



# NEW DEVELOPMENT AND VALIDATION FOR STANDARD EM

*V.Ivanchenko for the standard EM group*

14<sup>th</sup> Geant4 User and Collaboration Workshop

Catania (Italy) 19-23 October 2009

# OUTLINE

- Status for 9.3 release
- Infrastructure upgrade
  - G4PhysicsVector
  - Initialisation speed-up
  - Cut per recoil
  - G4Pow class
  - G4EmConfigurator
- *ApplyCuts* option
- New validations
- Discussion items

# SUMMARY OF DEVELOPMENTS FOR EM STANDARD FOR 9.3

- Major developments ready or have good chances to be ready:
  - Improved Physics Vectors (A.Bagulya )
  - Fixed G4UniversalFluctuation model (L.Urban talk)
  - Tuned G4UrbanMscModel2 (L.Urban talk)
  - New G4GouldsmitSaunderstonModel for msc (O.Kadri talk)
  - LPM effect for gamma conversion (A.Schaelicke talk)
  - Cut per recoil (H.Kurashige)
  - Minor improvement in G4Wentzel msc model and single scattering model
  - Fixed recoil for ion scattering (C.Consaldi)
  - Fixed ICRU'73 data for water , water-vapor and some other materials (A.Lechner talk)
  - Revised density effect (A.Bagulya arrive next week)
- New validations:
  - “ApplyCuts” option for CMS
  - New benchmark for electron scattering (J.Pperl talk)
  - New benchmark for Si detectors (F.Dupertuis talk)

# INFRASTRUCTURE UPGRADE

# G4PHYSICSVECTOR UPGRADE

(A.BAGULYA, G.COSMO, V.IVANCHENKO)

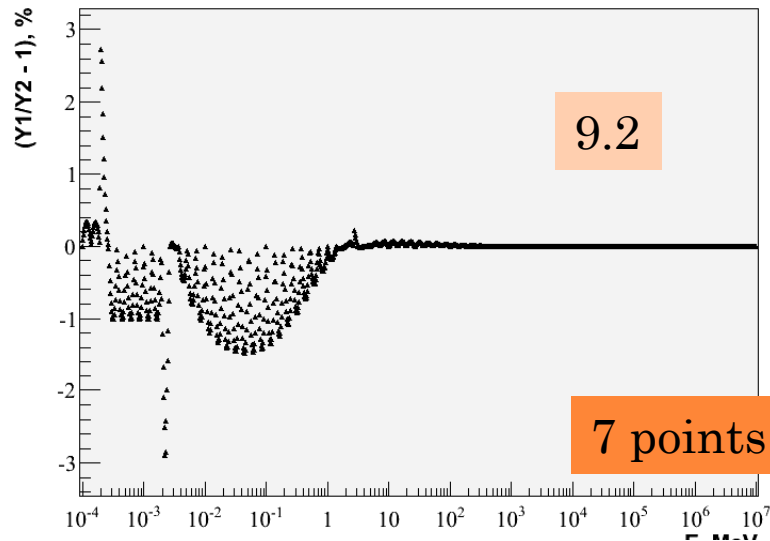
- Exist since 1<sup>st</sup> Geant4 release, high quality code but was done initially using Rogue Wave, there were some concerns, especially to edges of vectors
- Spline interpolation have been improved for 9.3beta
- ‘Hidden’ bin has been removed and a cleanup of the based and derived classes have been performed
  - *G4PhysicsLogVector(nbin,emin,emax)* creates vector of size nbin+1
  - *G4LPhysicsFreeVector(n,emin,emax)* creates vector of size n
  - Main new user methods: *G4double Energy(G4int index);*  
*G4double Value(G4double energy);*
- Copy constructors were cleaned up
- Would recommend to migrate to G4PhysicsVector for low-energy EM and hadronics

# CUBIC SPLINE INTERPOLATION (A.BAGULYA)

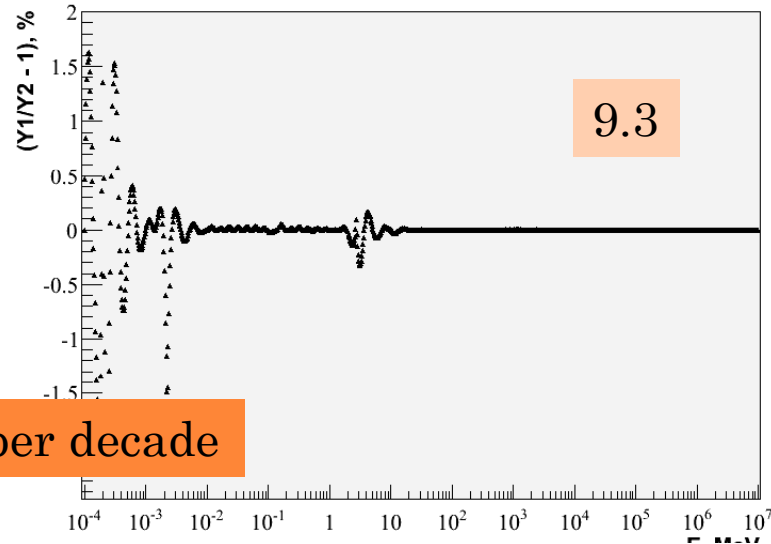
- To prepare cubic spline it's necessary to specify two further conditions, typically taken as boundary conditions at  $x_1$  and  $x_N$
- The most common variants:
  - set one or both of  $y_1''$  and  $y_N''$  equal to zero (so-called natural cubic spline) – was in the first implementation and is discarded for 9.3
  - values of the first derivative are given at the endpoints of the segment  $[x_1, x_N]$  – the most precise cubic spline interpolation (G4PhysicsVector::ComputeSecondDerivative(y1, yN)
    - Minimum N=4
  - “not-a-knot” endpoint condition where adjacent polynomials nearest to the end points coincide:  $S_1(x)=S_2(x)$  and  $S_{N-1}(x)=S_N(x)$ , that is third derivatives in points  $x_2$  and  $x_{N-1}$  are equal (G4PhysicsVector::FillSecondDerivative() - default)
    - Minimum N=5

# ELECTRON STOPPING POWER IN LEAD

DEDX.eloni.e-.asc\_7bins.out / 100 pts per order, Pb

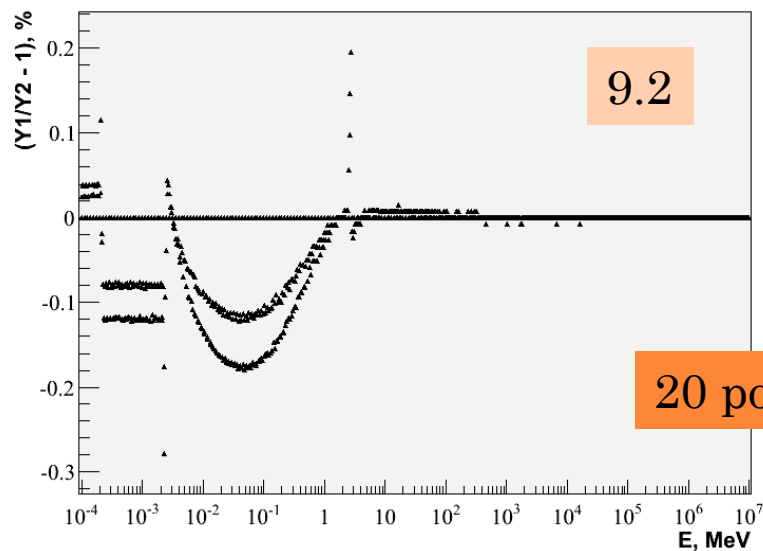


DEDX.eloni.e-.asc\_7bins\_spl.out / 100 pts per order, Pb

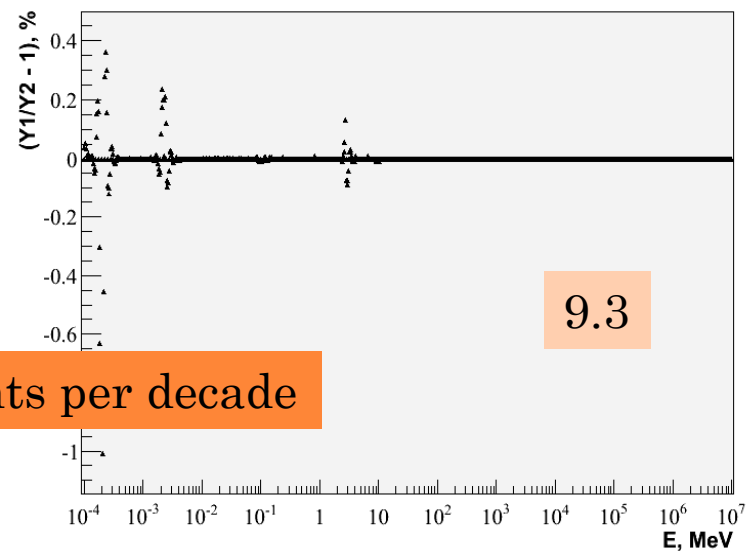


7 points per decade

DEDX.eloni.e-.asc\_20bins.out / 100 pts per order, Pb



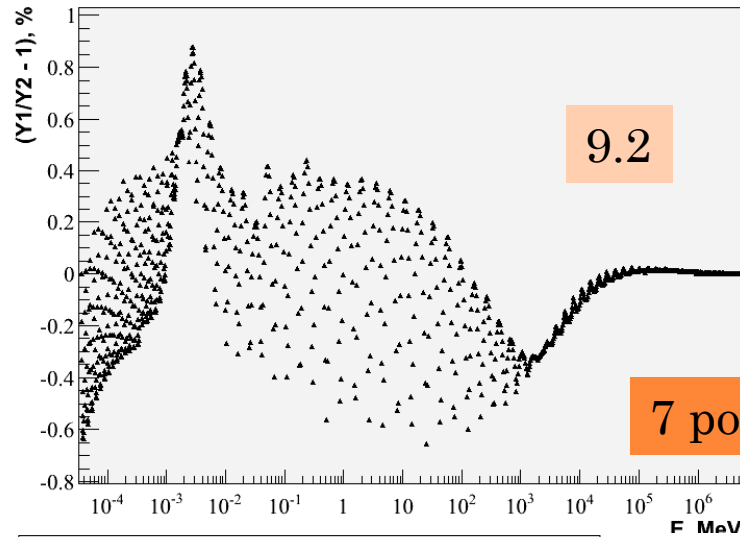
DEDX.eloni.e-.asc\_20bins\_spl.out / 100 pts per order, Pb



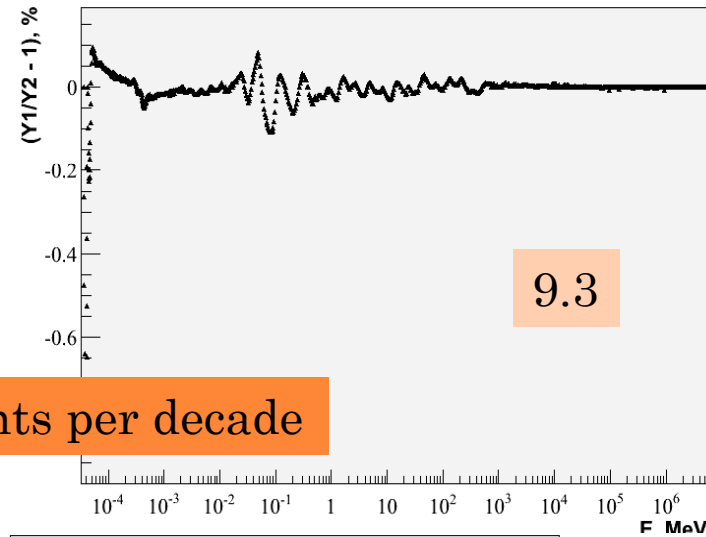
20 points per decade

# PROTON INVERSE RANGE IN LEAD

InverseRange.hloni.proton.asc\_7bins.out / 100 pts per order, Pb

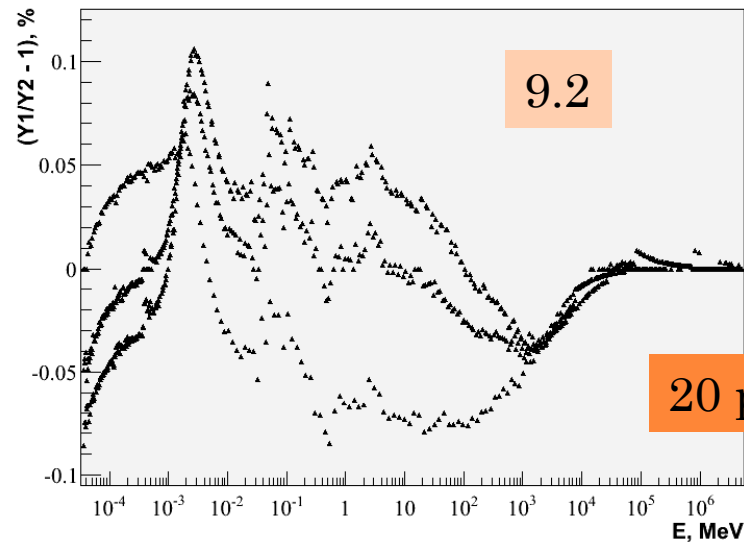


InverseRange.hloni.proton.asc\_7bins\_spl.out / 100 pts per order, Pb

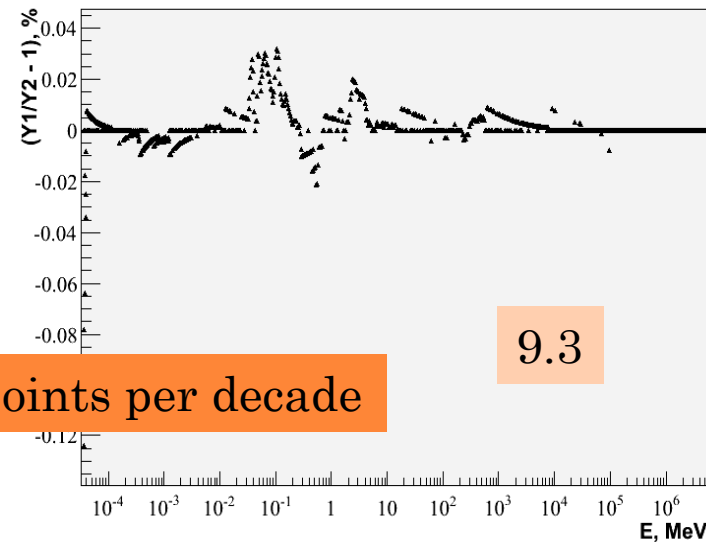


7 points per decade

InverseRange.hloni.proton.asc\_20bins.out / 100 pts per order, Pb



InverseRange.hloni.proton.asc\_20bins\_spl.out / 100 pts per order, Pb

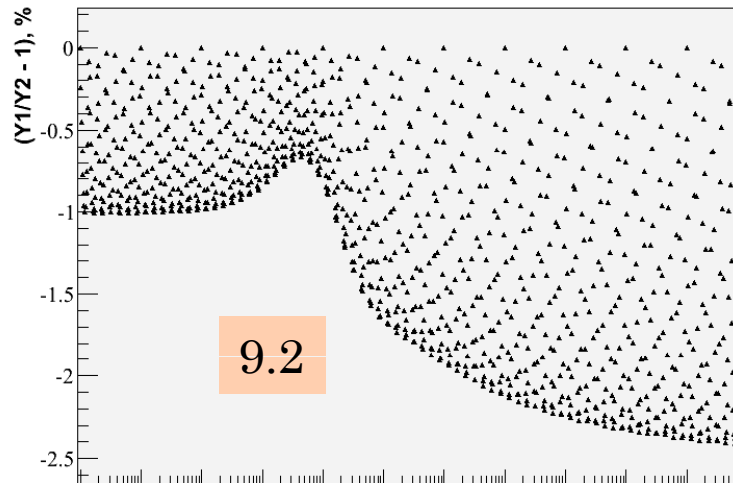


20 points per decade

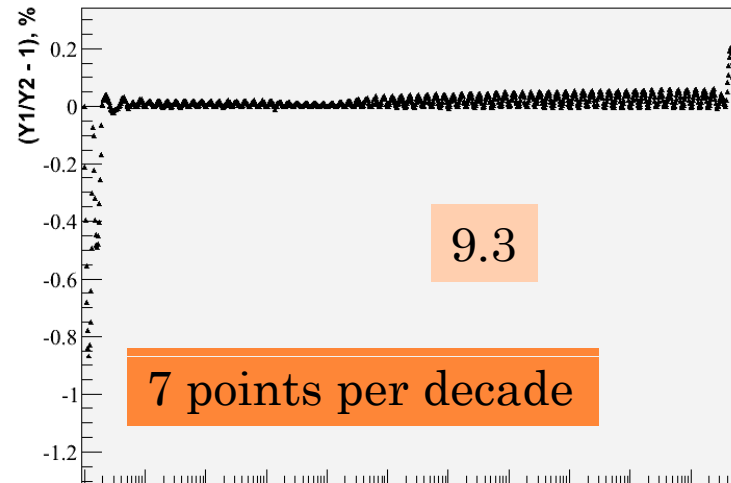


# POSITRON ANNIHILATION CROSS SECTION

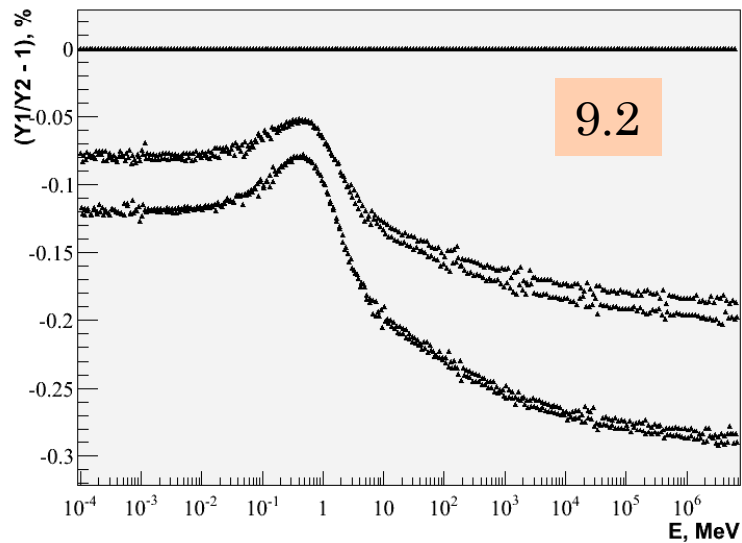
Lambda.annihil.e+.asc\_7bins.out / 100 pts per order, Pb



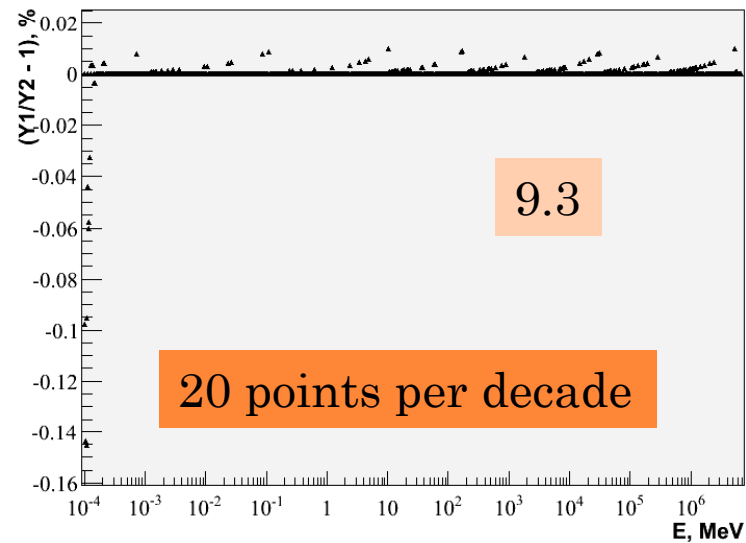
Lambda.annihil.e+.asc\_7bins\_spl.out / 100 pts per order, Pb



Lambda.annihil.e+.asc\_20bins.out / 100 pts per order, Pb



Lambda.annihil.e+.asc\_20bins\_spl.out / 100 pts per order, Pb



# IMPROVEMENTS OF INITIALISATION FOR STANDARD EM PHYSICS FOR GEANT4 9.3

- Revised convertor of cut in range to production thresholds (H.Kurashige)
- Cleaned up standard EM initialisation using **copy-constructor** (V.Ivanchenko)
- Work was activated by Makoto

CPU for initialisation of EM standard physics for setup with 289 materials

Geant4 version	amd 32-bit	amd 64-bit
G4 9.2	147 s	179 s
G4 9.3	51 s	56 s

# CUT PER RECOIL == CUT FOR PROTON (H.KURASHIGE)

- **Cut per recoil** is long standing requirement from space users – needed for nuclear stopping and SEE simulation
  - Was agreed at Hebden Bridge and confirmed at Kobe
- **Implemented as a *cut per proton***
- **Convertor cut in range to cut in energy is linear:**  
1 mm -> 100 keV (default cut and energy threshold for 9.2)
- **Is used in single scattering and in hadron elastic scattering – proposed for 9.3**
- **One can expect some CPU performance improvement**

# NEW G4POW CLASS HAS BEEN DEVELOPED (A.BALULYA, G.COSMO, V.IVANCHENKO)

- Providing fast computation of frequently used mathematical functions for integer or double argument in limited interval 1 - 255:
- static G4Pow\* GetInstance();
- inline G4double G4Pow::Z13(G4int Z);
- inline G4double G4Pow::A13(G4double A);
- inline G4double G4Pow::logZ(G4int Z);
- inline G4double G4Pow::logA(G4double A);
- inline G4double G4Pow::log10Z(G4int Z);
- inline G4double G4Pow::log10A(G4double A);
- inline G4double G4Pow::powZ(G4int Z, G4double y);
- inline G4double G4Pow::powA(G4double Z, G4double y);
- Inline G4double G4Pow::factorial(G4int Z);

## CPU BENCHMARK FOR G4POW

Function	G4Pow with G4int	G4Pow with G4double	<cmath> library
$X^{1/3}$	0.03	0.52	3.27
$X^{2/3}$	0.02	0.54	3.25
Log(x)	0.02	0.49	1.23

- CPU advantage for the case of integer argument Z
- Some advantage for double argument A (but limited accuracy)

## G4EMCONFIGURATOR CLASS

- Allowing to add a model to existing EM physics
- Simplifying development of new EM models – easier to try alternative models
- Example of usage is shown in TestEm5 and TestEm7
- The main interface should be called before initialisation of EM physics:
  - `AddEmModel(“e-”, “msc”, new G4UrbanMscModel2());`

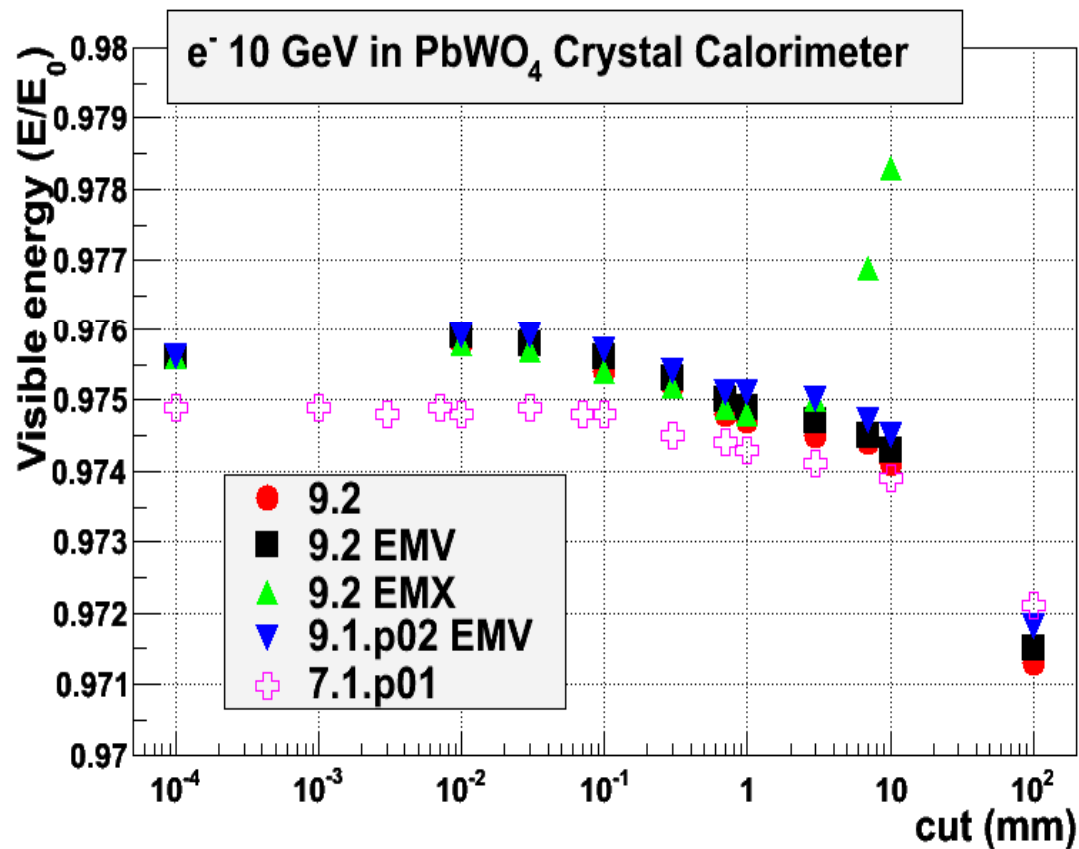
# APPLYCUTS OPTION

## “APPLY CUTS” OPTION HISTORY

- Since 1<sup>st</sup> Geant4 release exist in *G4SteppingManager* for all processes – removal of secondary *G4Track*
  - Is in a problematic place, potentially biased results, because it would good if energy deposition by a process is correct after its *PostStepDoIt*
  - *G4Scintillation* is called earlier than *G4SteppingManager*
- Was exist inside *PostStepDoIt* of all EM processes
- Was removed by Michel from photon processes many year ago, because make process more complicate but no obvious benefit at that time
- J.Apostolakis many times asked to repeat a check
- In the new Standard model design exist in generic *PostStepDoIt* of *G4VEmProcess* and can be switch **ON/OFF** via UI interface – removal of secondary *G4DynamicParticle* (*gamma, electron only*)

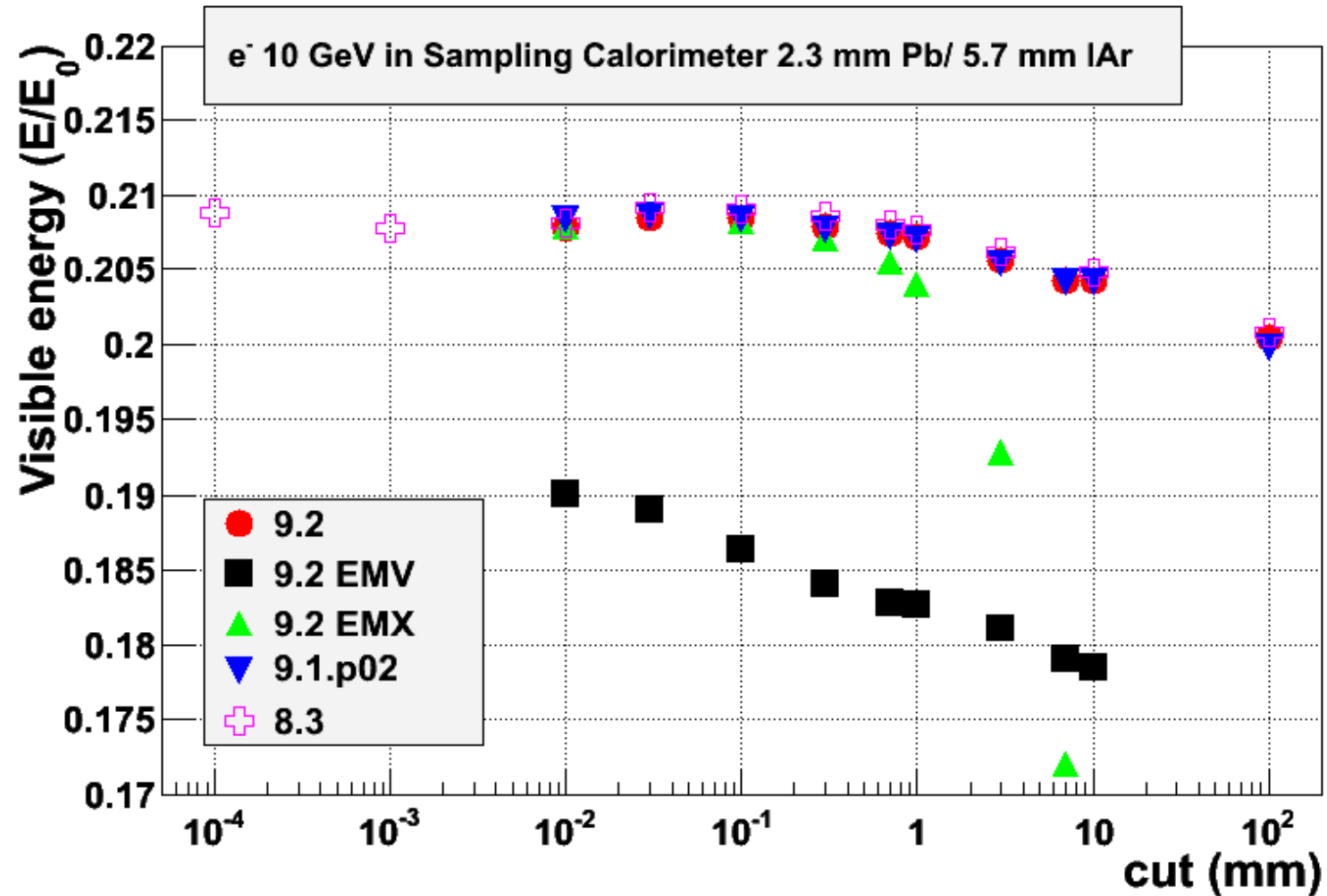


# APPLYCUTS OPTION IN $\text{PbWO}_4$ CMS-TYPE CRYSTAL CALORIMETER



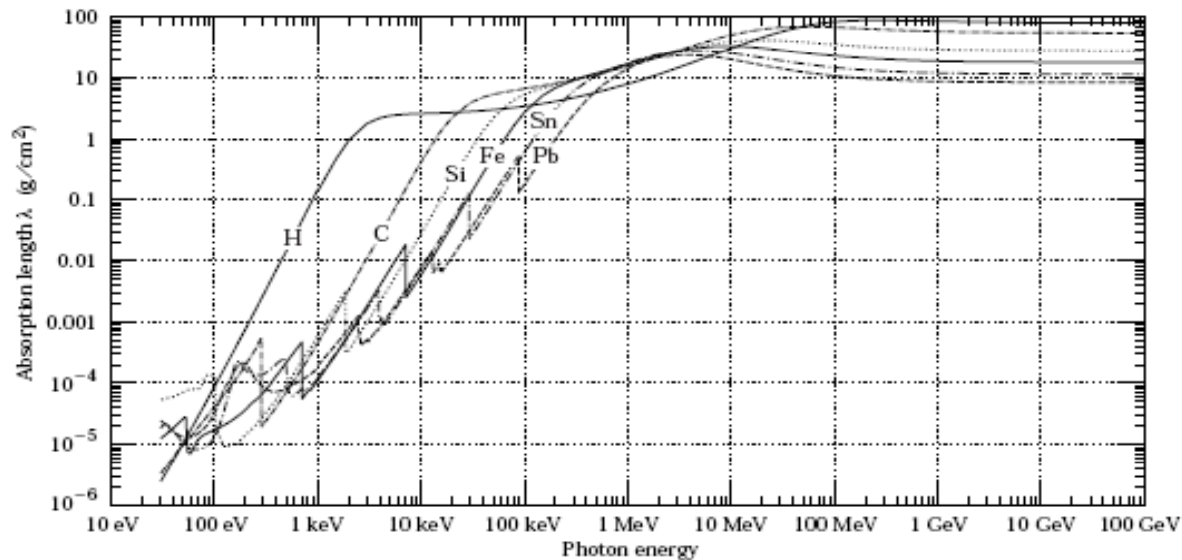
- **EMX** – enable *ApplyCuts*
- Energy deposition is more sensitive to the value of cut
- Limit is 3 mm

# ATLAS BARREL TYPE CALORIMETER



# WHY STRONG CUT DEPENDENCE?

22 27. Passage of particles through matter



- PDG plot
- Strong dependence of cross section on gamma energy
- No energy leak via boundaries for cuts > 1 mm for major solid media

Cuts for Iron

Cut(mm)	Cut $\gamma$ (keV)	Cut e- (MeV)
1	20.8	1.28
3	36.5	3.60
10	60.4	12.95
30	105.4	45.4
100	626	209.2



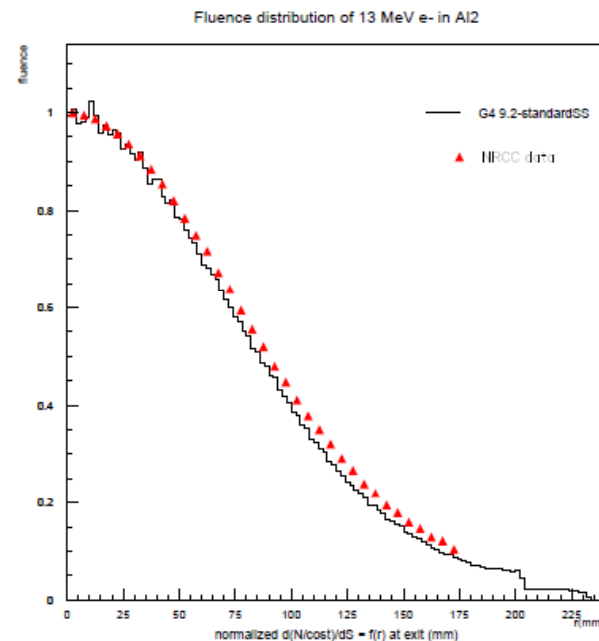
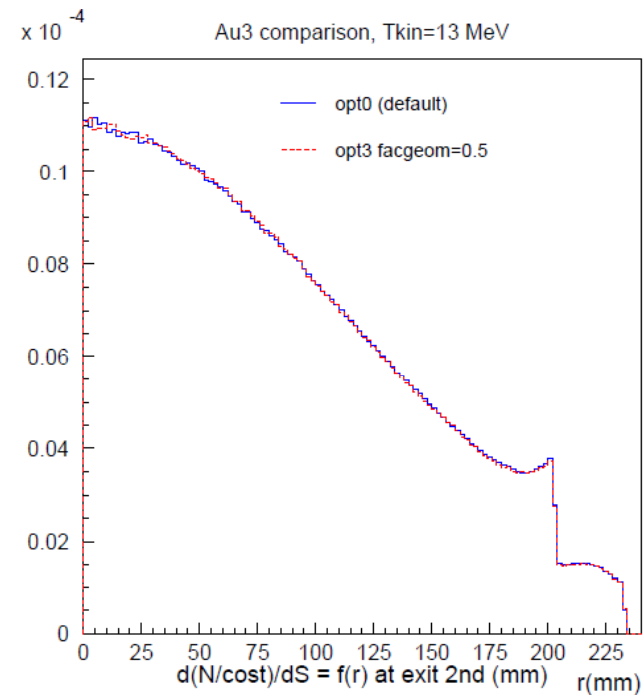
## APPLY CUTS OPTION SUMMARY

- Using “Apply cuts” option saves approximately 20% CPU for CMS production
  - In default Physics List it is OFF
- It is potentially dangerous to use for cut  $> 1$  mm (biased results)
- It is useless if cut  $\ll 1$  mm
- In the current implementation G4DynamicParticle is killed if its kinetic energy below cut, G4Track is not created
- Can it be improved?
  - If implementation will be returned to the level of models this G4DynamicParticle object will be not created – it is the **most effective solution**
  - **Old variant** – creation of G4Track and killing by G4SteppingManager may work if the check is done after each PostStepDoIt – less effective but uniform over different categories and processes

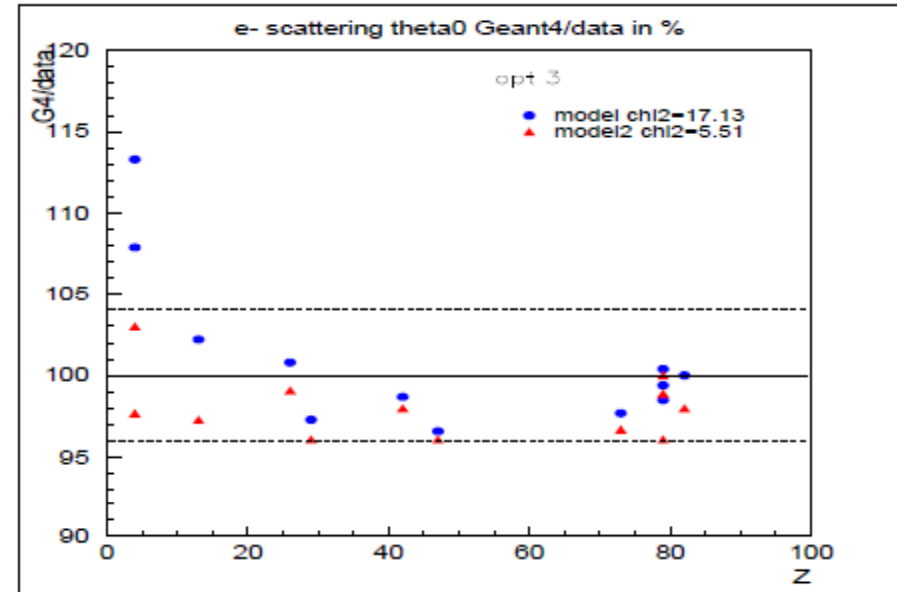
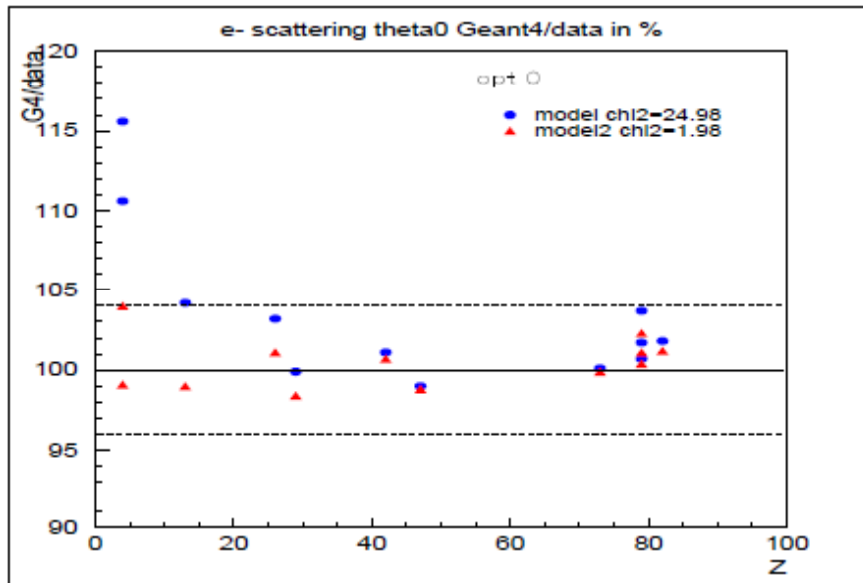
# NEW VALIDATIONS

# ELECTRON BENCHMARK

- New electron msc benchmark results B.A.Faddegon, I.Kawrakov, Yu.Kubyshin, **J.Pperl**, J.Sampau, **L.Urban** Phys.Med.Biol. 54 (2009) 6151
- Detailed data for electron scattering at 13 – 20 MeV
- Geant4 9.2 is not bad but EGSnrc and Penelope statistically better
- See details in J.Pperl talk
- **New examples**  
*electronScattering* are **released** (traditional scoring versus G4Scorer facility)



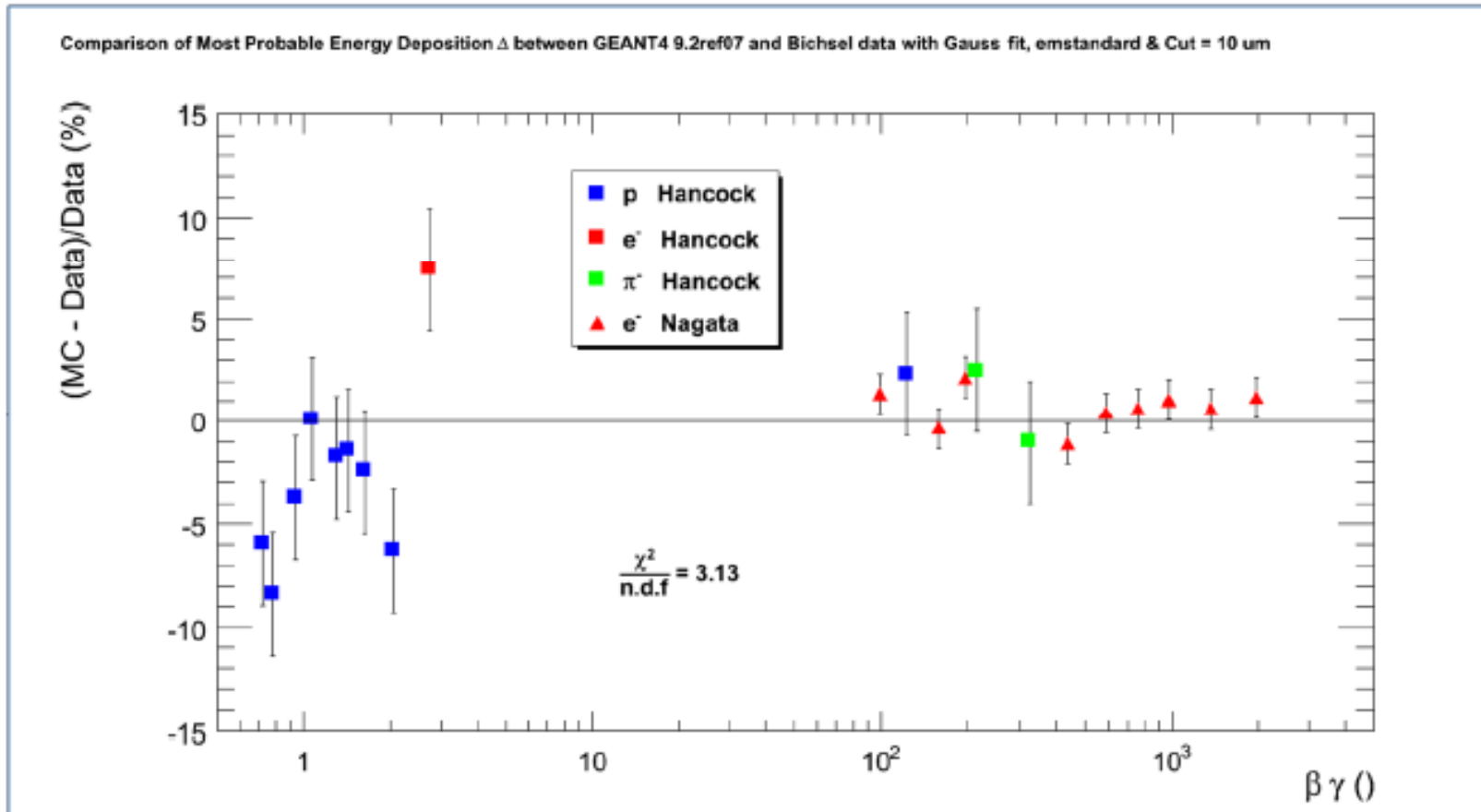
# NEW TUNING OF URBAN MODEL



- Tuning of the Urban model – G4UrbanMscModel2
- Details in the L.Urban talk at parallel session

# NEW TEST ON SI VERTEX DETECTOR

(DETAILS AT PARALLEL SESSION)



F.Dupertuis, CERN summer student, 2009



## DISCUSSION ITEMS FOR 9.3

# PROPOSAL FOR EM TABLES

- For the default EM physics to use:
  - $E_{\min} = 1 \text{ keV}$ ,
  - $E_{\max} = 10 \text{ TeV}$ ,
  - nbins = 70, 20% save in space
- For the option3 physics to use:
  - $E_{\min} = 0.1 \text{ keV}$ ,
  - $E_{\max} = 10 \text{ GeV}$ ,
  - nbins = 160, 25% save in space
- Will be discussed in details at EM parallel section
- Any feedback?

# MEAN IONISATION POTENTIAL FOR G4\_WATER

- In ICRU'37 report for liquid water  $I = 75 \text{ eV}$
- In the recent (fixed) ICRU'73 value  $I = 78 \text{ eV}$ 
  - GSI suggesting
  - There are number of publications for light ion stopping supporting the change
  - Have been introduced in 9.3beta
- Not yet confirmed by proton data
- We need feedback from users

# A PROPOSAL FOR CONFIGURATION OF MULTIPLE SCATTERING

- Use G4UrbanMscModel (9.2 version of msc) as a default and for Opt1 EM physics
  - LHC production will be not affected
- Use G4UrbanMscModel2 for electron/positrons for other Physics Lists
- Do not change defaults for other particle type
- Will be discussed in details at EM parallel section
- Any feedback?

## SUMMARY

- We complete a good part of development and validation planned for 2009
- Some performance improvements are achieved
- Two new benchmarks were introduced
- New problems identified
- We need to discuss EM builders configurations for 9.3 at parallel sessions