Parallel Session 2A: Biasing

- 4 talks, unfortunately ran out of time for discussion

1) Progress on Generic Biasing – Marc

2) EM Biasing – Vladimir (with contribution from D. Sawkey)

3) Introducing Channelling Effect – Enrico Bagli

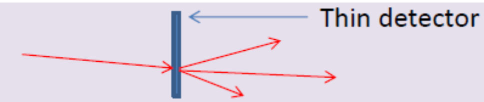
4) G4RMC – Laurent (presented by Alex)

Progress on Generic Biasing (1/3)

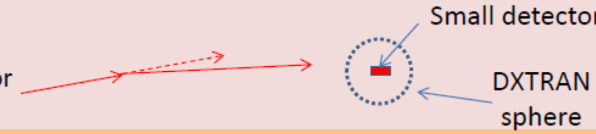
- Generic biasing scheme to extend physics based biasing using wrapper and helper classes
- Available in many other MC codes
- Prototype running
- Will be released in Geant4.10

Introduction / reminder (1/2)

- Geant4 proposes biasing options
  - Geometrical importance sampling, Leading particle biasing, Radioactive decay biasing, G4WrapperProcess, Reverse MC
- But misses others
  - Exponential transform: $p(\ell) = \sigma \cdot e^{-\sigma\ell} \rightarrow p'(\ell) = \sigma' \cdot e^{-\sigma'\ell}$
    - Change total cross-section
    - Make change direction dependent
  - forced interaction:
    - Force interaction in thin volume

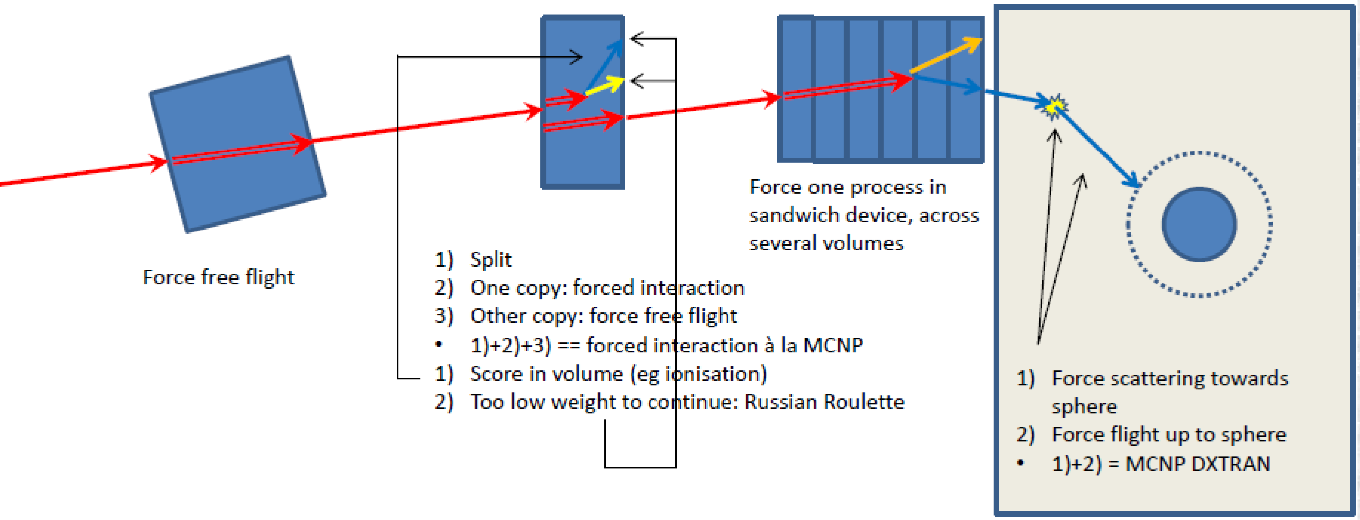


  - forced flight (towards detector)
    - So called DXTRAN
    - Force scattering towards detector



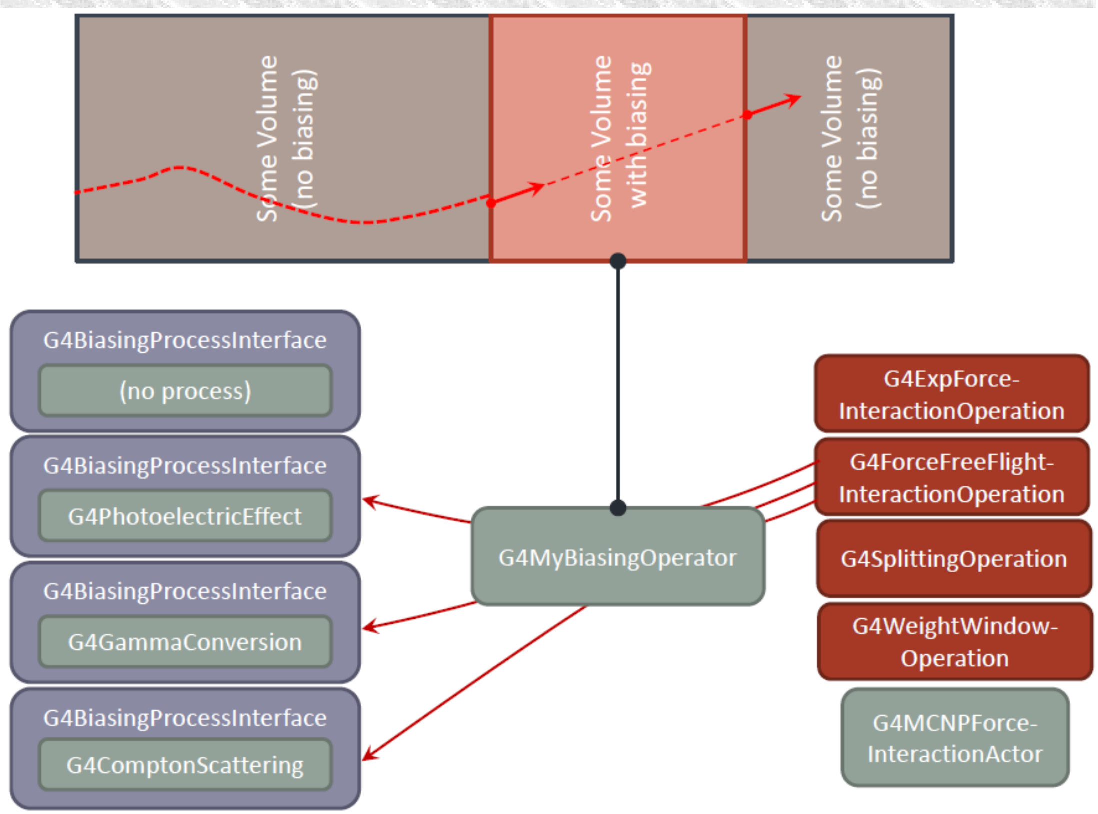
  - etc.
- These options implies changing the behavior of either
  - the interaction probability (PostStep GPIL)
  - the generation of the final state (PostStep DoIt)

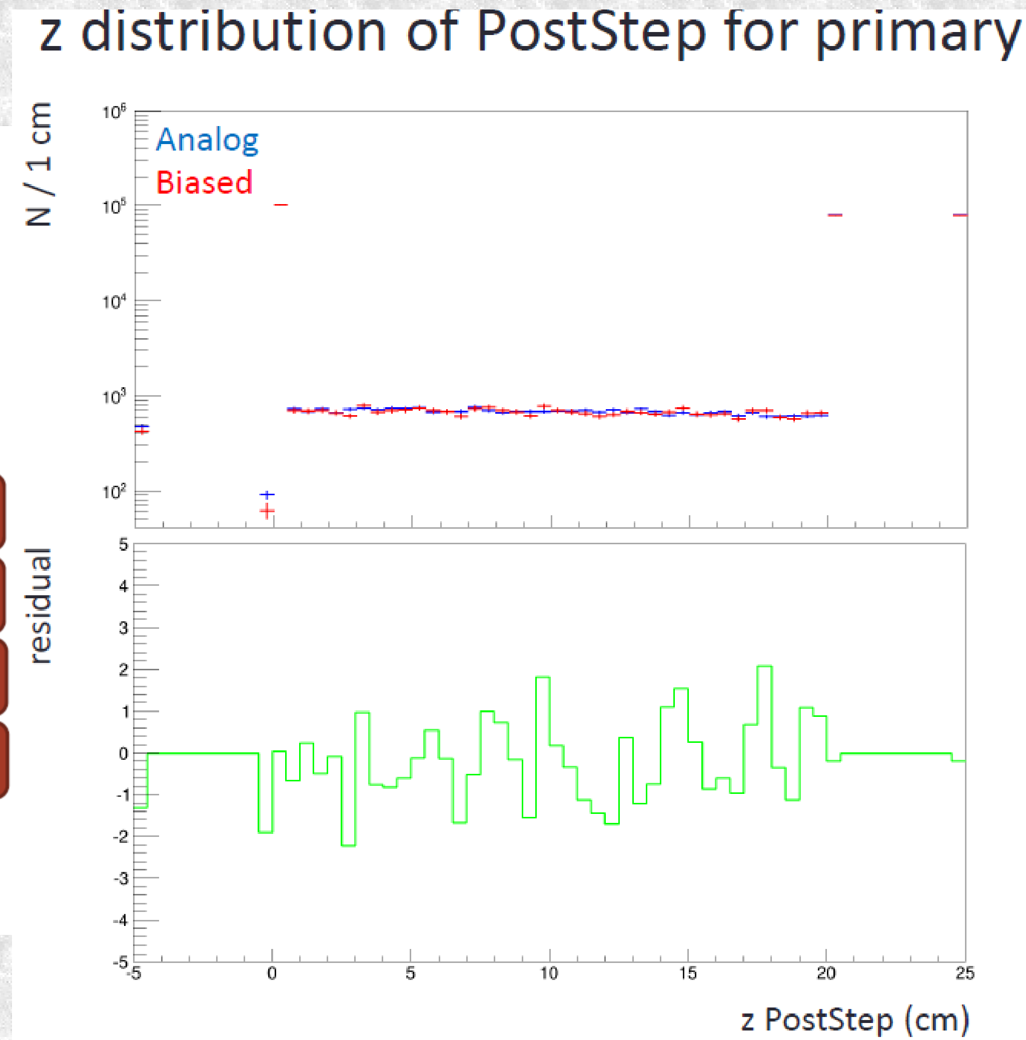
A cartoon



Progress on Generic Biasing (2/3)

- Formalism involves a biasing operator to take care of wrapping
- User defines type, bias amount etc...
- Residuals show good agreement with analogue case





Progress on Generic Biasing (3/3)

- Comparing biasing functionality with FLUKA and MCNPX:
  - We can quite simply offer many of them
  - Ongoing plan for the coming year
  - Together with MT will offer significant benefit and uniqueness in performance

FLUKA / Geant4 biasing functionalities

Biasing options in FLUKA from http://www.fluka.org/content/manuals/fluka2011.manual	Options in Geant4, present or future
Leading particle biasing for electrons and photons: region dependent, below user-defined energy threshold and for selected physical effects. → ?	Will be done, and will be shared with other "leading".
Russian Roulette and splitting at boundary crossing based on region relative importance.	Existing. Will be "re-provided" with new design, prototyped.
Region-dependent multiplicity tuning in high energy nuclear interactions.	Can be done and more general.
Region-dependent biased downscattering and non-analogue absorption of low-energy neutrons.	Can be done.
Biased decay length for increased daughter production.	Will be done. Prototyped.
Biased inelastic nuclear interaction length.	Will be done. Prototyped.
Biased interaction lengths for electron and photon electromagnetic interactions.	Will be done. Prototyped.
Biased angular distribution of decay secondary particles.	Can de done.
Region-dependent weight window in three energy ranges (and energy group dependent for low energy neutrons).	Existing. Can be "re-provided" and more general.
Bias setting according to a user-defined logics.	(need more info in FLUKA, but is actual purpose of this dev.)
User-defined neutrino direction biasing.	Can be done, easily.
User-defined step by step importance biasing.	Can be done, easily.

Simple for neutral. More difficult for charged but understood.

MCNPX / Geant4 biasing functionalities

Biasing options in MCNPX From LA-UR-03-1987, MCNP5 manual	Options in Geant4, present or future
Energy Cutoff & Time Cutoff	Existing (not considered as biasing)
Geometry Splitting with Russian Roulette	Existing. Will be "re-provided" with new design, prototyped.
Energy Splitting/Roulette and Time Splitting/Roulette	Can be done easily.
Weight Cutoff	Existing (in some way). Easy.
Weight Window	Existing. Will be "re-provided" with new design. Can be made more general.
Exponential Transform	Will be done. Prototyped.
Implicit Capture (or "Implicit capture," "survival biasing," and "absorption by weight reduction")	Can be done.
Forced Collisions	Will be done. Prototyped.
Source Variable Biasing	Existing.
Point Detector Tally (?)	(not biasing ?)
DXTRAN	Planned, need more work. Doable.
Correlated Sampling	Not planned for now "à la MCNP". But doable with user's invest.

EM Biasing (1/2)

- EM biasing has been present for some time
- A number of (UI or C++) options
- Internal to EM domain, so different from generic wrapper
- Works well for splitting and russian roulette

EM built-in biasing options

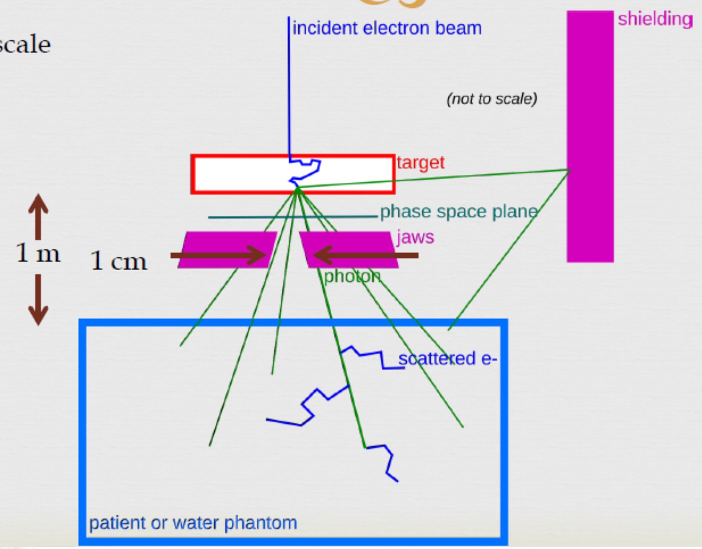
- Available since Geant4 9.5
- Fully functional with Geant4 9.6
- List of options:
  - Cross section biasing
  - Force interaction
  - Secondary splitting
  - Russian roulette
  - Electron range
- Basing options are enable via UI commands or C++ interface per process and detector region, for example
  - /process/em/setSecBiasing eBrem World 0.5 5 MeV

Wrapper versus built-in

EM Biasing (2/2)

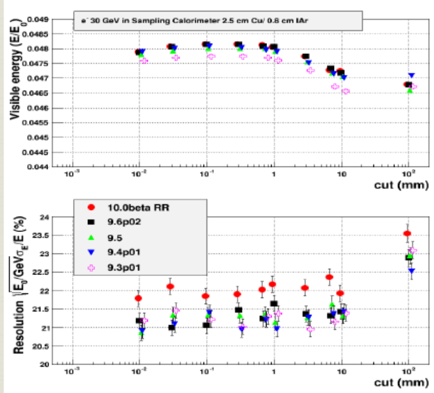
Brem splitting for medical linac

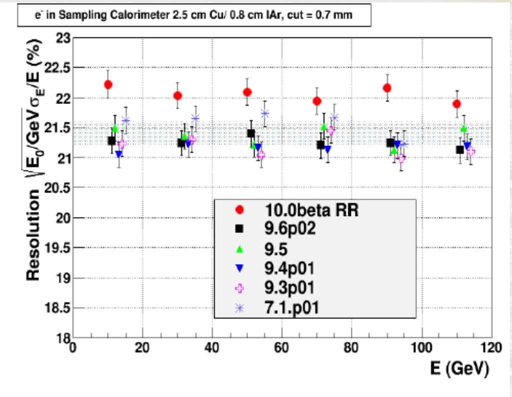
Not to scale



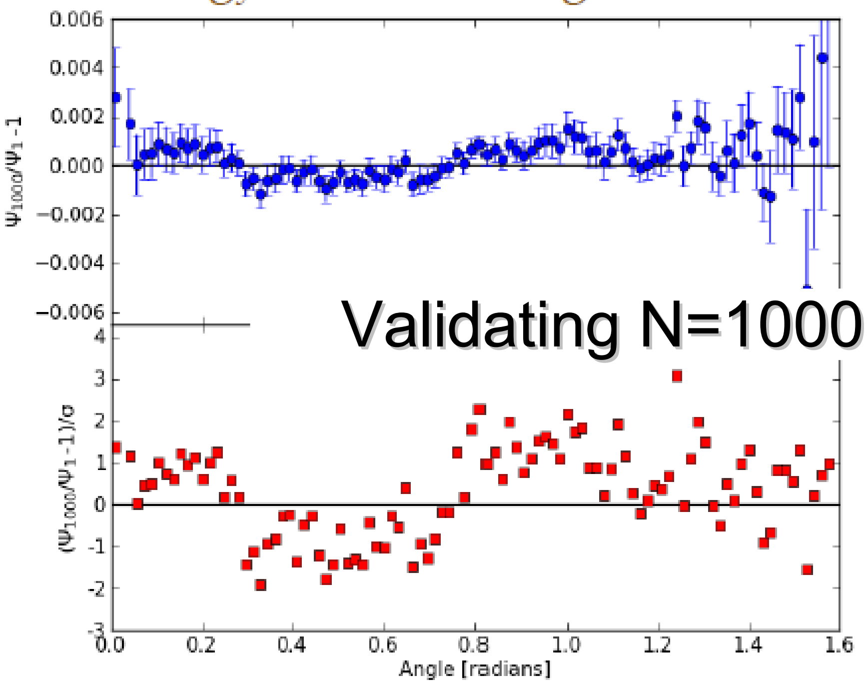
Russian roulette for ATLAS-hec type calorimeter

Russian roulette is applied on Gamma below 5 MeV with the factor 0.5 – some CPU is saved

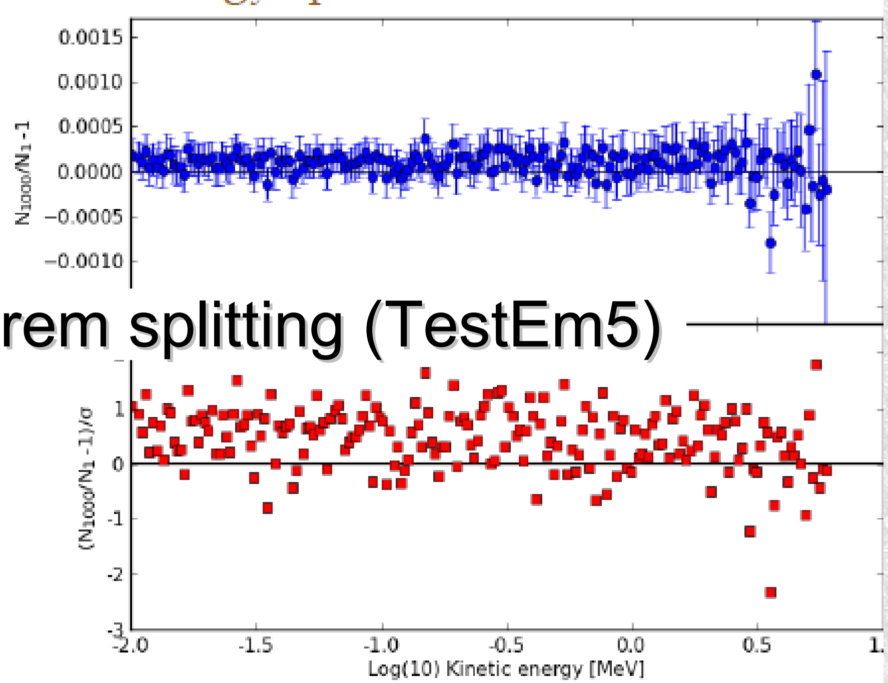




Energy fluence vs. angle



Energy spectrum



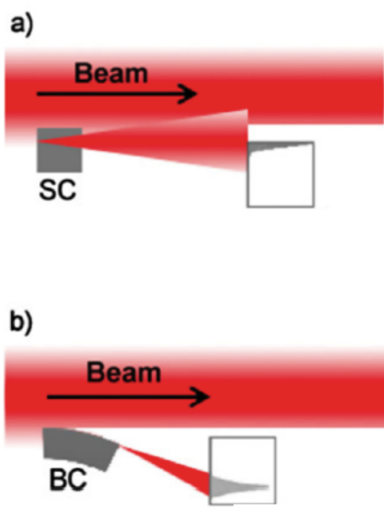
Validating N=1000 Brem splitting (TestEm5)

Introducting Channelling Effect (1/3)

- Channelling is the phenomenon of charged particles following the lattice planes in crystals due to the EM potential well
- Useful for beam collimation and extraction
- Implementation follows that of phonons in solid state
- Wrapping of physics processes to modify according to potential well

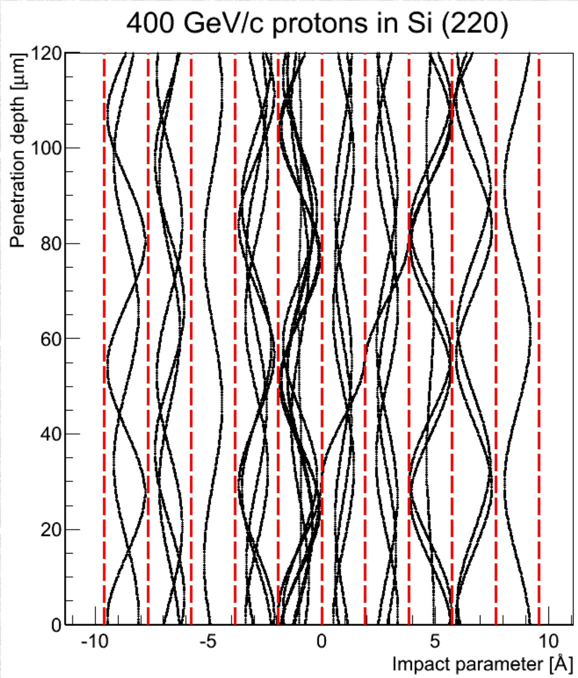
Crystal collimation

- Crystal can be used as a primary collimator to deflect particles of the halo toward a secondary collimator.
- Main advantage is the possibility to deflect the beam out and reduce the beam losses.



a) standard collimation system
b) crystal collimation system

- Ordered pattern of atoms.
- Aligned atoms can be seen as planes or axes.
- Strong electromagnetic field between planes and between axes (GeV/cm).
- Channeling if particle direction aligned with planes or axes

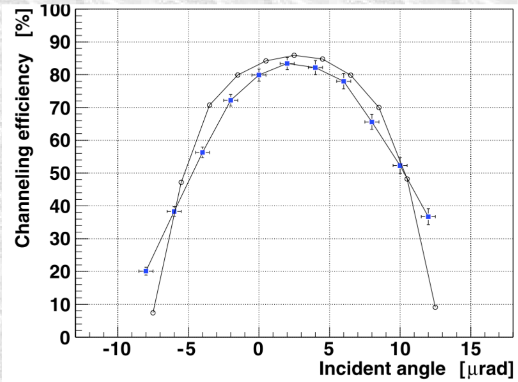


Introducing Channelling Effect (2/3)

- Channelling condition implemented
- Compares well with data vs. incident angle

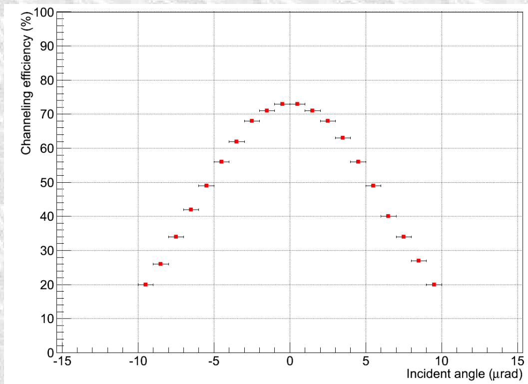
Channeling efficiency vs. incoming angle

W. Scandale et al., Phys. Lett. B 680 (2009) 129



Experimental measurements UA9

Geant4 Channeling

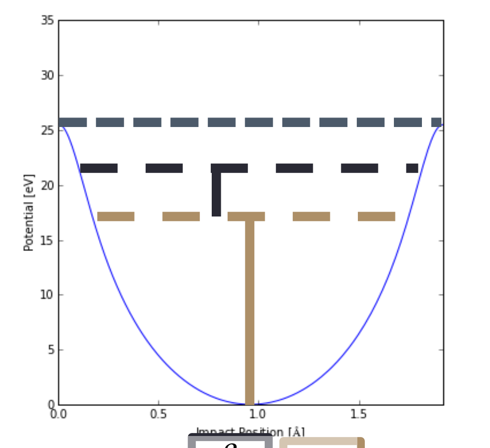


simulations

Condition for channeling

Straight crystal

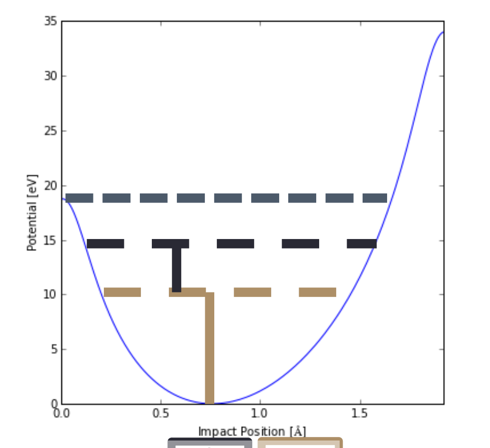
$E_T < U_{\max}$



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

Bent crystal

$E_T' < U_{\max}'$



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

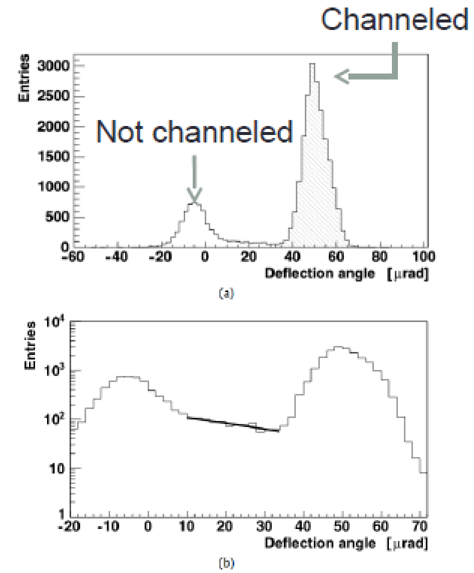
Geant4

Introducing Channelling Effect (3/3)

- Nice functional agreement between data and Geant4
- Absolute values are (slightly) different
- Still very impressive!
- Will be released next year (with phonons)

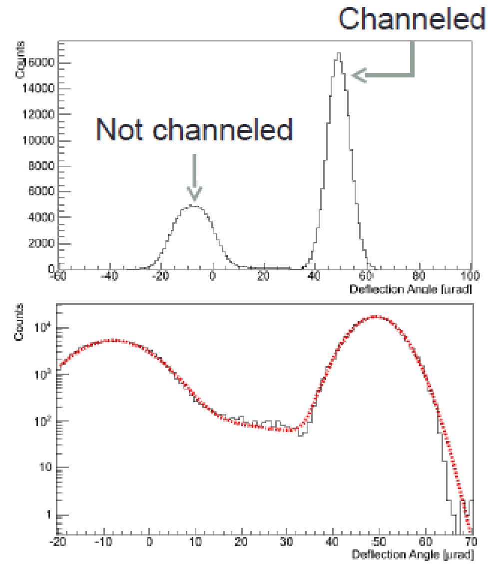
Nuclear dechanneling length

W. Scandale et al., Phys. Lett. B 680 (2009) 129



Ln = (1.53 ± 0.35 ± 0.20) mm

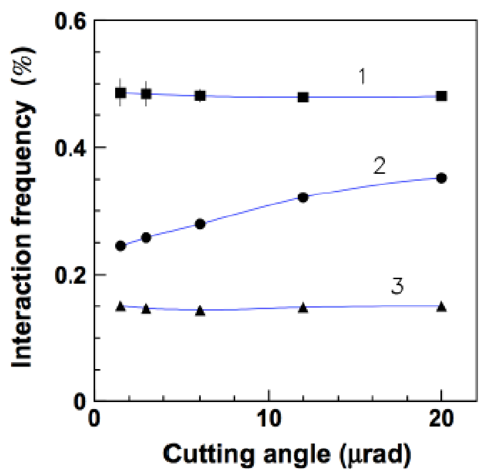
Geant4 Channeling



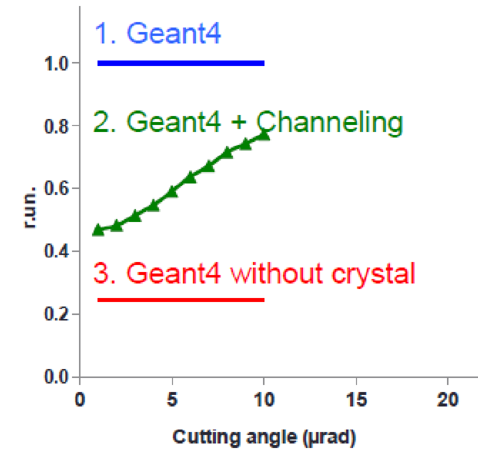
Ln = (1.31 ± 0.05) mm

Interaction rates vs. integration angle

W. Scandale et al., NIMB 268 (2010) 2655



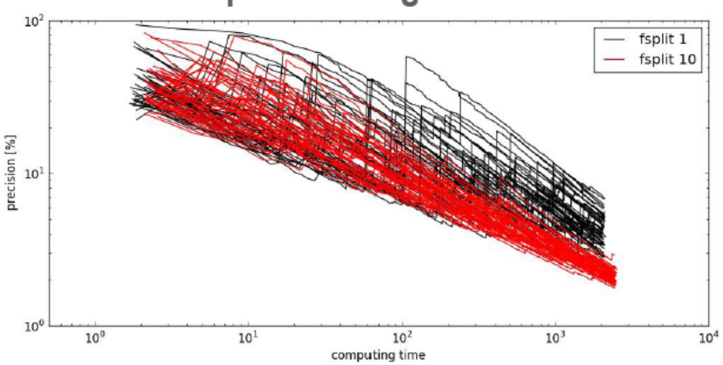
Geant4 Channeling

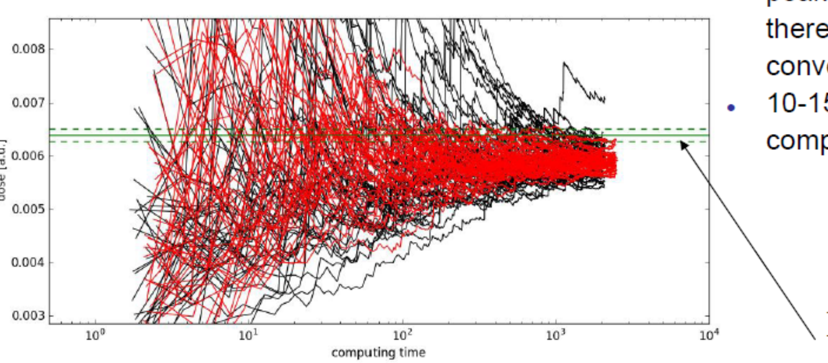


G4RMC Status (1/1)

- Very short update on Reverse Monte Carlo
- Convergence testing shows systematic lower does
- MT migration almost done, but blocked
- Work ongoing...

Example Convergence Ta 2mm housing





- 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

Ongoing Migration to MT mode

- Migration to MT implies important changes in the Reverse MC
- Forward and backward trackings are now handled in the same event in order to be treated by the same worker
- New class G4MTAdjointRunManager to control the adjoint simulation from the master side
- New class G4AdjointUserActionInitialization
  - Replace the UserActionInitialization
  - In Build and BuildForMaster call the Build and BuildForMaster methods of UserActionInitialization
- Status of development:
  - Main code developed
  - ReverseMC compiled in non MT mode is working as before
  - Test of the ReverseMC in MT mode block at some barrier->still need to figure out why

Summary

- Very interesting presentations of two new major developments
- Generic biasing will be released in Geant4.10
- EM biasing is present and shows good performance gain for brem splitting
- Crystal channelling will be in a future release (framework is extensible to biasing wrappers)
- RMC is being investigated for convergence testing and migration to MT