Model Approach for Standard EM Physics

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Outline

- Introduction
- Motivation
- Design, implementation, testing
- Ions
- Multiple scattering
- Integral approach
- dE/dx and ranges
- Conclusions and plans

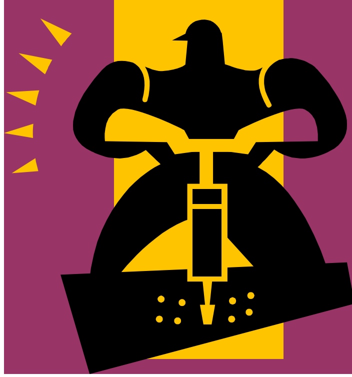
Introduction

- EM physics was naturally designed on base of Geant3 experience and in 1998 it was one of the first complete Geant4 physics packages
- Time is going and a set of design problems were identified
- Geant4'00 Paris – discussion at joint meeting of standard and lowenergy groups
- January 2002 - prototype
- September 2002 – STD processes
- 2003 cut per region implementation
- Various tests process by process have been performed by M.Maire and L.Urban in 2003
- STD processes were tested in BaBar (D.Wright)
- STD processes were tested in CMS (P.Arce)
- Become the main standard approach from Geant4 6.0
- Currently at the head of G4 cvs model variant substitutes old standard packages

Requirements to model design

- **Physics should be unchanged**
- **The same user interface as before should be available**
- **High energy and low energy models should work together for any particle**
- **Ionization and Bremsstrahlung should be decoupled**
- **Performance should be at least the same**
- **Different physical models for different regions and energy ranges**
- **Different models of energy loss fluctuations for different particles**
- **Integral approach as an alternative**

Design and implementation

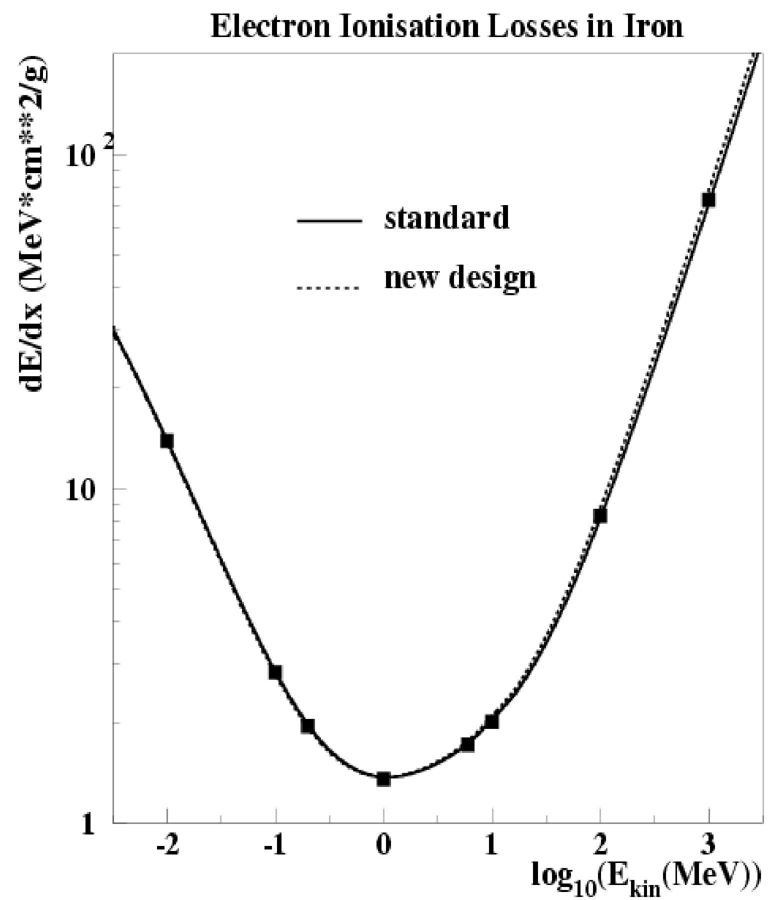


- Feature driven design
- Physics is decoupled from management
- Number of static objects very limited
- No peaces of repeated software
- Old interfaces are kept
- Old messenger is used
- New and old processes currently can be used in the same Physics List

- Fine steps (~20) implementation
- About 15 different tests were running after each iteration
- Tests against results with old standard processes and/or data
- Code review is done
- Performance optimization is on the way

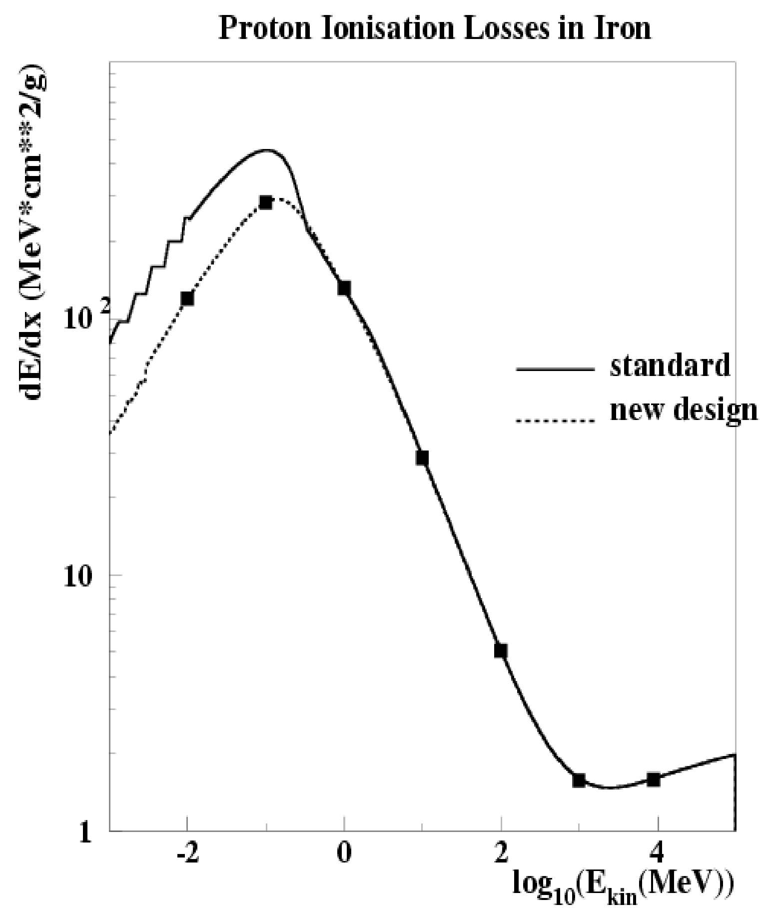
Electron energy loss

- **Two processes contribute to energy loss: ionization and bremsstrahlung**
- **For both processes only one standard model for the energy region E>1keV**
- **Data from ICRU'37**

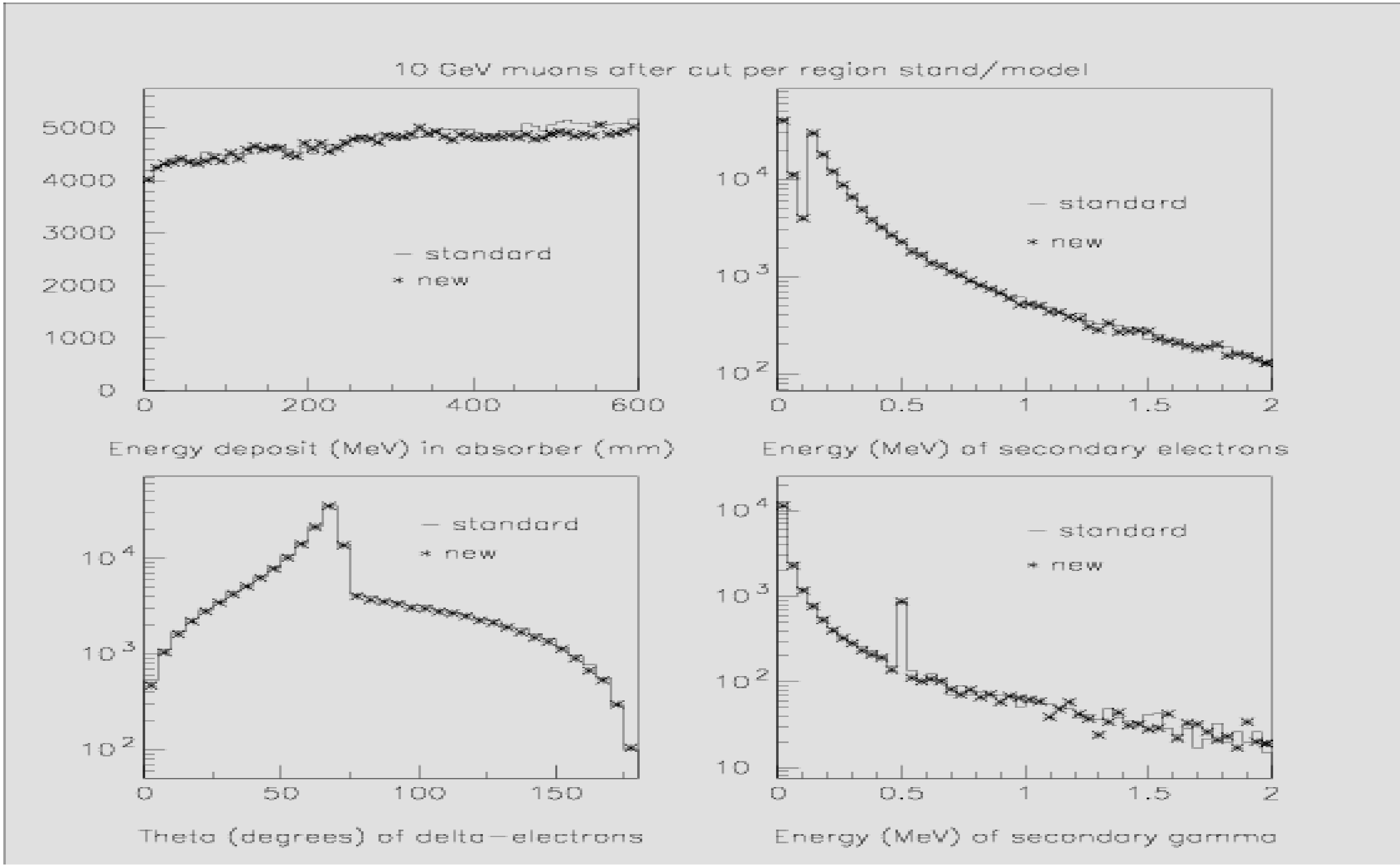


Proton energy loss

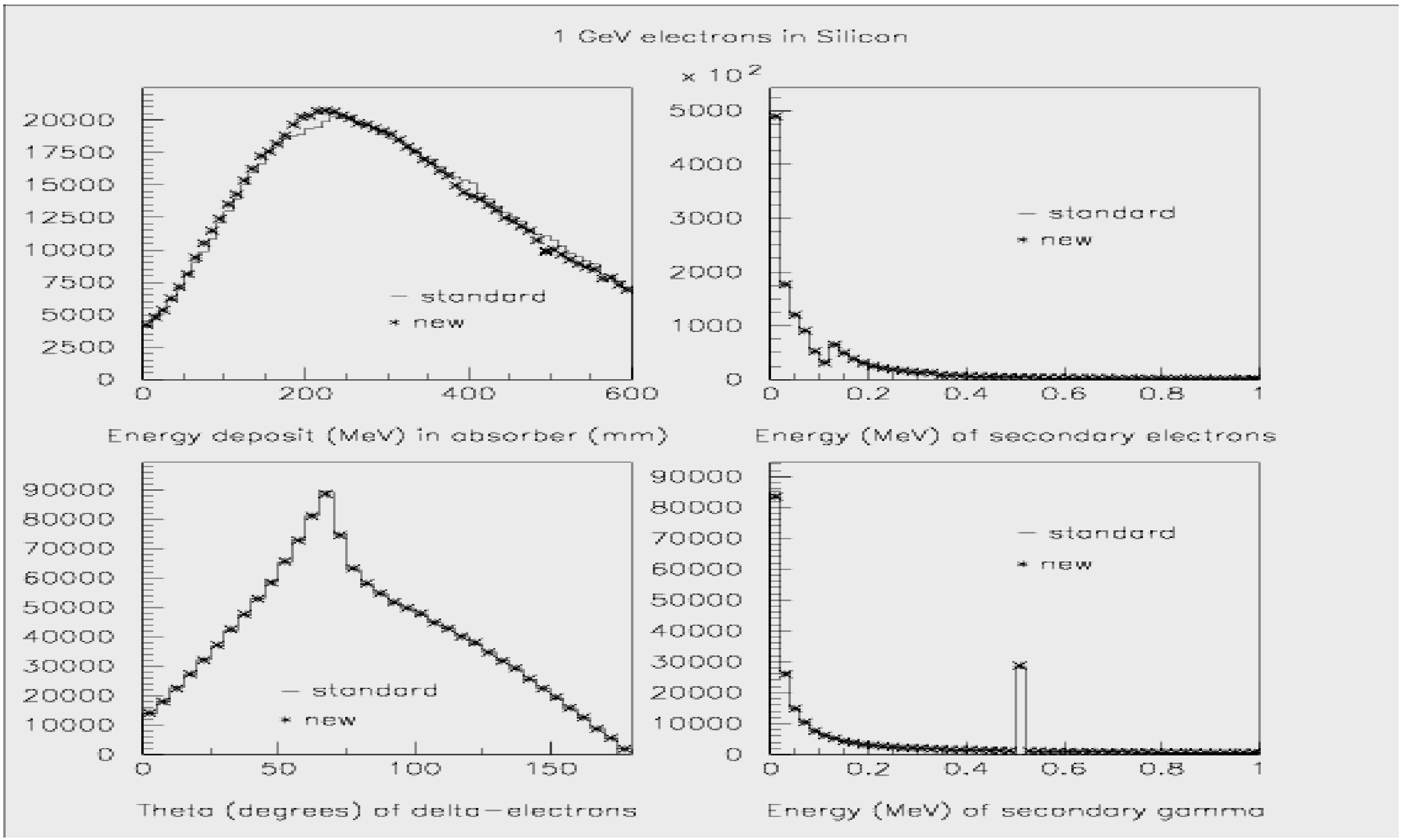
- **Only one process**
- **Two models – standard for E>2MeV and low energy below**
- **Ionization for other hadrons is scaled from proton ionization**
- **Data from ICRU’49**
- **Bragg’s peak problem is fixed**



Test for muons model/standard



Test for electrons model/standard



Performance test new/old

22.09.02 G4 4.1-ref-02

OS	Em1	Em2	Em3	Em4	BTeV	BTeV	ATLAS ECAL	ATLAS ECAL
E(GeV)	1	1	1	1	10	40	20	250
Linux egcs	0.67	0.89	0.94	0.88	-	-	0.64	0.68
Linux g++	0.76	0.84	0.81	0.81	0.89	0.91	-	-

BaBar test on Geant4 performance (D.Wright)

G4 version	4.0	5.2	5.2 + STD
BBar	3.68	3.77	3.58
$\mu^+\mu^-$	0.54	0.52	0.40
e^+e^-	6.22	5.93	5.80

Results and new features

- Model EM physics is working for energy loss processes and multiple scattering
- Physics is the same as in standard
- Integral approach is available
  - *"/eloss/integral true"*
- Models can be defined by region and by energy - alternative models for different regions
  - *Process->AddModel(ord,model,fluc_model,region)*
- Number of tables can be reduced in 2 times as well as the initialization time
- Interface for G4 propagator is available
  - *Process->GetTotalDEDX(….)*
  - *Process->GetDispertion(…)*

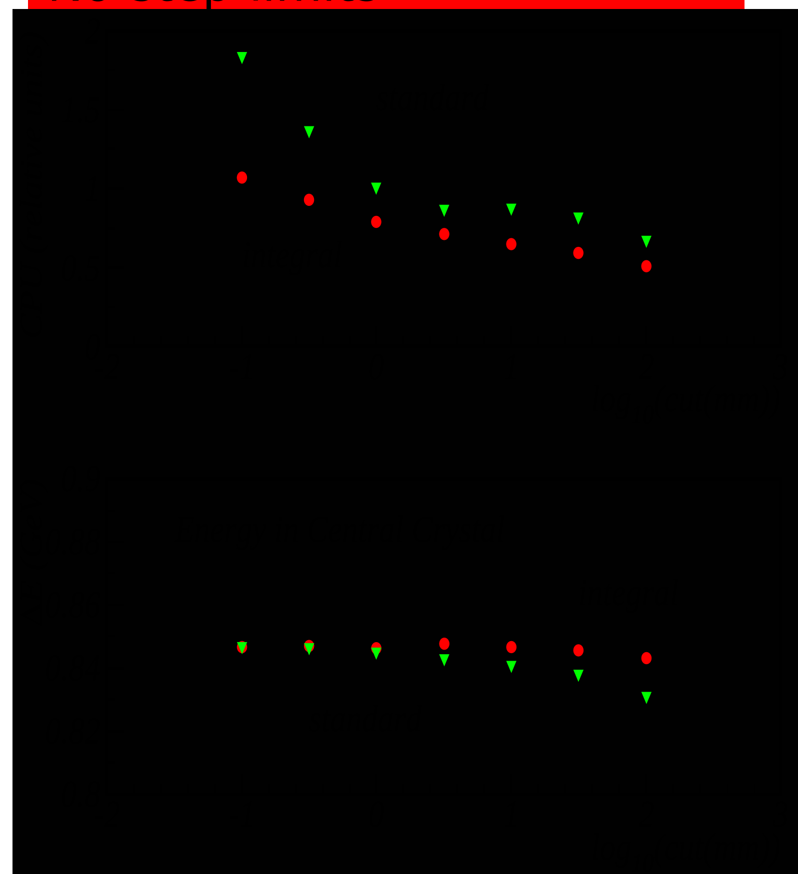
New development on base of model approach

- G4ionIonisation
- One set of tables for all ions
- Original model for fluctuations
- Dynamic charge approach – the charge of ion is changed after each step
- Multiple scattering was realized in model variant
- For ions MFP table is not built but MFP is recalculated on fly

New EM example TestEm9

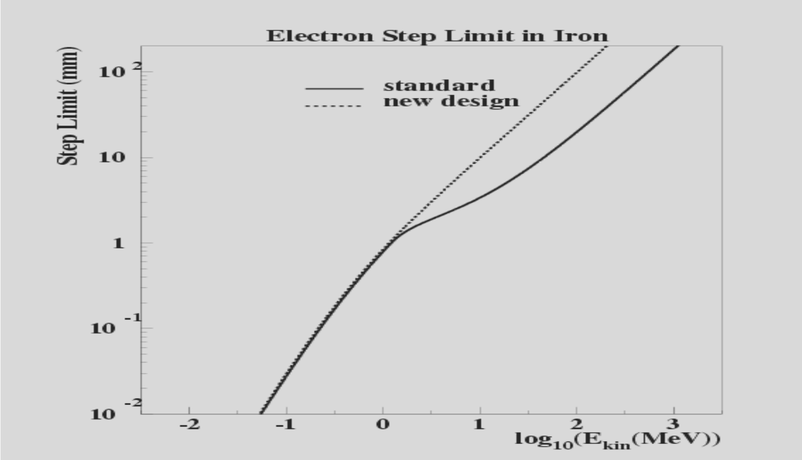
- Demonstration of “cut per region” facility and physics of crystal calorimeter
- Geometry:
  - Vertex detector
  - Calorimeter:5x5 matrix of crystals
  - Muon detector
- Modular Physics List:
  - Standard
  - Model
  - Integral
- Results are confirmed by CMS test (P.Arce)

1 GeV e- in CsI calorimeter
The same cuts for e- and γ
No step limits



Integral approach

- EM cross sections continuously increase with energy
- Precision of interaction probability depends on step size and energy change
- Integral approach – probability of interaction is sampled using Monte Carlo integration
- Integral approach allows any step size!



standard

$$p = \exp\{-\sum_i \sigma(E_i) n \Delta s_i\}$$

integral

$$p = \exp\{-\int \sigma(E) n ds\}$$

dE/dx and range

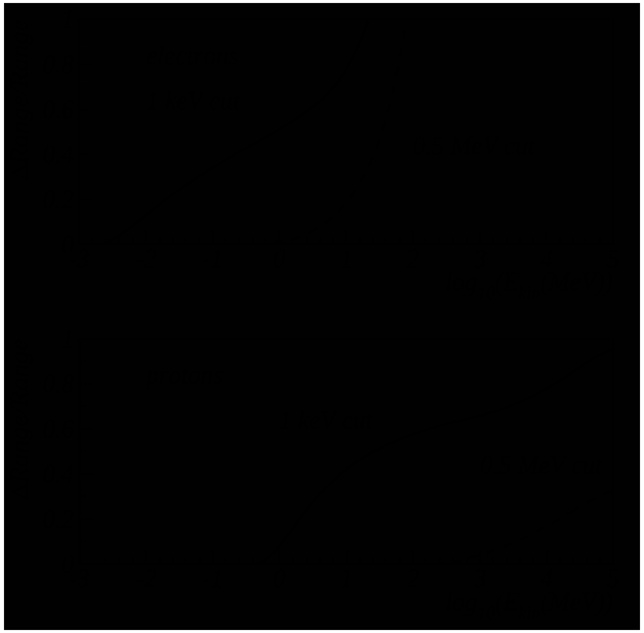
- What one gets from GetDEDX(…) or GetRange(…) methods?
- dE/dx table is filled as a "restricted energy loss table"
- Range table is the inverse integral of a dE/dx table
- In model approach the additional dE/dx table ("total energy loss") may be built - true DEDX and Range table will be available
  - "/eloss/preciseRange true"

$$\frac{dE}{dx} = \int_0^{cut} n \frac{d\sigma(T)}{dT} T dT$$

restricted

$$\frac{dE}{dx} = \int_0^{T\max} n \frac{d\sigma(T)}{dT} T dT$$

total



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Some remarks and plans for standard

- Model/integral approach is the way to improve EM physics and performance
- The optimization of MC for an application requires factorization of Physics Lists – hadronic and EM physics should be decoupled
- Why not to try integral approach for hadronic physics?
- Why not to try for low energy?

- From G4 6.0 model variant will be default
- Old standard EM physics from 5.2 will be available as an alternative
  - G4hIonisation → G4hIonisation52
  - G4hIonisationSTD → G4hIonisation
- Further development:
  - Integral variant of e^+ annihilation
  - PAI model
  - New ion model (GSI)
  - Alternative MSC models (Hitland, Moliere….)

Conclusions

- Model approach is implemented for standard EM physics
- Physics is the same or better
- Performance is improved
- New features are available:
    - Integral approach
    - Precise range
    - Ion dynamic charge
    - Flexible MSC model
    - Several fluctuation models
    - Models per region
    - Interface to G4 propagator
- From 6.0 in will be default for standard
- Feedback is needed before 6.0 is released