Report from parallel 5B
“Biasing & Channeling”

Plenary 8 - Report from Parallel Sessions

Fermilab Geant4 Collaboration Meeting

2nd October 2015

Marc Verderi

LLR/Ecole polytechnique

Session Overview

- Session devoted to biasing and in general to any physics problems in which interaction laws divert from standard exponential one, like channeling.
- Discuss status of biasing, channeling, use of G4VAuxiliaryTrackInformation, needs, etc.

- 08:30 - Session Introduction
  - Presenter(s): Dr. Enrico BAGLI (INFN), Marc VERDERI (LLR, Ecole polytechnique)
- 08:35 - Status of Geant4 Reverse MC
  - Presenter(s): Dr. Giovanni SANTIN (ESA / ESTEC)
- 08:55 - Generic-based versus Standard Geometrical Importance Biasing
  - Presenter(s): Dr. Alexander HOWARD (ETH, Zurich)
- 09:25 - Status of Channeling, and requirements from Parallel 2C 'Solid State Physics'
  - Presenter(s): Dr. Enrico BAGLI (INFN)
- 09:55 - Status of Generic Biasing
  - Presenter(s): Marc VERDERI (LLR, Ecole polytechnique)
- 10:15 - General Discussion

Geant4 Collaboration Meeting

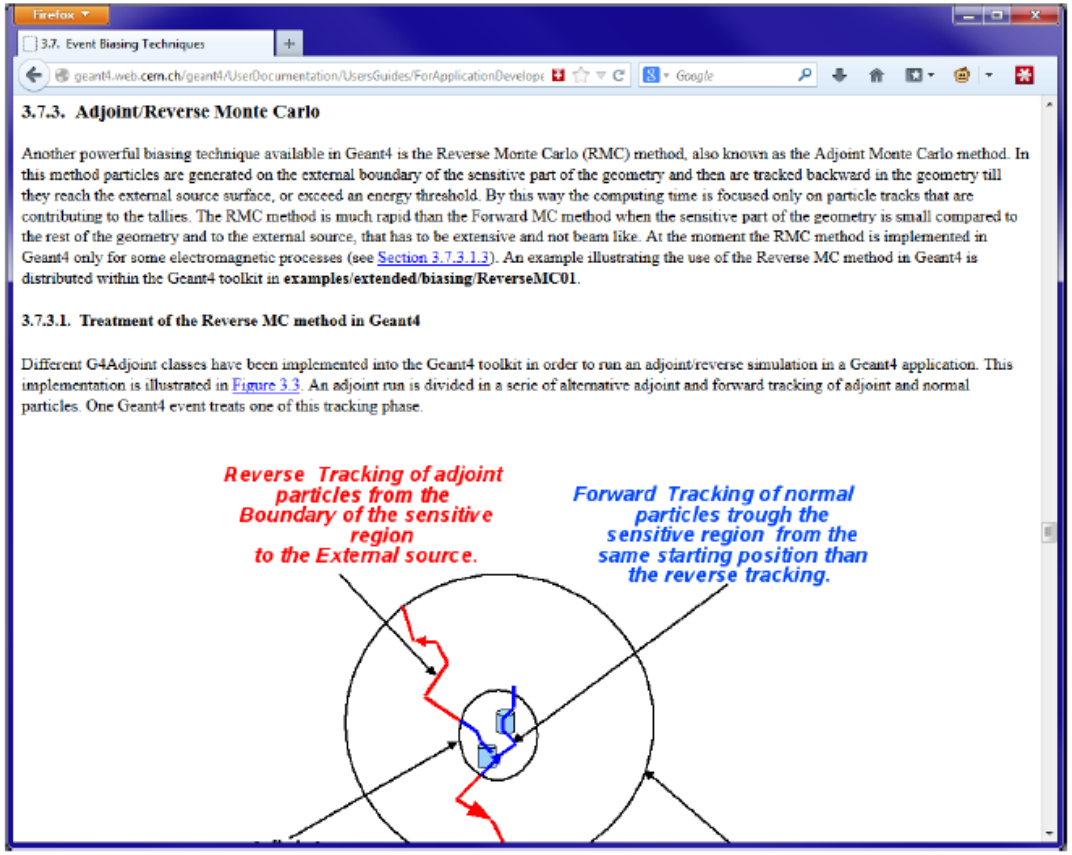
REVERSE MONTE CARLO – STATUS, PERSPECTIVE

Giovanni Santin, ESA/ESTEC
Laurent Desorgher, CHUV

Fermilab
28 September - 3 October 2015

Reverse Monte Carlo in Geant4

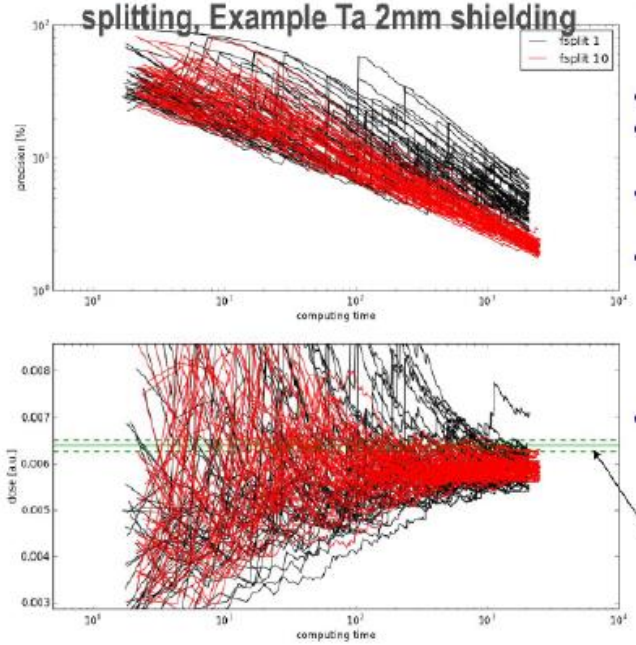
- Base adjoint classes and reverse processes distributed in the G4 toolkit (ESA funded)
- Documentation in the Geant4 user guide for application developer
  - Geant4 example extended/biasing/ReverseMC1
  - Publication in NIMA:
  - L. Desorgher, F. Lei, G Santin, NIM A, 2010
- Implemented reverse processes:
  - Ionisation (continuous and discrete) for e-, proton and ion
  - Multiple scattering
  - Bremsstrahlung
  - Compton scattering
  - Photo-electric effect



⇒ Works well, and is also used in GRAS.

Some problems though (next page).

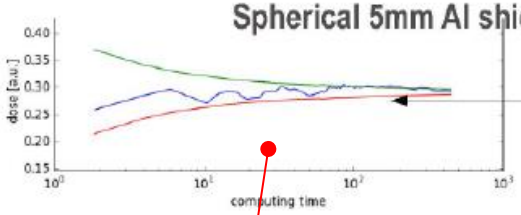
Improvments of dose convergence with gamma splitting, Example Ta 2mm shielding



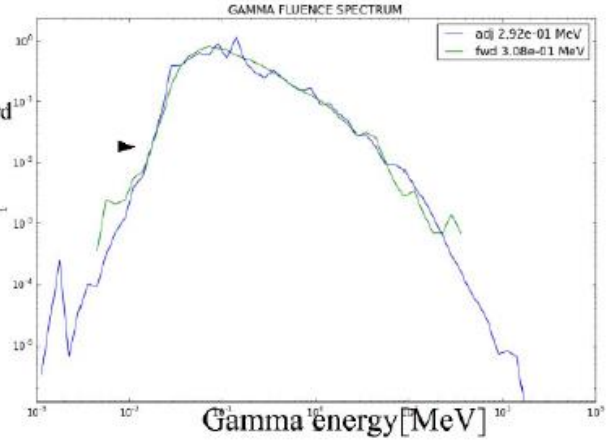
- 50 simulations
- No gamma splitting fsplit=1
- Gamma splitting fsplit =10
- Splitting of gamma remove a lot of dose peak and increase therefore the convergence
- 10-15% Lower dose compared to forward

Fwd dose

Spherical 5mm Al shield, Jupiter e-



Rapid convergence



Good comparison with forward
- Flux of secondary
- Dose

Convergence fine with thin shields, but more difficult for thick ones.

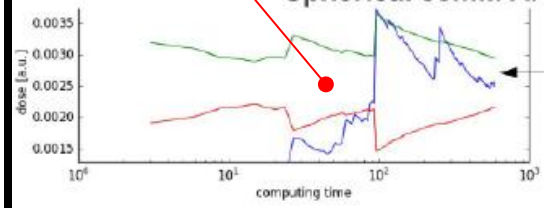
Proposed Splitting of reverse tracking to speed up convergence

- Detection of peak in tally
  - Implemented in GRAS

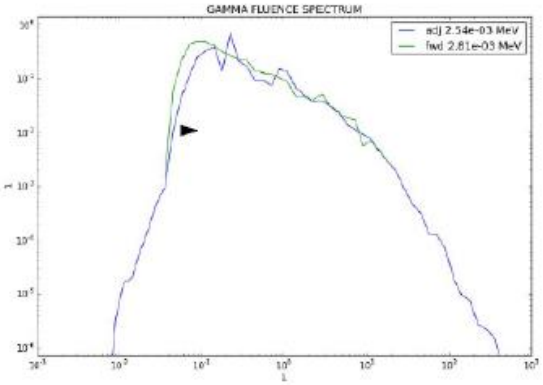
Convergence affected by large event weights. Partly understood and alleviated

- When a peak occurs use splitting of reverse tracking
  - Scale weight of the last track by 1/N
  - Generate the next N-1 adjoint primary as exact copy of the last adjoint primary particle
  - Do N-1 new reverse tracking
  - Scale weight of reverse track at the end of tracking by factor 1/N
- Development plan
  - First version by next release

Spherical 50mm Al shield, Jupiter e-



- Slow convergence
- Peak dose contribution



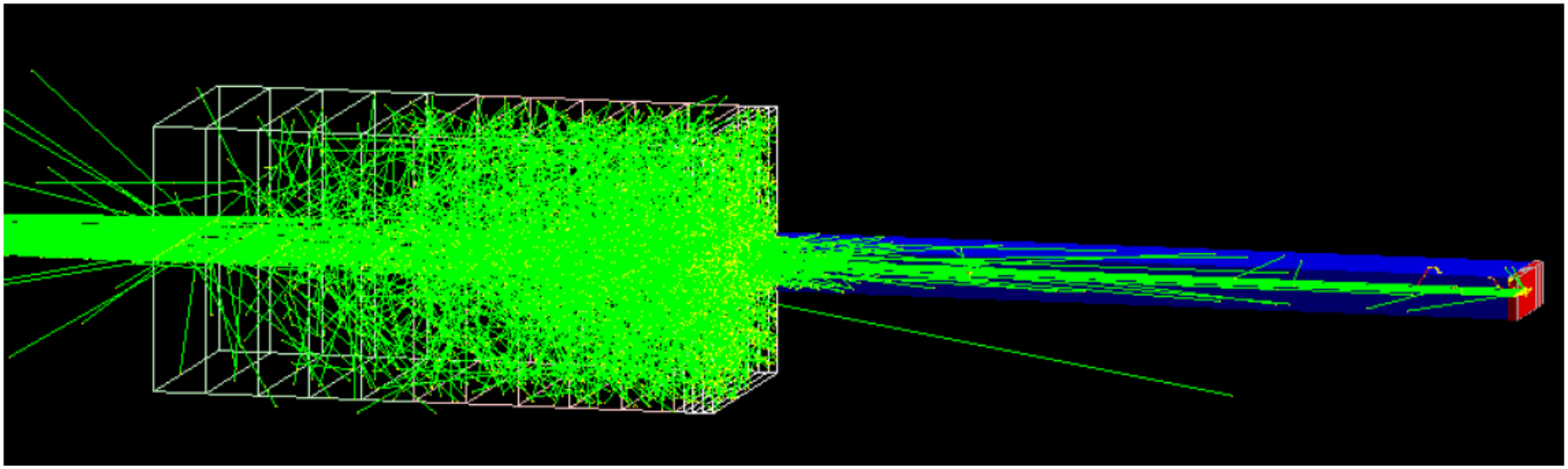
Some discrepancy with forward
- Lower flux of secondary gamma
- Lower dose

Plan to clarify origin of large weights, and target a ~5% accuracy on estimated doses. Note a high demand for such Reverse MC tool !

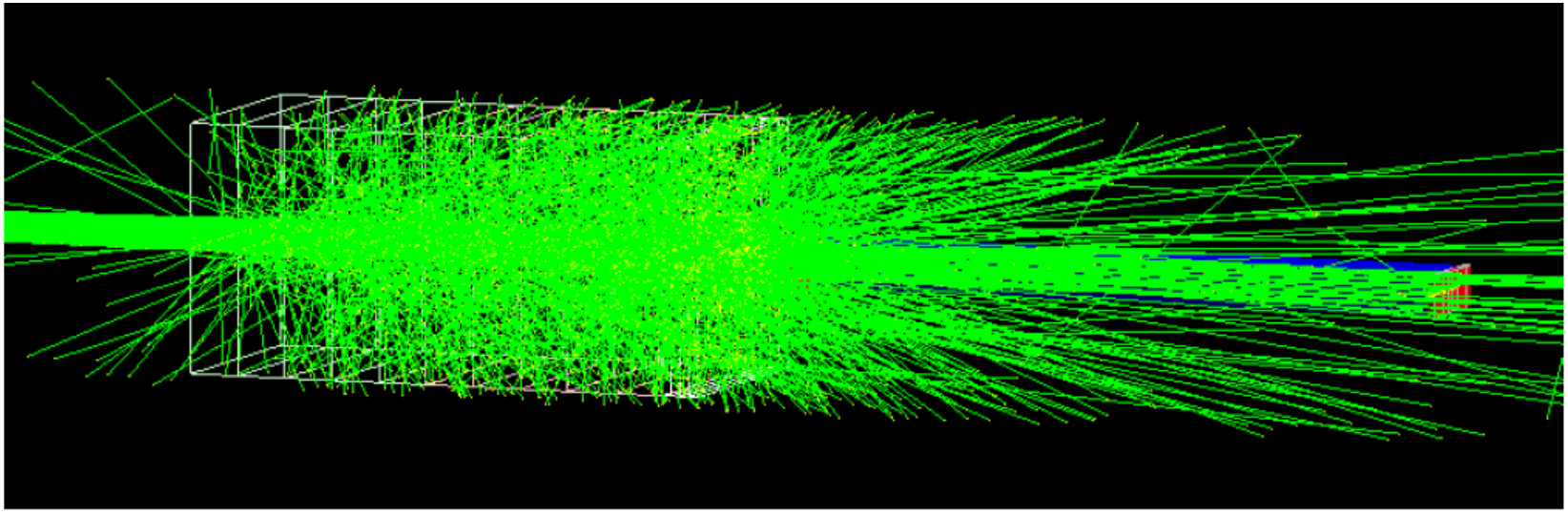
Generic vs. Conventional Importance Biasing

1. Simple set-up
2. Results
3. Features of generic biasing
4. Next steps
5. Mu3e use of GB (bhabha cross-section) ☺

“Normal” importance biasing

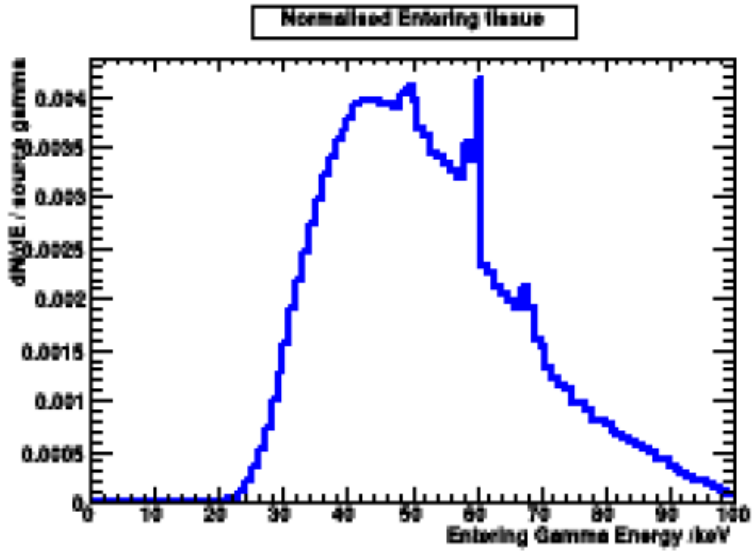


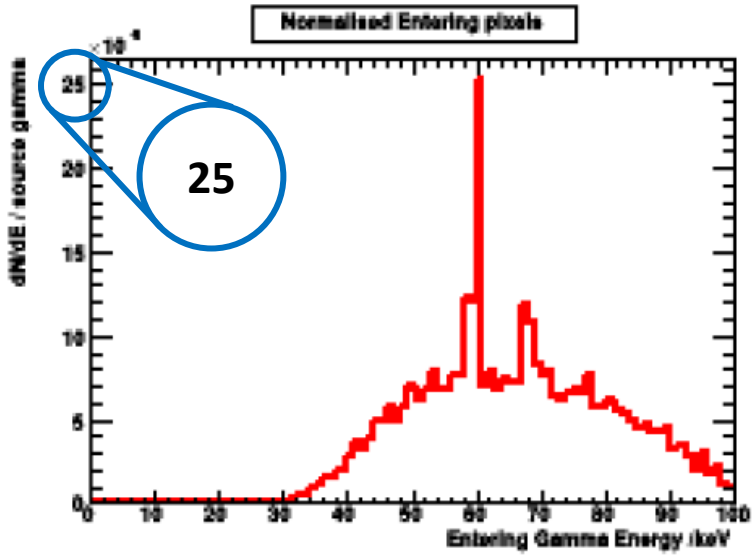
Generic Biasing



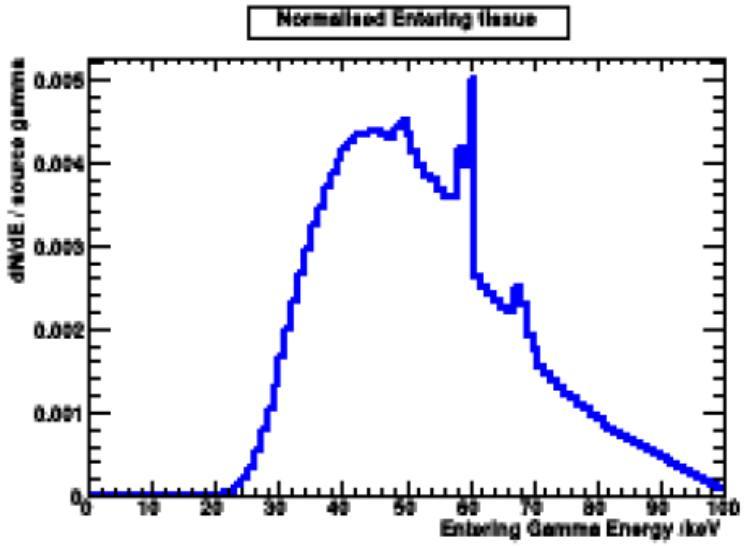
Normalised Flux

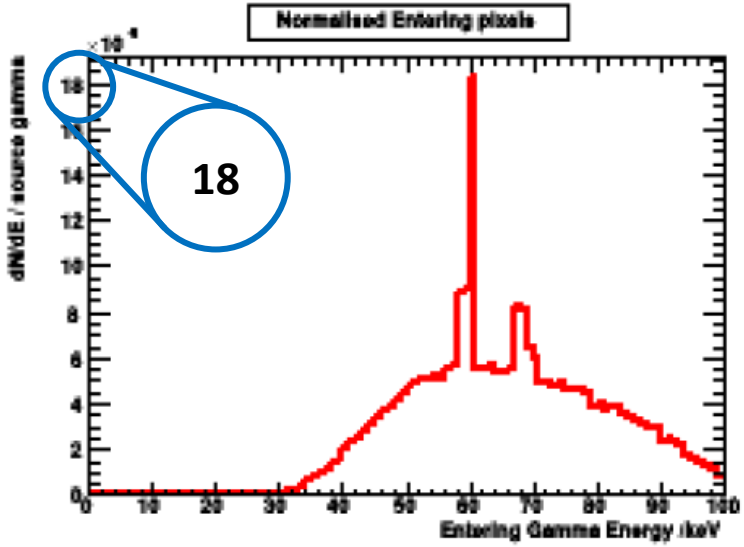
conventional





Generic Biasing

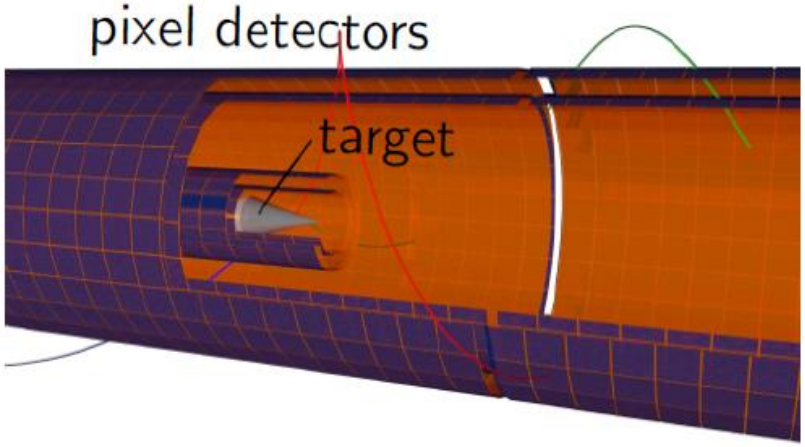




Some differences in height ! To be understood…

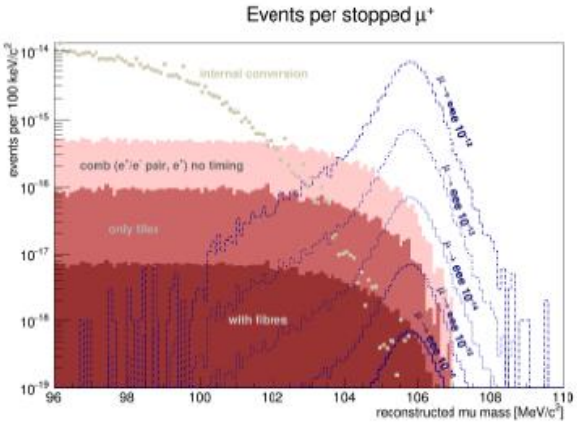
Physics Based Biasing in Mu3e

The Experiment: $\mu^+ \to e^+e^-e^+$



$p_e < 53\,\text{MeV}$
$\to$ resolution ($\sim$0.5 MeV) is multiple scattering dominated

The Goal: Background estimate



Work in progress, example plot to illustrate bg sources.

e^+ scattering in target dominates combinatorical BG ($e^+ Target \to e^+e^-$)

Implementation *(Work in progress)*
Biasing e^+ scattering (Bhabha) only in target to generate large sample, but to retain momentum resolution properties of reconstruction (given by the scattering in all the other parts, e.g. pixels).

CHANNELING STATUS

Solid state support classes

- Rotation from/to lattice
- Potential
- Electric field
- Density
- …
- Useful for other processes (e.g., x-ray diffraction)

Channeling process

- Limited to a few functions
- Ready to be “biased”

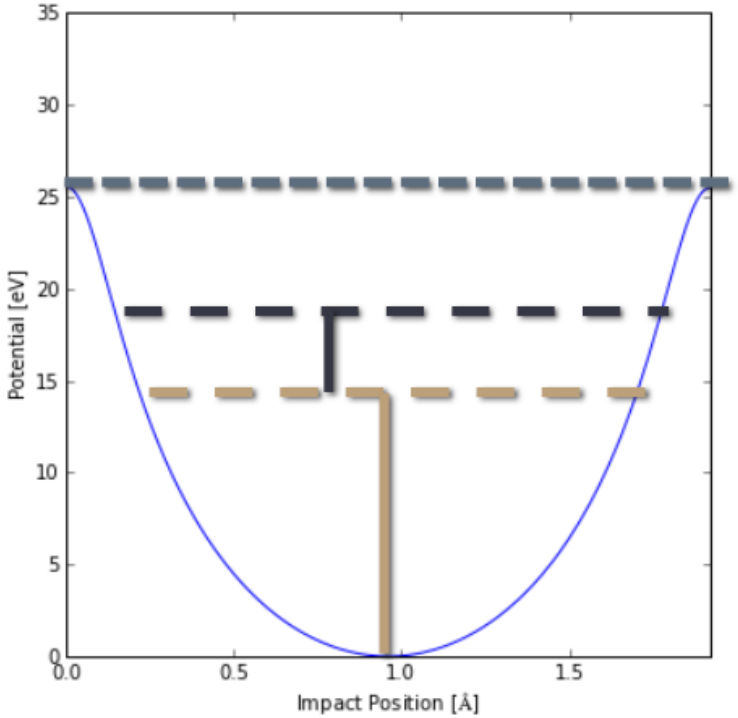
Channeling support class

- Calculation of quantity of interest for channeling
- Analytical function, not used during simulations

Condition for channeling

Straight crystal

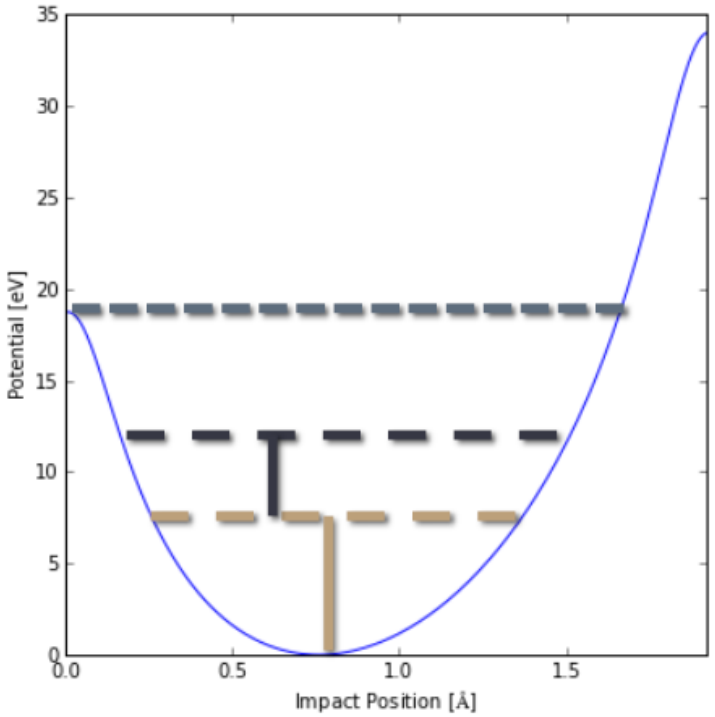
$$E_T < U_{\max}$$



$$E_T' = \frac{p\beta}{2}\theta^2 - U'(x)$$

Bent crystal

$$E_T' < U'_{\max}$$

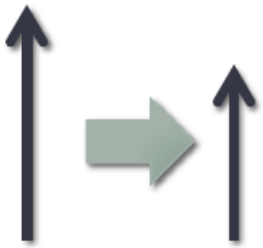


$$E_T = \frac{p\beta}{2}\theta^2 + U(x)$$

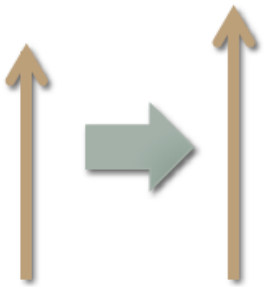
Modified density

Geant4 Mean Free Path Modification

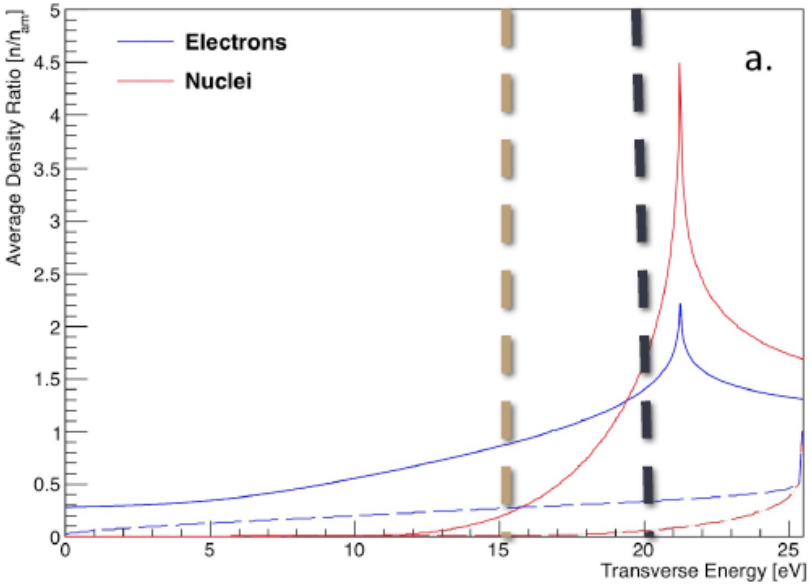
(@20 eV) Density Ratio = 1.5



(@15 eV) Density Ratio = 0.8



Density Ratio



Depending on the transverse energy of the particle, the density “seen” is different

CHANNELING BIASING REQUIREMENTS

On/Off:

- Each process which modify position (e.g., Multiple Scattering processes) **disabled inside the crytal**.
- Processes to substitute Multiple Scattering (e.g., Single Scattering?) **enabled only inside crystal**.

Cross section:

- PostStep/AlongStep processes:
  - Biased Cross-Section changes linearly with density ratio in the crystal.
- AtRest processes: no changes
- Applicable to charged particles only
- Two different density ratio (nuclei,electrons) for processes
  - manual map for all G4 processes?

AuxiliaryTrackInfo

- Position/Momentum in the crystal reference frame
- Density ratio for nuclei and electrons

Status of Generic Biasing

Parallel 5B - Biasing & Channeling

Fermilab Geant4 Collaboration Meeting
29th September 2015

Marc Verderi
LLR/Ecole polytechnique

Overview

- What's new:
  - Introduction of G4VAuxiliaryTrackInformation for robust track fate bookkeeping.
    - And related revision in generic biasing classes
  -
    - All together, introduction of G4VAuxiliaryTrackInformation induces some amount of changes, but I believe that the generic biasing will gain:
      - In robustness
      - Readability
      - And maybe speed (less overhead).

    (technical presentation of modifications to be made to adapt to G4VAuxiliaryTrackInformation)
- Still…:
  - The long list of items which need progress…

Progress needed in:

- Items for 2015 work plan
- Improvements:
  - Allow/demonstrate use of parallel worlds (with generic biasing)
- Feasibility studies/prototyping:
  - Biasing of charged particles, with cross-section changing over the step
    - Formalism exists, not easy to apply
    - Might not be a problem in several concrete cases, where the physics processes actually don't take into account this change over a step
  - Use of occurrence biasing to allow continuous density change inside a same volume
    - Should be provided under the form of an example
  - DXTRAN-like biasing
    - Involve the uneasy question of biasing dependence upon other physics packages
    - Or of "generic classes" for final state description to avoid these dependences (a dream).
  - Material/isotope biasing
    - Option to enhance the contribution of an isotope as being the only one generating a measurable signal at the end
  - Woodcock tracking
    - A reimplementation of a technique already present in GATE for example
- Testing:
  - Statistical test suite to verify correctness of biasing wrt to analog

Things moving as f(limited manpower).

Discussion

- During discussion, considered opportunities for mini-workshop:
  - Coupled radioactive decay – biasing workshop ?
  - Dedicated biasing workshop ?
- Need to converge on a decision.