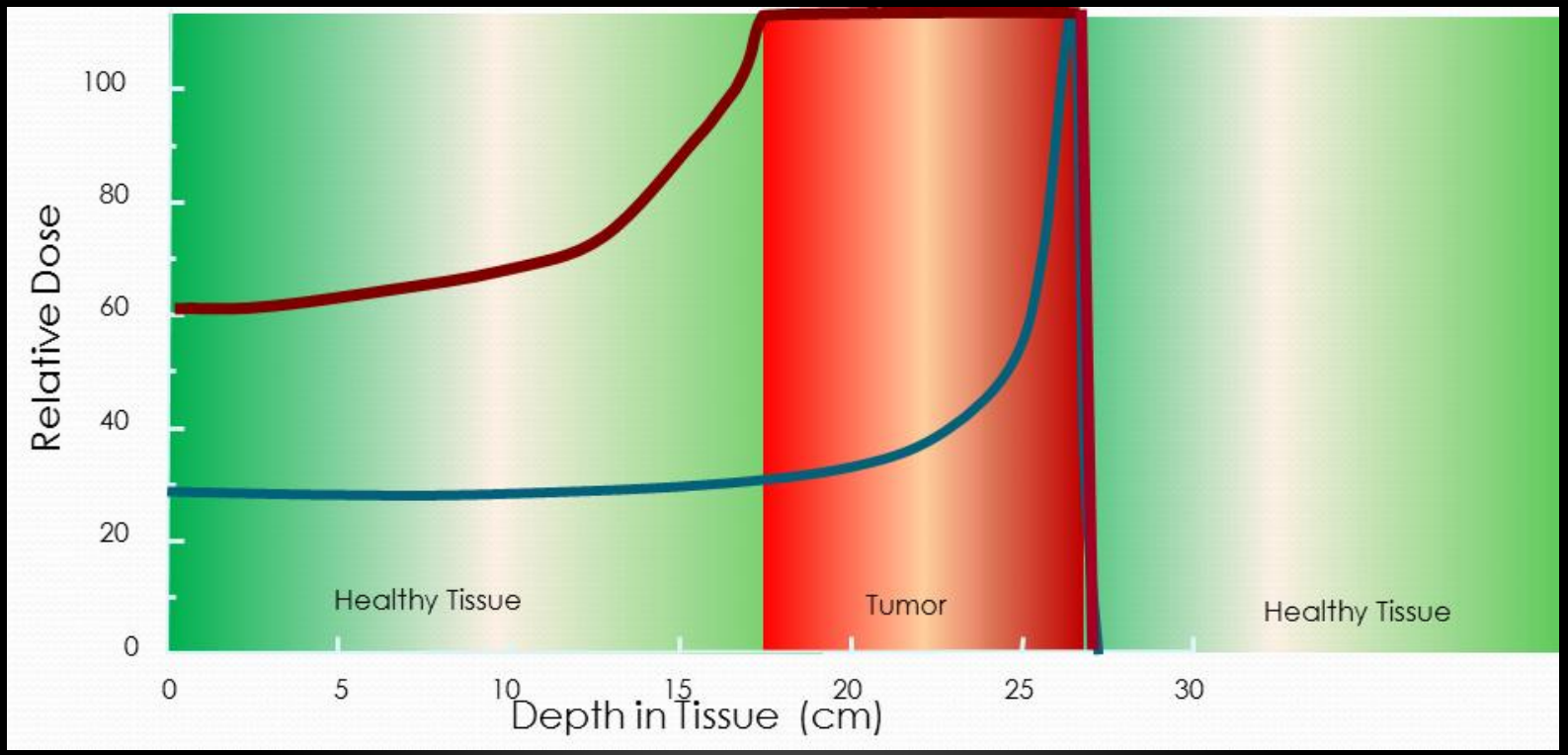
EXAMPLE IN MEDICINE: PROTON THERAPY

- Bethe-Bloche equation describes the stopping power as a function of the change in energy of the bean per change in distance and
- $-\frac{dE}{dx} = Kz^2 \frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_e c^2\beta^2\gamma^2 T_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right]$
- $K \equiv 4\pi N_A r_e^2 m_e c^2/A$



EXAMPLE IN MEDICINE: PROTON THERAPY

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

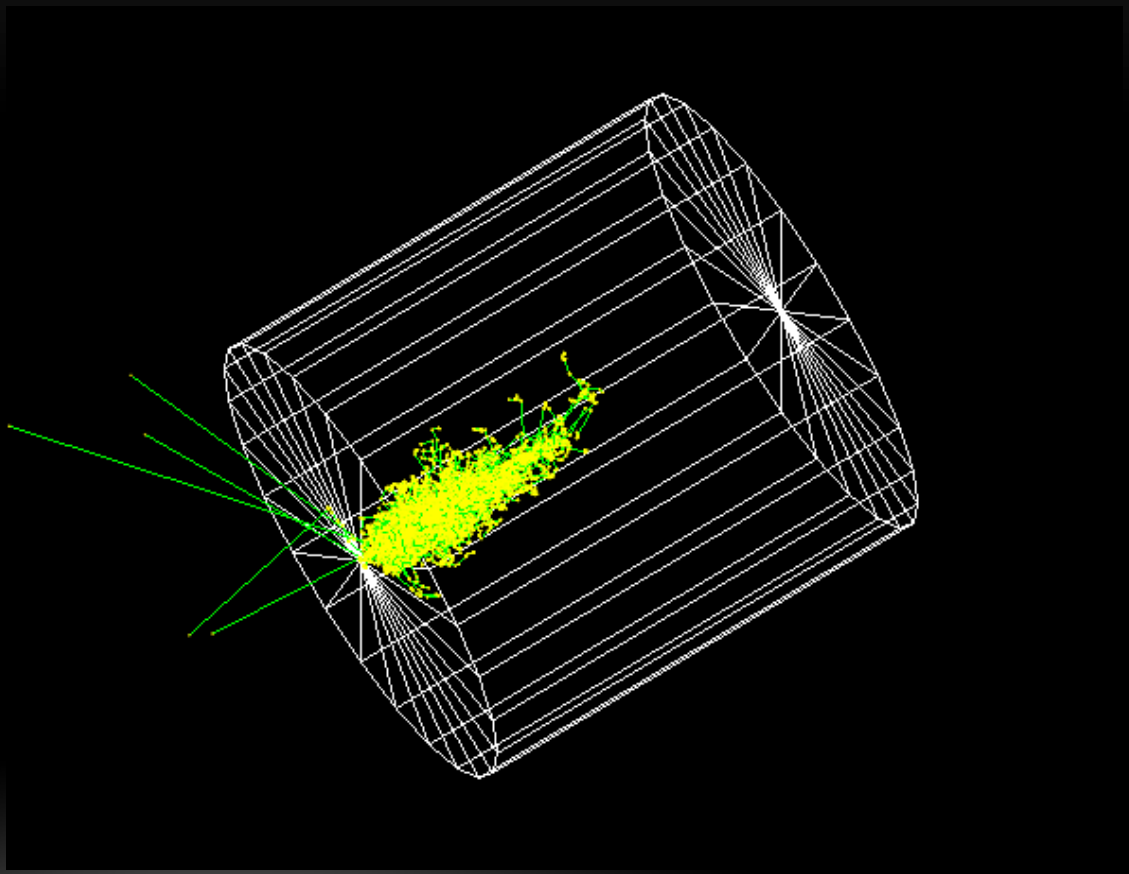


LIQUID ARGON

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

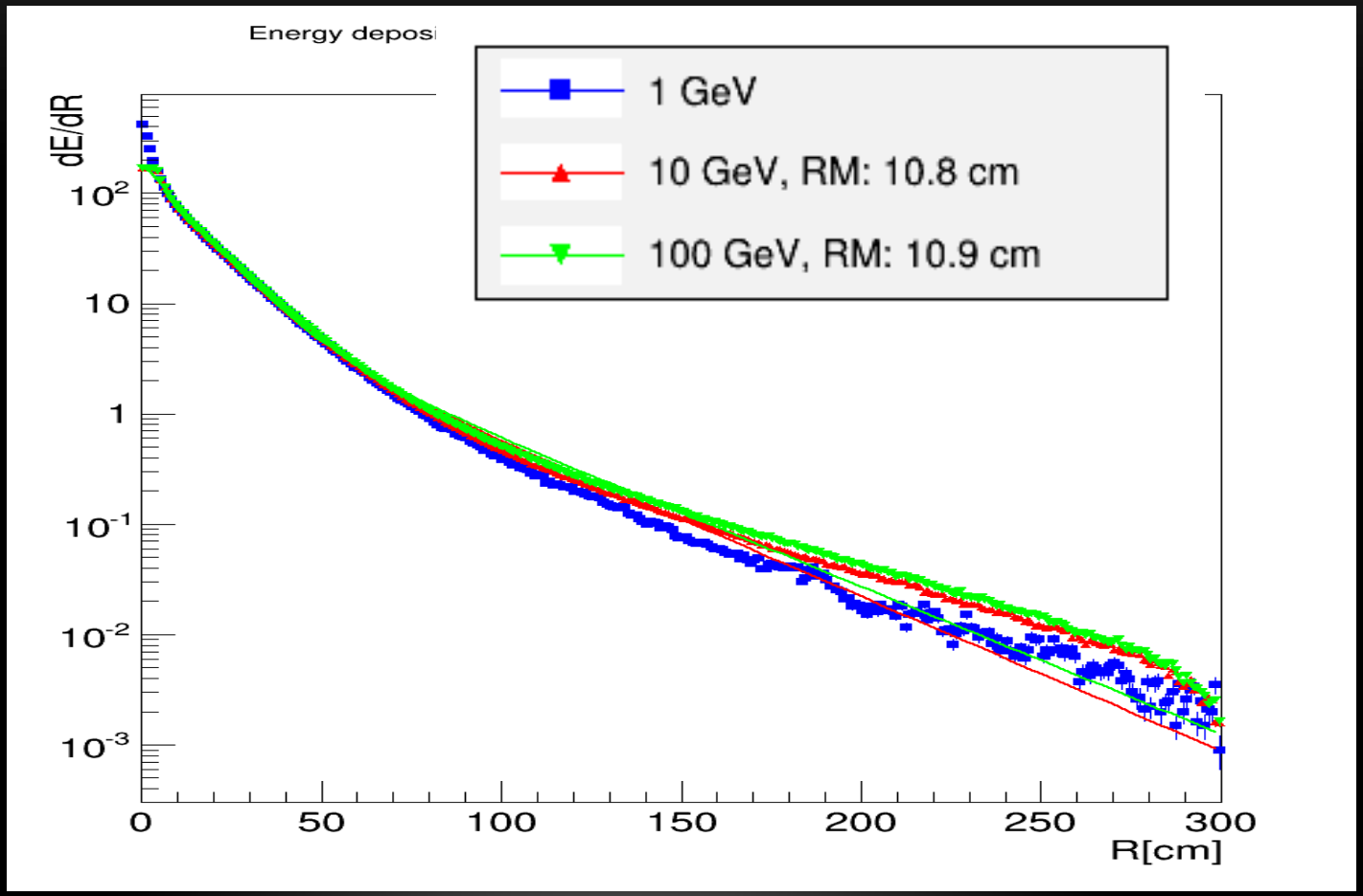


TRANSVERSE ELECTROMAGNETIC SHOWER PROFILE

- 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.

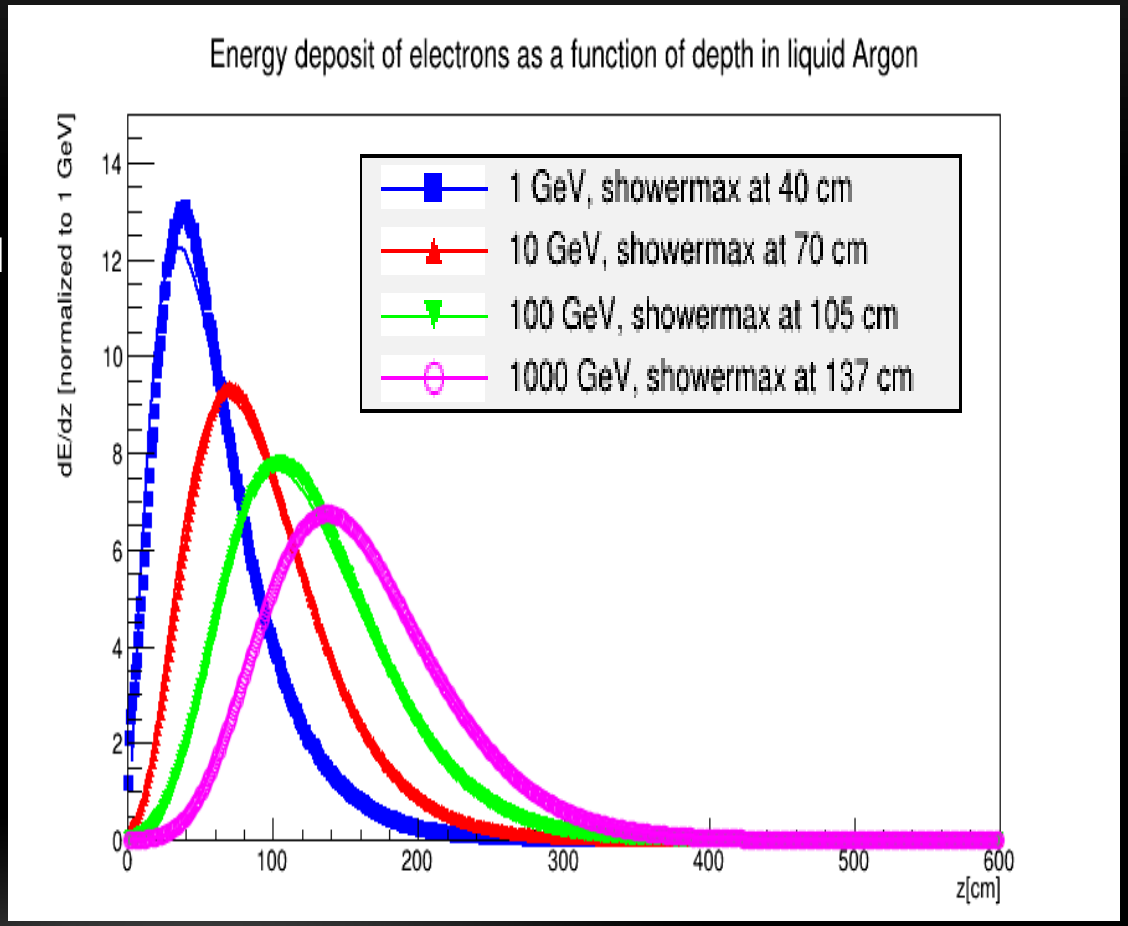
TRANSVERSE ELECTROMAGNETIC SHOWER PROFILERADIUS (M_R)

- 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})