Report of parallel 2B session

Progress on biasing and fast simulation

Conveners:
Alexander Howard
Marc Verderi

Session agenda

Mon 23/09

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16:00	**Introduction / general news**	*Marc Verderi*	*L102, Jefferson Lab*	16:00 - 16:10
	Update on GFlash revision (remote or local speaker)	*Anna Zaborowska*	*L102, Jefferson Lab*	16:10 - 16:40
	From Woodcock viewpoint to weight calculation for occurrence biasing of charged particles	*Marc Verderi*	*L102, Jefferson Lab*	16:40 - 17:10
17:00	**Discussion**		*L102, Jefferson Lab*	17:10 - 17:30

Update on GFlash parametrisation

Anna Zaborowska, CERN

24th GEANT4 Collaboration Meeting

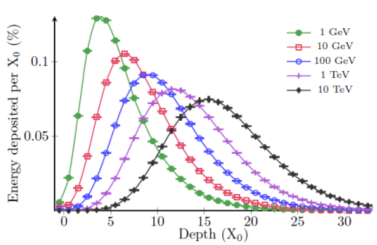
23/09/2019

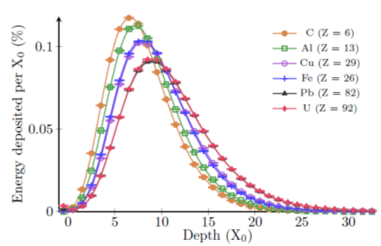
GFlashShowerModel

- The only implementation of G4VFastSimulationModel in GEANT4 (outside `examples/`).
- Based on arXiv:hep-ex/0001020, details also in physics reference manual, chapter 18
- Parametrisation of electromagnetic cascades:

$$dE(\bar{r}) = Ef(t)dtf(r)drf(\varphi)d\varphi$$

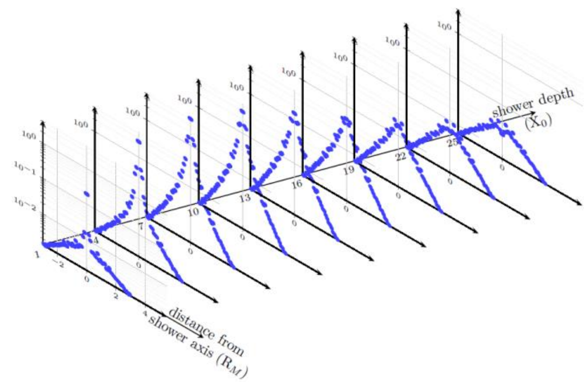
Longitudinal profile





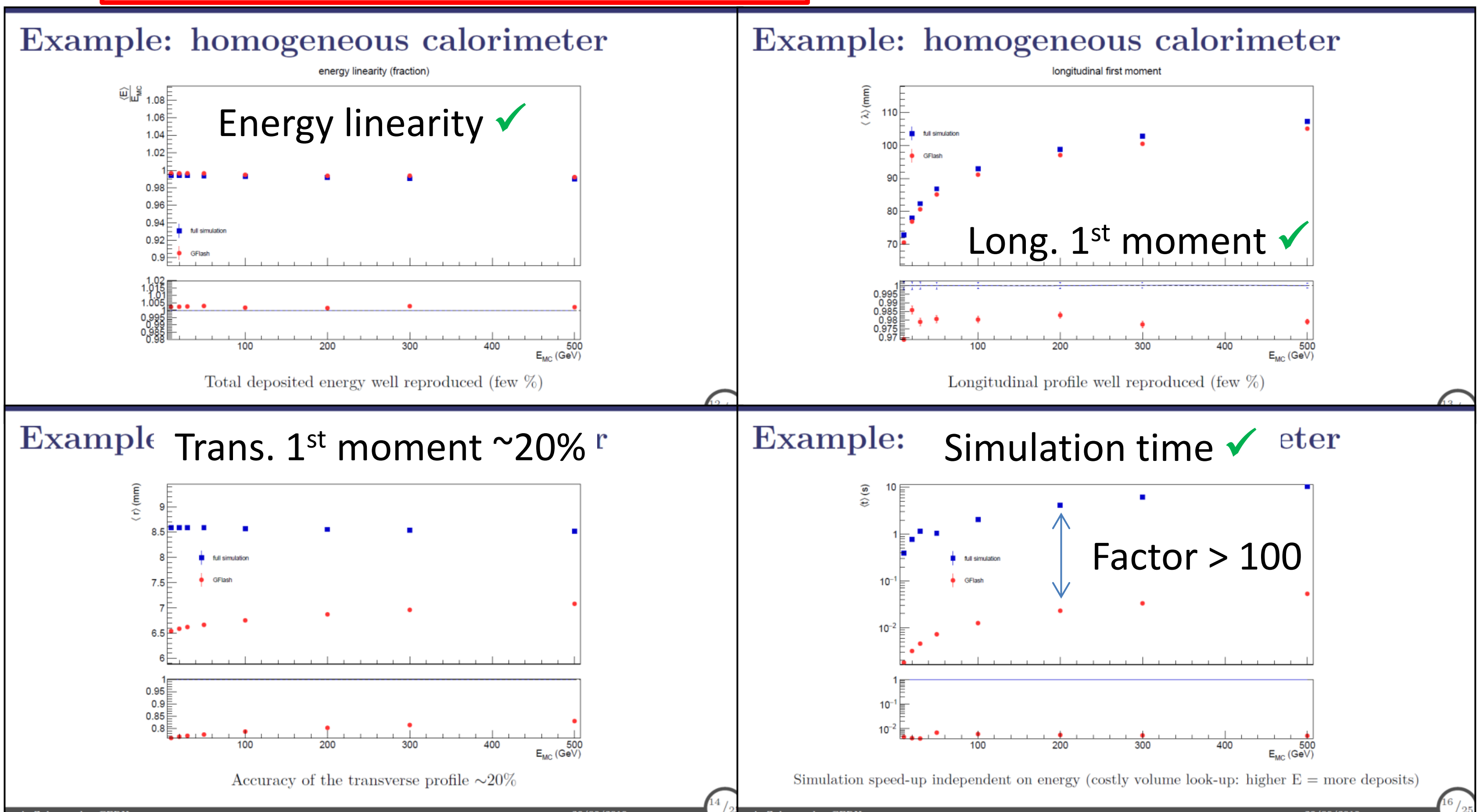
$T \sim \ln E$

Lateral profile



Example: homogeneous calorimeter

- $PbWO_4$ homogeneous calorimeter
- $25 \times 25 \times 25$ 10 mm cells
- 5k electrons per energy
- comparison of GFlash to the full simulation:



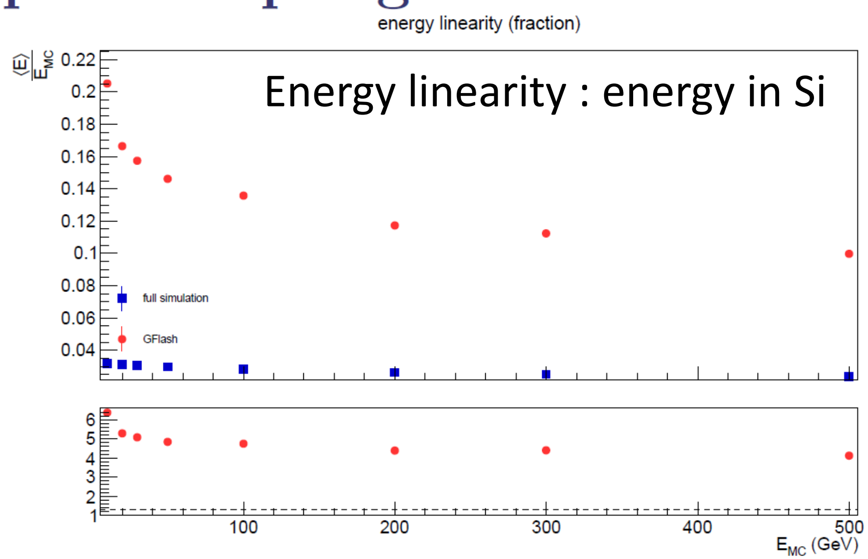
Example: sampling calorimeter

- SiW sampling calorimeter (1.9 mm W, 0.5 mm Si)
- $25 \times 25 \times 25$ 5 mm cells
- 5k electrons per energy
- comparison of GFlash to the full simulation:
  - no distinction of the material distribution

    $4-6$ times more energy deposited in Si than in full simulation

    not visible if deposit from both active and passive material is registered

Example: sampling calorimeter



Energy collected only from the active material (Si), but no distinction between materials in parametrisation, hence overestimation.

Tuning the parameters

- parameters may be extracted for specific geometry (material, granularity)
- better accuracy
- less parameters (no material dependency)
- cu
- on

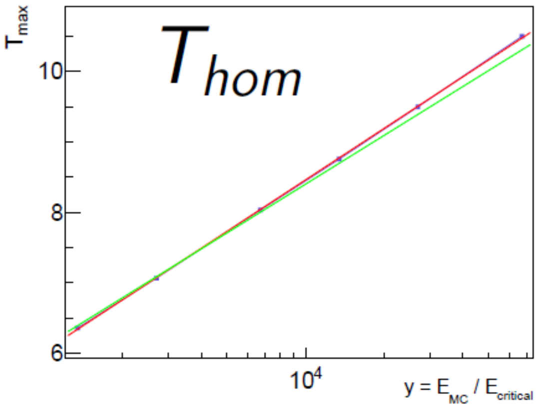
Towards user-friendly tuning

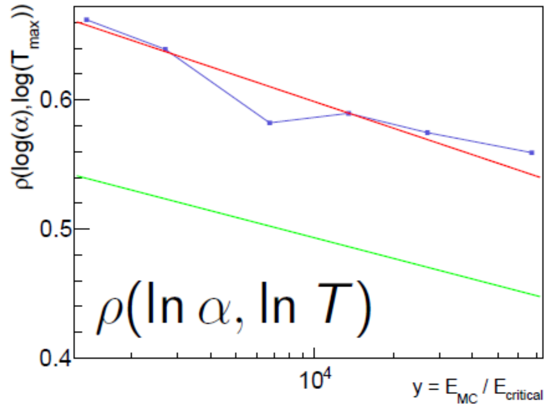
- Model parameters stored in a file, read in at the initialization
- Path to the parameters can be given by user - facilitate testing of several parametrisations

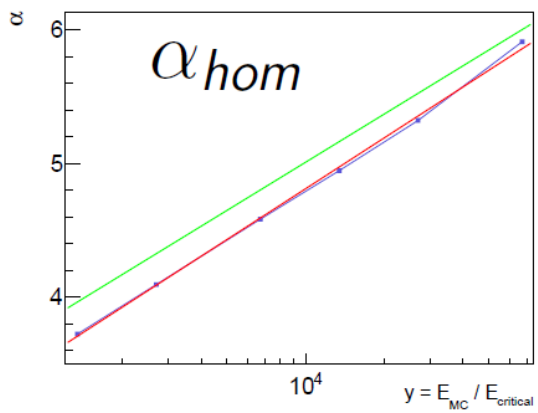
How to obtain the new parameters?

- Run full simulation, store energy deposits
- Analyse shower distributions (average profiles, individual profiles, number of deposits) - one recipe, can be automated
  - one recipe if following GFlash, more flexibility can be added (which formula fits radial profile, fit of either $\ln \alpha$ or α distributions for individual longitudinal profiles, etc...)
- Save generated parameters in a file ready to be read by GEANT4
- Ready and working for longitudinal profile, radial profile on-going...

Longitudinal profile parameters (Pb)





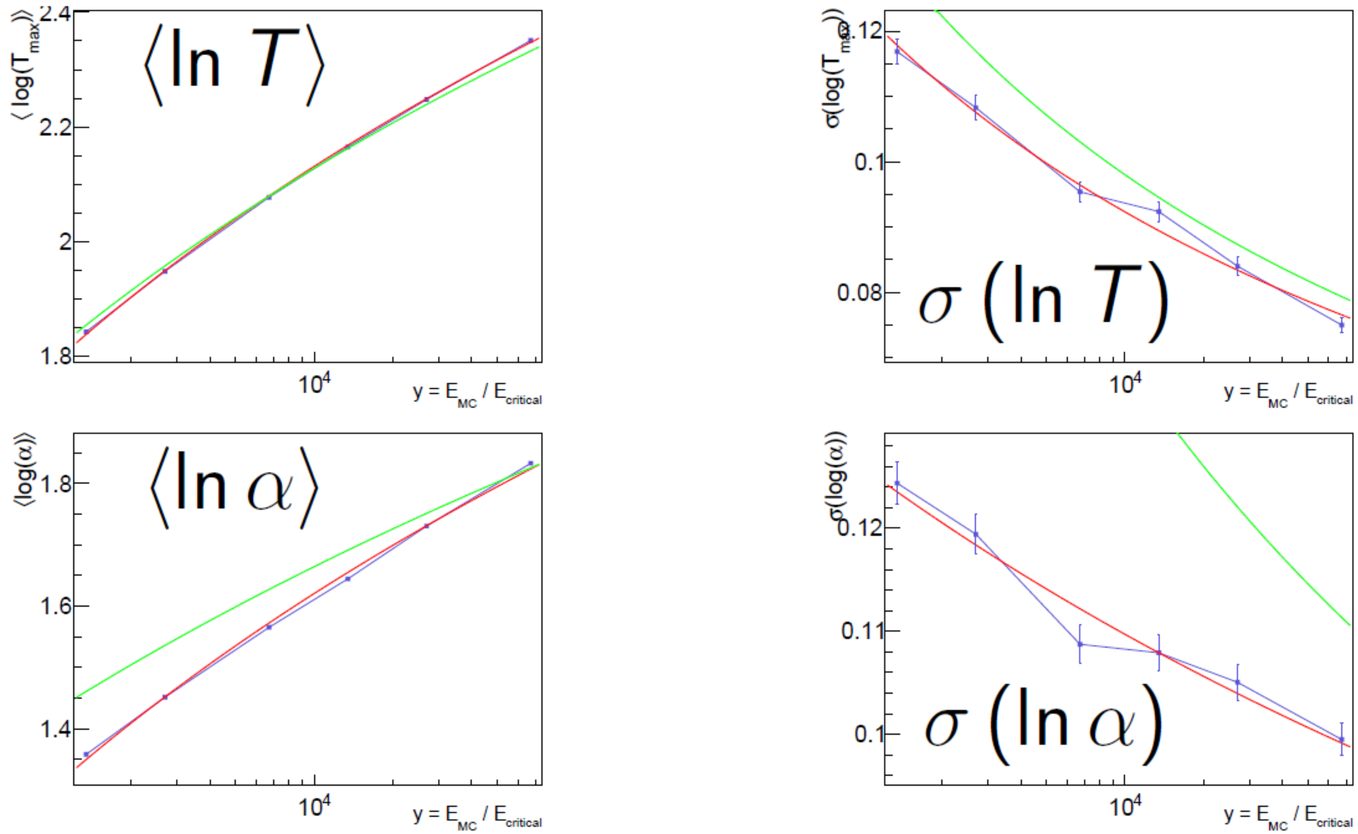


green line - original parameters from arXiv:hep-ex/0001020

blue points - from full simulation on Pb

red line - fit to full simulation, new parameters (no Z dependency)

Longitudinal profile parameters (Pb)



Summary

On-going work on the shower parametrisation in Geant4:

- Revision of current implementation of shower parametrisation:
  - investigate and address the sampling calorimeter issue
  - efficient creation of deposits/location of volumes
  - more technical code revision (by Igor & Marc, LLR)
- Work on user-friendly tuning facilities:
  - specific to given geometry
  - less parameters (no material dependency)
  - better accuracy
  - in good shape for longitudinal profile, on-going work on the radial profile and validation
- Other items:
  - introduction of shower start point parametrisation
  - rethinking the parametrisation of the number of created energy deposits

Igor (LLR)

Applications for GFLASH testing

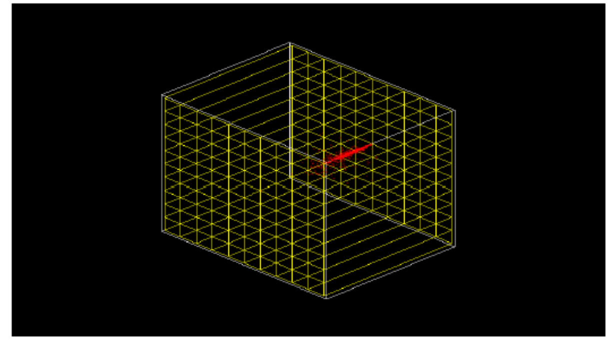
The application with allow compare and tune GFALSH sower parametrization versus full Geant4 shower development.

A. GFlash homogeneous shower parameterization.

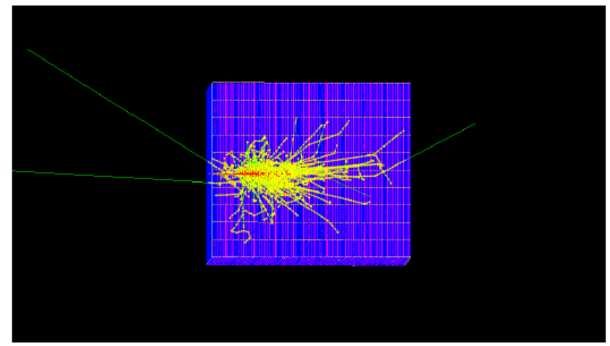
- Some enhancement in Messenger
- More histograms

B. GFlash sampling shower parameterisation.

- GFLASH integration undergoing
- Geometry based scorer



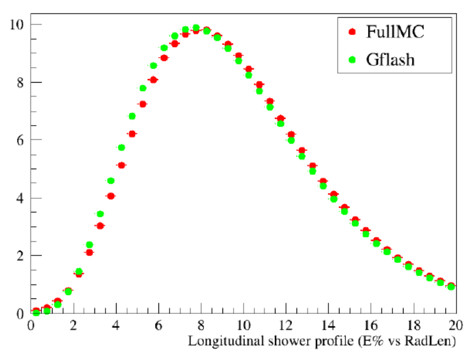
A. GFLASH Hits in homogeneous calorimeter

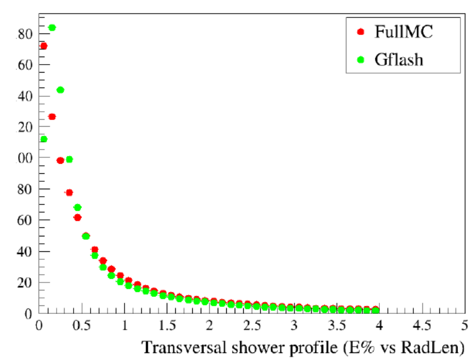


B. Full MC shower in sampling calorimeter

Homogeneous shower parameterization.

The good agreement between Geant4 and GFLASH shower development.
Example of profiles for 40 GeV e⁻ shower in $PbWO_4$ crystals





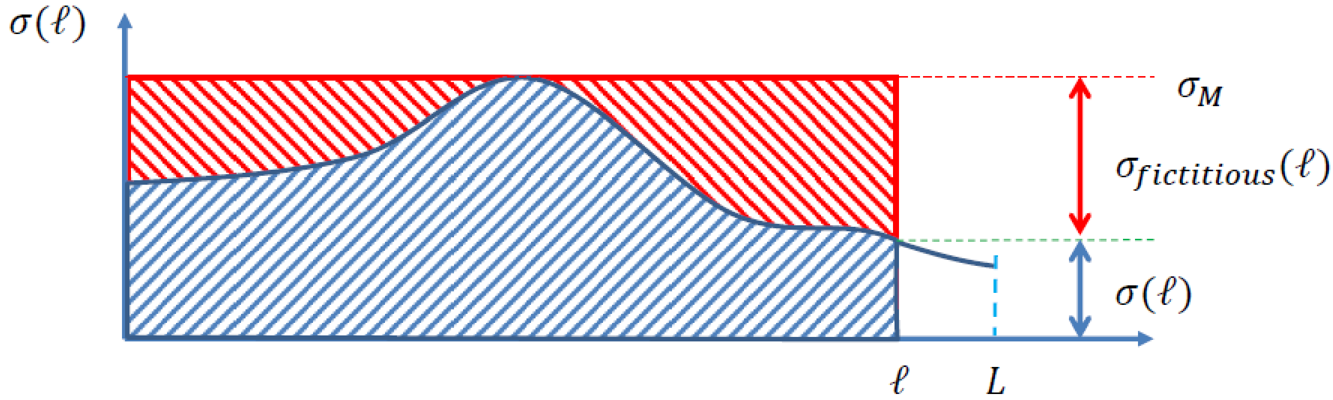
Marc (LLR)

Using Woodcock viewpoint for weight calculation of occurrence biasing of charged particles

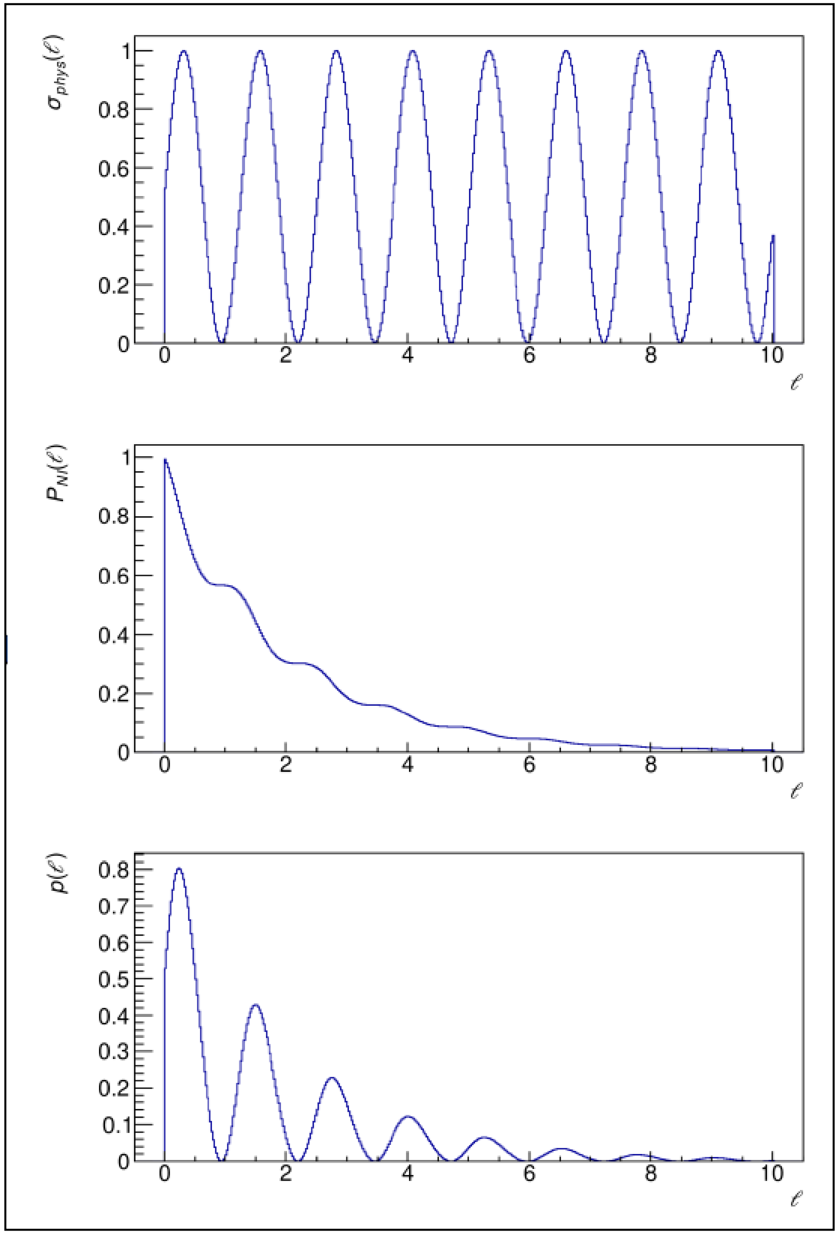
Jefferson Lab Collaboration Meeting
Parallel Session 2B
23/09/2019

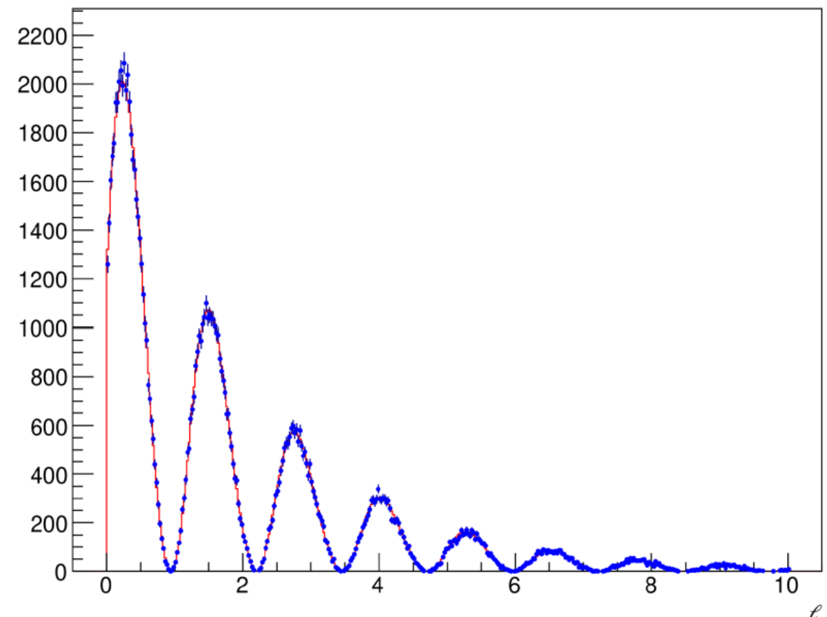
Marc Verderi, LLR

Woodcock viewpoint



- The Woodcock tracking (invented for medical) rephrases the problem saying that:
  - We have a total (and constant) cross-section σ_M
  - This one is the sum of two physics process cross-sections:
    - The physical one $\sigma(\ell)$
    - And $\sigma_{fictitious}(\ell)$ which generates "fictitious interactions"
      - These are simply "void" interactions, from the fictitious process, which does nothing
- Algorithm is essentially the same as before
  - Determine σ_M on $[0, L]$; Sample ℓ according to total cross-section σ_M; Move track to ℓ
  - **And chose randomly between the two "processes"**
    - depending on their relative cross-sections at that point.
- This makes *de facto* the exact same sampling than the rejection one !
- But the Woodcock viewpoint –with the fictitious process- makes a tremendous change for what moving to biasing is concerned





Distribution of interactions obtained by Woodcock sampling technique (100 k events)

Woodcock & Biasing

Invention ?
Re-invention ?
Re-phrasing of an existing technique ?

- The Woodcock viewpoint makes it easy the move to biasing:
  - In the analog world we have total physical and fictitious cross-sections:

$$\sigma_M^a = \sigma_{phys}^a(\ell) + \sigma_{fictitious}^a(\ell)$$

  - That we replace by their biased version in the biased world:

$$\sigma_M^b = \sigma_{phys}^b(\ell) + \sigma_{fictitious}^b(\ell)$$

- From there, we apply the formalism we already know (see last general paper):
  - For a step ending with no interaction (eg : geometry), we multiply the track weight by the non-interaction weight, ratio of the non-interaction probabilities $P_{NI}^{a(b)}(0 \to \ell)$:

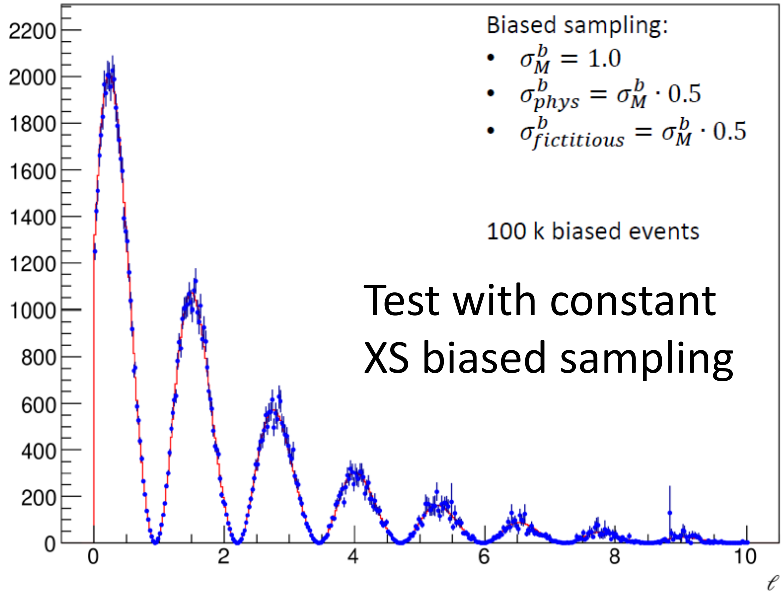
$$w_{NI}(0 \to \ell) = \frac{P_{NI}^a(0 \to \ell)}{P_{NI}^b(0 \to \ell)}$$

$$P_{NI}^{a(b)}(0 \to \ell) = \exp\left(-\int_0^\ell \sigma_M^{a(b)} \cdot ds\right) = \exp\left(-\sigma_M^{a(b)} \cdot \ell\right)$$

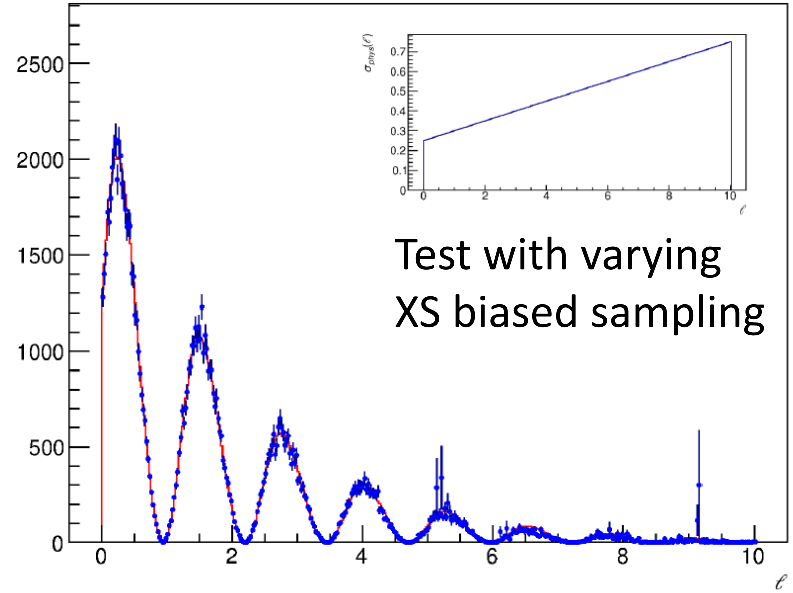
  - For a step ending with an interaction by process i, i = "physical" of "fictitious", we multiply the track weight by the interaction weight:

$$w_I(\ell) = w_{NI}(0 \to \ell) \cdot \frac{\sigma_i^a(\ell)}{\sigma_i^b(\ell)}$$

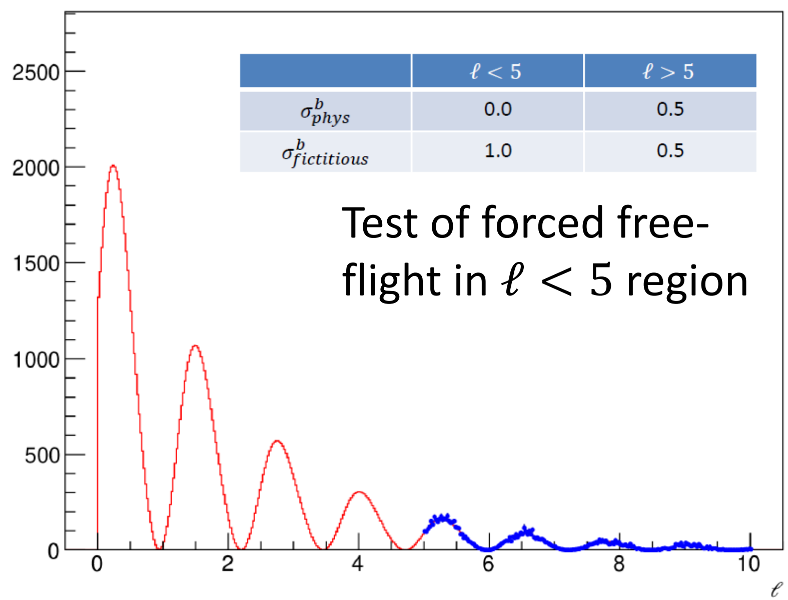
- And we're done !



Reconstructed distribution of physical interactions using biasing



Reconstructed distribution of physical interactions using biasing



Reconstructed distribution of physical interactions : they are only present at $\ell > 5$, and with the proper normalization, hence correct weight, as desired !

Conclusion

- The smart Woodcock viewpoint of interpreting a track which makes a step with no interaction as a "fictitious interaction" is very convenient to allow to take into account the variation of cross-sections
- And it allows an easy application to biasing !
- On Toy MC samples, the biasing technique looks working well
  - Tested with constant and varying biased cross-sections
    - To reconstruct analog distributions from varying cross-sections
  - Tested with a free-flight scheme
  - It looks to have interesting observables to help diagnosing poor biased sampling:
    - Eg : comparison of weighted and unweighted distributions as function of the number of fictitious interaction
  - It looks to have interesting handle(s) to improve poor sampling:
    - Eg : amount of fictitious interactions
- Generalization ?
  - Going from constant maximum to varying upper bound cross-section
  - Needed for the forced interaction scheme for example
- Moving to G4 implementation will require technical help:
  - how to know or calculate the maximum cross-section over a step
- (And of course and as usual : manpower remains a issue…)

Discussion

- Topic of discussion was the `ExclusivelyForced` versus `StronglyForced` flags

- Anna found that `StronglyForced` processes are called even if `ExclusivelyForced` is used
  - Making `ExclusivelyForced` not exclusive
- This creates inconsistencies:
  - Like having twice the energy deposited in case of parallel world scoring:
    - One deposit by the shower parameterisation
    - One deposit –all in one cell, where the track was killed- by the parallel world process scorer

- I understand we agreed to restore `ExclusivelyForced` as exclusive