# Status of event biasing & fast simulation

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on behalf of Generic Processes and Materials WG

24th GEANT4 Collaboration Meeting

25/06/2019

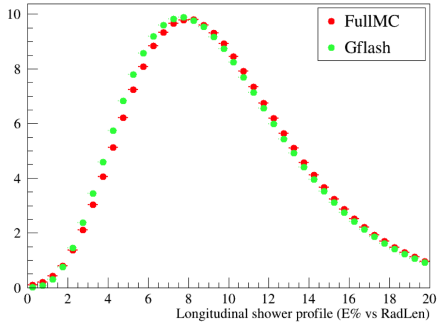
# Outline

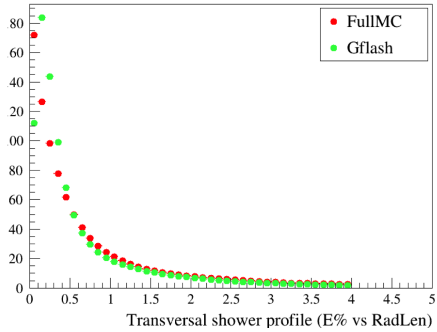
1. Development/revision of the GFlash parametrisation;
2. Ongoing work on the validation tools for biasing techniques;
3. Occurrence biasing of the charged particles (Woodcock tracking);
4. Example application of generic biasing facilities to non-biasing use-case (ALICE);
5. `G4ForceCondition` and issue of `ExclusivelyForced`;

# Revision of the GFlash implementation

*Igor Semeniouk*

- Work on code revision started with preparation of validation utilities;
- Preparation of histograms (currently output is not interpreted in any way);
- Almost ready, still improving the messenger, etc.;
- Further extension of existing example (`extended/parametrisation/gflash/`) to sampling calorimeter (on-going);



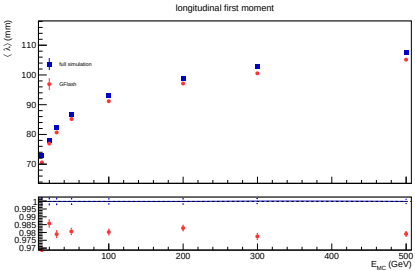
# Shower parametrisation

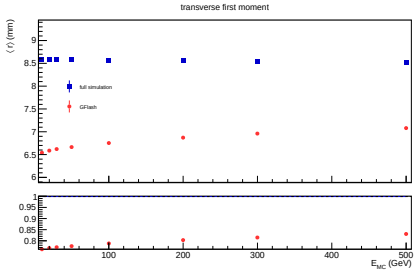
*Anna Zaborowska*

- Based on GFlash arXiv:hep-ex/0001020;
- Parametrisation of electromagnetic cascades:

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

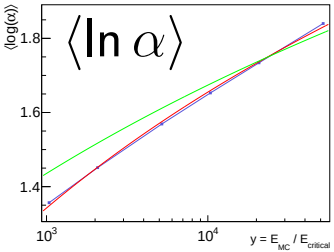
  - flat distribution in azimuthal angle $f(\varphi) = \frac{1}{2\pi}$
  - $f(t)$ and $f(r)$ parameterised as a function of particle's energy ($E$) and medium ($Z$)
  - $t$ and $r$ are expressed in units of $X_0$ and $R_M$
  - Parameterised number of created energy deposits
- Limited accuracy - much better longitudinal profile than transverse;
- More than 100× speed-up;

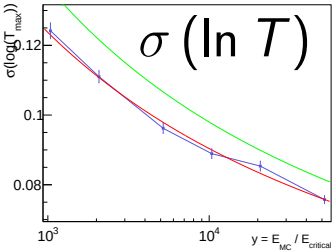


# Shower parametrisation - tuning

- Current parameters extracted for selected materials, granularity, energy, ...
- In GEANT4 parameters are hard-coded
- Re-tuning parameters time-consuming
- Tuning requires following 'recipe', more automated way feasible, being implemented
  - tuned to specific geometry (material, granularity)
  - less parameters (parameters no longer universal, no material dependency




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

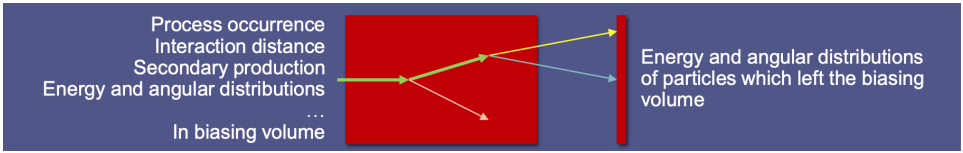
blue points - from full simulation on Pb

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

# Validation tools for biasing techniques

*Kyungseop Yoon*
*(supervised by A.Zaborowska, W.Pokorski)*

- Need for verification tool for biasing applications
- Many observables common to various biasing options
- Used as a high-statistics validation (e.g. geant-val) and for development of new techniques




Marc Verderi (23th Collaboration Meeting)

- Started as a generalisation of `biasing/` examples (importance sampling, weight window biasing in radiation protection)

# First results

## Event Biasing Example B01

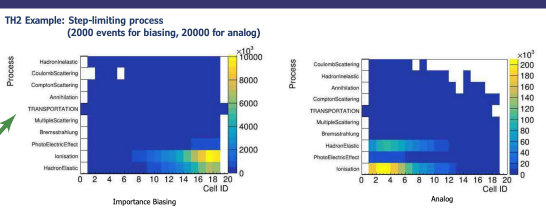
Default output:

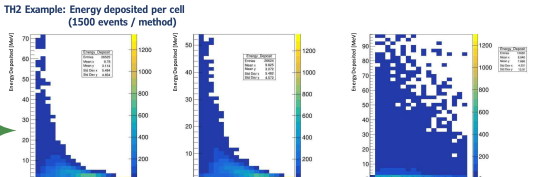
```
-------------------End of Global Run-------------------
Number of event processed : 100
============================================================
```

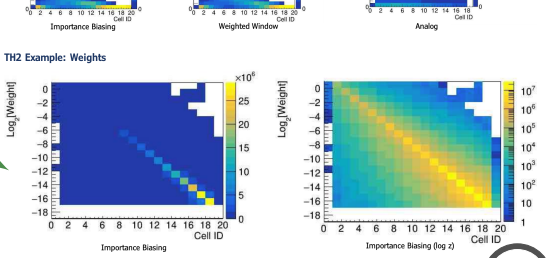
| Volume | Tr.Entering | Population | Collisions | Coll*WGT | NumWGTedE | FluxWGTedE | Av.Tr.WGT | SL | SLW | SLW_v | SLWE | SLWE_v |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| cell_00 \| | 35 \| | 129 \| | 35 \| | 0.0155897 \| | 2.62983 \| | 1 \| | 6193.92 \| | 6193.92 \| | 371641.5 \| | 16289 \| | 579.32 \| | |
| cell_01 \| | 149 \| | 175 \| | 497 \| | 0.0188688 \| | 4.51875 \| | 1 \| | 21945.8 \| | 21945.8 \| | 141137 \| | 99167.5 \| | 2663.09 \| | |
| cell_02 \| | 200 \| | 284 \| | 1359 \| | 679.5 \| | 0.00924091 \| | 2.66639 \| | 0.5 \| | 49101.7 \| | 24750.9 \| | 224504 \| | 61995.4 \| | 2074.62 \| |
| cell_03 \| | 295 \| | 449 \| | 2528 \| | 632 \| | 0.00638027 \| | 1.92865 \| | 0.25 \| | 81588.5 \| | 20397.1 \| | 218239 \| | 39339 \| | 1392.42 \| |
| cell_04 \| | 349 \| | 496 \| | 2894 \| | 361.75 \| | 0.00444105 \| | 1.64978 \| | 0.125 \| | 92173.8 \| | 11521.7 \| | 154576 \| | 19008.3 \| | 686.479 \| |
| cell_05 \| | 390 \| | 550 \| | 3468 \| | 216.75 \| | 0.00312744 \| | 1.39716 \| | 0.0625 \| | 102854 \| | 6428.37 \| | 109476 \| | 8981.46 \| | 342.378 \| |
| cell_06 \| | 360 \| | 523 \| | 3252 \| | 101.625 \| | 0.00308389 \| | 1.34062 \| | 0.03125 \| | 94757.1 \| | 2961.16 \| | 48865.4 \| | 3969.8 \| | 150.695 \| |
| cell_07 \| | 334 \| | 514 \| | 3082 \| | 48.1562 \| | 0.00386281 \| | 1.49702 \| | 0.015625 \| | 93823.8 \| | 1466 \| | 21361.4 \| | 2194.03 \| | 82.3151 \| |
| cell_08 \| | 297 \| | 446 \| | 2858 \| | 22.3281 \| | 0.00381525 \| | 1.31973 \| | 0.0078125 \| | 84864.8 \| | 663.006 \| | 9118.96 \| | 874.991 \| | 34.7911 \| |
| cell_09 \| | 272 \| | 411 \| | 2514 \| | 9.82031 \| | 0.00269239 \| | 1.01579 \| | 0.00390625 \| | 73276.9 \| | 286.238 \| | 4509.84 \| | 290.759 \| | 12.1422 \| |
| cell_10 \| | 254 \| | 390 \| | 2344 \| | 4.57812 \| | 0.00287907 \| | 1.09141 \| | 0.00195312 \| | 72294.9 \| | 141.201 \| | 2305.68 \| | 154.108 \| | 6.6382 \| |
| cell_11 \| | 252 \| | 340 \| | 2219 \| | 2.16699 \| | 0.00255482 \| | 1.12982 \| | 0.00097656 \| | 66024.5 \| | 64.4771 \| | 1215.83 \| | 72.8474 \| | 3.10623 \| |
| cell_12 \| | 243 \| | 347 \| | 2441 \| | 1.19189 \| | 0.00236057 \| | 0.893011 \| | 0.00048828 \| | 70962 \| | 34.6494 \| | 592.294 \| | 30.9437 \| | 1.39815 \| |
| cell_13 \| | 202 \| | 320 \| | 2163 \| | 0.528076 \| | 0.00239099 \| | 1.04823 \| | 0.0002441 \| | 59907.3 \| | 14.6258 \| | 265.618 \| | 15.3312 \| | 0.635091 \| |
| cell_14 \| | 172 \| | 263 \| | 1945 \| | 0.237427 \| | 0.00171936 \| | 0.804492 \| | 0.00012207 \| | 51556.4 \| | 6.29351 \| | 134.733 \| | 5.06308 \| | 0.231654 \| |
| cell_15 \| | 149 \| | 211 \| | 1488 \| | 0.0908203 \| | 0.00162713 \| | 0.819761 \| | 6.10352e-05 \| | 40386.9 \| | 2.46502 \| | 57.1373 \| | 2.02073 \| | 0.0929697 \| |
| cell_16 \| | 118 \| | 165 \| | 1274 \| | 0.0388794 \| | 0.00212628 \| | 0.899531 \| | 3.05176e-05 \| | 35318.6 \| | 1.07784 \| | 20.6002 \| | 0.969548 \| | 0.0438019 \| |
| cell_17 \| | 95 \| | 141 \| | 810 \| | 0.0123596 \| | 0.00342718 \| | 1.16751 \| | 1.52588e-05 \| | 24405.4 \| | 0.372397 \| | 5.74955 \| | 0.472016 \| | 0.0197047 \| |
| cell_18 \| | 63 \| | 118 \| | 550 \| | 0.00419617 \| | 0.00319346 \| | 1.28816 \| | 7.62939e-06 \| | 18023.1 \| | 0.137505 \| | 2.23348 \| | 0.17713 \| | 0.00713254 \| |
| cell_19 \| | 41 \| | 41 \| | 41 \| | 0.000312805 \| | 0.0152833 \| | 2.11464 \| | 7.62939e-06 \| | 6161.48 \| | 0.0470084 \| | 0.234429 \| | 0.0994057 \| | 0.00358284 \| |

based on slides from summary talk by Kyungseop

- Comparison of histograms to be implemented (on-going)
- Extension to other examples needed



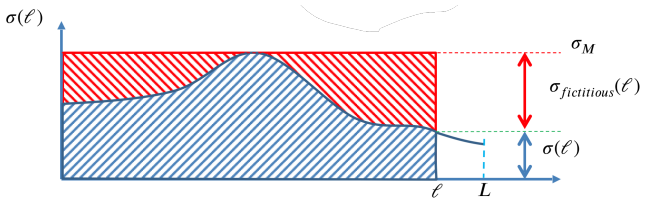



# Occurrence biasing of charged particles

*Marc Verderi*

- Main difficulty with charge particles: changing cross section over the simulation step (energy loss);
- from Laurent's calculations in 2012 - correctness of rejection technique;
- Same principle rephrased in the Woodcock tracking - elegant solution to weight calculation for changing cross section;

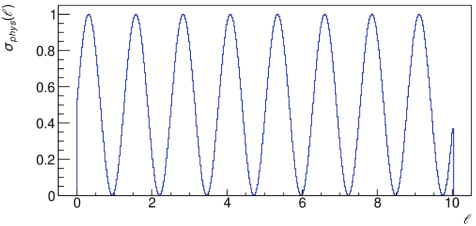



- $\sigma_{tot} = \sigma_M = \sigma(l) + \sigma_{fictitious}(l)$
- random number: decide if interaction or not (=fictitious)
- at end of step: multiply track weight by interaction weight

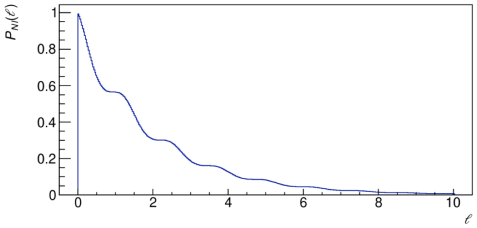
More details in Marc's presentation from Monday and in the note.

# Occurrence biasing of charged particles

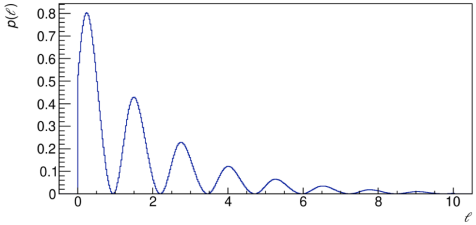
"Physical" test cross-section



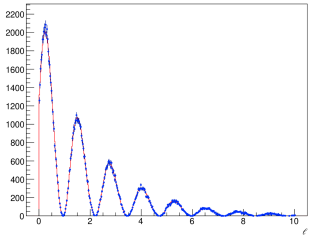

Related non-interaction probability




Related probability density function of interactions (product of the two above functions)




Woodcock sampling (100k events)




More details in Marc's presentation from Monday and in the note.

# Occurrence biasing of charged particles

- Idea tested on toy MC samples
- Works on constant and varying biased cross-sections, and on free-flight
- MC itself an interesting diagnostic tool
  - comparison of weighted and unweighted distributions as function of the number of fictitious interaction
  - improving poor sampling - amount of fictitious interactions
- Moving to G4 implementation will require technical help:

  how to know or calculate the maximum cross-section over a step

More details in Marc's presentation from Monday and in the note.

# Application of generic biasing facilities

*Alberto Ribon*

## Hadronic Model per Region

- Geant4 physics list is defined globally, not per region
- Sometimes users would like to use a reference physics list, e.g. FTFP_BERT, but replacing a hadronic physics model in a region with a more precise model
  - Recent request from ALICE : to be able to use INCLXX in the Tracker region, while using BERT elsewhere
    - INCLXX describes better the production of light ions by primary pions and nucleons interacting in the beam pipe and silicon tracker
    - The overhead in CPU time for ALICE of using FTFP_INCLXX instead of FTFP_BERT if about a factor of 2
- An elegant and efficient solution is provided by the "**Generic Biasing**" capability of Geant4
  - It naturally allows a treatment per-region and per-particle
  - No "occurrence" biasing, only "final-state operation" biasing
    - Kept the natural cross sections, but changed final-state hadronic model [1]
    - It is "biasing" but with weight = 1.0 (as in analogous simulations)

# G4ForceCondition

```
enum G4ForceCondition {
  InActivated,
  // This PostStepDoit is inactivated by a user
  Forced,
    // This PostStepDoIt is forced to invoke if particle is not a state of StopAndKill.
  NotForced,
    // This PostStepDoIt is not forced to invoke.
  Conditionally,
    // This PostStepDoIt is forced to invoke only when corresponding
    // AlongStepDoIt limits the Step.
  ExclusivelyForced,
    // Only this PostStepDoIt (or AtRestDoIt) is exclusively forced
    // to invoke - all other DoIt including AlongStepDoIts are ignored.
  StronglyForced
   // This PostStepDoIt is really forced to invoke, anyway.
};
```

Discovered inconsistent behaviour for physics lists that include processes that are `ExclusivelyForced` and `StronglyForced` - important dependency on ordering parameter.

(Potential) clashes of fast simulation with generic biasing, scoring, and sensitive detector in parallel world.

# ExclusivelyForced in G4SteppingManager

```
void G4SteppingManager::DefinePhysicalStepLength() {
  ...
  for(size_t np=0; np < MAXofPostStepLoops; np++) {
    ...
    if (fCondition==ExclusivelyForced) {
      for(size_t nrest=np+1; nrest < MAXofPostStepLoops; nrest++){
        (*fSelectedPostStepDoItVector)[nrest] = InActivated;
      }
    return;  // Take note the 'return' at here !!!
    }
    else {
      if(physIntLength < PhysicalStep ){
        PhysicalStep = physIntLength;
        fStepStatus = fPostStepDoItProc;
        fPostStepDoItProcTriggered = G4int(np);
        fStep->GetPostStepPoint()->SetProcessDefinedStep(fCurrentProcess);
      }
    }
  ...
  }
  ...
}
void G4SteppingManager::InvokePostStepDoItProcs() {
  ...
```

Deactivate all **remaining** processes. If there was any `StronglyForced` process with **higher** ordering, it was already marked 'to be invoked'.

# StronglyForced in G4SteppingManager

```
void G4SteppingManager::InvokePostStepDoItProcs() {
   ...
   // Exit from PostStepLoop if the track has been killed,
   // but extra treatment for processes with Strongly Forced flag
   if(fTrack->GetTrackStatus() == fStopAndKill) {
      for(size_t np1=np+1; np1 < MAXofPostStepLoops; np1++) {
         G4int Cond2 = (*fSelectedPostStepDoItVector)[MAXofPostStepLoops-np1-1];
         if (Cond2 == StronglyForced)
            InvokePSDIP(np1);
   ...
}
```

1. Invoke processes in reverse order - first `ExclusivelyForced`.
2. Update G4Step (e.g. kill particle, deposit all energy in place).
3. Even if particle is killed, invoke PostStepDoIt for `StronglyForced` processes on **updated** G4Step.

# G4ForceCondition - for discussion

In addition to updating the documentation on G4ForceCondition, we could change `G4SteppingManager`:

```
    if (fCondition==ExclusivelyForced) {
       for(size_t nrest=np+1; nrest < MAXofPostStepLoops; nrest++){
          (*fSelectedPostStepDoItVector)[nrest] = InActivated;
       }
    return;  // Take note the 'return' at here !!!
```

To deactivate **all**, not only **remaining** (= lower order) processes.

So `ExclusivelyForced` is **always** exclusive, no matter what other `StronglyForced` processes are included and with what ordering.

(Currently, in the core GEANT4 source code, only `G4FastSimulationManagerProcess` is `ExclusivelyForced`).

Alternatively, `SteppingControl` flag of `G4VProcessChange` can be used — requiring user (developer of fast sim model) to set it!

# Summary

- On-going work GFlash parametrisation: validation, improvement, extension to sampling calorimeter, tuning of parameters;
- Validation tools for biasing techniques started by summer student, to be continued;
- Prototyped (on toy MC) occurrence biasing of the charged particles (using Woodcock tracking);
- Generic biasing facilities useful to non-biasing use-case;
- `ExclusivelyForced` flag to be discussed...