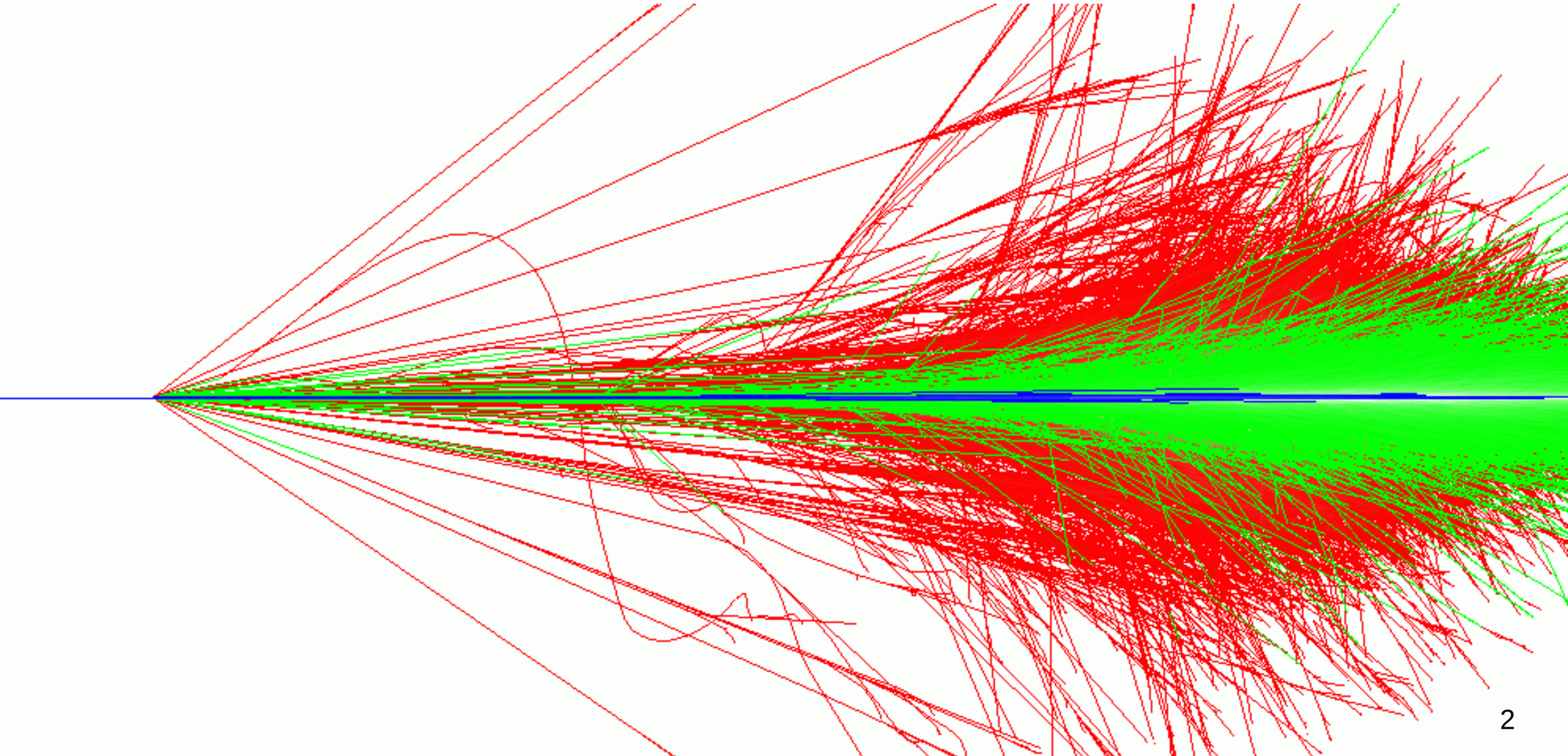
More about the Geant4 Toolkit

Third African School of Physics
Aug 2014

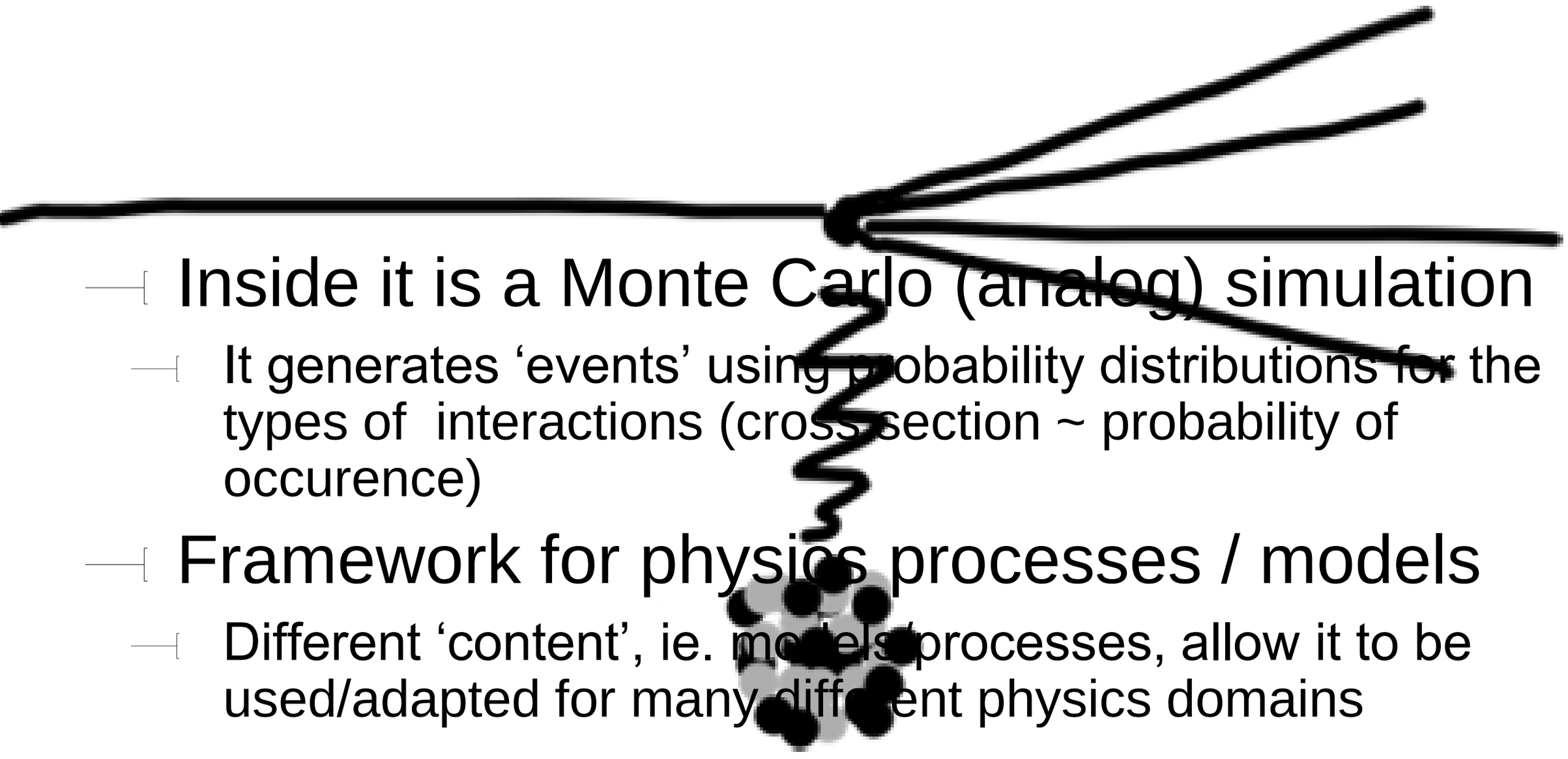
J. Apostolakis (CERN)

Some material **adapted** from talk by **Andrea Dotti** (now SLAC- before CERN or Geant4 Associates Intl) at the Second African School of Physics, August 2012

What is under the ‘hood’ ?

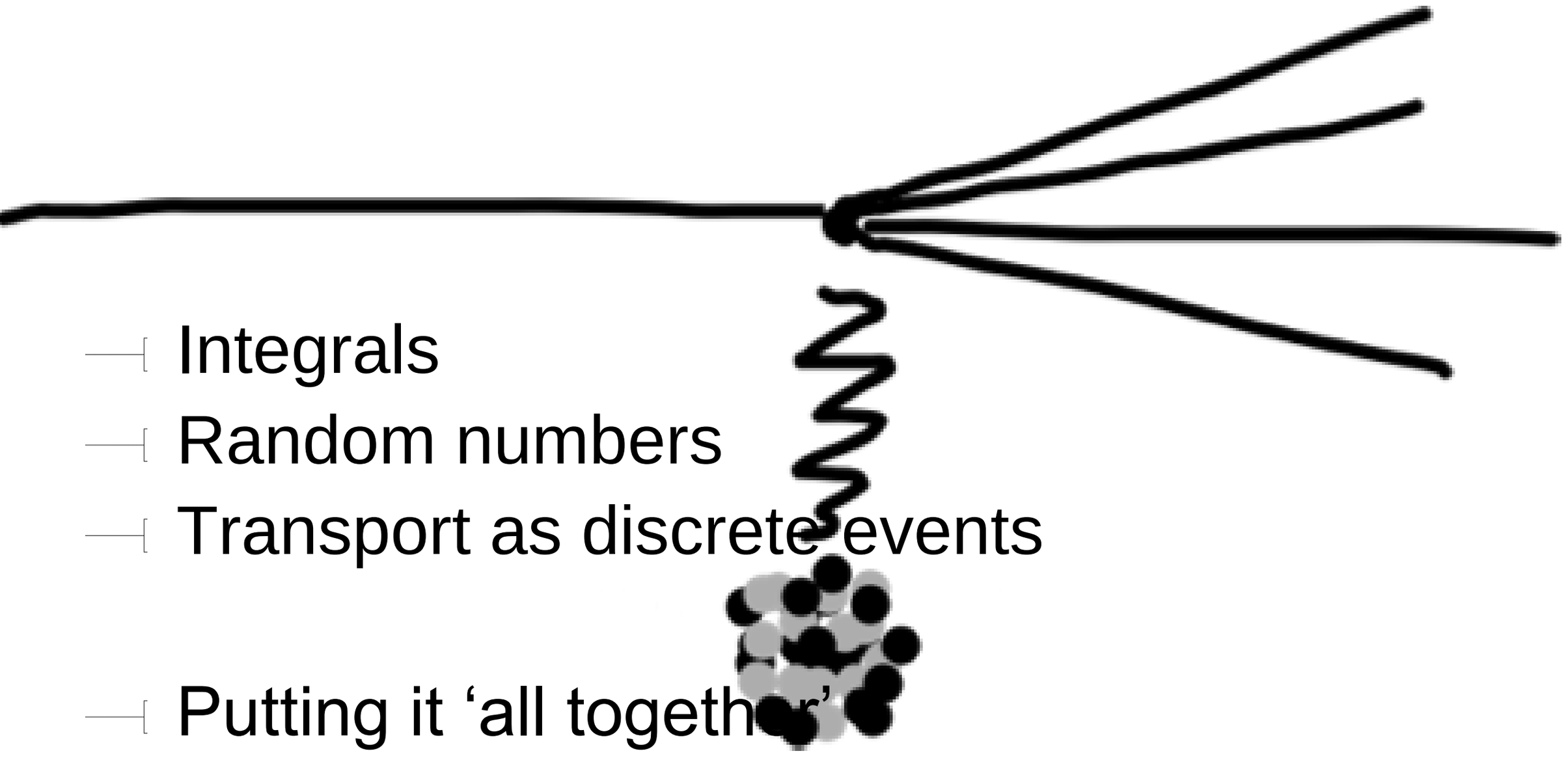


How does Geant4 work?



- Inside it is a Monte Carlo (analog) simulation
  - It generates ‘events’ using probability distributions for the types of interactions (cross section ~ probability of occurence)
- Framework for physics processes / models
  - Different ‘content’, ie. models / processes, allow it to be used/adapted for many different physics domains

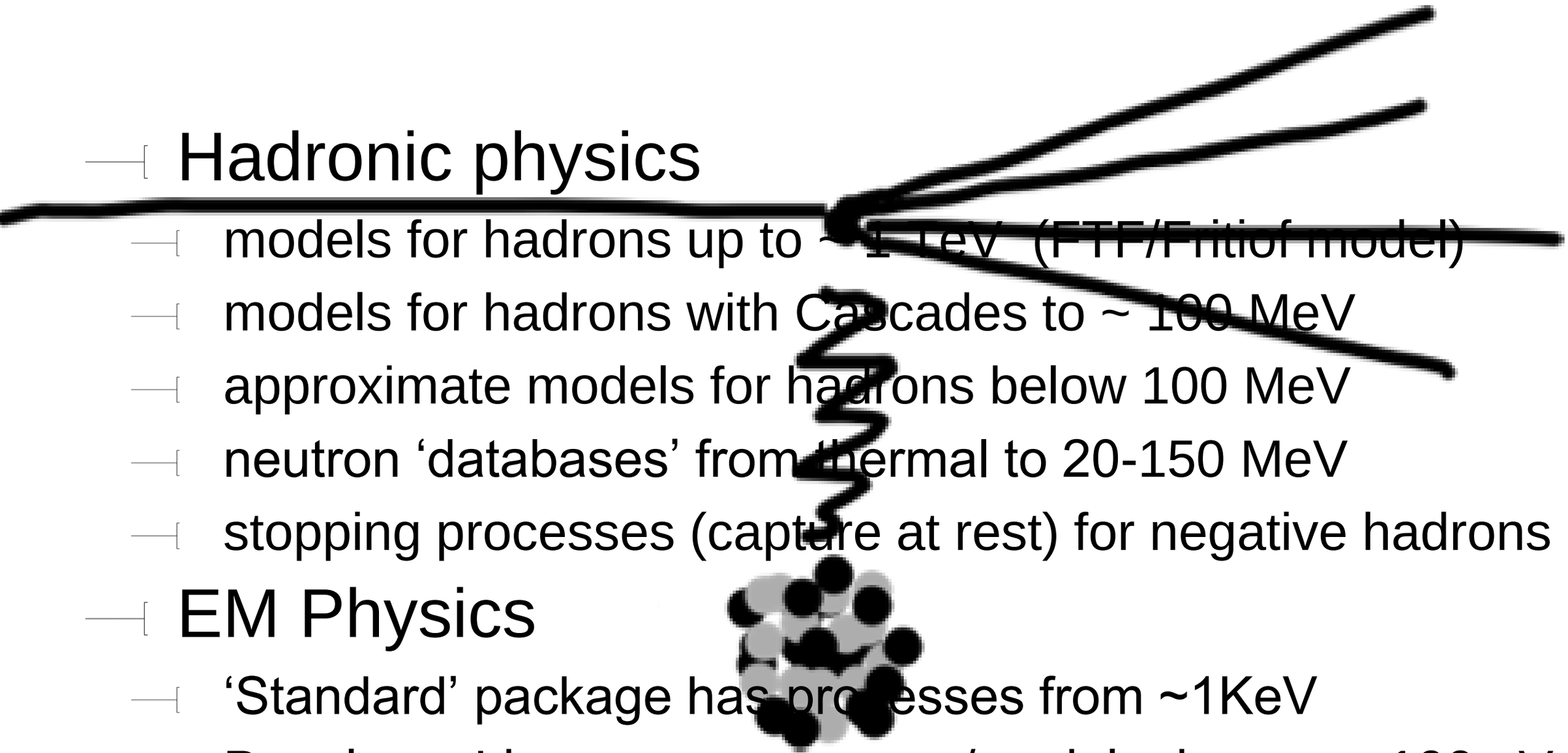
What is Monte Carlo?



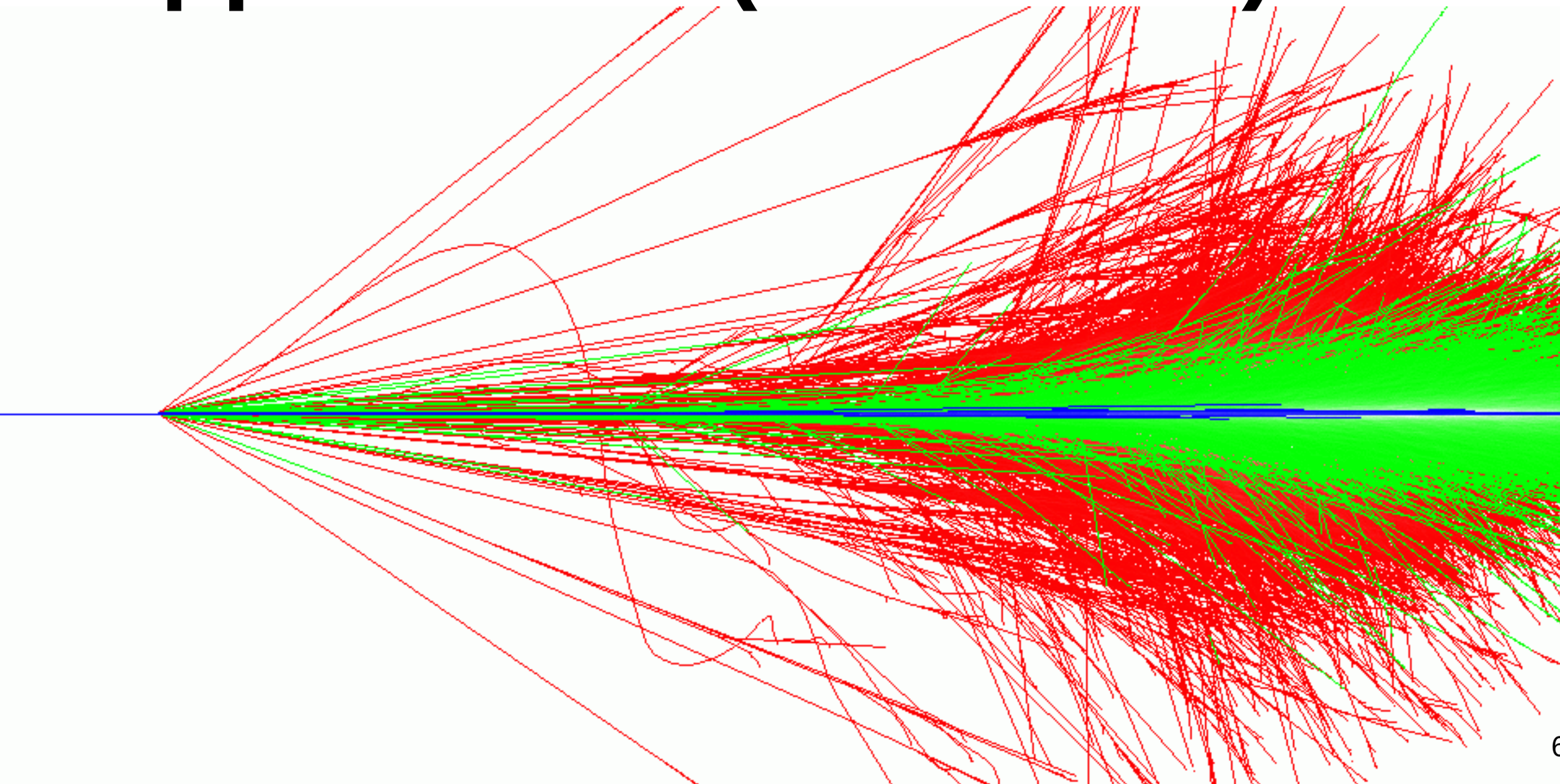
- Integrals
- Random numbers
- Transport as discrete events
- Putting it ‘all together’

Range of applicability

- Hadronic physics
  - models for hadrons up to ~ 1 TeV (FTF/Fritiof model)
  - models for hadrons with Cascades to ~ 100 MeV
  - approximate models for hadrons below 100 MeV
  - neutron ‘databases’ from thermal to 20-150 MeV
  - stopping processes (capture at rest) for negative hadrons
- EM Physics
  - ‘Standard’ package has processes from ~1KeV
  - Penelope, Livermore processes/models down to ~100 eV
  - G4DNA: models for specific materials, to a few eV



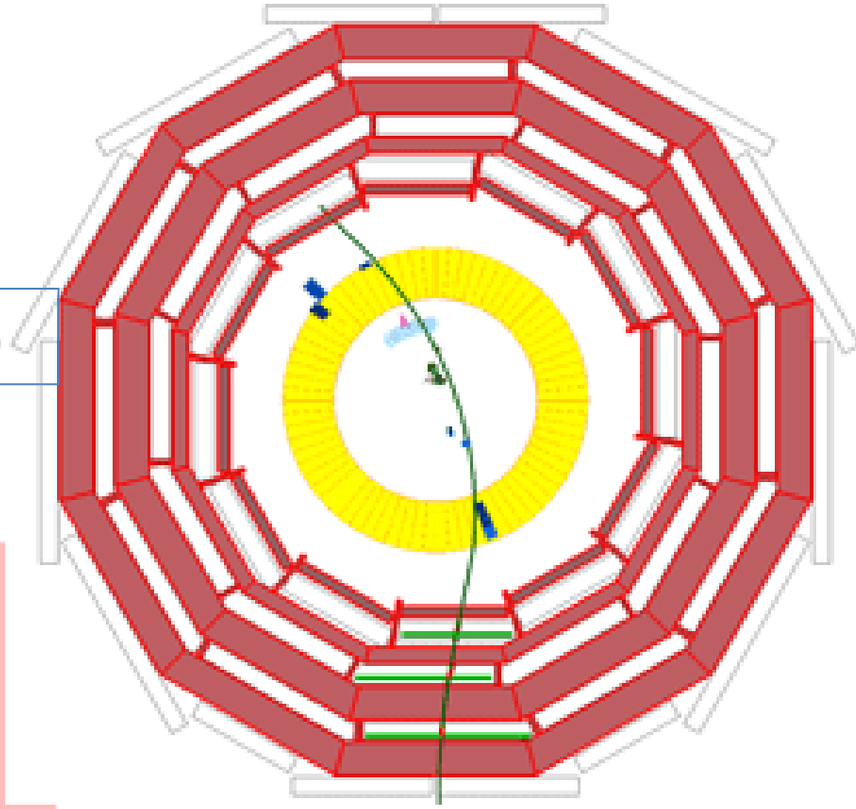
Applications (continued)



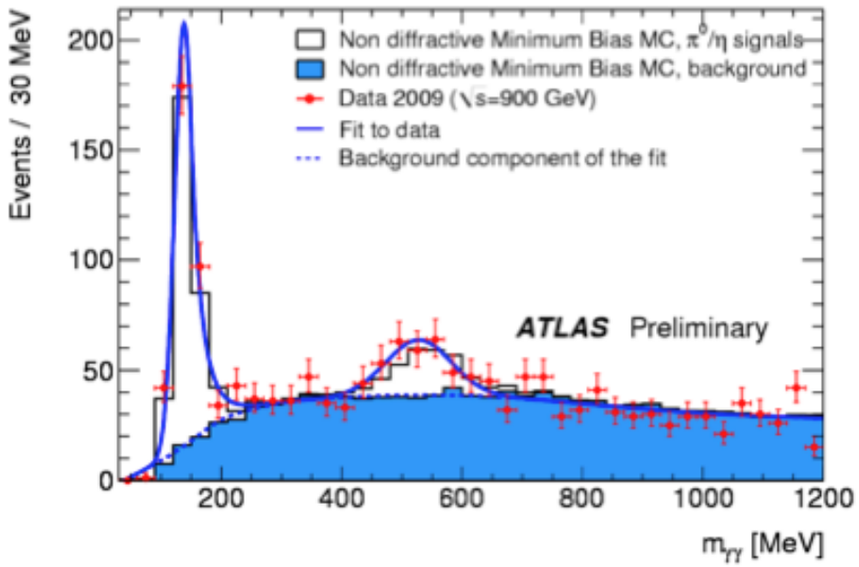
Geant4 has been successfully employed for

- Detector design
- Calibration / alignment
- First analyses

T. LeCompte (ANL)



GEANT4 Comparisons with the Calorimeters



Invariant mass of pairs of well-isolated electromagnetic clusters.

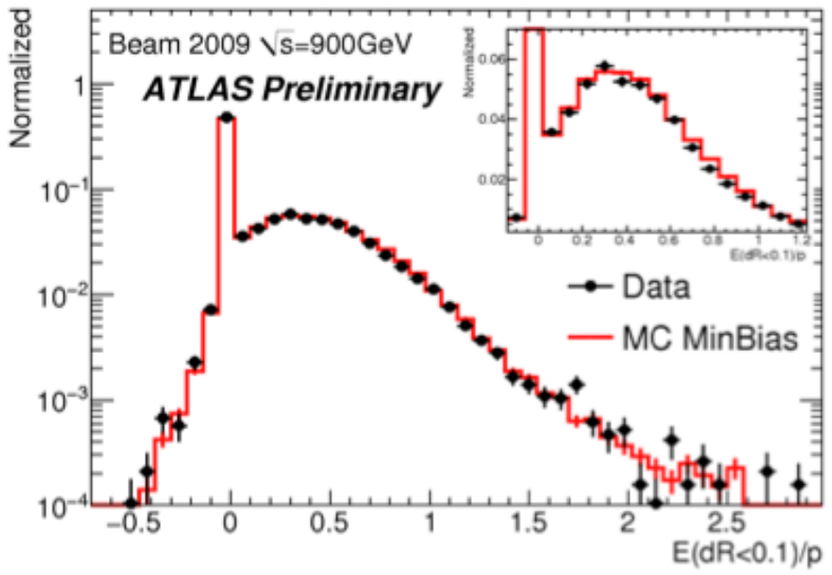
The π^0 mass is within 0.8 ± 0.6% of expectations.

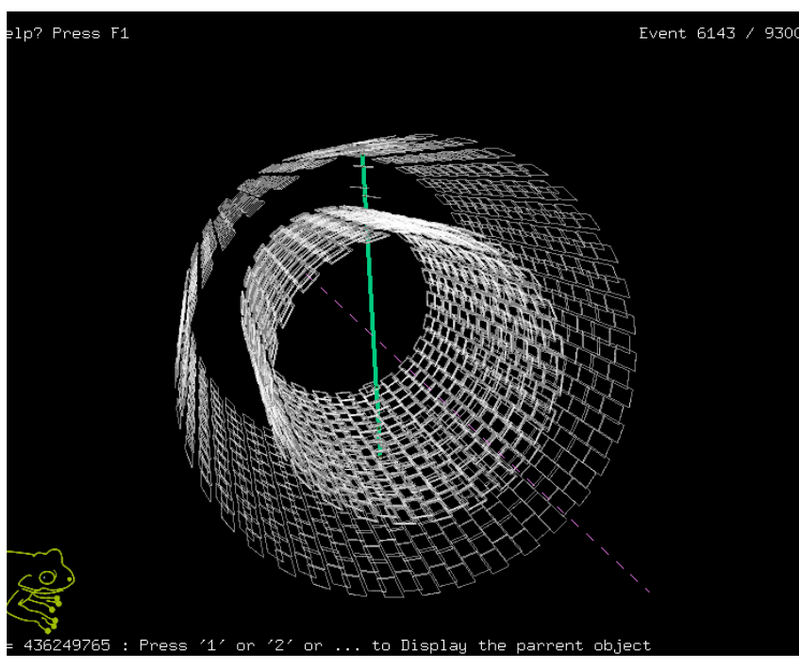
The η^0 mass is within 3 ± 2% of expectations.

The detector uniformity is better than 2%.

Response of the calorimeter to single isolated tracks. To reduce the effect of noise, topological clusters are used in summing the energy.

This plot agreed better than we ever expected. (I sent the student who made it back to make sure that they didn't accidentally compare G4 with G4.

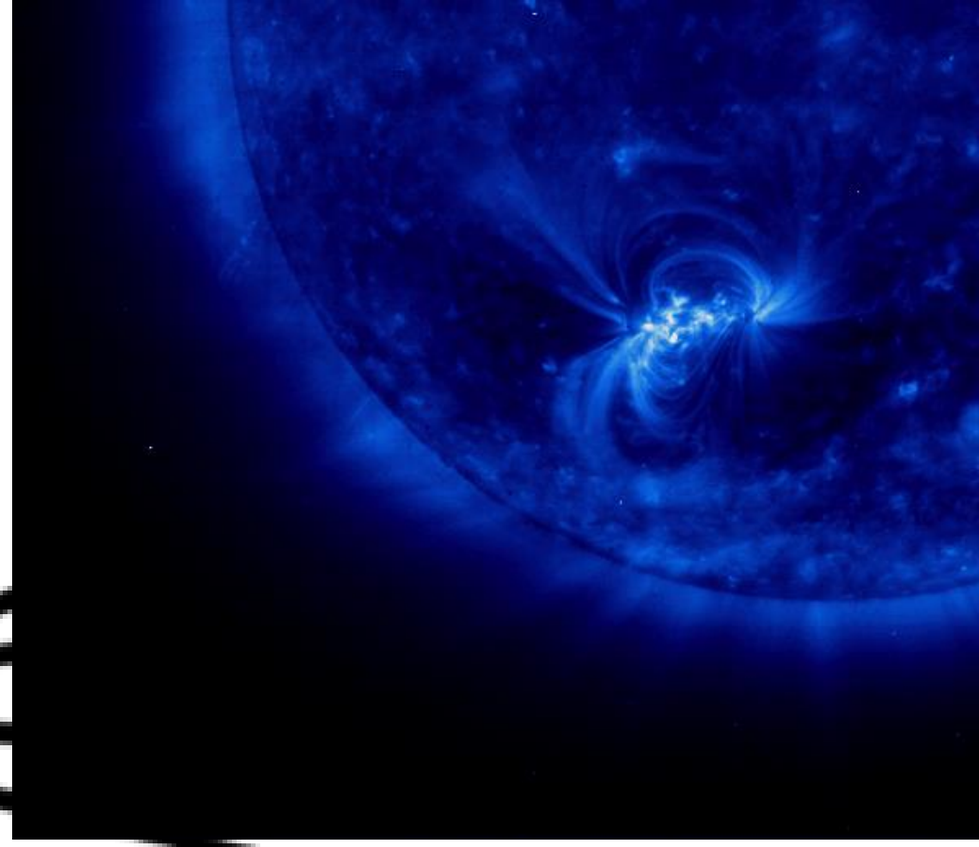


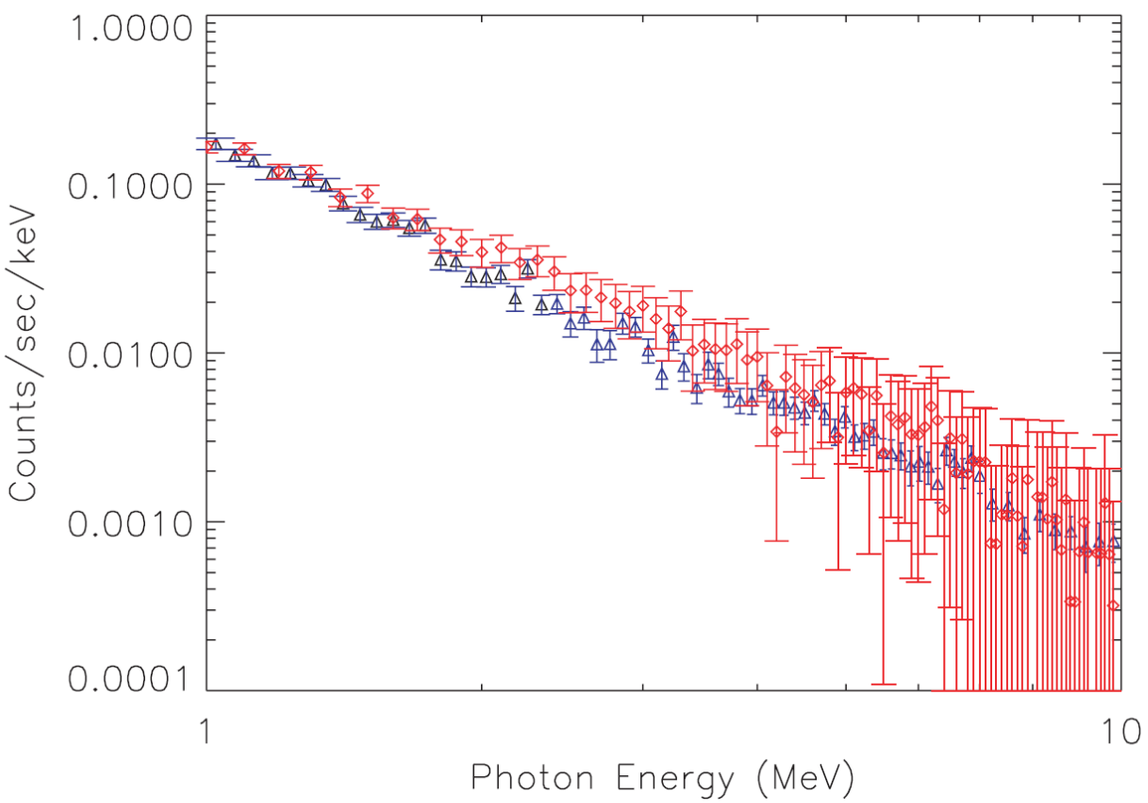


Figures from CMS

Solar event gamma-rays

- Electron Bremsstrahlung – induced gammas in solar flares
- Compton back-scattering
- → observable gamma-ray spectrum
- much softer than predic simple





Effects of Compton scattering on the Gamma Ray Spectra of Solar flares

Jun'ichi KOTOKU
National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo 181-8588, JAPAN
junichi.kotoku@nao.ac.jp
Kazuo MAKISHIMA[1] and Yukari MATSUMOTO[2]
Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo, 113-0022
and
Mitsuhiro KOHAMA, Yukikatsu TERADA and Toru TAMAGAWA
RIKEN (Institute of Physical and Chemical research), Wako-shi, Saitama
[1]*Also at RIKEN*
[2]*Present address: Mitsubishi Electric Co., Ltd.*

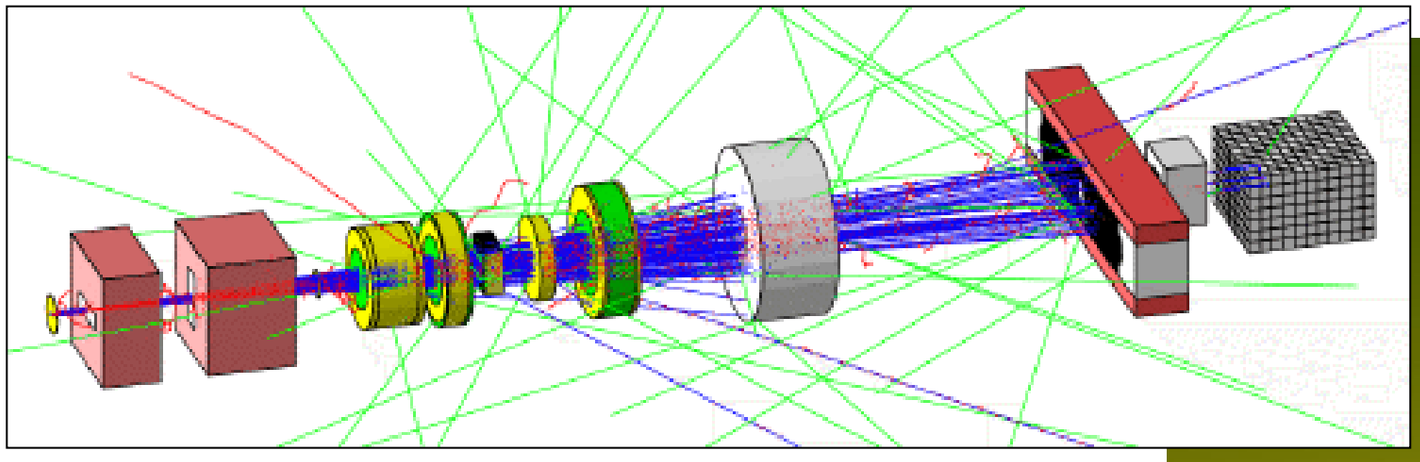
(Received ; accepted)

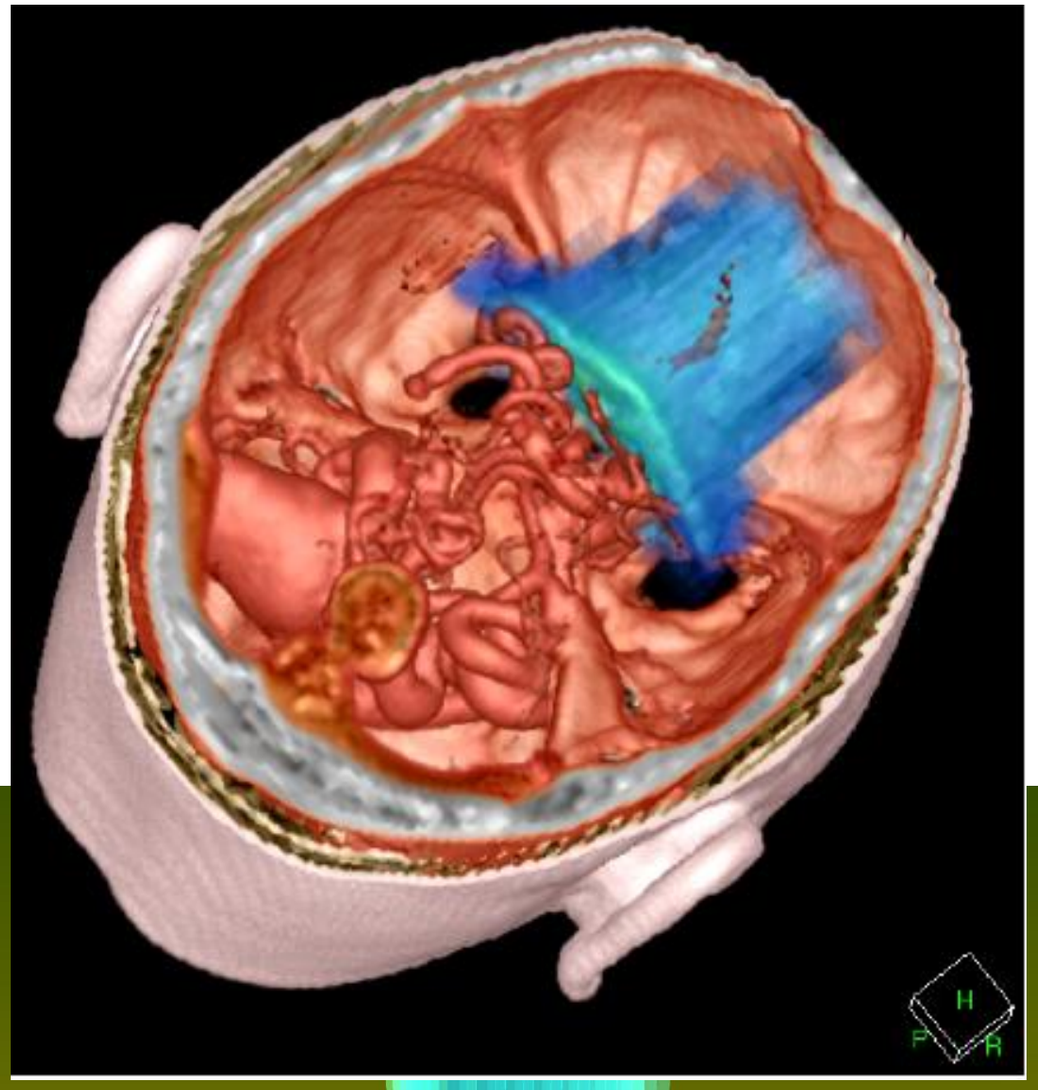
Abstract

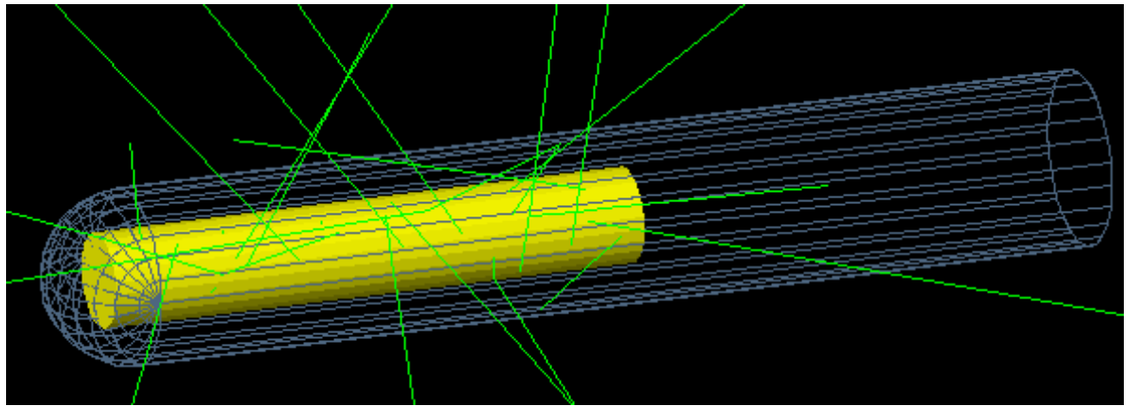
Using fully relativistic GEANT4 simulation tool kit, the transport of energetic electrons generated in solar flares was Monte-Carlo simulated, and resultant bremsstrahlung gamma-ray spectra were calculated. The solar atmosphere was ap-

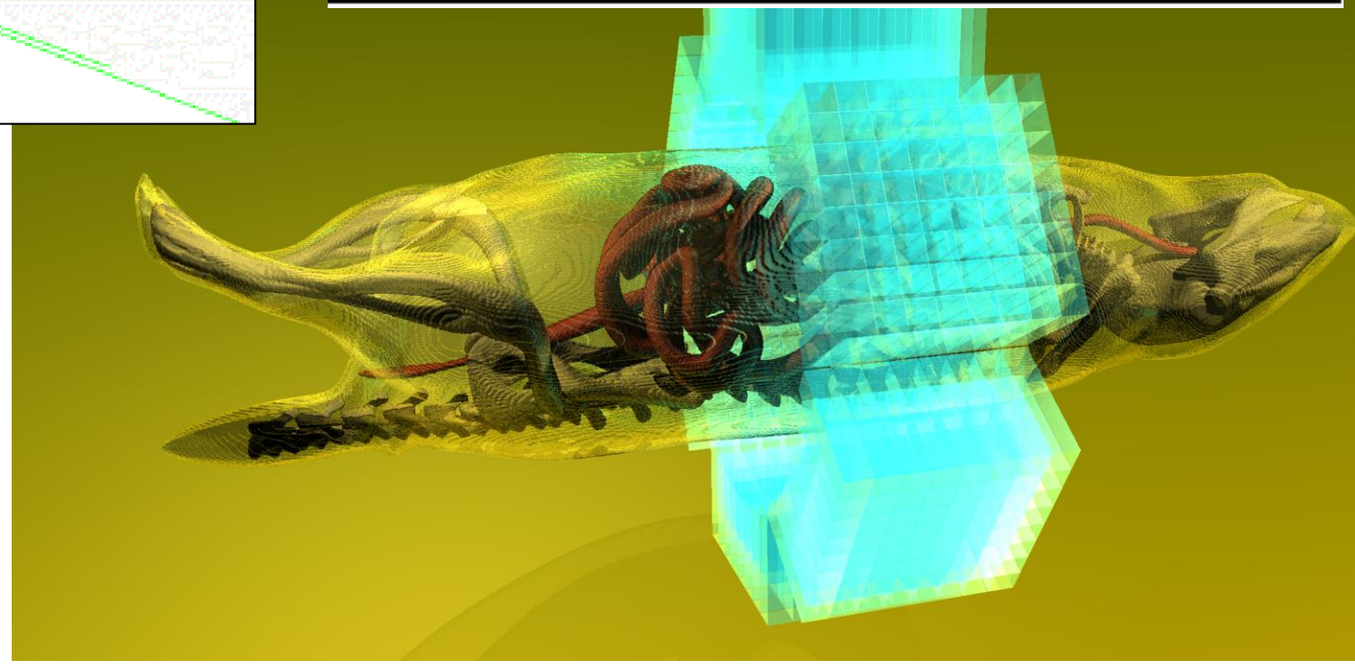
Geant4 @ Medical Science

- Four major use cases
  - Beam therapy
  - Brachytherapy
  - Imaging



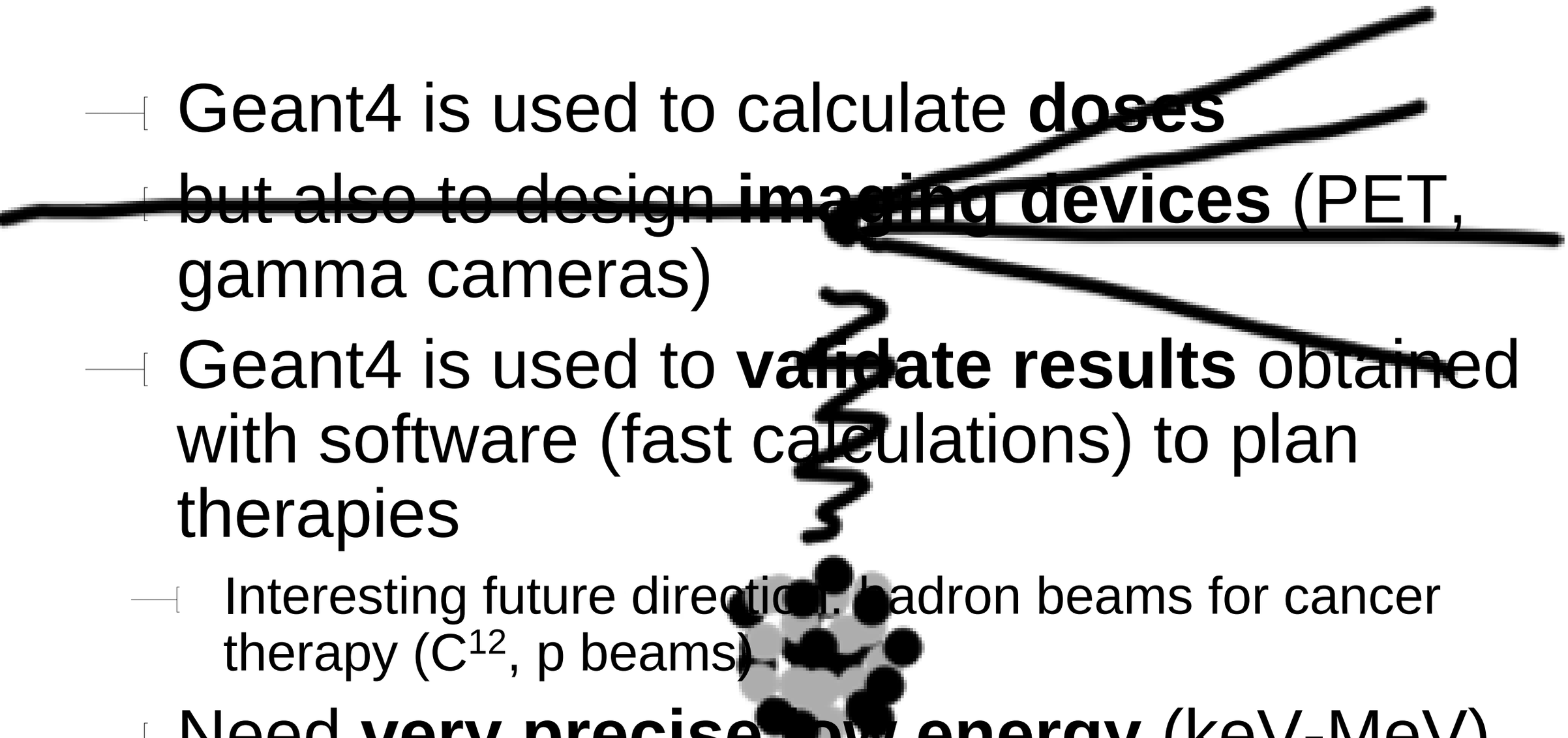




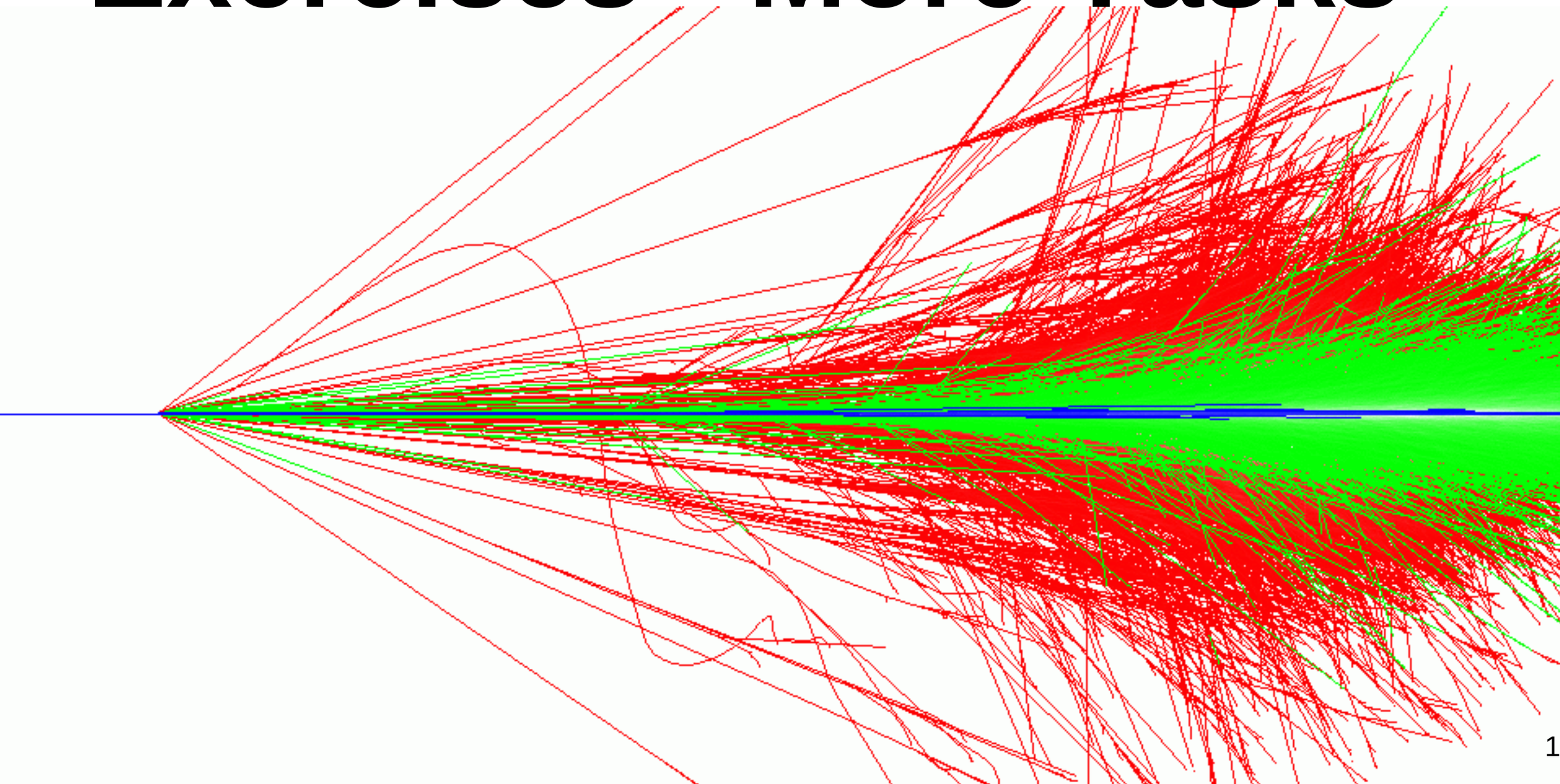


Medical Physics

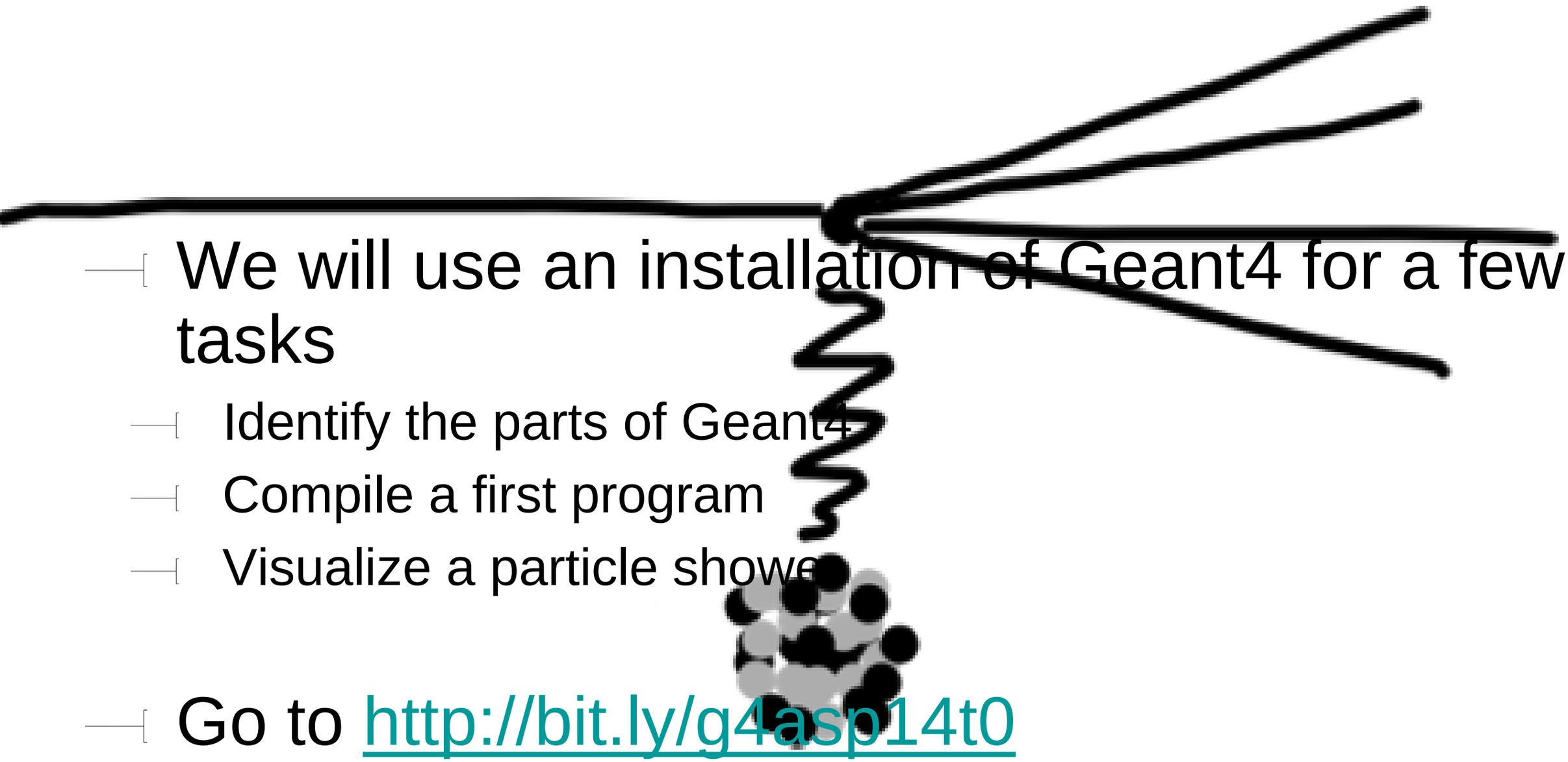
- Geant4 is used to calculate **doses**
- but also to design **imaging devices** (PET, gamma cameras)
- Geant4 is used to **validate results** obtained with software (fast calculations) to plan therapies
  - Interesting future direction: hadron beams for cancer therapy (C^{12}, p beams)
- Need **very precise low energy** (keV-MeV) em physics description (at the opposite of the spectra with compared to HEP)



Exercises - More Tasks

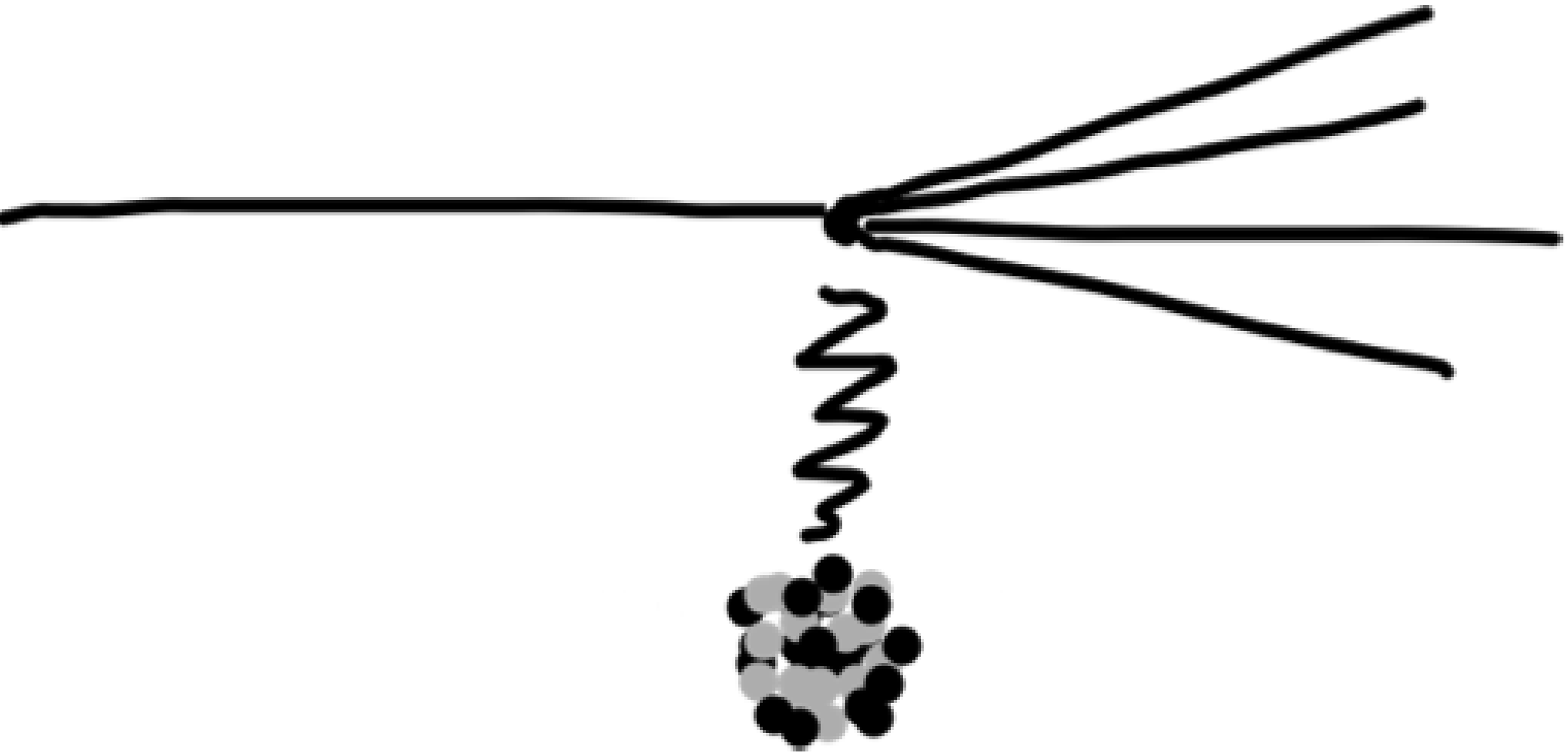


Practical exercises (cont.)

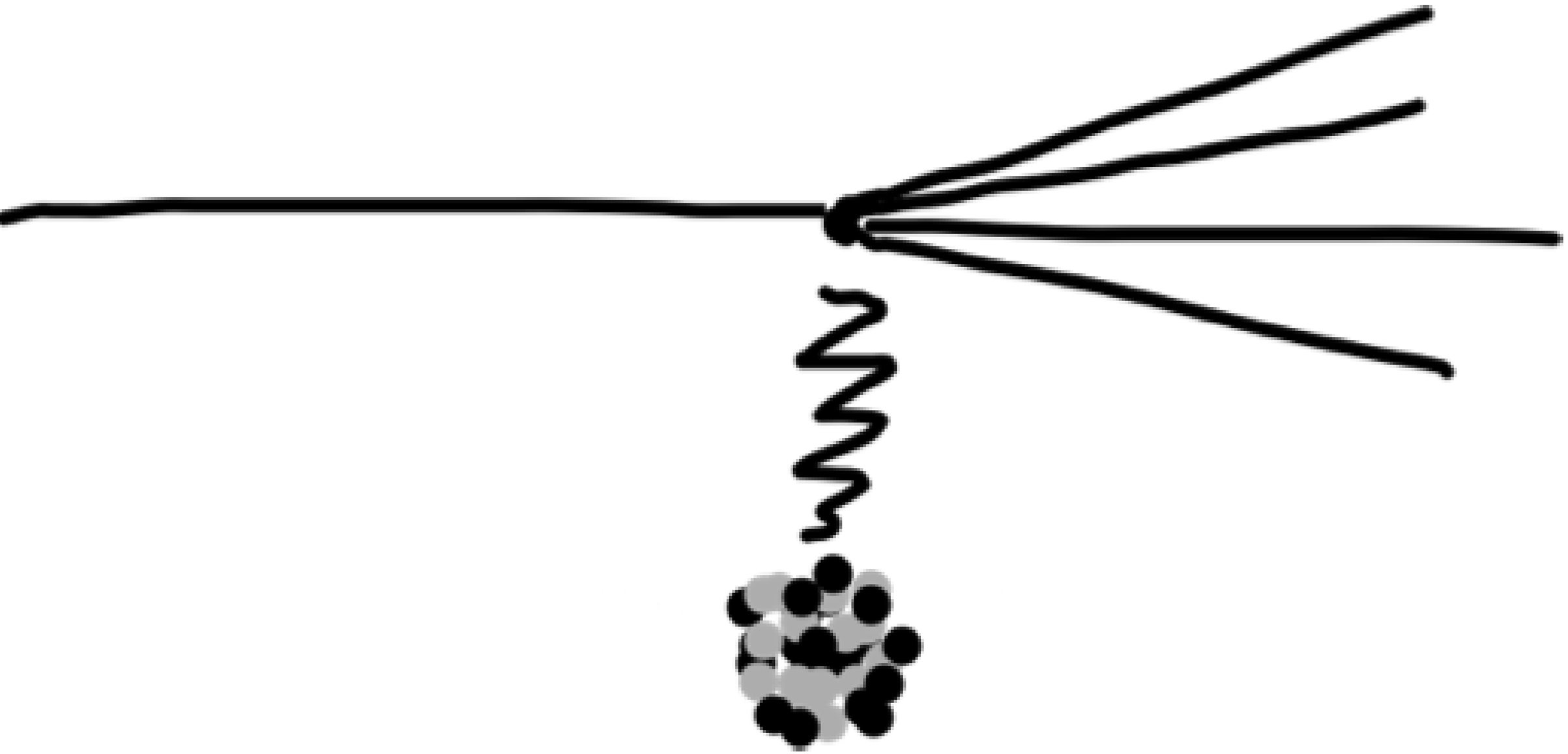


- We will use an installation of Geant4 for a few tasks
  - Identify the parts of Geant4
  - Compile a first program
  - Visualize a particle shower
- Go to http://bit.ly/g4asp14t0

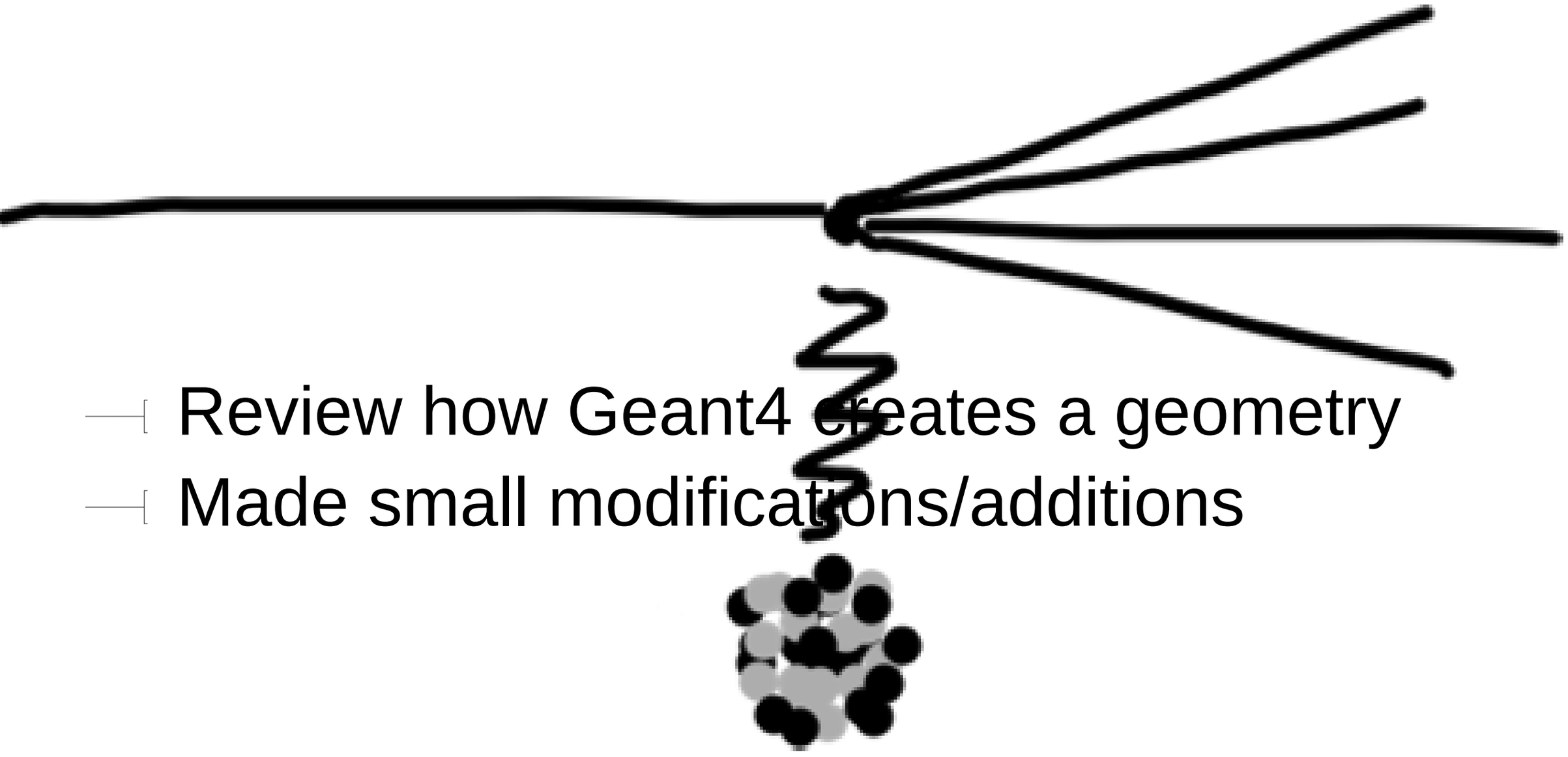
Task 1 - revisited



Task 2 - scoring

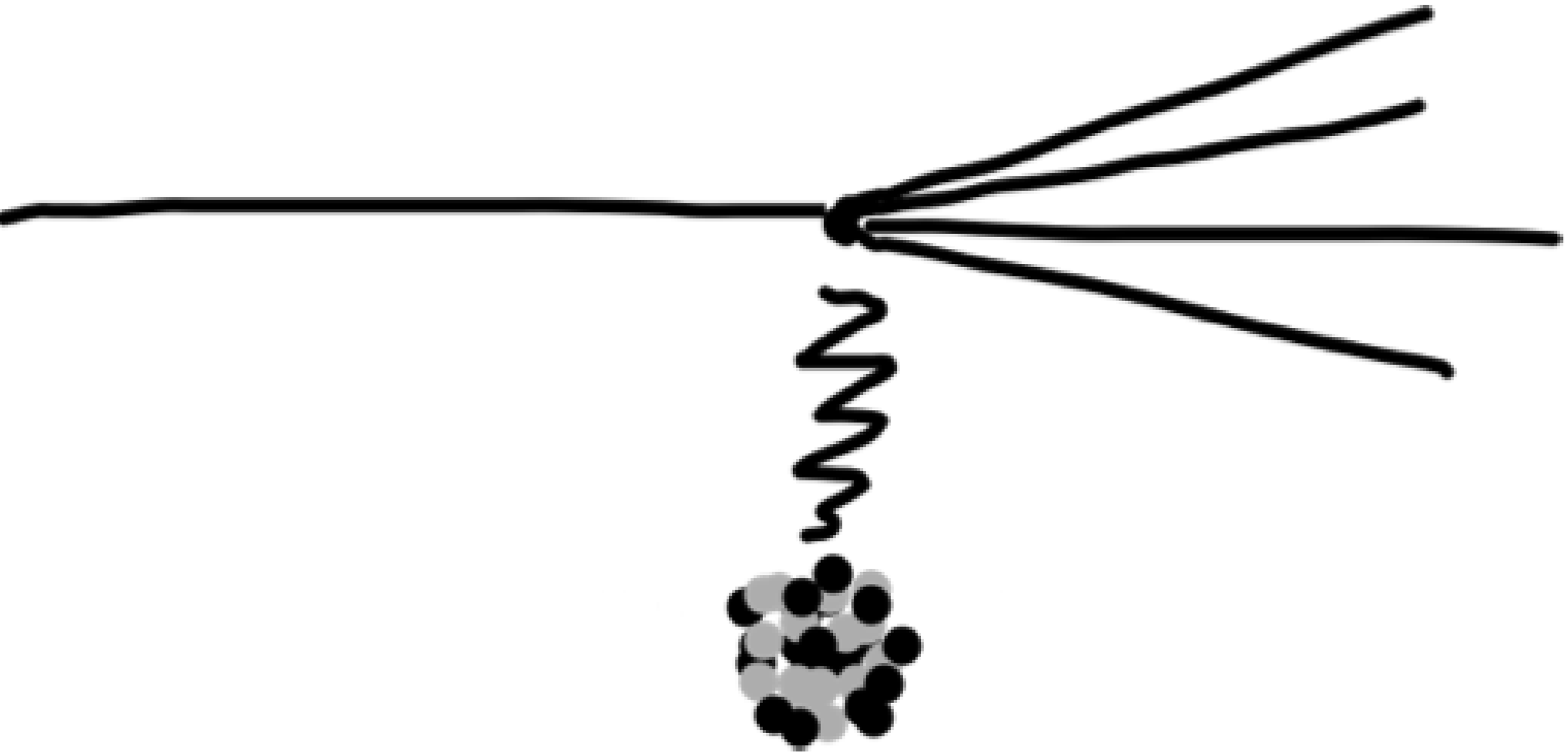


Task 3 - Geometry



- Review how Geant4 creates a geometry
- Made small modifications/additions

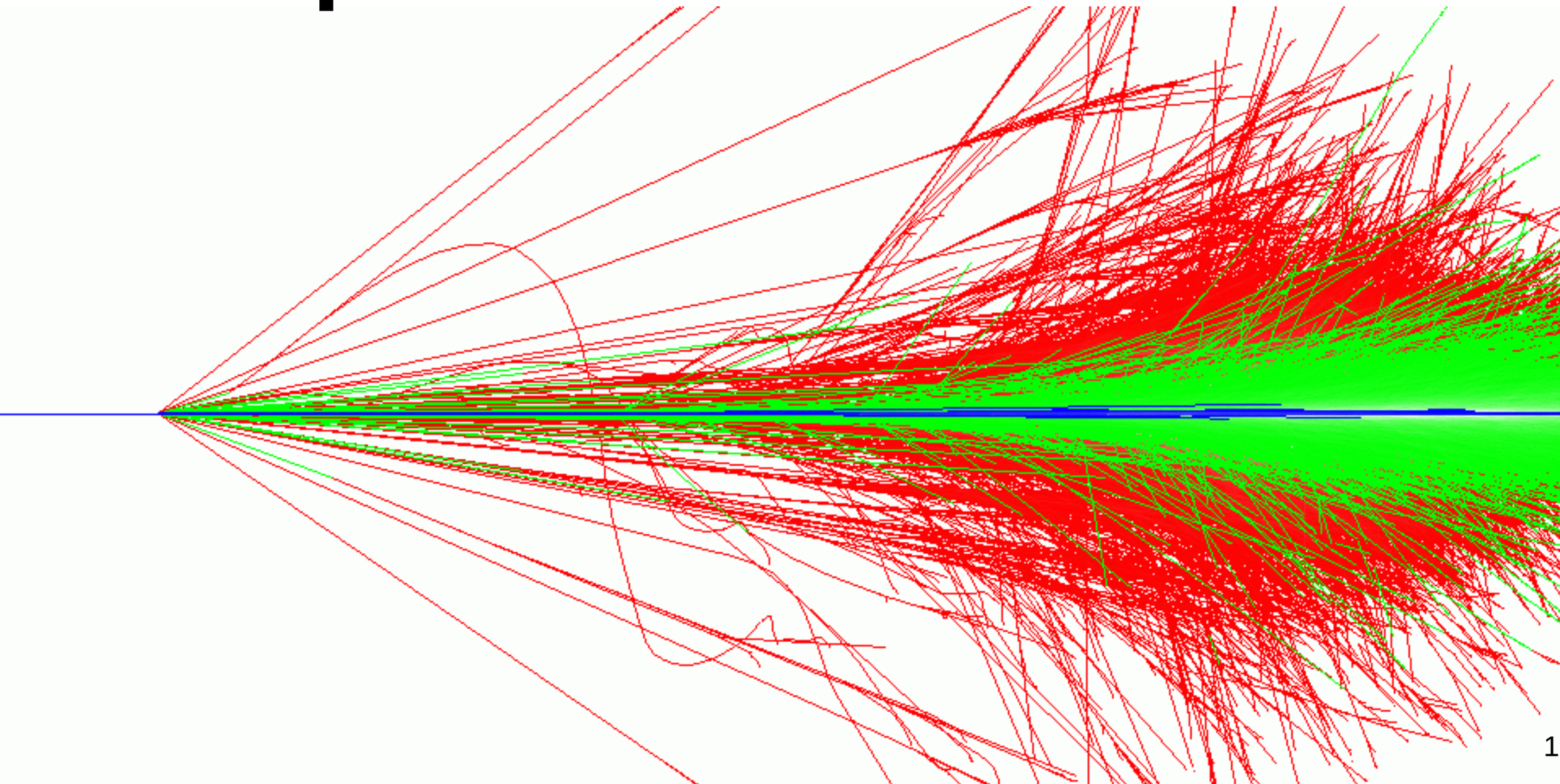
Task 4 - Visualisation



Task 5 - Installation

- We will follow the standard method of installing Geant4
  - Geant4 Installation Guide - building from source code
    - Install cmake for your system
    - Get the source code
    - Build (compile) Geant4
  - Alternative installation - if pre-built binaries exists for your OS
    - Download source and binaries for your system
- Small modification:
  - you will get the (larger) files that need to be downloaded on a USB key

Comparison with test beam



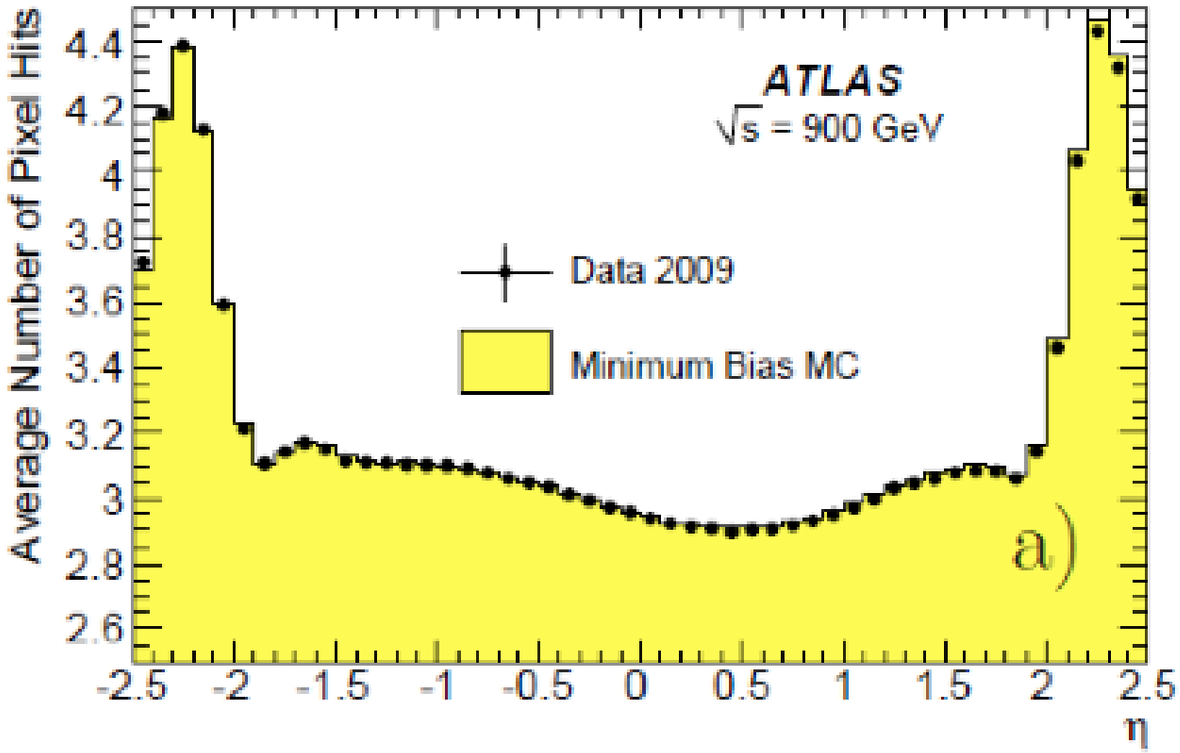
Test-beam summary (G4 9.4.p01)

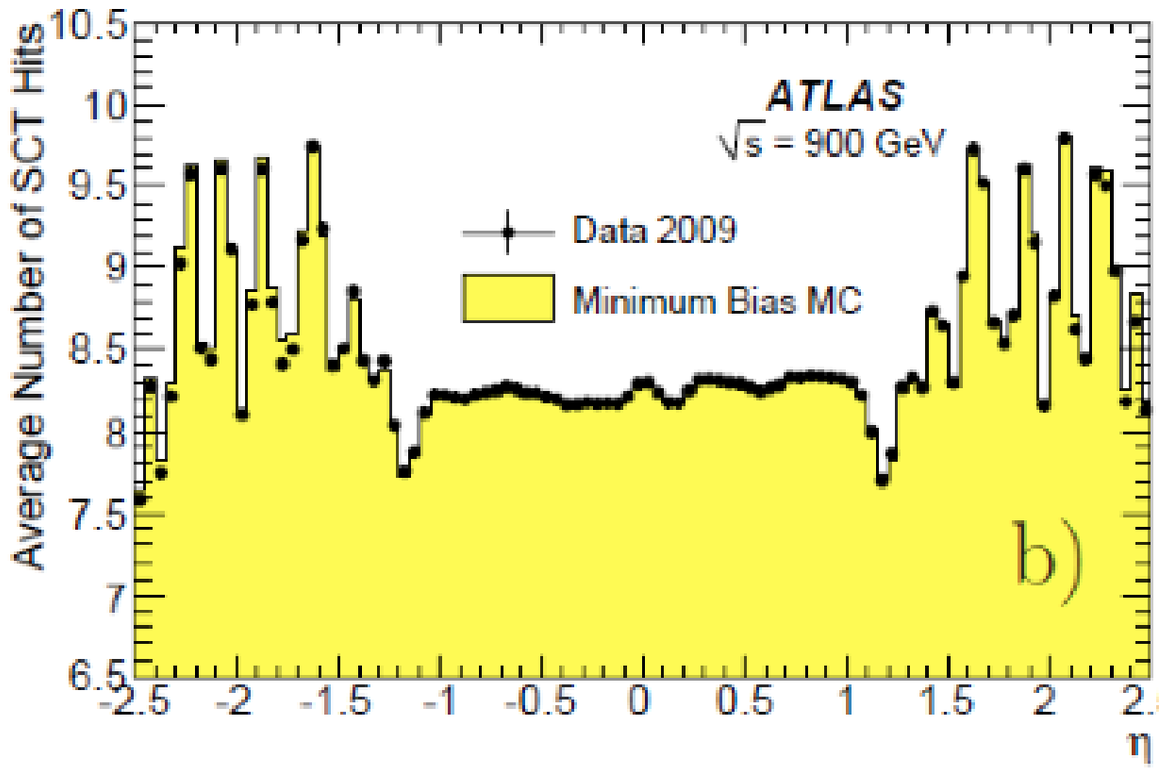
Status Sept-Oct 2011

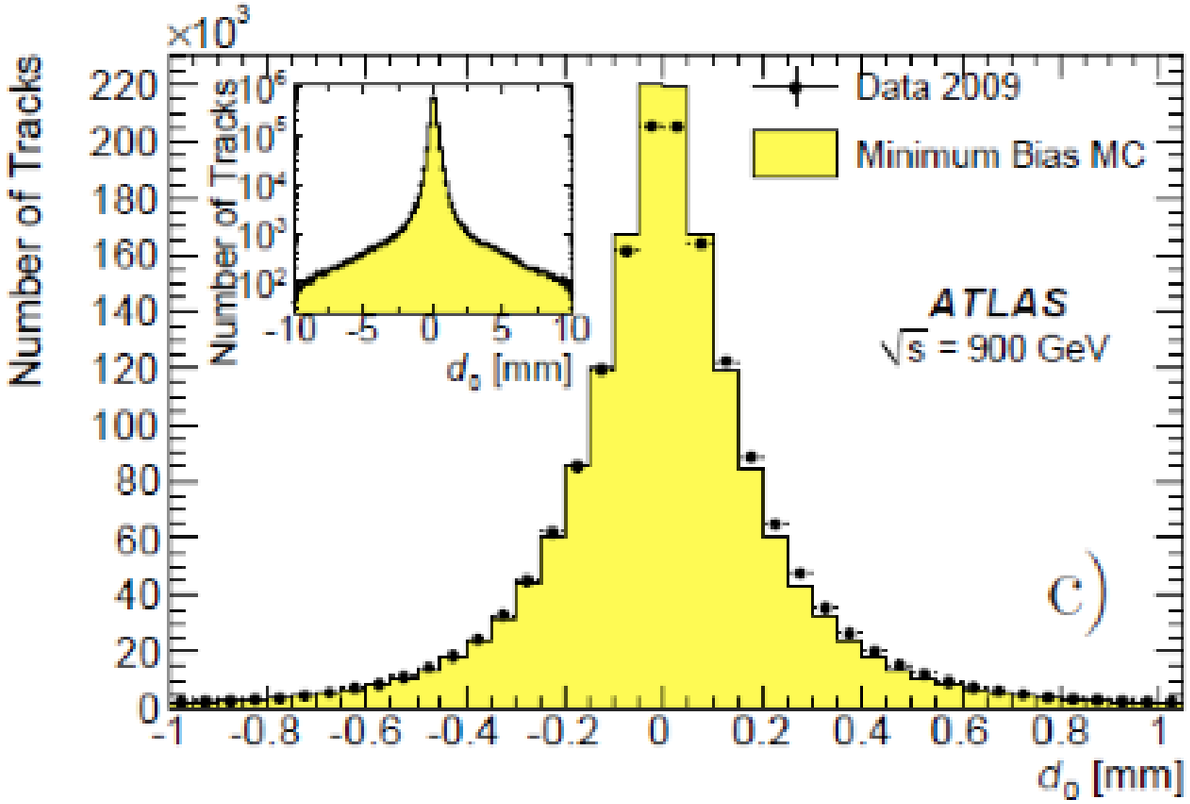
	Response	**Resolution**	**Smoothness**	**Lateral Shape**	**Longitudinal Shape @10λ**	**Peculiarities, comments**
QGSP_BERT	+(1-3)%	-(5-10)%	Δ~5%@10GeV	π,p: -(10-20)%	π: -10% p: -20%	Extensive use of LHEP
FTFP_BERT **QGSP_FTFP_BERT**	**+(0-5)%** **(***)**	**-(3-7)%**	**Δ~0**	**π: -(10-20)%** **p: -(3-10)%**	**π: +10%** **p: +(10-20)%**	**anti-nucleons, hyperons via CHIPS(*), no LHEP**
CHIPS	+(5-10)%	-(10-20)%	Δ~0	π: -(3-10)% p: -(10-20)%	π: -10% p: -20%	anti-nucleons, hyperons, single model
FTF_BIC(**)	+(3-5)%	-(2-6)%	Several irregularities	-	π: +10%	Implements re-scattering at high E, Extensive use of LHEP

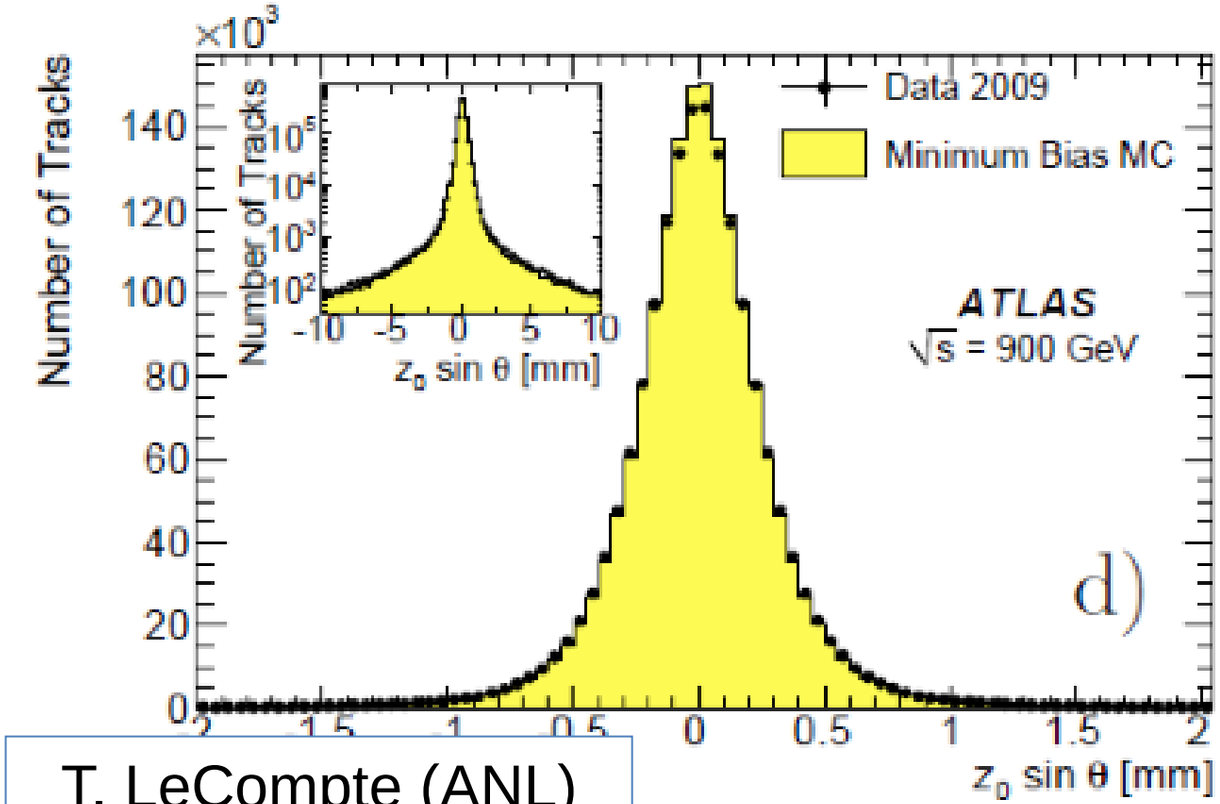
(*): Native FTF model under testing
(**): Much less tested at LHC
(***): Lower limit: CMS; Upper limit ATLAS

Data and simulation agreements









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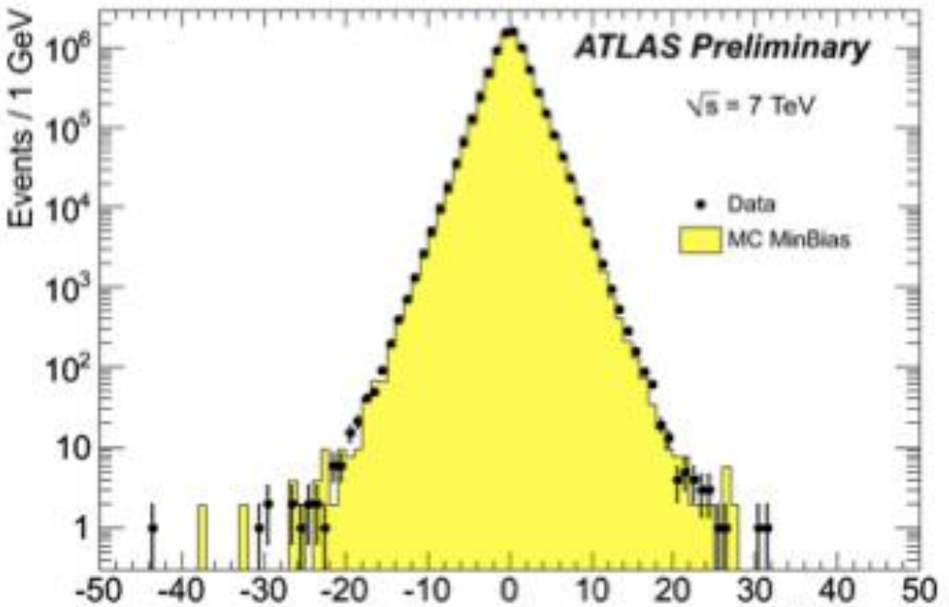
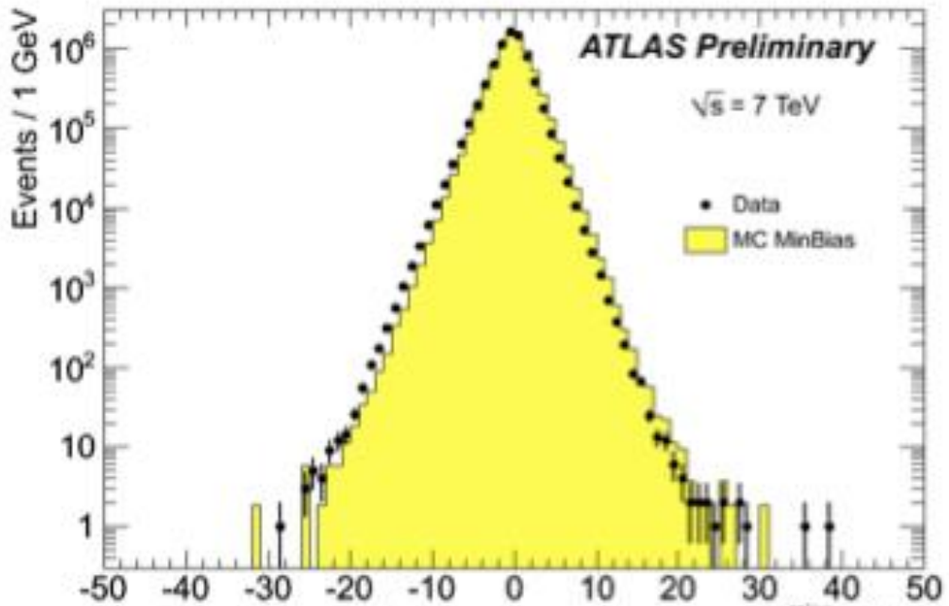
Missing E_T

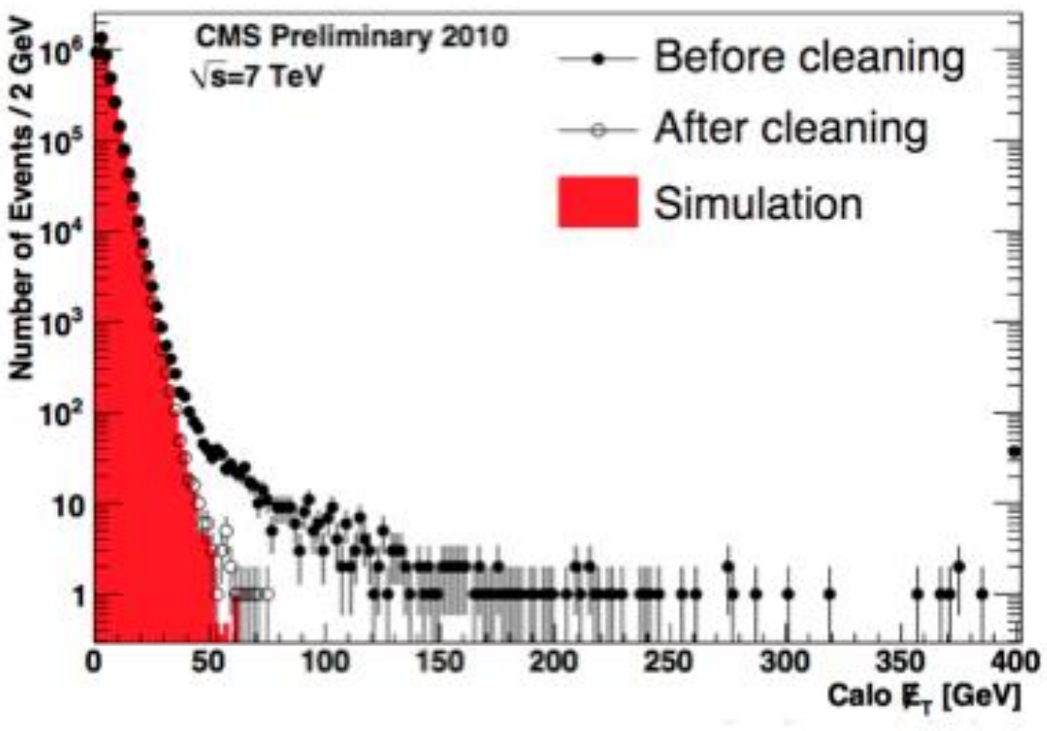


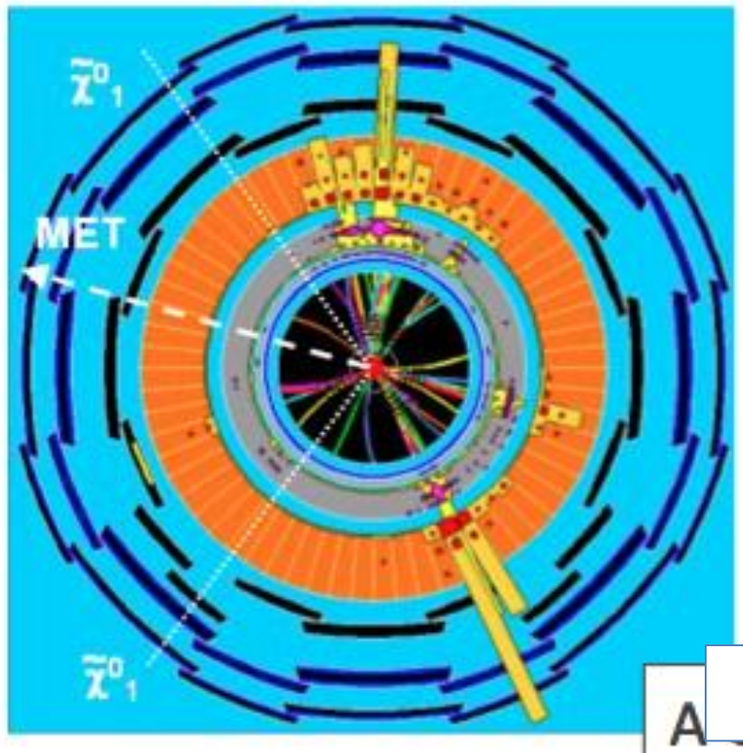


This is one of the hardest things to get right. MET incorporates everything measured in the detector and attempts to identify non-interacting particles, such as neutrinos or dark matter.

Agreement is astounding.

You can even see that the ATLAS detector is not quite centered – in both data and MC.





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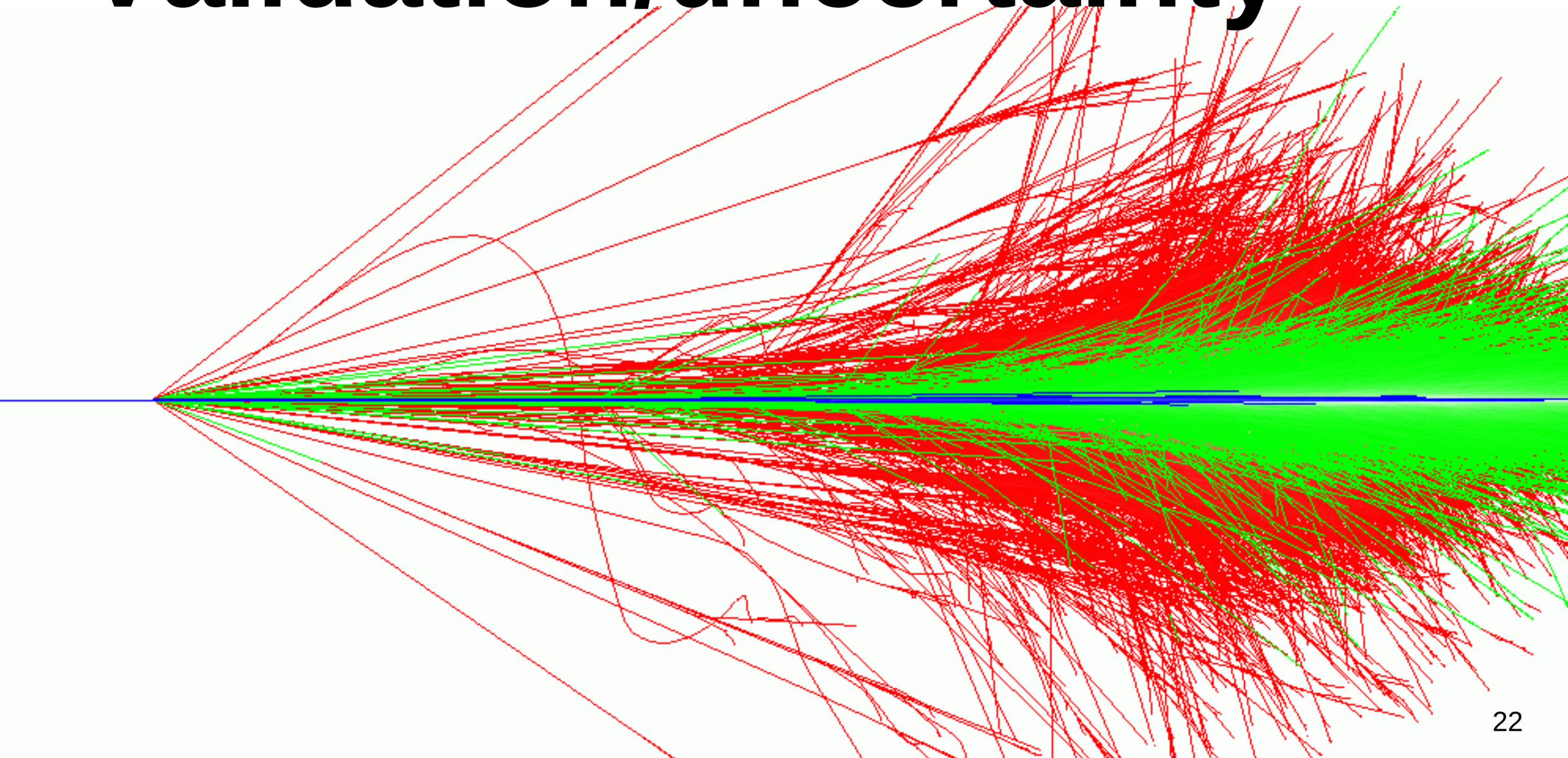
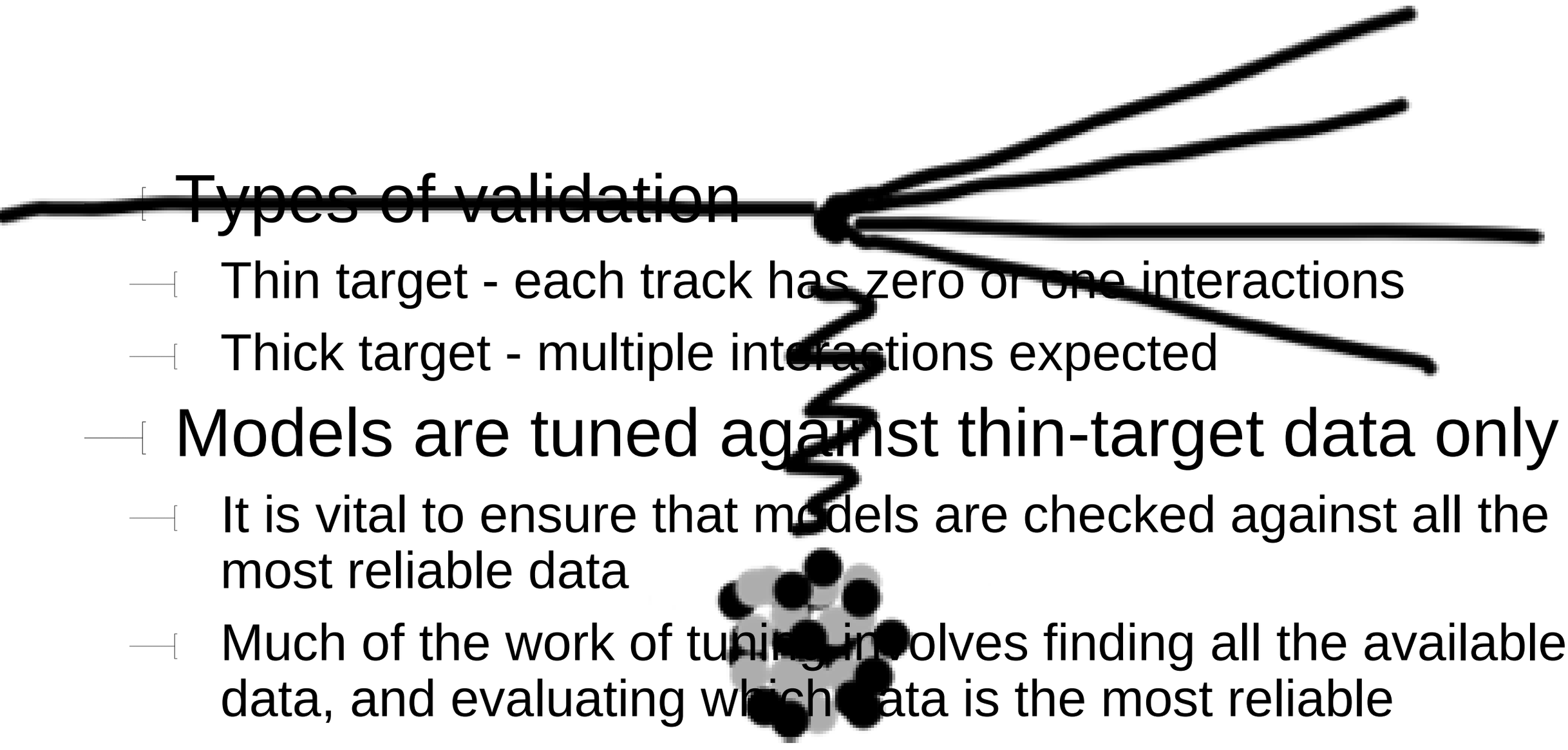
Both ATLAS and CMS plots are made from a tiny piece of the very earliest data.

Validation/uncertainty

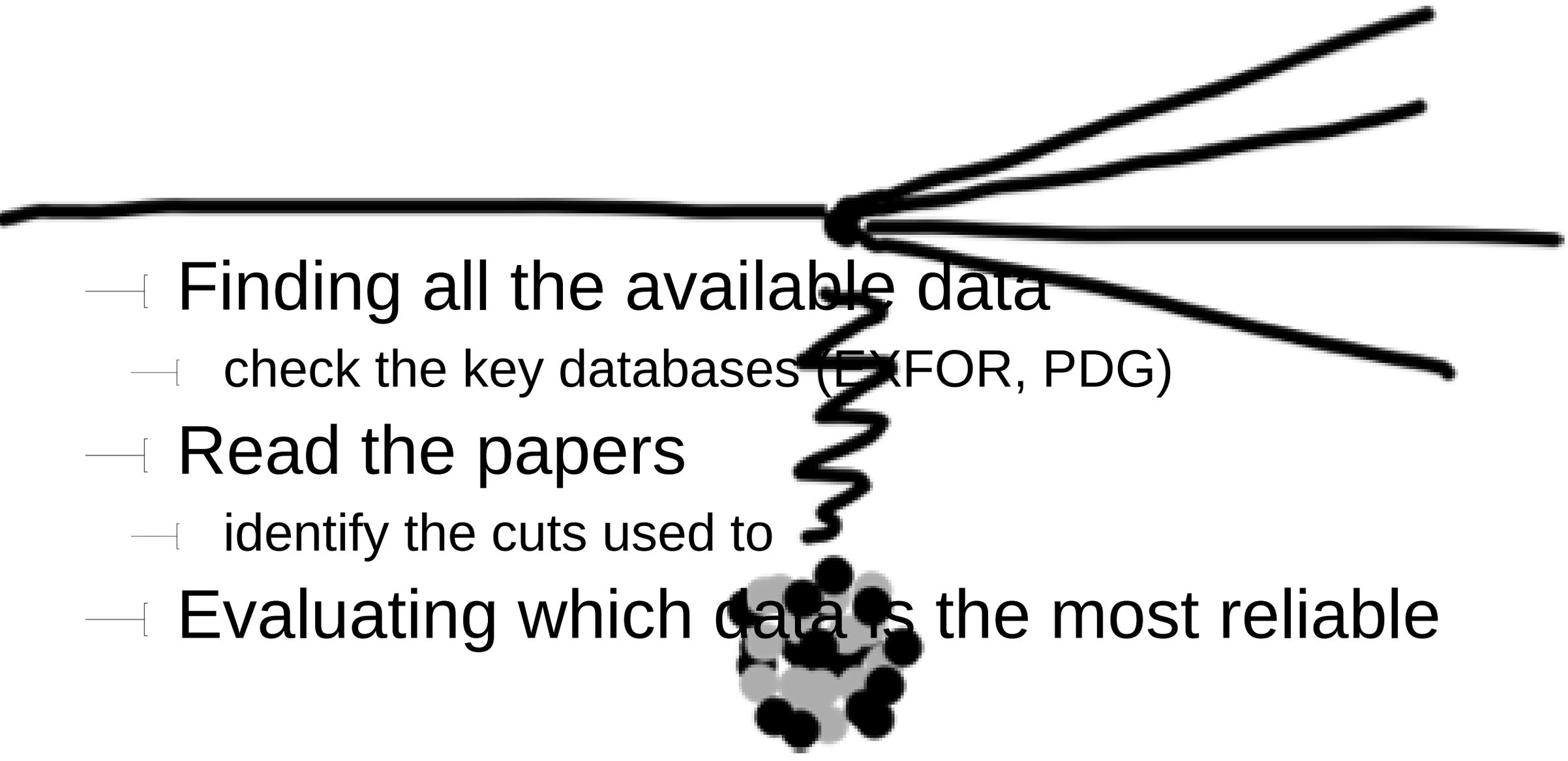


Comparison with data

- Types of validation
  - Thin target - each track has zero or one interactions
  - Thick target - multiple interactions expected
- Models are tuned against thin-target data only
  - It is vital to ensure that models are checked against all the most reliable data
  - Much of the work of tuning involves finding all the available data, and evaluating which data is the most reliable

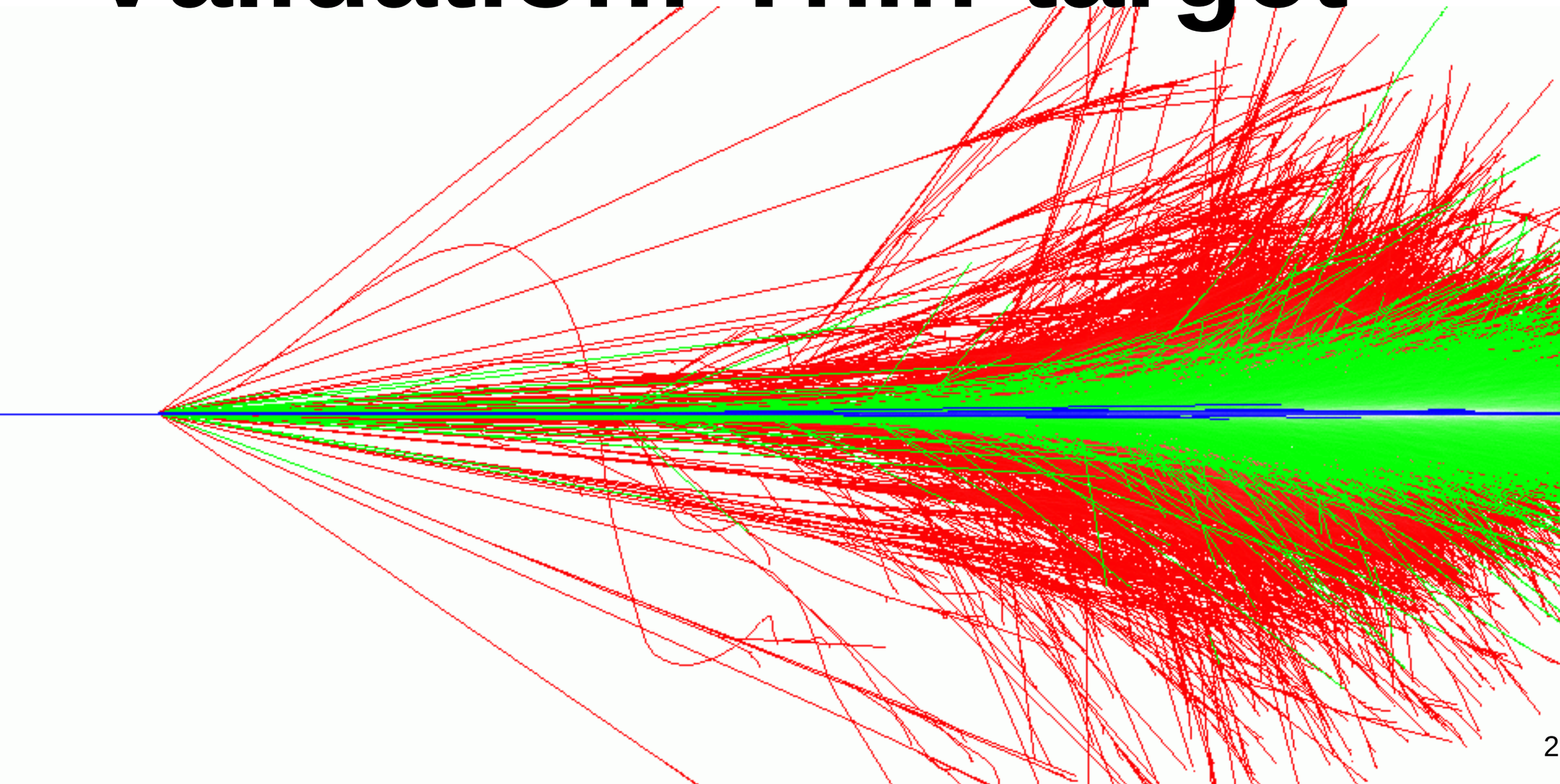


Create a validation test



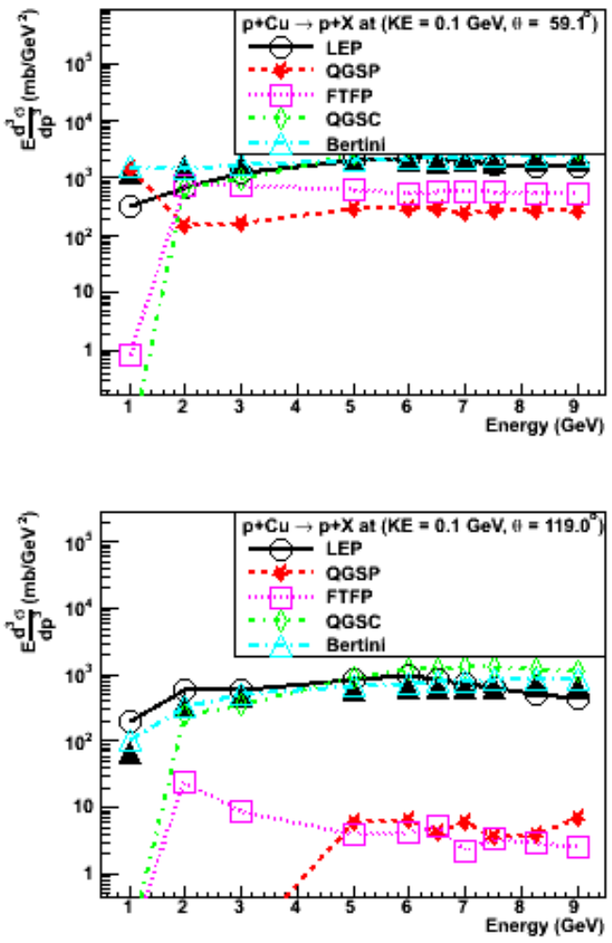
- Finding all the available data
  - check the key databases (EXFOR, PDG)
- Read the papers
  - identify the cuts used to
- Evaluating which data is the most reliable

Validation: Thin-target



More Validation Examples

p cross-sections for various models at different angles



p on Cu with kinetic energy of 0.1/0.2 GeV